



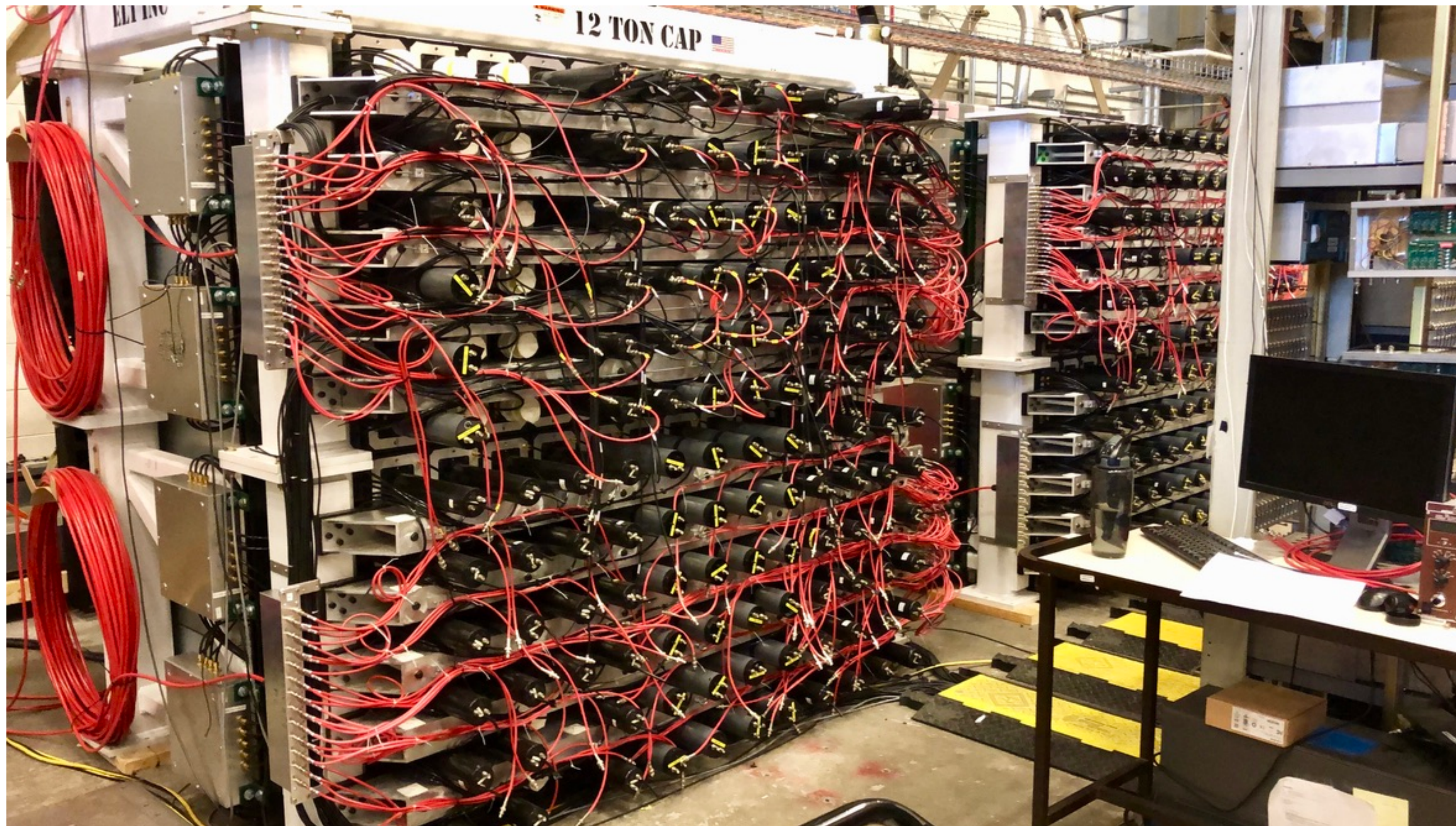
HCAL LED CALIBRATION

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HCAL design



288 modules (each $15 \times 15 \text{ cm}^2$) in a matrix of 24 modules in length and 12 in width

Weight ~ 40 tons

Iron thickness: 1.5 cm

Scintillator material PPO-only (2,5-Diphenyloxazole) thickness: 1.0 cm

WLS placed at the center of the each module, carries on the light on the **PMTs**

4 “crane-able” subassemblies and a **Rollable stand** to move gantry + HCAL-J together without need to disconnect cables.

HCAL-J Requirements

✱ **Matching acceptance with SBSmagnet/polarimeter**

✱ **Linear energy response and good energy resolution**

✱ **95% efficiency with trigger threshold at 25% peak signal**

✱ **Spatial resolution ~ 5 cm rms**

✱ **Time resolution < 1.0 ns rms**

✱ **Angular resolution 5 mrad**

LED runs: general info



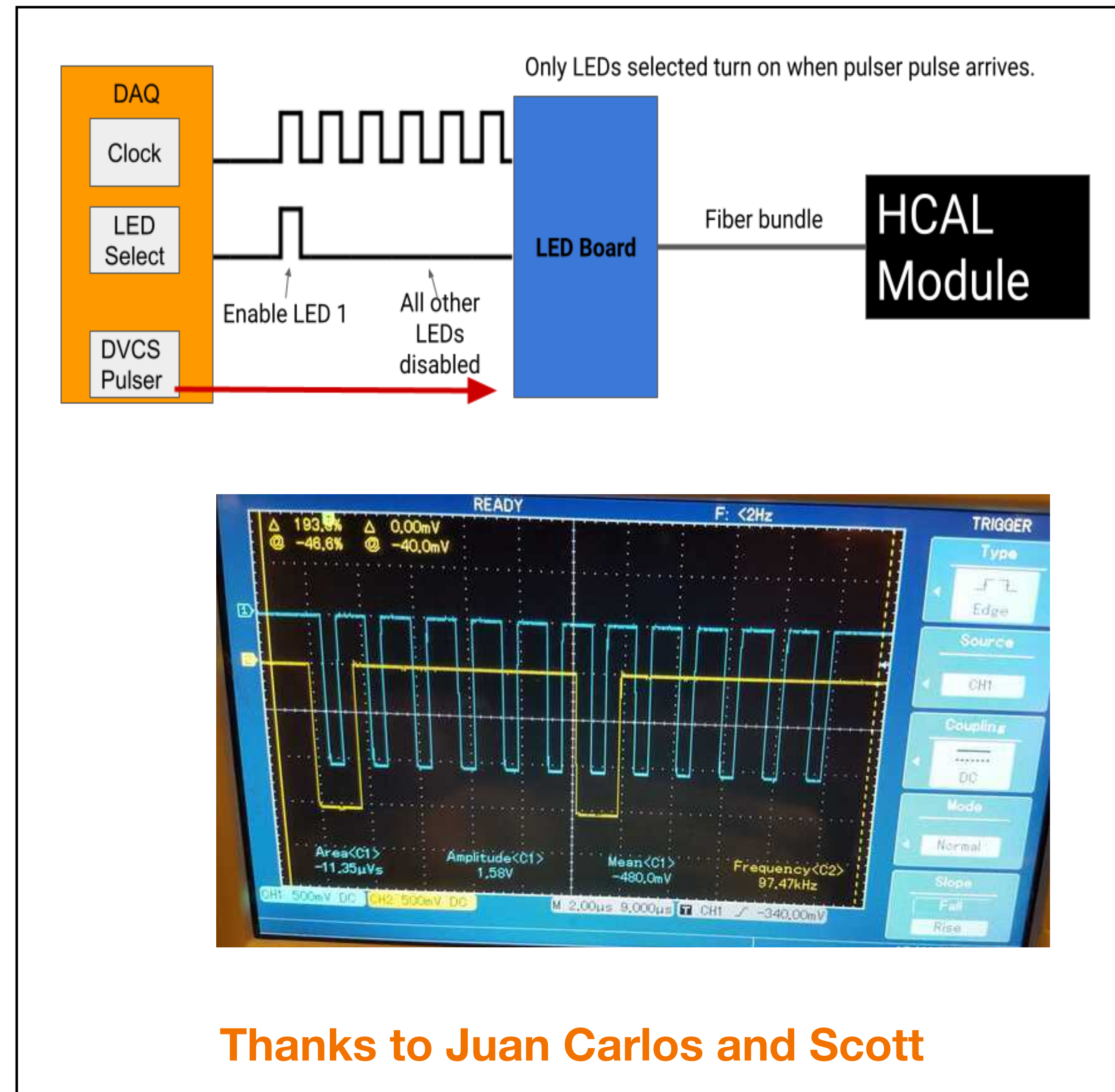
HCal has a series of **6 LEDs** that can illuminate each PMT. Each subsequent LED lights up twice as much as the previous one

LED cycles programmable

LED0 → LED1 → LED2 → LED3 → LED4 → LED5

1000 triggers and then you move on to the next one

Each run ~ 5000 event



HCAL: LED runs, general info

CMU PMTs: 19-pin, 12-stage XP2262 (192 PMTs)

JLAB PMTs: 21-pin, 8-stageXP2282 (96 PMTs)

144	145	146	147	148	149	150	151	152	153	154	155
156	157	158	159	160	161	162	163	164	165	166	167
168	169	170	171	172	173	174	175	176	177	178	179
180	181	182	183	184	185	186	187	188	189	190	191
192	193	194	195	196	197	198	199	200	201	202	203
204	205	206	207	208	209	210	211	212	213	214	215
216	217	218	219	220	221	222	223	224	225	226	227
228	229	230	231	232	233	234	235	236	237	238	239
240	241	242	243	244	245	246	247	248	249	250	251
252	253	254	255	256	257	258	259	260	261	262	263
264	265	266	267	268	269	270	271	272	273	274	275
276	277	278	279	280	281	282	283	284	285	286	287

LEFT half HCAL

0	1	2	3	4	5	6	7	8	9	10	11
12	13	14	15	16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31	32	33	34	35
36	37	38	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57	58	59
60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83
84	85	86	87	88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103	104	105	106	107
108	109	110	111	112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127	128	129	130	131
132	133	134	135	136	137	138	139	140	141	142	143

RIGHT half HCAL

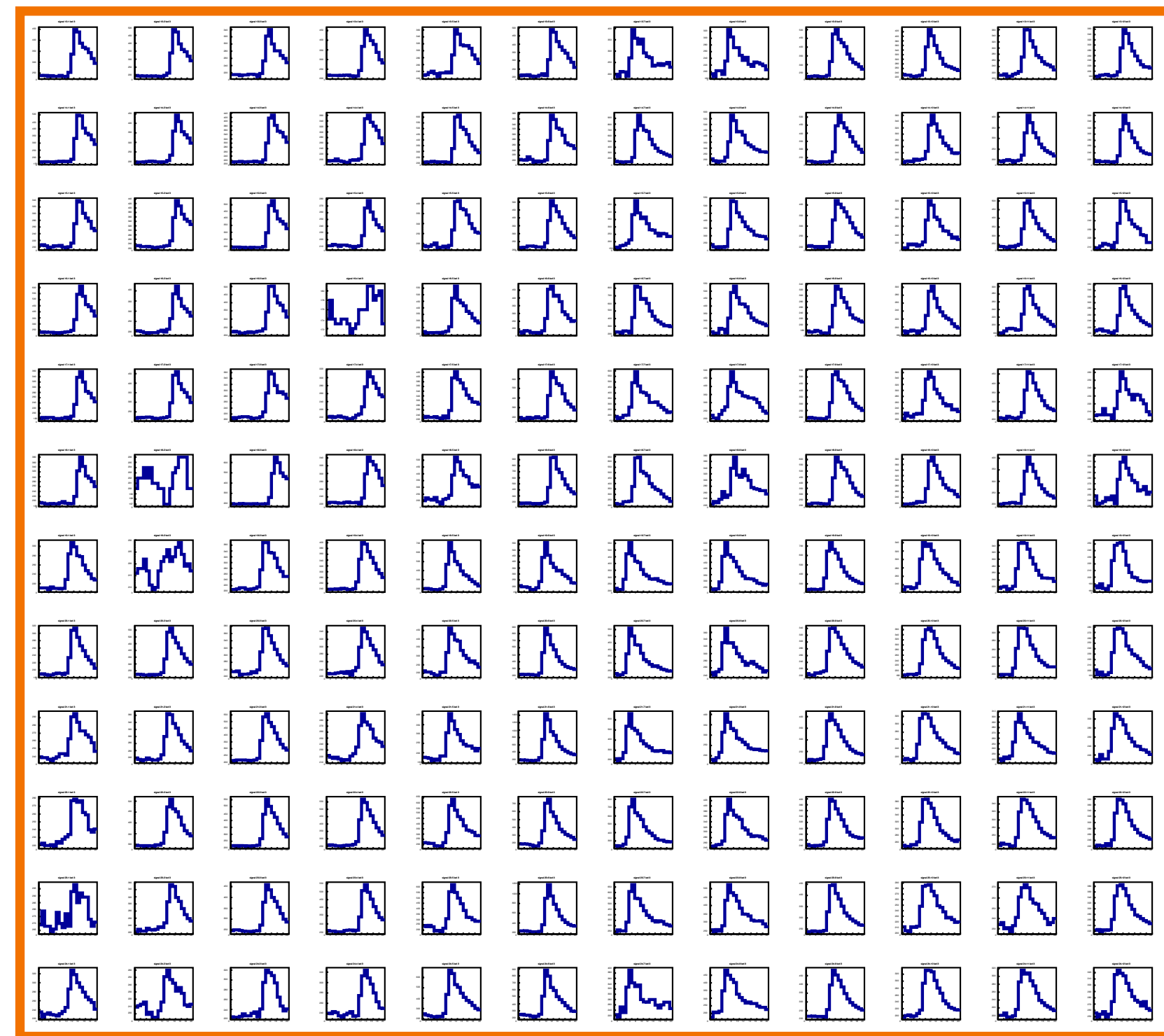
Off for LED runs

Run Number	CMU PMT Voltage	JLab PMT Voltage
1303	-1675V	-2050 V
1302	-1650 V	-2000 V
1300	-1600 V	-1900 V
1297	-1575 V	-1850 V
1294	-1550 V	-1800 V
1293	-1520 V	-1750 V
1192	-1500 V	-1700 V
1291	-1475 V	-1650 V
1290	-1450 V	-1600 V
1289	-1425 V	-1550 V
1288	-1400 V	-1500 V
1286	-1350 V	-1450 V

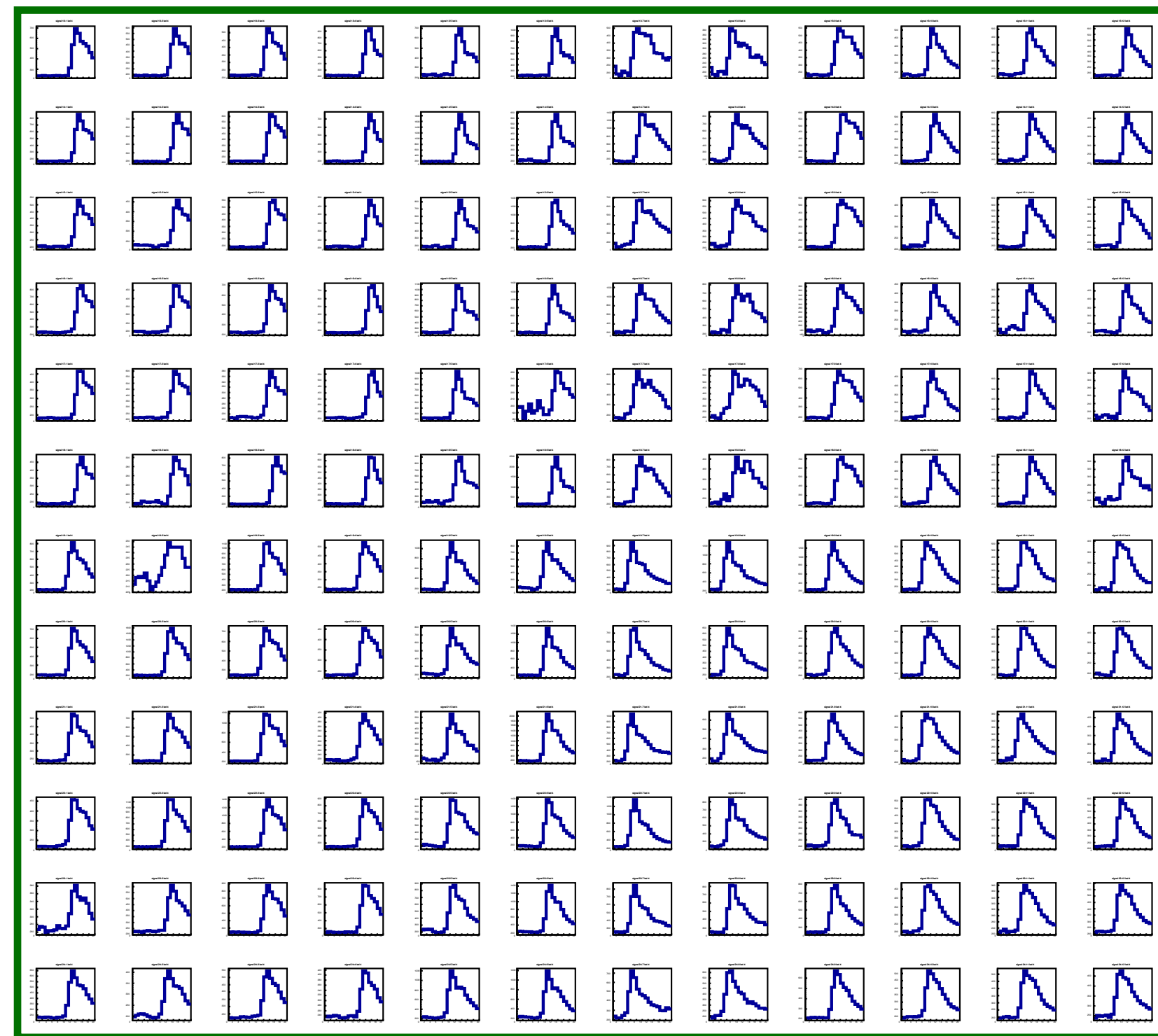
LED runs: FADC response

RUN 1286 : CMU PMTs -1350 V ; JLABs PMTs -1450

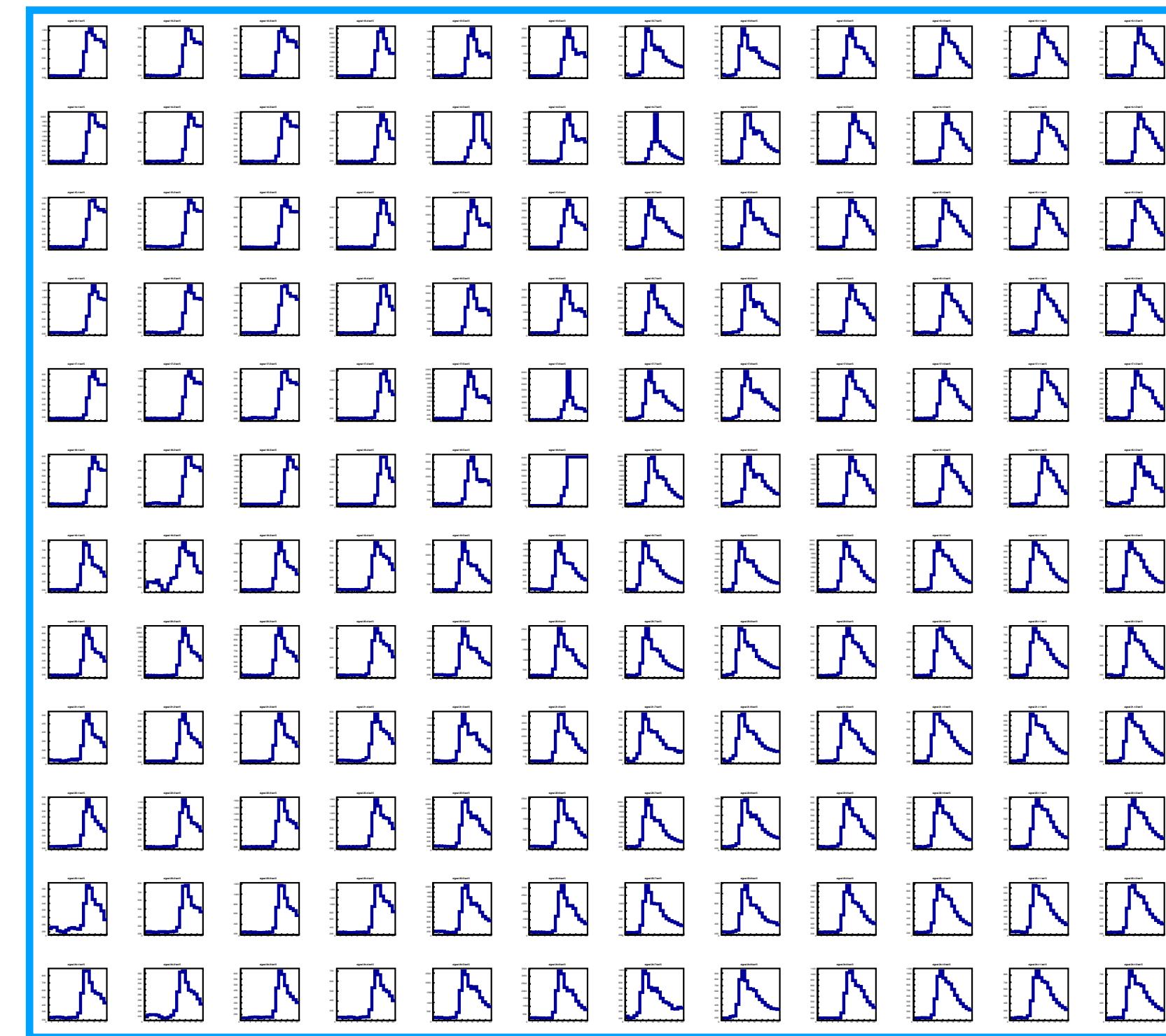
LED3 event n° 3500



LED4 event n° 4500



LED5 event n° 5000

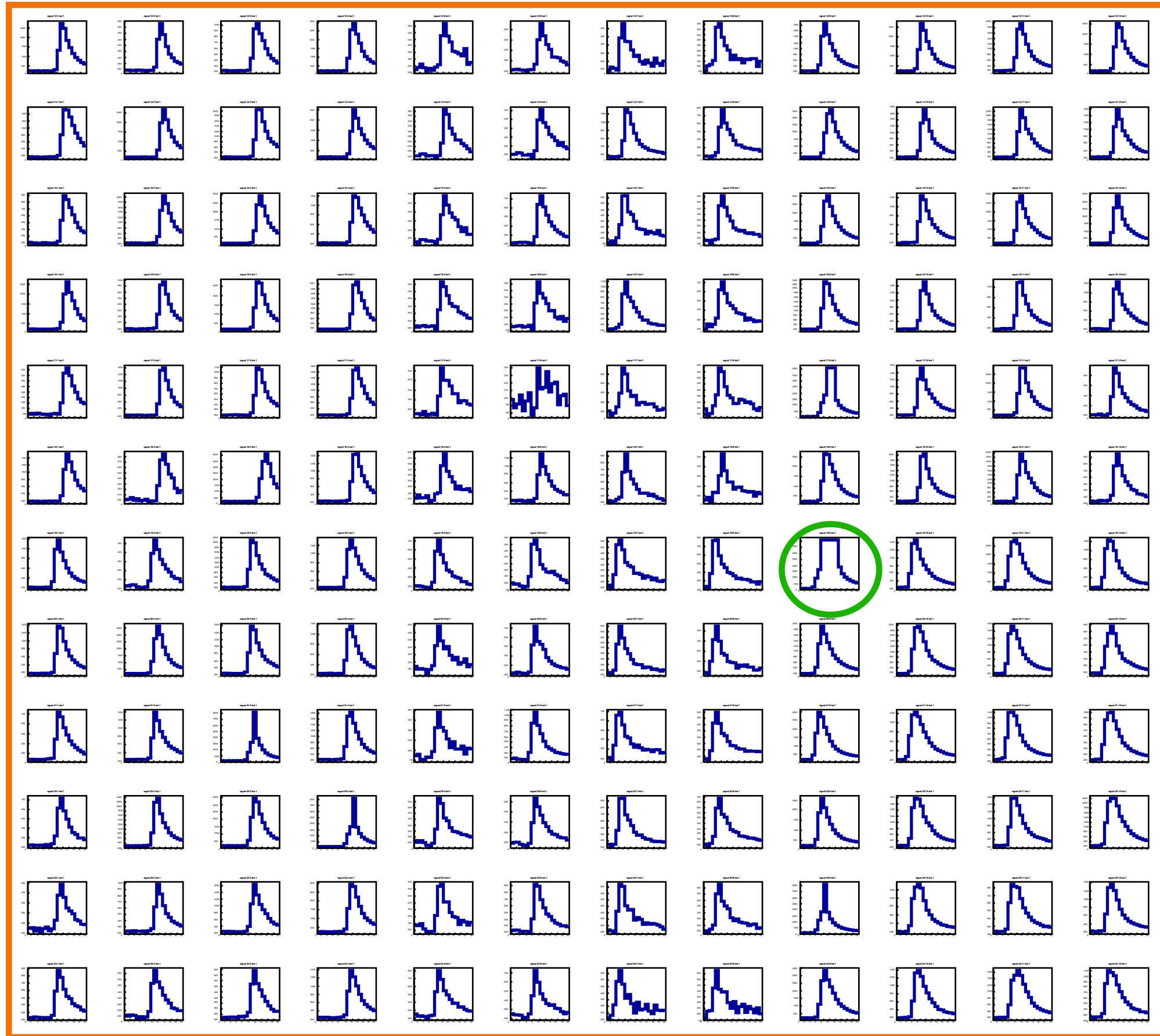


HV is not too high so no saturated FADC

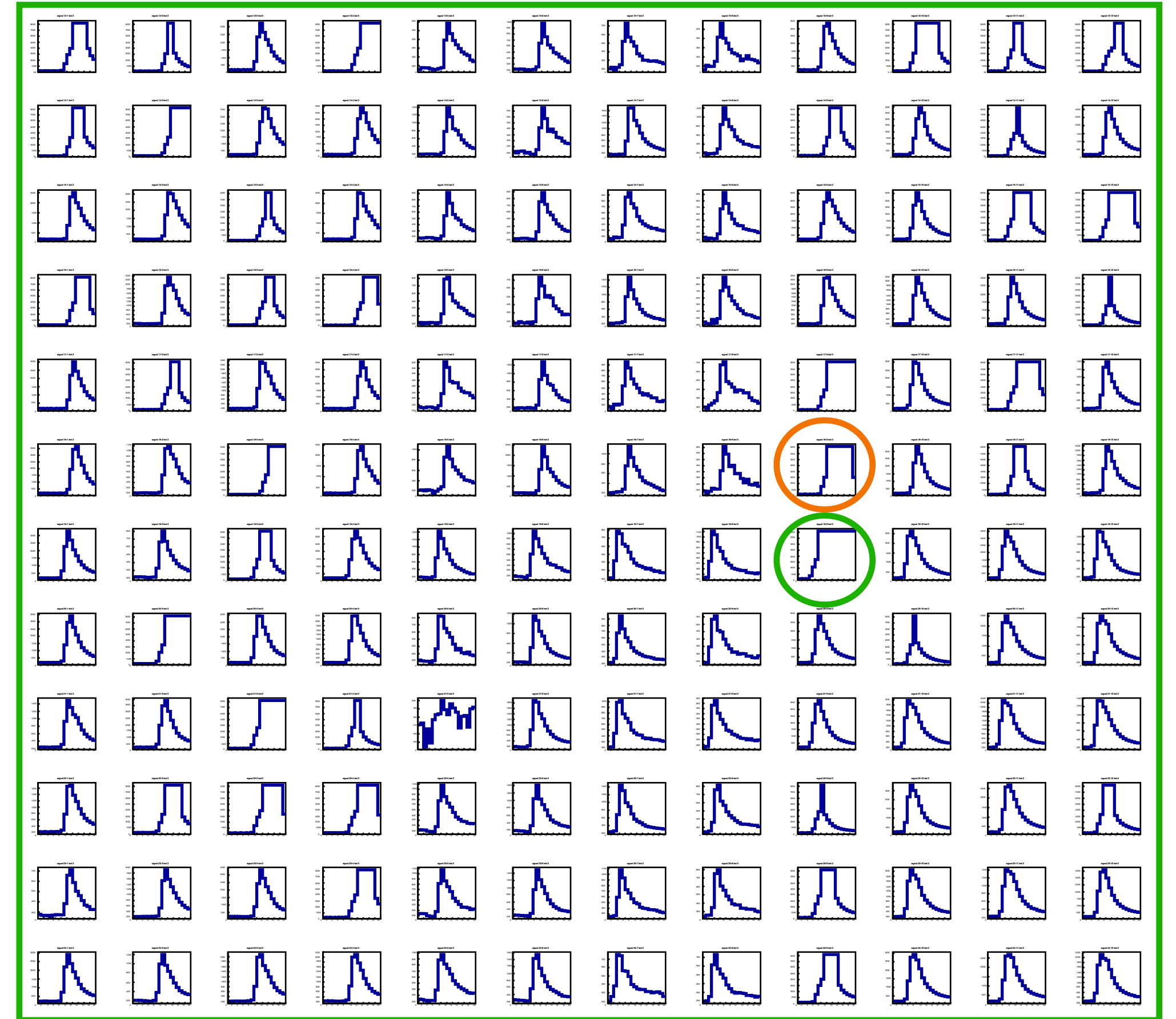
LED runs: FADC response

RUN 1300 : CMU PMTS -1600 V ; JLABs PMTs -1900

LED1 event n° 1500



LED2 event n° 2500



We can look FADC saturation already for LED2

LED runs: Pedestal

RAU Raw ADC Units

sRAU summed Raw ADC Units

LED0 is off so we use the first 1000 event to calculate the pedestal

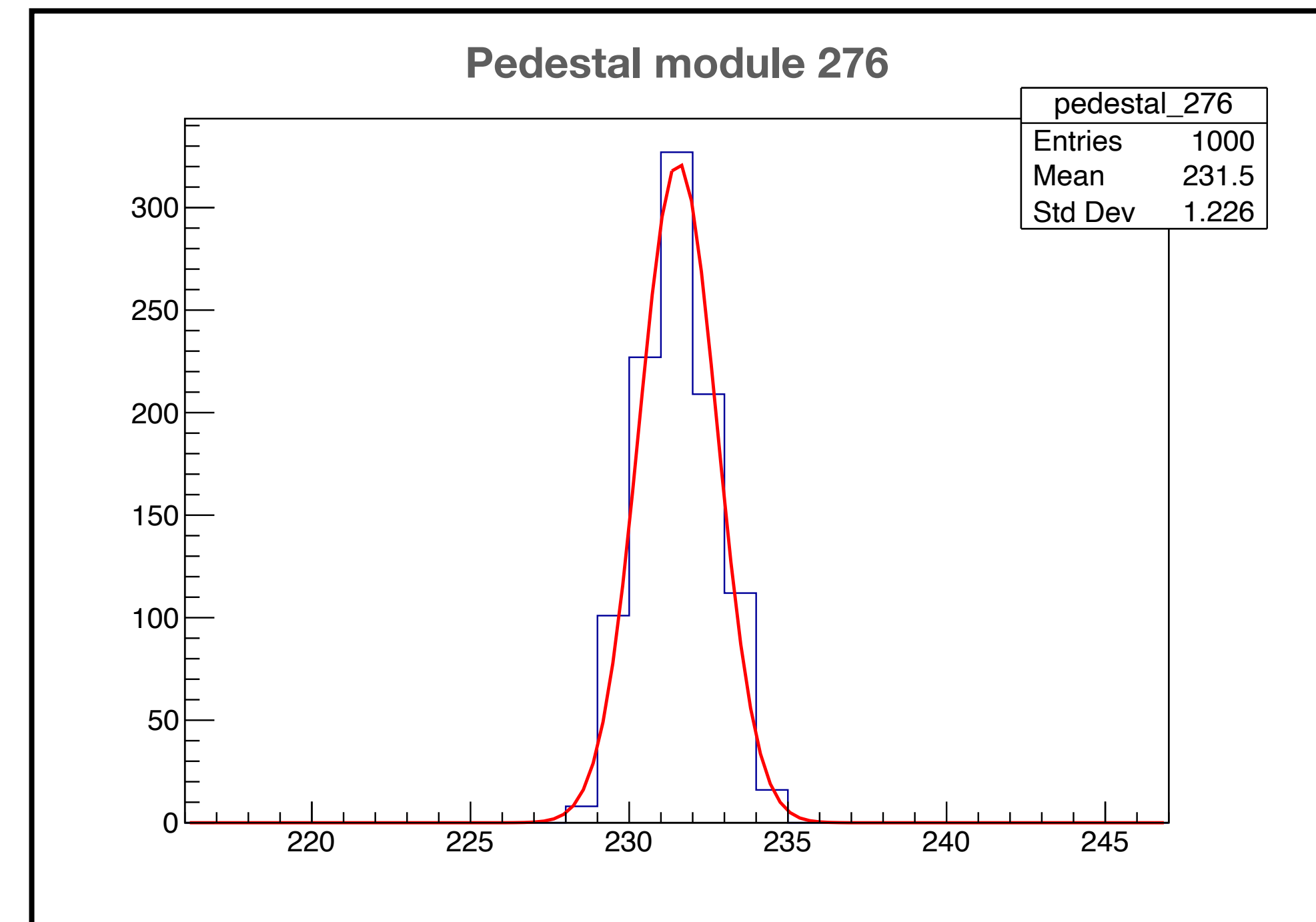
Pedestal histogram for each module filled with the average RAU value



Pedestal histogram fitted with a Gaussian Function



Mean of Gaussian subtracted from each event



LED Runs_sRAU VS HV

After pedestal subtraction, create the integrated value FADC spectrum for each run and LED



Fill the maximum value histogram (max RAU)for each module and LED



Fill sRAU event histogram for each module and for each LED

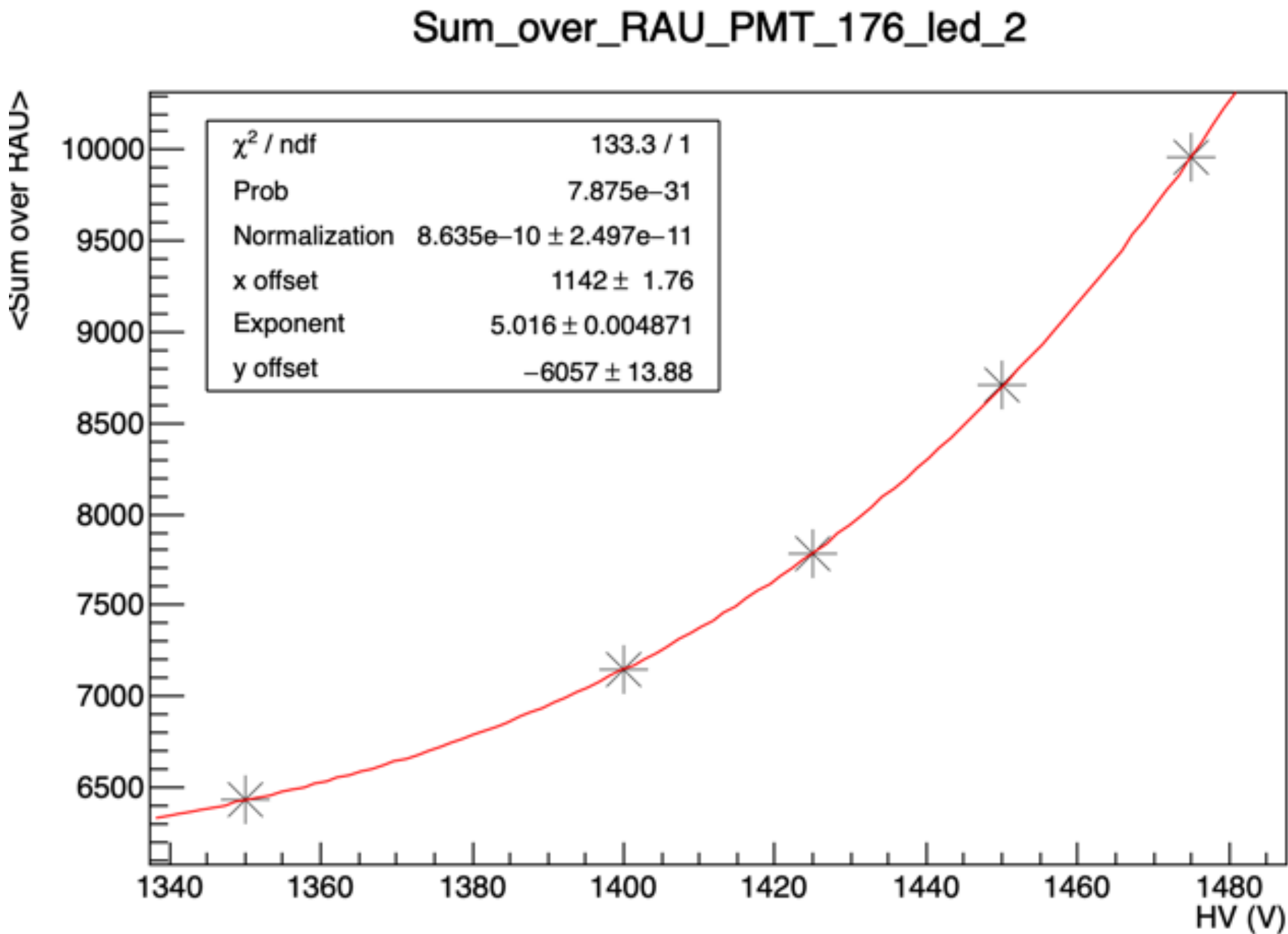
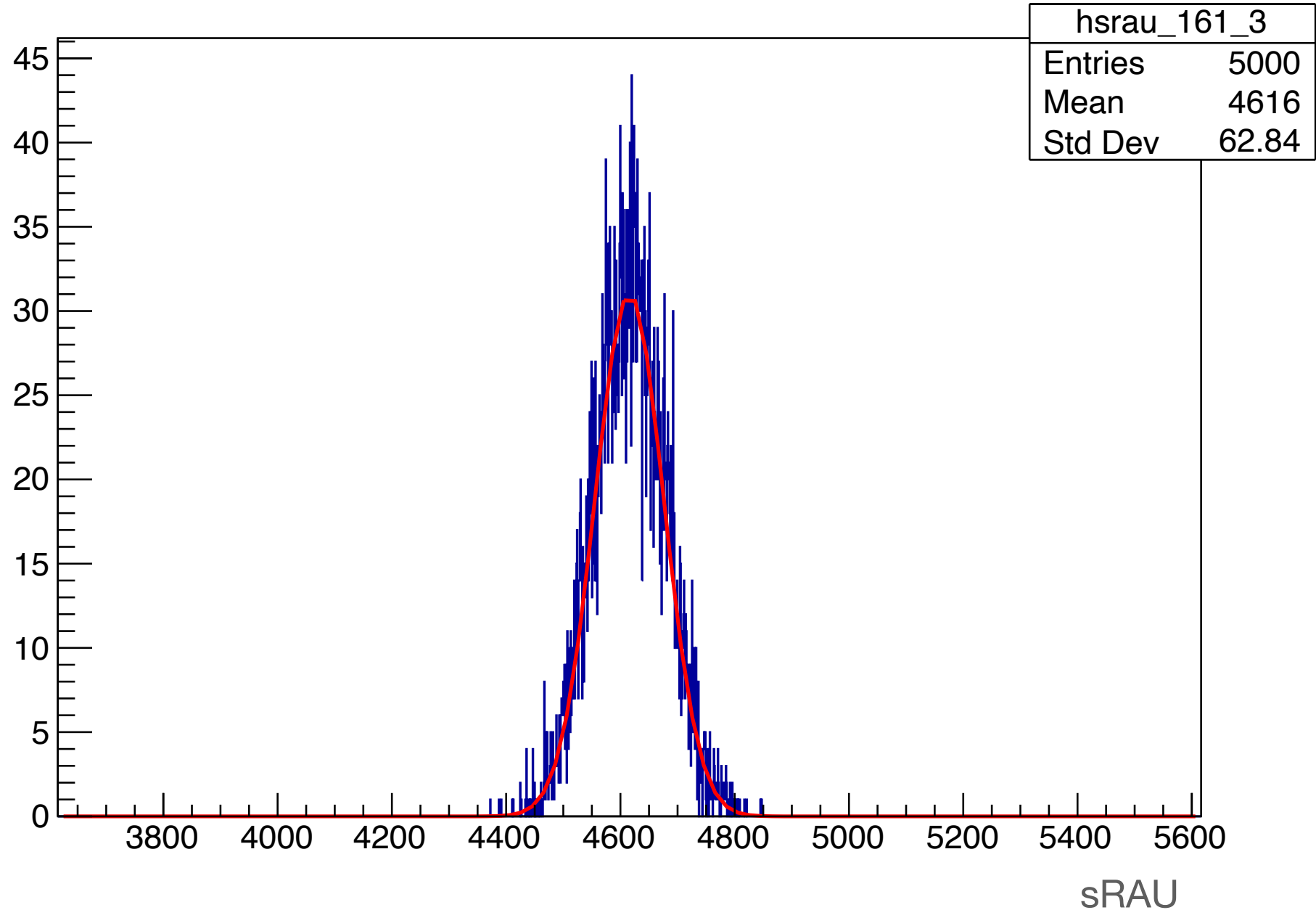


Create plot sRAU vs HV for each module and LED

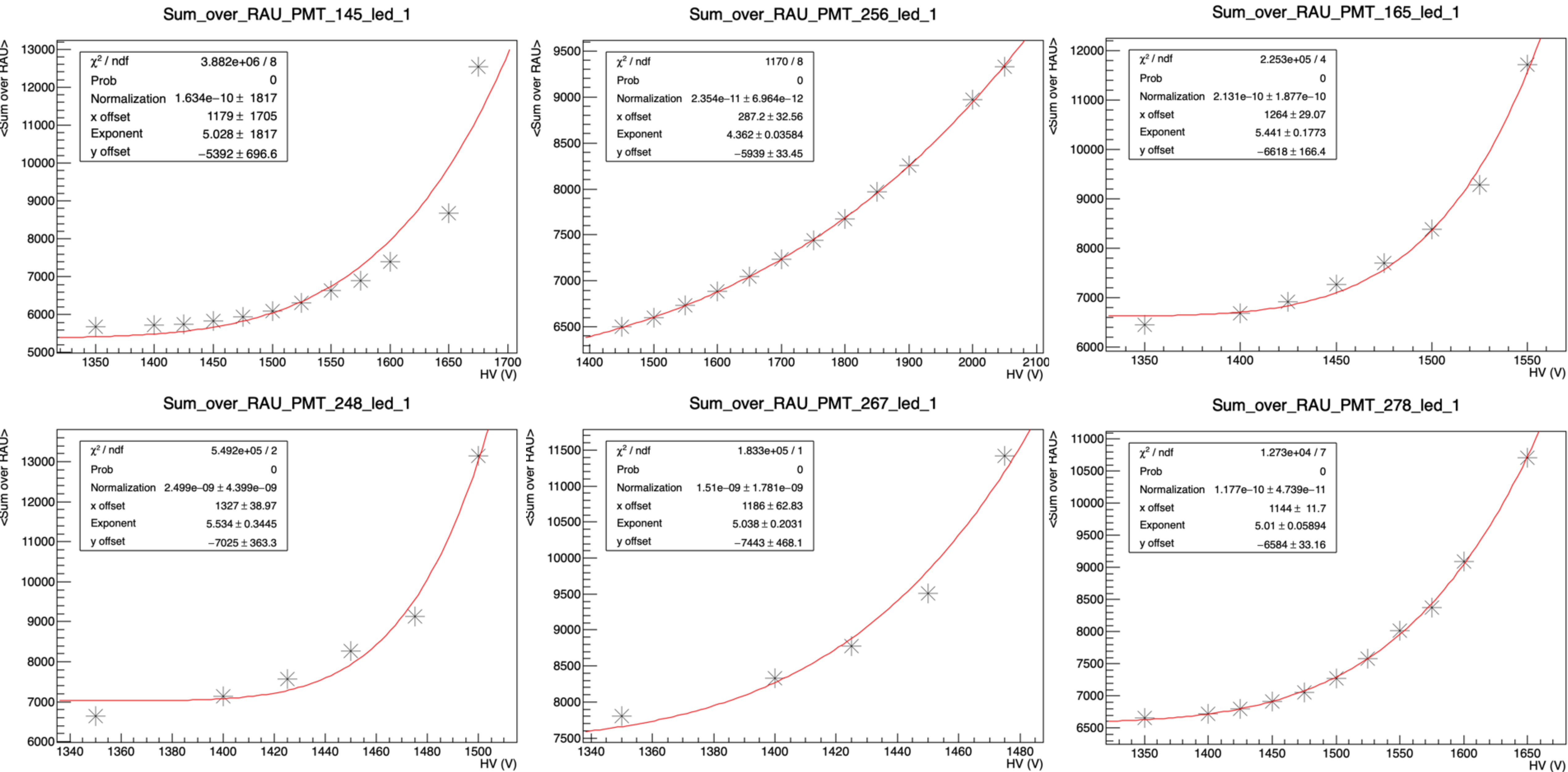
Fitting function: $p0 * (HV - p1)^{p2} - p3$



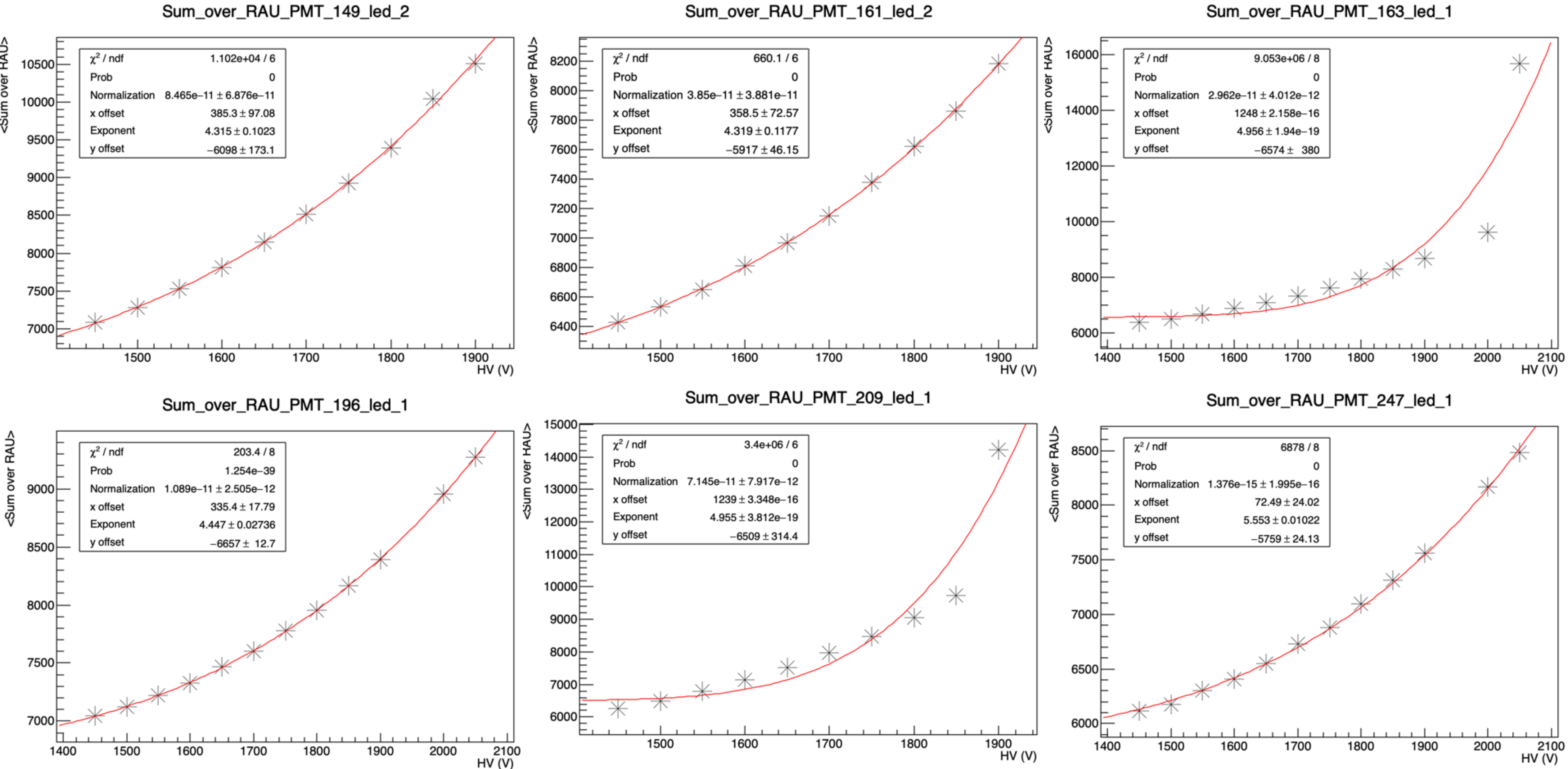
- P0 = “Normalization”
- P1 = “x offset”
- P2 = “Exponent”
- P3 = “Y offset”



LED Runs_sRAU VS HV CMU PMTs



LED Runs_sRAU VS HV JLAB PMTs



LED Runs: npe analysis

For each run, LED0 is off so we use these first 1000 events to calculate the pedestals for each module.

$$npe = \left(\frac{\langle ADC \rangle}{\langle RMS \rangle} \right)^2$$

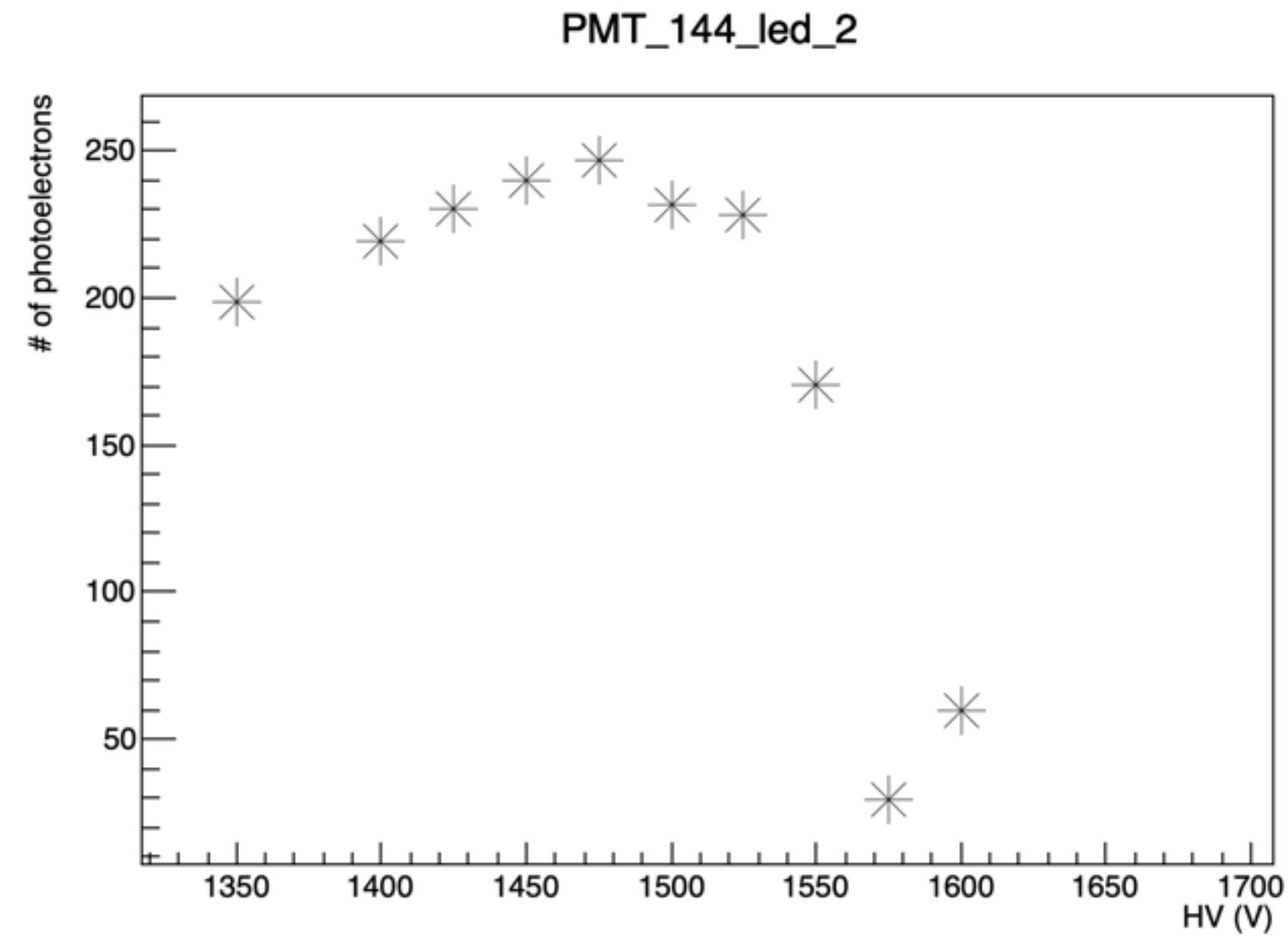
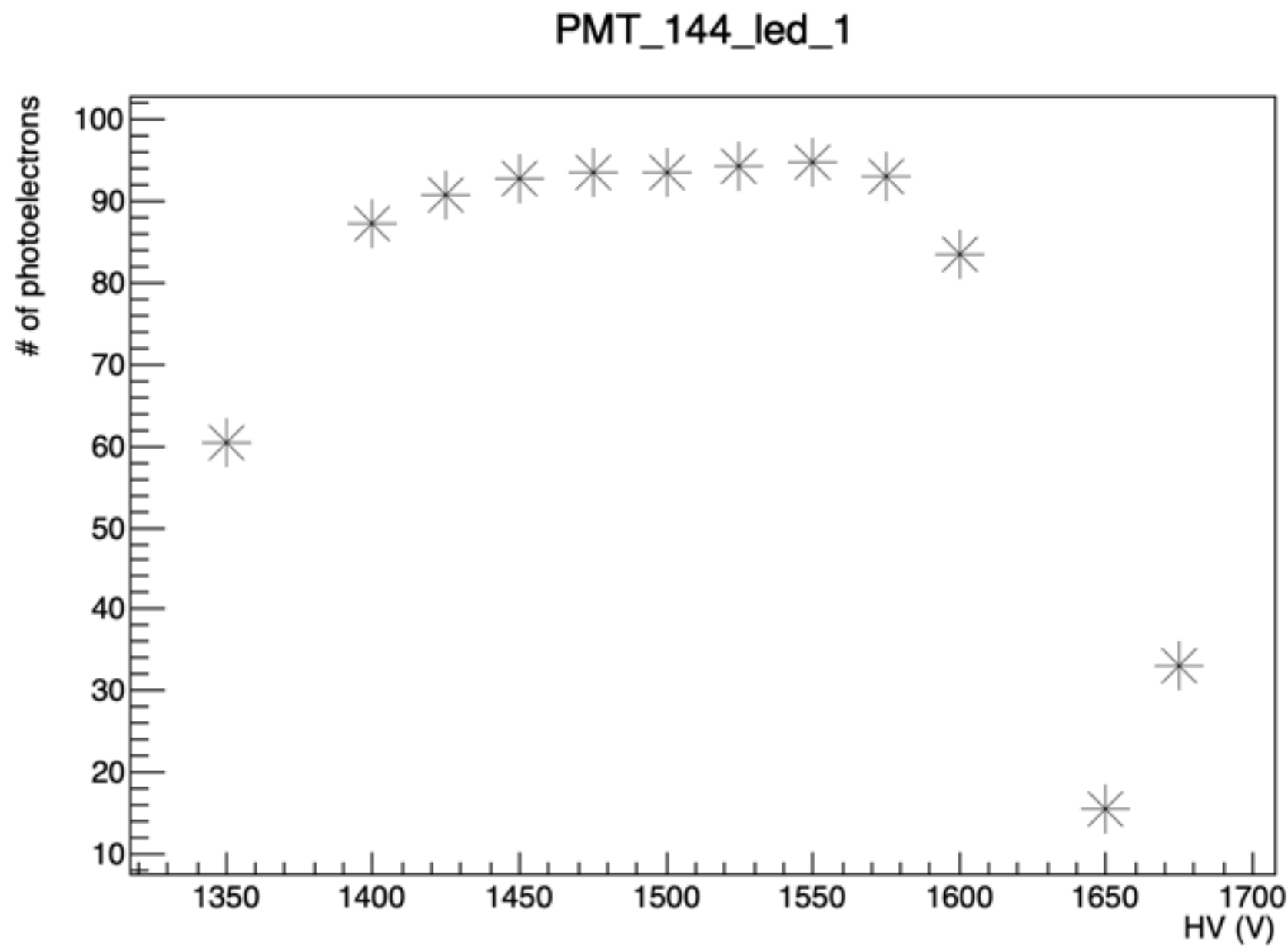
module	HV	npe_led0	npe_led1	npe_led2	npe_led3	npe_led4	npe_led5
0	1300	0.0181602	14.3942	81.2481	251.861	823.897	2856.1
1	1300	0.000924625	1.05361	73.8905	433.772	714.063	1252.49
2	1300	0.000788495	12.6464	70.6155	211.962	795.555	1521.58
3	1300	0.0168812	60.1159	197.758	279.619	843.839	2410.77
4	1300	0.00621666	23.3298	57.7633	233.426	1051.39	3215.32
5	1300	0.0150063	77.2698	171.293	393.292	1026.9	3629.81
6	1300	0.030347	111.805	183.935	354.656	876.154	2256.97
7	1300	0.0446752	37.0869	47.7924	233.692	450.033	1781.18
8	1300	0.000186323	20.0021	79.8818	455.625	819.764	2528.53
9	1300	0.000458829	42.4185	166.871	315.959	593.199	1697.11
10	1300	0.0162071	37.1784	127.878	239.94	525.087	1159.54
11	1300	0.00614375	33.7983	98.0645	188.85	432.928	628.041
12	1300	0.000232769	12.3032	85.1393	286.144	587.321	1157.09
13	1300	0.00993669	24.3971	138.982	230.35	632.422	1357.84
14	1300	0.0553263	20.6874	100.101	385.95	1037.28	2967.19
15	1300	0.0202919	40.8602	97.0707	267.977	1086.41	2938.63
16	1300	0.0039115	24.6474	233.454	407.798	1505.36	4603.24
17	1300	0.0161915	28.009	80.2812	264.945	886.729	3955.73
18	1300	0.0263531	169.5	280.094	702.534	1608.83	3871.48
19	1300	0.0571229	114.128	277.28	642.706	1425.38	3241.6
20	1300	0.00501389	45.9292	98.6213	372.53	779.479	2263.61
21	1300	0.000965104	25.0992	122.574	224.786	625.34	1556.4
22	1300	0.00182935	33.6954	113.865	285.946	715.063	1701.19
23	1300	0.00108433	15.0991	47.1867	164.307	464.1	1163.59
24	1300	0.0445758	4.89975	50.8715	198.138	577.765	1326.02
25	1300	0.00577963	28.3636	87.2226	294.803	427.516	1317.48
26	1300	0.0612241	43.2536	110.639	327.348	459.056	949.802
27	1300	0.0222424	15.6497	69.7654	73.5518	805.796	3933.96
28	1300	0.282778	74.7215	177.155	386.691	1046.79	4232.07
29	1300	1.50317e-06	61.4425	111.54	336.533	1123.68	3802.54

module	HV	npe_led0	npe_led1	npe_led2	npe_led3	npe_led4	npe_led5
30	1300	0.00168077	92.24	220.208	458.064	1193.67	3086.96
31	1300	0.00224143	118.821	239.397	634.961	1033.83	2839.76
32	1300	0.0301238	76.0352	116.498	505.183	1138	2852.6
33	1300	0.0113424	29.8181	114.88	229.087	607.768	1451.13
34	1300	0.00212329	34.2277	102.729	254.995	411.933	862.697
35	1300	0.0112461	43.3246	77.5239	294.188	735.305	1441.6
36	1300	0.0118533	21.4355	91.1195	328.726	617.235	1362.6
37	1300	0.0988822	3.70933	43.2611	304.26	560.446	1597.3
38	1300	0.00330114	15.0722	67.948	341.547	801.662	3397.66
39	1300	0.0298811	5.61716	24.4198	0.892753	379.571	2304.34
40	1300	0.0398458	51.4368	131.263	463.58	1152.38	4168.38
41	1300	0.0103736	111.83	170.202	522.608	1741	4615.56
42	1300	0.0119505	148.584	226.453	747.446	1427.69	3833.48
43	1300	0.034558	193.116	287.154	623.178	1319.29	2156.17
44	1300	0.0246042	17.3084	22.7224	249.348	568.449	1919.58
45	1300	0.0939594	19.4958	50.1961	153.399	494.727	1541.04
46	1300	0.175135	9.02565	35.0283	129.319	187.145	1155.93
47	1300	0.00956429	11.8981	60.5271	172.998	520.845	1203.06
48	1300	0.00103172	3.75212	93.8745	293.841	607.841	1688.29
49	1300	0.0365002	18.2697	112.867	380.912	718.311	958.953
50	1300	4.85156e-05	10.4718	45.7289	273.615	344.352	1401.85
51	1300	0.00427273	10.1418	46.2557	111.571	819.077	3359.41
52	1300	0.00318437	87.3398	143.859	401.027	1571.52	4166.97
53	1300	0.00084487	1.48346	186.752	467.973	37.9084	3984.29

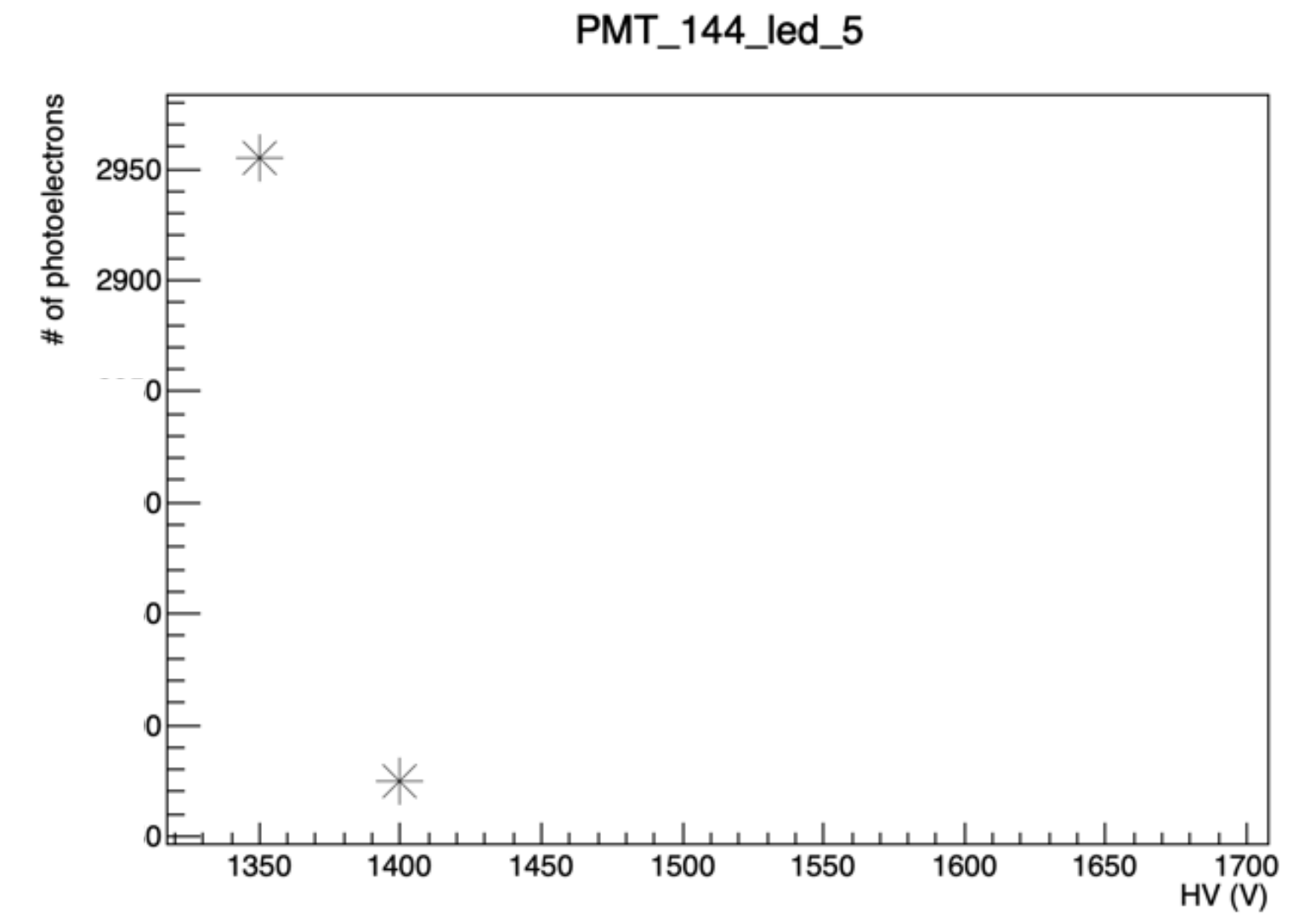
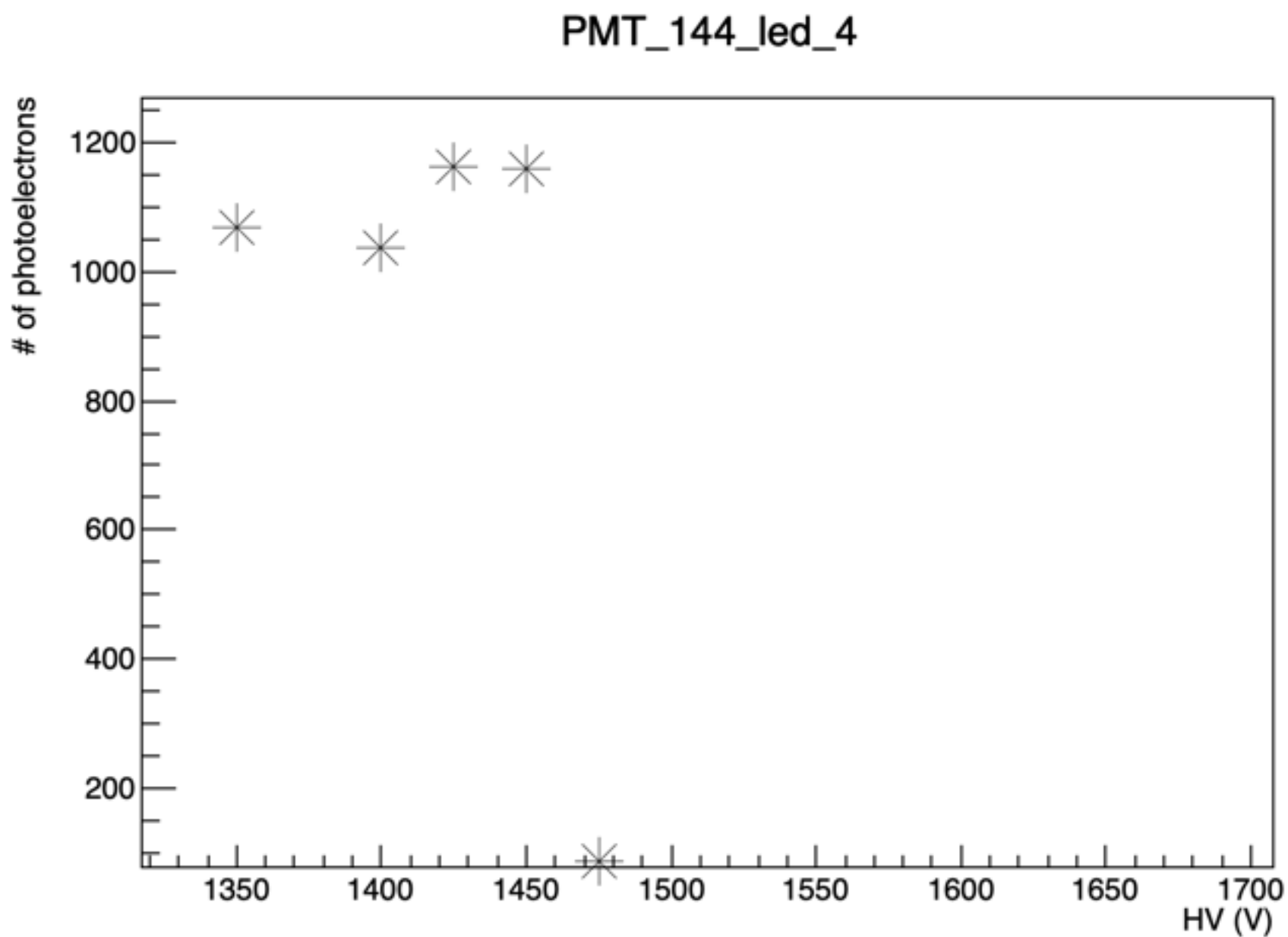
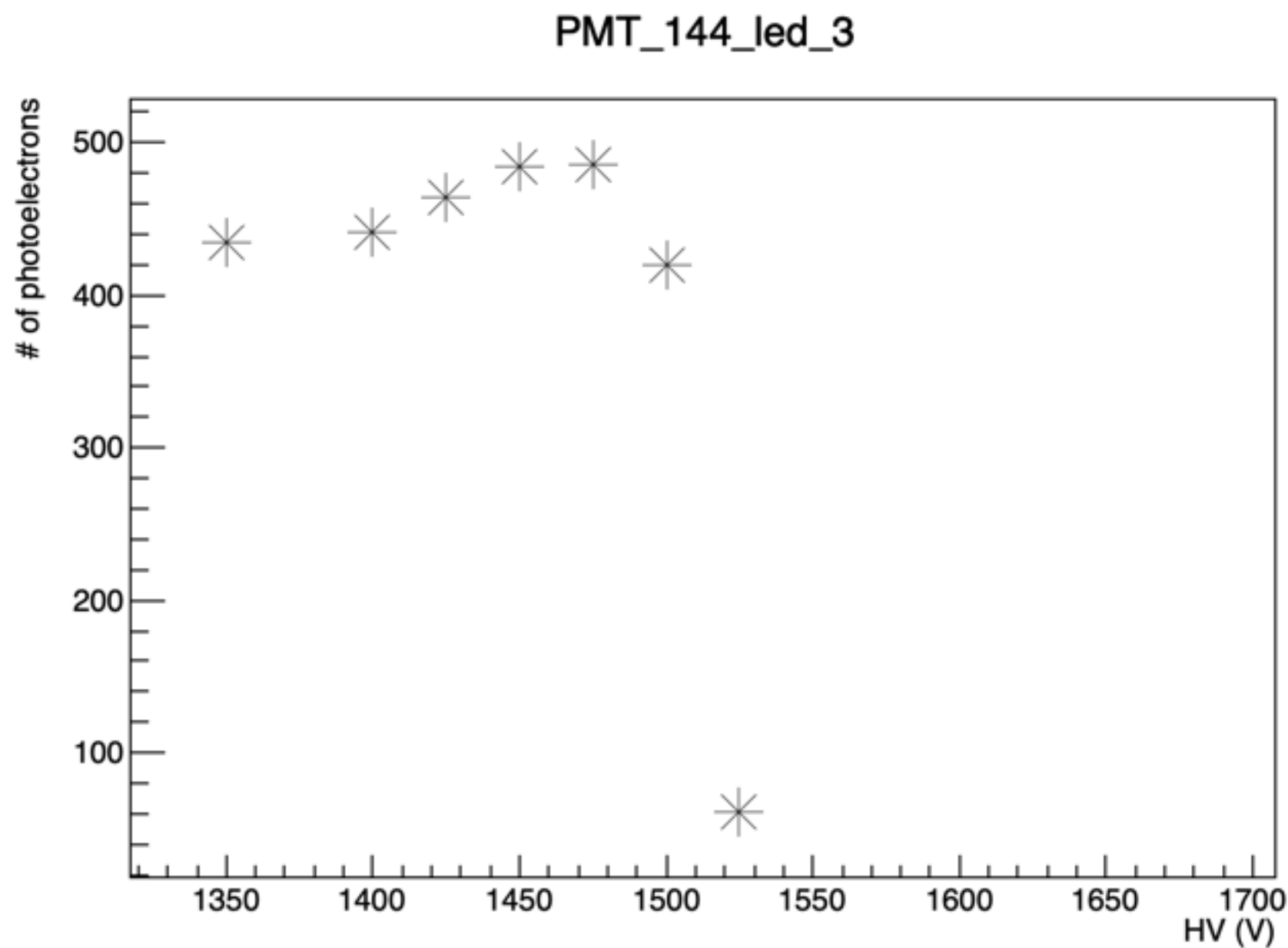
The number of photoelectron increases with LED luminosity.

LED Runs_npe VS HV

CMU PMTs

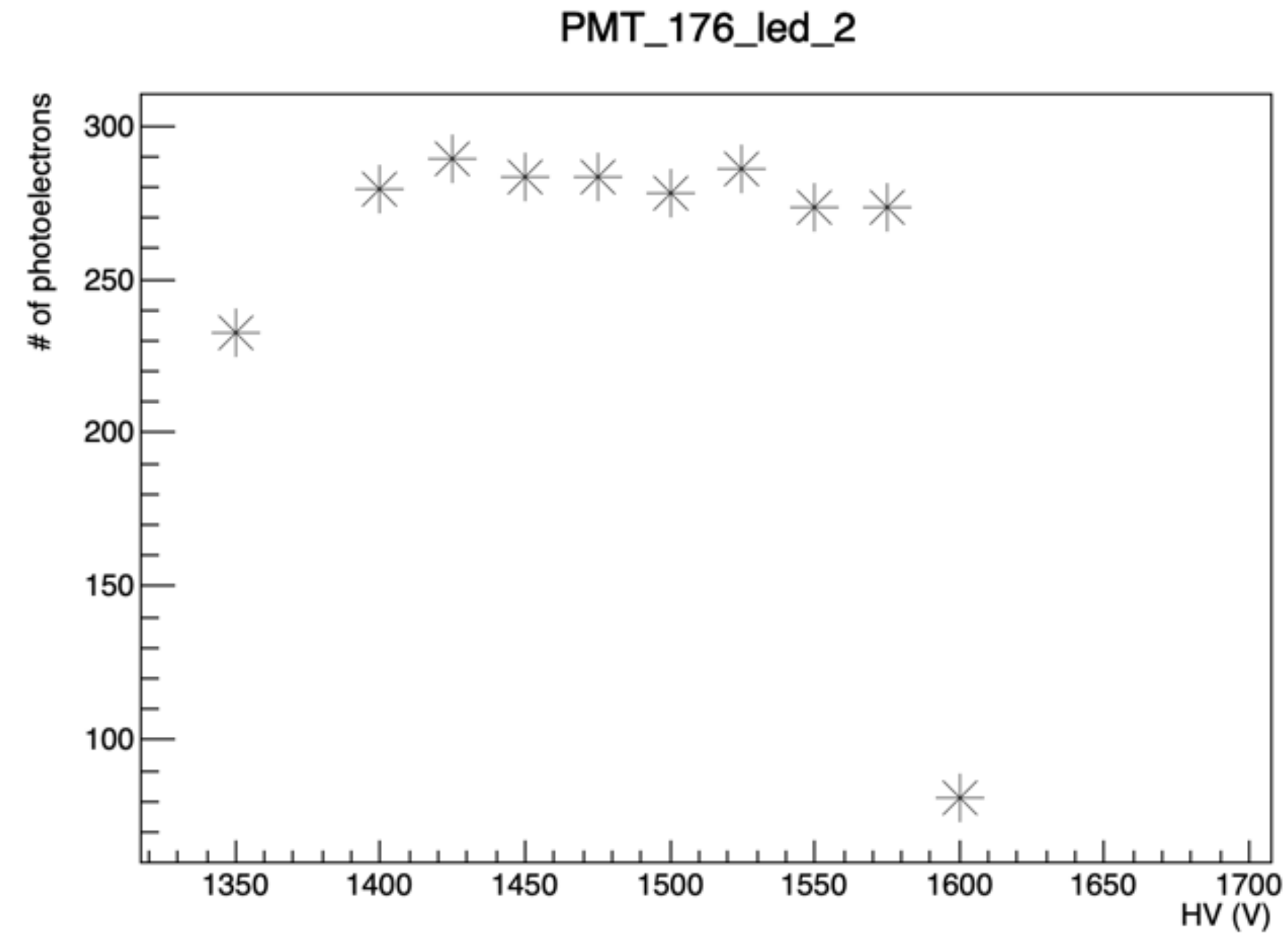
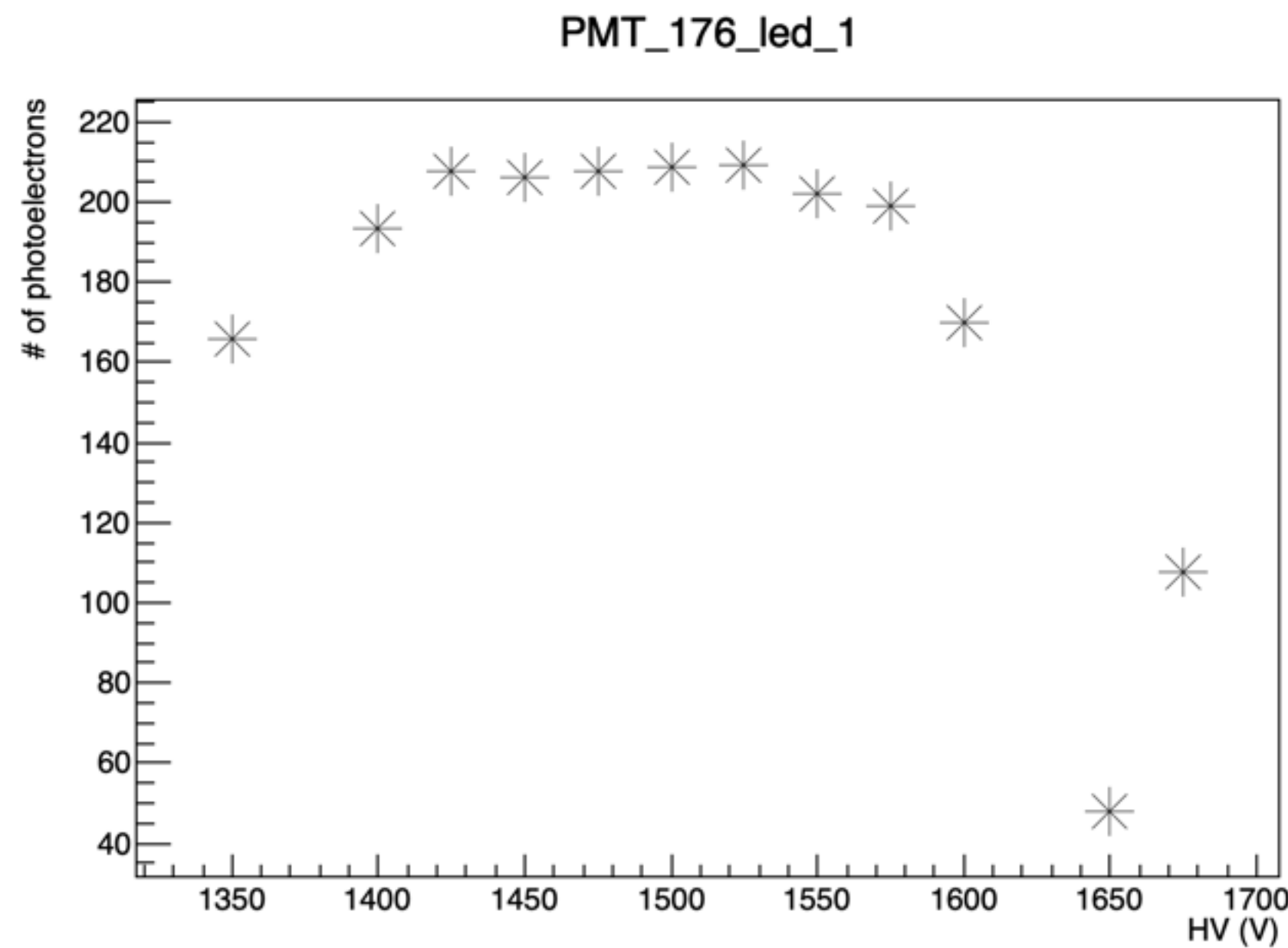


Npe quickly reaches the plateau

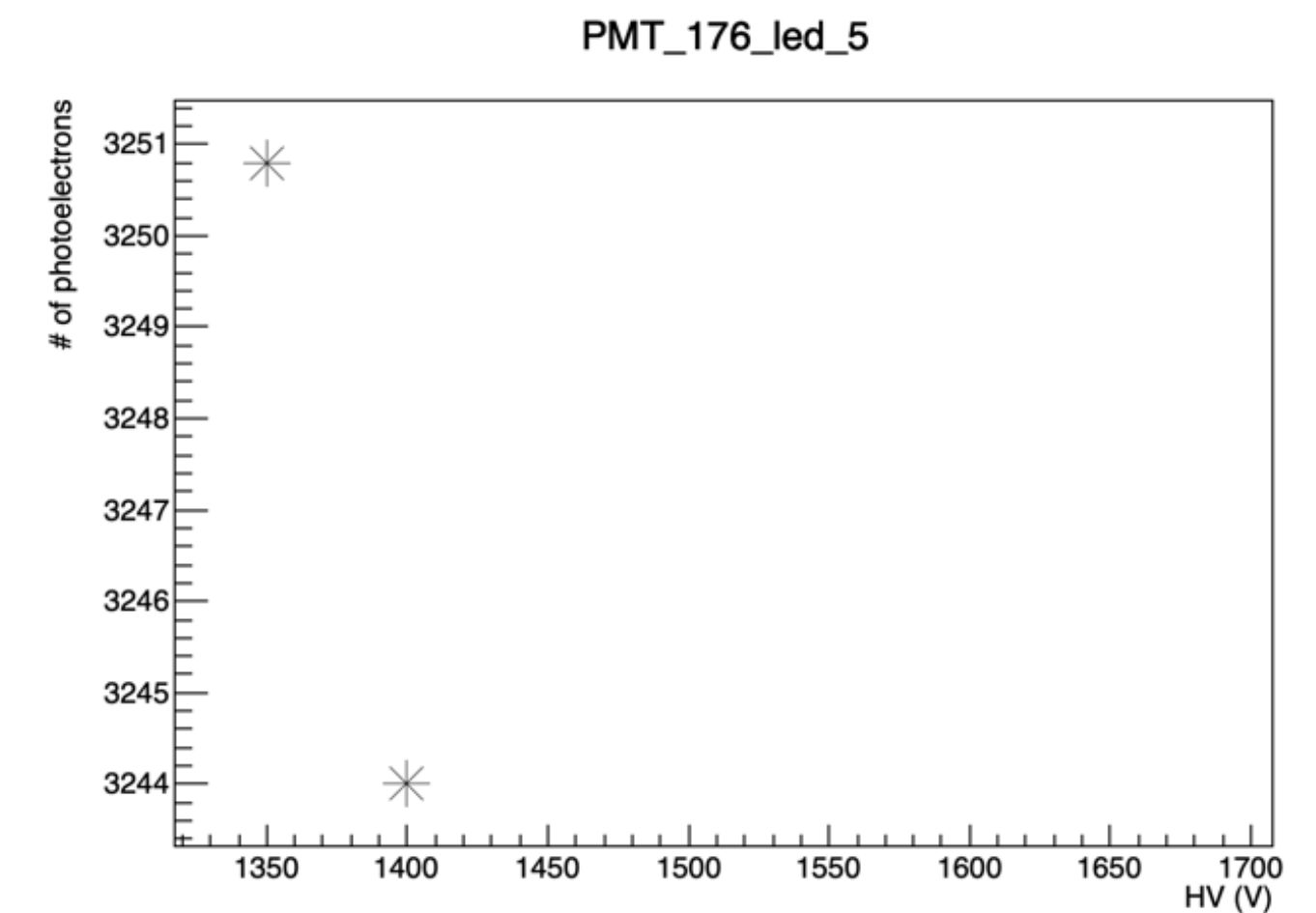
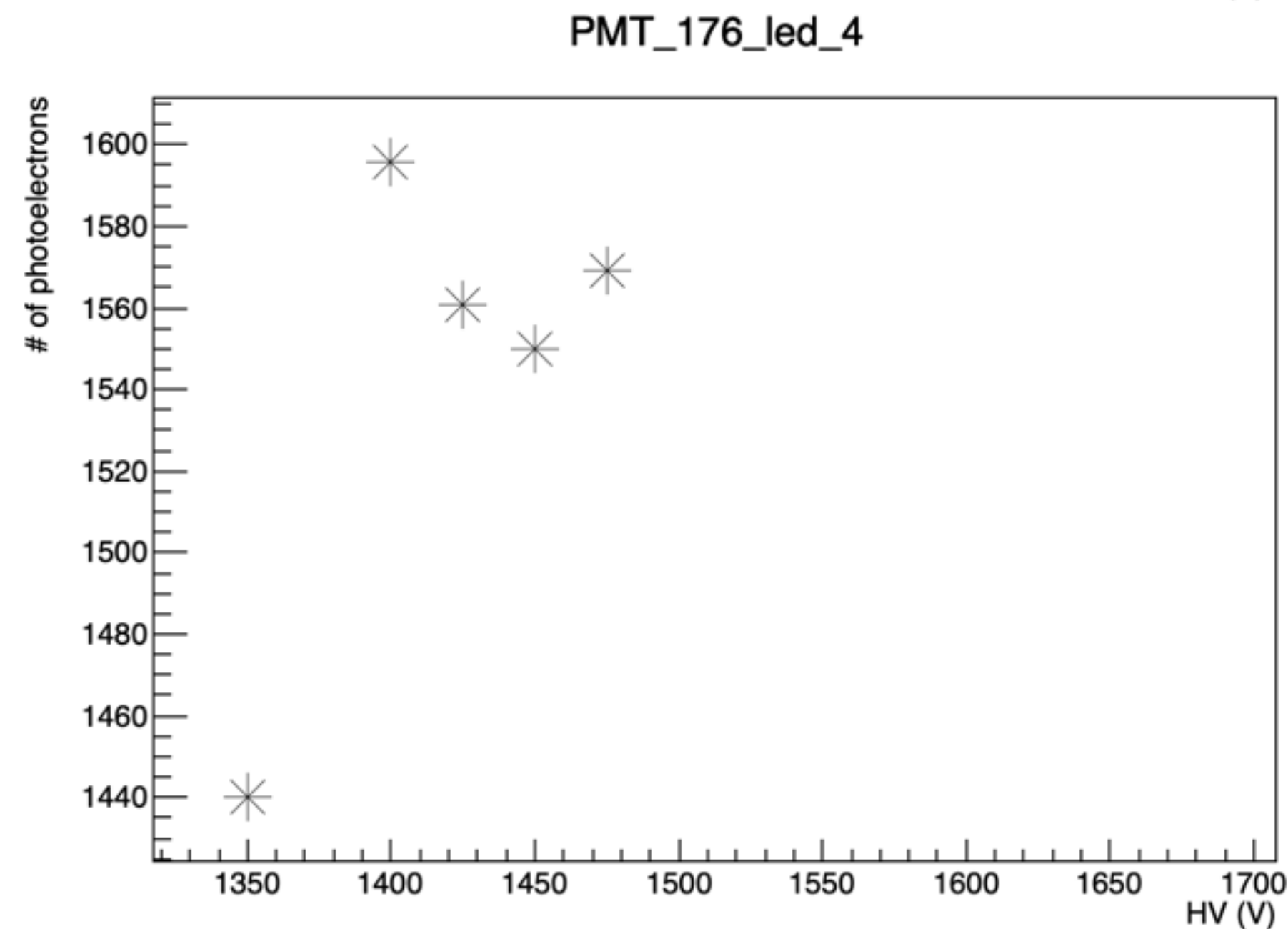
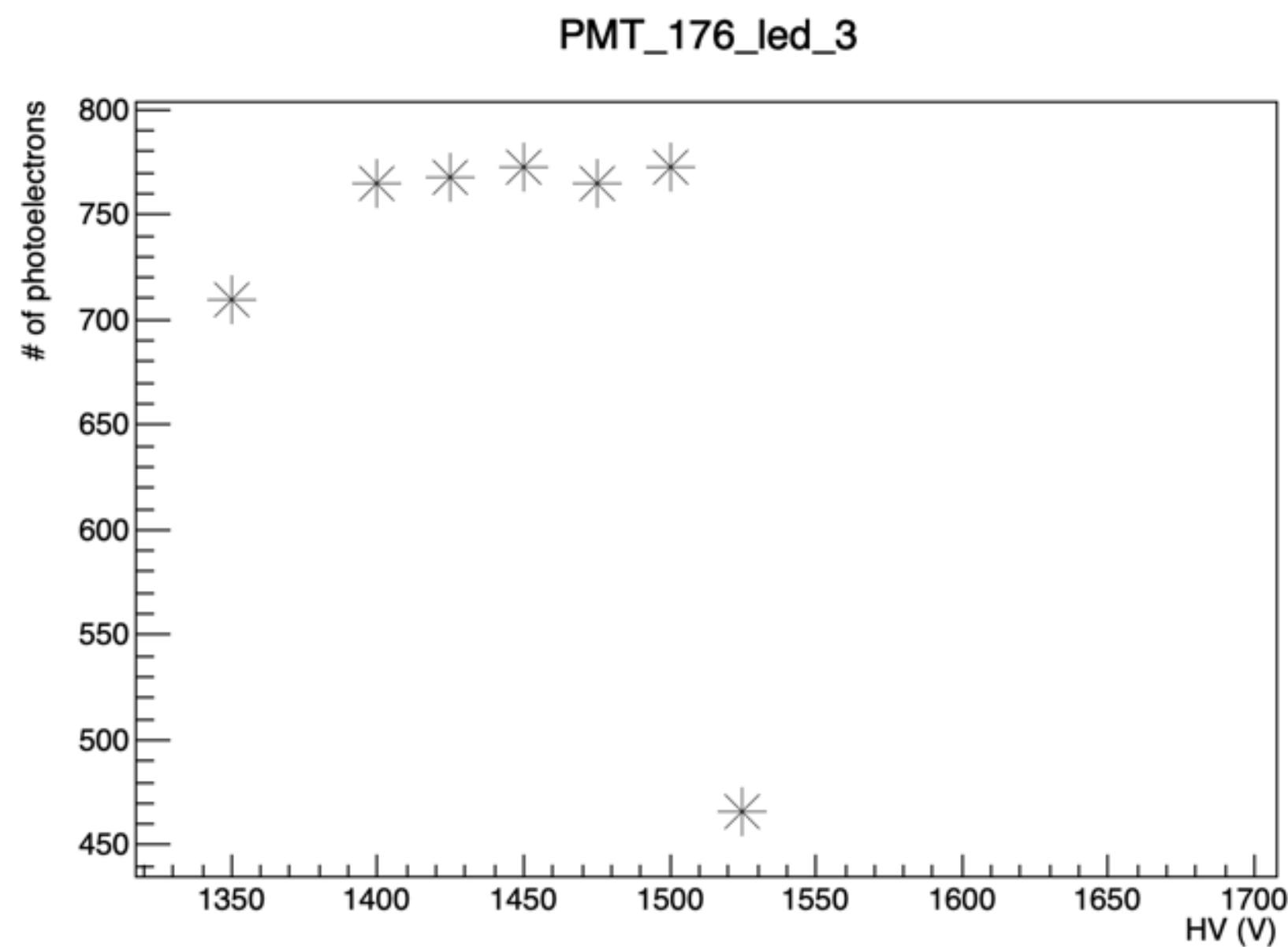


LED Runs_npe VS HV

CMU PMTs

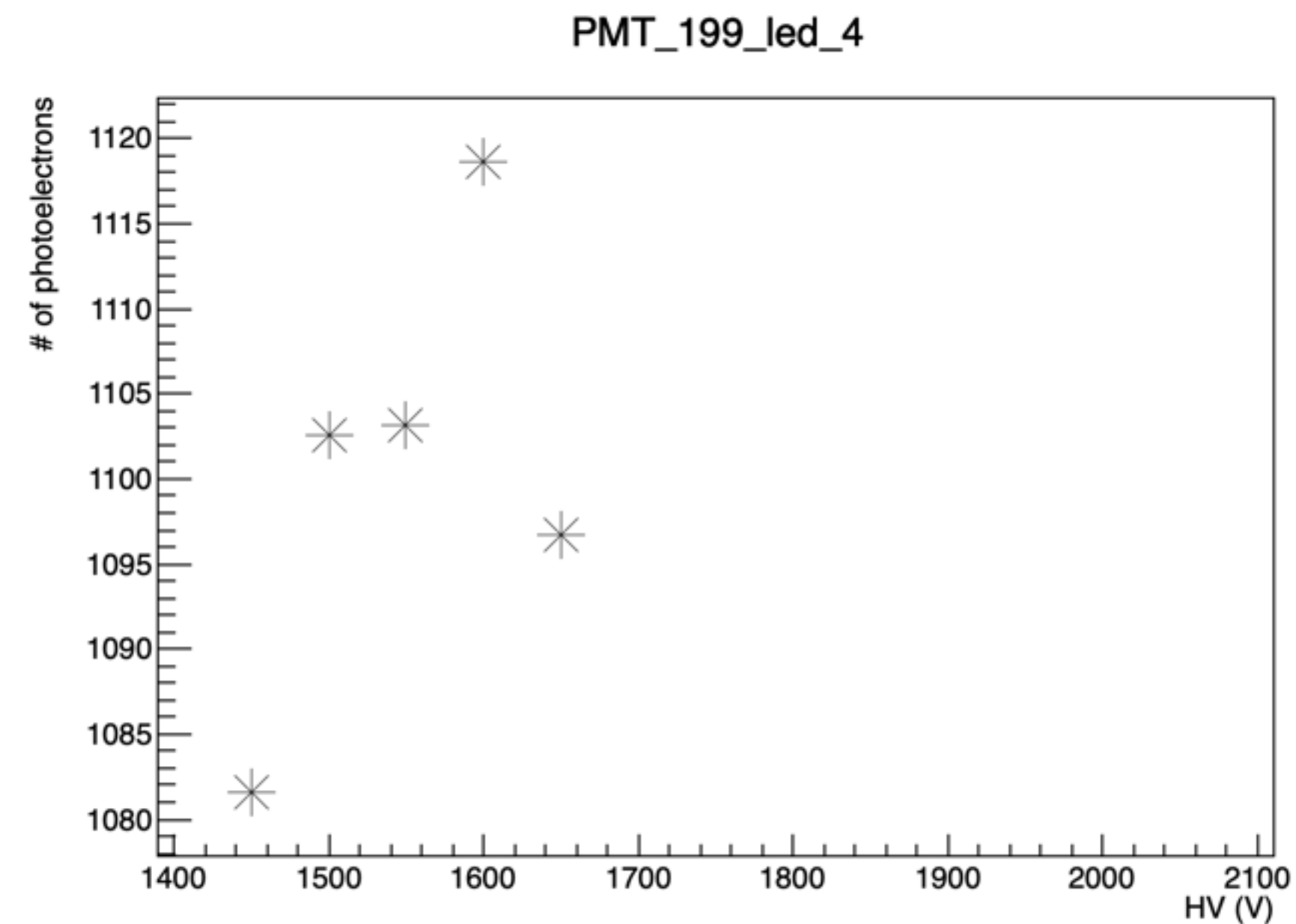
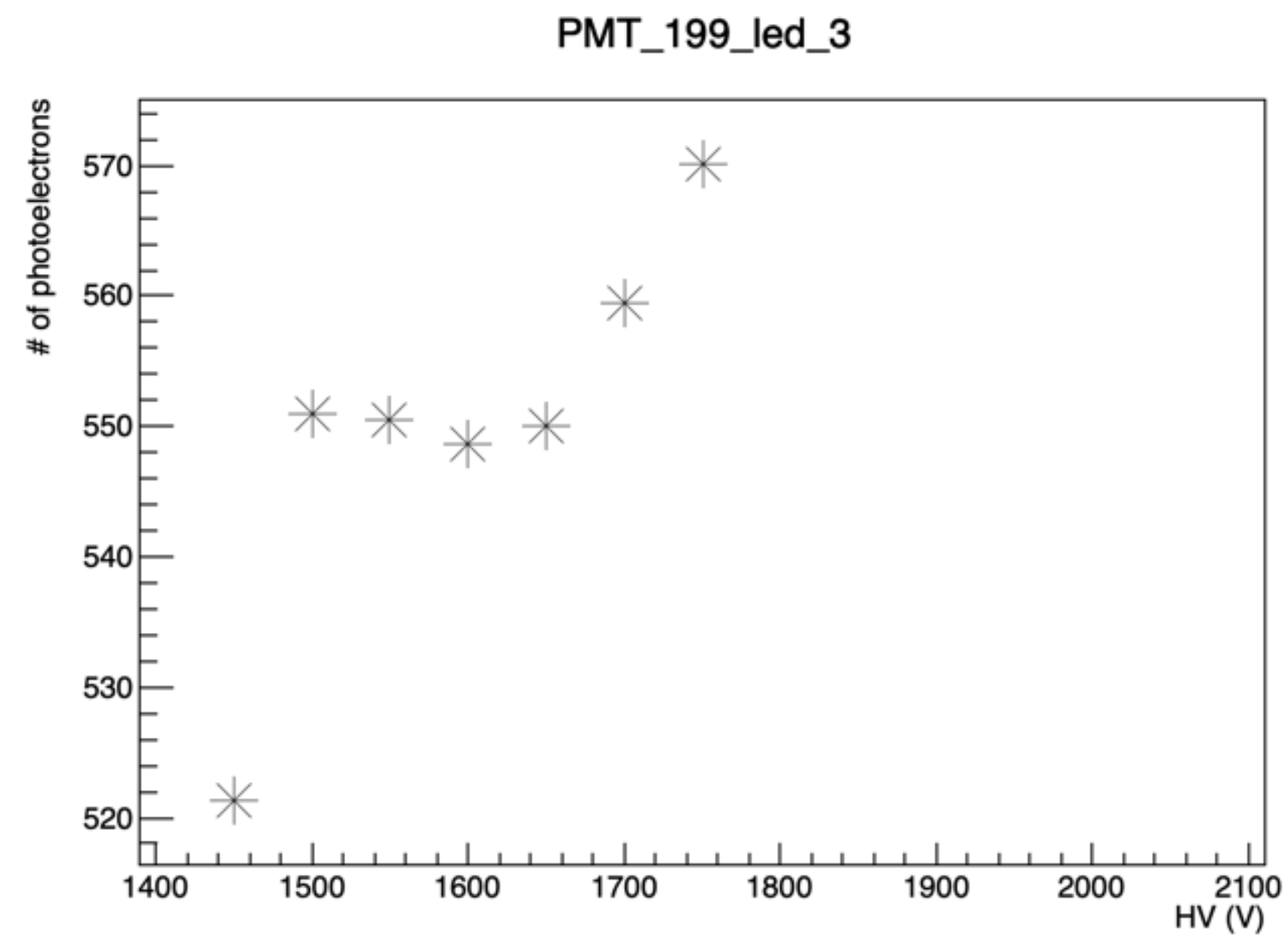
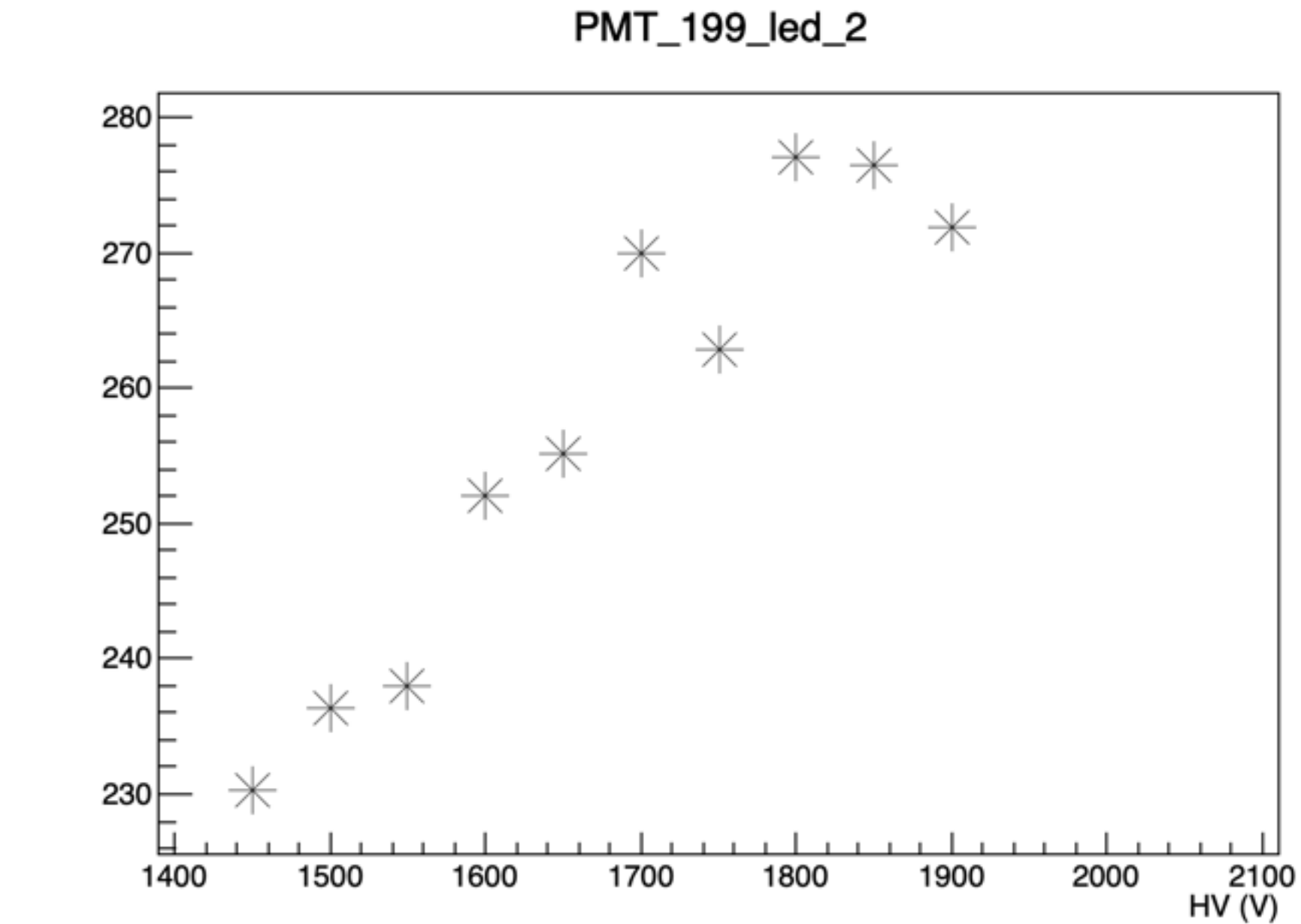
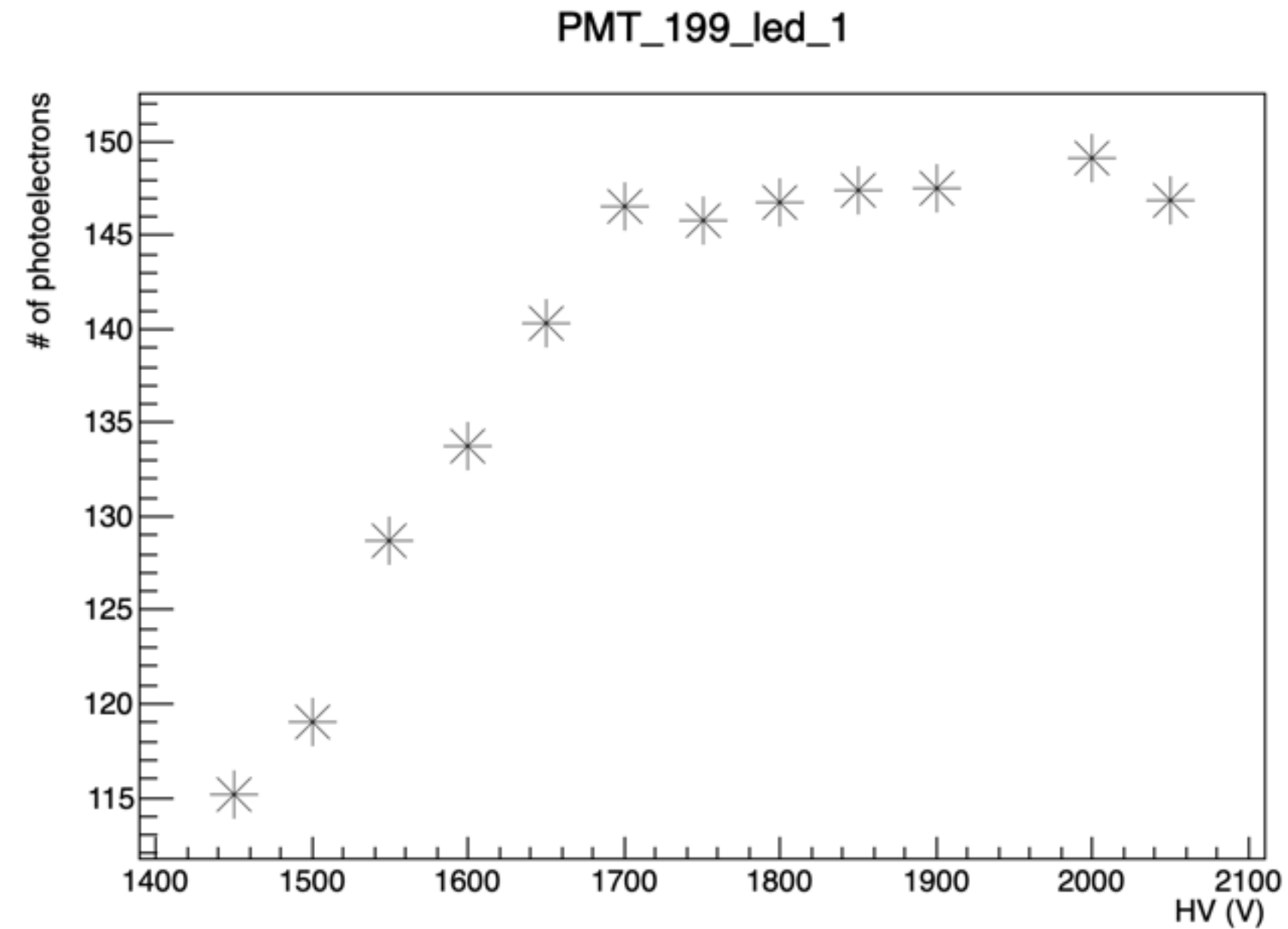


Npe quickly reaches the plateau

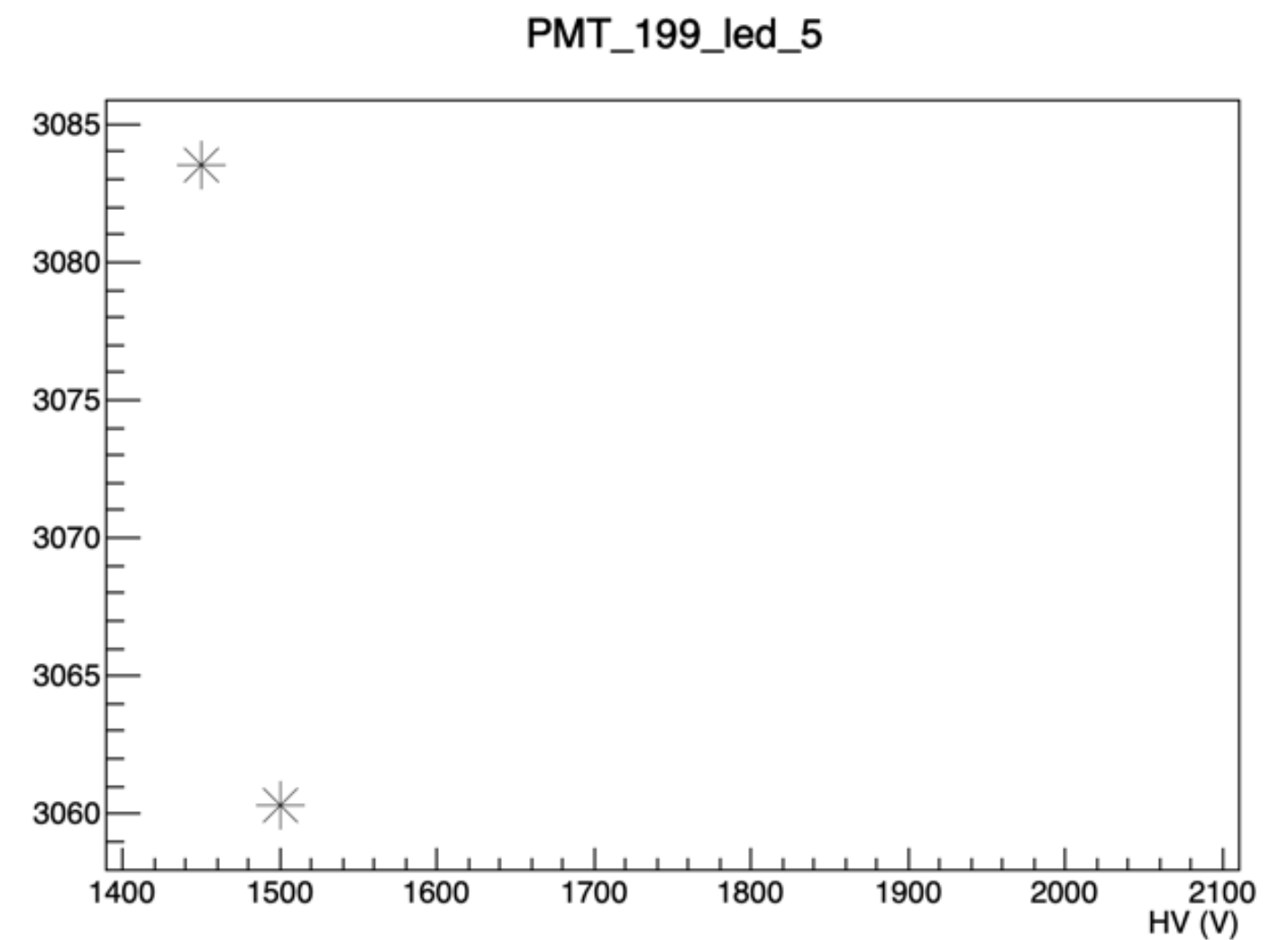


LED Runs_npe VS HV

JLAB PMTs



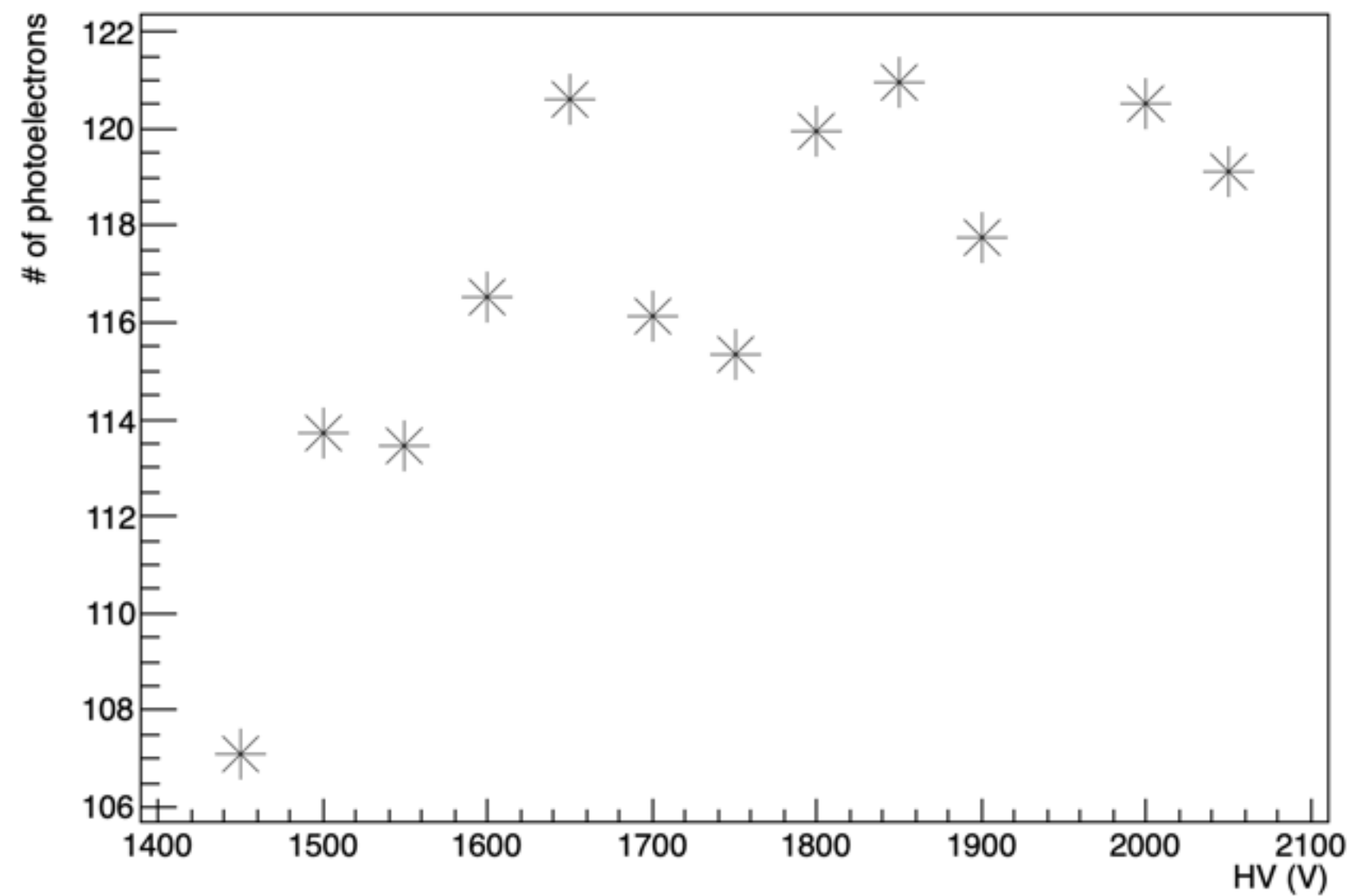
Npe reaches the plateau at higher HV.



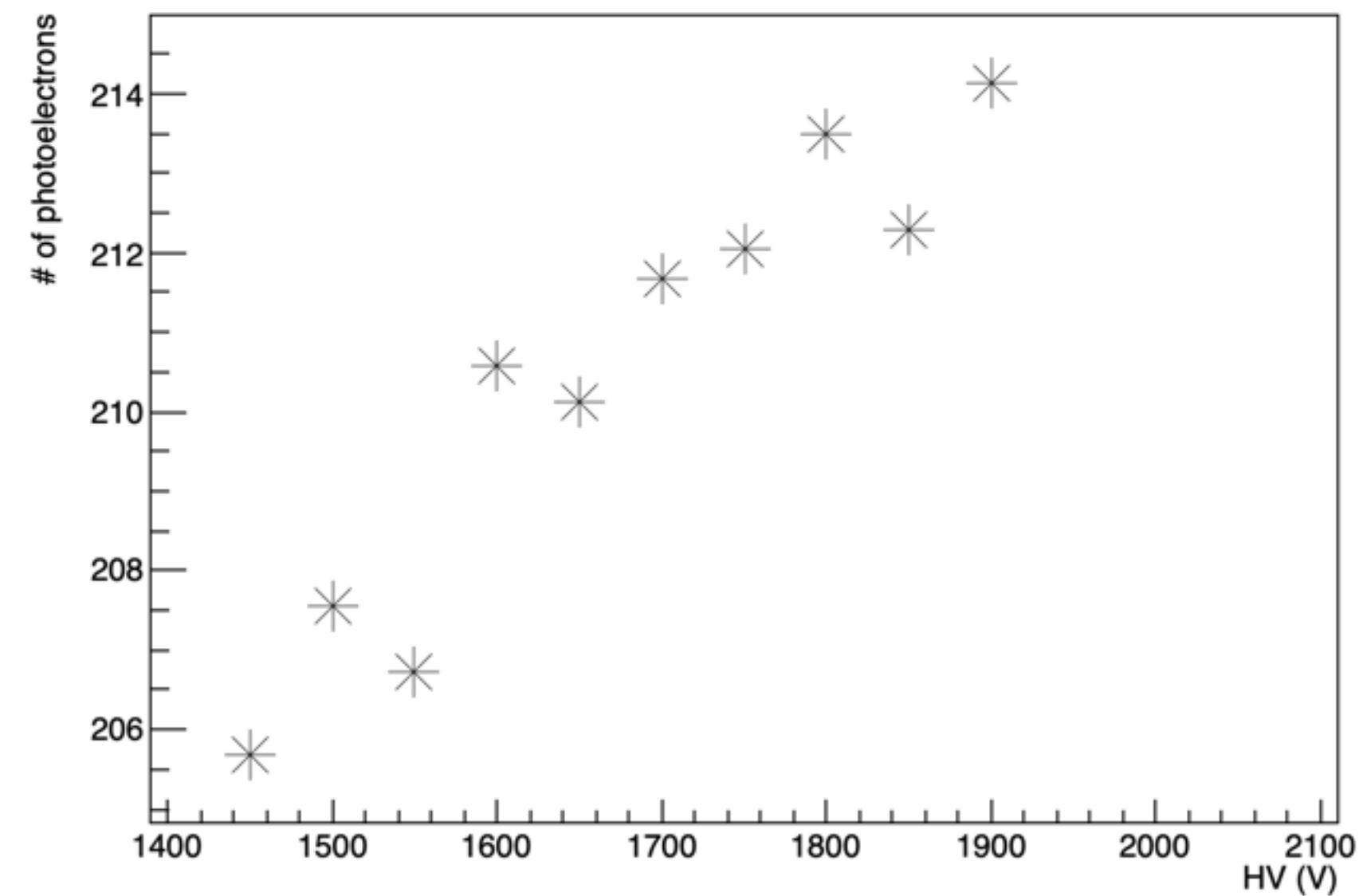
LED Runs_npe VS HV

JLAB PMTs

PMT_269_led_1

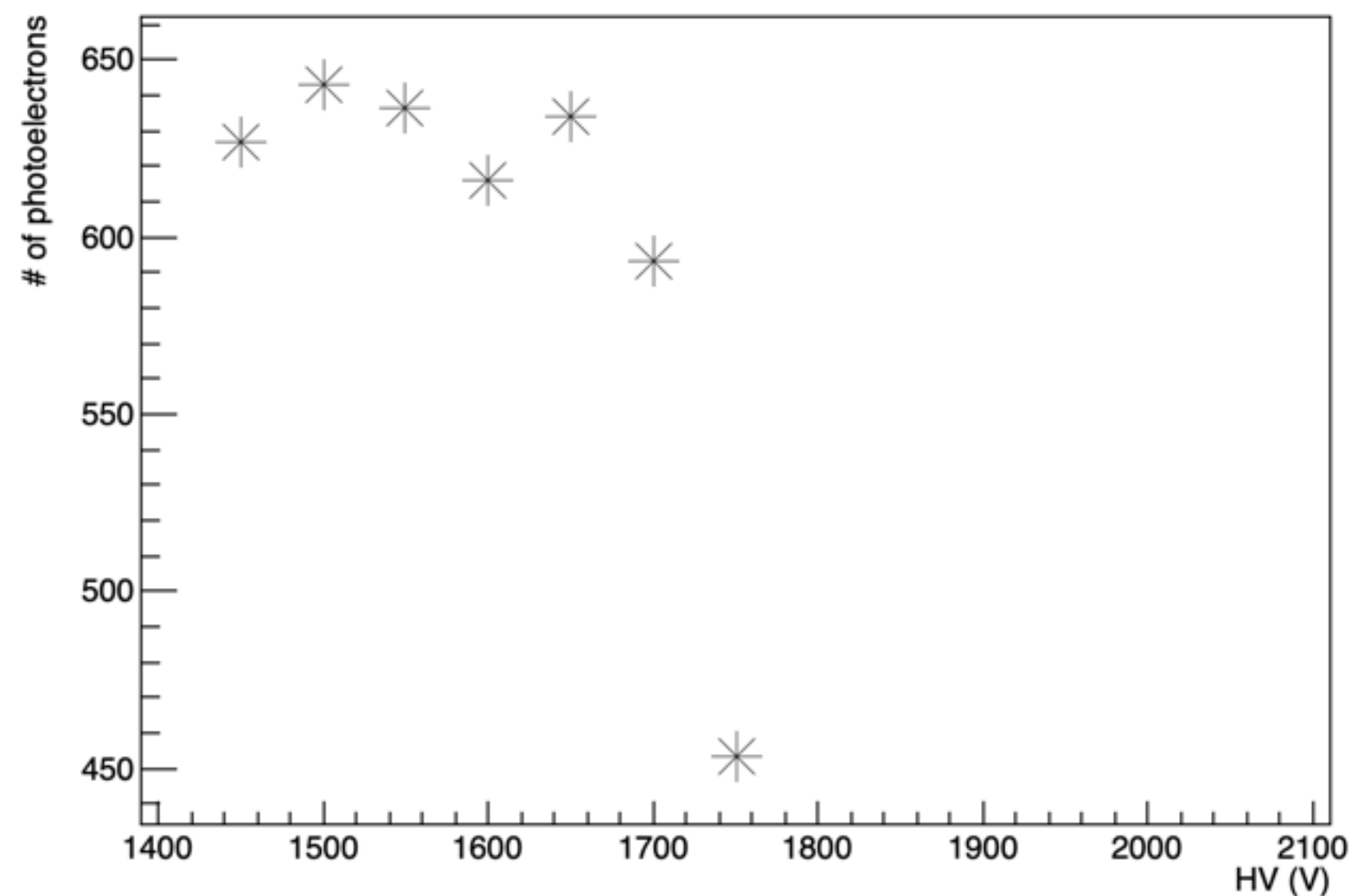


PMT_269_led_2

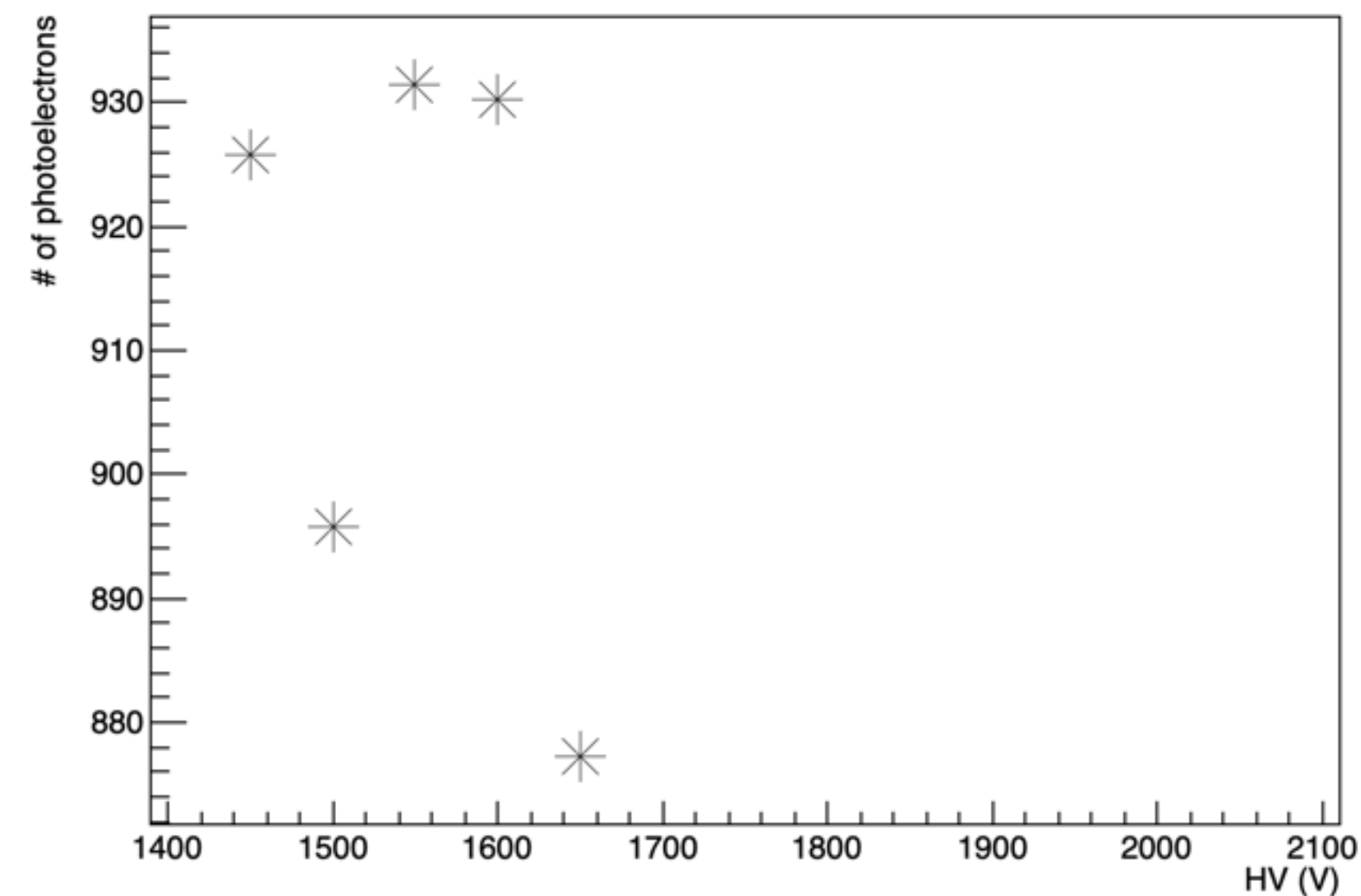


Npe reaches the plateau at higher HV.

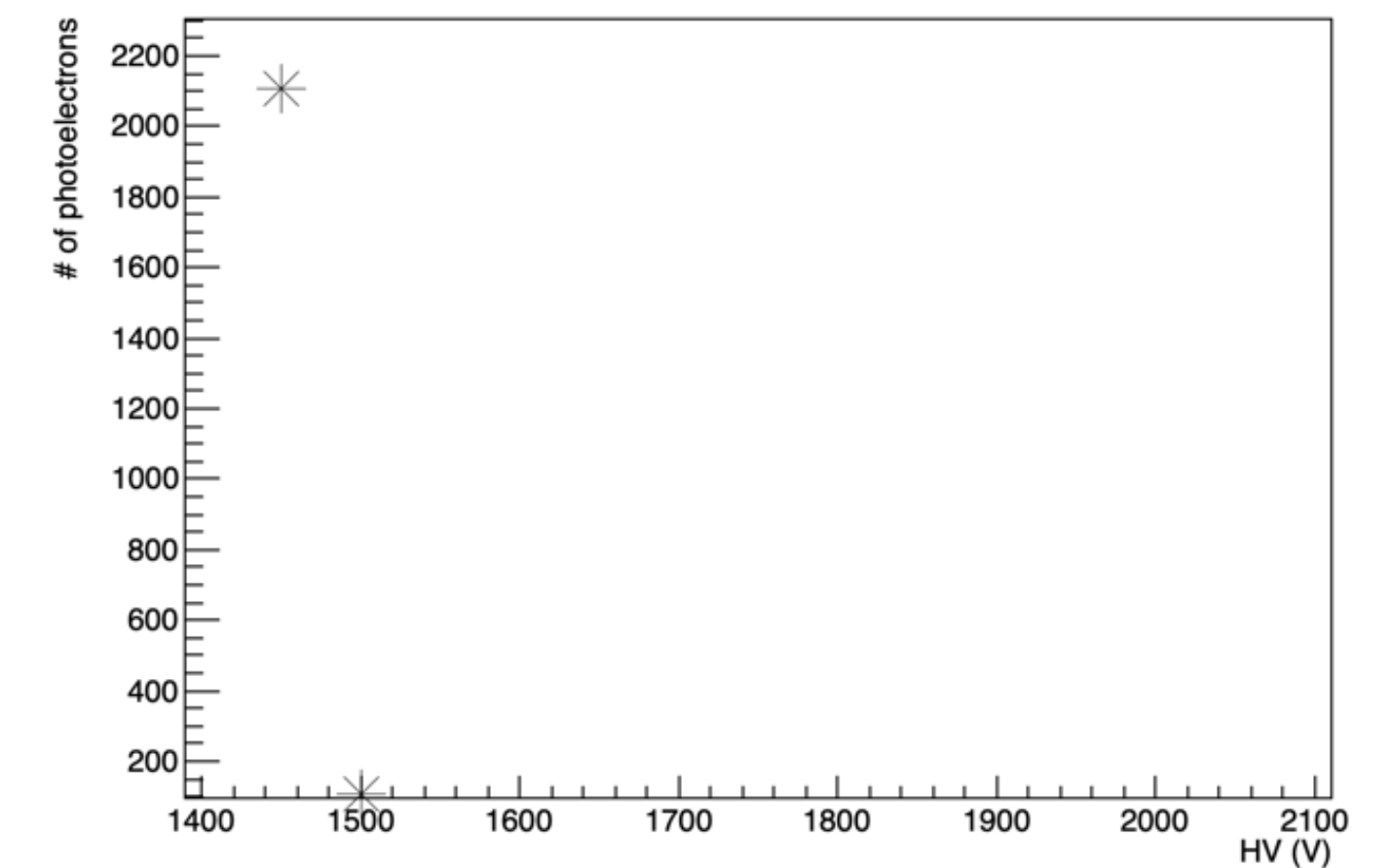
PMT_269_led_3



PMT_269_led_4



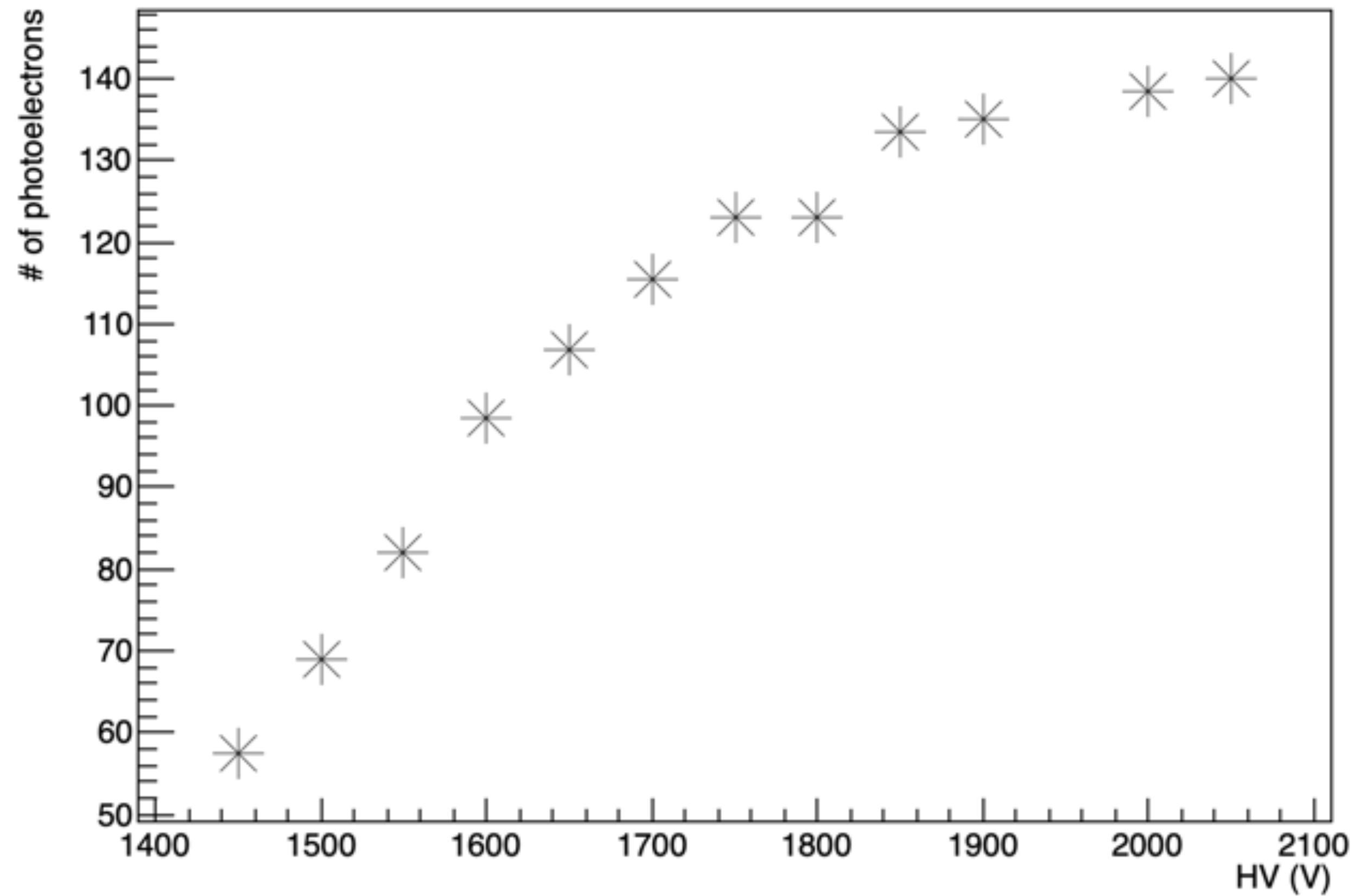
PMT_269_led_5



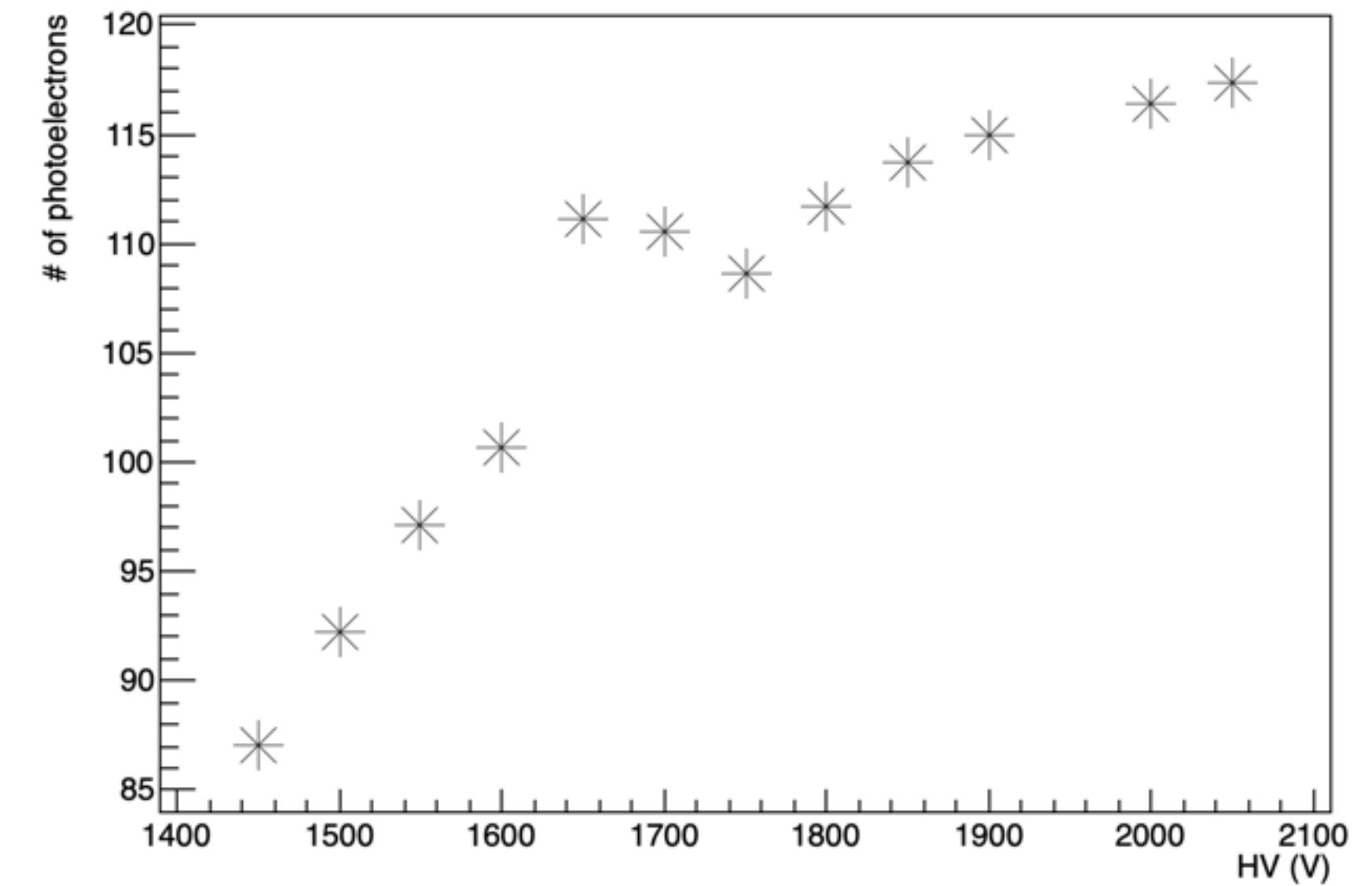
LED Runs_npe VS HV

JLAB PMTs

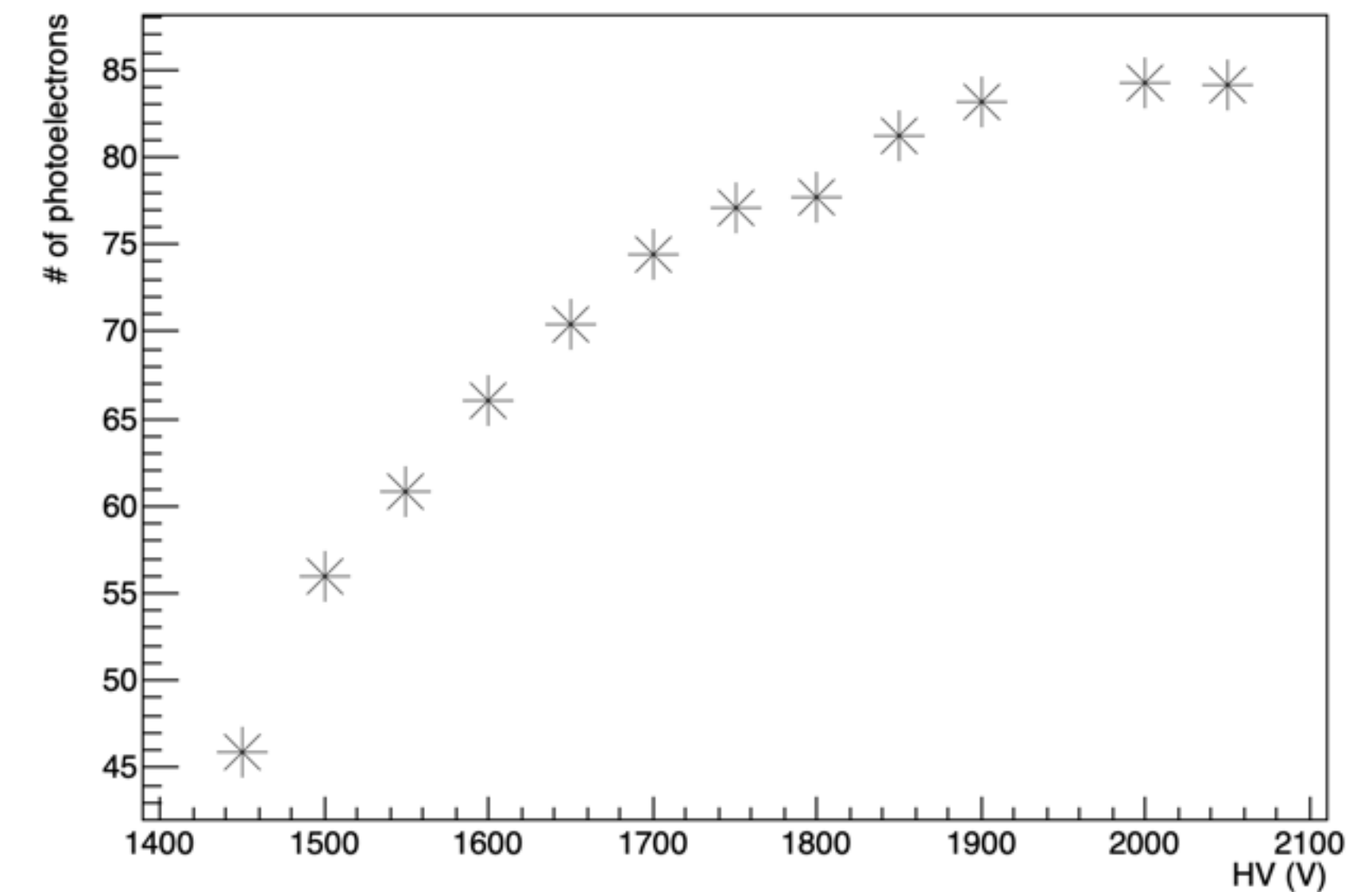
PMT_161_led_1



PMT_268_led_1



PMT_148_led_1



There are some JLABs tube that not seem to reach the plateau

Needed other runs, with higher HV value



Thanks to the entire HCAL group: B. Wojtsekhowski, B. Quinn, D. Jones, J. Napolitano
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