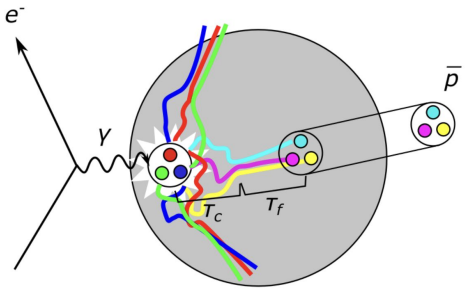
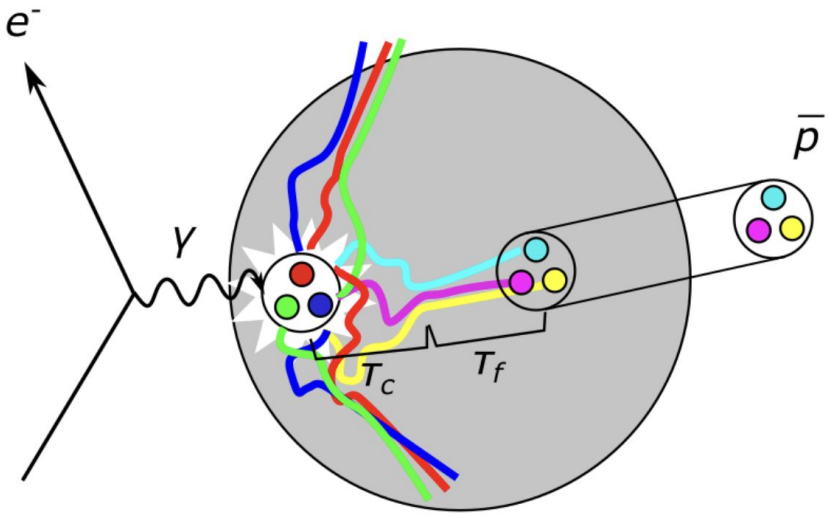
Antiproton production in eA scattering with CLAS12 RG-E data

Sebouh Paul
Old Dominion University
11/18/2026



Why antiprotons?

- Antiproton production in eA scattering acts as a baseline to compare analogous studies on baryon production to.
  - Antiprotons cannot be produced from struck diquarks, unlike p, n, Λ
  - Antiprotons don’t already exist in nucleus so no background from secondary knockout, unlike p, n

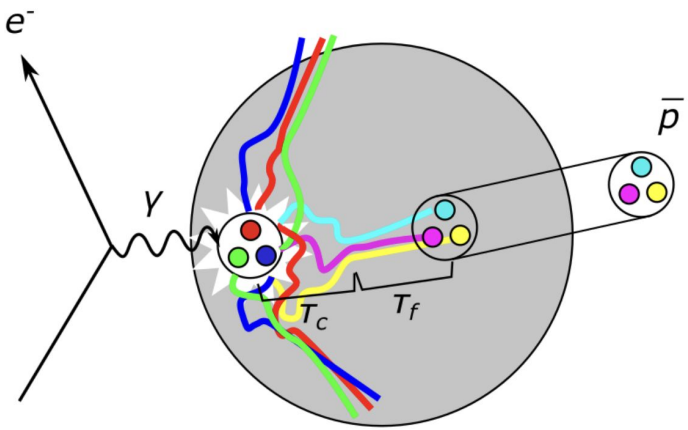


Observables

- Multiplicity ratio $R_h = \frac{(N_{e'h}/N_{e'})^A}{(N_{e'h}/N_{e'})^D}$
  - Probes the attenuation of hadrons in nucleus through absorption (or in this case, also annihilation)
  - Also sensitive to secondary production
- Transverse-momentum broadening

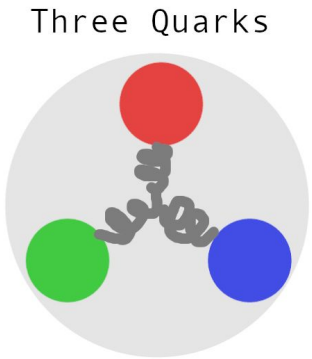
$$\Delta\langle p_T^2\rangle = \langle p_T^2\rangle_A - \langle p_T^2\rangle_D$$

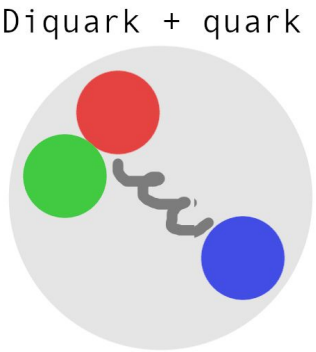
  - Probes how much the forming hadron undergoes multiple scattering

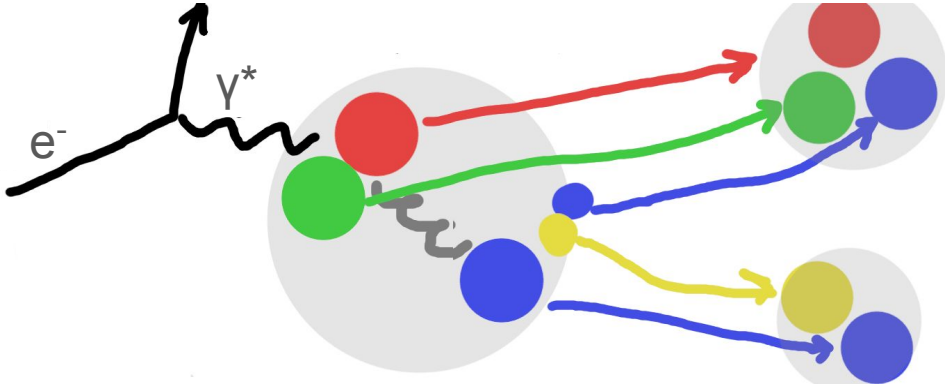


Diquark

- Pair of quarks that act as a combined entity, in a diquark+quark configuration
- Can theoretically be struck by a virtual photon, and then recombine with a quark in the hadronization process.
  - Could be faster than producing a baryon from 3 independent (anti)quarks
  - May effect the cross sections of the hadronization reactions

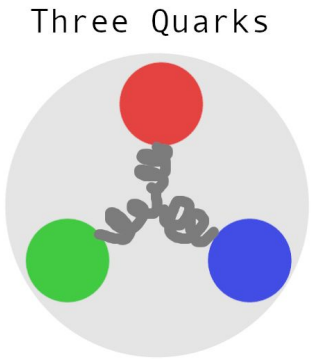


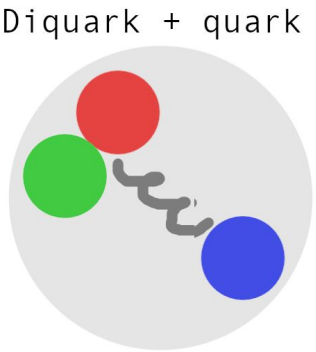


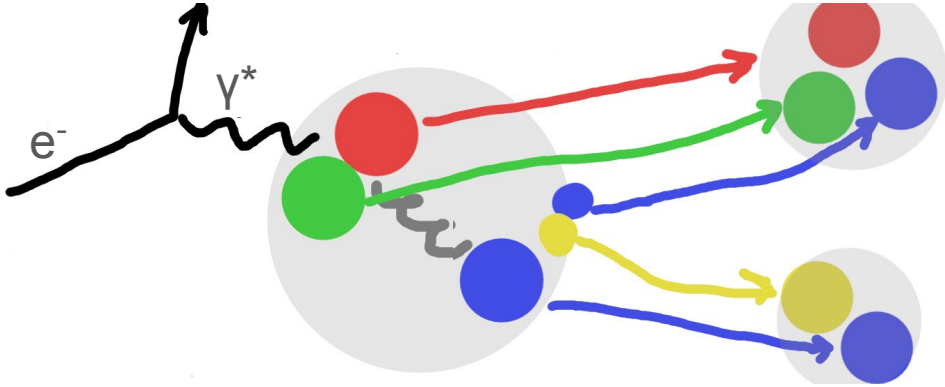


Diquark

- ud diquark in proton could be struck, producing either a p, n, Λ^0 or Λ_c^+
- Diquark is a massive colored object with spatial extent, therefore it would interact more strongly with nucleus in the color phase
    - This could cause more transverse momentum broadening for these baryons than for antibaryons and mesons







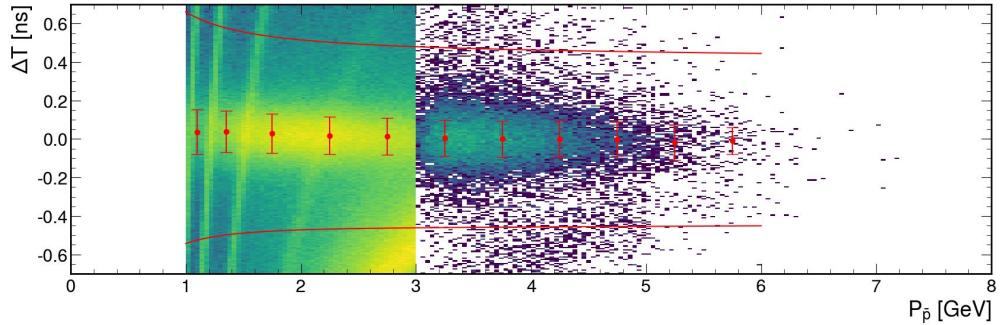
Selection criteria

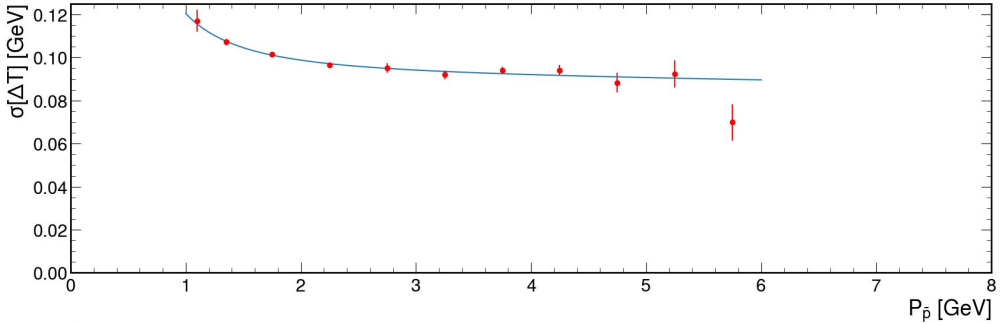
- Dataset:
  - RGE, inbending data
- Basic cuts:
  - Electron calorimetry and vertex cuts from RGE common analysis note
  - Electron momentum > 1.6 GeV
  - DIS cuts: $Q^2>1$ GeV^2, $y<0.85$, $W> 2$ GeV
  - $|v_{z,e}-v_{z,h}|<3$ cm
  - Fiducial cuts for electrons same as those for IB configuration in RG-D.
  - Fiducial cuts in DC for anti-p same as those for π- in IB configuration in RG-D.
- For P>3 GeV (above RICH threshold):
  - Mass reconstructed using RICH between 0.75 and 1.3 GeV
  - At least 3 photoelectrons in RICH
  - RICH RQ>0.3 (tightened to RQ>0.4 for P>5 GeV)

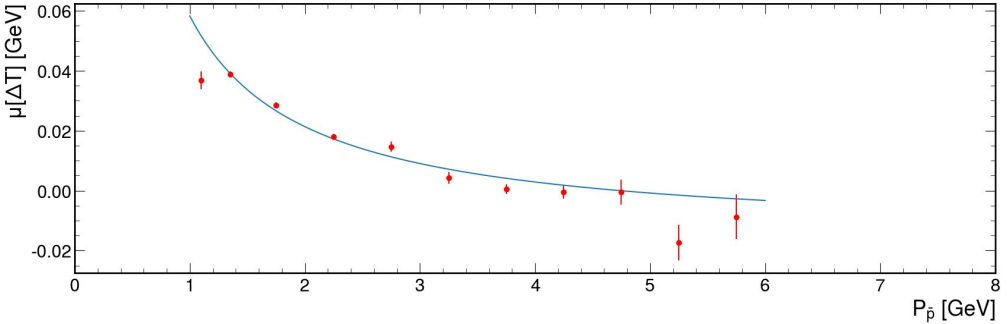
Timing resolution

Extracted ΔT resolution within slices in p using gauss+poly fit.

Assign $z_{\Delta T}=(\Delta T-\mu(P))/\sigma(P)$ for each event.



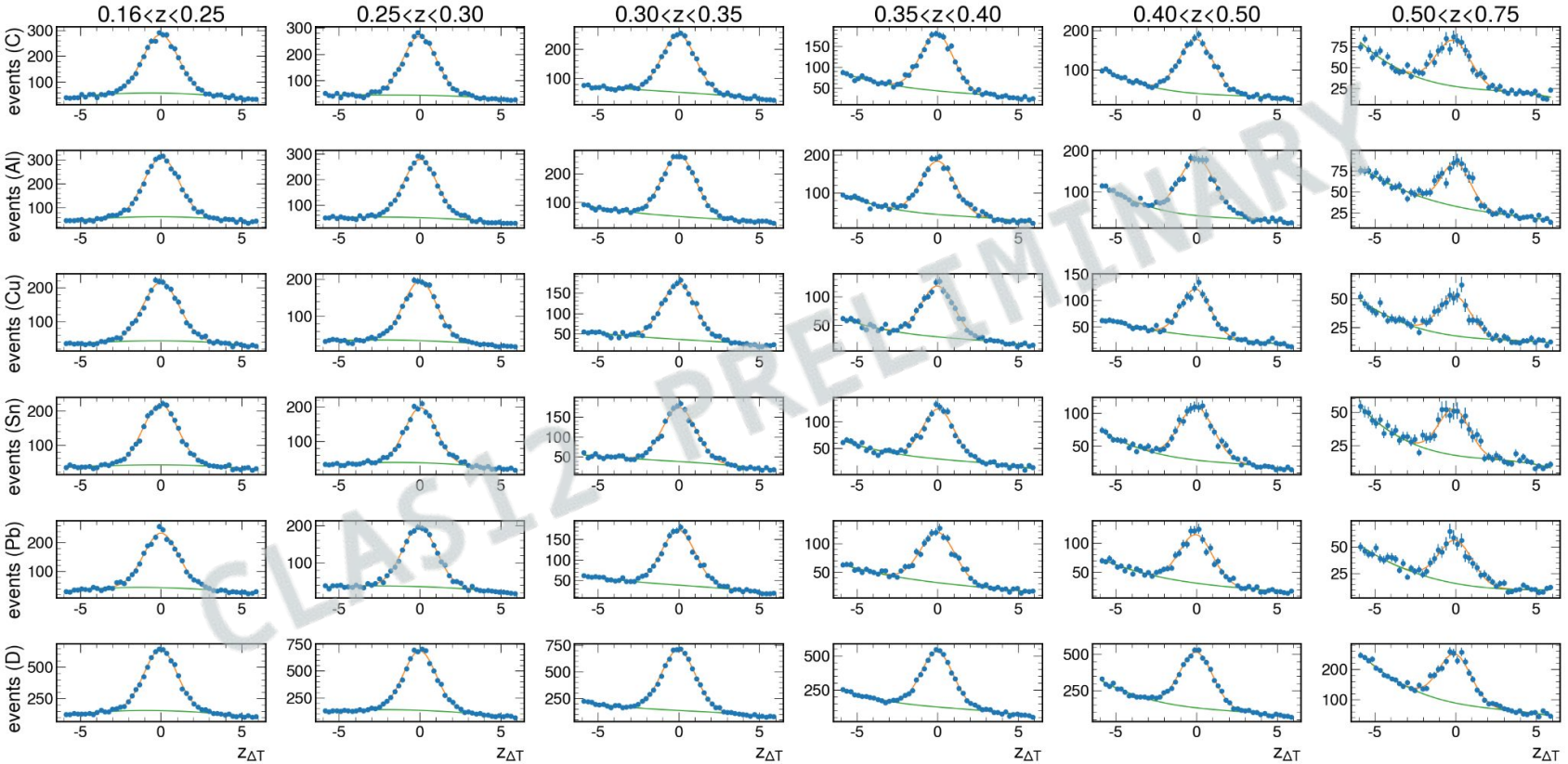




Extraction of the yields

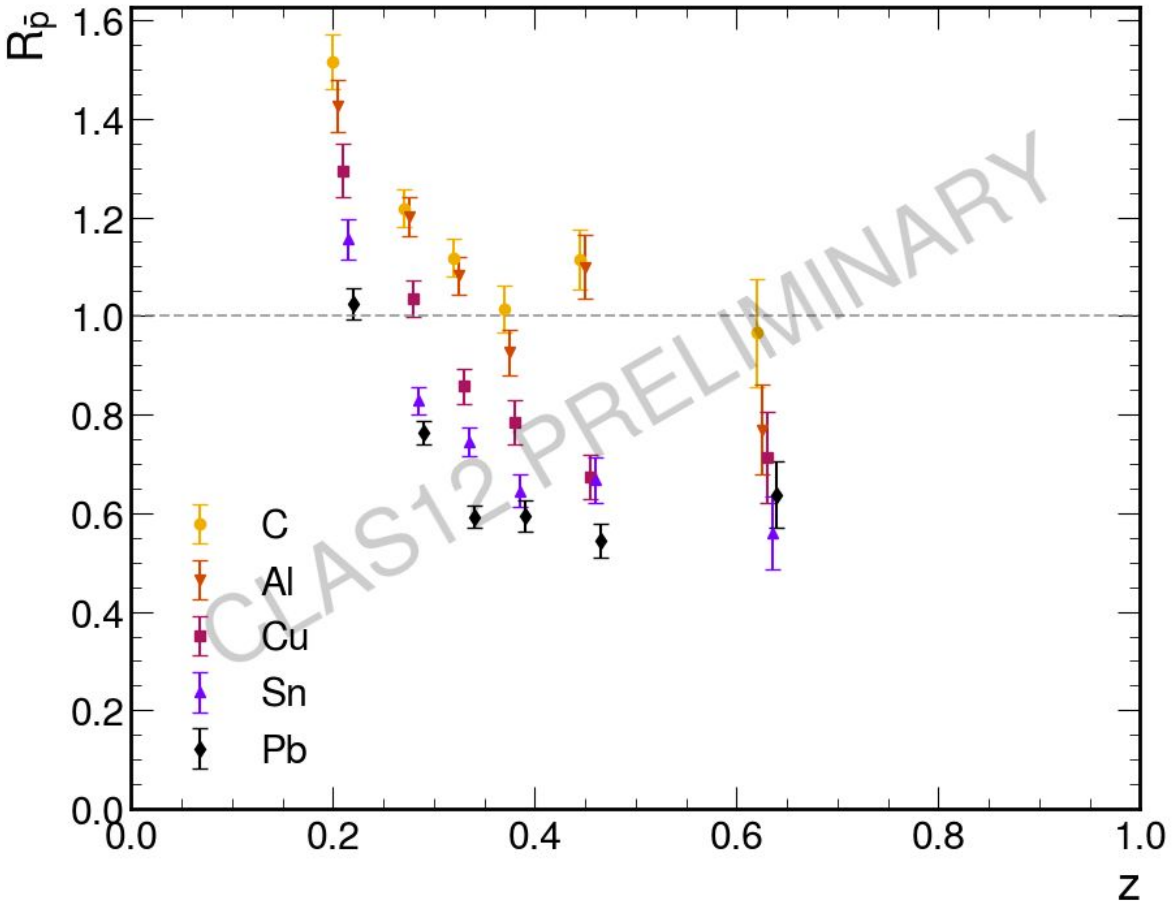
Within each kinematic bin, we fit the distributions of the $z_{\Delta T}$ to a gaussian+3rd order poly, and then take the area of the gaussian part of the fit.

Events above RICH threshold are weighted 3x as much due to fewer sector coverage



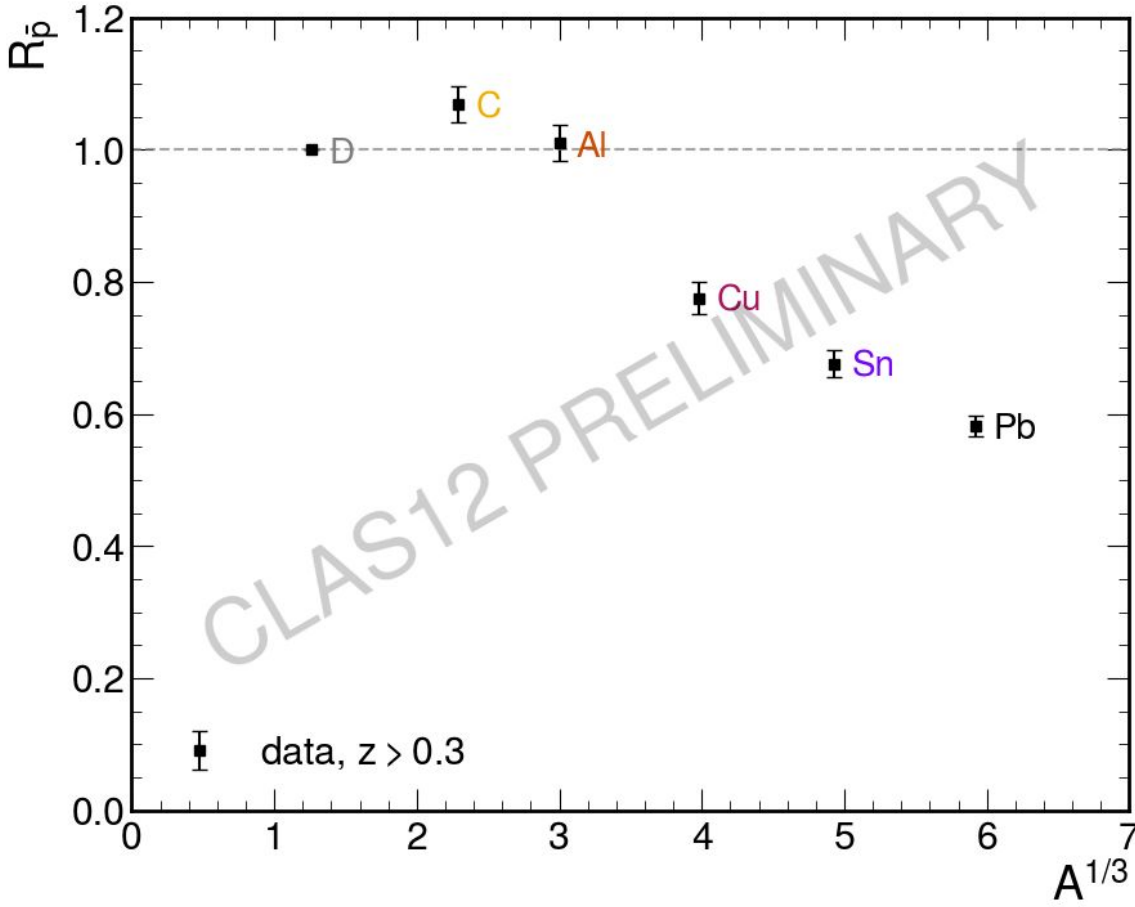
Multiplicity ratio vs z

- $z=E_h/v$
- Aluminum and carbon have multiplicity ratios close to one for z>0.3
- Multiplicity ratio decreases with larger z and with larger nuclear sizes



Integrated over z>0.3

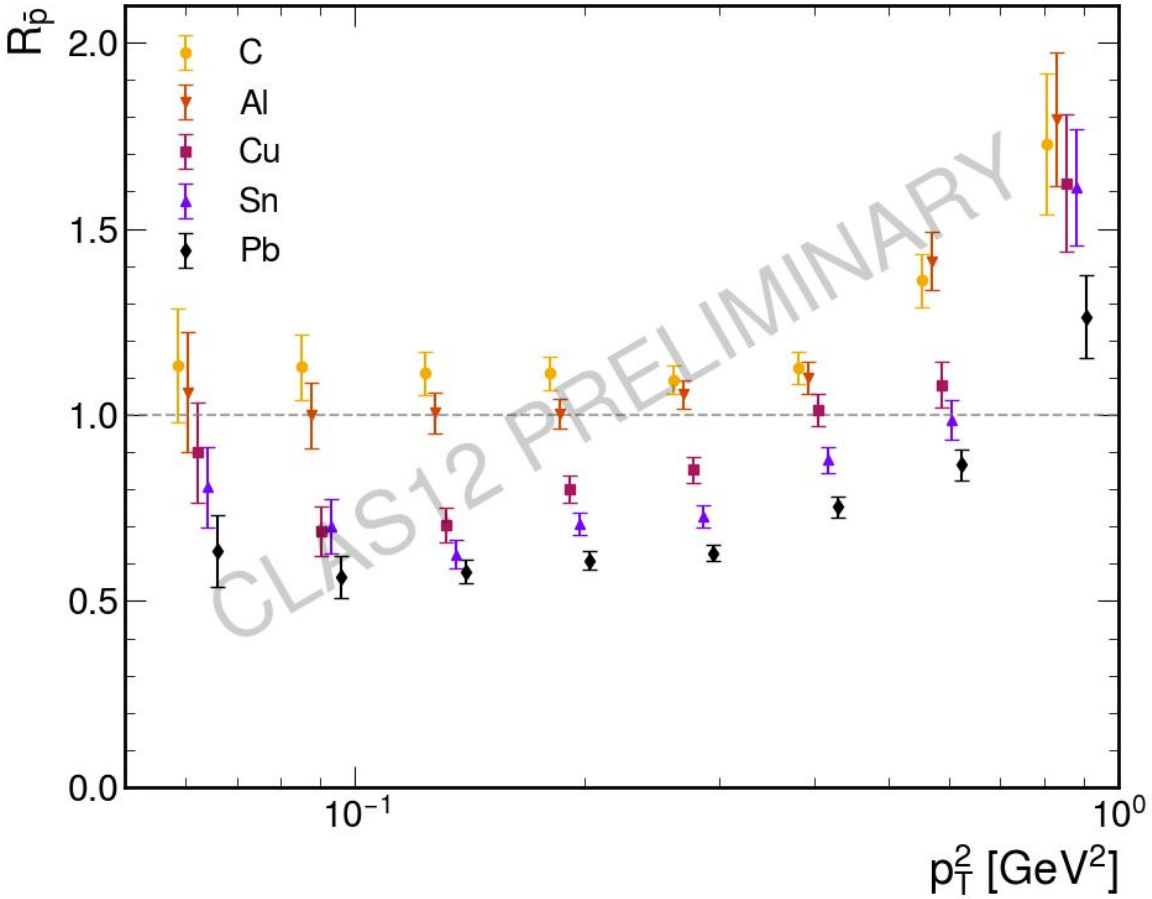
- Why is the ratio for aluminum close to 1?
- Maybe the distance it takes to fully form (and be able to subsequently annihilate with a bound proton) is in between the diameter of an aluminum and a copper nucleus?



Multiplicity ratio vs p_T^2

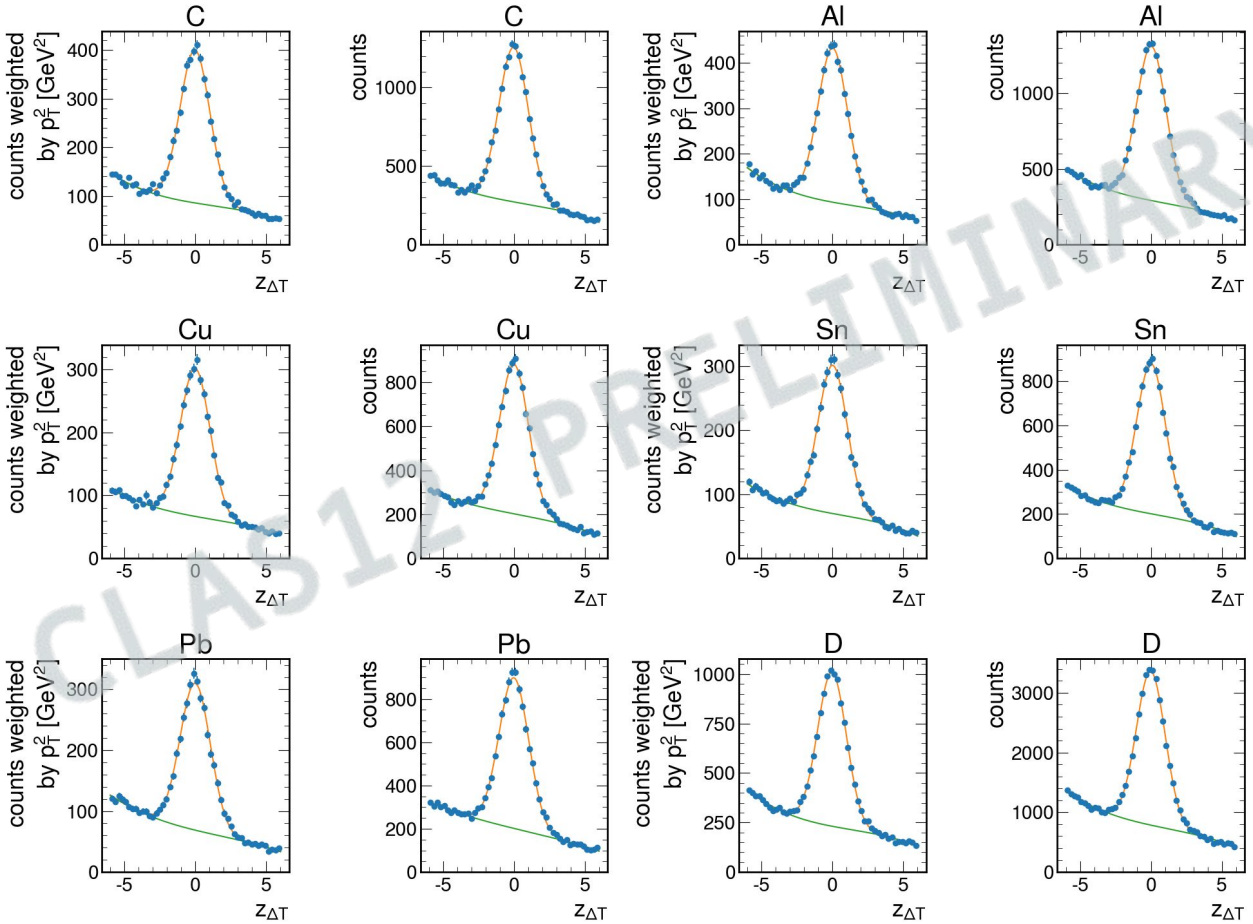
High p_T^2 events are more common for heavy nuclei than for deuterium.

Similar to trends seen for other hadrons.



p_T^2 broadening

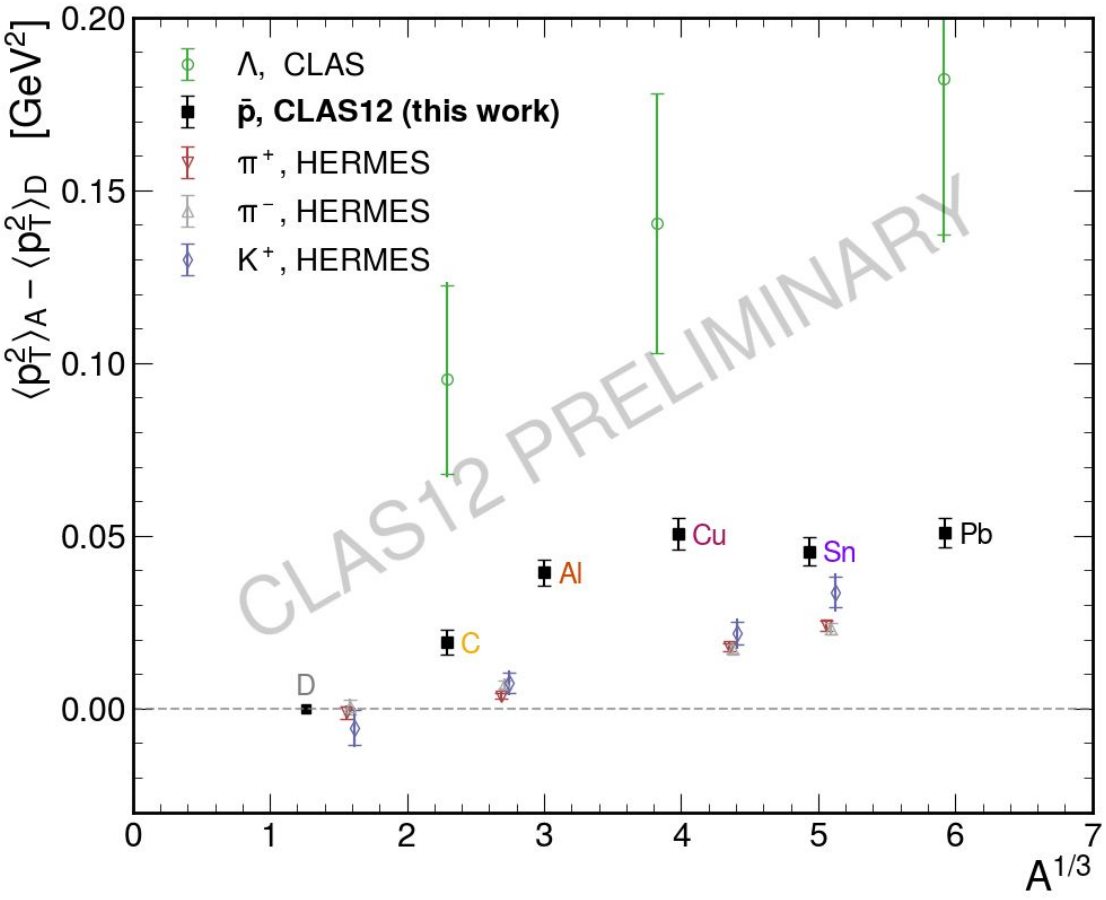
- To get the $\langle p_T^2 \rangle$, create a histogram of the distribution of $z_{\Delta T}$, with the events weighted by p_T^2 and the sector-multiplicity factor
- fit this to a gaussian + poly, and take the area of the gaussian.
- divide by the event count yield described earlier.



CLAS12 PRELIMINARY

p_T^2 broadening

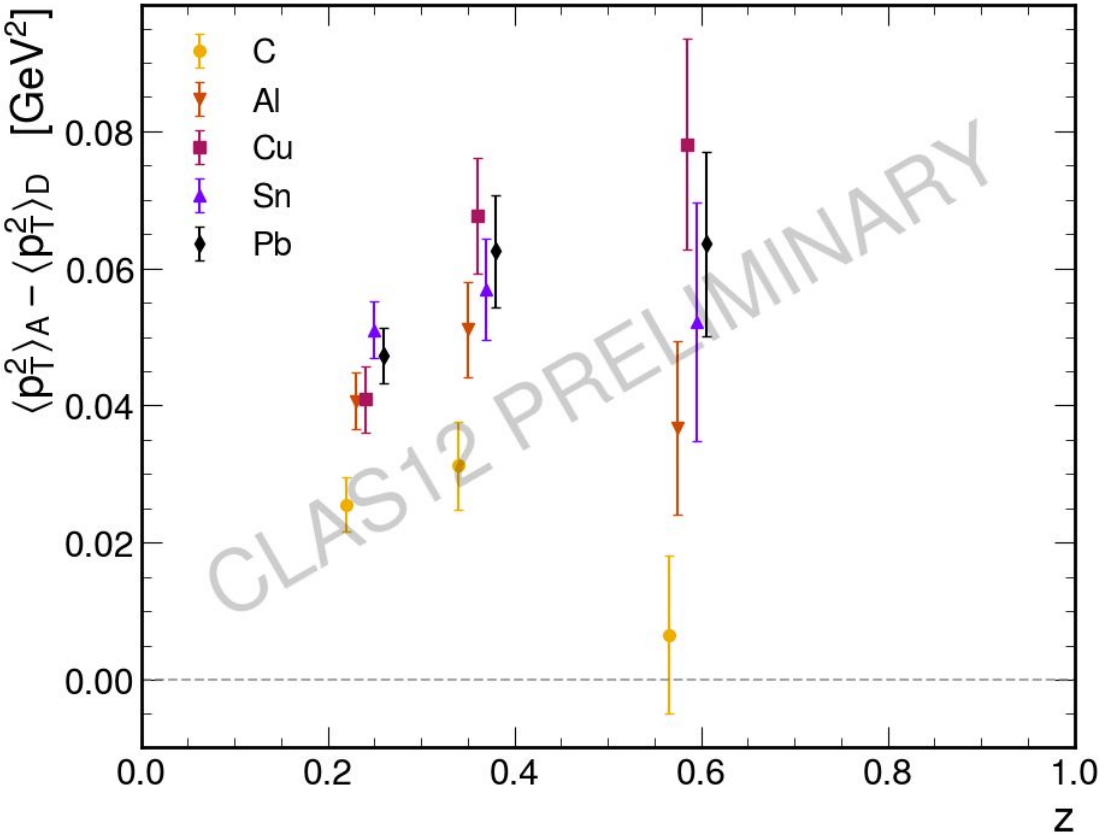
- $\Delta\langle p_T^2\rangle$ for antiprotons is in between that of mesons and lambda baryons.
- Slope abruptly diminishes between aluminum and copper



Light mesons, HERMES:
http://dx.doi.org/10.1016/j.physletb.2010.01.020
Λ baryons, CLAS:
https://doi.org/10.1103/PhysRevLett.130.142301

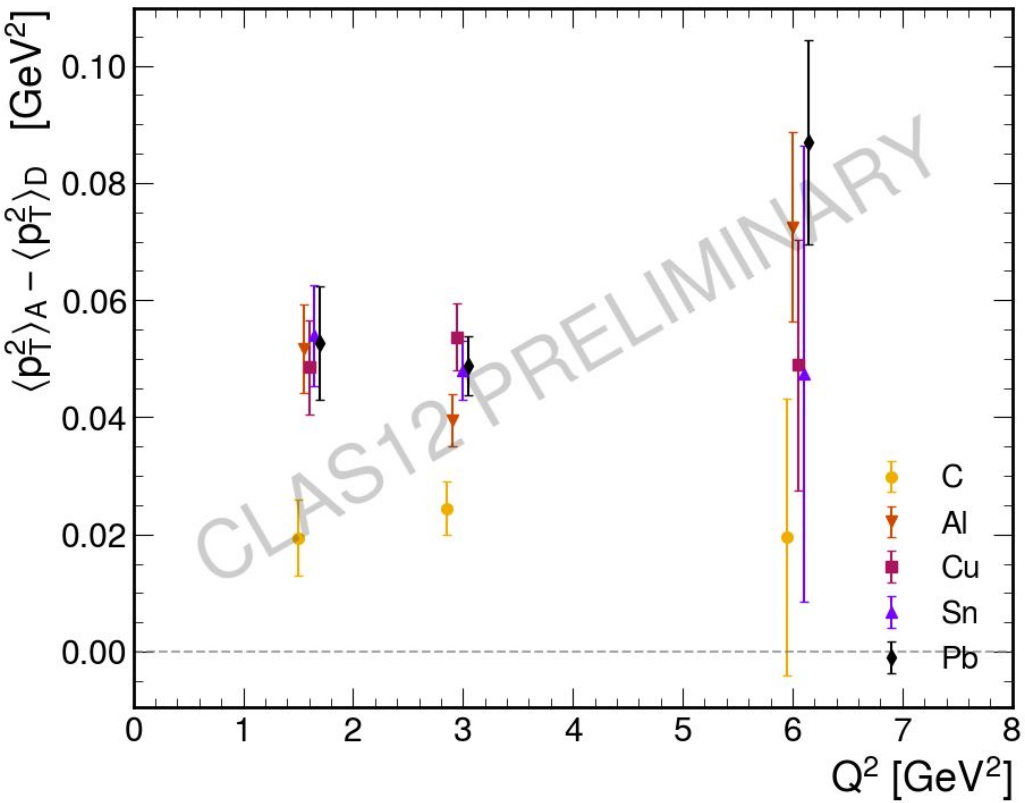
p_T^2 broadening vs z

- Dependence on z observed, but statistics are limited.



p_T^2 broadening vs Q^2

- No clear Q^2 dependence with the statistical precision available



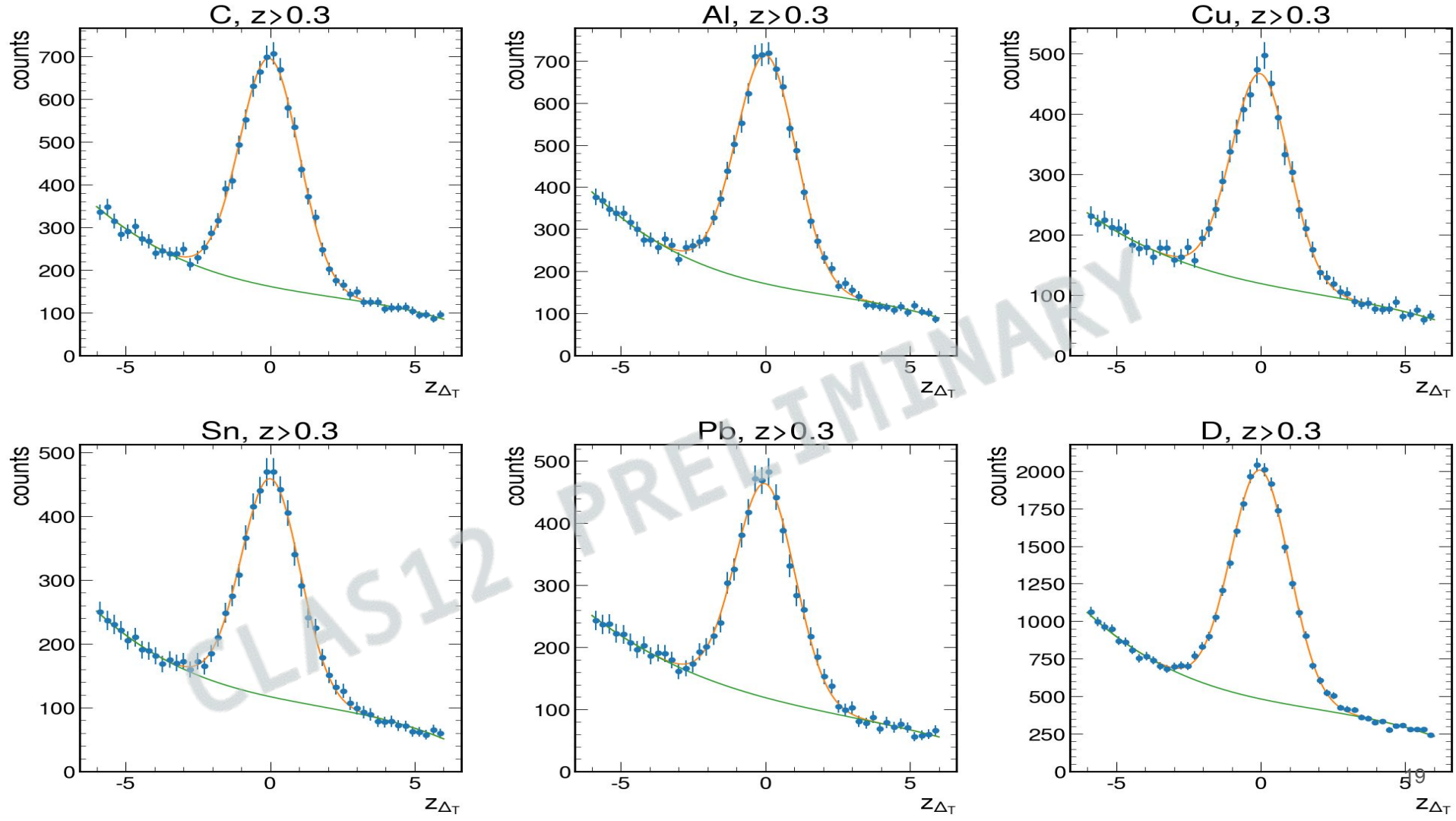
Conclusions

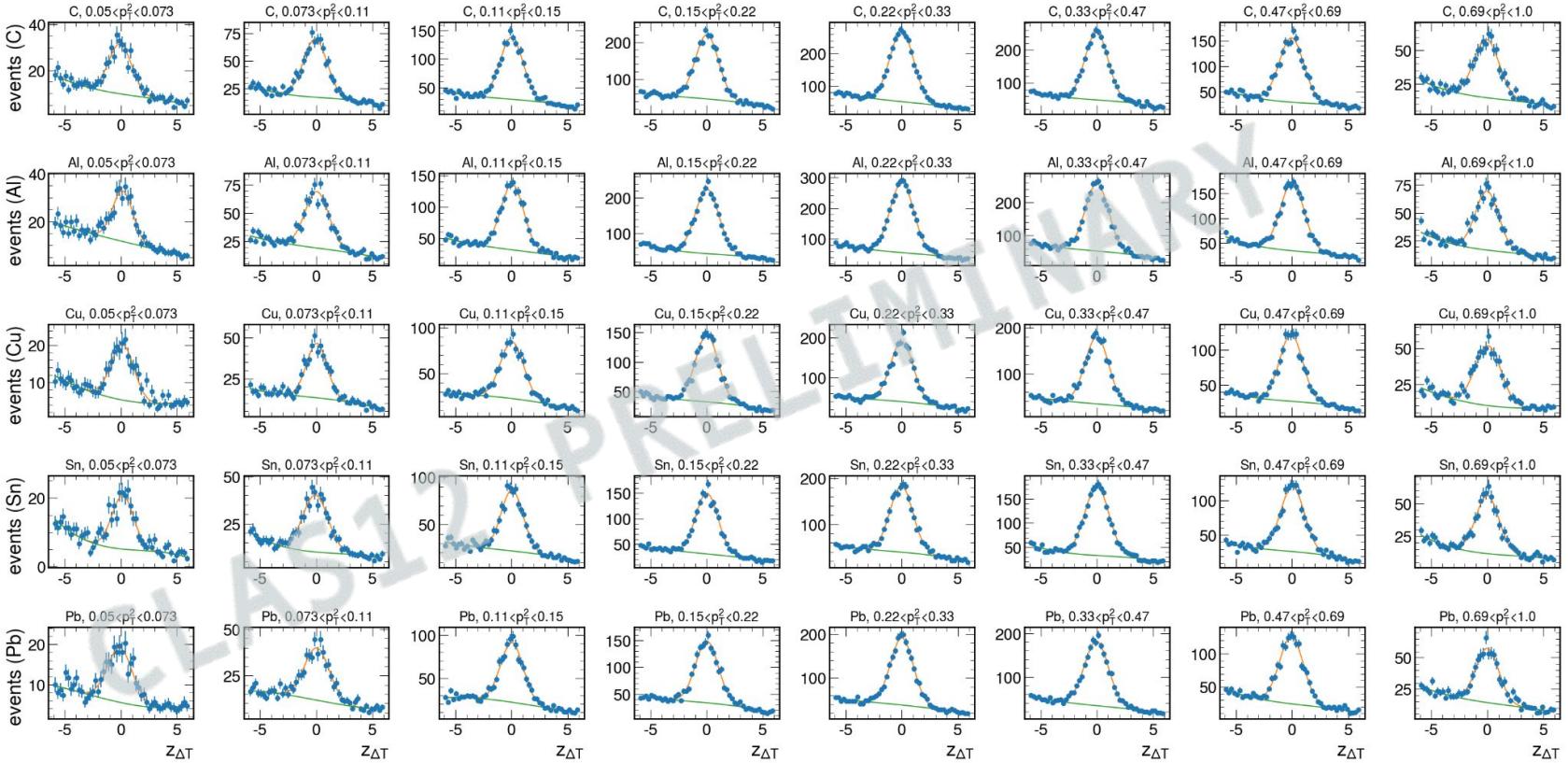
- Multiplicity ratios decrease with z and nuclear size
  - Abrupt change in multiplicity ratio between aluminum and copper.
- p_T^2 broadening is in between the values published for the Λ baryon and that of the light mesons.
- Abrupt change in slope for $\Delta\langle p_T^2 \rangle$ after aluminum.
- More studies are needed for determining systematic uncertainties and corrections for energy loss, endcaps, acceptance, and radiative effects

Backup slides

pT2 broadening: Statistical uncertainty

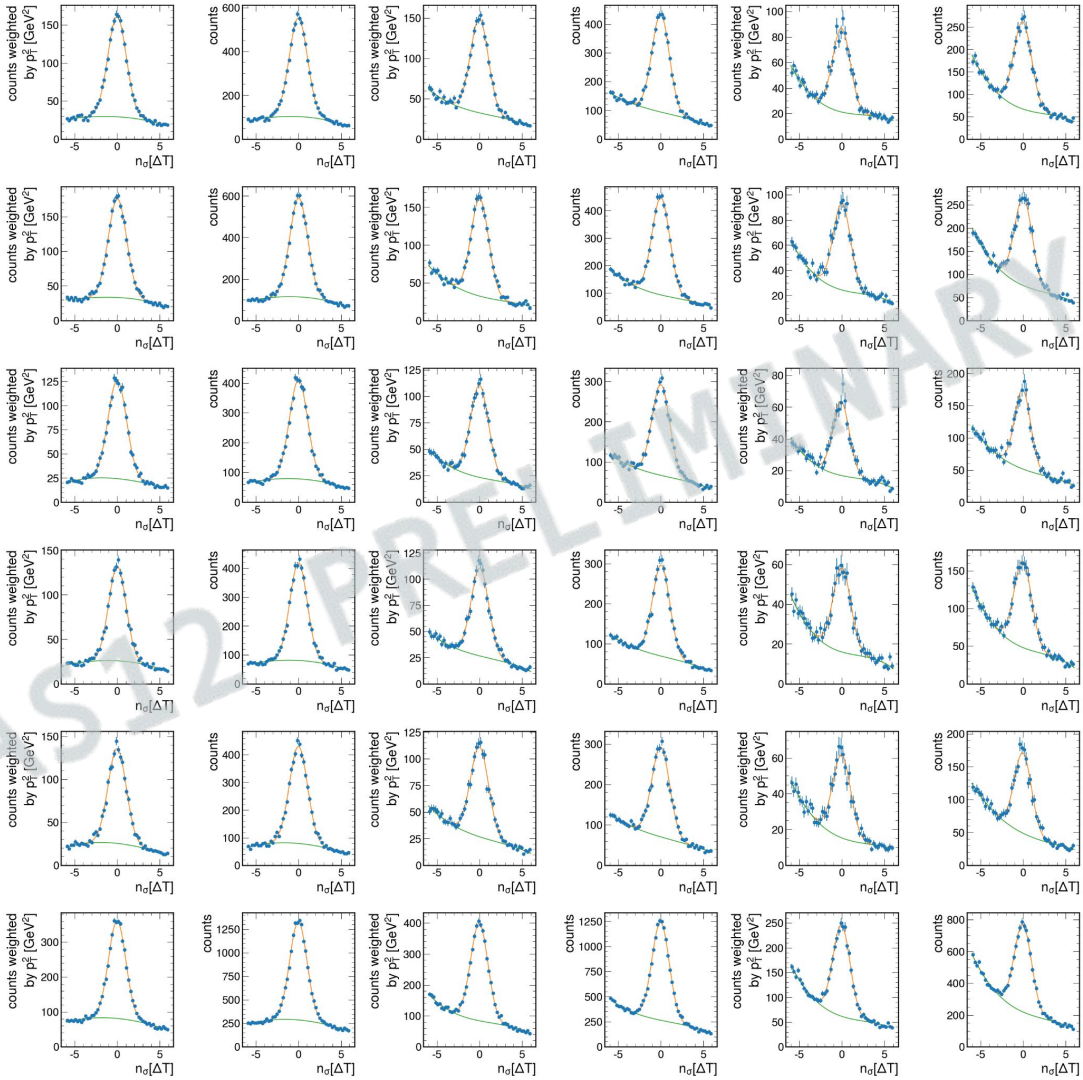
- For the systematic uncertainty, the events are weighted by $(p_T^2 - \langle p_T^2 \rangle)^2$ and then fit to a gaussian plus polynomial, and divide by yield to get $\sigma[p_T^2]$.
- Multiply $\sigma[p_T^2]$ by $\Delta N/N$ to get $\Delta\langle p_T^2 \rangle$


C, z>0.3
Al, z>0.3
Cu, z>0.3
Sn, z>0.3
Pb, z>0.3
D, z>0.3
counts
z_{Δ_T}
CLAS12 PRELIMINARY



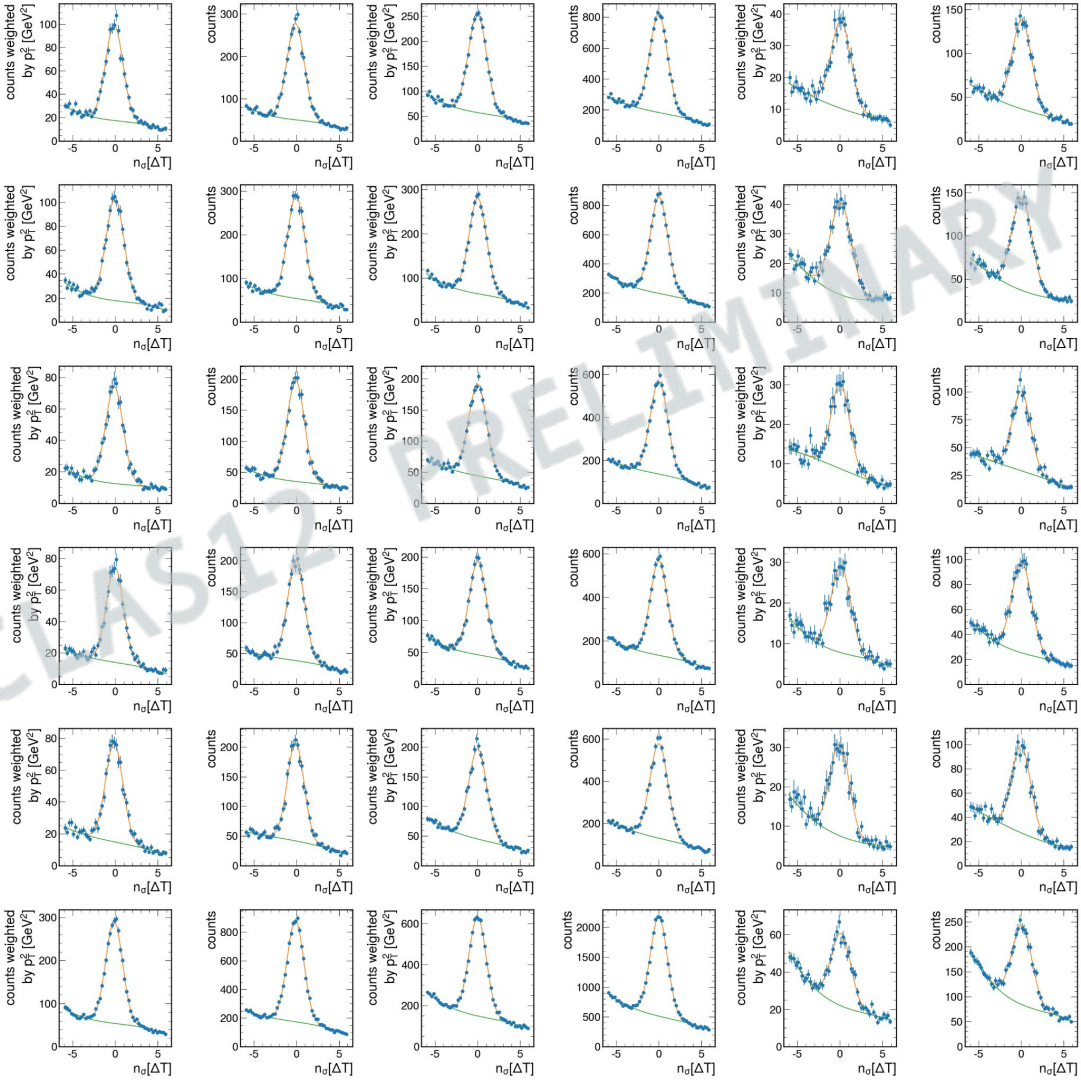
CLAS12 PRELIMINARY

pT2 broadening
Z bins



CLAS12 PRELIMINARY

Pt2 broadening Q2 bins



CLAS12 PRELIMINARY