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

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The Ohio State University

WPCF 2024 Toulouse

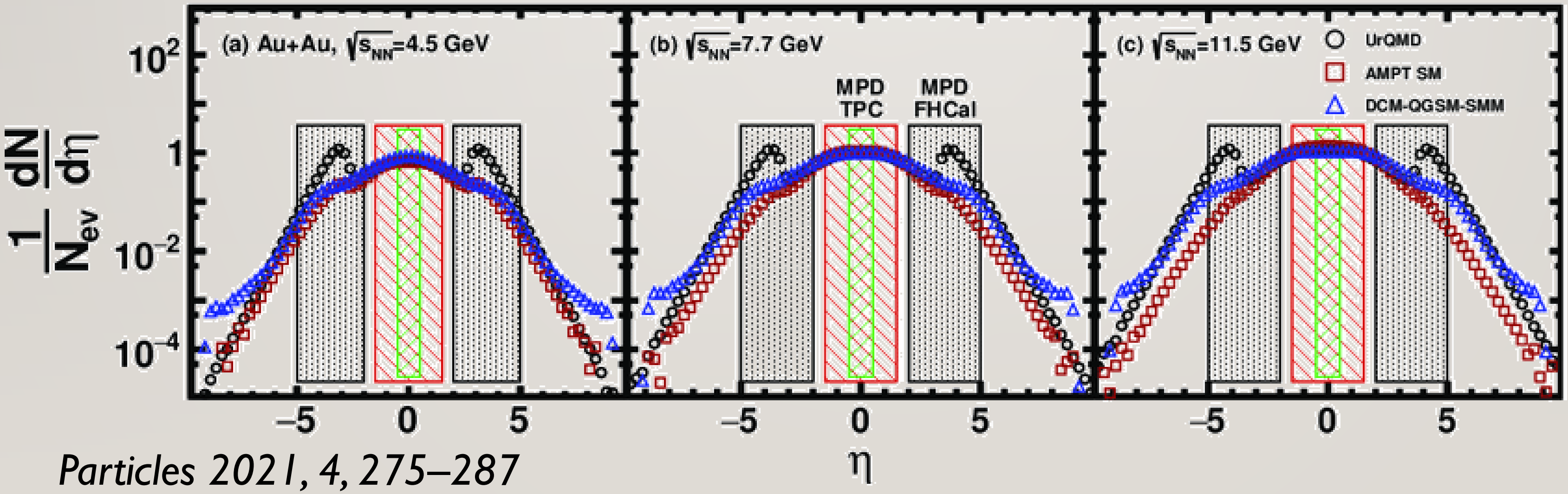
Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

STAR

THE OHIO STATE UNIVERSITY

MOTIVATION

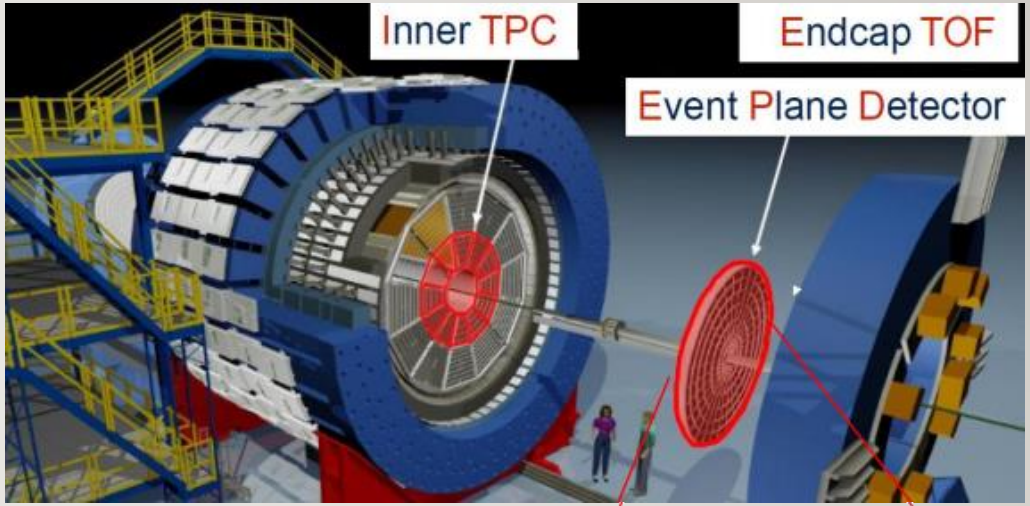
- $dN_{ch}/d\eta$ important for the tuning of models
  - Midrapidity: models agree with each other and with data
  - Forward rapidities: models disagree
- Few measurements at forward rapidities
  - Non at all BES-II energies

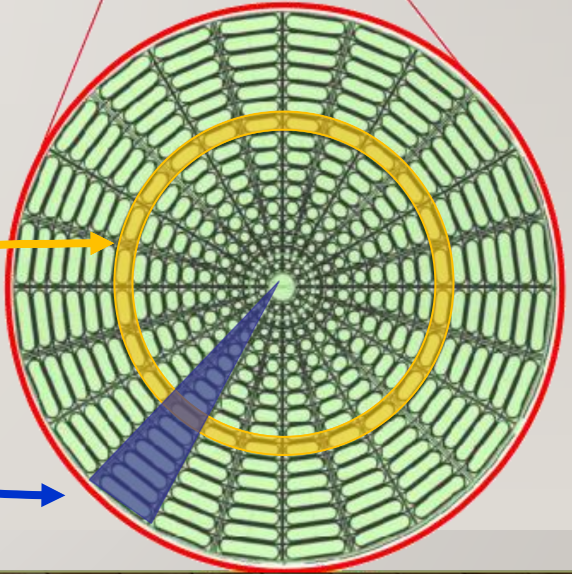


Particles 2021, 4, 275–287

THE STAR EVENT PLANE DETECTOR

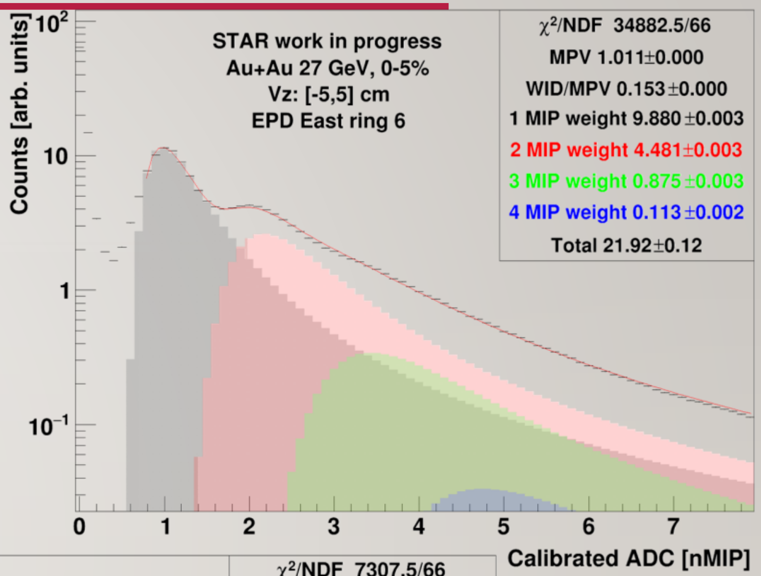
- Part of the upgrade for BES-II
- Motivations:
  - Centrality determination
  - Event plane resolution
  - Triggering
- Characteristics:
  - Detects charged particles
  - Located at ±375 cm from the interaction point (East and West EPD)
  - Large pseudorapidity coverage: 2.14<|η|<5.09
  - High η and 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

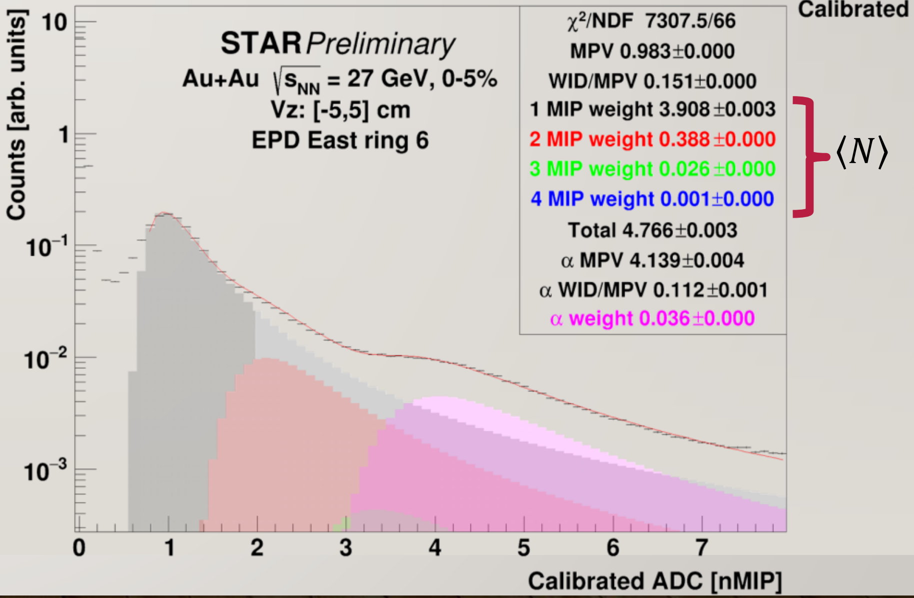




4 /15 LANDAU FITS – DETERMINING #MIPS IN EACH RING

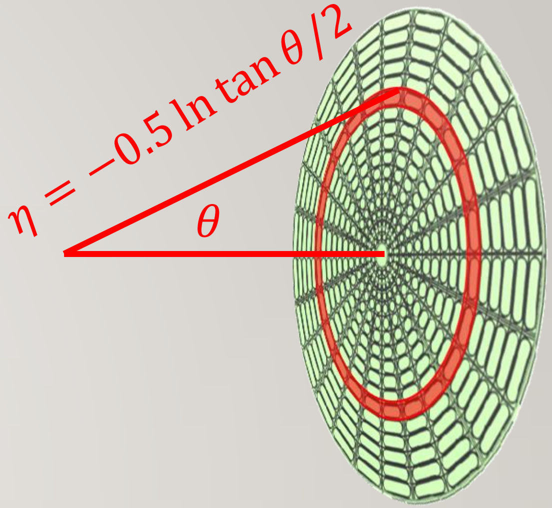
- EPD measures energy deposited via ionization
- Mostly Minimum Ionizing Particles (MIPs)
- Deposited energy has Landau distribution for single MIP
- Multiple MIPs → convoluted Landau distributions
- Average #MIPs in each ring ($N(i_{Ring})$) from convoluted Landau fit:
  - $N(i_{Ring}) = \sum_n n \cdot nMIPweight$
- 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

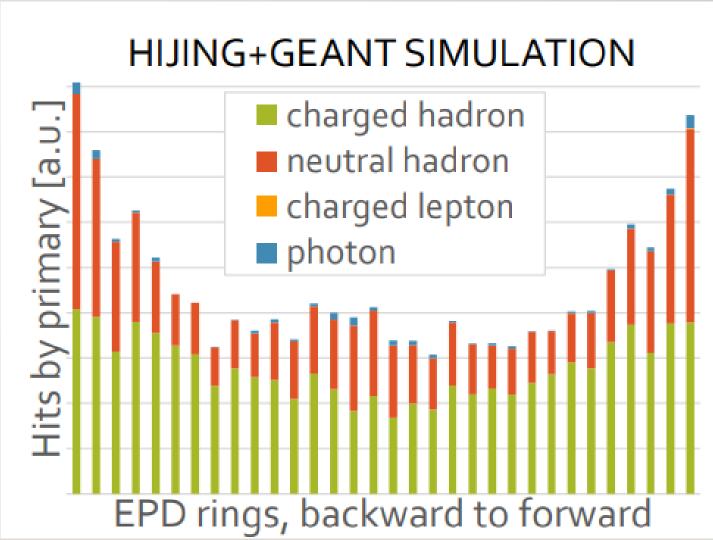




HOW (NOT) TO MEASURE $dN_{ch}/d\eta$ WITH THE EPD

- 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!





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

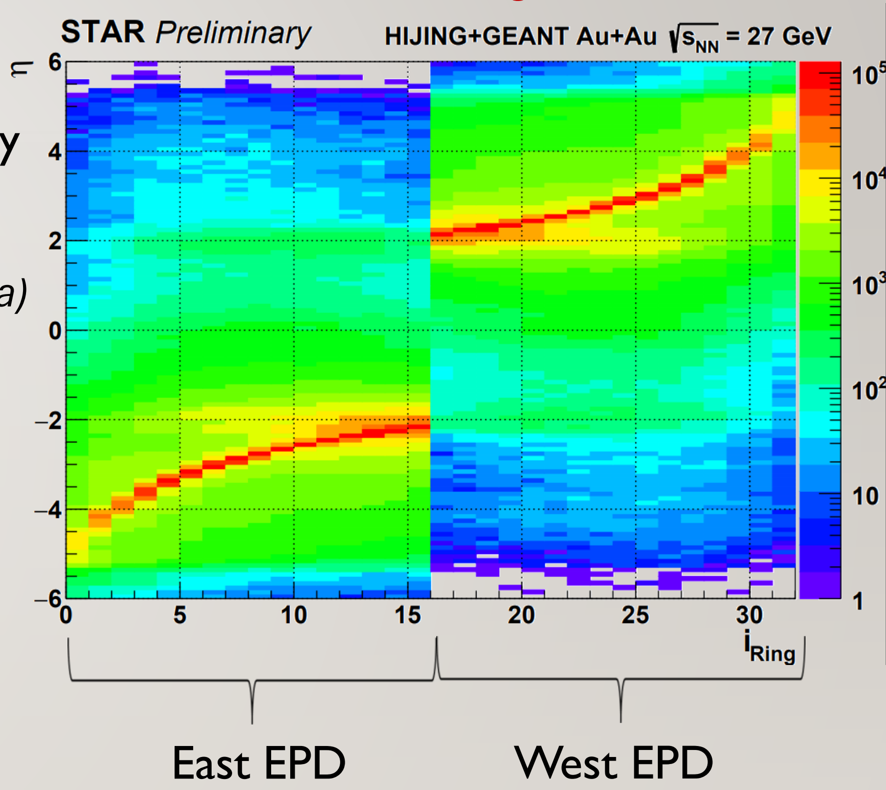
$$N(i_{Ring}) = \int R(\eta, i_{Ring}) \frac{dN}{d\eta} d\eta$$

- 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*

UNFOLDING PROCEDURE

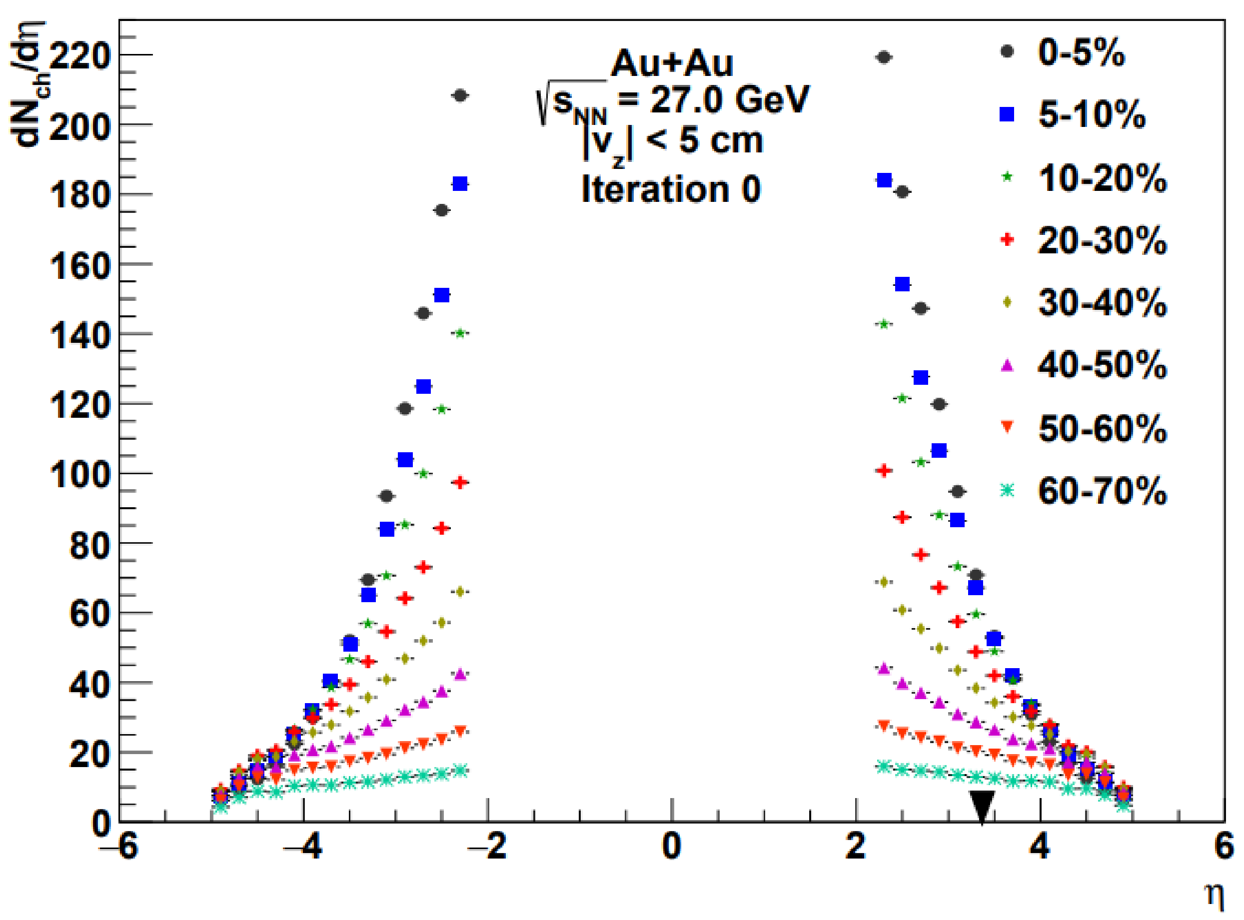
1. Create the response matrix
   - HIJING+GEANT simulation – at same energy as data
   - For each primary track create list of EPD hits originating from that primary
     - If no EPD hit for a primary: *ResponseMatrix->Miss(TrackEta)*
     - For each EPD hit of a primary: *ResponseMatrix->Fill(EPDRingNumber, TrackEta)*
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

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



8/15 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
  - Only do 1 iteration for now
  - Next iteration has <5% effect



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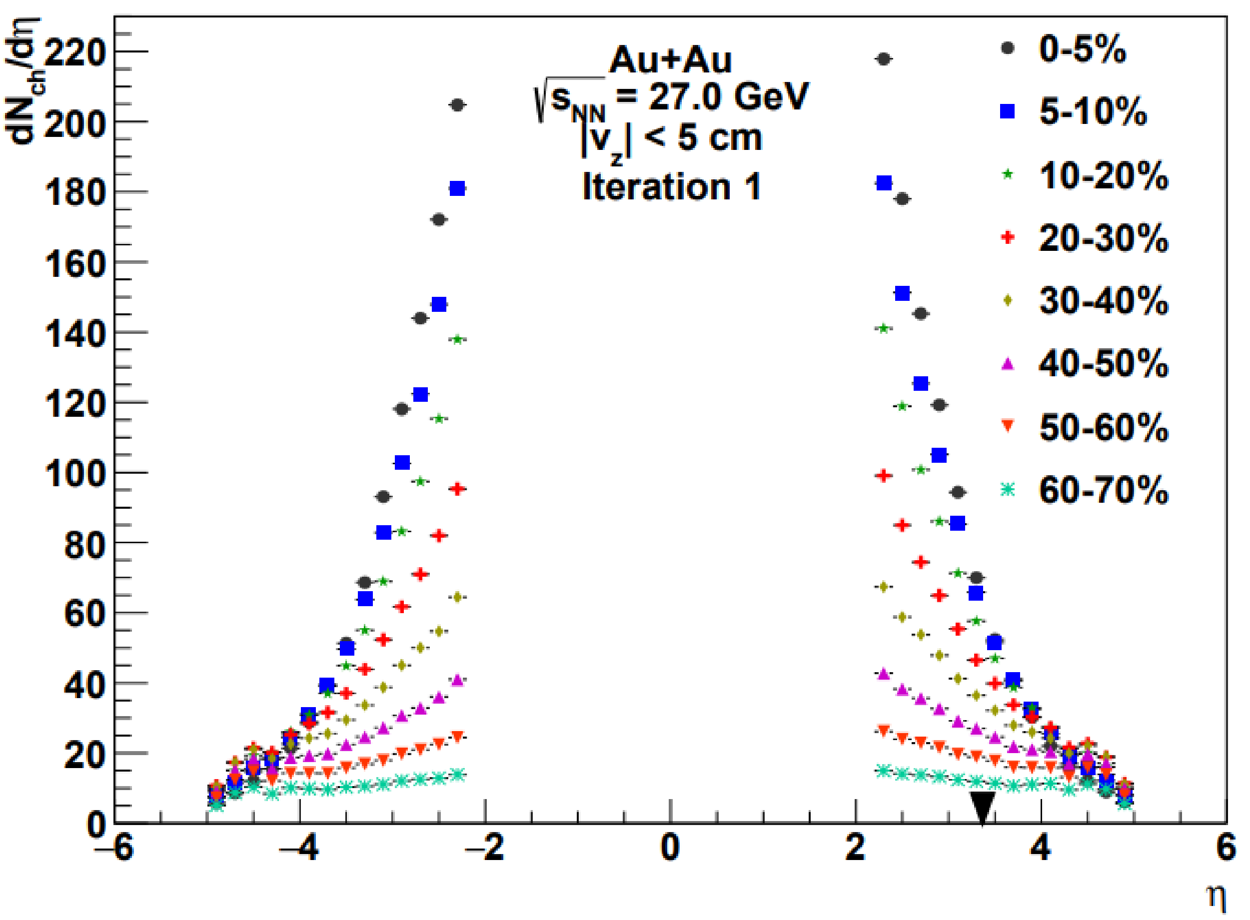


SYSTEMATIC UNCERTAINTIES

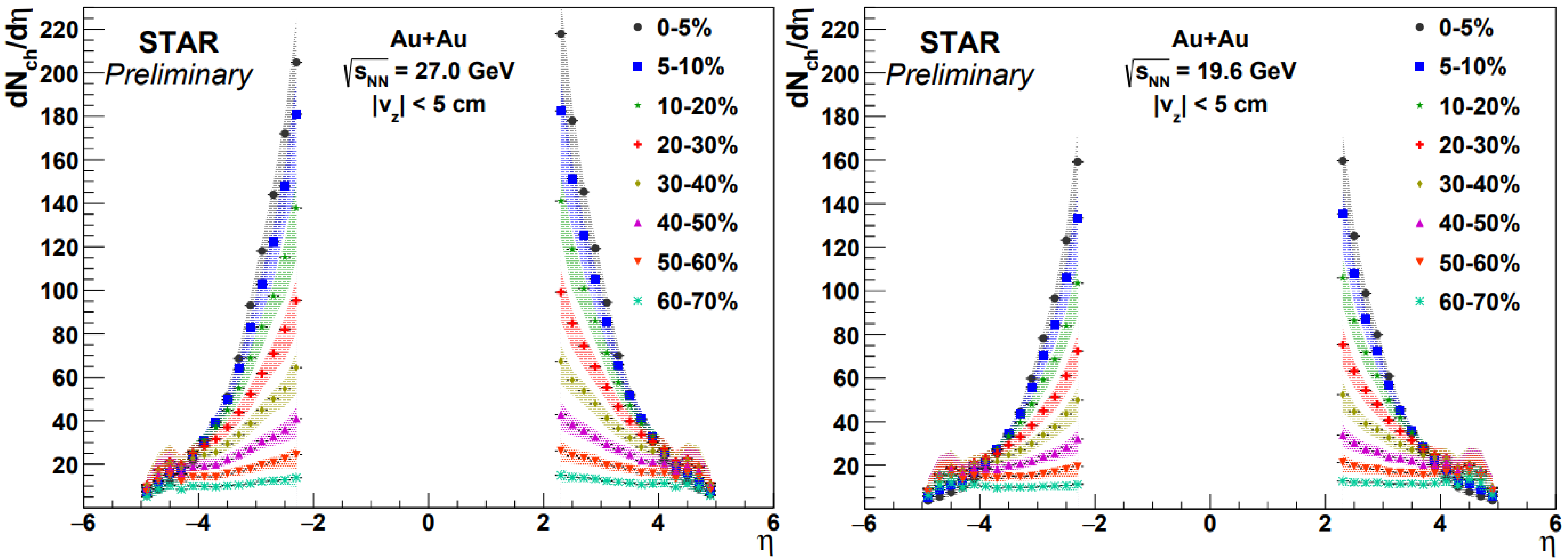
- Systematic checks in the unfolding:
  - Scale 27 GeV MC to 200 GeV and 7GeV MC:
    - Charged/neutral ratio → 4%
    - Baryon/meson ratio → 4%
    - Input $dN/d\eta$ → 6%
    - Momentum distribution → 3%
  - Unfolding method (difference of the three methods of obtaining $dN_{ch}/d\eta$) → 7%
- Centrality 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

↓

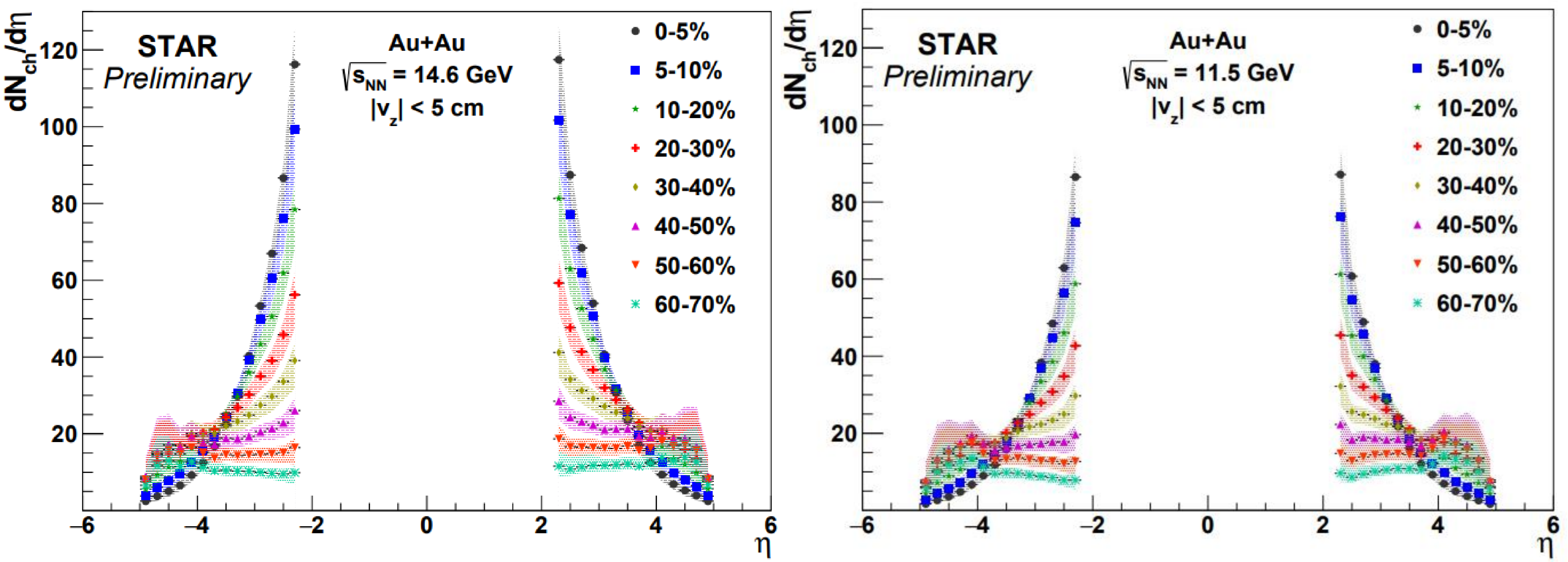
Might need to calculate for each energy separately in the future

11 /15 RESULTS AT 27 AND 19.6 GEV



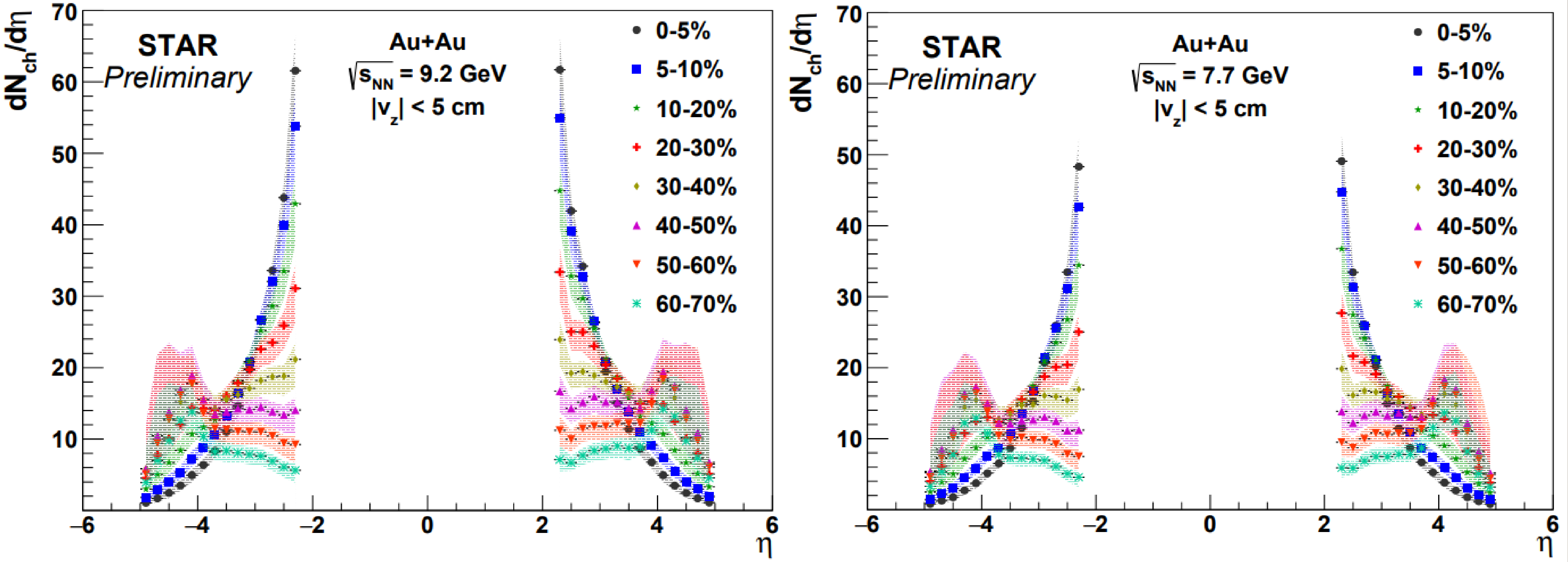
Bump appears at large η → caused by spectators

12 /15 RESULTS AT 14.6 AND 11.5 GEV



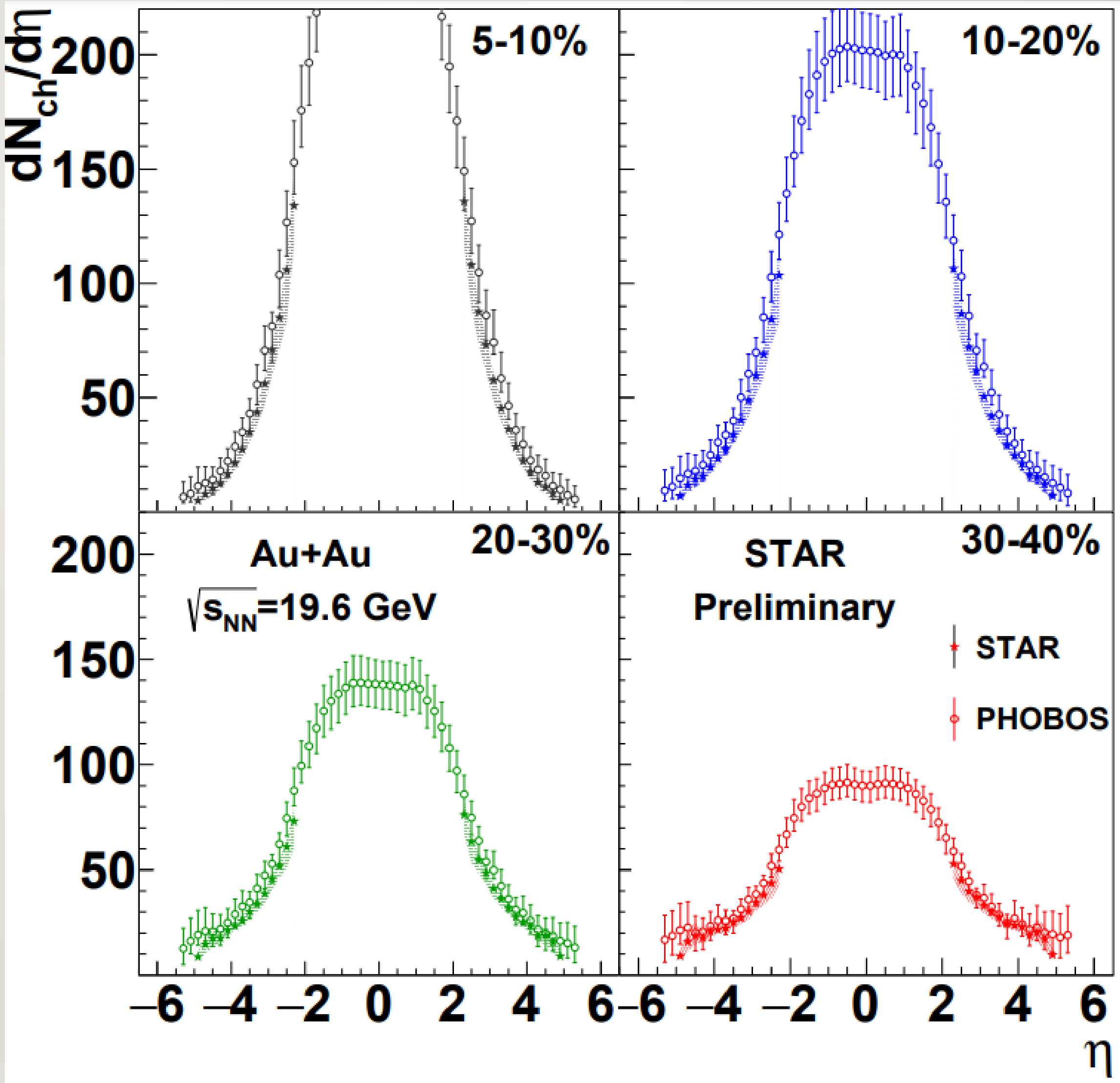
Bump becomes relatively larger at smaller energies

13 /15 RESULTS AT 9.2 AND 7.7 GEV



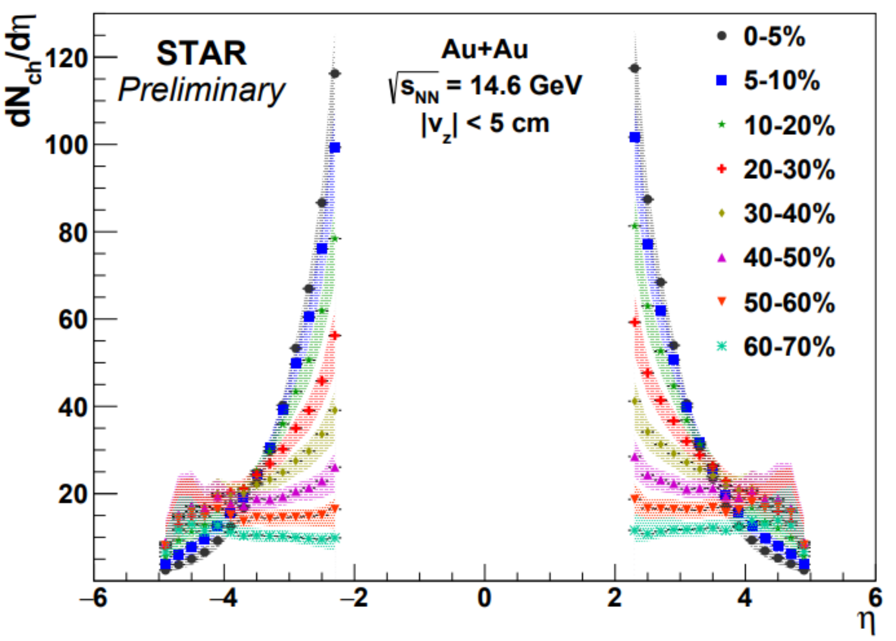
COMPARISON TO PHOBOS

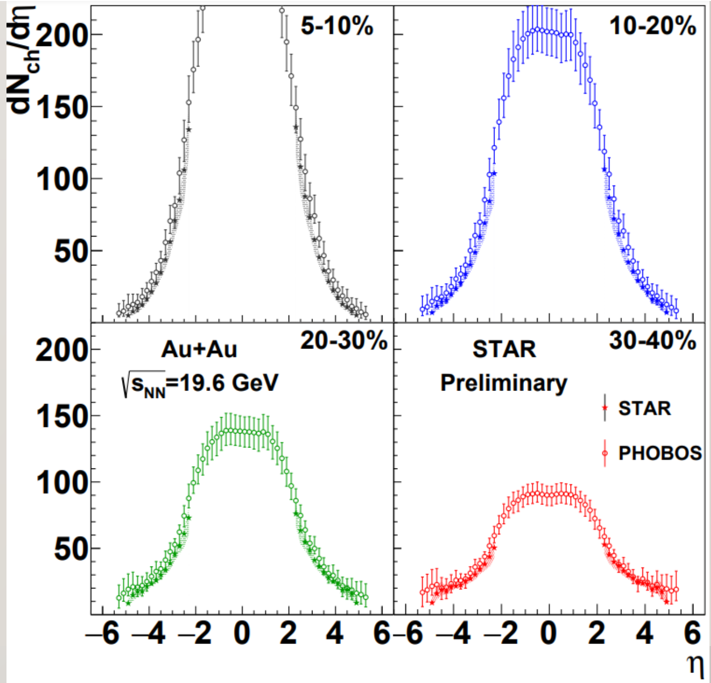
- PHOBOS $dN_{ch}/d\eta$ paper
  - *Phys. Rev. C 83 (2011) 024913*
  - Results at 19.6, 62.4, 130, 200 GeV
- Comparison at 19.6 GeV:
  - Same shape
  - Slightly smaller at STAR
  - Agreement within uncertainties in most cases



SUMMARY

- Measurement of $dN_{ch}/d\eta$ with the EPD
  - All 6 Beam Energy Scan II energies
  - Roughly expected η, centrality and $\sqrt{s_{NN}}$ dependence
  - Spectator contribution apparent
  - Detailed systematic studies
- Good agreement with PHOBOS results at 19.6 GeV





THANK YOU FOR YOUR ATTENTION!

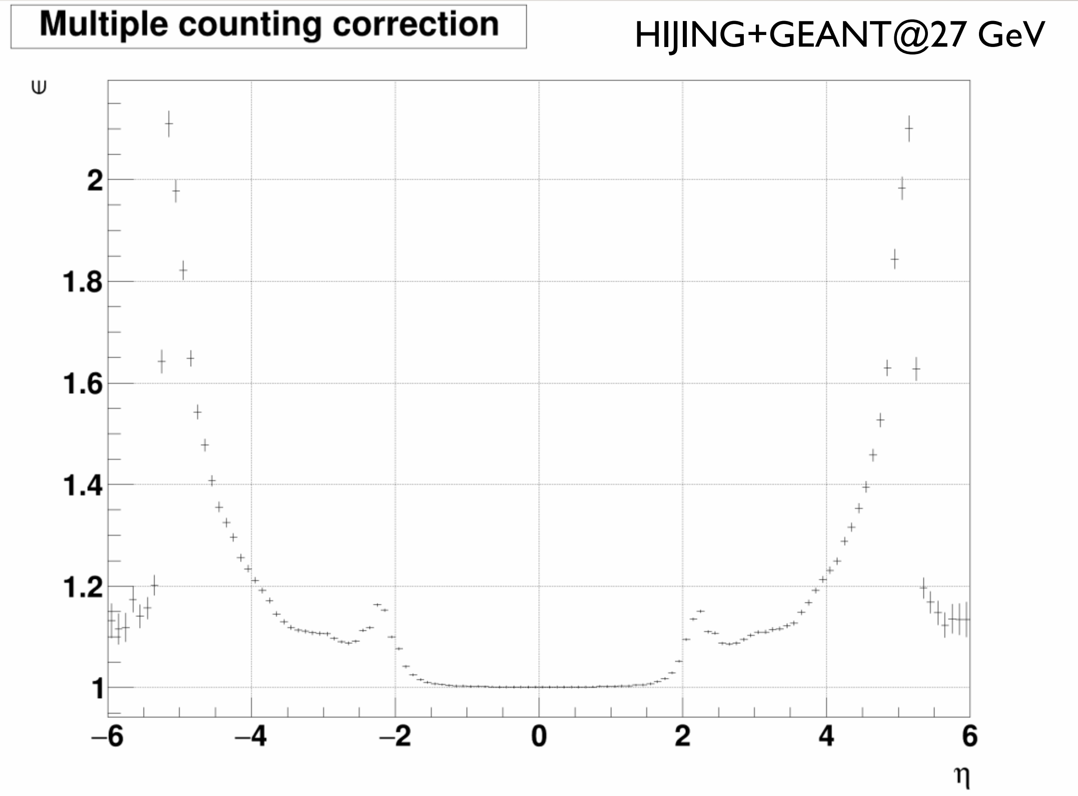
BACKUP SLIDES

18 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

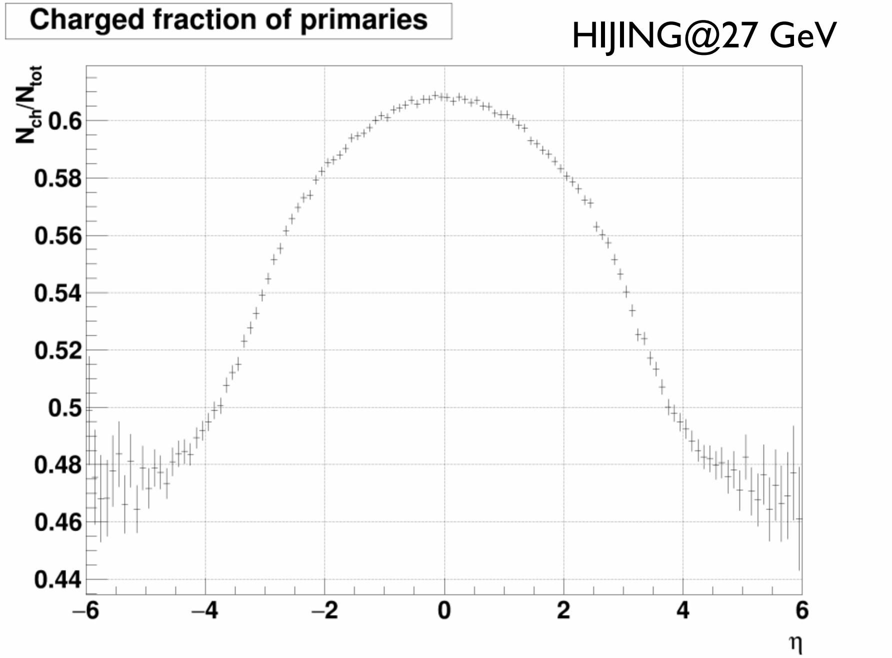
19 MULTIPLE COUNTING CORRECTION

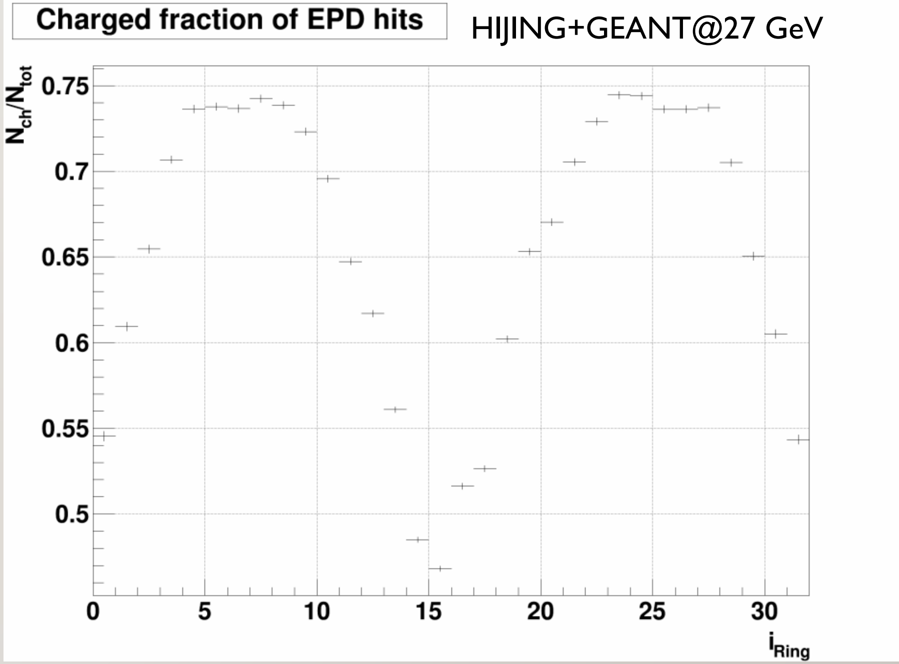
- Need to correct for multiple counting (multiple hits from one primary track)
- Check "inverse efficiency": how many hits on average from primary particles at given η
- Largest at around $|\eta| \approx 5$
- Edge of EPD, support structures



20 CHARGED FRACTION CORRECTION

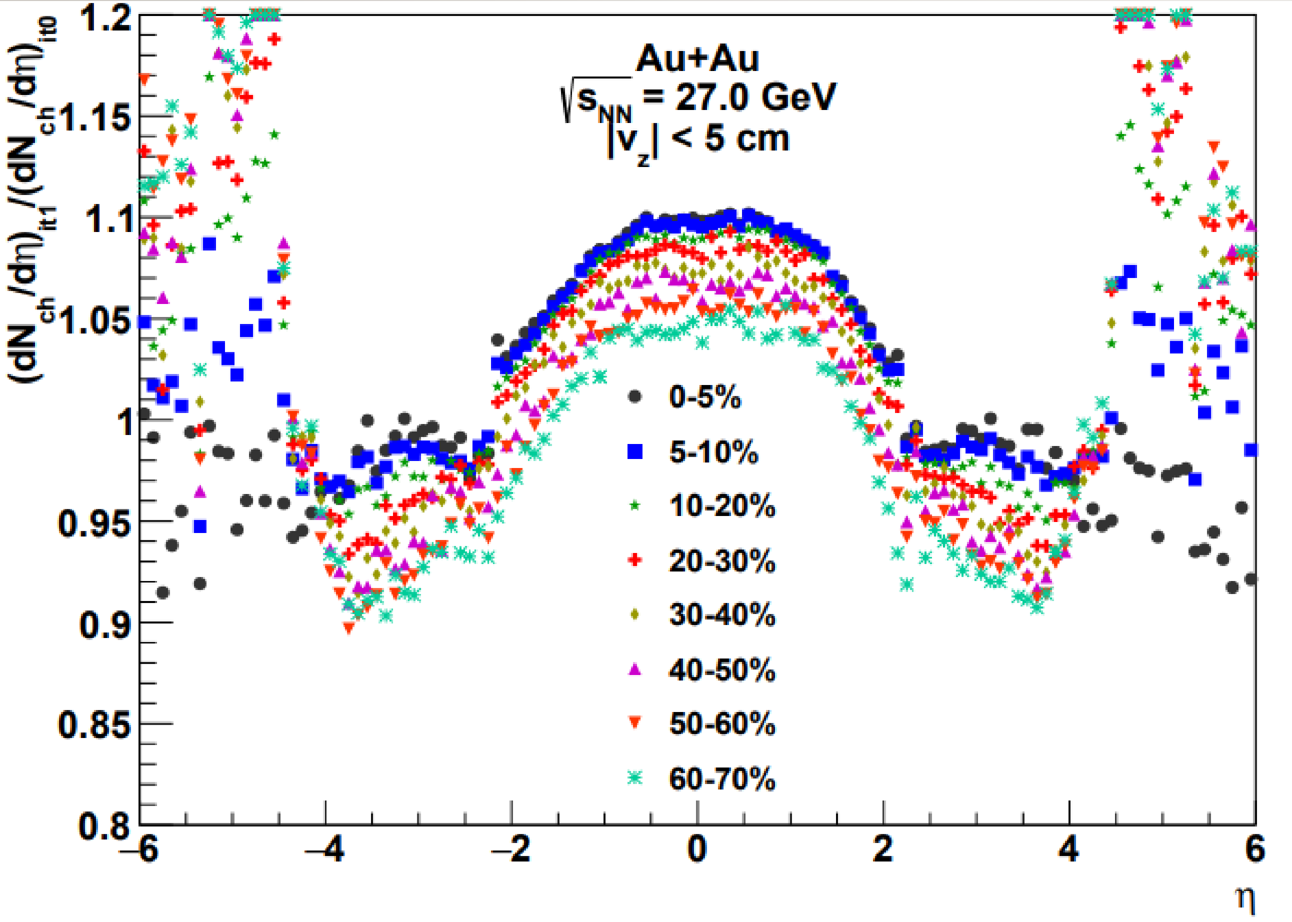
- From simulations: charged particle fraction
  - For primary tracks and for EPD hits (based on primary cause)
- Applied 3 different methods:
  1. Unfolding $dN/d\eta$; correcting via $N_{ch}(\eta)/N_{tot}(\eta)$
  2. Correcting via $N_{ch}(i_{ring})/N_{tot}(i_{ring})$, unfolding "corrected" EPD distribution
  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





21 CHANGE BETWEEN ITERATIONS

Iteration1/iteration0



Iteration2/iteration1