Blinded by the Light: a Cherenkov Calibration

2018 CAP Congress – Dalhousie University (Halifax, NS)

Ryan Ambrose

Supervisor: Dr. G. M. Huber

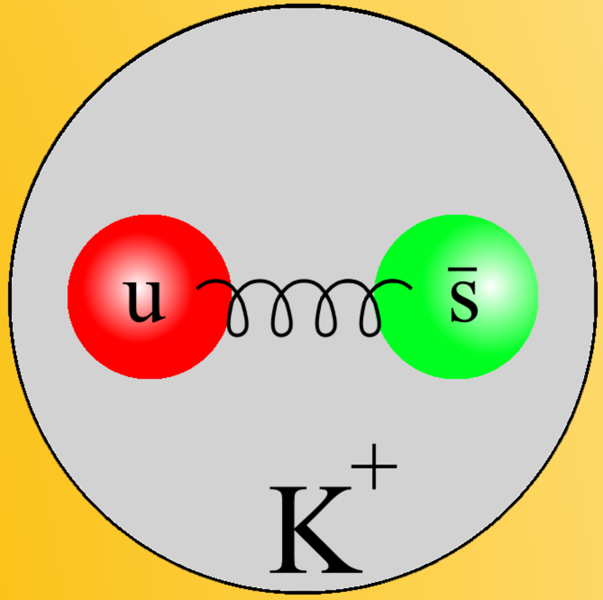
University of Regina

Sapin-2016-00031

Scientific Motivation – E12-09-11 – $p(e,e'K^+)\Lambda,\Sigma^o$

- What are the form factors for strange mesons?
- How accurately does QCD predict hadronic structure?

- Meson valence structure ($q\bar{q}$) provides easy testing grounds
- Pions have been studied ($u\bar{d}$), however not much is known about strangeness

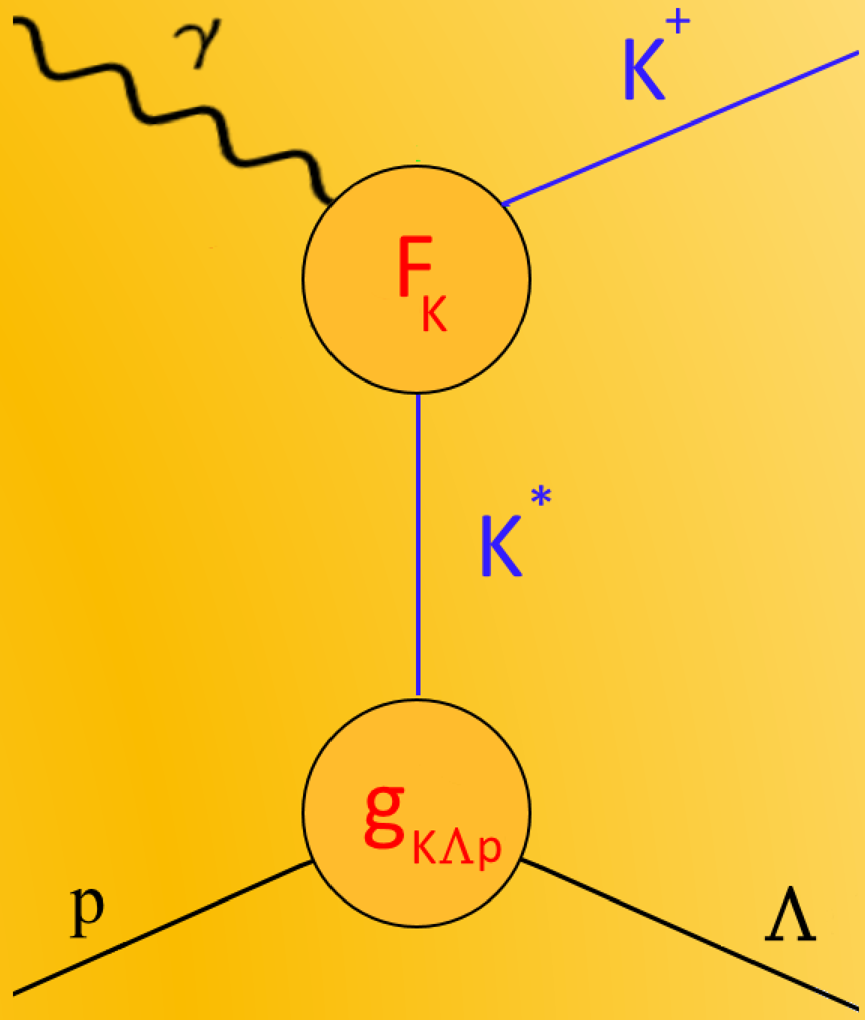


Scientific Motivation – p(e,e'K$^+$)Λ,Σ^o

- Coupling constants & form factors measured indirectly
  - "Meson Cloud"

$$|p\rangle = |p\rangle_o + |n\pi^+\rangle + |\Lambda K^+\rangle + \cdots$$

- $\sigma_L \approx \frac{-tQ^2}{(t-m_K^2)^2}\left(g_{K\Lambda p}\right)^2 F_K^2(Q^2)$



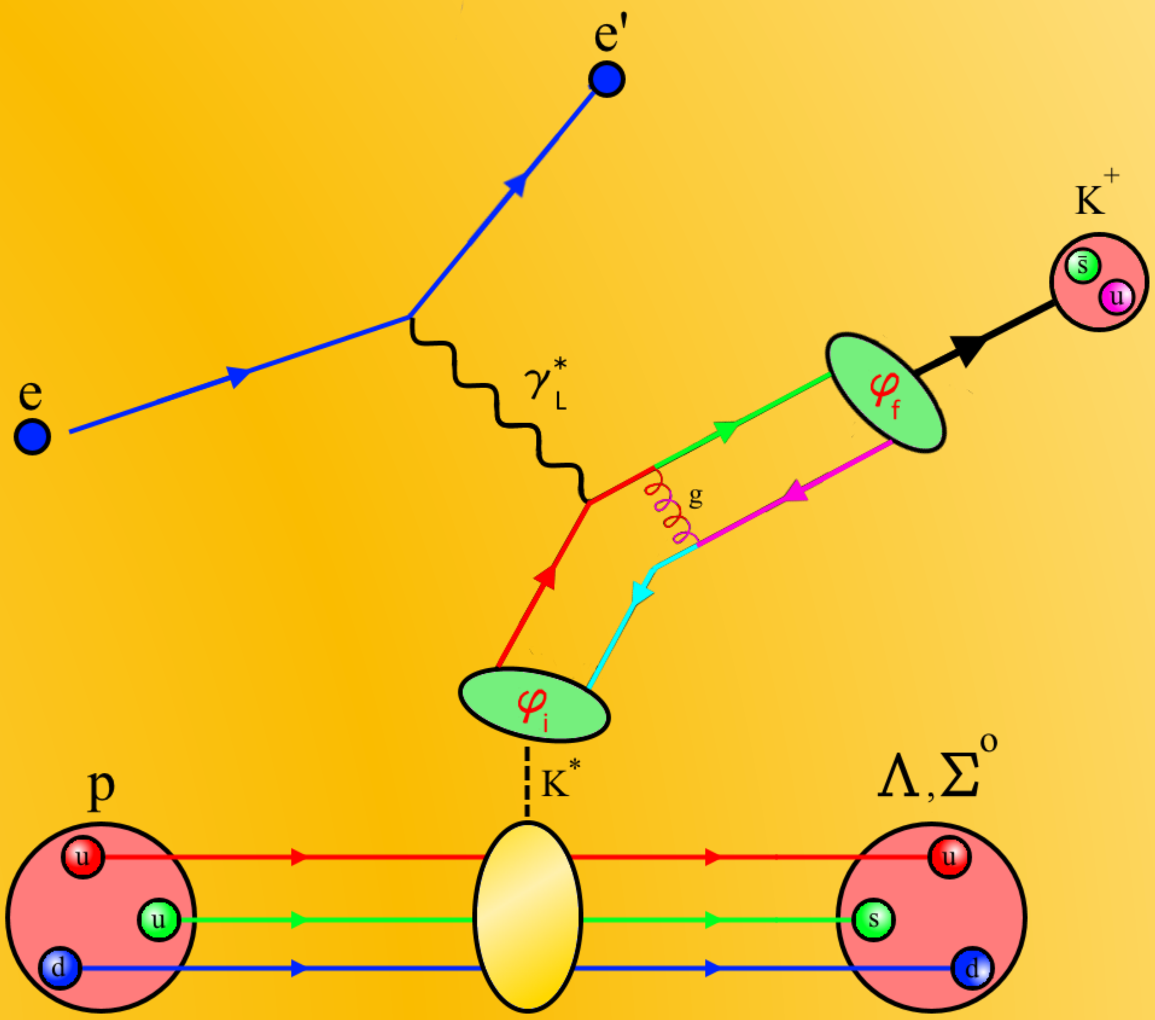
Experimental Goals

- Can proton "kaon cloud" be used to extract kaon form factor?

- Can study Λ, Σ° channels

$$\frac{\sigma_L(\gamma^* p \to K^+\Sigma^0)}{\sigma_L(\gamma^* p \to K^+\Lambda)} \stackrel{?}{=} \frac{g^2_{K\Sigma p}}{g^2_{K\Lambda p}}$$

- Reveals new flavor degrees of freedom for QCD model building

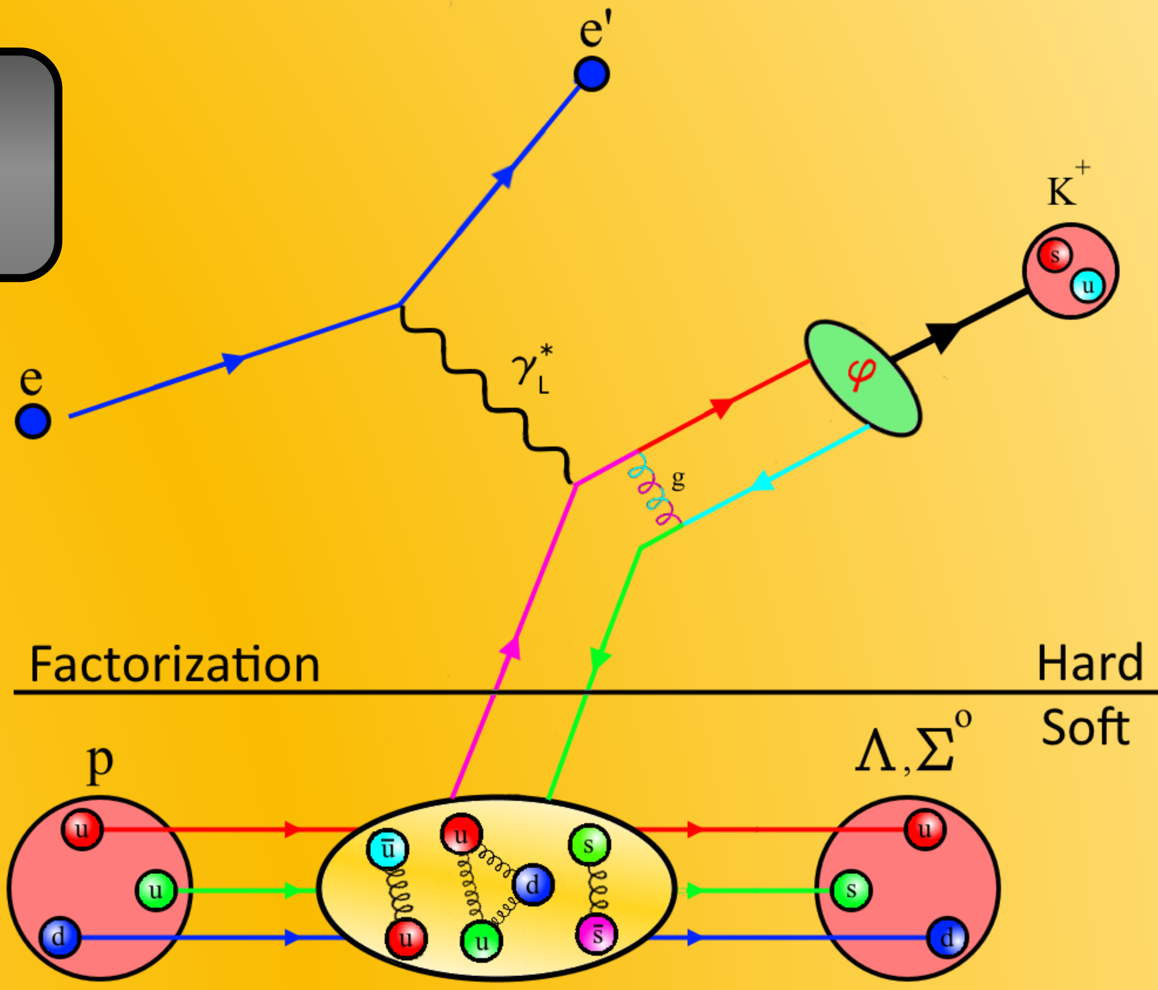


Experimental Goals

- Can kaon electroproduction reveal transition from hadronic to partonic degrees of freedom?

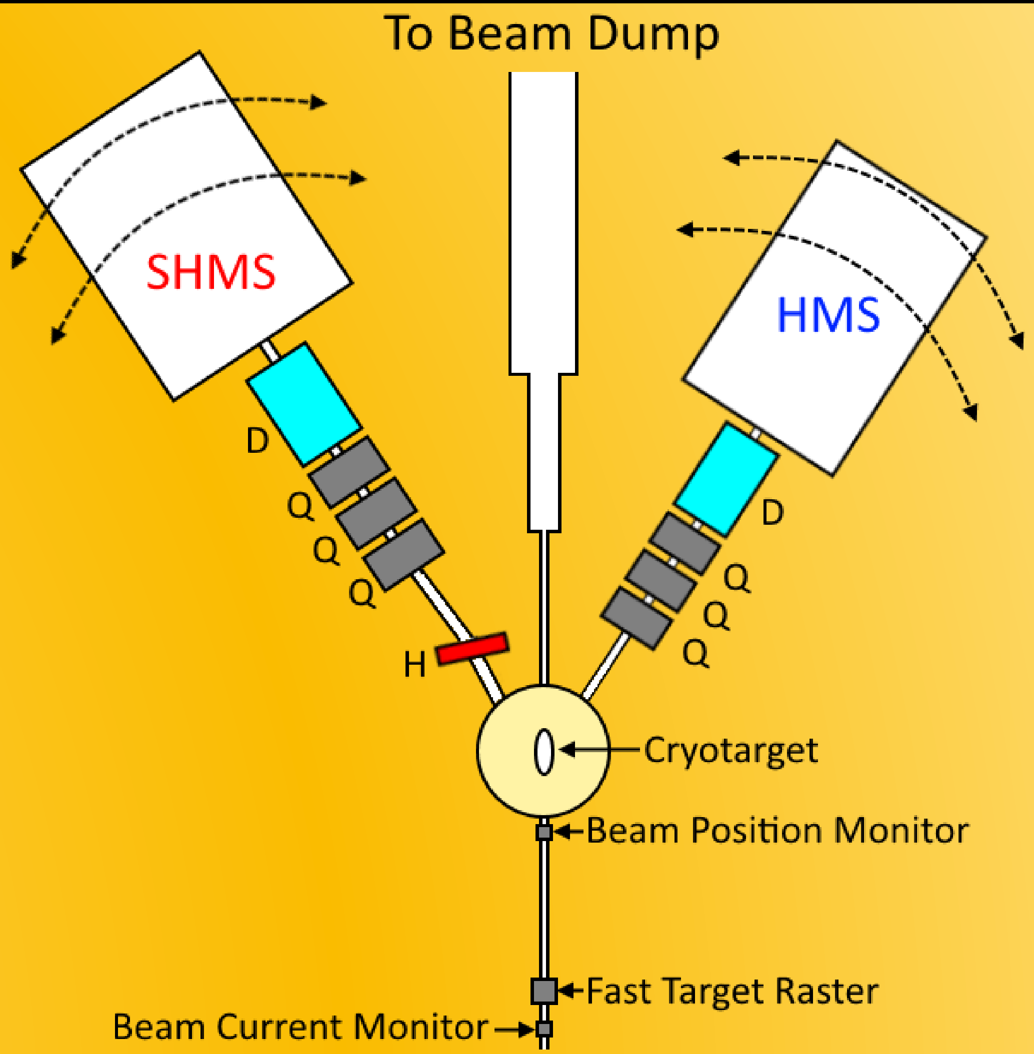
- Test Q^2 dependence of **p(e,e'K⁺)Λ,Σ°** cross section

- $\sigma_L \propto Q^{-6}$
- $\sigma_T \propto Q^{-8}$
- As Q^2 gets large, $\sigma_L \gg \sigma_T$



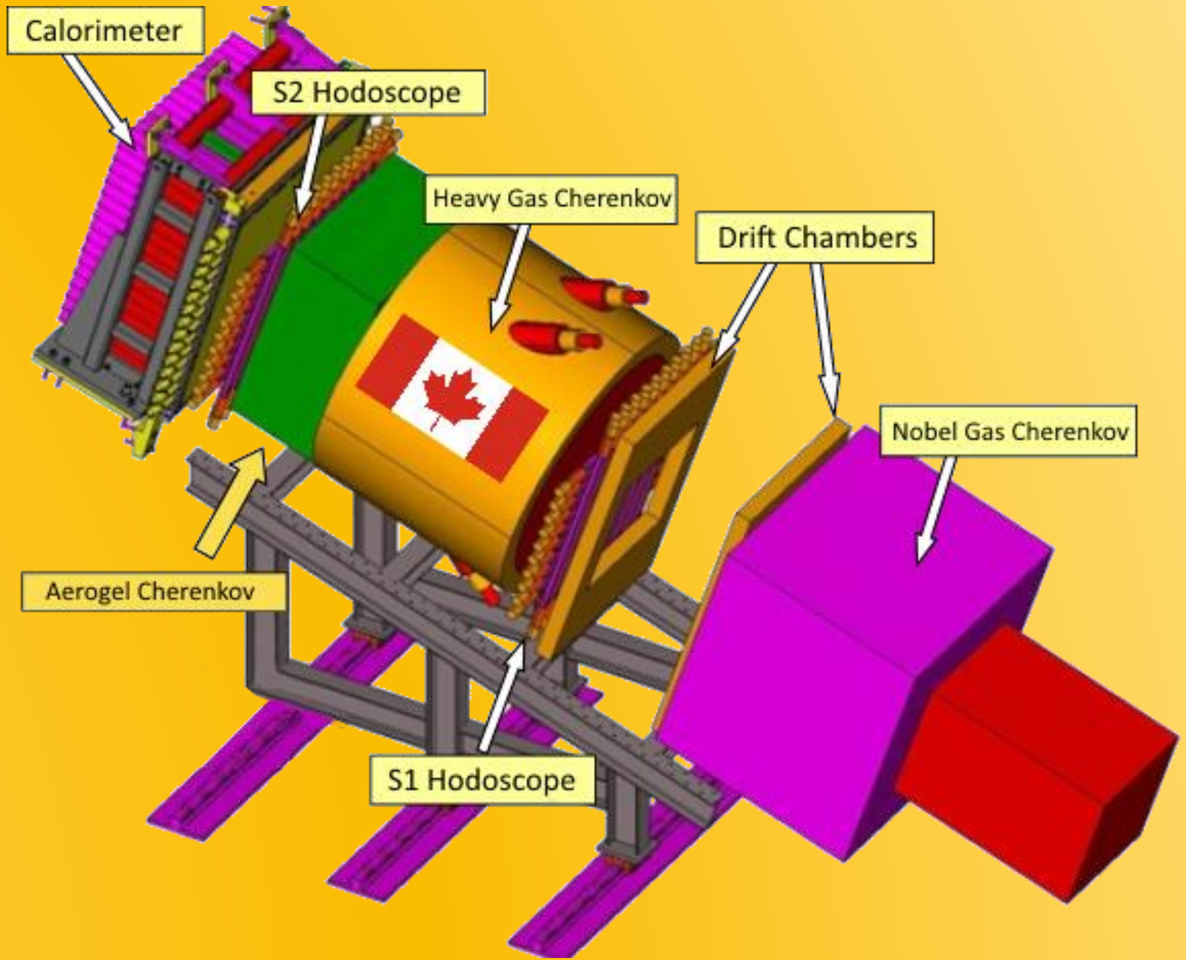
Experimental Set-up

- Beam Energy 2.2 - 12 GeV
- Beam Current up to 80 μA
- K^+& e^- detected in coincidence
  - HMS for e^- detection
    - 10.6° minimum angle
    - $0.9 - 6.9$ GeV/c
  - SHMS for K^+ detection
    - 5.5° minimum angle
    - $2.6 - 7.1$ GeV/c
- LH2 & Al Dummy Target



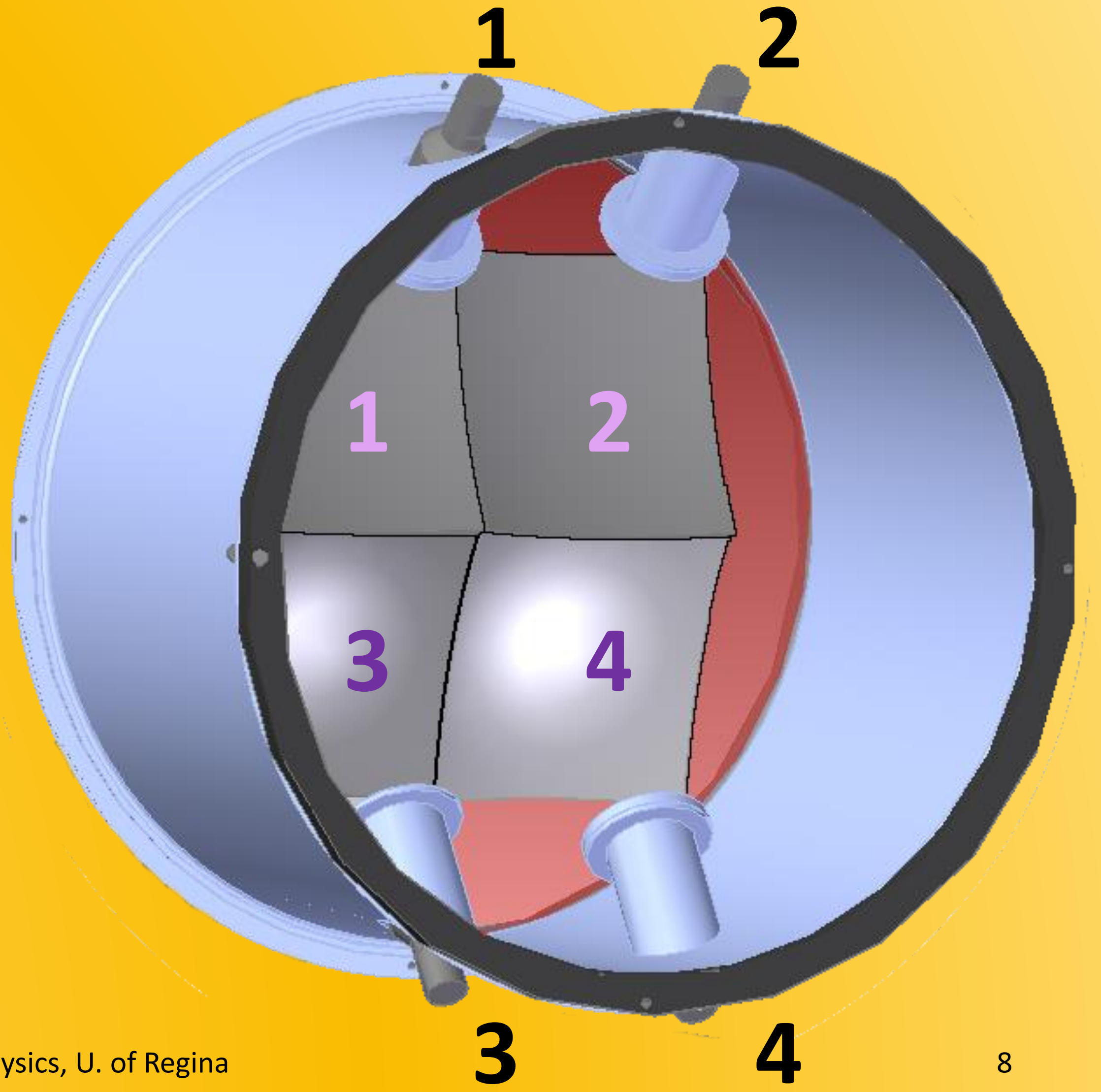
Experimental Set-up

- Particle Identification
  - Heavy Gas Cherenkov for **pion/kaon** separation
    - ***n*** = 1.0011
  - Aerogel Cherenkov for **kaon/proton** separation
    - ***n*** = 1.030, 1.011
  - Noble Gas Cherenkov for **electron/pion** separation
    - ***n*** = 1.0003
  - Calorimeter for **electron/hadron** separation



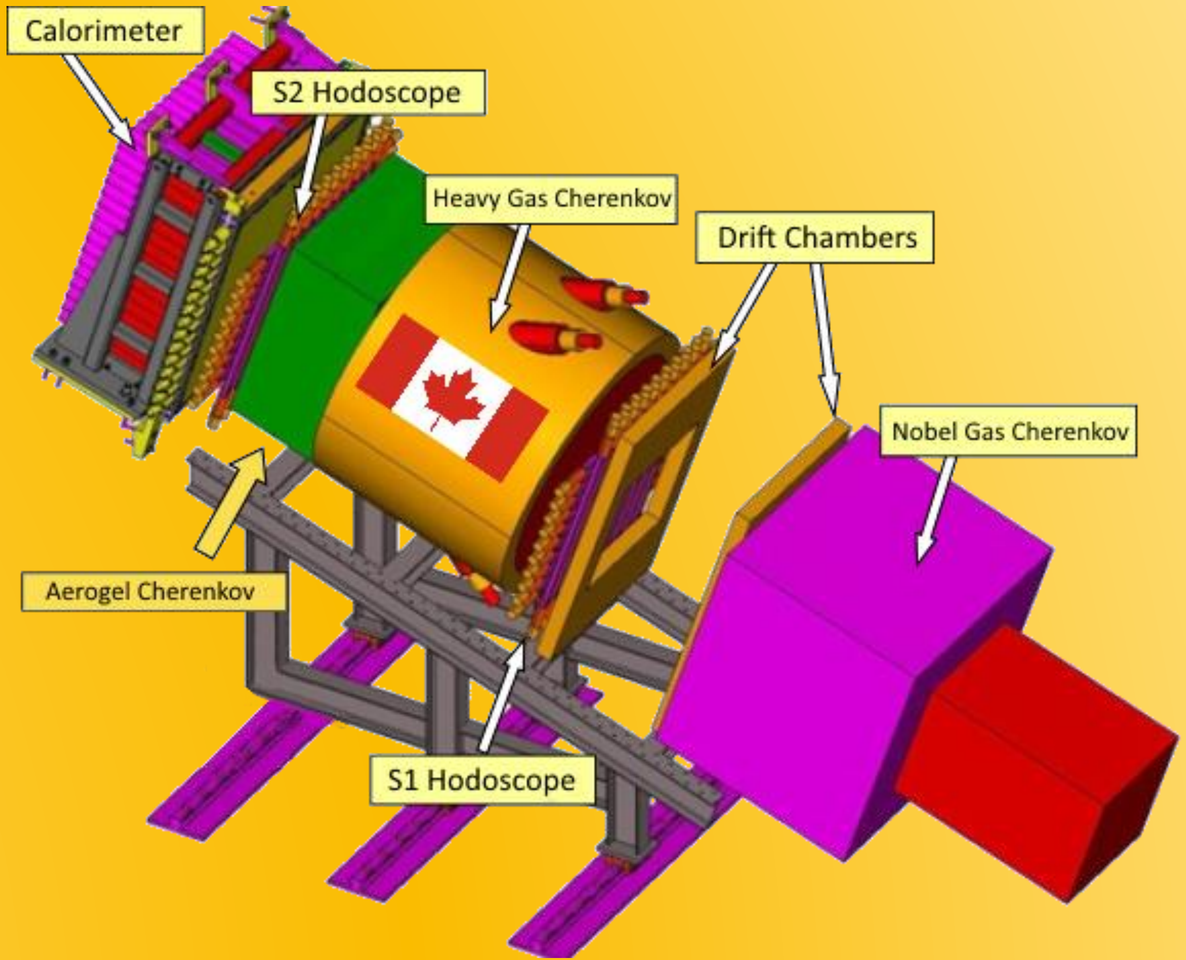
Experimental Set-up

- Particle Identification
  - Heavy Gas Cherenkov for **pion/kaon** separation
    - n = 1.0011
  - Aerogel Cherenkov for **kaon/proton** separation
    - n = 1.030, 1.011
  - Noble Gas Cherenkov for **electron/pion** separation
    - n = 1.0003
  - Calorimeter for **electron/hadron** separation



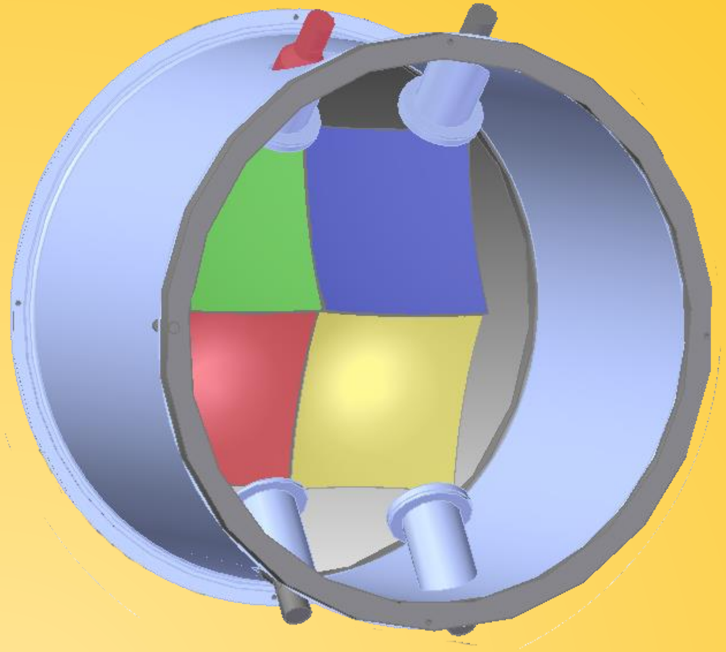
Experimental Set-up

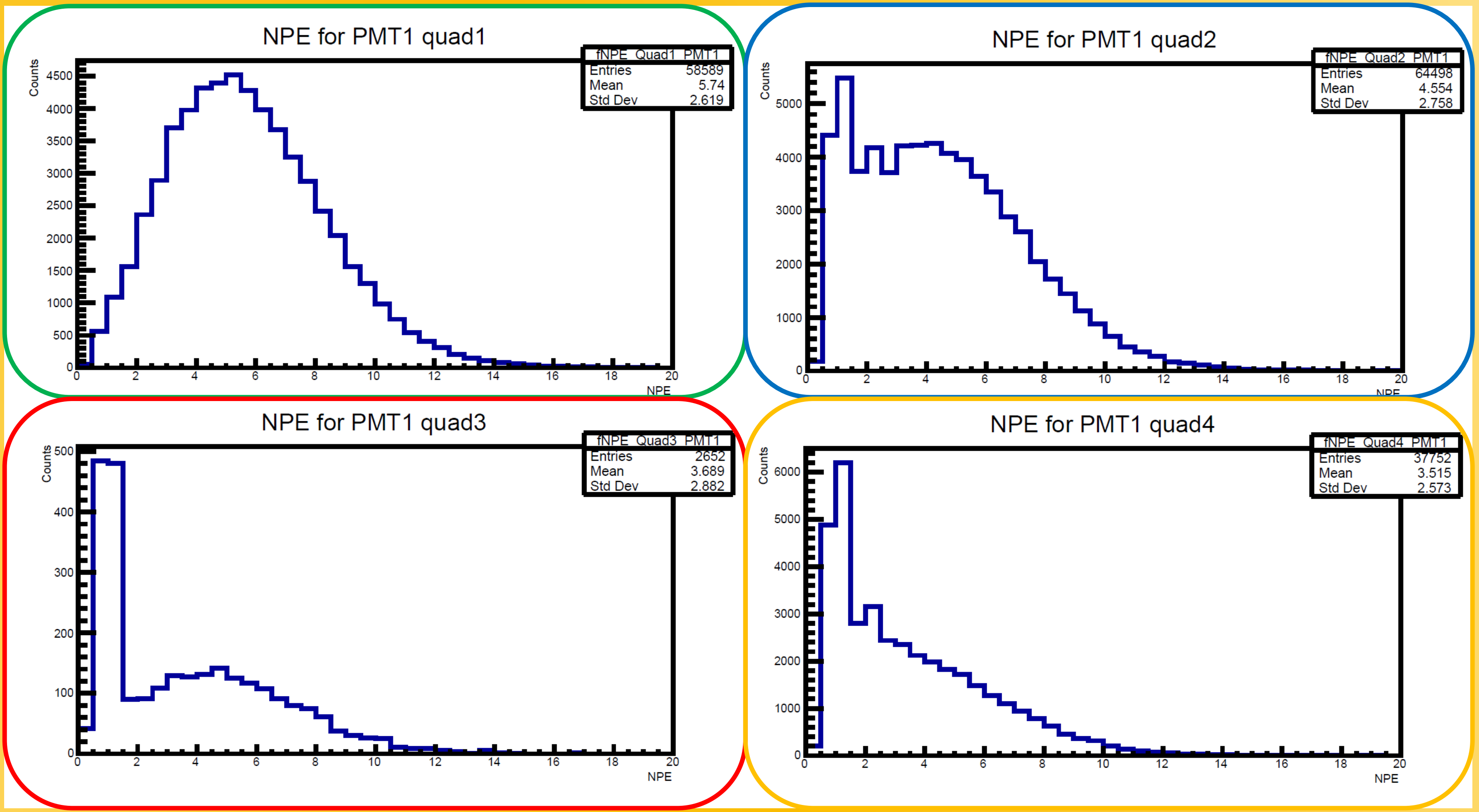
- Particle Identification
  - Heavy Gas Cherenkov for **pion/kaon** separation
    - $n = 1.0011$
  - Aerogel Cherenkov for **kaon/proton** separation
    - $n = 1.030, 1.011$
  - Noble Gas Cherenkov for **electron/pion** separation
    - $n = 1.0003$
  - Calorimeter for **electron/hadron** separation



Detector Calibration

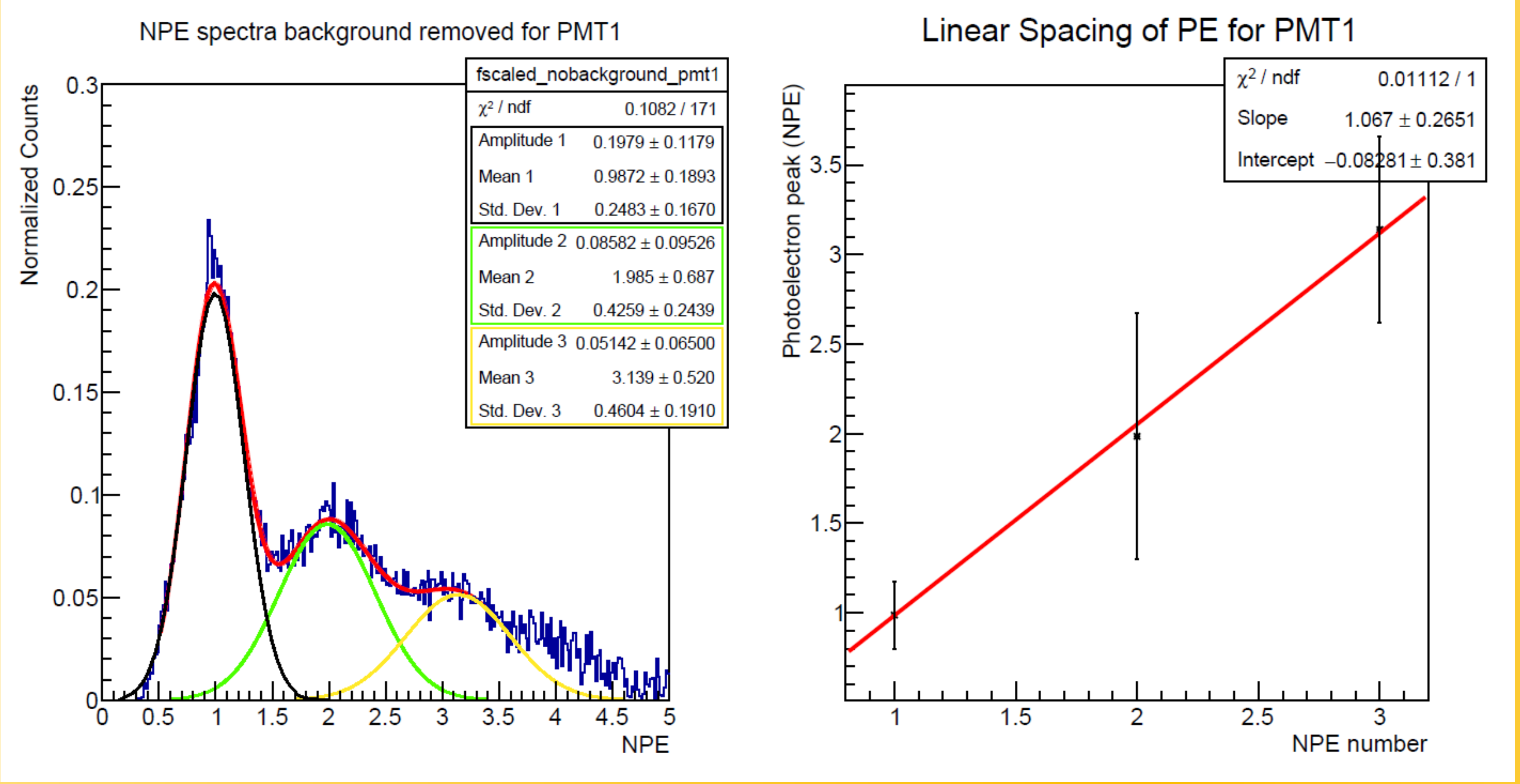
- Separate signal for each PMT to get SPE





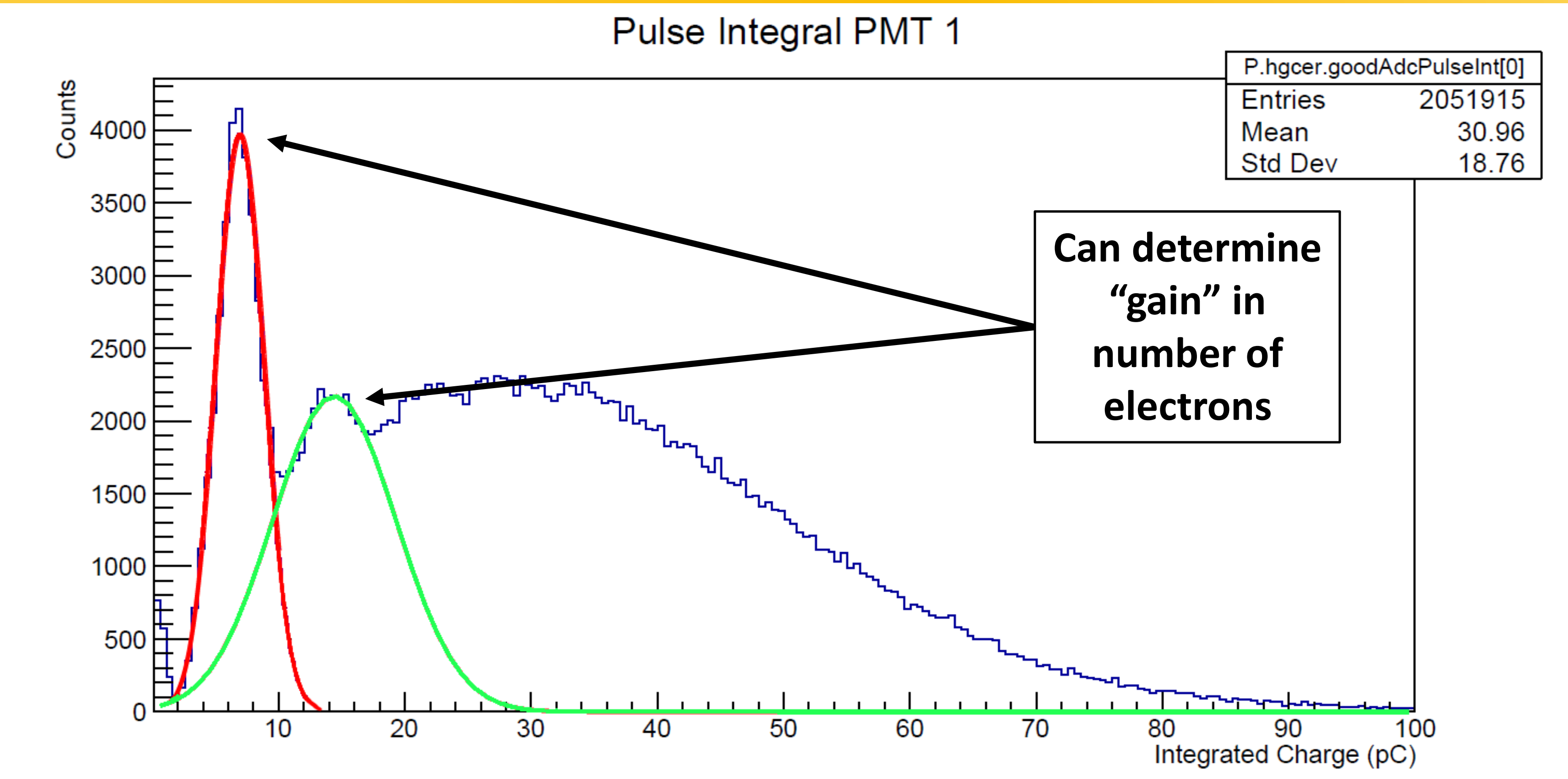
Detector Calibration

- Verify calibration with 2nd and 3rd peak's linearity



Detector Calibration

- Same method can be used to verify PMT gain



Detector Calibration

- Same method can be used to verify PMT gain

PMT Number	Previous Measurement	Current Measurement
PMT 1	3.06×10^7	1.55×10^7
PMT 2	7.47×10^7	4.22×10^7
PMT 3	9.62×10^7	5.36×10^7
PMT 4	5.81×10^7	3.41×10^7

- Off by a factor of 2?
  - Signal now passes through a 50:50 splitter

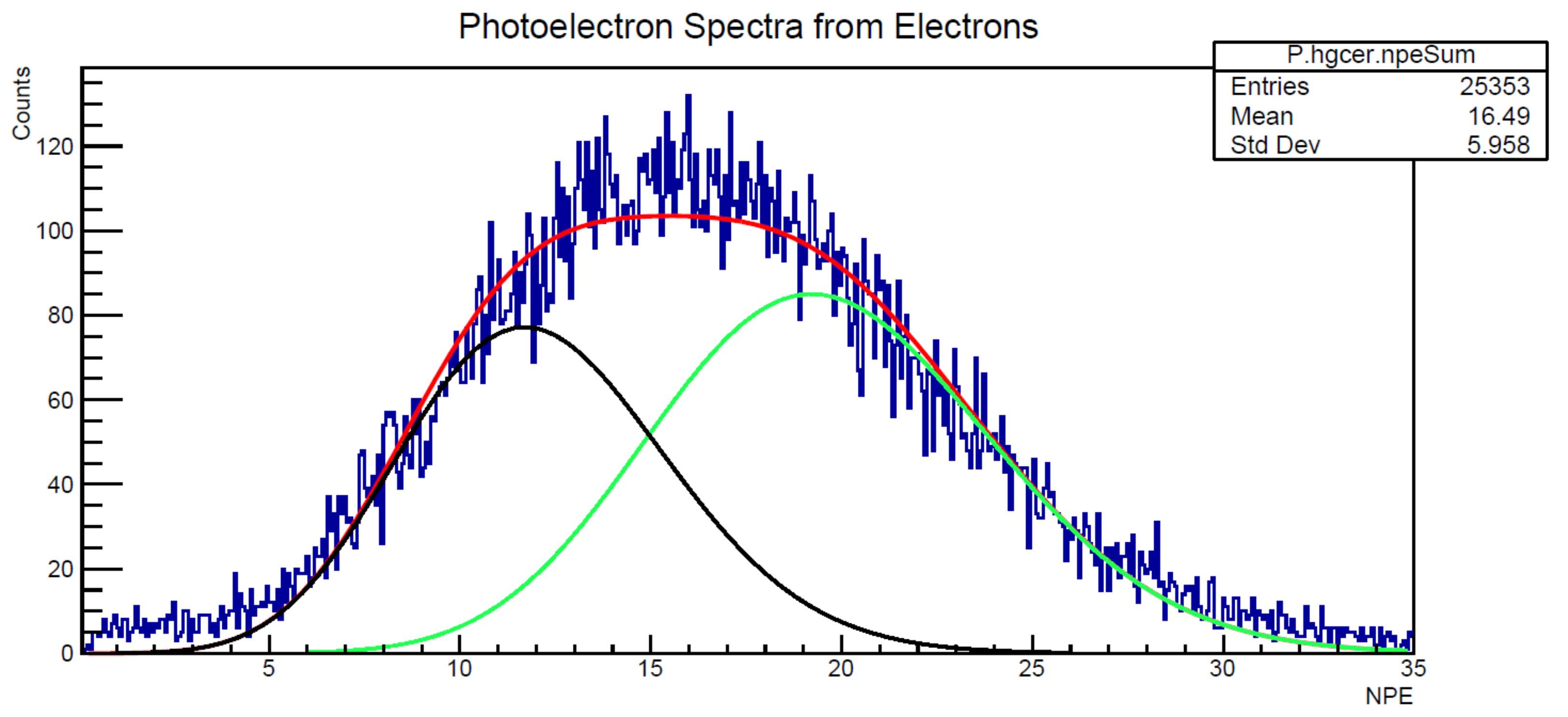
Detector Calibration

- Verify calibration by checking distribution profile

- Fit with sum of two Poison distributions

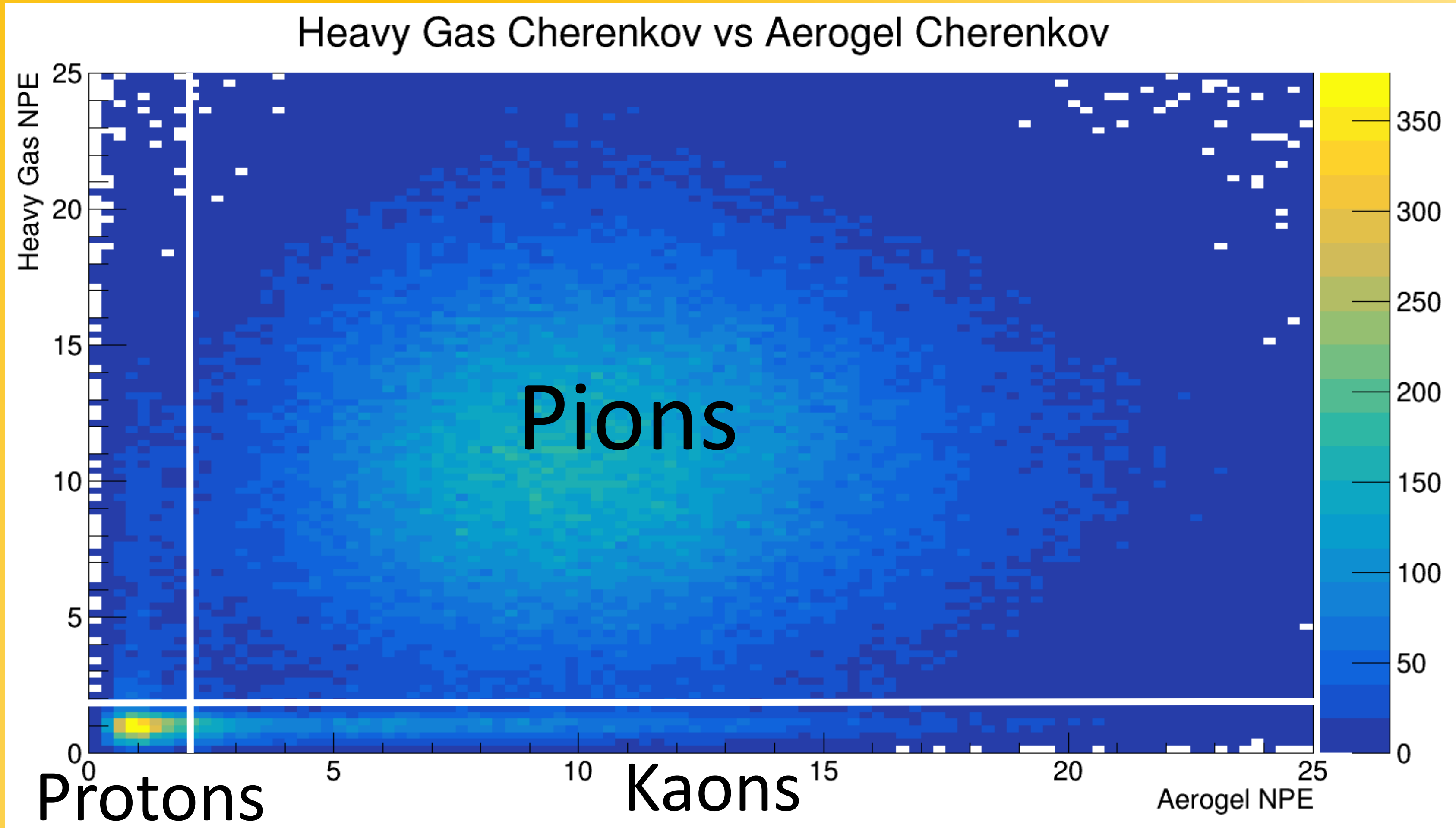
$$\frac{\mu^x e^{-\mu}}{\Gamma(x+1)}$$

- Two sources from different focusing?



Particle Identification

- Calibrated HGC and AGC
- Able to perform particle ID based off number of photoelectrons (NPE)



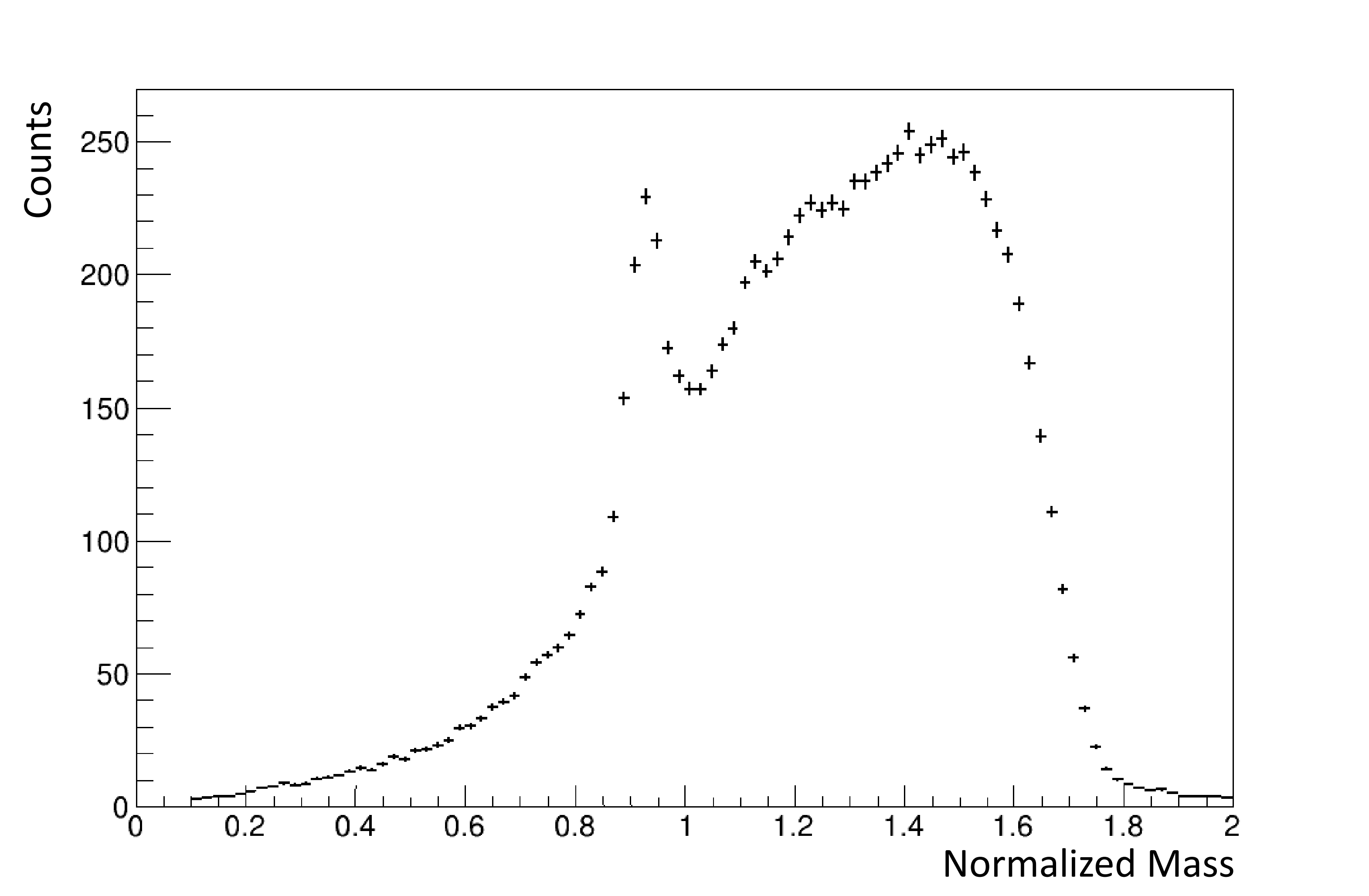
Particle Identification – p(e,e’K$^+$)Λ

- Able to identify neutron and Λ missing masses

+ : Data

: Particle ID

: Simulation



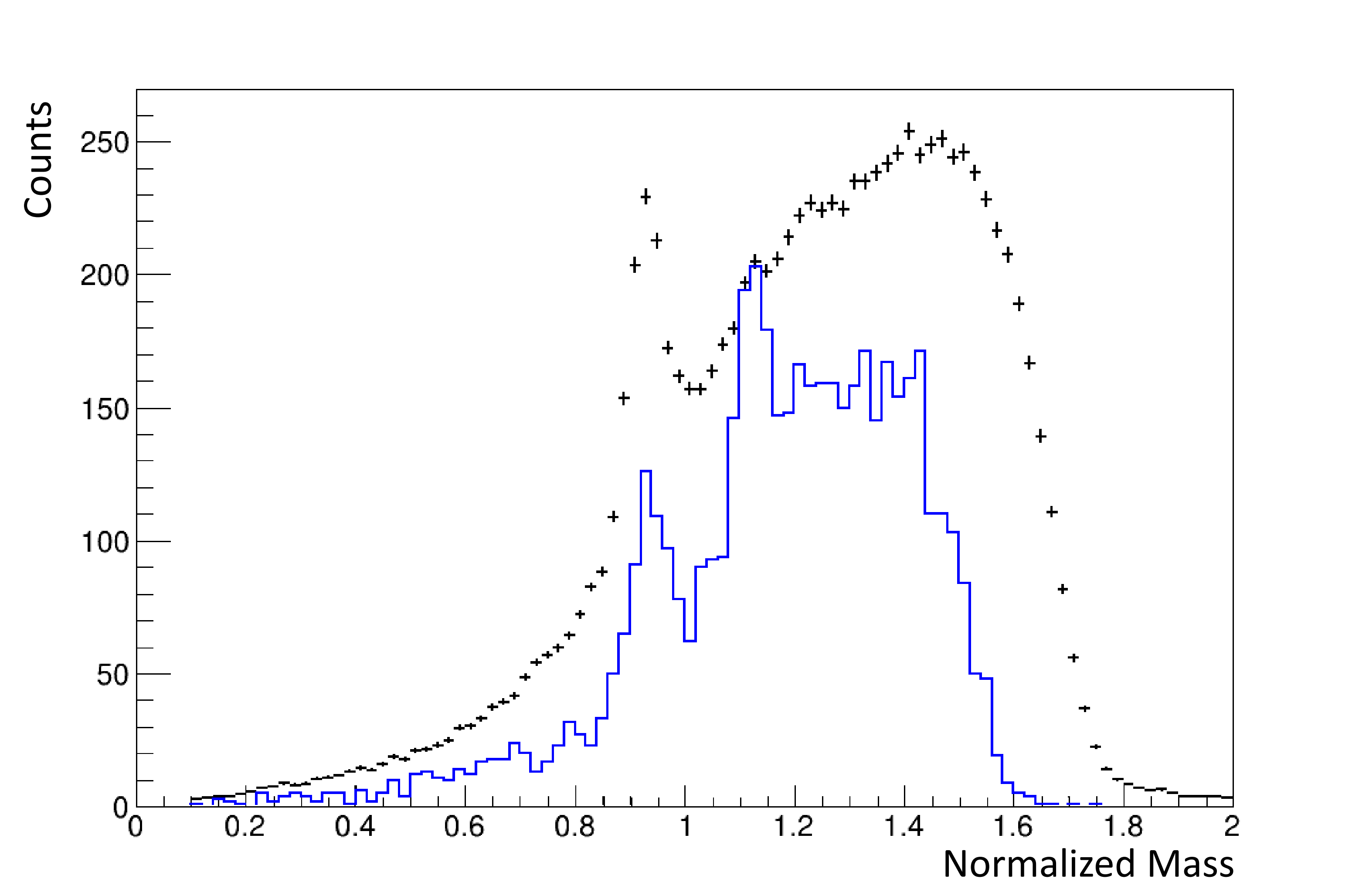
Particle Identification – p(e,e'K$^+$)Λ

- Able to identify neutron and Λ missing masses

+ : Data

: Particle ID

: Simulation



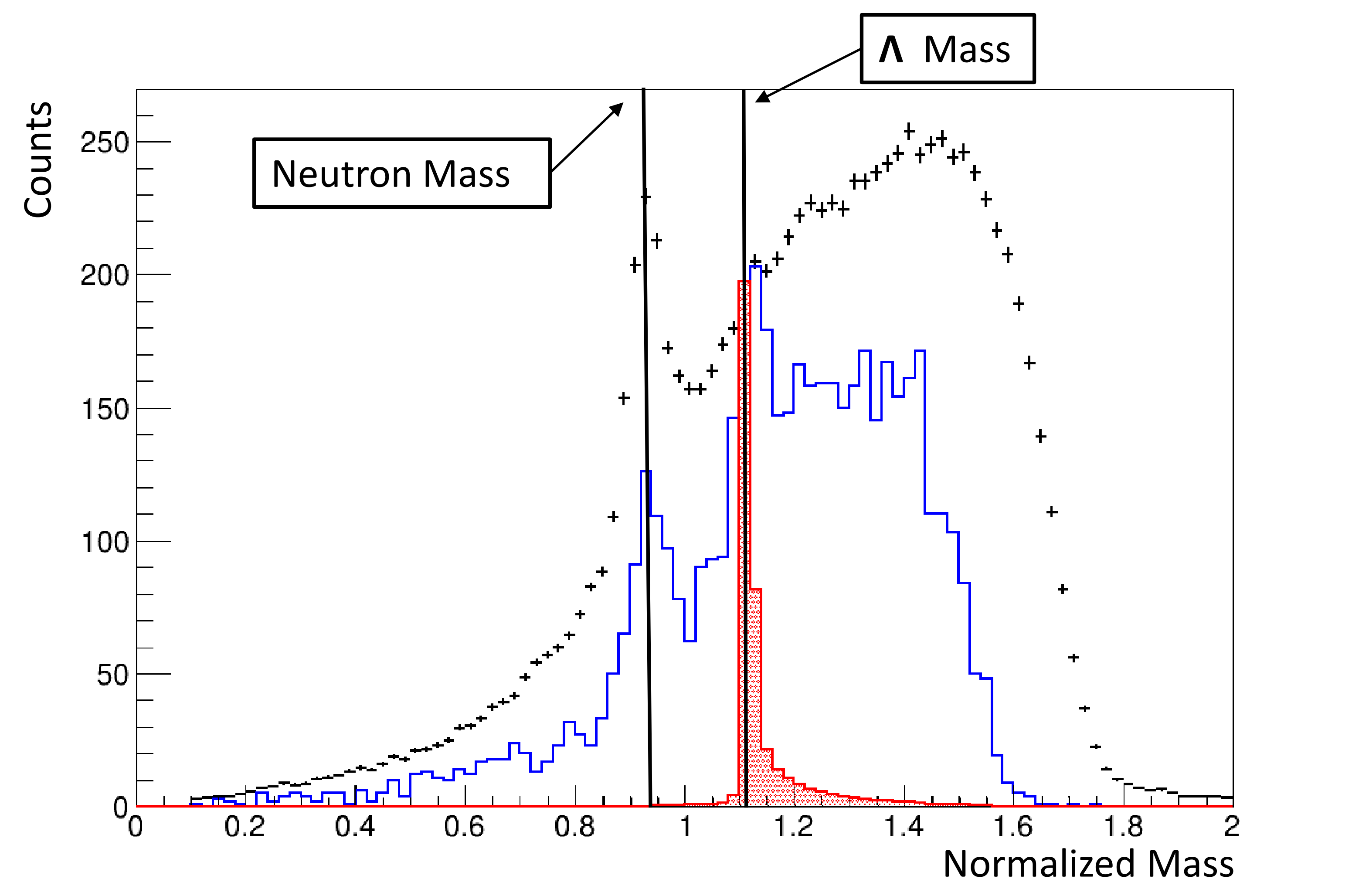
Particle Identification – p(e,e’K$^+$)Λ

- Able to identify neutron and Λ missing masses

+ : Data

: Particle ID

: Simulation



Detector Calibration

- Determine efficiency with other detectors

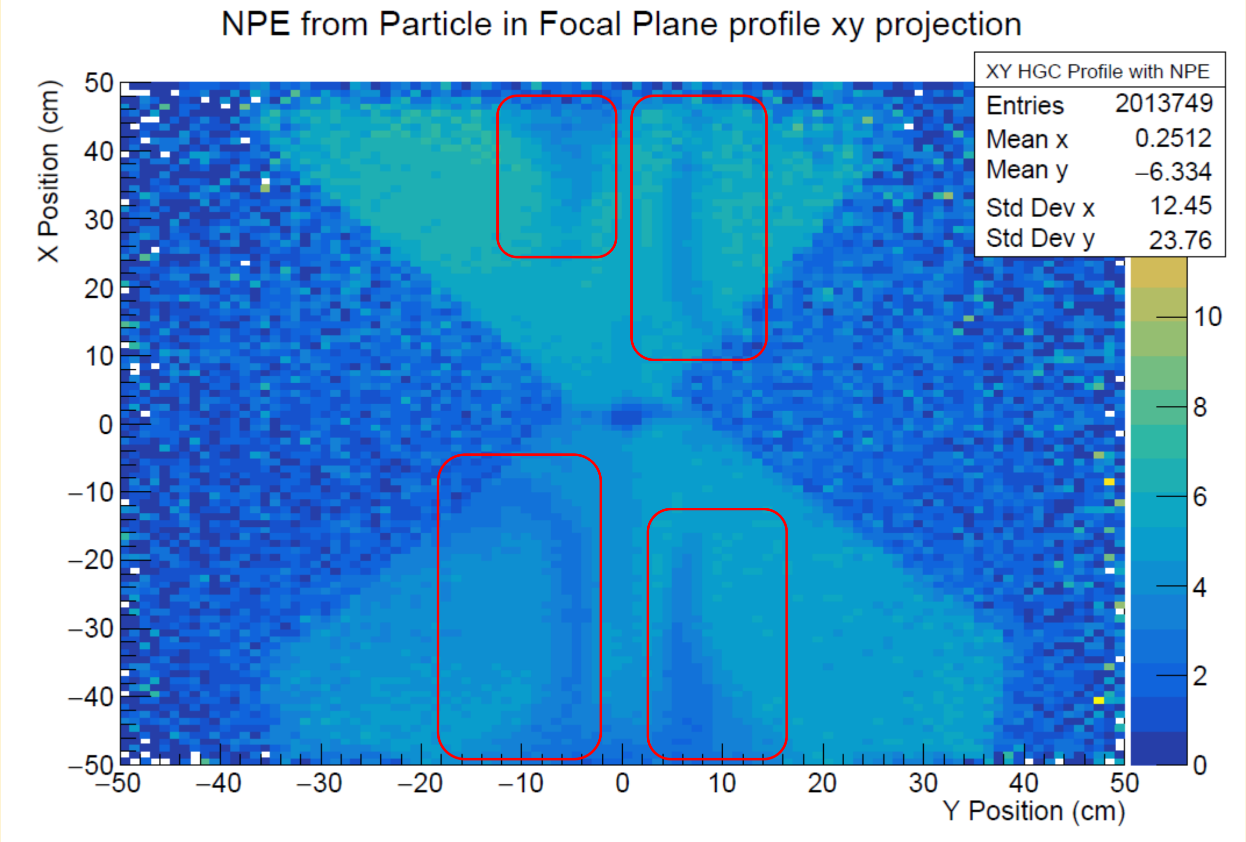
$$\text{electron efficiency} = \frac{[\text{calorimeter } e^-][\text{NGC } e^-][\text{HGC } e^-]}{[\text{calorimeter } e^-][\text{NGC } e^-]} \times 100\%$$

$$\text{pion contamination} = 1\!:\frac{[\text{calorimeter } e^-][\text{NGC } e^-][\text{HGC } e^-]}{[\text{calorimeter } \pi^-][\text{NGC } \pi^-][\text{HGC } e^-]}$$

NPE cut on HGC	Electron efficiency	Pion contamination
0.5	99.97%	1:41
1.0	99.73%	1:49
1.5	99.35%	1:64
2.0	99.02%	1:75

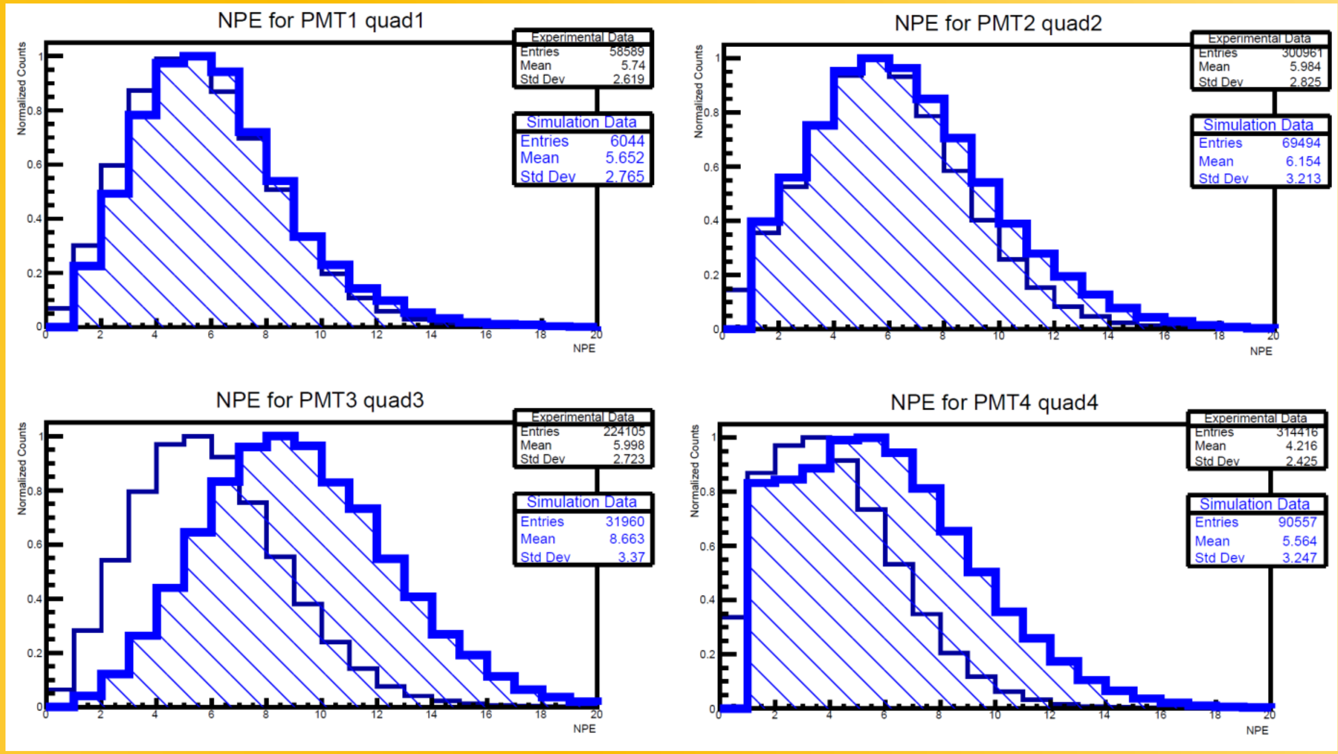
Outlook

- Detector performance can be improved
  - Localized inefficiencies
  - Disagreement with simulation
- Currently testing optical alignment
- Testing new optical configuration to improve performance



Outlook

- Detector performance can be improved
  - Localized inefficiencies
  - Disagreement with simulation
- Currently testing optical alignment
- Testing new optical configuration to improve performance



Back up Slides

Experimental Goals

- Rosenbluth Separation to isolate σ_L

$$2\pi \frac{d^2\sigma}{dtd\phi} = \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)} \frac{d\sigma_{LT}}{dt} \cos\phi + \varepsilon \frac{d\sigma_{TT}}{dt} \cos 2\phi$$

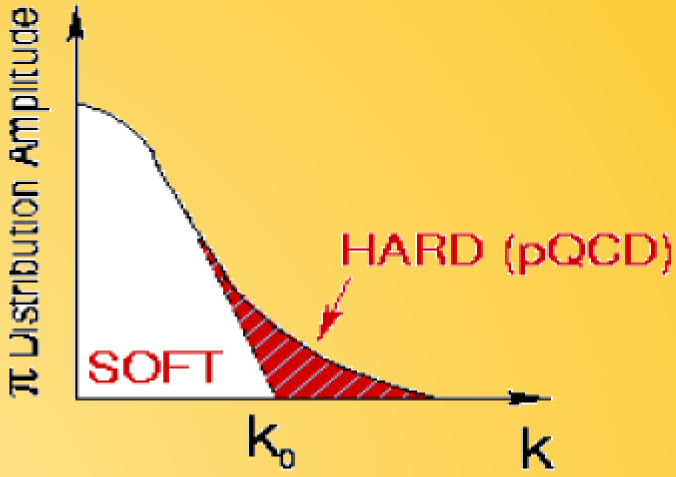
$$\varepsilon = \left(1 + 2\frac{(E_e - E_{e'})^2 + Q^2}{Q^2}\left(\tan\frac{\theta_{e'}}{2}\right)^2\right)^{-1}$$

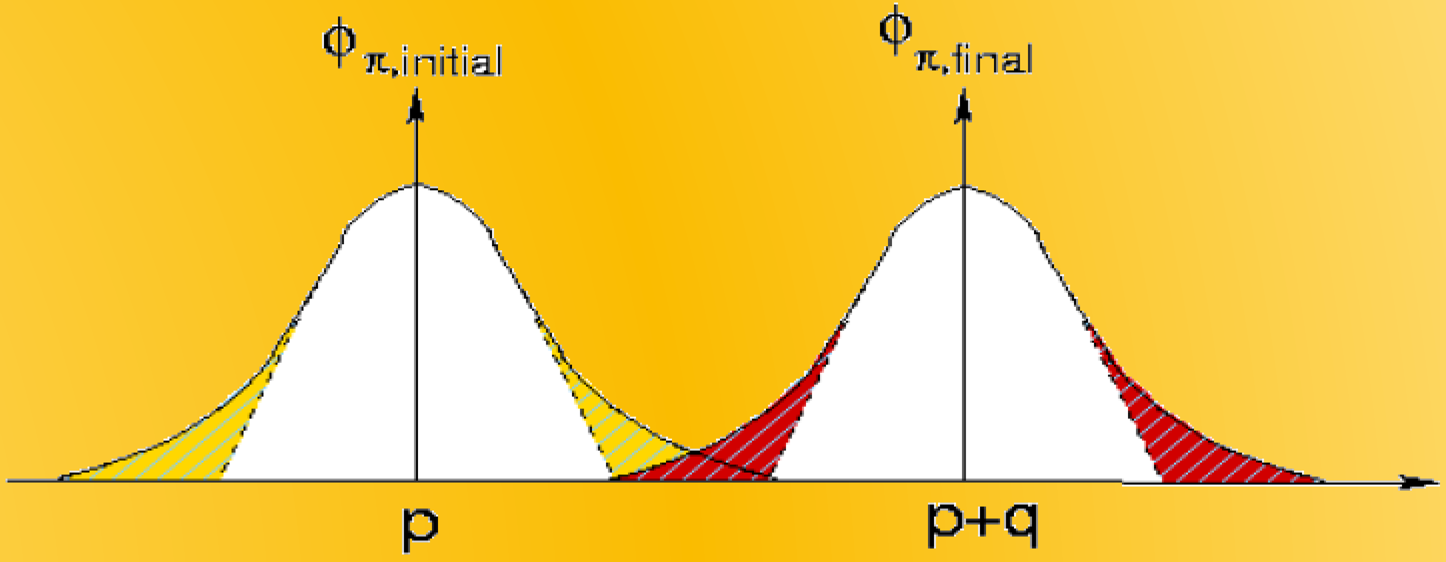
- Measure cross section at fixed $(W, Q^2, -t)$ at two beam energies
- Simultaneous fit of two ε values to determine contributions

Experimental Goals

- In quantum theory, form factor is the overlap integral

$$F_K(Q^2) = \int \varphi_i^*(p)\varphi_f(p+q)\mathrm{d}p$$



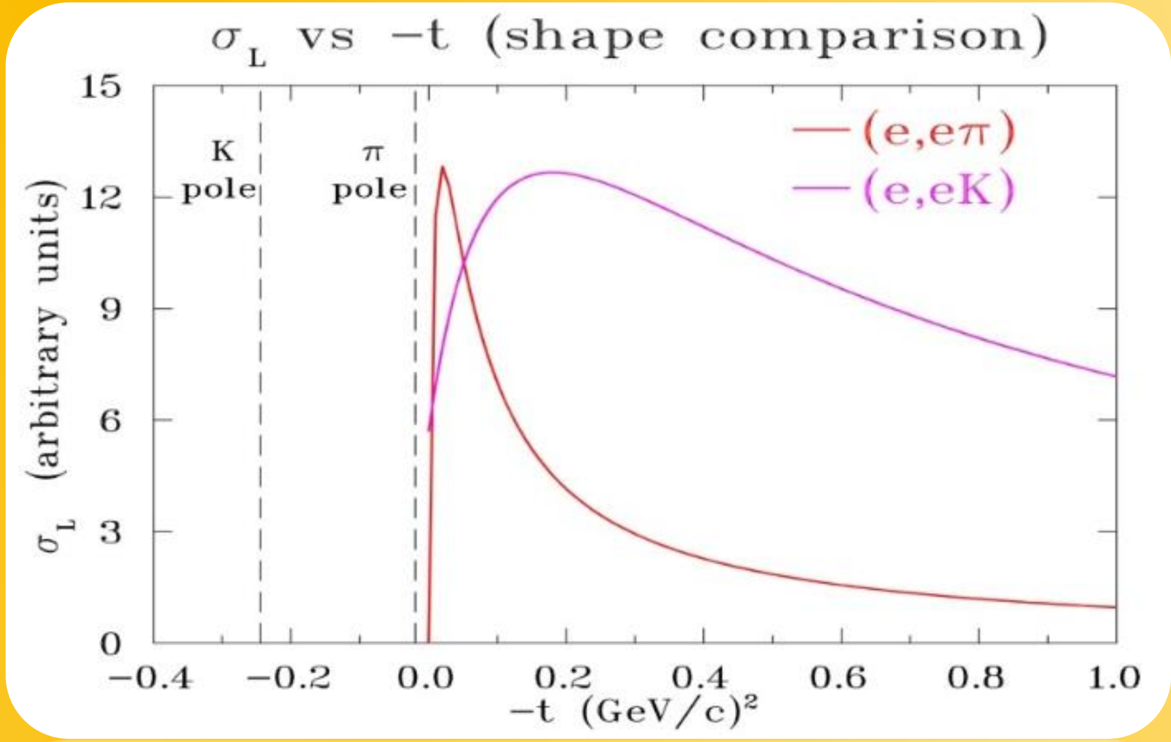


Experimental Goals

- Can proton "kaon cloud" be used to extract kaon form factor?

- Kaon pole further from kinematically allowed region
- Form factor from Regge VGL model

$$\sigma_L \approx \frac{-2tQ^2}{(t-m_K^2)^2} k\left(e g_{K\Lambda p}\right)^2 F_K^2(Q^2)$$

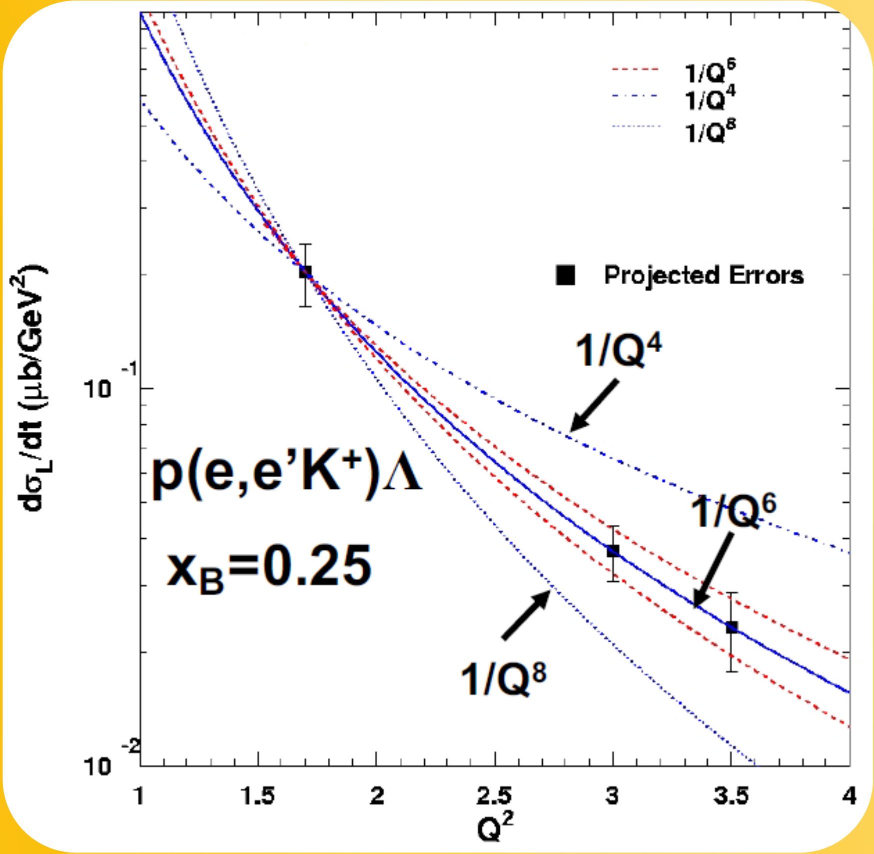


Experimental Goals

- Can kaon electroproduction shed light on factorization regime?

- What Q^2 is needed for factorization to apply?

- Nothing is known with strangeness dimension

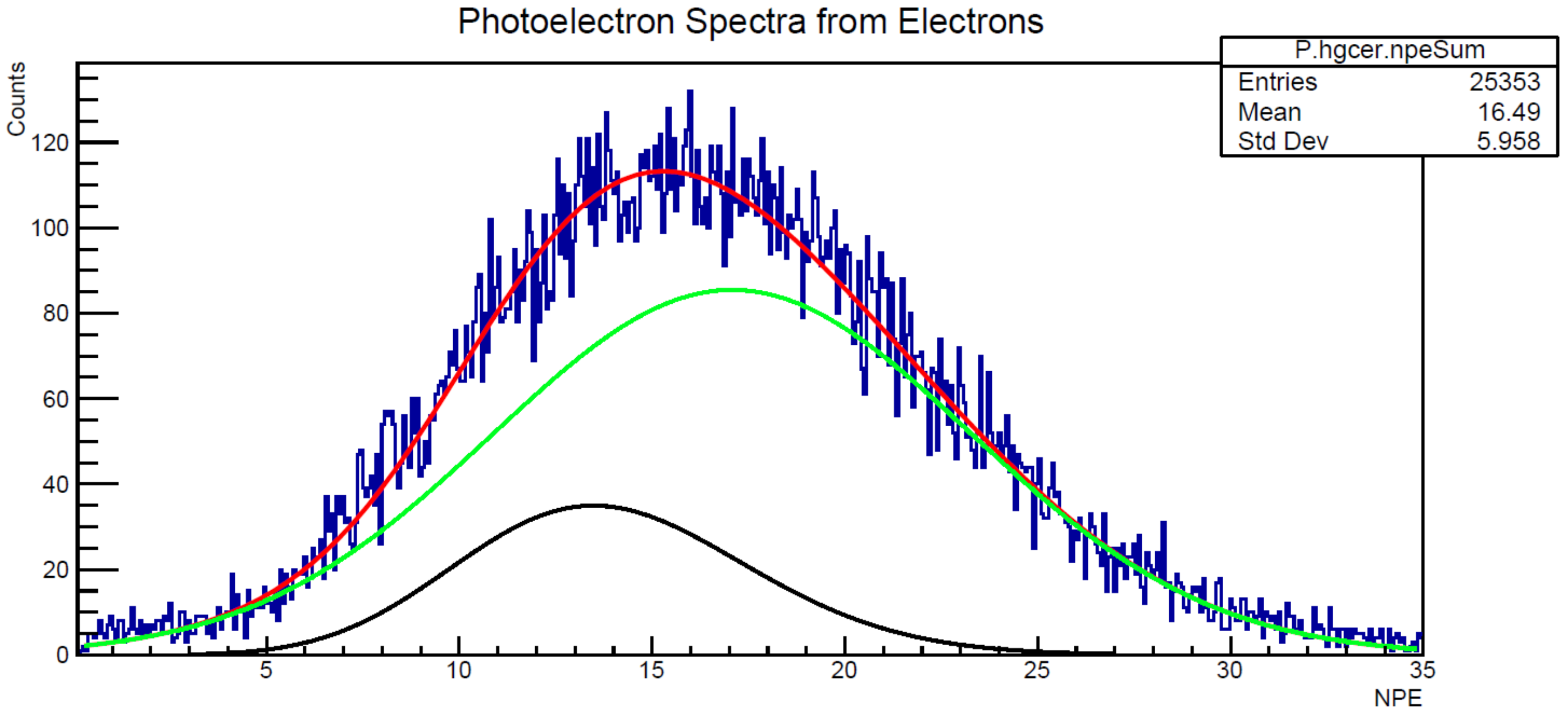


Detector Calibration

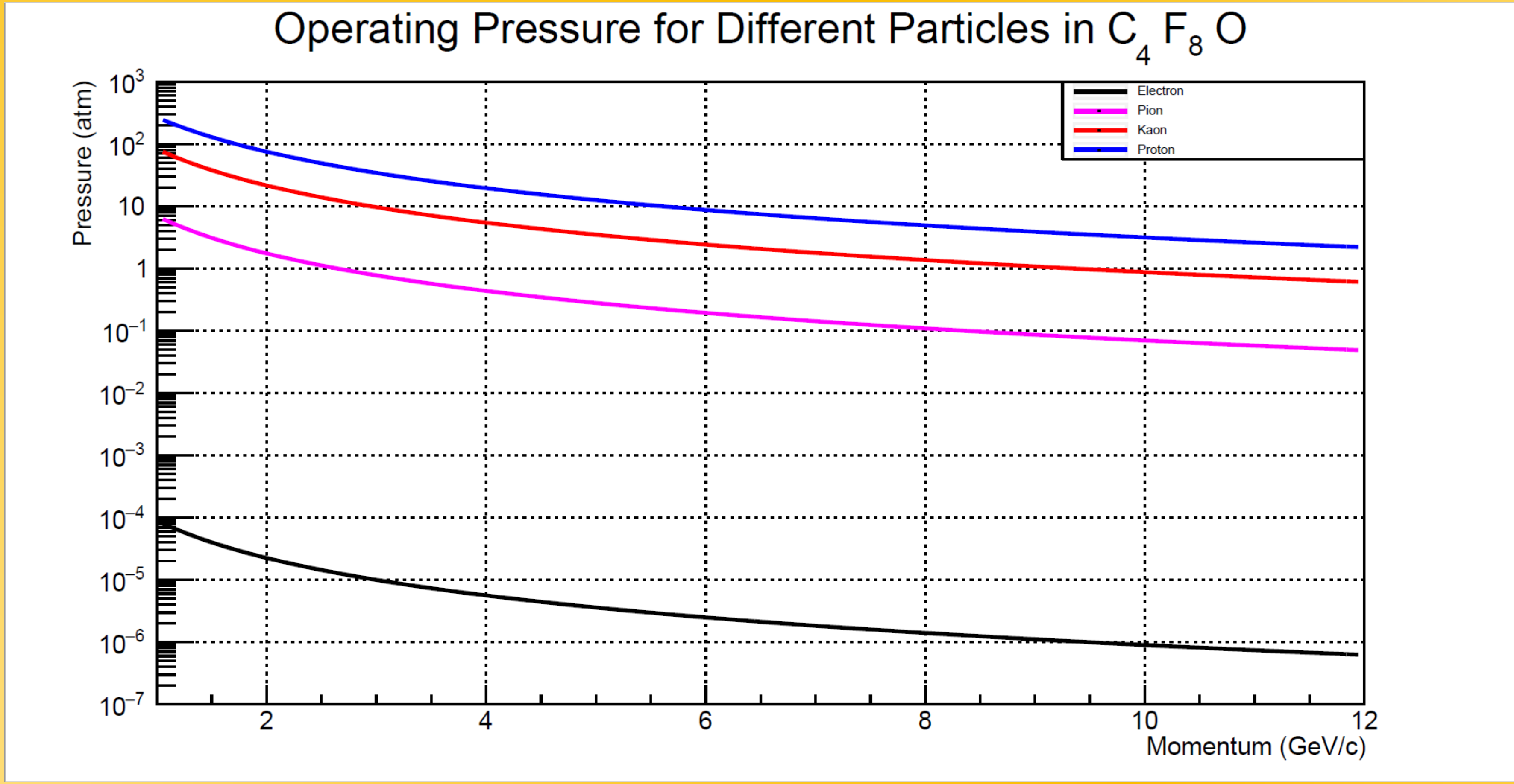
- Verify calibration by checking distribution profile

- Fit with sum of Poison and Gaussian Distribution

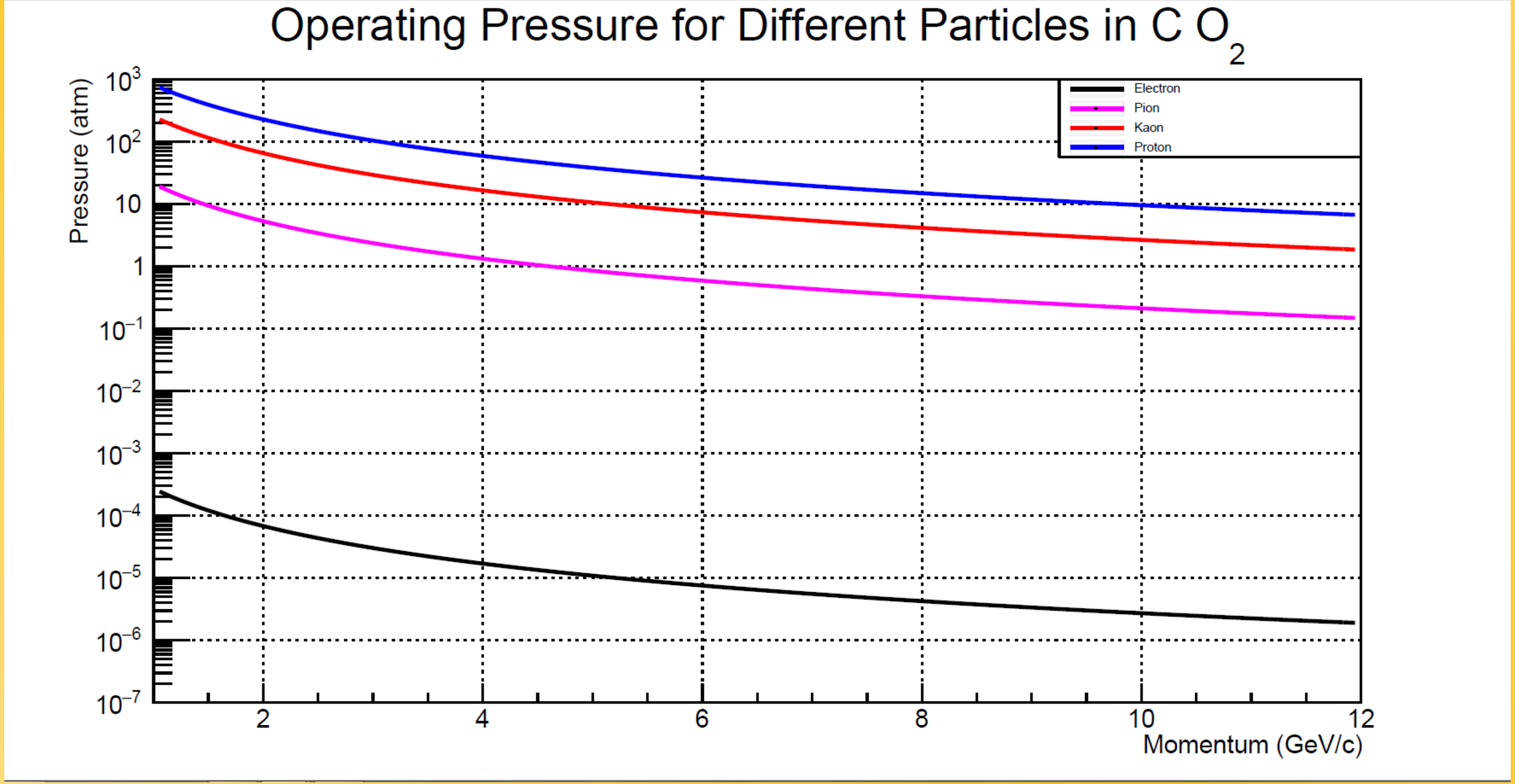
$$\frac{\mu^x e^{-\mu}}{\Gamma(x+1)} + e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$



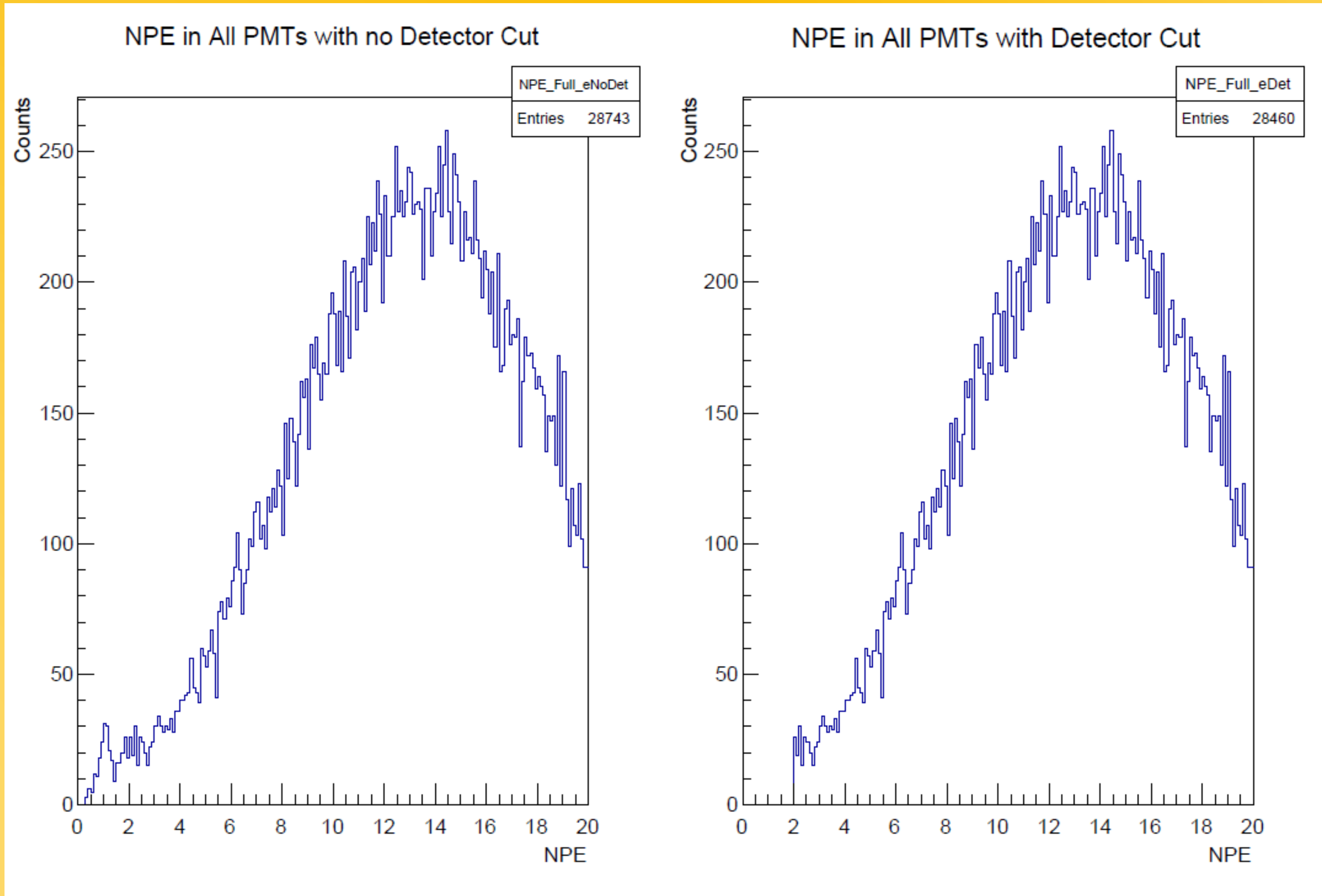
Detector Calibration



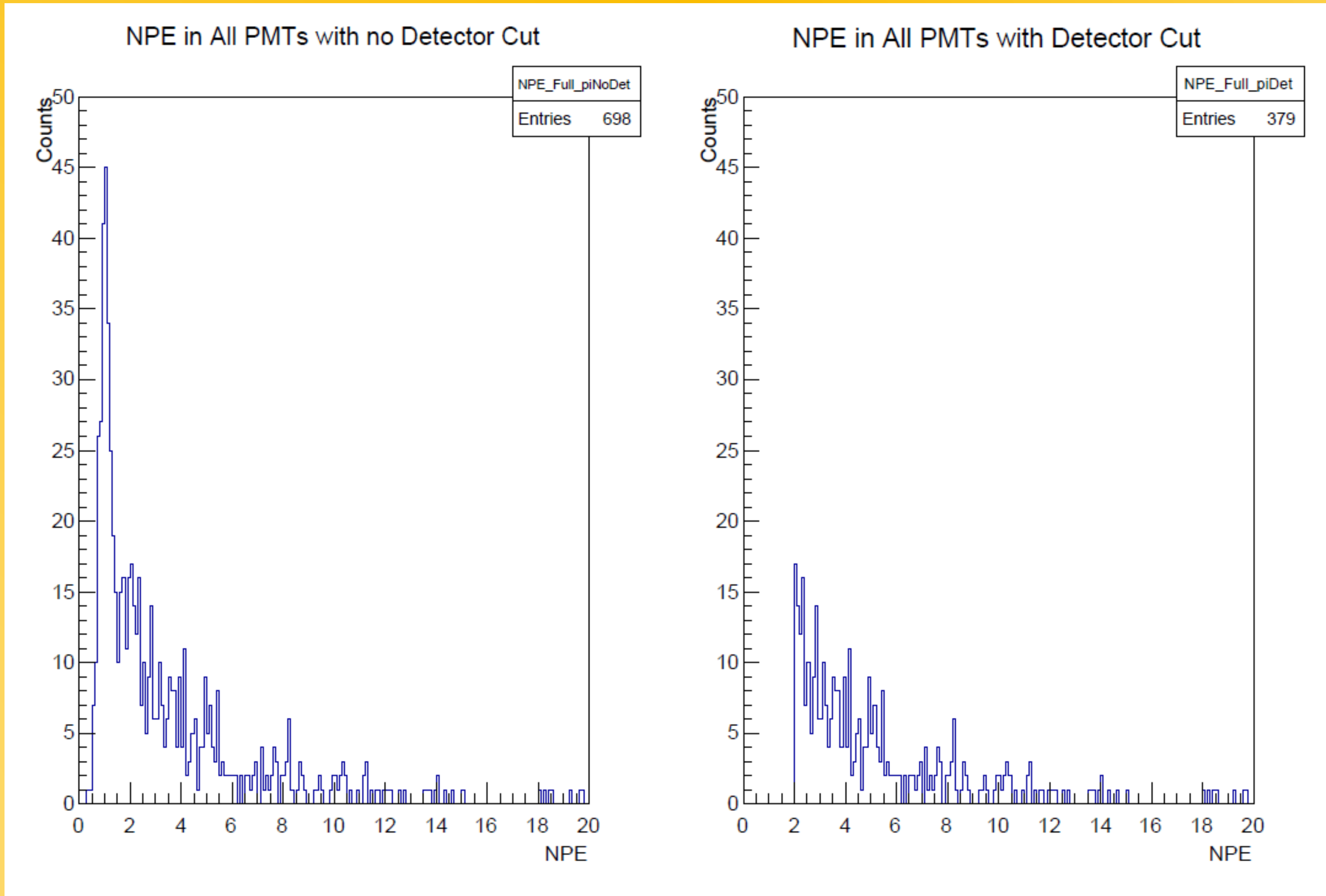
Detector Calibration



Detector Calibration



Detector Calibration



Run Conditions

- Run 1583
  - SHMS set to -2.214 GeV with 10 uA beam, HGC filled with 1 atm CO_2

- Run 3423
  - SHMS set to +5.05 GeV with 10 uA beam, HGC filled with 1 atm C_4F_8O