Detector Calibration & PID Status

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Temple University

Polarized ^{3}He Collaboration Meeting
March 25, 2021

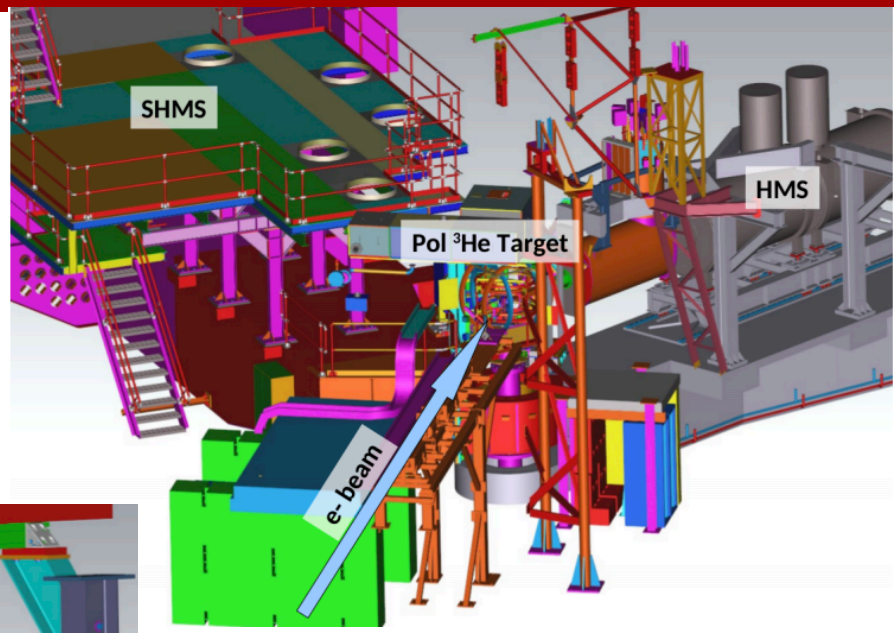
Outline

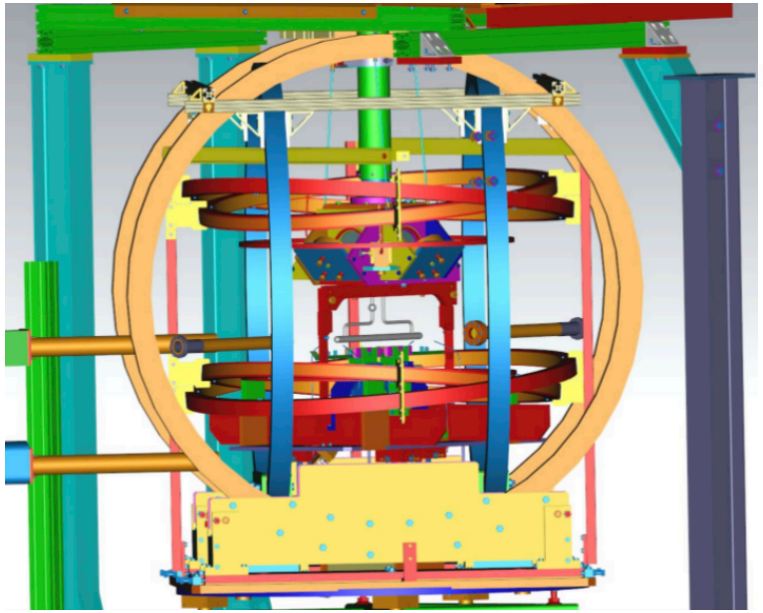
Calibrations

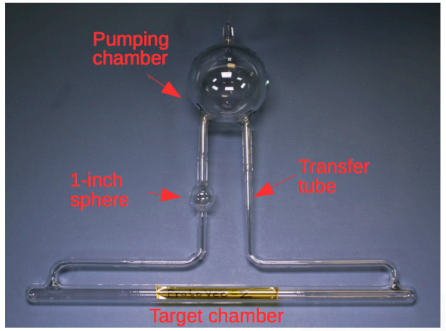
- BCM
- Hodoscopes (Mingyu Chen)
- Drift Chambers (Junhao Chen)
- Noble Gas (SHMS) and Gas (HMS) Cherenkovs (Murchhana Roy)
- Calorimeters
    - Improved SHMS calibration using the Dec. 2019 defocused runs and lots of statistics from the 2.6 GeV DIS setting

Particle Identification Studies

- Efficiencies, pion rejection, and pion contamination for A_1^n low-momentum DIS setting

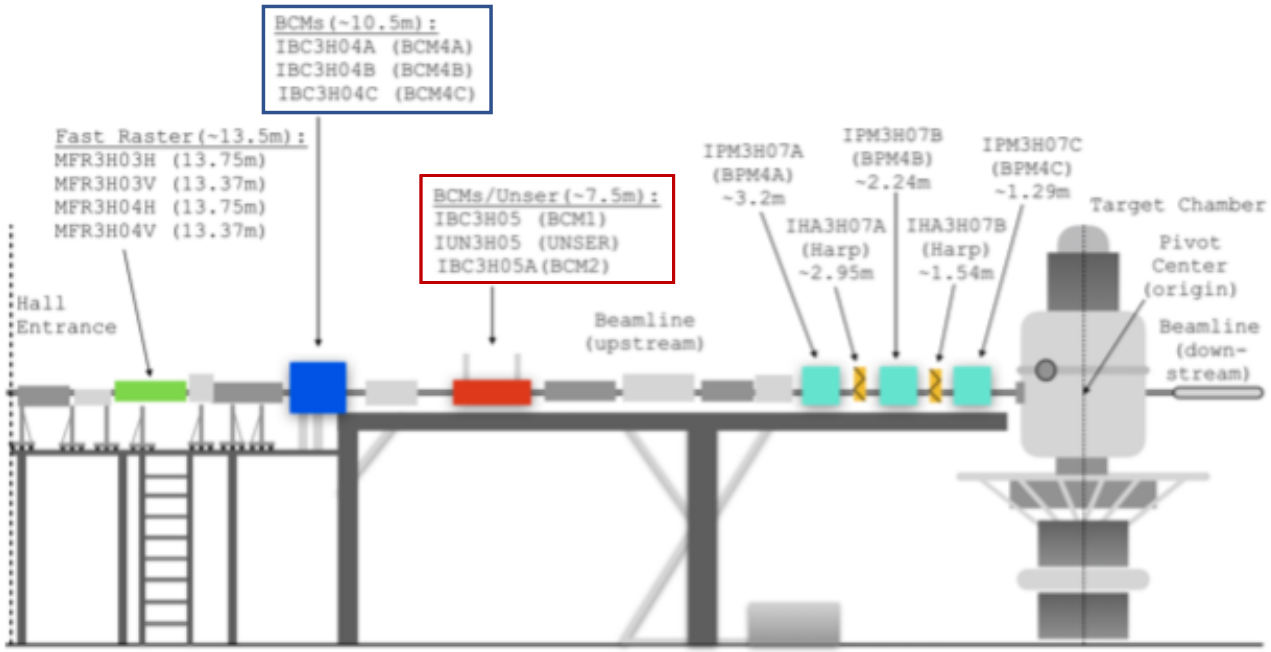






BCM Calibrations

- BCM runs were done twice during A_1^n running:
  - December 18, 2019: SHMS run 9728 and HMS run 2556
  - February 20, 2020: SHMS runs 10402 & 10403, HMS runs 3206 & 3207
  - 5 BCMs: BCM1, BCM2, BCM4A, BCM4B, BCM4C

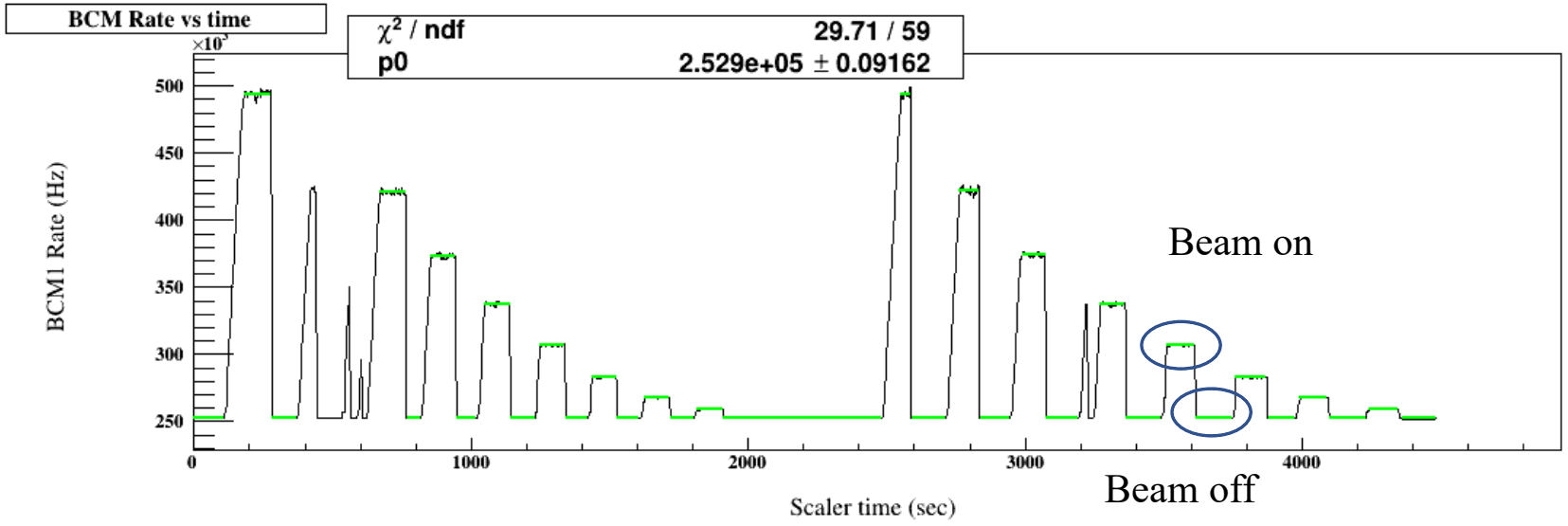


- Checked against calibration done by Dave Mack on the SHMS – our results are consistent with each other
- Gain constants for each BCM derived from each calibration run were used to replay 10 runs across the A1n running period – calculated currents all agreed to less than 1% (usually 0.1%)
- Currently, **results from SHMS 9728 are used in the replay**. Will take the average of the results from both the SHMS and HMS and update the parameter file

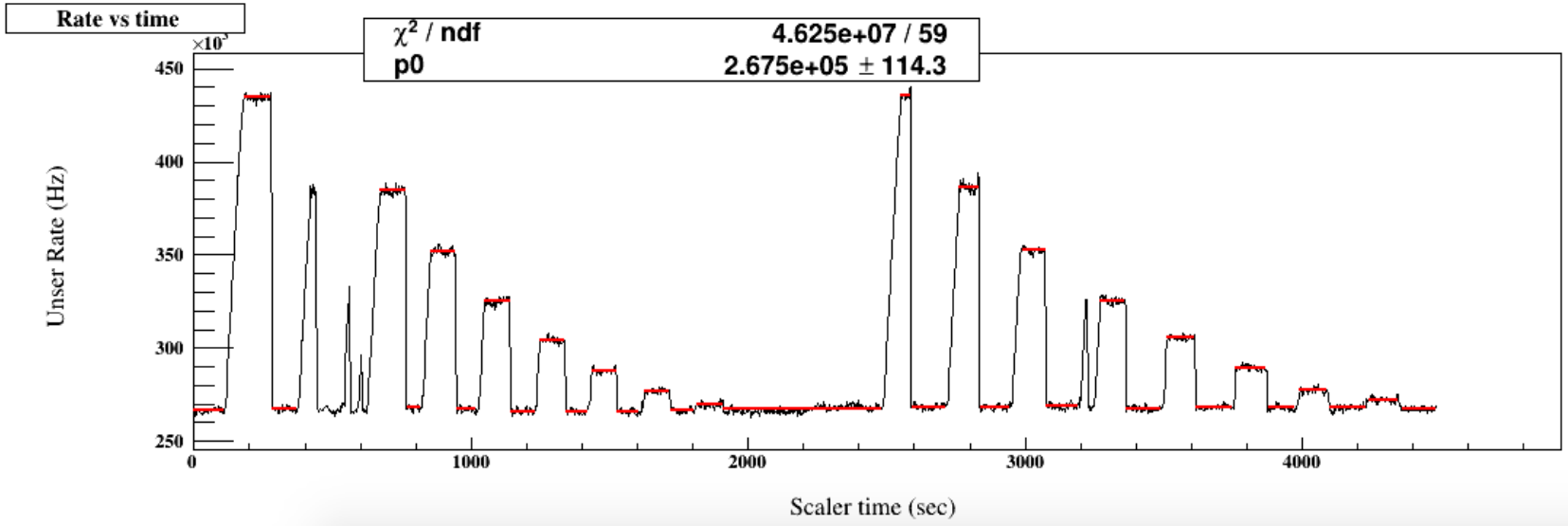
BCM Calibrations

December 18, 2019: SHMS 9728

BCM 1



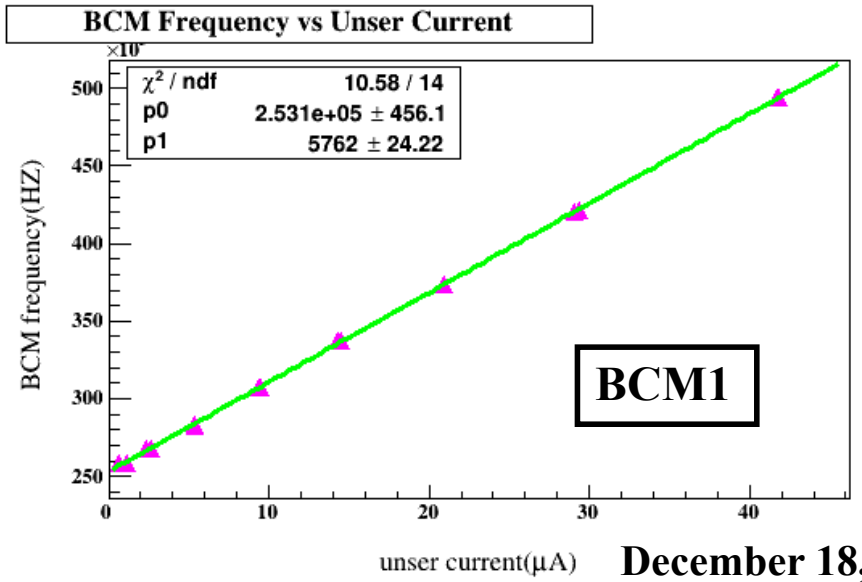
Unser

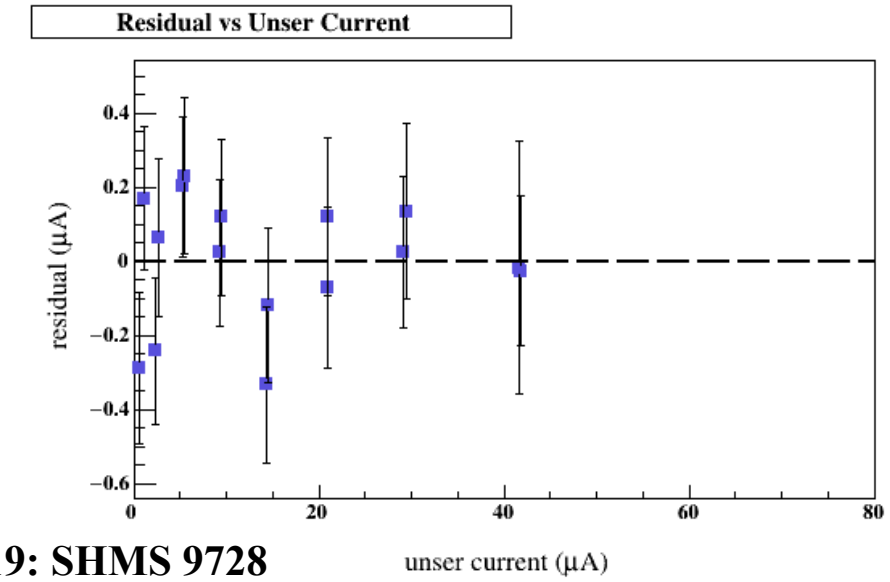


Beam is turned off and on every ~ 2 minutes and incremented in certain steps

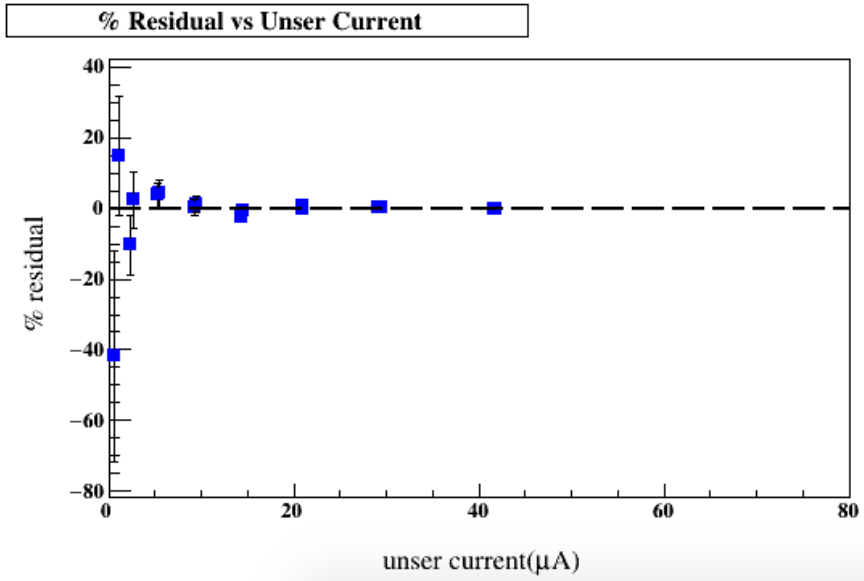
Thank you to Debaditya Biswas for his calibration code!

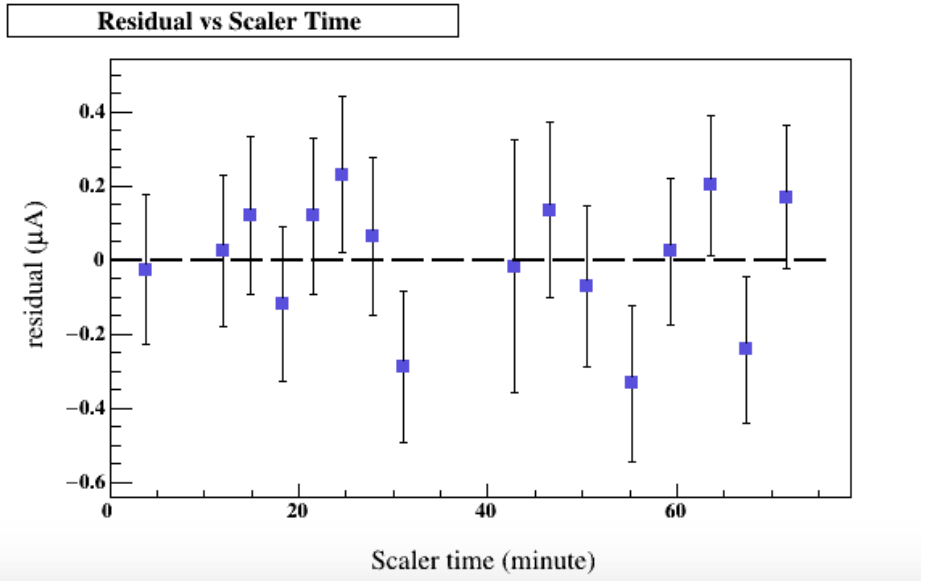
BCM Calibrations





December 18, 2019: SHMS 9728





Unser Current = Unser Gain*Δf_{BCM}

0.0002492 uA/Hz

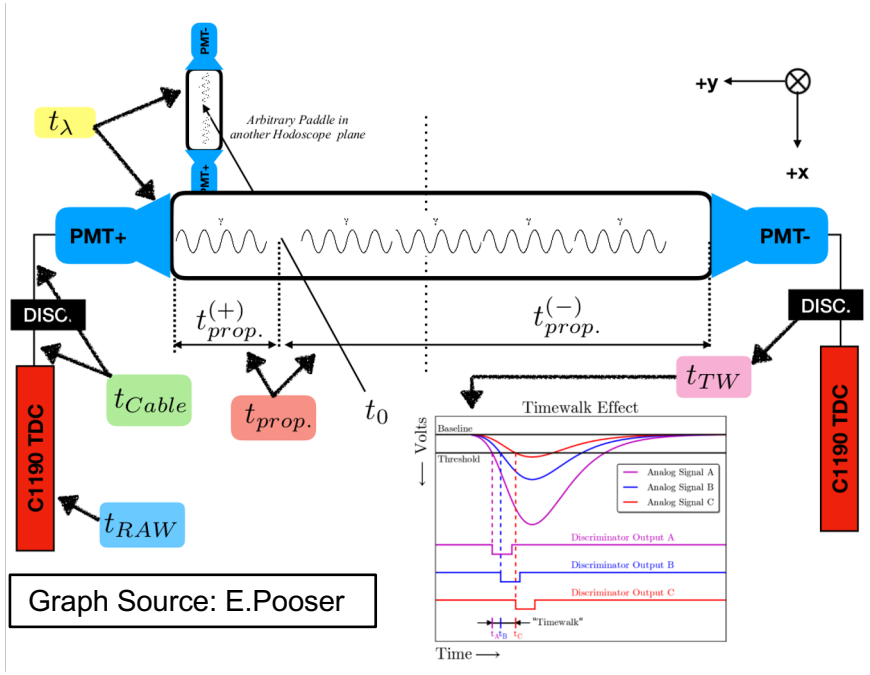
Residual (uA) = $I_{Unser} - I_{BCM}$

$$I_{BCM} = \frac{\Delta f - offset}{gain}$$

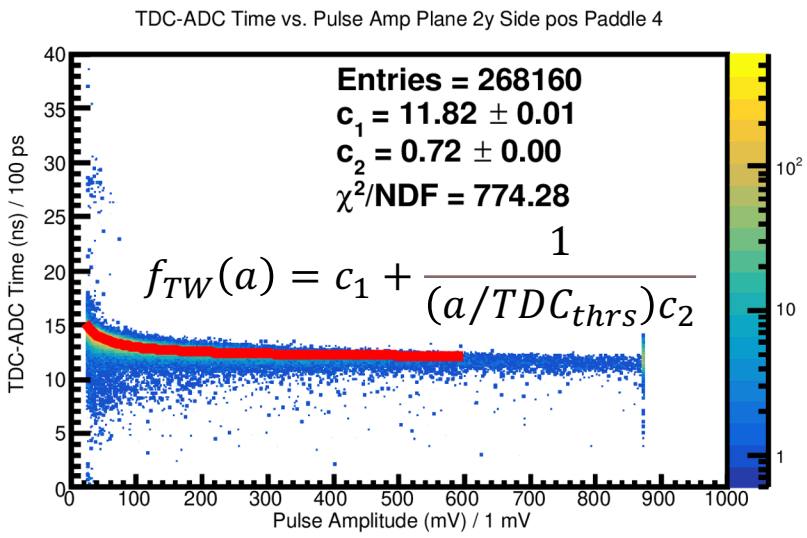
p1 = "gain" is in [Hz/uA] (so technically 1/gain)

p0 = offset [Hz]

HMS Hodoscope Calibration



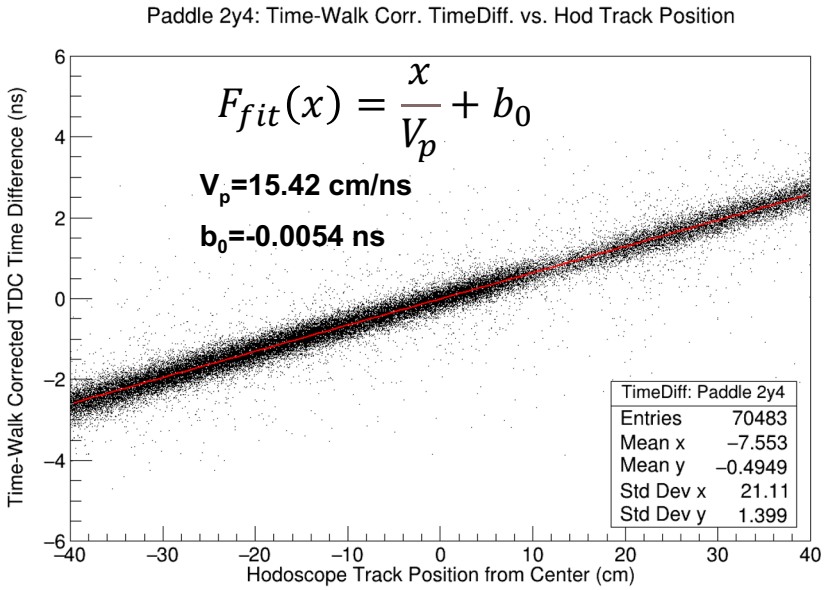
Graph Source: E.Pooser



- HMS 3994: ^{3}He DIS, d_2^n
- Longitudinal 180 deg
- Kin-B: E_p=6.4 GeV, 14.5°
- Trigger: 3/4 (hTRIG1)

- a is ADC amplitude; TDC_{thrs}=120 mV

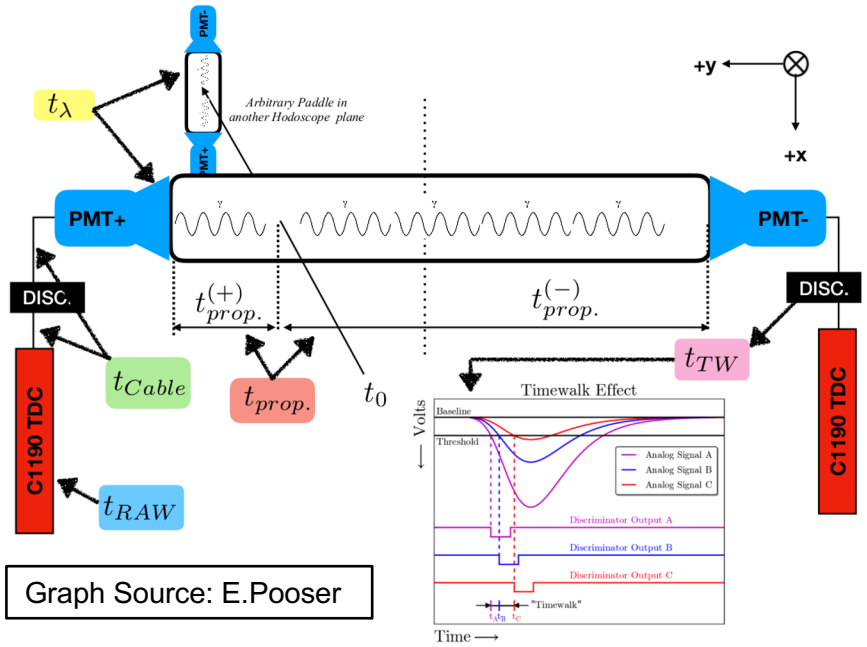
$$t_{Corr} = t_{RAW} - t_{TW} - t_{Cable} - t_{propagation} - t_\lambda$$



- t_{TW} : Time-walk Corrections
- t_{cable}: Cable Time Corrections
- t_{prop}: Propagation Time Corrections
- t_λ: Hodoscope Planes Time Difference Corrections

Slides courtesy of Mingyu Chen, University of Virginia

HMS Hodoscope Calibration



Graph Source: E.Pooser

$$t_{Corr} = t_{RAW} - t_{TW} - t_{Cable} - t_{propagation} - t_{\lambda}$$

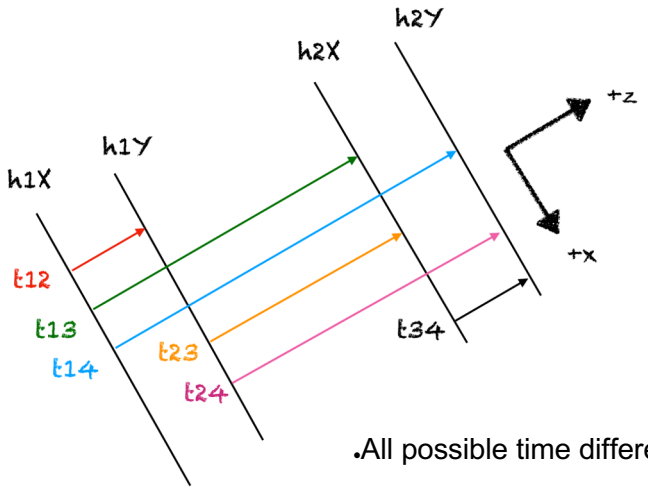
$$t^{(+)}_{Corr.} = t^{(+)}_{Corr.} - (L_+ - \text{hit})\frac{1}{v_p}, \text{ where } t^{(+)}_{prop.} \equiv (L_+ - \text{hit})\frac{1}{v_p}$$

$$t^{(-)}_{Corr.} = t^{(-)}_{Corr.} - (\text{hit} - L_-)\frac{1}{v_p}, \text{ where } t^{(-)}_{prop.} \equiv (\text{hit} - L_-)\frac{1}{v_p}$$

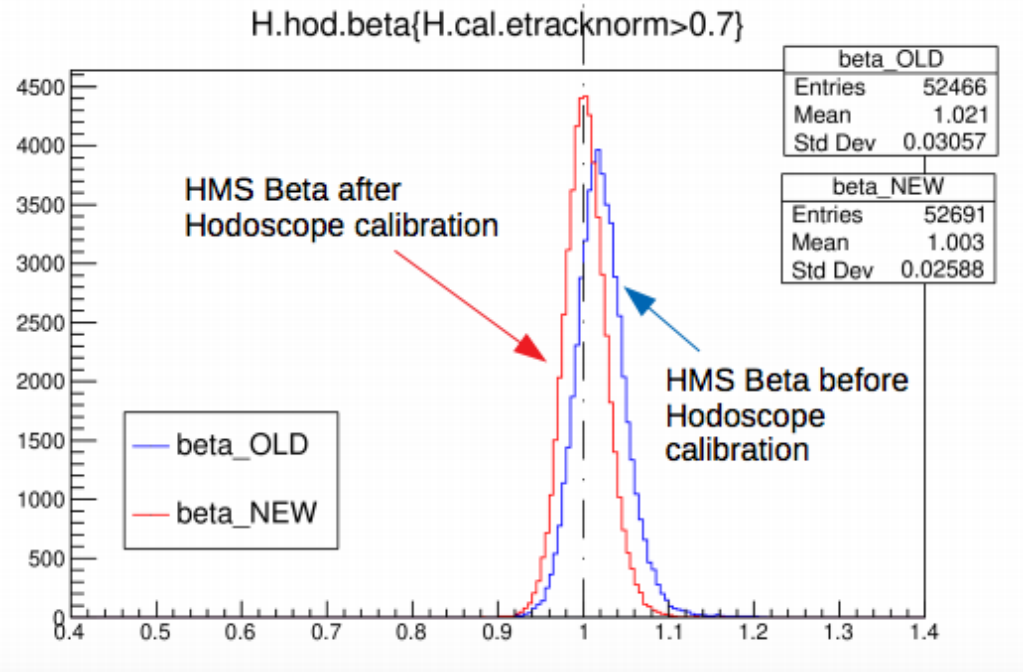
$$t_{avgCorr.} = \frac{1}{2}(t^{(+)}_{Corr.} + t^{(-)}_{Corr.}) = \frac{1}{2}(t^{(+)}_{TW_{Corr.}} + t^{(-)}_{TW_{Corr.}})$$

- This correction is done in hcana.

- HMS 3994: ^{3}He DIS, d_2^n
- Longitudinal 180 deg
- Kin-B: E_p=6.4 GeV, 14.5°
- Trigger: 3/4 (hTRIG1)

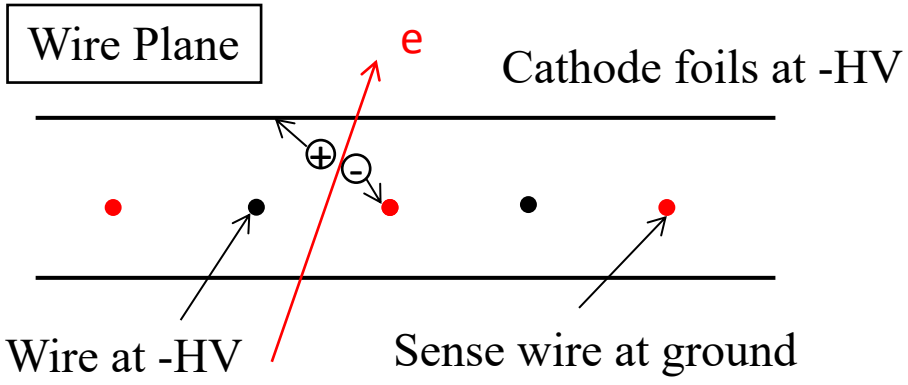


- All possible time difference combinations considered;
- solve the system of six linear equations.

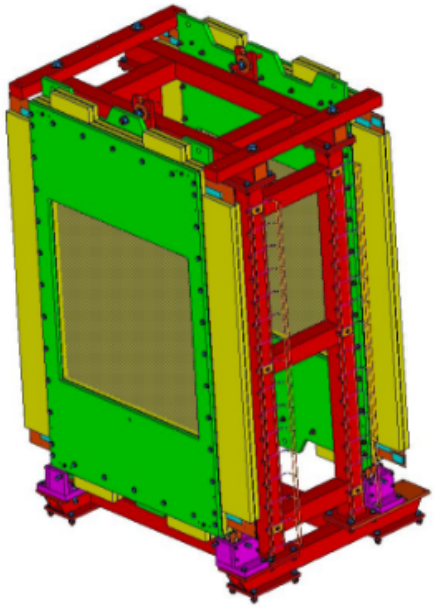


Slides courtesy of Mingyu Chen, University of Virginia

SHMS & HMS DC Calibrations



Drift Chamber



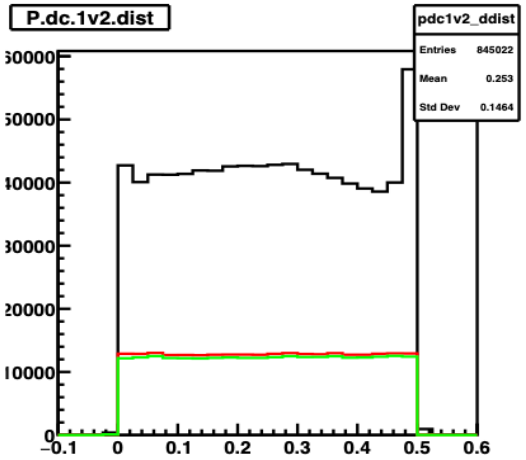
- Validated HMS Drift Chamber calibration with existing calibration parameters
- Due to updated SHMS Hodoscope calibration parameters, recalibrated SHMS Drift Chamber for different versions of Hodoscope calibration params.
- Developed a more reliable t_0 per wire fitting method
  - Fit t_0 integrated drift time with piecewise function.
  - For wires without enough events, combined adjacent wires for fitting t_0. A flexible combination of the pre-existing per-wire and per-card fitting method.

Related Talks:
https://hallcweb.jlab.org/DocDB/0008/000863/003/HallC-Software-Workshop_pdf.pdf
https://hallcweb.jlab.org/elogs/A1n-d2n+Combined+Analysis/41
https://hallcweb.jlab.org/elogs/A1n-d2n+Combined+Analysis/201013_135648/New_Method_tzero_Fit_per_Wire.pdf

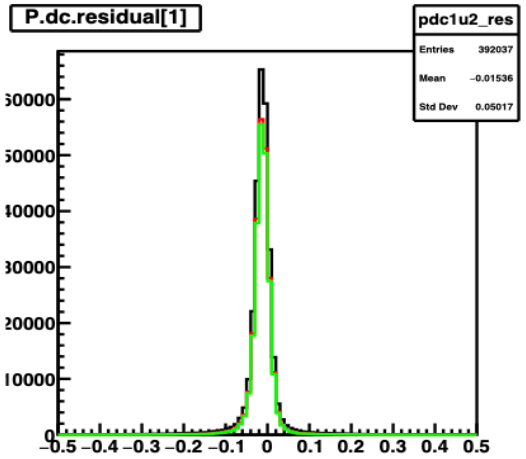
Slides courtesy of Junhao Chen, College of William & Mary

SHMS & HMS DC Calibrations

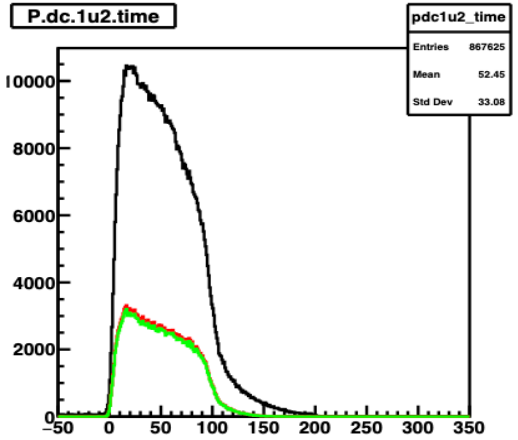
Calibrated Drift Distance



Calibrated Residual

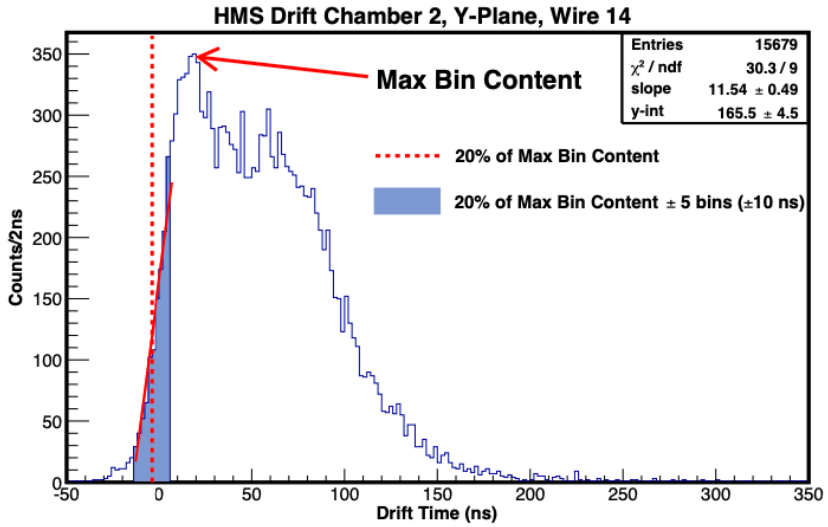


Calibrated Drift Time

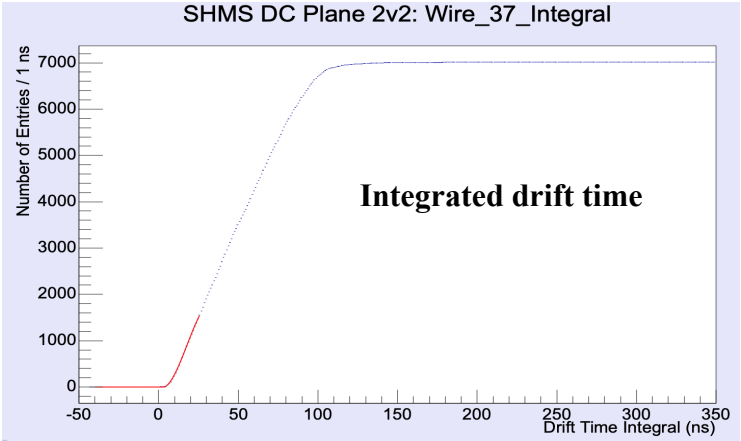


no cut
nhit. = 1 cut
electron cut

Slides courtesy of Junhao Chen, College of William & Mary



Original t_0 fitting, t_0 is the intersection of the fit line (red) and x-axis. Plot credit to Carlos Yero.



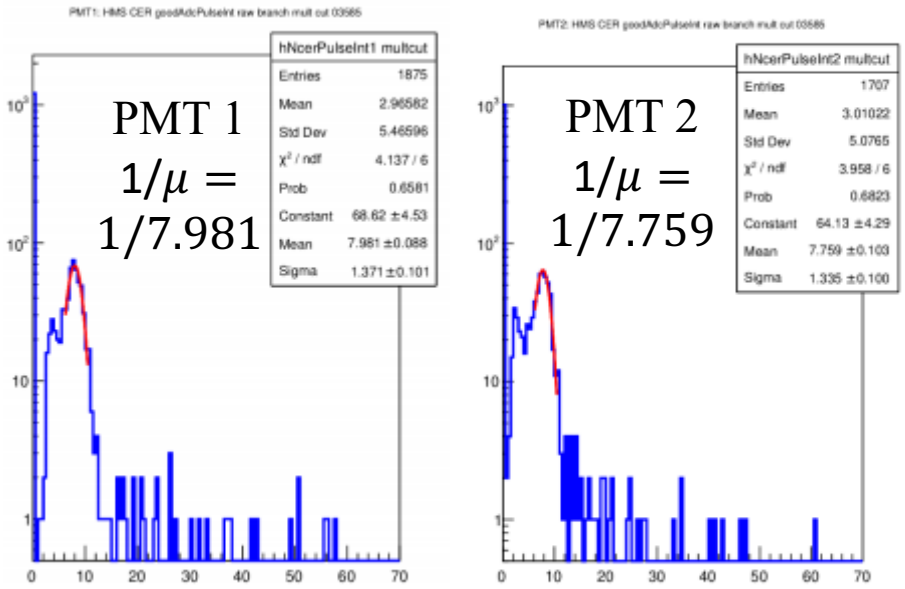
New t_0 fitting method: t_0 is the discontinuity point of the piecewise function (red).

SHMS & HMS Cherenkov Calibrations

HMS Cosmics Run 3585:

Gaussian Fit to

`goodAdcPulseInt(multiplicity ==1)`

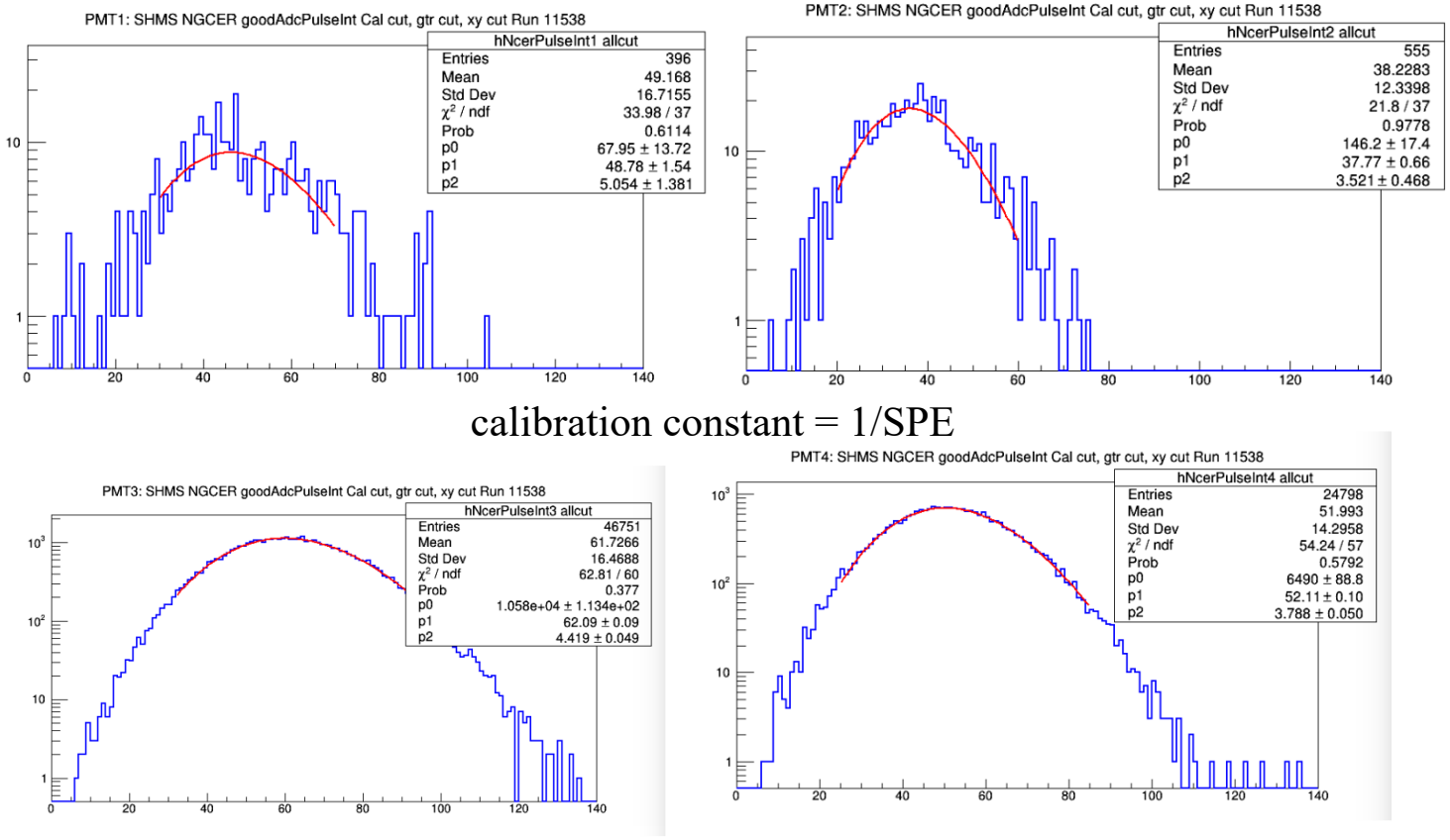


Plots courtesy of Murchhana Roy, University of Kentucky

SHMS Run 11538

$NPE \sim \mu^2/\sigma^2$

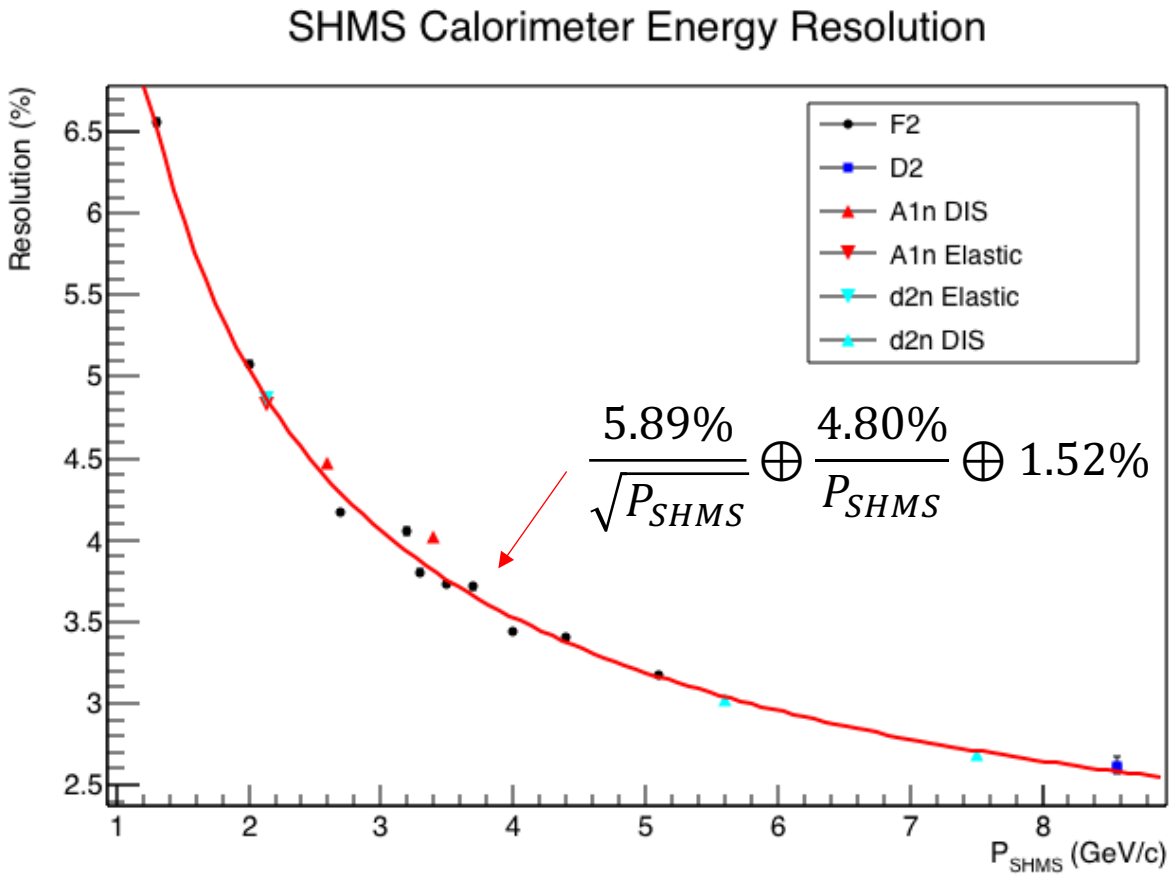
$\text{SPE} \sim \mu/NPE$



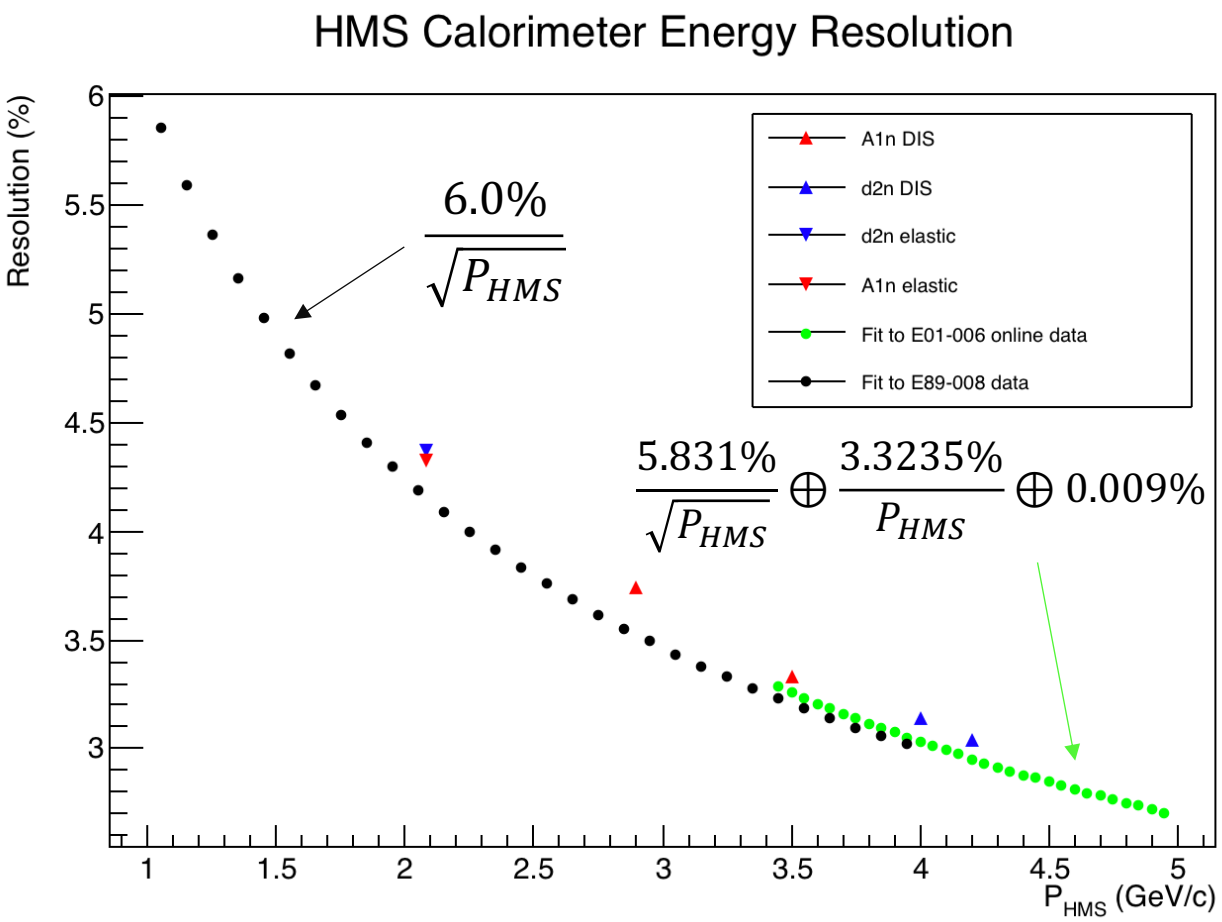
calibration constant = 1/SPE

- `0.80 < P.cal.etottracknorm < 1.4` to choose electrons
- X & Y cuts at the mirror planes
- Gaussian Fit to `goodAdcPulseInt(multiplicity ==1)` to ensure only the PMT under calibration has a hit

SHMS & HMS Calorimeter Energy Resolution

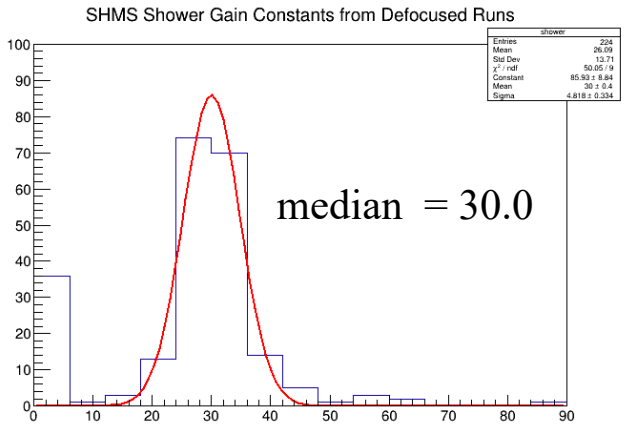


Resolution is extracted from the gausssian fit of the E/P peak (σ/μ)



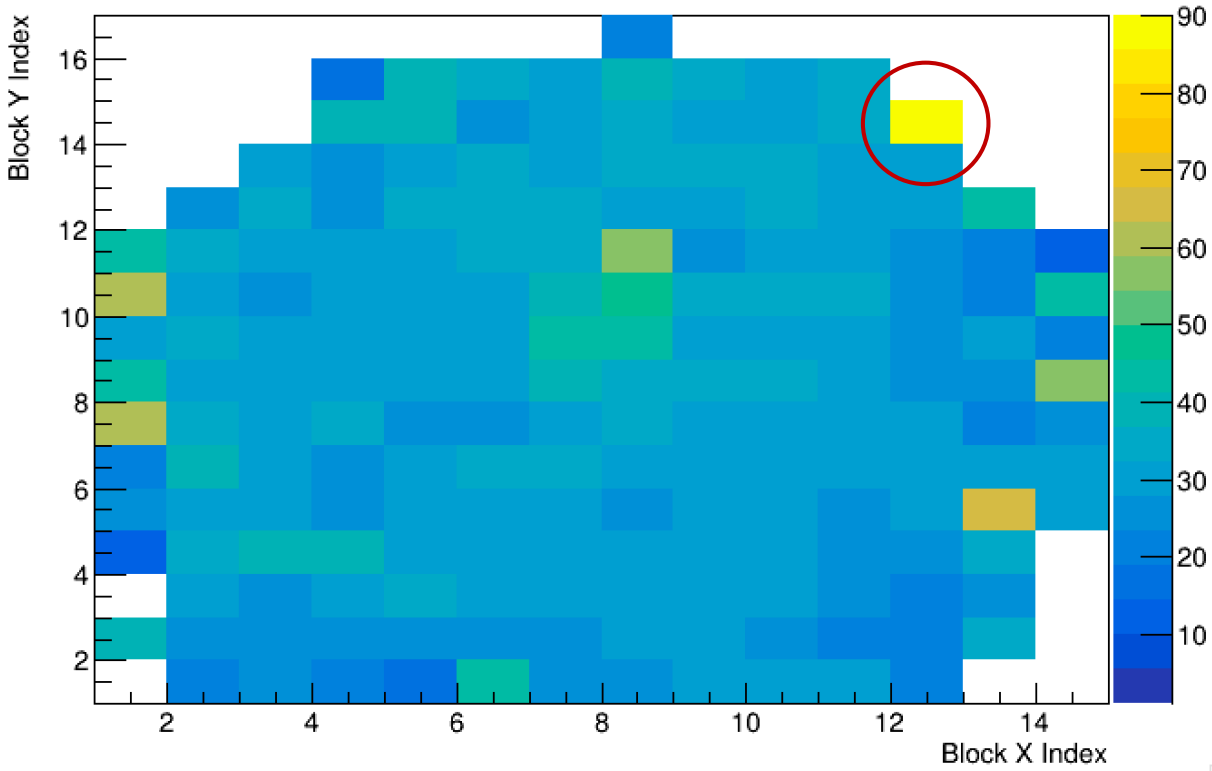
✓ A1n/d2n points are consistent with one another

Improving the SHMS Defocused Runs Calibration

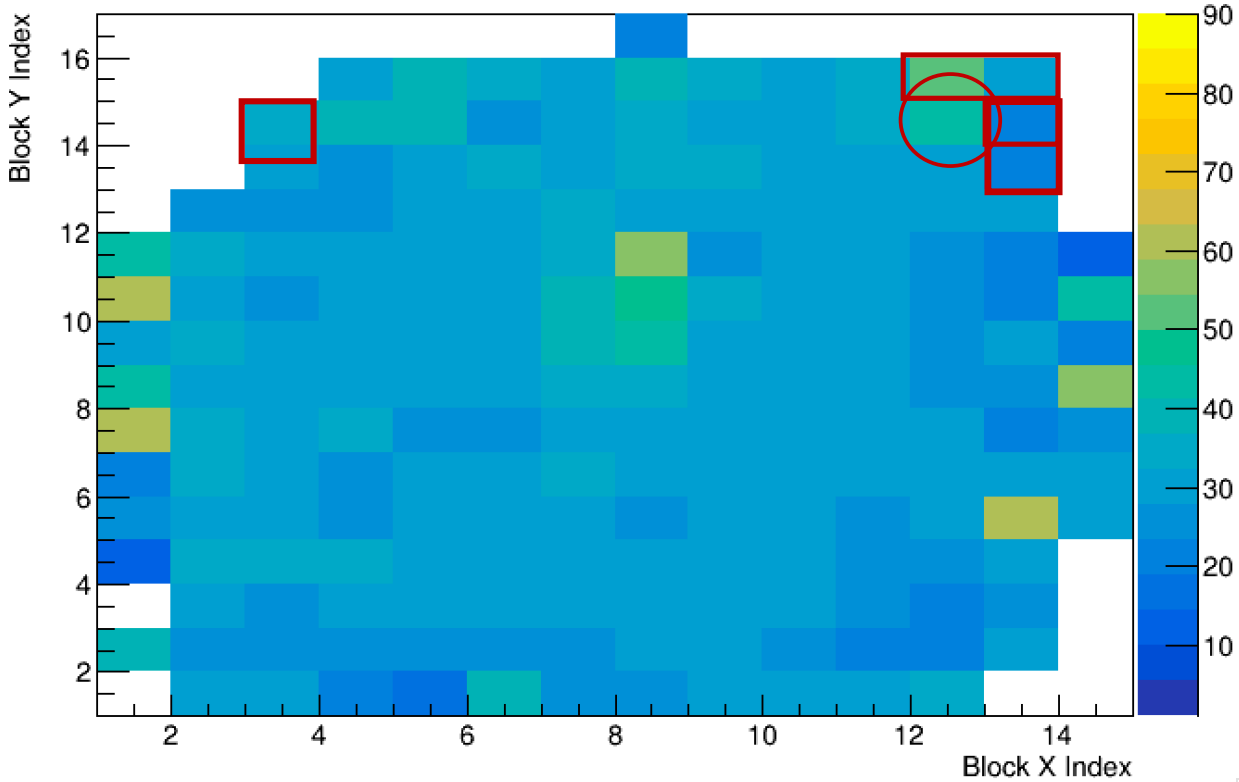


- **Defocused Runs** were taken in Dec. 2019 to illuminate as many blocks of the shower array as possible for calibration
- Gains of a few PMTs largely deviated from the median value

- Calibrating a large set of 2.6 GeV DIS runs provided events for some blocks not covered with the defocused runs
- The two sets were **merged** to bring the PMT gain constants towards closer agreement



SHMS Shower Map: Merged Gain Constants



Particle Identification (PID) Studies

We're measuring an asymmetry, so we need **clean electron** detection

The SHMS & HMS have two independent detectors for PID:

1. The **Gas Cherenkov**

$$Cherenkov\ Efficiency = \frac{electron\ sample\ that\ passed\ the\ Cherenkov\ cut}{electron\ sample\ selected\ with\ the\ Calorimeter}$$

$$Cherenkov\ PR\ Factor = \frac{pion\ sample\ selected\ with\ the\ Calorimeter}{pion\ sample\ that\ passed\ the\ Cherenkov\ cut}$$

→ e^-, π samples determined by the Calorimeter, Cherenkov used for PID

2. The Lead-Glass **Calorimeter**

$$Calorimeter\ Efficiency = \frac{electron\ sample\ that\ passed\ the\ etracknorm\ and\ eprtracknorm\ cut}{electron\ sample\ selected\ with\ the\ Cherenkov}$$

$$Calorimeter\ PR\ Factor = \frac{pion\ sample\ selected\ with\ the\ Cherenkov}{pion\ sample\ that\ passed\ the\ etracknorm\ and\ eprtracknorm\ cut}$$

→ e^-, π samples determined by the Cherenkov, Calorimeter used for PID

Combined Pion Rejection Factor = $PRF_{cherenkov} * PRF_{calorimeter}$

PID: Noble Gas Cherenkov (NGC) Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

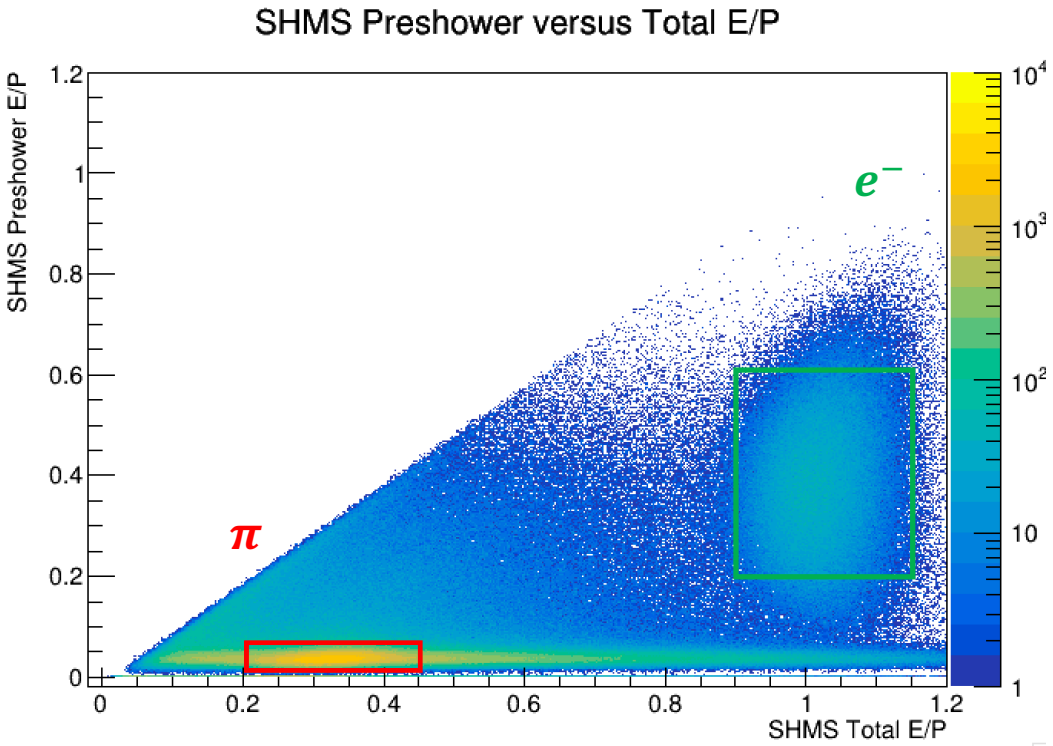
Noble Gas Cherenkov (NGC)

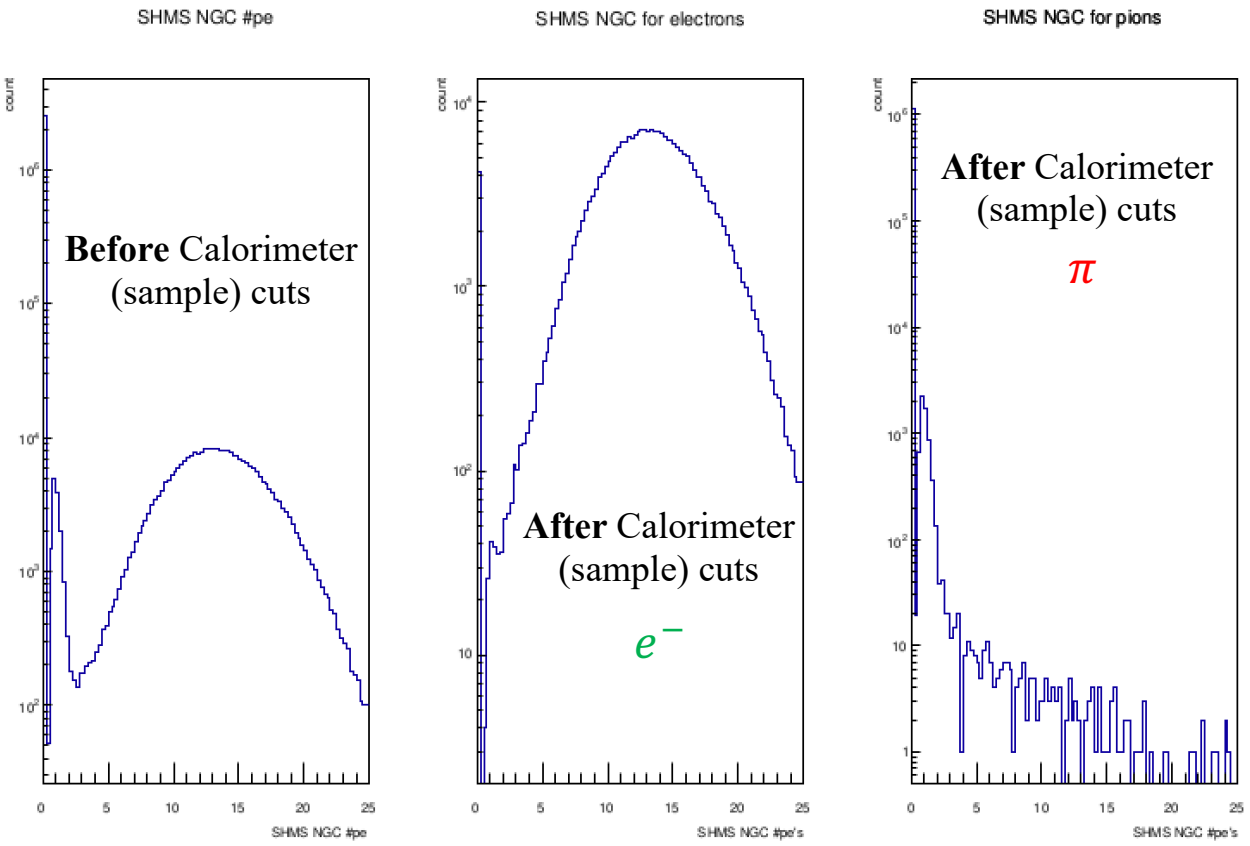
Step 1: Use 2D Graphical Cuts to determine π and e^- samples

Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV
$\theta_c = 1.35°$

`0.90 < Total E/P < 1.15`
`&&`
`0.20 < Preshower E/P < 0.60`

`0.20 < Total E/P < 0.45`
`&&`
`0.02 < Preshower E/P < 0.05`





PID: Noble Gas Cherenkov (NGC) Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

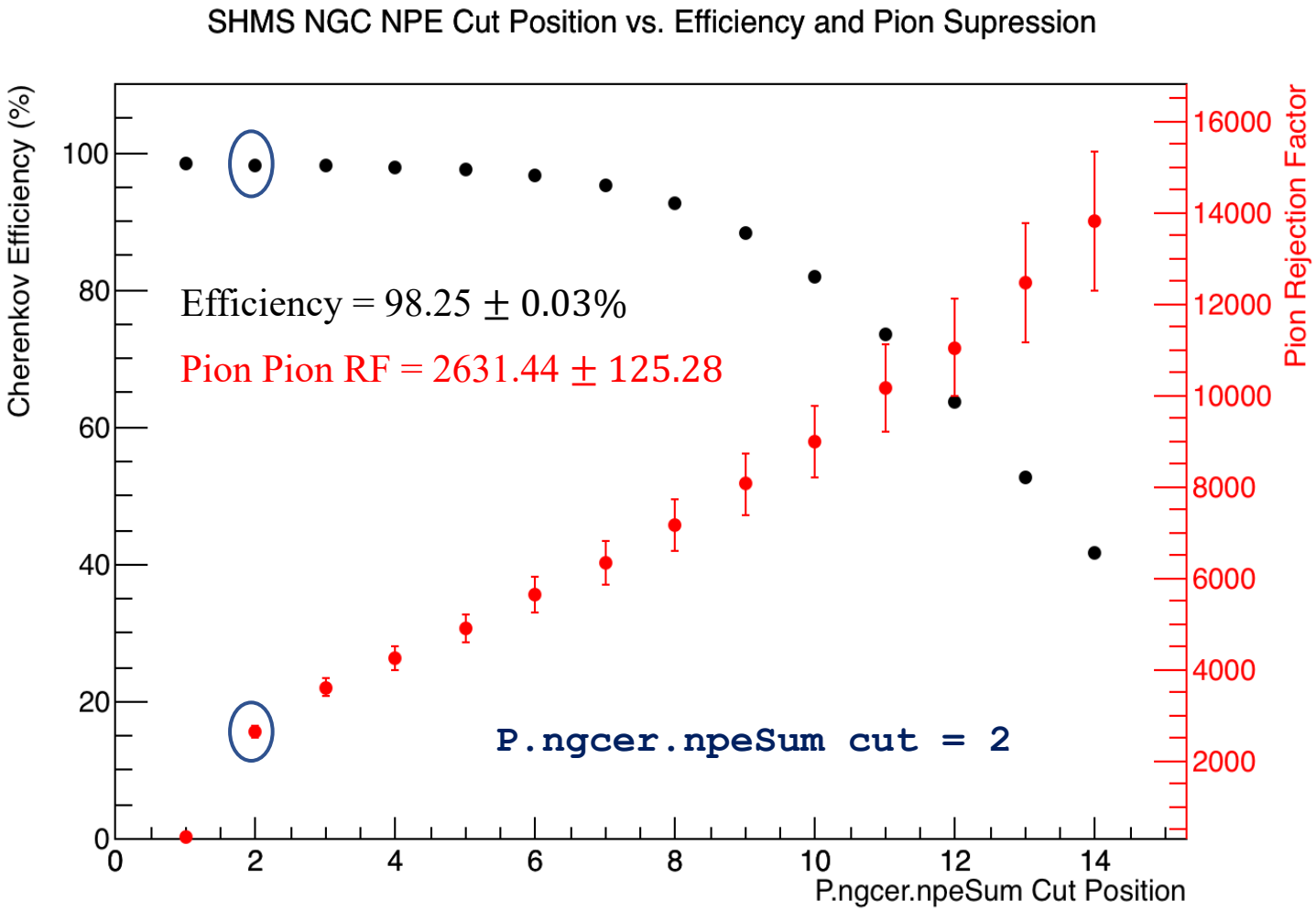
Noble Gas Cherenkov (NGC)

Step 2: Determine how many
e^- and π pass the NGC sum cut

Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV
$\theta_c = 1.35°$

```
0.90 < Total E/P < 1.15
&&
0.20 < Preshower E/P < 0.60
```

```
0.20 < Total E/P < 0.45
&&
0.02 < Preshower E/P < 0.05
```



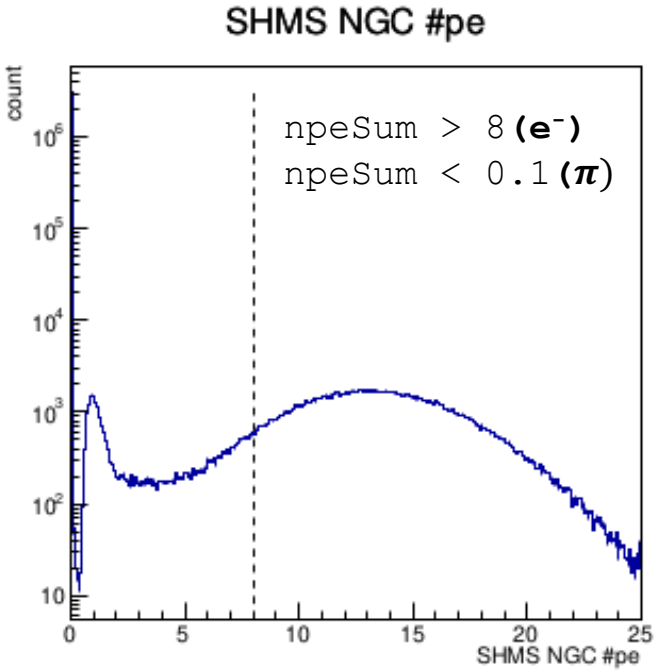
Acceptance Cuts:
```
-12 < P.gtr.dp < 25
|P.gtr.ph| < 0.07
|P.gtr.th| < 0.05
|P.react.z| < 22
shower E/P > 0
```

PID: Calorimeter Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

Calorimeter

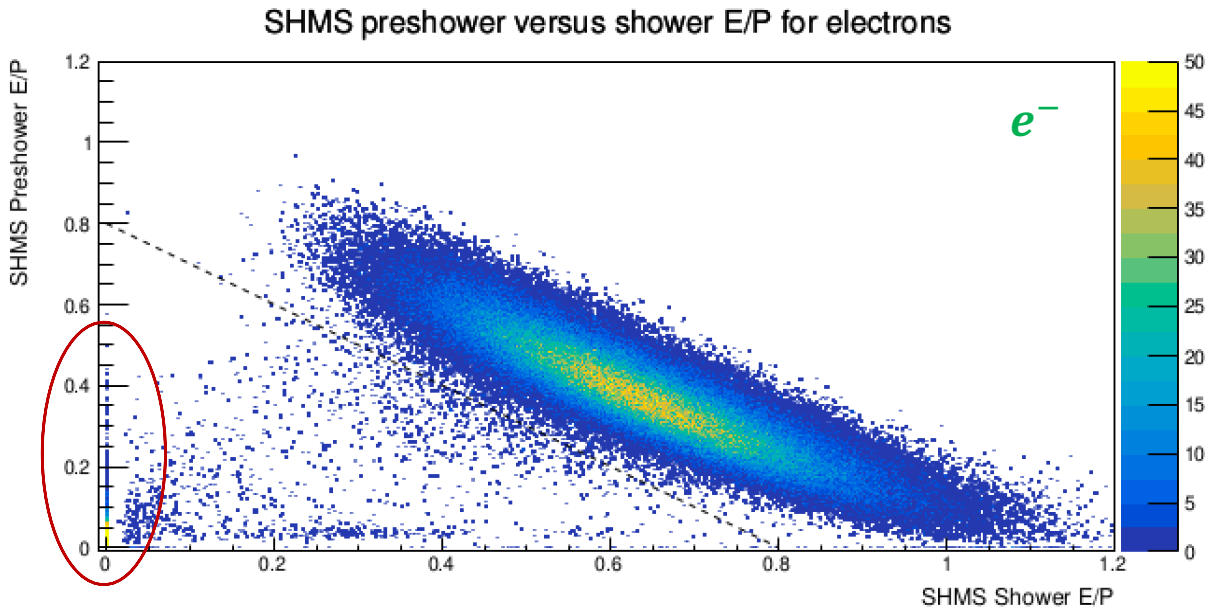
Step 1a: Use the NGC npe sum cut to determine π and e^- samples

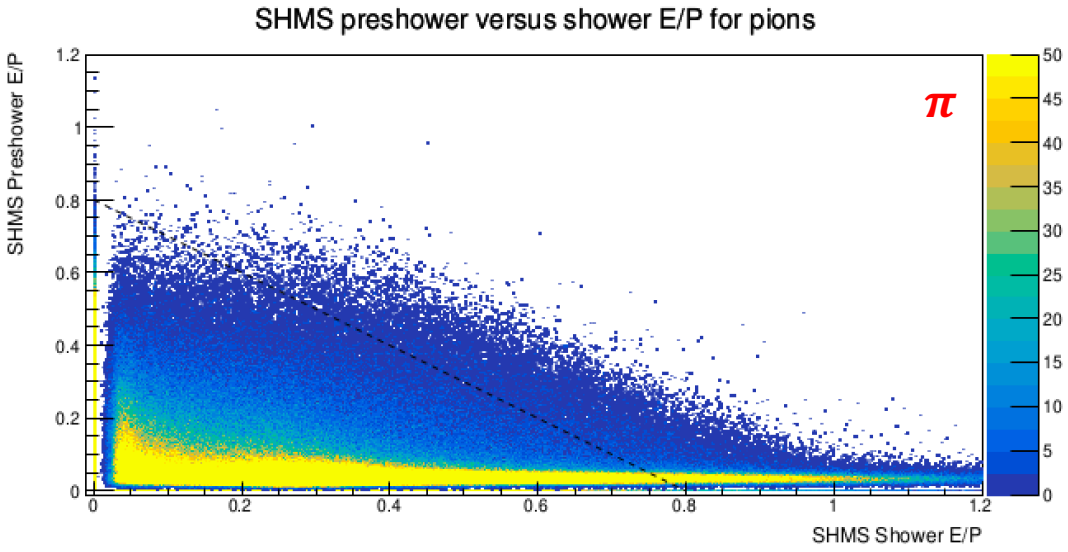


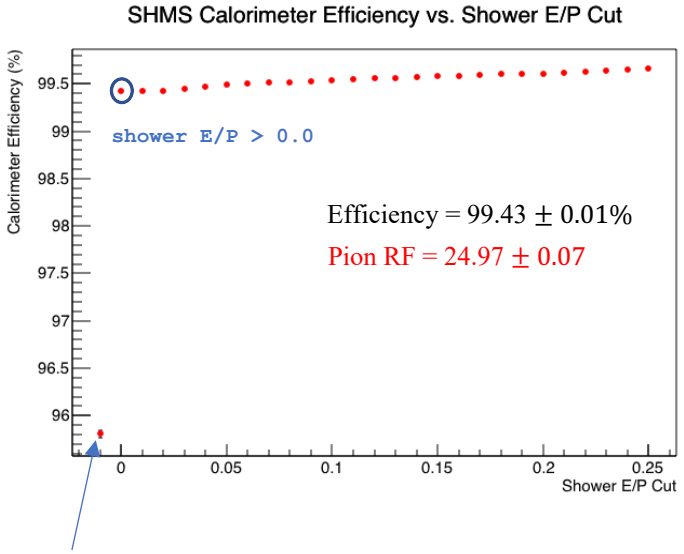
Low-energy electrons are surviving the Cherenkov cut but not making the total calorimeter cut (dying in the pre-shower)

Step 1b:

To ensure we're counting only good electrons, impose a **cut on the shower energy > 0.0**







no shower E/P cut

PID: Calorimeter Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

Calorimeter

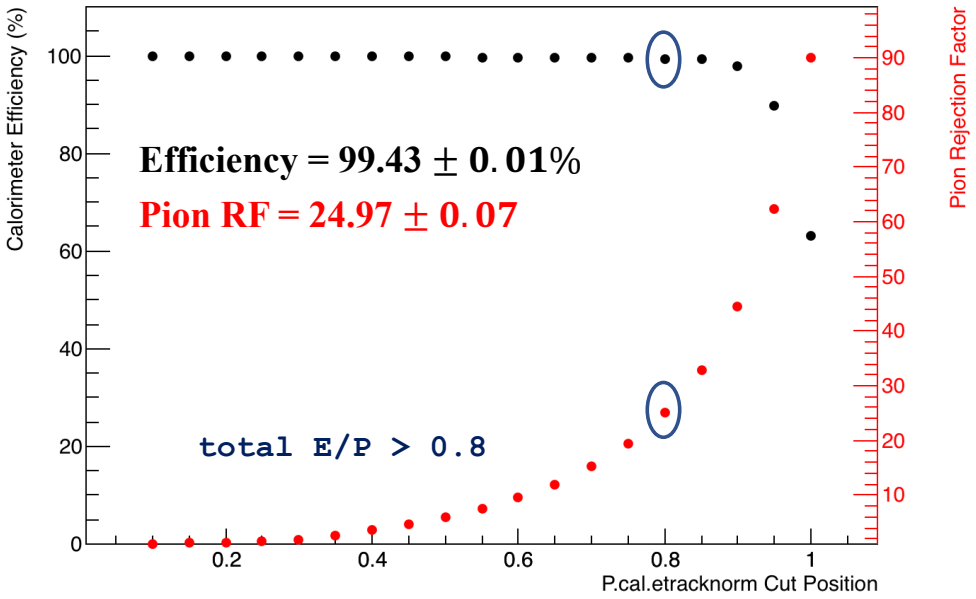
Acceptance Cuts:
`-12 < P.gtr.dp < 25`
`|P.gtr.ph| < 0.07`
`|P.gtr.th| < 0.05`
`|P.react.z| < 22`

Sample Cuts:
`P.ngcer.npeSum > 8` **(e^-)**
`P.ngcer.npeSum < 0.1` **(π)**

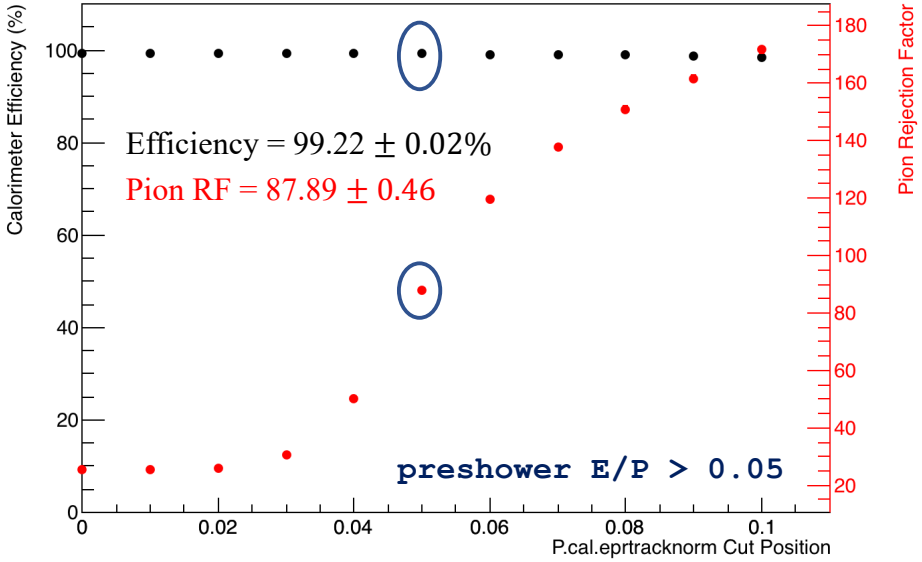
PID Cuts:
`P.cal.etracknorm > 0.80`

Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV

Step 2: Determine how many e^- and π pass the total E/P cut



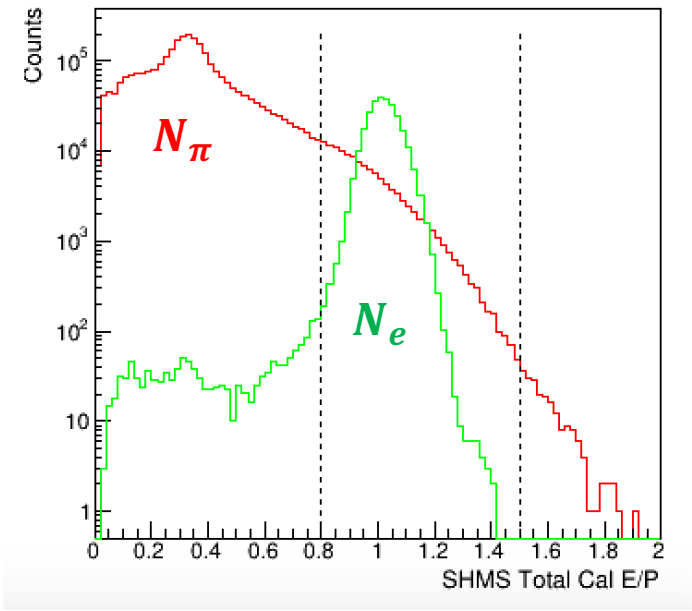
→Add a preshower cut to the PID cut for a PRF boost



Pion Contamination with a Preshower Cut
pion contamination = N_π/N_e

PID Cuts: `Preshower E/P > 0.05`

`npeSum > 8 && shower E/P > 0`
`npeSum < 0.1`



PC from Calorimeter Only:

Histogram is integrated over `[0.80,1.50]` to **find percentage of pions in electron sample** = **12.93%**

∗ (1/PRF) @ 2 npeSum cut from NGC study (1/2631.44)

PC from Calorimeter + NGC: = **0.01%**

✓ goal is a contamination of < 0.4%

PID: Gas Cherenkov Efficiency & Pion Rejection

HMS Runs:
3181-3183
3186-3205
DIS, Long.
E_p= -2.9 GeV, 30°

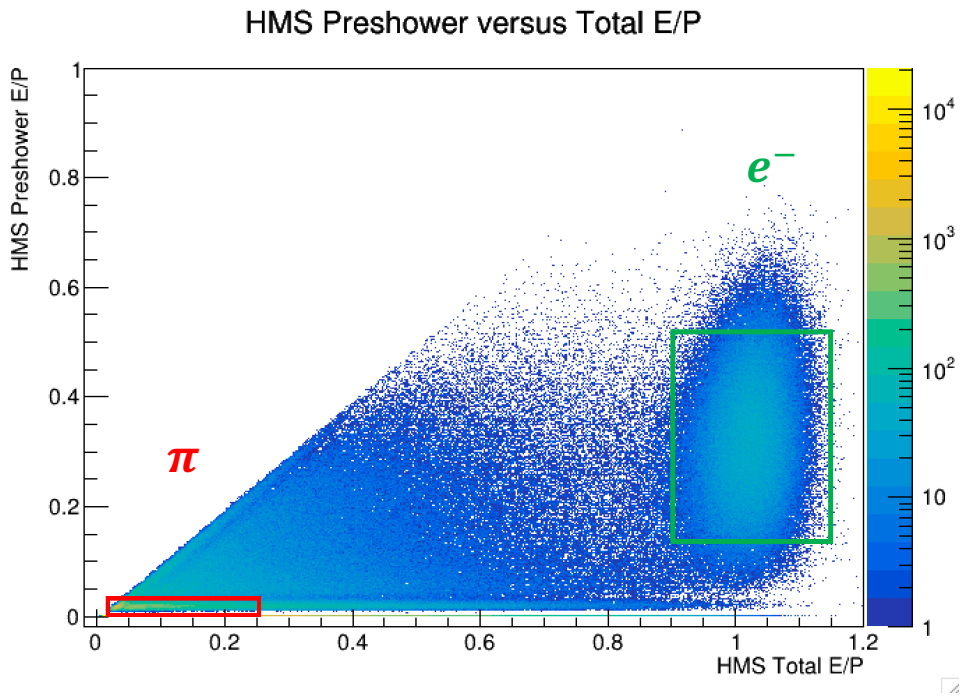
Gas Cherenkov

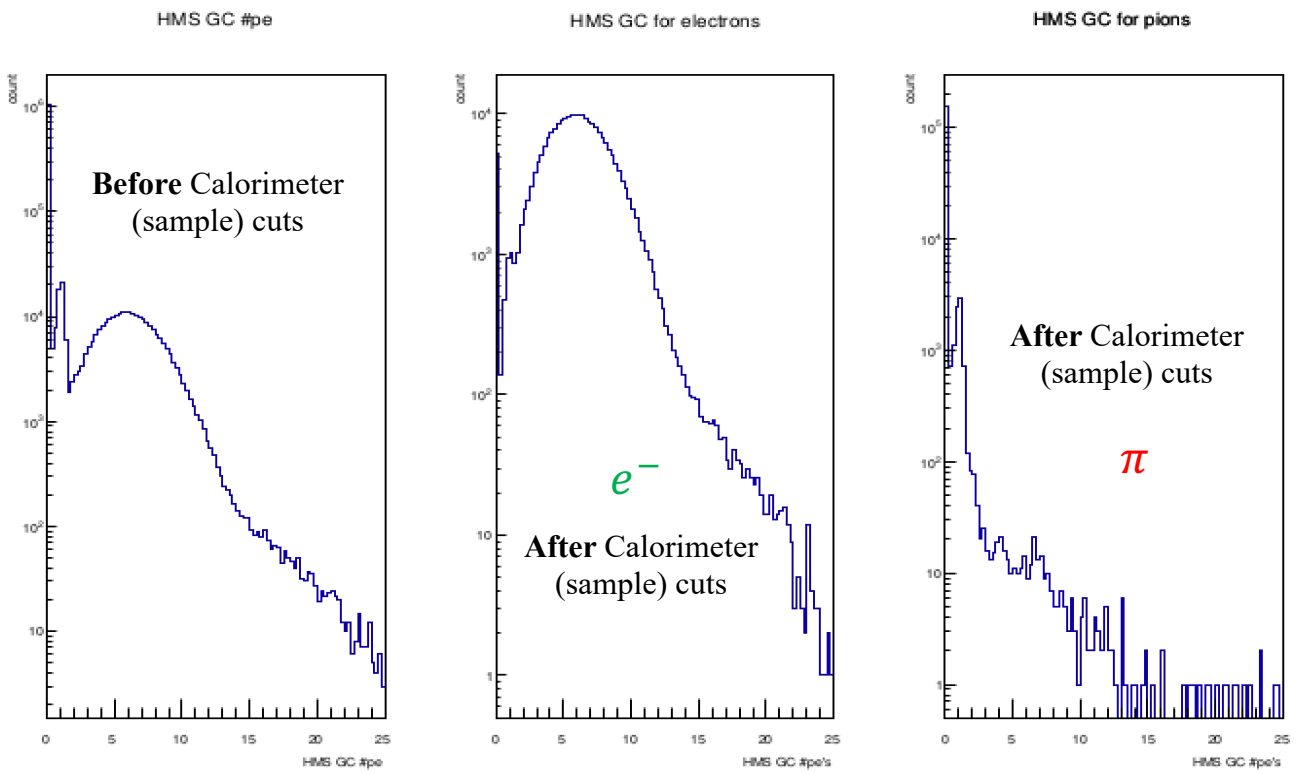
Threshold Energy
C_4F_8O @ 0.225 atm
$\pi^{+,-}$: 5.5 GeV

Step 1: Use 2D Graphical Cuts to determine π and e^- samples

```
0.90 < Total E/P < 1.15
&&
0.10 < Preshower E/P < 0.50
```

```
0.02 < Total E/P < 0.25
&&
0.01 < Preshower E/P < 0.03
```





HMS Cherenkov # npe's

PID: Gas Cherenkov Efficiency & Pion Rejection

HMS Runs:
3181-3183
3186-3205
DIS, Long.
E_p= -2.9 GeV, 30°

Gas Cherenkov

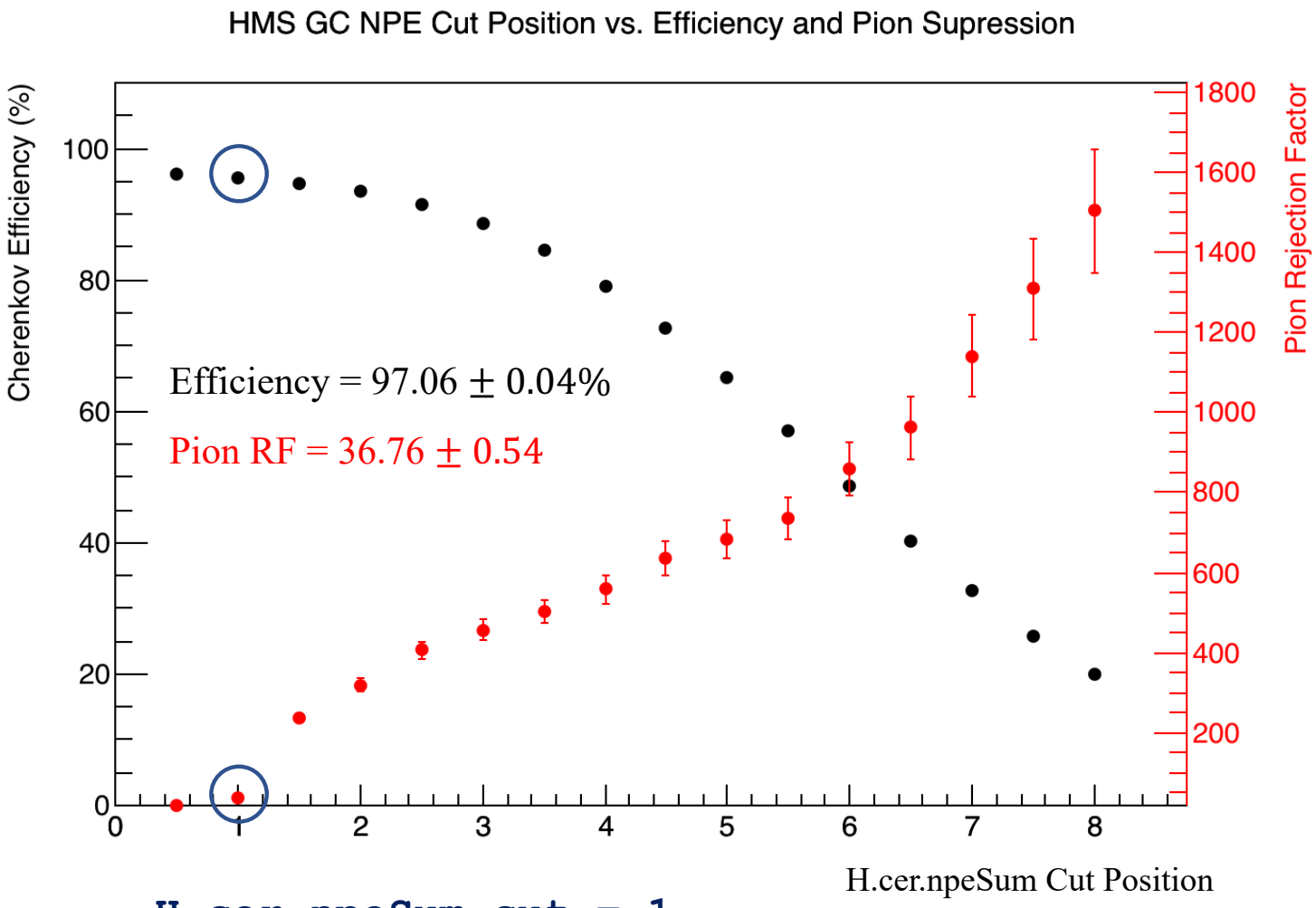
Step 2: Determine how many e^- and π pass the GC sum cut

Threshold Energy
C_4F_8O @ 0.225 atm
$\pi^{+,-}$: 5.5 GeV

```
0.80 < Total E/P < 1.20
&&
0.10 < Preshower E/P < 0.50
```

```
0.03 < Total E/P < 0.25
&&
0.01 < Preshower E/P < 0.03
```

Acceptance Cuts:
```
-10 < H.gtr.dp < 10
|H.gtr.th| < 0.1
|H.gtr.ph| < 0.06
-22 < H.react.z < 22
shower E/P > 0
```



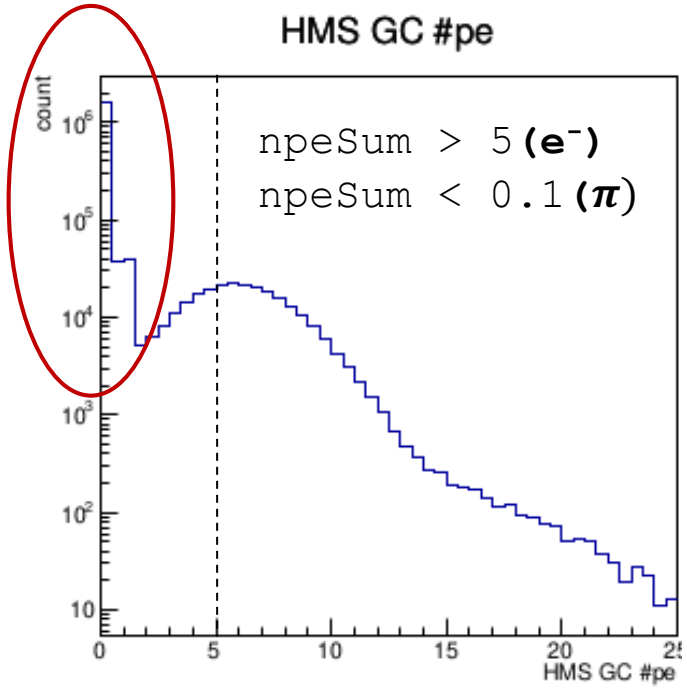
H.cer.npeSum cut = 1

PID: Calorimeter Efficiency & Pion Rejection

HMS Runs:
3181-3183
3186-3205
DIS, Long.
E_p= -2.9 GeV, 30°

Calorimeter

(causing low cherenkov efficiency)

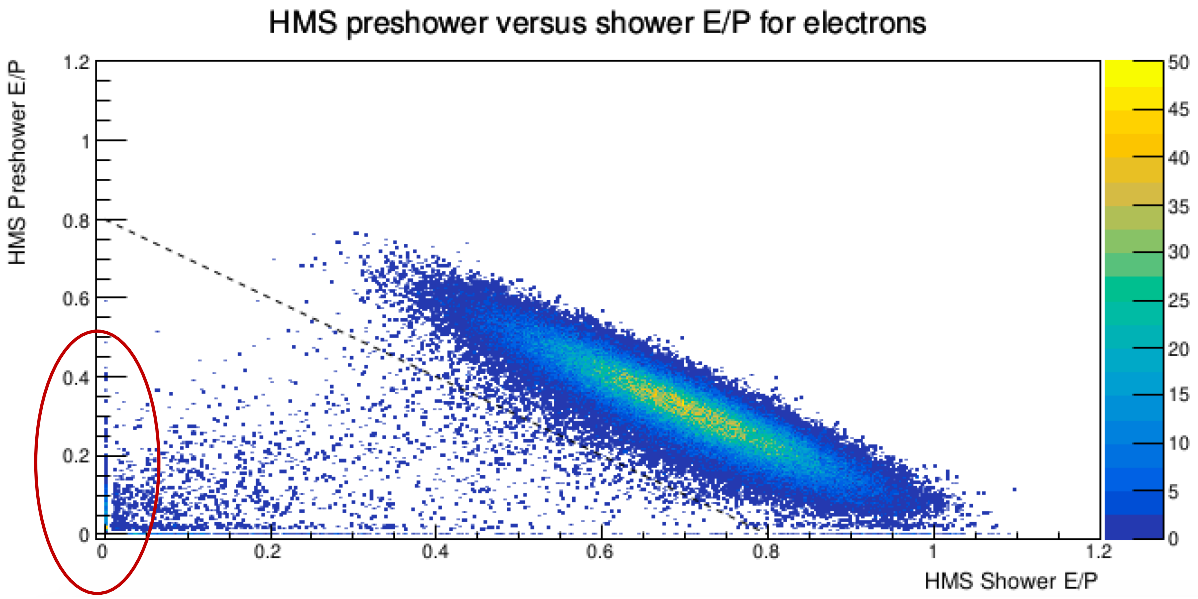


Step 1a: Use the cherenkov npe sum cut to determine π and e^- samples

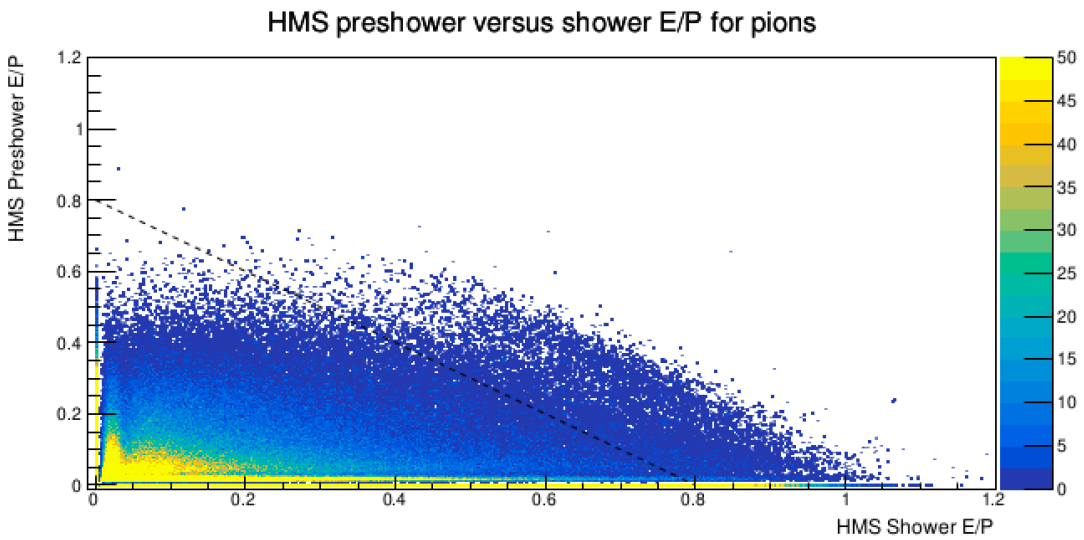
Low-energy electrons are surviving the Cherenkov cut but not making the total calorimeter cut (dying in the pre-shower)

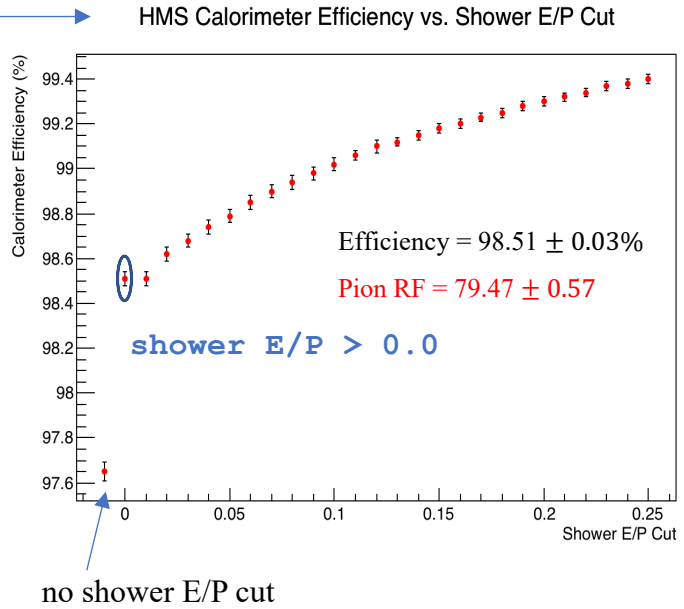
Step 1b:

To ensure we're counting only good electrons, impose a **cut on the shower energy > 0.0**



need to explore upward trend in efficiency against shower E/P cut





PID: Calorimeter Efficiency & Pion Rejection

HMS Runs:
3181-3183
3186-3205
DIS, Long.
E_p= -2.9 GeV, 30°

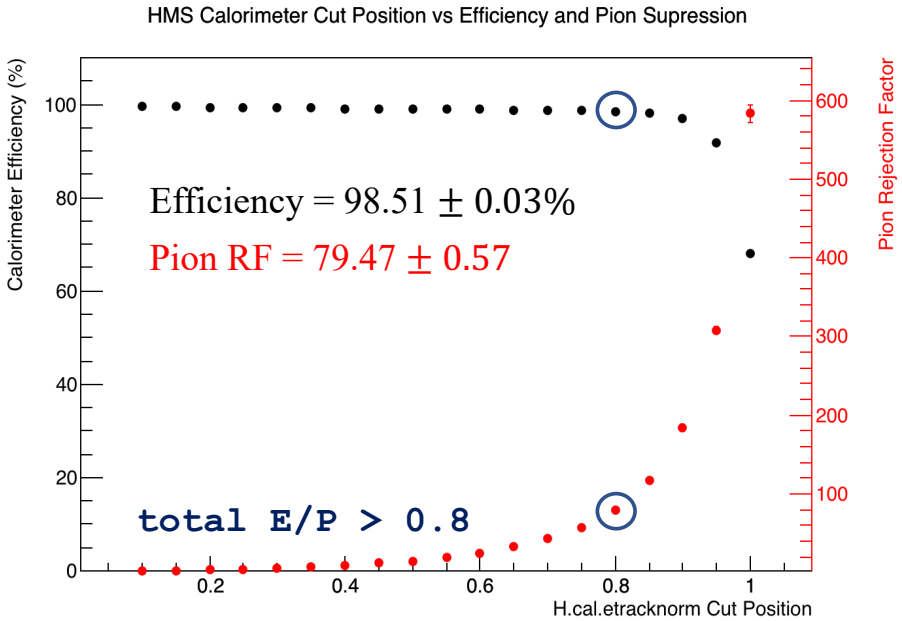
Calorimeter

Acceptance Cuts:
`-10 < H.gtr.dp < 10`
`|H.gtr.th| < 0.1`
`|H.gtr.ph| < 0.06`
`-22 < H.react.z < 22`

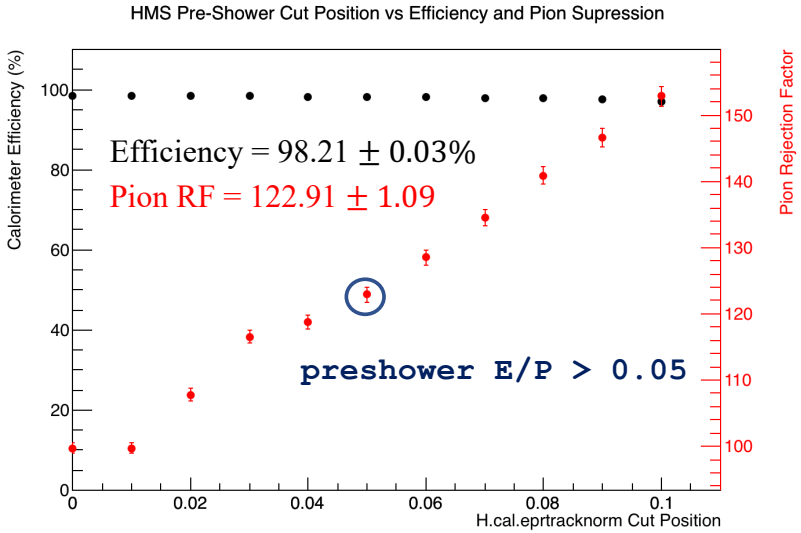
Sample Cuts:
`H.cer.npeSum > 5` **(e^-)**
`H.cer.npeSum < 0.1` **(π)**

PID Cuts:
`H.cal.etracknorm > 0.80`

Step 2: Determine how many e^- and π pass the total E/P cut



→Add a preshower cut to the PID cut for a PRF boost



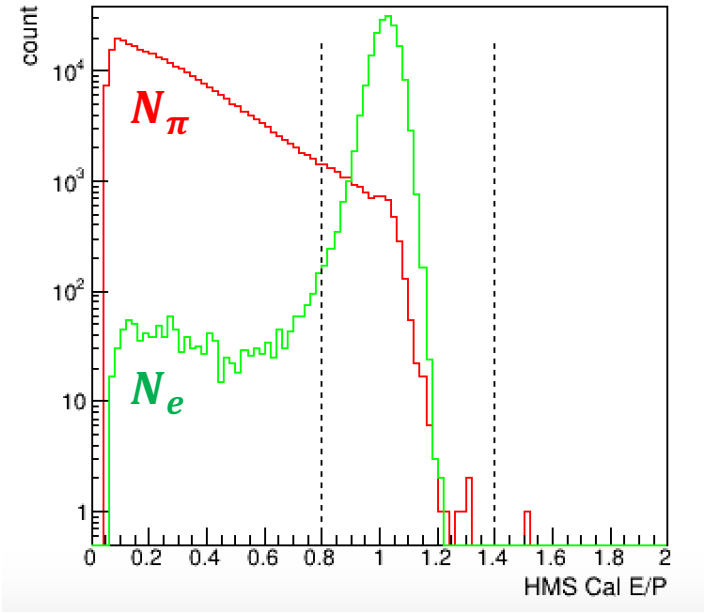
Pion Contamination with a Preshower Cut

Step 3: find the **percentage of pions in electron sample**

pion contamination = N_π / N_e

PID Cuts: `Preshower E/P > 0.05`

`npeSum > 5 && shower E/P > 0` (e^-)
`npeSum < 0.1` (π)



Histogram is integrated over [`0.80,1.40`] to **find percentage of pions in electron sample**

PC from Calorimeter Only: = **7.50%**

∗ (1/PRF) @ 1 npeSum cut from GC study (1/36.76)

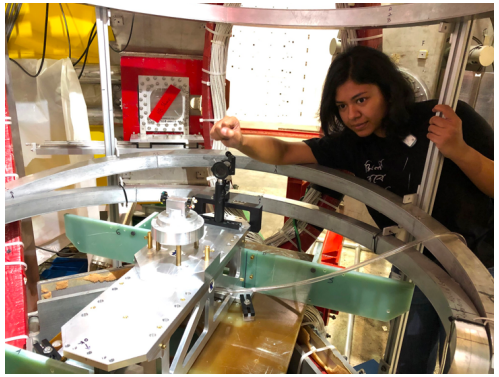
PC from Calorimeter + GC: = **0.20%**

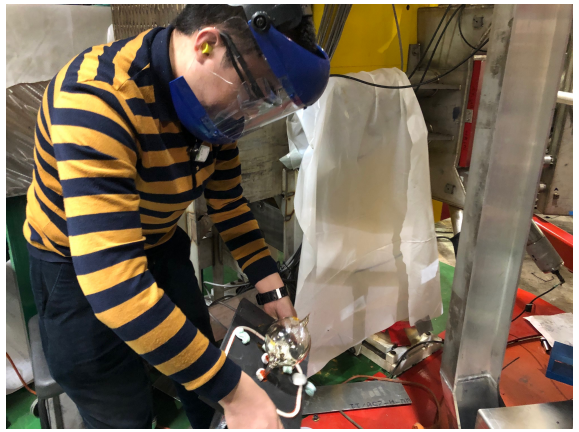
Acknowledgements:
The Polarized ^{3}He Run Group Collaboration (A_1^n/d_2^n)

D. Androic, W. Armstrong, T. Averett, X. Bai, J. Bane, S. Barcus, J. Benesch, H. Bhatt, D. Bhetuwal, D. Biswas, A. Camsonne, G. Cates, J-P. Chen, J. Chen, M. Chen, C. Cotton, M-M. Dalton, A. Deur, B. Dhital, B. Duran, S.C. Dusa, I. Fernando, E. Fuchey, B. Gamage, H. Gao, D. Gaskell, T.N. Gautam, N. Gauthier, C.A. Gayoso, O. Hansen, F. Hauenstein, W. Henry, G. Huber, C. Jantzi, S. Jia, K. Jin, M. Jones, S. Joosten, A. Karki, B. Karki, S. Katugampola, S. Kay, C. Keppel, E. King, P. King, W. Korsch, V. Kumar, R. Li, S. Li, W. Li, D. Mack, S. Malace, P. Markowitz, J. Matter, M. McCaughan, Z-E. Meziani, R. Michaels, A. Mkrtchyan, H. Mkrtchyan, C. Morean, V. Nelyubin, G. Niculescu, M. Niculescu, M. Nycz, C. Peng, S. Premathilake, A. Puckett, A. Rathnayake, M. Rehfuss, P. Reimer, G. Riley, Y. Roblin, J. Roche, M. Roy, M. Satnik, B. Sawatzky, S. Seeds, S. Sirca, G. Smith, N. Sparveris, H. Szumila-Vance, A. Tadepalli, V. Tadevosyan, Y. Tian, A. Usman, H. Voskanyan, S. Wood, B. Yale, C. Yero, A. Yoon, J. Zhang, Z. Zhao, X. Zheng, J. Zhou

PhD Candidates

Spokespeople





This work is supported in part by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract **No DE-FG02-94ER4084**

Backup Slides

PID: Calorimeter Efficiency & Pion Rejection

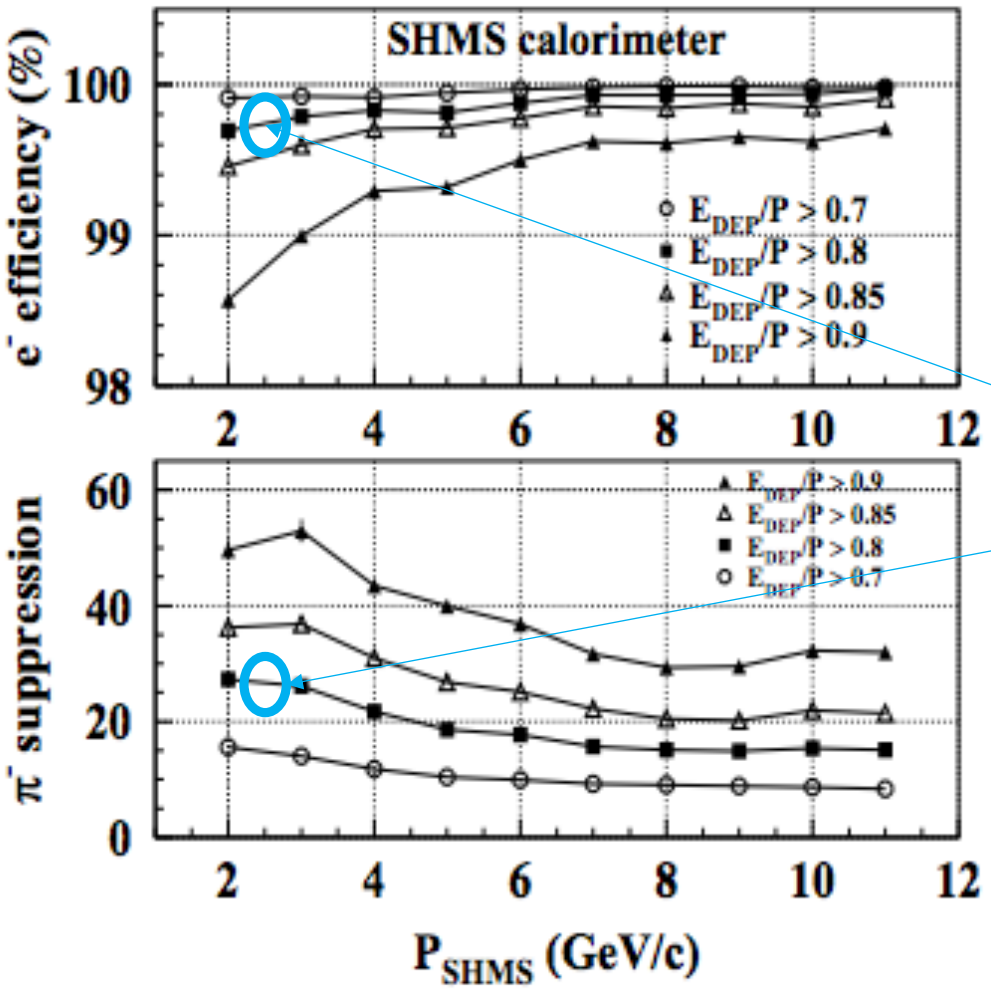
SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV
θ_c = 1.35°

Acceptance Cuts:
```
-12 < P.gtr.dp < 25
|P.gtr.ph| < 0.07
|P.gtr.th| < 0.05
|P.react.z| < 22
```

Sample Cuts:
```
P.ngcer.npeSum > 8 (e⁻)
P.ngcer.npeSum < 0.1 (π)
```

PID Cuts:
```
P.cal.etracknorm > 0.80
```



Efficiency = 99.43 ± 0.01%
Pion RF = 24.97 ± 0.07

PRF normal, but the efficiency is a little low (should be closer to 99.8%)

Calorimeter

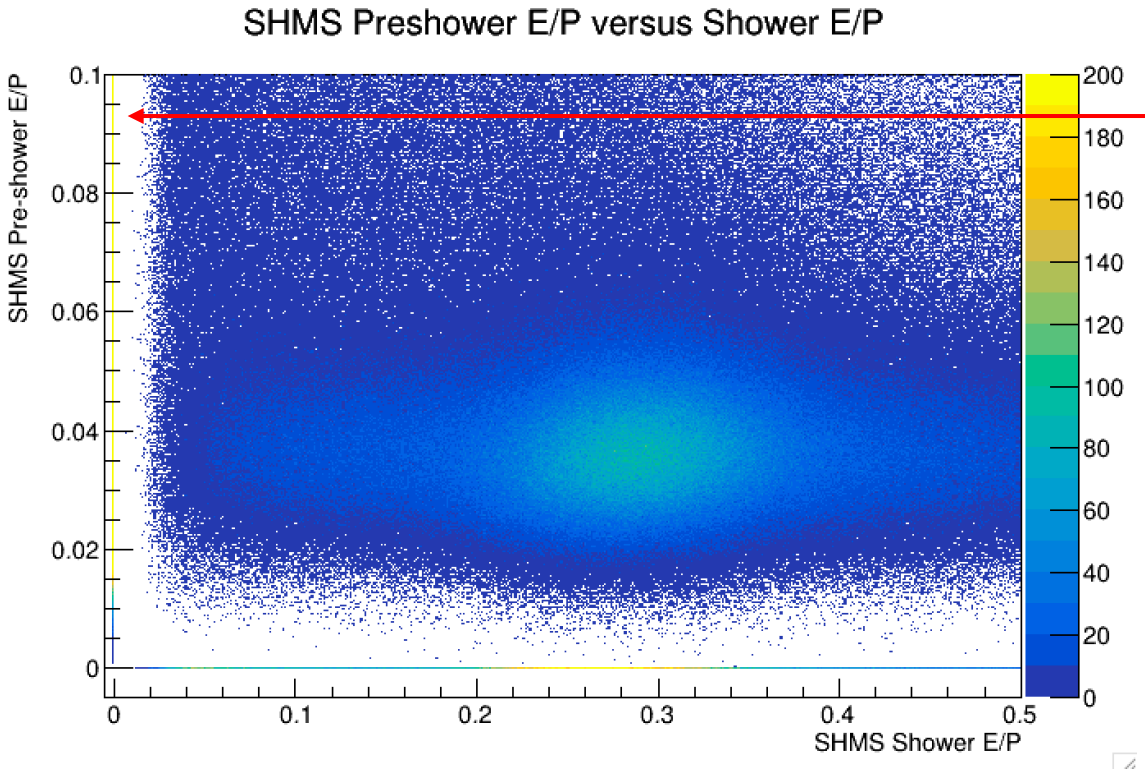
SHMS Runs:
10334-10347,
DIS, Longitudinal
E_p= -2.6 GeV, 30°

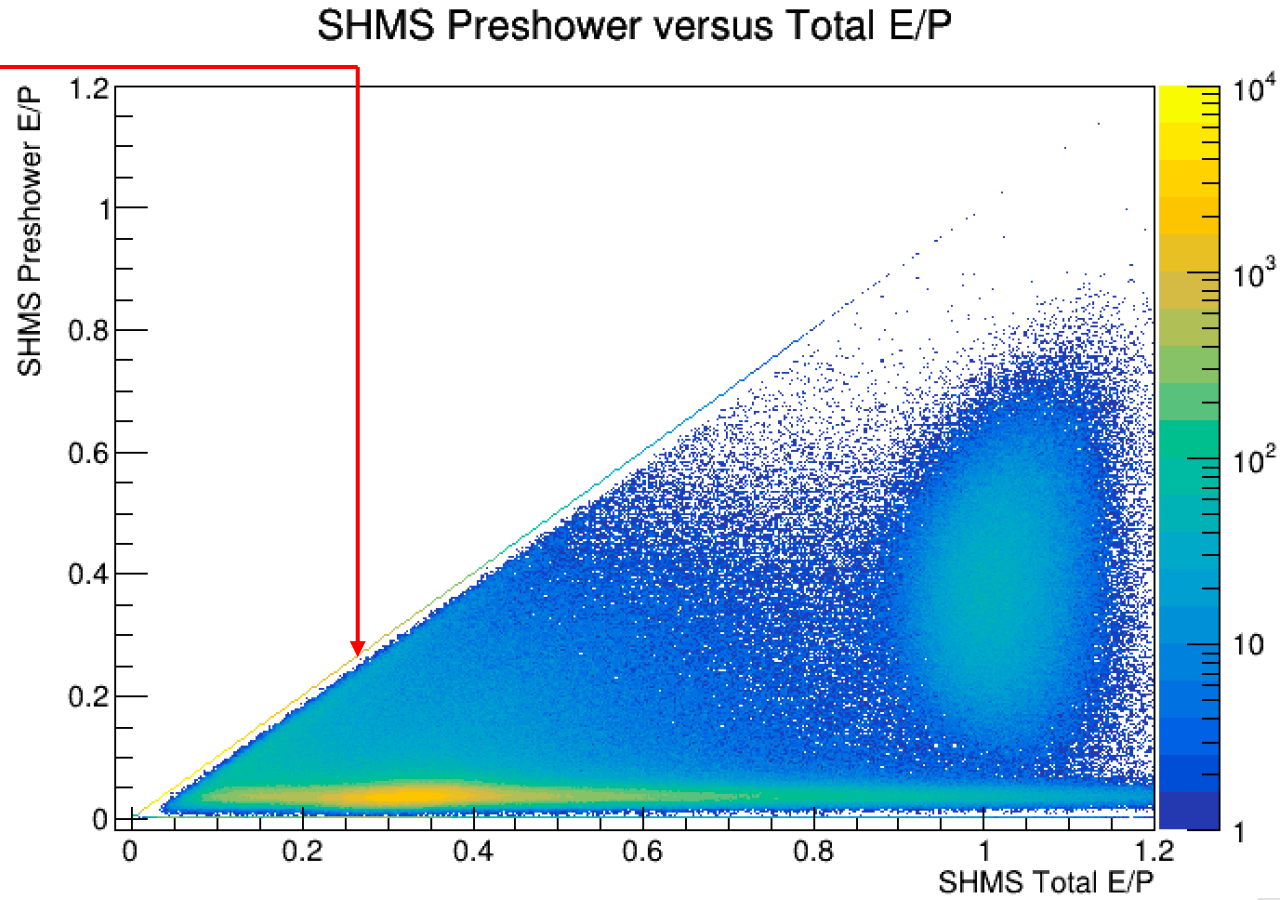
PID: **NGC** Efficiency & Pion Rejection Factors

Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV
$\theta_c = 1.35°$

NGC

low energy particles at
`shower E/P = 0`
&
`preshower E/P = 0`





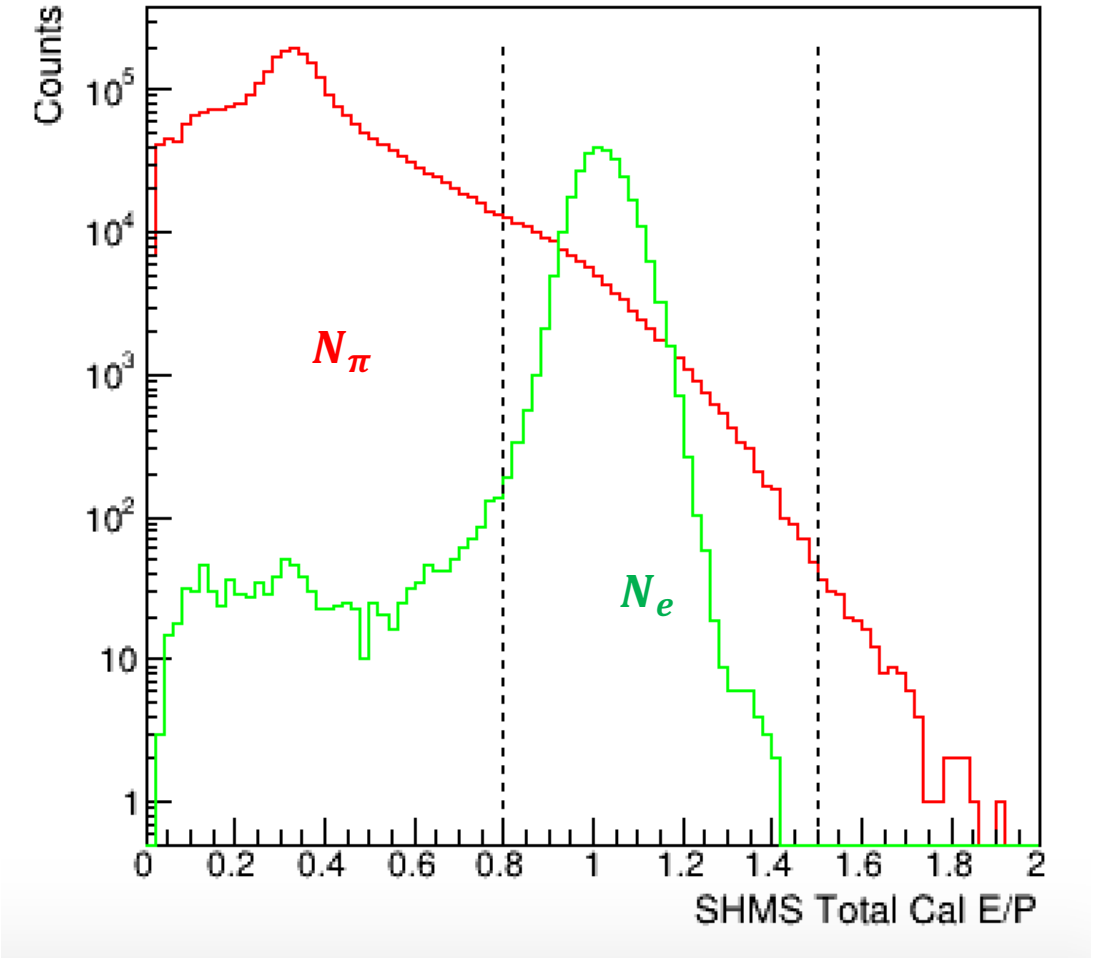
Acceptance Cuts:
```
-12 < P.gtr.dp < 25
|P.gtr.ph| < 0.07
|P.gtr.th| < 0.05
|P.react.z| < 22
```

SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

PID: Pion Contamination w/ a Preshower Cut

Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV
$\theta_c = 1.35°$

Calorimeter



Acceptance Cuts:
```
-12 < P.gtr.dp < 25
|P.gtr.ph| < 0.07
|P.gtr.th| < 0.05
|P.react.z| < 22
```

```
npeSum > 8 && shower E/P > 0
```

```
npeSum < 0.1
```

PID Cuts:
```
Preshower E/P > 0.0
```

pion contamination = N_π/N_e

Histogram is integrated over [0.80,1.50] to **find percentage of pions in electron sample**

PC from Calorimeter Only:

44.66%

$*$ (1/PRF) @ 2 npeSum cut from NGC study (1/2631.44)

PC from Calorimeter + NGC:

0.02%

SHMS Runs:
10334-10347,
DIS, Long. & Trans.
E_p= -2.6 GeV, 30°

PID: **Calorimeter** Efficiency & Pion Rejection Factors

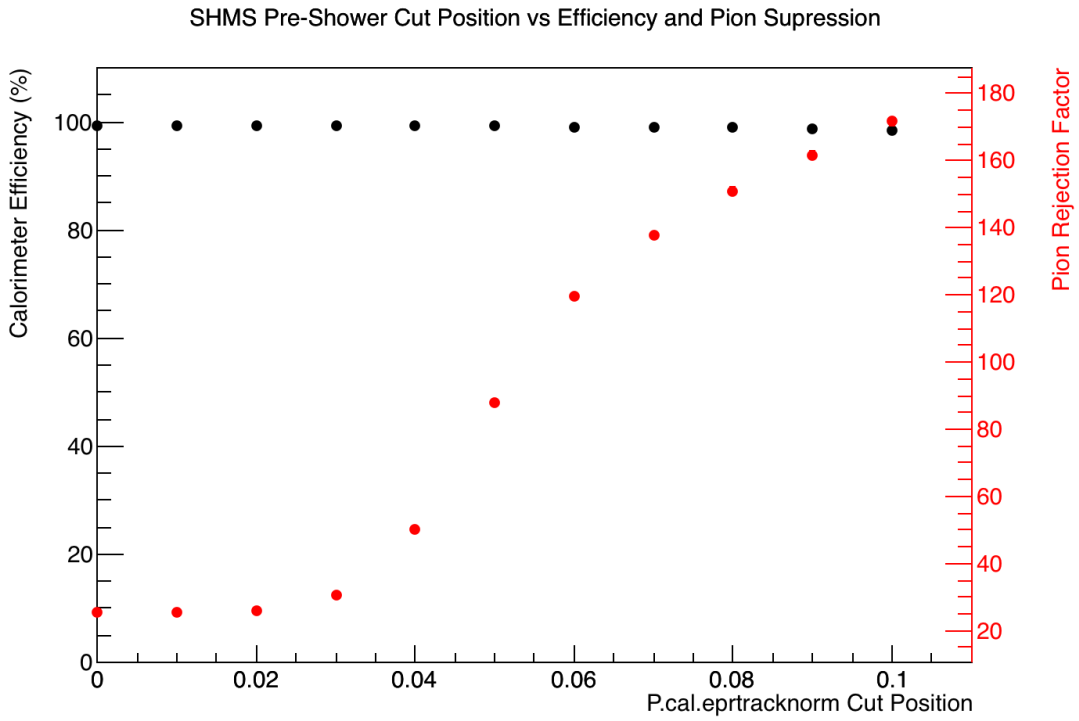
Threshold Energies
N_2 @ 1atm, 20°C
e^- : 21.6 MeV
$\pi^{+,-}$: 5.9 GeV
$\theta_c = 1.35°$

Calorimeter

Acceptance Cuts:
```
-12 < P.gtr.dp < 25
|P.gtr.ph| < 0.07
|P.gtr.th| < 0.05
|P.react.z| < 22
```

Sample Cuts:
```
P.ngcer.npeSum > 8 (e⁻)
&& shower E/P > 0
P.ngcer.npeSum < 0.1 (π)
```

PID Cuts:
```
P.cal.etracknorm > 0.80
```



Preshower Cut	Efficiency (%)	Δ∈(%)	Pion Rejection Factor	ΔPRF
No cut	99.43	0.01	24.97	0.07
P.cal.eprtracknorm > 0.00	99.39	0.01	25.37	0.07
P.cal.eprtracknorm > 0.01	99.38	0.01	25.38	0.07
P.cal.eprtracknorm > 0.02	99.37	0.02	25.82	0.07
P.cal.eprtracknorm > 0.03	99.34	0.02	30.59	0.09
P.cal.eprtracknorm > 0.04	99.29	0.02	50.01	0.20
P.cal.eprtracknorm > 0.05	**99.22**	**0.02**	**87.89**	**0.46**
P.cal.eprtracknorm > 0.06	99.14	0.02	119.56	0.74
P.cal.eprtracknorm > 0.07	99.02	0.02	138.01	0.91
P.cal.eprtracknorm > 0.08	98.87	0.02	151.05	1.05
P.cal.eprtracknorm > 0.09	98.69	0.02	161.57	1.16
P.cal.eprtracknorm > 0.10	98.47	0.02	171.63	1.27

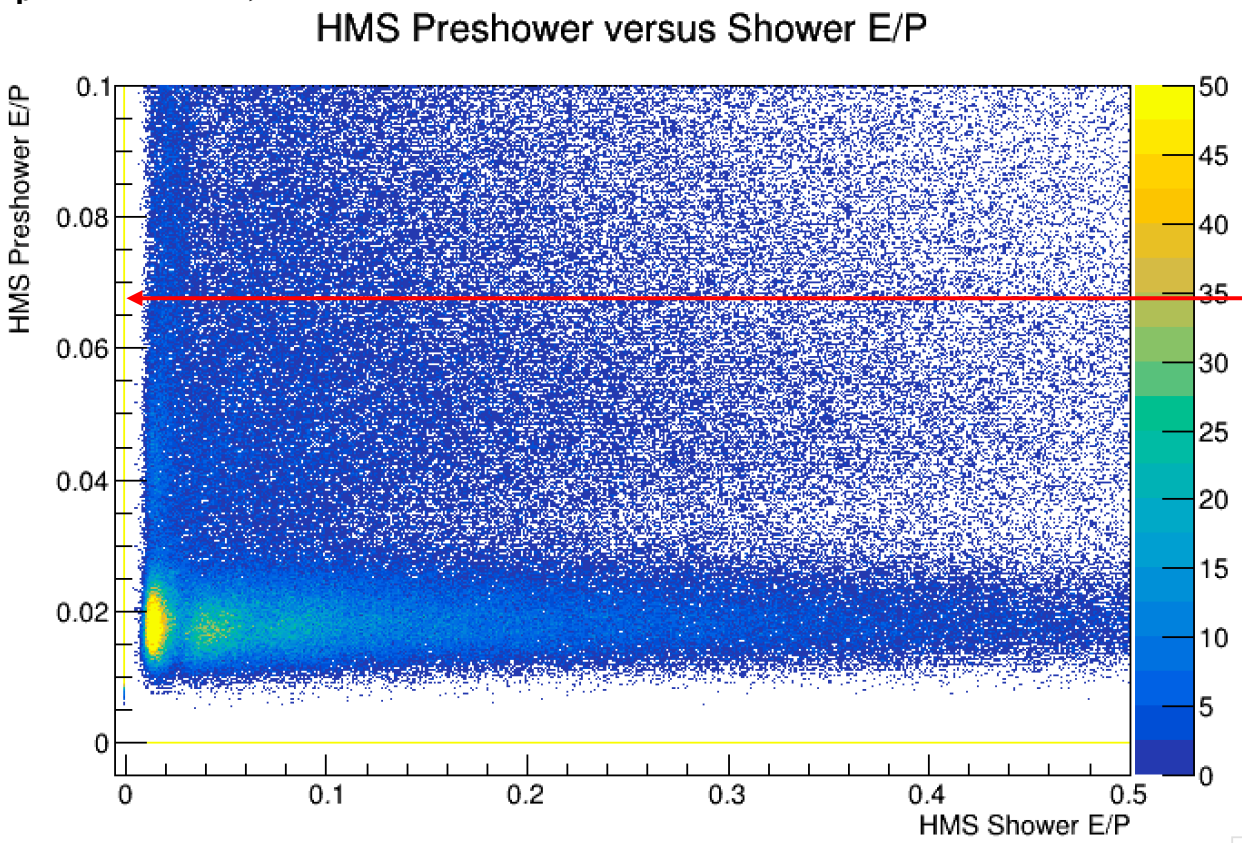
HMS Runs:
3181-3183
3186-3205
DIS, Longitudinal
E_p= -2.9 GeV, 30°

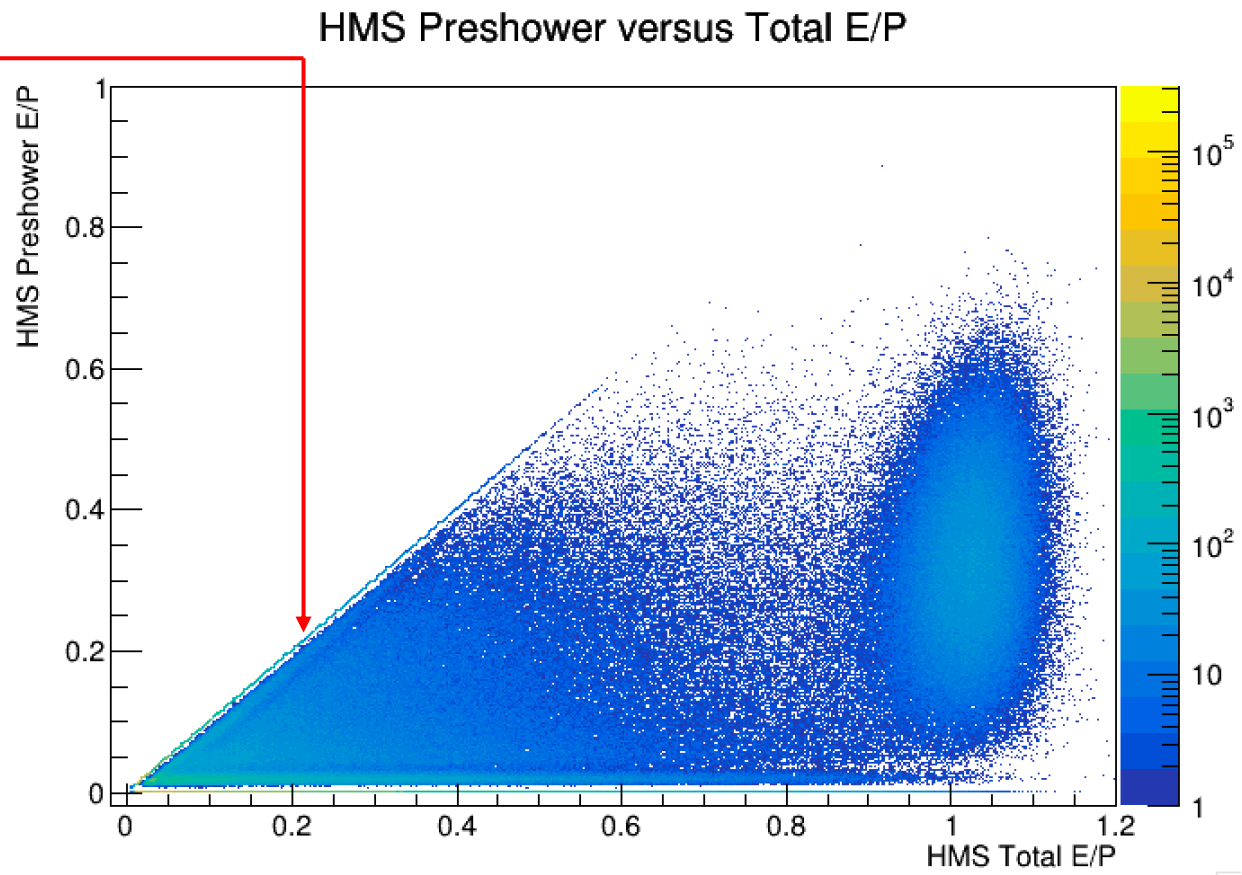
PID: **GC** Efficiency & Pion Rejection Factors

Threshold Energy
C_4F_8O @ 0.225 atm
$\pi^{+,-}$: 5.5 GeV

GC

low energy particles at
shower E/P = 0
&
preshower E/P = 0





Acceptance Cuts:
-10 < H.gtr.dp < 10
|H.gtr.th| < 0.1
|H.gtr.ph| < 0.06
-22 < H.react.z < 22

HMS Runs:
3181-3183
3186-3205
DIS, Longitudinal
E_p= -2.9 GeV, 30°

PID: **Calorimeter** Efficiency & Pion Rejection Factors

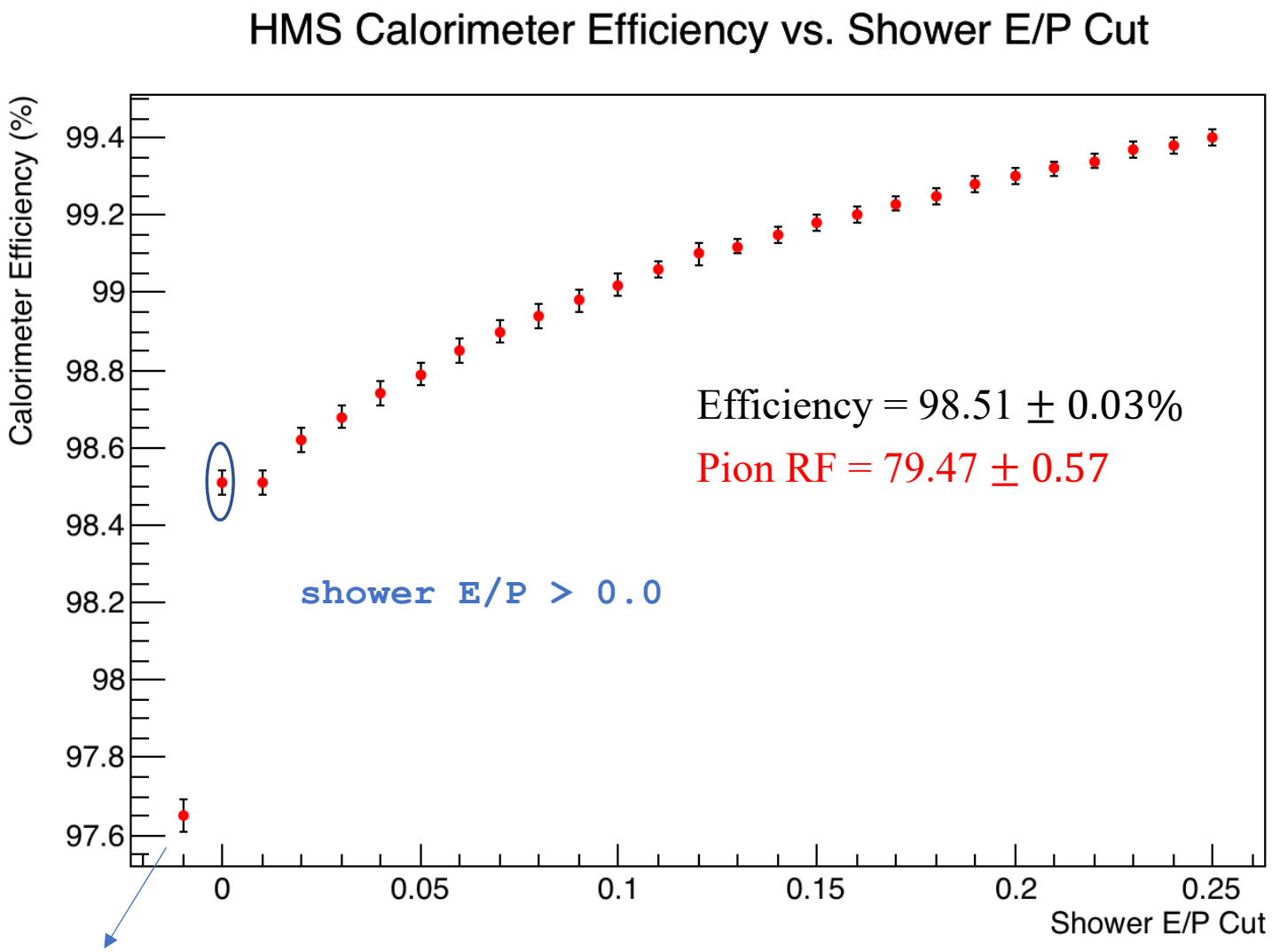
Threshold Energy
C_4F_8O @ 0.225 atm
$\pi^{+,-}$: 5.5 GeV

Calorimeter

Acceptance Cuts:
`-10 < H.gtr.dp < 10`
`|H.gtr.th| < 0.1`
`|H.gtr.ph| < 0.06`
`-22 < H.react.z < 22`

Sample Cuts:
`H.cer.npeSum > 5` **(e^-)**
`H.cer.npeSum < 0.1` **(π)**

PID Cuts:
`H.cal.etracknorm > 0.80`



0.89% difference

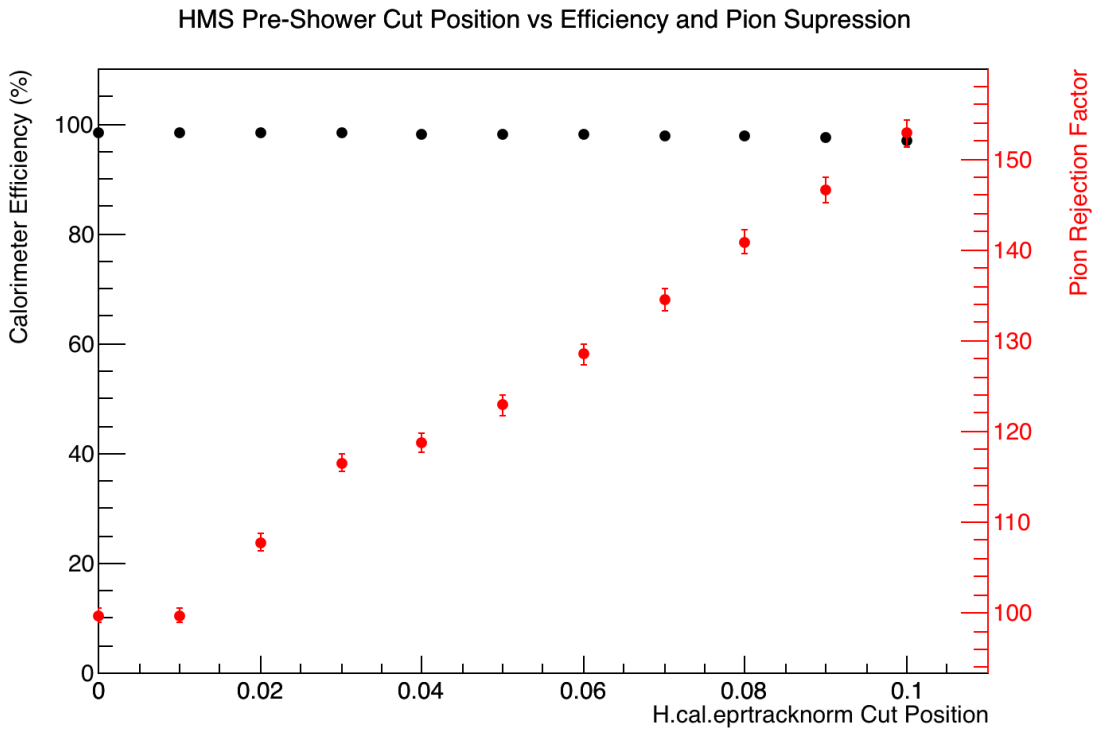
No Cut

Sample Cut for e^-

HMS Runs:
3181-3183
3186-3205
DIS, Longitudinal
E_p= -2.9 GeV, 30°

PID: **Calorimeter** Efficiency & Pion Rejection Factors

Threshold Energy
C_4F_8O @ 0.225 atm
$\pi^{+,-}$: 5.5 GeV



Acceptance Cuts:
```
-10 < H.gtr.dp < 10
|H.gtr.th| < 0.1
|H.gtr.ph| < 0.06
-22 < H.react.z < 22
```

Sample Cuts:
```
H.cer.npeSum > 5 (e⁻)
H.cer.npeSum < 0.1 (π)
```

PID Cuts:
```
H.cal.etracknorm > 0.80
```

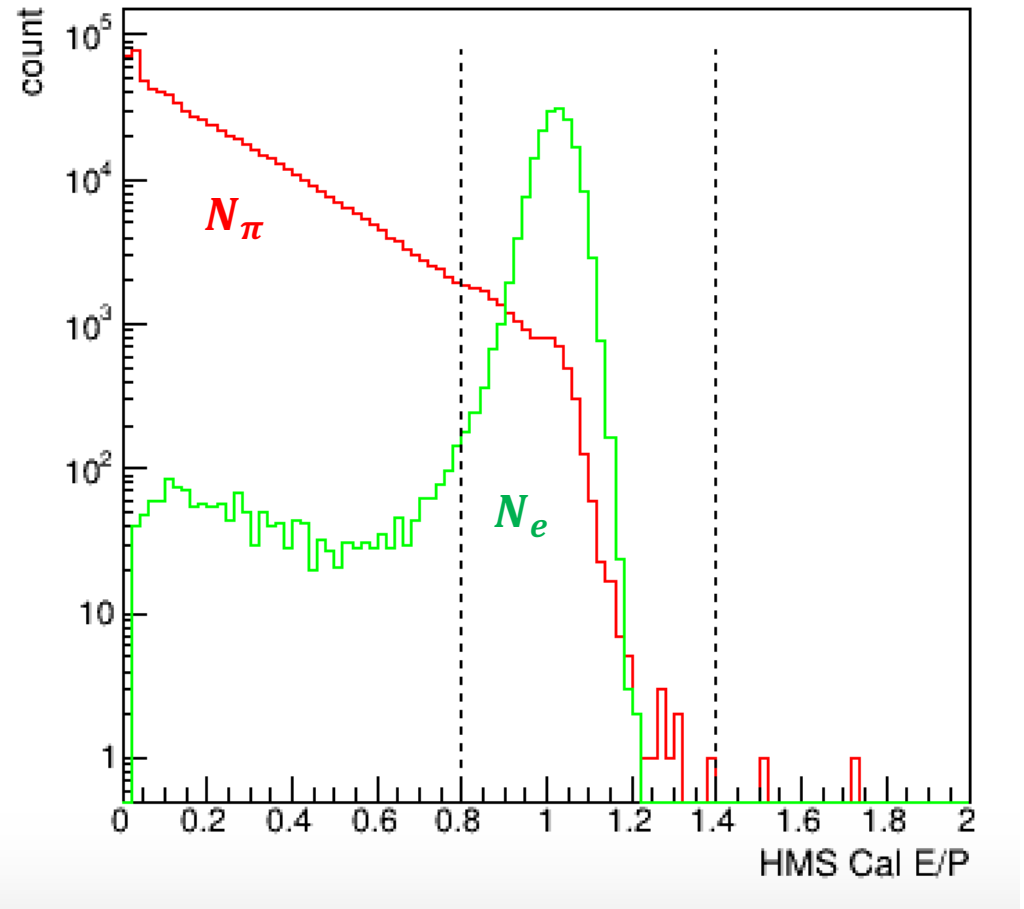
Preshower Cut	Efficiency (%)	Δ∈(%)	Pion Rejection Factor	ΔPRF
No cut	98.51	0.03	79.47	0.57
H.cal.eprtracknorm > 0.00	98.41	0.03	99.71	0.80
H.cal.eprtracknorm > 0.01	98.41	0.03	99.72	0.80
H.cal.eprtracknorm > 0.02	98.38	0.03	107.81	0.90
H.cal.eprtracknorm > 0.03	98.31	0.03	116.55	1.01
H.cal.eprtracknorm > 0.04	98.27	0.03	118.72	1.04
H.cal.eprtracknorm > 0.05	98.21	0.03	122.91	1.09
H.cal.eprtracknorm > 0.06	98.11	0.03	128.49	**1.17**
H.cal.eprtracknorm > 0.07	97.96	0.03	134.47	1.25
H.cal.eprtracknorm > 0.08	97.71	0.04	140.86	1.34
H.cal.eprtracknorm > 0.09	97.41	0.04	146.66	1.42
H.cal.eprtracknorm > 0.10	97.02	0.04	152.86	1.51

HMS Runs:
3181-3183
3186-3205
DIS, Longitudinal
E_p= -2.9 GeV, 30°

PID: Pion Contamination w/ a Preshower Cut

Threshold Energy
C_4F_8O @ 0.225 atm
$\pi^{+,-}$: 5.5 GeV

Calorimeter



Acceptance Cuts:
```
-10 < H.gtr.dp < 10
|H.gtr.th| < 0.1
|H.gtr.ph| < 0.06
-22 < H.react.z < 22
```

`npeSum > 5 && shower E/P > 0`

`npeSum < 0.1`

PID Cuts:
`Preshower E/P > 0.0`

pion contamination = N_π/N_e

Histogram is integrated over `[0.80,1.40]` to **find percentage of pions in electron sample**

PC from Calorimeter Only:

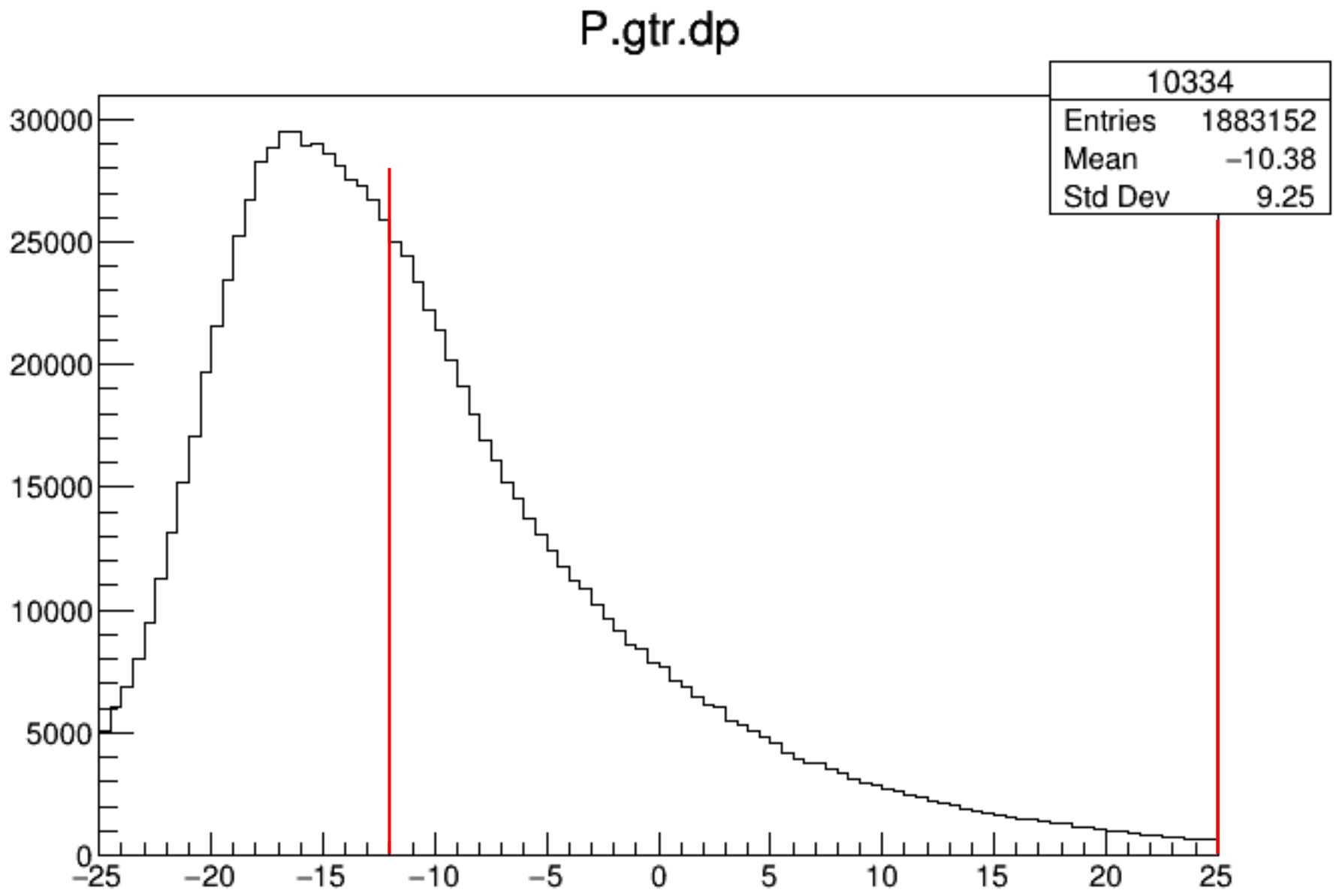
9.23%

$*$ (1/PRF) @ 1 npeSum cut from GC study (1/36.76)

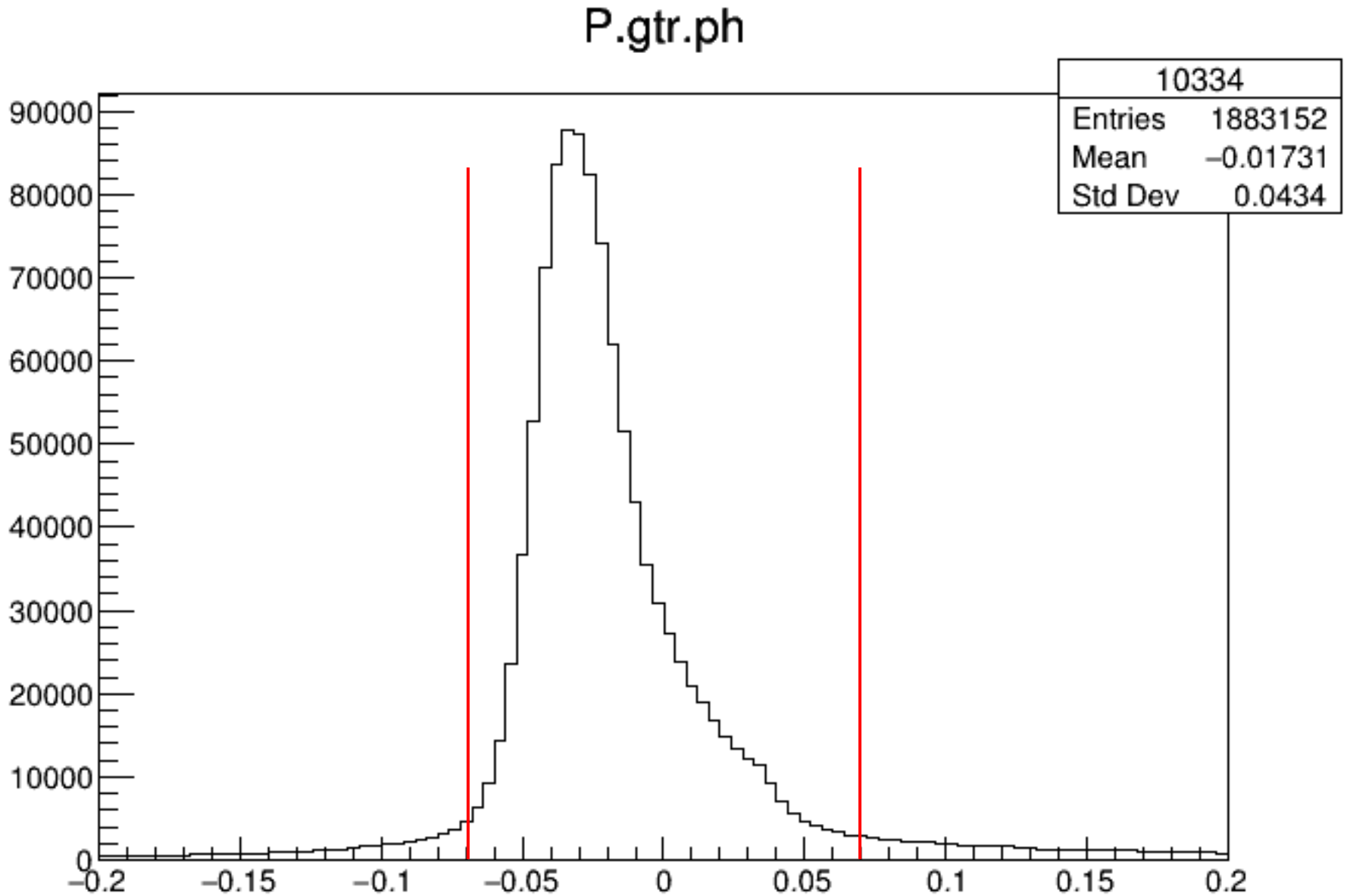
PC from Calorimeter + GC:

0.25%

SHMS Acceptance Cuts

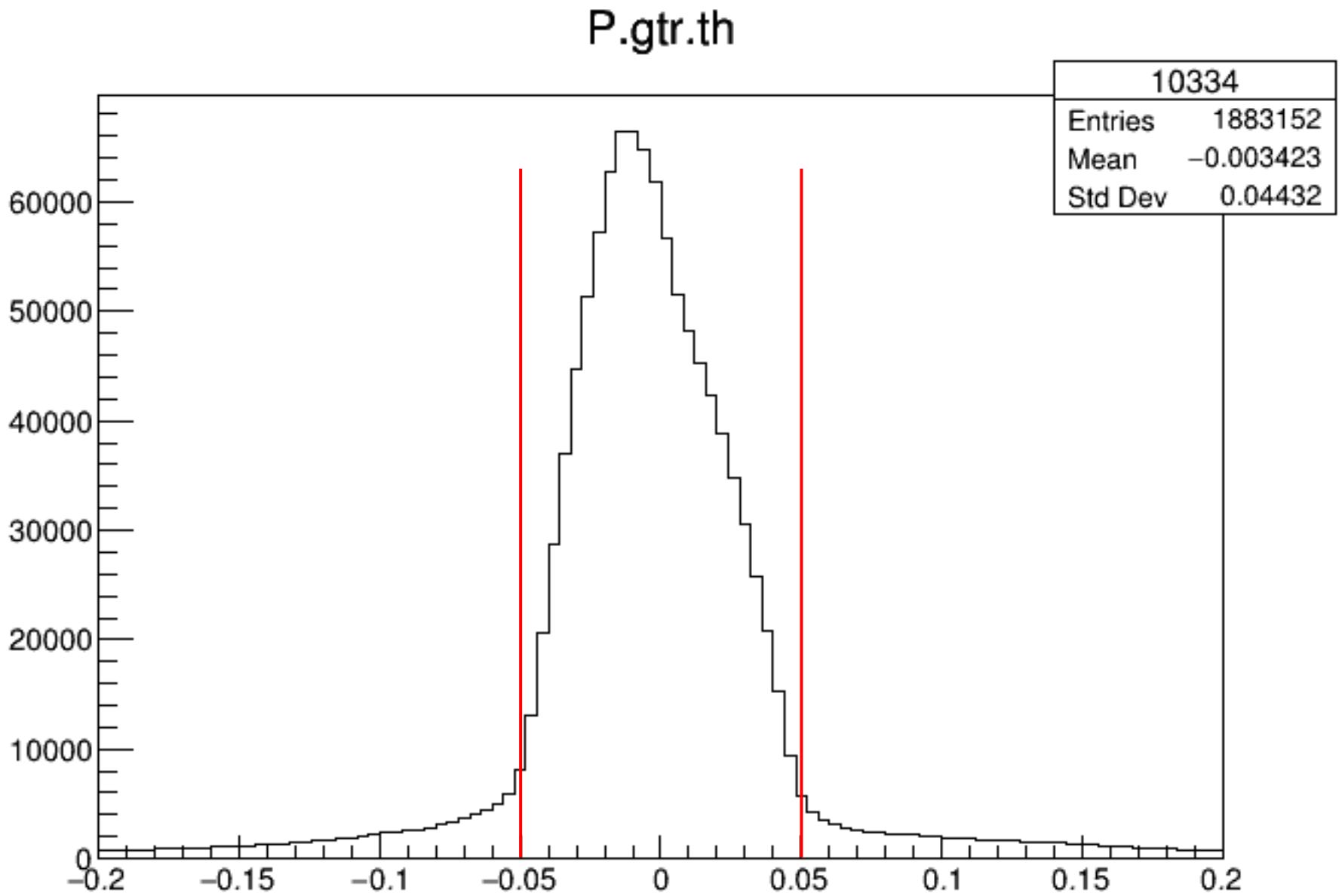

P.gtr.dp
10334
Entries 1883152
Mean −10.38
Std Dev 9.25
30000
25000
20000
15000
10000
5000
0
−25
−20
−15
−10
−5
0
5
10
15
20
25

(yptar)

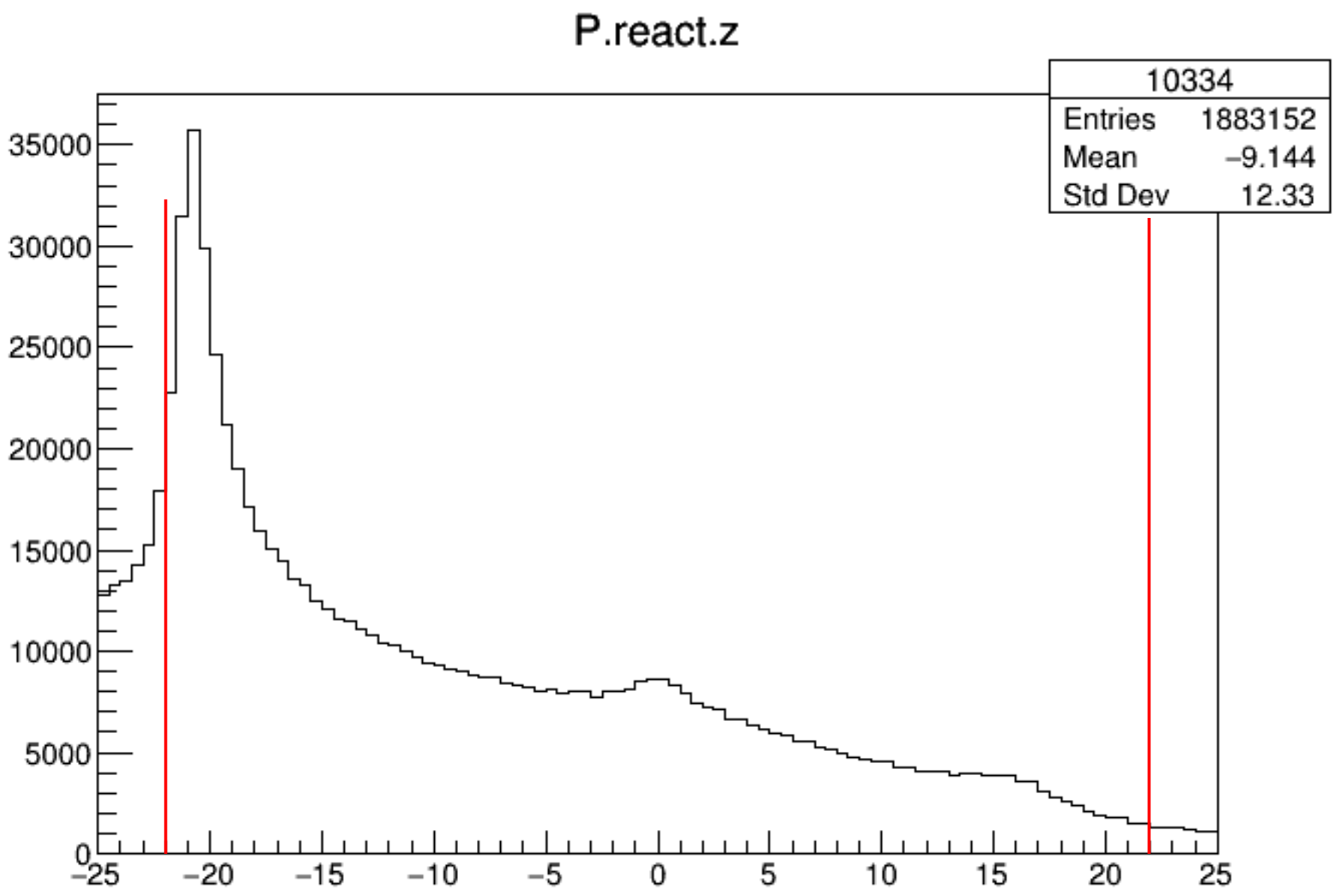


dy/dz (horizontal) rad

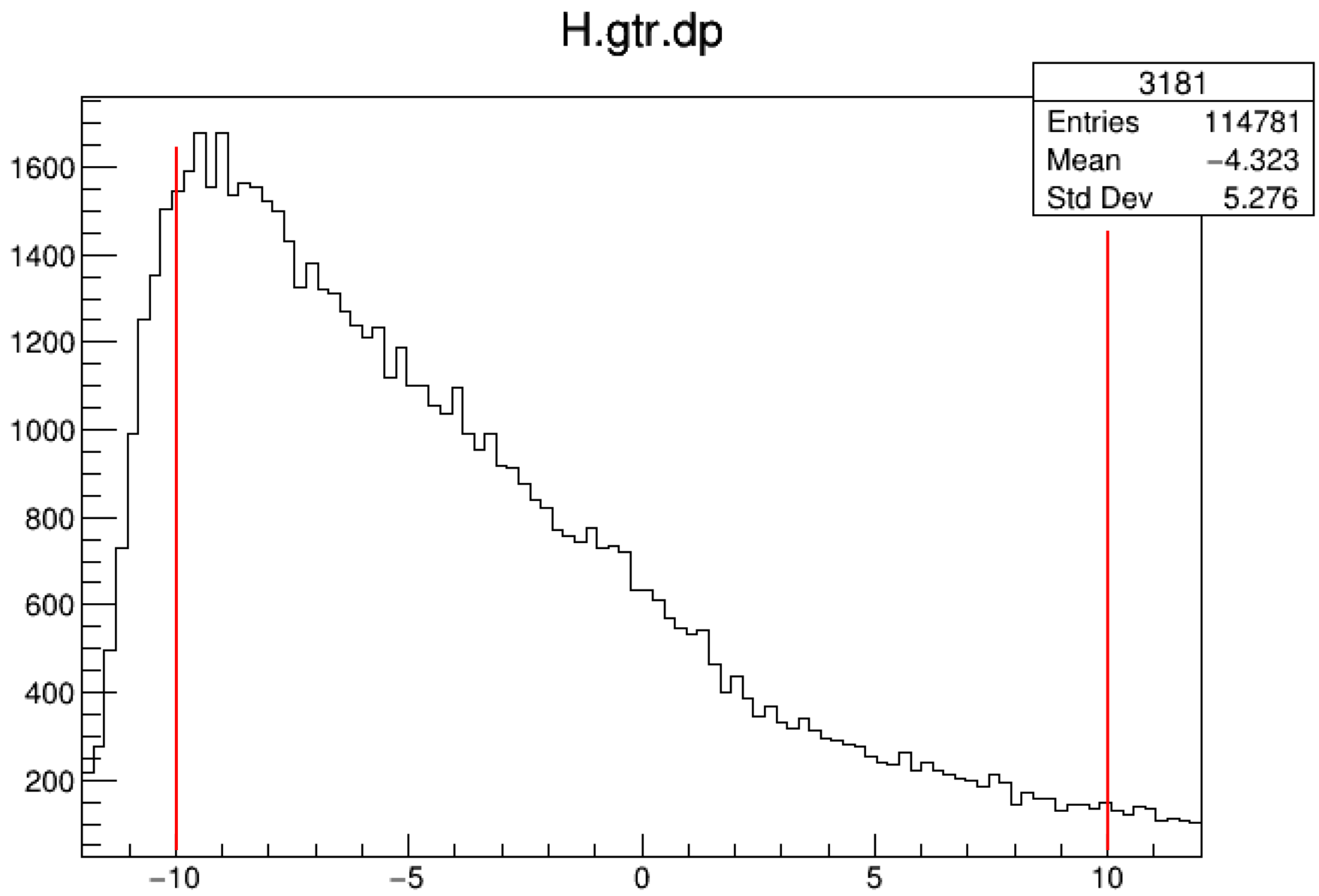
(xptar)



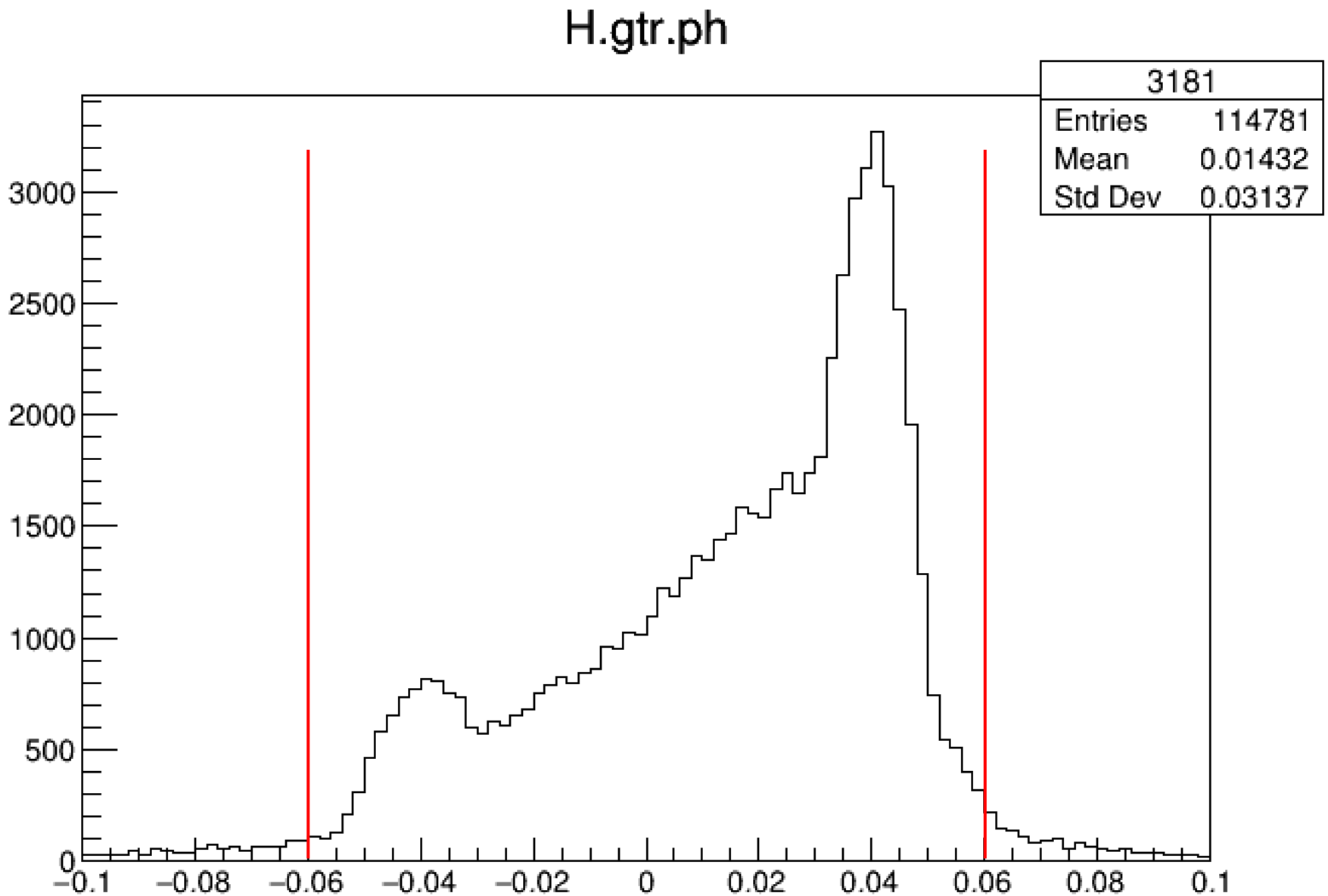
dx/dz (vertical) rad


P.react.z
10334
Entries 1883152
Mean −9.144
Std Dev 12.33
35000
30000
25000
20000
15000
10000
5000
0
−25
−20
−15
−10
−5
0
5
10
15
20
25

HMS Acceptance Cuts

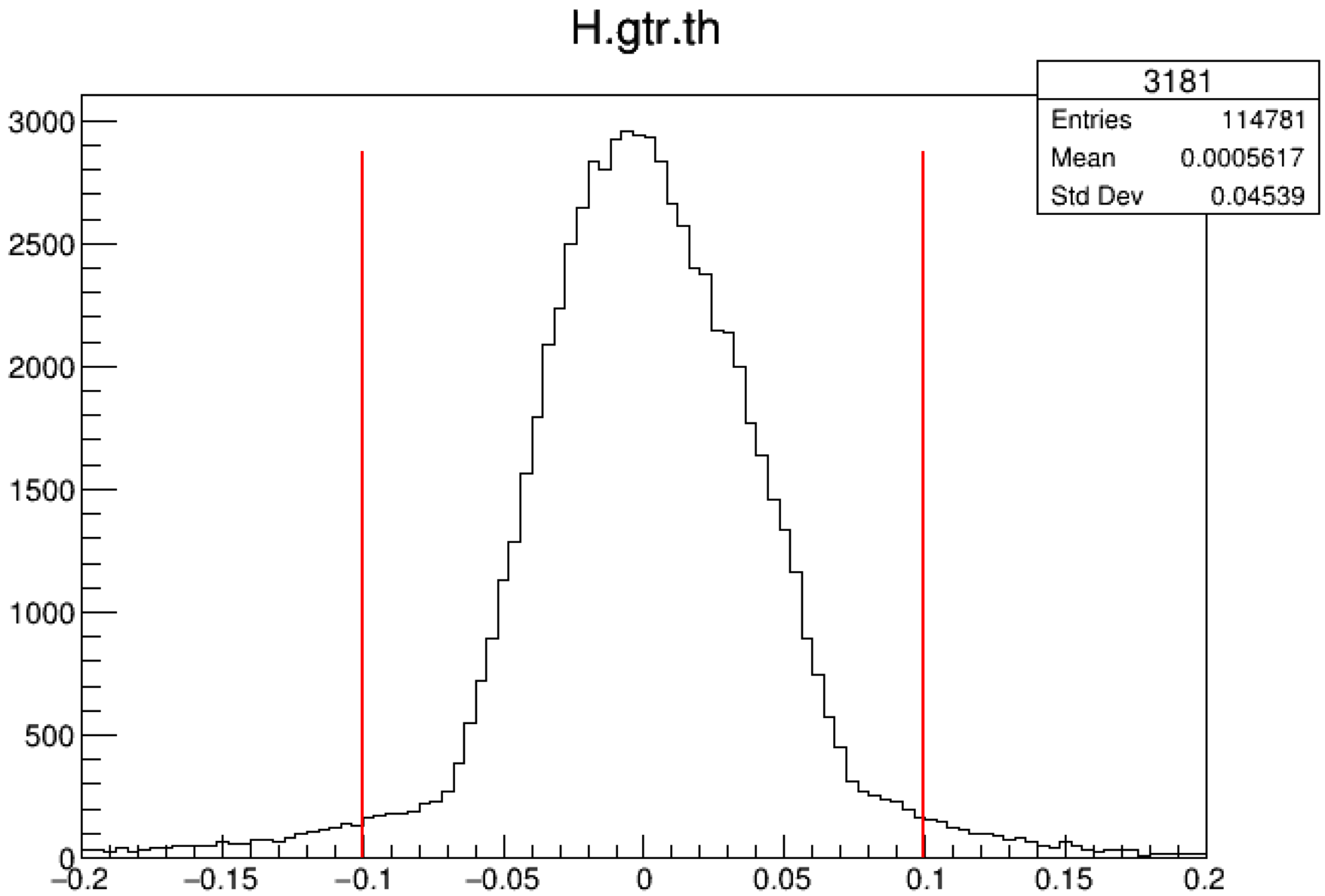

H.gtr.dp
3181
Entries 114781
Mean −4.323
Std Dev 5.276
1600
1400
1200
1000
800
600
400
200
−10
−5
0
5
10

(yptar)

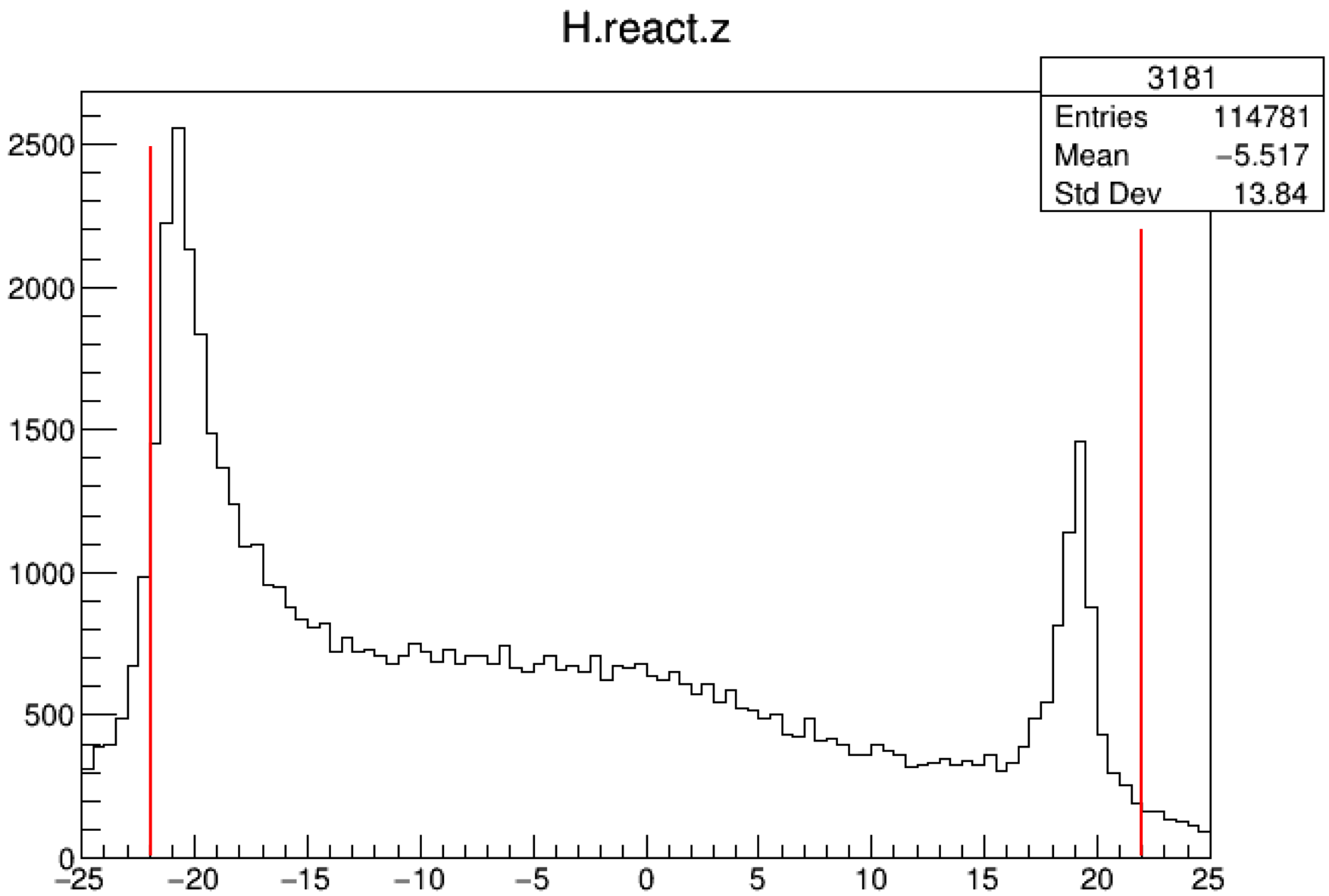


dy/dz (horizontal) rad

(xptar)



dx/dz (vertical) rad


H.react.z
3181
Entries 114781
Mean −5.517
Std Dev 13.84
2500
2000
1500
1000
500
0
−25
−20
−15
−10
−5
0
5
10
15
20
25

Calculations of Errors

Efficiency: Bayesian Statistics

$$\epsilon = \frac{k}{n}, \qquad \Delta\sigma_\epsilon^2 = \frac{(k-1)(k+2)}{(n+2)(n+3)} - \frac{(\mathrm{k}+1)^2}{(\mathrm{n}+2)^2}$$

Pion Rejection Factor: Binomial Statistics

$$PRF = \frac{n}{k}, \qquad \Delta\sigma_{PRF} = \left(\frac{n}{k}\right)\sqrt{\frac{1-\left(\frac{k}{n}\right)}{k}}$$

see: https://indico.cern.ch/event/66256/contributions/2071577/attachments/1017176/1447814/EfficiencyErrors.pdf

Calorimeter PID Quantities

Calorimeter PID quantities

etot - total energy deposition in the calorimeter (not associated to any track, hence not corrected for coordinate);

etotnorm - total energy deposition divided by the spectrometer's central momentum (again, not corrected for coordinate);

etrack - energy deposition of the best track, i.e. energy of the hit cluster associated to the best track (corrected for Y coordinate of the track at the calorimeter);

etracknorm - energy deposition of the best track divided by its momentum (Y coordinate corrected);

eprtrack - energy deposition in the Preshower for the best track (i.e. Y coordinate corrected energy deposition of the hit cluster in the first layer of the calorimeter);

eprtracknorm - energy deposition in the Preshower for the best track divided by its momentum (Y coordinate corrected);

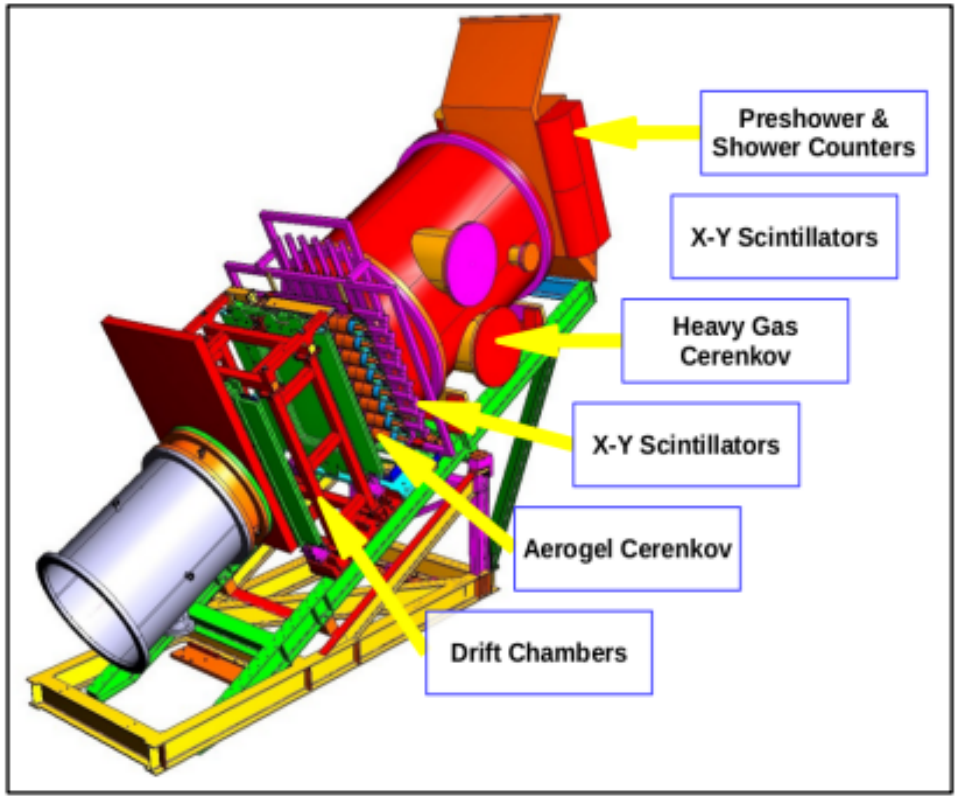
etottracknorm - total energy deposition in the calorimeter divided by momentum of the best track (no coordinate correction).

The **tot** quantities correspond to the total energy in the calorimeter, and **track** quantities correspond to the energy in the hit cluster matched to the best track.

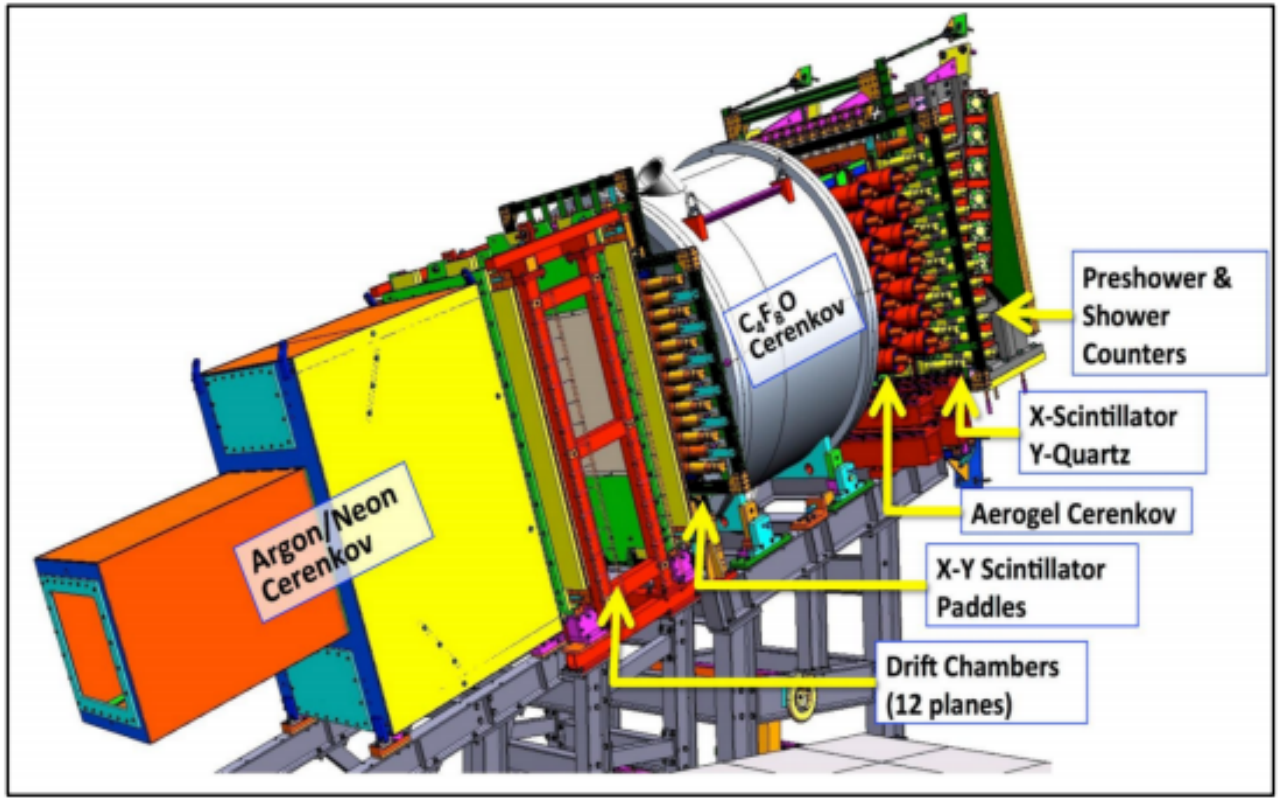
The **tot** quantities are not corrected for the track coordinate, the **track** quantities are corrected for the Y coordinate of the track at the calorimeter. A special case is *etottracknorm*, which is not coordinate corrected.

Hall C Spectrometers & Detectors

HMS detectors



SHMS detectors



Spectrometer	Central Momentum (GeV/c)	Momentum Acceptance	Momentum Resolution	Scattering Angle	Solid Angle Acceptance (msr)	Horizontal Acceptance (mrad)	Vertical Acceptance (mrad)
HMS	0.5 – 7.5	(-9%, 9%)	0.02%	12.5° - 90°	8.1	±32	±85
SHMS	2.0 - 11.0	(-10%, 22%)	0.03% - 0.08%	5.5° - 40°	> 4.0	±24	±40