Charged particle pseudorapidity distributions measured with the STAR EPD

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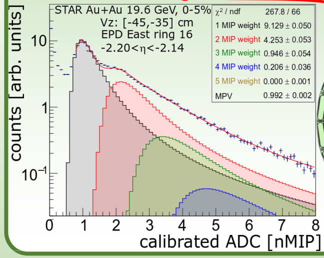
22nd Zimányi School Winter Workshop
December 5-9, 2022
Budapest, Hungary

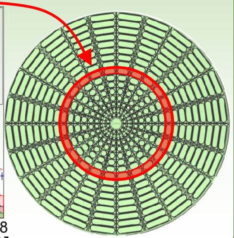
Abstract

In 2018, STAR installed the Event Plane Detector (EPD) with a pseudorapidity coverage of 2.14<|η|<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 extract 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 low 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)
- Fine 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





NIMA 968 (2020) 163970

Unfolding $dN/d\eta$

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

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

Detector response simulated via HIJING + GEANT

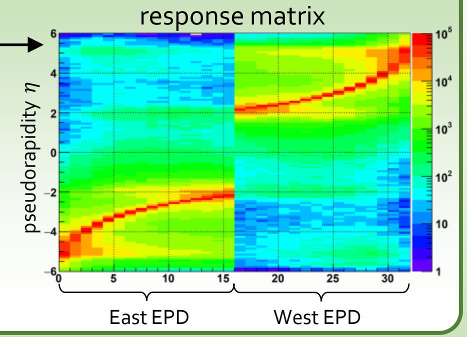
Given EPD ring yields particles mostly, but not only, at given η

Invert via unfolding: RooUnfold

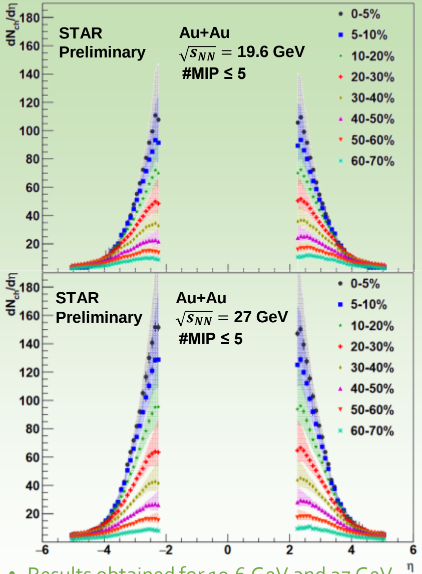
Three methods for extracting $\frac{dN_{ch}}{d\eta}$

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

Intramethod difference included in systematics



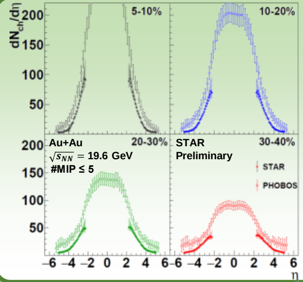
Results



- 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

Systematic uncertainties

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

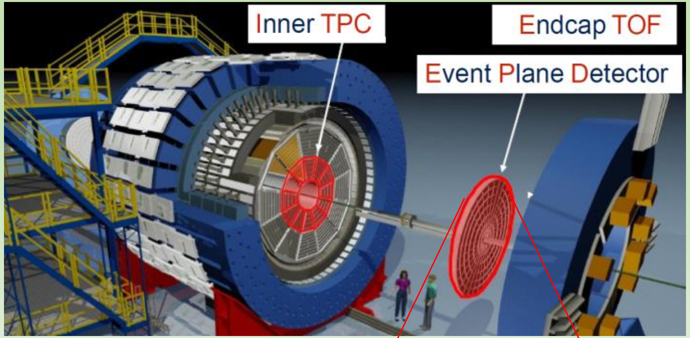
- Pseudorapidity distributions measured with the EPD
- Thorough systematic analysis
- Rapidity, centrality and energy dependence: qualitatively consistent with expectations
- Method to be extended to other $\sqrt{s_{NN}}$ values
- Inputs to model tuning
- $\sqrt{s_{NN}} = 19.6$ GeV: PHOBOS also measured $dN_{ch}/d\eta$
- Significant difference compared to PHOBOS
  - Possible reasons: unfolding vs. correction, segmentation?
  - PHOBOS papers: PRC83,024913 and PRC94,024903

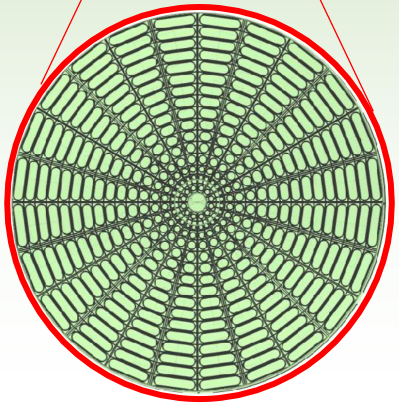
Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science
NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION OFFICE HUNGARY

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, and centrality
  - LEReC: electron cooling for low energy RHIC running
- EPD motivations:
  - Independent centrality for fluctuation measurements
  - Event plane reconstruction with a large rapidity gap
  - EP measurement also important for isobaric and BES-II data
  - Triggering for BES-II





The STAR Event Plane Detector

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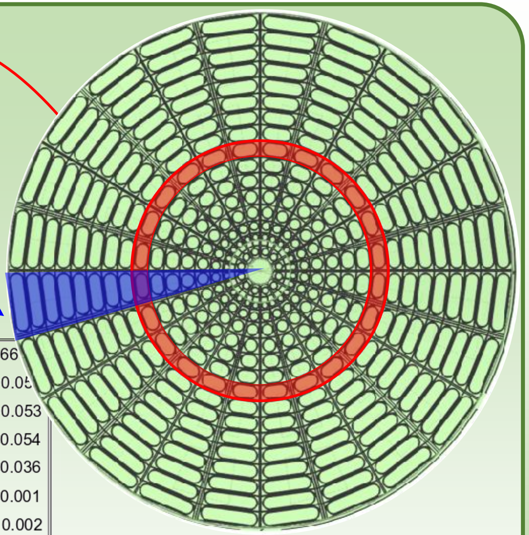
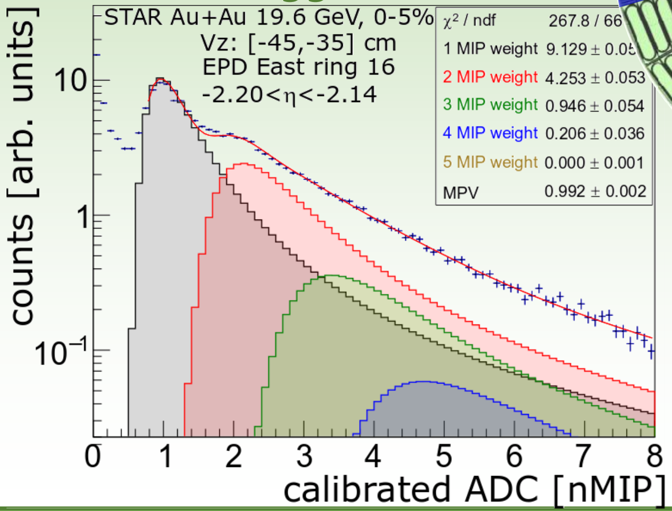
- Much higher granularity compared to BBC
  - BBC: 36 tiles (only 18 inner used) ⇒ EPD: 372 tiles
  - Also larger acceptance: [3.3,5.0] ⇒ [2.1,5.1]
  - 16 radial segments (rings)
  - 24 azimuthal segments (sectors)
- Radial segmentation driven by flow, vertex, trigger
- Azimuthal segmentation driven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

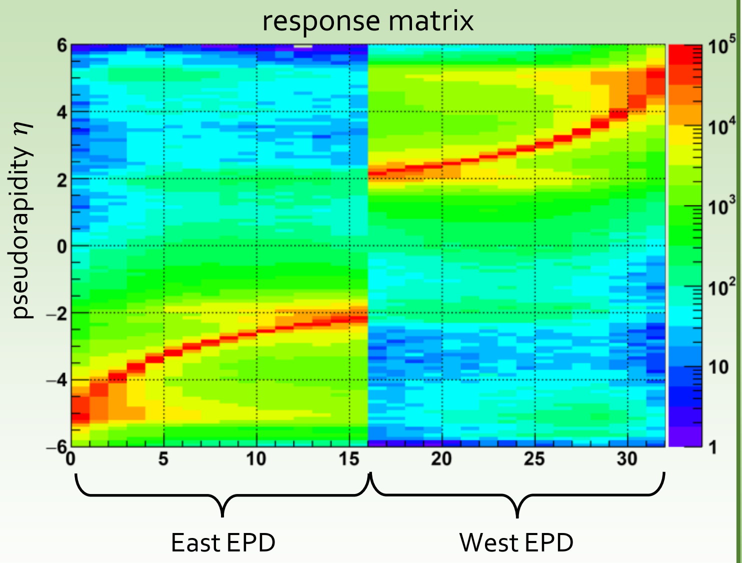




The EPD Response Matrix

- 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**, associated to the primary track
- The above is possible in HIJING+GEANT simulation
  - 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)
  - Change in charged/neutral ratio in the training sample (±15%)
  - Change in transverse momentum slope in the 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
- 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

Systematics summary

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