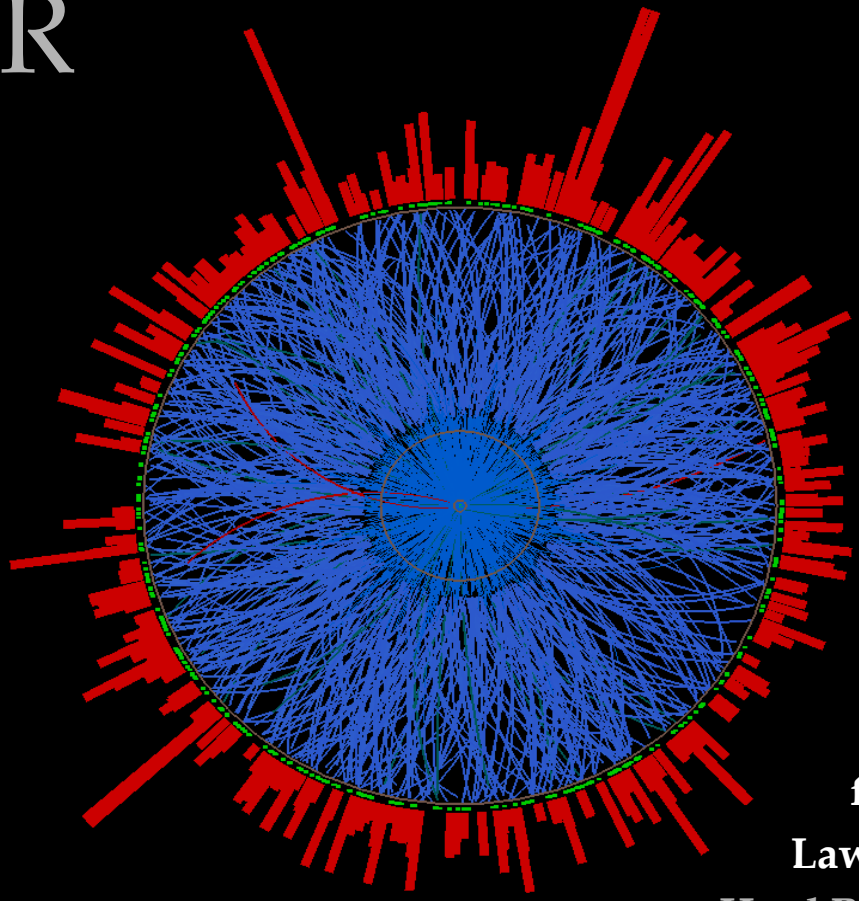
Jet Production in Au+Au Collisions at STAR



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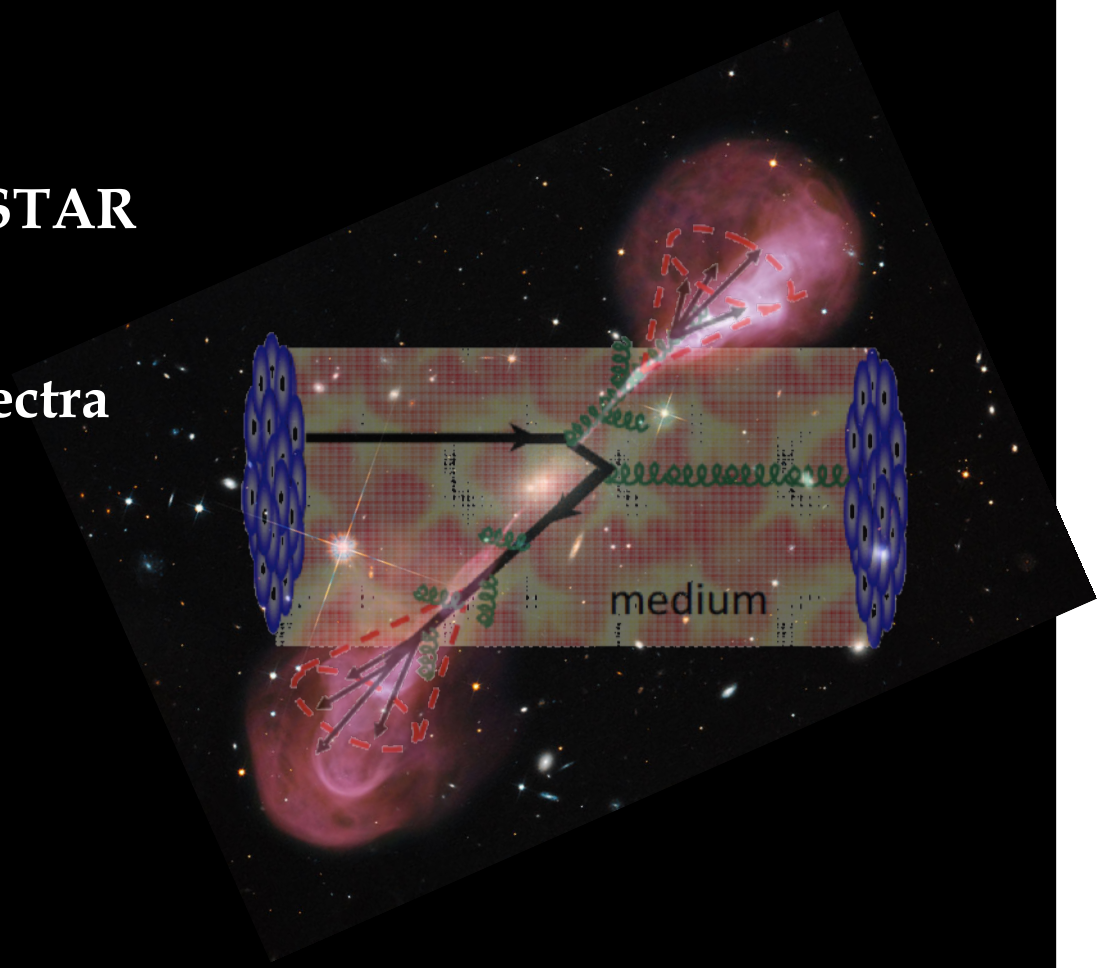
Hard Probes 2015 in Montreal/Canada

BERKELEY LAB

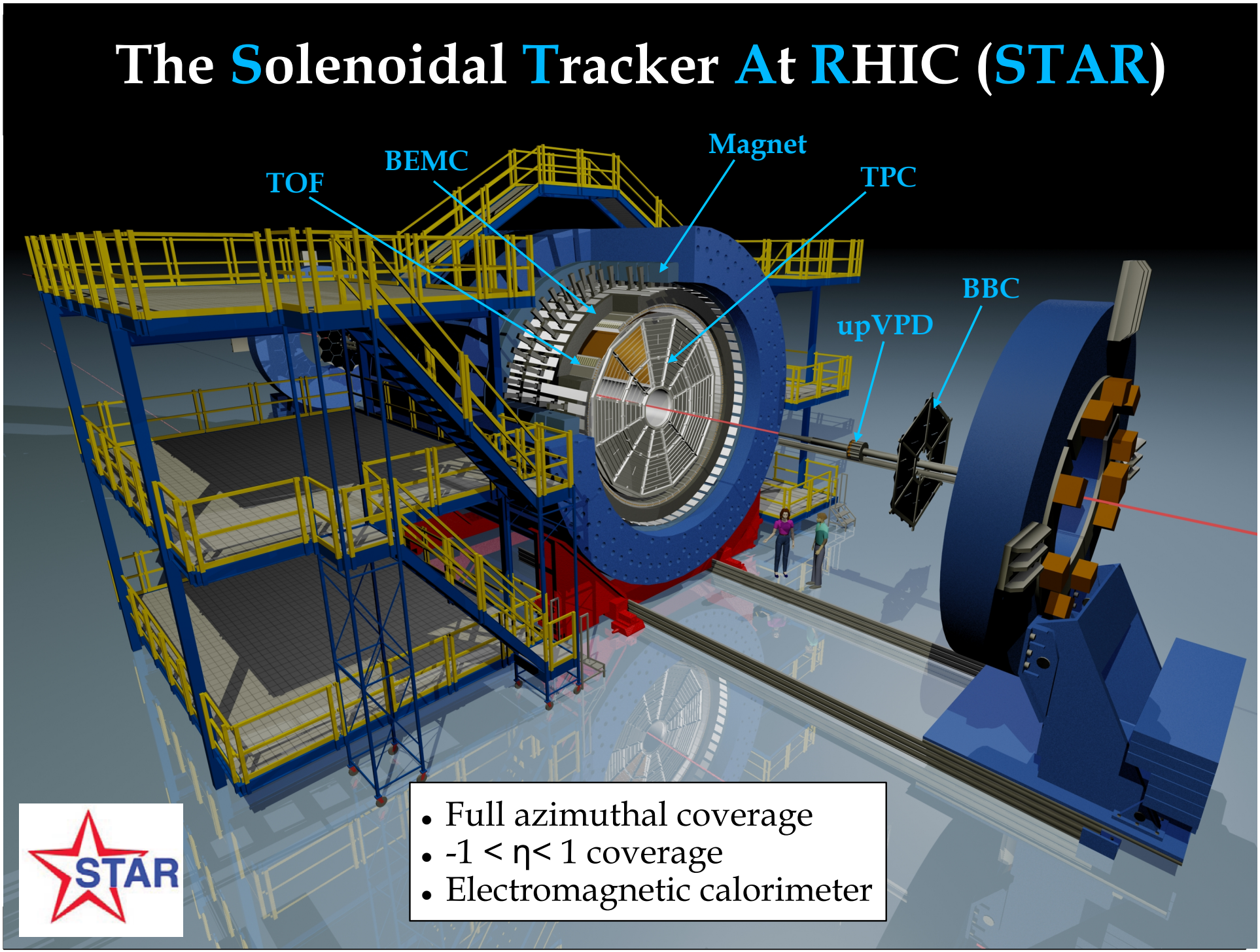
U.S. DEPARTMENT OF ENERGY

Outline

- **Recoil Jet Reconstruction at STAR**
- **Semi-Inclusive Recoil Jet Spectra**
- **Large Angle Scattering (Δϕ)**
- **Summary and Outlook**

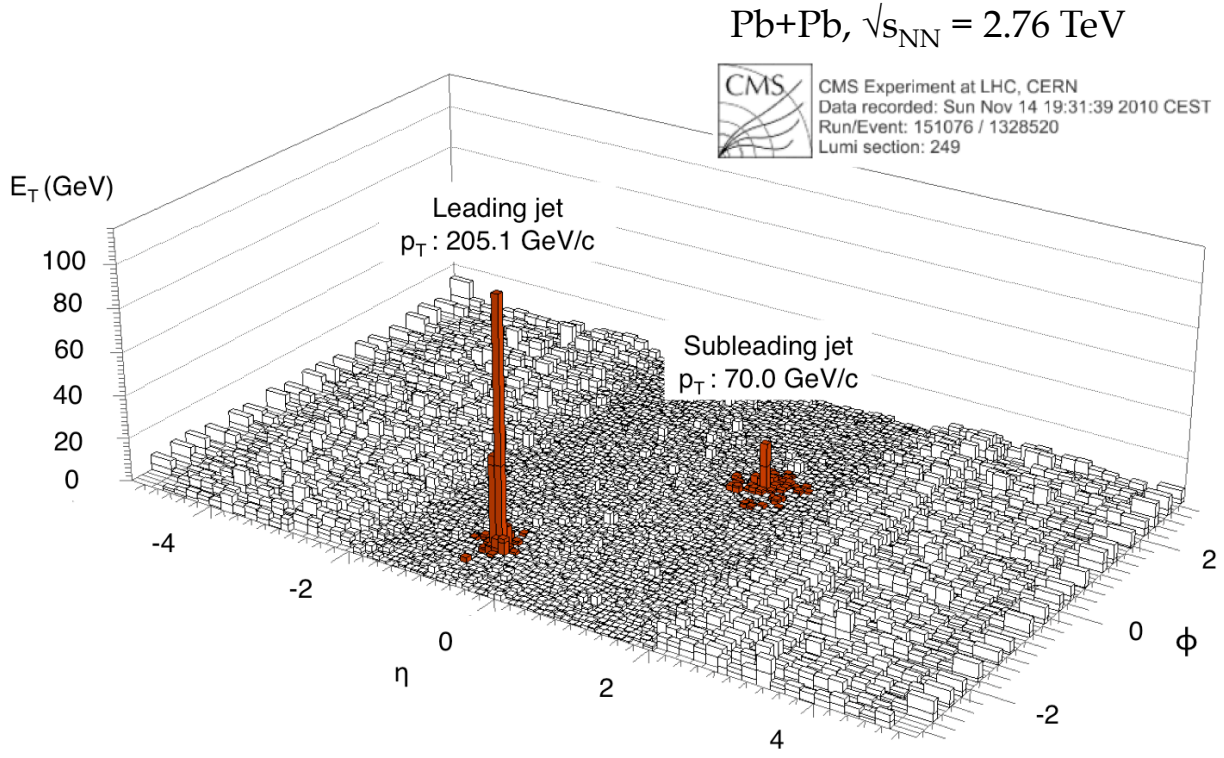


The Solenoidal Tracker At RHIC (STAR)



- Full azimuthal coverage
- $-1 < \eta < 1$ coverage
- Electromagnetic calorimeter

Jet Finding at LHC

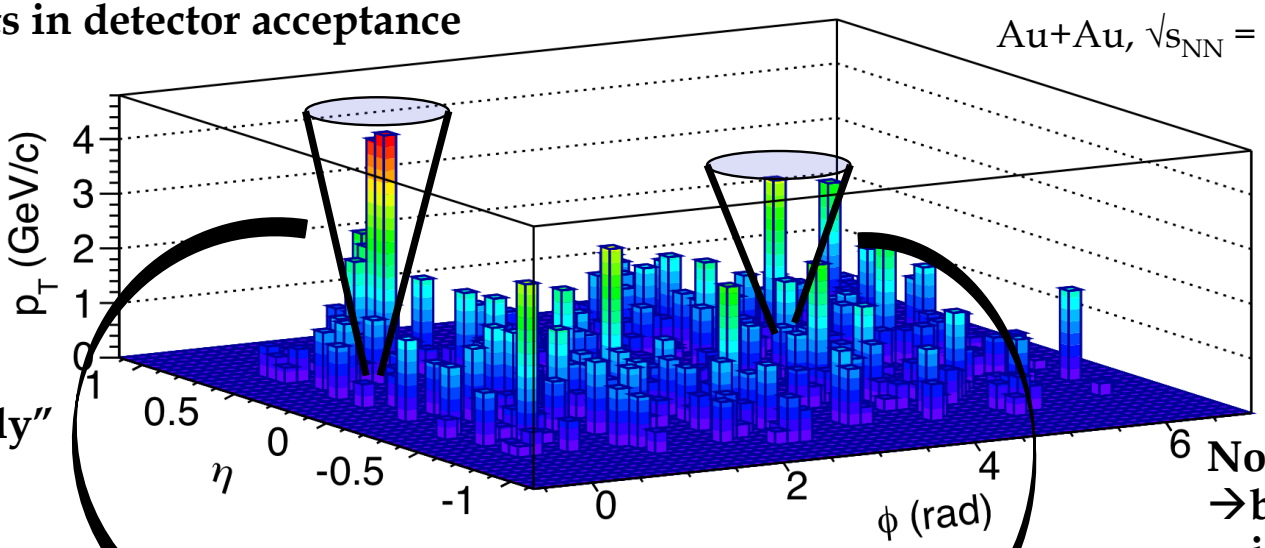


- High p_T objects, clearly seen over the heavy-ion background
  → Clear jet identification (at high p_T)
  → But measuring is not straight forward

Jet Finding at RHIC

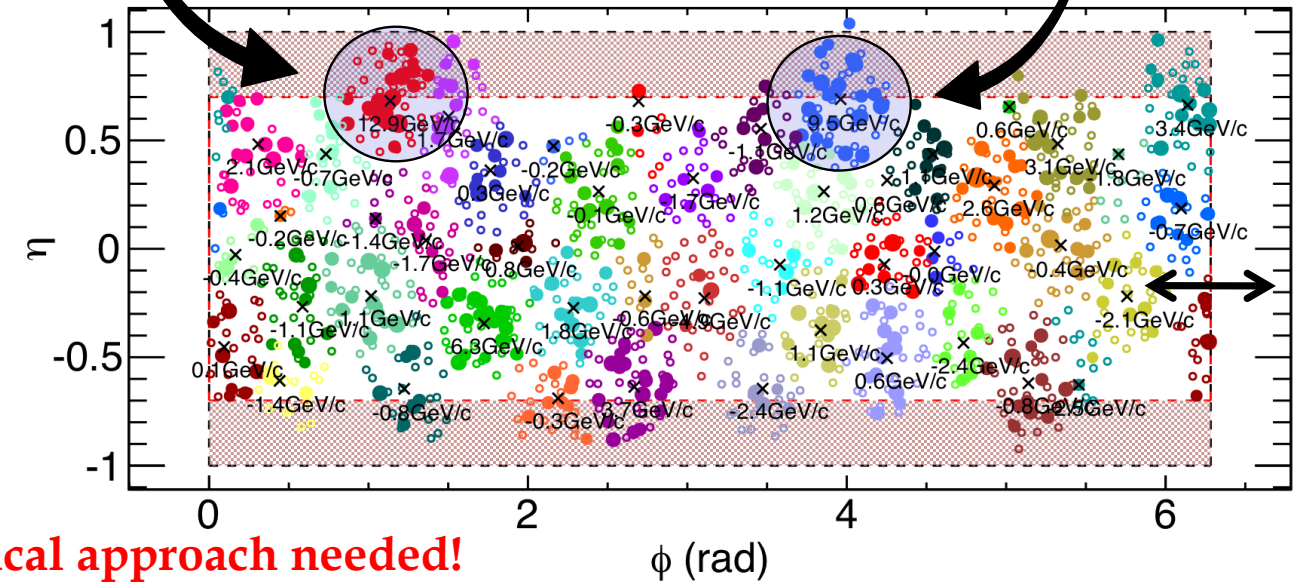
Tracks and jets in detector acceptance

Au+Au, $\sqrt{s_{NN}}$ = 200 GeV



Can be "visually" identified

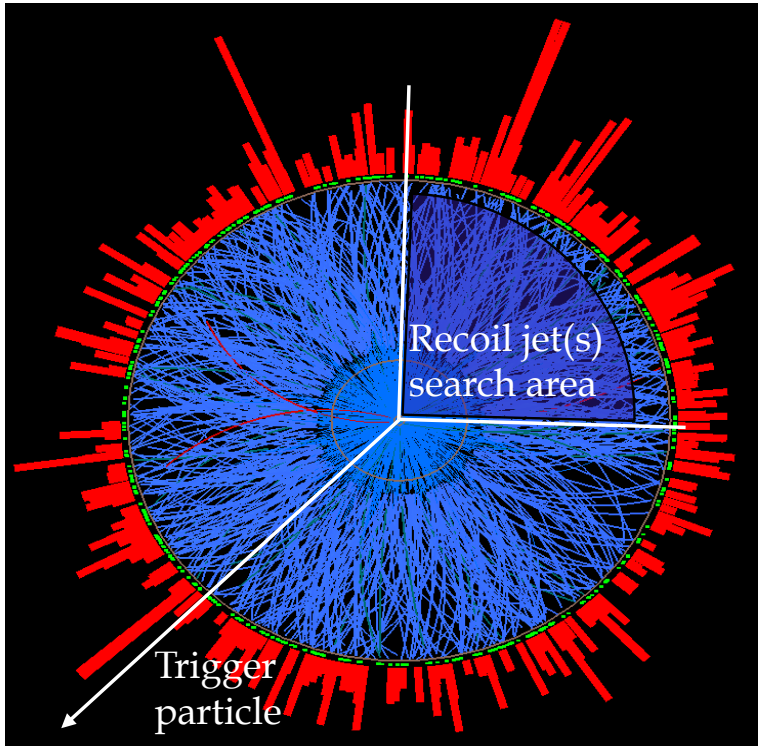
Not obvious →background is huge!



$p_{T,jet}^{reco} = p_T - \rho A$

→ Statistical approach needed!

Semi-Inclusive Recoil Jets



Semi-inclusive yield of jets* recoiling from a high p_T hadron trigger

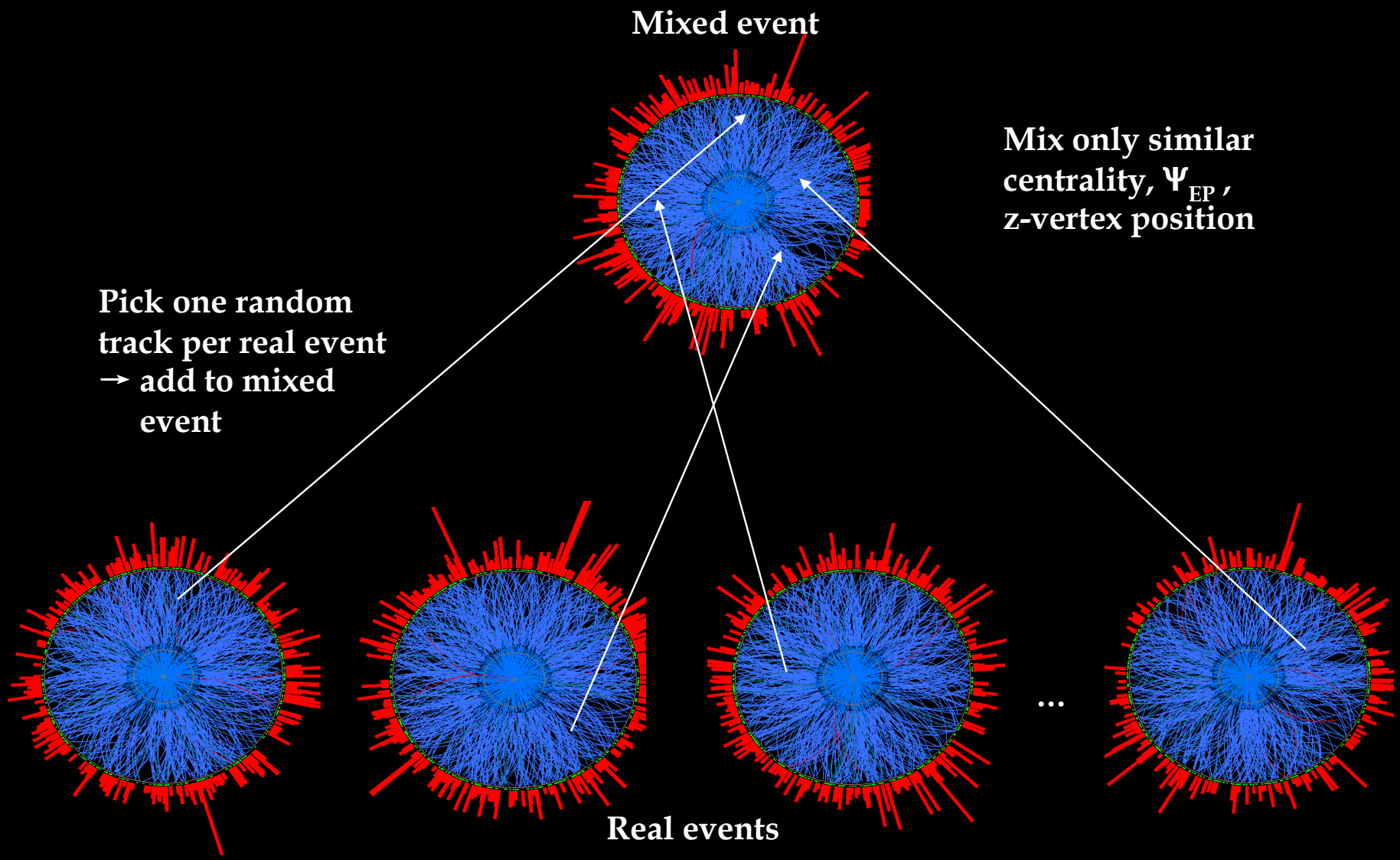
$$\frac{1}{N^h_{trig}}\frac{dN_{jet}}{dp_{T,jet}} = \frac{1}{\sigma^{pp\to h+X}}\frac{d\sigma^{pp\to h+jet+X}}{dp_{T,jet}}$$

Measured Calculable in pQCD

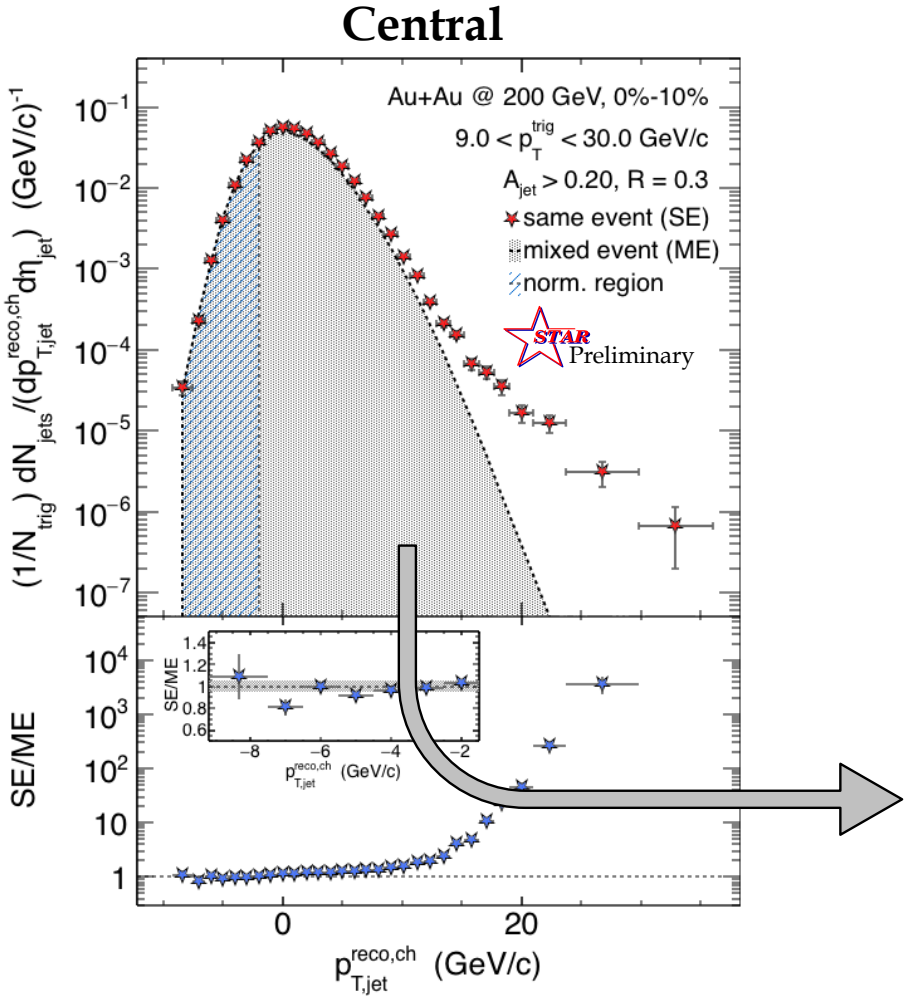
- Trigger on high p_T hadron → Selection of a high p_T process
- Use all jet candidates on the other azimuthal hemisphere within +/- 45 degree → **no fragmentaion bias on recoil side**!
- **How to deal with combinatorial recoil jets?**

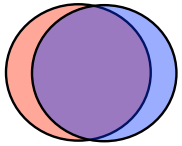
*charged jets

Mixed Event Generation for Jets



Charged Raw Recoil Jet Spectrum: Central

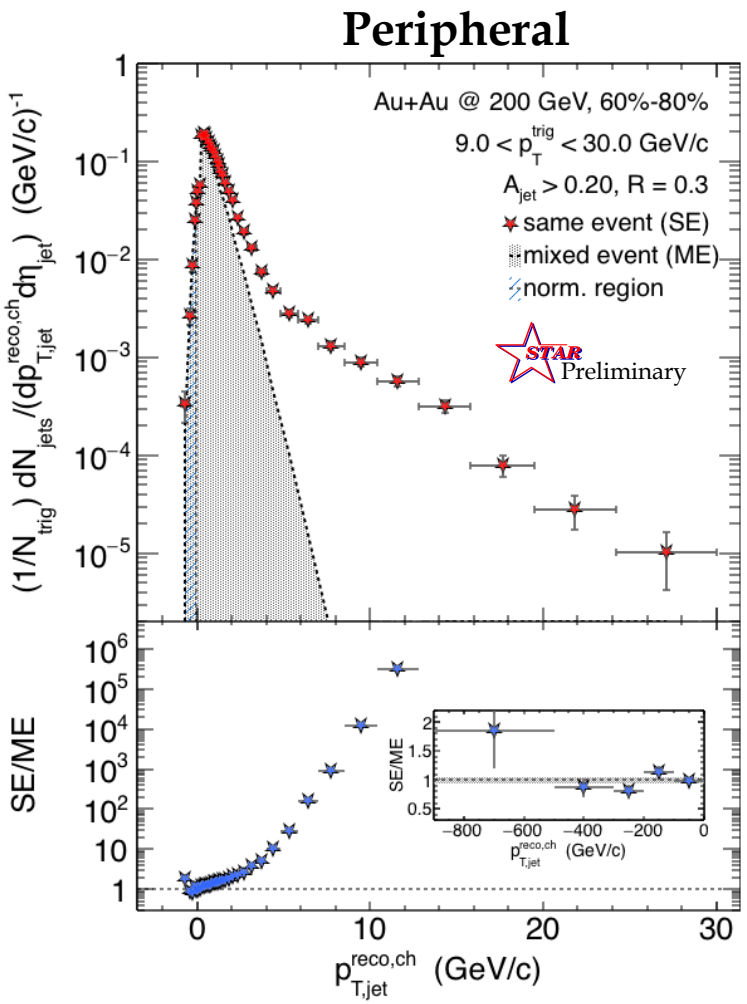


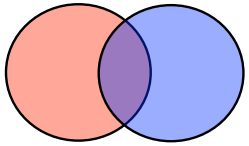


- Excellent description of low p_T SE spectrum with ME
- Normalization region varied systematically
- Significant jet signal at p_T-ρA > 10 GeV/c

Combinatorial jet background → statistically described by mixed event technique

Charged Raw Recoil Jet Spectrum: Reference

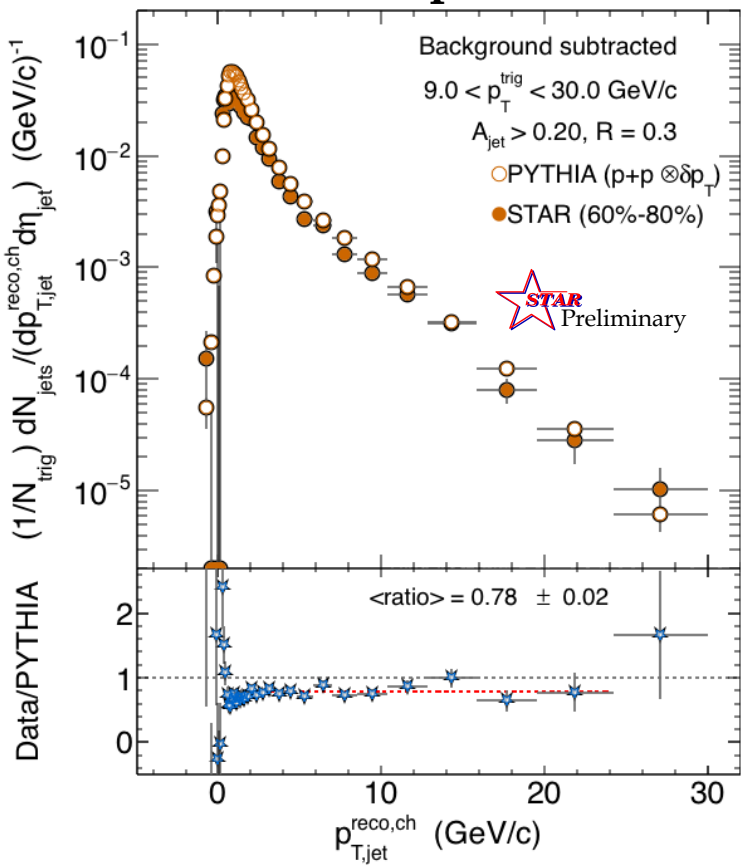


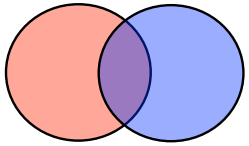


- Reference spectrum: peripheral collisions
- Much less combinatorial background compared to most central data
- Excellent signal/background ratio down to 3 GeV/c

Reference vs. PYTHIA

Peripheral

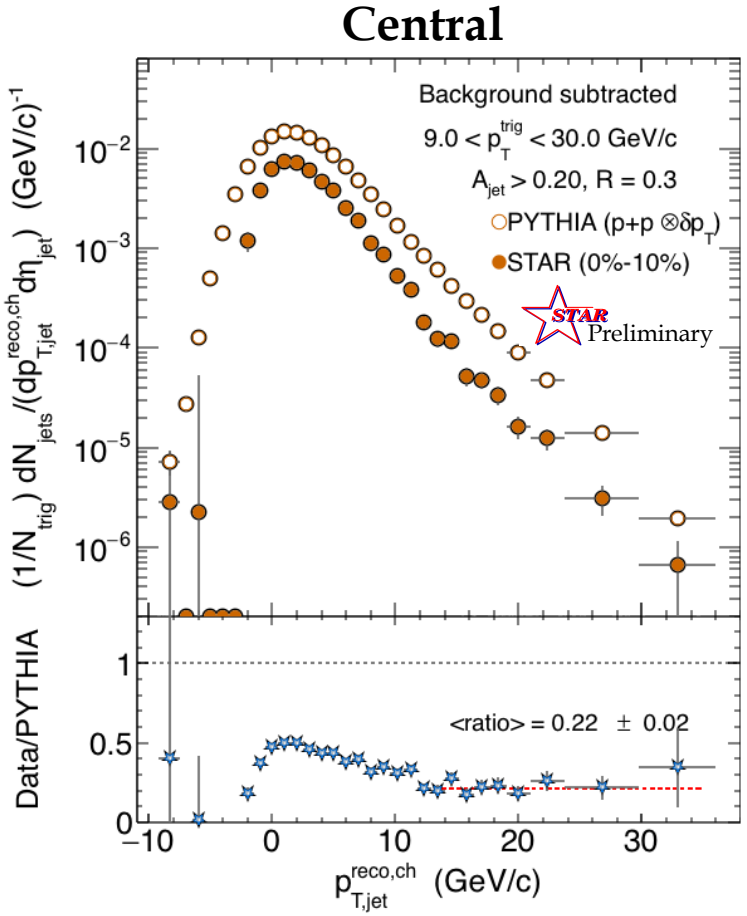


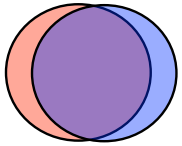


- Background-subtracted spectrum in 60%-80% Au+Au in comparison with smeared* PYTHIA
- PYTHIA shape + yield in good agreement with 60%-80% data

*PYTHIA $\otimes \delta p_T$

Recoil Jet Energy Loss

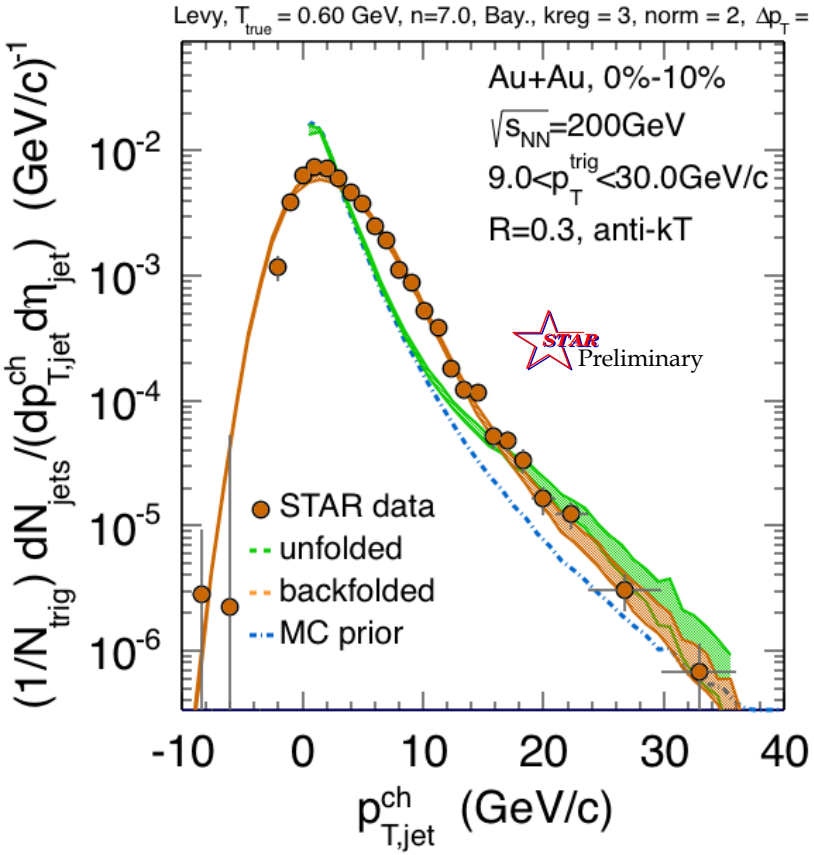




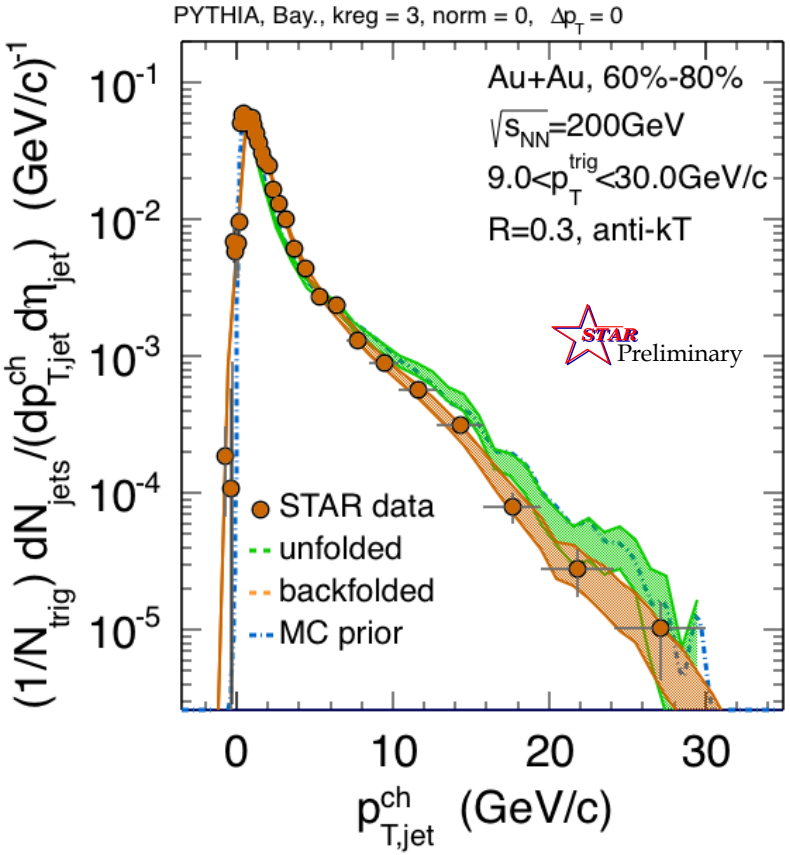
- Significant suppression (central/smeared PYTHIA) over whole p_T range
  → energy loss
- Very similar shape over 4 orders of magnitude

Unfolding Examples

Central (Levy prior example)

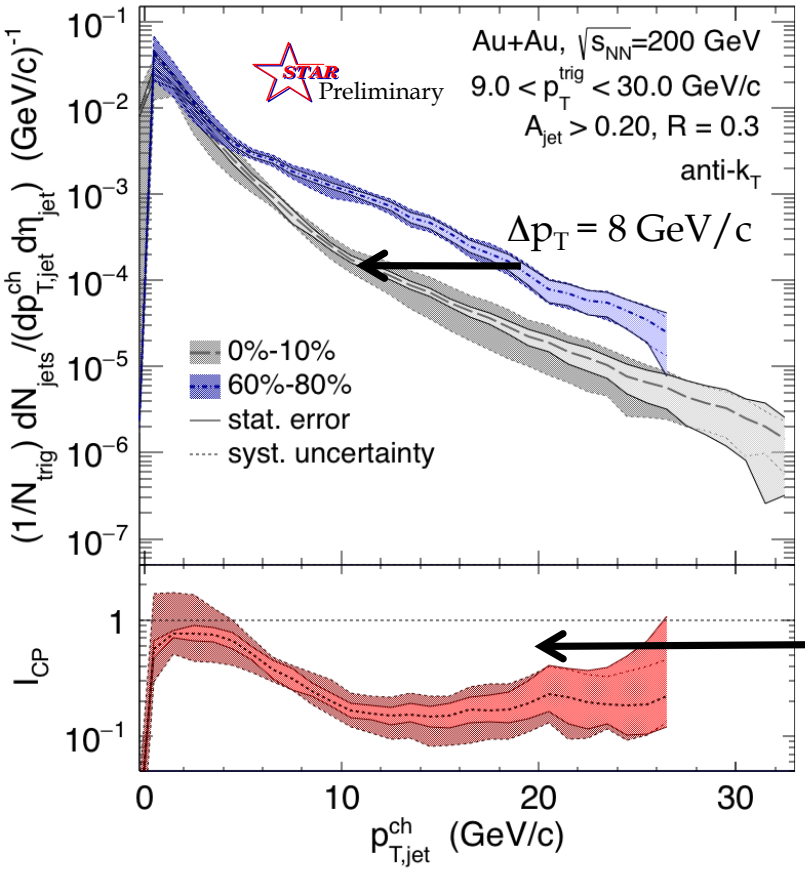


Peripheral (PYTHIA prior example)



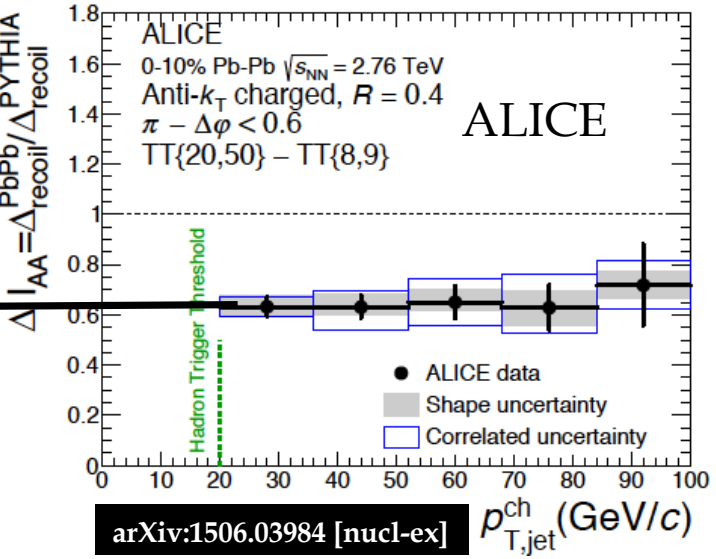
- SVD and Bayesian unfolding used
- Systematic variation of: Prior → {Levy function (T, n), PYTHIA}, regularization parameter, +/-5% efficiency variation, ME normalization, δp_T distribution (single particle embedding, PYTHIA jet embedding)
- Check based on backfolding χ^2

Comparison Central-Peripheral: I_{CP}



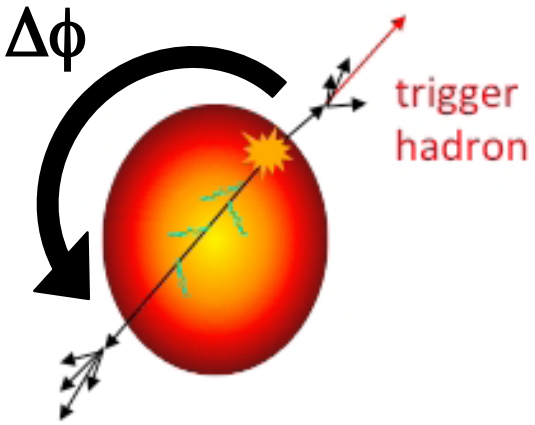
- Errors show combined systematics of unfolding (see previous slide) and track reconstruction

- Significant suppression (~0.2) at $p_T > 10$ GeV/c, similar to pion R_{CP}
- I_{CP} close to 1 at low p_T
- Larger suppression compared to LHC energies! (caveat: different R compared)
  → but similar shift in Δp_T (-8+/-2 GeV/c for ALICE)

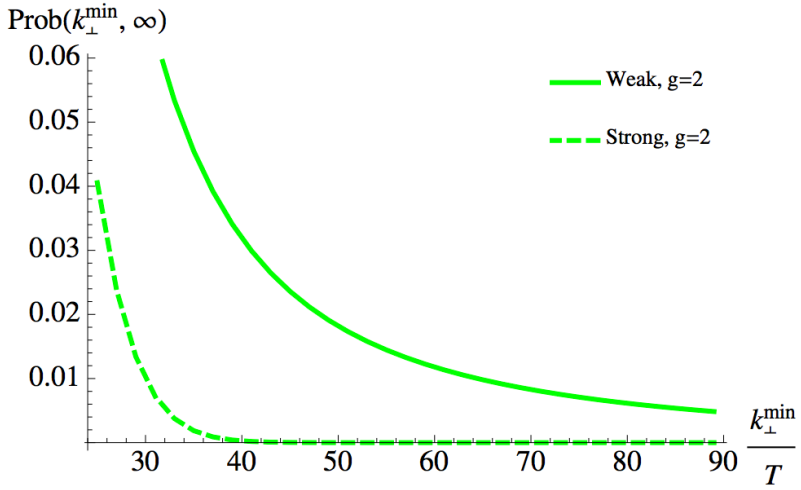


arXiv:1506.03984 [nucl-ex]

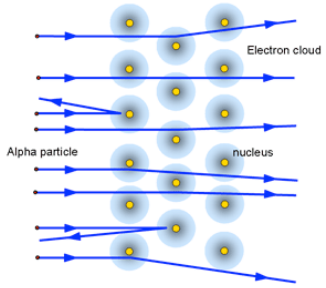
Large Angle Scattering off the QGP?



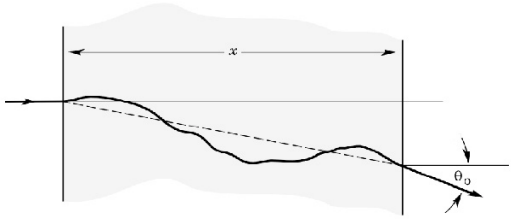
JHEP 1305 (2013) 031



Discrete scattering centers or effectively continuous medium?



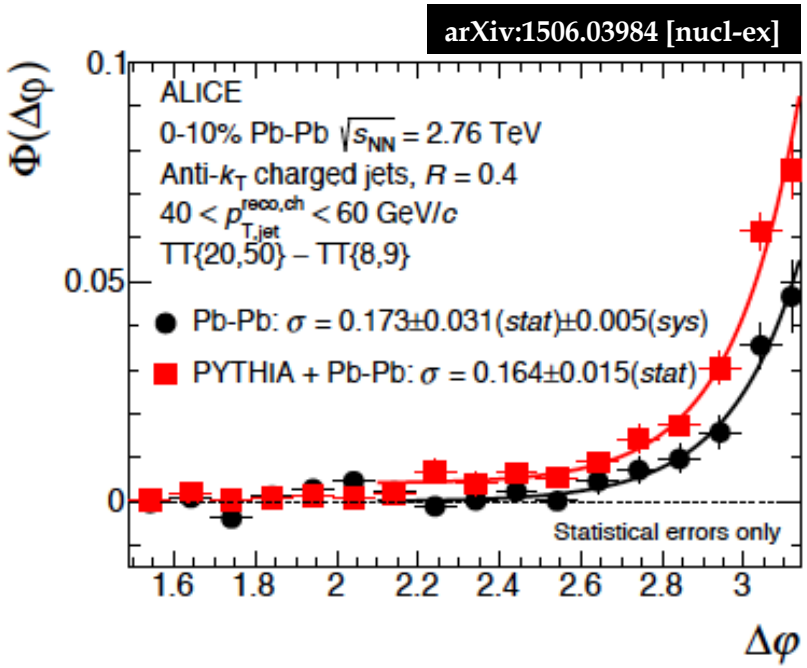
"Weak"
multiple scattering

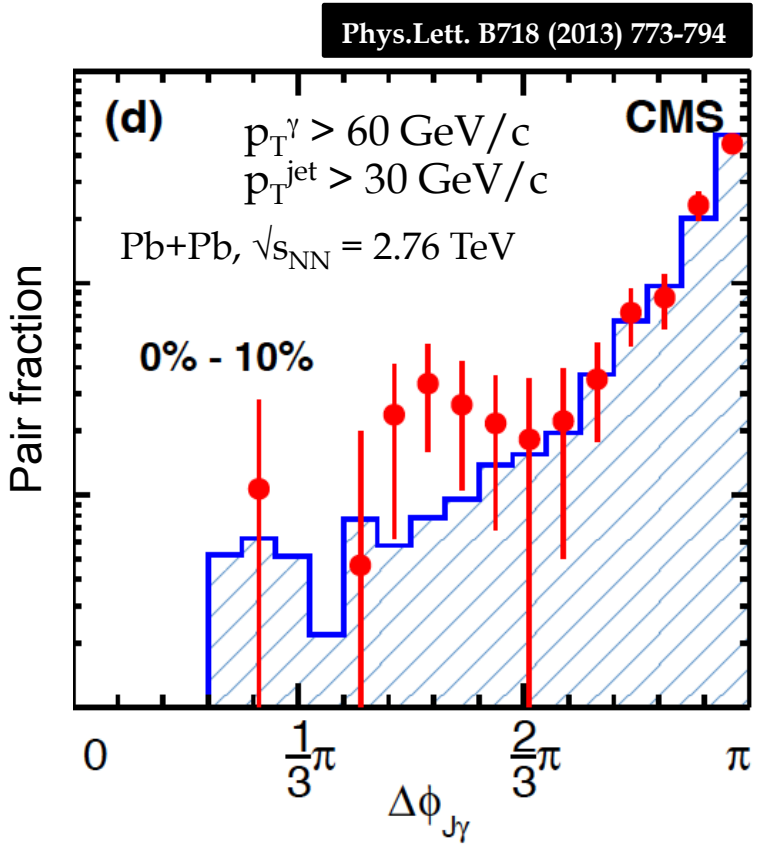


"Strong"
Continuous E-loss

- Scattering probability can give us important information about coupling
  → strongly/weakly coupled QGP
  → quasiparticles?

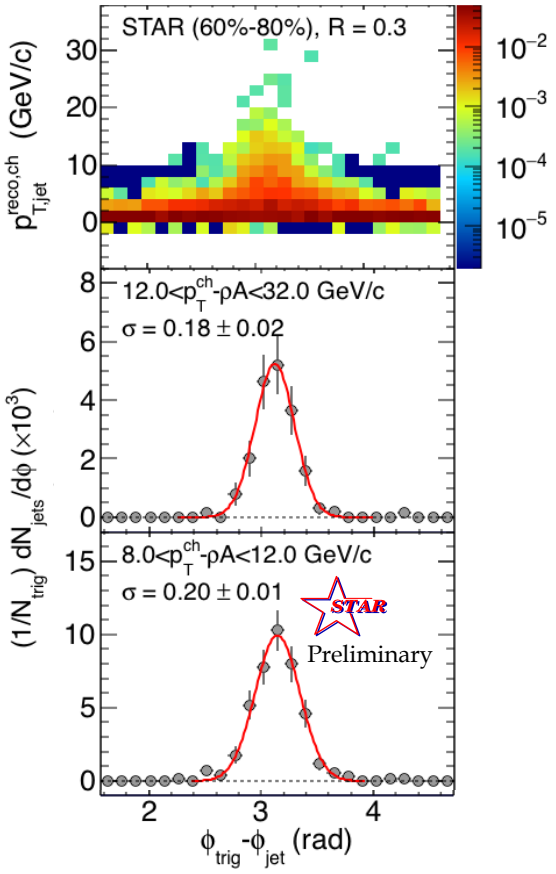
Large Angle Scattering at LHC

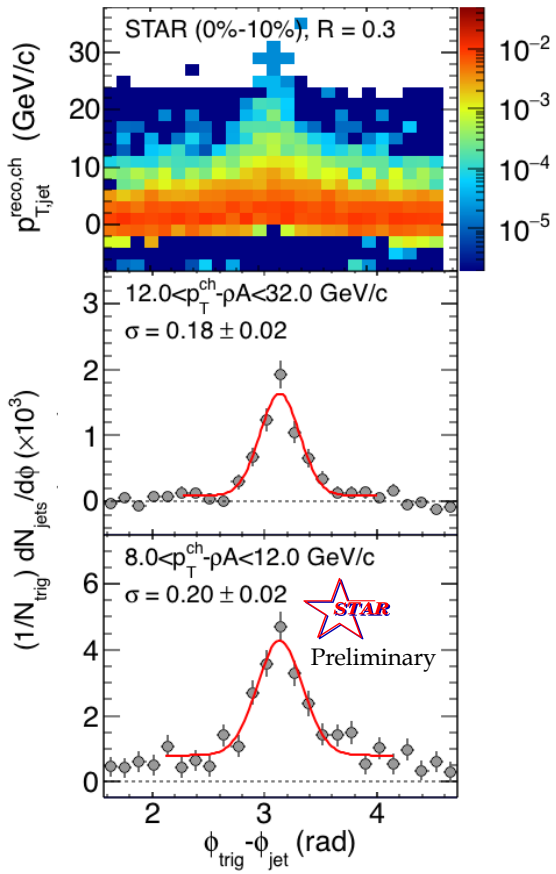




- No additional broadening observed in Pb+Pb compared to p+p so far

$\Delta\Phi$ at high p_T, R = 0.3

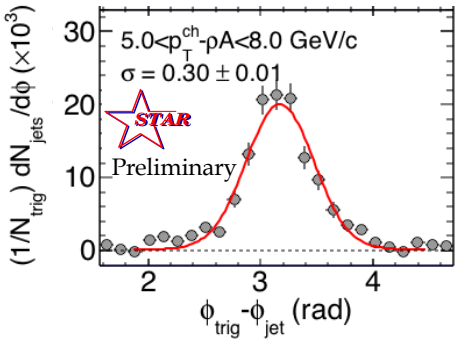




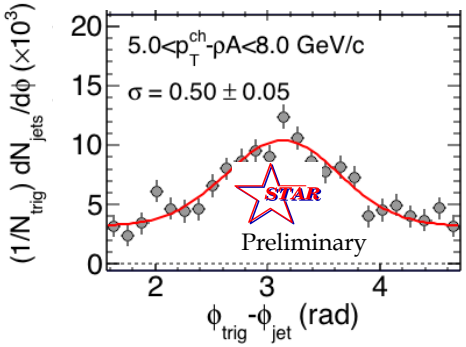
- $\Delta\phi = \phi_{trig} - \phi_{jet}$
- Projections for different recoil jet p_T
- Gaussian + constant
- Fit results do not depend on ME normalization
- Some pedestal for 0%-10%, almost no pedestal for 60%-80%
- Same width for both centralities

ΔΦ, at low p_T

Peripheral

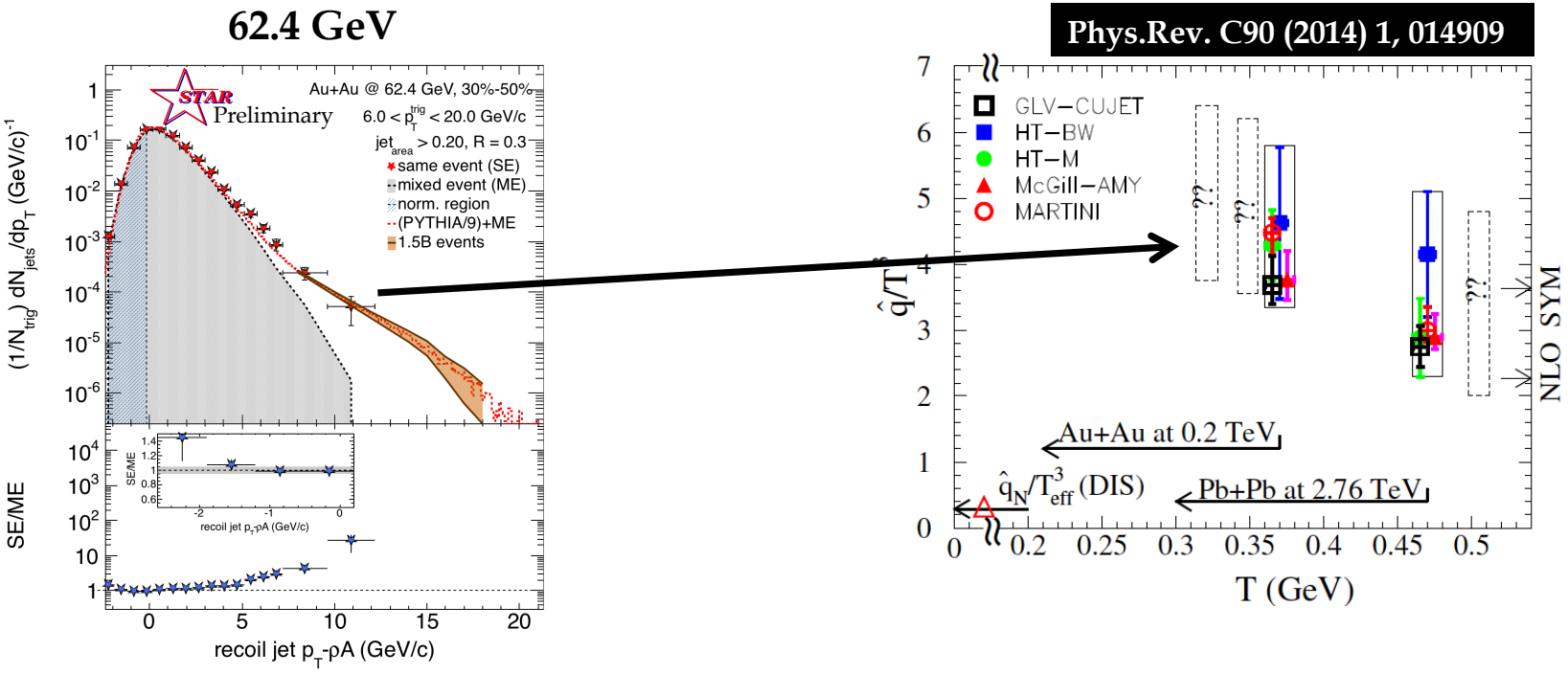


Central



- Significant difference at $5 < p_T\text{-}\rho A < 8$ GeV/c
  → Flow?
  → Φ dependent normalization needed?
  → Background from multiple interactions?
  → More studies needed!

Outlook



- Jet transport parameter has most likely a Temperature dependence
  → high statistics 62.4 GeV + full jet reconstruction!
  → STAR Beam Request for 1.5 B events for next year (under discussion)

Summary

Hadron triggered recoil jet spectra

- New mixed event technique can reproduce combinatorial jet background
  - → Low p_T jets accessible, and no bias on recoil jet side
  - → Direct comparison to pQCD calculations possible
  - → Suppression at 20 GeV/c (~0.2) is larger compared to LHC energies (caveat: different R)
  - →$\Delta\phi$ shows no difference between central and peripheral, except for lowest p_T (interpretation needs more studies)

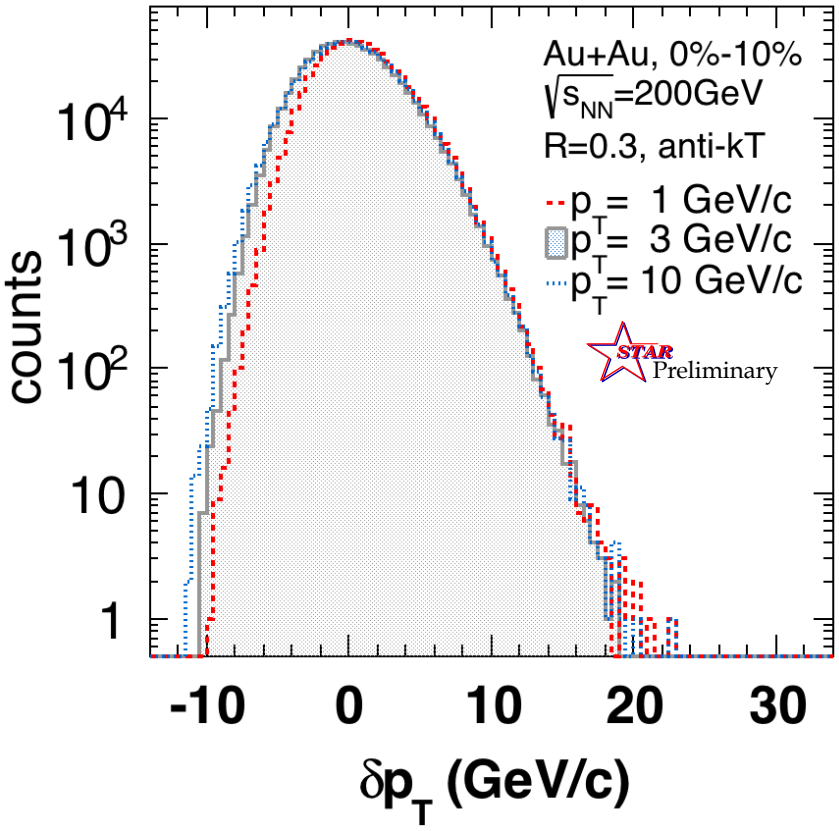
Outlook

- Full jet reconstruction @ 200 GeV+ more statistics soon
- Cone size dependence of jet suppression
- Low energy (Au+Au @ 62.4 GeV) jet reconstruction


Thanks!

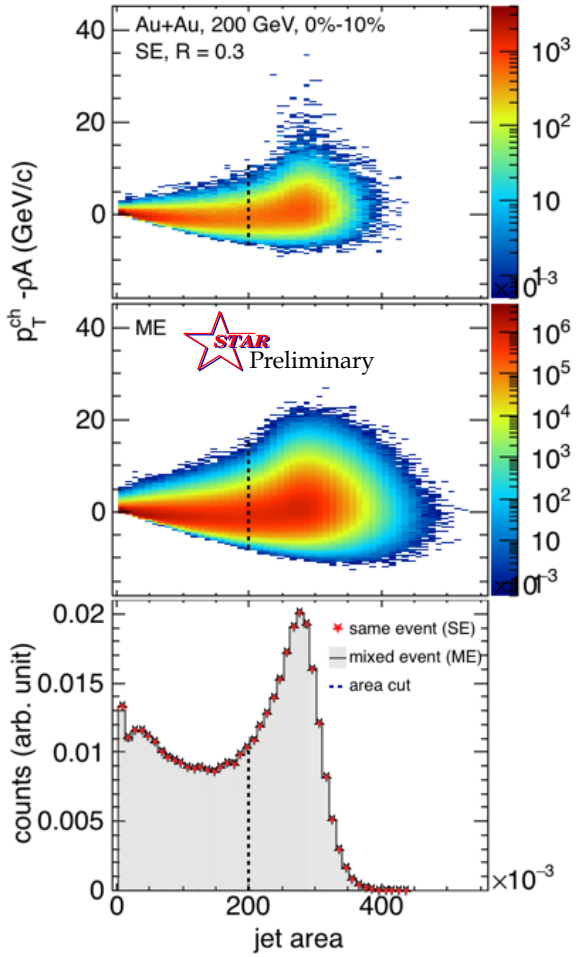
Background Fluctuations

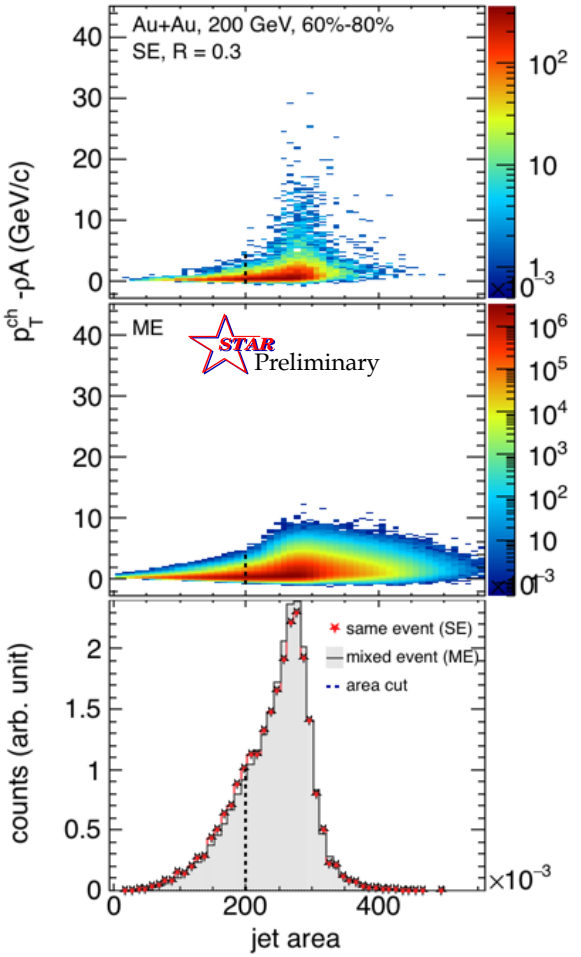
Smearing of "true" recoil jet due to underlying thermal background



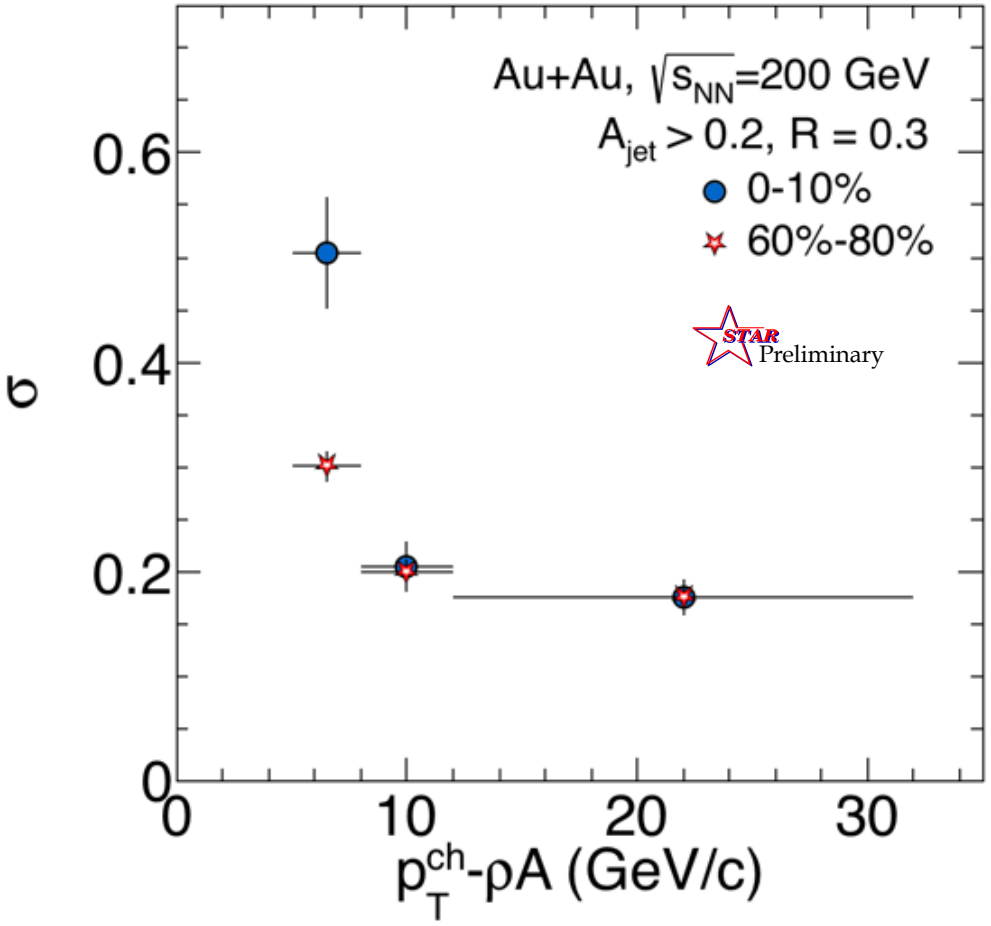
- True jet candidate is still contaminated by thermal background
  → jet momentum is smeared
  → δp_T
- Embed particles into real events to determine fluctuation
- Depends little on embedded particle momentum
- δp_T used to unfold the spectrum

R = 0.3, Area Distributions



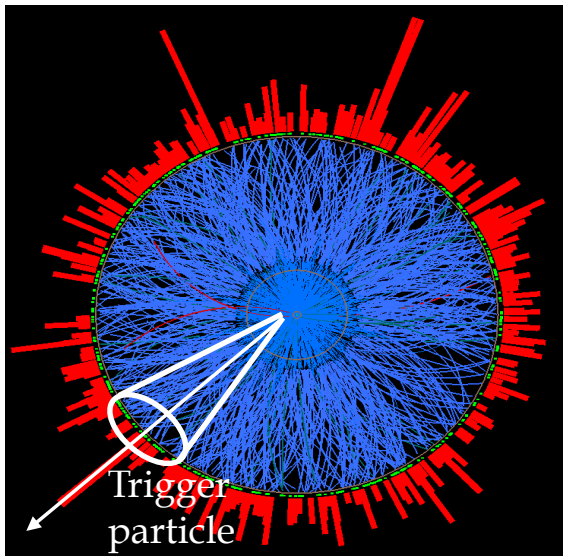


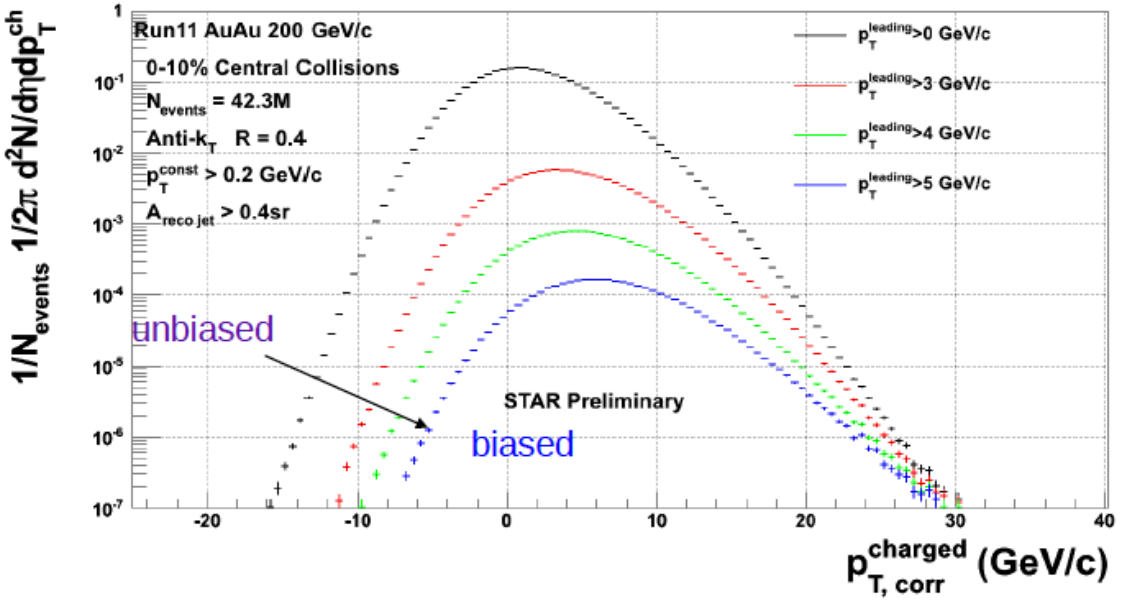
ΔΦ width, 0%-10%, R = 0.3



- Width is identical for 0%-10% and 60%-80% for p_T > 8 GeV/c
- Significant difference at low p_T → background effect (flow)?

Inclusive Jet Reconstruction

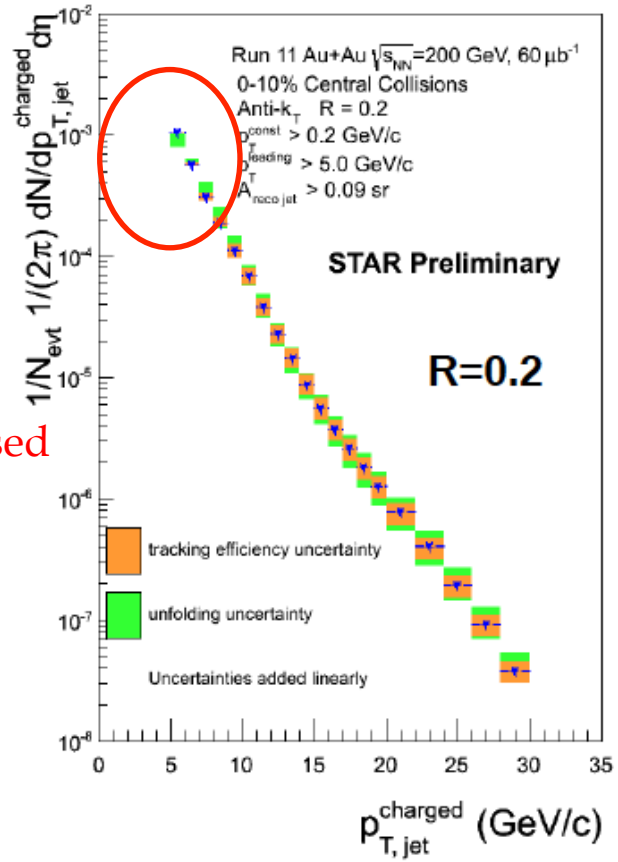


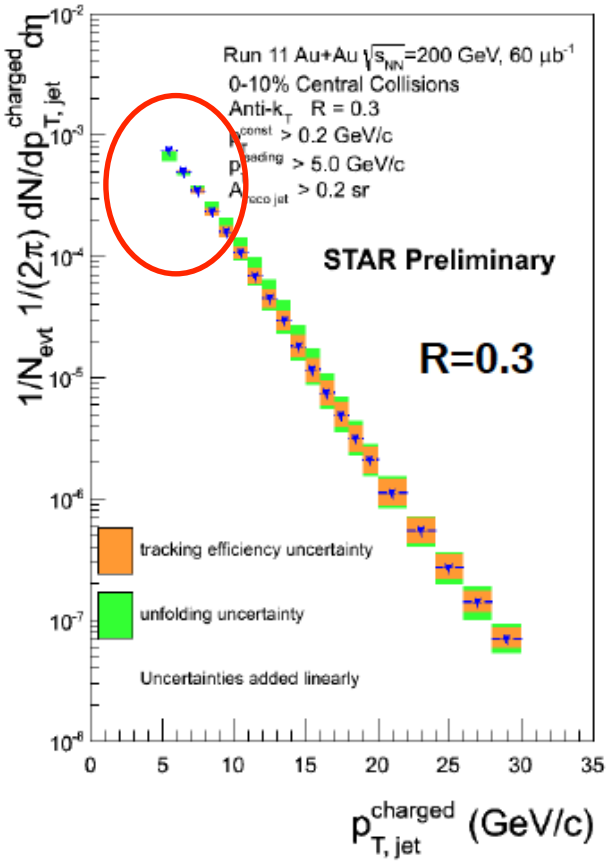


- To suppress the underlying background a high p_T hadron trigger is required
  - → Reconstructed jets are biased
  - → Background fluctuations still smear the reconstructed jet energy

Inclusive Charged Jet Spectra

Trigger biased





- Bayesian unfolding, ~5% jet energy resolution
- Steeply falling spectrum, biased at low p_T due to leading hadron trigger
  → Next step: R_{AA}