STAR
Event Plane Detector Upgrade

Prashanth Shanmuganathan
*(For the **STAR** Collaboration)*
Lehigh University

Talk Outline

- **Motivation for an Event Plane Detector**
- **Design and Construction**
- **2017 Engineering Run Achievements**
- **Preparations for full Installation (2018)**

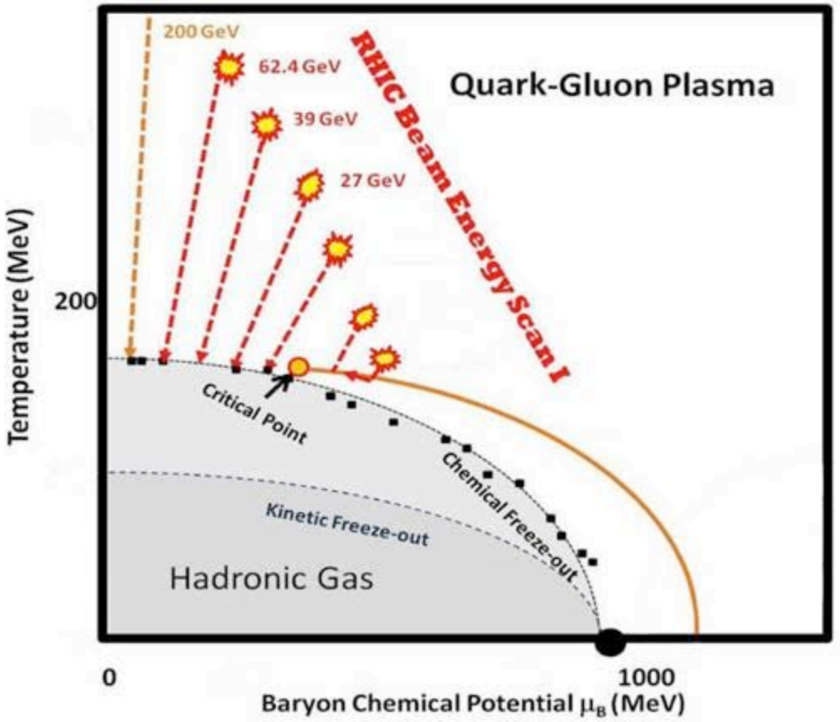
LEHIGH UNIVERSITY

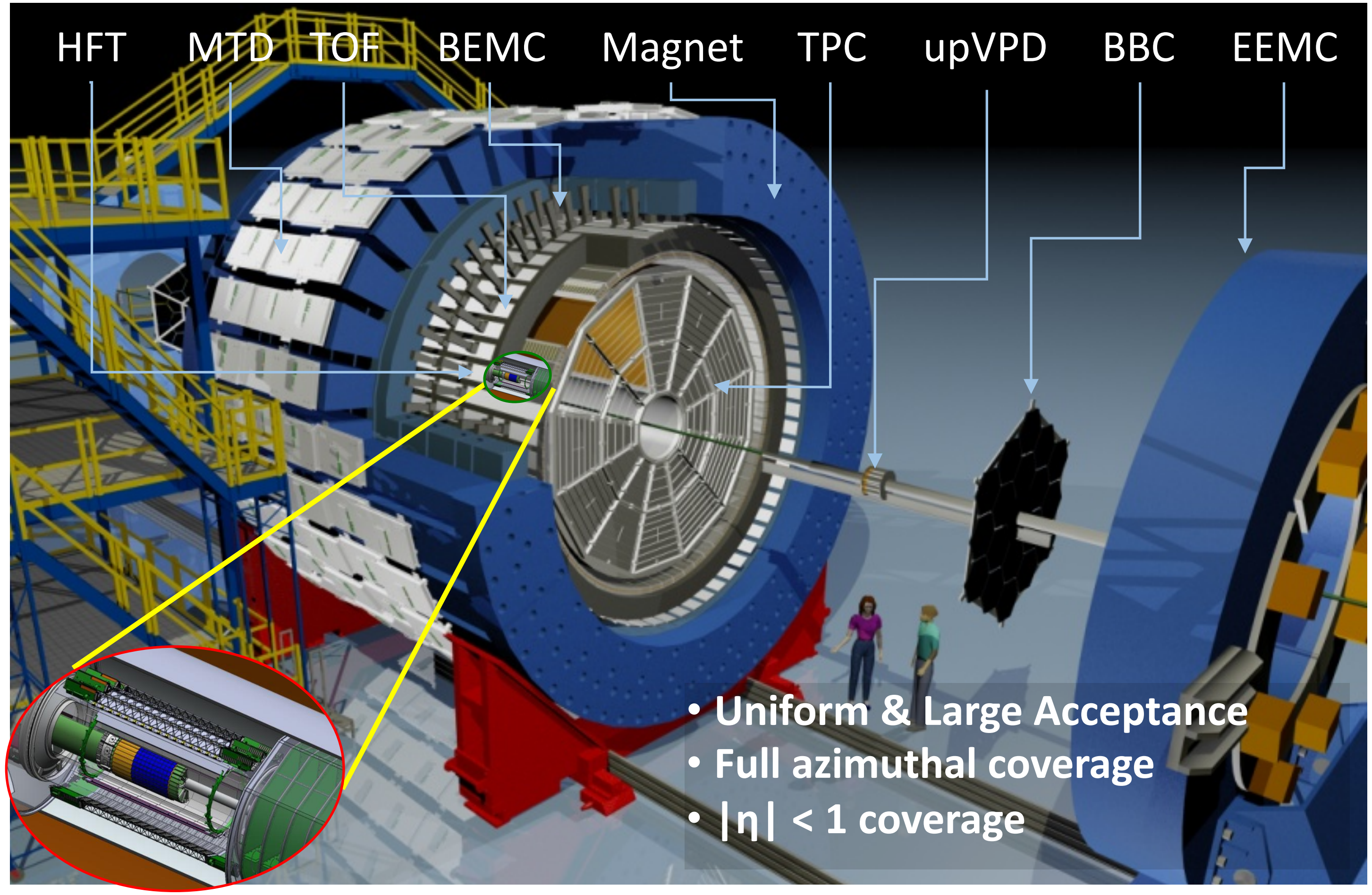
STAR

U.S. DEPARTMENT OF ENERGY | Office of Science

NSF

BES Program at STAR



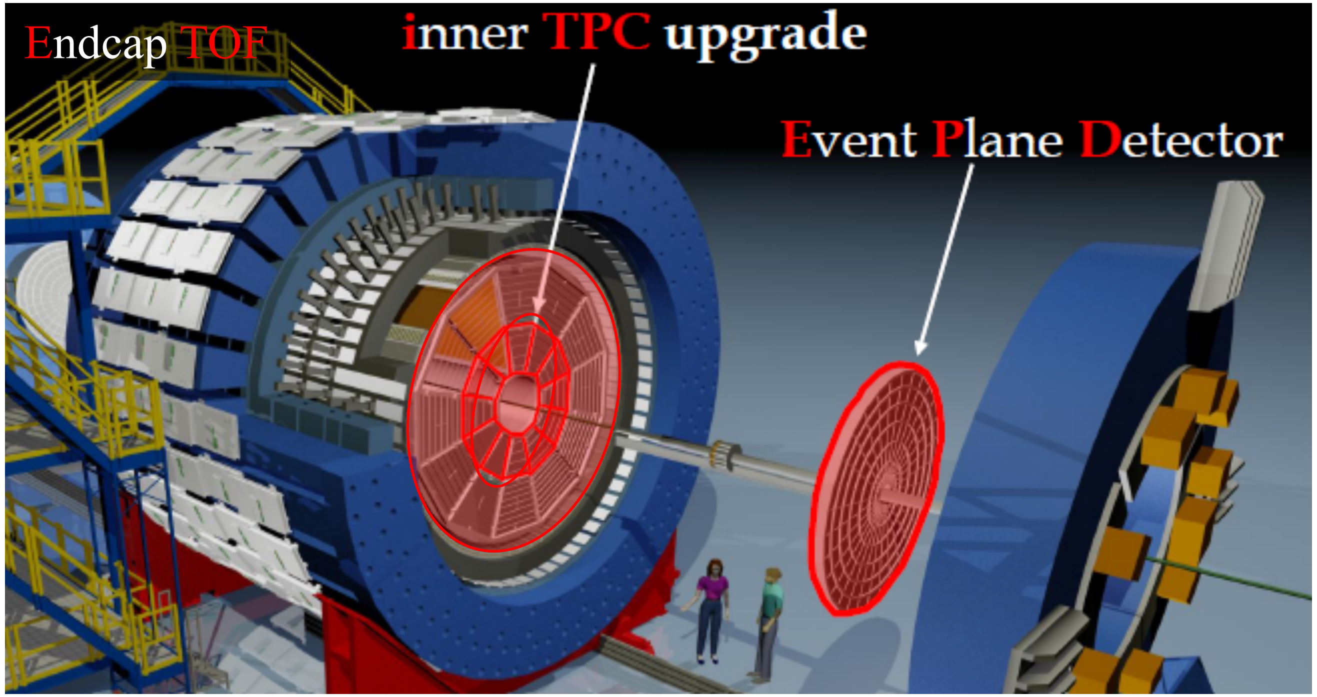


Goals of BES :

Explore QCD phase diagram

- Search for a Critical Point
- Signatures of Phase Transition
- Map turn-off of QGP signatures

Upgrades



eTOF $\boxed{\text{EPD}}$ iTPC Larger Acceptance

$\boxed{\text{EPD}}$
- Independent Centrality definition & better Event plane resolution

iTPC eTOF
- Improved PID capabilities

$\boxed{\text{EPD}}$ LEReC*
- Higher Statistics (CAD) & Improved Trigger

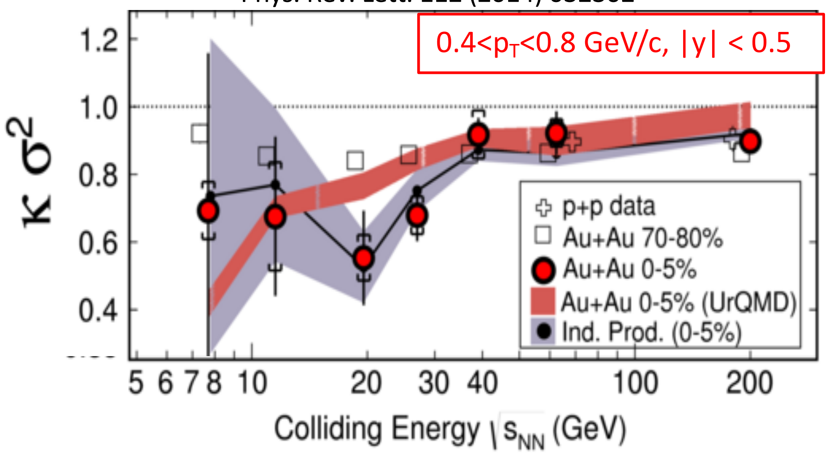
*LEReC: Accelerator Upgrade
Electron Cooling for low energy RHIC running
Increase luminosity

Motivation for an Event Plane Detector

- Fluctuation analyses Esha, Monday 10:00 Llope, Thursday 9:00
  - Moments, Forward-Backward correlations and Balance functions
  - Needed =>Independent Centrality Measurement
- Flow measures & Correlations Singha, Tuesday 9:00 Wen, Wednesday 9:00 Upsal, Wednesday 11:00
  - Directed Flow & Higher Harmonics, Global Λ Polarization, HBT, CME & CMW
  - Needed => Improved Event Plane Resolution
  - Iso-Baric Run next year (Ru+Ru & Zr+Zr)
- Fixed Target Collisions Meehan, Friday 9:00
  - Improved independent reaction plane measurement
- Trigger on Good Collisions in high luminosity environment (BES-II)

Independent Centrality Measurements: Moments

Phys. Rev. Lett. 112 (2014) 032302



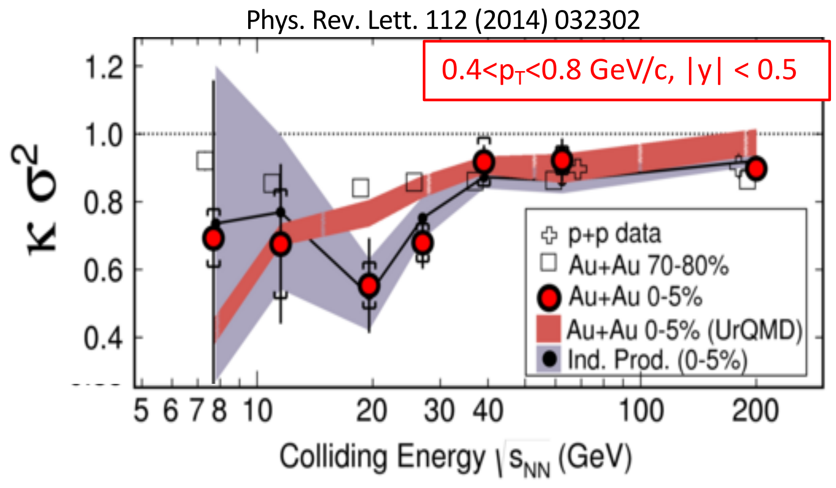
- Near CP ratios of cumulants ($\kappa\sigma^2$ or $S\sigma$) of the net-particle multiplicity distributions should diverge

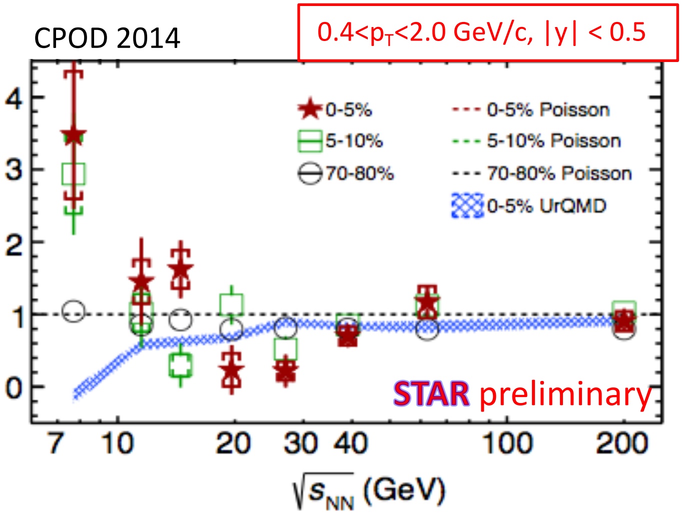
  =>2-3σ deviation from Poisson distribution seen

Esha, Monday 10:00

Llope, Thursday 9:00

Independent Centrality Measurements: Moments





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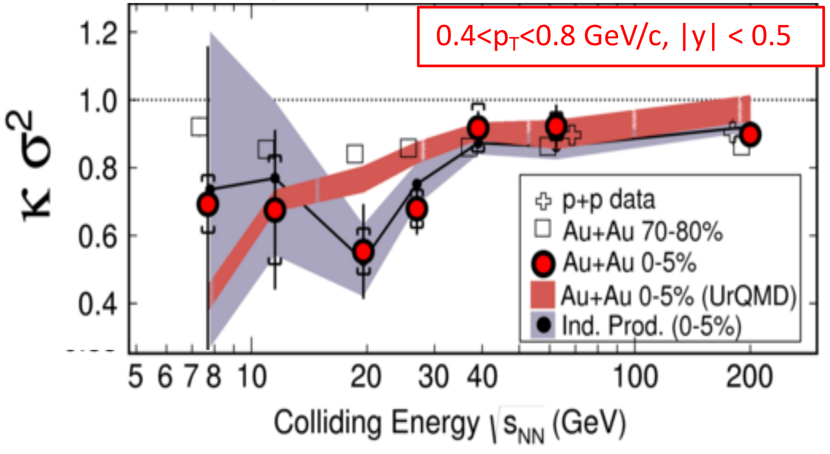
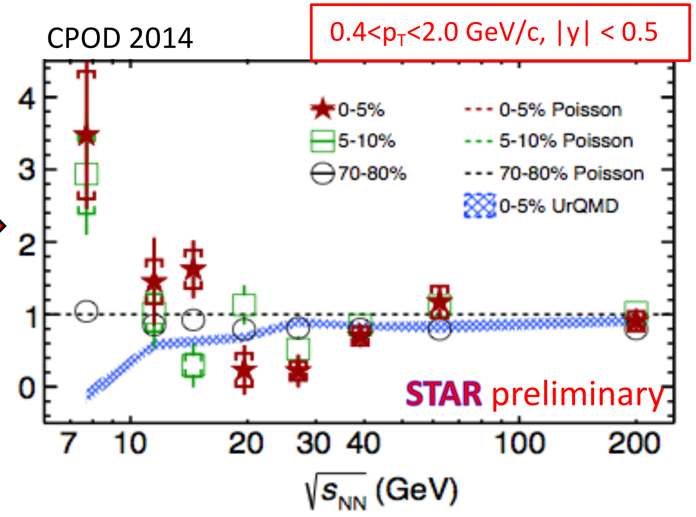
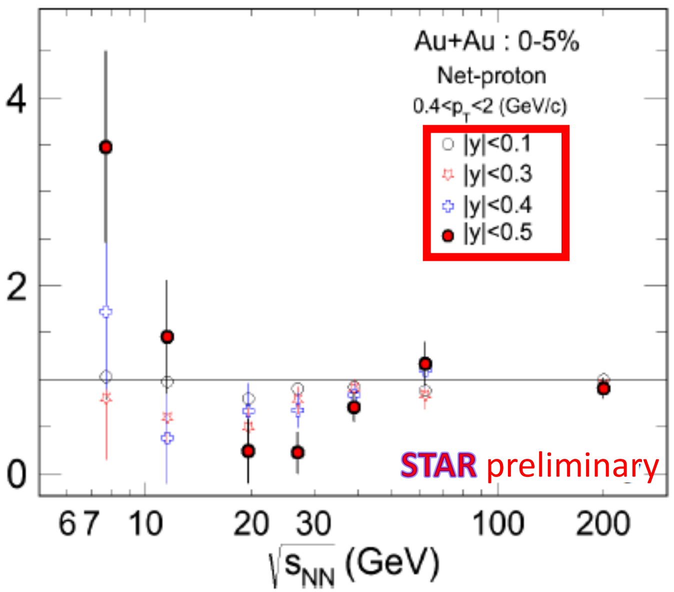


CPOD 2014



QM2015



- Near CP ratios of cumulants ($\kappa\sigma^2$ or $S\sigma$) of the net-particle multiplicity distributions should diverge

  =>2-3σ deviation from Poisson distribution seen

Limitation in Analysis

- Large uncertainty (Limited statistics)
- Need wider p_T acceptance
- Need wider y acceptance
- Centrality determined within mid-rapidity

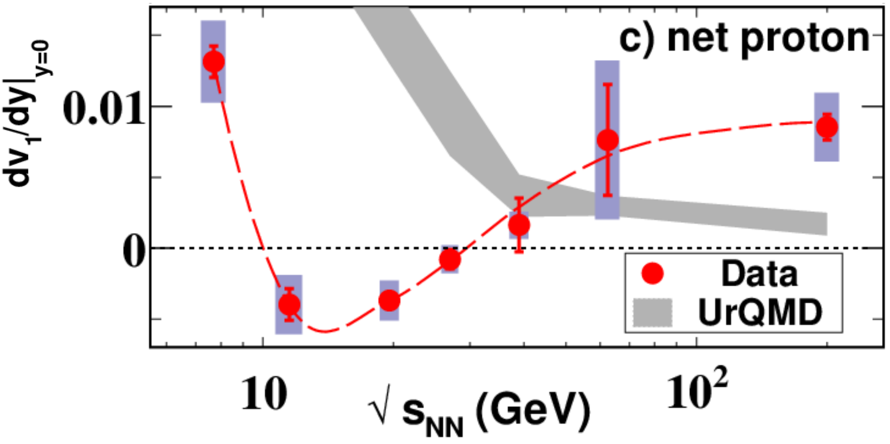
  => Sacrificed TPC acceptance

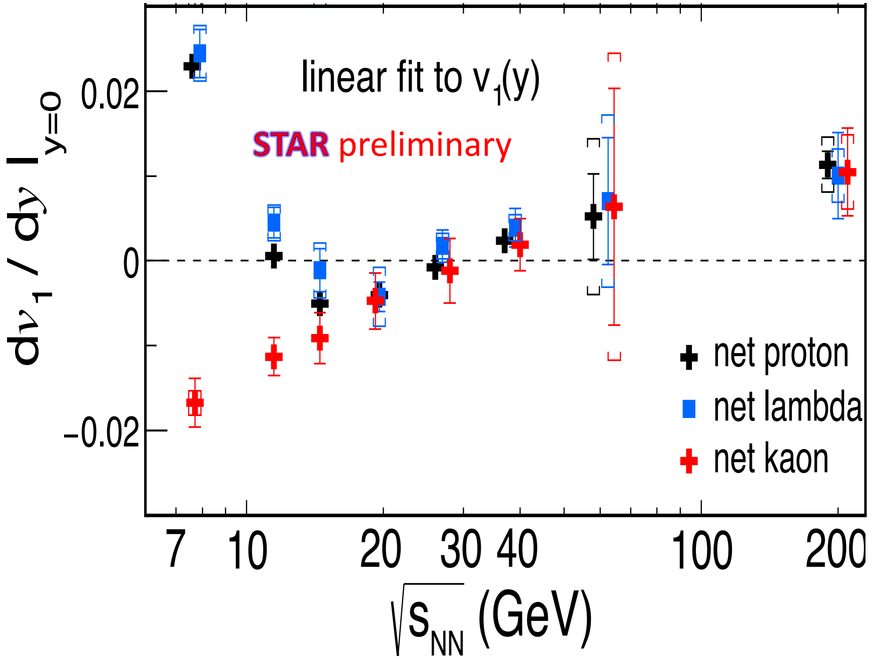
Esha, Monday 10:00

Llope, Thursday 9:00

Event Plane Estimation: Directed Flow

Phys. Rev. Lett. 112 (2014)]

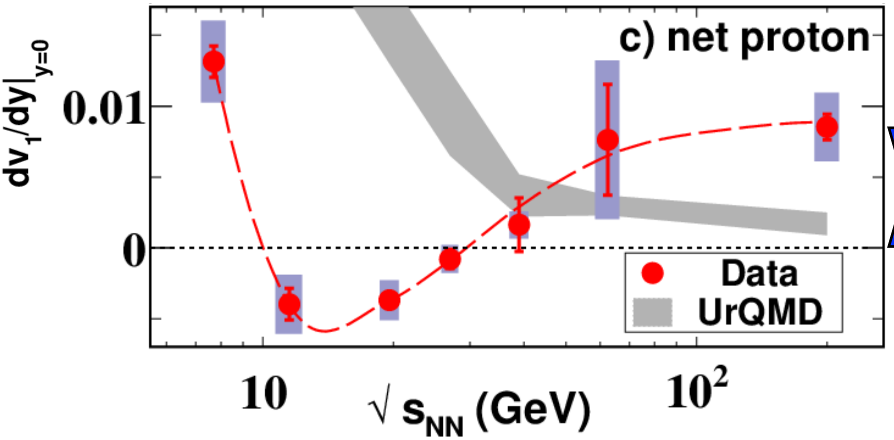


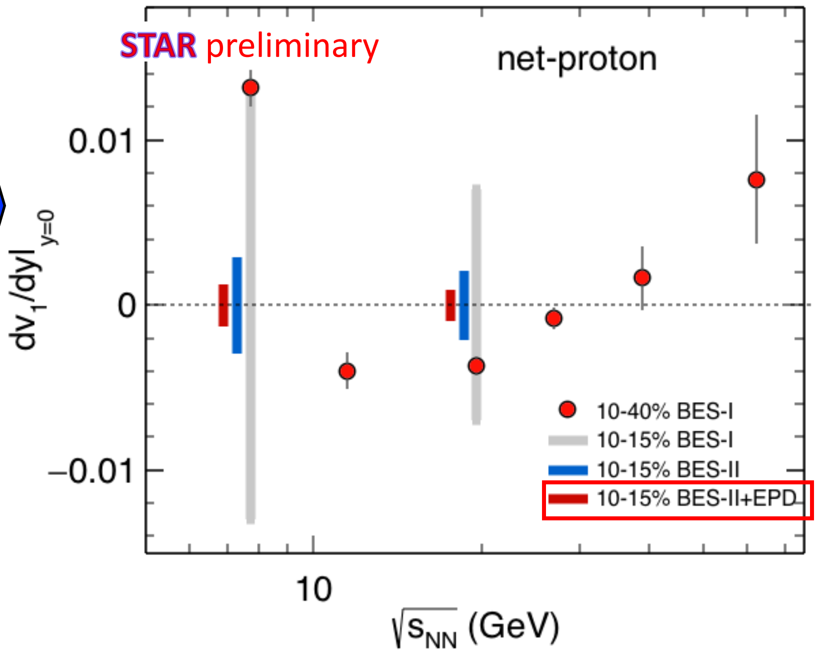


- Hydro calculations suggests minimum in baryon dv_1/dy vs. beam energy is softening of EOS
- Softening of EOS can be interpreted as 1^{st} order phase transition
    - Proton dv_1/dy shows a minimum
    - Λ – baryons dv_1/dy shows similar trend

Singha, Tuesday 9:00

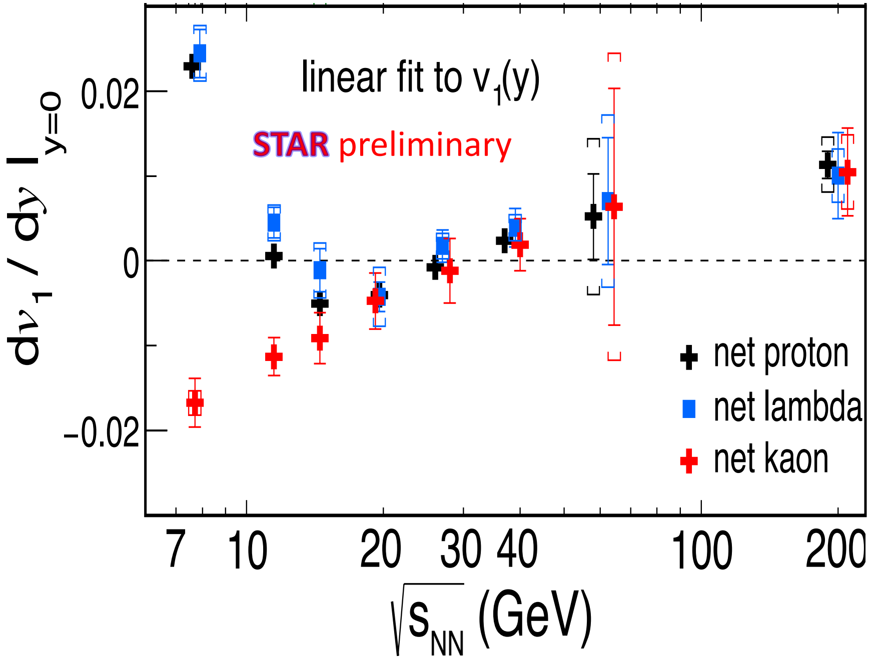
Event Plane Estimation: Directed Flow





Limitation in analysis

- Poor reaction plane resolution
- Systematic analysis of centrality dependence
- Large uncertainty (Limited statistics)



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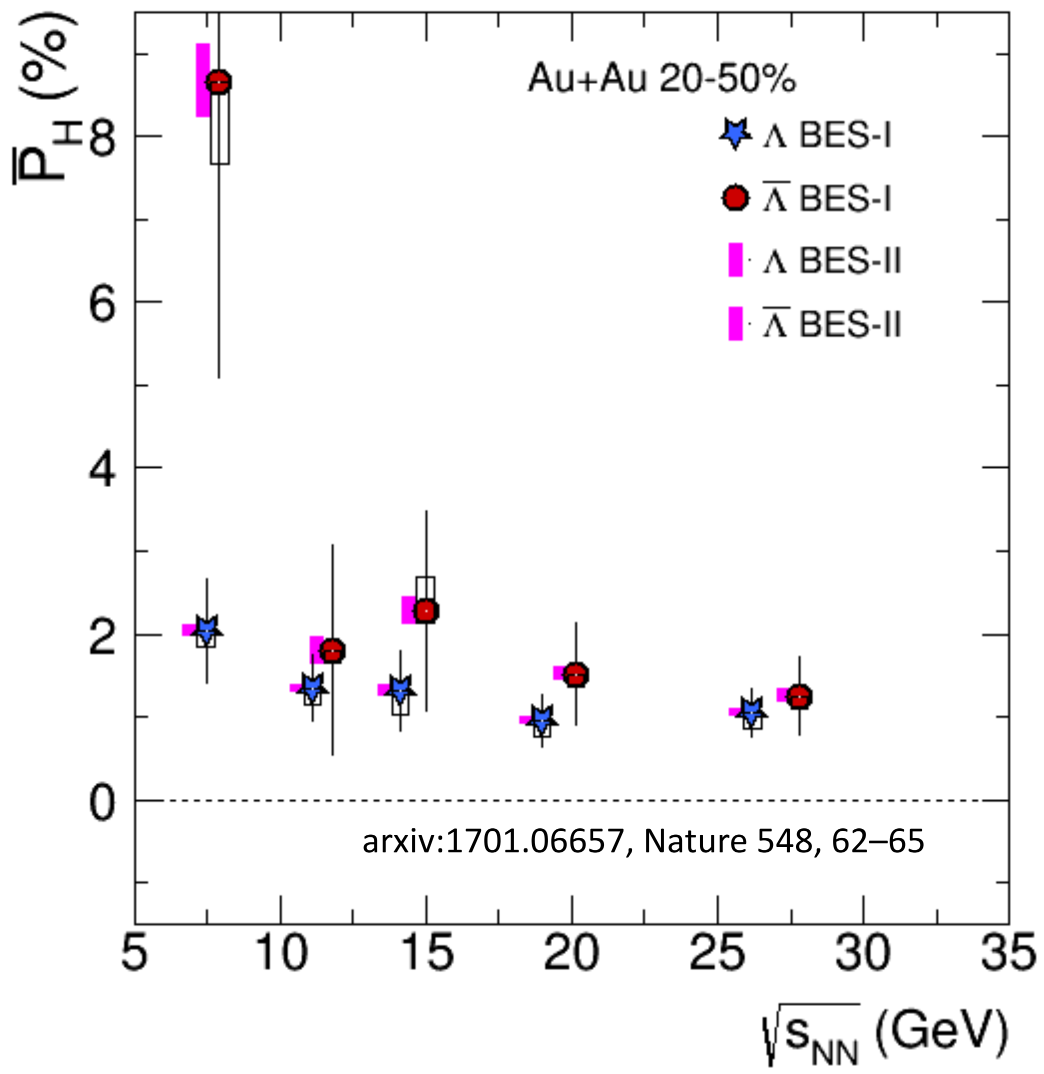
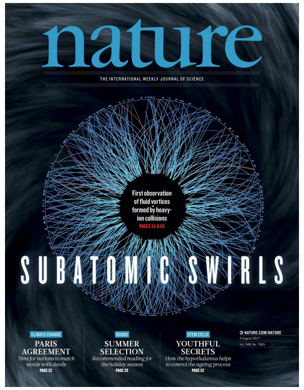
Singha, Tuesday 9:00

Event Plane Estimation : Polarization Measurements



- Lambda global polarization as a probe of fluid vorticity
- Λ and anti-Λ shows positive polarization
- Analysis is challenged by statistics and Event Plane Resolution
- Enhanced precision using 1 billion minimum bias events and EPD

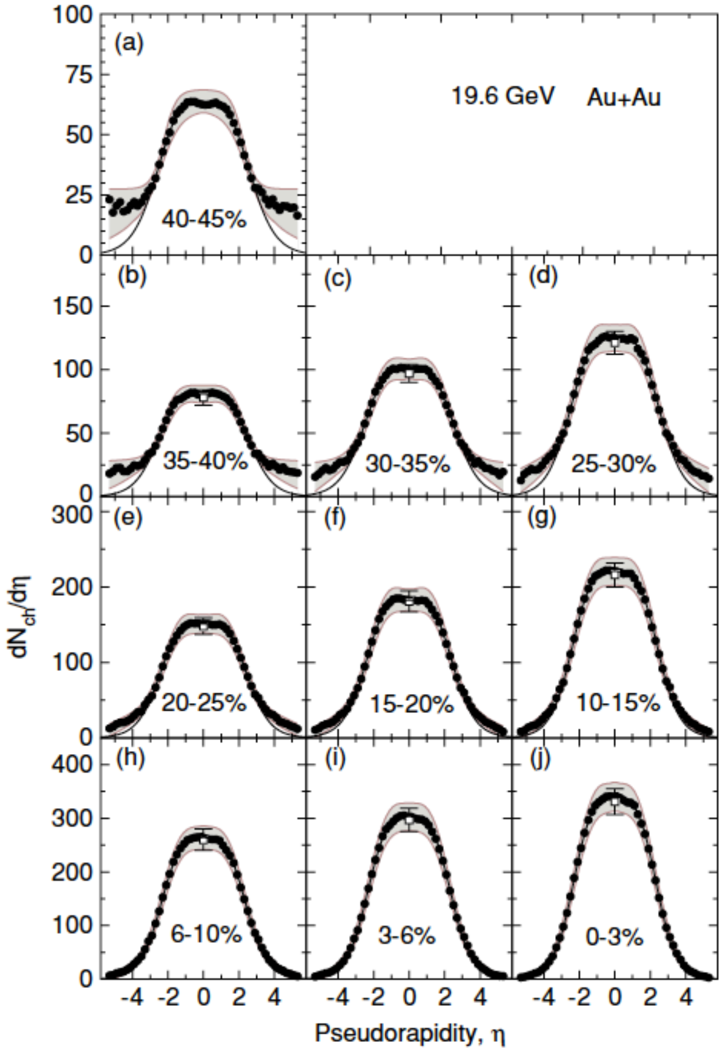


Upsal, Wednesday 11:00

Forward $dN_{ch}/d\eta$ Measurements

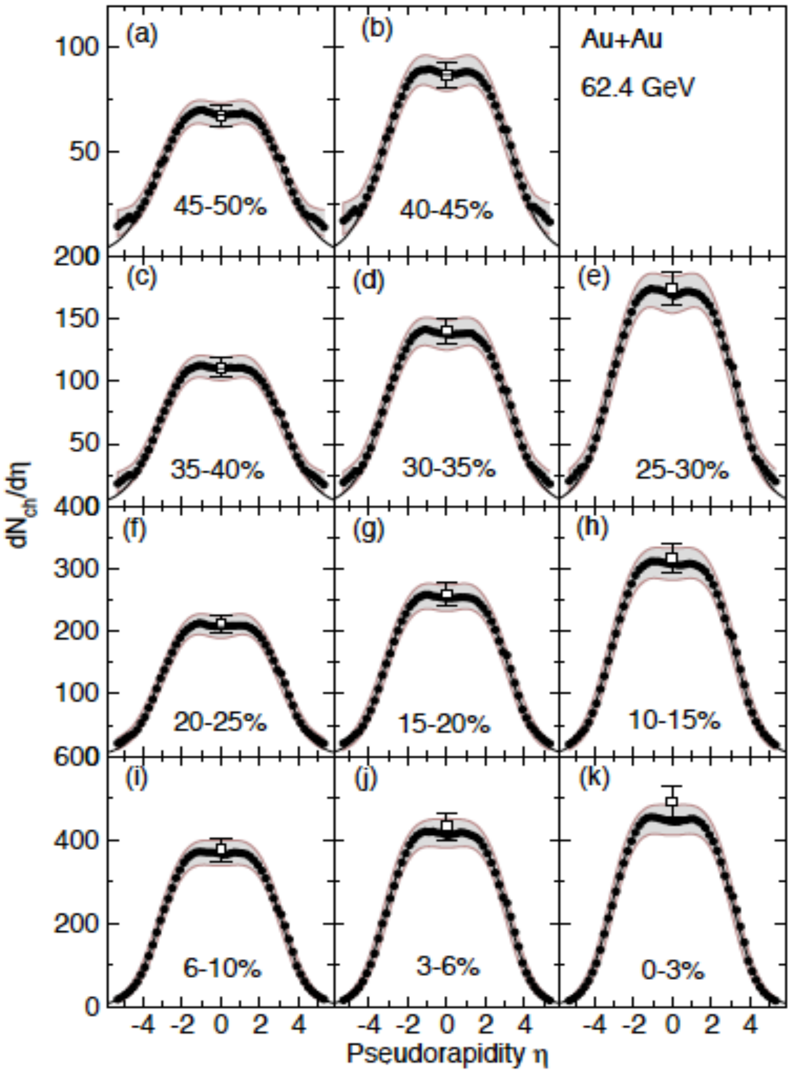
PHOBOS PRC 83, 024913

Au+Au 19.6 GeV



Expected multiplicity in EPD ~ 150-400

Au+Au 62.4 GeV



Expected multiplicity in EPD ~ 900

Forward $dN_{ch}/d\eta$ Measurements

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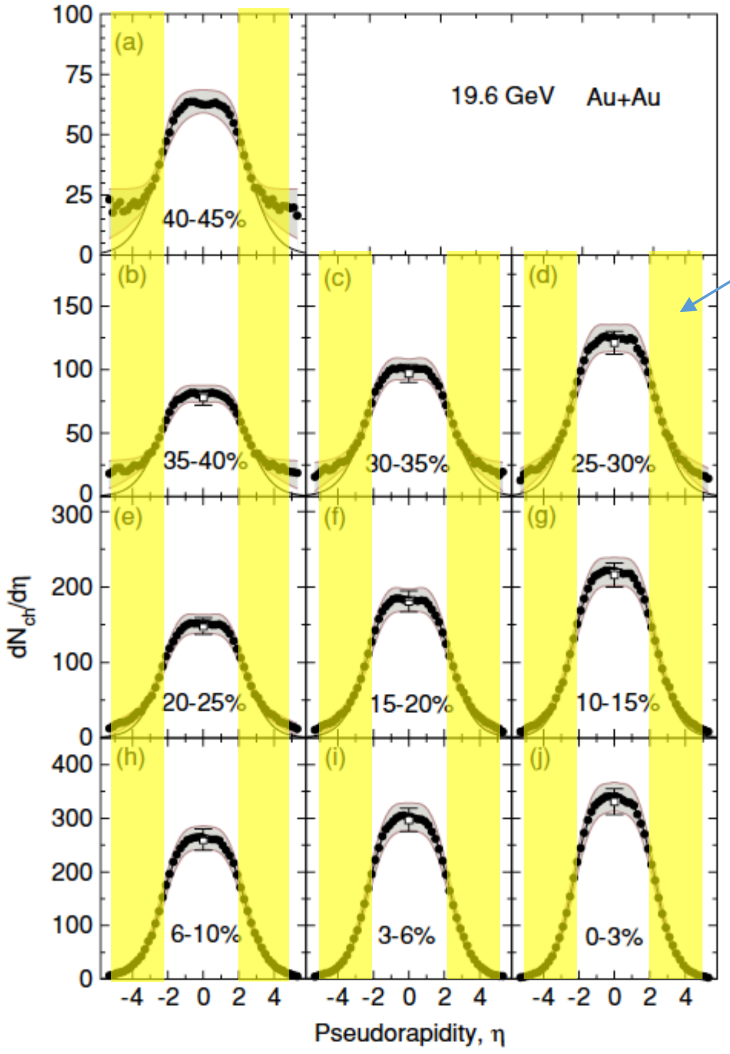
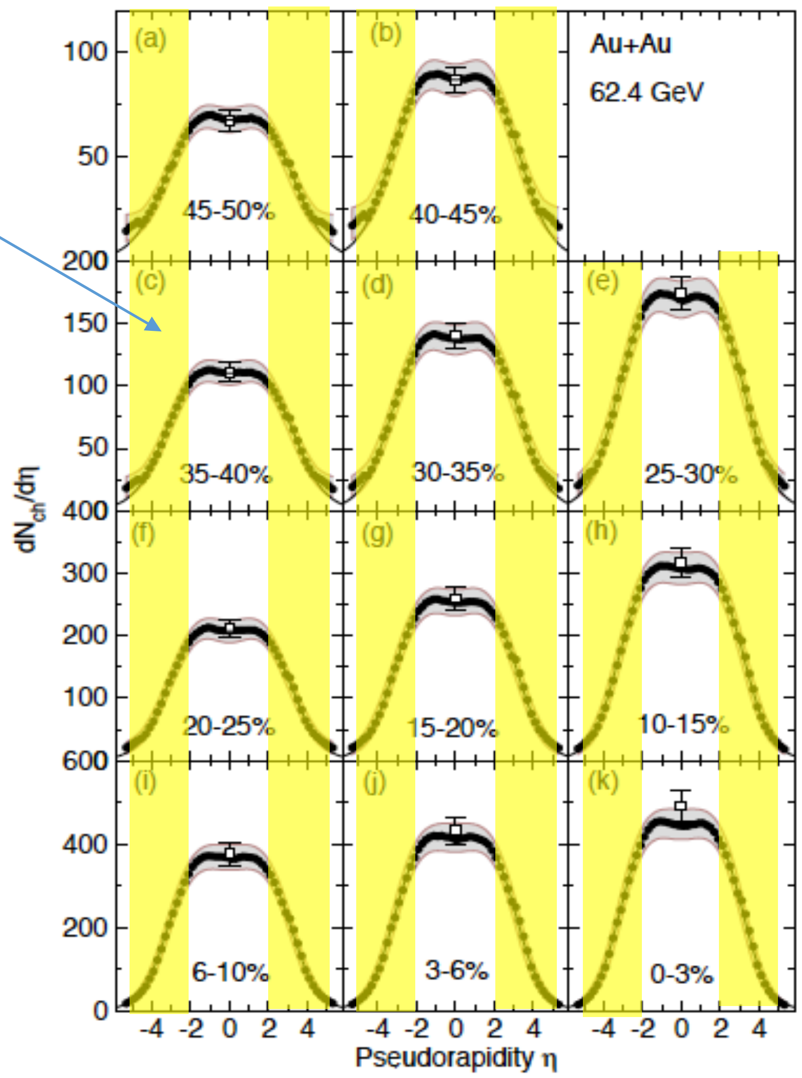


EPD acceptance

Au+Au 62.4 GeV



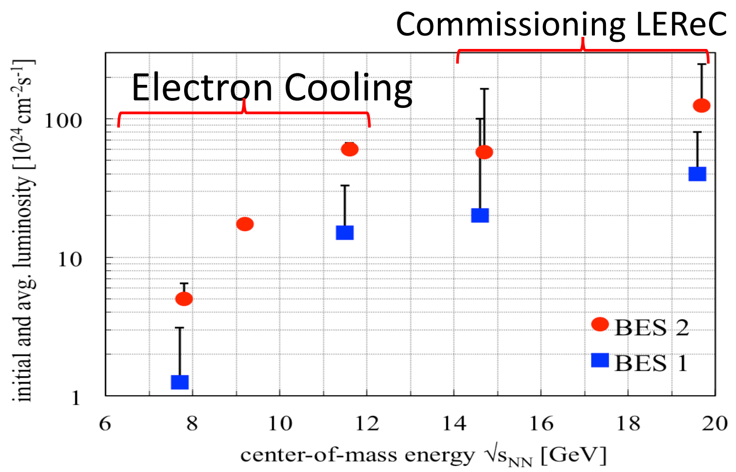
Expected multiplicity in EPD ~ 150-400

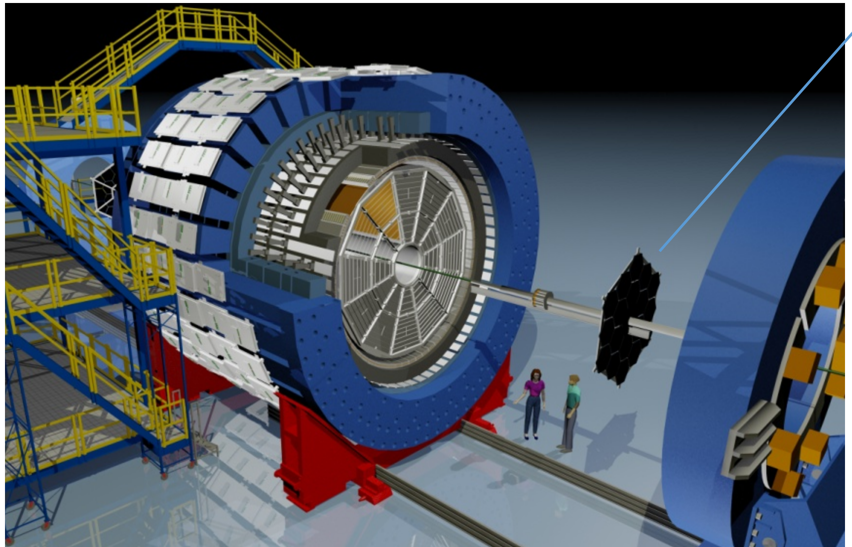
Expected multiplicity in EPD ~ 900

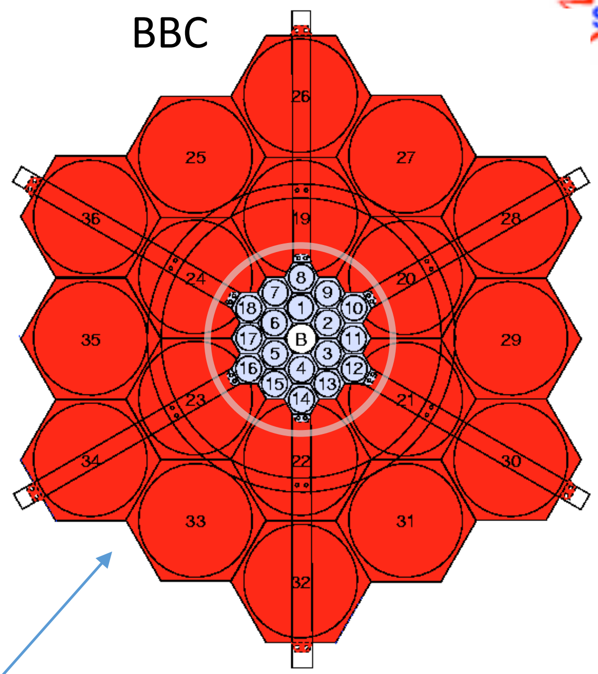
Design and Construction

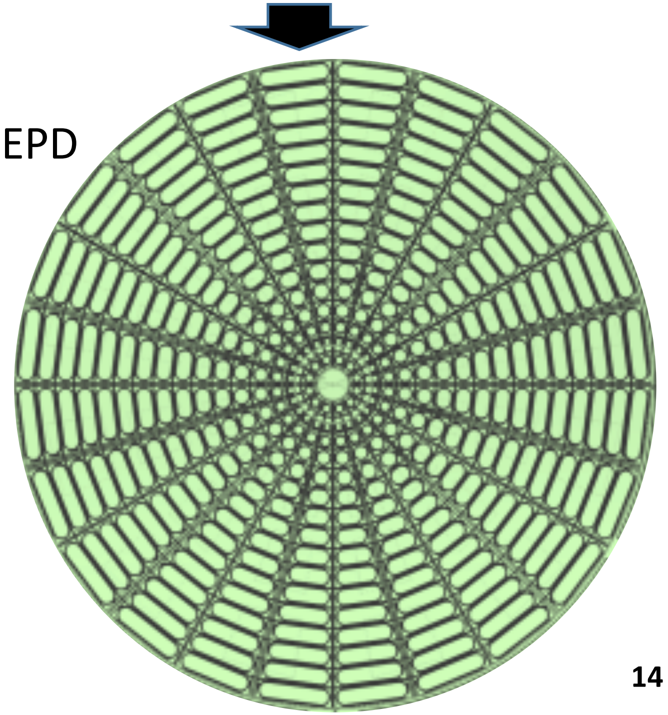
EPD Design Features

- EPD is proposed to complement/replace the Beam-Beam-Counter (BBC):
  - Higher Granularity
  - Larger Acceptance
  - To be placed in the location of BBC (z = ± 375 cm from the center of TPC)
  - Radially 4.5 cm to 90 cm from beam axis
  - Improved Trigger Capabilities at high-luminosity collisions for BES-II

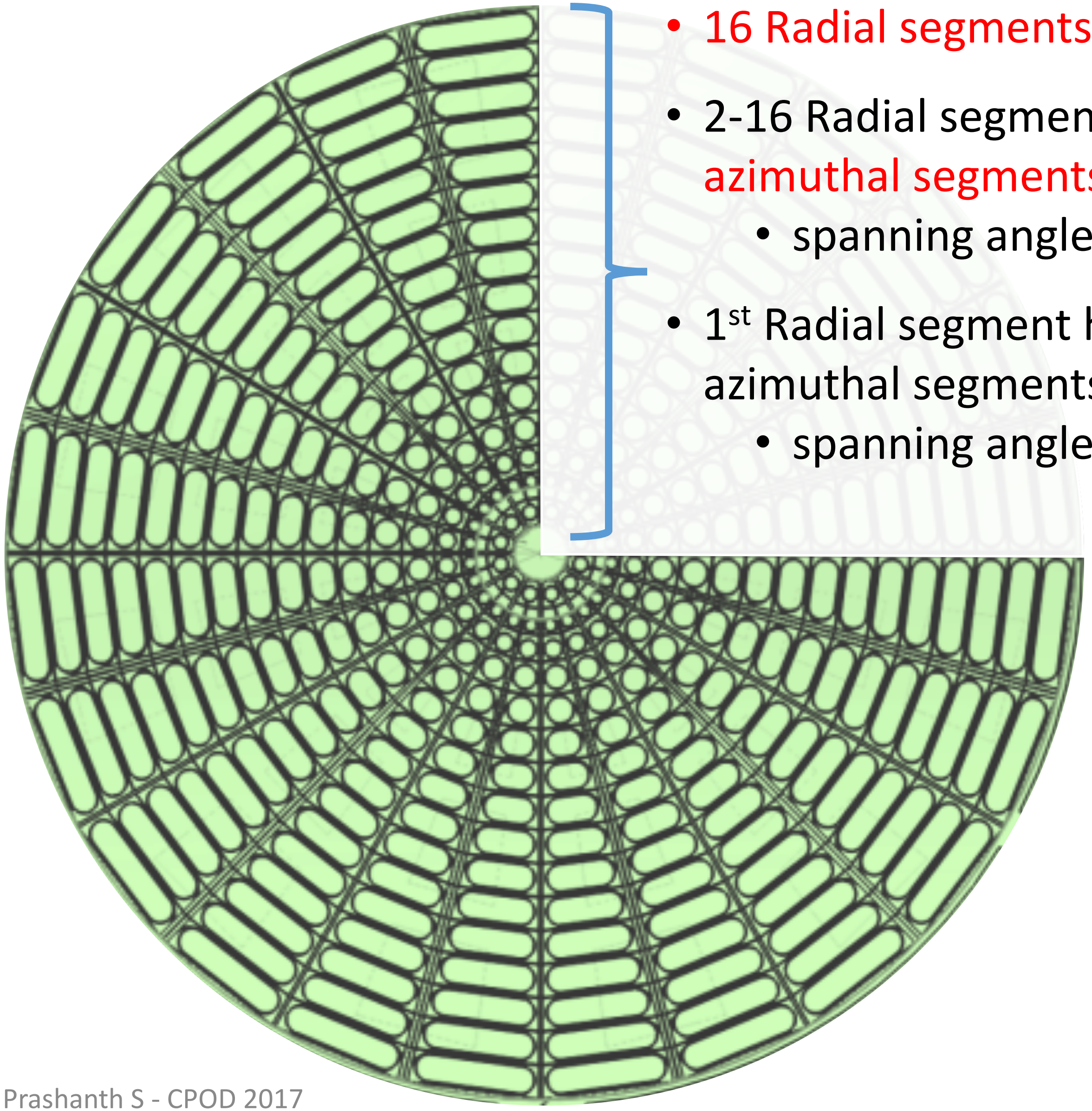








EPD Design

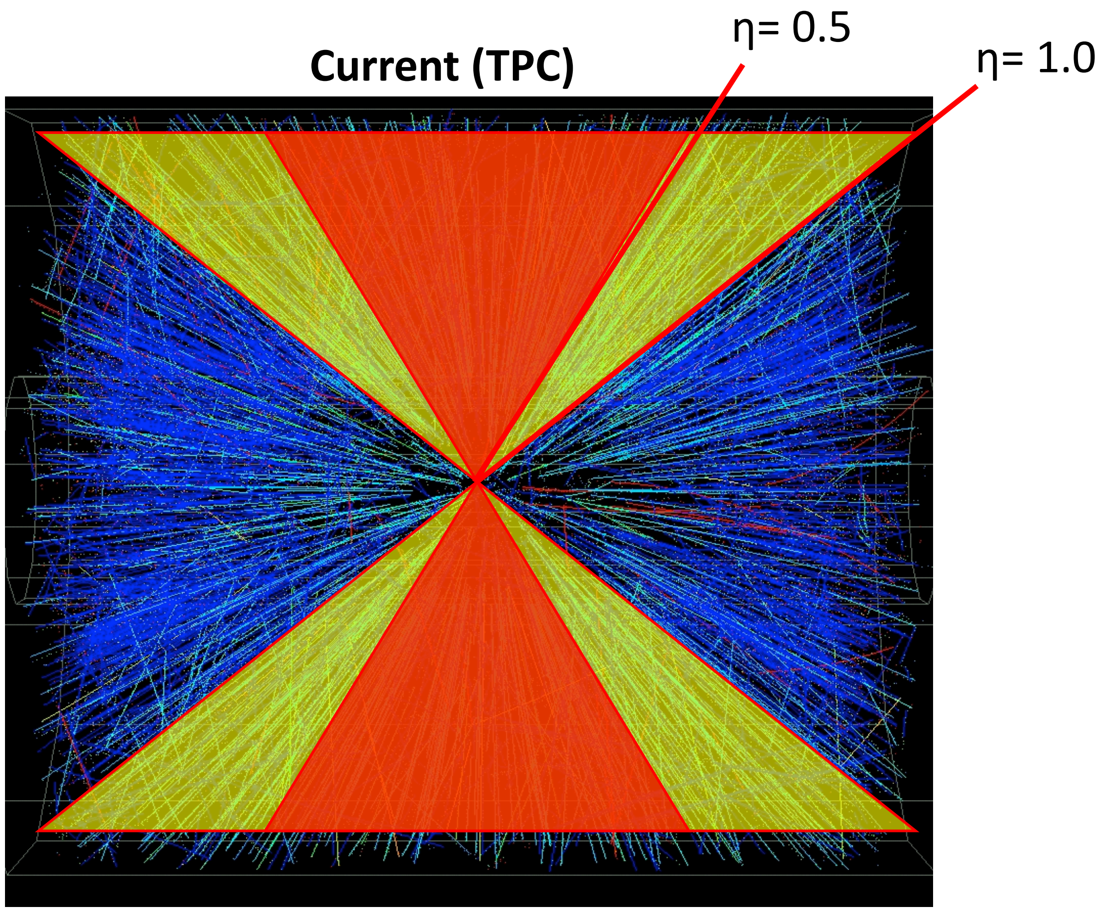


- 16 Radial segments
- 2-16 Radial segments have 24 azimuthal segments
  - spanning angle of 15^0
- 1st Radial segment has 12 azimuthal segments
  - spanning angle of 30^0

- Radial segmentation driven by many aspects like directed flow, z-vertex position, trigger etc
- Azimuthal segmentation is driven by higher flow harmonics
- Tile structure is optimized for less than 10% multi-hit probability in a same tile at 19.6 GeV from PHOBOS measurements

Phys. Rev., C83:024913, 2011

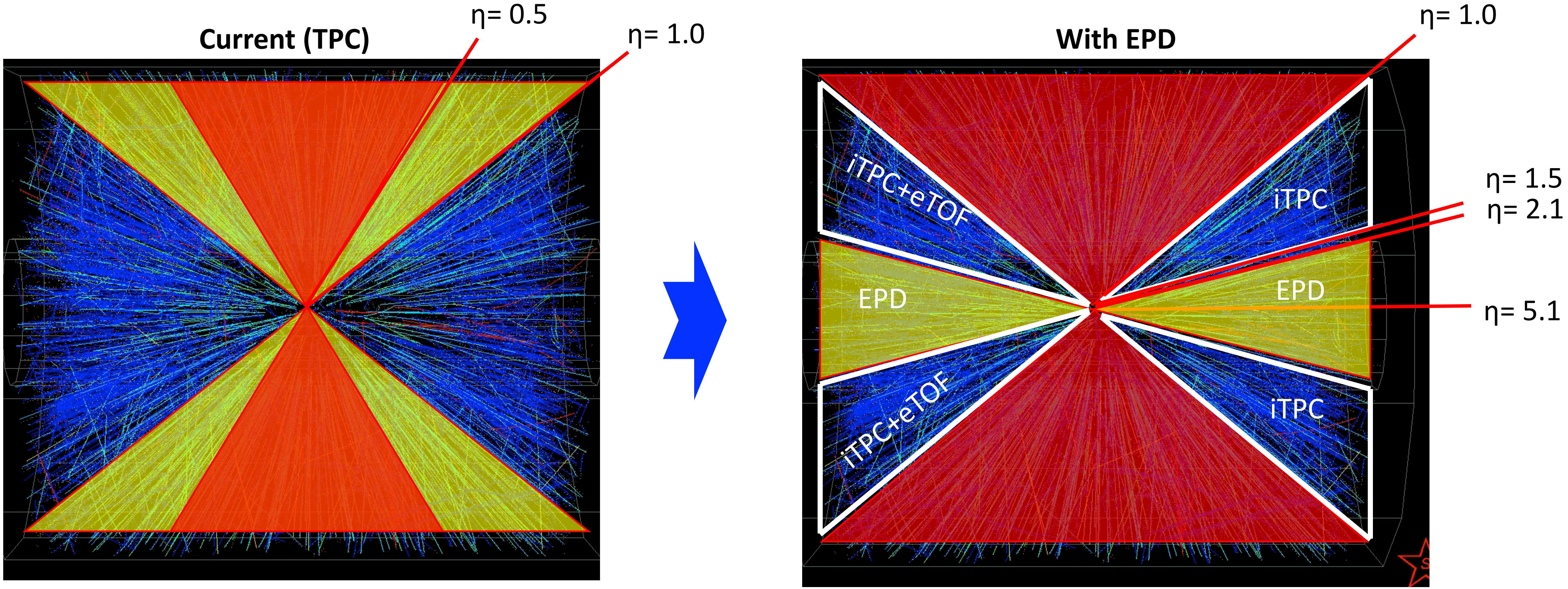
EPD Measures Centrality Outside of Mid-Rapidity



*Red region: Analysis/Study
*Yellow region: Centrality estimation

A small change in phasespace => Qualitatively different results

EPD Measures Centrality Outside of Mid-Rapidity
=> Allows Full use of TPC acceptance



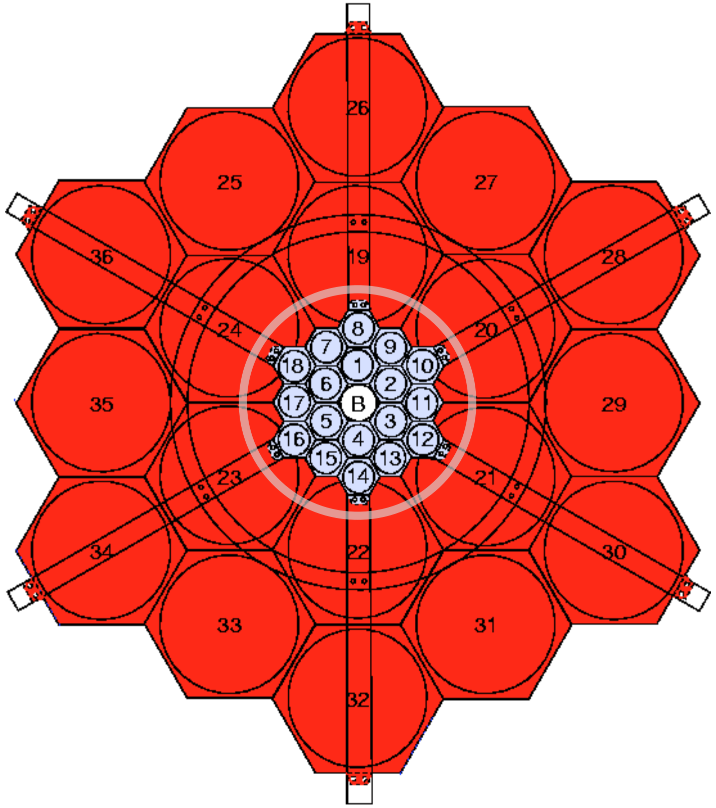
*Red region: Analysis/Study
*Yellow region: Centrality estimation

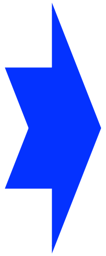
A small change in phasespace => Qualitatively different results

EPD - Improves Event Plane Resolution

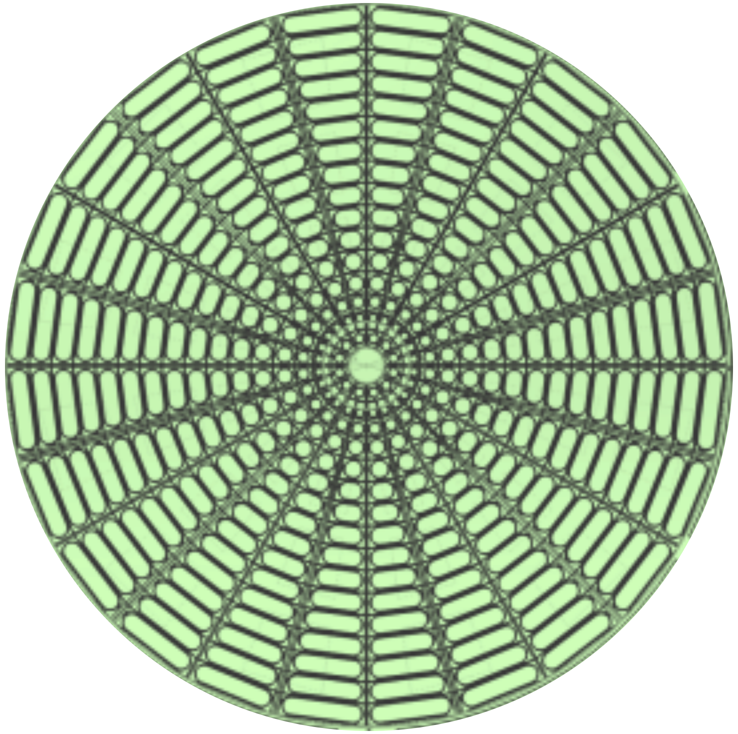
BBC

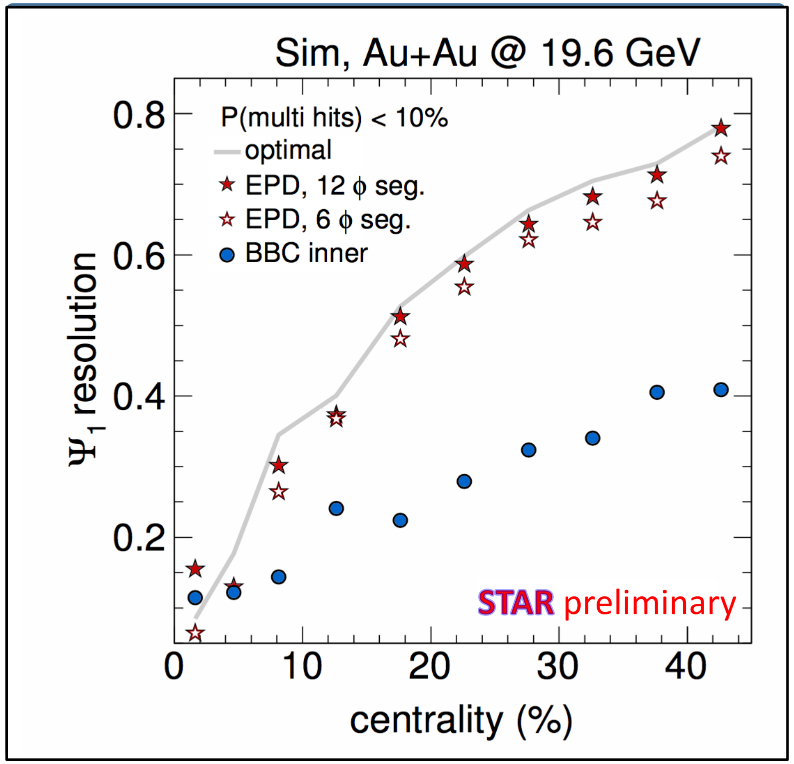
(Beam Beam Counter)





EPD





36 tiles, *only 18 inner tiles used*

372 tiles
16 eta segments
24 phi segments (12 at highest eta)

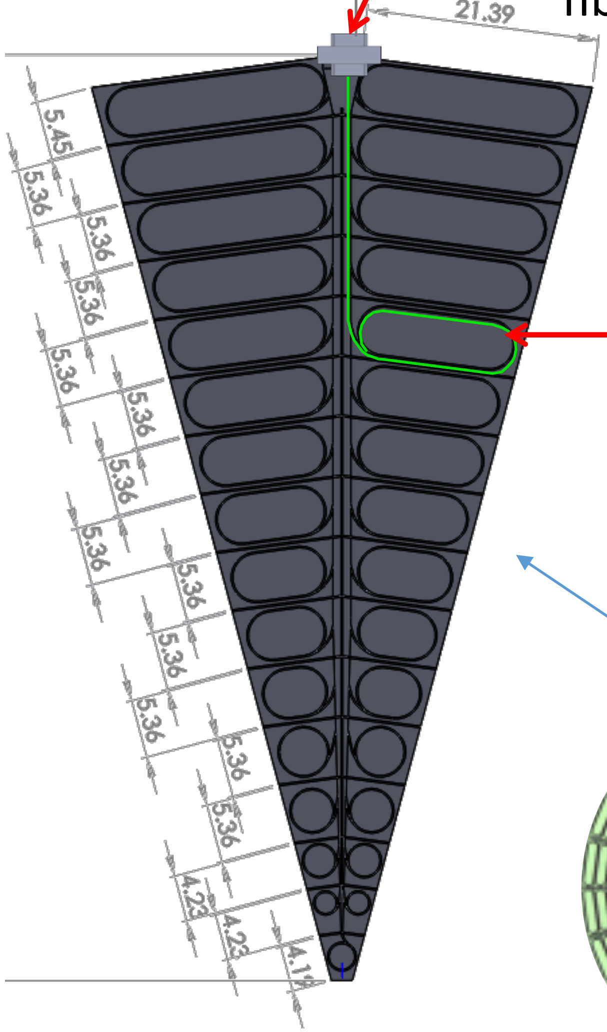
$3.3 < |\eta| < 5.0 \rightarrow$ **$2.1 < |\eta| < 5.1$**

Design- Scintillator

- 2 Wheels, each composed of 12 ‘super-sectors’
- Super-sectors :Scintillator wedges, milled to form 31 tiles each
  - Optically separated by TiO_2-loaded epoxy
- 3 turns of WLS fiber
  - 3 turns ~doubles light output relative to 1 turn

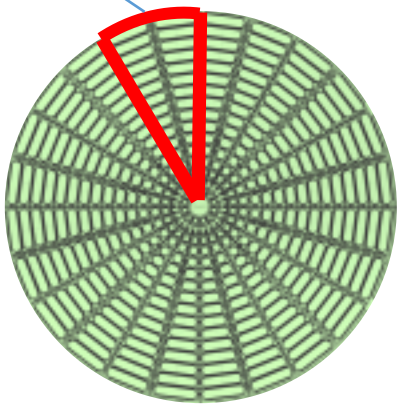
Clear fibers

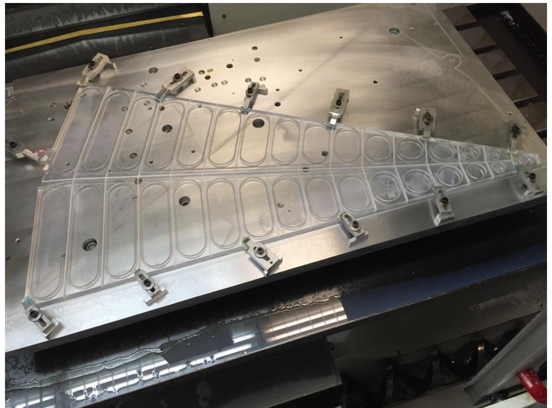
31-channel fiber-to-fiber connector



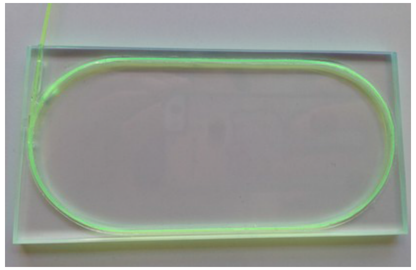
Embedded WLS fibers

1/12 of a wheel

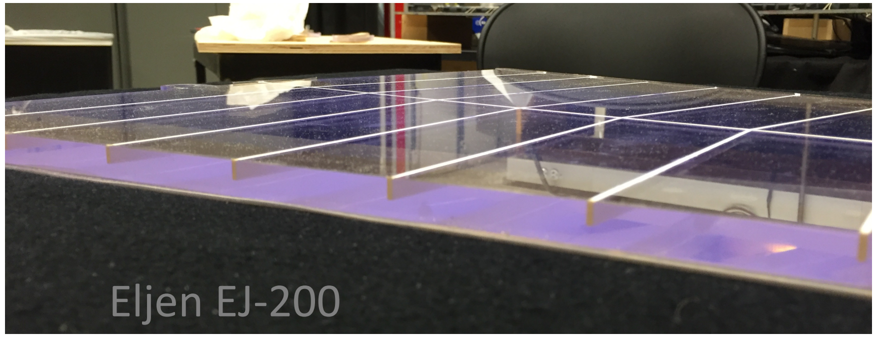




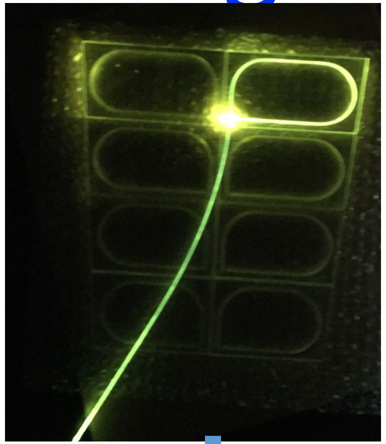
A test tile



Half milled Super-sector



Design- Light Collection

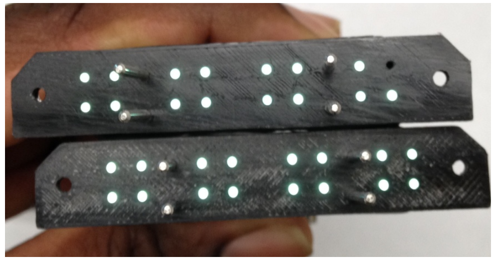


3D-printed custom connectors

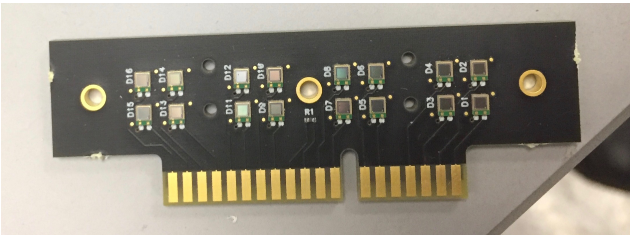
- Wavelength-shifting fiber transports light to outer-edge connector
- Contact connection to 5.5-m optical fiber bundles
- Read out by 25 μm-pixel silicon photomultipliers and custom front-end electronics
- Existing electronics are used to digitize and trigger

31 channel, 5.5 m long clear fiber bundle

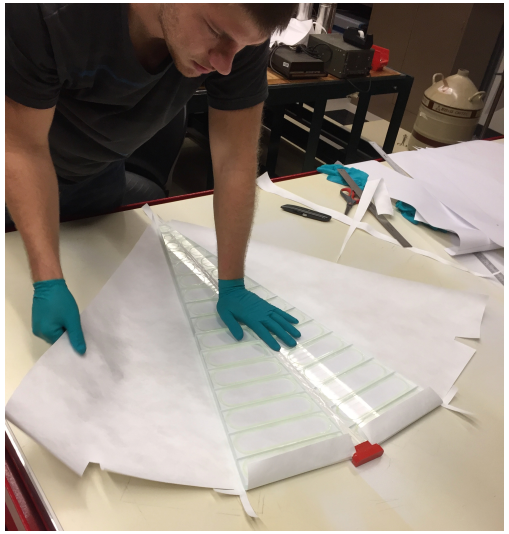
Far end of optical bundles

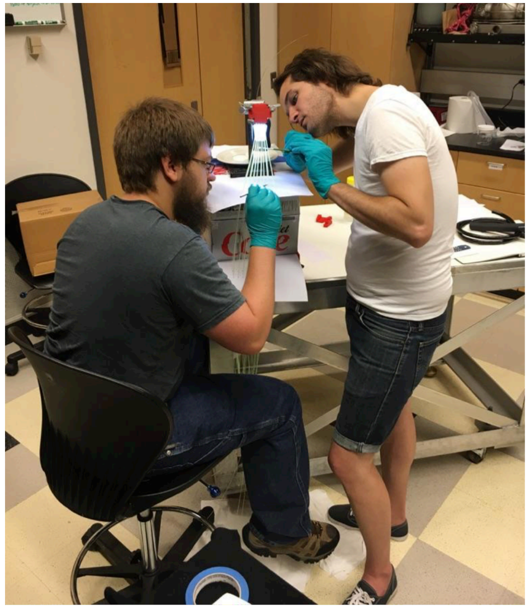


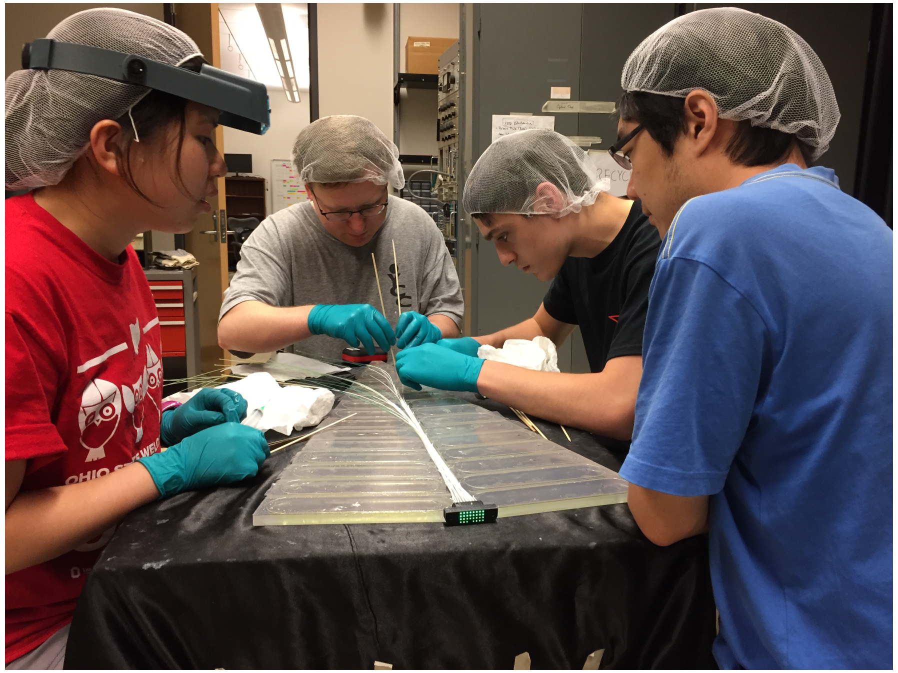
16 channel SiPM board



Preparations for full Installation (2018)



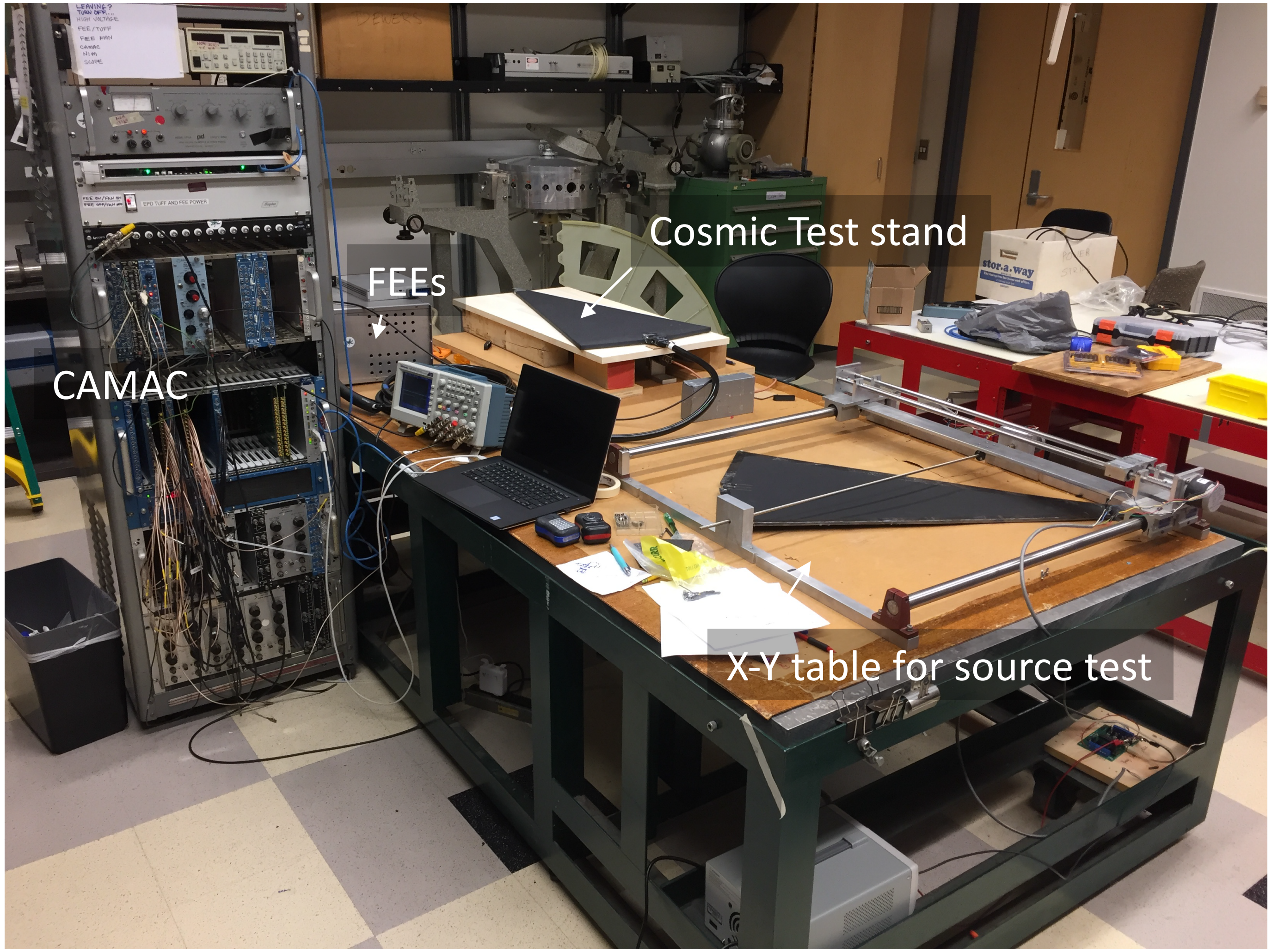




- Super-sector construction at Ohio State
- Fiber bundle construction at Lehigh University
- Electronics design / production at Indiana University / USTC
- Mechanical infrastructure at Brookhaven
- **On track to full completion by end of 2017**

  =>Will be ready for Isobars & BES-II

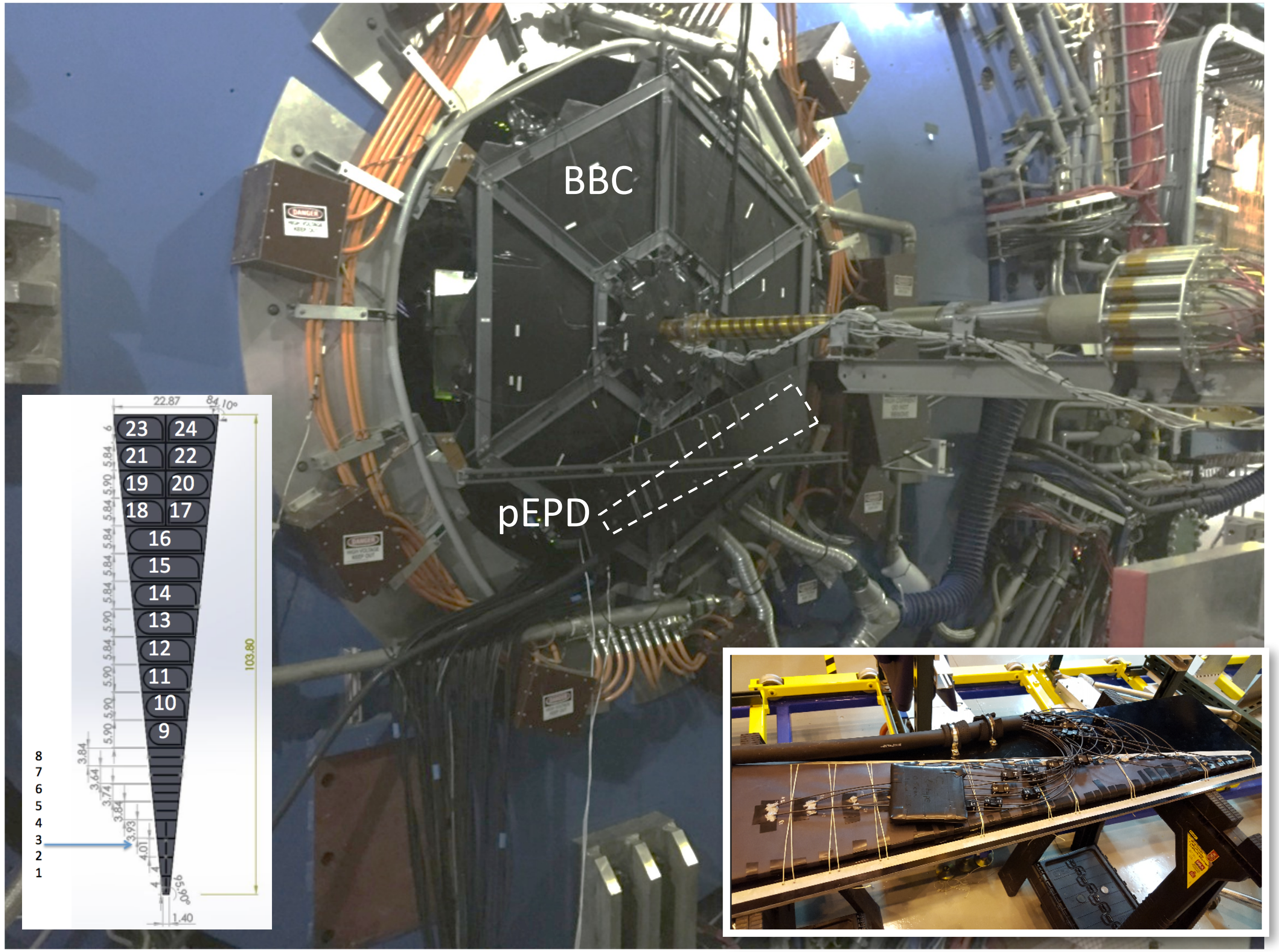
Cosmic and Source Test Stand (Ongoing work)

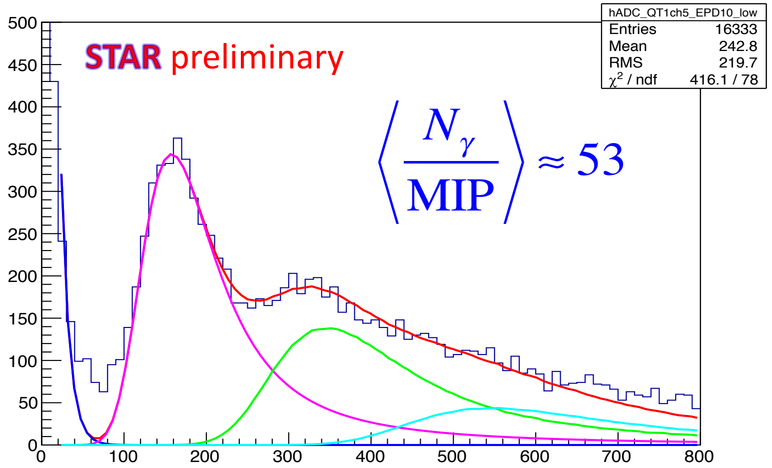


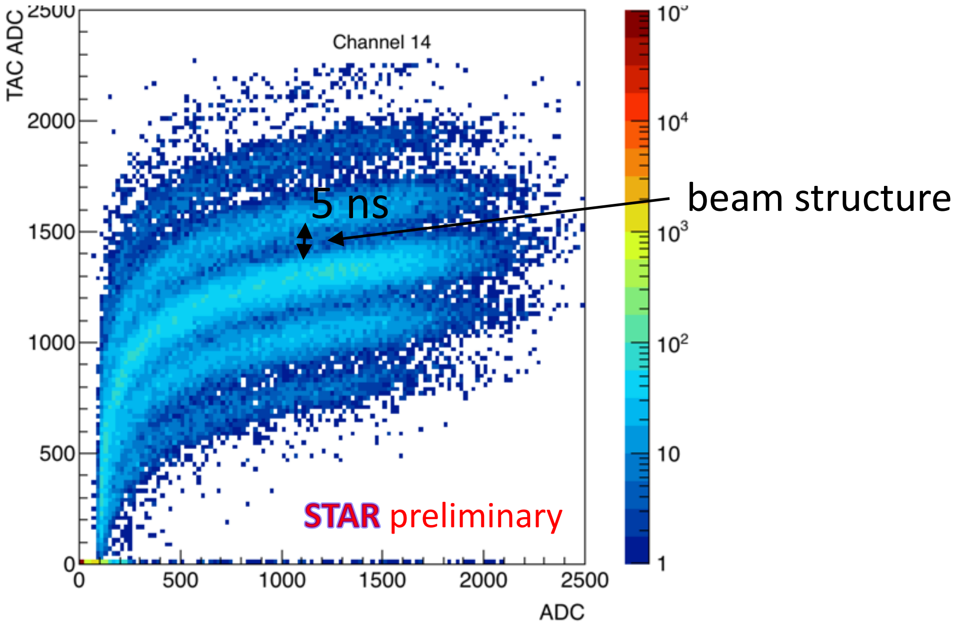
- Relative calibration of light yield in different SS or in tiles
- Position dependent light yield in (larger) tiles using Sr source
- Test light tightness
- Dark current measurements
- Mapping test in SS

EPD- Run 16 Prototype

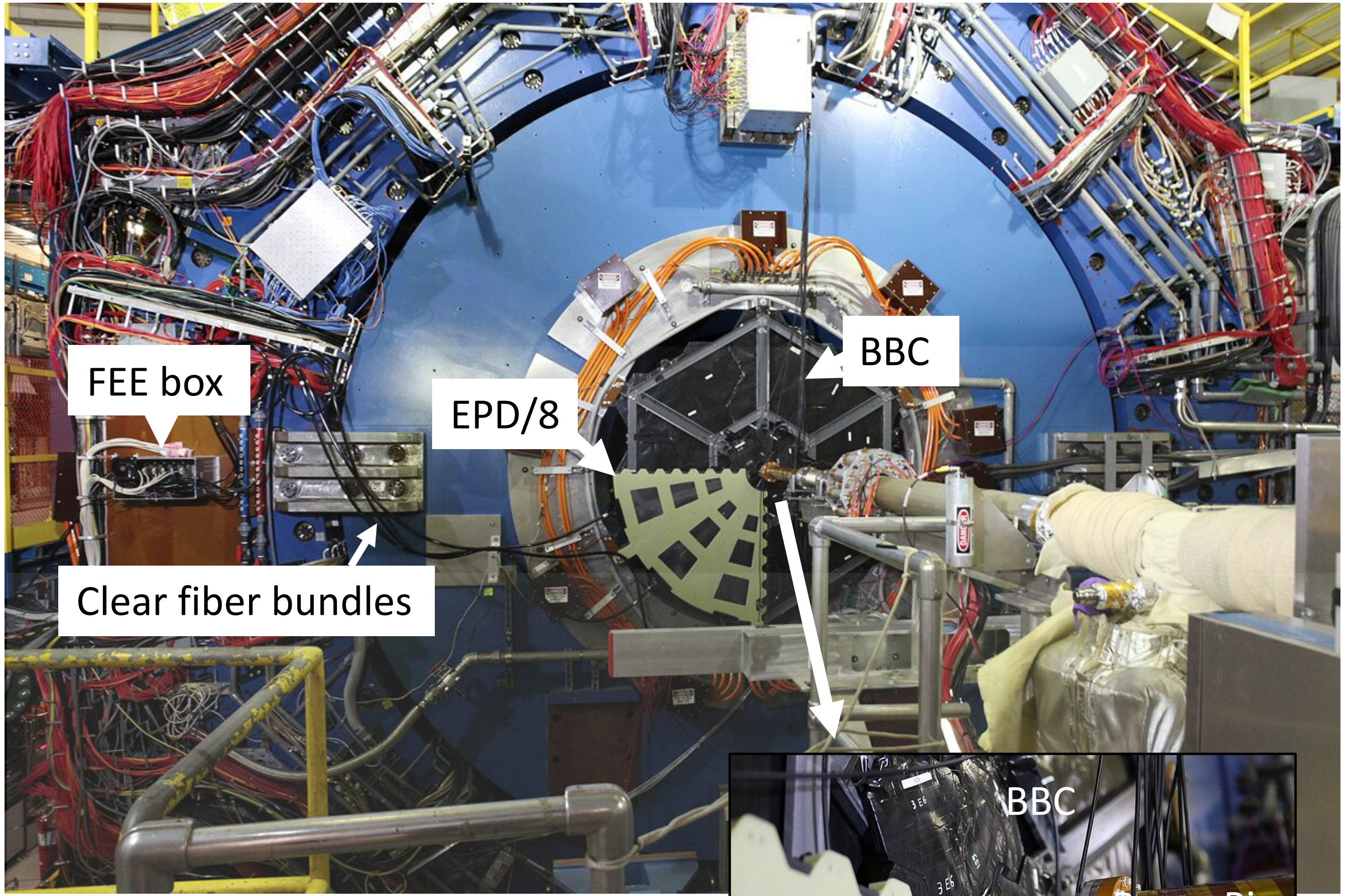
- 24 channel prototype
- Data shows 53 photons per MIP

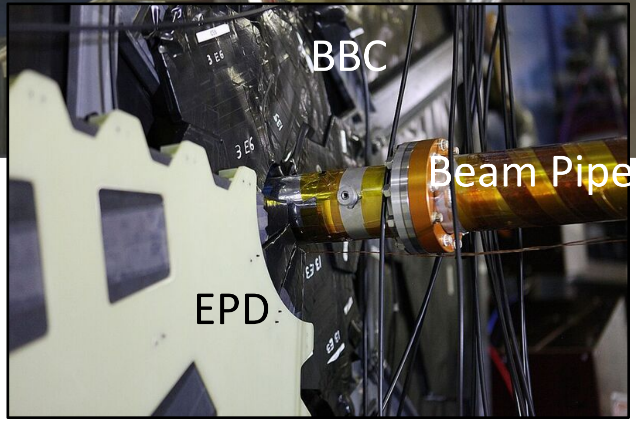






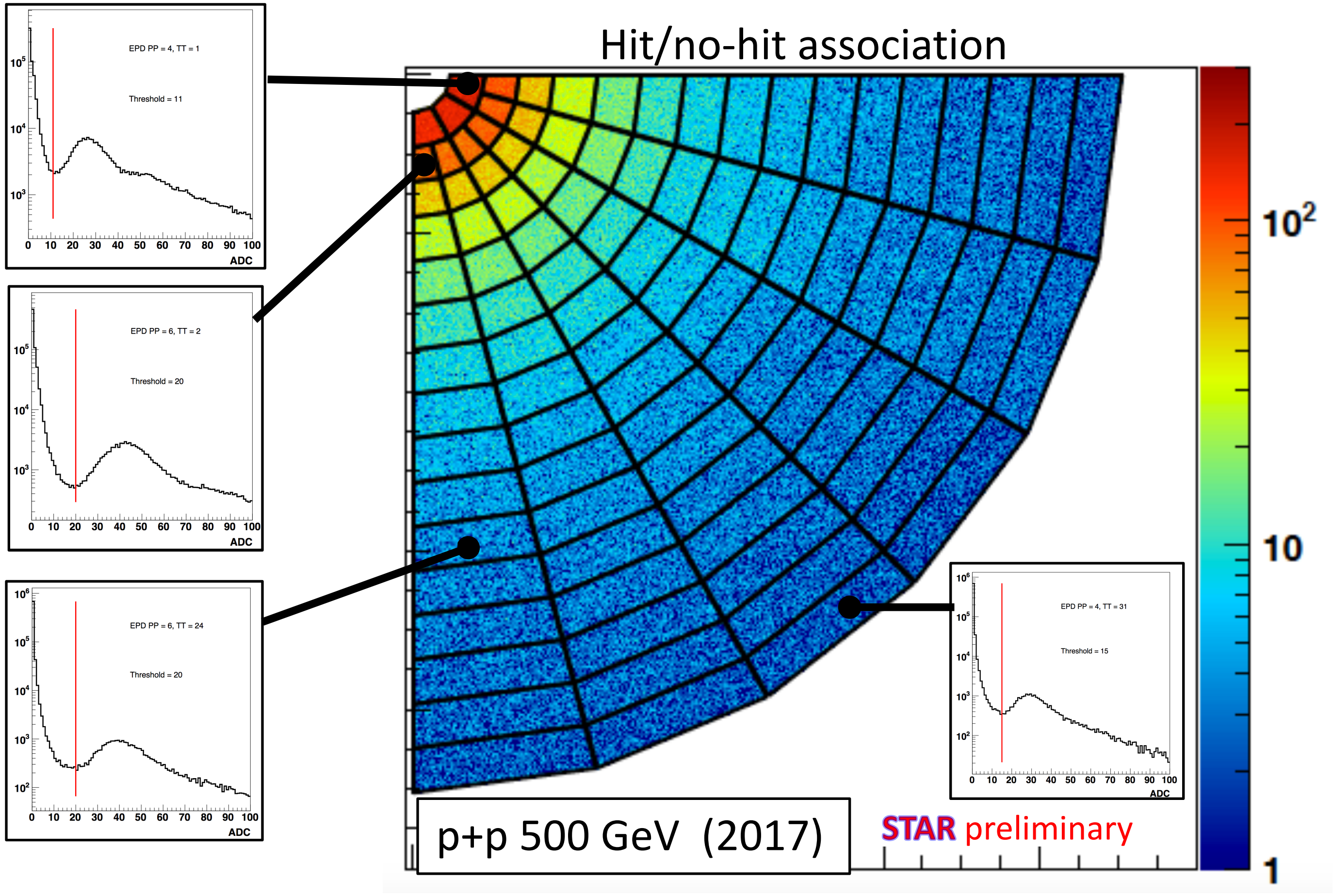
EPD- Run 17 Engineering Run

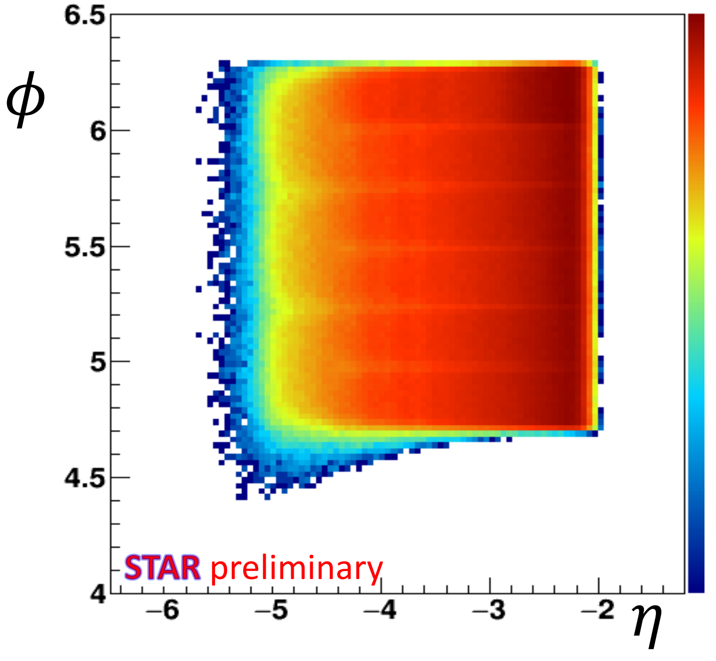


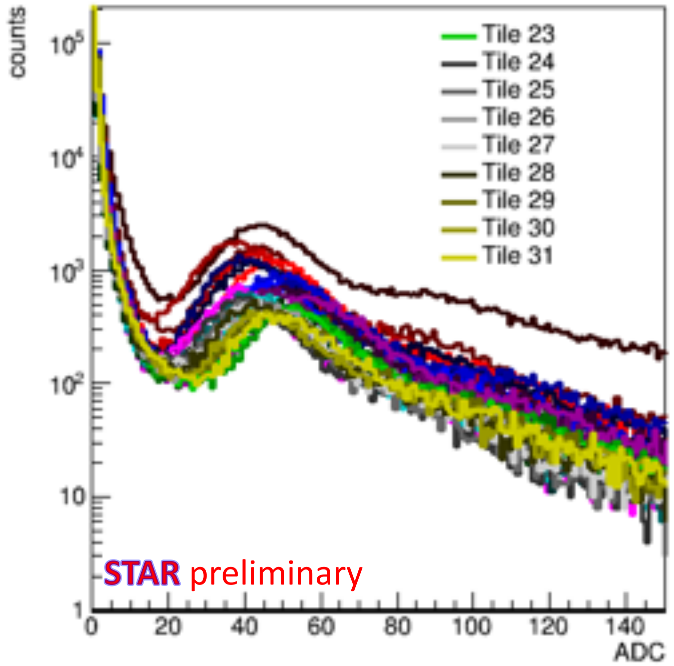


- ¼ of the wheel (1/8 of the detector) installed on the east side of STAR
- Commissioned during *p+p* 500 GeV collisions
- Clear MIP peaks seen in all tiles
- Uniform response from the detector
- Fully commissioned for Au+Au 54.4 GeV collisions

EPD- Run 17 Performance







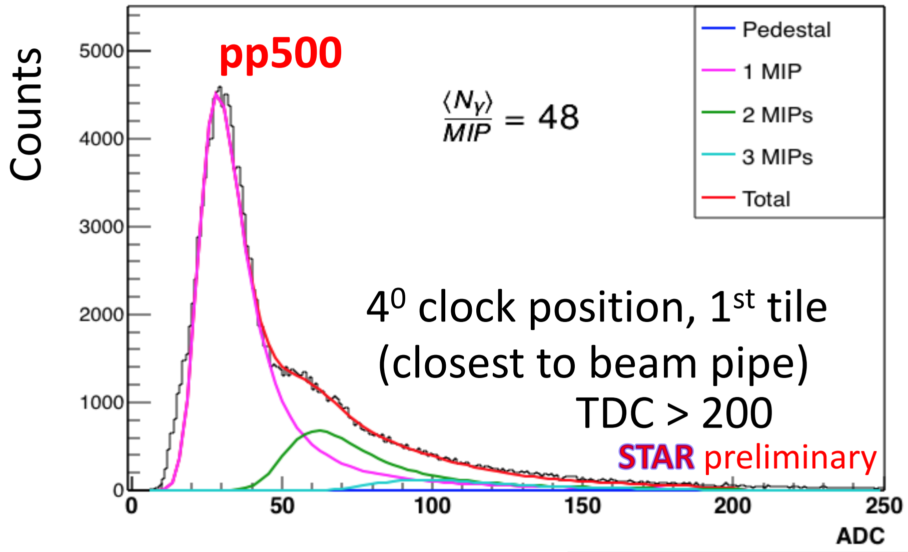
- ✓ All 93 channels show MIP peeks
- ✓ Excellent uniformity in all channels

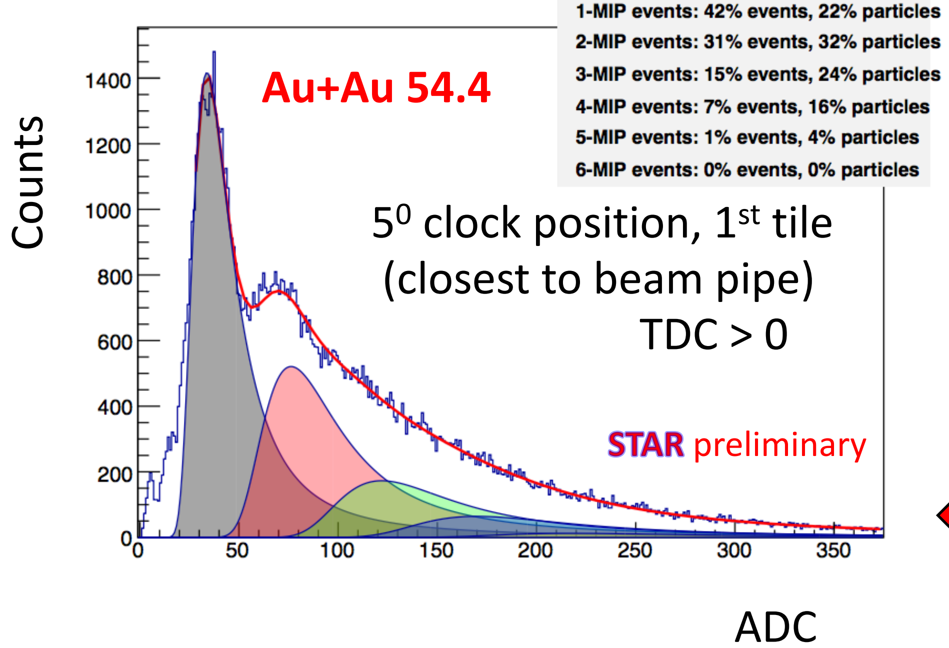
** Low-ADC dark-current contribution is eliminated by cutting on time

Rough MIP matching to set bias voltage

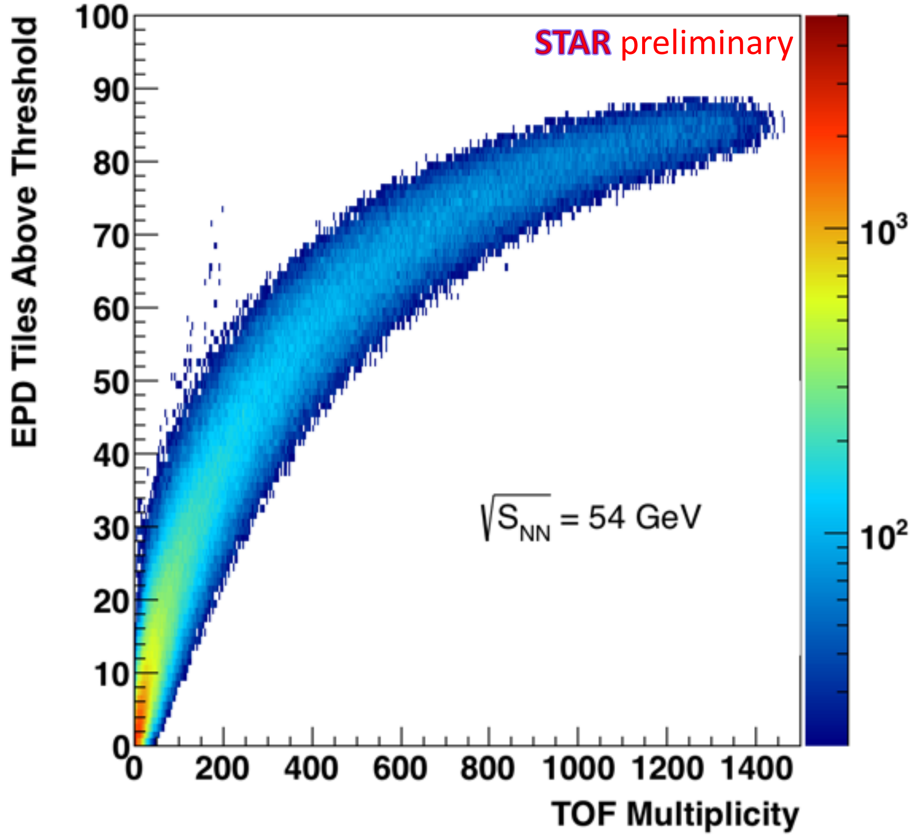
EPD- Run 17 Performance

ADC Distribution



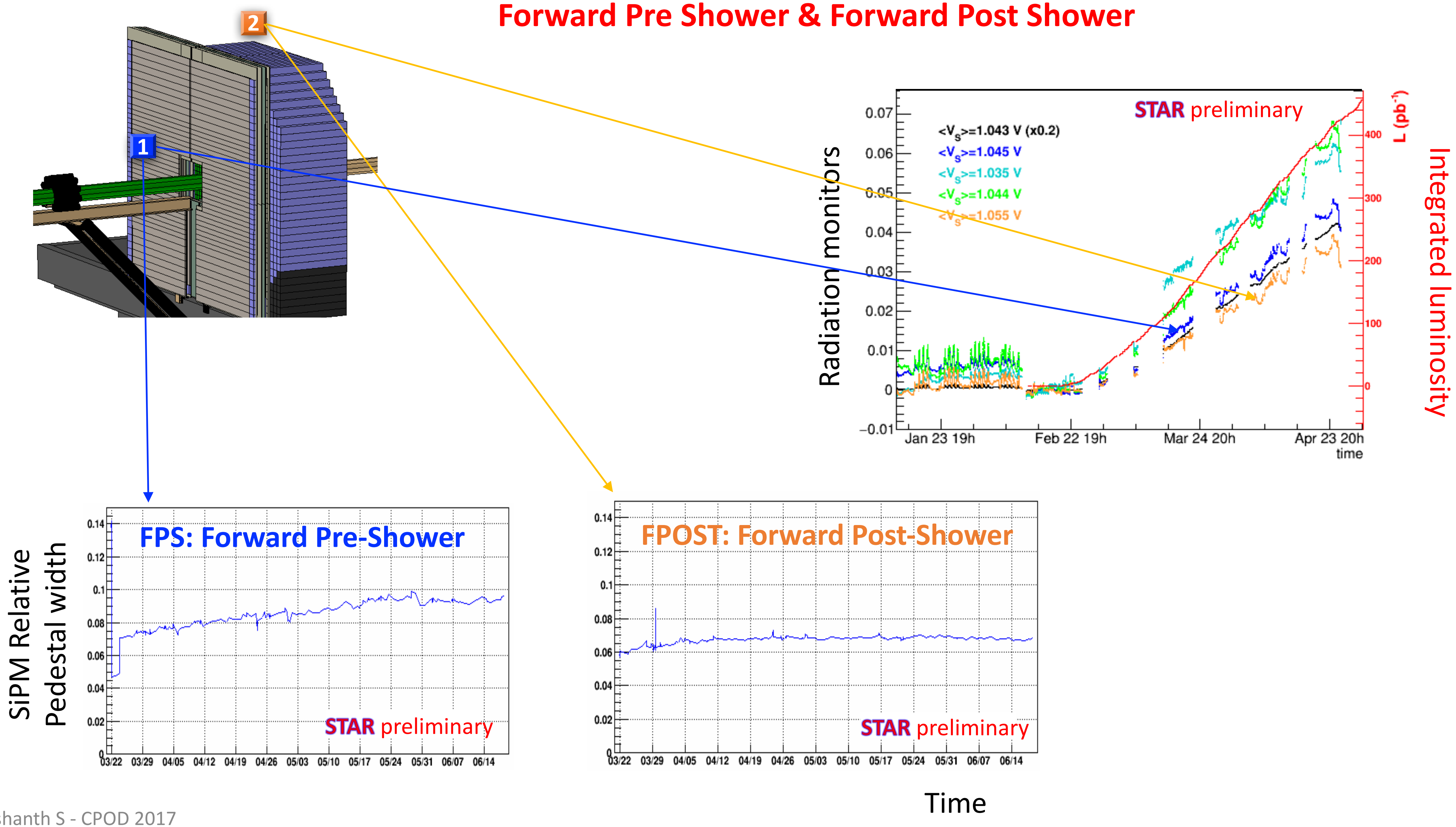


Multiplicity in the barrel TOF vs the EPD



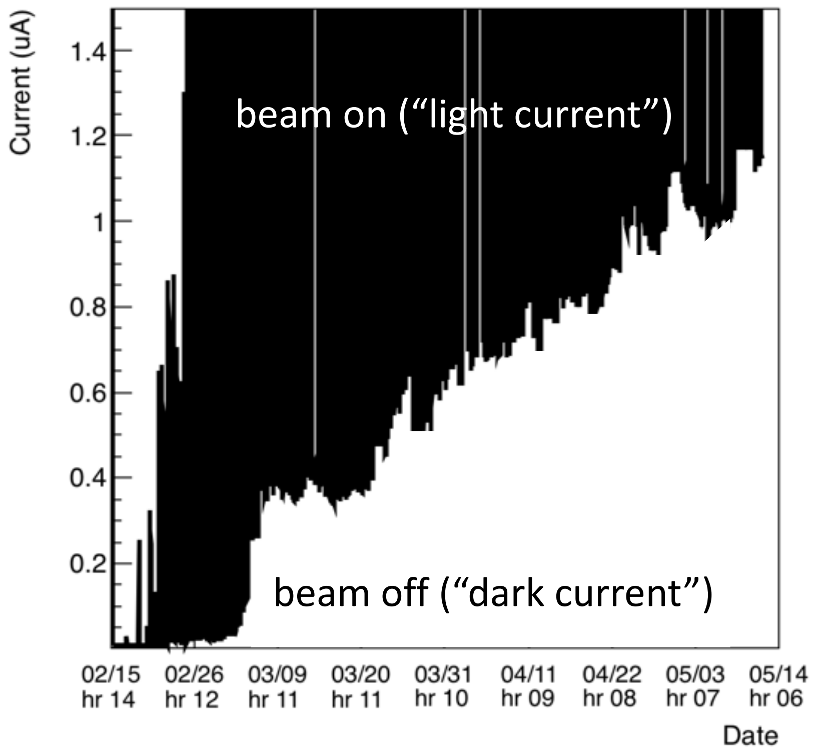
- ADC distribution fitted for multiple hits
- About 45 photoelectrons per MIP
- **ADC distribution very well understood, including multiple-hit contributions**

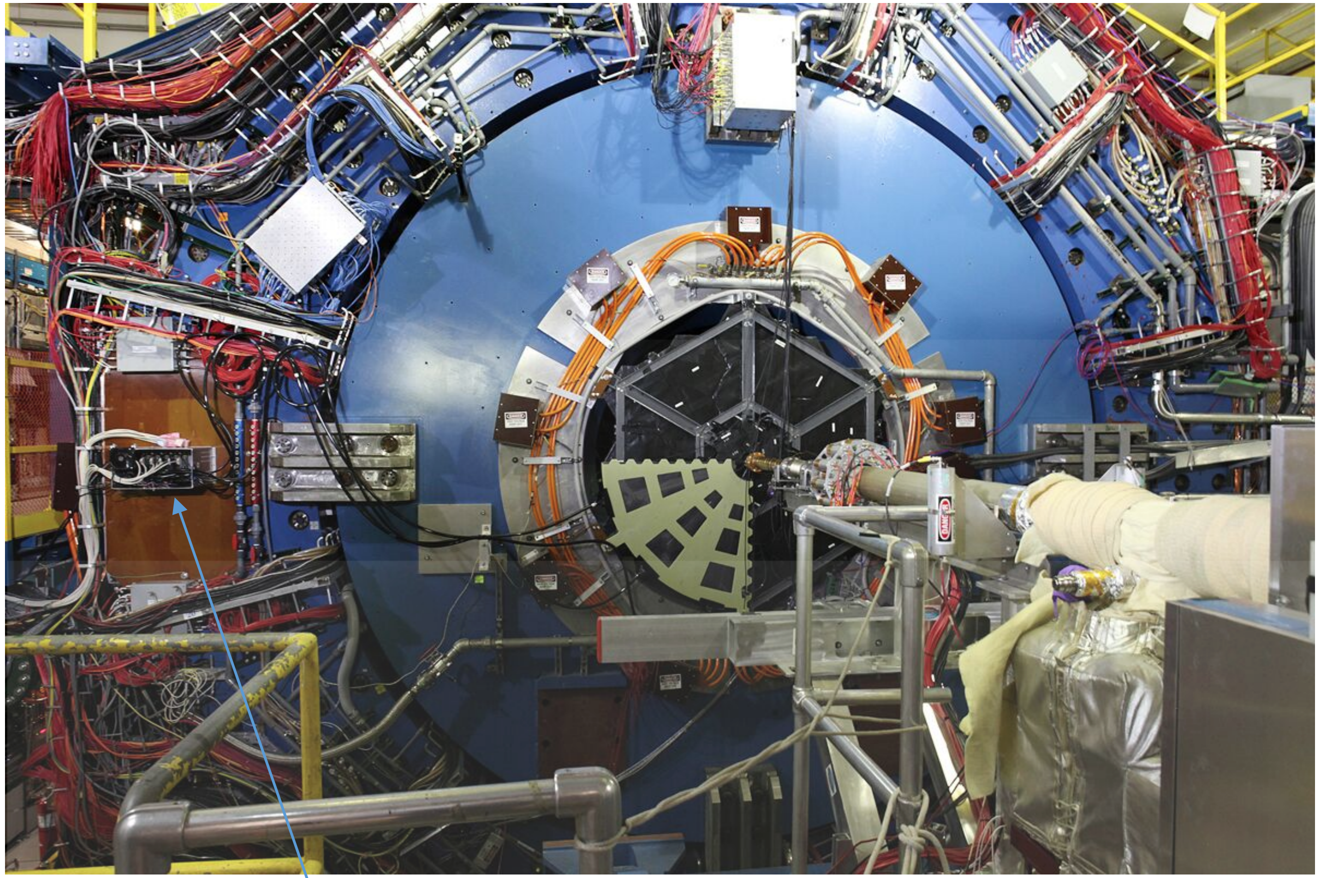
SiPM Performance in STAR Upgrades



SiPM Performance in STAR Upgrades

EPD SiPM Dark Current





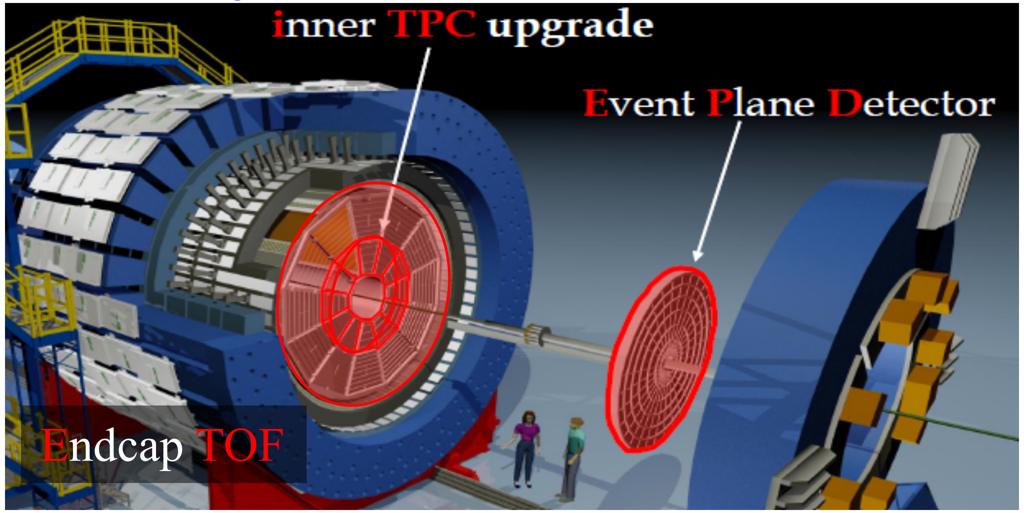
- Presently dark current ~1uA
  - MIP resolution unaffected.
- Much smaller radiation damage expected in Au+Au

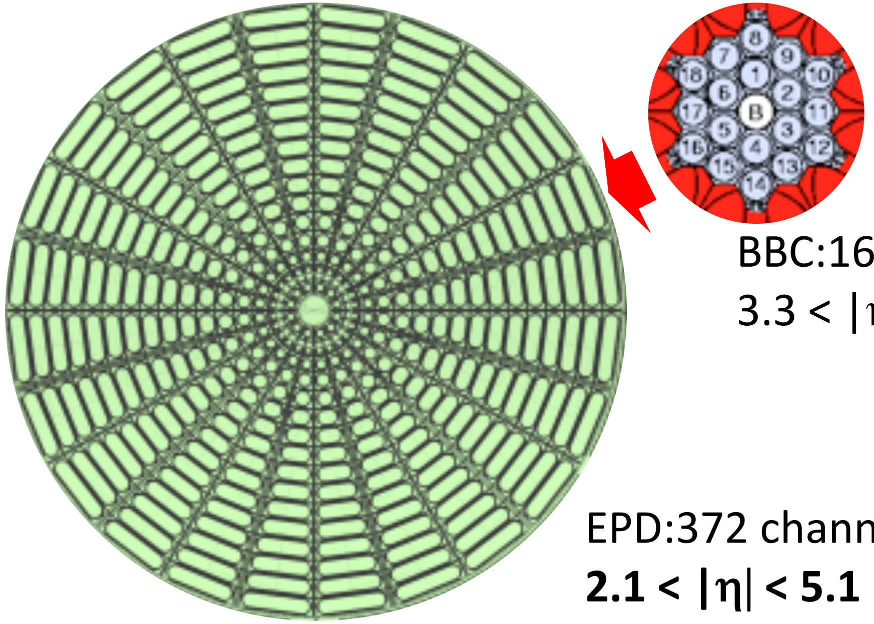
EPD SiPMs Located far away from beam (~4m)

Trigger Capabilities

- Needed efficient minimum bias trigger detector for BES-II and Fixed Target program
  - Efficient Background reduction needed for high-luminosity RHIC collisions
- EPD design exceeds minimum radial segmentation needed for effective Trigger
- EPD performed well in Run 17, met our goals for going through the trigger chain
  - Data is being analyzed

Summary





BBC:16 channels
3.3 < |η| < 5.0

EPD:372 channels
2.1 < |η| < 5.1

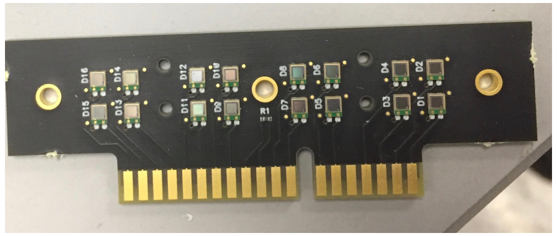
- Opens up phase-space: Significant azimuthal & radial segmentation (372 x 2 channels)
- Measure Centrality outside mid-rapidity
- Provides better Event Plane Resolution
- EPD can improve Trigger efficiency
- Excellent performance in 'engineering' run 2017. Expect publishable results
- To be completed end of this year (**Isobar** and **BES II collisions**)
- **Electron Colling** together with STAR detector upgrades provide good control of statistical fluctuations and systematics for BES II

BES I ➛ BES II

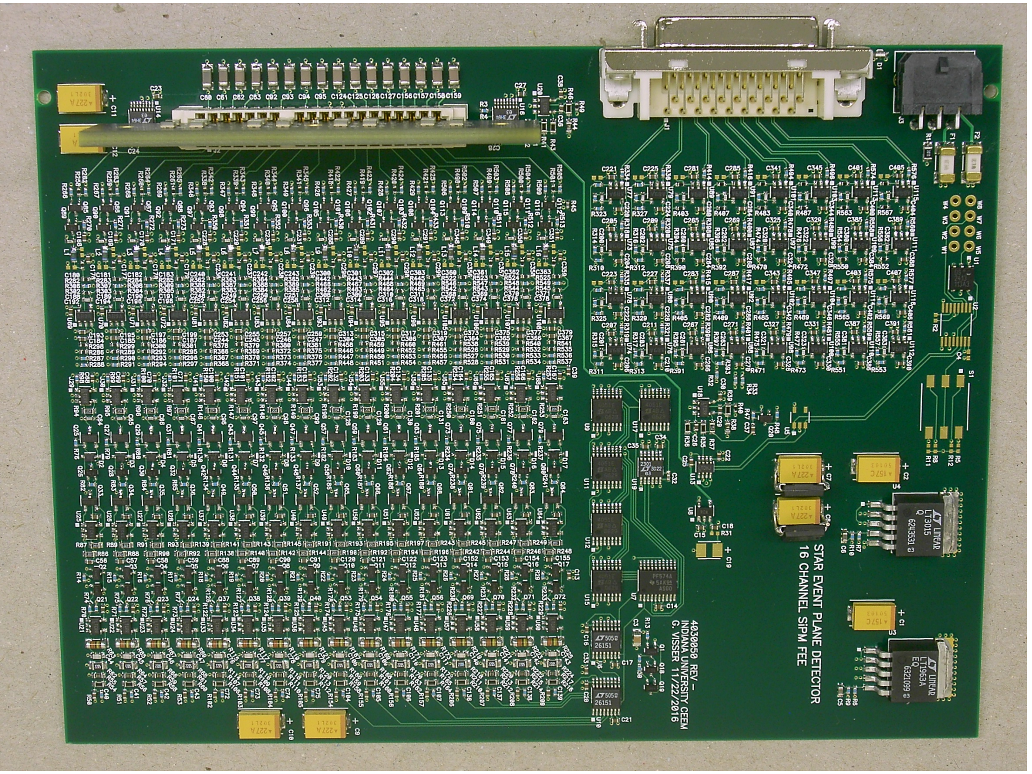
Qualitative Statements ➛ Quantitative Measurements

Backup

Front End Electronics

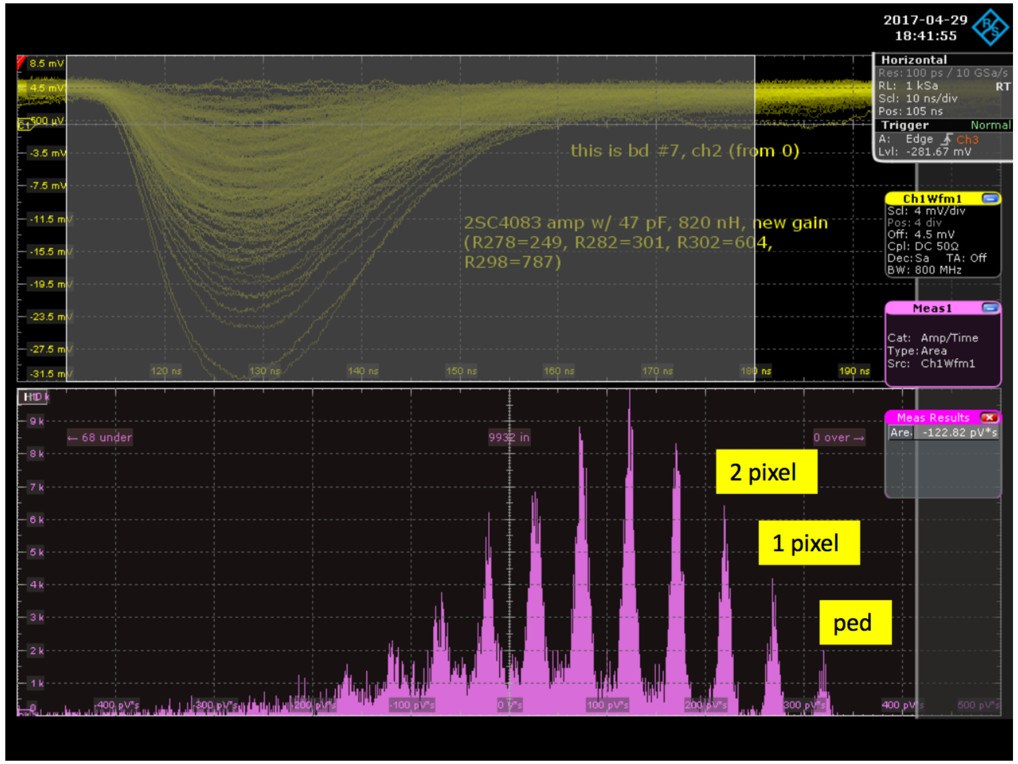


16 Channel SiPM board



16 Channel Pre-Amp

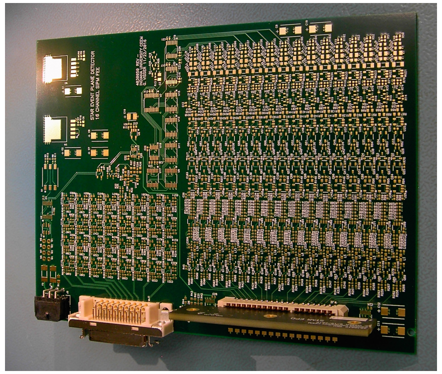
SiPM Single Pixel response

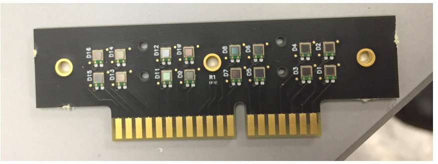


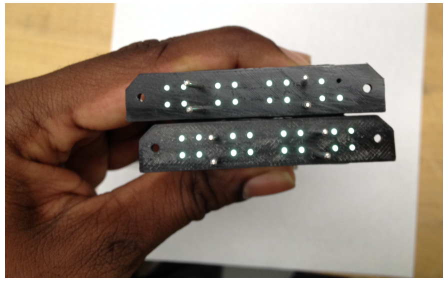
- Gain 1pC/pixel, linear up to 1300 pixels
- Resolution is much more than adequate

EPD Project Scope

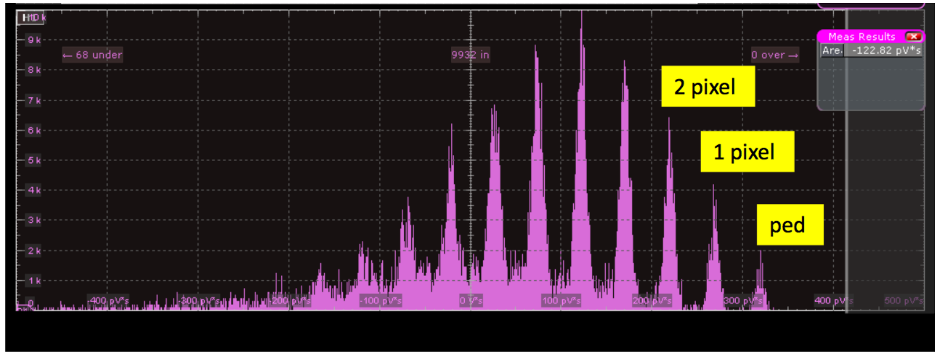
- Super Sectors (1/12th of a wheel)
  - 1.2 cm Eljen scintillator wedges, milled to form 31 tiles
  - optically separated by TiO_2-loaded epoxy
  - Construction is in progress at OSU
- Coupling to electronics
  - 5.5-m-long Clear fiber bundles
  - All connector components custom-designed and 3D printed
  - Construction is in progress at Lehigh University
- Electronics
  - Hamamatsu SiPMs
  - Excellent resolution, linearity
  - About 50 photoelectrons per MIP (MPV)
- Engineering Run 17
  - 1/8th of the detector installed
- **EPD will be ready for Run 18**





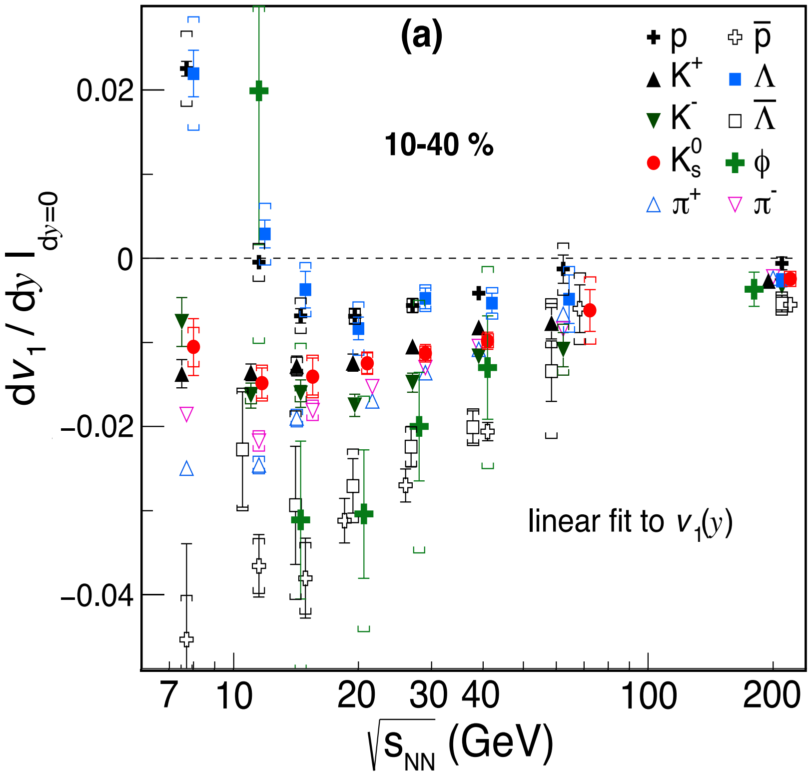


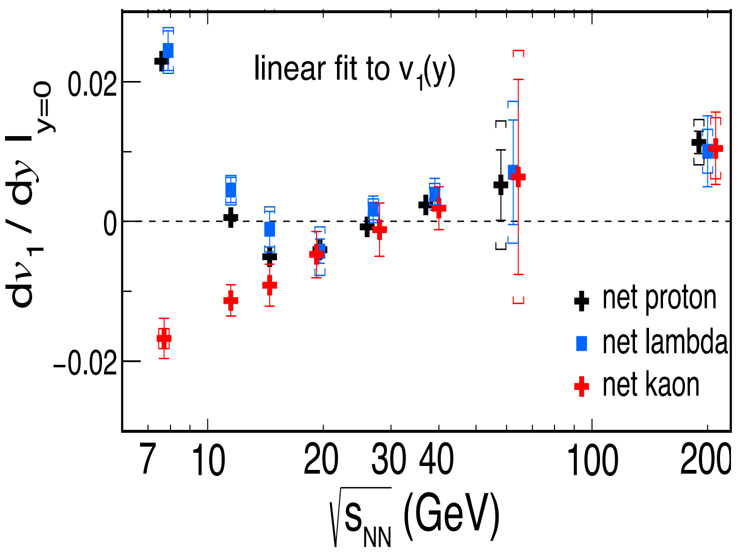
FEEs designed by G. Visser



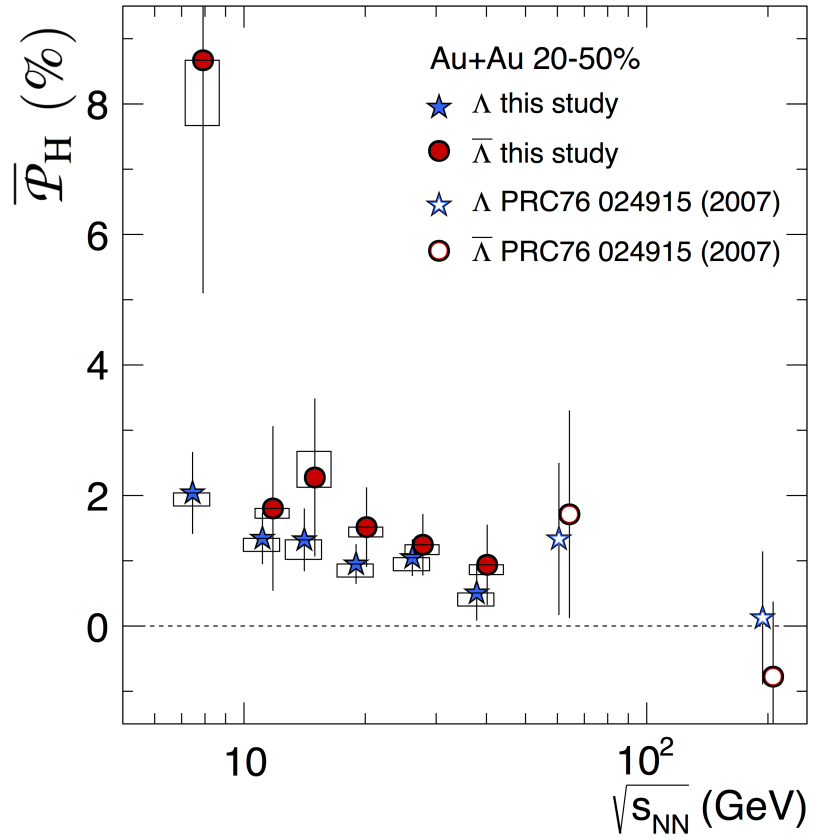
Motivation-II: Event Plane Estimation

Directed Flow





Polarization Measurements



Limitation in analysis

- Poor reaction plane resolution
- Systematic analysis of centrality dependence
- Large uncertainty (Limited statistics)