RG-E Spring-24 Experimental Run & Data Processing Status

(30 PAC days from 60 granted)

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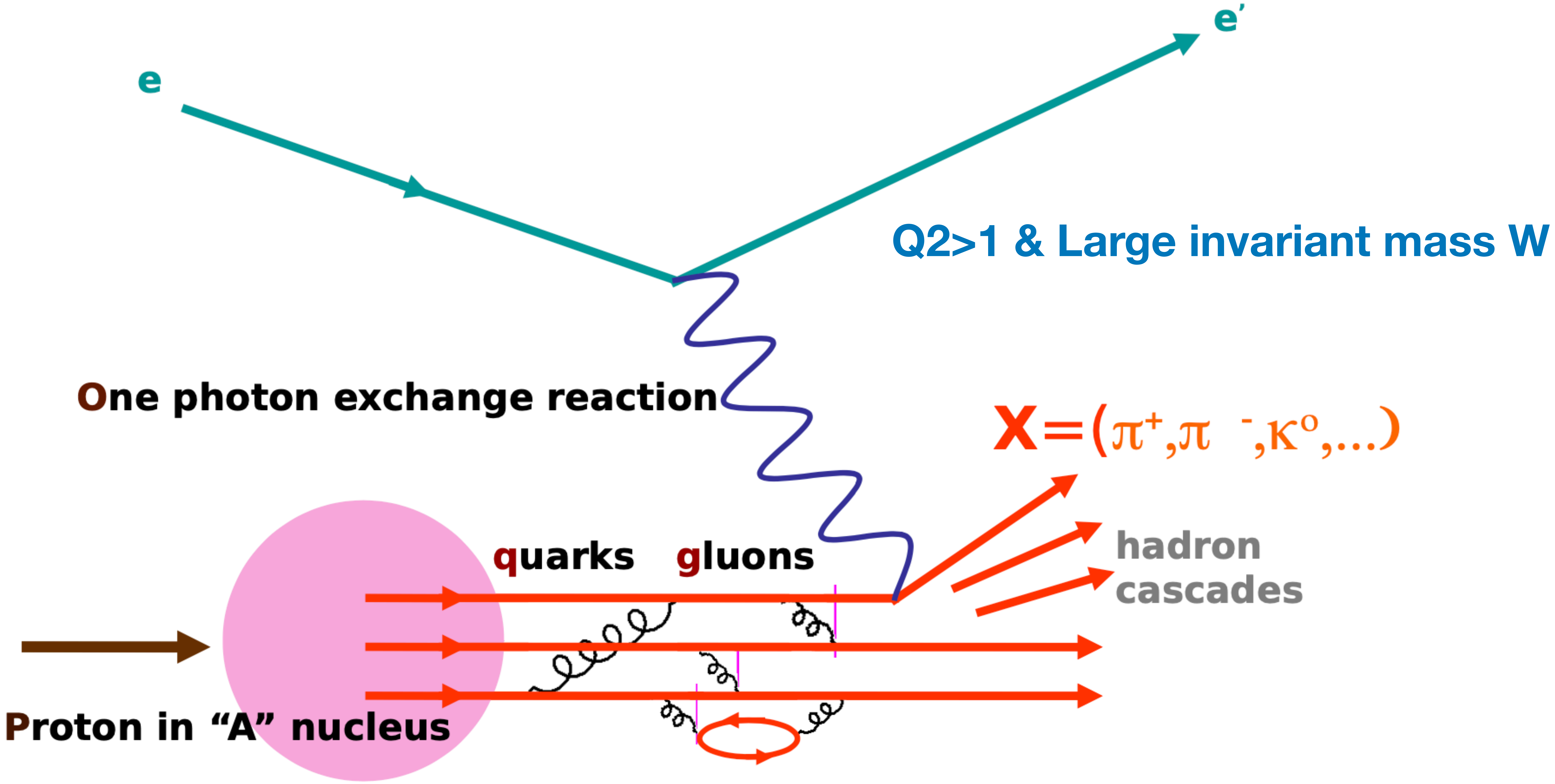
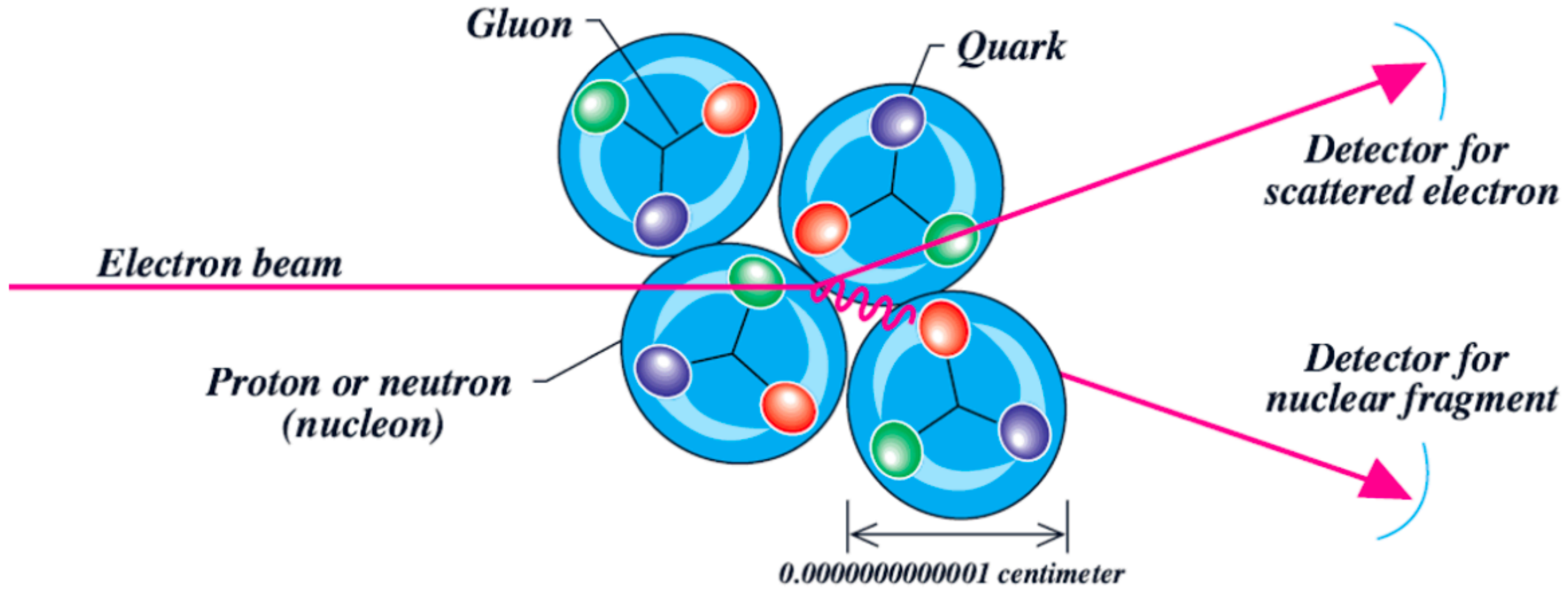
CLAS Collaboration Meeting, June, 2024 (remotely)

Schematic diagram describing semi-inclusive Deep Inelastic Scattering of a lepton off a nucleon





To conduct a thorough investigation into how the nuclear medium influences quark hadronization, it is essential to perform a multidimensional cinematical analysis on a range of different hadrons in nuclei of different size. This approach not only uncovers the color properties inherent to the nuclear medium but also provides a comprehensive understanding of the phenomenon.

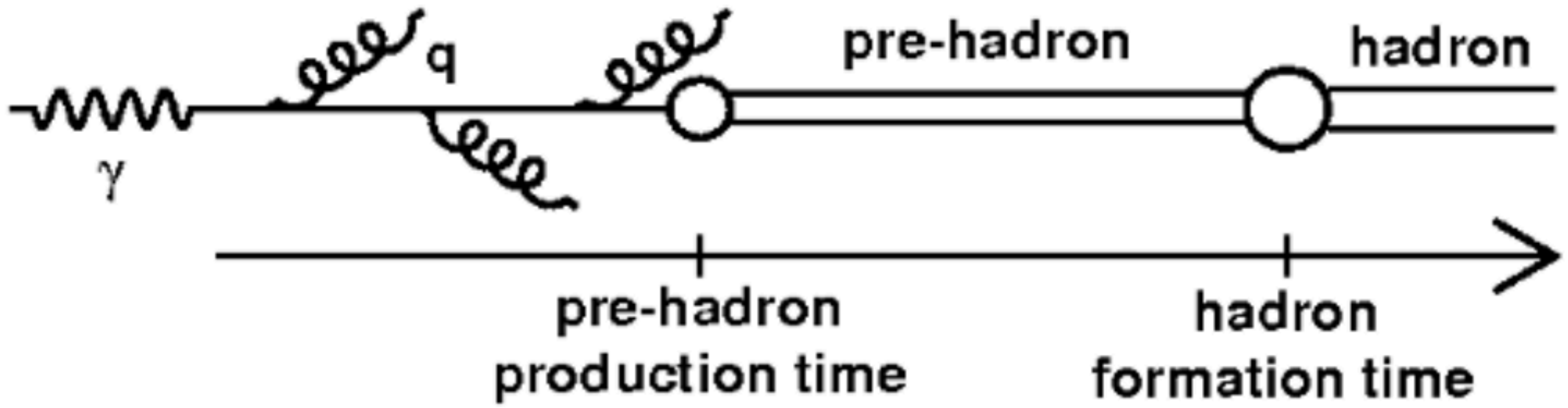
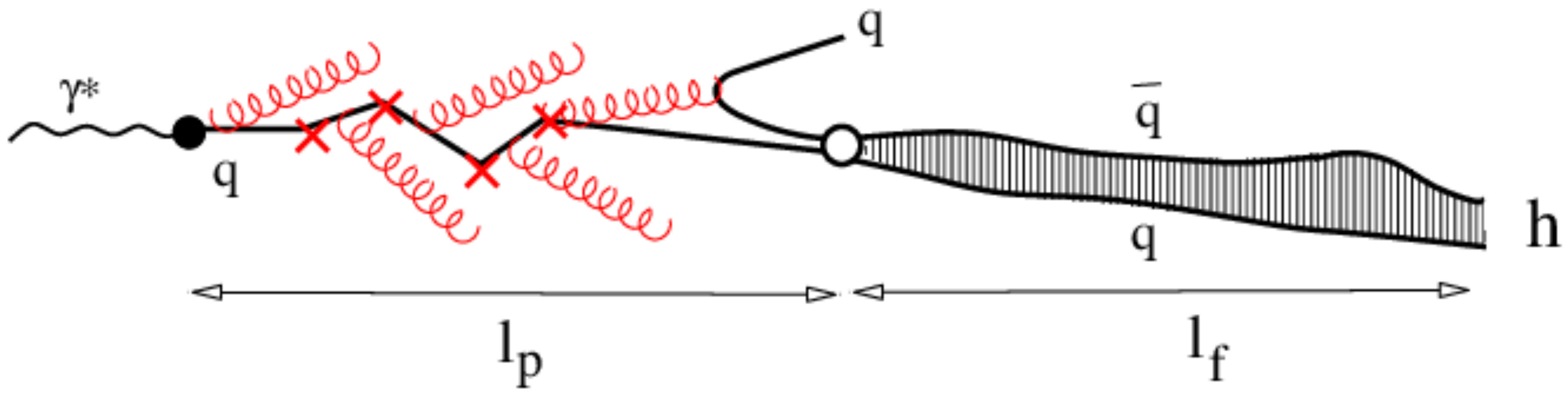
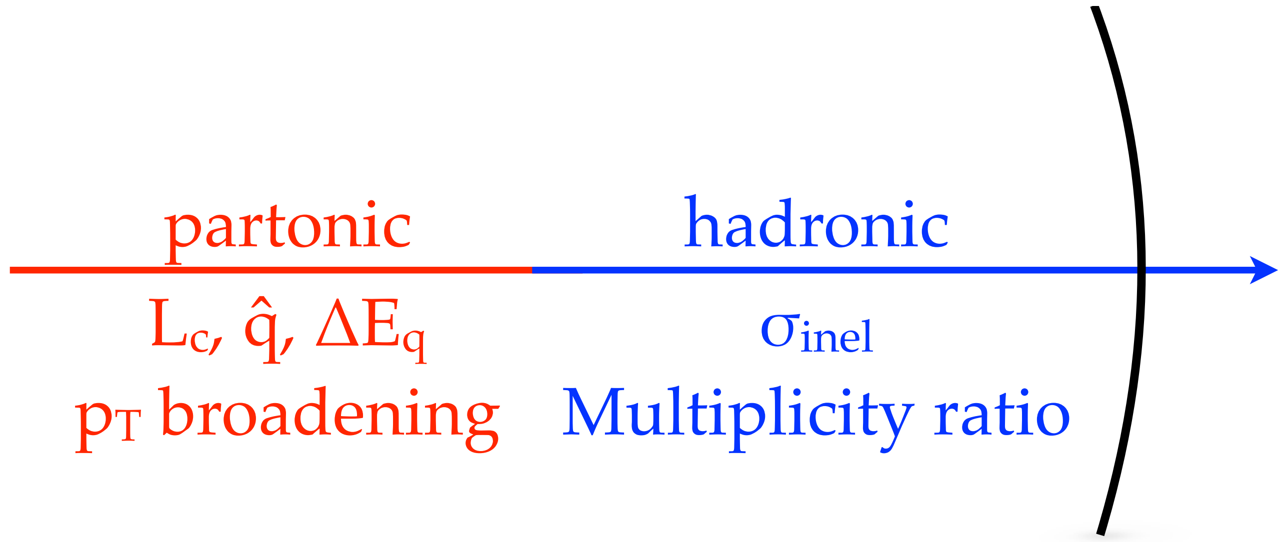
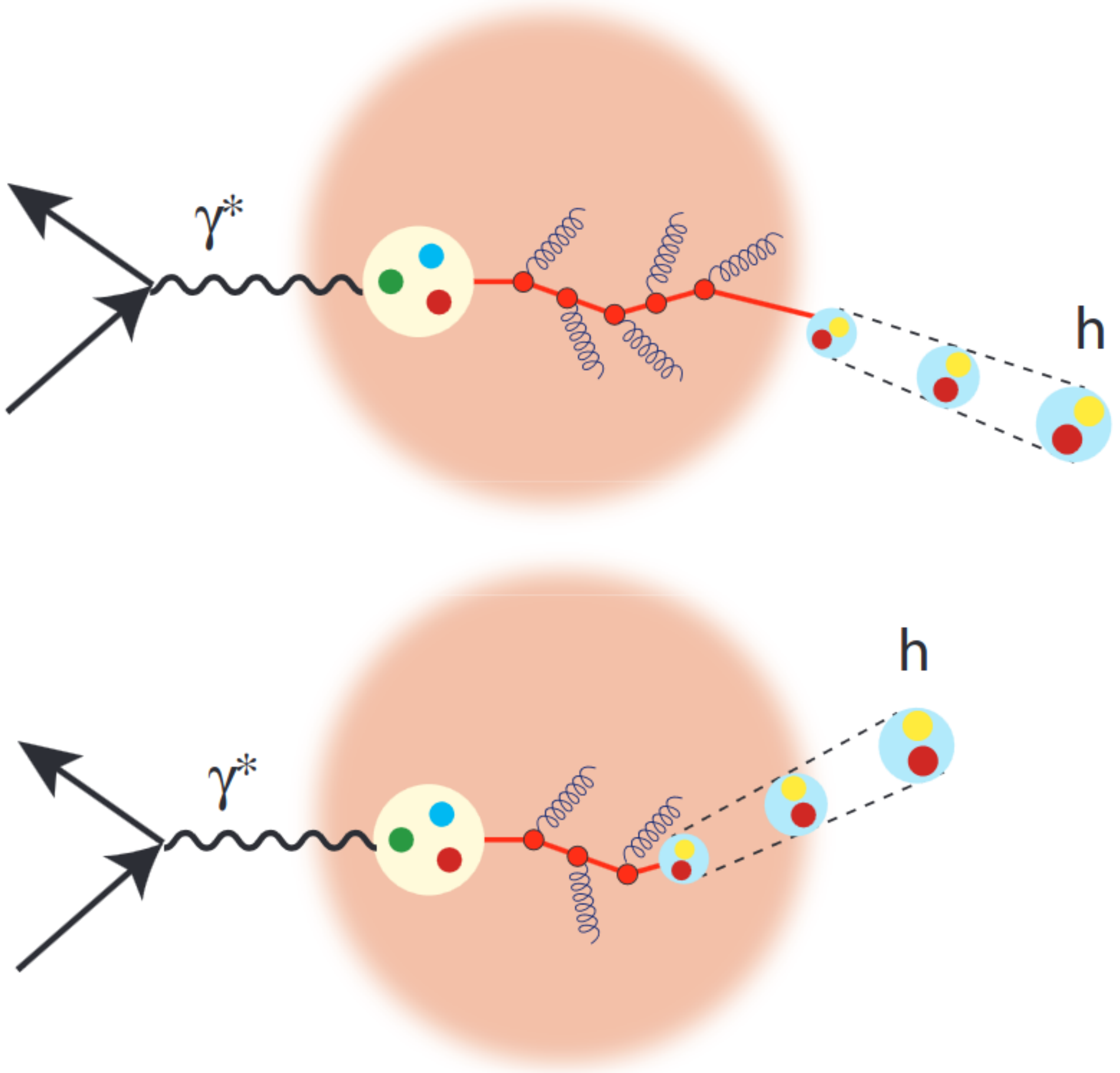


Illustration of a parton moving through nuclear media. At the top the prehadron is formed outside the nuclei and at the bottom it is formed inside.



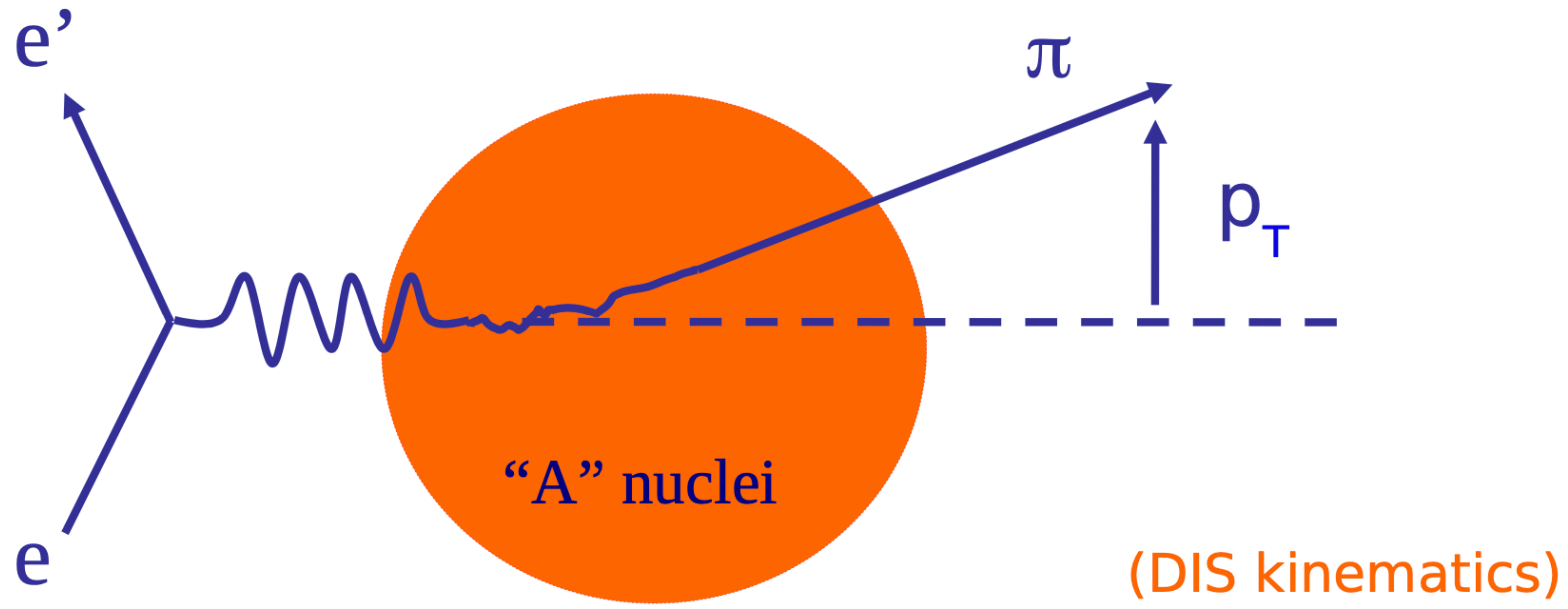
Path of (struck) quark is divided into "partonic phase" and "hadronic phase"





Experimental observables

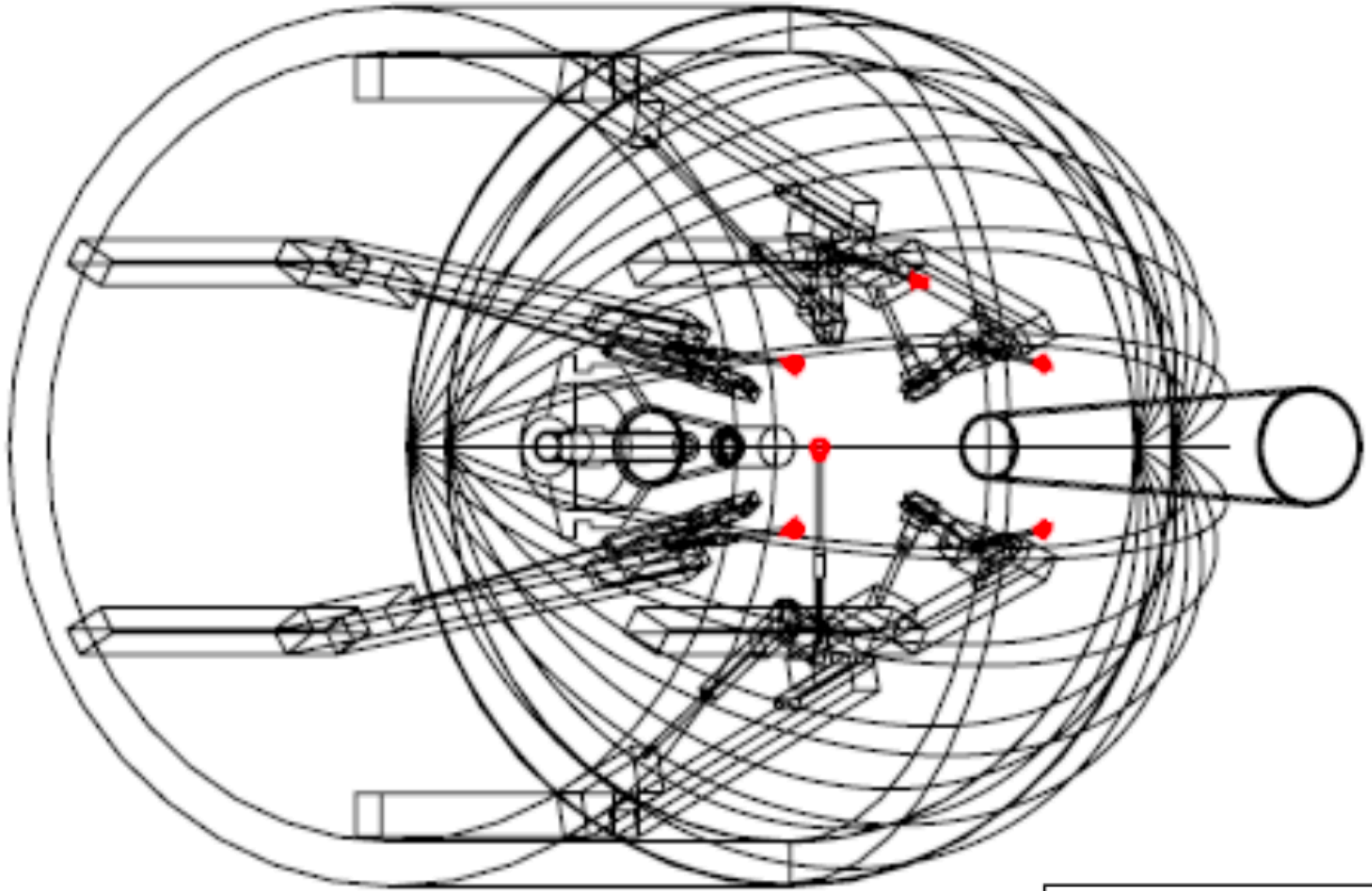
Transverse momentum broadening: $\Delta p_T^2 = p_T^2(A) - p_T^2(^2H)$

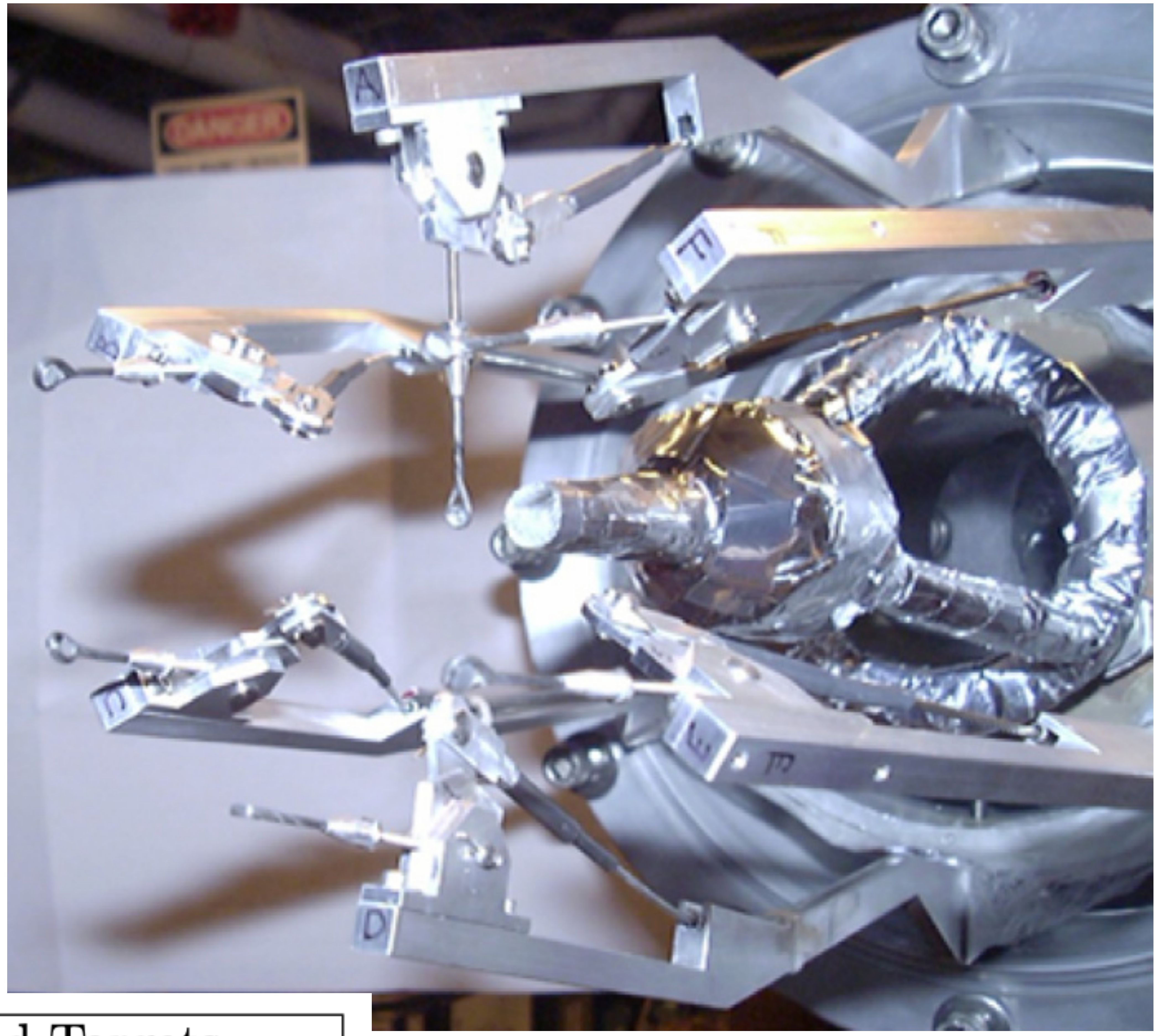


Hadronic multiplicity ratio:

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

Eg2 Double-Target

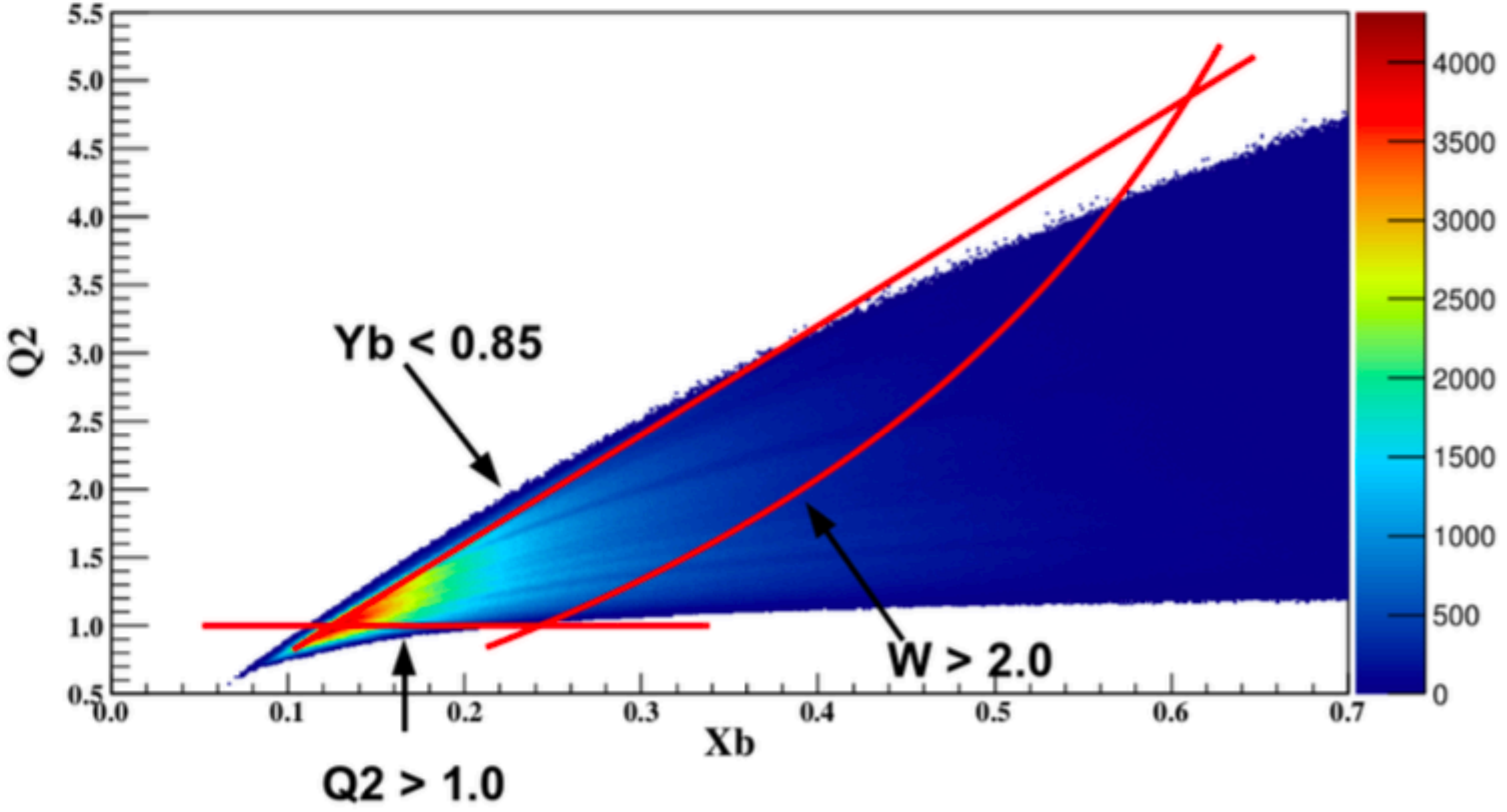


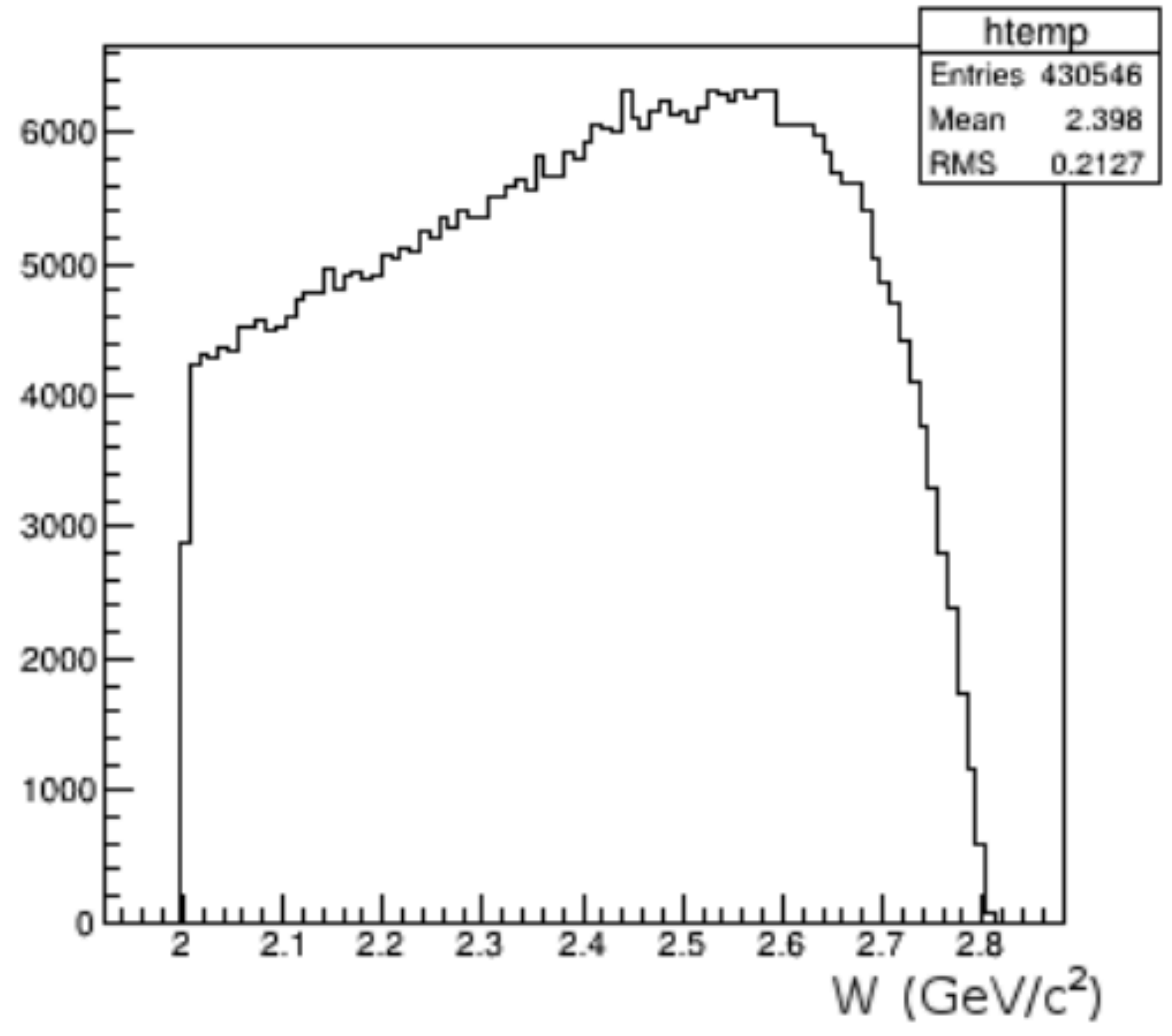


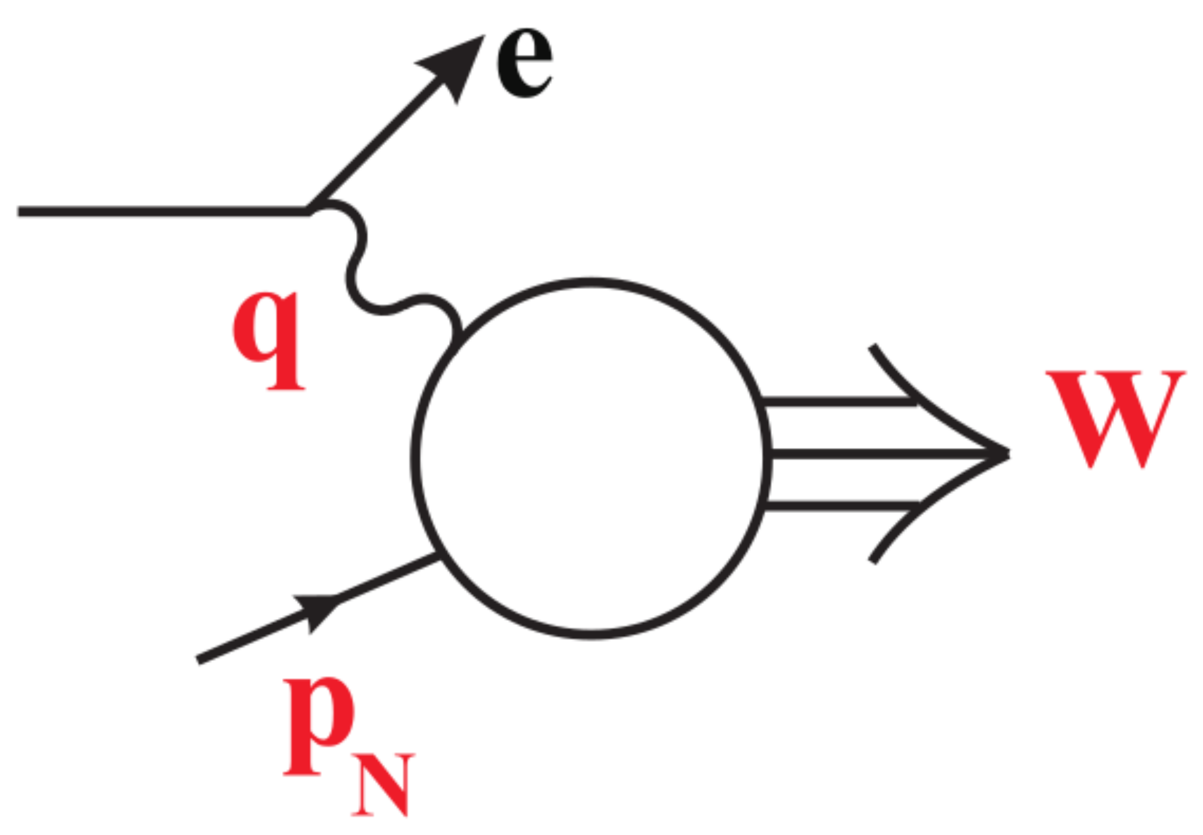
Thickness of Solid Targets		
Target	Thickness (cm)	ρ_A/ρ_D
C	0.17	0.894
Fe	0.04	0.949
Pb	0.014	0.478

H. Hakobyan, W. Brooks et al, Nucl. Instrum. and Meth. A592:218-223, 2008.

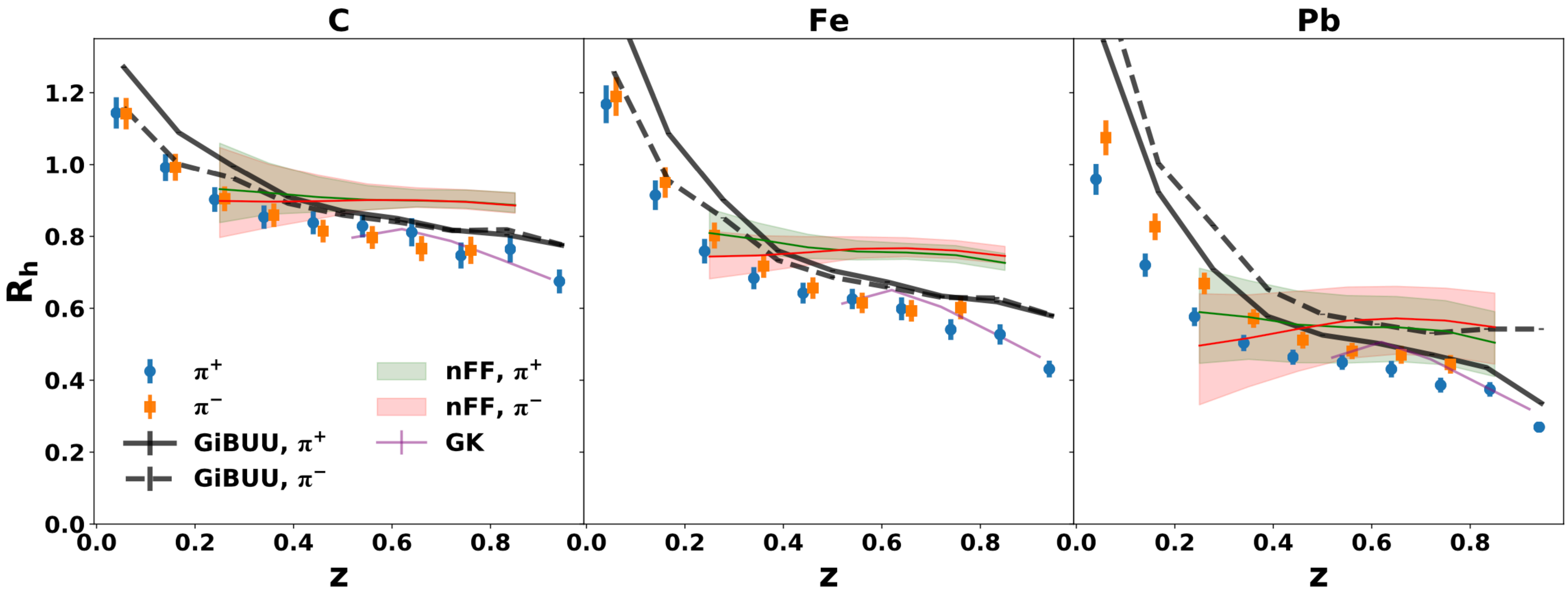
DIS cinematics on CLAS6





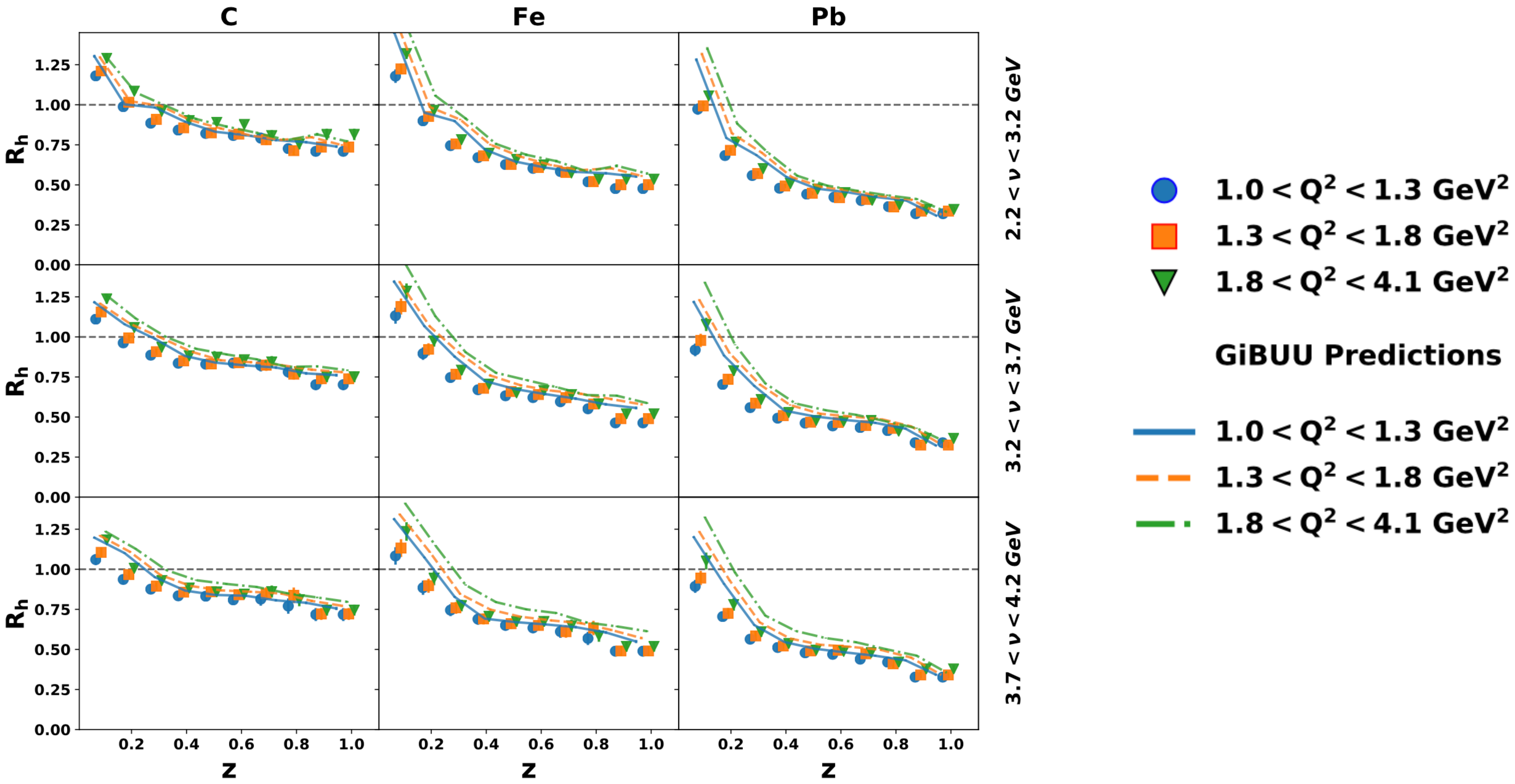


Charged pions - multiplicity ratio



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

Charged pions - multiplicity ratio - multidimensional

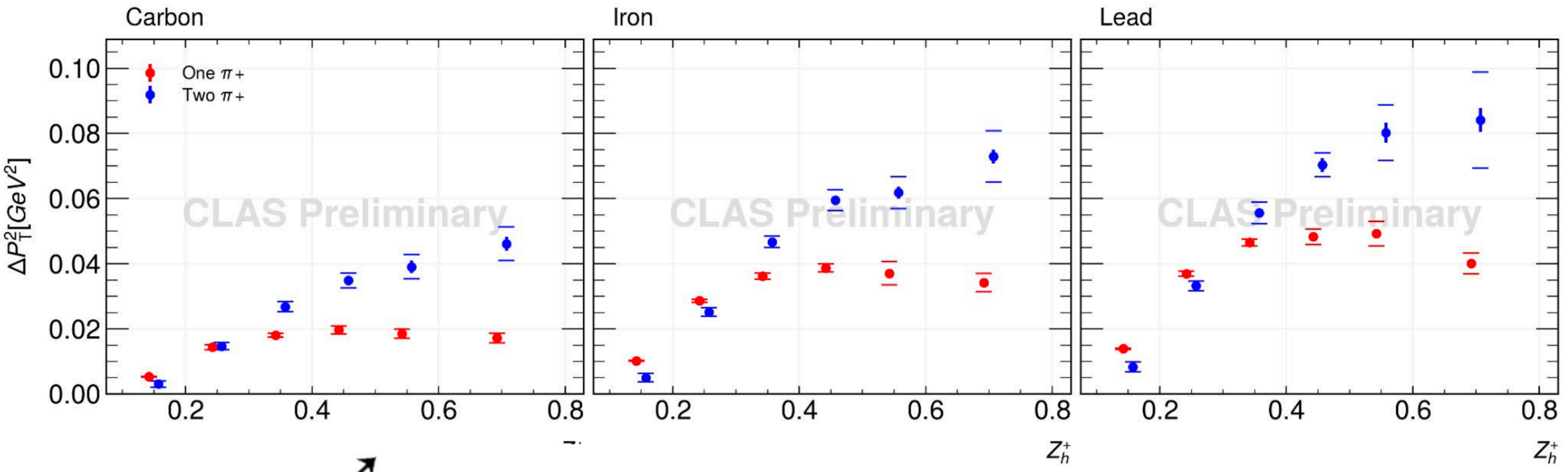


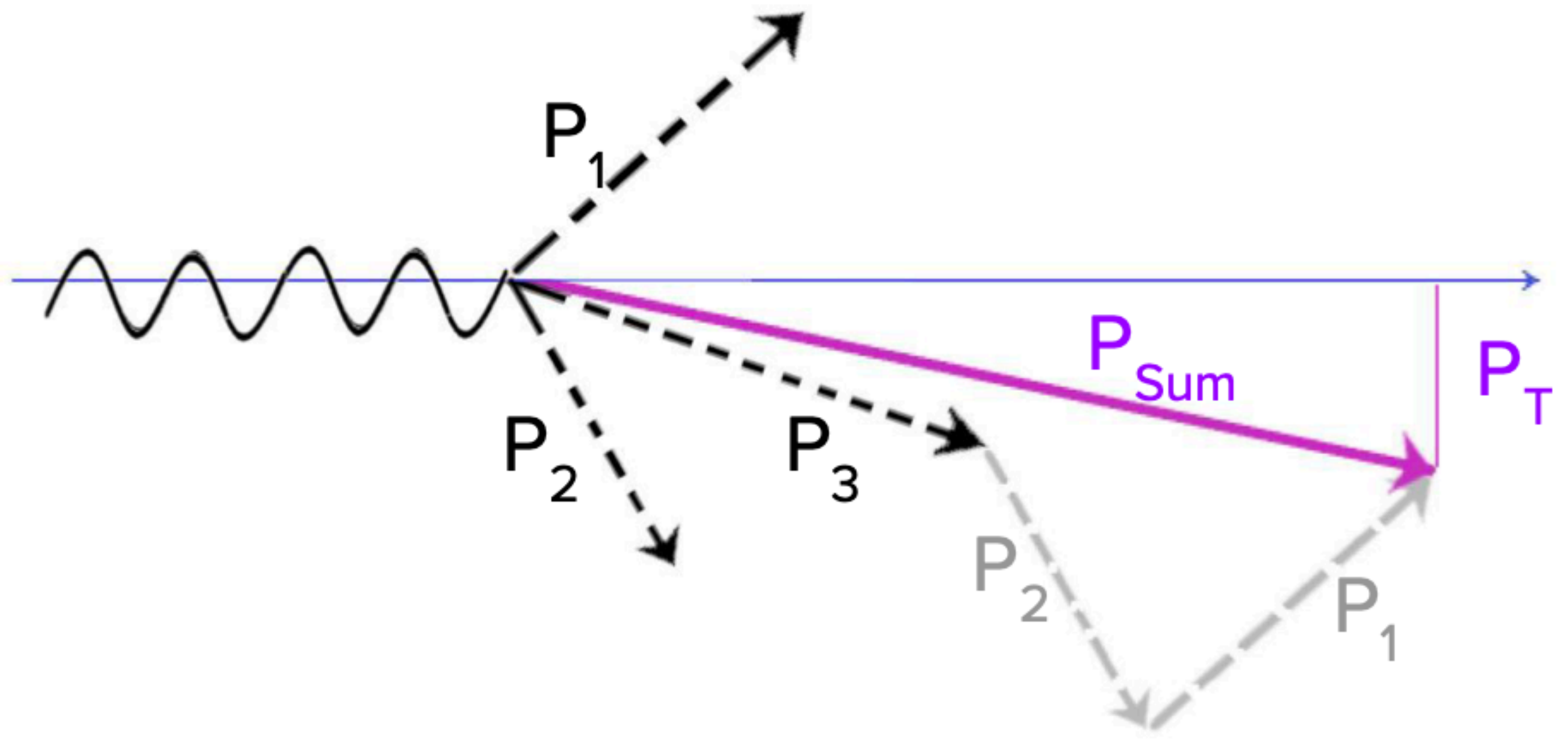
S. Moran, et al. (CLAS collaboration). Phys. Rev. C **105**, 015201 – January, 2022

Transverse momentum broadening is shown as a function of the sum of Zh (with all other variables integrated), with each box representing a different target. Single-pion events are depicted in red, and two-pion events are depicted in blue.

M.Barría Thesis

https://repositorio.usm.cl/handle/11673/56688





The pT broadening is larger for two pion events for $Z_h > 0.3$ and this difference increases with Z_h

Etas and Omegas

Andres Borquez, Orlando Soto et al. (CLAS PRELIMINARY).

Studies performed with EG2 data

- Hadronization studies in nuclear medium (all types of pions, neutral kaons, lambdas, protons, etas, omegas)
- Color transparency
- Short-Range Nuclear correlations
- Two-pion BEC correlations
- Dihadron supresión
- Etc.

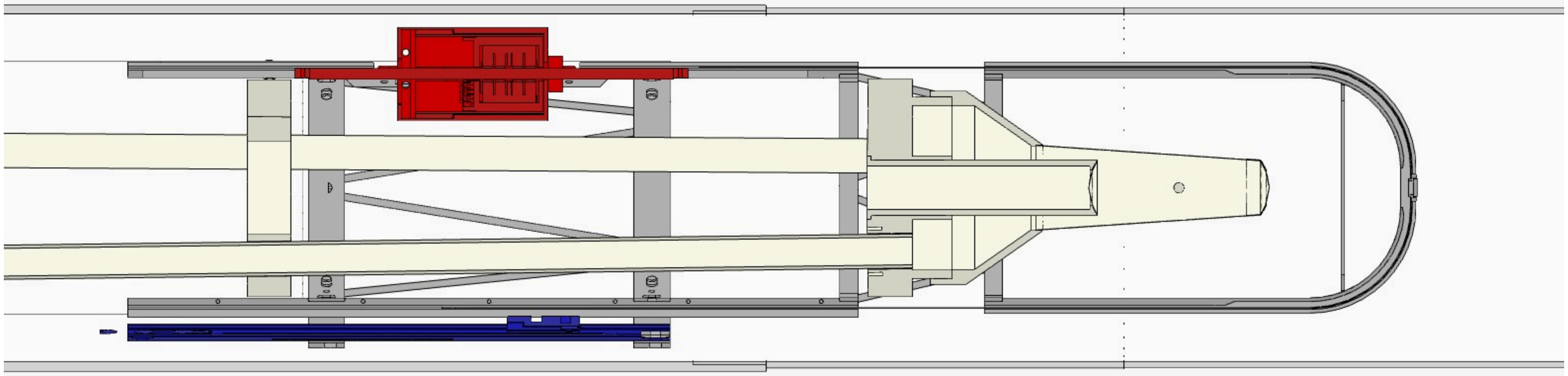
Experiment Context: CLAS12 RG-E Experimental Target Conditions

CCTVal

1. Reduced Space in Beamline, 85mm
2. High Vacuum, 10-6 mbar
3. Strong Magnetic Field, 5 Tesla
4. Cryogenic Temperatures, 22 Kelvin cryo-cell
5. 11 GeV Beam energy

- Interchangeable solid targets system in high vacuum
- Remote control system
- Resistant to high radiation
- Non-magnetic materials
- High vacuum resistant materials (no out-gassing)
- Fit in a 85mm diameter, cylindrical room
- Estimation of temperature in targets and devices

RGE Experiment Double Target System



Exchanging solid targets from one to another from the counting house was taking less than one minute.

Double Target for RG-E

The target configuration during the run (27 PAC days)

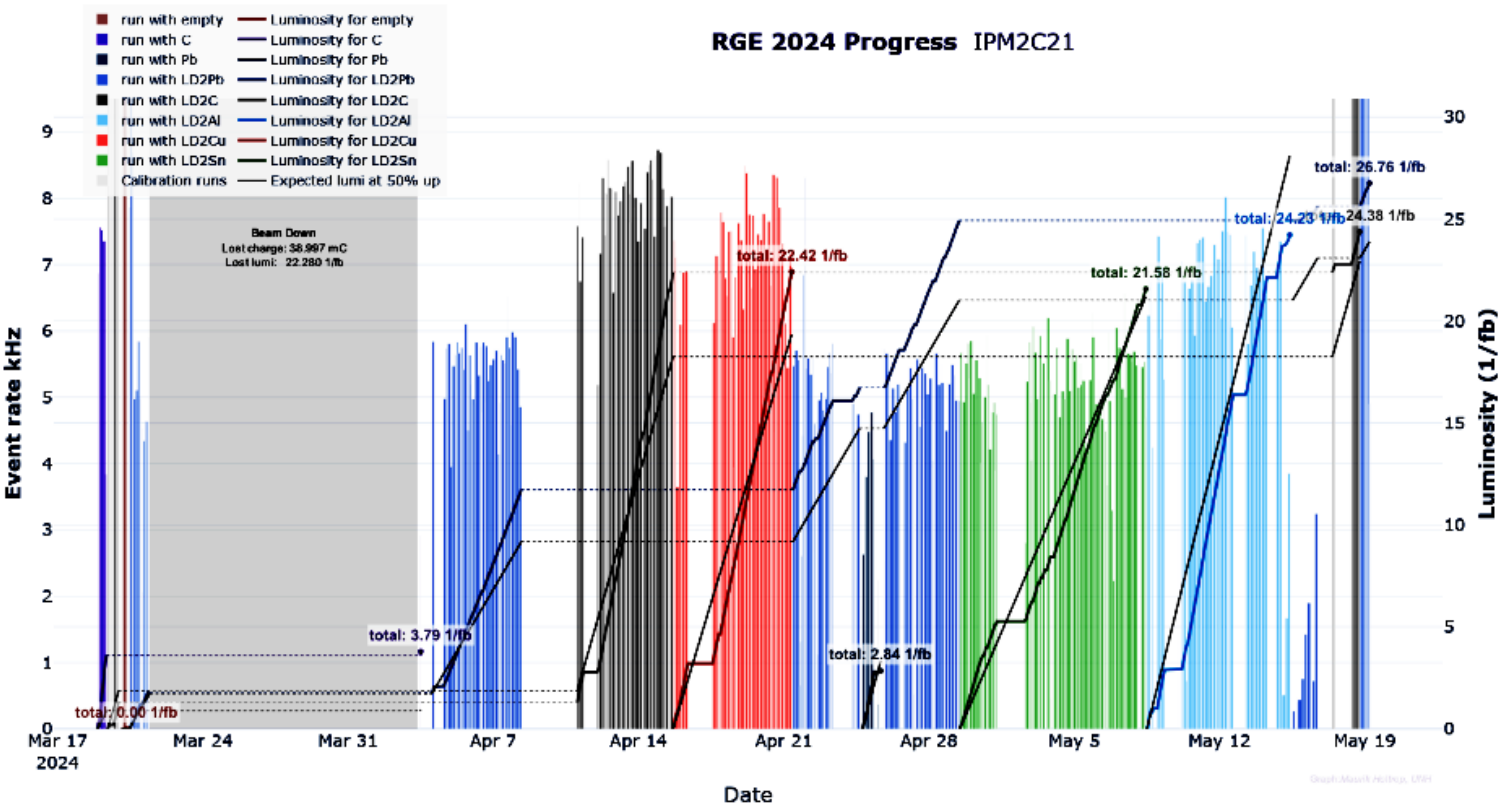
	Solid target thickness in mm	Solid target density in g/cm3	Total Luminosity Achieved
2cm LD2 + C	1.51	1.7	23 1/fb
2cm LD2 + Al	1.21	2.6	24 1/fb
2cm LD2 + Cu	0.34	8.3	22 1/fb
2cm LD2 + Sn	0.29	7.1	22 1/fb
2cm LD2 + Pb	0.14	10.6	26 1/fb

Three important objectives achieved during the target installation and RG-E launching:

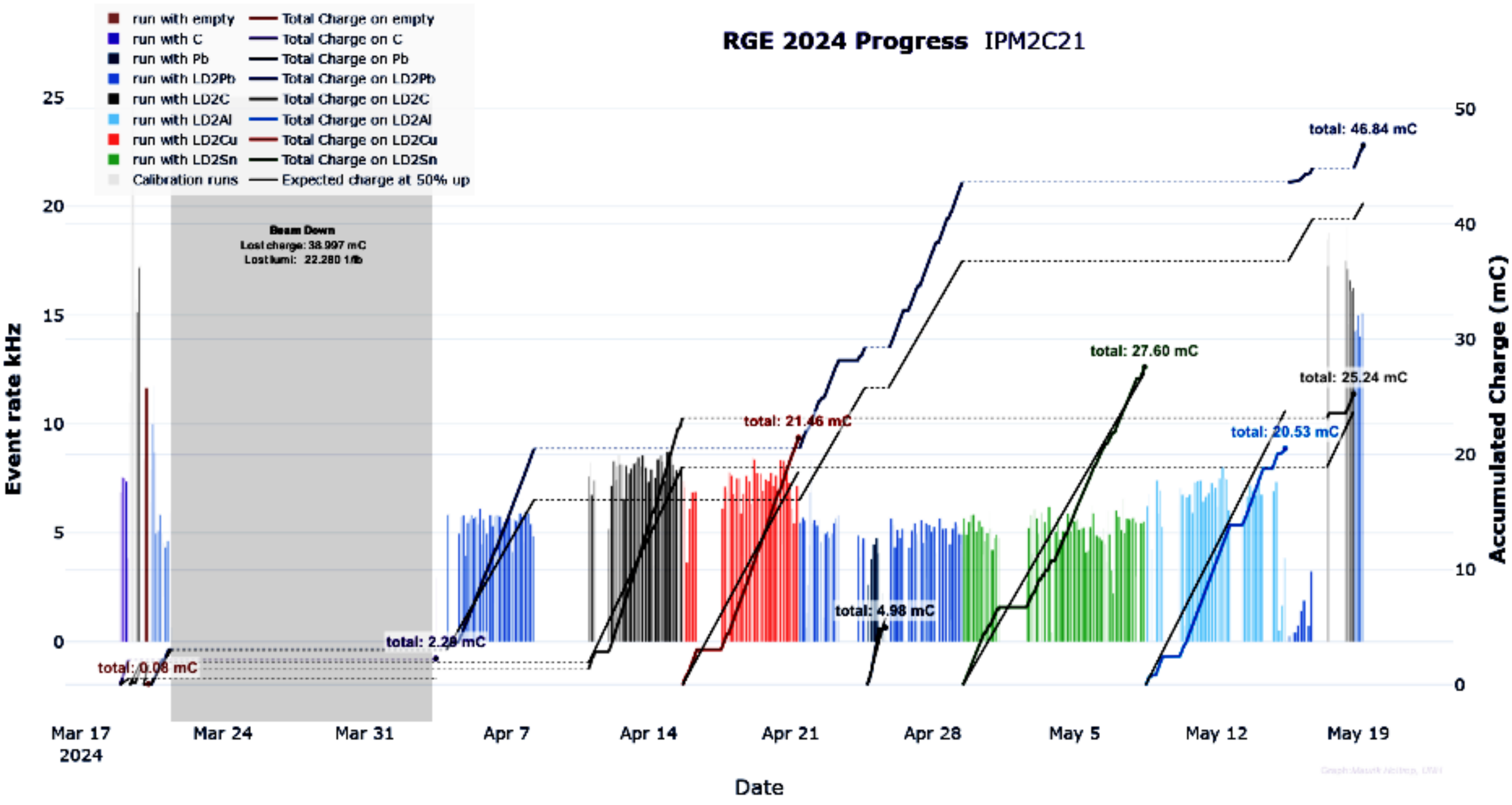
1. Alignment between liquid cell and solid target.
2. Liquid deuterium condensation with the Double-Target heat load.
3. Electron beam alignment with the centers of liquid and each of solid targets after their movement.

Special Runs:

1. Luminosity scan for different beam currents;
2. Beam polarization studies, Moller measurements once per week;
3. Zero field alignment runs;
4. Empty cryotarget run with C and Pb on;
5. Streaming test with Pb configuration;
6. Outbending runs with Pb;
7. Others.

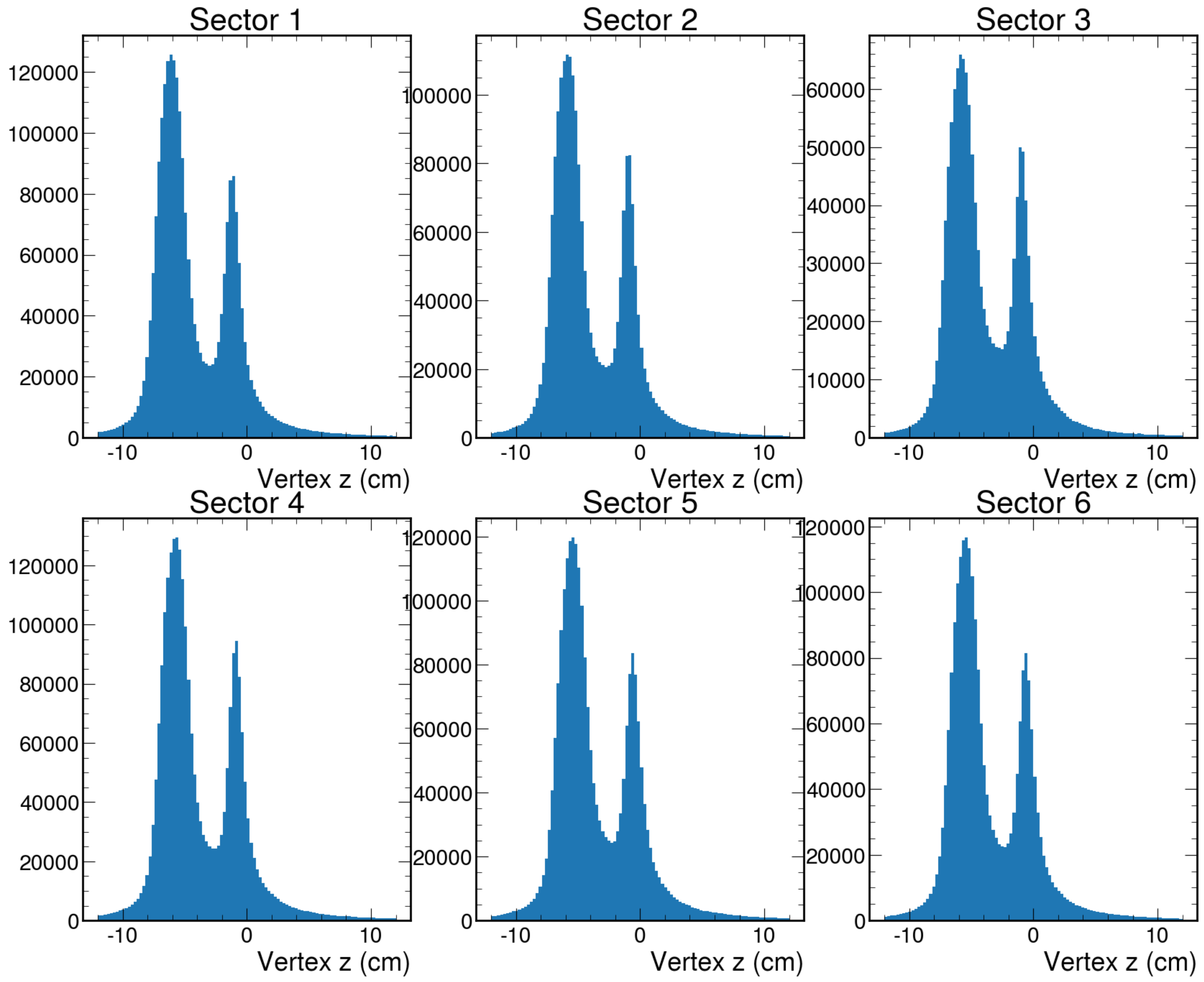


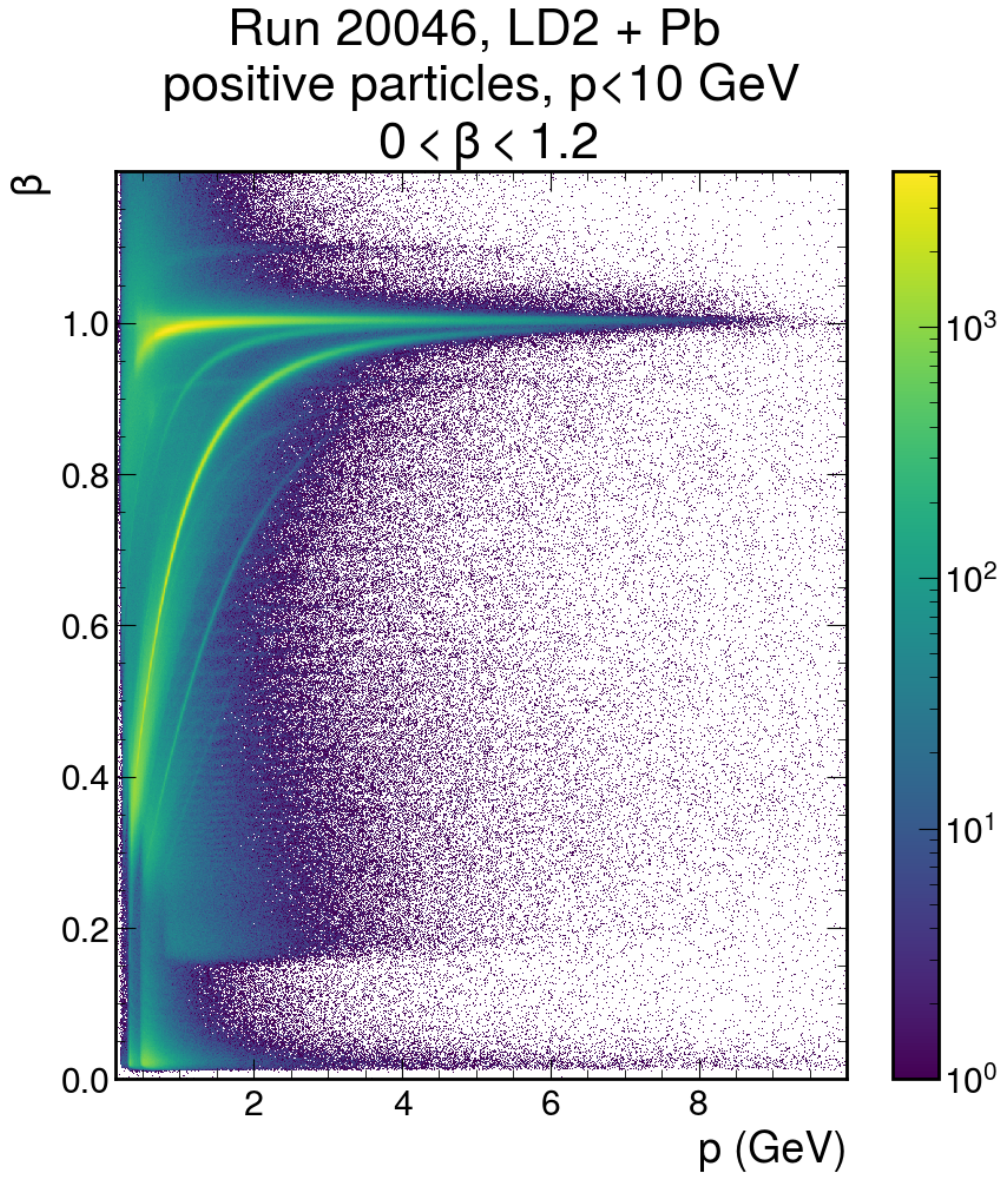
RGE 2024 Progress IPM2C21
run with empty
run with C
run with Pb
run with LD2Pb
run with LD2C
run with LD2Al
run with LD2Cu
run with LD2Sn
Calibration runs
Luminosity for empty
Luminosity for C
Luminosity for Pb
Luminosity for LD2Pb
Luminosity for LD2C
Luminosity for LD2Al
Luminosity for LD2Cu
Luminosity for LD2Sn
Expected lumi at 50% up
Beam Down
Lost charge: 38.997 mC
Lost lumi: 22.280 1/fb
total: 0.00 1/fb
total: 3.79 1/fb
total: 22.42 1/fb
total: 2.84 1/fb
total: 21.58 1/fb
total: 24.23 1/fb
24.38 1/fb
total: 26.76 1/fb
Event rate kHz
Luminosity (1/fb)
Date
Mar 17 2024
Mar 24
Mar 31
Apr 7
Apr 14
Apr 21
Apr 28
May 5
May 12
May 19



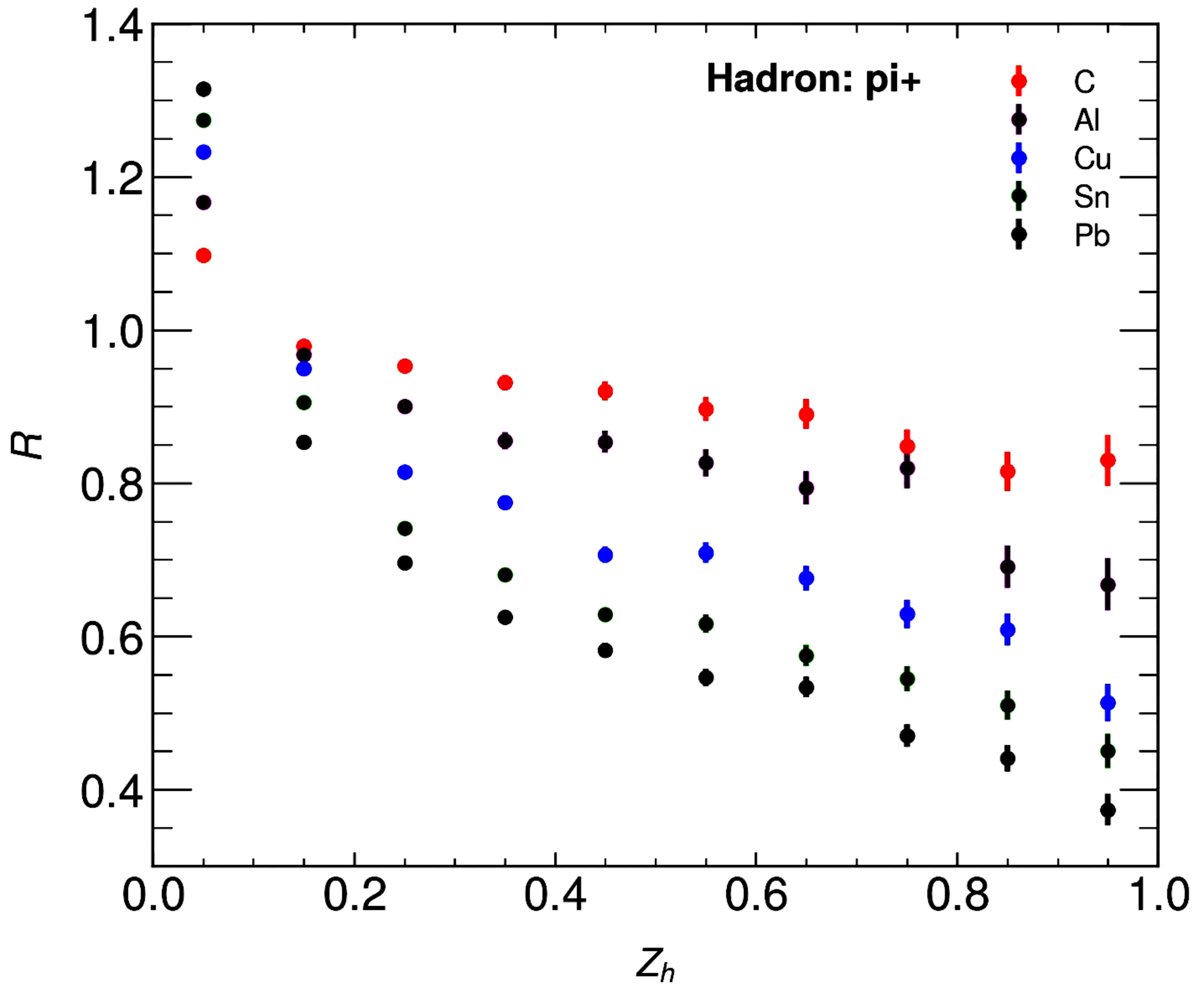
RGE 2024 Progress IPM2C21
run with empty
run with C
run with Pb
run with LD2Pb
run with LD2C
run with LD2Al
run with LD2Cu
run with LD2Sn
Calibration runs
Total Charge on empty
Total Charge on C
Total Charge on Pb
Total Charge on LD2Pb
Total Charge on LD2C
Total Charge on LD2Al
Total Charge on LD2Cu
Total Charge on LD2Sn
Expected charge at 50% up
Beam Down
Lost charge: 38.997 mC
Lost lumi: 22.280 1/fb
total: 46.84 mC
total: 27.60 mC
total: 25.24 mC
total: 21.46 mC
total: 20.53 mC
total: 4.98 mC
total: 2.28 mC
total: 0.08 mC
Event rate kHz
Accumulated Charge (mC)
Date
Mar 17 2024
Mar 24
Mar 31
Apr 7
Apr 14
Apr 21
Apr 28
May 5
May 12
May 19
0
5
10
15
20
25
30
40
50

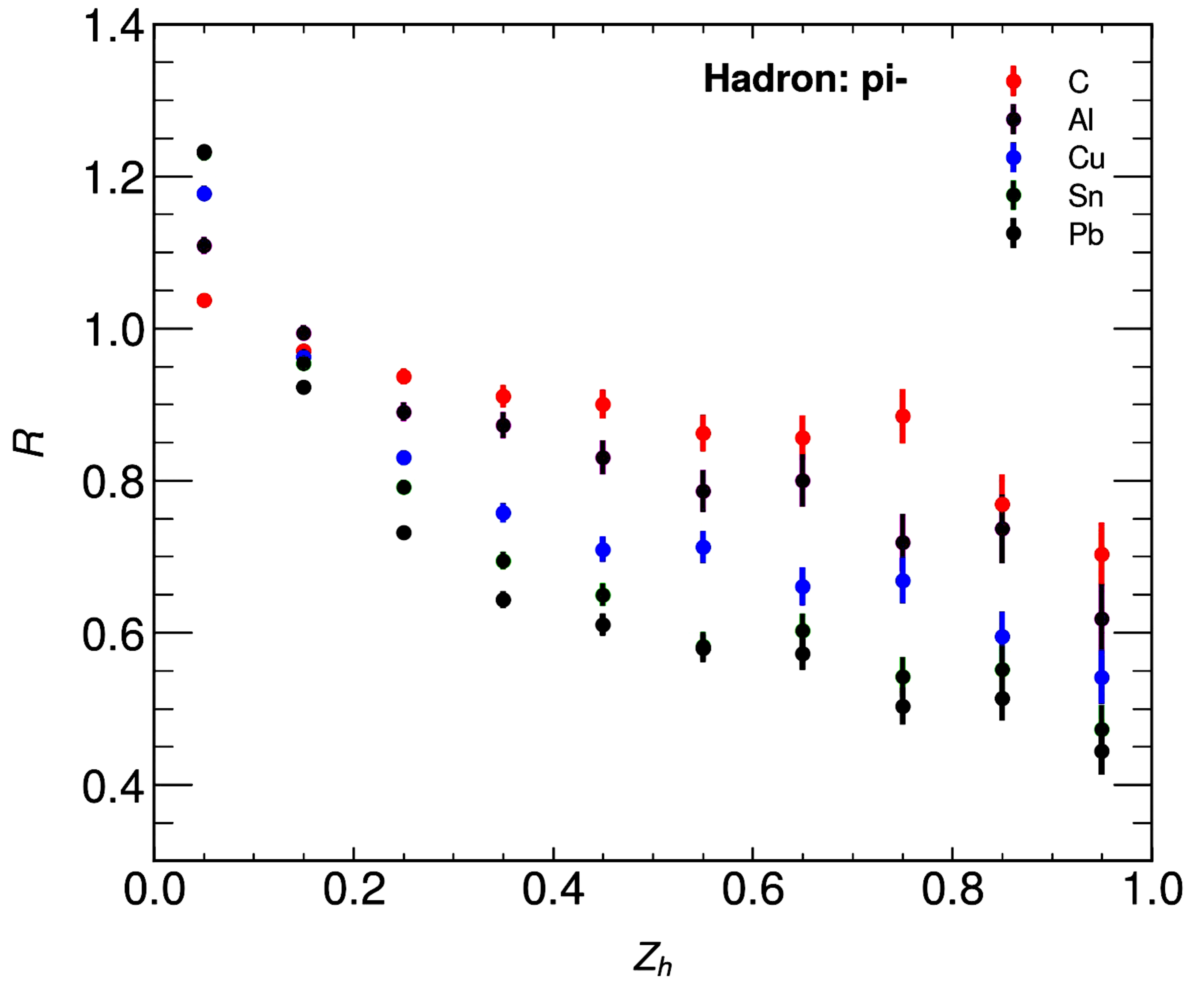
First Preliminary RG-E measurements



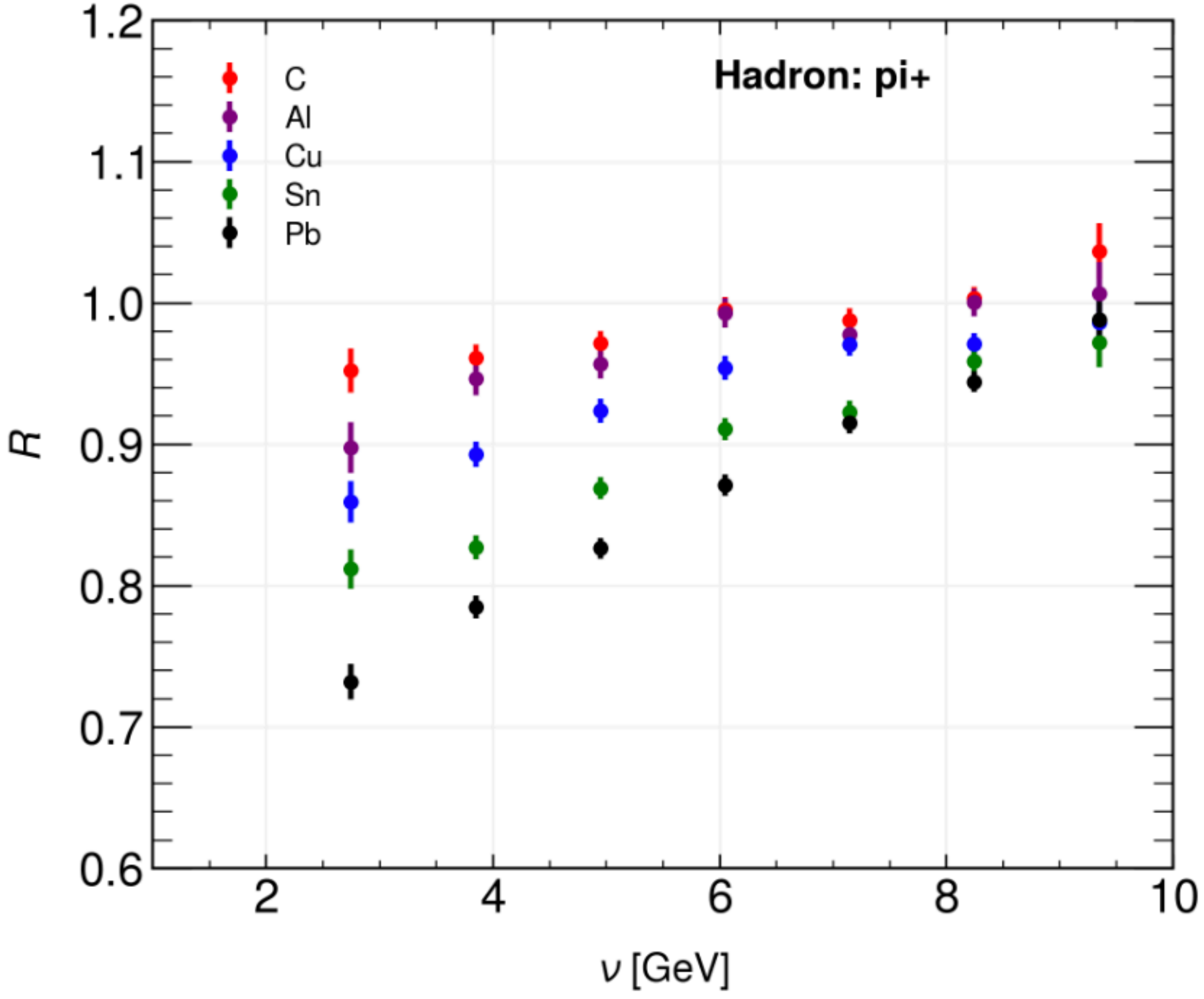


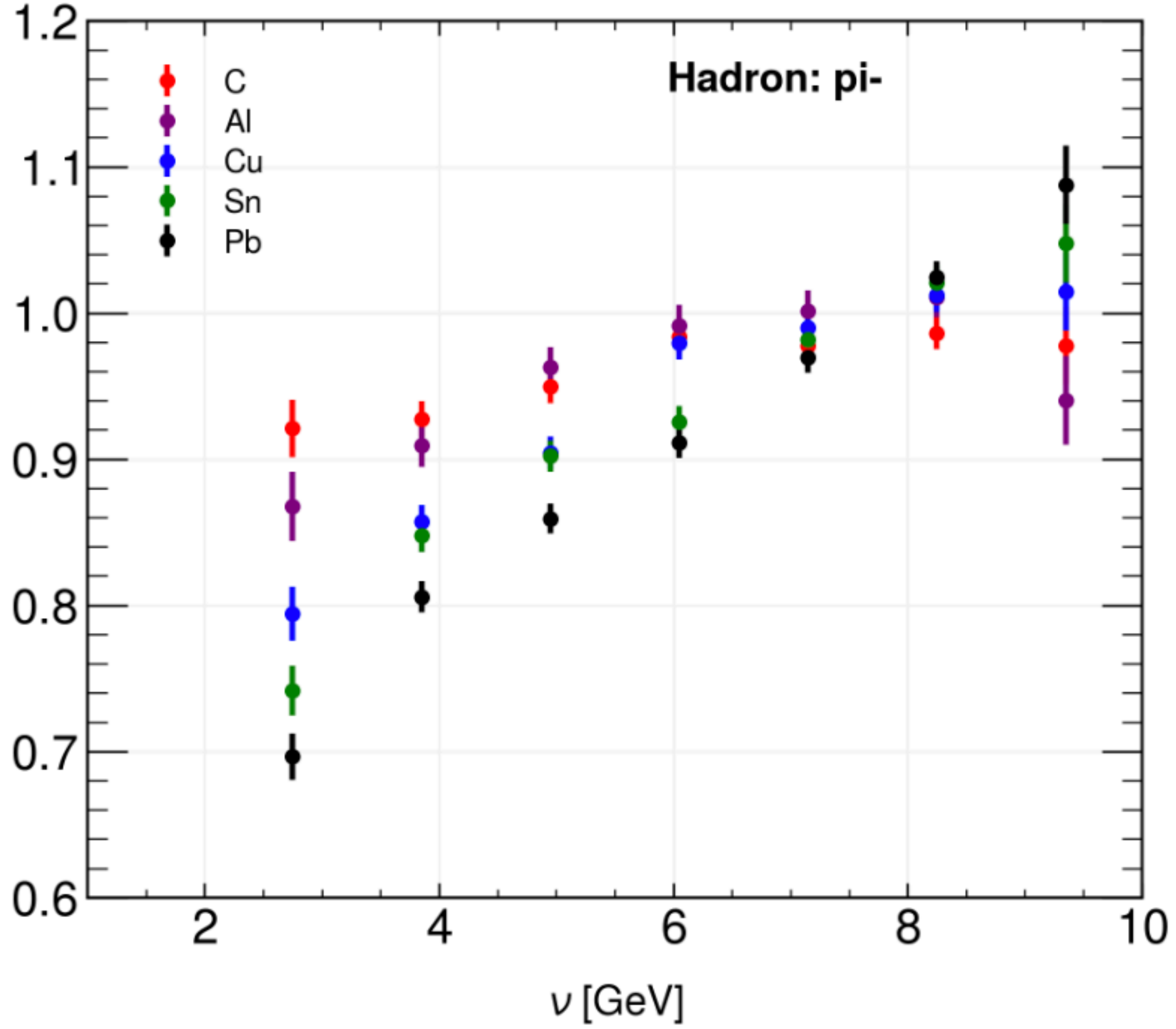
First Preliminary RG-E measurements
Multiplicity Ratio vs Z with DIS cuts





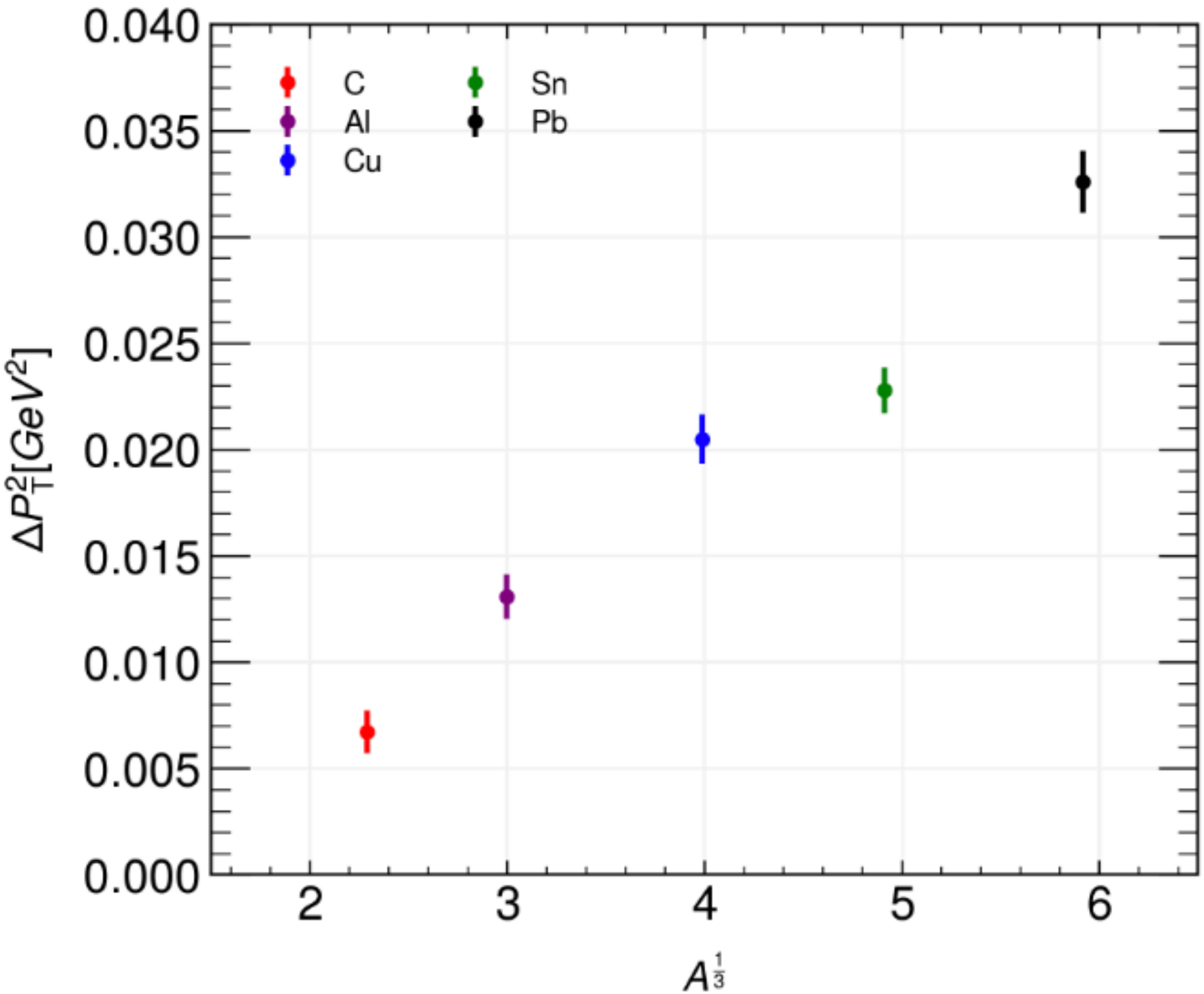
First Preliminary RG-E measurements
Multiplicity Ratio vs Nu with DIS cuts



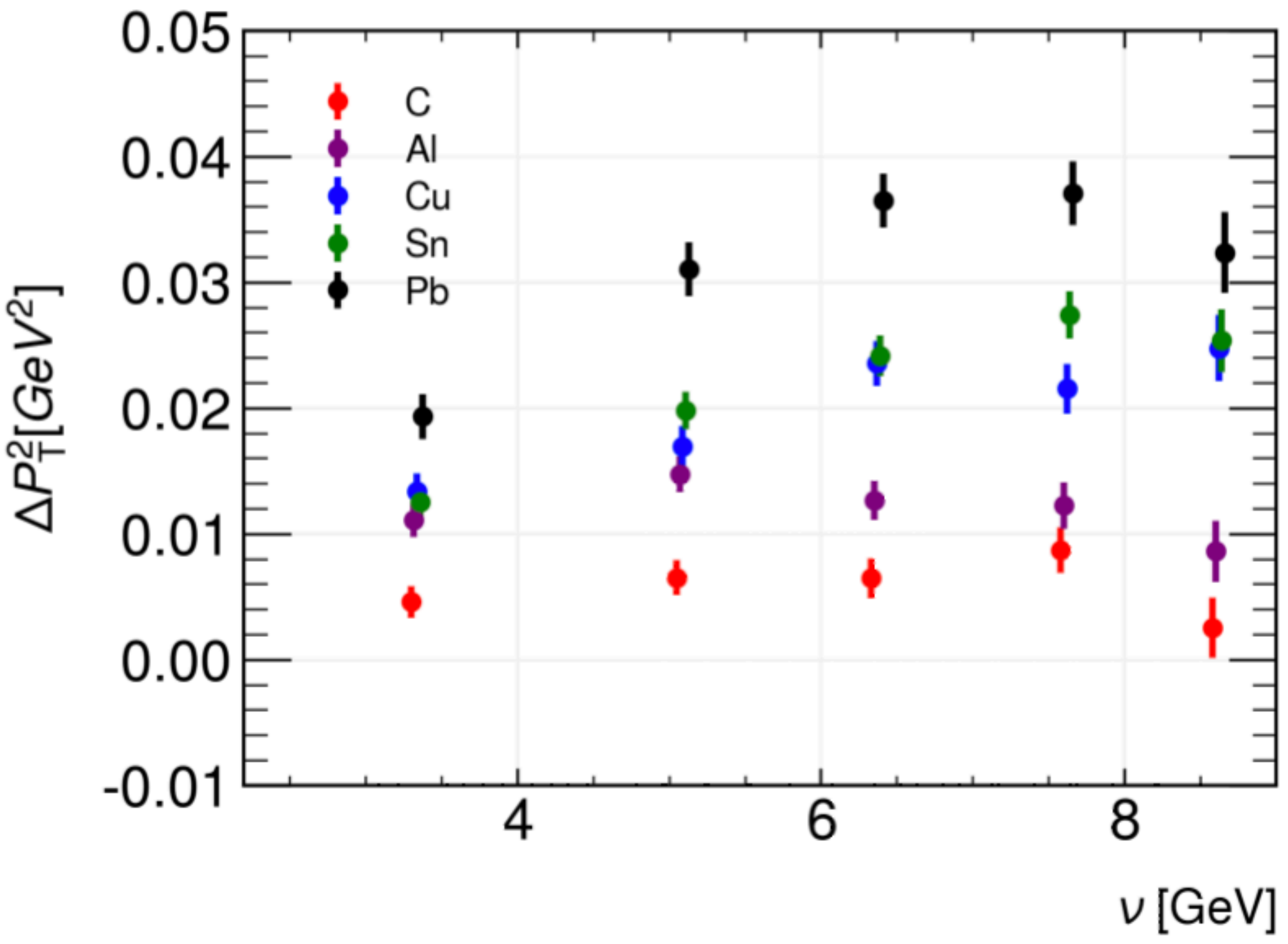


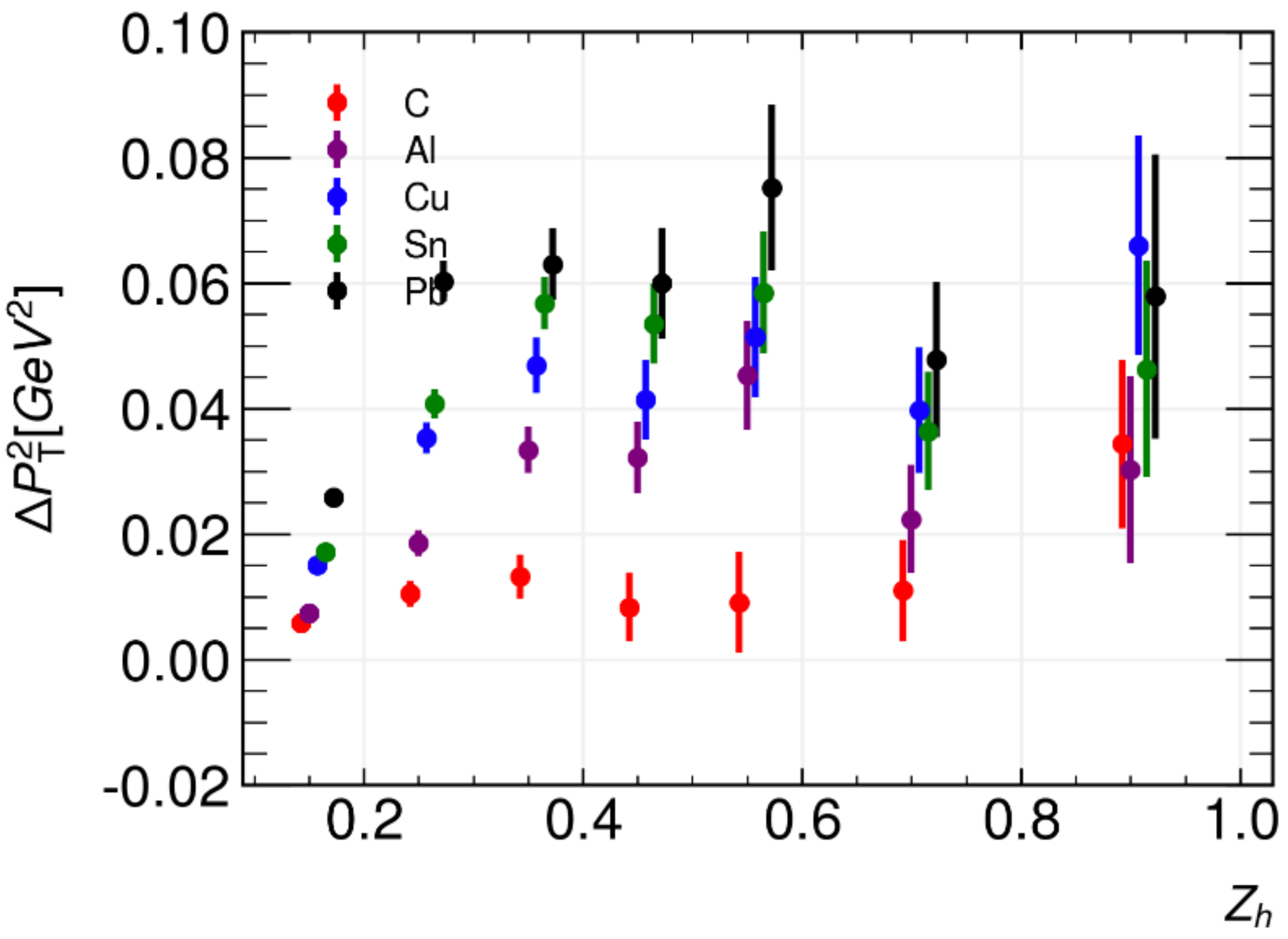
First Preliminary RG-E measurements

Transverse momentum broadening vs A1/3 with DIS cuts



First Preliminary RG-E measurements
Transverse momentum broadening vs Nu & Zh with DIS cuts

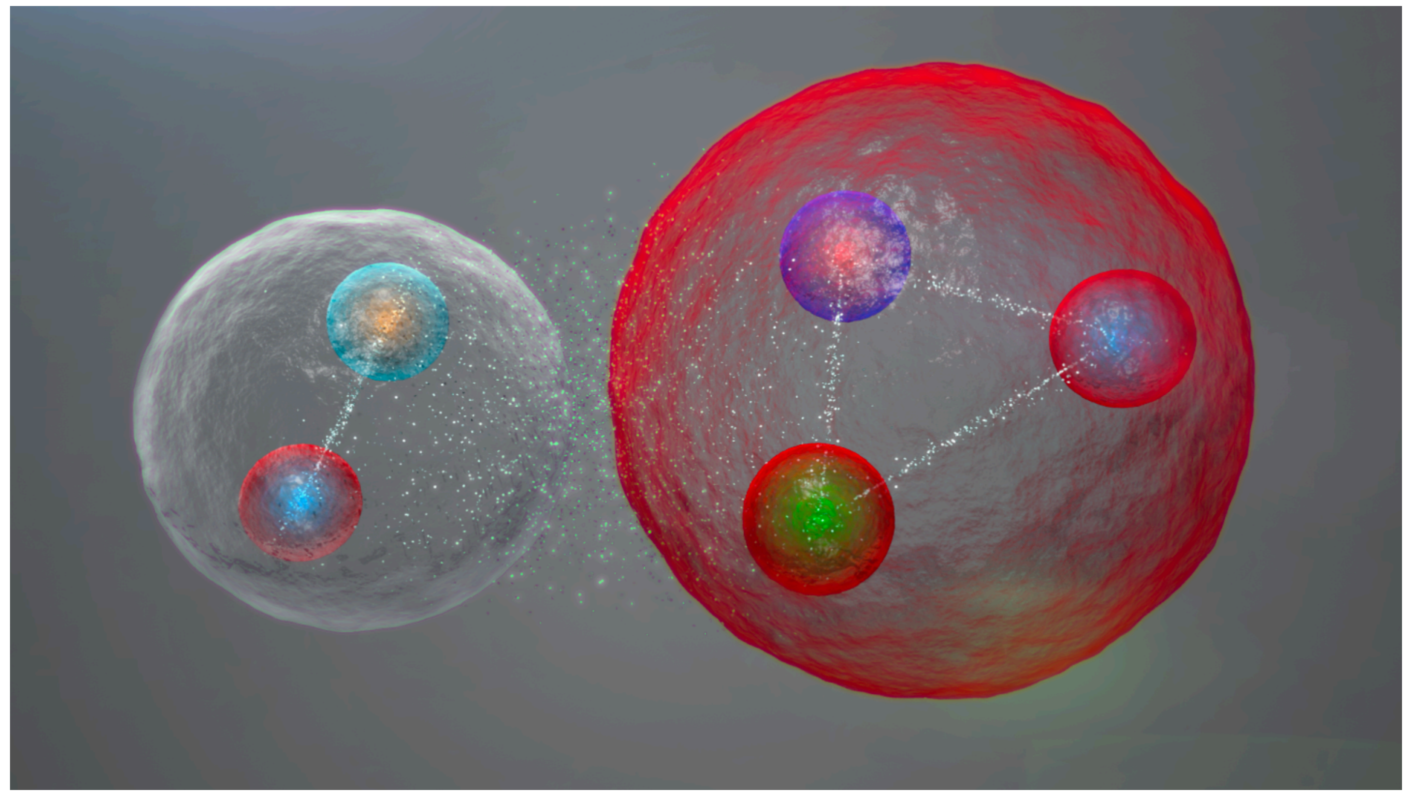




Quark Propagation and Hadronization at CLAS12

hadron	cτ	mass	flavor content	limiting error (60 PAC days)
π^0	25 nm	0.13	uūdd̄	5.7% (sys)
π^+, π^-	7.8 m	0.14	ud̄, dū	3.2% (sys)
η	170 pm	0.55	uūdd̄ss̄	6.2% (sys)
ω	23 fm	0.78	uūdd̄ss̄	6.7% (sys)
η'	0.98 pm	0.96	uūdd̄ss̄	8.5% (sys)
ϕ	44 fm	1	uūdd̄ss̄	5.0% (stat)*
f1	8 fm	1.3	uūdd̄ss̄	-
K^0	27 mm	0.5	ds̄	4.7% (sys)
K^+, K^-	3.7 m	0.49	us̄, ūs	4.4% (sys)
p	stable	0.94	uud	3.2% (sys)
$\bar{p}$	stable	0.94	ūūd̄	5.9% (stat)**
Λ	79 mm	1.1	uds	4.1% (sys)
$\Lambda(1520)$	13 fm	1.5	uds	8.8% (sys)
Σ^+	24 mm	1.2	uus	6.6% (sys)
Σ^-	44 mm	1.2	dds	7.9% (sys)
Σ^0	22 pm	1.2	uds	6.9% (sys)
Ξ^0	87 mm	1.3	uss	16% (stat)*
Ξ^-	49 mm	1.3	dss	7.8% (stat)*

More Luminosity More Acceptance Better Particle ID



First look at GeV-scale meson formation!

Measurements of baryon formation!

Closing remarks:

- The successful run of the first phase of the CLAS12-RGE experiment, conducted on various types of nuclear targets, provides a unique opportunity to measure a wide range of nuclear medium variables, such as hadronic multiplicity ratios, transverse momentum broadening, and correlation functions. These measurements on a wide range of hadron species offer a valuable opportunity to gain a comprehensive understanding of the hadronization phenomena within the nuclear medium.

- RG-E data cooking and calibration are in progress, with completion planned for this year. In parallel, data analysis is advancing and gaining momentum as well.

- Looking forward to the second experimental phase of RG-E, which corresponds to another 30 PAC days. This is necessary for access to hadrons with smaller cross-sections and more complex decays channels. Outbidding data is also planned to take during this phase in its majority.

- The RG-E, being a lower-energy electron-nuclei collider, is on a pathway towards the future Electron-Ion Collider.

For the successful RGE run, I want to thank Jefferson lab and everyone involved in the experiment

- Hall-B Staff
- Hall-B Engineering Team
- CLAS12 Calcom Team

- **CEBAF Accelerator Staff**
- **JLab Target Group Team**

- CCTVal engineering team for designing and fabrication of the Double-Target

- Run group E students, postdocs, and spokespersons
- RG-E Run Coordinators
- RG-E shift takers

https://indico.cern.ch/e/hepnp2025