RG-E Pion Multiplicity Ratio Updates

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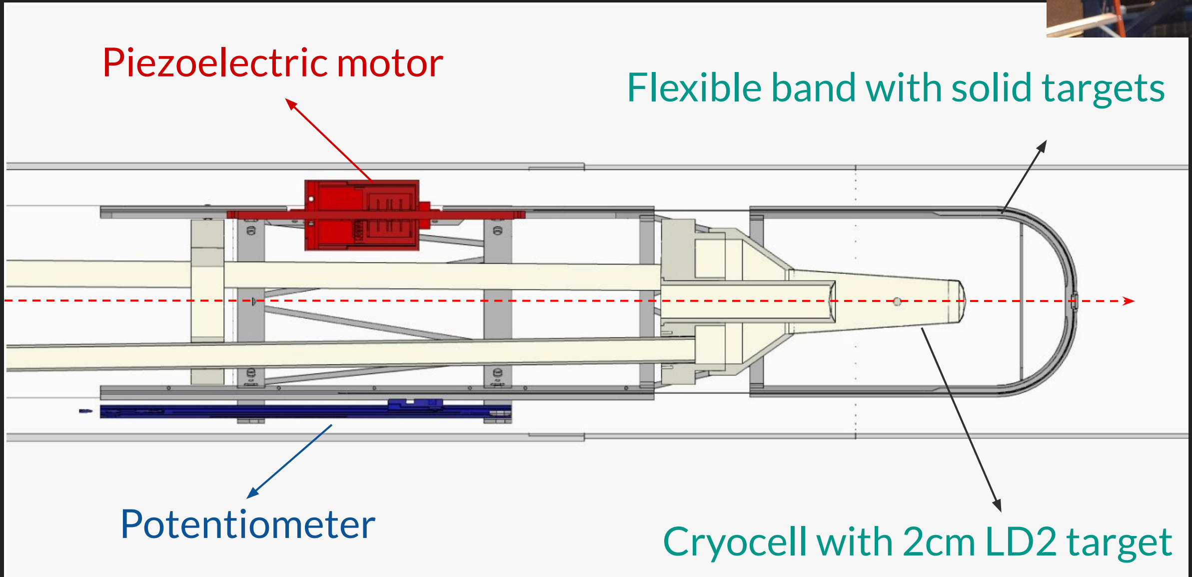
CLAS collaboration meeting
June 30th 2026

RG-E Double-target system



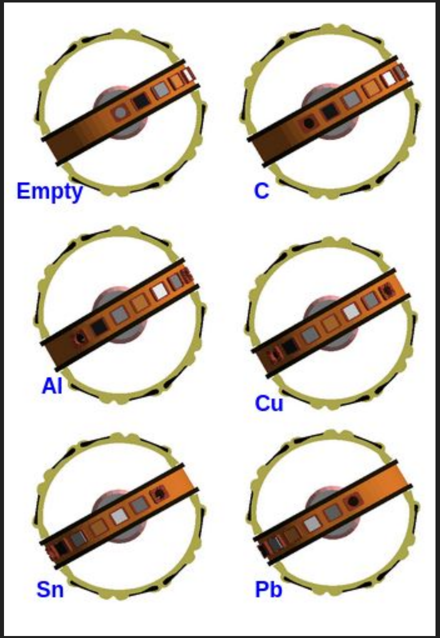
Solid target
- Carbon
- Aluminum
- Copper
- Tin
- Lead

Liquid target
- Deuterium

Run summary and data collected

- Data taken in Spring 2024 from March 15th to May 19th
- 10.547 GeV electron beam
- Standard CLAS12 configuration with FT-OFF
- Three layers of FMT
- ~93% of data taking with inbending torus polarity

Target	Production current (nA)	Accumulated charge (mC)	Integrated luminosity (1/fb) (Solid target)	Events
LD2+C	85	25.24	24.38	3,391,704,235
LD2+Al	70	20.53	24.23	2,445,718,954
LD2+Cu	75	21.46	22.42	2,488,996,497
LD2+Sn	65	27.6	21.58	2,754,243,416
LD2+Pb	70	46.84	26.76	4,631,998,074
C only	85	2.29	3.79	148,150,553
Pb only	160	4.98	2.84	23,516,294



Pass1 Cooking summary

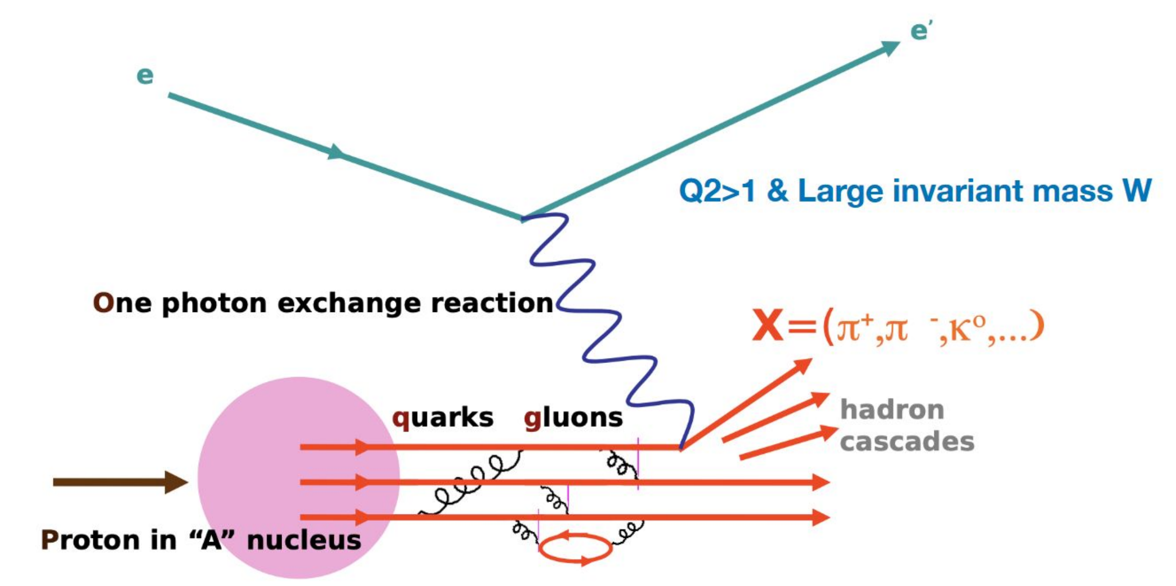
- Pass1 review on December 12th 2025
- Pass1 cooking started on April 1st 2026
- Pass1 finished cooking on May 11th 2026
- 381 Runs cooked
- Three trains included in the cooking:
  - Anti-proton
  - Lambda
  - Jpsi/TCS

```
ANTIP:
  forward: 11:-2212:X+:X-:Xn
 LAMBDA:
  forward: 11:2212:-211:X+:X-:Xn
 JPSITCS:
```

- Data location in tape:
  - /mss/clas12/rg-e/production/spring2024/pass1/

```
.
└── pass1/
    ├── torus-1/
    │   ├── C_D2
    │   ├── Al_D2
    │   ├── Cu_D2
    │   ├── Sn_D2
    │   ├── Pb_D2
    │   ├── C_only
    │   ├── Al_only
    │   ├── Pb_only
    │   └── empty
    ├── torus+1/
    │   ├── C_D2
    │   └── Pb_D2
    └── zero/
        └── empty
```

Semi-Inclusive Deep Inelastic Scattering (SIDIS)



ν: energy of the virtual photon (energy loss of the incoming electron).

Q2: square of four-momentum transferred.

Q2 > 1 GeV2: Deep process to look inside the structure of the nucleus.

W: invariant mass of the final state X.

W > 2 GeV: Inelastic. This cut removes the resonance region.

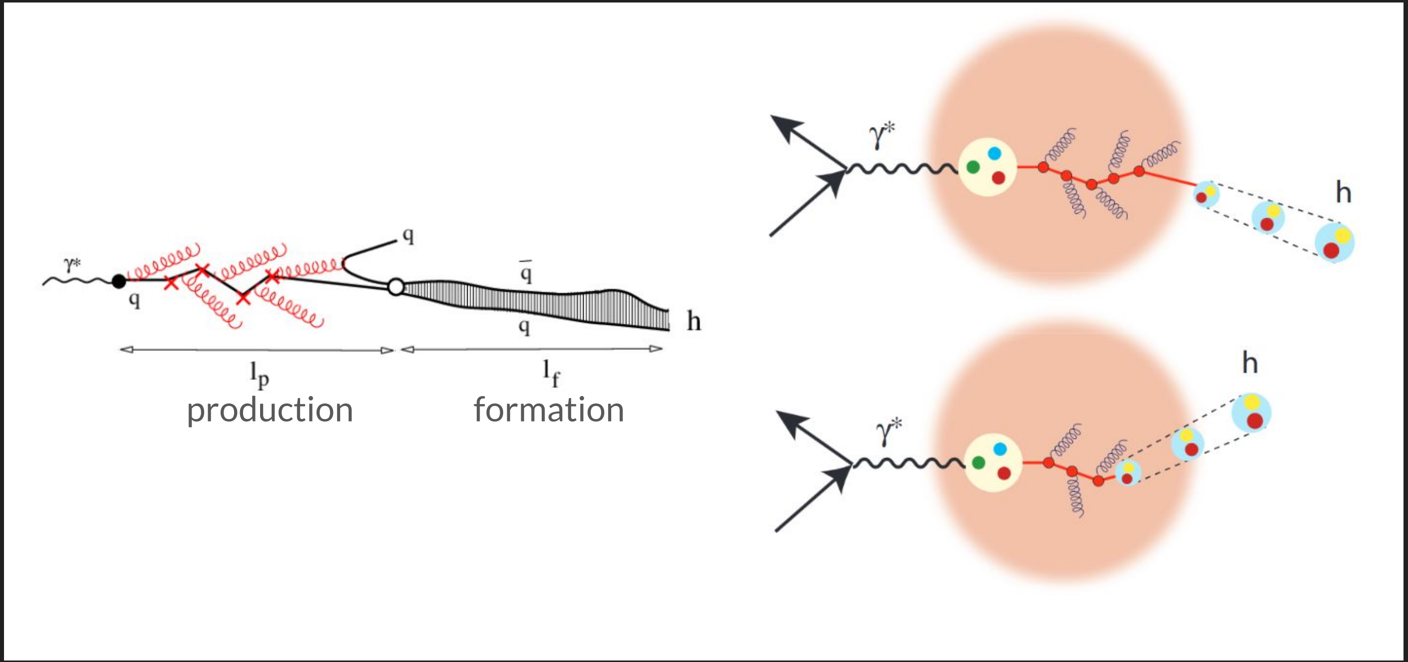
y: fraction of the energy of the initial electron transferred to the virtual photon.

y < 0.80: reduce radiative effects.

Zh: fraction of the virtual photon energy carried to the produced hadron.

Pt: transverse momentum of the hadron with respect to the virtual photon.

Hadronization in nuclear media

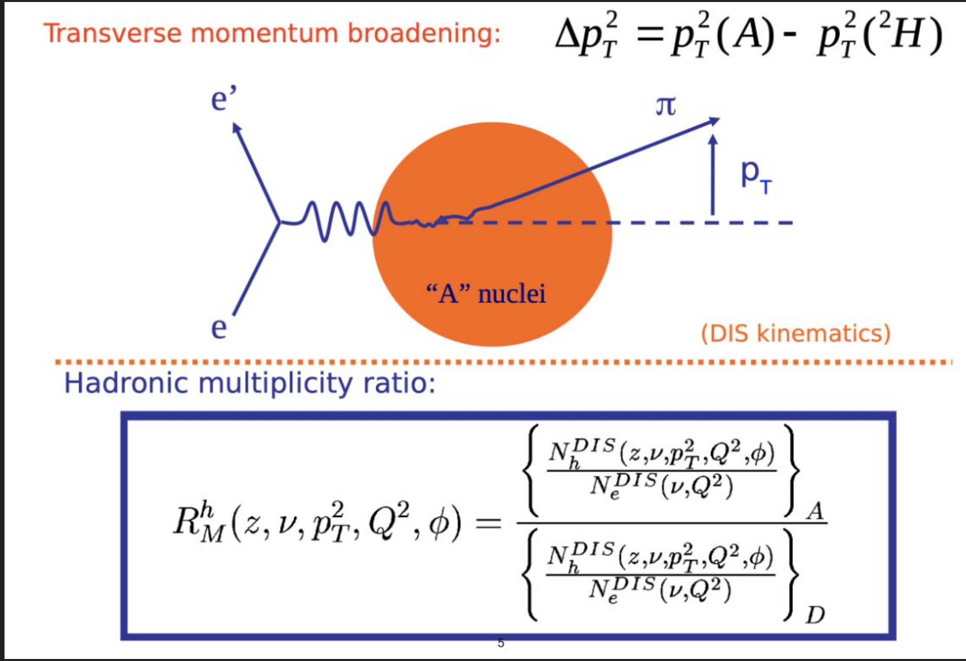


Prehadron formed **outside** the nucleus

Prehadron formed **inside** the nucleus

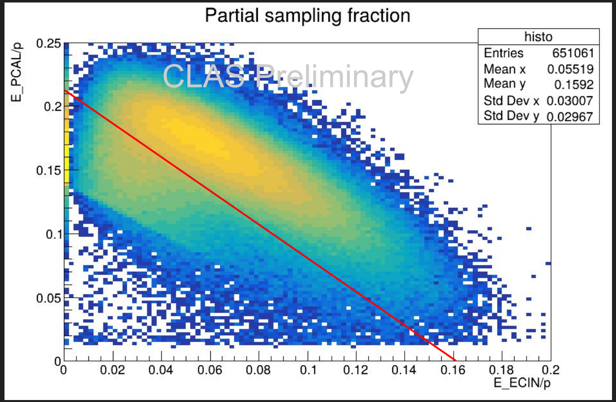
- l_p: production length. Quark propagates as a colored object.
- l_f: formation length. Color neutral prehadron propagates until becoming a final state hadron.

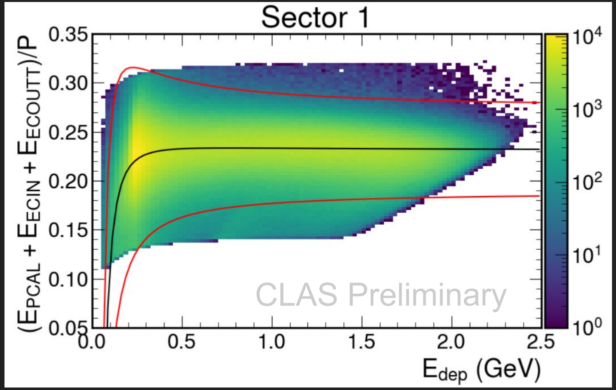
Physics and observables



Electron identification

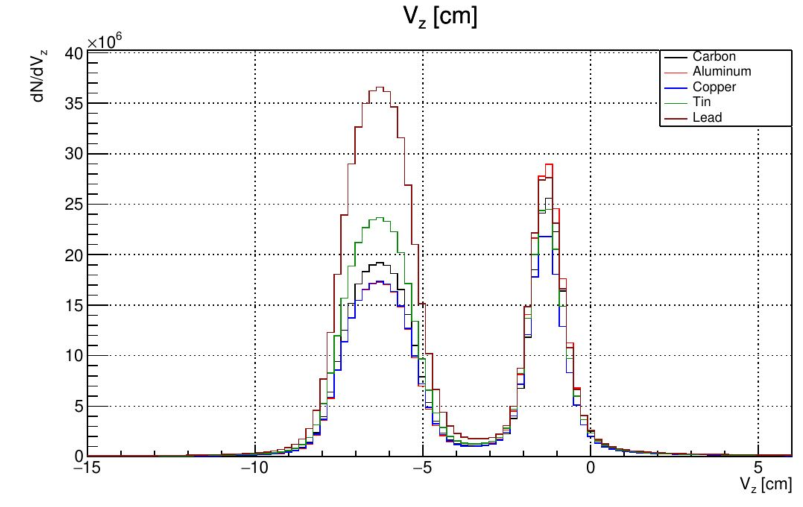
- Start from particles reconstructed as electrons in reconstruction software.
- DIS cuts:
  - Q2 > 1 GeV^2
  - W > 2 GeV
  - y < 0.8
  - $\theta > 5°$
- Fiducial cuts
  - PCAL V > 9 cm
  - PCAL W > 9 cm
  - DC R1 to edge > 4.5 cm
  - DC R2 to edge > 3.5 cm
  - DC R3 to edge > 7.5 cm
- Partial sampling fraction cuts per sector
- Sampling fraction cuts cuts per sector



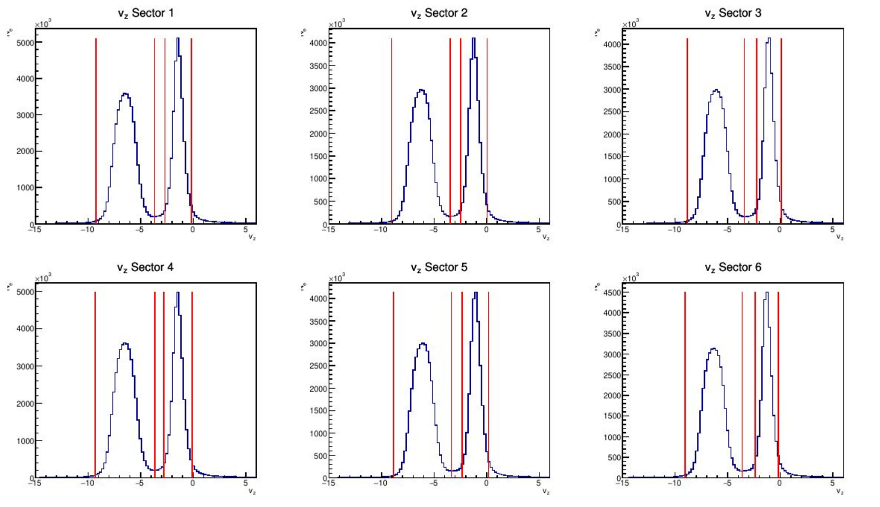


Electron vertex cuts

- Vertex cuts depending on sector
- Minimal difference in cuts between targets.



All targets
All sector combined



Sector by sector

Pion identification

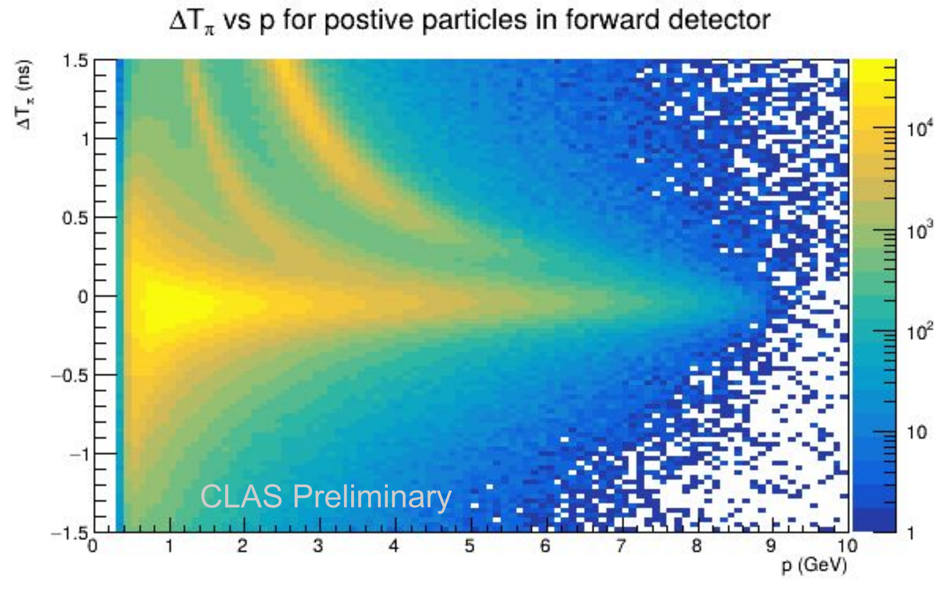
- Positive and Negative pions selection using similar approach.
- Start from particles reconstructed as pions in reconstruction software.
- From an DIS event with a valid trigger electron.
- Forward detector only.
- DC fiducial cuts
- Δ_{T} based cut refinement

p vs ΔTOF

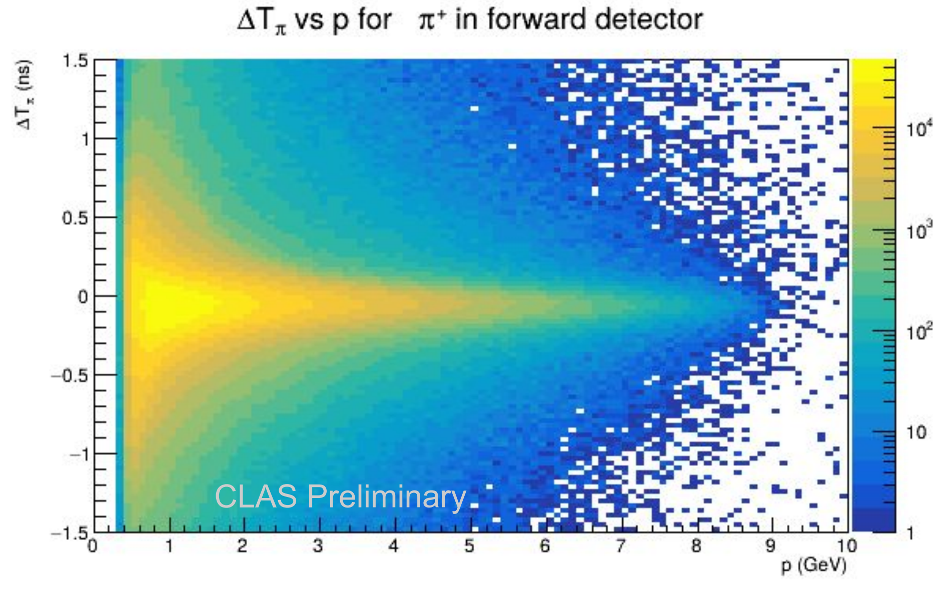
$\Delta T_{\pi+} = (T_{FTOF} - T_{start}) - (l_{path}/c \cdot \beta_{\pi+})$

measured time — theoretical time

$\beta_{\pi+} = p/\sqrt{(p^2+m^2_{\pi+})}$



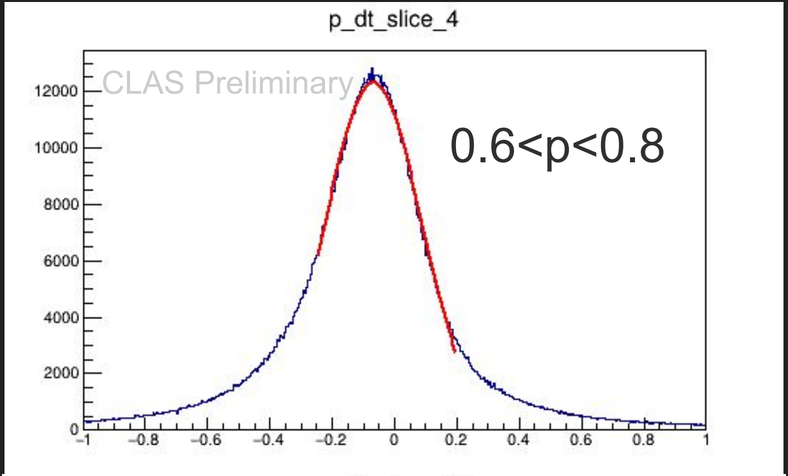
All positives

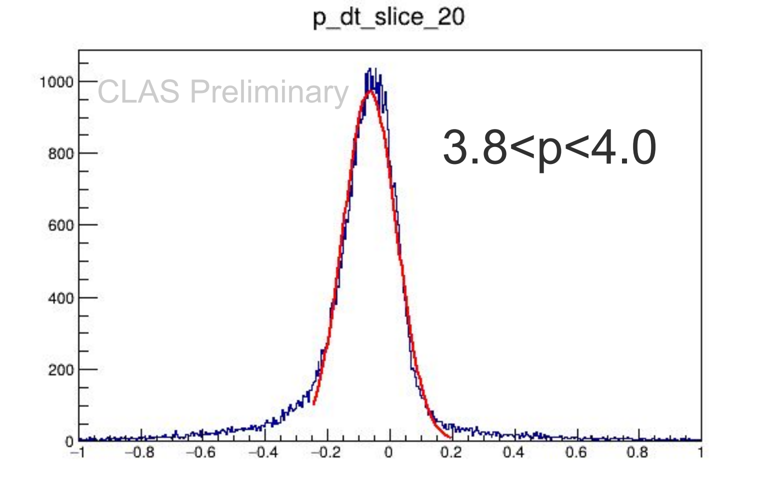


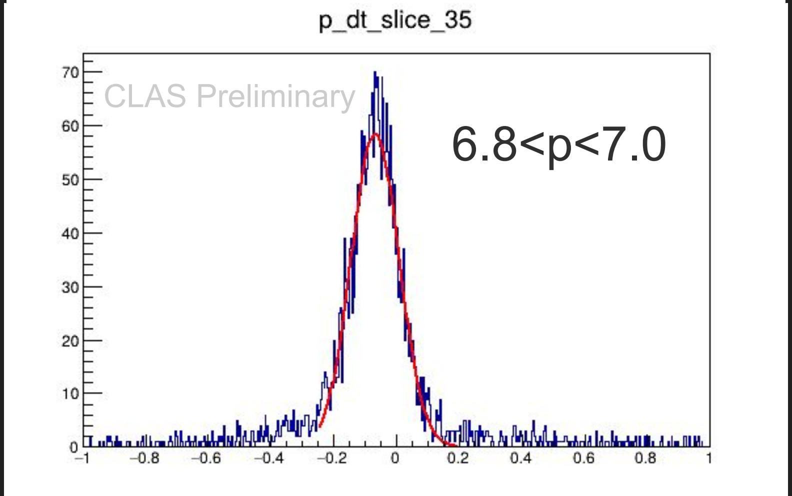
π+ (pid = 211 from reconstruction)

Cut procedure

- Divide $\Delta T_{\pi+}$ vs p in 45 bins from 0 to 9 GeV
- Fit each bin with a gaussian fit
- Extract μ and σ from the fit







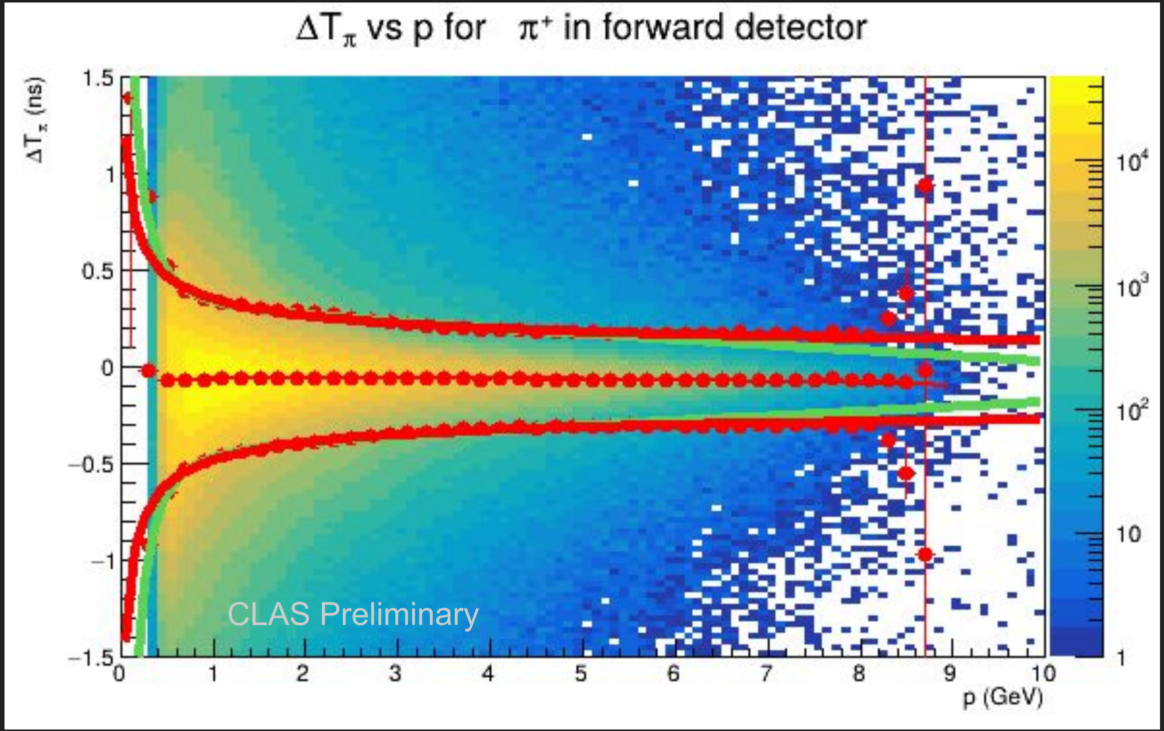
Final ΔT cut

- In each p bin sum $\mu \pm 3\sigma$
- Fit upper and lower point with functions:

➔ $(-)\sqrt{s^2 + \left(\frac{k}{p}\right)^2} + c \cdot p$

➔ $(-)\sqrt{a^2 + \left(\frac{b}{p^\alpha}\right)^2}$

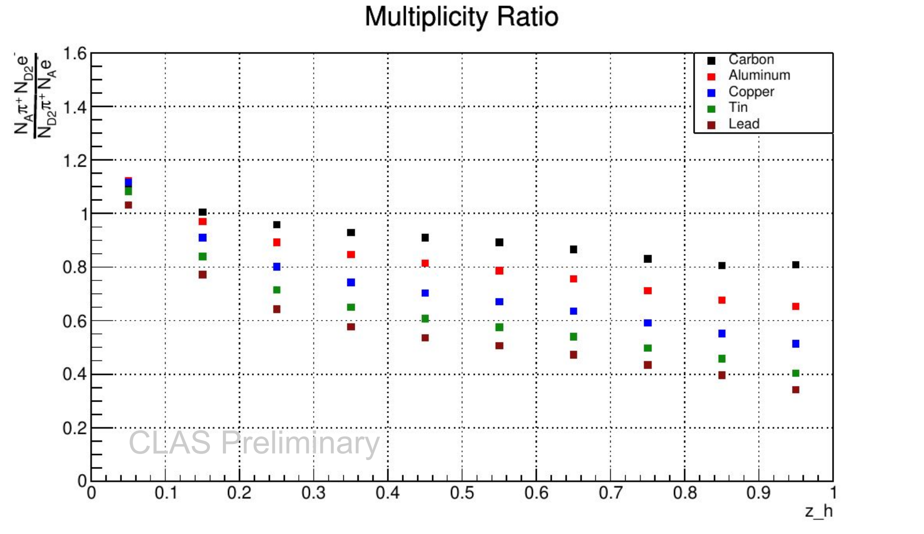
- Where (-) is for lower bound
- The second function was selected for final cuts



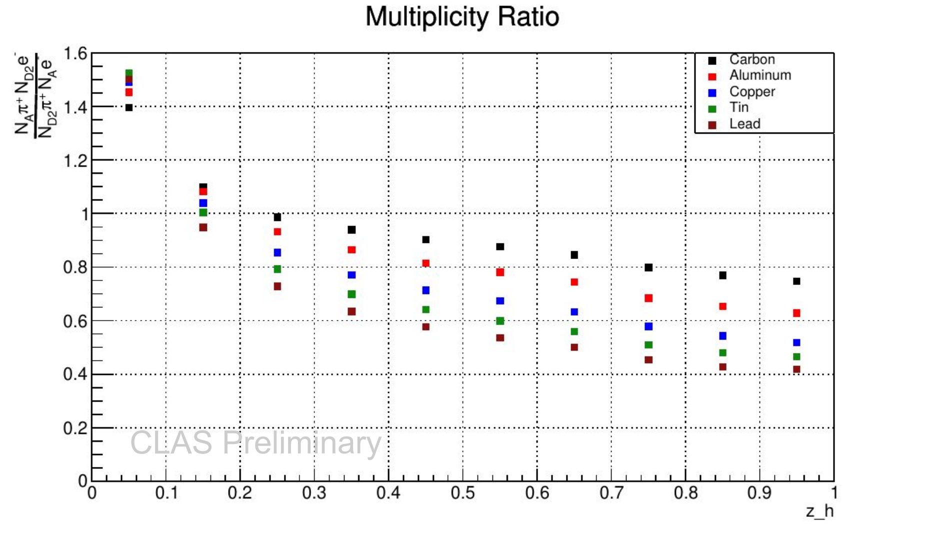
Total number of DIS electrons and pions

Target Configuration	DIS Electrons		Positive pions		Negative pions	
	D2	Solid	D2	Solid	D2	Solid
D2+C	2.3×10^8	1.5×10^8	8.5×10^7	5.5×10^7	3.7×10^7	2.5×10^7
D2+Al	2.1×10^8	1.7×10^8	7.8×10^7	5.9×10^7	3.3×10^7	2.7×10^7
D2+Cu	2.1×10^8	1.3×10^8	7.8×10^7	4.1×10^7	3.4×10^7	1.9×10^7
D2+Sn	2.8×10^8	1.5×10^8	1.1×10^8	4.3×10^7	4.6×10^7	2.1×10^7
D2+Pb	4.4×10^8	1.7×10^8	1.6×10^8	4.3×10^7	7.1×10^7	2.2×10^7

Multiplicity Ratio studies - Zh

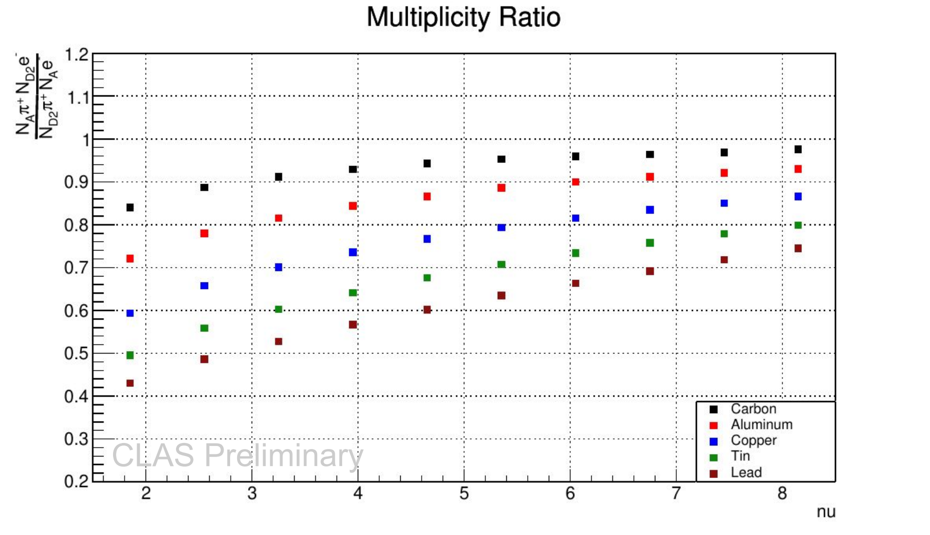


Positive pions

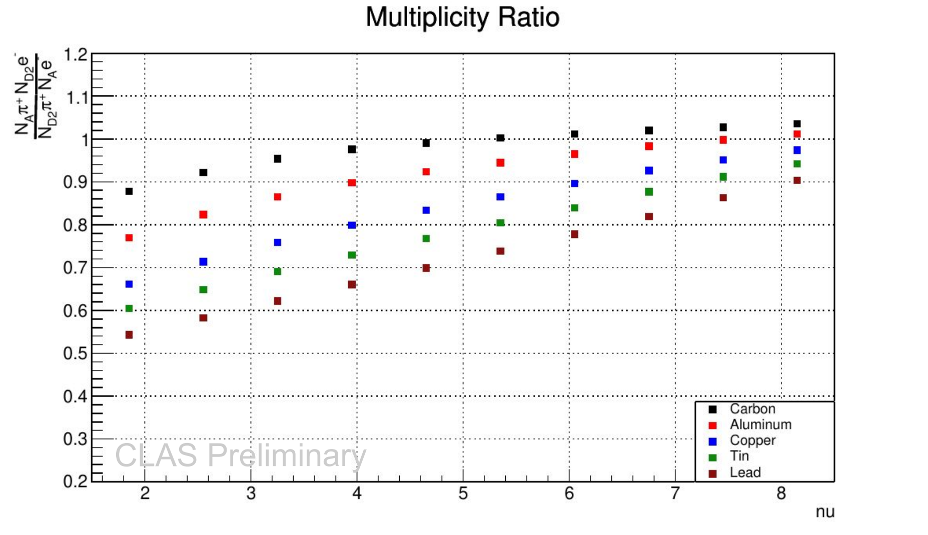


Negative pions

Multiplicity Ratio studies - Nu

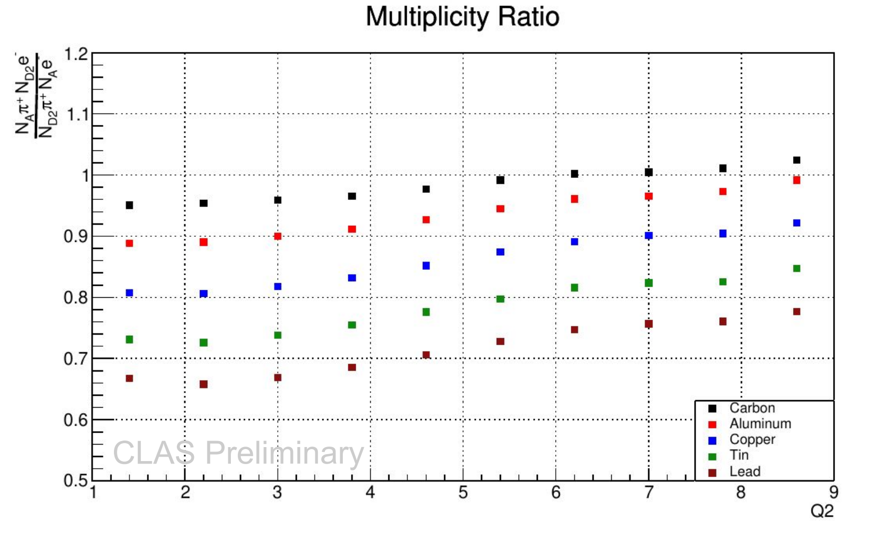


Positive pions

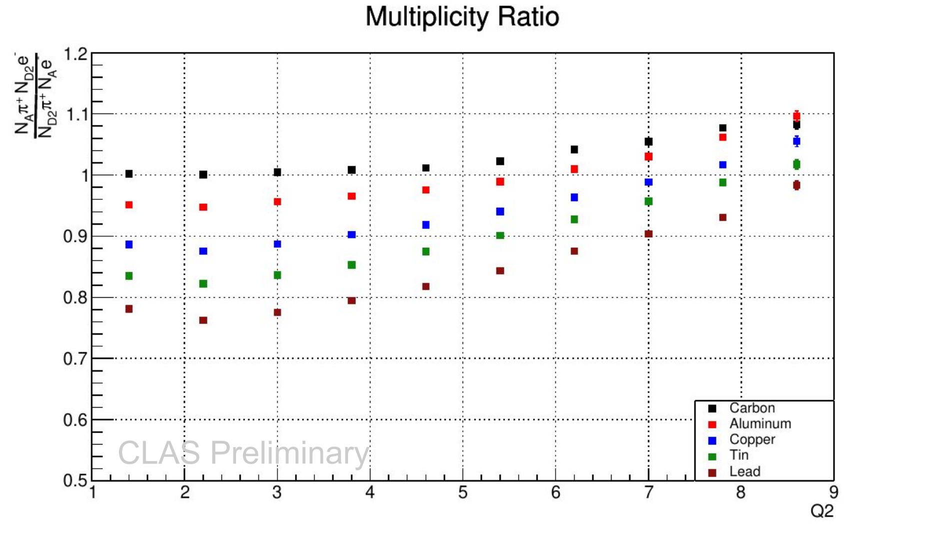


Negative pions

Multiplicity Ratio studies - Q2

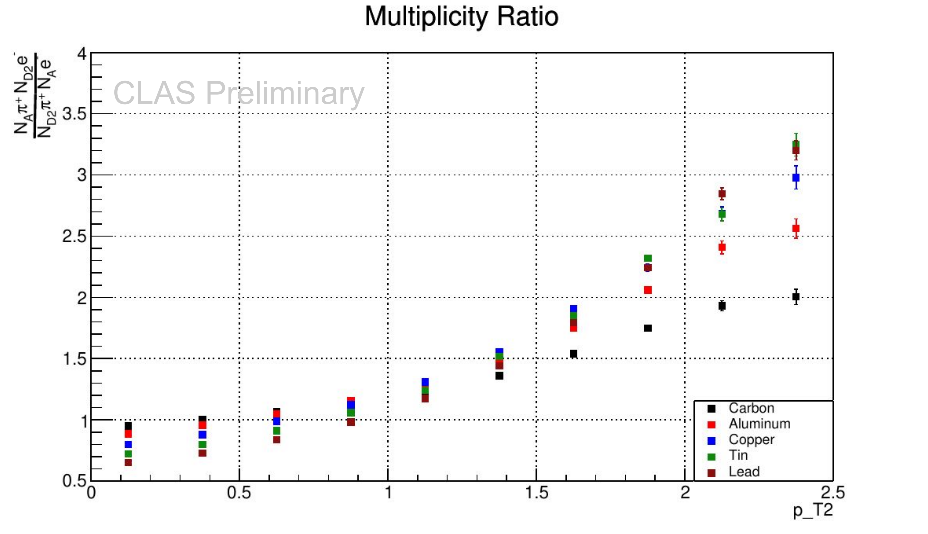


Positive pions

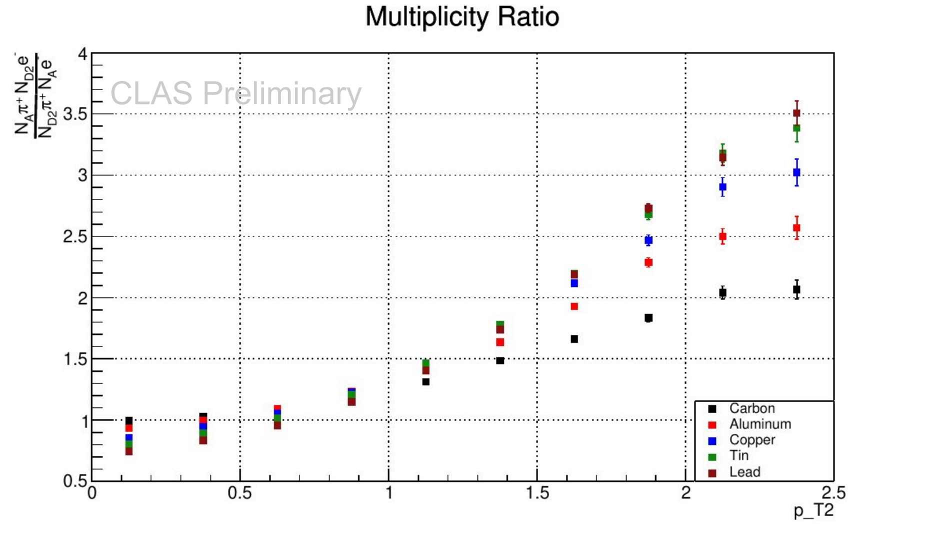


Negative pions

Multiplicity Ratio studies - Pt2

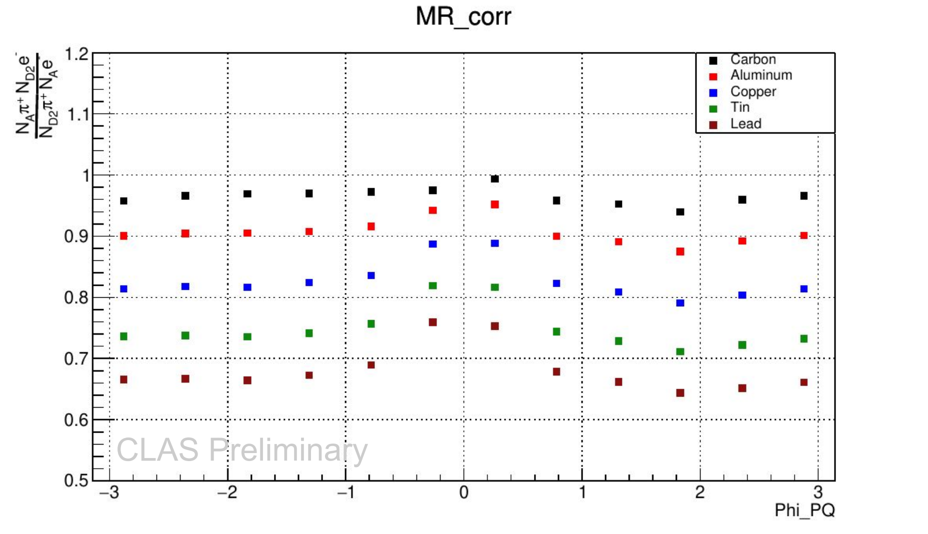


Positive pions

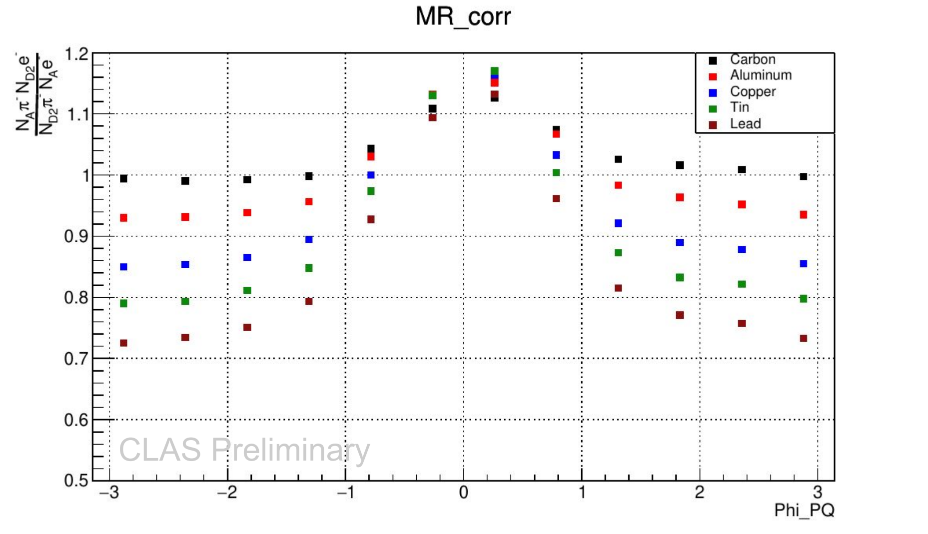


Negative pions

Multiplicity Ratio studies - PhiPQ

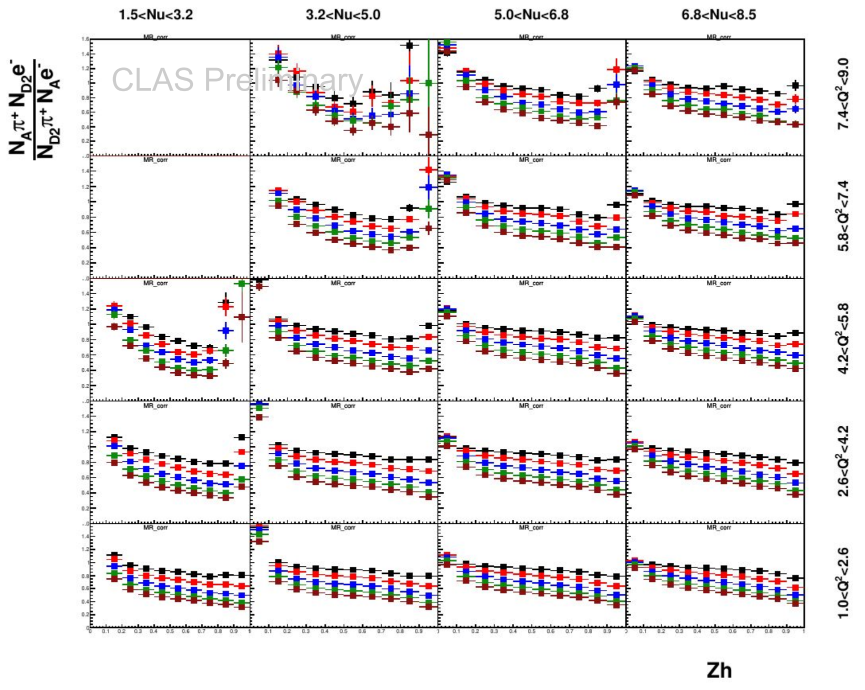


Positive pions

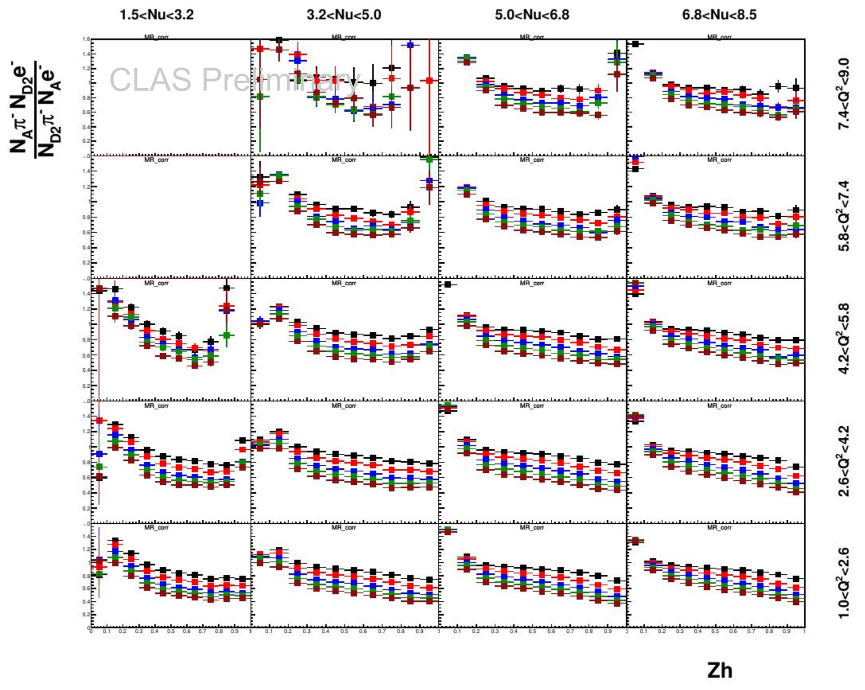


Negative pions

Multiplicity Ratio studies - Multibinning Zh

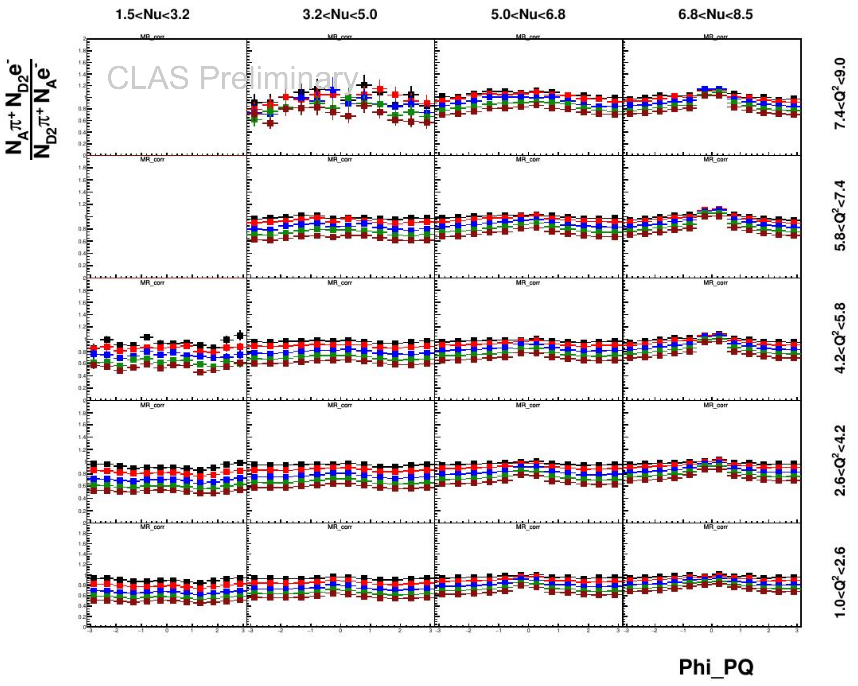


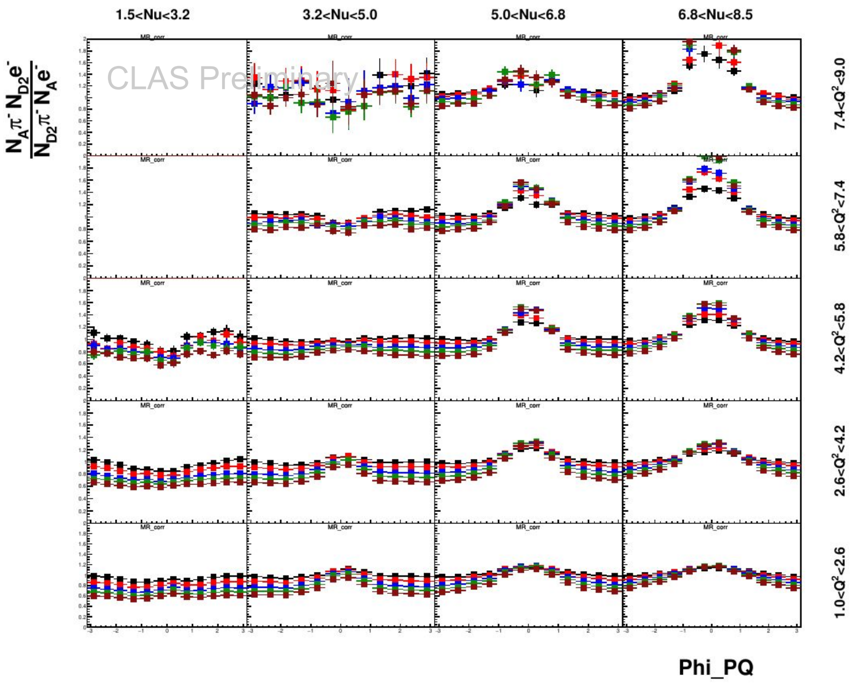
Positive pions



Negative pions

Multiplicity Ratio studies - Multibinning PhiPQ





Positive pions

Negative pions

TO DO

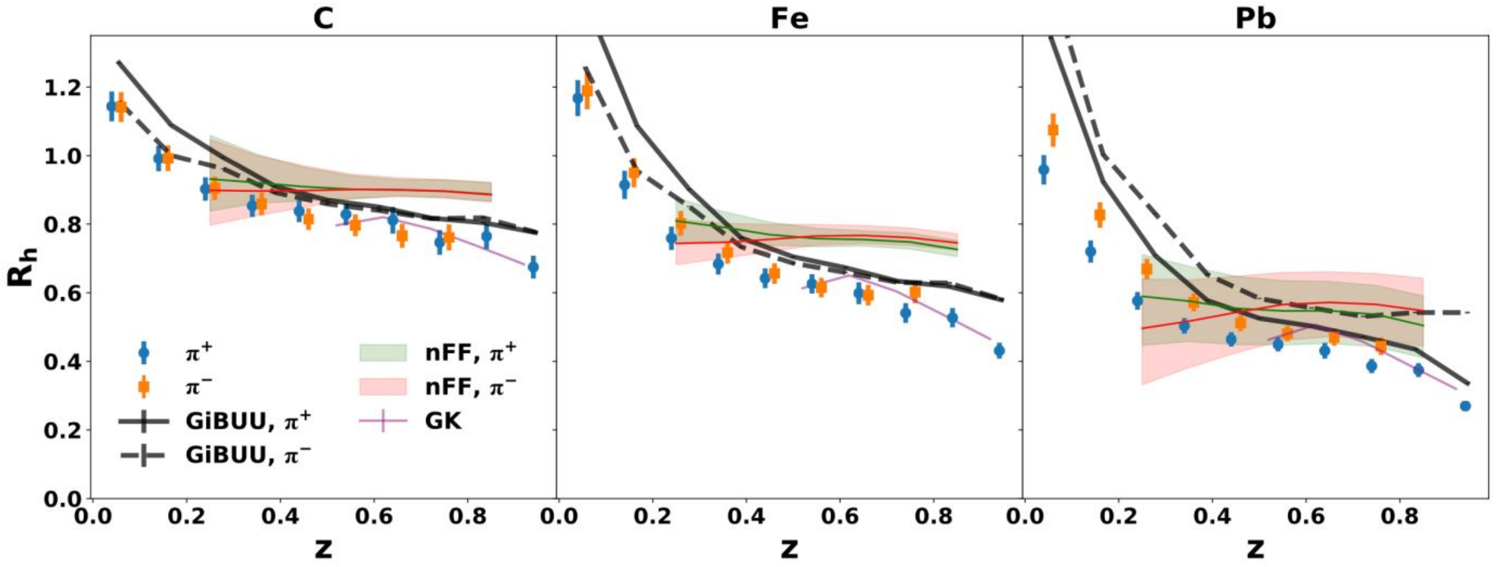
- Final refinement of selection cuts
- Create simulations for Acceptance corrections
- Include Radiative corrections
- Include Coulomb corrections
- Redo the analysis for outbending data
- Look at central detector pions
- Compare results with CLAS6 data

Summary

- The pass1 cooking for the RG-E dataset is completed
- Preliminary cuts for electron and pion selection were developed
- MR preliminary results with the full inbending FD dataset were presented
- Statistics allow MR studies for charged pions in one and multidimensional binning
- Corrections must be applied and outbending dataset has to be studied

BACK UP - Multiplicity Ratio CLAS6 results

Charged pions - multiplicity ratio



S. Moran, et al. (CLAS collaboration). Phys. Rev. C **105**, 015201 – January, 2022