CLAS Collaboration Meeting, JLAB

07/10 – 07/13/2018

First Studies of Exclusive Reactions in the Resonance Region with CLAS12

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Outline and Introduction

- Physics motivation
- Particle identification
- e p → e‘ p‘ π^0
- e p → e‘ p‘ K^+ K^- [Φ(1020) and Λ(1520)]

- run 3432 (~ 1400 files)
  - → 10.6 GeV
  - → solenoid -100%, torus -100%
  - → cooked with coatjava version 5b.3.3

- run 4013 (~ 1800 files)
  - → 10.6 GeV
  - → solenoid -100%, torus -100%
  - → cooked with coatjava version 5b.5.0

Physics motivation for exclusive channels

Goal for RGA:

- Measure exclusive electroproduction cross sections from an unpolarized proton target with polarized electron beam for Nπ, Nη, Nππ, KY

  → E_b = 10.6 GeV, Q^2 = 3 - 12 GeV², W → 3.0 GeV

  with nearly complete coverage of the final state phase space

Physics motivation:

- Study the structure of all prominent N* states in the mass range up to 3.0 GeV vs. Q^2 up to 12 GeV²
- CLAS12 is the only facility to map-out the N* quark structure with minimal meson-baryon cloud contributions

Short term goal:

Extract beam spin asymmetries in the kinematic range of CLAS 12

Particle ID

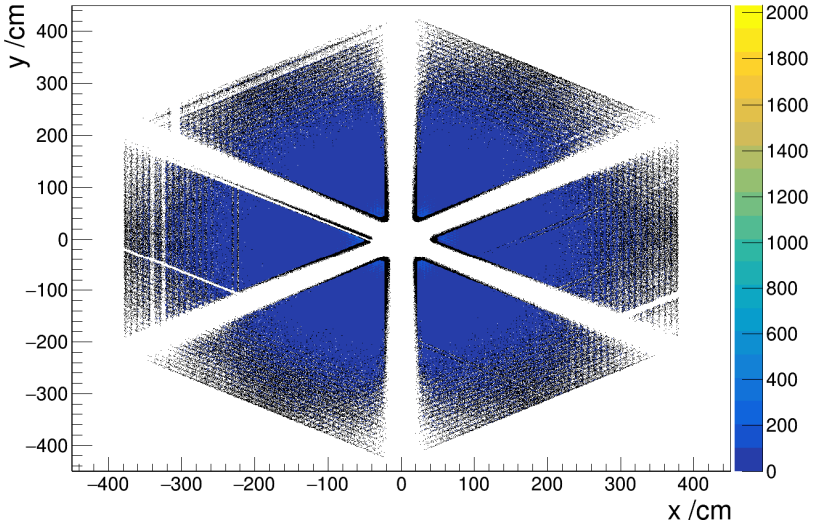
- If the detector is well understood and all kinematic variables are correctly reconstructed, a precise particle ID is not mandatory

→ Exclusivity cuts on missing mass / energy / momentum / angle can be used for event selection

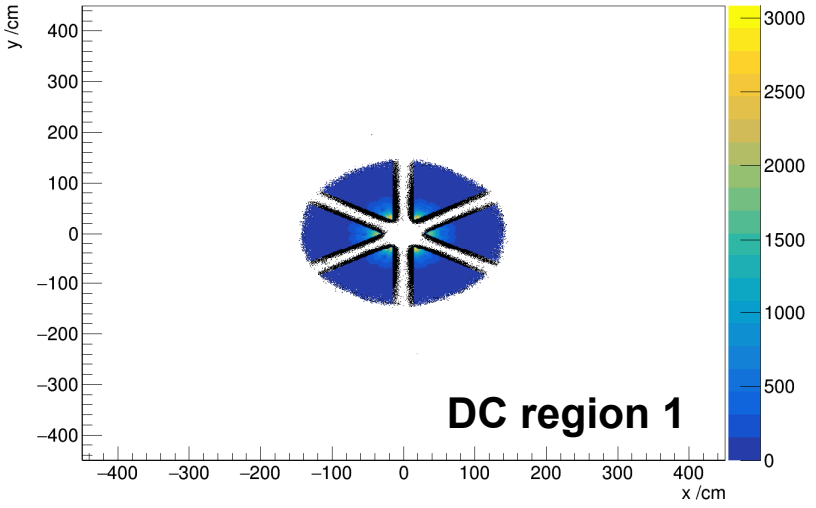
→ If also resolutions are under controll, a kinematic fit can be applied

a) Electron ID → Based on eventbuilder PID

+ fiducial cuts for PCAL

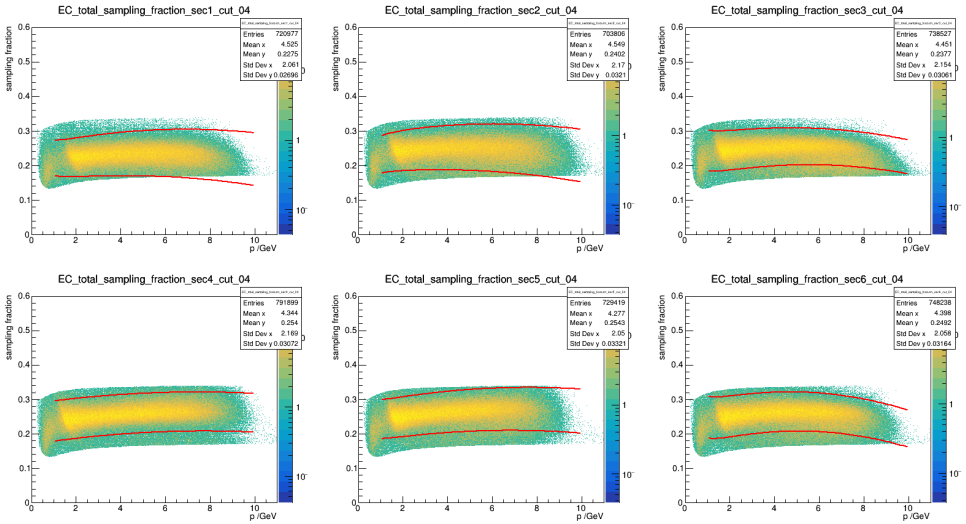


+ fiducial cuts for DC region 1+2+3



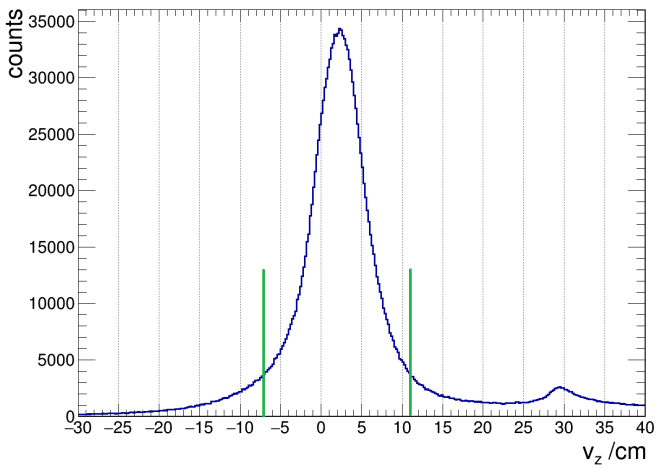
Electron and Photon ID

+ Calorimeter sampling fraction cut limitted to real 3σ region



+ E > 1.5 GeV @ 10.6 GeV

+ relatively wide z vertex cut

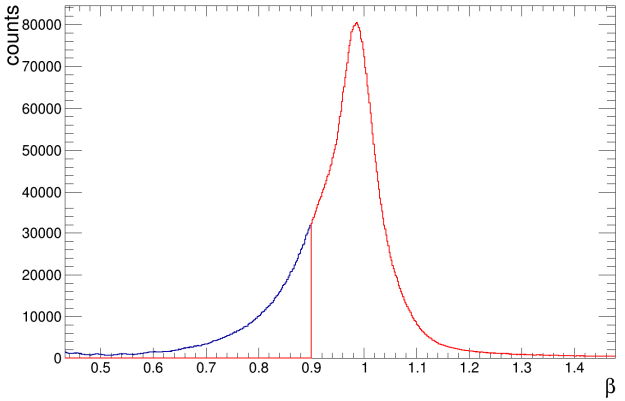


b) Photon ID

→ Based on standard PID

+ fiducial cuts for PCAL

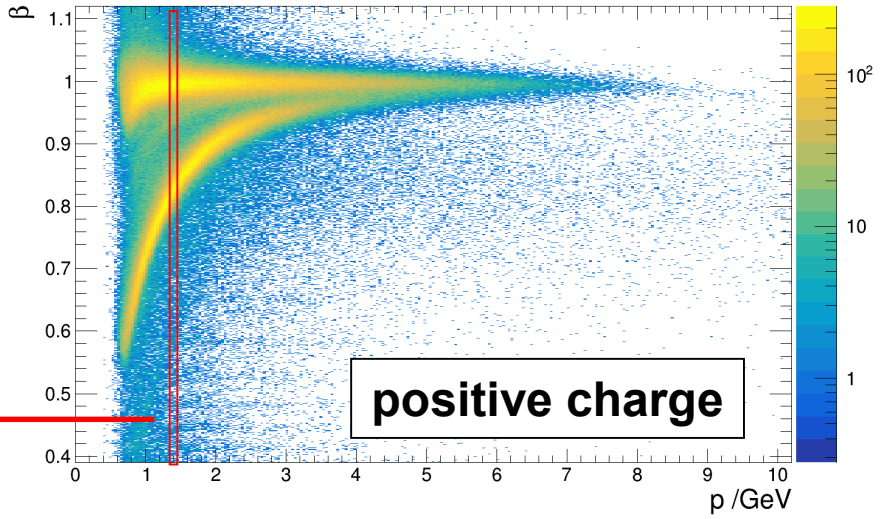
+ β > 0.95

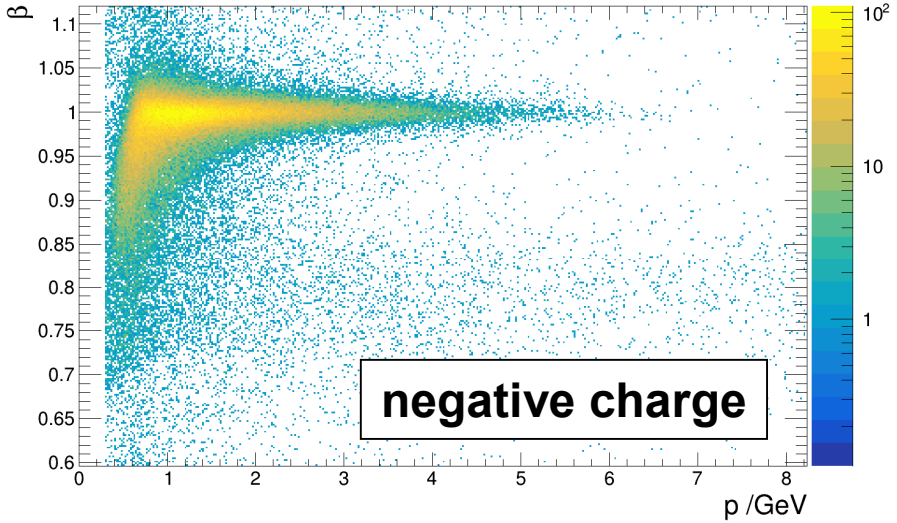


c) Hadron Particle ID

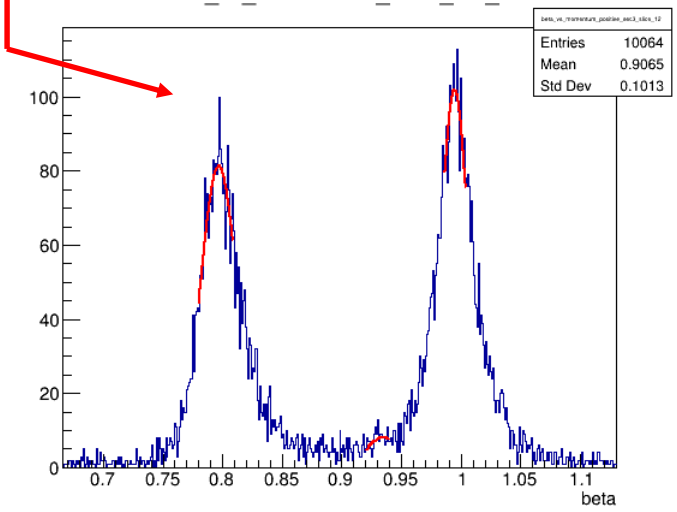
i) Fiducial cuts on the 3 Driftchamber regions

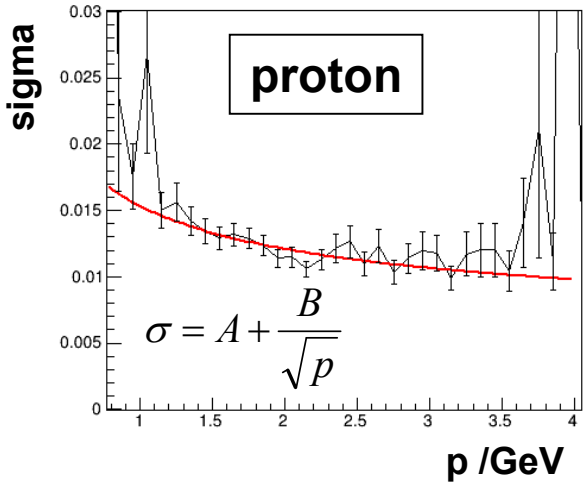
ii) Particle selection based on β vs p correlation

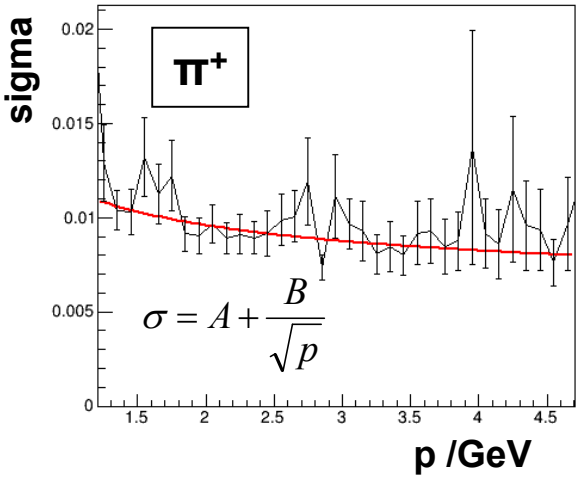




100 MeV p slices for each sector

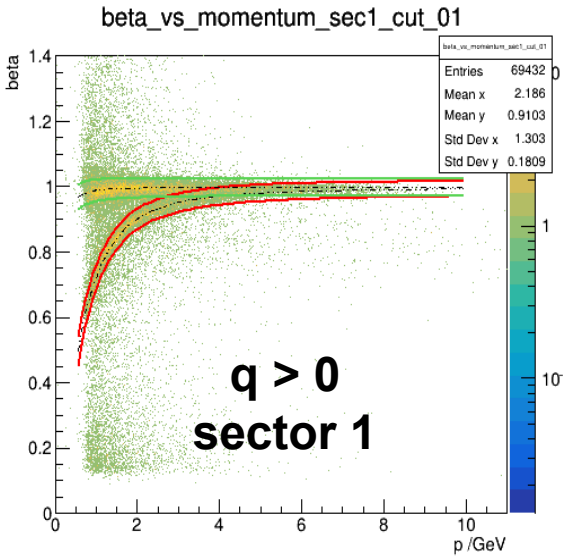


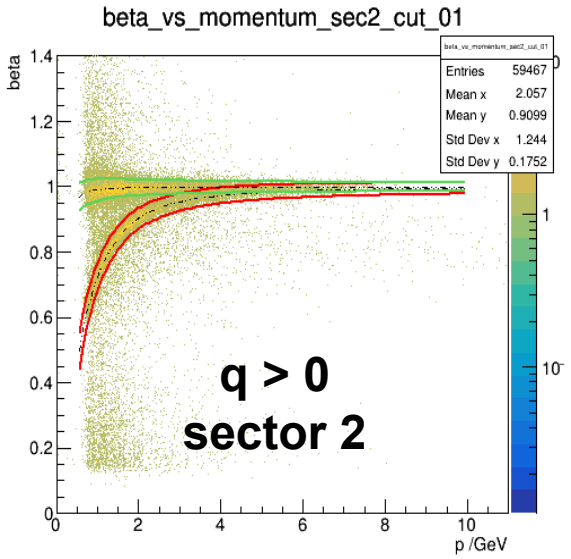


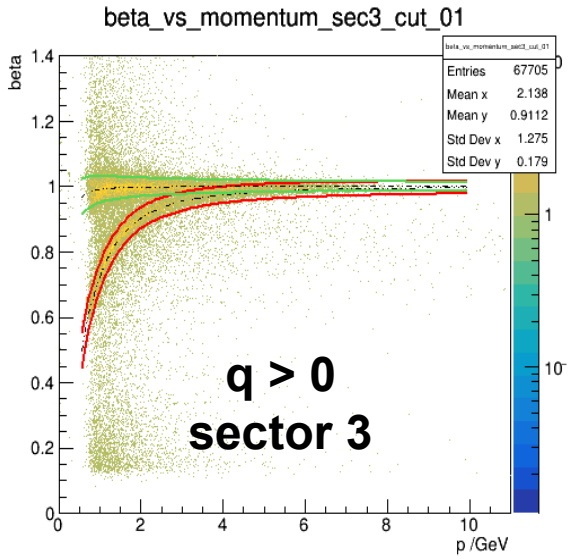


Mean and 3 sigma region

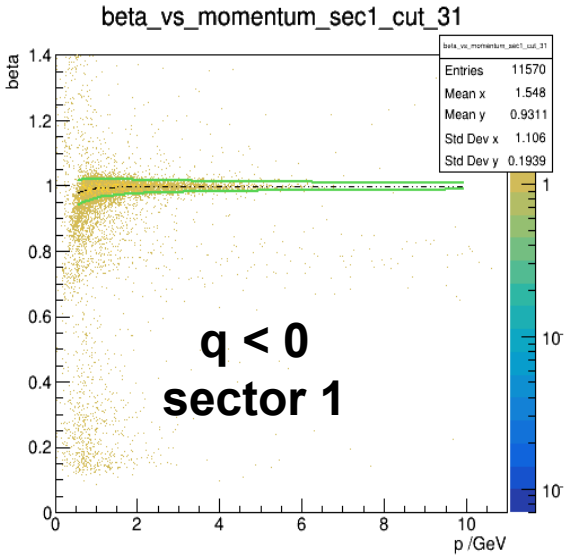
q > 0

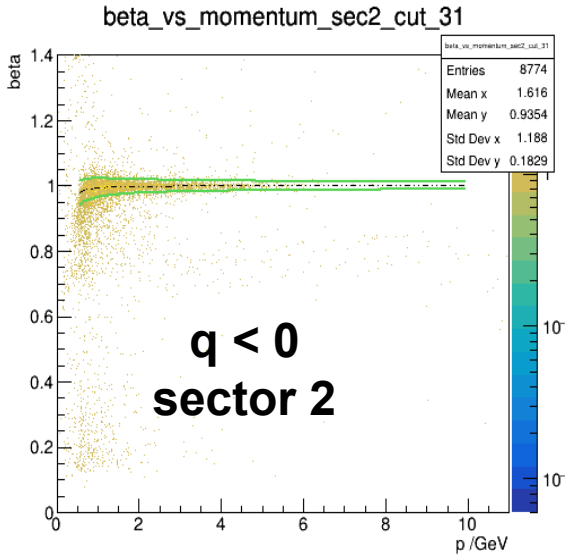


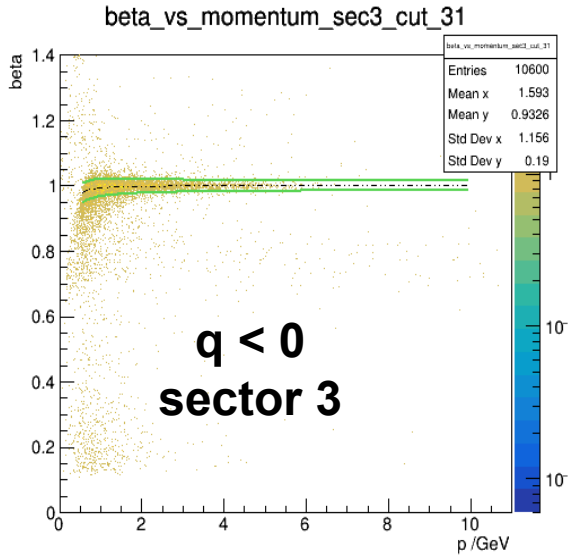




q < 0



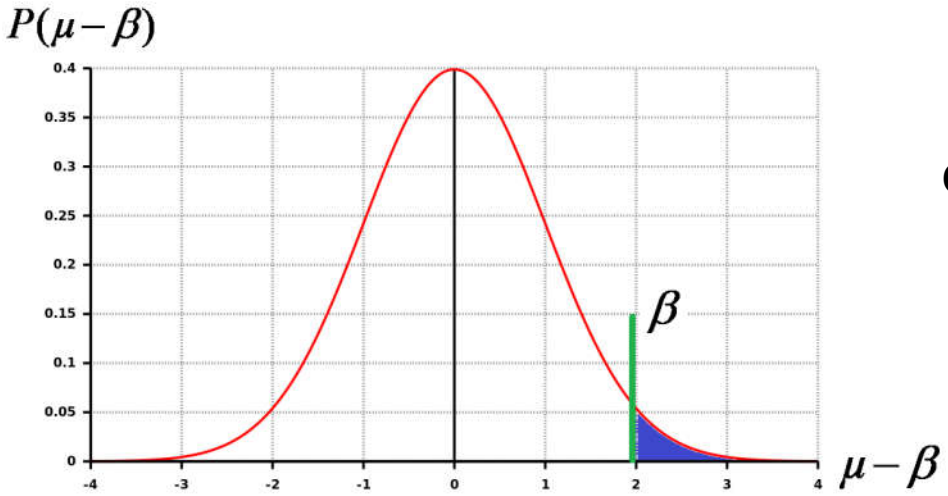




Maximum Likelihood Particle ID

- Simple β vs p cut: particles are double assigned in the overlap region

  ➔ Assignment of each particle based on statistical probabilities



$$P(\beta) = \frac{1}{\sqrt{2\pi}\sigma} \cdot \exp\left(-\frac{1}{2}\left(\frac{\beta-\mu}{\sigma}\right)^2\right)$$

Consider: Particles have momentum dependend population fractions

$$n_{\pi^+}(p) = \frac{N_{\pi^+}(p)}{N_{\pi^+}(p) + N_P(p) + N_{K^+}(p)}$$

$$p_{\pi^+} = n_{\pi^+}(p) \cdot P(\beta, p)$$

→ Calculate p(β) for each particle species

→ Assign particle to species with the highest probability

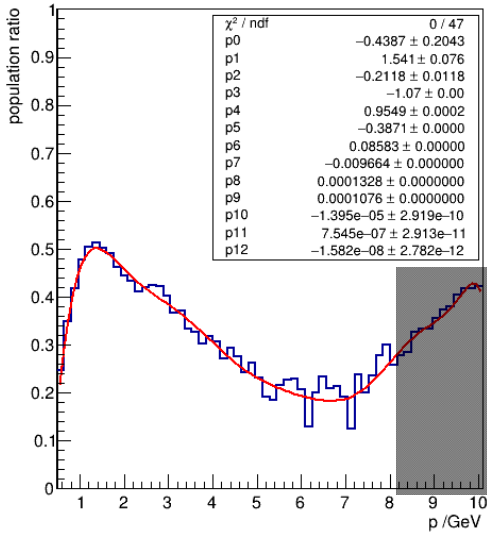
→ Calculate the confidence level for the particle species

→ Check if particle is within the 3 sigma region (conf. lev. > 0.27%)

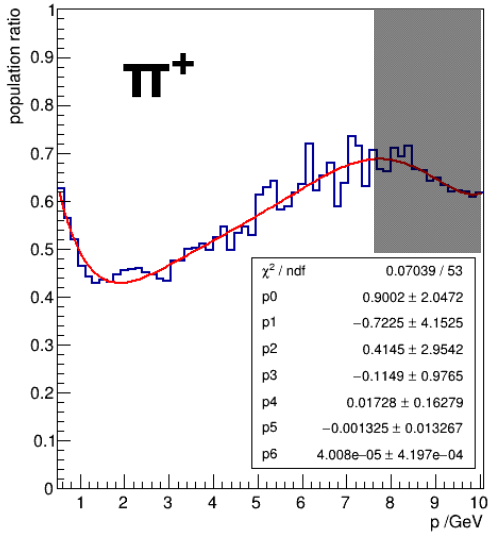
Population ratio for detected particles (outbending)

positive charge

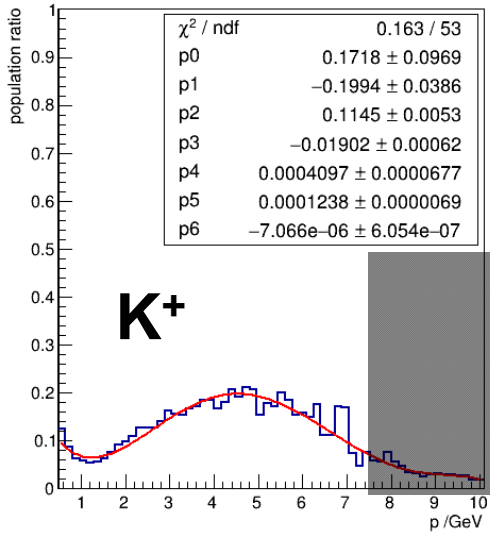
proton population ratio



pip population ratio

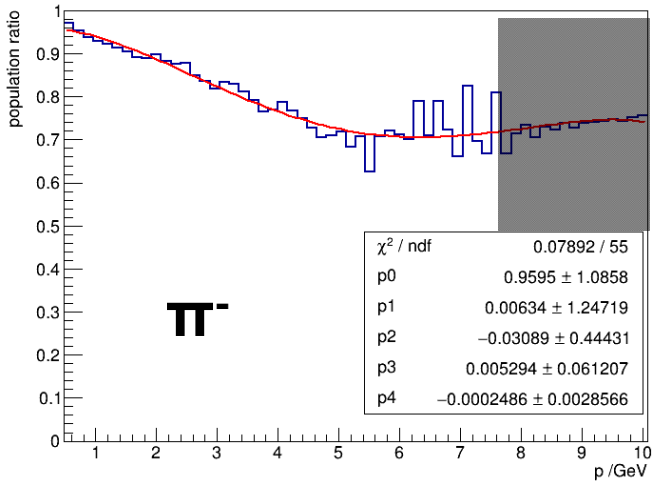


Kp population ratio

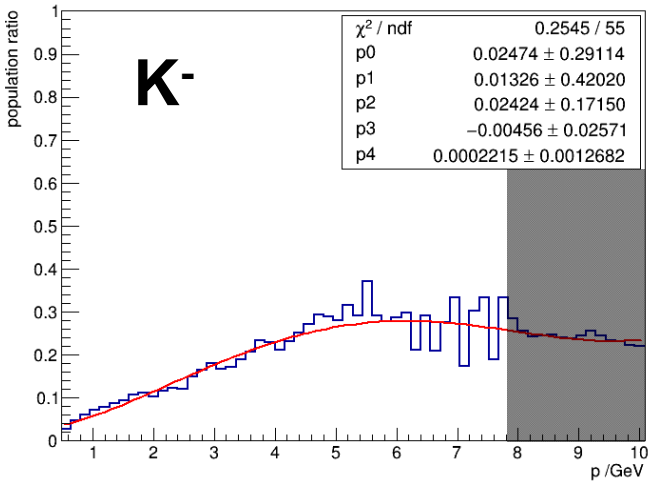


negative charge

pim population ratio



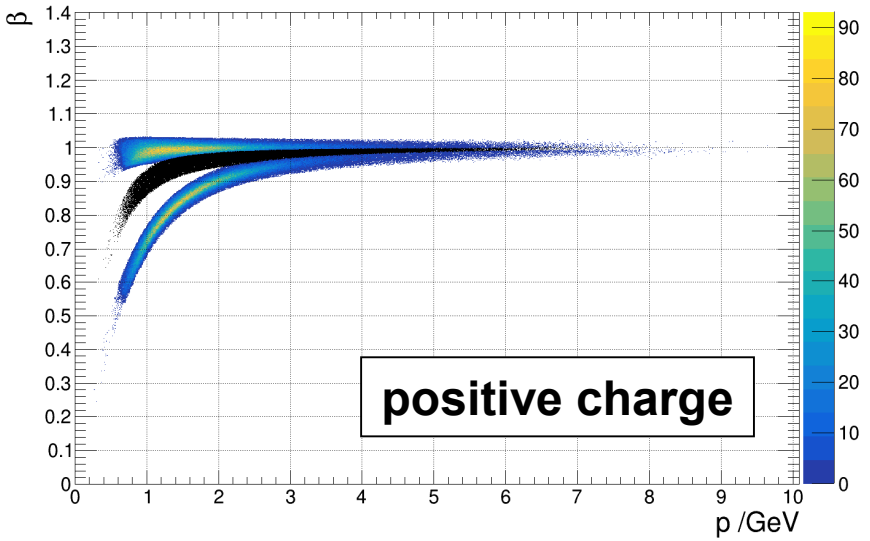
Km population ratio

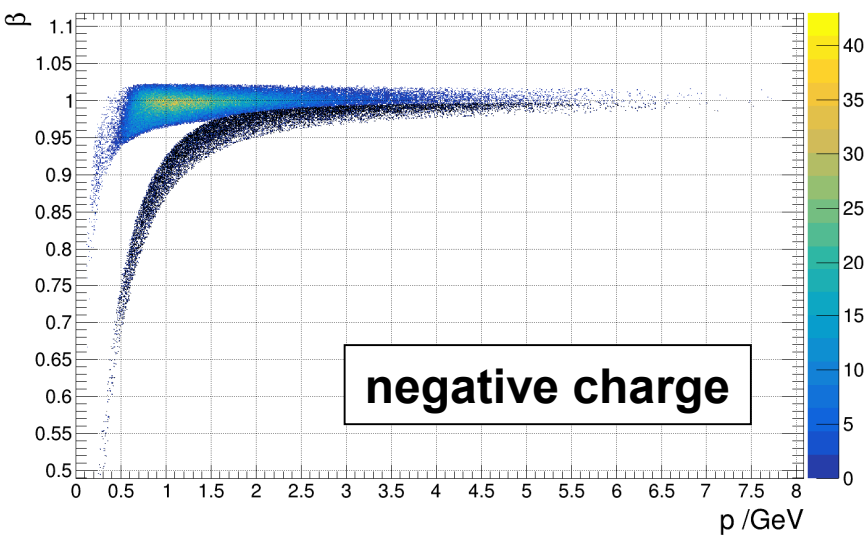


based on SIDIS simulations

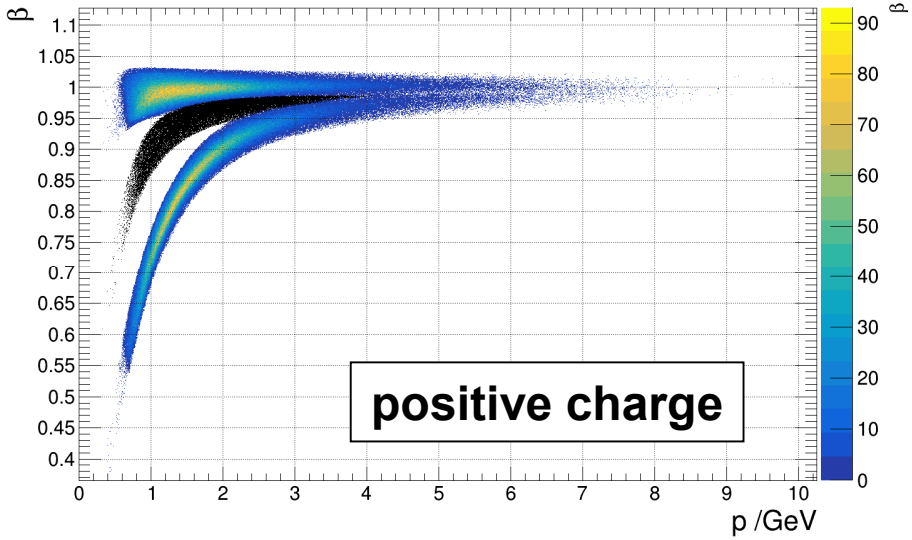
Maximum Likelihood Particle ID

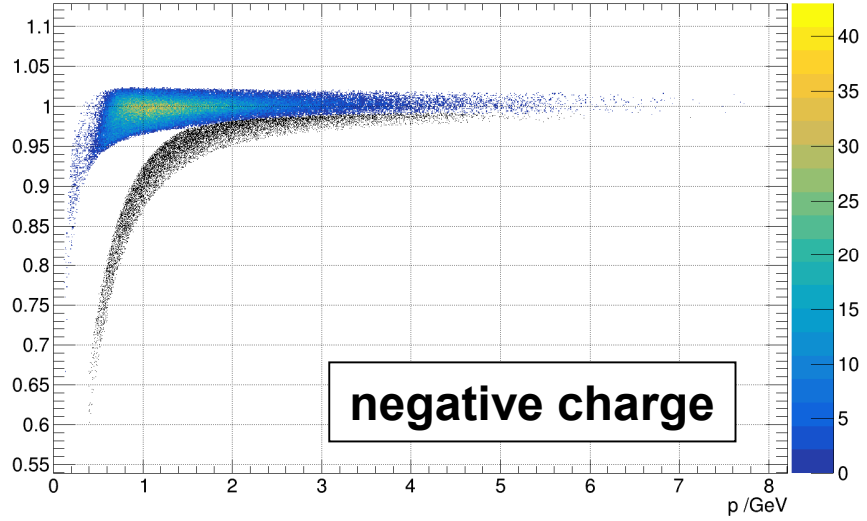
no population weighting





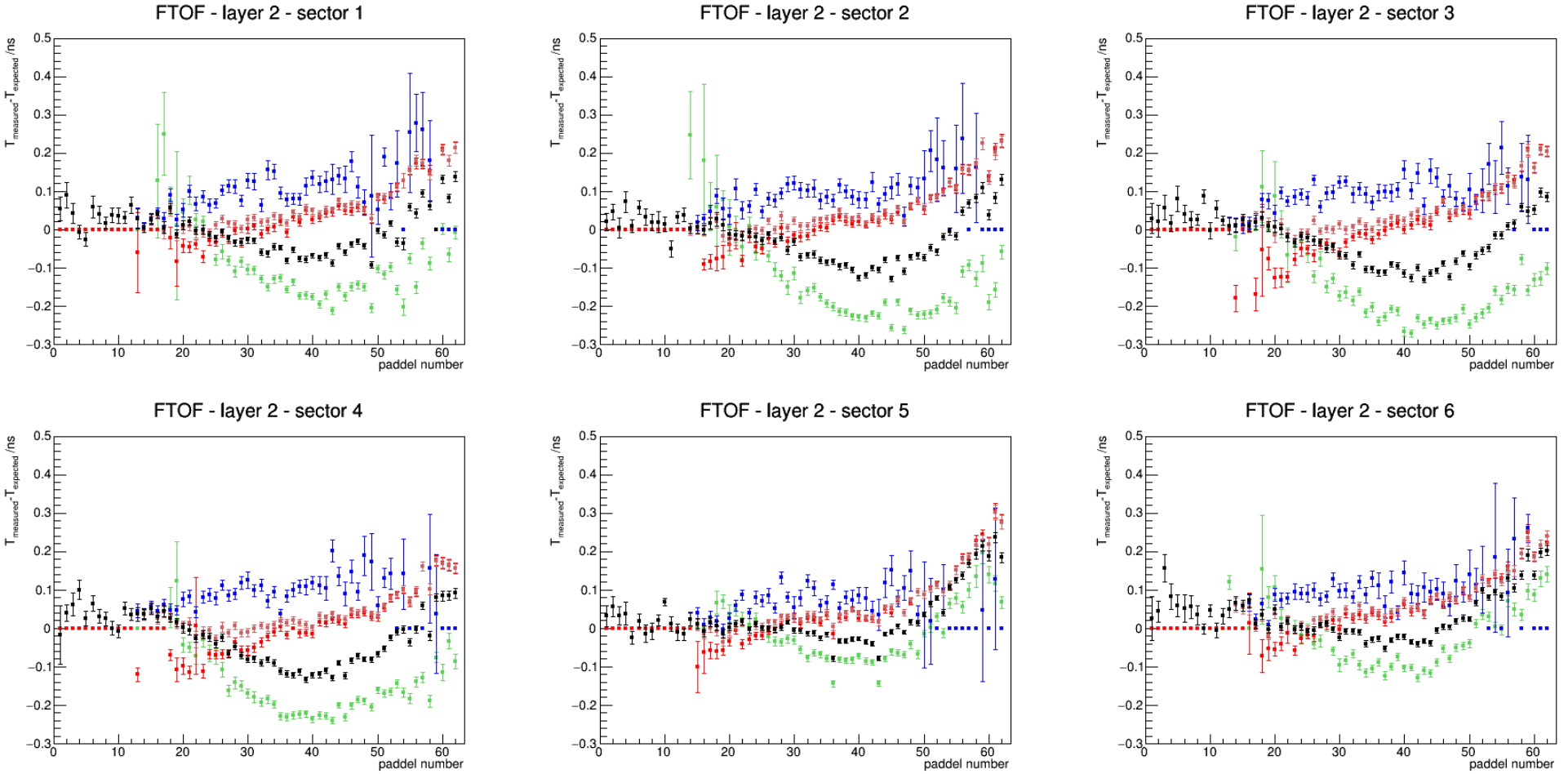
population weighting





➔ Same particle ID implemented for CD

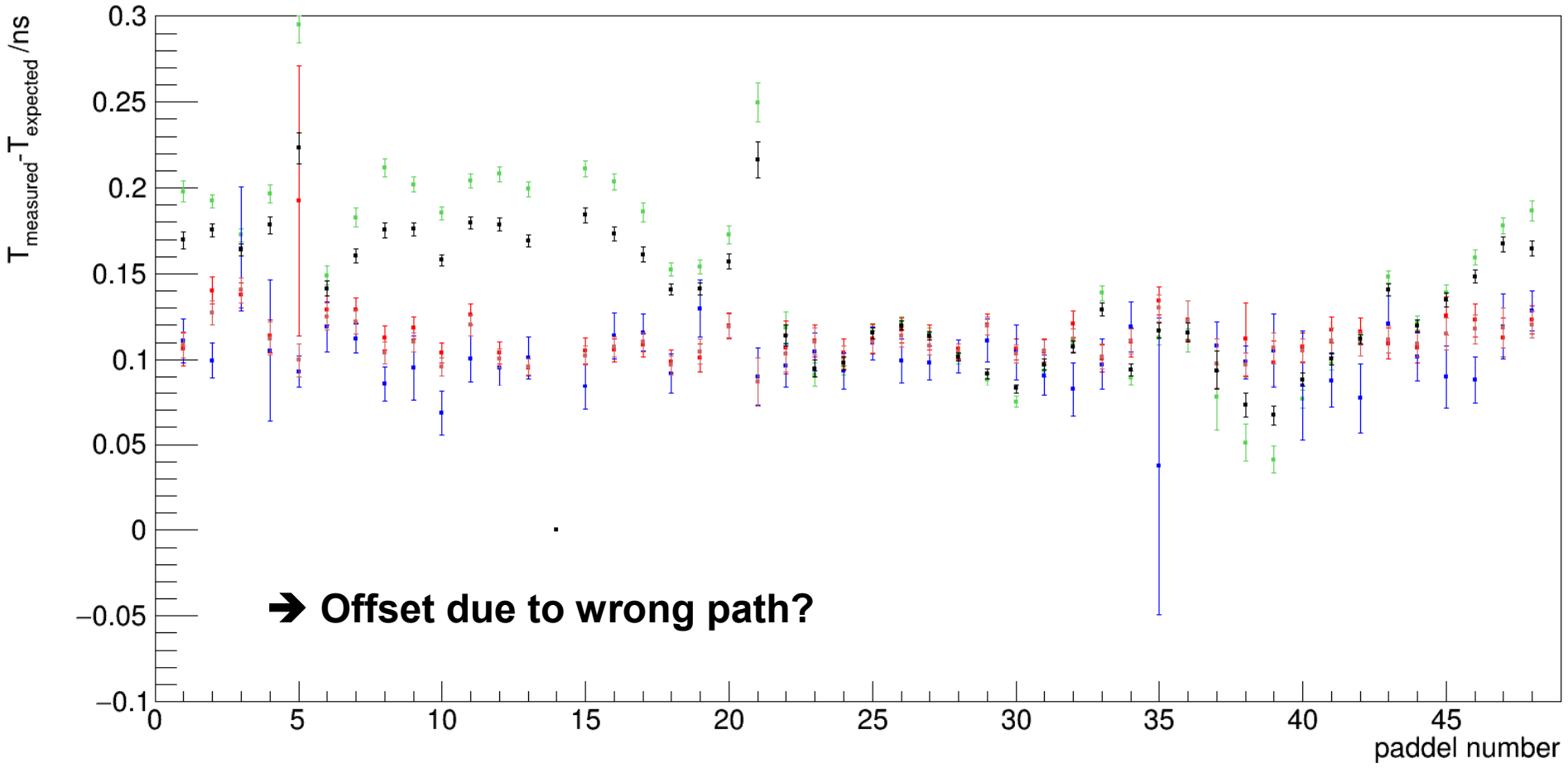
Limitations and improvements of the particle ID



π^-: blue, π^+:red proton: green pion combined: brown all combined: black

➔ Use LTTC to contribute to the maximum likelyhood probability for π/K separation

Limitations and improvements of the particle ID



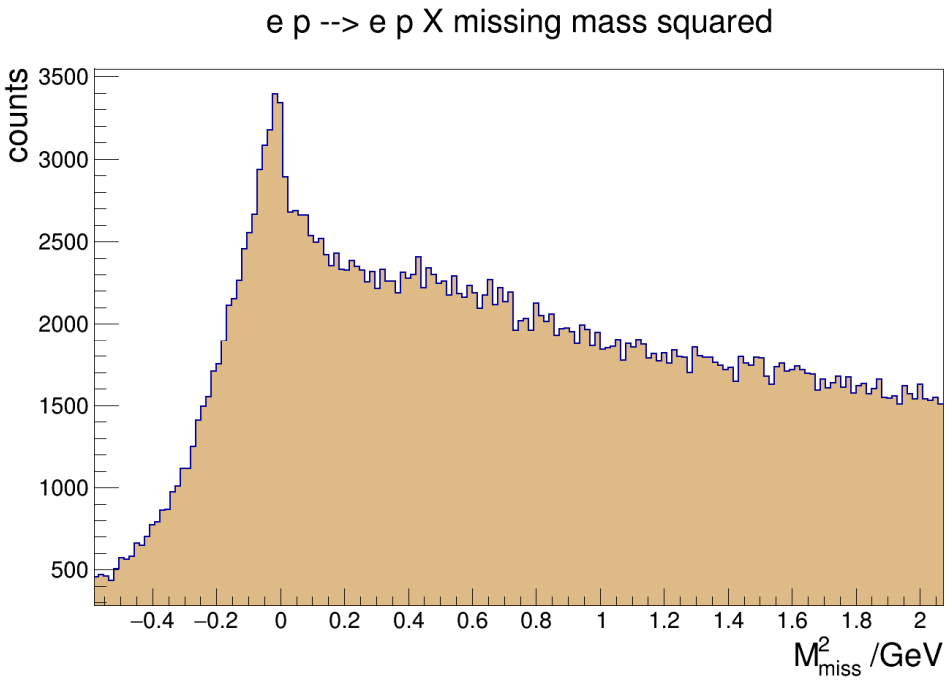
π^-: blue, π^+:red proton: green

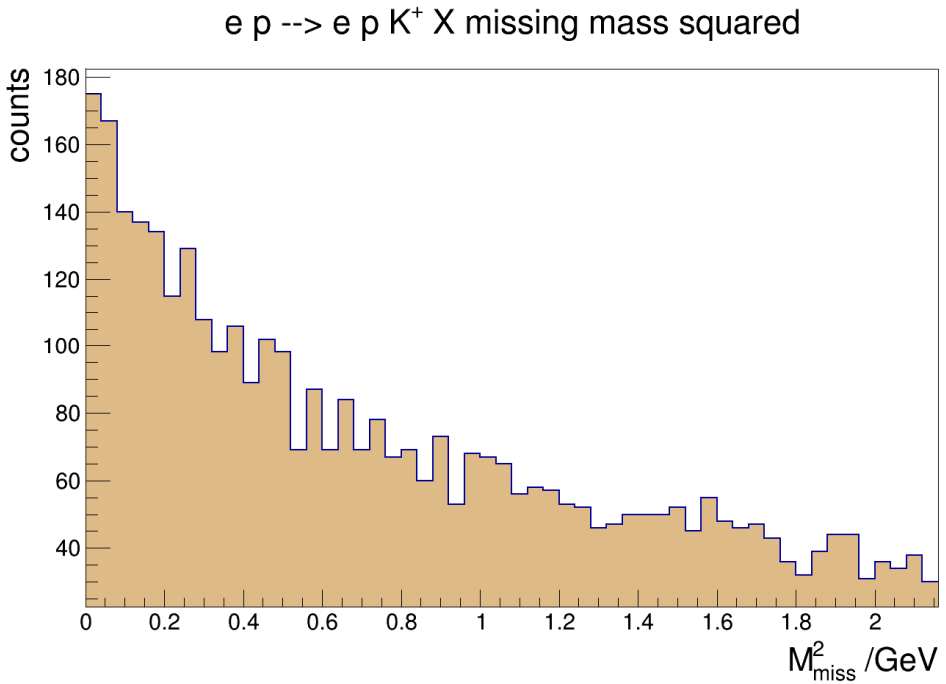
pion combined: brown all combined: black

e p → e‘ p‘ (π^0)

$$e\ p \rightarrow e'\ K^+\Lambda(1520) \rightarrow e'\ K^+ p'\ (K^-)$$

• Missing mass distributions at 10.6 GeV





→ Similar picture for e π^+ X (only small shoulder for missing neutron)

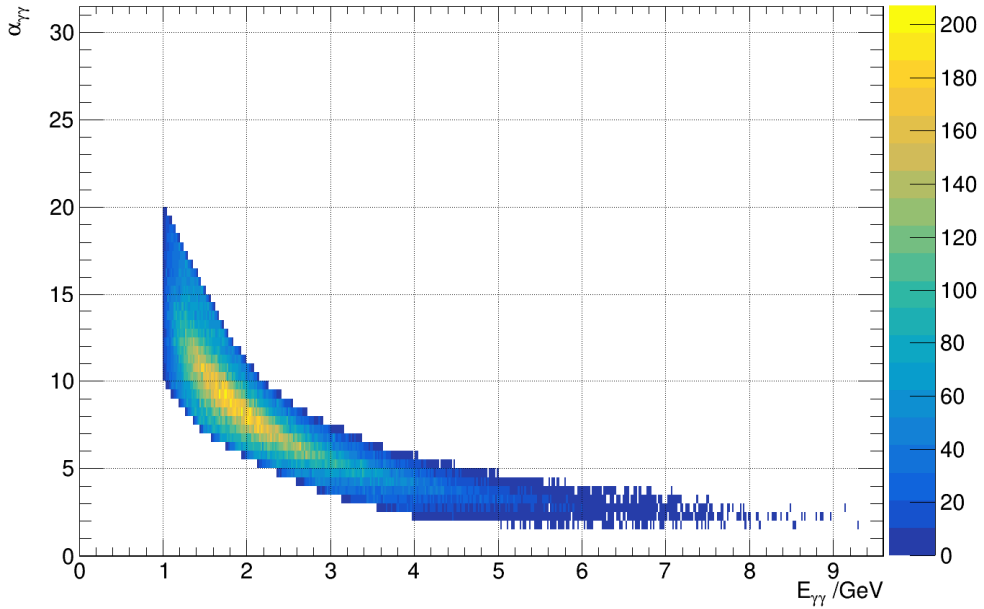
e p → e‘ p‘ π^0 - π^0 Selection

- Consider all combinations of up to 8 photons (highest energy)

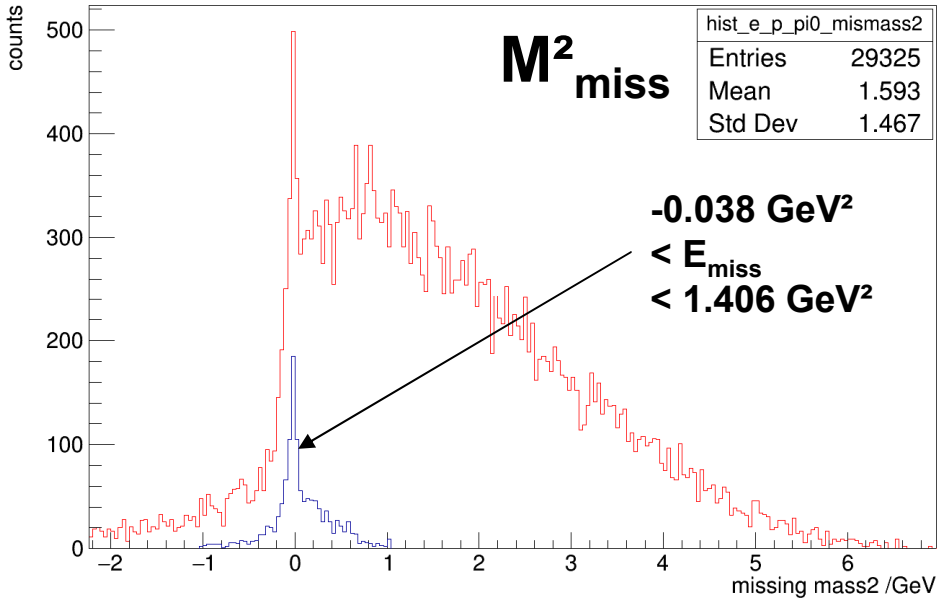
→ both photon > 500 MeV

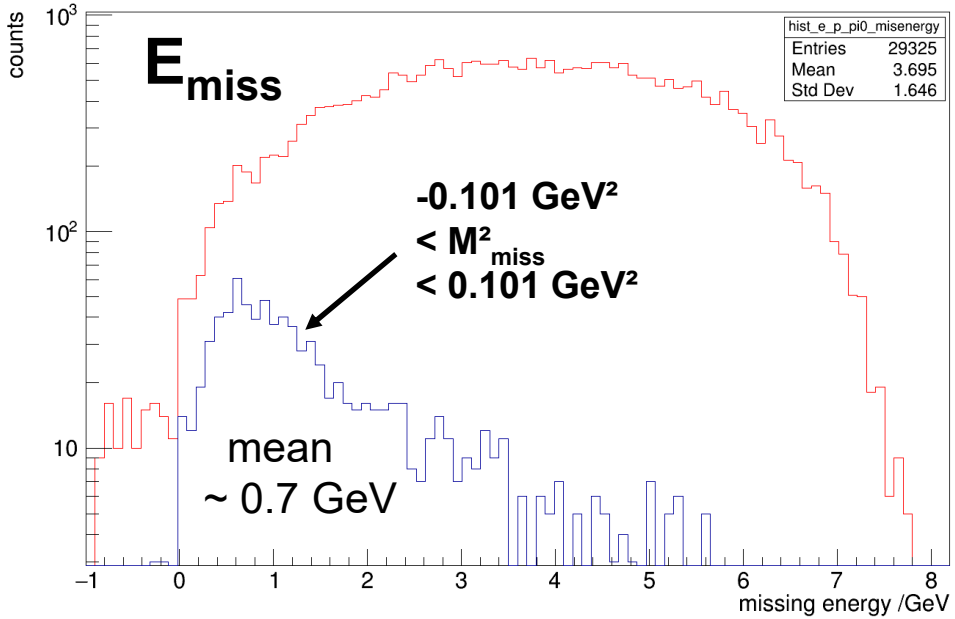
(lower thresholds down to 200 MeV have been tested)

cut on opening angle vs energy
of π^0 candidate



e p → e‘ p‘ π⁰ - exclusivity cuts



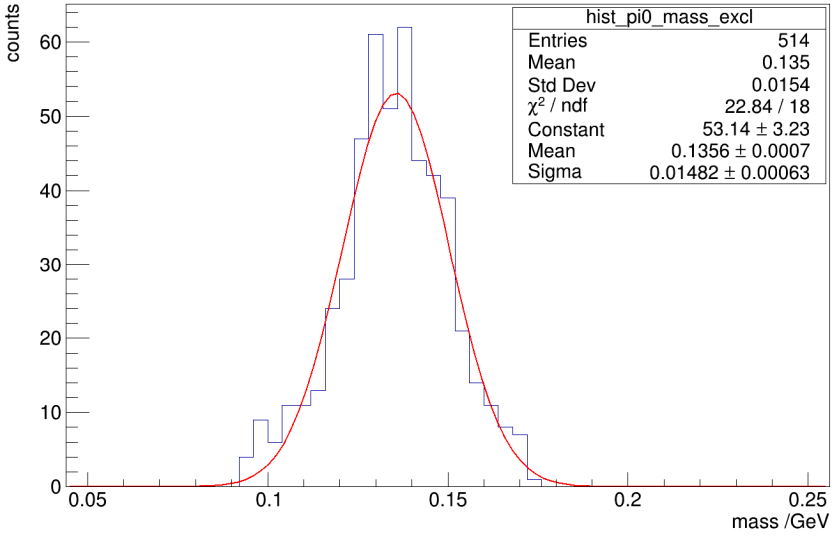


Resulting π⁰ peak after the exclusivity cuts:

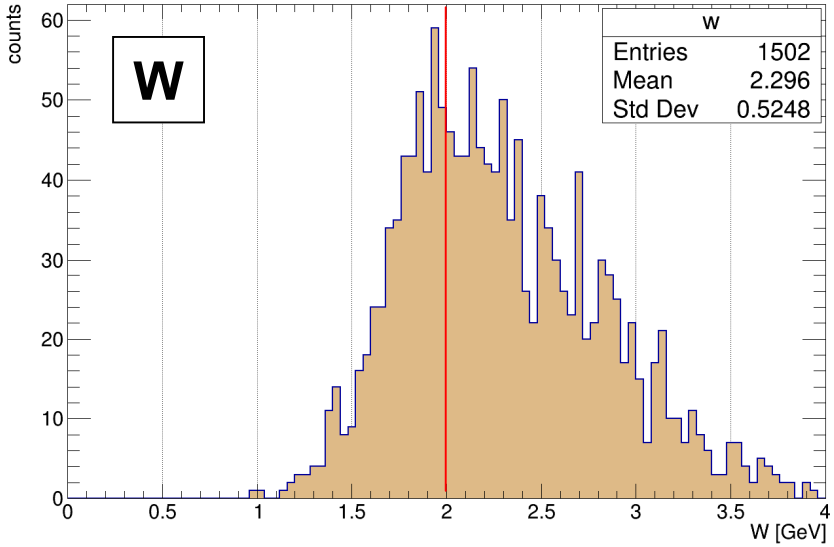
mean = 135.6 MeV

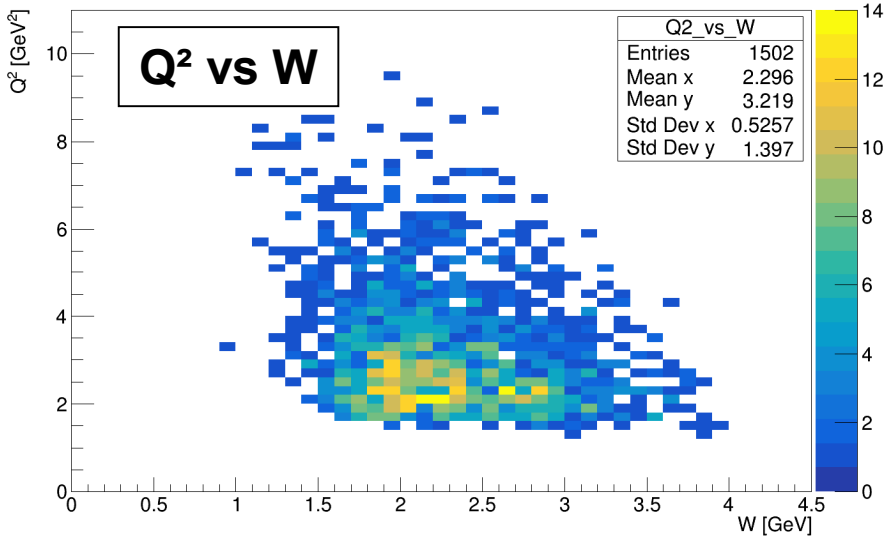
σ = 13.6 MeV

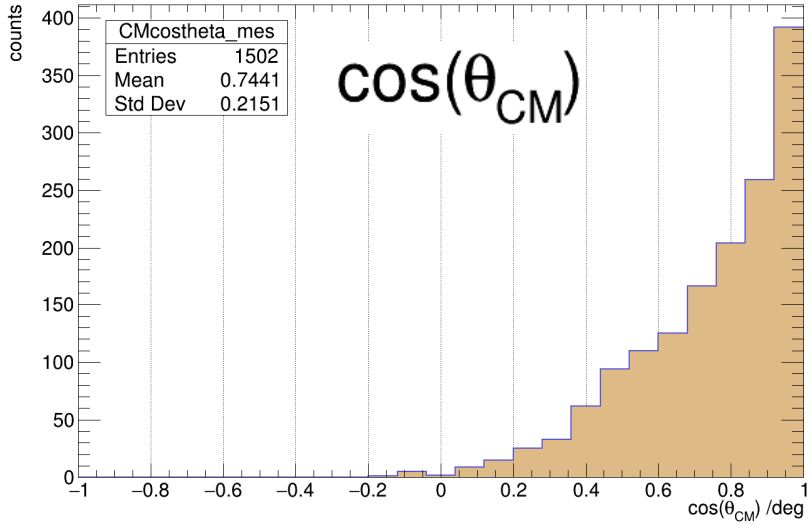
values for run 3432, shifted to ~ 124 MeV for run 4013 !

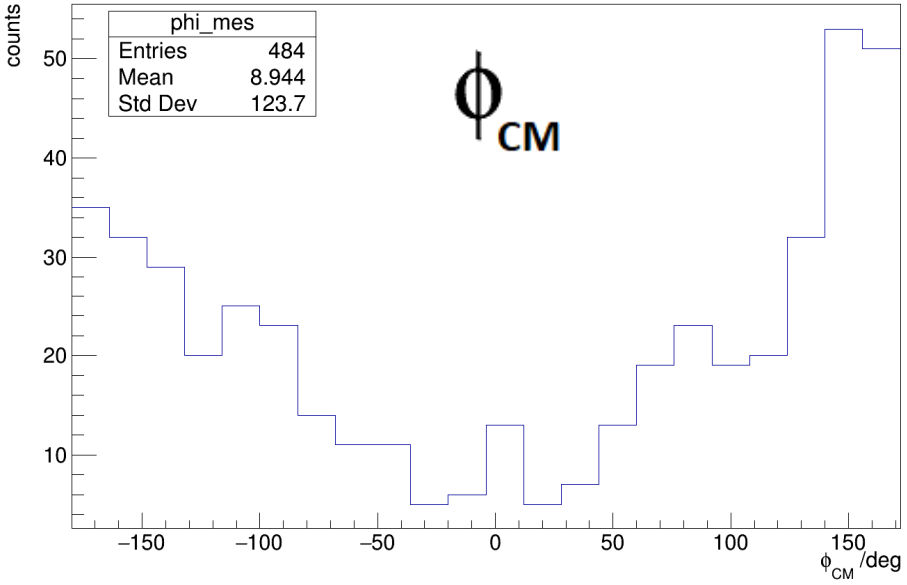


Kinematics

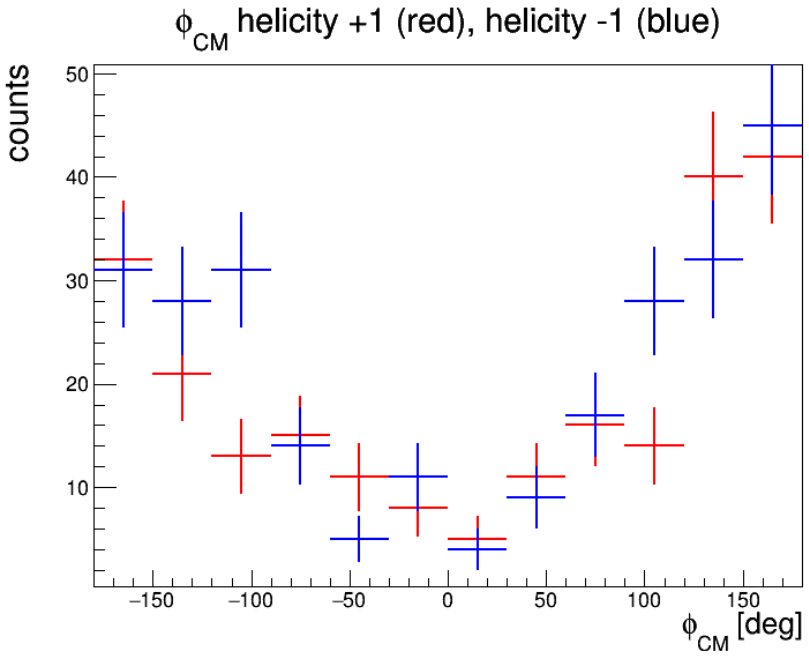

W
w
Entries 1502
Mean 2.296
Std Dev 0.5248
counts
W [GeV]

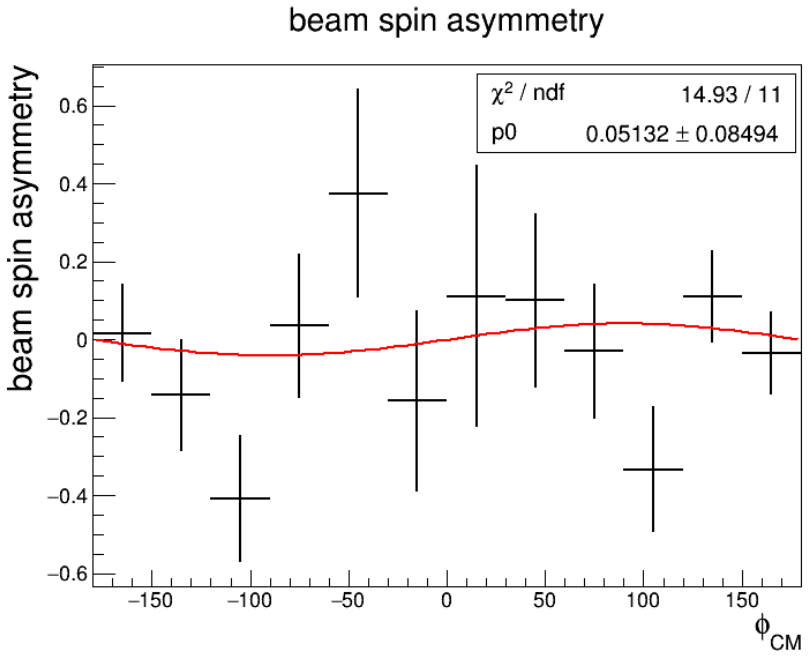

Q² vs W
Q2_vs_W
Entries 1502
Mean x 2.296
Mean y 3.219
Std Dev x 0.5257
Std Dev y 1.397
Q² [GeV²]
W [GeV]


CMcostheta_mes
Entries 1502
Mean 0.7441
Std Dev 0.2151
cos(θCM)
counts
cos(θCM) /deg


phi_mes
Entries 484
Mean 8.944
Std Dev 123.7
ϕCM
counts
ϕCM /deg

First Beam Spin Asymmetry Extraction and Statistics





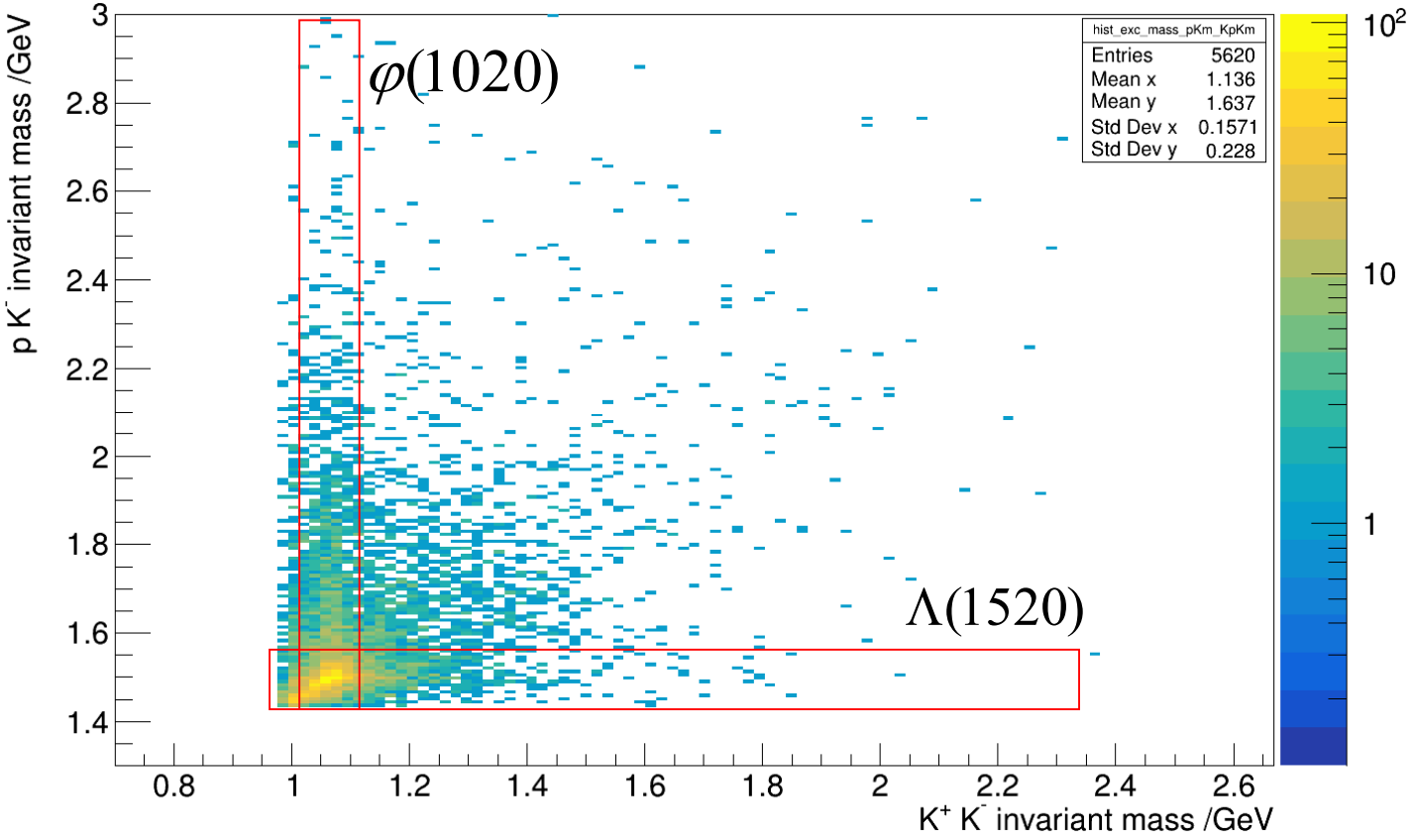
- Used dataset corresponds to 0.3 % of the spring run data
- 10 % of the spring run would provide 33.3 times more statistics
  → The detected 484 events will increase to ~ 16,000 events
  → 100 % of the spring run will provide ~ 160,000 events

$$e\ p \rightarrow e'\ p'\ \varphi(1020) \rightarrow e'\ p'\ K^+K^-$$
$$e\ p \rightarrow e'\ K^+\Lambda(1520) \rightarrow e'\ K^+\ p'\ K^-$$

- Select the inclusive channel with all 4 final state particle detected

Results without exclusivity cuts: $e\ p \rightarrow e'\ p'\ K^+K^-X$

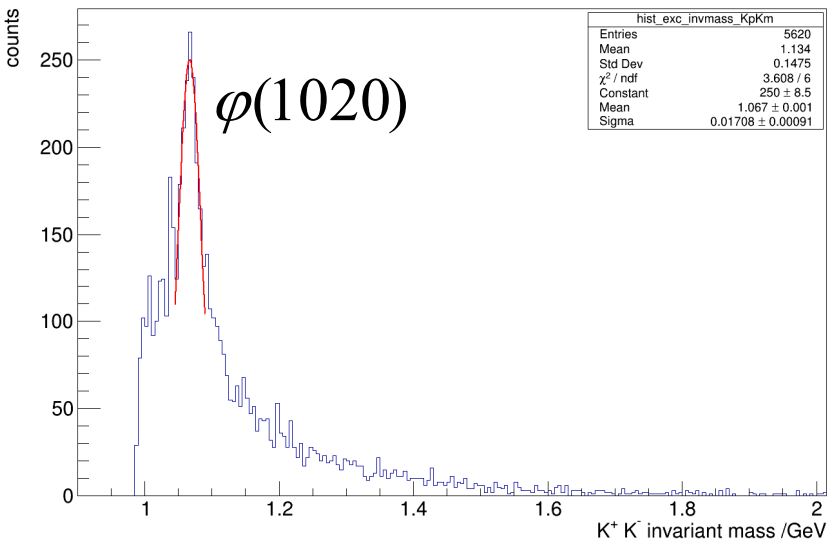
- Use weighted maximum lieklyhood particle in FD and eventbuilder for CD
- φ and Λ band clearly visible but strong pion contamination in CD



Invariant Masses

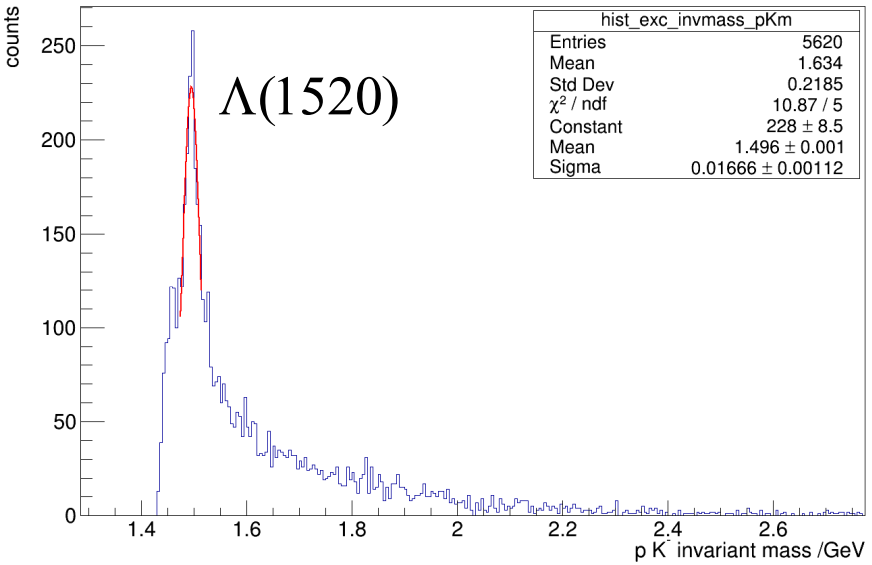
no exclusivity cuts

$K^+ K^-$ invariant mass



mean = 1067 MeV
sigma ~ 17 MeV

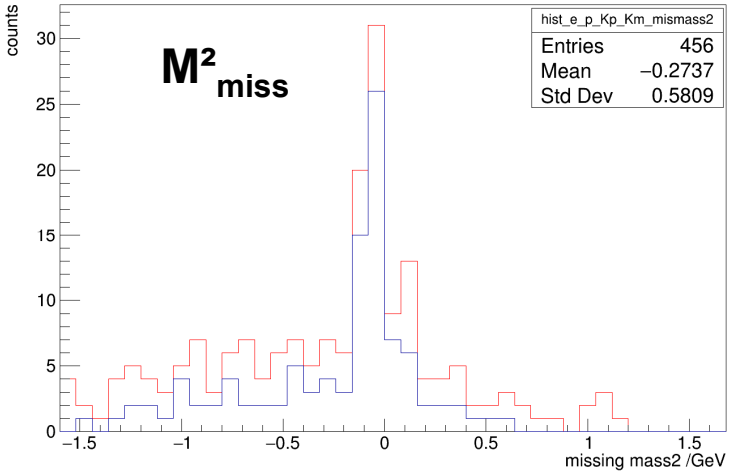
$p K^-$ invariant mass

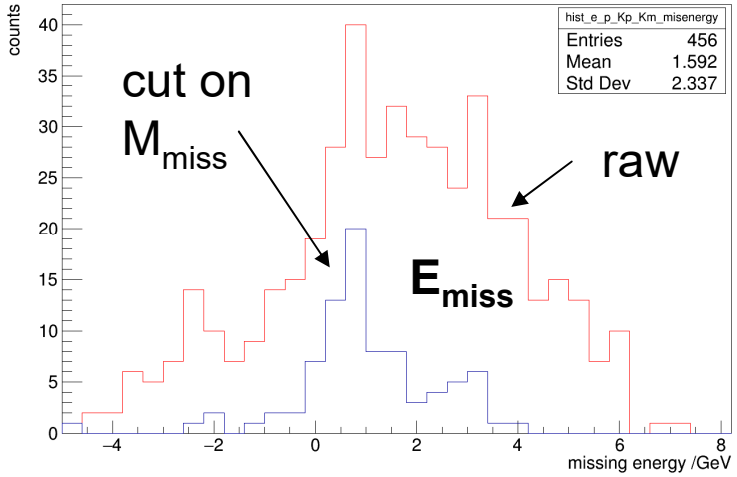


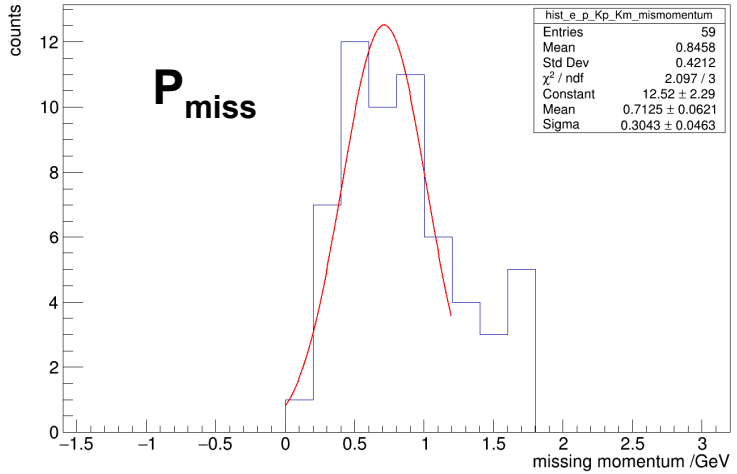
mean = 1496 MeV
sigma ~ 16.6 MeV

Missing mass, energy and momentum

- Apply weighted maximum likelyhood particle ID for FD and CD to obtain a clean particle sample and to minimize contamination

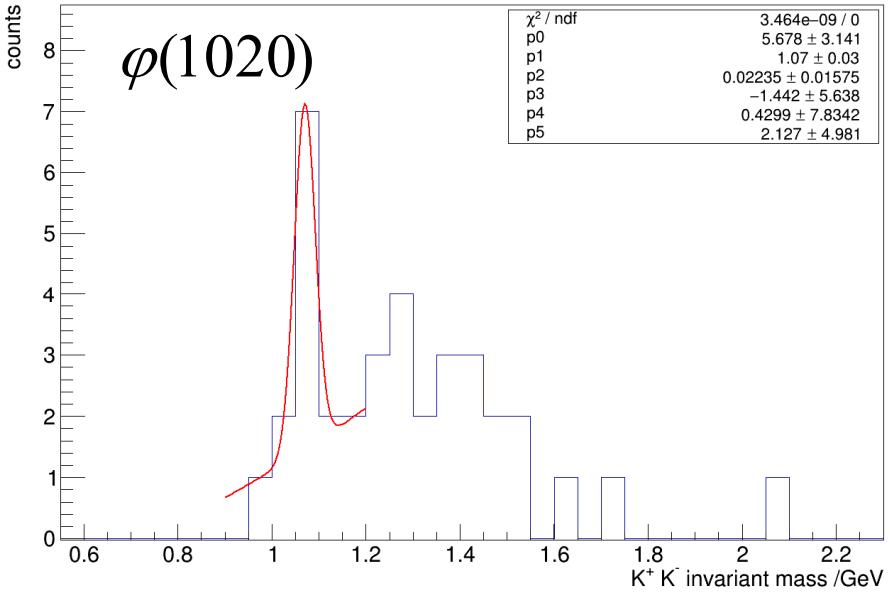


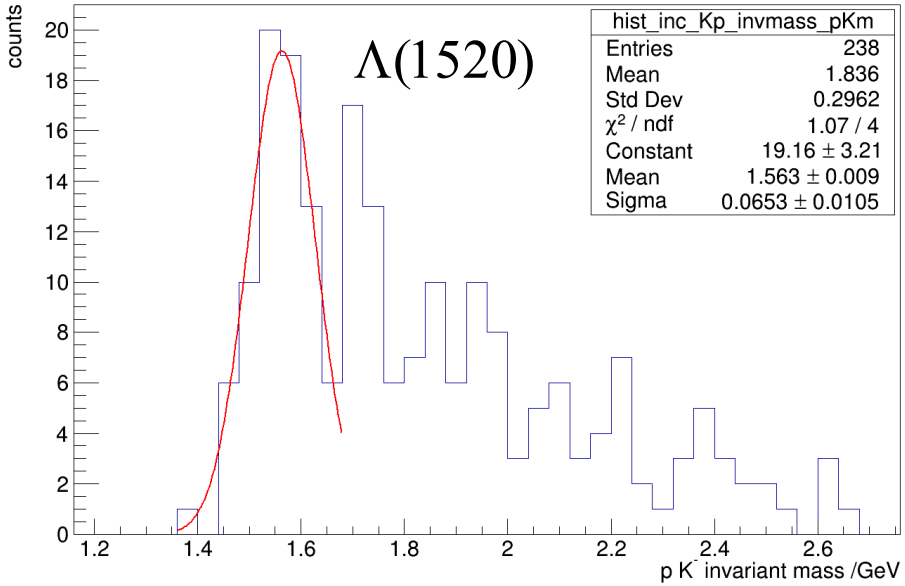




- Missing mass around 0, similar to e p π^0 reaction
- Missing energy ~ 0.7 GeV, similar to e p π^0 reaction
- Missing momentum at 0.7 GeV

Invariant mass





mean = 1070 MeV

mean = 1563 MeV

→ Statistics significantly reduced, but significantly cleaner signals

→ More statistics is needed

- Used dataset corresponds to 0.3 % of the spring run data
- 10 % of the spring run would provide 33.3 times more statistics

Summary and Outlook

- Fully exclusive channels can be already well identified with CLAS12
- For e p π^0 the resonance region can be clearly identified in the W spectrum
  - Missing energy problem seems to improve for the new coatjava version and run 4013

Goal for DNP:

- Determine BSA for the resonance region for e p π^0

→ 10 % of the spring run data should enable some first kinematic binning

- Extract clean φ(1020) and Λ(1520) signals and determine some first integrated BSA