Yale University Wright Laboratory

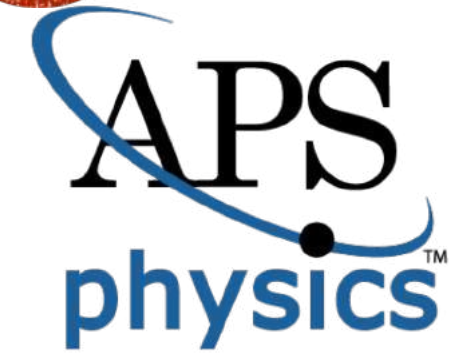
In part supported by U.S. DEPARTMENT OF ENERGY Office of Science

INCLUSIVE JET MEASUREMENTS IN SMALL SYSTEM COLLISIONS AT $\sqrt{s_{NN}} = 200$ GeV AT STAR

Tong Liu (Yale University) for the STAR collaboration

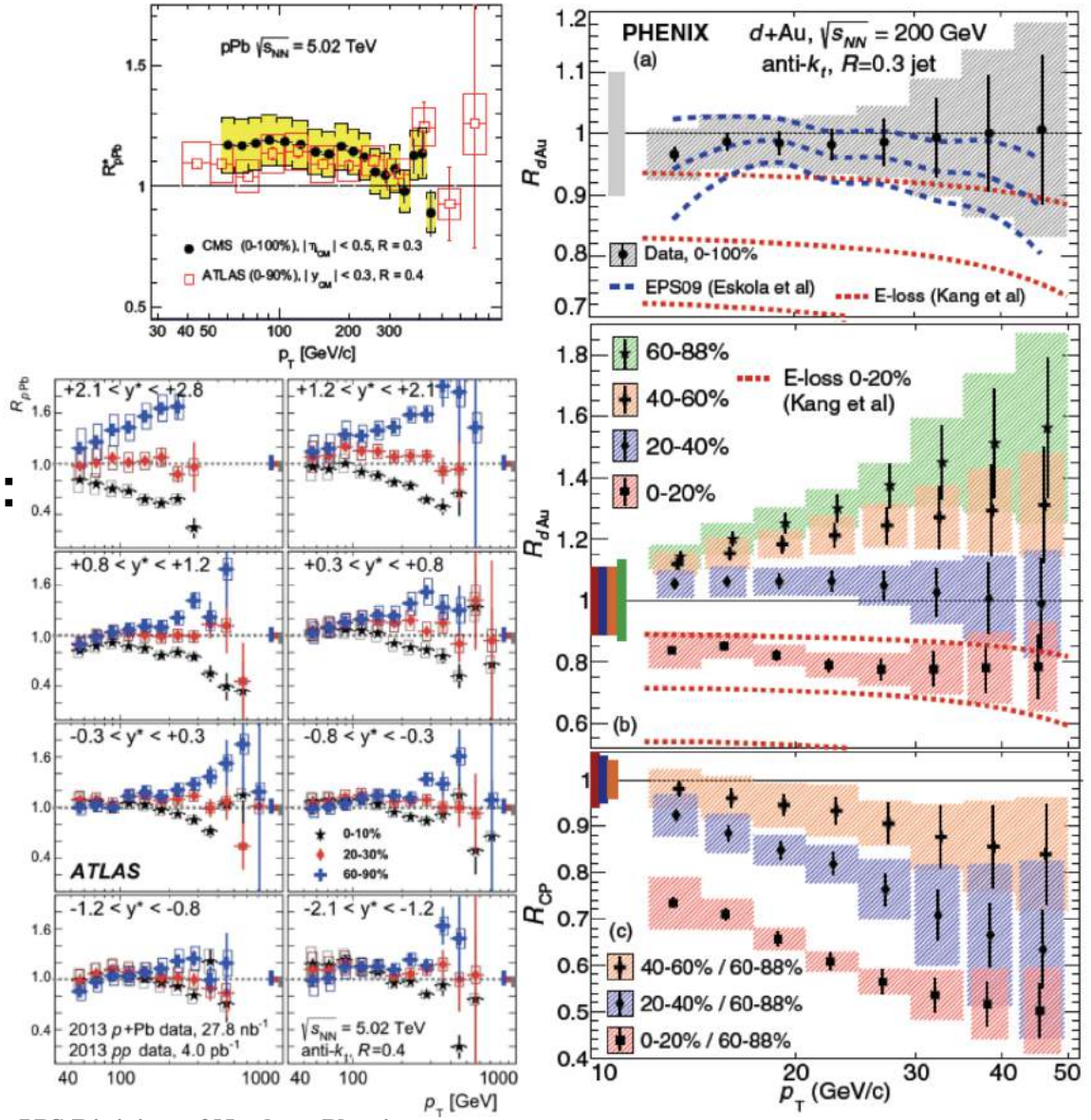
2020 Fall Meeting of the Division of Nuclear Physics

Oct 30, 2020



SMALL SYSTEM COLLISIONS: A HISTORY

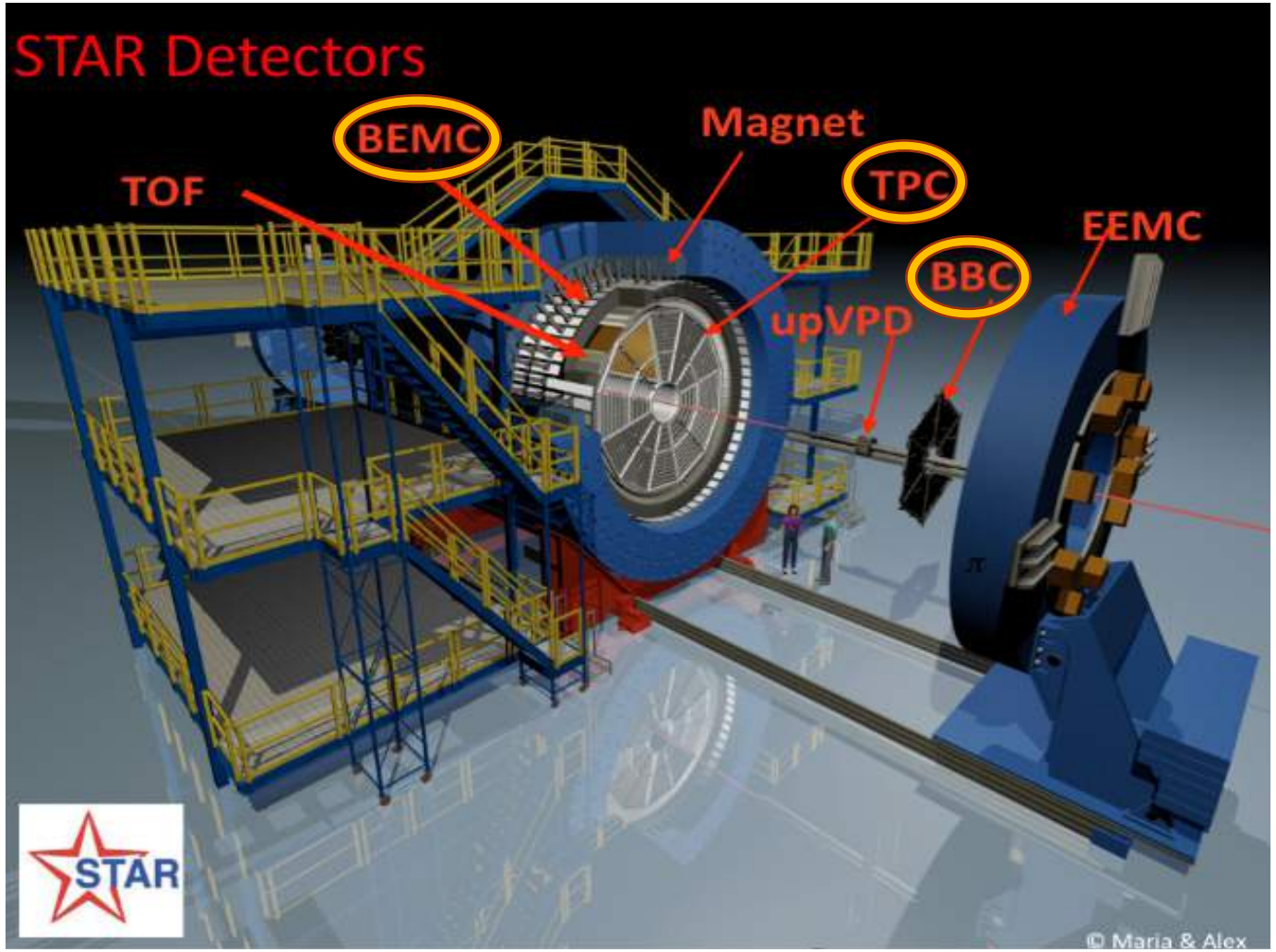
- <2010: Benchmark for large system collisions
- 2012: Possible collective flow
  - QGP creation: open question
- 2015-16: Jet measurements in small systems from various collaborations:
  - Inclusive nuclear modification factor consistent with unity
  - Event Activity (EA) dependence of yield observed
- Today: *p*+Au jet measurement from STAR
  - Inclusive: this talk
  - Semi-inclusive: David Stewart, EB.00005



PHENIX, Phys. Rev. Lett., 116:122301;
CMS, Eur. Phys. J. C, 76(7):372, 2016;
ATLAS, Phys. Lett. B, 748:392 – 413, 2015

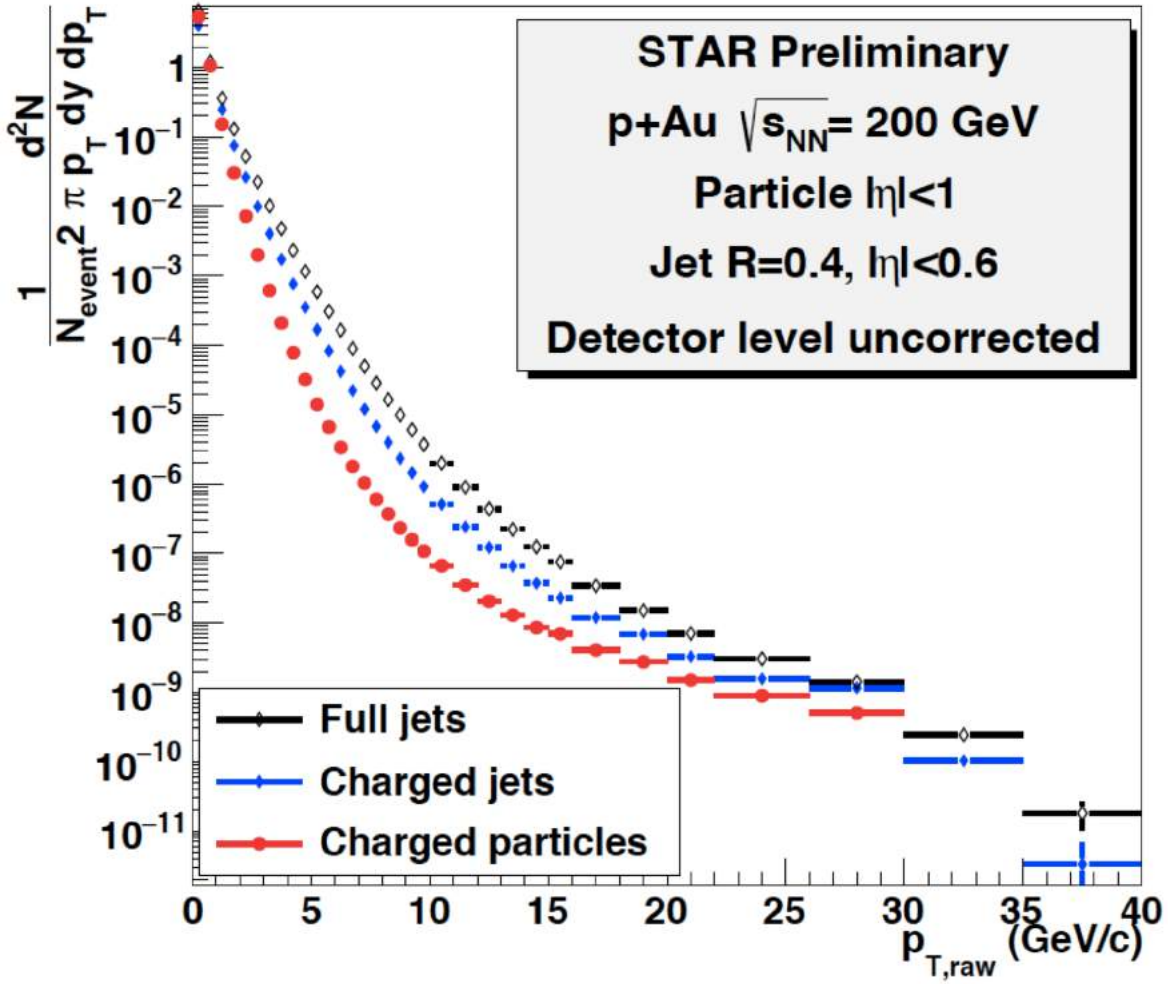
THE STAR DETECTOR

- **Time Projection Chamber (TPC)**
  - Methane-argon TPC
  - Momentum reconstruction for charged tracks
  - $|\eta| < 1$, 2π coverage
- **Barrel Electro-Magnetic Calorimeter (BEMC)**
  - Lead/Scintillator stack towers
  - Energy deposition detection for charged and neutral particles
  - $|\eta| < 1$, 2π coverage
- **Beam-Beam Counter (BBC)**
  - Scintillator clusters at east & west of collision point
  - Outer ring $2 < |\eta| < 3.4$, inner $3.4 < |\eta| < 5$



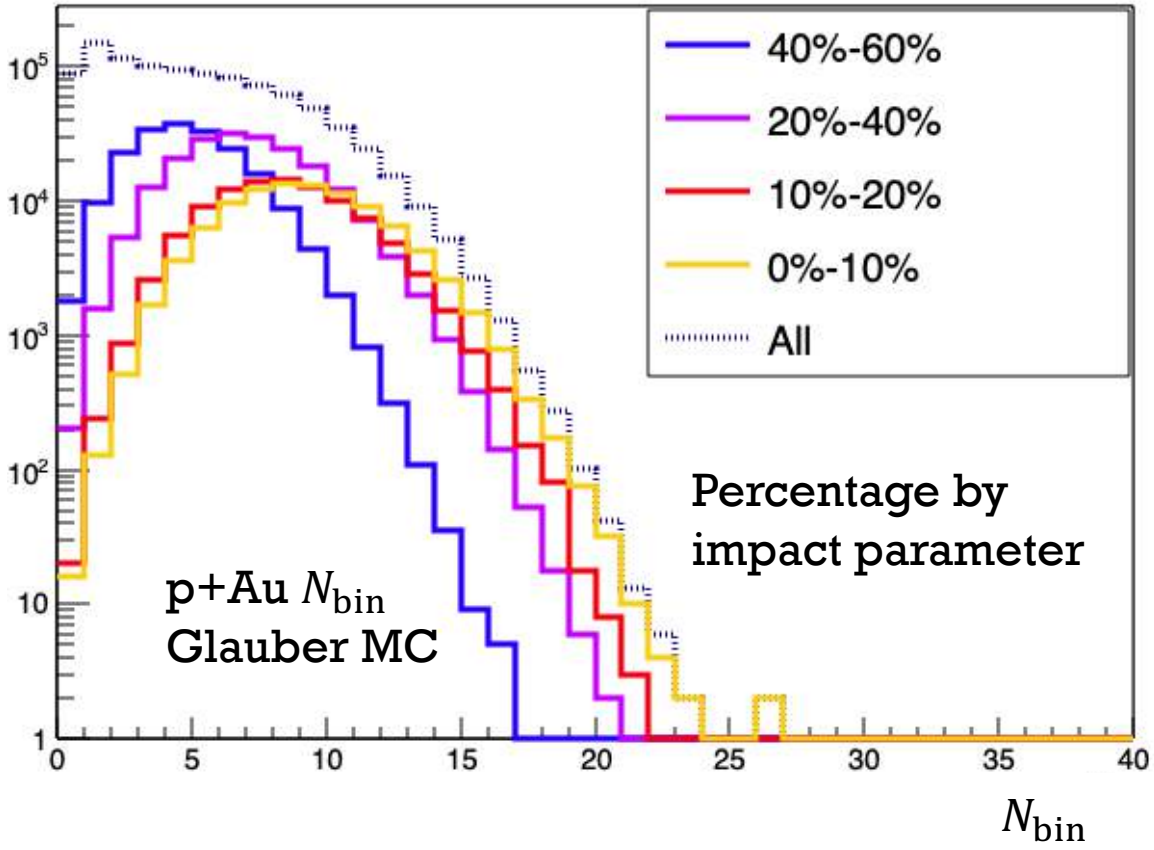
DATASET AND SELECTION

- Data: 2015 p+Au @ 200 GeV
- Particle selection:
  - TPC tracks & BEMC Towers
  - $0.2 < p_{\mathrm{T}} < 30$ GeV/c, $|\eta|$<1
  - Hadronic correction for charged particles
- Jet reconstruction:
  - anti-k_{T} algorithm
  - R=0.4
  - $|\eta|$<1-R
- Jet reach:
  - Inclusive spectrum: $\lesssim$ 40 GeV/c
  - EA-binned spectrum: $\lesssim$ 30 GeV/c



EVENT ACTIVITY IN SMALL SYSTEMS

- Asymmetric small system: geometric parameters like $\langle N_{\mathrm{bin}} \rangle$ don't correlate as well with impact parameter as in A+A collisions
- Concept of centrality is not trivial for small systems



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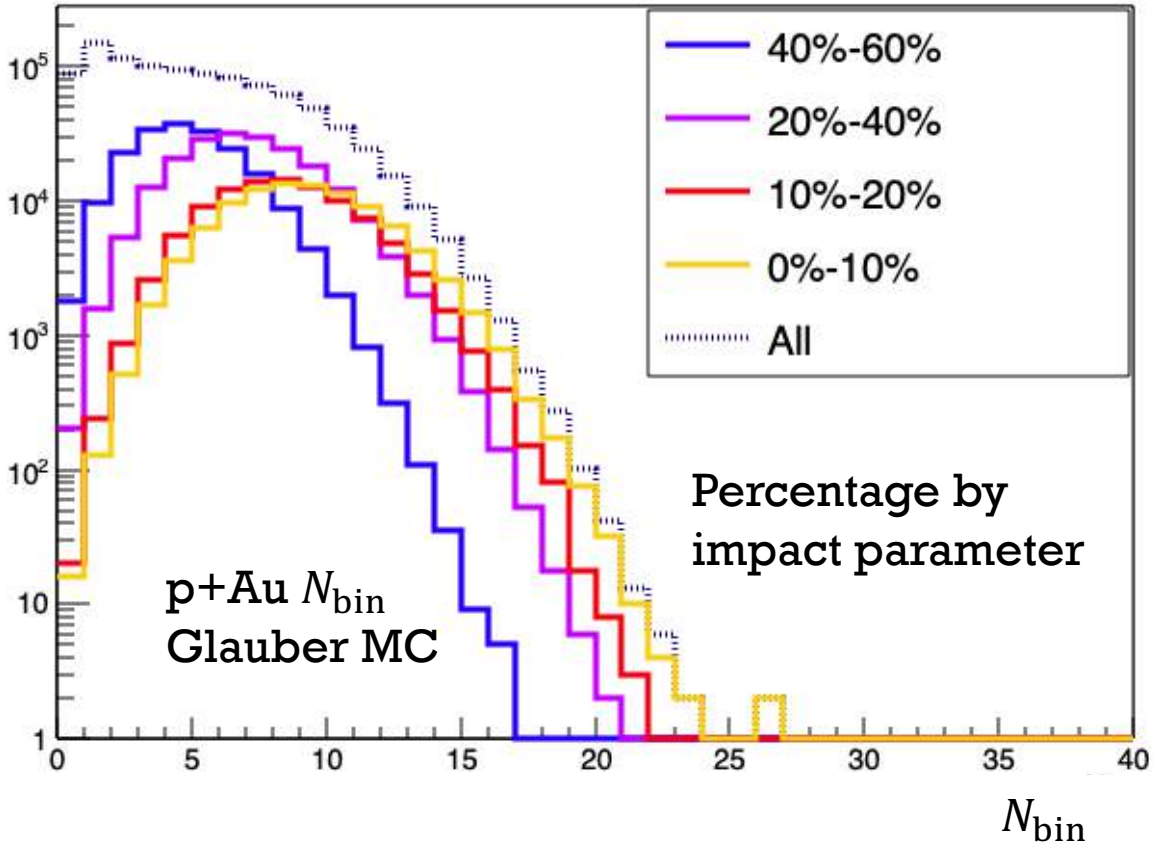
- EA: degree of violence of the collision
  - Expressed as percentage with 0% being the most intense, 100% being missing
- EA indicator: experimental observable that best correlates with EA



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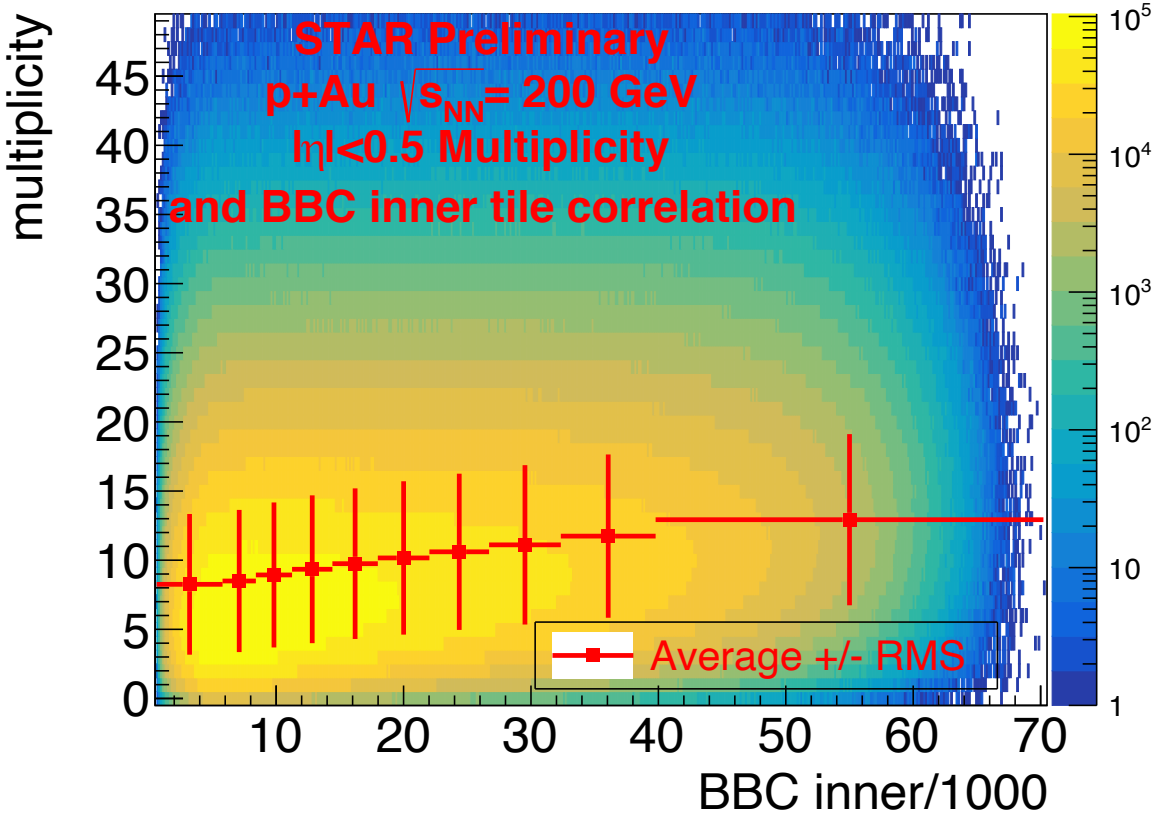

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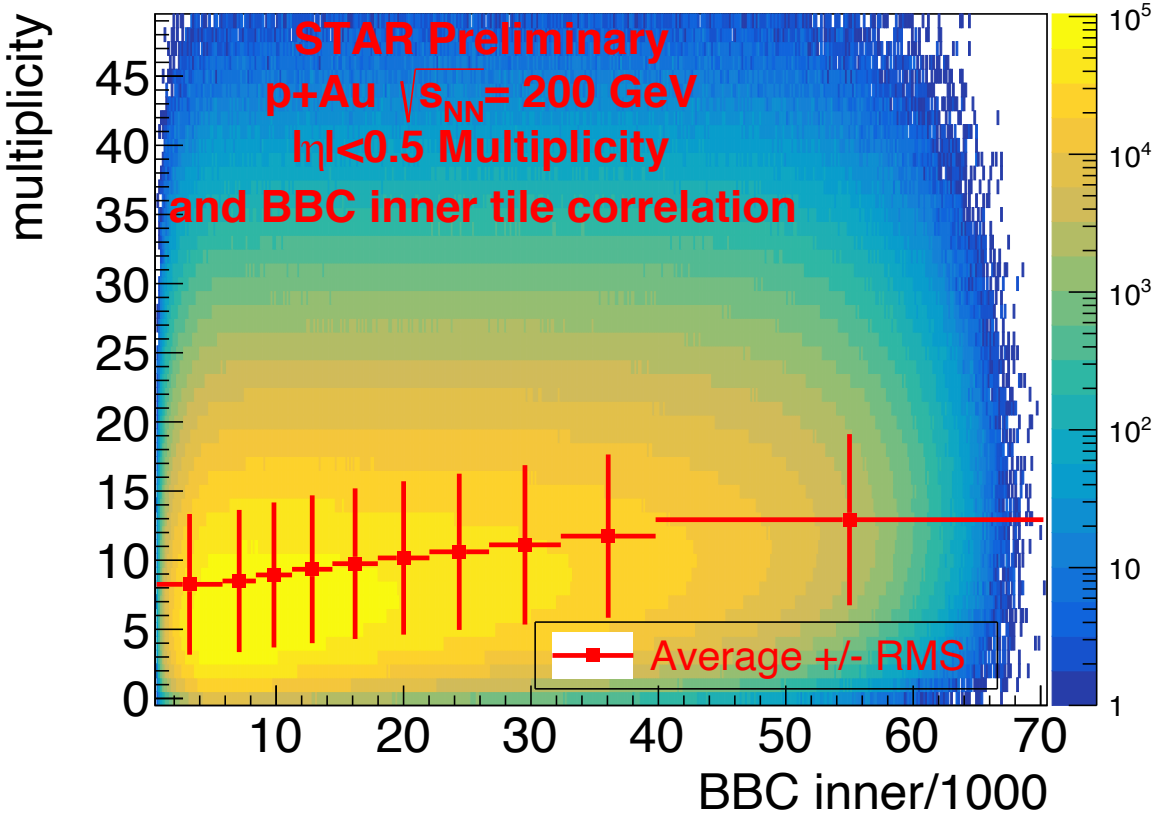
TL, QM2019



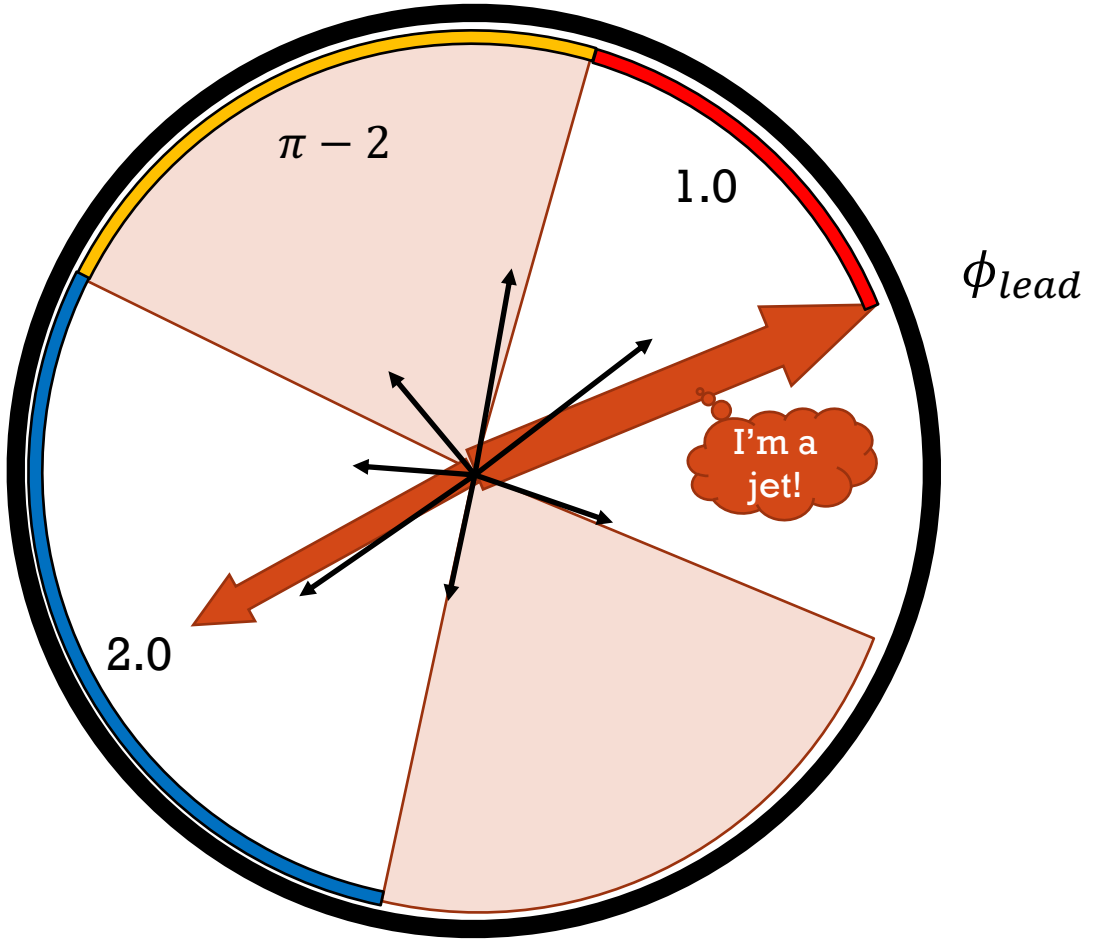
UNDERLYING MULTIPLICITY AS EA

- *Inspiration: Veronica Verkest (Sat LB.00005)*

➢ Region **transverse to leading jet ϕ** as UE acceptance

➢ Selected track multiplicity in *transverse-to-jet* UE acceptance as EA indicator for jet events: $UE_{\mathrm{mult}}^{\mathrm{trans}}$

- Indicator of "soft" physics, i.e. excluding jet



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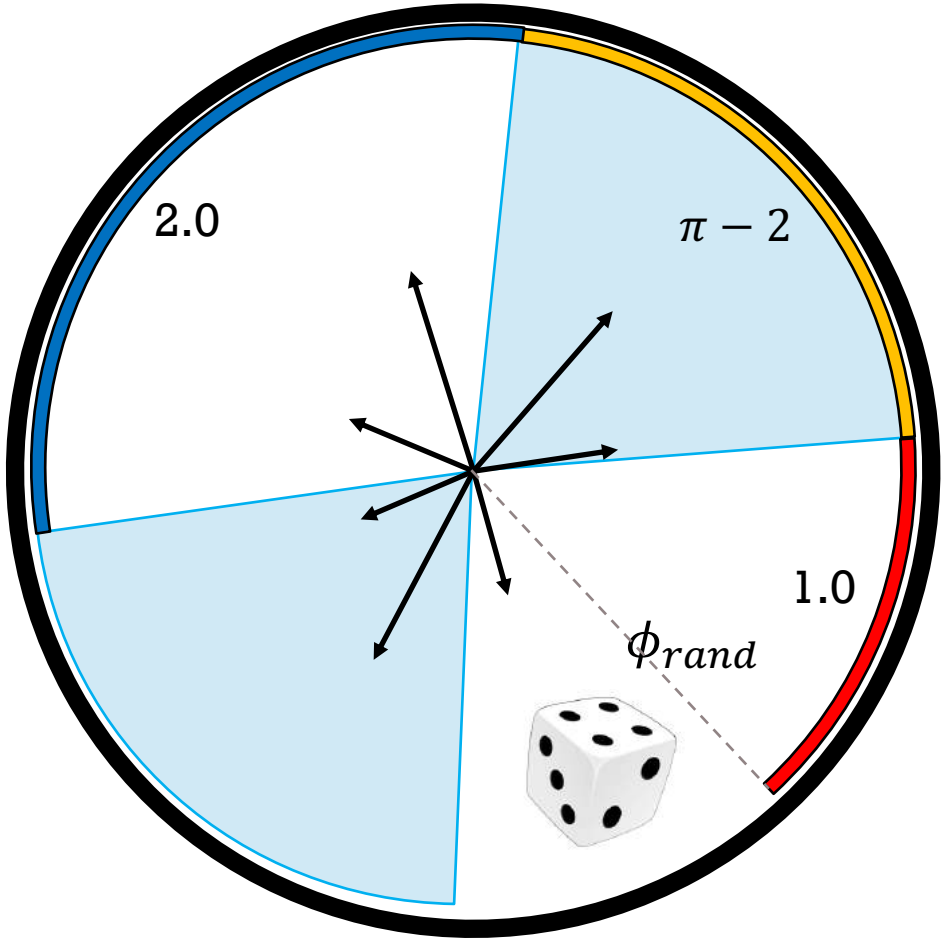
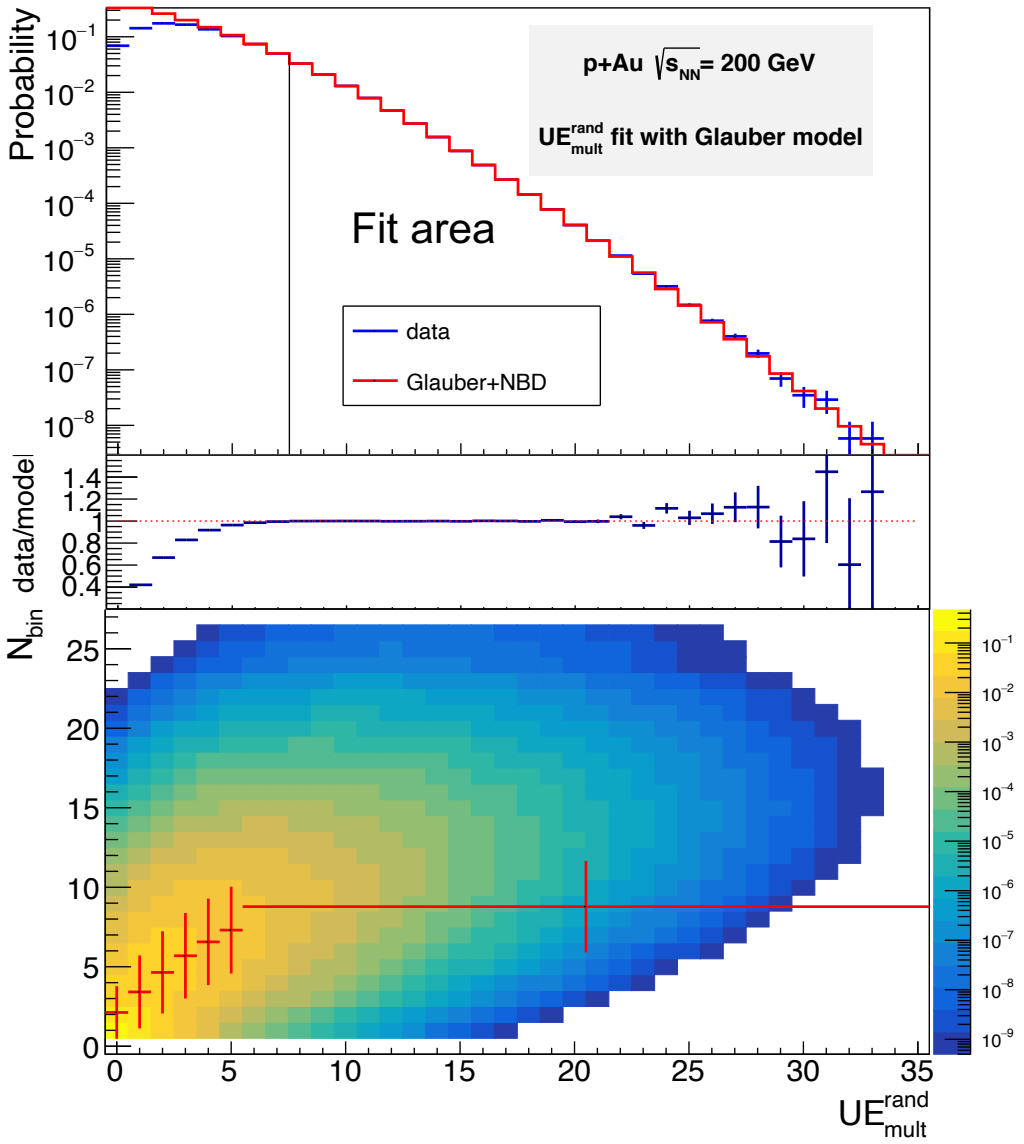
- Indicator of "soft" physics, i.e. excluding jet

➢ Multiplicity **transverse to random direction** as minimum-bias reference for defining percentage: $UE_{\mathrm{mult}}^{\mathrm{rand}}$
- Avoid bias from artificially choosing the "empty" part of the event and migrating towards low multiplicity



GLAUBER MODELING OF COLLISIONS

- Glauber MC of minimum-bias p+Au collision
- Convoluted with Negative-Binomial Distribution to fit to $UE_{\mathrm{mult}}^{\mathrm{rand}}$ distribution at high end
  - $\chi^2/ndf = 0.79$
- Group (high end) into deciles & get $\langle N_{\mathrm{bin}} \rangle$ for each $UE_{\mathrm{mult}}^{\mathrm{rand}}$ bin
- Low end of multiplicity: ratio as trigger efficiency



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- Glauber model scaled jet yield

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

N_x^{rand}: number of x with $UE_{\mathrm{mult}}^{\mathrm{rand}}$ within the range of a~b

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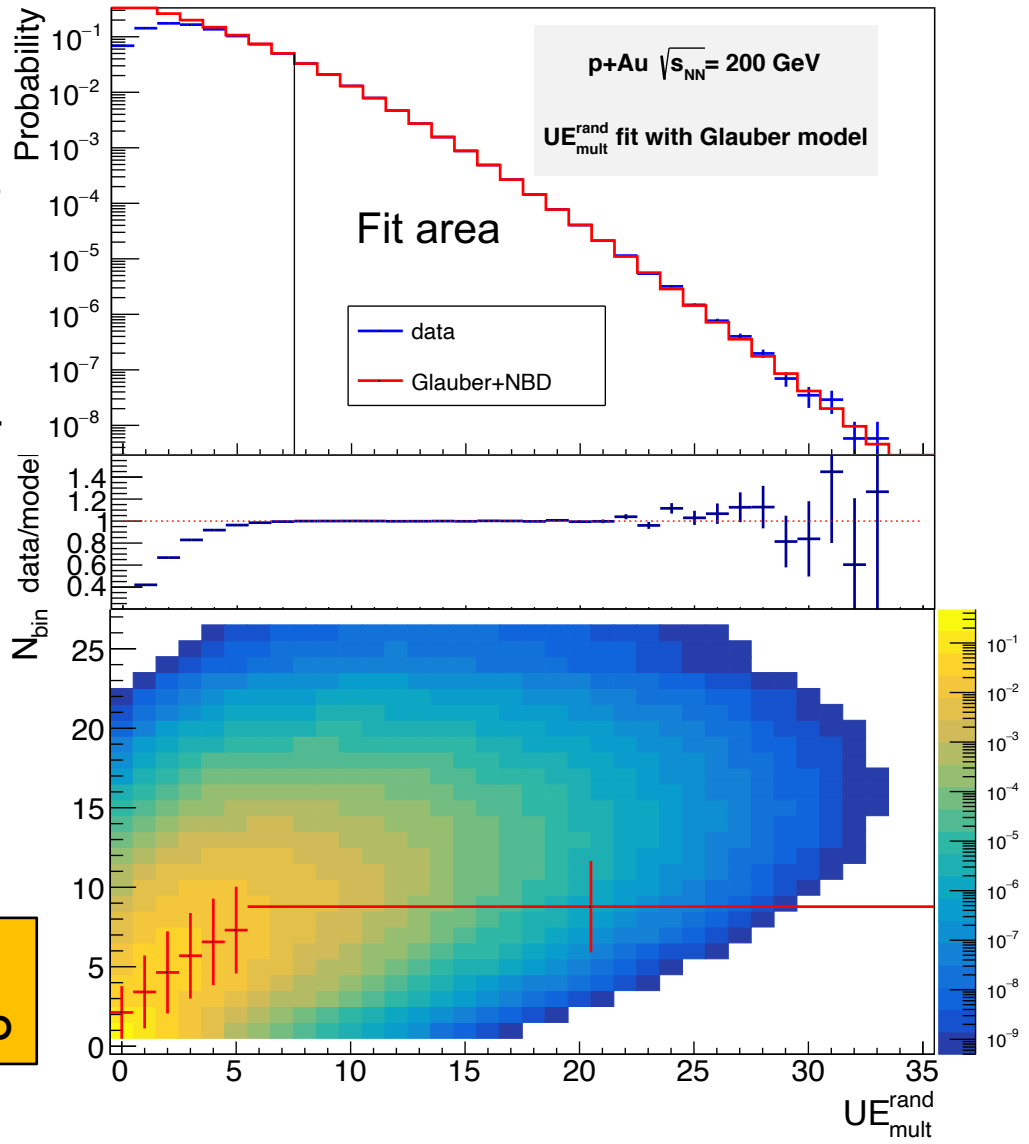

EA SELECTION & NORMALIZATION

- Goal: capture the underlying event activity originating from soft physics
- Two effects to avoid:
  - Minimum-bias events: artificial migration
  - High-p_T jet events: jet contamination
- Assumption: soft physics process is intrinsically isotropic; azimuthal angles of jets are uncorrelated with soft physics

EA SELECTION & NORMALIZATION

- Selection: deciding which category a *jet* event belongs to
- Looking at p_T > 10 GeV/c *jet events*

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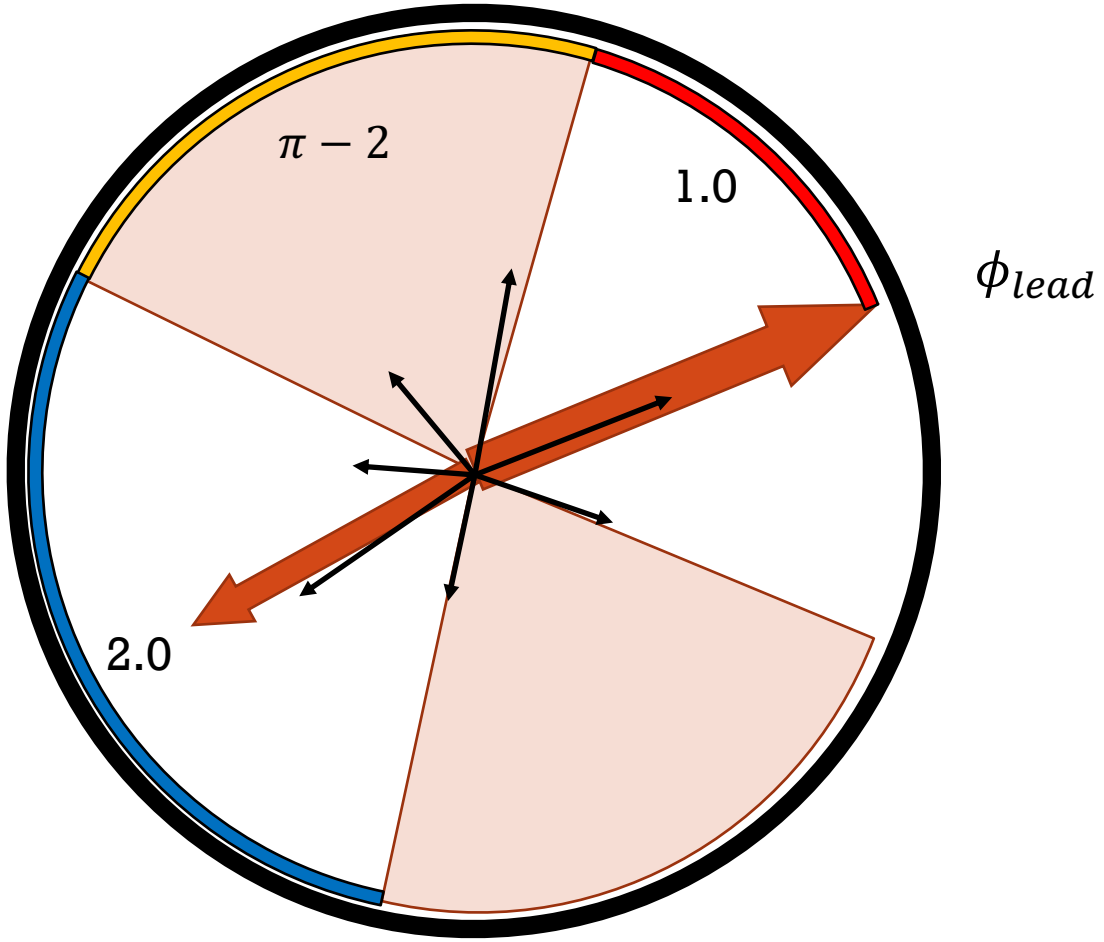

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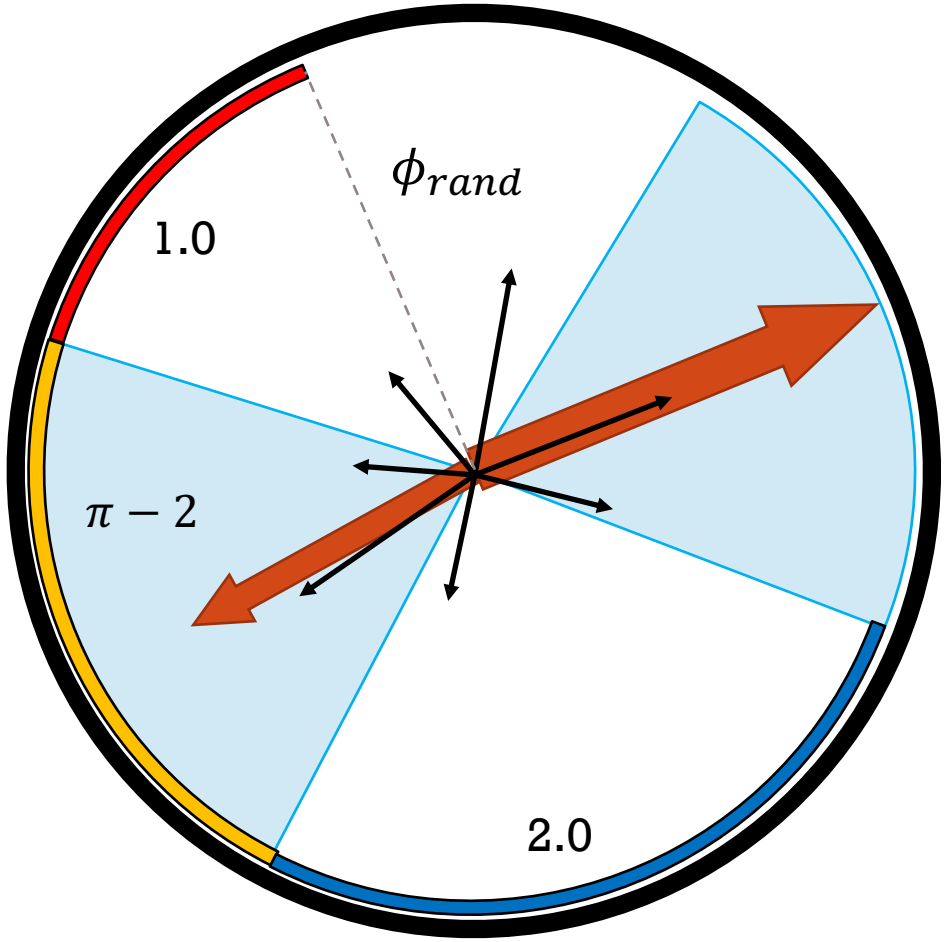

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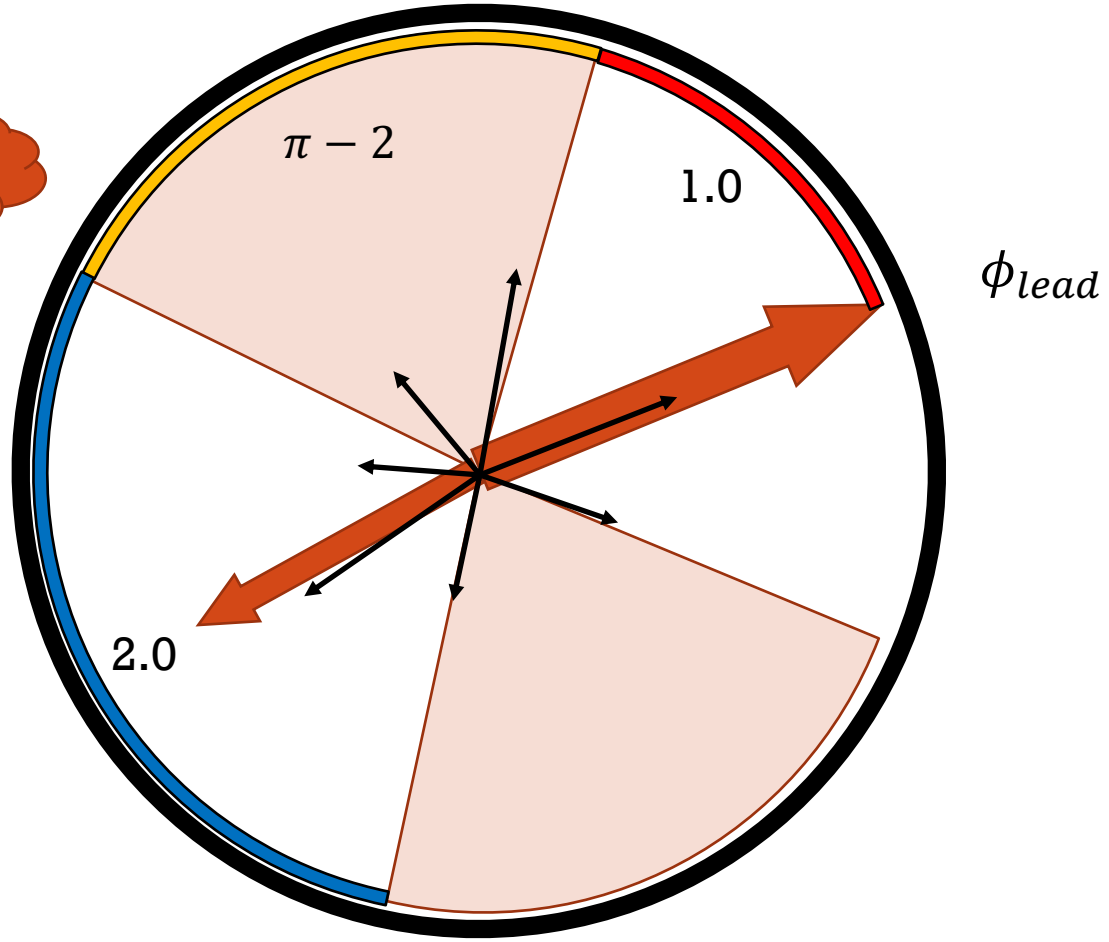

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- Normalization: determining the number of *minimum-bias* events that belong to this category
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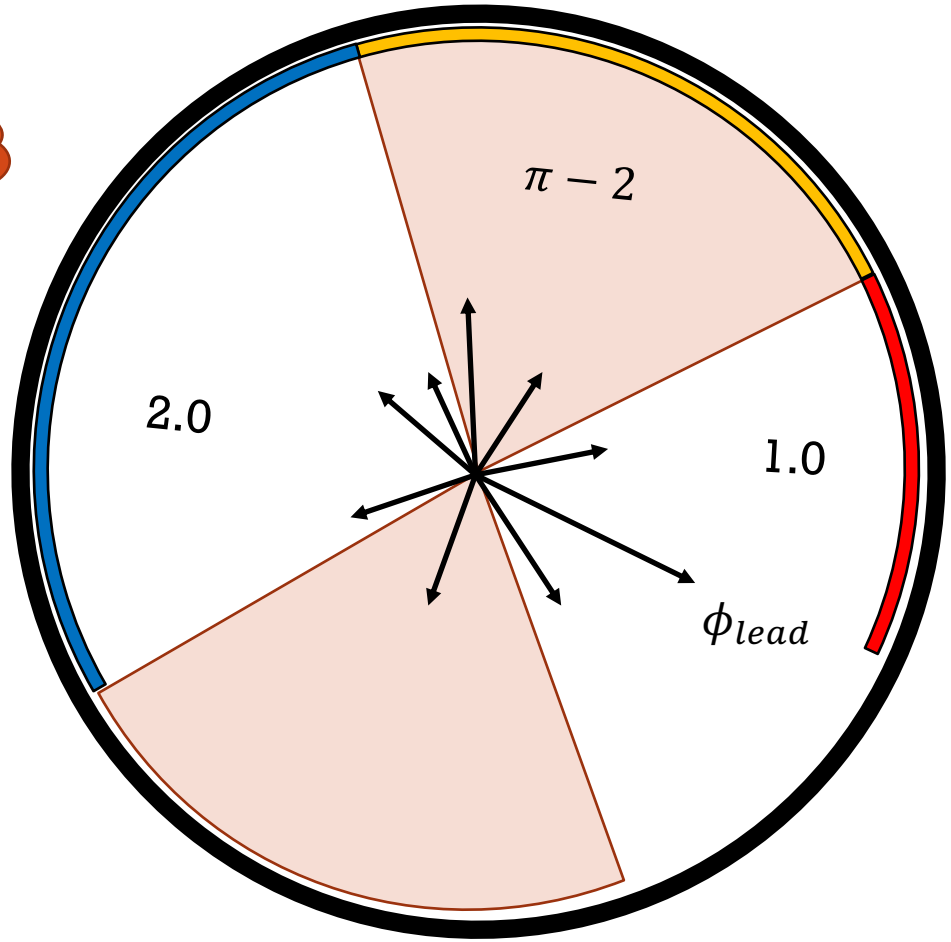

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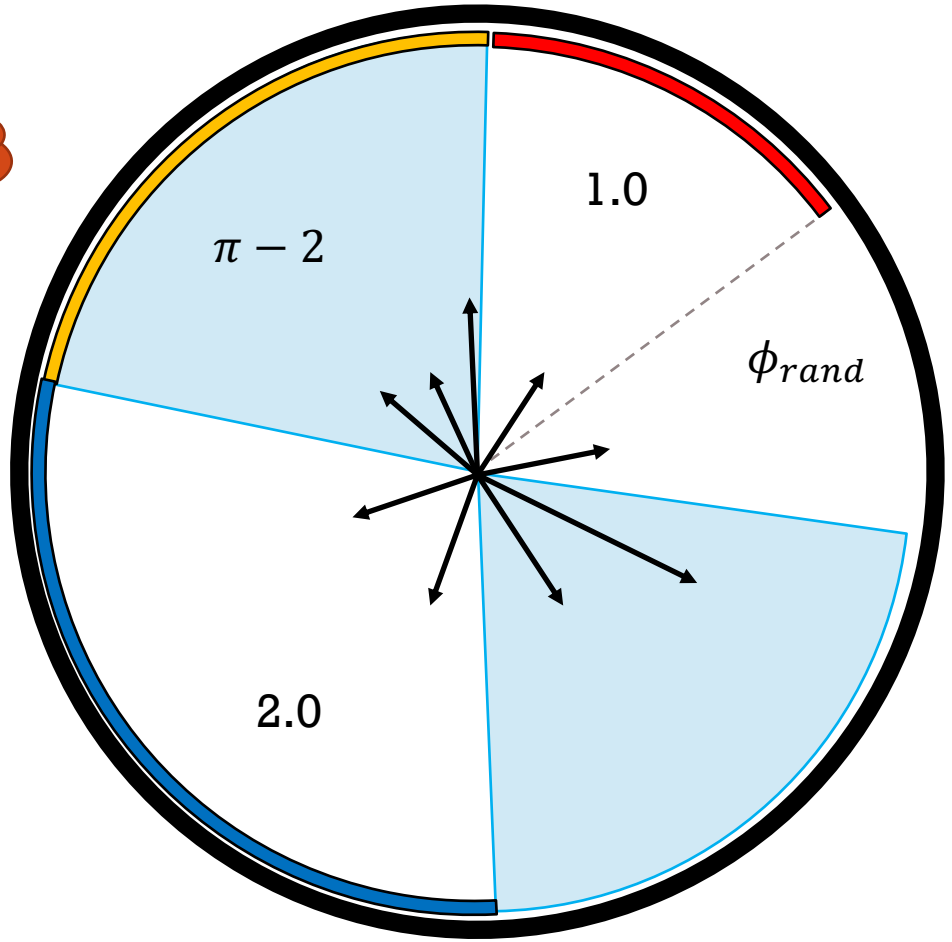

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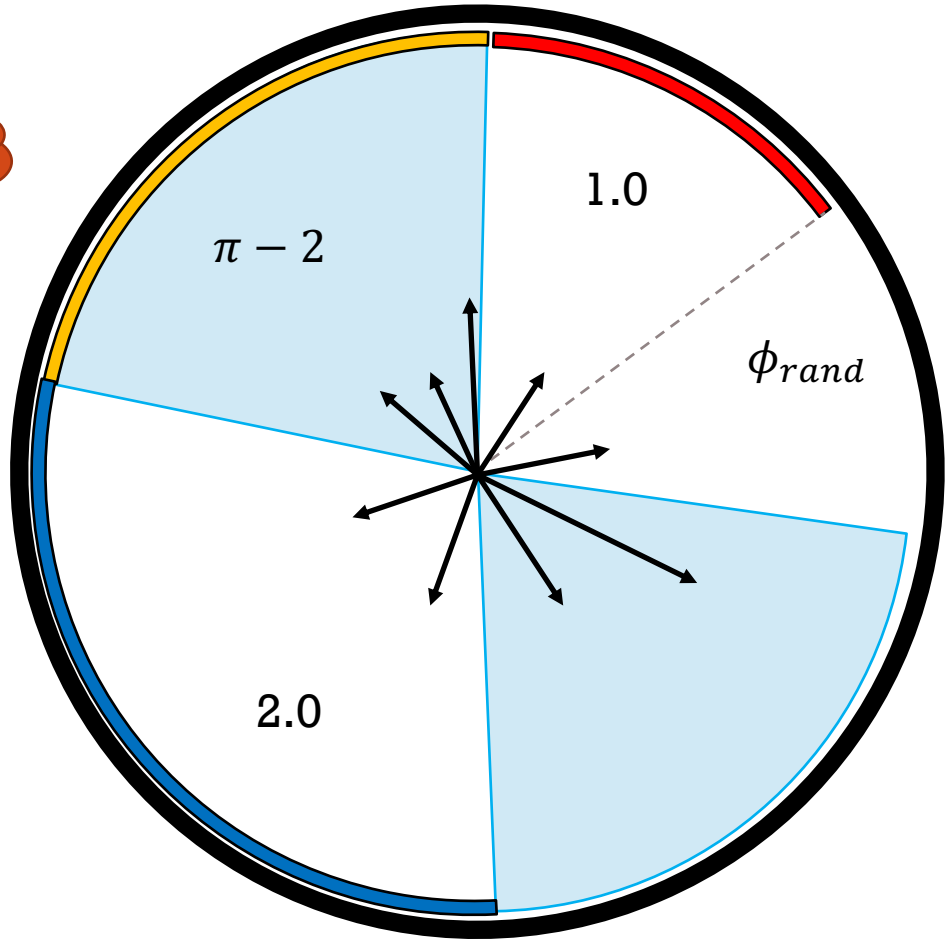

EA SELECTION & NORMALIZATION

- Closure test: insert toy physics and check which normalization works
  - Take a portion of the real data (as soft background); Claim its N_{ev}^{rand} distribution as "true"
  - Insert a 200 GeV/c toy jet (20 GeV/c particles × 10 in R=0.03 cone) into random 1% of the events
  - Re-perform the analysis as usual;
  - Ratio between high- and low-EA yield at 200 GeV/c should be close to unity

Sample size: 4.4M Events

Category	Toy jet $N_{\mathrm{jet}}^{\mathrm{trans}}$	"true" $N_{\mathrm{ev}}^{\mathrm{rand}}$	$N_{\mathrm{ev}}^{\mathrm{rand}}$	$N_{\mathrm{ev}}^{\mathrm{trans}}$
High: UE_{mult} >10	3999	406k	421k	288k
$\boldsymbol{Y_{\mathrm{hi}} = N_{\mathrm{jet,hi}}^{\mathrm{trans}} / N_{\mathrm{ev}}^{\mathrm{hi}}}$	/	**0.99%**	**0.95%**	**1.39%**
Low: UE_{mult} =3	5503	551k	548k	604k
$\boldsymbol{Y_{\mathrm{lo}} = N_{\mathrm{jet,lo}}^{\mathrm{trans}} / N_{\mathrm{ev}}^{\mathrm{lo}}}$	/	**1.00%**	**1.00%**	**0.91%**
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Artificial migration

SUMMARY & OUTLOOK

- ✓Performed measurement of inclusive jets in $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV p+Au collisions
- ✓Developed the method of using UE_{mult} as an event activity indicator
- ✓Validated selection & normalization method
- ✓Matched Glauber model to $UE_{\mathrm{mult}}^{\mathrm{rand}}$ distribution
- ➢Include High-Tower triggered data into analysis
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