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Inclusive Spectrum of Fully Reconstructed Jets in Central Au+Au Collisions at $\sqrt{s_{NN}}$=200 GeV by the STAR Collaboration

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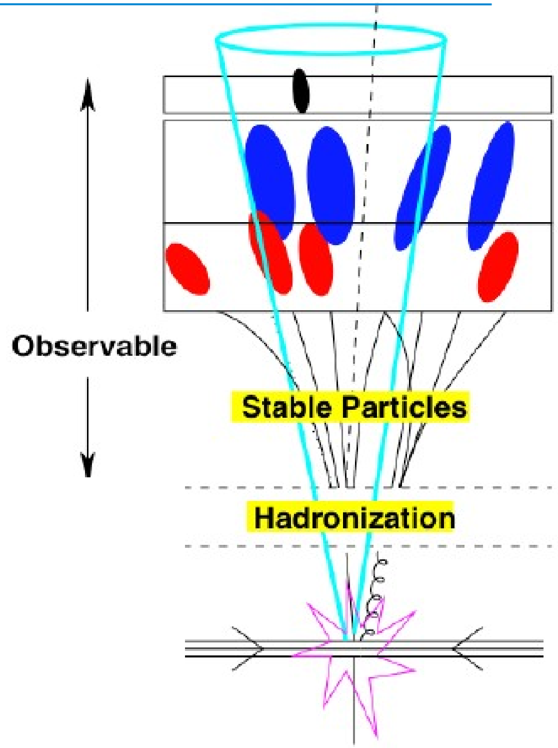
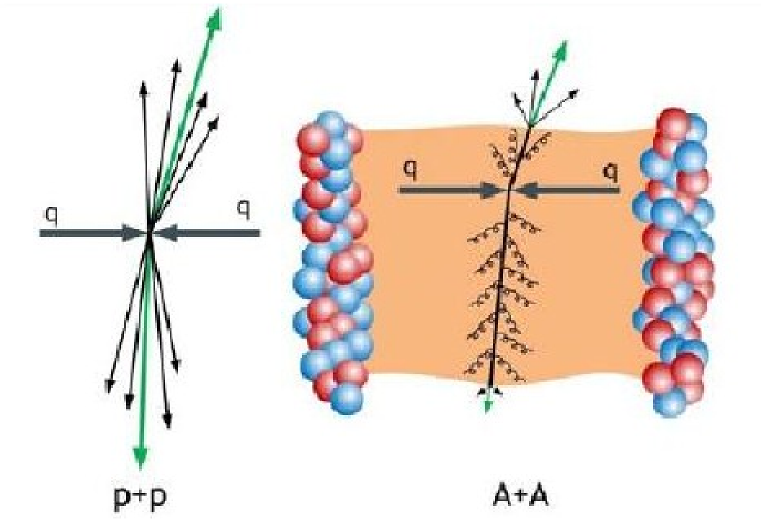
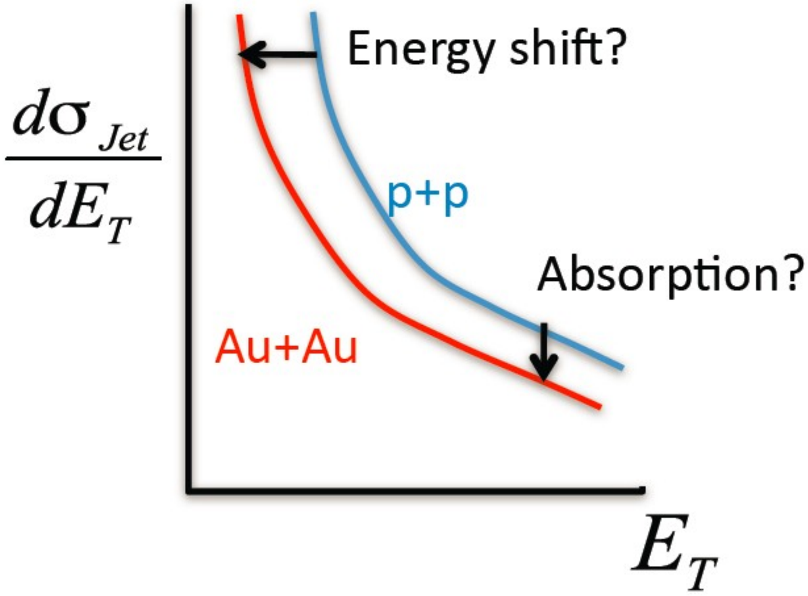
Motivation: jets as a probe of nuclear matter

- jets are collimated sprays of hadrons created by fragmentation and hadronization of hard-scattered partons
- in elementary collisions: test of perturbative QCD
- in heavy-ion collisions: probe of hot and dense nuclear matter

  jet quenching – softening and broadening of fragmentation







However: Jet reconstruction is an extremely challenging task in the high multiplicity environment and large and fluctuating background …

Jet tomography in A+A collisions: requirements

- well defined and transparent selection of jet population

  - *understand what biases we impose*

- direct comparison to theory

  - *jet distributions corrected for background and instrumental effects to particle level*

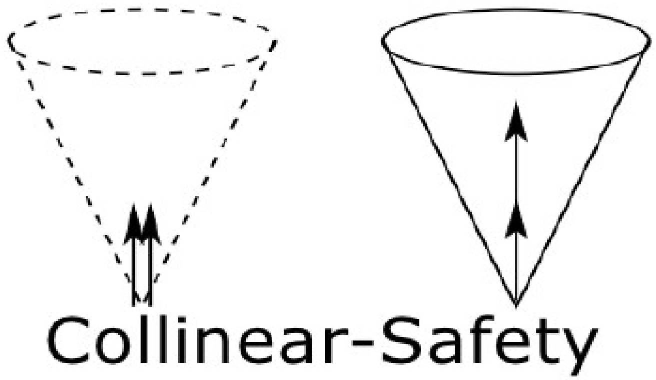
- same approach and algorithms at RHIC and LHC over the full jet kinematic range: p_T^{jet} > ~15-20 GeV/c

  → *to achieve a well controlled energy evolution of quenching*

- collinear safety, low infrared (IR) cutoff:

  - *proper choice of jet reconstruction algorithm*

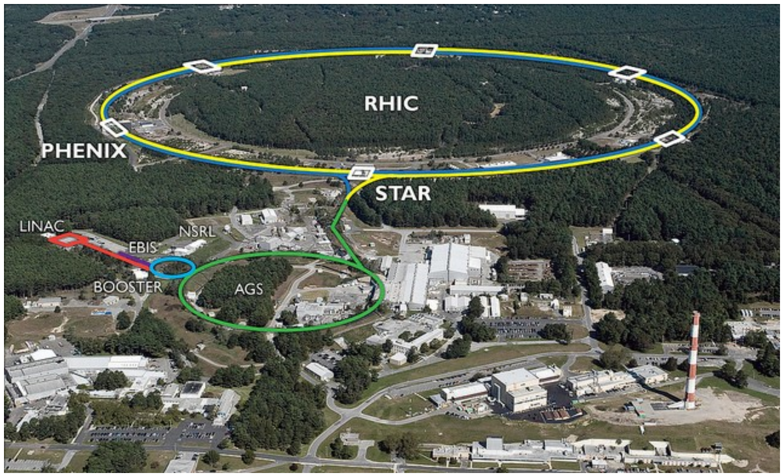
  → *no background suppression via cuts on jet constituents*



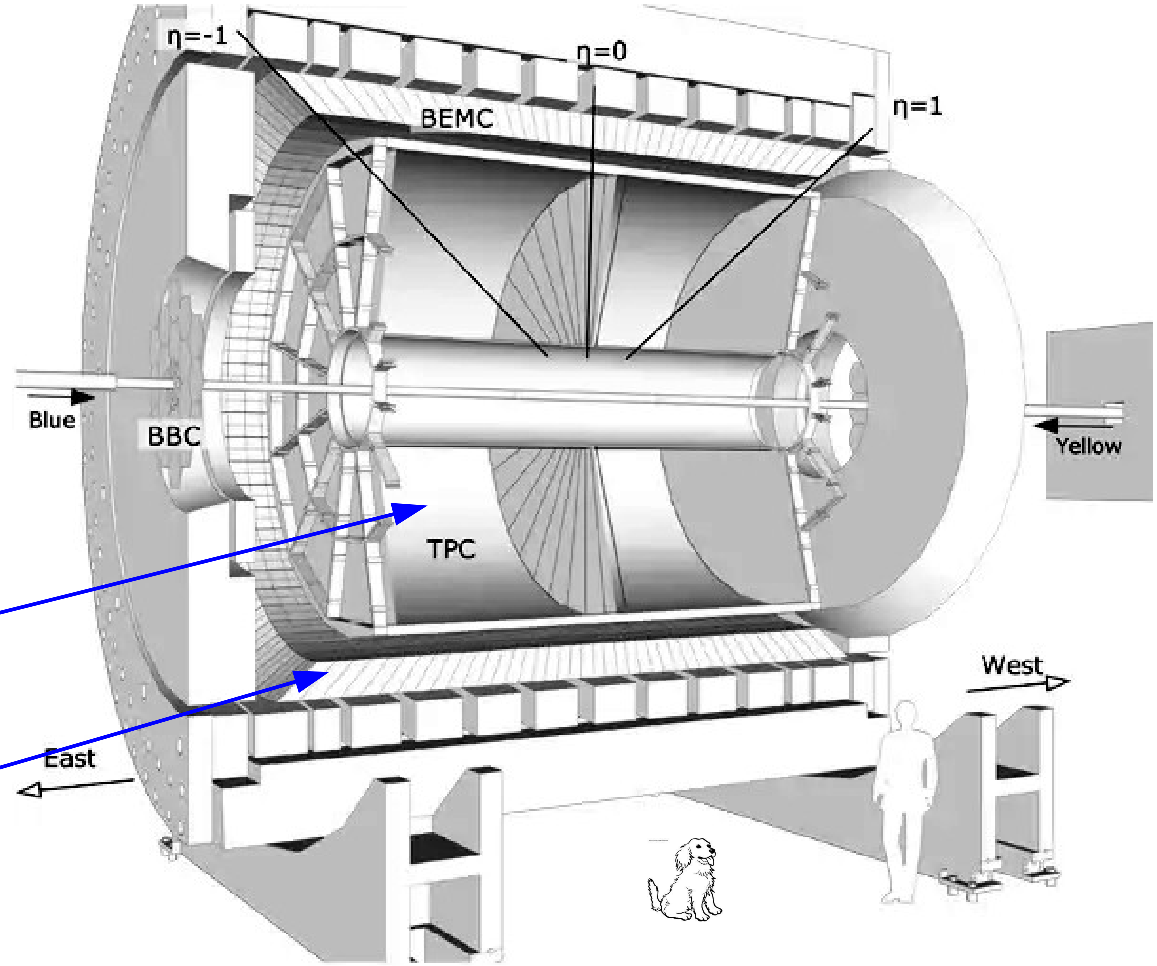
Caveat! Detector response also imposes infrared cutoffs

→needs to be assessed and corrected for

Relativistic Heavy Ion Collider (RHIC)



Solenoidal Tracker at RHIC (STAR)



Time Projection Chamber

Barrel Electromagnetic Calorimeter

full azimuthal coverage
pseudo-rapidity coverage: $-1<\eta<1$

Data Sample and Charged Jet Analysis

Data set:
RHIC Run11 data
Au+Au @ $\sqrt{s_{NN}}$=200 GeV
Minimum Bias (MB) events
BEMC High-Tower (HT) triggered events (work in progress)

Event cuts:
|z(vertex)|<30cm
10% most central Au+Au collisions

Charged track selection:
reconstructed in TPC
DCA < 1cm
Number of fit hits > 20
# of fit hits/# of max. available > 0.55

Jet reconstruction:

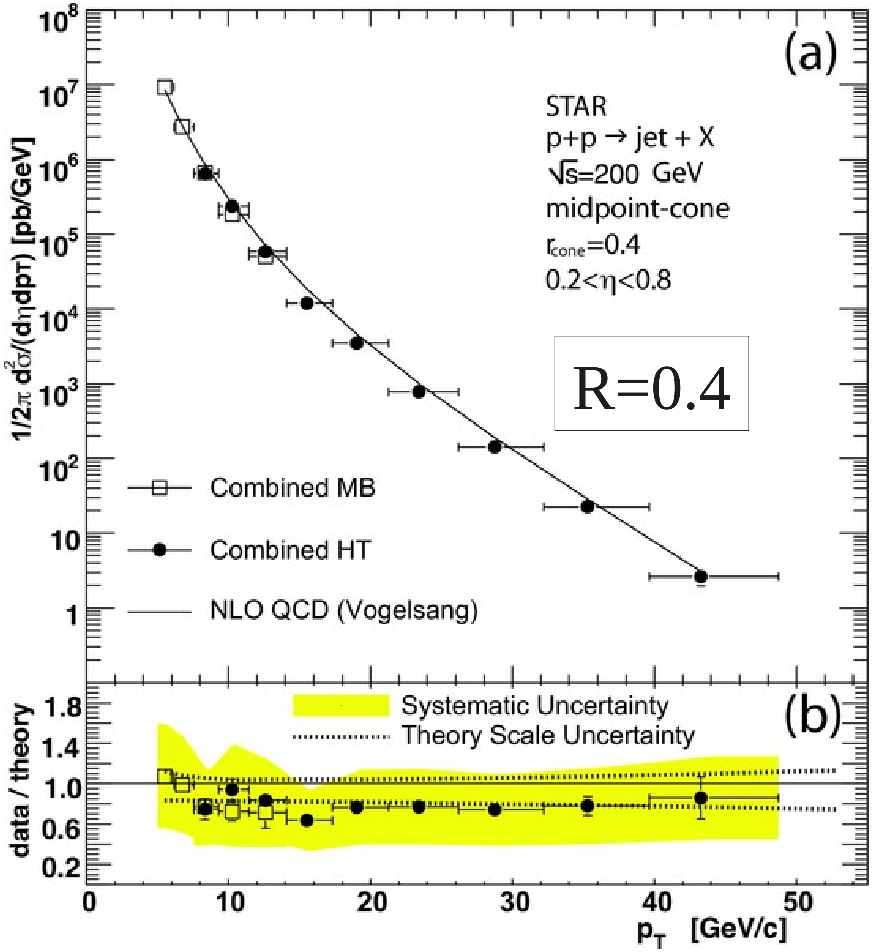
- Charged jets
- anti-k_T jet reconstruction algorithm

resolution parameter: R=0.2 and 0.4

- very low IR cutoff:
  p_T(constituent) > 0.2 GeV/c
- jet active area: A > 0.4 Sr (R=0.4)
  A > 0.09 Sr (R=0.2)
- fiducial jet acceptance: $|\eta|<1-R$

Estimate of jet yields in Run11 Au+Au data

p+p jet spectrum (from Run 3 + 4)



[STAR, Phys. Rev. Lett. 97 (2006) 252001]

Run 11 Au+Au integrated luminosity:
~ 2.8/nb

Estimate jet production yield
(i.e. R_{AA}=1):

$$\sim T_{AA} \cdot \frac{d\sigma_{pp}^{jet}}{dp_T d\eta}$$

10% central Au+Au in Run11:
We expect ~2K jets with p_T>50 GeV/c
(full jets with BEMC).

Our analysis:
charged-only jets, no trigger, 40 million "unbiased" events (~ 0.14/nb)

Response of jet to soft background: $\delta(p_T)$ distribution

What is the response of jet to presence of soft background?

- embedding of a simulated jet into an event → jet reconstruction → response

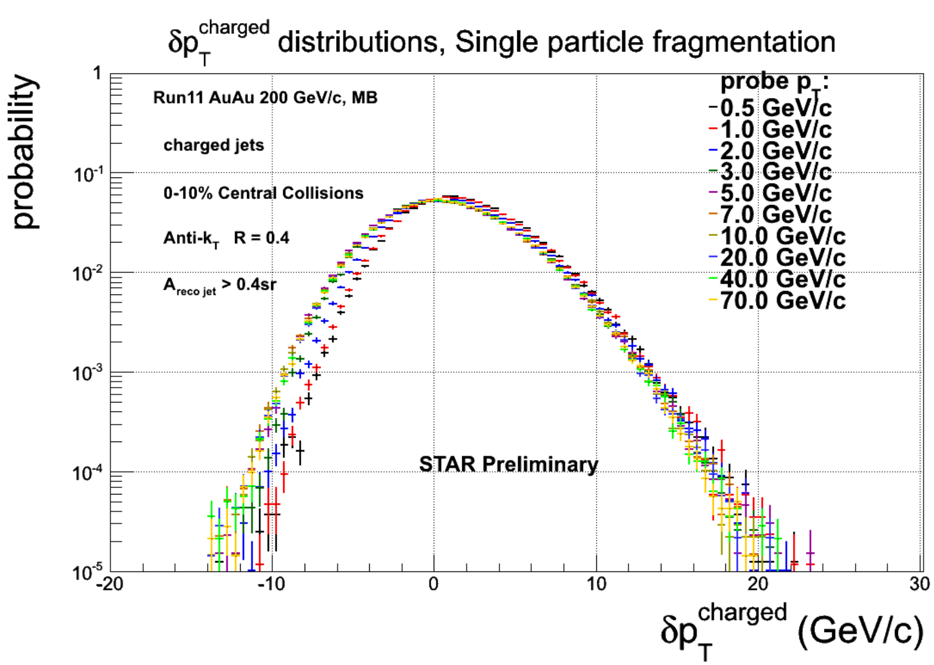
$$\delta p_T = p_{T,corr} - p_{T,emb} = p_T - A_{jet} \times \rho - p_{T,emb}$$

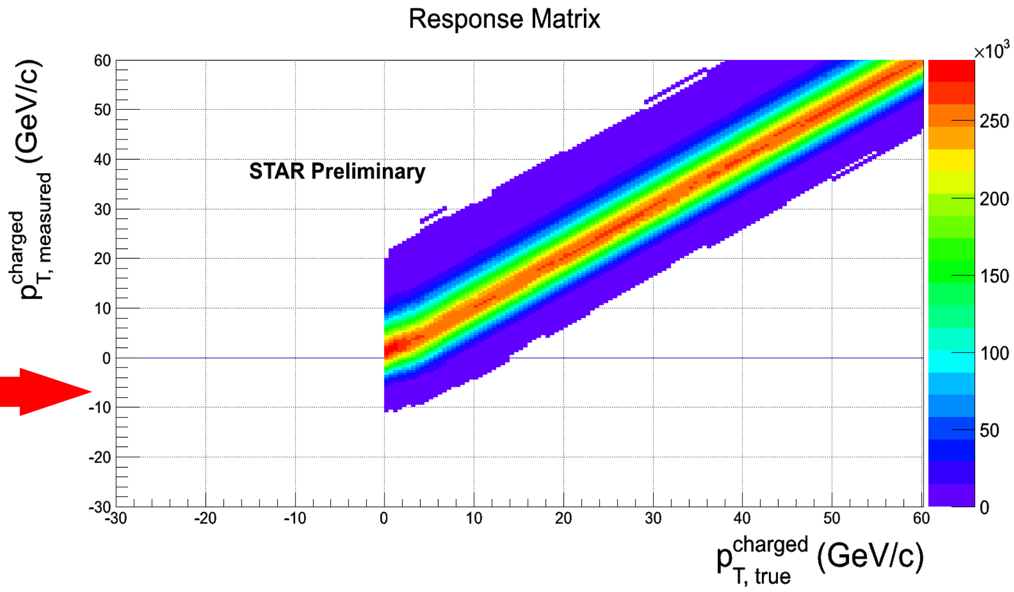
ρ ~ 29 GeV/Sr, $A_{R=0.4}$~0.5 Sr

- ensemble-averaged $\delta(p_T)$ distribution → determination of the response matrix

Corrections of jet candidate distribution for the p_T smearing due to background

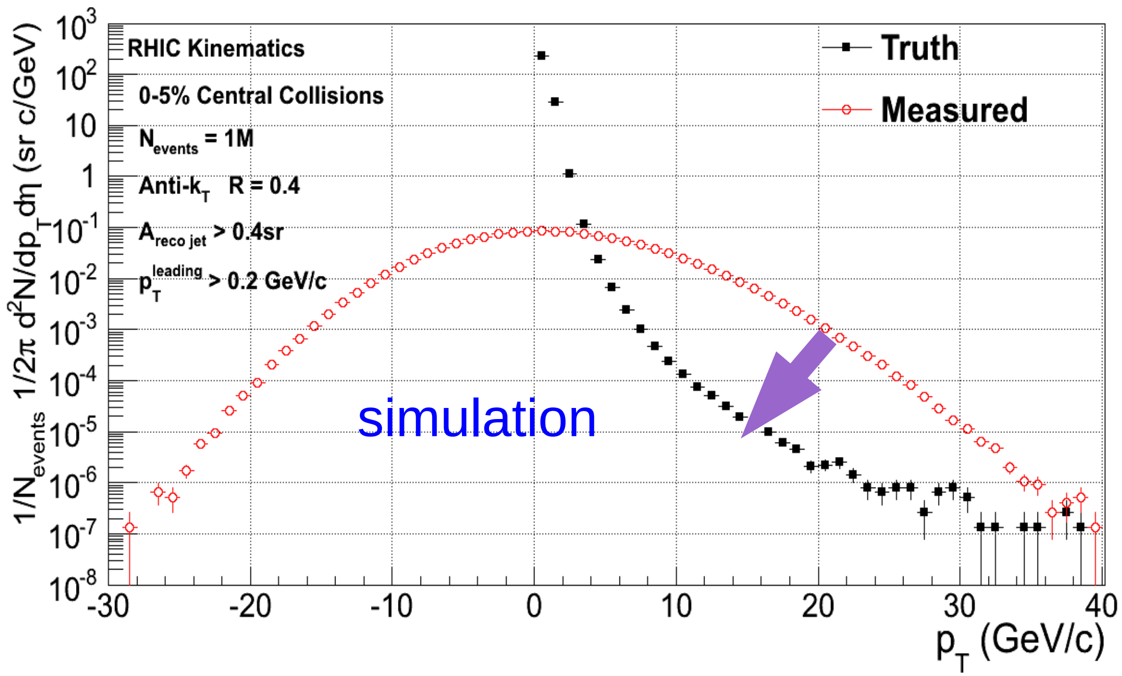
Bayesian, Singular Value Decomposition (SVD), χ^2 minimization …





Unfolding of Measured Spectra

- Undo the effects of background fluctuations on hard jet spectrum



- “Inversion” of response matrix → unfolding matrix
- Correction for BG fluctuations only
- Correction for detector effects in progress
- We use iterative method based on Bayes' theorem *[G. D'Agostini, arXiv:1010.0632]*

→Unfolding parameters:

- prior pT distribution
- number of iterations

Toward the Inclusive Jet Spectrum

- Stable unfolding of inclusive jet spectrum:

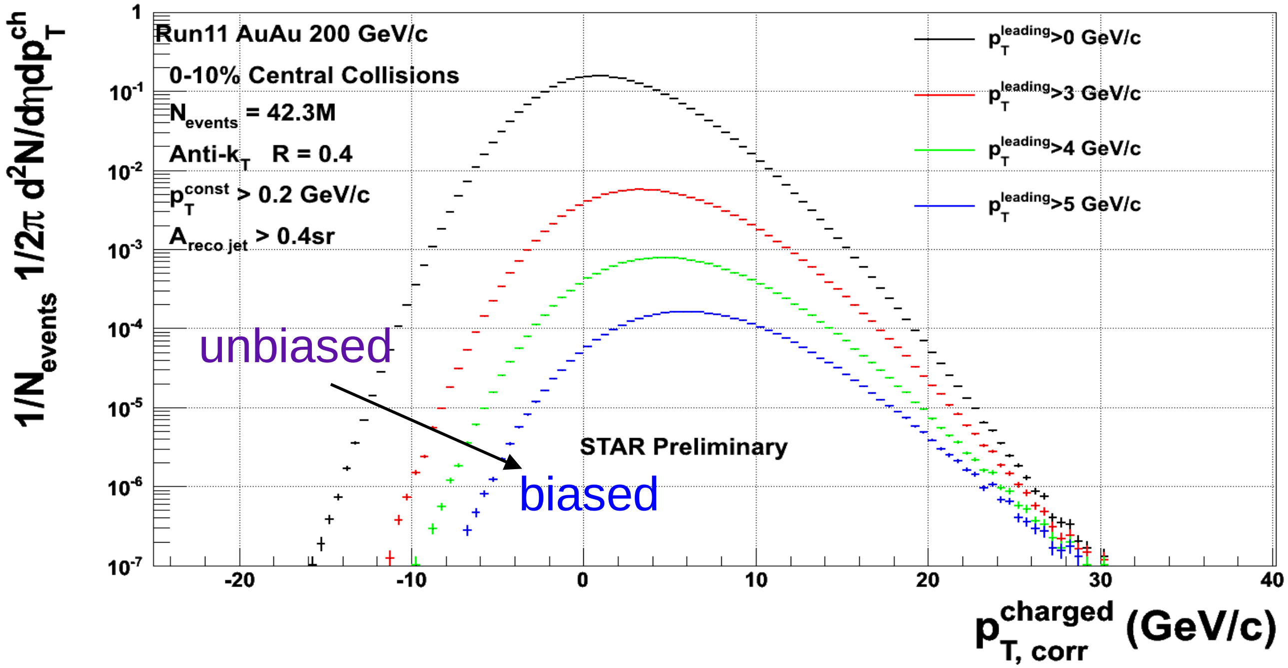
  need to reduce the combinatorial background prior to unfolding

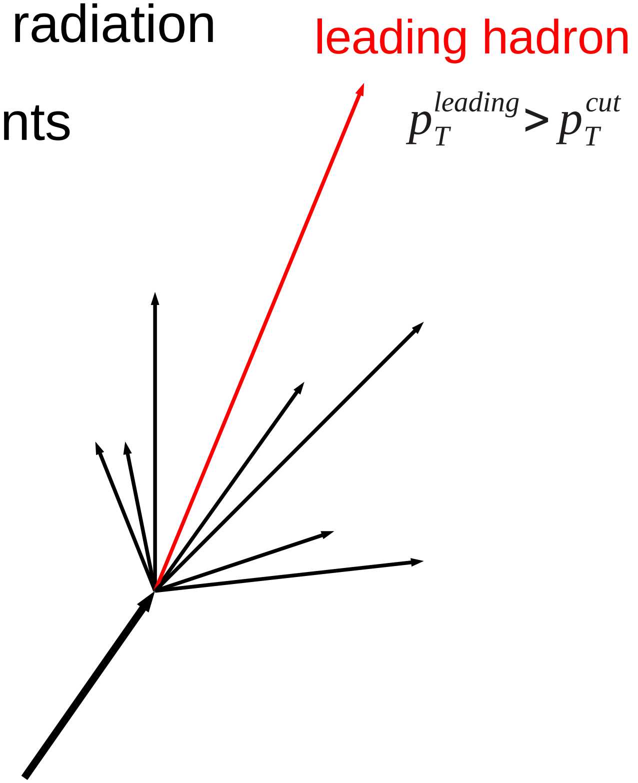
  [G. de Barros et. al, Hard Probes 2012, arXiv:1208.1518v2]

- Combinatorial background is reduced by p_T cut on jet's leading hadron

- Large fraction of jet energy can be carried by soft radiation
  - May be important for jet quenching measurements

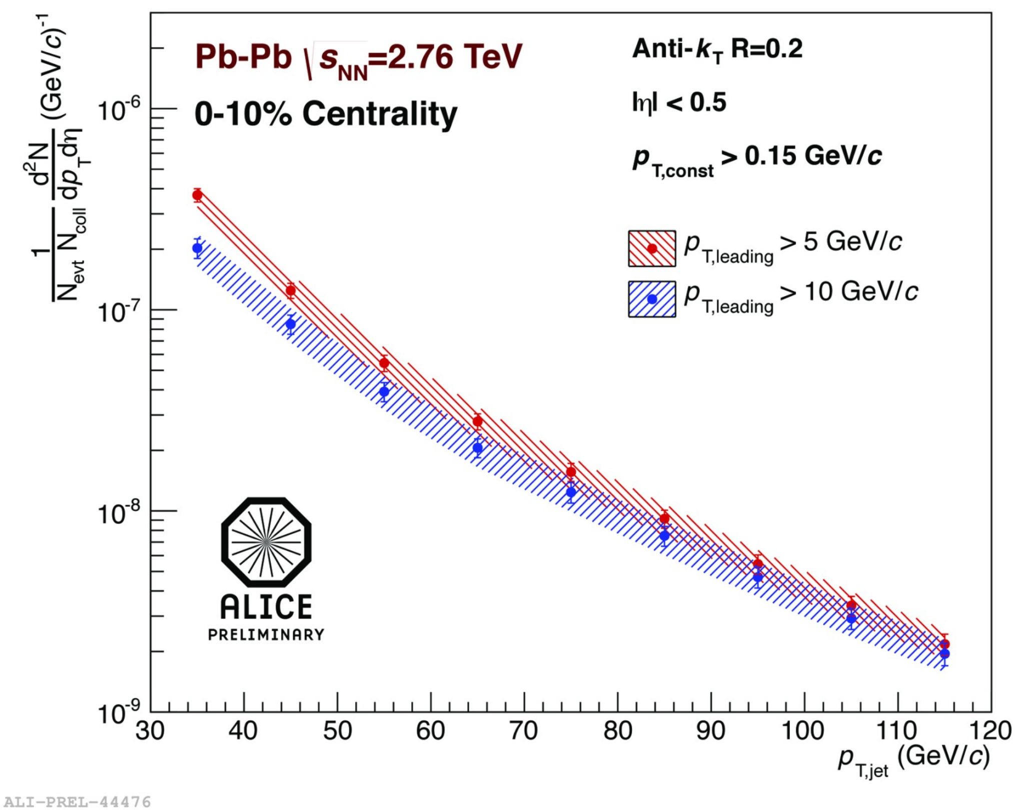
$p_T^{leading} > 0, 3, 4, 5$ GeV/*c*



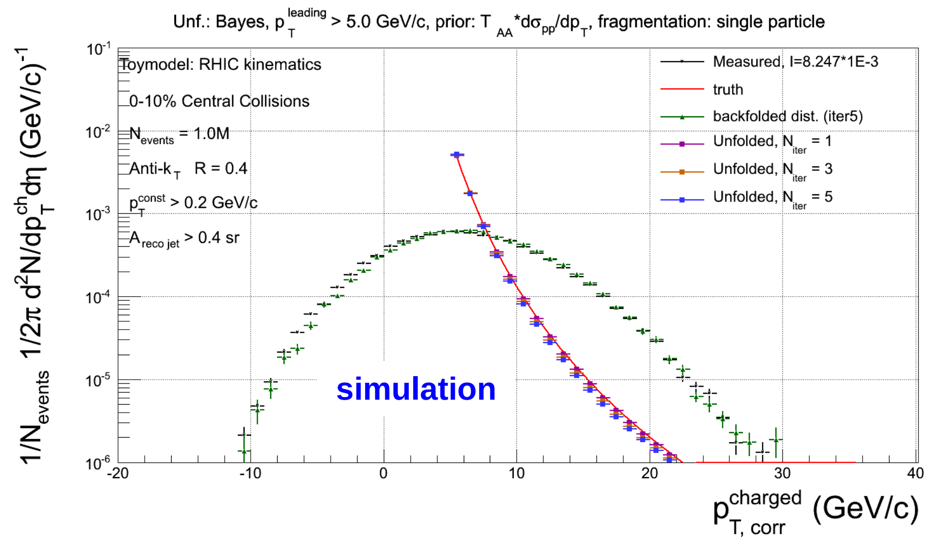


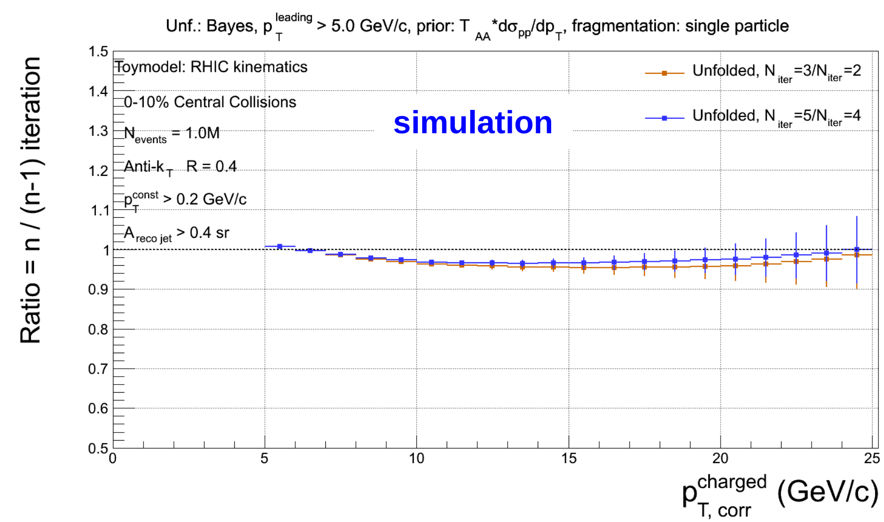
Methodology

- Method has been successfully used by ALICE collaboration
- We have tested the method on toymodel and now we are applying the same method to STAR data



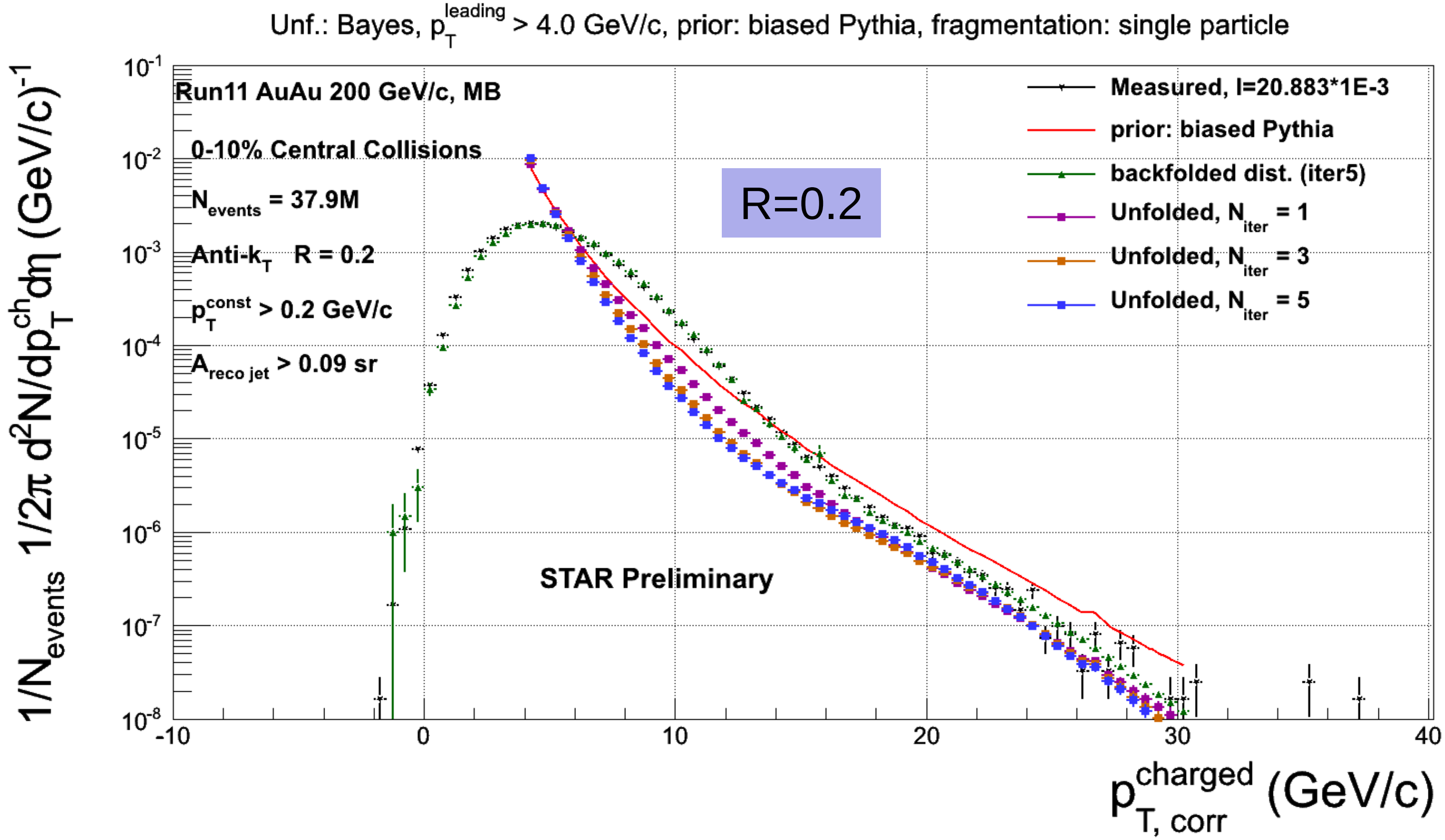
[ALICE collaboration, arXiv:1304.6668]





Testing Unfolding at RHIC Data

- We have stable unfolding solution



- We need to study it in a systematic way:
  - Input prior sensitivity
  - Fragmentation model sensitivity
  - Effect of varying R on convergence
  - Optimal number of iterations
  - Comparison to SVD unfolding

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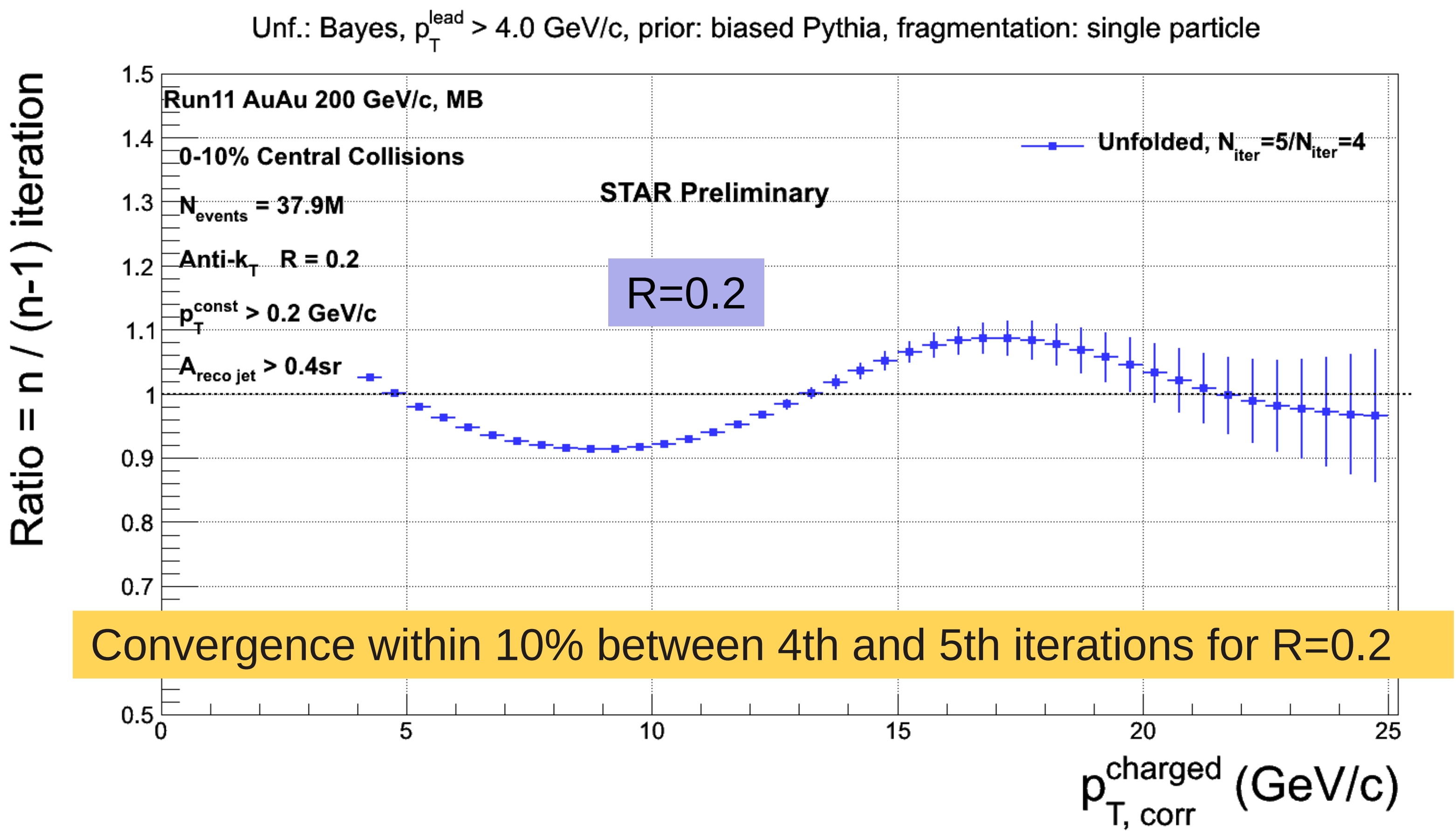

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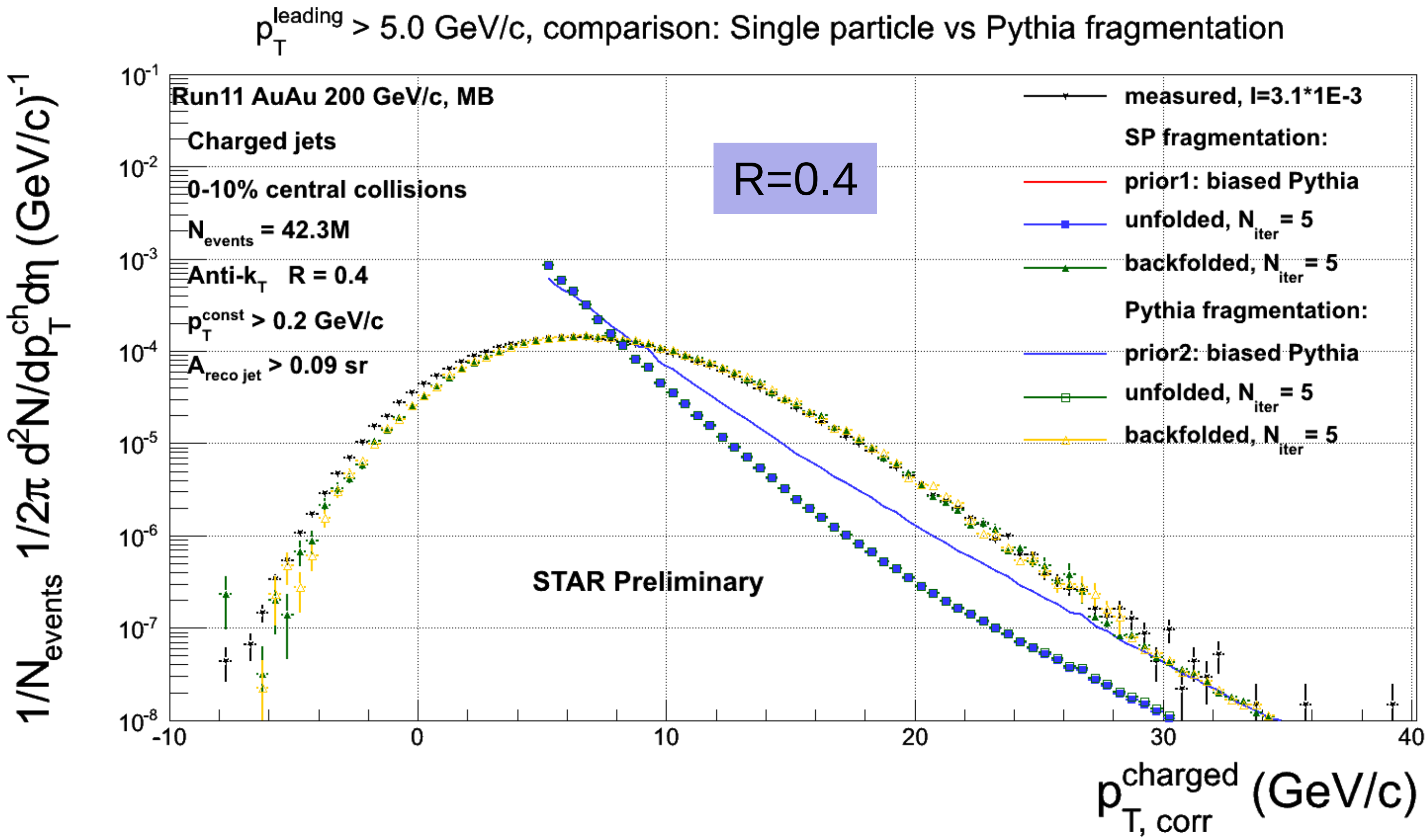
Unfolding of Real Data

dependence on fragmentation model

- Response Matrix is calculated using different fragmentation models (single particle, Pythia)
- Results should not depend on the choice of fragmentation model



Comparisons of single particle and PYTHIA fragmentation show negligible sensitivity to fragmentation model for Response matrix

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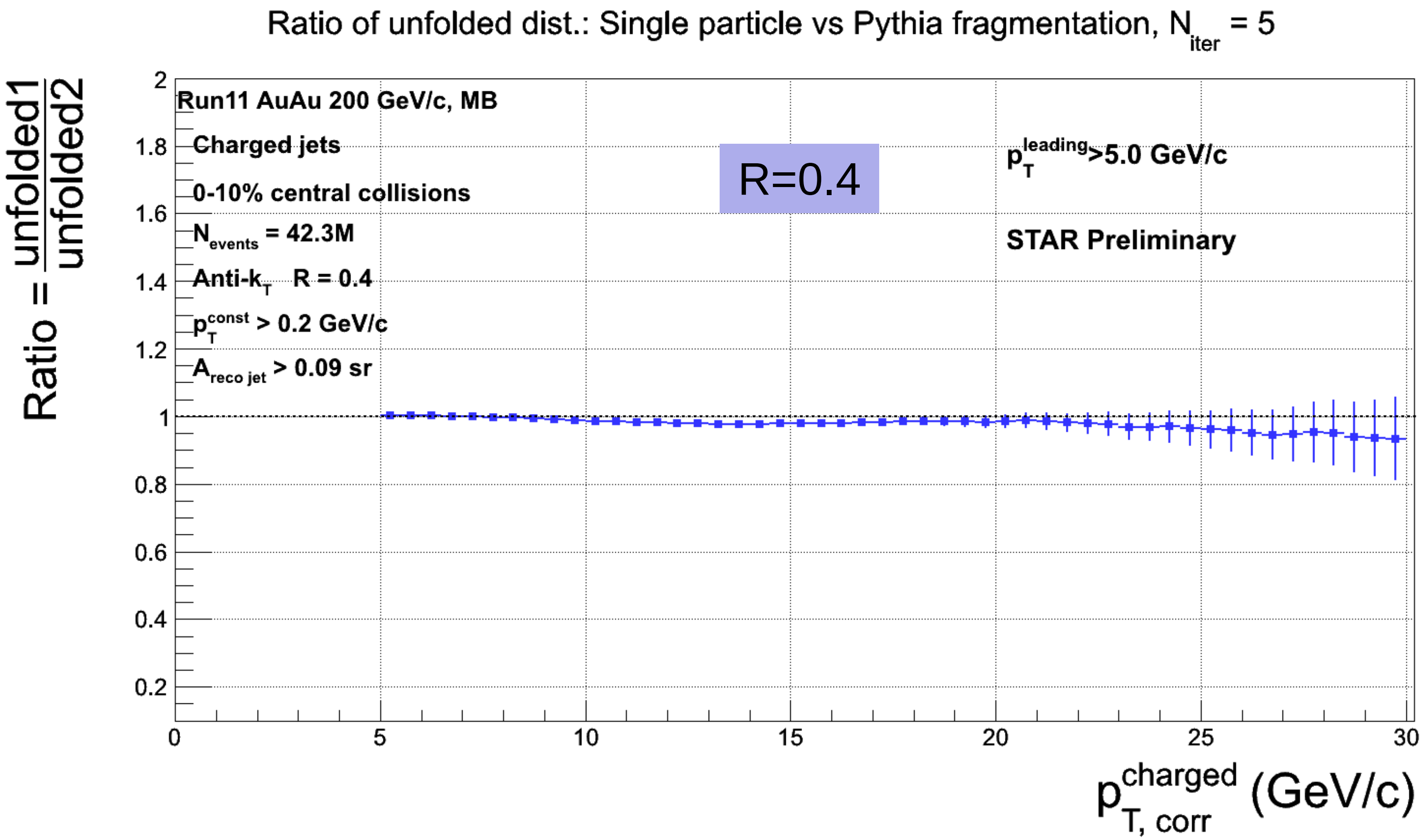

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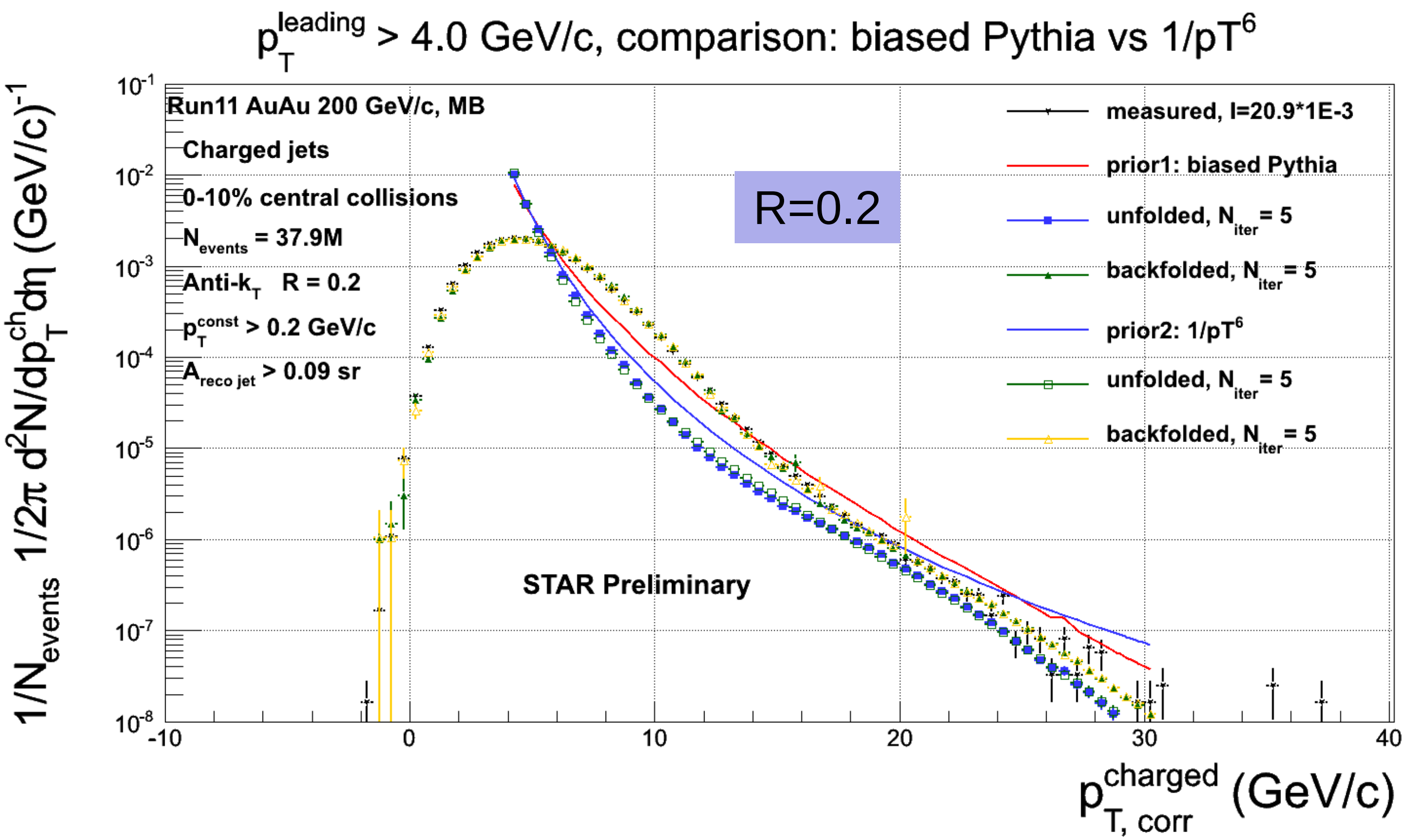
prior dependence

- Bayesian unfolding => we need a prior distribution as the starting point
- Results should be independent on our choice of (a reasonable) prior



- *R*=0.2: weak dependence on prior choice (p_T^{-5}, p_T^{-6}, Pythia with $p_T^{leading}$ cut)
- *R*=0.4: under study

R = 0.2, p_T(leading)>4 GeV/*c:* Weak dependence on the prior (within 20%).

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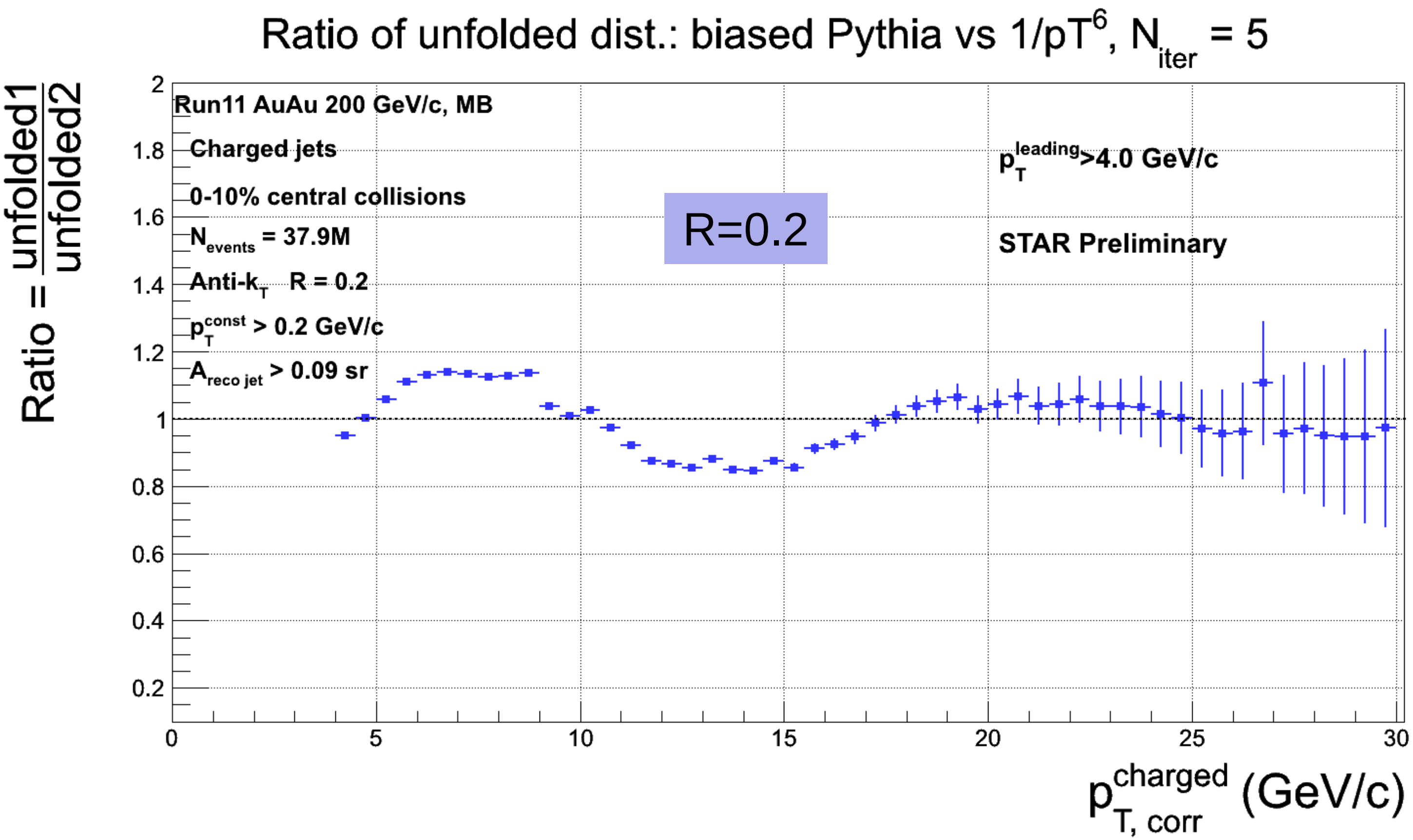

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Summary and outlook

- Working framework for jet reconstruction in Au+Au collisions in STAR
- First step to reliable comparison between STAR and ALICE jet analysis

Next steps:

- Further systematic studies of sensitivity to prior and convergence with different resolution parameters
- Correction for TPC tracking efficiency
- Charged+neutral jets (using BEMC)
- Compare to different unfolding procedures (e.g. Singular Value Decomposition)
- Jet R_{AA} - all the major pieces are in place

  => STAY TUNED

BACKUP SLIDES

Testing methods on a MC Toymodel

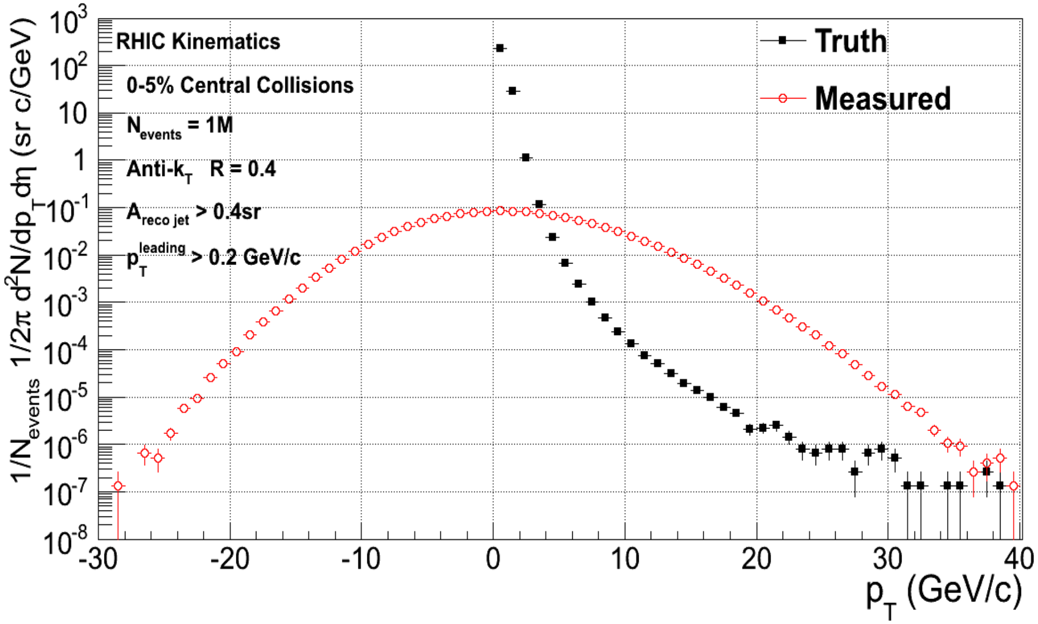
- simple model, yet able to capture main features of heavy-ion collision environment
- primary charged particles within the STAR acceptance (no decays)
- no detector effects and no elliptic flow effects included
- two components: soft Boltzman background component with <p_T> = 500 MeV/c

  hard jet component with distribution $T_{AA} \cdot \frac{d\sigma_{jet,pp}}{dp_T}$

  nuclear overlap function from Glauber model

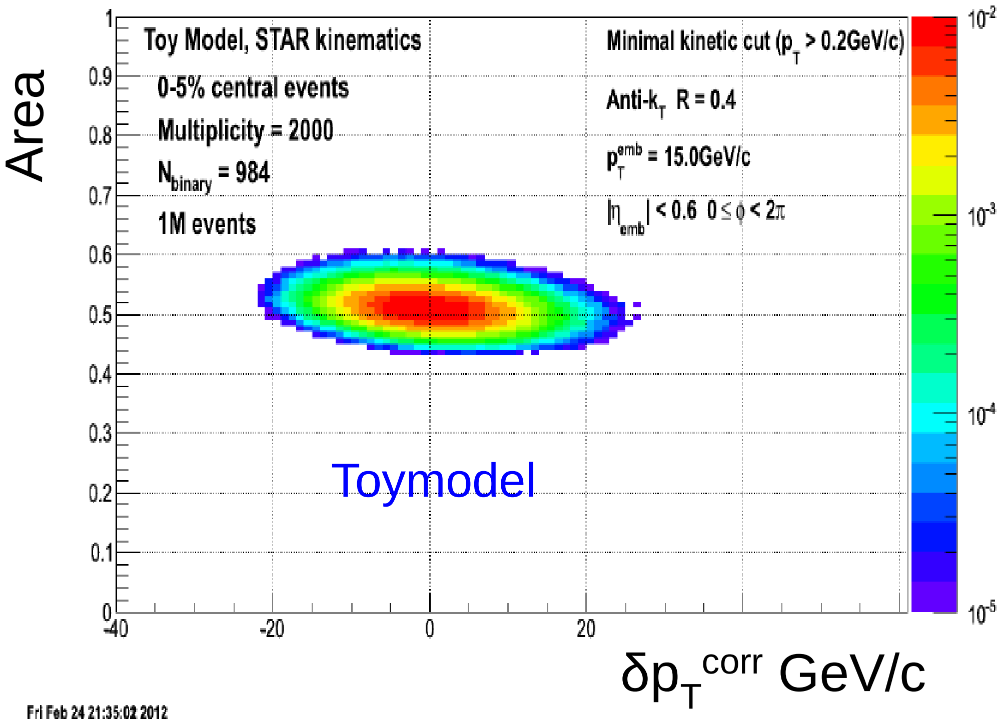
  from Pythia or p+p collisions

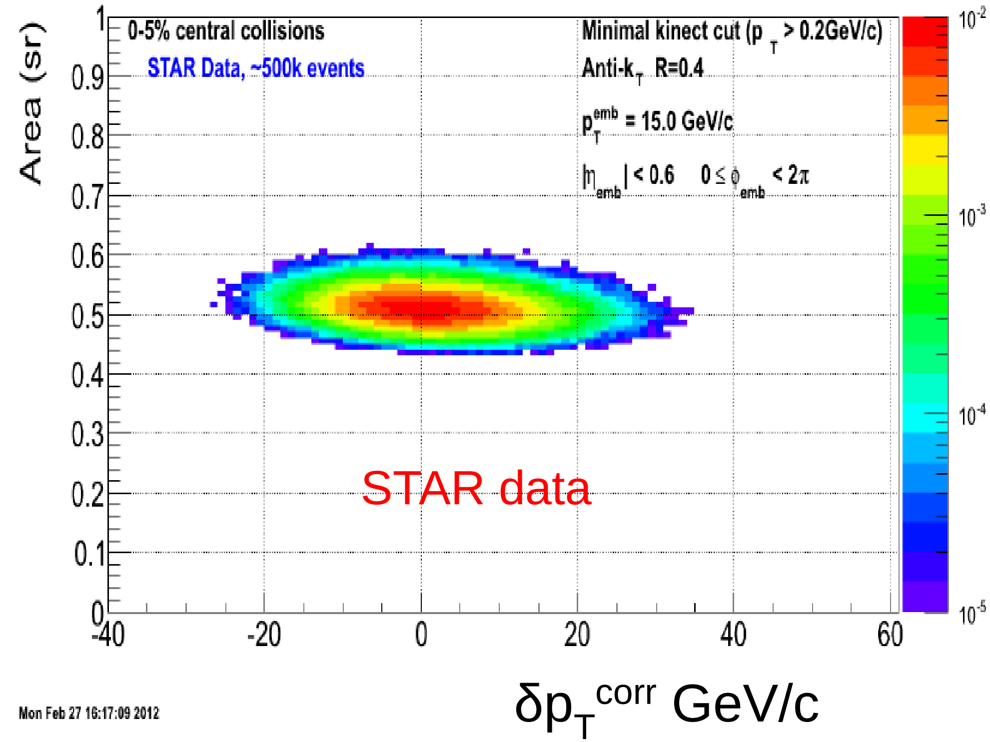
- fragmentation models: single particle, PYTHIA

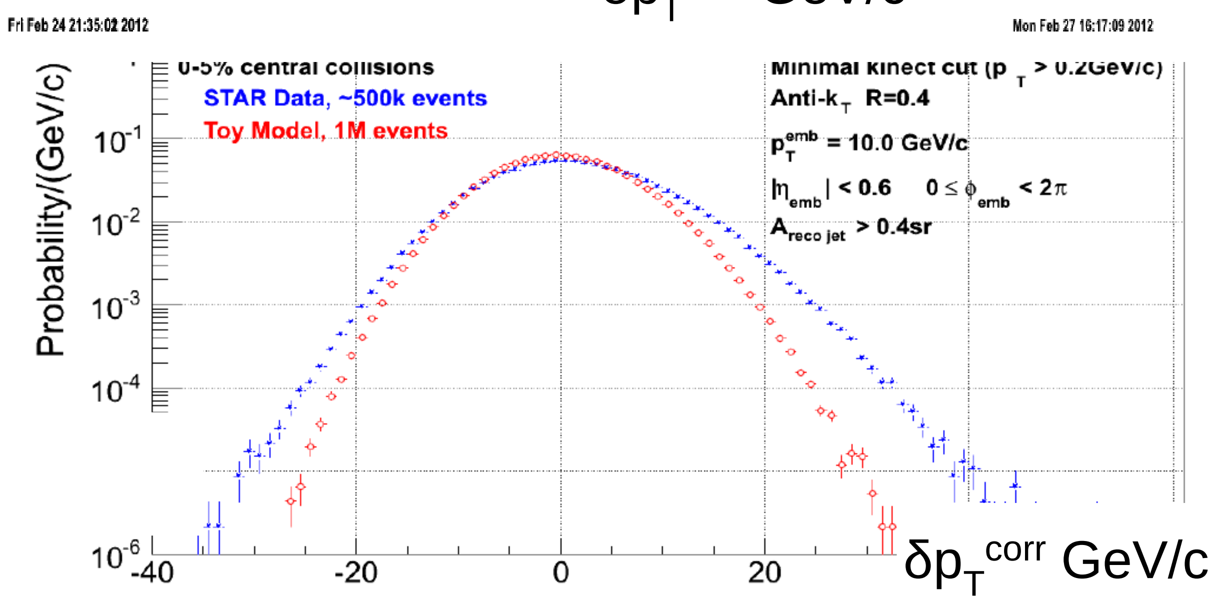


Toymodel vs STAR data

jet area vs. fluctuations in jet response δpT





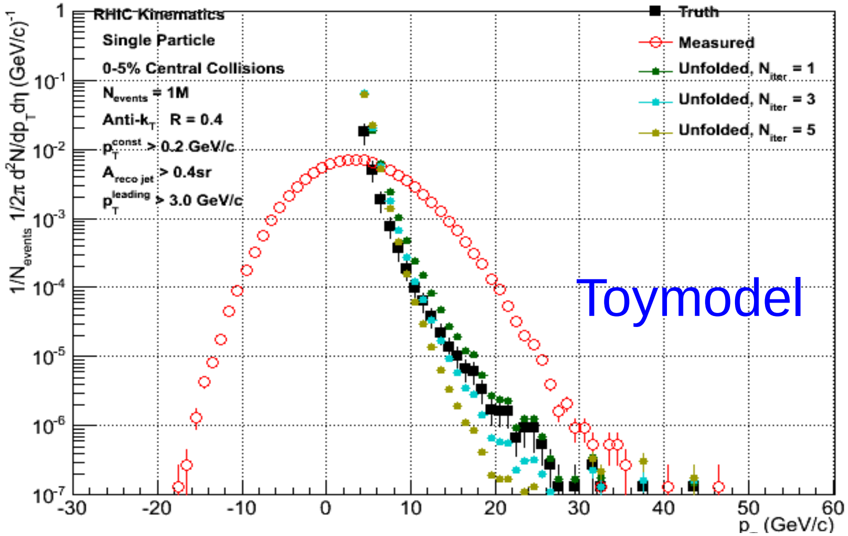


Carried out extensive comparison of the STAR data and Toymodel:

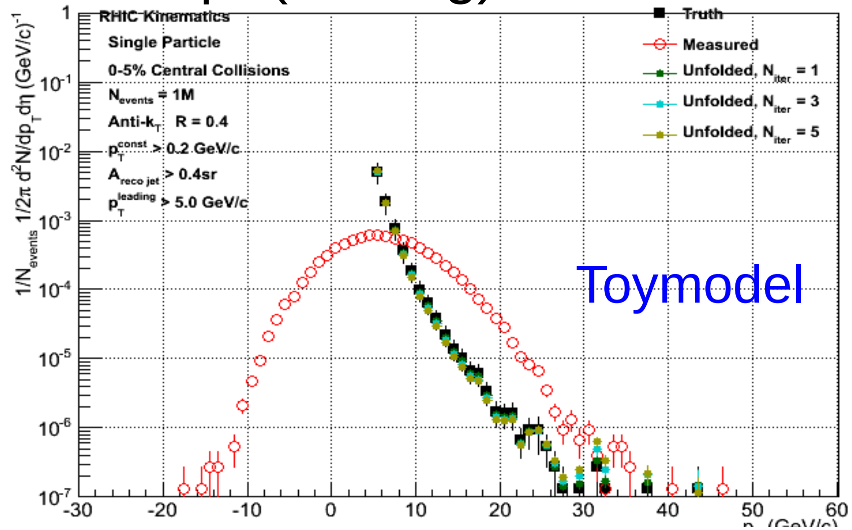
Toymodel gives qualitatively and even quantitatively similar results as data.

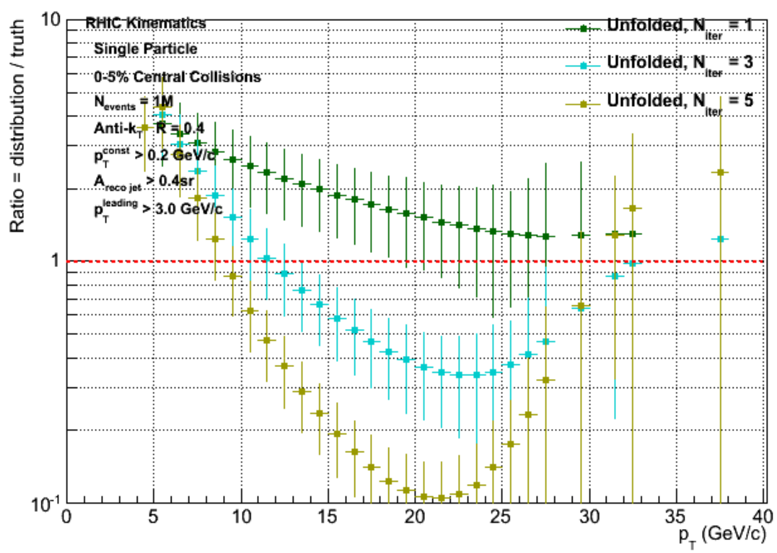
Testing unfolding on Toymodel

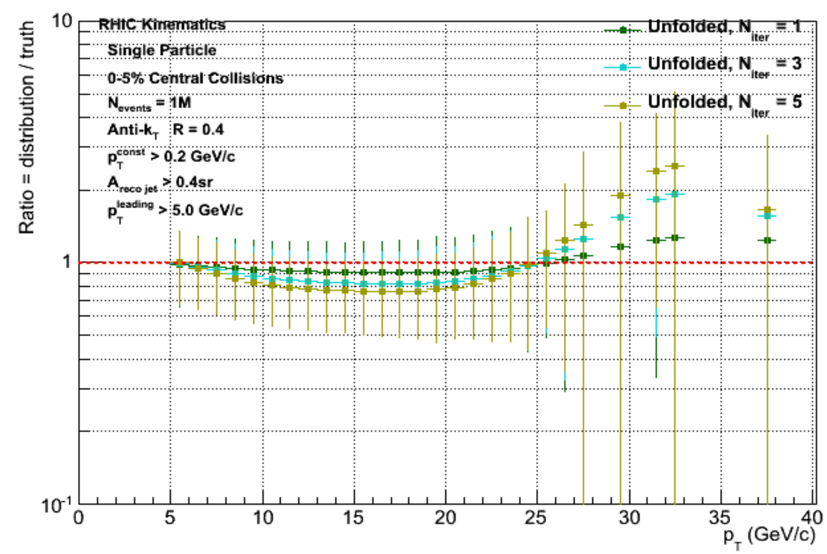
pT(leading)>3GeV/c



pT(leading)>5 GeV/c







With a sufficiently large pT(leading) cut the unfolding converges to correct answer.