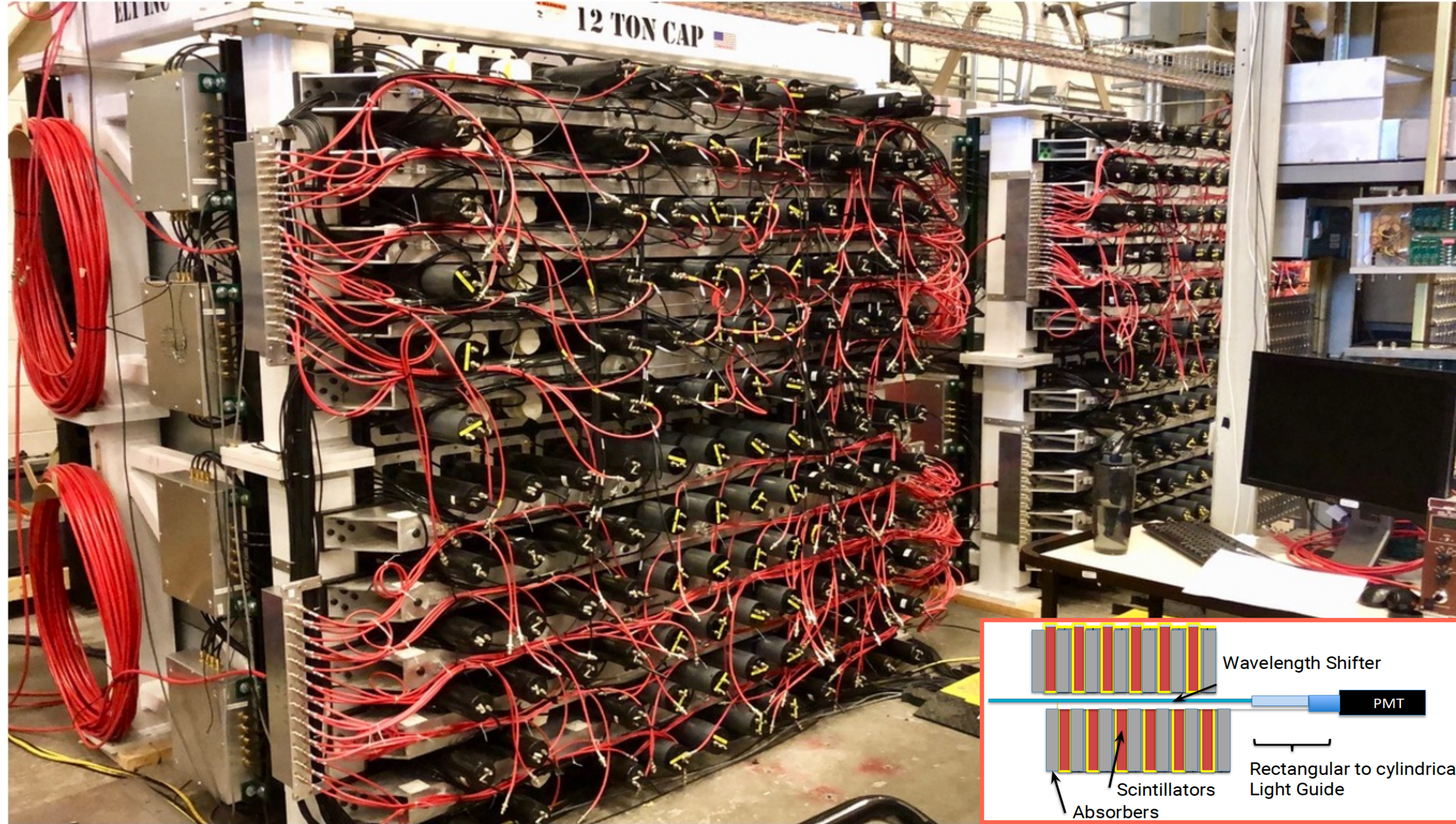


HCAL-J: calorimeter for the study of Nucleons Form Factors

Vanessa Brio

HCAL-J Design



LEDs System



HCal has a series of 6 LEDs that can illuminate each PMT.

Each subsequent LED lights up twice as much as the previous one.

288 modules (each 15x15 cm²) 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**

HCAL-J at Test Lab

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

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

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

Several tests were carried out for:

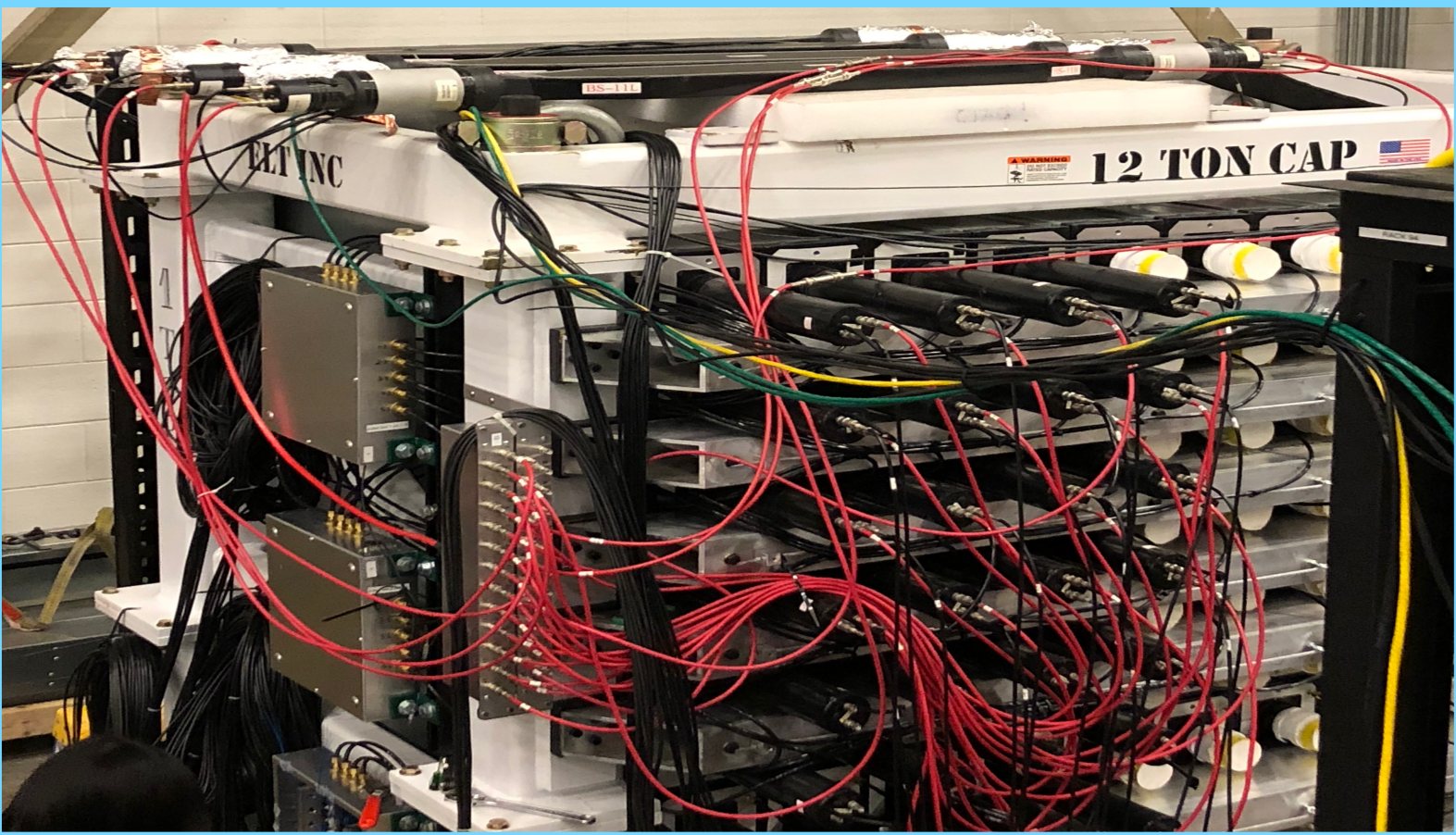
4X4 Matrix of modules

4x6 Matrix of modules

12x12 Matrix of modules

12x24 Matrix of modules

As a triggers we always used 4 scintillating
paddles placed on the top of the calorimeter!



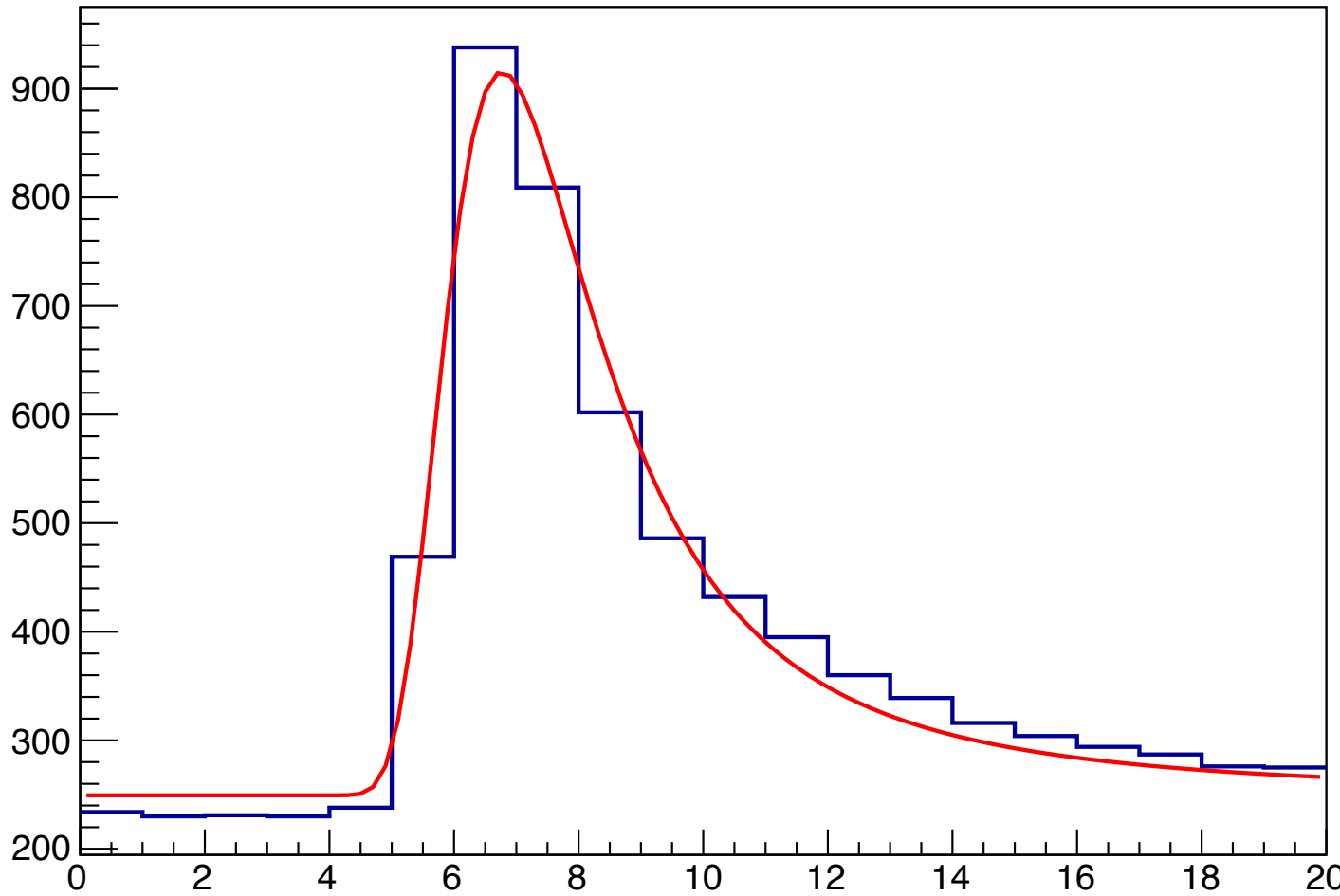
HCAL-J cosmic tests

Left and right HCAL parts are separately studied.



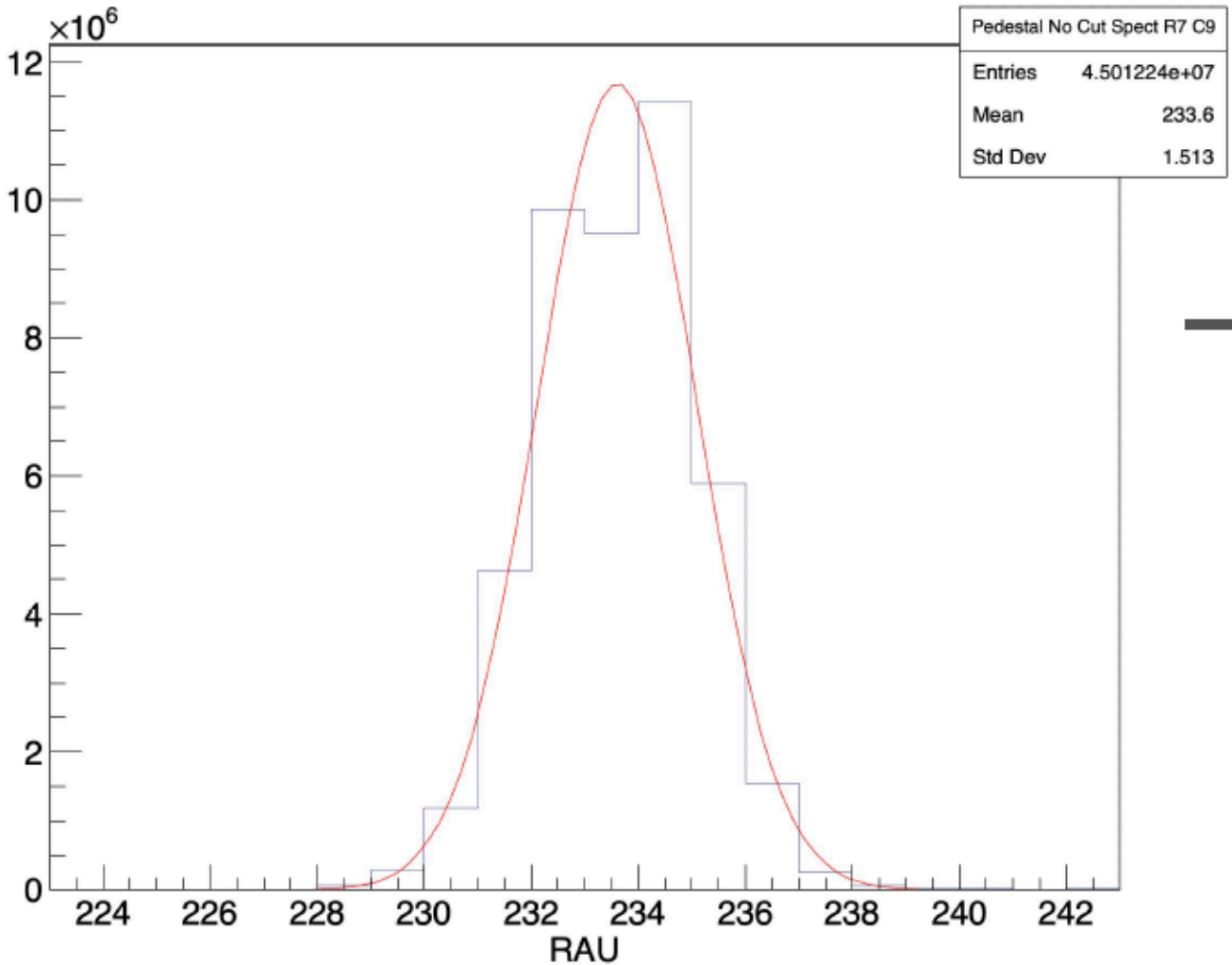
7 cosmic runs for each part, at different HV values

FADC signal



PMT_87

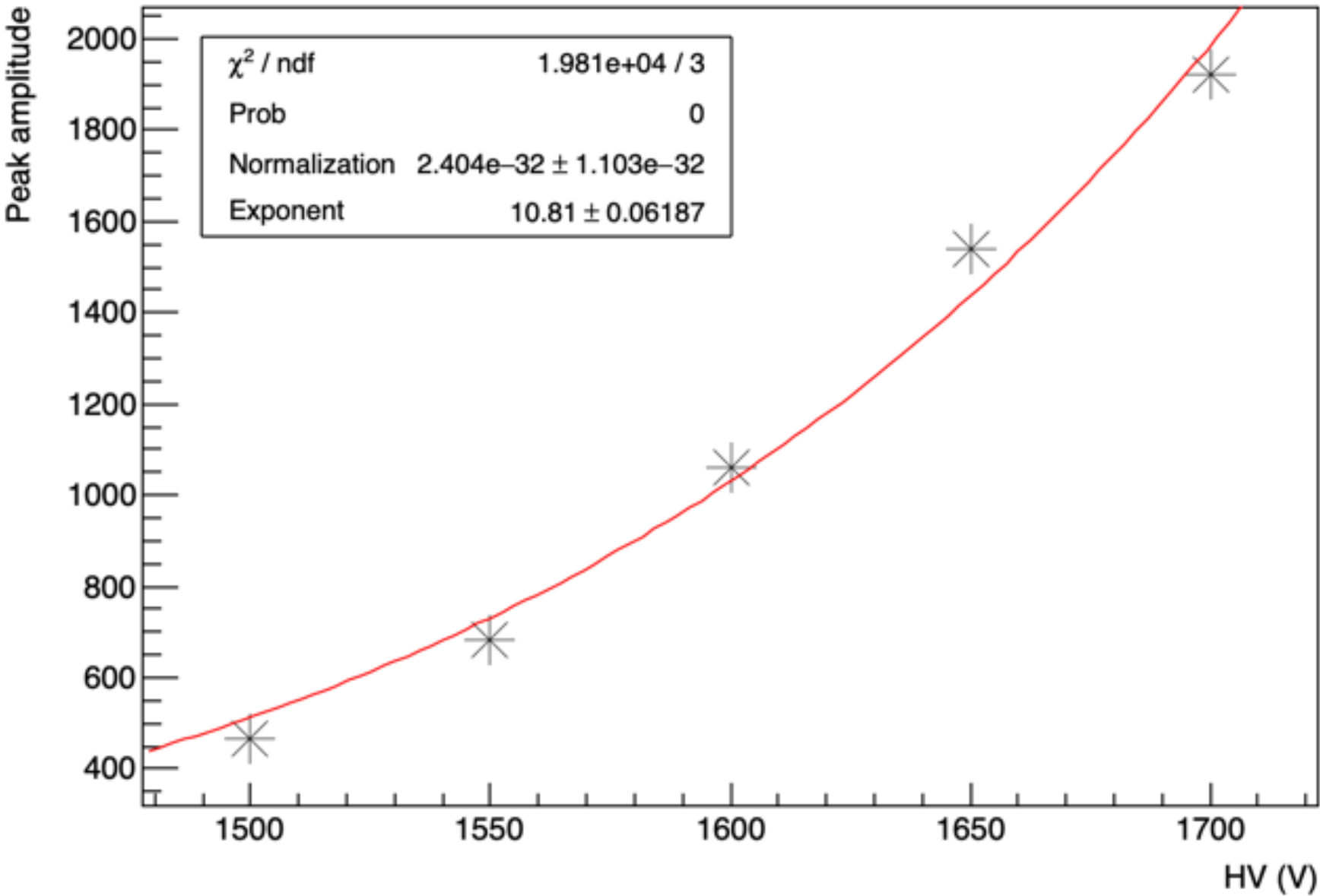
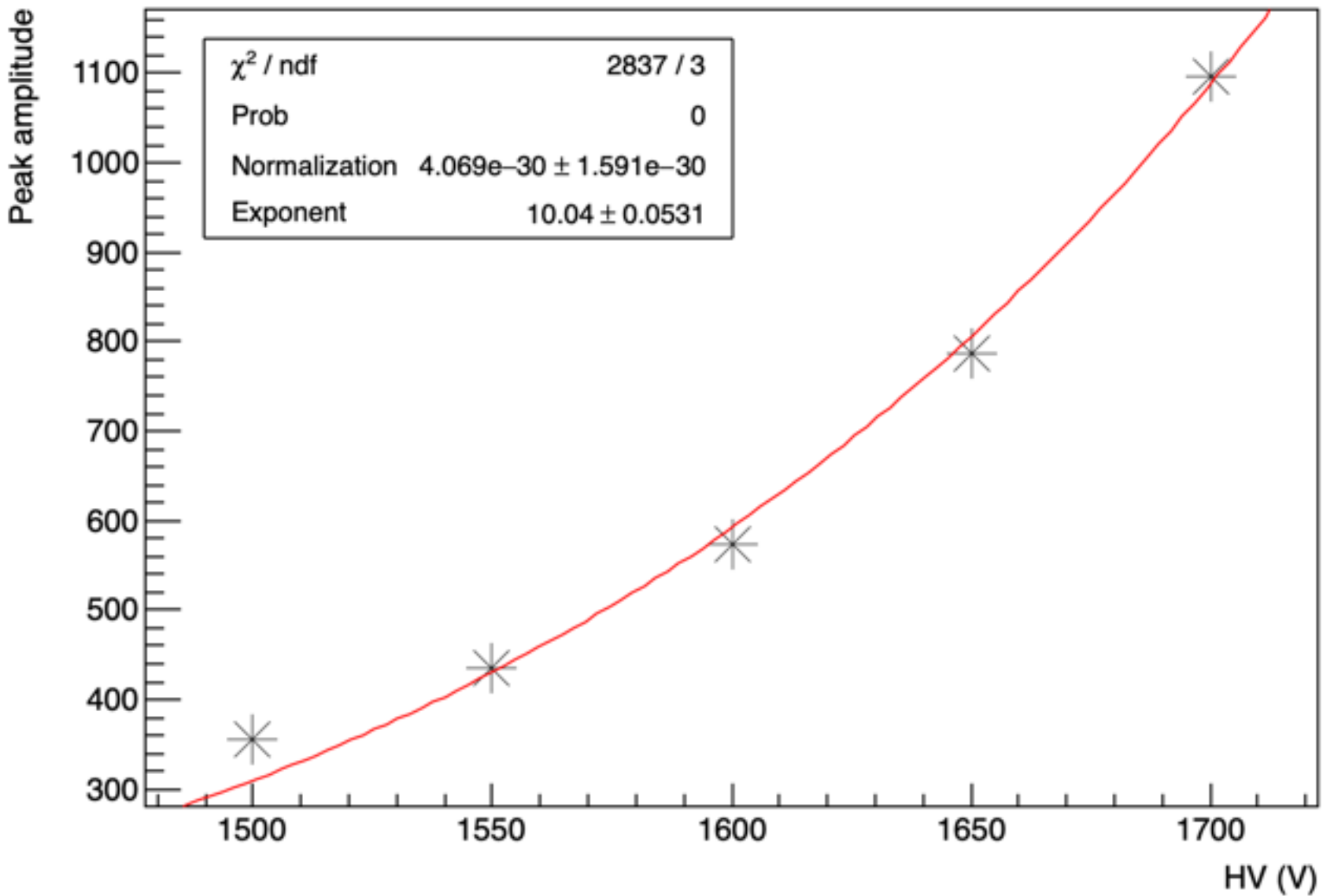
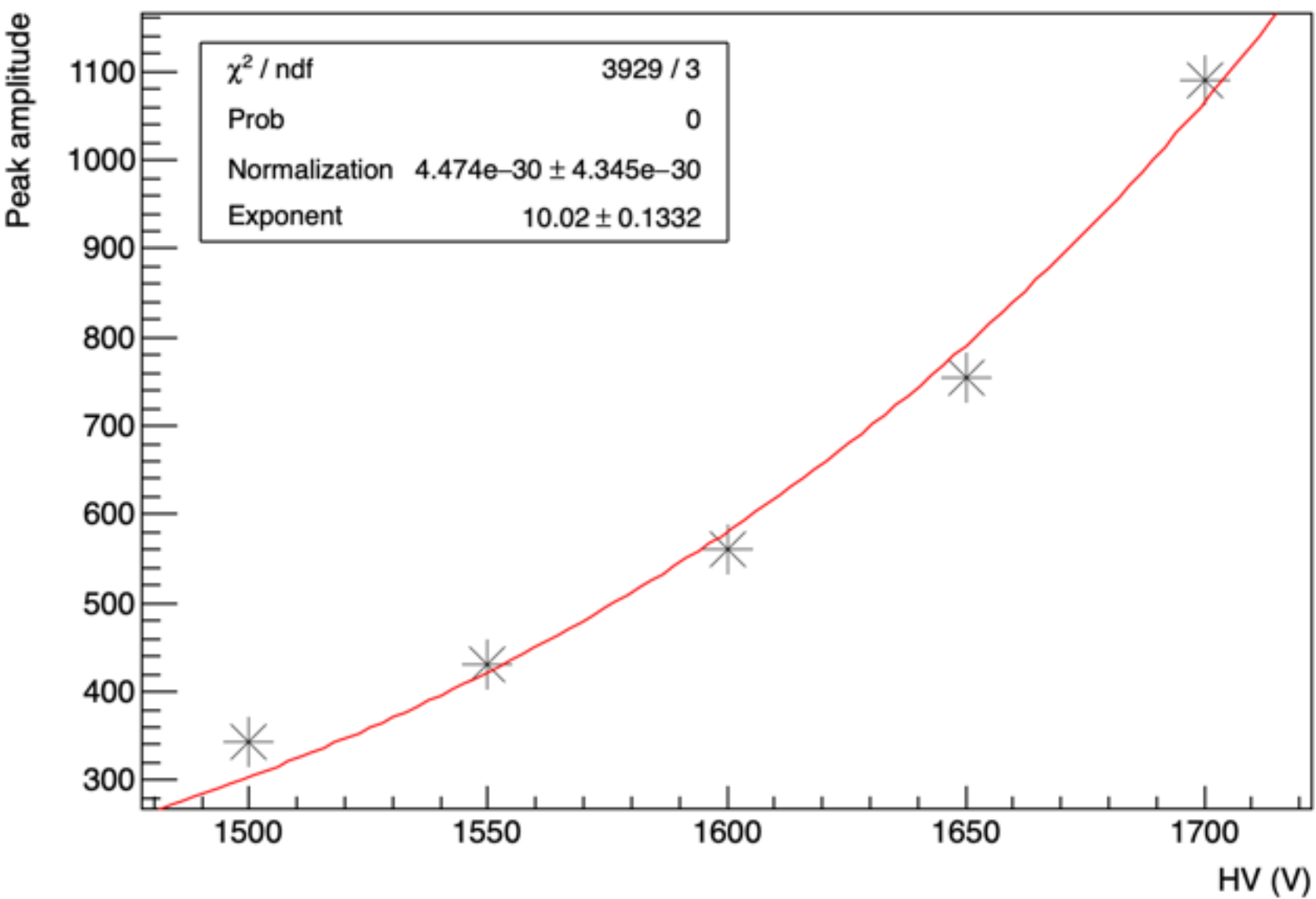
Pedestal Spect No Cut R7 C9



PMT_141

Gain curve

PMT_14



Fitting function:

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

P0 = "Normalization"

P1 = "x offset"

P2 = "Exponent"

P3 = "Y offset"

HCAL-J cosmic tests

Number Of PhotoElectron Study

The single photoelectron peak is useful to calibrate the PMTs and to evaluate its absolute gain

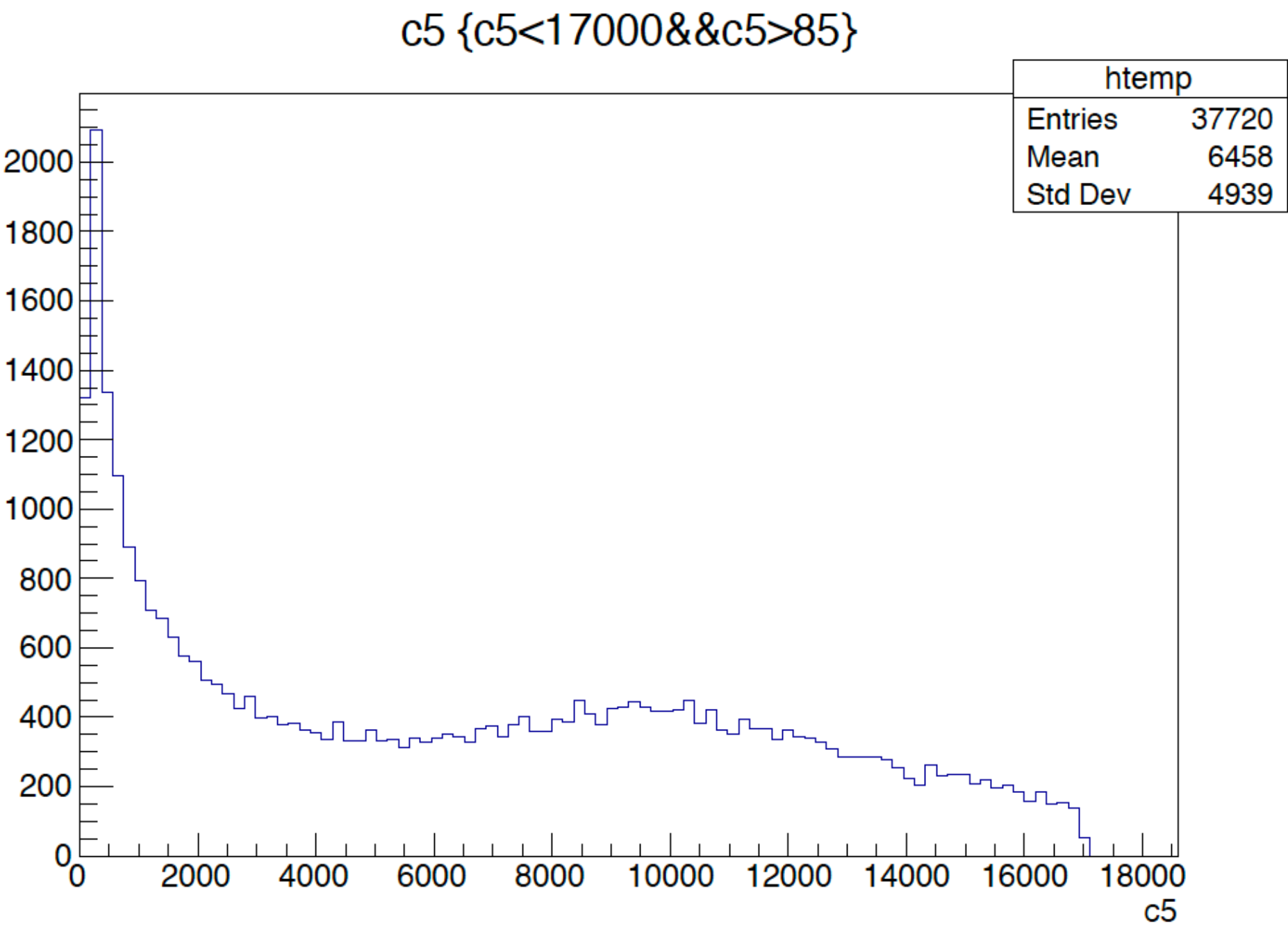


Figure 1: Spectrum of channel 5 in which we can see the 2 peaks together: single photoelectron peak and signal peak.

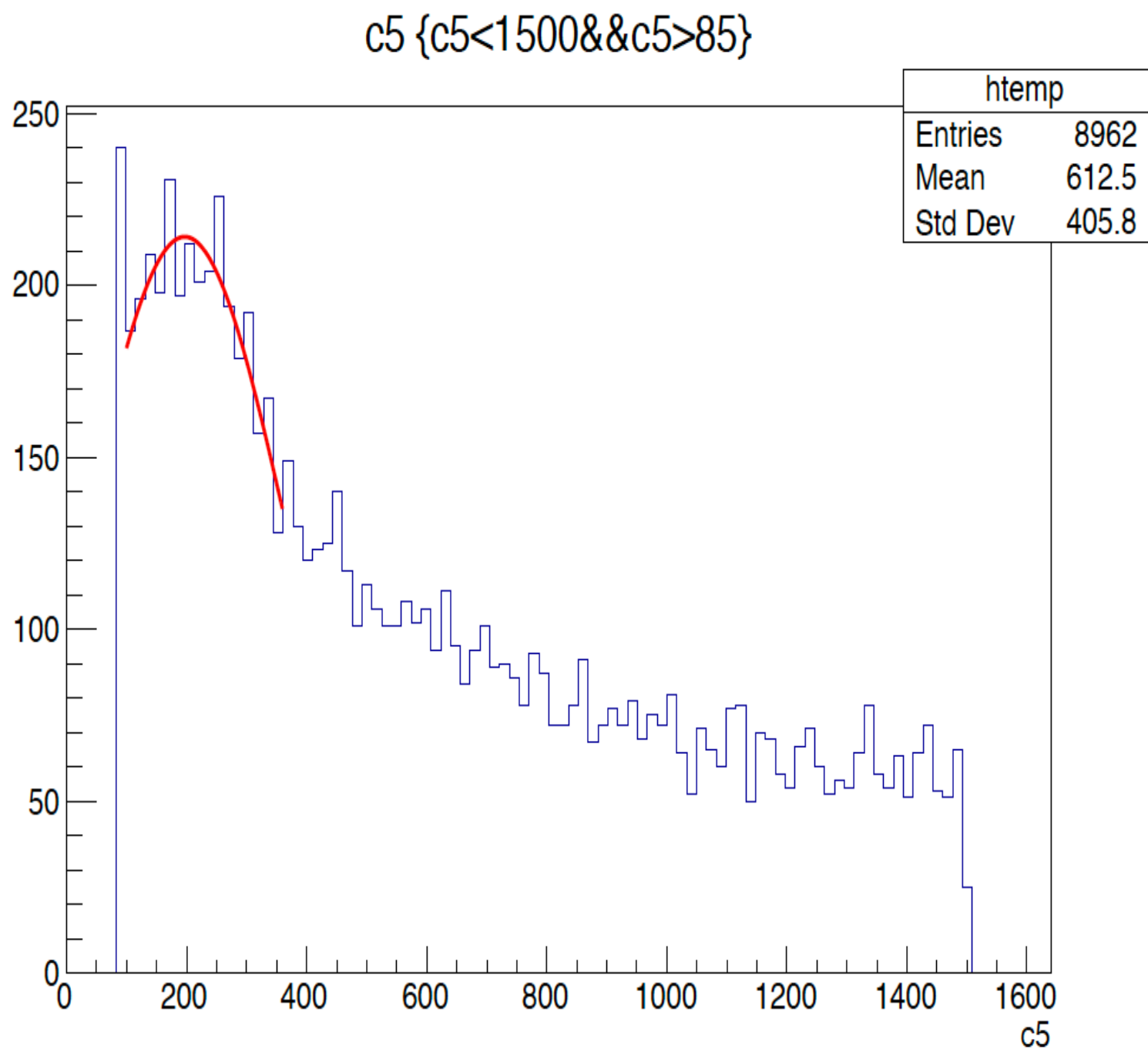


Figure 4: Spectrum of photoelectron peak in channel 5. The macro h_timeV.C should subtract the pedestal.

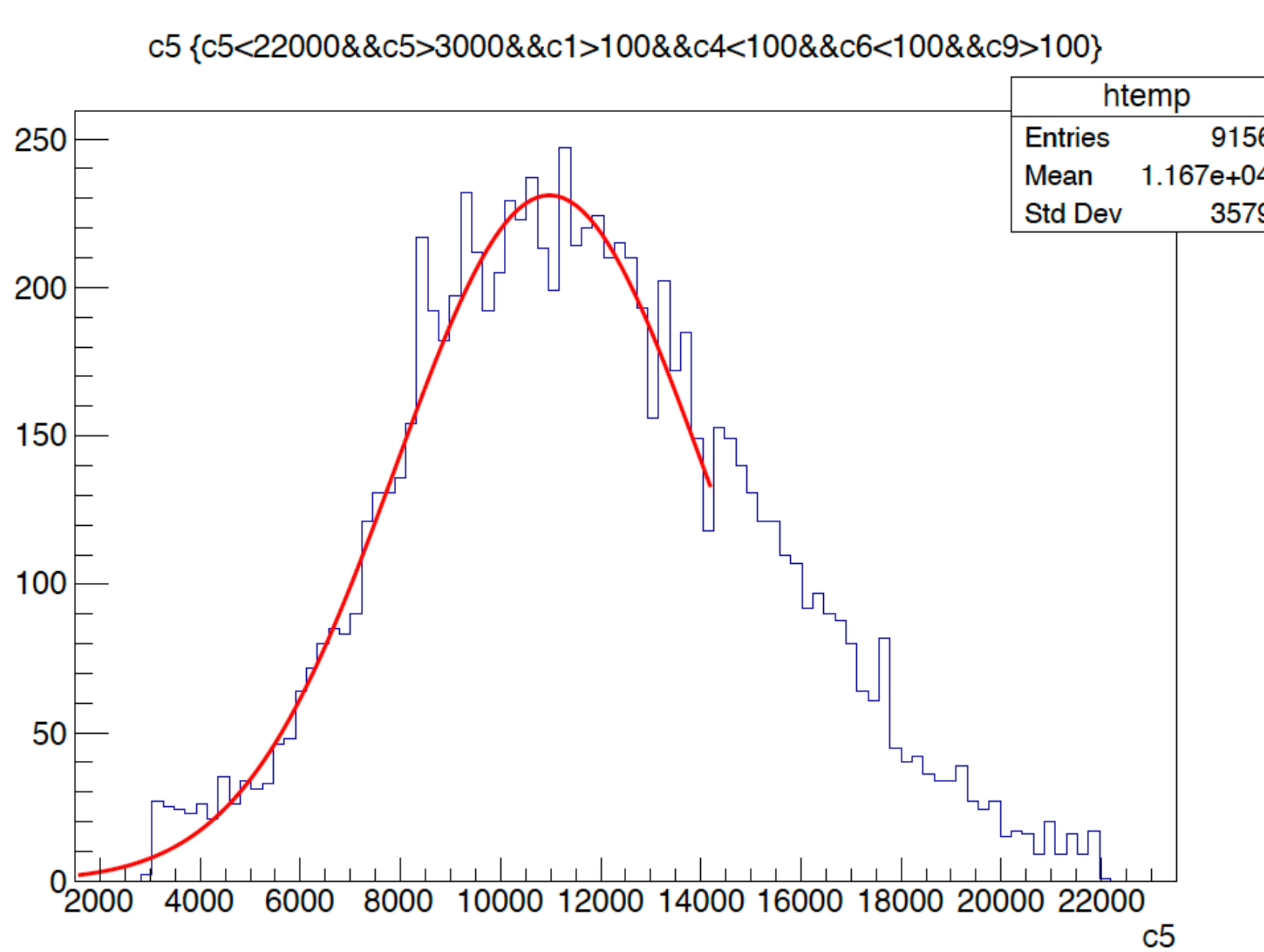


Figure 5: Spectrum of ADC signal peak for channel 5

Run 200 ➡ 1501 Volt

$N_{pe} = Q(\text{signal}) / Q(1phe) = 56.$

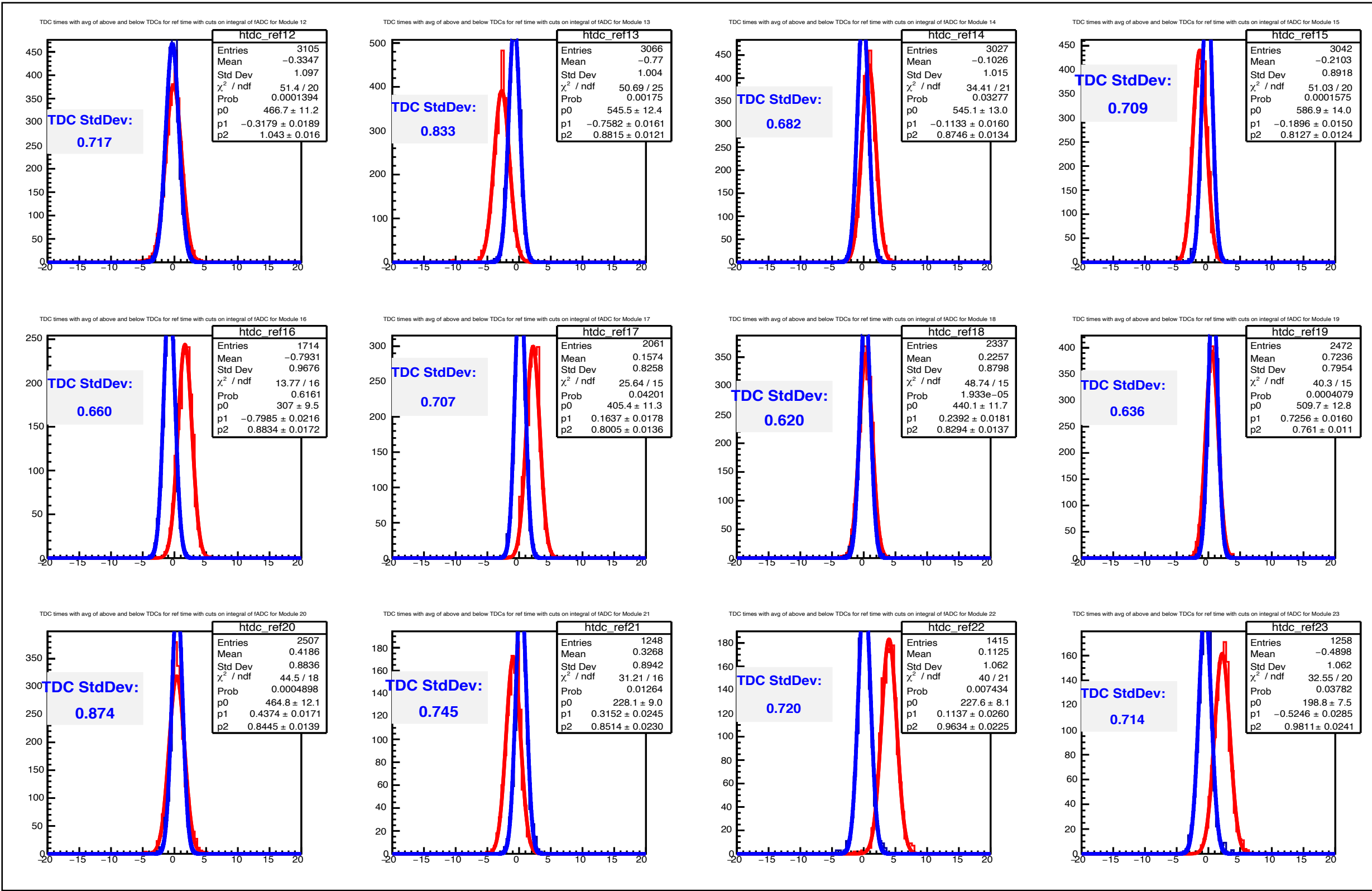
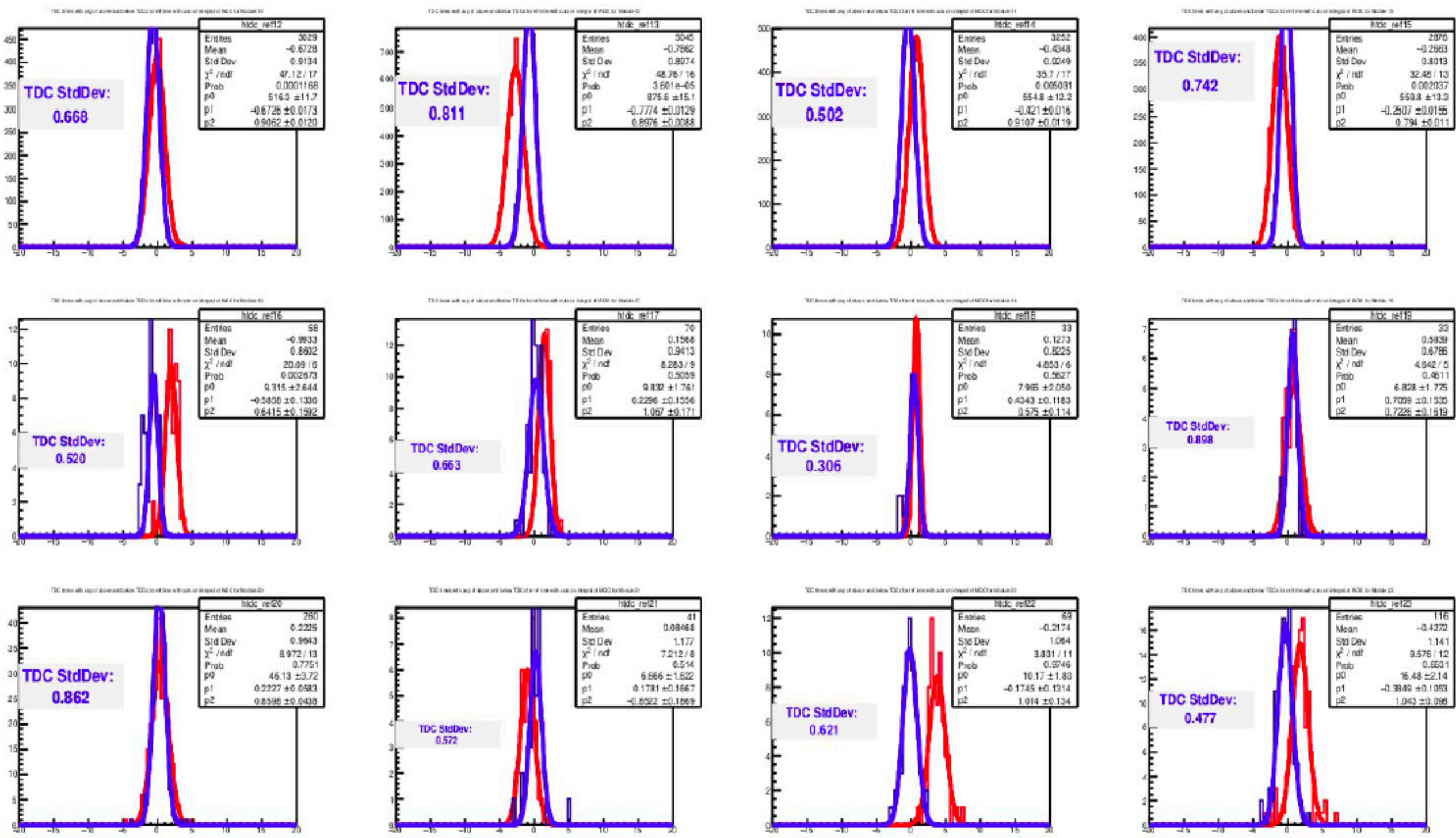
Run 200 ➡ 1601 Volt

$N_{pe} = Q(\text{signal}) / Q(1phe) = 71$

Agreement with
the simulations
results!!

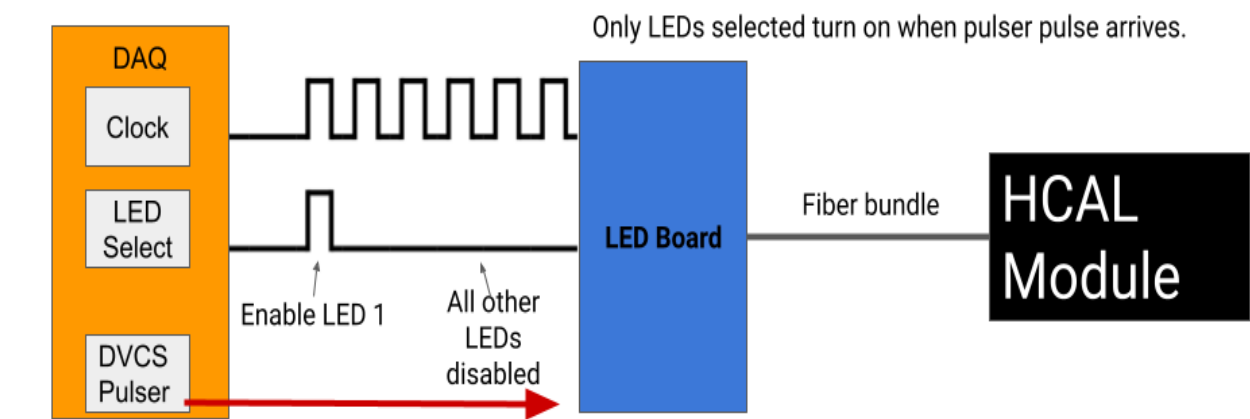
HCAL-J cosmic tests

Timing Resolution of a module → 3 other phototubes in vertical coincidence are fired and 6 surrounding ones are not fired



Very good timing resolutions!!

HCAL-J LEDs tests



LED cycles programmable

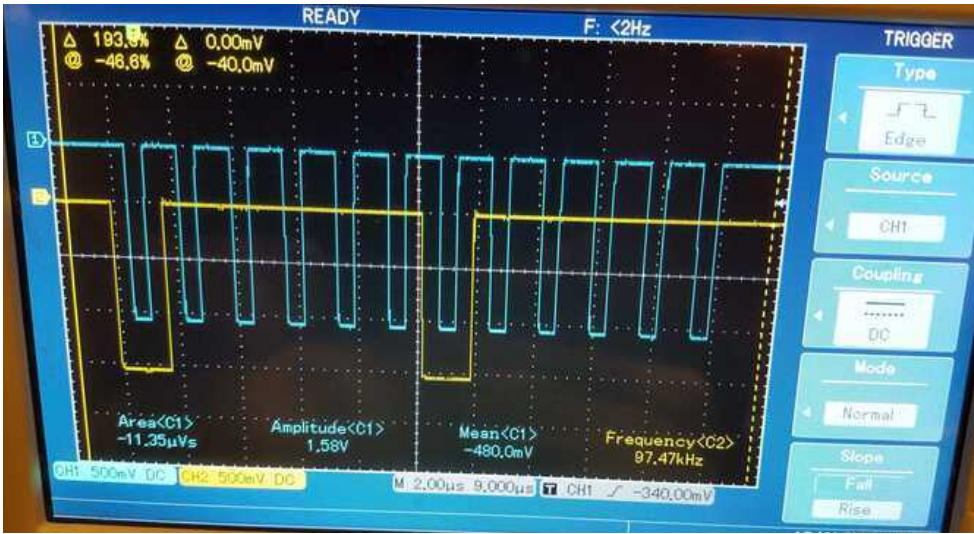
LED0 → LED1 → LED2 → LED3 → LED4 → LED5

1000 triggers and then you move on to the next one

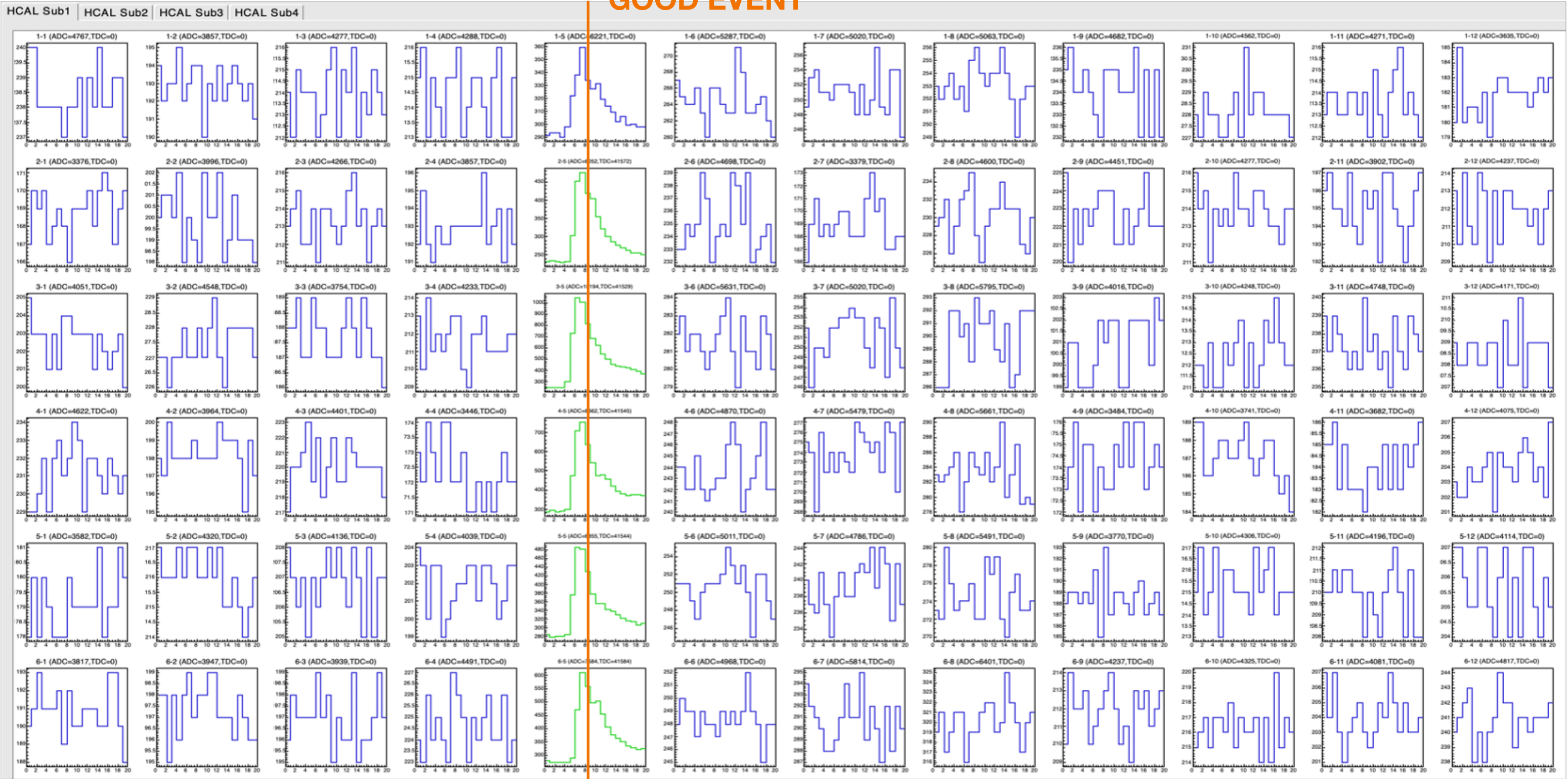
Each run ~ 5000 event

Left and right HCAL parts are separately studied.

12 LEDs runs for each part, at different HV values



GOOD EVENT



CMU PMT Voltage	JLab PMT Voltage
-1675V	-2050 V
-1650 V	-2000 V
-1600 V	-1900 V
-1575 V	-1850 V
-1550 V	-1800 V
-1520 V	-1750 V
-1500 V	-1700 V
-1475 V	-1650 V
-1450 V	-1600 V
-1425 V	-1550 V
-1400 V	-1500 V
-1350 V	-1450 V

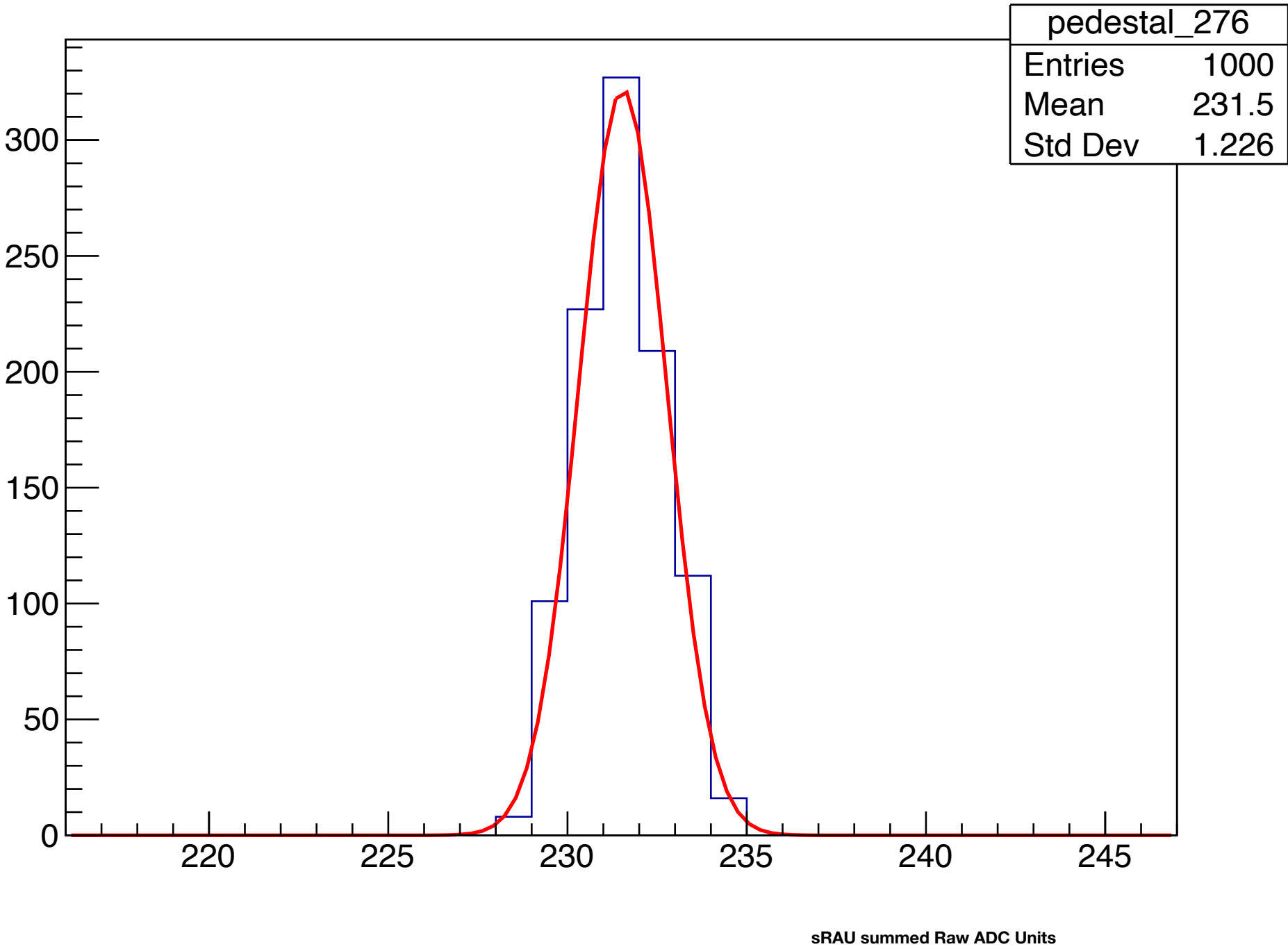
HCAL-J LEDs tests

RAU = Raw ADC Units

sRAU = summed Raw ADC Units

Pedestal calculation

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



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

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

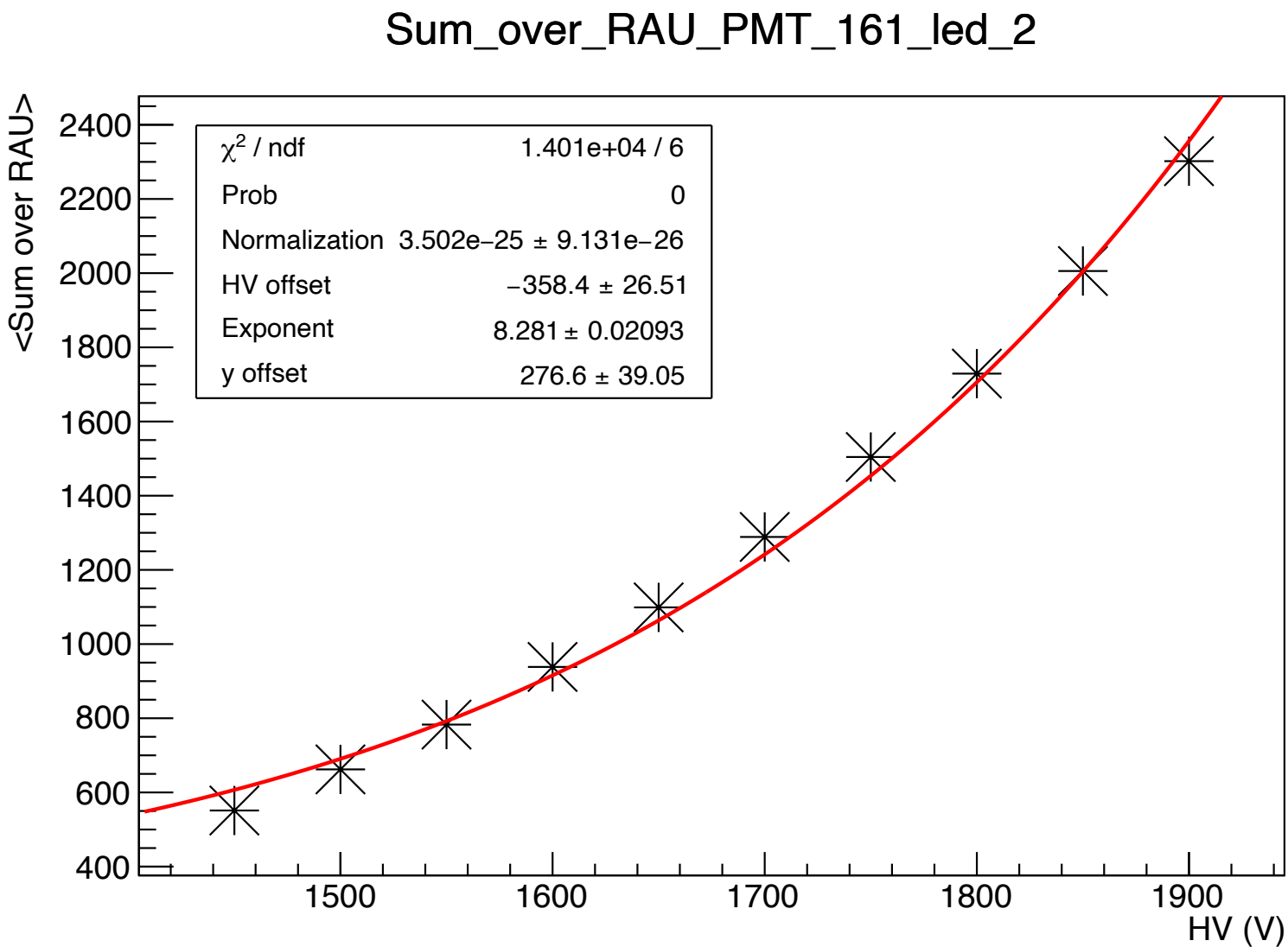
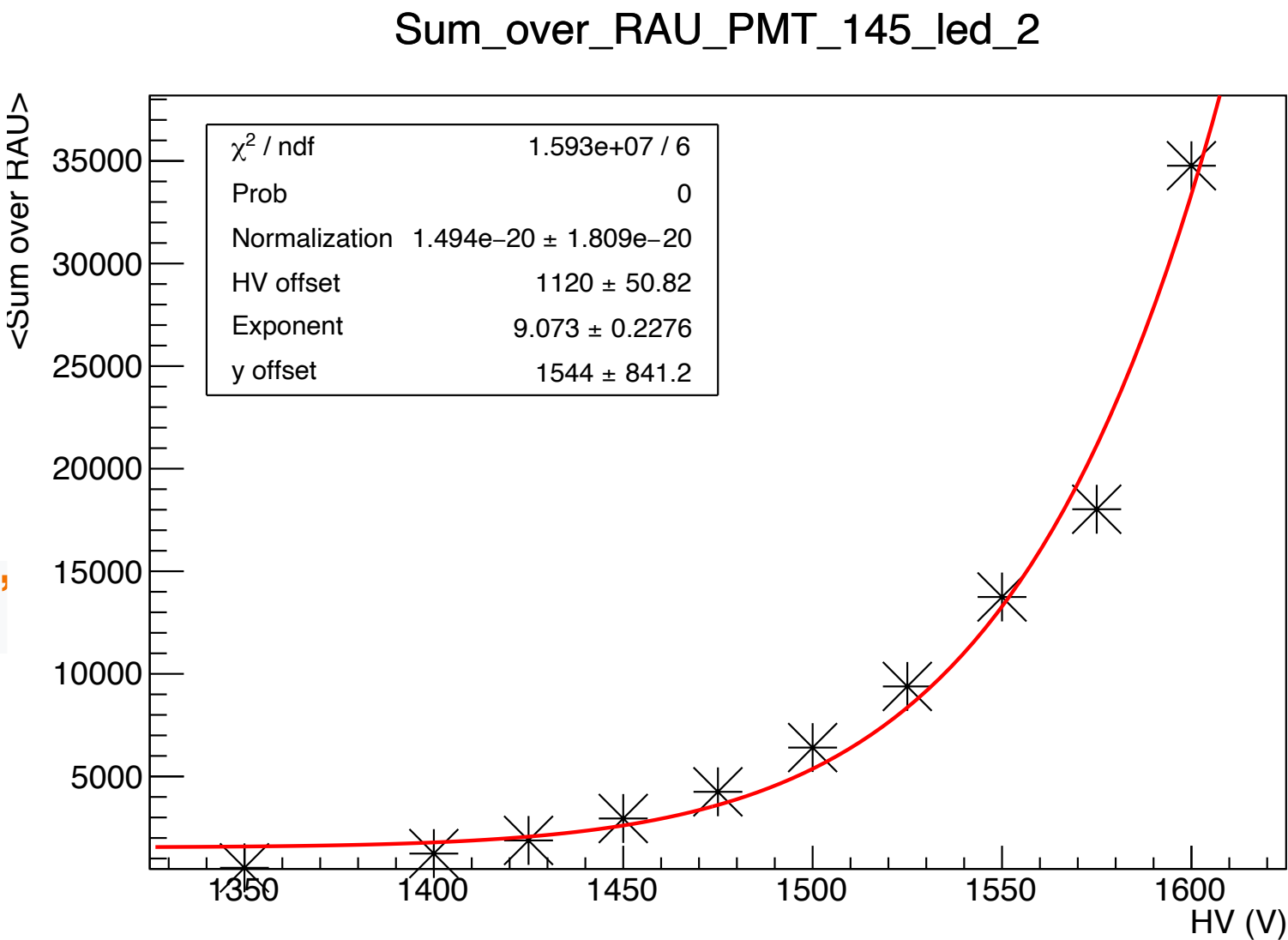
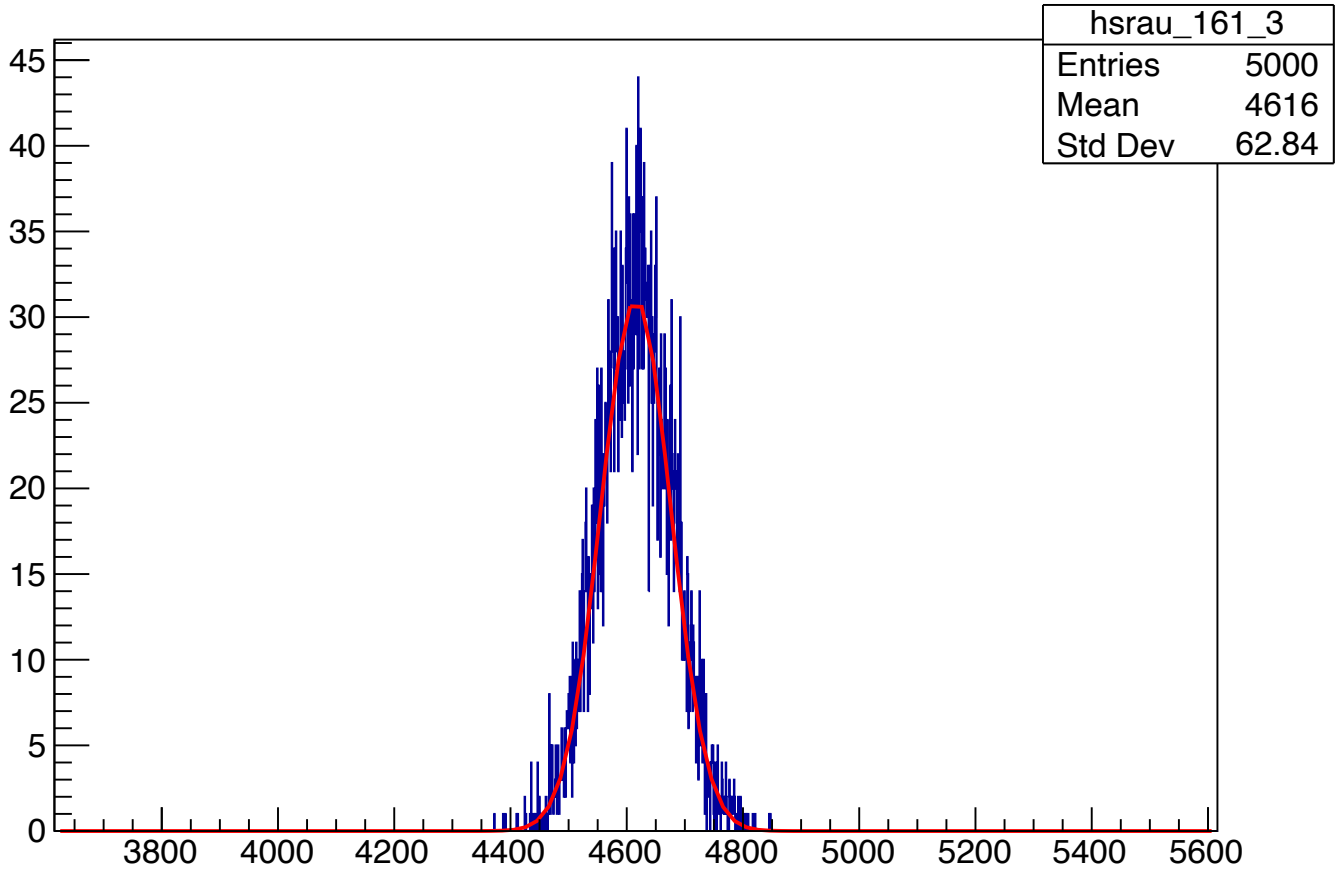
After pedestal subtraction, create the integrated value FADC spectrum for each run and LED



Fill sRAU event histogram for each module and for each LED



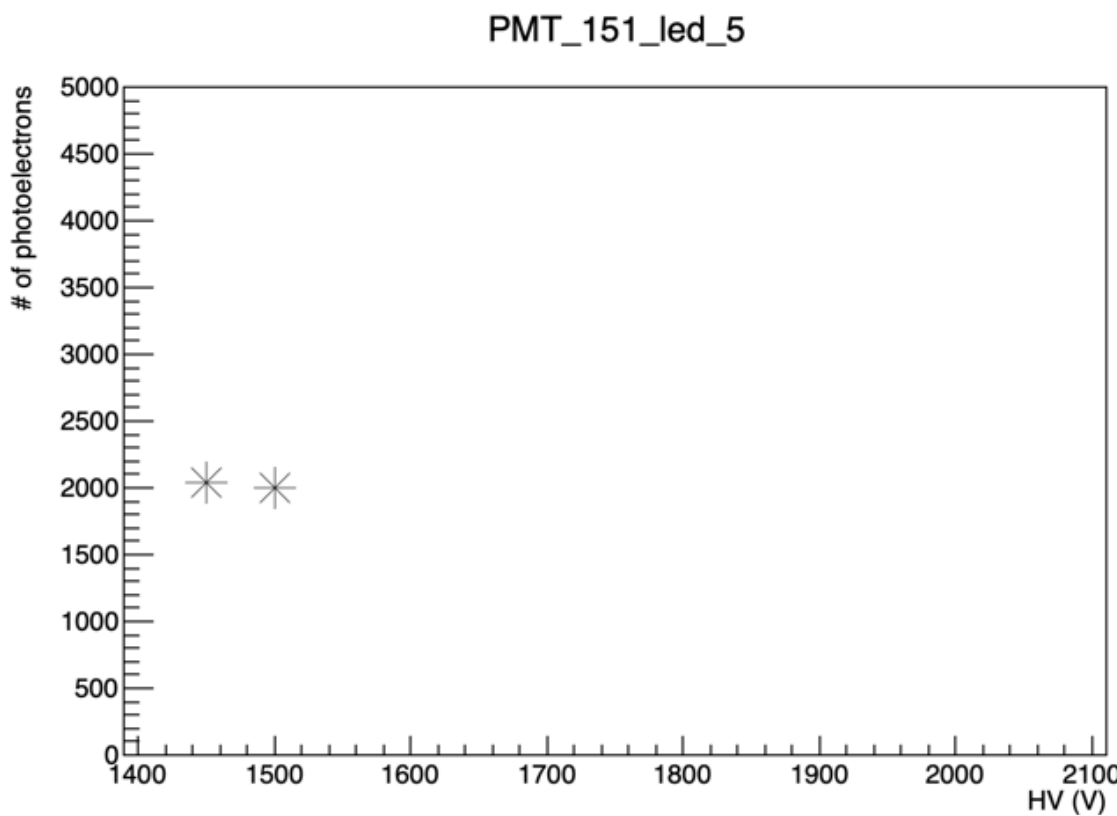
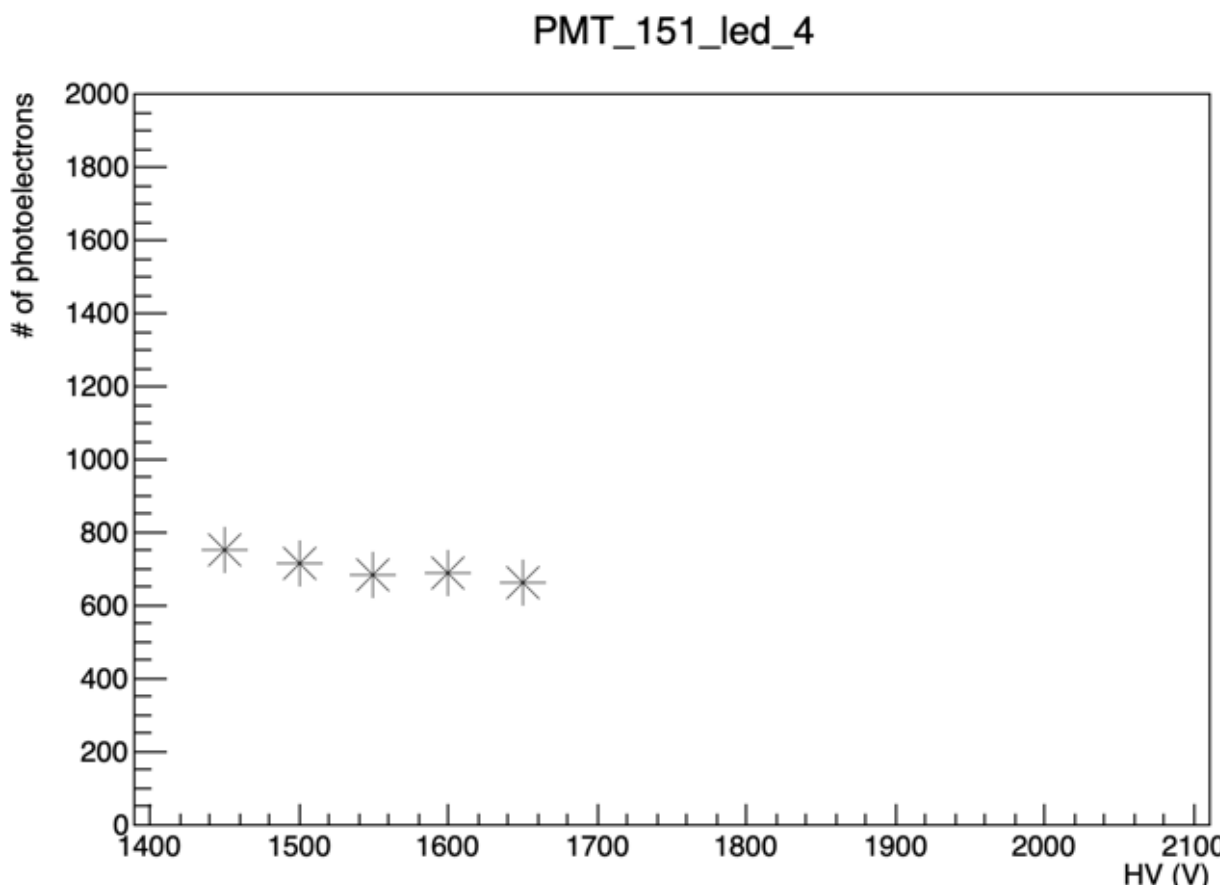
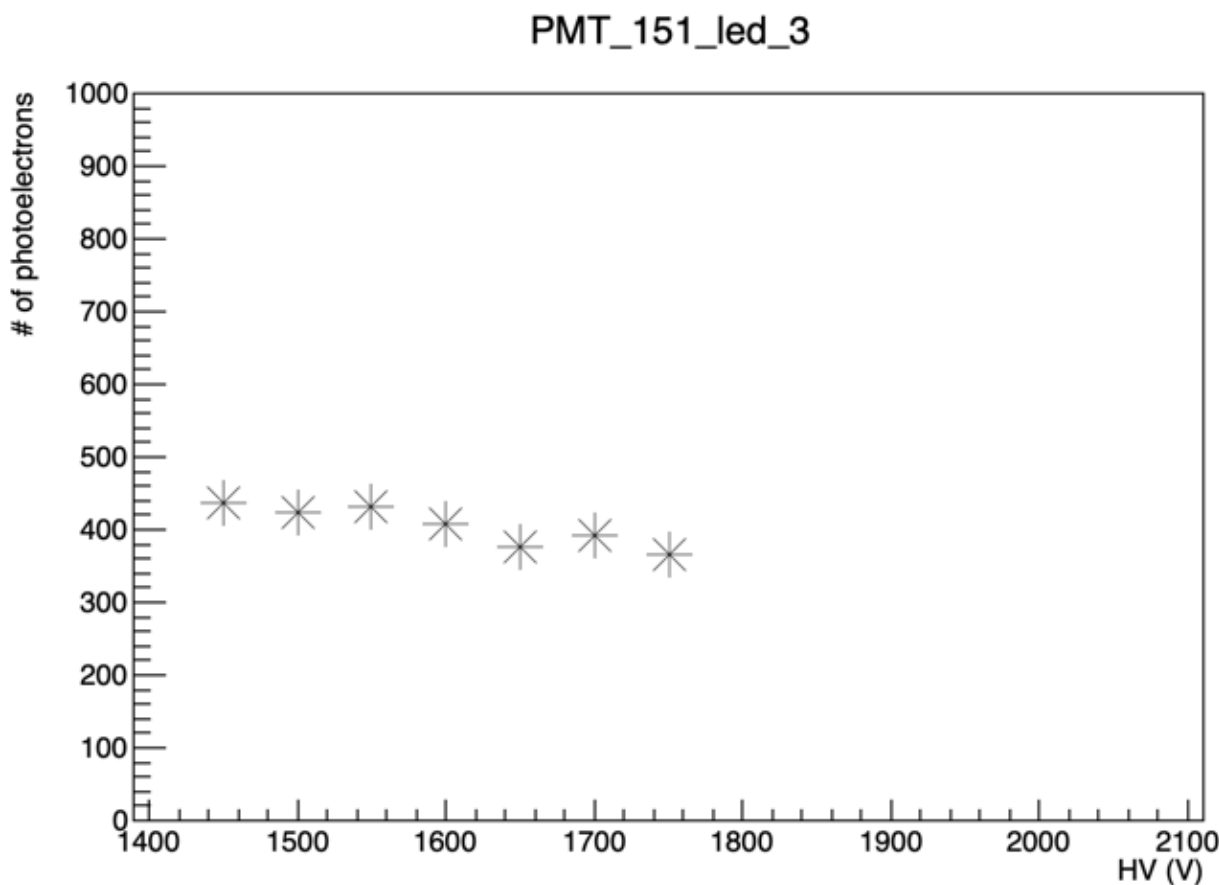
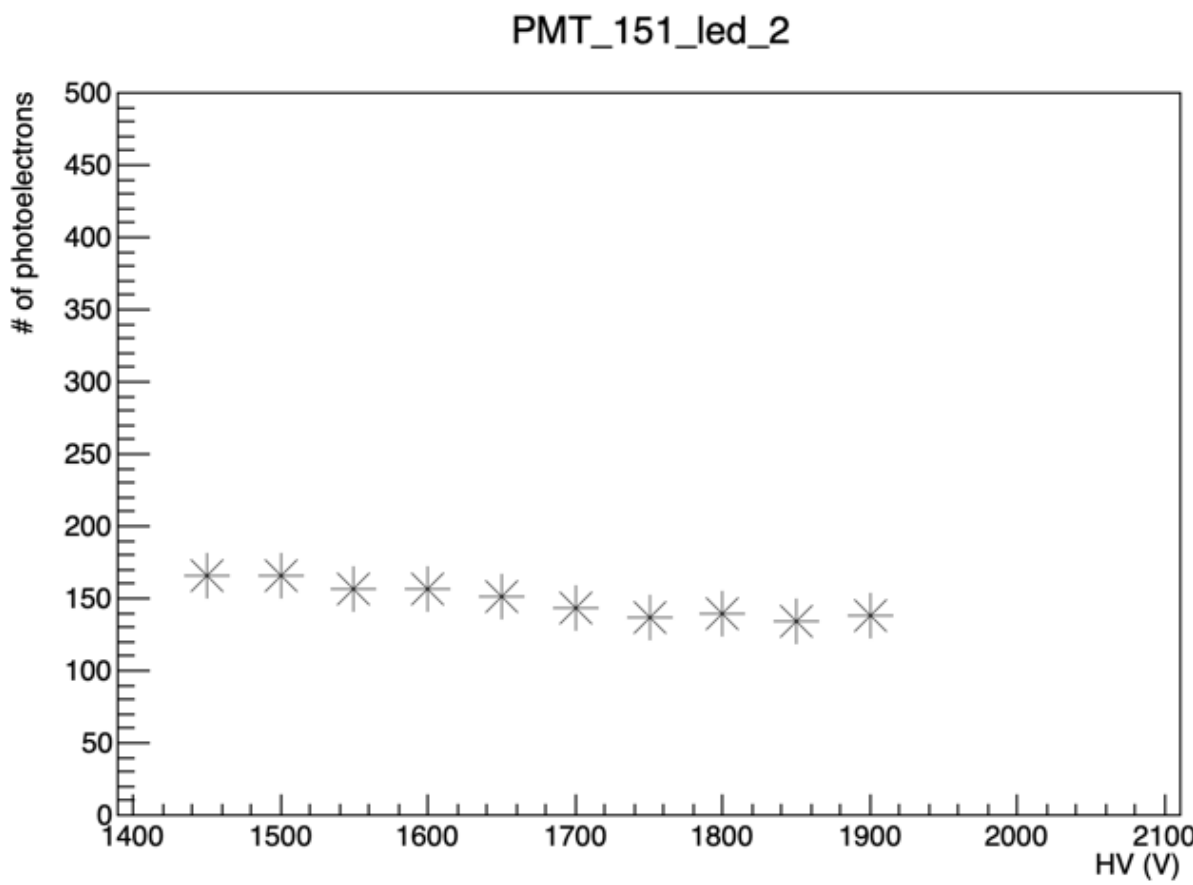
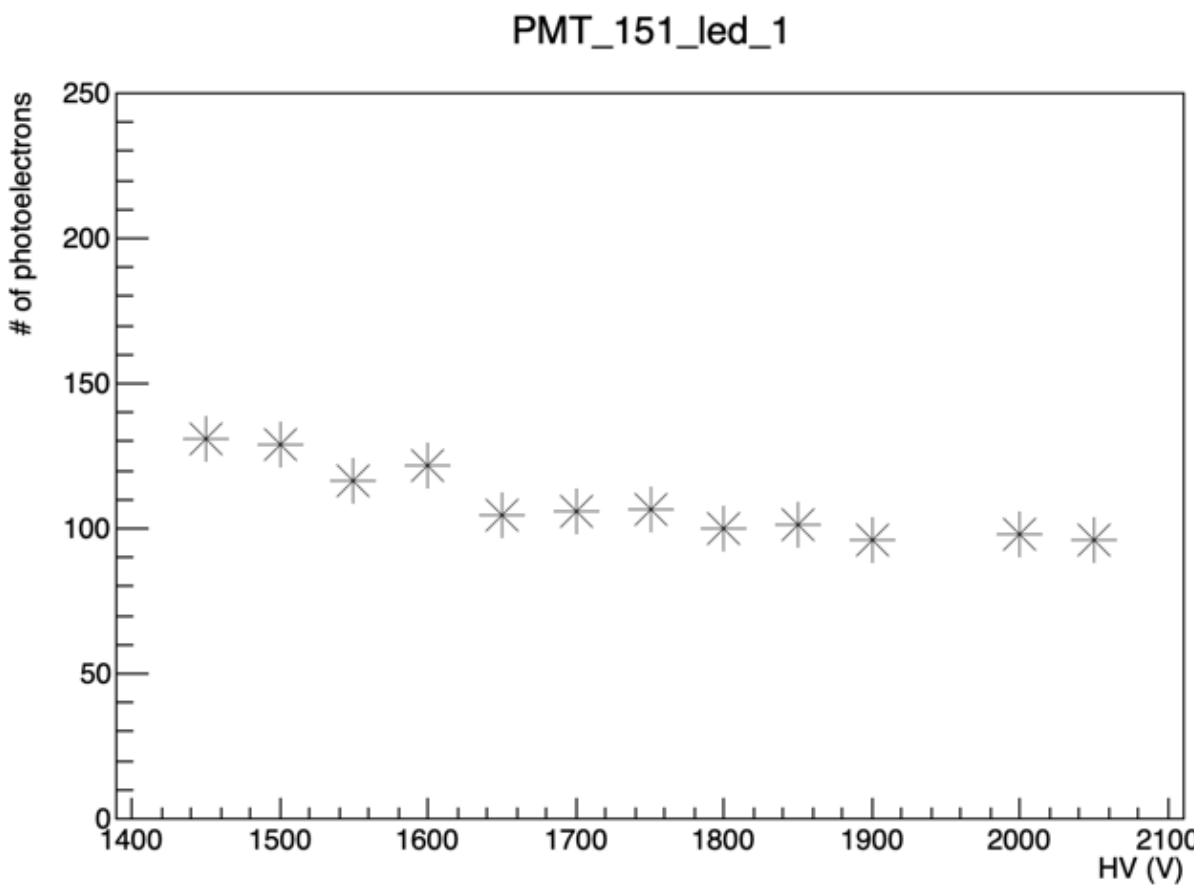
Create plot sRAU vs HV for each module and LED



LED Runs: npe analysis

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

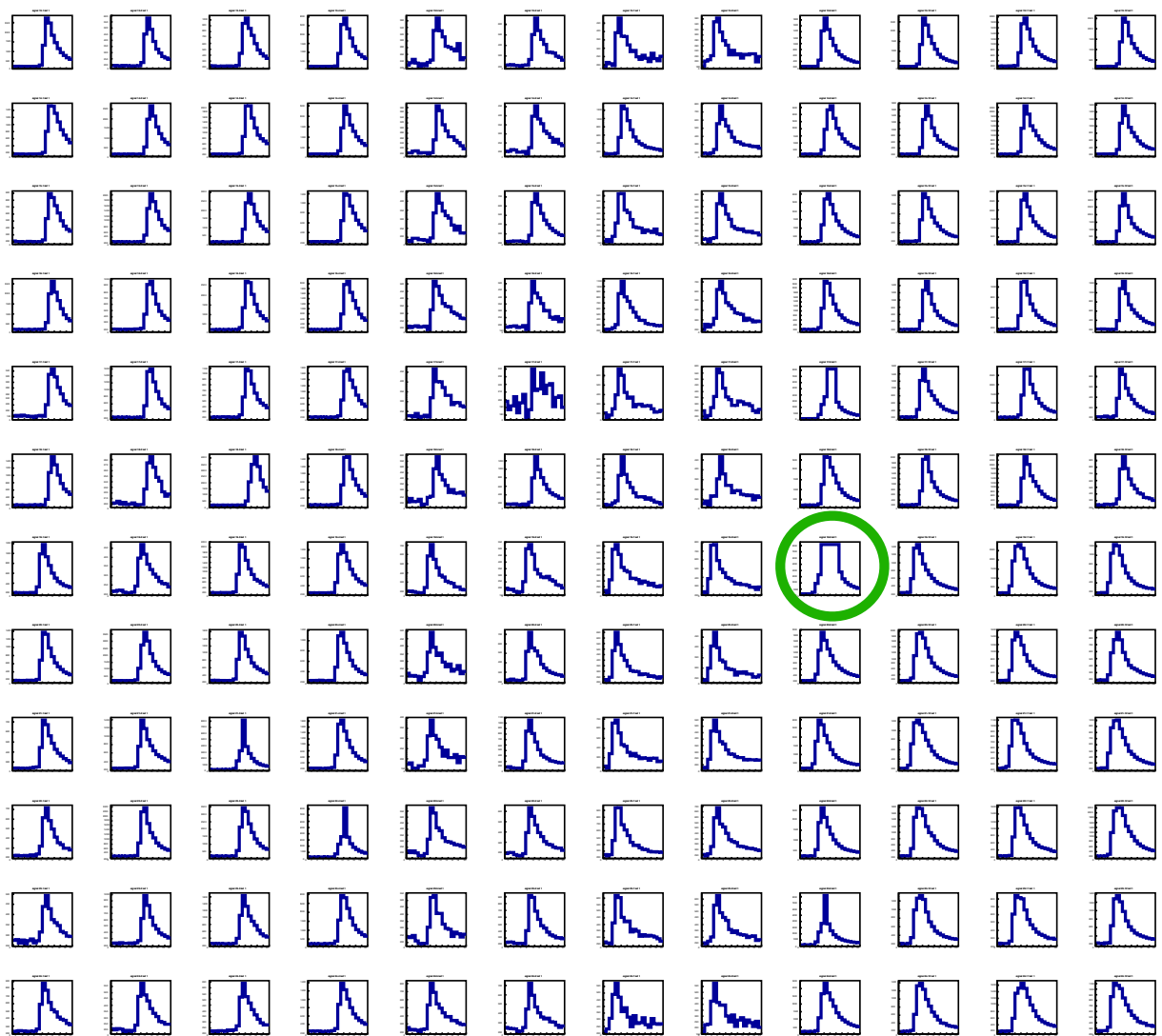
$$npe = \left(\frac{\langle ADC \rangle}{\langle RMS \rangle} \right)^2$$



Each LED doubles the brightness of the previous one

The missing point in the major LEDs are due to the FADC saturation

FADC Saturation



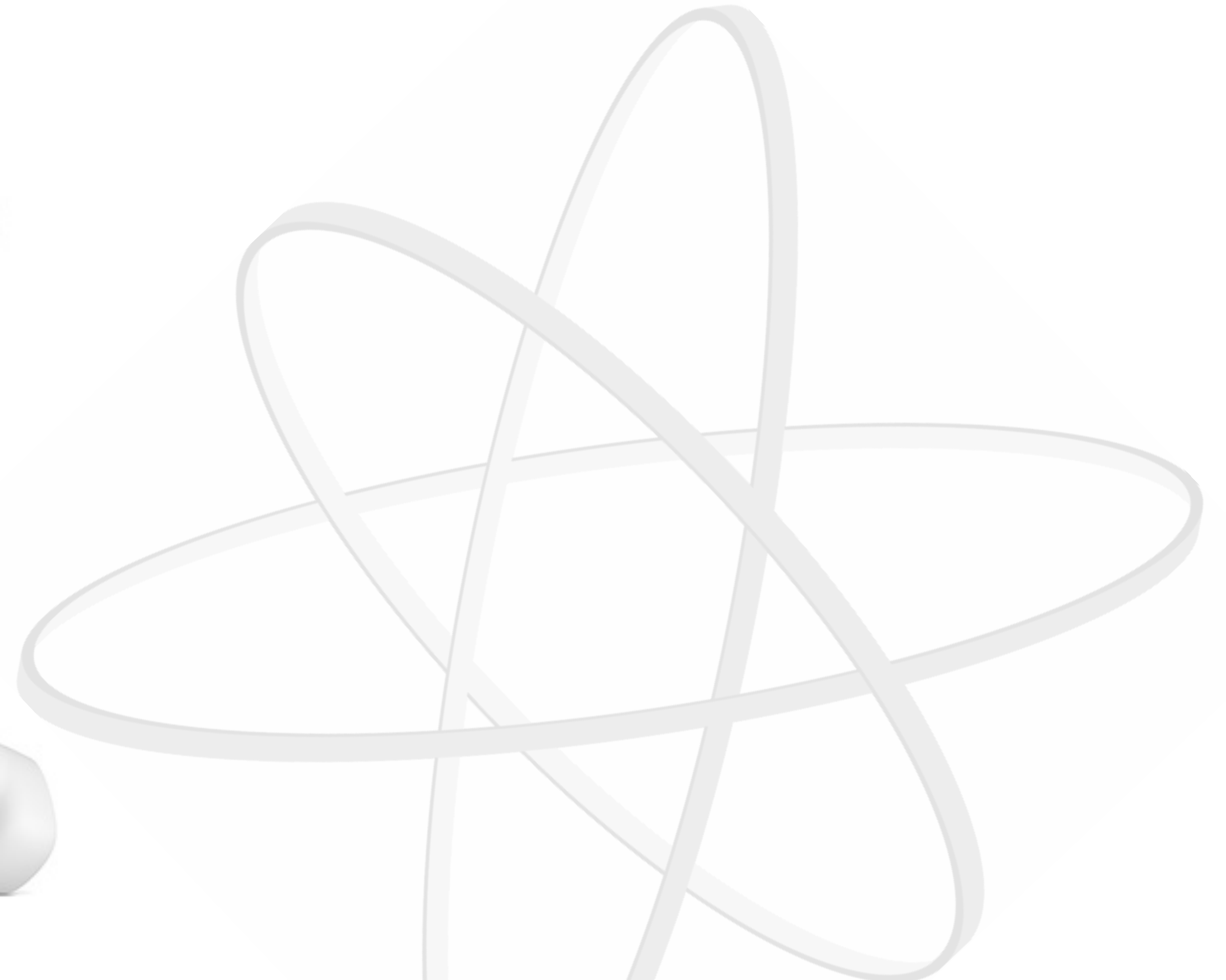


HCAL-J is ready to be moved in HALL A !!!!

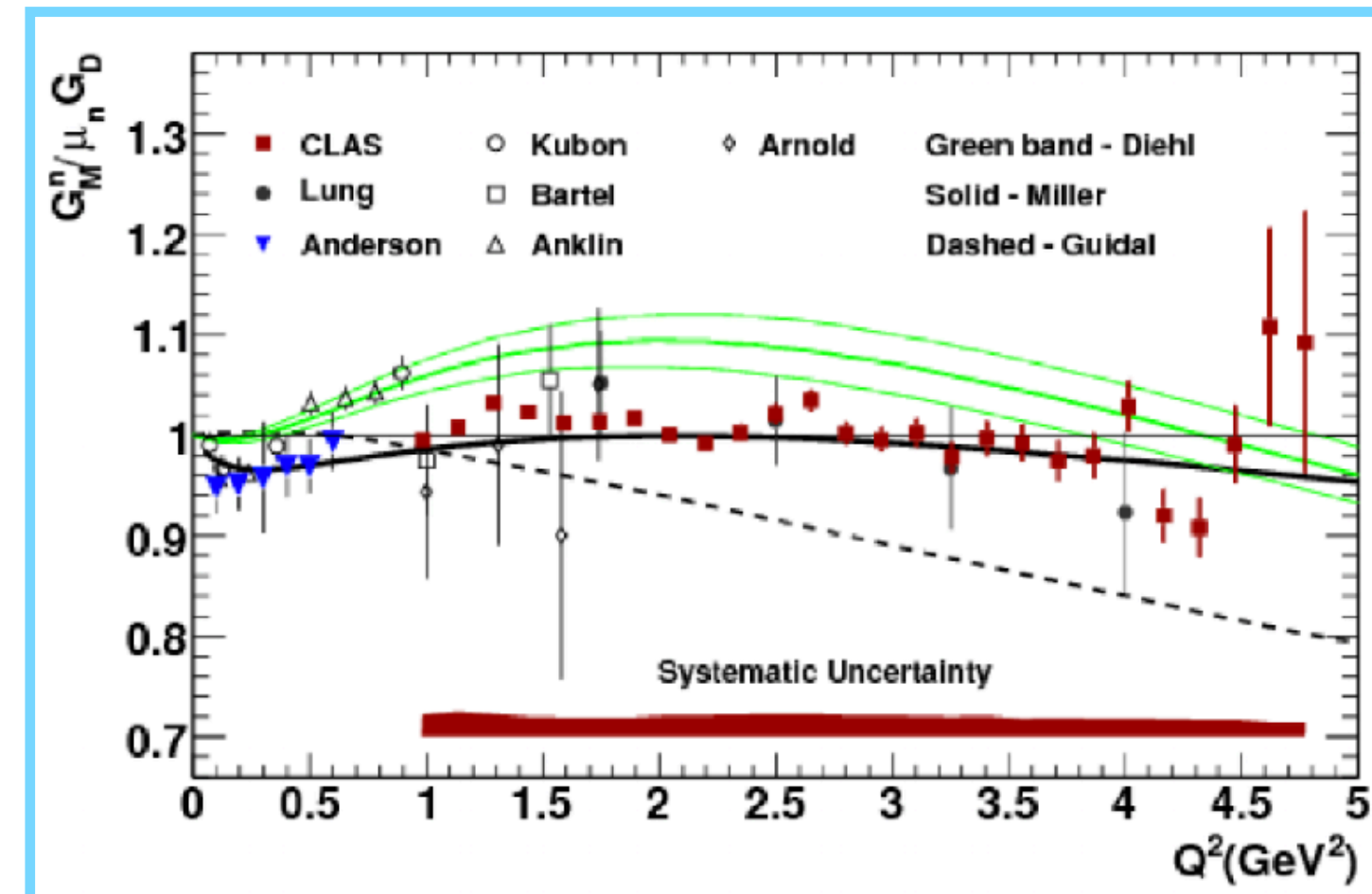


Thanks!!!

Backup Slides



GMn experiment



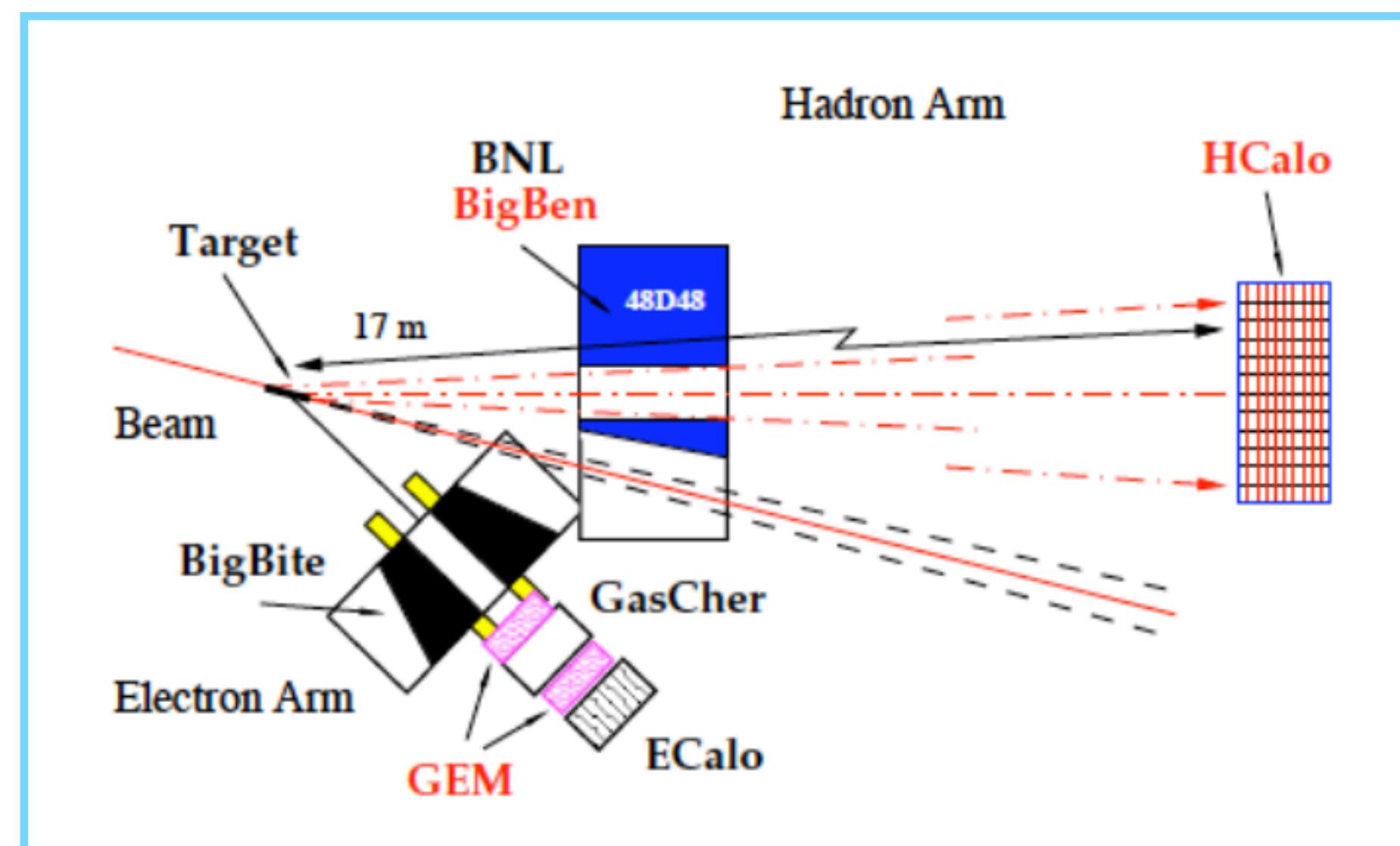
Ratio Method for GMn

Use the ratio method requires the measurement of both neutron-tagged, $d(e,e'n)$, and proton-tagged, $d(e,e'p)$, quasi-elastic scattering from the deuteron.

$$R'' = \frac{\frac{d\sigma}{d\Omega}(D(e, e'n))}{\frac{d\sigma}{d\Omega}(D(e, e'p))}$$

$$R = \frac{\eta \sigma_{Mott} \left(\frac{\tau/\epsilon}{1+\tau} G_M^n \right)^2}{\frac{d\sigma}{d\Omega} \big|_{p(e,e')}}^2$$

Knowing the form factors of the proton we can extract the neutron magnetic form factor from the previously ratio



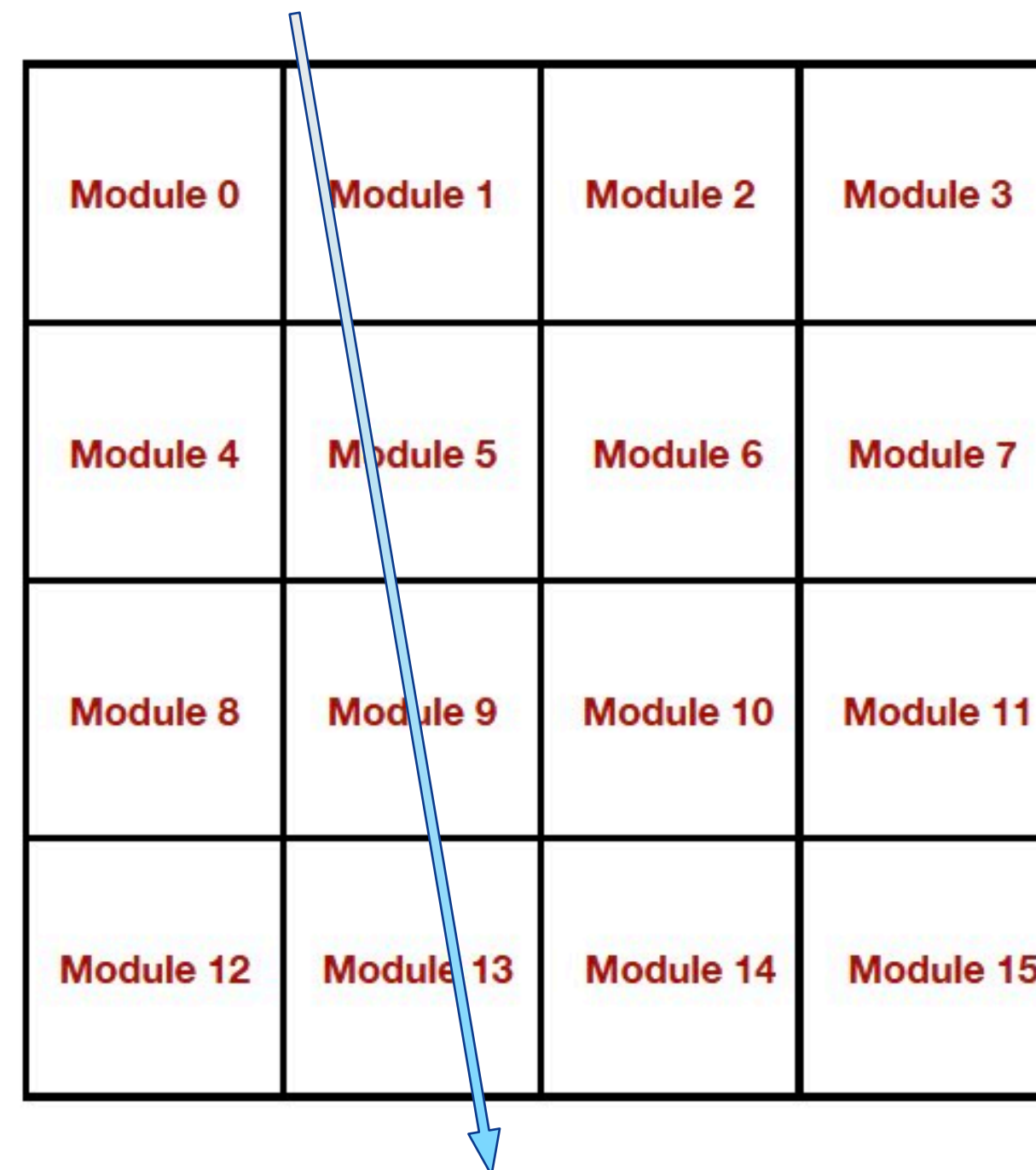
Study of the magnetic Form Factor of the neutron

Beam current: 10.5 μ A

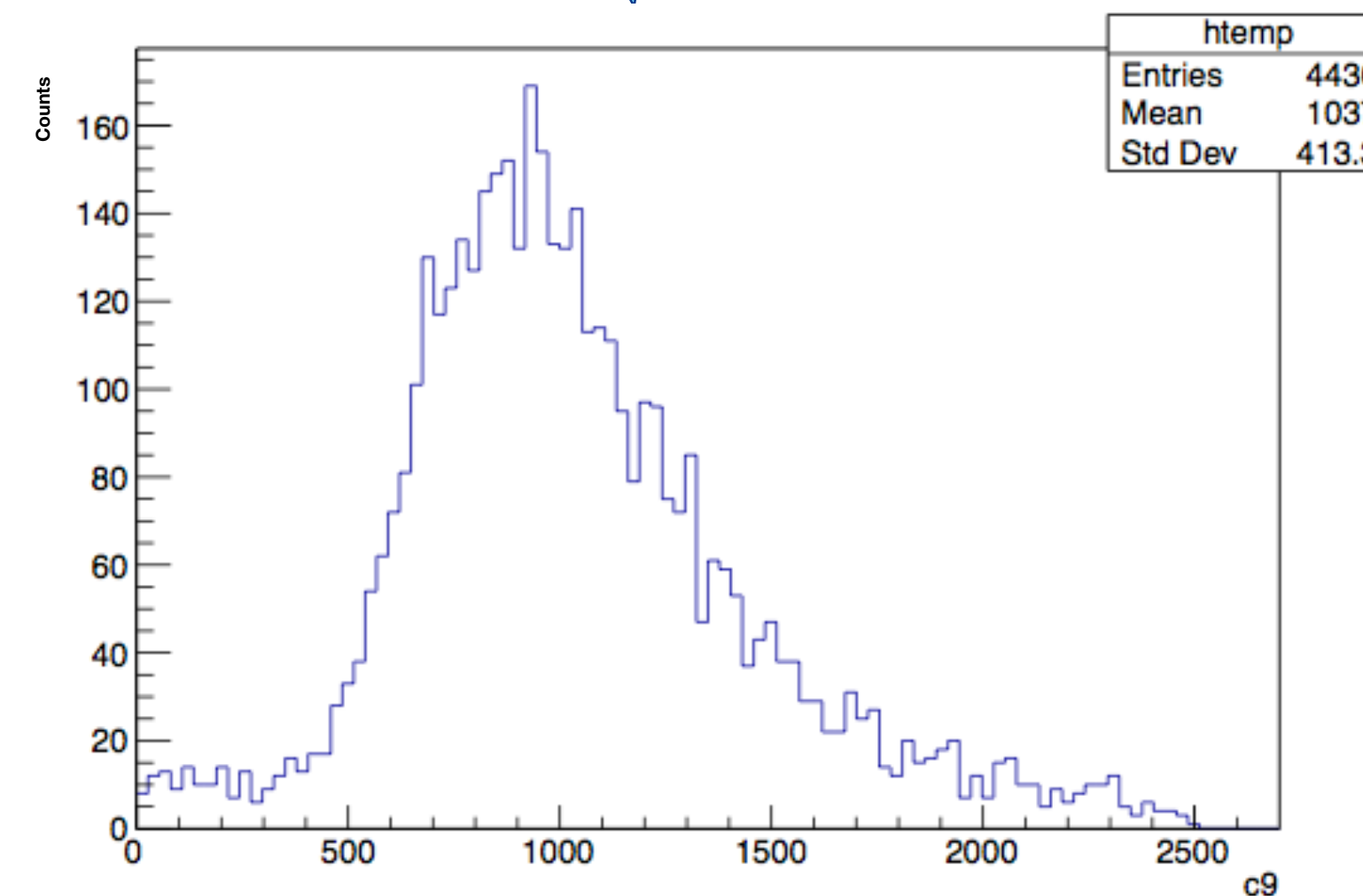
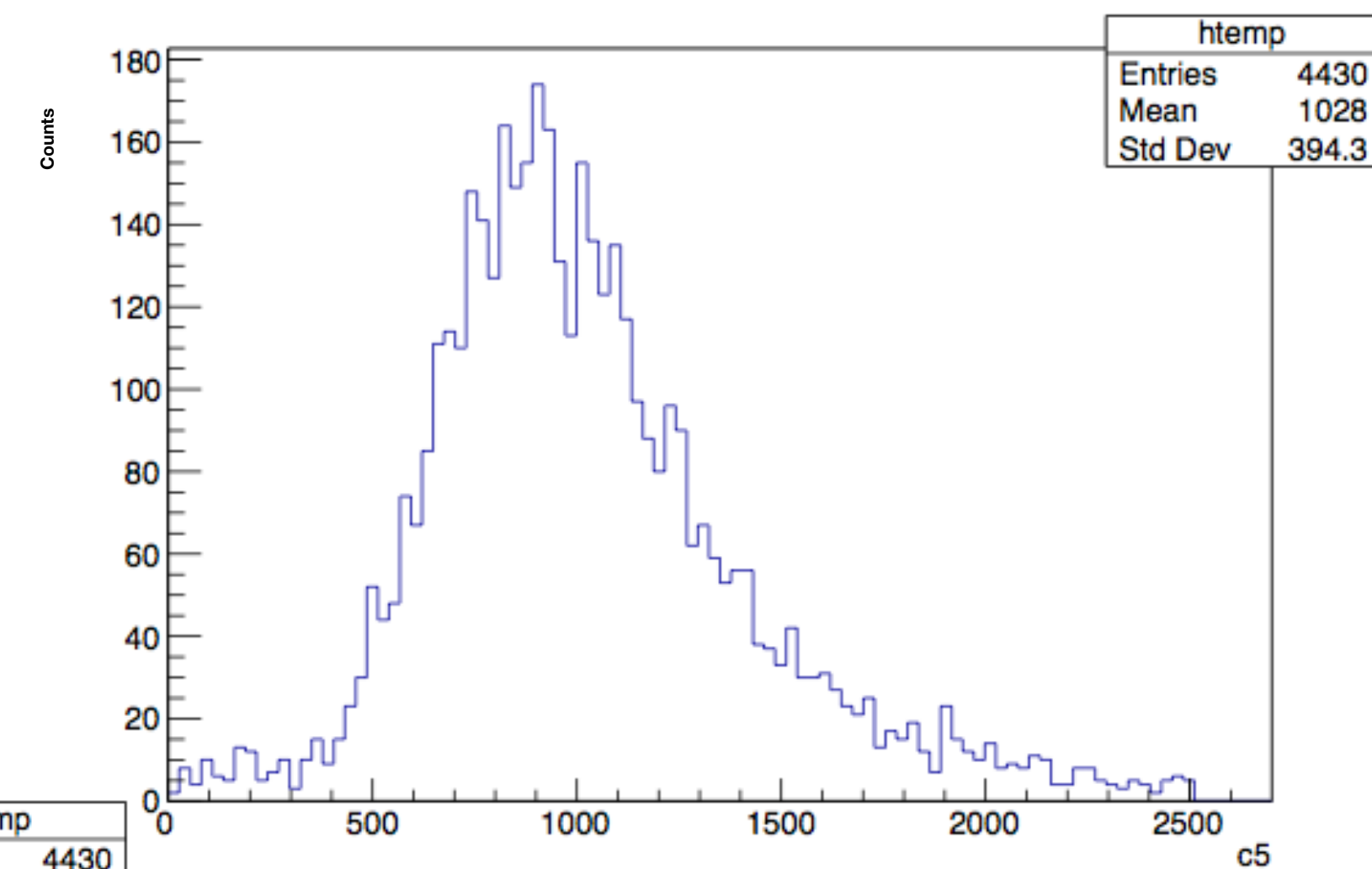
Target: 10 cm non-polarized liquid deuterium

Q^2 range: $4.5 < Q^2 < 18.0$ (GeV/c)²

HCAL-J: Cosmic Ray Test



“**Good event**” = cosmic ray that crosses 4 modules in the same vertical path

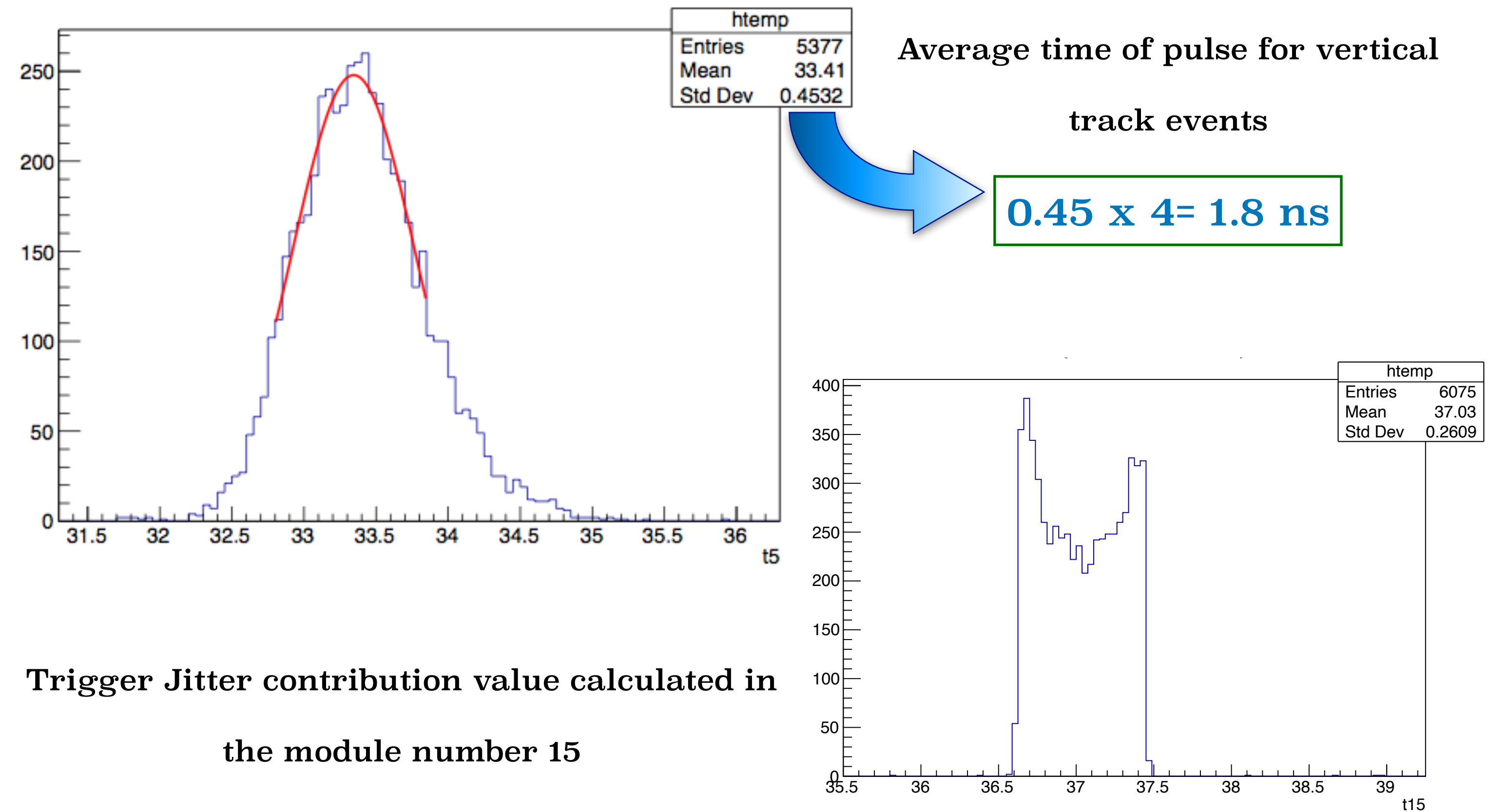


Typical spectra for the modules 5 and 9, when imposing the quadruple coincidence for the vertical path identified by the modules 1, 5, 9 and 13.

Time Resolution Study

Study of the window where there is the signal:

the signal is present in the range 30-45 bins



Time resolution about 1.4 ns in 15 cm path in module