Yale University Wright Laboratory

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Inclusive Charged Hadron Measurements In p+Au Collisions At $\sqrt{s_{NN}} = 200$ GeV In STAR

Tong Liu (Yale University) for the STAR collaboration

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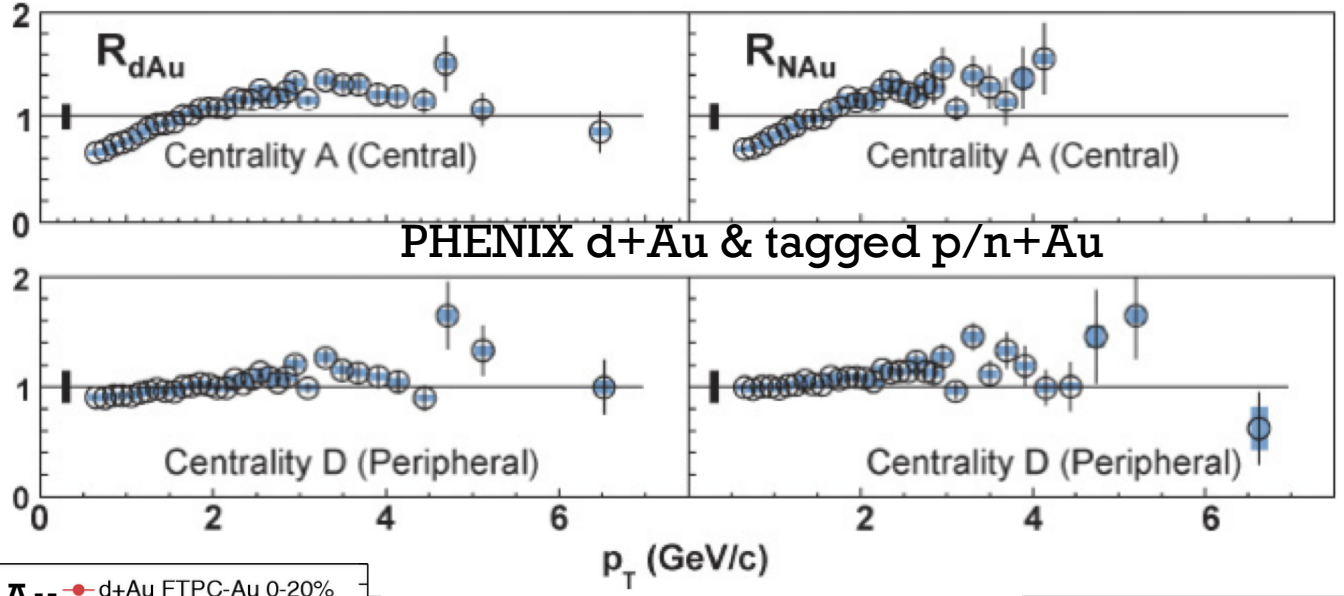
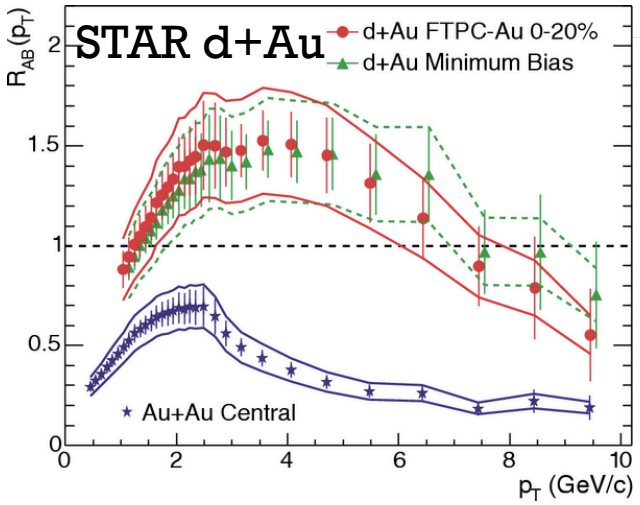
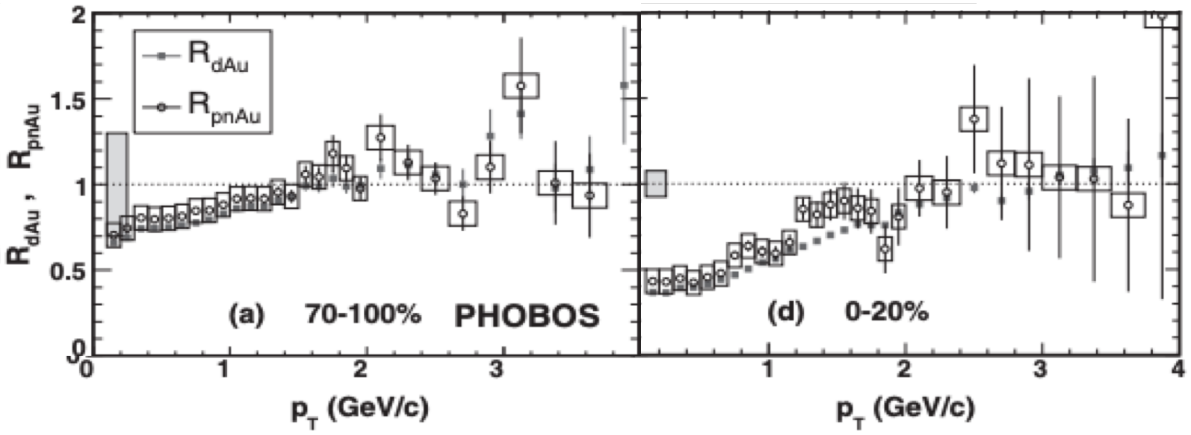
Hadron Yield In Small Systems

- **Sensitive probe across p_T**
  - High p_T : proxy for jets
  - Intermediate p_T : Cronin effect
  - Low p_T : possible radial flow effect
- **Previous measurements**
  - Central bins show larger suppression than peripheral bins at low p_T; R_{dAu} rises with p_T
  - Some tension between measurements, no definitive conclusion
  - Only d+Au & tagged p/n+Au so far



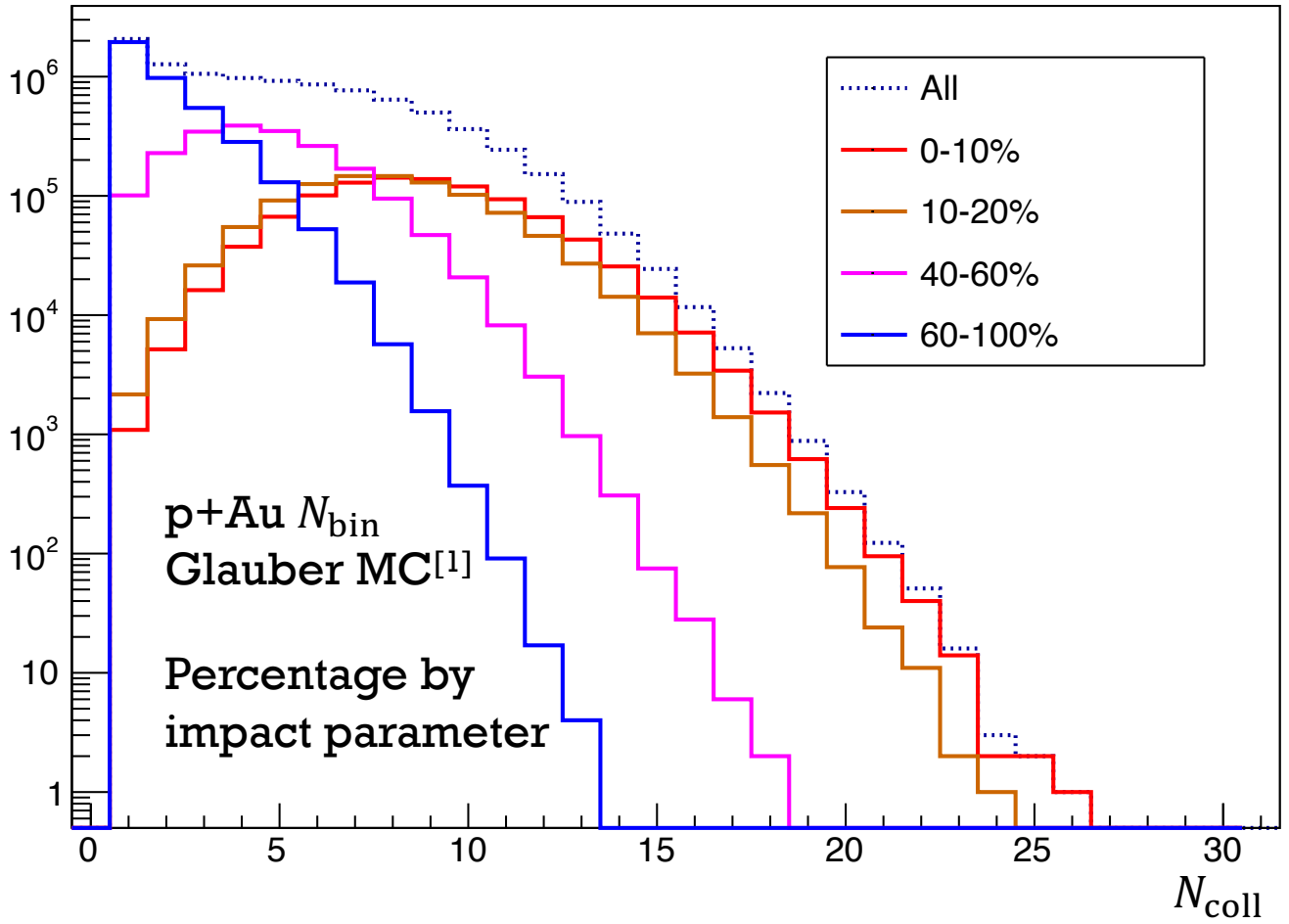




PHENIX, Phys. Rev. C 77, 014905 (2008)
STAR, Phys. Rev. Lett. 91, 072304 (2003)
PHOBOS, Phys. Rev. C 92, 034915 (2015)

Event Activity (EA) In Small Systems

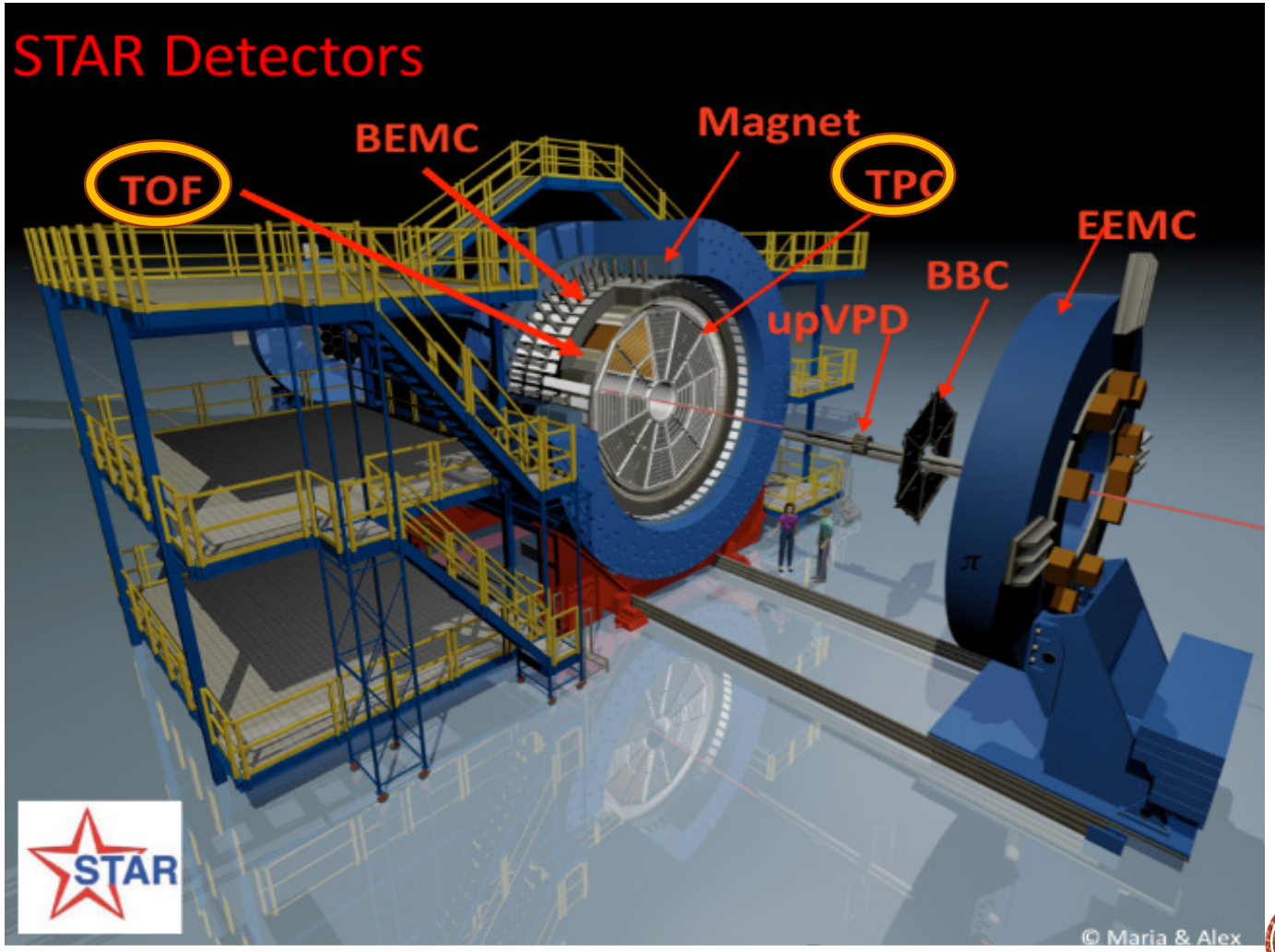
- Concept of centrality is not trivial for small systems
- Asymmetric small system: correlation between $\langle N_{\mathrm{coll}} \rangle$ and collision geometry significantly smeared compared to A+A collisions
- EA: degree of violence of the collision
- EA indicator: experimental observable that best correlates with EA
- Mid-rapidity multiplicity: auto-correlation for spectrum measurement
- Underlying multiplicity UE_{mult}



Code from: C. Loizides, Phys. Rev. C 94 (2016) 024914

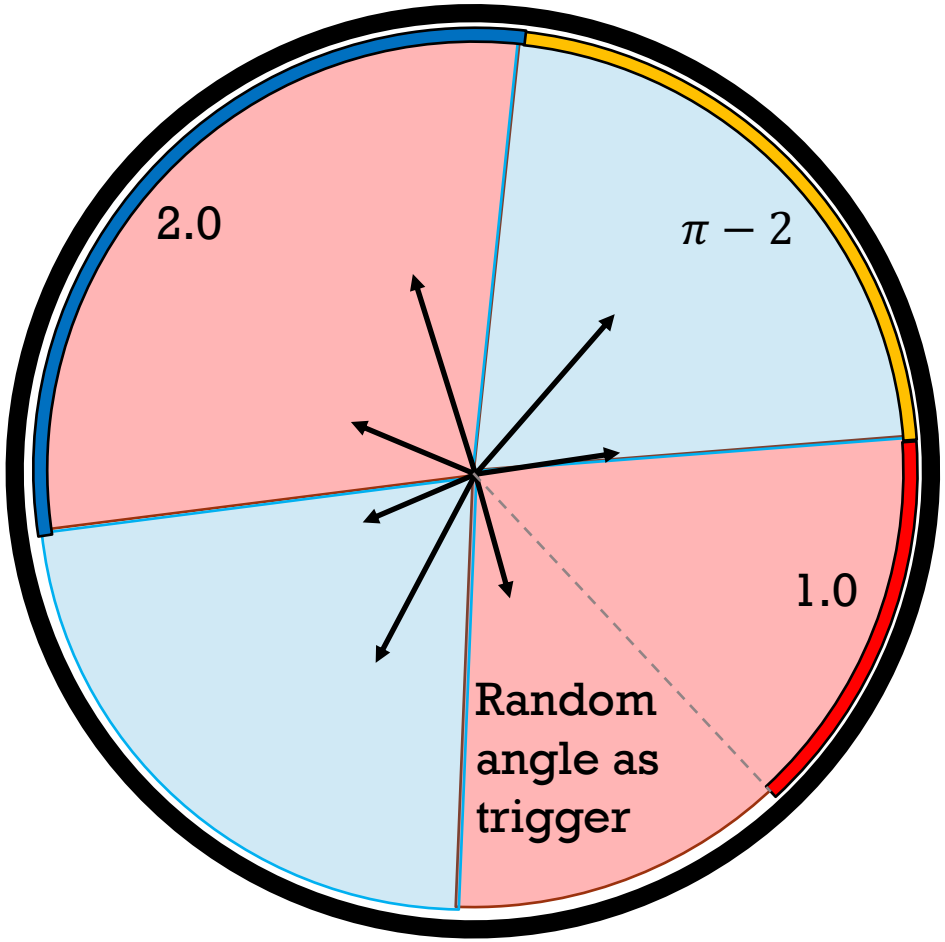
The STAR Detector

- **Time Projection Chamber (TPC)**
  - Methane-argon gas mixture
  - Momentum reconstruction for charged tracks
  - $|\eta| < 1$, full azimuthal coverage
- **Time Of Flight (TOF)**
  - MRPC technology providing PID info
  - TOF-matching used for pileup rejection
  - $|\eta| < 1$, full azimuthal coverage
- **Zero Degree Calorimeter (ZDC, out of view)**
  - Used for triggering & luminosity monitoring
- **Data: 2015 *p*+Au @ 200 GeV**
- **Particle selection:**
  - Charged particles reconstructed by TPC
  - TOF-matched to reject pileup
  - $0.2 < p_T < 30$ GeV/c, $|\eta|<1$



Underlying Multiplicity As EA

- Divide TPC acceptance into different regions
- Count track multiplicity in regions **transverse to a random trigger angle** as EA indicator: $UE_{\mathrm{mult}}^{\mathrm{rand}}$
  - $N_{\mathrm{ev}}^{\mathrm{rand}}$: # of events in each $UE_{\mathrm{mult}}^{\mathrm{rand}}$ bin
- Tracks in trigger & recoil region: $dN_{ch}^{\mathrm{trig}}/dp_{\mathrm{T}}$



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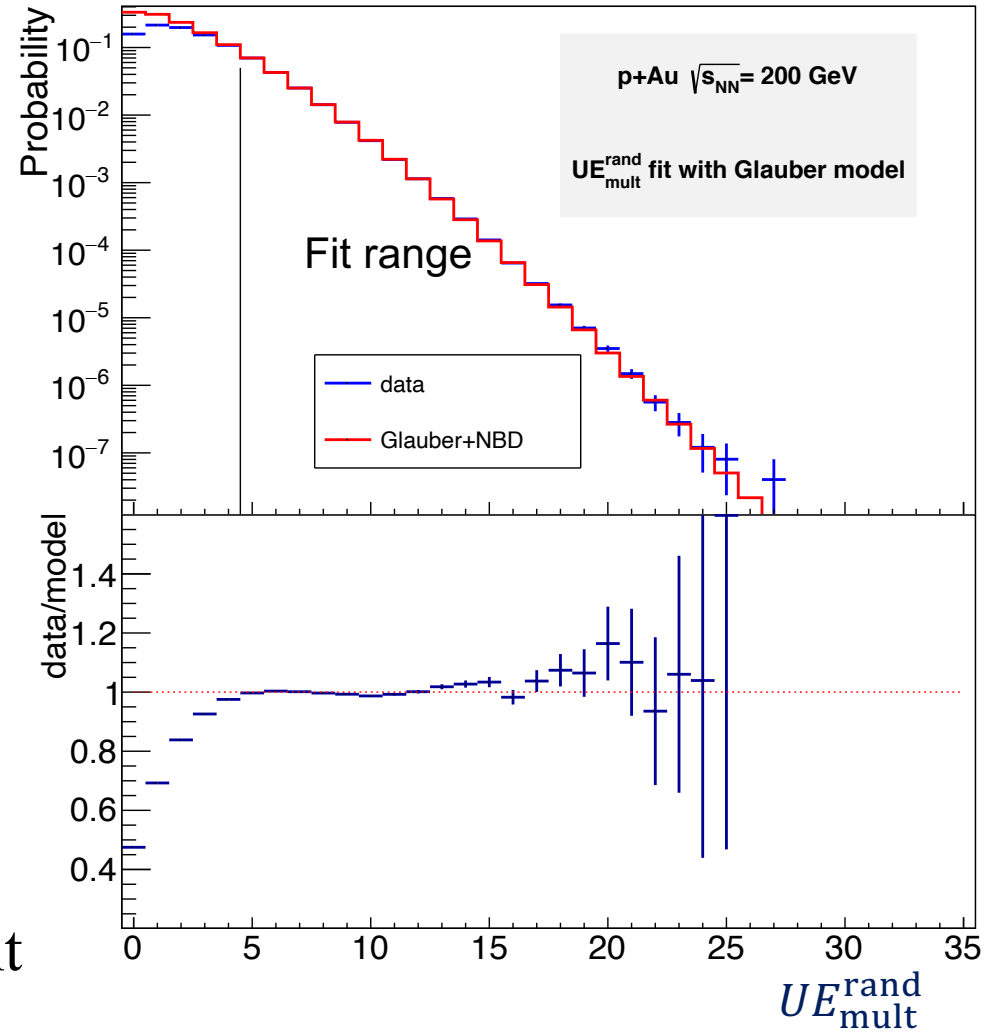
- Tracks in trigger & recoil region: $dN^{\mathrm{trig}}_{ch}/dp_{\mathrm{T}}$
- Glauber MC[1] ⊗ negative binomial distribution to fit $UE^{\mathrm{rand}}_{\mathrm{mult}}$ at high end
- Divide (fitted curve) into deciles & get $\langle N_{\mathrm{coll}} \rangle$ for each $UE^{\mathrm{rand}}_{\mathrm{mult}}$ bin
- Low end of multiplicity: mismatch due to event trigger inefficiency



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$$Y_{\mathrm{ch}} = \frac{1}{\langle N_{\mathrm{coll}} \rangle} \frac{1}{N_{ev}^{\mathrm{rand}}} \left(\frac{d^2}{d\eta d\phi} \frac{dN_{\mathrm{ch}}^{\mathrm{trig}}}{dp_{\mathrm{T}}} \right)$$

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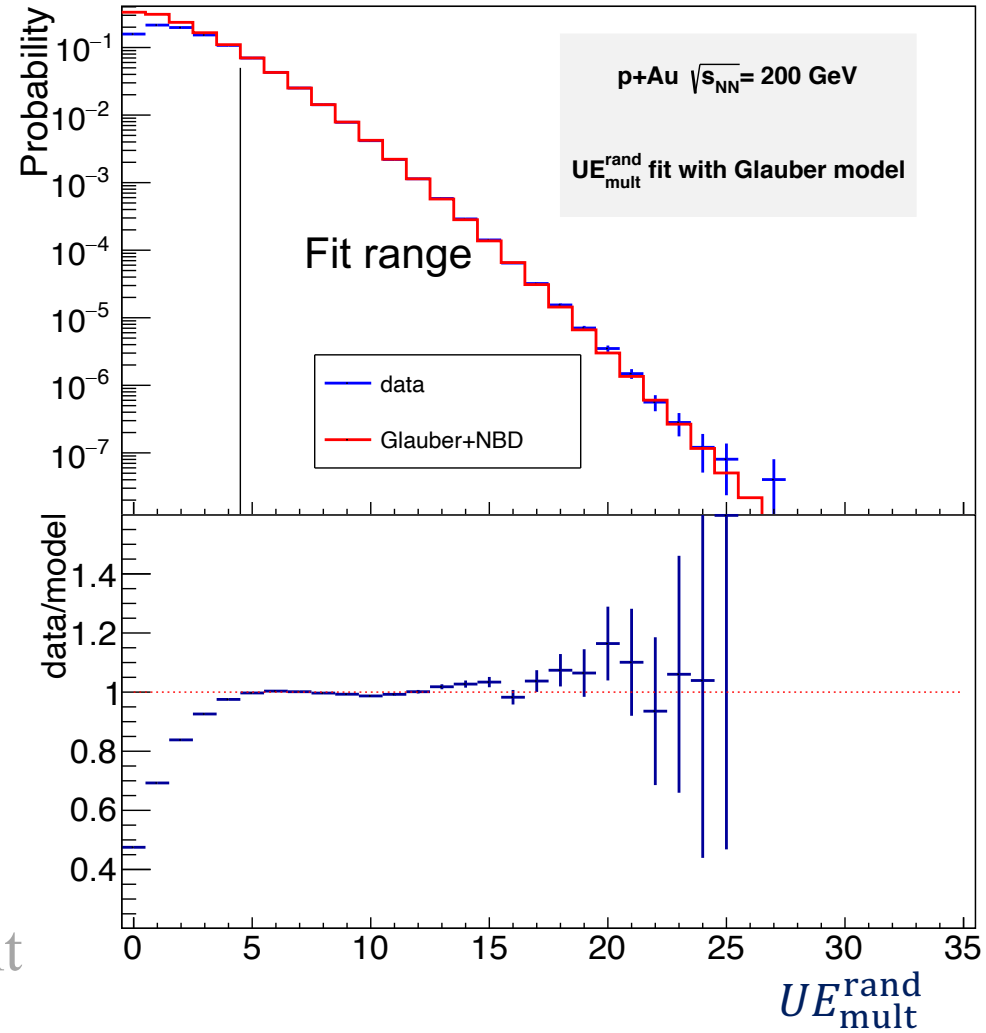

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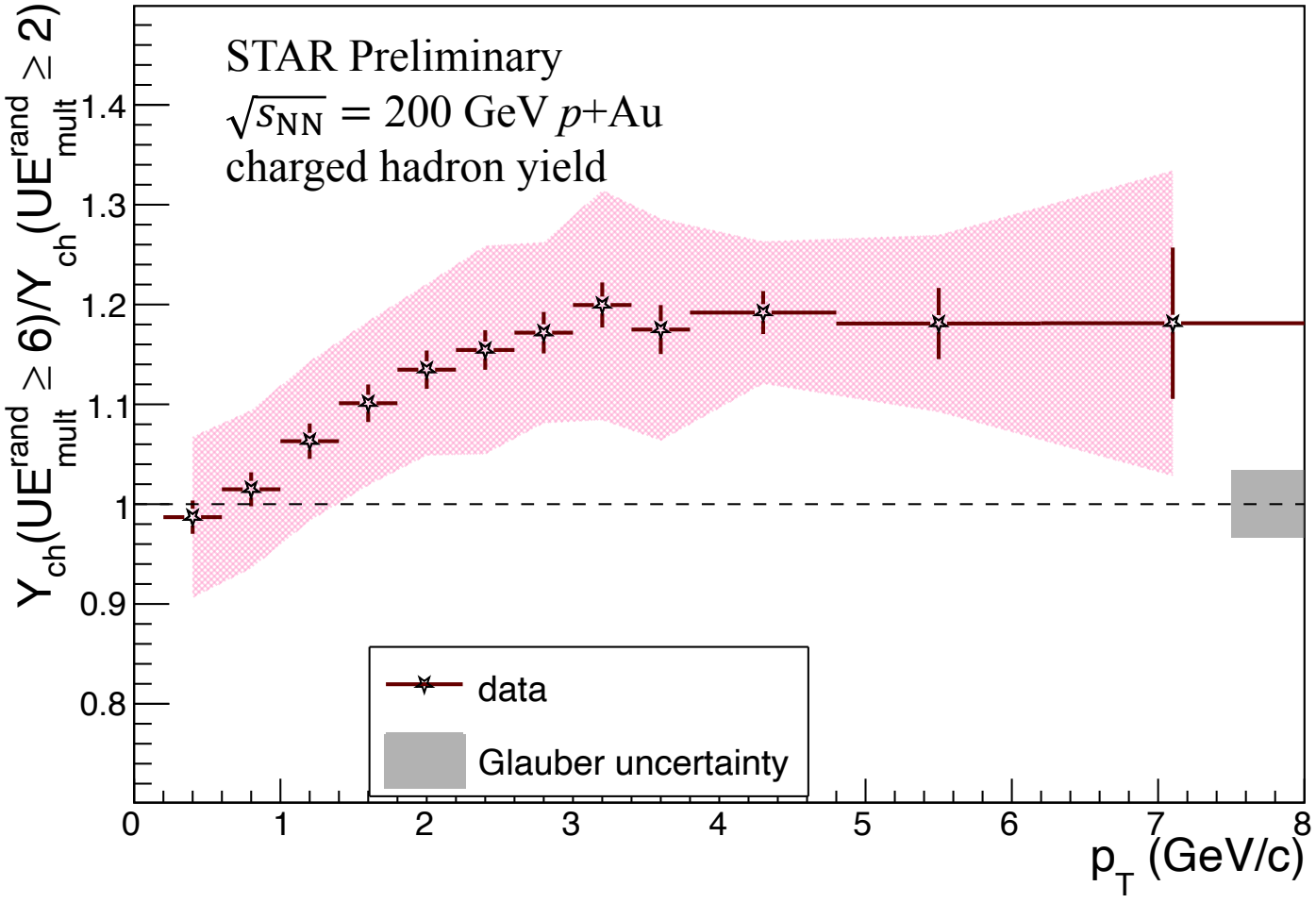
High-to-low EA Spectrum Ratio

- Corrected for detector effects (see backup)
- High-to-low EA ratio: systematic uncertainties partially cancel
- Per-event yield for $UE^{\text{rand}}_{\text{mult}} \geq 6$ divided by that for $UE^{\text{rand}}_{\text{mult}} \geq 2$
- Ratio ~ 1 @ low p_{T}, rise up at intermediate p_{T} and plateau above 3.5 GeV/c
- Slightly different observable than previous measurements
- Ideally: ratio to p+p collisions



Summary

- First inclusive charged hadron EA-dependent ratio measurement for $0.2 < p_{\mathrm{T}} < 8$ GeV/c charged hadrons in 200 GeV p+Au collisions at STAR
- Yield ratio between high and low-EA events: consistent with unity at low p_{T} and show hints of enhancement at intermediate & high p_{T}

Outlook

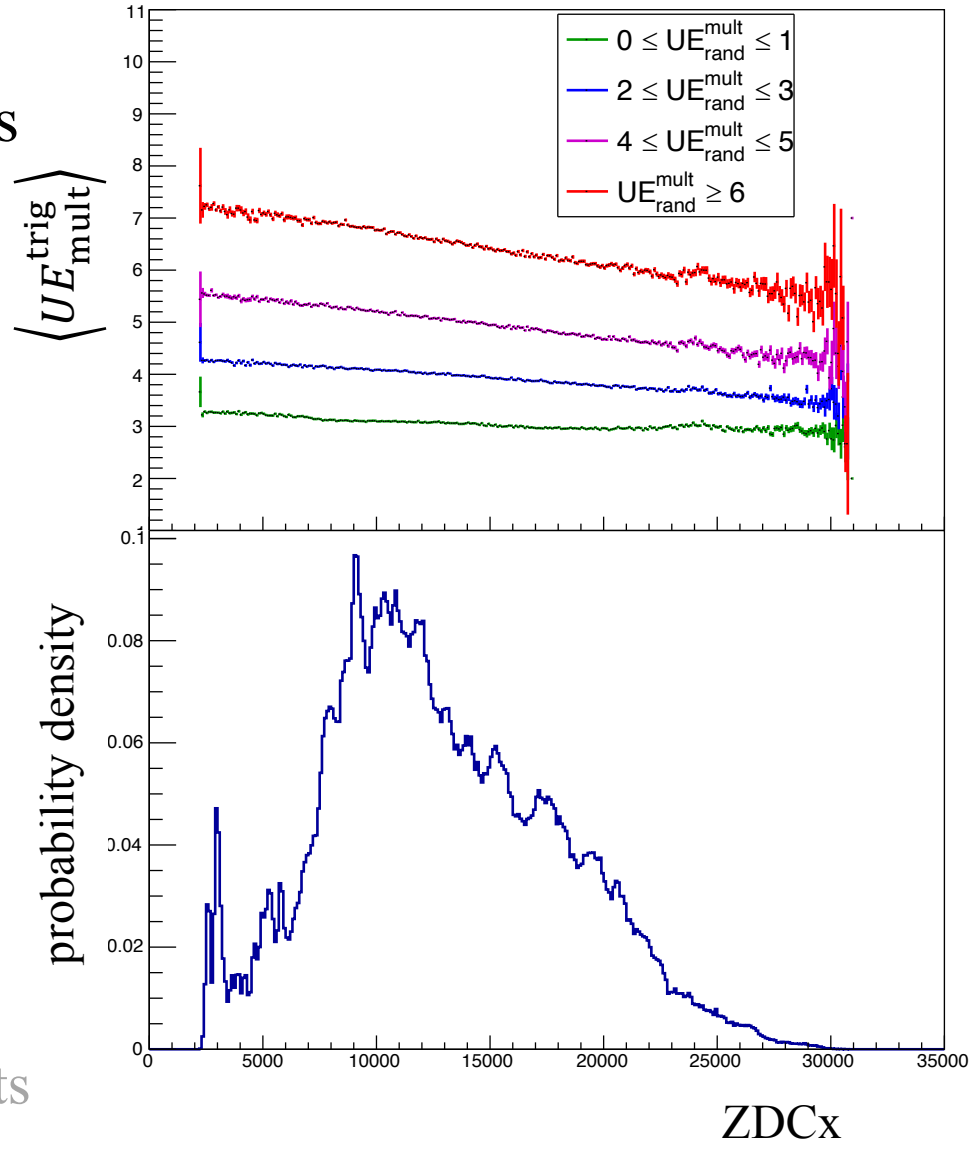
- Study different systematic effects and calculate absolute invariant yields
- Compare to STAR p+p yield and calculate $R_{p\mathrm{Au}}$
- Extend the measurement to charged & full jets

Thank you!

BACKUP

Detector Effect Correction

- Pileup: tracks from different physical collisions recorded in the same event
  - Use TOF-matching to reject pileup
- Event trigger efficiency: low-EA events might not be able to fire the trigger
  - Reweight events by Glauber-fitting ratio
- Vertex & luminosity correction: Average multiplicity has artificial dependence
  - Assign weight factor from polynomial fitting
- Track momentum resolution & tracking efficiency: tracks reconstructed with wrong p_T or completely missed
  - Use embedding data to correct for detector effects



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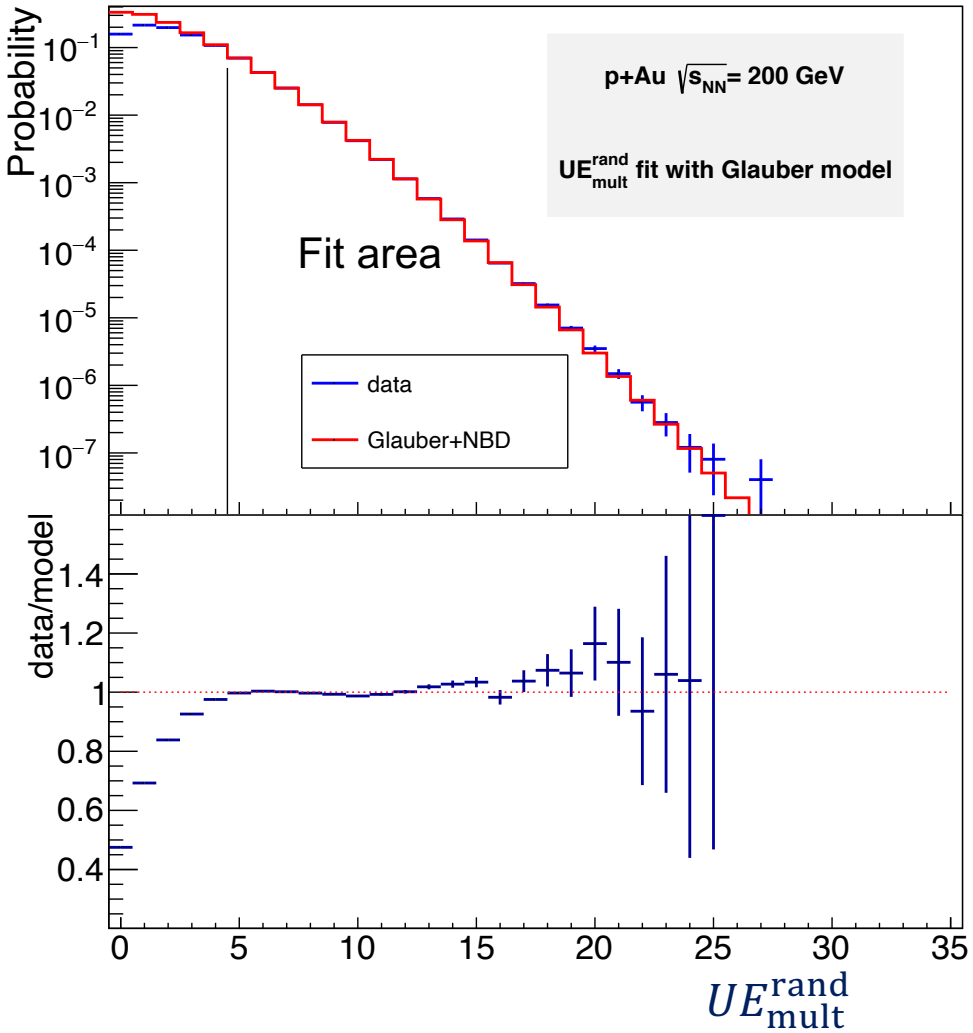

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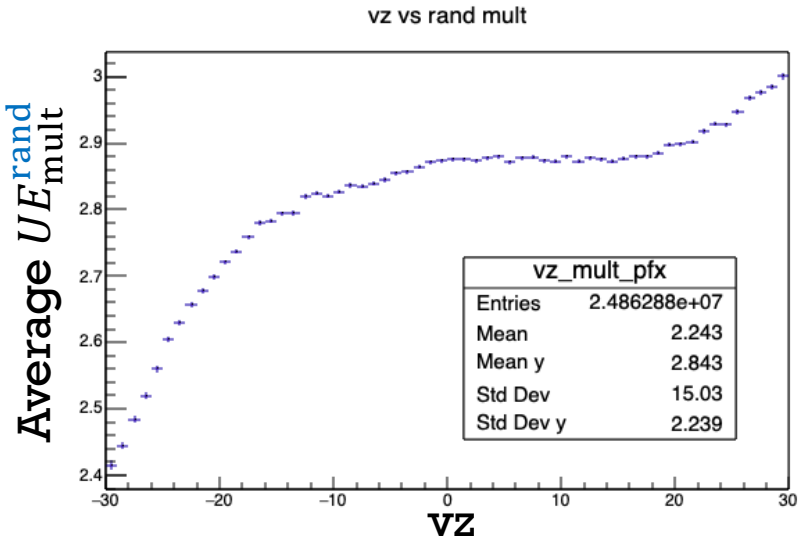

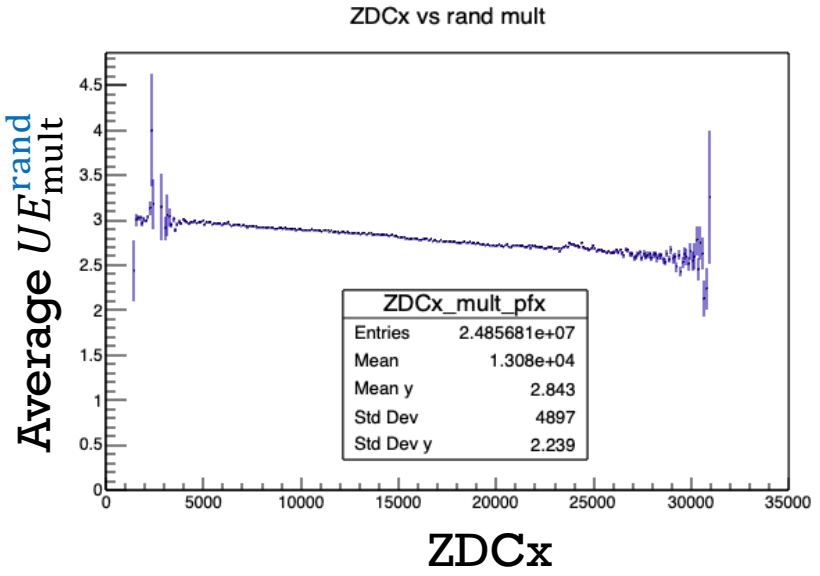

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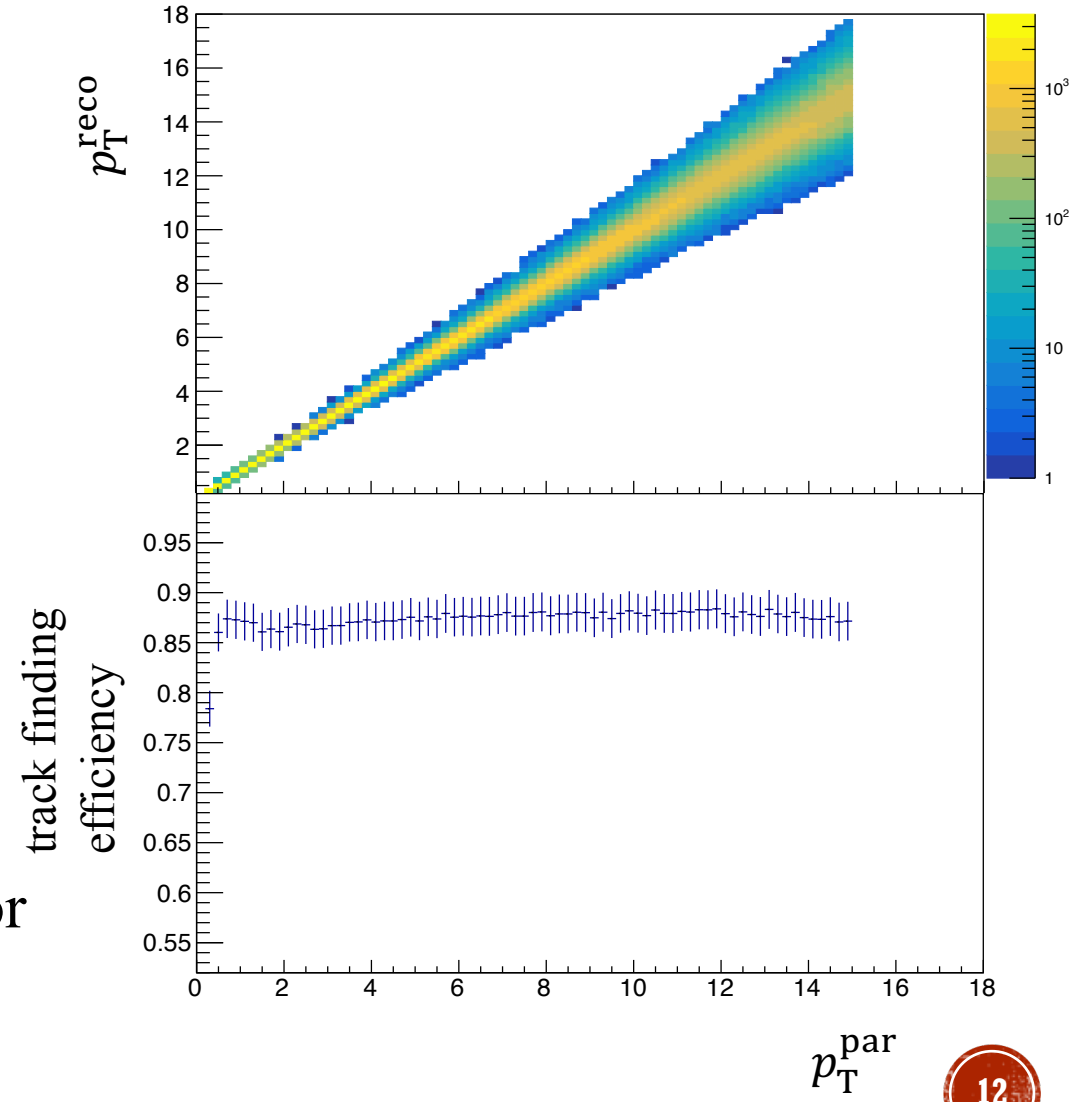

Systematic Uncertainties

- Pink band (along the curve): TOF matching uncertainty
  - TOF-matching is always required for EA-indicator tracks
  - Nominal spectrum uses TOF-matched tracks to get rid of pileup
  - Variation 1: alternative pileup elimination method – low ZDCx events (0-8000 HZ), don't require TOF-matching for tracks
  - Variation 2: Closest to "Ideal" case: low ZDCx + TOF matching
  - Currently quoting the bigger difference to nominal spectrum as uncertainty
- Gray box on the right: Glauber uncertainty
  - Nominal: σ_{NN}=42 mb, R(Au)=6.38 fm, d=0.535 fm (skin depth), Hard-core collision profile
  - Variation 1: R+= 2%, d-=10%, or R-= 2%, d+=10%
  - Variation 2: σ_{NN} +/- = 1 mb
  - Uncertainty: for each variation, quote the bigger difference to nominal spectrum; then add in quadrature
  - Assuming uncertainty uncorrelated in different bins (adding in quadrature)