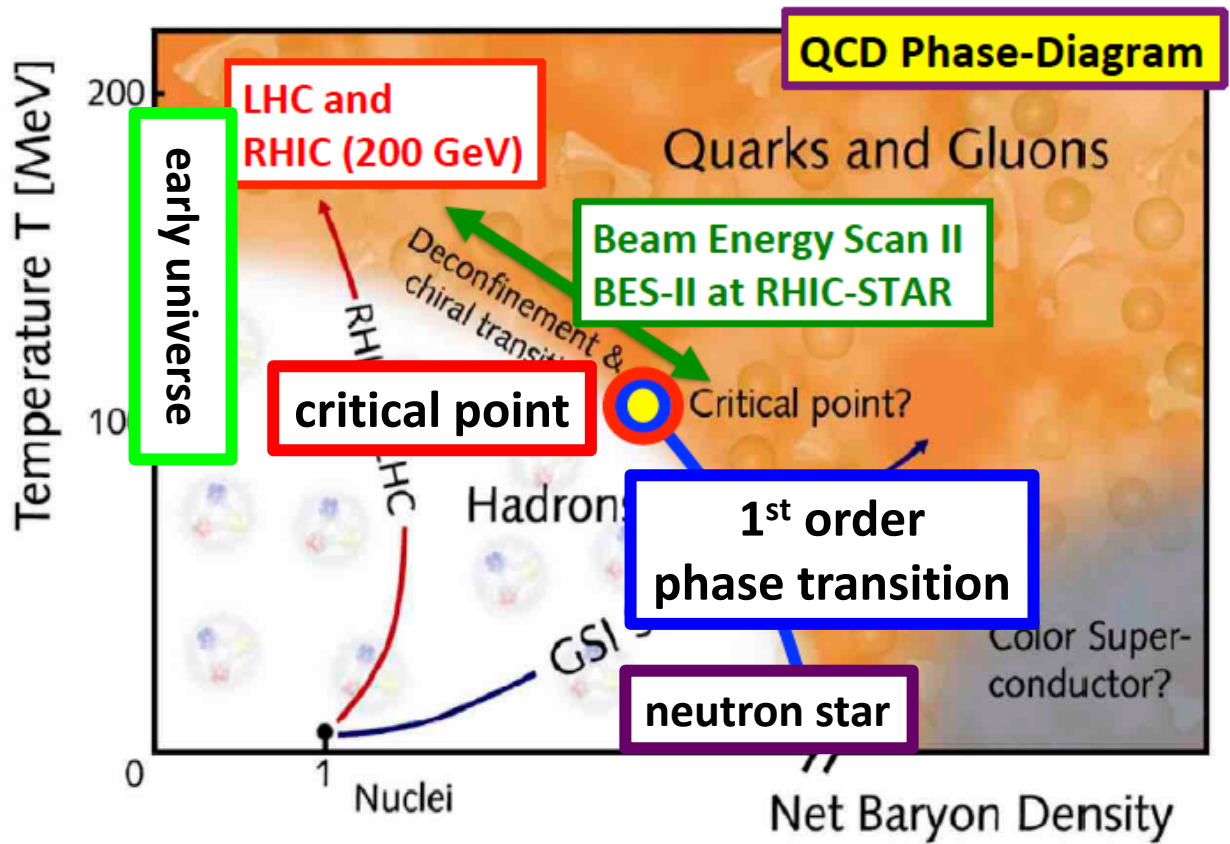


Centrality determination in STAR at RHIC

in BES-II and Fixed-Target program



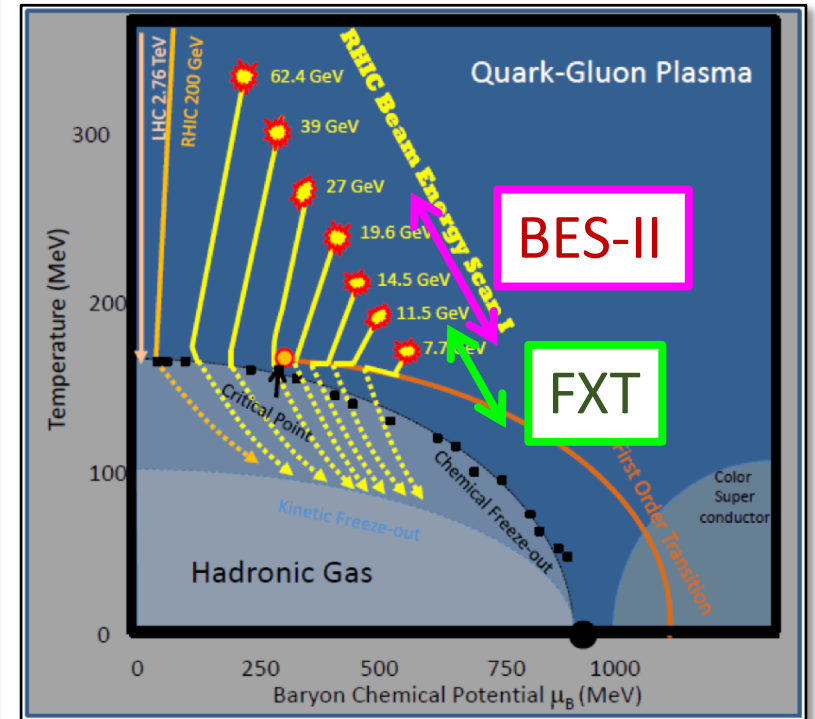
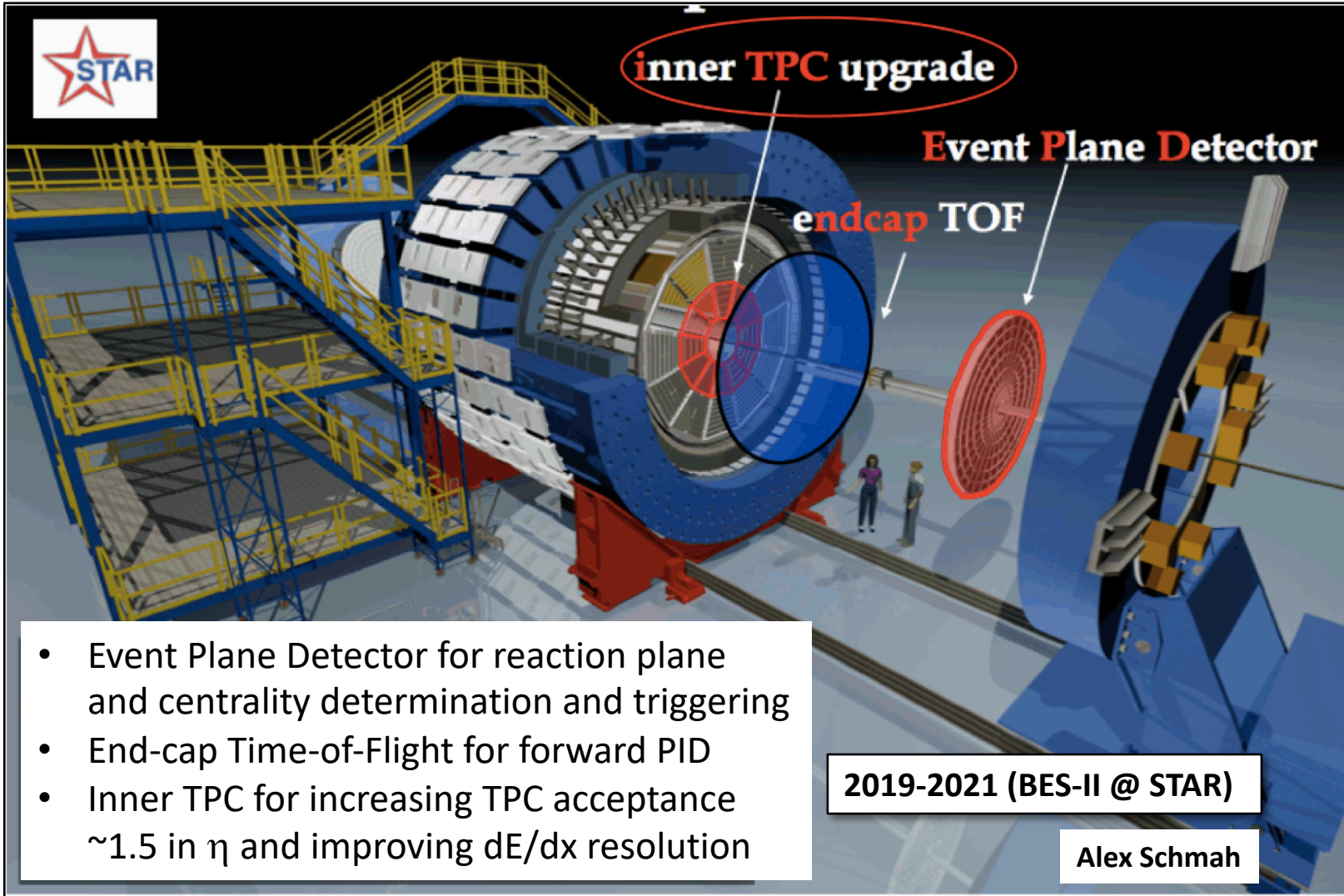
Shinichi Esumi for the STAR collaboration
 Inst. of Physics, Univ. of Tsukuba
 Tomonaga Center for the History of the Universe

Contents

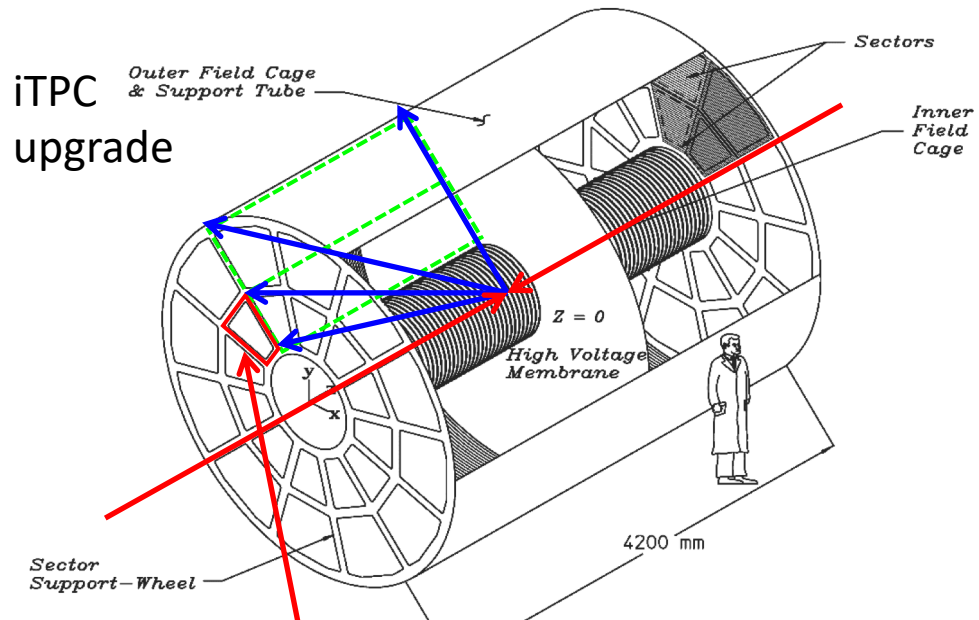
- Detector upgrades and runnings
- Physics motivations
- Event Plane Detector (EPD $|\eta| = 2 - 5$)
- E.P. and centrality determination
- Geant simulation
- Pile-up rejection study



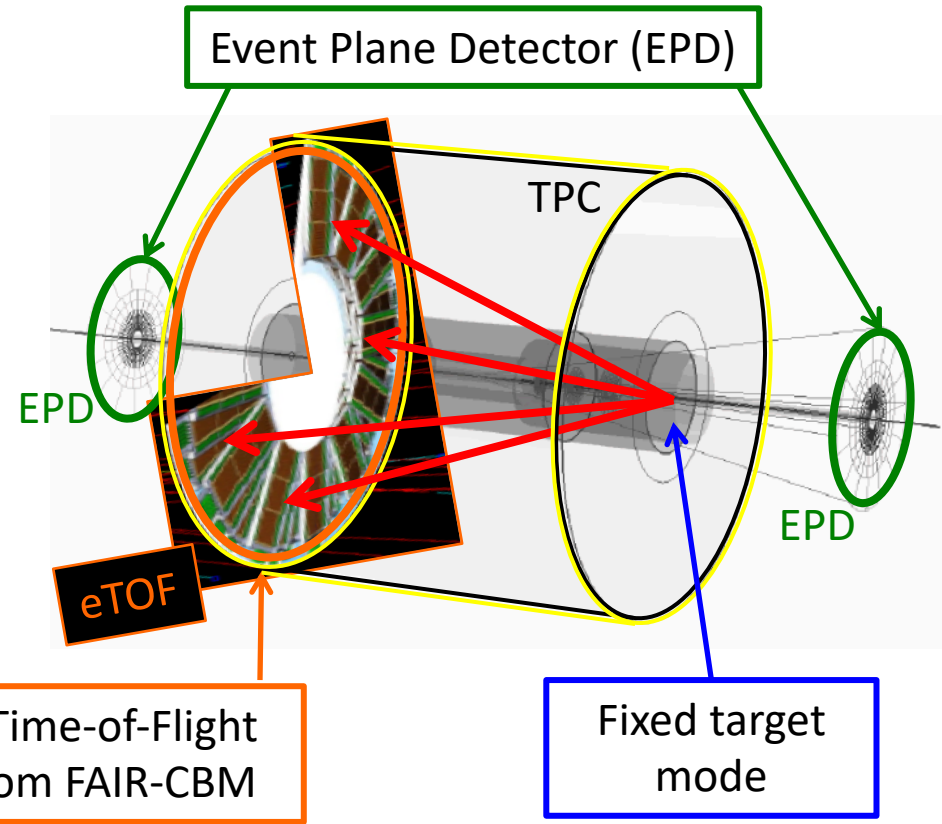
Beam Energy Scan Phase-II @ STAR



STAR detector upgrades for BES-II program



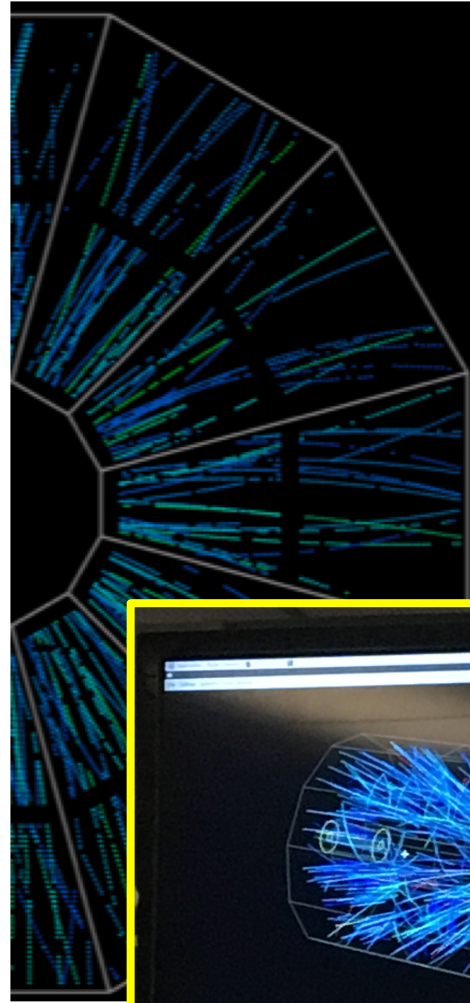
TPC inner sector readout with more segmentation



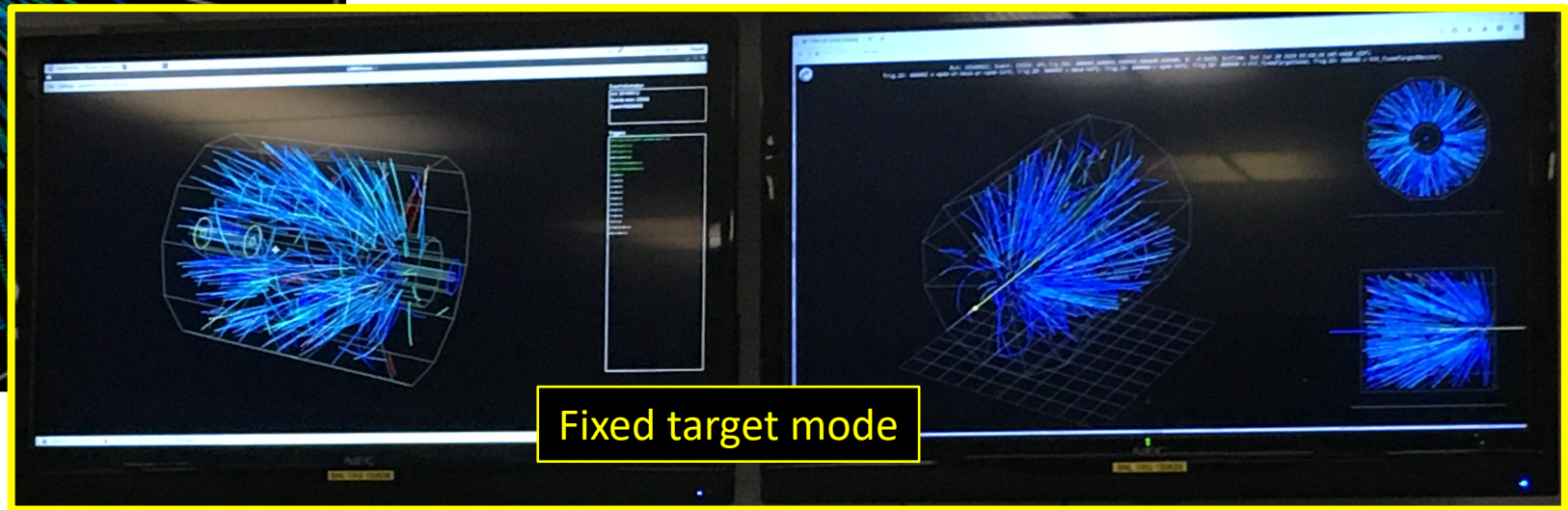
End-cap Time-of-Flight (eTOF) from FAIR-CBM

Fixed target mode

Recent and coming RHIC runs

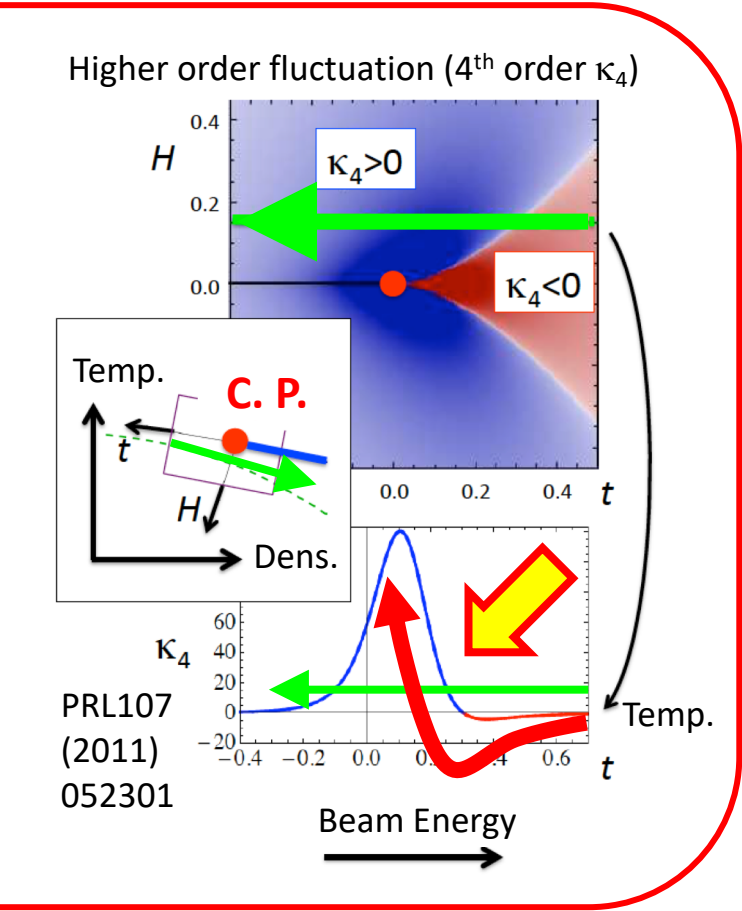
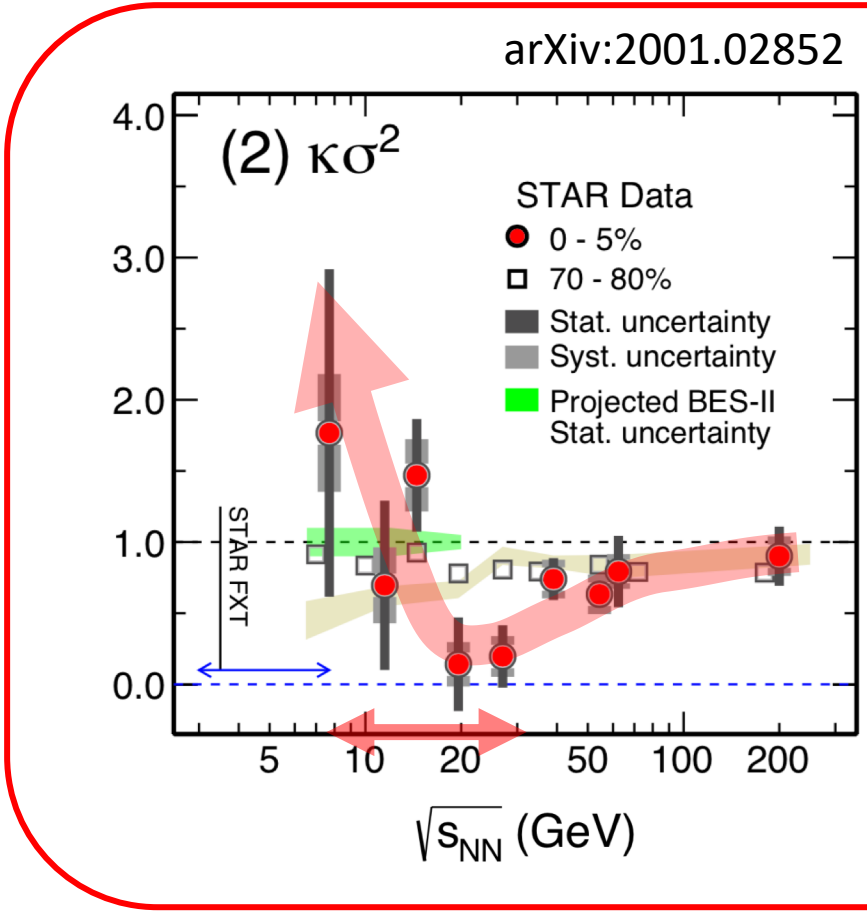
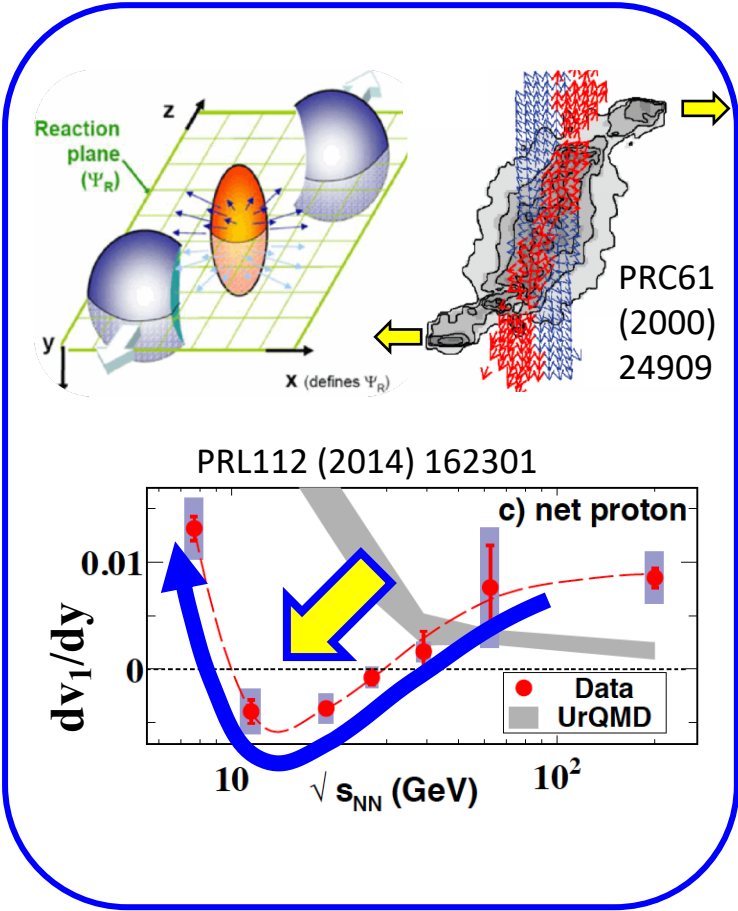


RUN17	510 GeV p+p 54.4 GeV Au+Au
RUN18	200 GeV Zr+Zr, Ru+Ru 27 GeV Au+Au Fix target (3-7 GeV)
RUN19 RUN20	14.6, 19.6 GeV Au+Au 9.2, 11.5 GeV Au+Au Fixed target (3.5-7.7 GeV)
RUN21	7.7 GeV Au+Au
RUN22 RUN23-25	510 GeV p+p 200 GeV p+p, p+Au, Au+Au

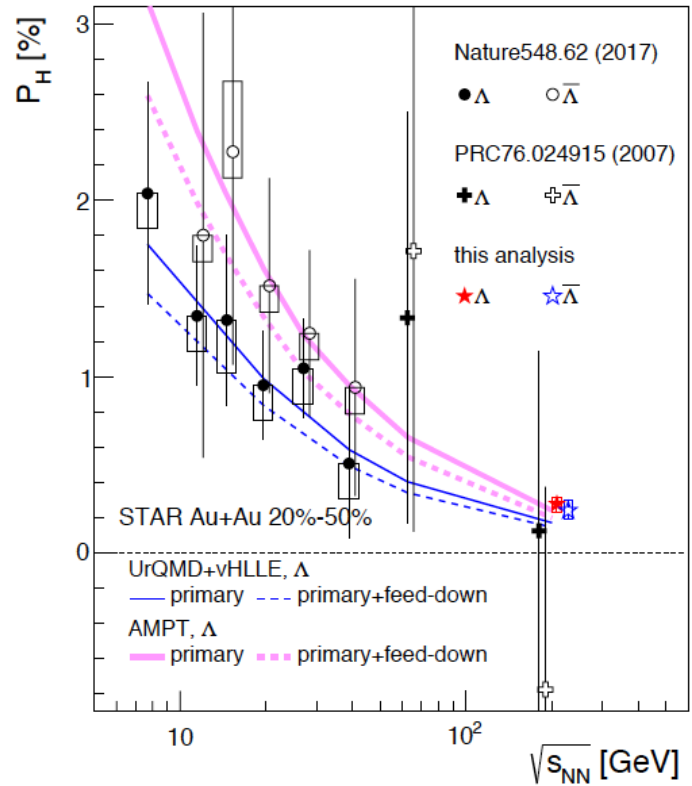
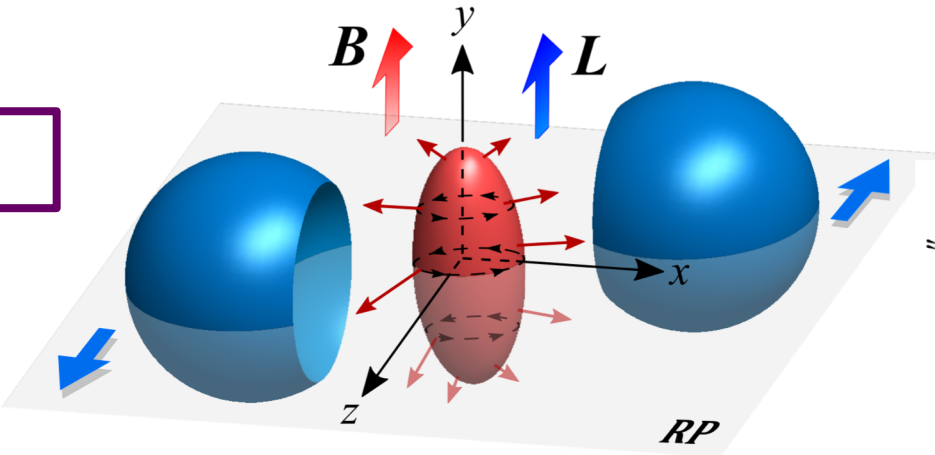


Fixed target mode

Net-proton flow and fluctuation

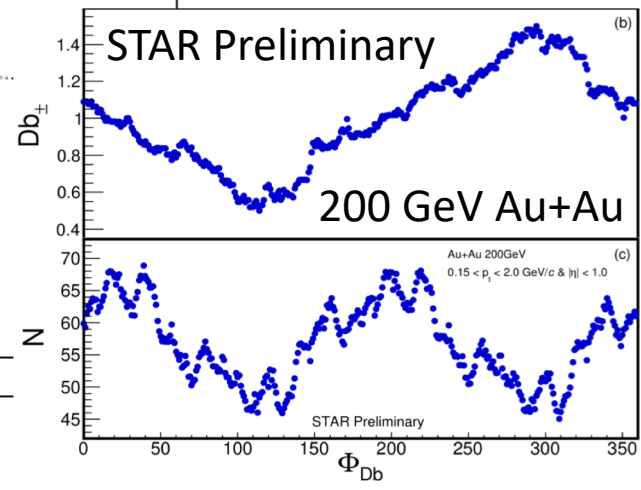
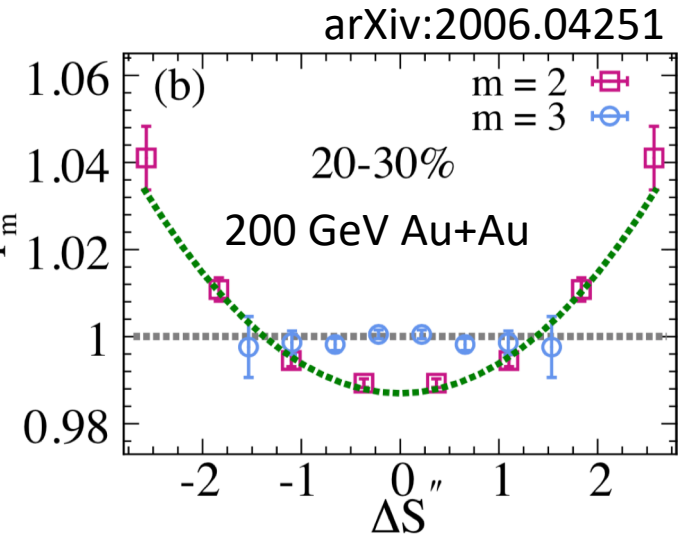
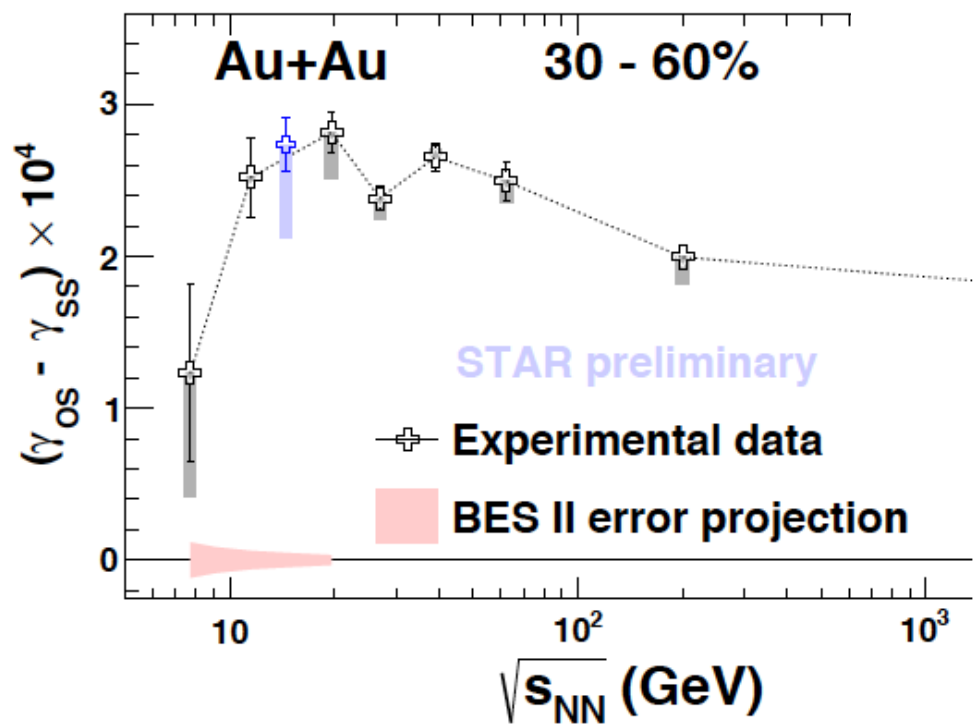


Vorticity and CME/CMW



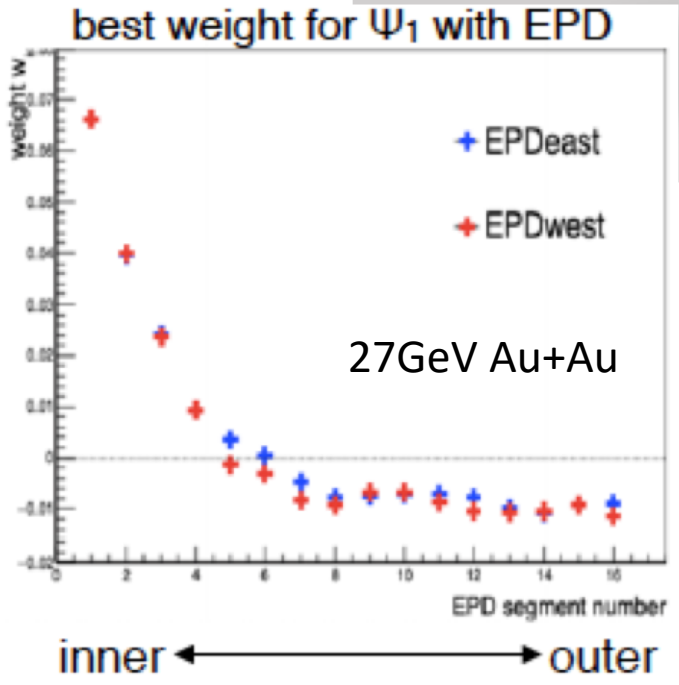
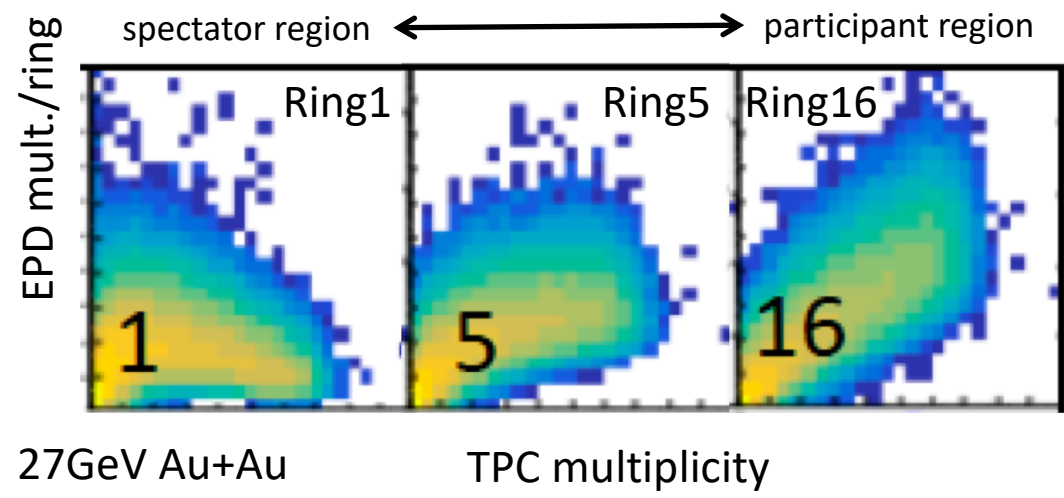
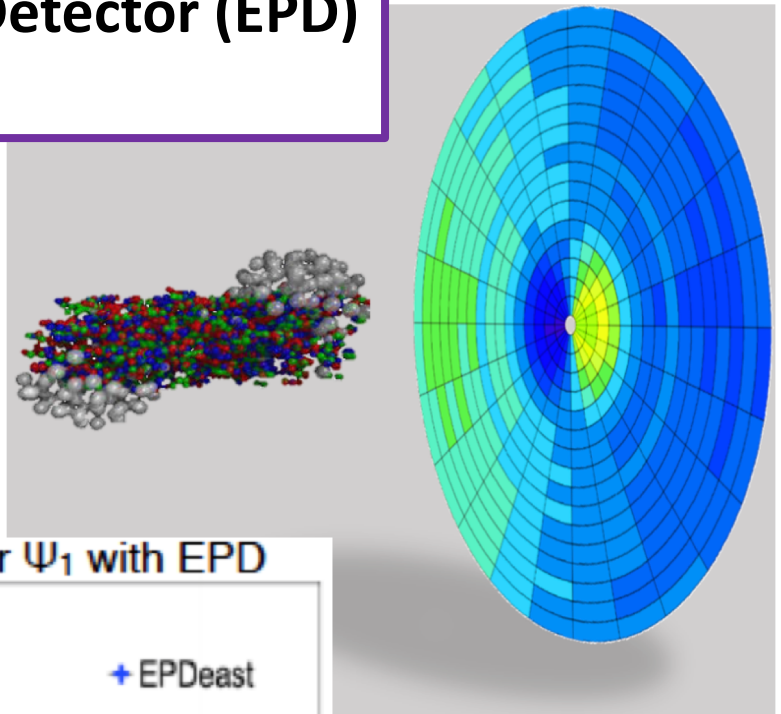
PRC98 (2018) 14910

PRL113 (2014) 052302

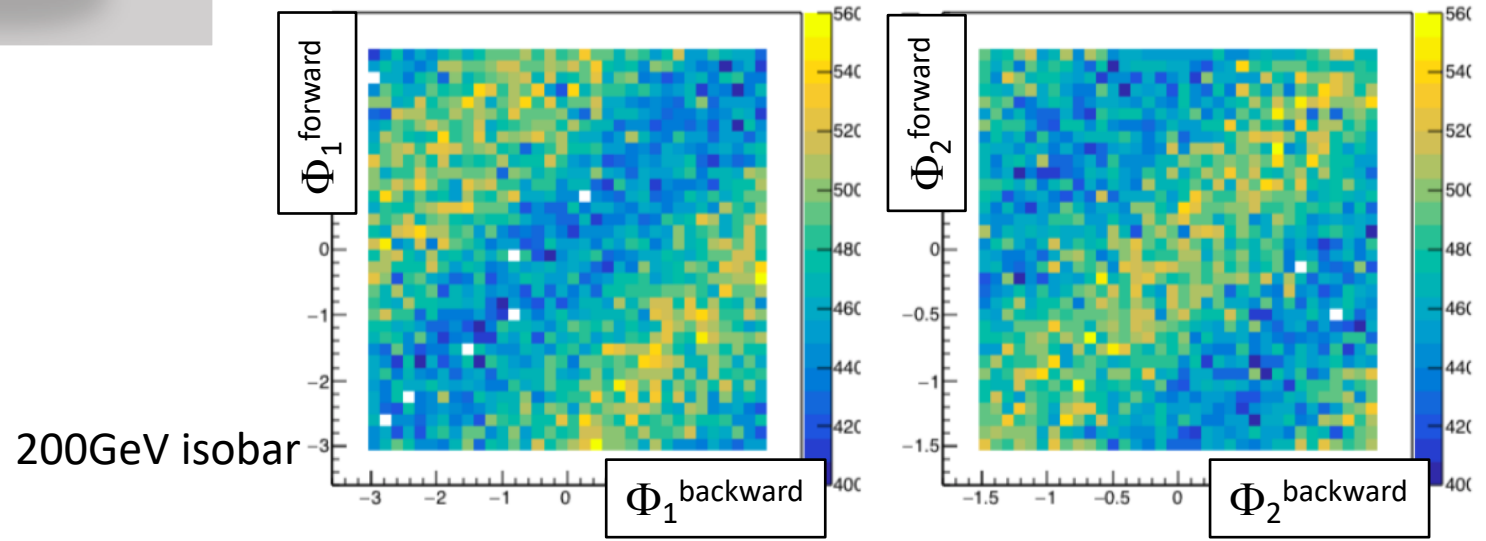


Event Plane Detector (EPD)

$$|\eta|=2 - 5$$

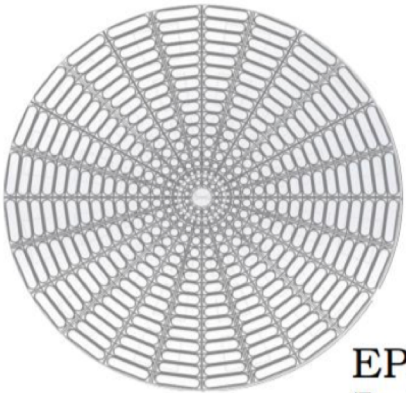


Forward-backward event-plane correlation

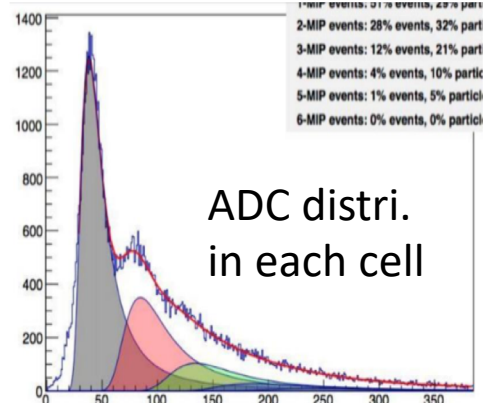


Landau fluctuation (1cm thick scintillator with single fiber to SiPM)

- nMax=1
- nMax=3
- nMax=5
- nMax=7
- nMax=10
- nMax=20
- nMax=50



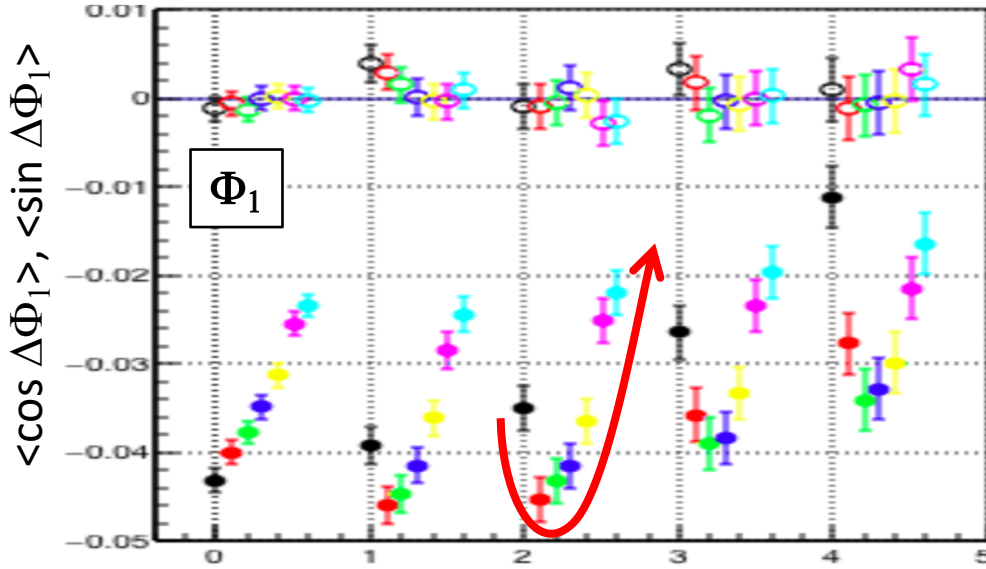
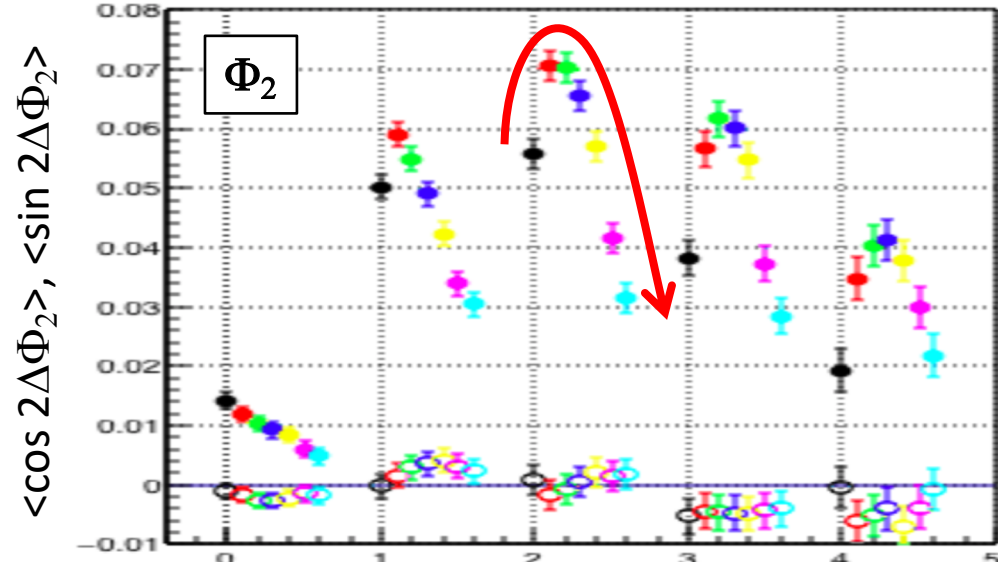
EPD
(Event Plane Detector)



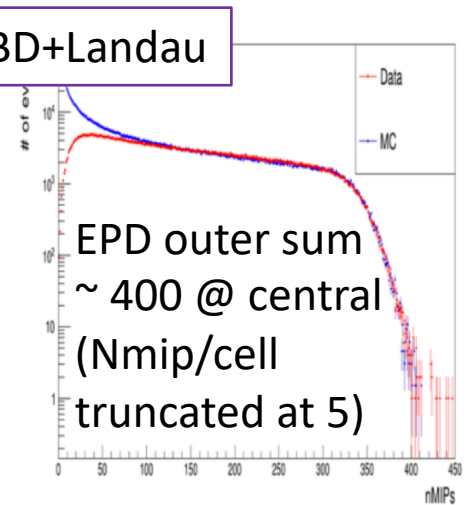
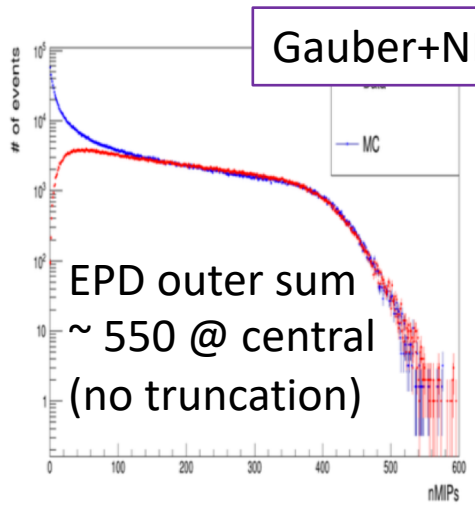
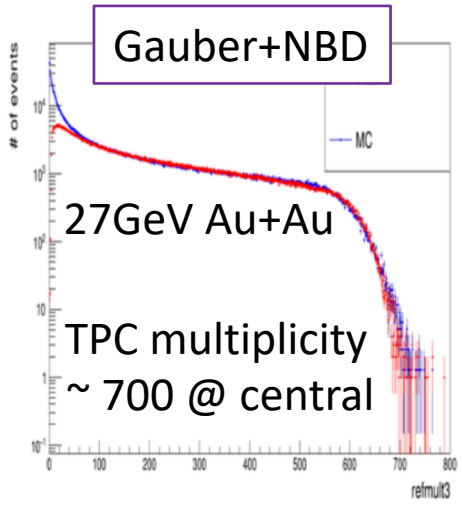
ADC distri.
in each cell

Event plane and centrality resolution optimization possible with nMax

Event plane correlation between two opposite arms 200GeV isobar

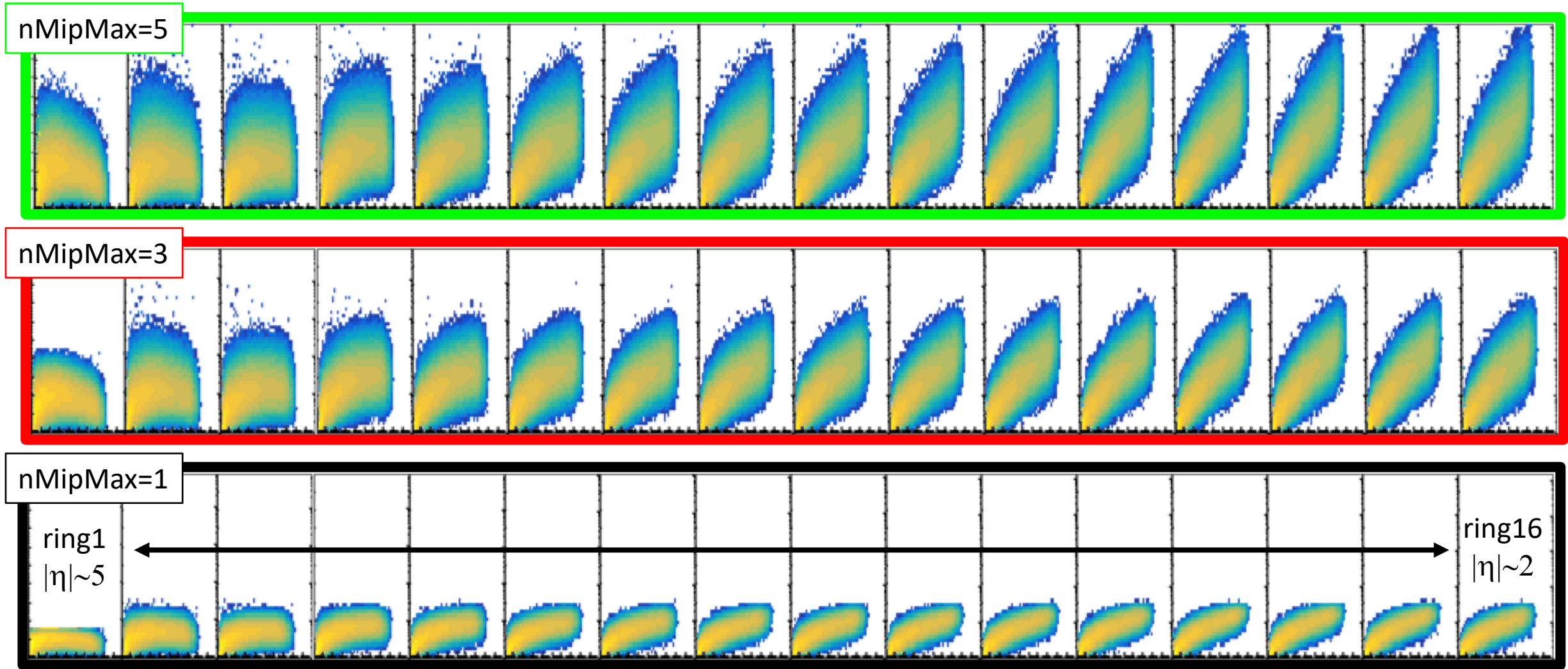


TPC multiplicity bin (5bins)



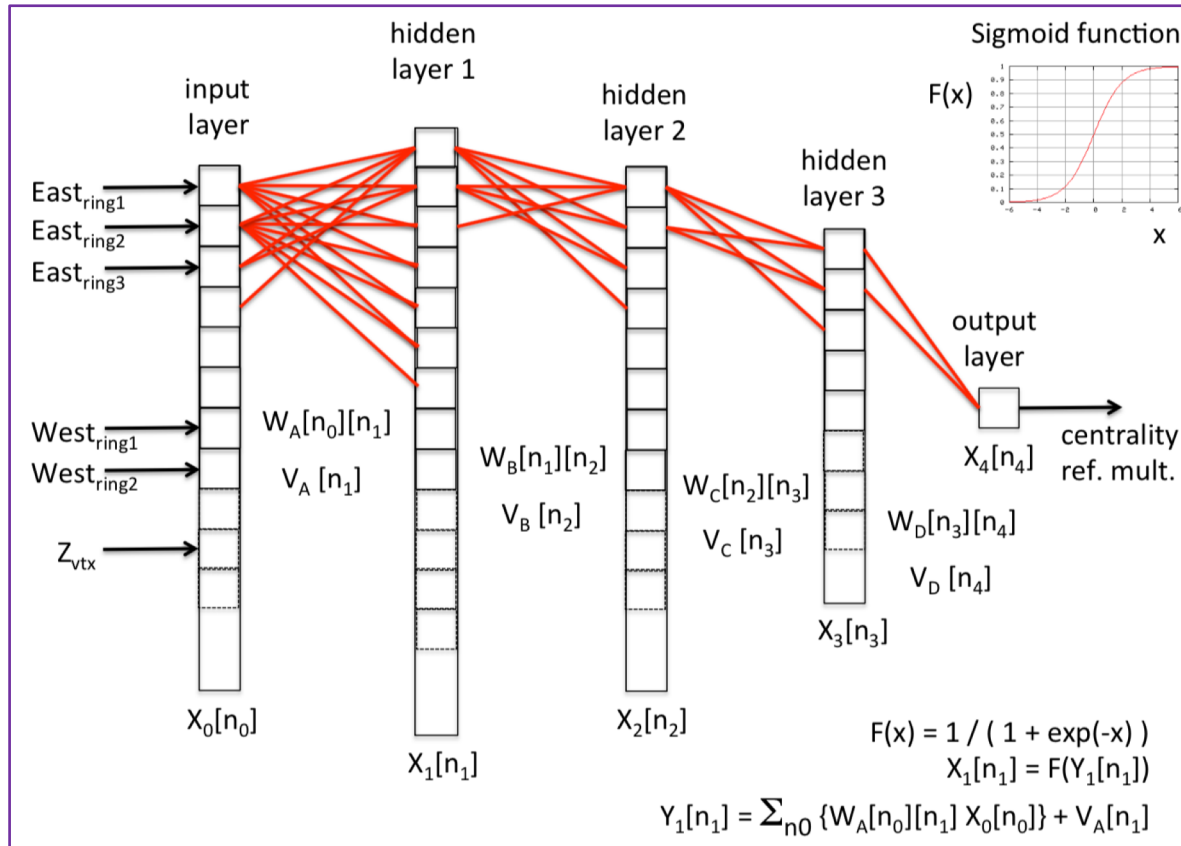
EPD nMip Sum (ring#) vs TPC multiplicity

27GeV Au+Au



TPC multiplicity (RefMult3)

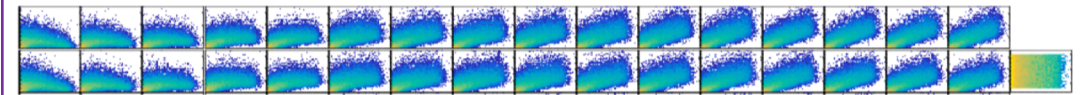
Machine learning of centrality with neural network



“old-standard” back-propagation :
with EPD ring inputs plus z-vertex
educated to the measured TPC multiplicity

27GeV Au+Au 50k education events and 50k test events (EPD+TPC)

16 ADC sum values from 2 arms + zvertex = 33 input neurons



3 hidden layers (n1=66, n2=30, n3=10 neurons)

back-propagation to modify weight W and bias V

Error (target-output) : $E = 0.5 (X_T[n_4] - X_4[n_4])^2$
 $dE/dX_4 = X_T - X_4$, $dX_4/dY_4 = F'(X_4)$, $dY_4/dW_D = X_3$

$dE/dW_D = (dE/dX_4) (dX_4/dY_4) (dY_4/dW_D)$

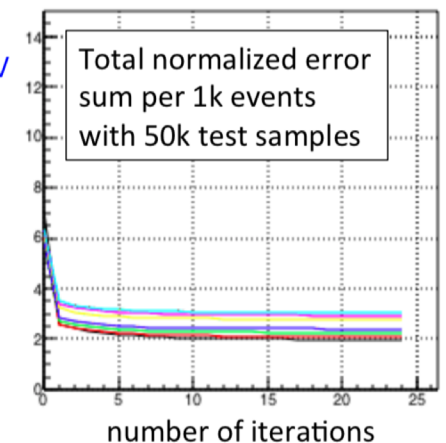
$W_D = W_D + \alpha (X_T - X_4) F'(X_4) X_3$

$V_D = V_D + \alpha (X_T - X_4) F'(X_4)$

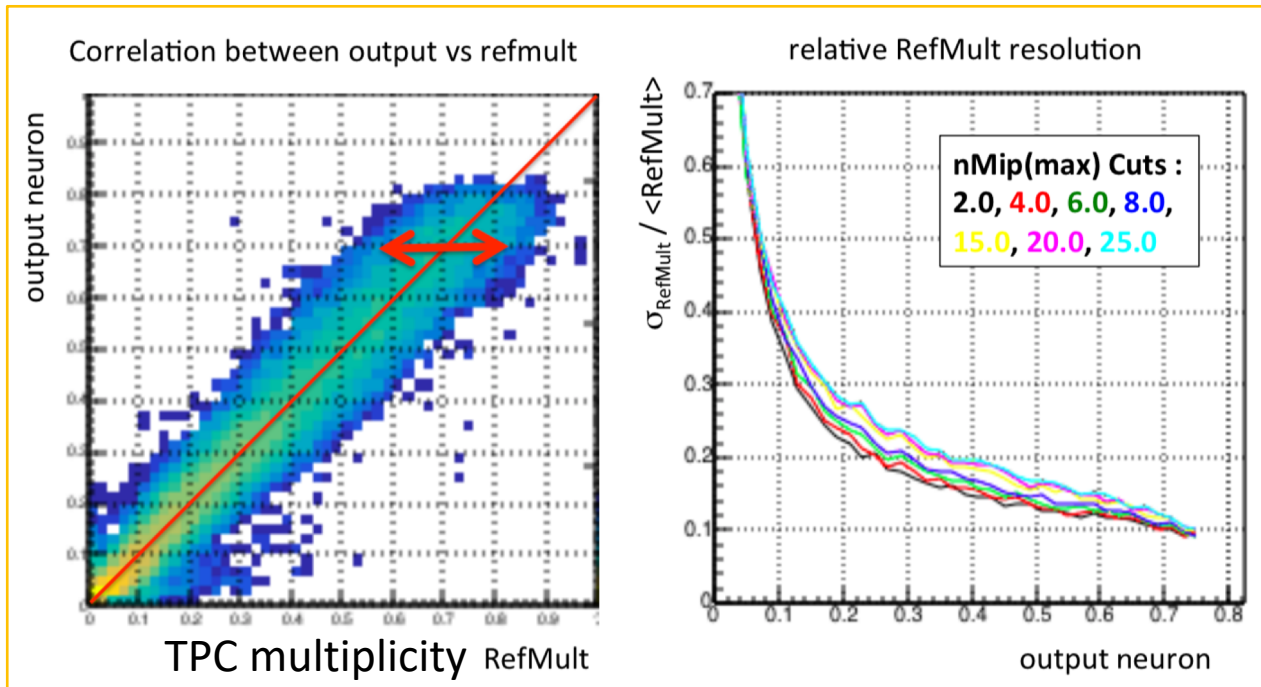
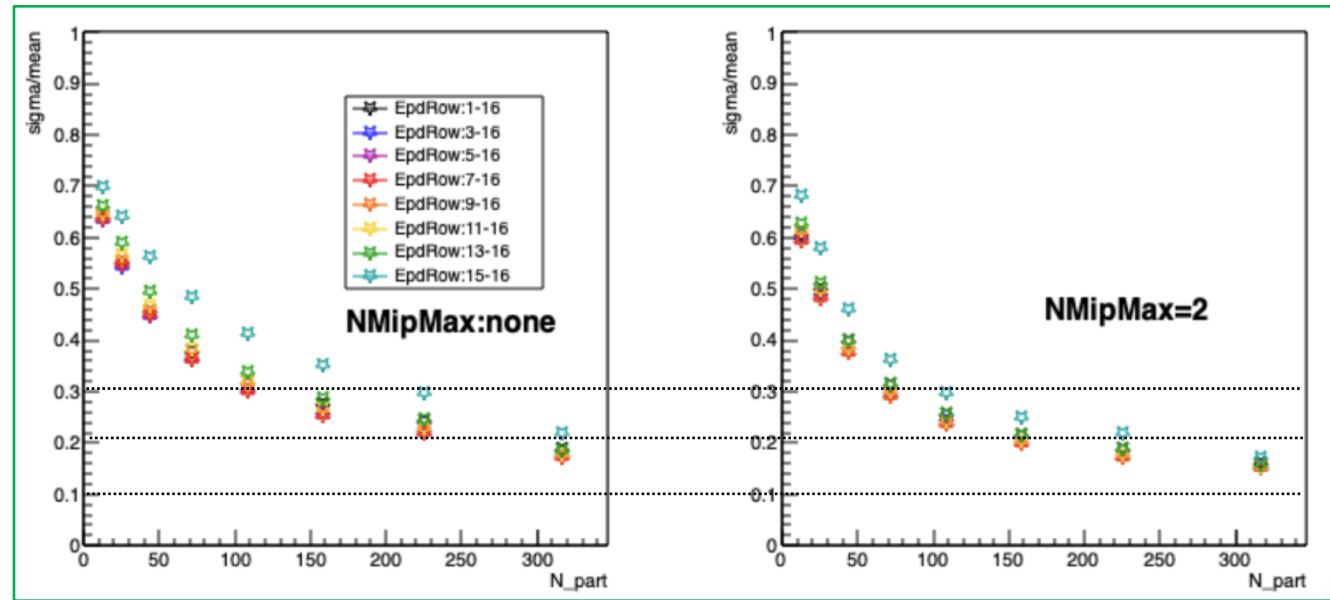
$dE/dX_3 = (X_T - X_4) F'(X_4) W_D$

.....

1 output layer with 1 neuron (as refmult)



Centrality resolution with EPD
by summing of outer rings
or by neural network



nMip Sum centrality resolution in EPD
estimated via TPC multiplicity resolution
Optimum : EPD ring sum from 7 to 16
: nMipMax cut of 2

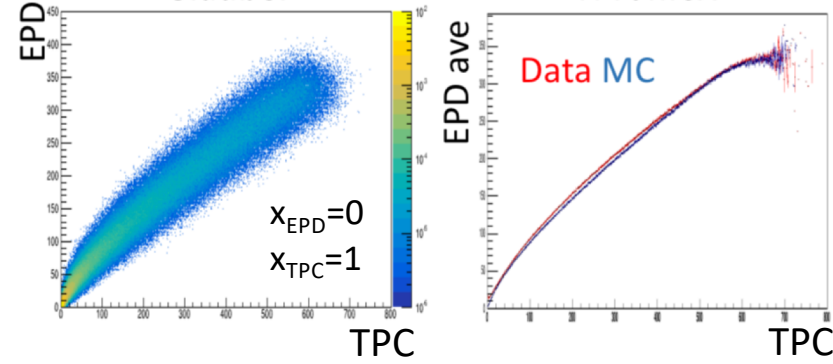
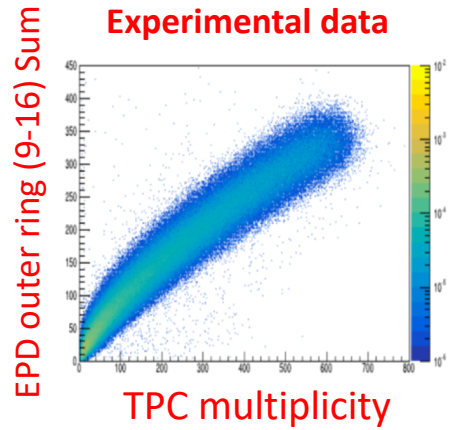
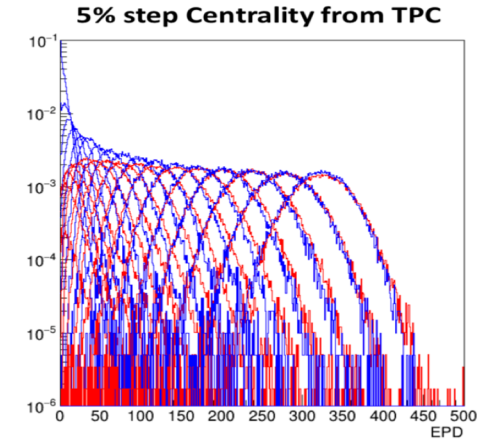
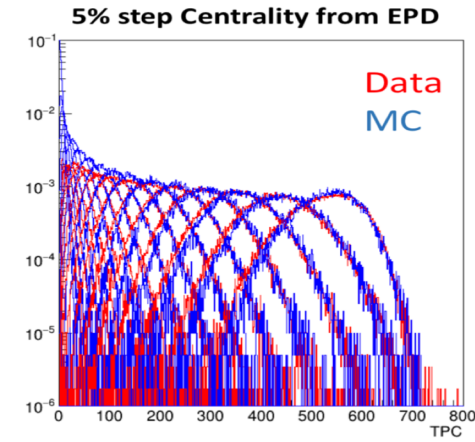
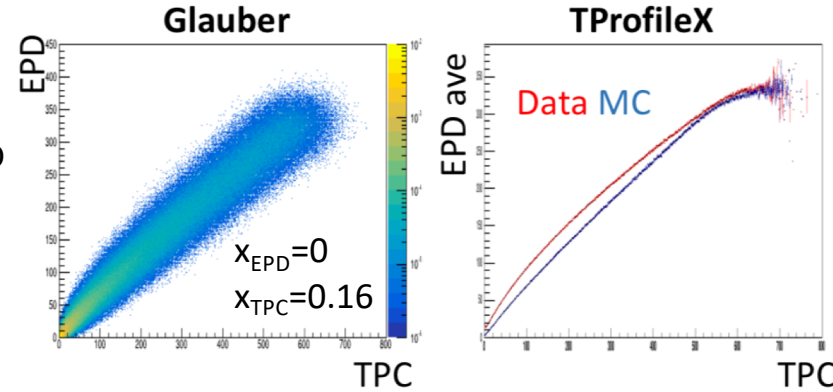
N.N. centrality resolution in EPD
estimated via TPC multiplicity resolution
Optimum : nMipMax cut of 2

$$N_{\text{source}} = (1-x) N_{\text{part}} + x N_{\text{coll}} \quad x : \text{fraction of } N_{\text{coll}}$$

Experimental data are not corrected for detector effects.

$$\text{case : } x_{\text{EPD}}=0 \quad x_{\text{TPC}}=1$$

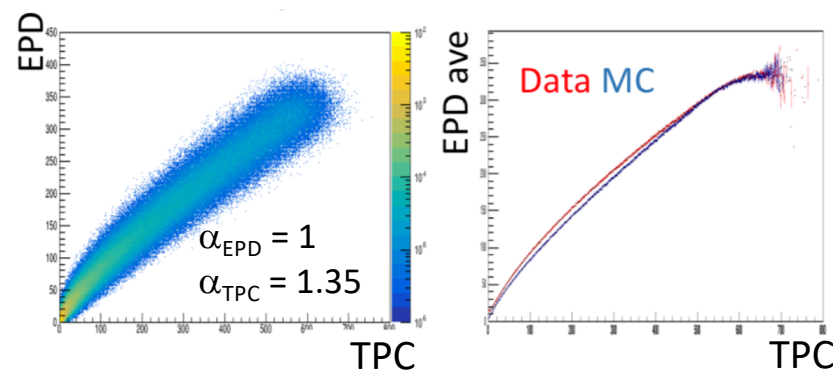
- 2 components; $N_{\text{part}}, N_{\text{coll}}$
- independent NBD for TPC, EPD
- mult. dep. $\text{eff}_{\text{Track}}$ for TPC
- Landau + truncation for EPD



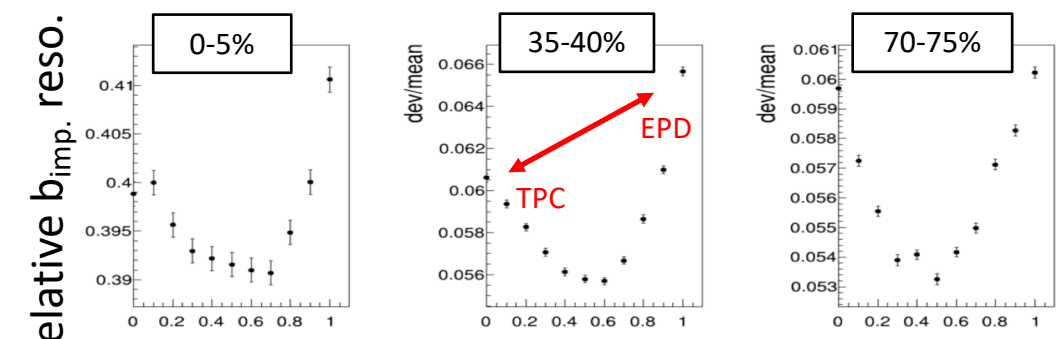
TPC+EPD combined b_{imp} resolution
 $\text{Ave} = (1-f) \text{TPC} + f \text{EPD}$

Alternative approach :

$$N_{\text{source}} = N_{\text{part}}^\alpha$$



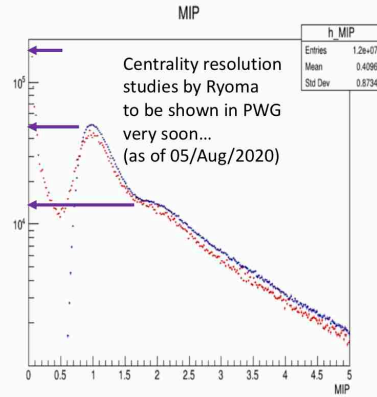
$(\sigma_b / \langle b \rangle)$



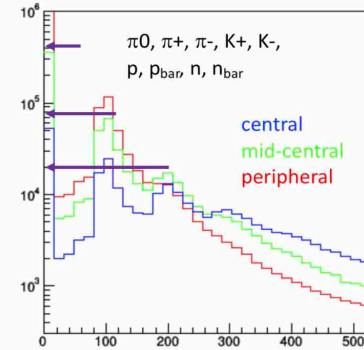
f : fraction of EPD

Full Geant simulation of EPD in STAR

Ryoma's Glauber simulation with Landau function compared with experimental data at 27GeV AuAu

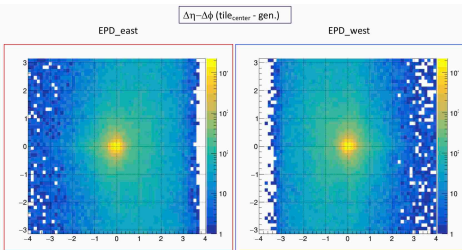
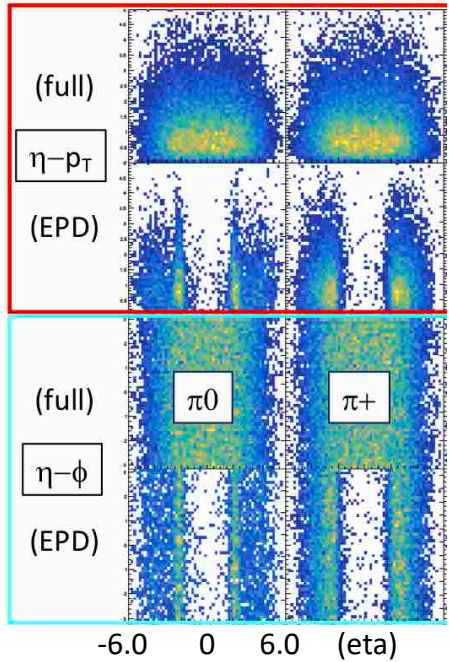
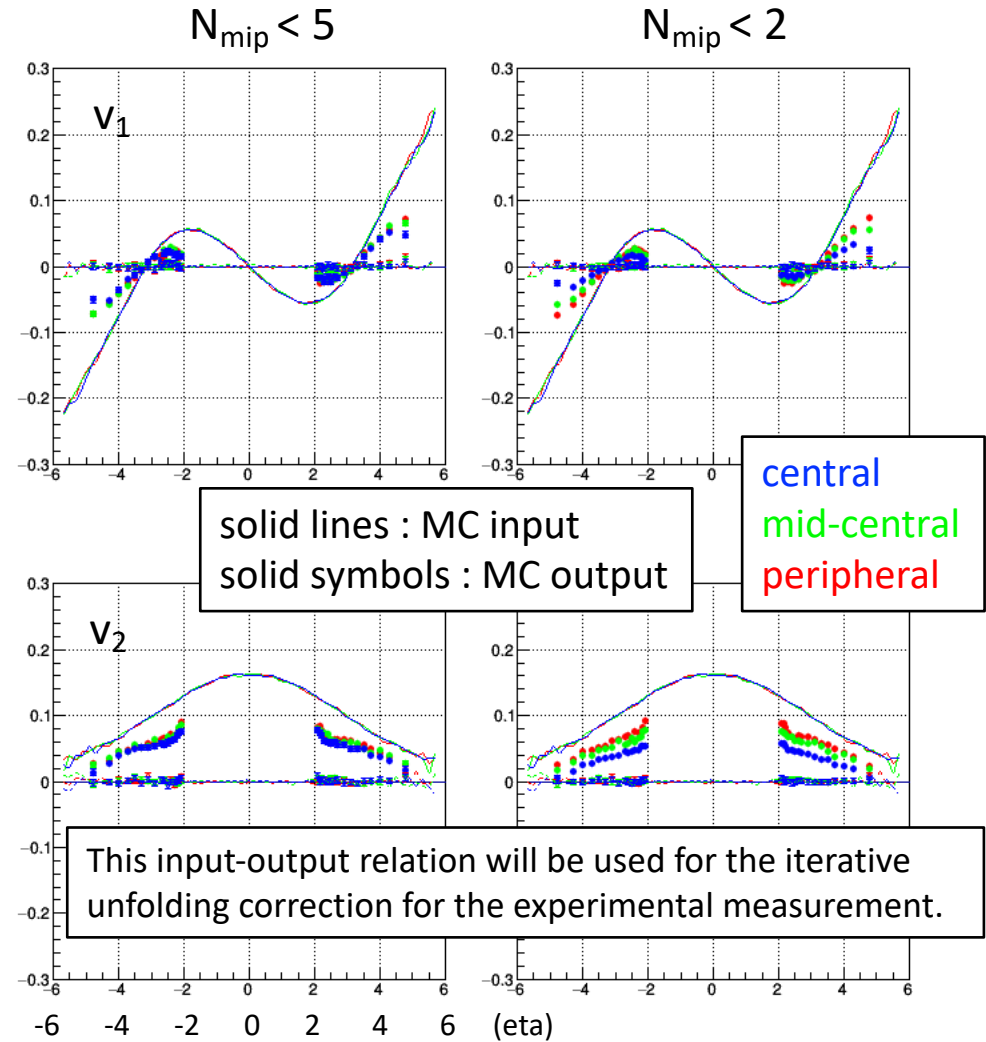
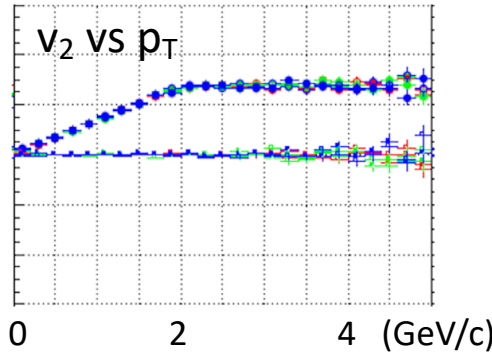
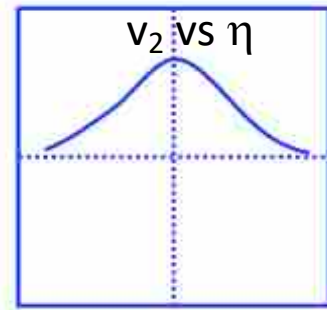
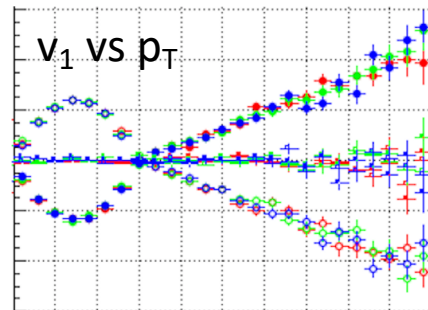
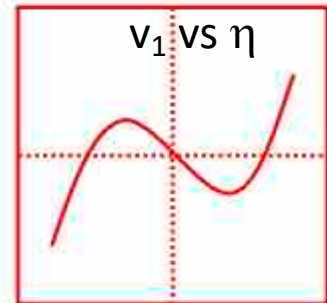


Full Geant simulation with multiplicities in 27GeV AuAu

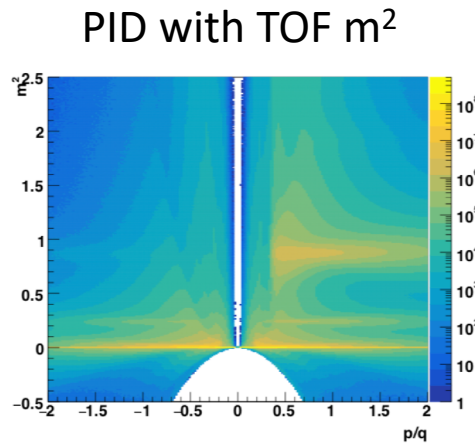
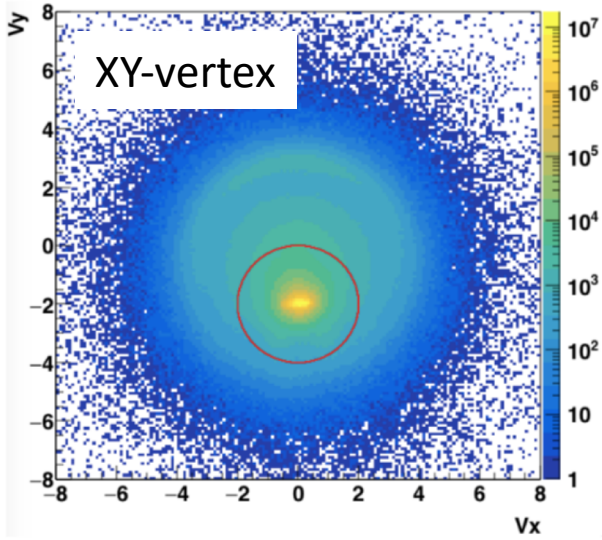
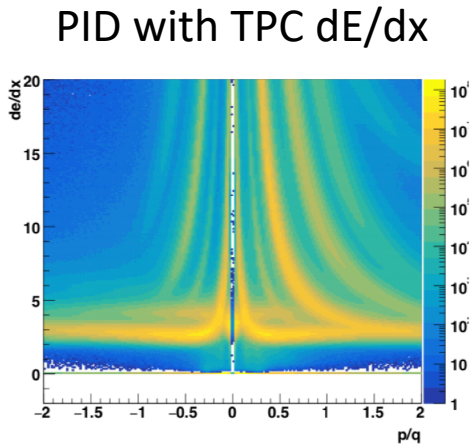
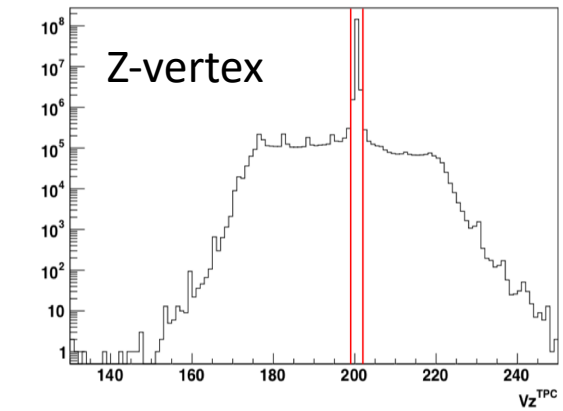


v_1, v_2 seen in EPD with full Geant MC

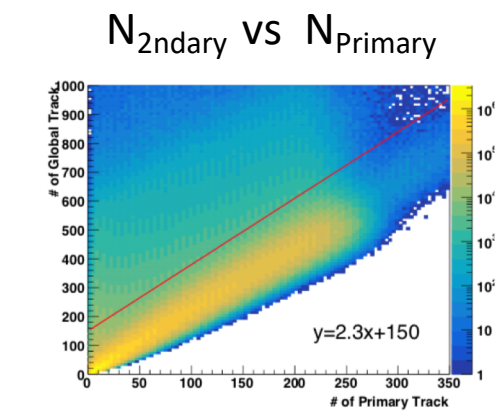
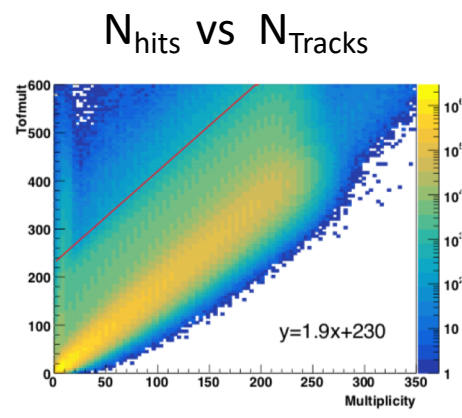
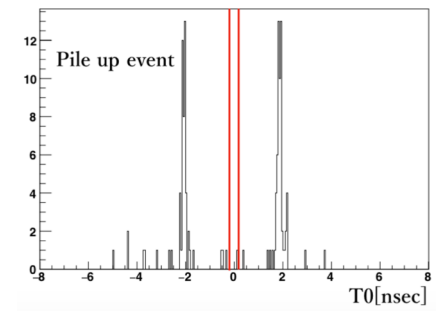
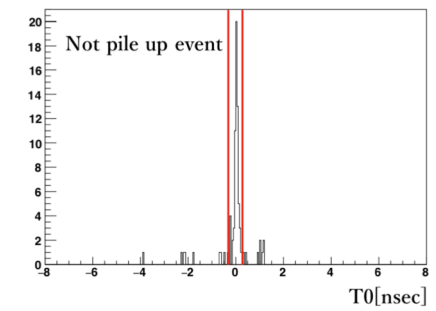
v_1, v_2 vs eta, p_T --- assumption



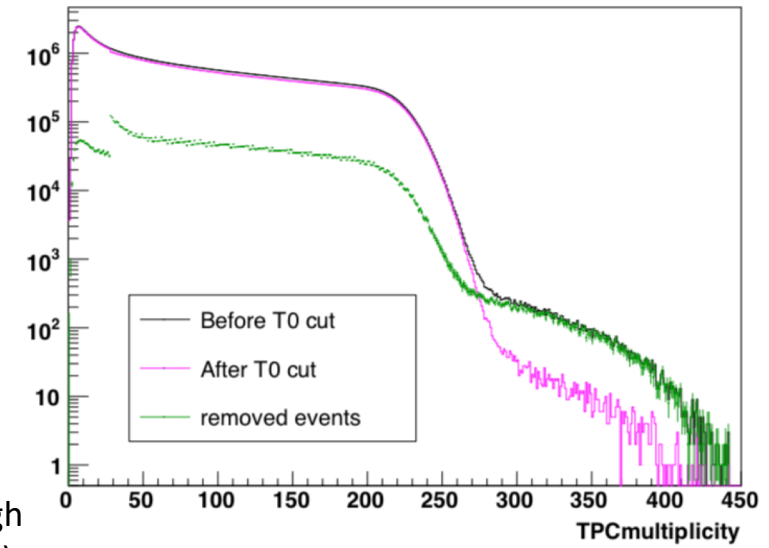
Event selection (pile-up rejection) for fixed target mode



use T0
distribution
for each event



with and without rejections



Momentum, flight path length
and arrival time at TOF with rough
PID from TPC gives start time (T0)
information for each track.

Summary

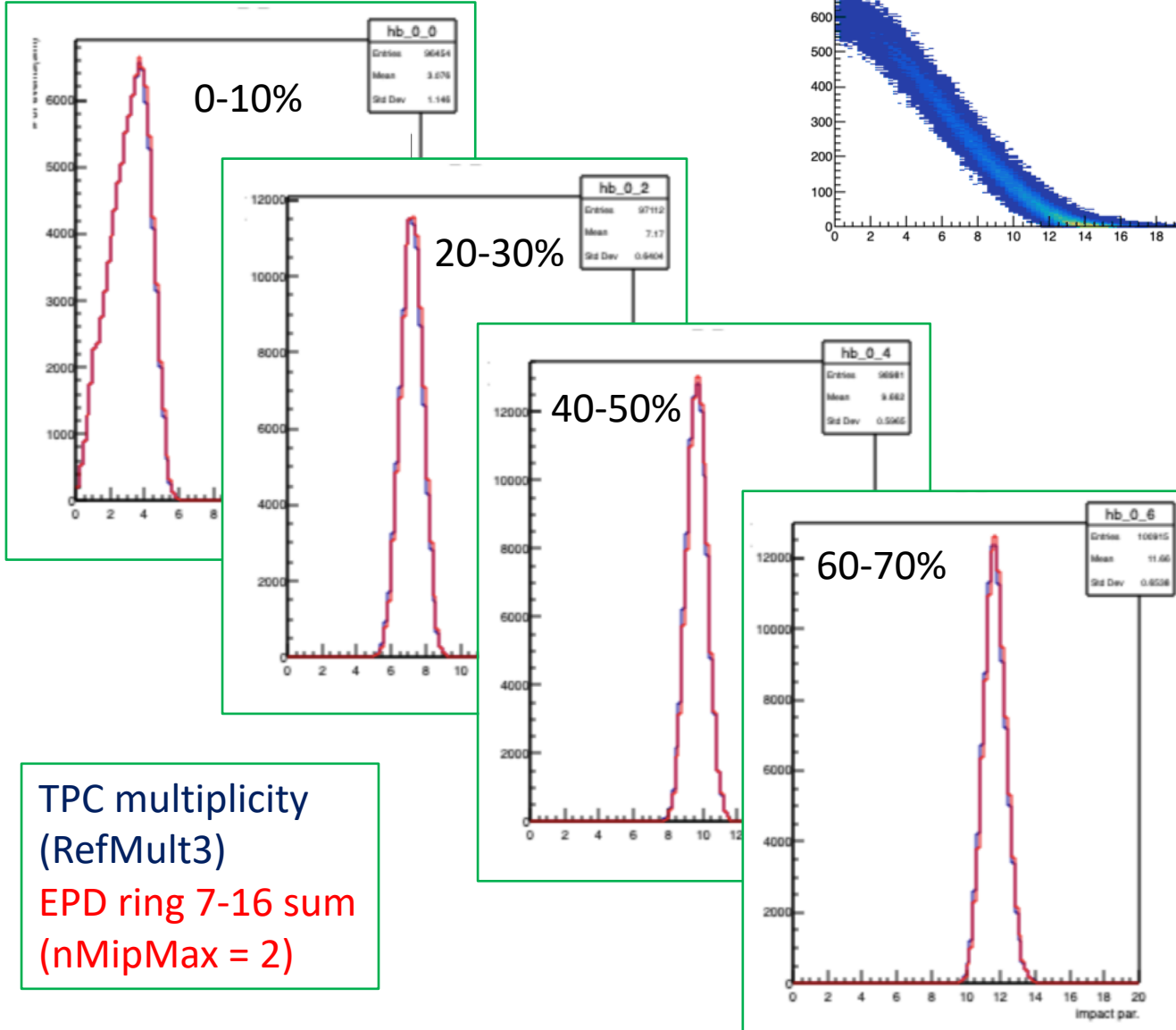
- Detector upgrades and runnings
- Event Plane Detector (EPD $|\eta| = 2 - 5$)
- E.P. and centrality determination
- Geant simulation
- Pile-up rejection study

Many thanks to our students in Tsukuba :

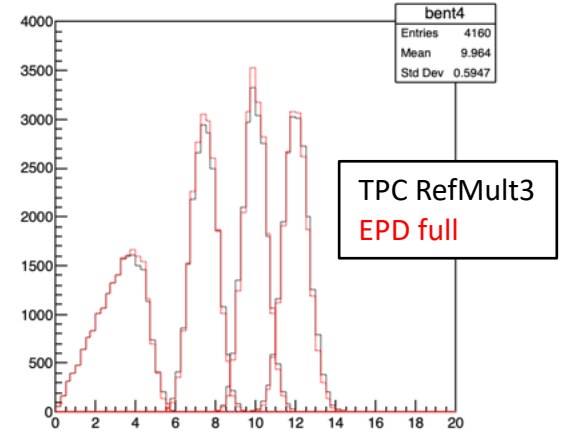
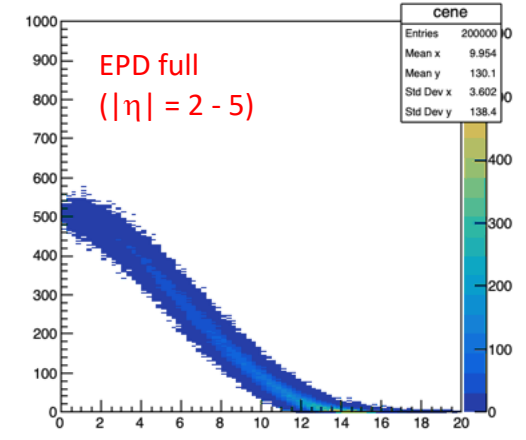
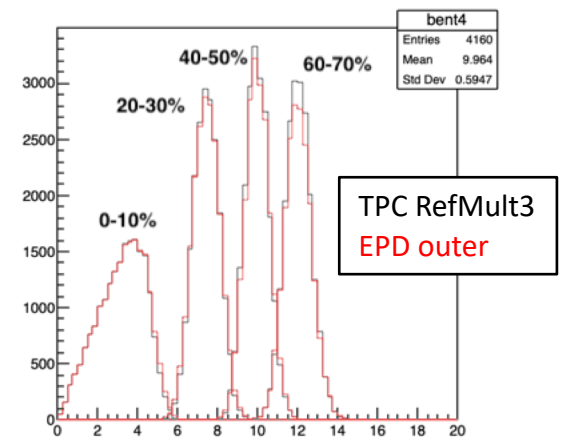
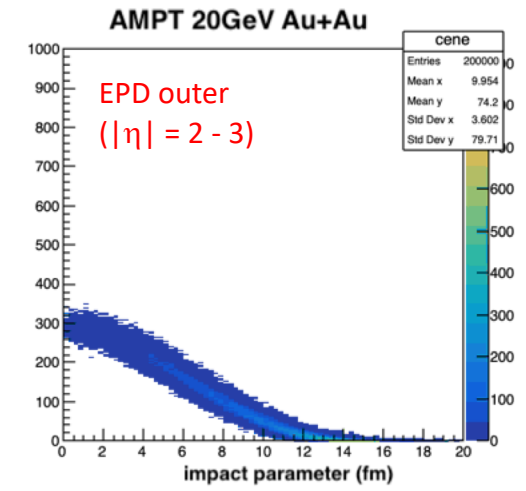
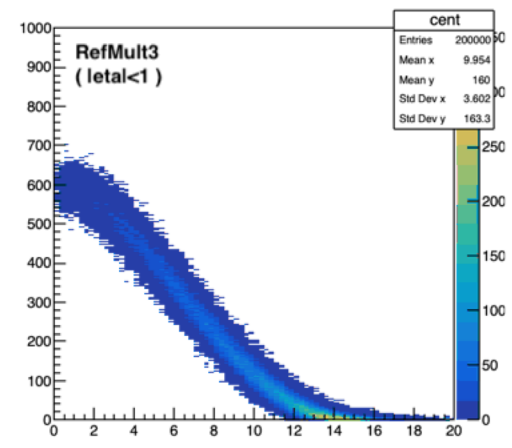
Ryoma Nakazato, Yuri Sato, Kosuke Okubo, Risa Nishitani, Moe Isshiki

Backup slides

27GeV Au+Au run18 with Glauber fit



TPC multiplicity
(RefMult3)
EPD ring 7-16 sum
(nMipMax = 2)



Phys. Rev. C 100, 044904 (2019)

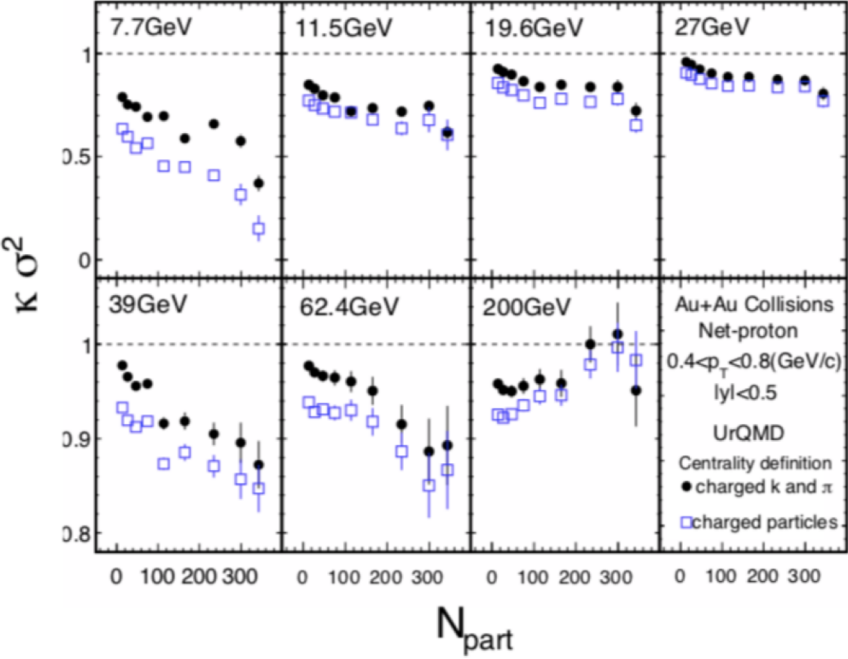
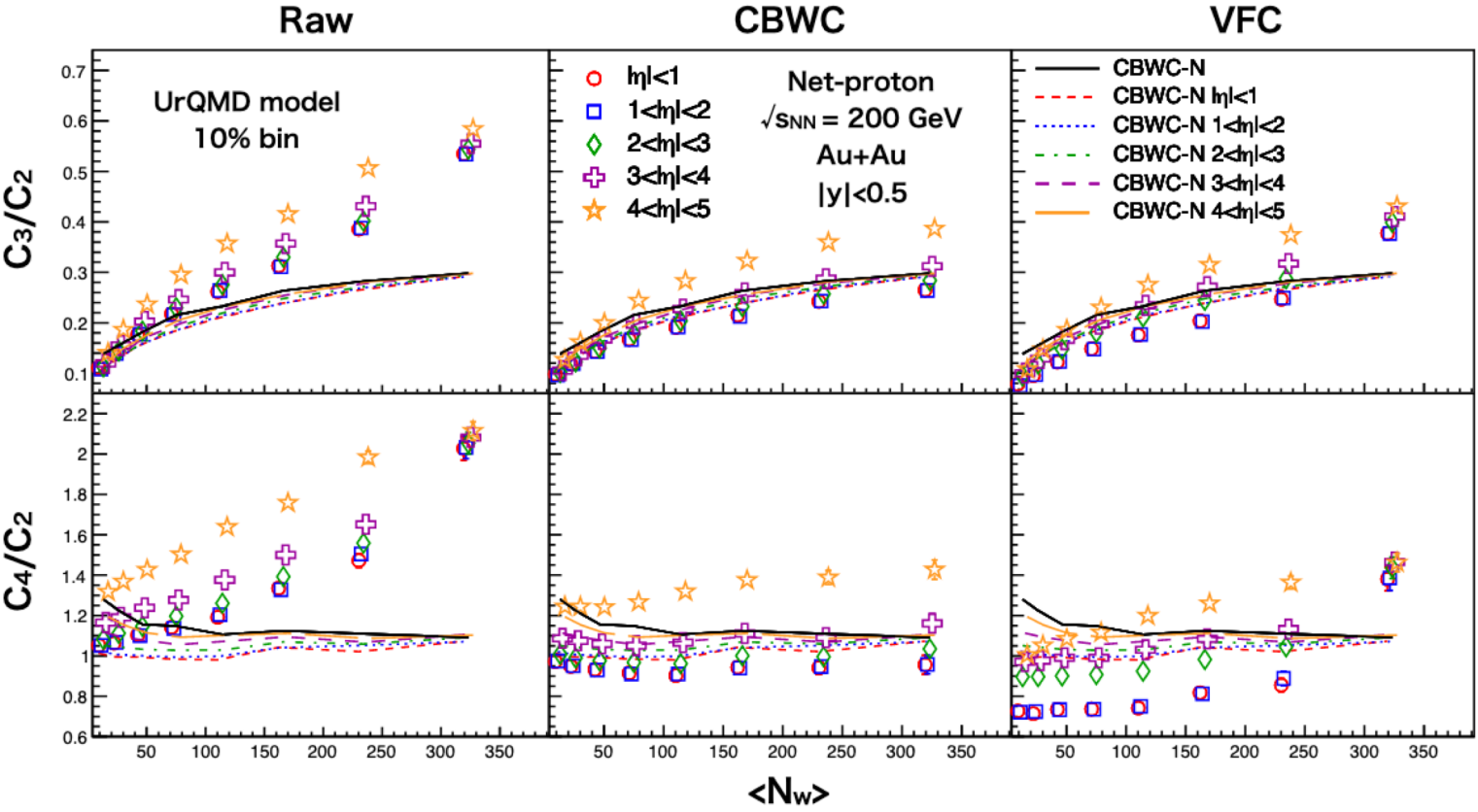


FIG. 6. C_3/C_2 and C_4/C_2 of net-proton distributions as a function of $\langle N_W \rangle$ by using UrQMD model simulation for 10% centrality divisions for different centrality definitions drawn in different markers. Centralities are determined in $|\eta| < 1$, $1 < |\eta| < 2$, $2 < |\eta| < 3$, $3 < |\eta| < 4$ and $4 < |\eta| < 5$ excluding proton (anti-proton) drawn in different colors. Raw, CBWC and VFC results are shown from left to right. CBWC-N results by definition2 and definition1 are shown in black solid lines and colored dotted lines, respectively.