Charged particle pseudorapidity distributions measured with the STAR EPD

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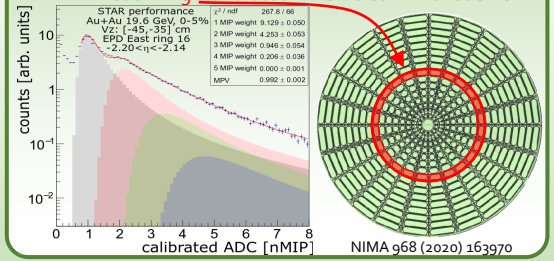
Abstract

In 2018, STAR installed the Event Plane Detector (EPD) with a pseudorapidity coverage of $2.15<|\eta|<5.09$. The EPD has enhanced STAR's capabilities in triggering, centrality measurement and event plane determination. Due to its fine radial granularity, it can also be utilized to measure pseudorapidity distributions of charged particles. In order to make such a measurement, the response of the detector material to the produced primary particles has to be understood. Monte Carlo simulations are used to determine the detector response matrix which is then used in an iterative unfolding procedure to obtain the corrected pseudorapidity distributions. As a first step towards such measurements at even lower energies, we present the results on charged particle pseudorapidity distributions measured with the EPD in 19.6 and 27 GeV Au+Au collisions.

The STAR Event Plane Detector

- Large fwd pseudorapidity coverage: $2.14 < |\eta| < 5.09$
- Installed at ±375 cm (East and West EPDs)
- High η and ϕ segmentation, good timing resolution
- 16 rings on each side, 24 azimuthal segments
- nMIP in each ring: calibrated ADC via conv. Landau fit



Unfolding $dN/d\eta$

Origin: $dN/d\eta$, result: $N(i_{\mathrm{Ring}})$, response $R(\eta, i_{\mathrm{Ring}})$

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

Response calculated via HIJING + GEANT simulations

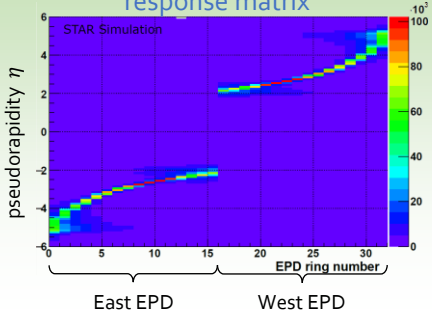
Given EPD ring yields particles mostly, but not only at given η

Invert via unfolding: RooUnfold

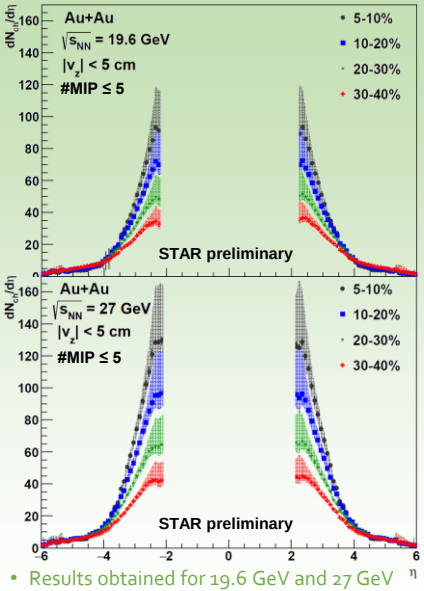
Three methods for extracting $\frac{dN_{ch}}{d\eta}$

1. Correcting unfolded $dN/d\eta$
2. Correcting raw EPD data
3. Utilizing RooUnfold's Fakes() method

response matrix



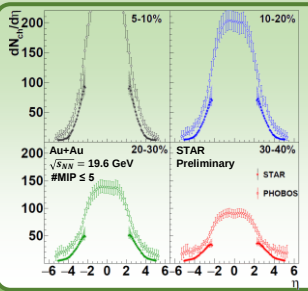
Results



- Results obtained for 19.6 GeV and 27 GeV
- Via HIJING+GEANT, without ion fragments
- EPD range: $2.14 < |\eta| < 5.09$
- Expected η, centrality, $\sqrt{s_{NN}}$ dependence

Systematics

charged fraction	6%
$dN/d\eta$ broadened	4%
$dN/d\eta$ tightened, shifted	6%
p_T slope	1%
centrality selection	2%
unfolding method choice	8%
z-vertex choice	1%
z-vertex selection	negligible
EPD electronics, efficiency	negligible



Conclusions

- Pseudorapidity distributions measured with the EPD
- Thorough systematic analysis
- Expected rapidity, centrality and energy dependence
- Method to be extended to other $\sqrt{s_{NN}}$ values
- May be important for the Beam Energy Scan
  - For example: tuning of models
- $\sqrt{s_{NN}} = 19.6$ GeV: PHOBOS also measured $dN_{ch}/d\eta$
- Significant difference compared to PHOBOS
  - PHOBOS paper: Phys. Rev. C 83 (2011) 024913 and Phys. Rev. C 94 (2016) 024903 (light fragments)

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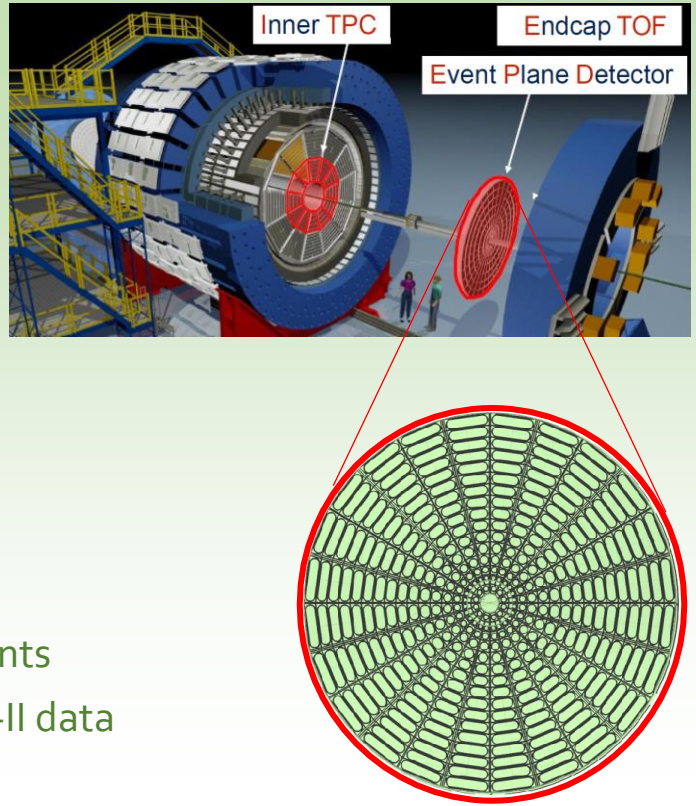
The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations

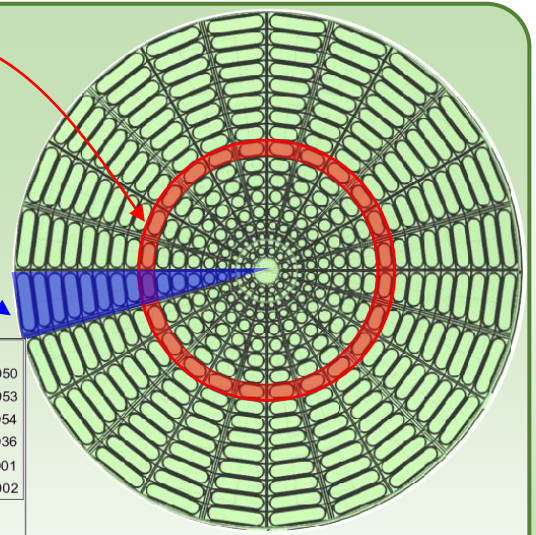
STAR Upgrades for BES-II

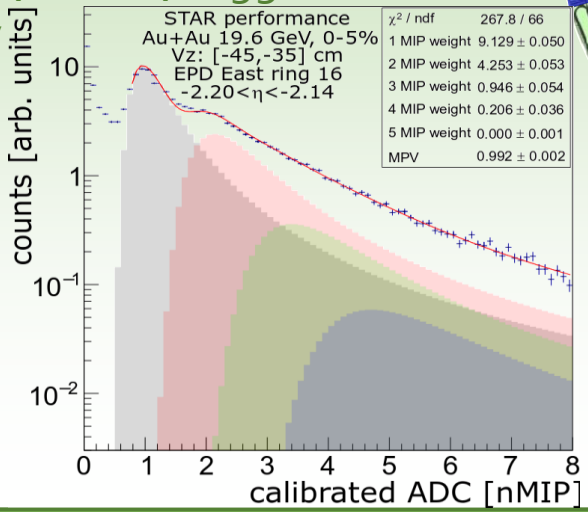
- STAR upgrades:
  - Fixed target program:
    down to $\sqrt{s_{NN}} \approx 3$ GeV, up to $\mu_B \approx 700$ MeV
  - innerTPC: better dE/dx (PID) and mom. resolution
  - Endcap TOF: extended forward PID
  - Event Plane Detector: better triggering,
    Event Plane resolution and centrality
  - LEReC: Electron Cooling for low energy RHIC running
- EPD motivations:
  - Independent centrality for fluctuation measurements
  - Improved Event Plane resolution for flow measurements
  - EP measurement also important for isobaric and BES-II data
  - Trigger in high luminosity environment (BES-II)



The STAR Event Plane Detector

- Much higher granularity compared to BBC
  - BBC: 36 tiles (only 18 inner used) ⇒ EPD: 372 tiles
  - Also larger acceptance: [3.3,5.0] ⇒ [2.1,5.1]
  - 16 radial segments (rings)
  - 24 azimuthal segments (sectors)
- Radial segmentation driven by flow, vertex, trigger
- Azimuthal segmentation driven by higher flow harmonics
- Each tile registering hits, mostly MIPs
  - Landau distribution of a single hit
  - Convolution for multiple hits
  - Poisson distribution of MIP weights

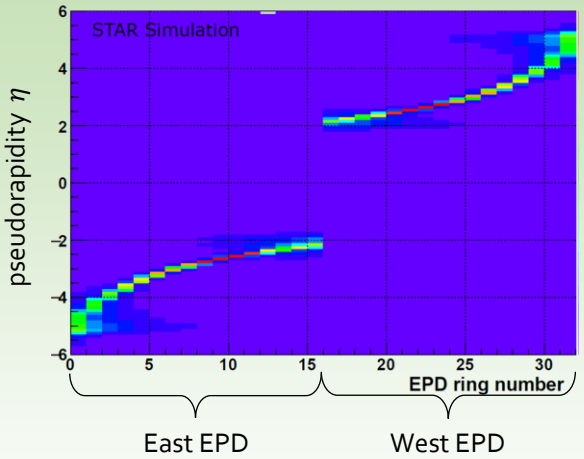




The EPD Response Matrix

- Use iterative unfolding, based on G. D'Agostini, Nucl. Instr. Meth. A362 (1995) 487
- Implemented in RooUnfold, response matrix to be calculated as:

```
for(PrimaryTracks)
{
  if(no EPD hits from that Primary Track)
  {
    R->Miss(TrackEta); //This track "missed" the EPD
  }
  else
  {
    for(EPD hits of that Primary Track)
    {
      R->Fill(EPDRingNumber,TrackEta);
    }
  }
}
```



- In the simulation, we need:
  - list of **primary tracks**
  - list of **EPD hits**, linked to the primary track causing them

- All possible in HIJING+GEANT simulator
  - Note: no (light) ion fragments in HIJING; note PHOBOS paper Phys.Rev.C 94 (2016) 024903

Systematic investigations

- Systematic checks in the unfolding
  - Determination of the longitudinal vertex position (±5 cm shift) & centrality (±5% change)
  - Comparison of several vertex intervals (+40 cm and -40 cm from geometric center)
  - Unfolding method:
    1. Unfolding $dN/d\eta$; correcting via $N_{ch}(\eta)/N_{tot}(\eta)$ from HIJING
    2. Correcting via $N_{ch}(i_{ring})/N_{tot}(i_{ring})$; unfolding "corrected" EPD distribution
    3. Use RooUnfold's "Fakes" (where neutrals ⇔ "fake" hits)
  - Charged/neutral ratio change in the training sample (±15%)
  - Transverse momentum change slope of training sample
  - Change in $dN/d\eta$ of training sample
    - Broadening to $\Delta\eta = 10$, tightening to $\Delta\eta = 2$
    - Shifting by ±3 units of rapidity

Systematics summary

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$dN/d\eta$ tightened, shifted	6%
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z-vertex selection	negligible
EPD electronics, efficiency	negligible

- EPD: number of MIPs ≤ 5, more systematic checks to be done
- Discrepancy with PHOBOS: several differences, multiple reasons possible
  - Unfolding vs correction, segmentation, simulation imperfection, neglections in raw signal