MEASUREMENT OF PSEUDORAPIDITY DISTRIBUTIONS WITH THE STAR EPD AT BES-II ENERGIES
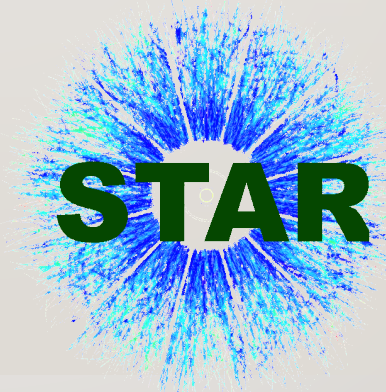
BALAZS KORODI for the STAR Collaboration

The Ohio State University
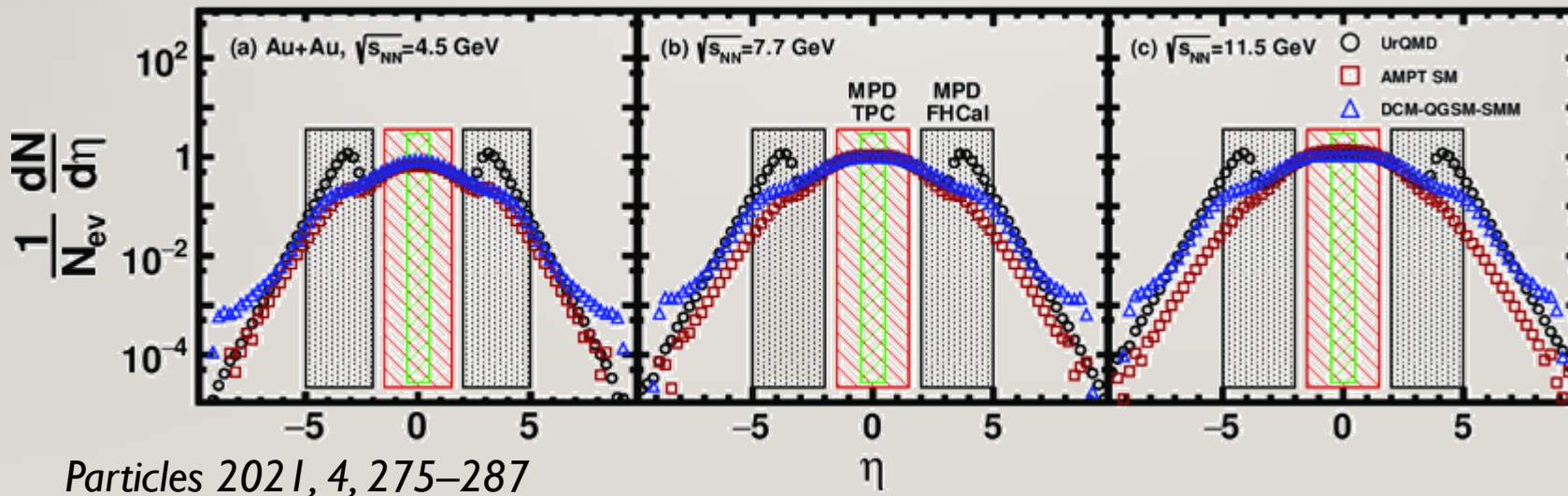
WPCF 2024 Toulouse

STAR

THE OHIO STATE UNIVERSITY

MOTIVATION

- $dN_{ch}/d\eta$ important for the tuning of models
  - Midrapidity: models give similar predictions to each other and to data
  - Forward rapidities: models disagree

- Few measurements at forward rapidities
  - None at all Beam Energy Scan II energies
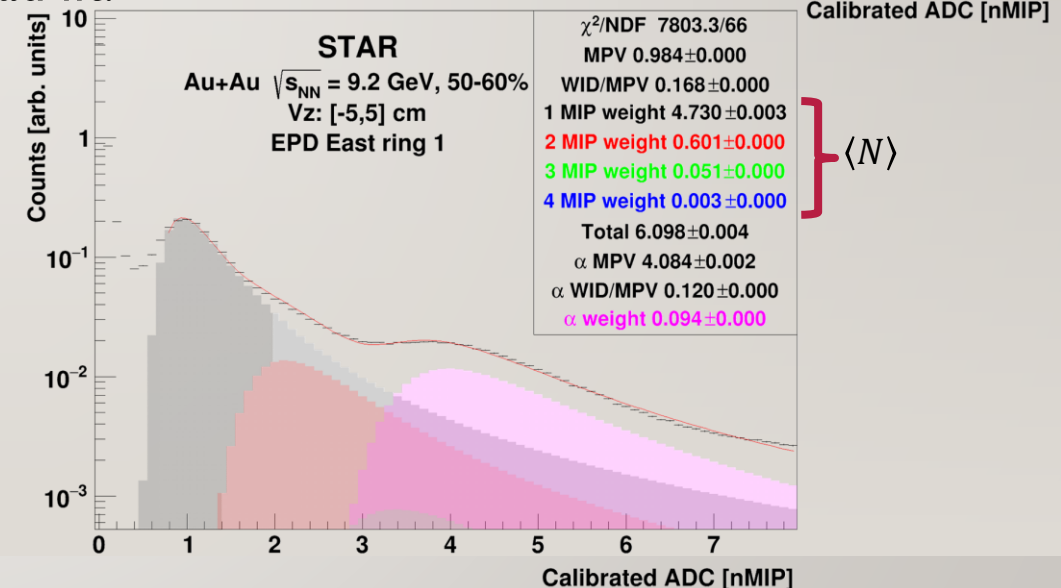

Particles 2021, 4, 275–287

THE STAR EVENT PLANE DETECTOR

- Part of the upgrade for BES-II

- Motivations:
  - Centrality determination
  - Event plane resolution
  - Triggering

- Characteristics:
  - Detects charged particles
  - Located at ±375 cm from the interaction point (East and West EPD)
  - Large pseudorapidity coverage: 2.14<|η|<5.09
  - High η and φ segmentation:
    - 16 radial segments (rings)
    - 24 azimuthal segments (sectors)

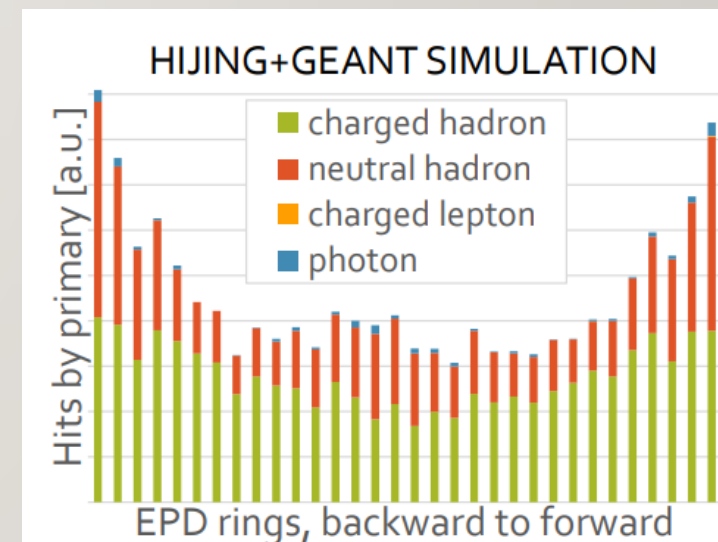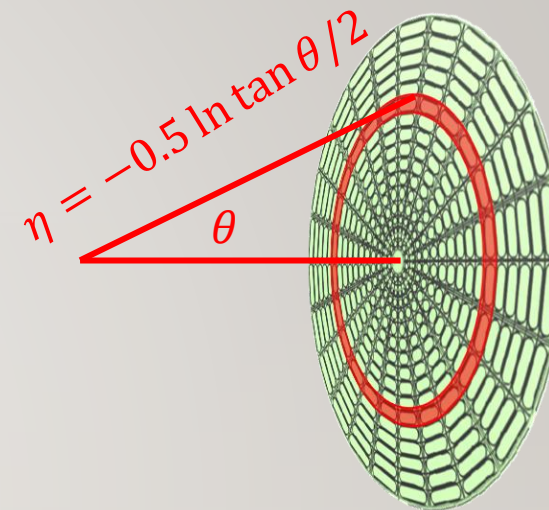- Can be used to measure $dN_{ch}/d\eta$ for 2.14<|η|<5.09
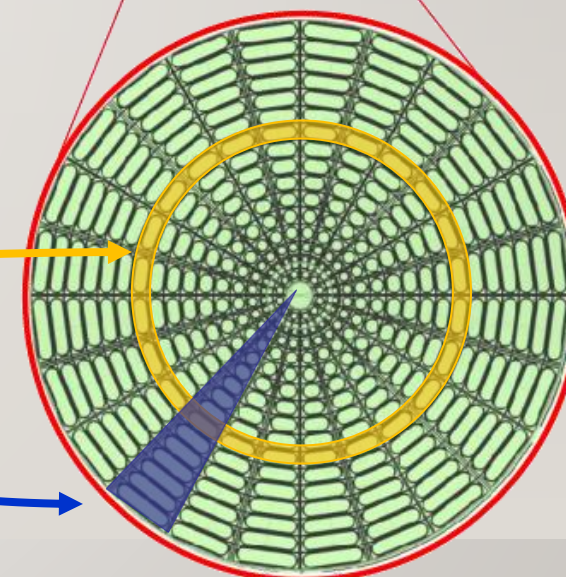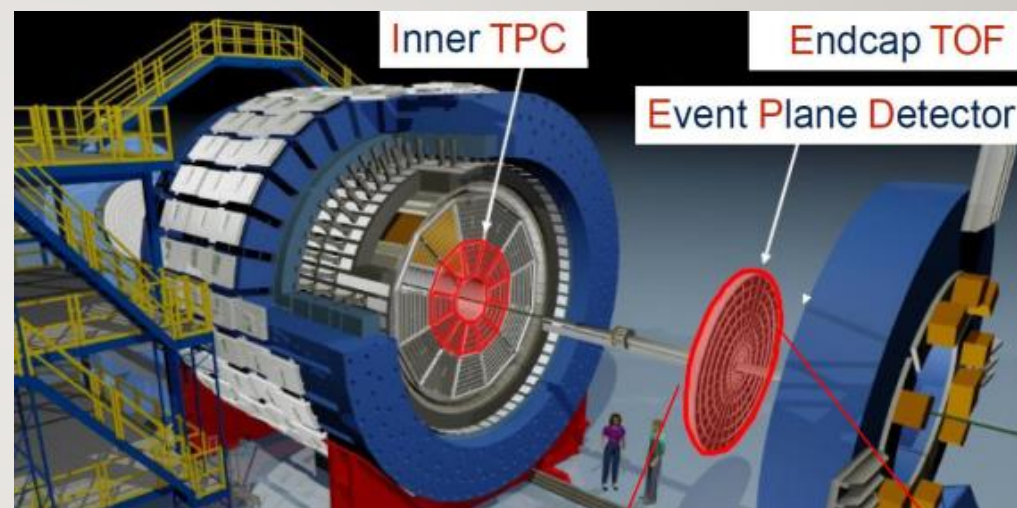
4 /13 LANDAU FITS – DETERMINING #MIPS IN EACH RING

- EPD measures energy deposited via ionization

- Mostly Minimum Ionizing Particles (MIPs)

- Deposited energy has Landau distribution for single MIP

- Multiple MIPs → convoluted Landau distributions

- Average #MIPs in each ring ($N(i_{Ring})$) from convoluted Landau fit:

  - $N(i_{Ring}) = \sum_n n \cdot nMIPweight$

- Inner rings:

  - α particles from projectile remnants need to be considered

  - Poisson distribution of nMIP weights enforced

- Use same fit method in all cases for consistency

STAR
Au+Au 27 GeV, 0-5%
Vz: [-5,5] cm
EPD East ring 6

χ²/NDF 34882.5/66
MPV 1.011±0.000
WID/MPV 0.153±0.000
1 MIP weight 9.880 ±0.003
2 MIP weight 4.481±0.003
3 MIP weight 0.875±0.003
4 MIP weight 0.113±0.002
Total 21.92±0.12

STAR
Au+Au $\sqrt{s_{NN}}$ = 9.2 GeV, 50-60%
Vz: [-5,5] cm
EPD East ring 1

χ²/NDF 7803.3/66
MPV 0.984±0.000
WID/MPV 0.168±0.000
1 MIP weight 4.730±0.003
2 MIP weight 0.601±0.000
3 MIP weight 0.051±0.000
4 MIP weight 0.003±0.000
Total 6.098±0.004
α MPV 4.084±0.002
α WID/MPV 0.120±0.000
α weight 0.094±0.000

$\langle N \rangle$

HOW (NOT) TO MEASURE $dN_{ch}/d\eta$ WITH THE EPD

- We could calculate $dN_{ch}/d\eta$ from raw EPD hit numbers, based on η corresponding to each ring

- This would not take into account scattering and decays:

  - Charged particles scatter in detector material, creating secondaries

    - Secondaries have large contribution to $dN_{ch}/d\eta$

  - Neutral particles contribute through decays (e.g., $\Lambda \to p + \pi$) and secondaries

    - Neutral particles also have a large contribution!

$\eta = -0.5 \ln \tan \theta/2$

θ

HIJING+GEANT SIMULATION

- charged hadron
- neutral hadron
- charged lepton
- photon

Hits by primary [a.u.]

EPD rings, backward to forward

6 /13 MEASURING $dN_{ch}/d\eta$ WITH THE EPD

- From Landau fits: number of hits in each ring: $N(i_{Ring})$

- Given the underlying $dN/d\eta$, $N(i_{Ring})$ can be calculated as

$$N(i_{Ring}) = \int R(\eta, i_{Ring}) \frac{dN}{d\eta} \, d\eta$$

- Here R is the response matrix: no. of hits in given ring originating from primary particle at η

- Calculate R via simulations, then determine $dN/d\eta$ via unfolding

  - Bayesian iterative unfolding, *G. D'Agostini, Nucl. Instr. Meth. A362 (1995) 487*

7 /13 UNFOLDING PROCEDURE

1. Create the response matrix

   - HIJING+GEANT simulation – at same energy as data

   - For each primary track create list of EPD hits originating from that primary

     - If no EPD hit for a primary: *ResponseMatrix->Miss(TrackEta)*

     - For each EPD hit of a primary: *ResponseMatrix->Fill(EPDRingNumber, TrackEta)*

   - Do not take particles created inside the EPD into account
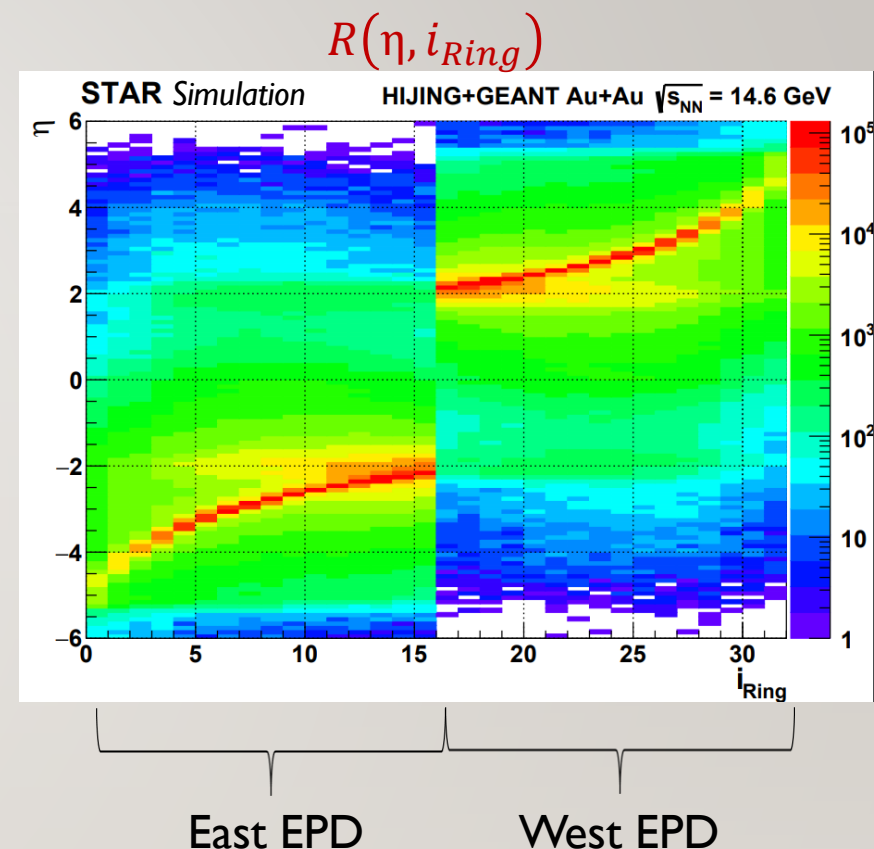
2. Perform Bayesian iterative unfolding

   - Implemented in RooUnfold

3. Apply multiple counting correction

   - Correct for multiple hits originating from the same primary

4. Apply charged fraction correction

   - Correct for hits originating from neutral primaries

   - 3 possible methods: correct then unfold, unfold then correct, RooUnfold "Fakes" method

$R(\eta, i_{Ring})$
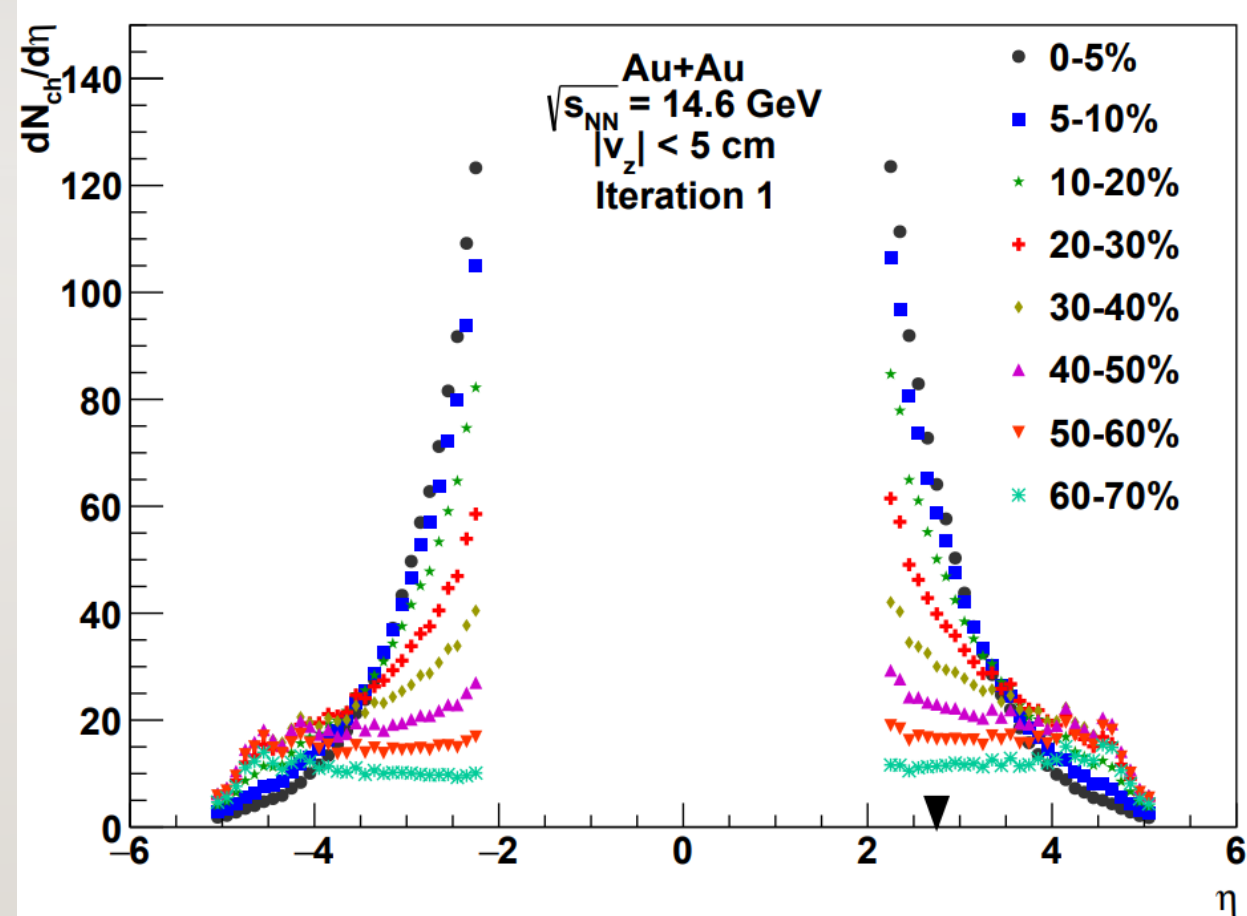

East EPD   West EPD

8/13 ITERATIVE APPROACH FOR INPUT $dN/d\eta$

- Unfolded $dN/d\eta$ depends on HIJING $dN/d\eta$

- Scale $dN/d\eta$ in simulation to unfolded $dN/d\eta$

- Unfold experimental data again

- Iterate until input = unfolded

- Issue:

  - Unfolding does not work at midrapidity (not in EPD range)

  - Influences results in EPD range especially through many iterations

  - Significant unwanted effect after the first iteration

  - Only do 1 iteration for now

  - Remaining dependence on HIJING $dN/d\eta \rightarrow$ systematics

Introduction   Analysis details   Results   Summary
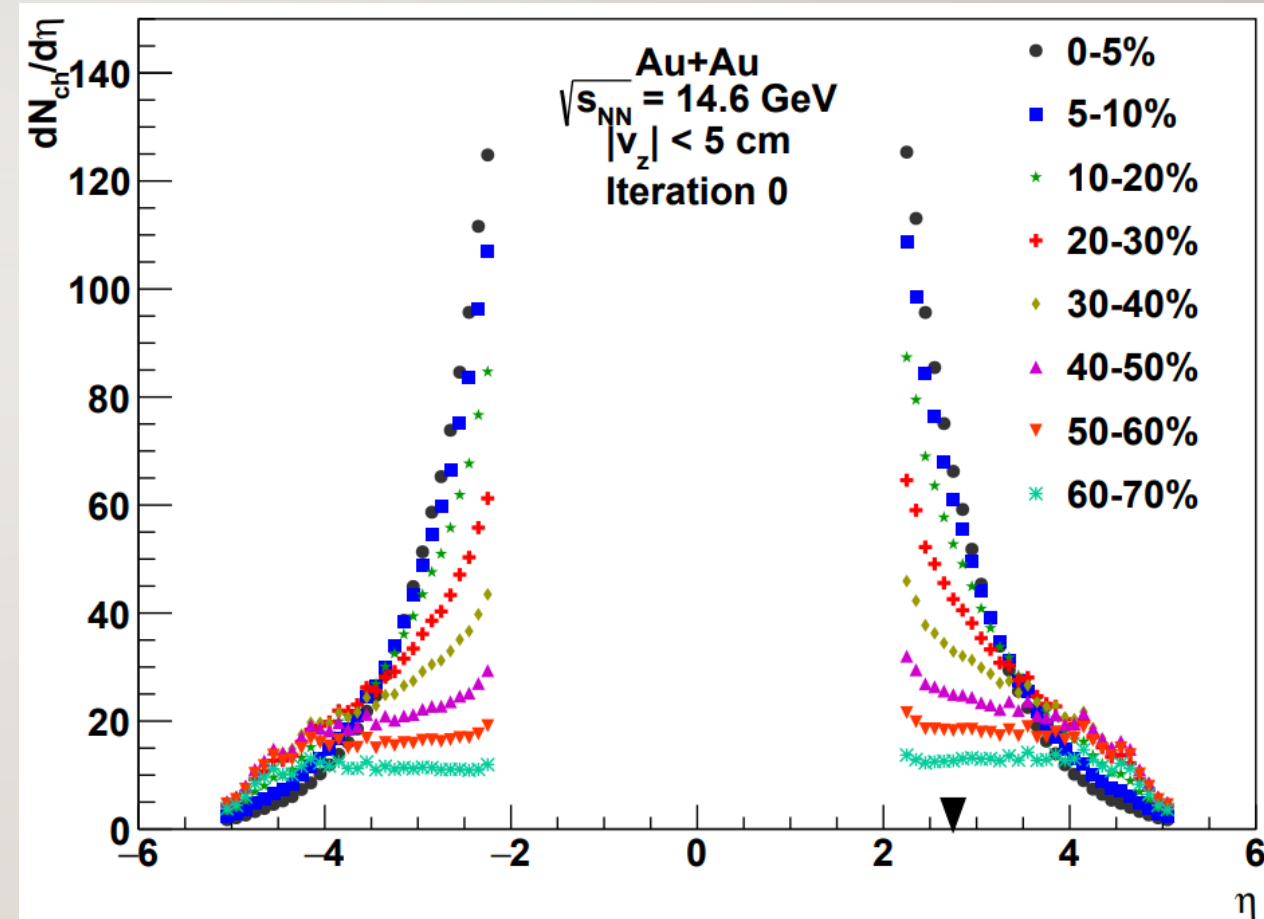
9/13 ITERATIVE APPROACH FOR INPUT $dN/d\eta$

- Unfolded $dN/d\eta$ depends on HIJING $dN/d\eta$

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- Unfold experimental data again

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- Issue:

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  - Only do 1 iteration for now

  - Remaining dependence on HIJING $dN/d\eta \rightarrow$ systematics

SYSTEMATIC UNCERTAINTIES

- Systematic checks in the unfolding:
  - Scale 27 GeV MC to 200 GeV and 7.7 GeV MC:
    - Charged/neutral ratio → 4%
    - Baryon/meson ratio → 4%
    - Input $dN/d\eta$ → 6%
    - Momentum distribution → 3%
  - Unfolding method (3 different methods for the charged fraction correction) → 7%
- Centrality selection ($\pm 5\%$ change) → 3%
- z-vertex resolution (± 5 cm shift) → 1%
- z-vertex choice (± 40 cm from geometric center) → 6%
- Landau fit (fit without α peak, fit without enforcing Poisson weights) → 5%

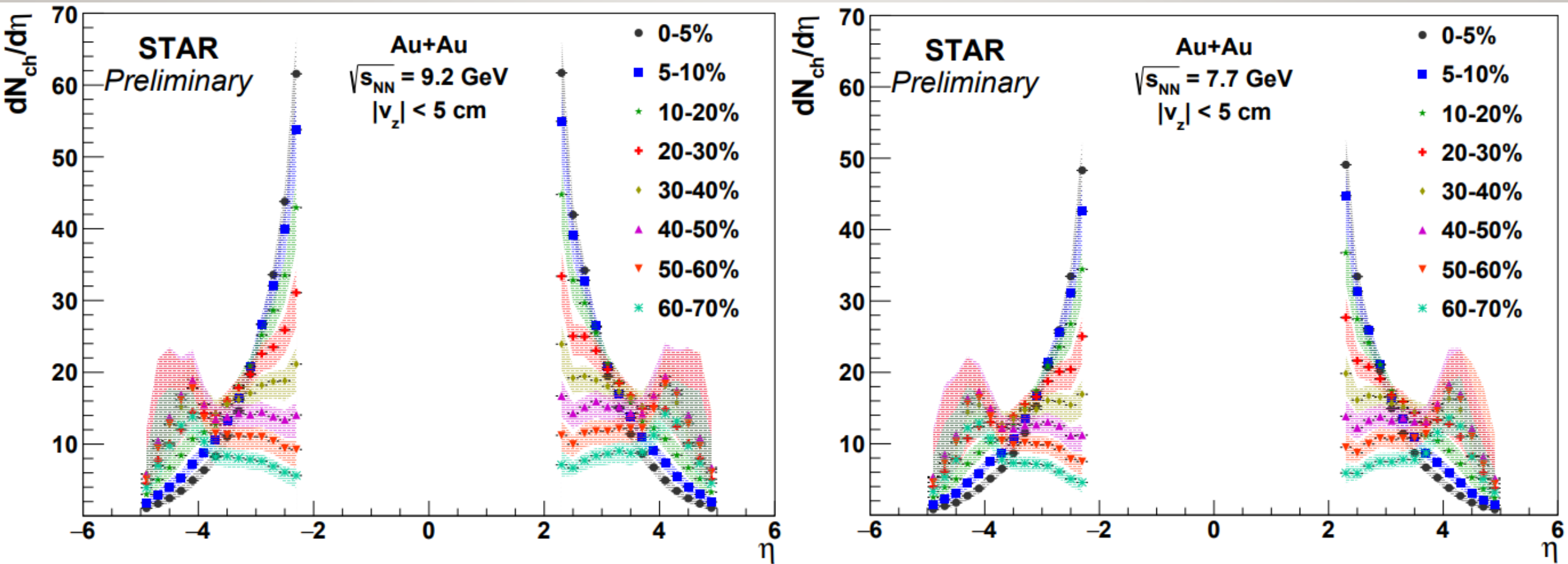Calculated using 27 GeV data

Used for all energies

RESULTS AT 14.6 AND 11.5 GEV
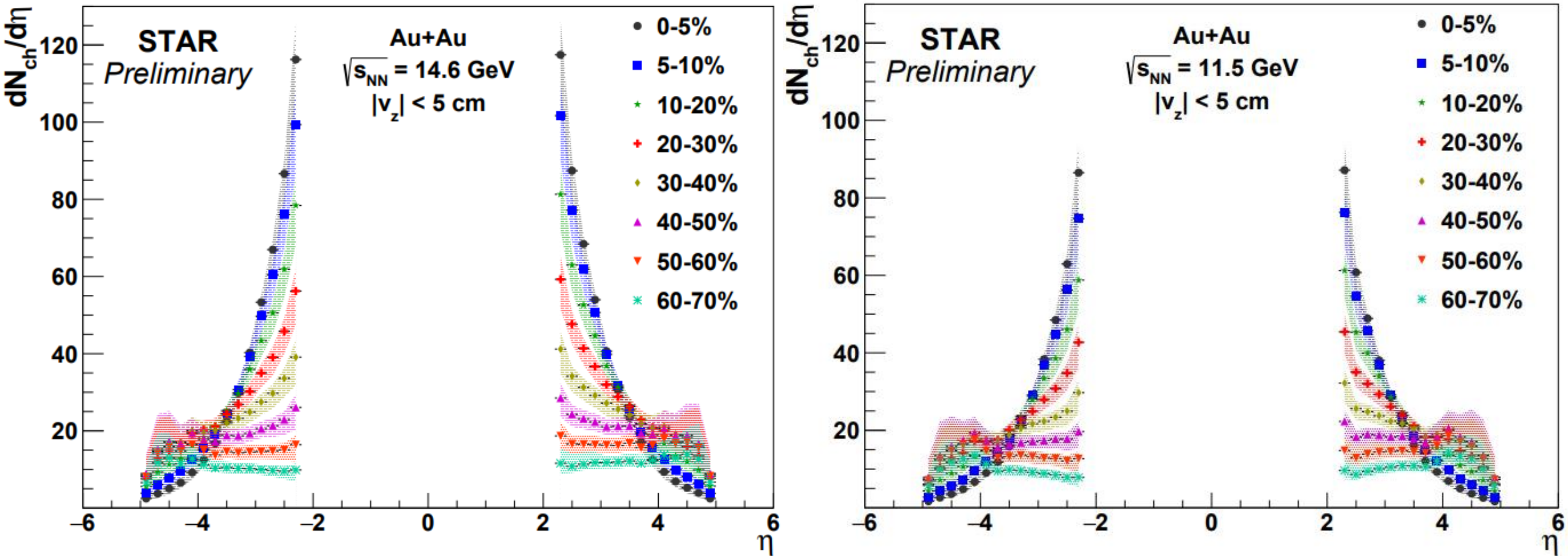

Bump appears at large η → caused by spectators

RESULTS AT 9.2 AND 7.7 GEV

Bump becomes relatively larger at smaller energies

SUMMARY

- Measurement of $dN_{ch}/d\eta$ with the EPD

  - Beam Energy Scan II energies

  - Roughly expected η, centrality and $\sqrt{s_{NN}}$ dependence

  - Spectator contribution apparent

- Final steps for publication:

  - 27 and 19.6 GeV data being analyzed

  - Try simulation with spectators, e.g., UrQMD

  - Refine iterative procedure

  - Calculate systematics separately for each energy
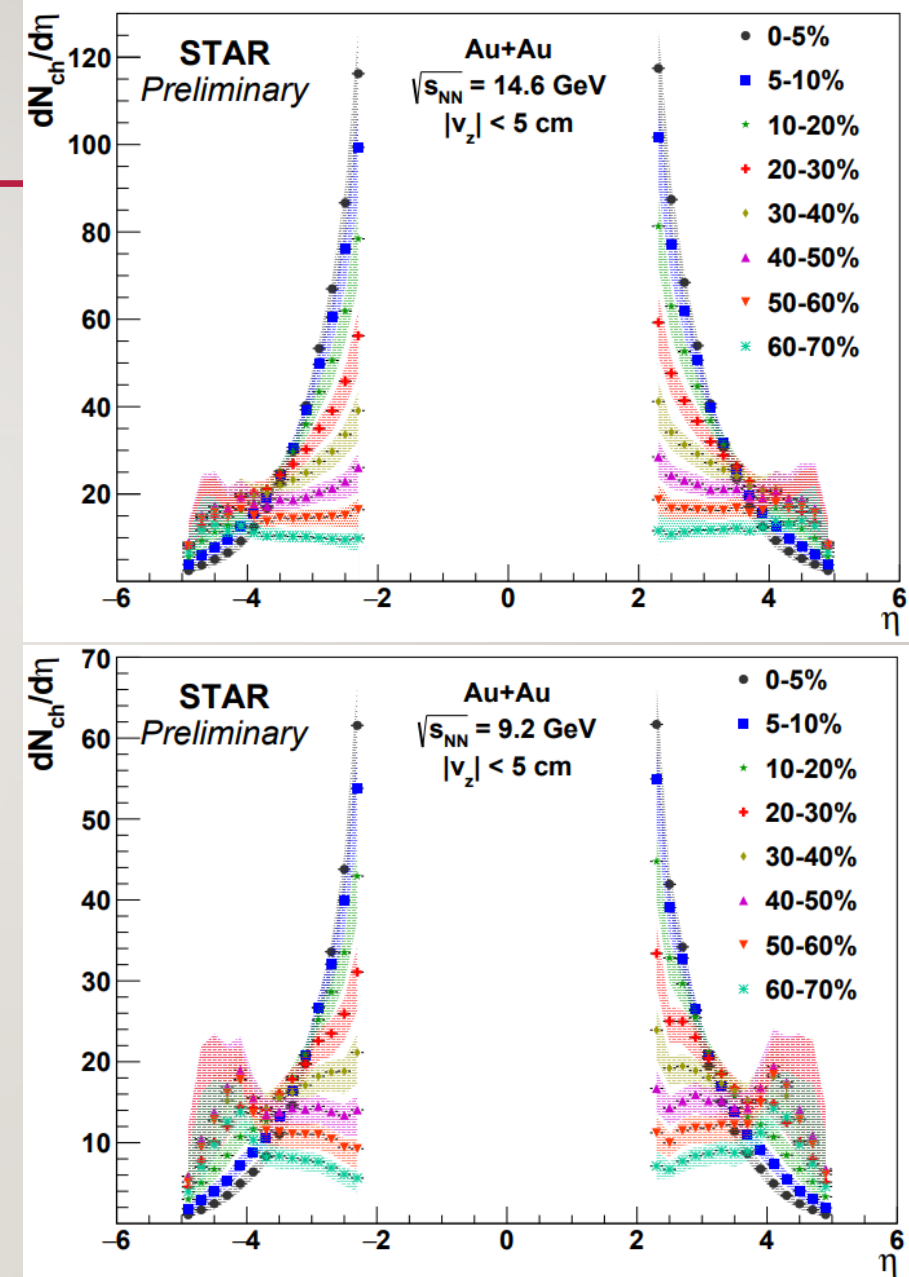
THANK YOU FOR YOUR ATTENTION!

BACKUP SLIDES

16 DATA SETS

- All BES-II energies: Au+Au@ 27, 19.6, 14.6, 11.5, 9.2, 7.7 GeV

- MinimumBias, 8 centrality classes: 0-70%

- |zvtx| < 5 cm

- Only data from EPD

- All available data used
 - Negligible statistical uncertainties

17 MULTIPLE COUNTING CORRECTION

- Need to correct for multiple counting (multiple hits from one primary track)

- Check "inverse efficiency": how many hits on average from primary particles at given η

- Largest at around $|\eta| \approx 5$

- Edge of EPD, support structures

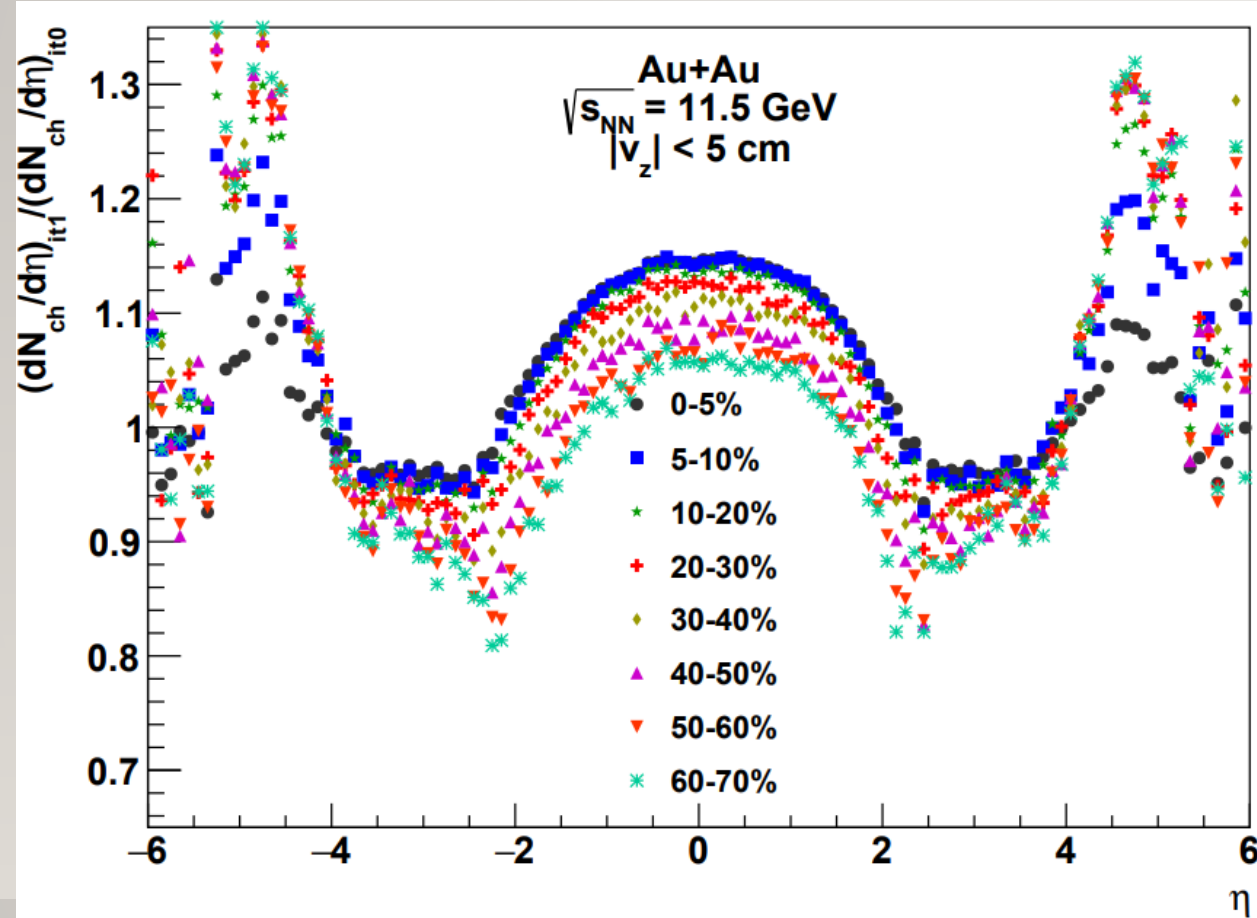**Multiple counting correction**   HIJING+GEANT@27 GeV
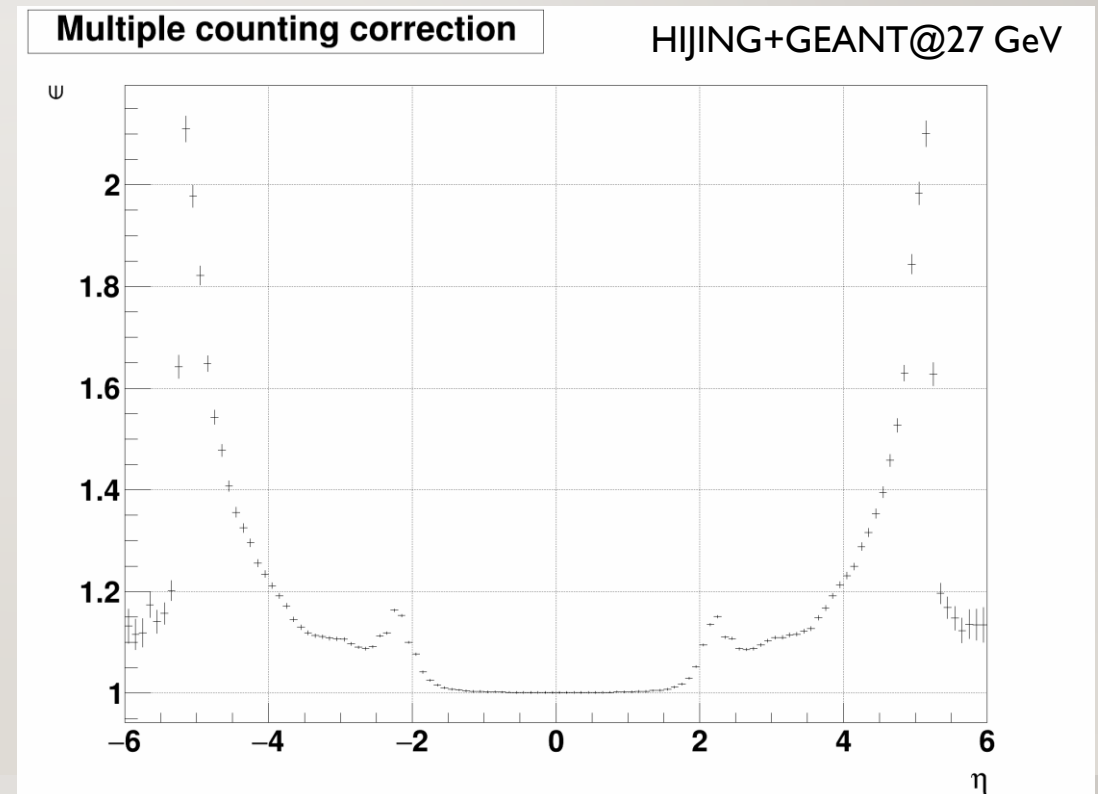
18 CHARGED FRACTION CORRECTION

- From simulations: charged particle fraction
  - For primary tracks and for EPD hits (based on primary cause)

- Applied 3 different methods:
  1. Unfolding $dN/d\eta$; correcting via $N_{ch}(\eta)/N_{tot}(\eta)$
  2. Correcting via $N_{ch}(i_{ring})/N_{tot}(i_{ring})$, unfolding "corrected" EPD distribution
  3. Use RooUnfold's "Fakes" (neutrals ⇔ "fake" hits)

- Closure test works for all: MC input recovered when unfolding simulated EPD data

- Difference of methods: incorporated in systematics

Charged fraction of primaries — HIJING@27 GeV

Charged fraction of EPD hits — HIJING+GEANT@27 GeV
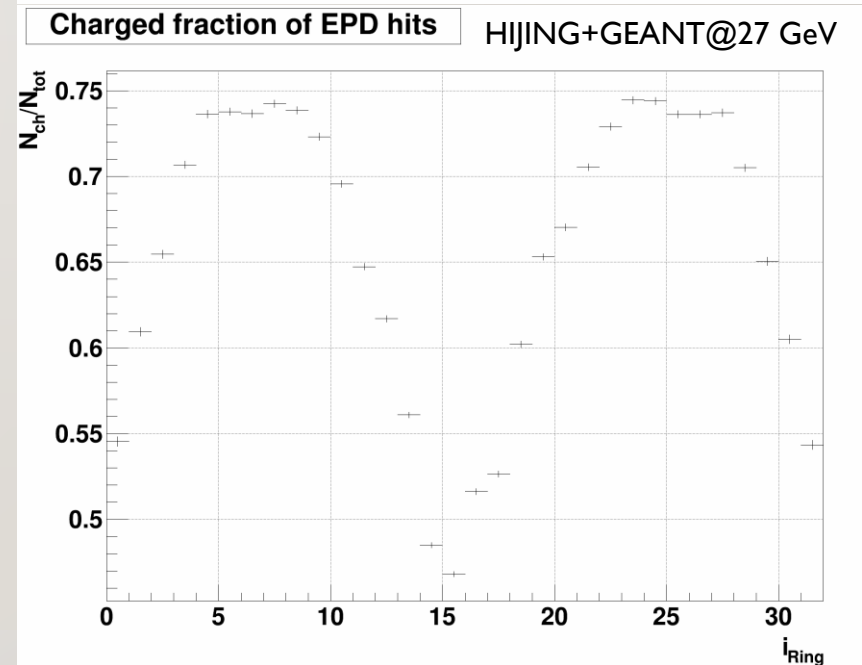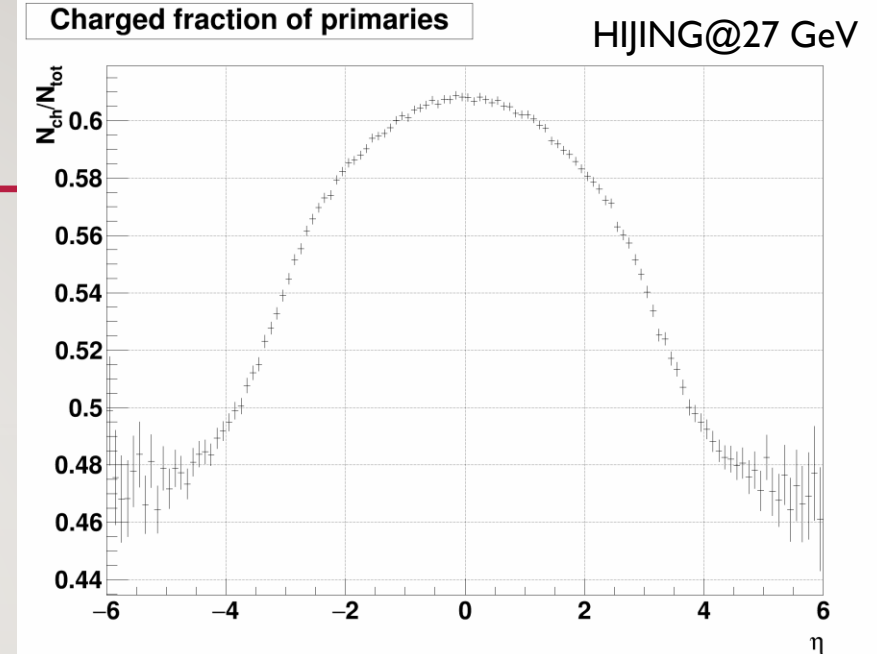
19 CHANGE BETWEEN ITERATIONS

Iteration1/iteration0

Iteration2/iteration1