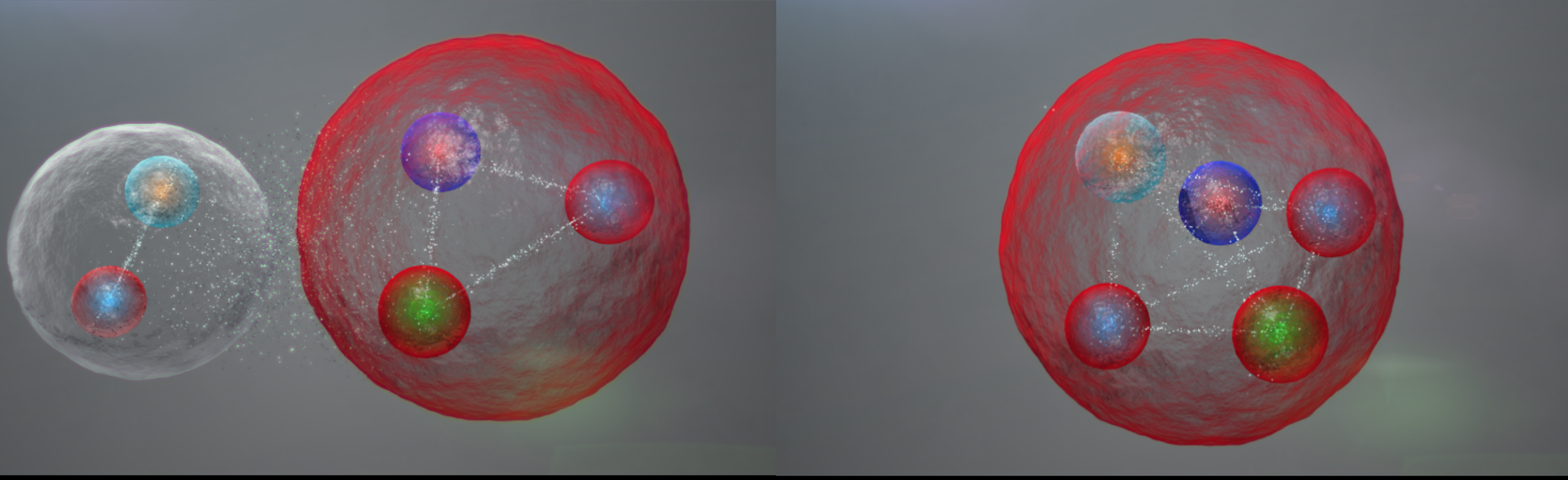


A SEARCH FOR THE LHCB PENTAQUARKS IN HALL C AT JEFFERSON LAB

BURCU DURAN

For the E12-16-007 Collaboration

Joint Hall A & C Summer Collaboration Meeting

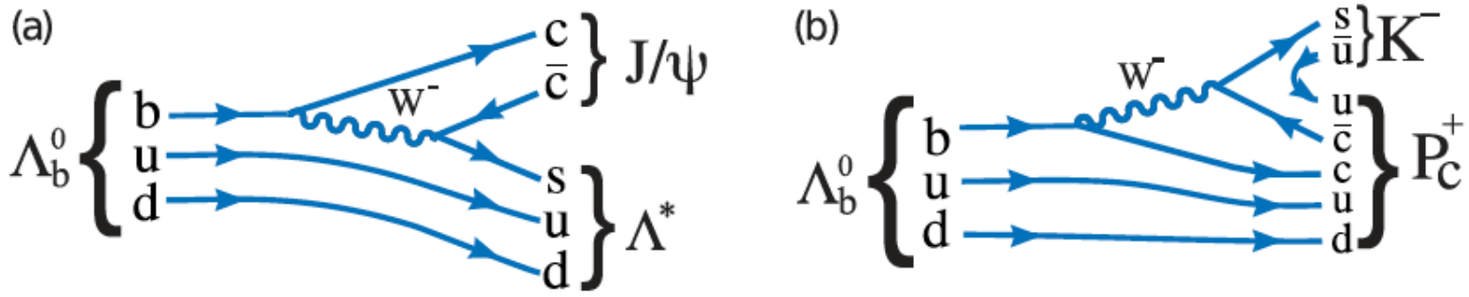
Jefferson Lab

6/27/2019

LHCB CHARMED (CHARMING!) "PENTAQUARK" P_c

$$\Lambda_b \rightarrow K^- p J/\Psi$$

Aaij, R, et. al (LHCb) PRL 115-7 (2015)



2 *Pc* states needed to describe the results:

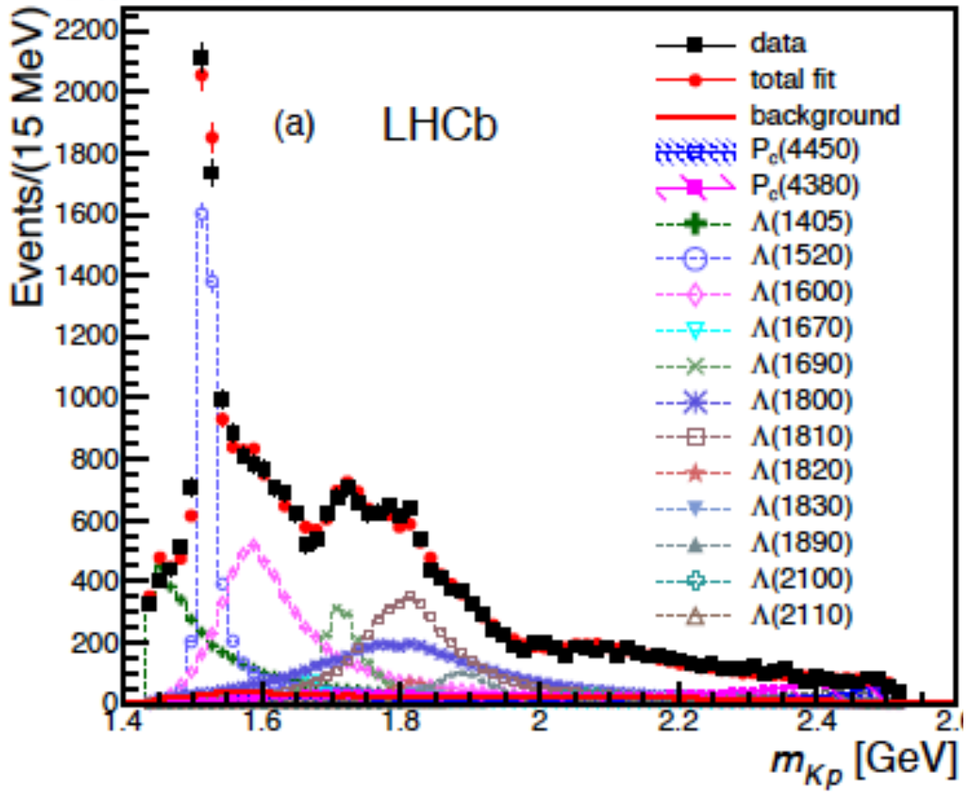
- ***Narrow***: *M: 4450 ± 2 ± 3 MeV*
  Γ: 39 ± 5 ± *19* MeV
- ***Wide***: *M: 4380 ± 8 ± 29 MeV*
  Γ: 205 ± *18* ± *86* MeV

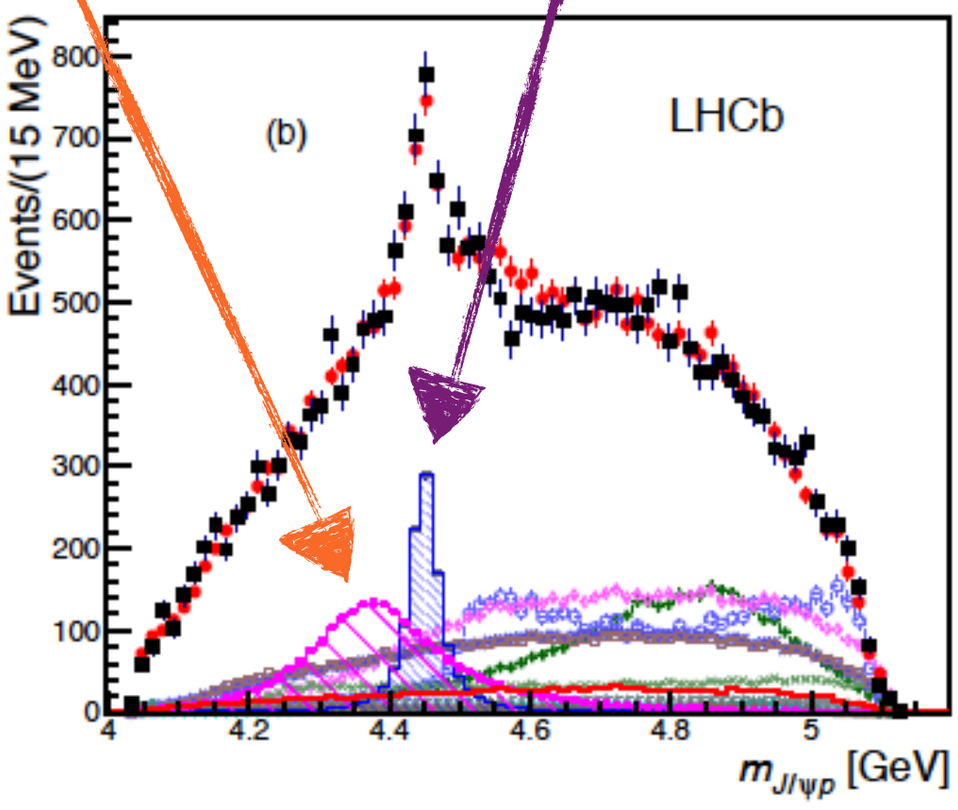
Spin parity either:

- 5/2+, 3/2- (most likely)
- 5/2-, 3/2+
- 3/2-, 5/2+

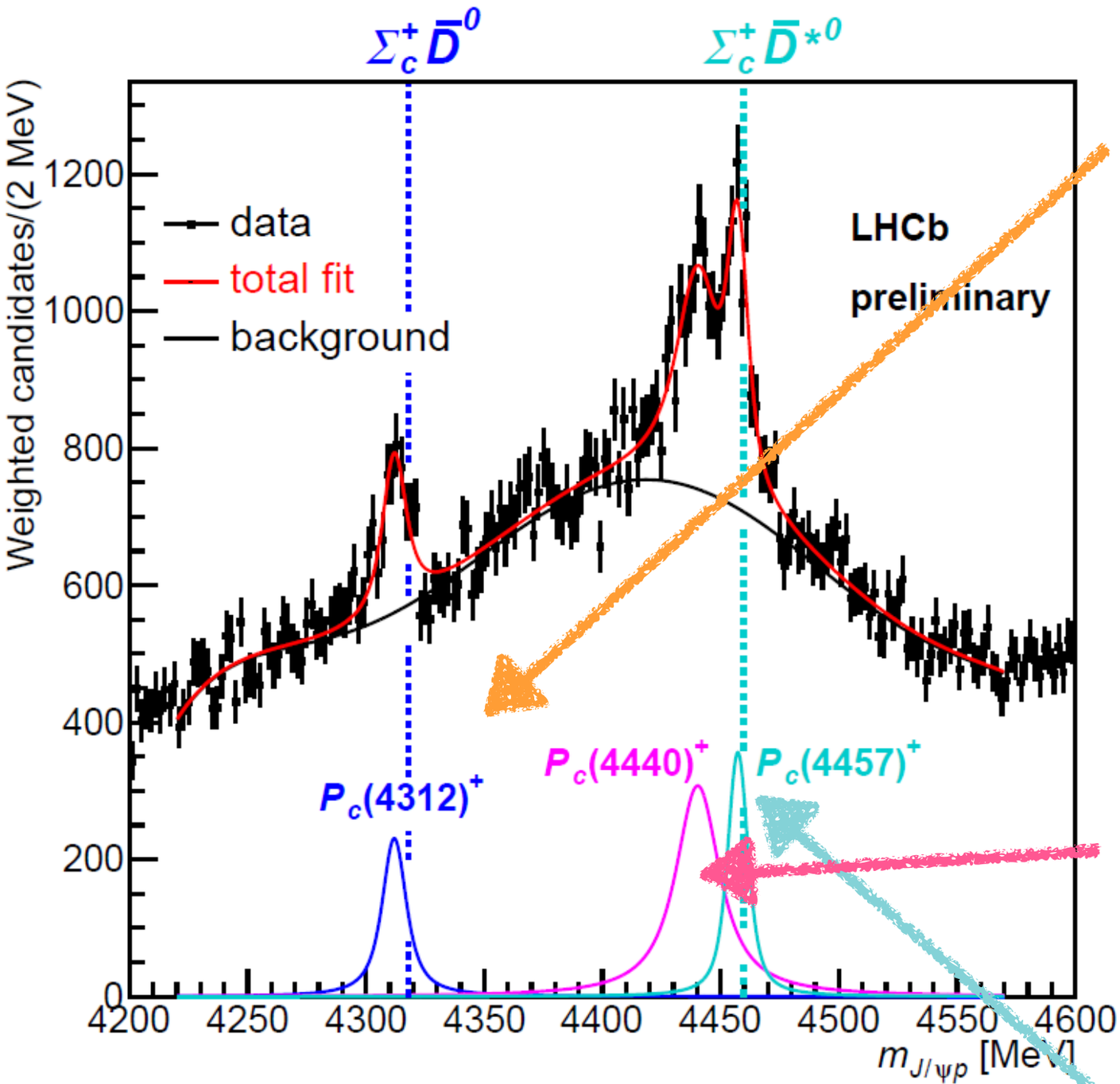
Pc(4380)

Pc(4450)





NEW LHCB RESULTS: OBSERVATION OF NEW PENTAQUARKS (26 MARCH 2019)



- **9x more data than 2015 paper**
- **Previous results are consistent**

BUT!!!

There is a new state:

M: 4311.9±0.7+6.8/-0.6 MeV

Γ: 9.8±2.7+3.7/-4.5 MeV

AND

***Pc(4450)* is resolved into 2 narrow peaks**

★ ***Pc(4440)***

M: 4440.3±1.3+4.1/-4.7 MeV

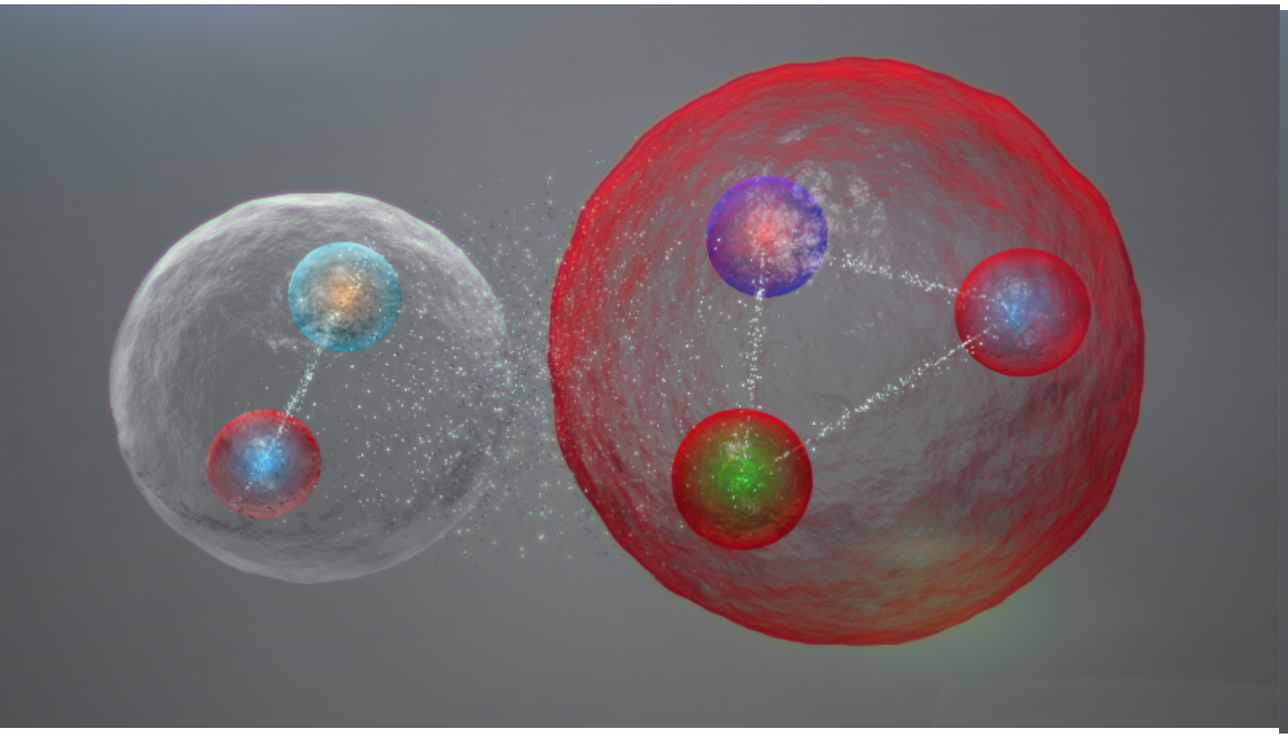
Γ = 20.6±4.9+8.7/-10.1 MeV

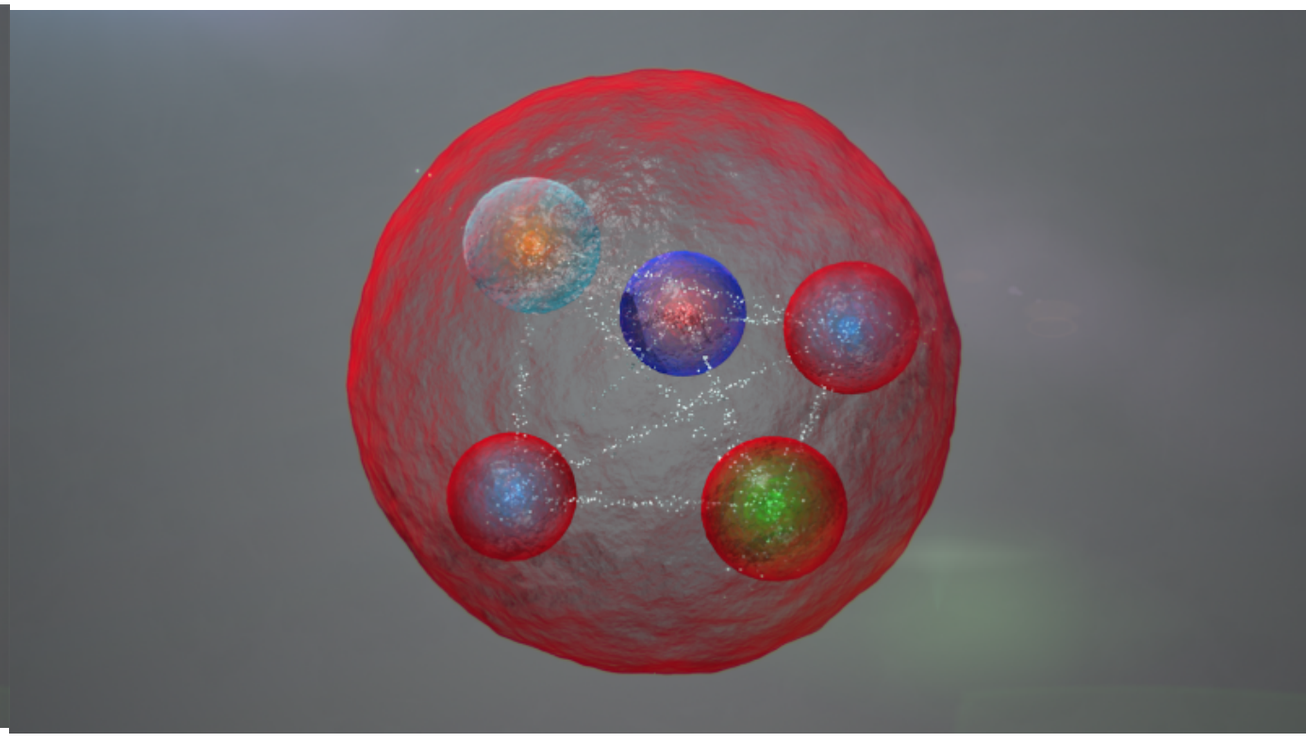
★ ***Pc(4457)***

M: 4457.3±0.6+4.1/-1.7 MeV

Γ = 6.4±2.0+5.7/-1.9 MeV

CHARMED “PENTAQUARK” IN PHOTO-PRODUCTION





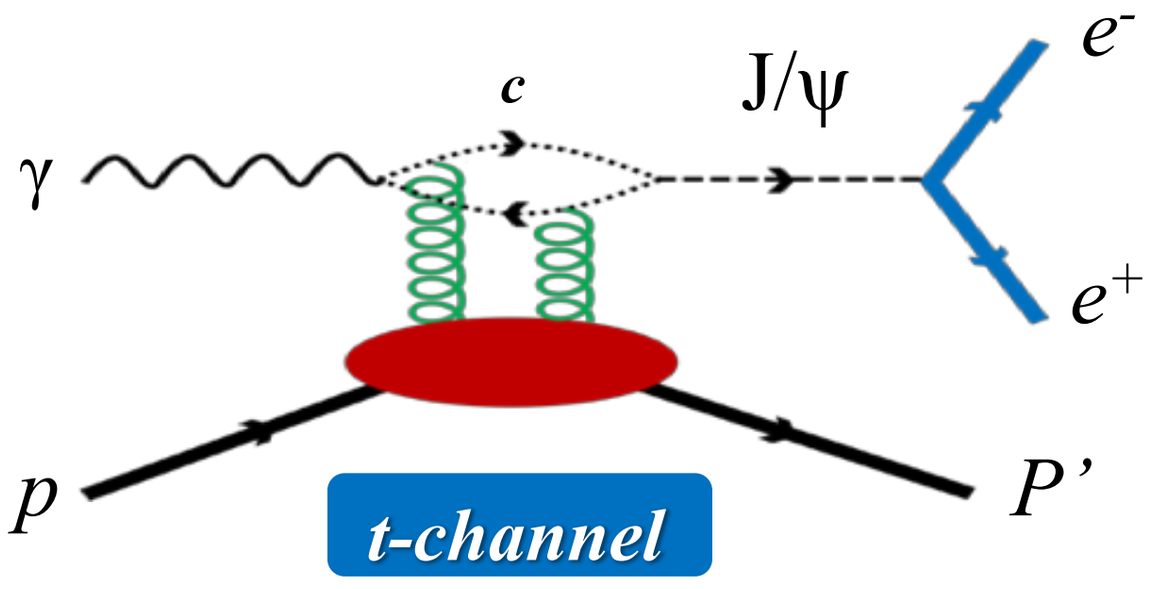
- **Common Interpretations for LHCb Observations**
  - **LHCb:** True resonant “pentaquark” states
  - **Alternative:** Kinematic enhancements through Anomalous Triangle Singularity (ATS)

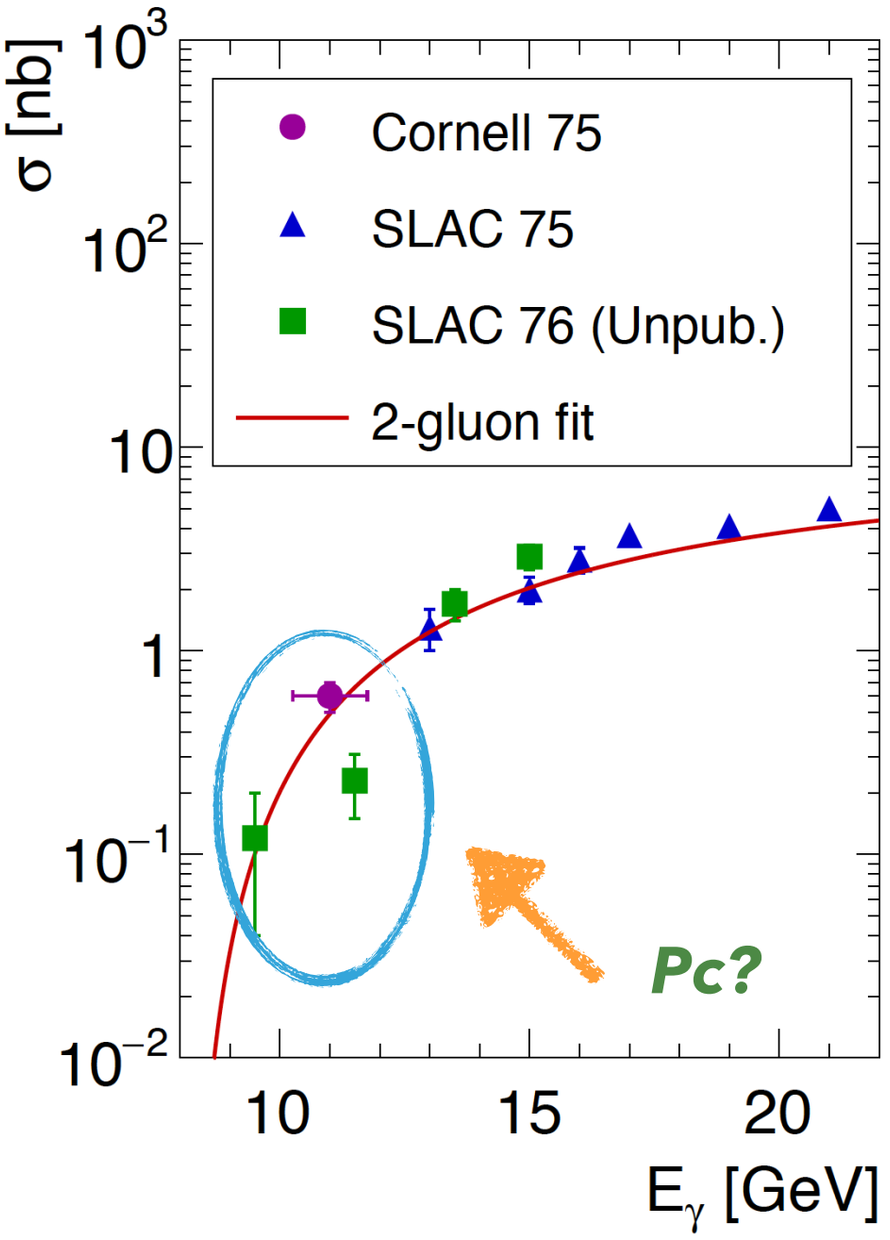
- The **photo production** is an ideal tool to distinguish between explanations
  - If Pc states are real states, should **also be created in photo-production**
  - Kinematic enhancement **through ATS not possible**

X-H Lui *et al.*, PLB 757, 231 (2016) and references therein
Q. Wang *et al.*, PRD 92-3 034022-7 (2015) and references therein

J/Ψ PHOTO-PRODUCTION: CURRENT DATA STATUS

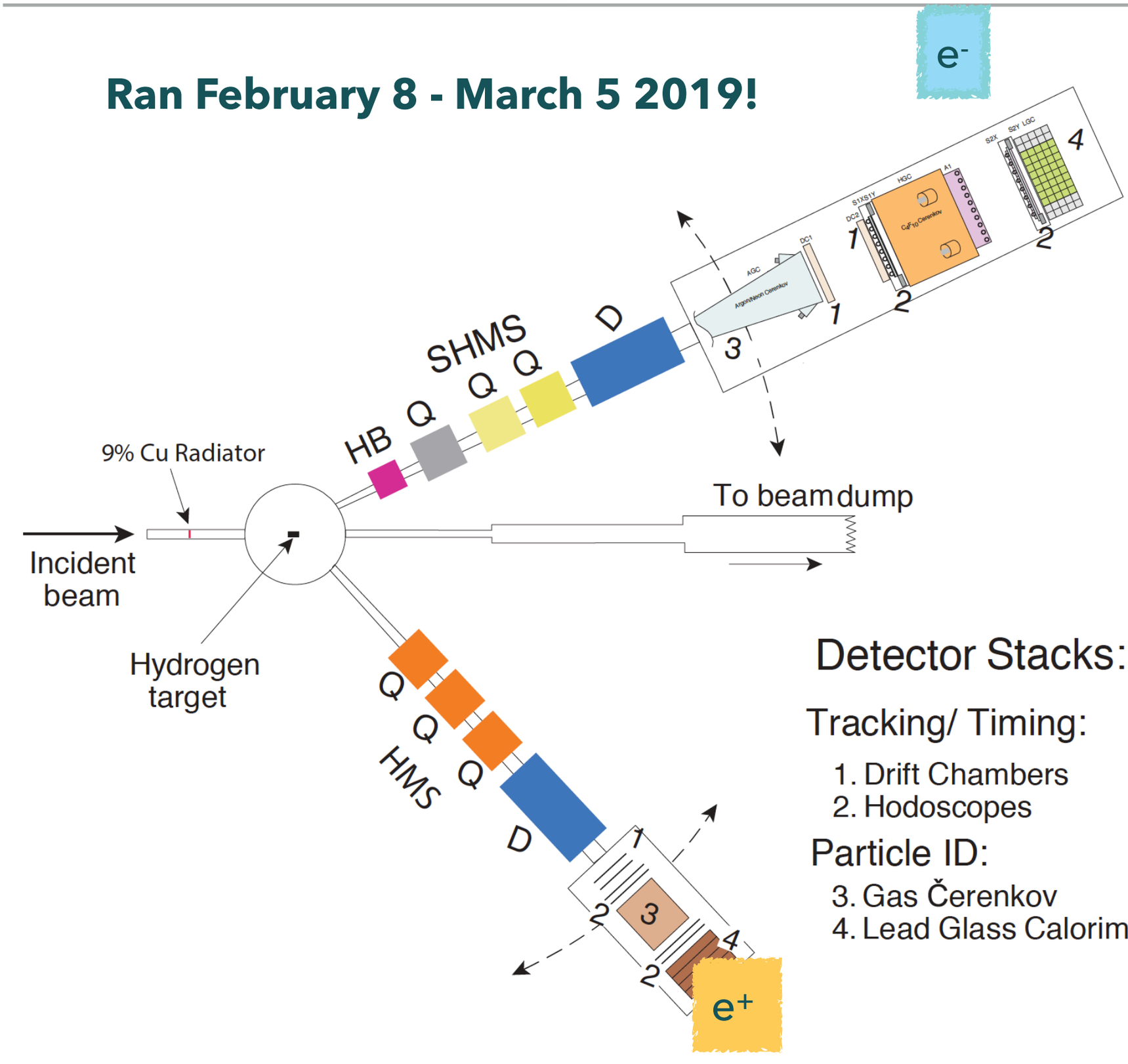
- Measured in many experiments at high $W_{\gamma p}$
  - dominated by t-channel 2-gluon exchange
  - Almost no data in threshold region





PENTAQUARK SEARCH WITH E12-16-007 EXPERIMENT IN HALL C

Ran February 8 - March 5 2019!



- ★ 10.6 GeV beam energy
- ★ 50 μA
- ★ 9% copper radiator
- ★ 10 cm LH2 target

Detector Stacks:

Tracking/ Timing:

1. Drift Chambers
2. Hodoscopes

Particle ID:

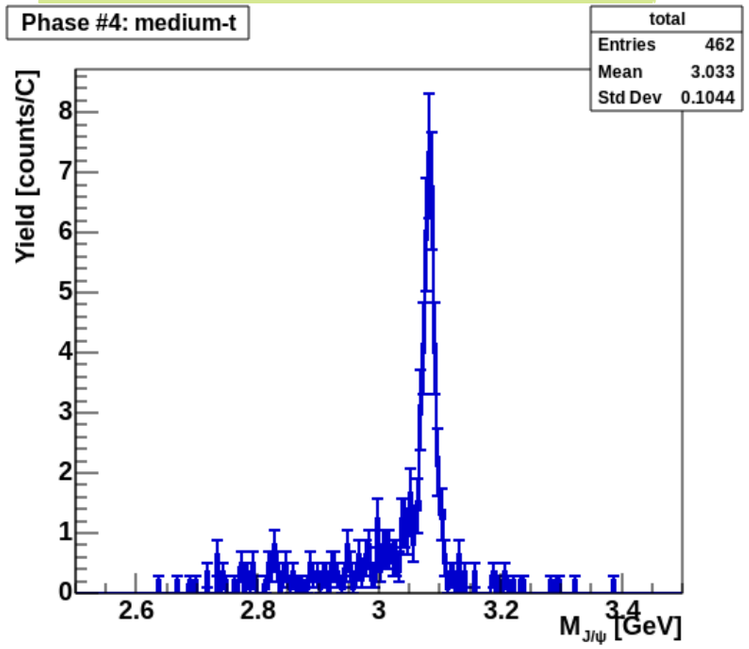
3. Gas Čerenkov
4. Lead Glass Calorimeter

E12-16-007 MEASUREMENTS

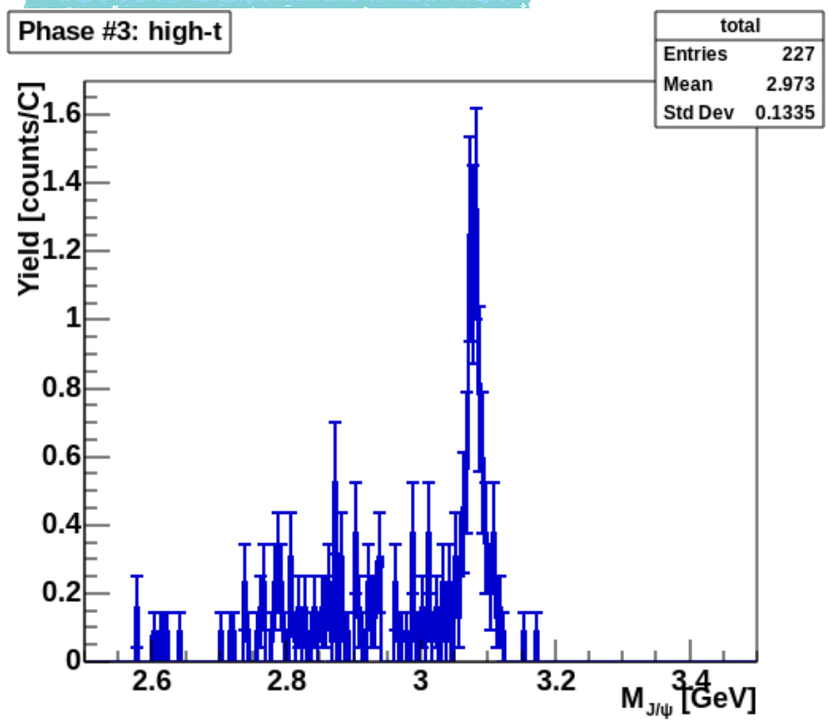
ONLINE ANALYSIS RESULTS

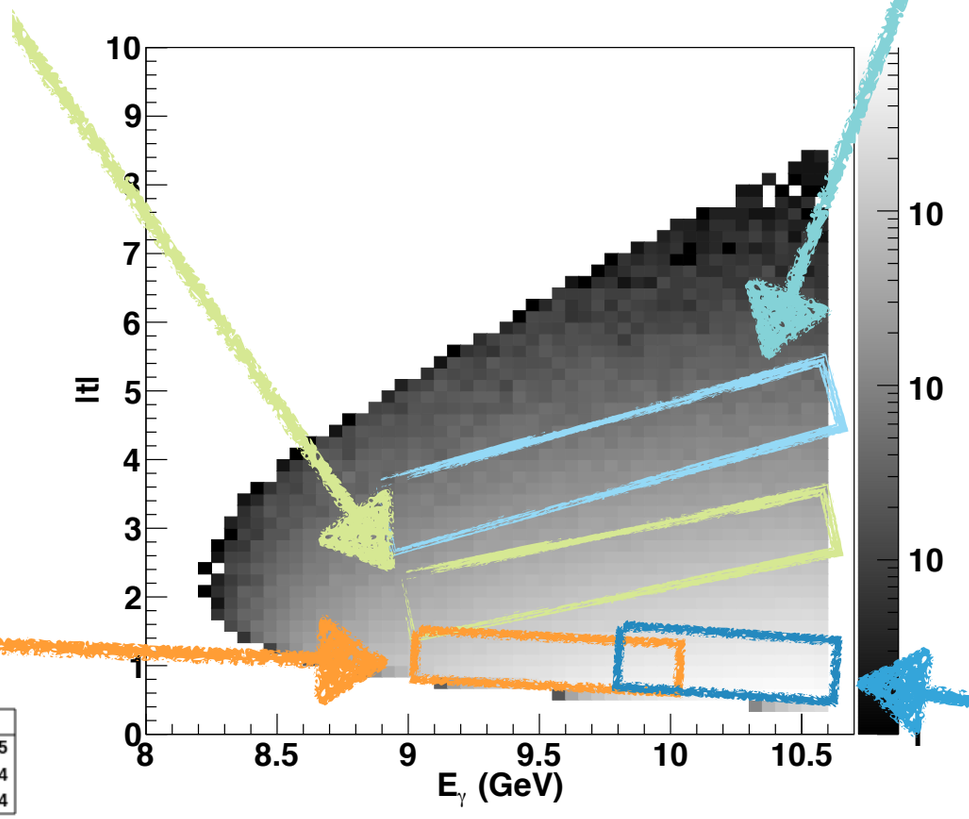
$$J/\psi \to e^+e^-$$

Phase 4: medium t

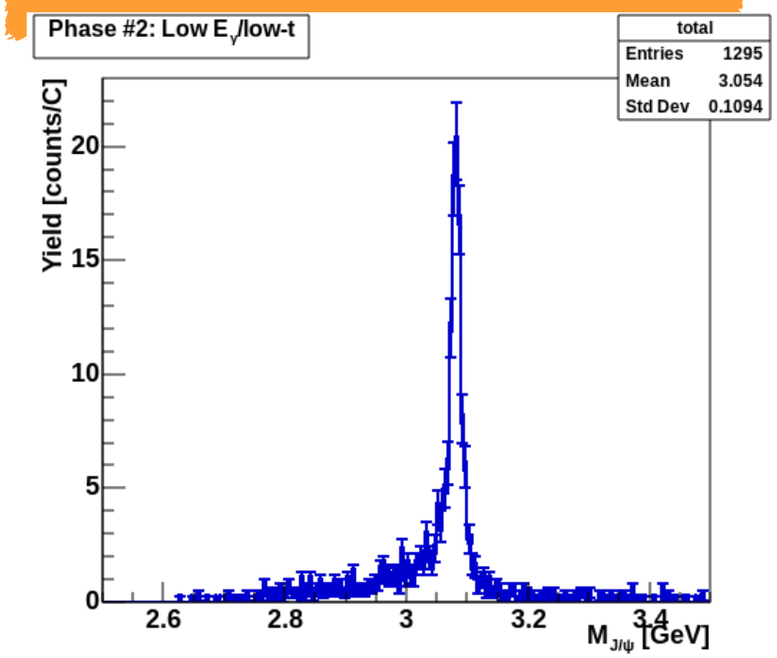


Phase 3: high t

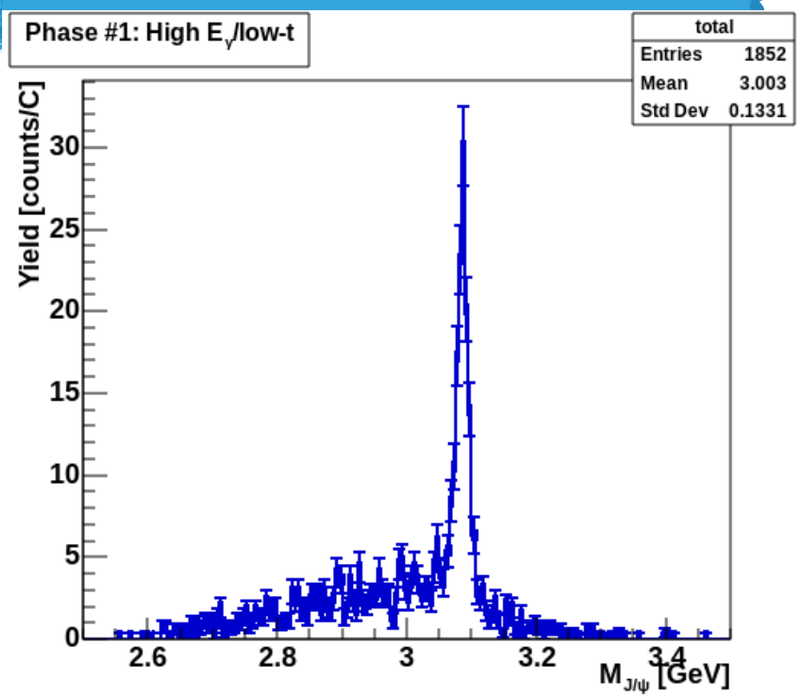




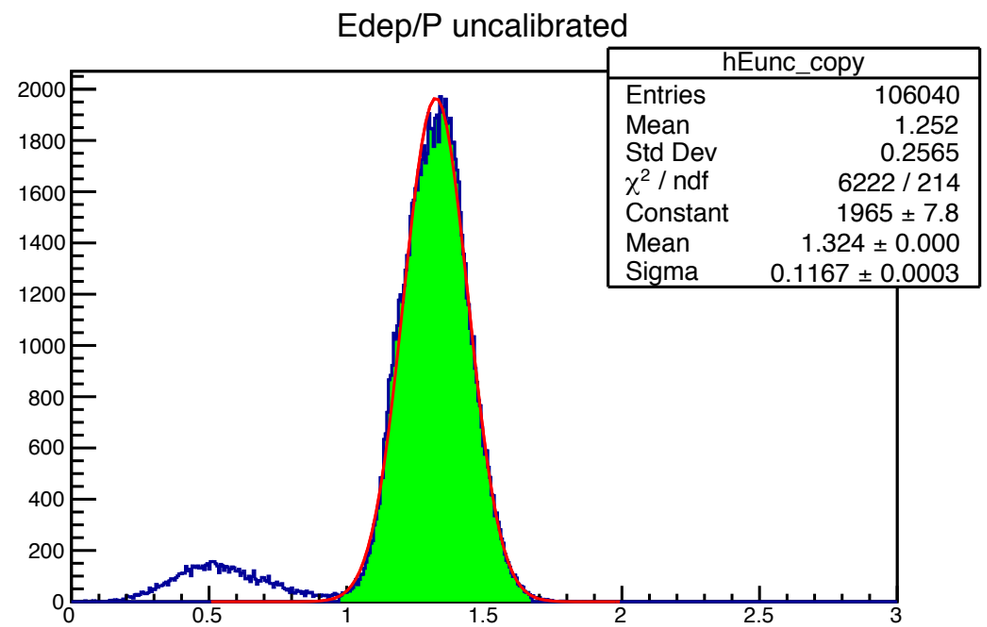
Phase 2: mid E_γ / low t

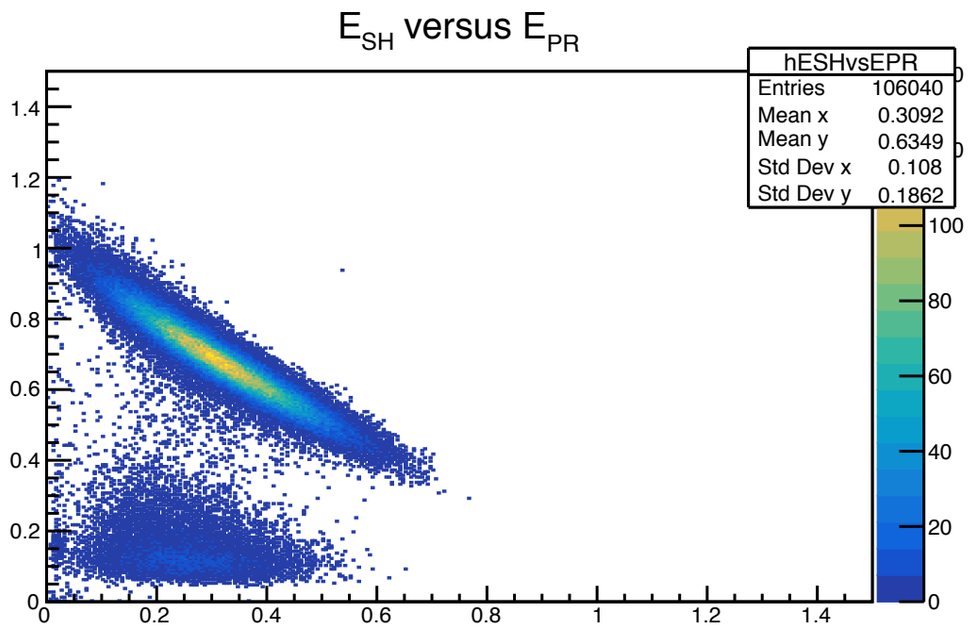


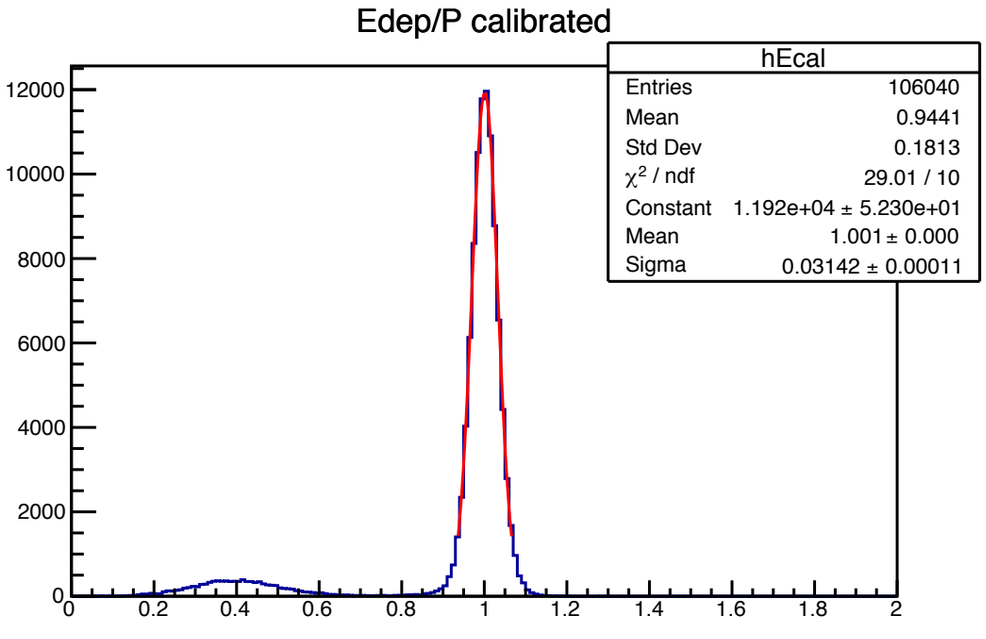
Phase 1: high E_γ / low t

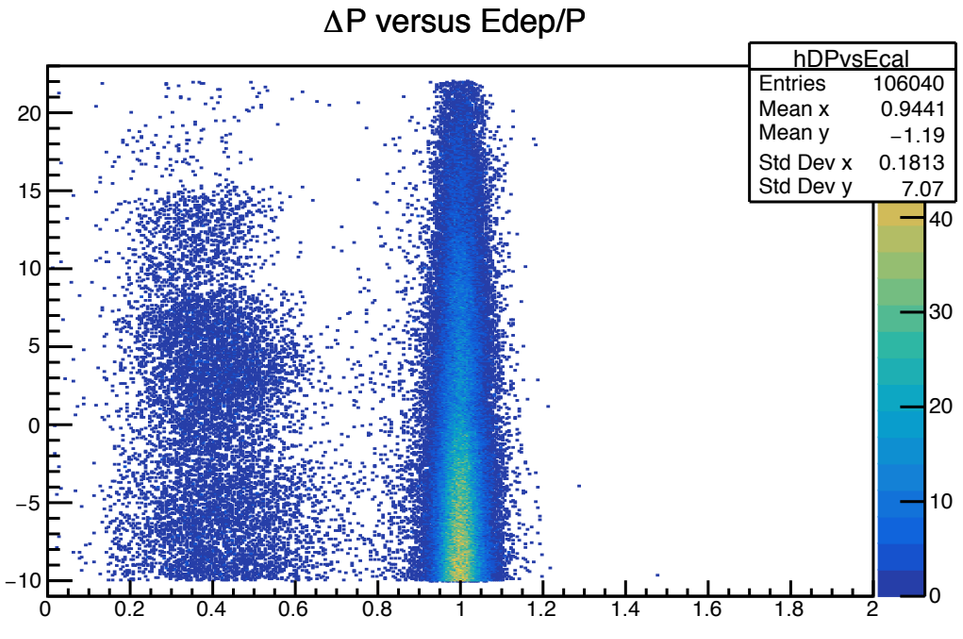


SHMS 7109 – 4.75 GEV, 21 DEG

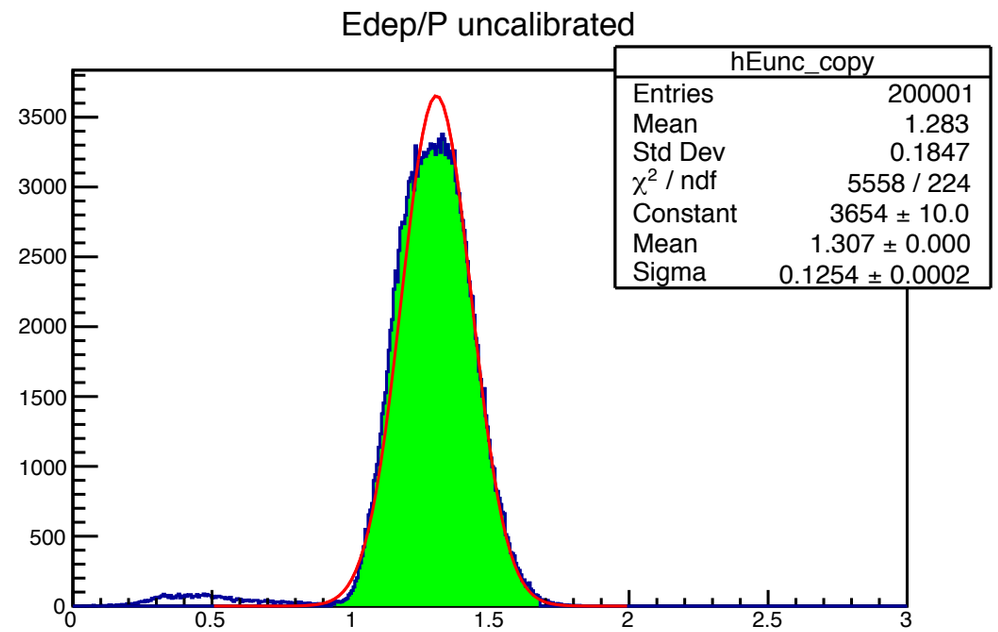


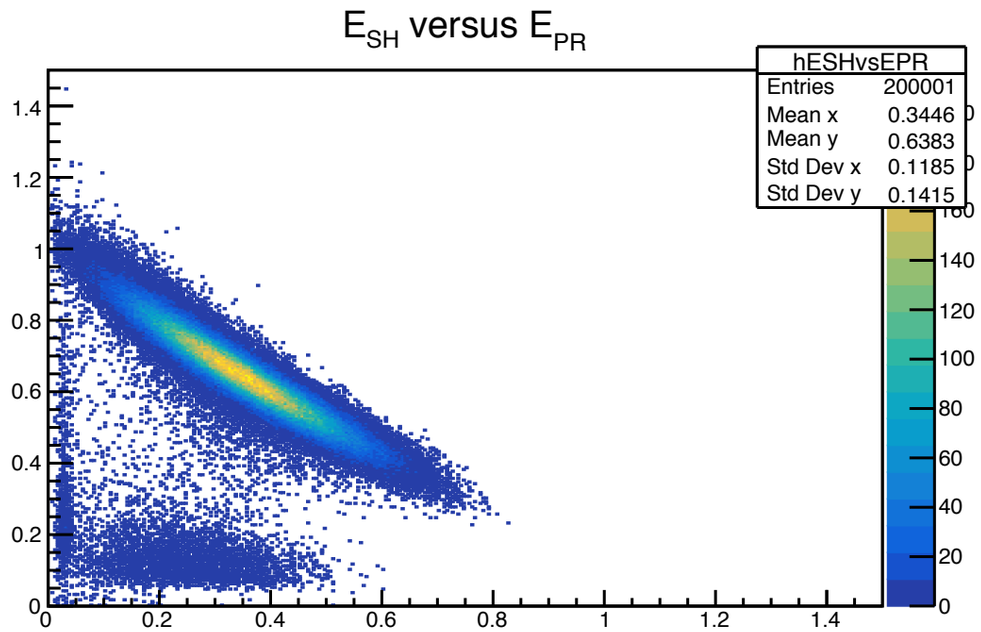


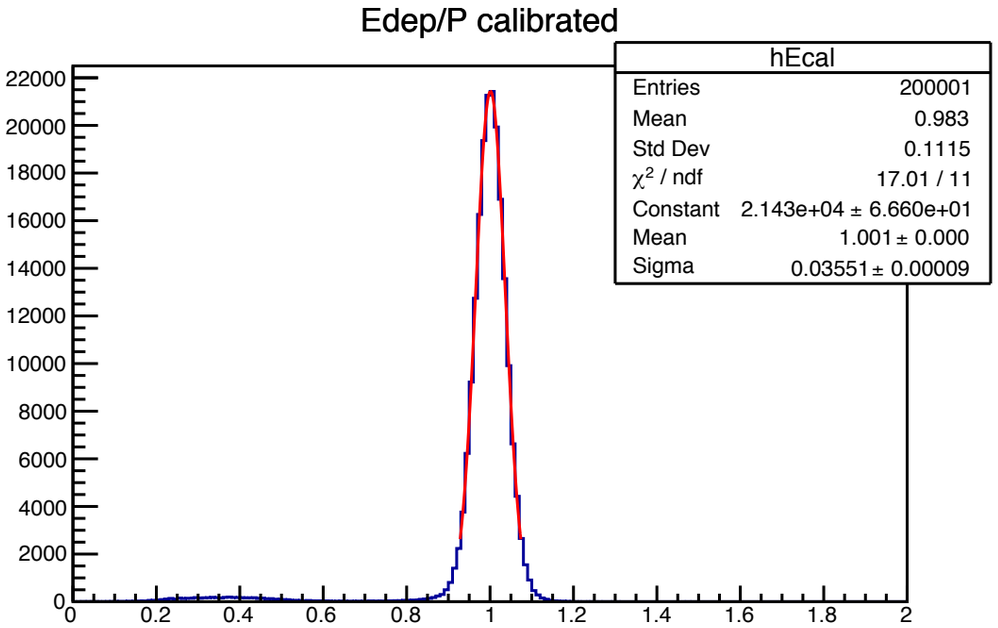


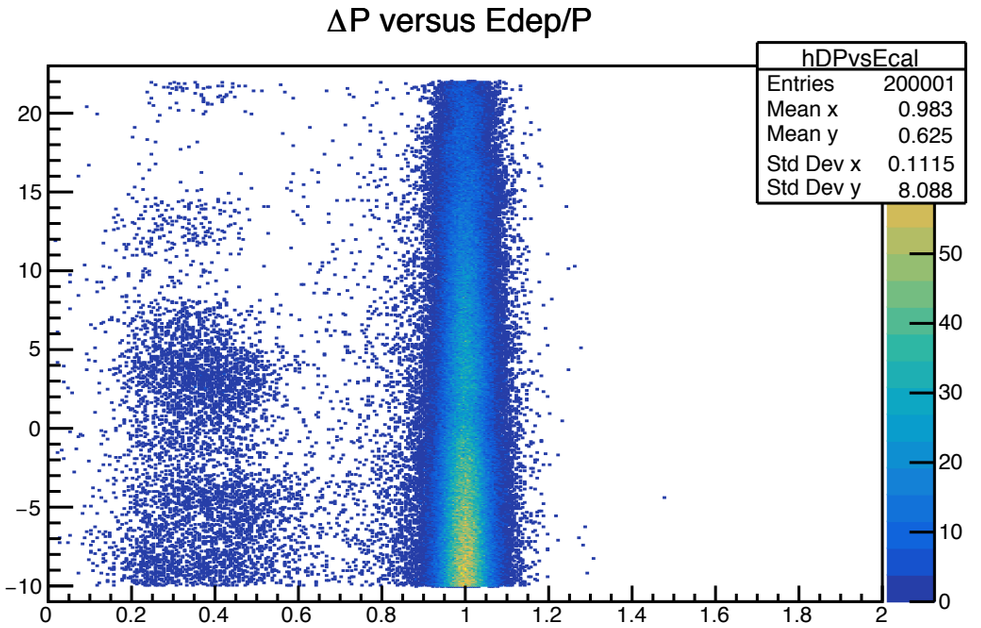


SHMS 7110 – 3.5 GEV, 25 DEG

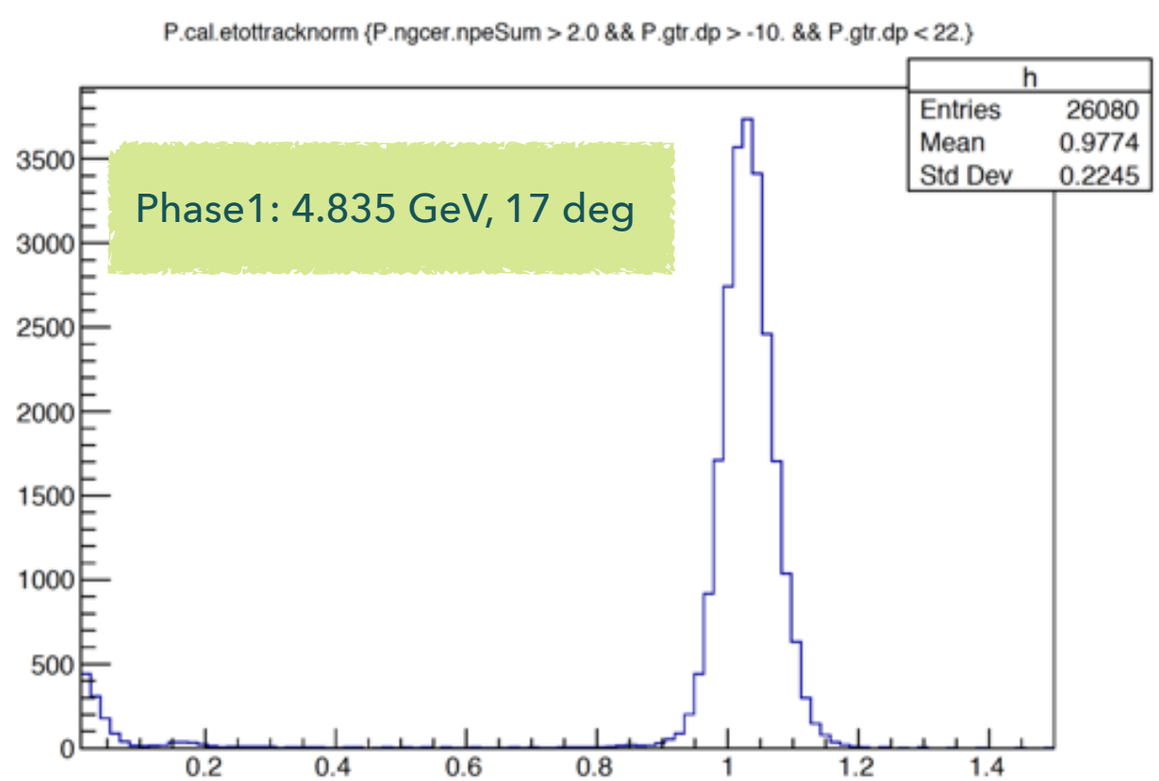


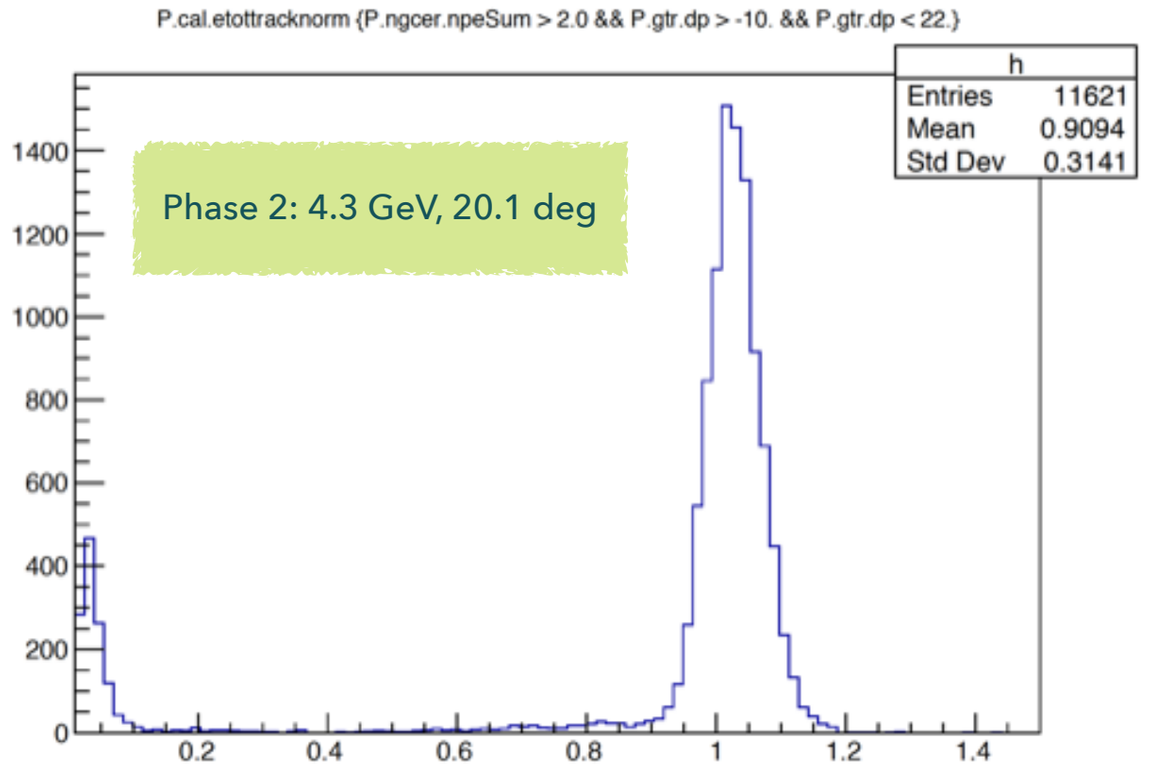


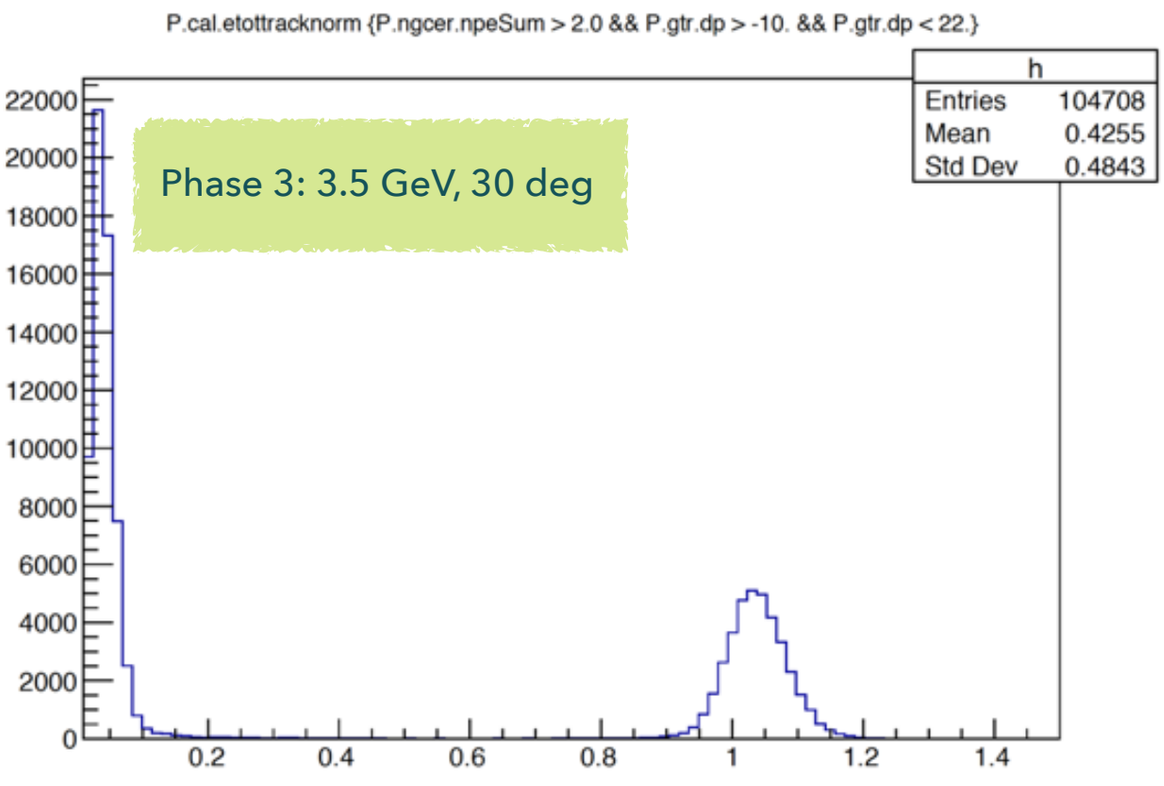


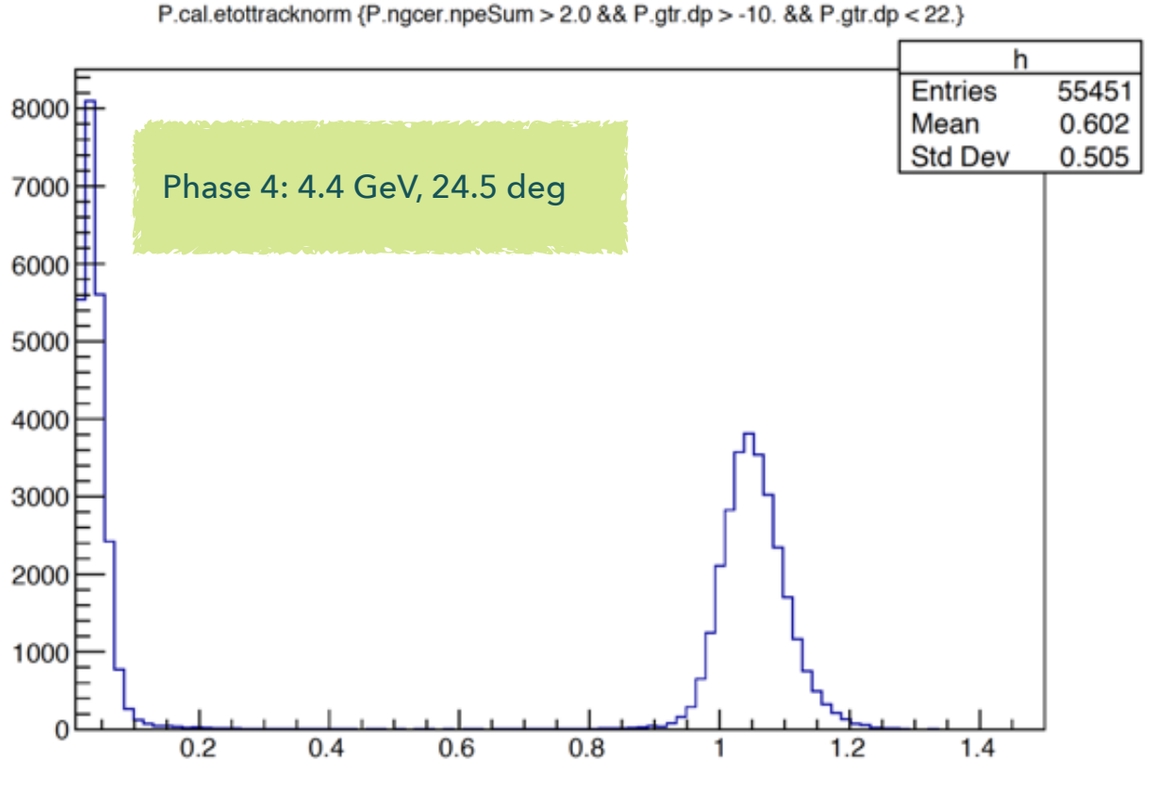


SHMS CALORIMETER CALIBRATION

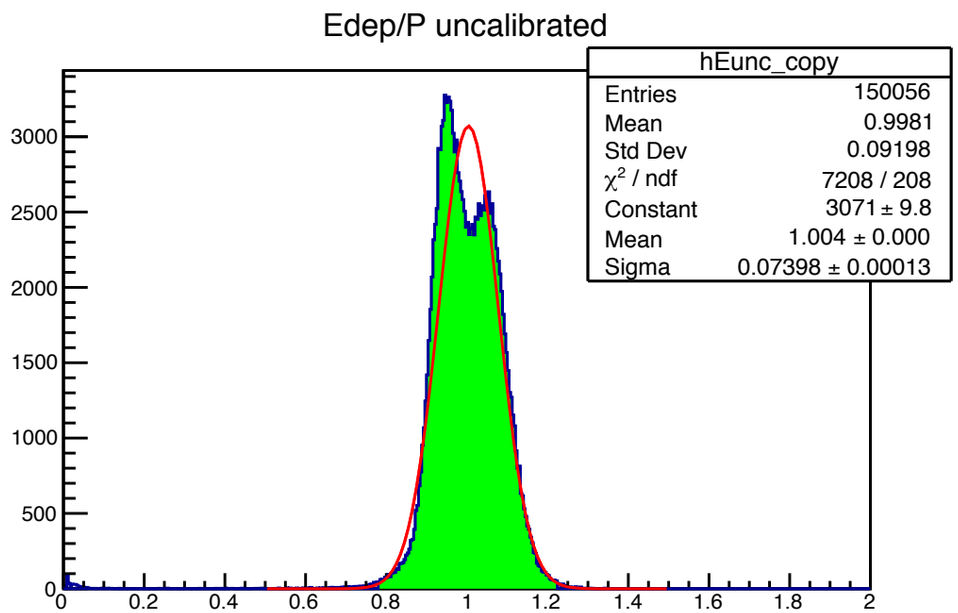


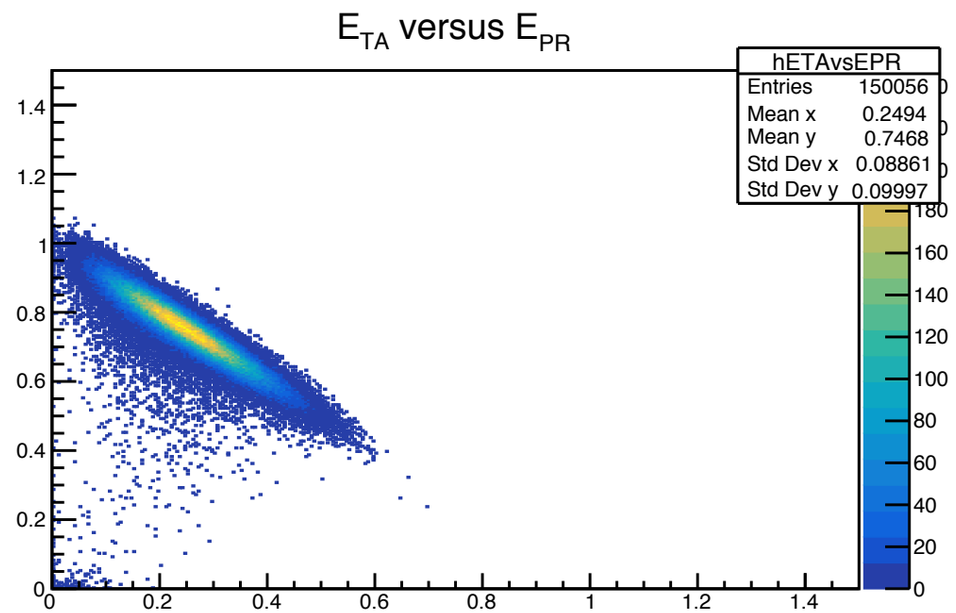


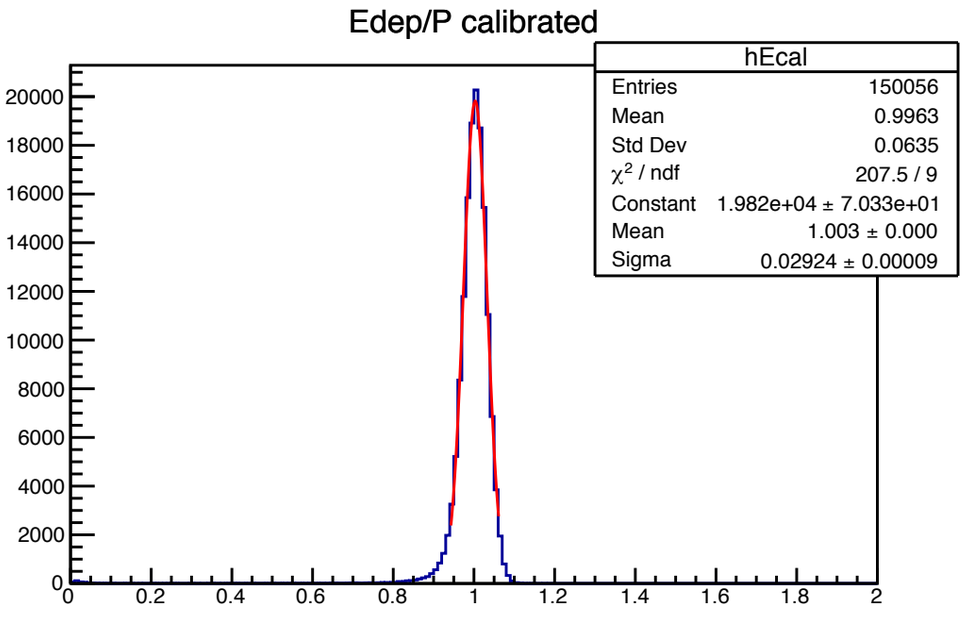


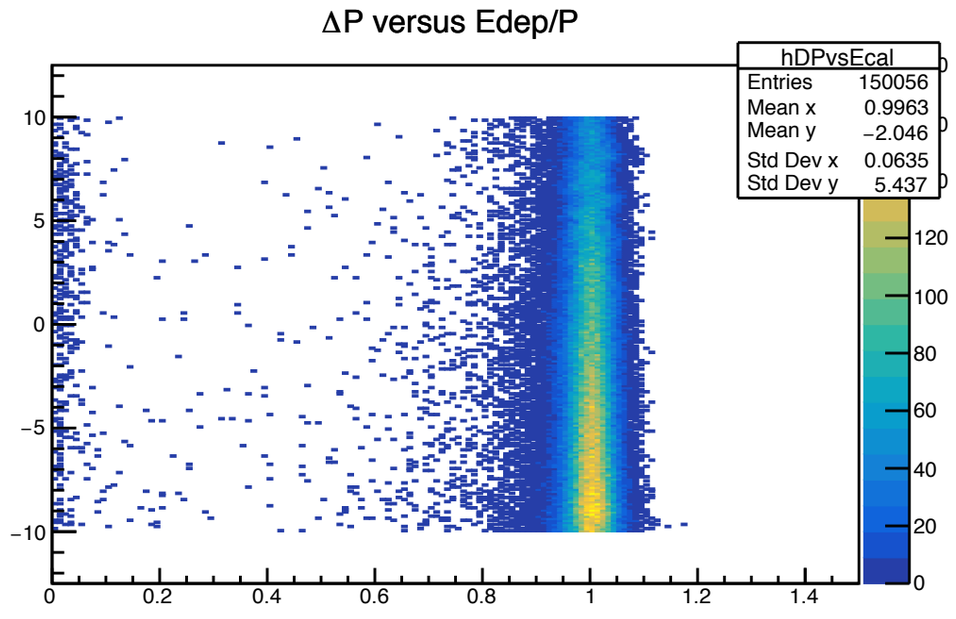


HMS 2368 – 4.75 GEV, 21 DEG

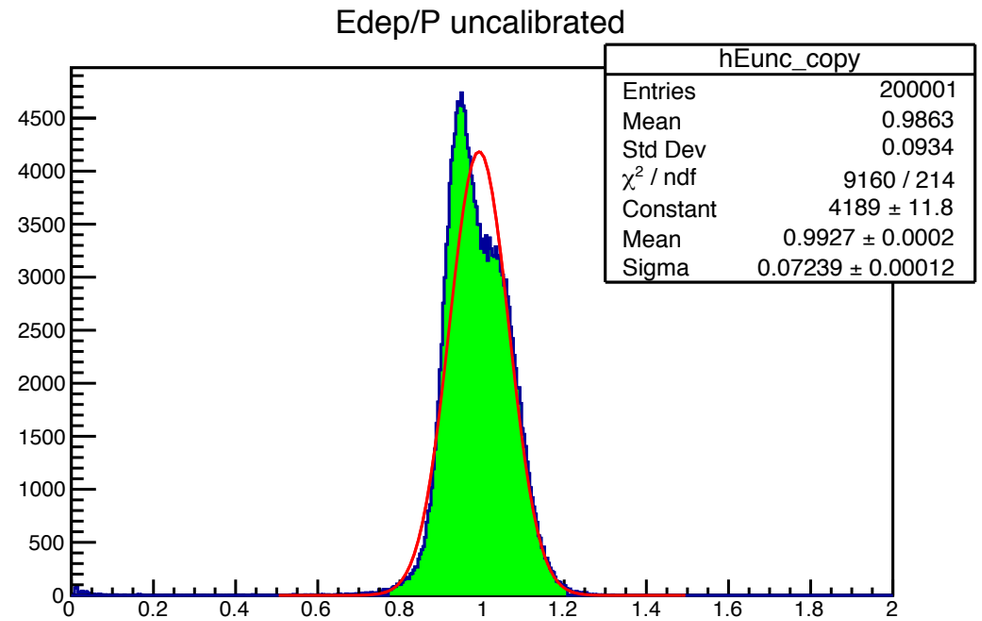


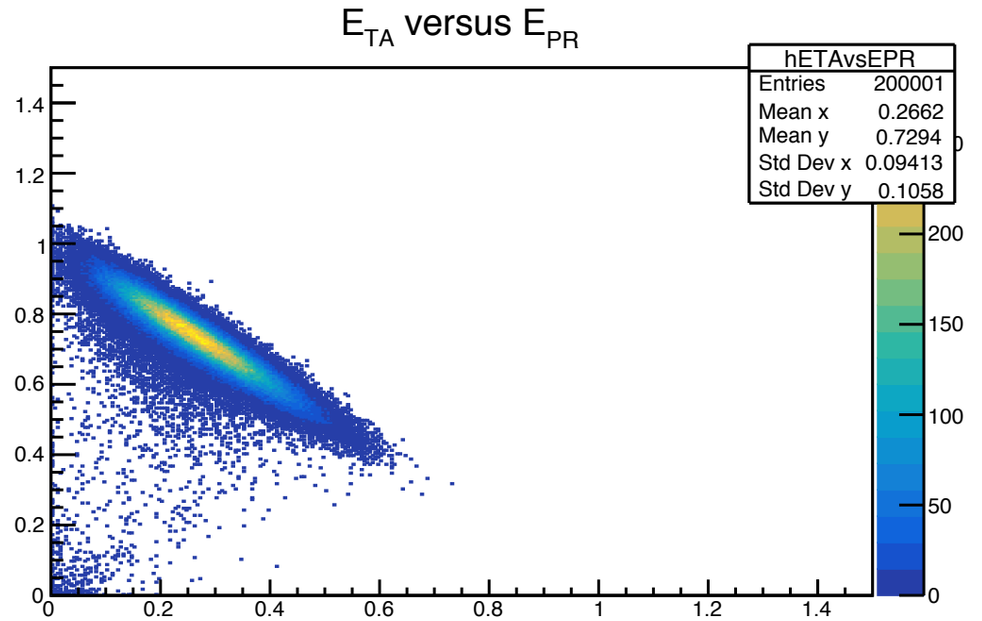


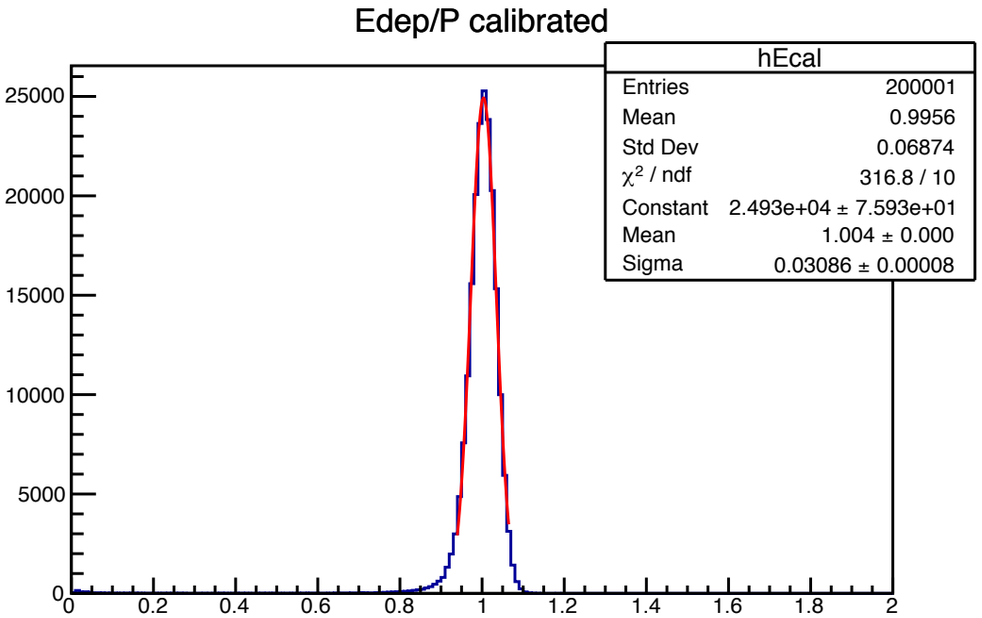


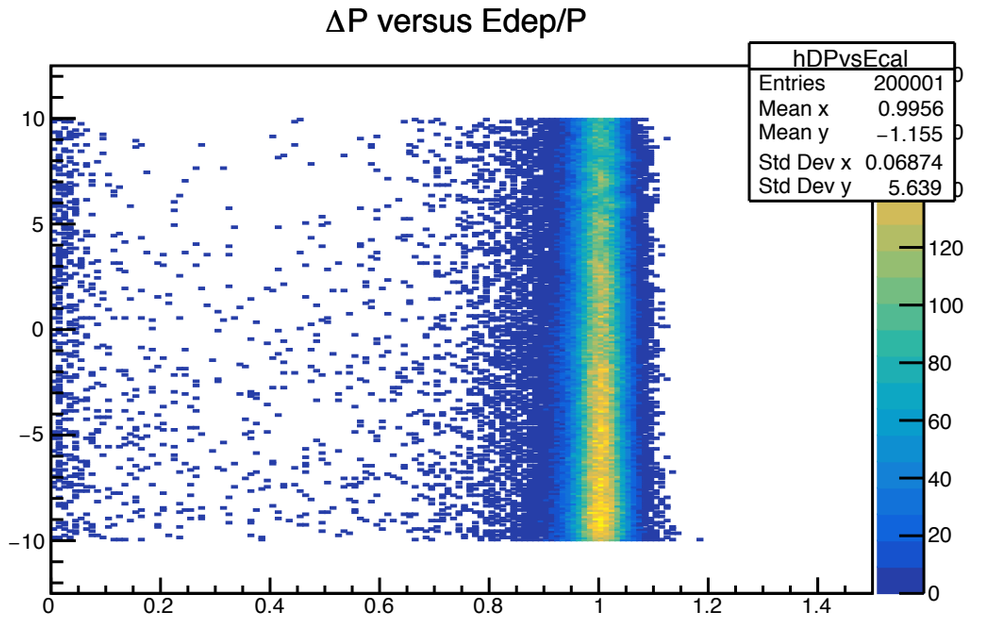


HMS 2369 – 4.1 GEV, 21 DEG

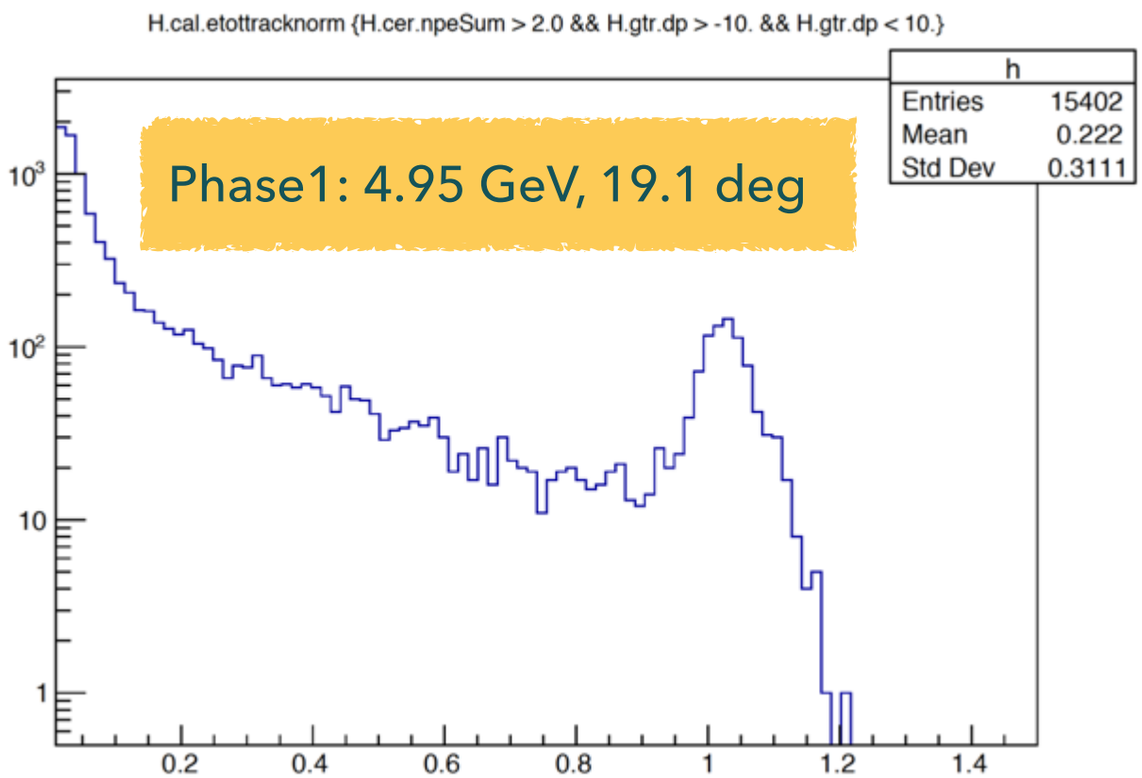


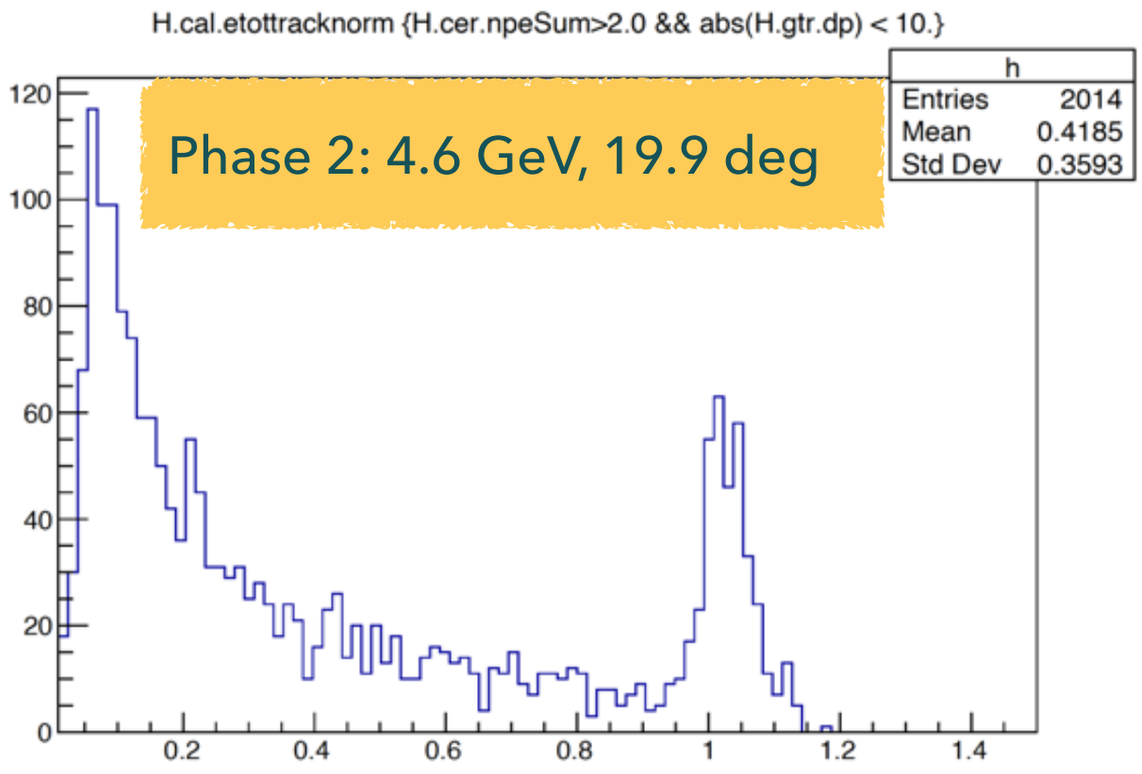


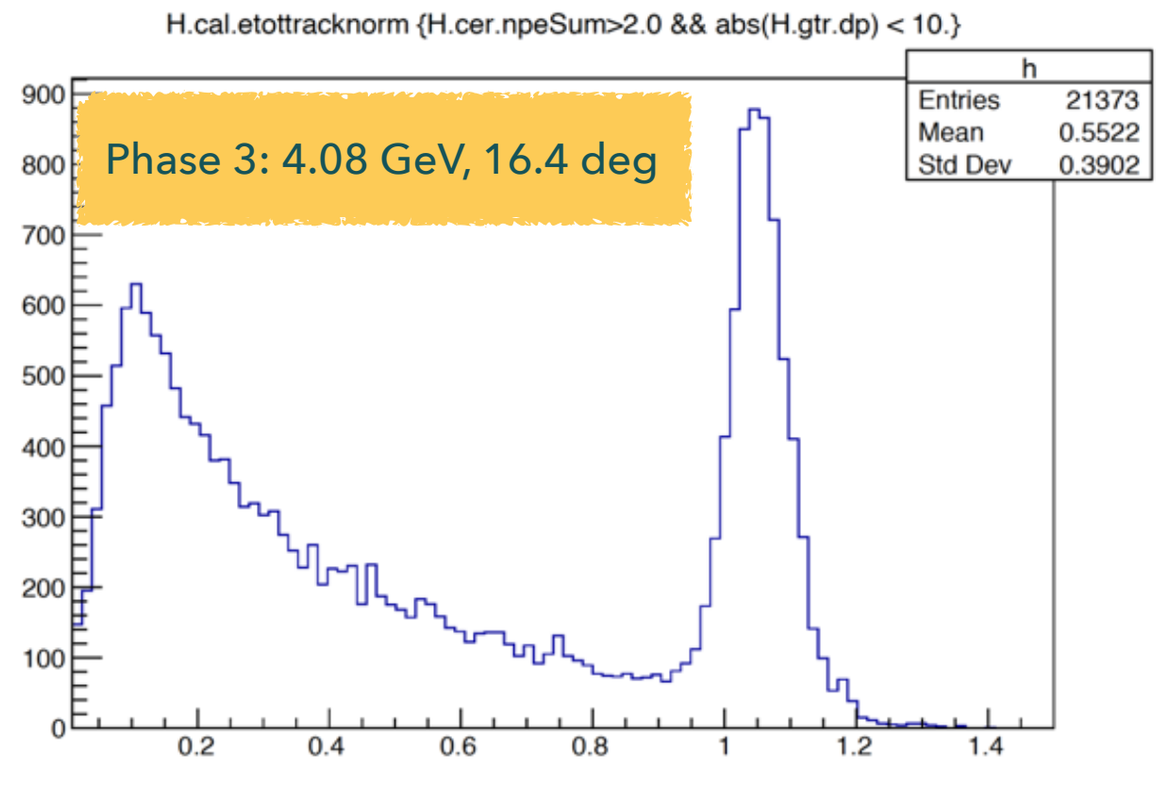


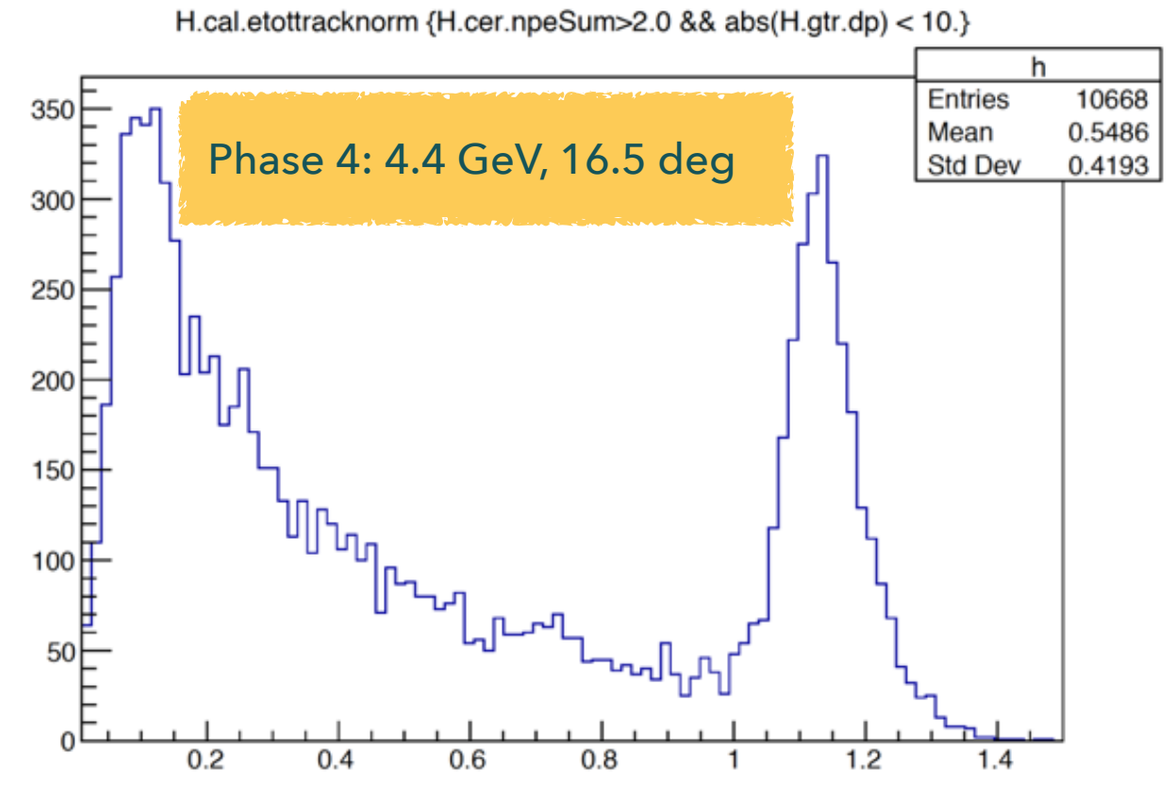


HMS CALORIMETER CALIBRATION





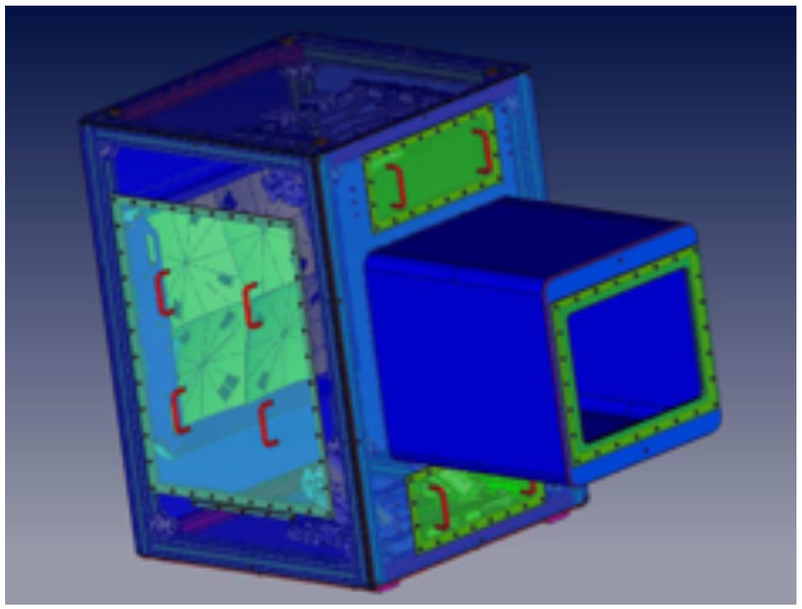




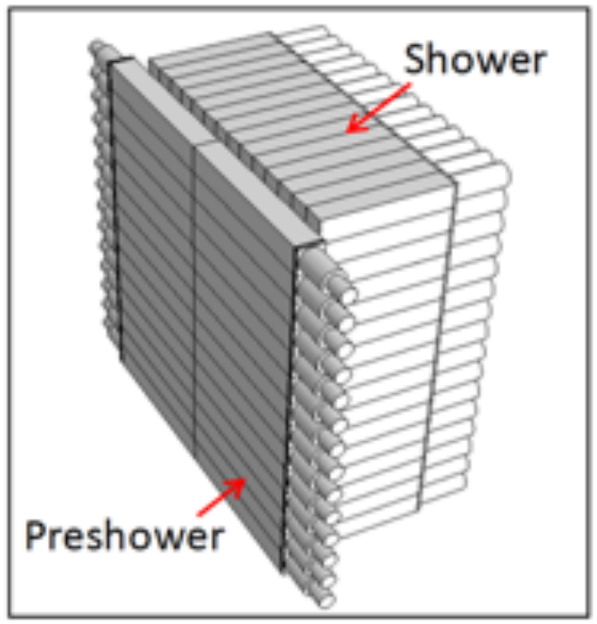
PARTICLE IDENTIFICATION

SHMS

Noble Gas Cherenkov: filled with N_2 at 1 atm

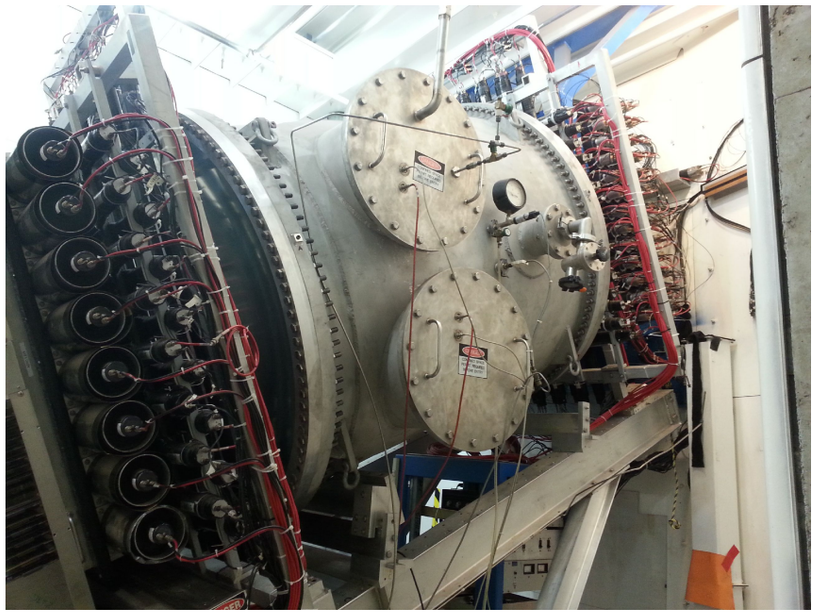


Lead Glass Electromagnetic Calorimeter

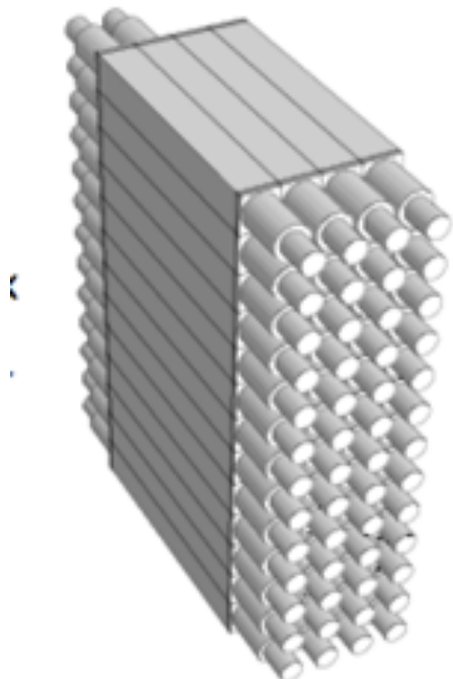


HMS

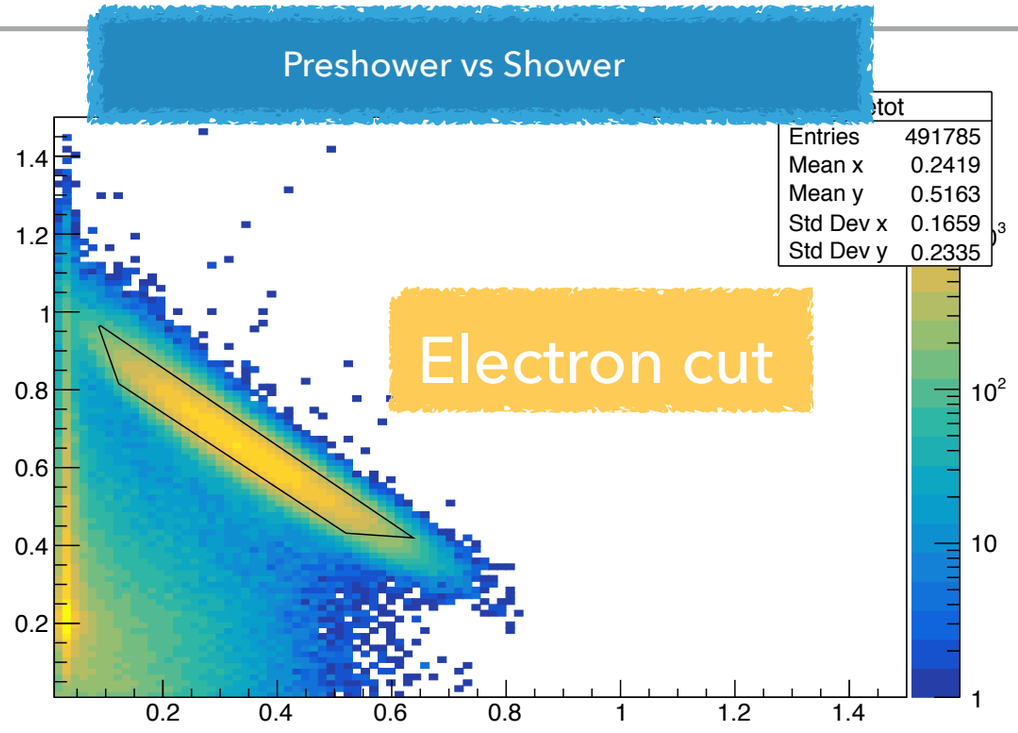
Cherenkov: filled with C4F8O at 0.225 atm

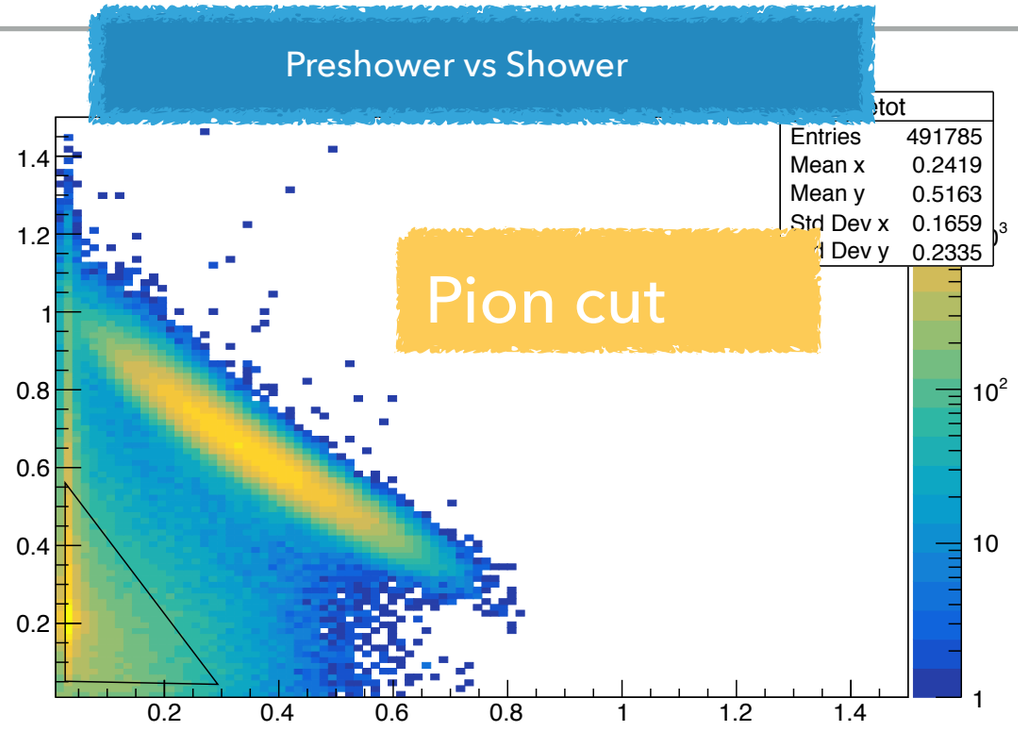


Lead Glass Electromagnetic Calorimeter



SHMS PARTICLE IDENTIFICATION (PID)

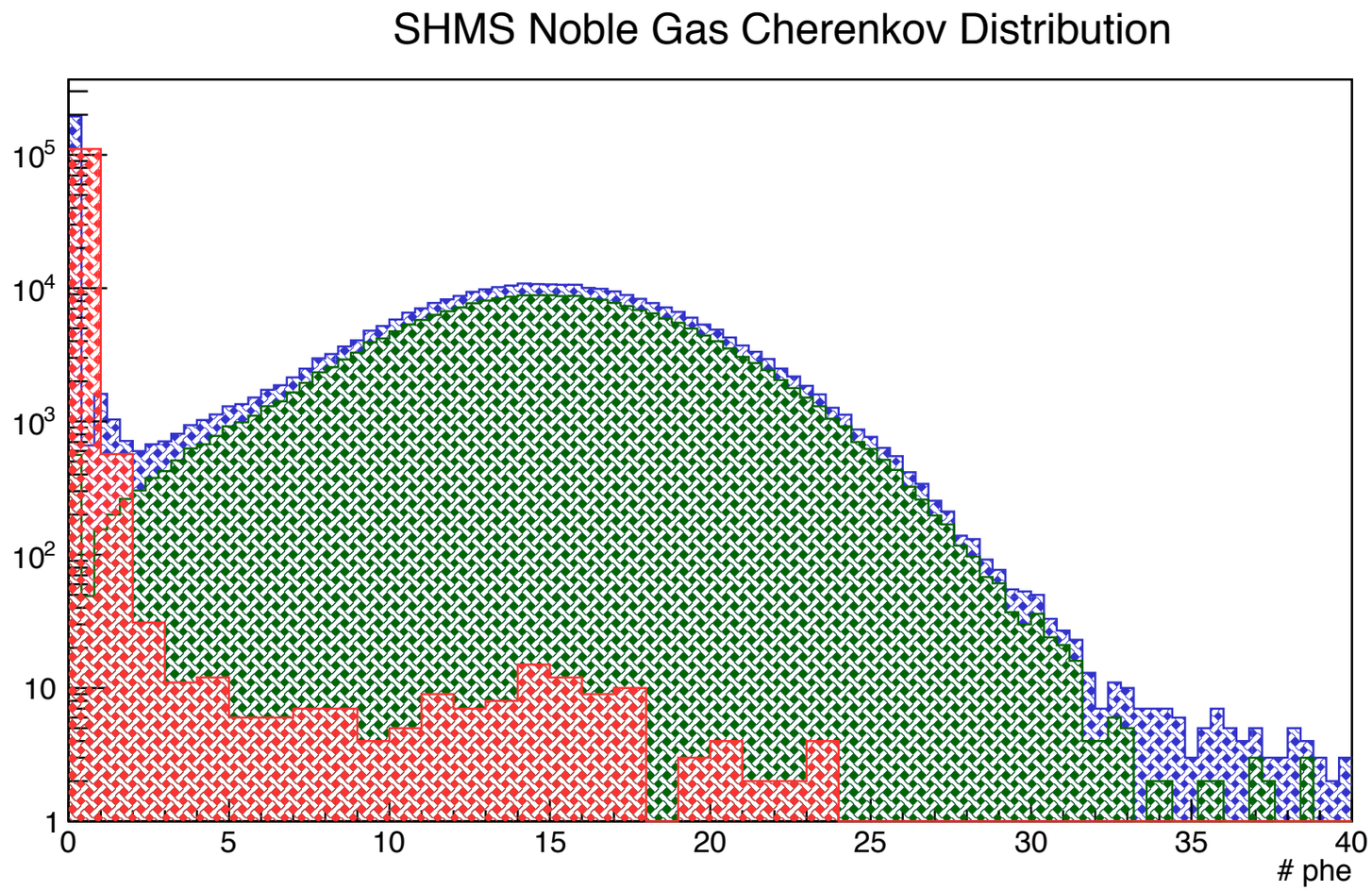




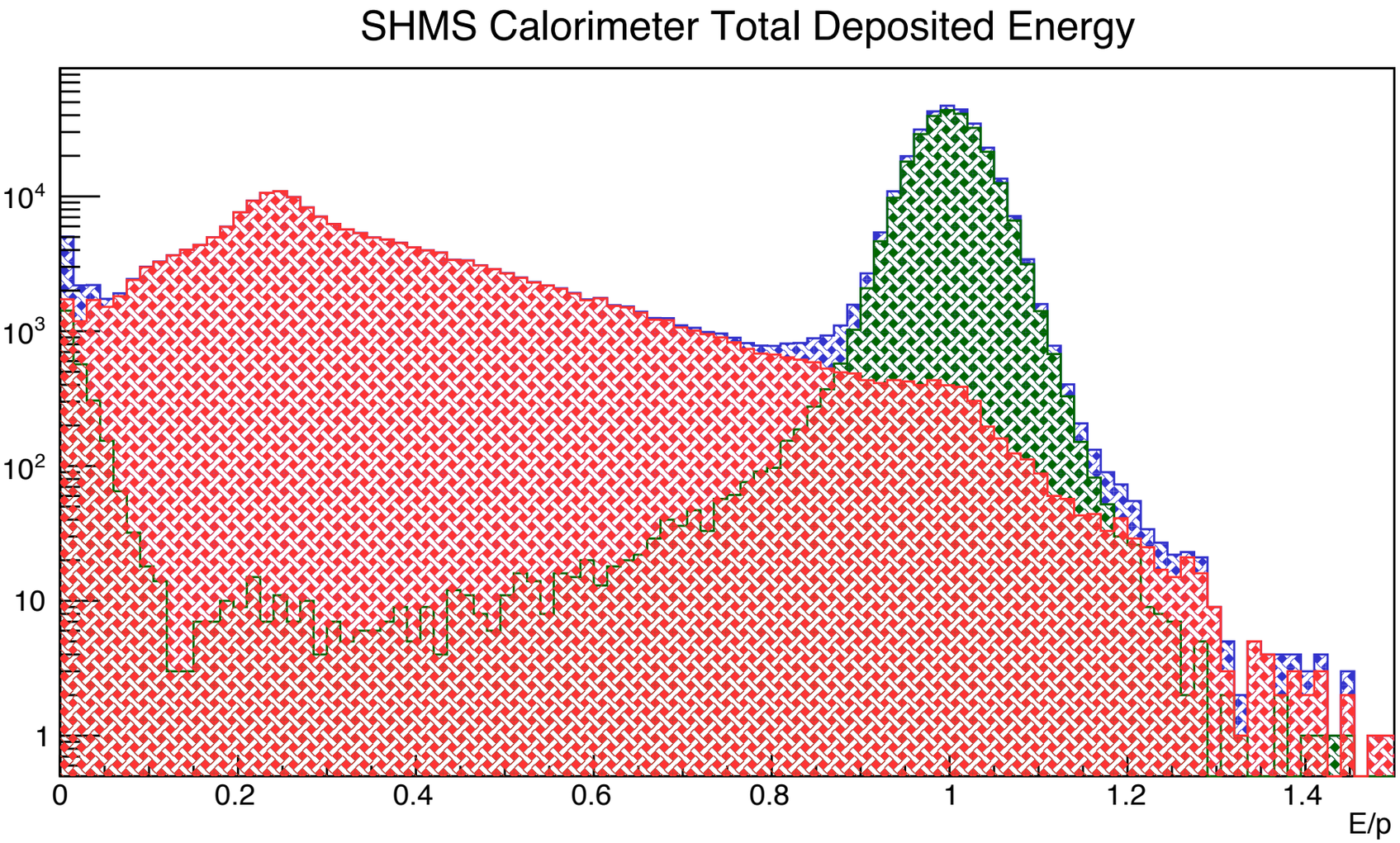
all events

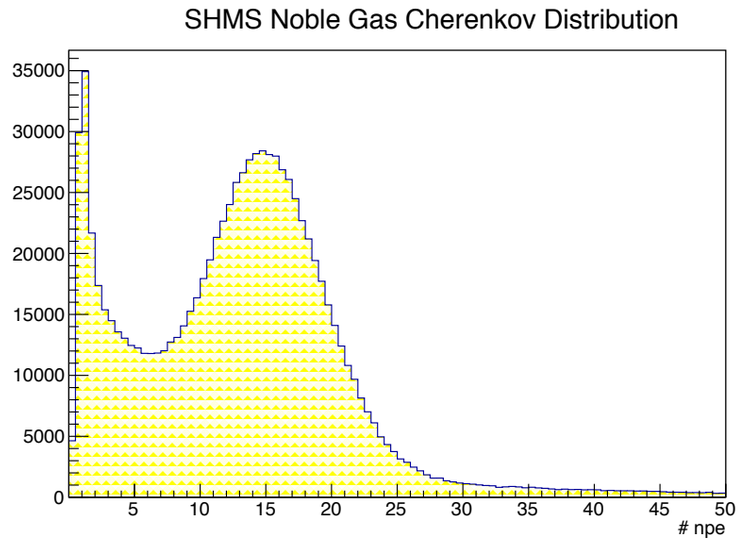
electrons selected by 2D calorimeter cut.

pions selected by 2D Calorimeter cut.



SHMS PARTICLE IDENTIFICATION (PID)



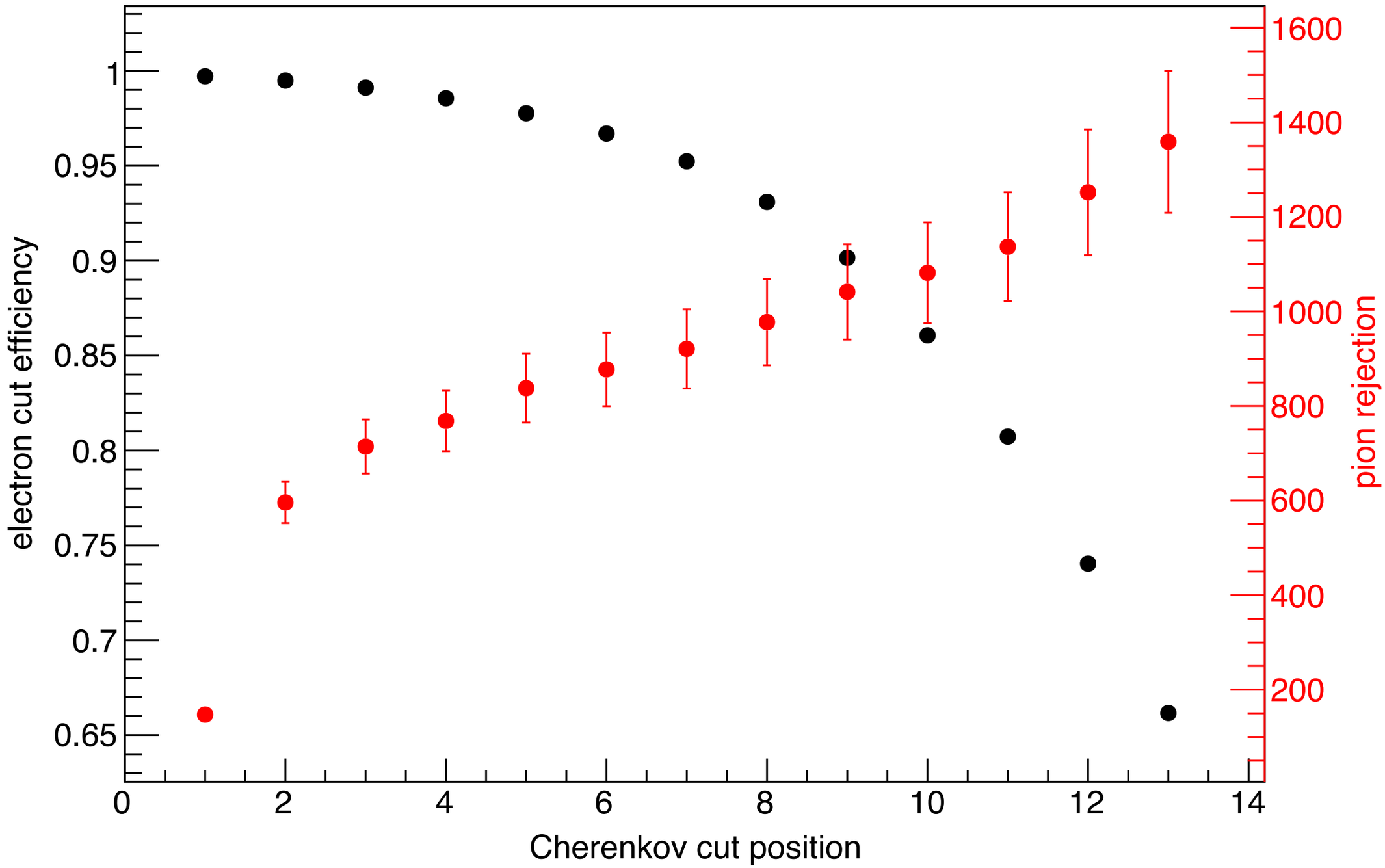


all events

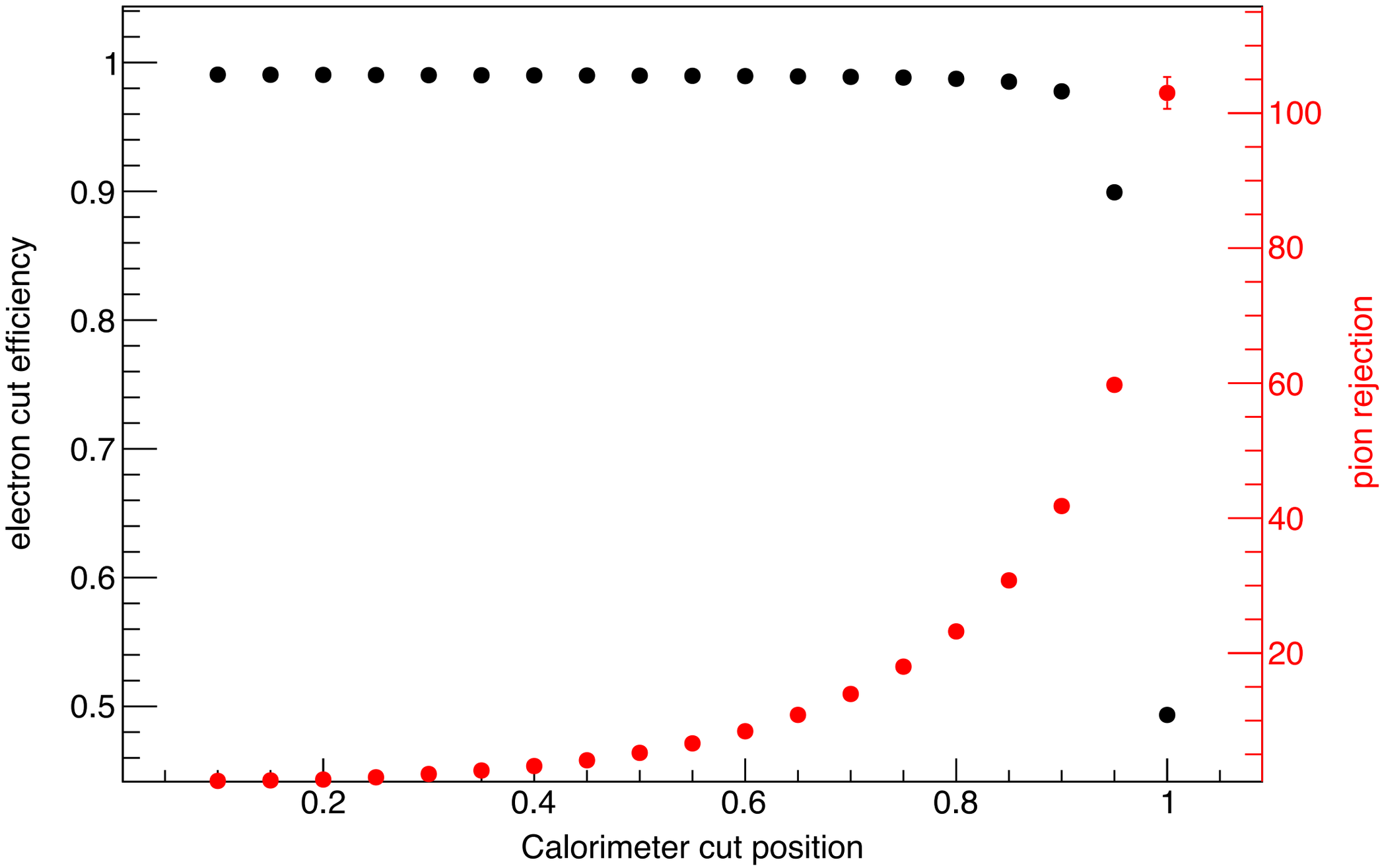
electrons selected by SHMS NGCER > 8 npe

pions selected by SHMS NGCER < 2 npe

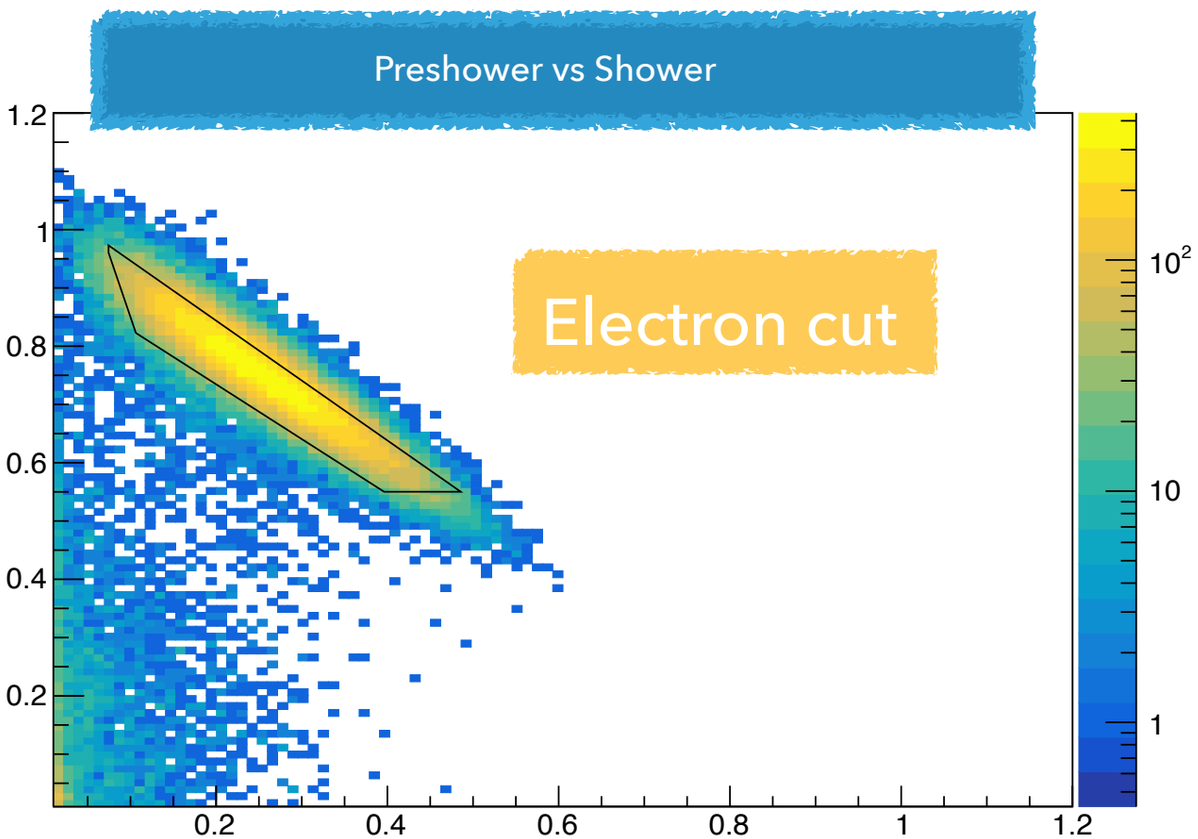
SHMS Cherenkov Cut Efficiency & Pion Rejection Factor

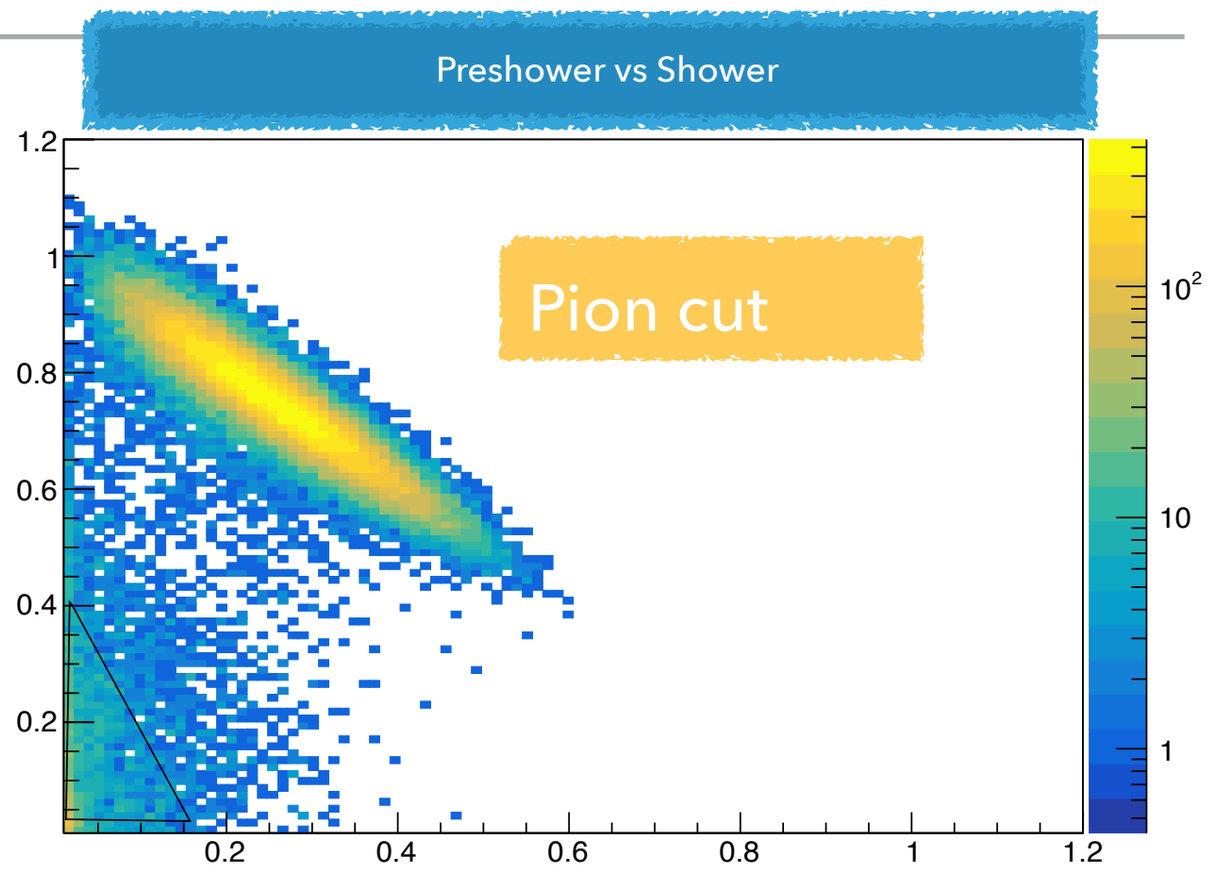


SHMS Calorimeter Cut Efficiency & Pion Rejection Factor



HMS PARTICLE IDENTIFICATION (PID)

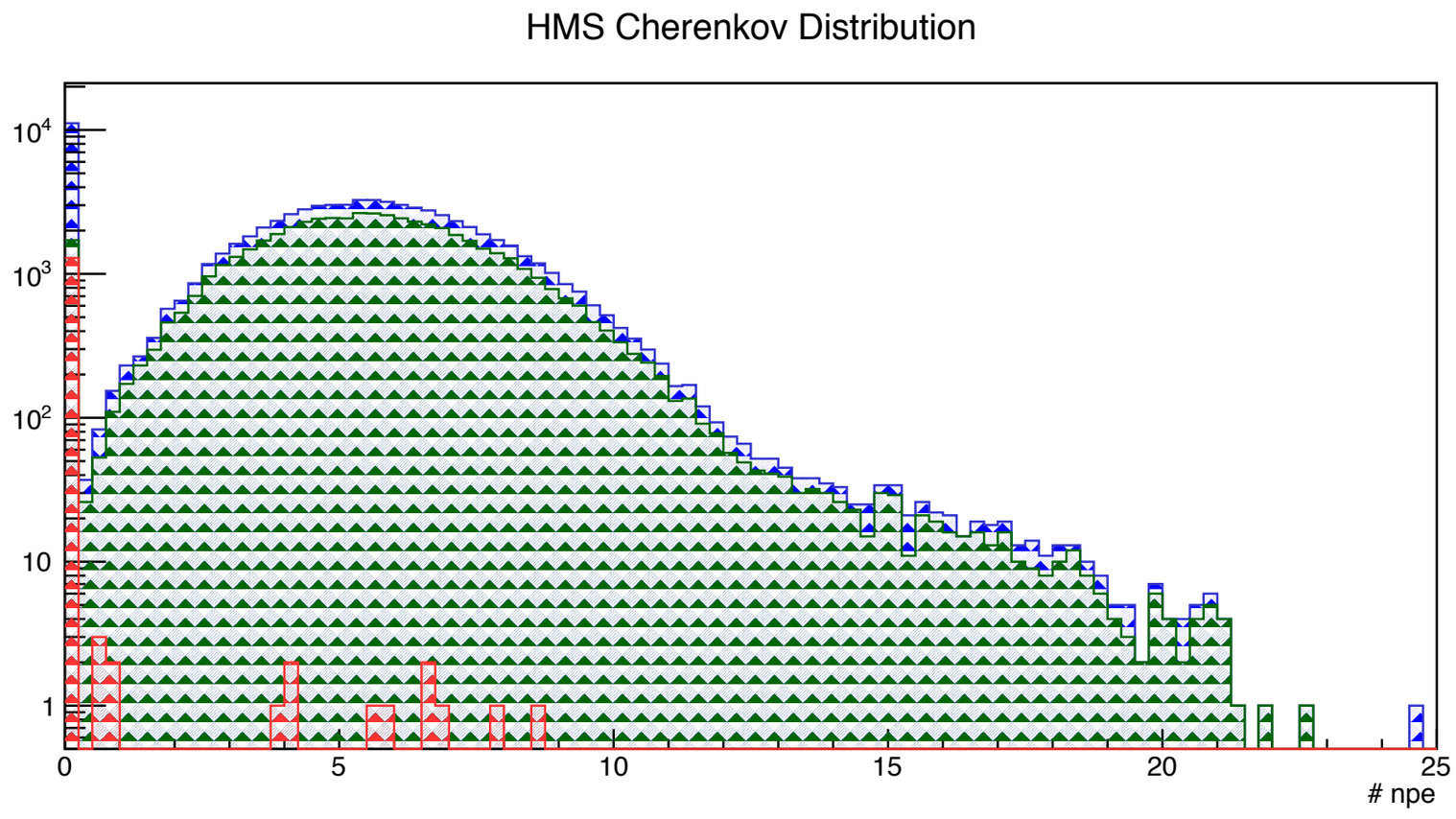




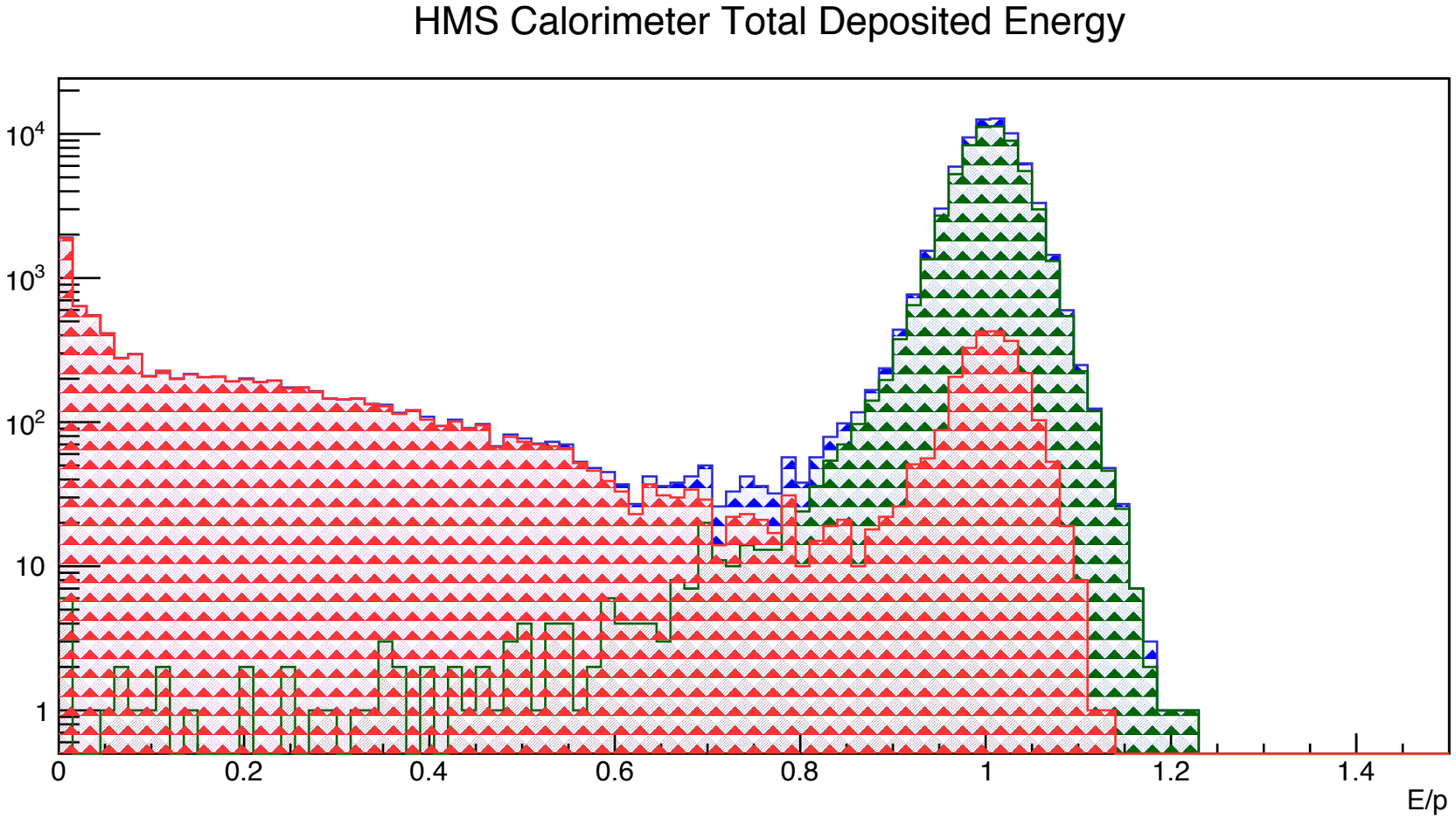
all events

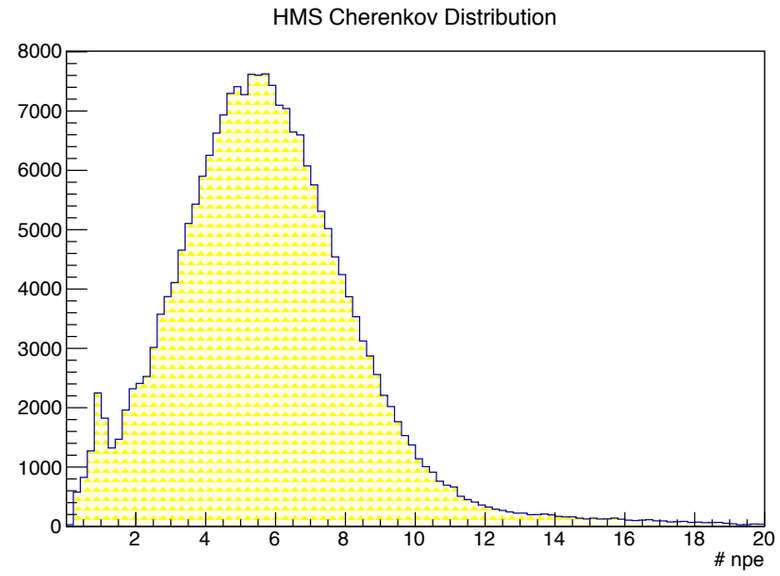
electrons selected by 2D calorimeter cut.

pions selected by 2D Calorimeter cut.



HMS PARTICLE IDENTIFICATION (PID)



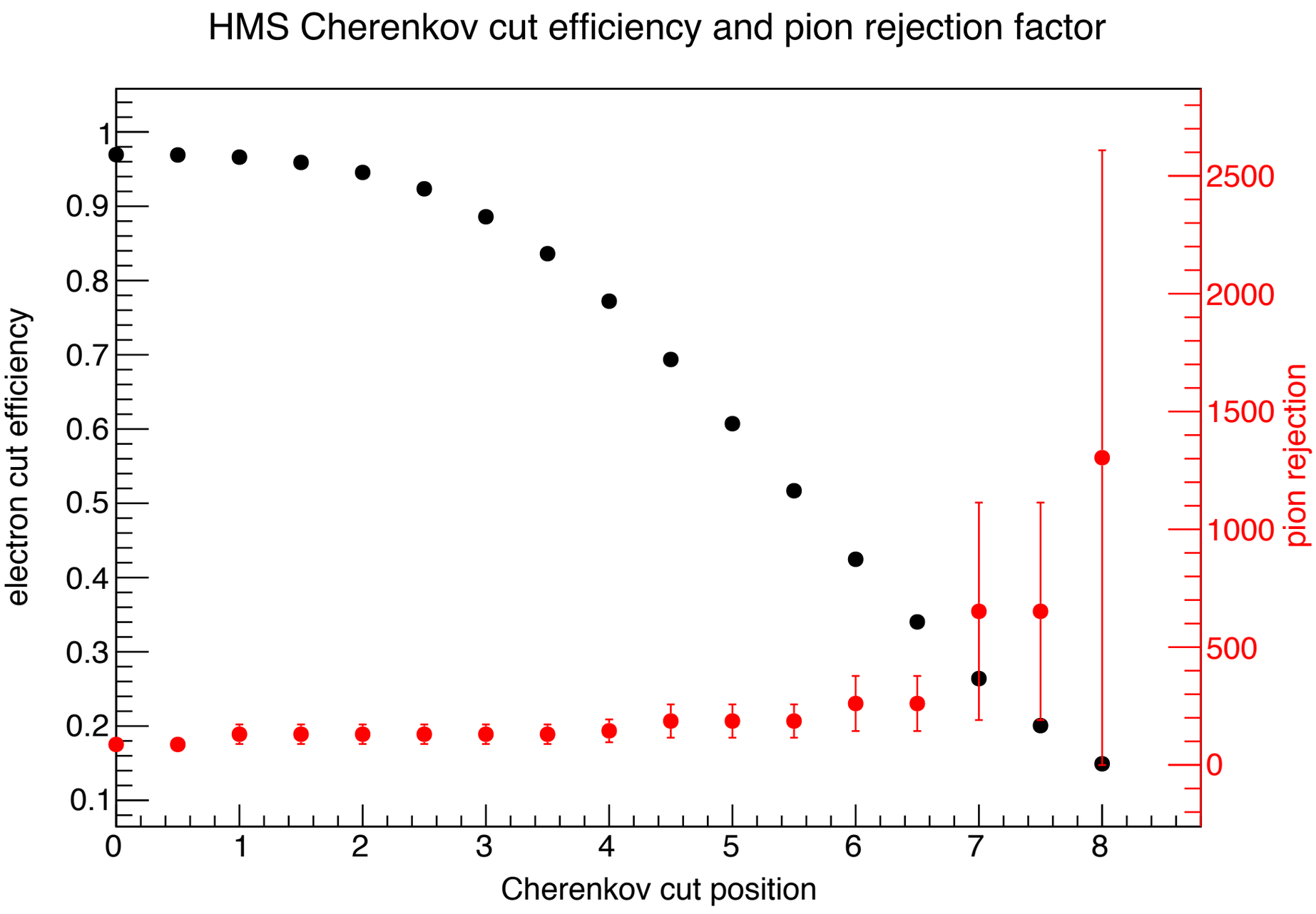


all events

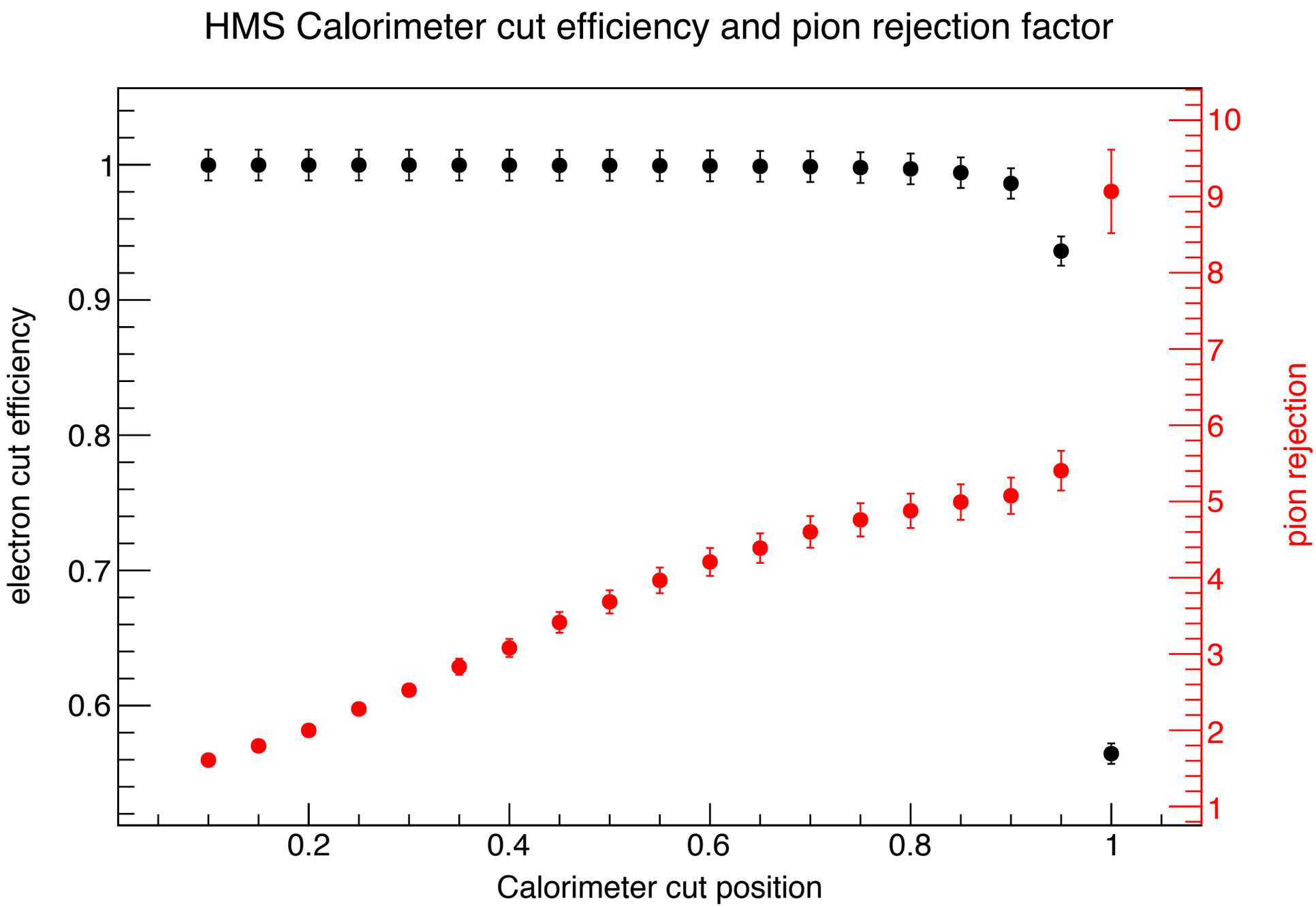
electrons selected by HMS CER > 3 npe

pions selected by HMS CER = 0 npe

HMS Cherenkov Cut Efficiency & Pion Rejection Factor

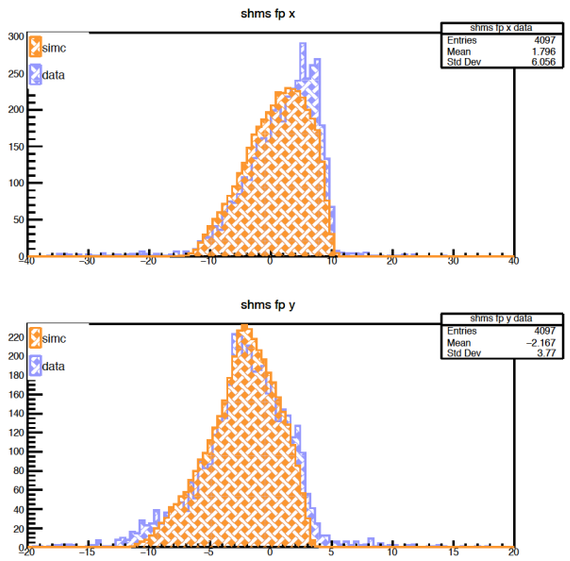


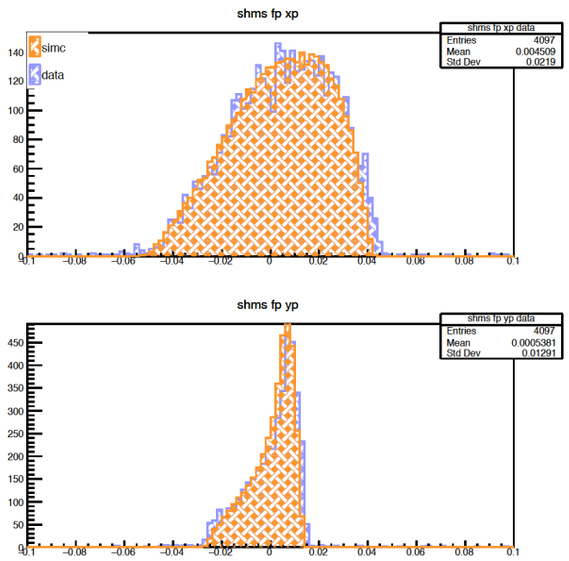
HMS Calorimeter Cut Efficiency & Pion Rejection Factor



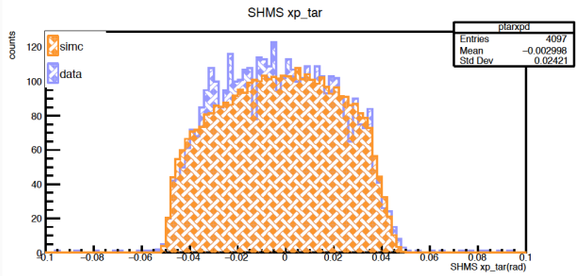
HYDROGEN ELASTIC DATA DURING J/PSI_007 EXPERIMENT

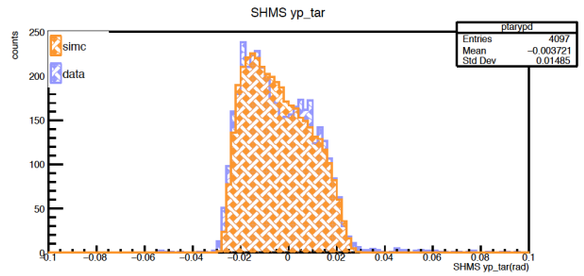
SHMS, 6.3 GeV, 20 deg, LH2, radiator out

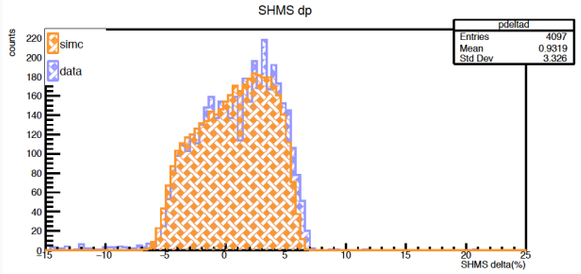


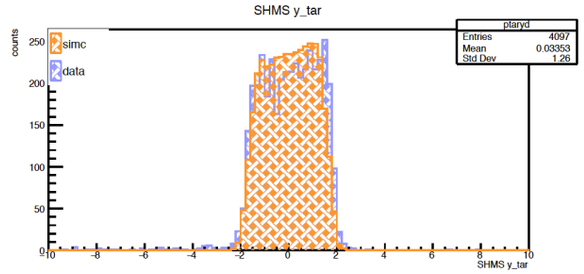


SHMS, 6.3 GeV, 20 deg, LH2, radiator out

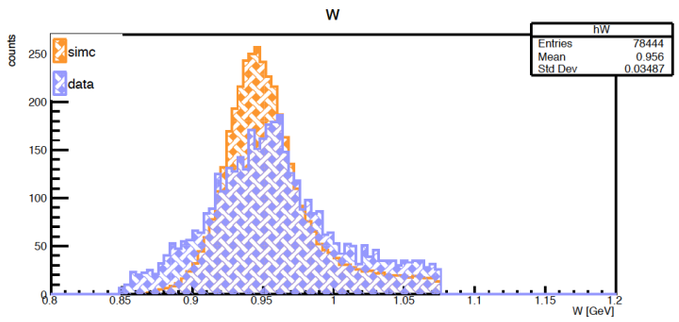


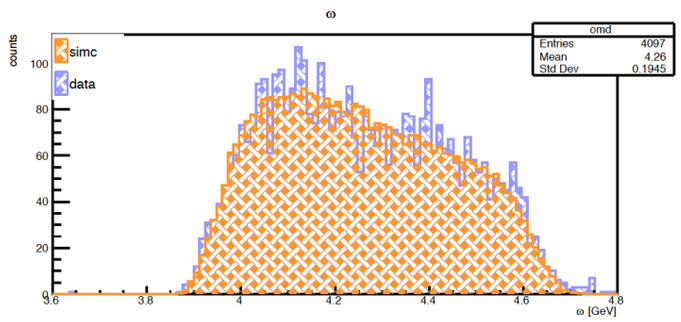


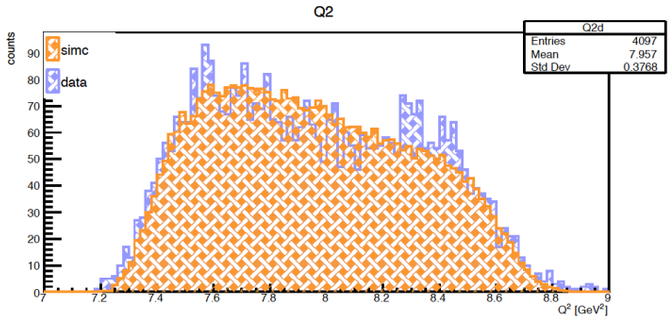


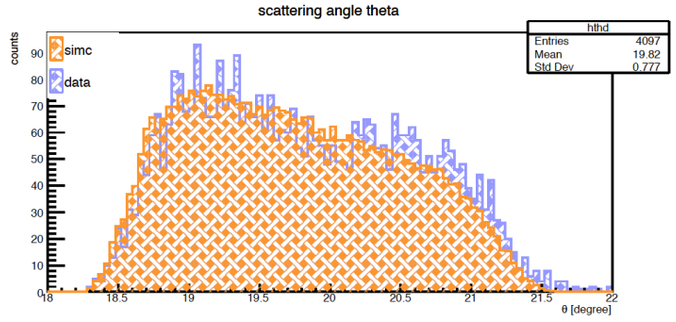


SHMS, 6.3 GeV, 20 deg, LH2, radiator out









SUMMARY

E12-16-007, high impact experiment

★ True nature of the LHCb pentaquark *"Pc"*

★ *J/Ψ photo production absolute cross section.*

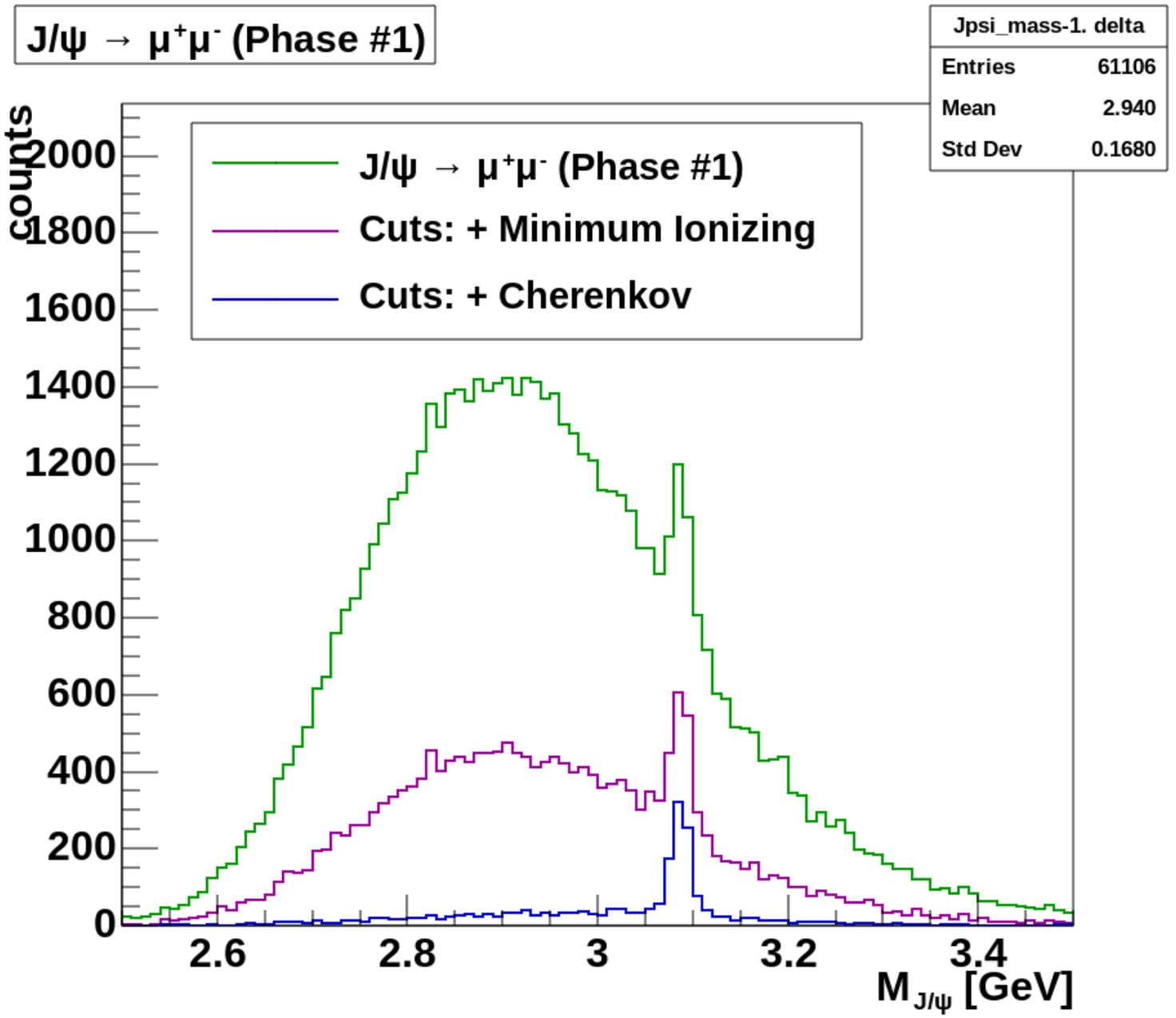
★ High precision measurement of t dependent cross section between 9-10.6 GeV

★ Largest dataset of ***J/ψ*** produced with real photon beam.

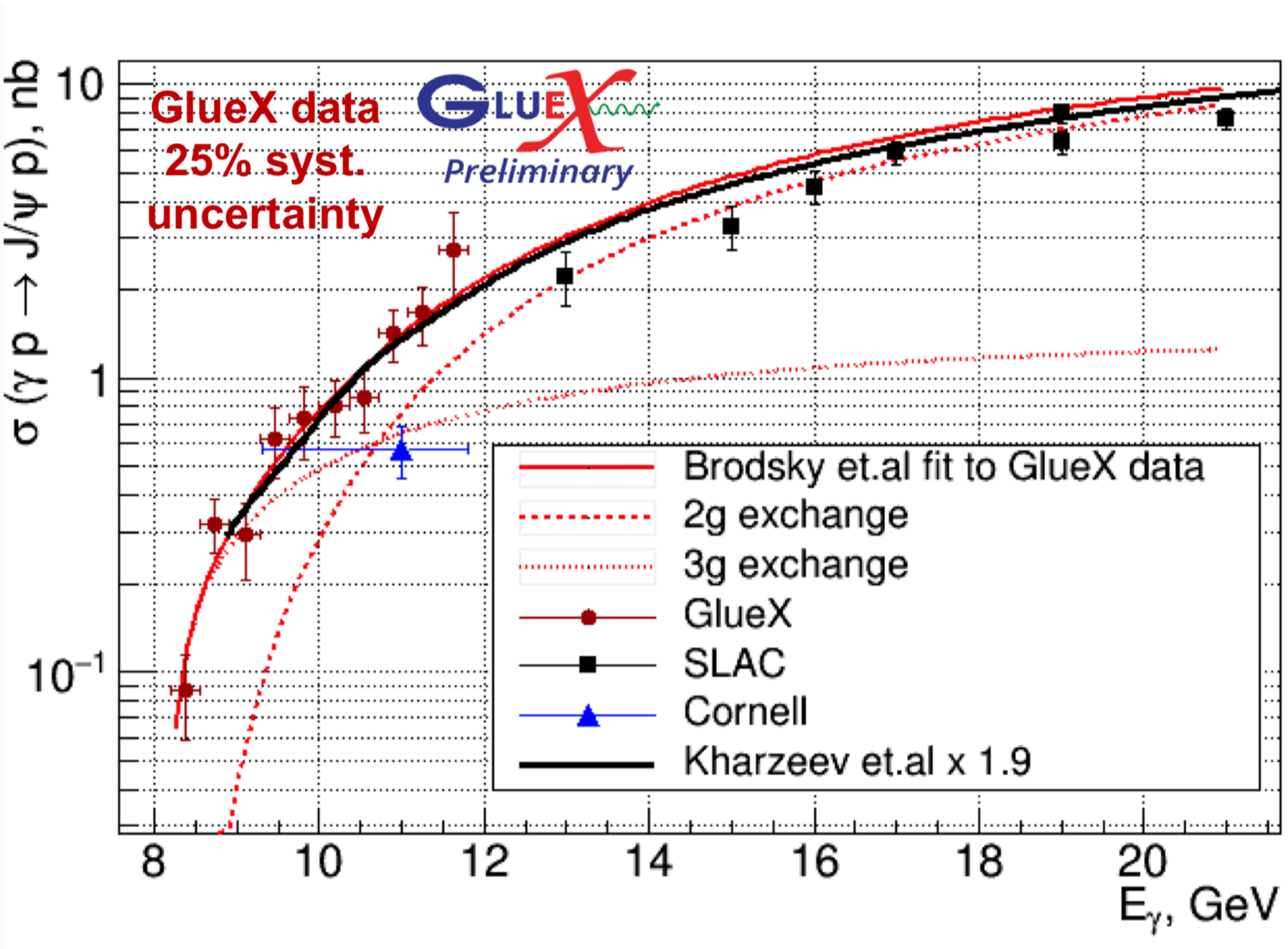
This work is supported by the Department of Energy through grant DE-FG02-94ER4084

BACK UP SLIDES

MUON CHANNEL: ONLINE RESULTS



GLUEX (LUBOMIR PENTCHEV'S SLIDE IN NOVEMBER 2018)



Background: Inelastic t Channel $\gamma p \to J/\psi p \pi$

- **Threshold at 9 GeV**
- **Reconstructed photon energy Erc is 1 GeV too low**
- Contribution to the **Contaminates the 8 GeV $<$ Erc $<$ 9.7 GeV range for a photon end-point energy of 10.7 GeV**
  - **not an issue for the Pc(4450) (Erc $>$ 9.7GeV)!**

Photon Energy Reconstruction

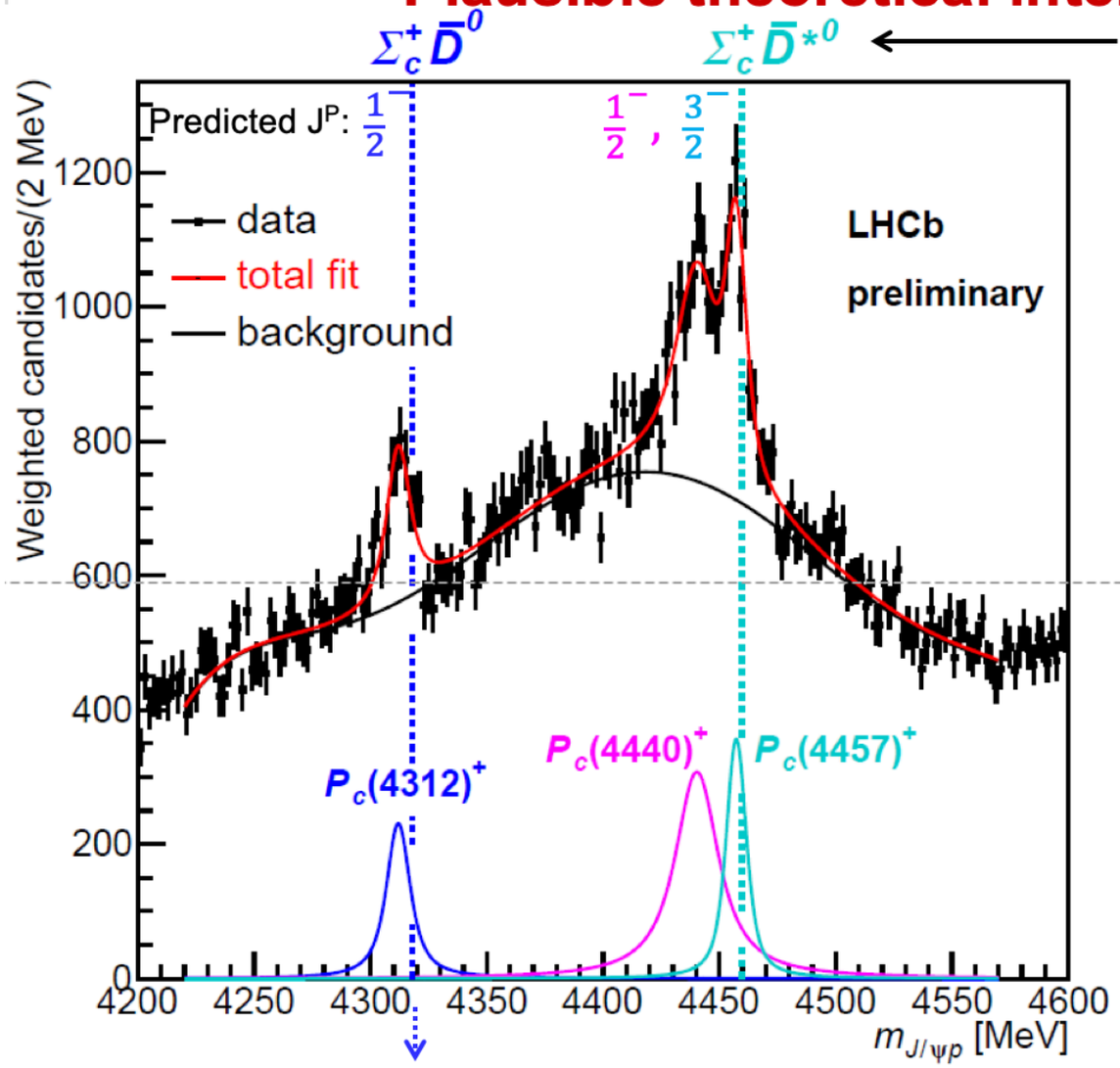
- Initial photon energy can be unambigously reconstructed from the reconstructed J/ψ momentum and energy

  - **Assumptions**

    - ★ proton target at rest
    - ★ photon beam along the z axis
    - ★ proton and J/ψ are the two final state particles

$$E_\gamma = \frac{M_\psi^2 - 2E_J M_P}{2(E_\psi - M_p - P_\psi \cos\theta_\psi)}$$

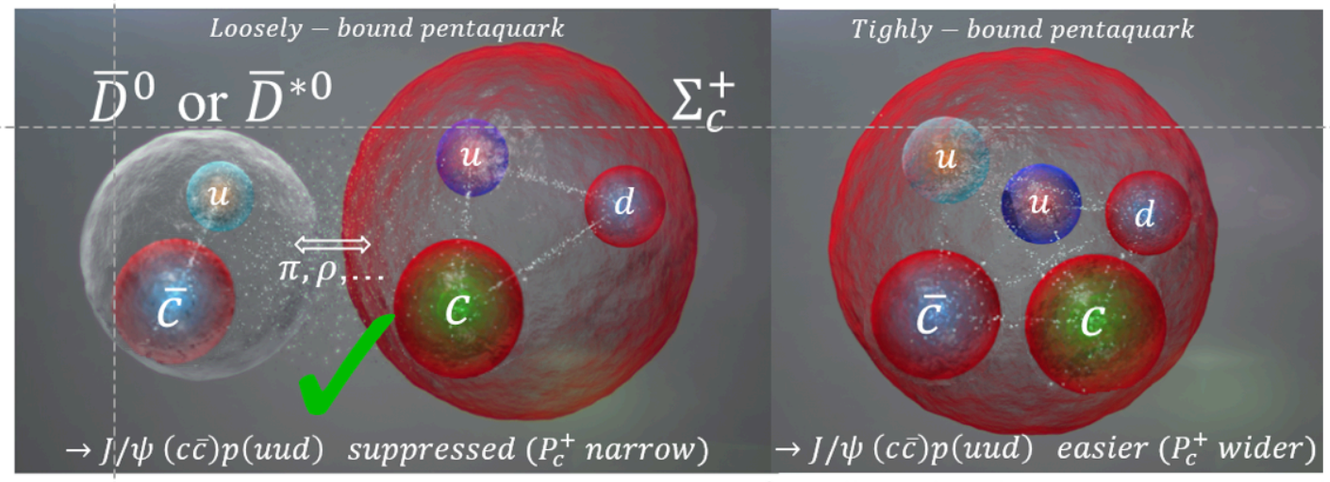
Plausible theoretical interpretation



The **only** thresholds below which molecular bound states are expected in this mass range

LHCb-PAPER-2019-014 in preparation

The near-threshold masses and the narrow widths of $P_c(4312)^+$, $P_c(4440)^+$ and $P_c(4457)^+$ favor "molecular" pentaquarks with meson-baryon substructure!



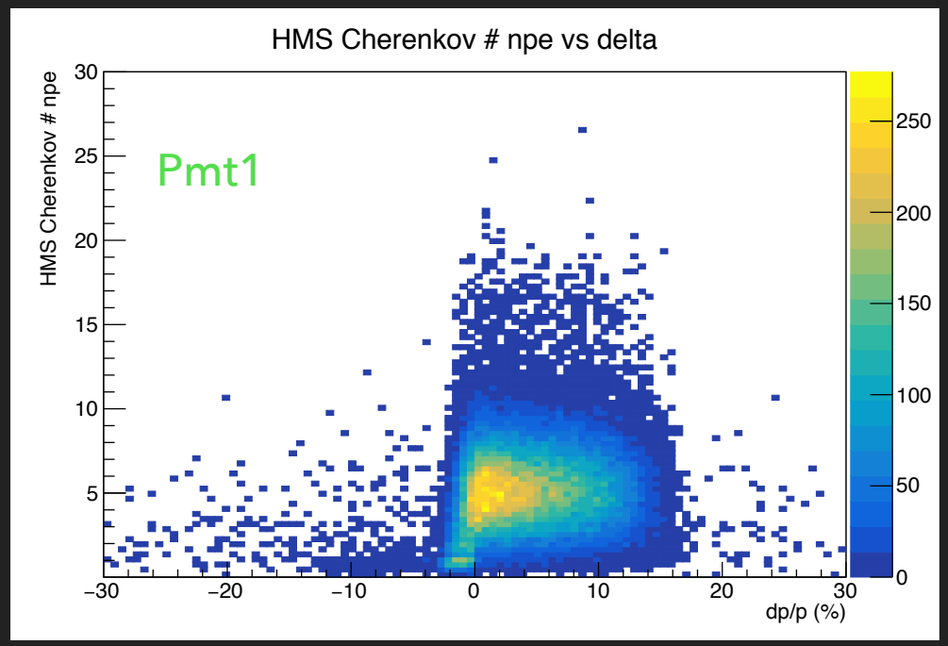
Existence of $\Sigma_c^+\bar{D}^0$ molecule would imply importance of ρ-exchange

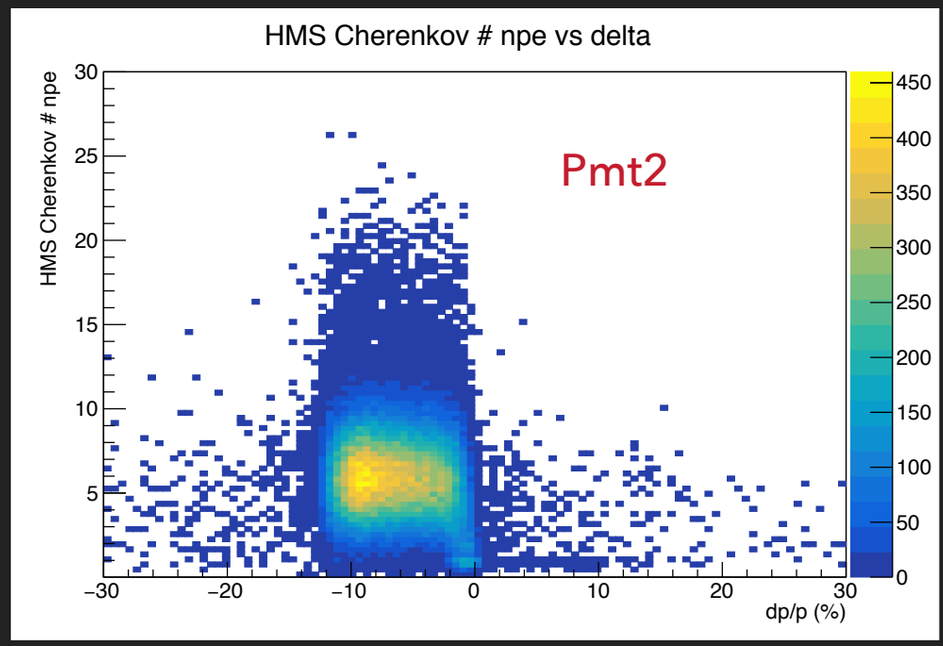
$P_c(4312)^+$, $P_c(4440)^+$ not near triangle diagram thresholds, $P_c(4457)^+$ is (see backup slides).

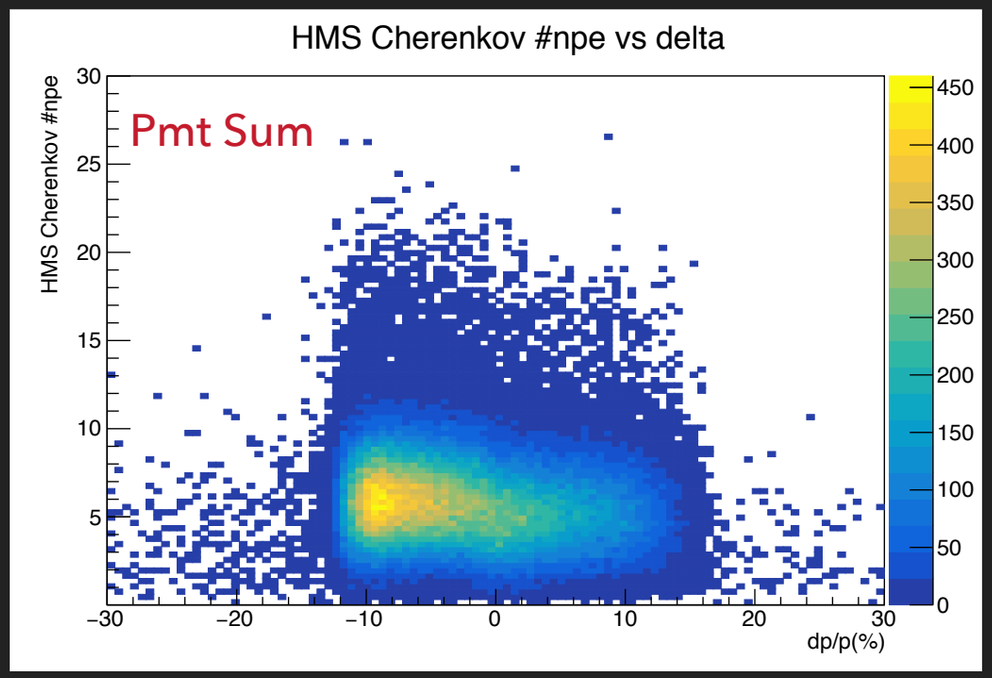
However, we need to measure J^Ps to confirm molecular hypothesis, find isospin partners, …

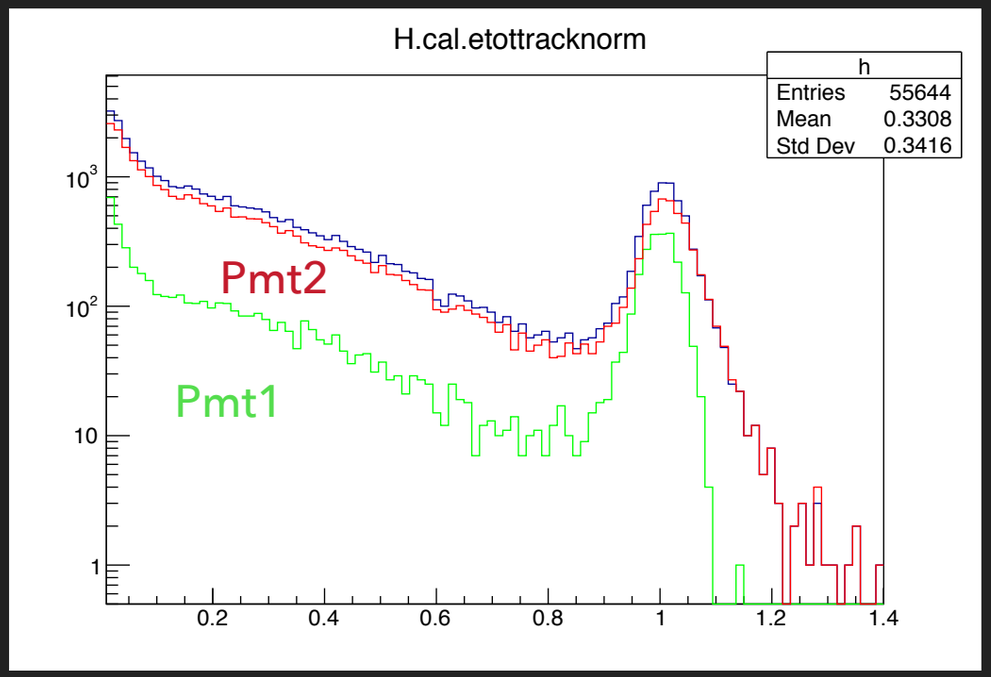
Can diquark substructure separated by a potential barrier [Maiani, Polosa, Riquer, PL,B778, 247 (2018)] produce width suppression?
Are masses near thresholds just by coincidence?
This hypothesis is not ruled out

TEXT


HMS Cherenkov # npe vs delta
HMS Cherenkov # npe
Pmt1
dp/p (%)


HMS Cherenkov # npe vs delta
HMS Cherenkov # npe
Pmt2
dp/p (%)


HMS Cherenkov #npe vs delta
HMS Cherenkov #npe
Pmt Sum
dp/p(%)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h
Entries 55644
Mean 0.3308
Std Dev 0.3416
Pmt2
Pmt1