

MEASUREMENT OF PSEUDORAPIDITY DISTRIBUTIONS WITH THE STAR EPD AT BES-II ENERGIES

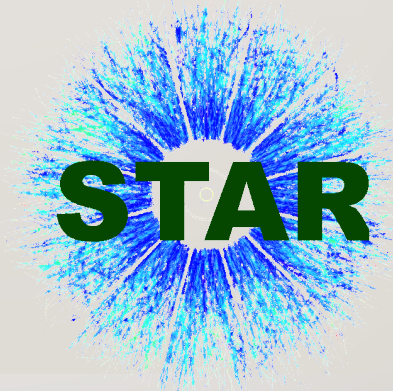
BALAZS KORODI for the STAR Collaboration

The Ohio State University

WPCF 2024 Toulouse



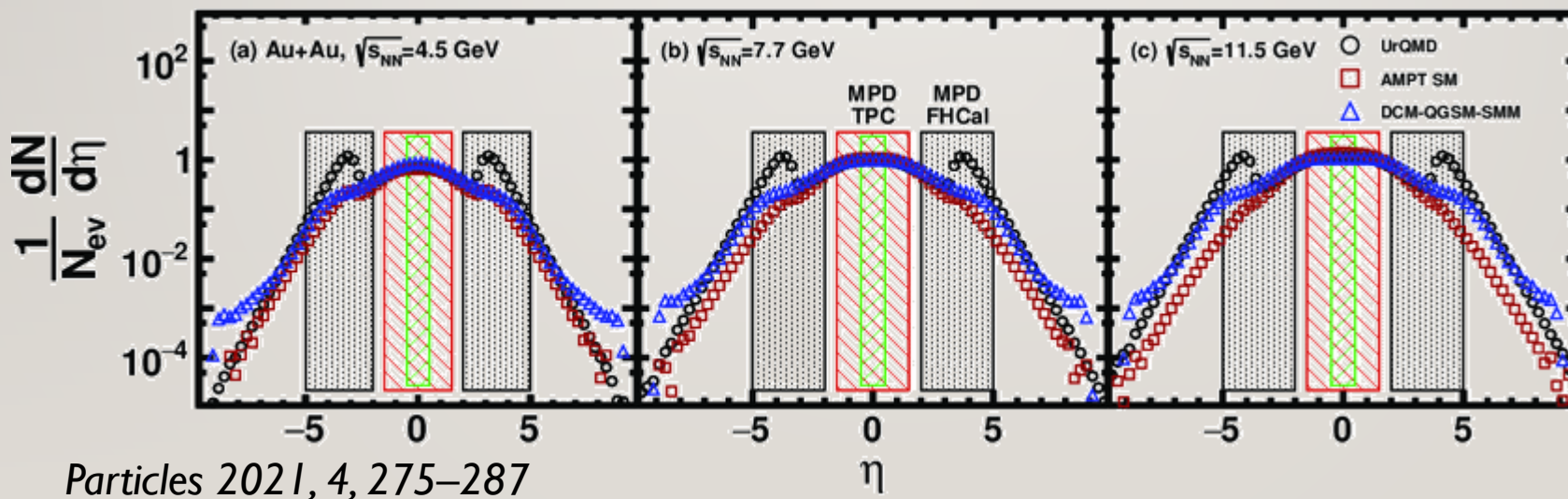
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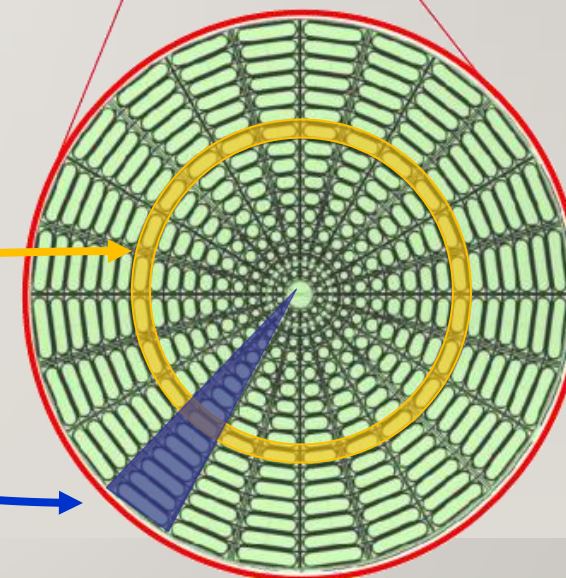
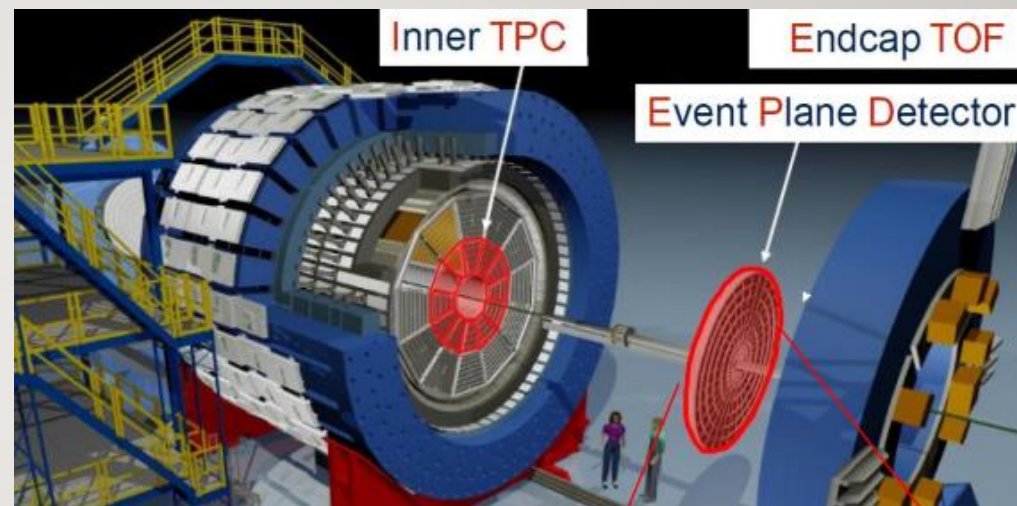
MOTIVATION

- $dN_{ch}/d\eta$ 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



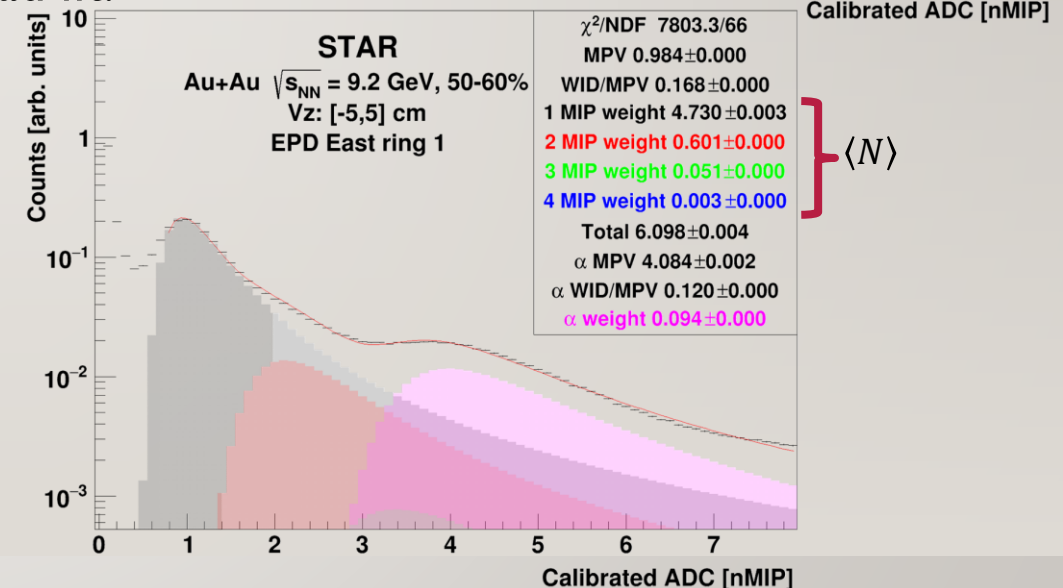
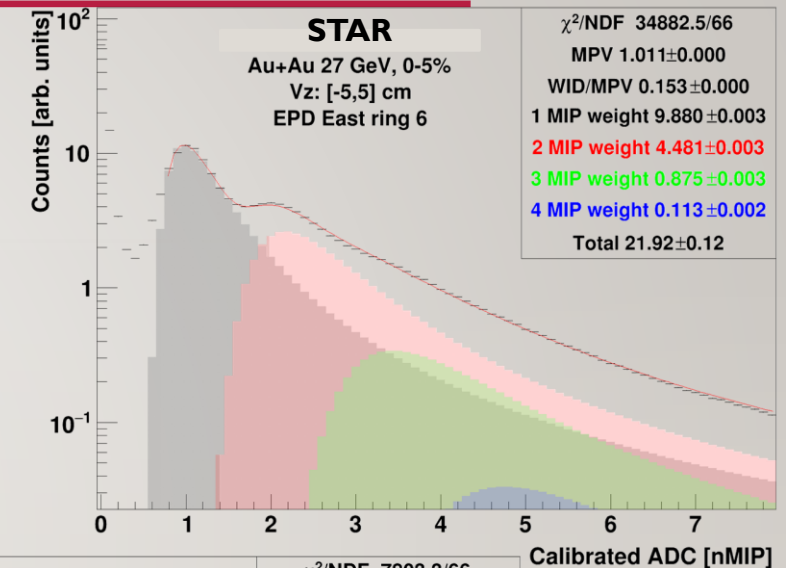
THE STAR EVENT PLANE DETECTOR

- 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: $2.14 < |\eta| < 5.09$
 - High η and ϕ segmentation:
 - 16 radial segments (**rings**)
 - 24 azimuthal segments (**sectors**)
- Can be used to measure $dN_{ch}/d\eta$ for $2.14 < |\eta| < 5.09$



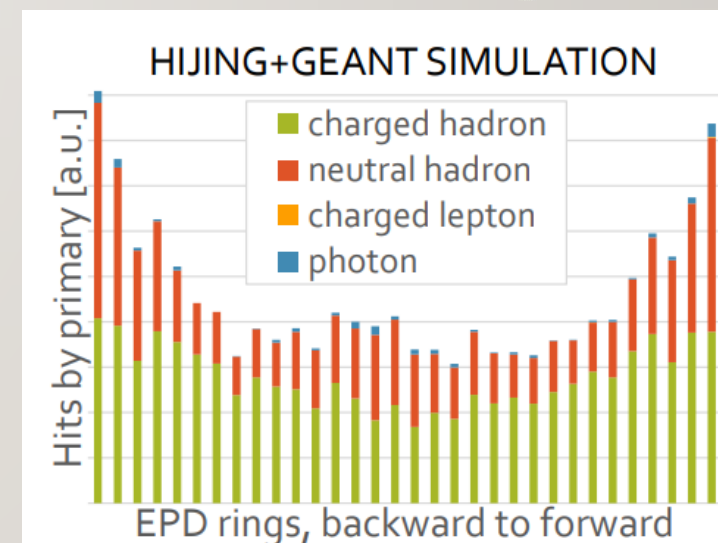
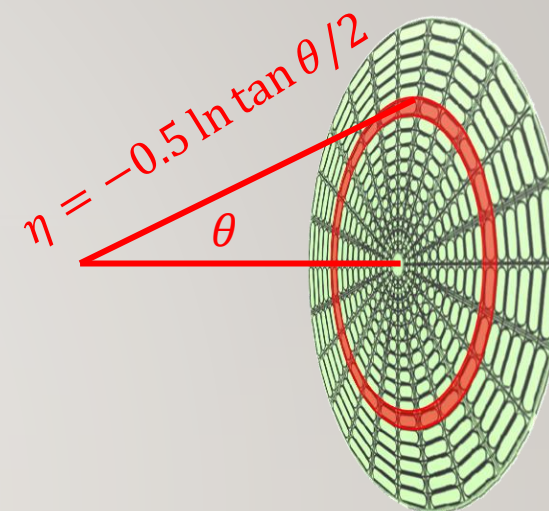
4 / 13 LANDAU FITS – DETERMINING #MIPS IN EACH RING

- 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



5 / 13 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., $\Lambda \rightarrow p + \pi$) and secondaries
 - Neutral particles also have a large contribution!



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: $ResponseMatrix \rightarrow Miss(TrackEta)$
 - For each EPD hit of a primary: $ResponseMatrix \rightarrow Fill(EPDRingNumber, TrackEta)$
- Do not take particles created inside the EPD into account

2. Perform Bayesian iterative unfolding

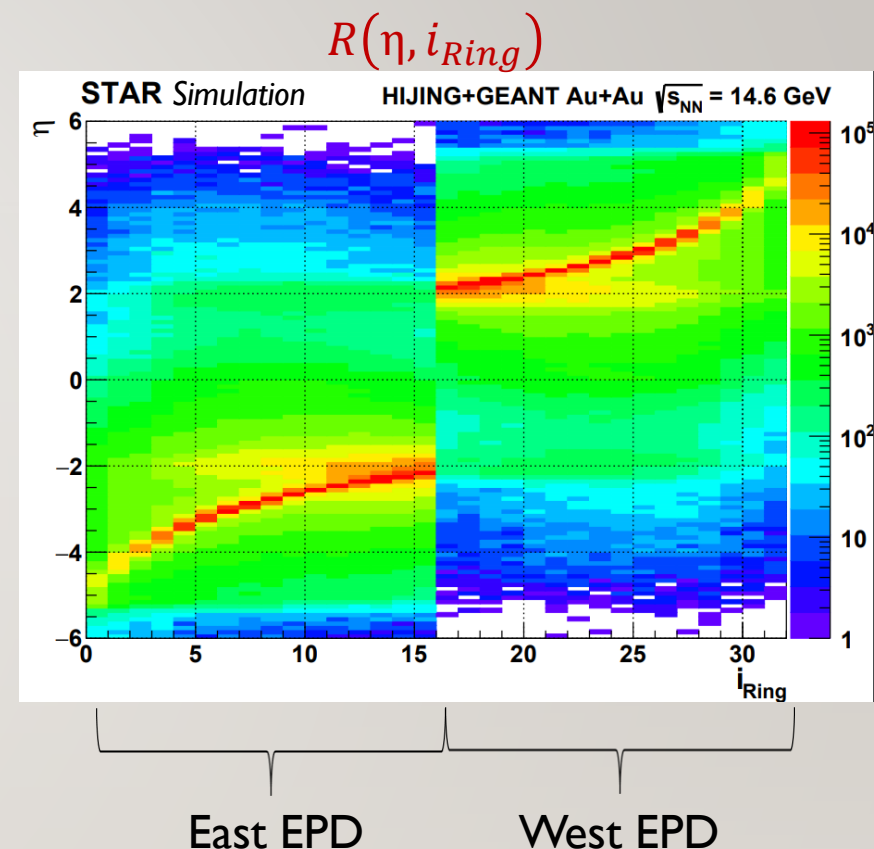
- Implemented in RooUnfold

3. Apply multiple counting correction

- Correct for multiple hits originating from the same primary

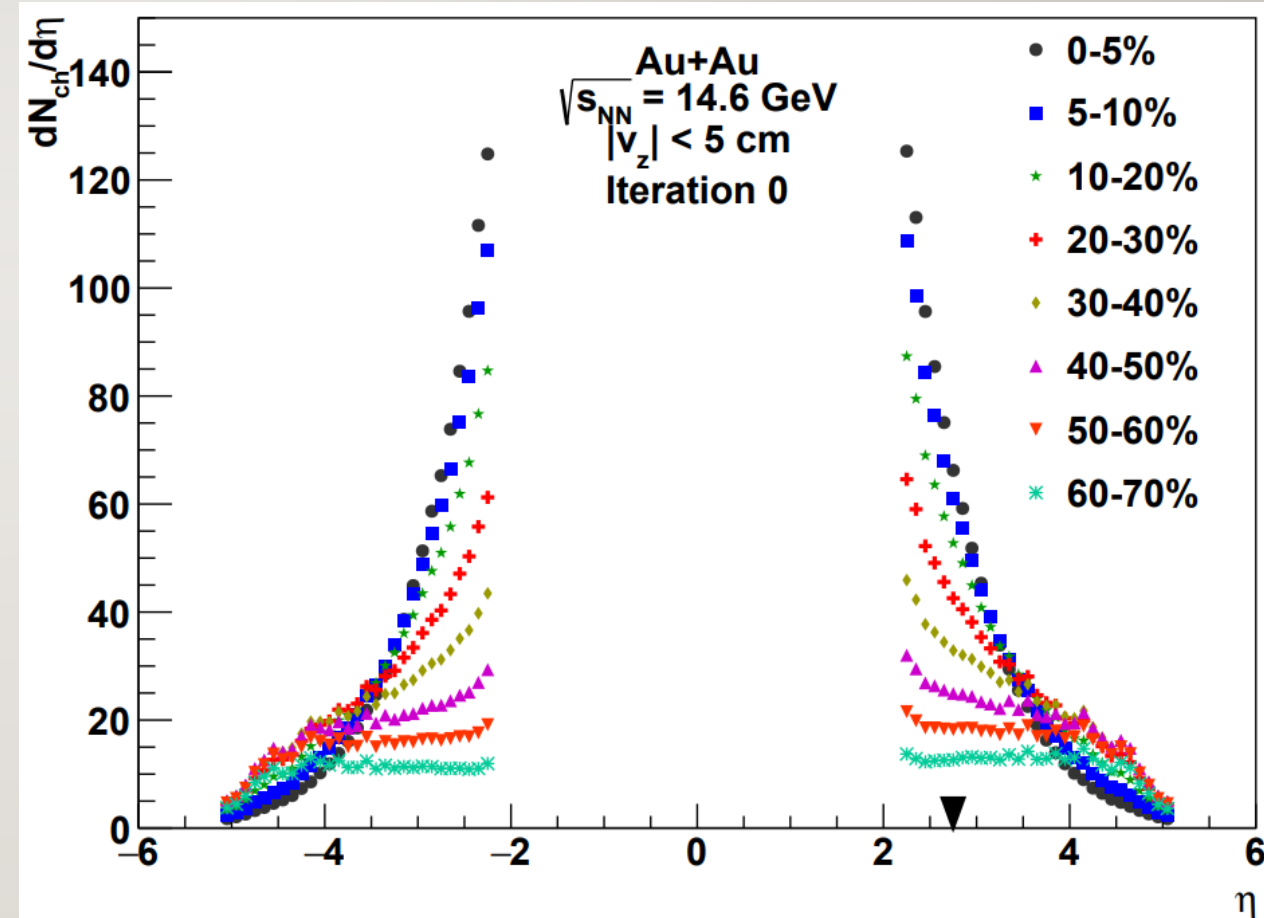
4. Apply charged fraction correction

- Correct for hits originating from neutral primaries
- 3 possible methods: correct then unfold, unfold then correct, RooUnfold “Fakes” method



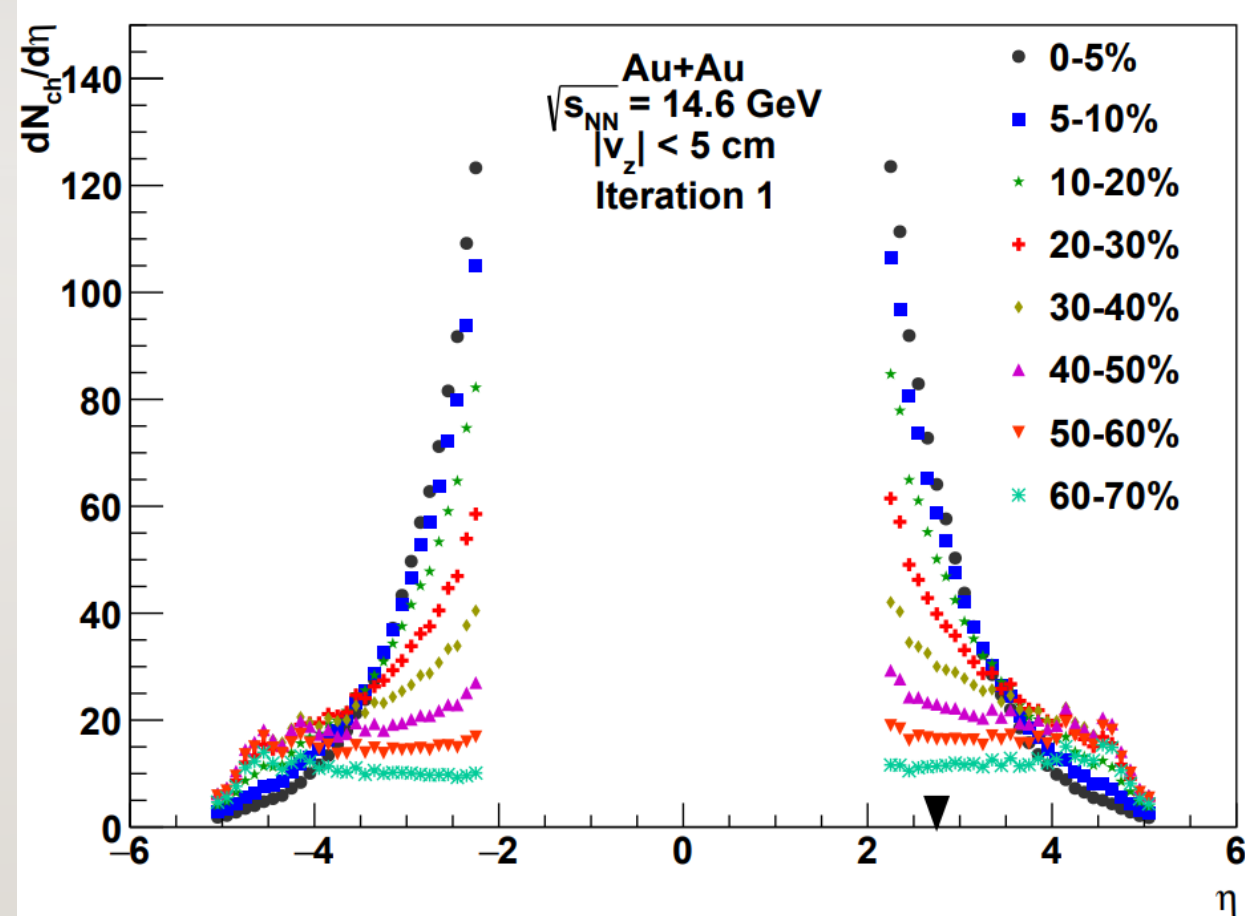
8/13 ITERATIVE APPROACH FOR INPUT $dN/d\eta$

- 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



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10/13 SYSTEMATIC UNCERTAINTIES

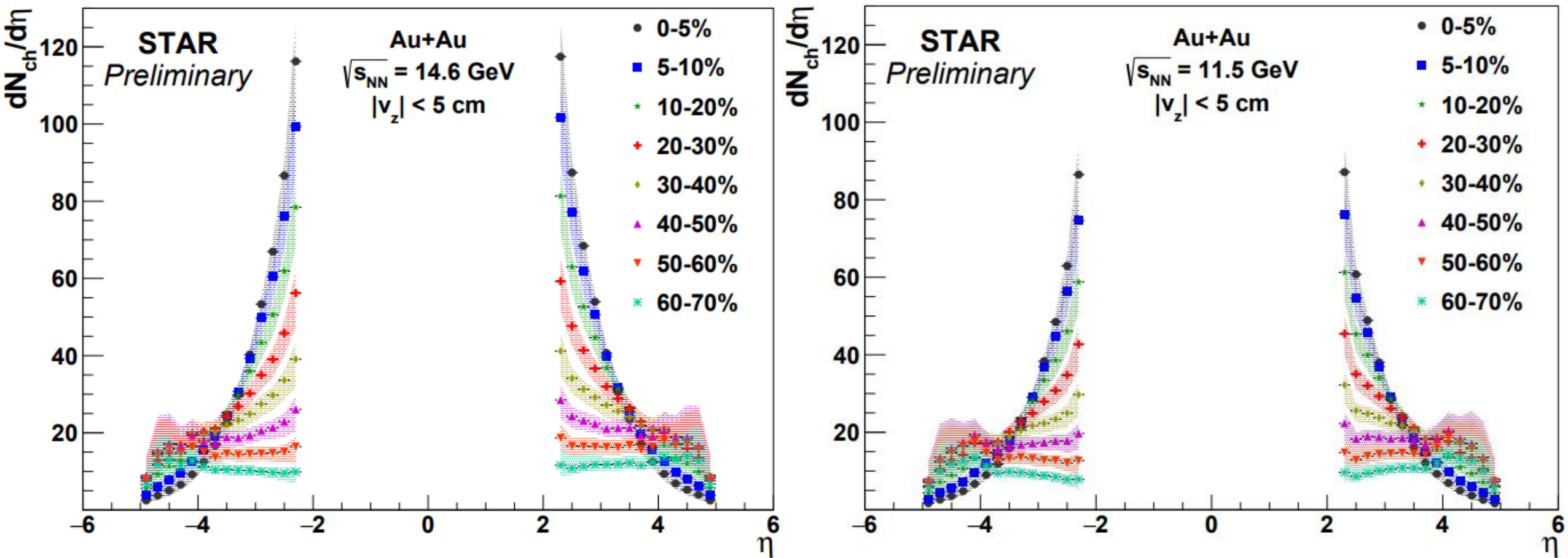
- Systematic checks in the unfolding:
 - Scale 27 GeV MC to 200 GeV and 7 GeV MC:
 - Charged/neutral ratio \rightarrow 4%
 - Baryon/meson ratio \rightarrow 4%
 - Input $dN/d\eta$ \rightarrow 6%
 - Momentum distribution \rightarrow 3%
 - Unfolding method (3 different methods for the charged fraction correction)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

Calculated using
27 GeV data



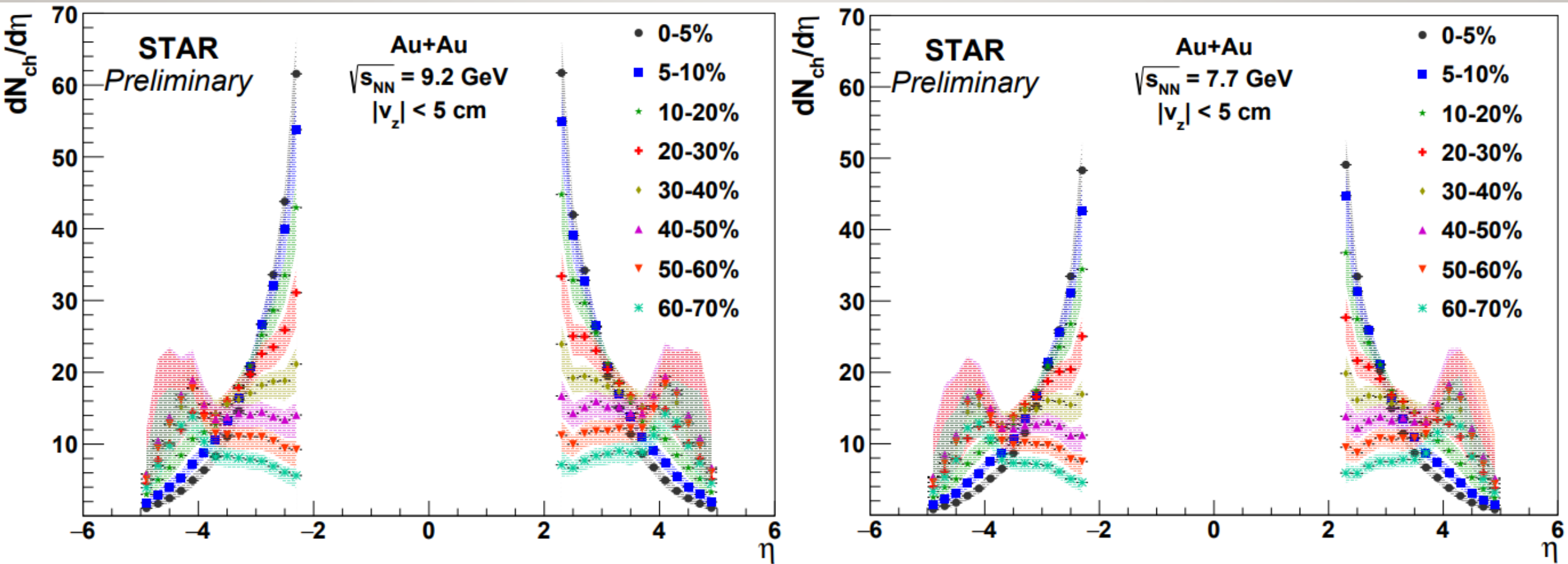
Used for all energies

RESULTS AT 14.6 AND 11.5 GEV



Bump appears at large η \rightarrow caused by spectators

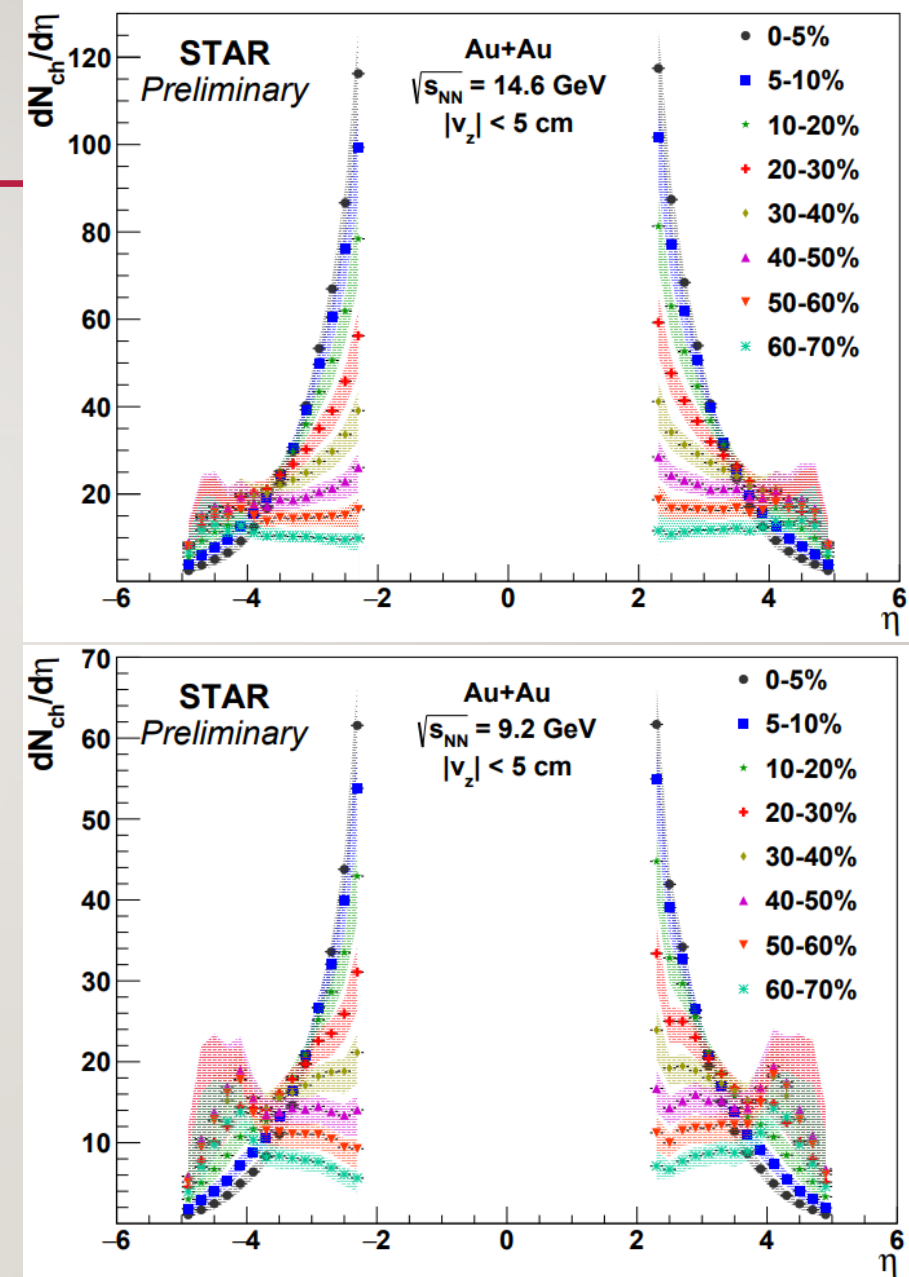
12 / 13 RESULTS AT 9.2 AND 7.7 GEV



Bump becomes relatively larger at smaller energies

13 / 13 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

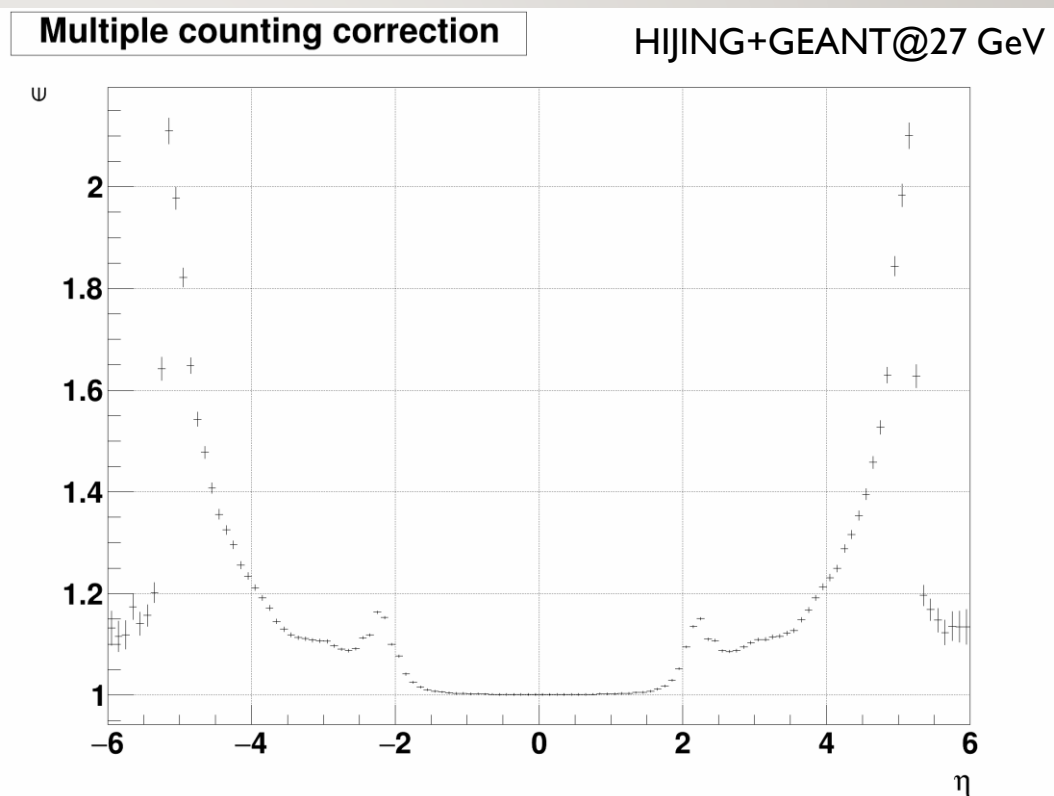


16 DATA SETS

- All BES-II energies: Au+Au@ 27, 19.6, 14.6, 11.5, 9.2, 7.7 GeV
- MinimumBias, 8 centrality classes: 0-70%
- $|z_{\text{vtx}}| < 5$ cm
- Only data from EPD
- All available data used
 - Negligible statistical uncertainties

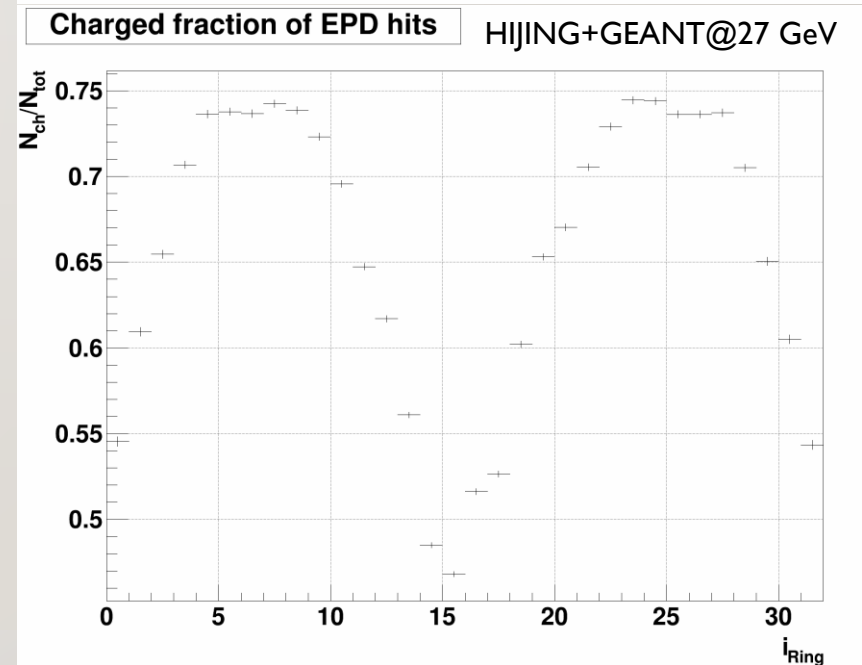
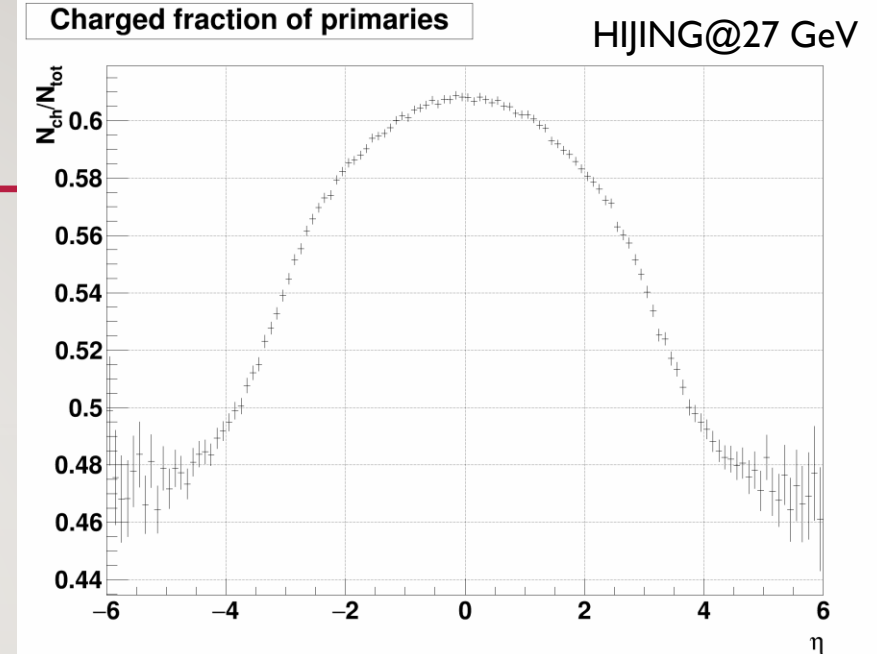
17 MULTIPLE COUNTING CORRECTION

- 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



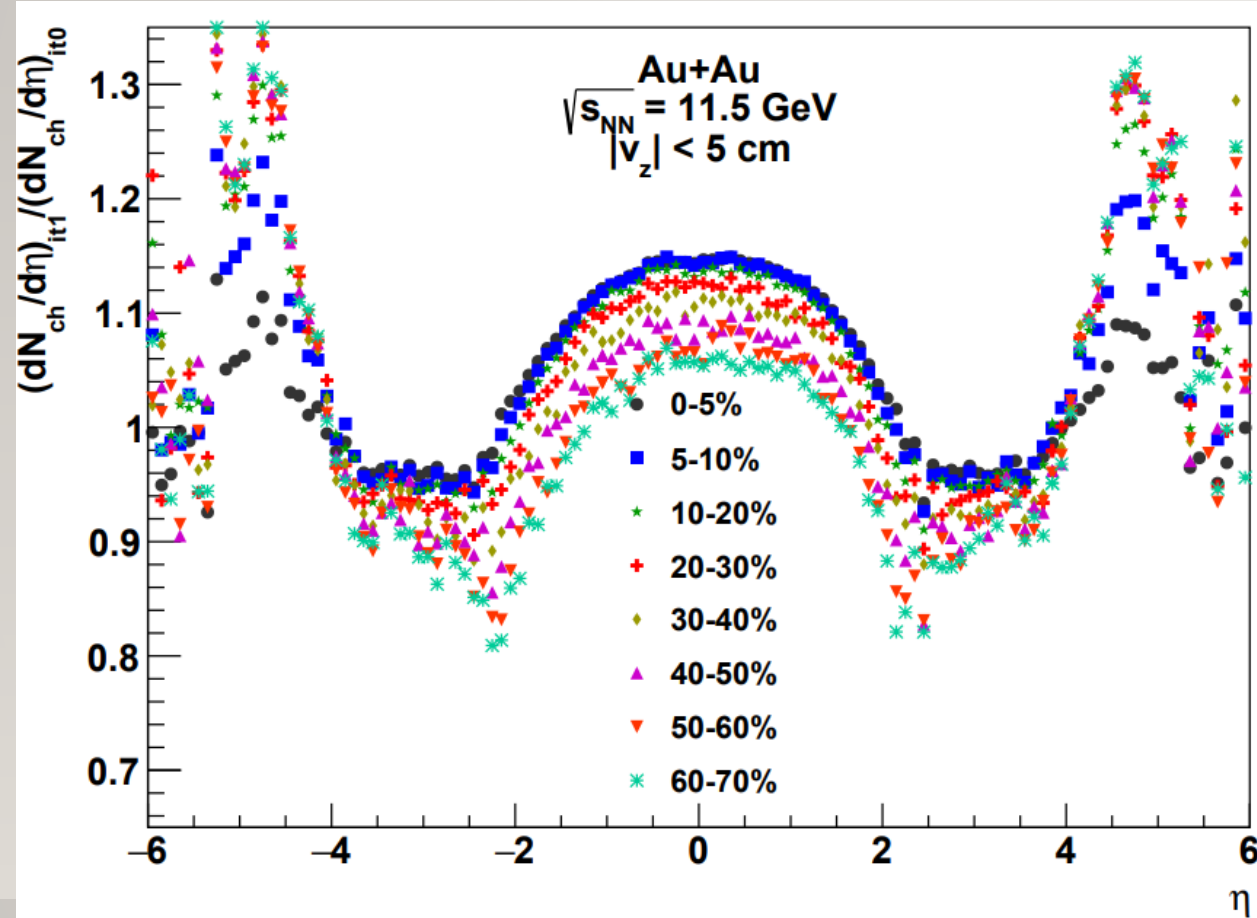
18 CHARGED FRACTION CORRECTION

- 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 \Leftrightarrow "fake" hits)
- Closure test works for all: MC input recovered when unfolding simulated EPD data
- Difference of methods: incorporated in systematics



19 CHANGE BETWEEN ITERATIONS

Iteration 1/iteration 0



Iteration 2/iteration 1

