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

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STAR

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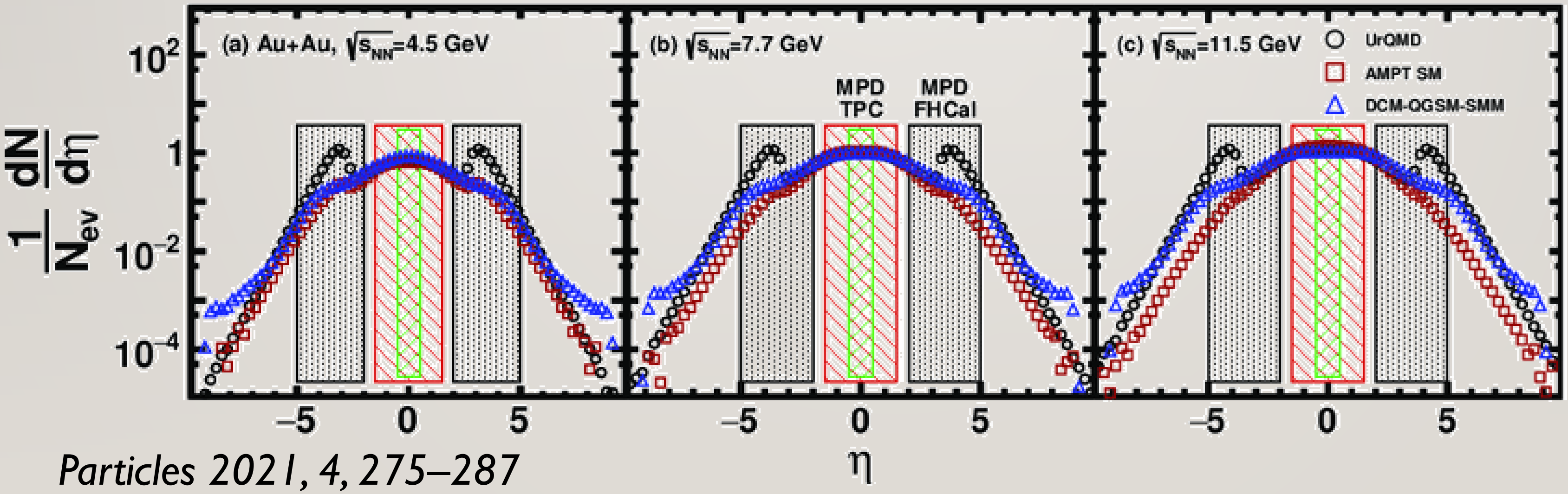
# MOTIVATION

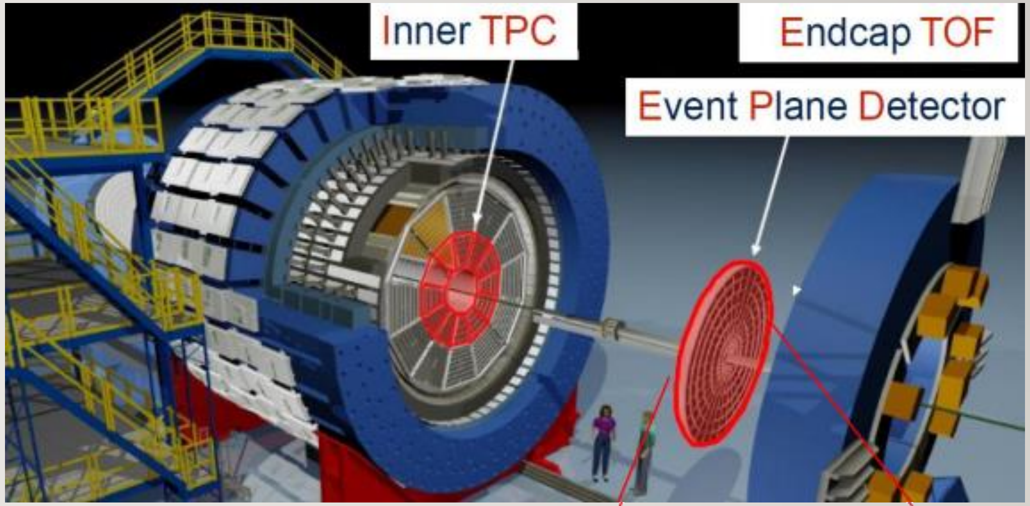
- $dN_{ch}/d\eta$ important for the tuning of models
  - Midrapidity: models give similar predictions to each other and to data
  - Forward rapidities: models disagree
- Few measurements at forward rapidities
  - None at all BES-II energies

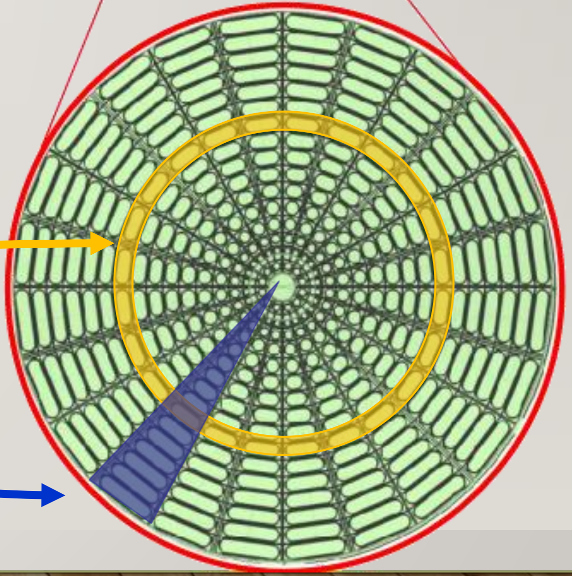



*Particles 2021, 4, 275–287*

# THE STAR EVENT PLANE DETECTOR

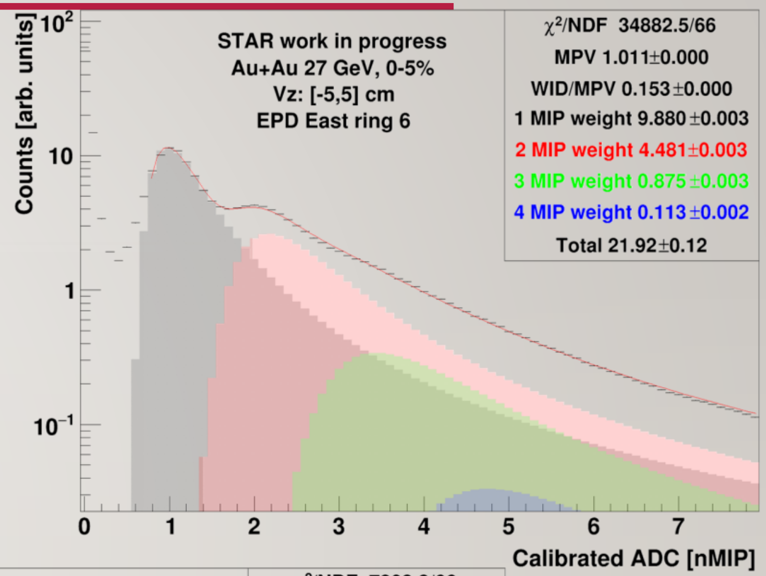
- Part of the upgrade for BES-II
- Motivations:
  - Centrality determination
  - Event plane resolution
  - Triggering
- Characteristics:
  - Detects charged particles
  - Located at ±375 cm from the interaction point (East and West EPD)
  - Large pseudorapidity coverage: 2.14<|η|<5.09
  - High η and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

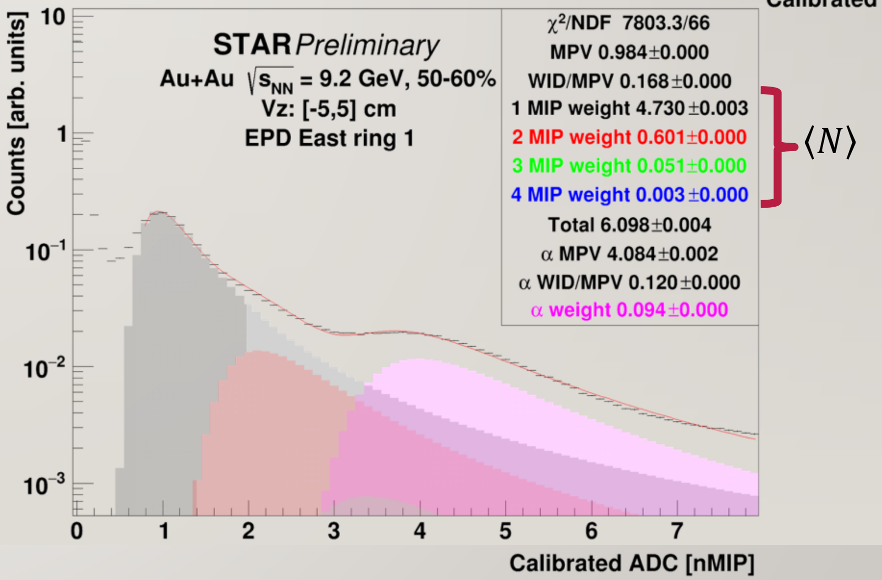


# 4 /13 LANDAU FITS – DETERMINING #MIPS IN EACH RING

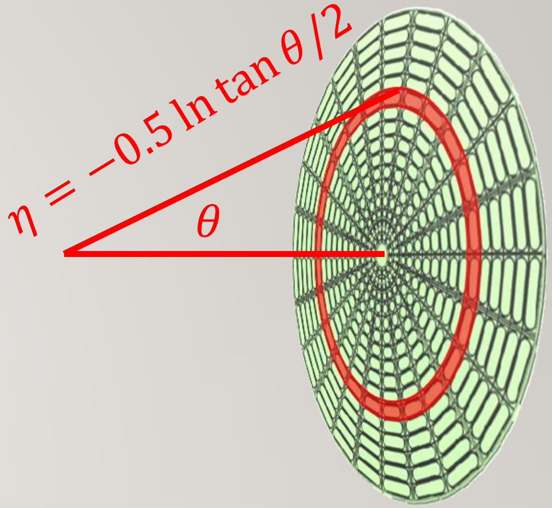
- EPD measures energy deposited via ionization
- Mostly Minimum Ionizing Particles (MIPs)
- Deposited energy has Landau distribution for single MIP
- Multiple MIPs → convoluted Landau distributions
- Average #MIPs in each ring ($N(i_{Ring})$) from convoluted Landau fit:
  - $N(i_{Ring}) = \sum_n n \cdot nMIPweight$
- Inner rings:
  - $\alpha$ particles from projectile remnants need to be considered
  - Poisson distribution of nMIP weights enforced
- Use same fit method in all cases for consistency



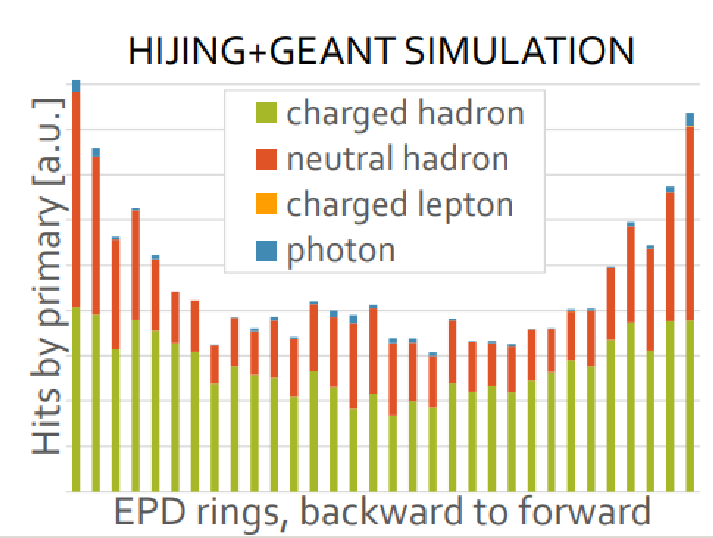



# HOW (NOT) TO MEASURE $dN_{ch}/d\eta$ WITH THE EPD

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

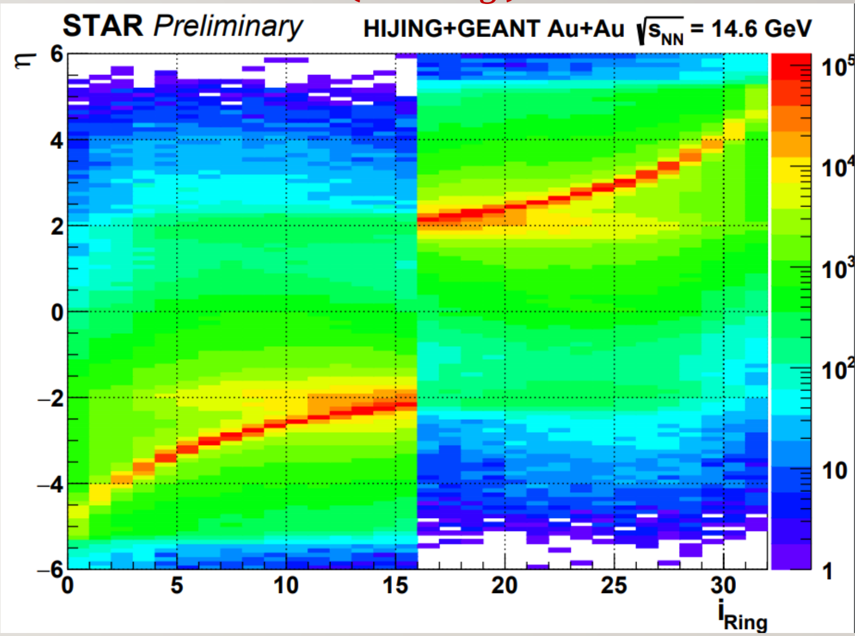
$$N(i_{Ring}) = \int R(\eta, i_{Ring}) \frac{dN}{d\eta} d\eta$$

- 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*

# 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

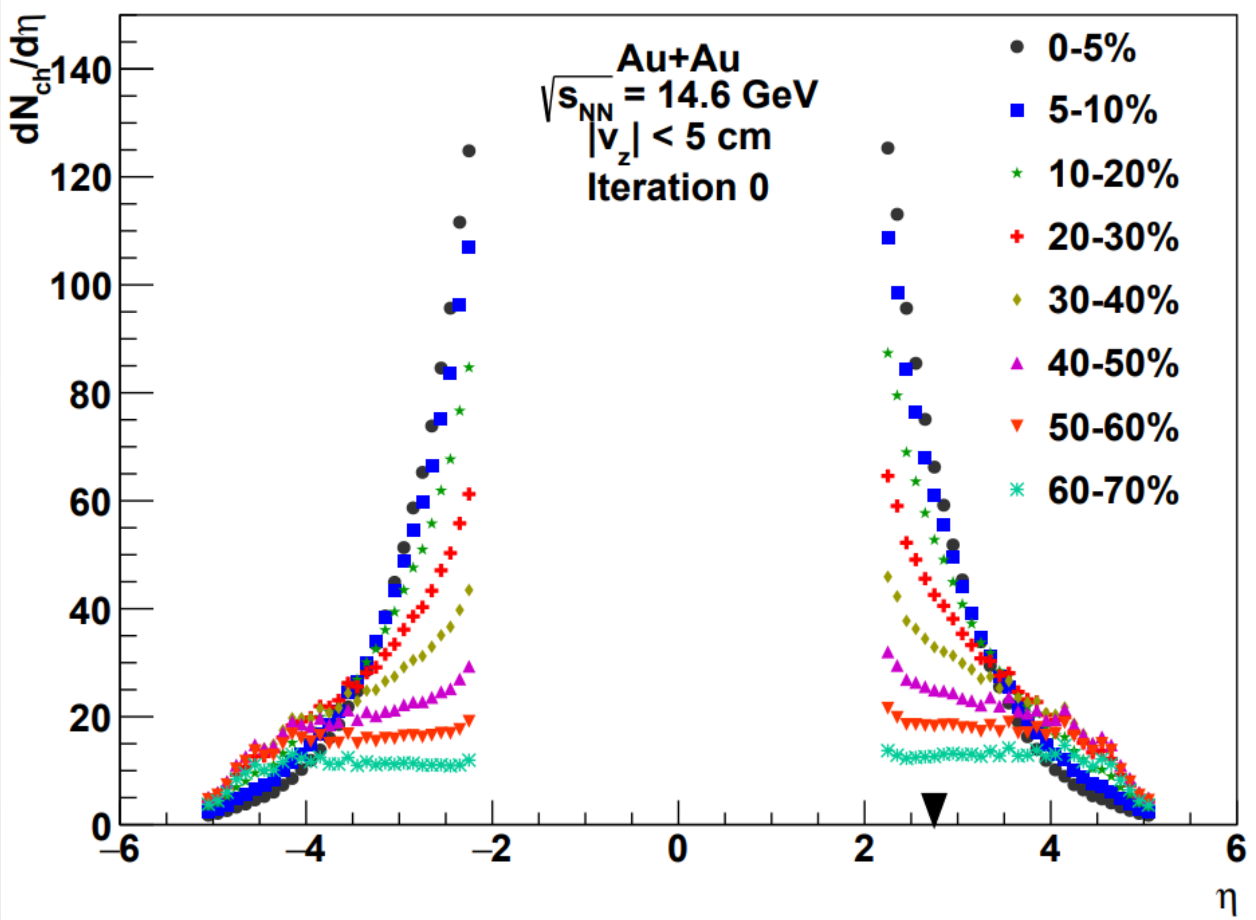
$R(\eta, i_{Ring})$




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



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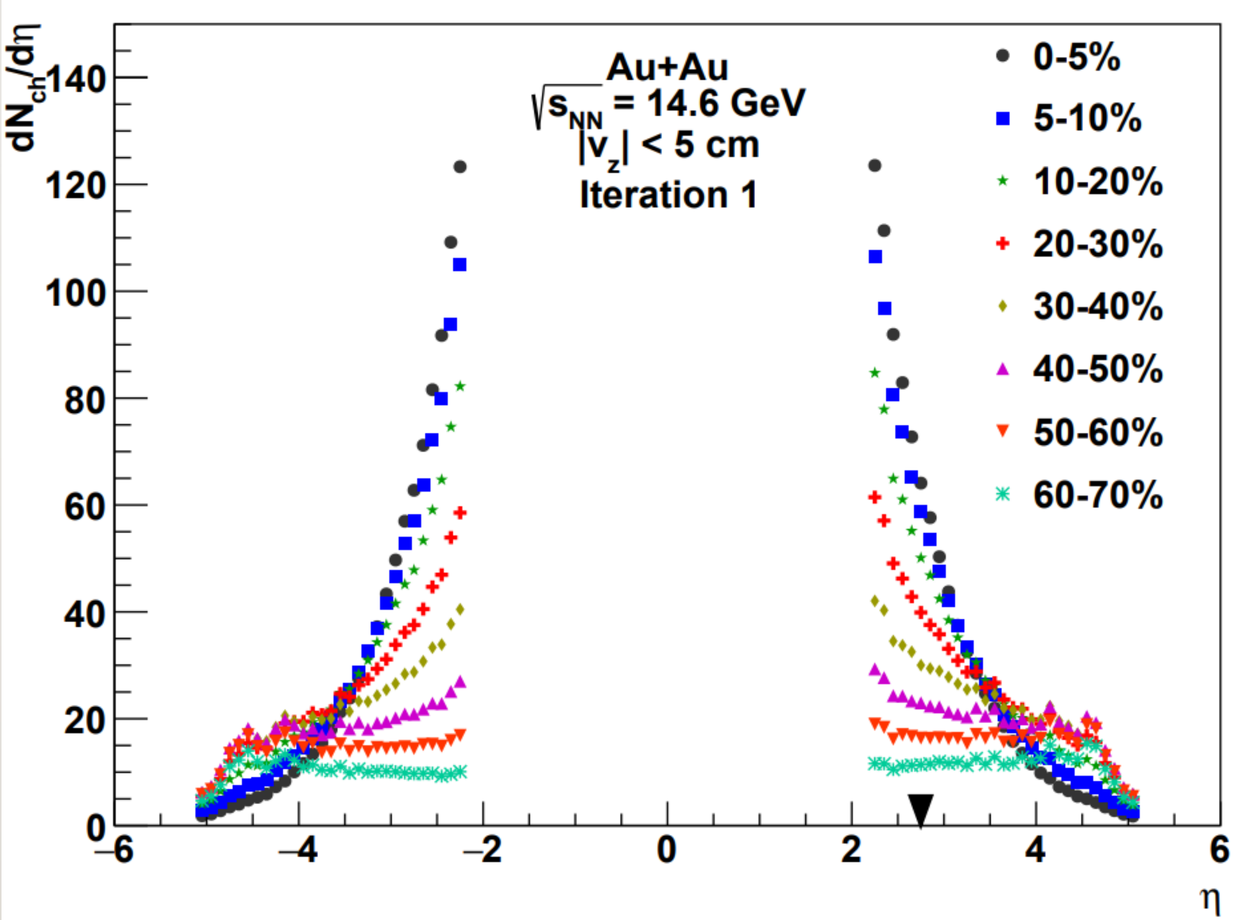
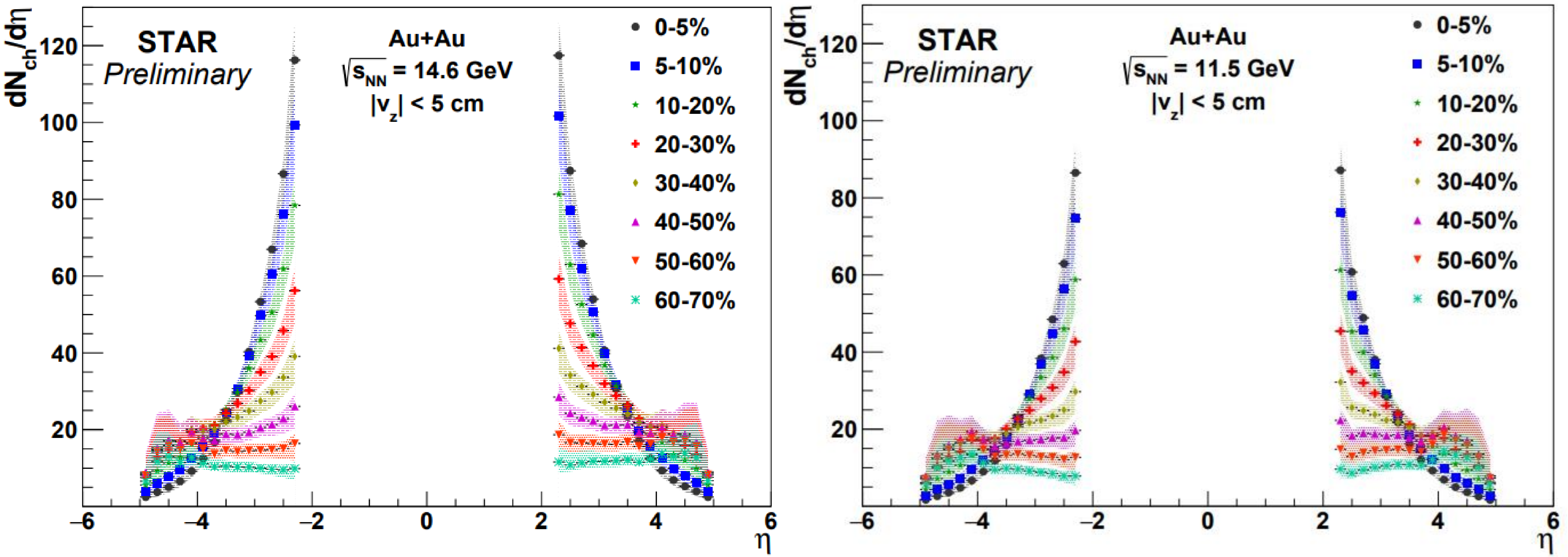


# 10/13 SYSTEMATIC UNCERTAINTIES

- 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 (3 different methods for the charged fraction correction) → 7%
- Centrality selection ($\pm 5\%$ change) → 3%
- z-vertex resolution ($\pm 5$ cm shift) → 1%
- z-vertex choice ($\pm 40$ cm from geometric center) → 6%
- Landau fit (fit without $\alpha$ peak, fit without enforcing Poisson weights) → 5%

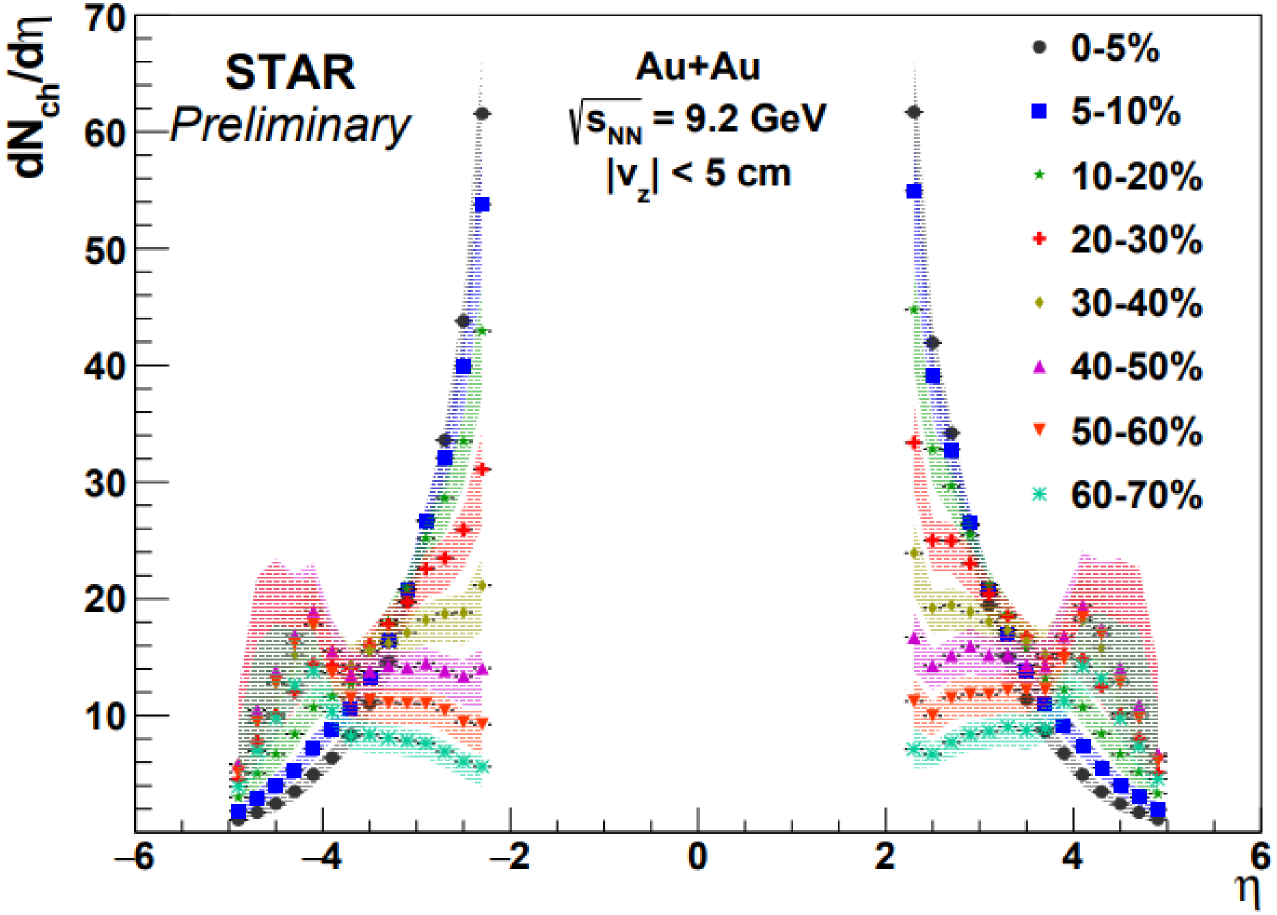
Calculated using 27 GeV data

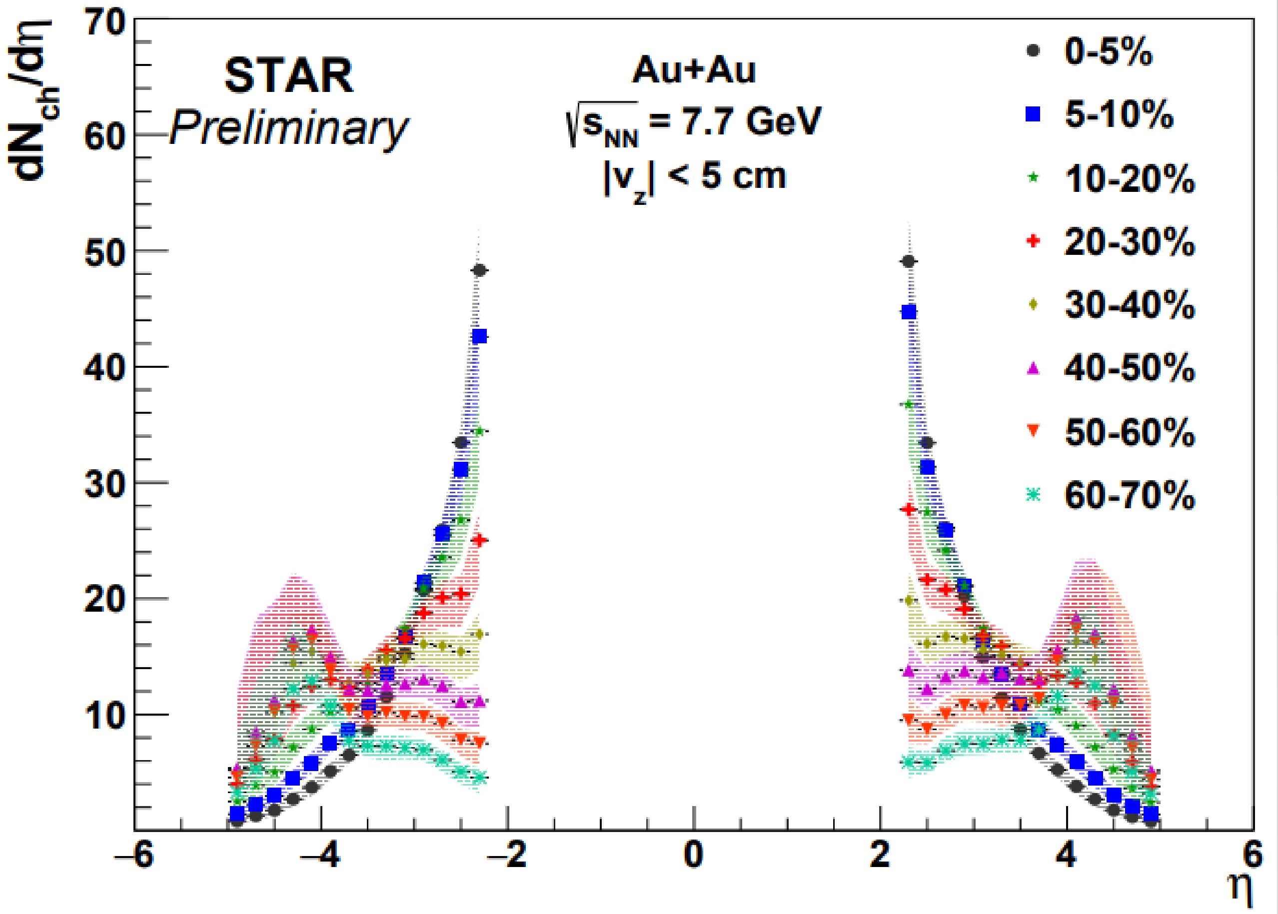
# 11 /13 RESULTS AT 14.6 AND 11.5 GEV




Bump appears at large η → caused by spectators

# RESULTS AT 9.2 AND 7.7 GEV

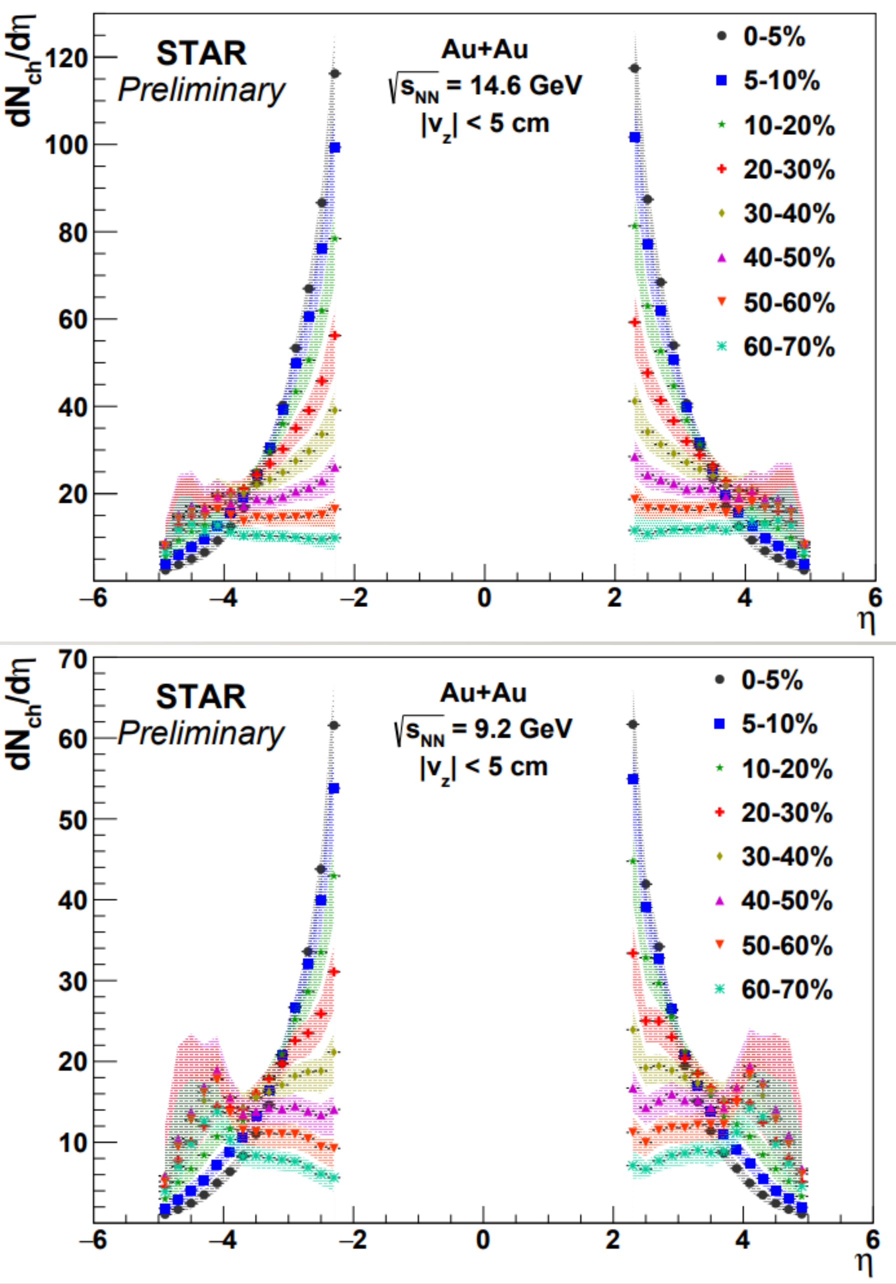



Bump becomes relatively larger at smaller energies

# 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!

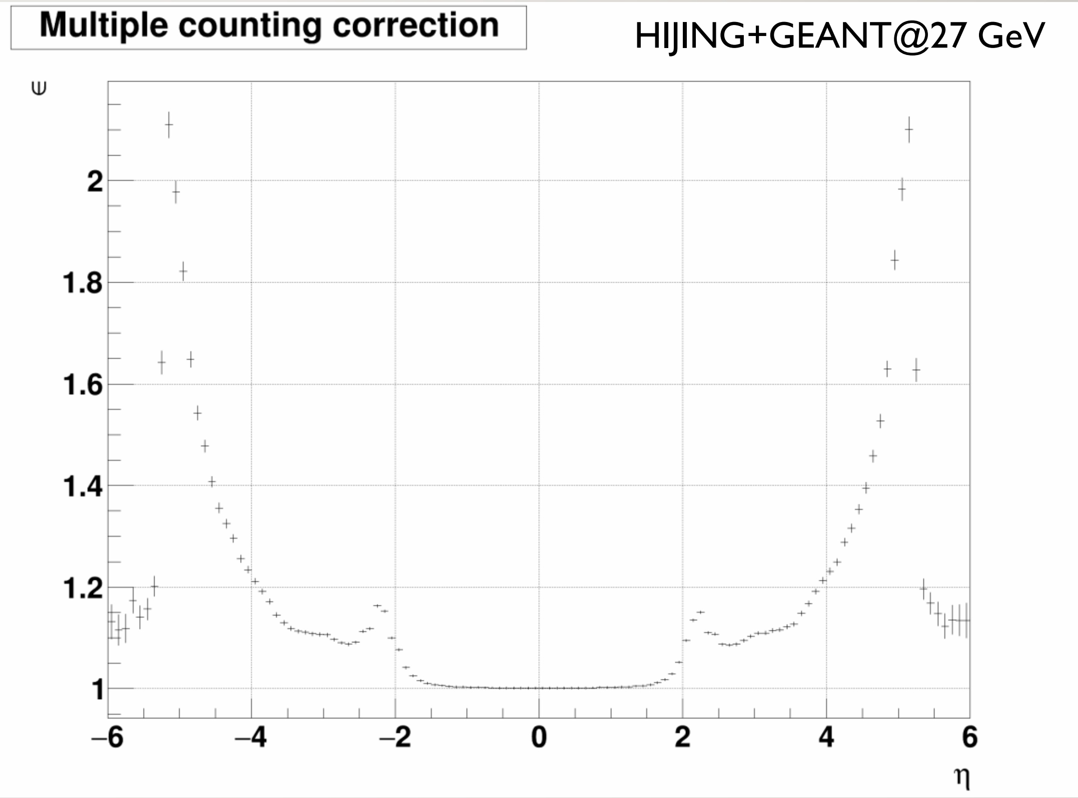
# BACKUP SLIDES

# 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

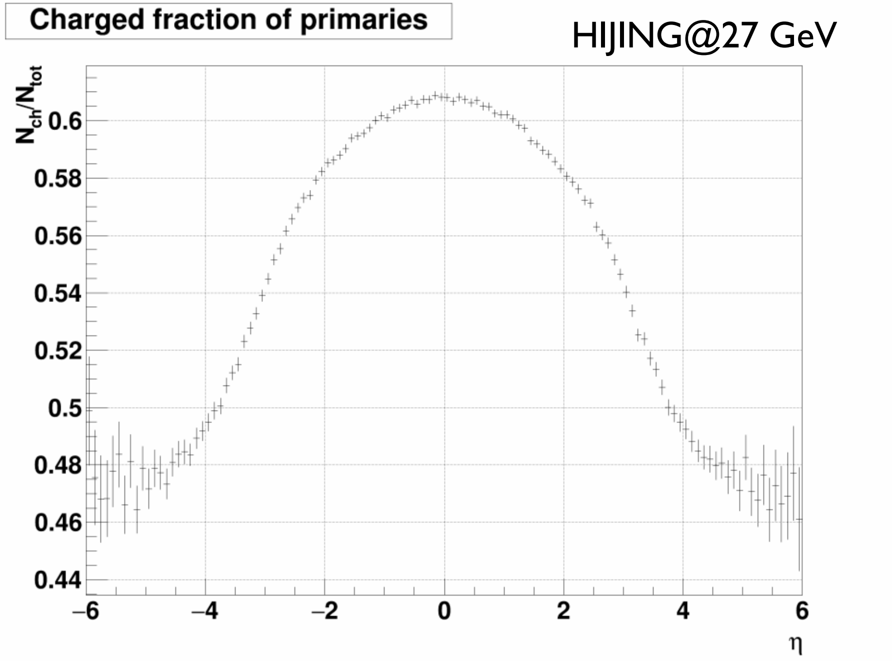
# 17 MULTIPLE COUNTING CORRECTION

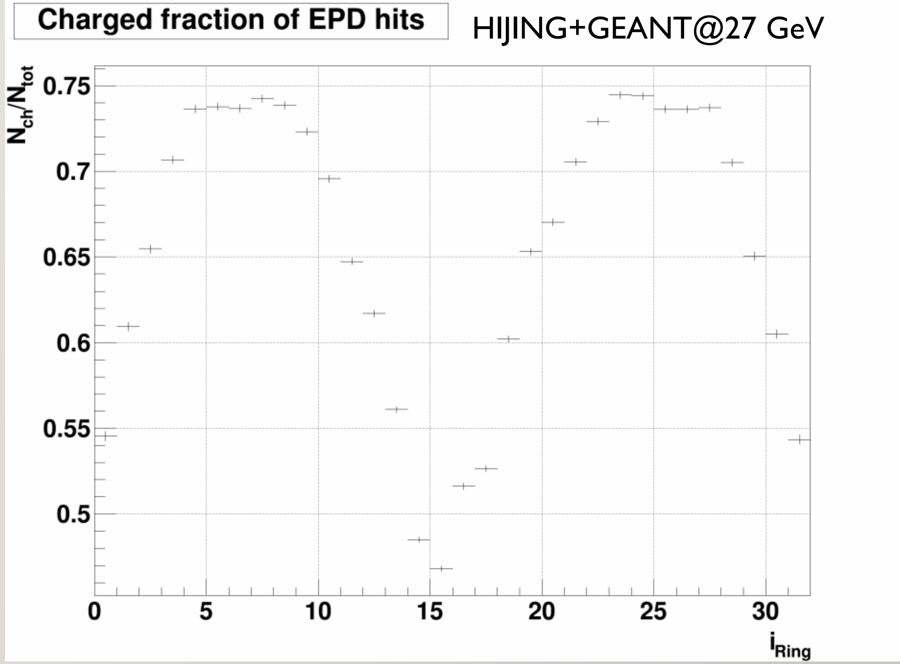
- Need to correct for multiple counting (multiple hits from one primary track)
- Check "inverse efficiency": how many hits on average from primary particles at given $\eta$
- Largest at around $|\eta| \approx 5$
- Edge of EPD, support structures



# 18 CHARGED FRACTION CORRECTION

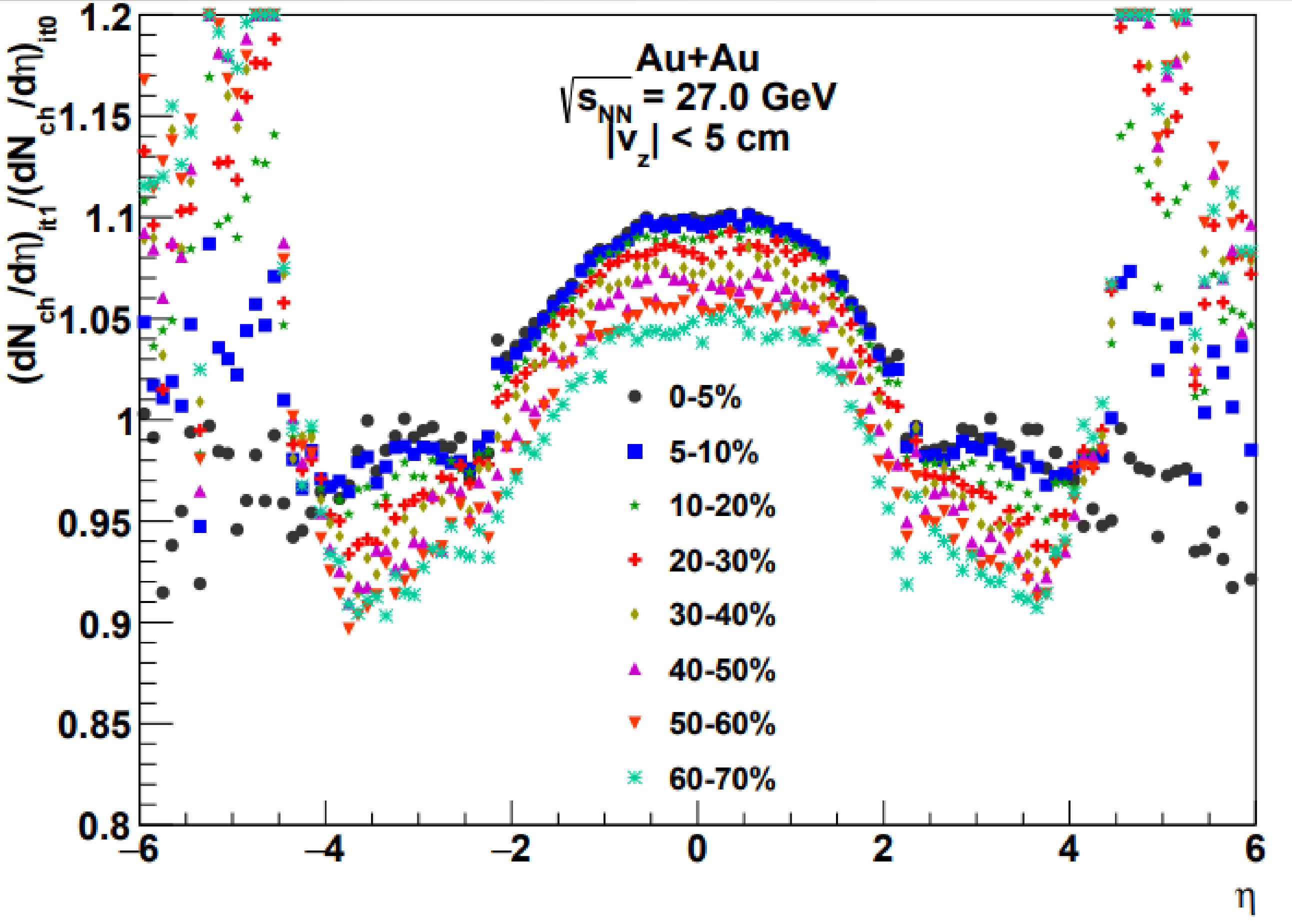
- From simulations: charged particle fraction
  - For primary tracks and for EPD hits (based on primary cause)
- Applied 3 different methods:
  1. Unfolding $dN/d\eta$; correcting via $N_{ch}(\eta)/N_{tot}(\eta)$
  2. Correcting via $N_{ch}(i_{ring})/N_{tot}(i_{ring})$, unfolding "corrected" EPD distribution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

Iteration1/iteration0




Iteration2/iteration1