Hadronization dynamics of Λ^0 baryon: Analysis progress

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July 27, 2015

Outline

- Motivation
- Previous measurements
- Analysis progress update
- Summary

Motivation

We know QCD is established and works in perturbative/partonic processes.

pQCD mechanisms dominate at
high energies and small distances

What energy is high enough for
pQCD to be unambiguously applicable?

How do we address this problem @ JLab

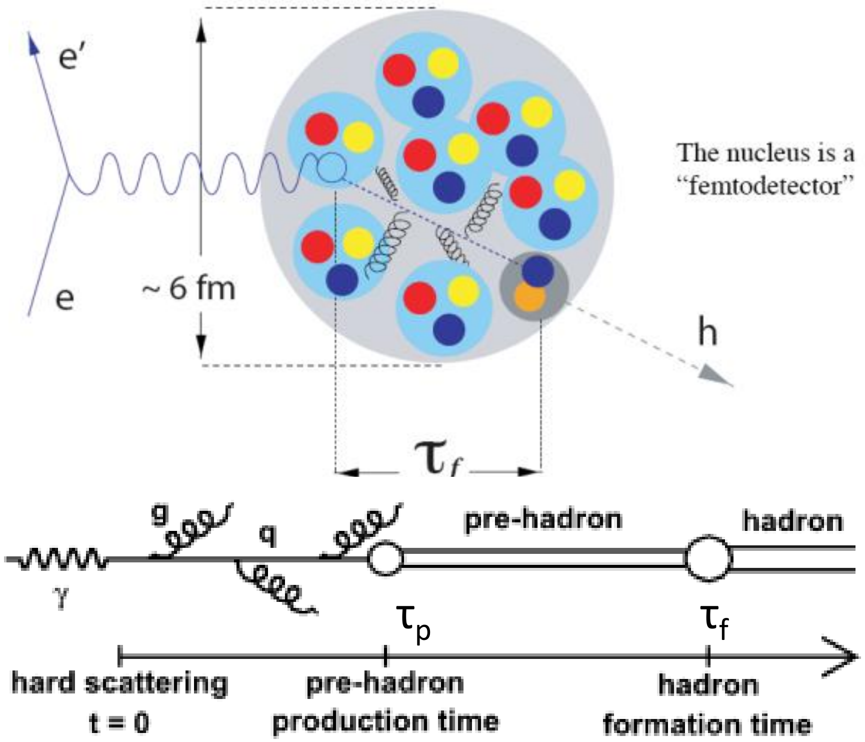
- Study space-time properties of parton propagation and fragmentation in QCD
- Look for signatures of QCD such as Color Transparency & Nuclear Filtering
- Study properties of quarks in-medium (e.g. unpacking the “EMC effect”).
- Study quark distributions at x>1 (super-fast quarks).

An understanding of the timescales and mechanisms of quark propagation and hadron formation is an integral part of this entire program and helps us understand both the partonic and hadronic processes.

Hadronization in DIS

Nuclei can be used as unique detectors at tiny distances (within the range of hadronization process) and allowing us to do direct measurements in search of answers to the following questions.

- What's the nature of the interaction of the struck quark before it neutralizes its color?
- What is the lifetime (τ_p) of the energetic free quark?
- How long (τ_f) does it take to form the color field of a hadron?
- What dynamics/mechanism leads to the color confinement?

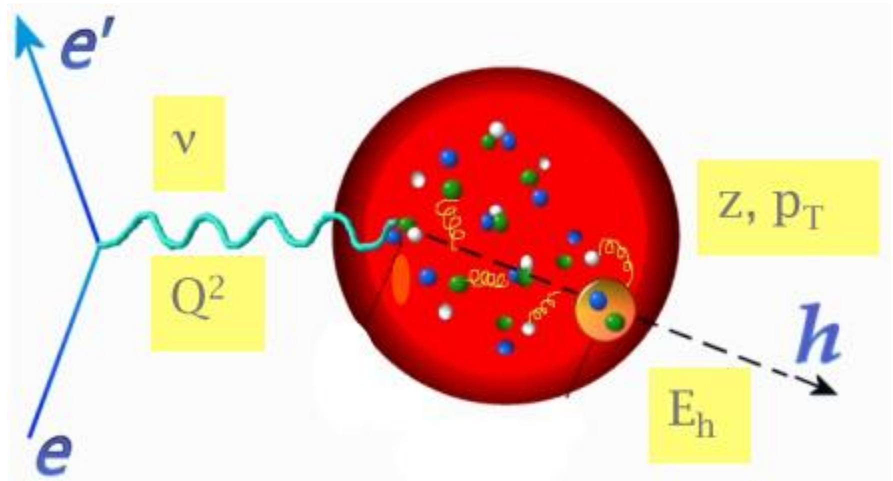


Experimental Variables

ν – electron energy loss,
= initial energy of struck quark (> 2 GeV here).

Q^2 – square of the four momentum transferred by the electron

W – invariant mass of the final state



$Z_h = E_{hadron} / \nu$, the fraction of the struck quark's initial energy carried by the hadron ($0<z_h<1$)

p_T – hadron momentum transverse to virtual photon (i.e., the struck quark).

Obervables (1)

Hadronic multiplicity ratio

$$R_M^h(z,\nu,p_T^2,Q^2,\phi) = \frac{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_A}{\left\{\frac{N_h^{DIS}(z,\nu,p_T^2,Q^2,\phi)}{N_e^{DIS}(\nu,Q^2)}\right\}_D}$$

⟺

R^h_M + $\tau_p(\nu,z,Q^2)$ allow access to $\tau_f\,(\nu,z,Q^2,p_T)$

Connects to hadronic phase

- hadron formation times and mechanisms
- in-medium cross sections

Obervables (2)

Transverse momentum broadening

$$\Delta P_T^2 = \langle P_T^2 \rangle_A - \langle P_T^2 \rangle_D$$

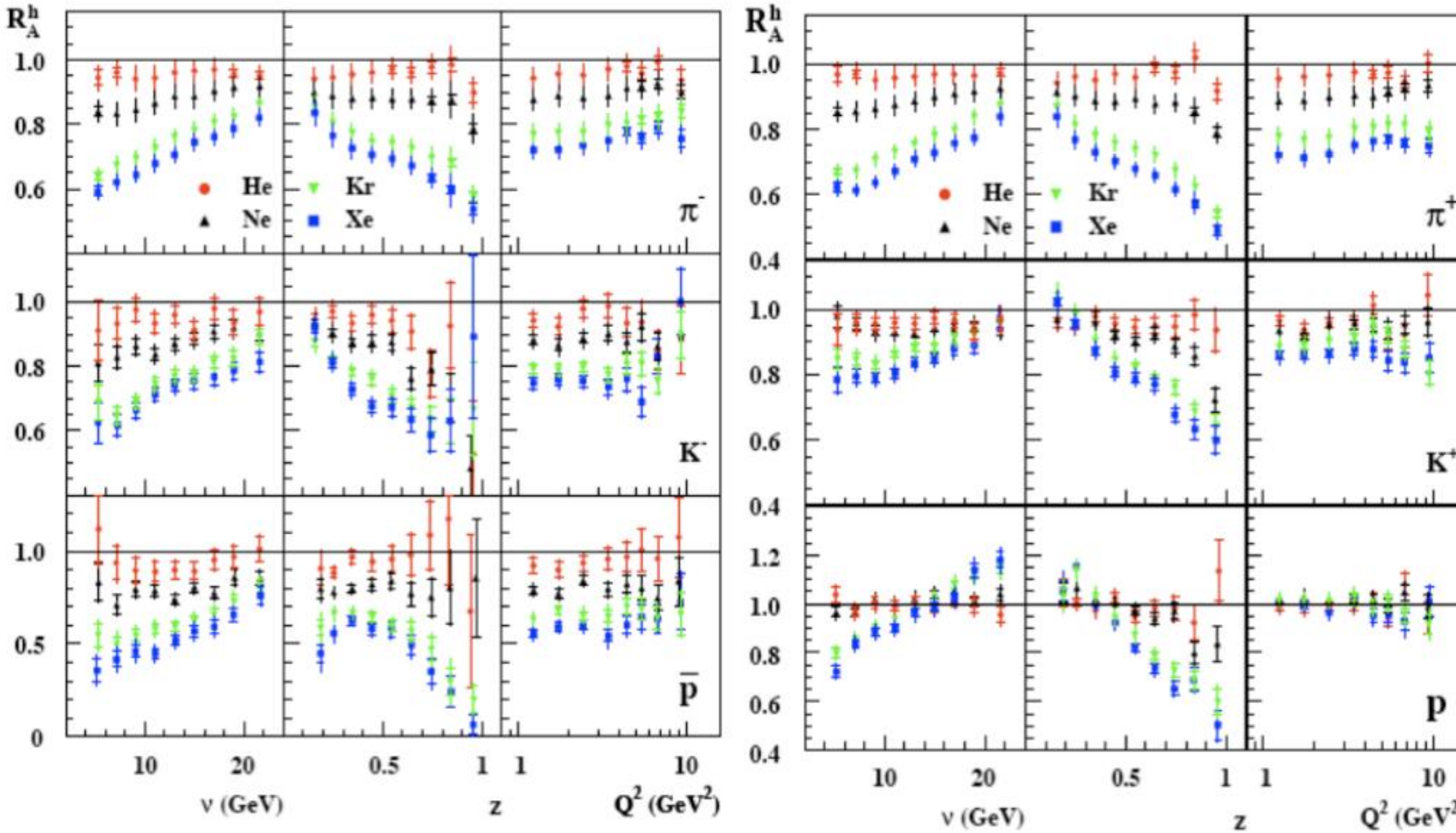
↔

Access $\tau_p(\nu,z,Q^2)$ via mesons (π,K) channels
+
New baryon (Λ^0) channel

Connects to partonic phase

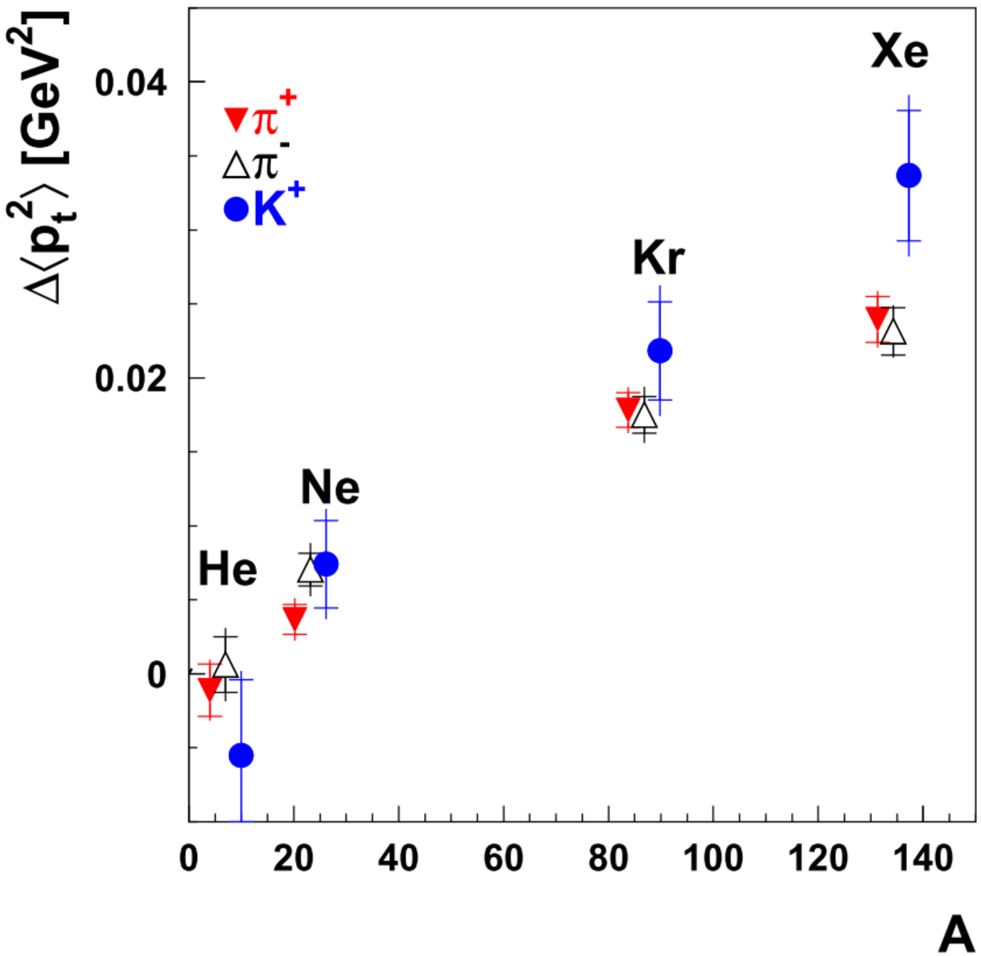
- in-medium partonic multiple scattering
- medium stimulated gluon emission
- quark energy loss

Existing HERMES data



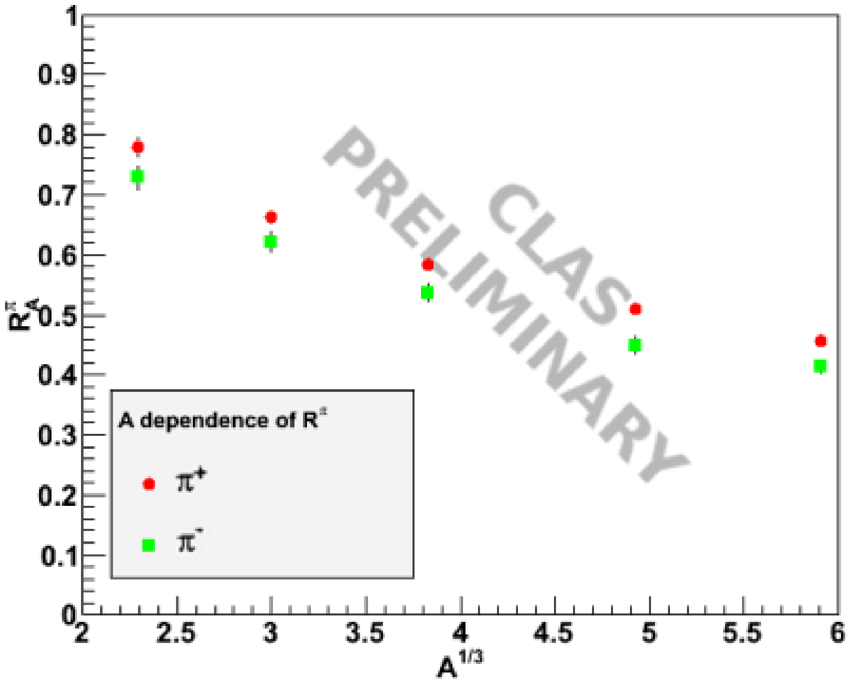
Each 1-D plot is intergrated over all other variables

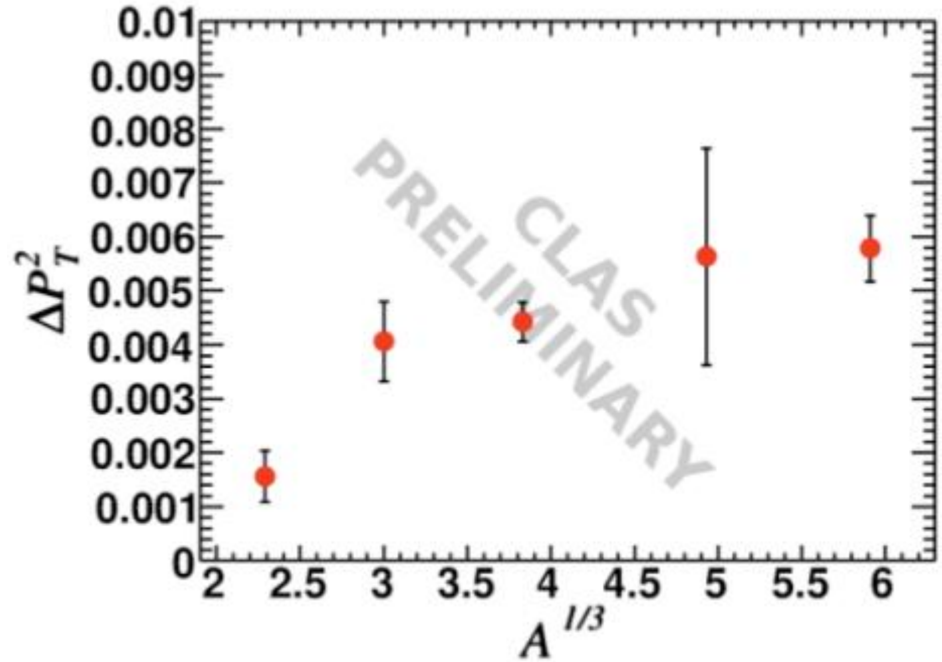
HERMES Data on p_t-broadening



- Large p_t-broadening of Kaons compared to pions
- No data on baryon channels.

CLAS Preliminary results

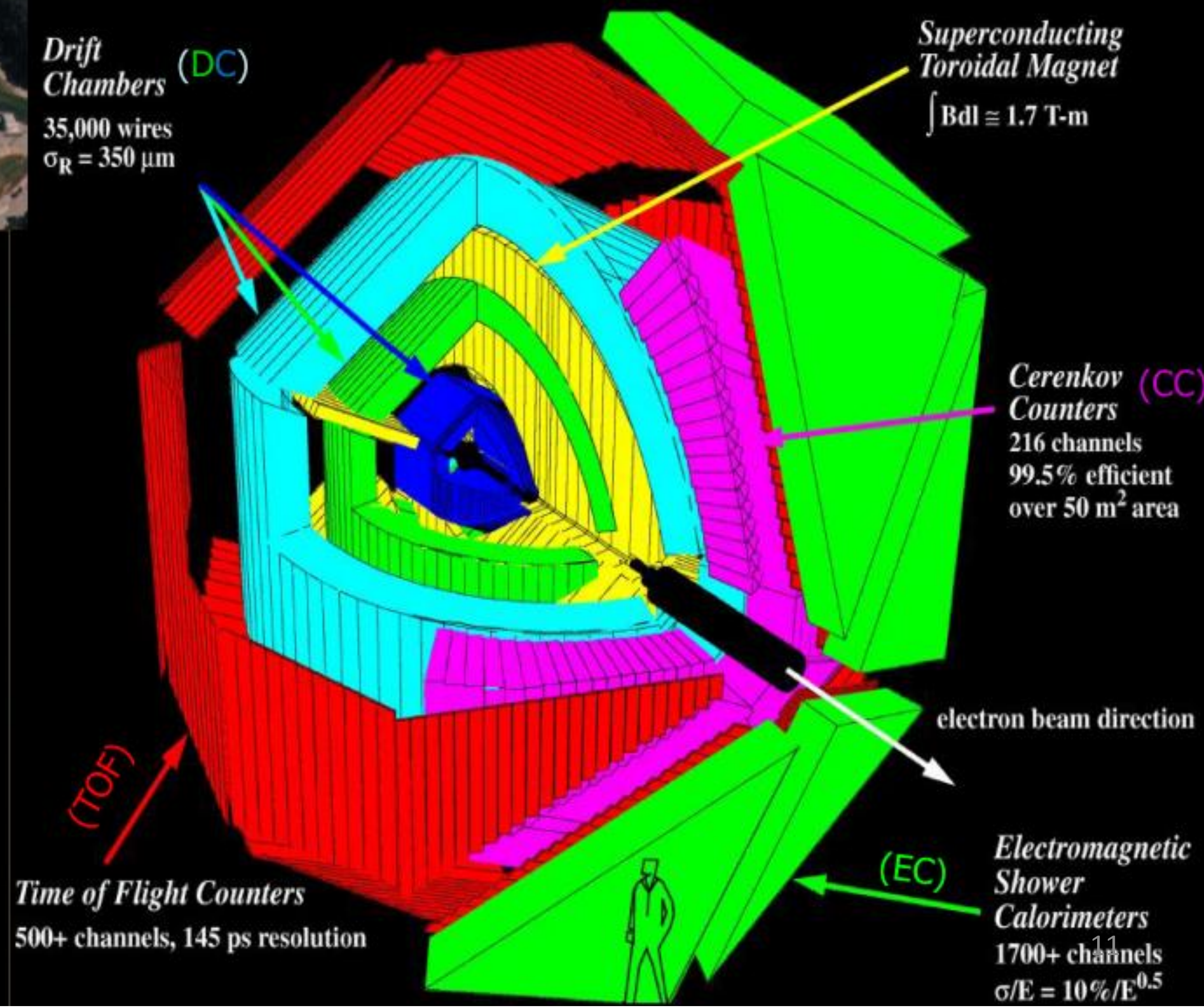




Experimental Setup of E02-104 & E02-110 @ E= 5 GeV

CEBAF: Continous Electron Beam Accelerator Facility

CLAS: CEBAF Large Angle Spectrometer



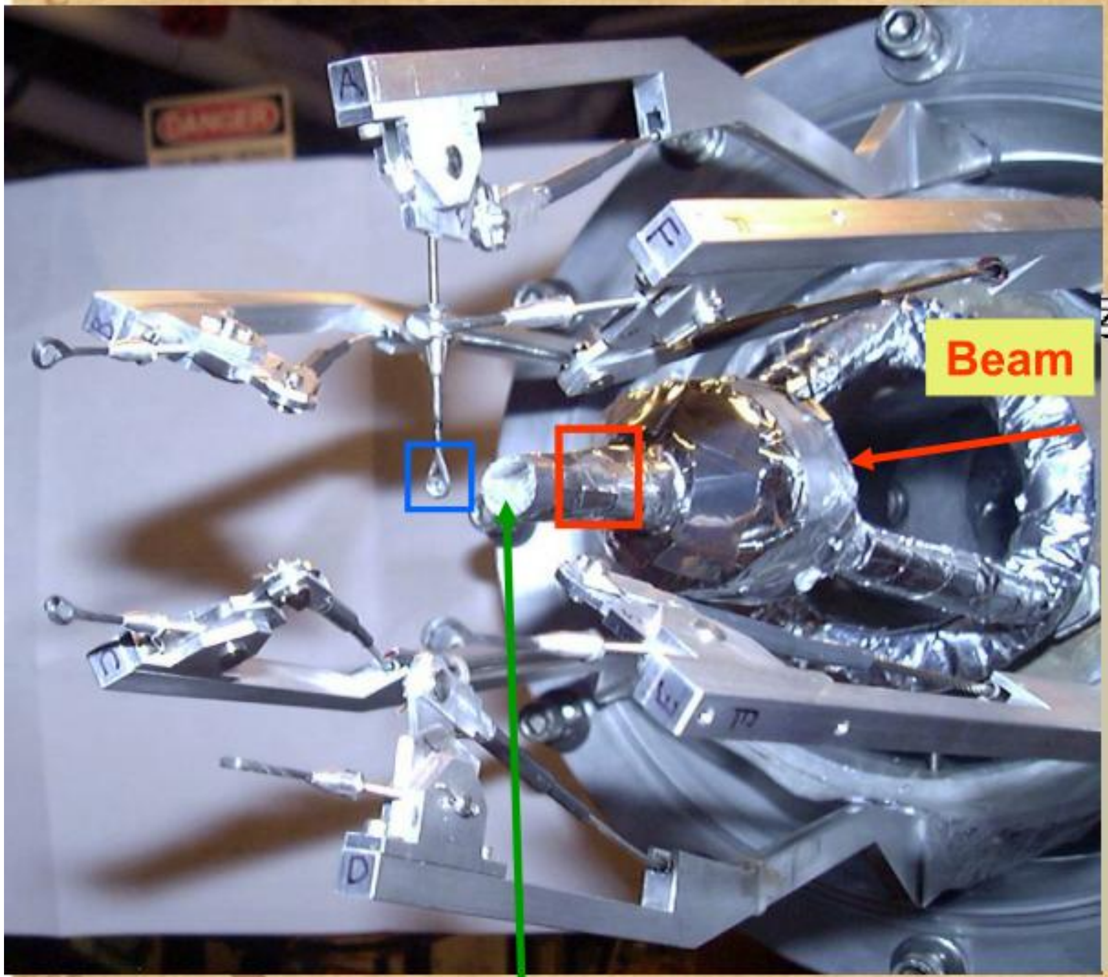
CLAS characterestics

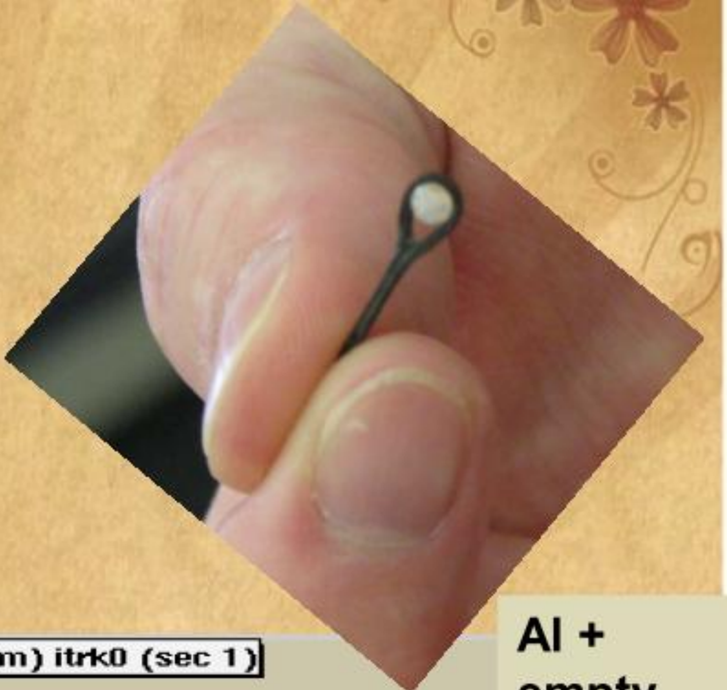
- Charged particle angles 8° - 144°
- Neutral particle angles 8° - 70°
- Momentum resolution ~0.5% (charged)
- Angular resolution ~0.5 mr (charged)
- Identification of p, π^+/π^-, K^+/K^-, e^-/e^+

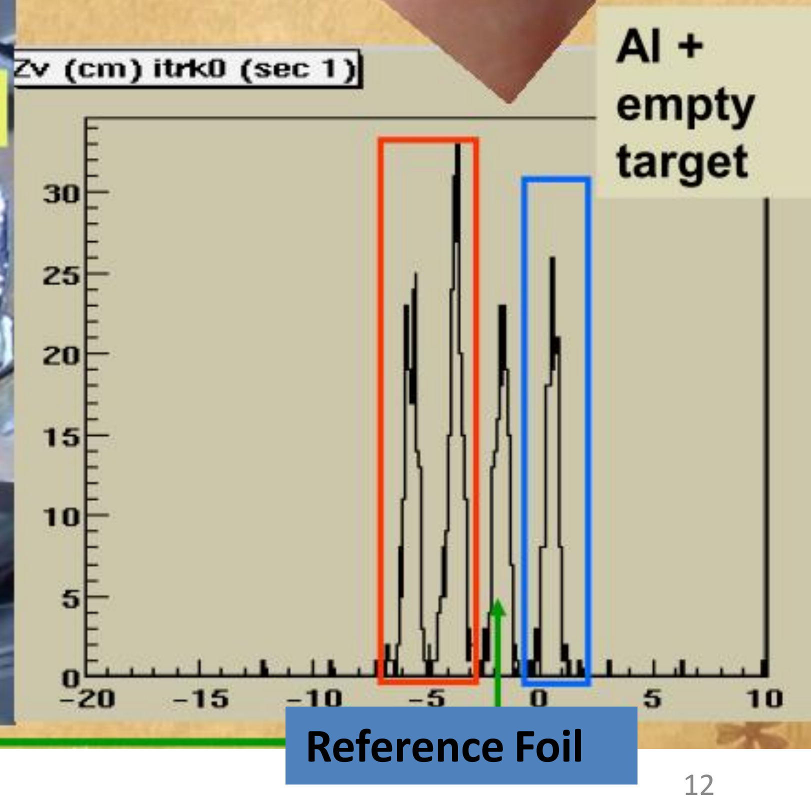
Experimental Setup: Targets

^{2}H + (Fe, C, Al, Sn, Pb)

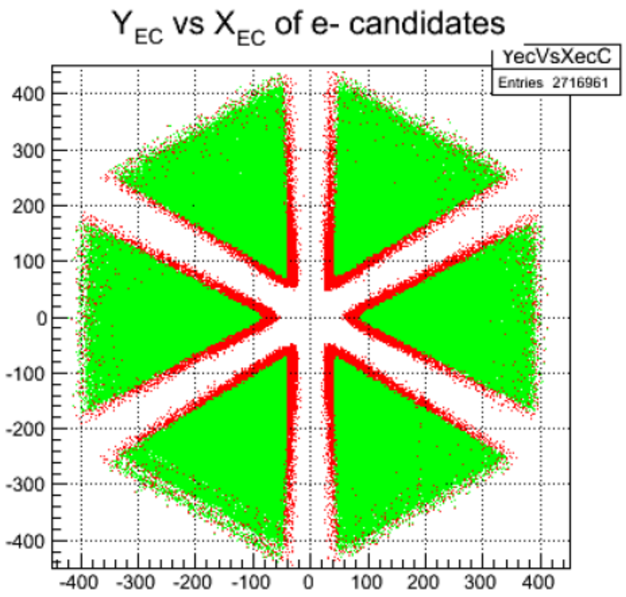
Collect roughly 6 billion triggers in 50 days



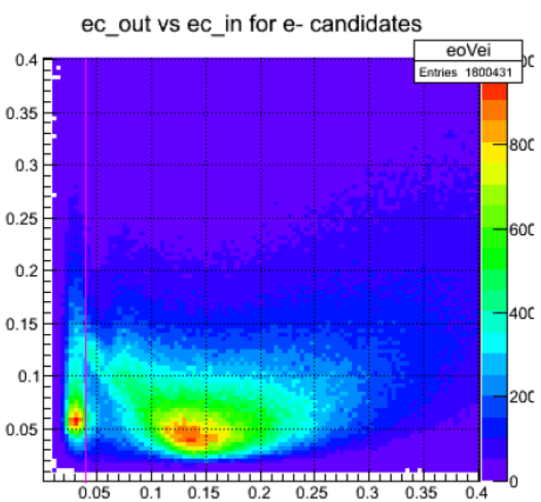


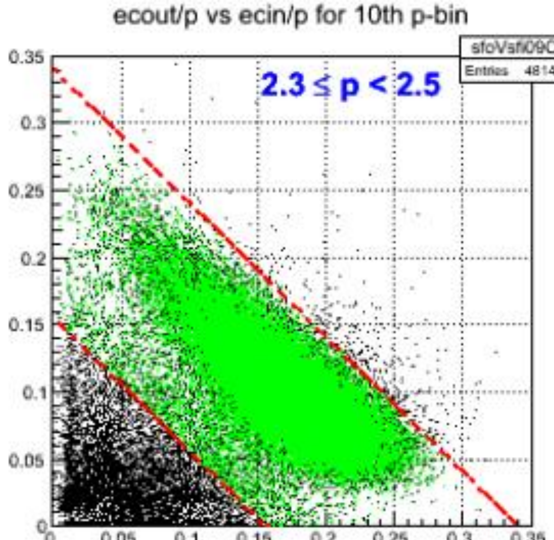


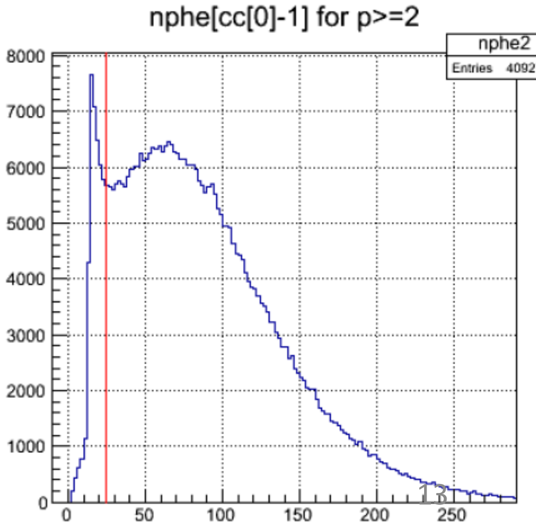
Particle IDs and Event Selection



- Combine DC + CC + TOF + EC time and energy information to identify the scattered electron.

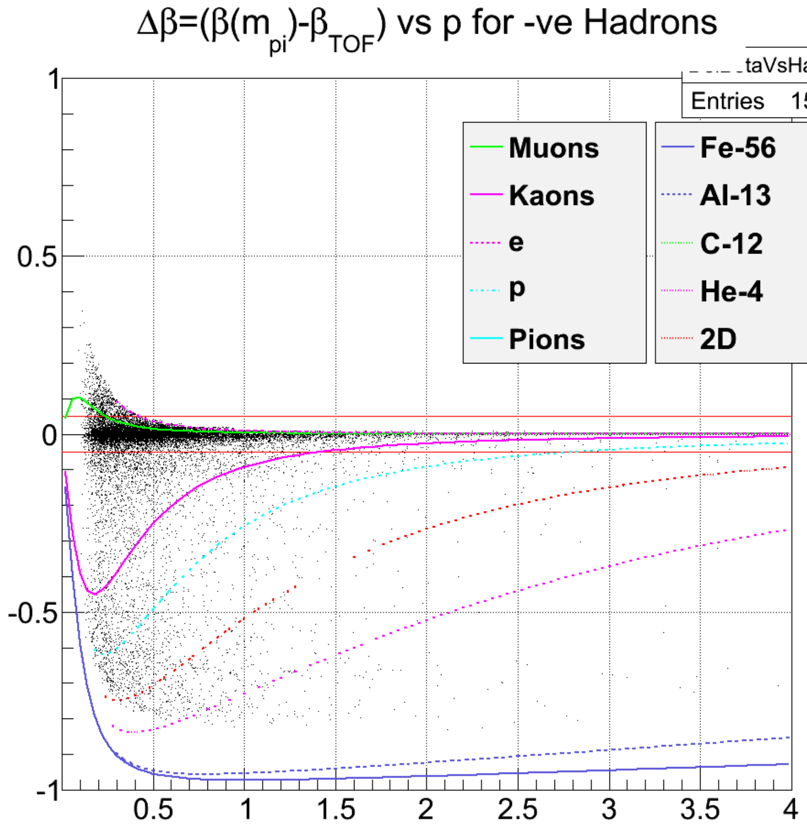


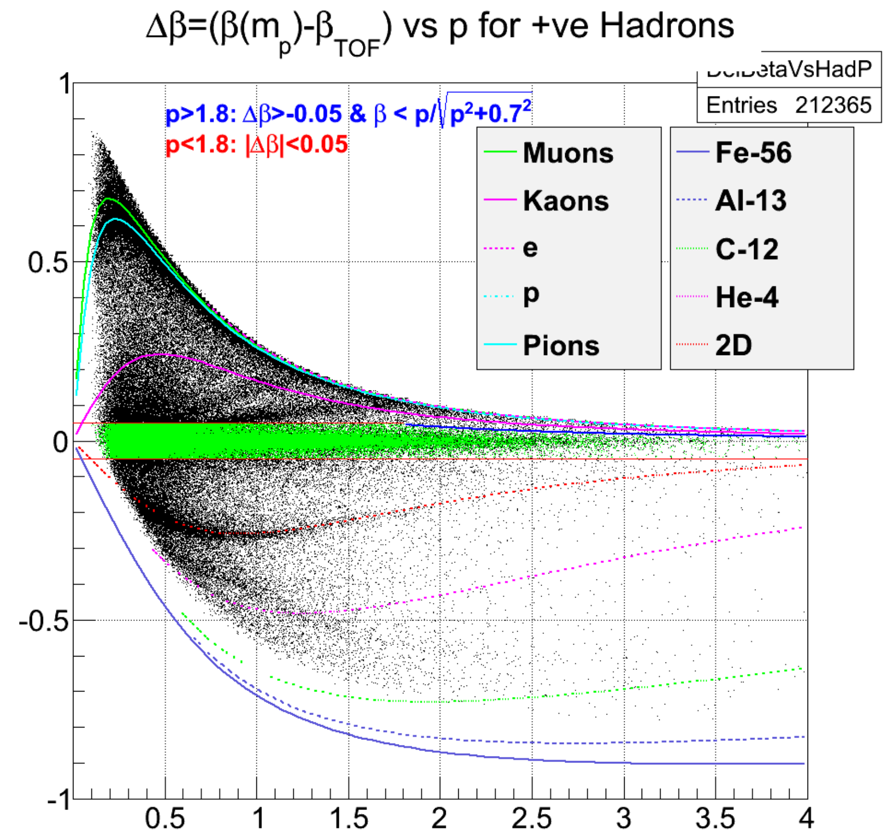




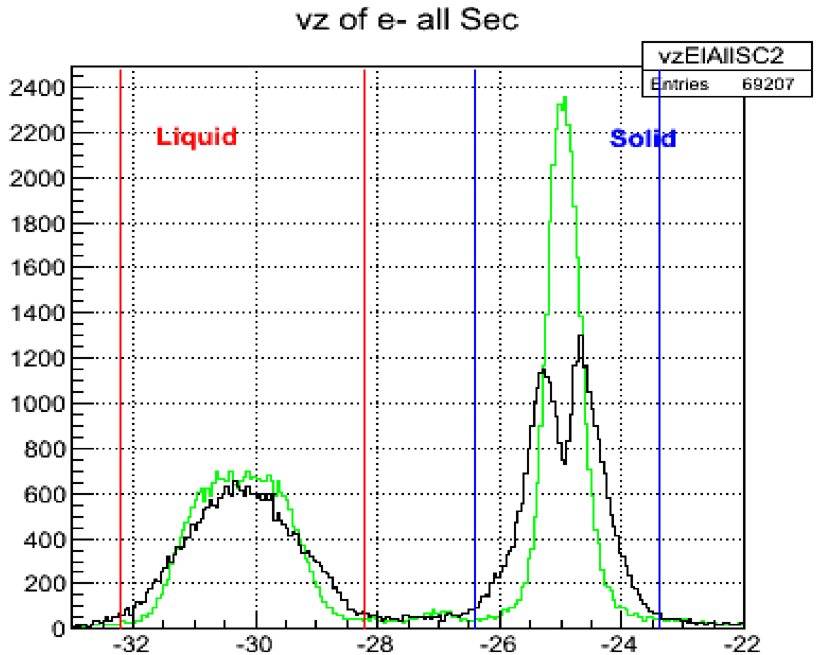
Particle IDs of Λ^0 decay products (^1H, π^-)

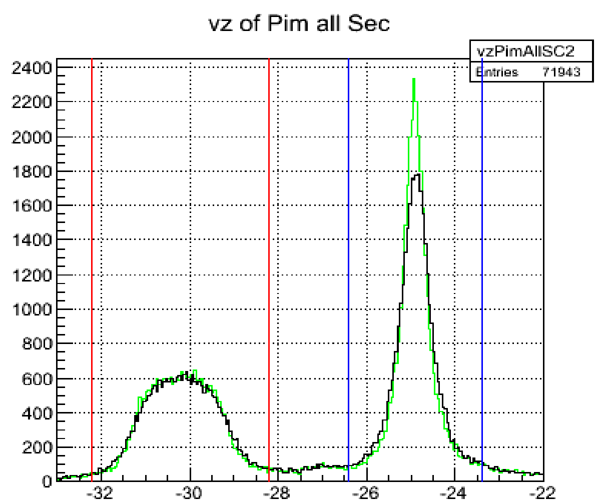
Δβ cuts to select the pions and protons



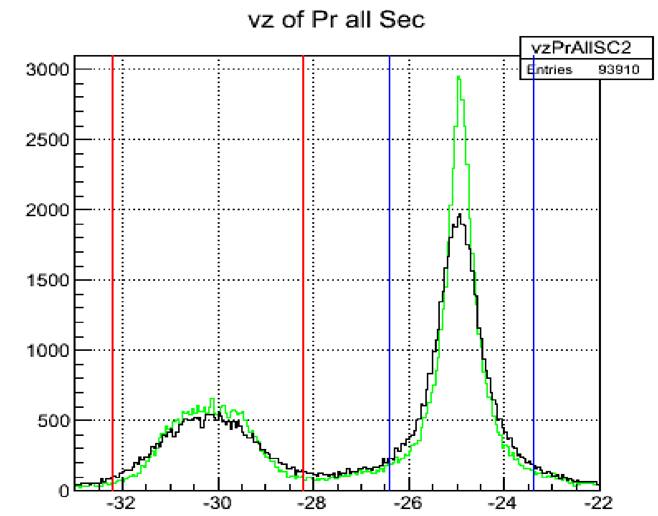


Particle IDs: Vertex cuts



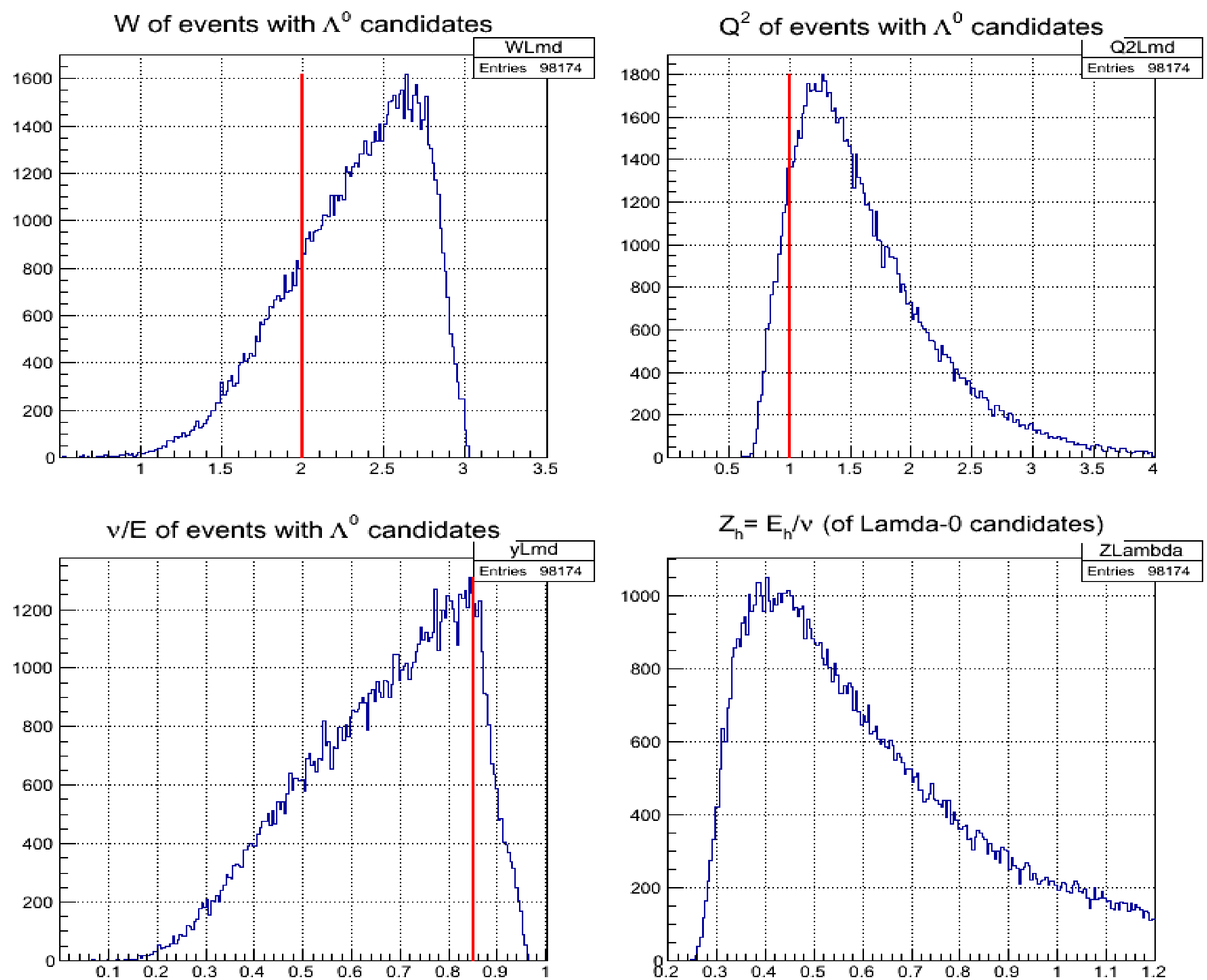


Apply vertex cuts to differentiate between the two targets.

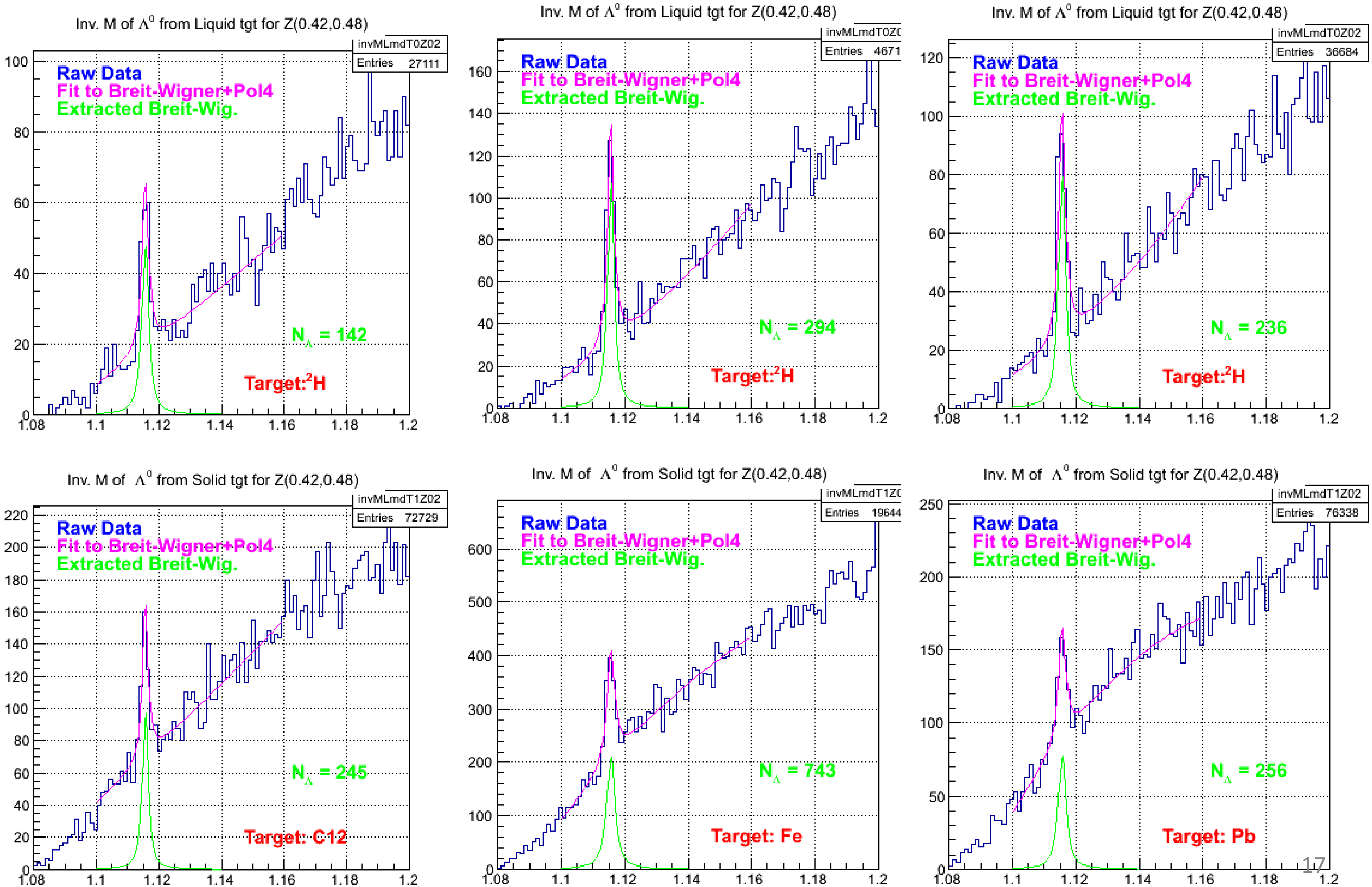


Kinematic variables & Cuts

- Apply kinematical cuts to select DIS region:
  - $Q^2 > 1$ GeV^2
  - $W > 2$ GeV
  - $y = \nu/E < 0.85$

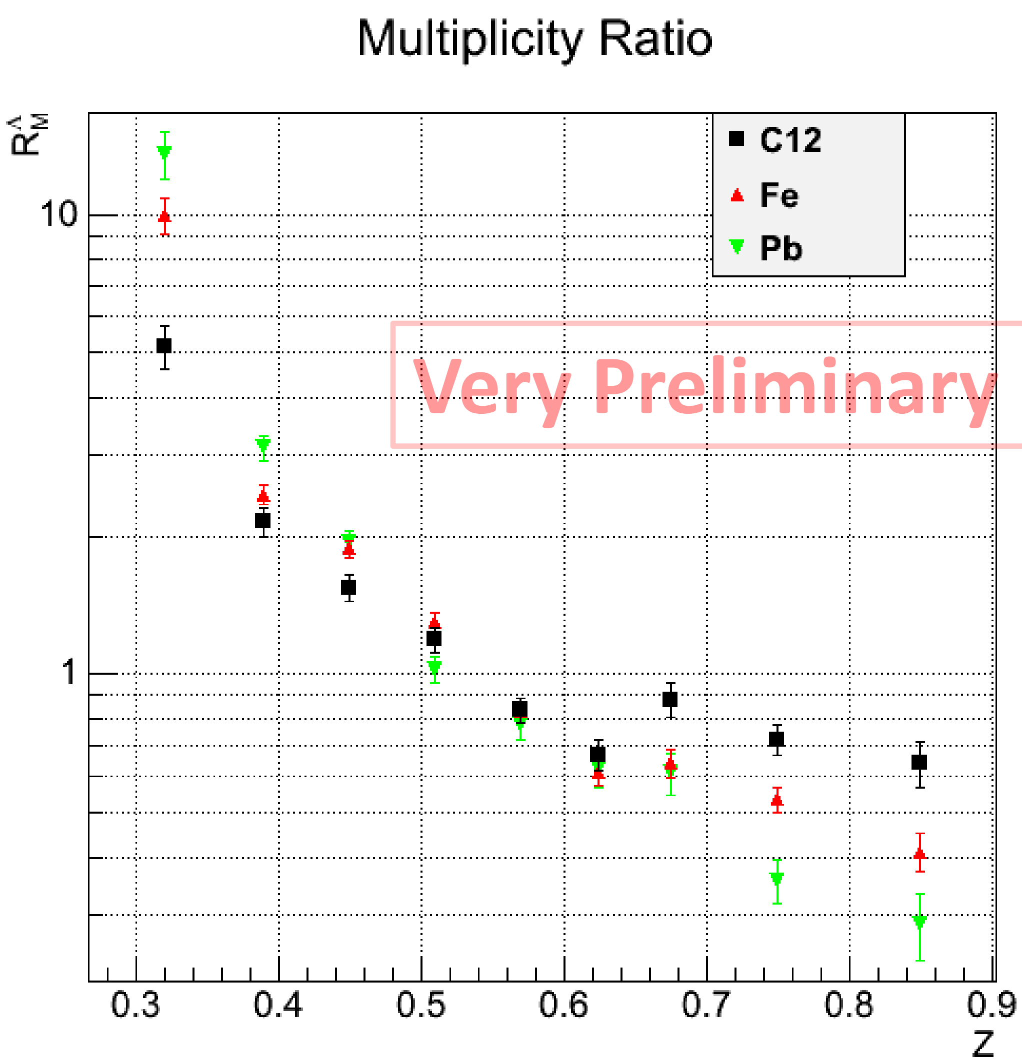


Extraction of Λ^0 (Background subtraction)



Multiplicity Ratio Measurement

- Results not corrected for acceptance and radiative effects and includes only statistical errors
- Unexpected and surprising results !!!
  - Due to acceptance and/or radiative or background effects?
  - Strong final state interaction? Modification of hadron structure and/or its formation in the nuclei?

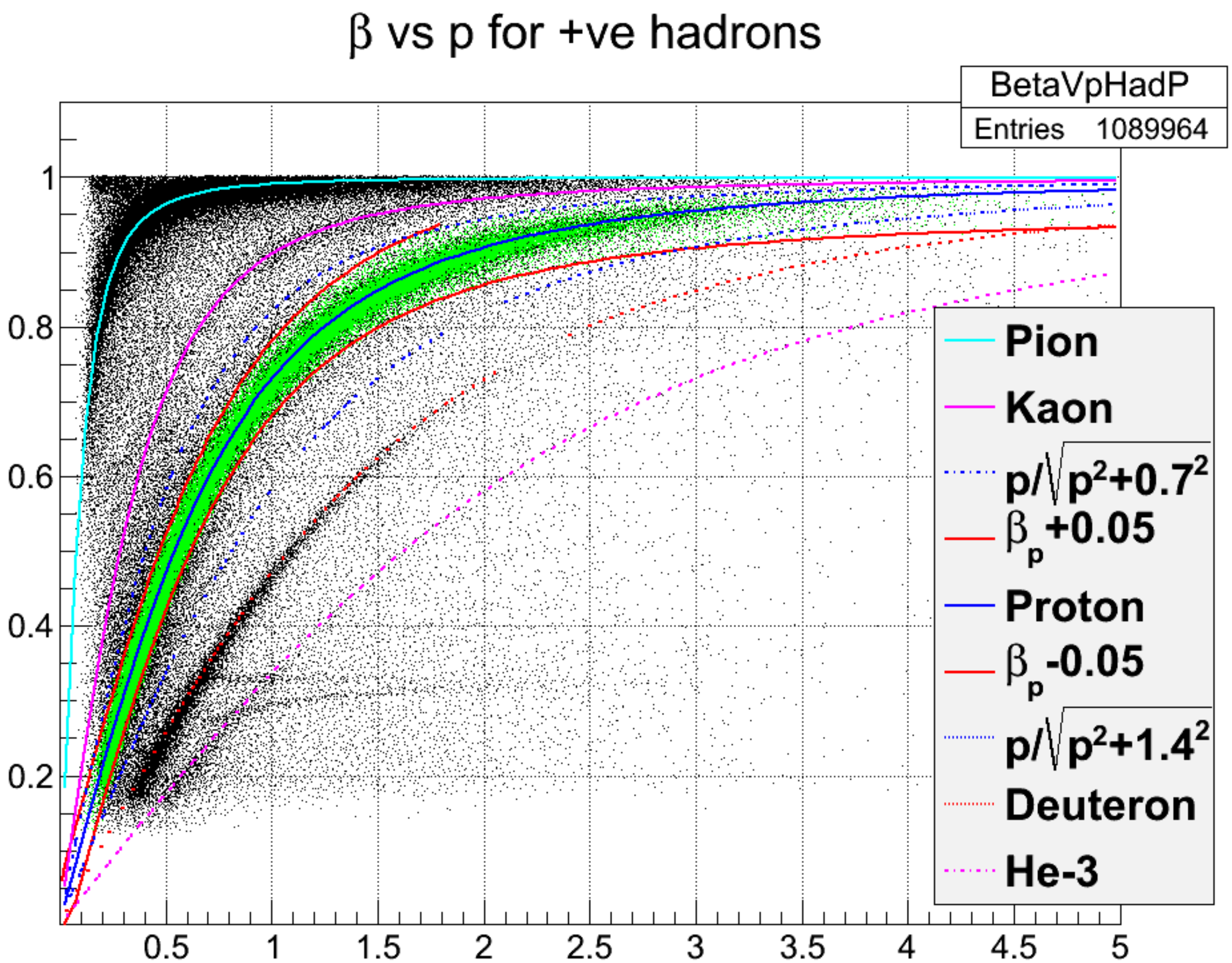


Summary & Future Work

- This new study will contribute to more detailed understanding of parton propagation and the timescales and mechanisms of hadron formation.
  - Hadron attenuation
  - Hadron production (τ_p) and formation times (τ_f).
- In the very preliminary stage of analysis. A lot remains to do.
  - Refining particle ID cuts (vertex, fiducial ..)
  - Background substraction
  - CLAS acceptance of all three final state particles
  - Radiative & Isospin effects.
  - Understand other systematic effects and uncertainties of the baryon production channel
- 12 GeV measurements at JLab will further improve our undestanding.

Thank you!!!

Particle IDs of Λ^0 decay products (^1H, π^-)

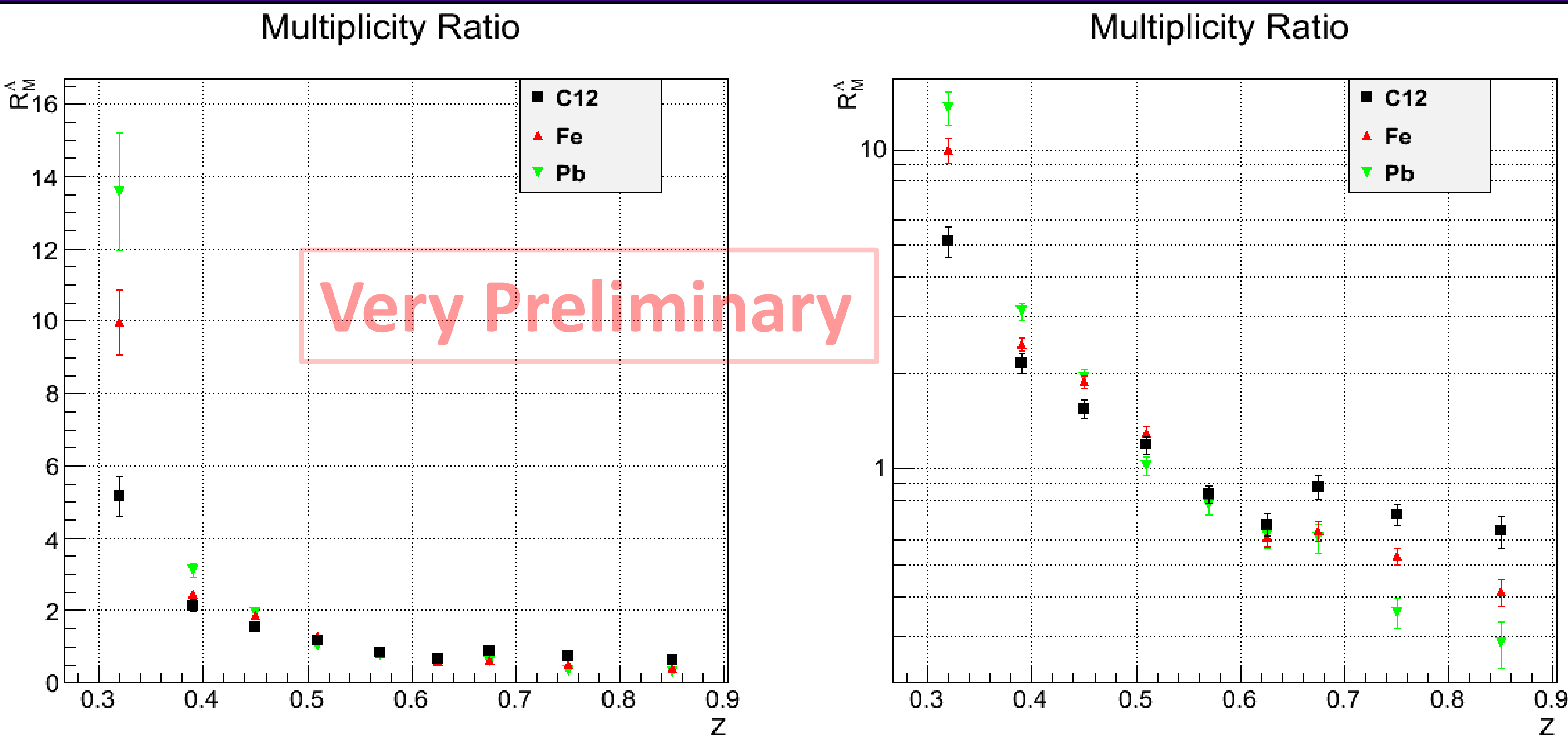


Statistical Error Calculation

$$\frac{\delta\left(R_A^h\right)}{R_A^h} = \sqrt{1/N_A^h + 1/N_A^e + 1/N_D^h + 1/N_D^e}$$

$$\left(\delta\left(\Delta\langle P_\perp^2\rangle\right)\right)^2 = \left(\langle P_\perp^4\rangle - \langle P_\perp^2\rangle^2\right)_A / N_A^h + \left(\langle P_\perp^4\rangle - \langle P_\perp^2\rangle^2\right)_D / N_D^h$$

Multiplicity Ratio Measurement



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p_T-broadening measurement

- Less broadening in Pb than in Fe?. Interesting and unexpected !!!
  – Large background effect?
  – Acceptance?
  – Or any physics?