

LHC-ALICE実験の高度化に向けた シリコン電磁カロリメータのための シリコンセンサーの性能評価

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2022/3/4

目次

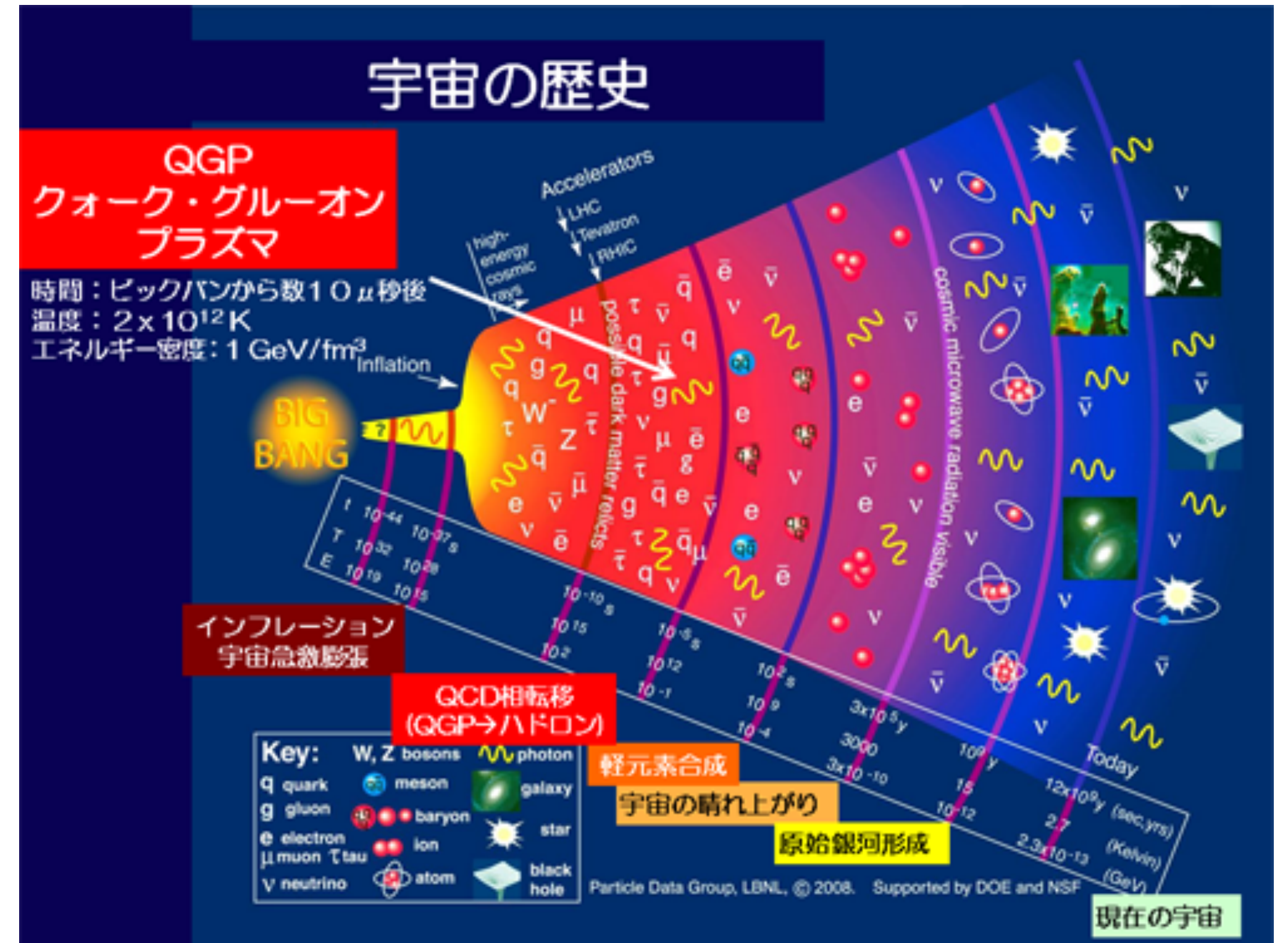
- 研究背景
- 測定について
- 測定結果
- まとめと今後の課題

研究背景

クォーク・グルーオンプラズマ (QGP)

- 通常強い相互作用により核子内に閉じ込められているパートンが、高温高密度状態で解放されている物質状態。
- ビックバンから数10マイクロ秒後に存在していたとされる。

QGP解明が
宇宙の起源解明の
手がかりに



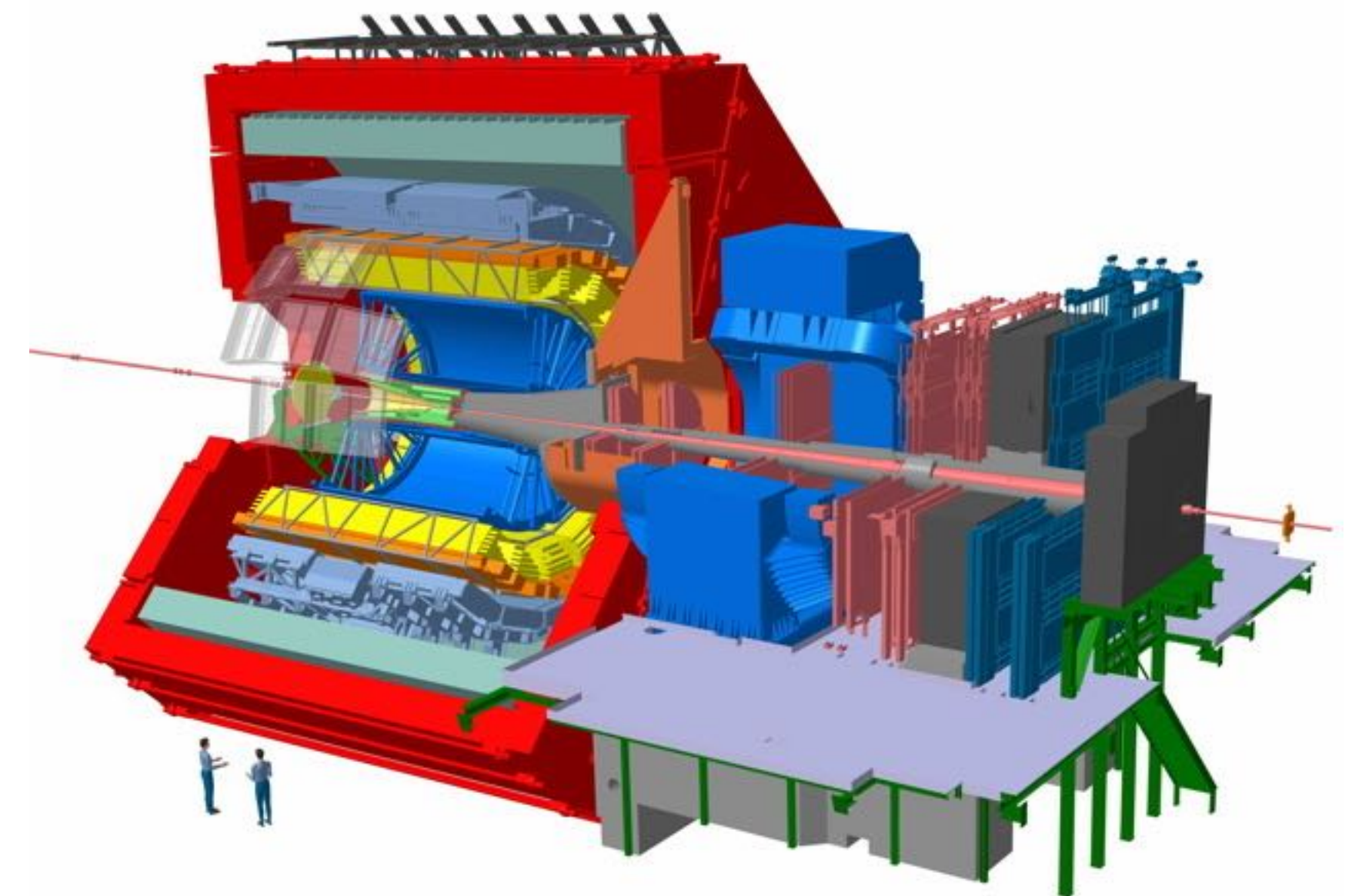
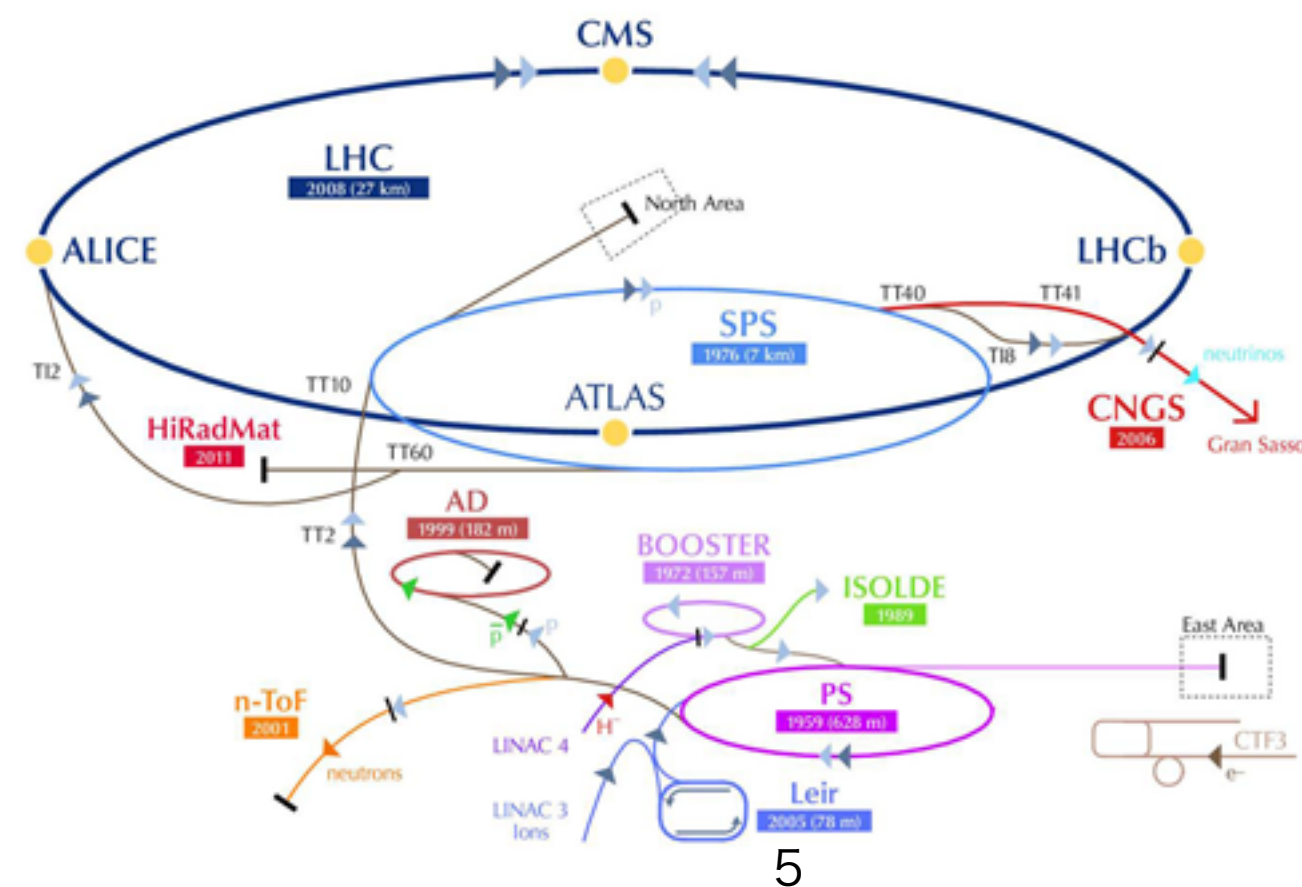
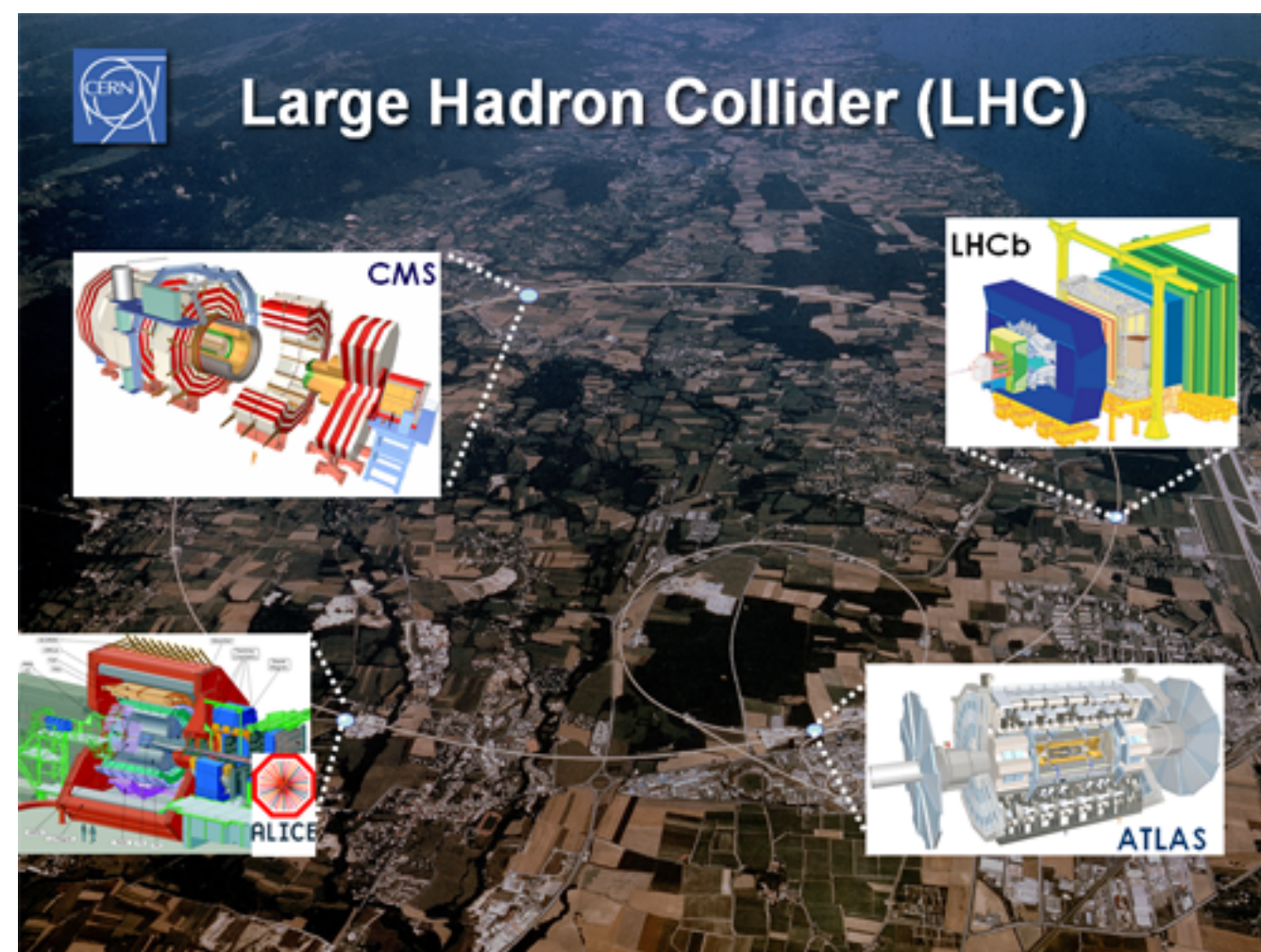
LHC-ALICE実験

LHC(Large Hadron Collider)

- ヨーロッパ共同原子核研究機構（CERN）により建設された世界最大のハドロン衝突型加速器。

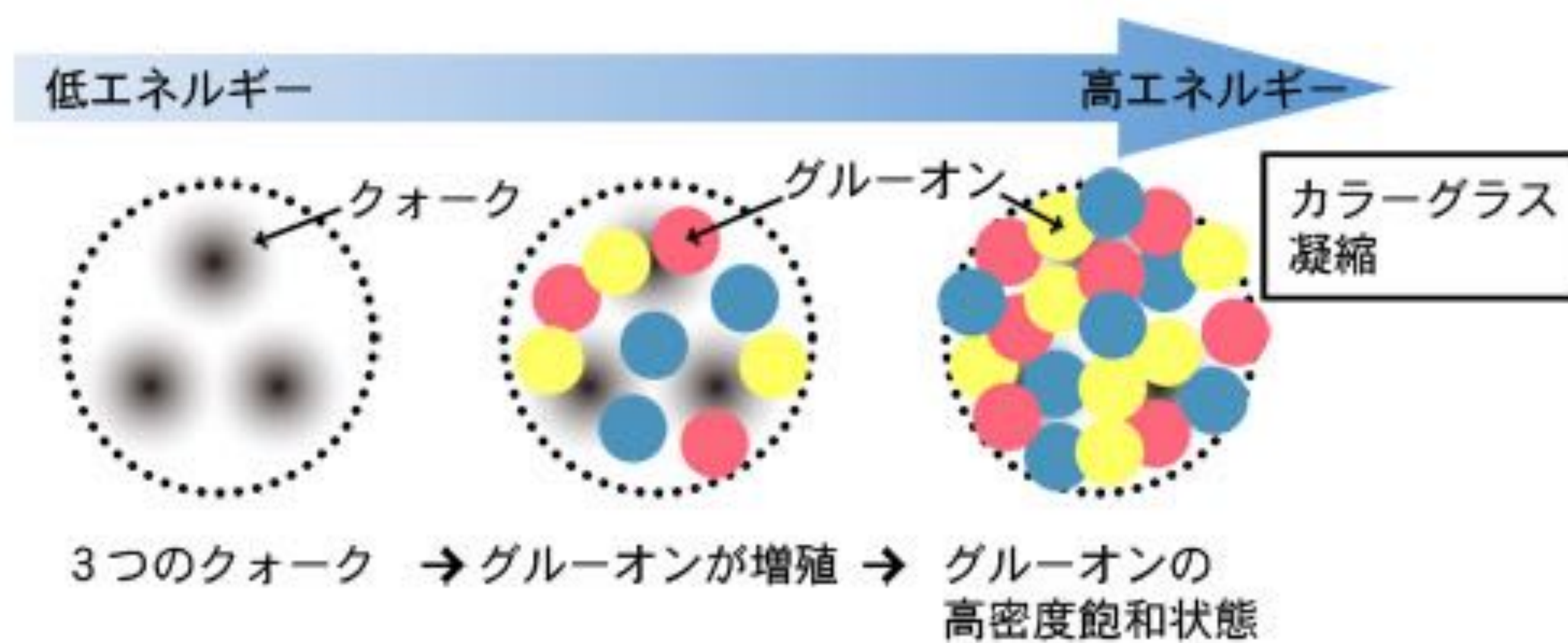
ALICE(A Large Ion Collider Experiment)実験

- QGPの生成・解明を目的としている。



カラーグラス凝縮 (CGC)

- グルーオンが高密度飽和状態になった物質状態。



引用：港陽子

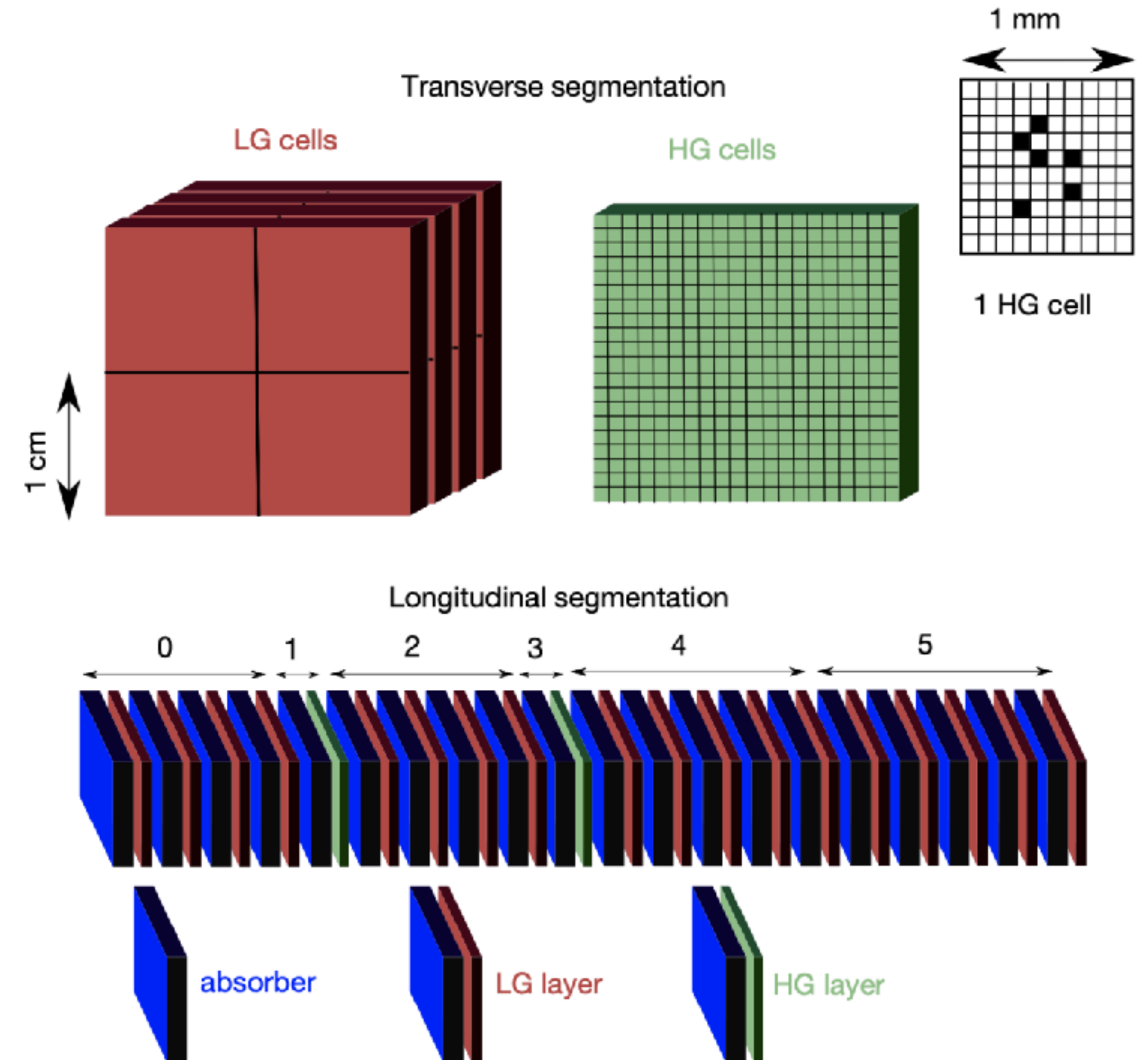
「LHC-ALICE実験の高度化に向けたシリコン電磁カロリメータの開発と性能評価」、2020年、5~6ページ
(http://webhepl.cc.nara-wu.ac.jp/old_HP/thesis/master/2019minato/mthesis_minato_final.pdf)

FoCal (Forward Calorimeter)

- CGCに感度が高い前方方向の直接光子を測定するための検出器。
- LHC-ALICE実験に導入する計画が立てられている。
- 直接光子を測定するためのFoCal-Eとハドロンを測定するためのFoCal-Hで構成される。
- 日本では筑波大を中心としてFoCal-Eの開発が進められている。

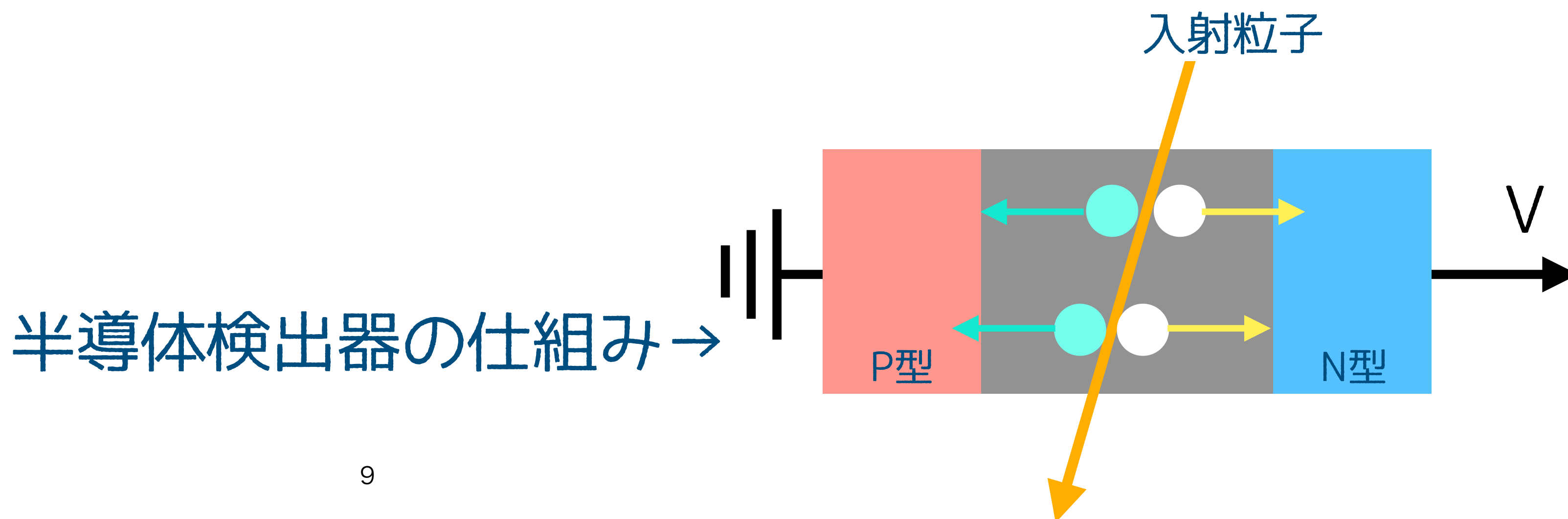
FoCal検出器の構造

- 検出層と吸収層が交互に20層並ぶ構造
- 検出層 (Si) は、高い位置分解能を持つHGL(High Granularity Layer)とエネルギー測定を行うLGL(Low Granularity Layer)の2種類
- 吸収層 (W) で入射した粒子を電磁シャワーにして、エネルギーを落とすやすくする



半導体検出器

- P-N接合付近は電氣的に中性な領域（空乏層）ができる。
- 空乏層に粒子が入射すると、電子と+電荷のものに分かれ、電子はN型、+電荷のものはP型にそれぞれ引き寄せられる。
- 両端の電極に粒子が到達すると、パルスが発生する。
- このパルスは入射粒子の損失エネルギーに対応する。
- 半導体検出器では逆バイアスを用いて、空乏層を広げ、検出効率を上げている。



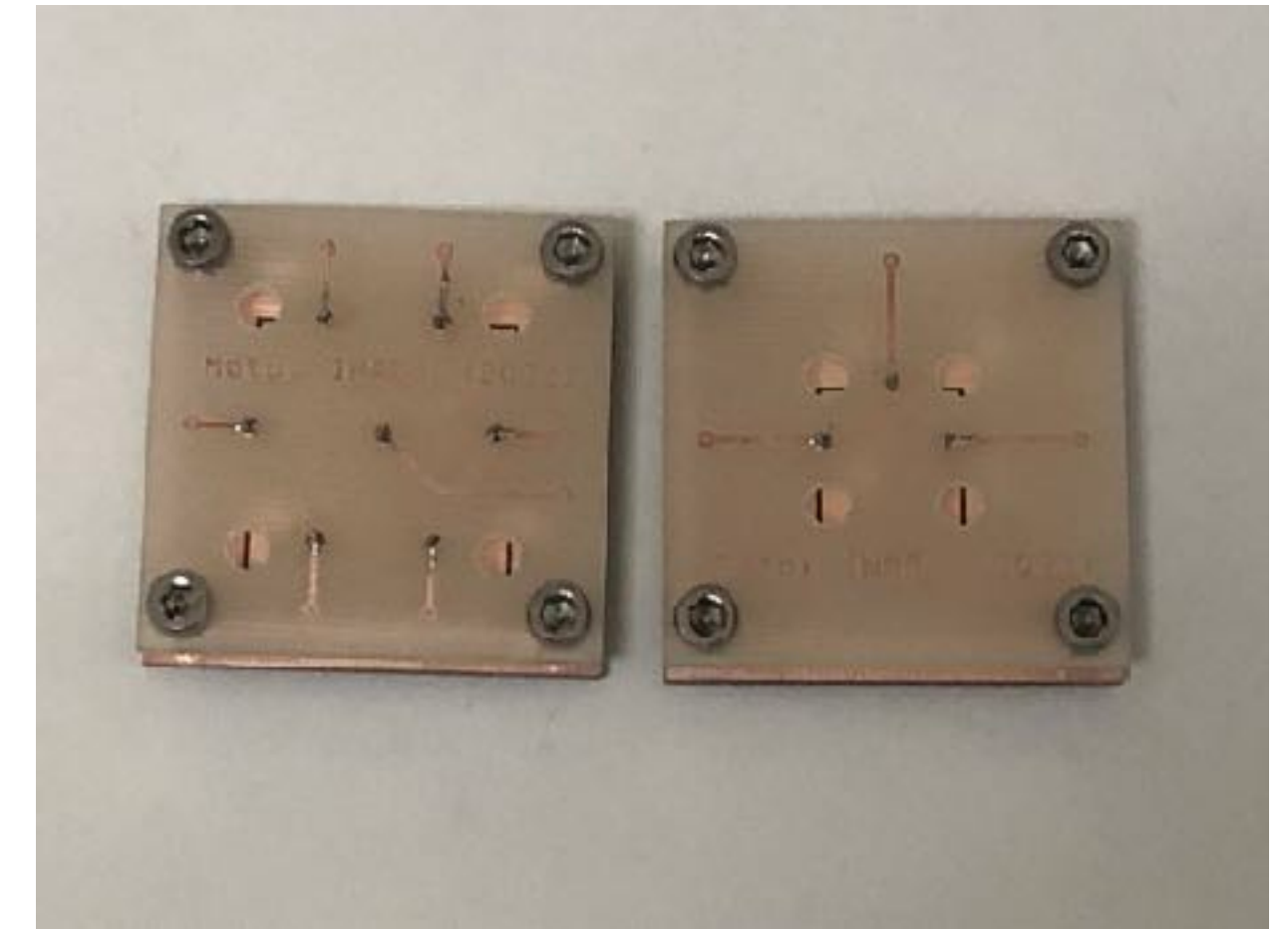
測定について

目的

- FoCal検出器に用いられるシリコンチップに放射線を照射し、前後の変化を調べる
- I-V特性の測定のためのセットアップを組む
- FoCal検出器に用いられるシリコンチップのI-V特性の測定
- 暗電流の小さいチップのI-V特性の温度依存性の測定

測定したシリコンチップ

- P型シリコンチップ
 - 1cm× 1cm : 24枚
 - 2cm× 2cm : 3枚
- チップの大きさに合わせた治具を用いて測定



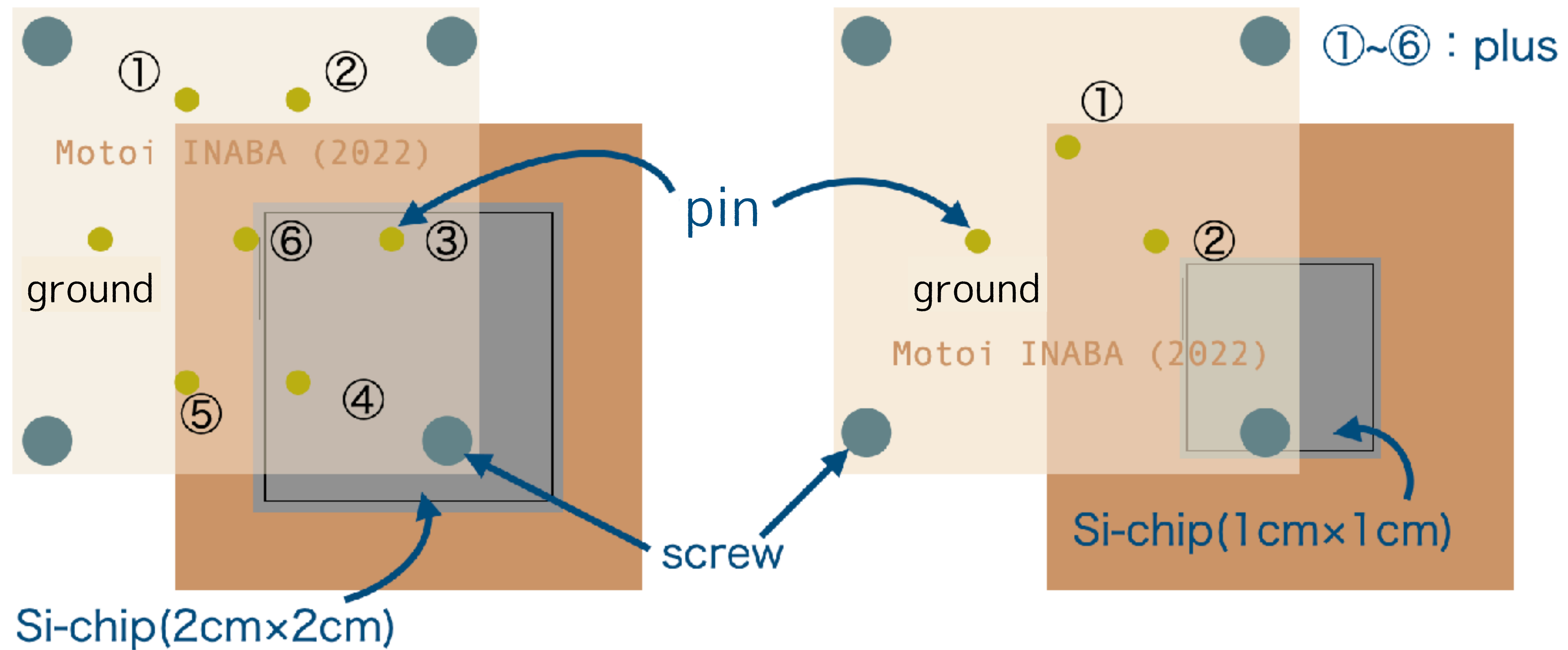
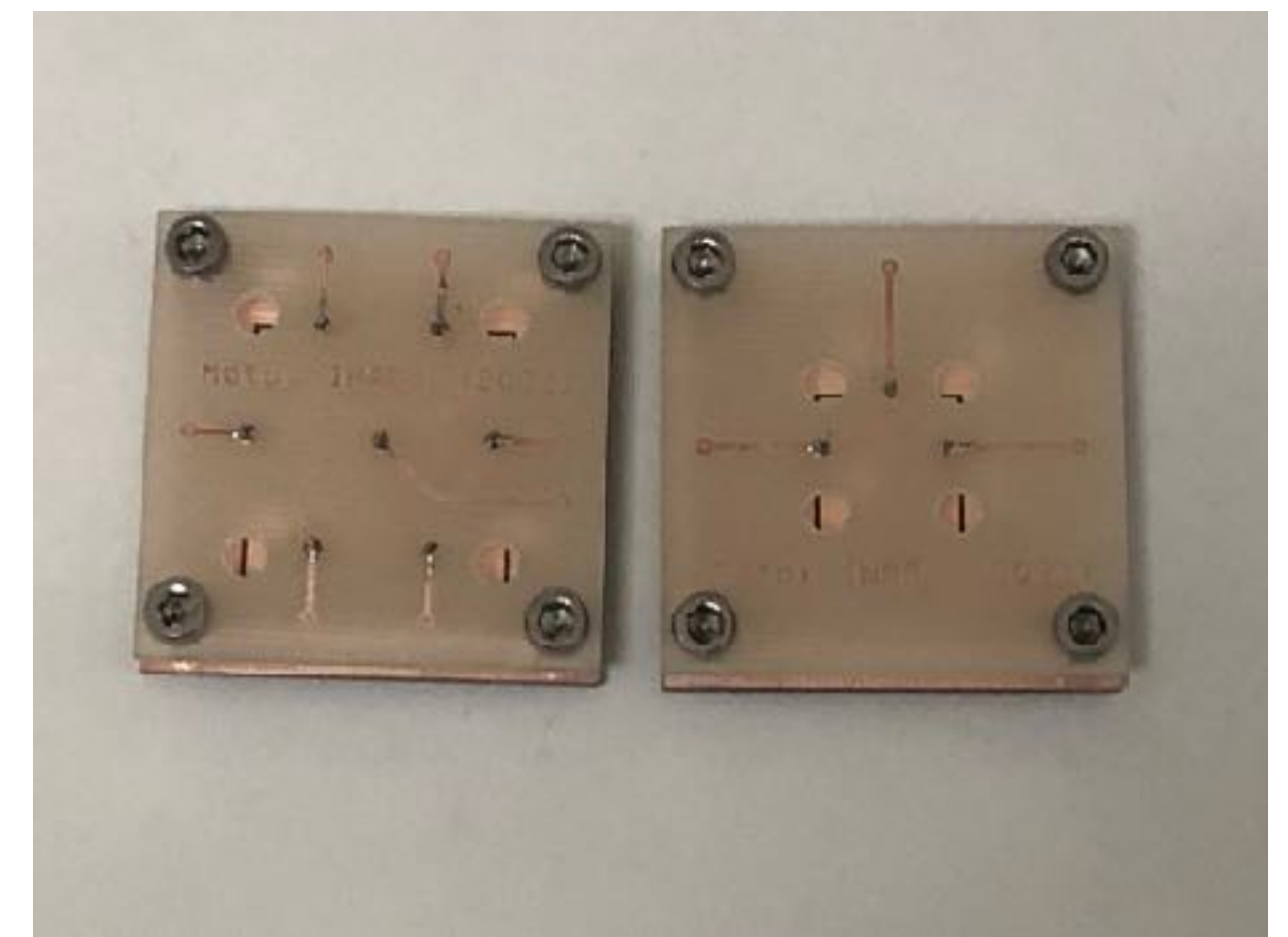
測定方法

- 全てのチップのI-V特性の測定
 - 50°C
 - 0~500V 1V刻み10回ずつ
- 数枚のチップについてI-V特性の温度依存性の測定
 - 20,30,40,50°C
 - 0~500V 5V刻み10回ずつ



治具のピン

- 1cm× 1cmは2ヶ所、 2cm× 2cmは6ヶ所で測定



測定に使用した装置



- ピコアンメータ/電圧源 (Model 6487, KEITHLEY)
 - 電圧最大値：500V
- 恒温槽 (Model OZONE GENTLE LU-113, ESPEC)
 - 設定温度範囲：-25~95°C



使用したソフトウェア

- W32-6487-N
(株式会社システムハウス・サンライズ)
- Excel上のアドインとして動作するソフトウェア
- 電圧、時間間隔、測定回数などを指定して測定できる



	A	B	C	D	E	F	G	H	I	J	K
1	0		Lapsed Time(sec)	VOLT(V)	電流(nA)						
2	0		0	0	-0.14645						
3	0		0.515	0	-0.14685						
4	0		0.984	0	-0.14754						
5	0		1.453	0	-0.14754						
6	0		1.906	0	-0.14754						
7	0		2.359	0	-0.14676						
8	0		2.828	0	-0.14634						
9	0		3.281	0	-0.14626						
10	0		3.734	0	-0.14634						
11	1		4.187	0	-0.14626						
12	1		4.64	1	-0.14524						
13	1		5.953	1	-0.1426						
14	1		6.422	1	12.07902						
15	1		6.89	1	12.08206						
16	1		7.343	1	12.08295						
17	1		7.797	1	12.08315						
18	1		8.25	1	12.08315						
19	1		8.703	1	12.08389						
20	1		9.172	1	12.08692						
21	2		9.656	1	12.08737						
22	2		10.109	2	12.08777						
23	2		10.562	2	12.09042						
24	2		11.031	2	12.3761						
25	2		11.484	2	12.3761						
26	2		11.937	2	12.37621						
27	2		12.39	2	12.3778						
28	2		12.843	2	12.38028						
29	2		13.297	2	12.37806						
30	2		13.75	2	12.37806						

(C)2009...2018 SYSTEMHOUSE SUNRISE Inc.

START PAUSE STOP

時間カウント 回数カウント SPOT ↑

KEITHLEY 6485/6487 Ver2a

FUNCTION 電流測定

CALC MODE OFF STORE ON

測定レンジ 積分時間 トリガ方法
AUTO MED パソコン

MEDIAN FILTER DIGITAL FILTER
ON TYPE
RANK 2 Non

ゼロ補正 RELATIVE AUTO_ZERO

表示単位 nA 係数/判定

GP-IBアドレス 22

OUTPUT VOLTAGE
ON FIX VAL A1 位置

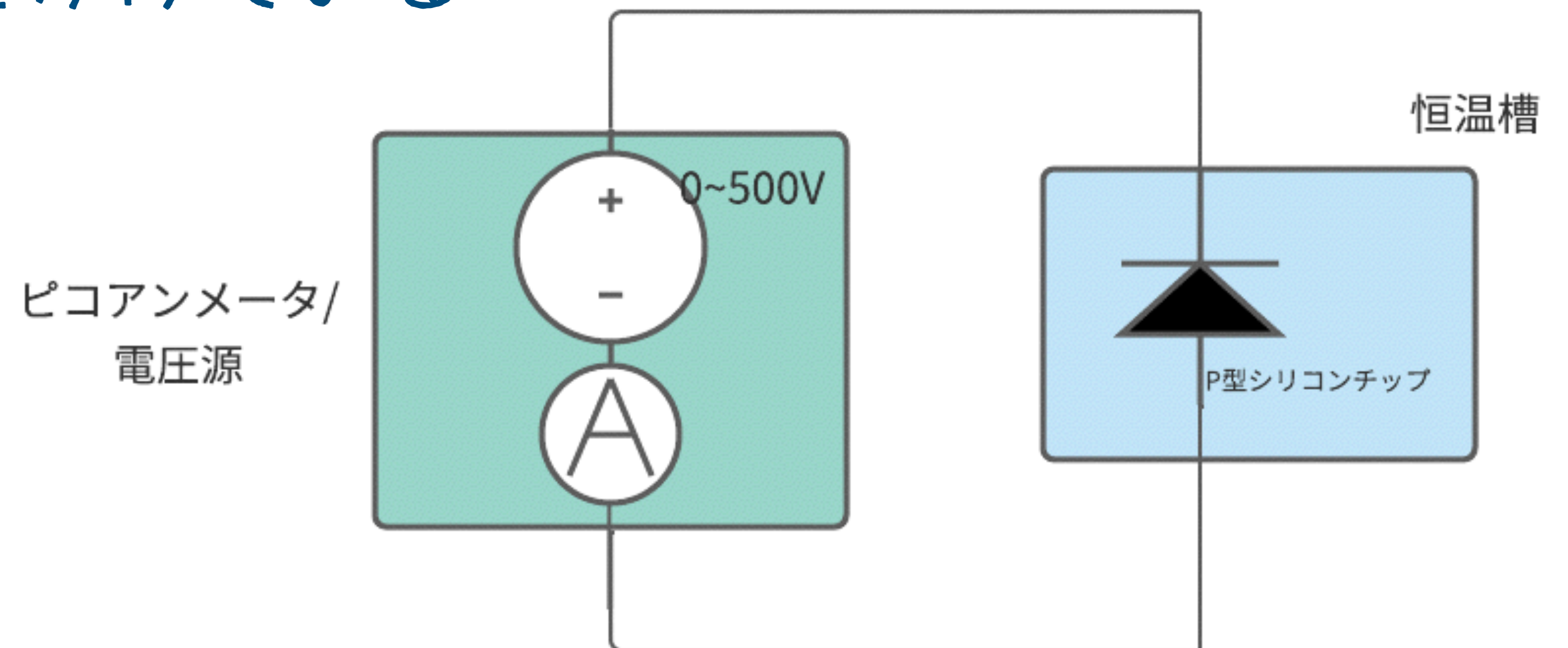
時間間隔 0 秒 作図 スクロール
ヘッダ

外部測定器を使用 経過時間入力 N

株式会社システムハウス サンライズ END

測定のセットアップ

- 恒温槽で温度を保ちながら測定
 - 温度の若干のずれがあるため他の温度計も使用
- ピコアンメータ/電圧源をPCで制御（ソフトウェア使用）
- シリコンチップには逆電圧をかけている



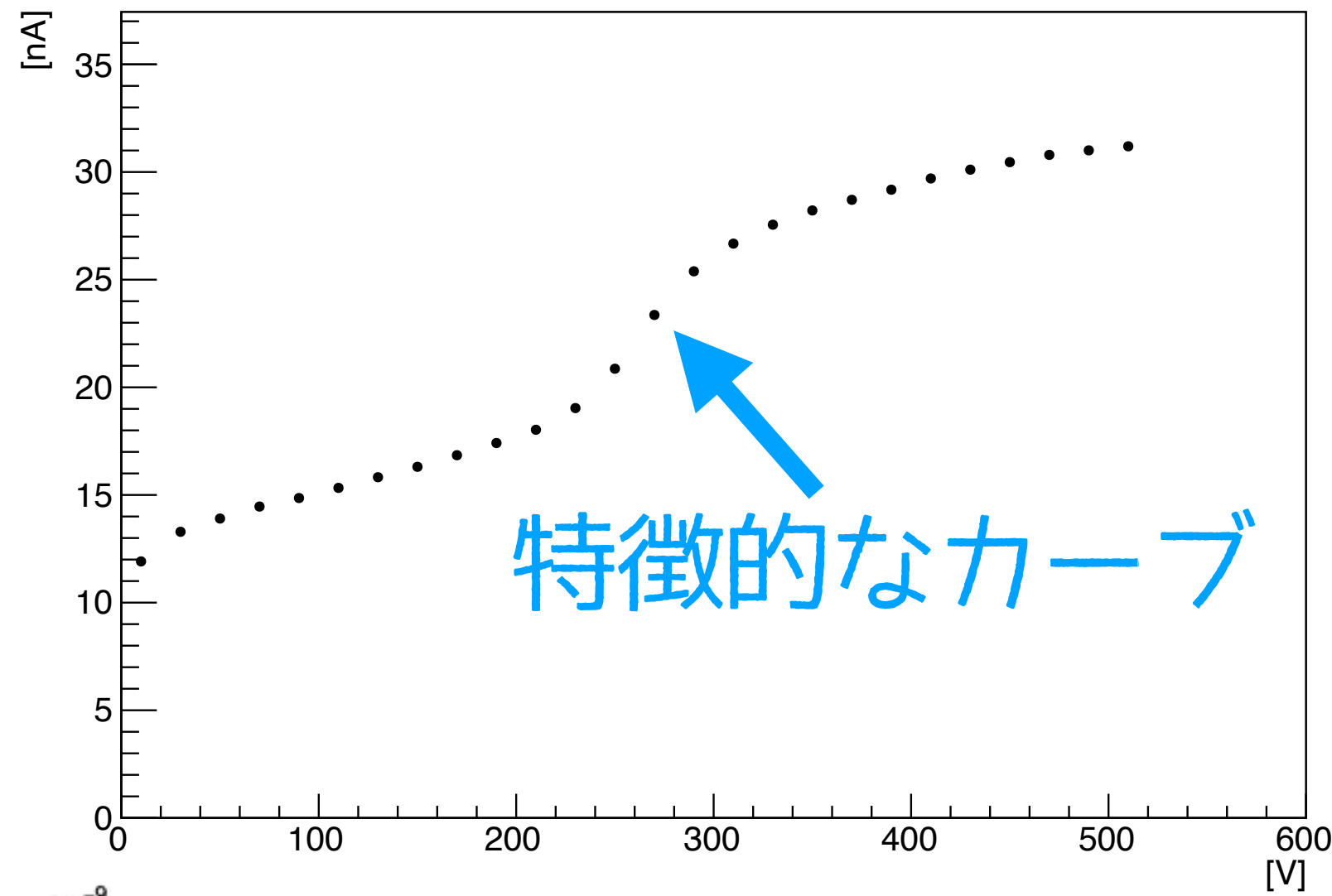
測定にかかる時間

- 恒温槽
 - 10°C変化 → 約10分
- ソフトウェアでの測定
 - 0~500V 1V刻み (約5000回計測) → 約15分
 - 5V刻み (約1000回計測) → 約5~10分

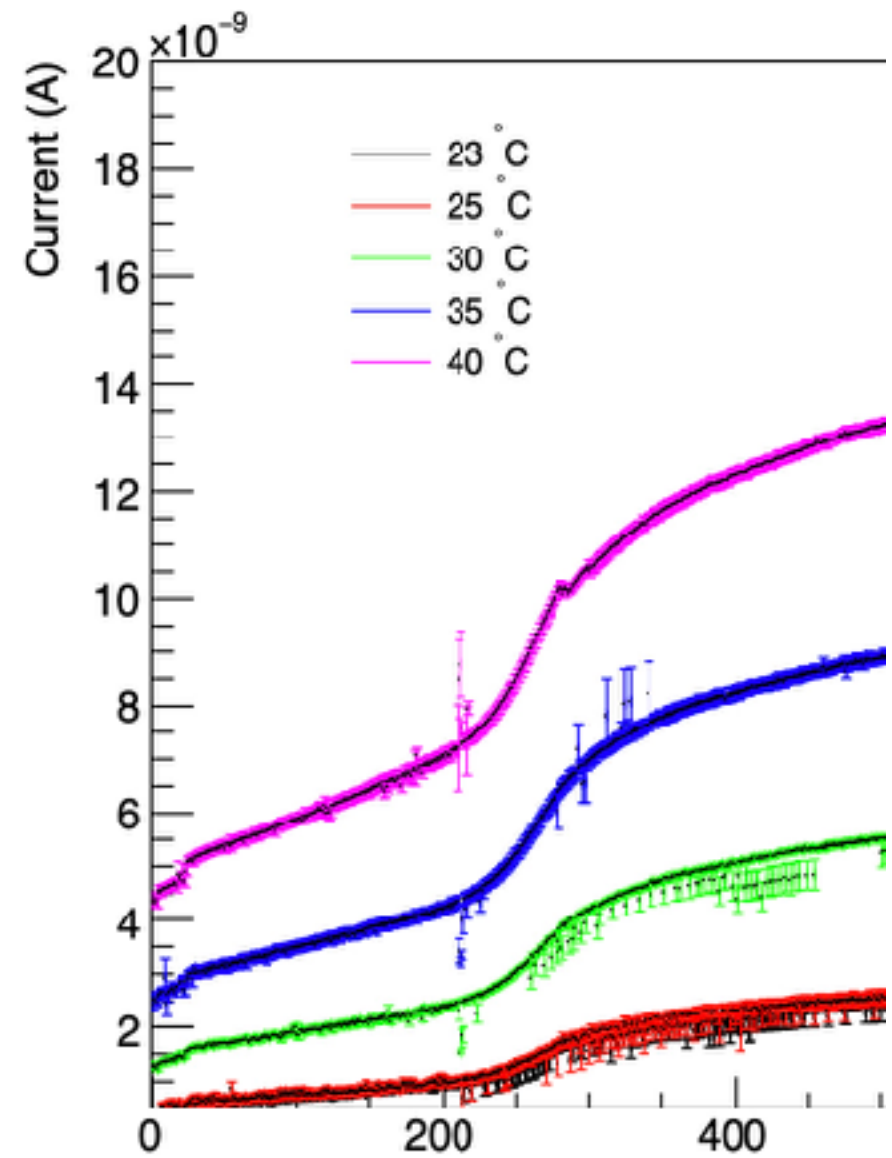
測定結果

50°Cでの測定

I-V 19T1_2



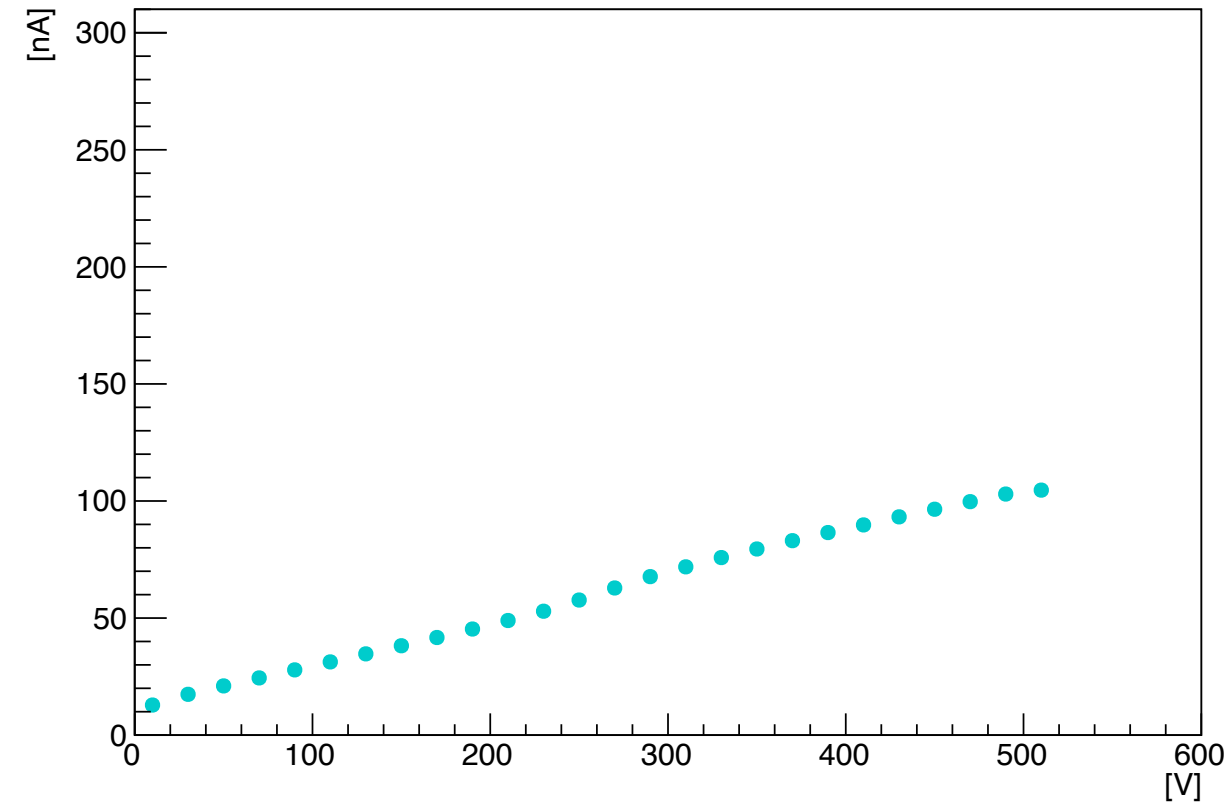
特徴的なカーブ



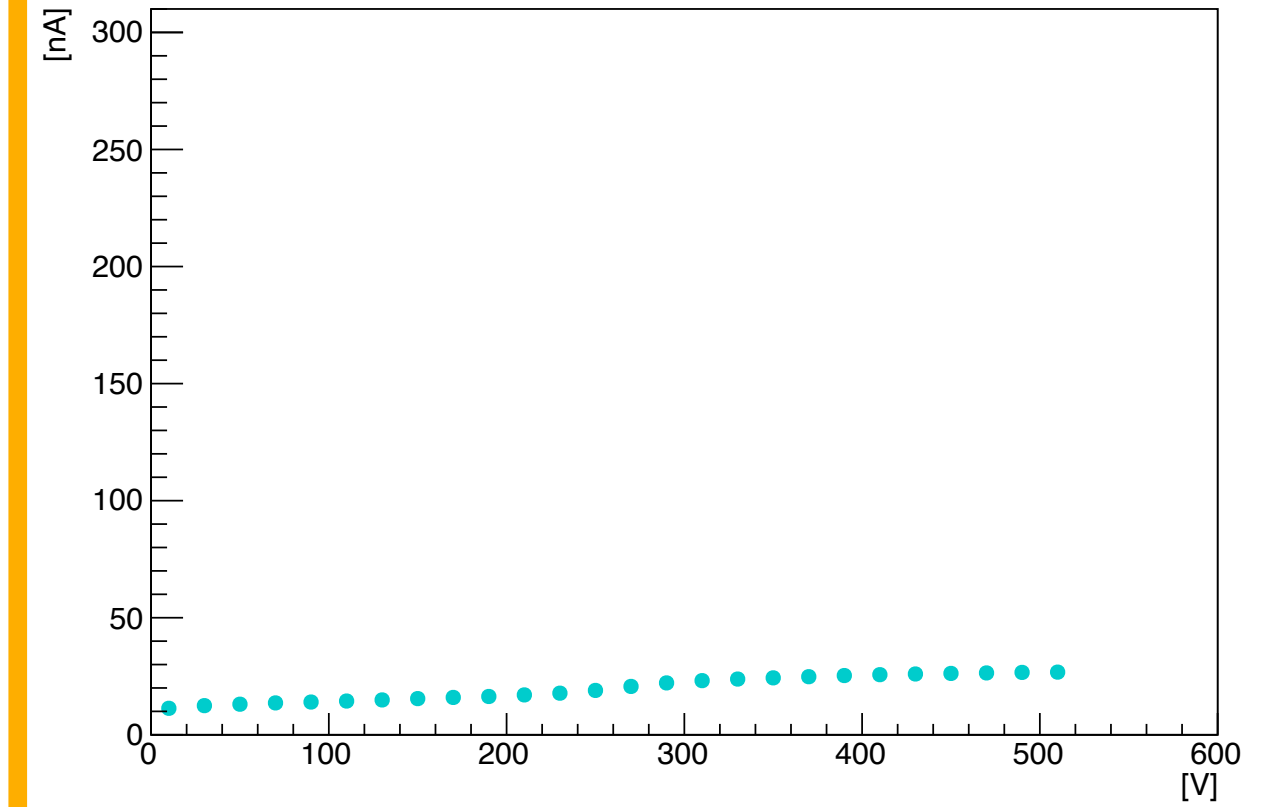
← 先行研究の結果

(参考文献：榎本真隆
「LHC-ALICE実験 超前方領域光子測定用電磁
カロリメータ開発に向けたP型シリコンセンサ
の性能評価」)

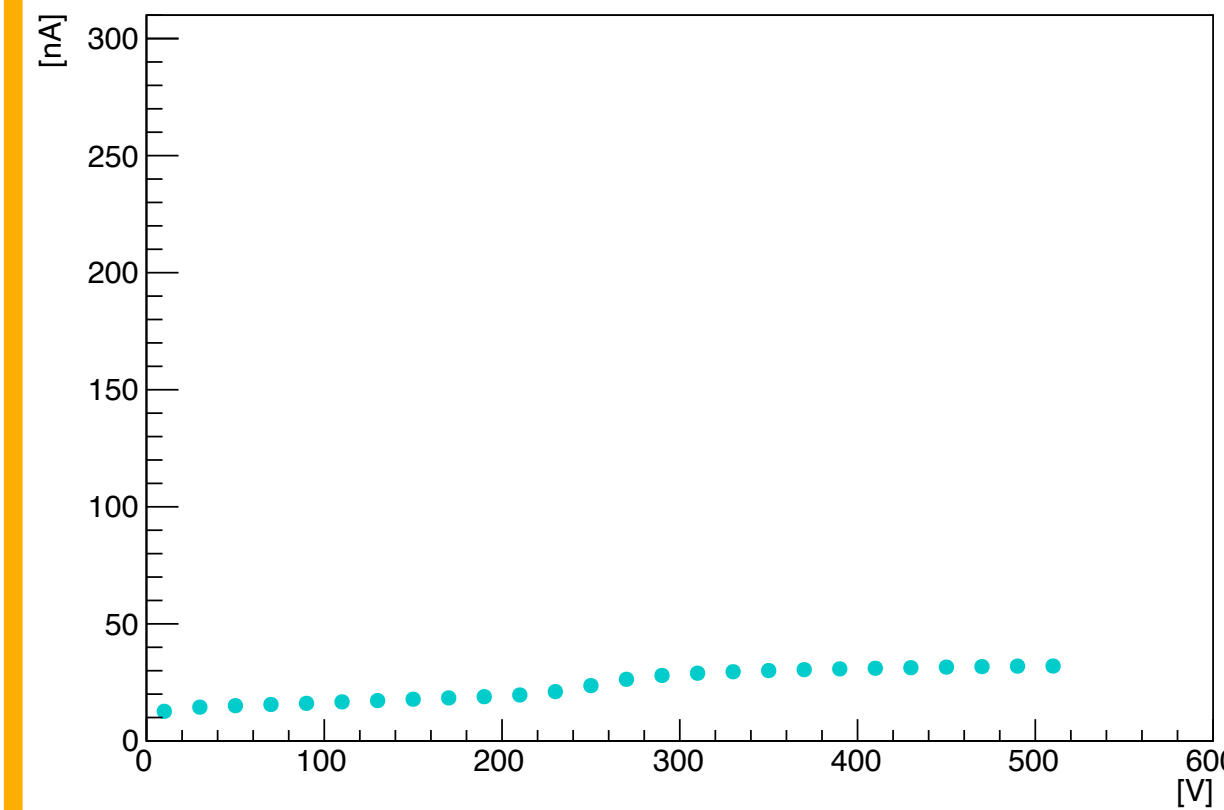
I-V 14L2_1



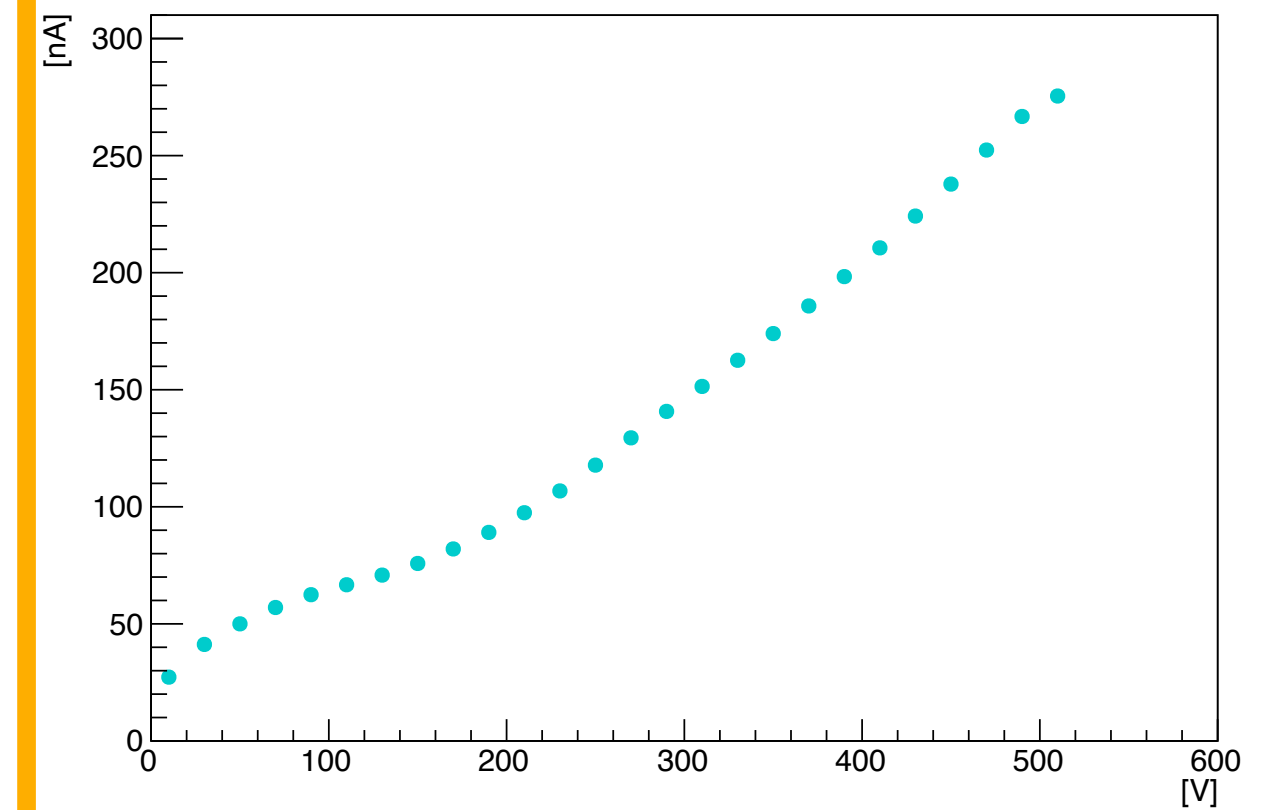
I-V 19R2_2



I-V 28B1_1



I-V 19B2_1



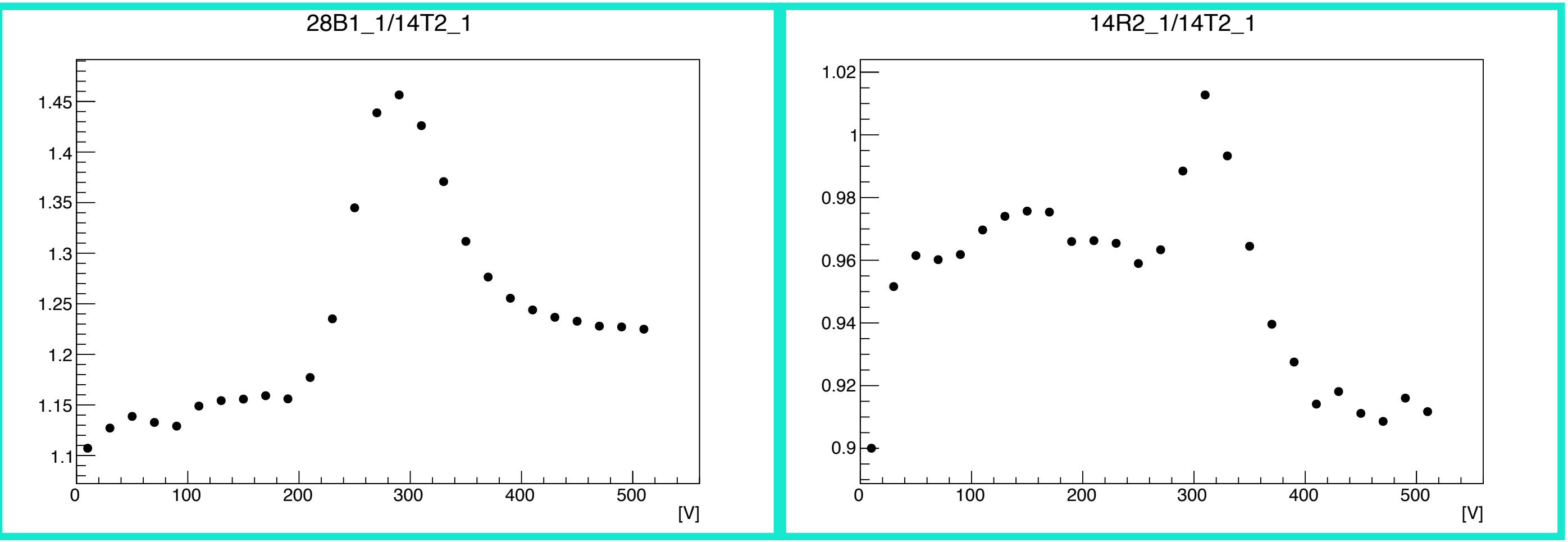
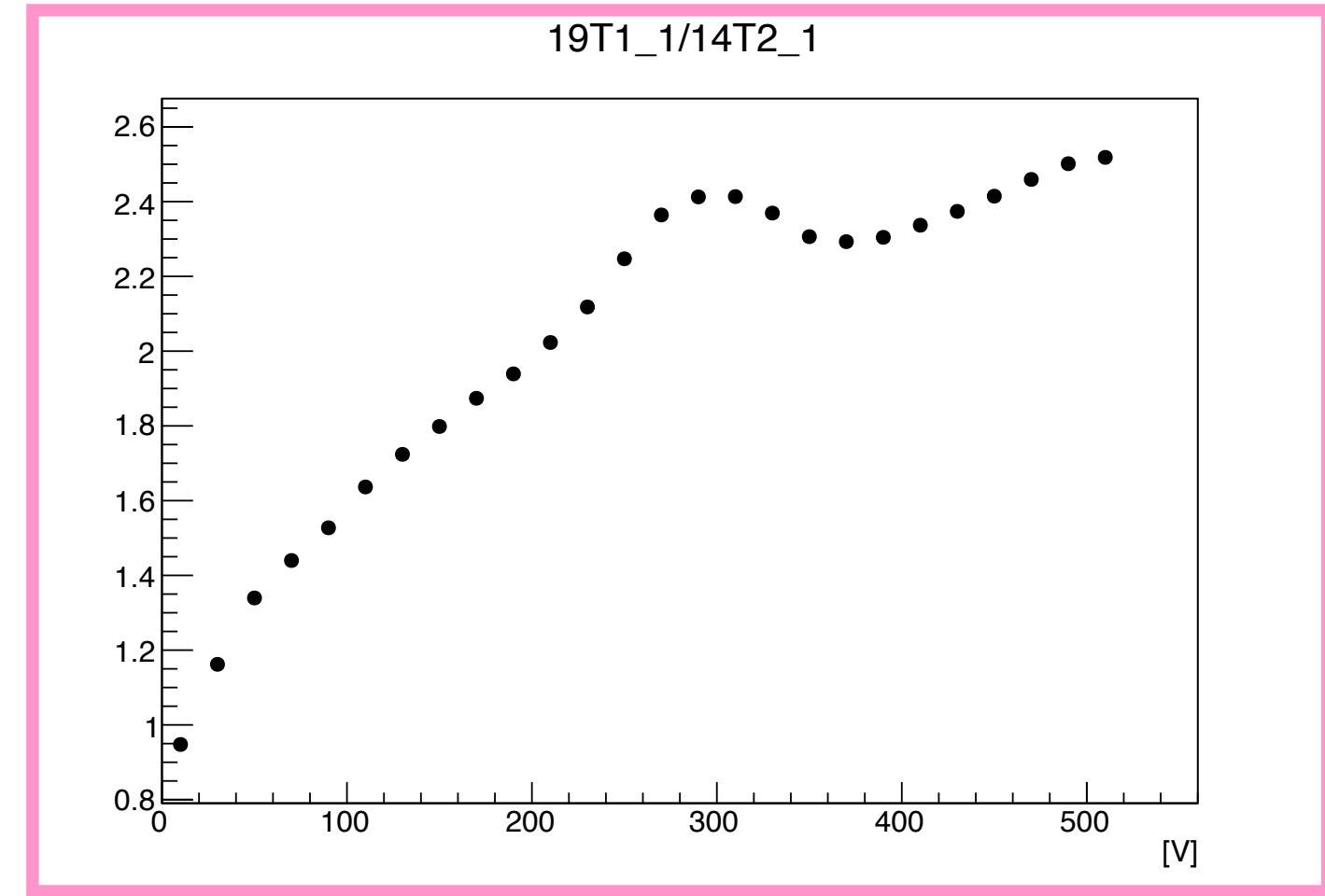
個体差がかなりある

→ 使用したいのは暗電流が小さいもの

→ 電流が小さいものについて詳しく調べる

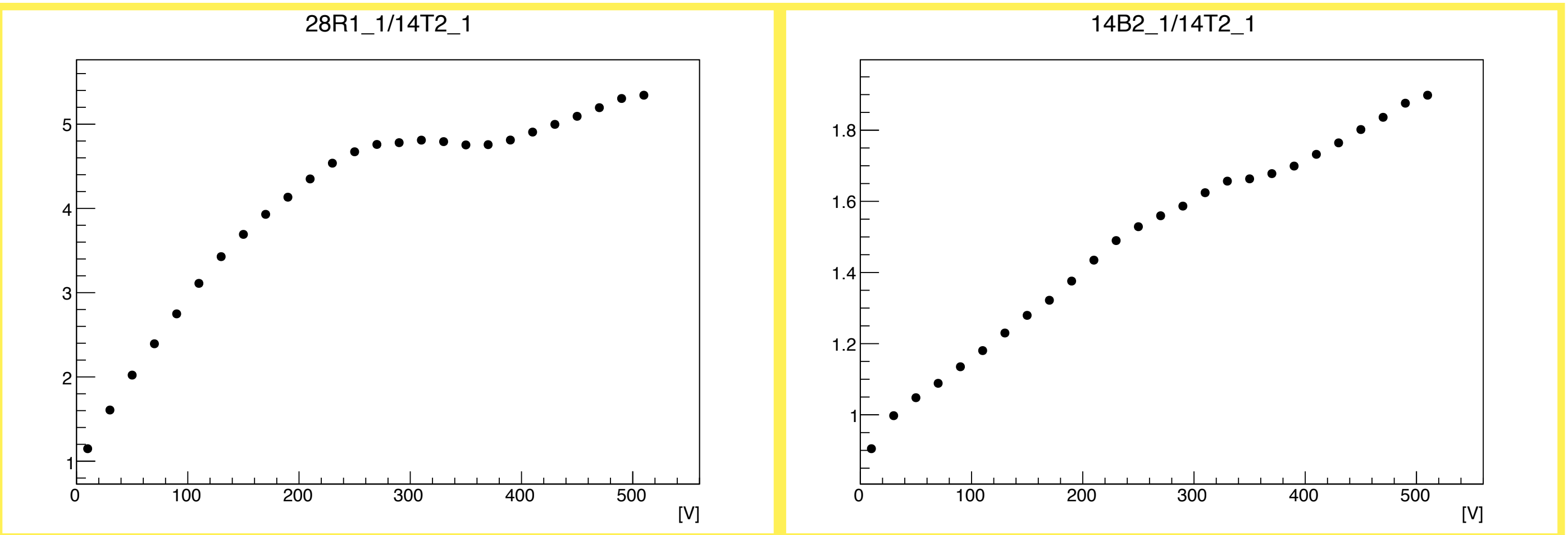
それぞれの結果/14T2の結果

少し凹凸が見えるものも...



凹凸が大きい → カーブ位置の違いが大きい

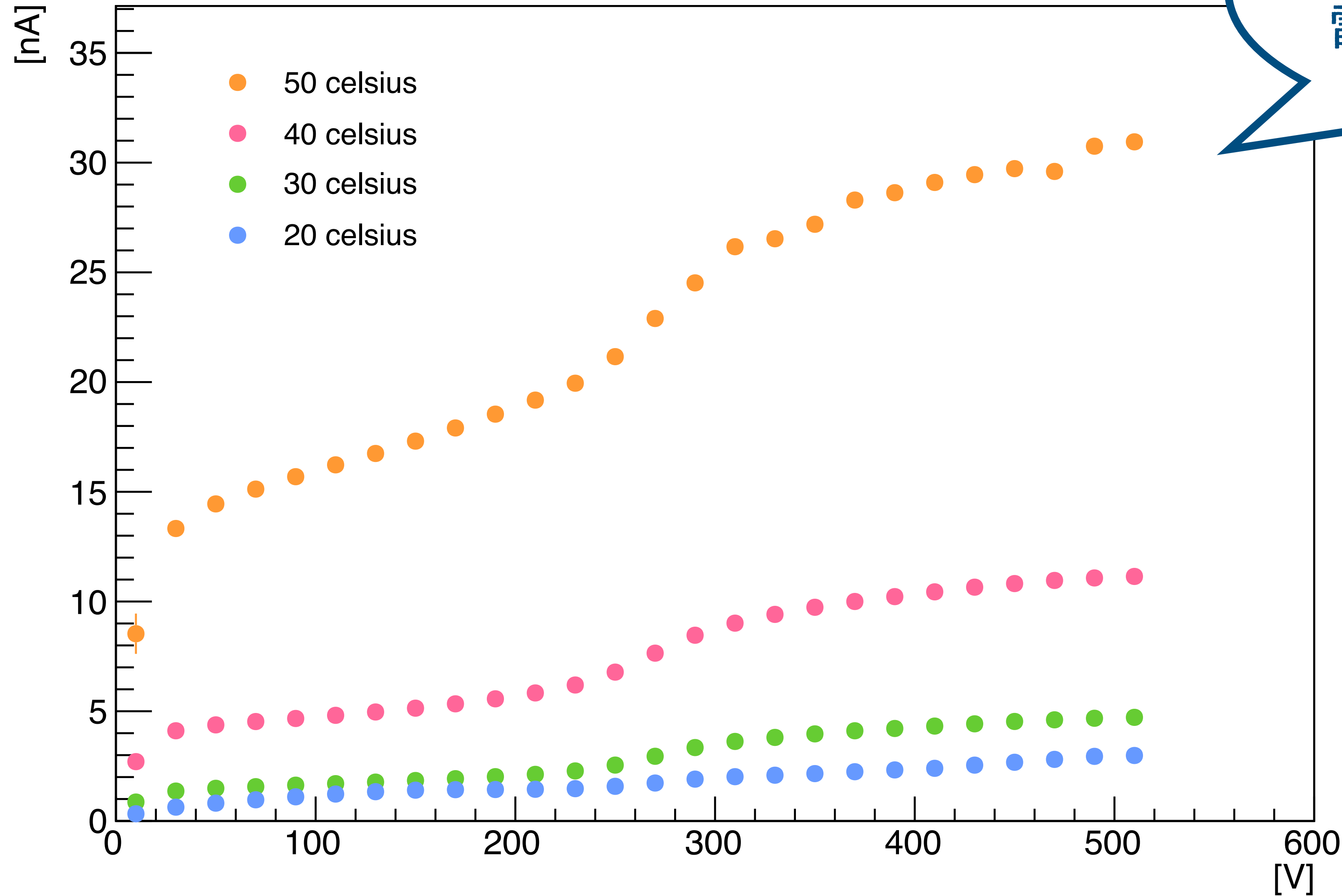
電流の立ち上がりが現れる電圧にも個体差がある



ほぼ凹凸なし → 位置の違いが小さい

温度依存性

I-V 28R2_2



温度を下げるほど
電流は小さくなる。

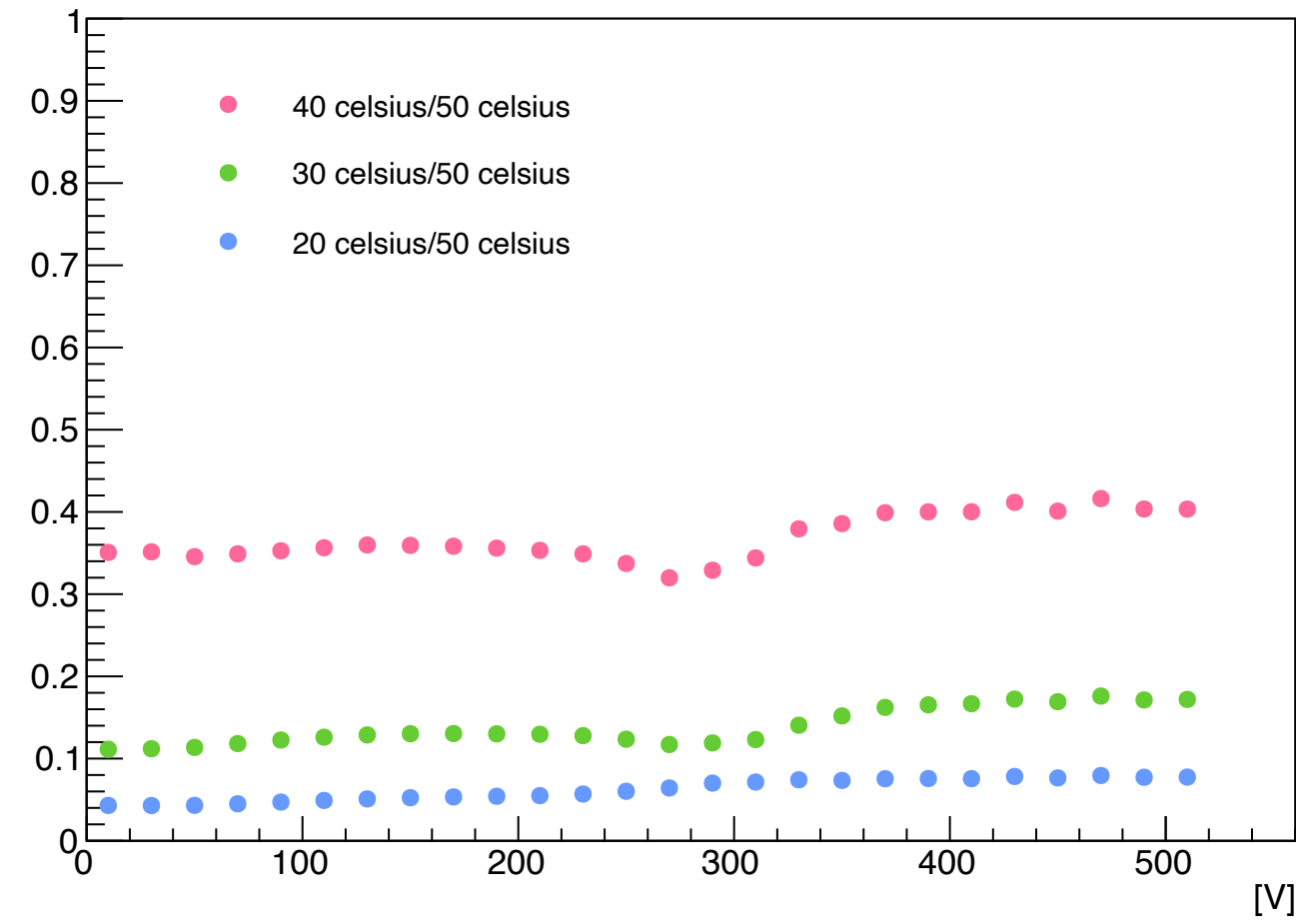
検出器で使用する時は
低めの温度にしたほう
が良い

(20,30,40°Cの結果)/50°Cの結果

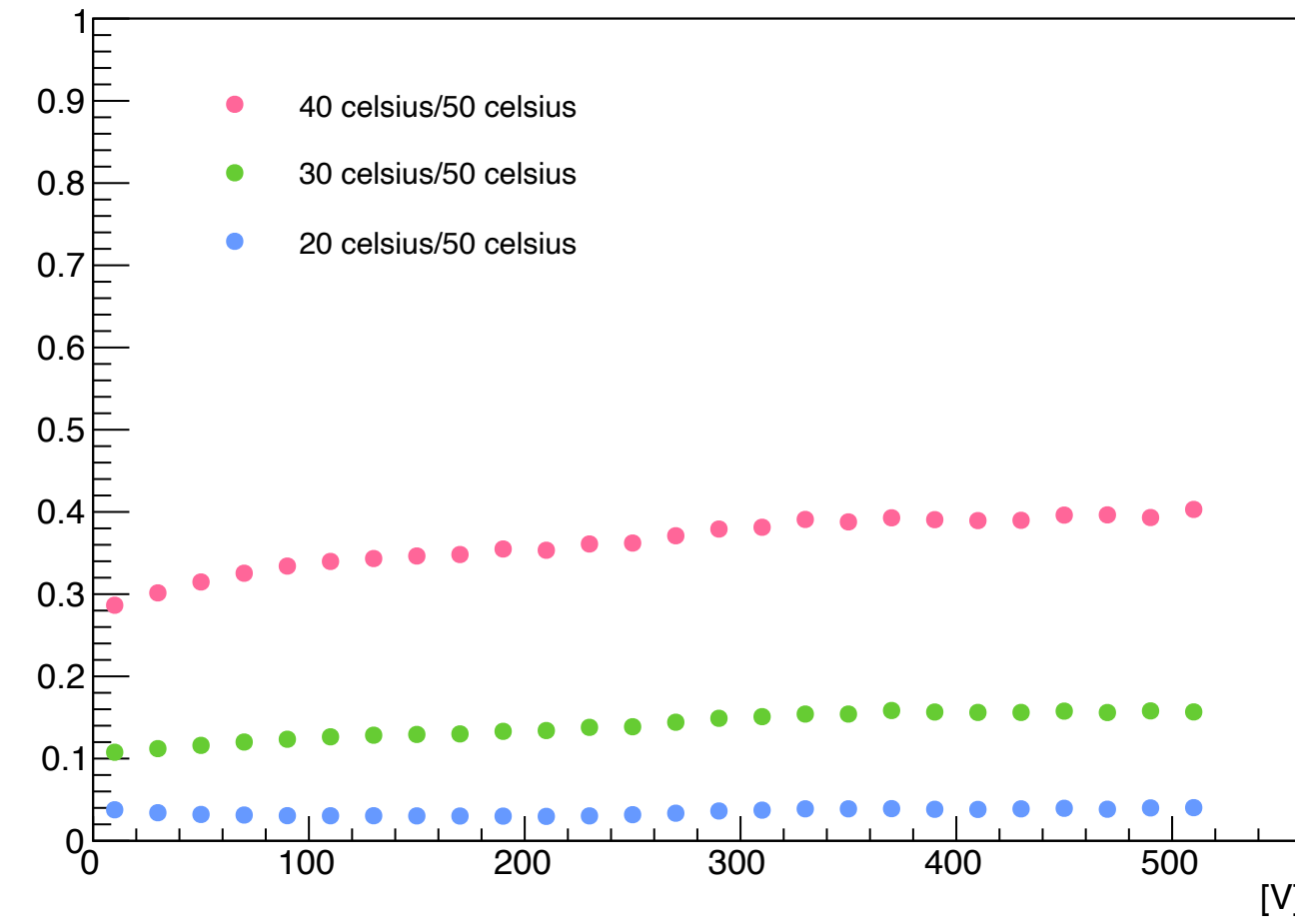
28T1, 28L2, 28B1 (1cm×1cm)

だいたい同じ高さのラインになる
→温度による違いには傾向がある？

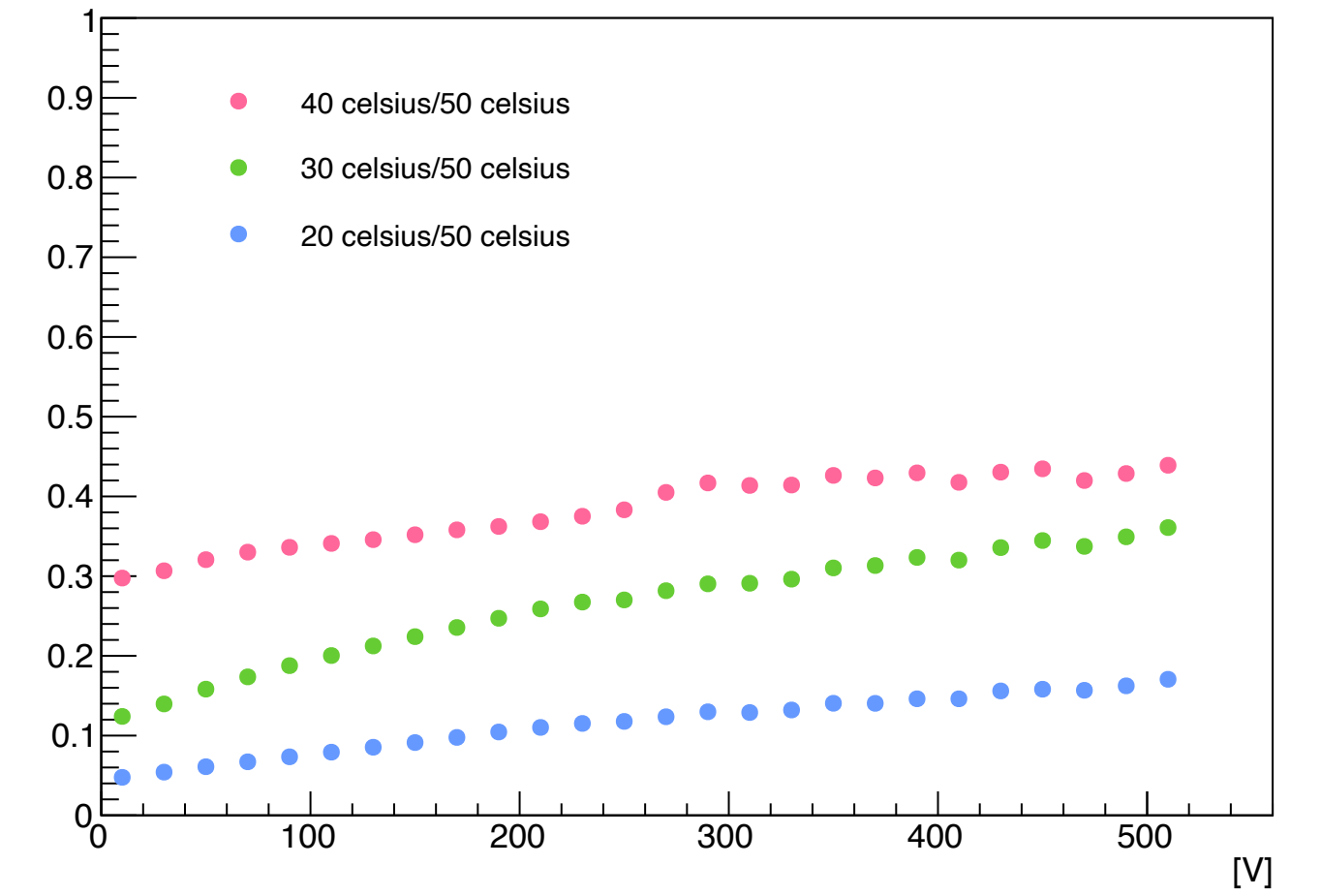
28T1_1



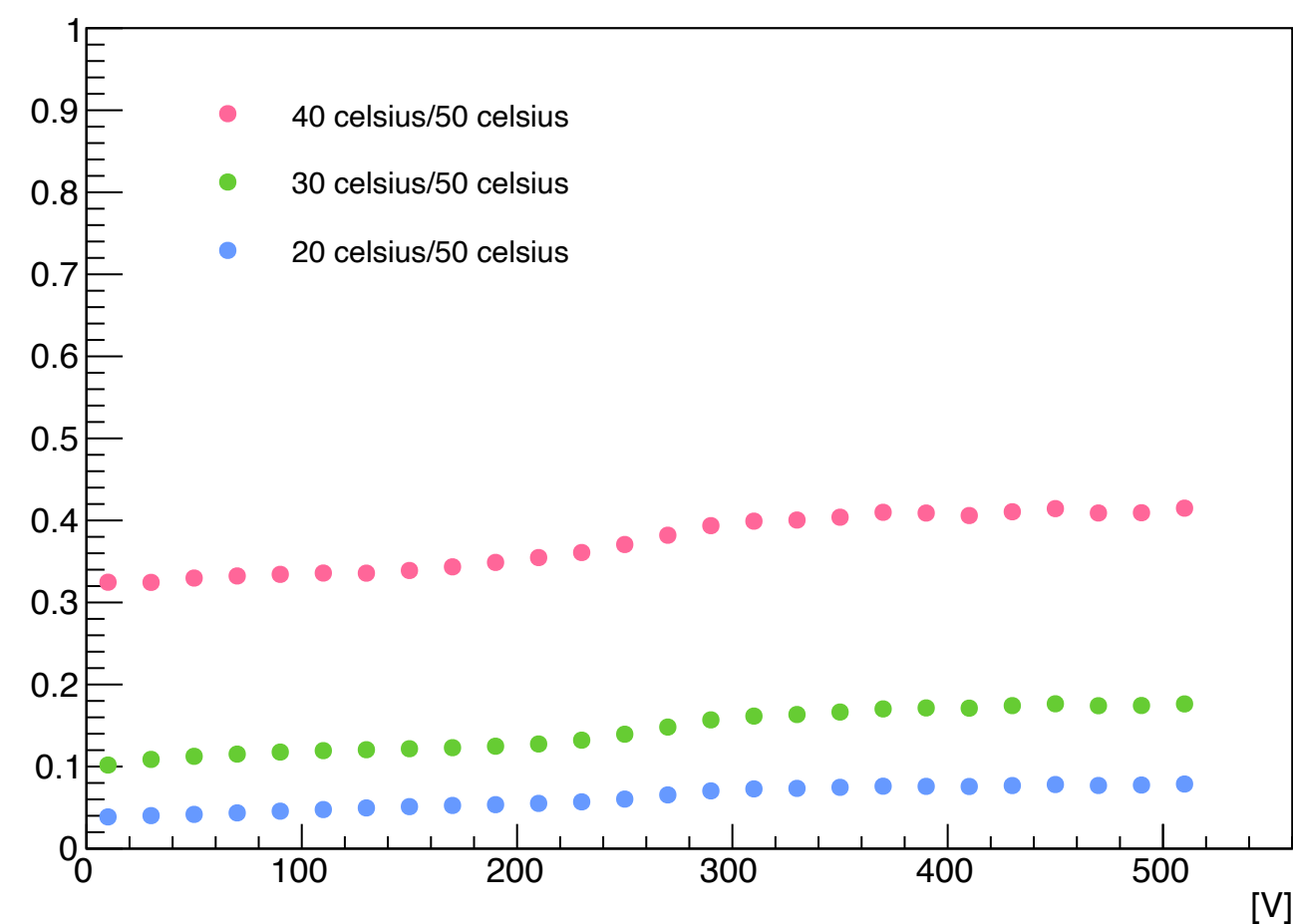
28L2_1



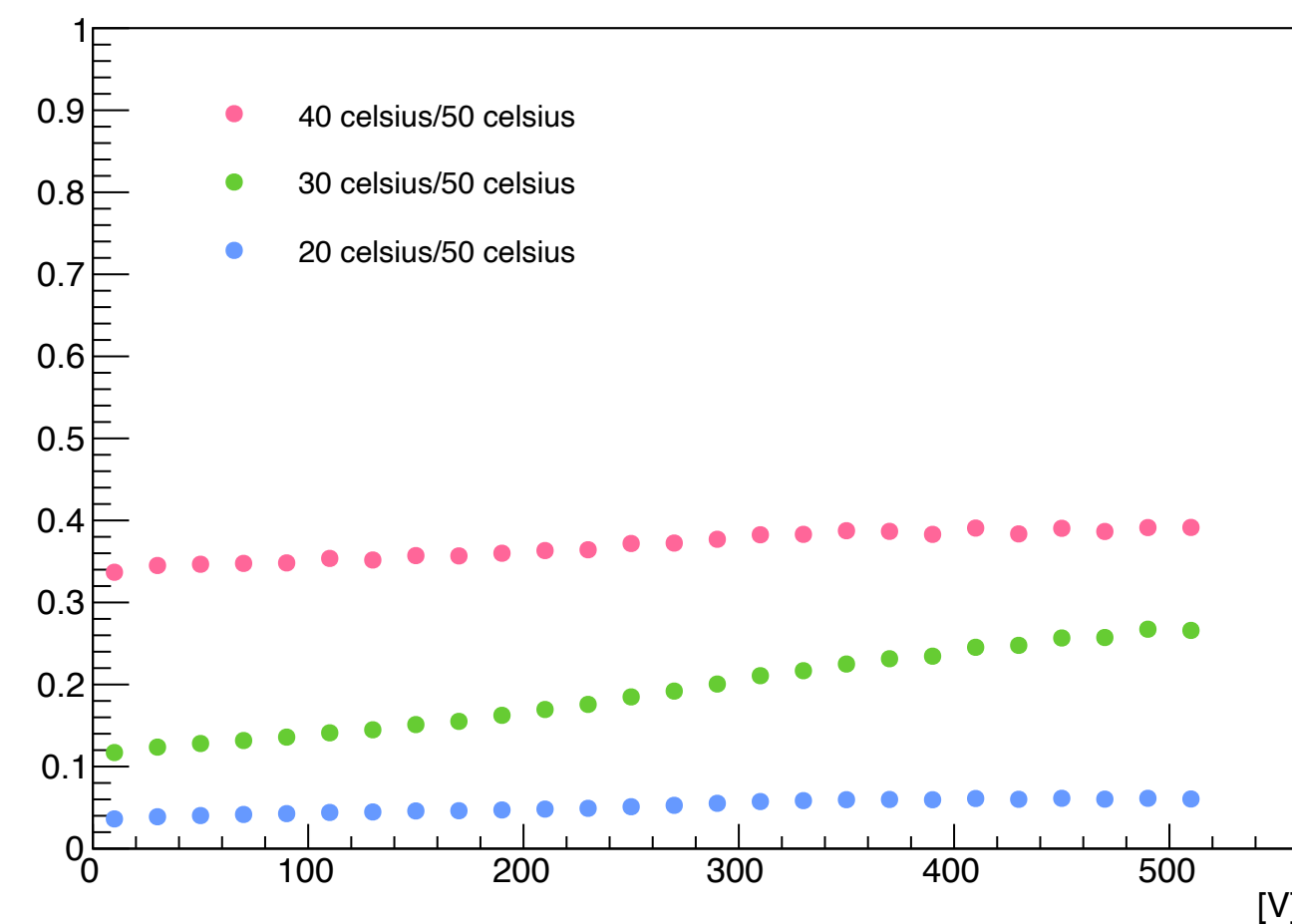
28B1_1



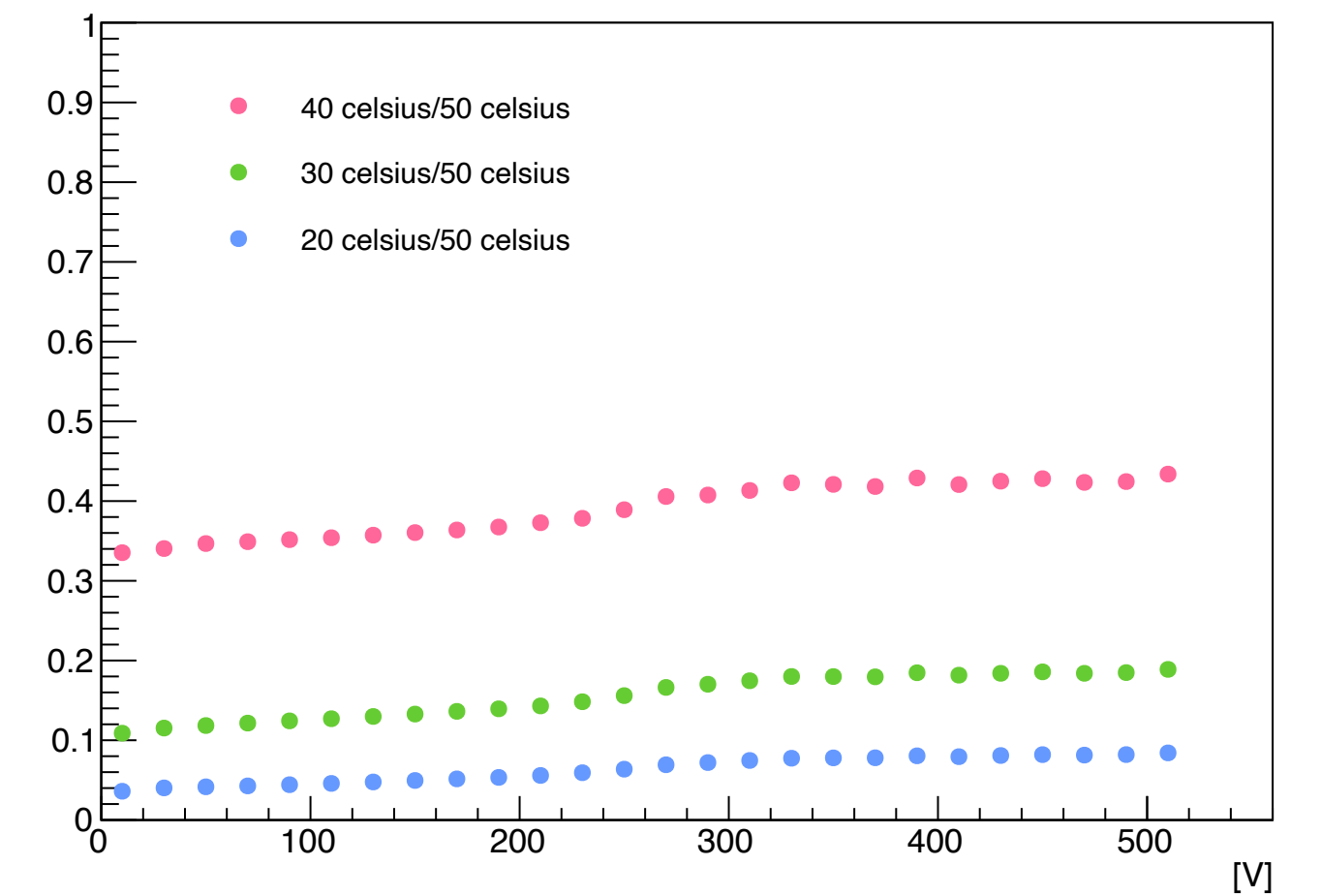
28T1_2



28L2_2



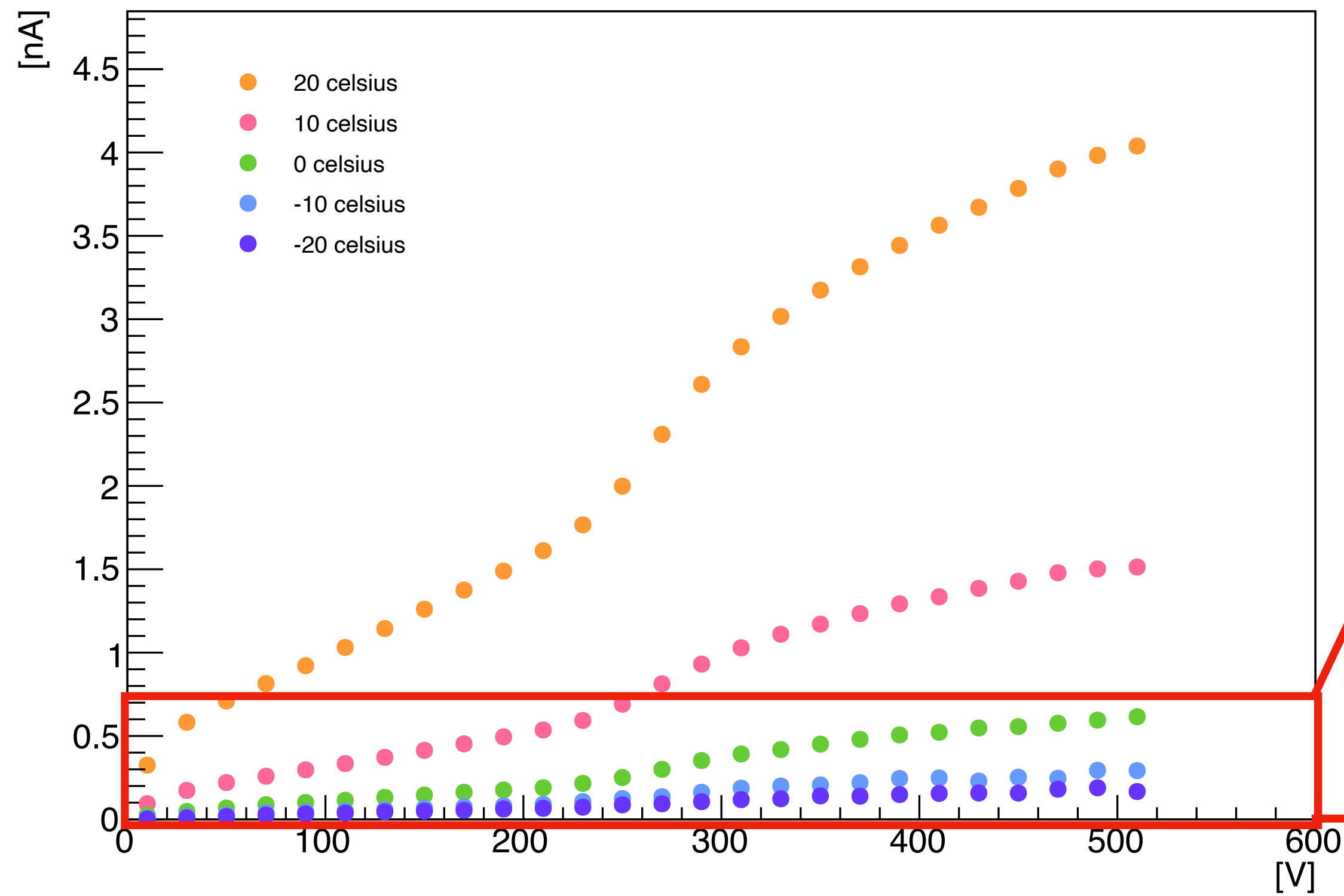
28B1_2



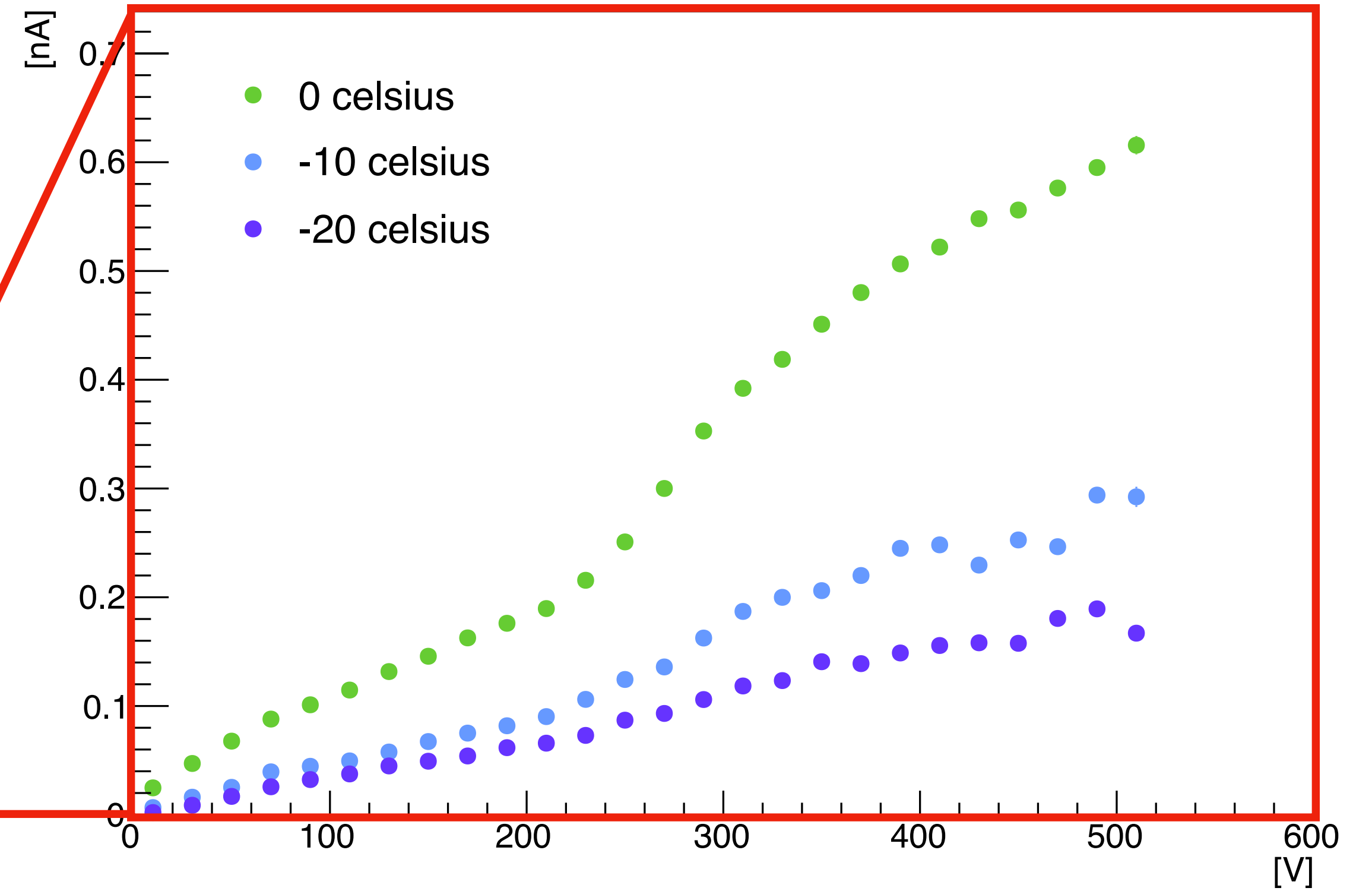
低温での測定

高温と同じように
温度を下げるほど
電流は小さくなる。

I-V 19L1_2 low temperature



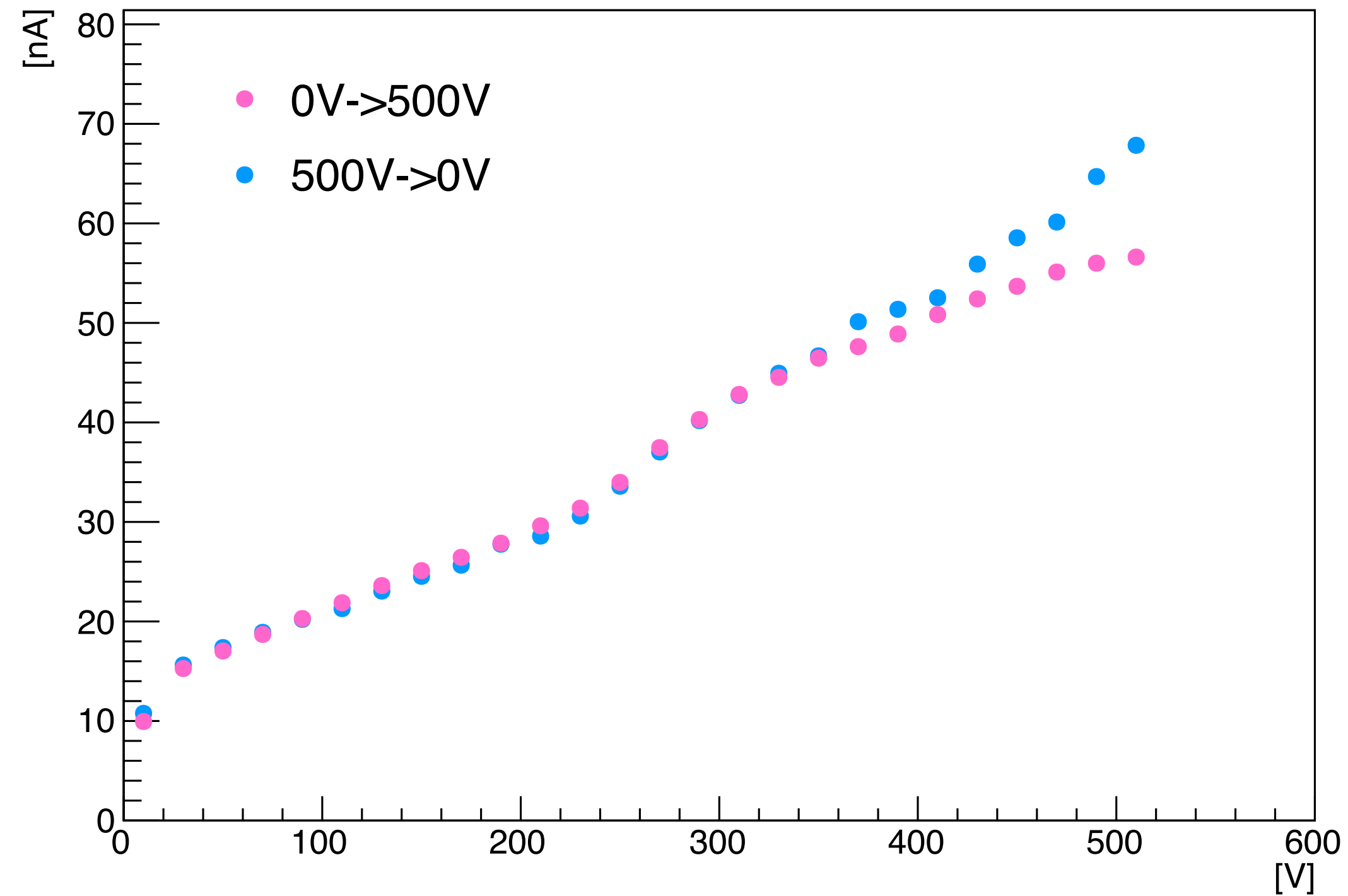
I-V 19L1_2 low temperature



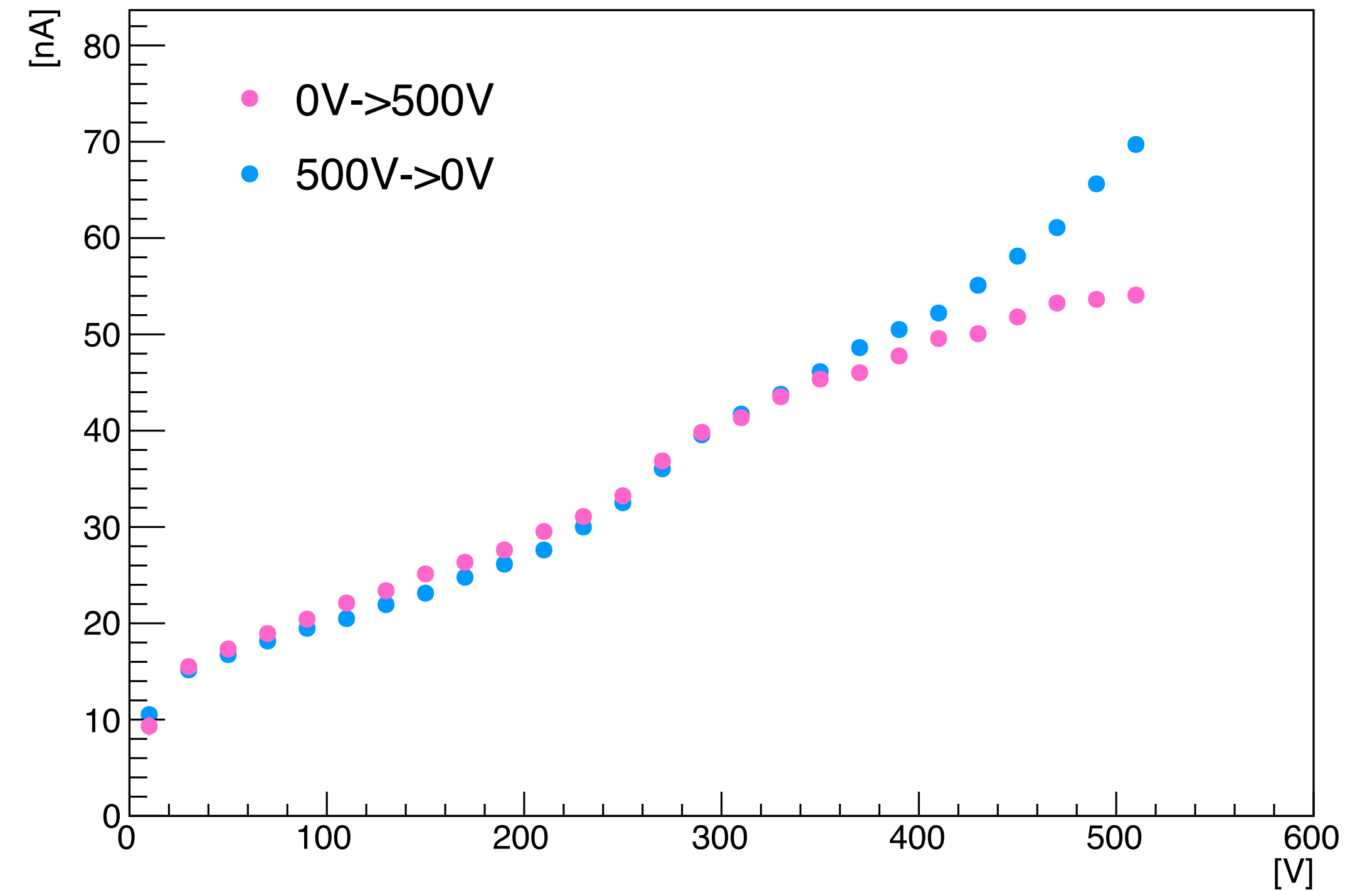
寄生容量の確認

0→500Vで測定した時と500→0V
で測定した時で差があった。
→寄生容量がある？

I-V 19L1_1



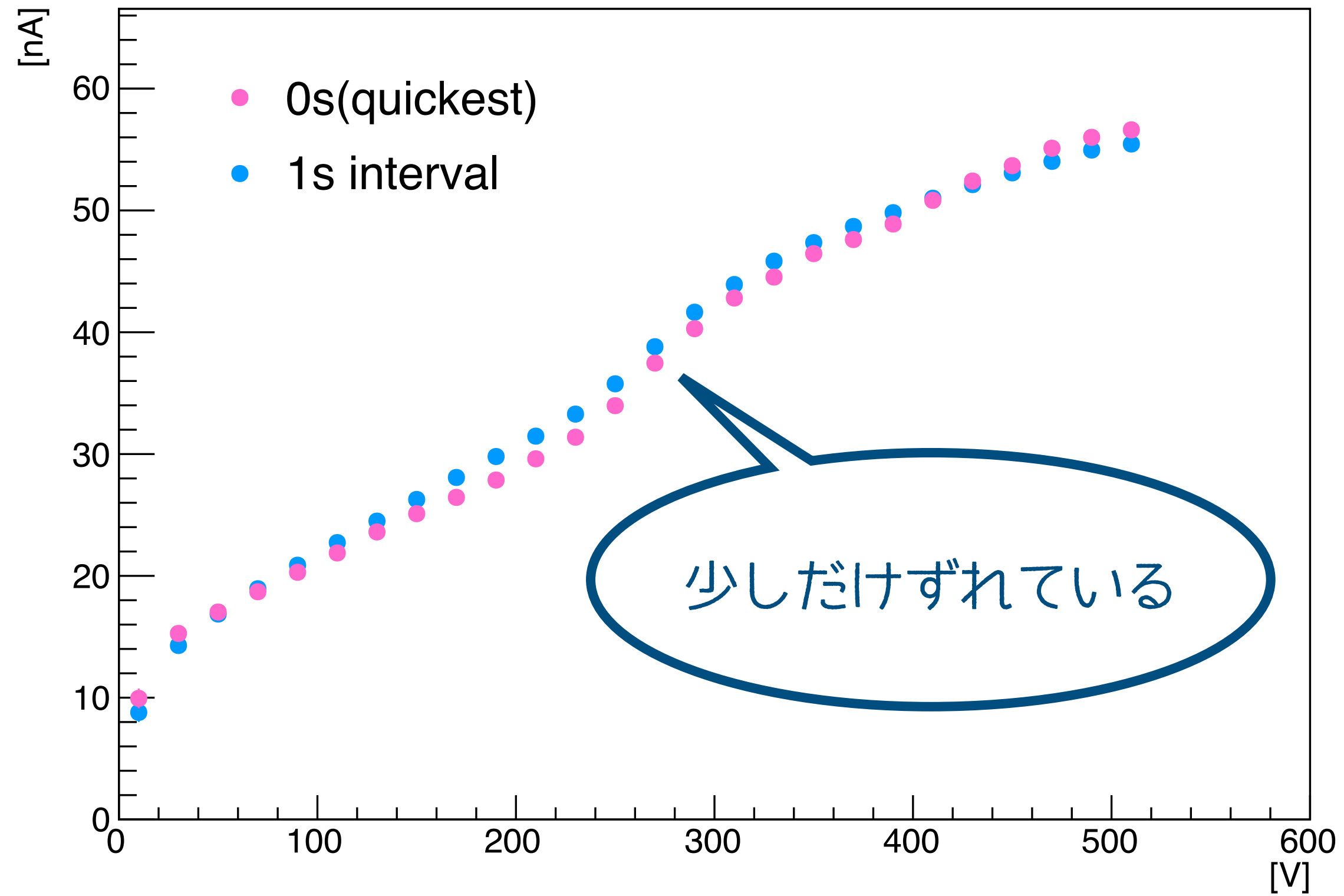
I-V 19L1_2



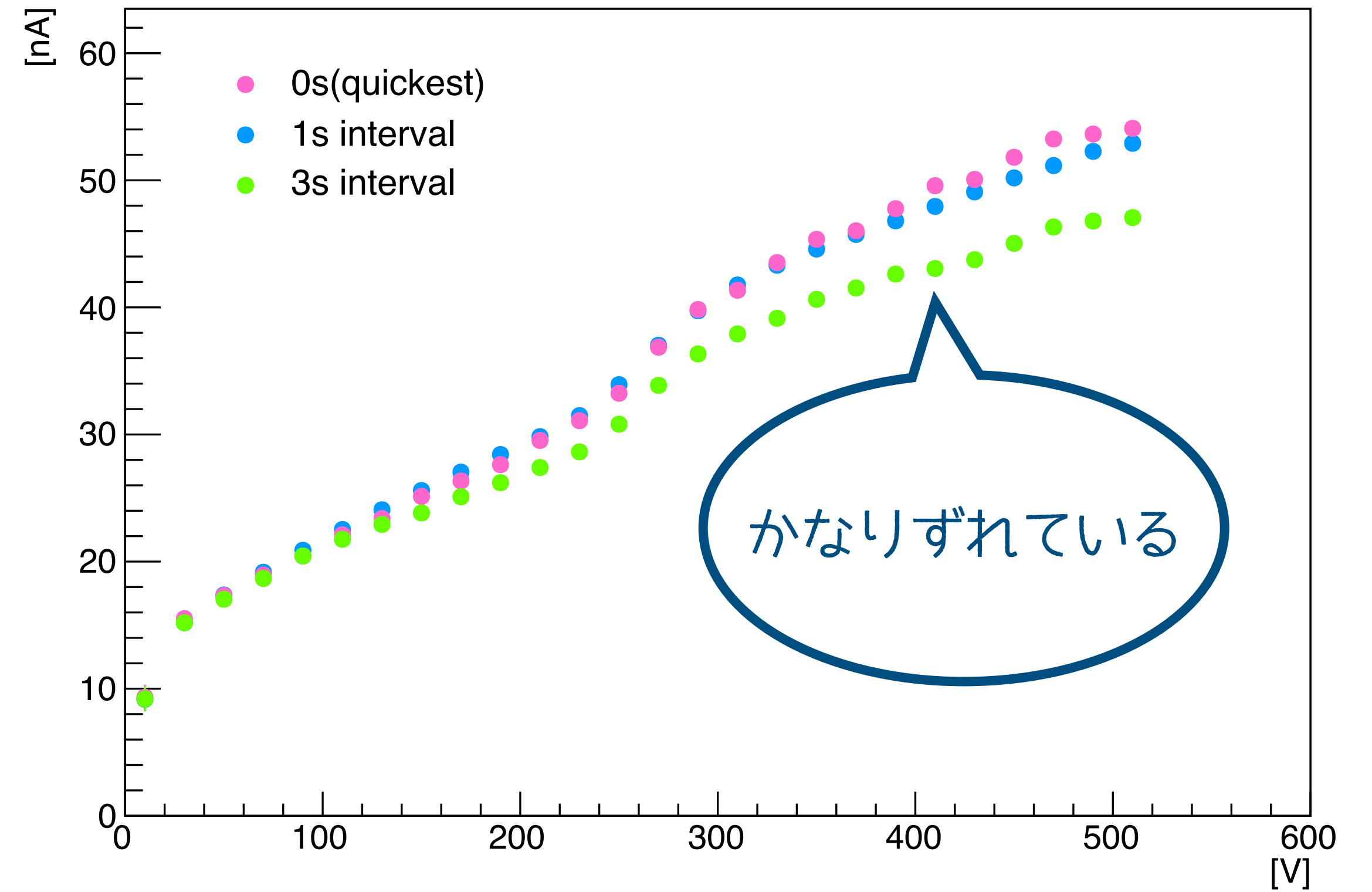
※位置などは全く変更なし

測定の時間間隔についての比較

I-V 19L1_1



I-V 19L1_2



ずれ→誤差となるはずのもの
→系統誤差を考慮する必要がある。

※位置などは全く変更なし

まとめと今後の課題

まとめ

- シリコンチップのI-V特性を測定するためのセットアップを構築した。
- 計27枚のチップのI-V特性を測定し、放射線照射前後で比較するための前段階の測定が完了した。
 - 構築したセットアップで測定が可能であると分かった。
 - それぞれのチップの暗電流が分かった。
- いくつかのチップについて温度依存性を調べた。
 - 温度による違いの特徴が分かった。

今後の課題

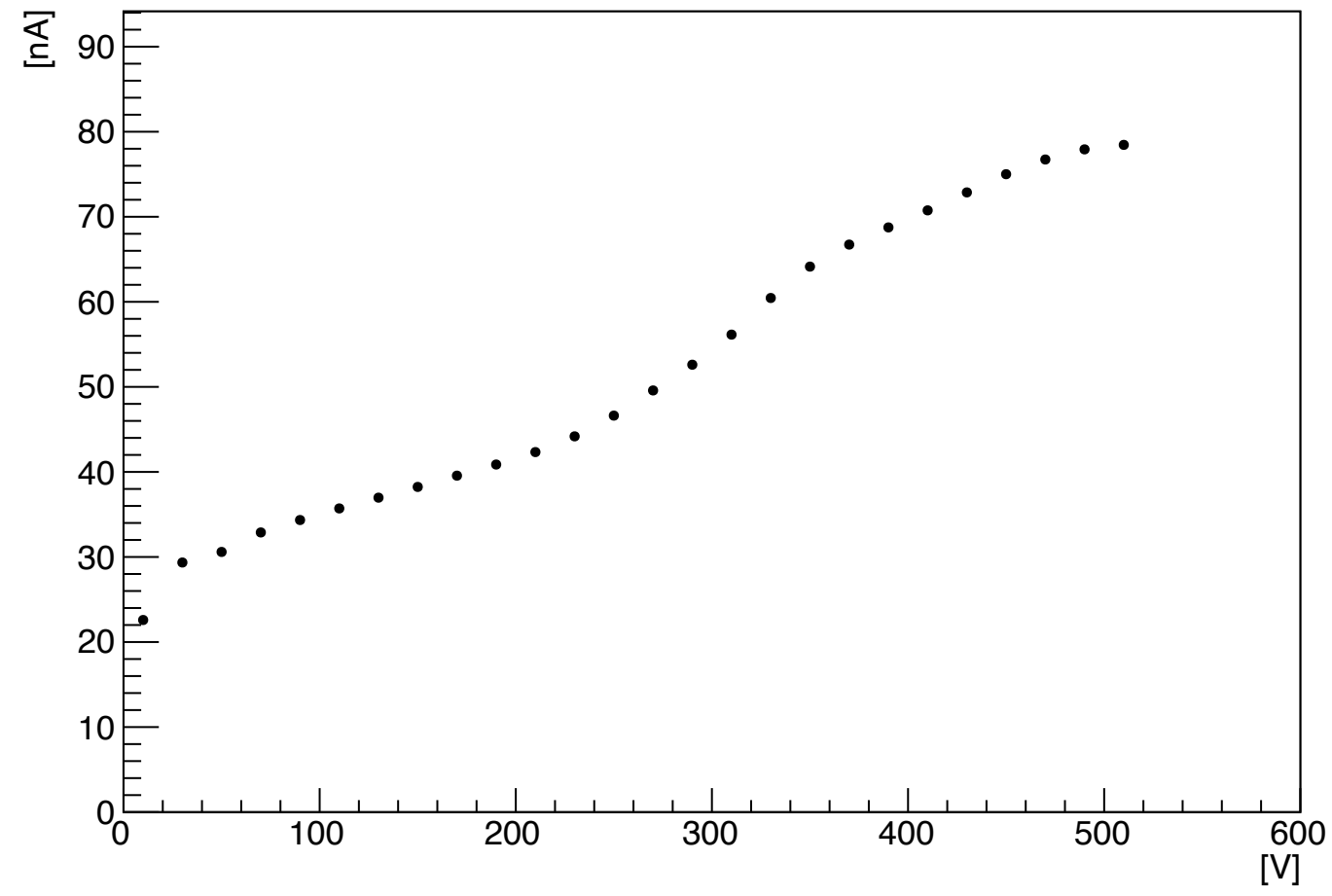
- 放射線照射後のチップのI-V特性を測定し、照射前後で比較する。
- 系統誤差について検討する。

Back Up

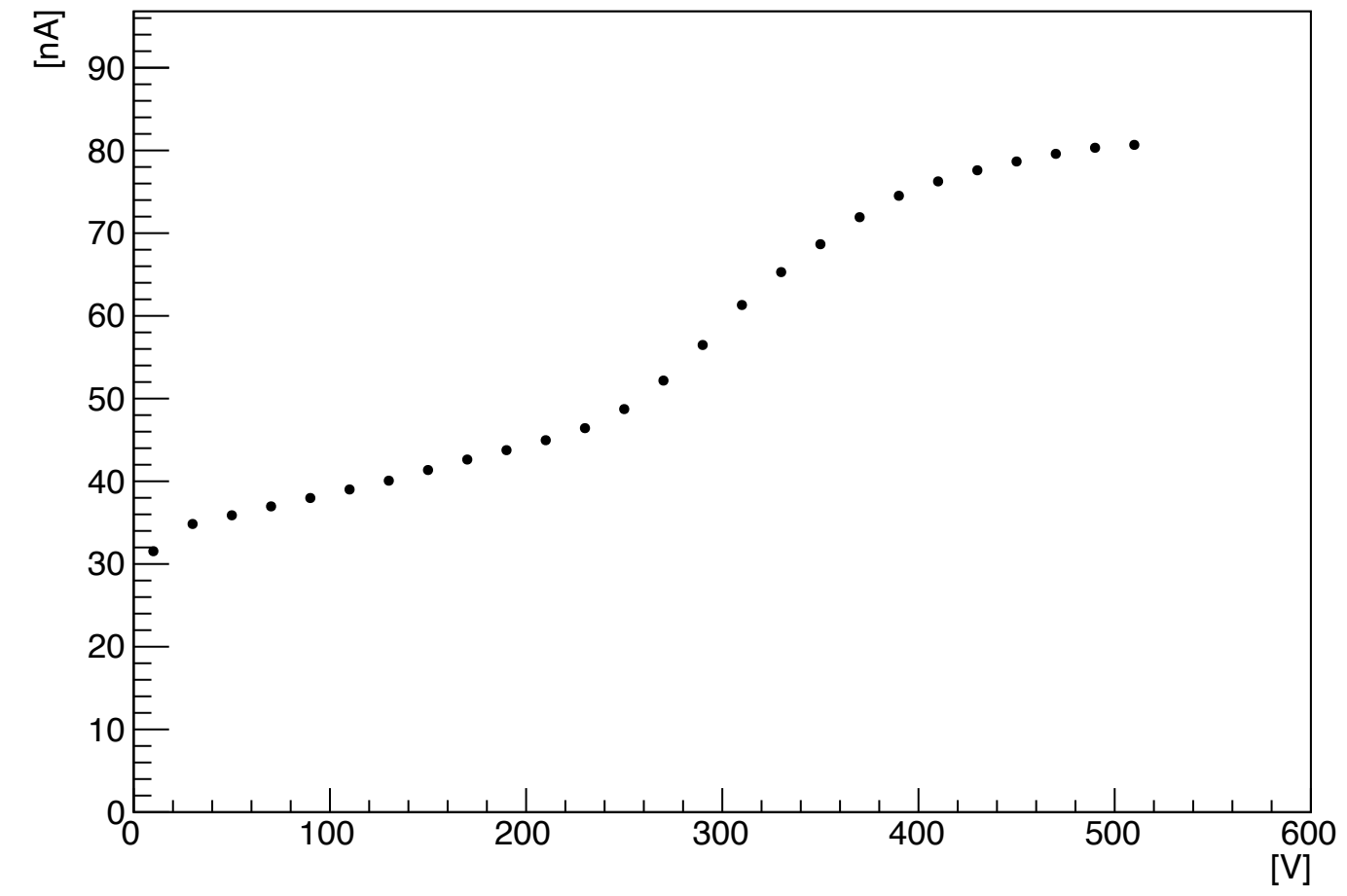
測定結果

14 (2cm× 2cm)

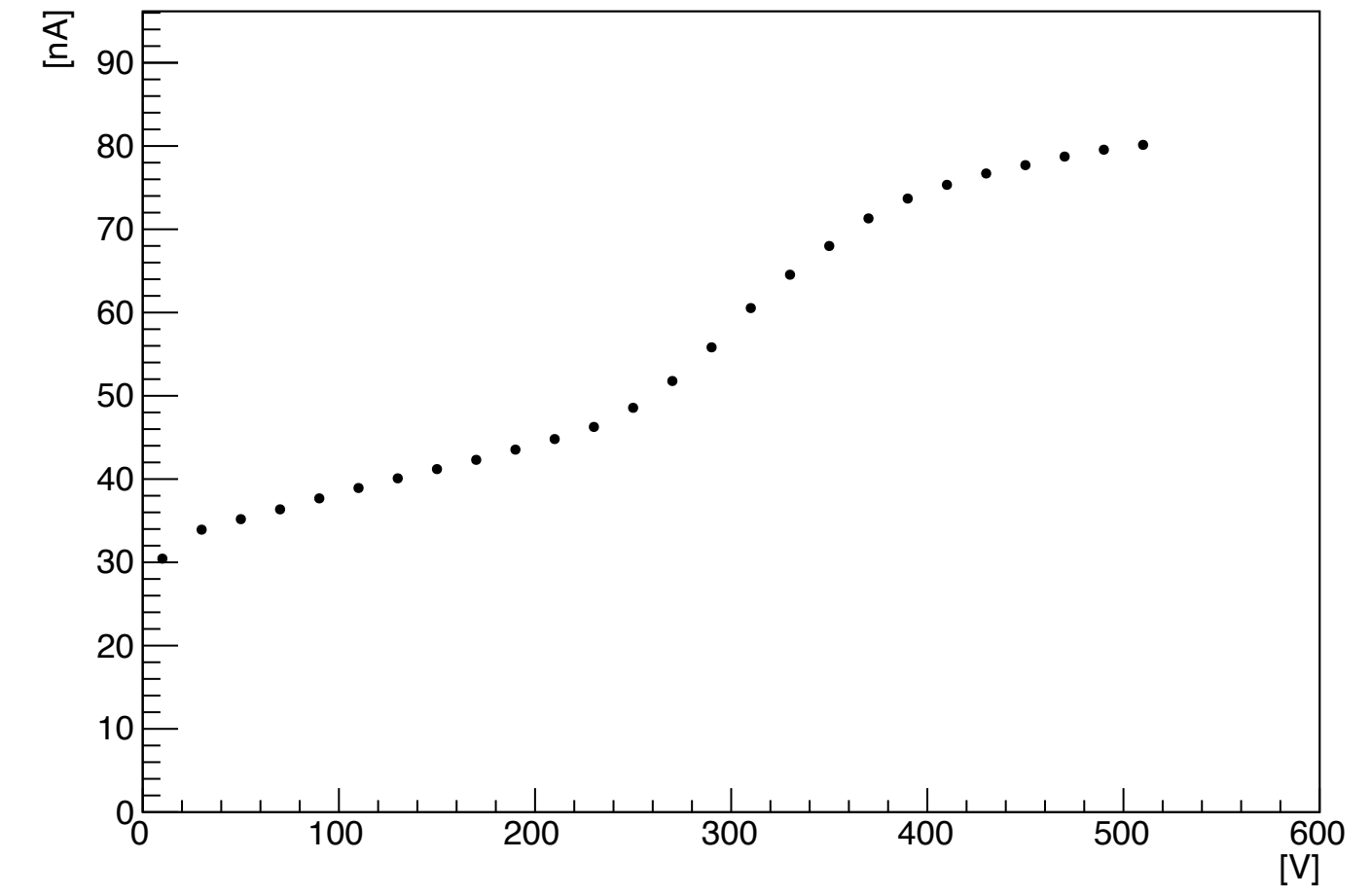
I-V 14_1



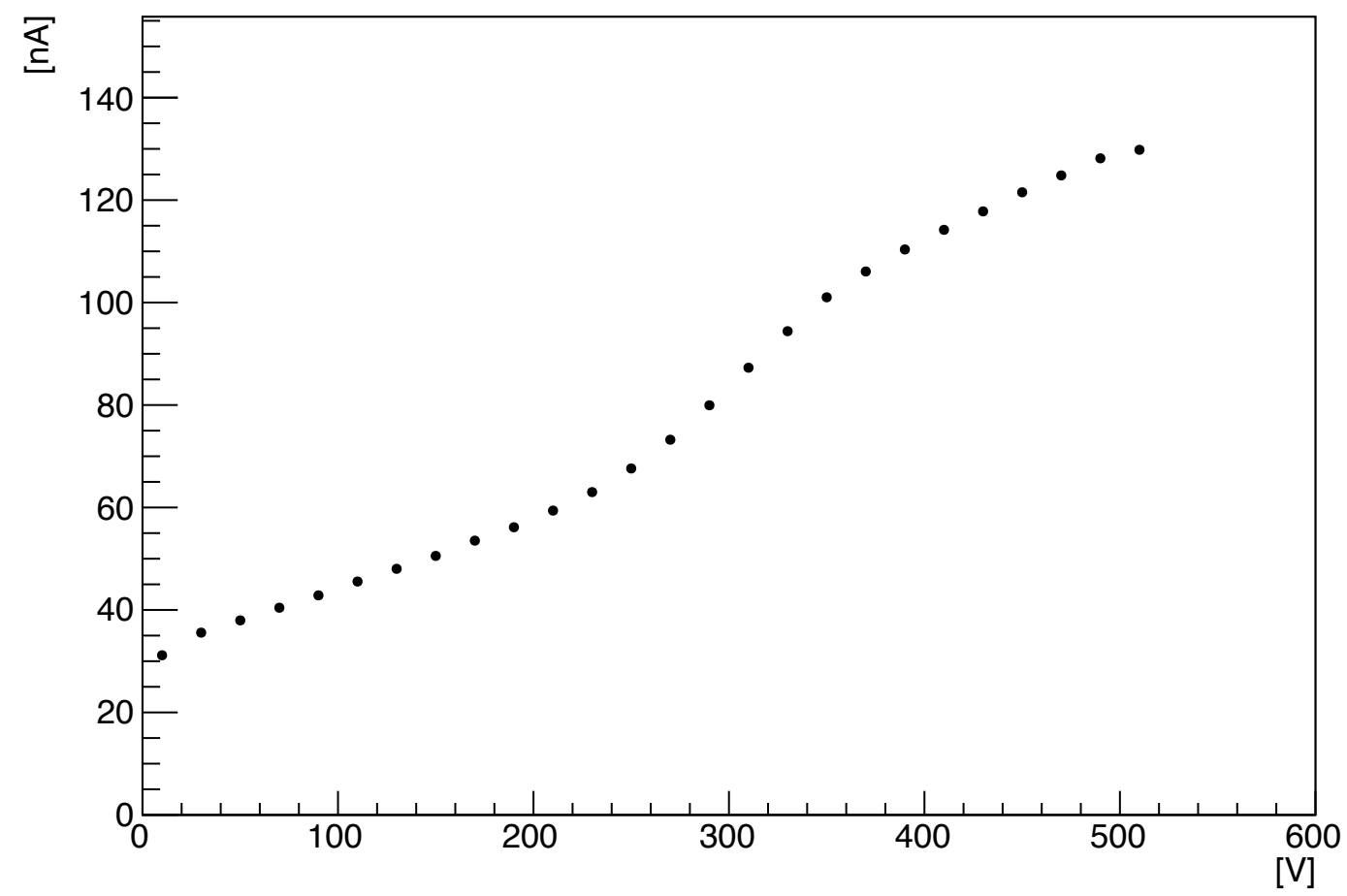
I-V 14_2



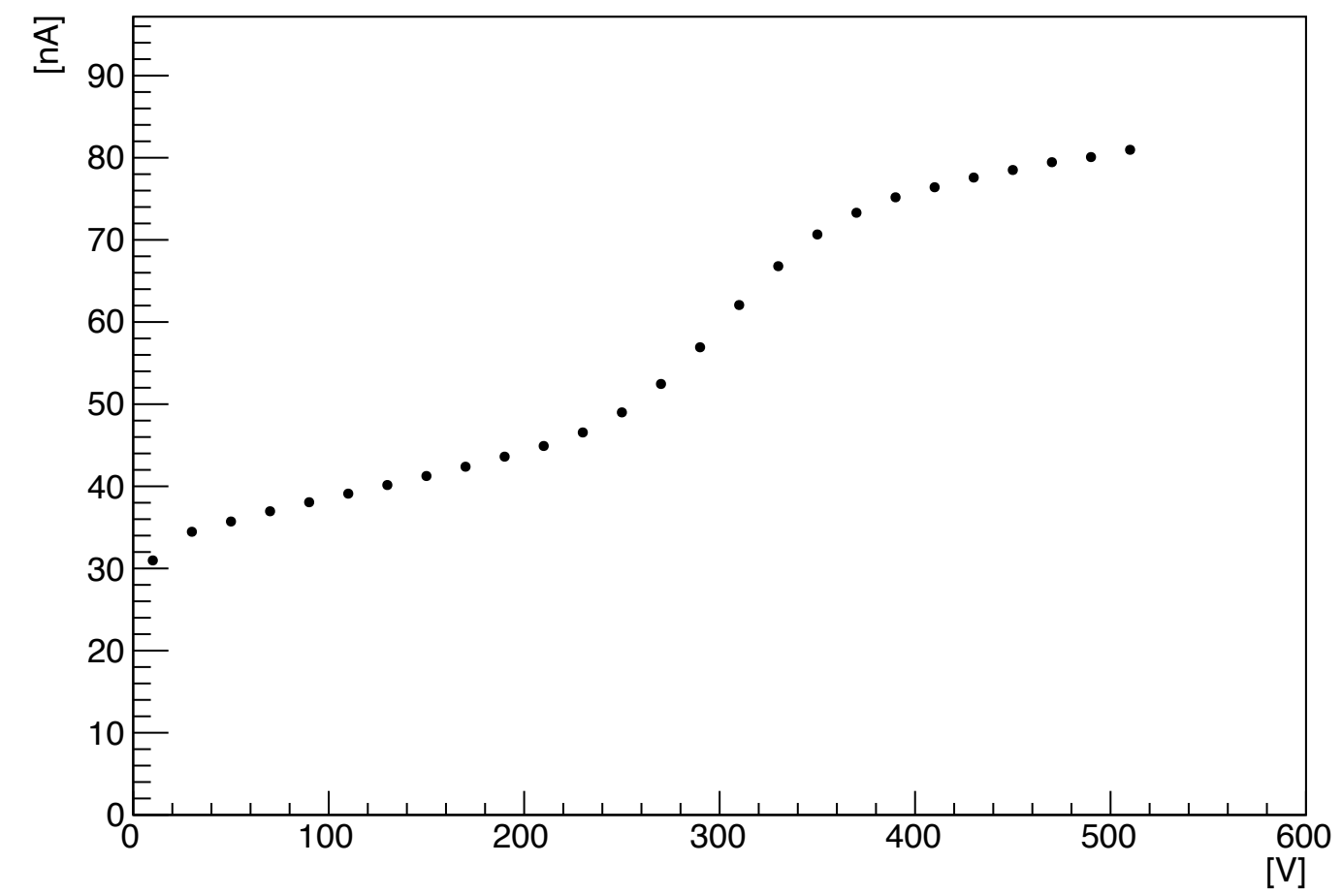
I-V 14_3



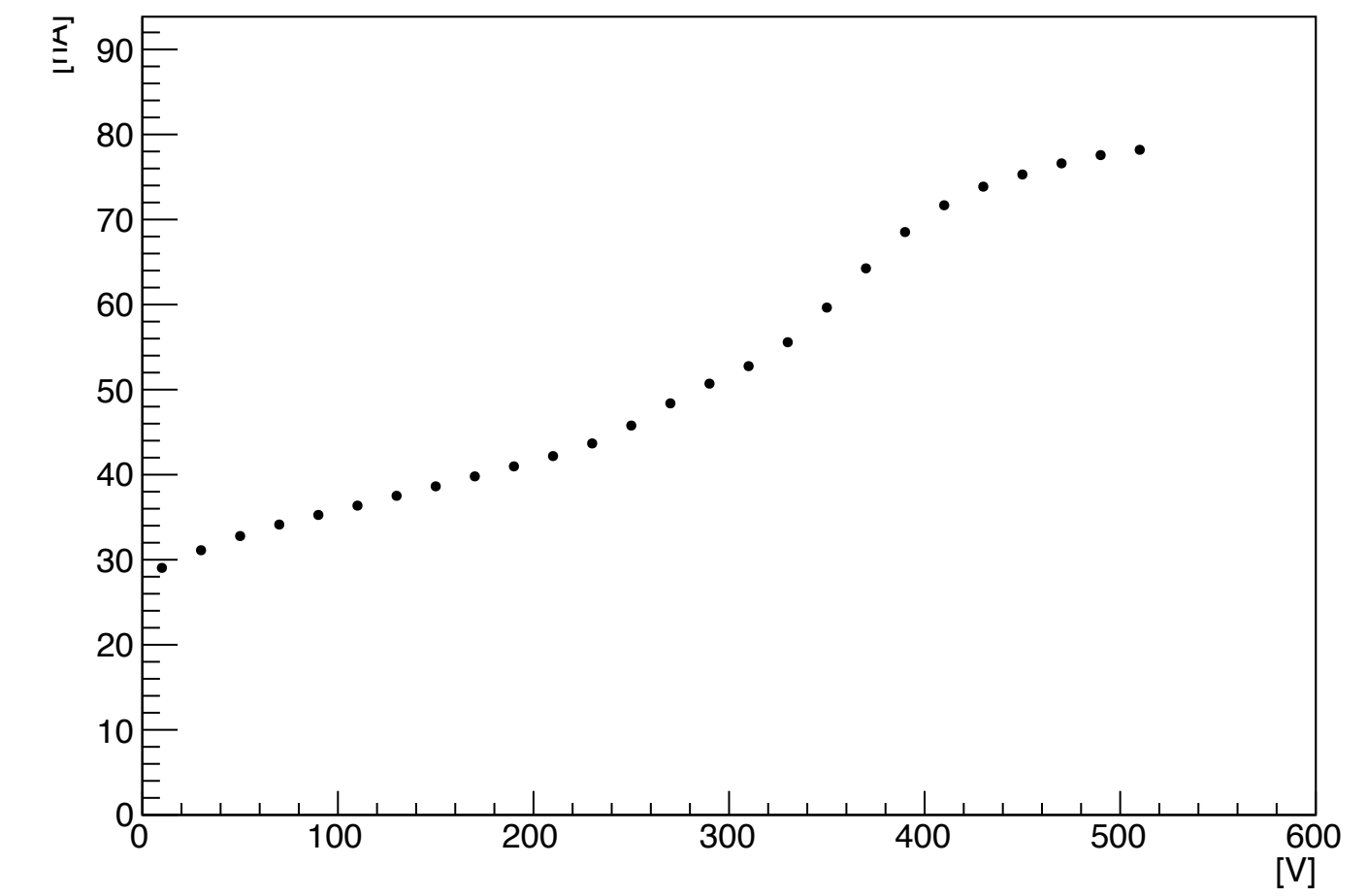
I-V 14_4



I-V 14_5



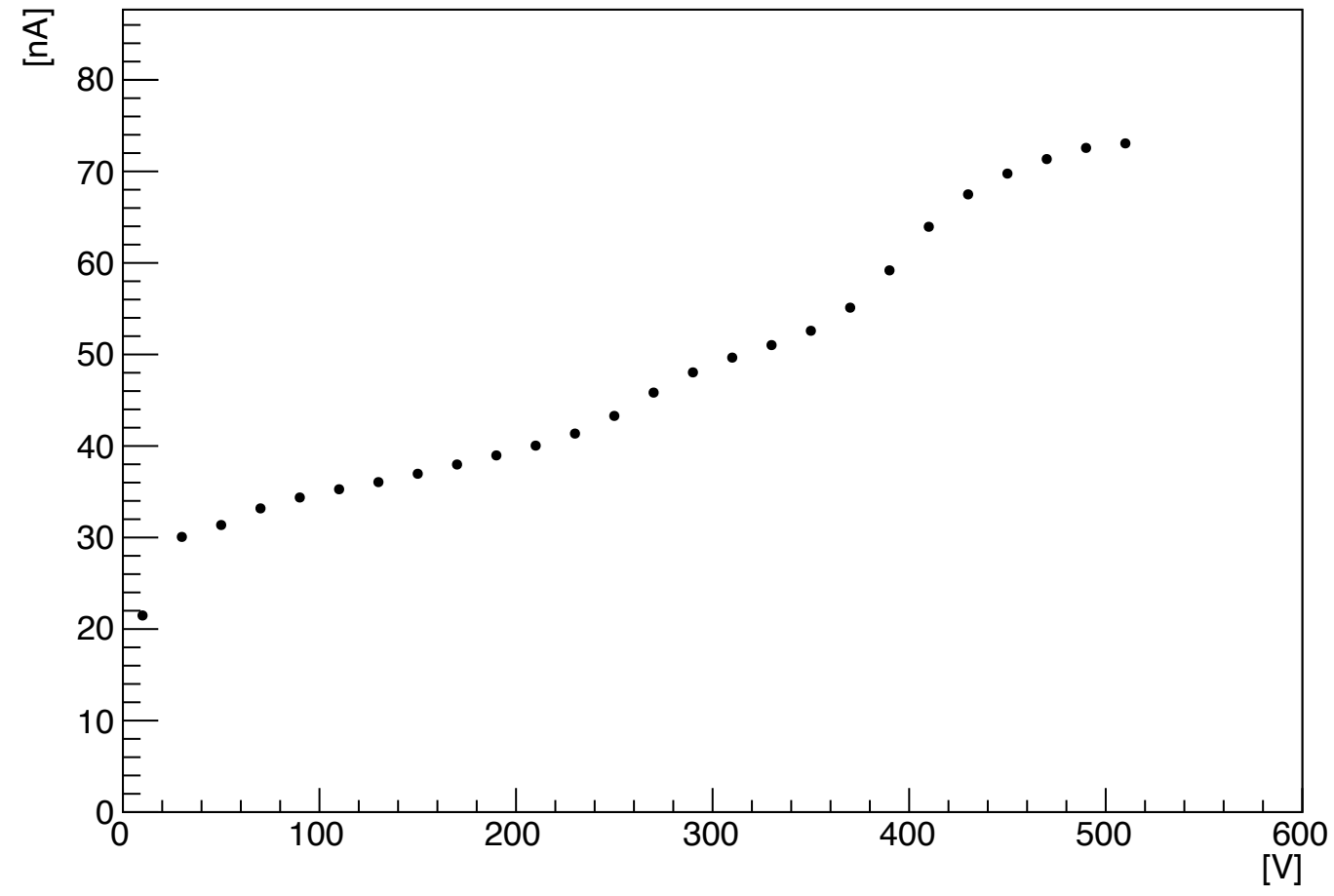
I-V 14_6



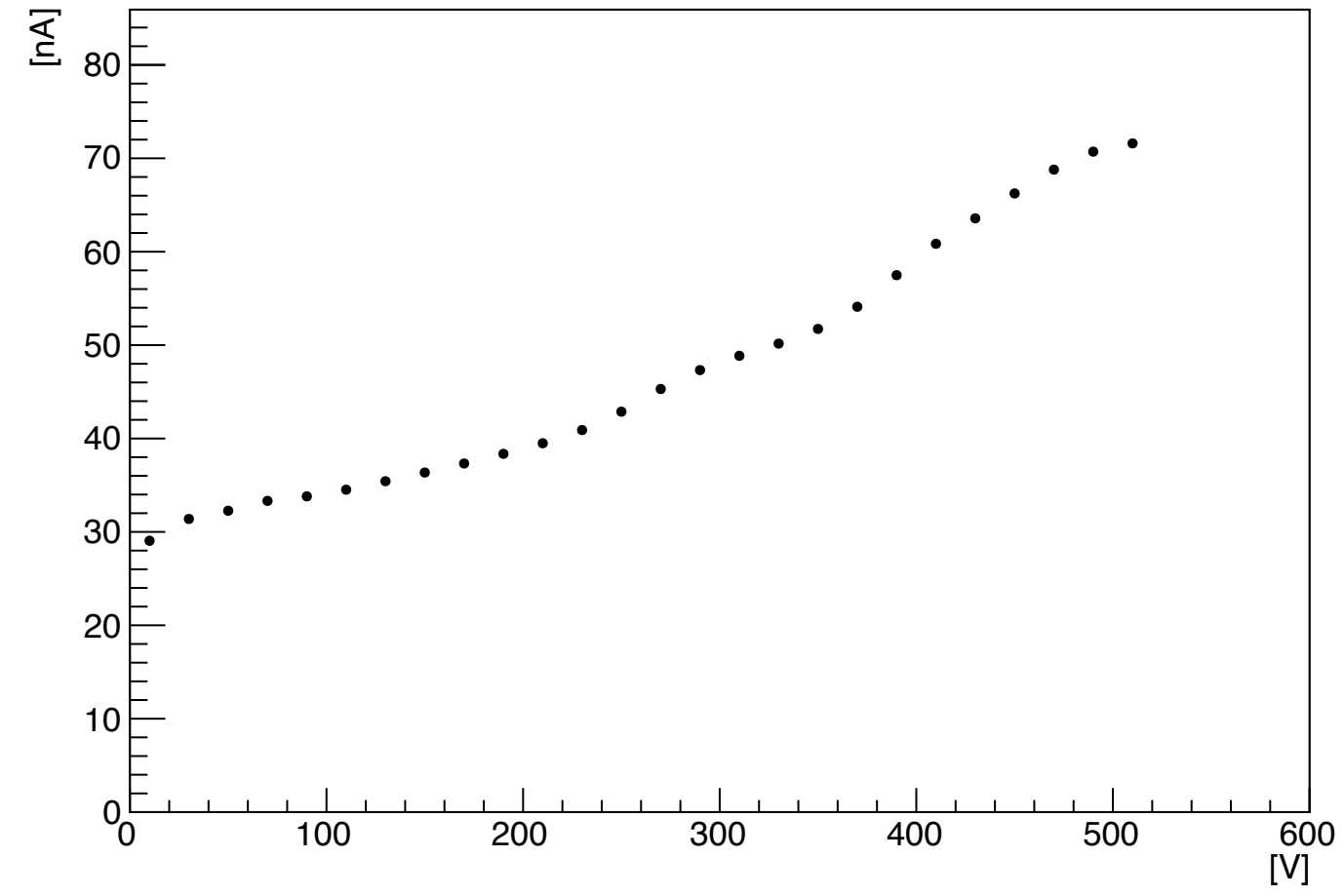
測定結果

19 (2cm× 2cm)

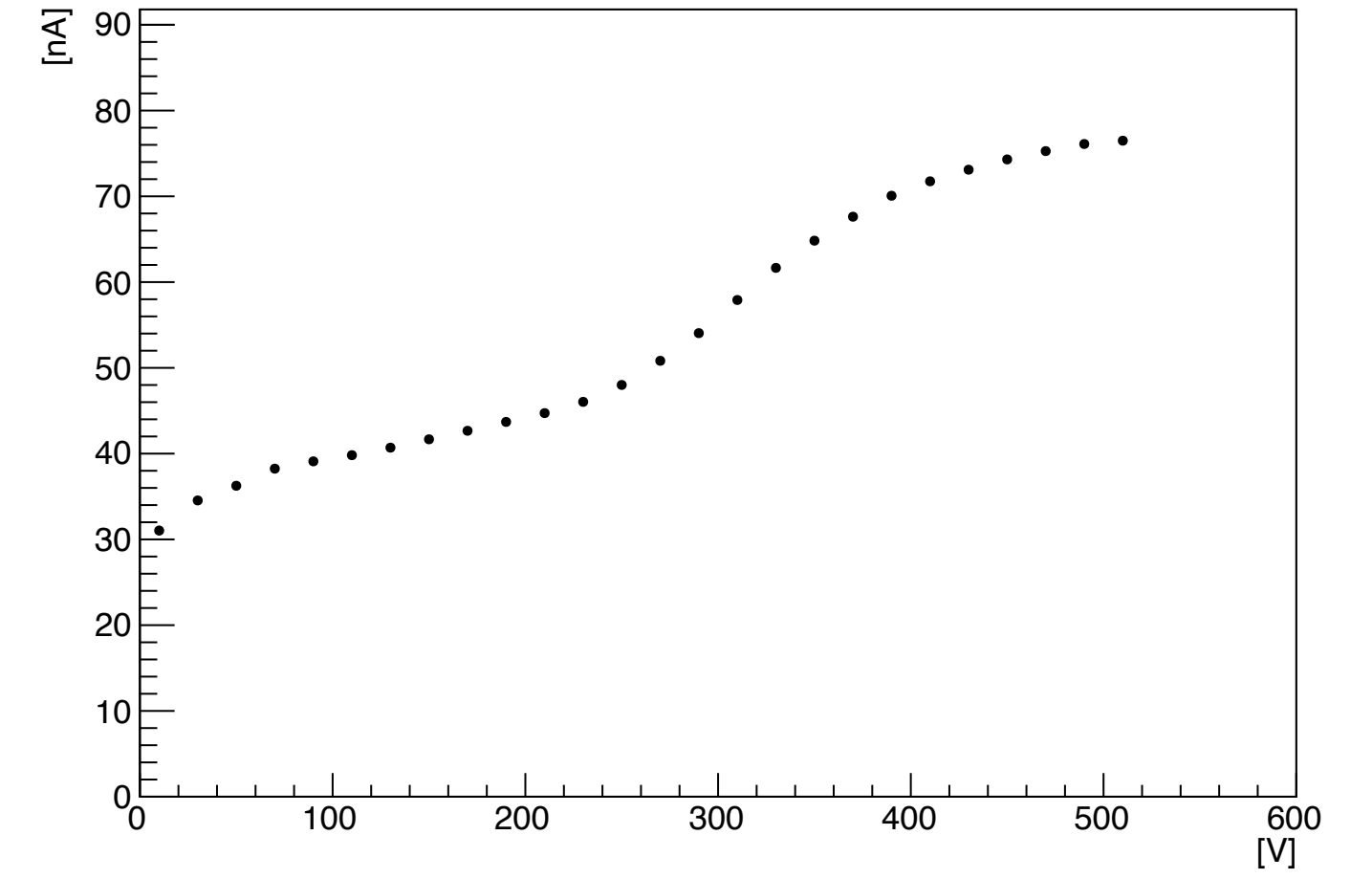
I-V 19_1



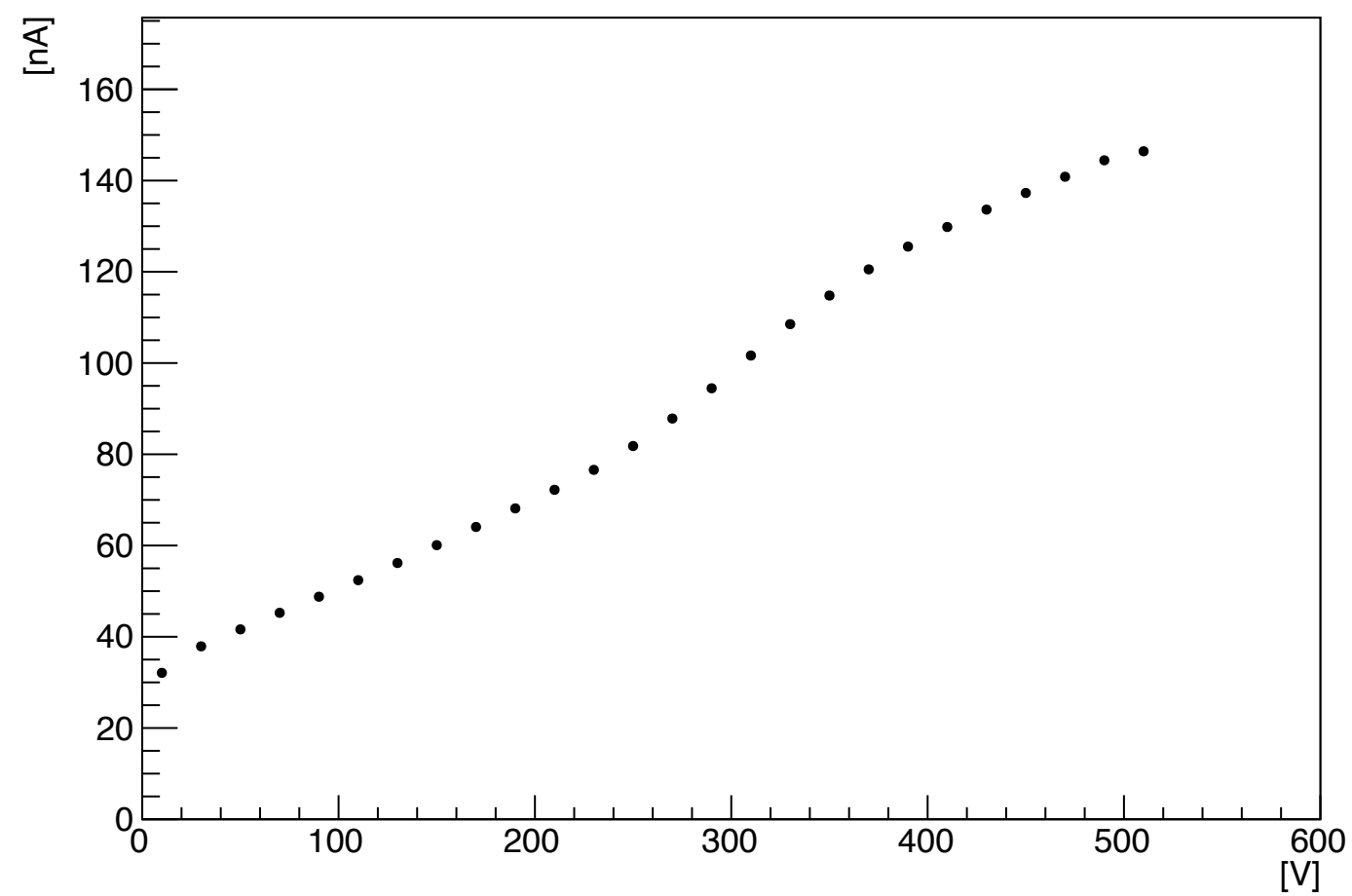
I-V 19_2



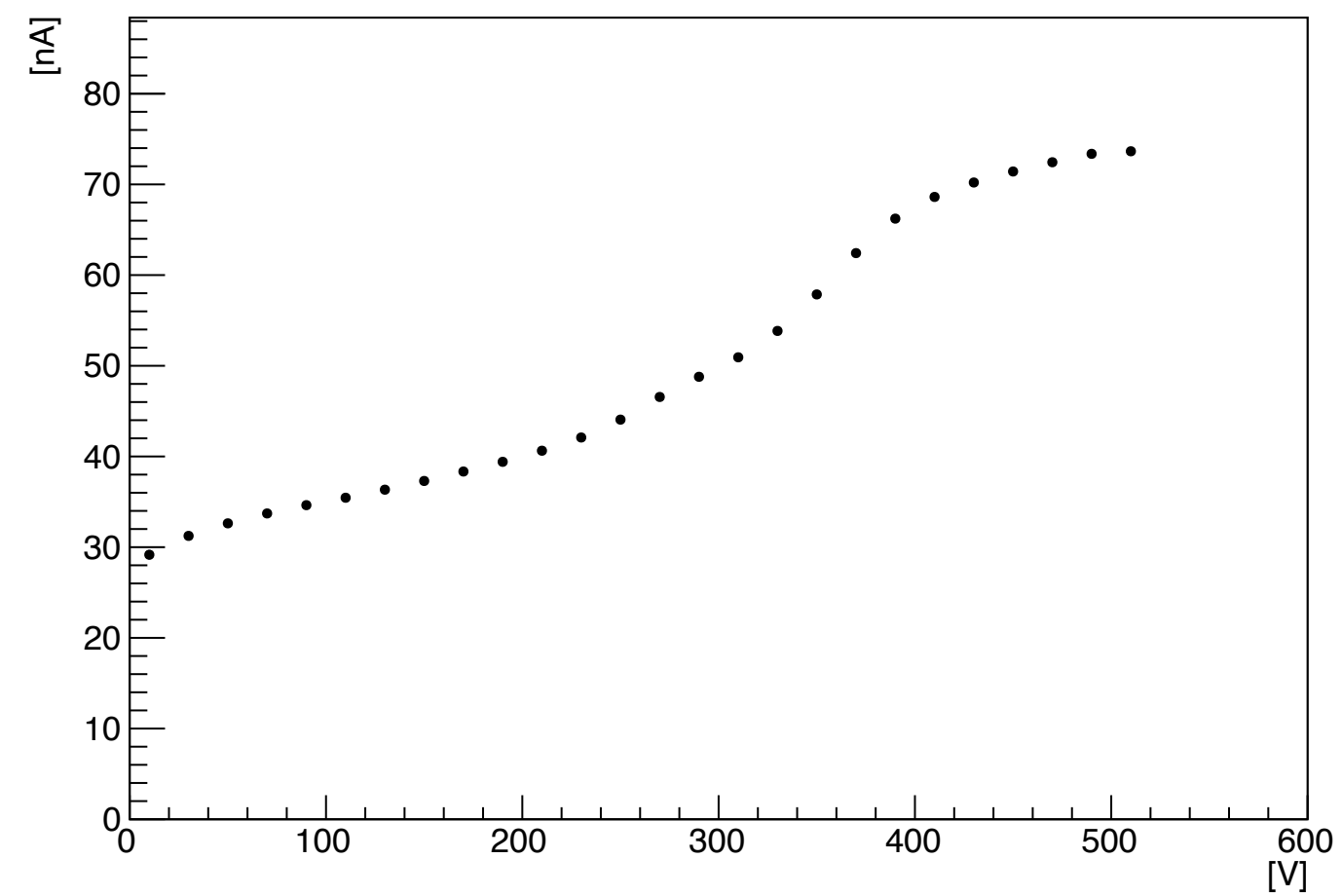
I-V 19_3



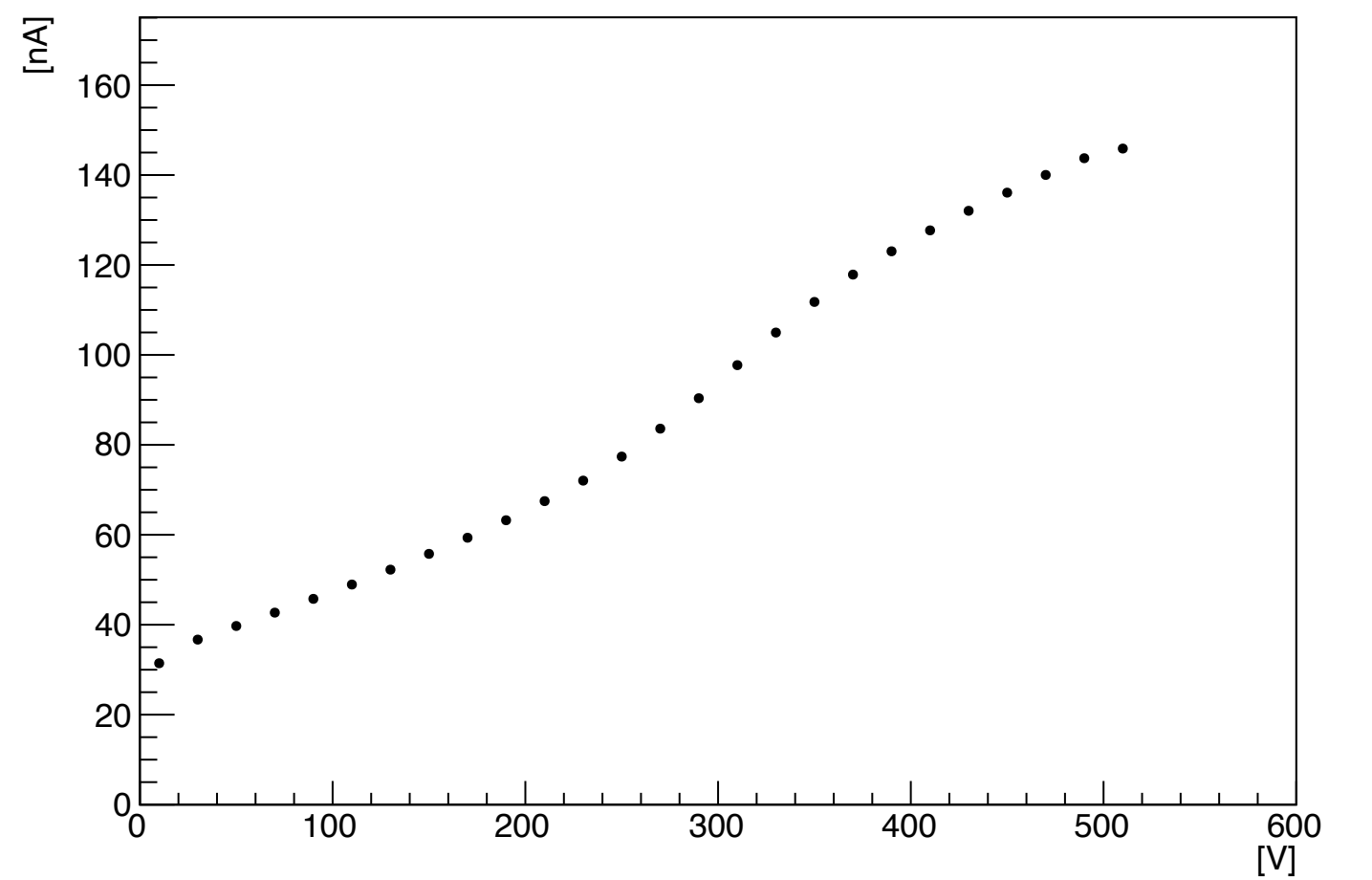
I-V 19_4



I-V 19_5



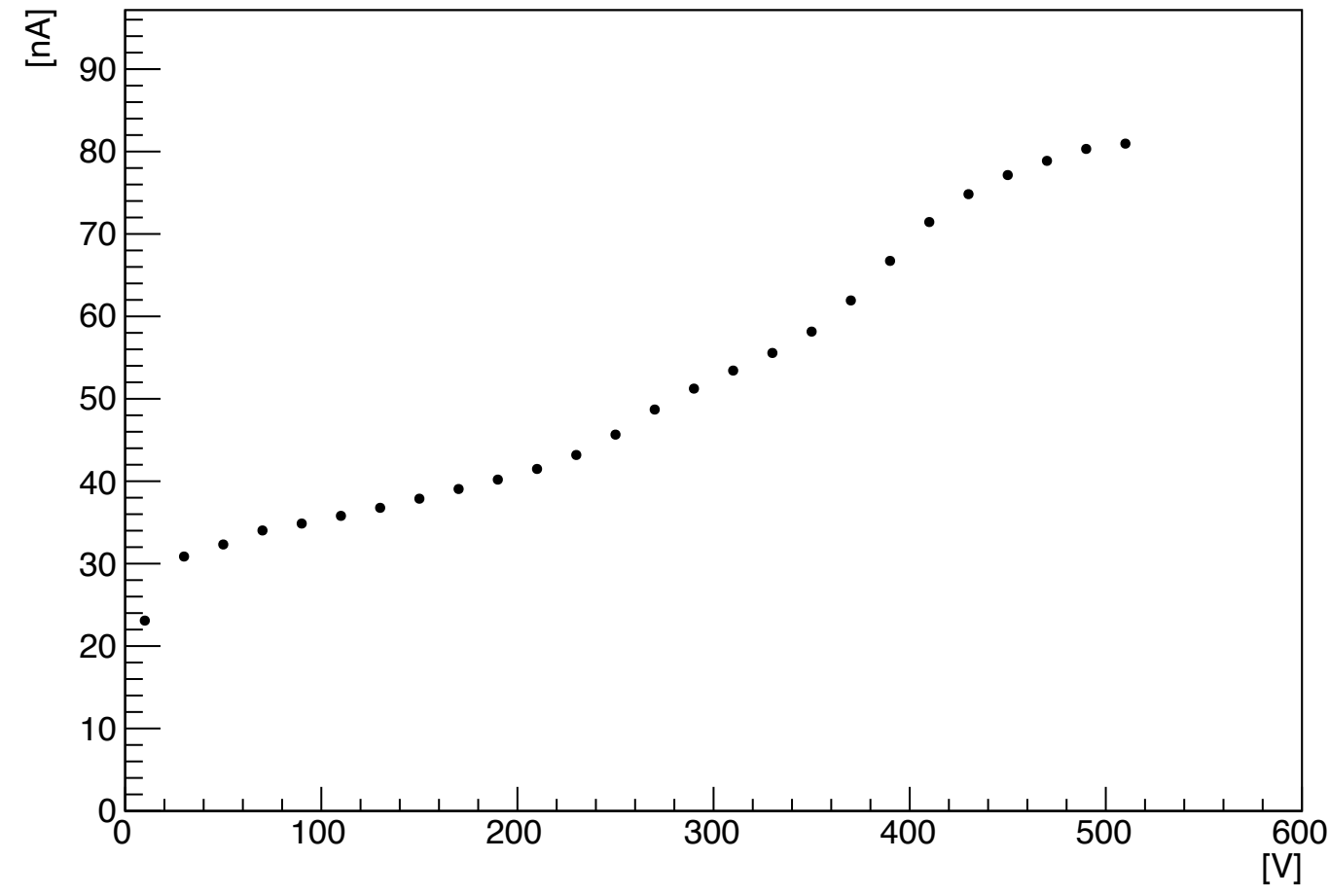
I-V 19_6



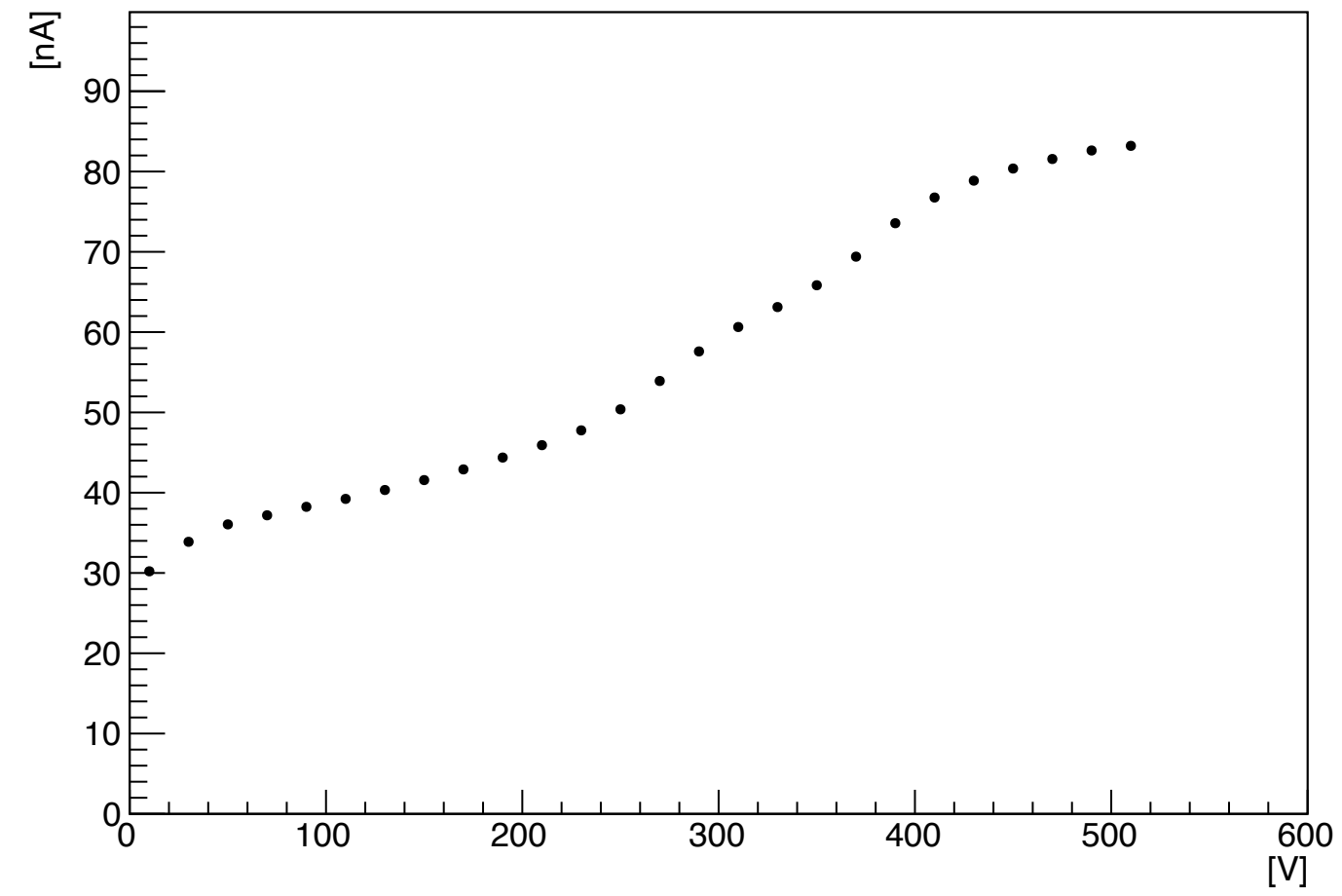
測定結果

28 (2cm× 2cm)

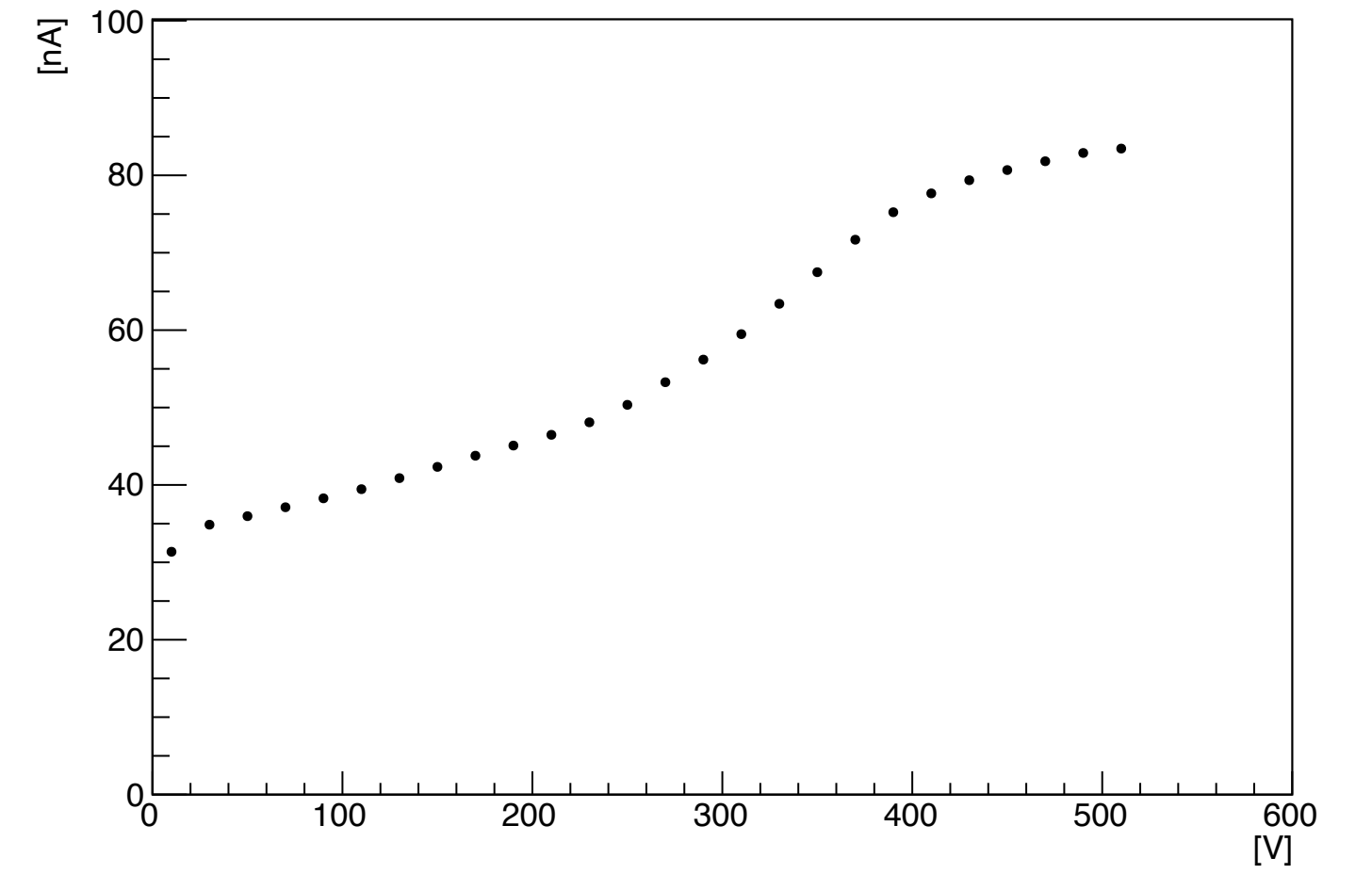
I-V 28_1



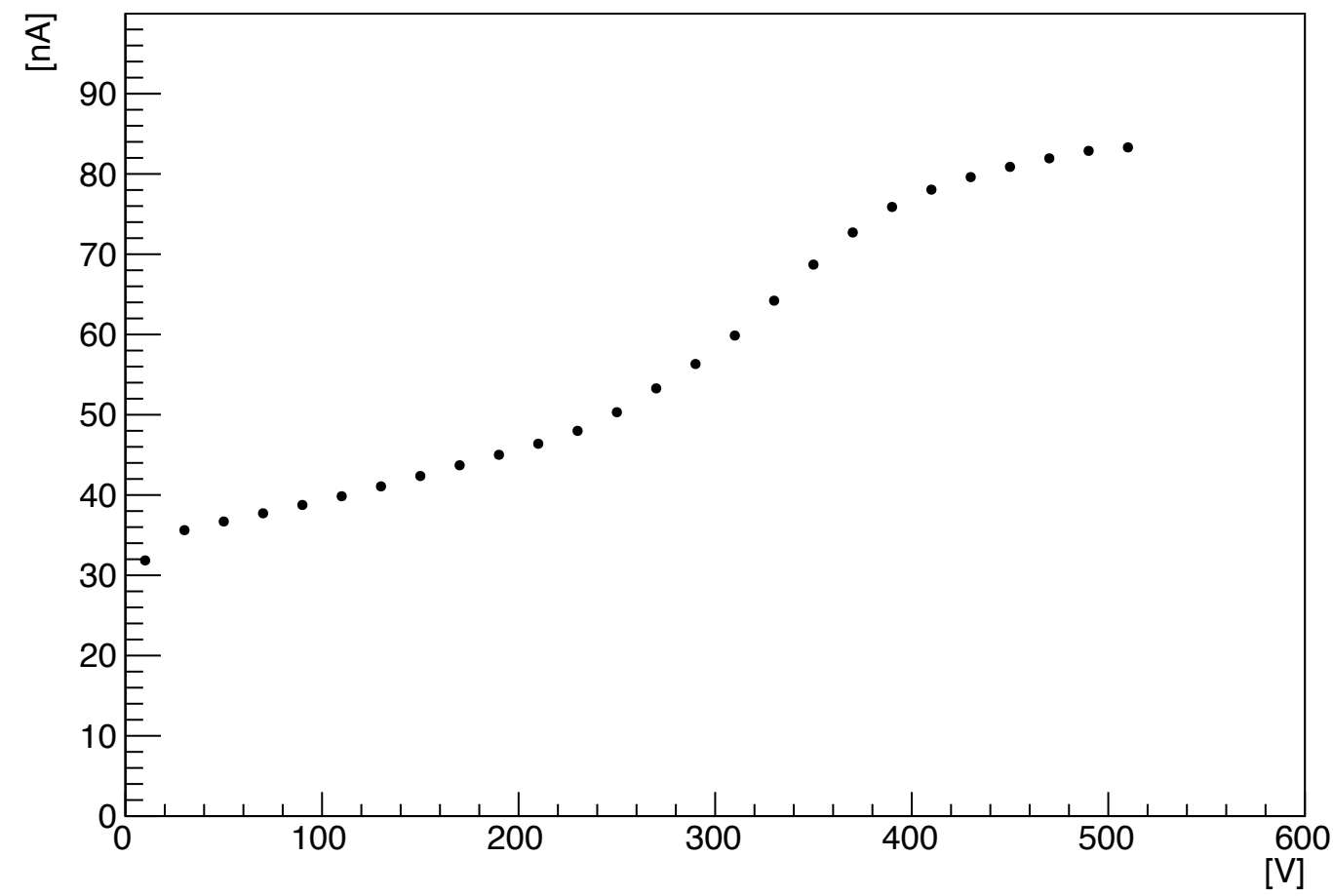
I-V 28_2



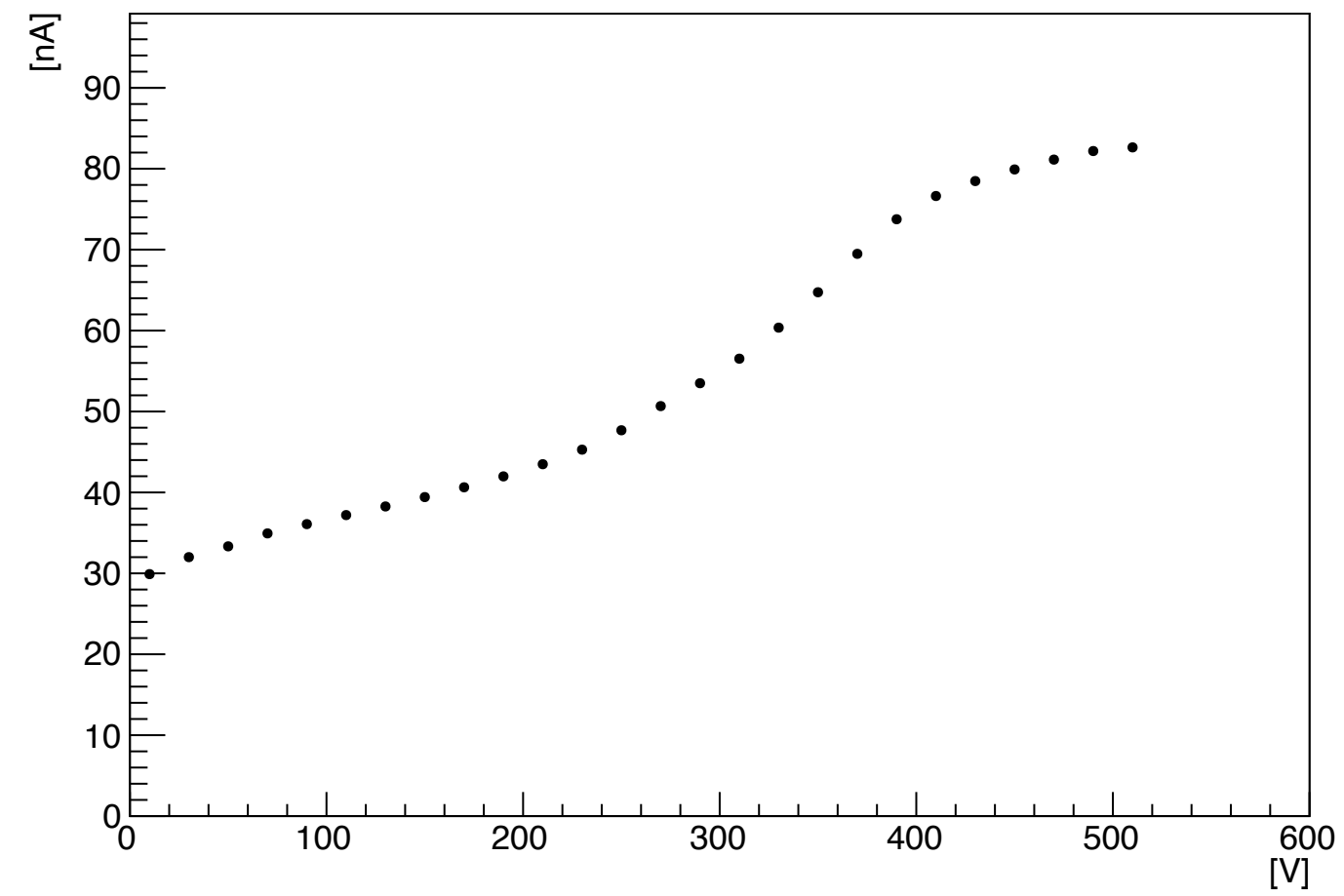
I-V 28_3



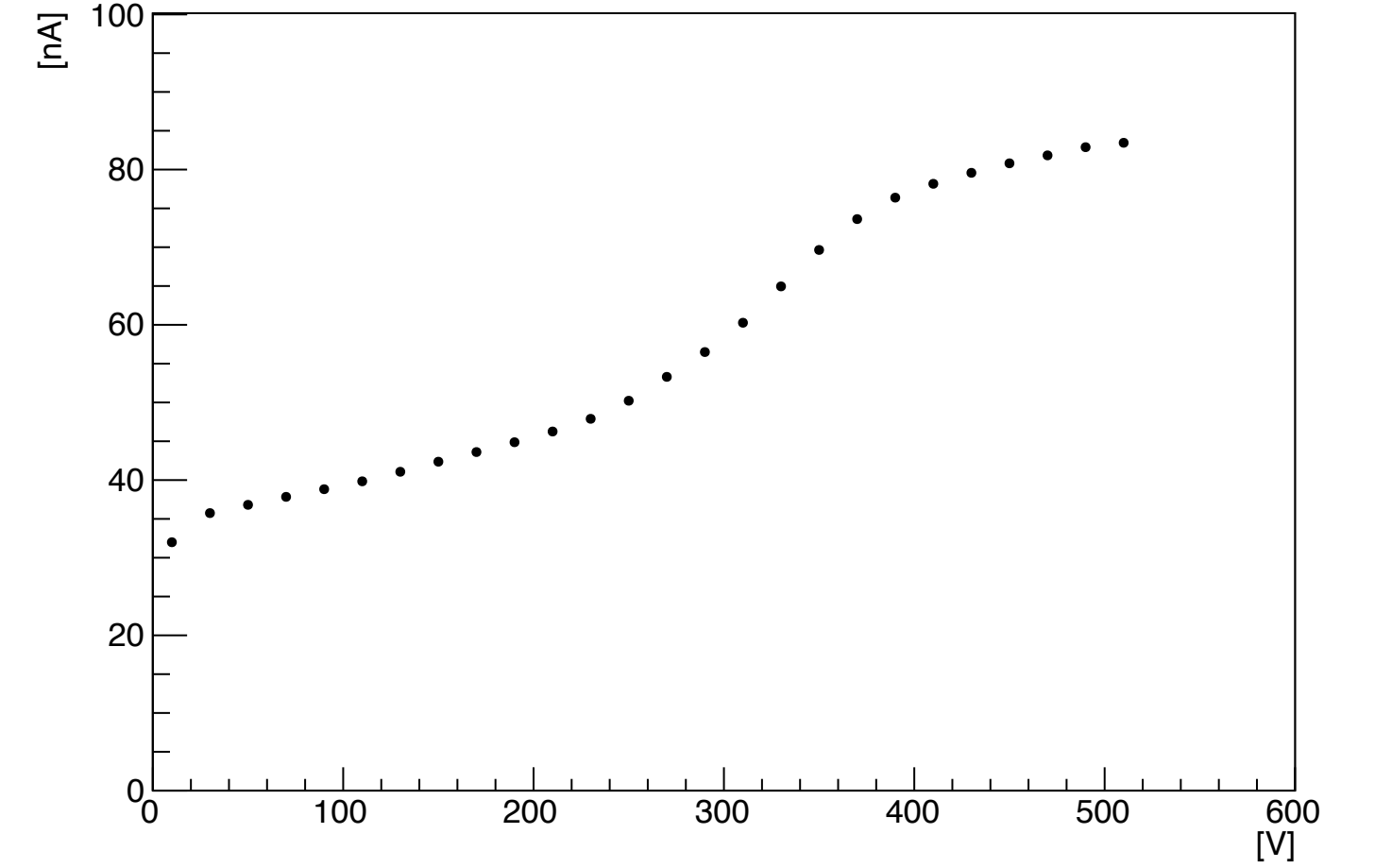
I-V 28_4



I-V 28_5



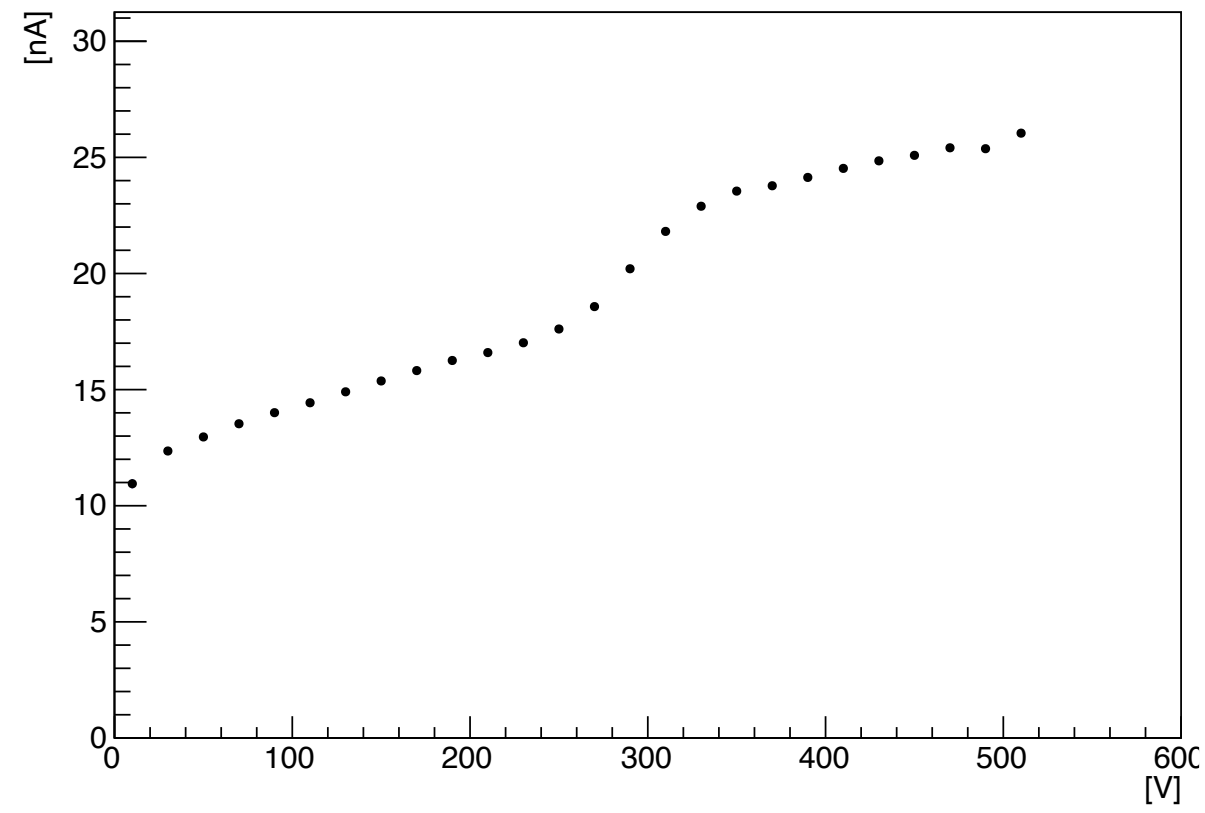
I-V 28_6



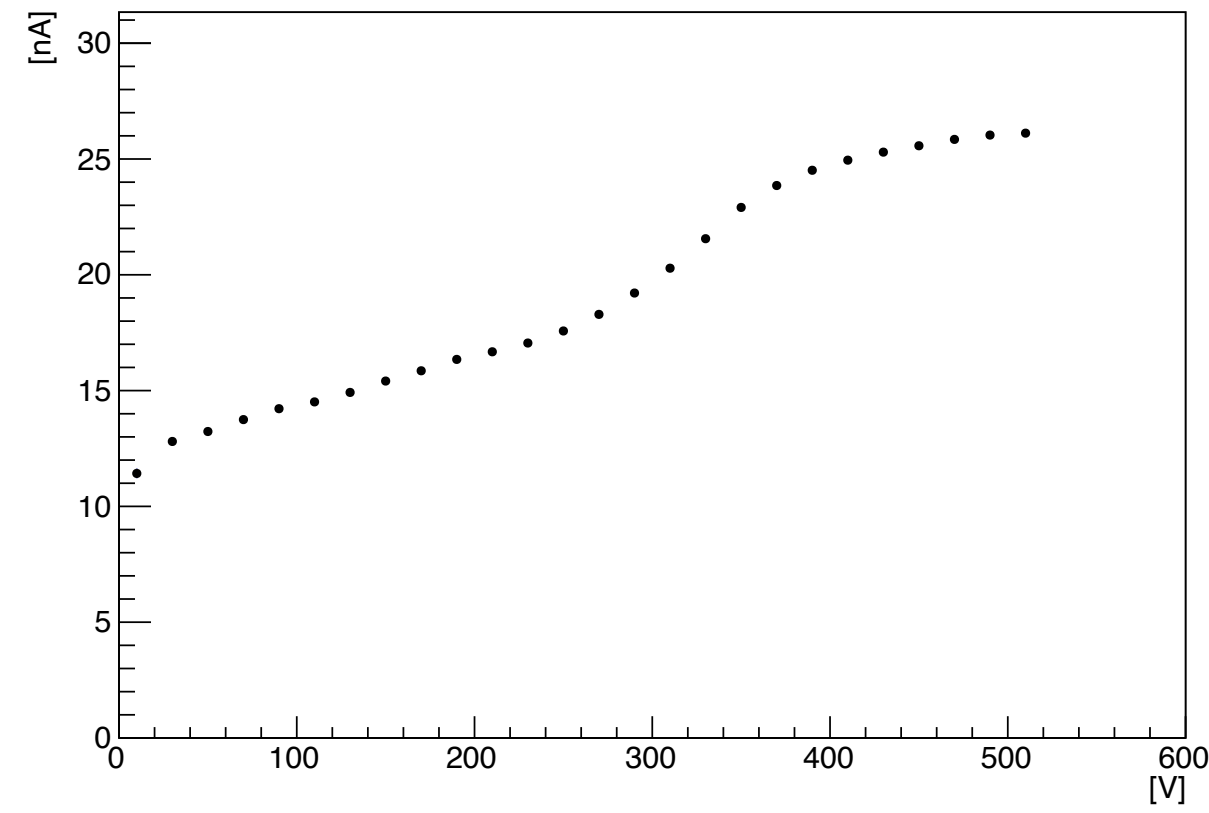
測定結果

14T1, 14T2, 14L1, 14L2 (1cm× 1cm)

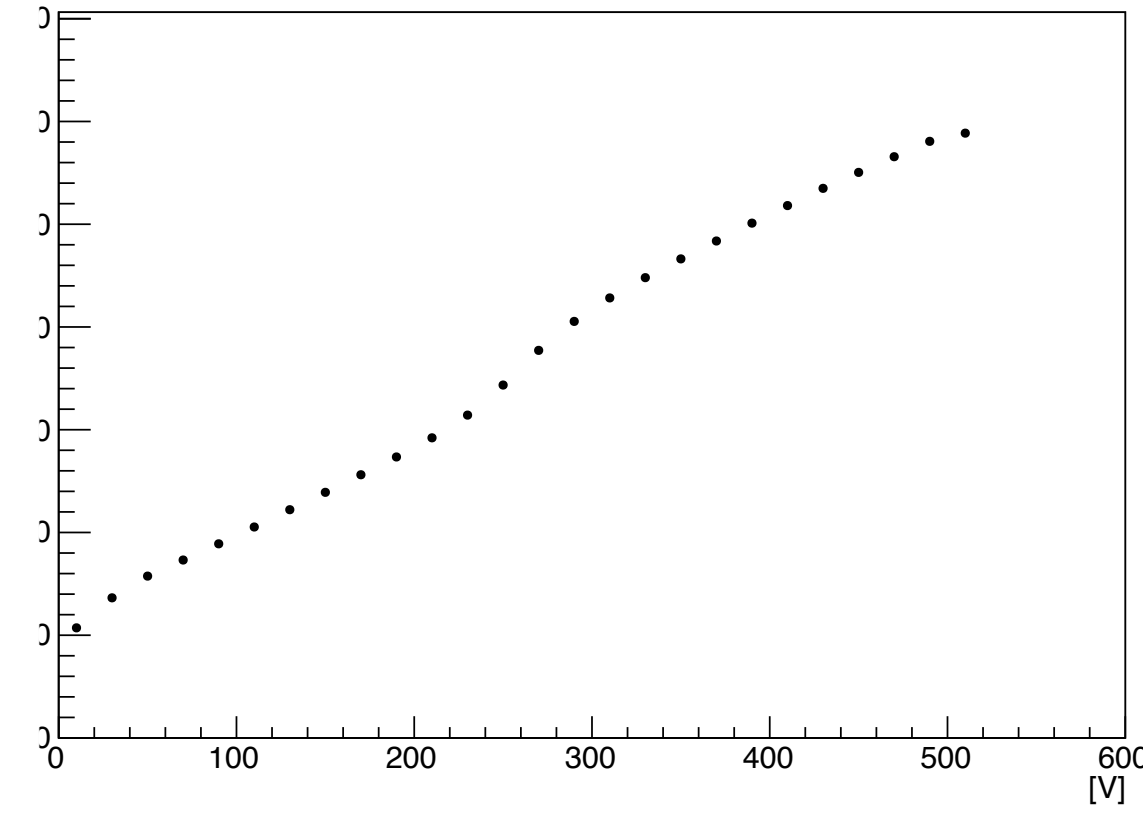
I-V 14T1-1



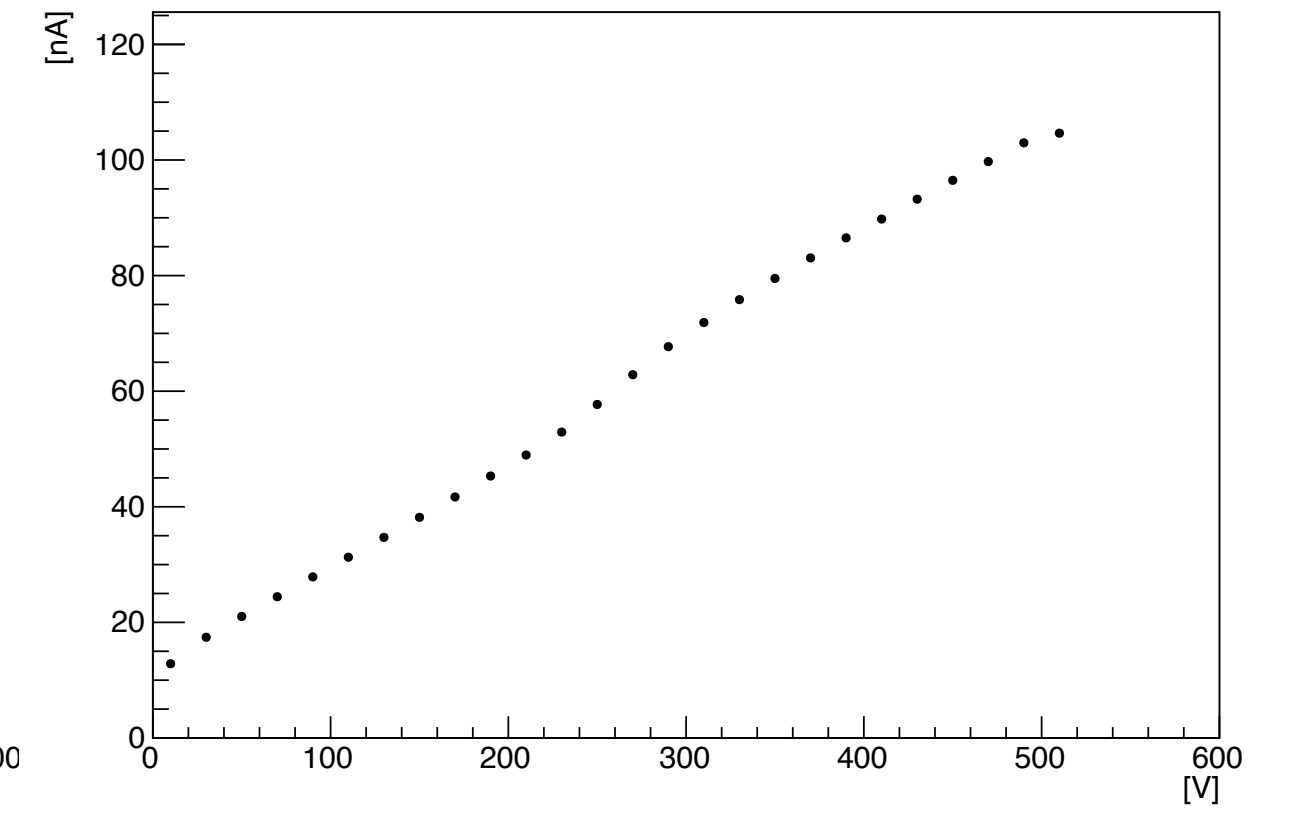
I-V 14T2_1



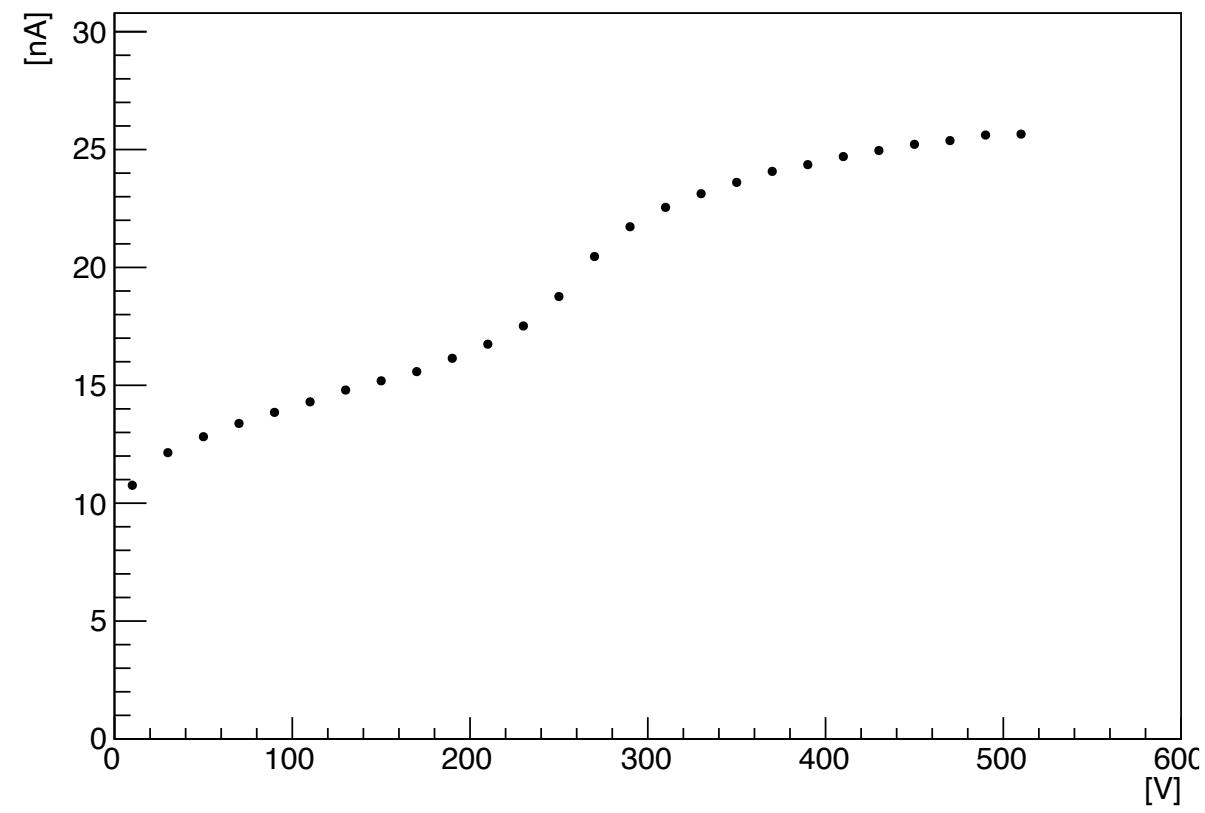
I-V 14L1_1



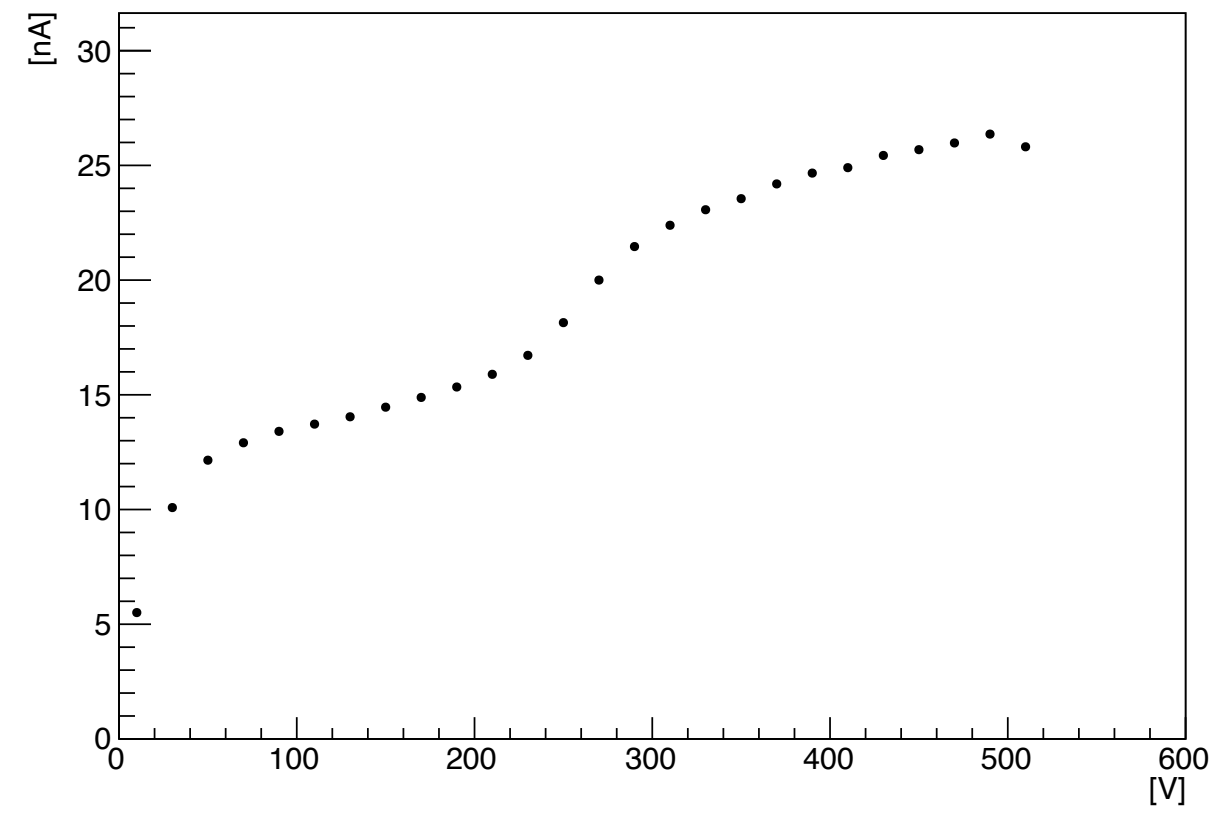
I-V 14L2_1



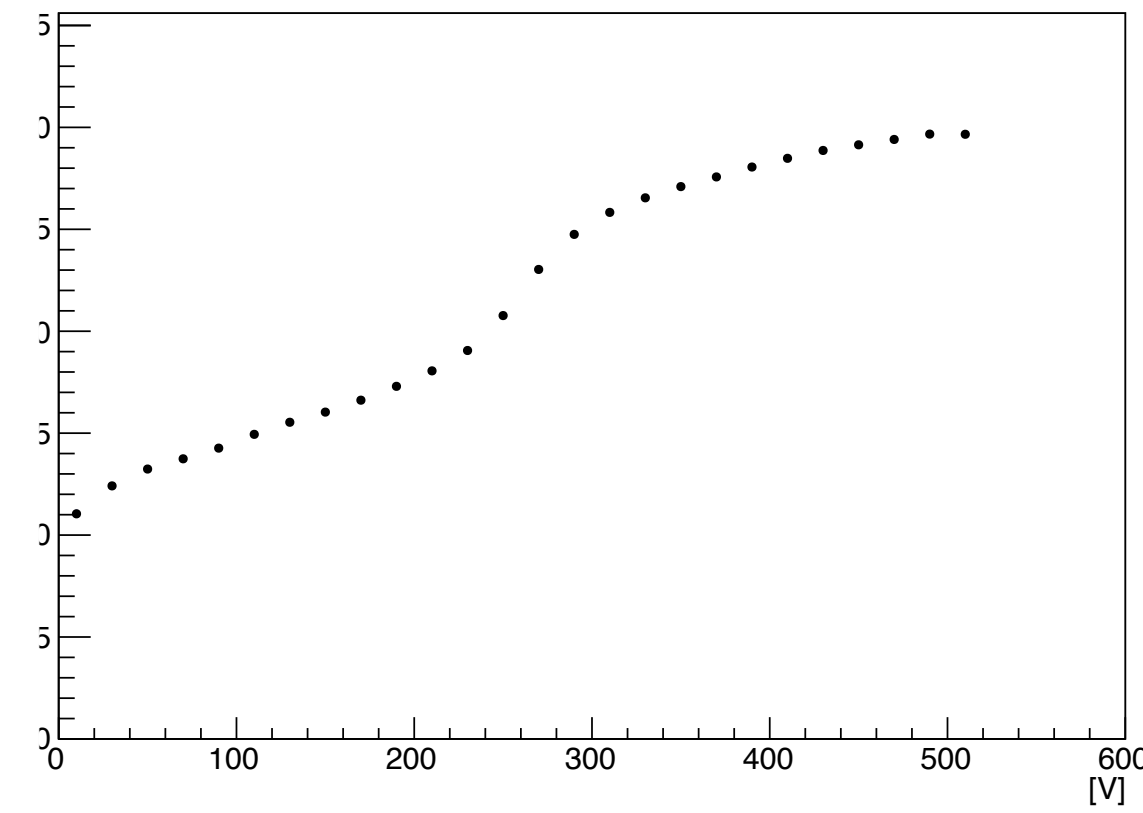
I-V 14T1-2



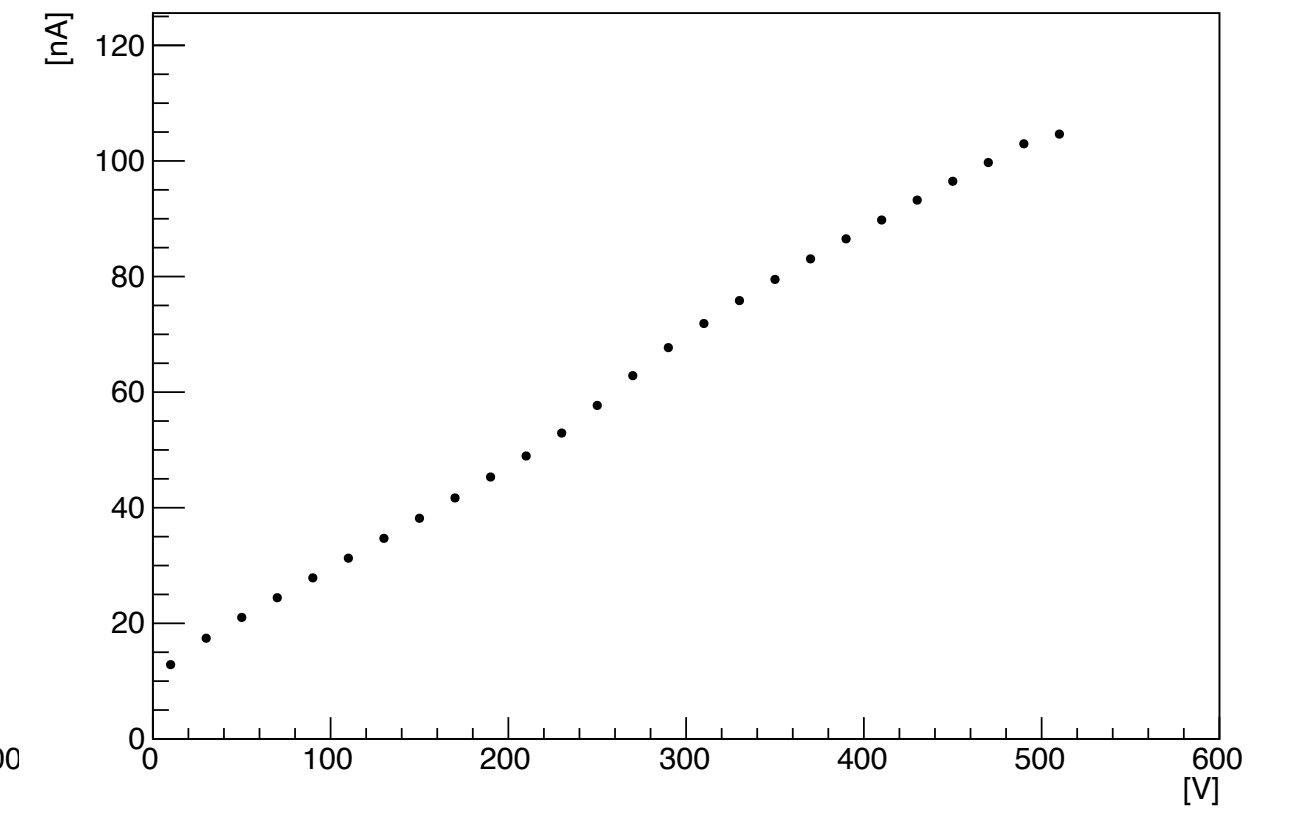
I-V 14T2_2



I-V 14L1_2



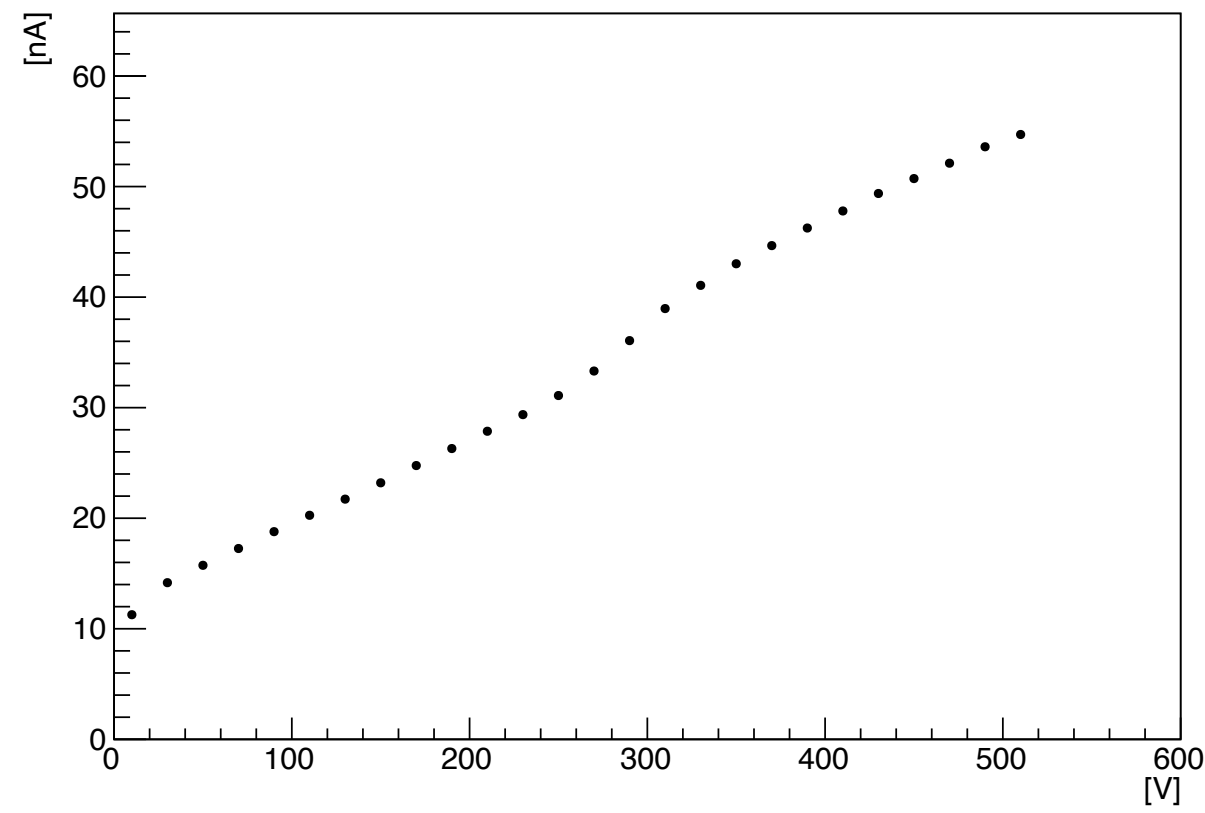
I-V 14L2_2



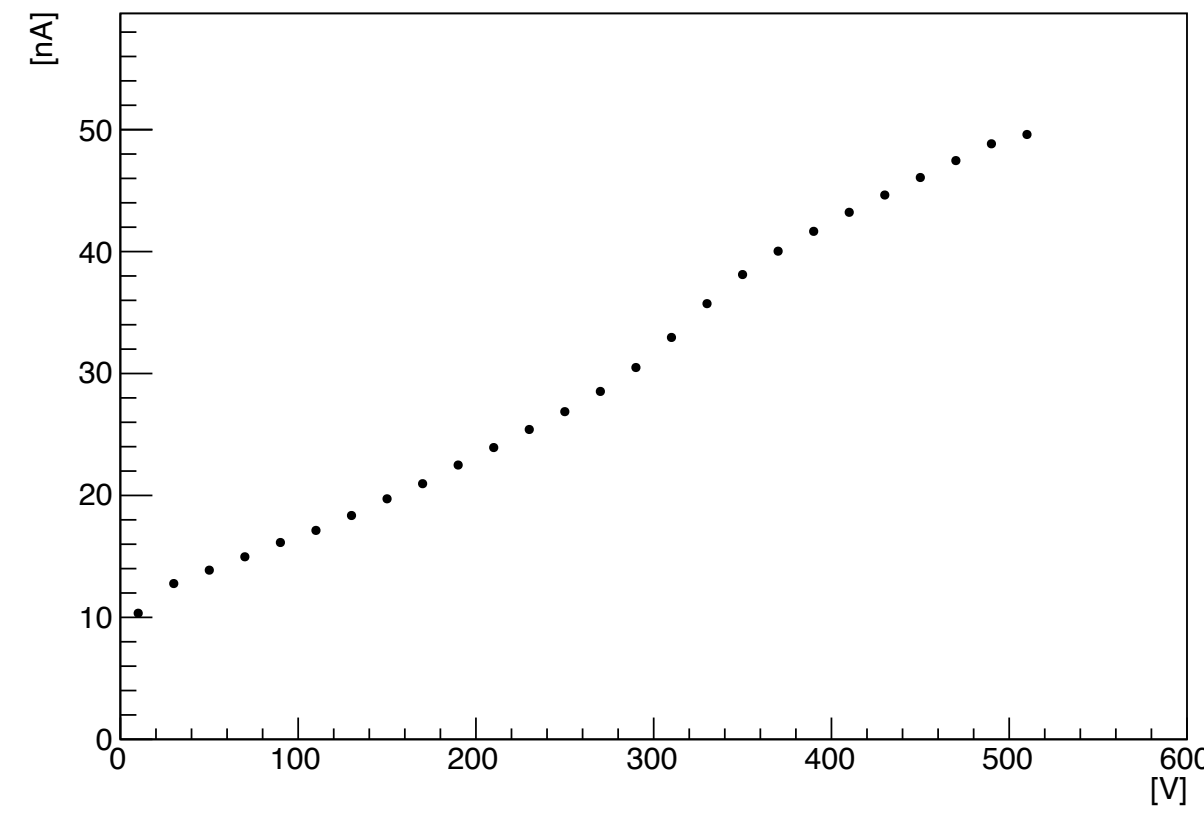
測定結果

14B1, 14B2, 14R1, 14R2 (1cm× 1cm)

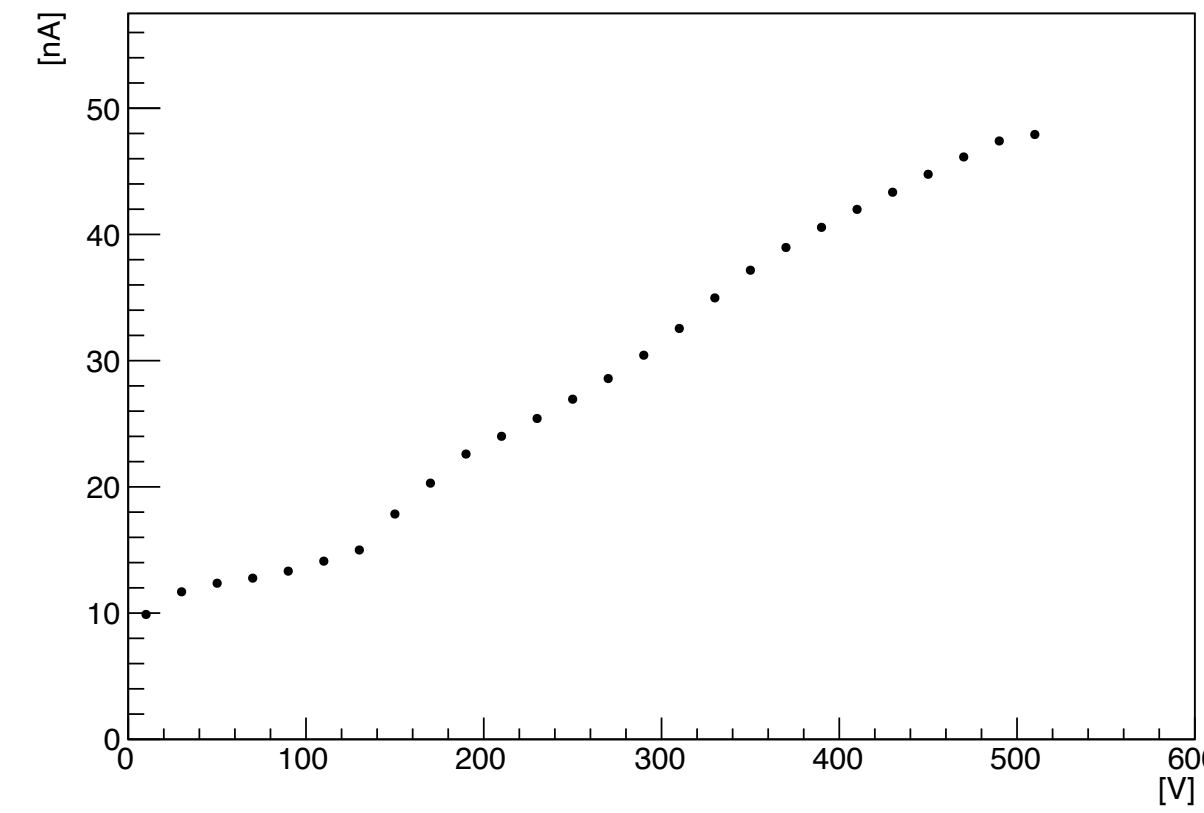
I-V 14B1_1



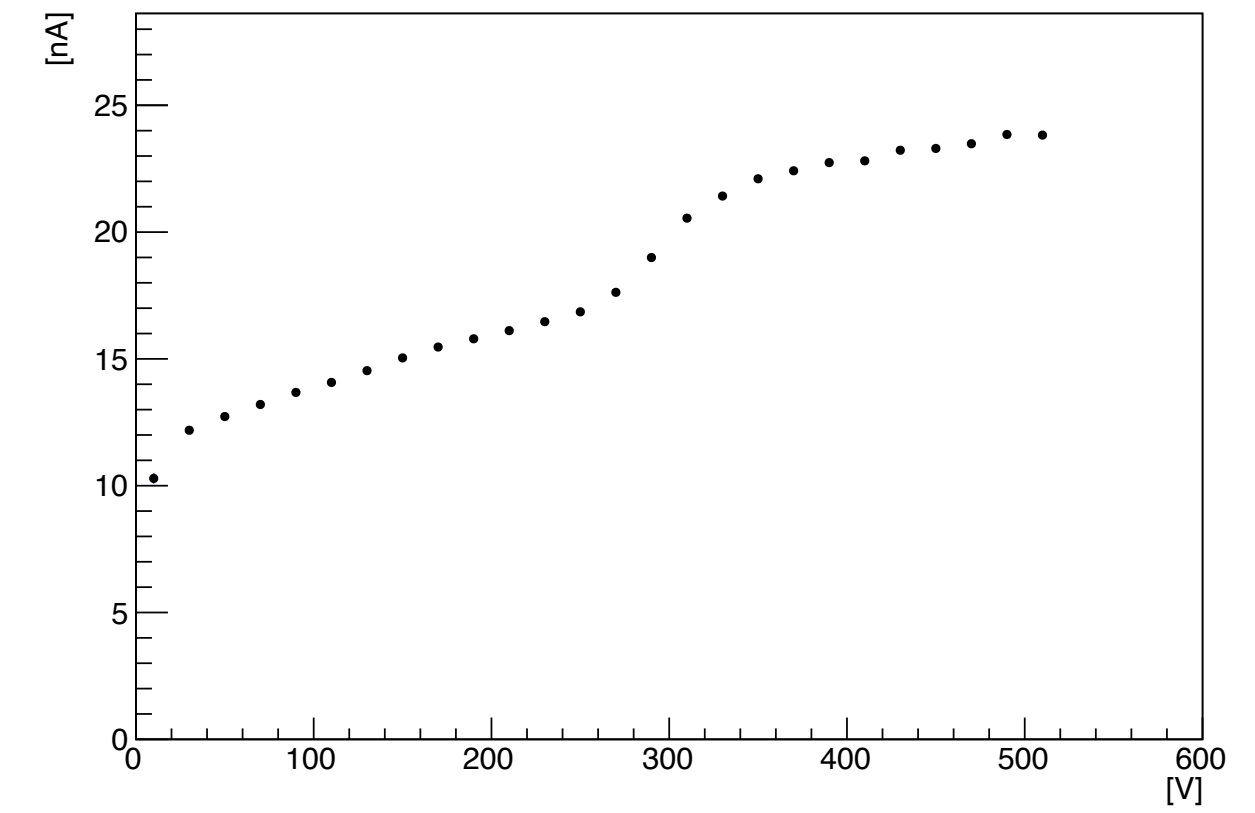
I-V 14B2_1



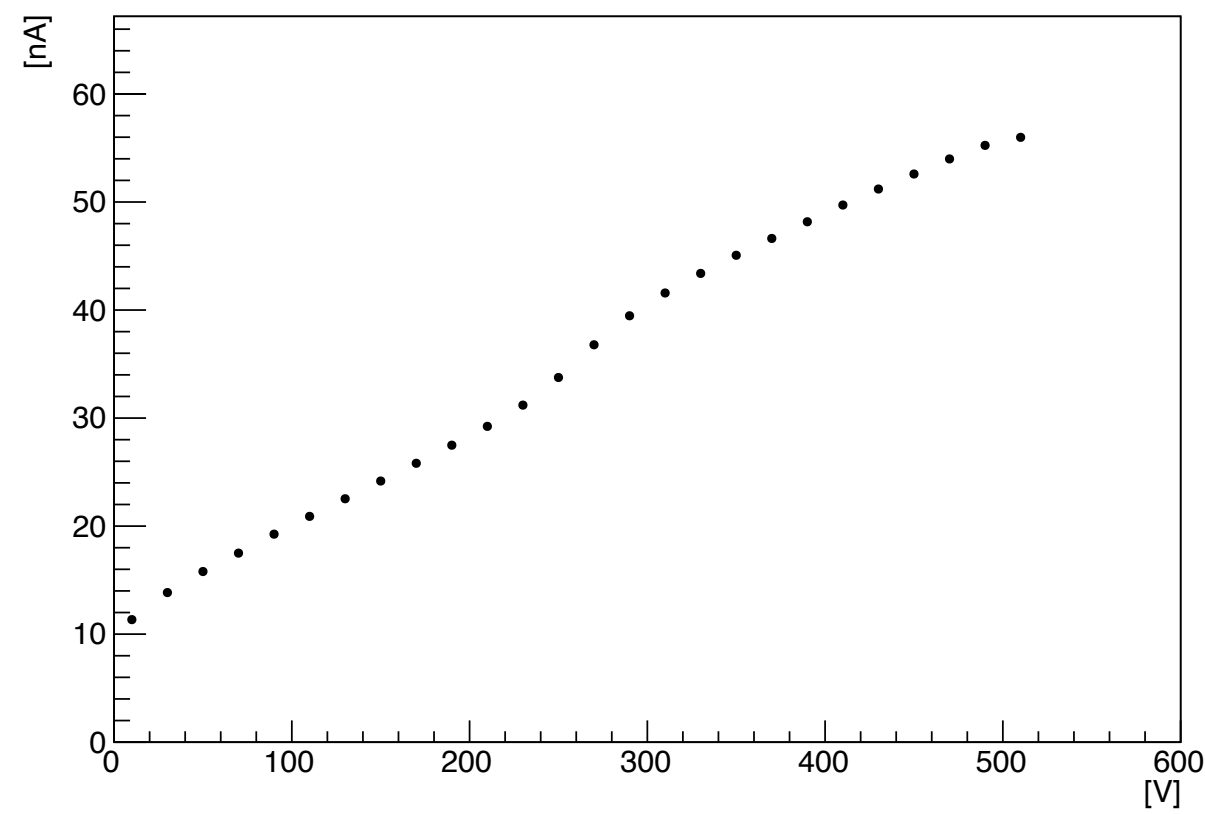
I-V 14R1_1



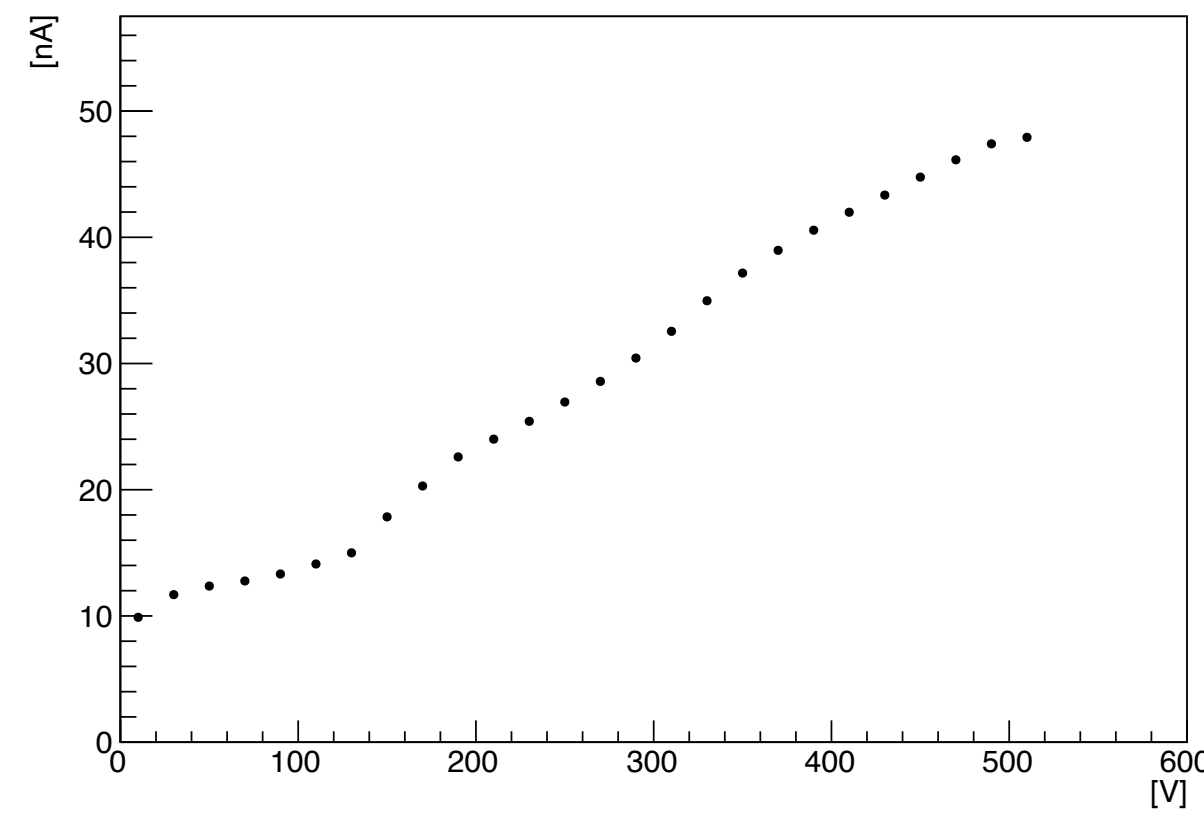
I-V 14R2_1



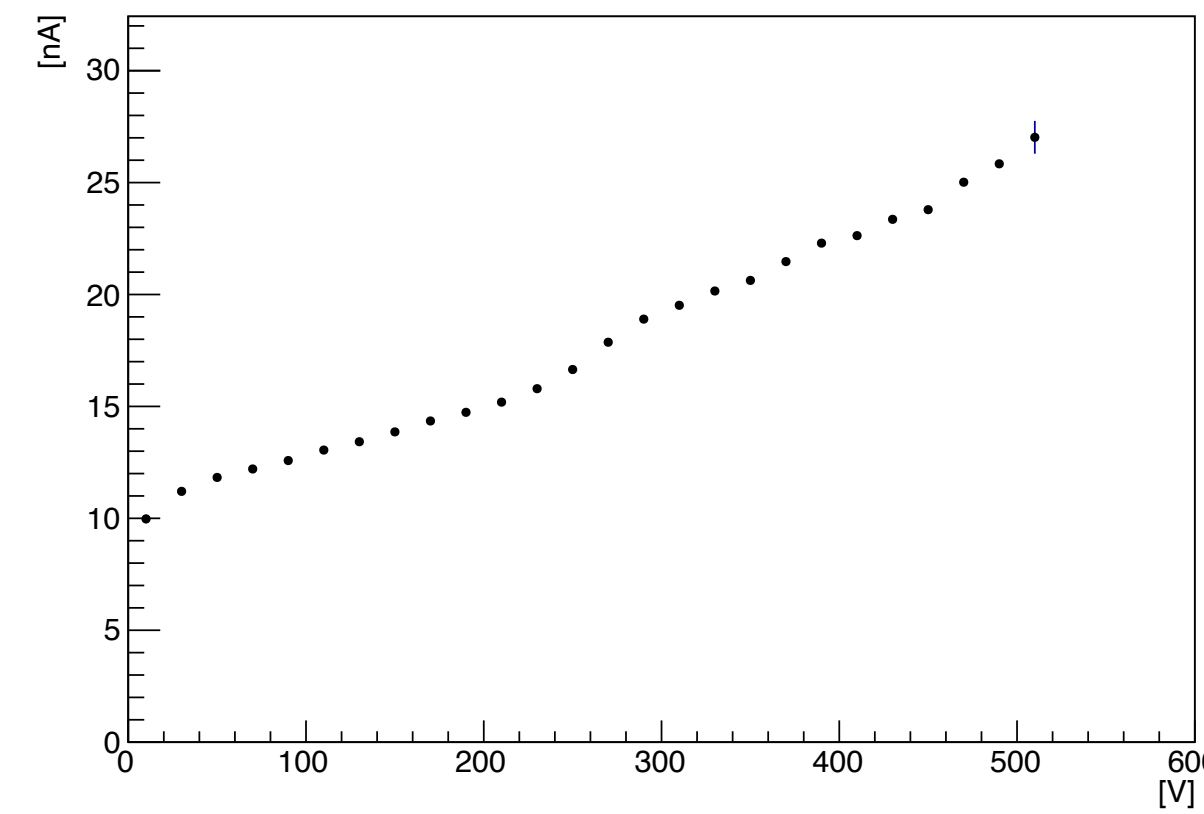
I-V 14B1_2



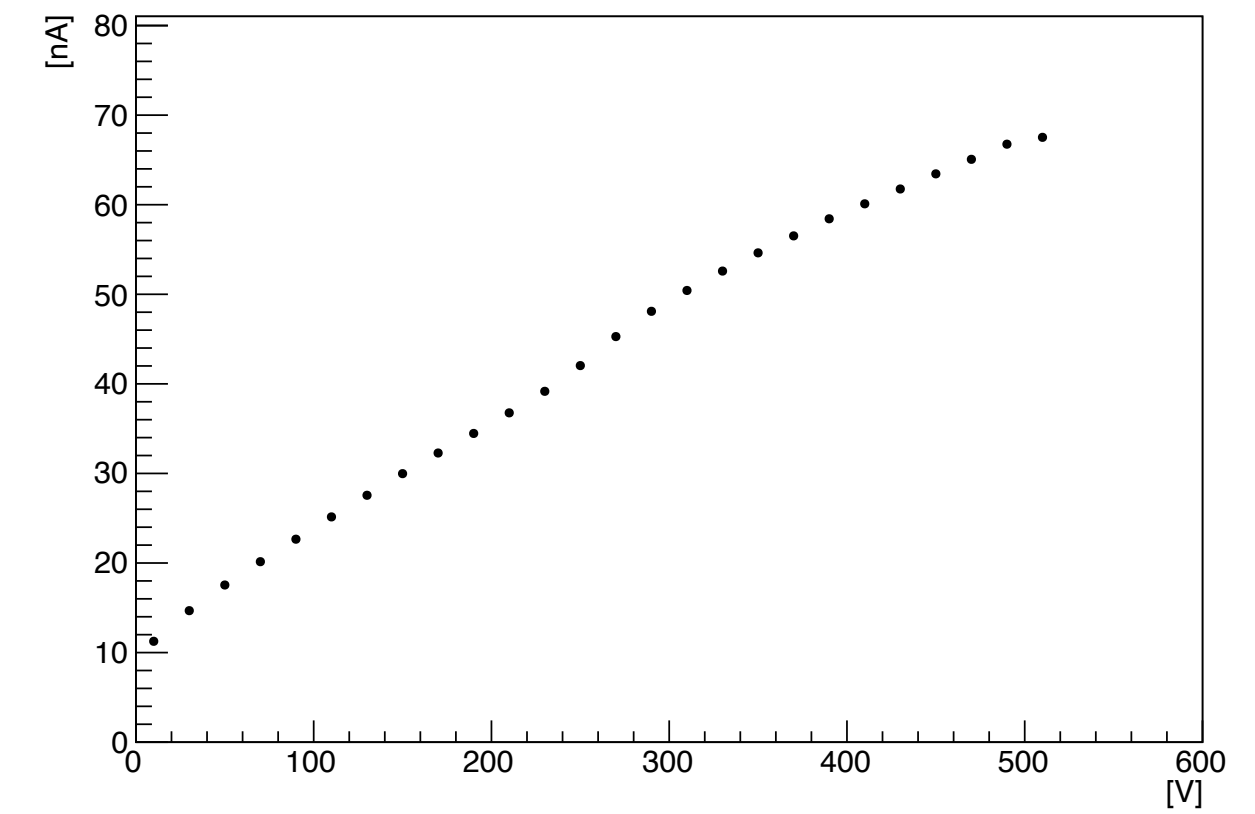
I-V 14B2_2



I-V 14R1_2



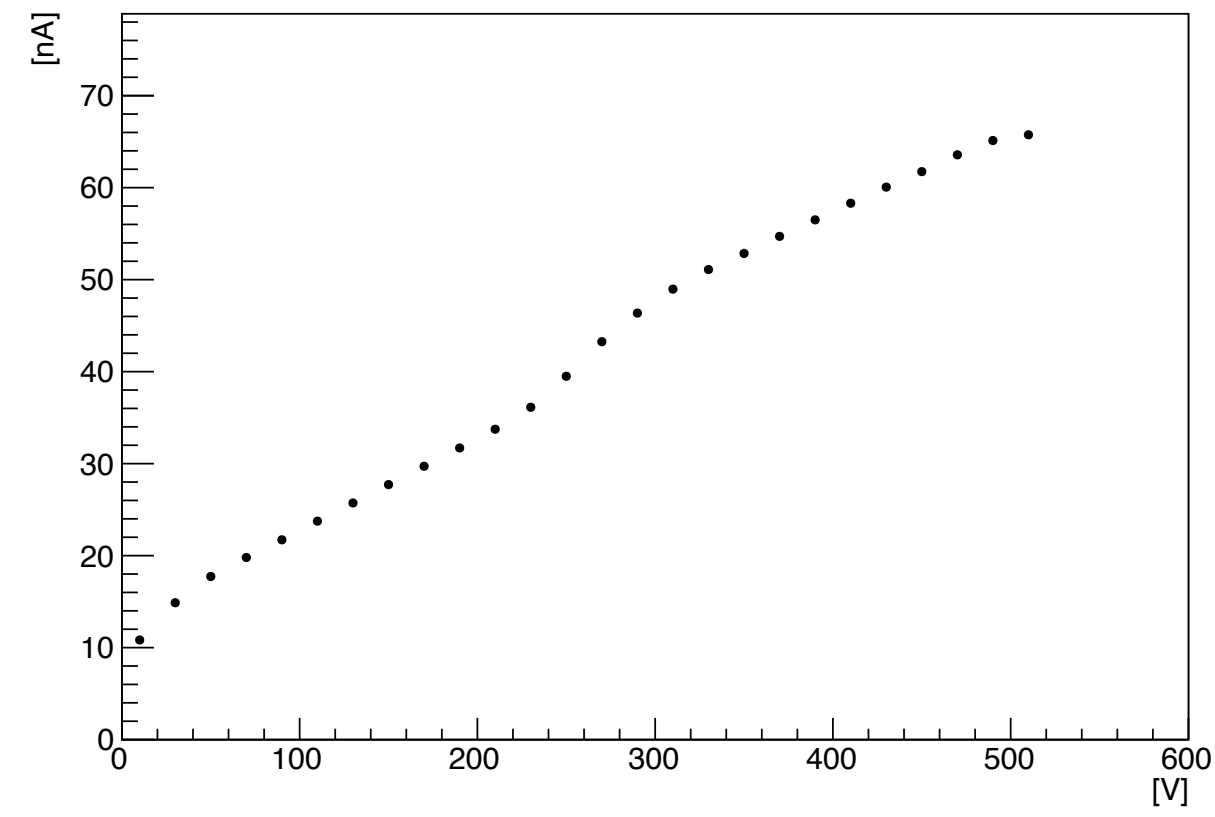
I-V 14R2_2



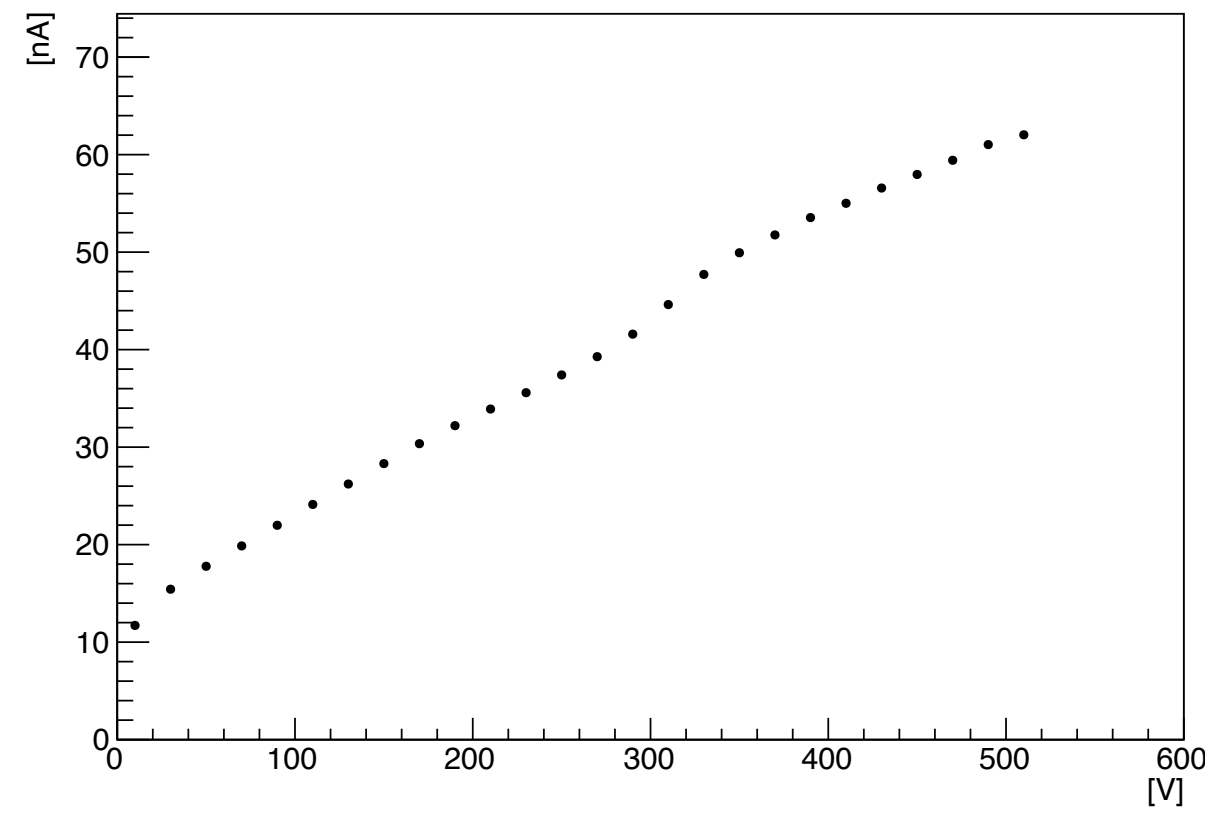
測定結果

19T1, 19T2, 19L1, 19L2 (1cm× 1cm)

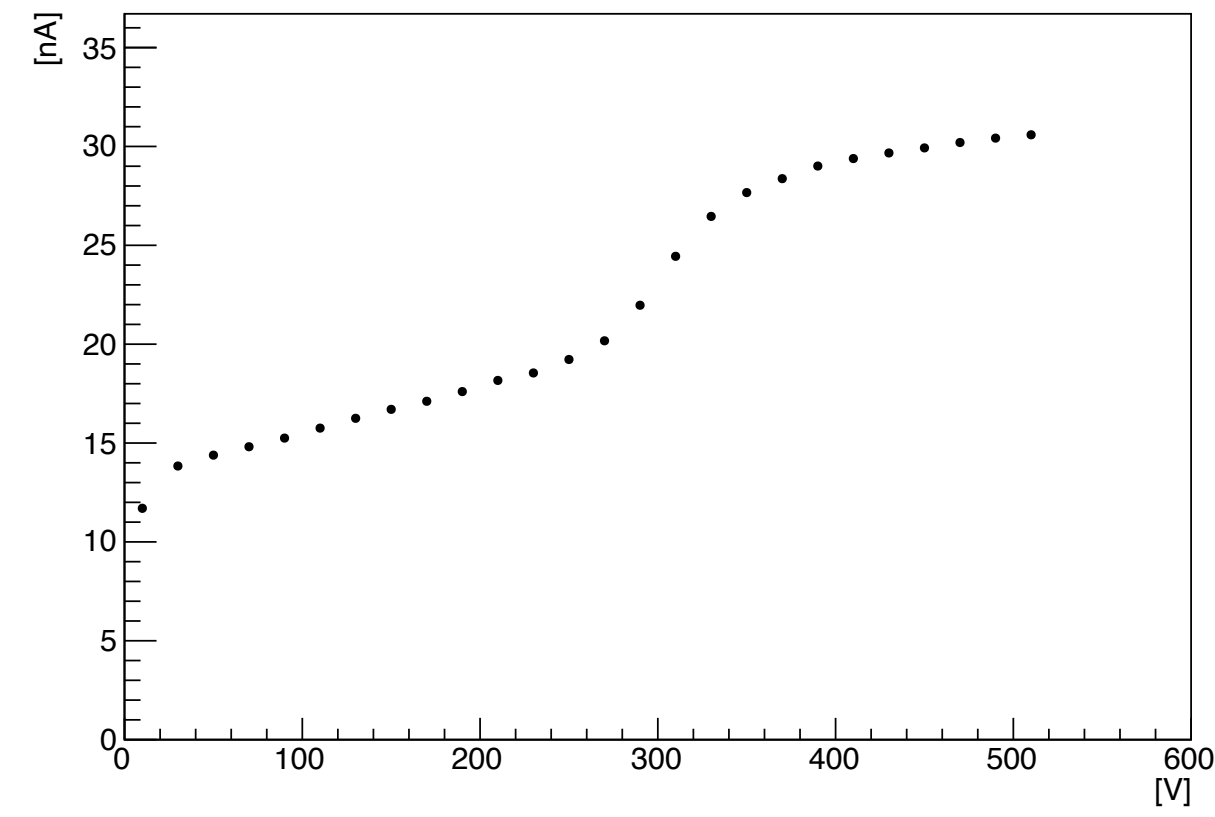
I-V 19T1_1



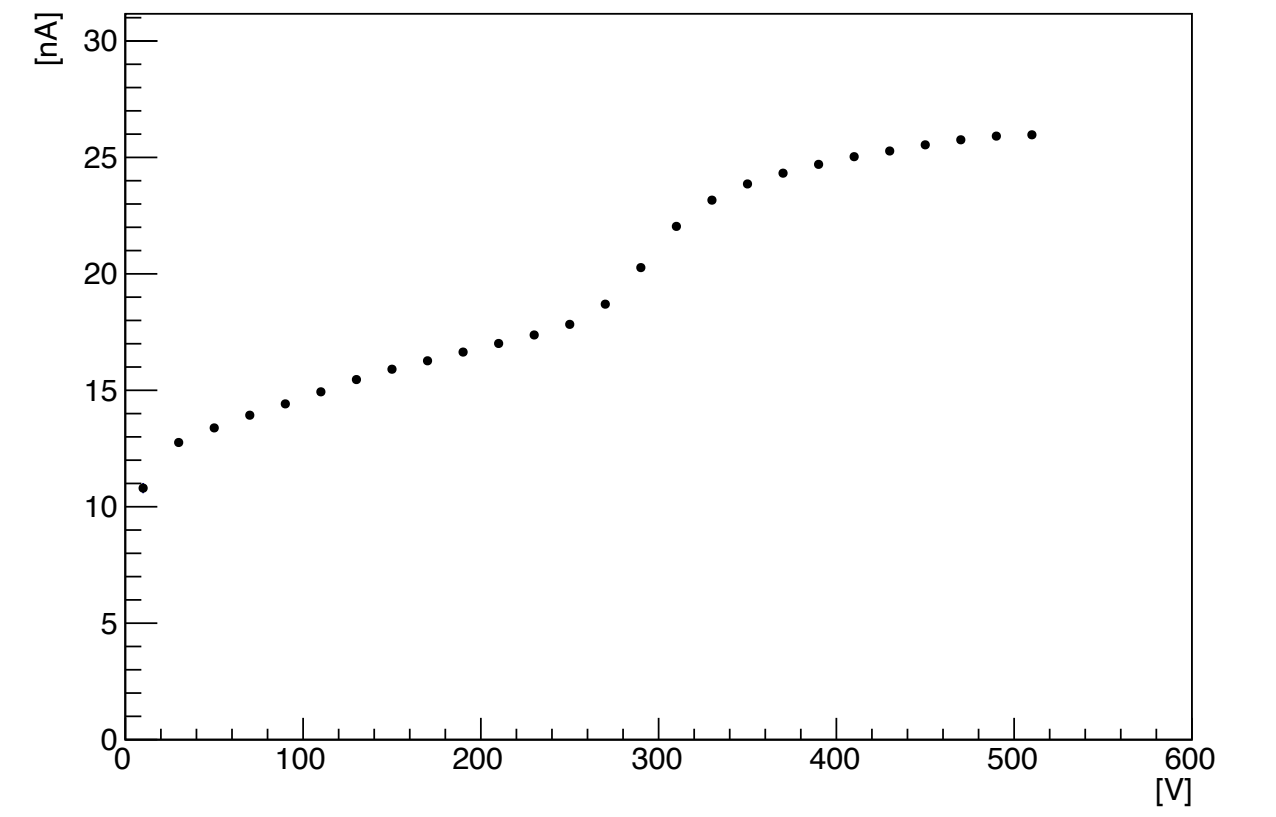
I-V 19T2_1



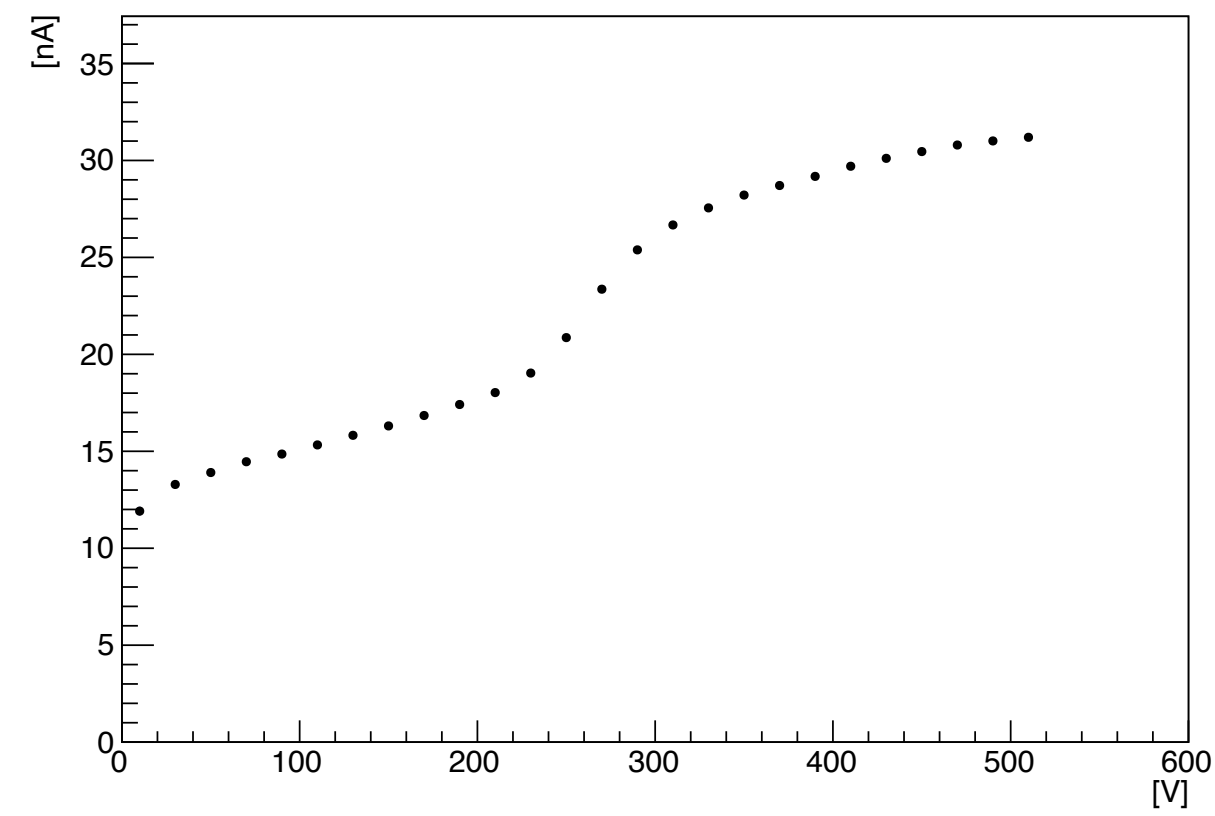
I-V 19L1_1



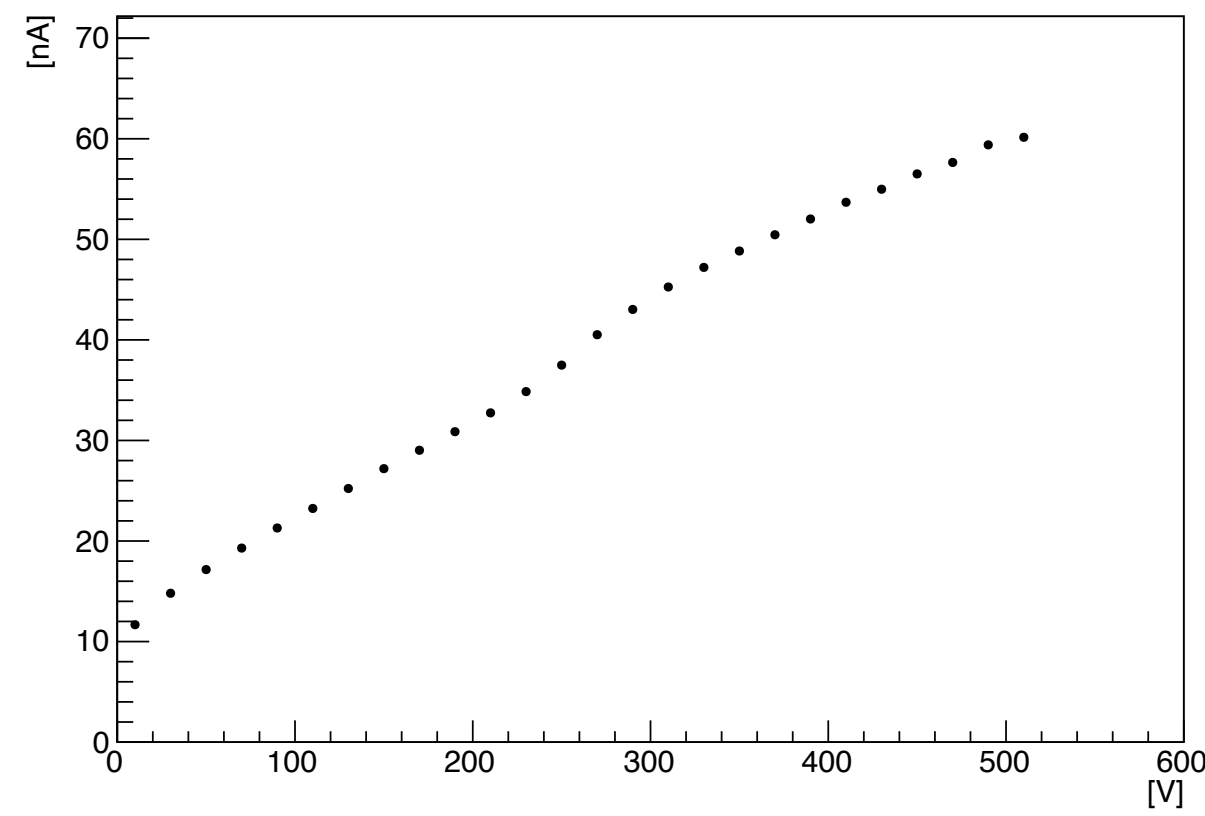
I-V 19L2_1



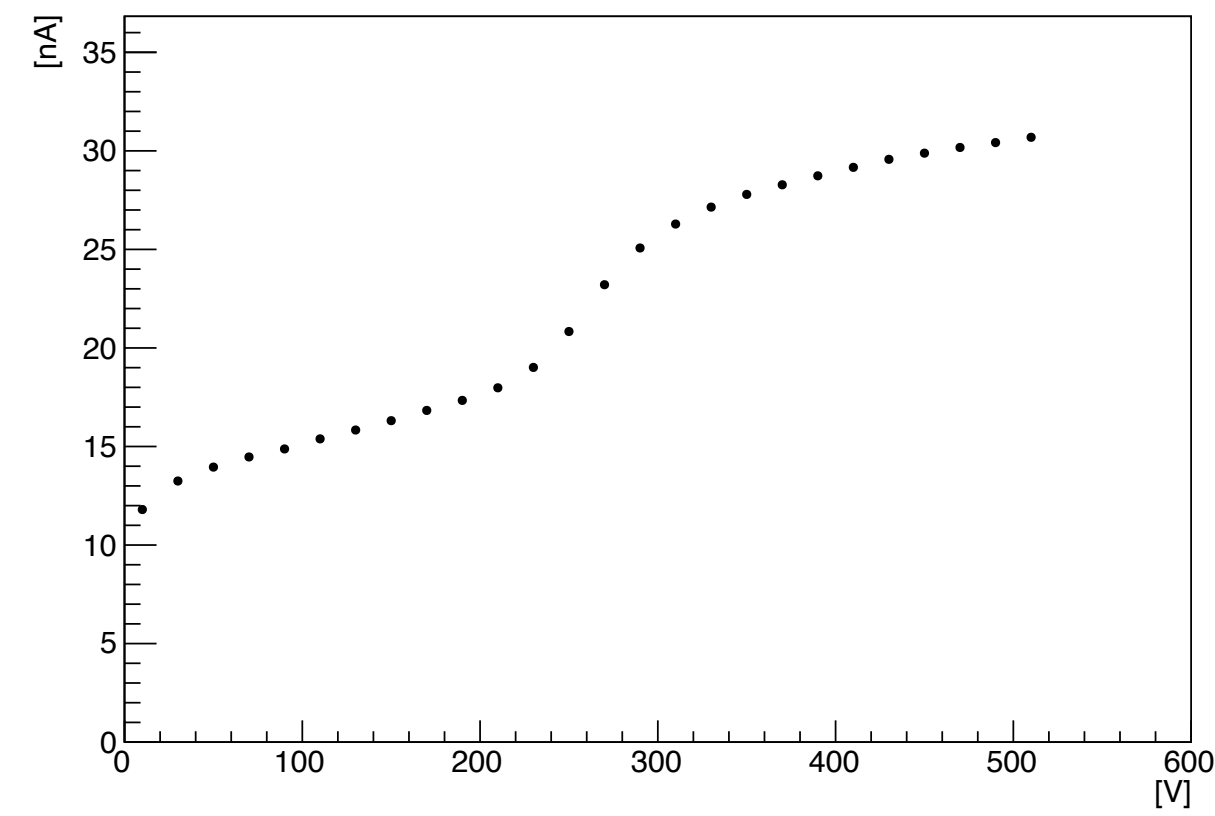
I-V 19T1_2



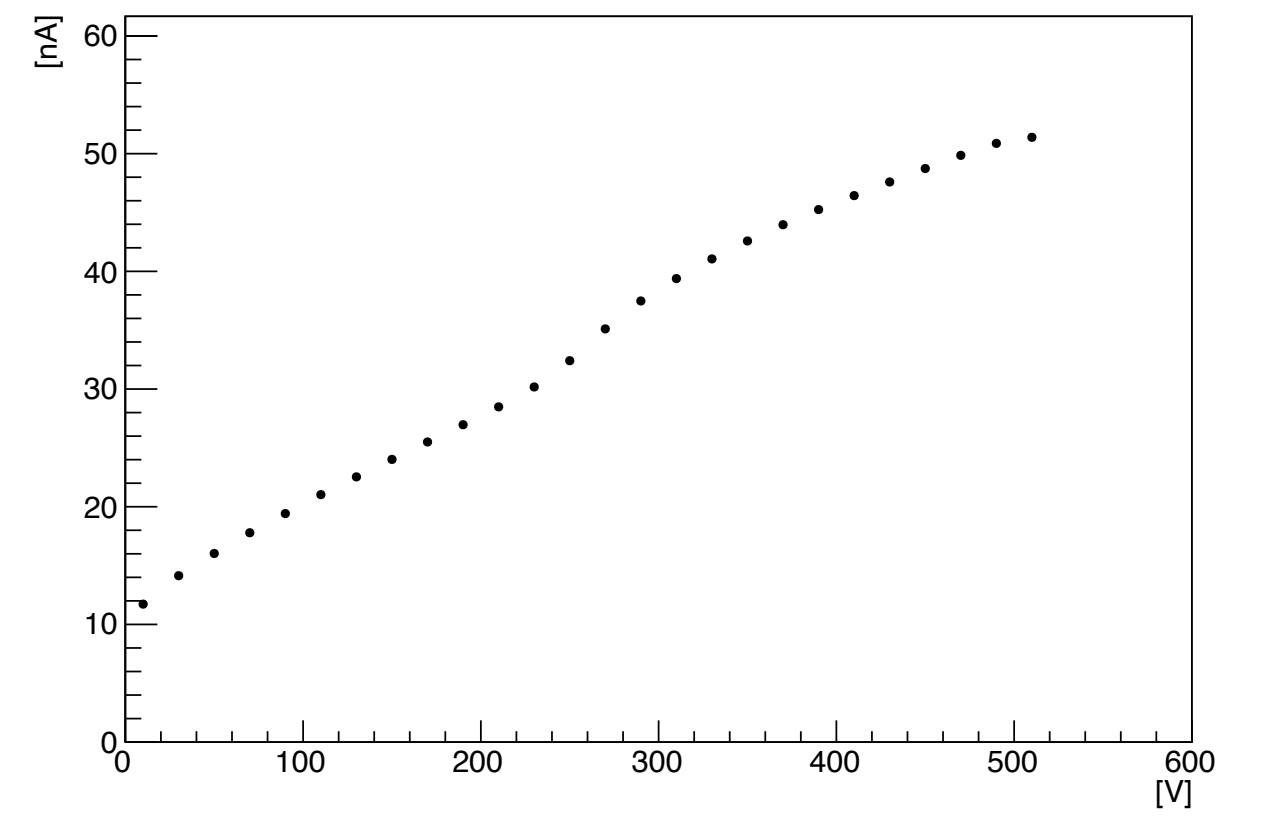
I-V 19T2_2



I-V 19L1_2



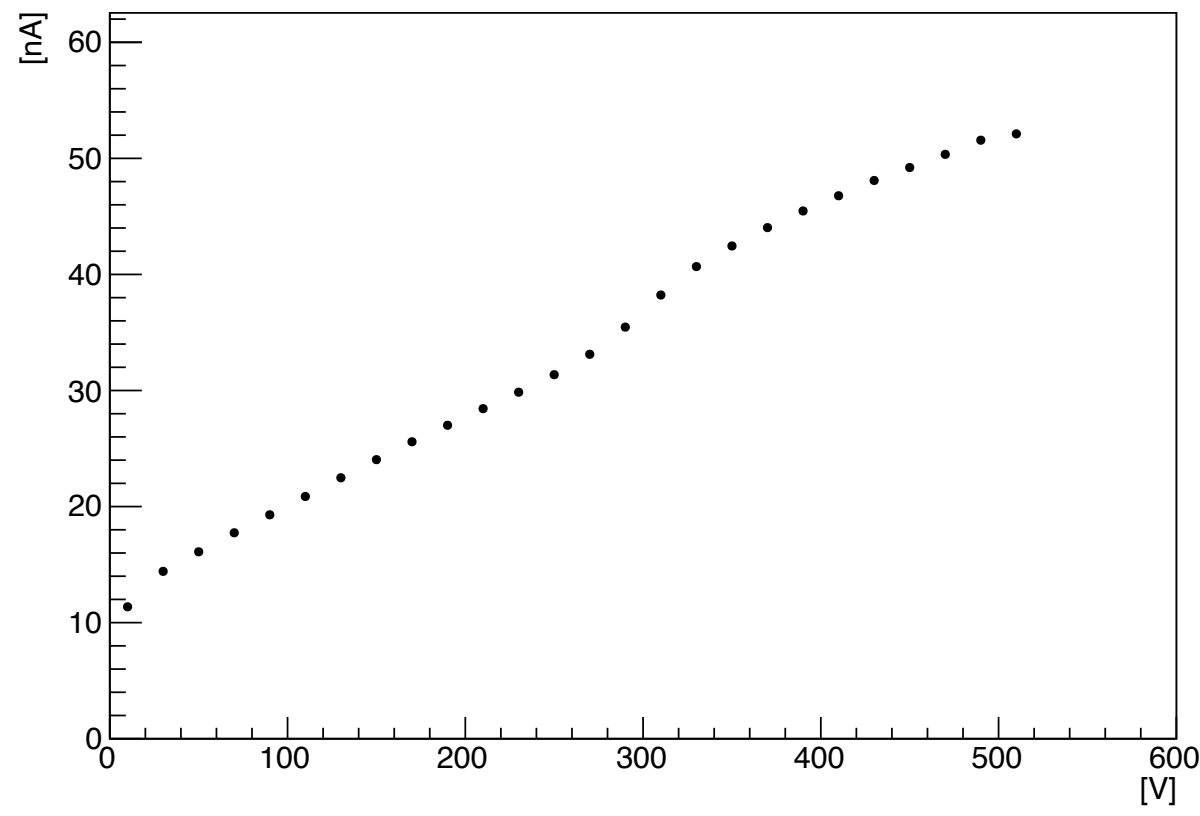
I-V 19L2_2



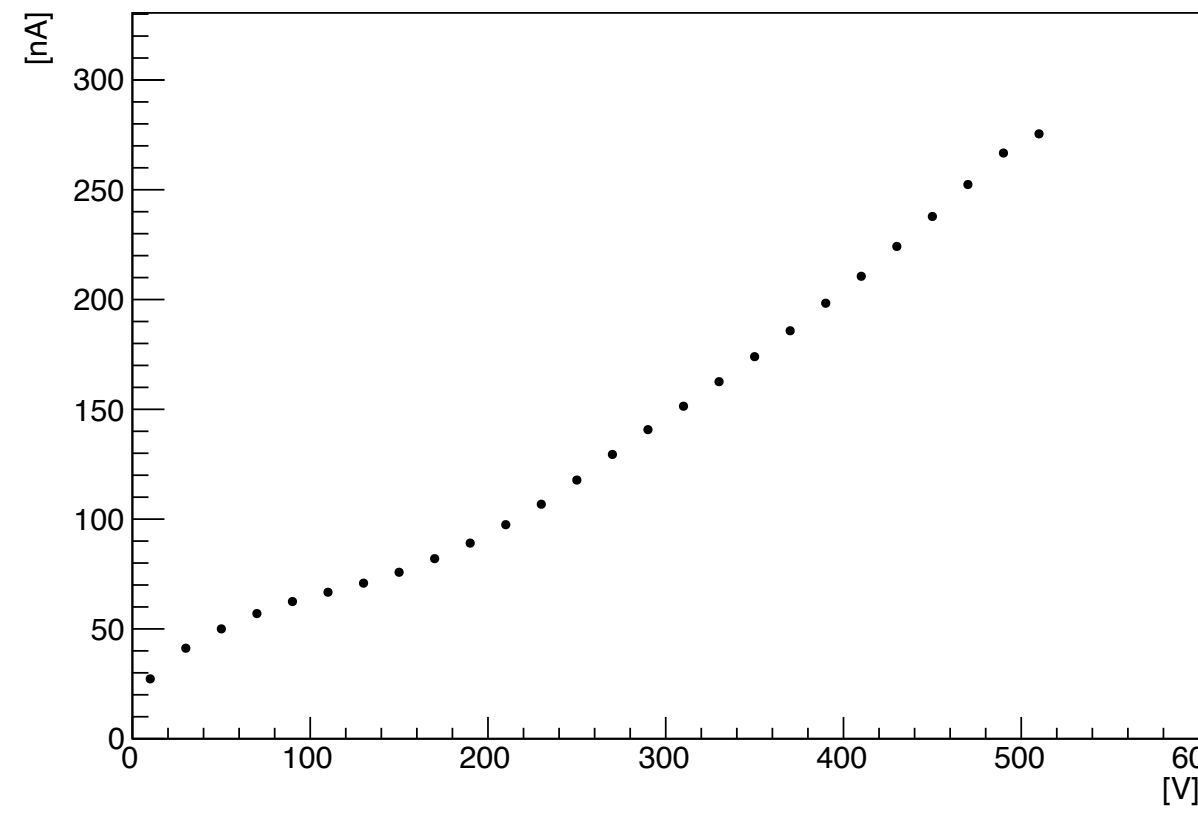
測定結果

19B1, 19B2, 19R1, 19R2 (1cm× 1cm)

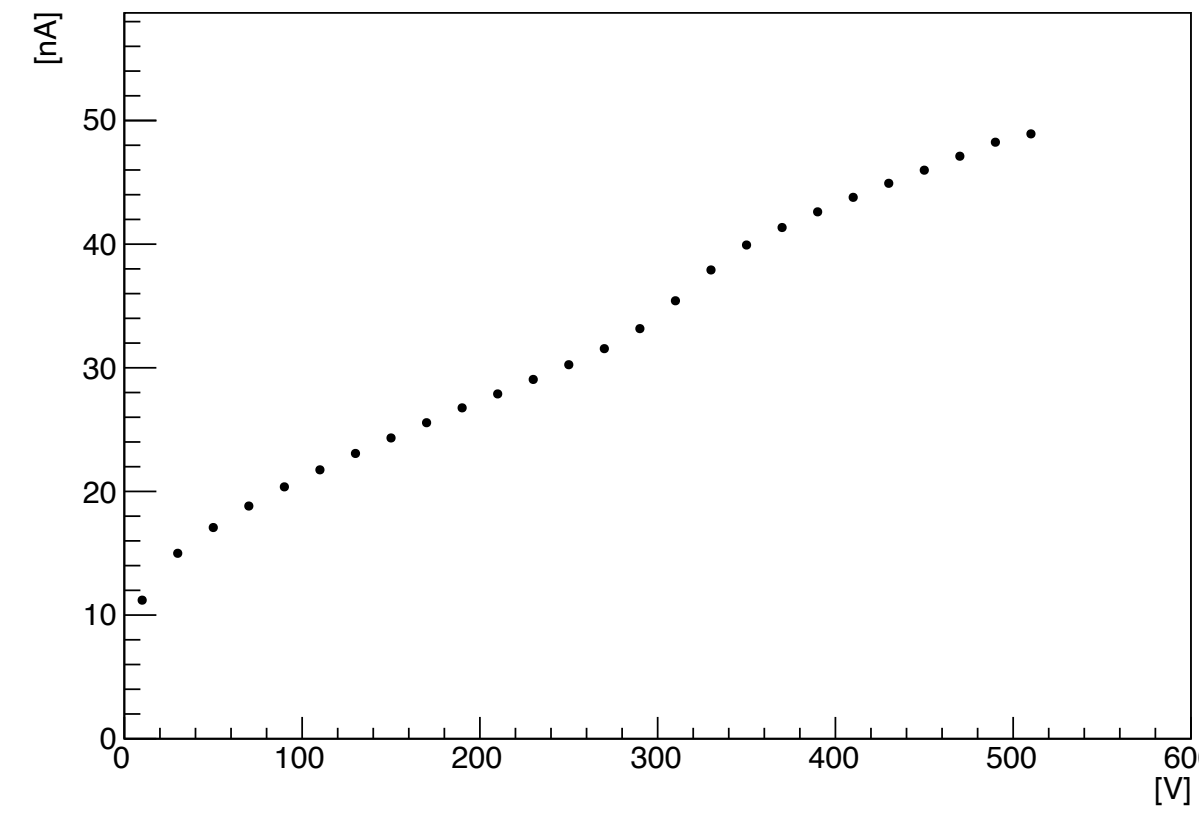
I-V 19B1_1



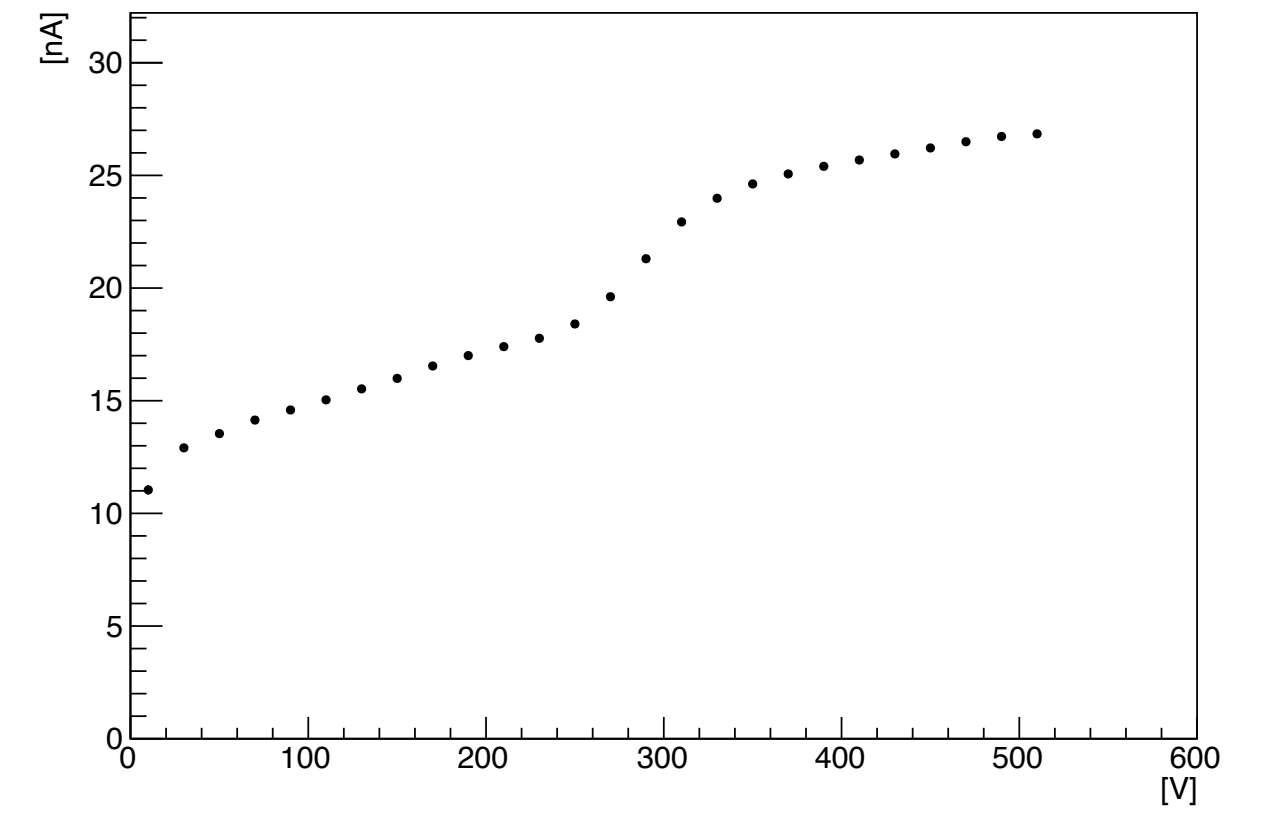
I-V 19B2_1



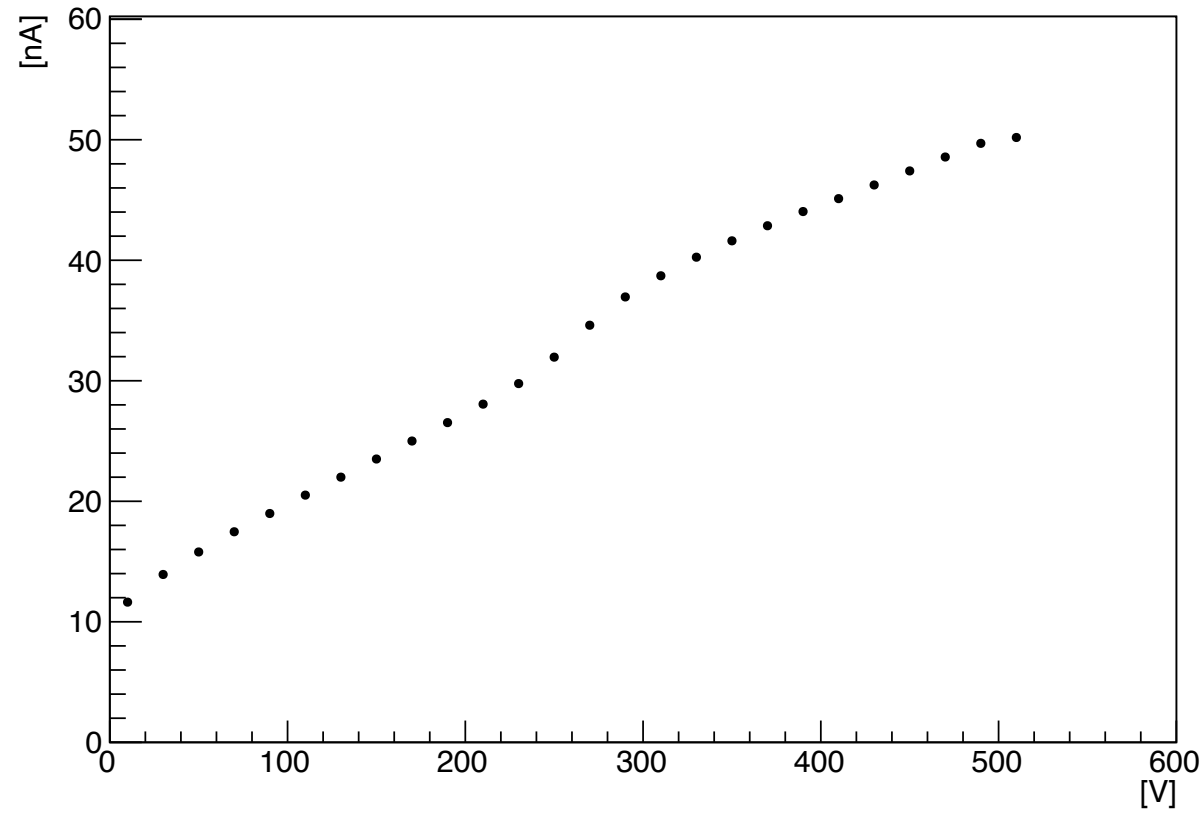
I-V 19R1_1



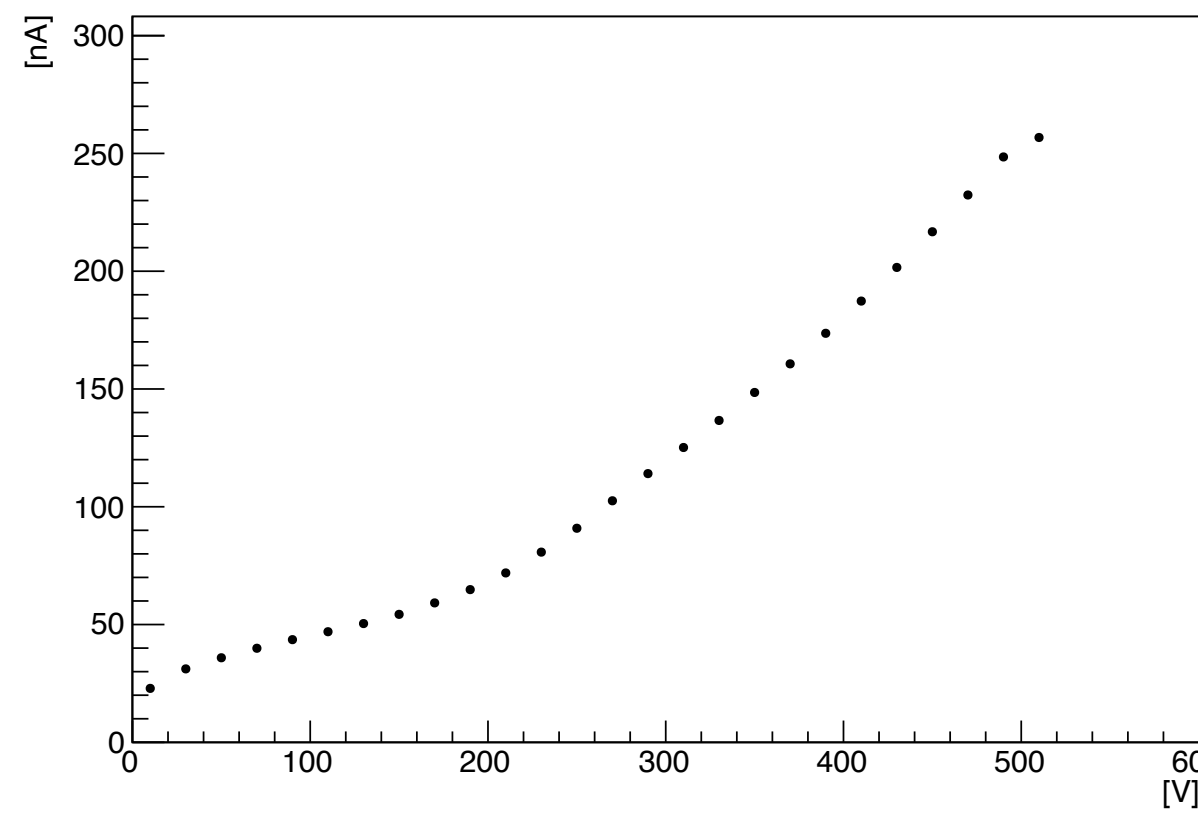
I-V 19R2_1



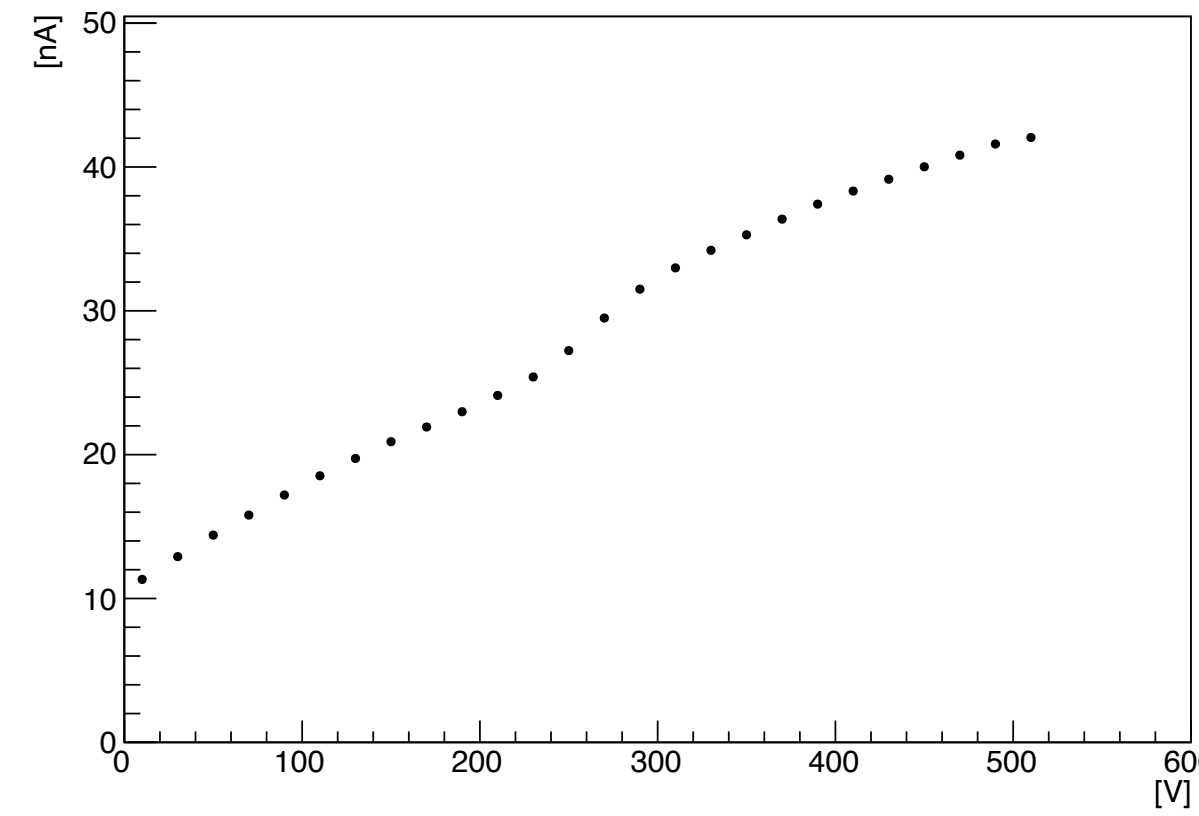
I-V 19B1_2



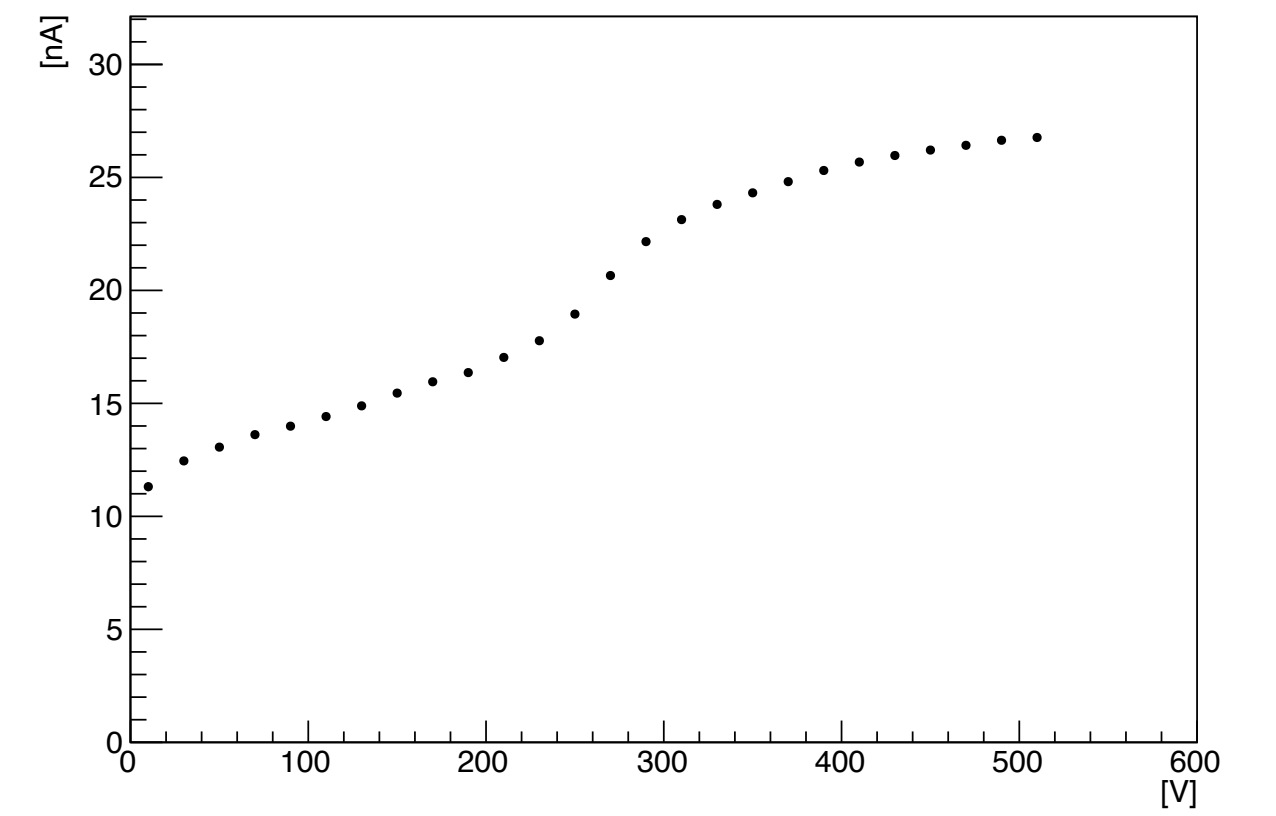
I-V 19B2_2



I-V 19R1_2



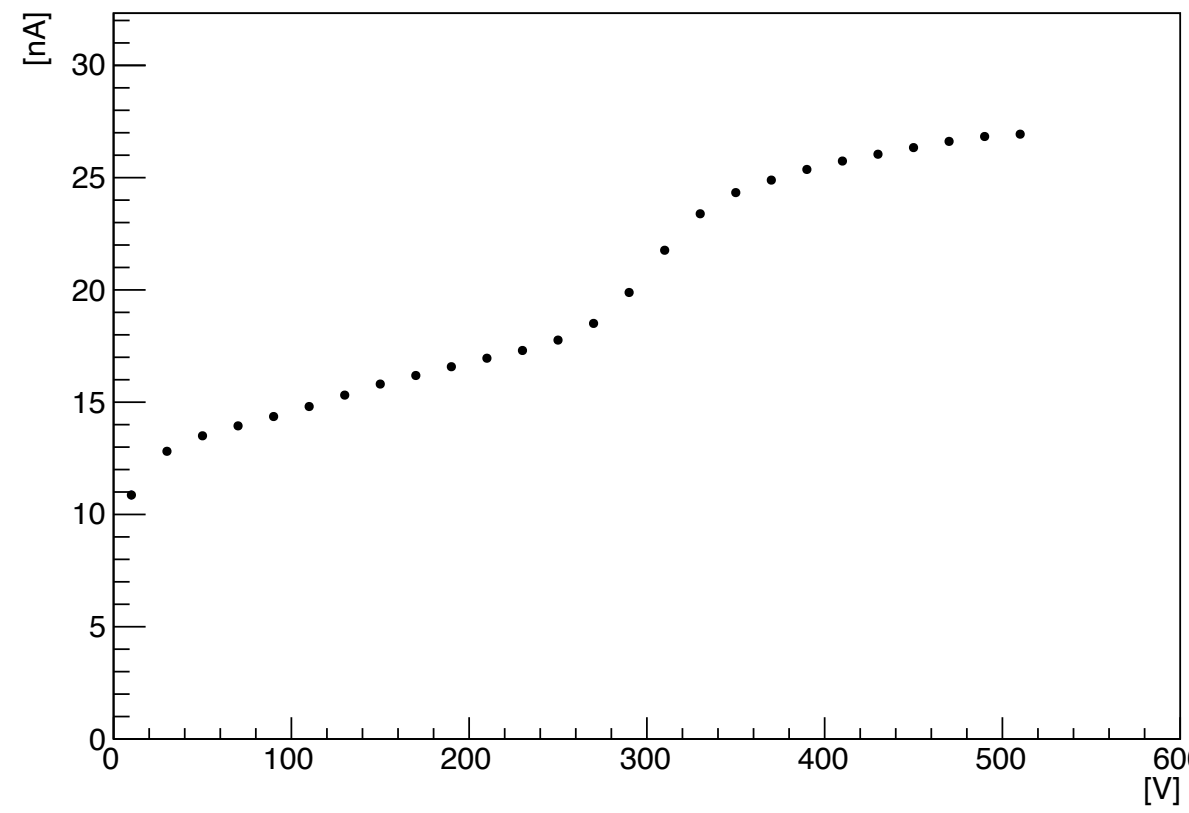
I-V 19R2_2



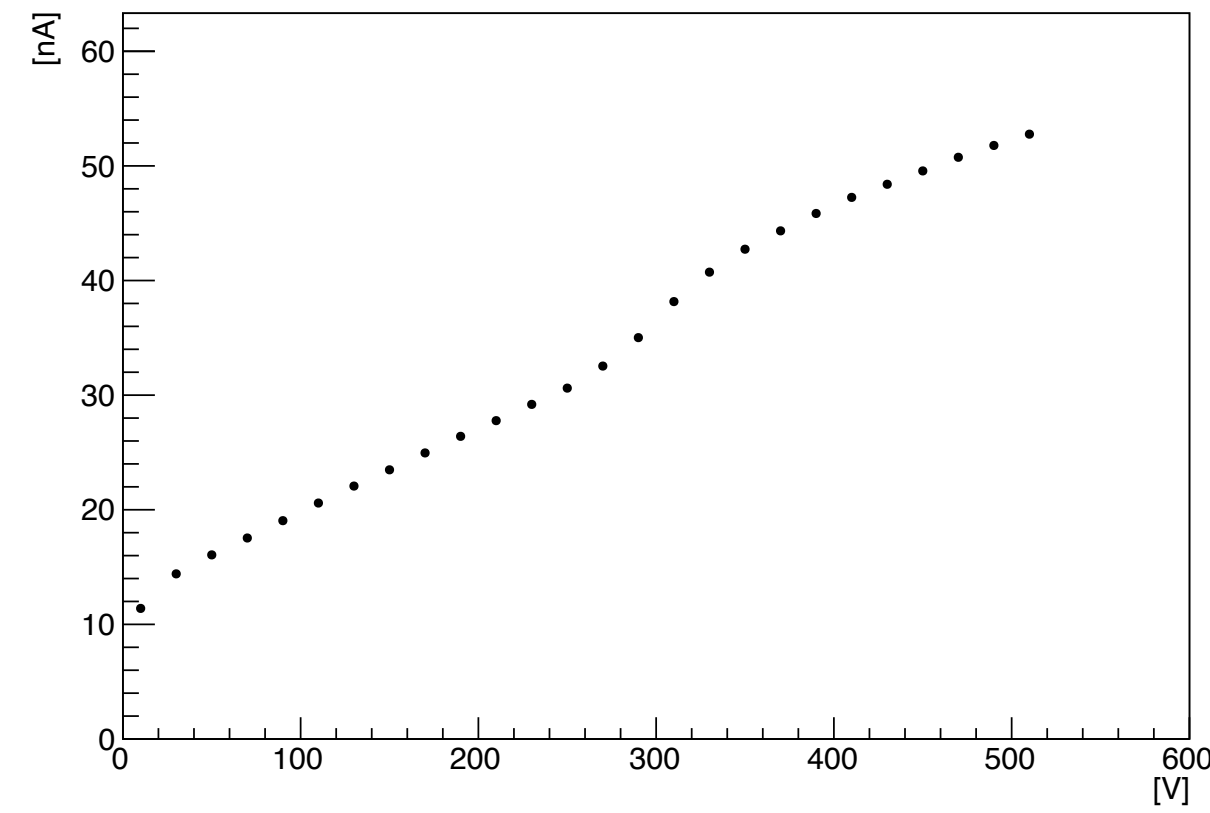
測定結果

28T1, 28T2, 28L1, 28L2 (1cm× 1cm)

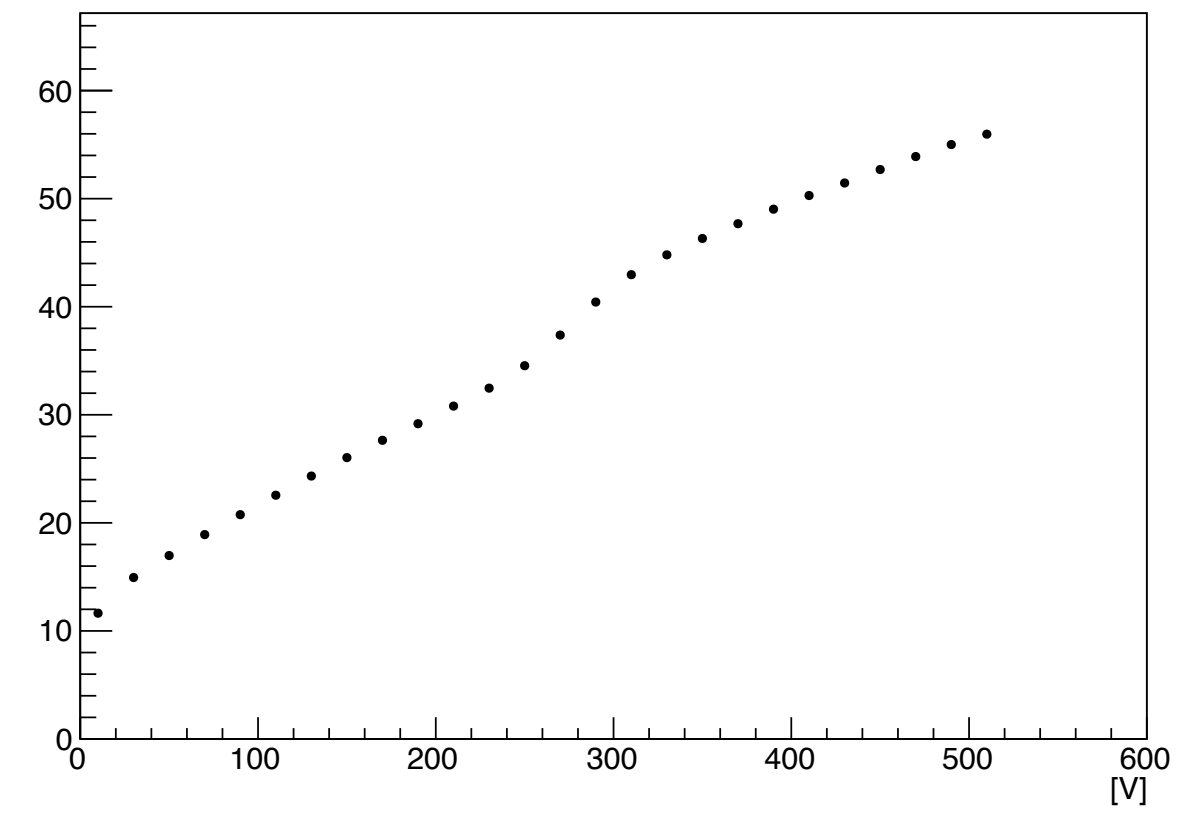
I-V 28T1_1



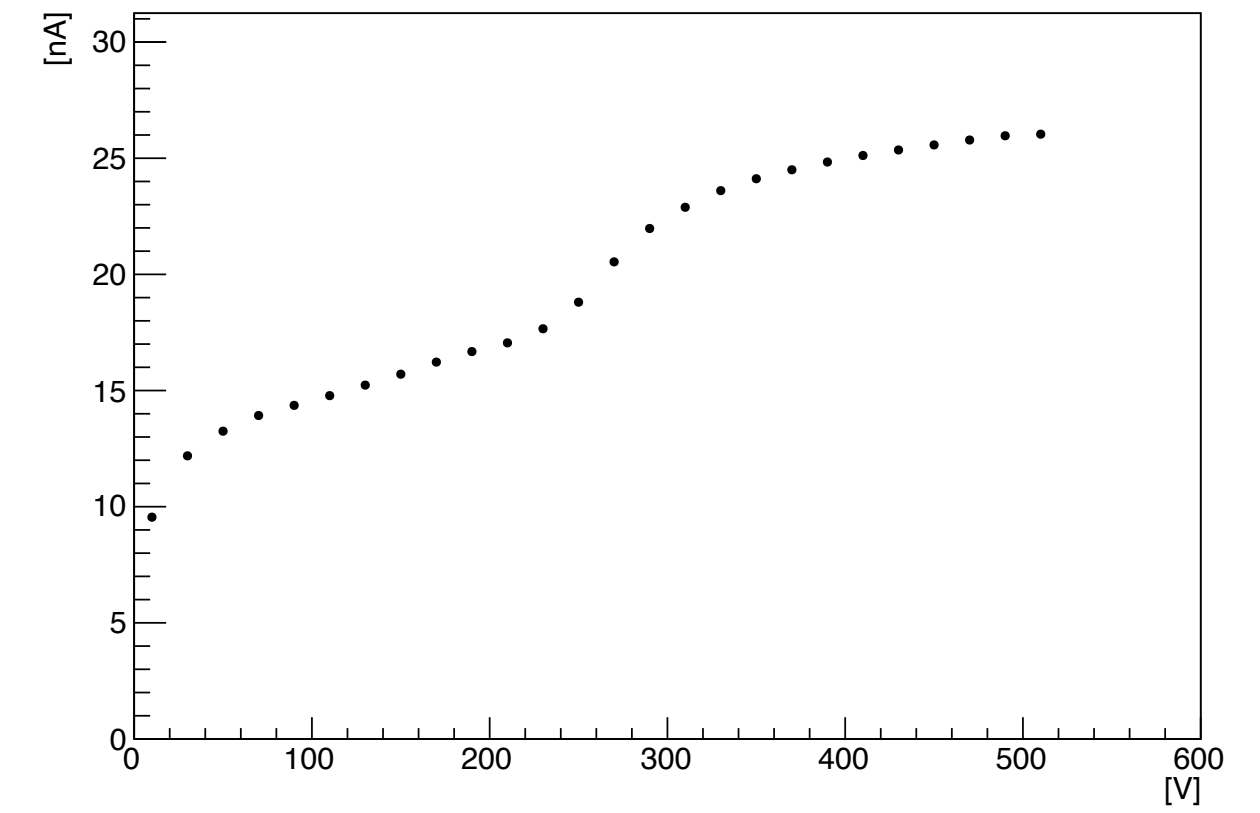
I-V 28T2_1



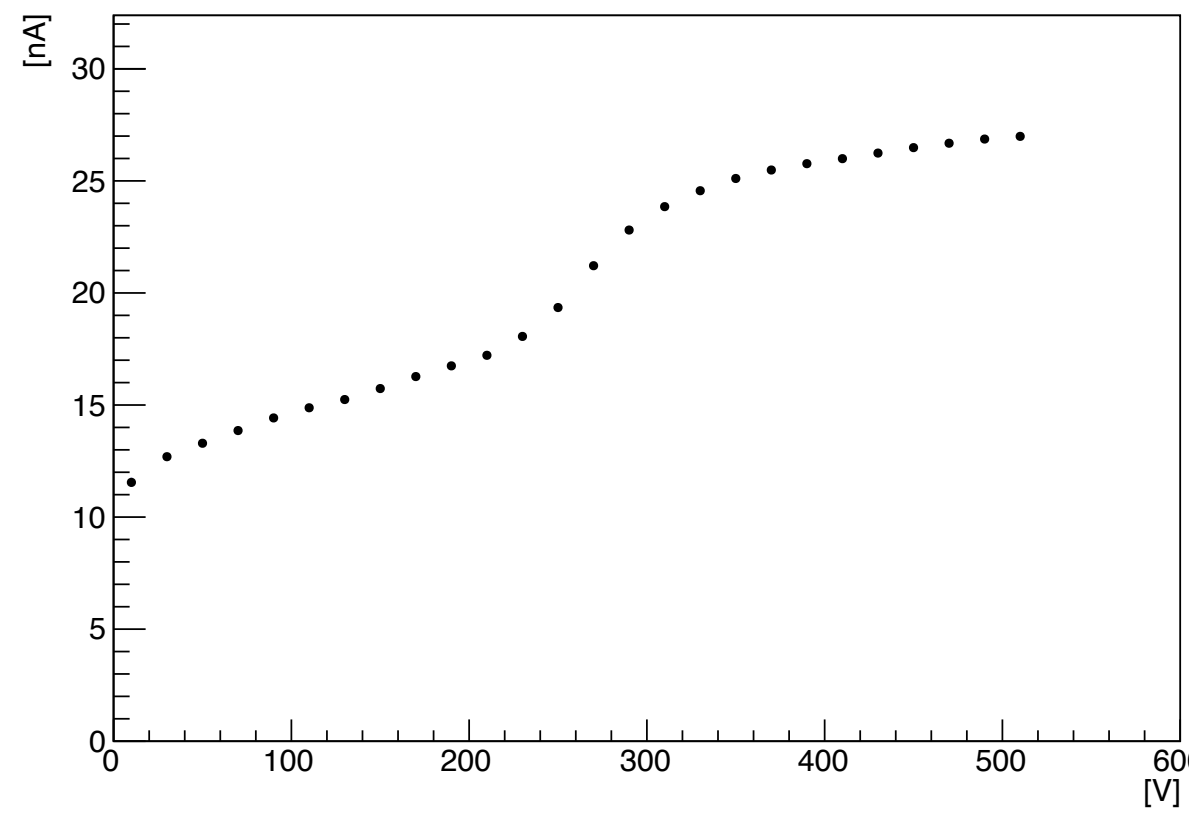
I-V 28L1_1



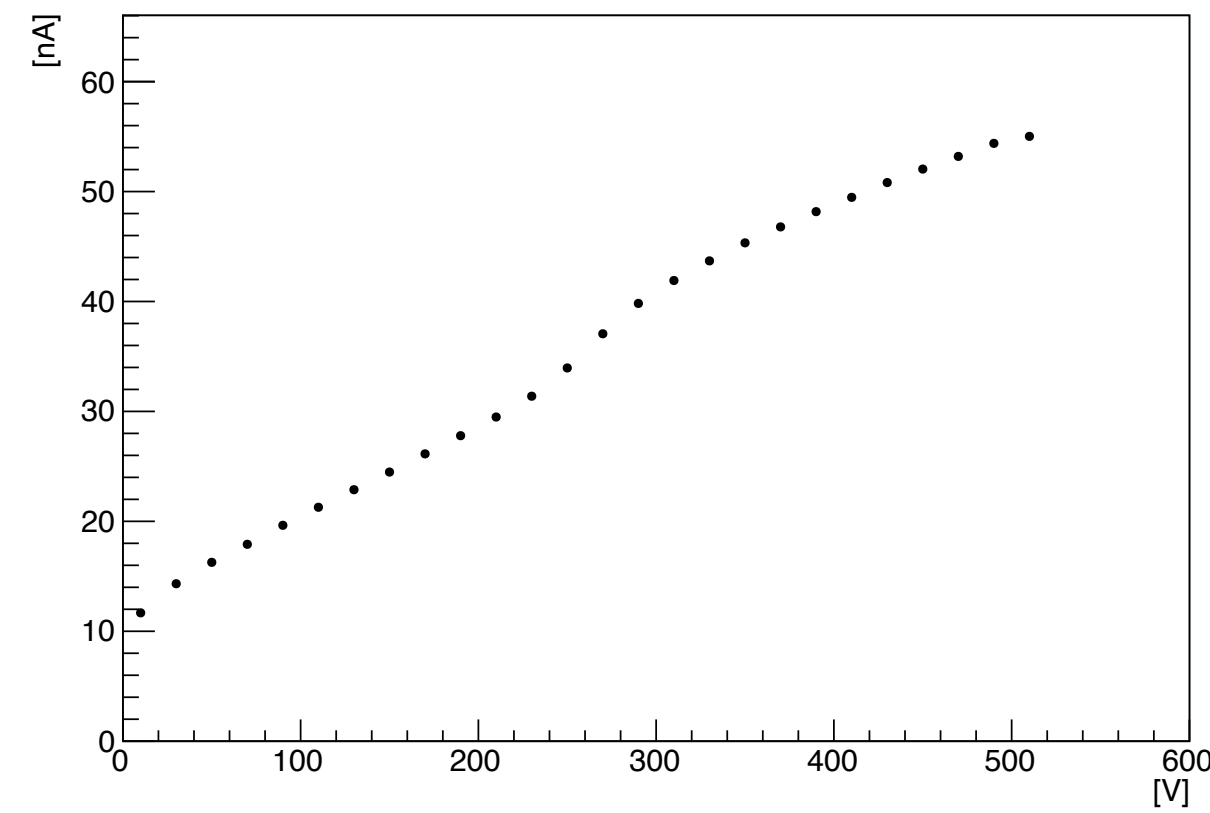
I-V 28L2_1



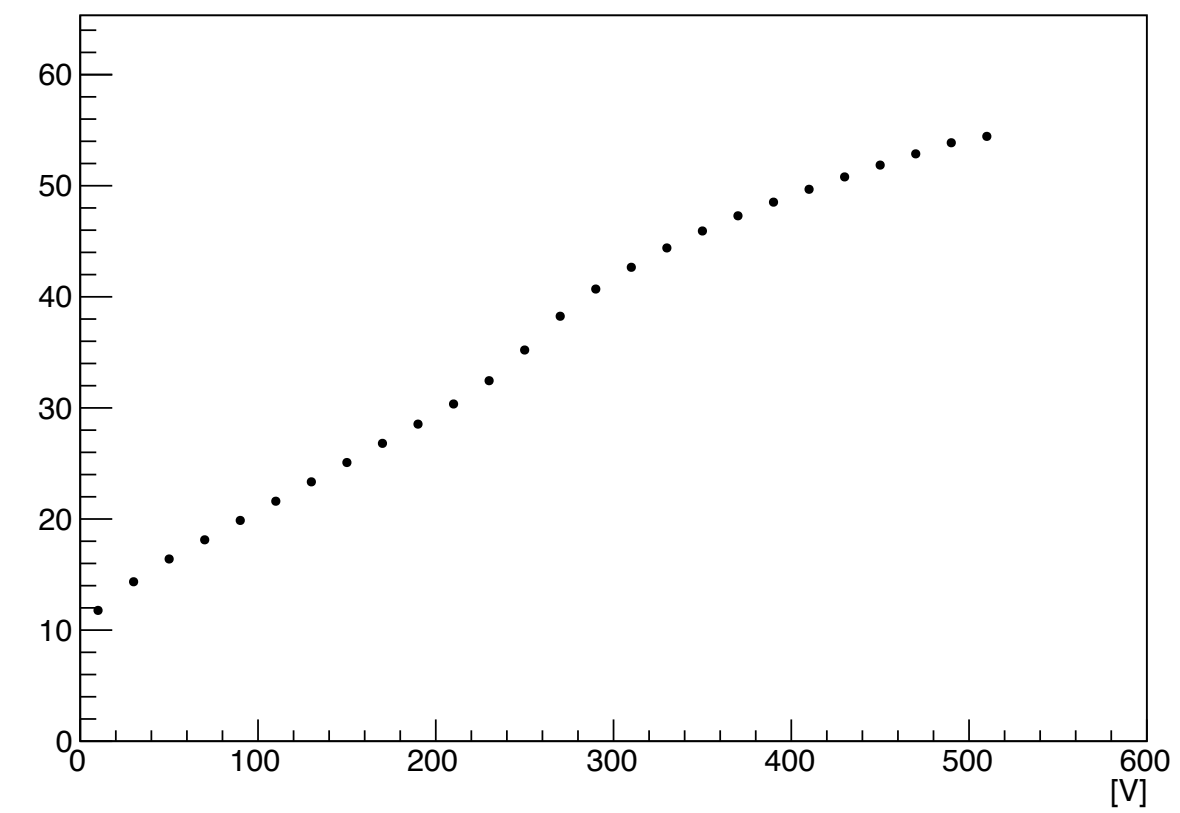
I-V 28T1_2



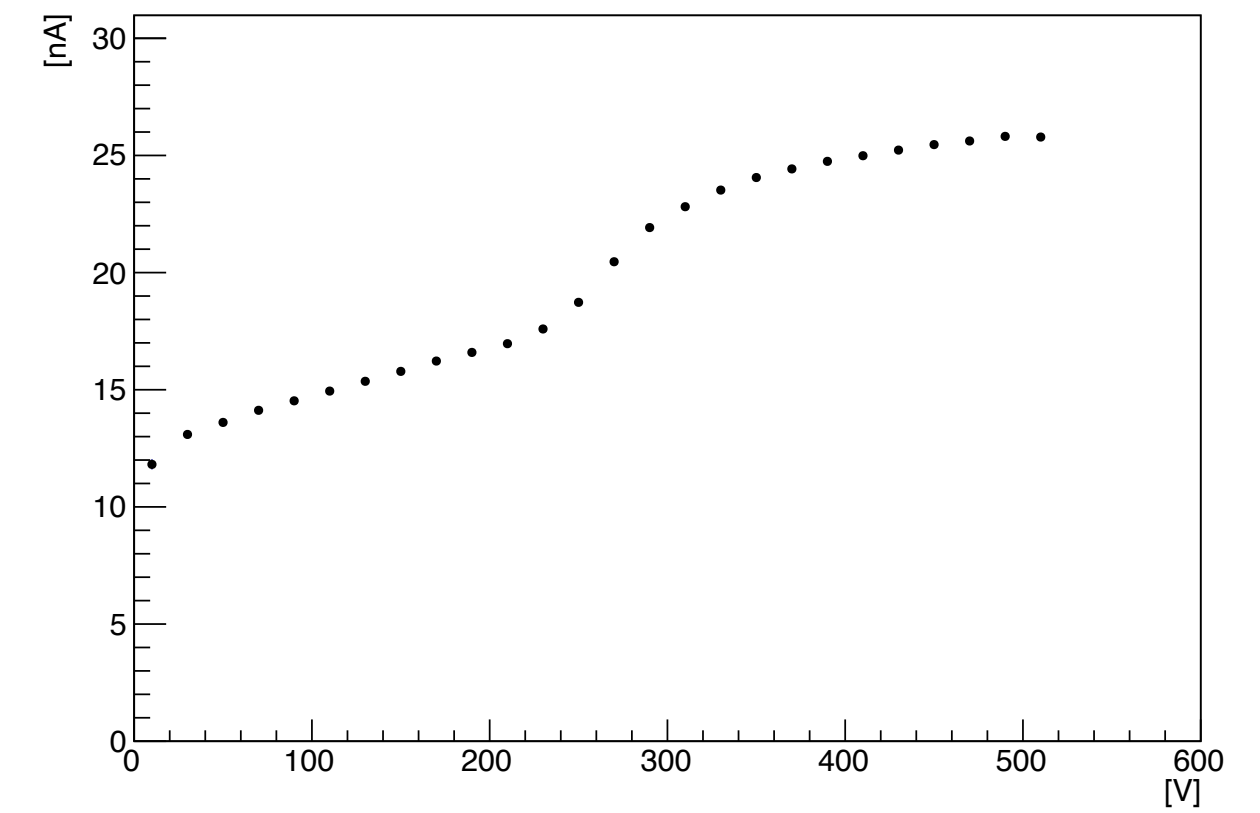
I-V 28T2_2



I-V 28L1_2



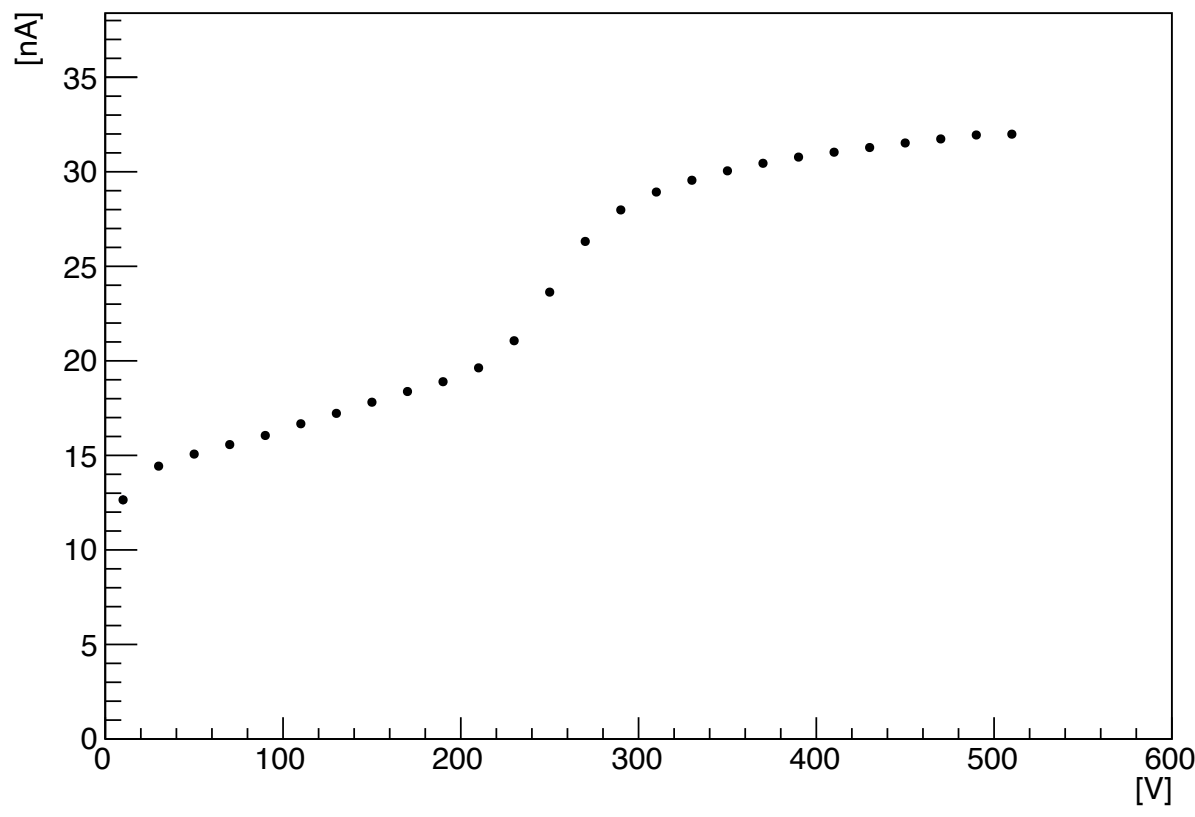
I-V 28L2_2



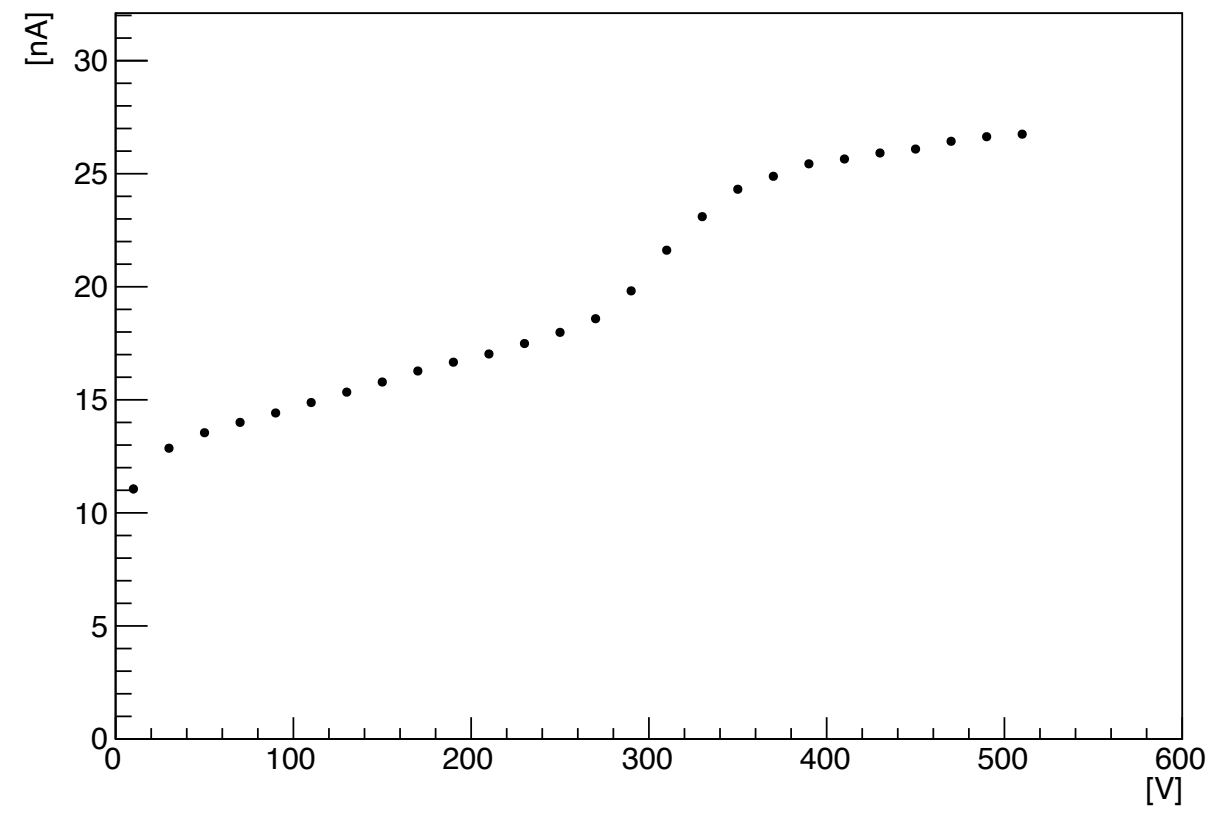
測定結果

28B1, 28B2, 28R1, 28R2 (1cm× 1cm)

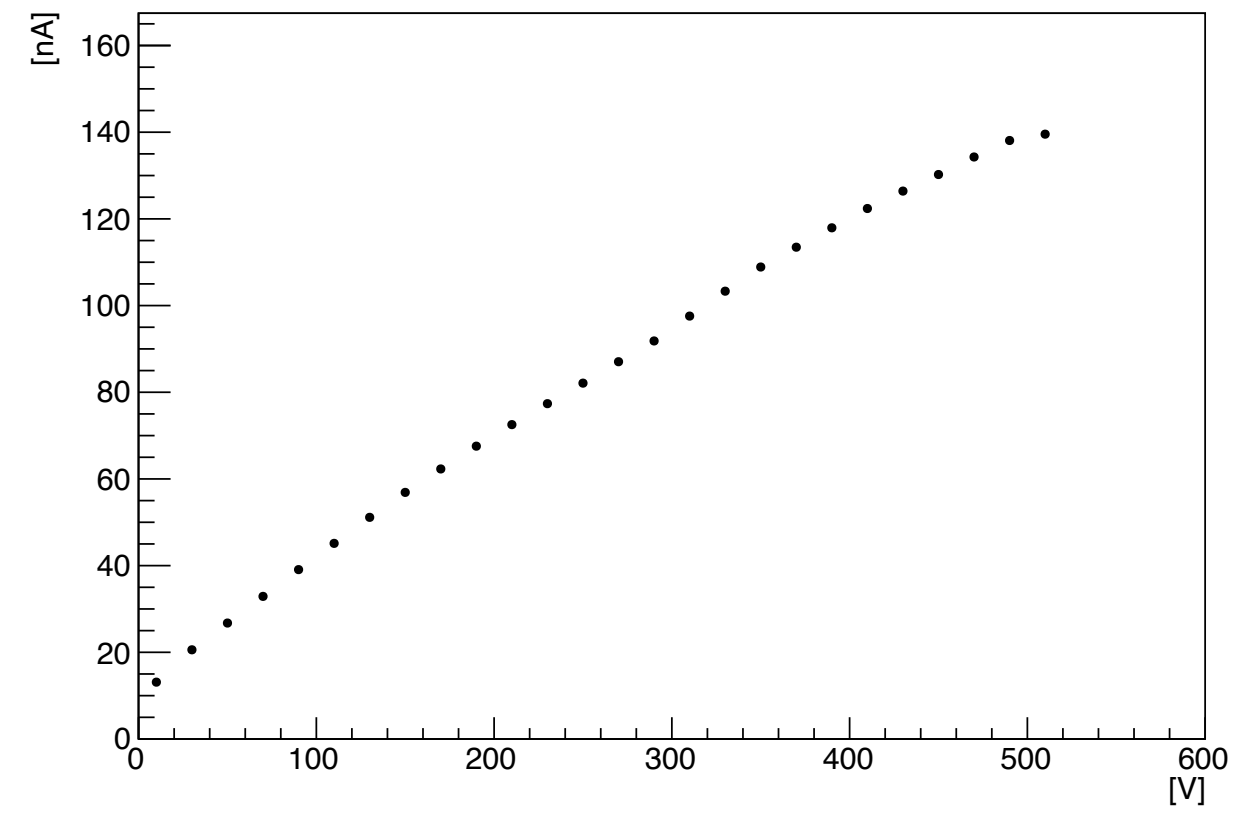
I-V 28B1_1



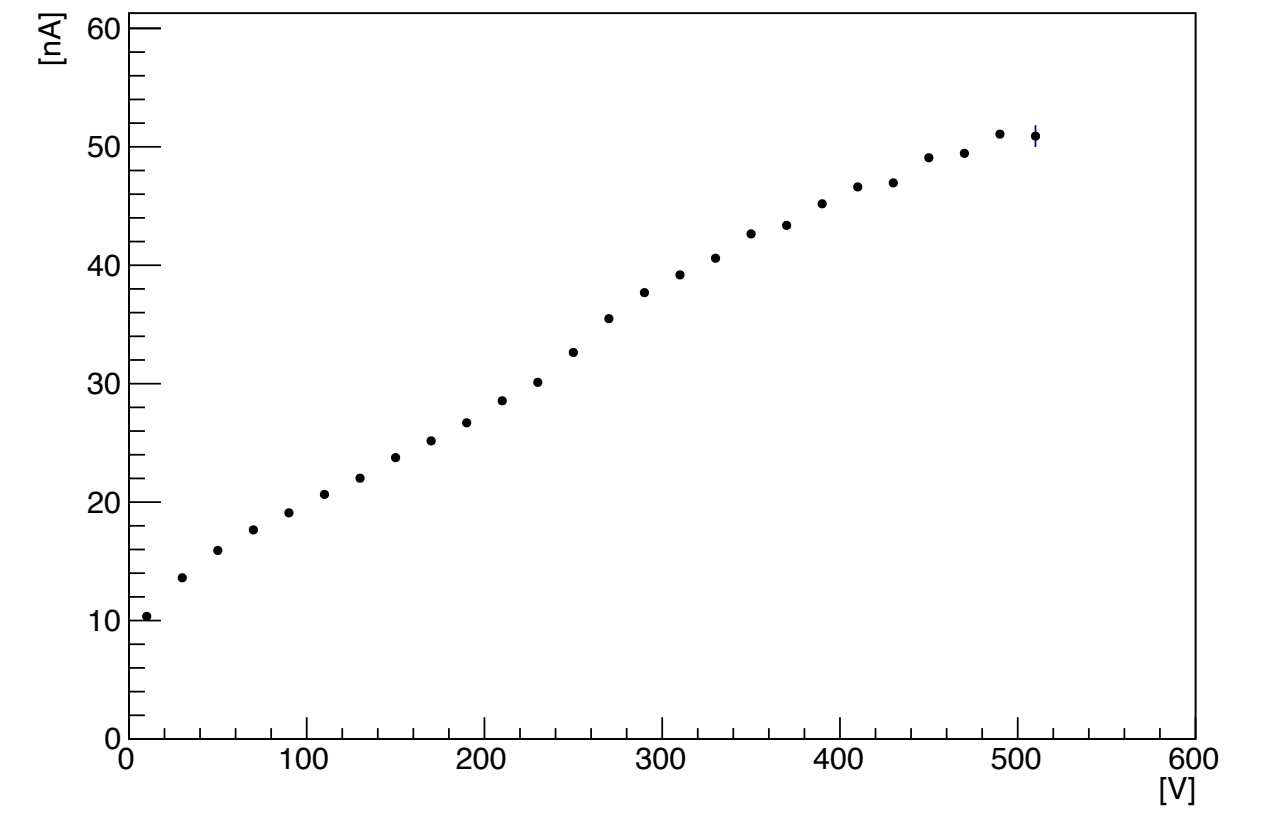
I-V 28B2_1



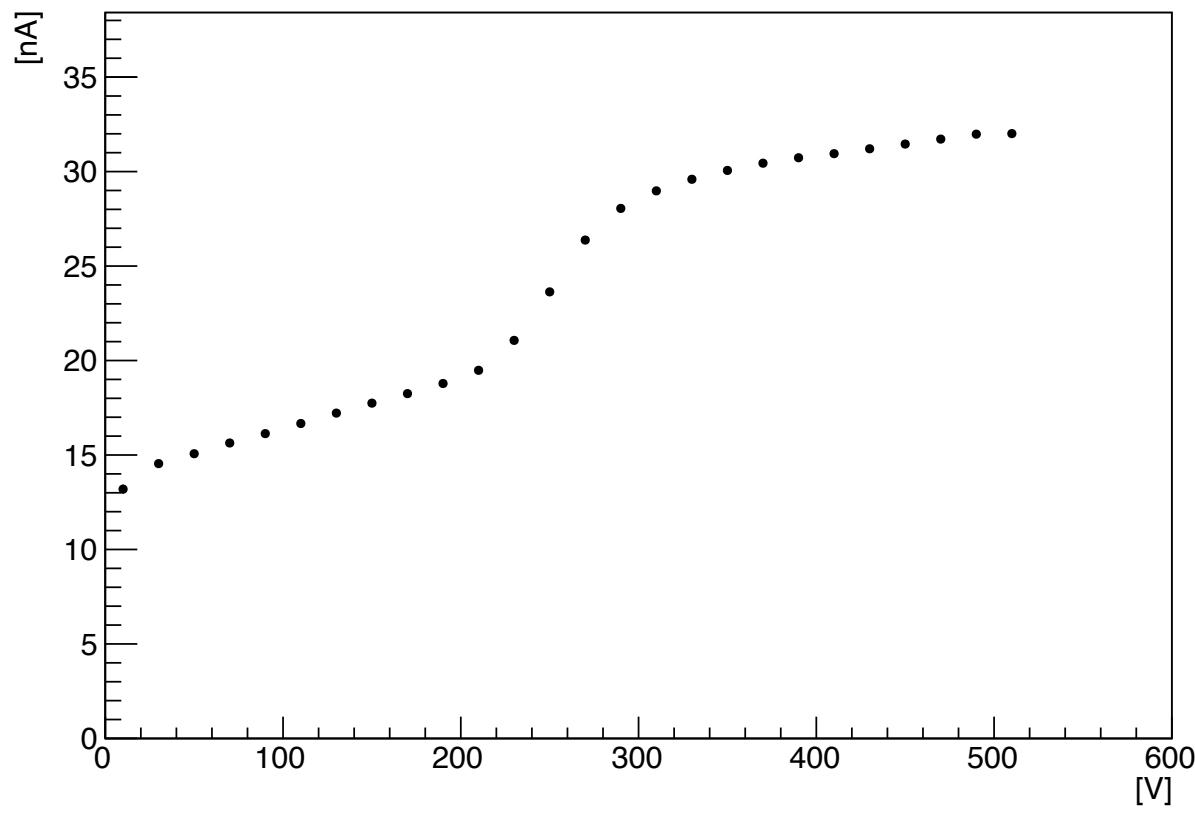
I-V 28R1_1



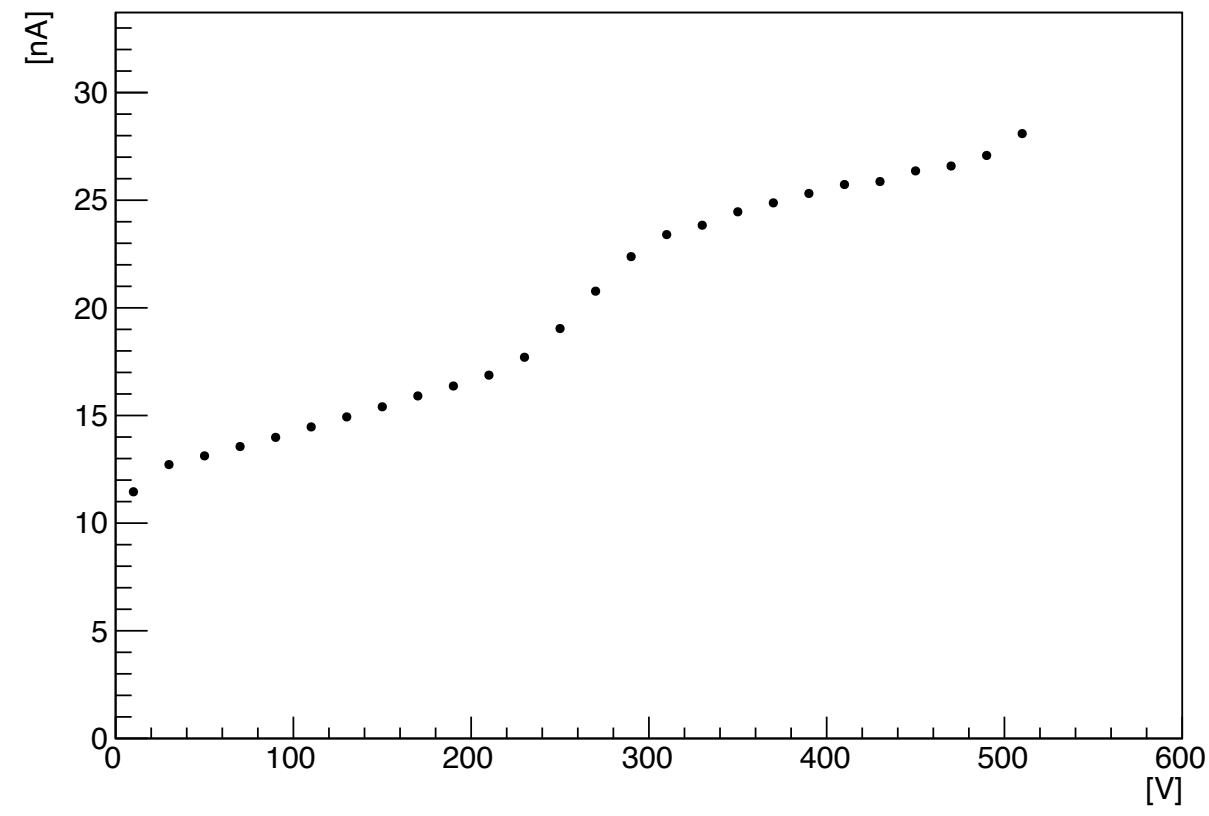
I-V 28R2_1



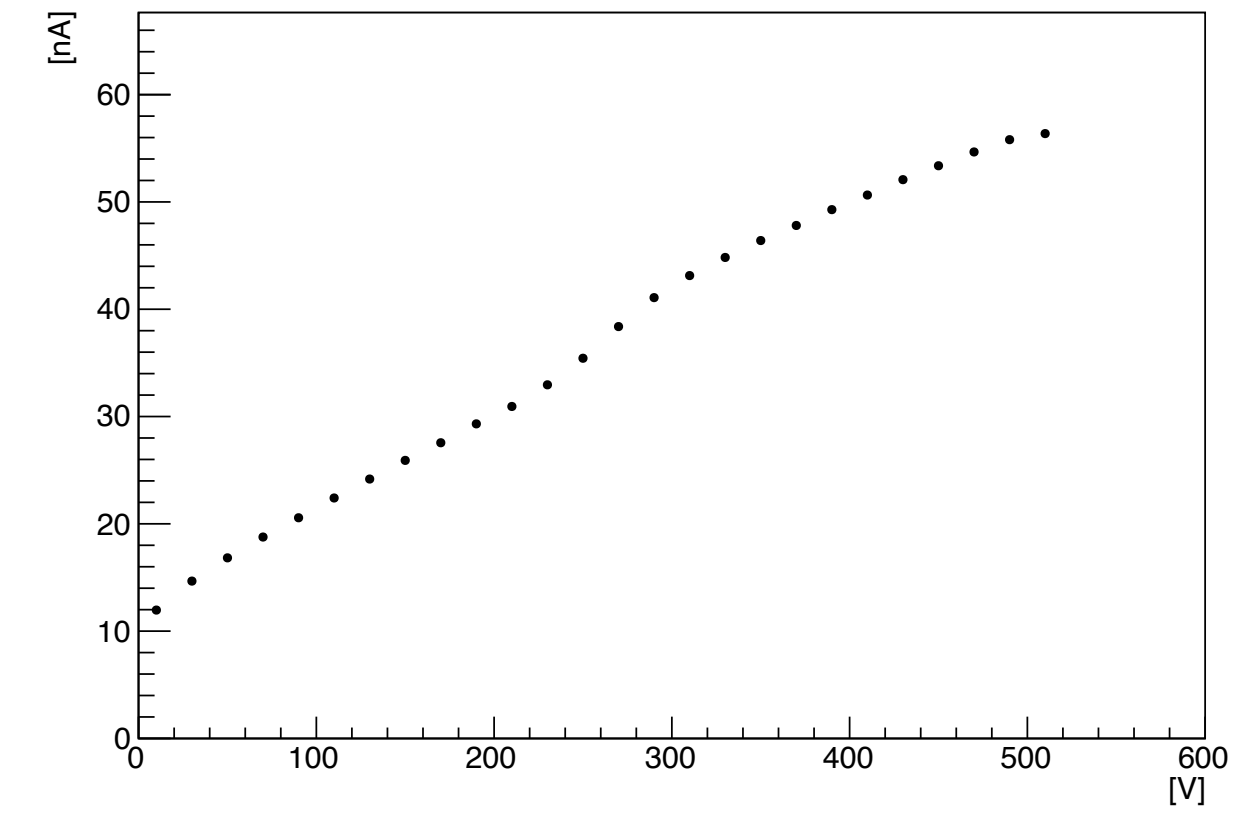
I-V 28B1_2



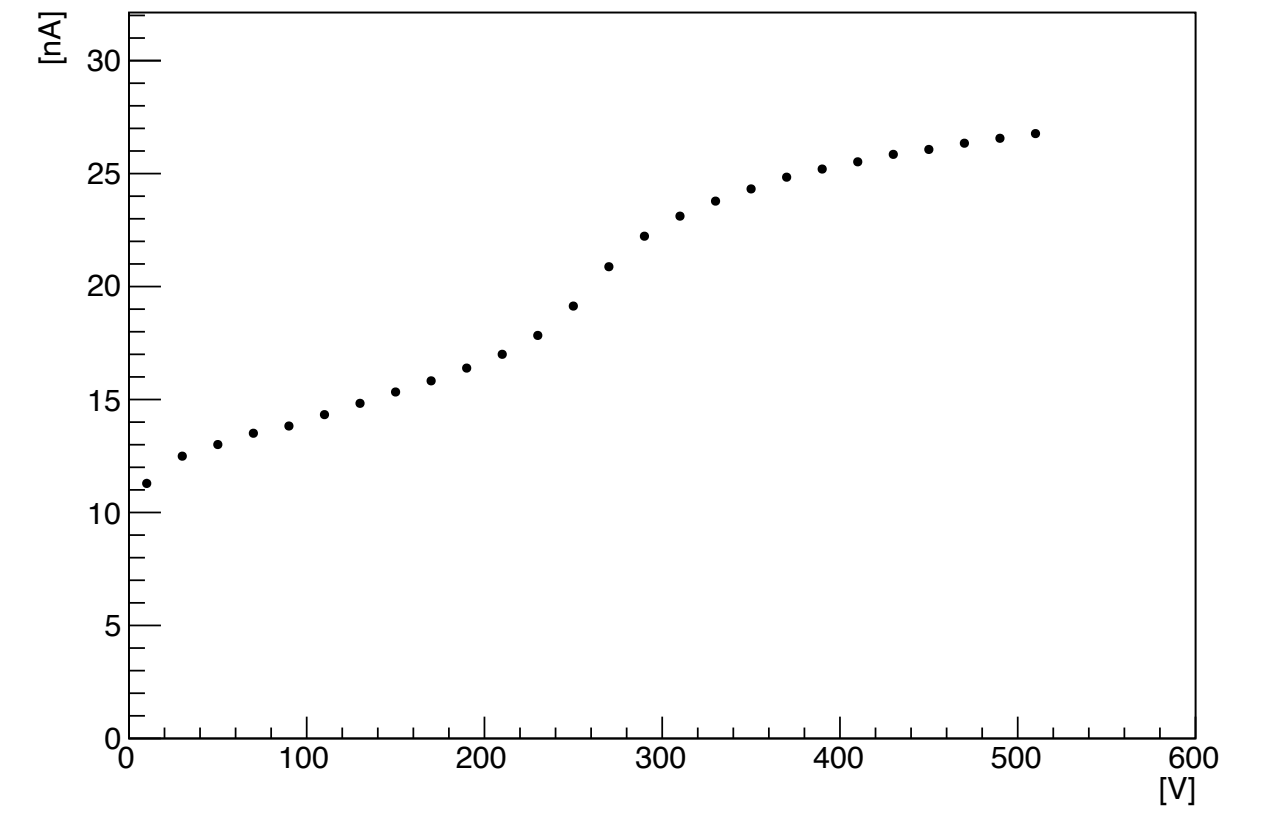
I-V 28B2_2



I-V 28R1_2



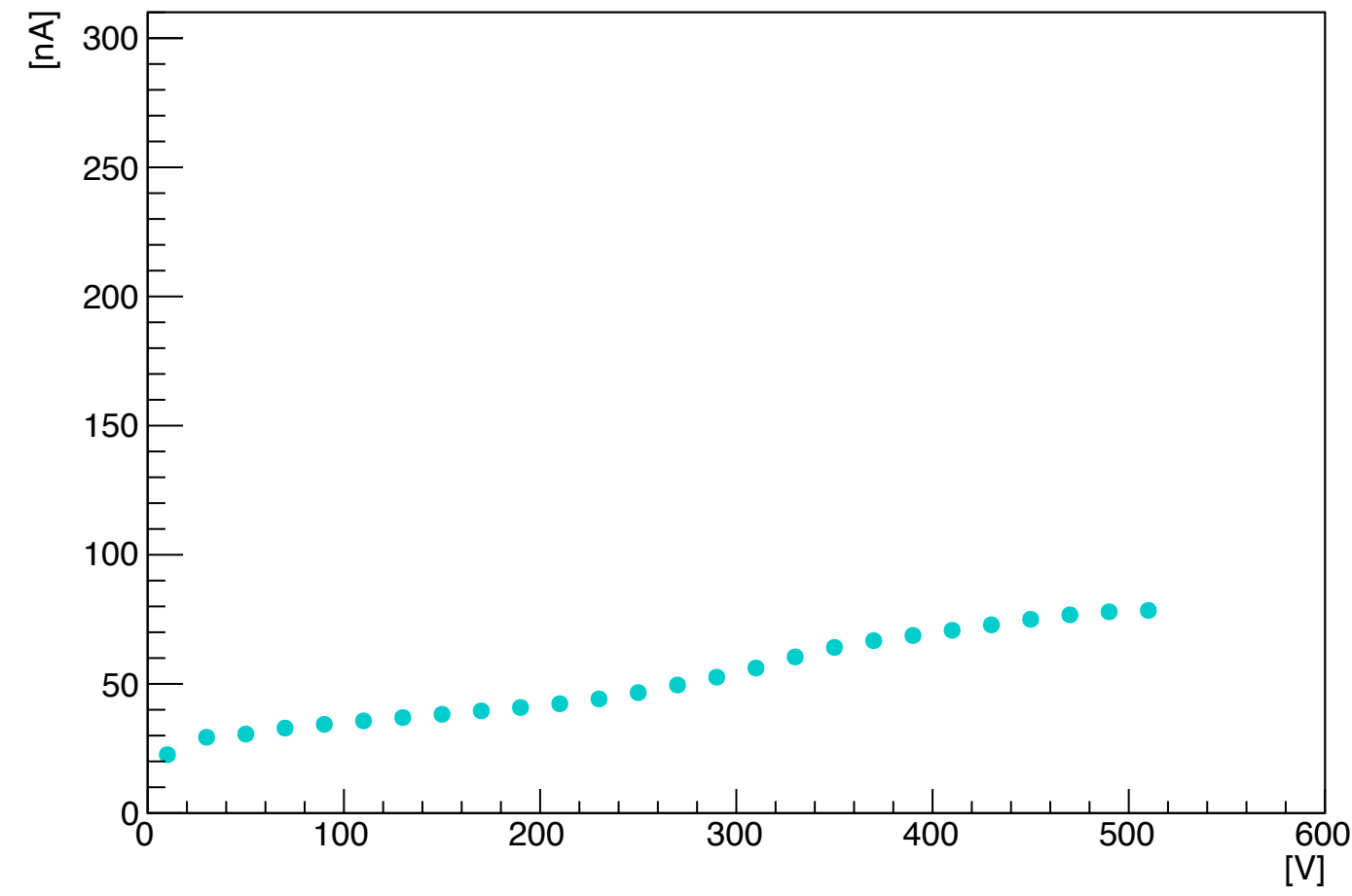
I-V 28R2_2



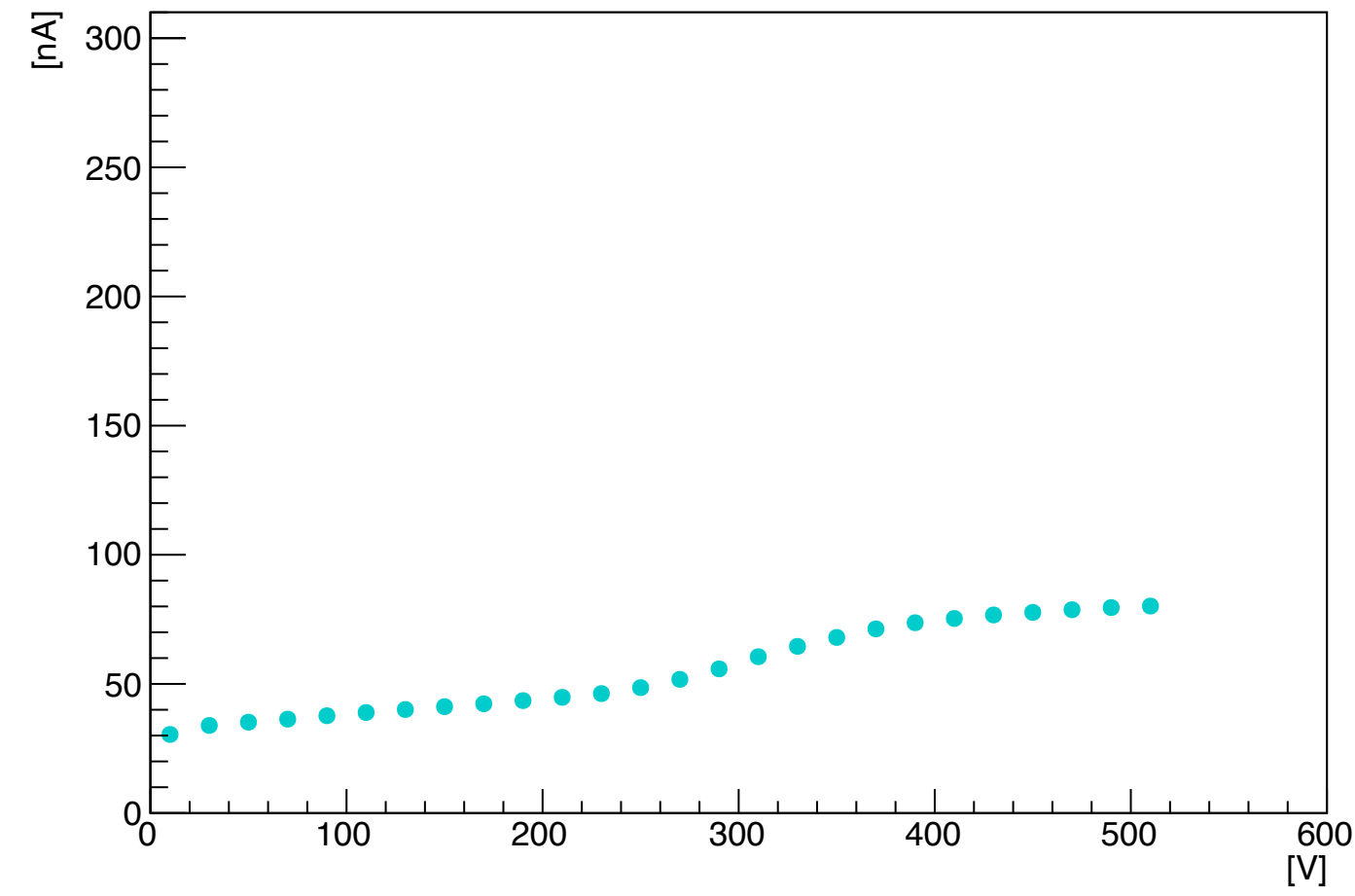
測定結果(軸を揃えたもの)

14 (2cm× 2cm)

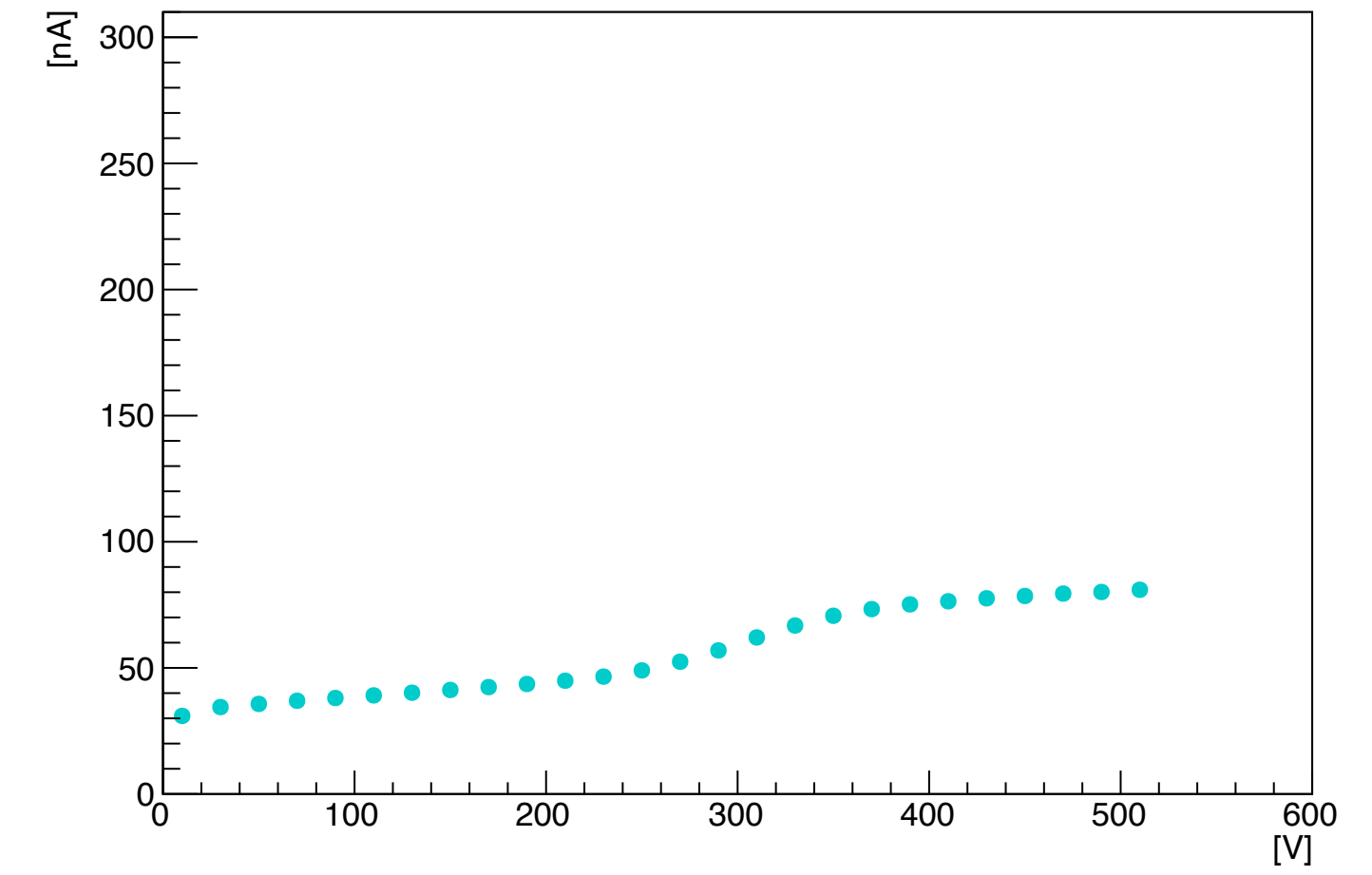
I-V 14_1



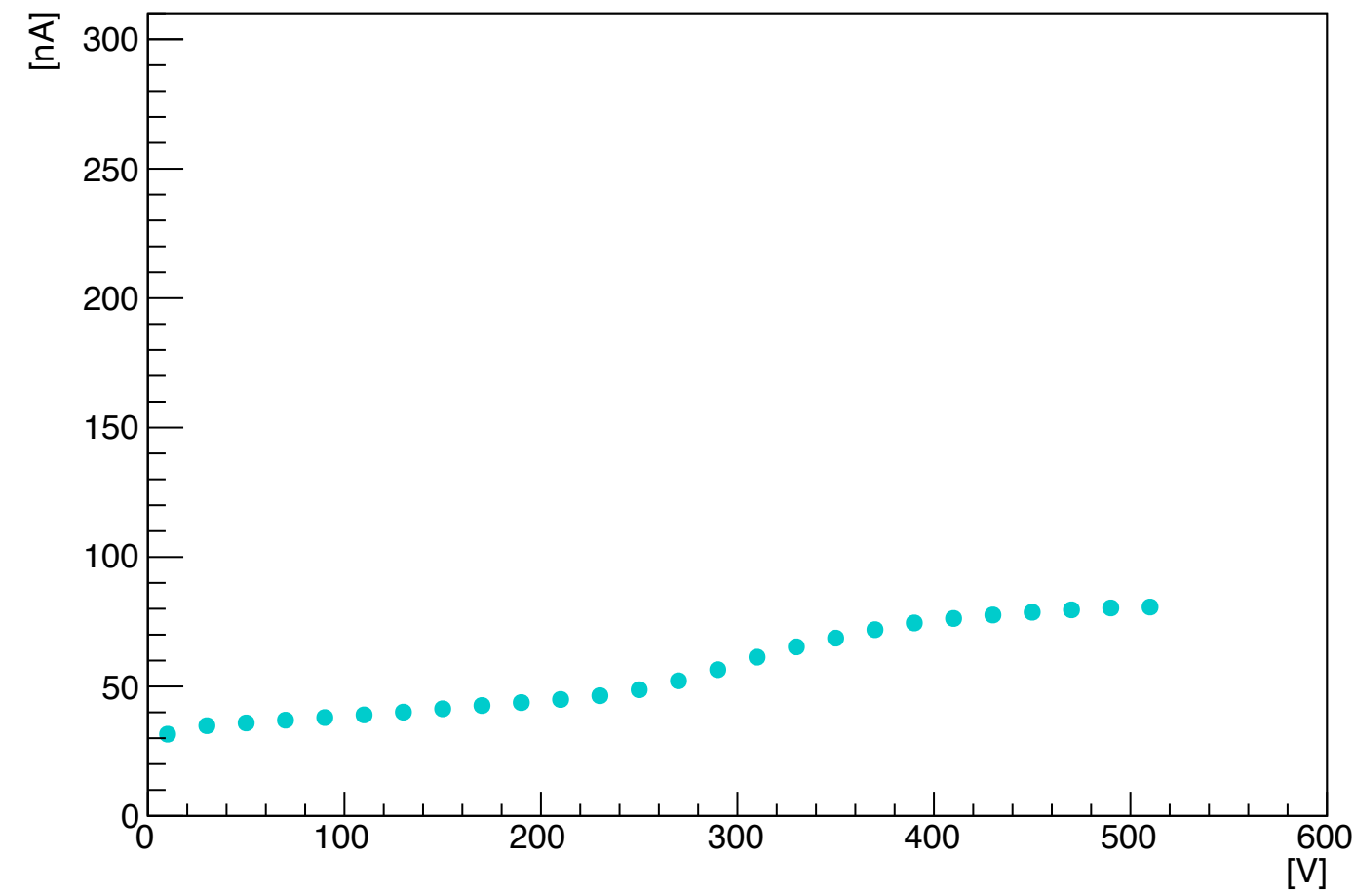
I-V 14_3



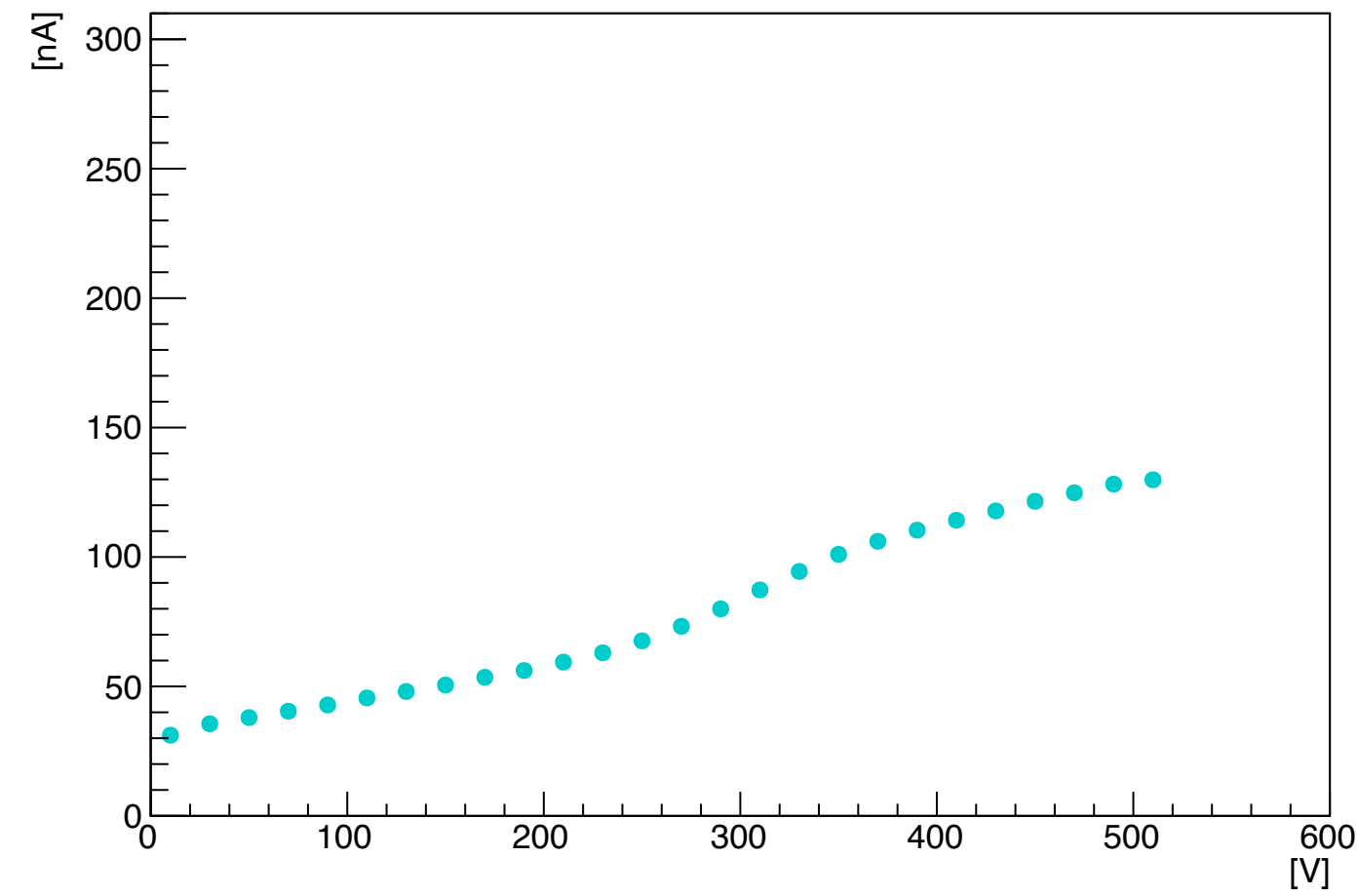
I-V 14_5



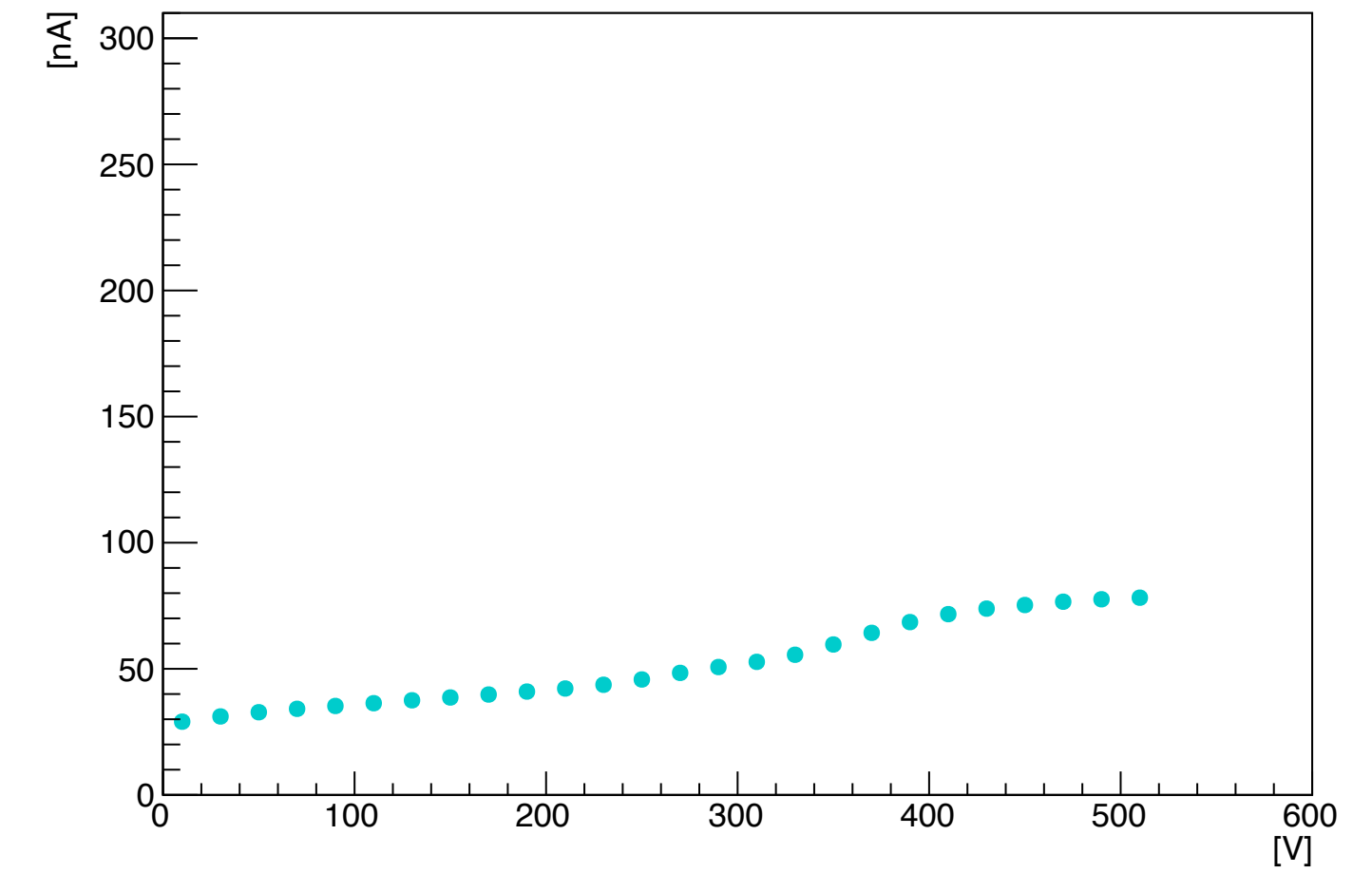
I-V 14_2



I-V 14_4



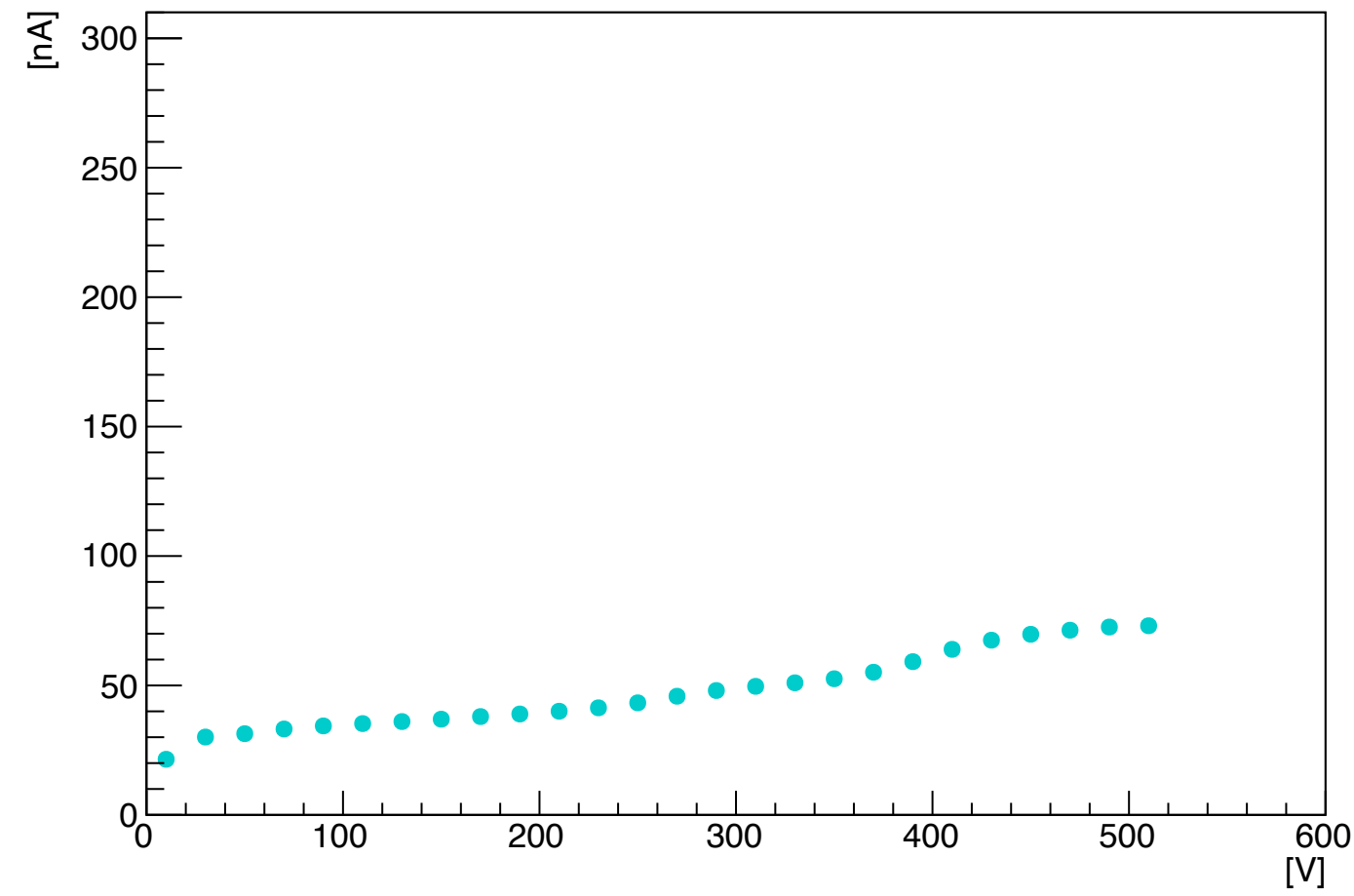
I-V 14_6



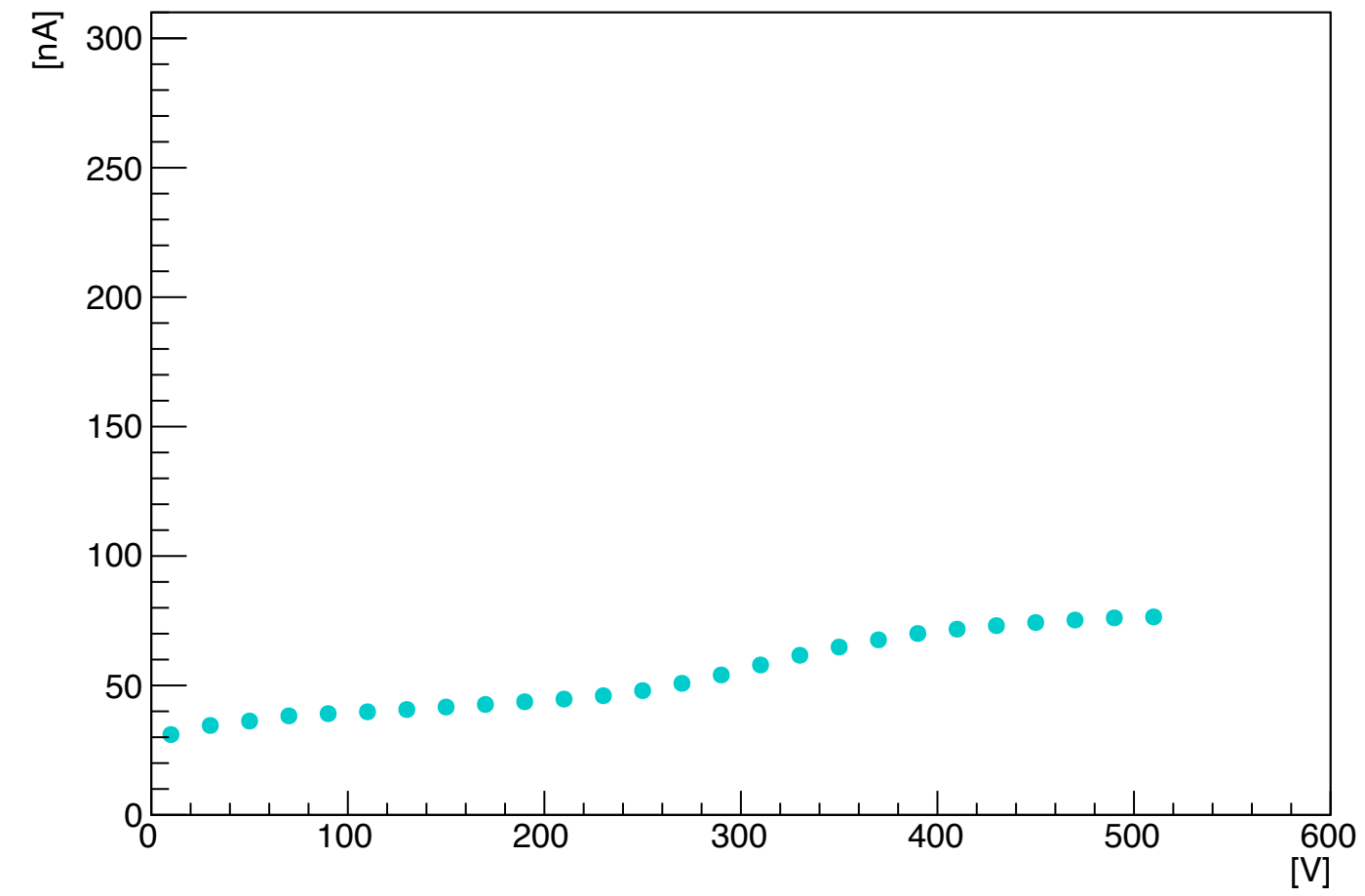
測定結果(軸を揃えたもの)

19 (2cm× 2cm)

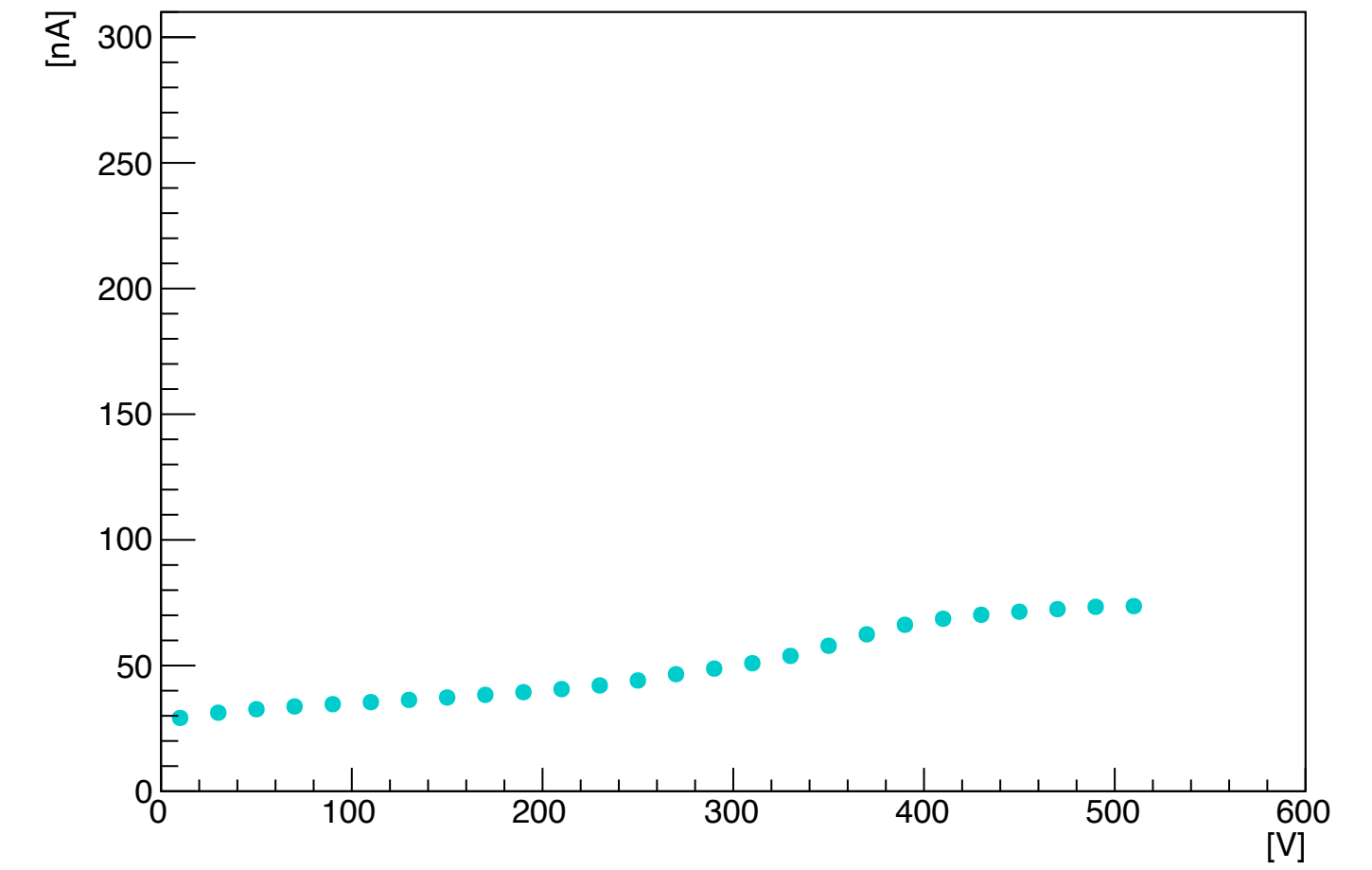
I-V 19_1



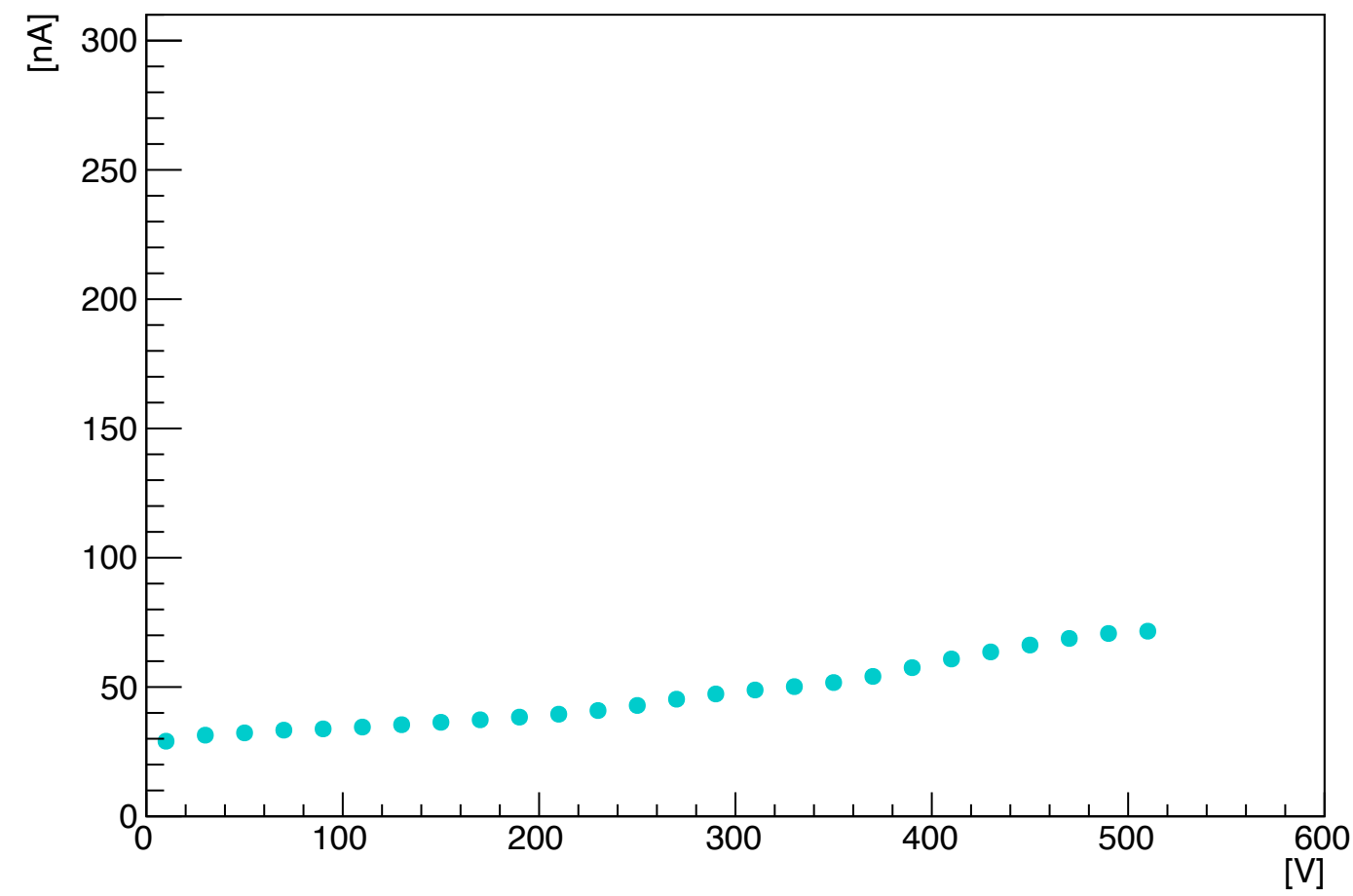
I-V 19_3



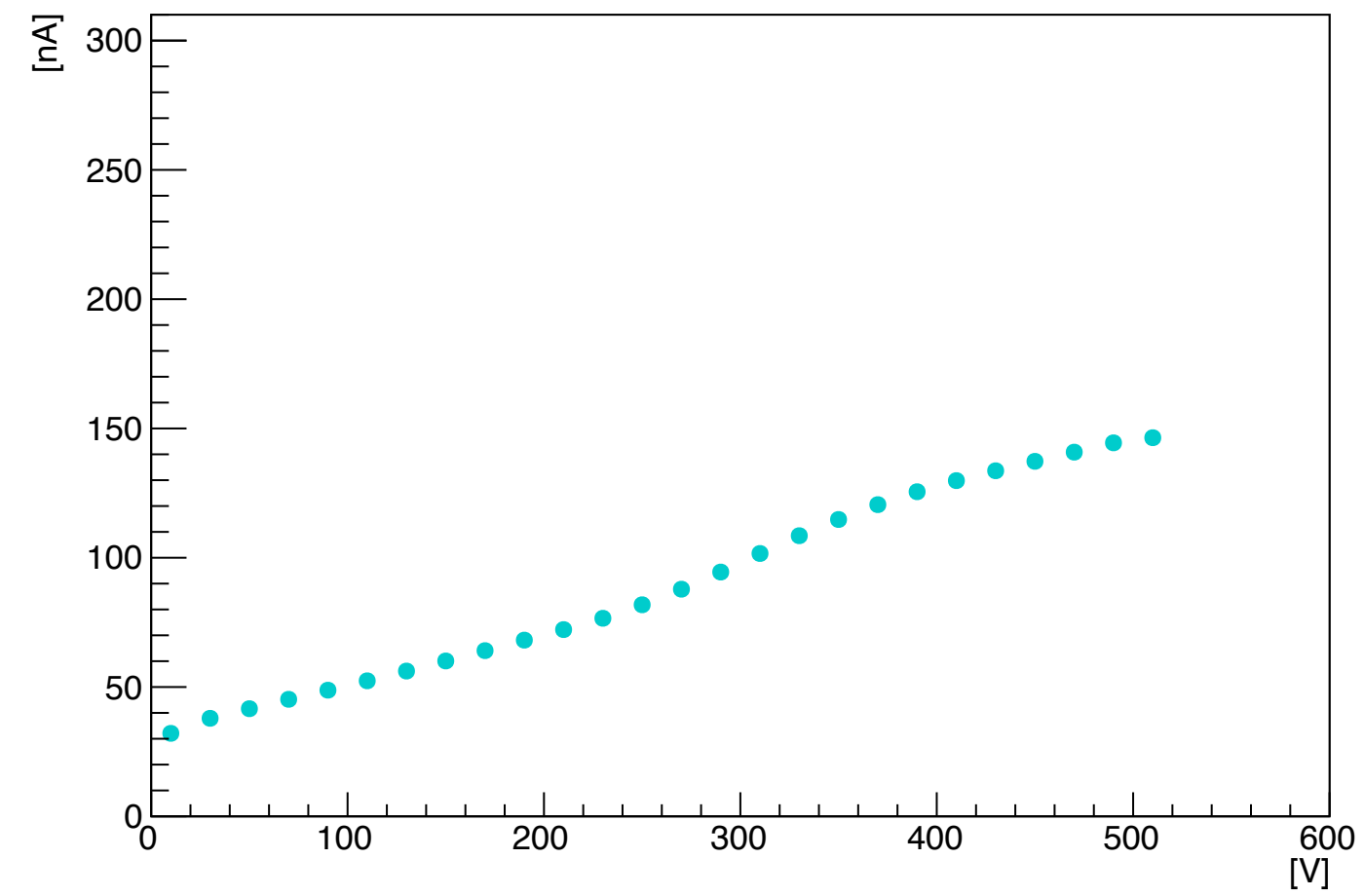
I-V 19_5



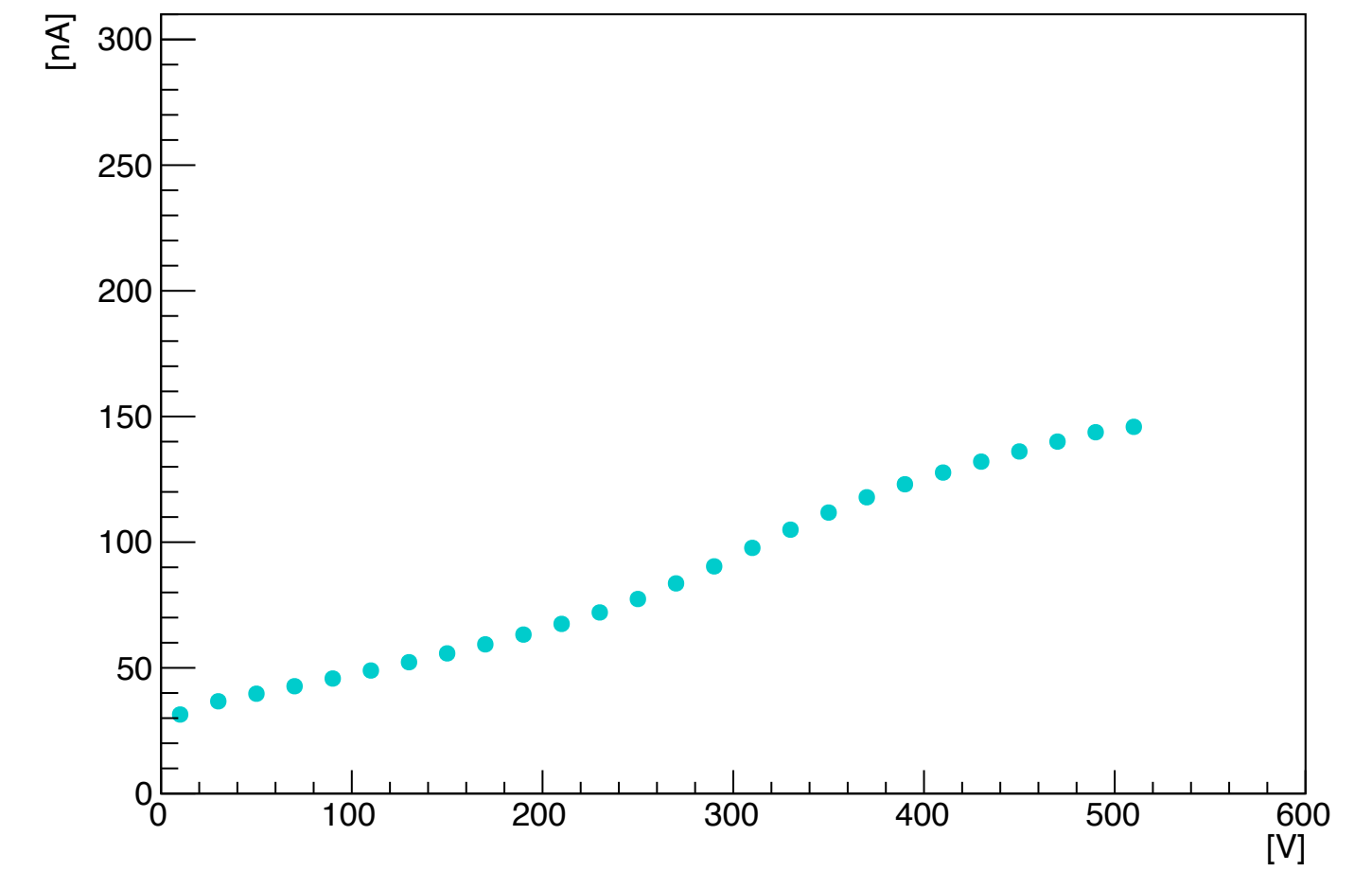
I-V 19_2



I-V 19_4



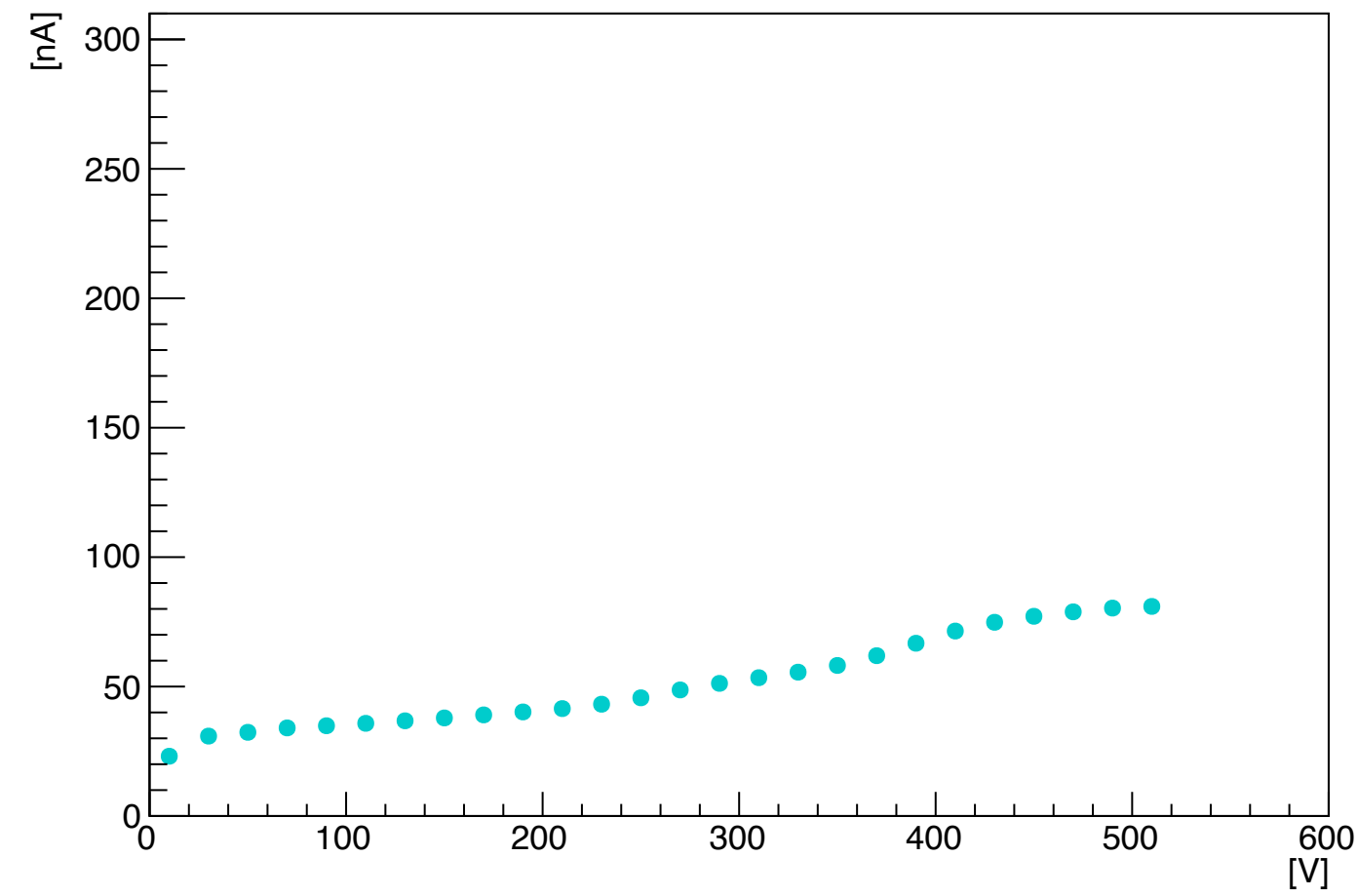
I-V 19_6



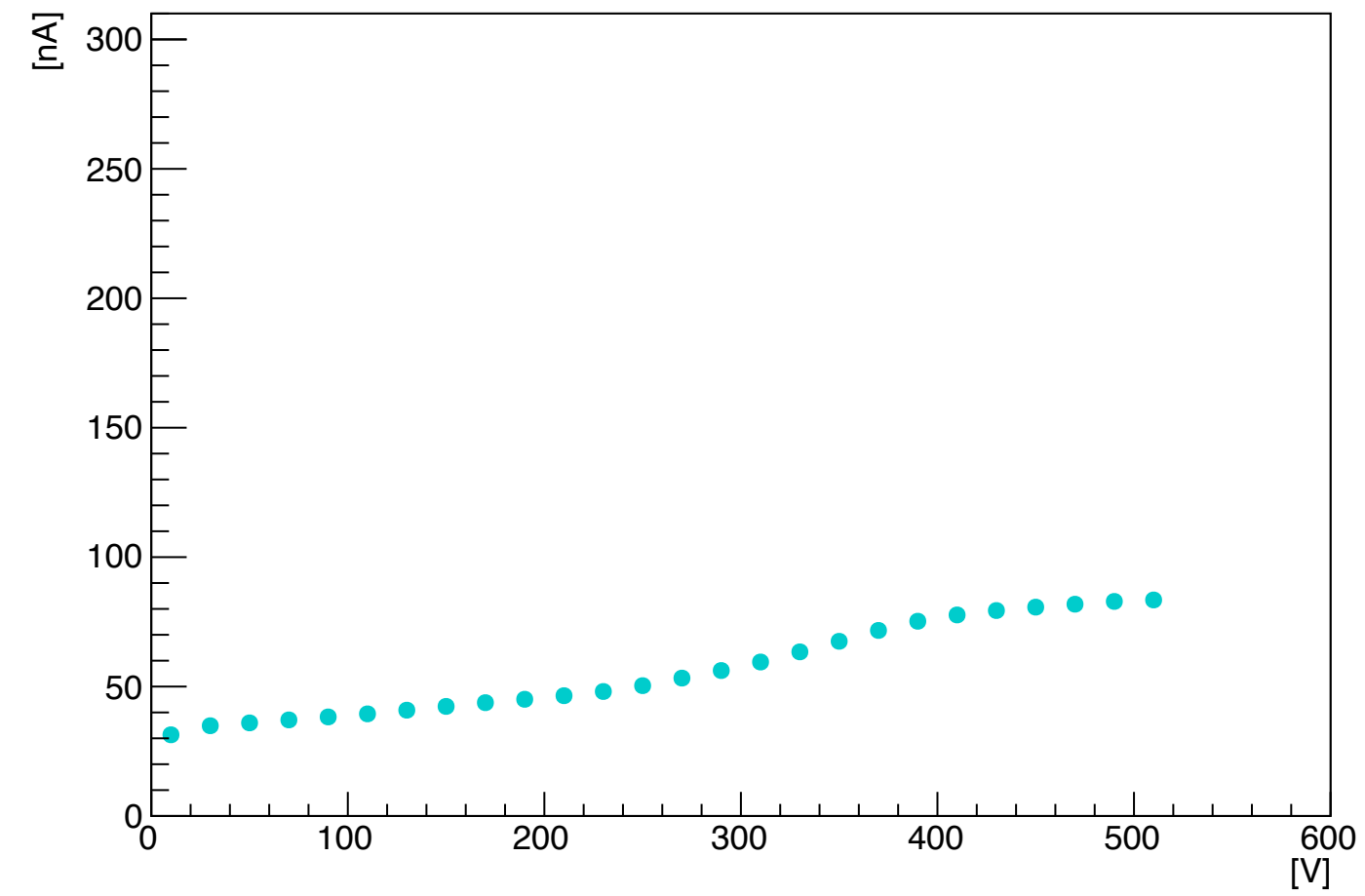
測定結果(軸を揃えたもの)

28 (2cm× 2cm)

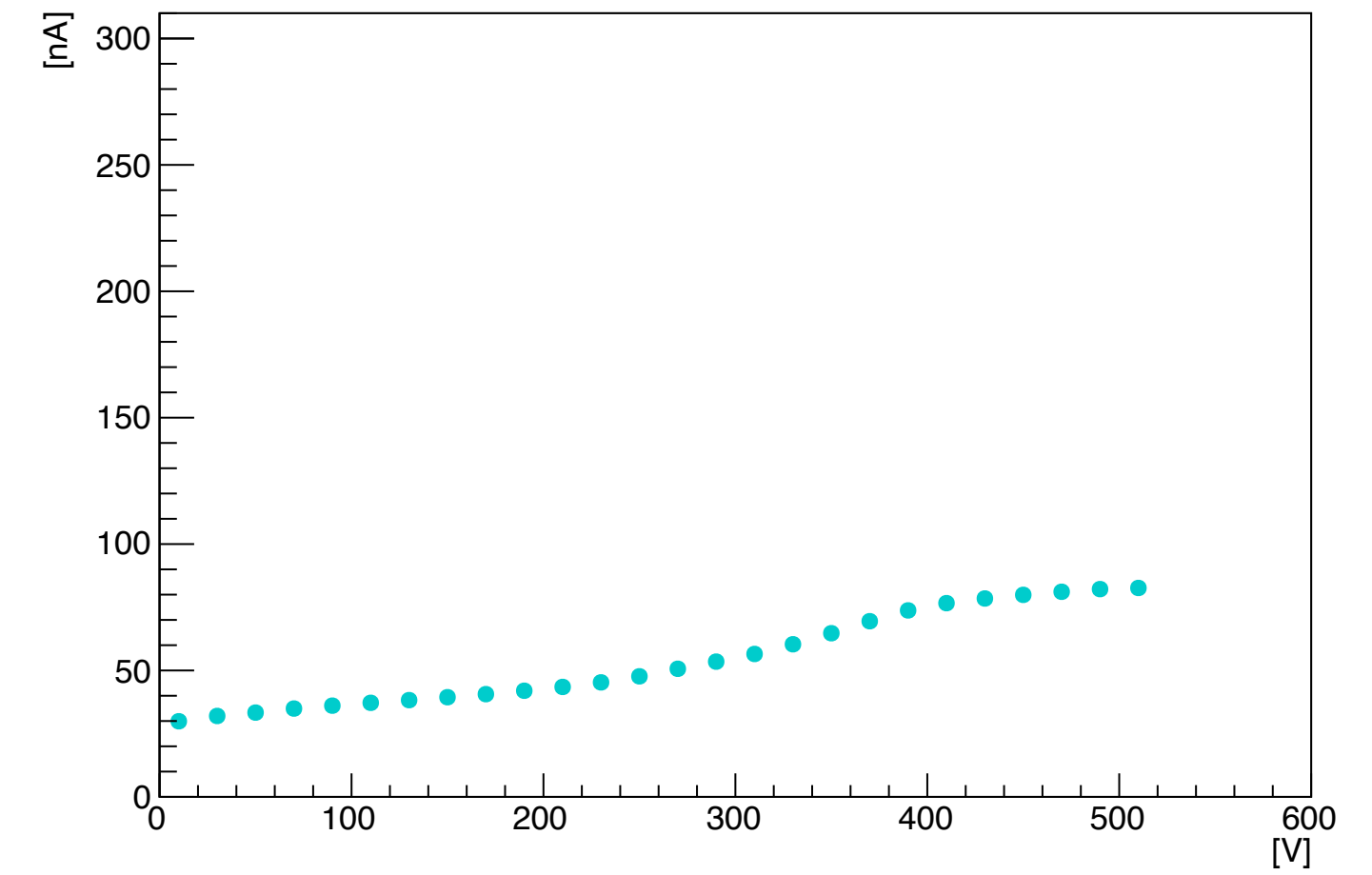
I-V 28_1



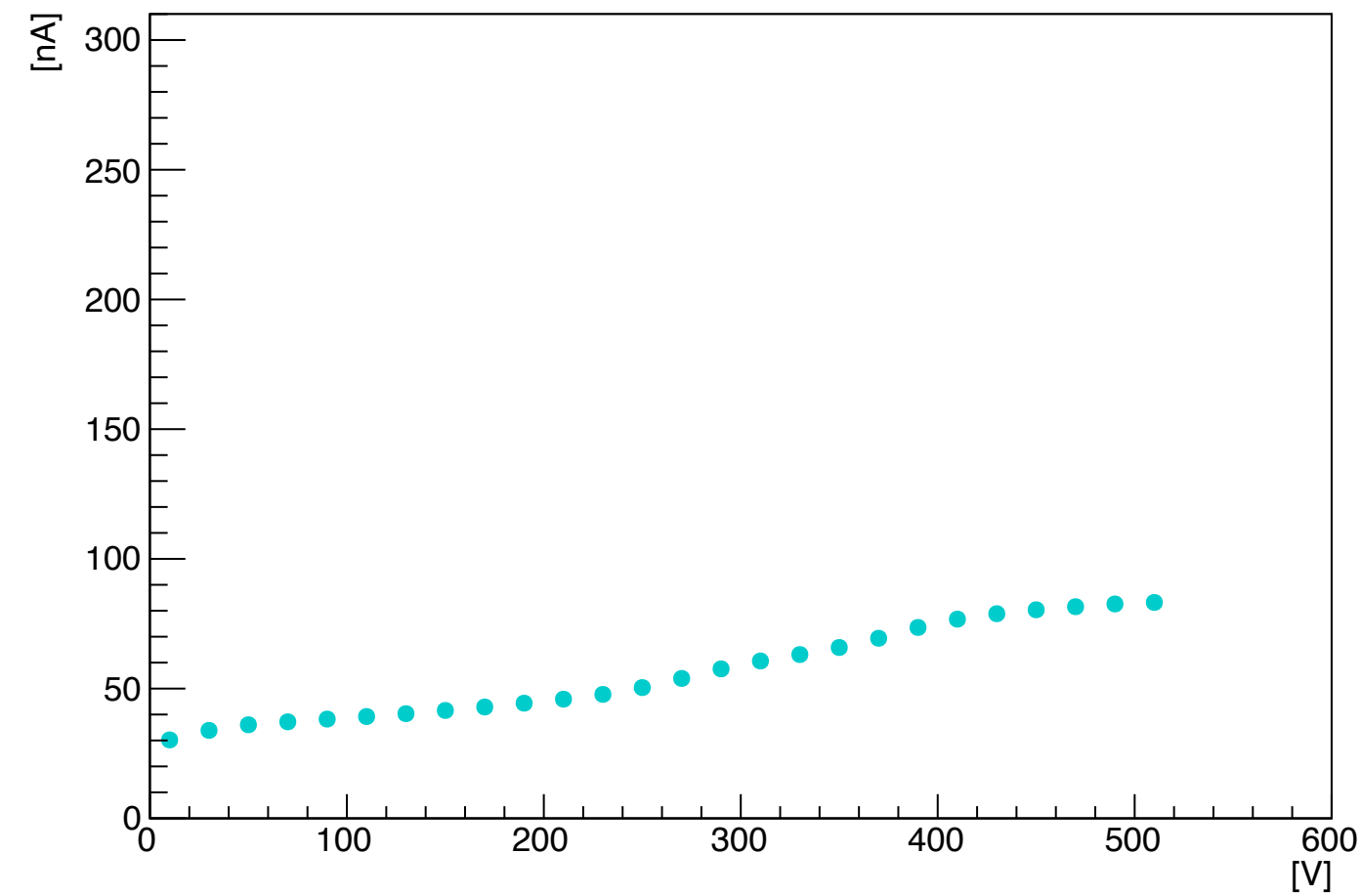
I-V 28_3



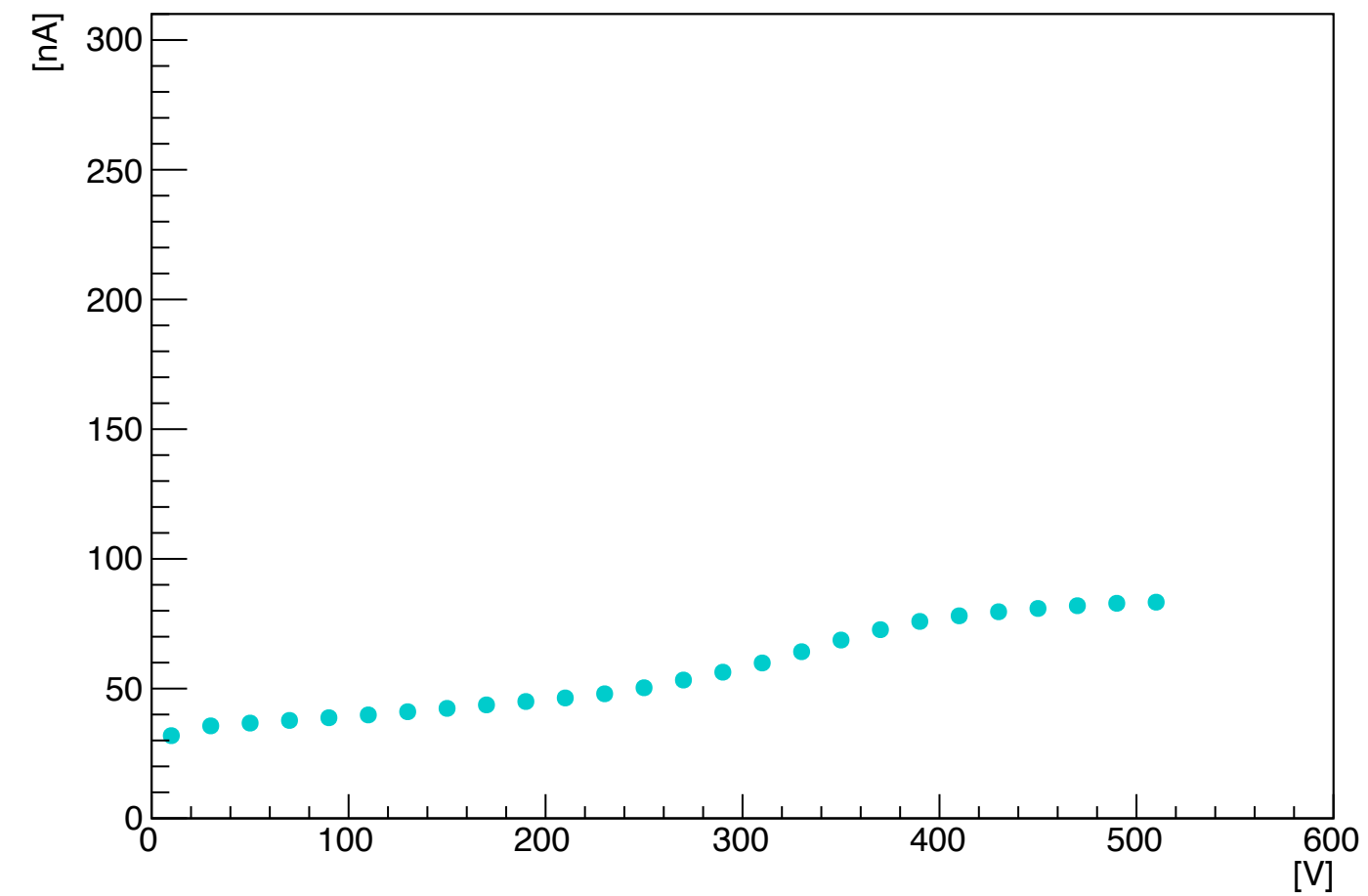
I-V 28_5



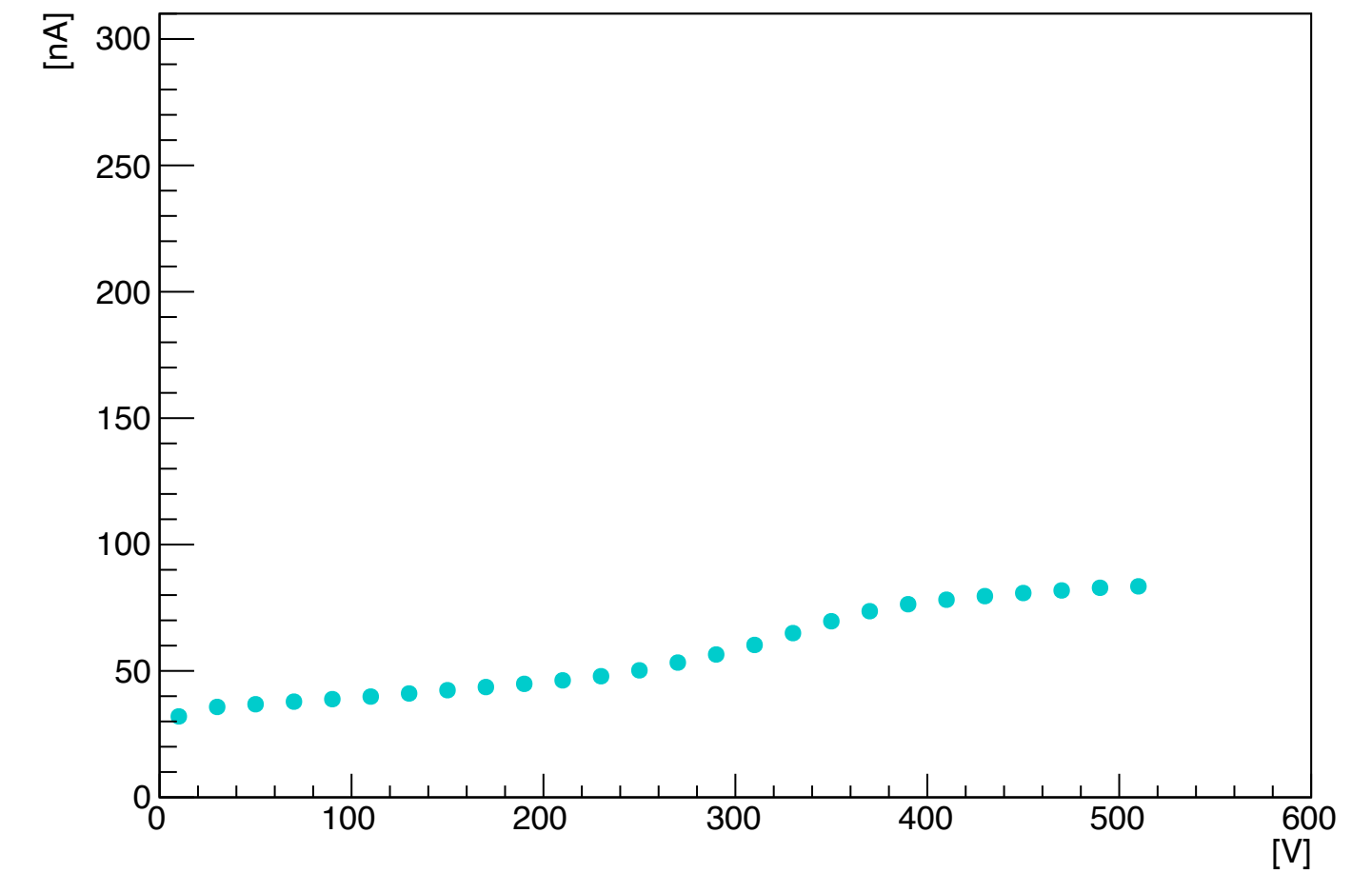
I-V 28_2



I-V 28_4



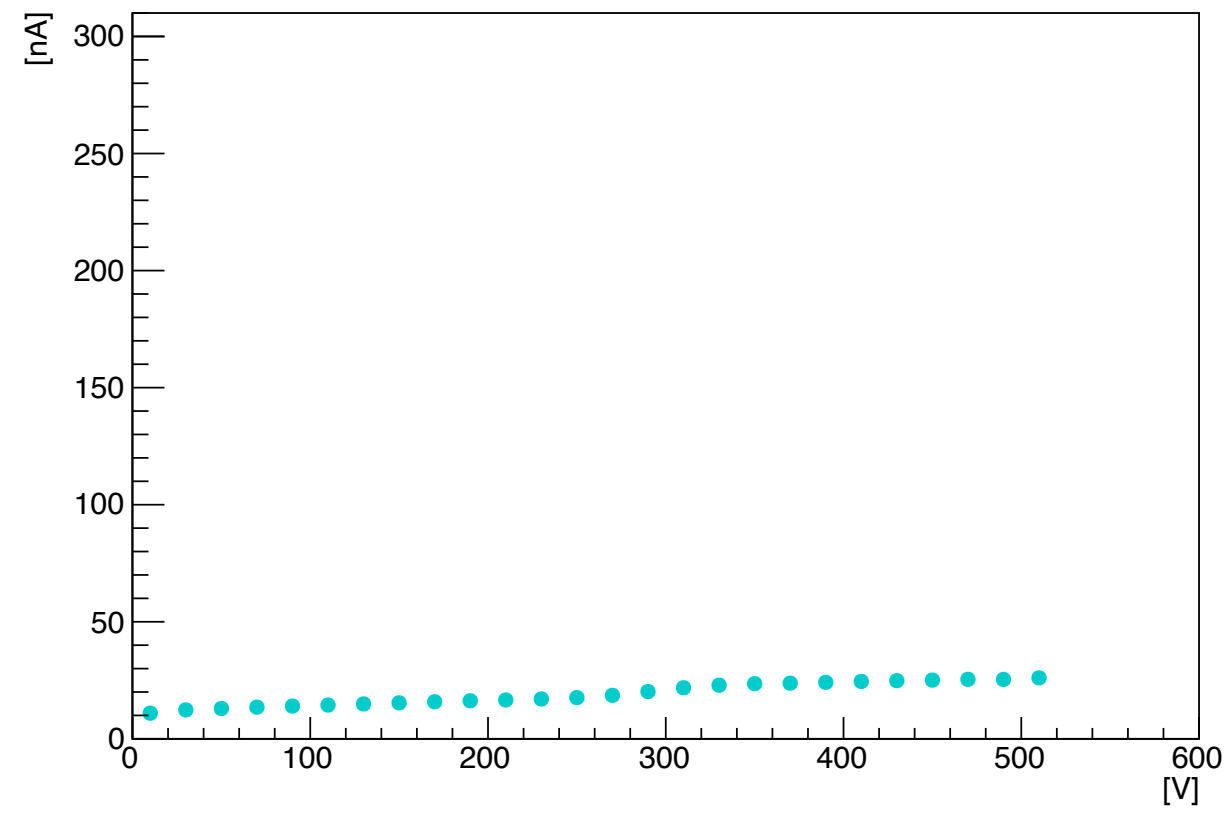
I-V 28_6



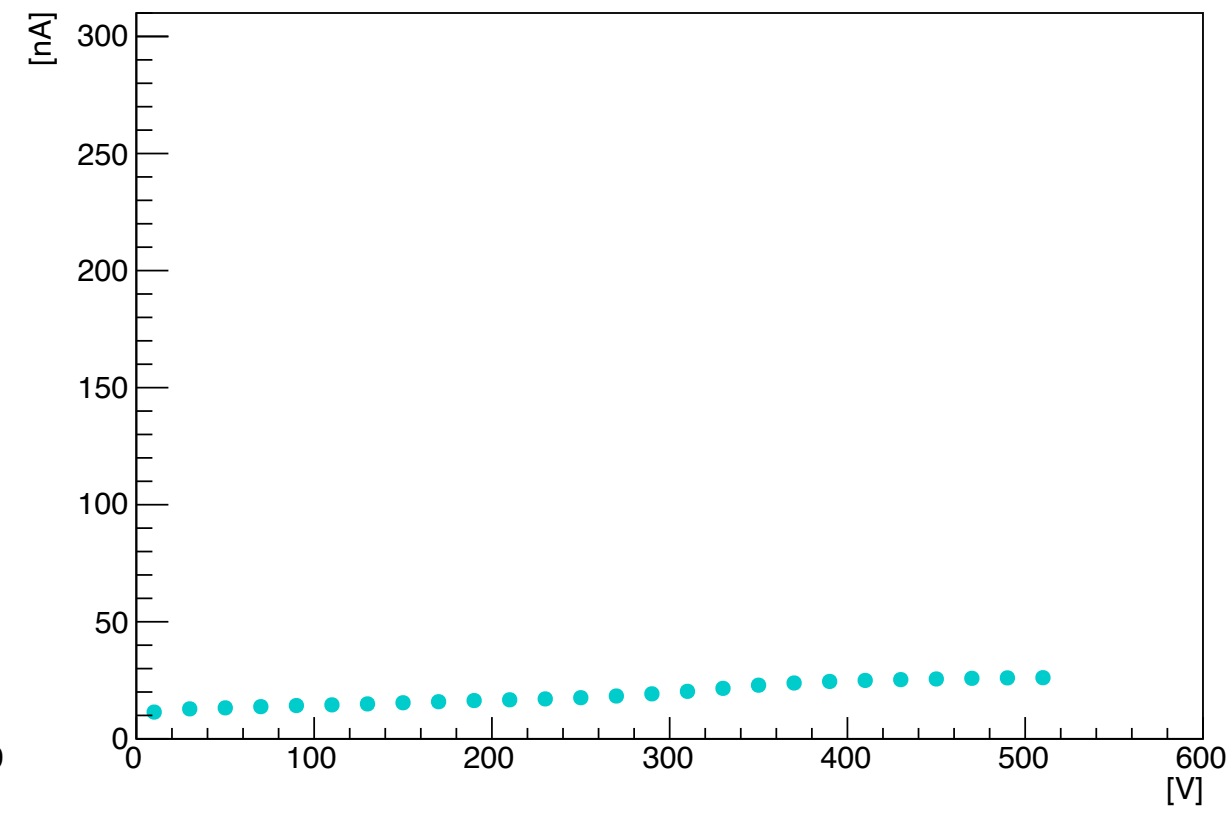
測定結果(軸を揃えたもの)

14T1, 14T2, 14L1, 14L2 (1cm× 1cm)

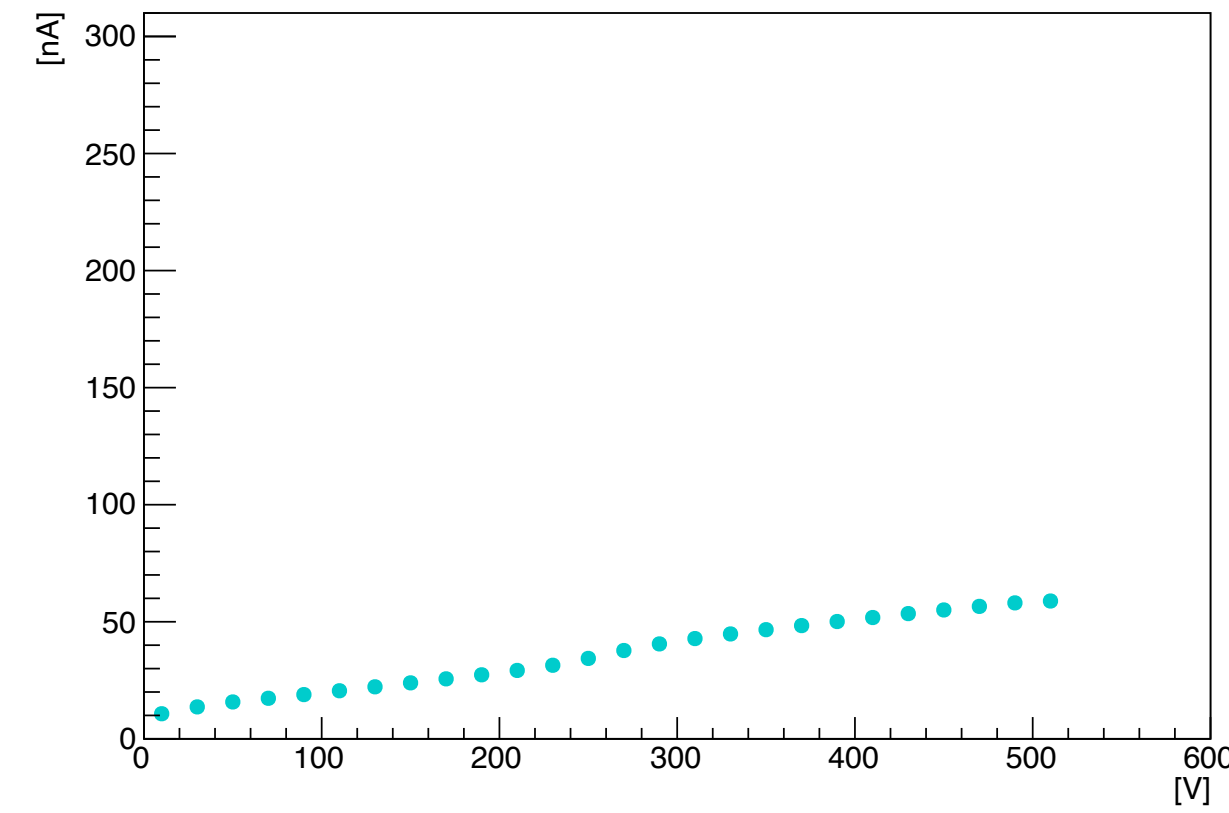
I-V 14T1_1



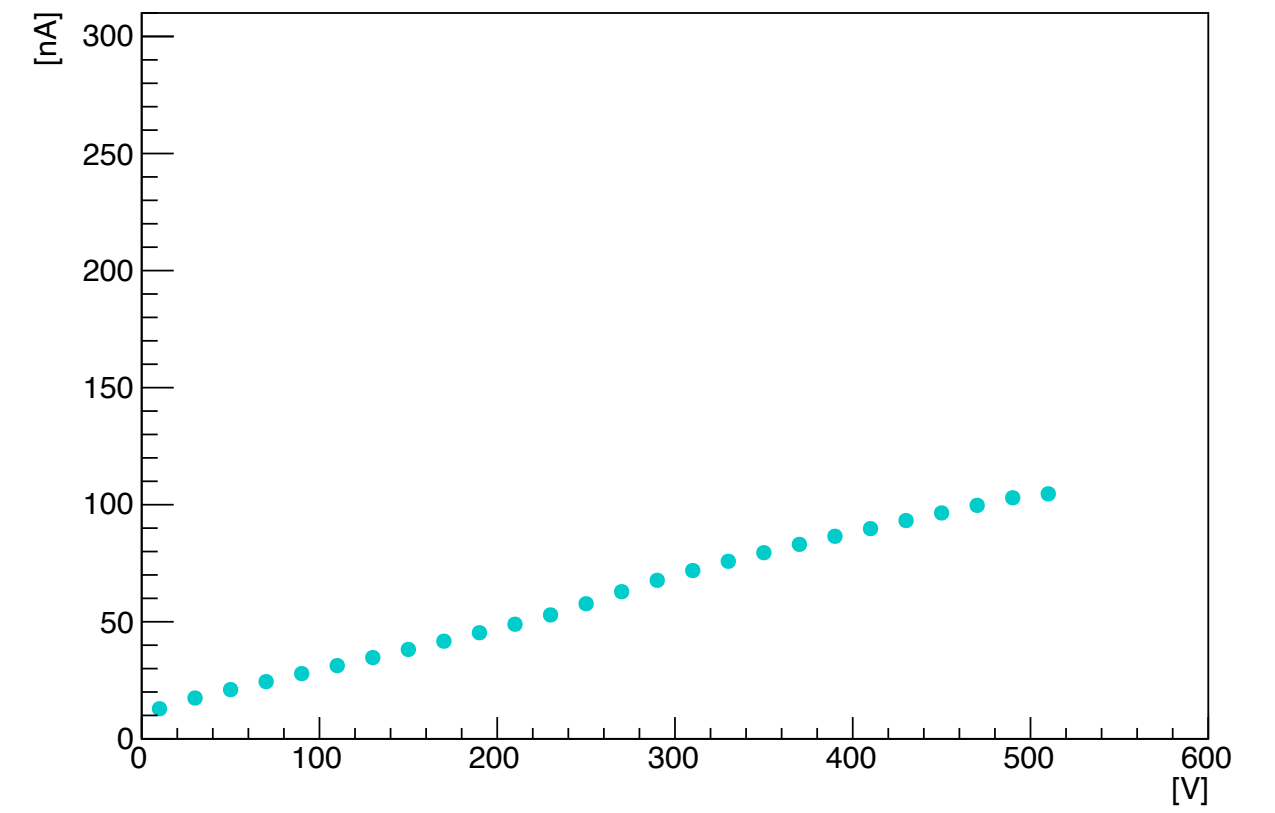
I-V 14T2_1



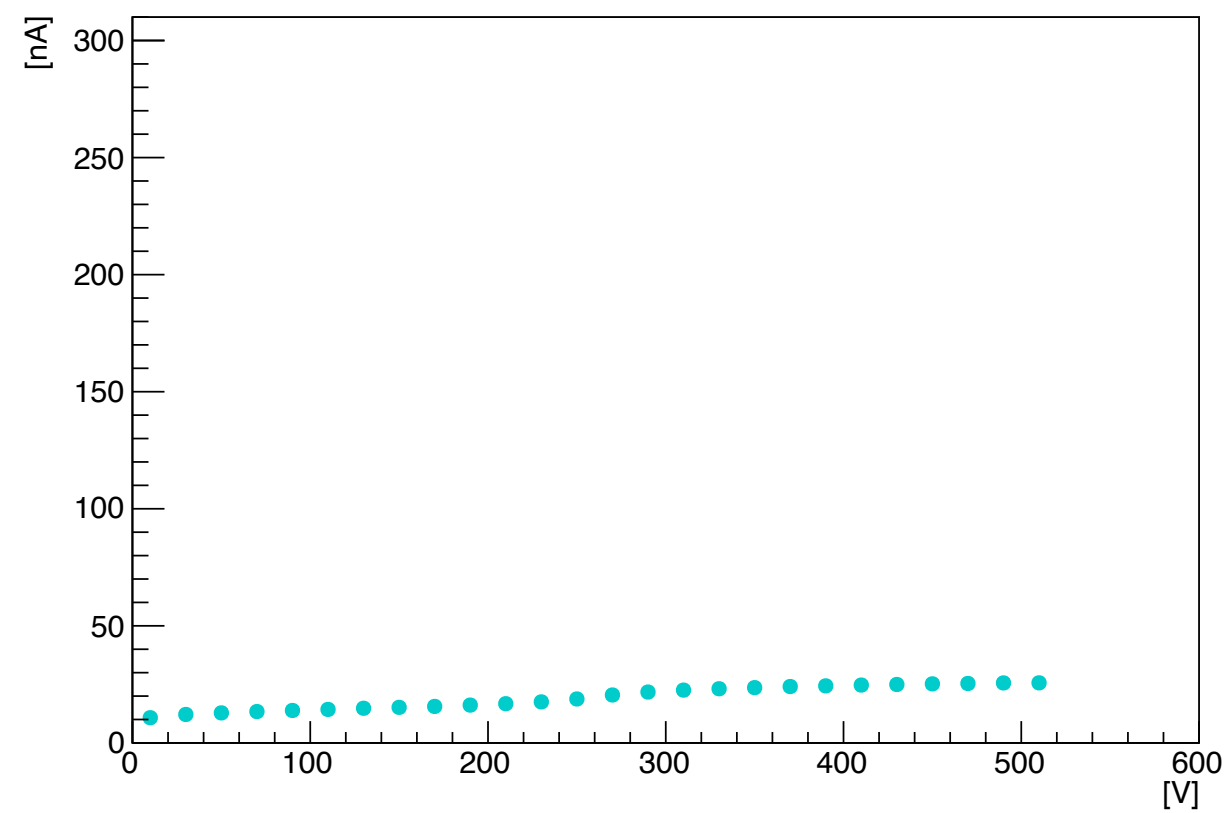
I-V 14L1_1



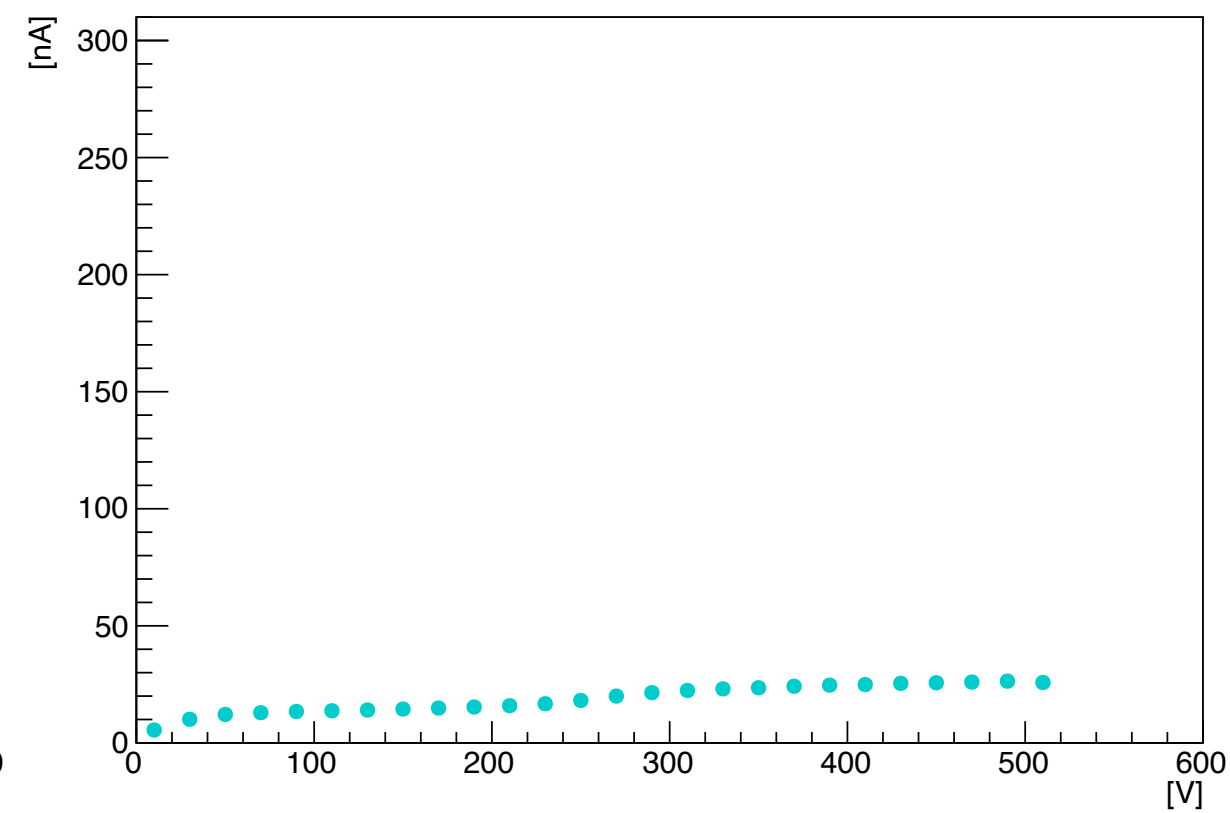
I-V 14L2_1



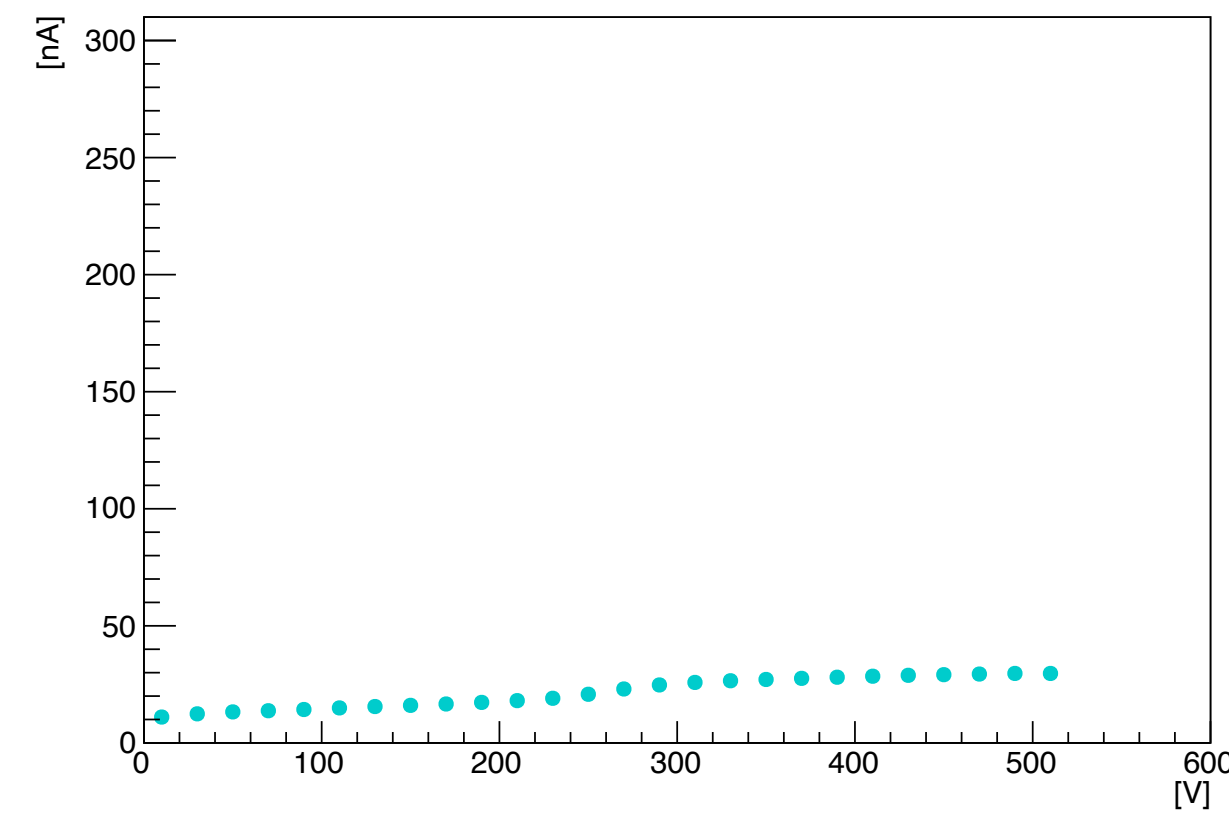
I-V 14T1_2



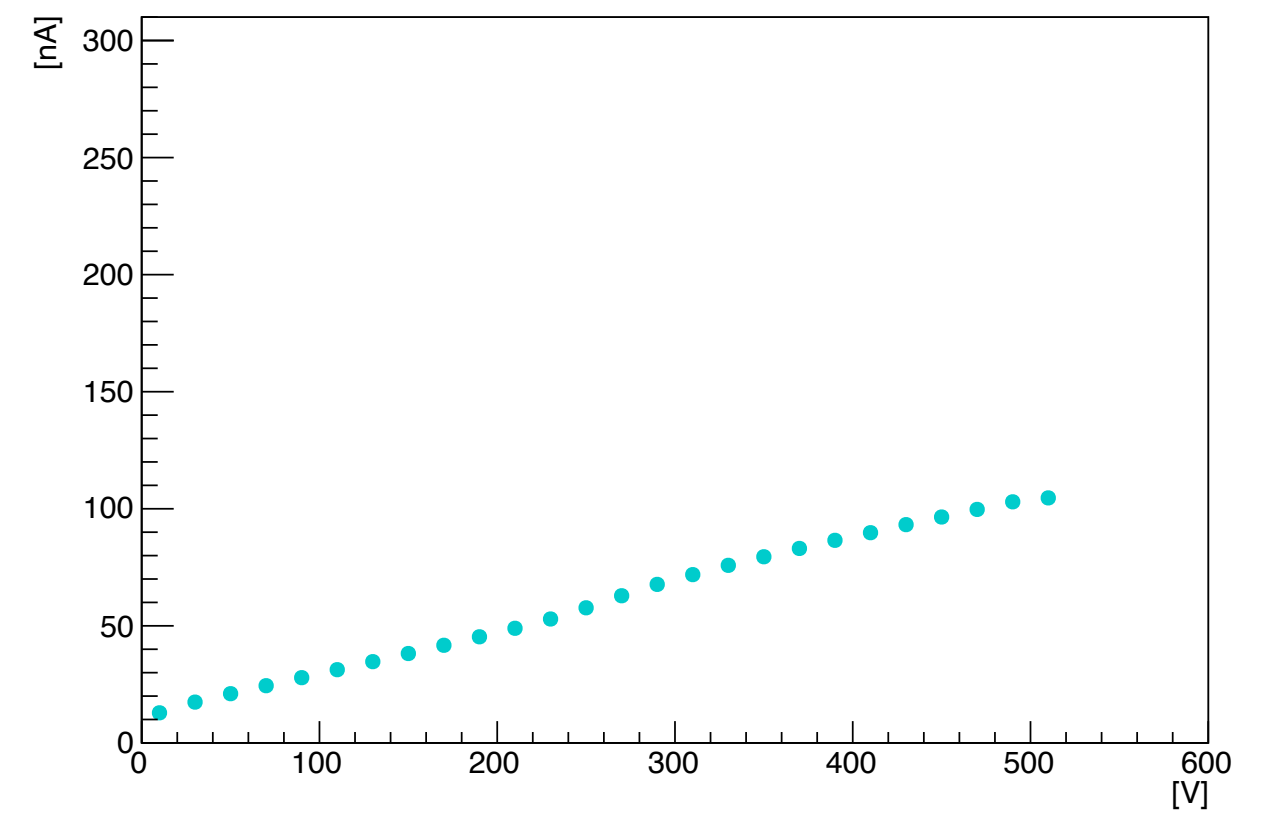
I-V 14T2_2



I-V 14L1_2



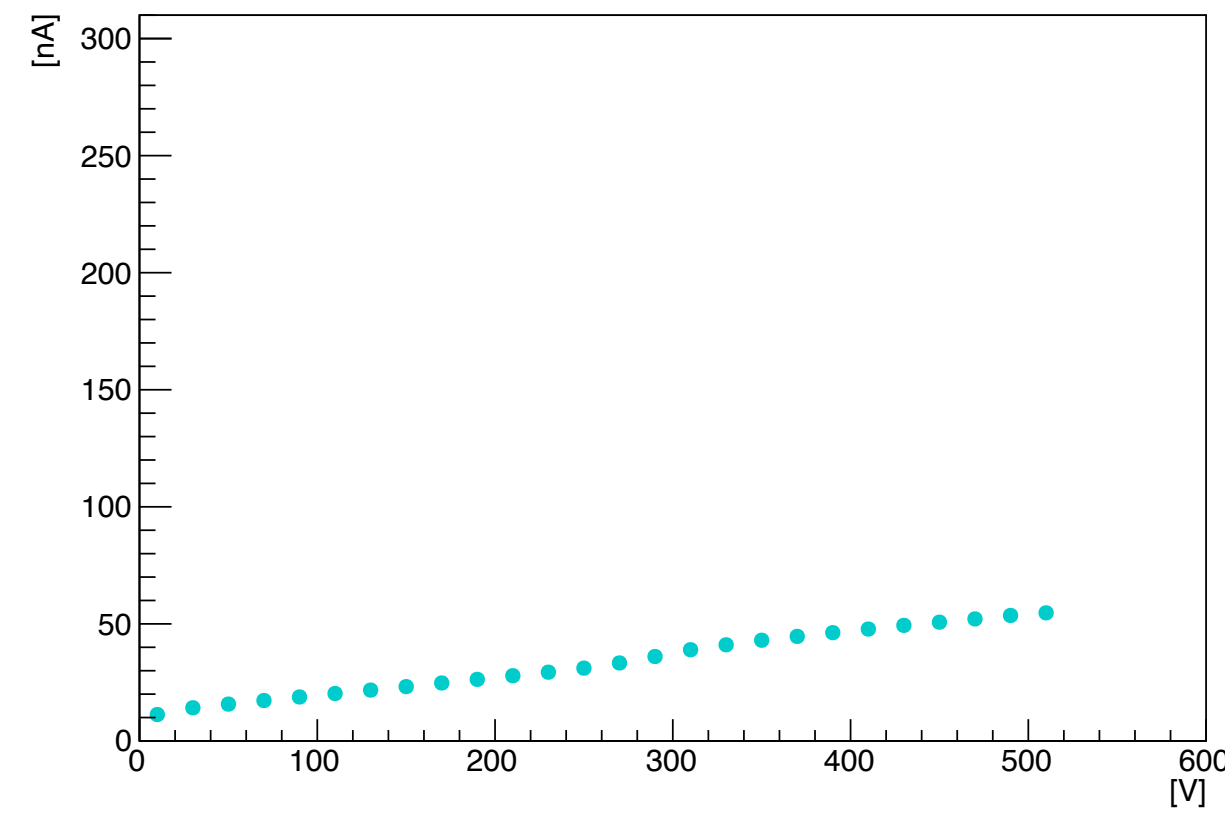
I-V 14L2_2



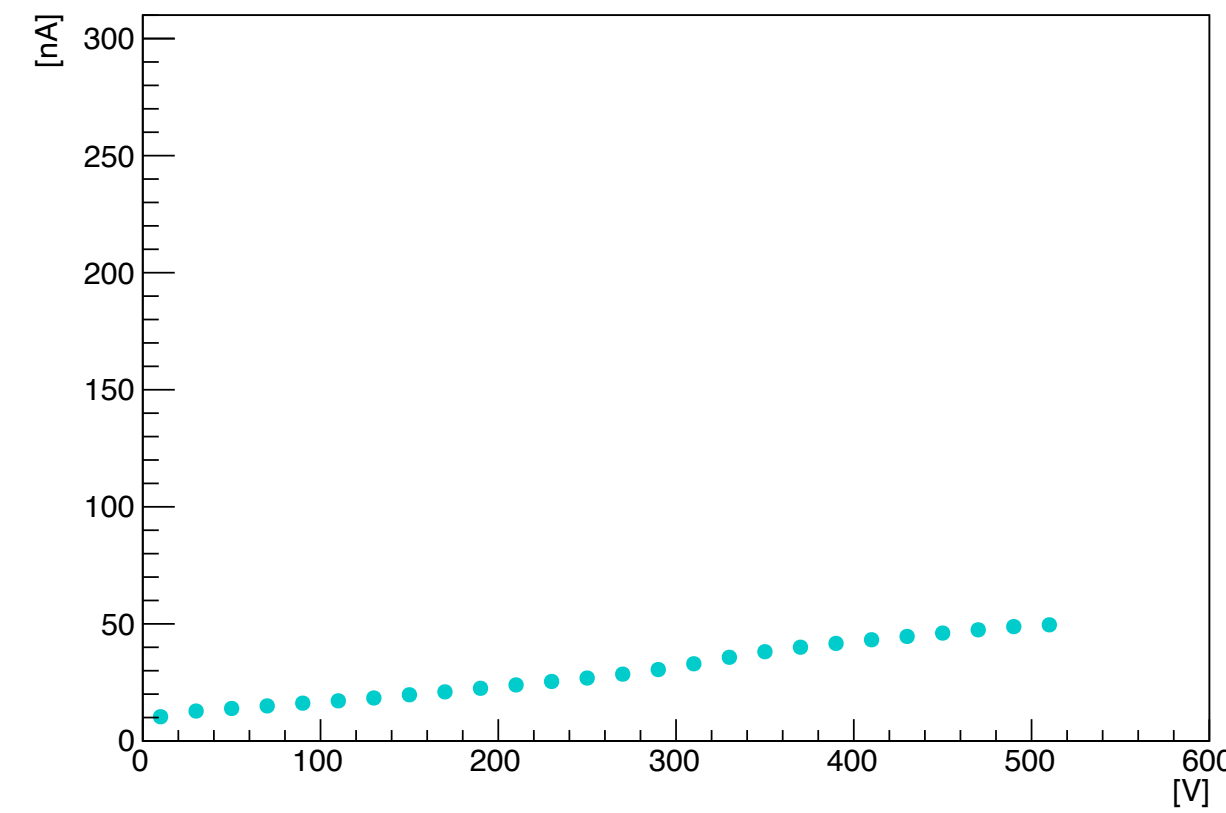
測定結果(軸を揃えたもの)

14B1, 14B2, 14R1, 14R2 (1cm× 1cm)

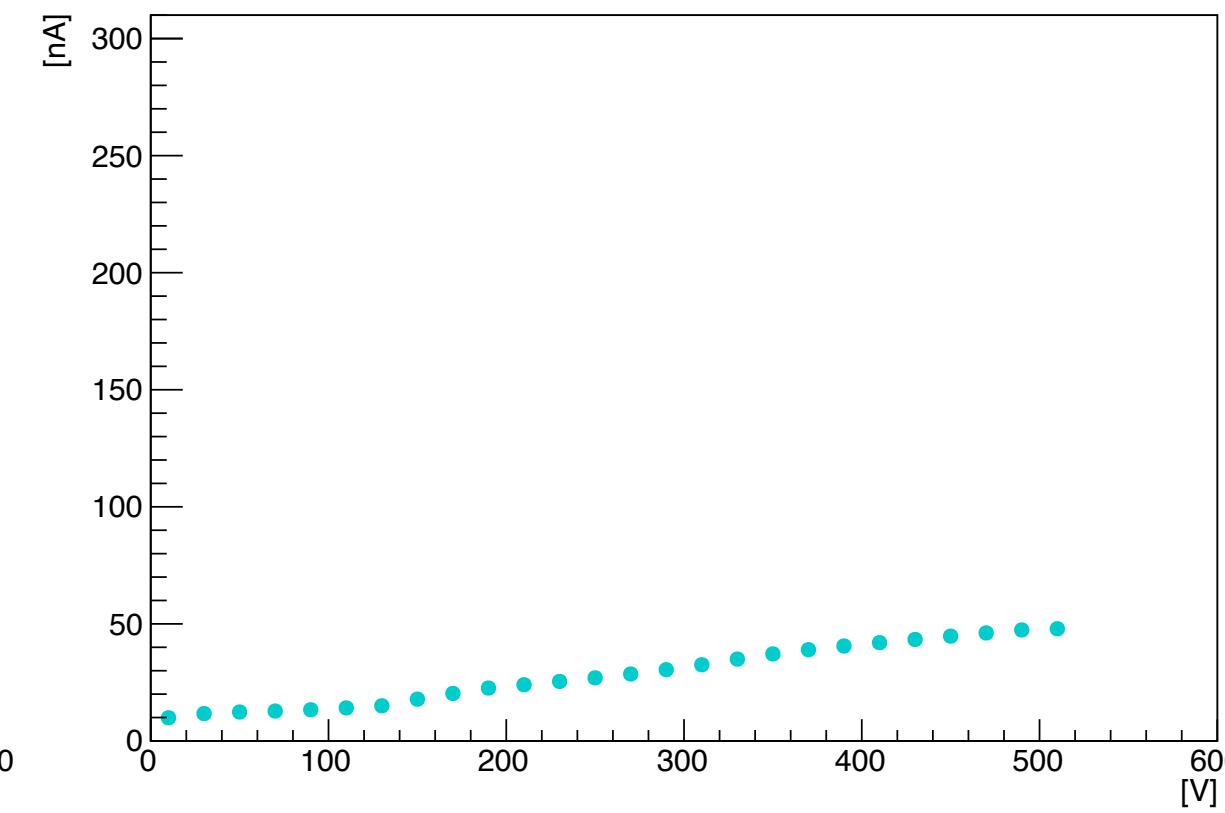
I-V 14B1_1



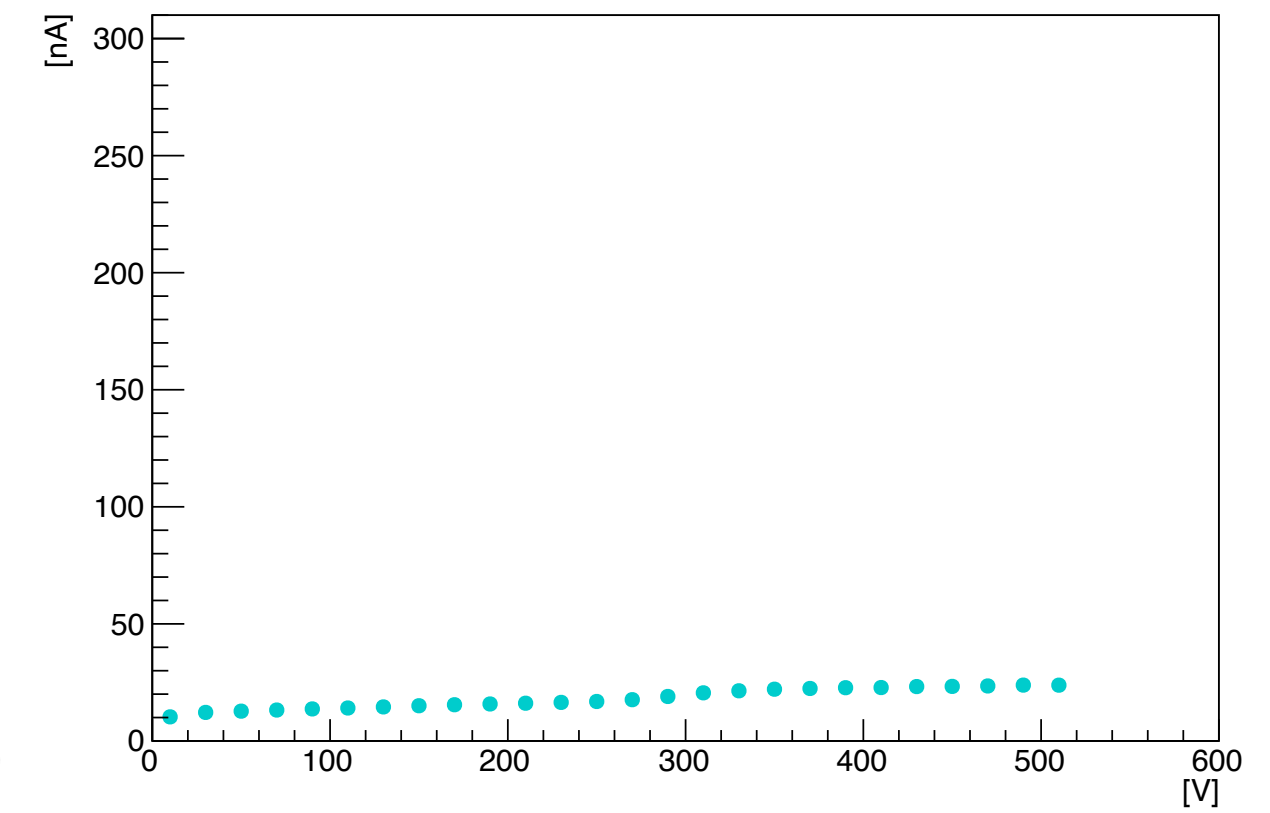
I-V 14B2_1



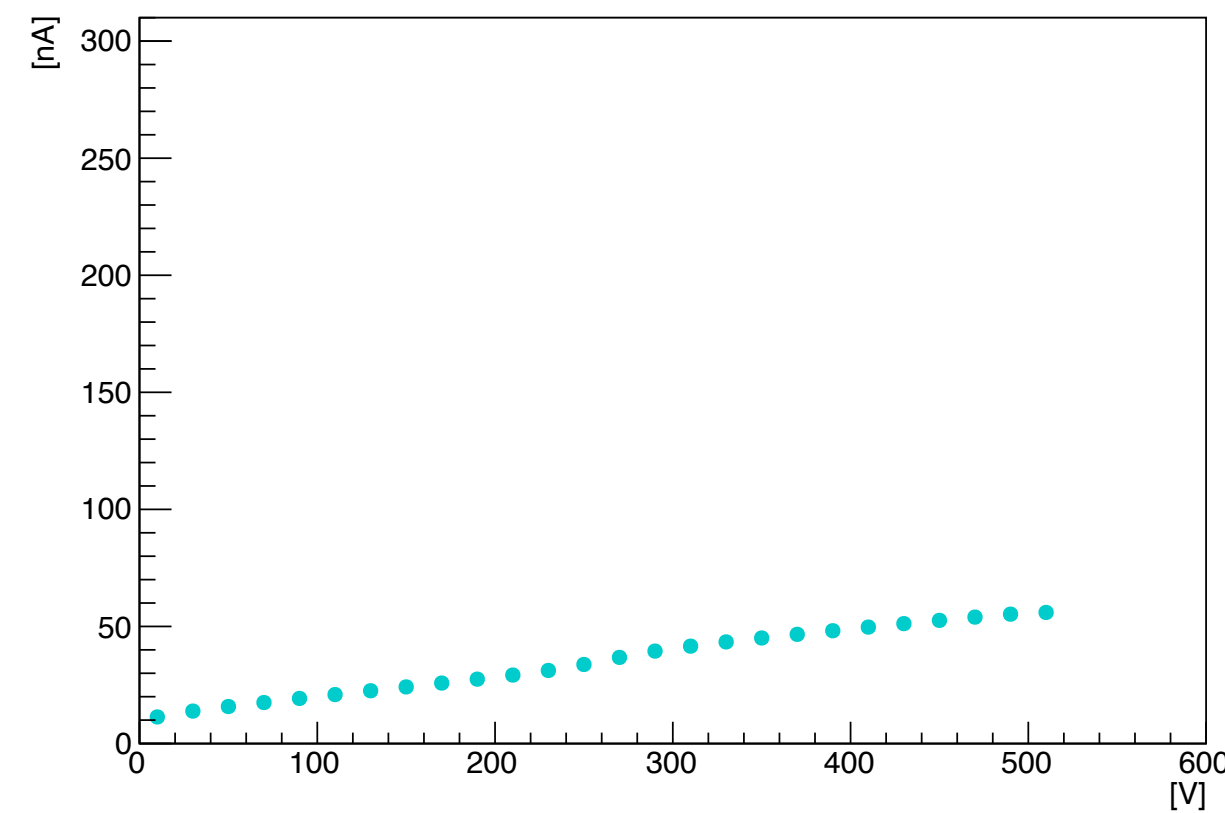
I-V 14R1_1



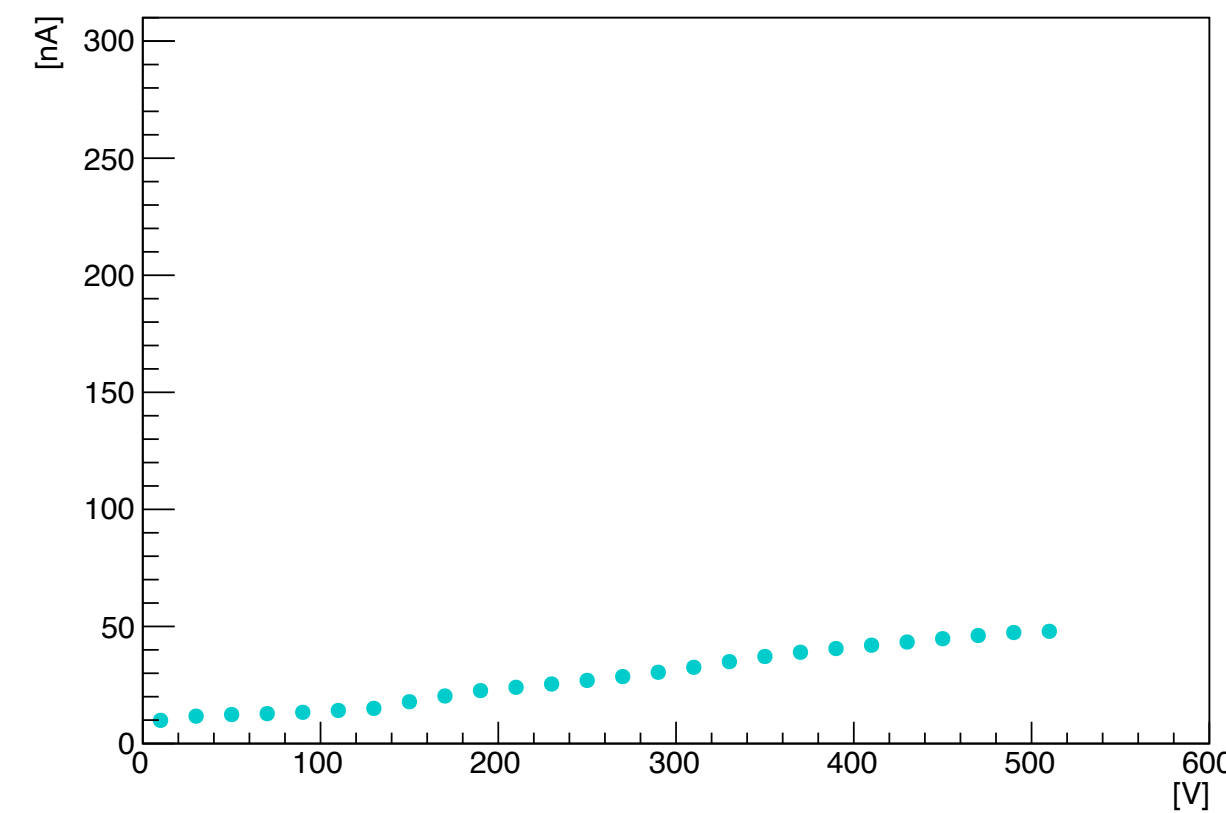
I-V 14R2_1



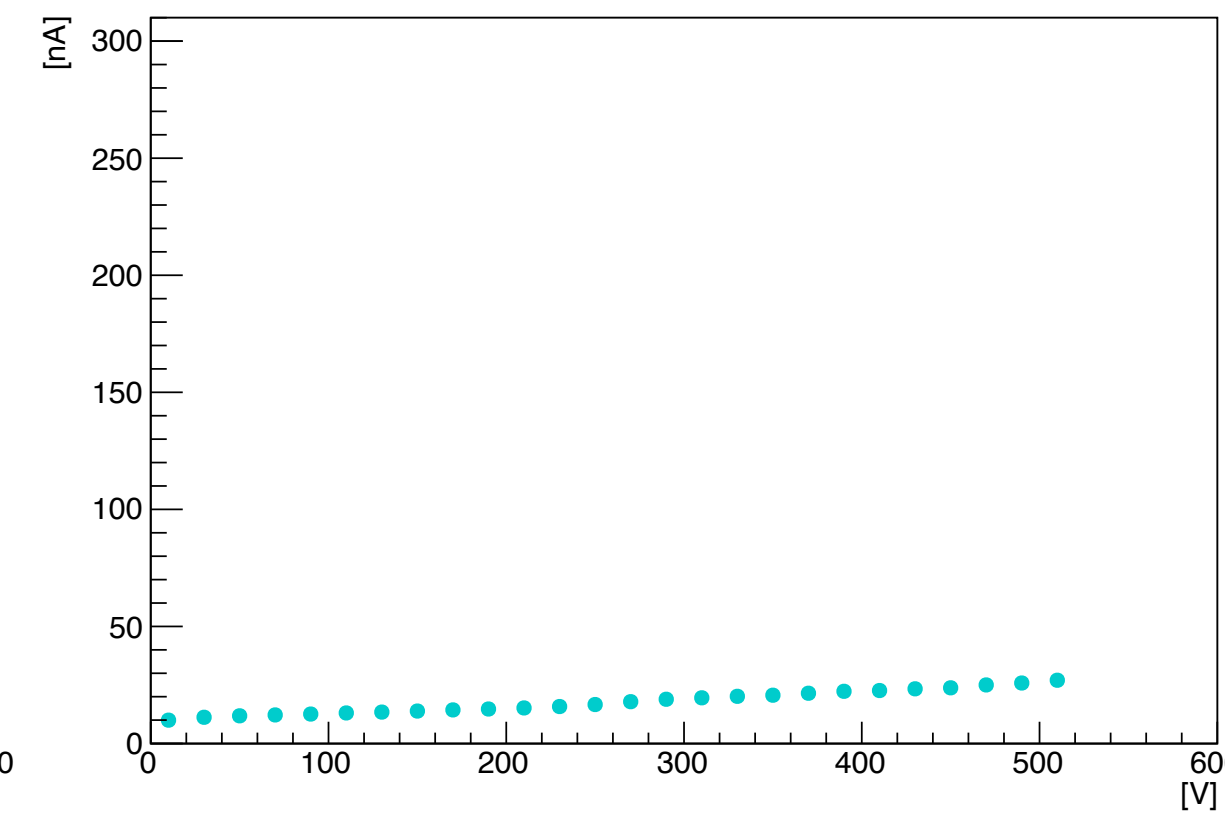
I-V 14B1_2



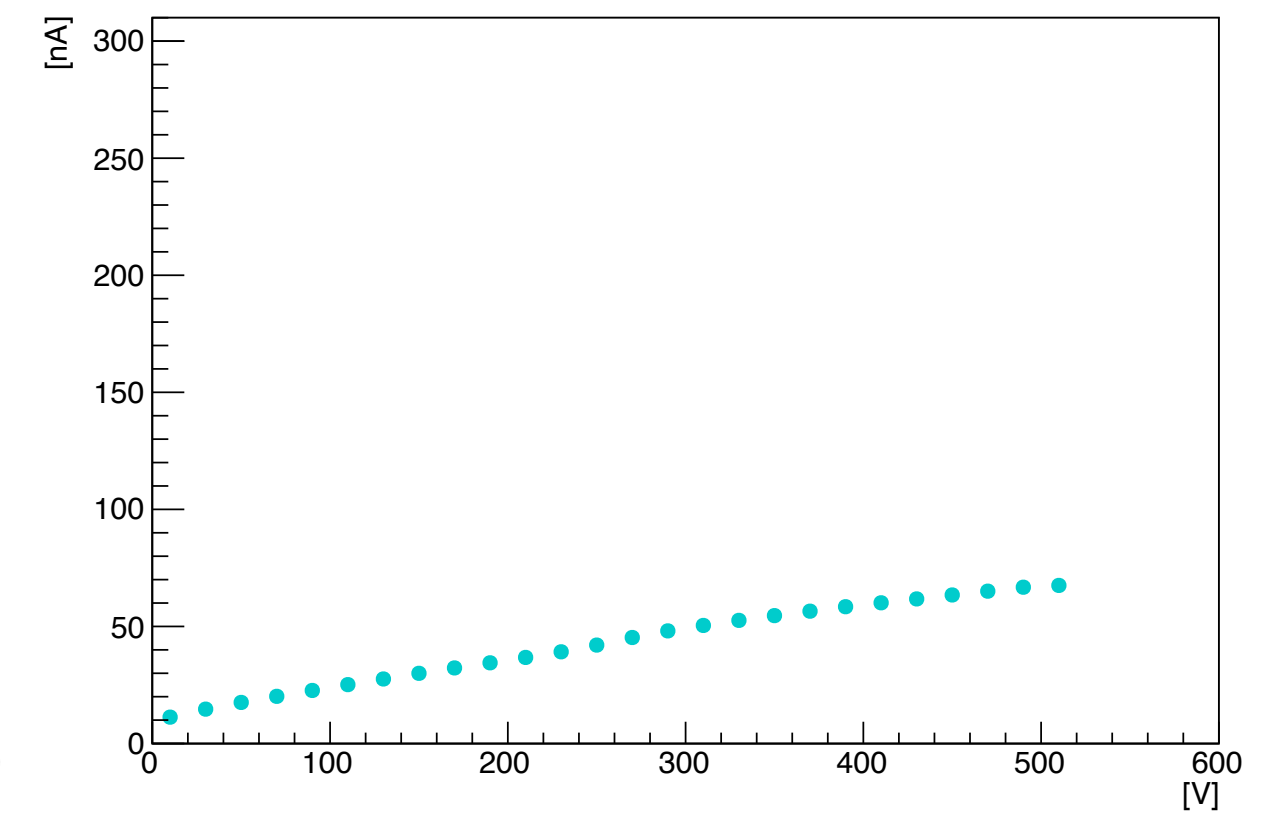
I-V 14B2_2



I-V 14R1_2



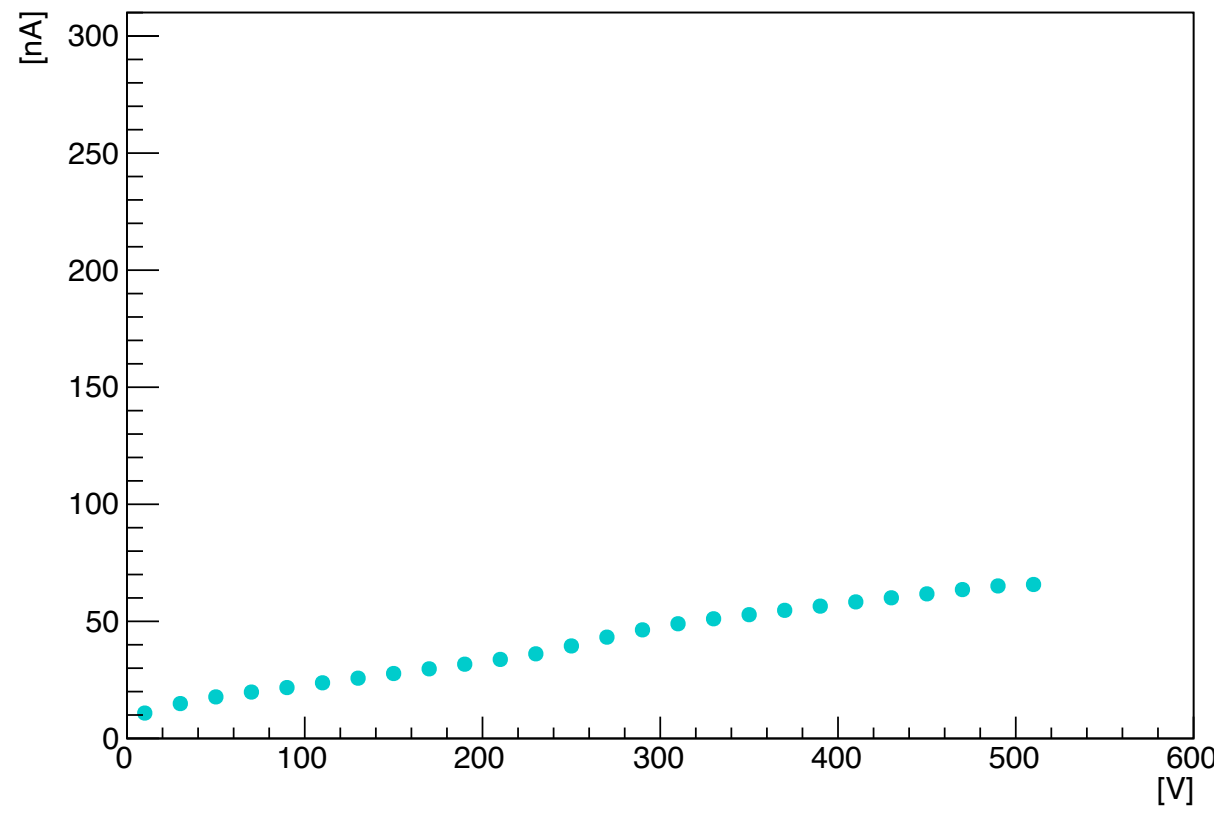
I-V 14R2_2



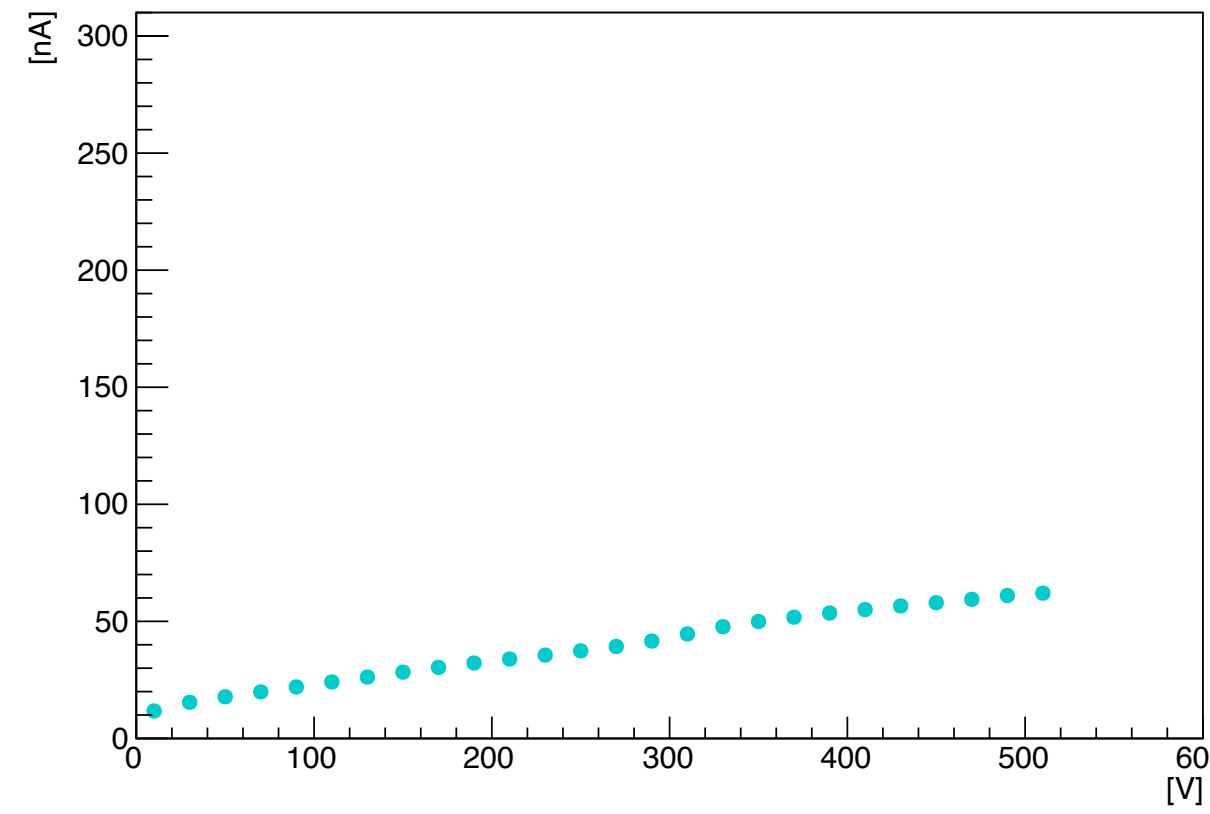
測定結果(軸を揃えたもの)

19T1, 19T2, 19L1, 19L2 (1cm× 1cm)

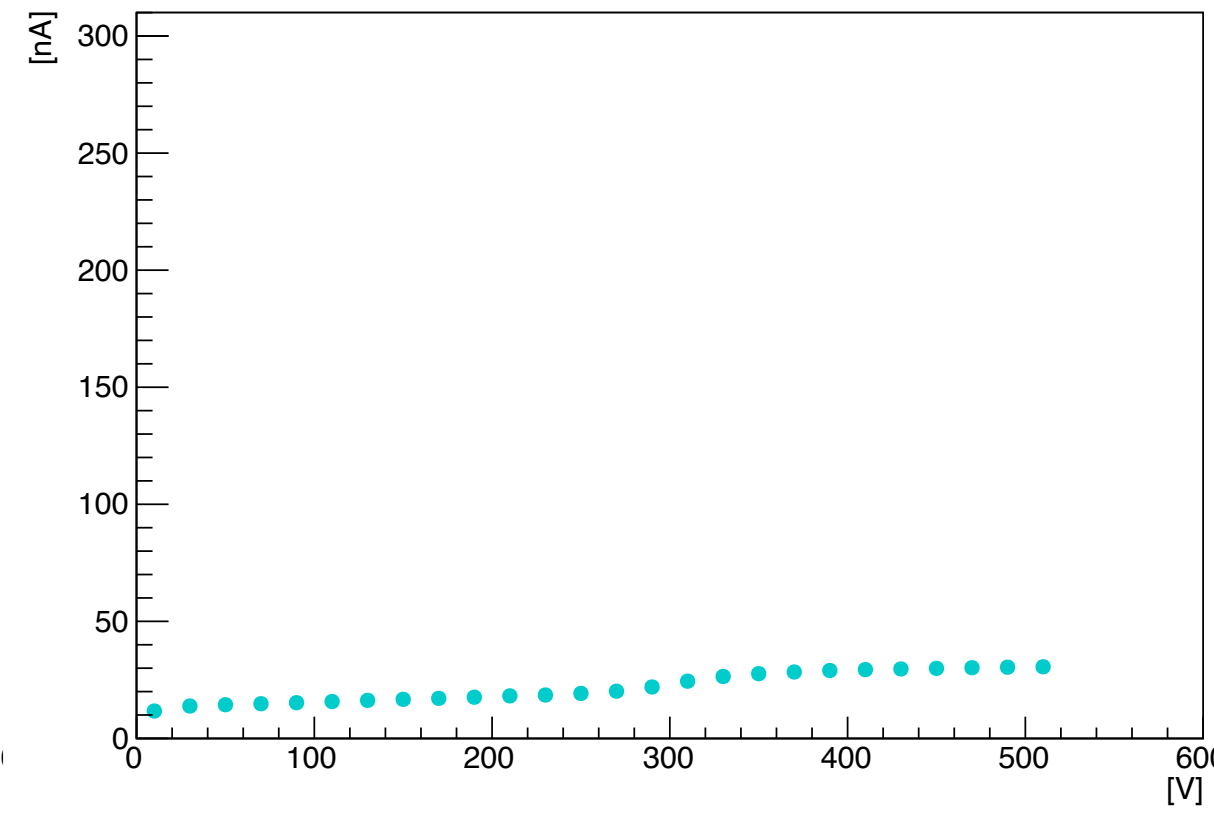
I-V 19T1_1



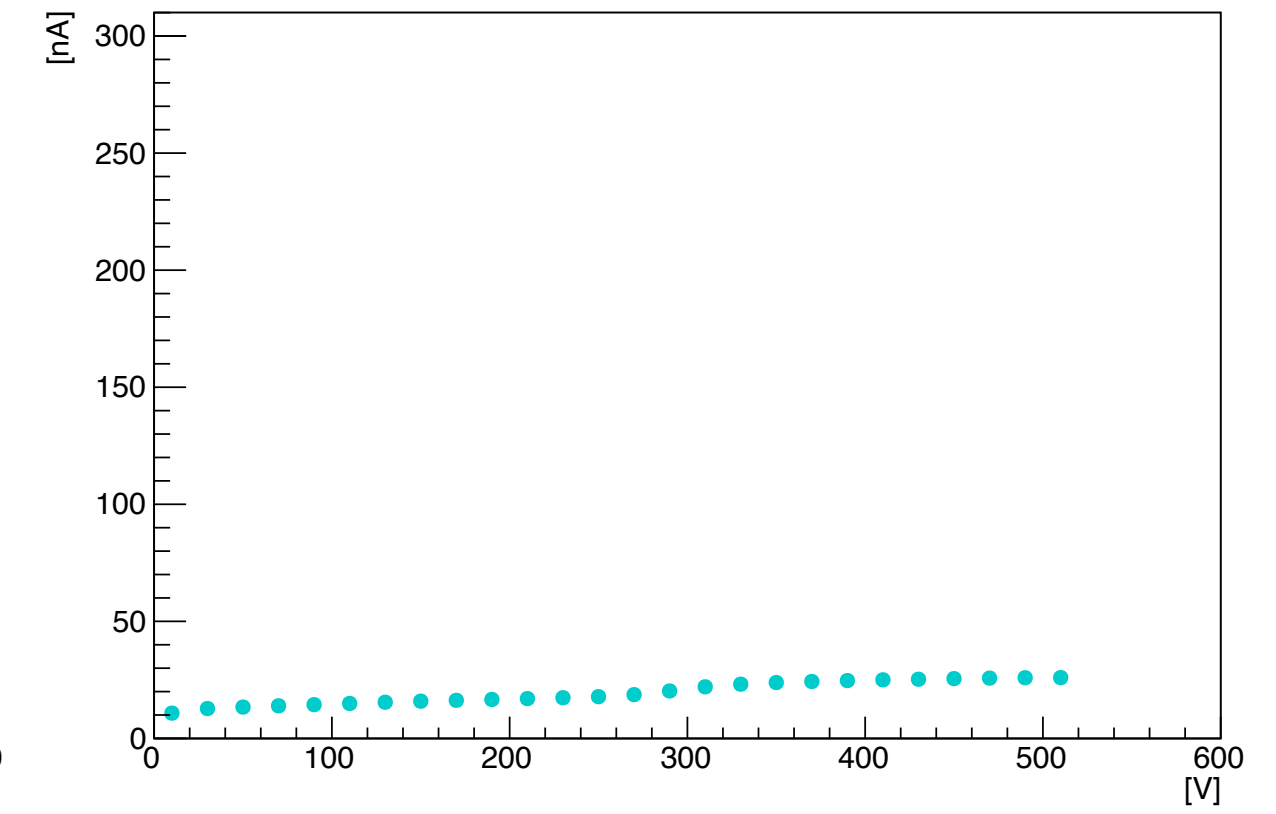
I-V 19T2_1



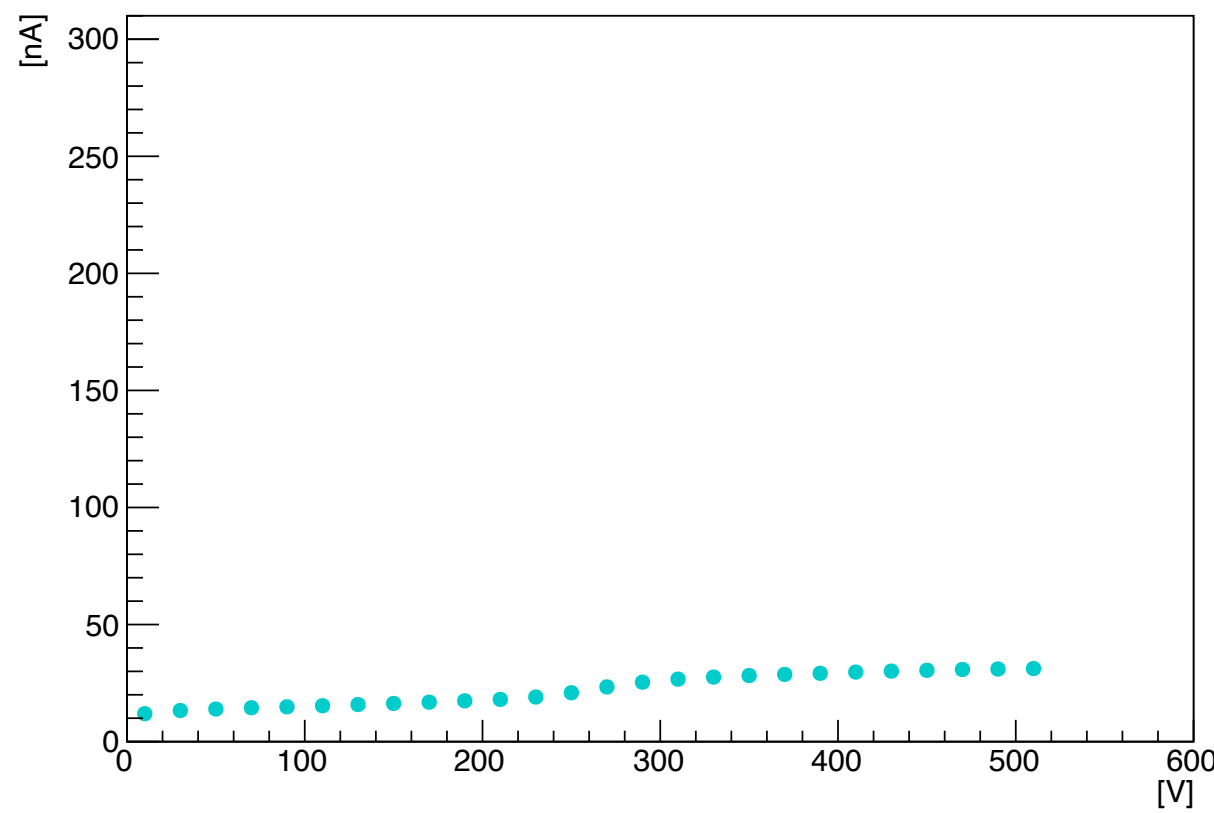
I-V 19L1_1



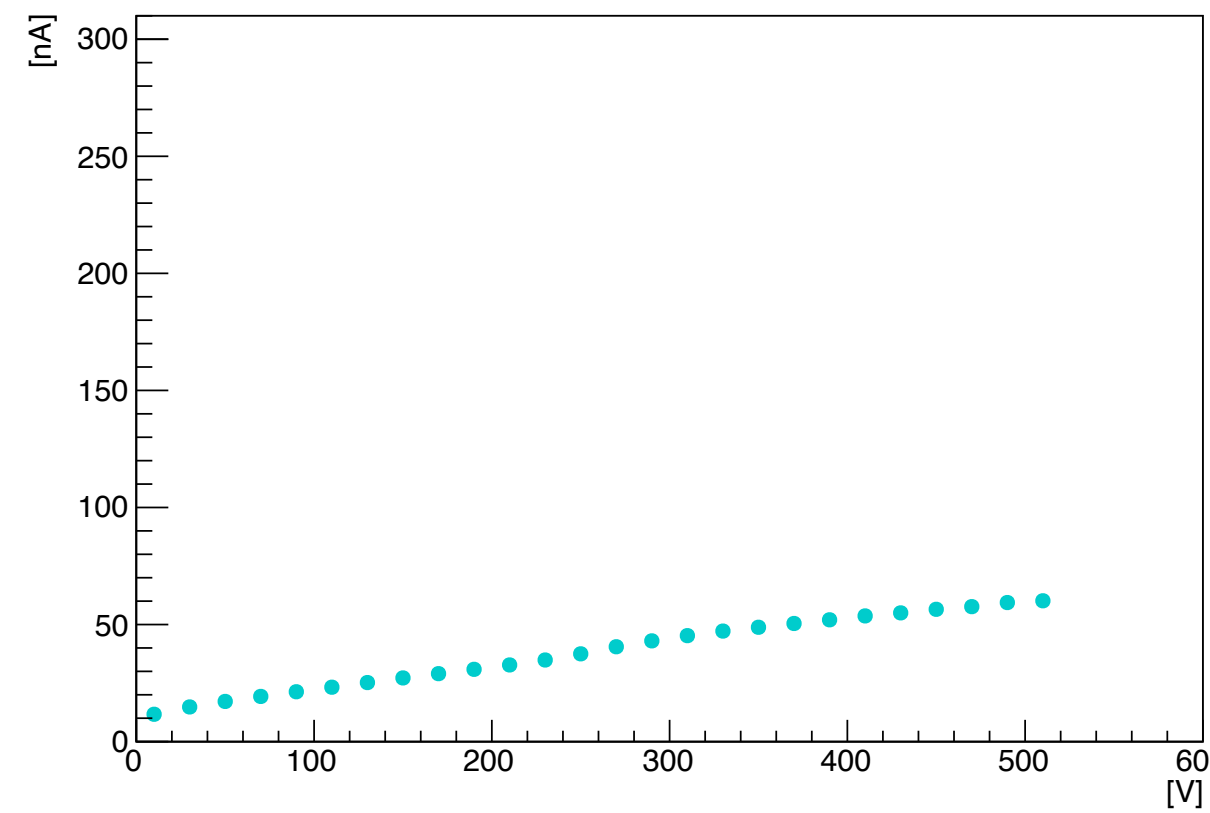
I-V 19L2_1



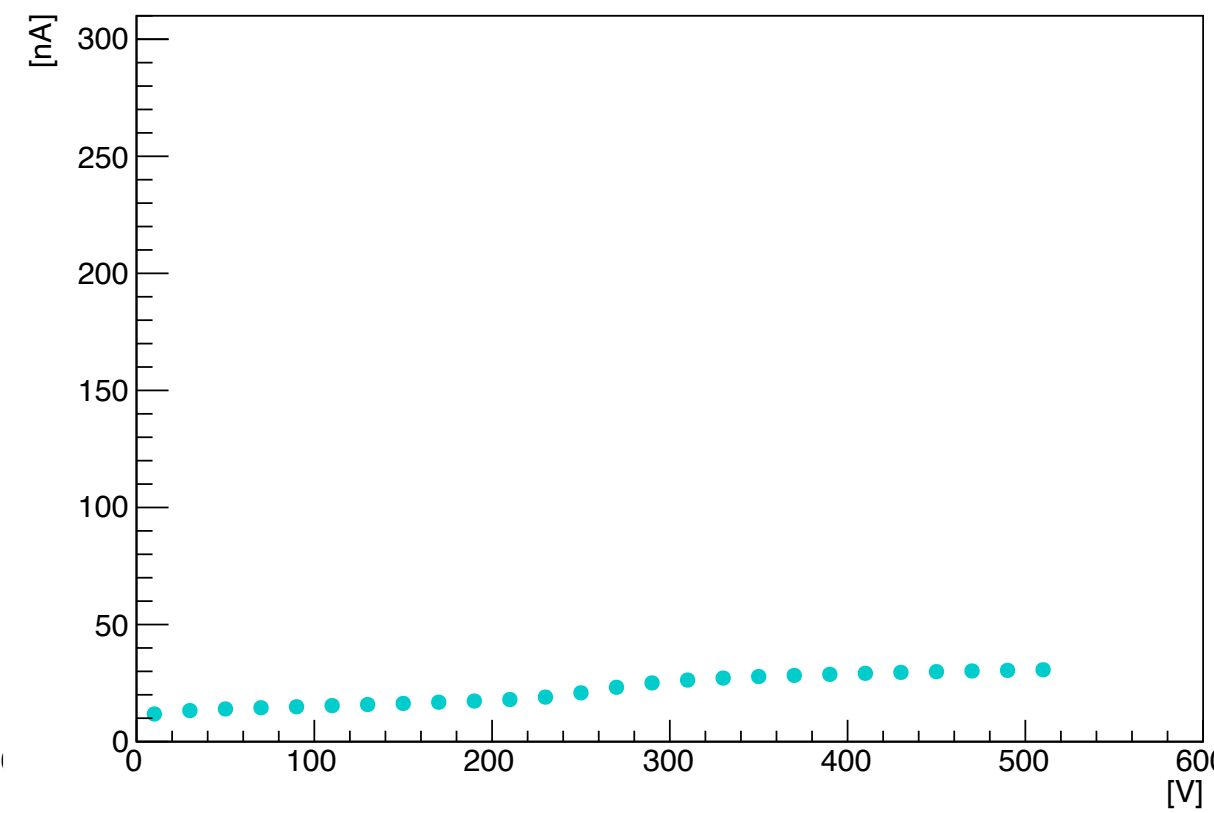
I-V 19T1_2



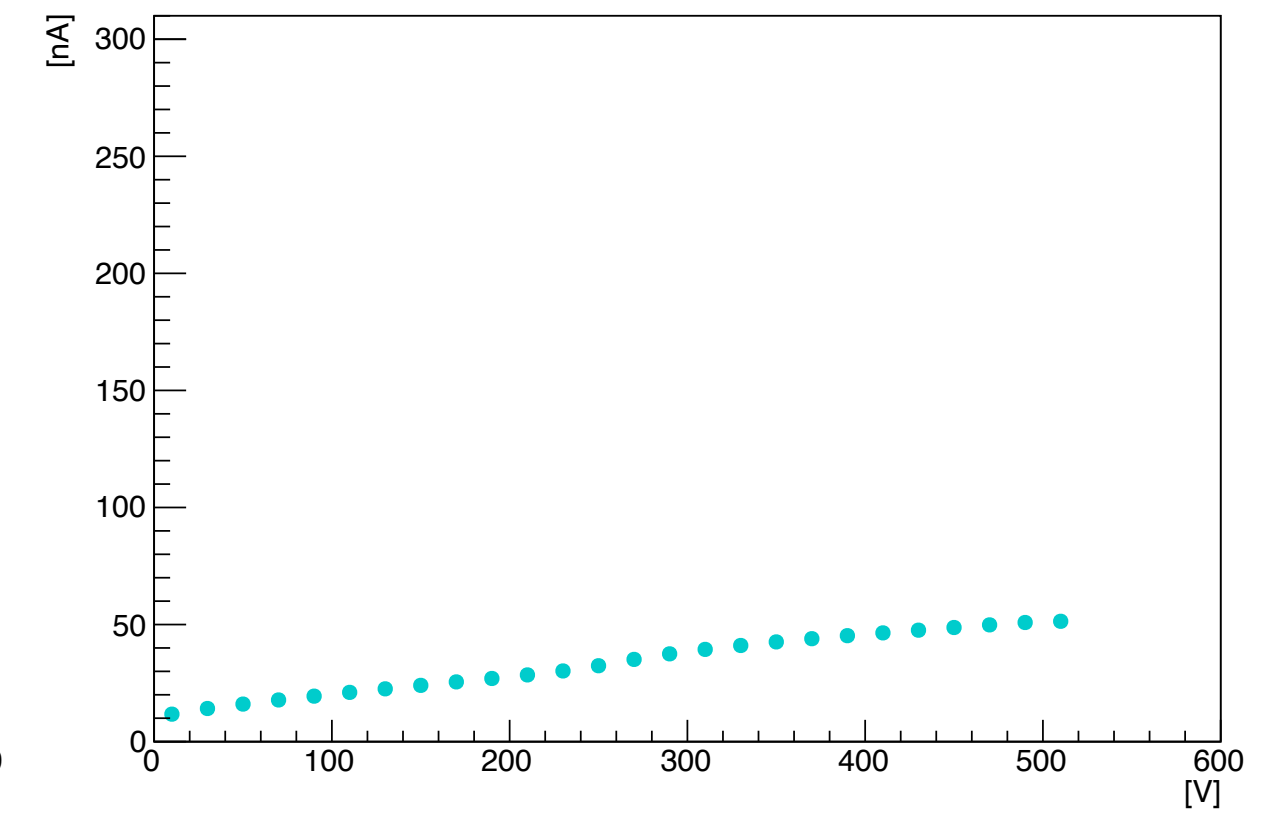
I-V 19T2_2



I-V 19L1_2



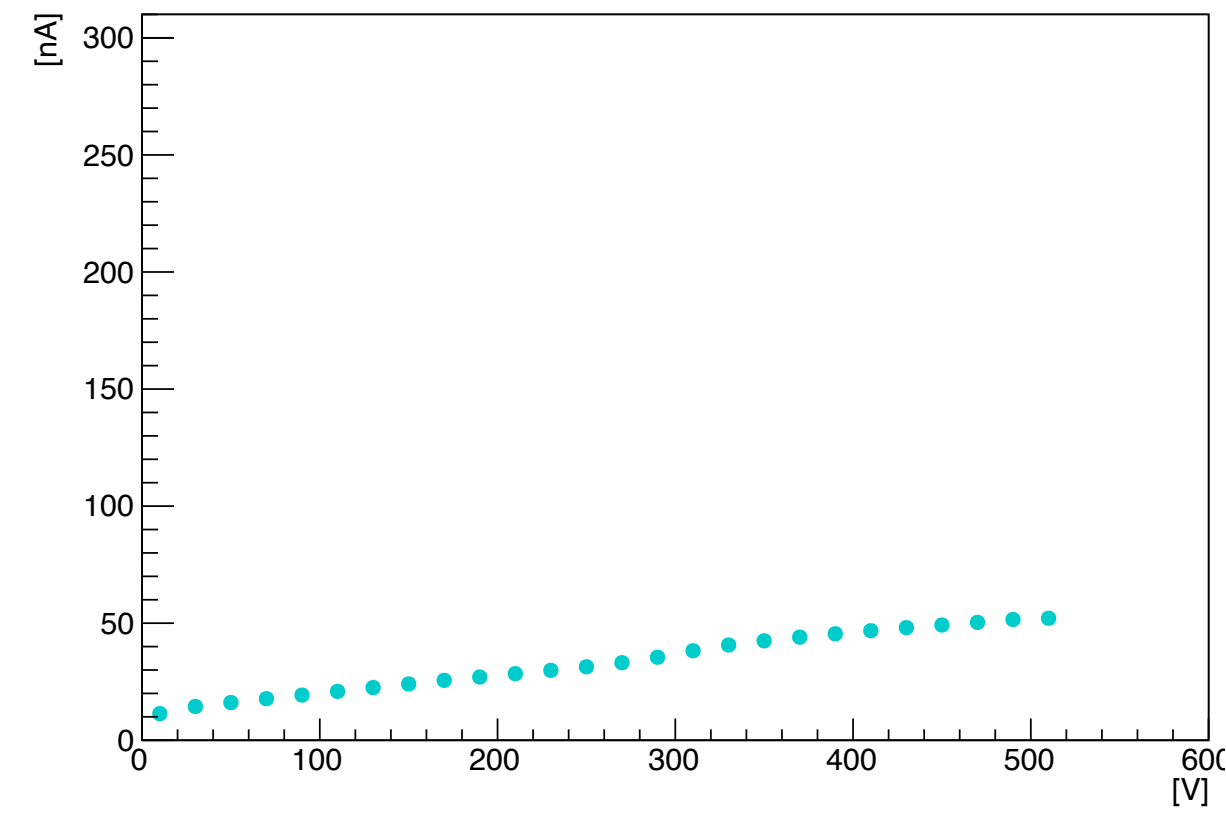
I-V 19L2_2



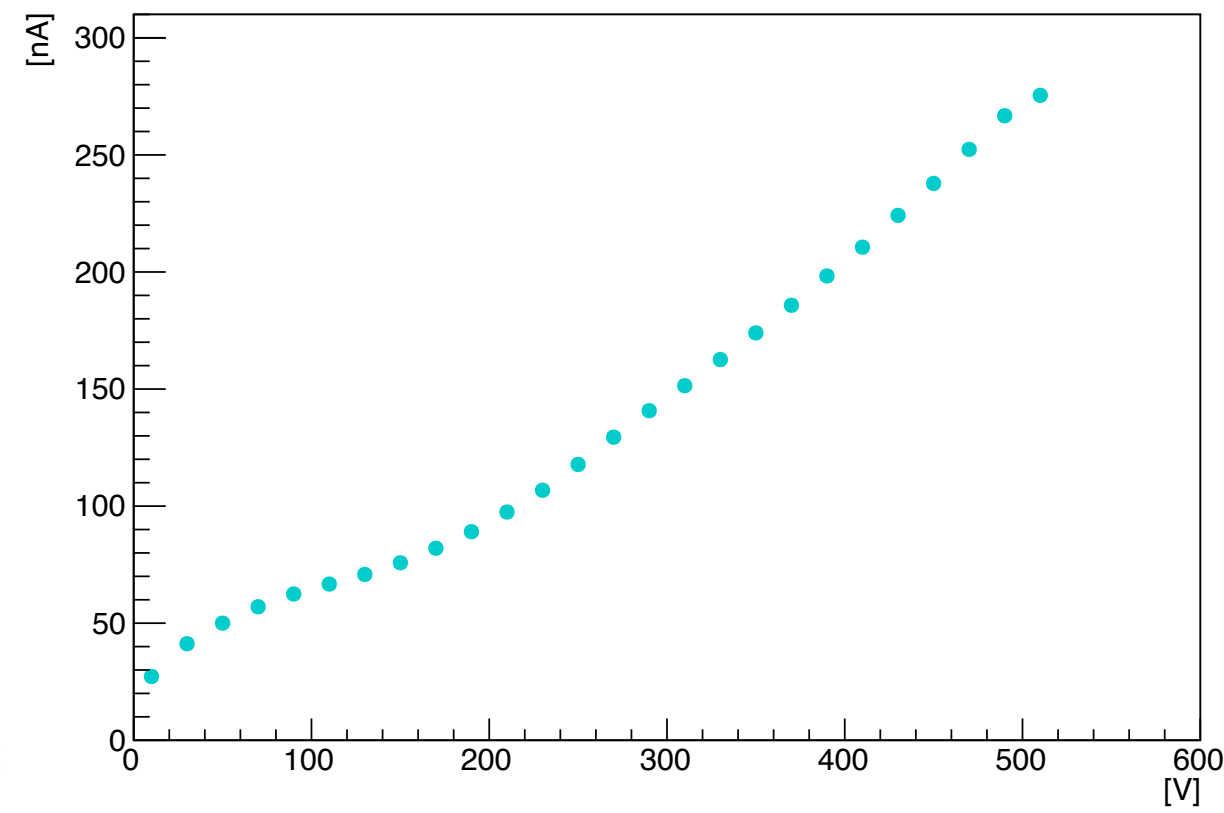
測定結果(軸を揃えたもの)

19B1, 19B2, 19R1, 19R2 (1cm× 1cm)

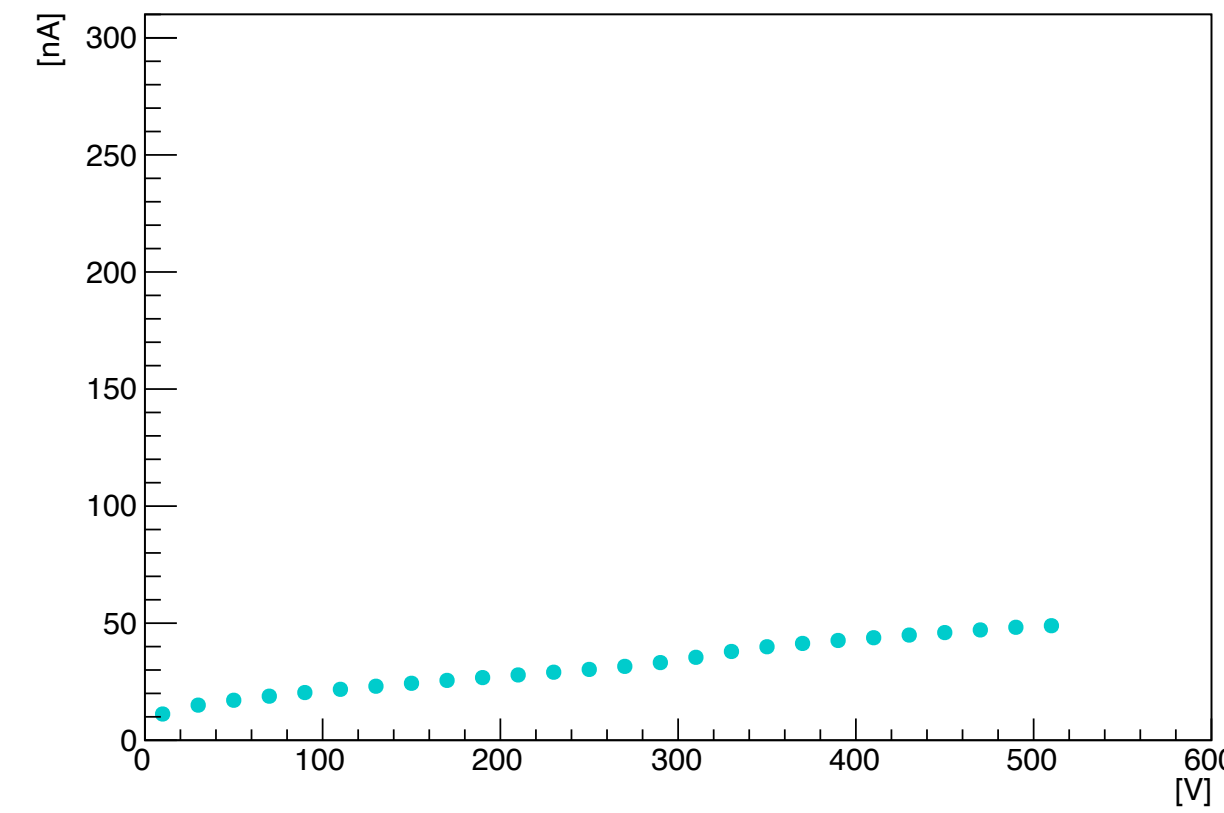
I-V 19B1_1



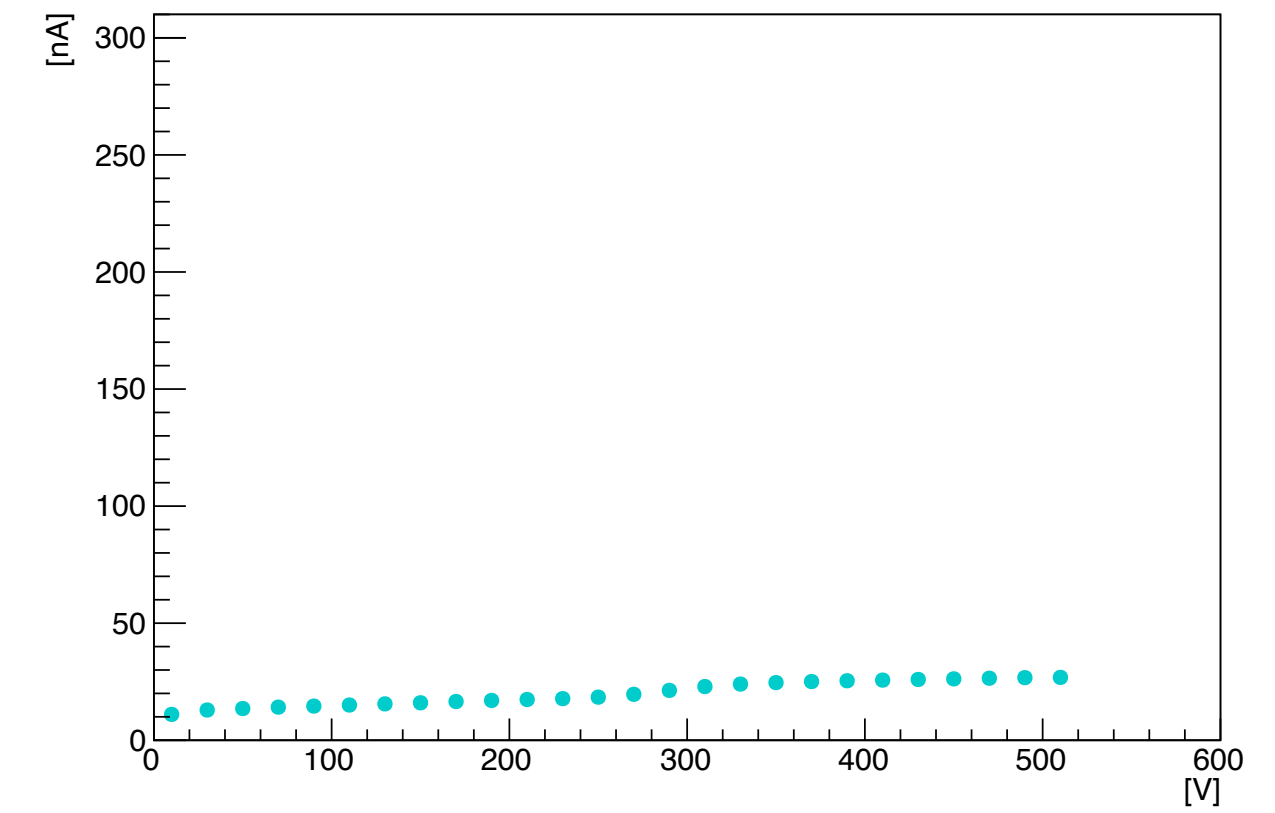
I-V 19B2_1



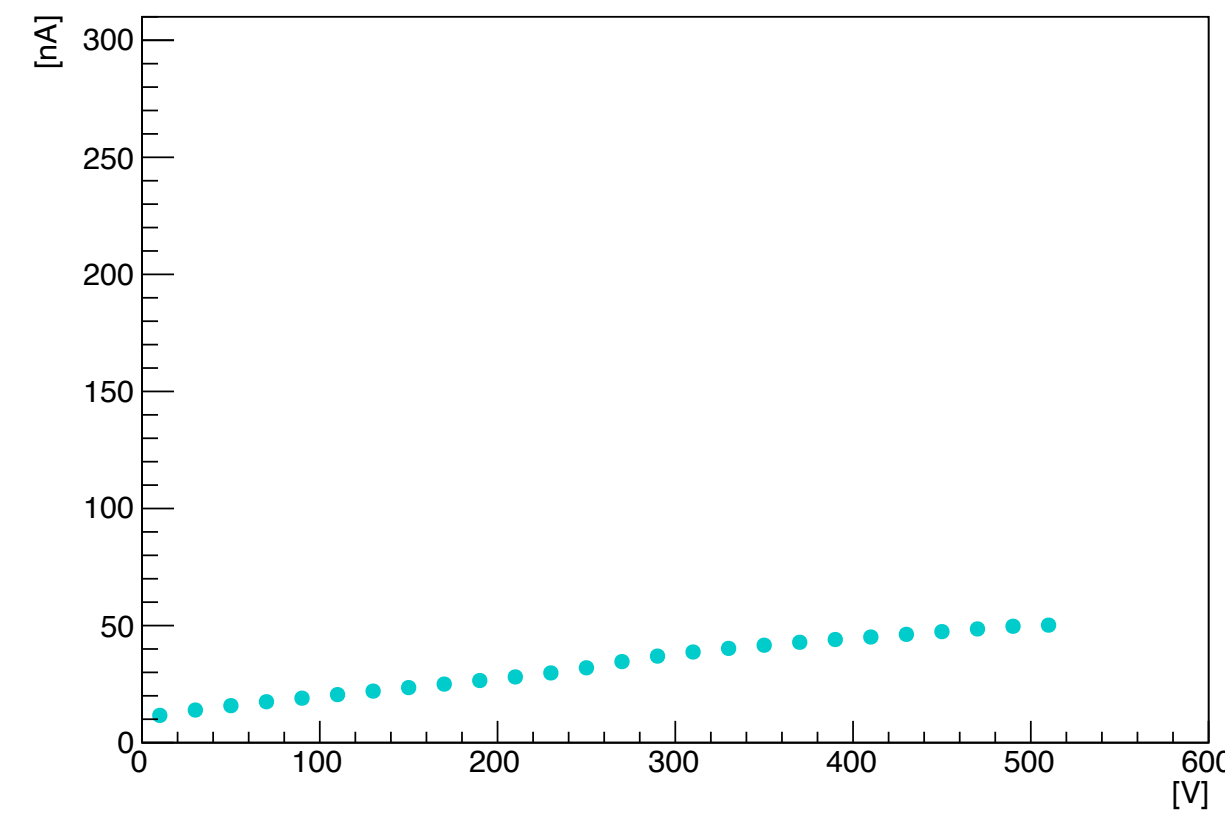
I-V 19R1_1



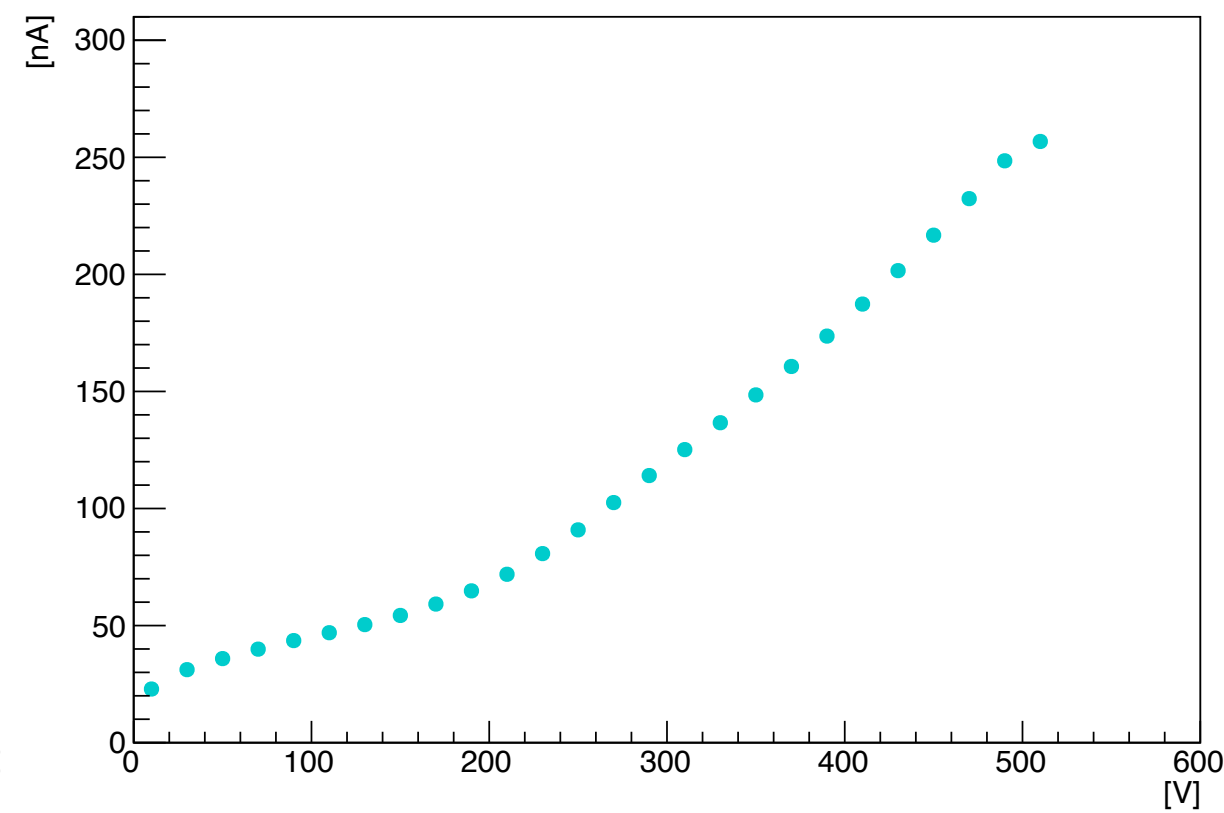
I-V 19R2_1



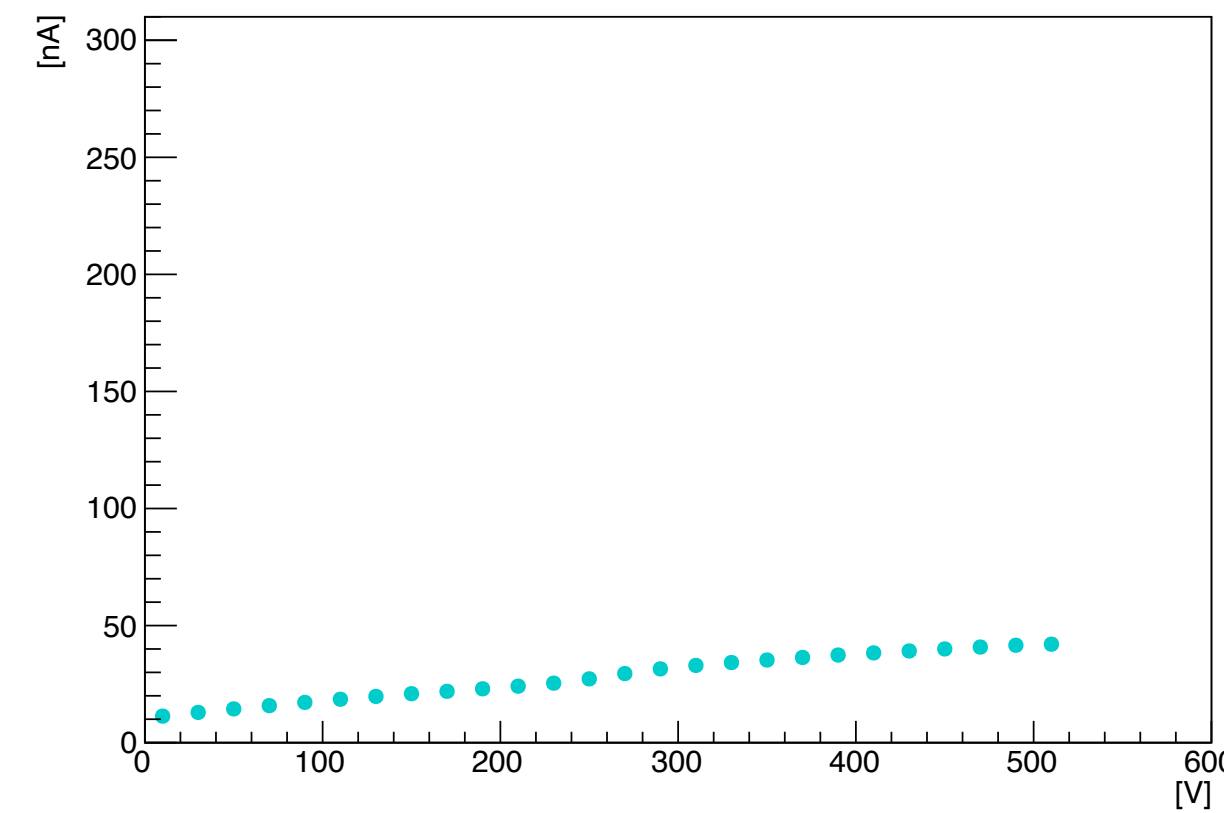
I-V 19B1_2



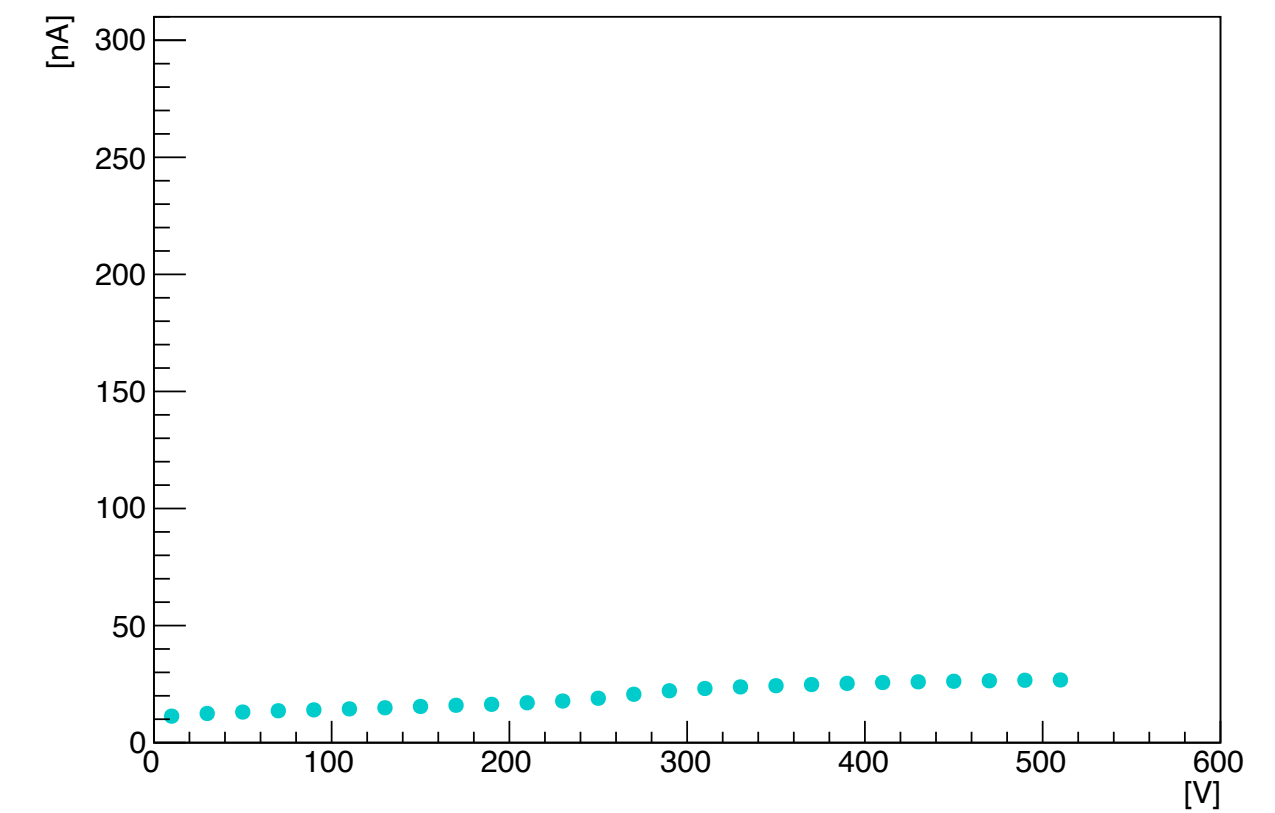
I-V 19B2_2



I-V 19R1_2



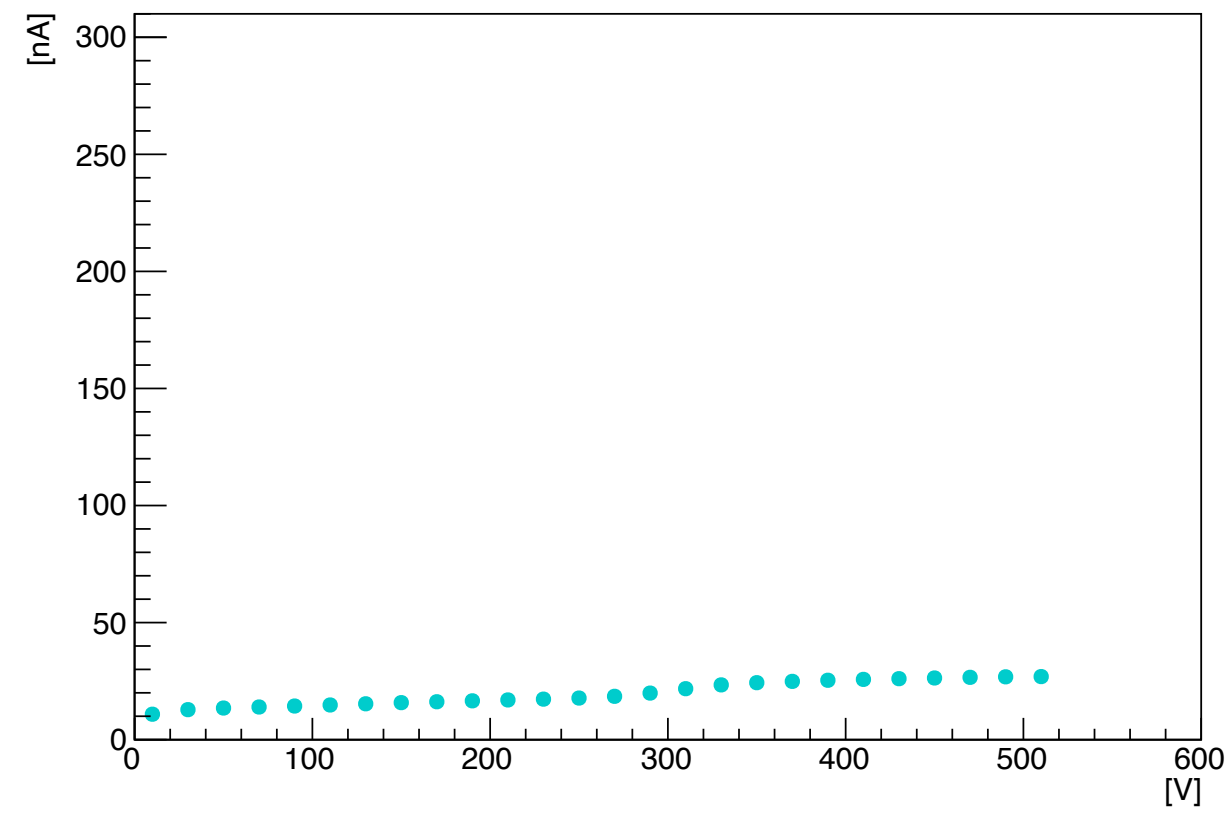
I-V 19R2_2



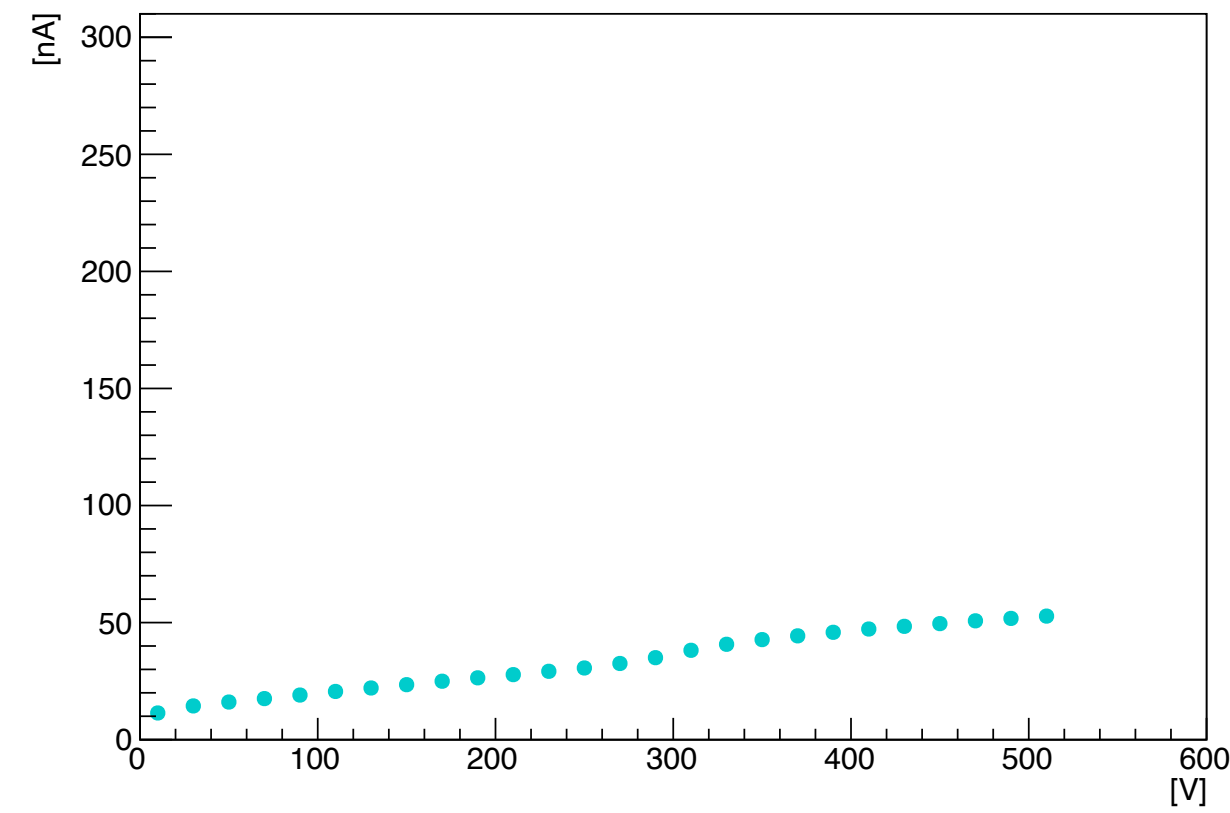
測定結果(軸を揃えたもの)

28T1, 28T2, 28L1, 28L2 (1cm×1cm)

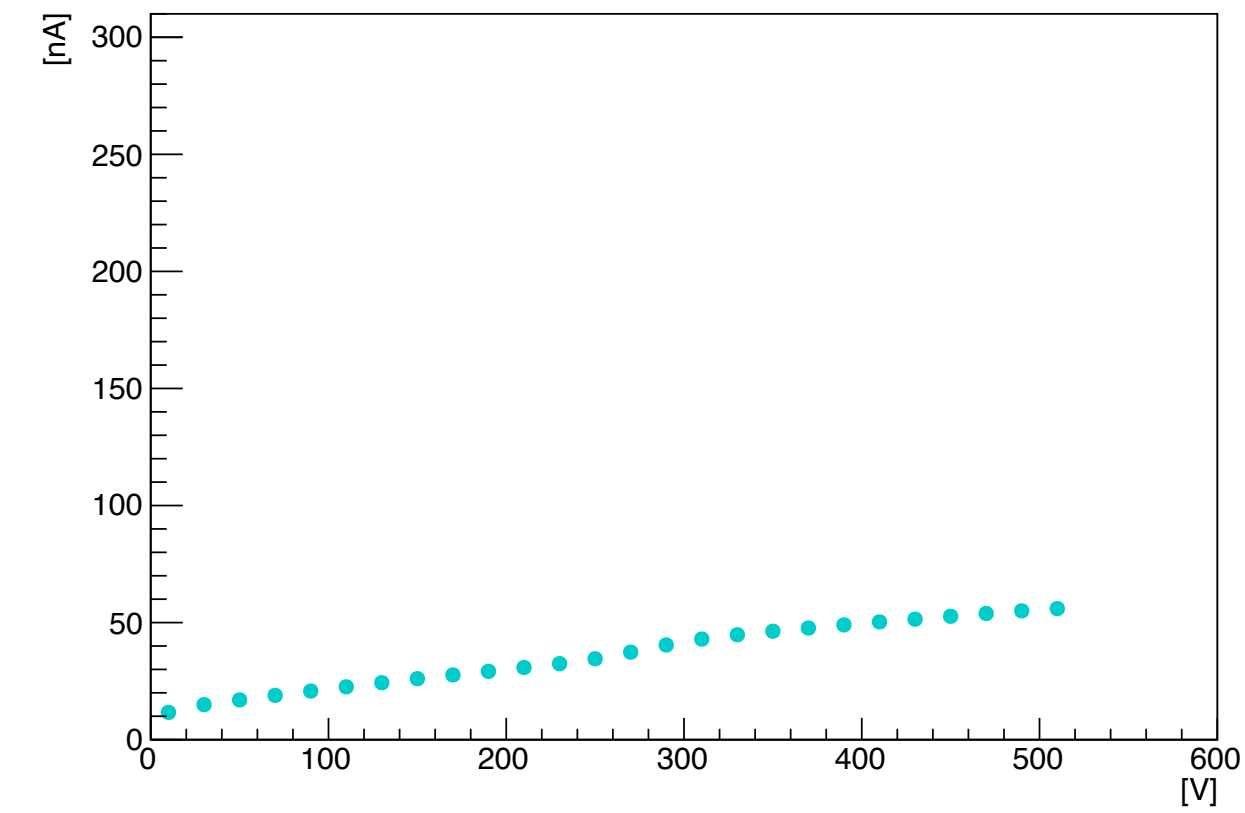
I-V 28T1_1



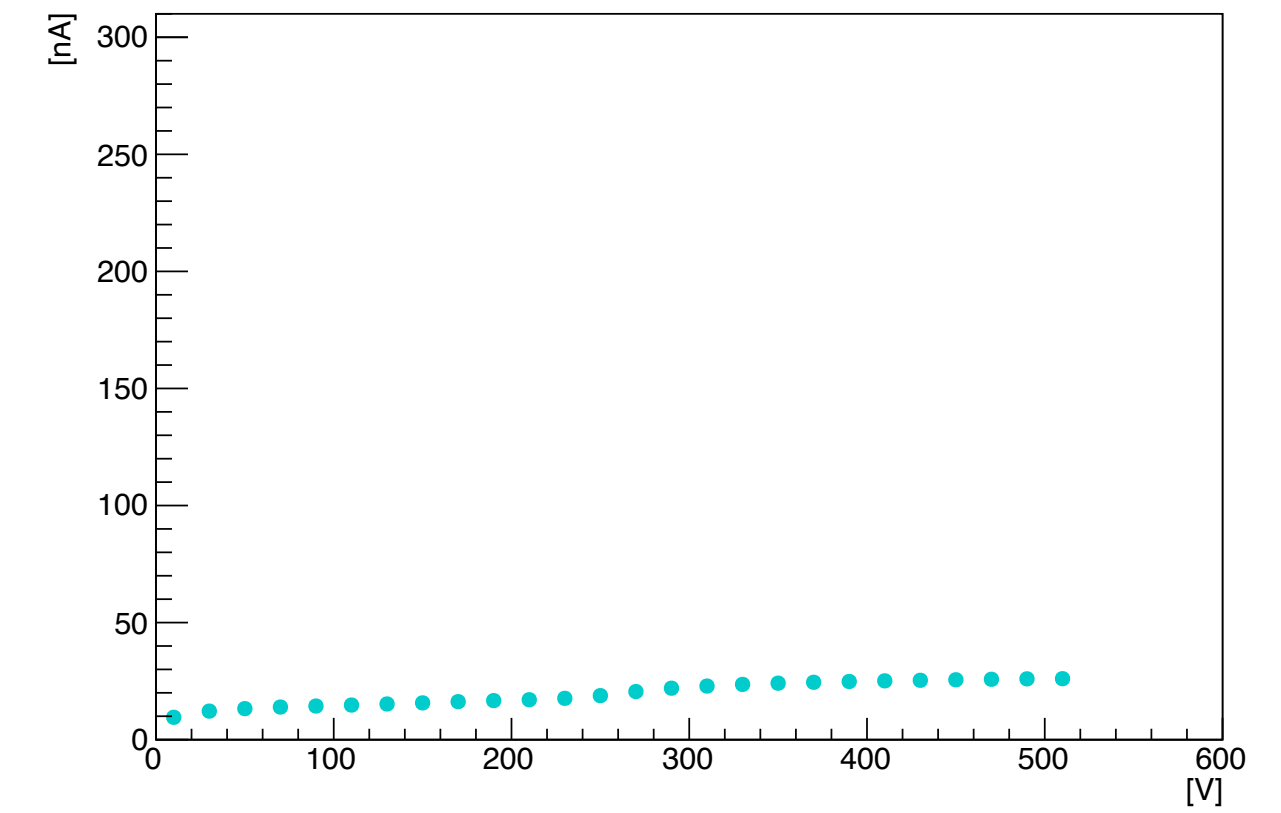
I-V 28T2_1



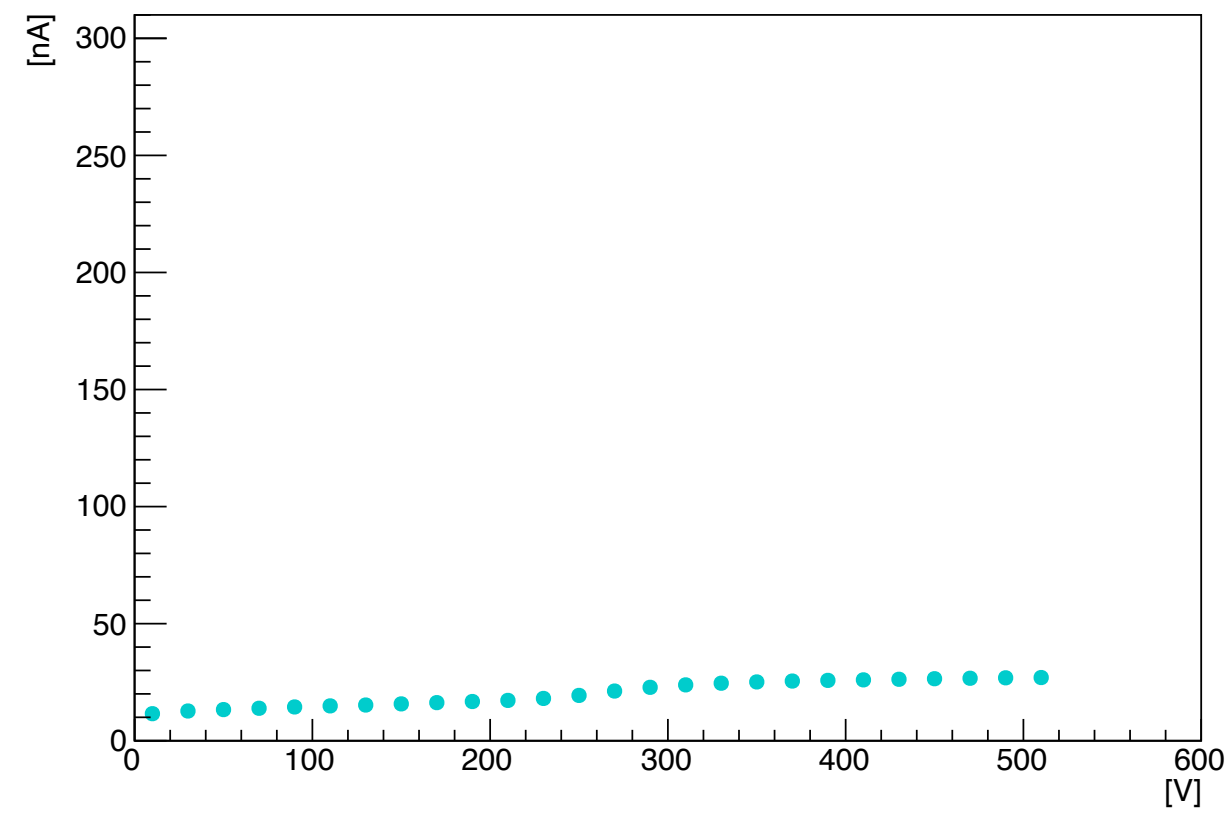
I-V 28L1_1



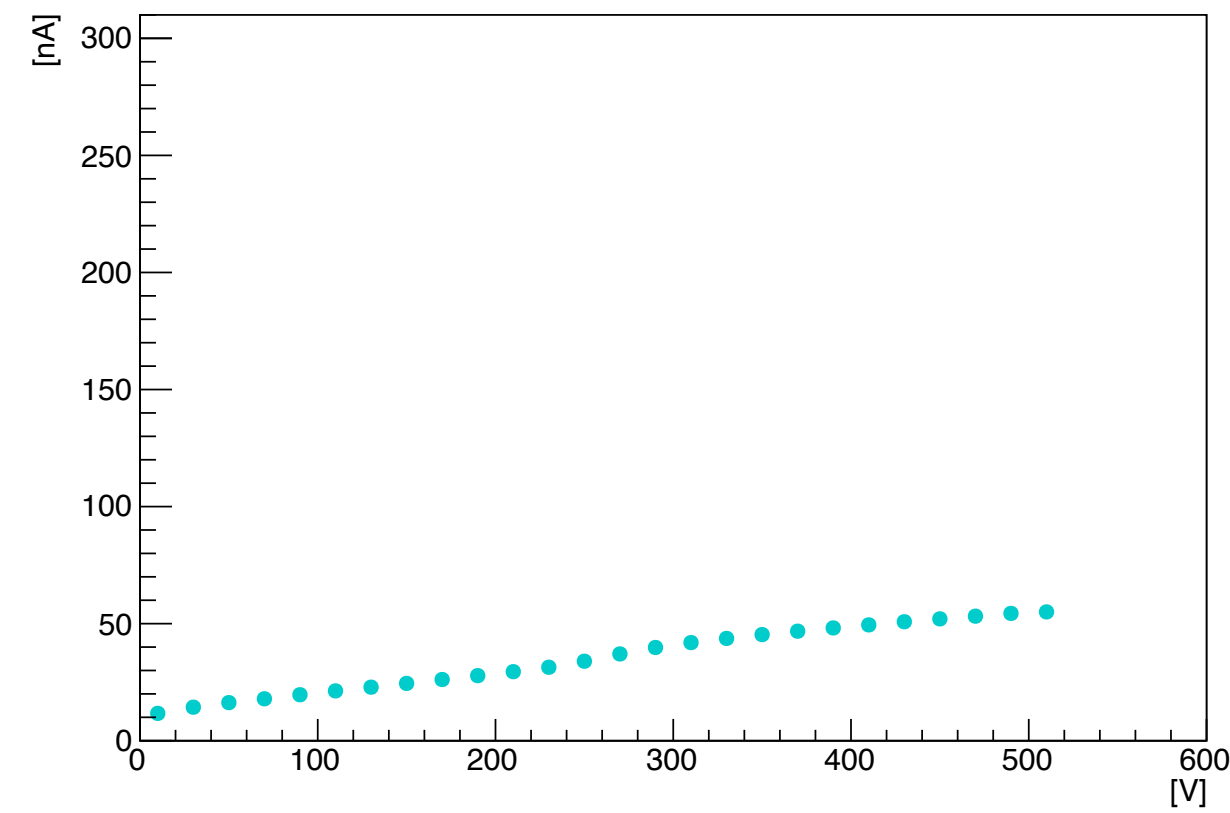
I-V 28L2_1



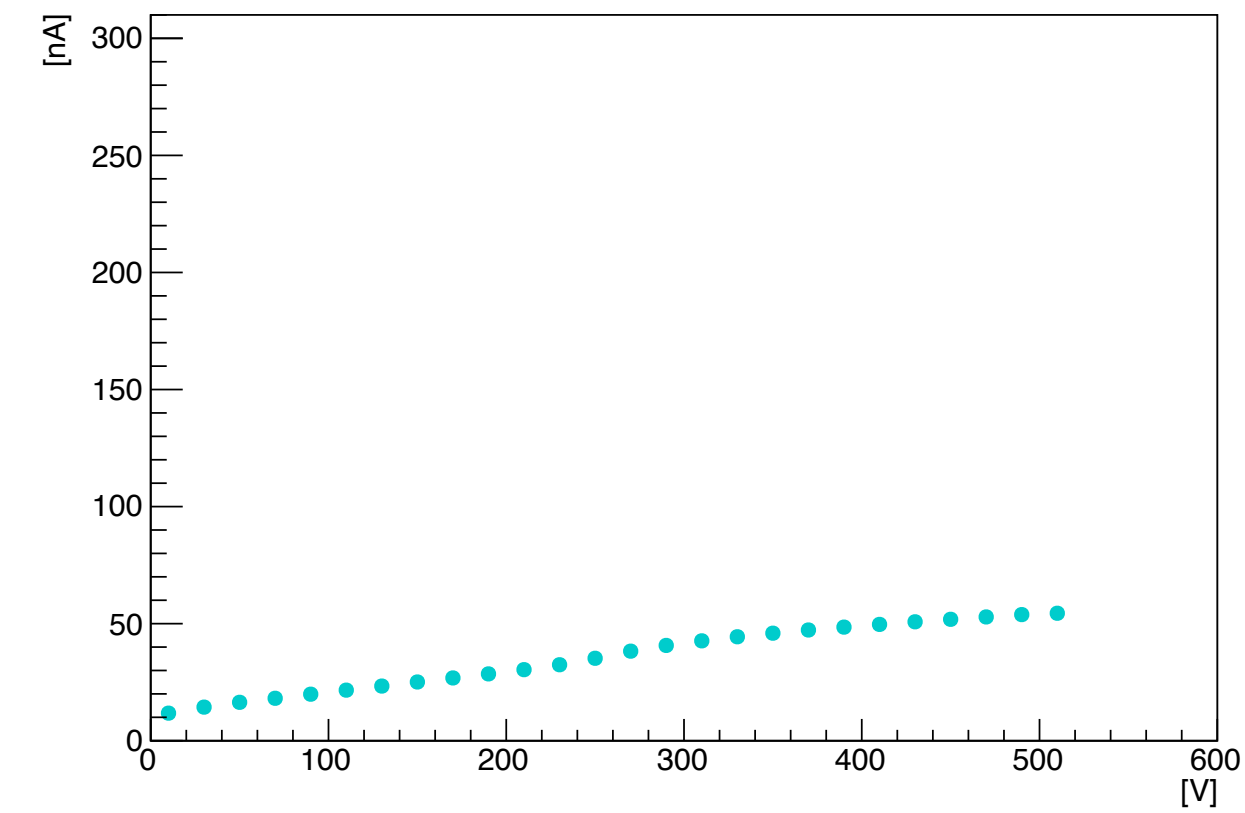
I-V 28T1_2



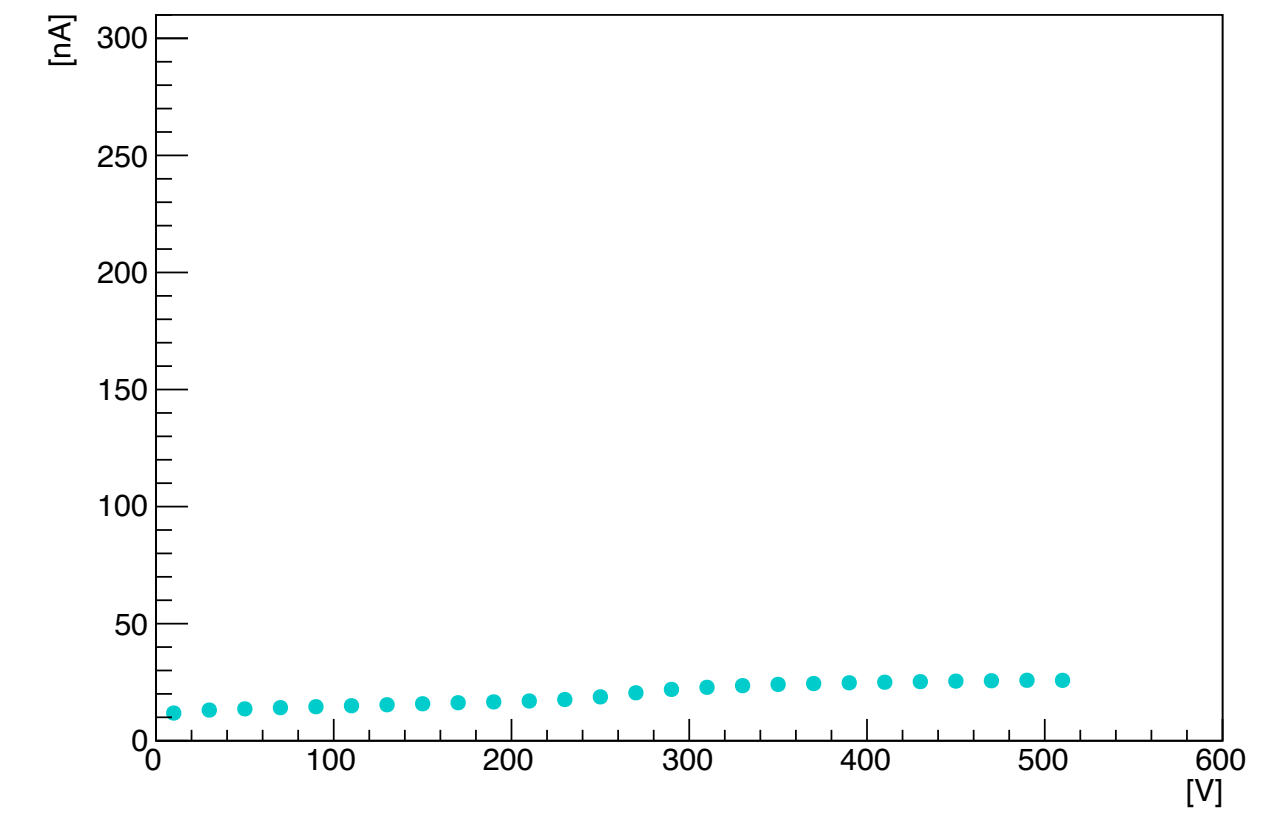
I-V 28T2_2



I-V 28L1_2



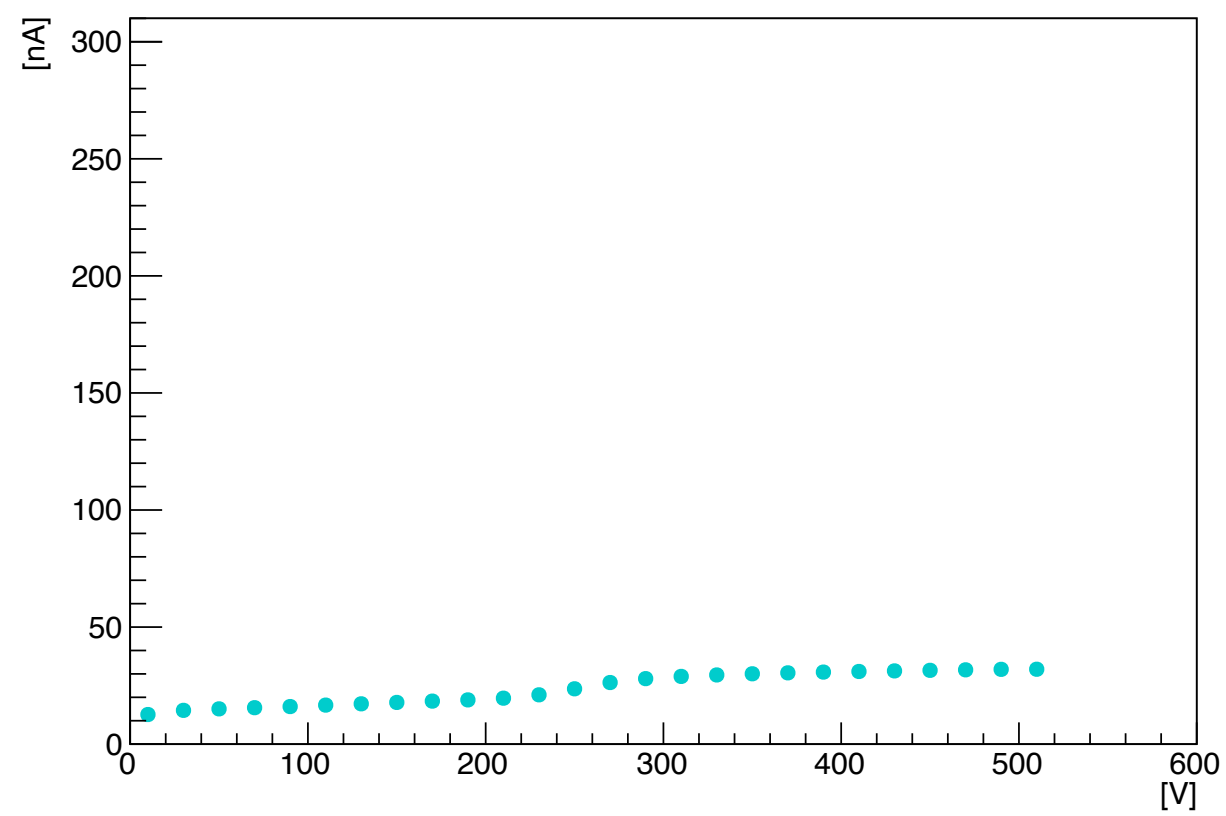
I-V 28L2_2



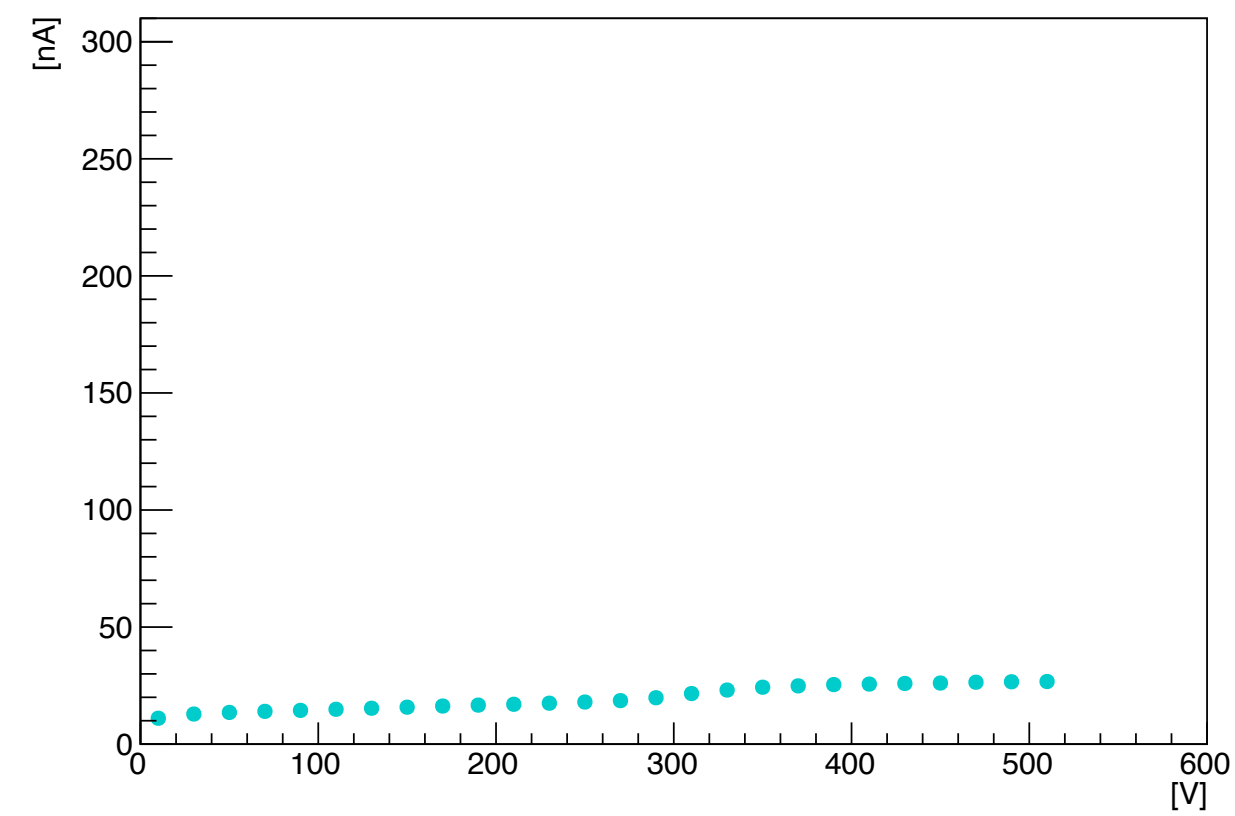
測定結果(軸を揃えたもの)

28B1, 28B2, 28R1, 28R2 (1cm× 1cm)

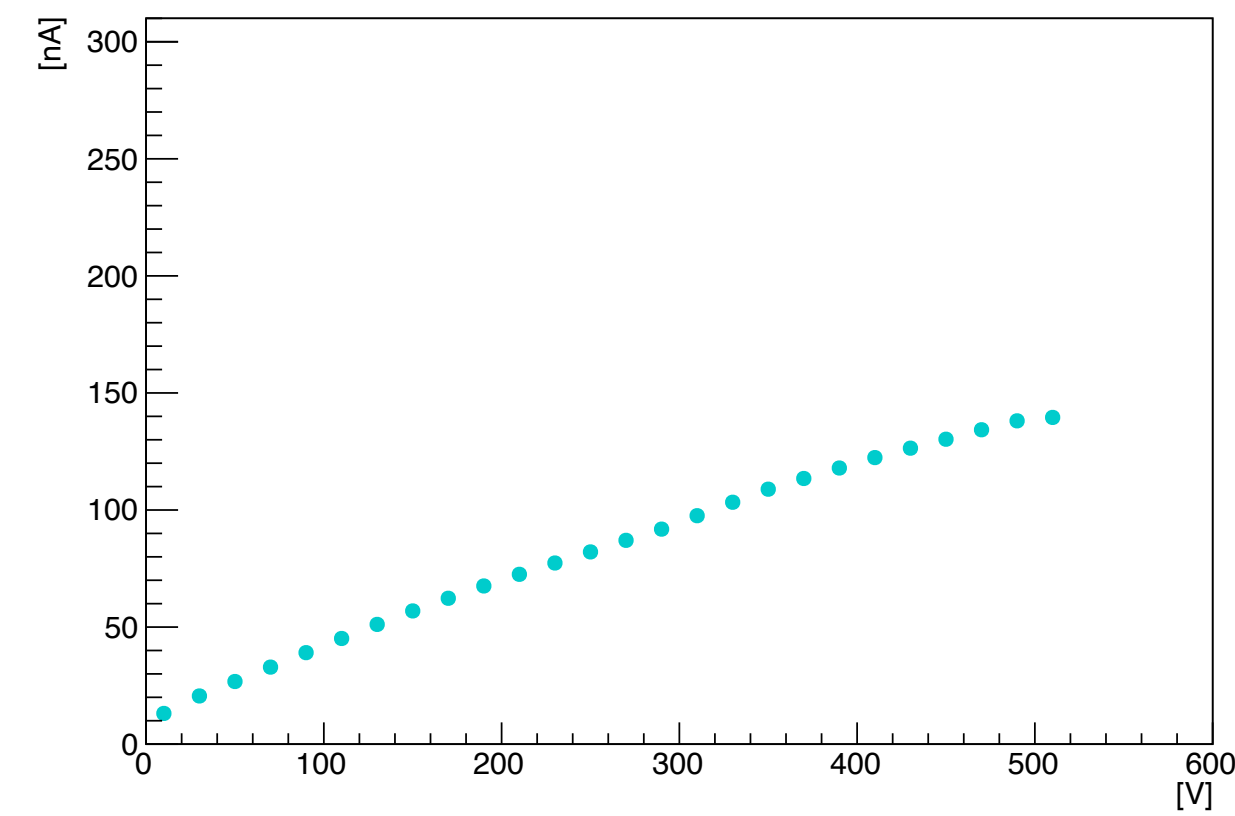
I-V 28B1_1



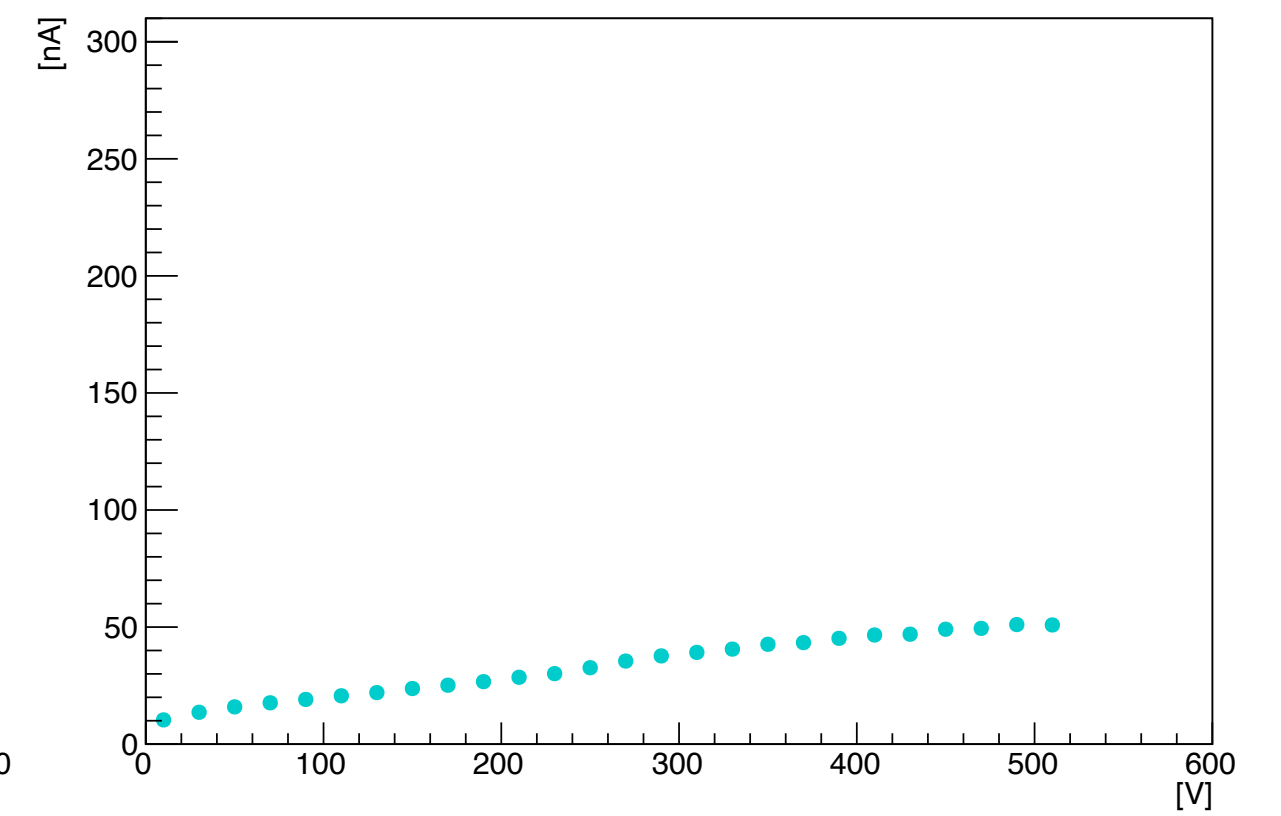
I-V 28B2_1



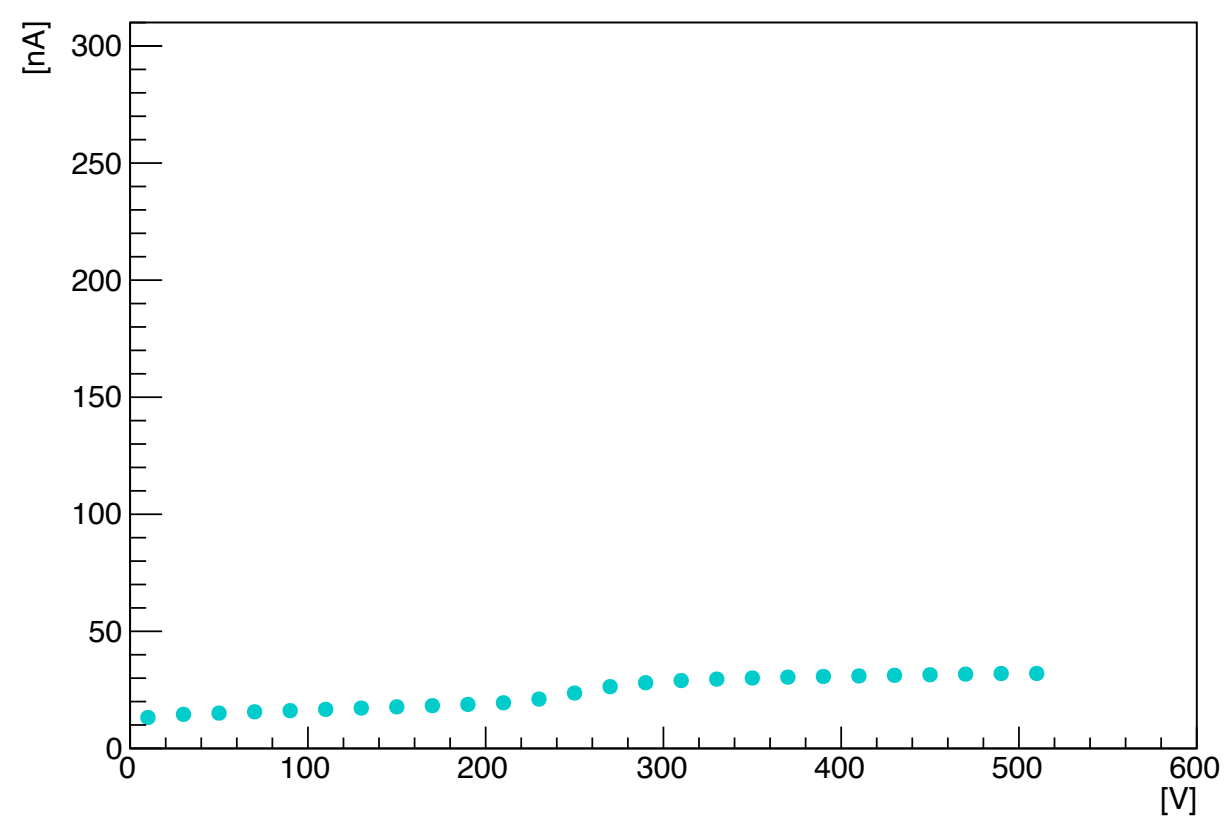
I-V 28R1_1



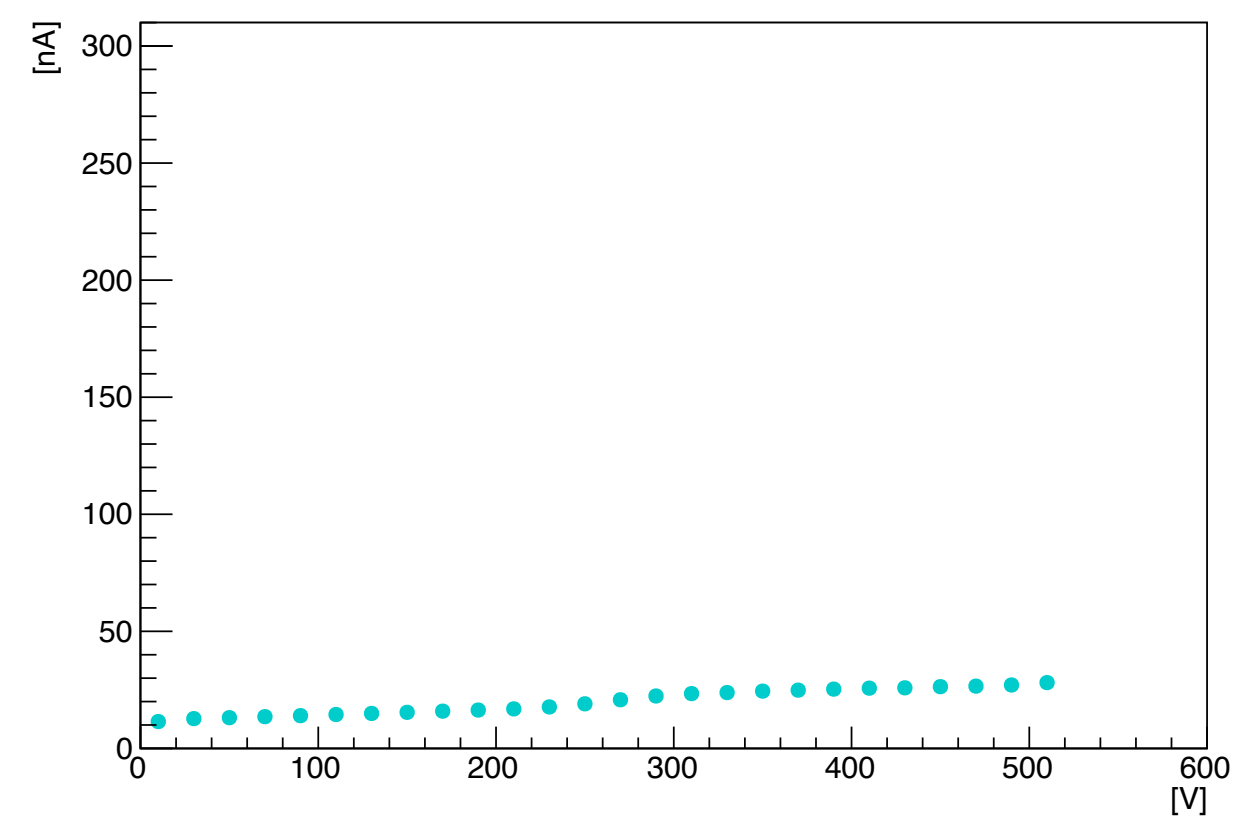
I-V 28R2_1



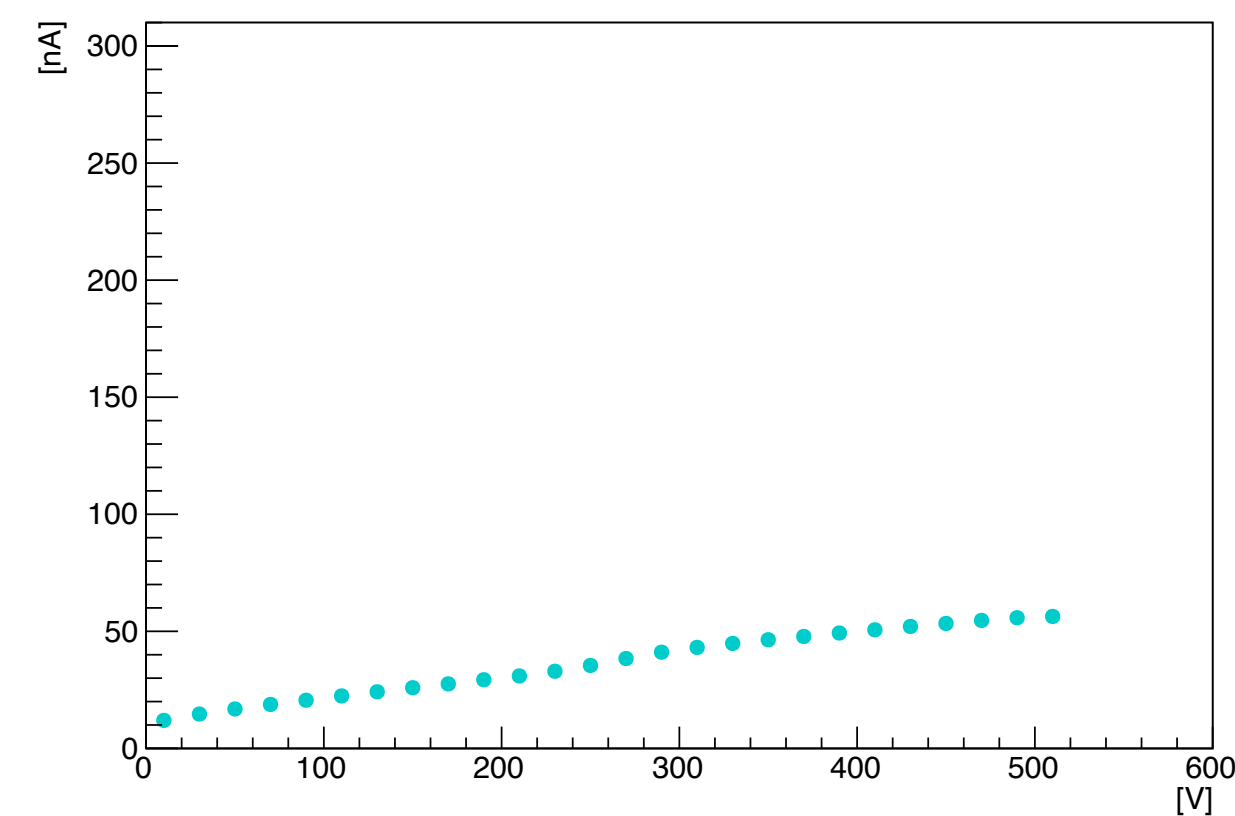
I-V 28B1_2



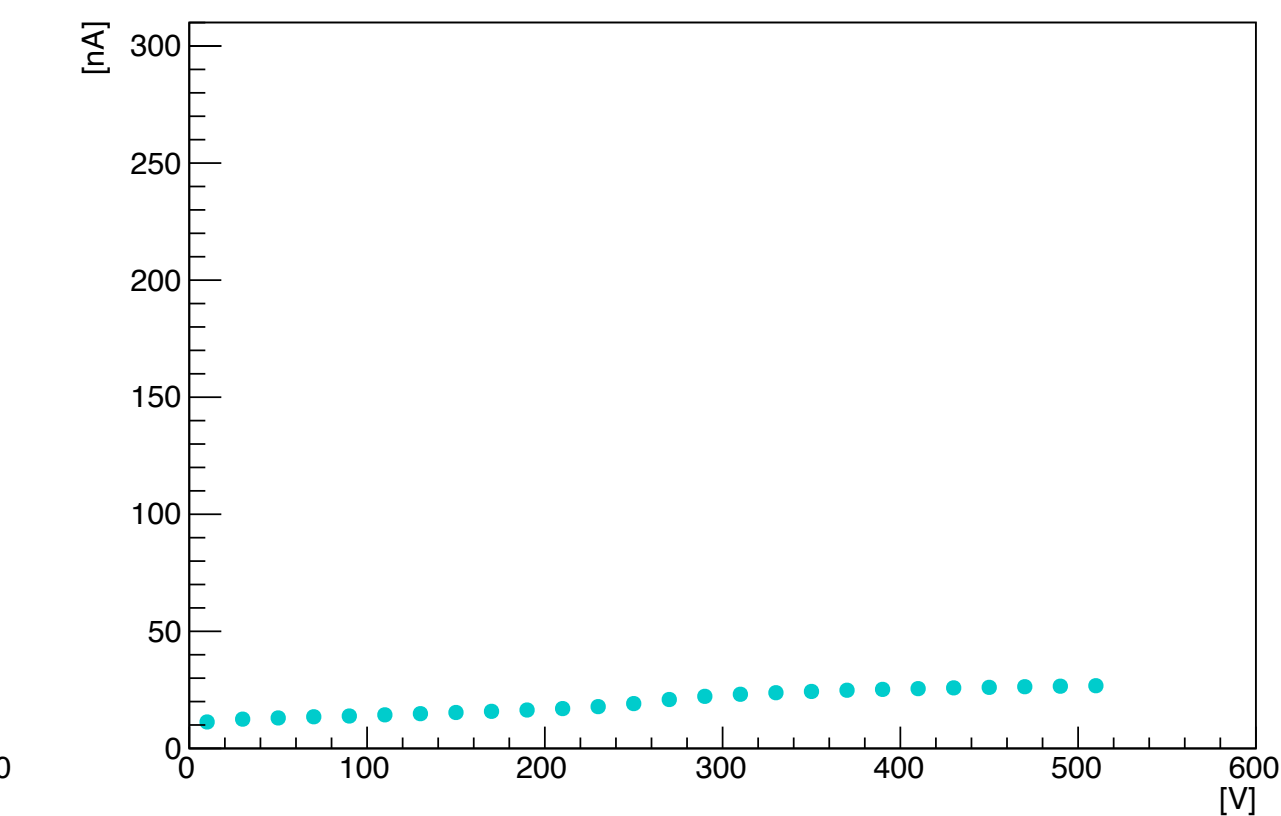
I-V 28B2_2



I-V 28R1_2



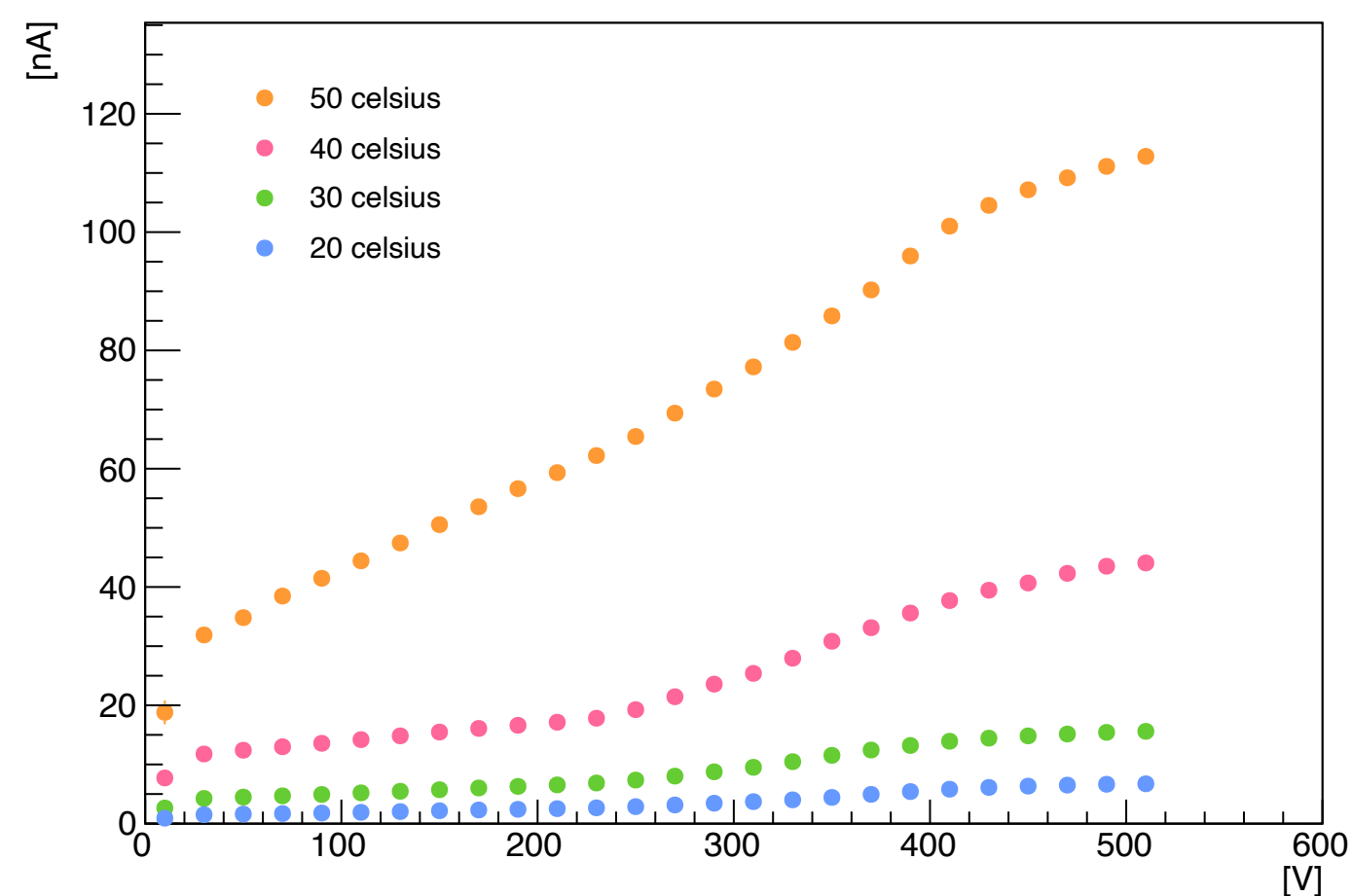
I-V 28R2_2



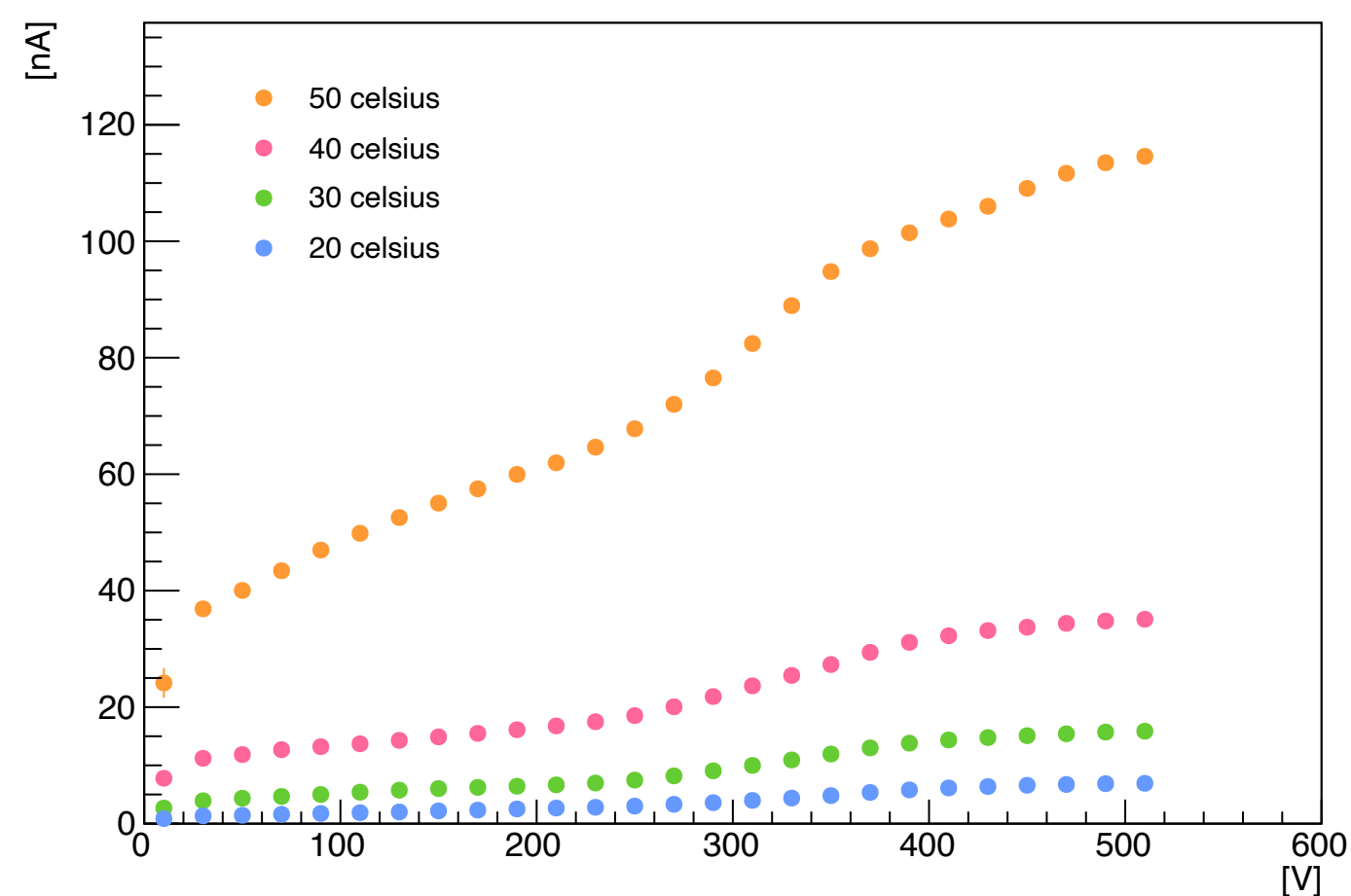
測定結果-温度依存

14(2cm× 2cm)

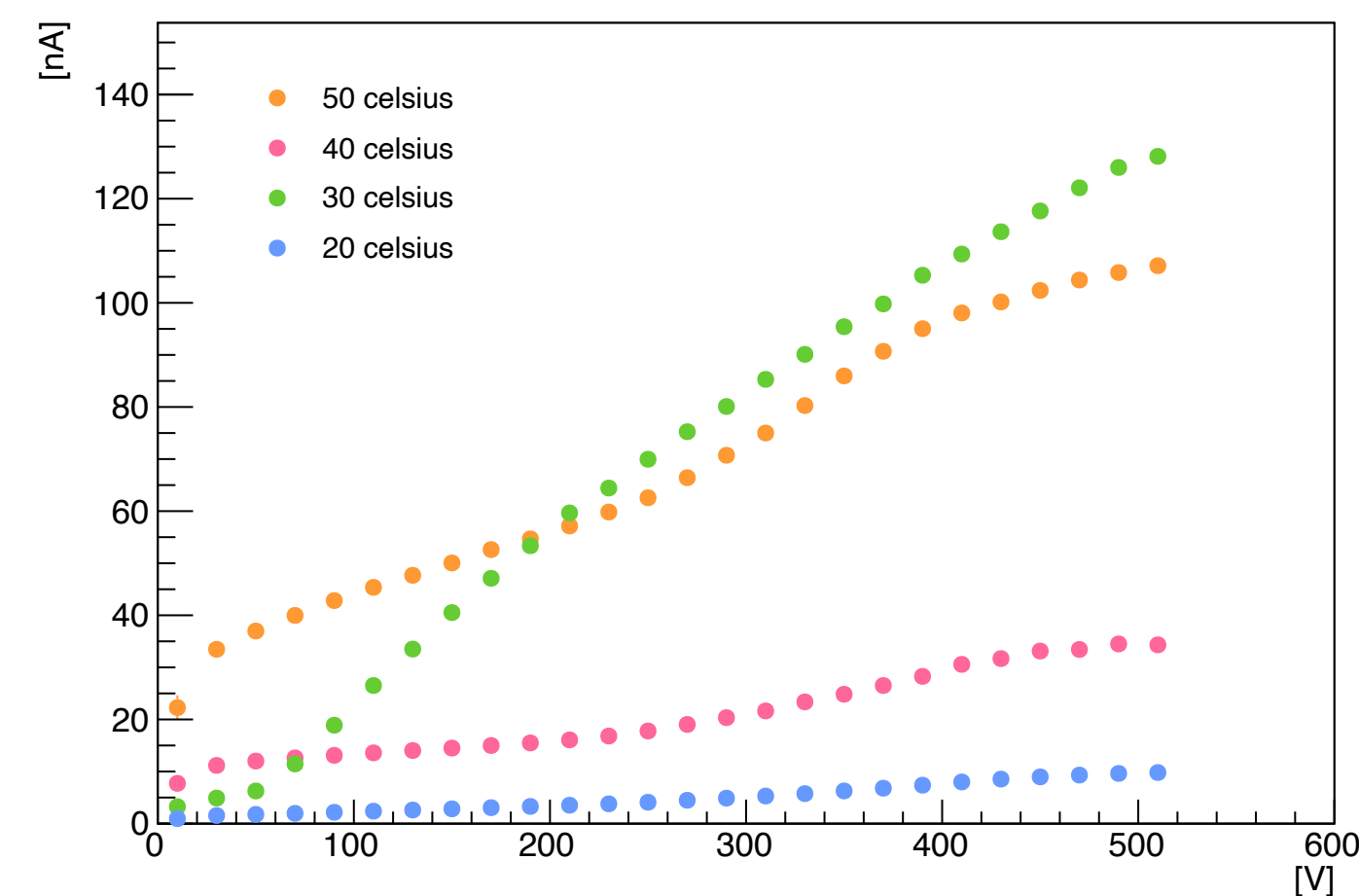
I-V 14_1



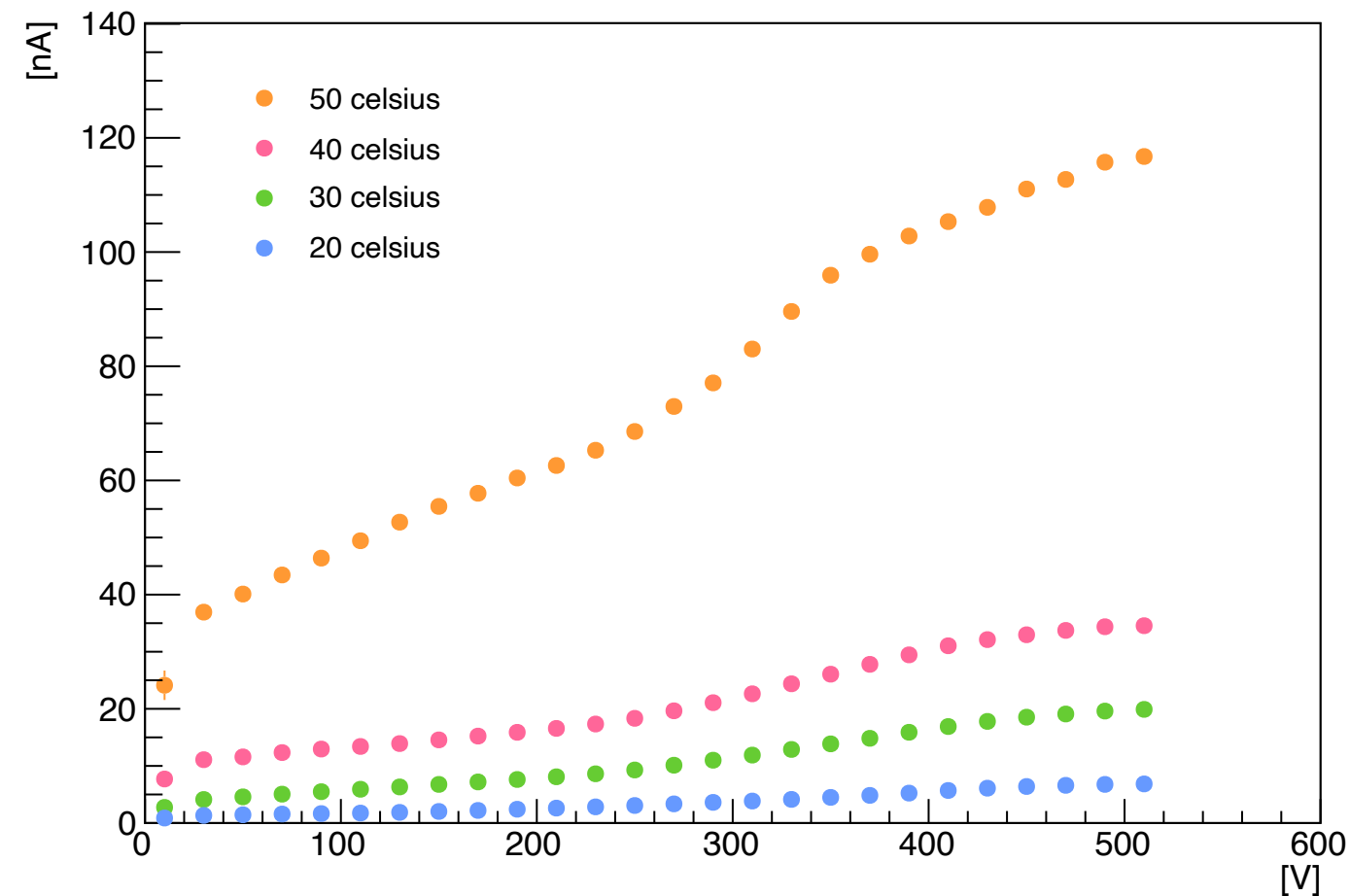
I-V 14_3



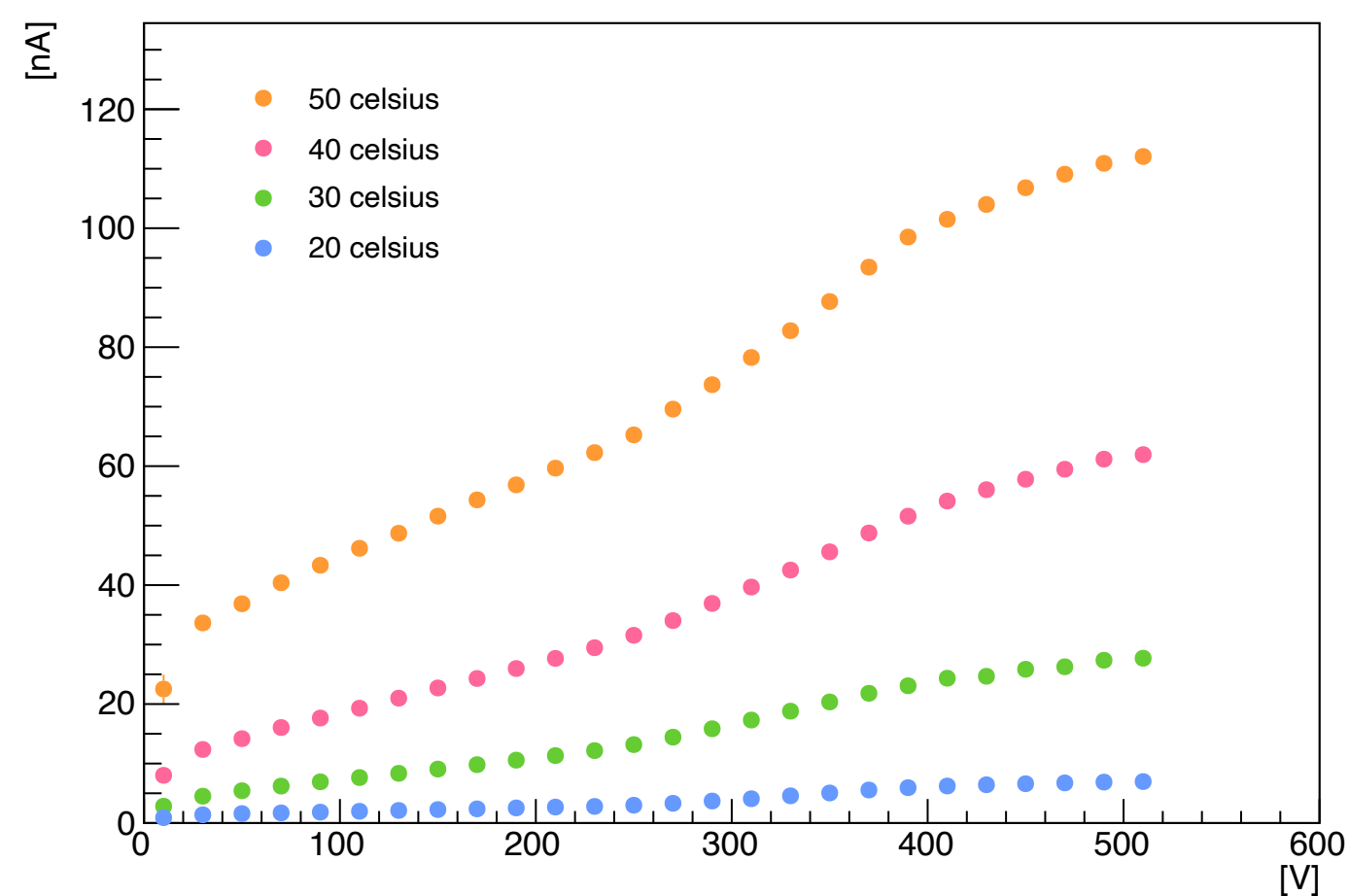
I-V 14_5



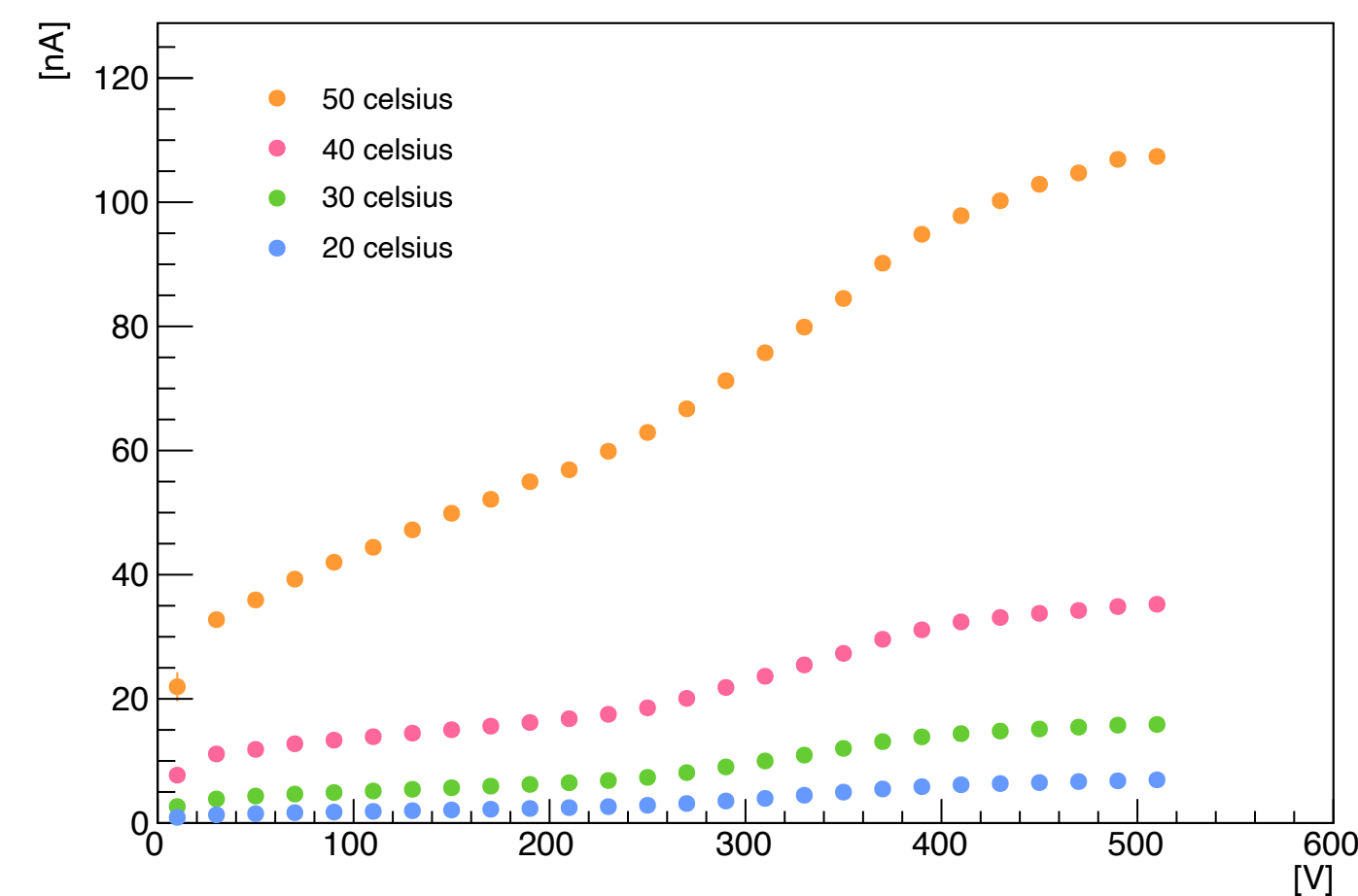
I-V 14_2



I-V 14_4



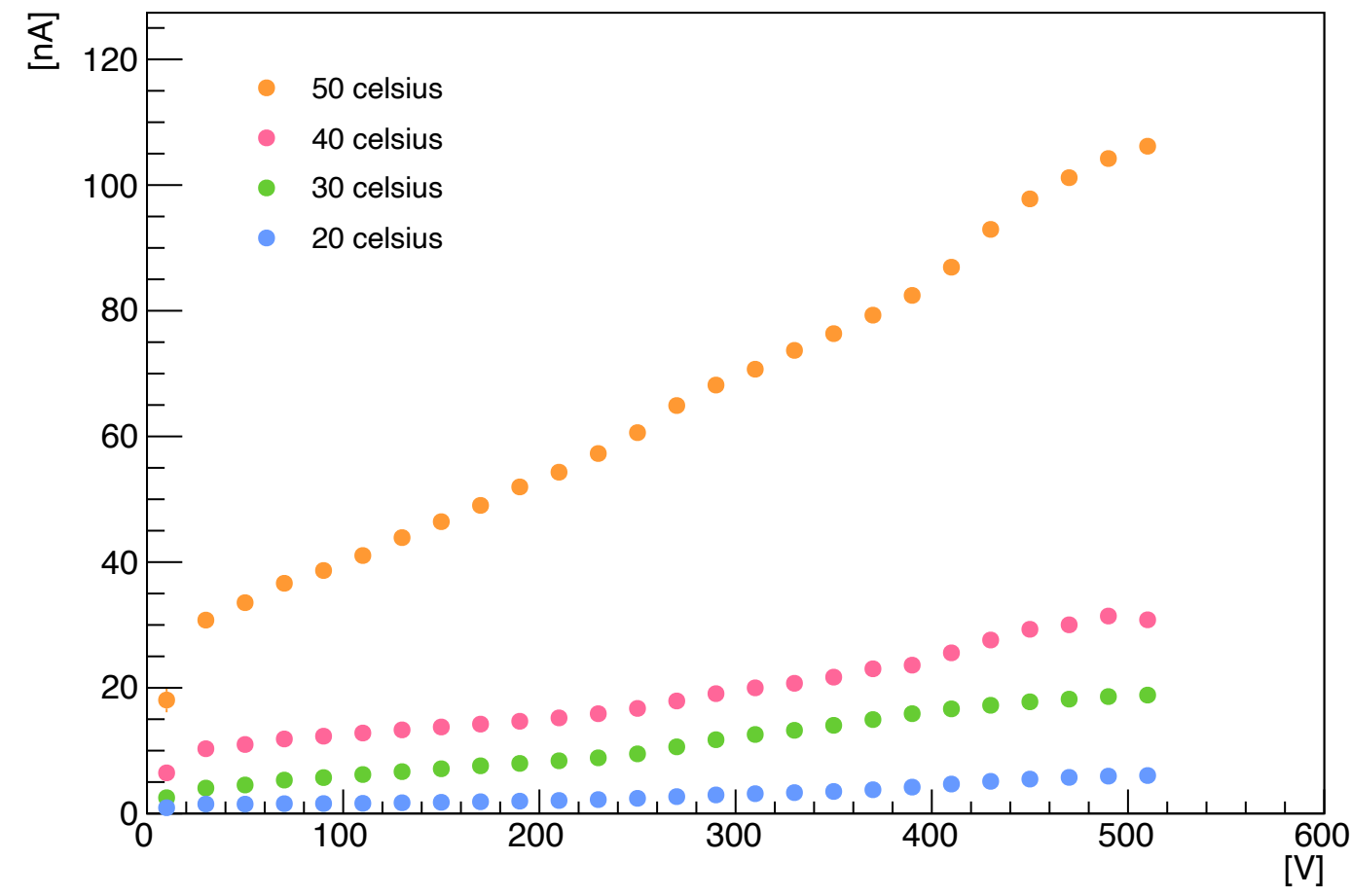
I-V 14_6



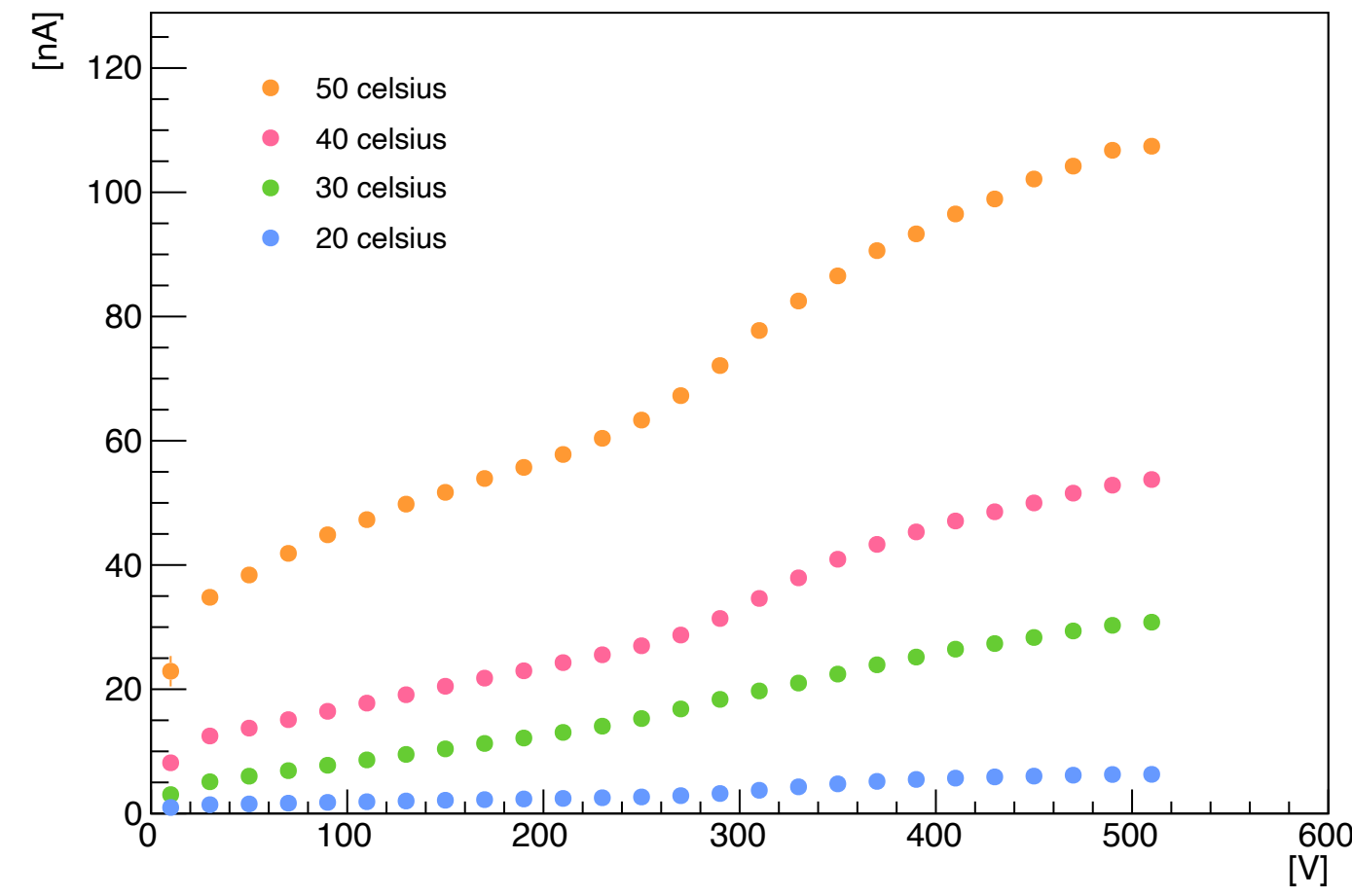
測定結果-温度依存

19(2cm× 2cm)

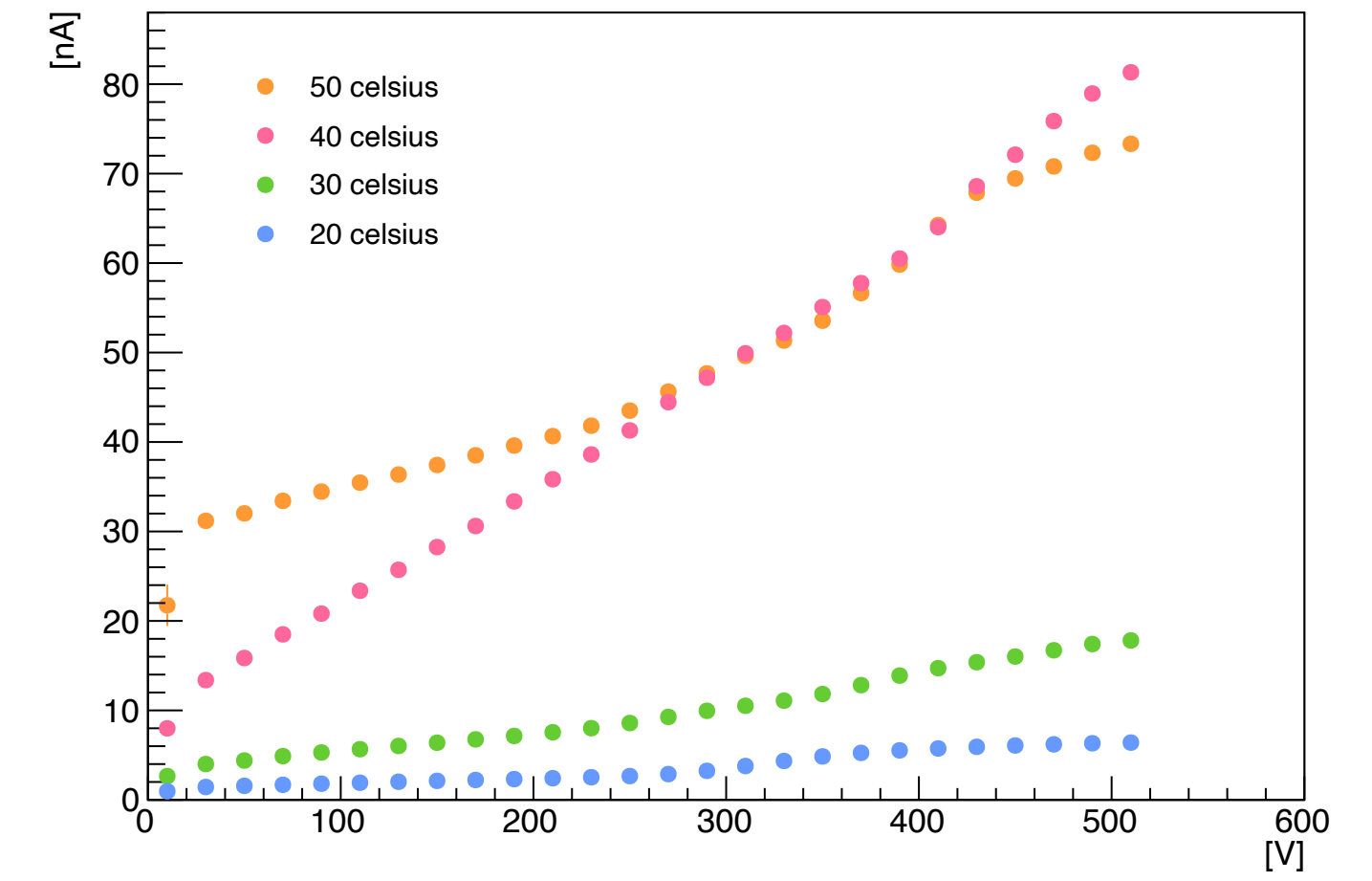
I-V 19_1



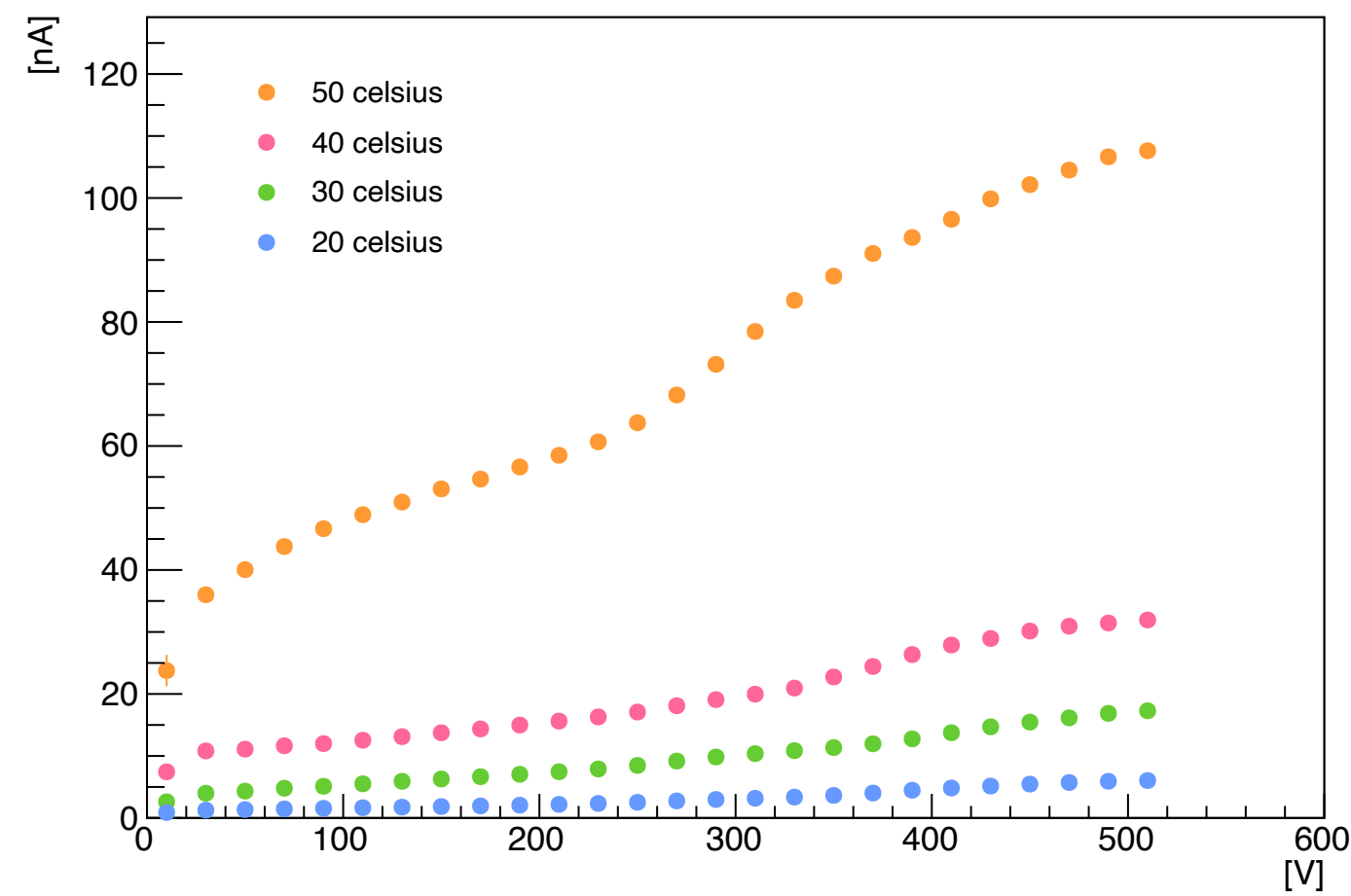
I-V 19_3



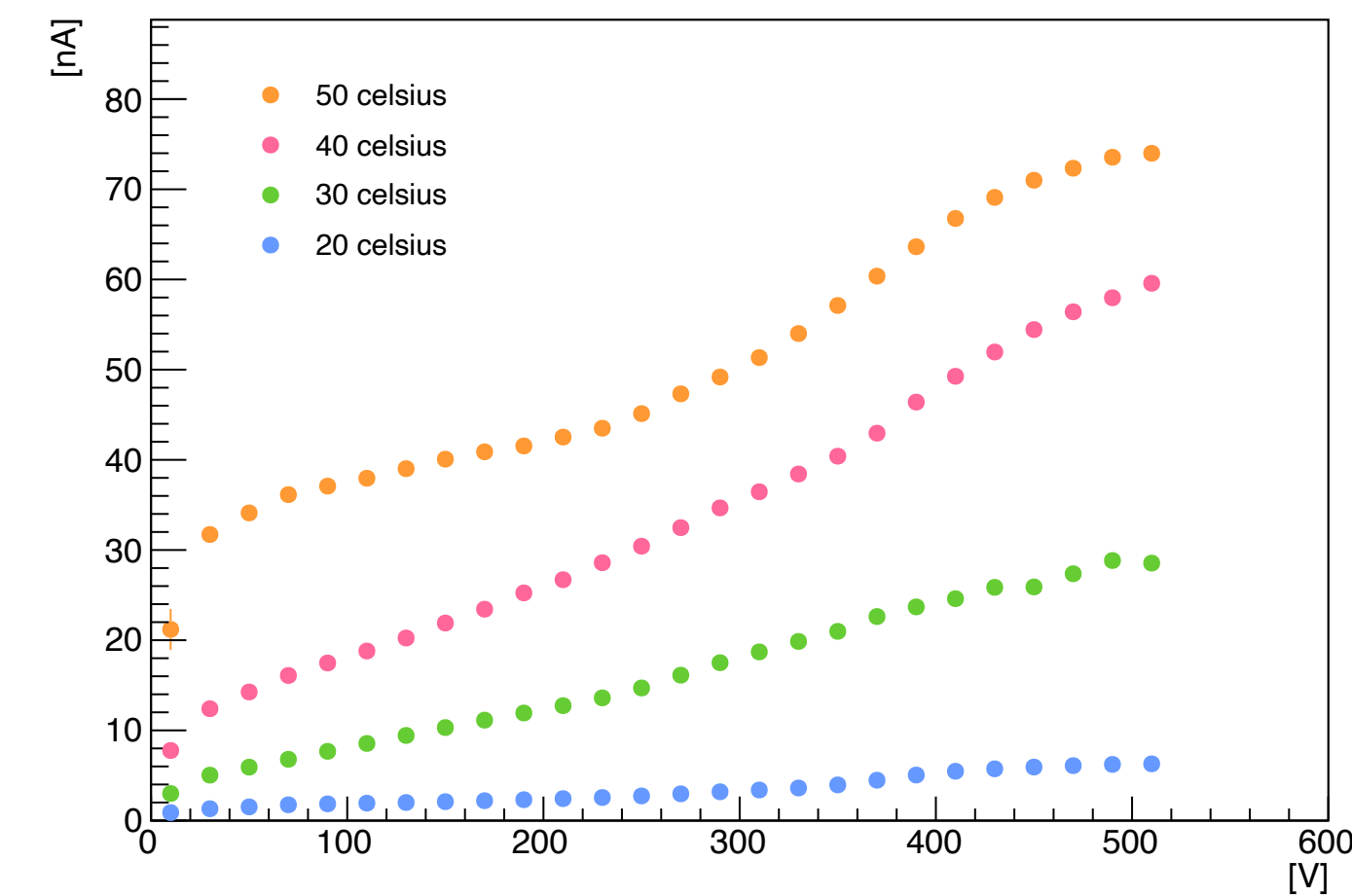
I-V 19_5



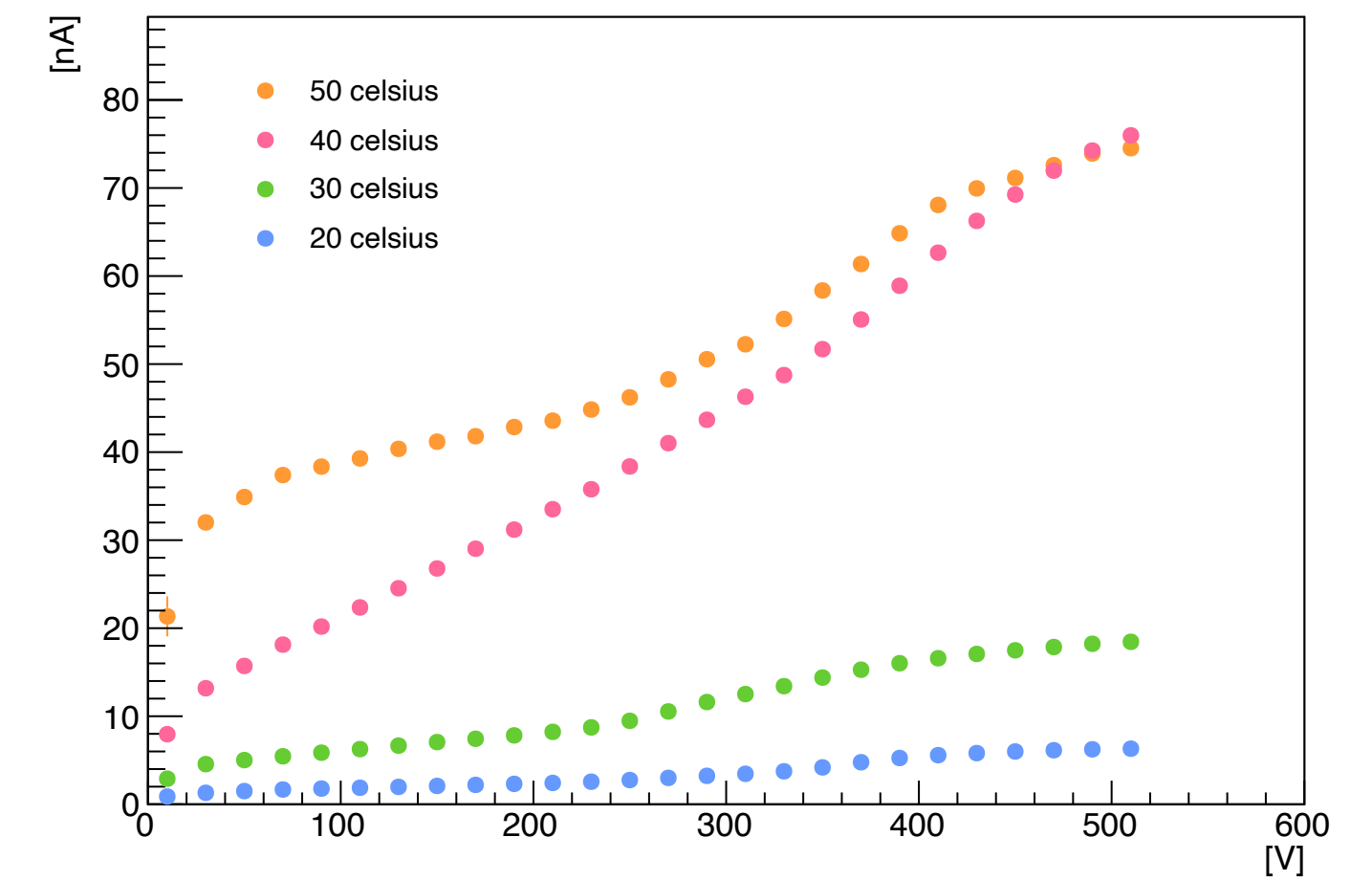
I-V 19_2



I-V 19_4



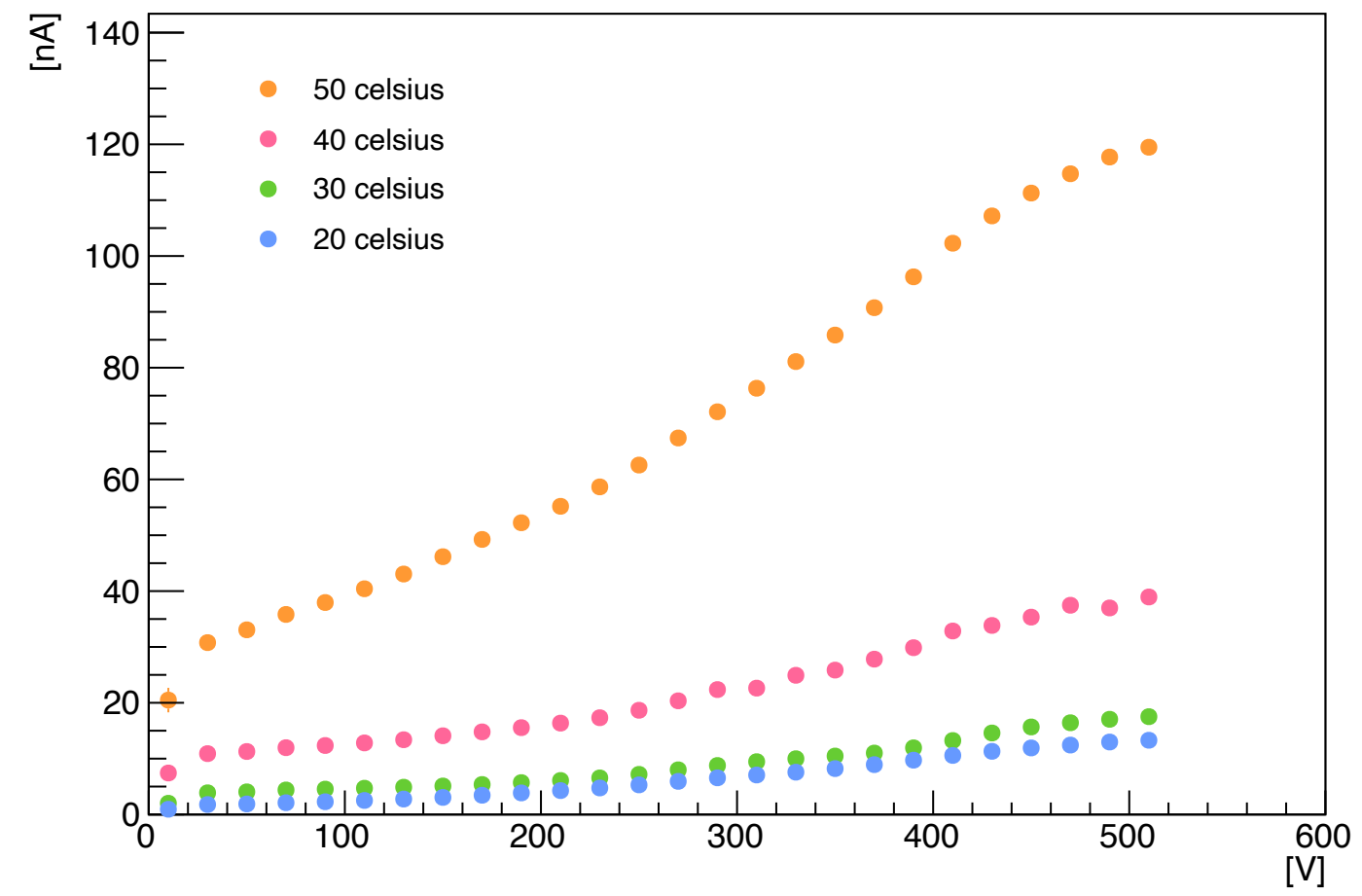
I-V 19_6



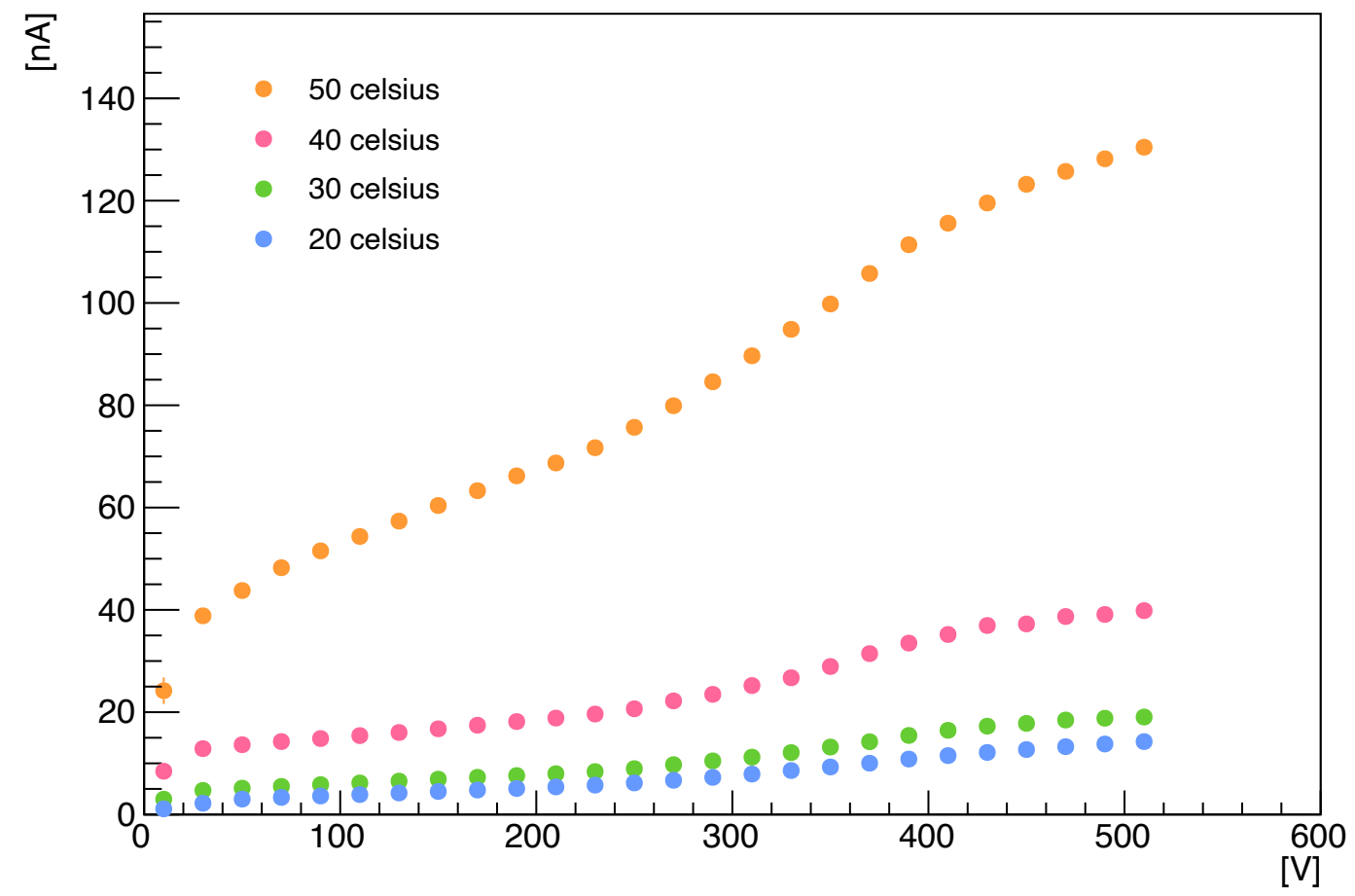
測定結果-温度依存

28(2cm× 2cm)

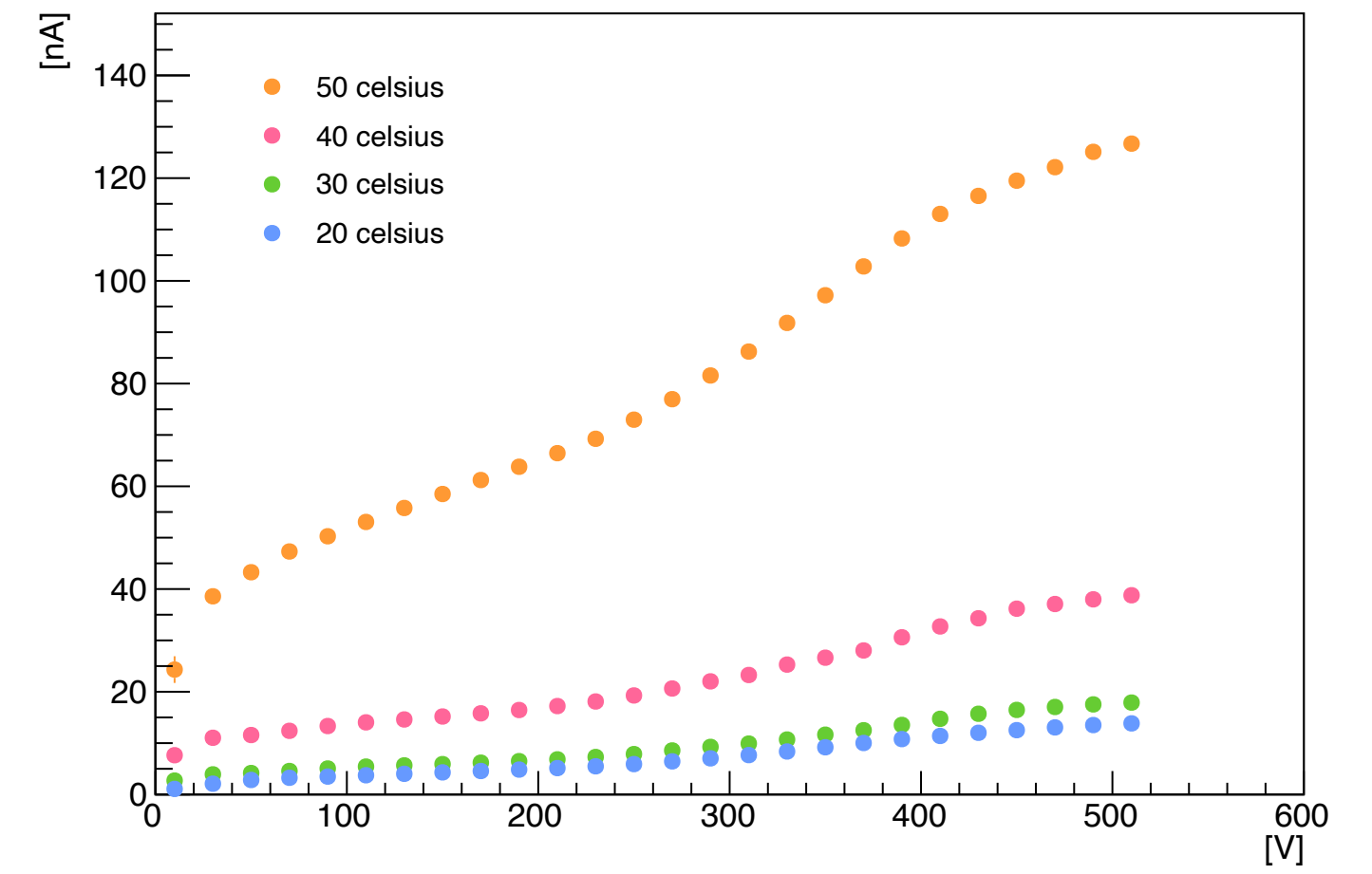
I-V 28_1



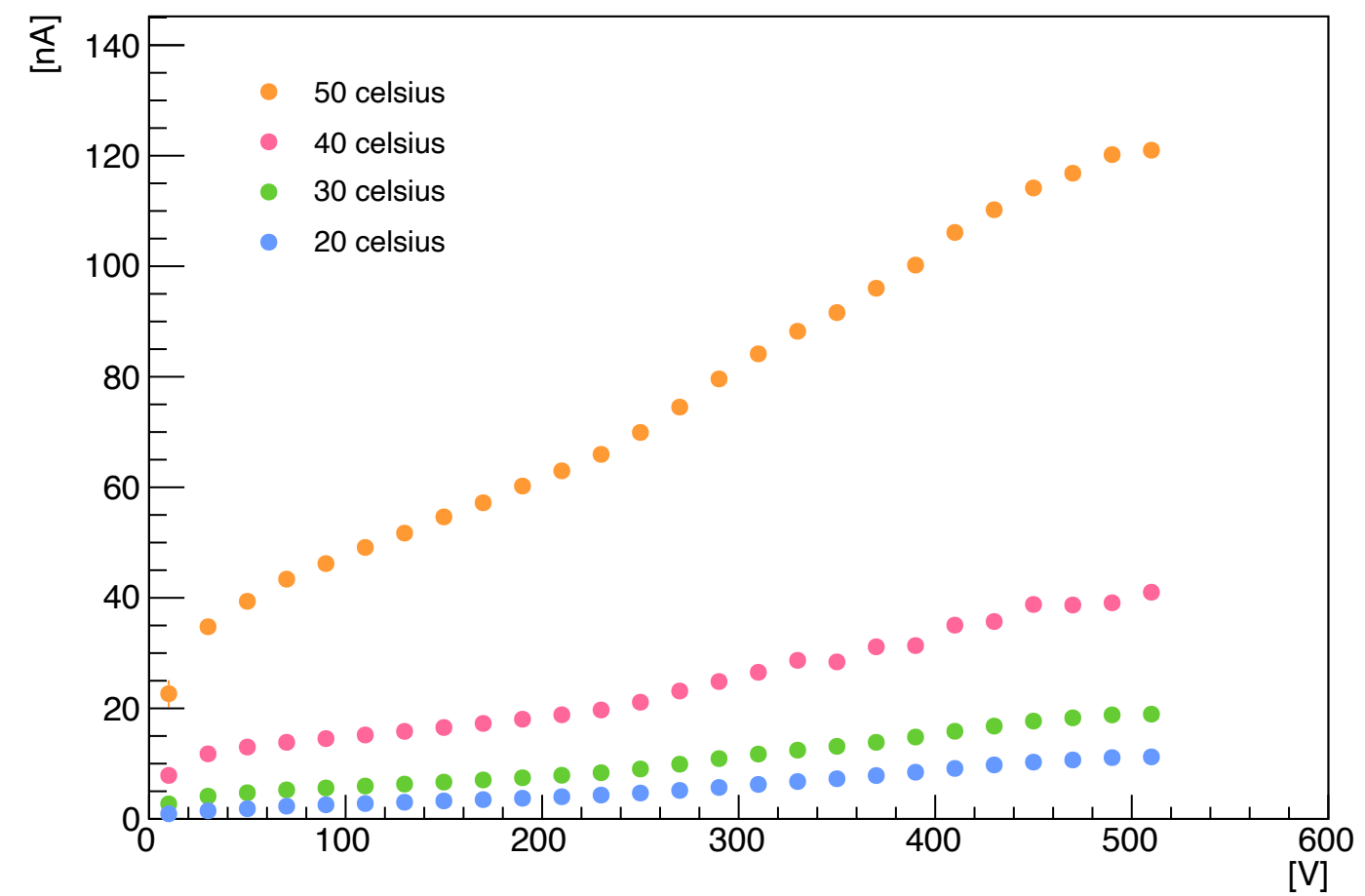
I-V 28_3



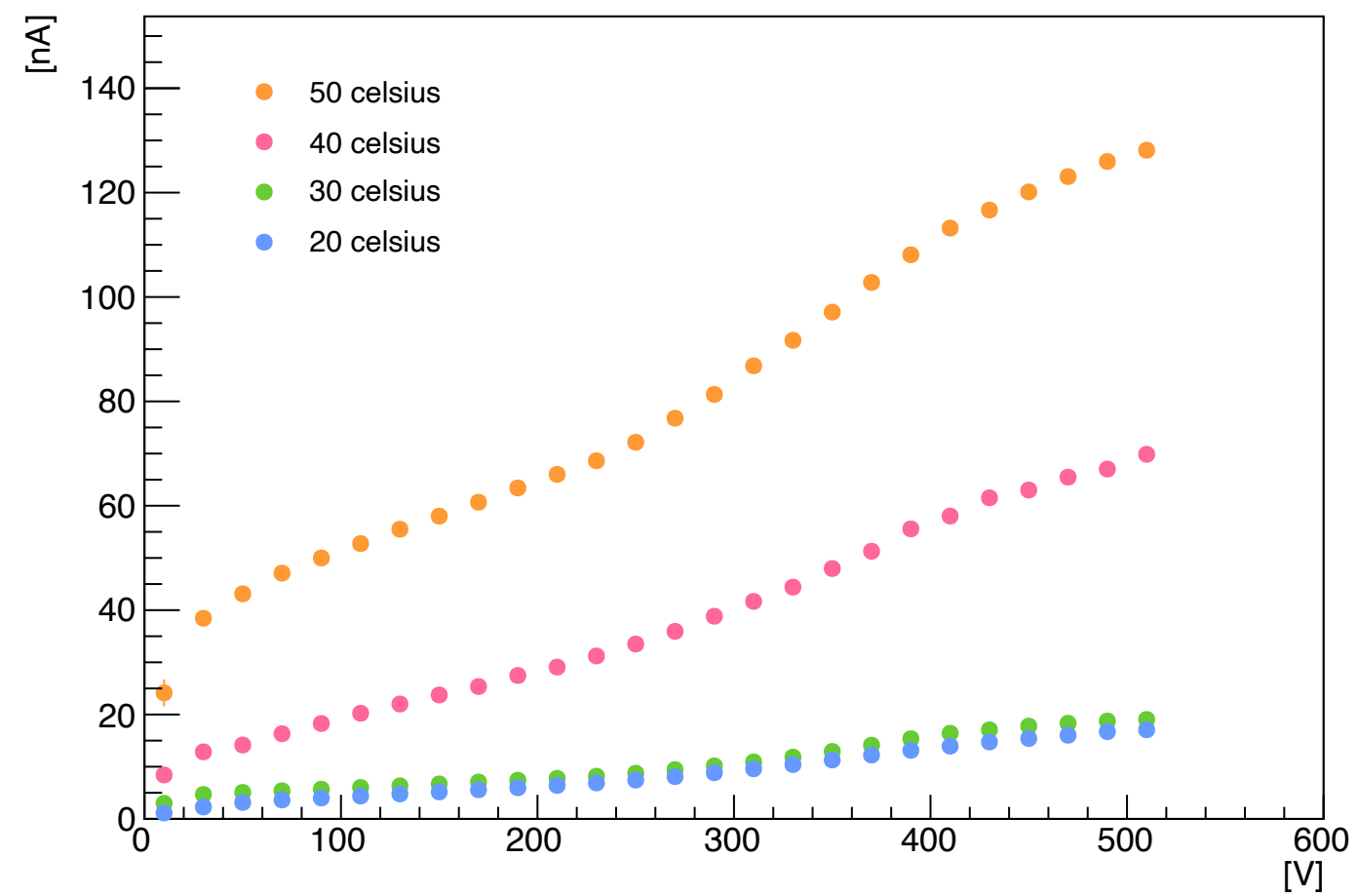
I-V 28_5



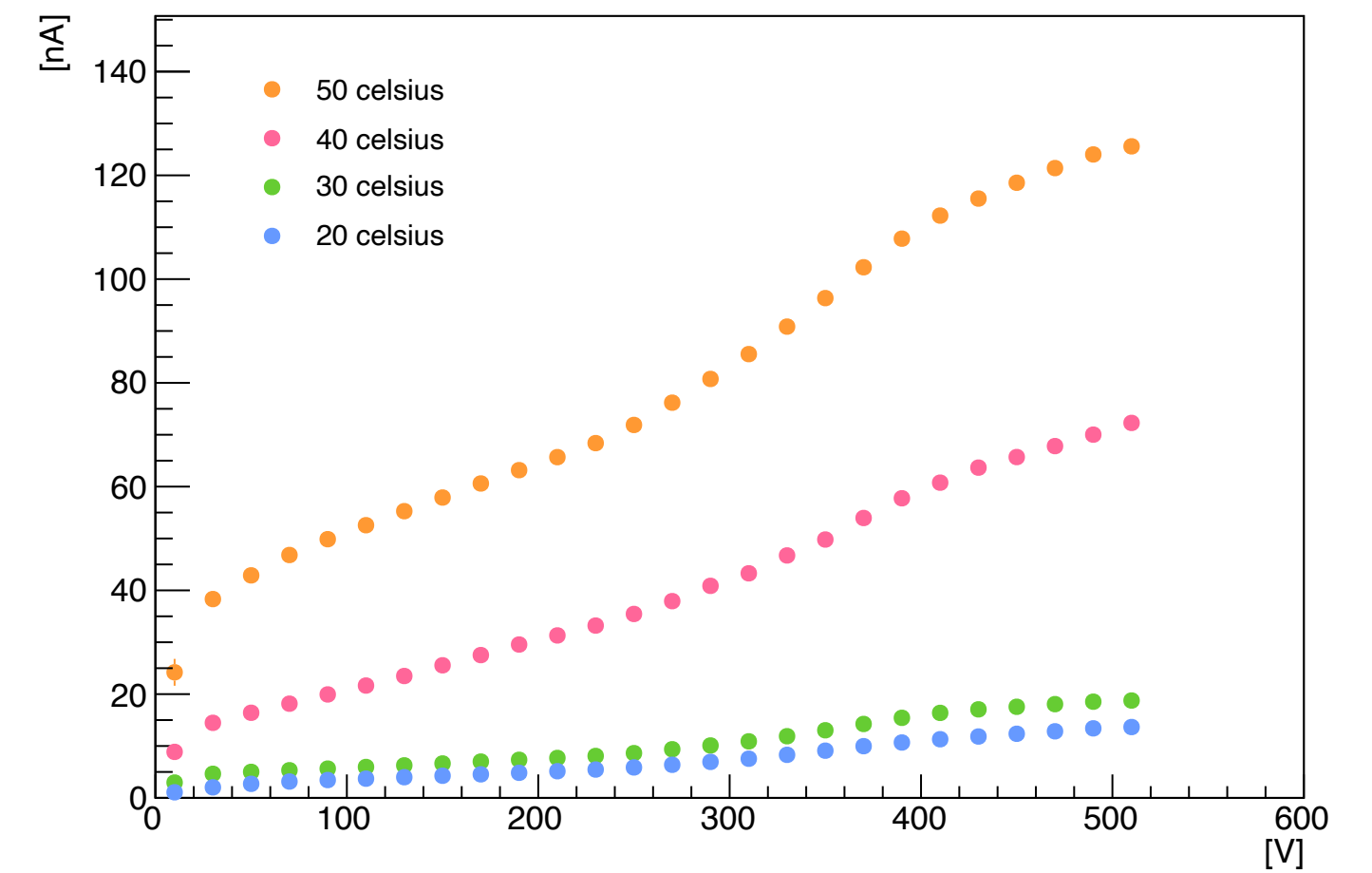
I-V 28_2



I-V 28_4



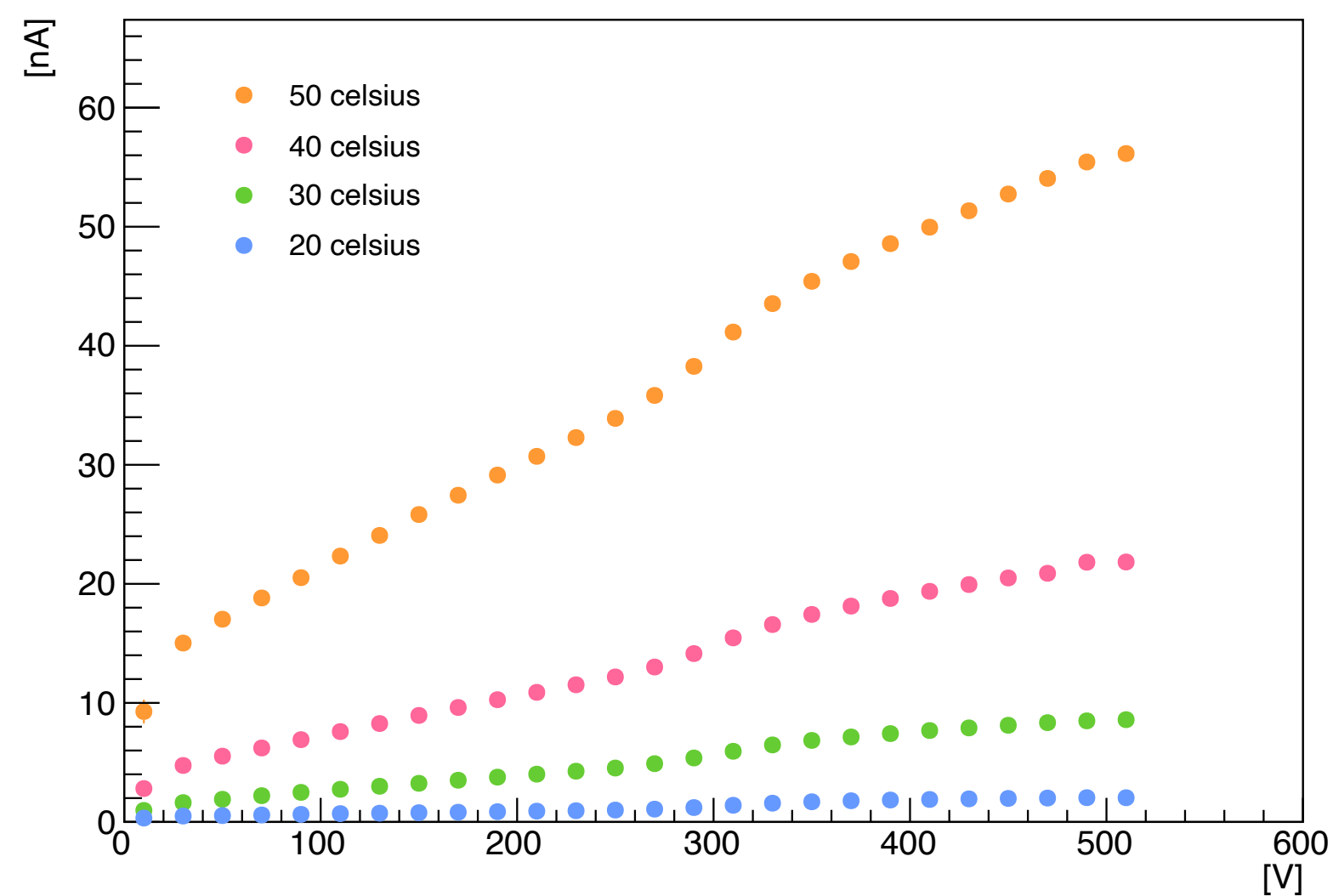
I-V 28_6



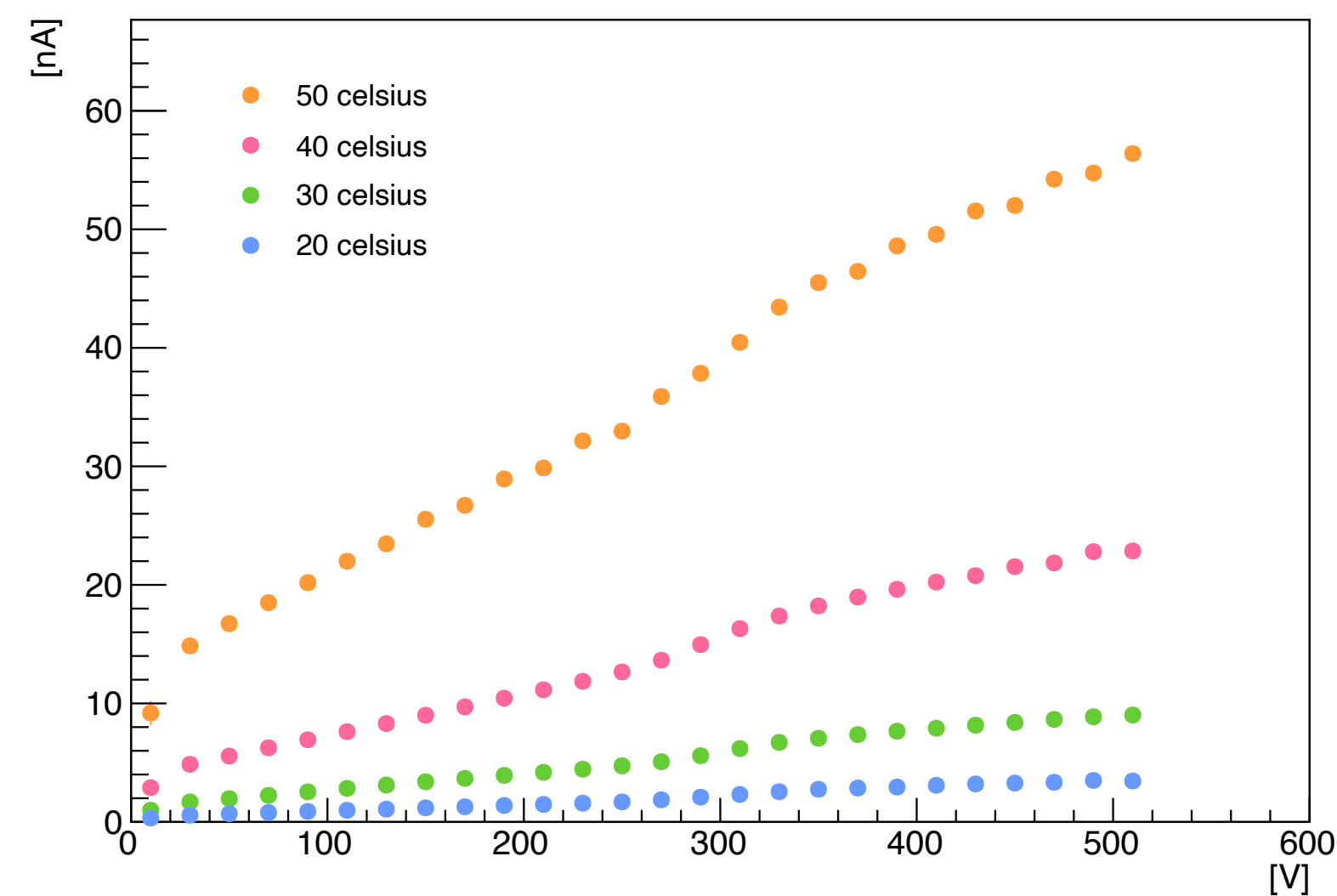
測定結果-温度依存

14T1, 14T2 (1cm× 1cm)

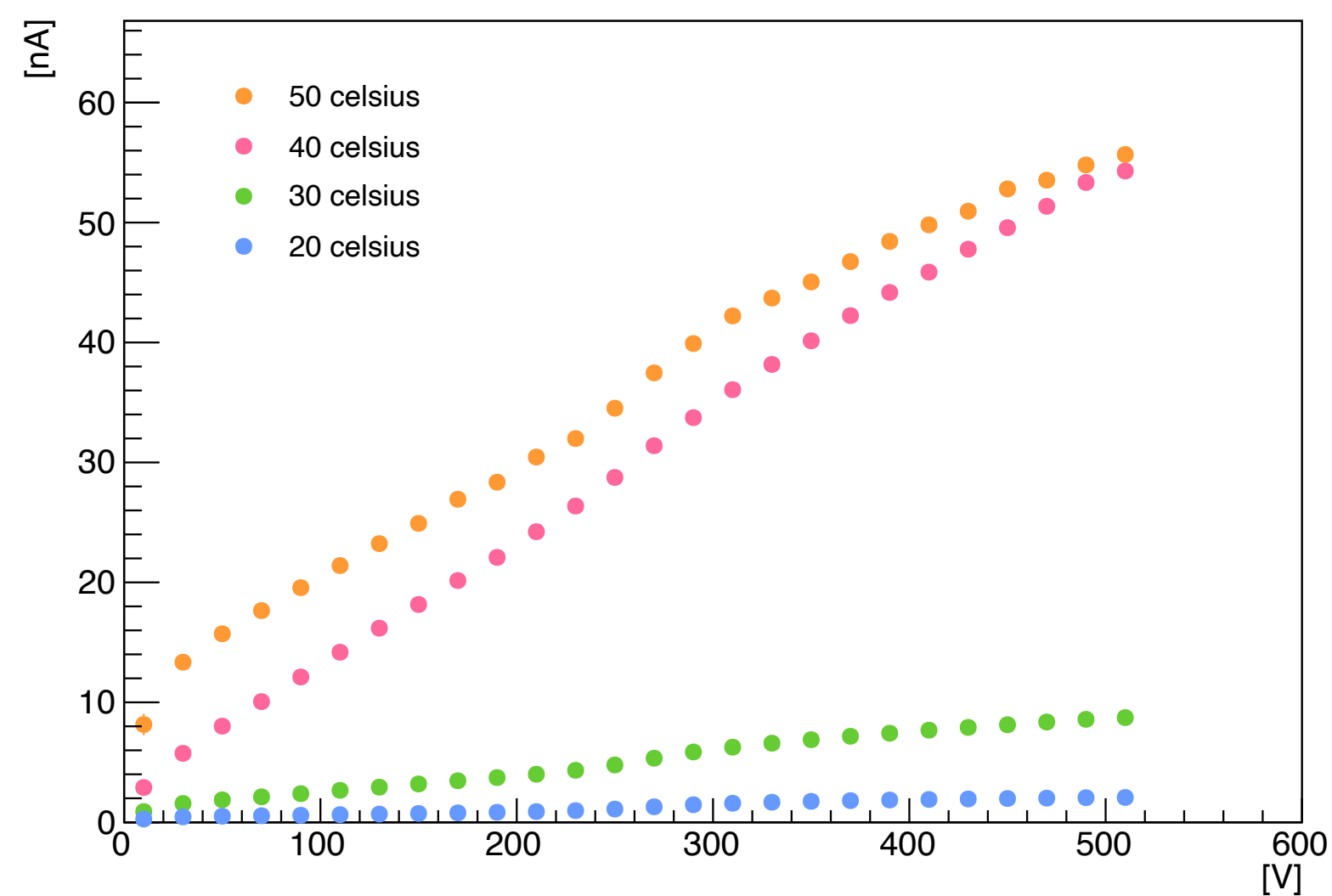
I-V 14T1_1



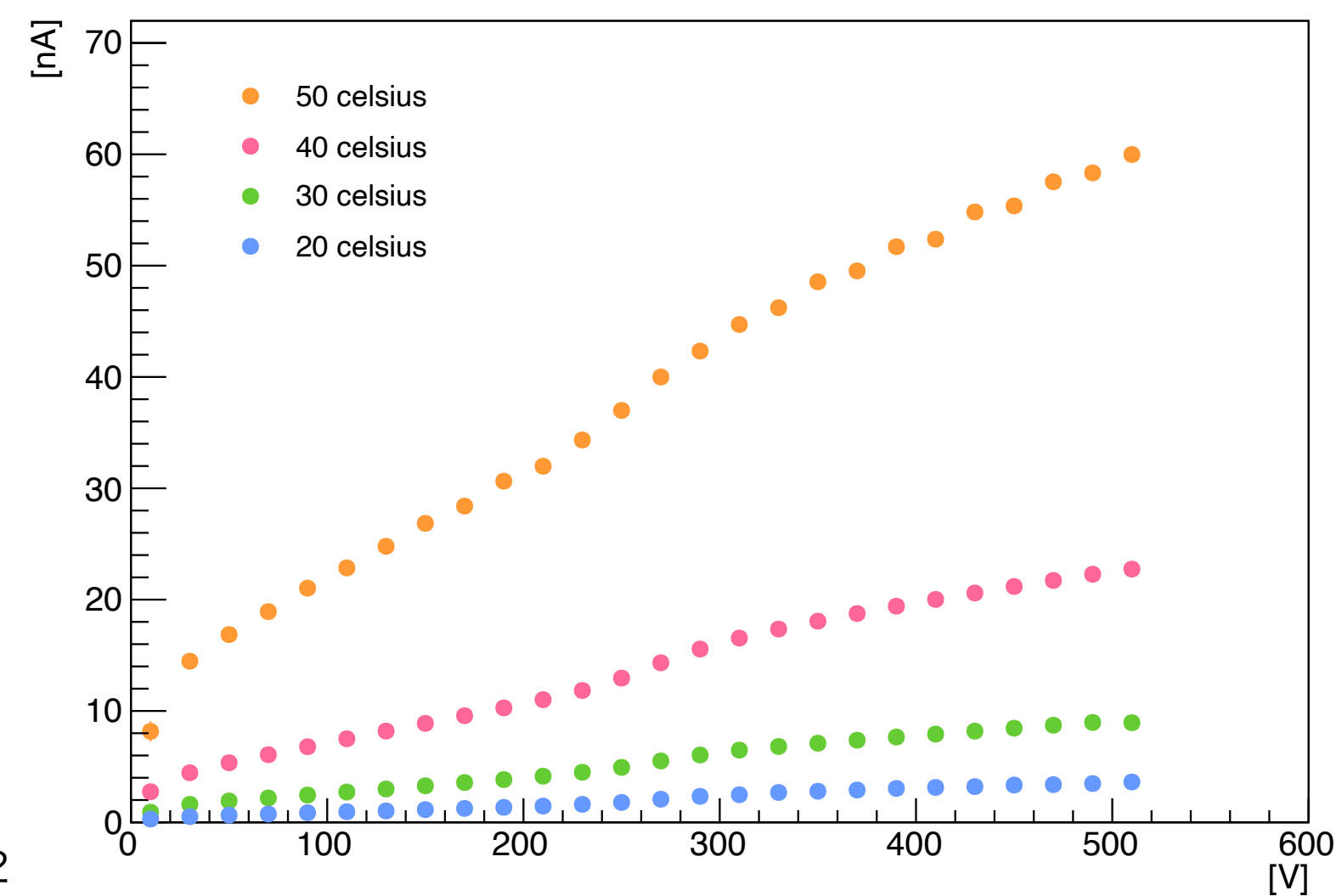
I-V 14T2_1



I-V 14T1_2



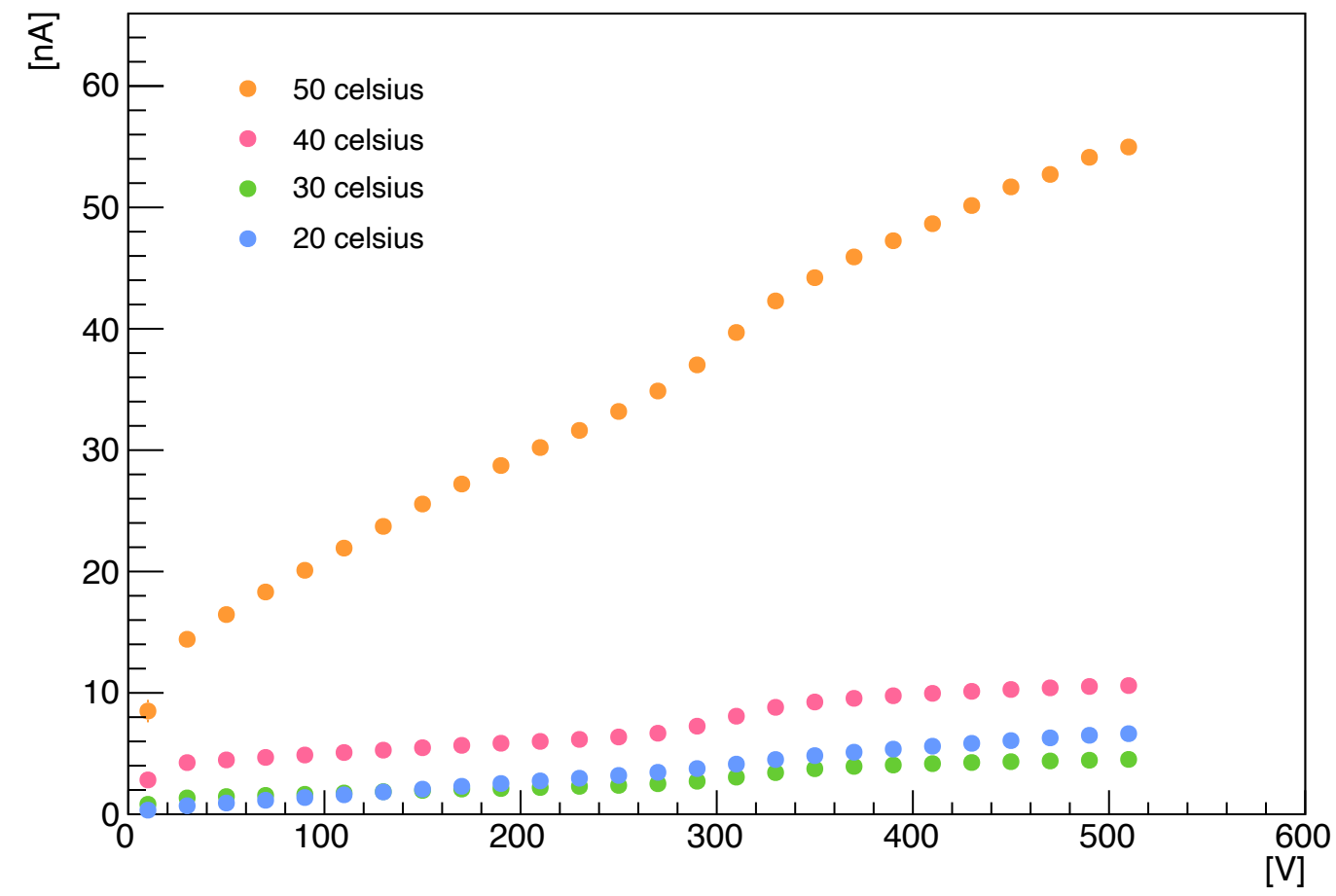
I-V 14T2_2



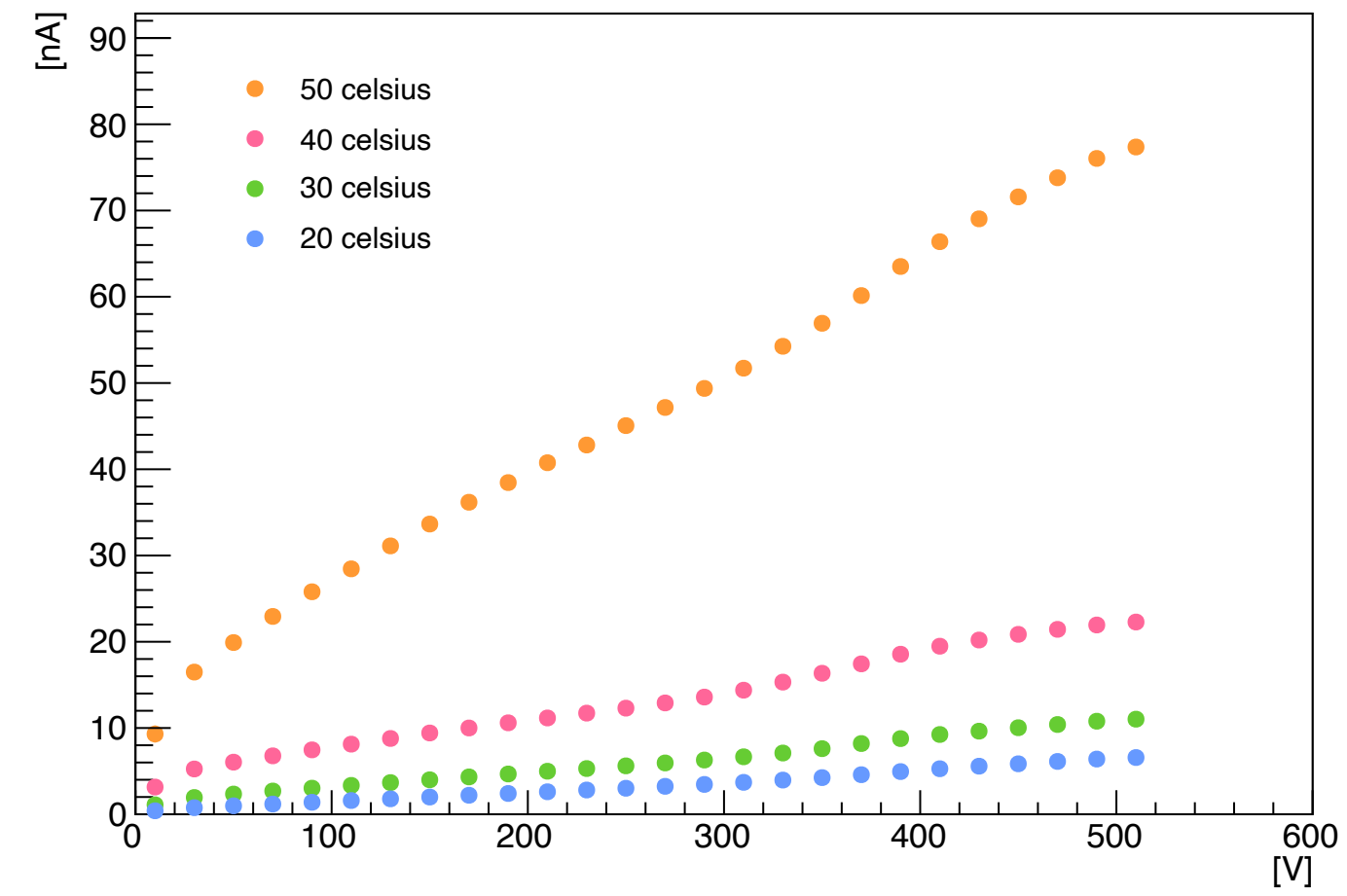
測定結果-温度依存

19B1, 19R1, 19R2 (1cm× 1cm)

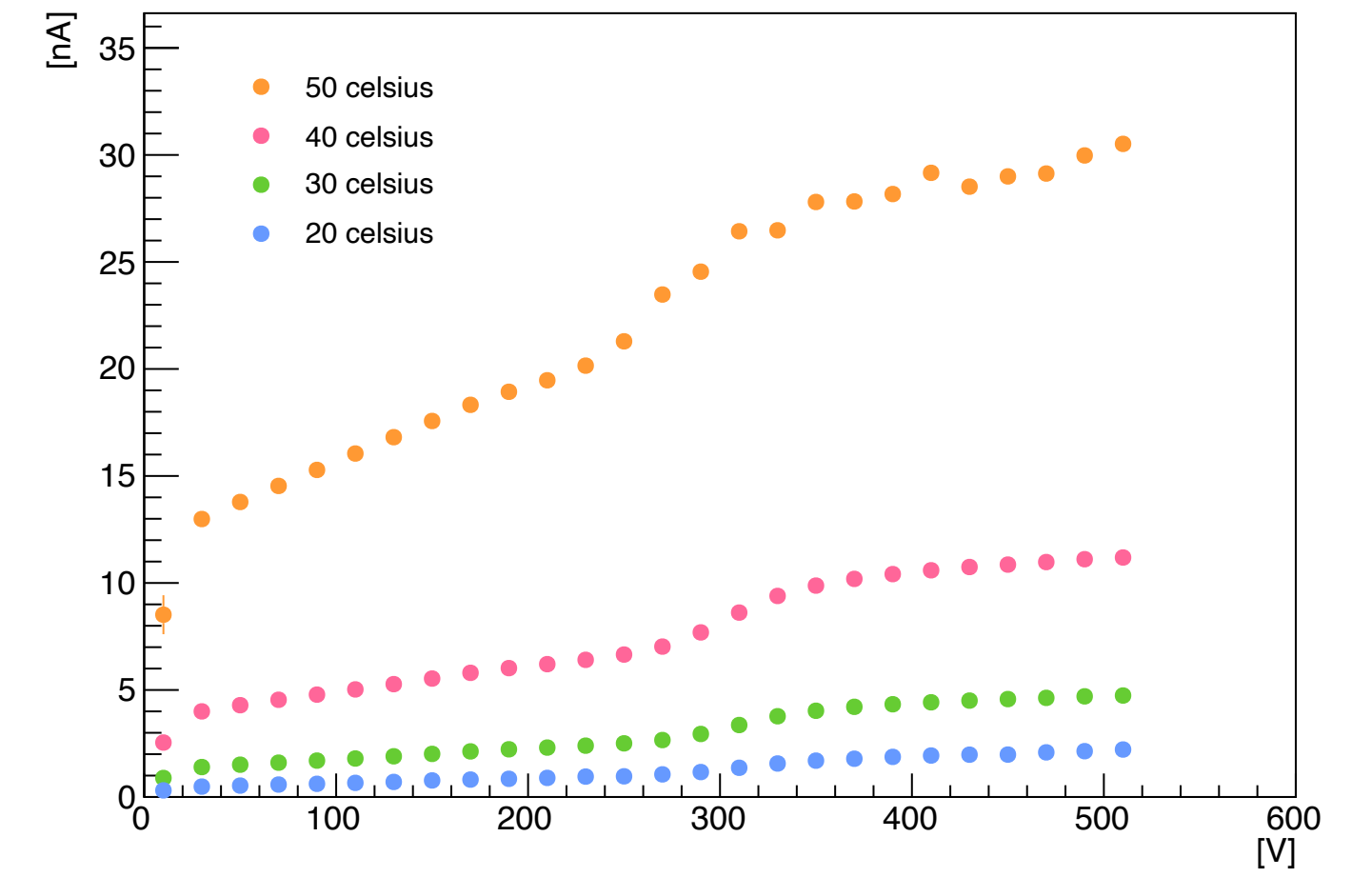
I-V 19B1_1



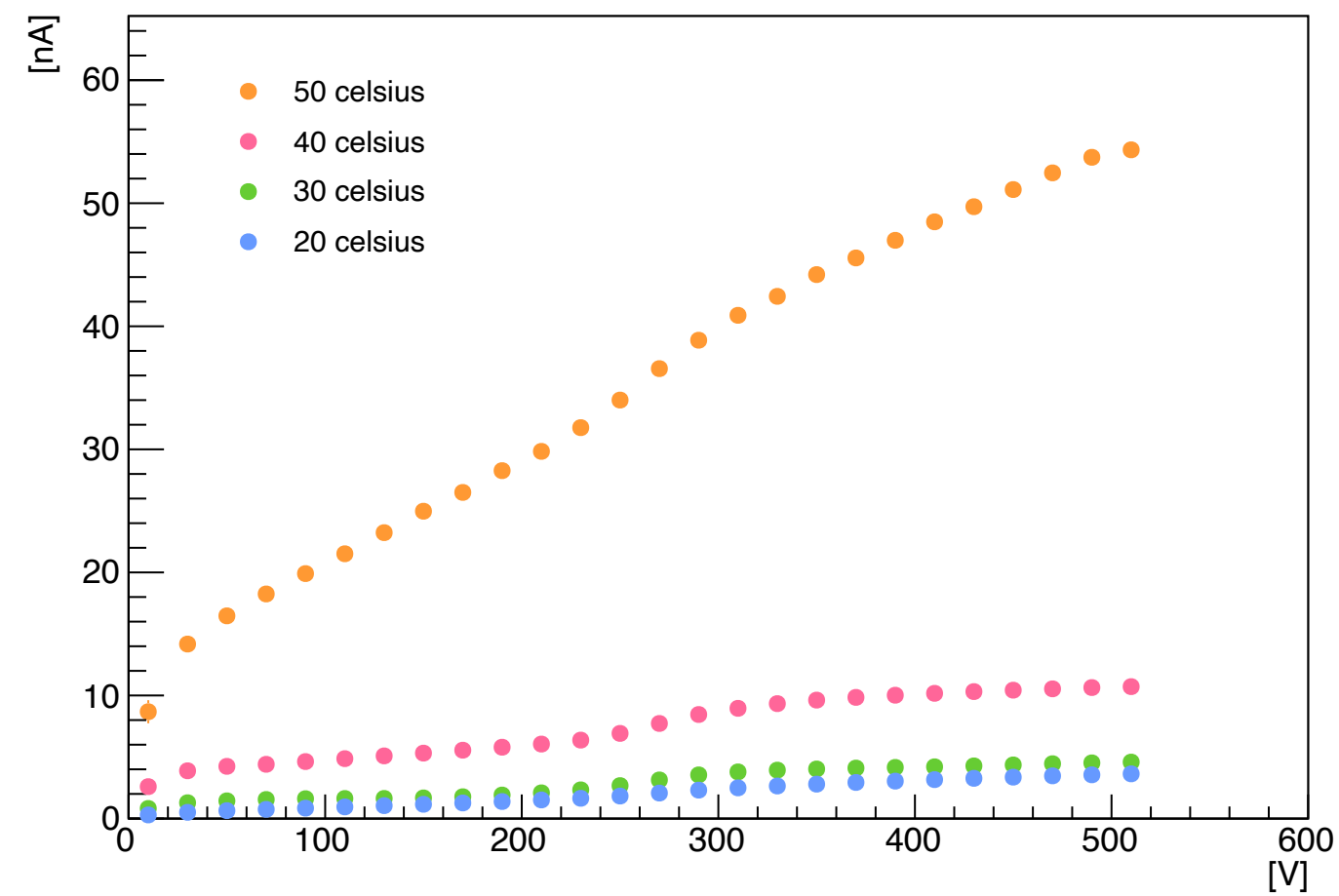
I-V 19R1_1



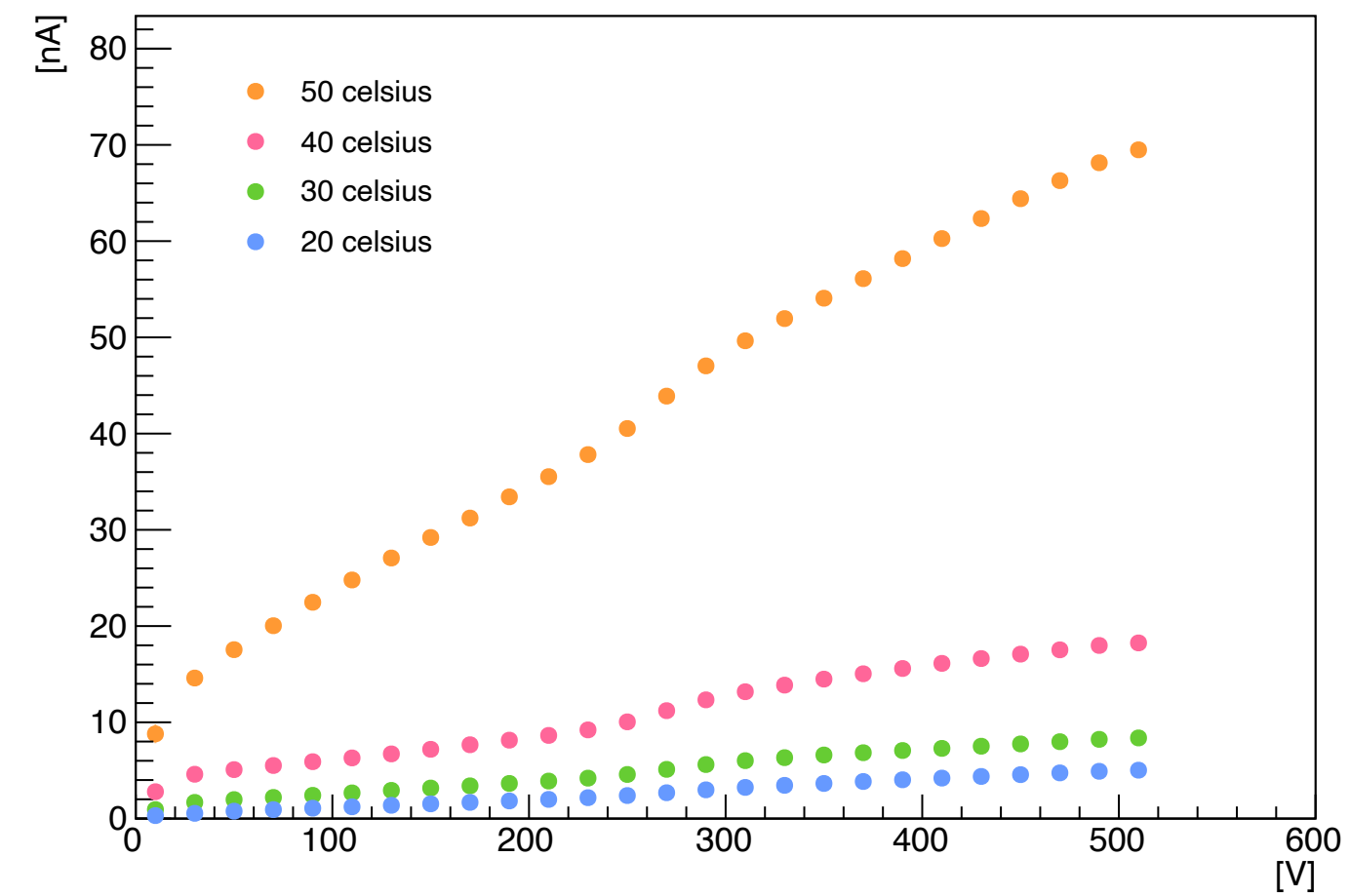
I-V 19R2_1



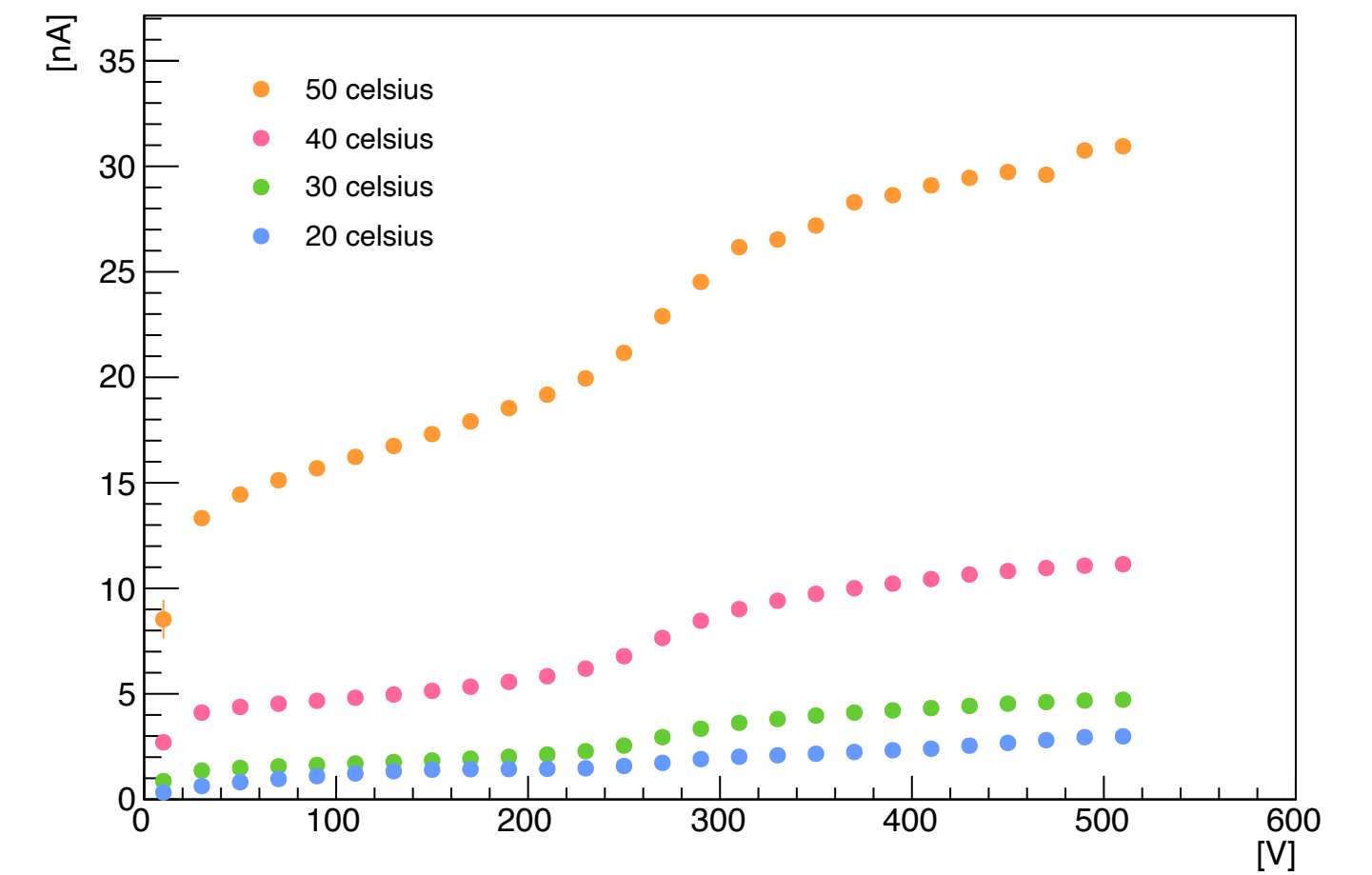
I-V 19B1_2



I-V 19R1_2



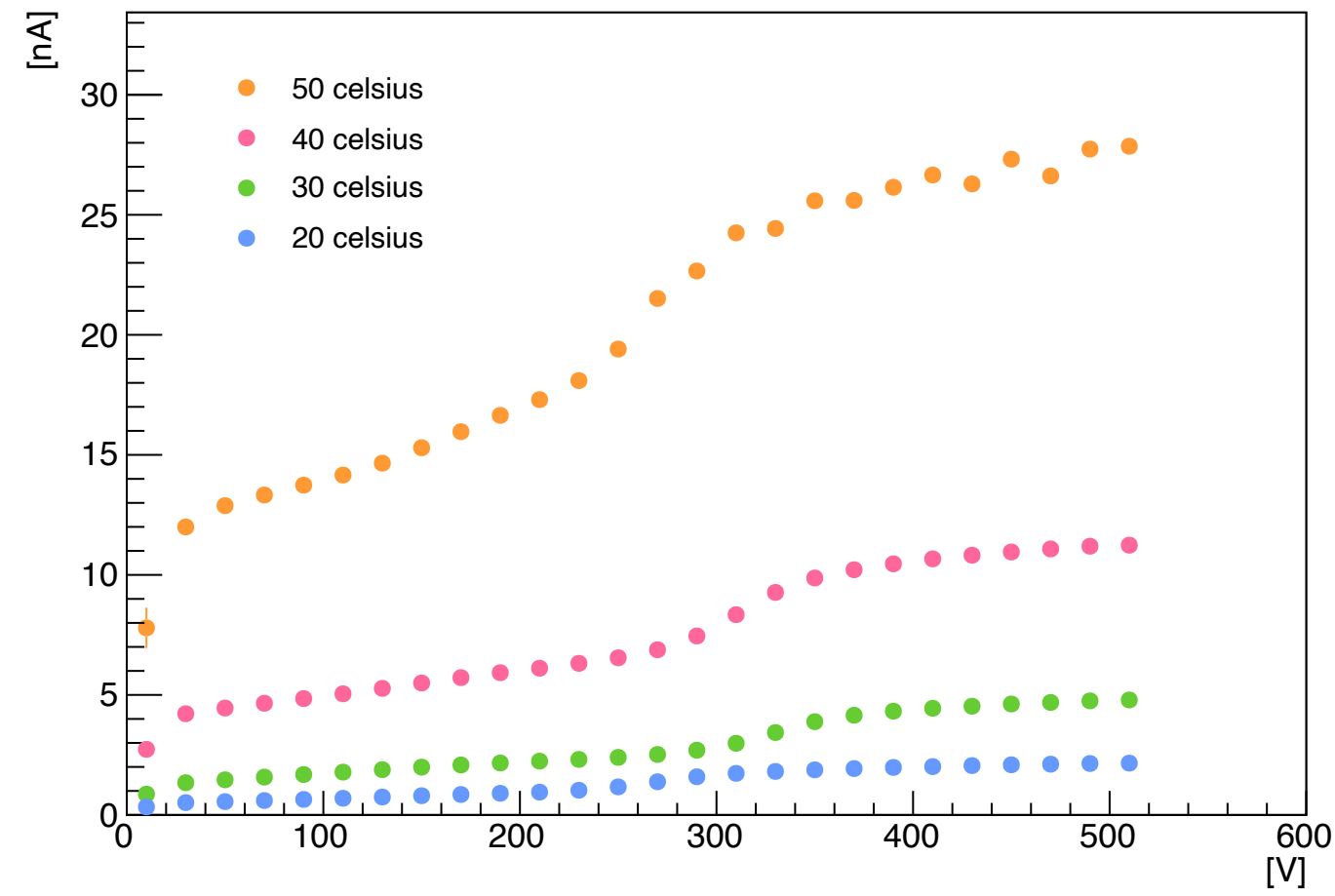
I-V 19R2_2



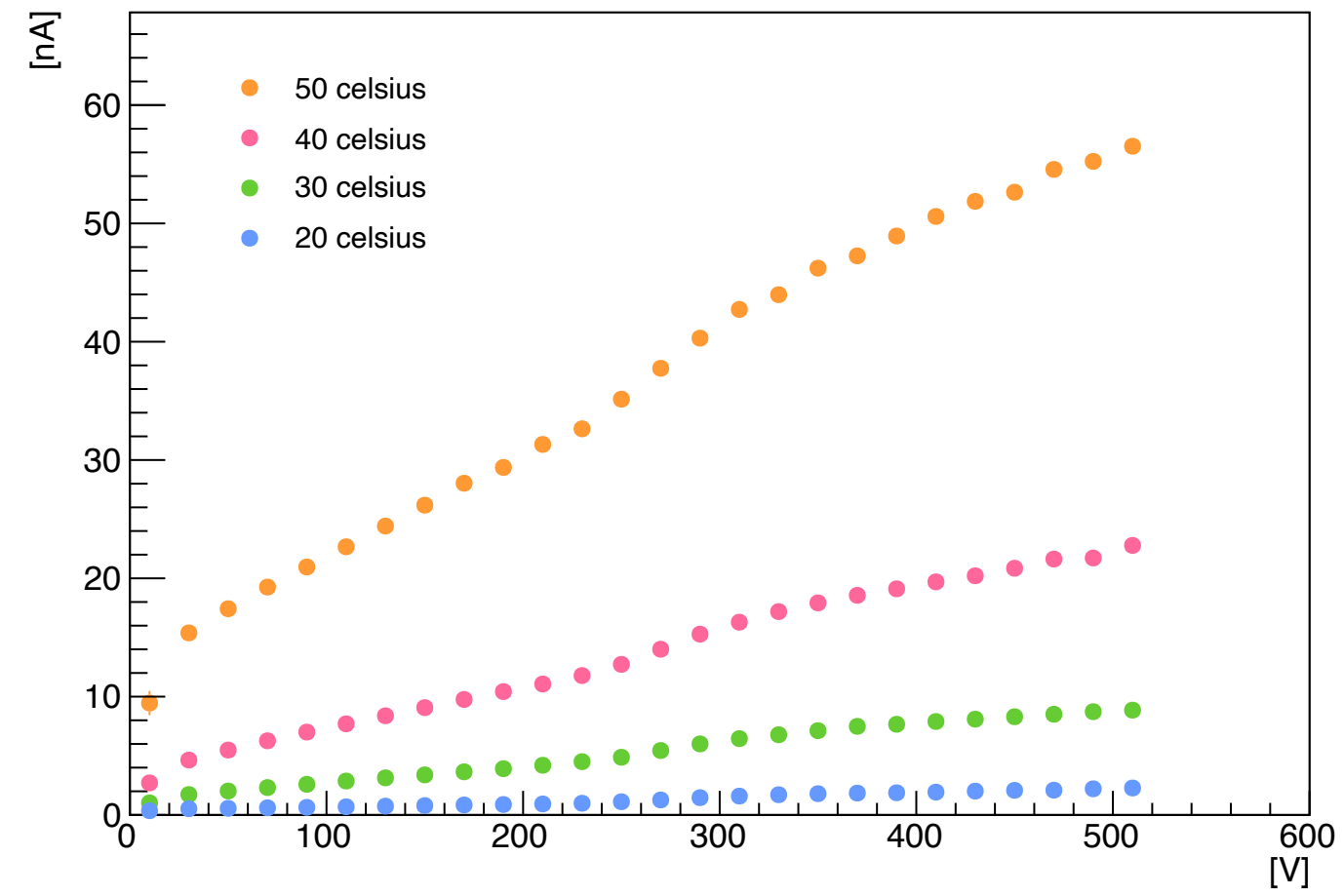
測定結果-温度依存

28T1, 28L2, 28B1 (1cm× 1cm)

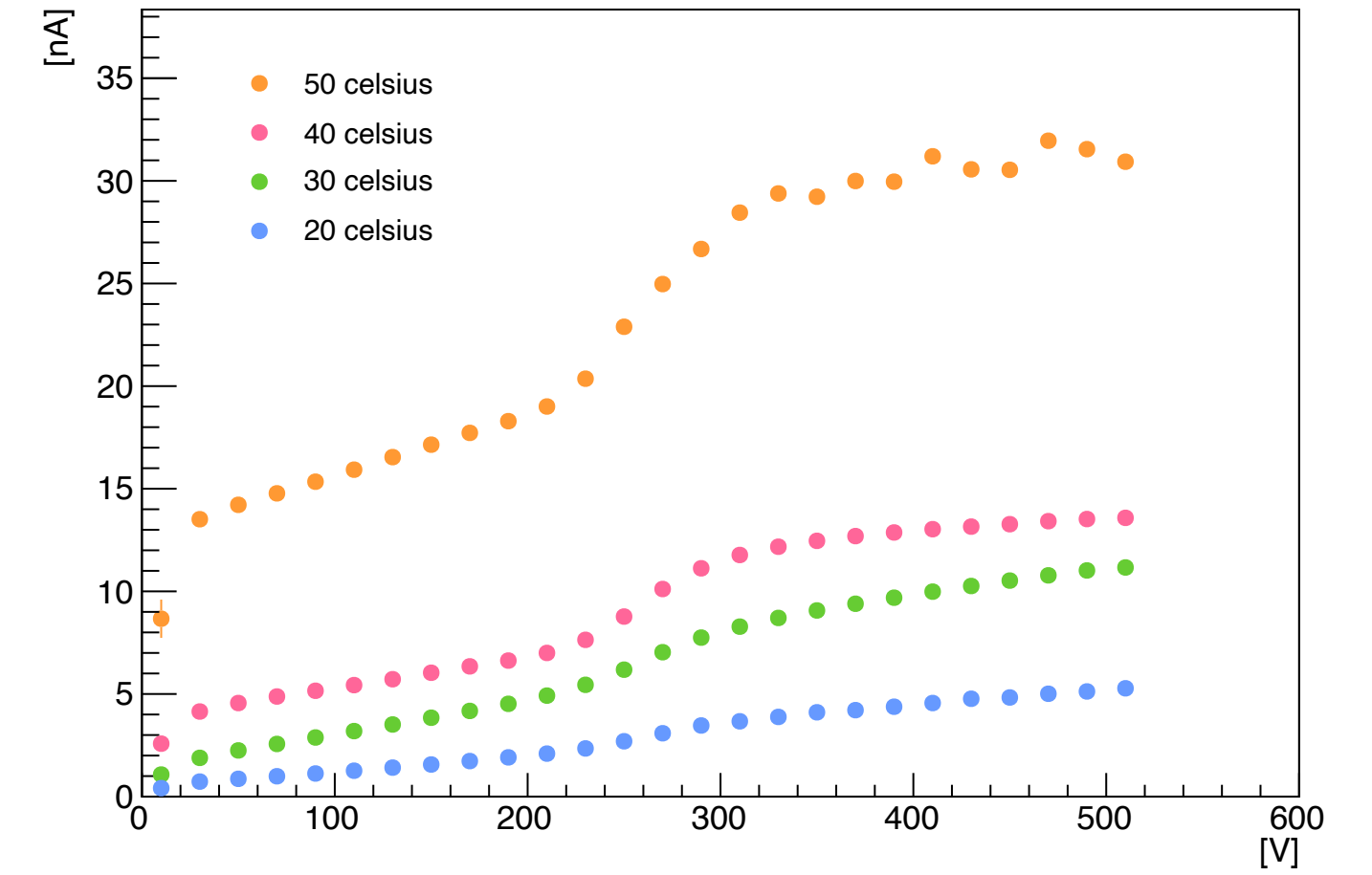
I-V 28T1_1



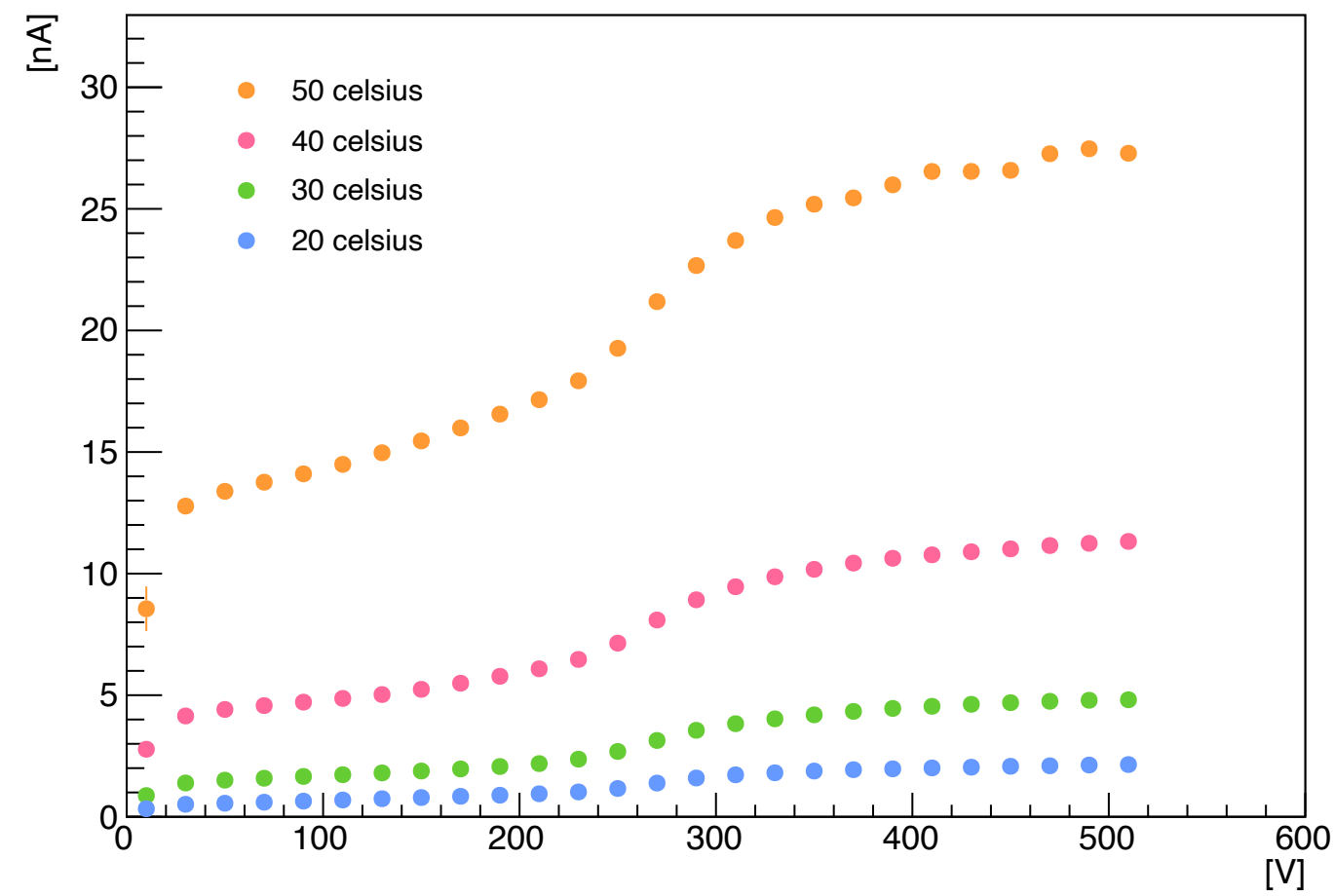
I-V 28L2_1



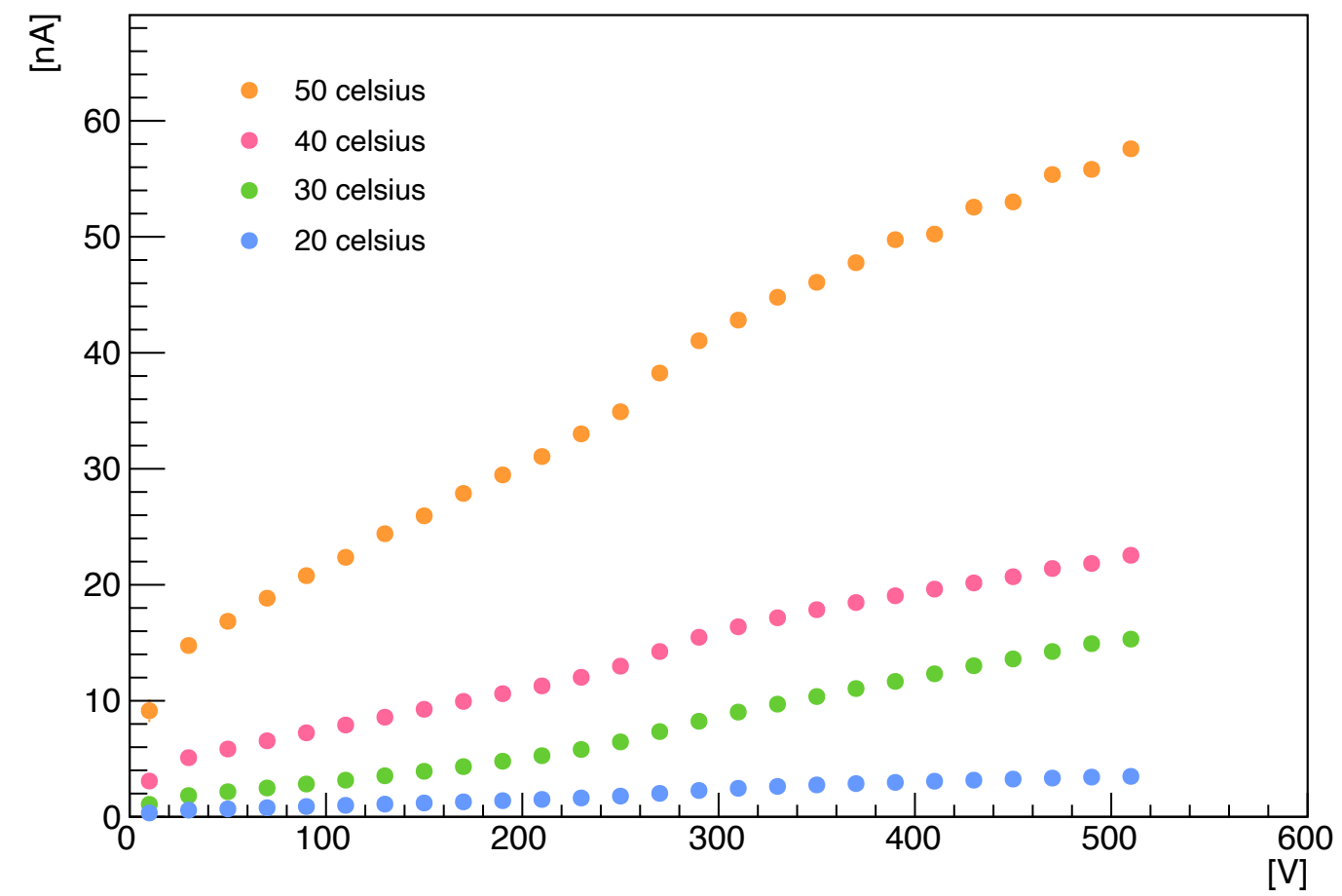
I-V 28B1_1



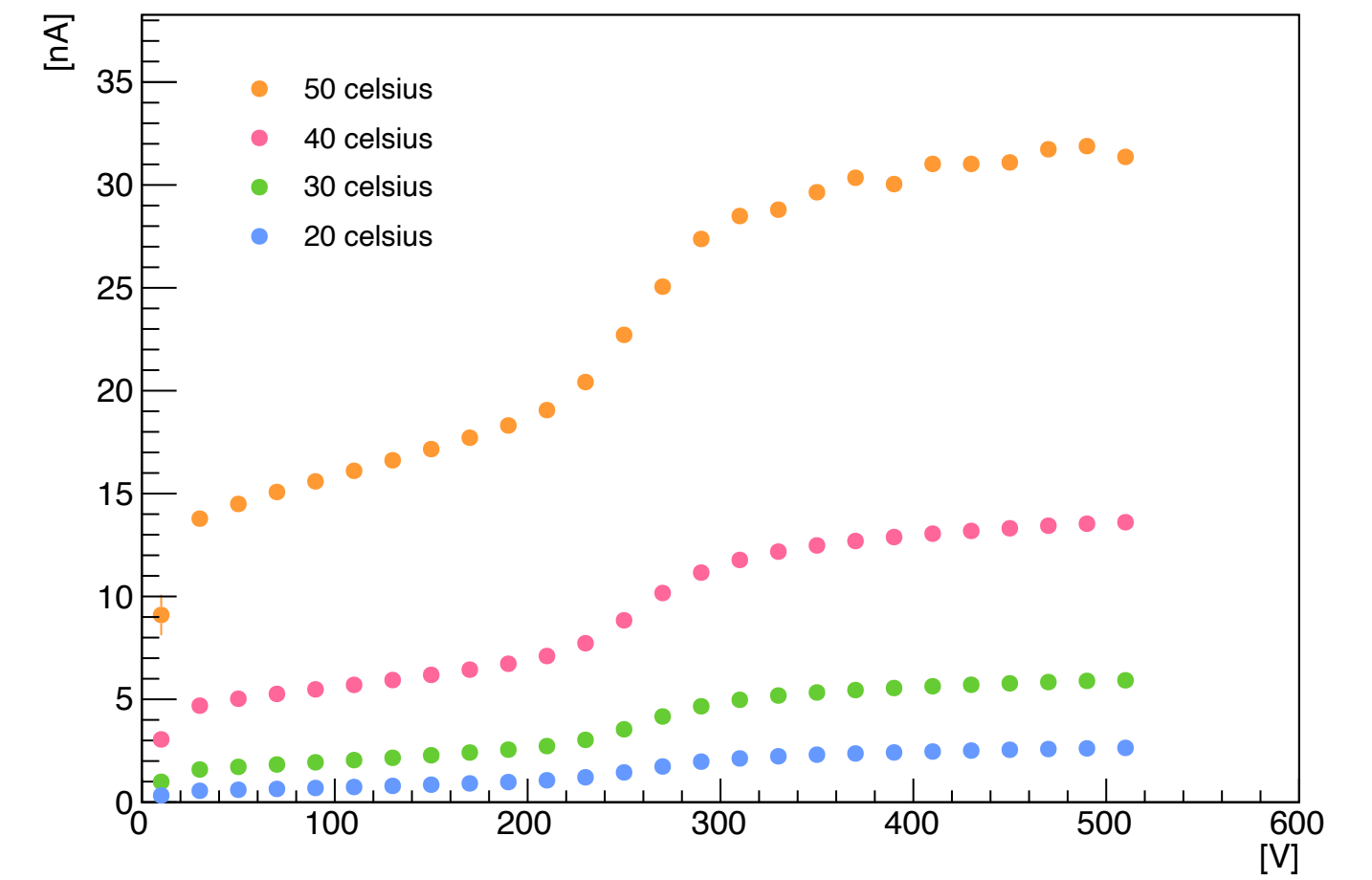
I-V 28T1_2



I-V 28L2_2



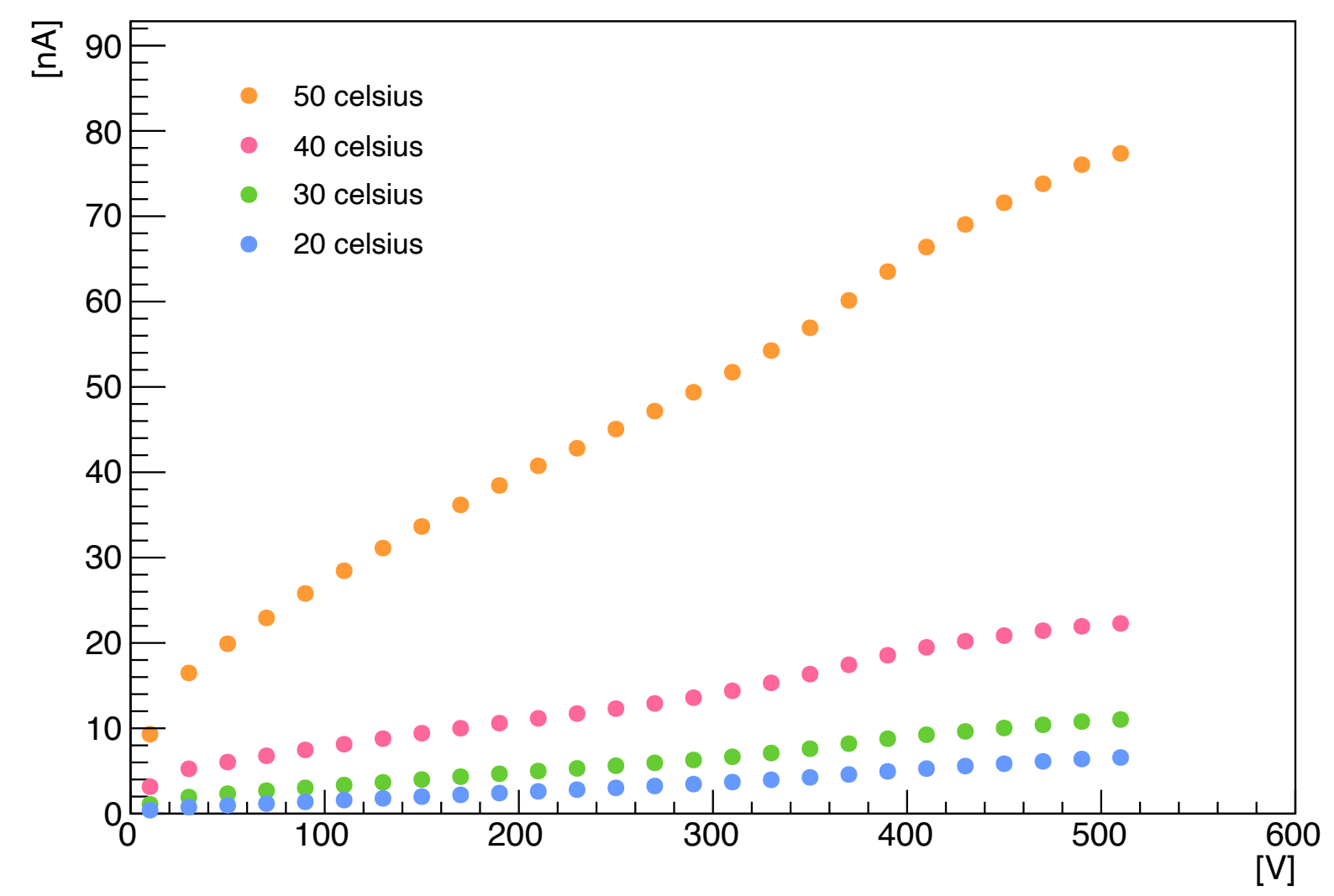
I-V 28B1_2



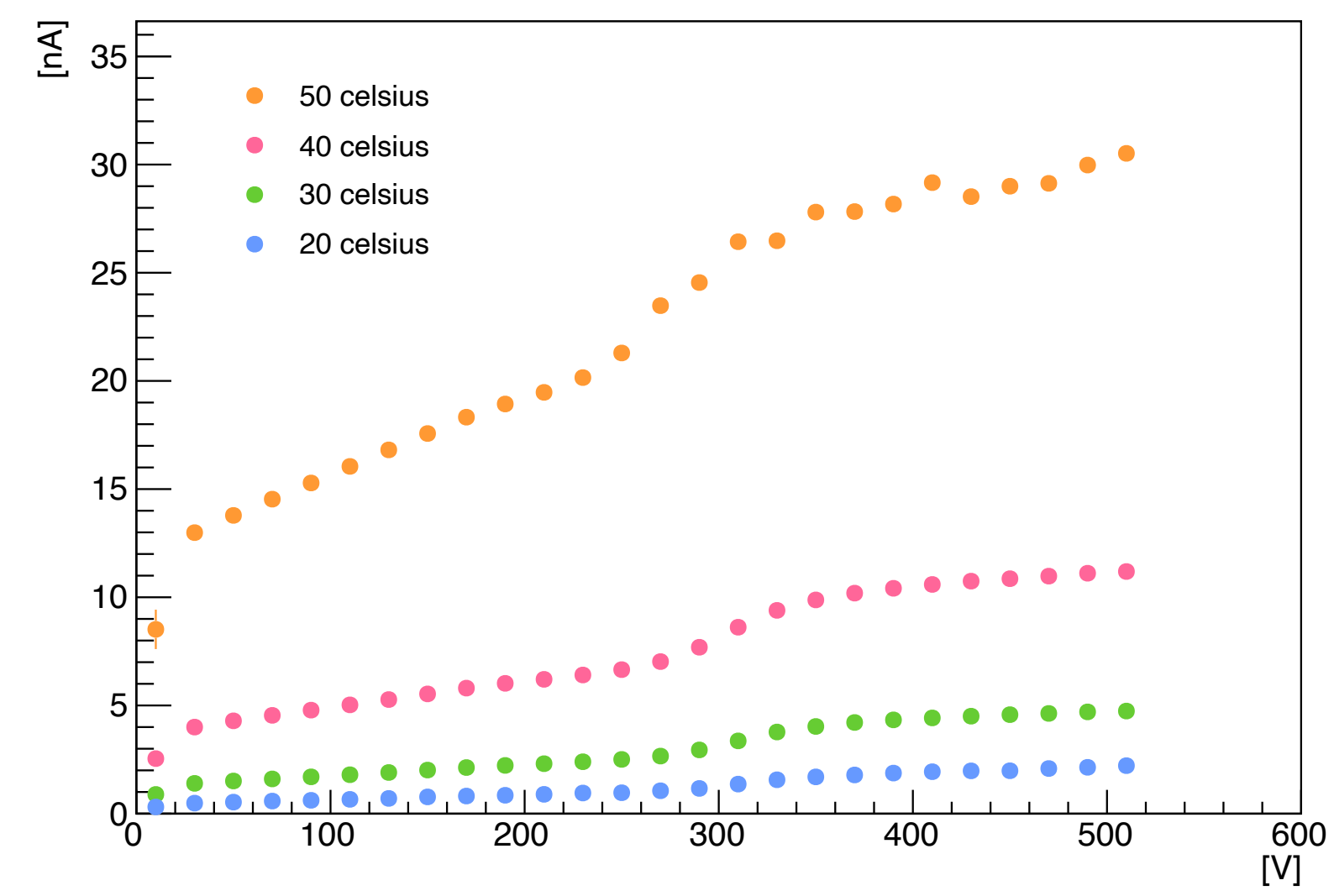
測定結果-温度依存

28R1, 28R2 (1cm× 1cm)

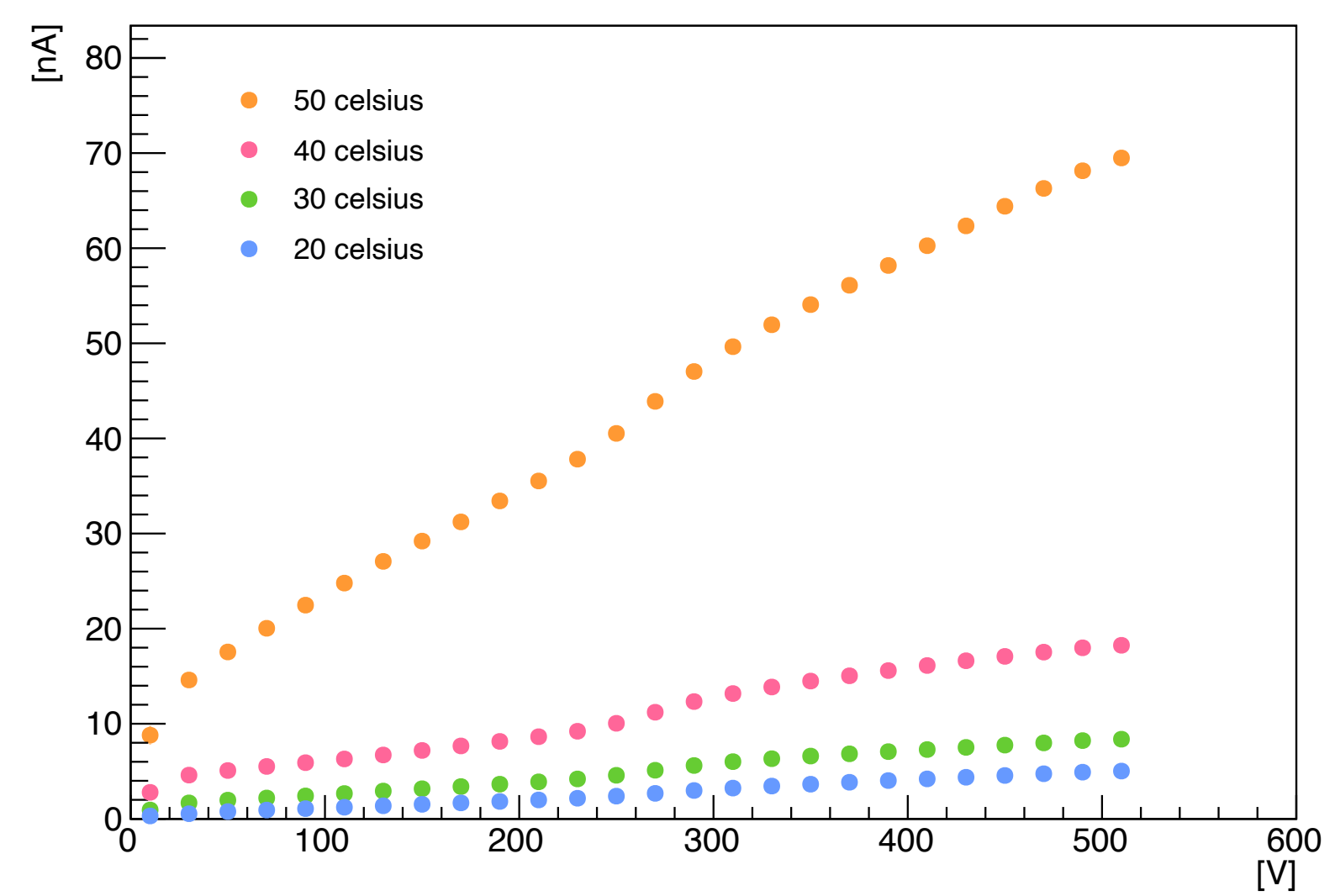
I-V 28R1_1



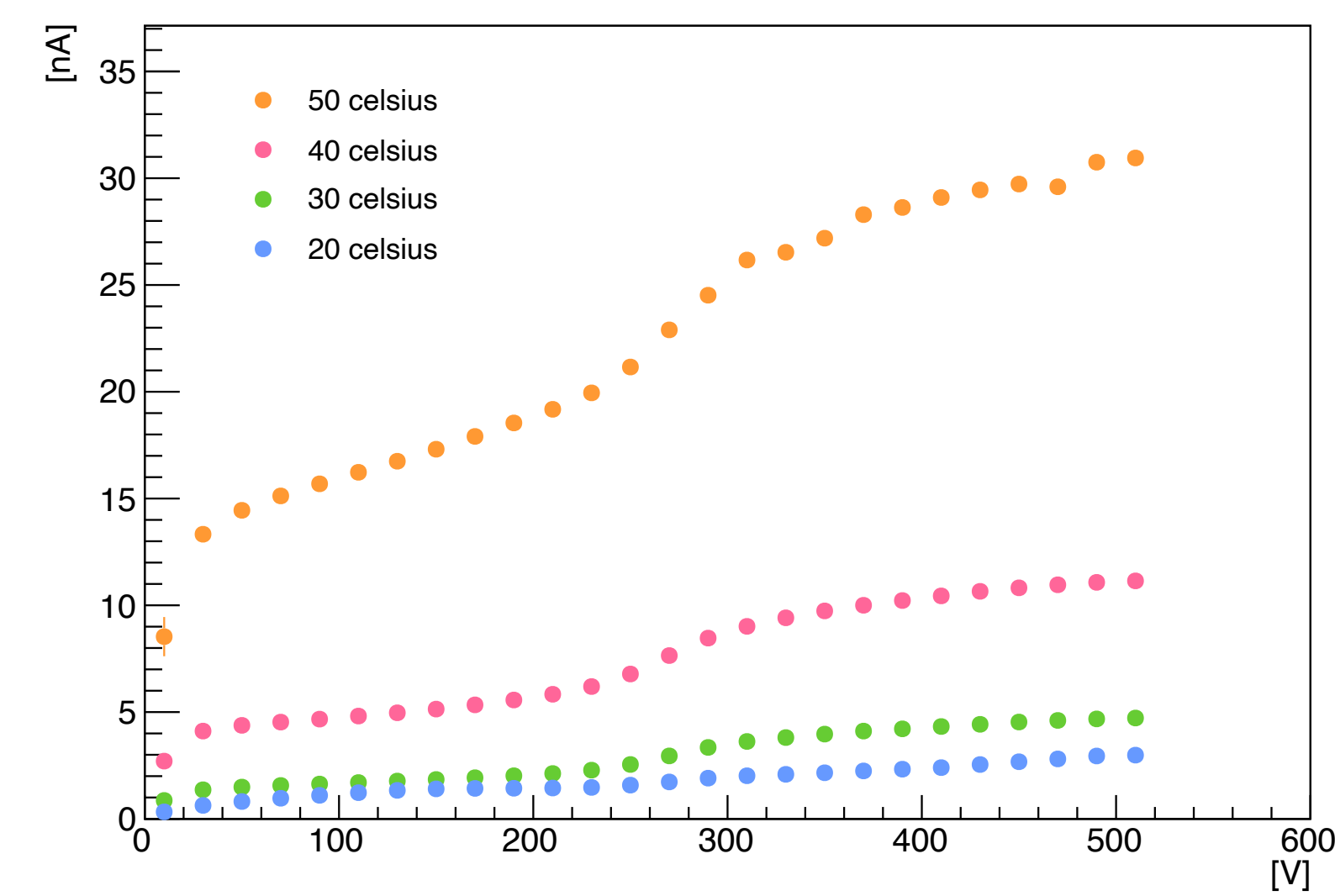
I-V 28R2_1



I-V 28R1_2

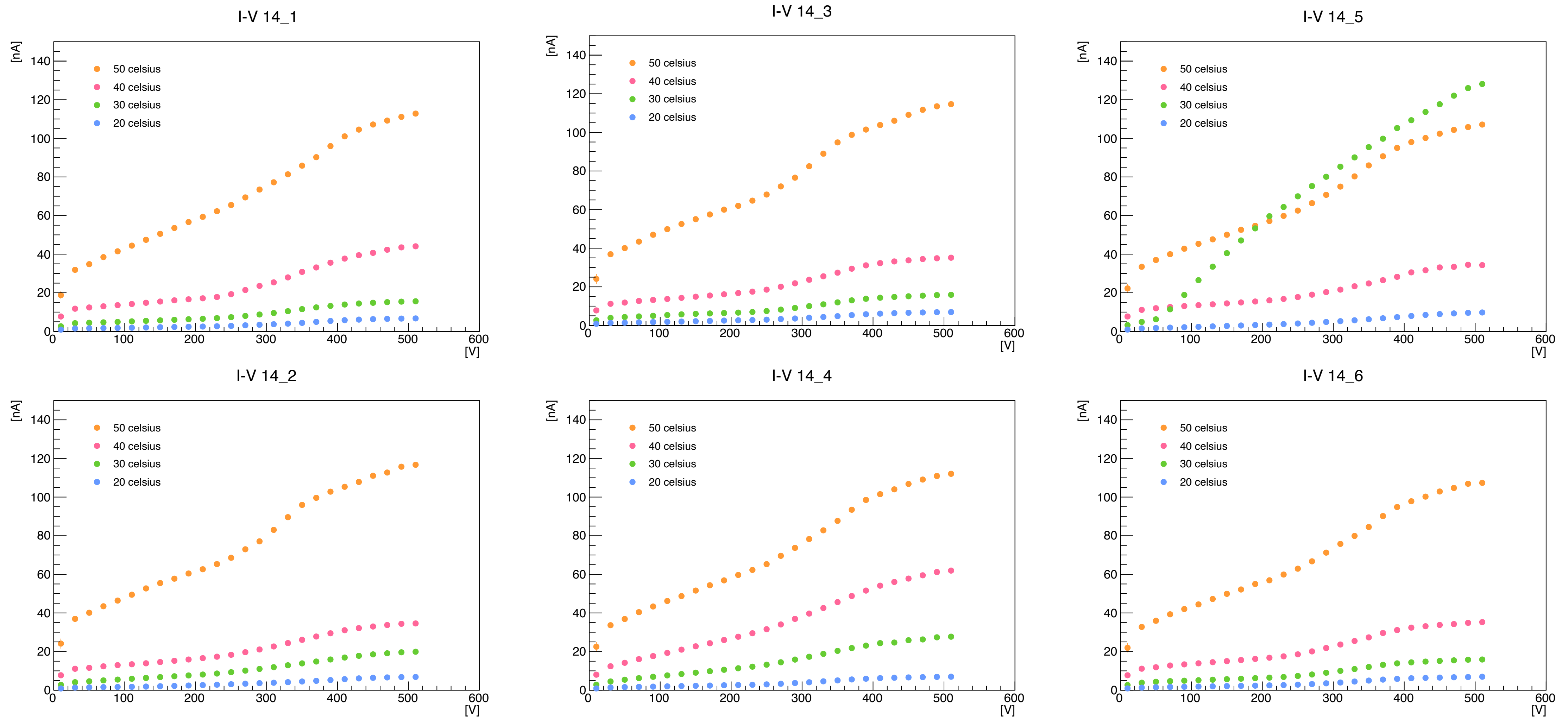


I-V 28R2_2



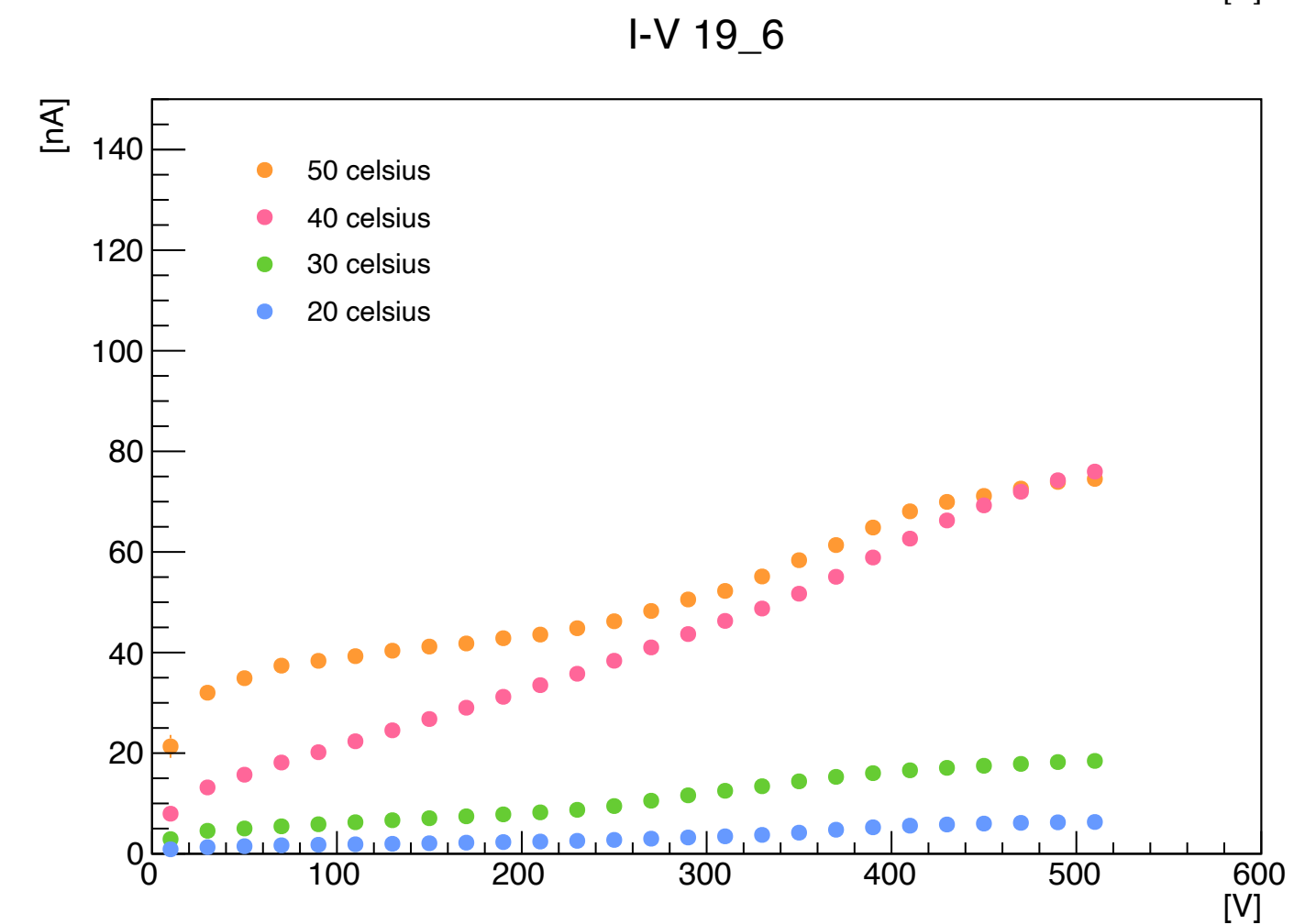
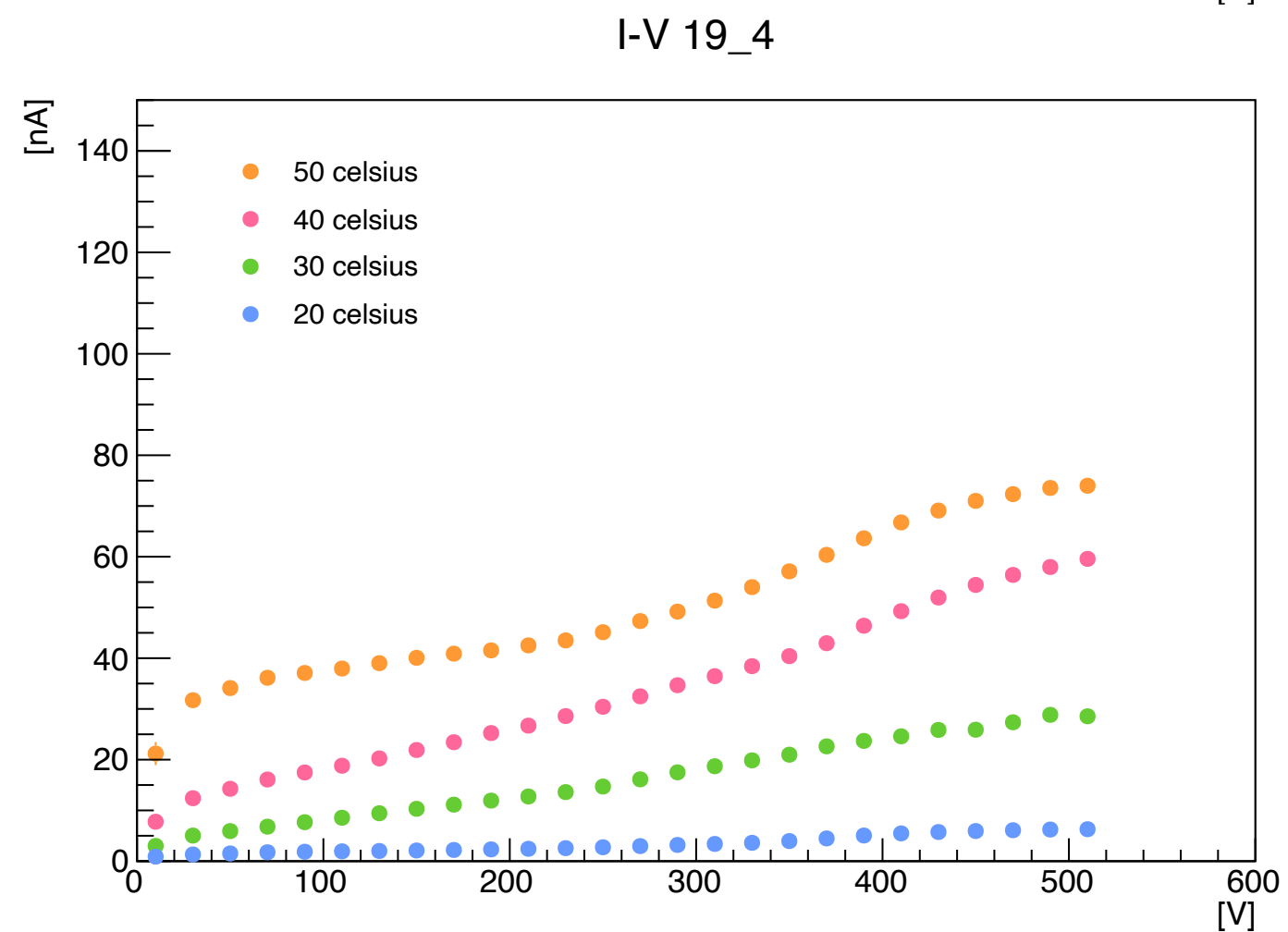
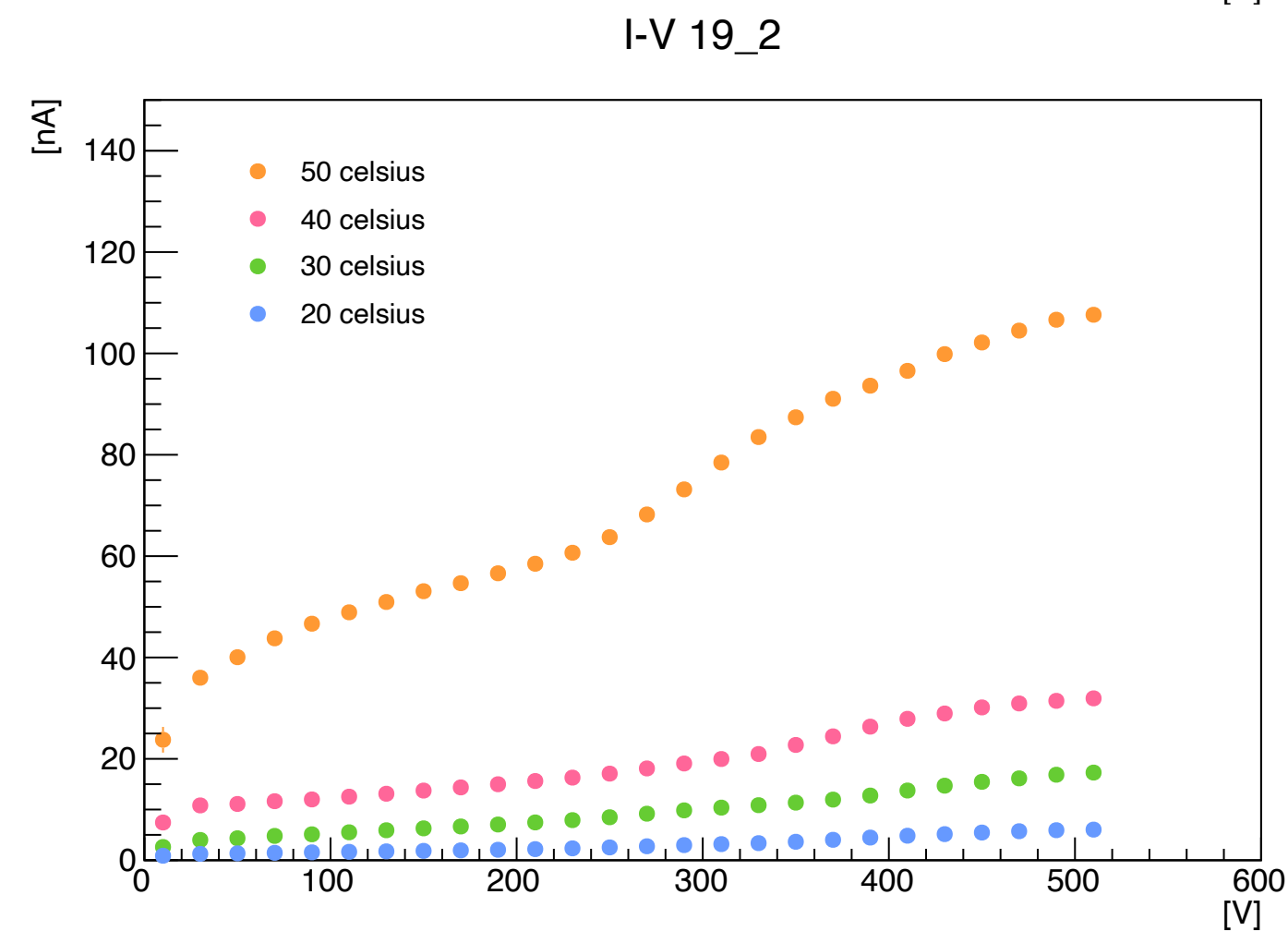
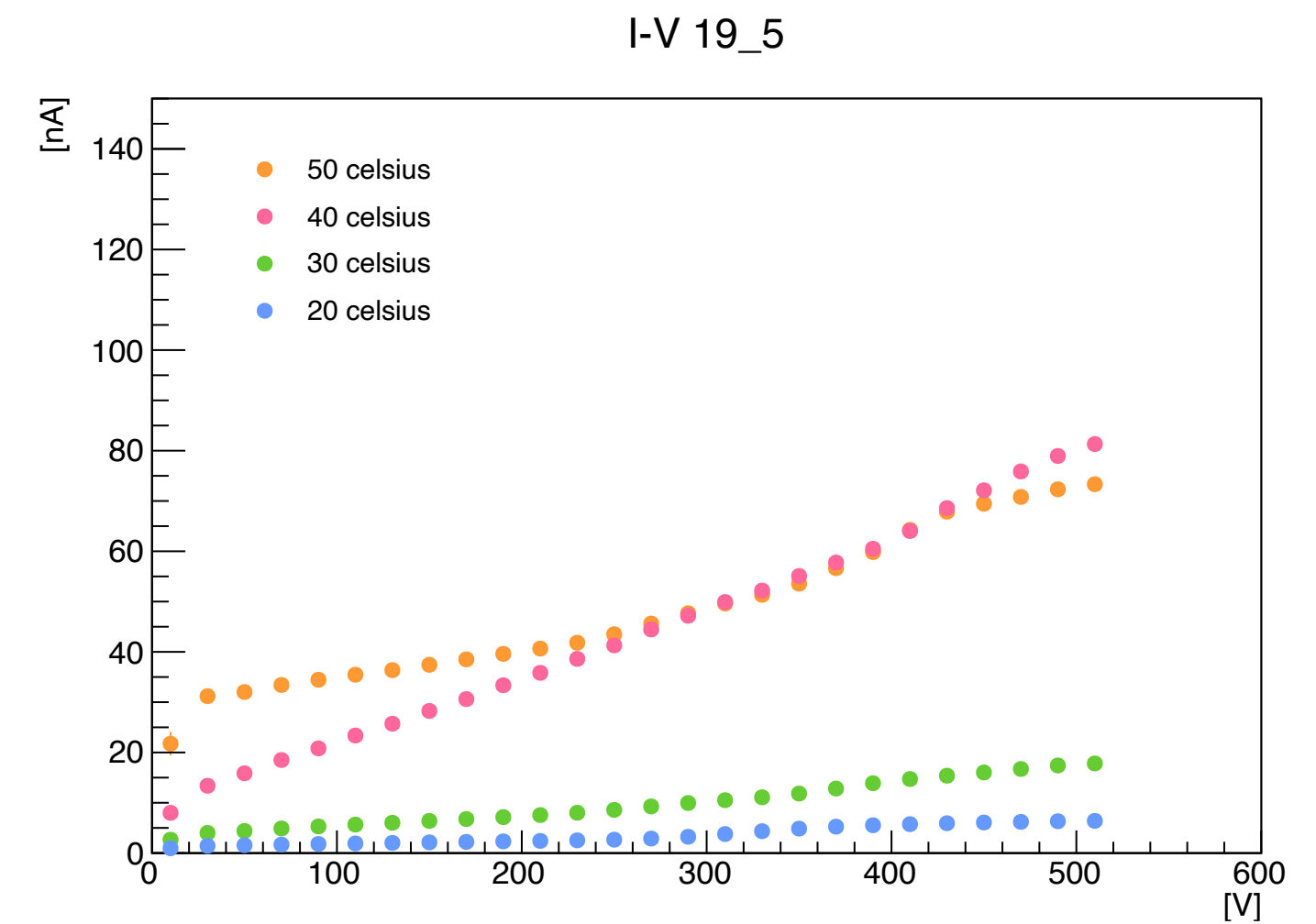
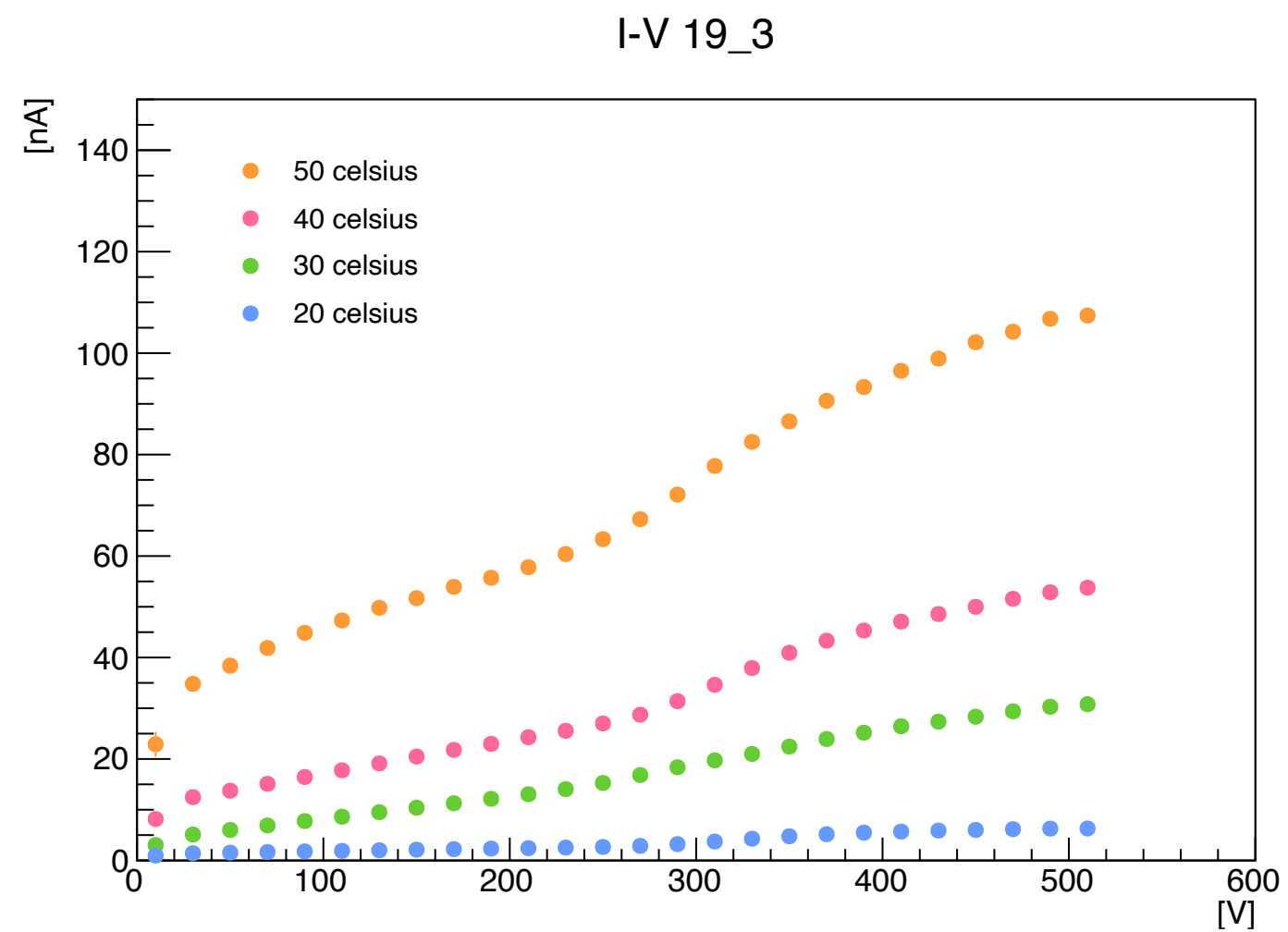
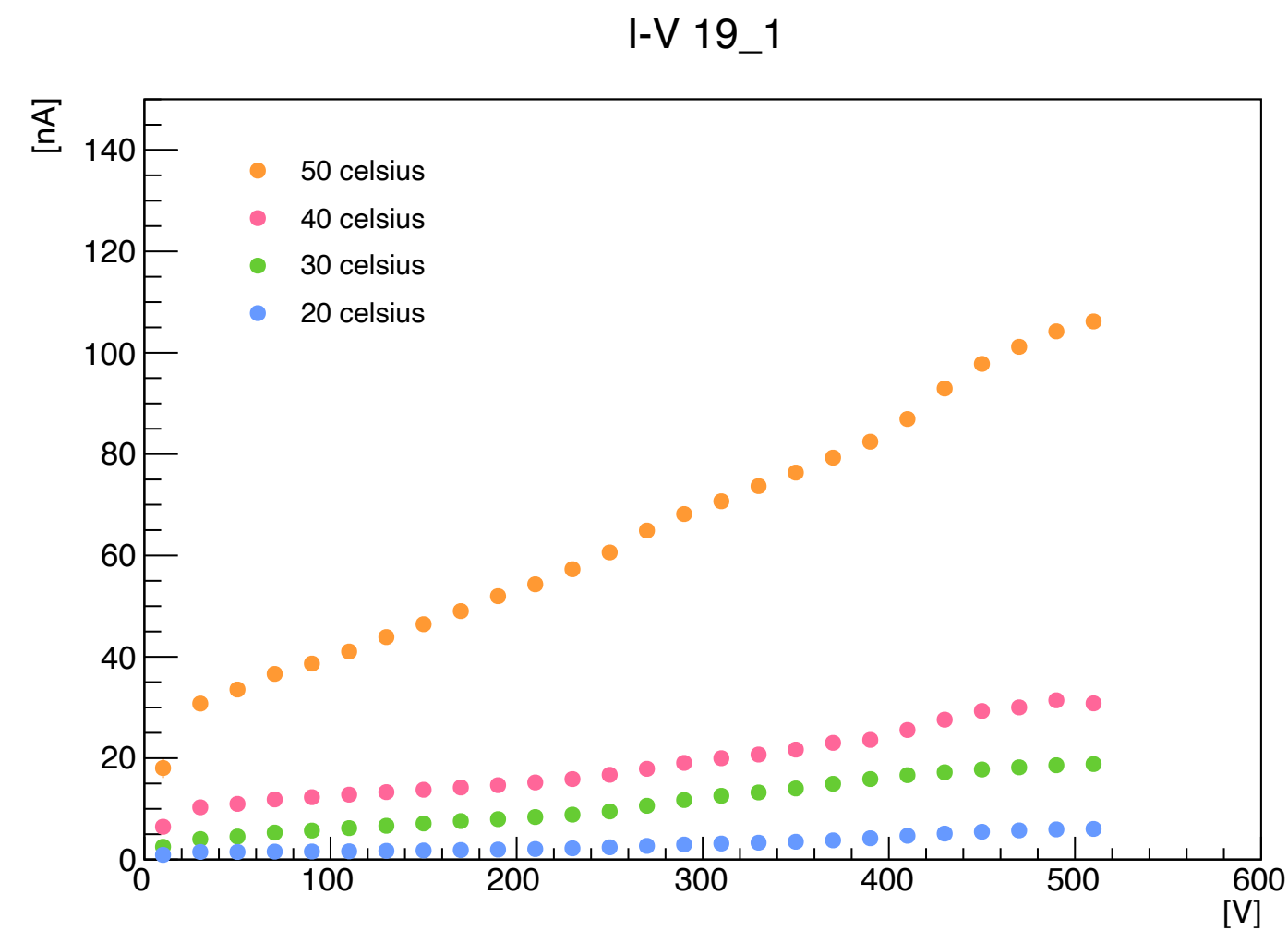
測定結果-温度依存(軸を揃えたもの)

14 (2cm x 2cm)



測定結果-温度依存(軸を揃えたもの)

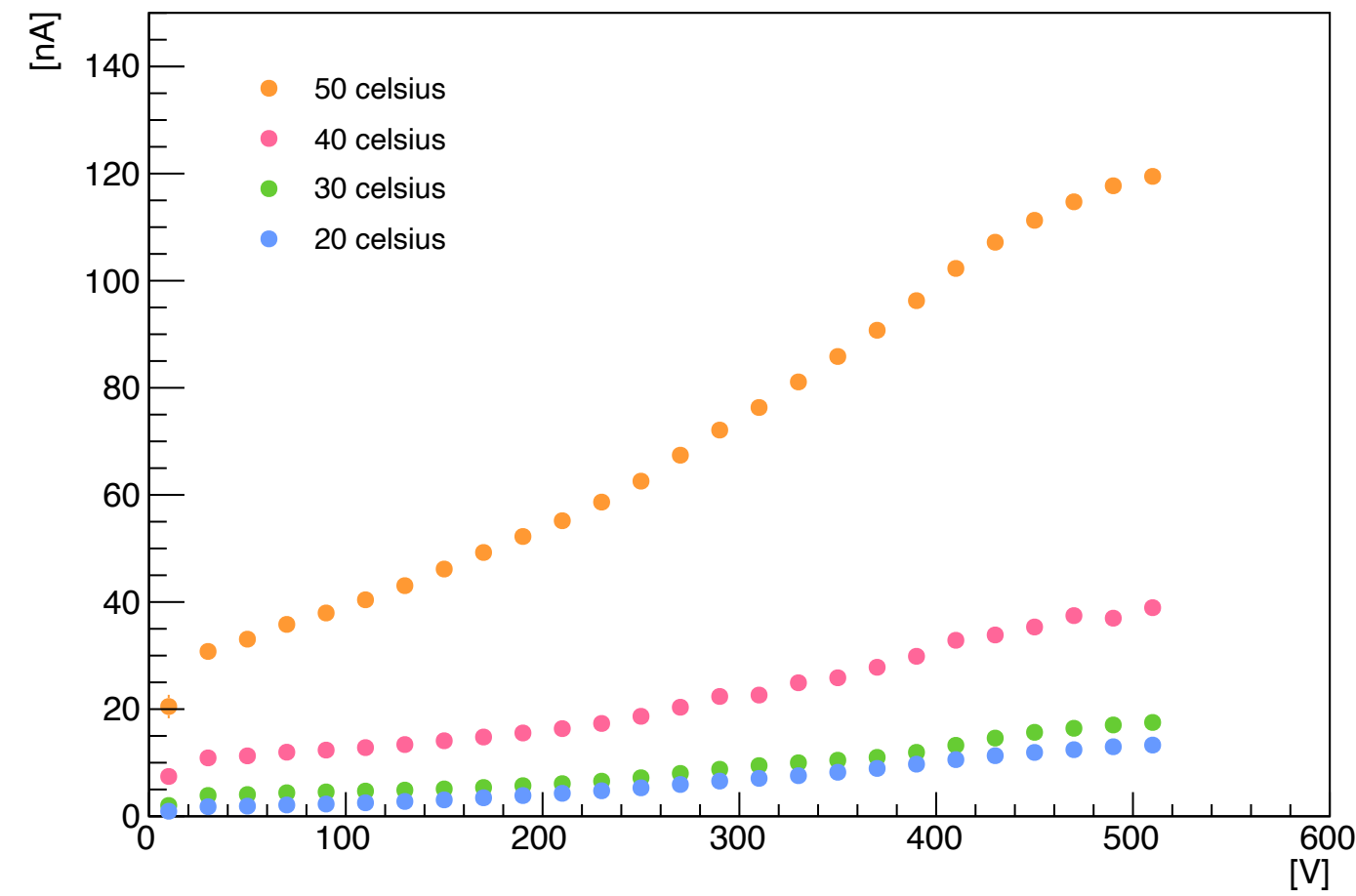
19 (2cm× 2cm)



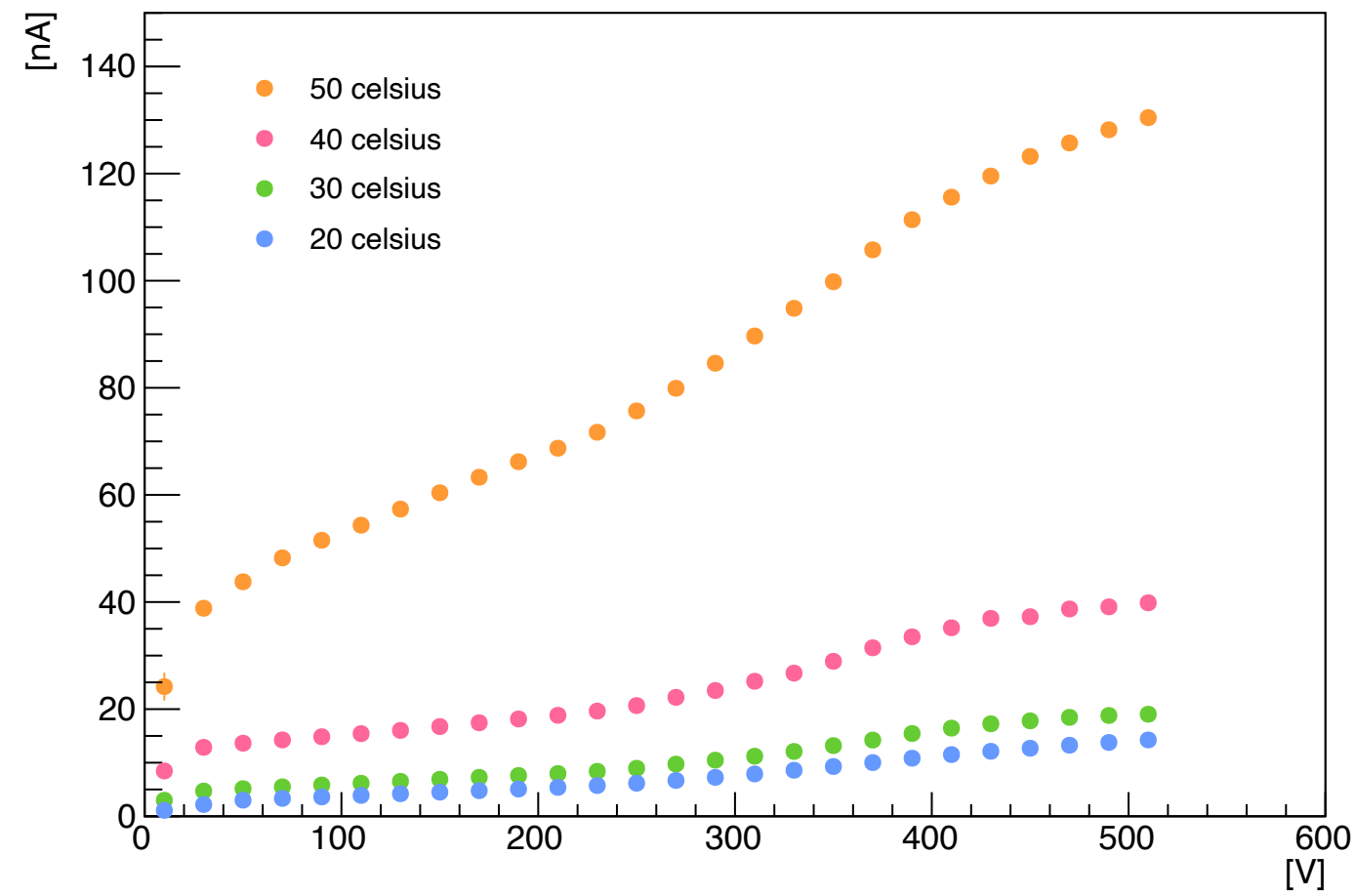
測定結果-温度依存(軸を揃えたもの)

28 (2cm× 2cm)

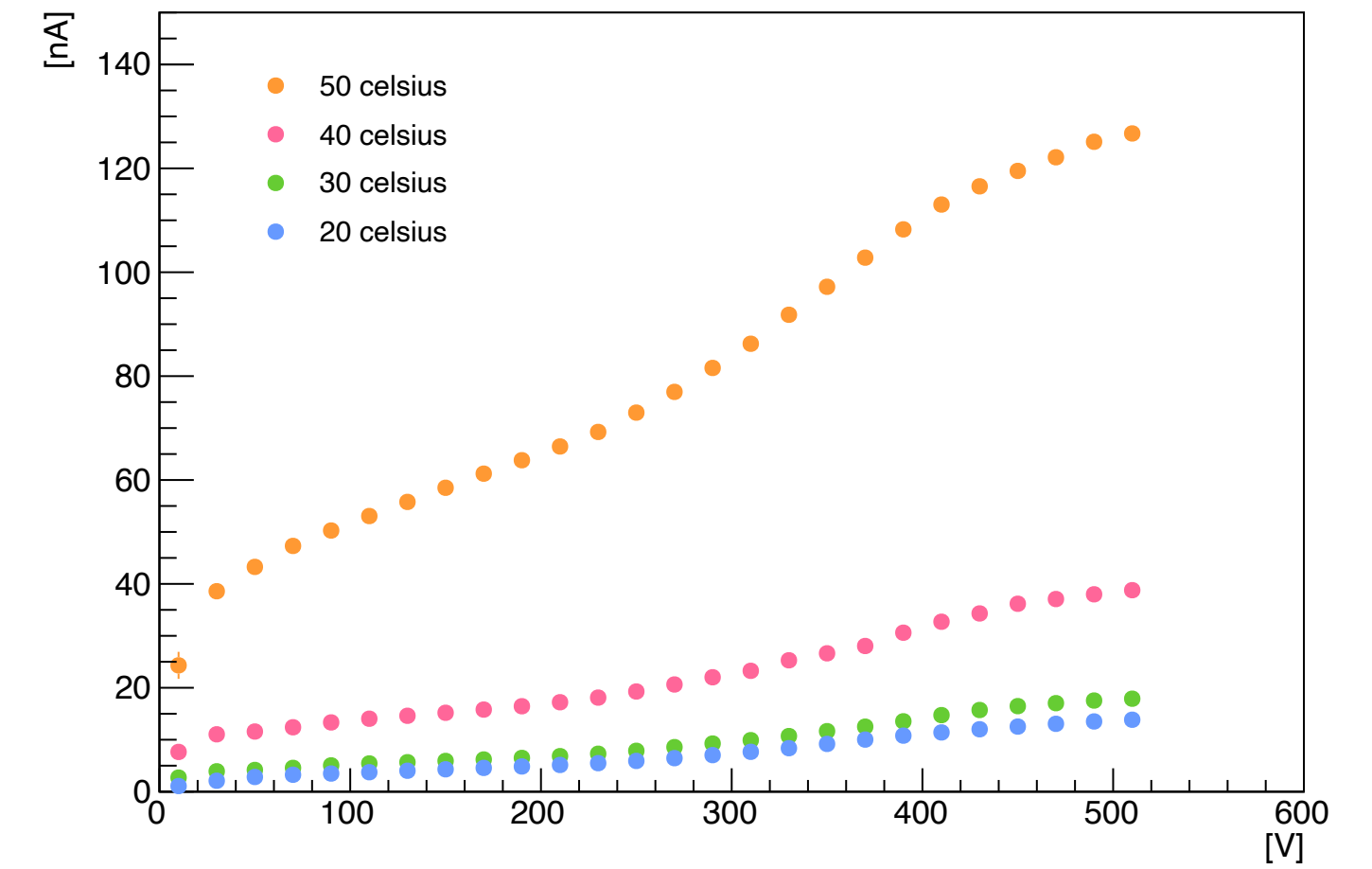
I-V 28_1



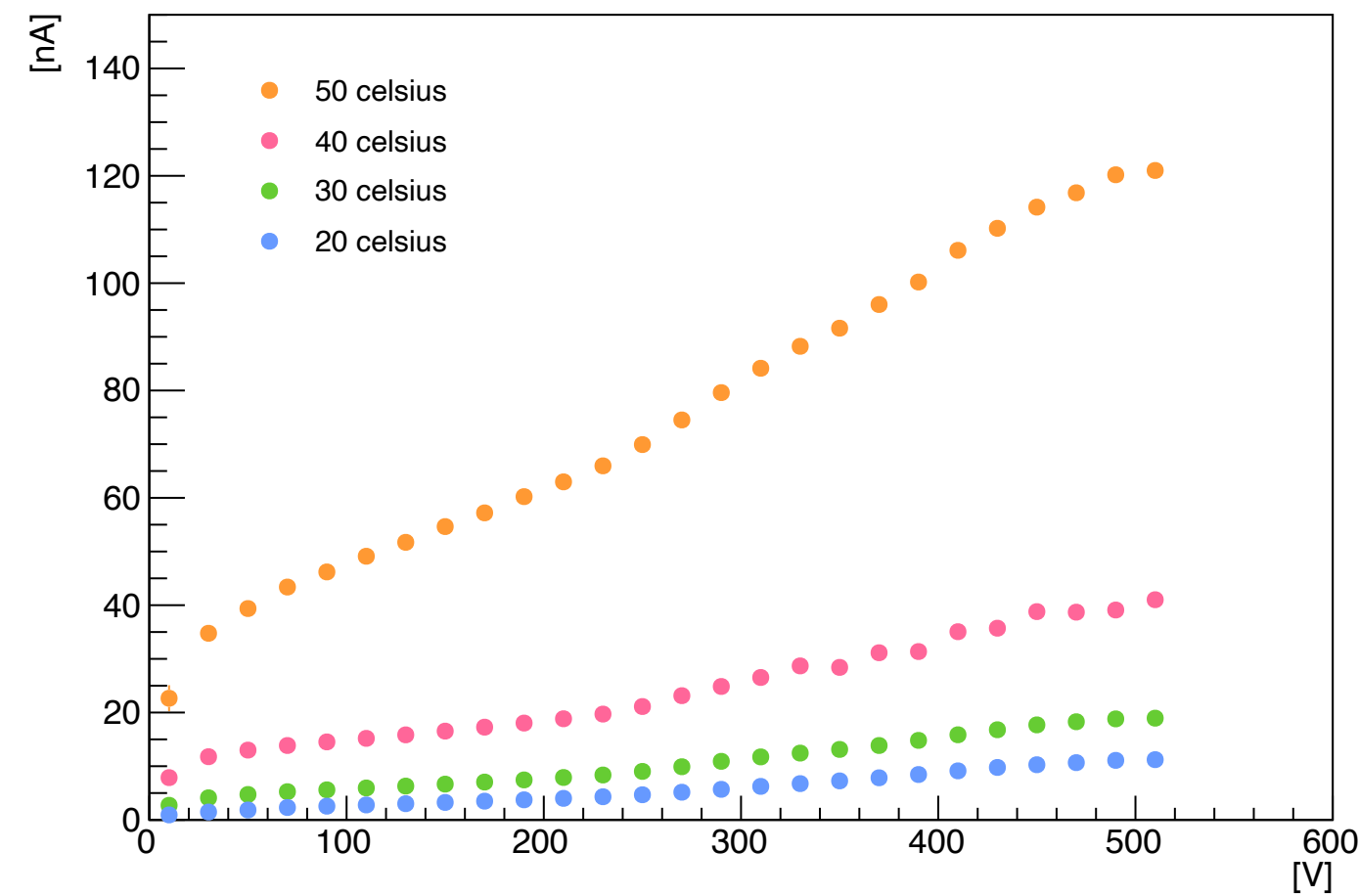
I-V 28_3



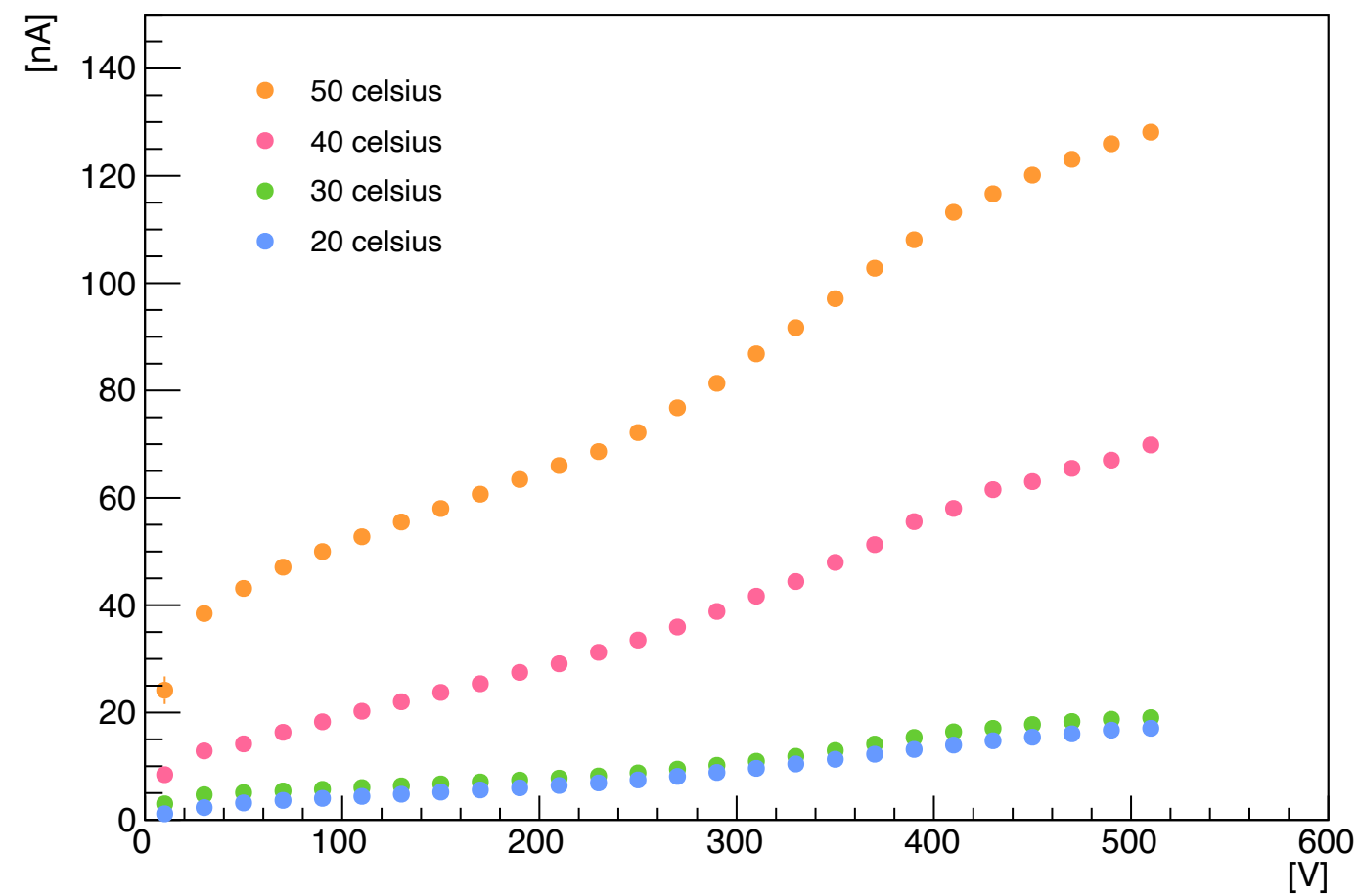
I-V 28_5



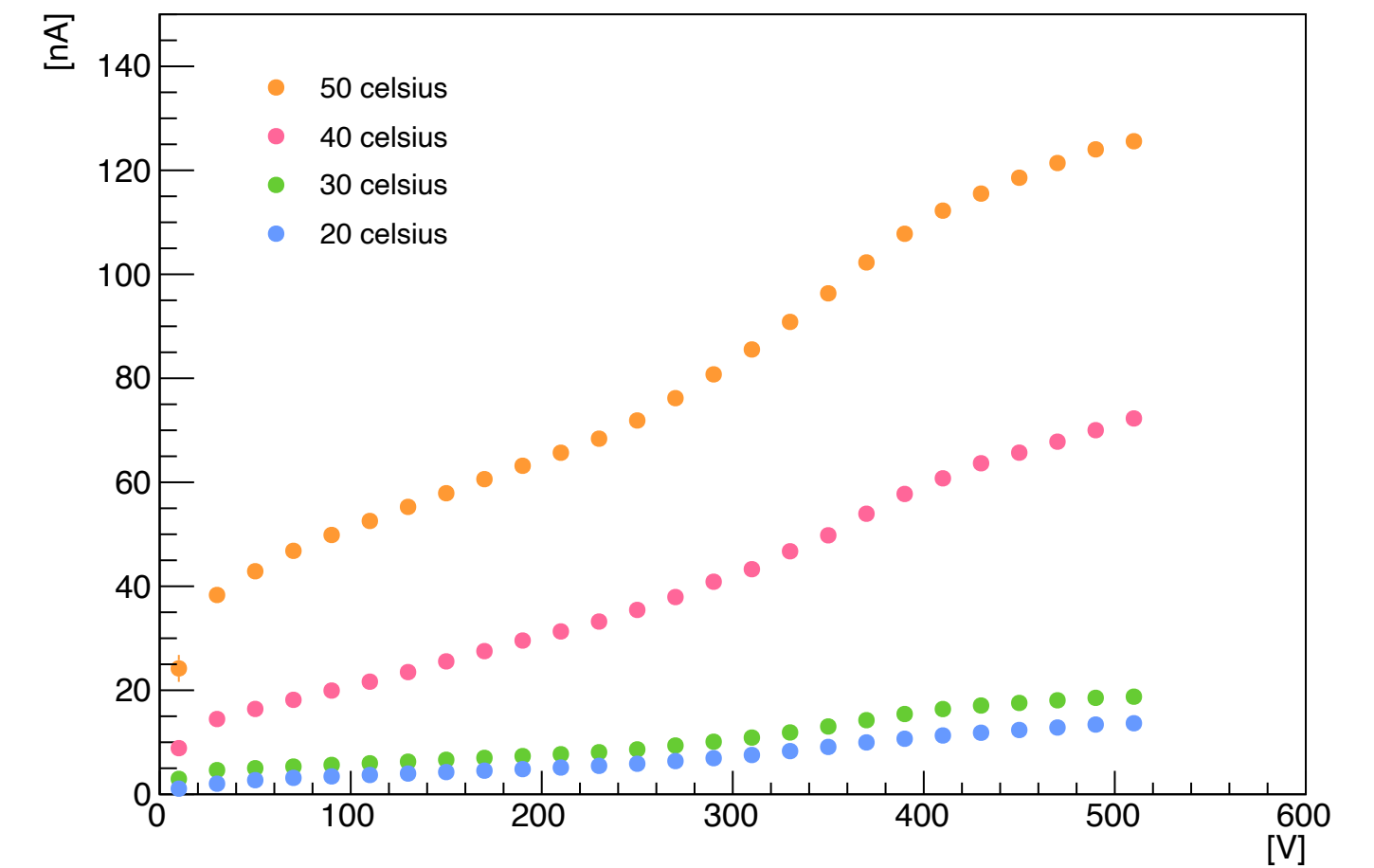
I-V 28_2



I-V 28_4



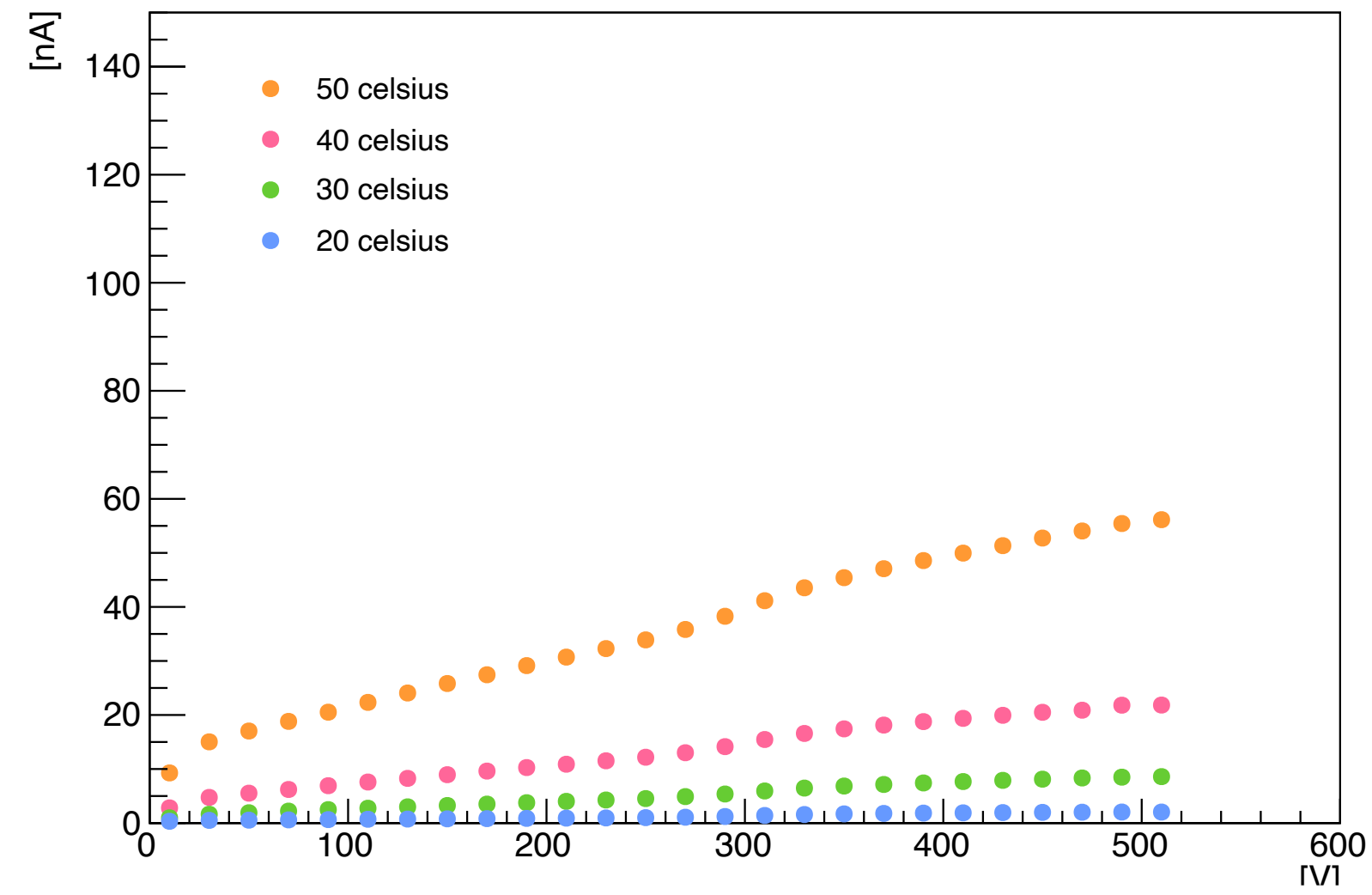
I-V 28_6



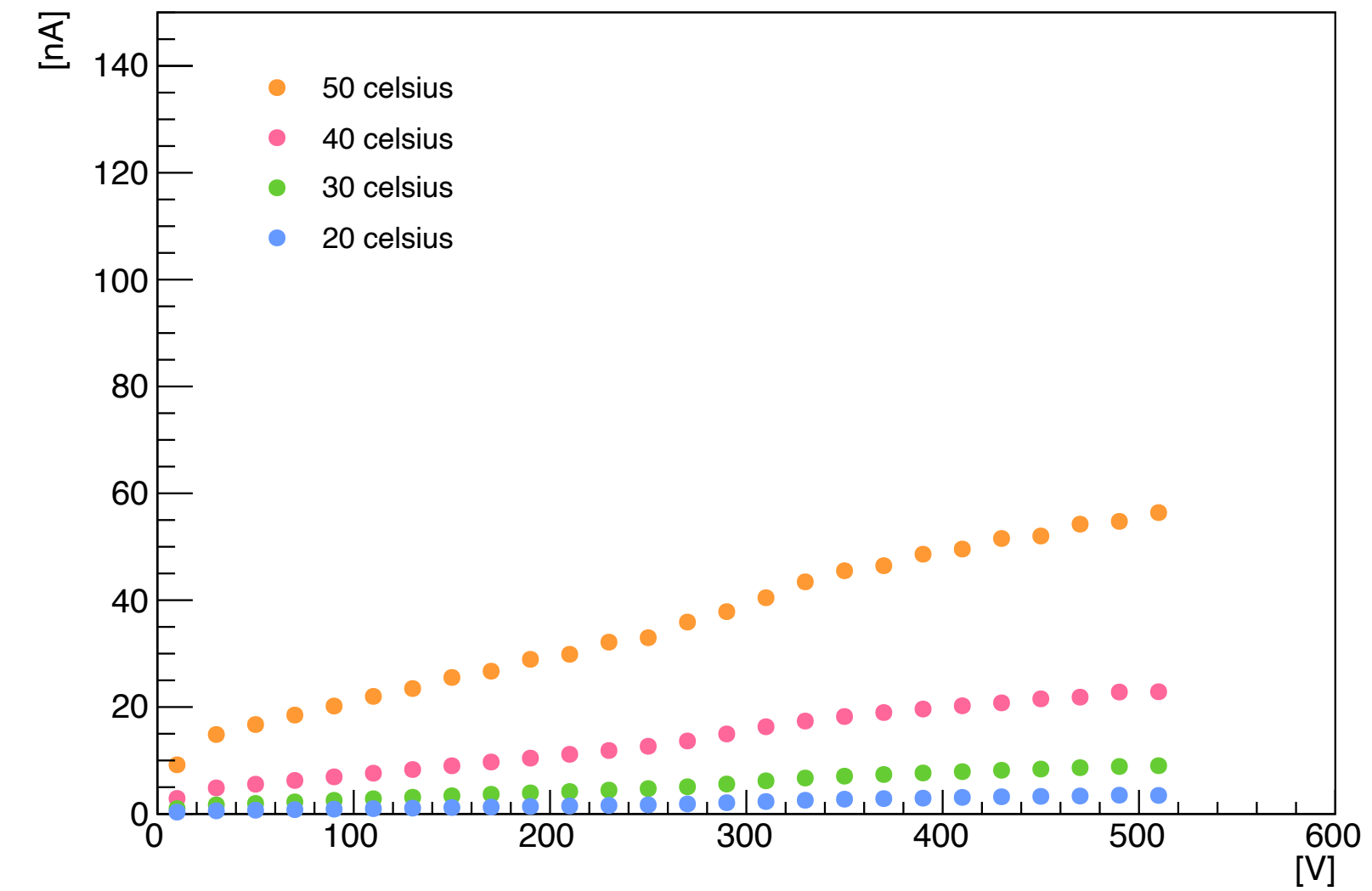
測定結果-温度依存(軸を揃えたもの)

14T1, 14T2 (1cm× 1cm)

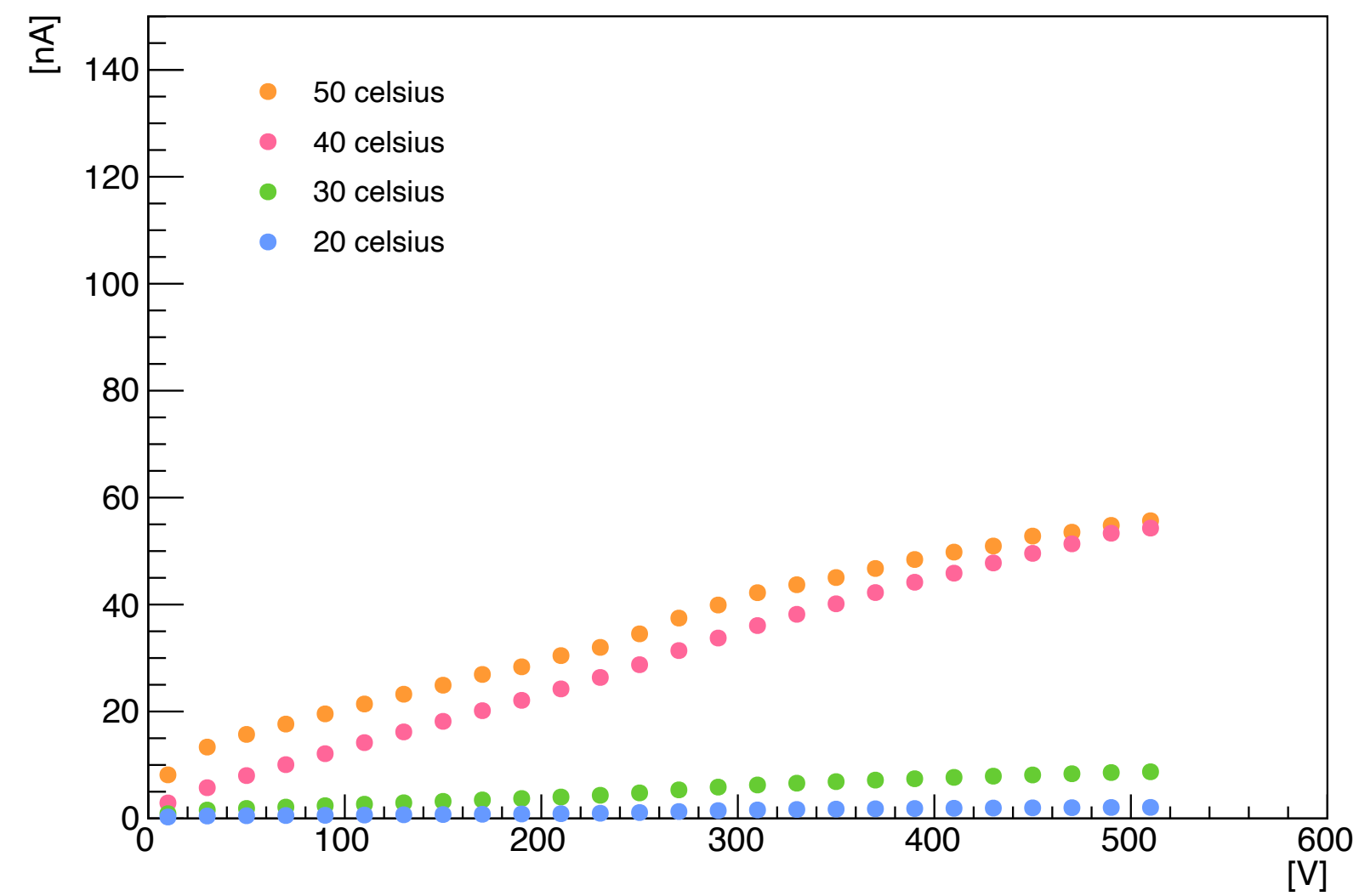
I-V 14T1_1



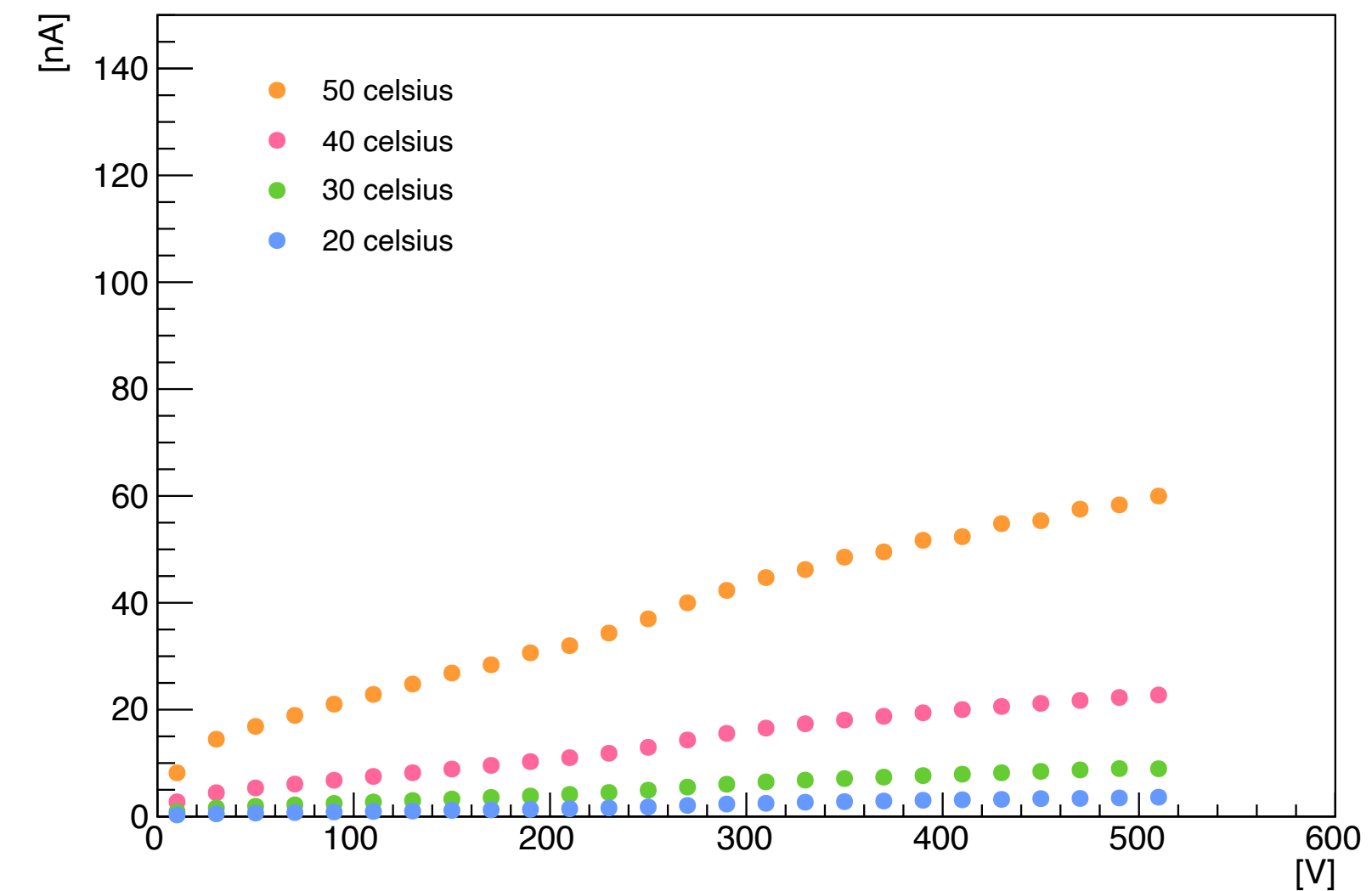
I-V 14T2_1



I-V 14T1_2



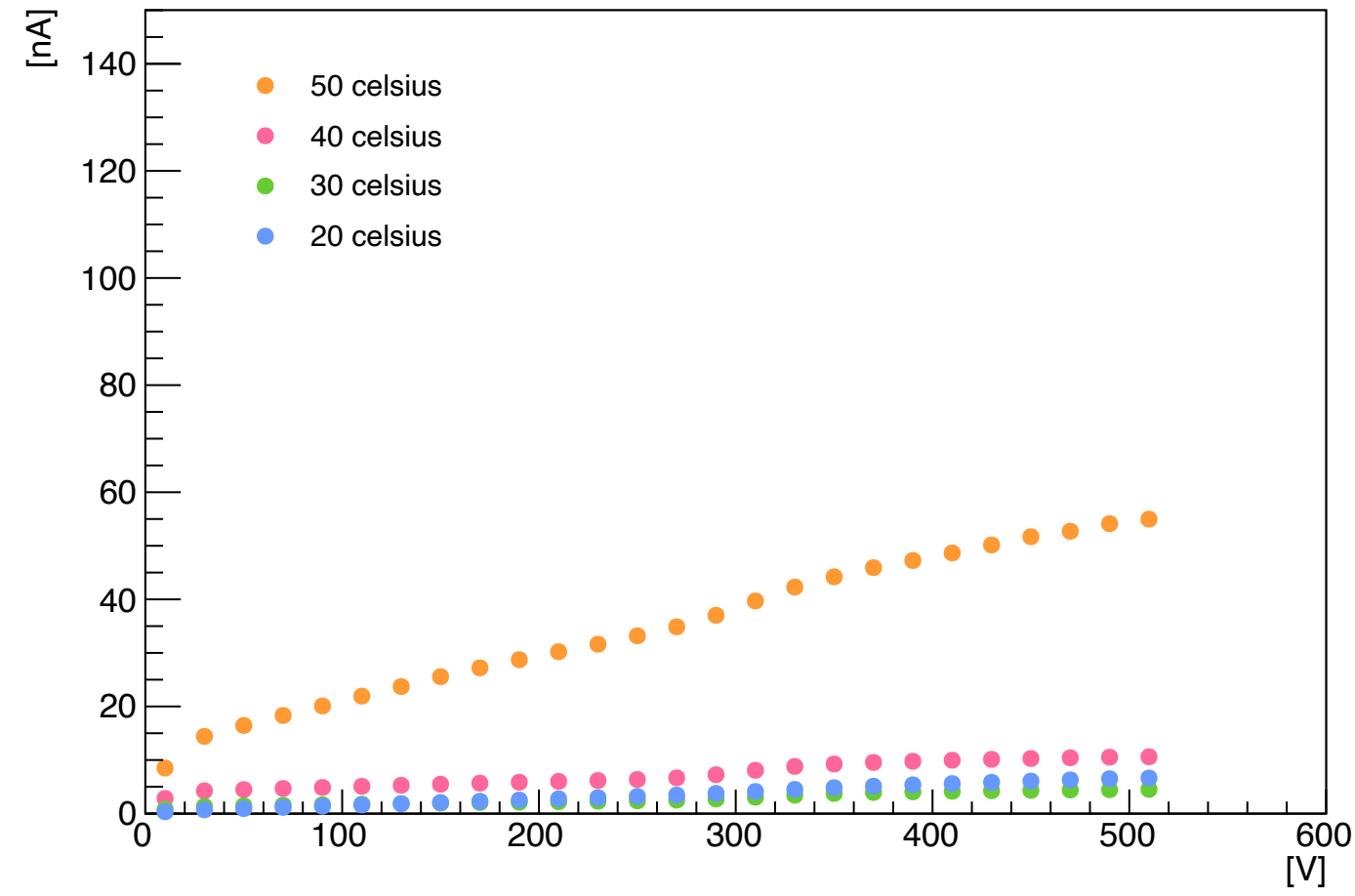
I-V 14T2_2



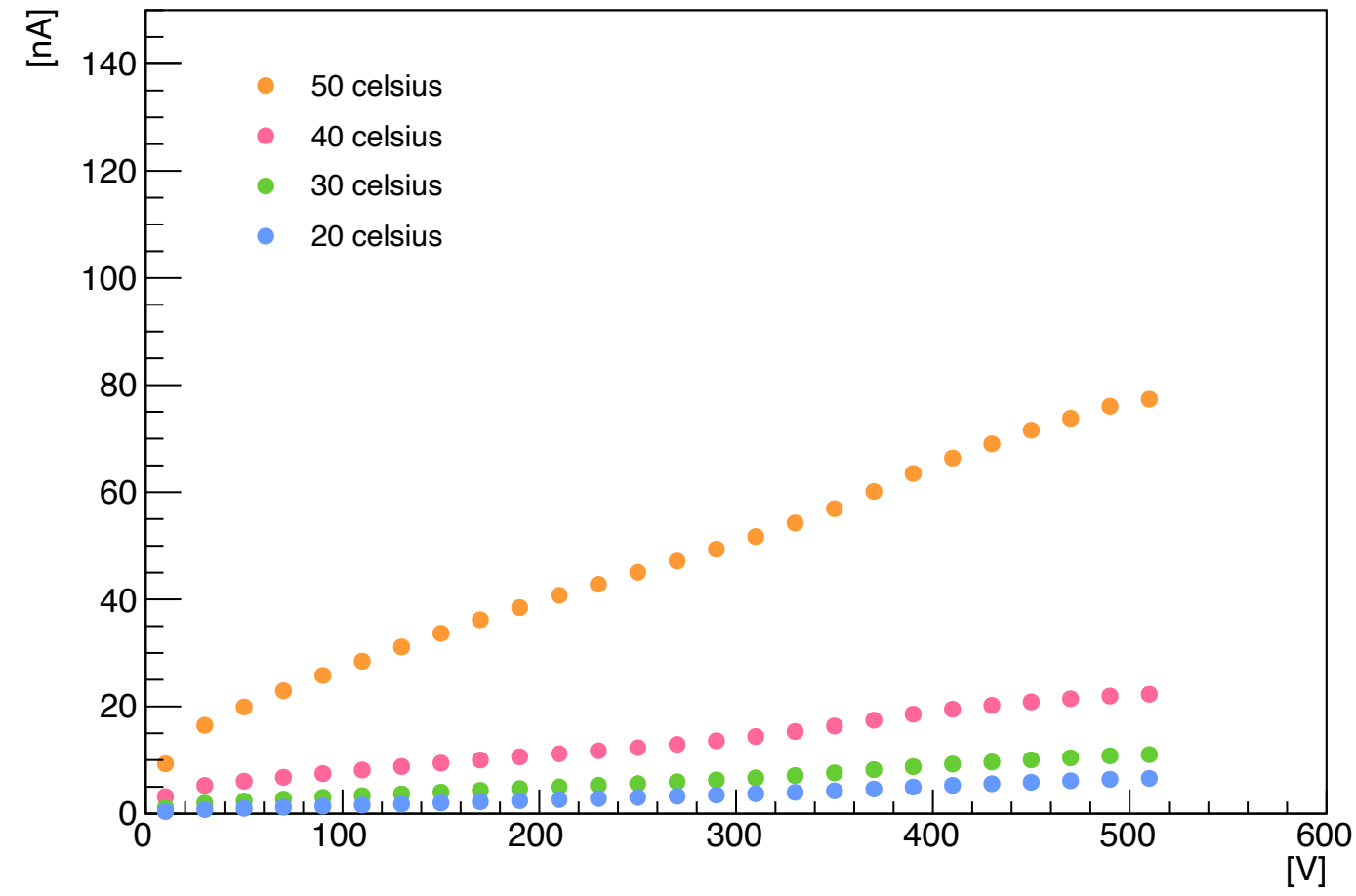
測定結果-温度依存(軸を揃えたもの)

19B1, 19R1, 19R2 (1cm× 1cm)

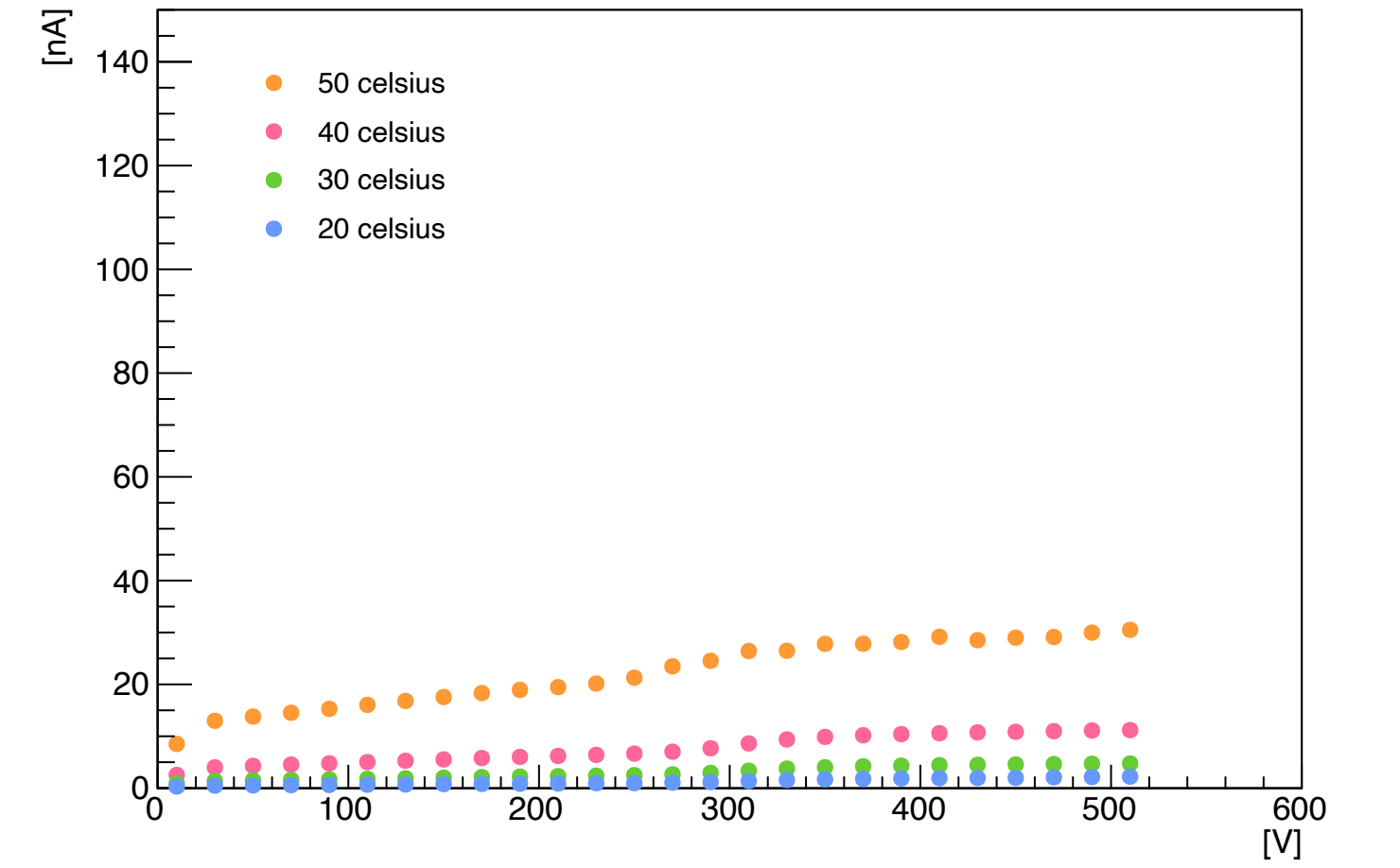
I-V 19B1_1



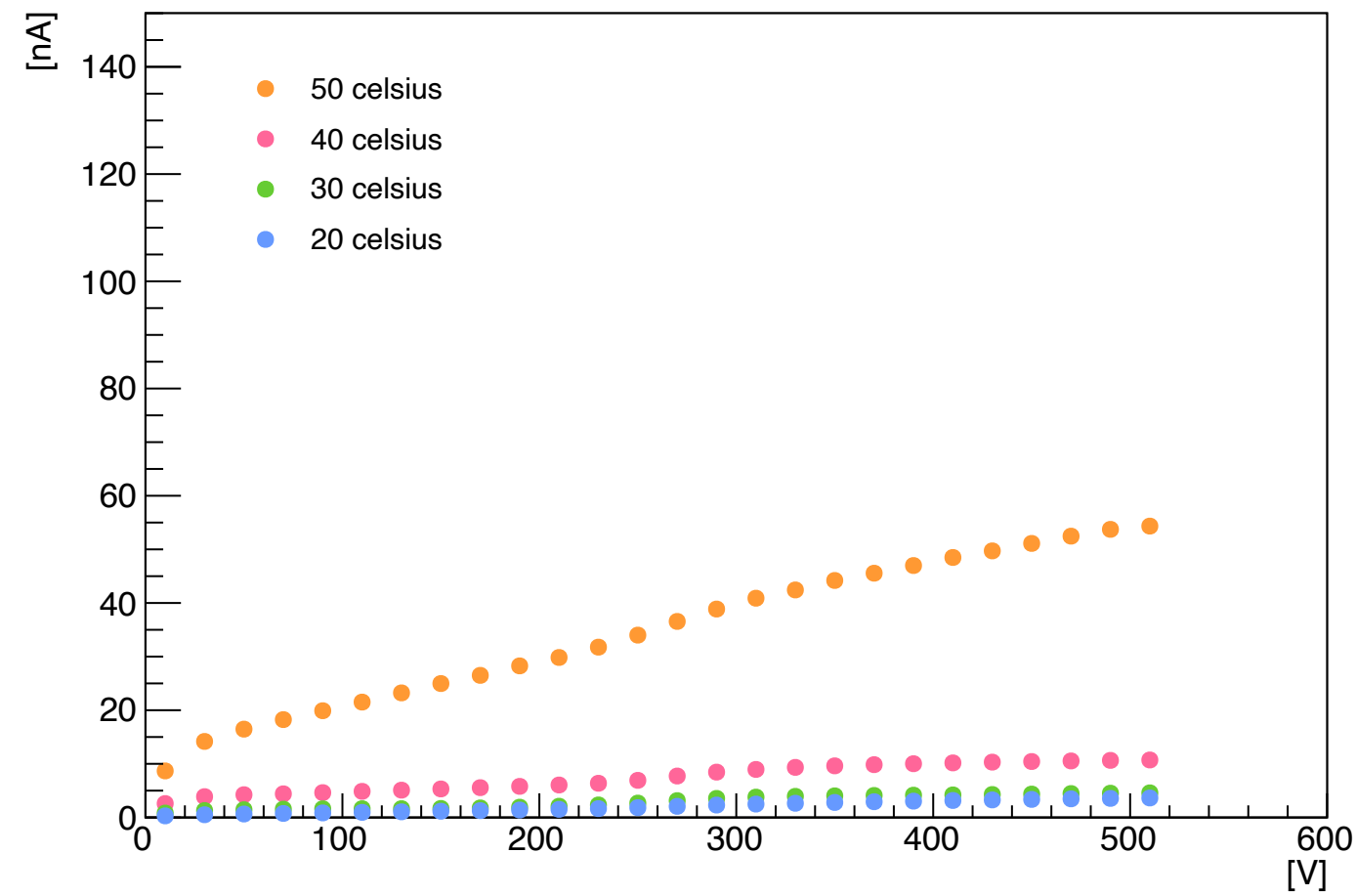
I-V 19R1_1



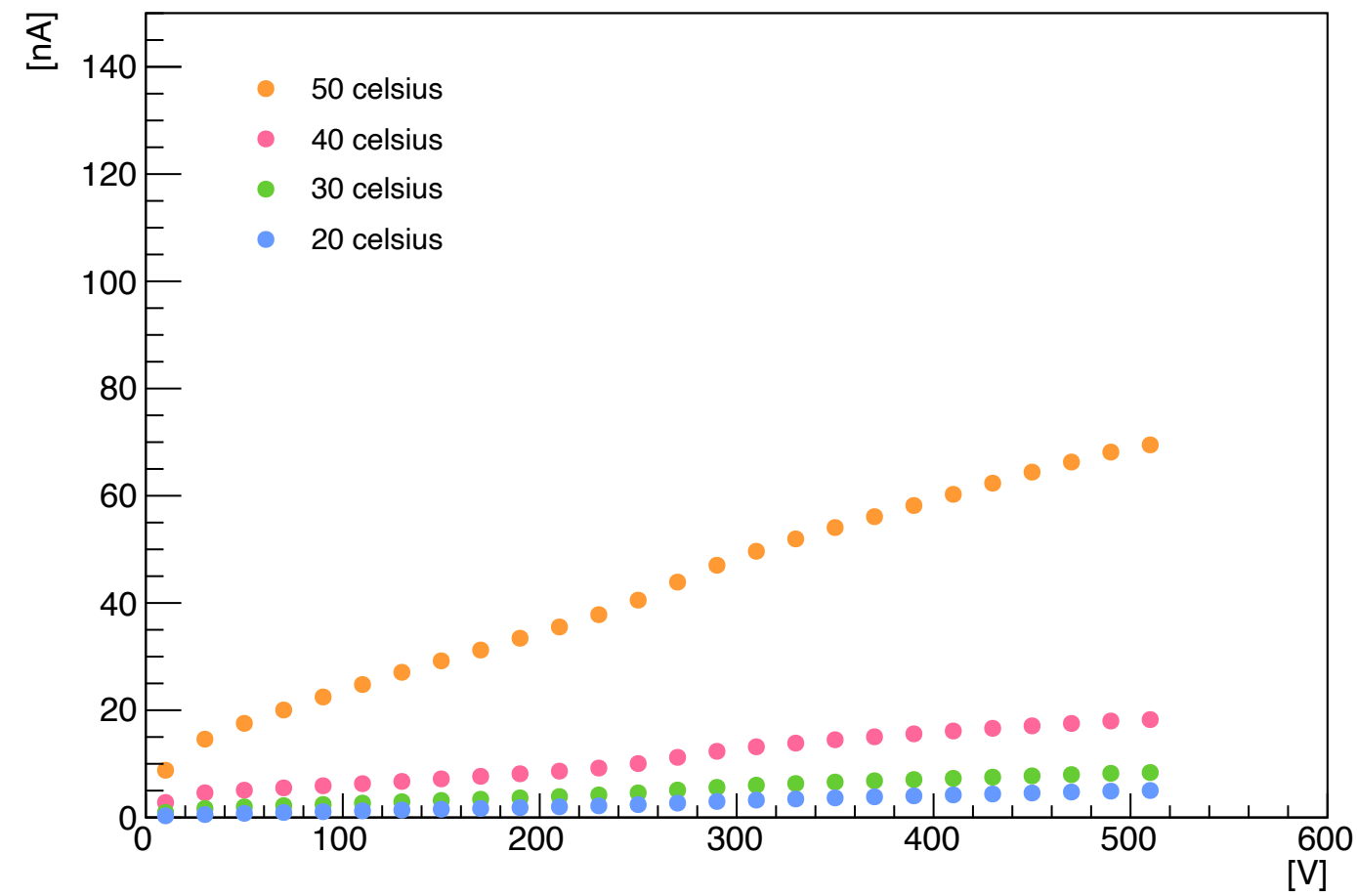
I-V 19R2_1



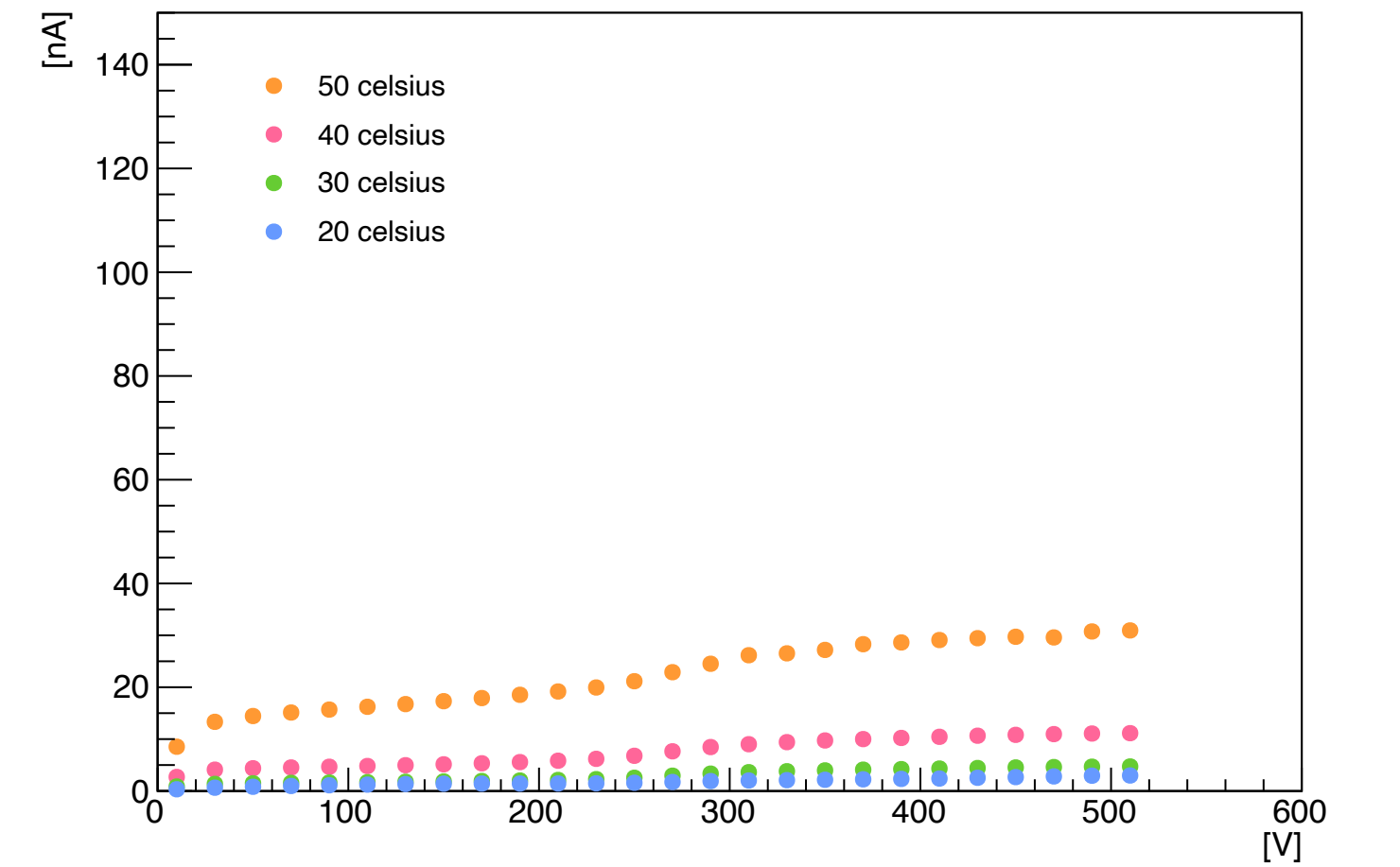
I-V 19B1_2



I-V 19R1_2



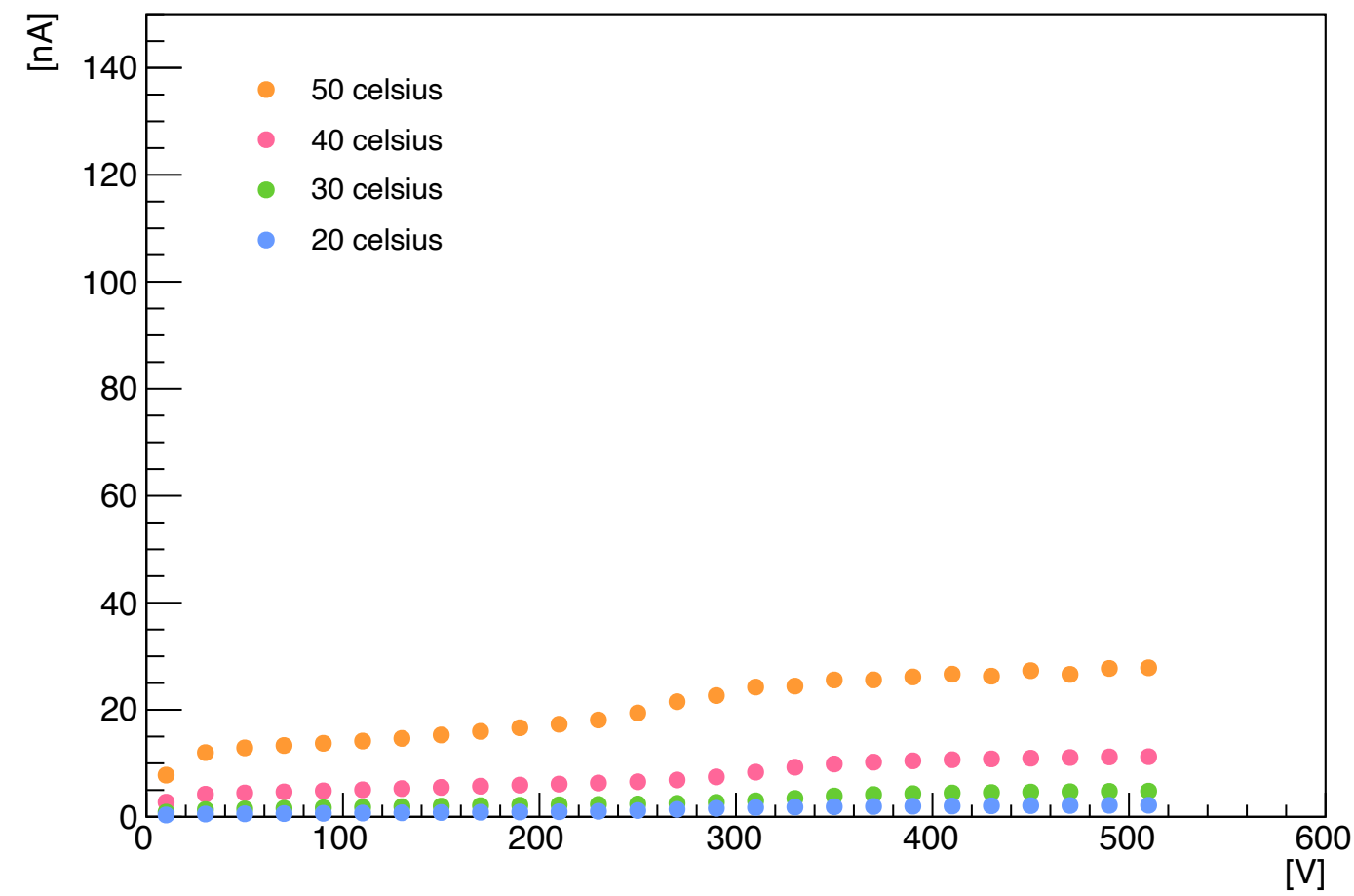
I-V 19R2_2



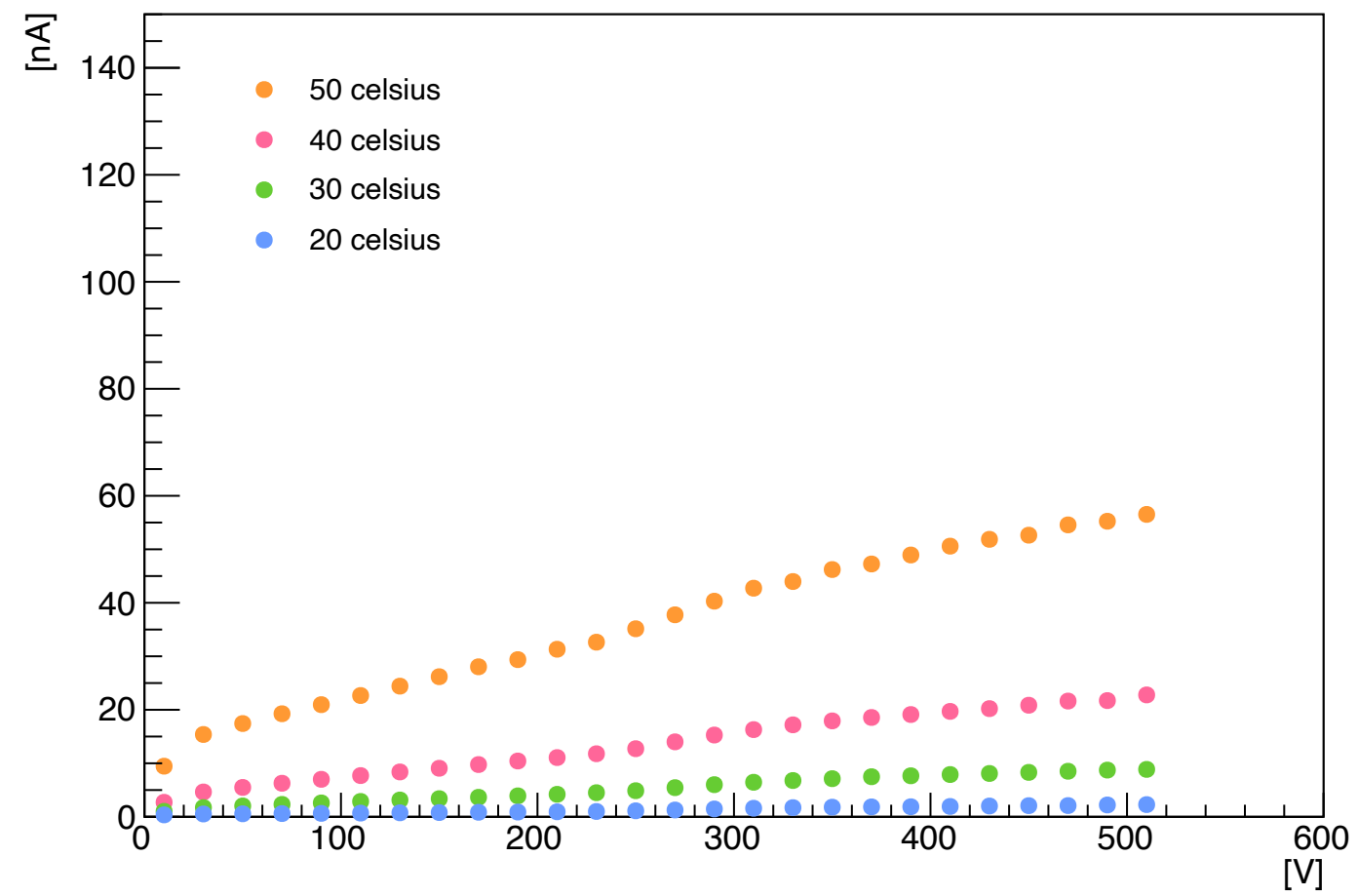
測定結果-温度依存(軸を揃えたもの)

28T1, 28L2, 28B1 (1cm×1cm)

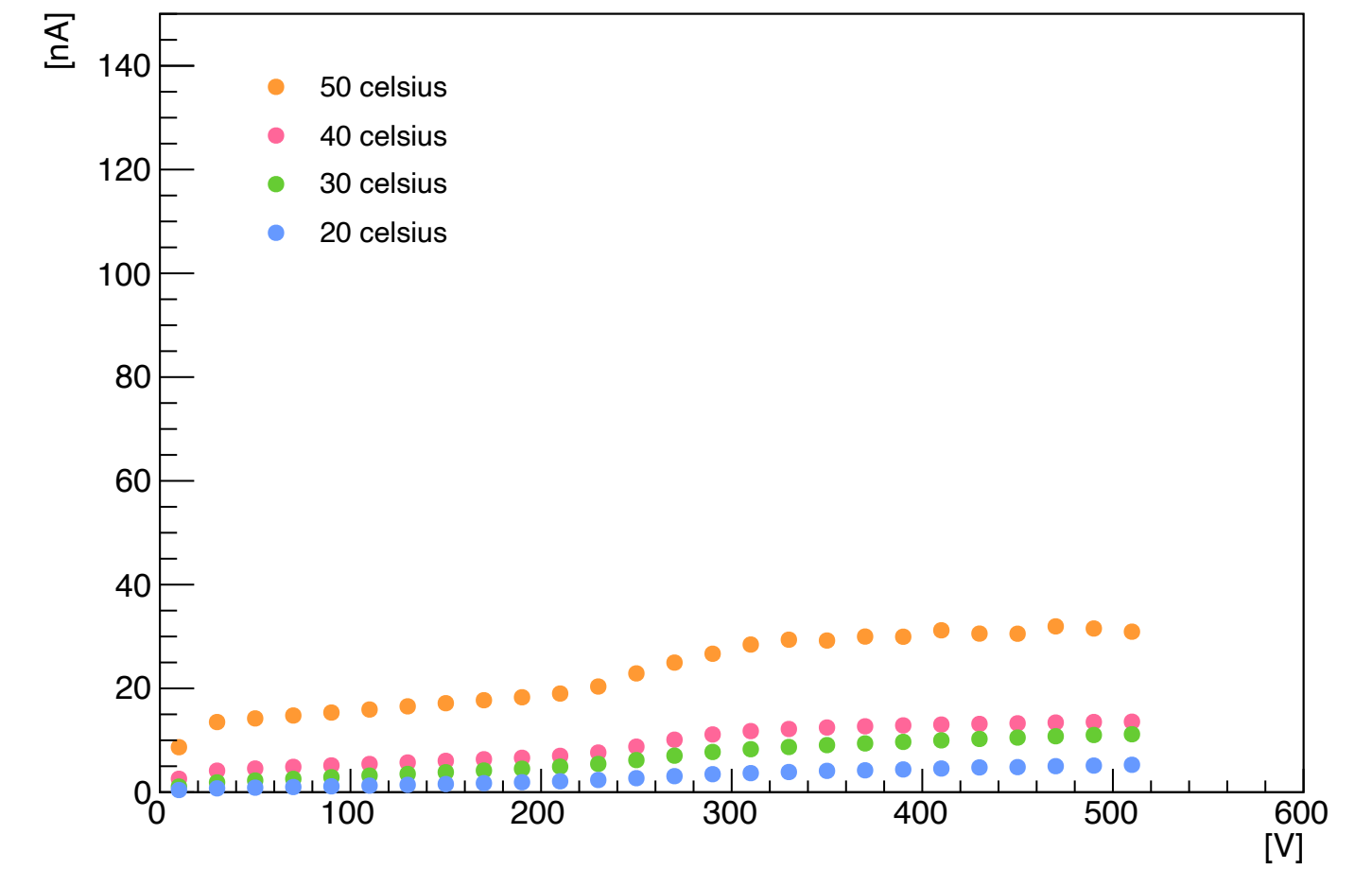
I-V 28T1_1



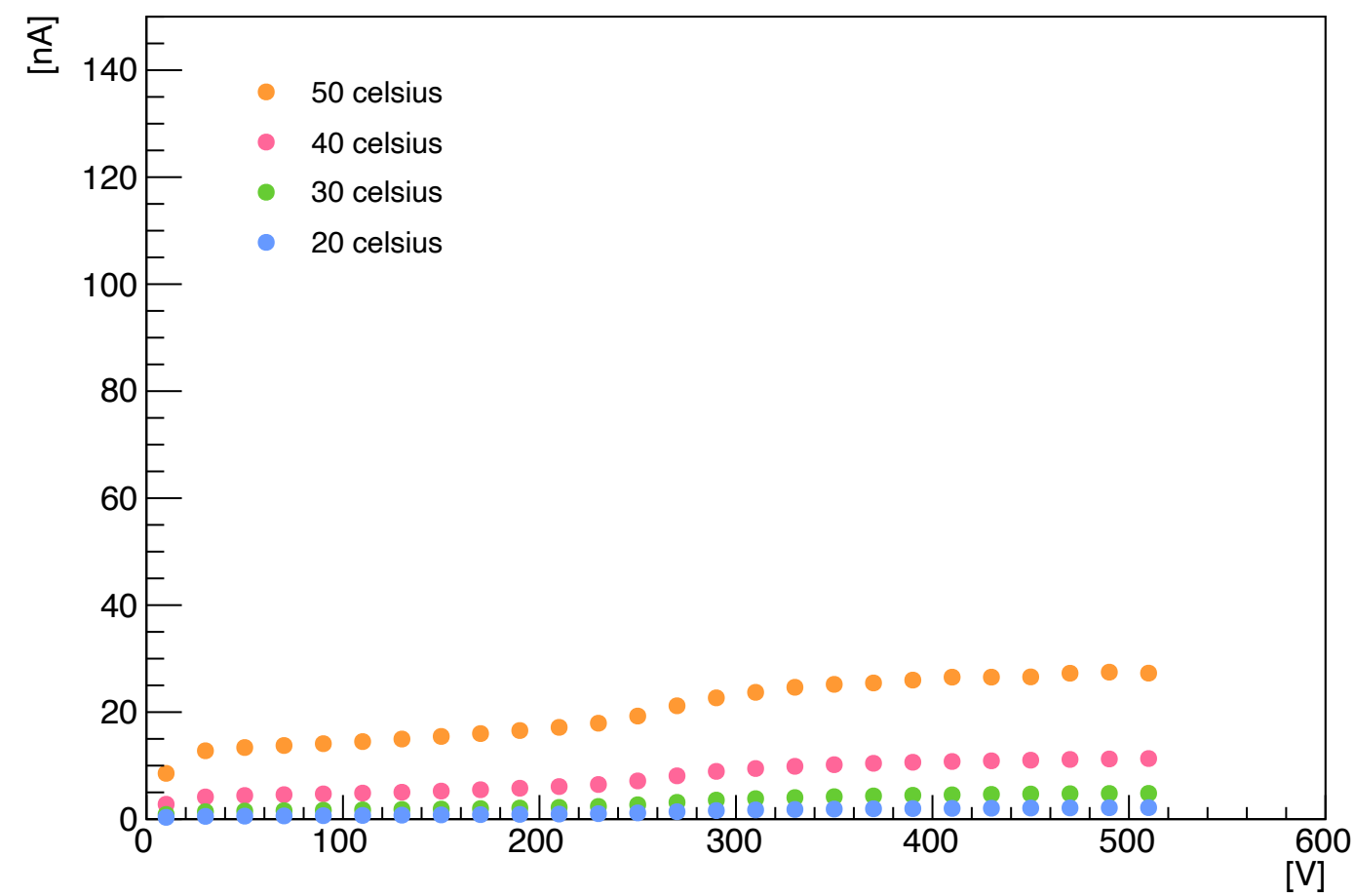
I-V 28L2_1



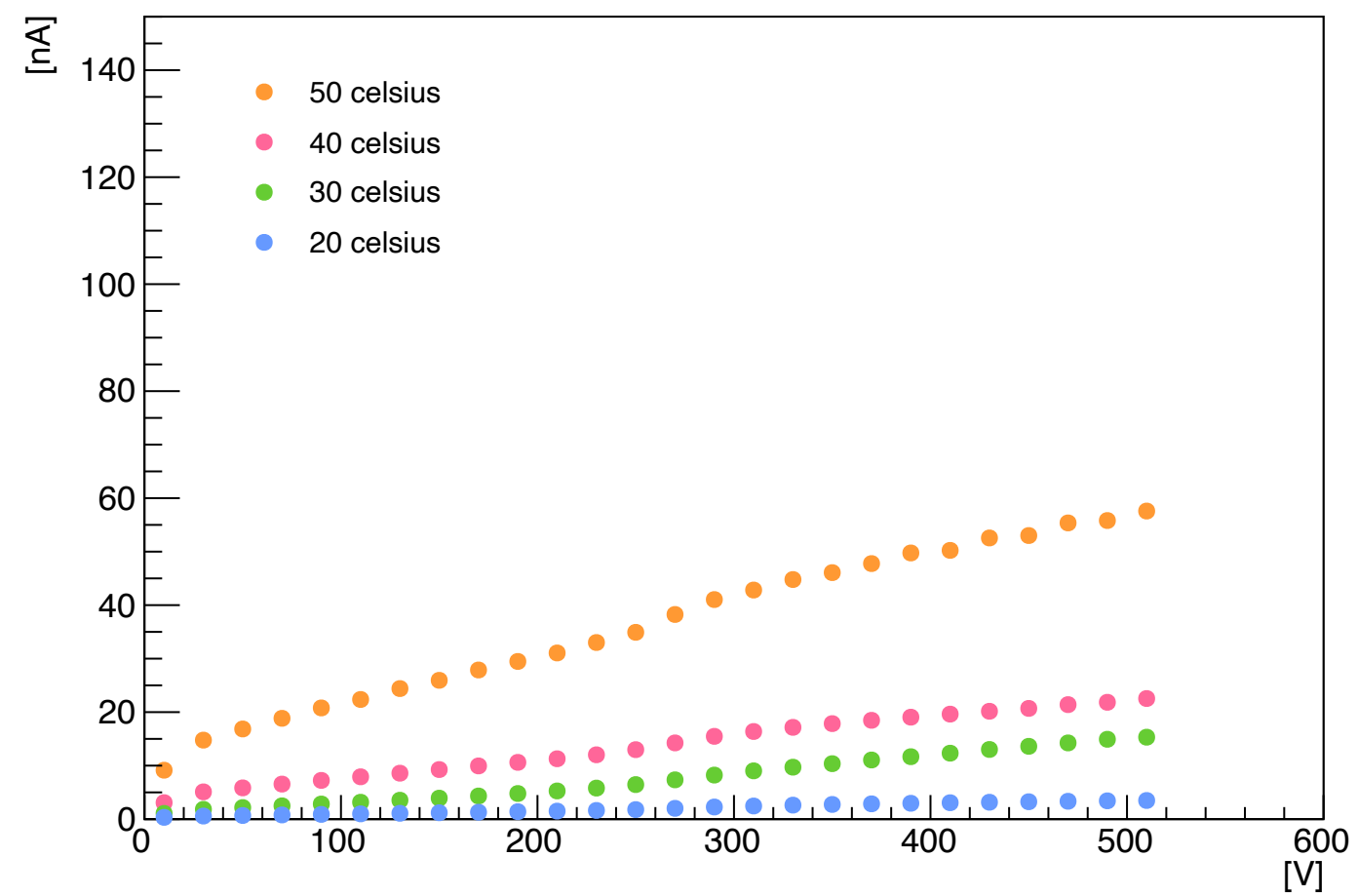
I-V 28B1_1



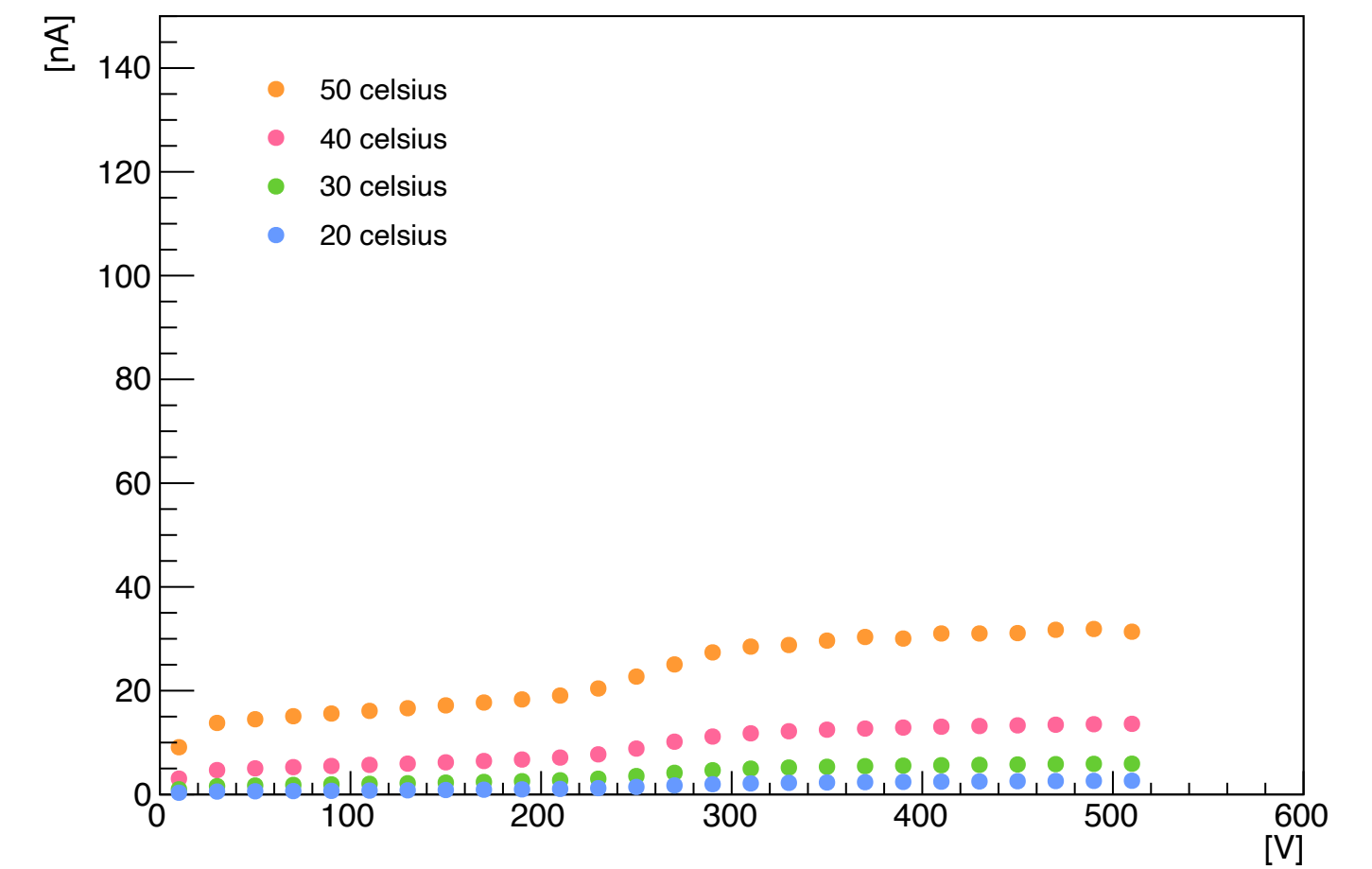
I-V 28T1_2



I-V 28L2_2



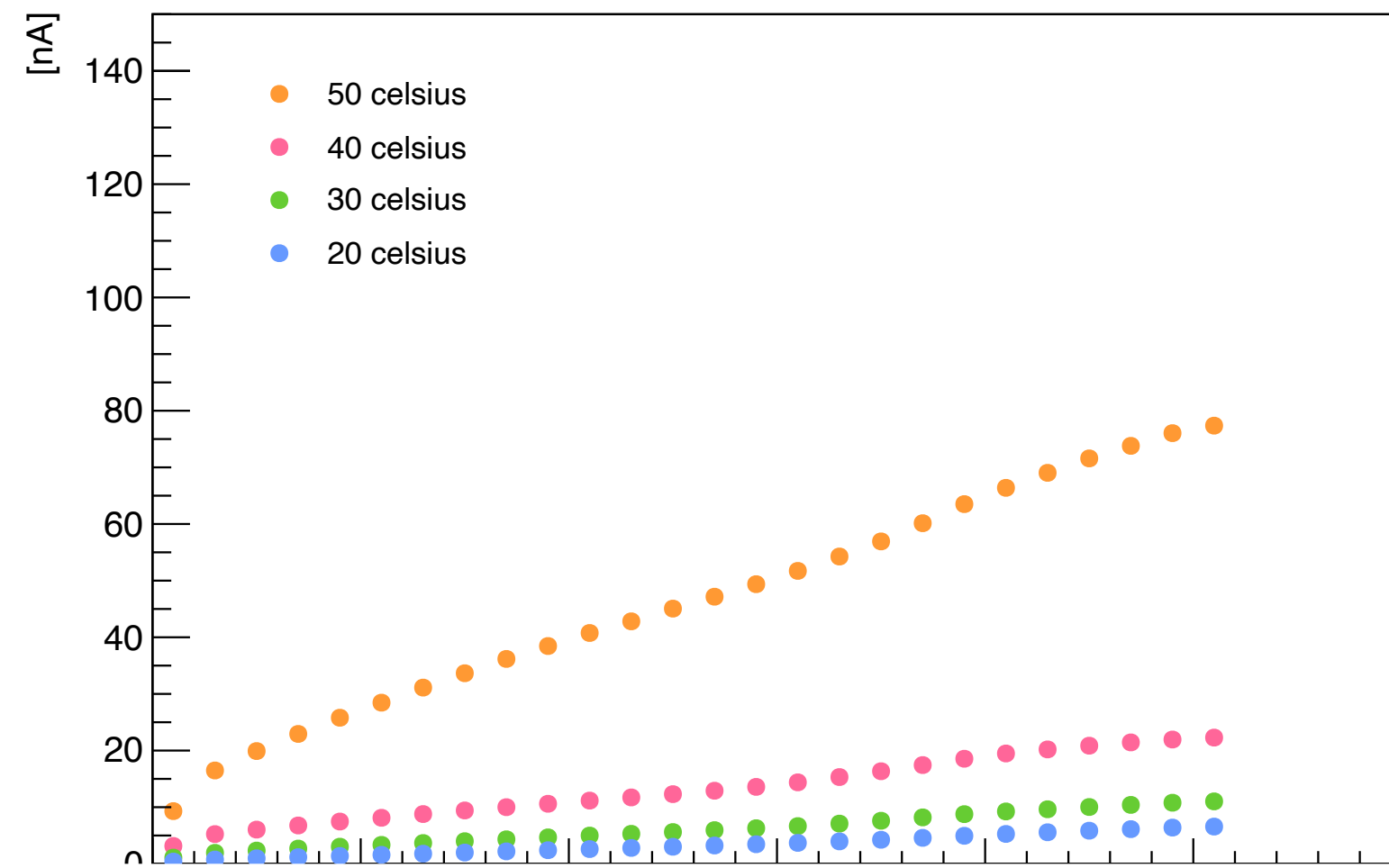
I-V 28B1_2



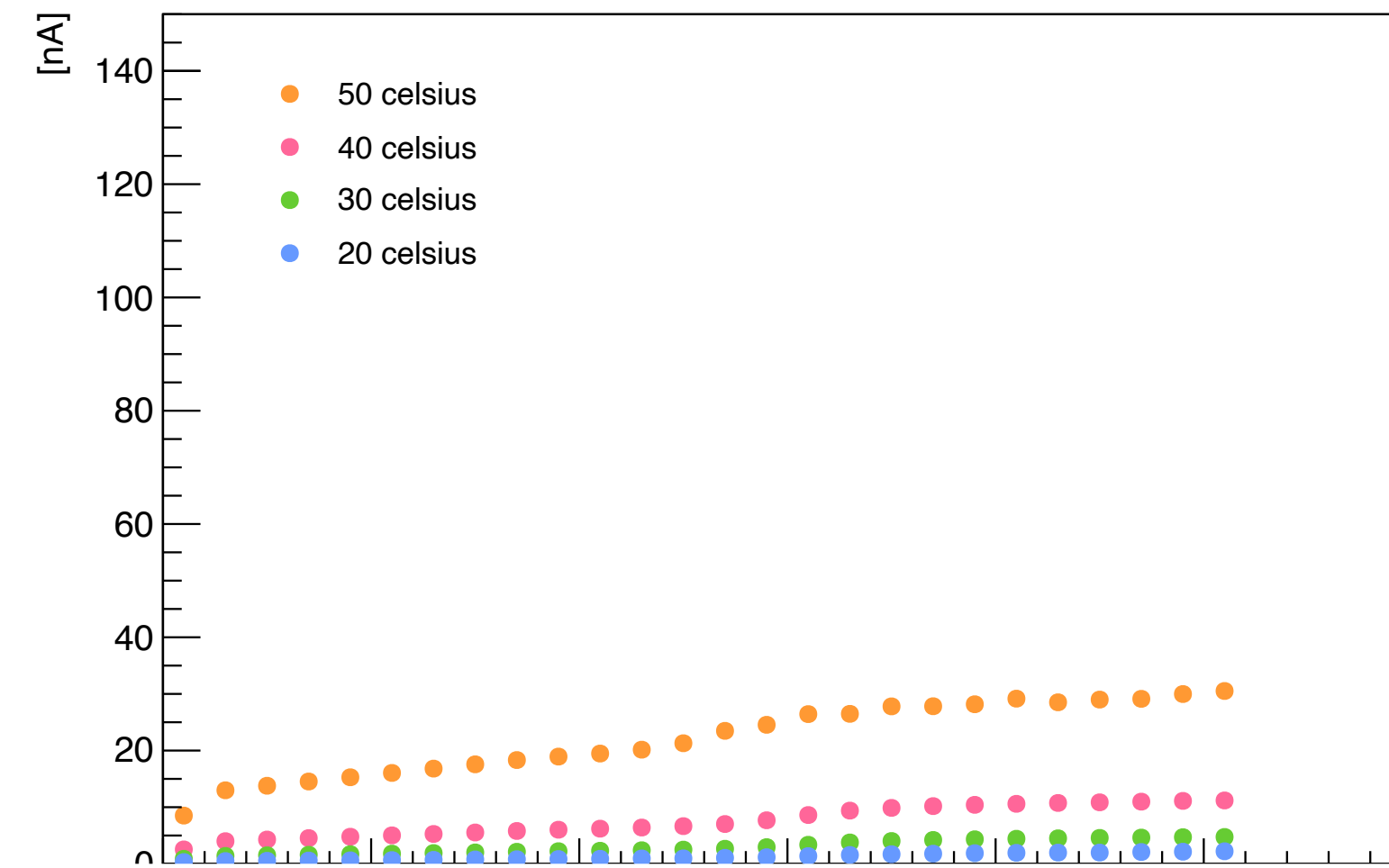
測定結果-温度依存(軸を揃えたもの)

28R1, 28R2 (1cm× 1cm)

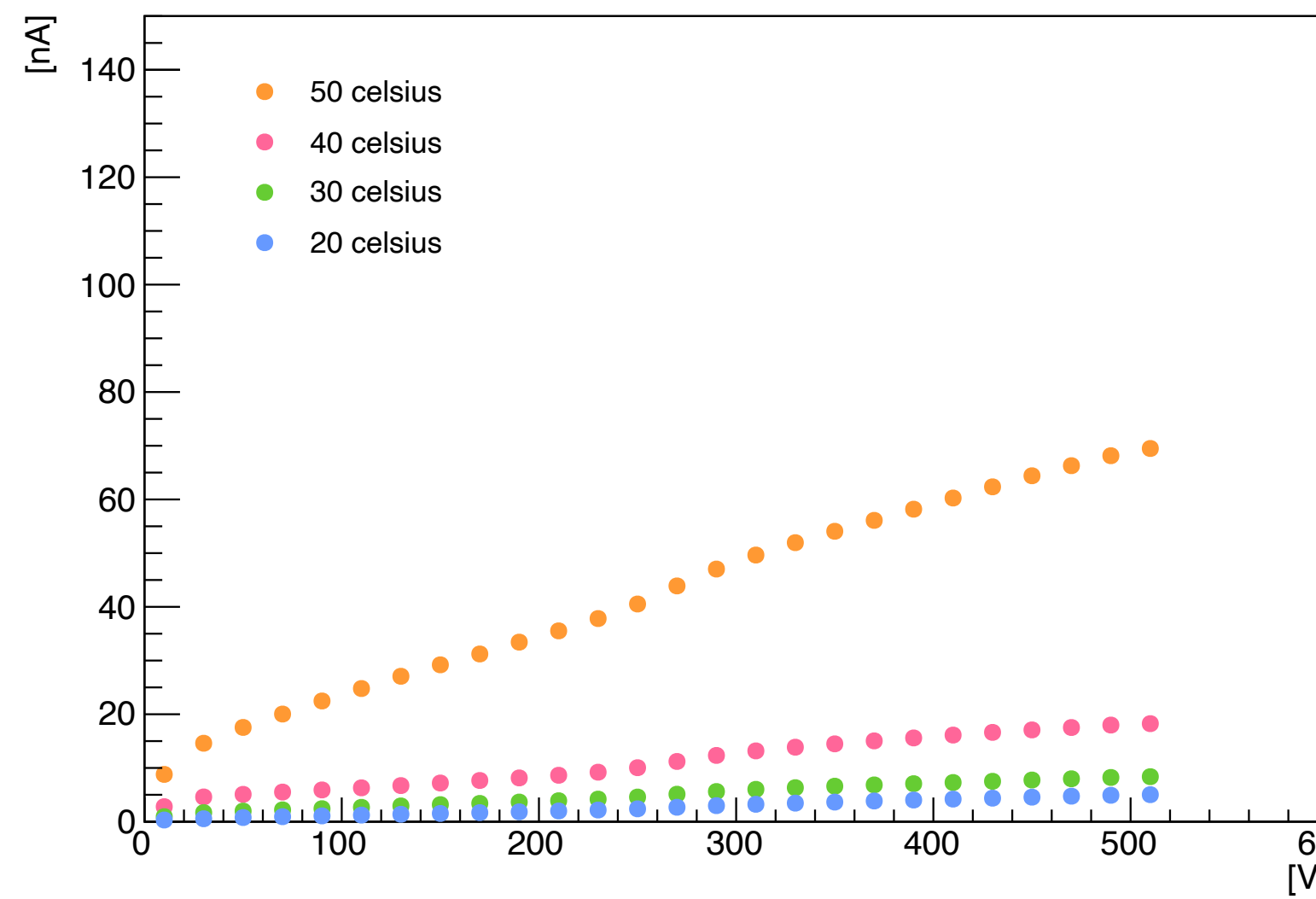
I-V 28R1_1



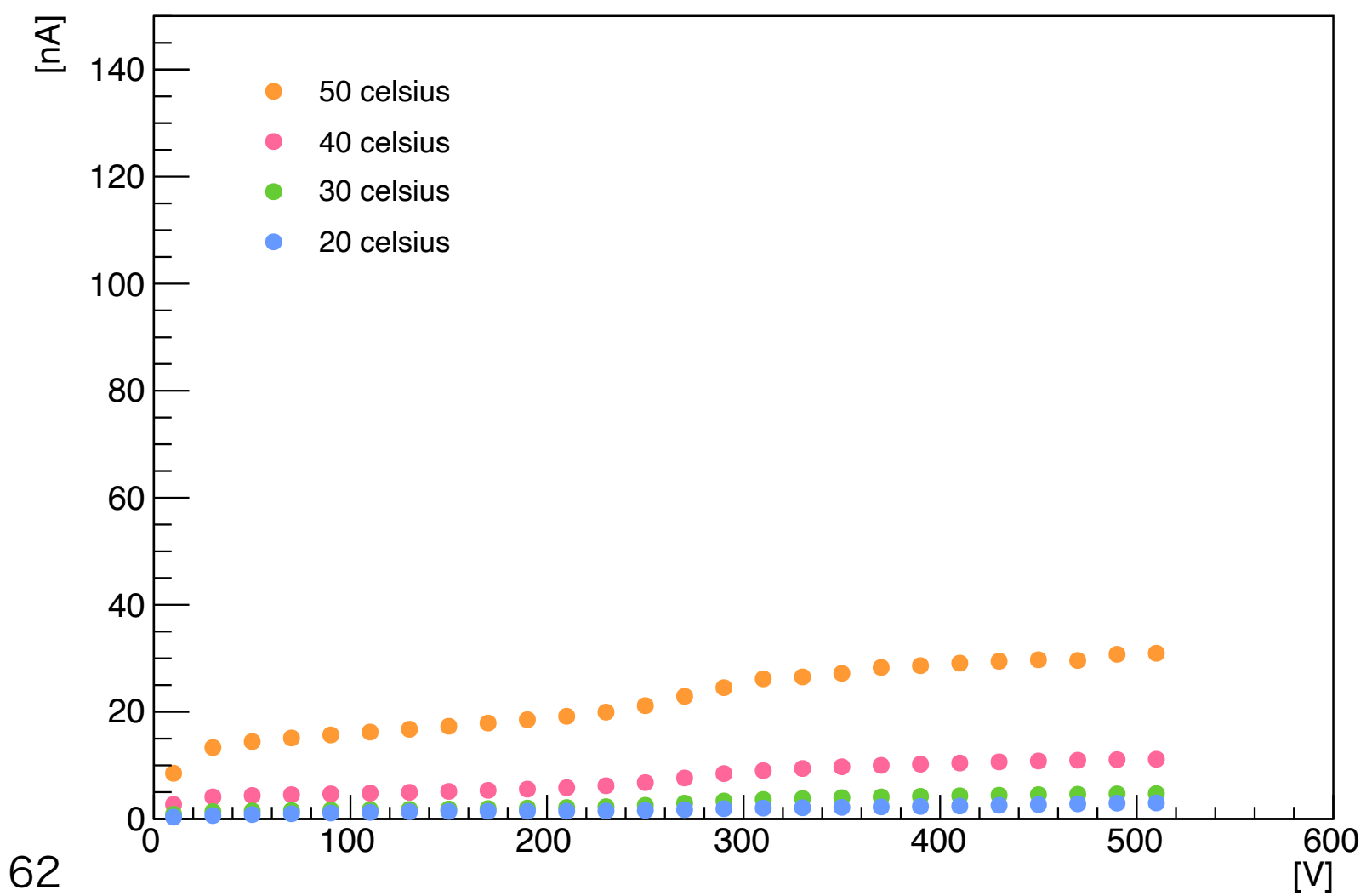
I-V 28R2_1



I-V 28R1_2



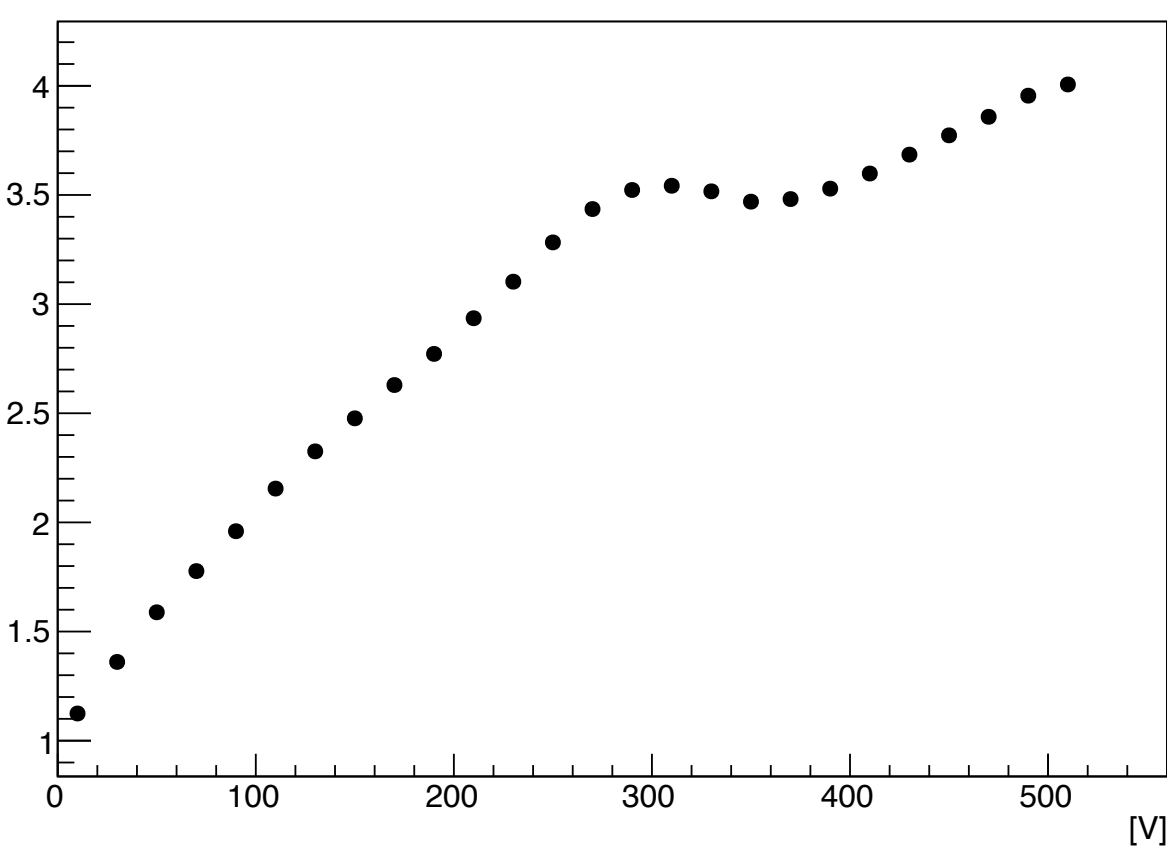
I-V 28R2_2



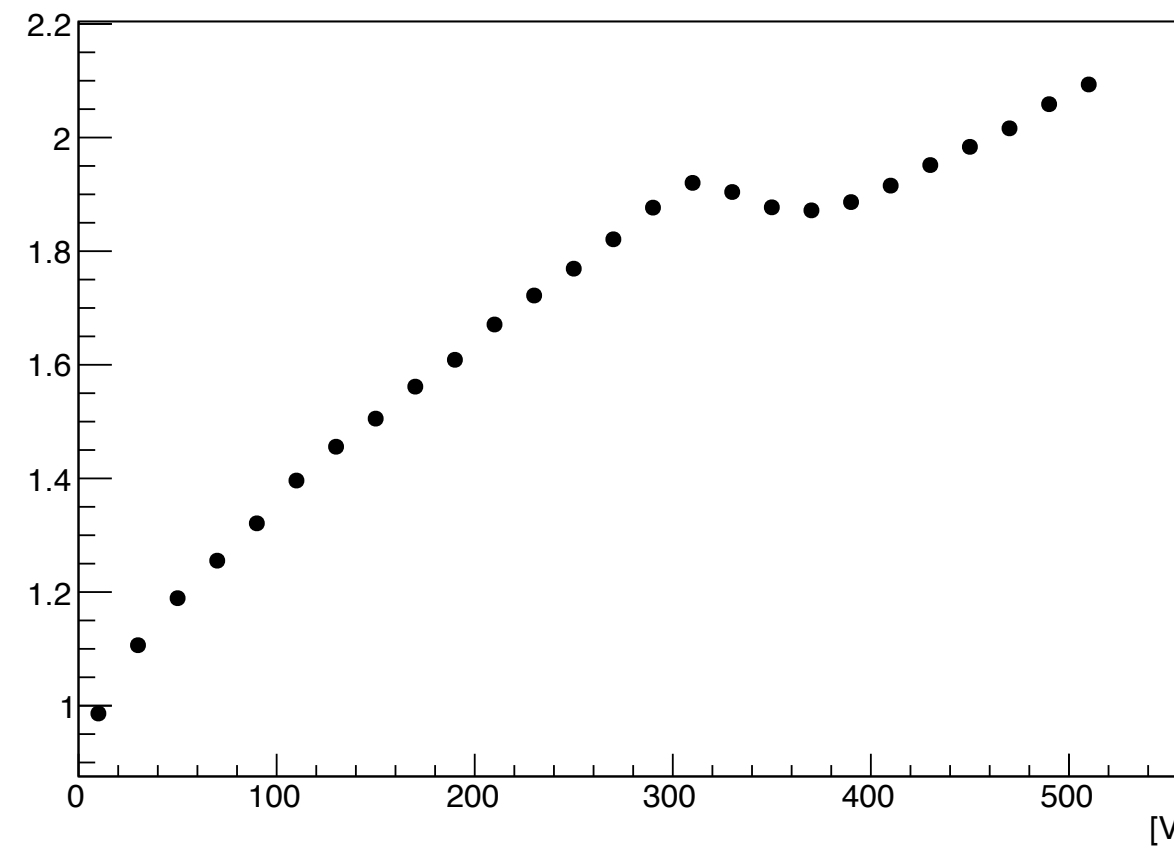
それぞれの結果/14T2の結果

1400 (1cm× 1cm)

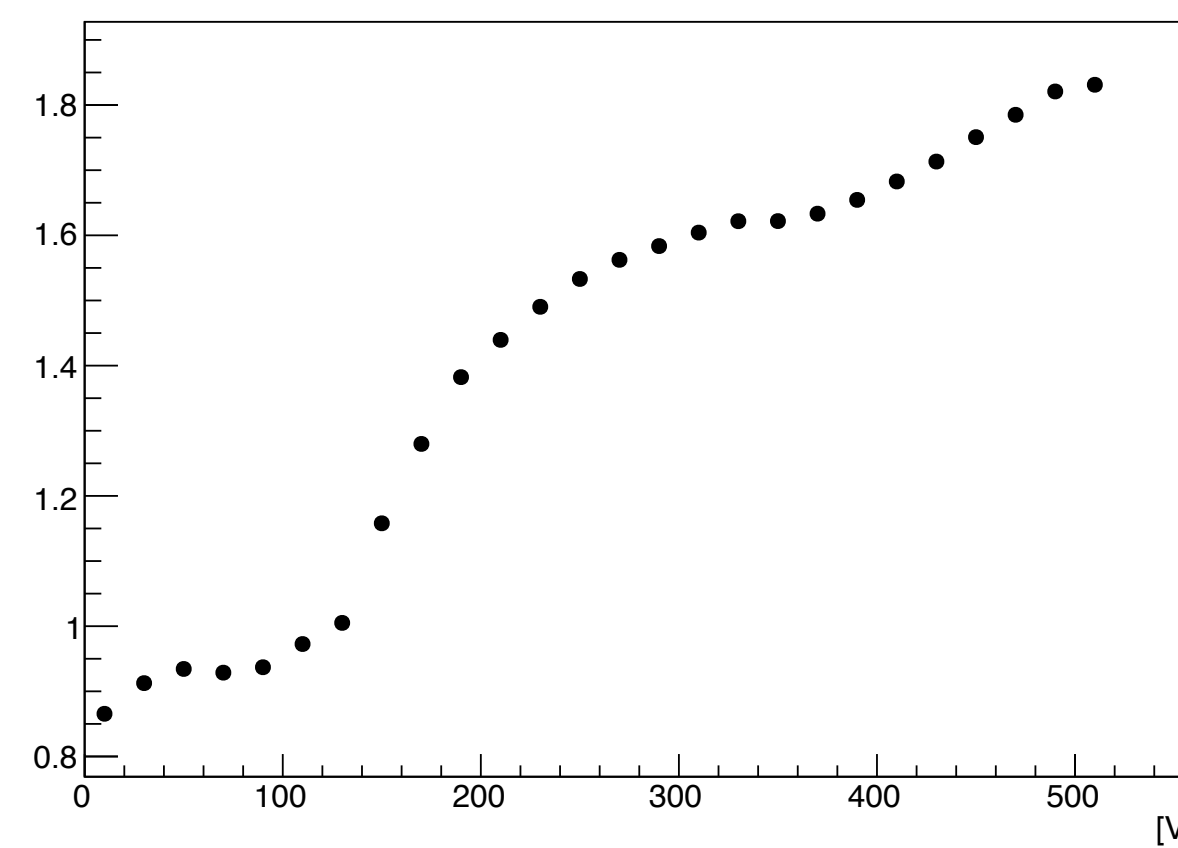
14L2_1/14T2_1



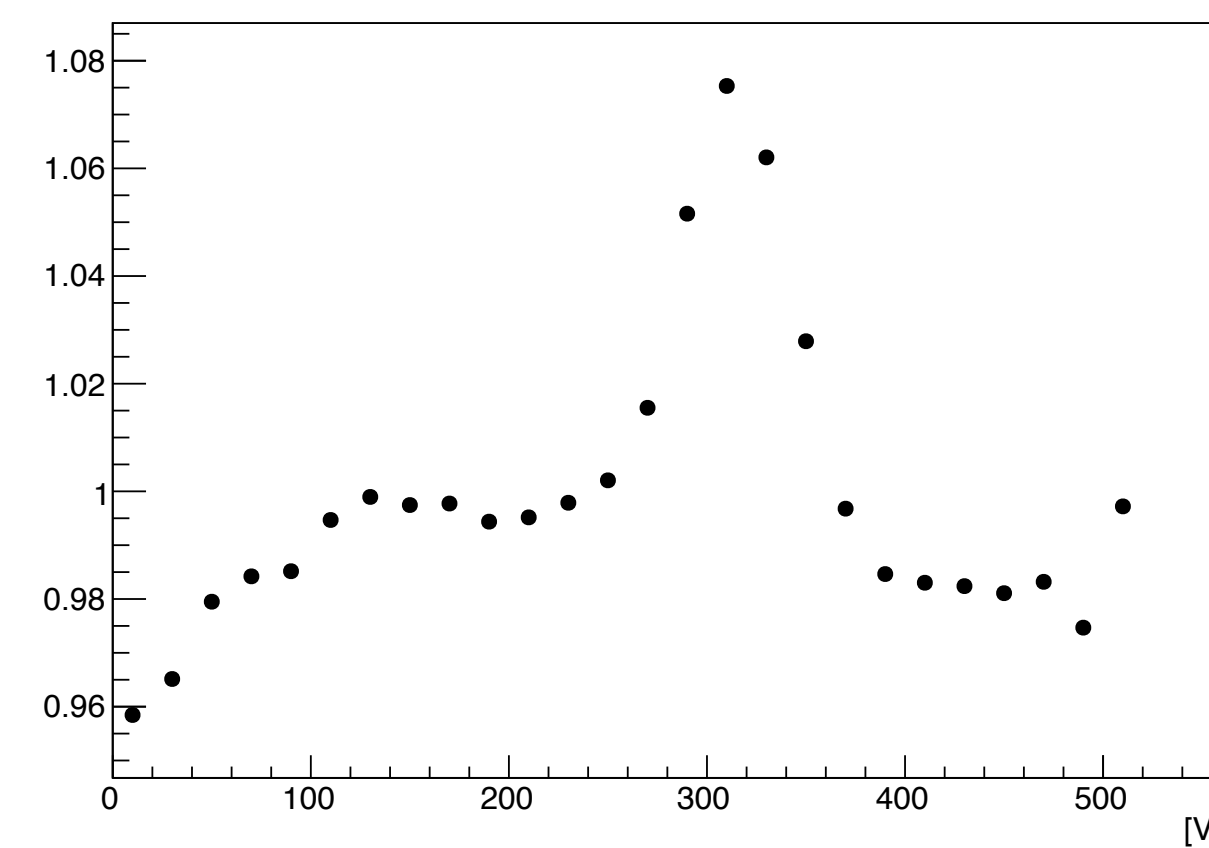
14B1_1/14T2_1



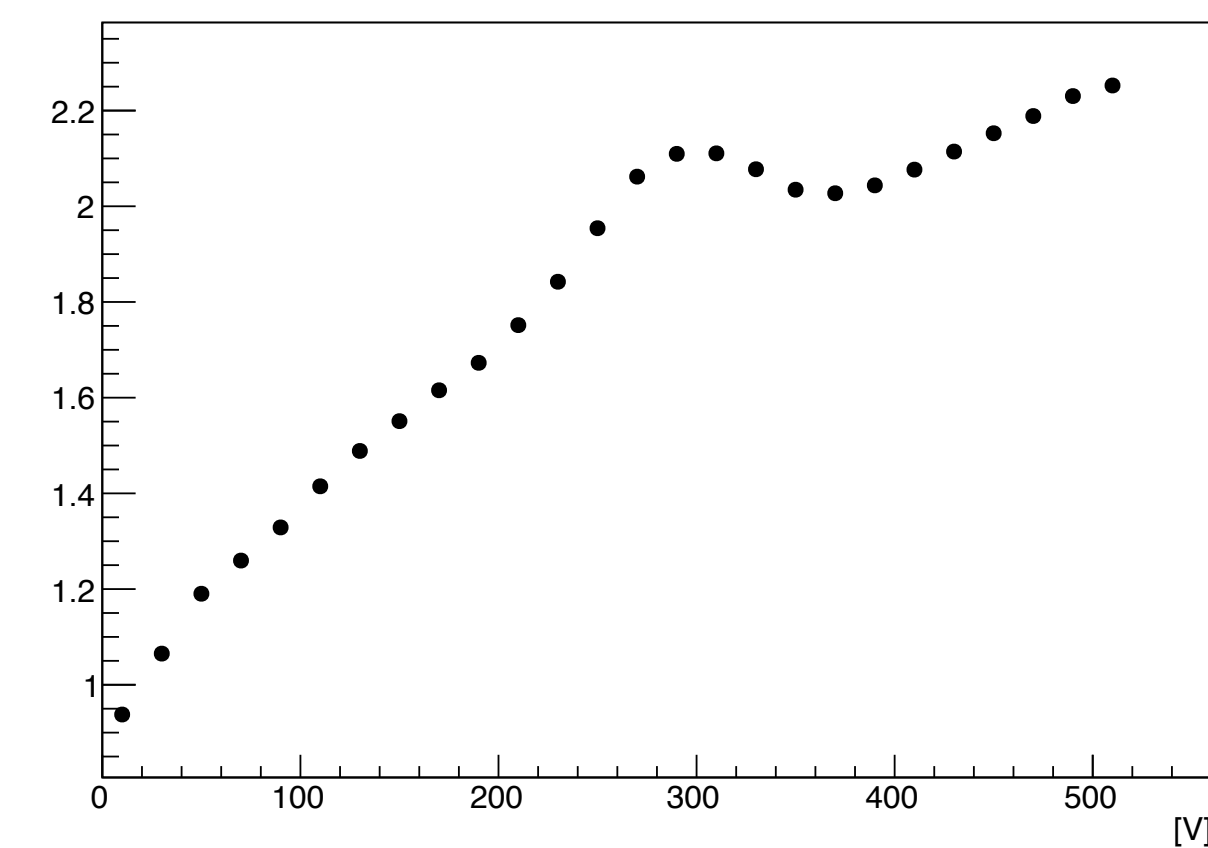
14R1_1/14T2_1



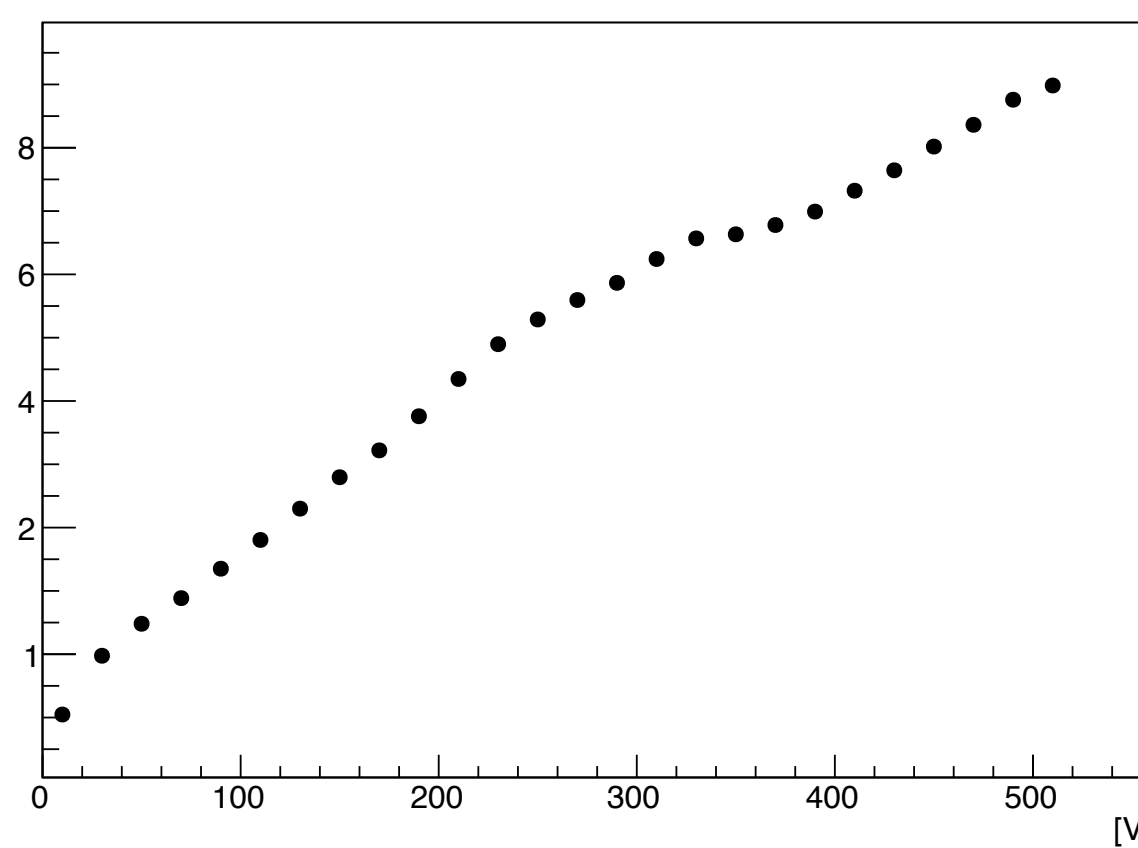
14T1_1/14T2_1



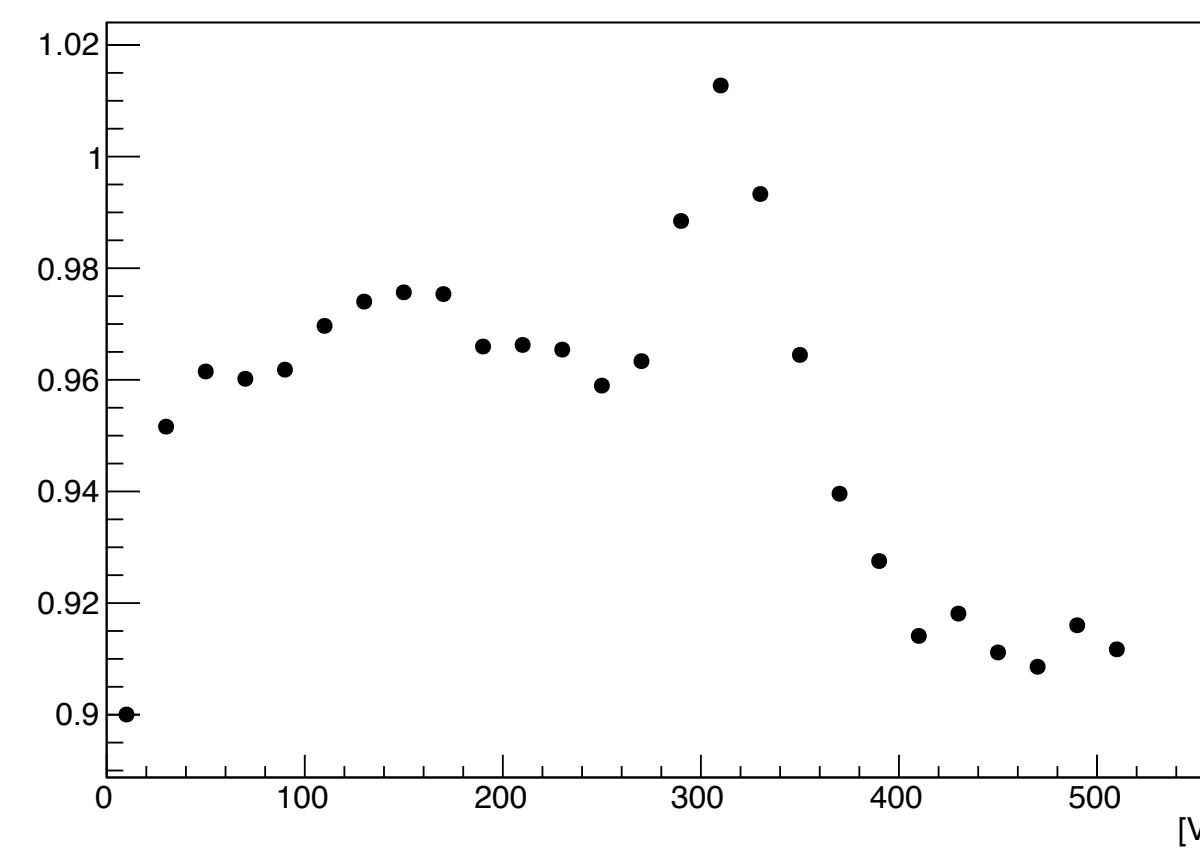
14L1_1/14T2_1



14B2_1/14T2_1



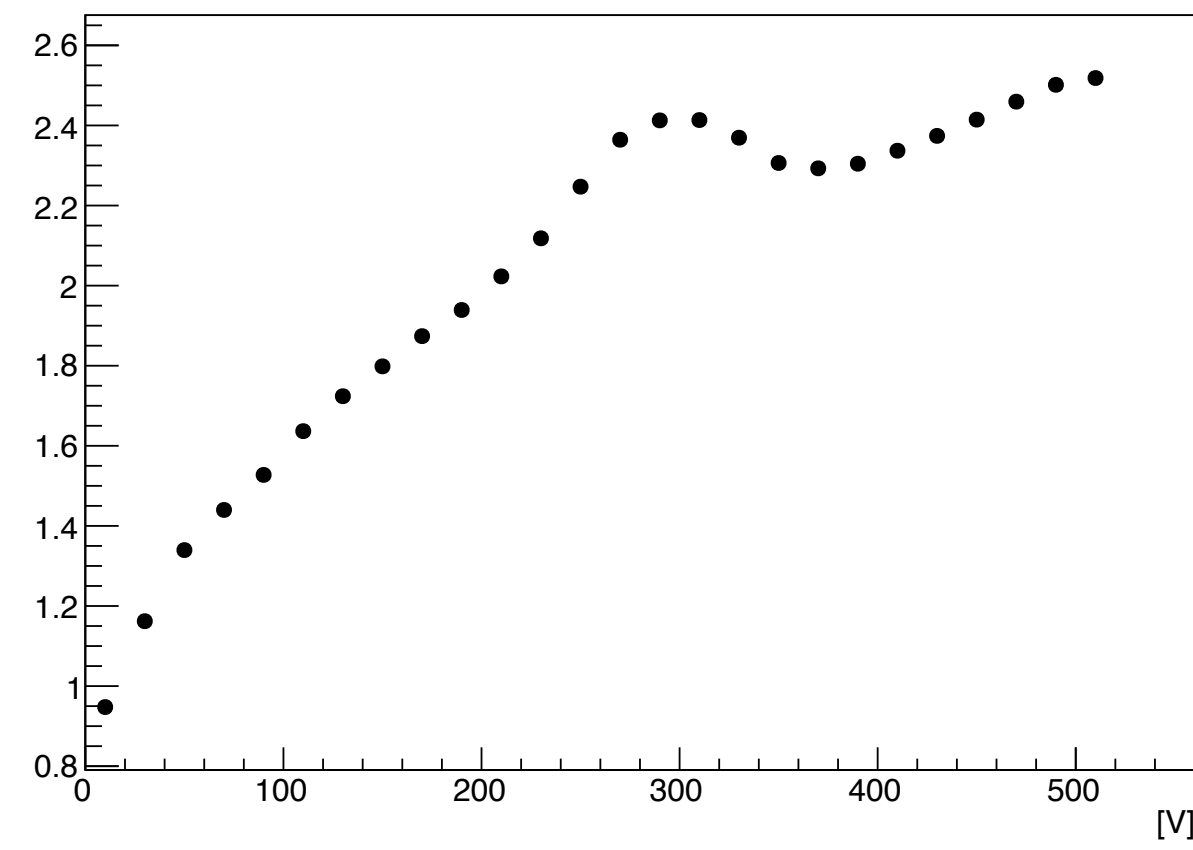
14R2_1/14T2_1



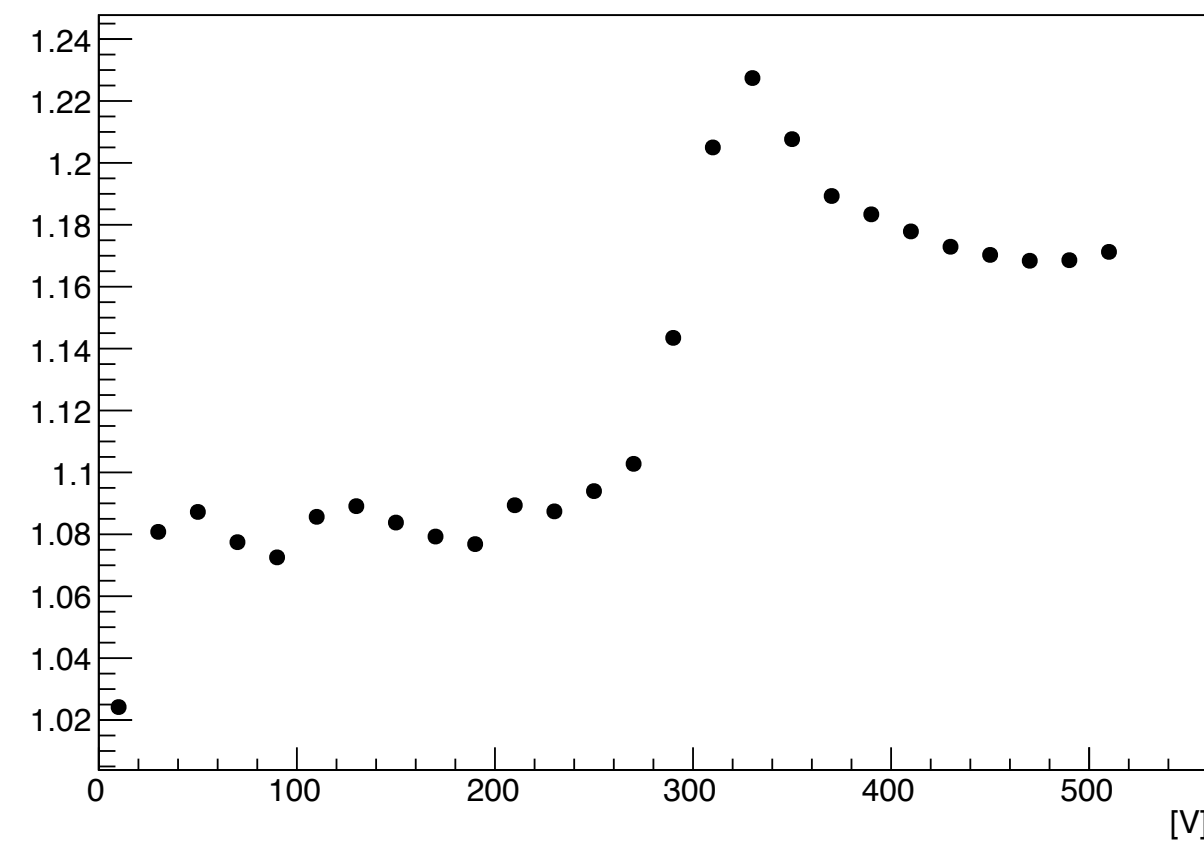
それぞれの結果/14T2の結果

1900 (1cm× 1cm)

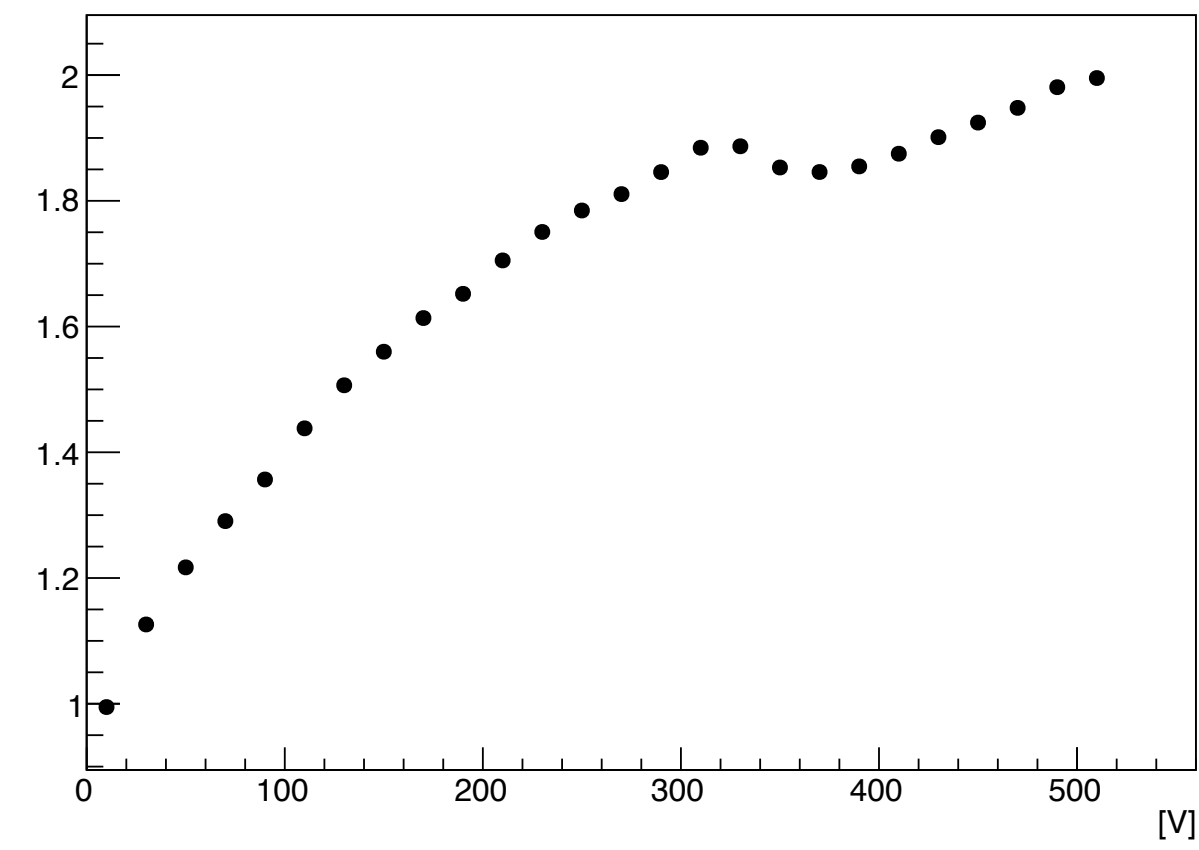
19T1_1/14T2_1



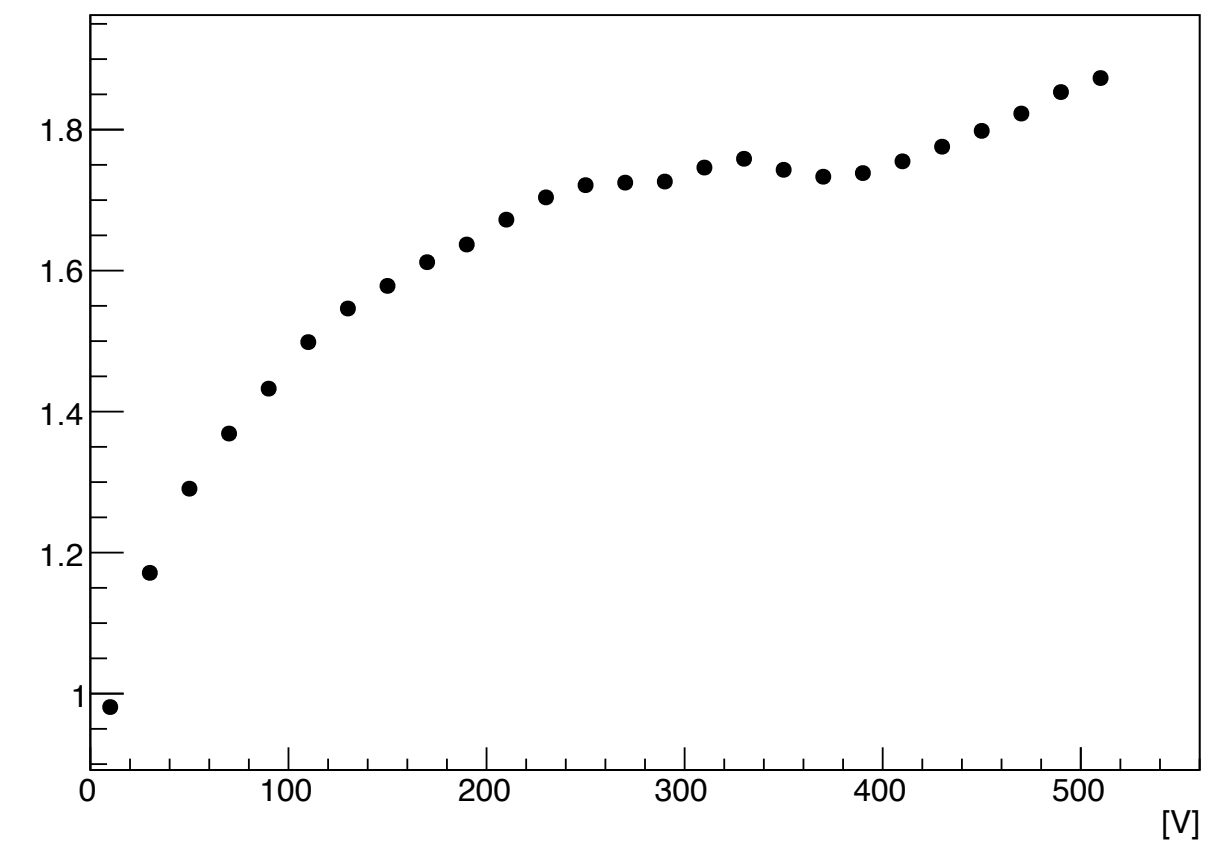
19L1_1/14T2_1



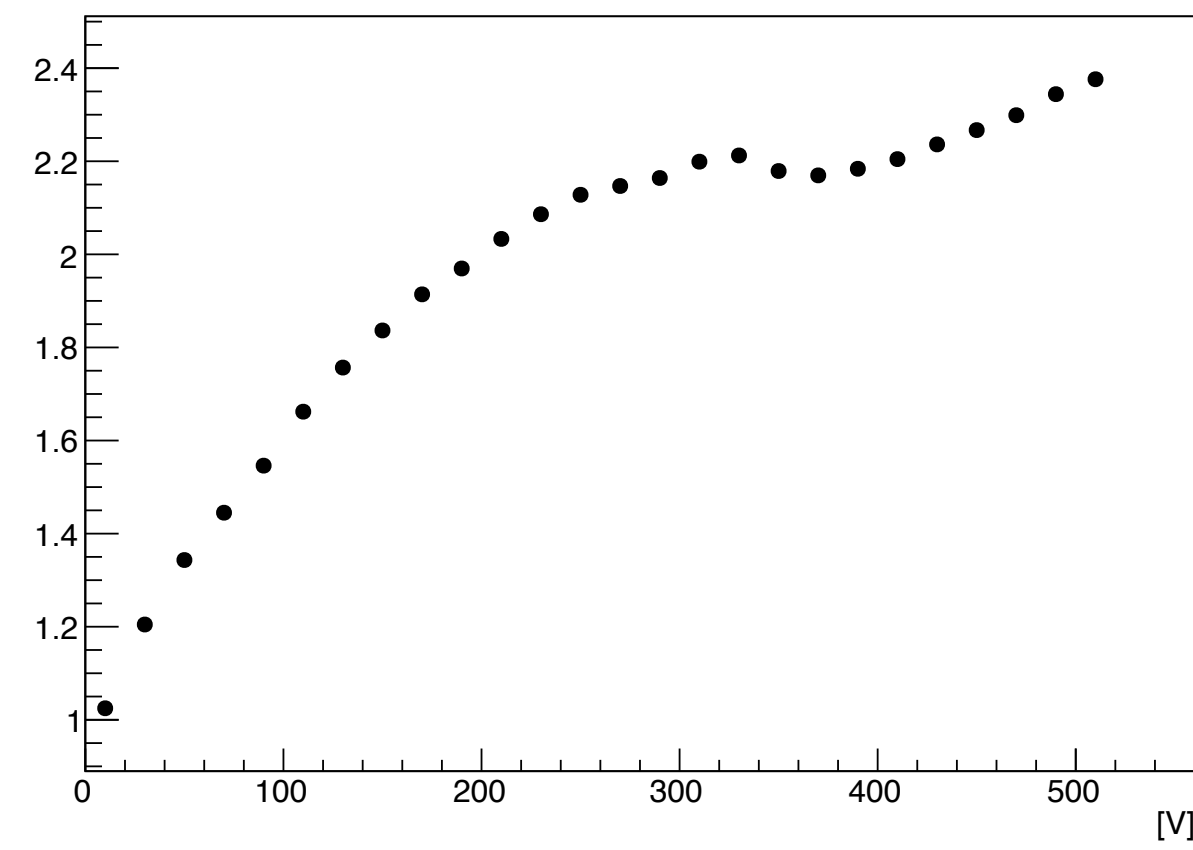
19B1_1/14T2_1



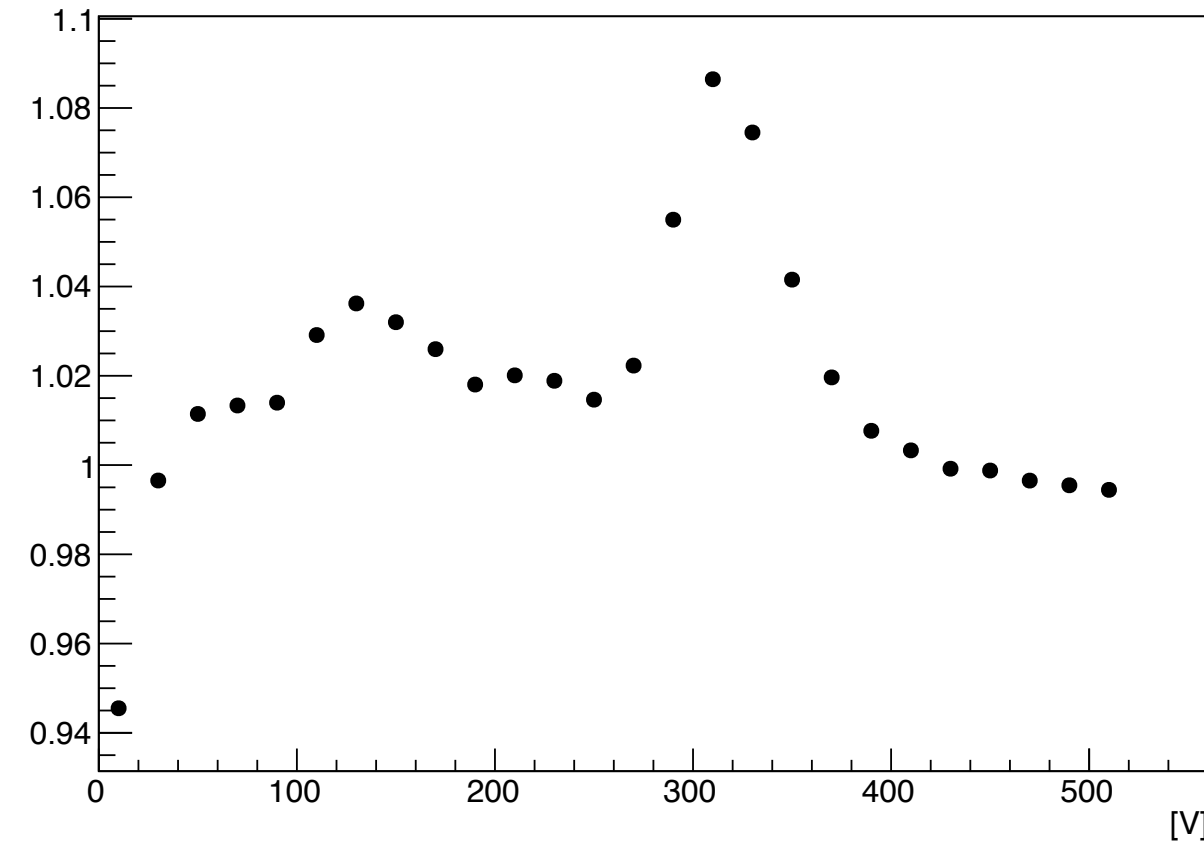
19R1_1/14T2_1



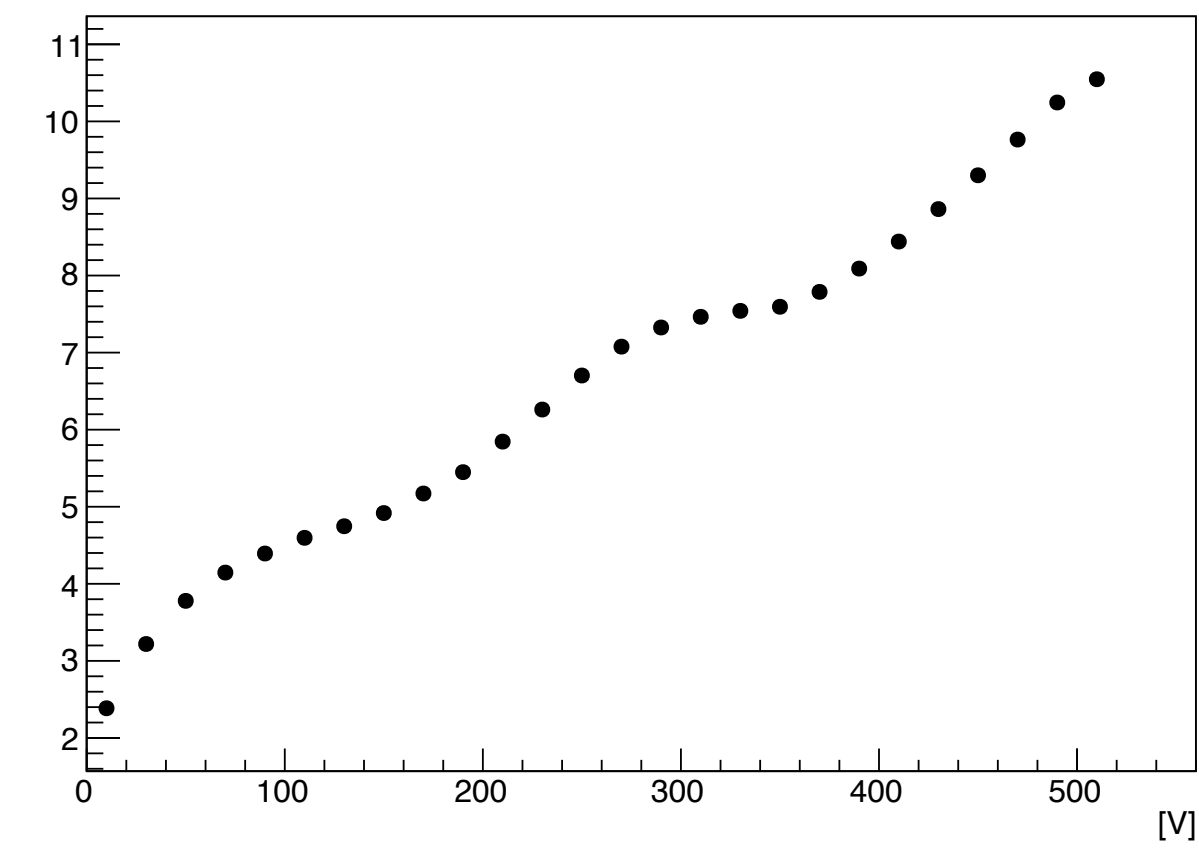
19T2_1/14T2_1



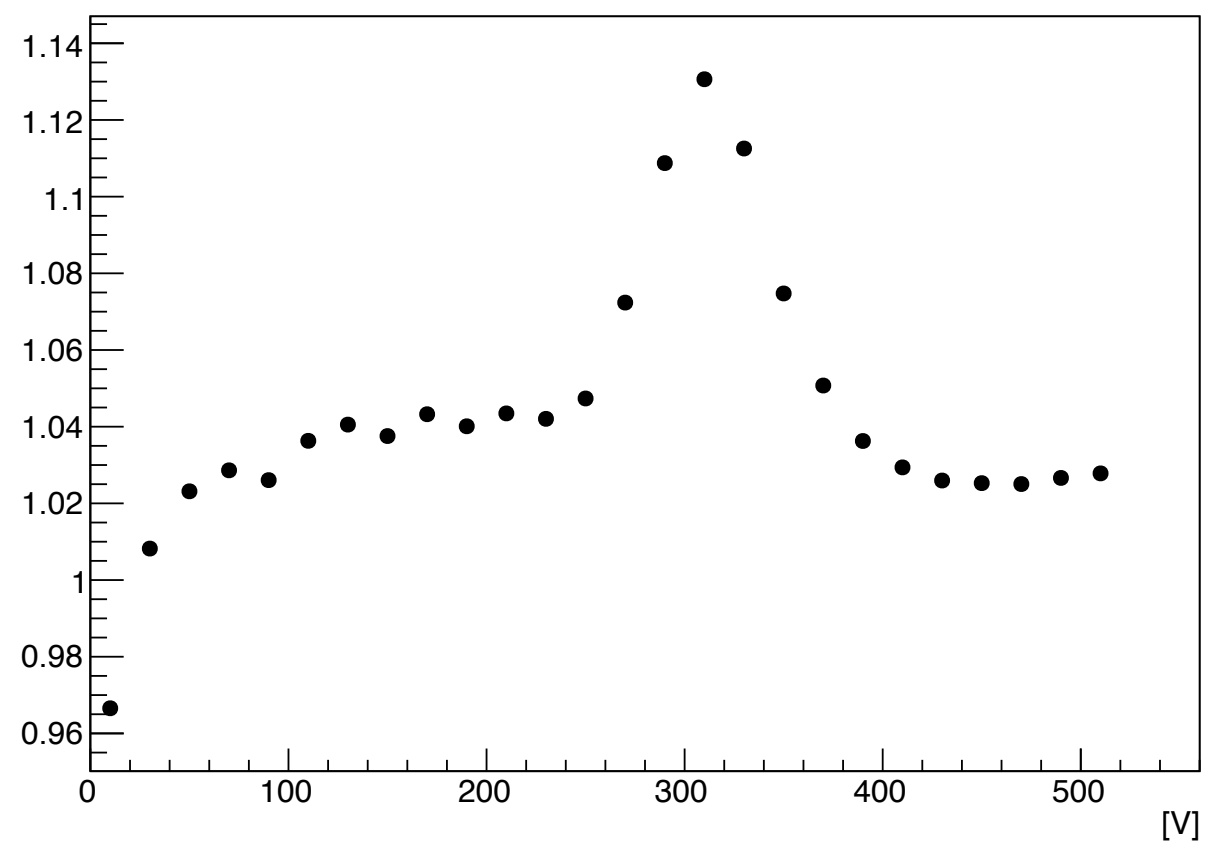
19L2_1/14T2_1



19B2_1/14T2_1



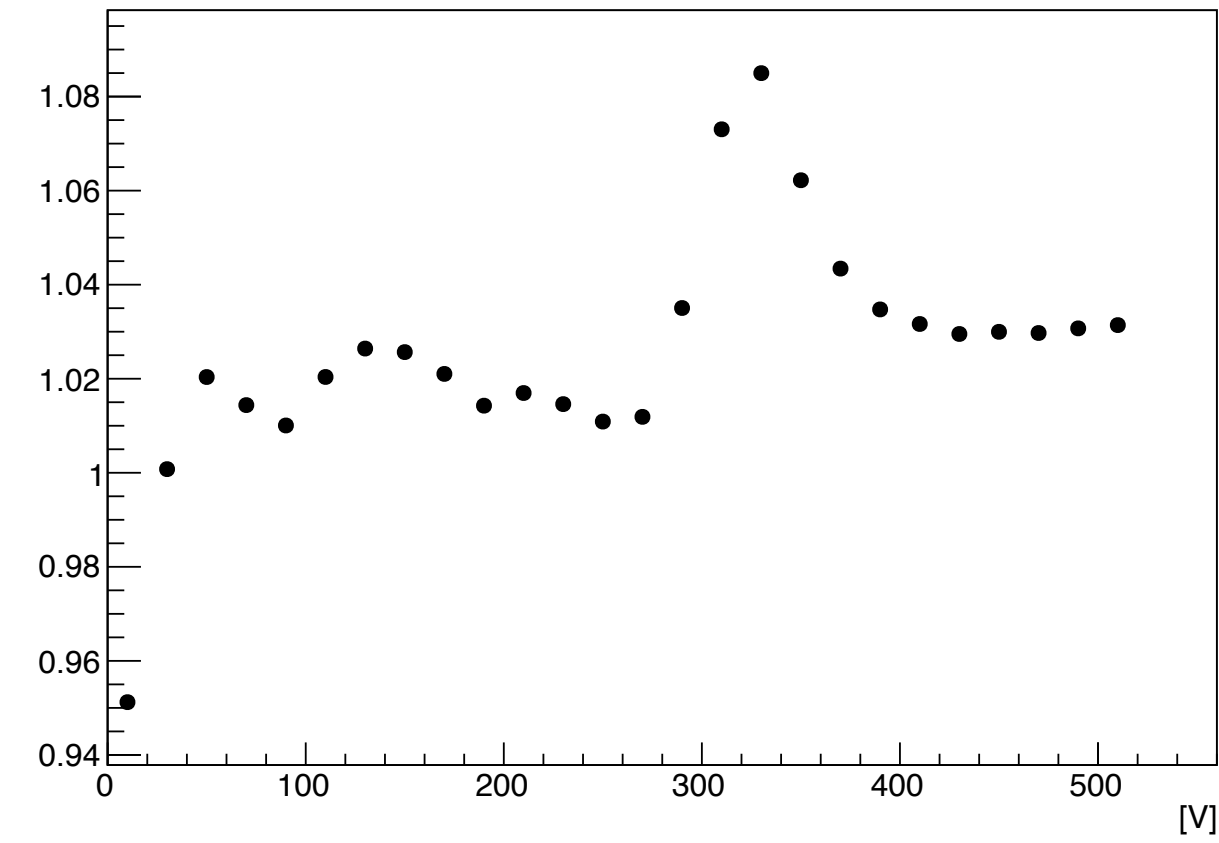
19R2_1/14T2_1



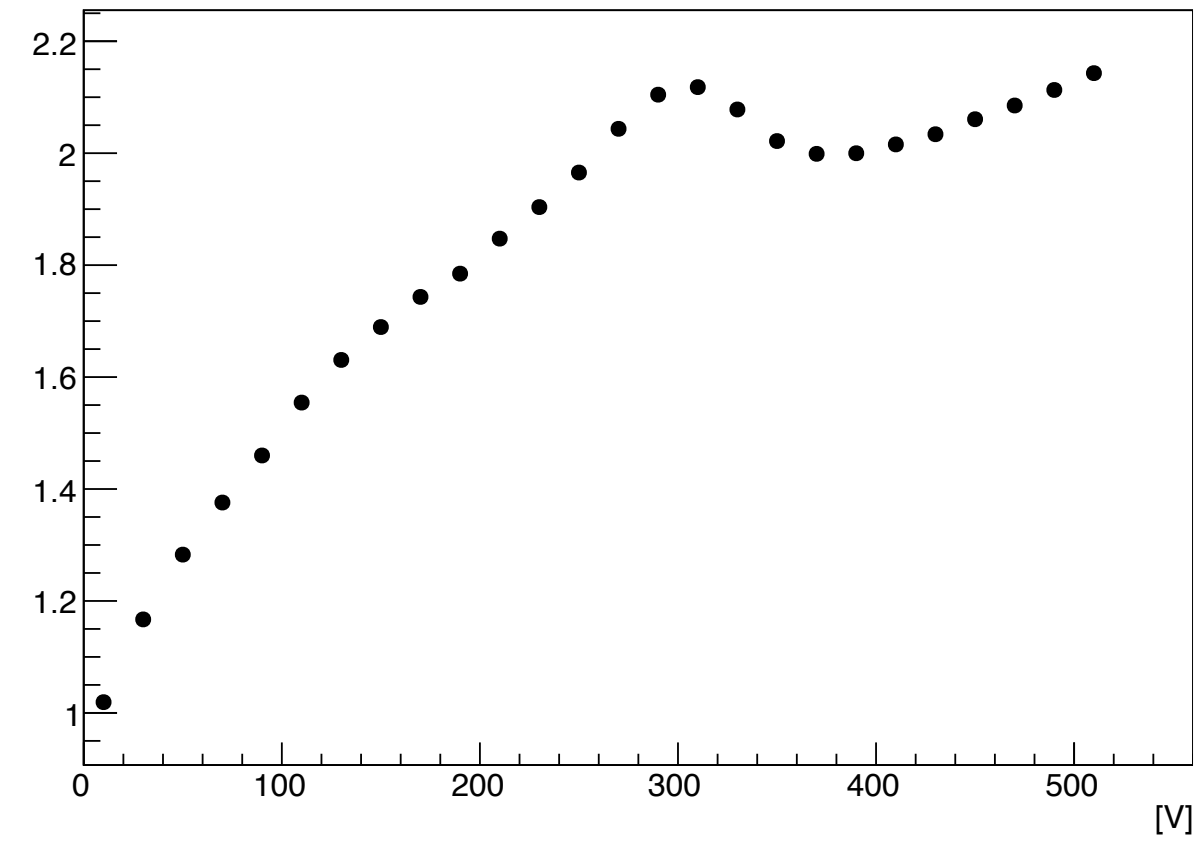
それぞれの結果/14T2の結果

2800 (1cm× 1cm)

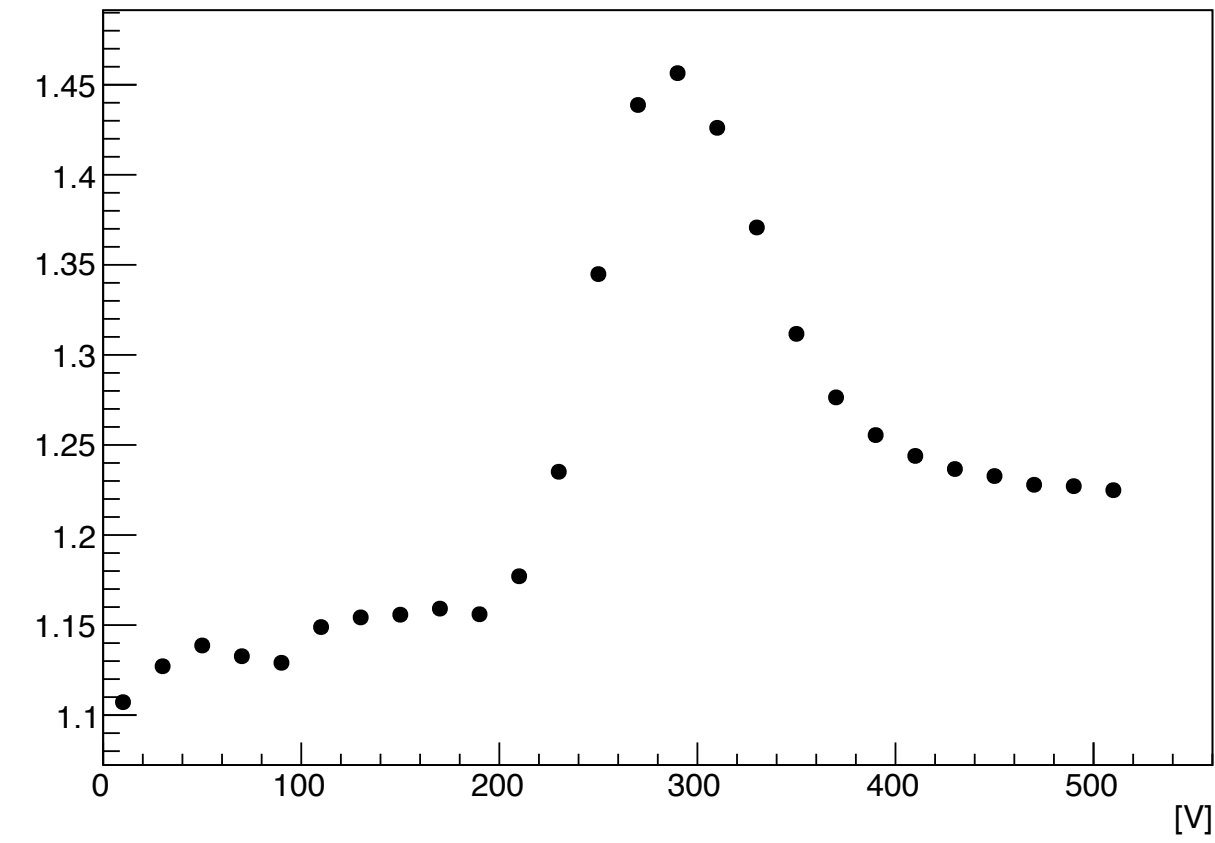
28T1_1/14T2_1



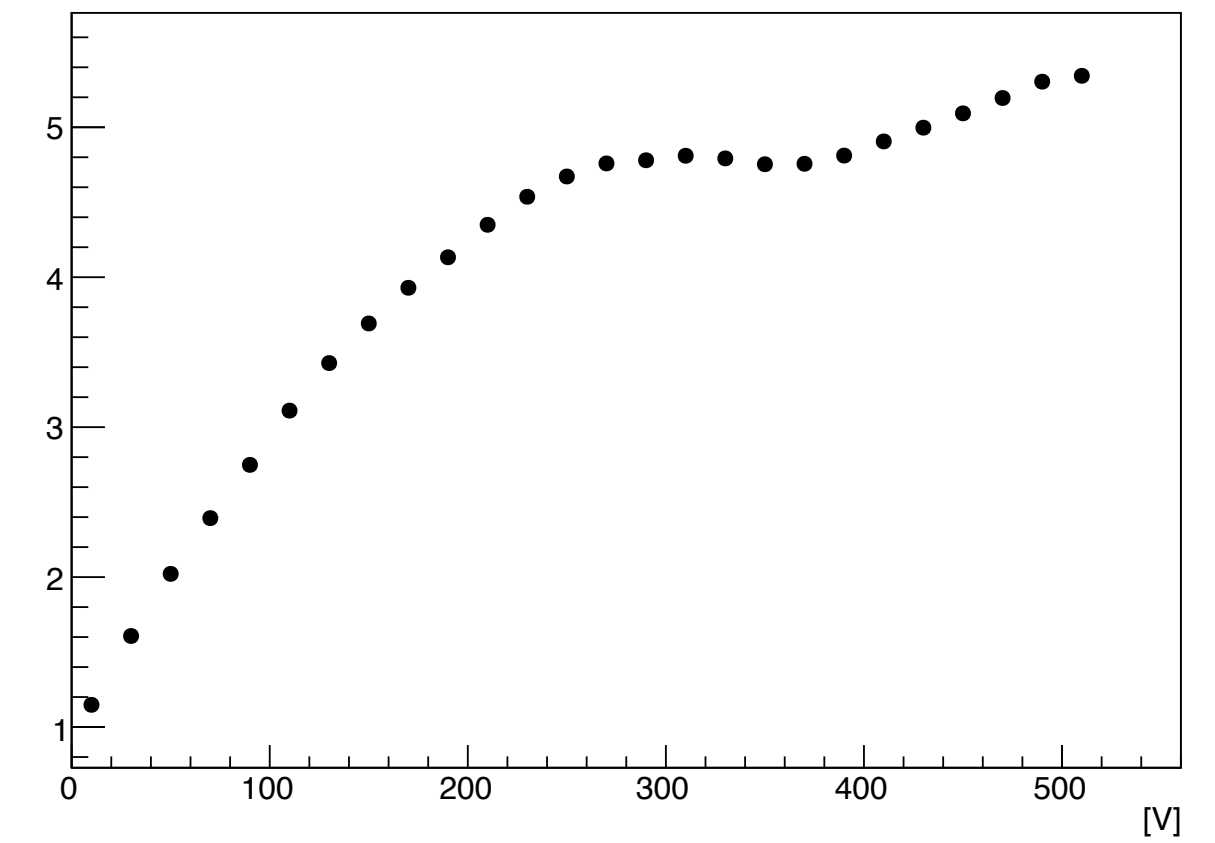
28L1_1/14T2_1



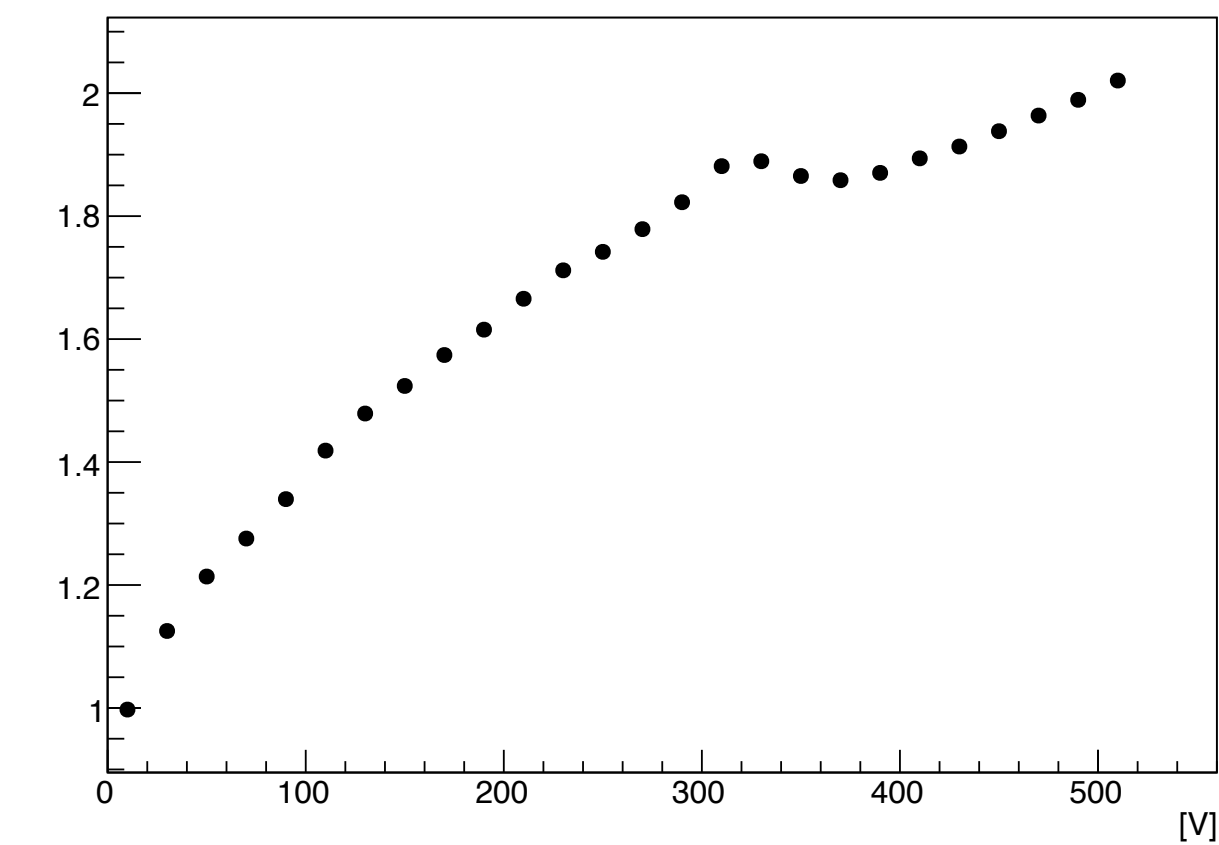
28B1_1/14T2_1



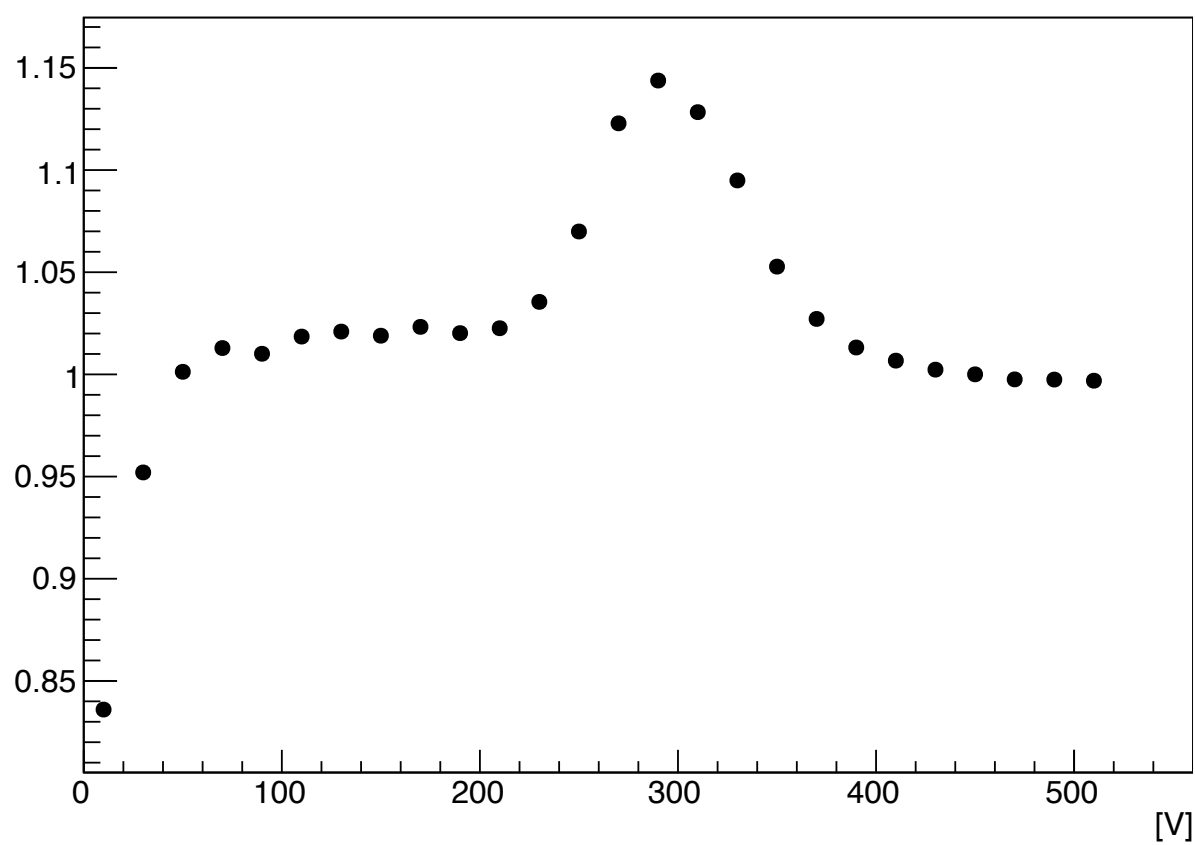
28R1_1/14T2_1



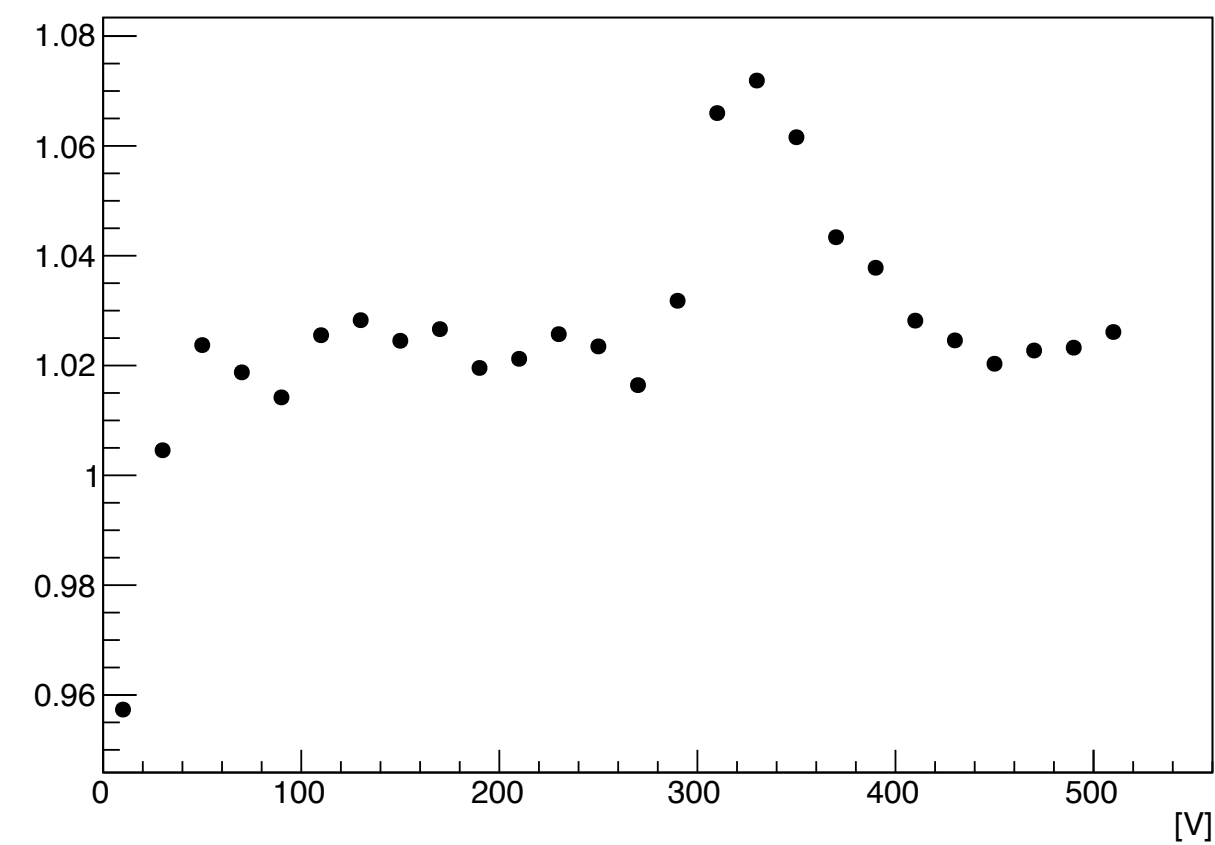
28T2_1/14T2_1



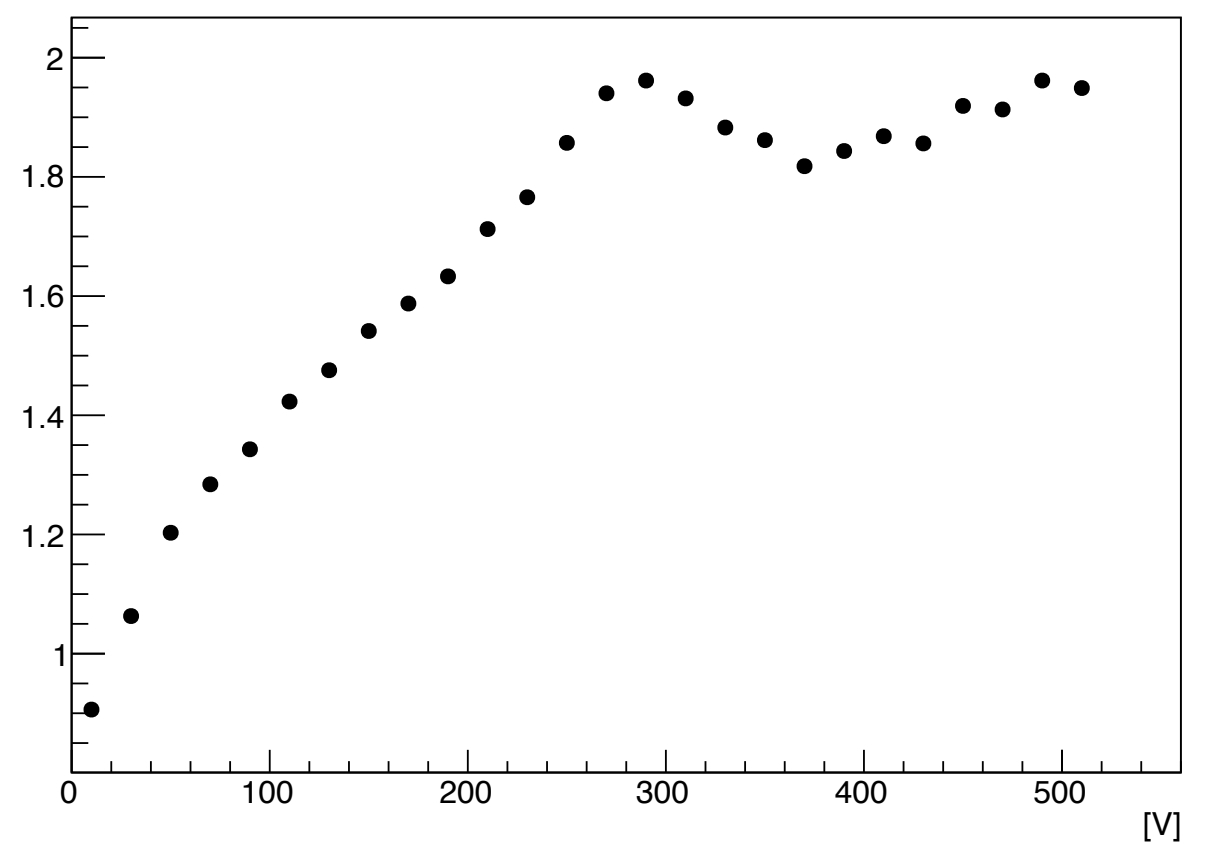
28L2_1/14T2_1



28B2_1/14T2_1



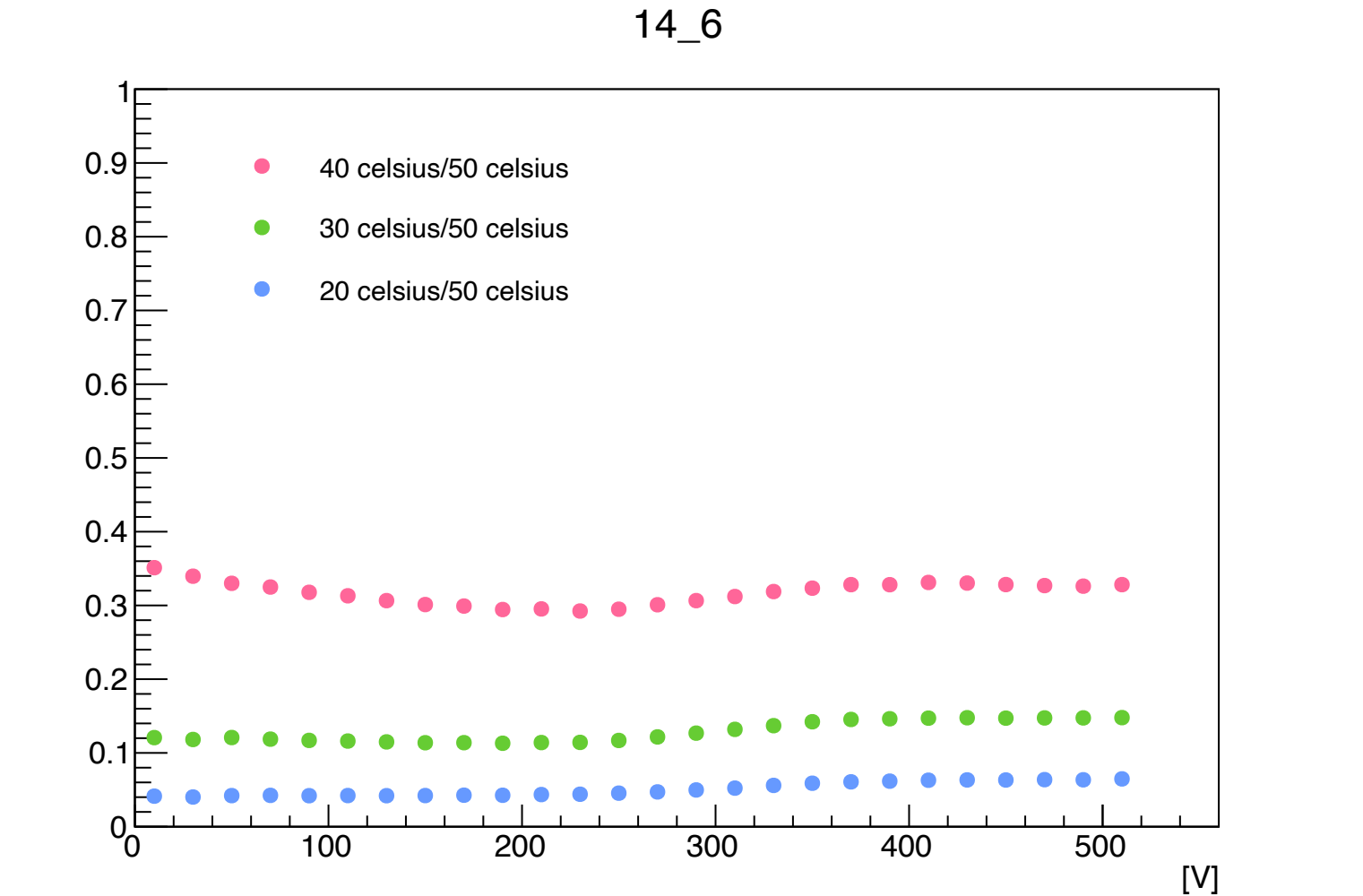
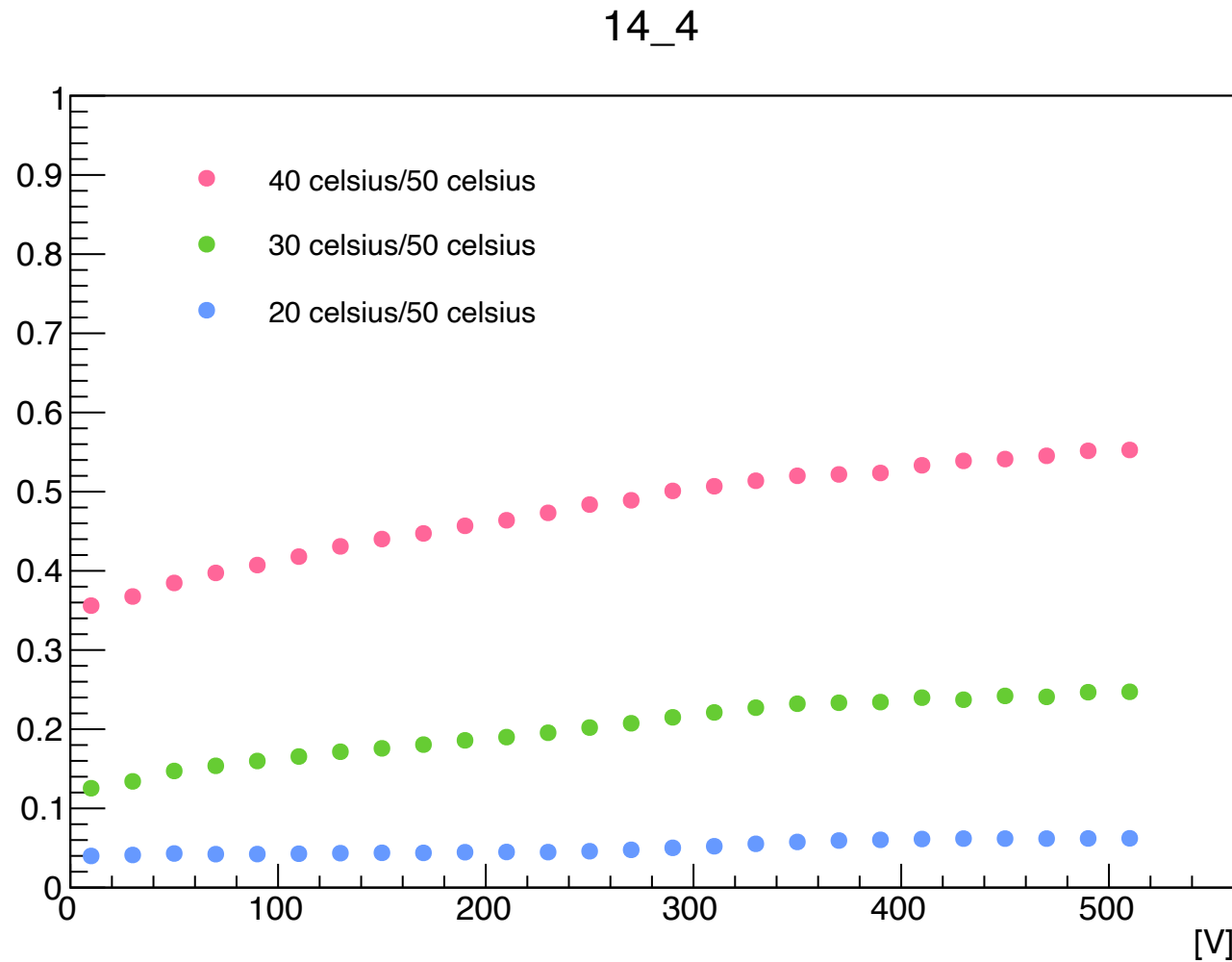
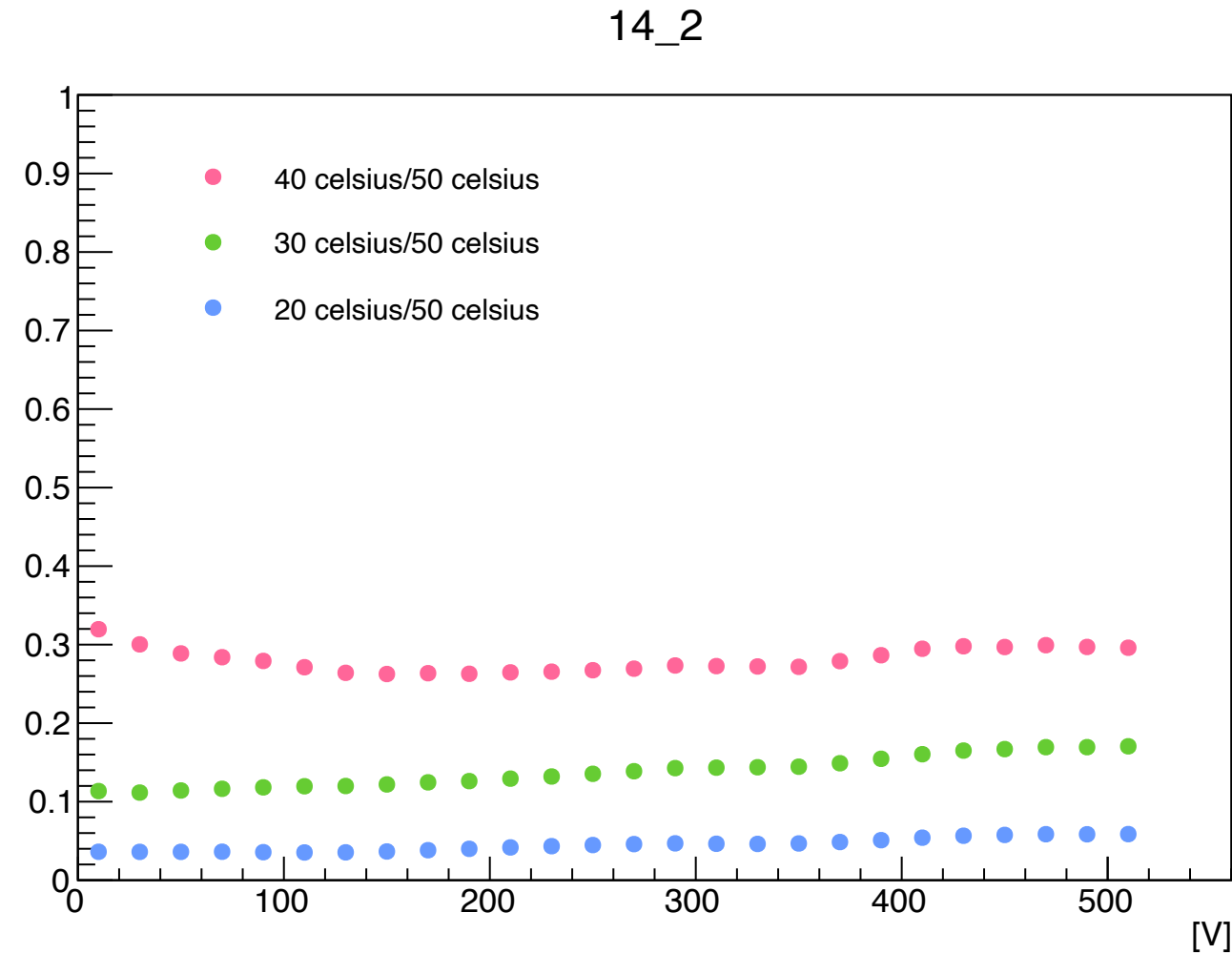
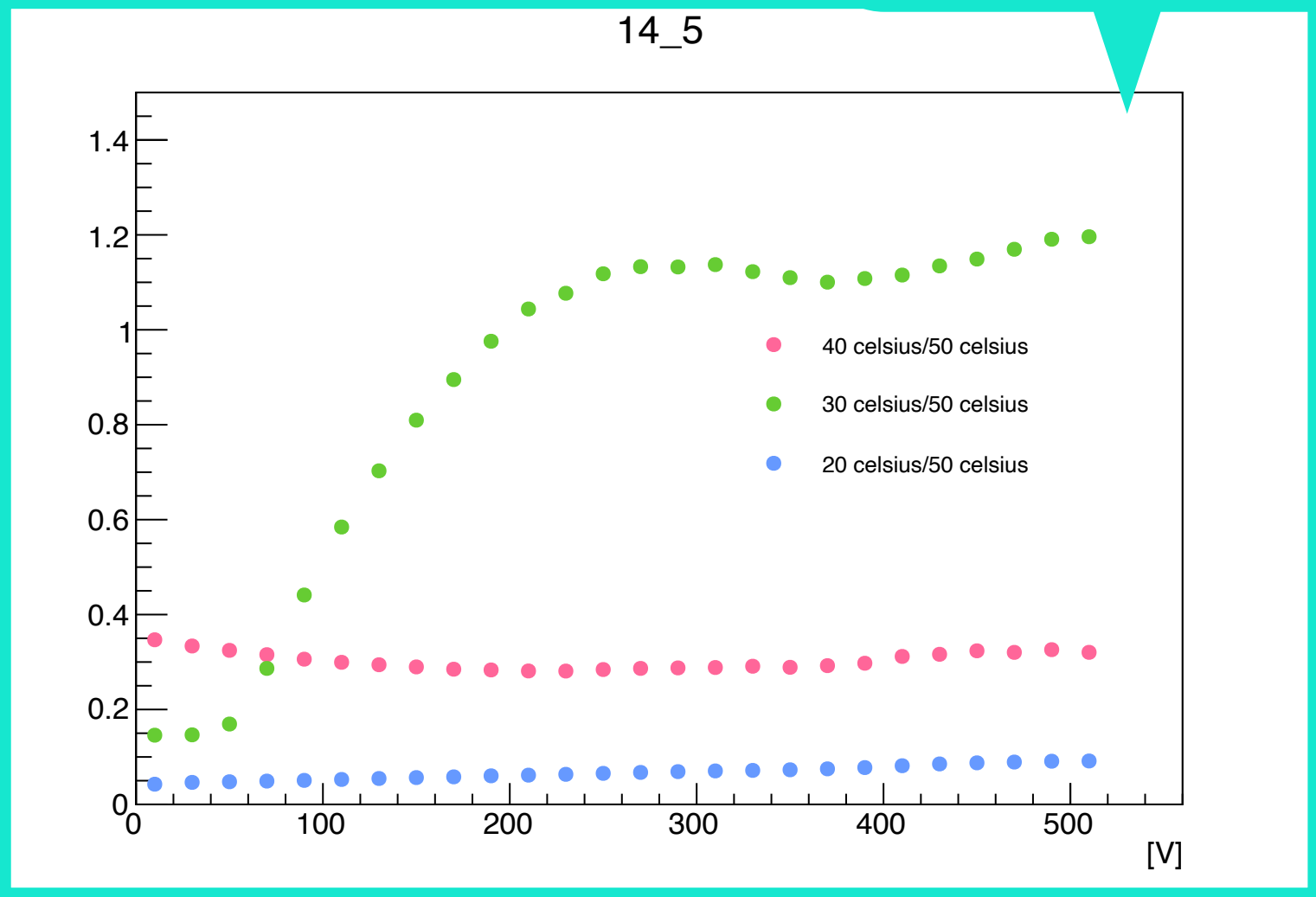
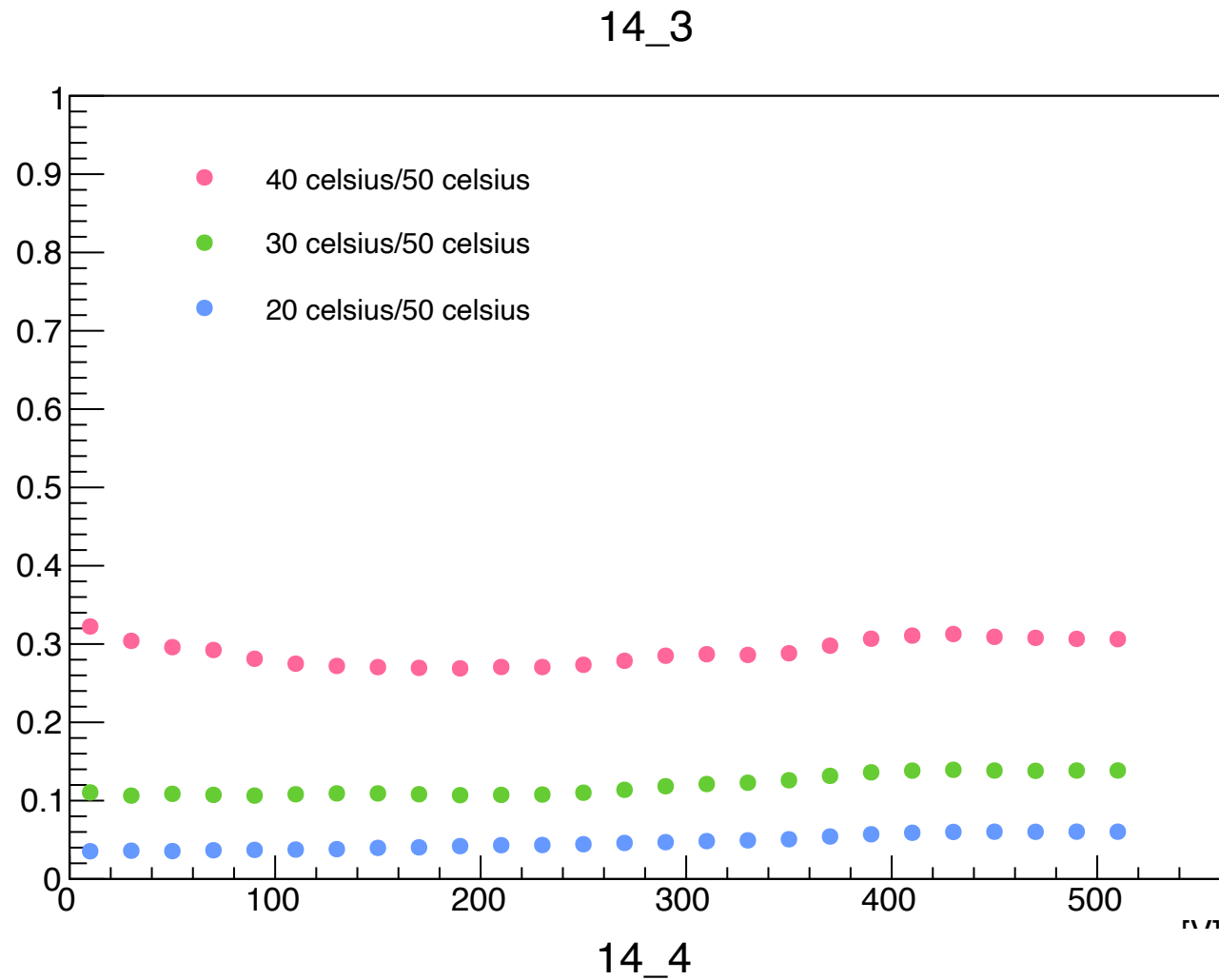
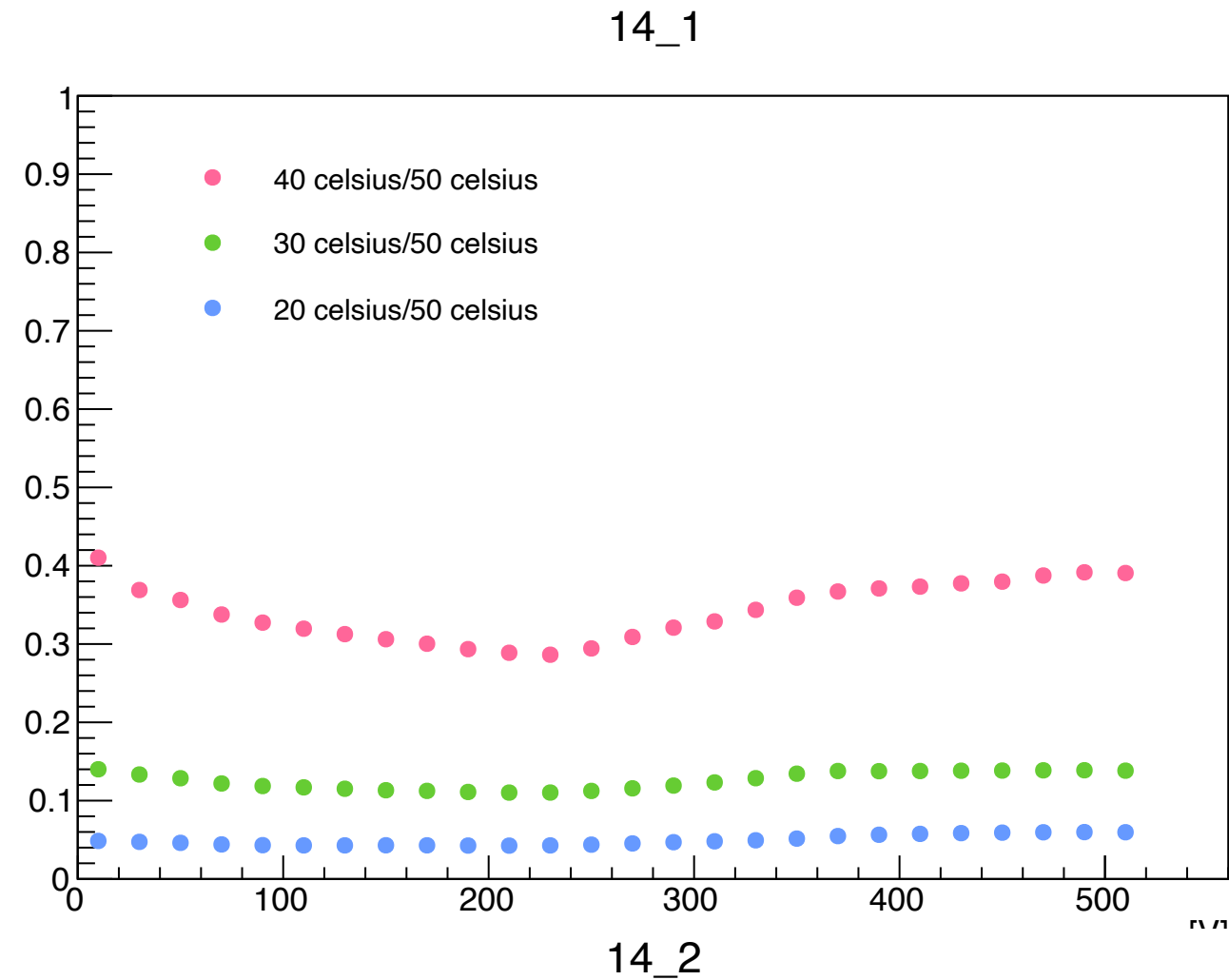
28R2_1/14T2_1



(20,30,40°Cの結果)/50°Cの結果

縦軸1.5倍

14 (2cm x 2cm)

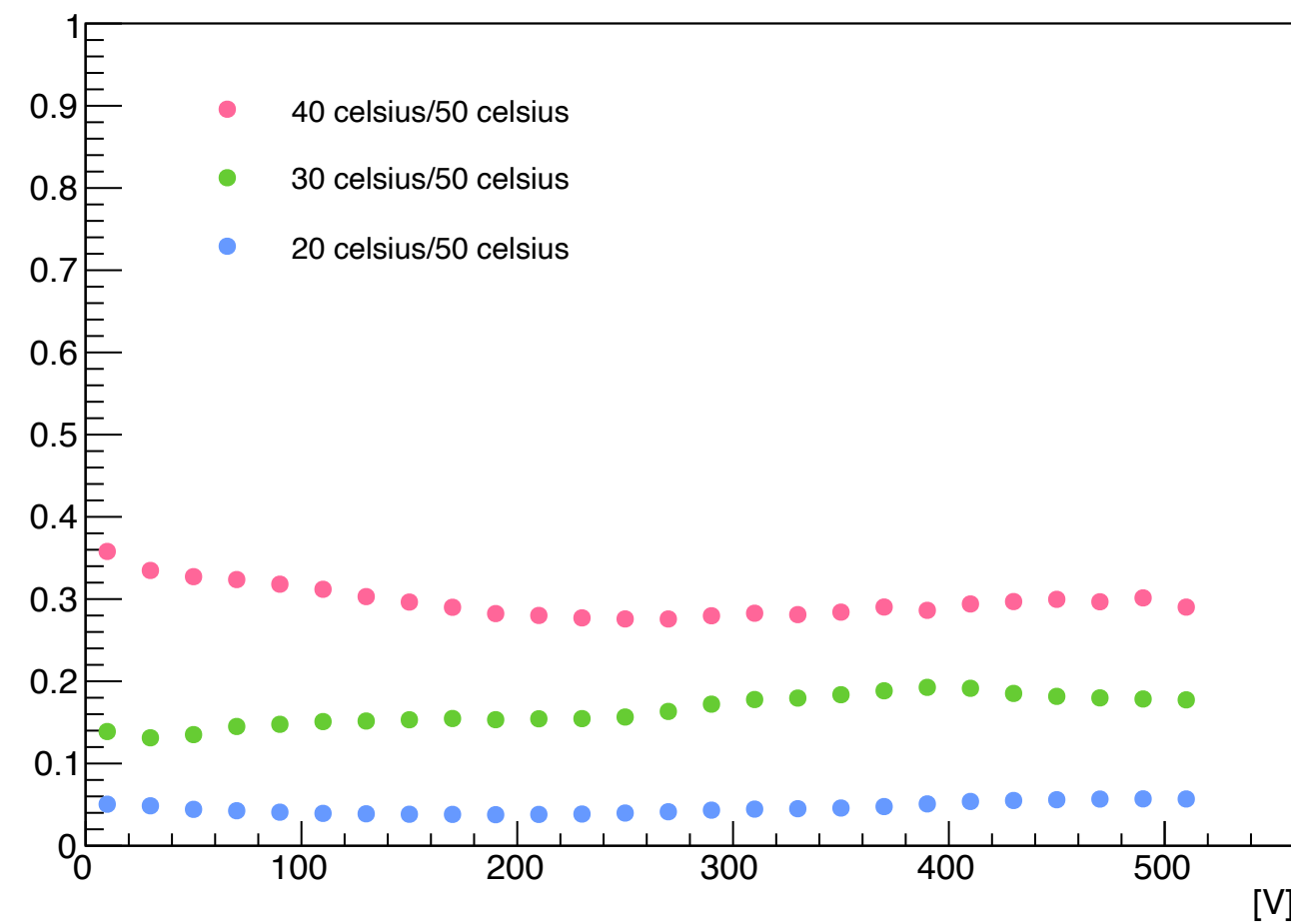


(20,30,40°Cの結果)/50°Cの結果

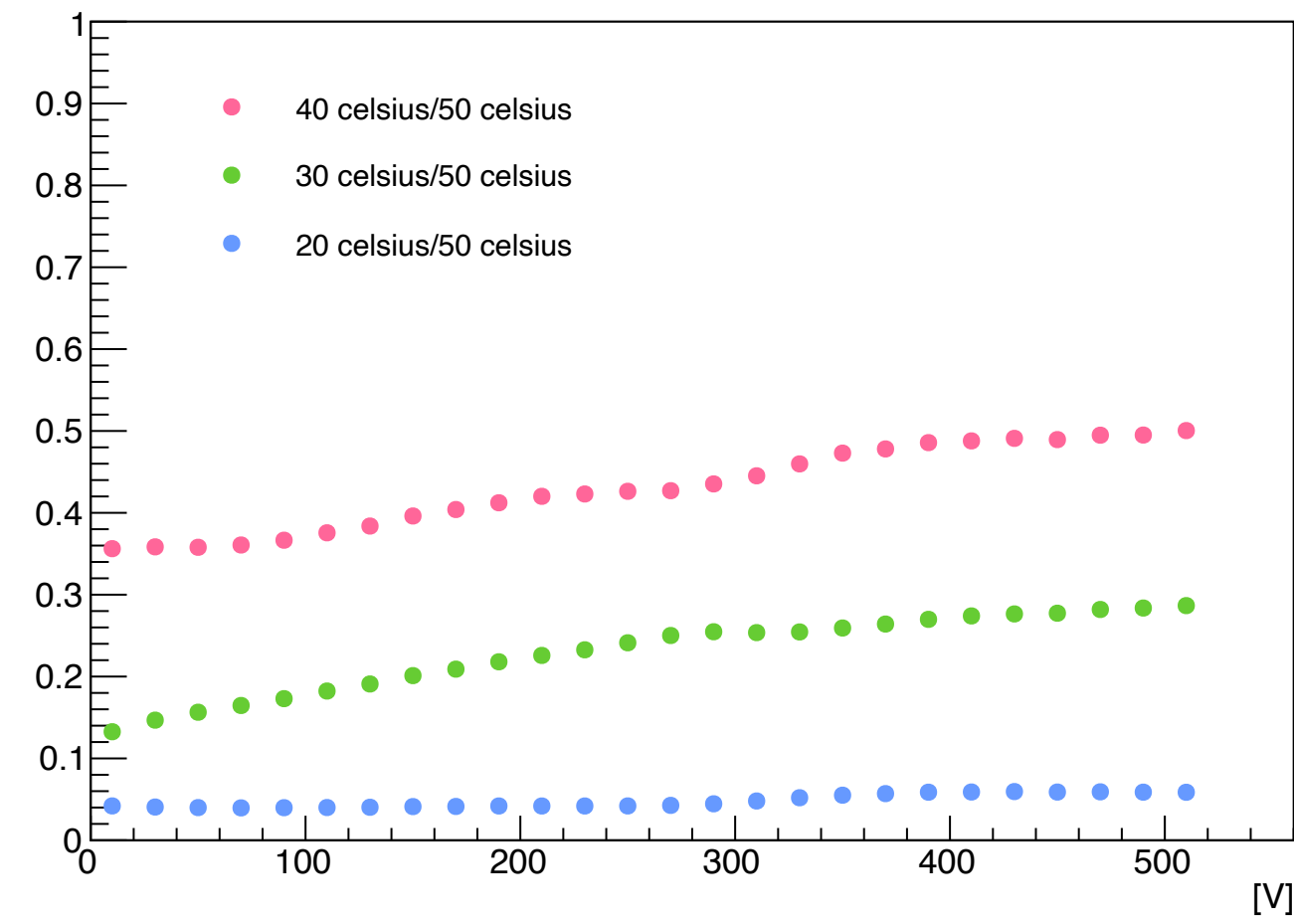
19 (2cm× 2cm)

縦軸 2倍

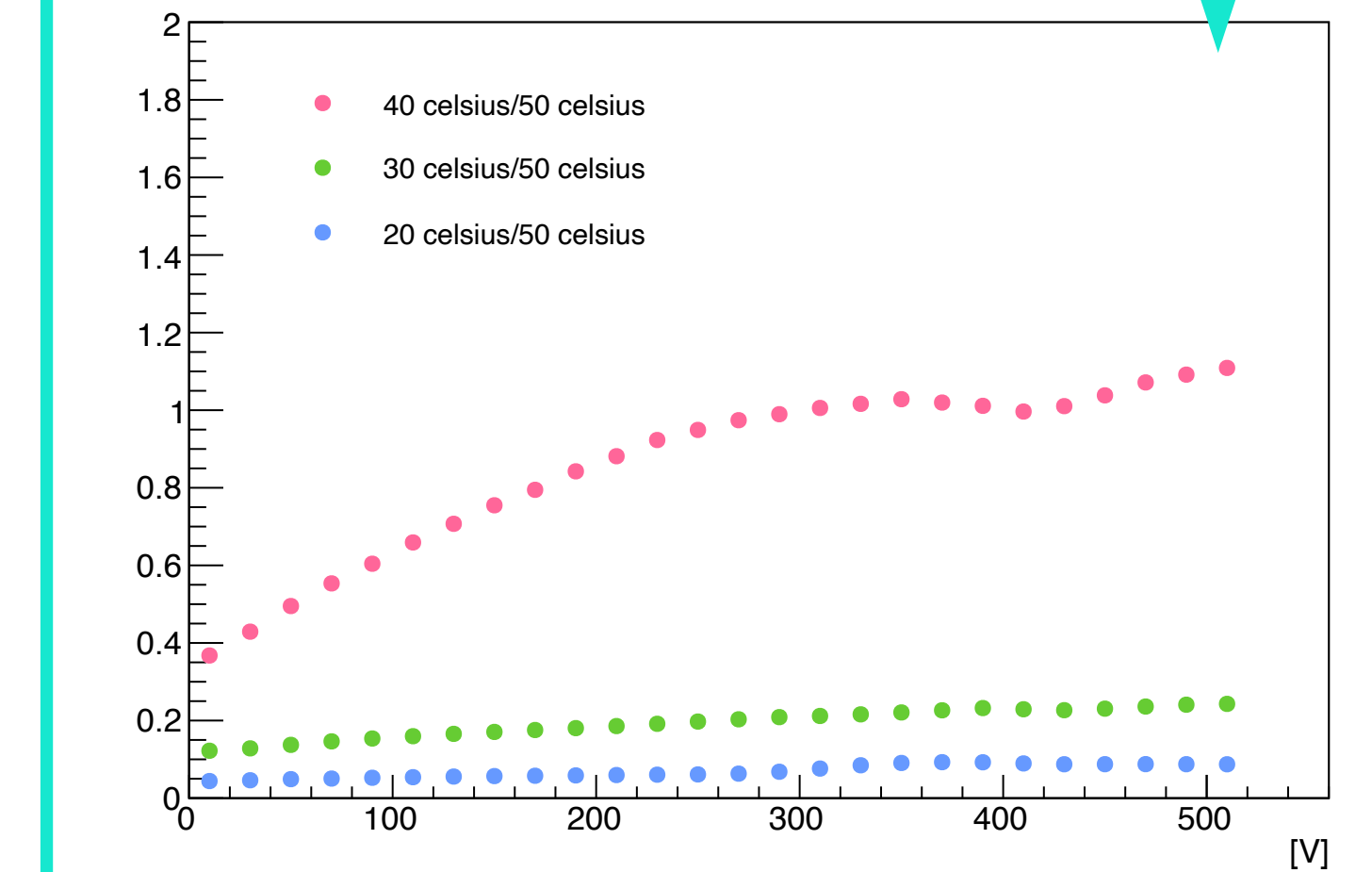
19_1



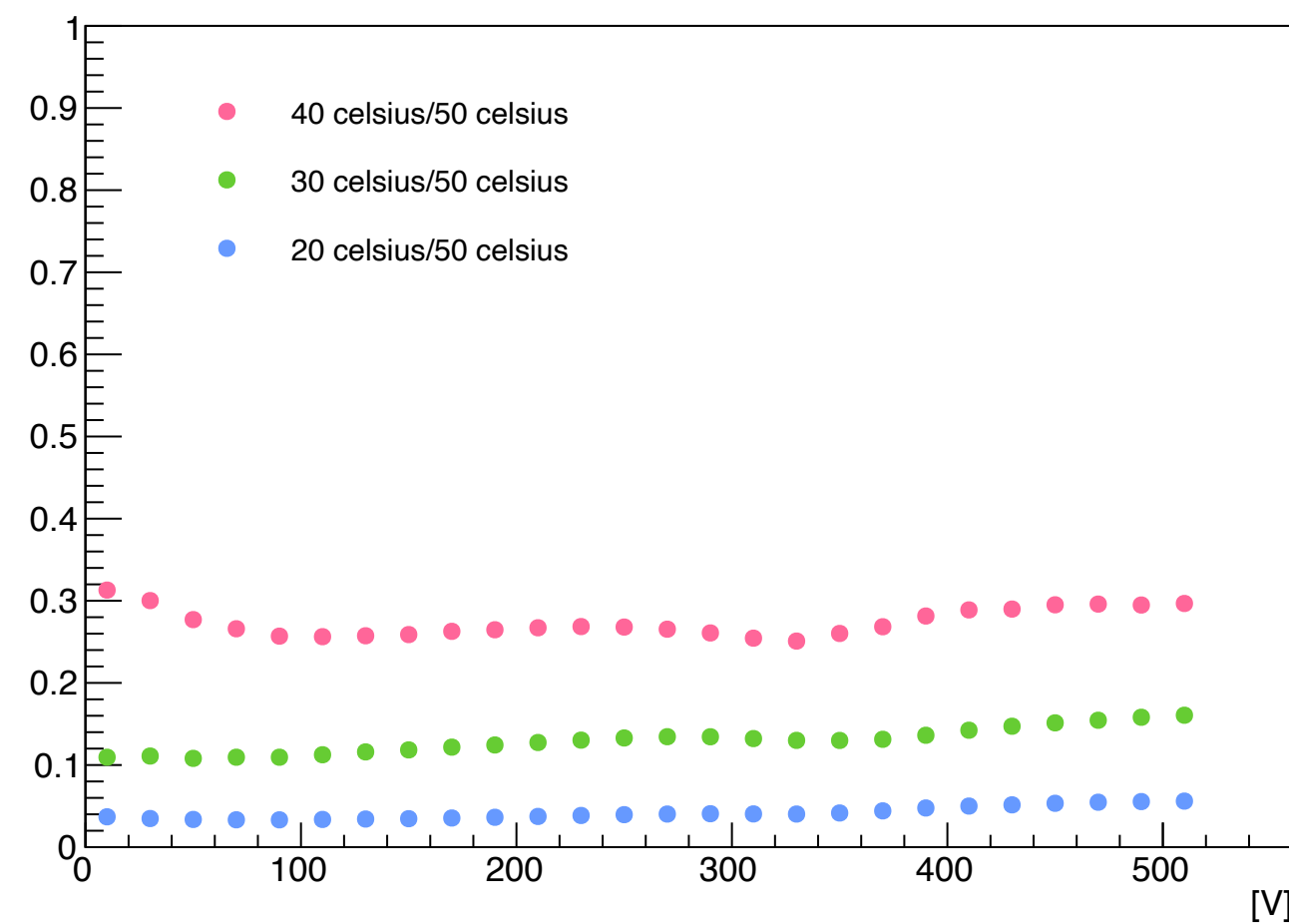
19_3



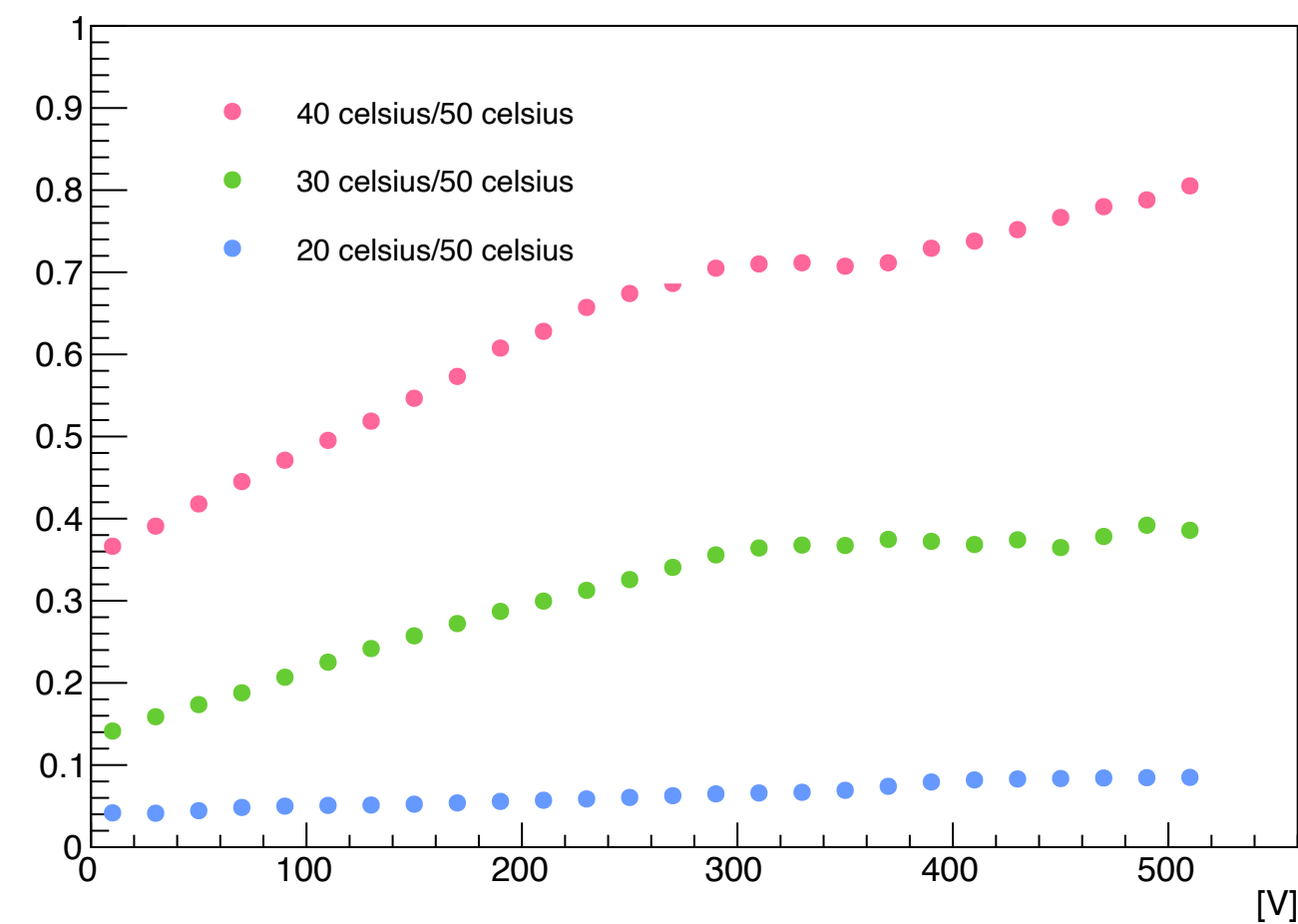
19_5



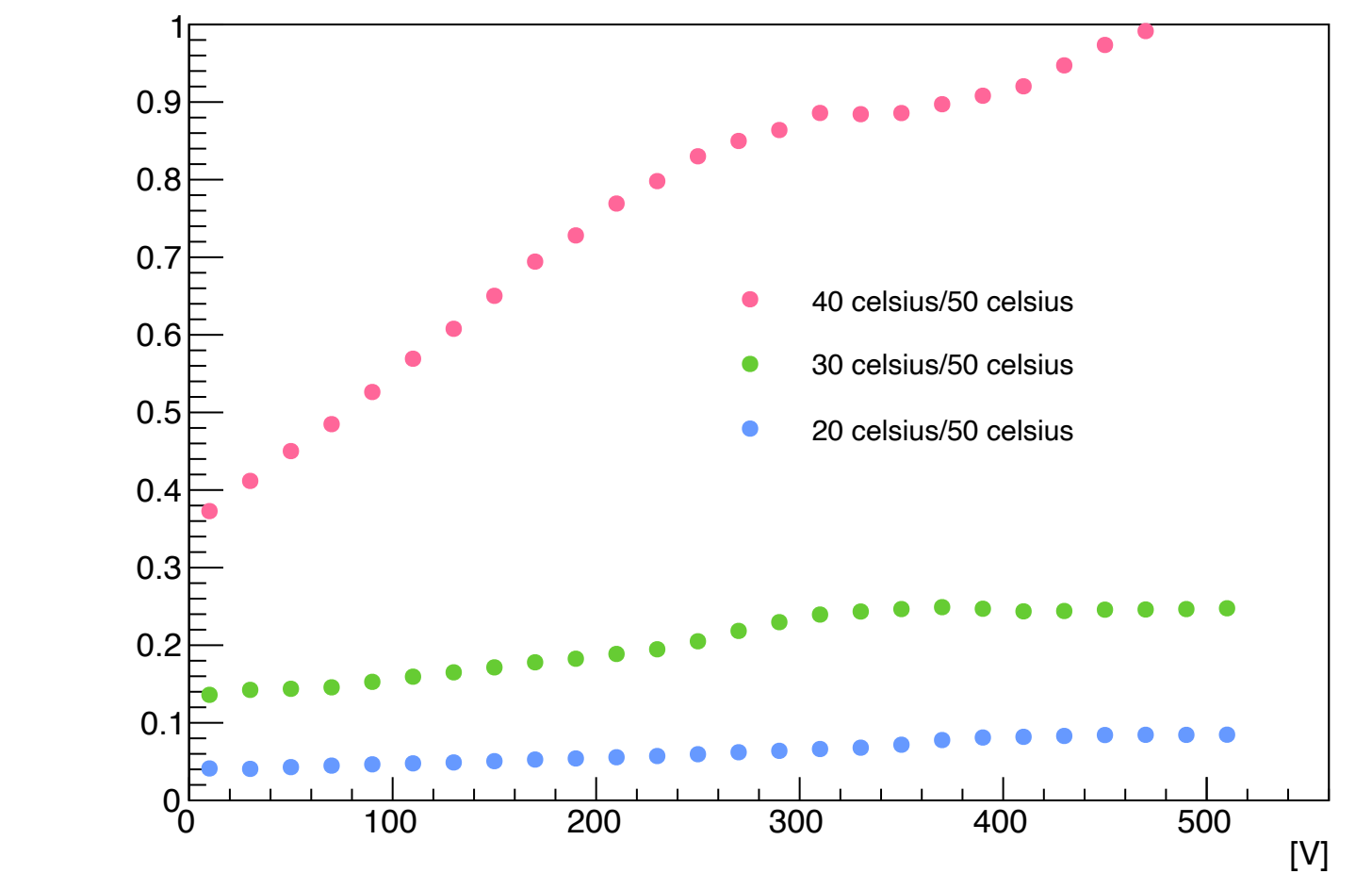
19_2



19_4



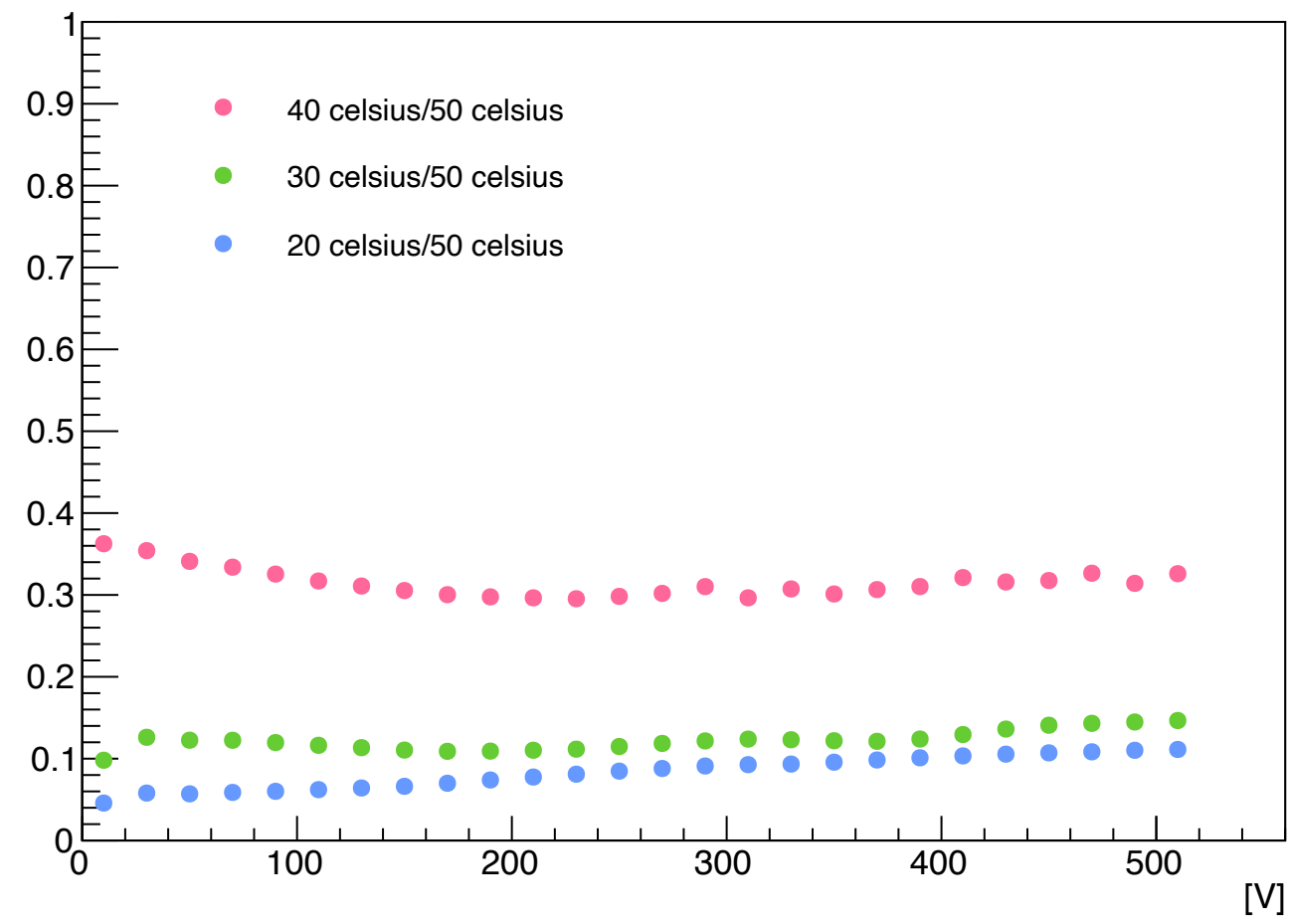
19_6



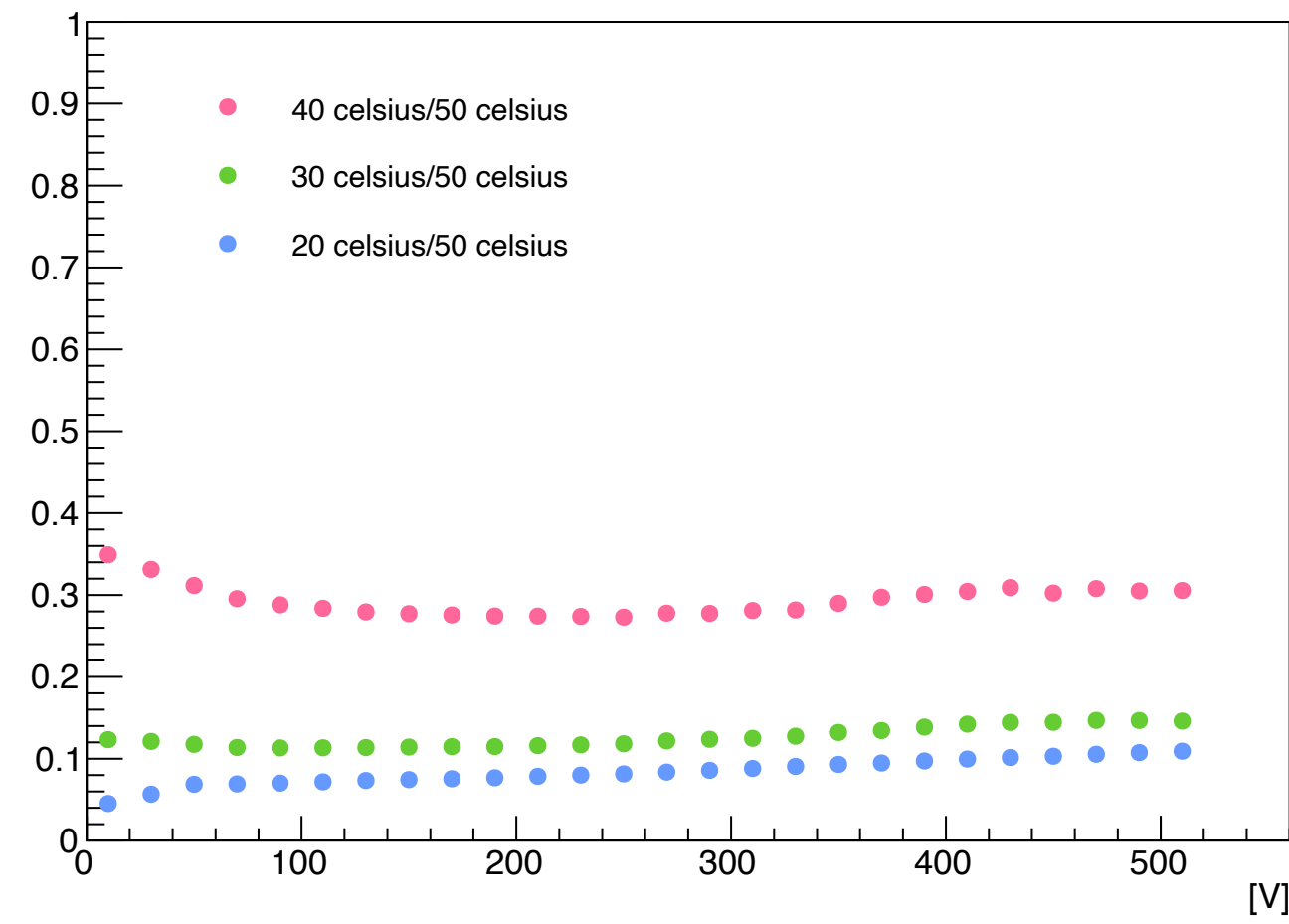
(20,30,40°Cの結果)/50°Cの結果

28 (2cm× 2cm)

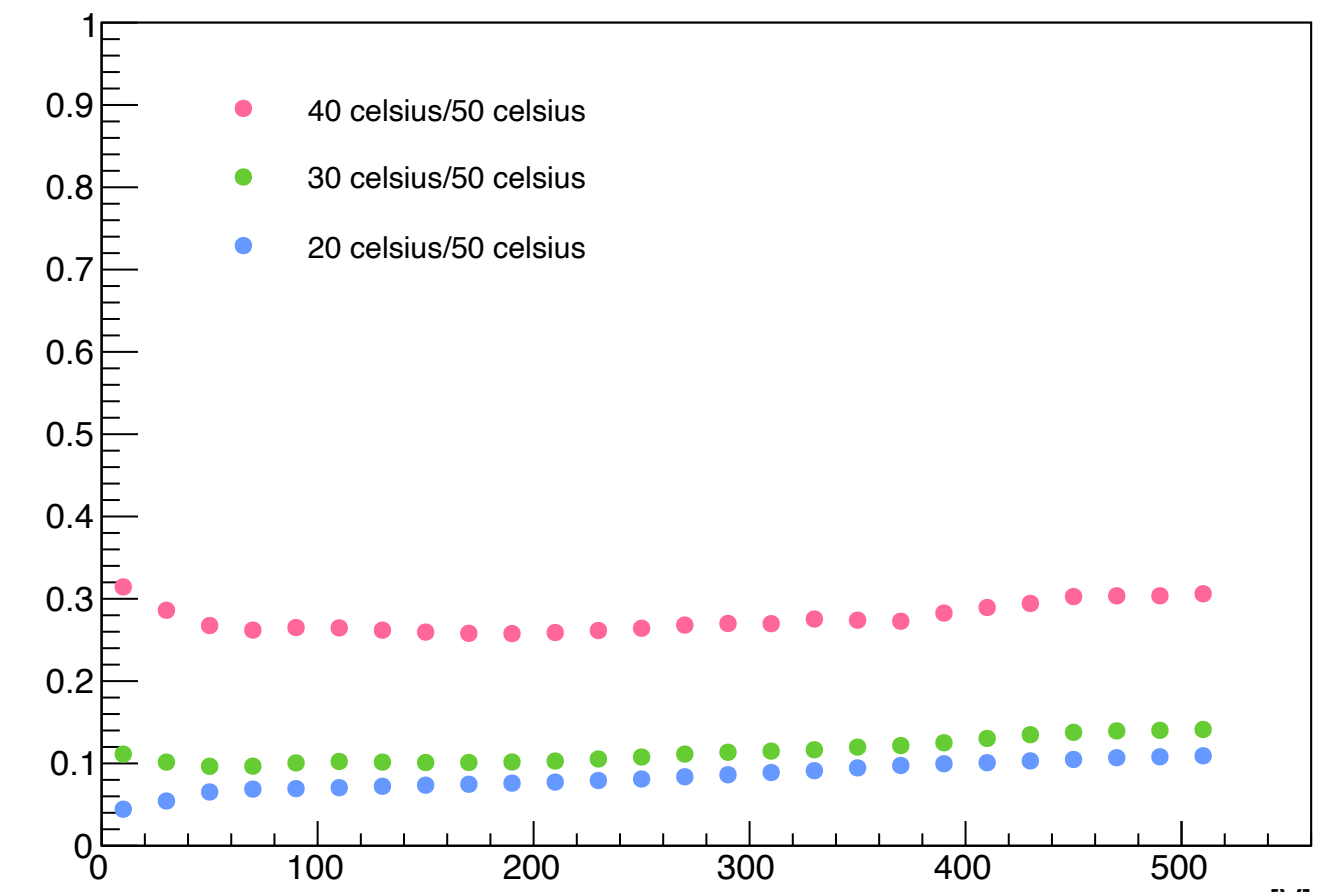
28_1



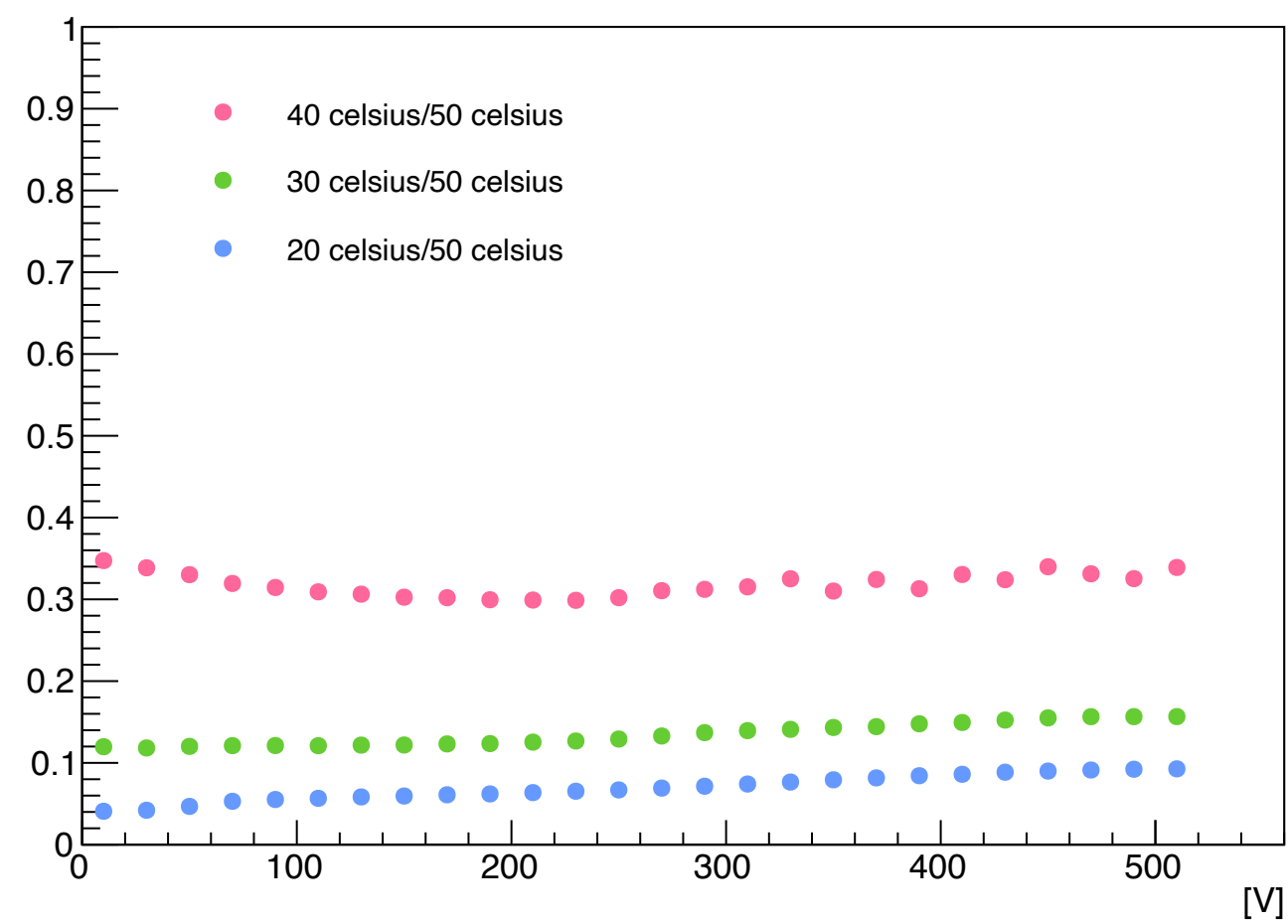
28_3



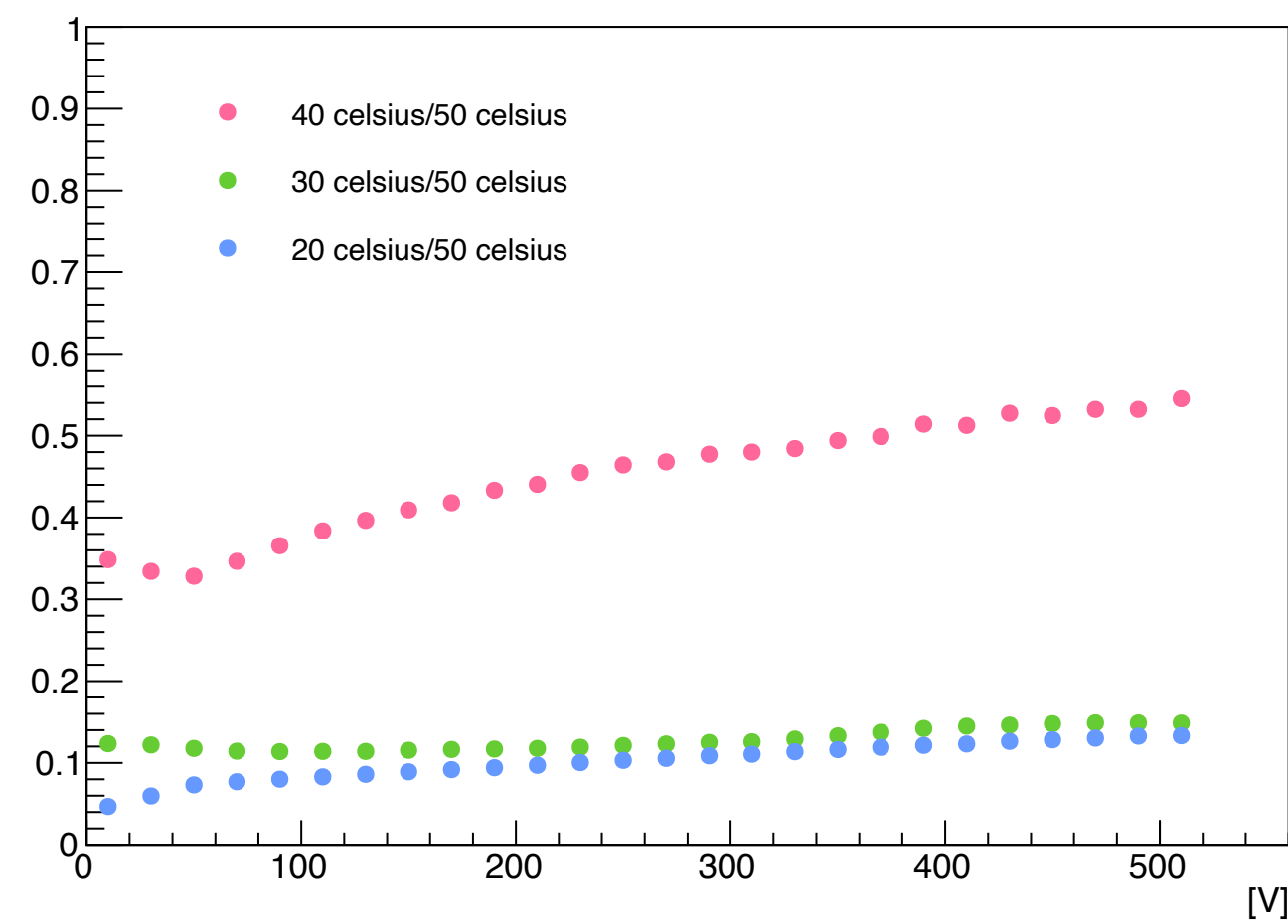
28_5



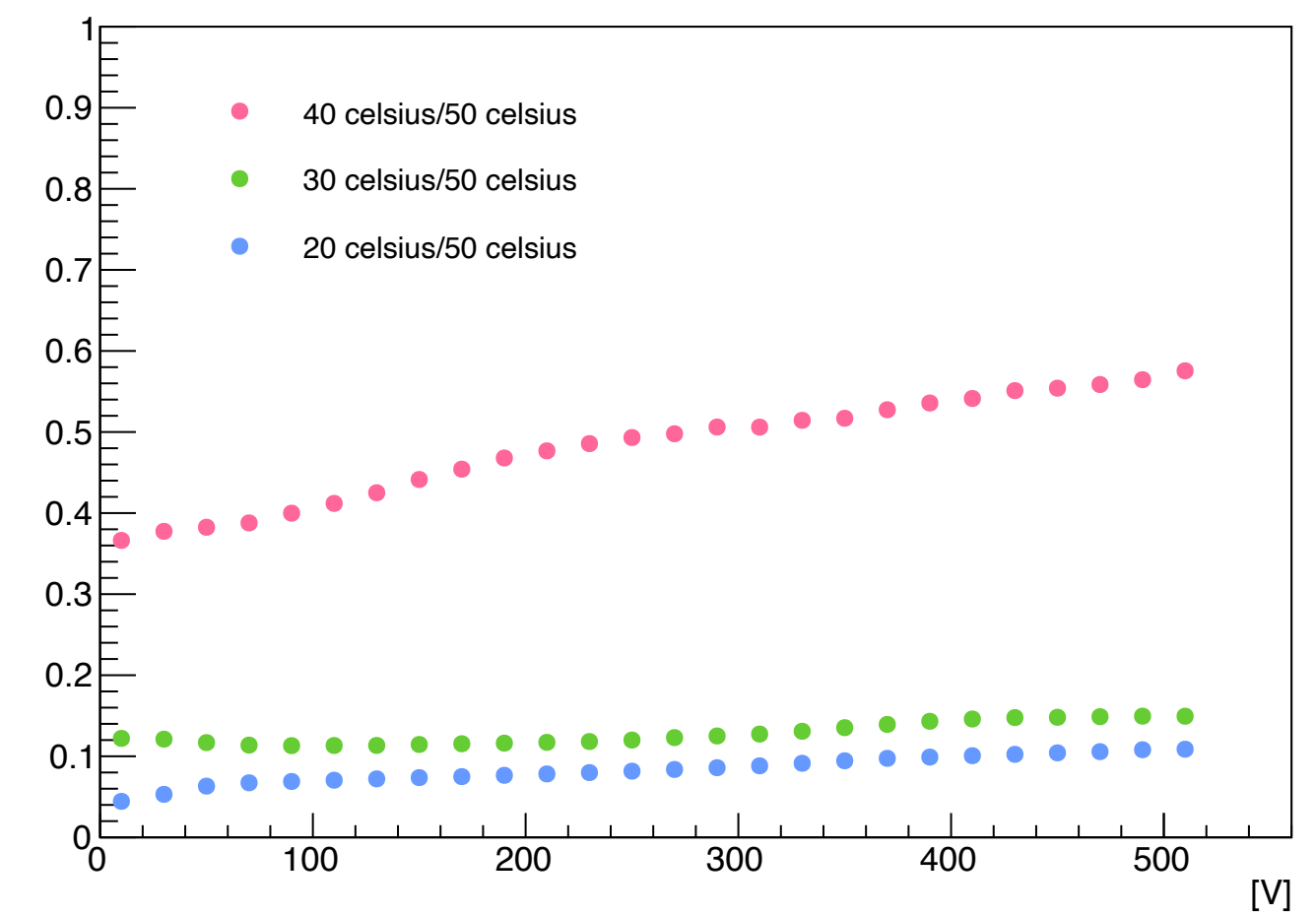
28_2



28_4

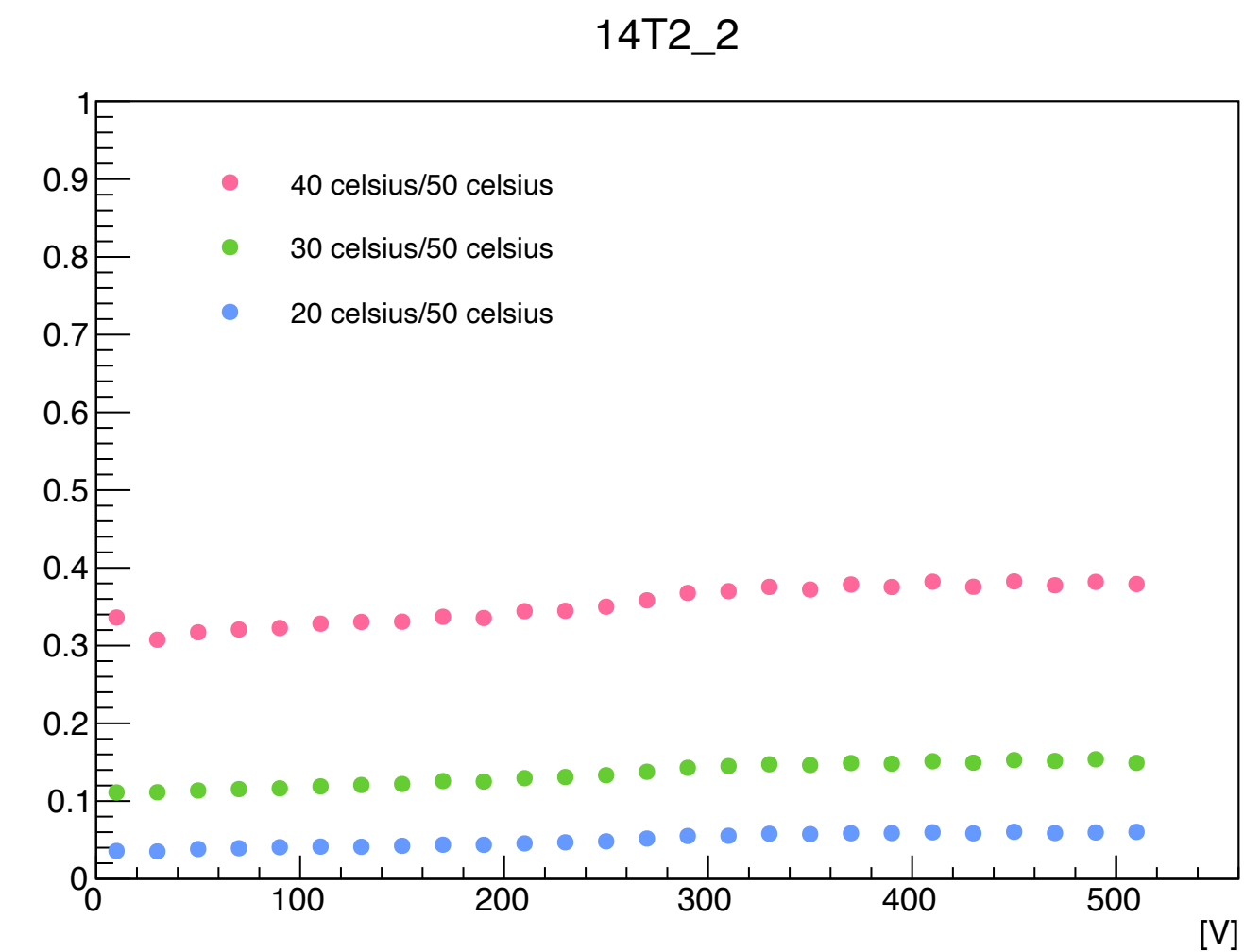
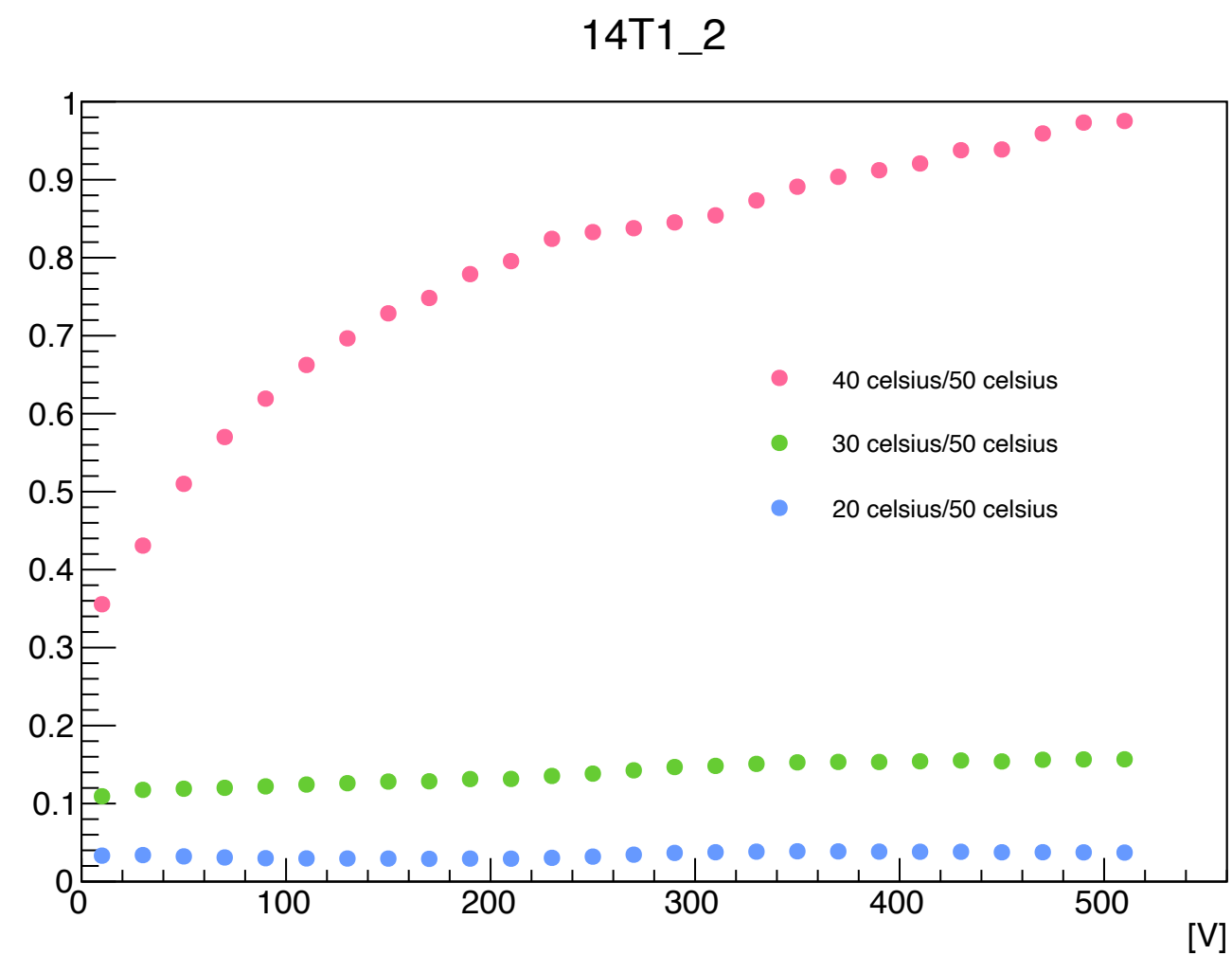
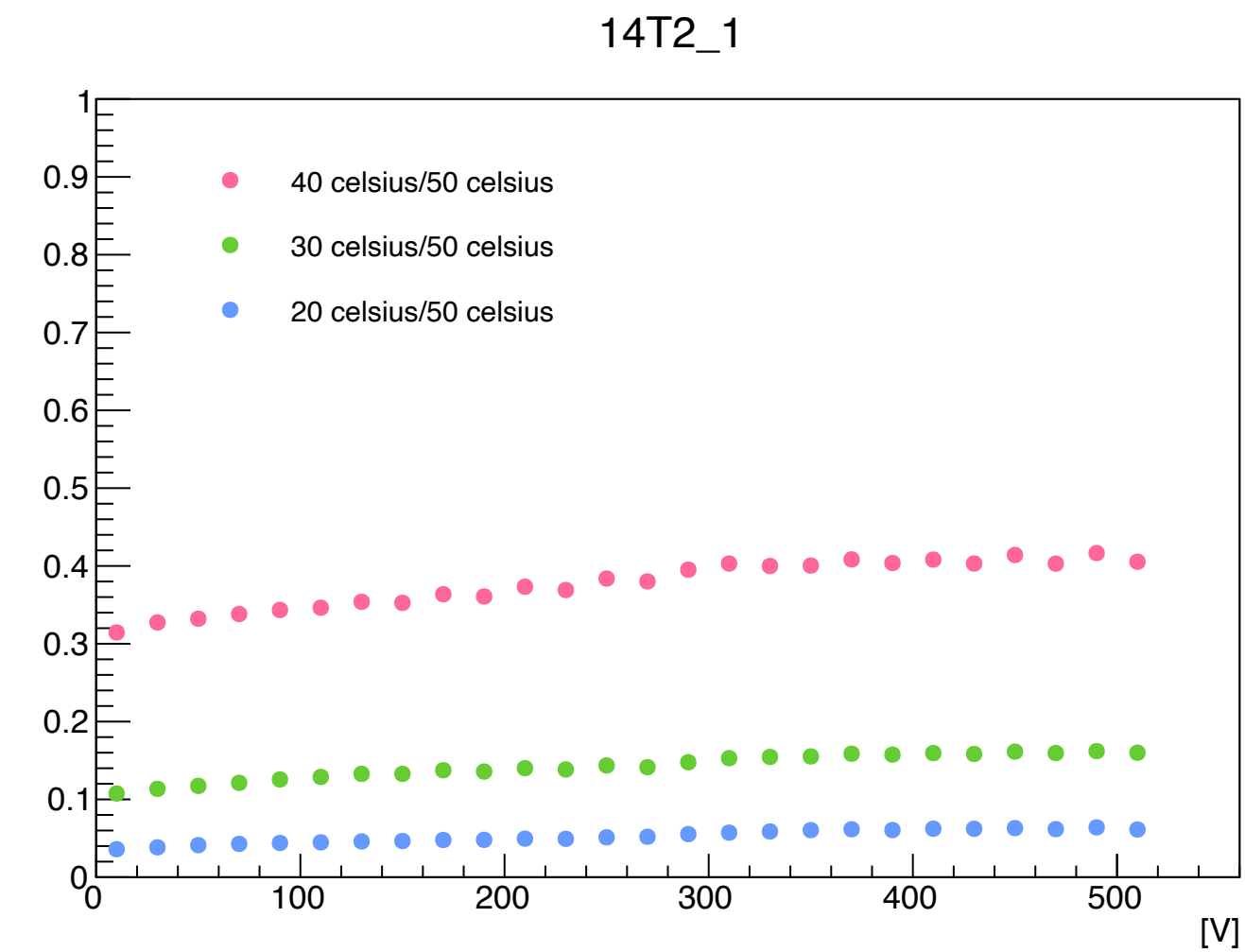
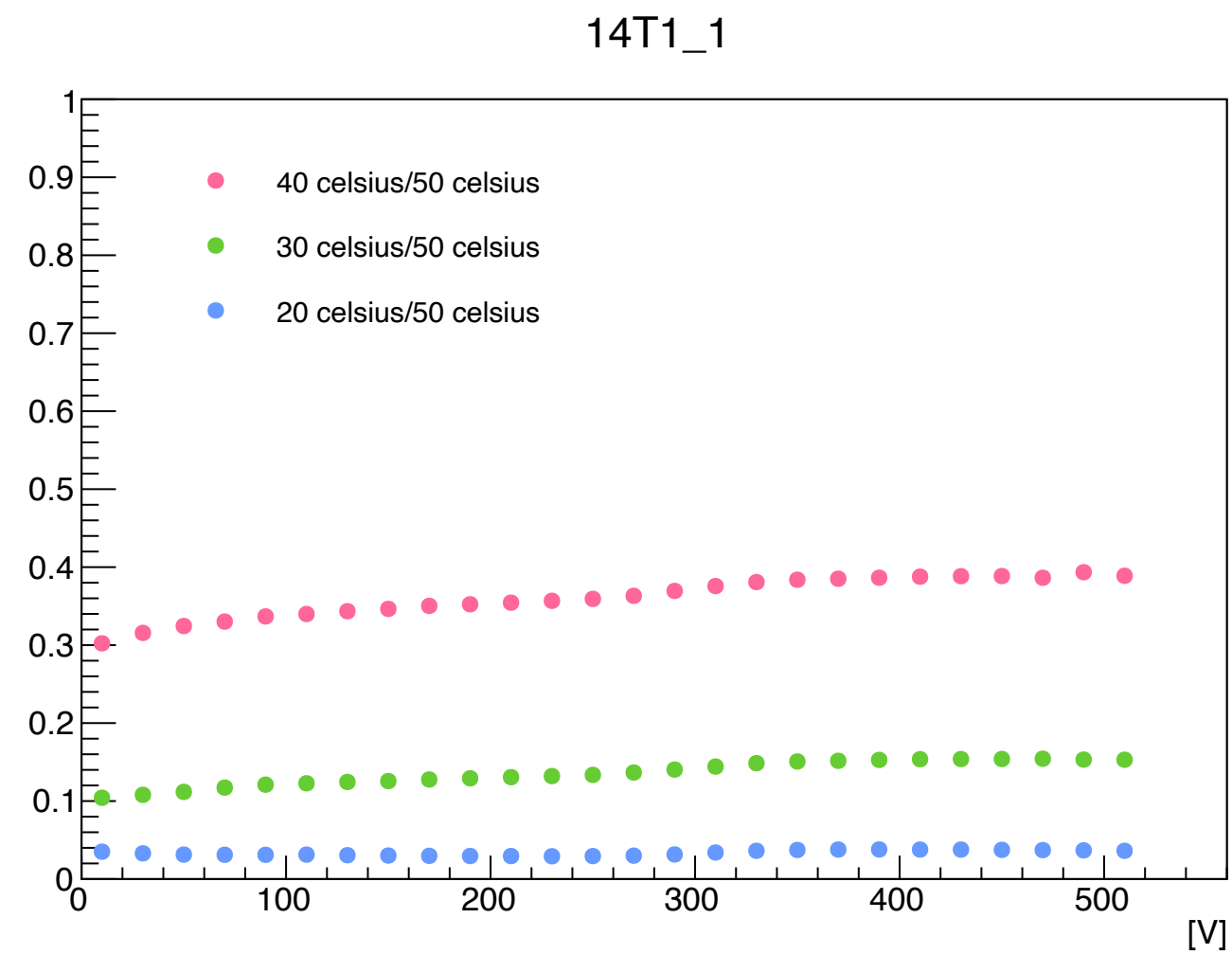


28_6



(20,30,40°Cの結果)/50°Cの結果

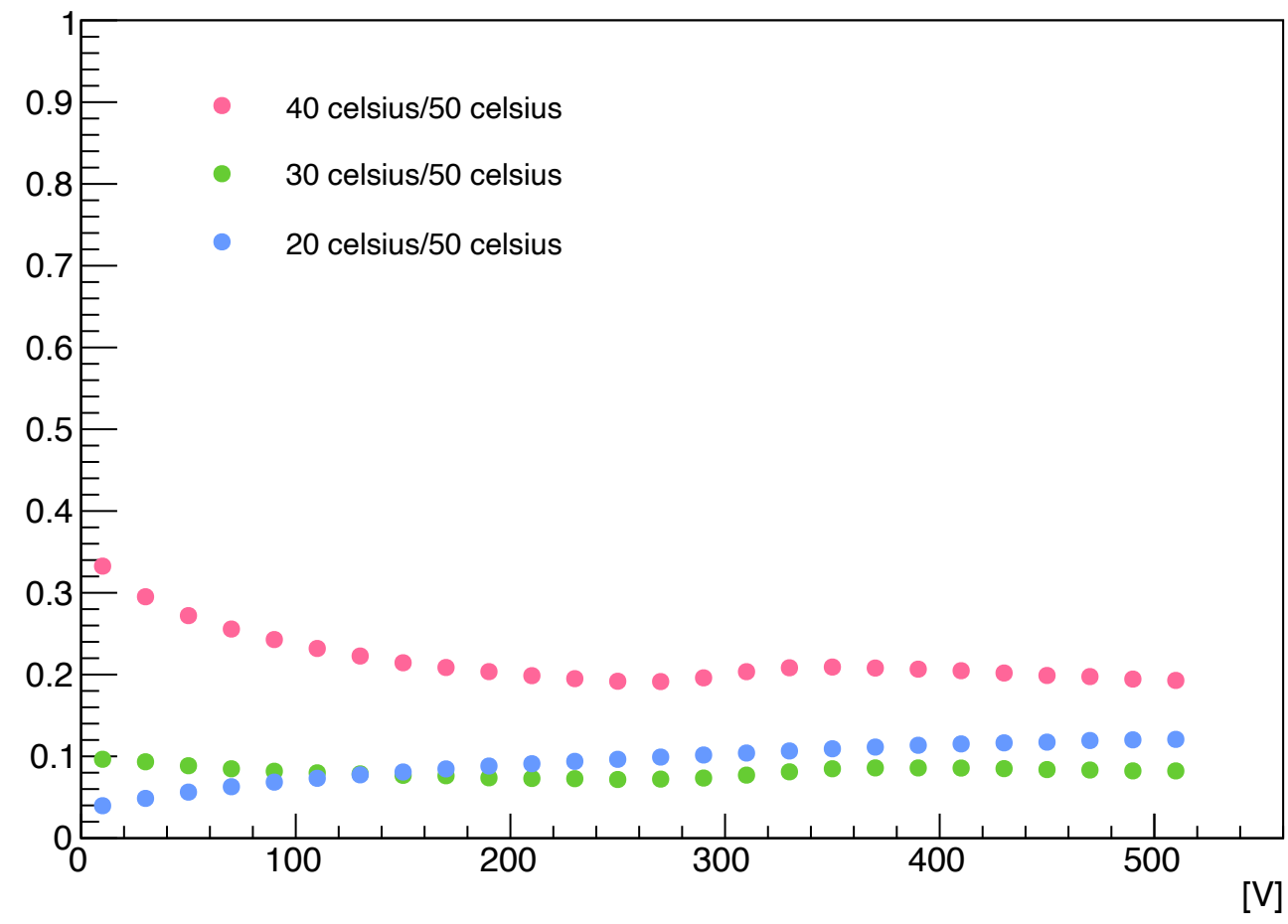
14T1, 14T2 (1cm× 1cm)



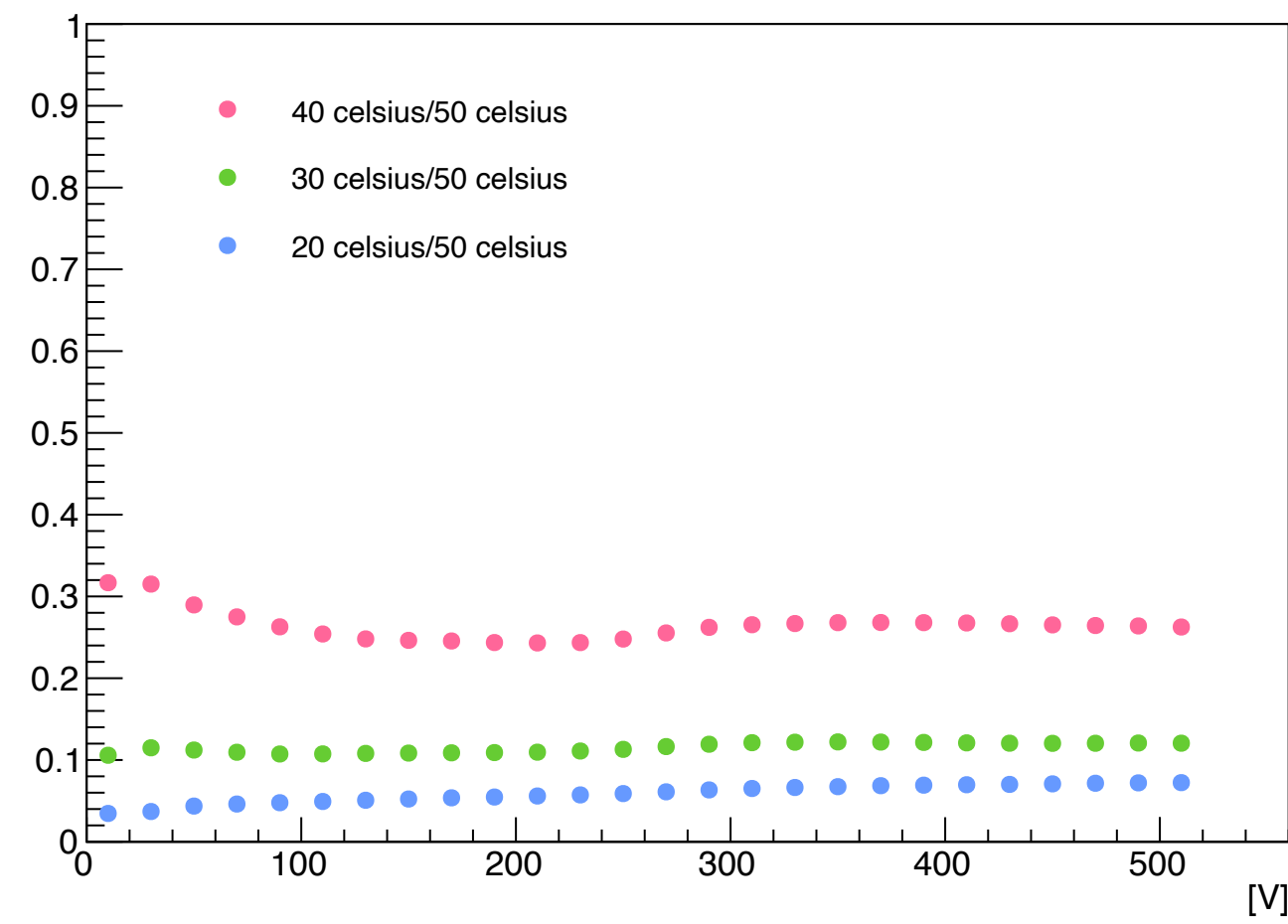
(20,30,40°Cの結果)/50°Cの結果

19B1, 19R1, 19R2 (1cm× 1cm)

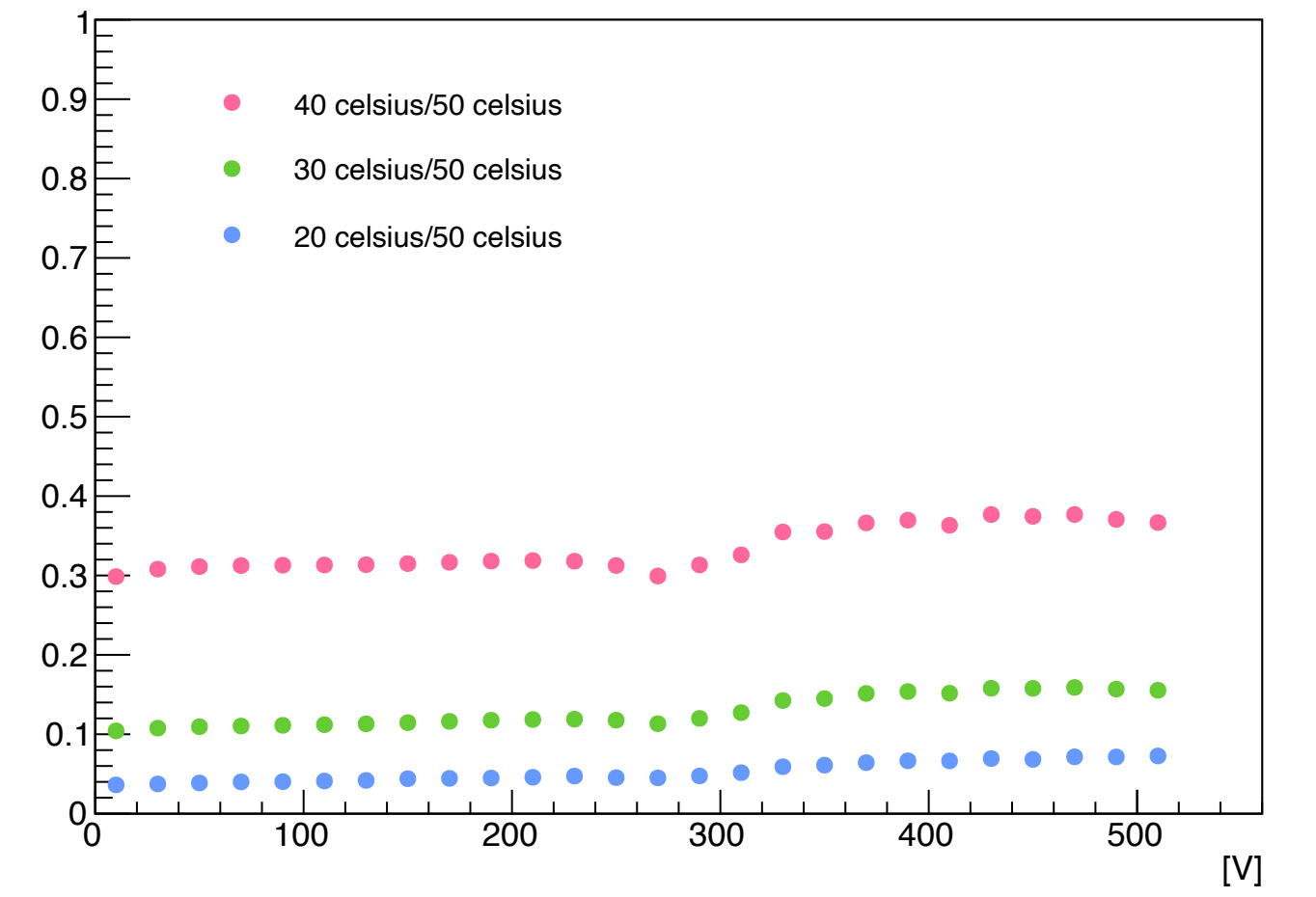
19B1_1



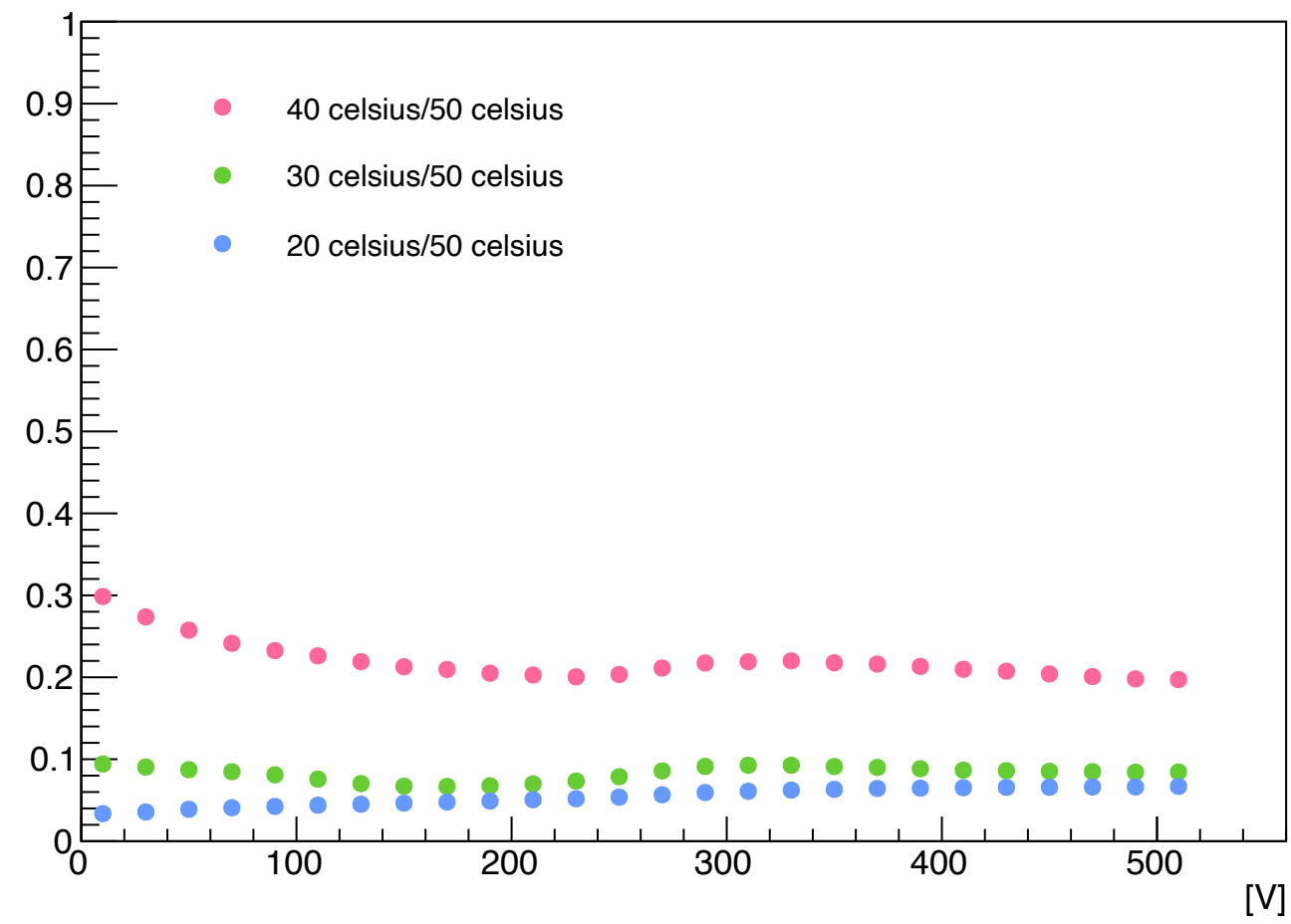
19R1_2



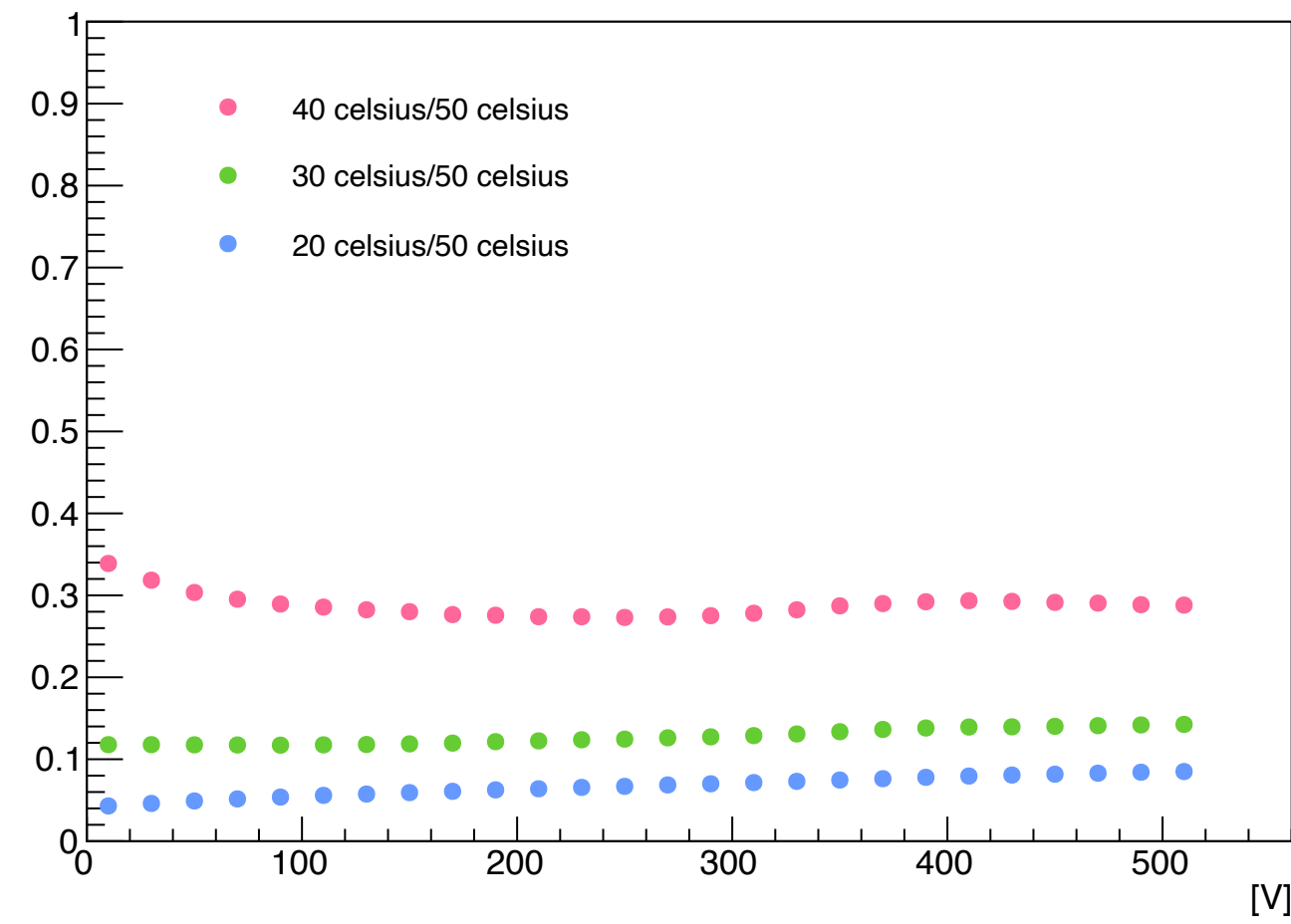
19R2_1



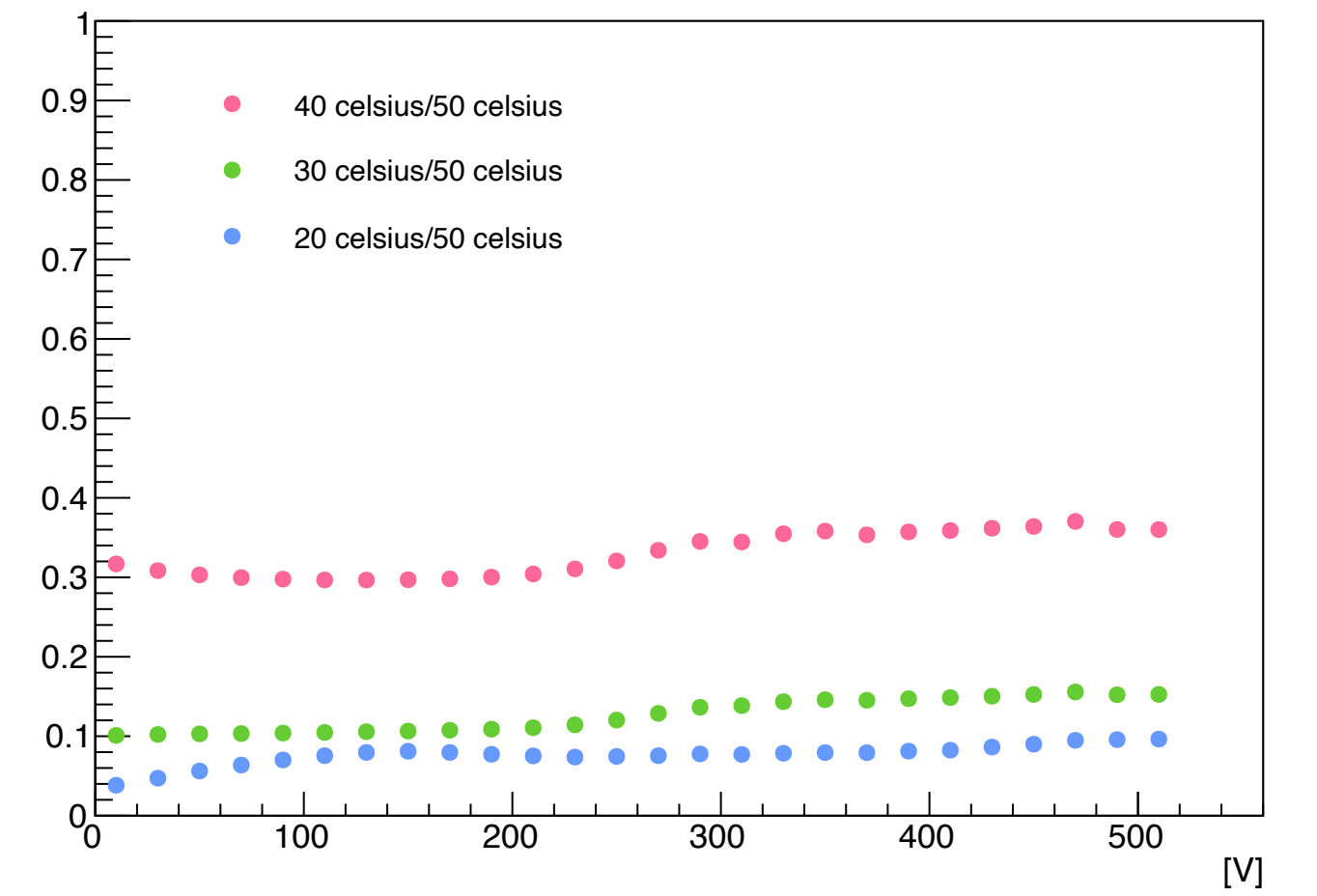
19B1_2



19R1_1

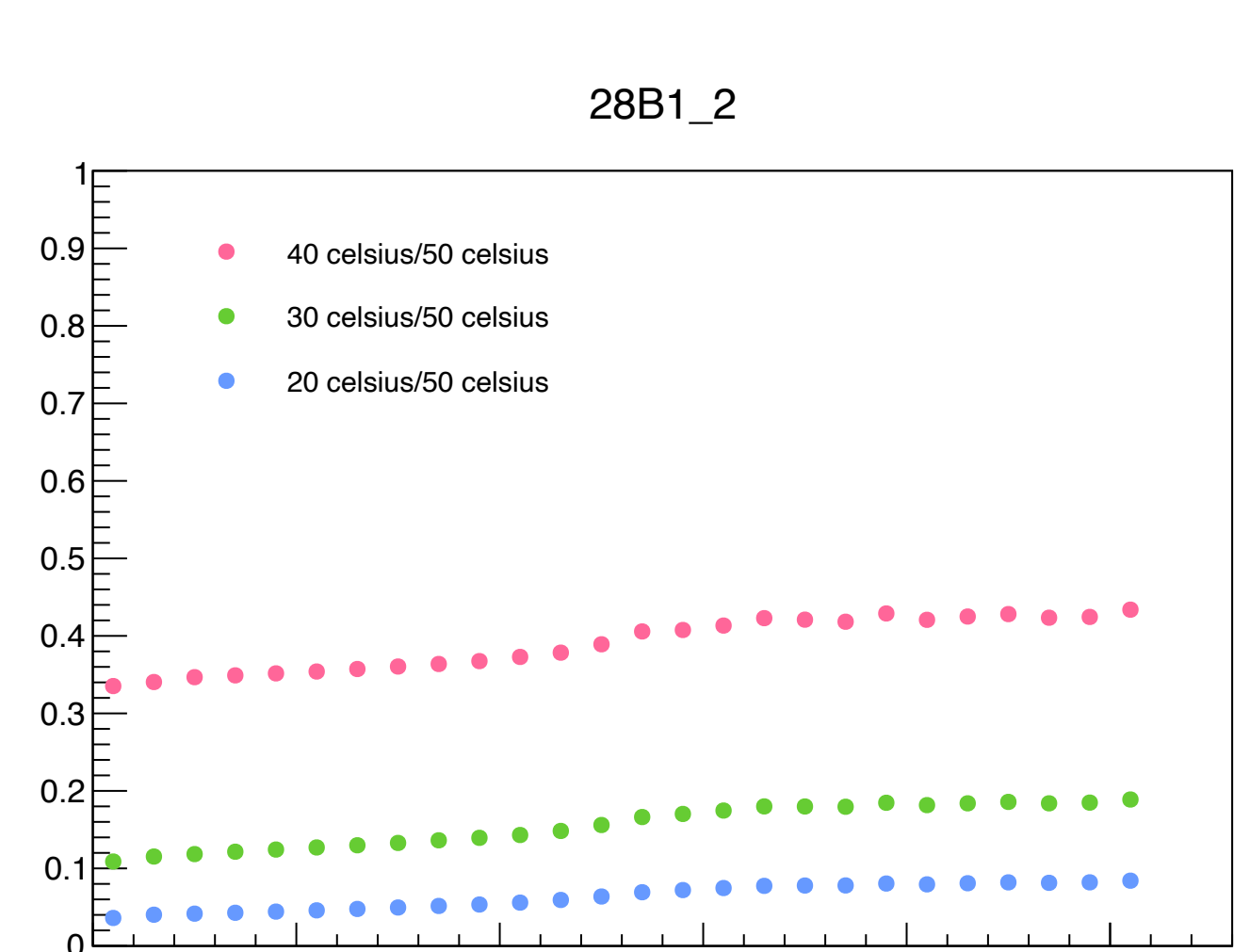
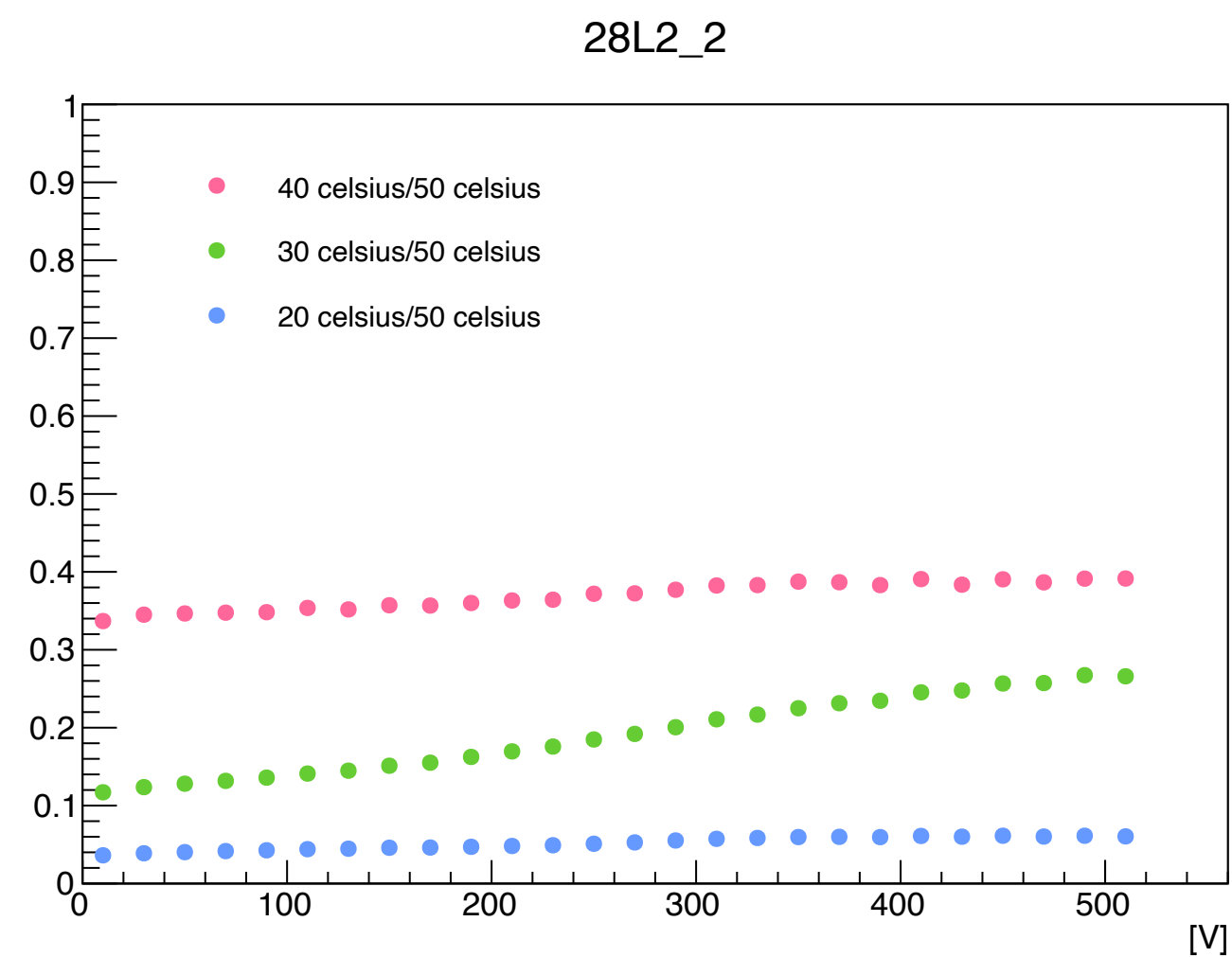
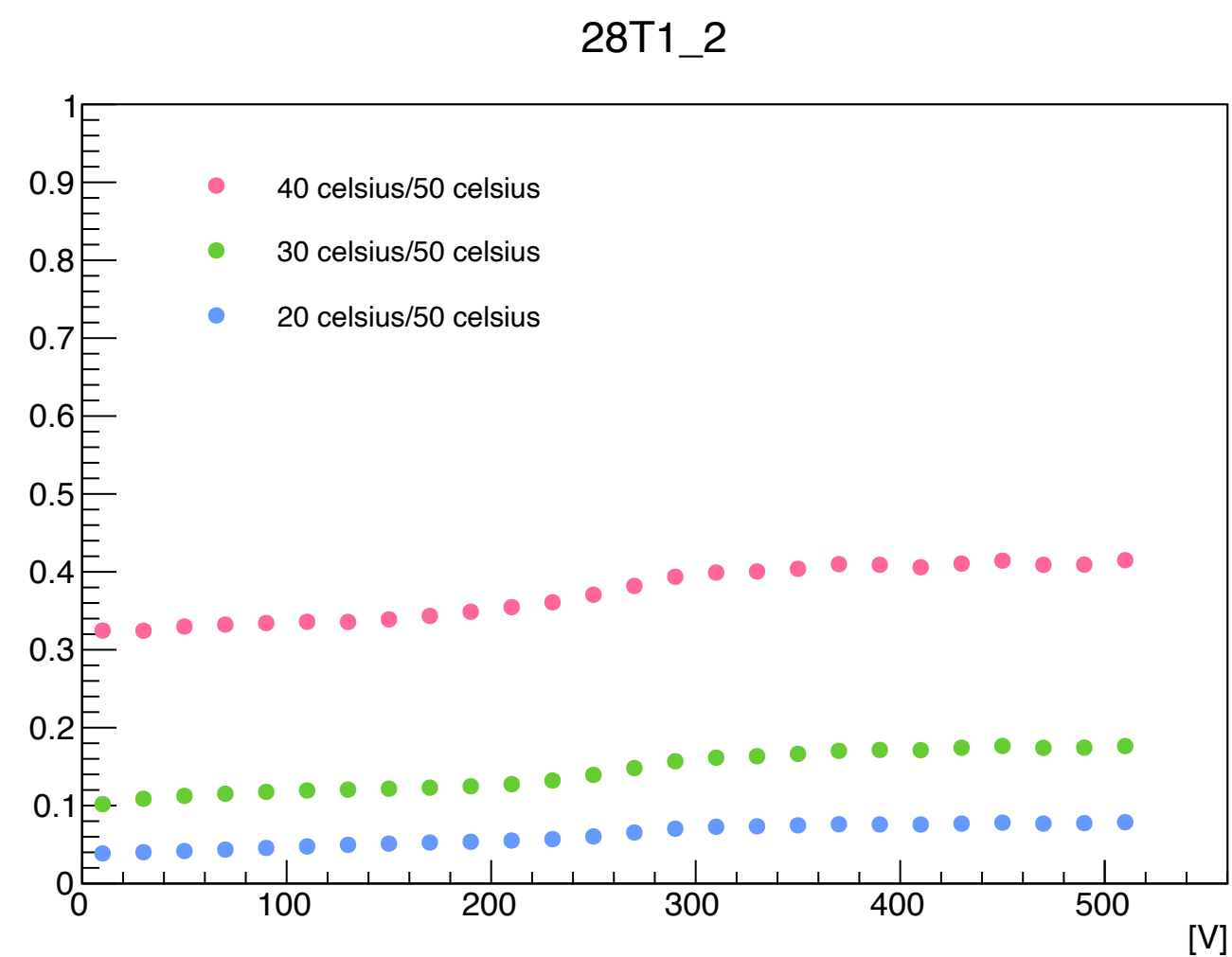
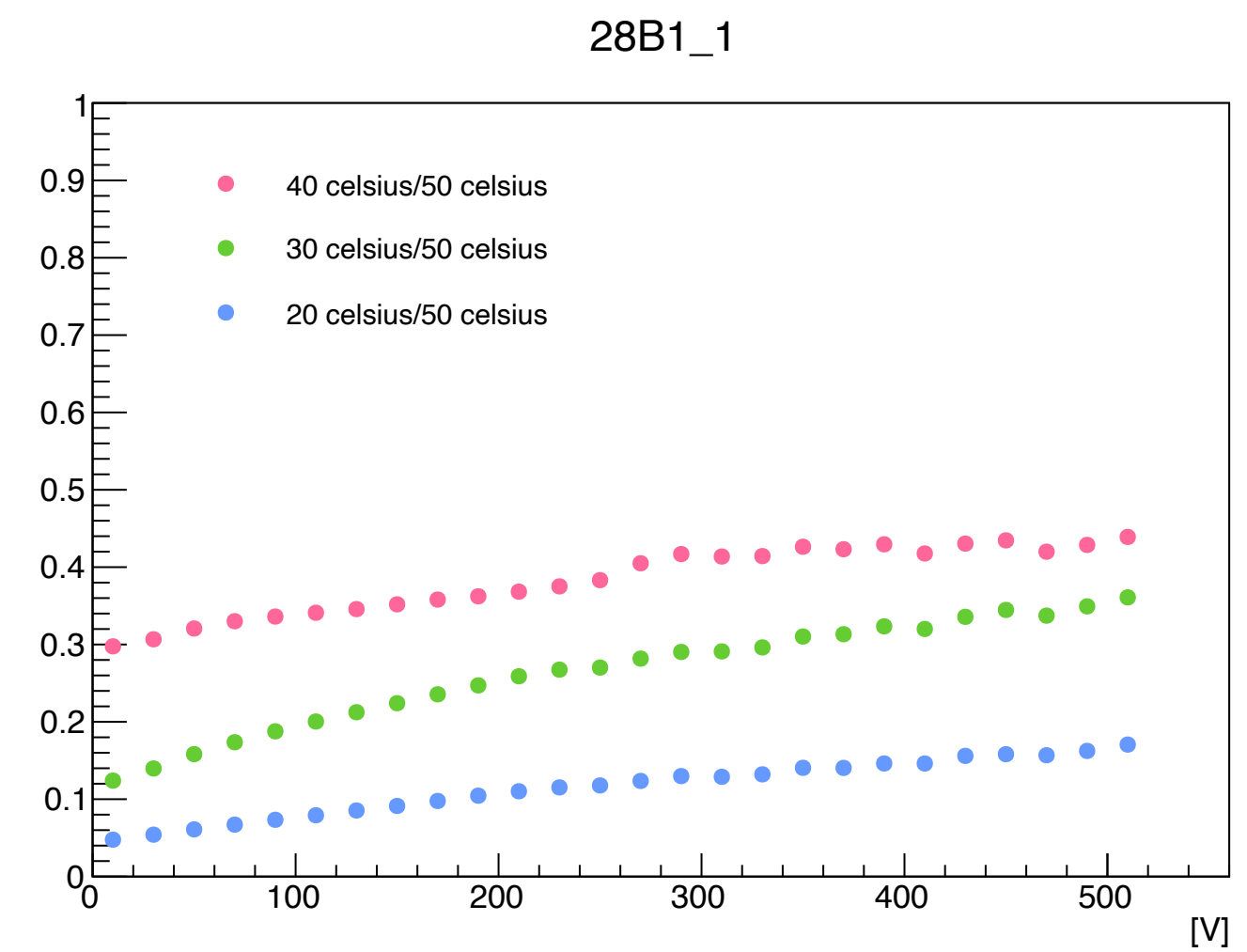
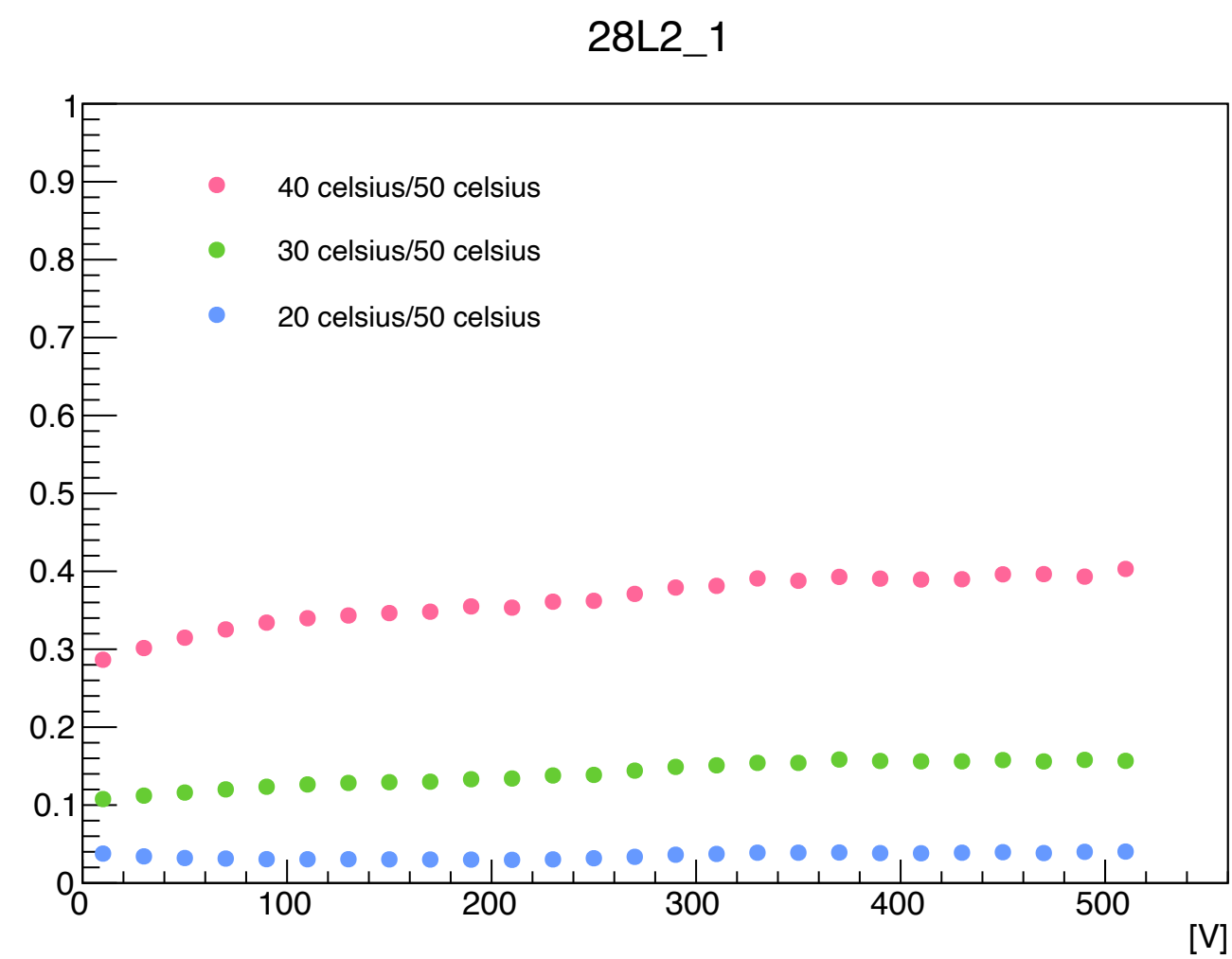
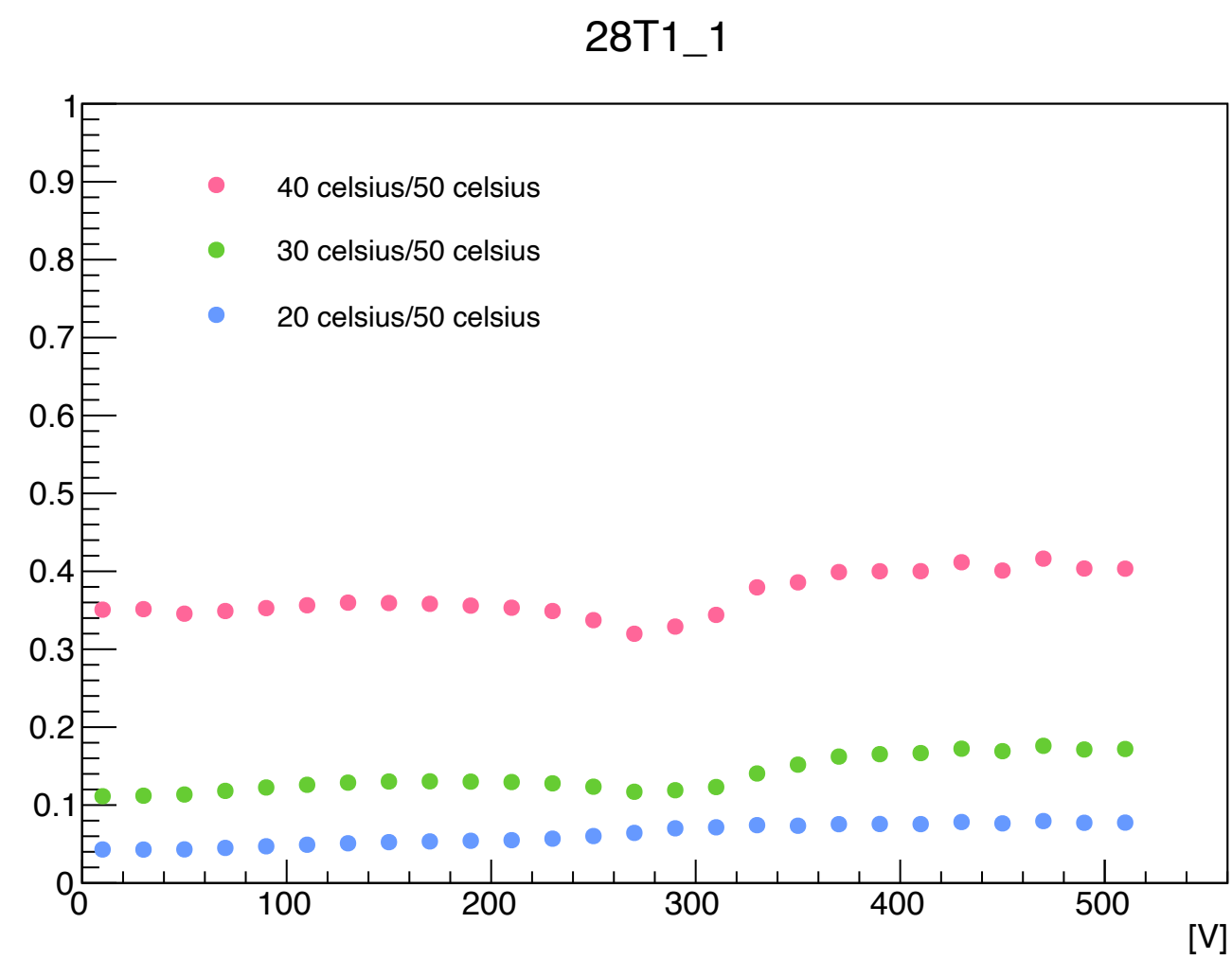


19R2_2



(20,30,40°Cの結果)/50°Cの結果

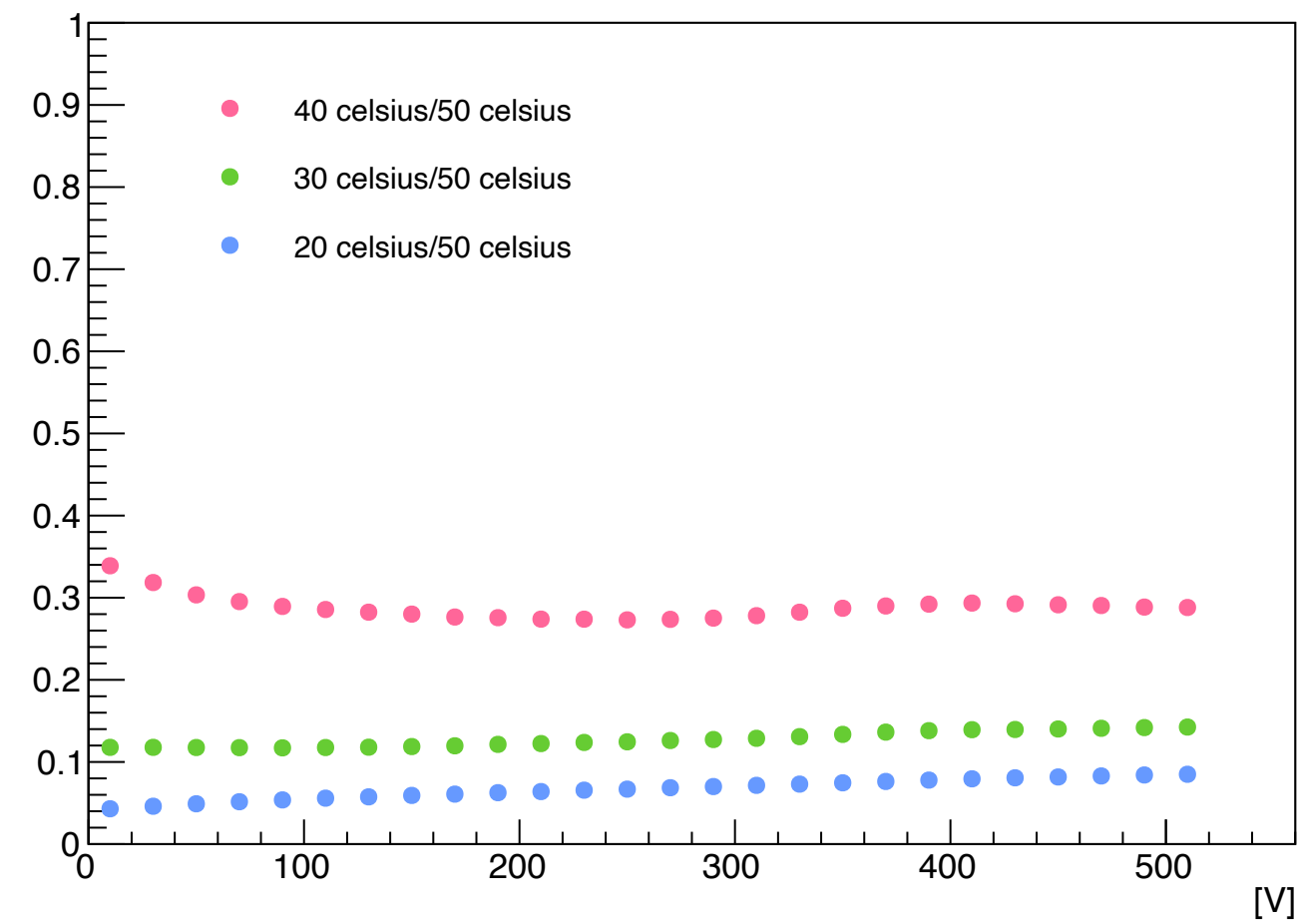
28T1, 28L2, 28B1 (1cm× 1cm)



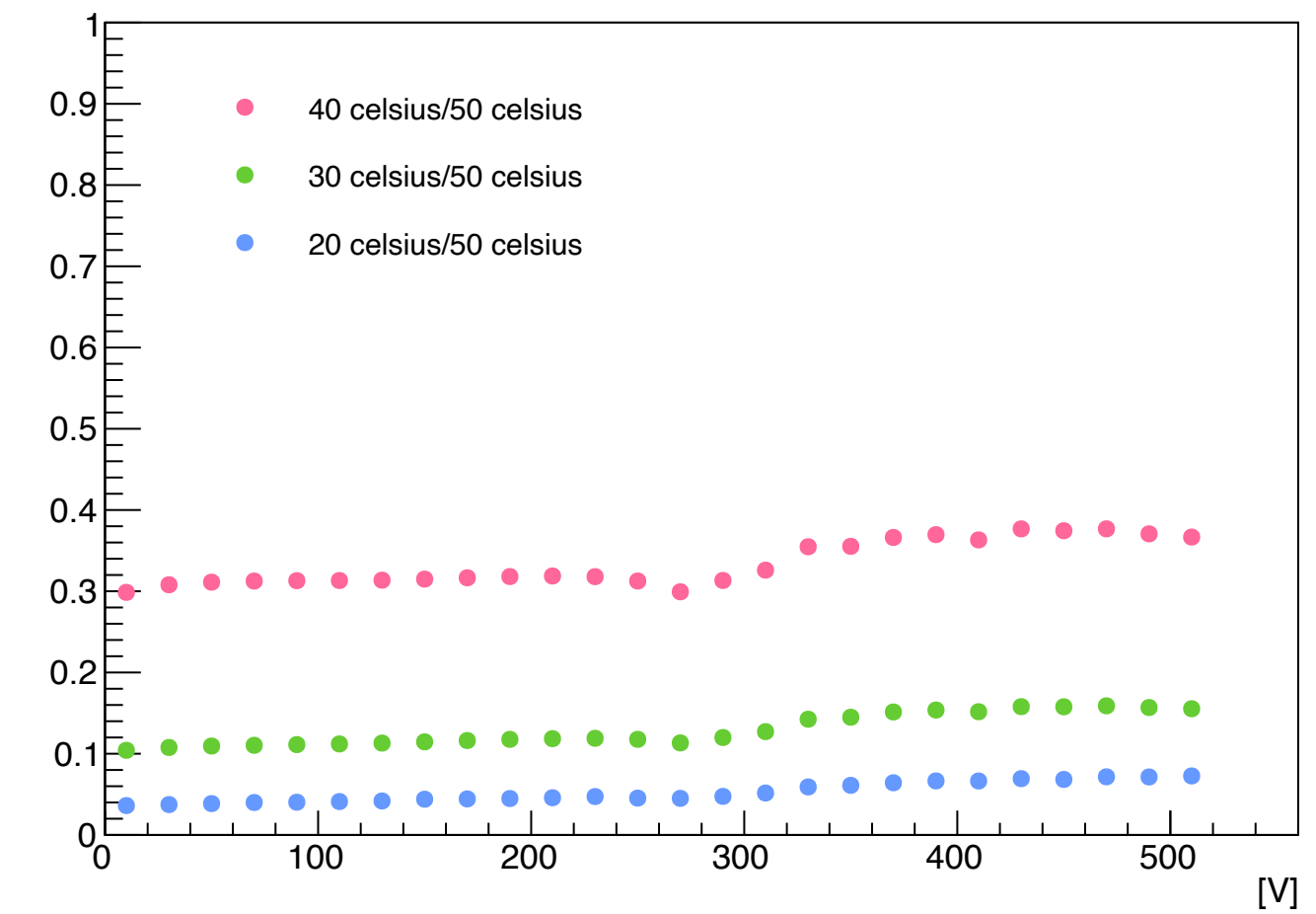
(20,30,40°Cの結果)/50°Cの結果

28R1, 28R2 (1cm× 1cm)

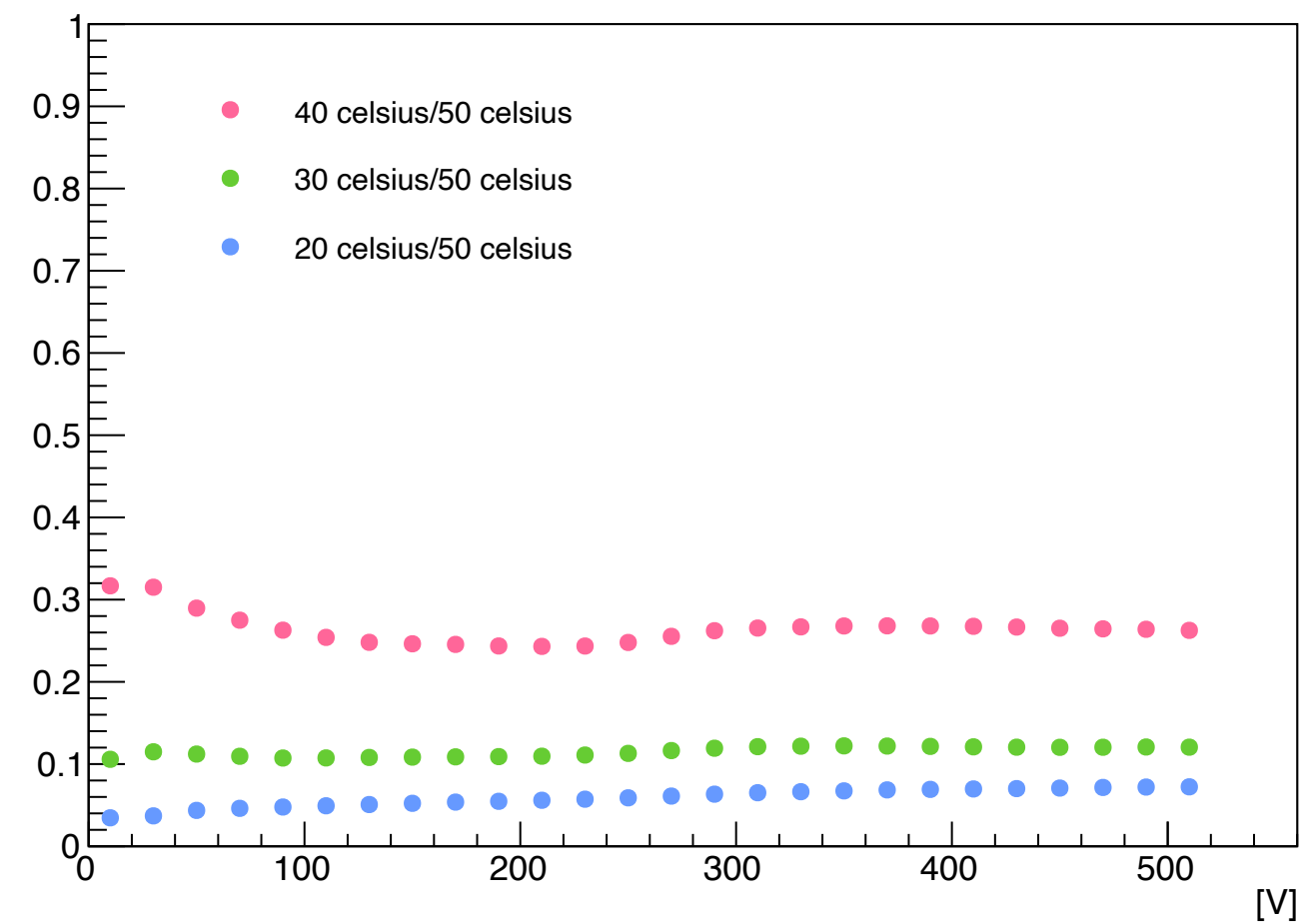
28R1_1



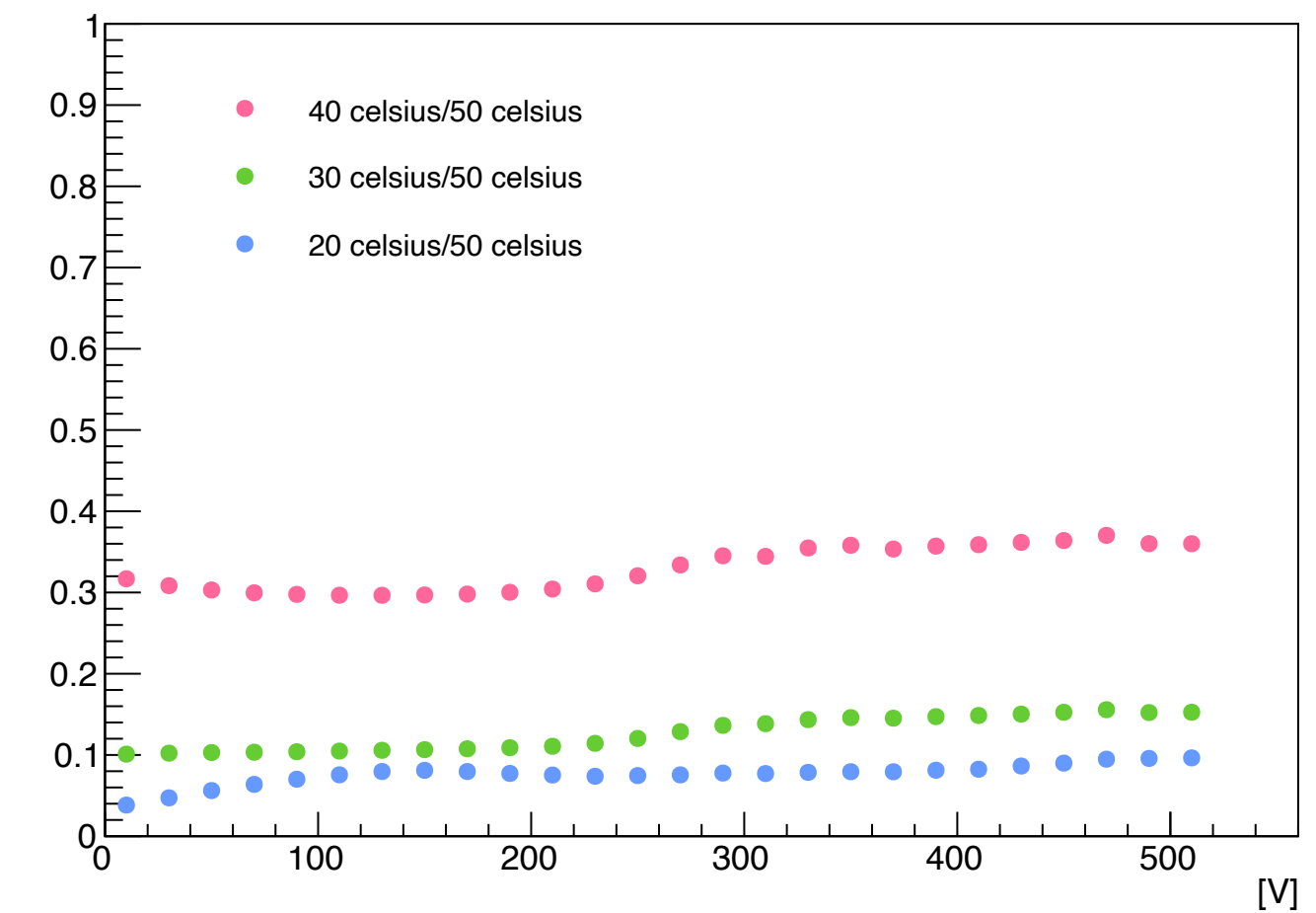
28R2_1



28R1_2



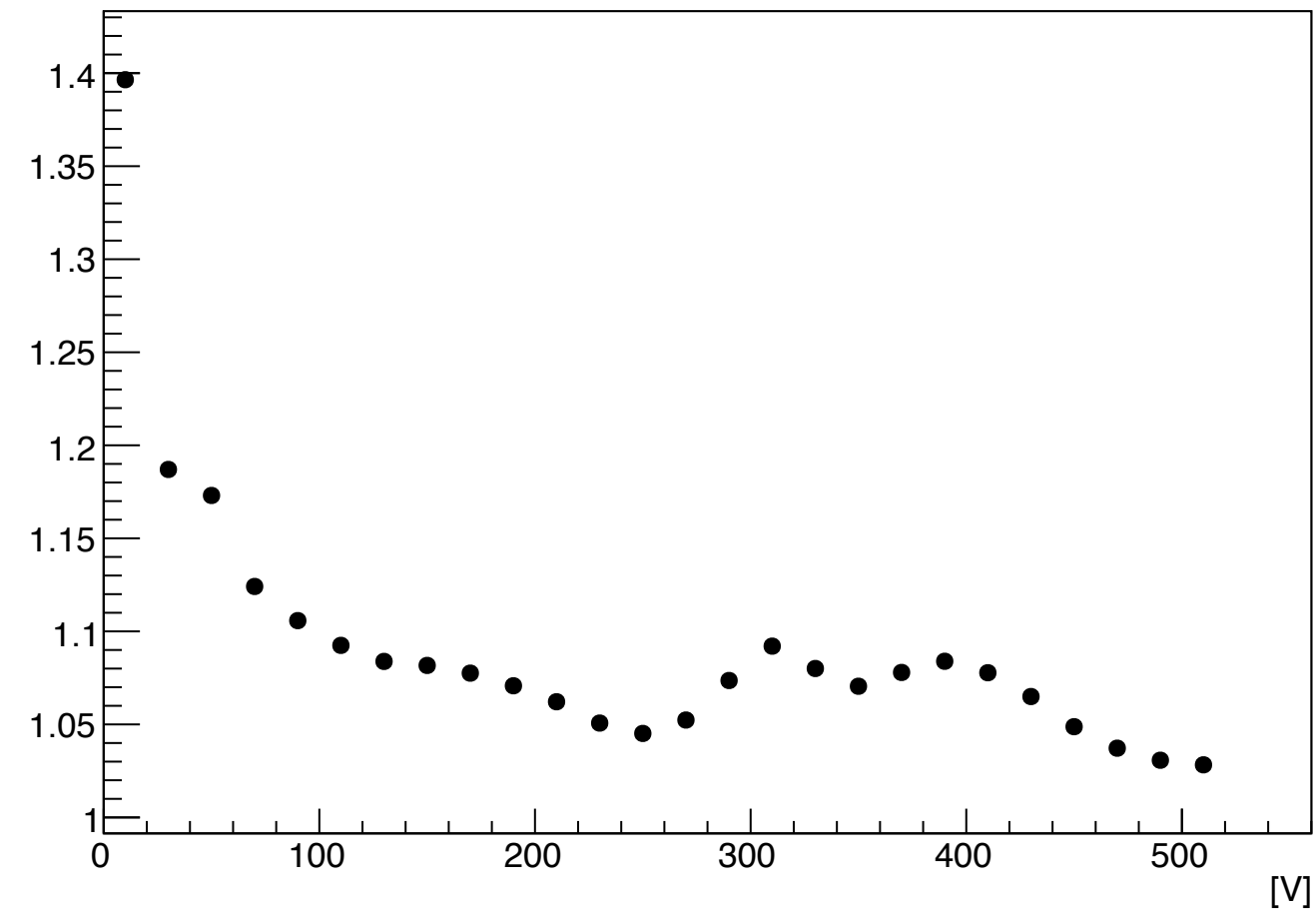
28R2_2



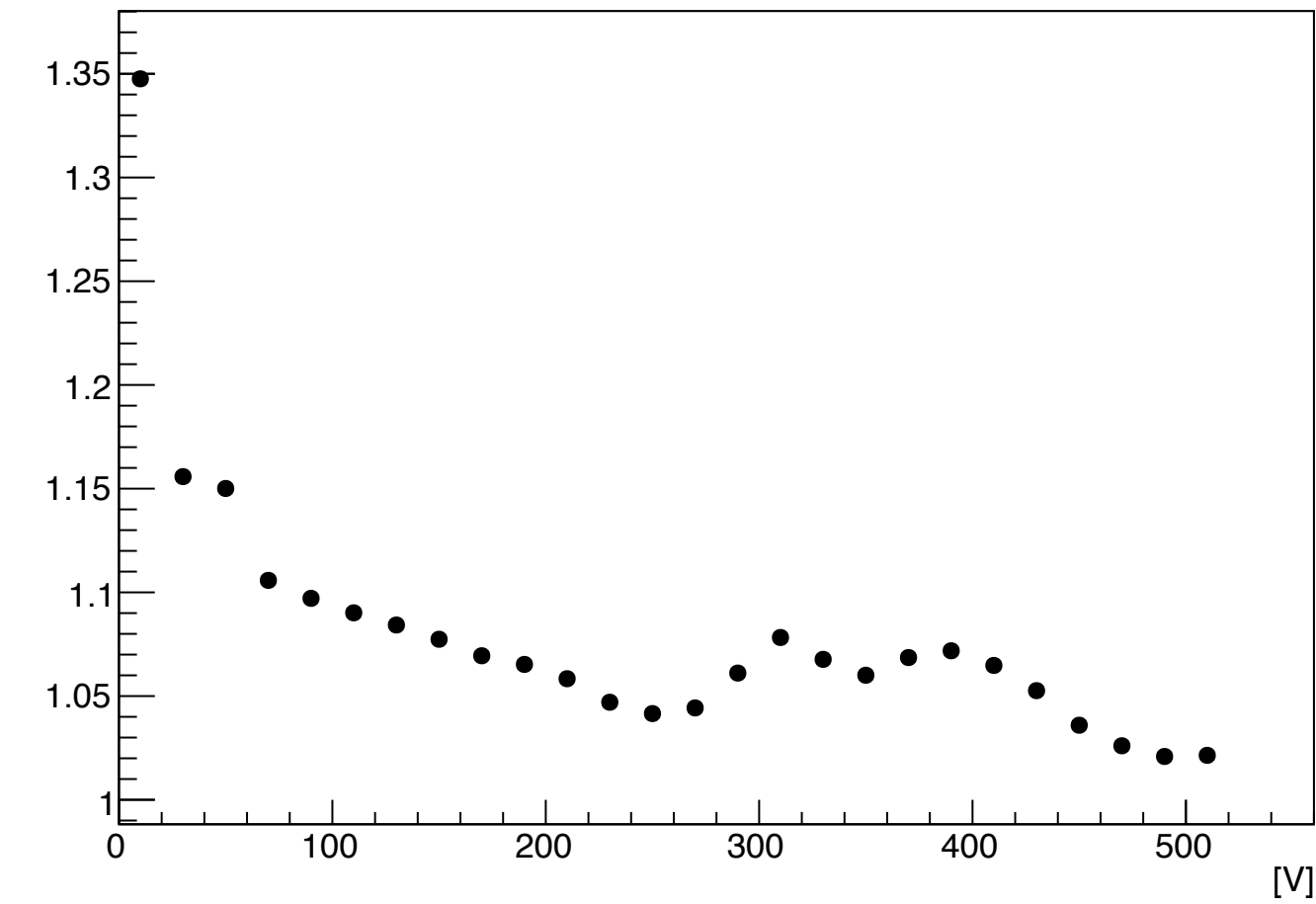
同じチップの位置違いの比較

14 (2cm× 2cm)

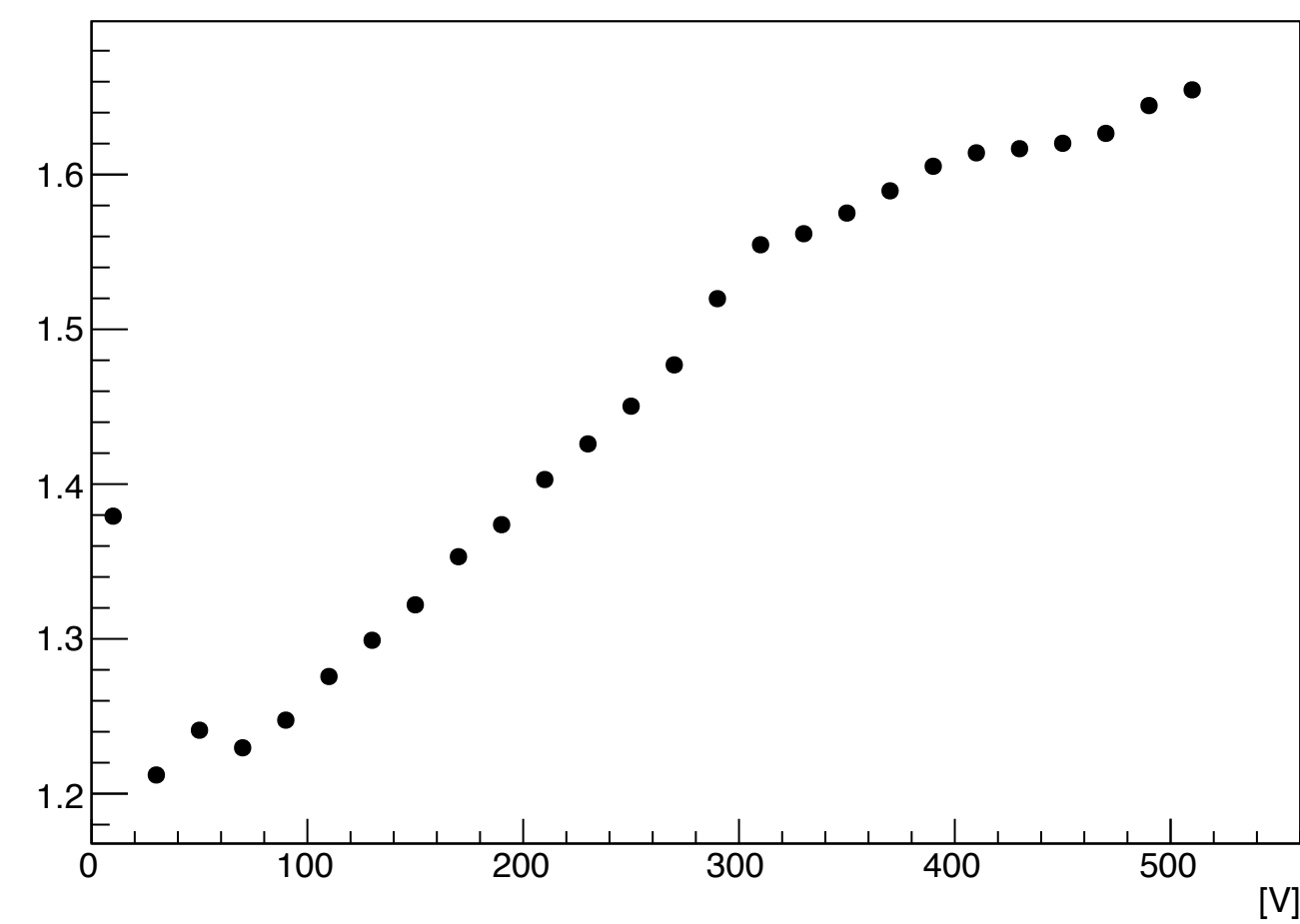
14_2/14_1



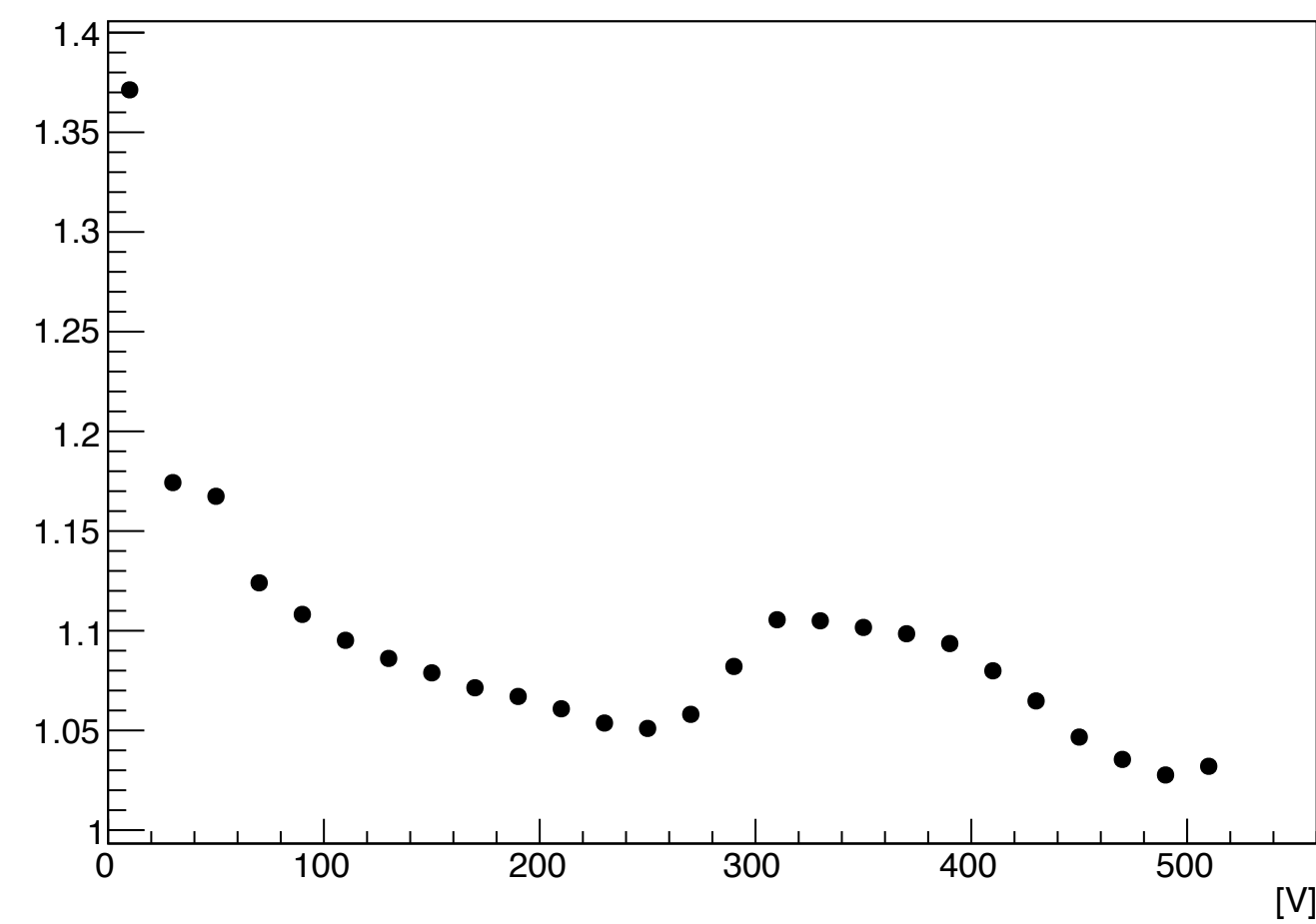
14_3/14_1



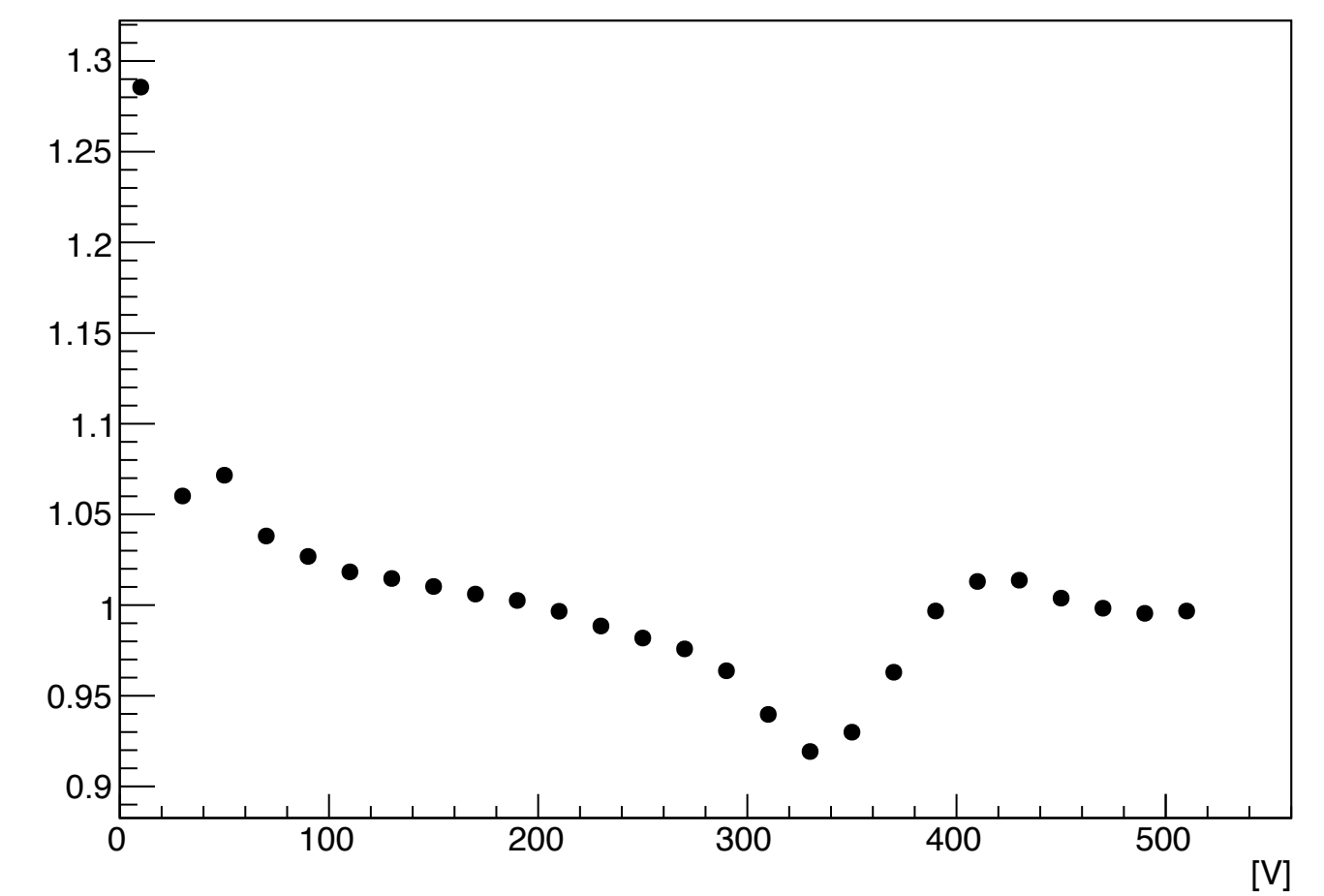
14_4/14_1



14_5/14_1



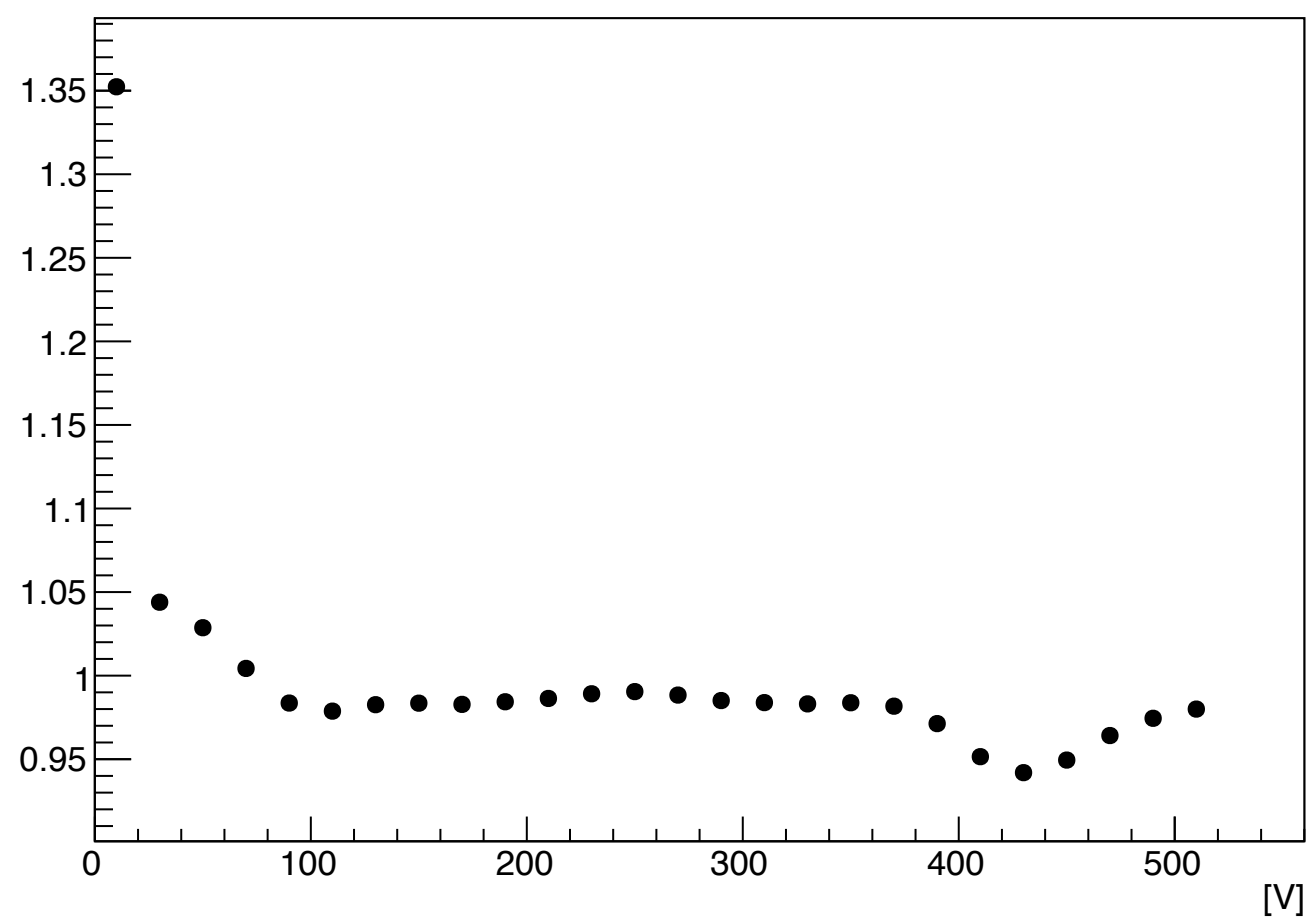
14_6/14_1



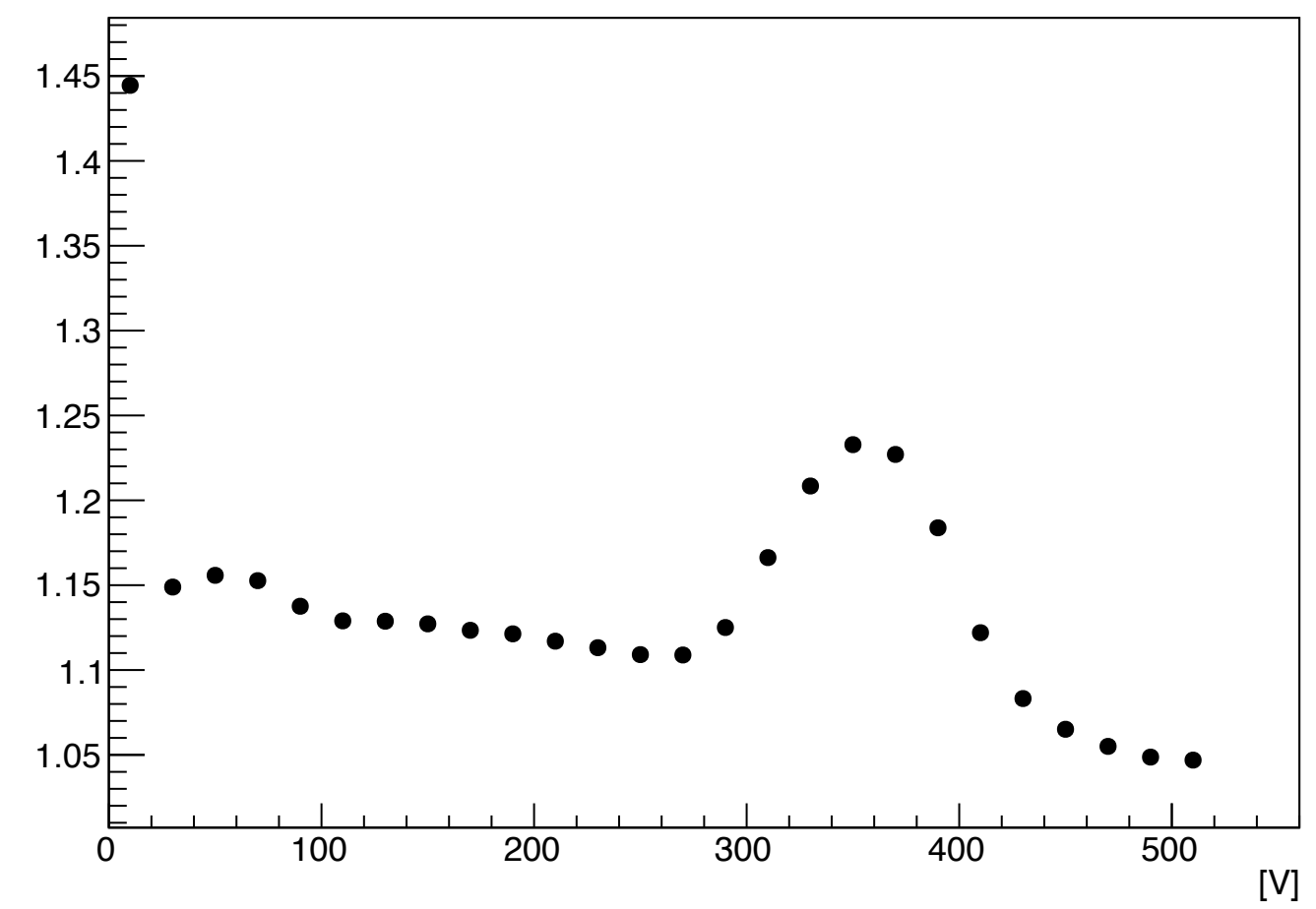
同じチップの位置違いの比較

19 (2cm× 2cm)

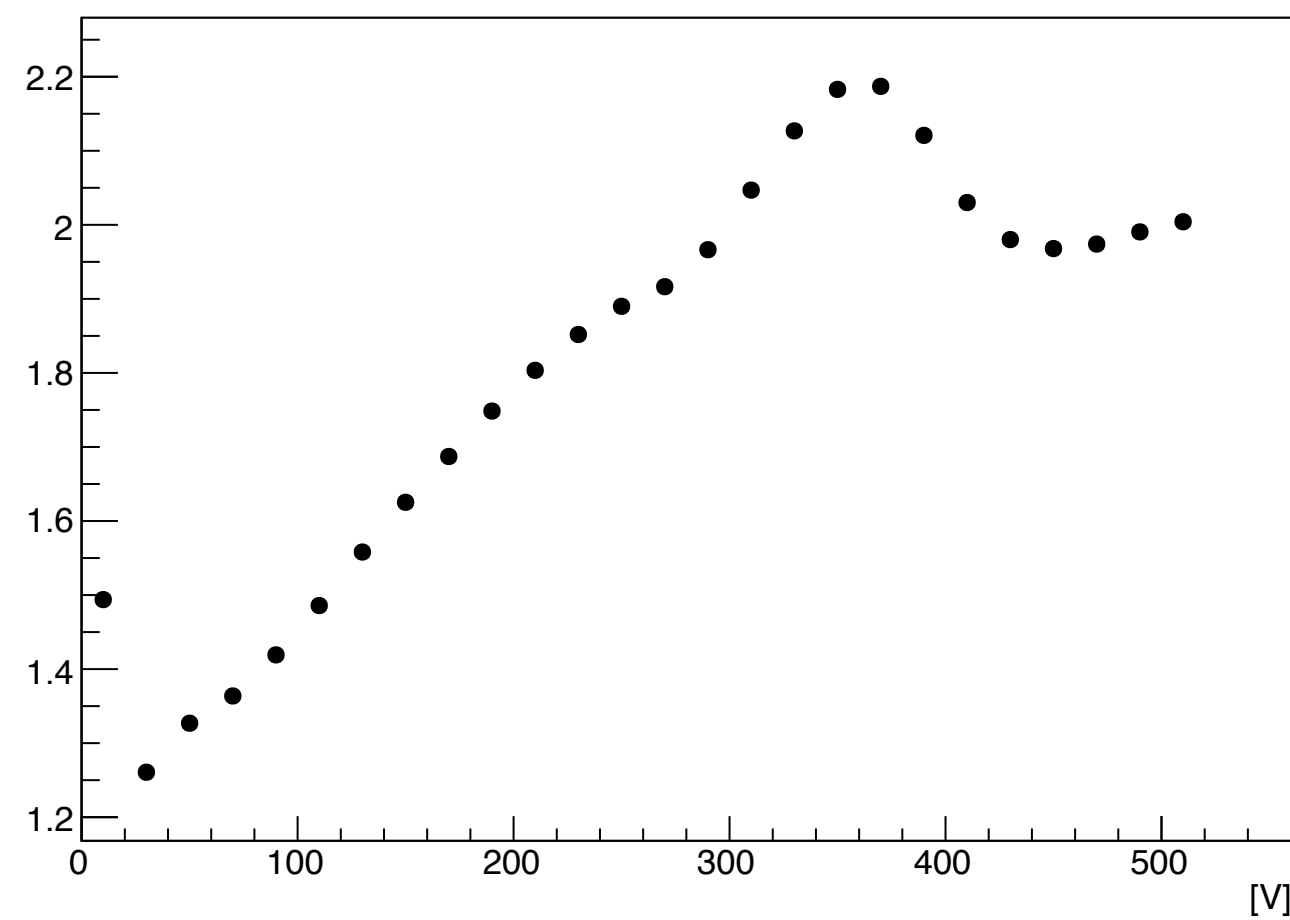
19_2/19_1



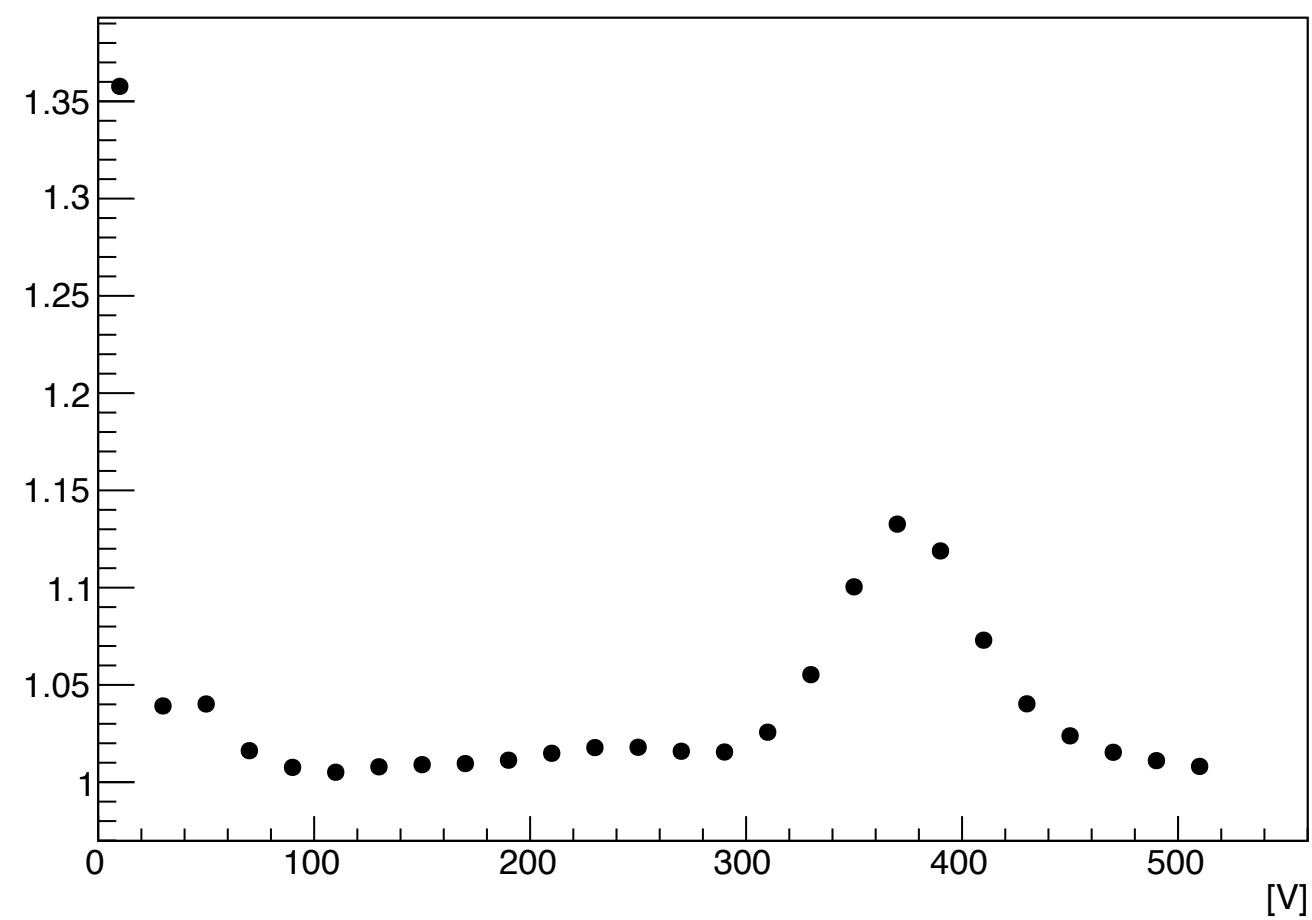
19_3/19_1



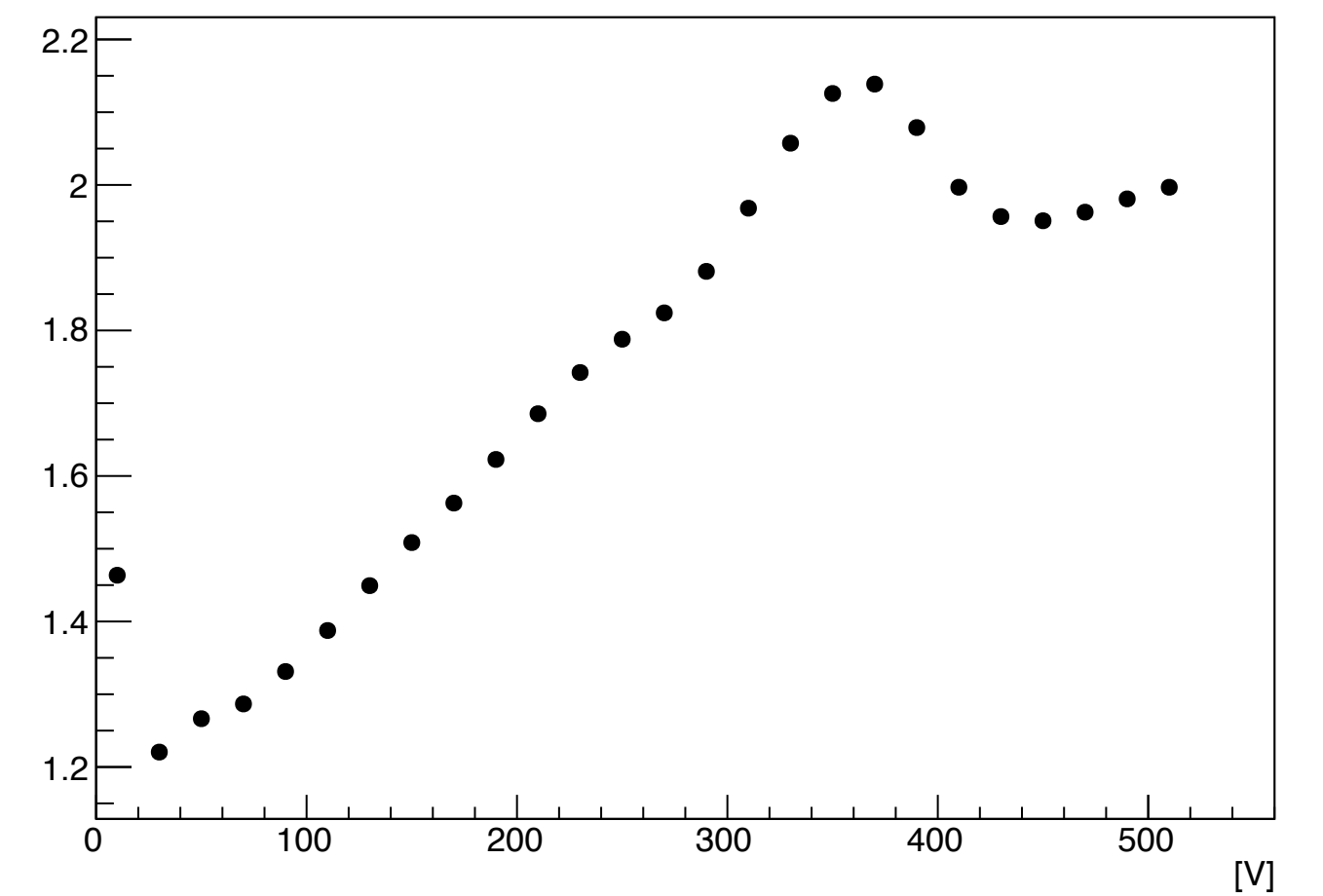
19_4/19_1



19_5/19_1



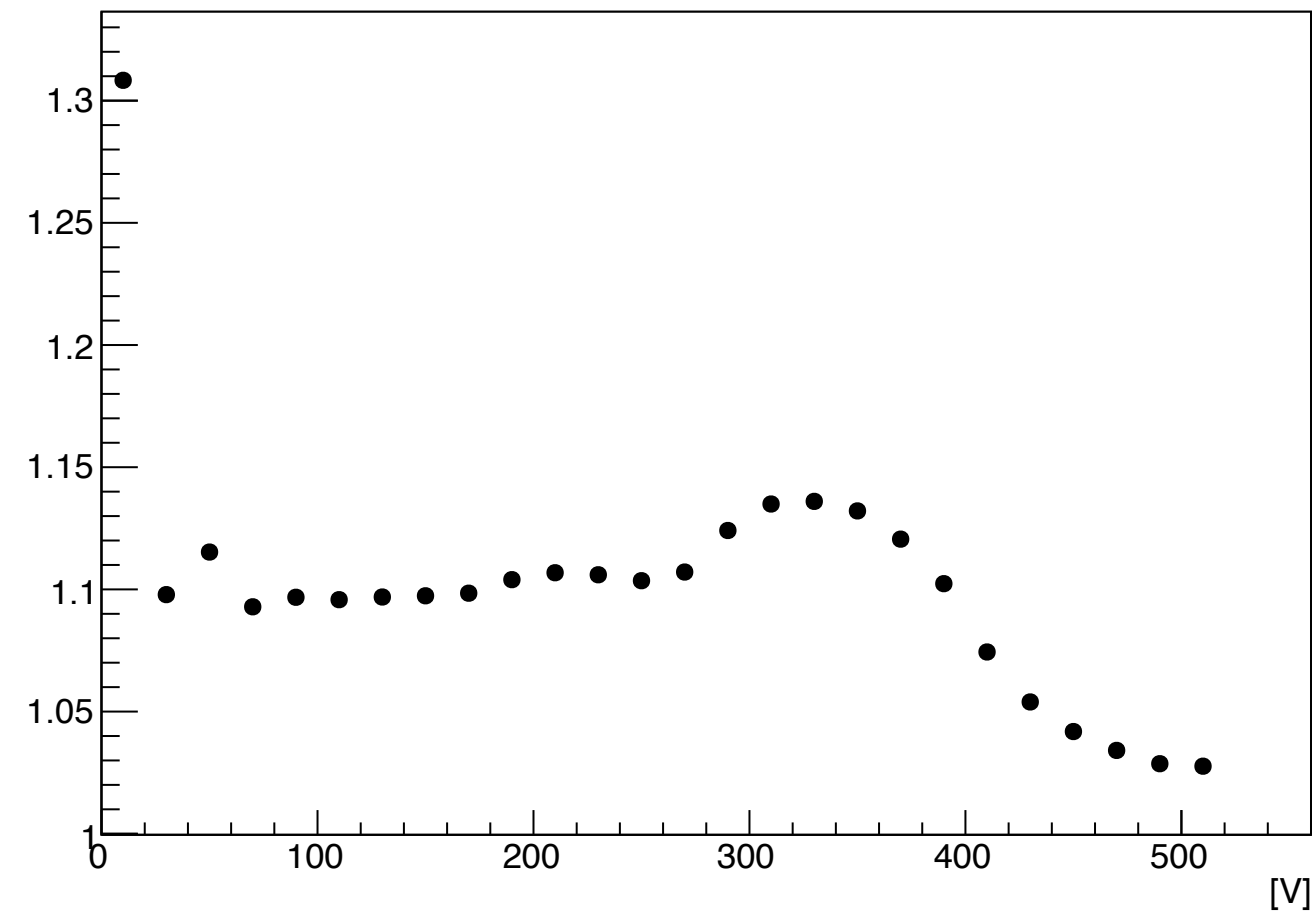
19_6/19_1



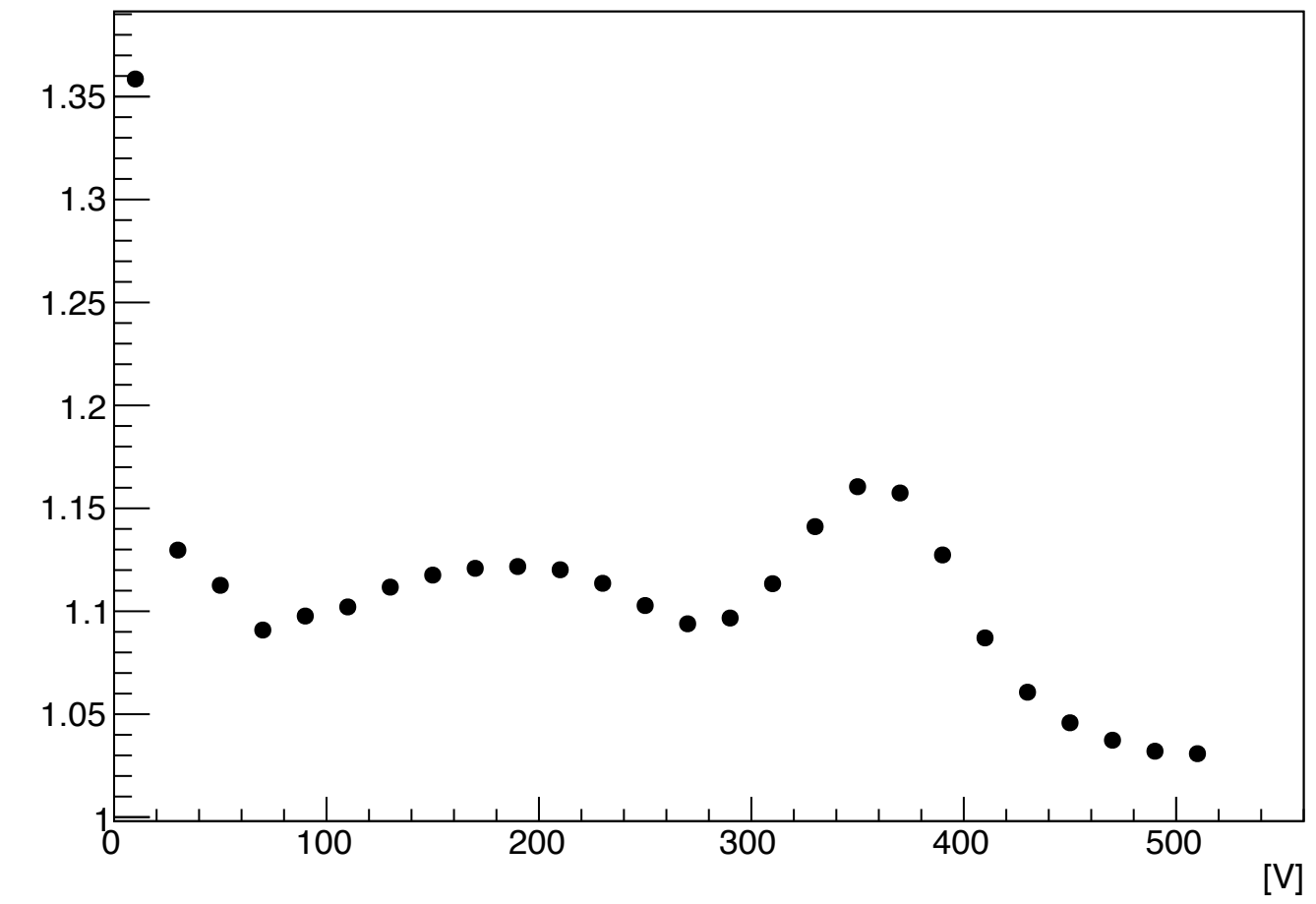
同じチップの位置違いの比較

28 (2cm× 2cm)

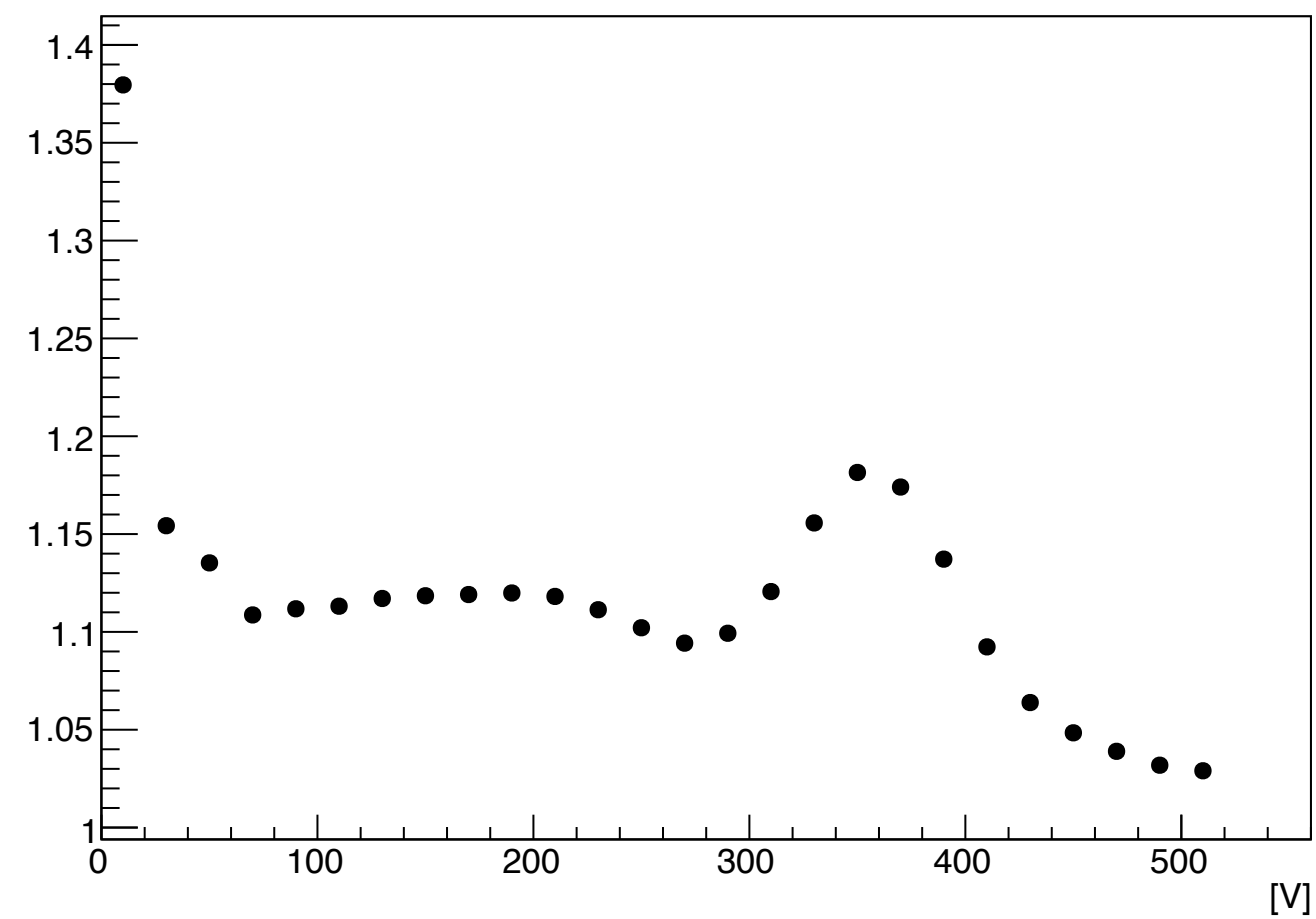
28_2/28_1



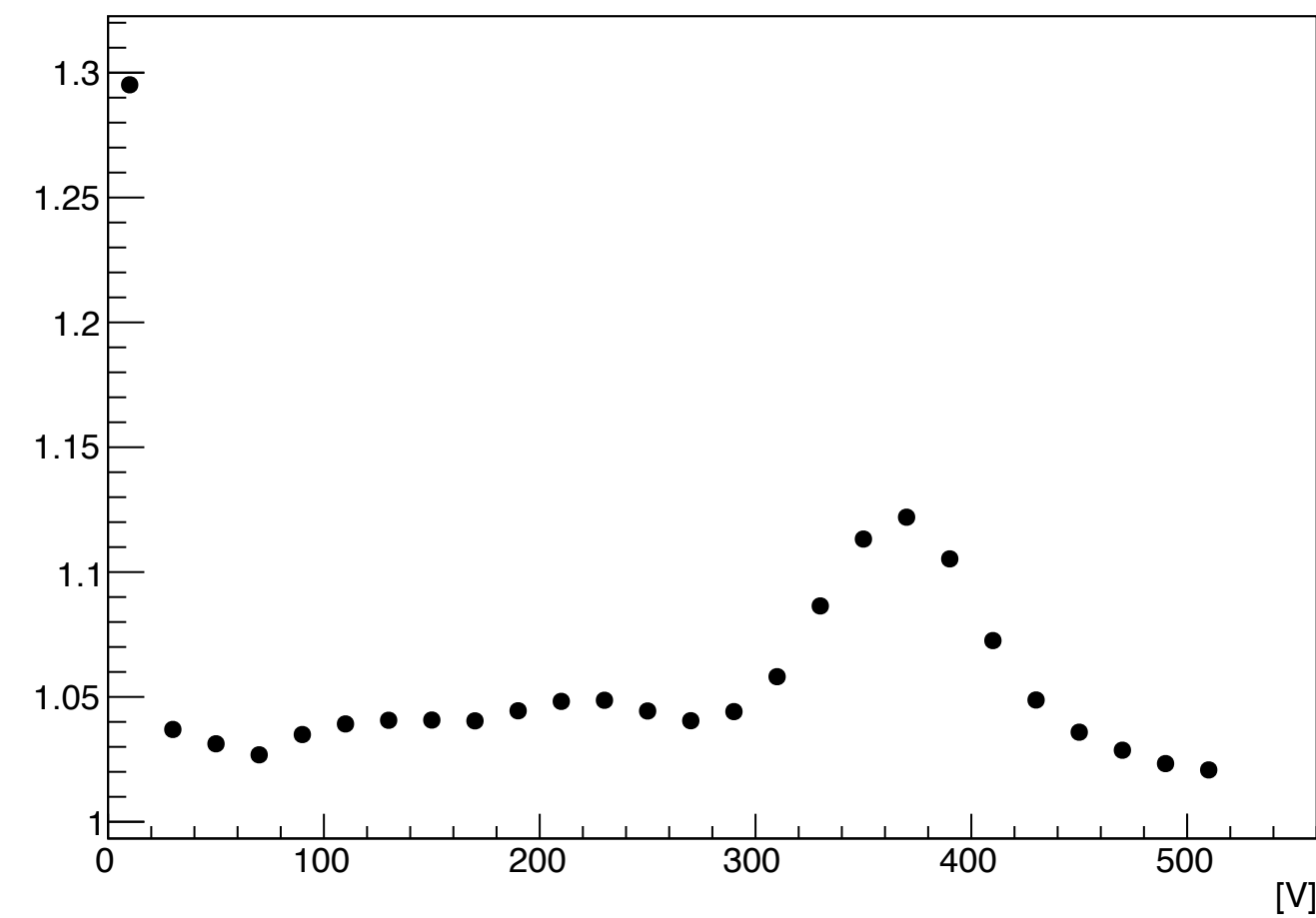
28_3/28_1



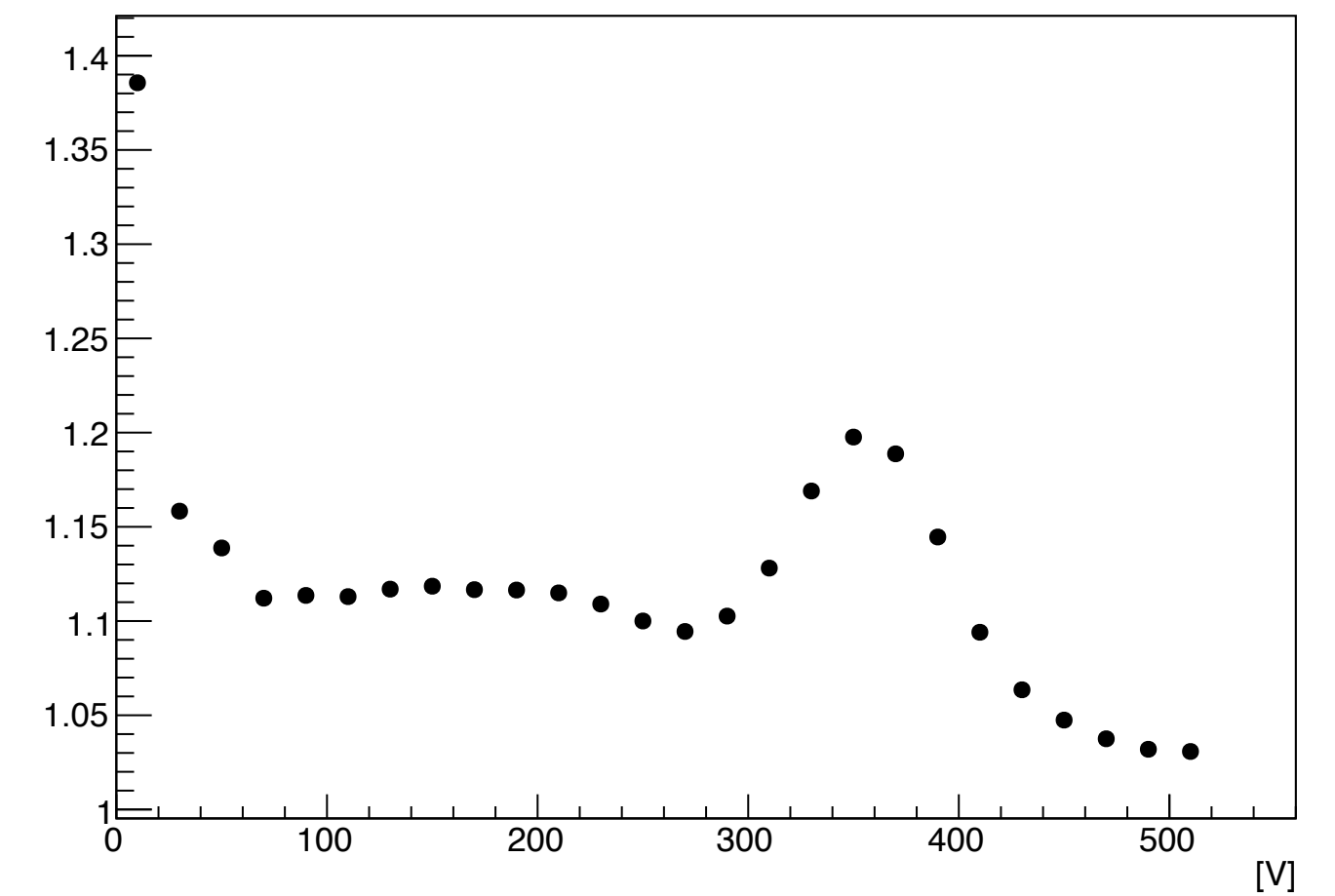
28_4/28_1



28_5/28_1



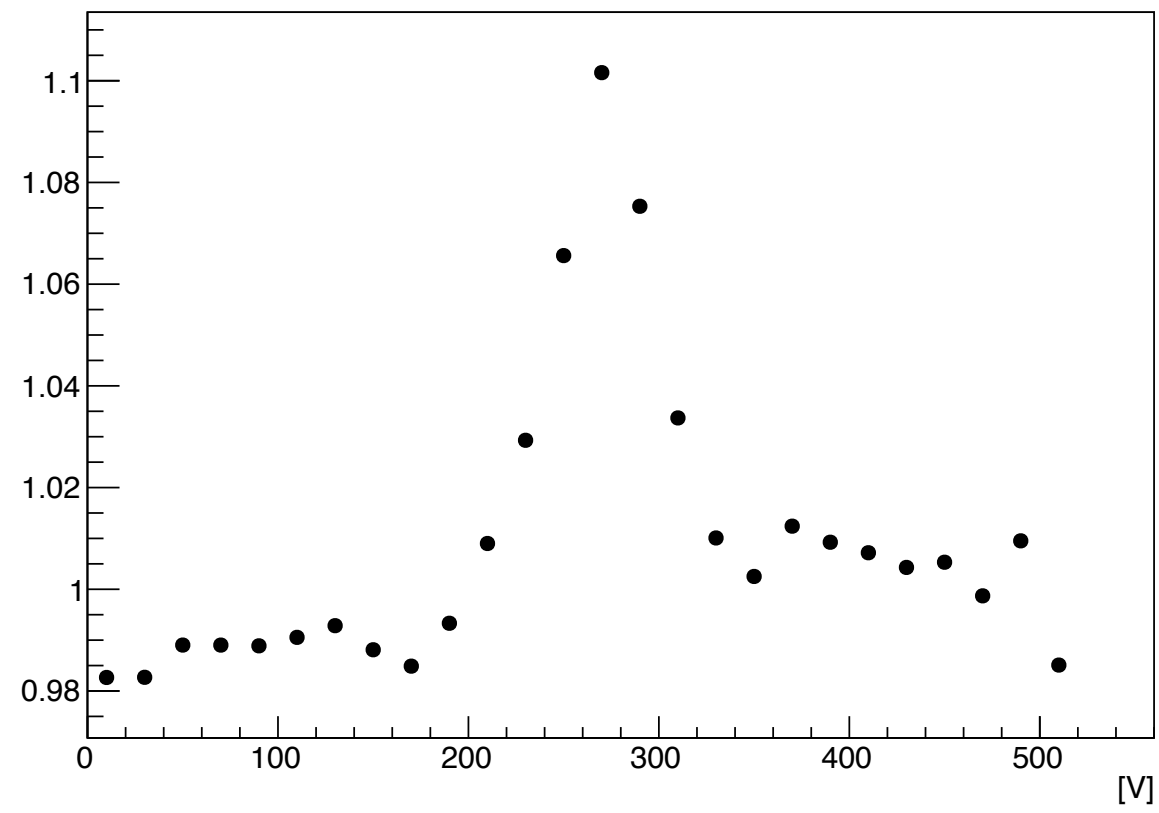
28_6/28_1



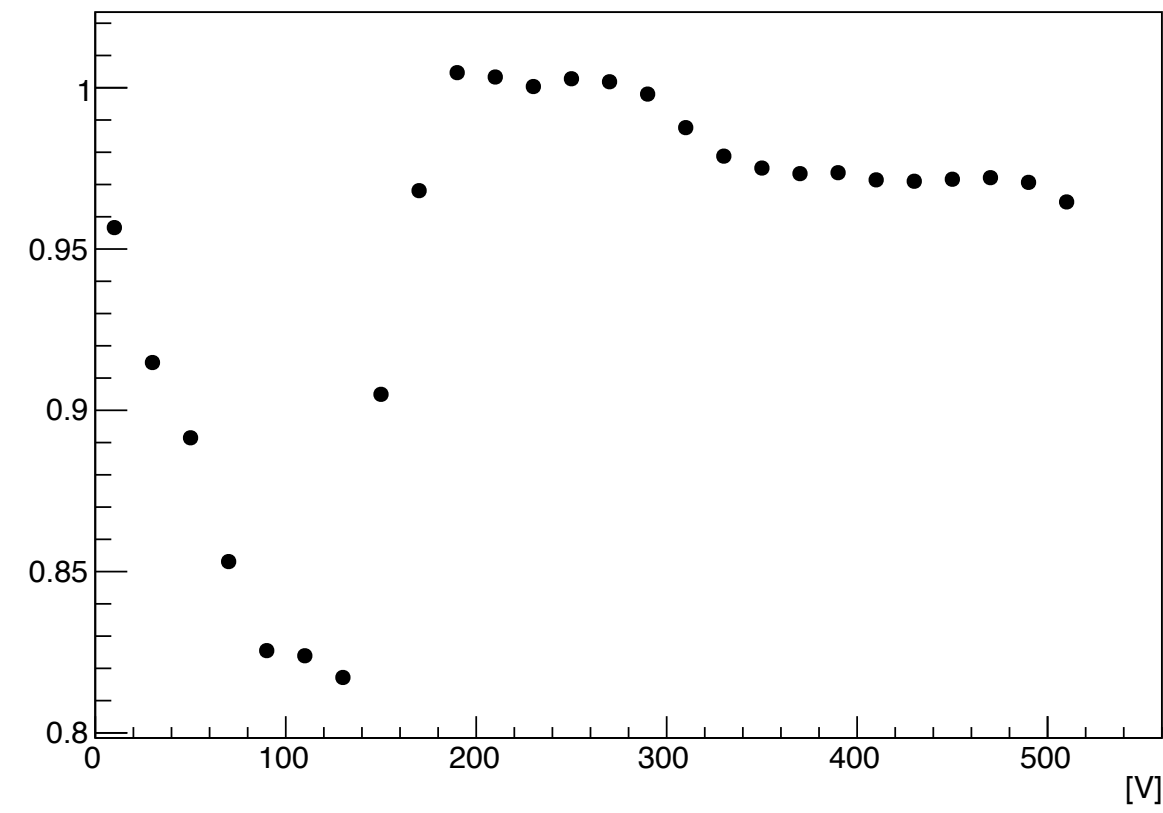
同じチップの位置違いの比較

1400 (1cm× 1cm)

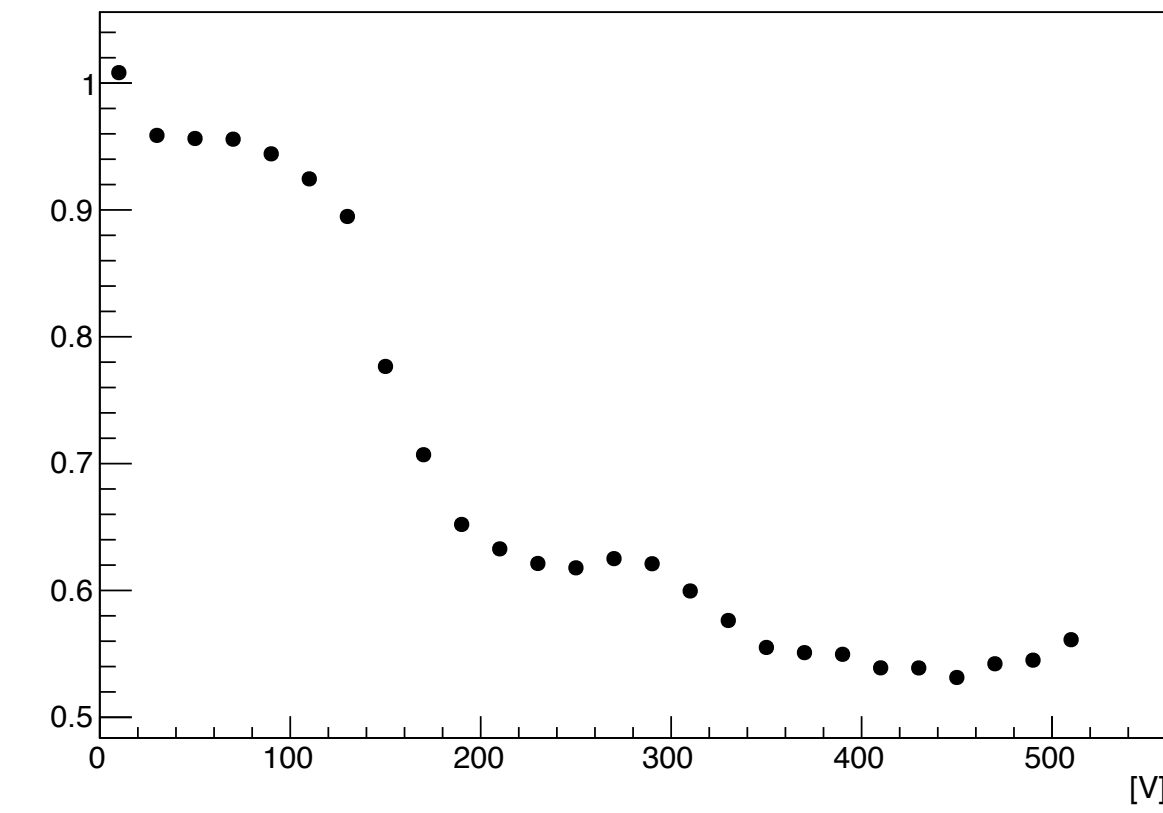
14T1_2/14T1_1



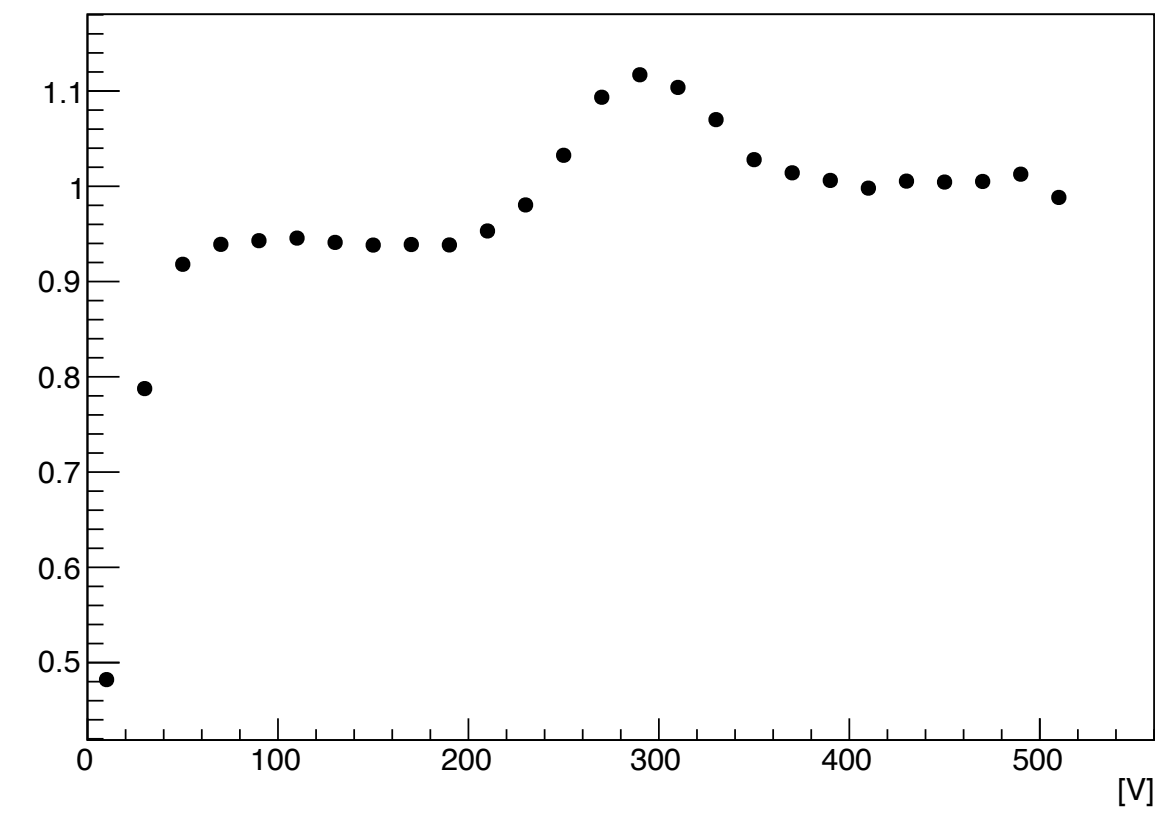
14B2_2/14B2_1



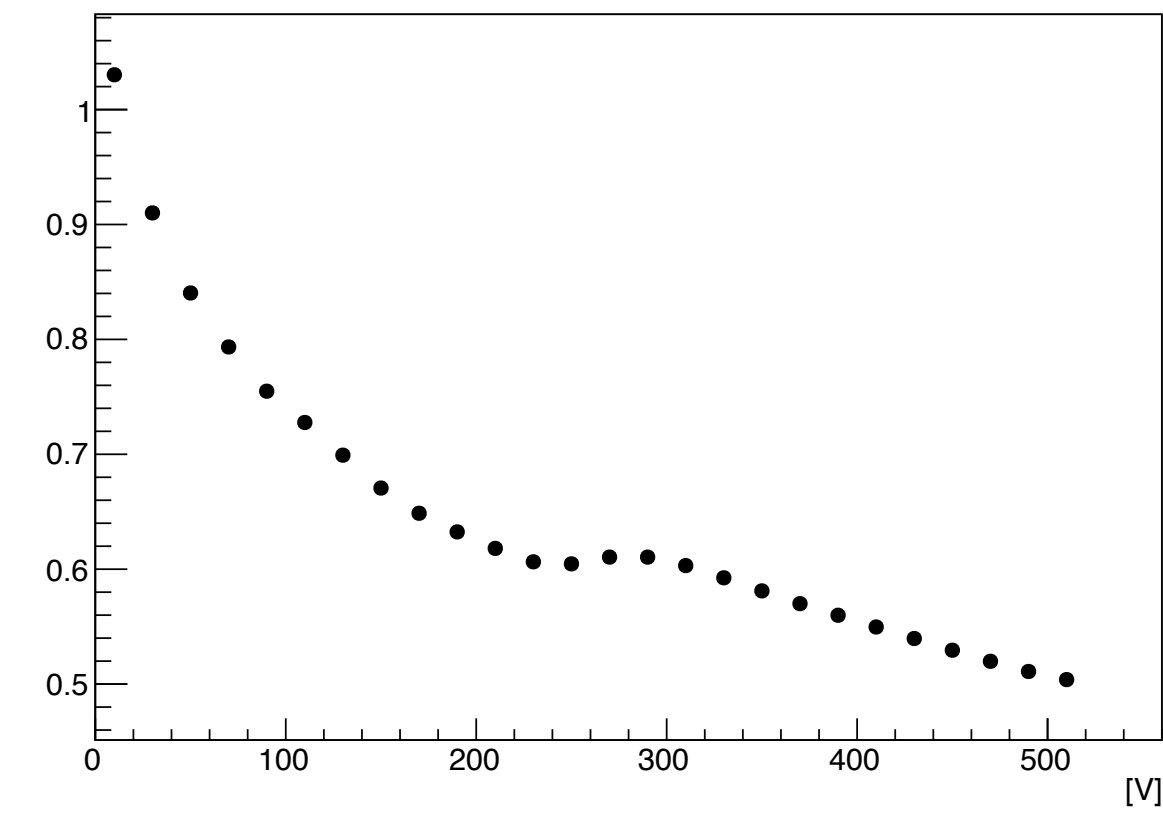
14R1_2/14R1_1



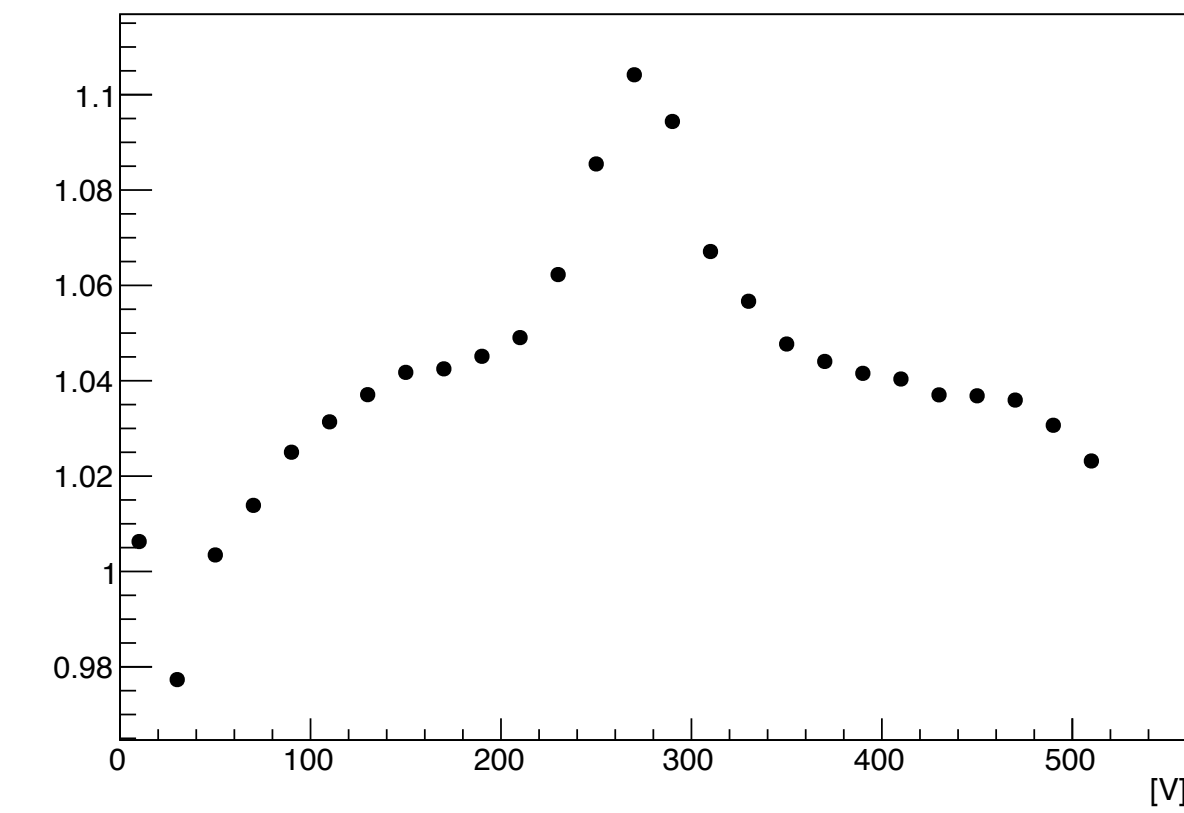
14T2_2/14T2_1



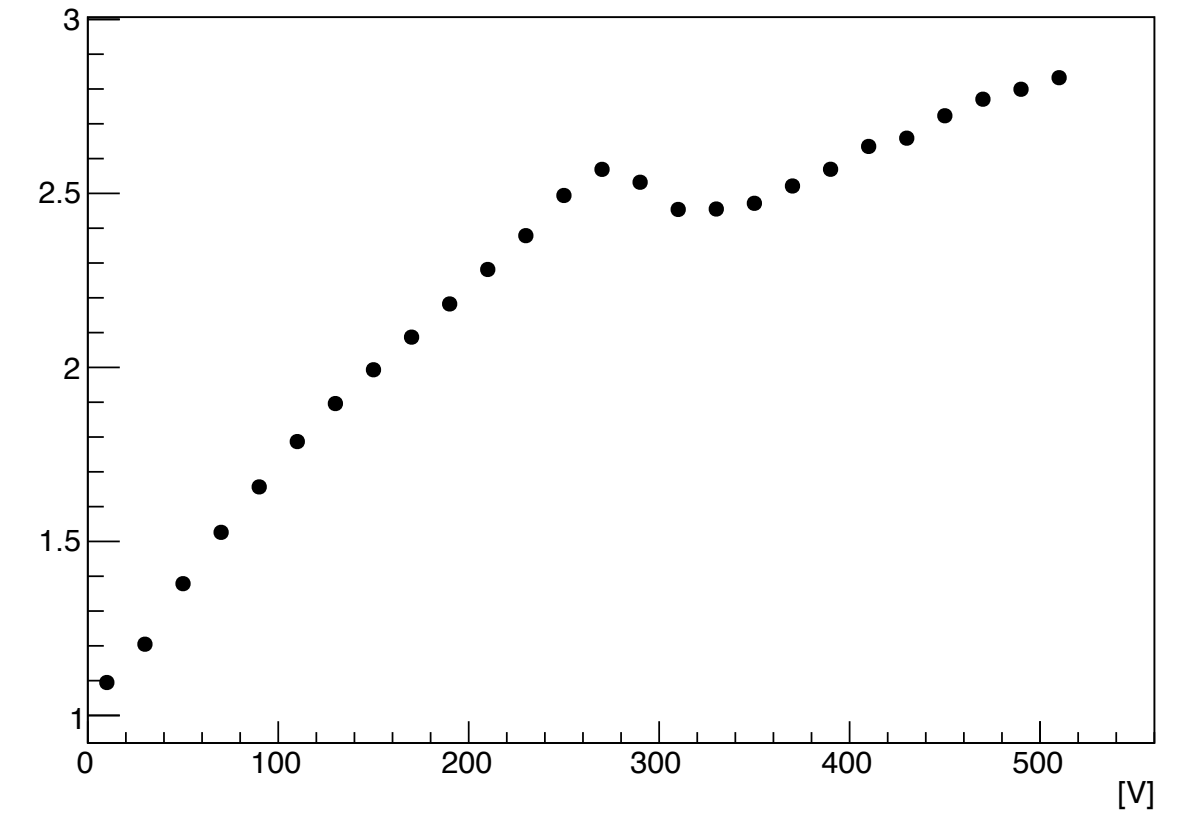
14L1_2/14L1_1



14B1_2/14B1_1



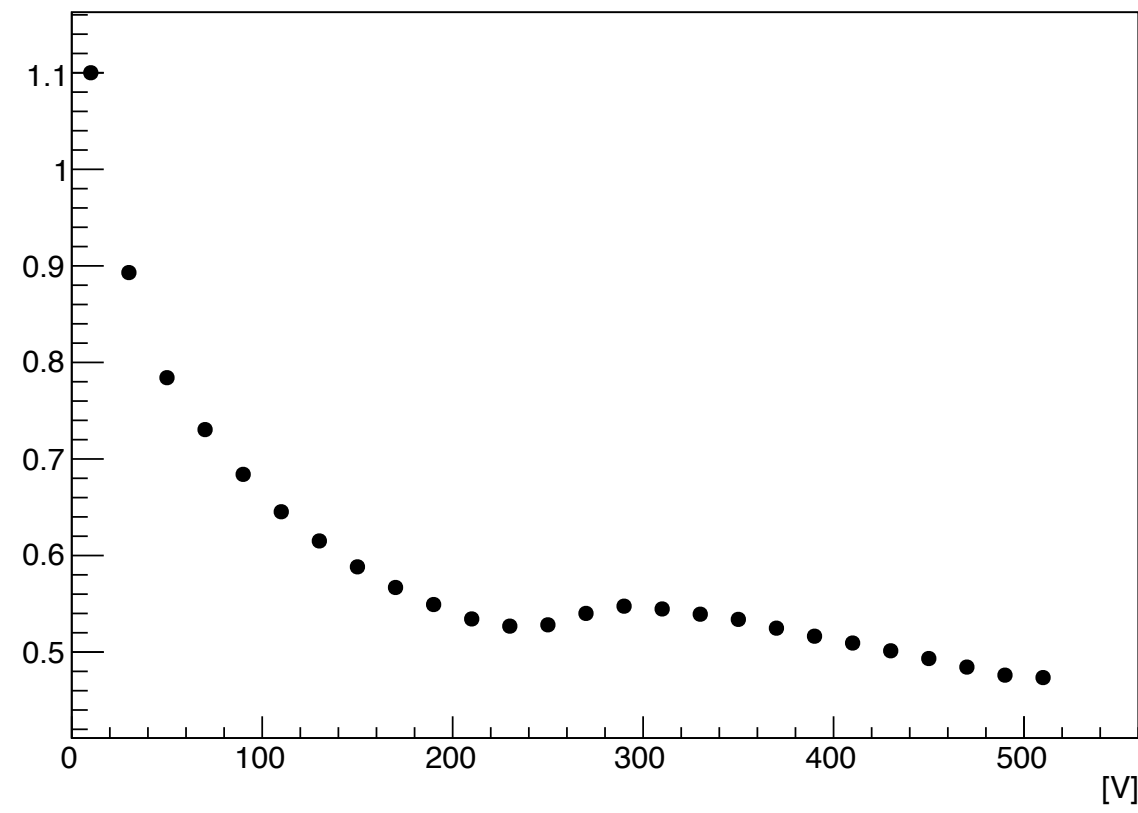
14R2_2/14R2_1



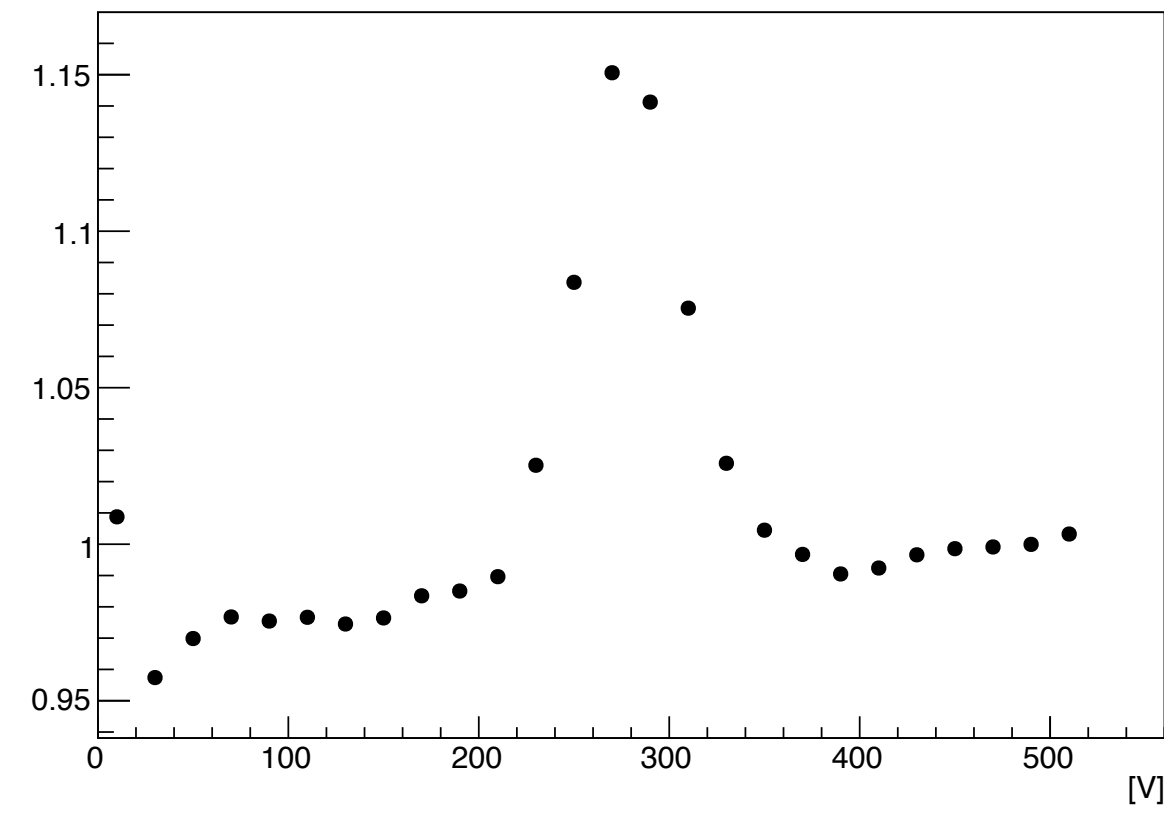
同じチップの位置違いの比較

1900 (1cm× 1cm)

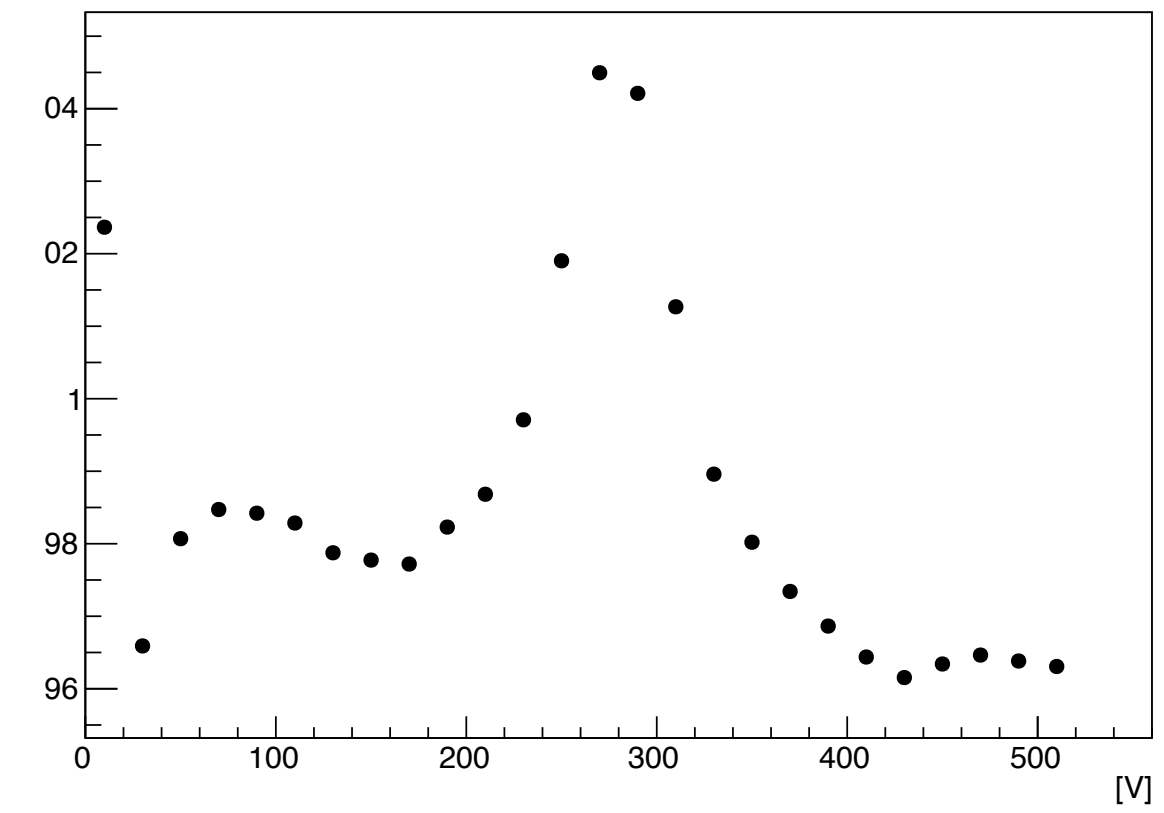
19T1_2/19T1_1



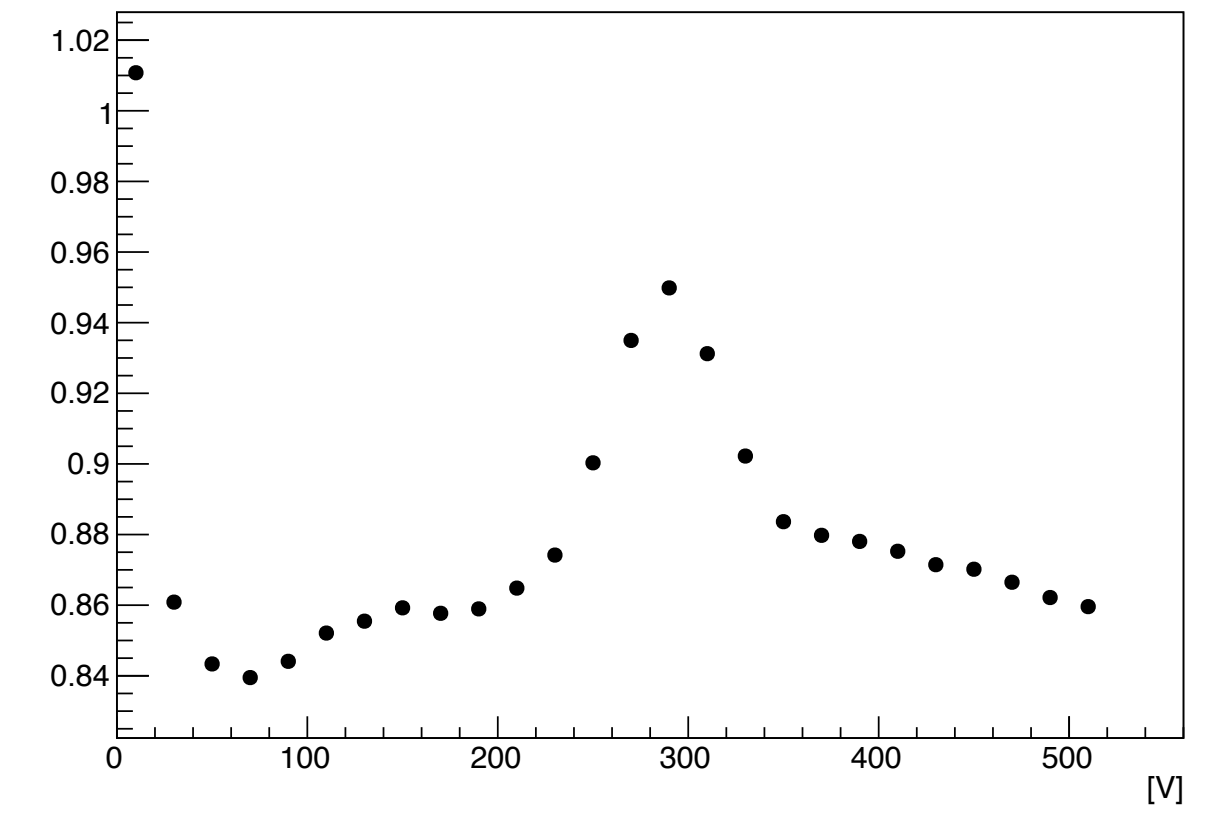
19L1_2/19L1_1



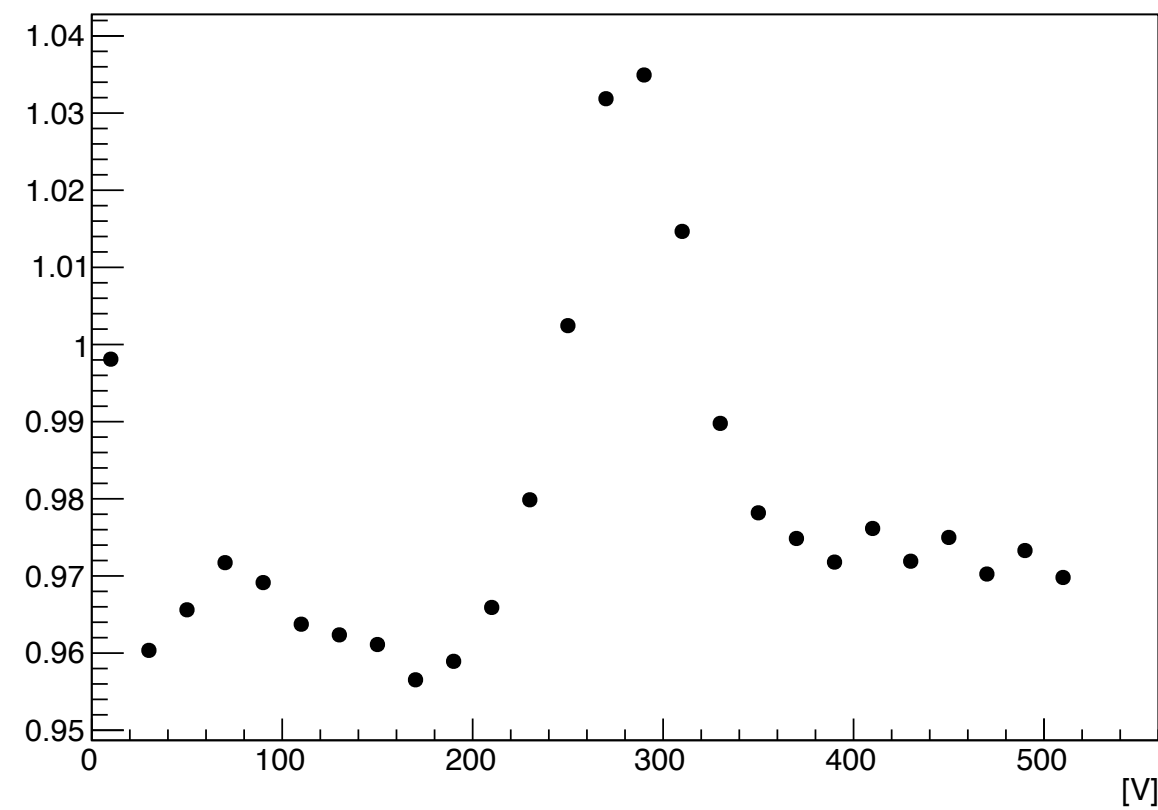
19B1_2/19B1_1



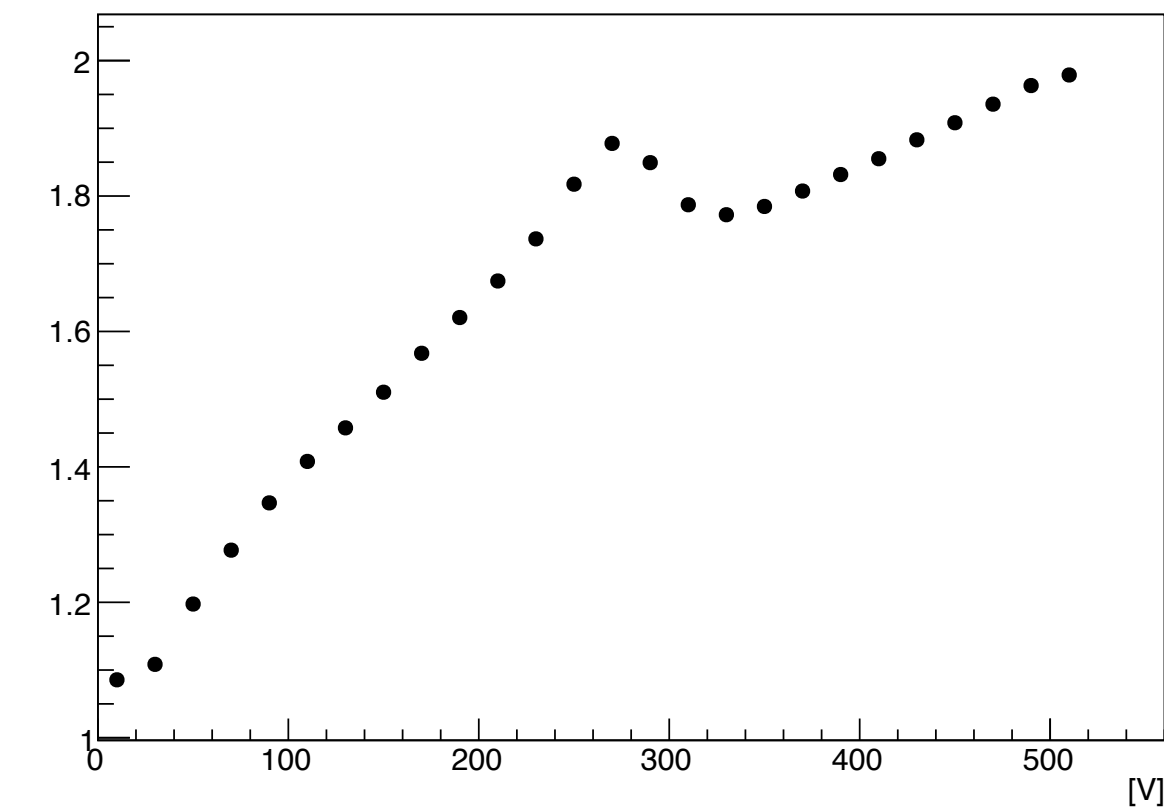
19R1_2/19R1_1



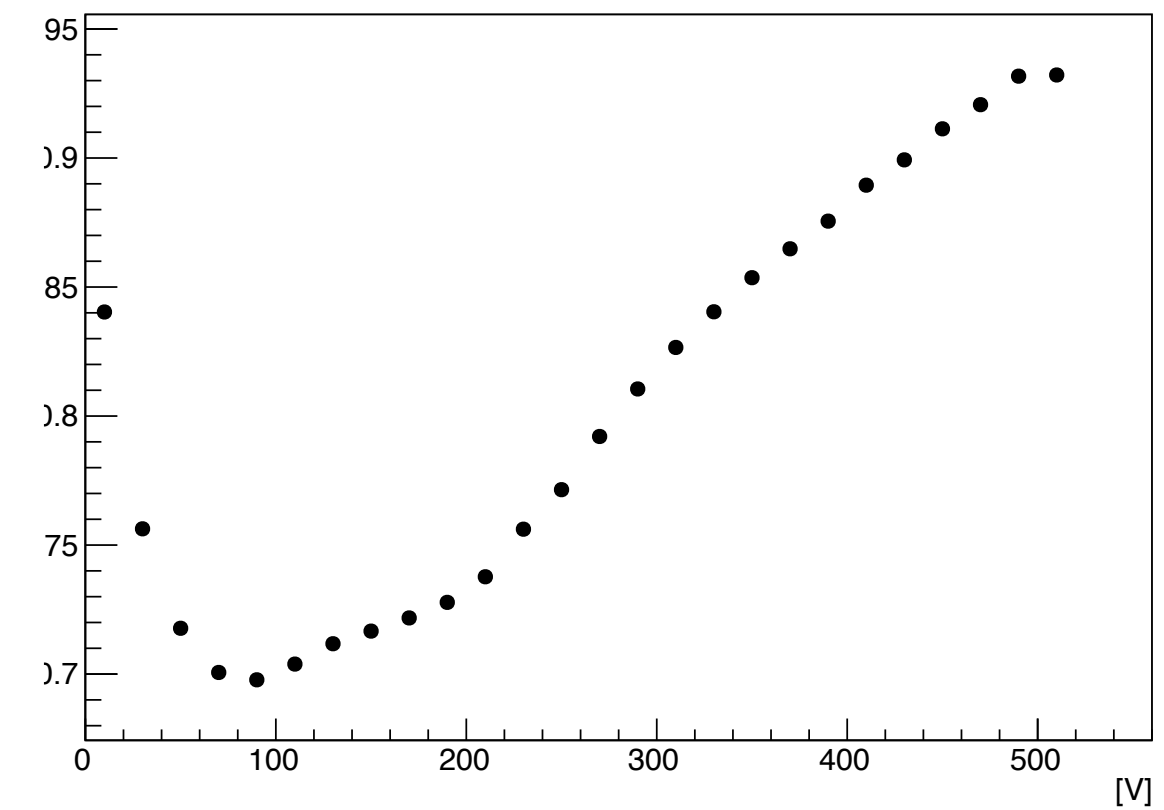
19T2_2/19T2_1



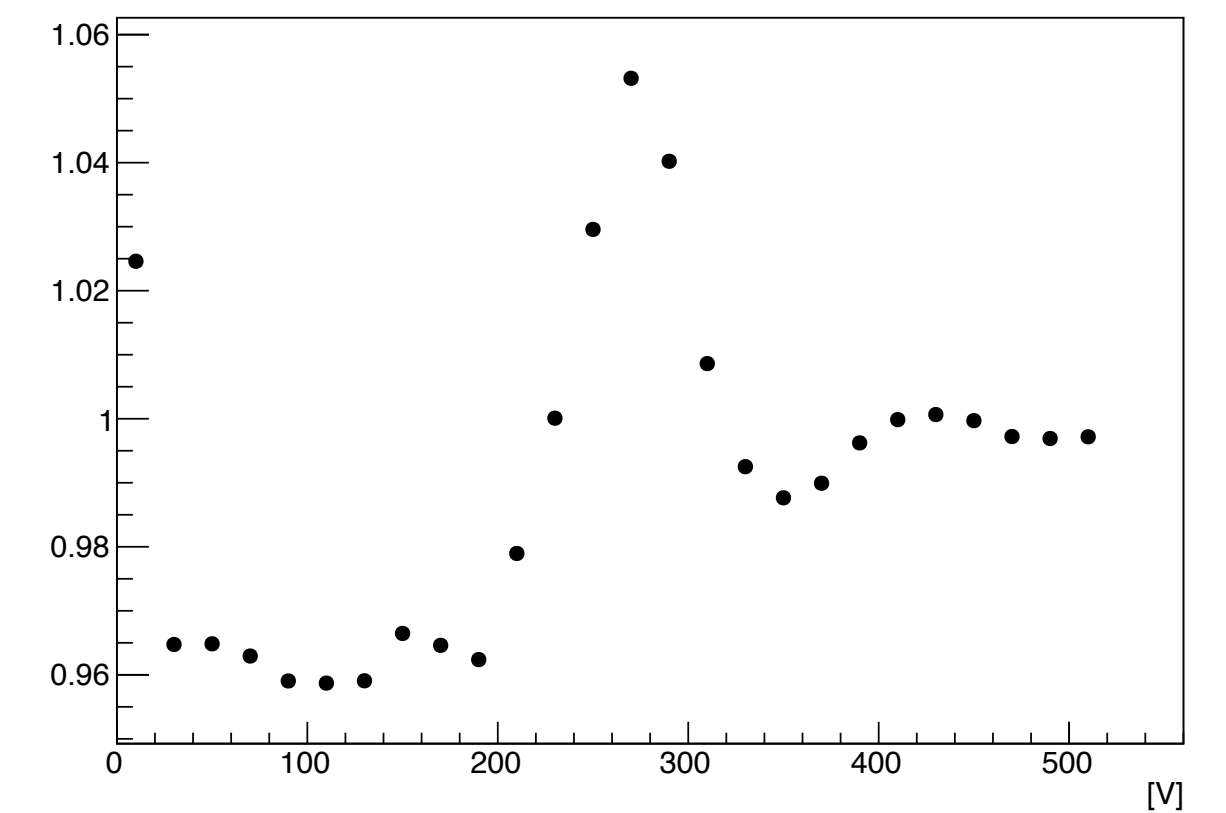
19L2_2/19L2_1



19B2_2/19B2_1



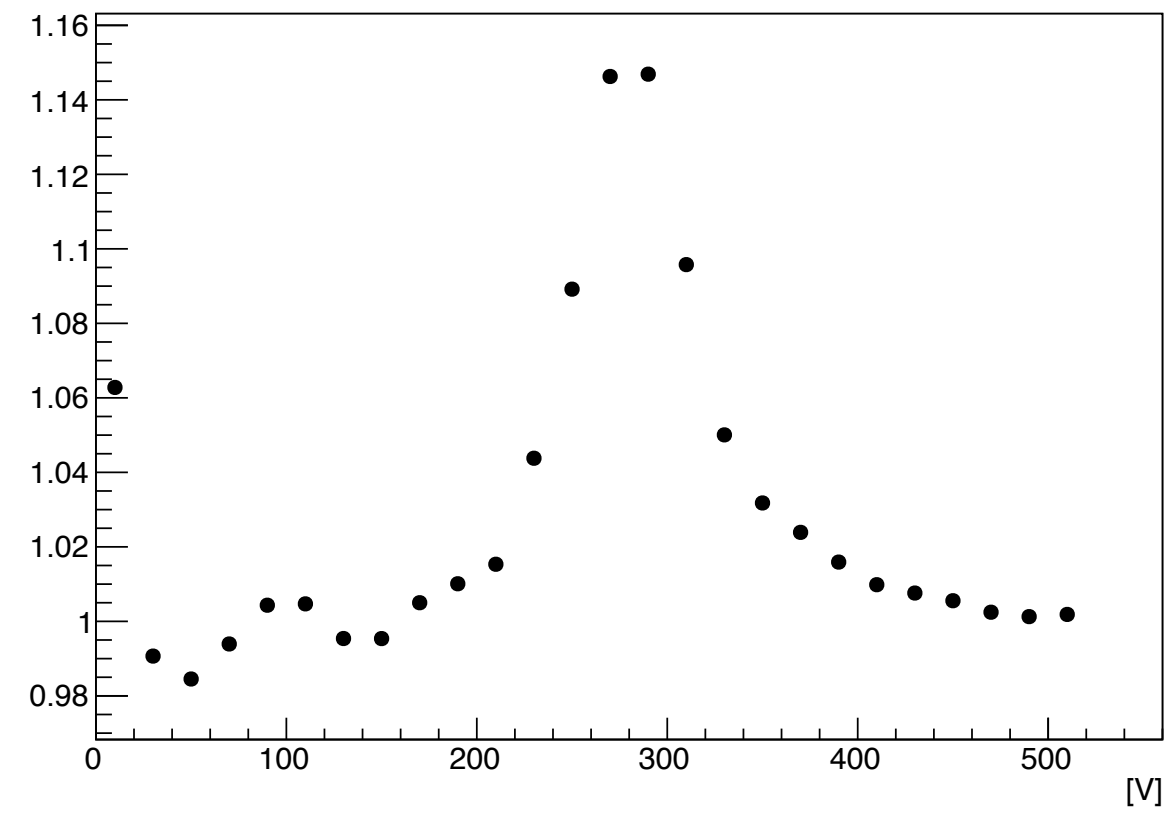
19R2_2/19R2_1



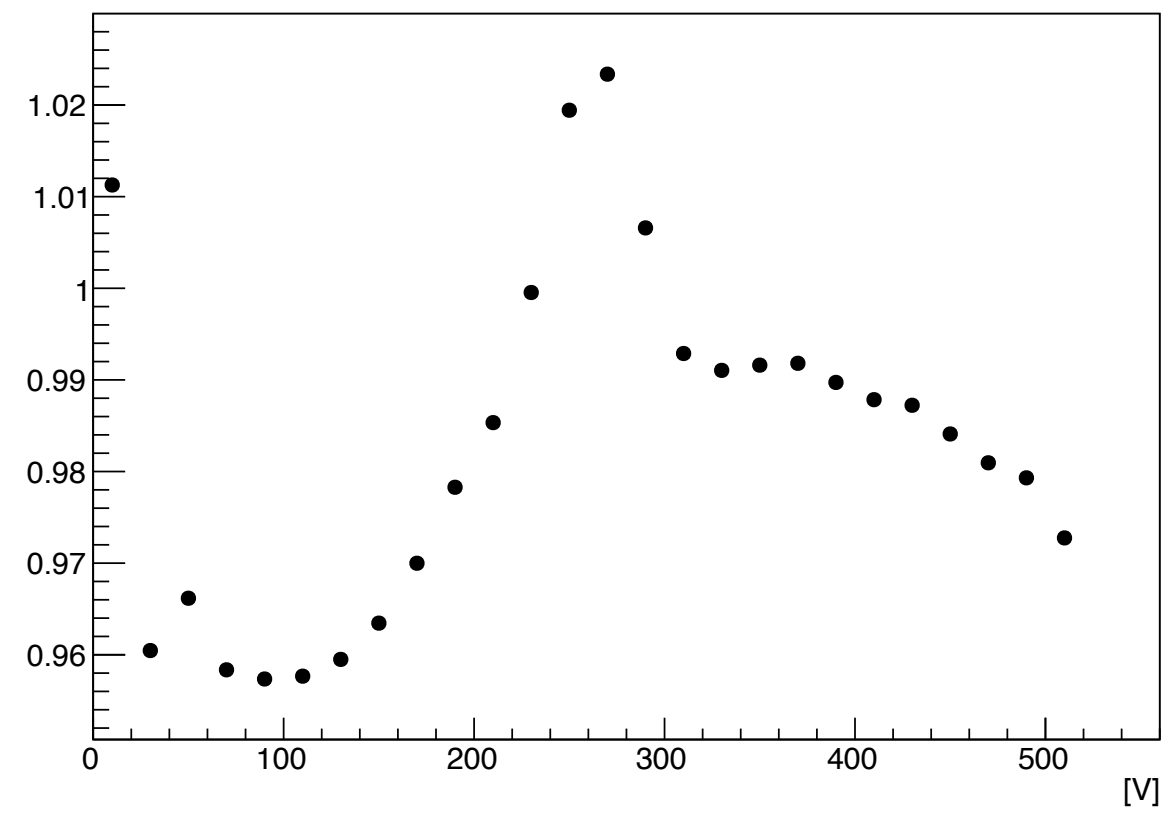
同じチップの位置違いの比較

2800 (1cm× 1cm)

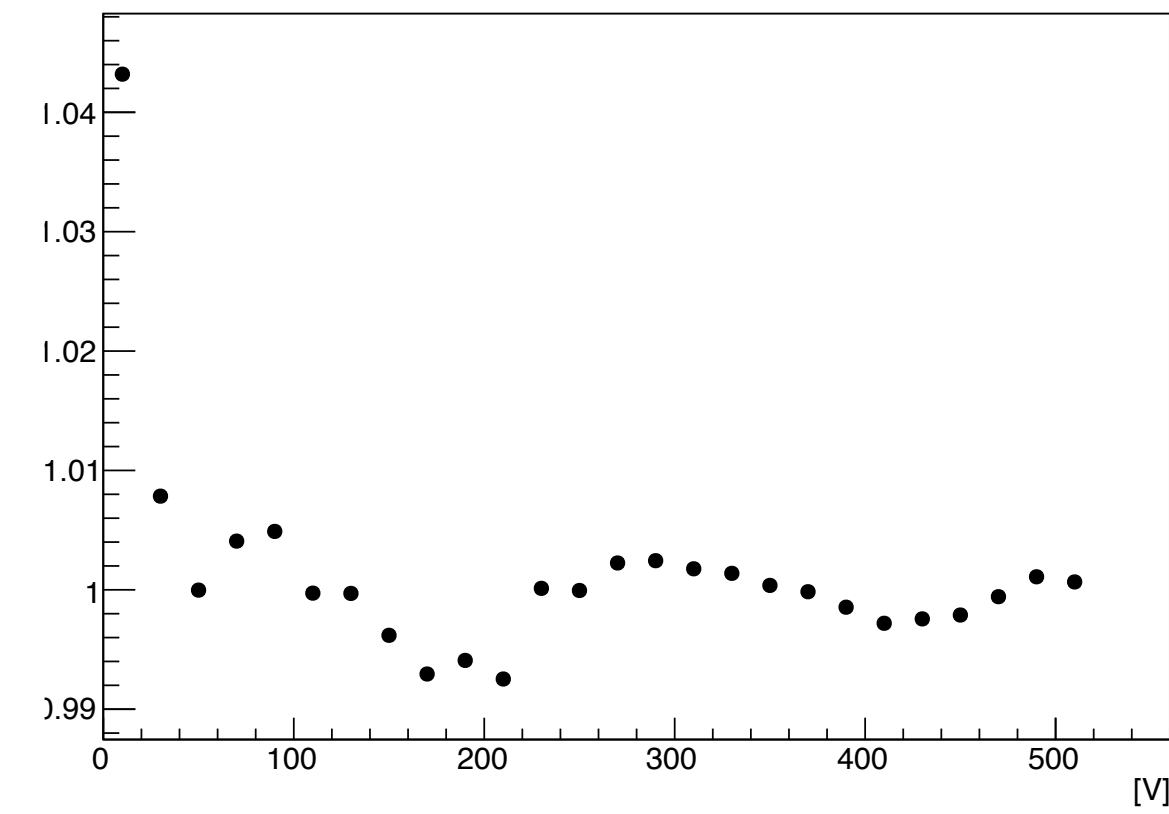
28T1_2/28T1_1



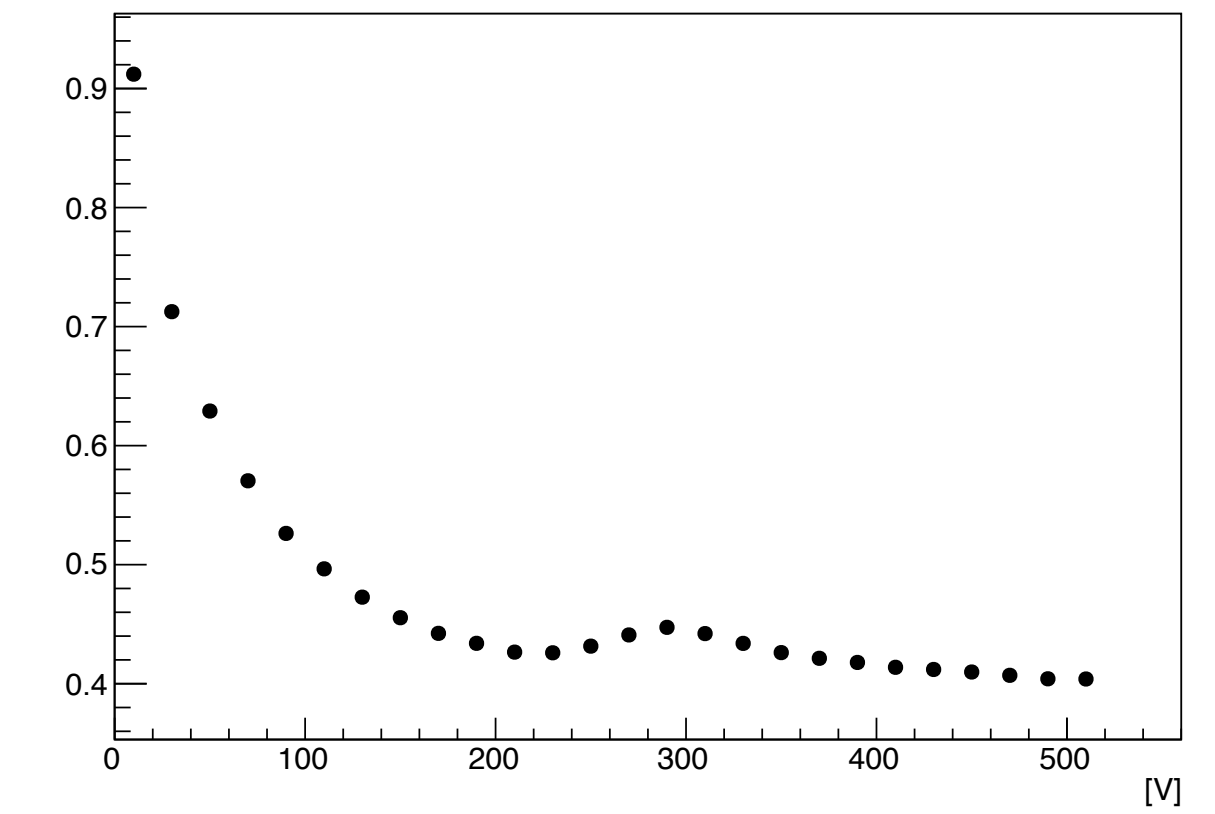
28L1_2/28L1_1



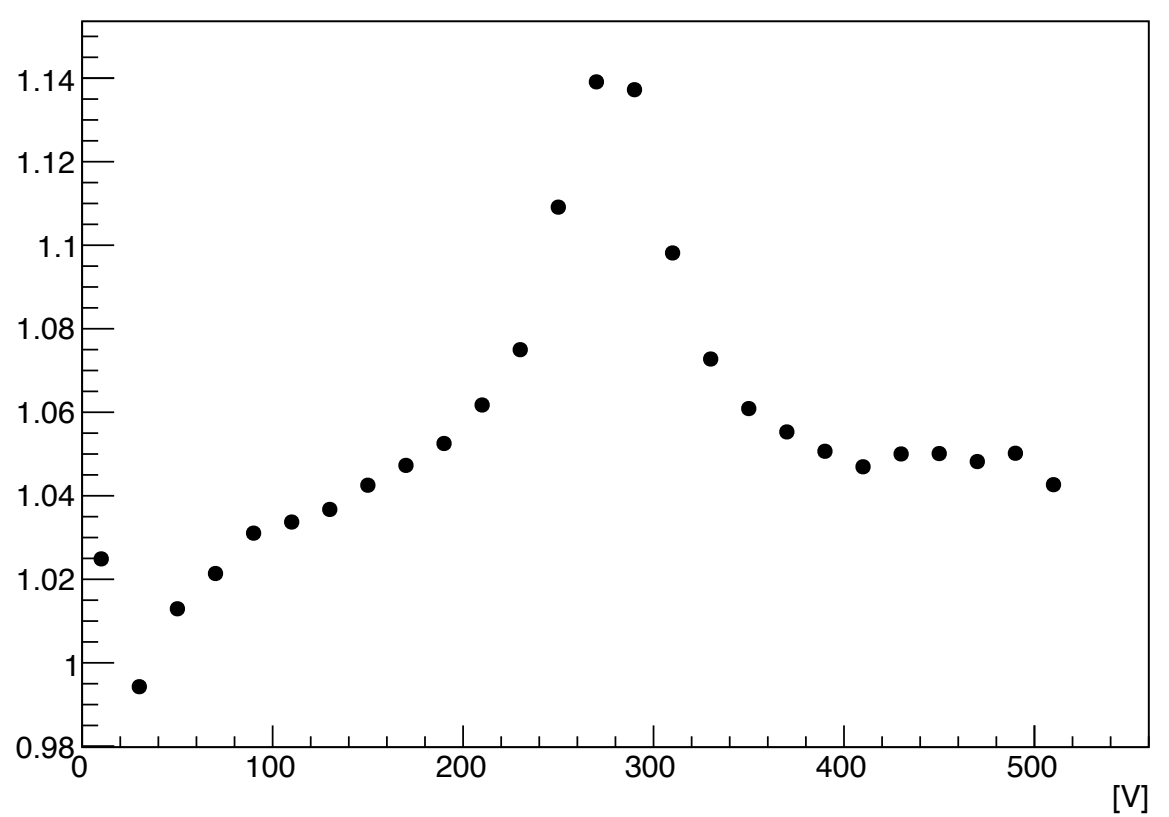
28B1_2/28B1_1



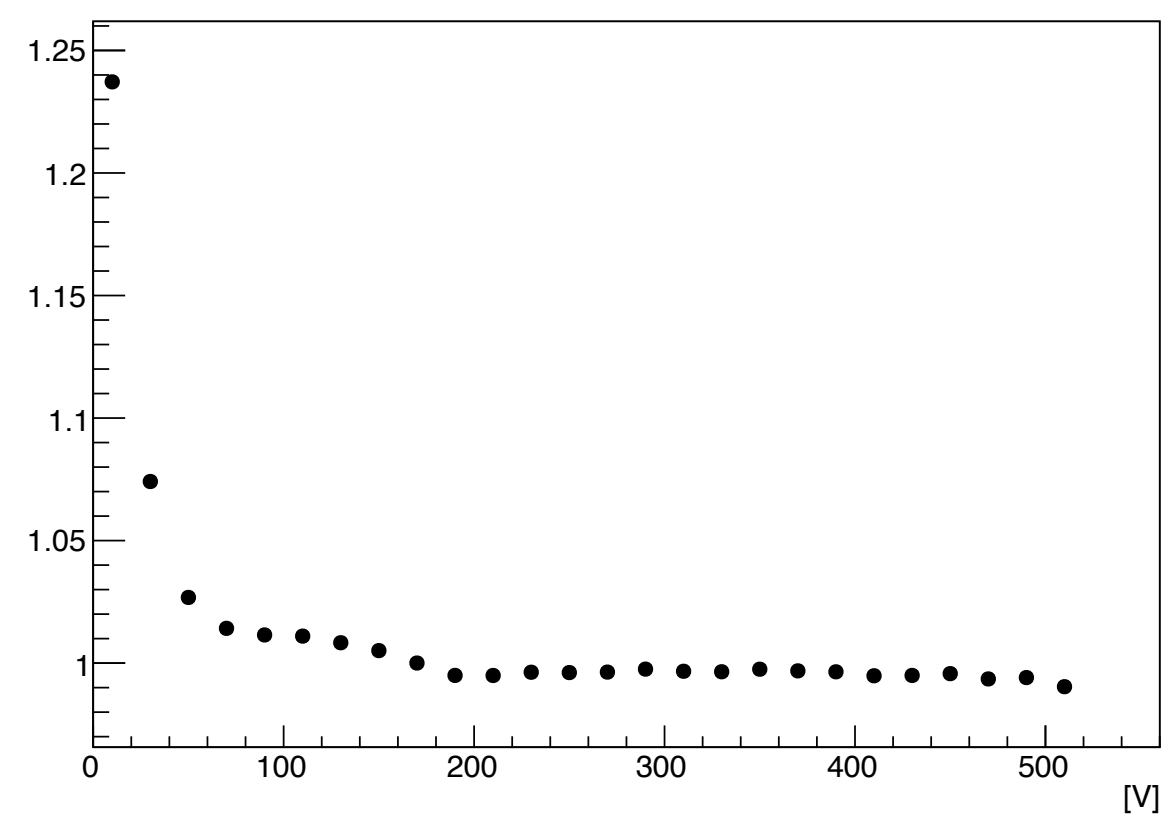
28R1_2/28R1_1



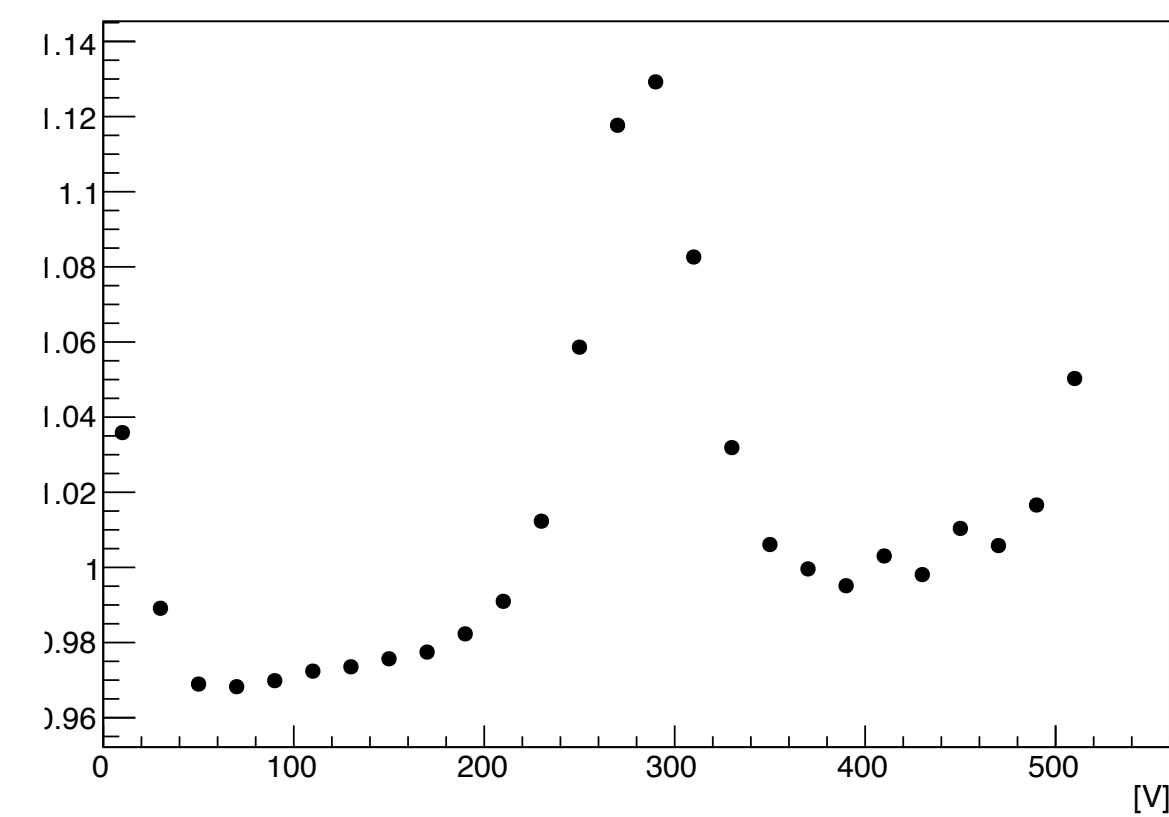
28T2_2/28T2_1



28L2_2/28L2_1



28B2_2/28B2_1



28R2_2/28R2_1

