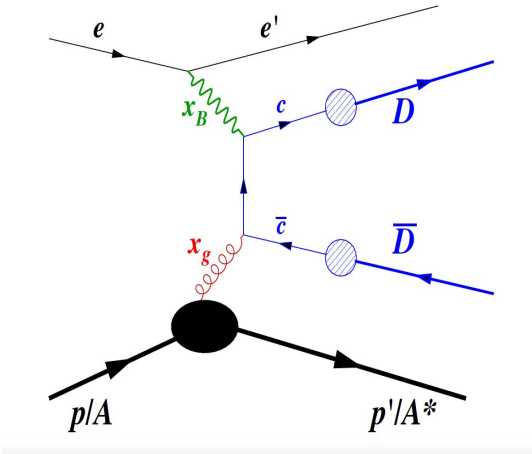
Jets&HF working group report at Early Science workshop

Olga Evdokimov, Rongrong Ma
04/25/2025

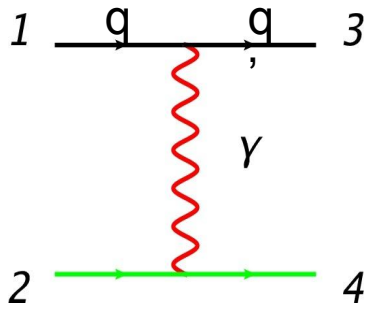
Production at LO

Charm quark pair

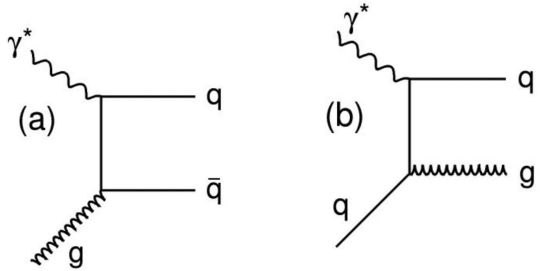


- Structure function, (n)PDF
- Cold nuclear matter effect
- Hadronization
- …

Single jet



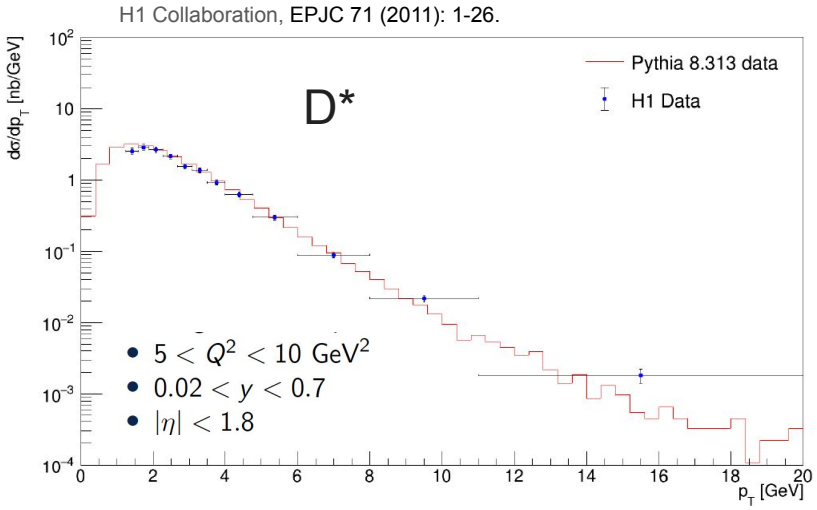
di-jet

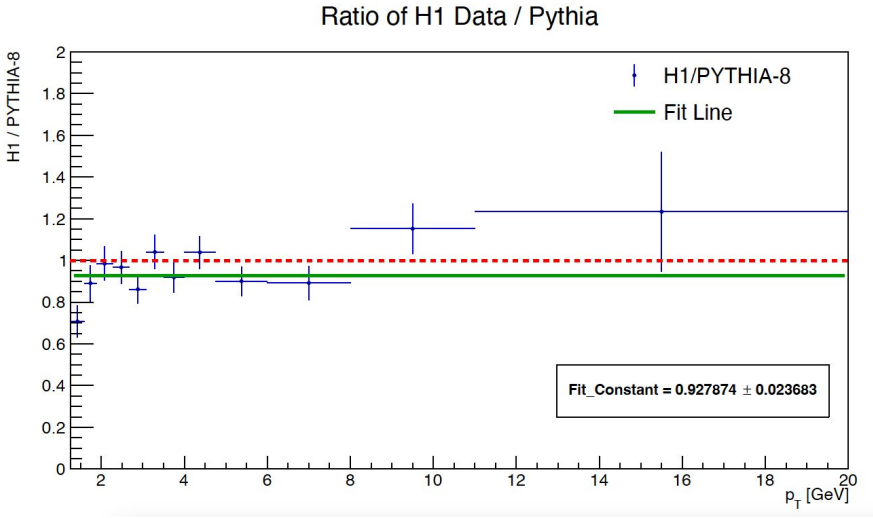


- (n)PDF
- Fragmentation function
- Asymmetries
- …

Validate PYTHIA8 for charm production

Amritanshu Thakur (Panjab)

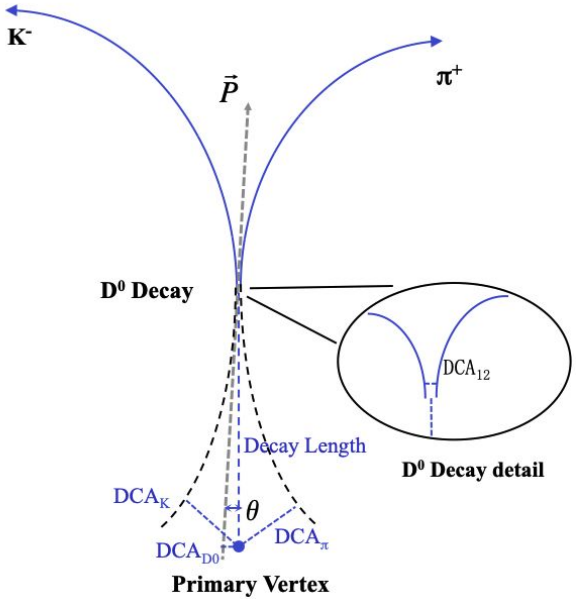




- Next: compare to other charm hadron measurements at HERA

D0 topological reconstruction

Reminder



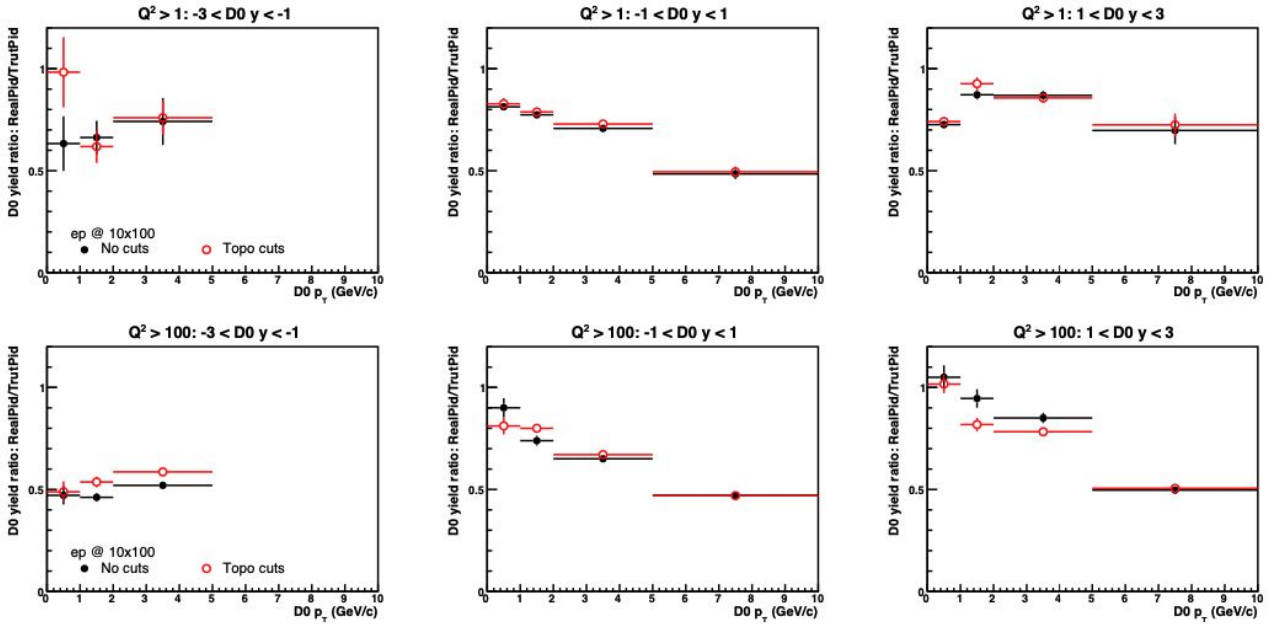
STAR, PRC 99, 034908 (2019)

- Topological variables
  - DCA_{π}, DCA_{K}, DCA_{12}
  - DCA_{D0}, decay length, cos(θ)
- Calculated based on helix swimming in a constant magnetic field
  - Adopted from STAR code
  - B = -1.7 T

Truth vs. Real PID: PID efficiency

Rongrong Ma (BNL)

ep

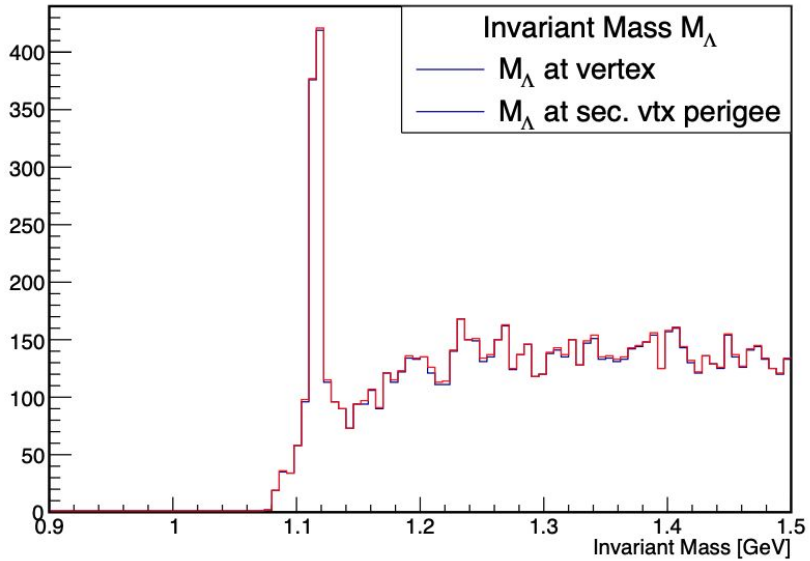


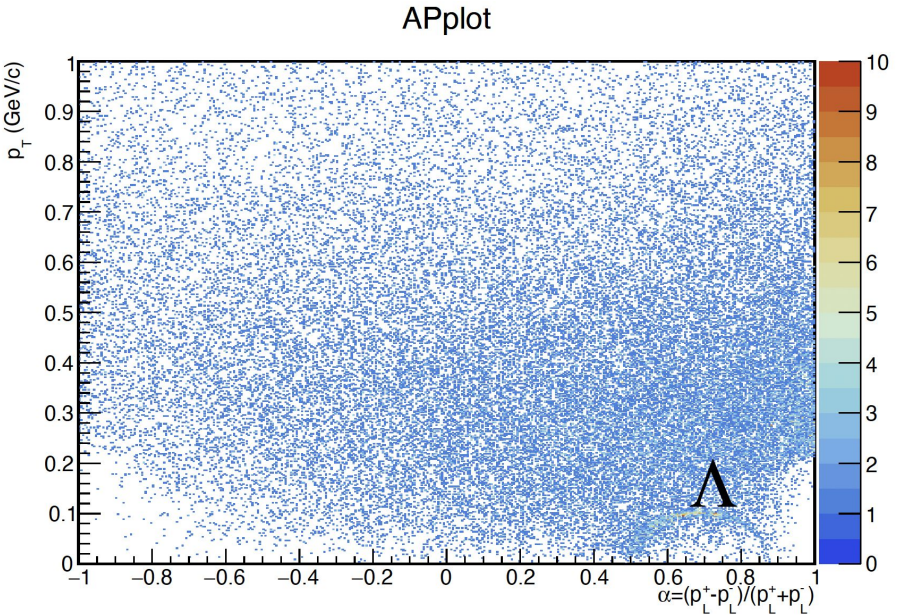
- Lose up to 50% D^0 signal counts with realistic PID

Secondary vertex: invariant mass

Bishoy Dongwi (SBU)

ACTS::AdaptiveMultiVertexFinder





- Next: evaluate efficiency and improve S/B ratio; tackle D^0 reconstruction

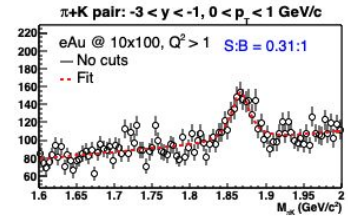
Simulation setup for e+Au

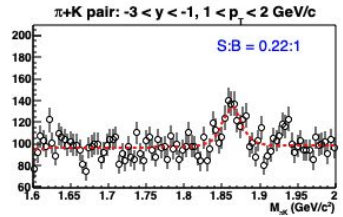
- BeAGLE v103, e+Au
- Energy: 10x100
- $Q^2_{min} > 1\ GeV^2$
- With beam effects: applied afterburner for eAu 10x110 configuration
- Two samples
  - HF-enriched sample
    - Select events with $D^0 \rightarrow \pi$ + K
  - DIS sample
- ePIC geometry: 25.03.1

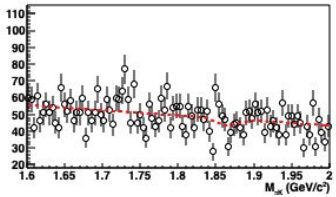
Simulation output

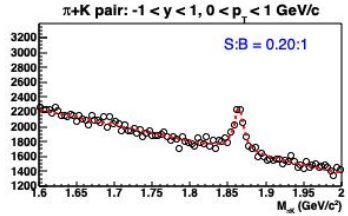
Event generator	**Decay channel**	**# of D0 events and x-sec**	**Luminosity**	**# of sampled DIS events and x-sec**	**Output location**
BeAGLE v103 eAu, 10x100 $Q^2 > 1$	$D^0 \rightarrow \pi$ + K	N = 25333	0.29 fb^{-1}	N = 9940000	/eic/u/rongrong/gpfs02/BeAGLE/D0/eAu_10x100_Q2min1/Geo25.03.1
BeAGLE v103 eAu, 10x100 $Q^2 > 1$	DIS	N = 31000 σ = 0.3413 ub	0.91e-3 fb^{-1}		/eic/u/rongrong/gpfs02/BeAGLE/DIS/eAu_10x100_Q2min1/Geo25.03.1

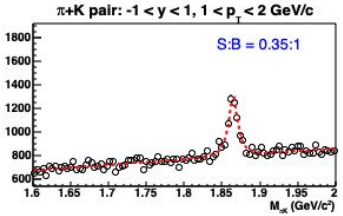
Fit D0 signal in e+Au collisions: all pairs

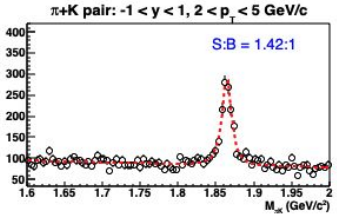


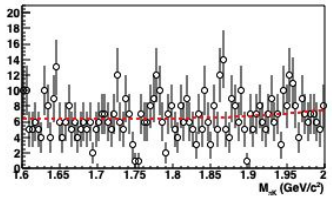


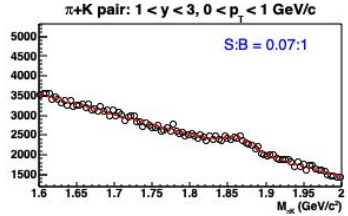


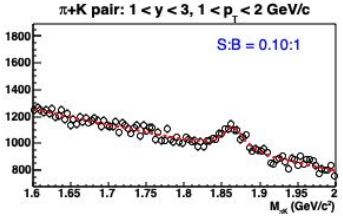


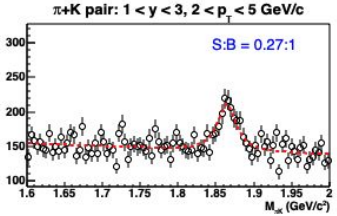




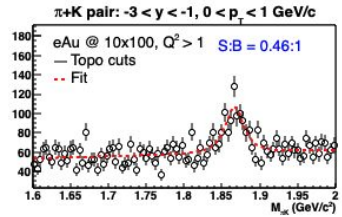


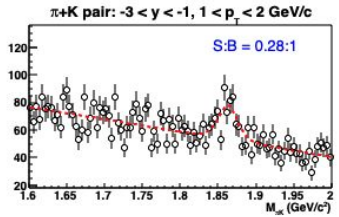


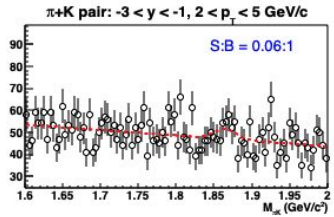


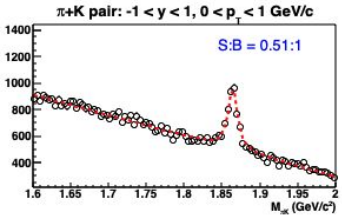


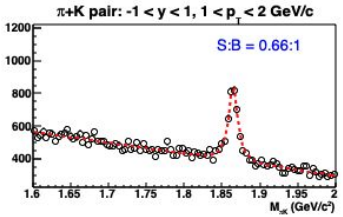
Fit D0 signal in e+Au collisions: w/ topological cuts

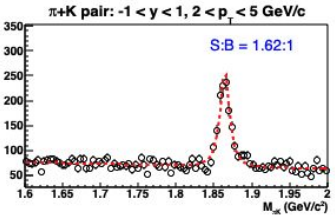


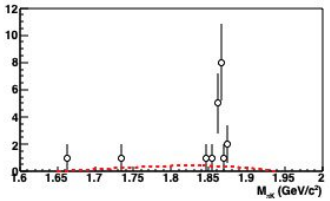


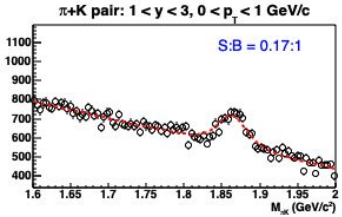


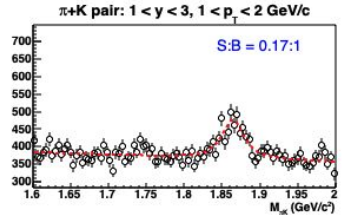


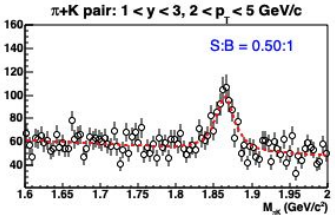












Expected running scenario

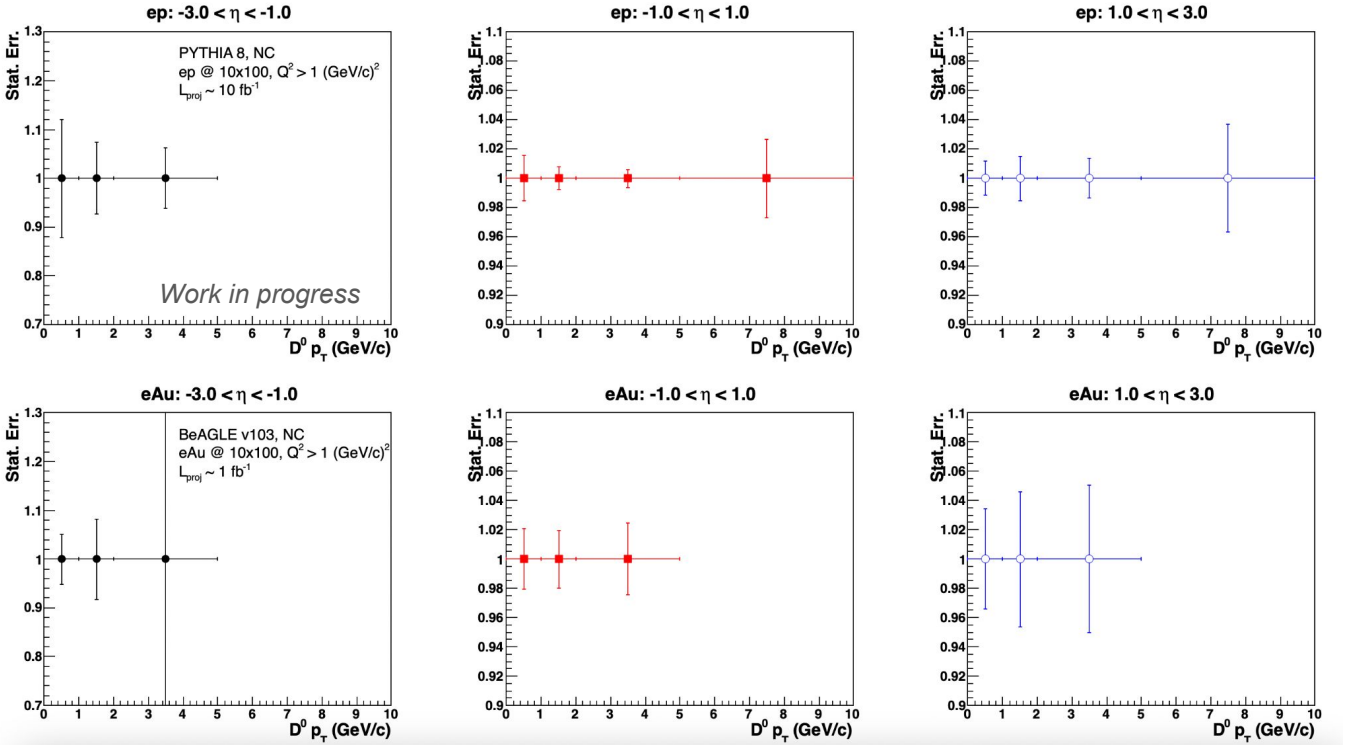
	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG
Note: the eA luminosity is per nucleon					

- Focus on e+Au @ 10x100
  - ep: $L \sim 10$ fb^{-1}
  - eAu: $L \sim 1$ fb^{-1}

Can we agree on a number?

Projection: D0 significance

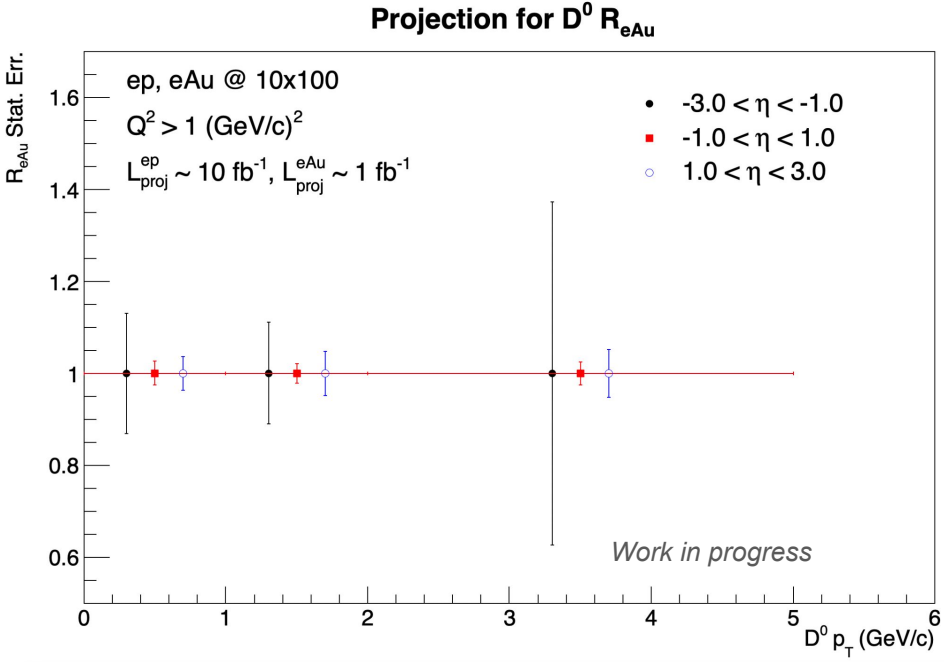
Rongrong Ma (BNL)



- Very preliminary results

Projection: D0 R_{eAu}

Rongrong Ma (BNL)

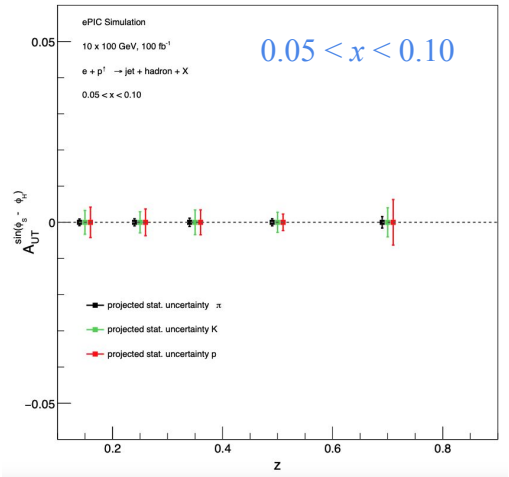


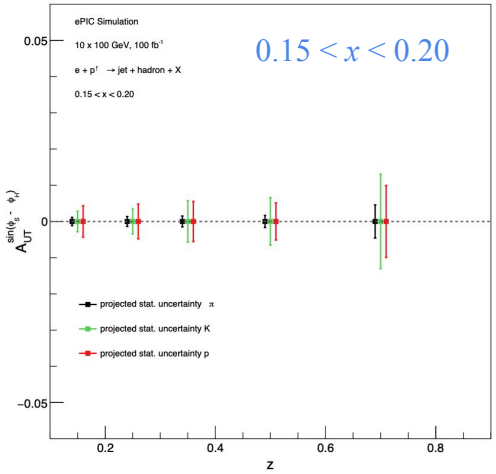
- Very preliminary results

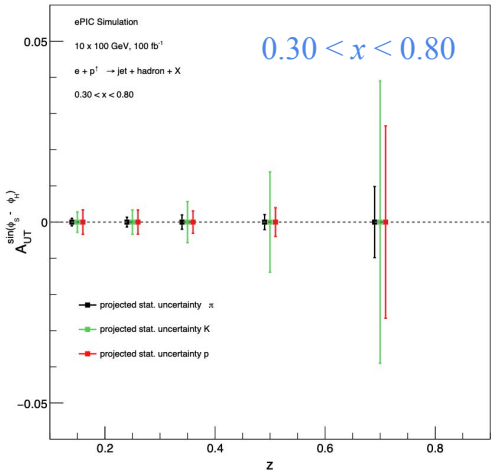
Hadron-in-jets: Collins Asymmetry

Kevin Adkins (Morehead)

ep @ 10x100, L = 100 fb^{-1}





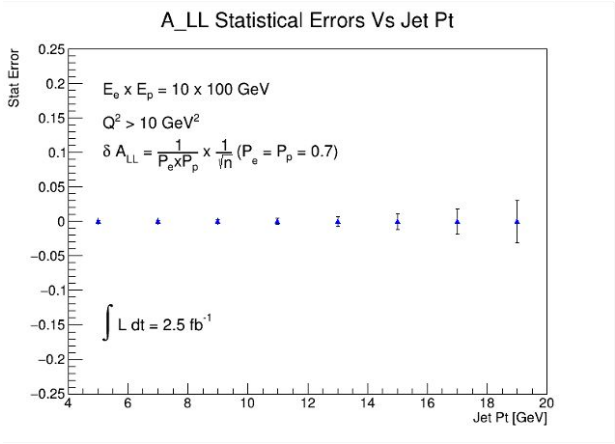


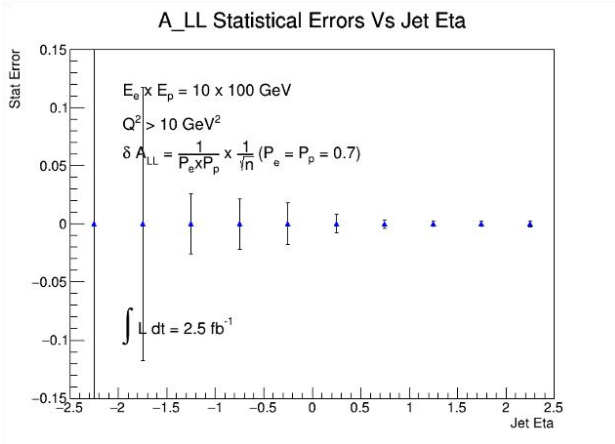
- Next: include Q^2 binning

Jets A_{LL}

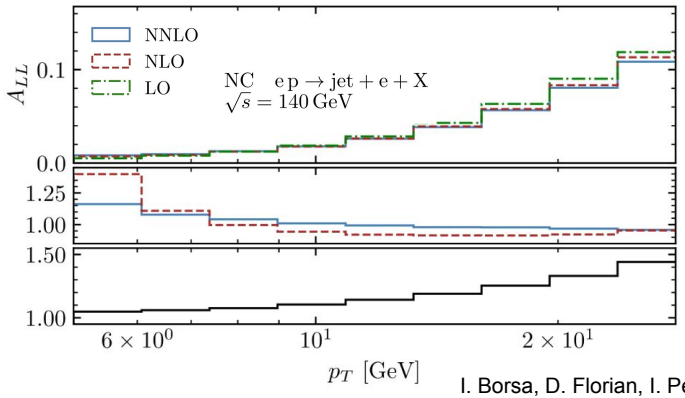
By Brian Page (BNL)

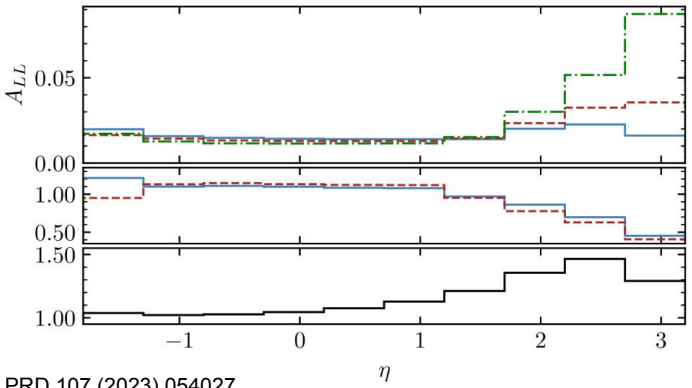
ePIC projection





Theory





I. Borsa, D. Florian, I. Pedron, PRD 107 (2023) 054027

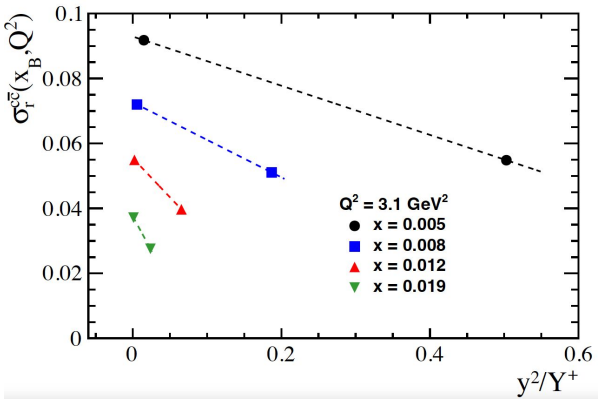
Summary & Outlook

- **Heavy flavor**
  - PYTHIA8 well reproduces D* spectrum measured at HERA
  - Further study of D^0 reconstruction in ep collisions (secondary vertexing, etc.)
  - First look at of D^0 measurement in e+Au collisions, which is promising
  - Next
    - Accumulate more statistics for e+Au
    - Detailed study of tracking performance in e+Au; refine signal extraction
    - Explore other topics: D^0 in jets, L_c/D^0 ratio, etc
- **Jets**
  - Binning in *x* for hadron-in-jet Collins asymmetry.
  - Next
    - Hardon-in-jet Collins: further bining in Q^2
    - Further exploration of jet physics for early science

Backup

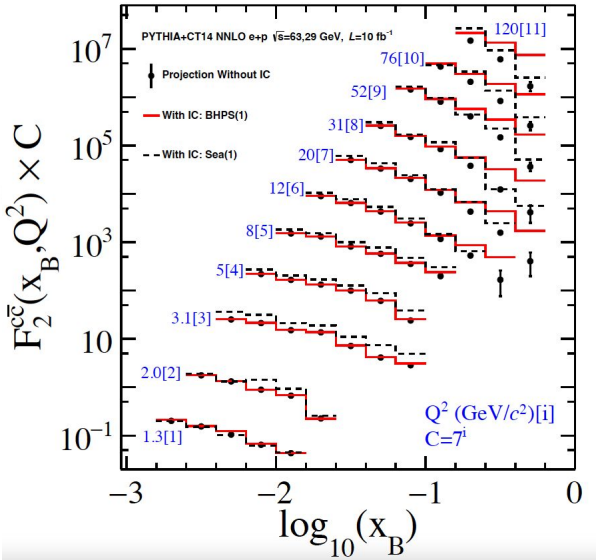
Charm structure function

$$\sigma_r^{c\bar{c}}(x_B, Q^2) = F_2^{c\bar{c}}(x_B, Q^2) - \frac{y^2}{Y^+} F_L^{c\bar{c}}(x_B, Q^2),$$



Matthew Kelsey
PRD 104 (2021) 054002

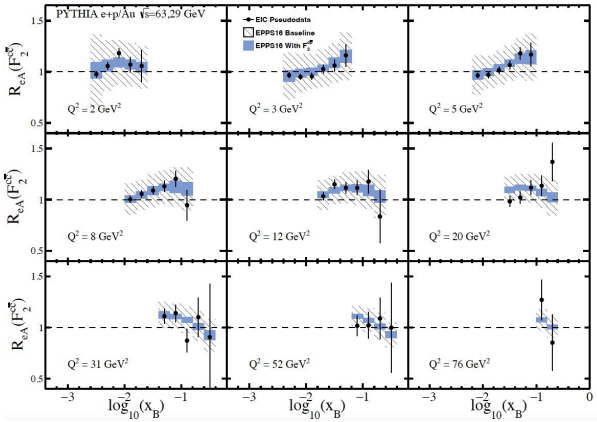
Projections with D-meson + DMT requirement



unpolarized e+p collisions:
5x41 GeV, 10 fb^{-1}
10x100 GeV, 10 fb^{-1}

- Extend charm structure function measurements at HERA to high x region

Gluon nPDF

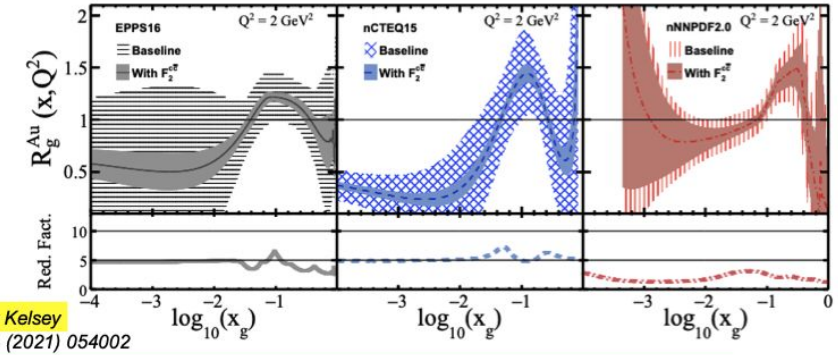


- Constrain gluon nPDF with ep/eA collision, especially at high x region

Projections with D-meson + DMT requirement

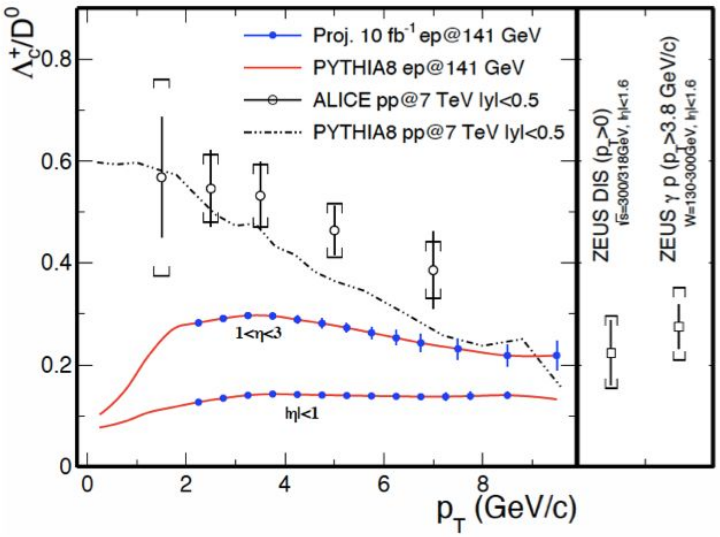
At each collision energy
5x41 GeV
10x100 GeV
1 fb^{-1} ep + **1 fb^{-1}/A eA**

Au beam is preferred!

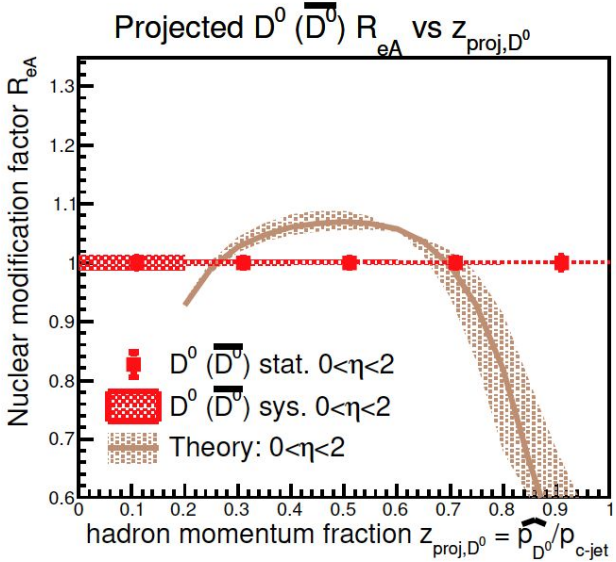


Matthew Kelsey
PRD 104 (2021) 054002

Fragmentation & hadronization

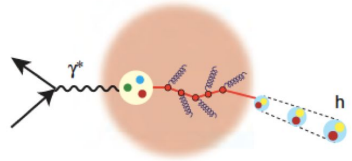


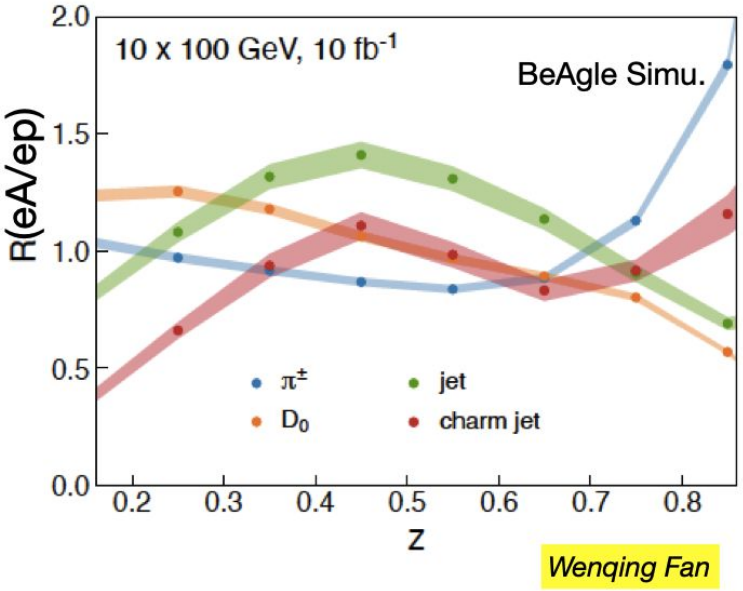
Yuanjing Ji
arXiv: 2102.08337

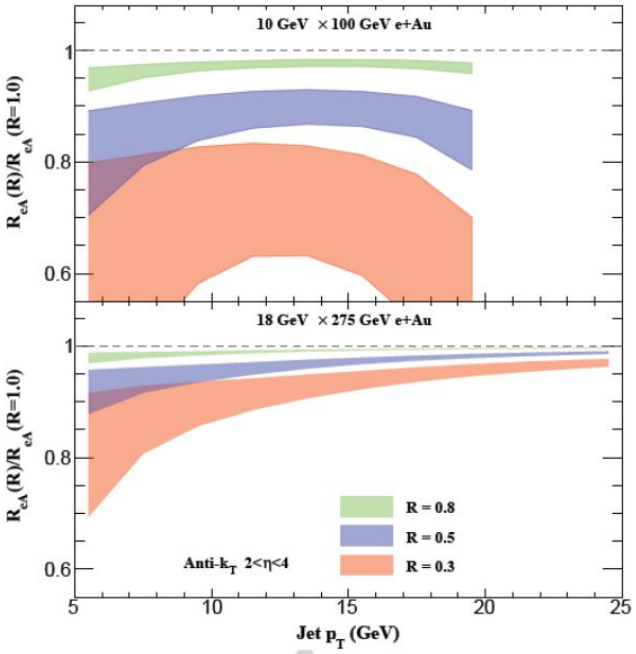


- Difference seen in e+e/p and p+p. How would that happen?
- Does charm quark fragment differently in e+p and e+A?

Parton propagation in a nucleus





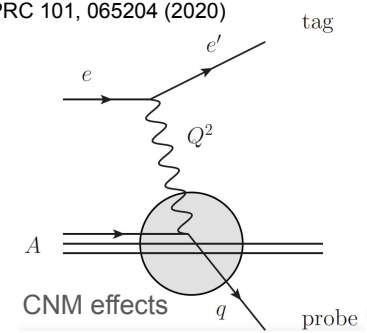


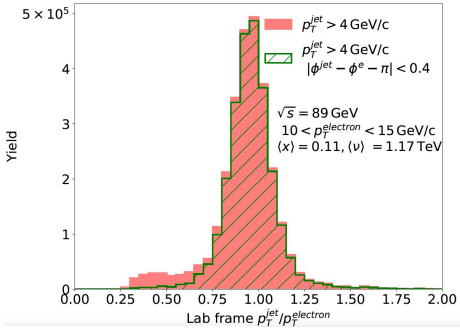
- How does nuclear environment alter parton propagation?

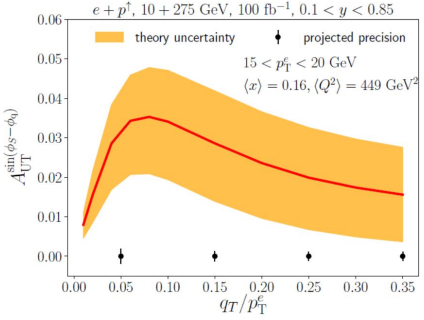
M. Arratia, et. al., PRC 101, 065204 (2020)

Jets

- Higher hadron beam energies open up phase space for more energetic jets which are easier to interpret theoretically - however, contributions will be possible at the lower energies proposed for the first several years
- Polarized runs starting in years 2 and 3 will allow first looks at jet-based TMD measurements complimentary to SIDIS
- Substructure studies for probing vacuum/medium fragmentation require good statistics







Sivers and Collins Asymm