DAC Scan runs in Au+Au collisions

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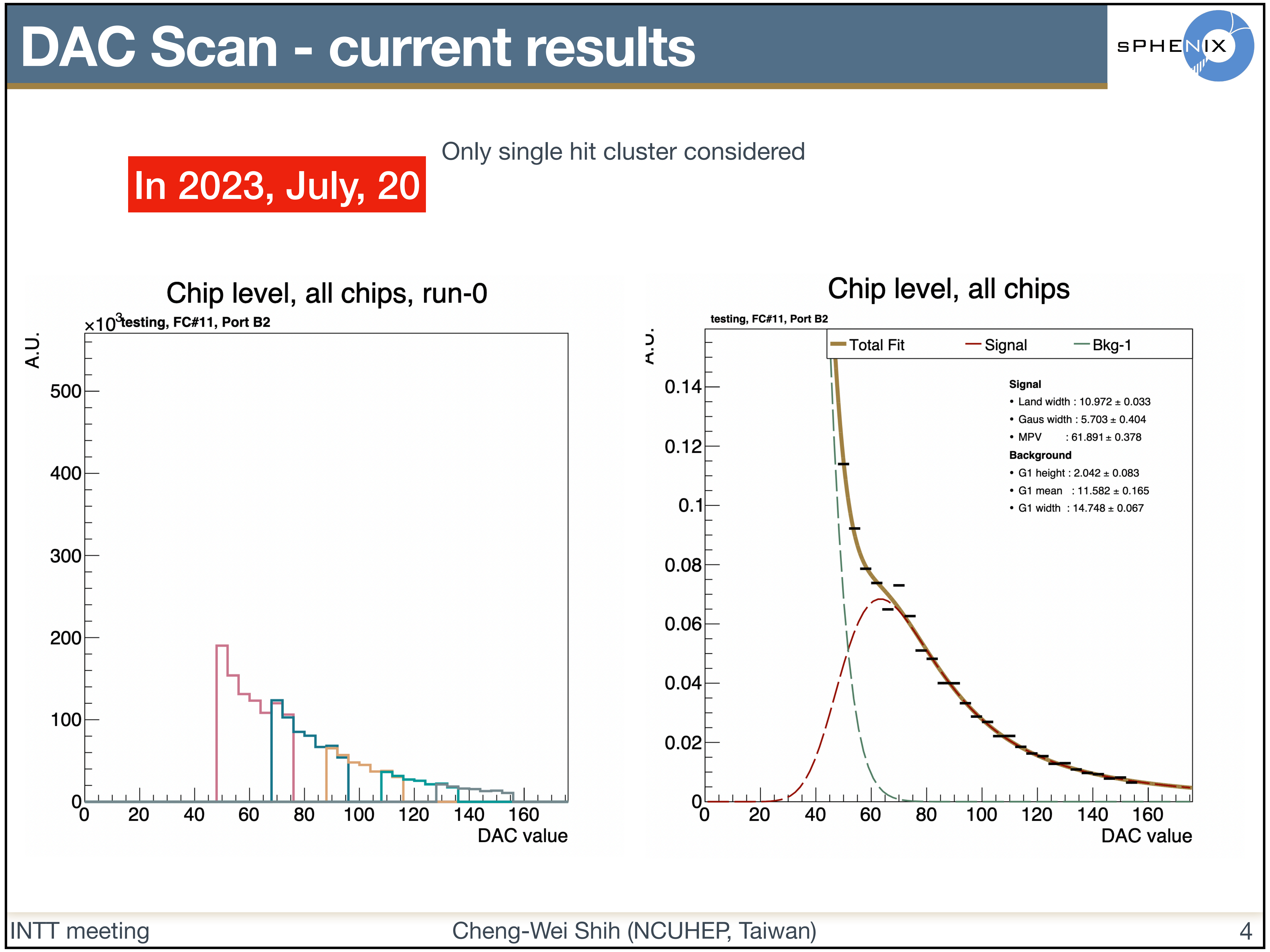
National Central University/RIKEN

Nov 7th, 2025
INTT meeting

Recap - the attempt to construct edep dist.



It seems not to work well; perhaps the cuts weren't being considered carefully

Indication of signal distribution (MPV ~ 62), but immersed in the HUGE background?

DAC-scan runs taken in Au+Au collisions

sPHENIX

8 runs
Triggered mode
Lcoal mode (no GL1, and no MBD vtxZ)
Field ON

Date/Time	Run#	Run Type	Mag	Link	)-	Active Felix List	DAC 0	L1 Delay	n_coll	open time	Modebit	Comments
2024/10/16 3:33	54692	beam	On			All Felix	8	114	100	60	intt_triggermode	DAC scan 8 12 16 20 24 28 32 36
2024/10/16 4:08	54694	beam	On			All Felix	28	114	100	60	intt_triggermode	DAC scan 28 32 36 40 44 48 52 56
2024/10/16 4:30	54695	beam	On			All Felix	48	114	100	60	intt_triggermode	DAC scan 48 52 56 60 64 68 72 76
2024/10/16 4:53	54696	beam	On			All Felix	68	114	100	60	intt_triggermode	DAC scan 68 72 76 80 84 88 92 96
2024/10/16 5:15	54698	beam	On			All Felix	88	114	100	60	intt_triggermode	DAC scan 88 92 96 100 104 108 112 116
2024/10/16 5:37	54699	beam	On			All Felix	108	114	100	60	intt_triggermode	DAC scan 108 112 116 120 124 128 132 136
2024/10/16 5:58	54700	beam	On			All Felix	128	114	100	60	intt_triggermode	DAC scan 128 132 136 140 144 148 152 156
2024/10/16 6:44	54708	beam	On			All Felix	148	114	100	60	intt_triggermode	DAC scan 148 152 156 160 164 168 172 176

runnumber	# events used in analysis	DAC range	comment
54692	500k	8 to 36	too noisy
54694	1M	28 to 56	
54695	2.5M	48 to 76	
54696	2.5M	68 to 96	
54698	2.5M	88 to 116	
54699	2.5M	108 to 136	
54700	2.5M	128 to 156	
54708	2.5M	148 to 176	

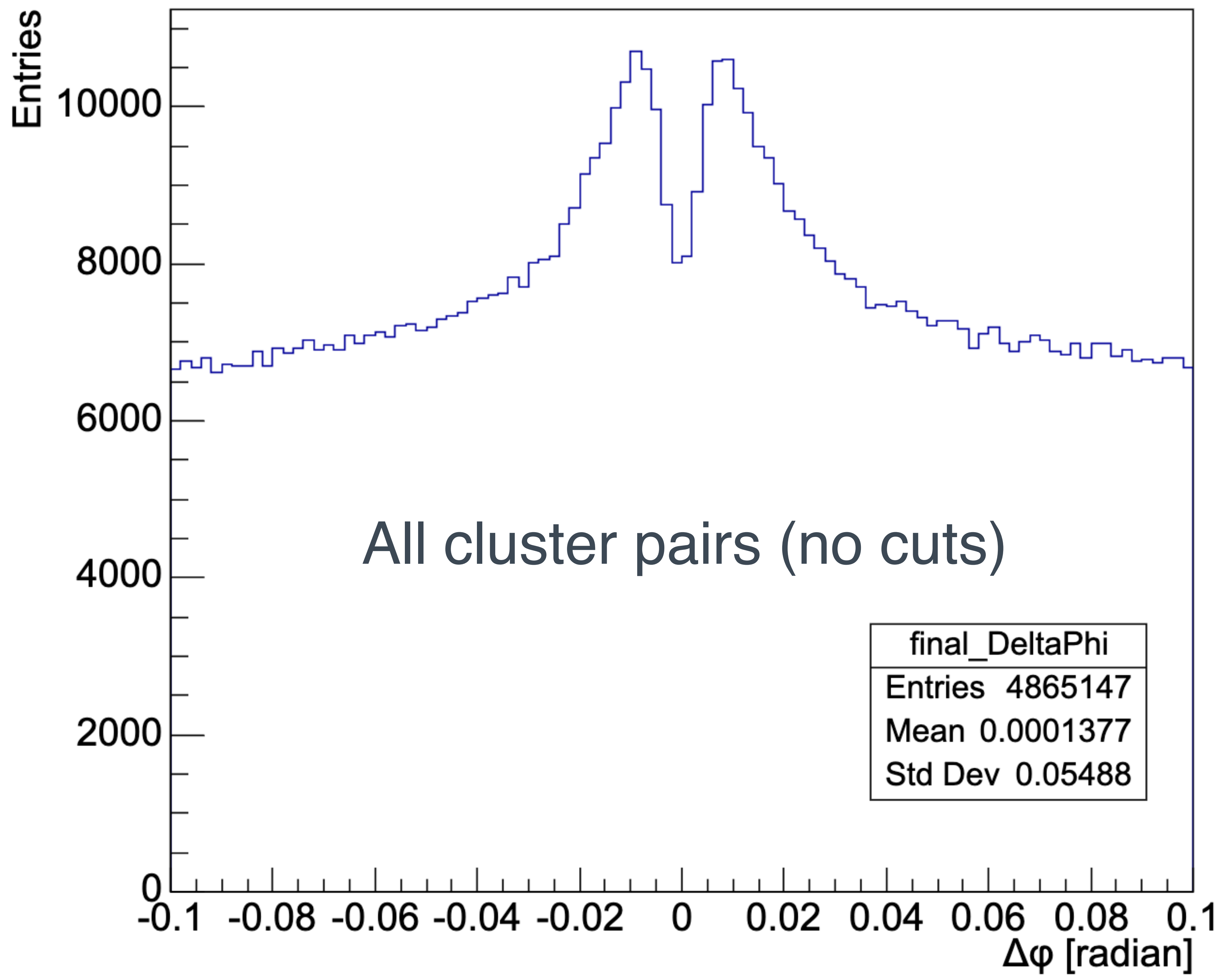
Procedures

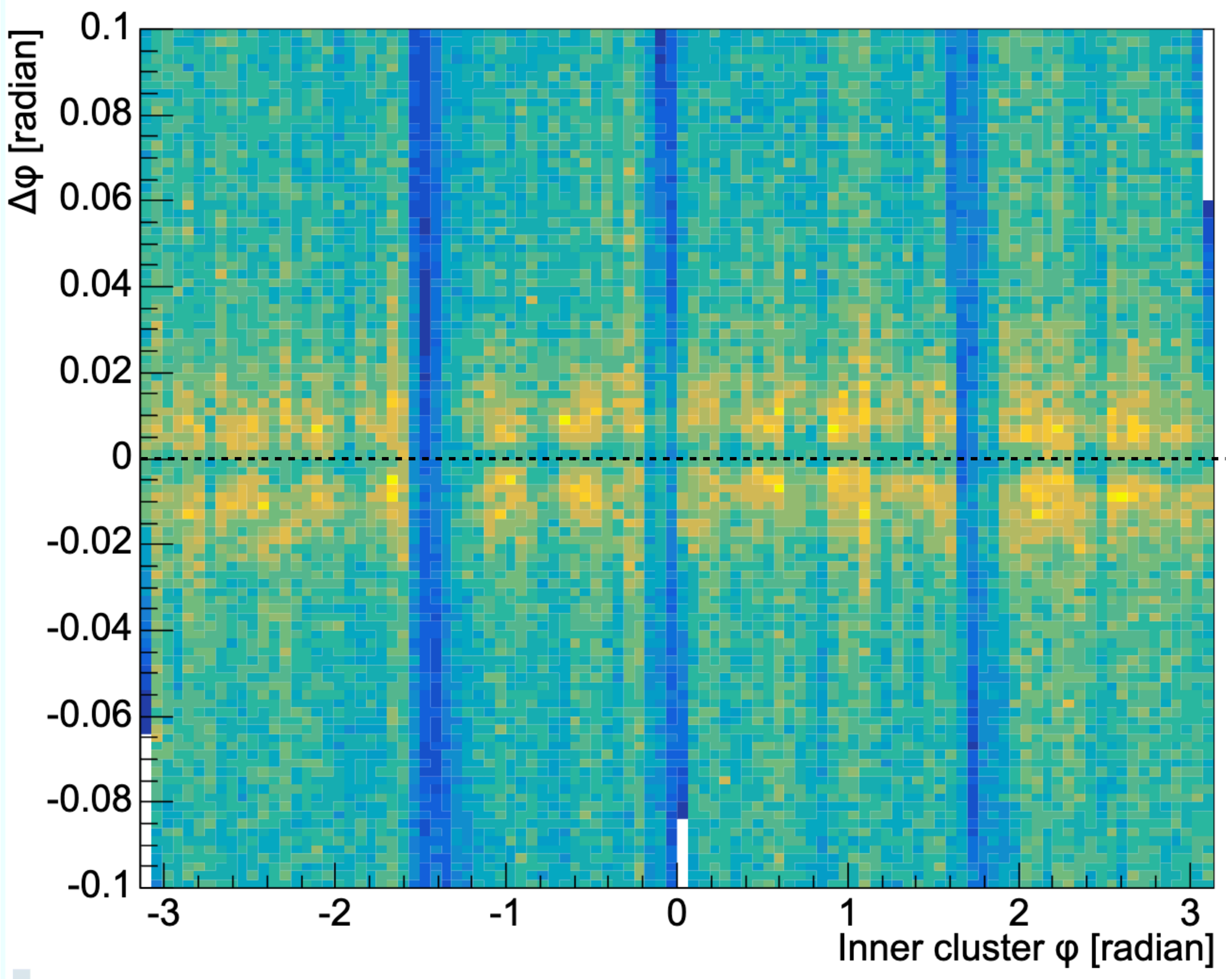
- In each run
  - .evt file to INTTRawHit DST file (meanwhile producing the bco_diff CDB file)
  - INTTRawHit DST to INTTCluster DST file
    - local mode & triggered mode
    - Bco_diff CDB file: run-by-run
    - Bad channel map: central map, run 54685 (local gen., 3.76% channels masked)
    - DAC conversion map: handmade CDB file, run-by-run
  - No average vertex XY reconstruction
    - Attempted, but failed
    - Used the average vertex XY from the dN/dη analysis, {-0.0220728 cm, 0.222956 cm}
    - Works quite well
  - Event-by-event z-vertex reconstruction
  - Energy deposit distribution preparation

Average vertex XY

Taking run 54694 [28 DAC to 56 DAC] as an example

Assume average vertex XY to be {-0.0220728 cm, 0.222956 cm}



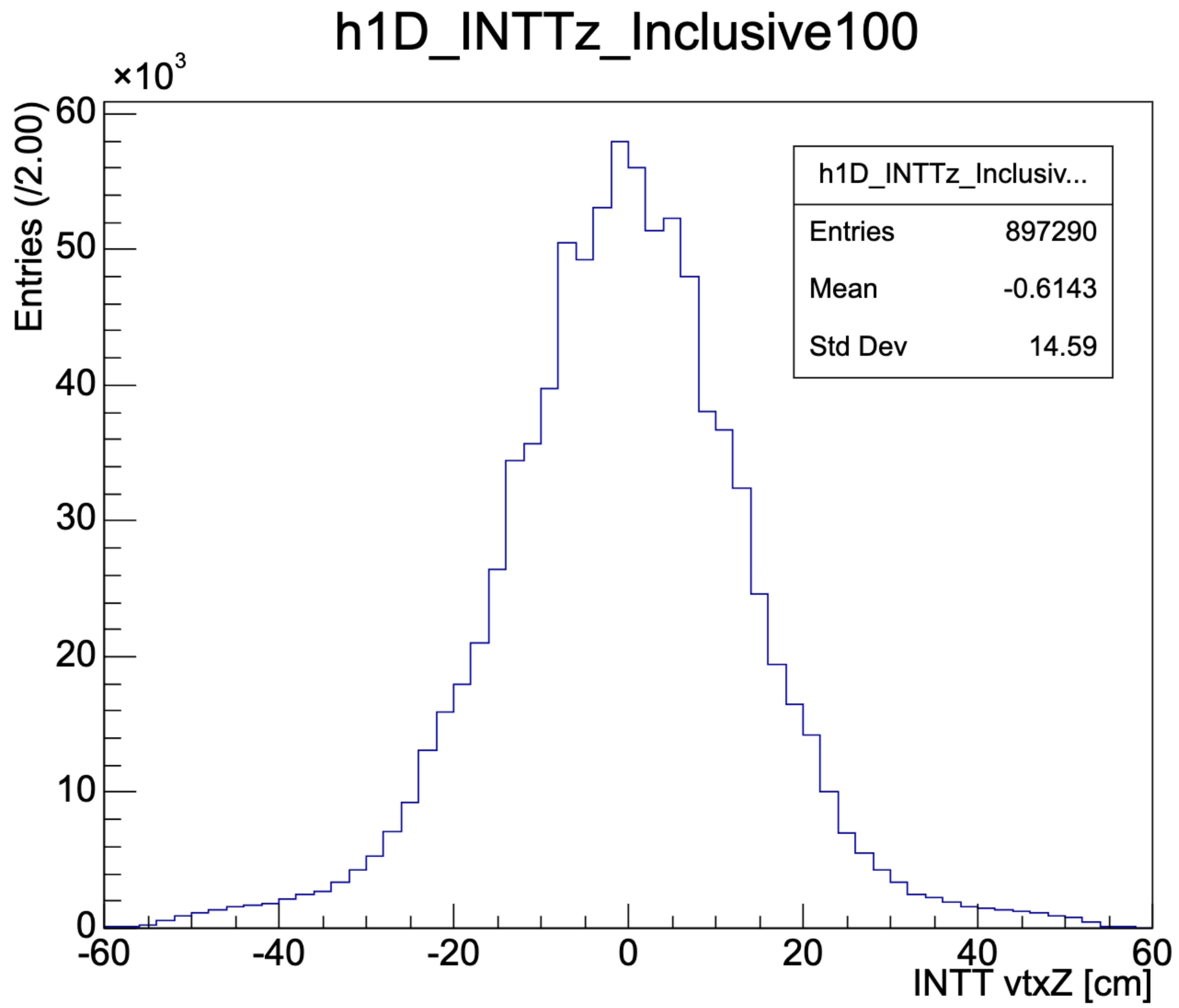


Negative and postive charged components can be separated cleraly

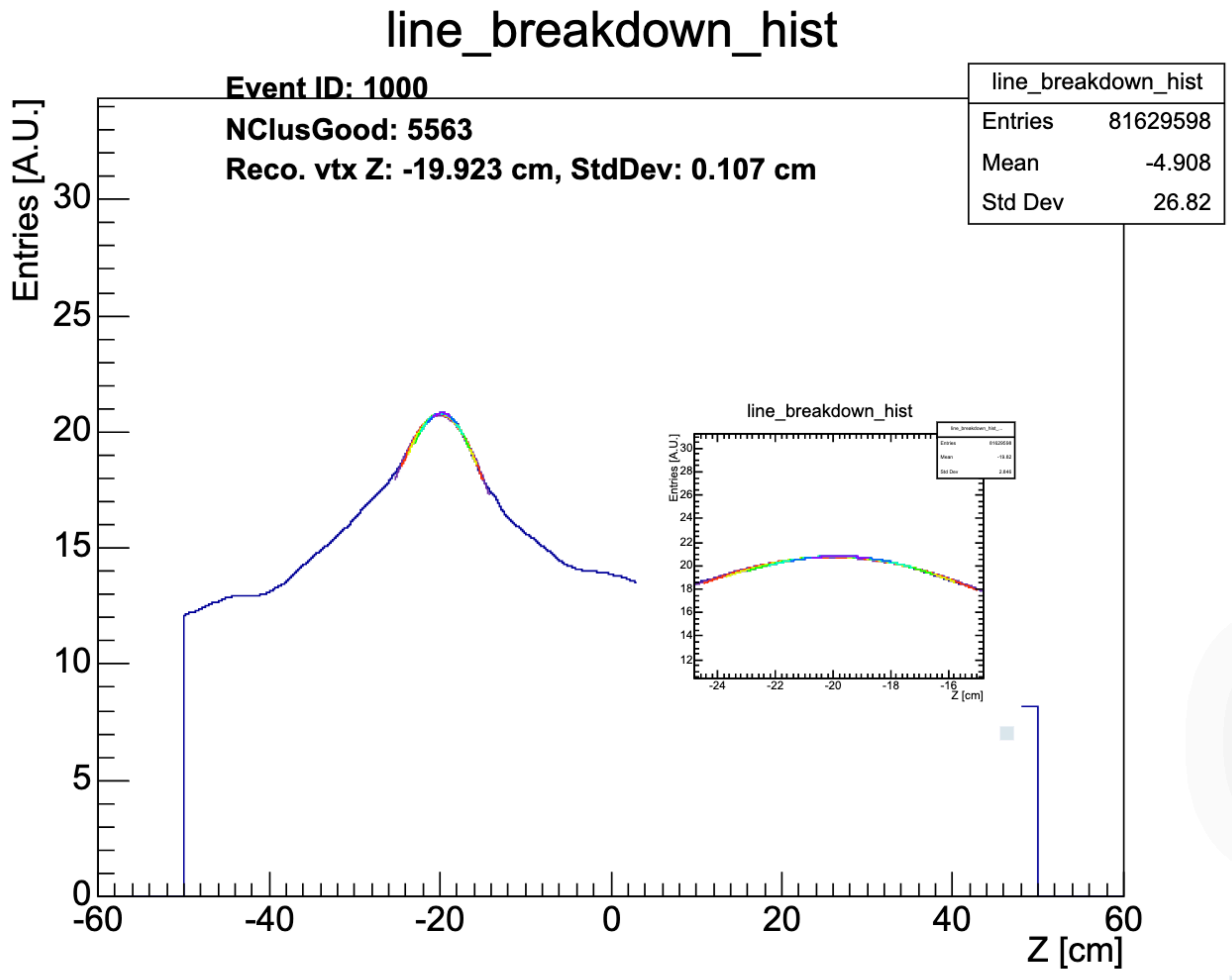
average vertex Z

Taking run 54694 [28 DAC to 56 DAC] as an example

Assume average vertex XY to be {-0.0220728 cm, 0.222956 cm}
(Events are required to have number of clusters > 100)



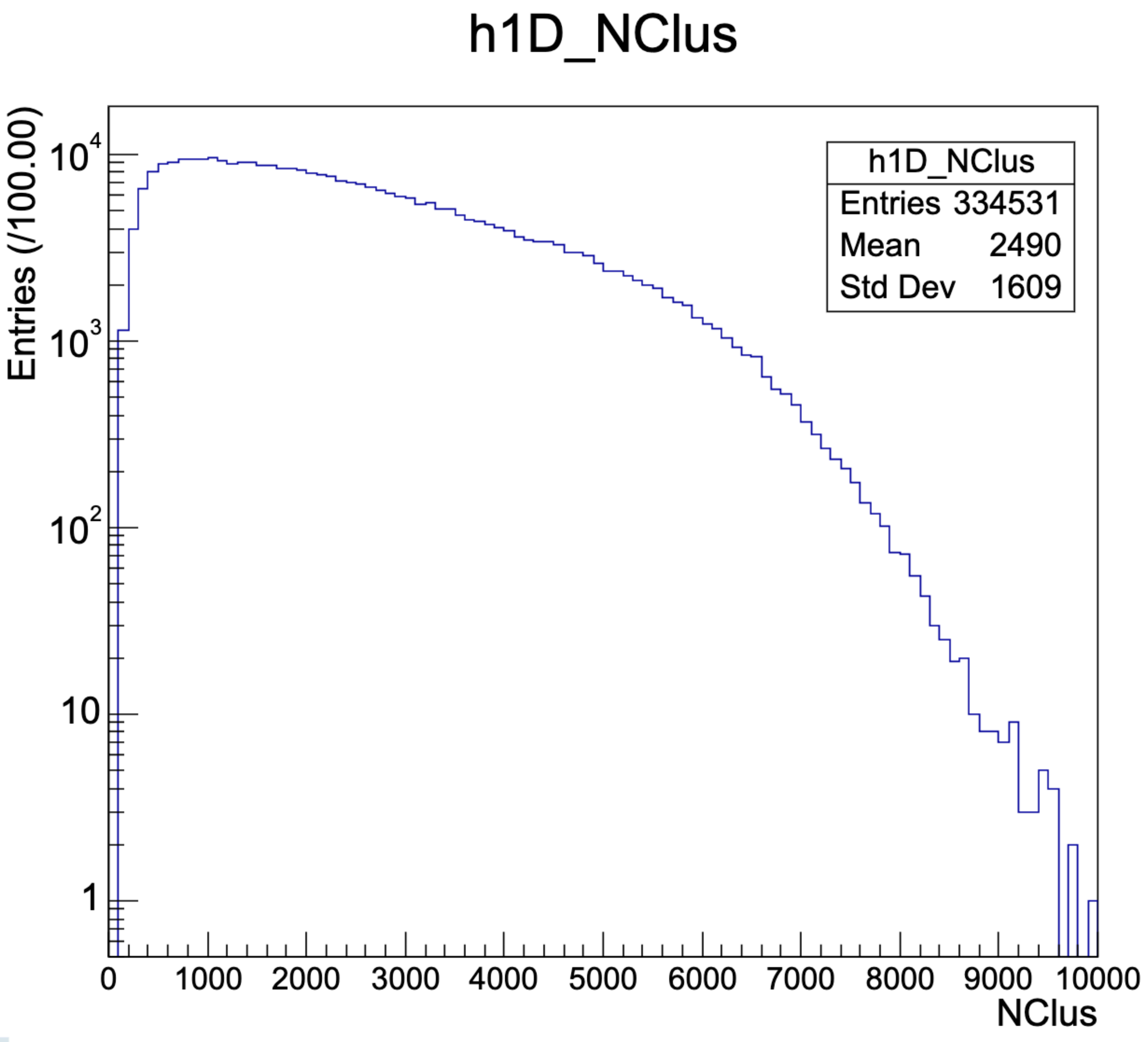
Distribution looks fine



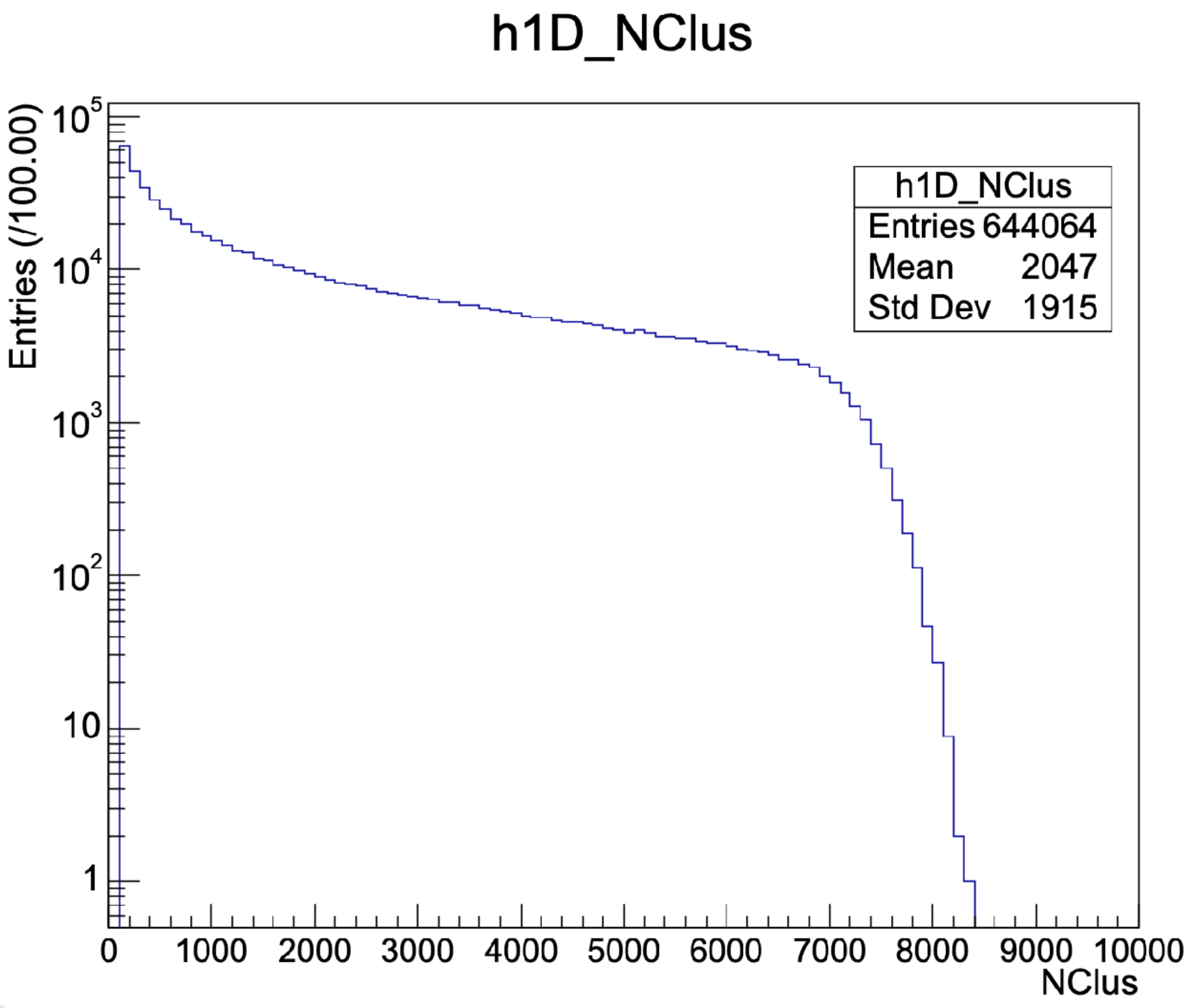
Single event
(Due to field on, loose angle cut leading to huge background)

Number of clusters

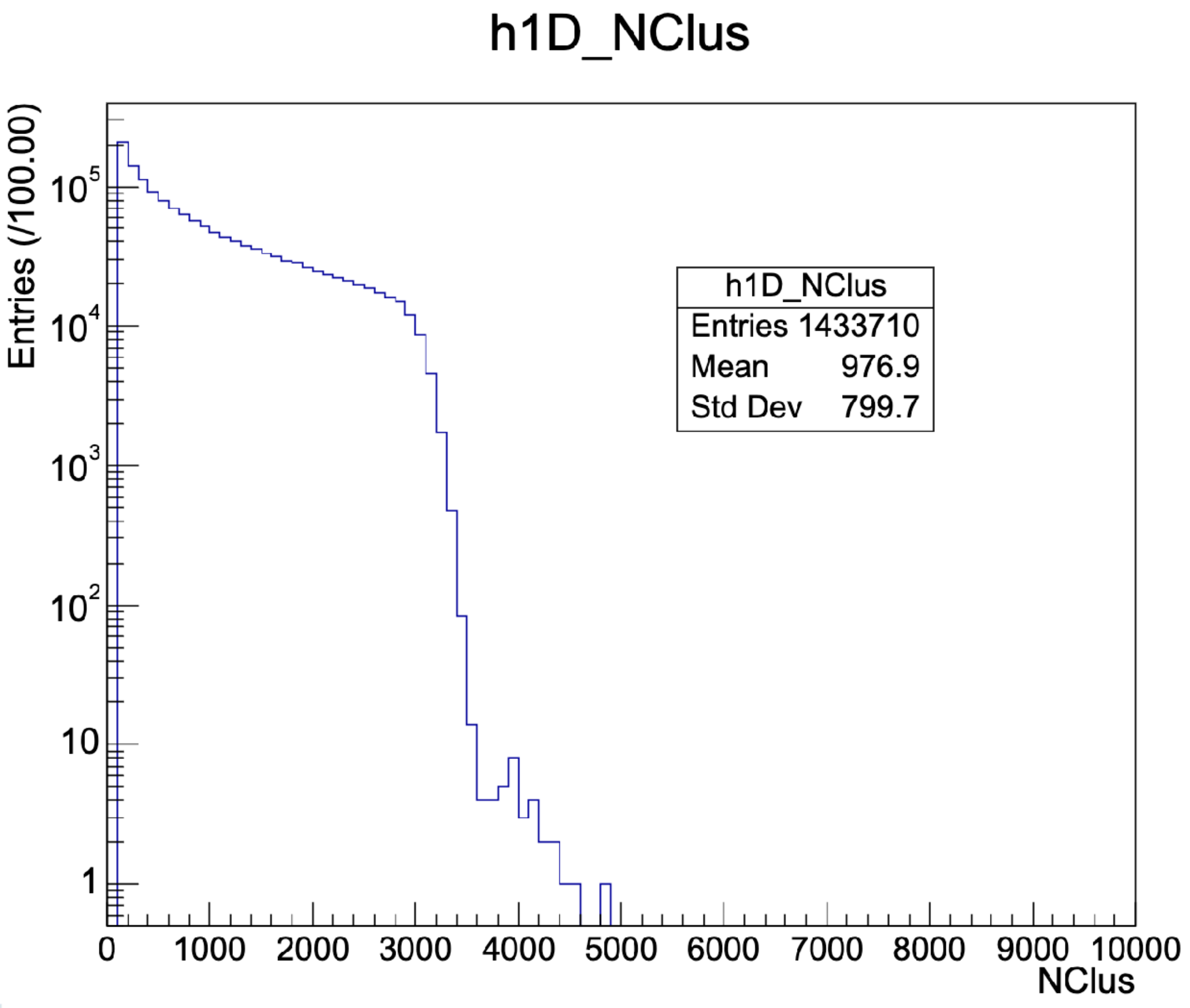
Run 54692
Threshold: 8



Run 54694
Threshold: 28



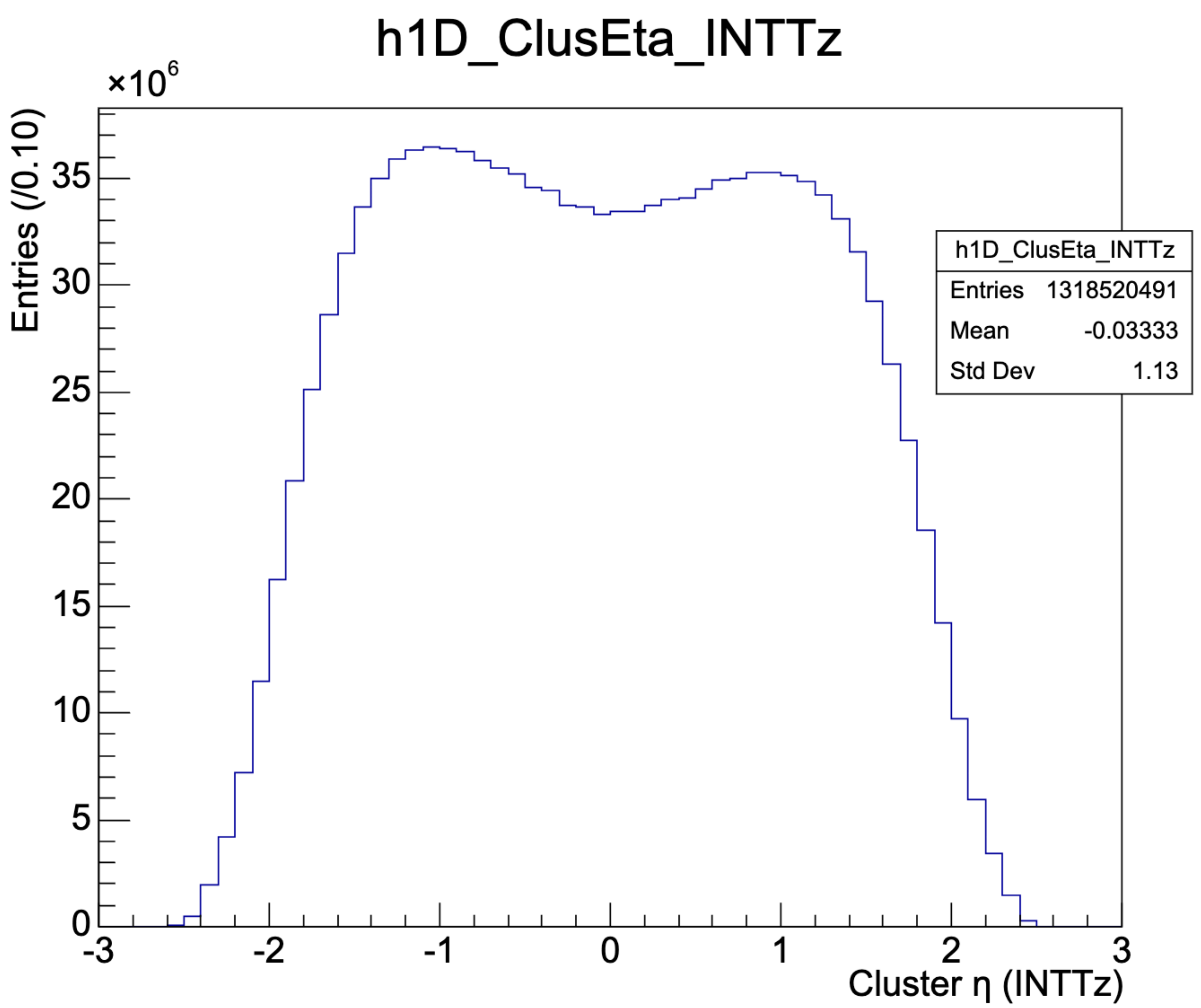
Run 54708
Threshold: 148



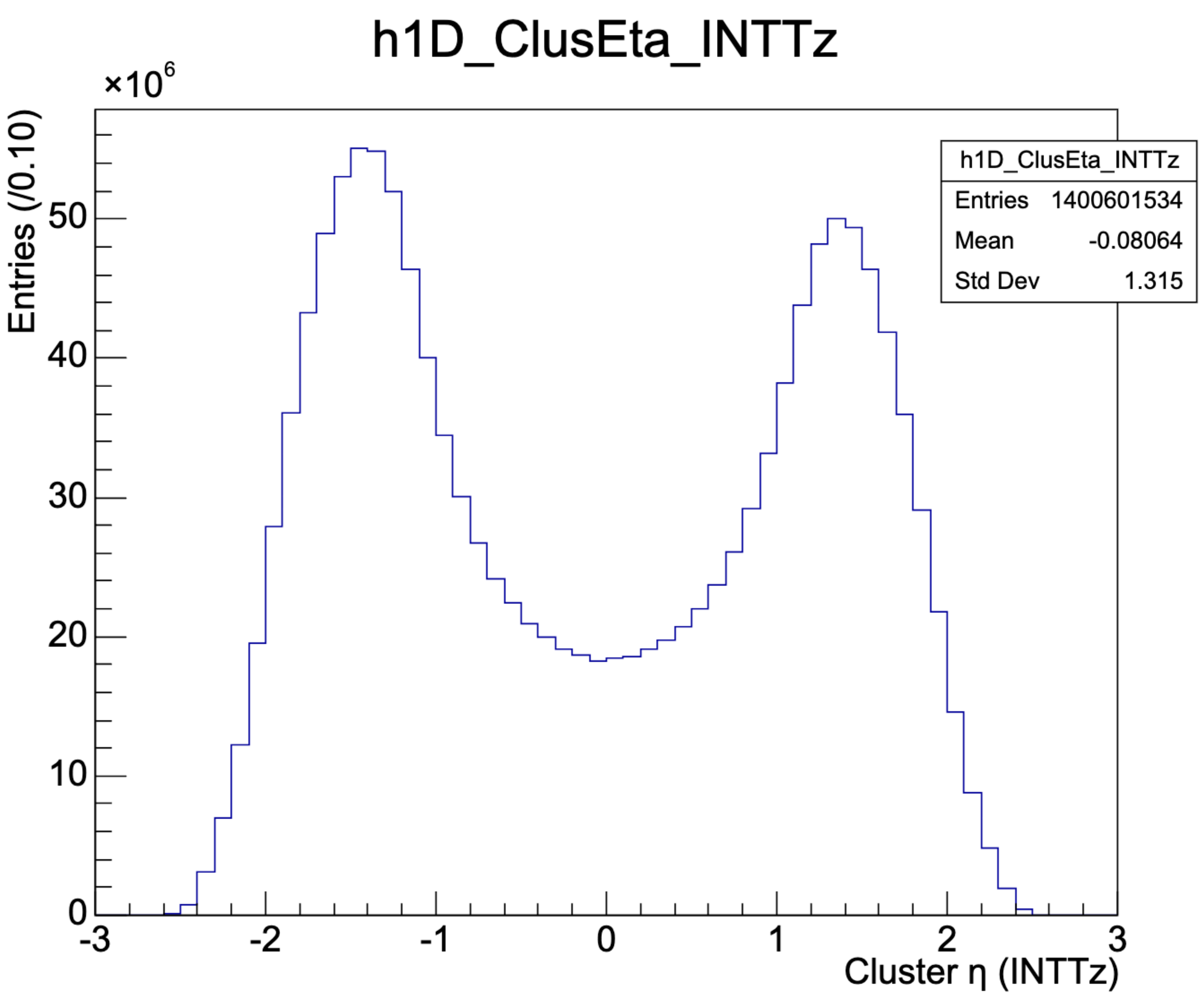
Dramatic number-of-clusters difference, indication of correct DAC-value configuration being assigned

Cluster eta distribution (corrected by z-vertex)

Run 54694
Threshold: 28



Run 54708
Threshold: 148

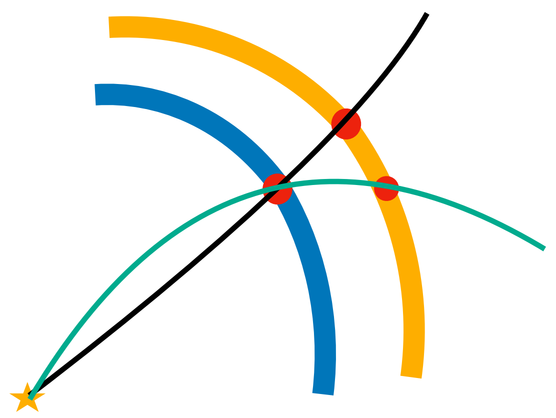


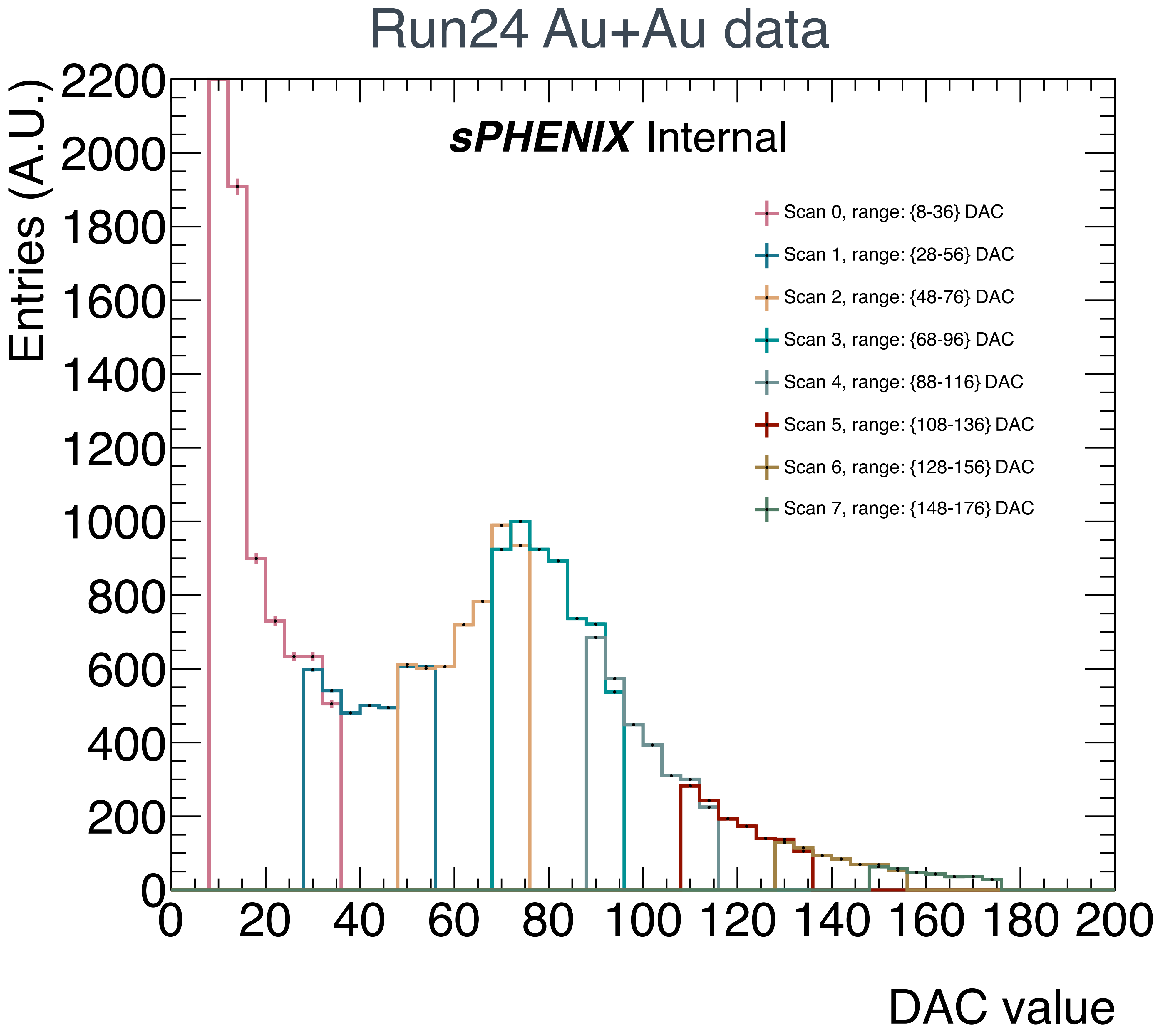
Distributions seem reasonable; high-energy-deposition hits are likely happened in the high eta region

Energy deposit distribution

- Event selections:
  - Event interval > 61 BCOs
  - z-vertex can be reconstructed
  - z-vertex QA cut
  - -15 cm < z-vertex < 15 cm
  - # clusters > 100

- Cluster selection
  - Has to be paired
    - Inner-and-outer-cluster pair links to the z-vertex
  - High pT pair
    - Cluster $|\Delta\phi| < 0.006$
  - Be perpendicular to the sensor
    - Inner and outer cluster η within ± 0.1
  - Has to be an isolation track pair (minimize ambiguity)
    - Given an inner cluster, the $|\Delta\phi|$ of outer clusters of <u>the pair with the highest pT</u> and <u>the pair with the second highest pT</u> > 0.035
  - One cluster only being filled up to once

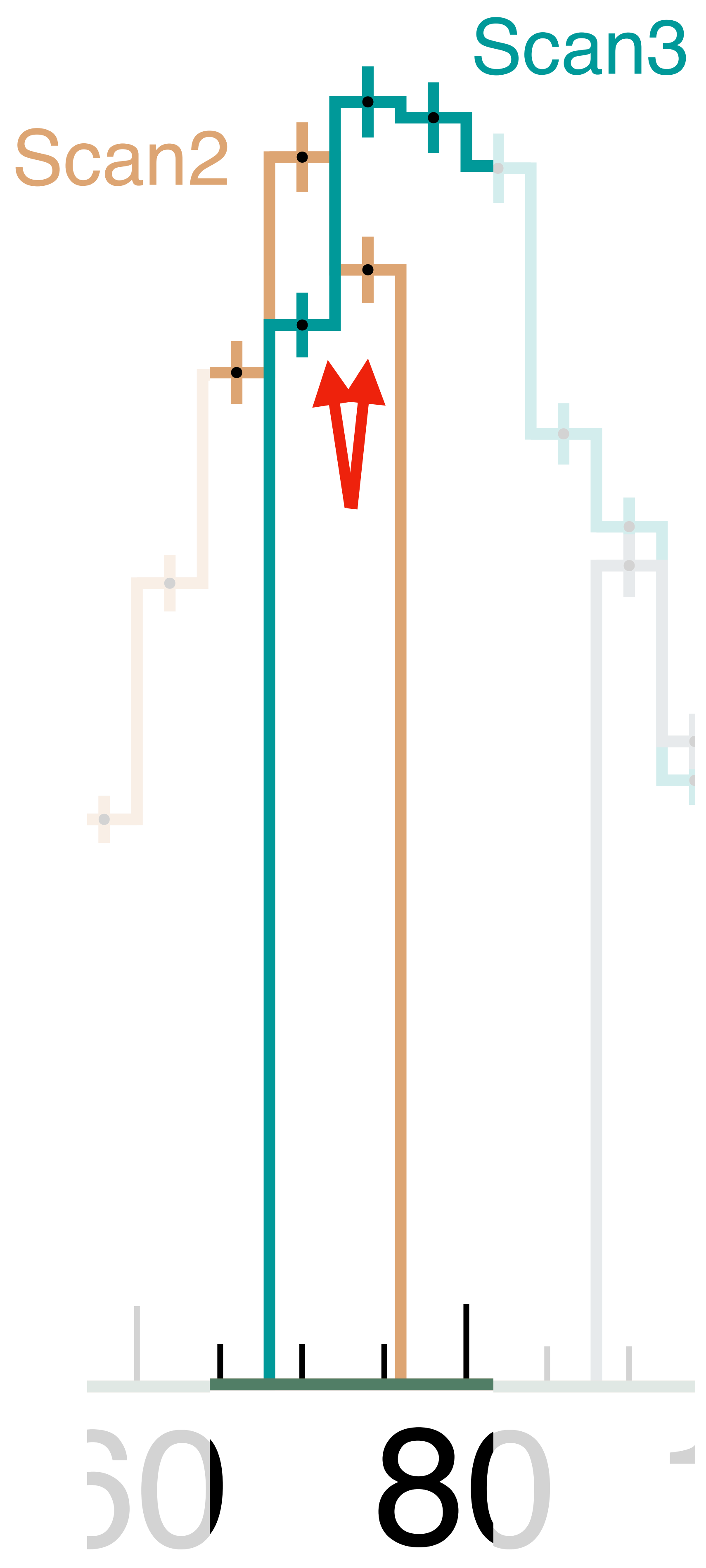


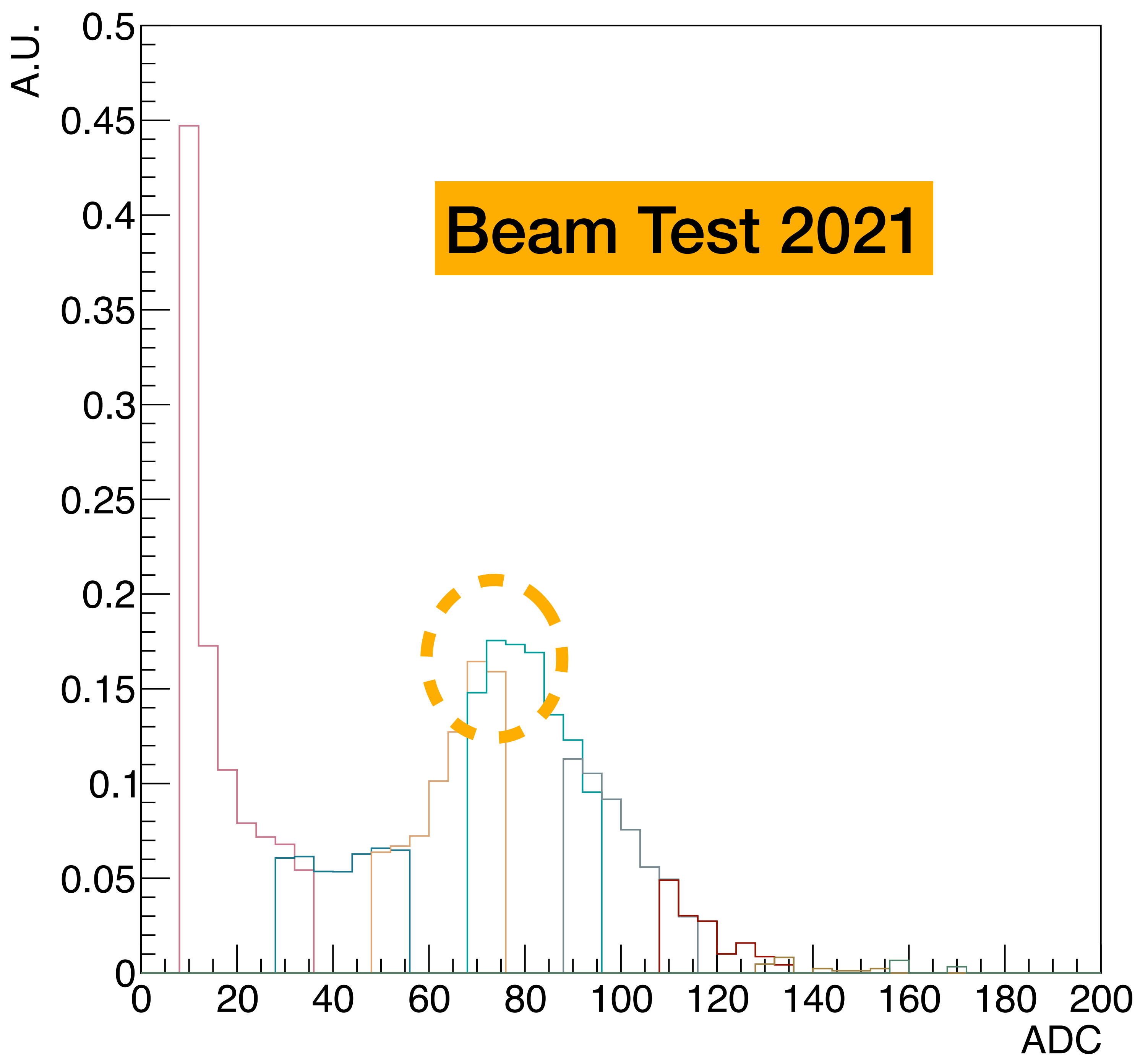


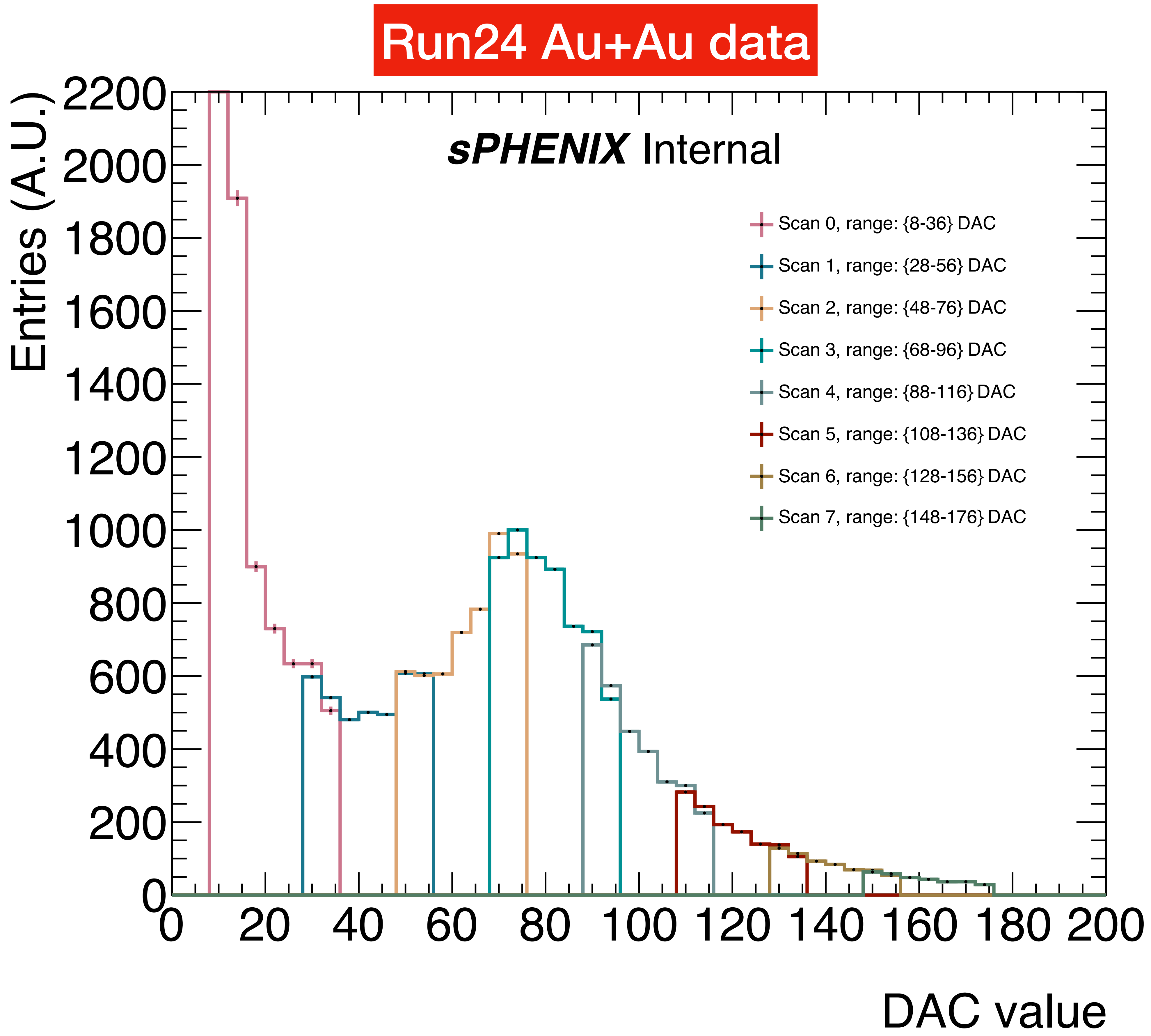
Here shows original scaling approach, using two overlapping bins

Energy deposit distribution

- The disagreement in the overlap bins between Scan2 and Scan3, observed in the past already
- The entries of the 7th bin seem to be systematically lower than that of the 6th bin



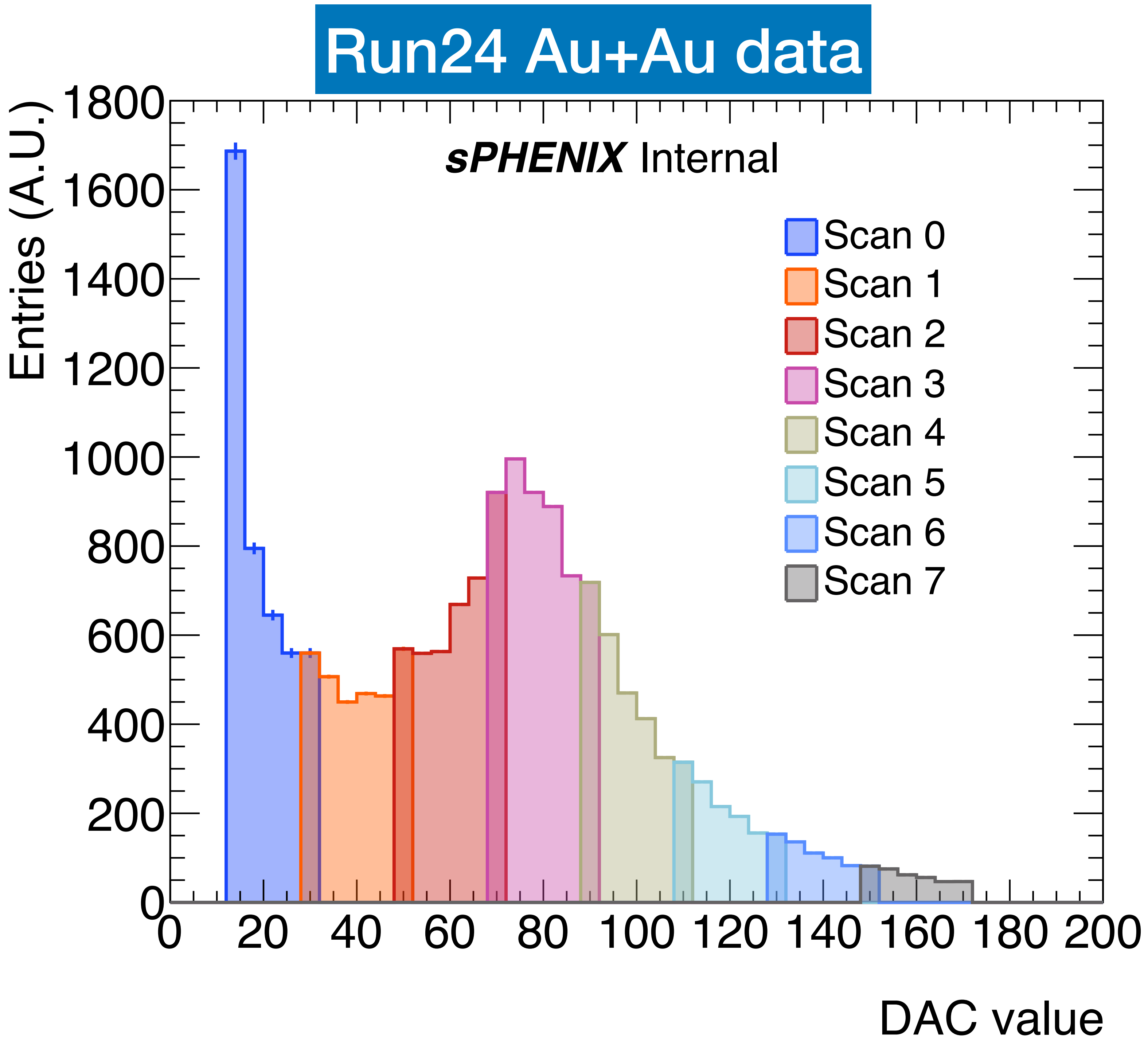


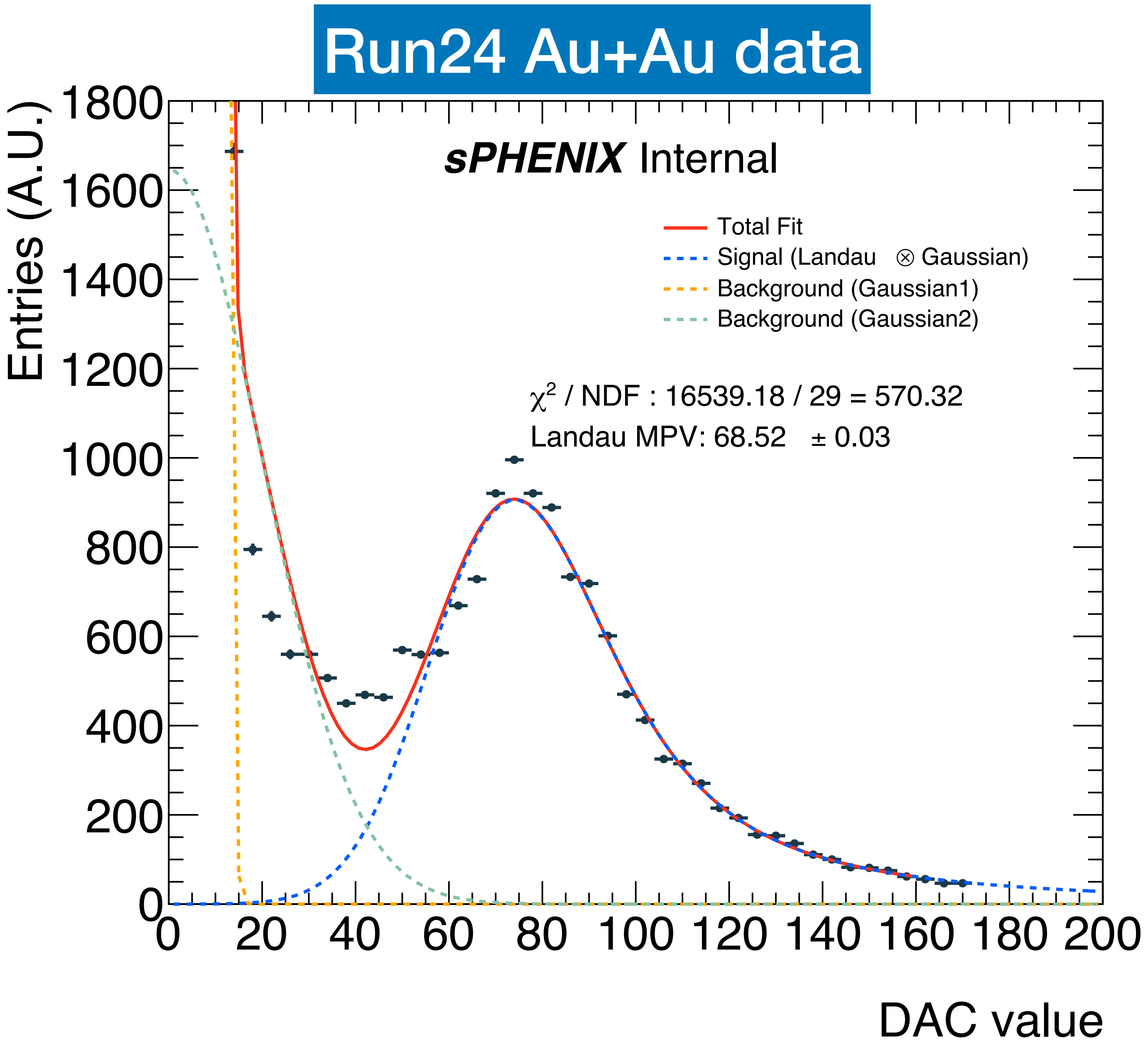


Same strucutre seen in both beam test and collision data

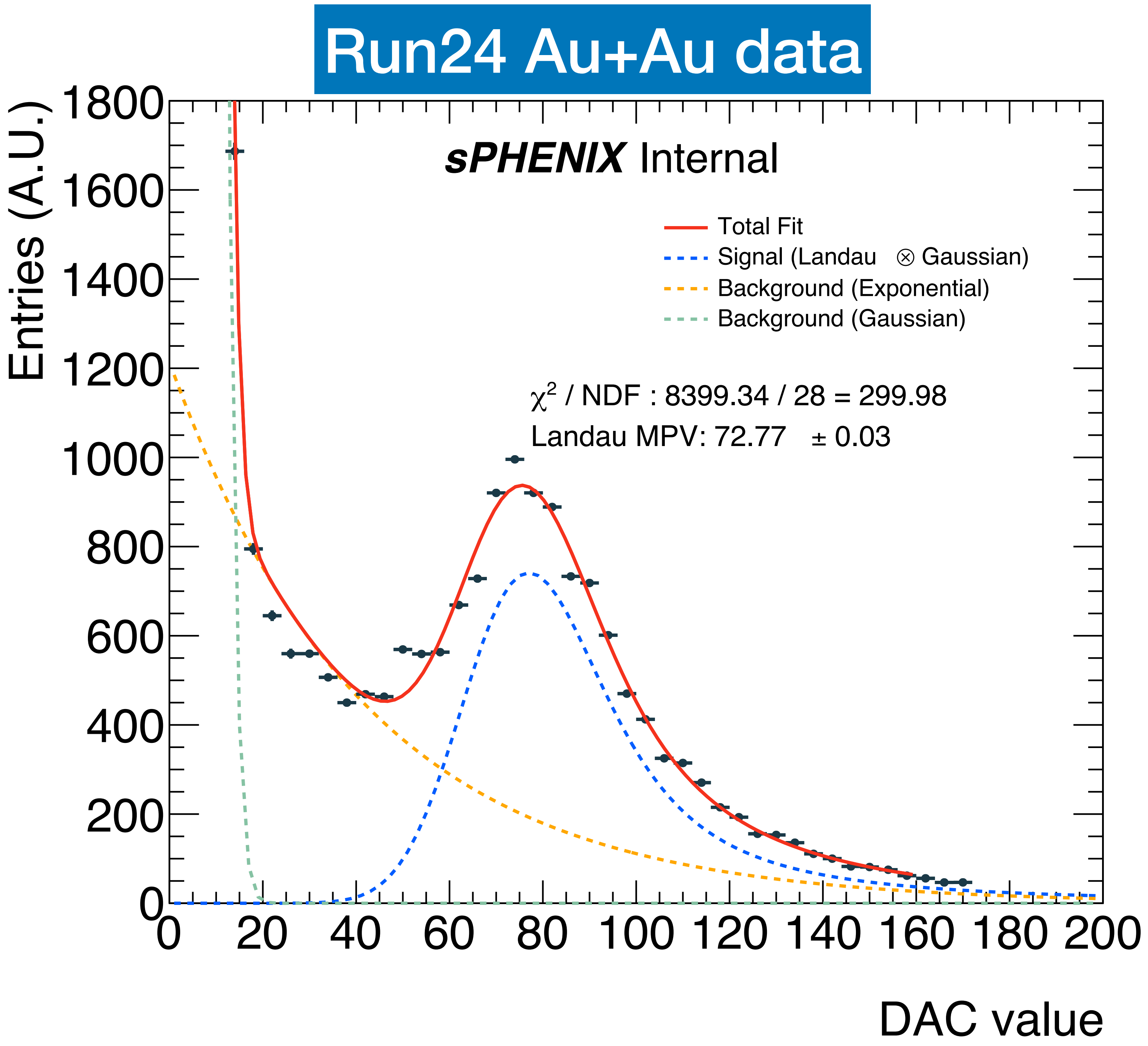
Energy deposit distribution

Switched back to using only the 6th to do the distribution matching, same approach as used in the beam test
First bin [8 DAC, 12 DAC) removed, as it is too noisy





Signal: Land-Gaus convolution
Bkg fit: Two Gaussian funcs

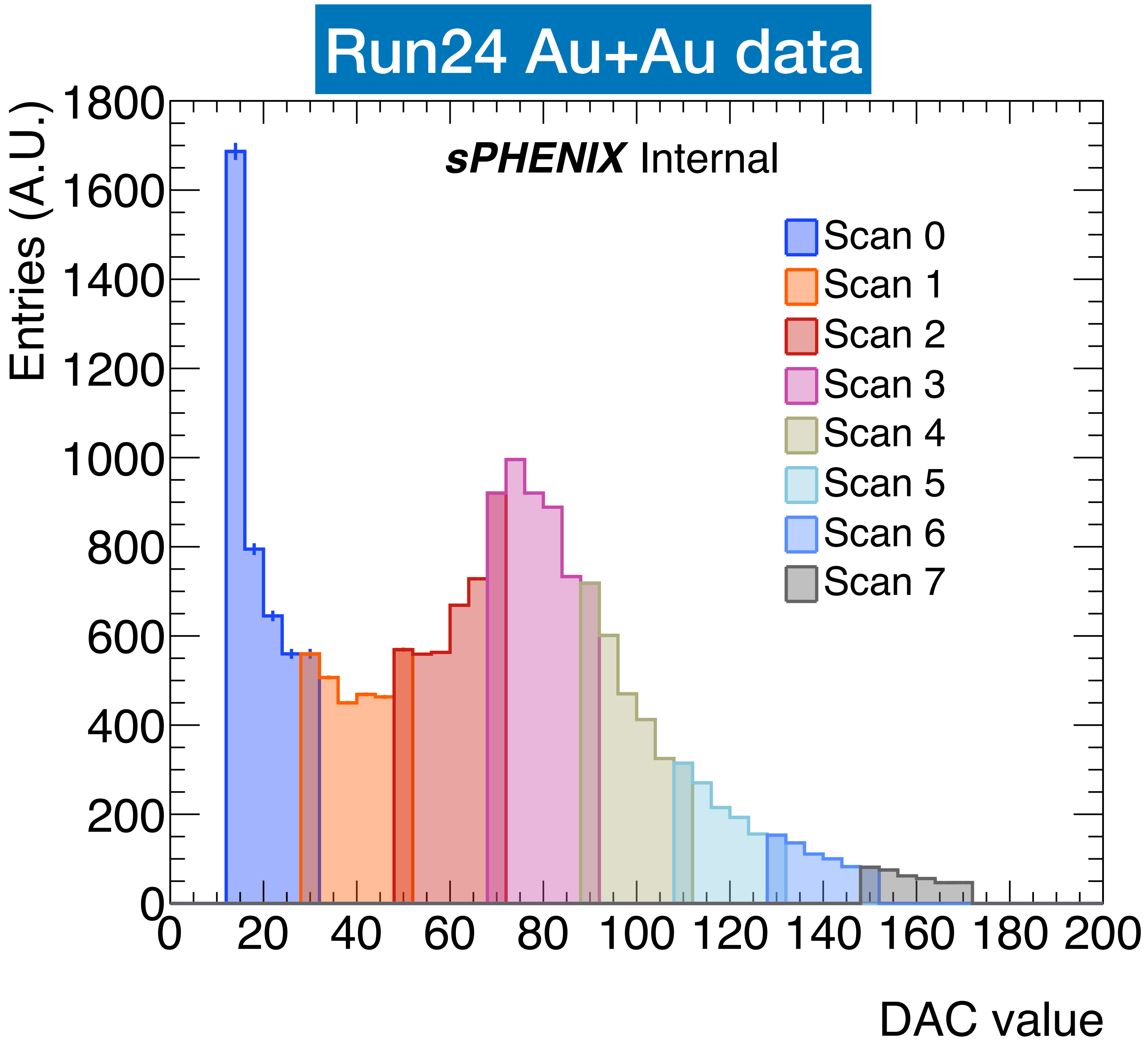


Signal: Land-Gaus convolution
Bkg fit: Gaus + Exp

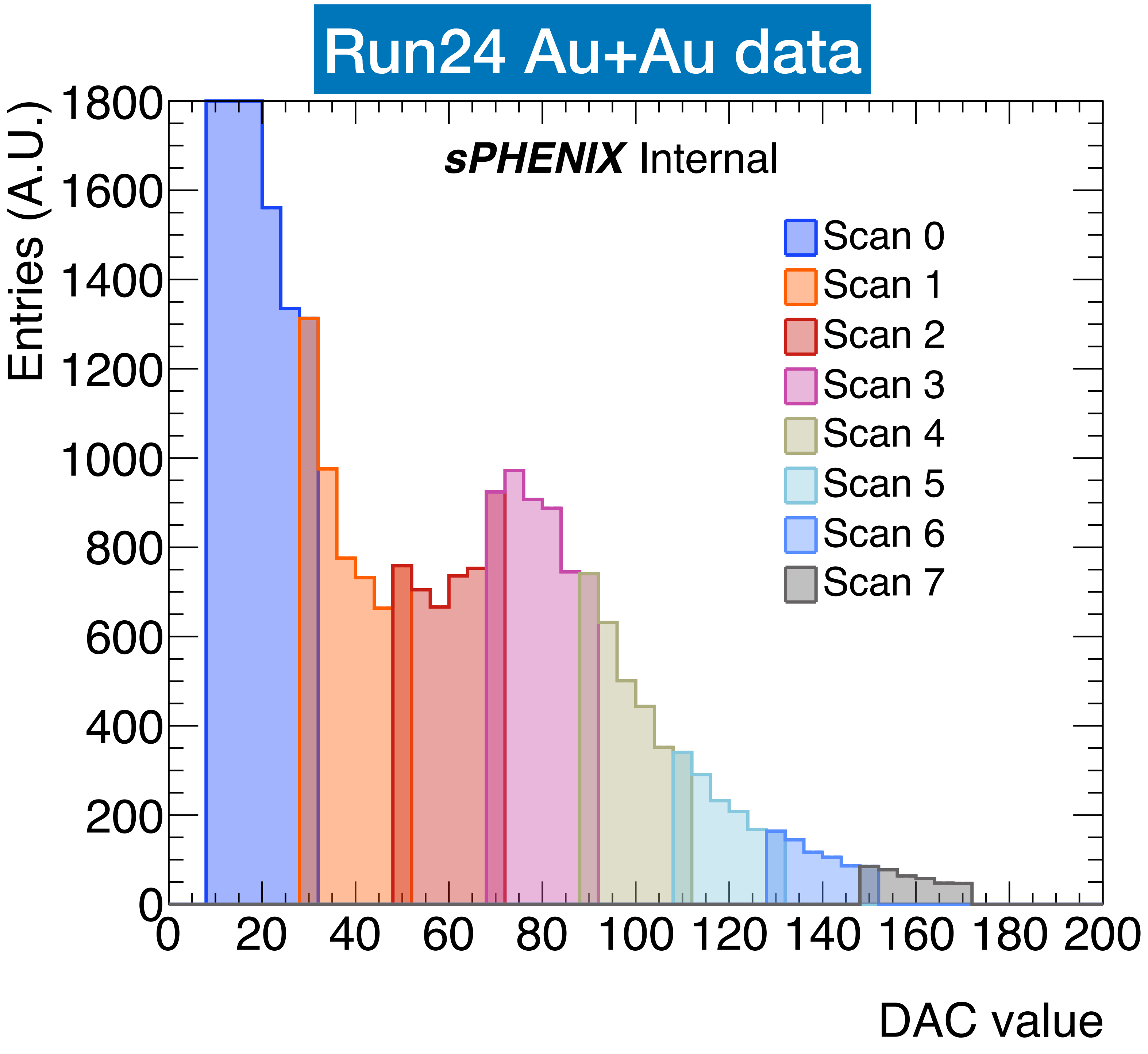
Regardless fit methods, background is huge

Energy deposit distribution - power of the cluster selection

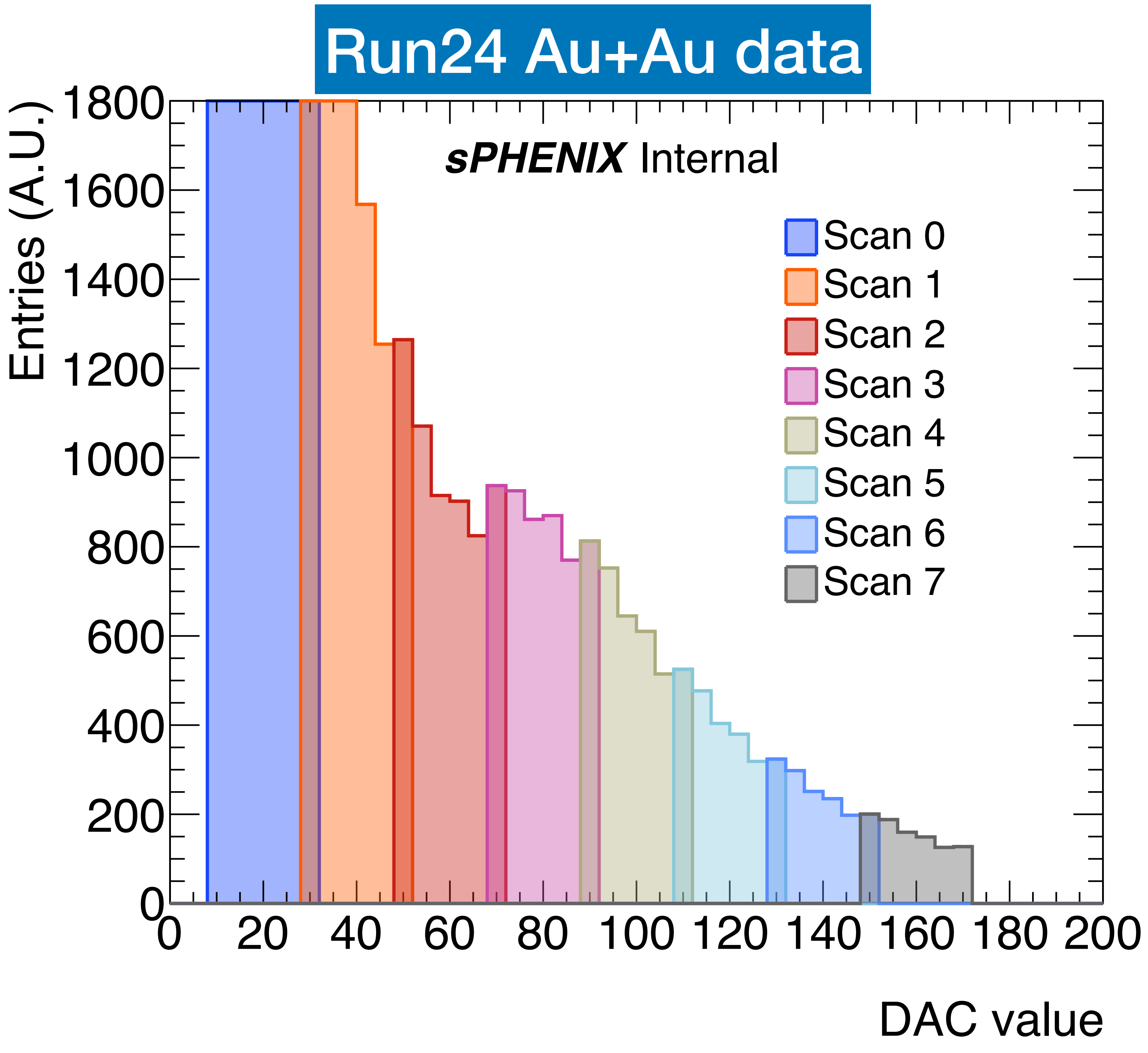
They all have the same event selection



Cluster selection mentioned previously



Requiring cluster size == 1
cluster |η| < 0.1



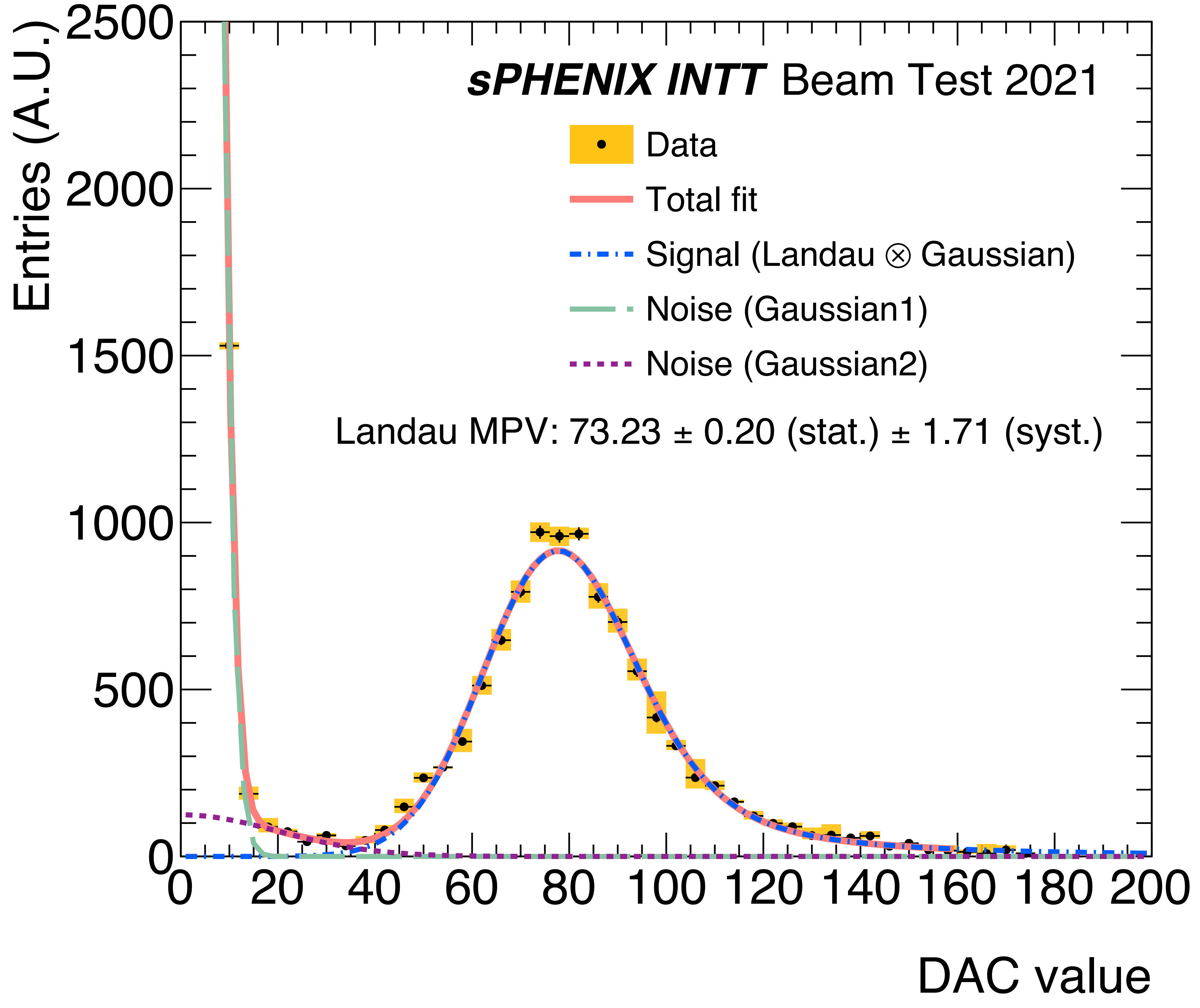
Only requiring cluster size == 1

Indication that maybe the DAC Scan data we took in Run23 were with the correct configuration, but the analysis framework was just not mature enough to suppress the background

Compare with beam test

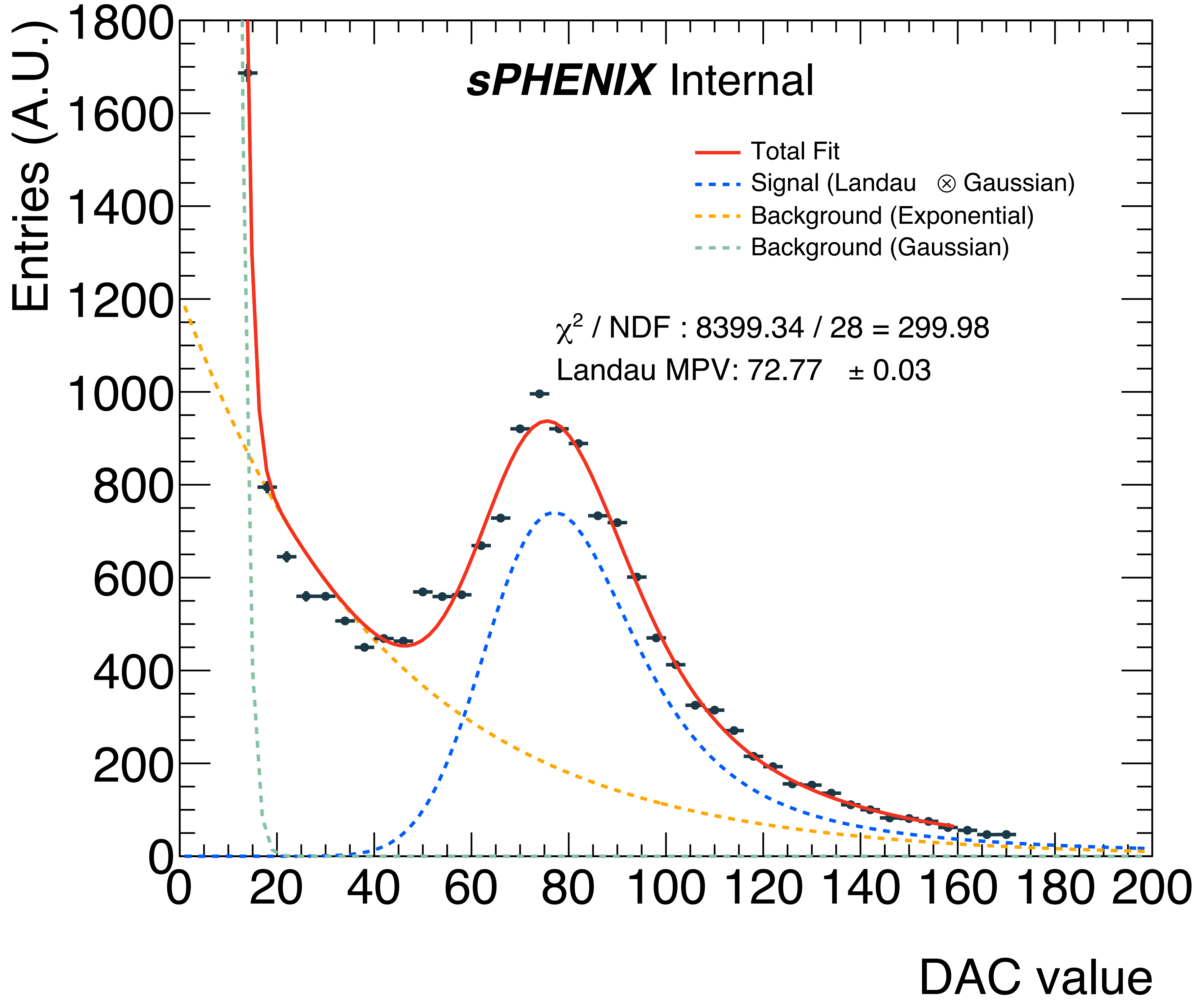
Beam Test 2021

50 V bias (full depletion: 57 V)
Positron beam with momentum of 1 GeV/c
Perpendicualr to the ladder



Run24 Au+Au data

Field-on Au+Au collision data
100 V bias
“control” sample



The MPV is basically the same between the two experiments!

Convert from ADC to eV

- We need to know the Gain and Offset (Vref) first
  - Vref=1 → Offset = 210 mV, GSel=2 → Gain = 100 mV/fC

- Conversion to mV: mV = Vref[mV] + (4[mV] * ADC) → mV = 210[mV] + (4[mV] * ADC)

- Elementary charge: e ≈ 1.6×10^{-19} C = $1.6\text{x}10^{-4}$[fC], (fC = 10^{-15}C)

- $\mathrm{mV} = \dfrac{\mathrm{edep[eV]} \times 1.6 \cdot 10^{-4}\mathrm{[fC]} \times \mathrm{gain[mV/fC]}}{3.6\mathrm{[eV]}}$ = 210[mV] + (4[mV] * ADC)

- edep [eV] = $\dfrac{4 \cdot \mathrm{ADC} + 210}{0.00444}$

	Beam	Bias voltage	silicon thickness	Landau MPV	edep (keV)
BeamTest 2019	Proton, 120 GeV	100 V	320 (um)	118.91	154.284
BeamTest 2021	Positron, 1 GeV	50 V	320 (um)	73.23	113.168
Run24	Au+Au collision @ 200 GeV	100 V	320 (um)	72.77	112.754

Convert from ADC to eV

Our data

	Beam	Bias voltage	silicon thickness	Landau MPV	edep (keV)	# eh pairs
BeamTest 2019	Proton, 120 GeV	100 V	320 (um)	118.91	154.284	42856.786
BeamTest 2021	Positron, 1 GeV	50 V	320 (um)	73.23	113.168	31435.644
Run24	Au+Au collision	100 V	320 (um)	72.77	112.754	31320.632

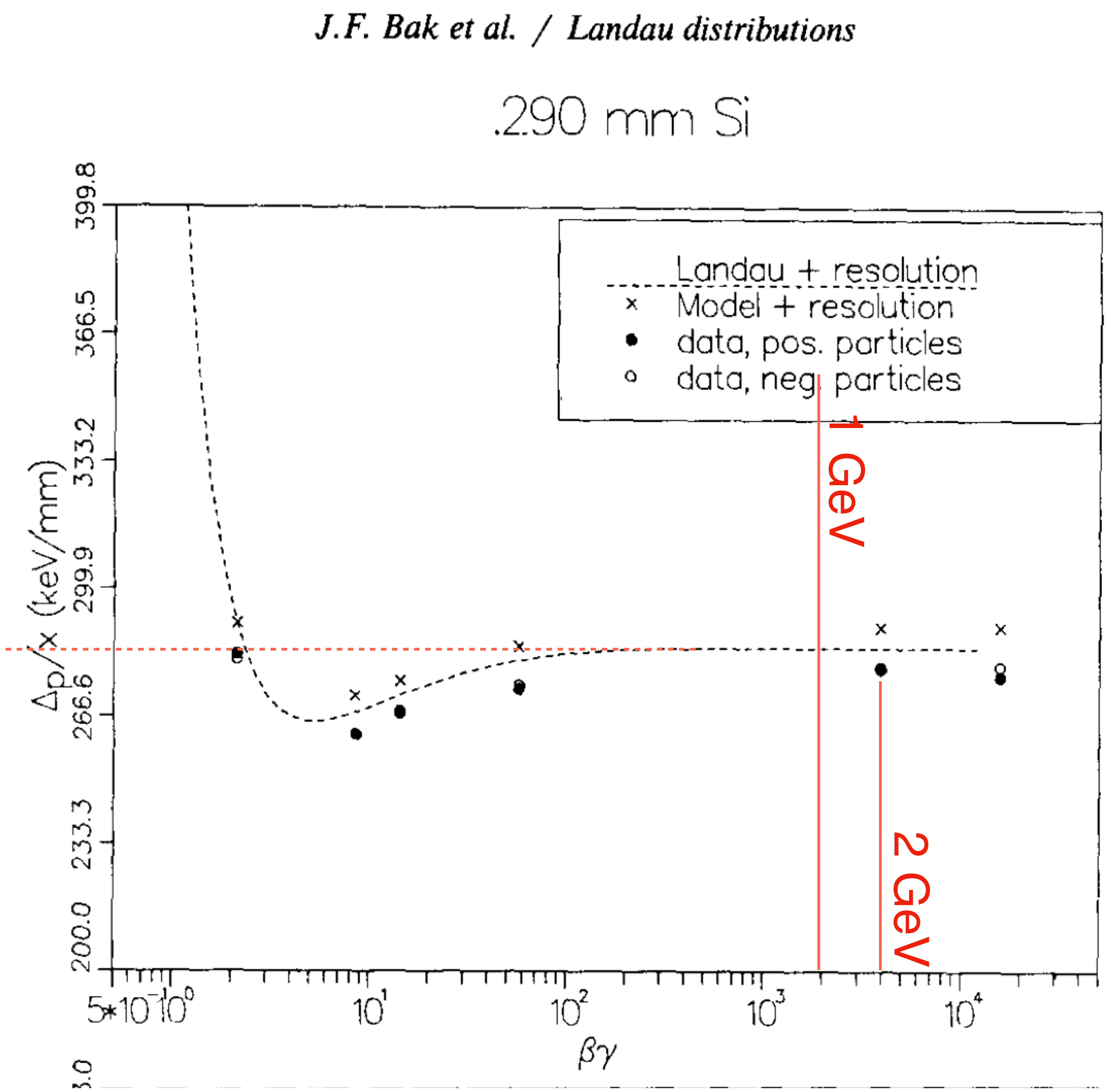
From world data

	Beam	Beam energy	silicon thickness	edep	# of eh pairs (edep / 3.62 eV)	Paper link	note
1	Proton	1 GeV	300 um	130.8 ± 3.8 keV	36132.60	link1	
2	Proton	115 GeV	300 um	85.5 ± 2.8 keV	23618.78		
3	Proton	50 GeV	300 um	85.79 keV	23698.90	link2	
4	Proton	50 GeV	320 um	92.4389 keV	25535.91		Interpolation from Table 2
5	Proton	12 GeV	320 um	90.158 keV	24905.52	link3	Extrapolation from Figure 11
6	Positron	2 GeV	290 um	~ 83.333 keV	23020.17	link4	From Fig. 12
7	Positron	2 GeV	290 um	81.2414 keV	22442.38	calculation	
8	Positron	1 GeV	320 um	90.2072 keV	24919.12		

In the world average: 320 um → 25k eh pairs

MPV as a function of momentum of positron

link4



βɣ of 2 GeV positron = 3913
βɣ of 2 GeV positron = 1956

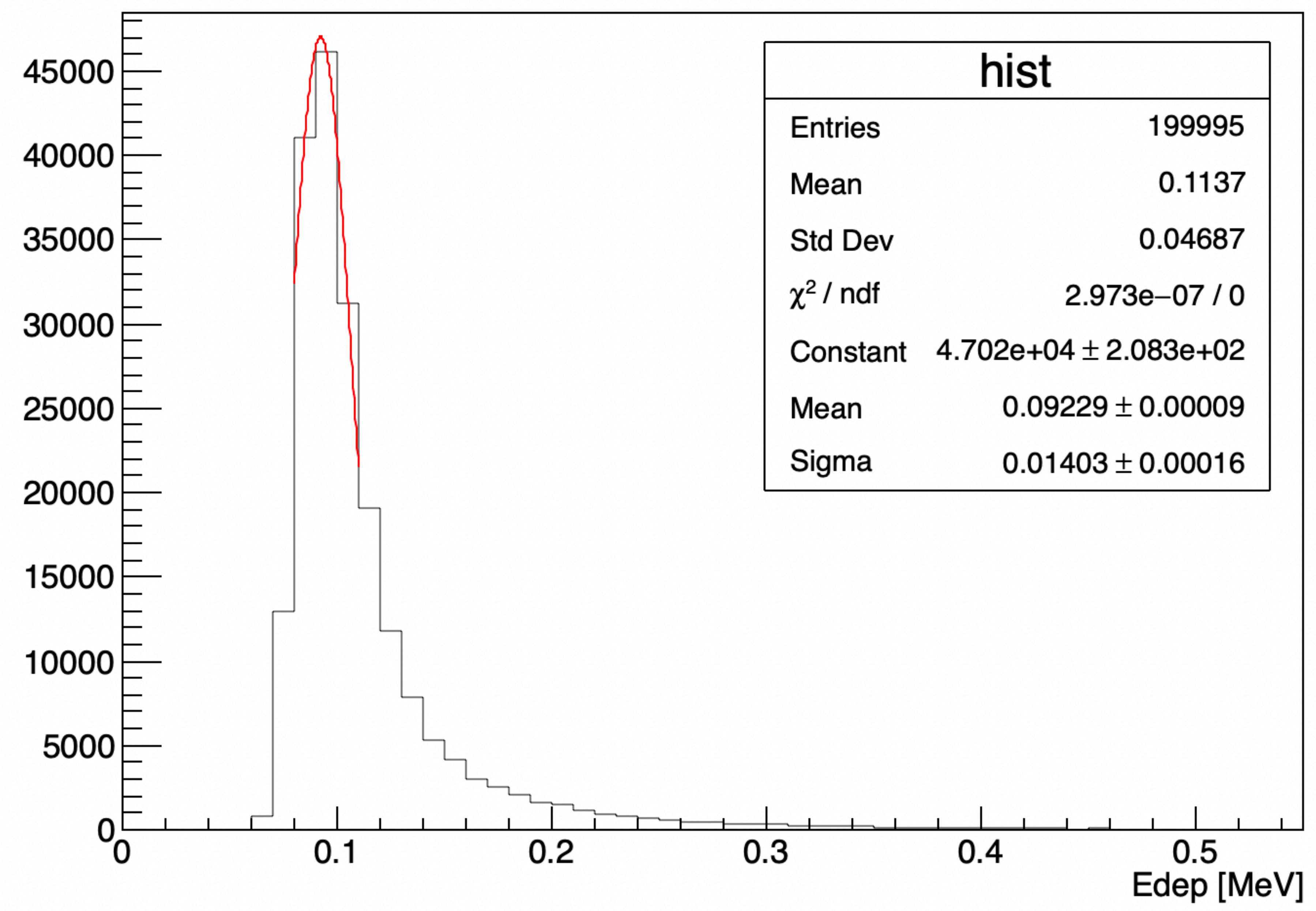
It basically rules that the MPV value of ~300 µm-thick silicon with a positron beam of 1 GeV/c momentum should be ~ 90 keV

The formular to calculate the MPV of edep

$$ _L\Delta_p = \xi \left[ln \frac{2m_e c^2 \beta^2 \gamma^2}{I^2} + ln \frac{\xi}{I} + 0.2 - \beta^2 - \delta \right] $$

I wrote a macro to calculate the MPV value…
320 um silicon with 1 GeV positron beam: 90.2072 keV

Geant4 with electron beam 1 GeV
(with 320 um silicon)



MPV = 0.09229 MeV → 25,494.48 eh pairs

Summary

- This marks the first time we have achieved constructing the energy deposit distribution using DAC Scan data taken in collisions

- Though now the edep distribution is available, I am not sure whether we want to include this in the INTT barrel NIM…
  - The background is huge…

- (Surprisingly?) The MPVs in beam test (50 V bias) and in collisions (100 V bias) are basically the same

- The calculated number of eh pairs from our data deviates from the world average…
  - World: 25k eh pairs vs. Our data: 31k eh pairs
  - We thought Offset = 210 mV and Gain = 100 mV/fC, but perhaps it may not be the case…

- I think the next thing I am gonna (maybe) do is to tune the sPHENIX charge-sharing model

Backup

Convert from ADC to eV

- We need to know the Gain and Offset (Vref) first

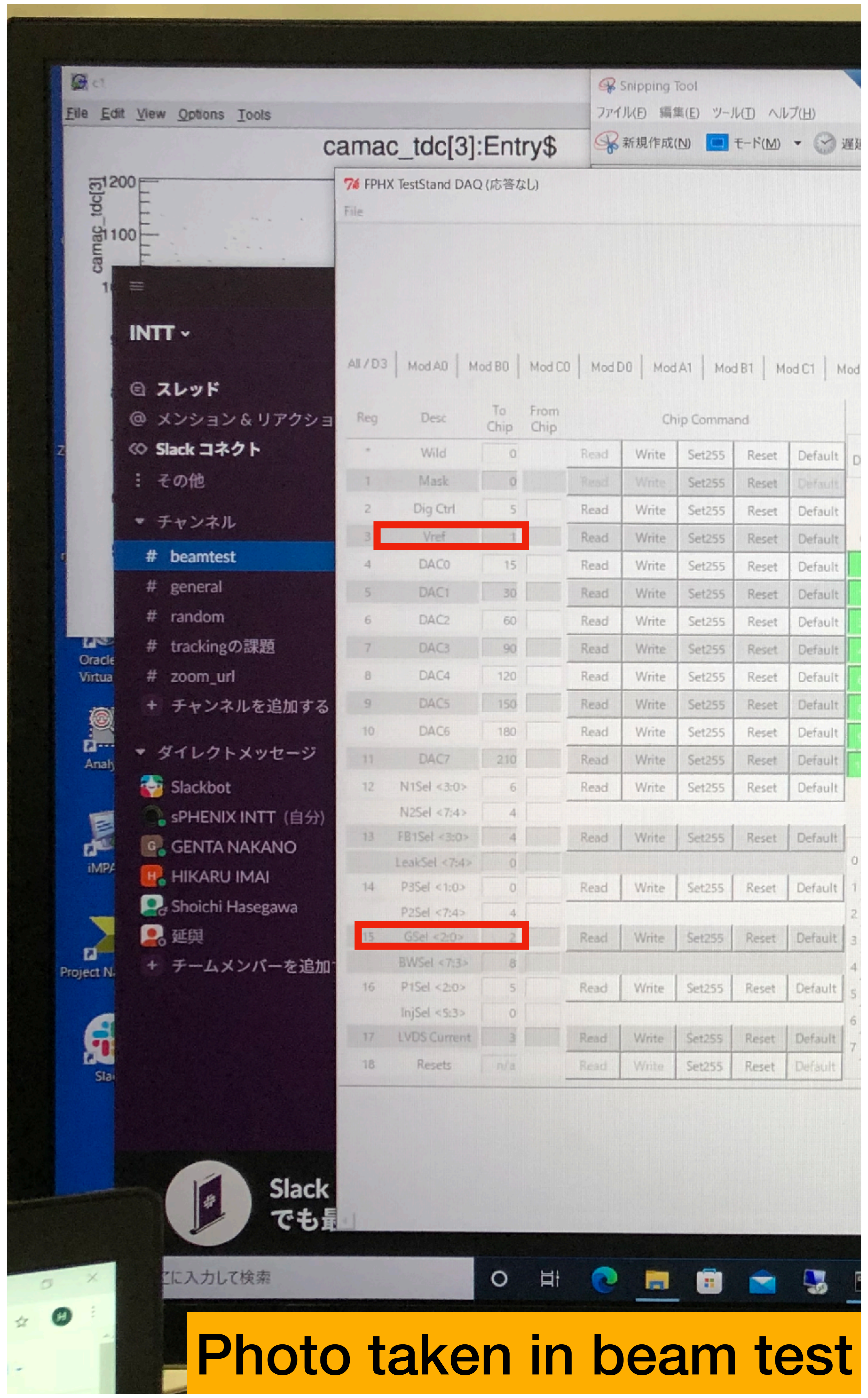


Photo taken in beam test

Gain

- **GSel<2:0>:** determines integrator feedback capacitance Cfb = 25fF + [(8.6fF)(GSel<0>) + (25fF)(GSel<1>) + (50fF)(GSel<2>)]. Default = 010.
- With a fixed shaper gain of about 5, the nominal system transfer gain can then be set to approximately 46, 50, 60, 67, 85, 100, 150, or 200 mV/fC.

Offset

- **Vref<1:0>:** Shaper DC reference voltage = 150mV + [(60mV)(Vref<1:0>)]. Default = 01. For maximum dynamic range, set Vref as low as possible while still maintaining linearity.

We set GSel=2 and Vref=1

Convert from ADC to eV

- We need to know the Gain and Offset (Vref) first
  - We set GSel=2 and Vref=1
- Vref=1 → Offset = 210 mV
- GSel=2 → Gain = 100 mV/fC?

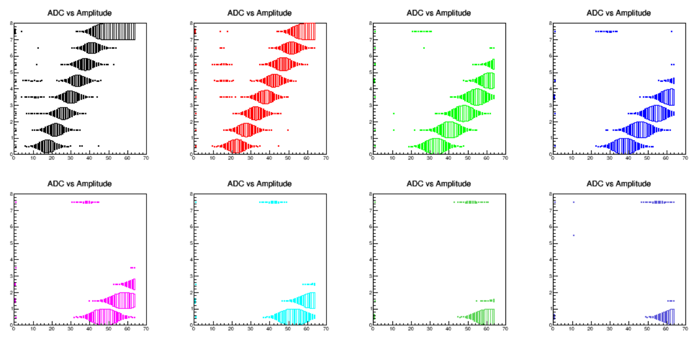
- **GSel<2:0>:** determines integrator feedback capacitance Cfb = 25fF + [(8.6fF)(GSel<0>) + (25fF)(GSel<1>) + (50fF)(GSel<2>)]. Default = 010.
- With a fixed shaper gain of about 5, the nominal system transfer gain can then be set to approximately 46, 50, 60, 67, 85, 100, 150, or 200 mV/fC.
- **Vref<1:0>:** Shaper DC reference voltage = 150mV + [(60mV)(Vref<1:0>)]. Default = 01. For maximum dynamic range, set Vref as low as possible while still maintaining linearity.

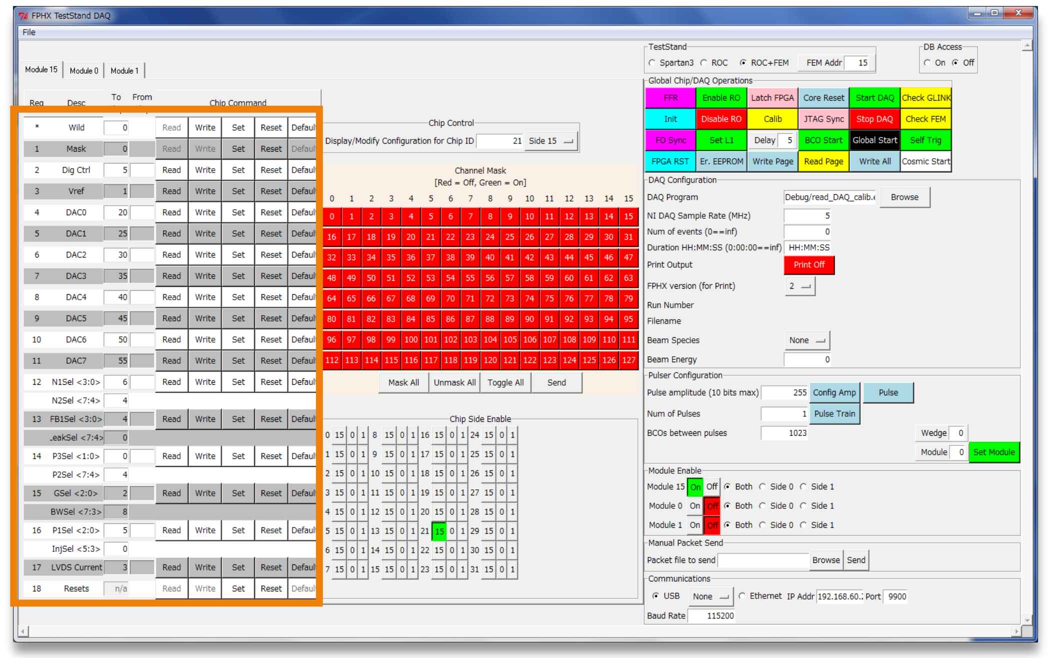
Slides from Miu Morita (NWU) in 2020

Set DAC and Gain value

- Threshold of DAC * 4 + 210= Amplitude
- You need to decide DAC value
- You need to decide GSel number

GSel number	Gain value
GSel=0	200
GSel=1	150
GSel=2	100
GSel=3	85
GSel=4	67
GSel=5	60
GSel=6	50
GSel=7	46



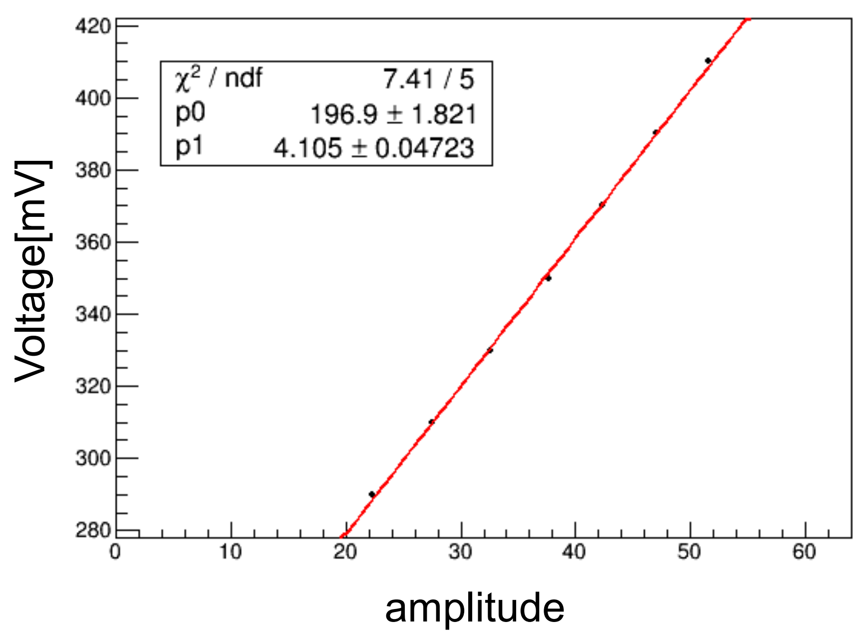


2020/6/16 How to obtain Pedestal: Miu Morita in NWU

Pedestal(offset)

- I make graph voltage[mV] vs amplitude

Gsel=1
Data:20200124-1828



Pedestal
mean: (200.8±6.0) mV

Data	GSel	Gain value	P0 (offset)	P1 (coefficient)	Threshold
20200124-1826	0	200	199.2	5.09	DAC0:20~DAC7:55(5)
20200124-1828	1	150	196.9	4.105	DAC0:20~DAC7:55(5)
20200124-1914	2	100	198.4	2.769	DAC0:20~DAC7:55(5)
20200124-1835	3	85	198.3	2.431	DAC0:20~DAC7:55(5)
20200124-1838	4	67	200.4	1.87	DAC0:20~DAC7:55(5)
20200124-1840	5	60	186.7	1.966	DAC0:20~DAC7:55(5)
20200304-1836	2	100	206.6	2.333	DAC0:20~DAC7:55(5)
20200304-1852	2	100	207	2.314	DAC0:20~DAC7:55(5)
20200304-1903	2	100	207	2.315	DAC0:20~DAC7:55(5)
20200304-1909	2	100	207	2.312	DAC0:20~DAC7:55(5)
20200304-1923	2	100	206.8	2.308	DAC0:20~DAC7:55(5)
20200304-1943	0	200	197.9	4.148	DAC0:20~DAC7:55(5)
20200304-1948	1	150	201.2	3.348	DAC0:20~DAC7:55(5)
20200304-1954	2	100	206.9	2.305	DAC0:20~DAC7:55(5)
20200304-2010	3	85	196	2.573	DAC0:12~DAC7:40(4)
20200304-2018	4	67	200.4	2.186	DAC0:12~DAC7:40(4)
20200304-2023	5	60	190.8	2.002	DAC0:6~DAC7:27(3)
20200305-1607	2	100	209.4	2.258	DAC0:20~DAC7:55(5)
20200305-1618	6	50	203.5	1.556	DAC0:4~DAC7:18(2)
20200305-1627	7	46	196.3	1.435	DAC0:4~DAC7:18(2)

2020/6/16 How to obtain Pedestal: Miu Morita in NWU

Inverse correlation between GSel and slope was observed → The smaller GSel the larger gain

Vref=1 → Offset = 210 mV, GSel=2 → Gain = 100 mV/fC

Convert from ADC to eV - function modification

- Offset = 210 mV, Gain = 100 mV/fC, Conversion to mV: mV = 210[mV] + (4[mV] * ADC)

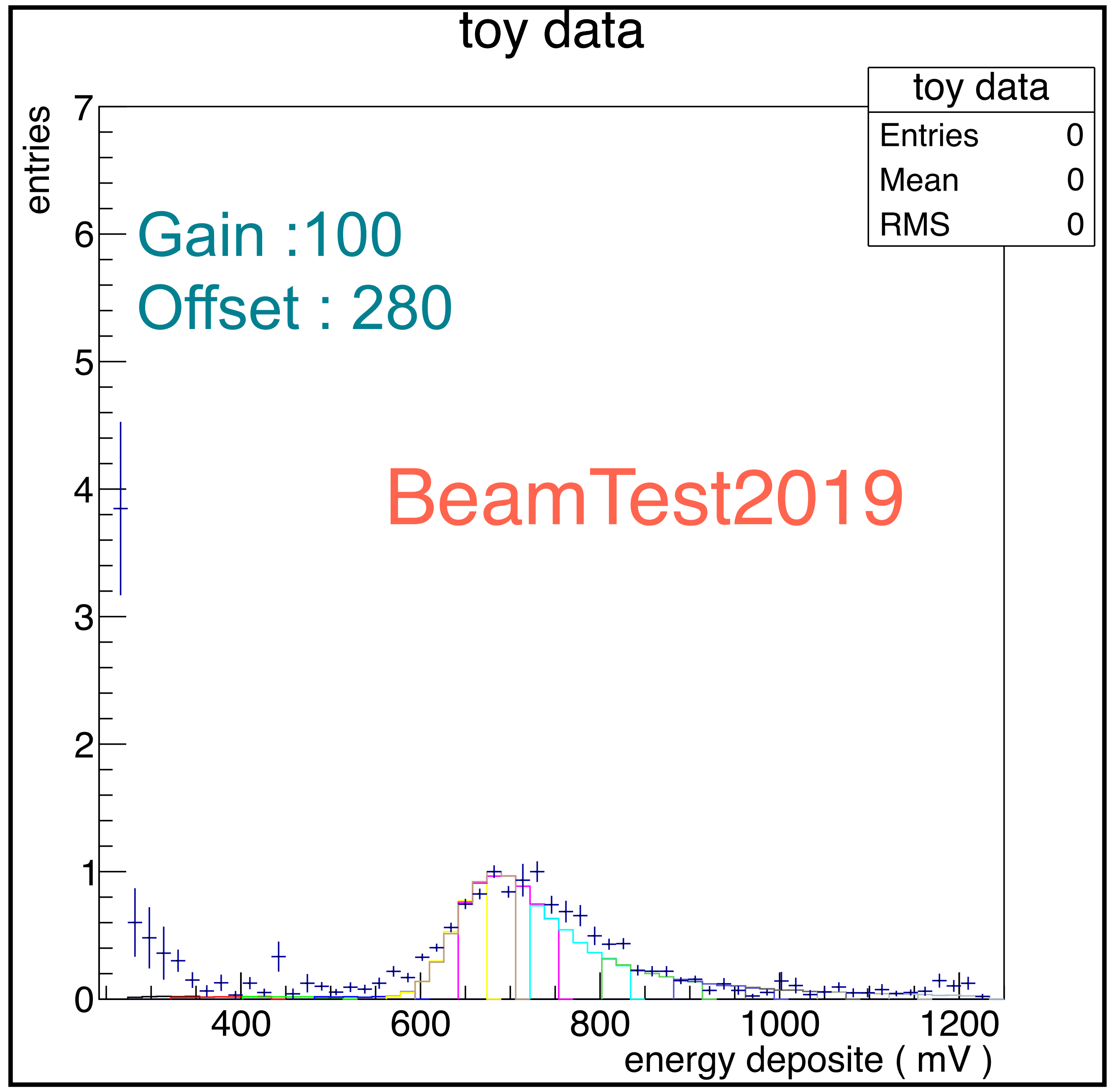
- $$\mathrm{mV} = \frac{\mathrm{edep[eV]} \times 1.6 \cdot 10^{-4}[\mathrm{fC}] \times \mathrm{gain[mV/fC]}}{3.6[\mathrm{eV}]} + \mathrm{Offset} = 210[\mathrm{mV}] + (4[\mathrm{mV}] * \mathrm{ADC})$$
  - The Offset seems to be a free parameter (280, according to beam test 2019)

- $$\mathrm{edep\ [eV]} = \frac{4 \cdot \mathrm{ADC} + 210 - \mathrm{Offset}}{0.00444}$$

	Beam	Bias voltage	silicon thickness	Landau MPV (ADC)	edep (keV)	# eh pairs
BeamTest 2019	Proton, 120 GeV	100 V	320 (um)	118.91	91.278	25355.036
BeamTest 2021	Positron, 1 GeV	50 V	320 (um)	73.23	50.162	13933.893

The number may not make sense → don't show the eV case

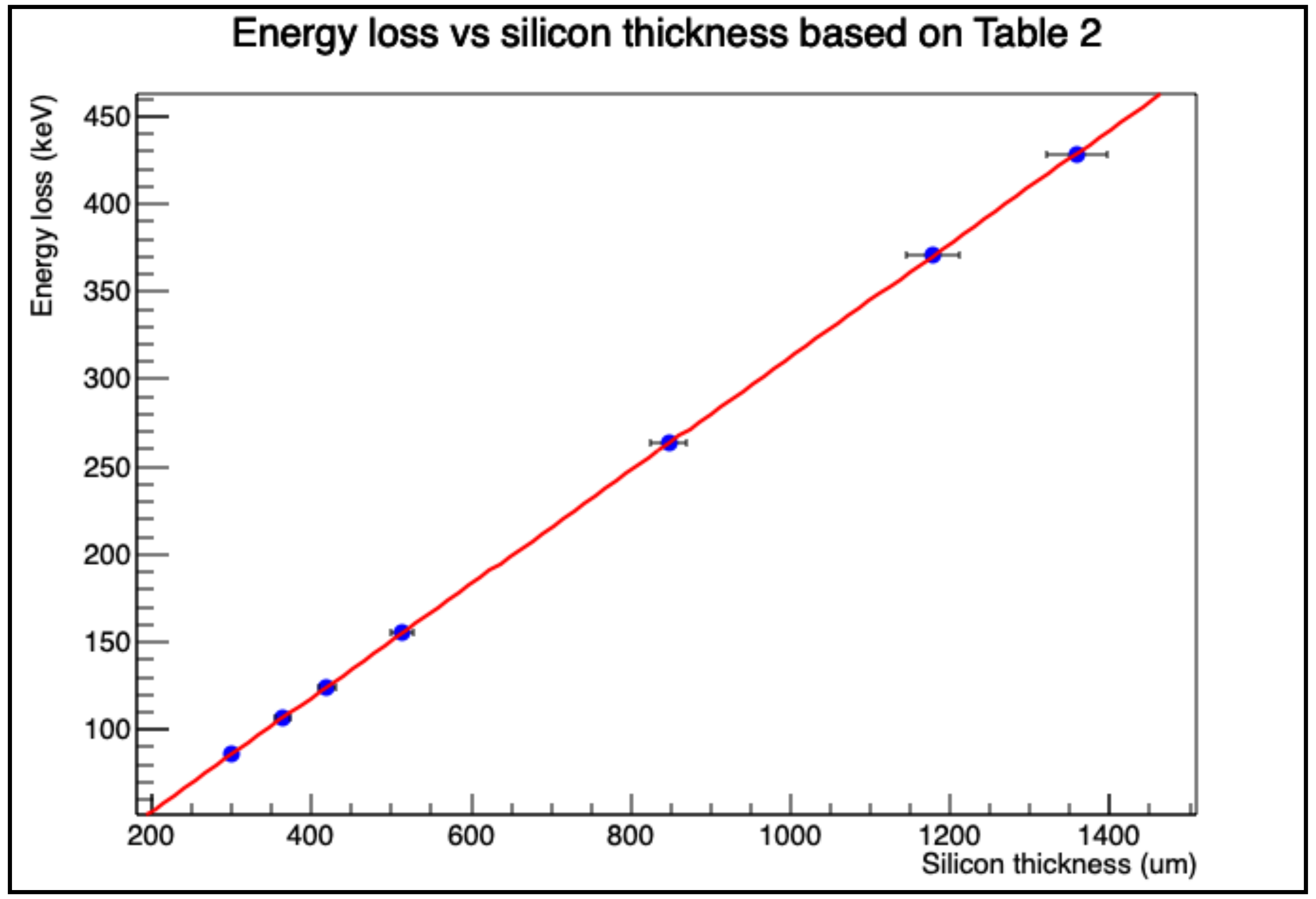
Slide from Cheng-Wei, 2020/03/06



Relative good agreement found with Offset = 280

Convert from ADC to eV - Supplementary

link 2 plot



Fit : Y = 3.23932e-01*X -1.12194e+01

link 3 plot

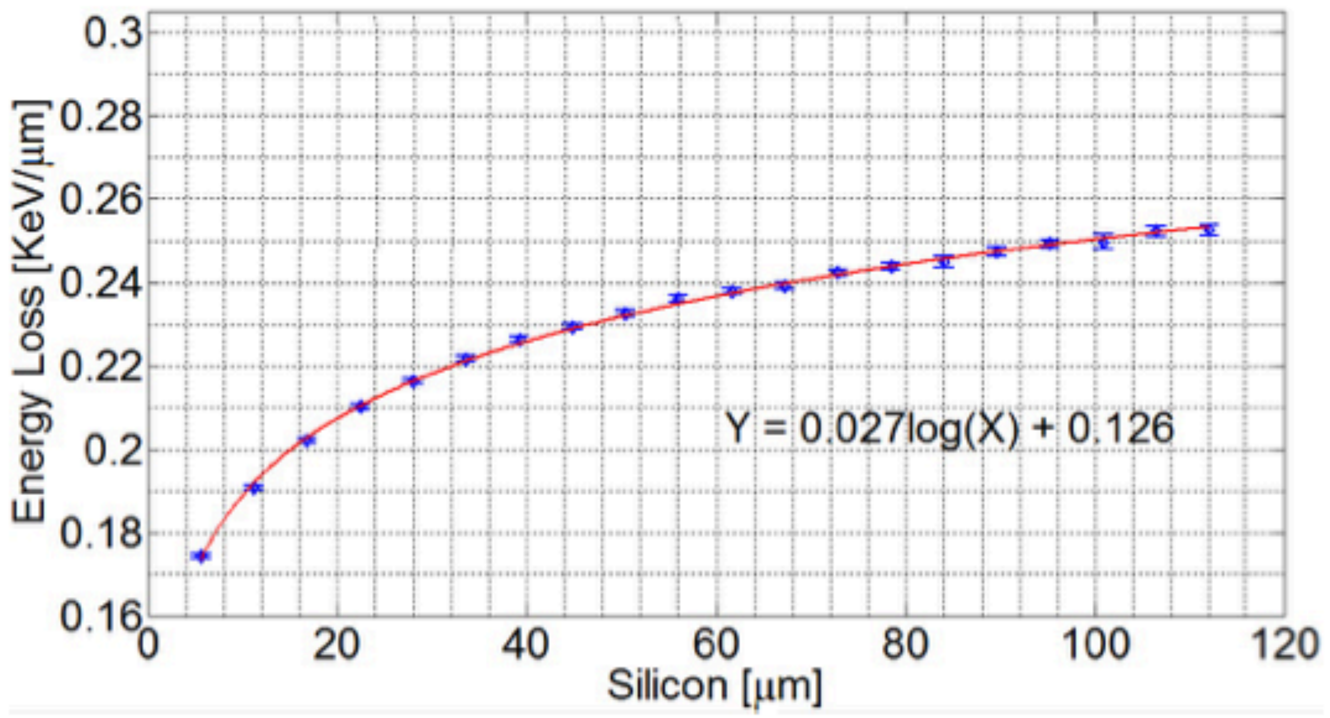


Figure 11. Energy loss for 12GeV protons passing through several silicon thickness.

Convert from ADC to eV - Supplementary

Report from Takashi

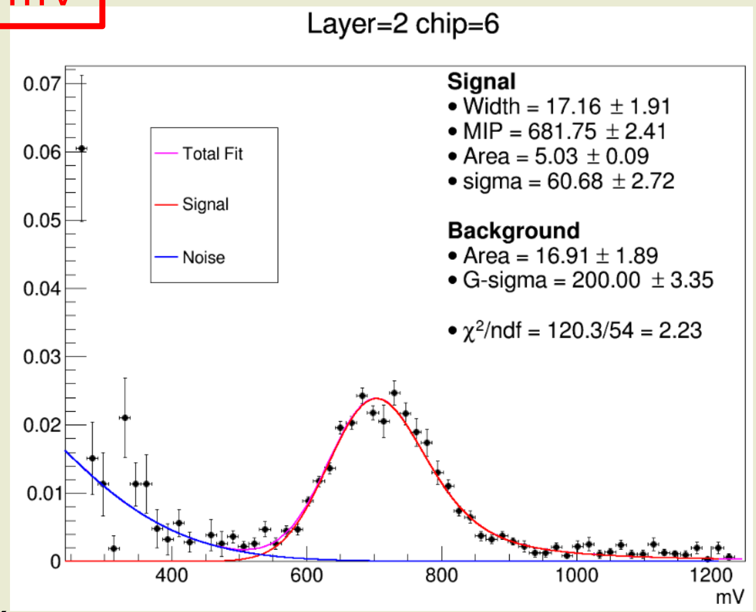
MIP Peak Puzzle

DAC*4+210 = mV

- What is MIP peak puzzle
  - MIP peak is ~700mV from the beam test and cosmic ray.
  - Expected MIP peak is 1100mV
    - E_{loss} ~ 100keV in 320um Si

$$\text{Energy loss [mV]} = \frac{\text{Edep} \times 10^6\ [\text{eV}] \times 1.6 \times 10^{-4}\ [\text{fC}] \times 300\ [\text{mV/fC}]}{3.6\ [\text{eV}]}$$

$$\frac{E_{loss}}{3.6eV} = 23000e$$



- Mika, Miu, and Ayaka found two bugs in the calculation of expected MIP peak
  - Gain value (G) (mV/fC)
  - Offset (O) (mV)

Conversion formula (Eloss/strip → V)

$$V(mV/strip) = G * \frac{E_{loss}}{3.6eV} + O$$

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Report from Takashi

Expectation of the MIP peak updated

- Current expected MIP peak is 1100mV
  - E_{loss} ~ 100keV in 320um Si
  - G = 300(mV/fC), O ~ 0 (mV)

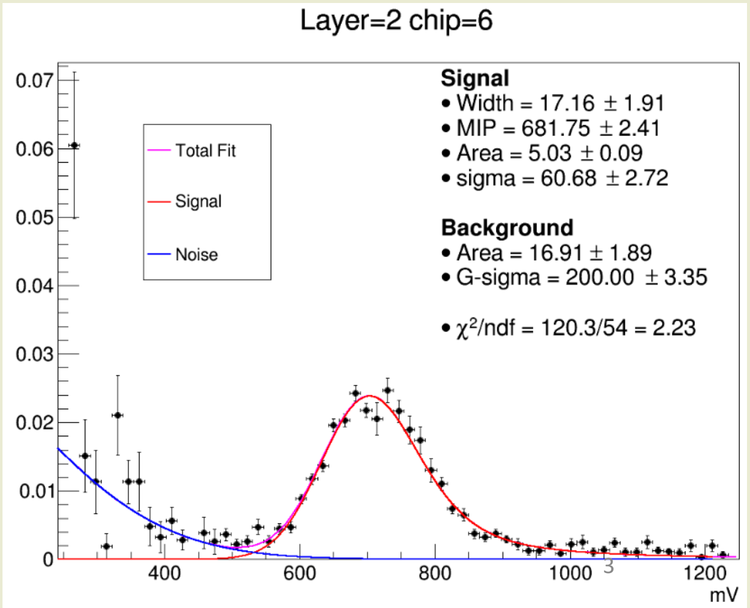
Conversion formula (Eloss/strip → V)

$$V(mV/strip) = G * \frac{E_{loss}}{3.6eV} + O$$

$$\frac{E_{loss}}{3.6eV} = 3.8fC$$

- New expected MIP peak is 600mV
  - G = 100(mV/fC), O ~ 200 (mV)

$$\text{Energy loss [mV]} = \frac{\text{Edep} \times 10^6\ [\text{eV}] \times 1.6 \times 10^{-4}\ [\text{fC}] \times 300\ [\text{mV/fC}]}{3.6\ [\text{eV}]}$$



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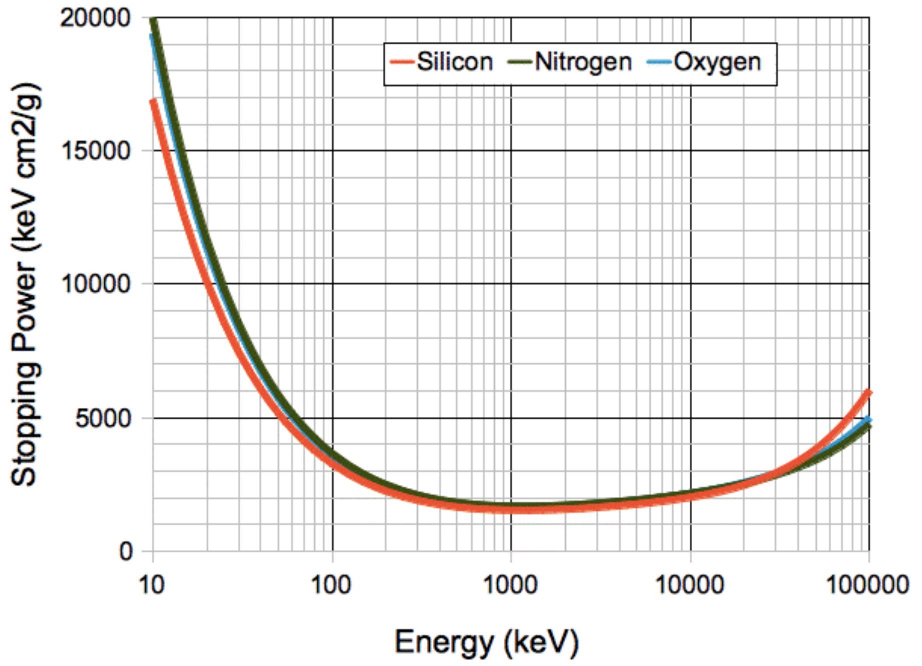
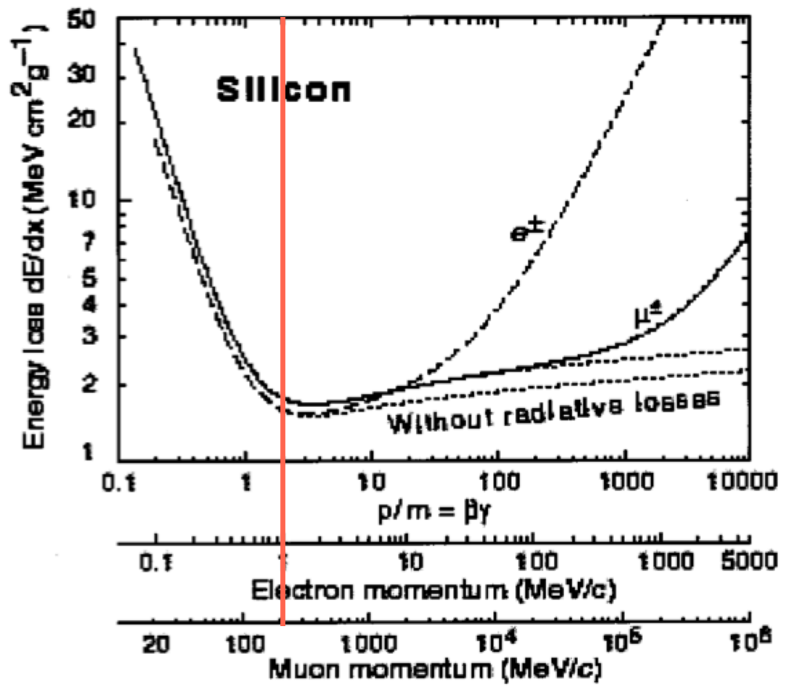
Convert from ADC to eV - Supplementary

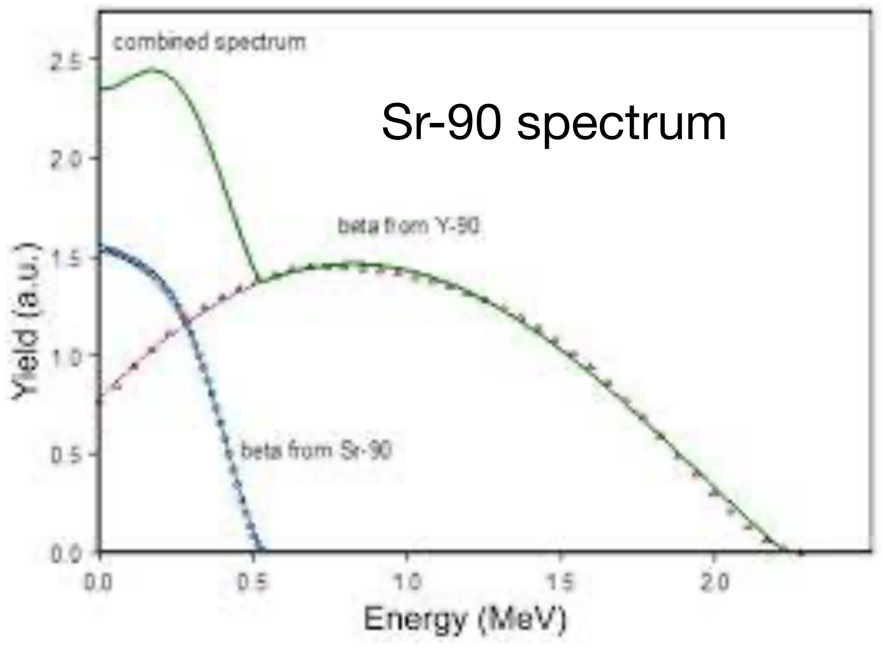
Energy deposit of Sr-90 (Y-90) in thin silicon

Electron stopping power



Paper link





Electron stopping power @ 1 MeV

Calculated by web

(required) Kinetic Energy (MeV)	Stopping Power (MeV cm²/g) Collision	Radiative	Total	Density Effect Parameter
1.000E+00	1.507E+00	2.360E-02	1.531E+00	3.424E-01

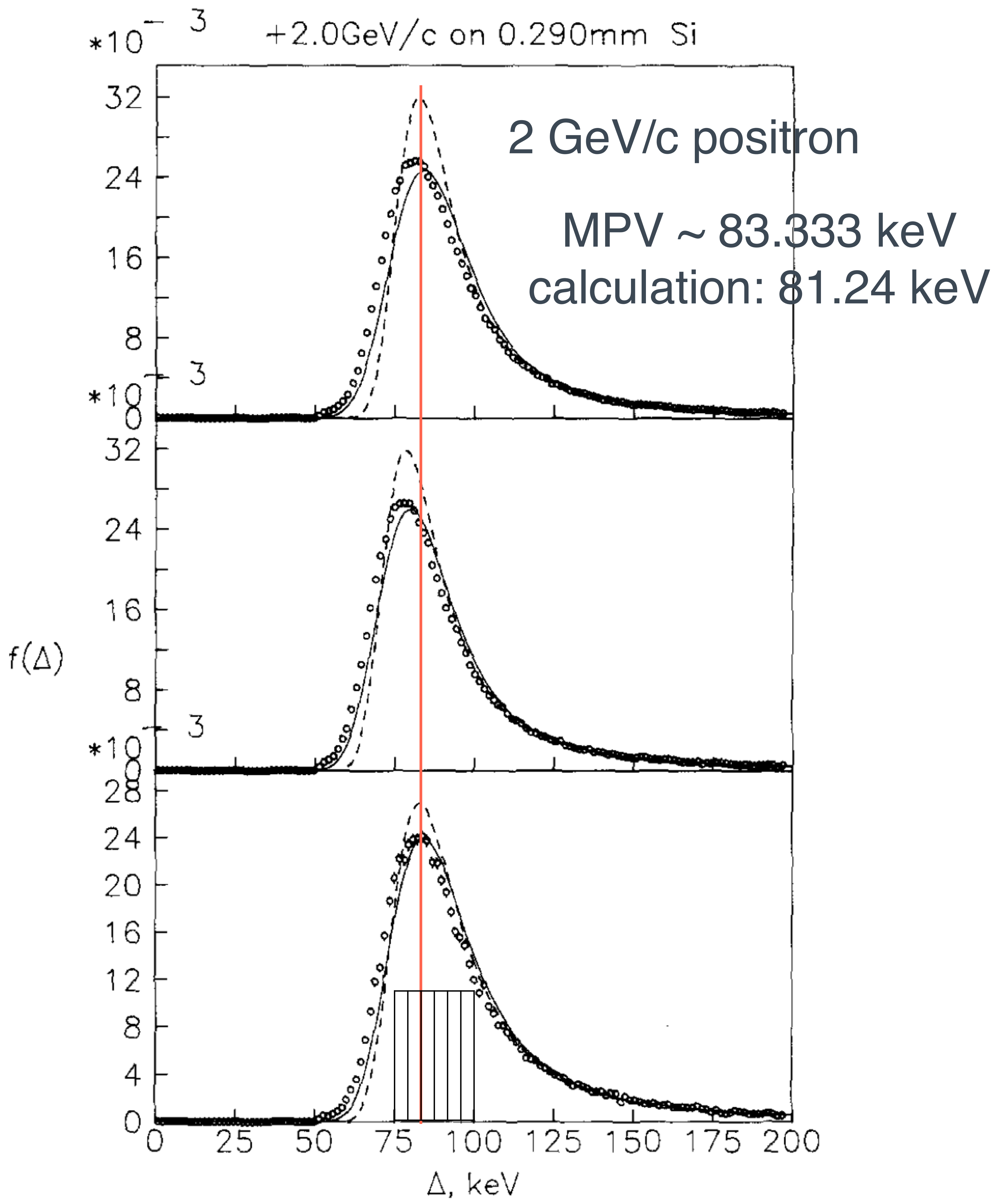
$$\frac{1.531\ (MeV\ cm^2/g) \times 2.33 (g/cm^3) \times 320\ (\mu m)}{10^4} = 0.114\ MeV$$

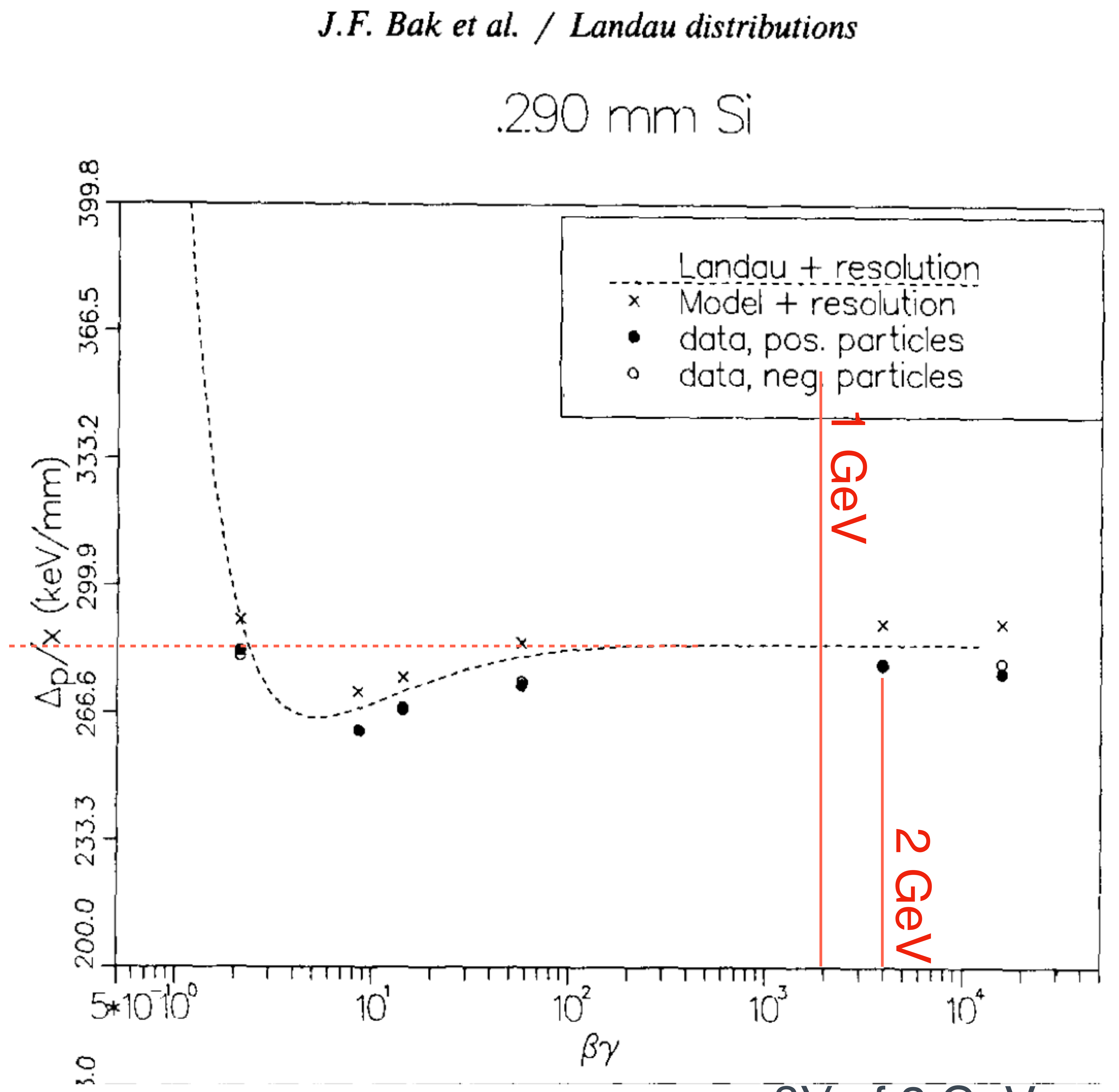
From paper : minimum ionization energy of muon in silicon : 1.664 MeV cm2/g

edep summary table

Item	Peak position Land x Gaus	Peak position pure land	setting	note
Testbeam2021, 3 layer average	73.598		DAC scan	50 V
Testbeam2019	118.91		DAC scan	100 V
Source test	58.80	60.696	8 bins, self-trigger, threshold 20 adc (with sci.)	50 V
	70.19 (76.09)	69.62 (64.13)		100 V
	58.63	60.244	8 bins, with sci., customized adc setting (w/o first bin in fitting)	50 V
	64.59 (72.2)	64.171 (75.36)		100 V
		74.039	8 bins, threshold 40 adc	100 V
Cosmic test	82.11	73.626	8 bins, threshold 15 adc	100V, 2 scis

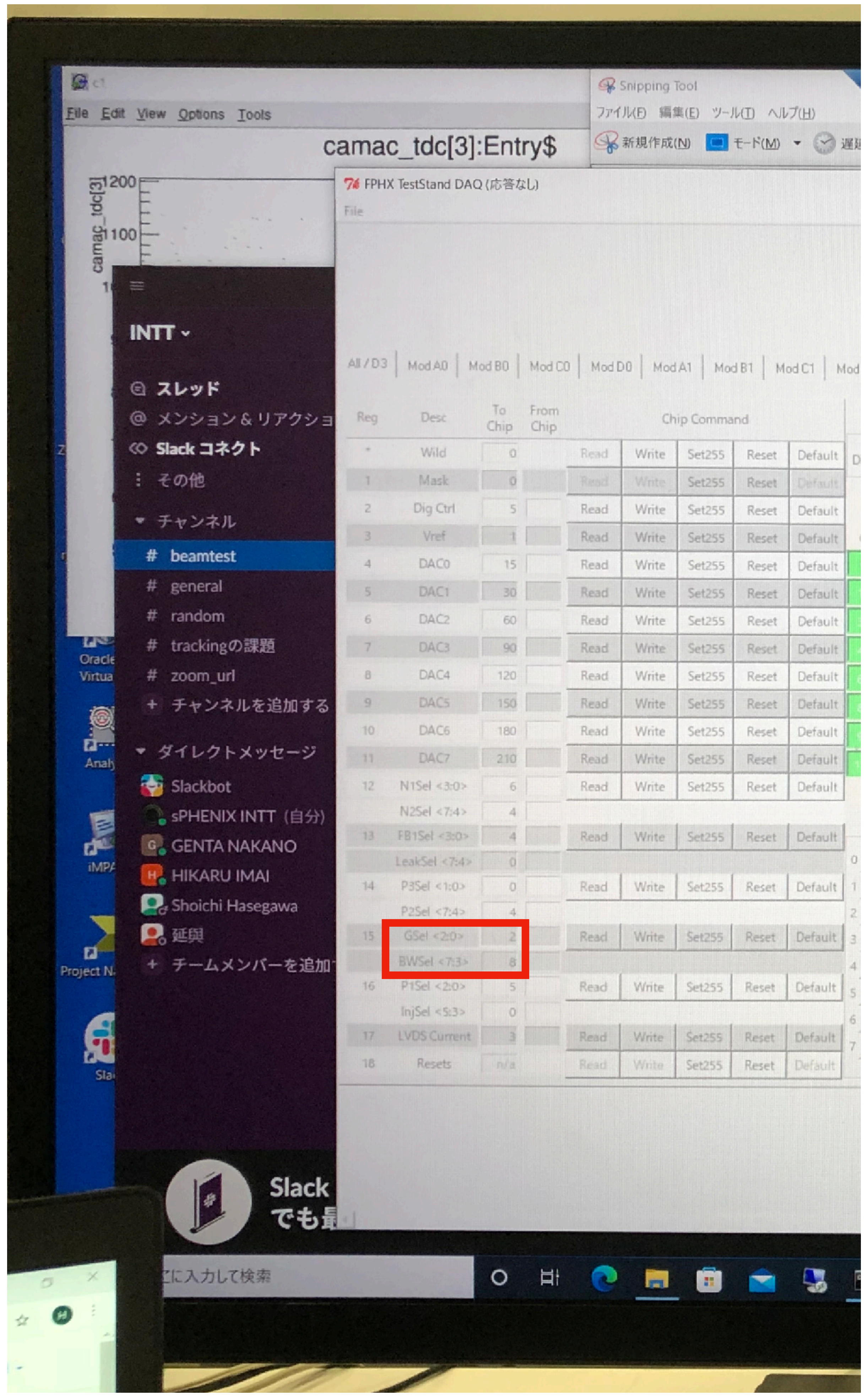
*thre 40, source test is from : NCU_fphx_raw_module_44_20211214-1935_0 link



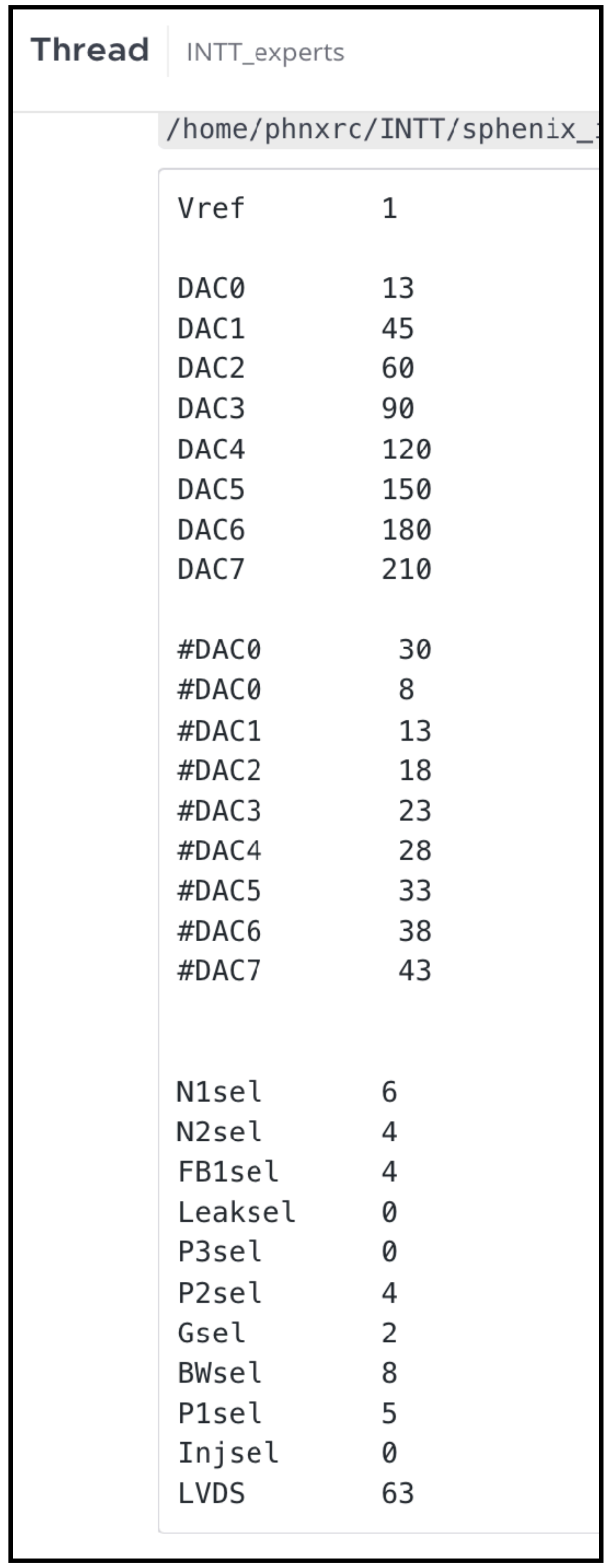


βɣ of 2 GeV positron = 3913
βɣ of 2 GeV positron = 1956

In beam test



In 1008


Thread INTT_experts

/home/phnxrc/INTT/sphenix_

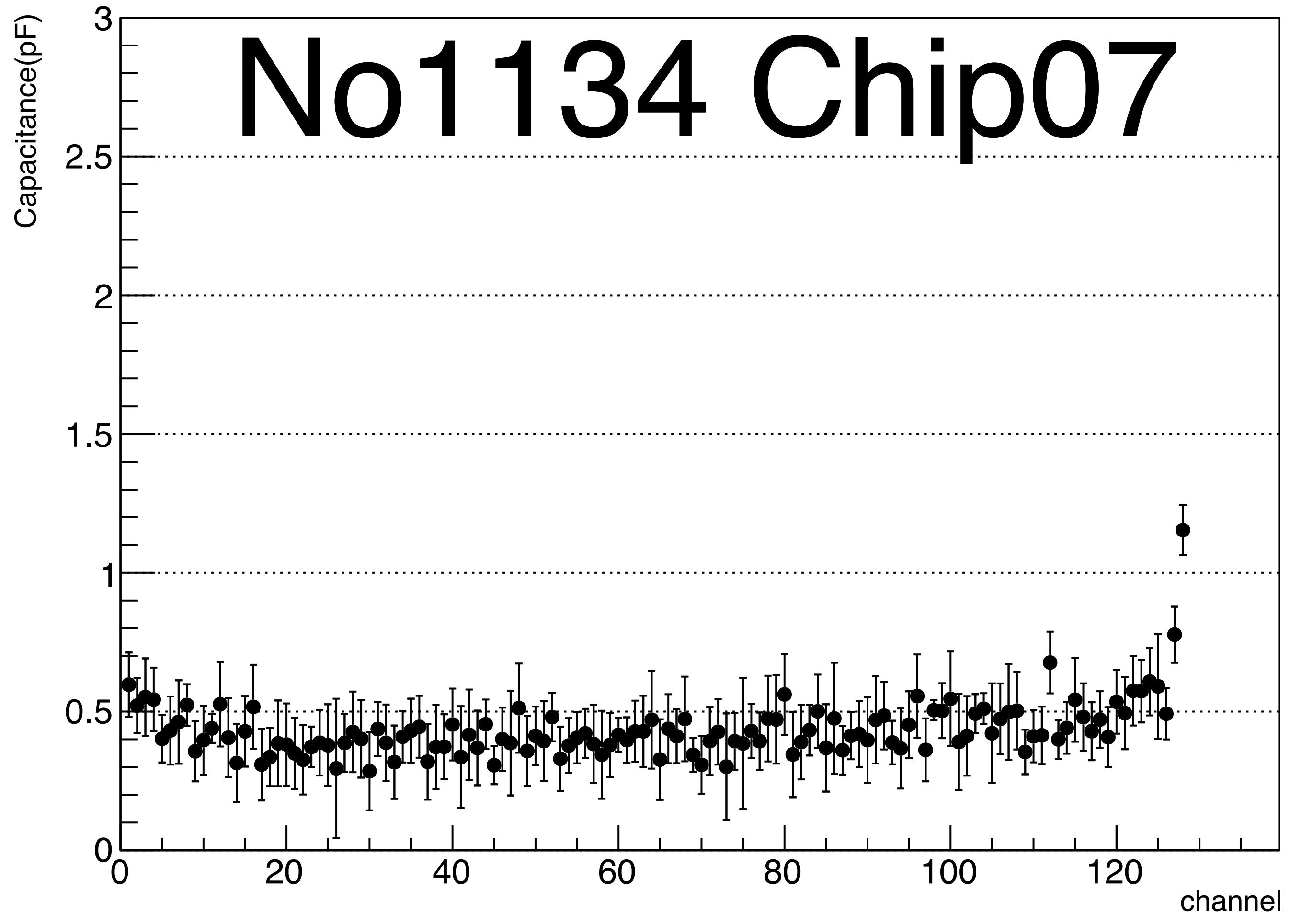
```
Vref     1

DAC0     13
DAC1     45
DAC2     60
DAC3     90
DAC4     120
DAC5     150
DAC6     180
DAC7     210

#DAC0     30
#DAC0     8
#DAC1     13
#DAC2     18
#DAC3     23
#DAC4     28
#DAC5     33
#DAC6     38
#DAC7     43


N1sel    6
N2sel    4
FB1sel   4
Leaksel  0
P3sel    0
P2sel    4
Gsel     2
BWsel    8
P1sel    5
Injsel   0
LVDS     63
```

- First determine **GSel** based on the desired approximate transfer gain (approx. 50 – 200 mV/fC).
- Then depending on the value of the input capacitance (Cin), program **BWSel** to achieve fast integrator response without ringing.
- For Cin = 2 pF (1.5 pF detector + 0.5 pF parasitic):
  - If **GSel** = 000, set **BWSel** = 00000
  - If **GSel** = 010, set **BWSel** = 00100
  - If **GSel** = 100, set **BWSel** = 01000
  - If **GSel** = 110, set **BWSel** = 01100
- For Cin = 1.5 pF (1 pF detector + 0.5 pF parasitic):
  - If **GSel** = 000, set **BWSel** = 00001
  - If **GSel** = 010, set **BWSel** = 00110
  - If **GSel** = 100, set **BWSel** = 01010
  - If **GSel** = 110, set **BWSel** = 01110
- For Cin = 1 pF (0.5 pF detector + 0.5 pF parasitic):
  - If **GSel** = 000, set **BWSel** = 00010
  - If **GSel** = 010, set **BWSel** = 01000
  - If **GSel** = 100, set **BWSel** = 01110
  - If **GSel** = 110, set **BWSel** = 10101



Our setting: GSel 2 → 0010
BWSel 8 → 01000