Analysis Update
Electroproduction of Lambdas in EG2 Data

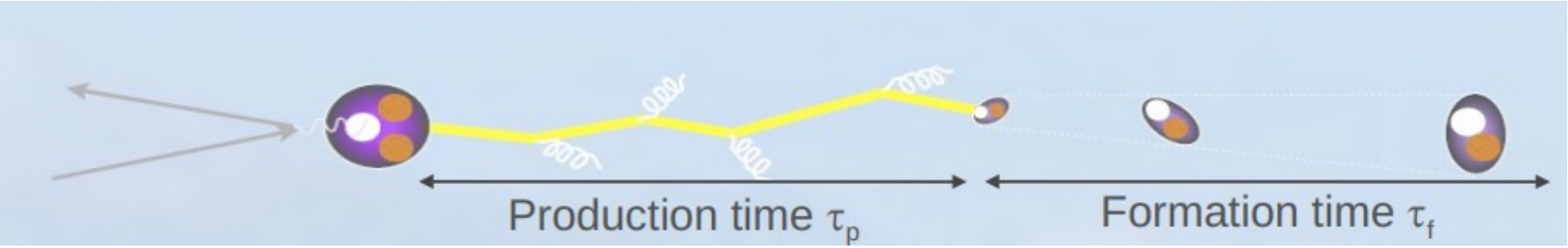
Sereres Johnston
Lamiaa El Fassi
March 8, 2018

Theoretical Interest

- Λ production: window to access fragmentation in current and target region
- Three areas of focus:
  - Multiplicity Ratio
  - Transverse Momentum Broadening
  - Fracture Functions
- Can access hadronization time scales
- Can provide information on spectator target evolution

First hyperon fragmentation study ever!

Multiplicity Ratio



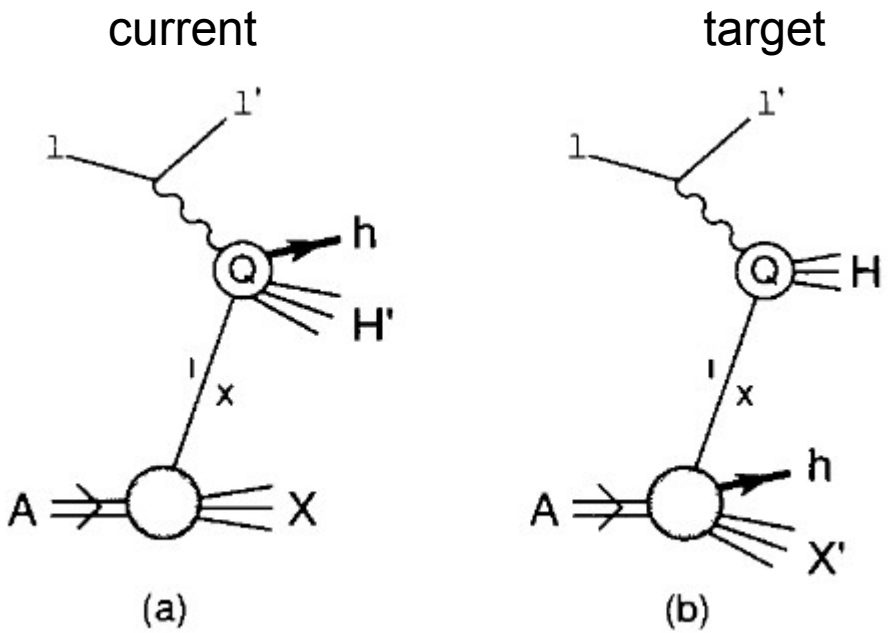
- Production time vs formation time.
- Comparison of production in heavy nuclei to deuterium, normalized by deep inelastic scattering (DIS) electrons originating from each nucleus.

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

Measurable, Universal Functions

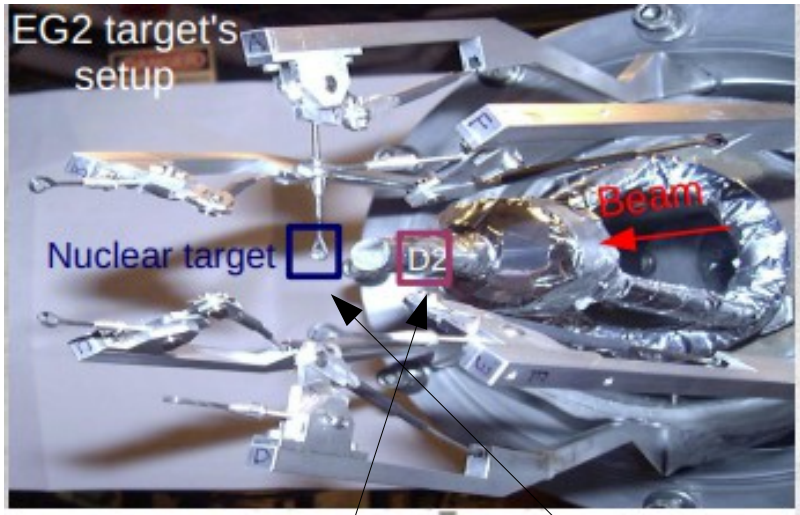
- Structure Functions: internal information of initial hadron configuration (valence, sea, gluon, polarization, ...)
- Fragmentation Functions: Struck quark evolution to hadron
- Fracture Function: Evolution of target spectators to hadron

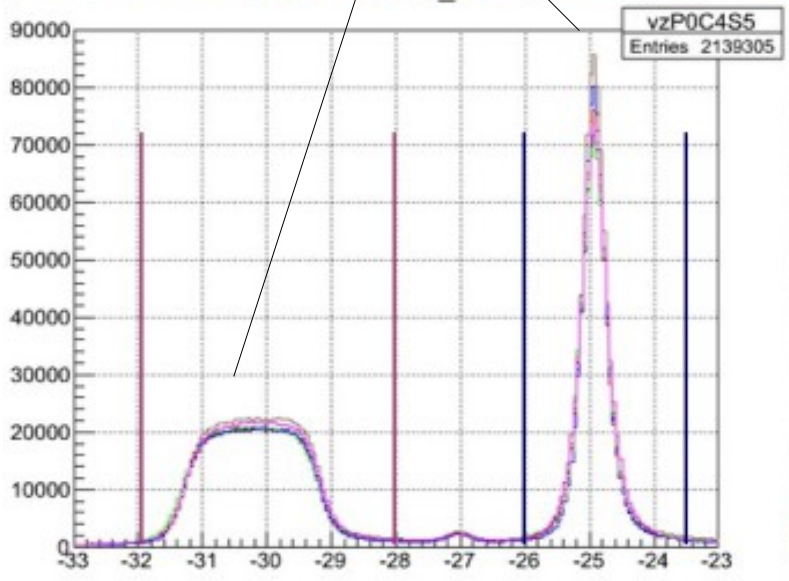
Measurable and universal functions, that we call “fracture” functions, which tell us about the structure function of a given target hadron once it has fragmented (hence its name) into another given final state hadron.

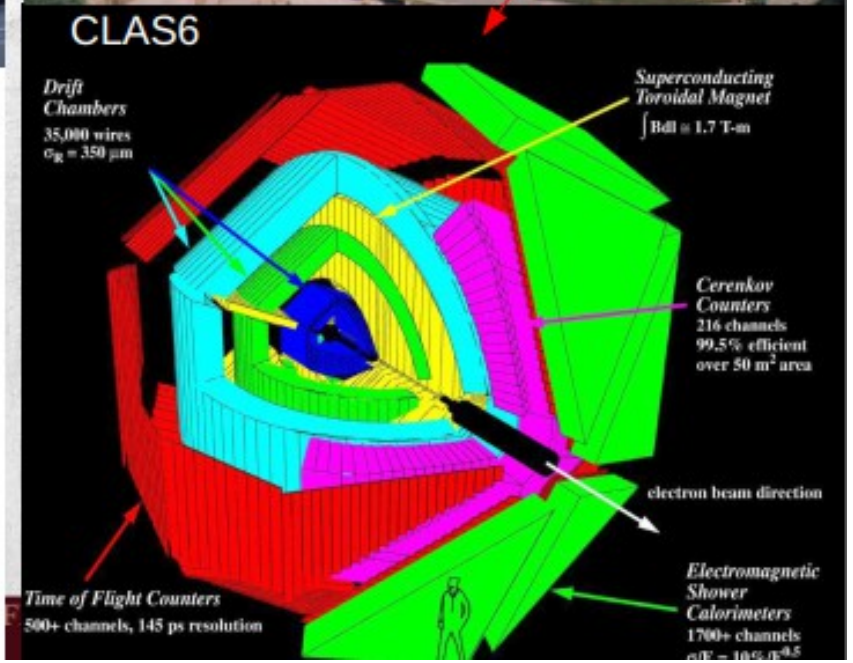


Quote and Image from: Phys. Let. B 323 (1994 201-211), Trentadue and Veneziano

EG2 Experiment







Slide courtesy of L. El Fassi

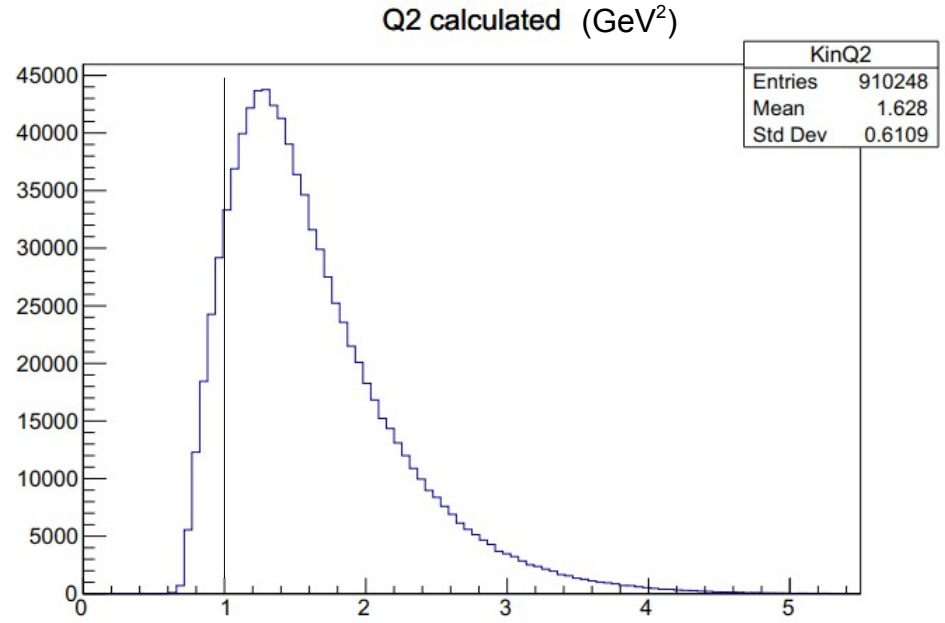
Reaction Channel

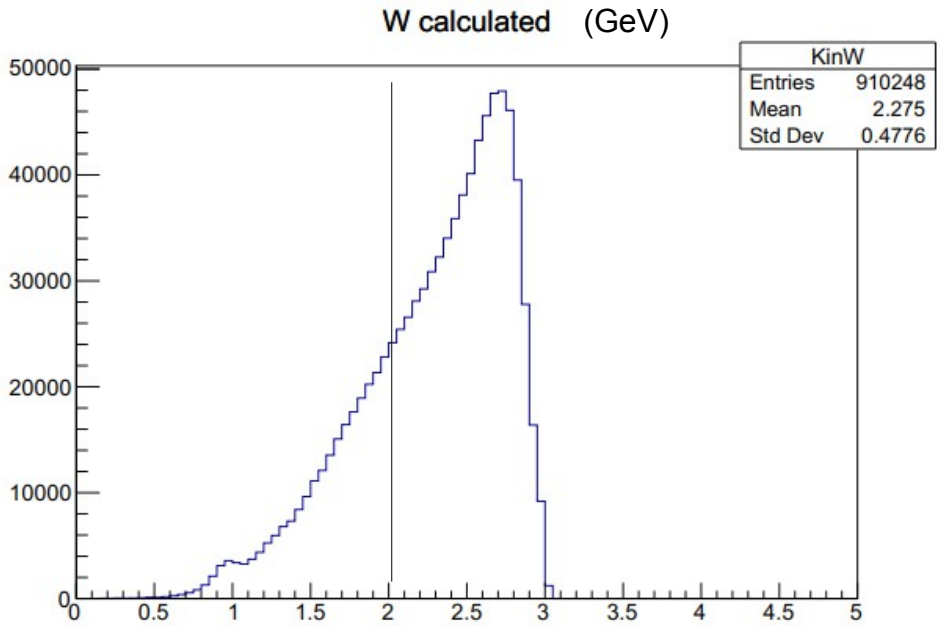
- Semi-Inclusive DIS (SIDIS):
  - electron + proton $\rightarrow$ e' +Λ^0 + X
  - Scattered electron and Λ decay products detected
- $\Lambda \rightarrow \pi^-$ + proton
  - (~64% branching ratio)
- Electron Identification:
  - Method from Approved Color Transparency Analysis
- Pion Identification
  - Method from Approved Color Transparency Analysis

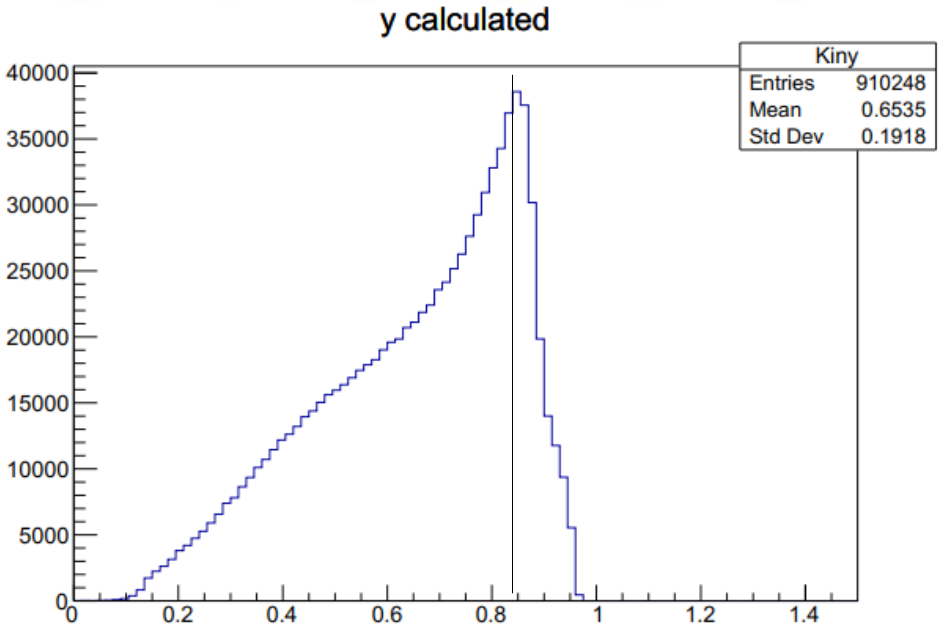
Kinematics

Select SIDIS Events

- Q2 > 1 (4-mom Transfer)
- W > 2 (Final State Hadronic Mass)
- Y < .85 (Struck Quark Energy Fraction)





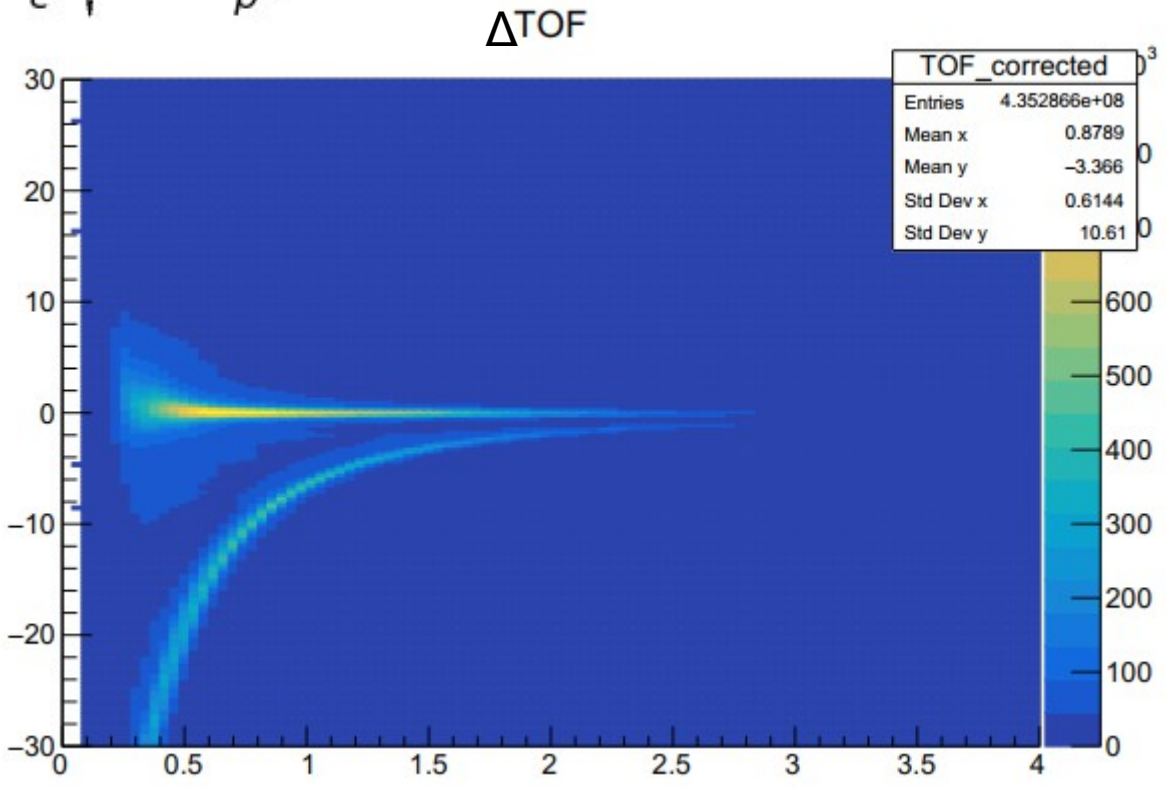


Proton Identification

- Use vertex time difference between electron and proton candidates

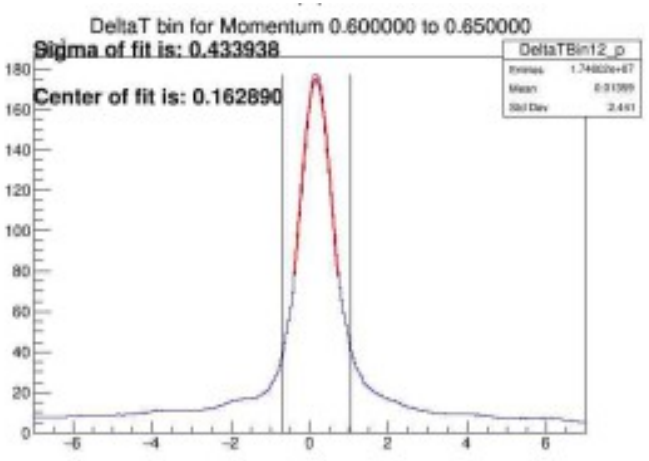
$$\Delta\ TOF = sc_t - tr_{time} - \frac{sc_t}{c}\sqrt{1 + \frac{M^2_{proton}}{p^2}}$$

- sc_t: Proton Time of Flight
- sc_r: Proton Path Length
- tr_{time}: Trigger time
- c: Light Speed
- p: Proton Candidate Momentum

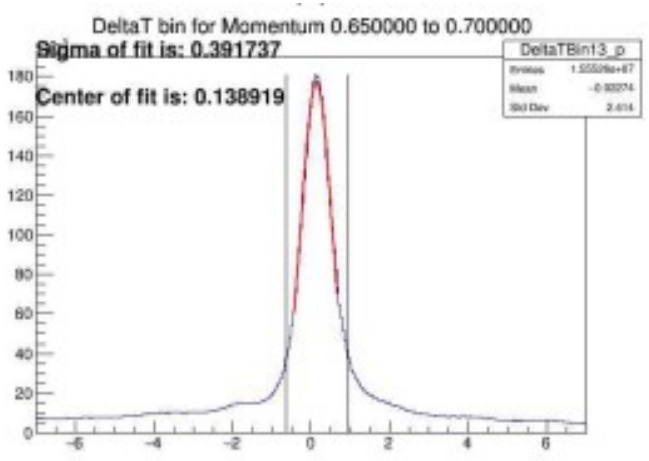


Proton Identification (Cont)

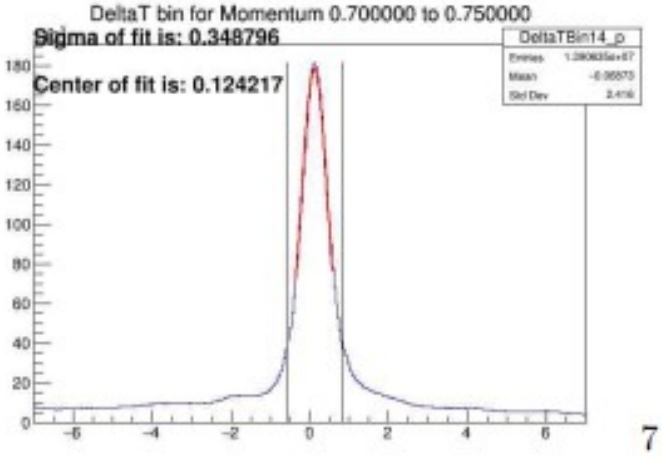
- Positively charged hadronic candidates
- 5 MeV ΔTOF bins
- 0-5 GeV full range
- Gaussian Fitting
- Peak to 0.5 max (above)
- Sigma, Center, recorded
- Lines at 2 sigma



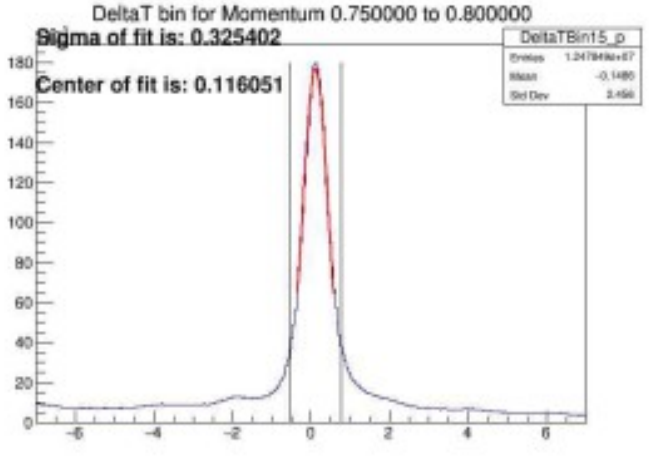
(e)



(f)



(g)

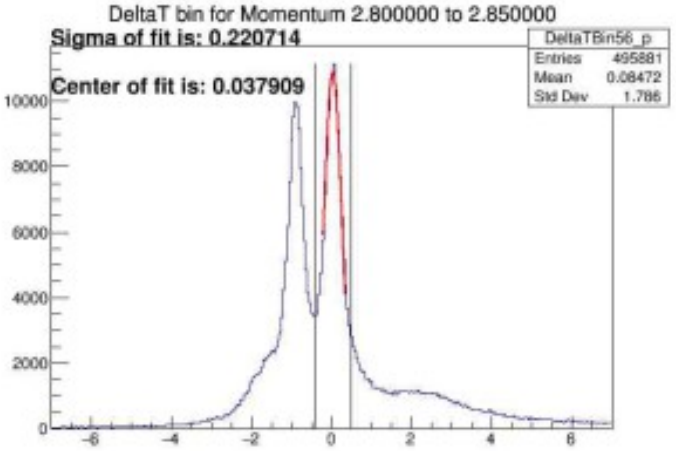


(h)

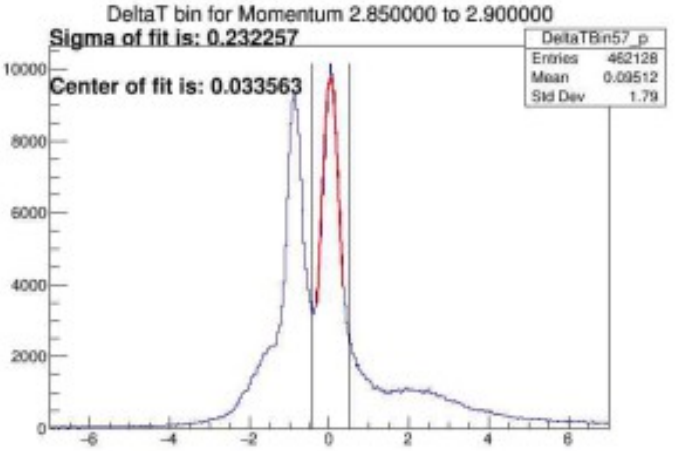
7

Proton Identification (Cont)

- Pion Population
- Proton Population
- Distinct at 2 sigma
- 3 GeV Maximum

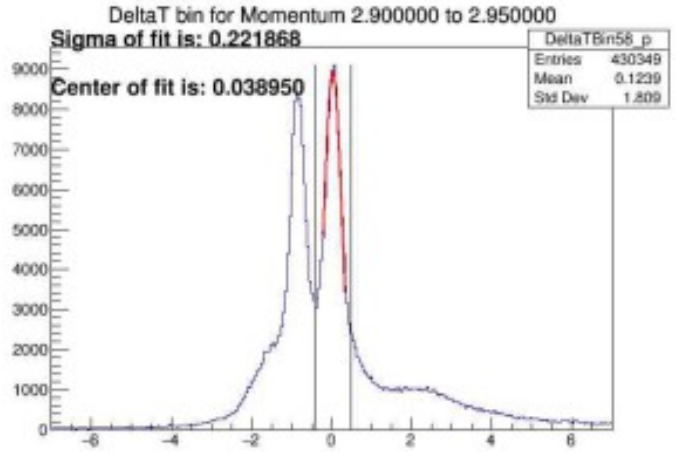


(a)

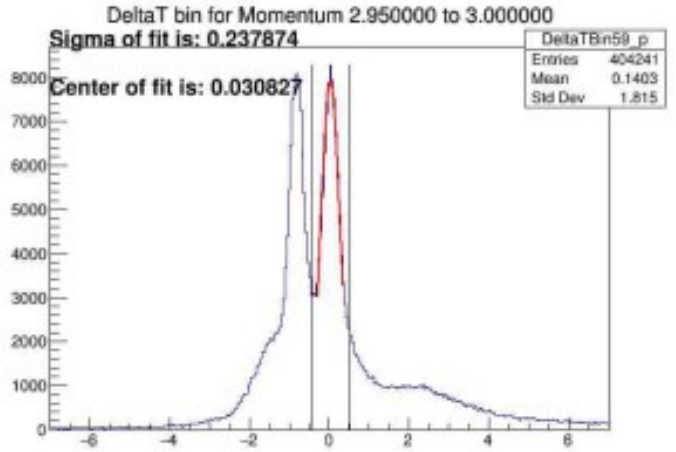


(b)

- No Separation >3GeV
- Protons > 3 GeV not identified



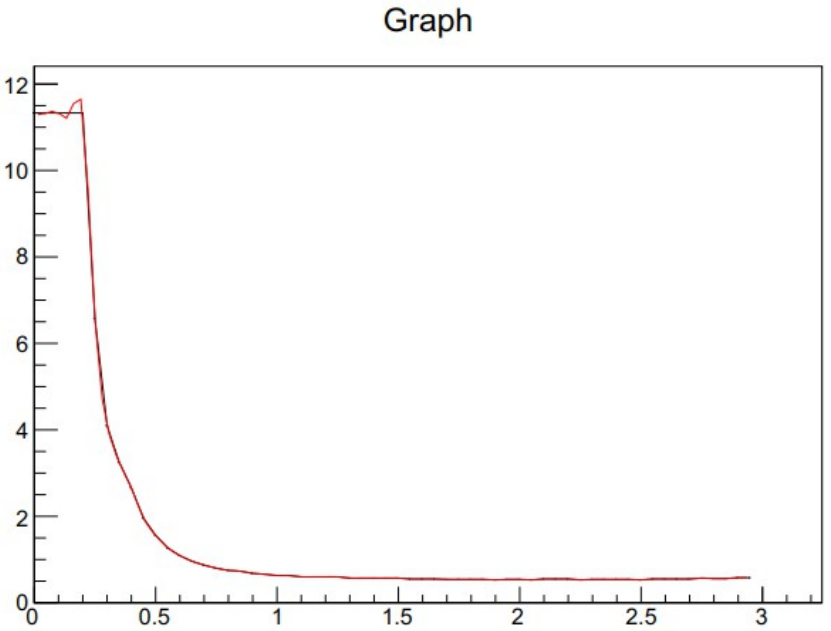
(c)

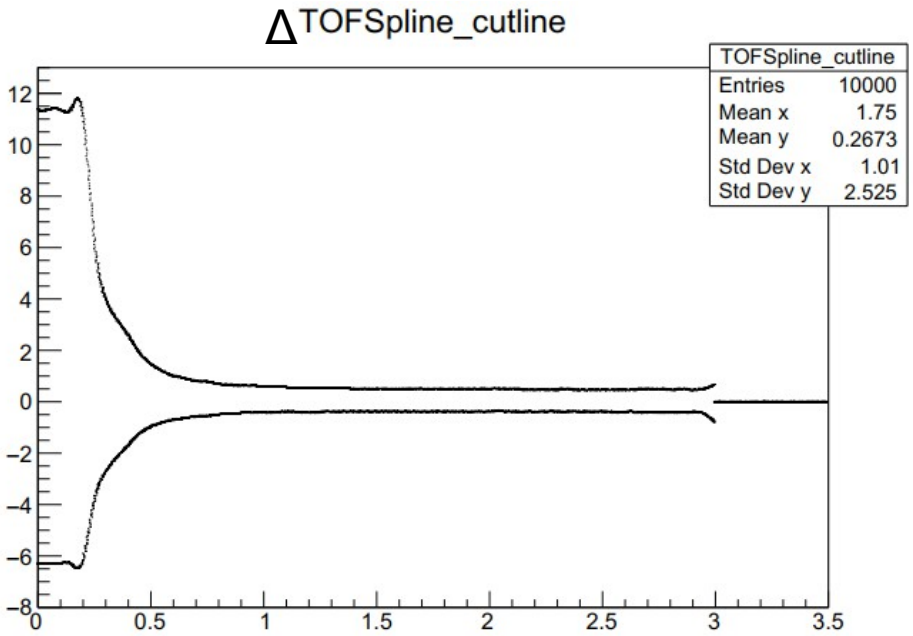


(d)

Spline Smoothing

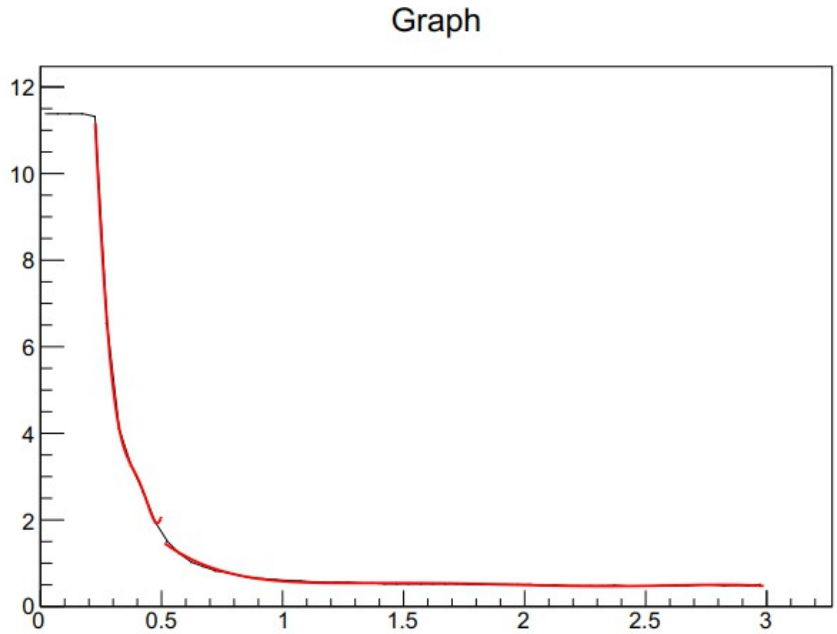
- Cubic Spline
  - Minimizes Curvature
- Smooth momentum bins
- Center +/- 2 sigma

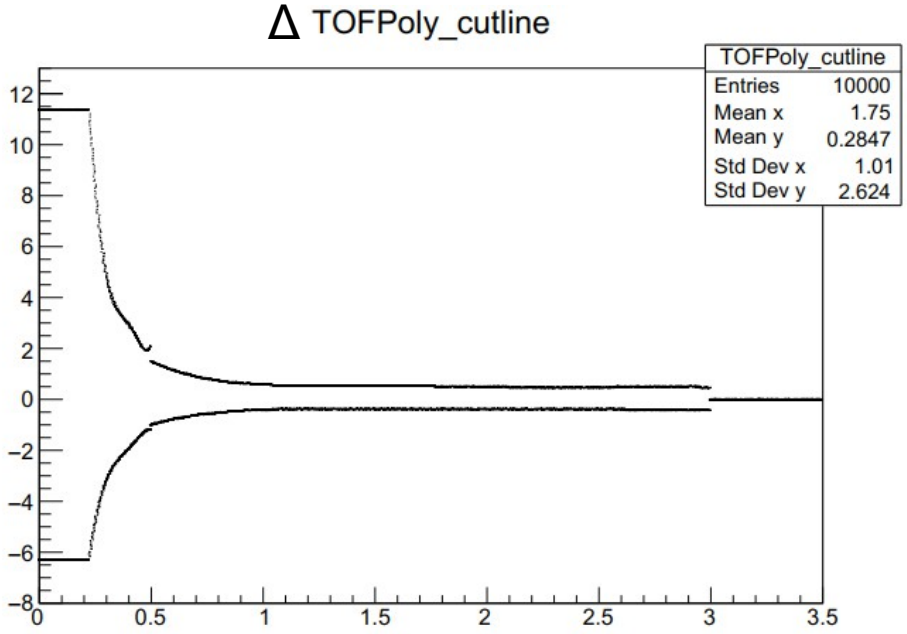




Polynomial Smoothing

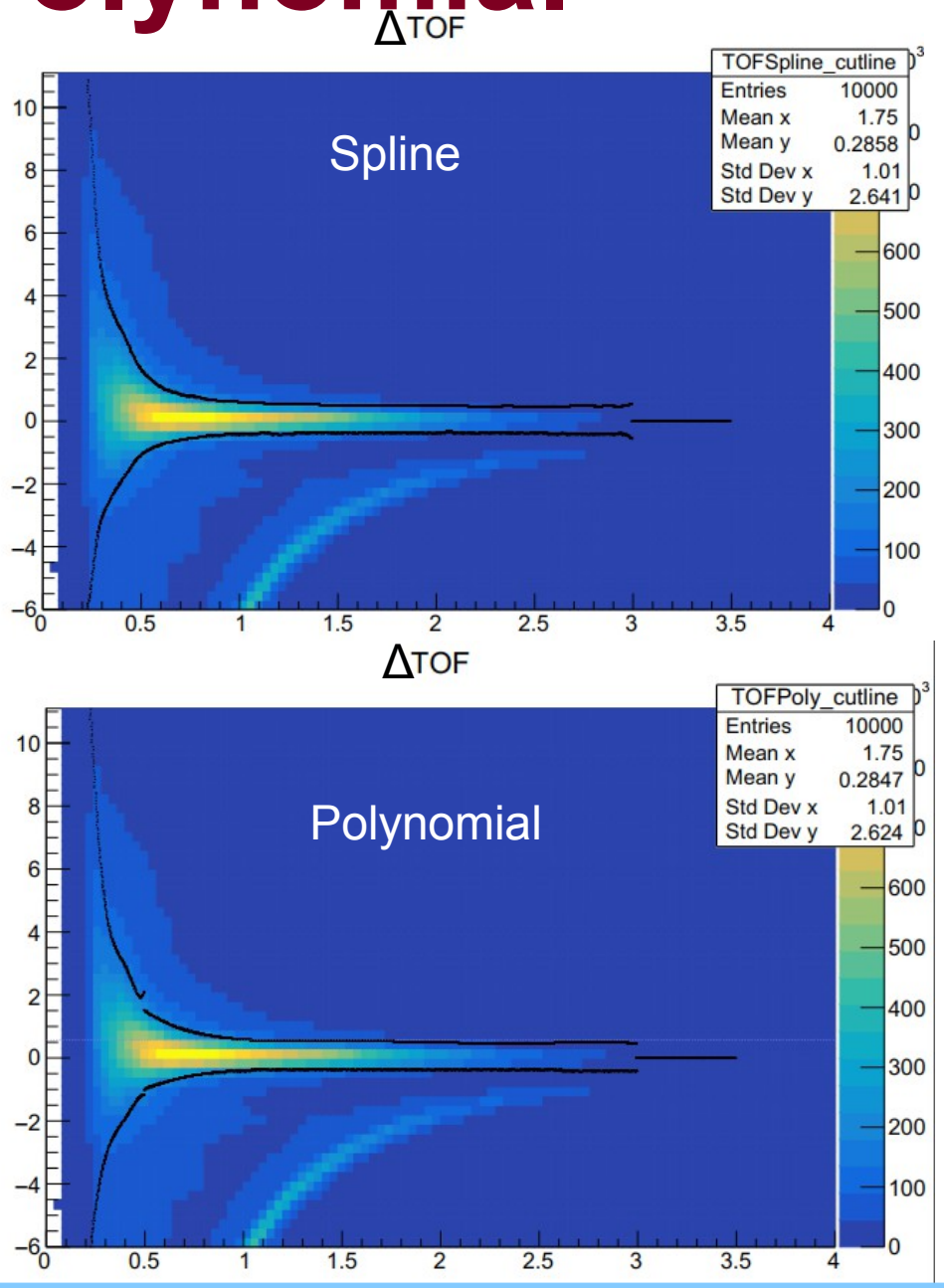
- Piecewise Poly
  - Rank 5, 2 pieces
- Smooth momentum bins
- Center +/- 2 sigma





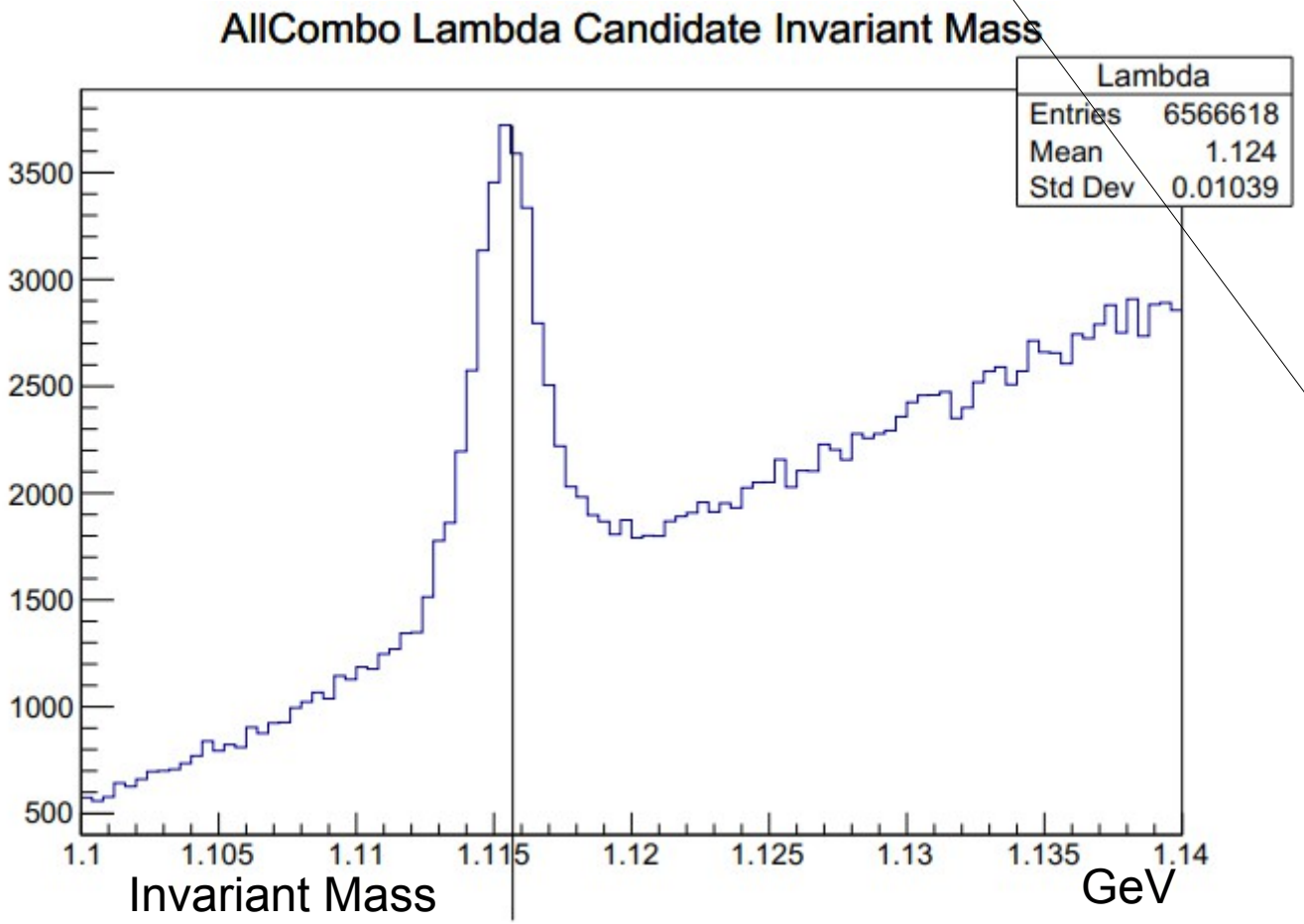
Spline vs Polynomial

- Passing Events:
  - Single Electron + Vertex Cuts
  - Contain > 0 good protons
- Spline
  - 37.78% passing events
- Polynomial
  - 37.7% passing events



Observed Lambda Candidates

$$\Lambda\ InvariantMass = \sqrt{E^2 - Mom_X^2 - Mom_Y^2 - Mom_Z^2}$$

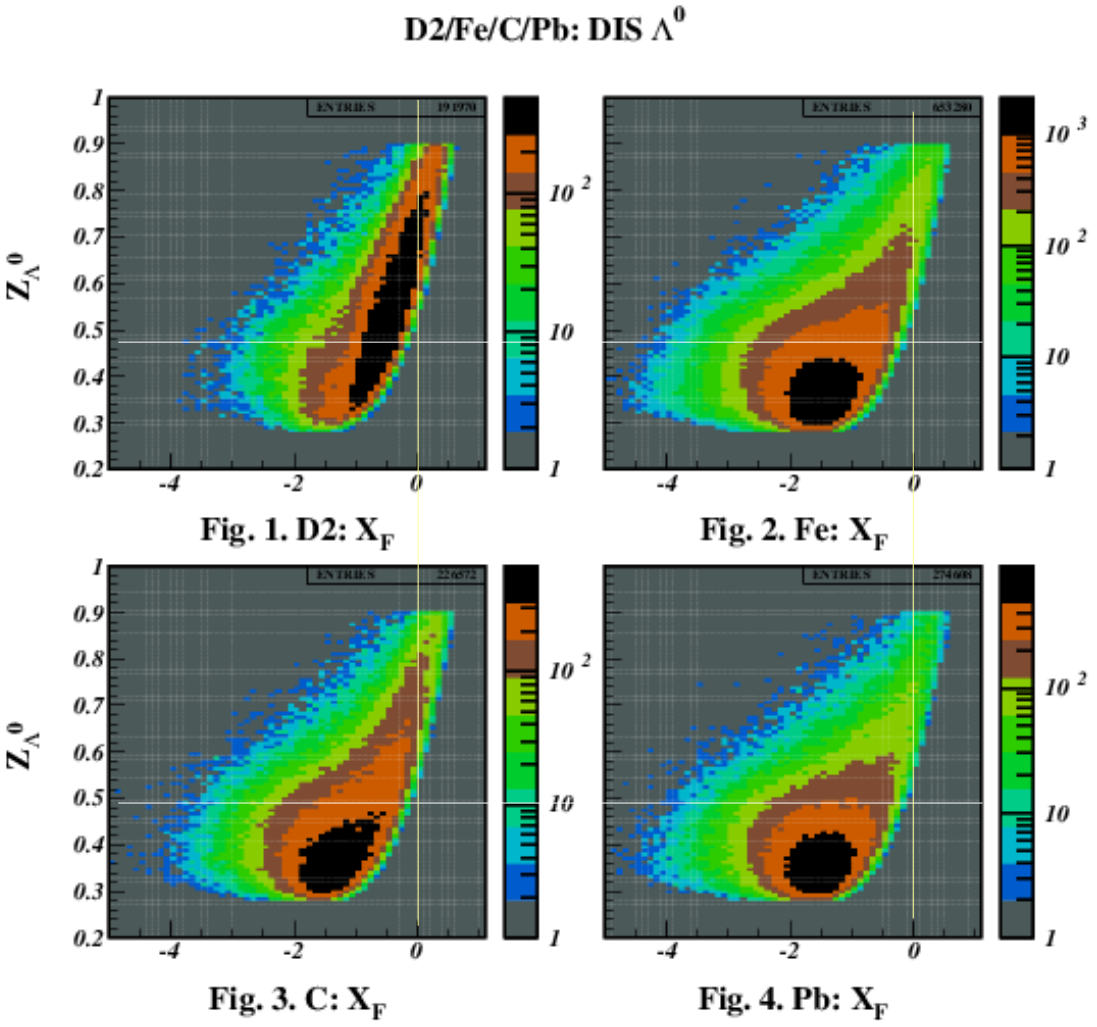


The momentum directional components are the sum of the proton and pi minus momentum in that direction

The energy component includes the momentum and the rest mass of both π^- and proton

Current Vs Backward Fragmentation

- x_F: Feynman scaling variable
- Expect distinct behavior from x_F positive vs negative
- Positive = Forward
  - Direction of virtual photon
- Negative = Backward
  - Direction of proton
- Z = 0.5
  - Separates leading quark from target region

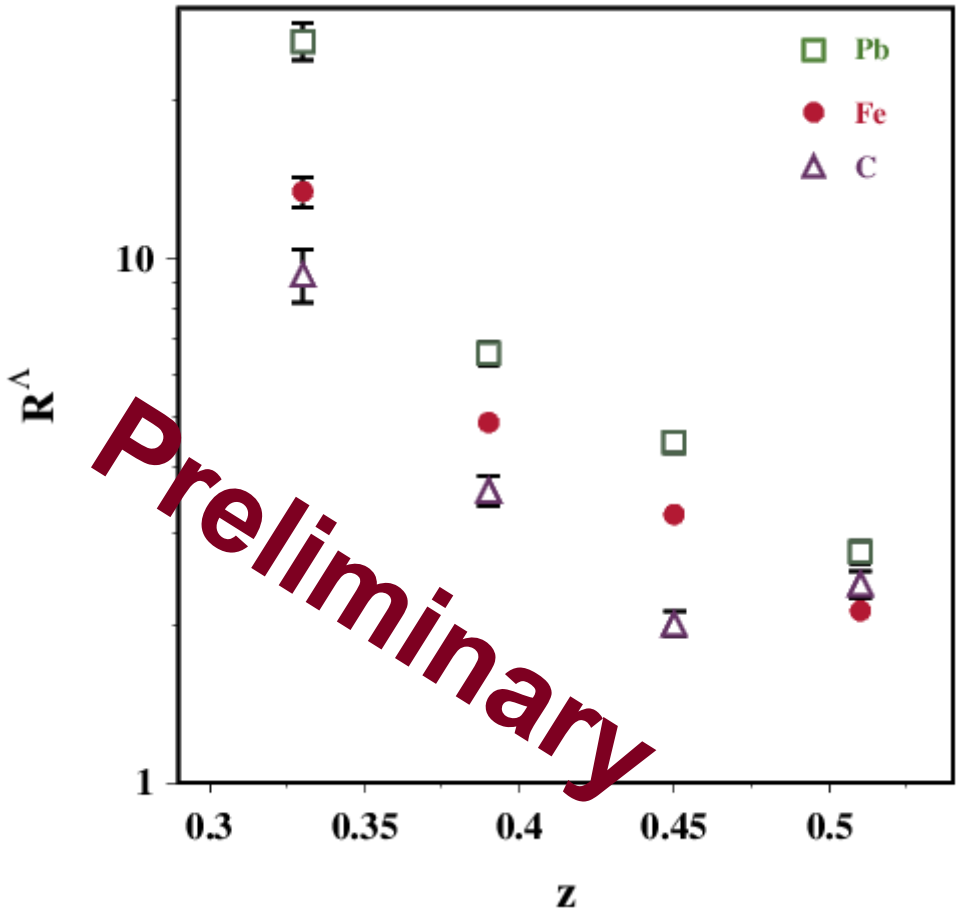


Images courtesy of L. El Fassi

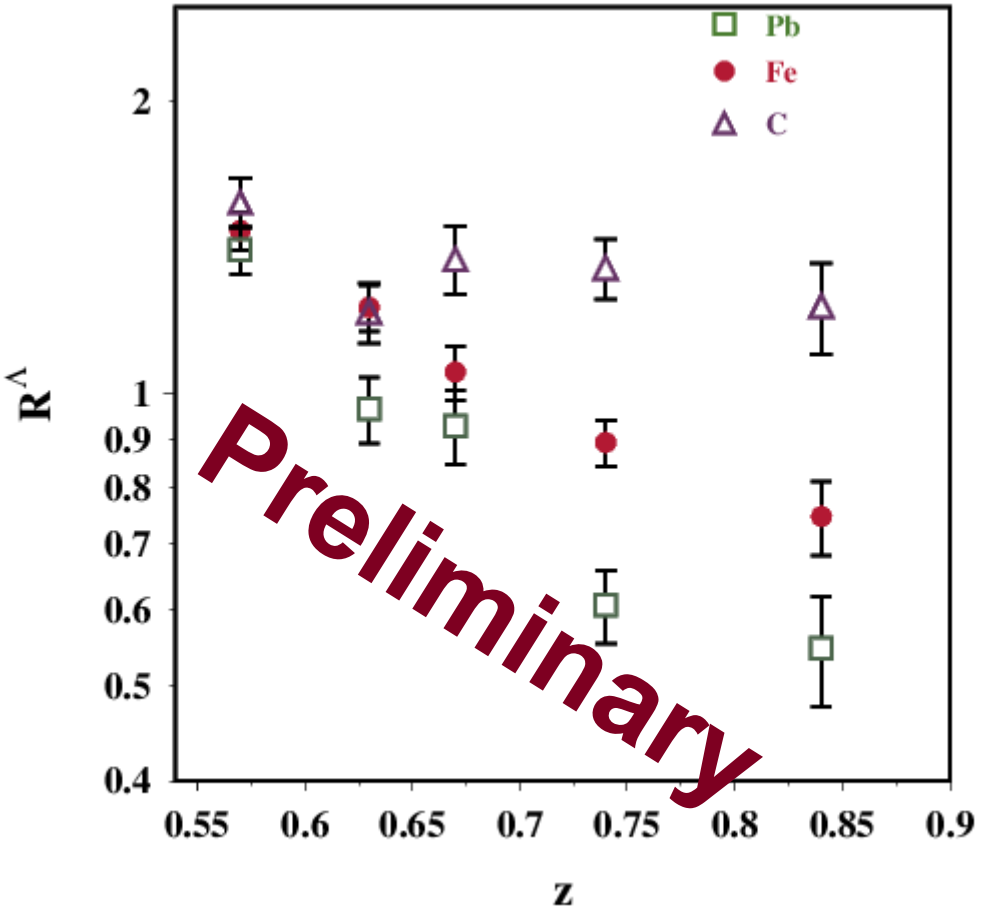
Lambda Multiplicity

Fitted Subtracted Background Λ Distribution

Low Z: Target Fragmentation



High Z: Current Fragmentation



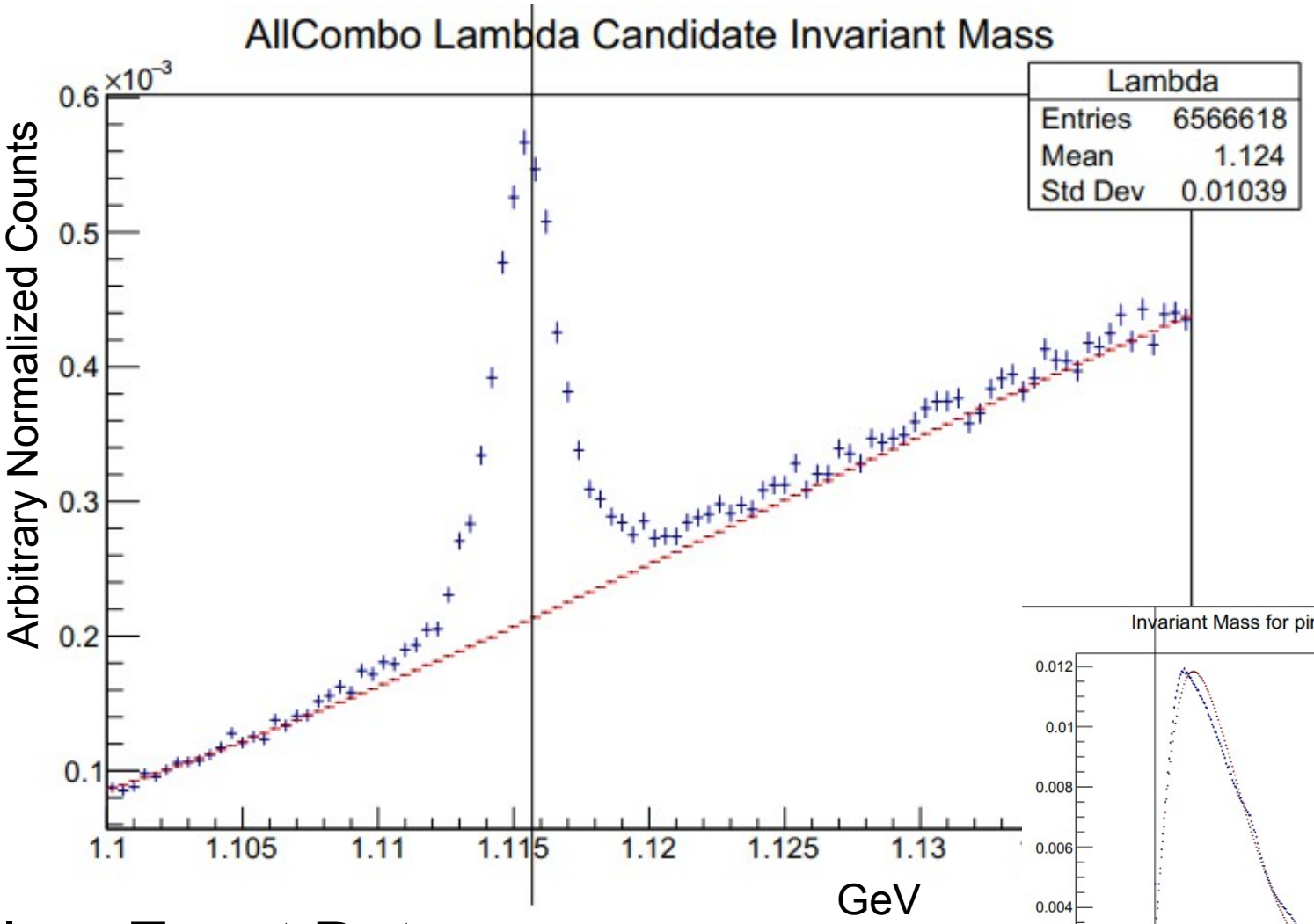
Images courtesy of L. El Fassi

Combinatorial Background

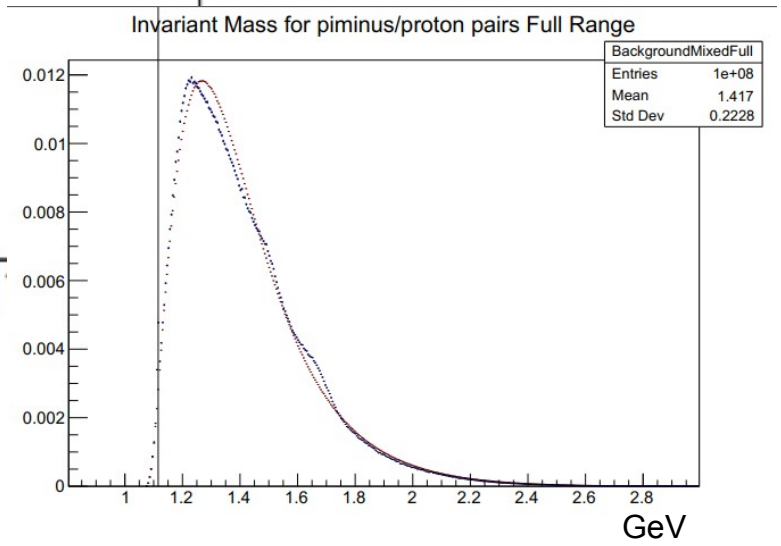
- Model Lambda Background by Event Mixing.
  - Need dataset similar to real events, with no Λs
  - Combine π^- from one event with proton from another

- Apply SIDIS cuts, and require electron, proton and π^-
- Require all particles from same target
- If event # is even, save π^- information
- If event # is odd, save proton information
- Find invariant mass for all π^- and proton combinations
- Shape should match background to Λ particles

Combinatorial Background



Full Iron Data Set



Blue: Event Data
Red: Event Mixed Background

Future Work

- Apply combinatorial background subtraction
  - Extract multiplicity ratios and transverse momentum broadening
- Correct for acceptance and radiative effects
- Extract Fracture function from deuterium target only (free from nuclear effects) as function of several kinematic variables: z, x_b, Q^2, x_F
- Complete systematic studies
- Stay Tuned!!