

Hadronization from CLAS6 and CLAS12

Studies of Hadronization from CLAS6 and Readiness for CLAS12

Latiful Kabir (MSU)
Lamiaa El Fassi (MSU)

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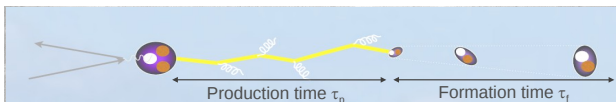
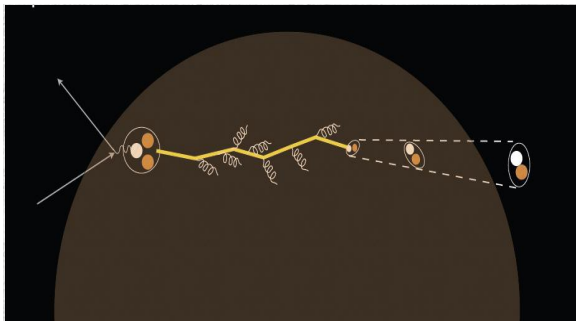


Outline

- ① Hadronization Studies
- ② Hadronization from CLAS6 (Lambda)
- ③ Readiness for CLAS12

Hadronization Studies

- Evolution of a colored bare quark into a fully dressed hadrons – Hadronization.
- Hadronization timescales:
Production time τ_p and
Formation time τ_f
- A direct probe of QCD confinement.
- Use semi-inclusive deep inelastic scattering (SIDIS) to gain access to physics observables.



Hadronization Studies


- Multiplicity ratio:

$$R_A^h(\nu, Q^2, z, p_T, \phi) = \frac{N_h(\nu, Q^2, z, p_T, \phi) \Big|_A}{N_e(\nu, Q^2) \Big|_{\text{DIS}}} \Big/ \frac{N_h(\nu, Q^2, z, p_T, \phi) \Big|_D}{N_e(\nu, Q^2) \Big|_{\text{DIS}}}$$

- Transverse momentum broadening:

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

DIS channels: *stable* hadrons, accessible with 11 GeV
JLab experiment PR12-06-117

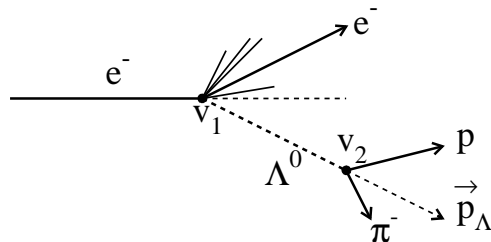
 Actively underway with existing 5 GeV data

<i>meson</i>	τ	mass	flavor content	<i>baryon</i>	τ	mass	flavor content
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$	p	stable	0.94	ud
π^+, π^-	7.8 m	0.14	$u\bar{d}, \bar{u}d$	\bar{p}	stable	0.94	$\bar{u}d$
η	170 pm	0.55	$u\bar{u}d\bar{d}s\bar{s}$	Λ	79 mm	1.1	uds
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$	$\Lambda(1520)$	13 fm	1.5	uds
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$	Σ^+	24 mm	1.2	us
ϕ	44 fm	1.0	$u\bar{u}d\bar{d}s\bar{s}$	Σ^-	44 mm	1.2	ds
f_1	8 fm	1.3	$u\bar{u}d\bar{d}s\bar{s}$	Σ^0	22 pm	1.2	uds
K^0	27 mm	0.50	$\bar{d}s$	Ξ^0	87 mm	1.3	us
K^+, K^-	3.7 m	0.49	$\bar{u}s, \bar{u}s$	Ξ^-	49 mm	1.3	ds

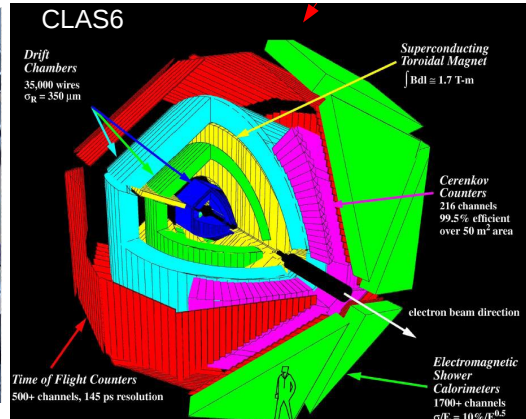
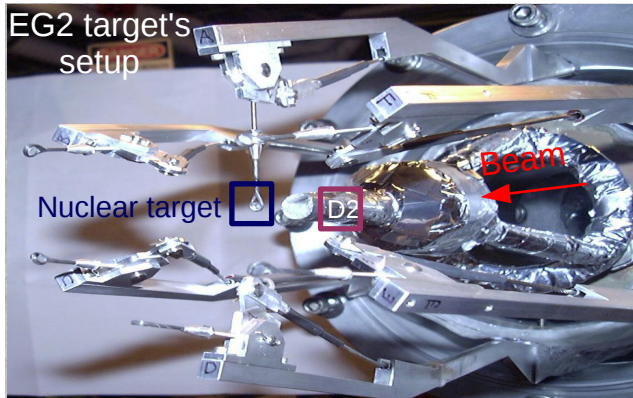
Lambda Hadronization From EG2

- PID: e^- , π^- , proton
- Vertex correction
- Data Quality: Normalized Yield
- SIDIS Cut
- Lambda Identification
- Background subtracted Lambda
- Correction for detector efficiencies and background

$$e + A \rightarrow e' + \Lambda + X$$



Experimental Setup



Setup for Analysis

```

Terminal
File Edit View Search Terminal Help
[msk@1402] ifarm1402:Analysis $ root

=====
| Welcome to EG2 Analysis Tool Integrated in ROOT |
| Type: 'help()' for a list of available options |
=====
Attempting to load libEG2.so ... attempt completed !!
Attempting to load libEG2Analysis.so ..attempt completed !!

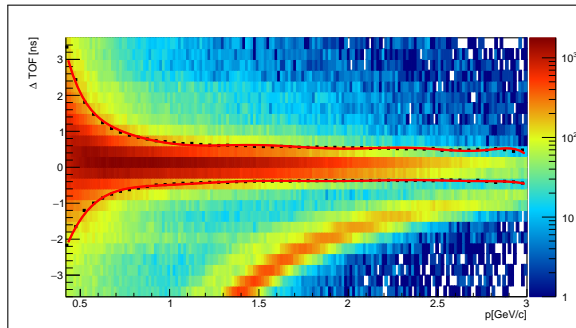
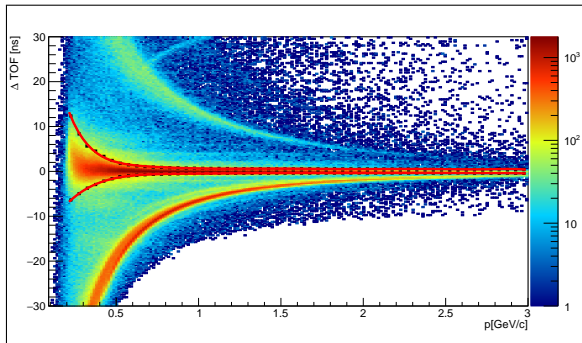
root [0] help()

=====
|                               Classes/Functions inside libEG2 |
=====
class TEG2                : Collection of static fields and functions
class TEG2Run             : The main Class for the EG2 to read run data
class TEG2RunReader       : The Class for the EG2 to read run data using TTreeReader
class TEG2DC              : Drift Chamber Detector Class
class TEG2EC              : Electromagnetic Calorimeter Detector Class
class TEG2CC              : Electromagnetic Calorimeter Detector Class
class TParticleID         : The particle identification class
class TEG2FitParameters   : Fit parameters
class TEG2Particle        : EG2 Particle Properties
class TEG2VertexCorrection : EG2 Vertex Correction
function Help             : Helper function
function help             : Helper function

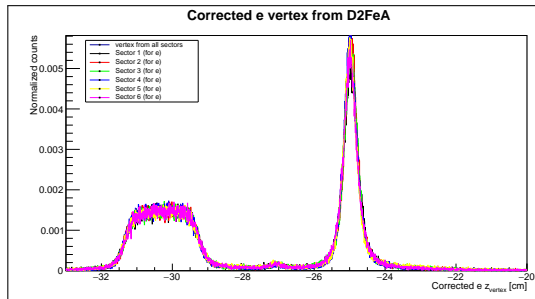
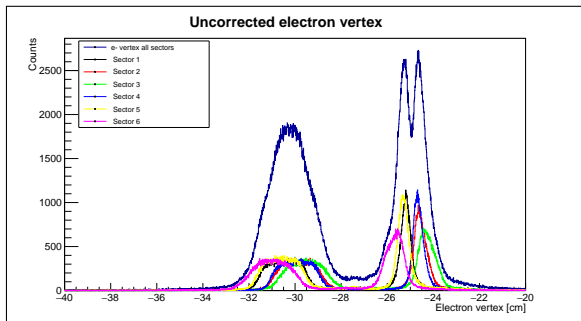
-----
| Type 'help("function or class name")' for details of any specific function or class |
-----
=====
|                               Functions inside Analysis |
=====
function EG2ParticleID    : Perform PID
function EG2ParticleCounter : Perform PID and count events or particles
function EG2ProtonTOFFit  : Fit for Delta TOF used for proton PID
function EG2BSVertexCorrection : Vertex correction using BS method. This is used for this analysis.
function EG2BSVertexByRunNumber : Vertex correction as a function of run number using BS method
function FitForBeamPosCorr : Fit for beam misalignment used for vertex correction in BS method.
function FitForPhi        : Fit for angle phi used for vertex correction in BS method.
function FitForTheta      : Fit for angle theta used for vertex correction in BS method

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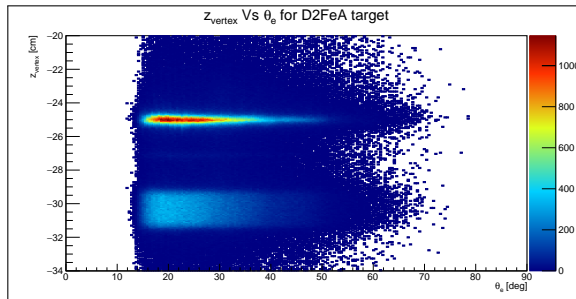
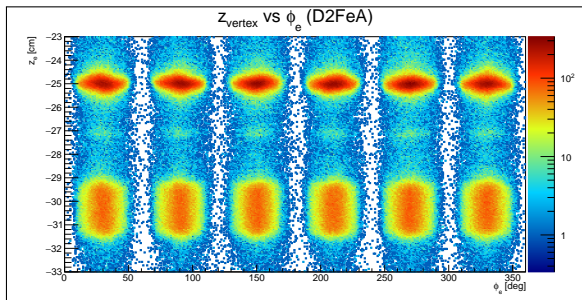
Proton Identification



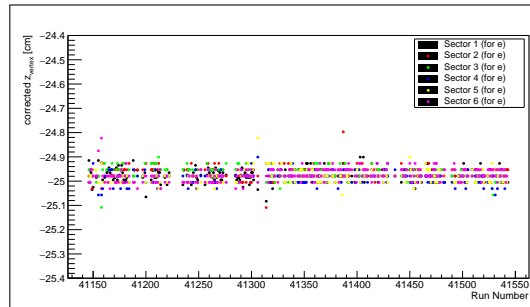
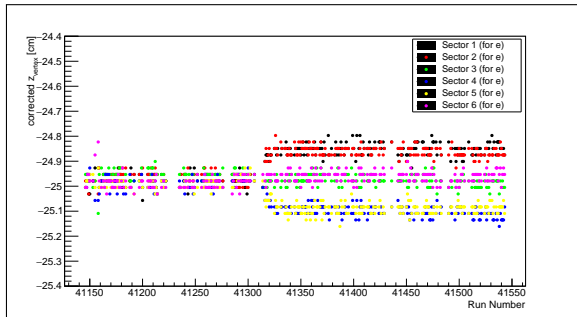
Vertex Correction



Vertex Correction

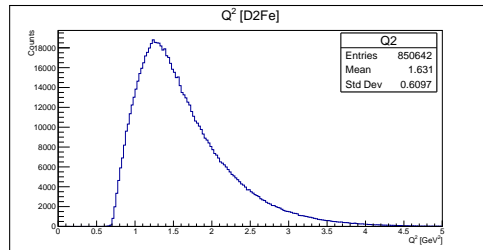
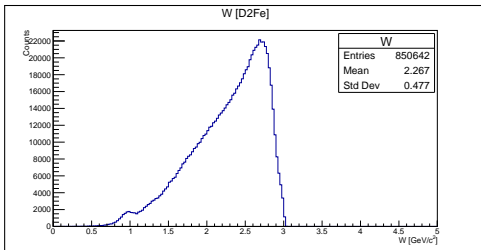


Vertex Correction

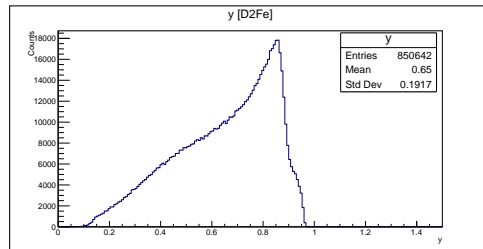


- First observed by Sereres Johnston (ANL)

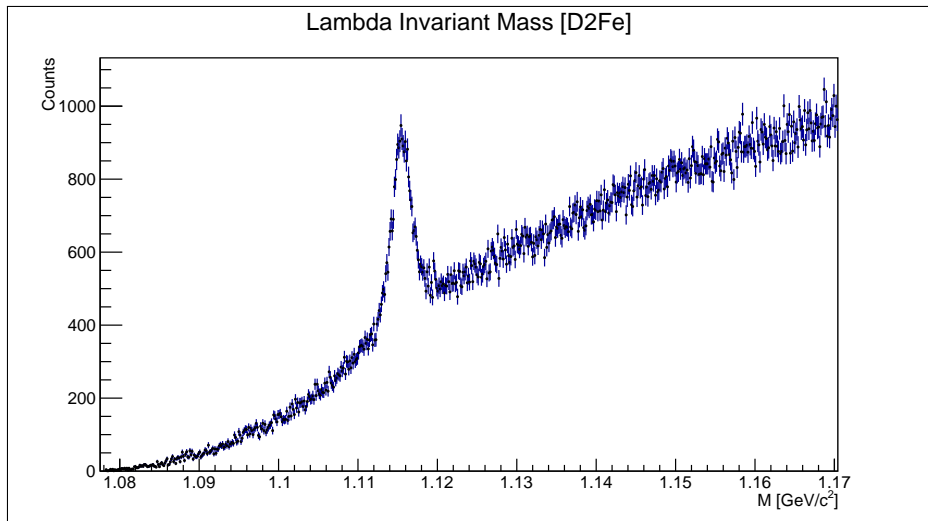
Kinematic Cuts to Select SIDIS Events



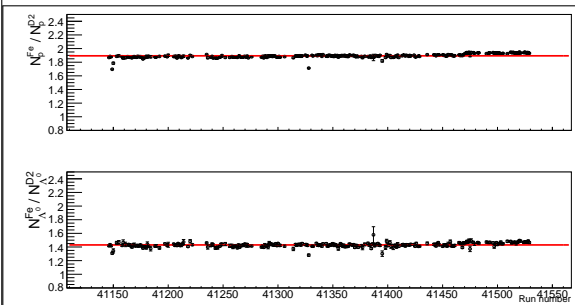
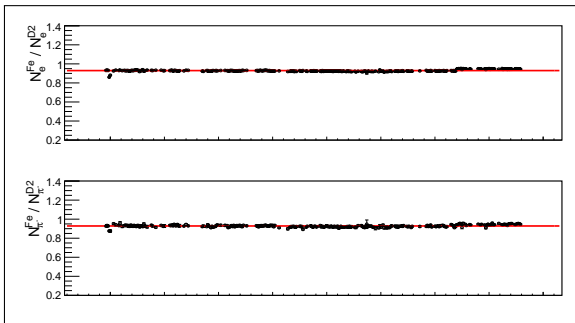
- $Q^2 > 1$ (4-momentum transfer)
- $W > 2$ (Hadronic mass)
- $y < 0.85$ (Struck Quark Energy Fraction)



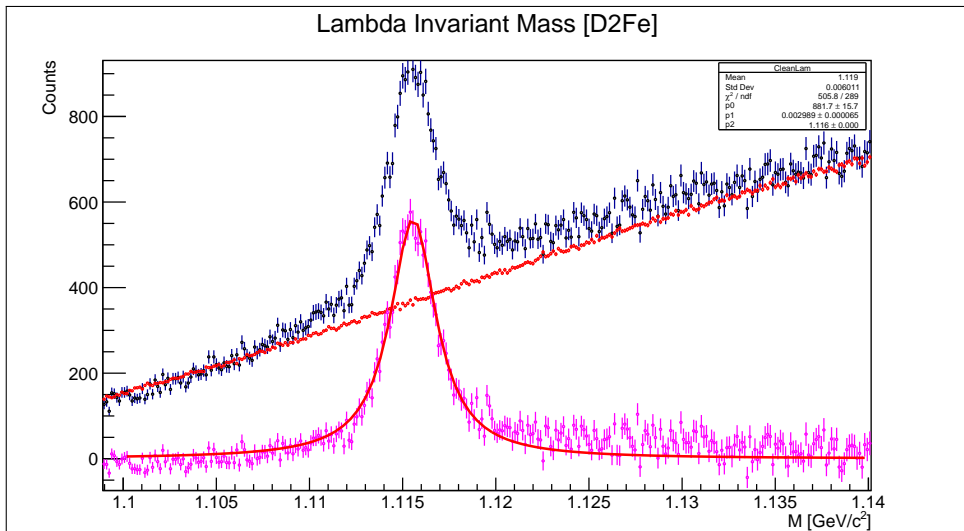
Lambda Identification



Data Quality



Background Subtraction

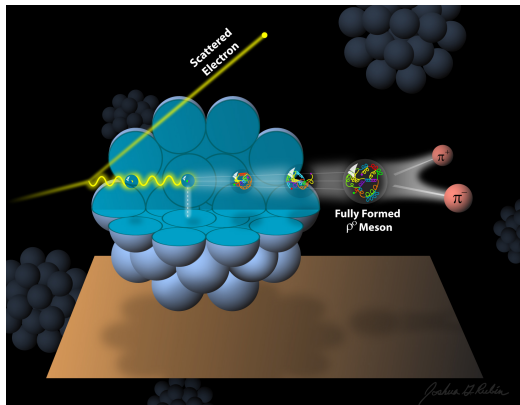
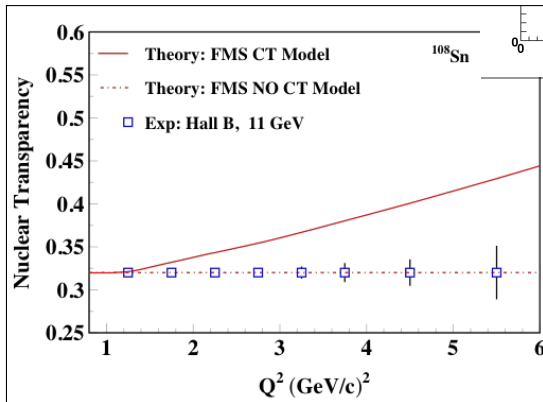


Ongoing Work

- Calculate multiplicity ratios for each data-set.
- Correct for radiative effects
- Correct for detector acceptance
- Finish systematic error budget

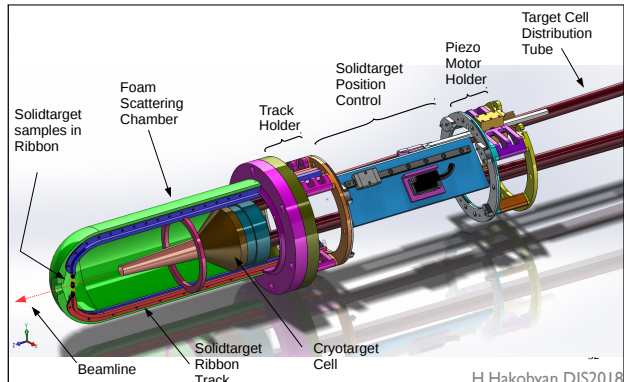
Readiness for CLAS12

- In addition to hadronization, we are also interested in CT in 12 GeV



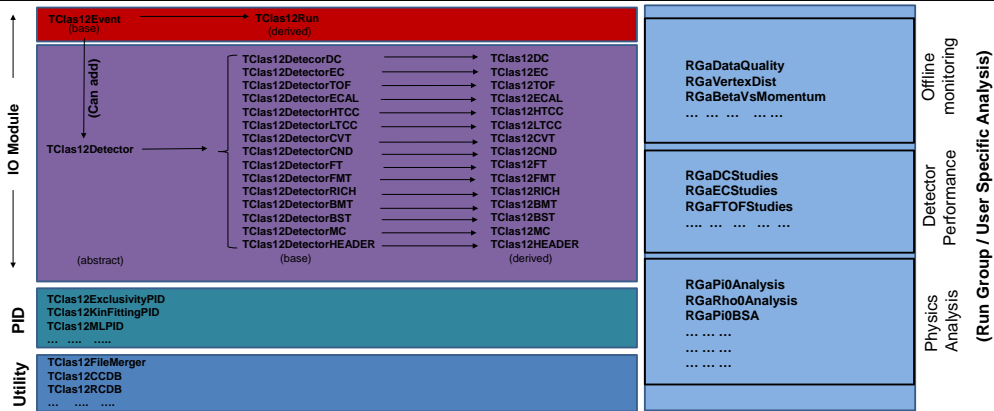
Target Status

- Dual nuclear target for CLAS12 under construction in Chile
- Target types: C, Cu, Sn, Pb and others
- 5T Magnetic field
- Cryotarget at 30⁰K
- Radiation hardness



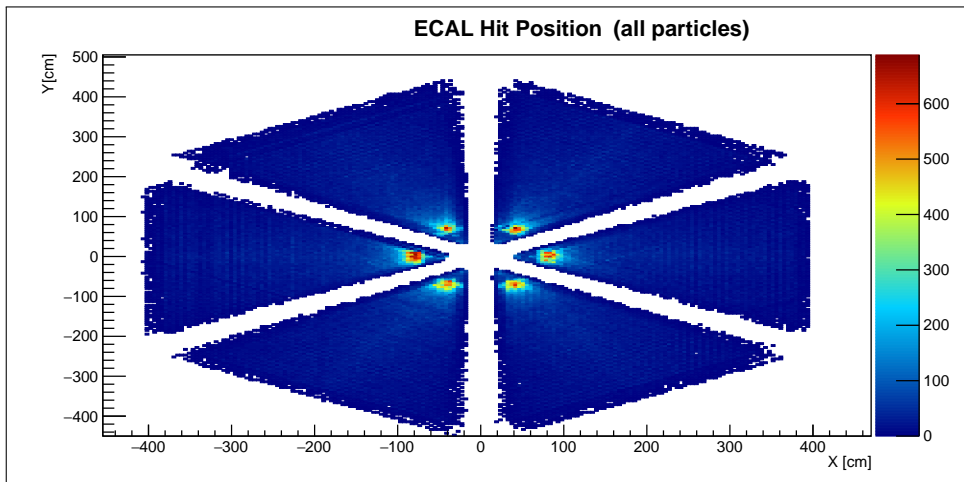
H.Hakobyan DIS2018

Dedicated Analysis Tool: The Architecture



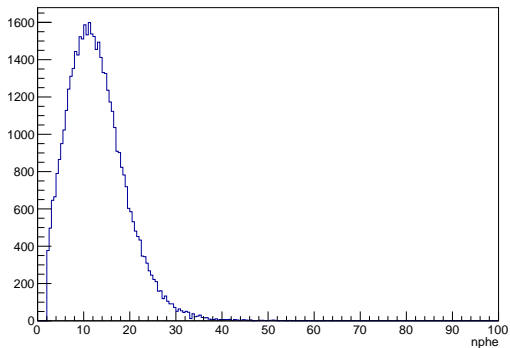
- ROOT based analysis tool on top of HIPO without requiring to convert to root files.
- Tailored to take full advantage of the batch farm resources.
- Data quality check, detector performance etc are intrinsic in the tool.

Data Quality

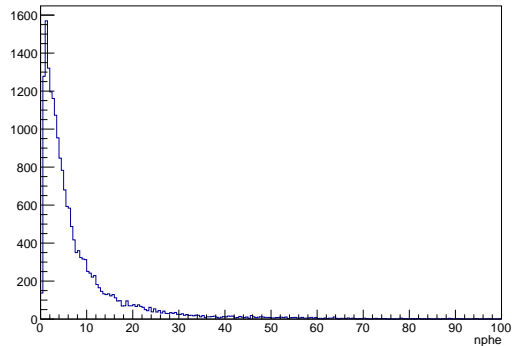


Data Quality

nphe distribution (HTCC)

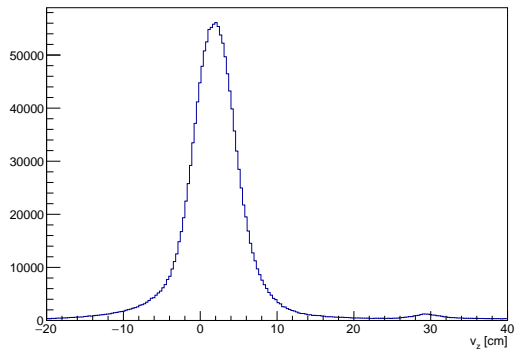


nphe distribution (LTCC)

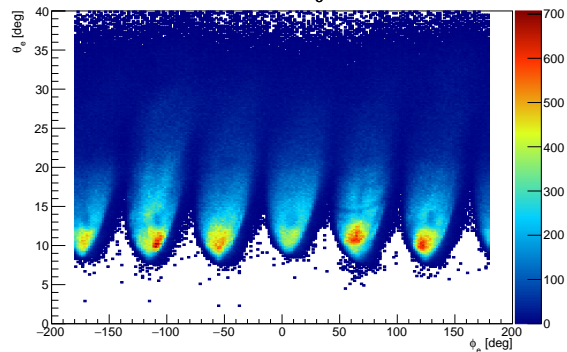


Data Quality

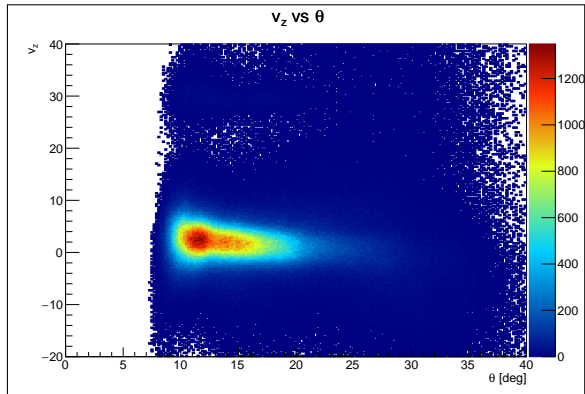
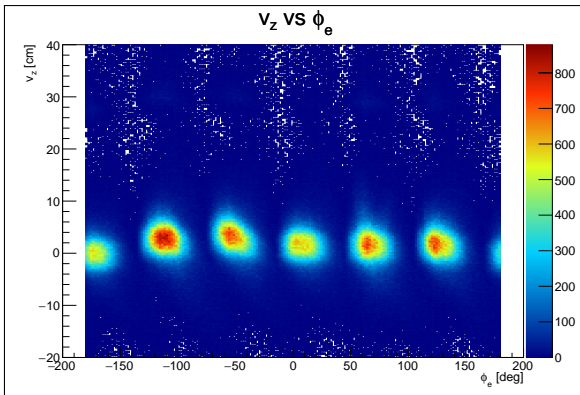
Vertex z_e distribution



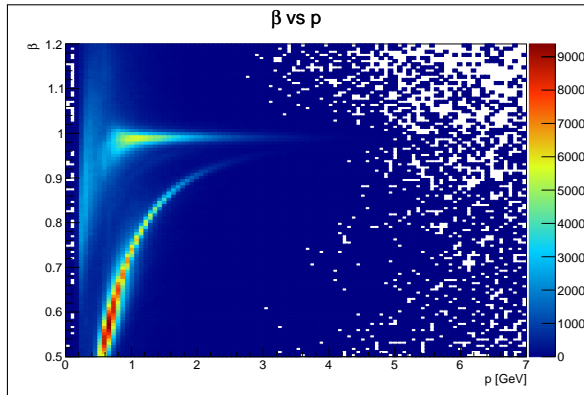
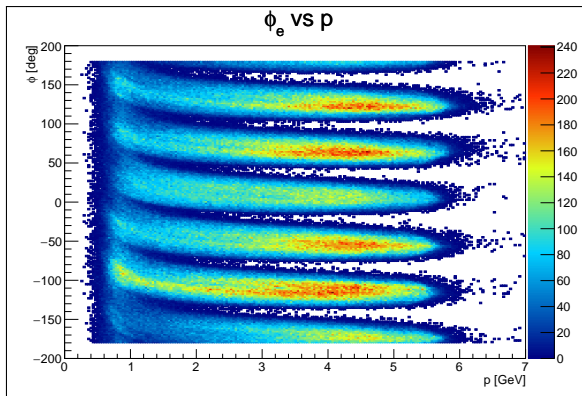
θ_e vs ϕ_e



Data Quality



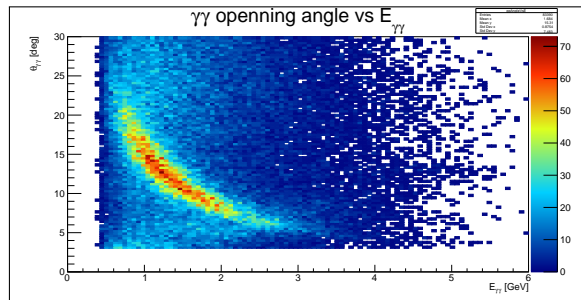
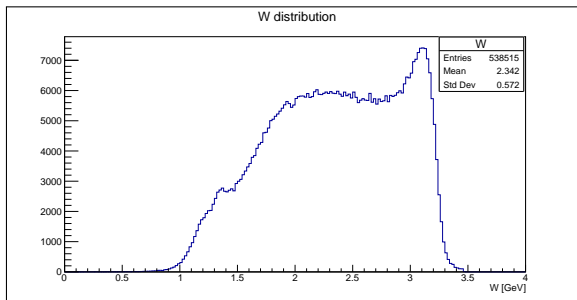
Data Quality

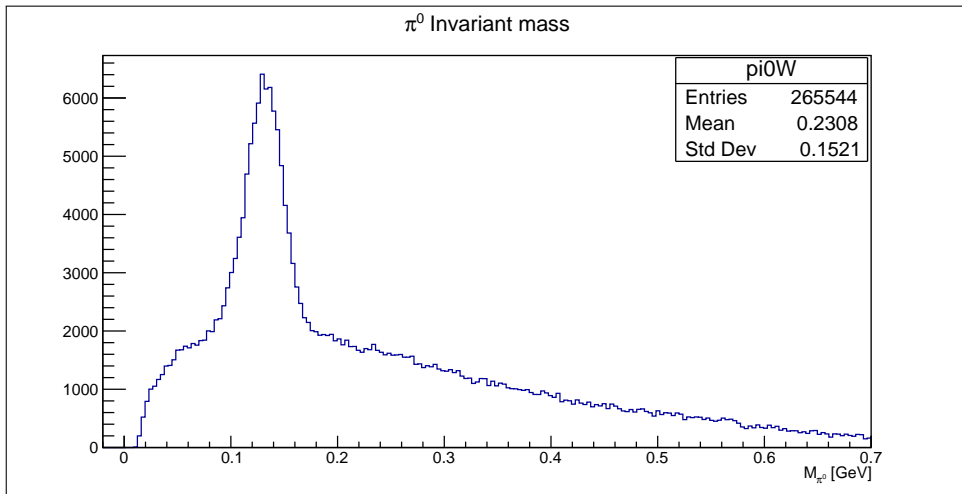


Let's Look At Some Reaction Channels

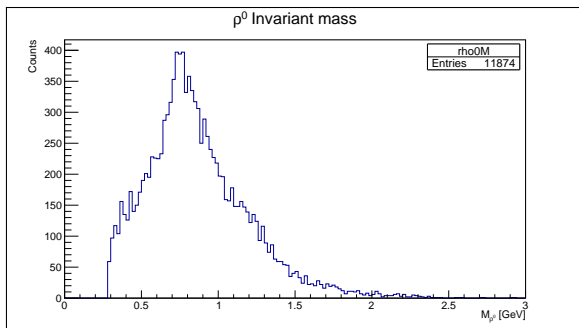
- $e + p \rightarrow e' + \pi^0 + X$
- $e + p \rightarrow e' + \rho^0 + X$
- $e + p \rightarrow e' + \Lambda + X$

Reaction Channel: π^0 ($e + p \rightarrow e' + \pi^0 + X$) 6.4 GeV Run, Old Cooking

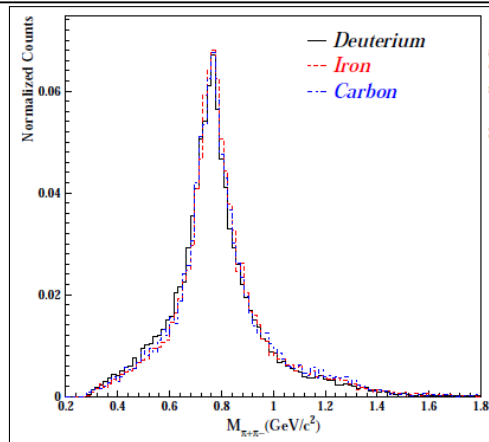


Reaction Channel: $\pi^0 (e + p \rightarrow e' + \pi^0 + X)$ 6.4 GeV Run, Old Cooking

Reaction Channel: $\rho^0 (e + p \rightarrow e' + \rho^0 + X)$ 10.6 GeV Run (3971), Old Cooking

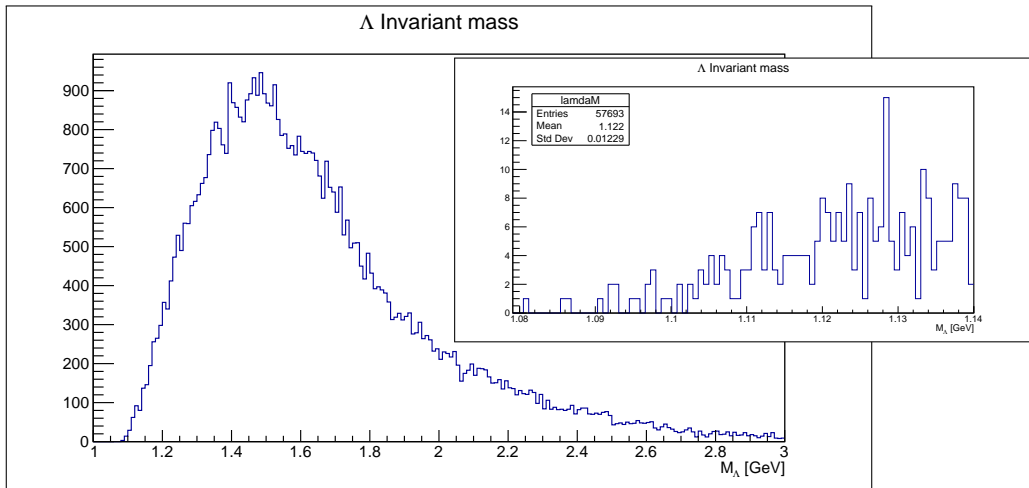


CLAS12 Data at 10.6 GeV



CLAS EG2 Data (CT Analysis Note) at 5 GeV

Reaction Channel: $\Lambda (e + p \rightarrow e' + \Lambda + X)$ 10.6 GeV Run (3971), Old Cooking



Summary

- Lambda hadronization analysis from EG2 data is in advanced stage.
- 6 GeV hadronization and color transparency physics programs are on track to be extended to 12 GeV as well.
- Dedicated analysis tools and manpower are in place to extract the physics.