Feasibility of neutron asymmetry measurements with NICA MPD

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Chiral Vortaic Effect

PHYSICAL REVIEW C **82**, 054910 (2010)

Chiral vortaic effect and neutron asymmetries in heavy-ion collisions

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(Received 17 June 2010; published 30 November 2010)

We study the possibility of testing experimentally signatures of P-odd effects related to the vorticity of the medium. The chiral vortaic effect is generalized to the case of conserved charges different from the electric one. In the case of baryonic charge and chemical potential, such an effect should manifest itself in neutron asymmetries measured by the Multipurpose Detector at the Nuclotron-Based Ion Collider Facility accelerator complex. The required accuracy may be achieved in a few months of accelerator running. We also discuss polarization of the hyperons and P-odd correlations of particle momenta (handedness) as probes of vorticity.

For estimation of the CVE we could explore three-particle correlator of azimuthal angels :

$$\langle \cos(\varphi_a + \varphi_b - 2\varphi_c) \rangle ,$$

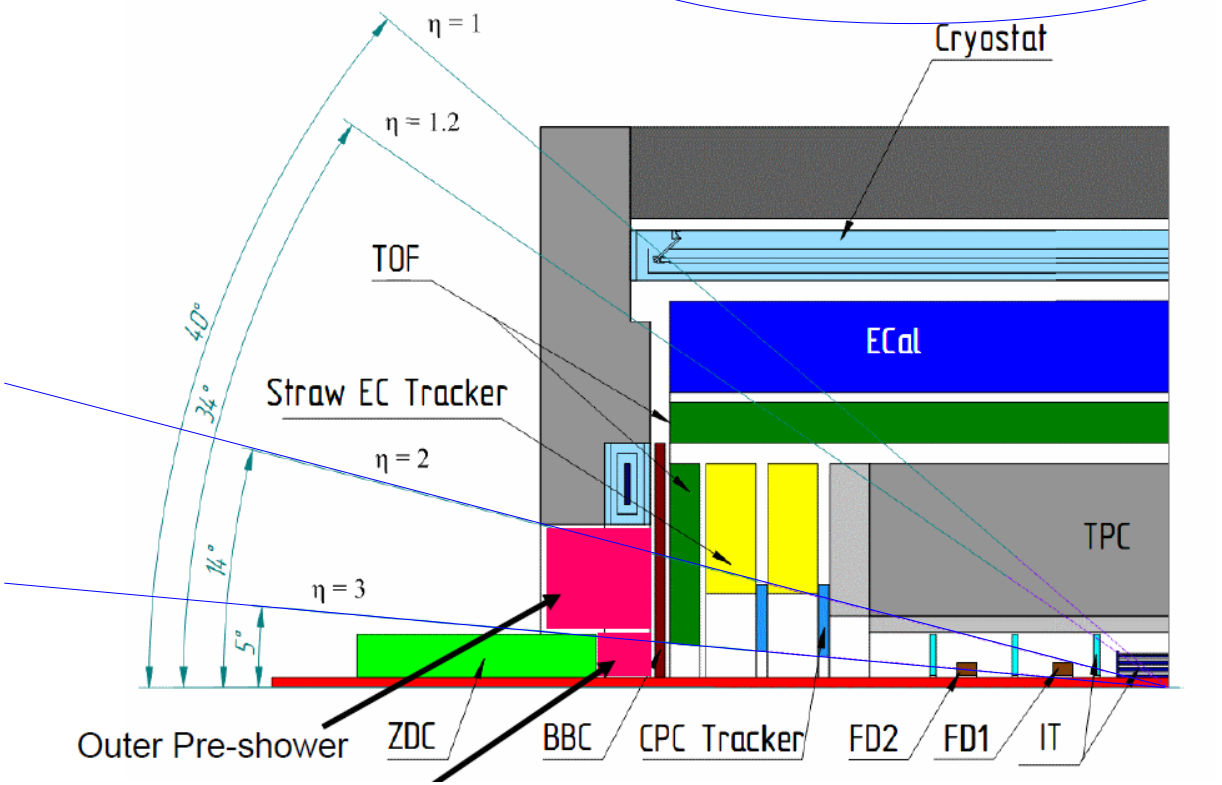
φ_a φ_b azimuthal angles of neutrons from midrapidiry $|\eta|<3$,

φ_c azimuthal angles of neutrons from high-rapidity $|\eta|>3$

Neutron detectors in MPD

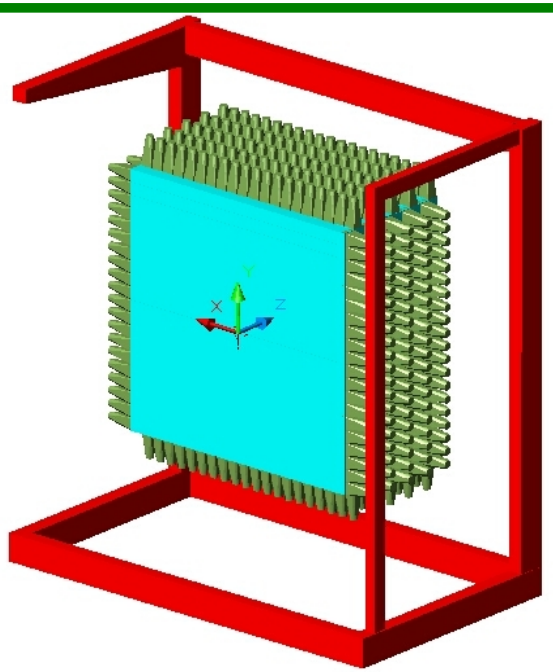
|η|<1 (Ecal, NDet)

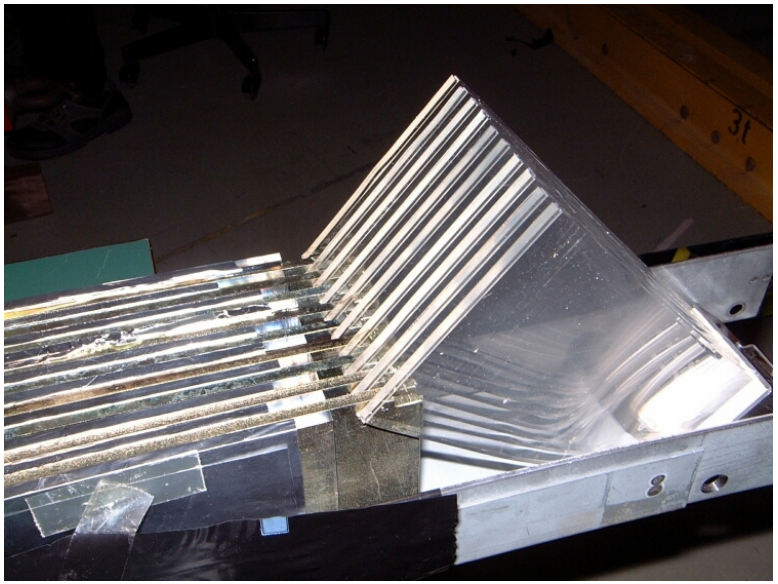
2<|η|<3



|η|>3 (ZDC)

The Large Area Neutron Detector (LAND at GSI)





NIM B 240(2005)863–870: Neutron yields from 1 GeV/nucleon ^{238}U ion beams on Fe target

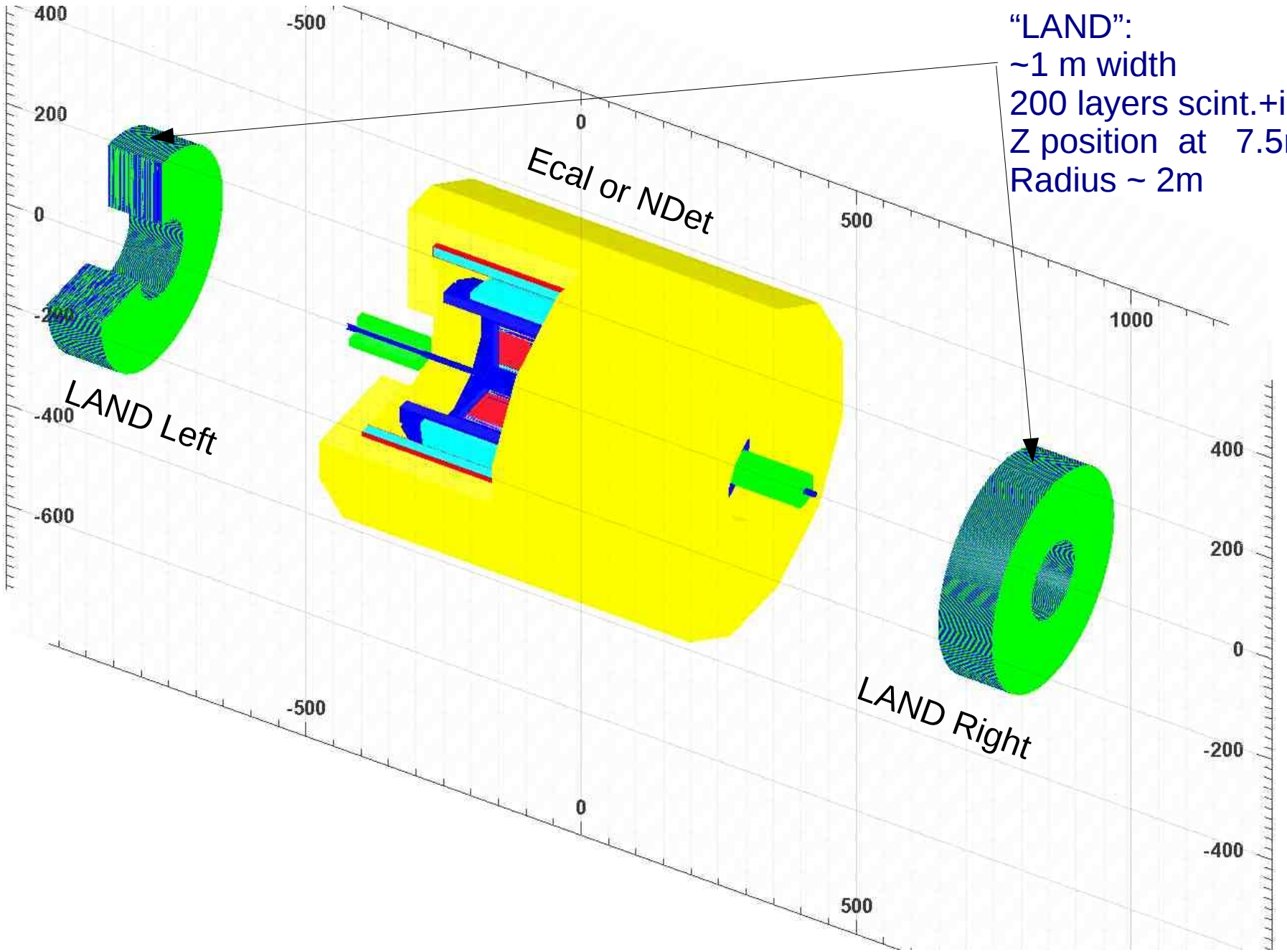
O. Yordanov, K. Gunzert-Marx, P. Adrich, T. Aumann, K. Boretzky,H. Emling, G. Fehrenbacher, F. Gutermuth, H. Iwase, H. Johansson,
K.L. Jones, A. Kovalov, T. Radon, D. Schardt

- LAND was designed to measure the momenta of high-energy neutrons with high efficiency; during the past decade it served in many experiments aiming at nuclear reaction and nuclear structure studies.

- LAND is built from 200 modules, each of 0.1 m x· 2 m cross section and 10 cm depth and consists of alternating layers (5 mm thickness) of iron and organic scintillator material.

- The intrinsic time resolution amounts to $\sigma_t \approx 250$ ps; the position resolution derived from the timing signals amounts to $\sigma_{pos} \approx 3$ cm, while the position uncertainty with respect to the other two coordinates is given by the geometry of the modules.

MPD with neutron detectors

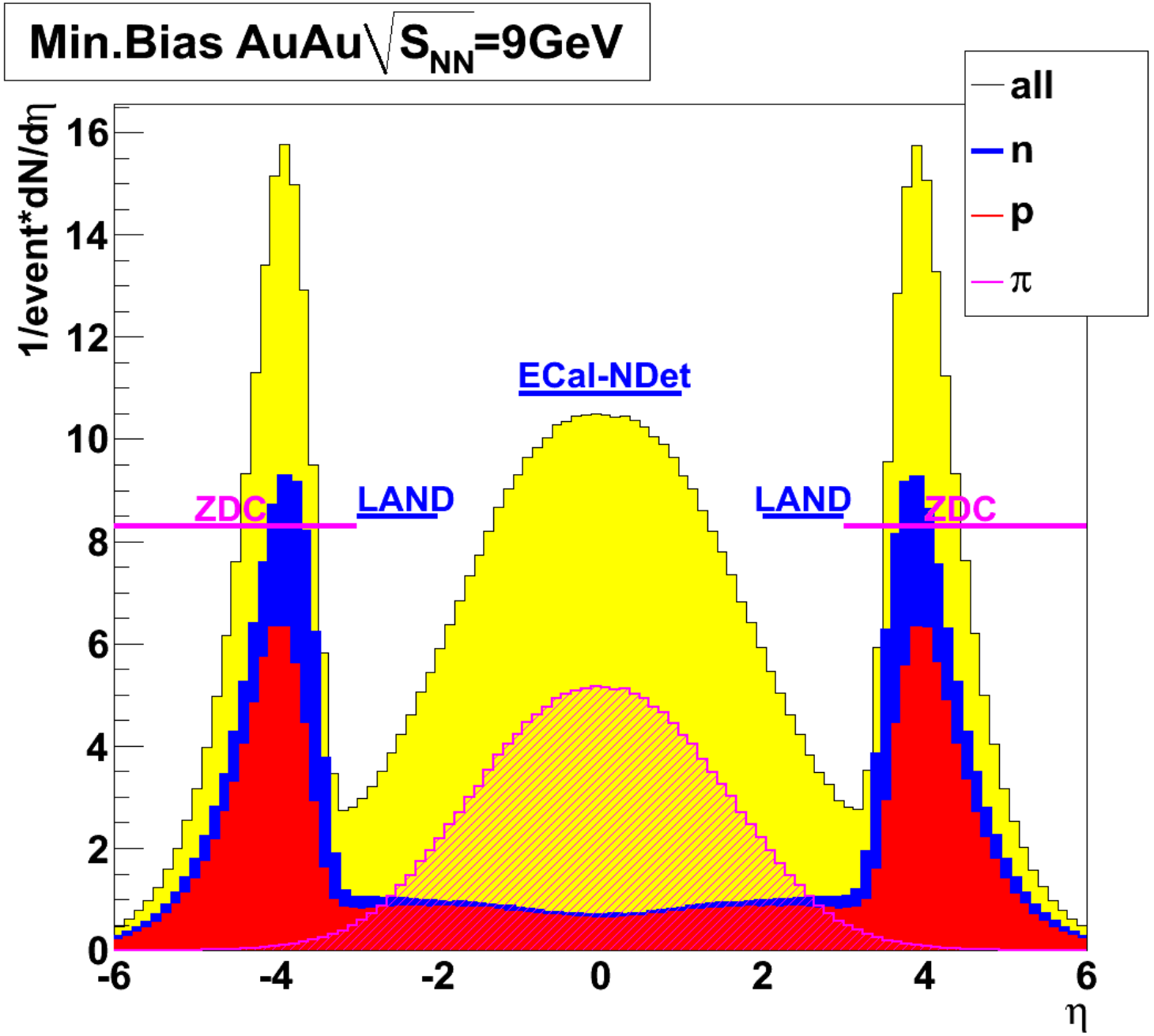


Simulation: software and input

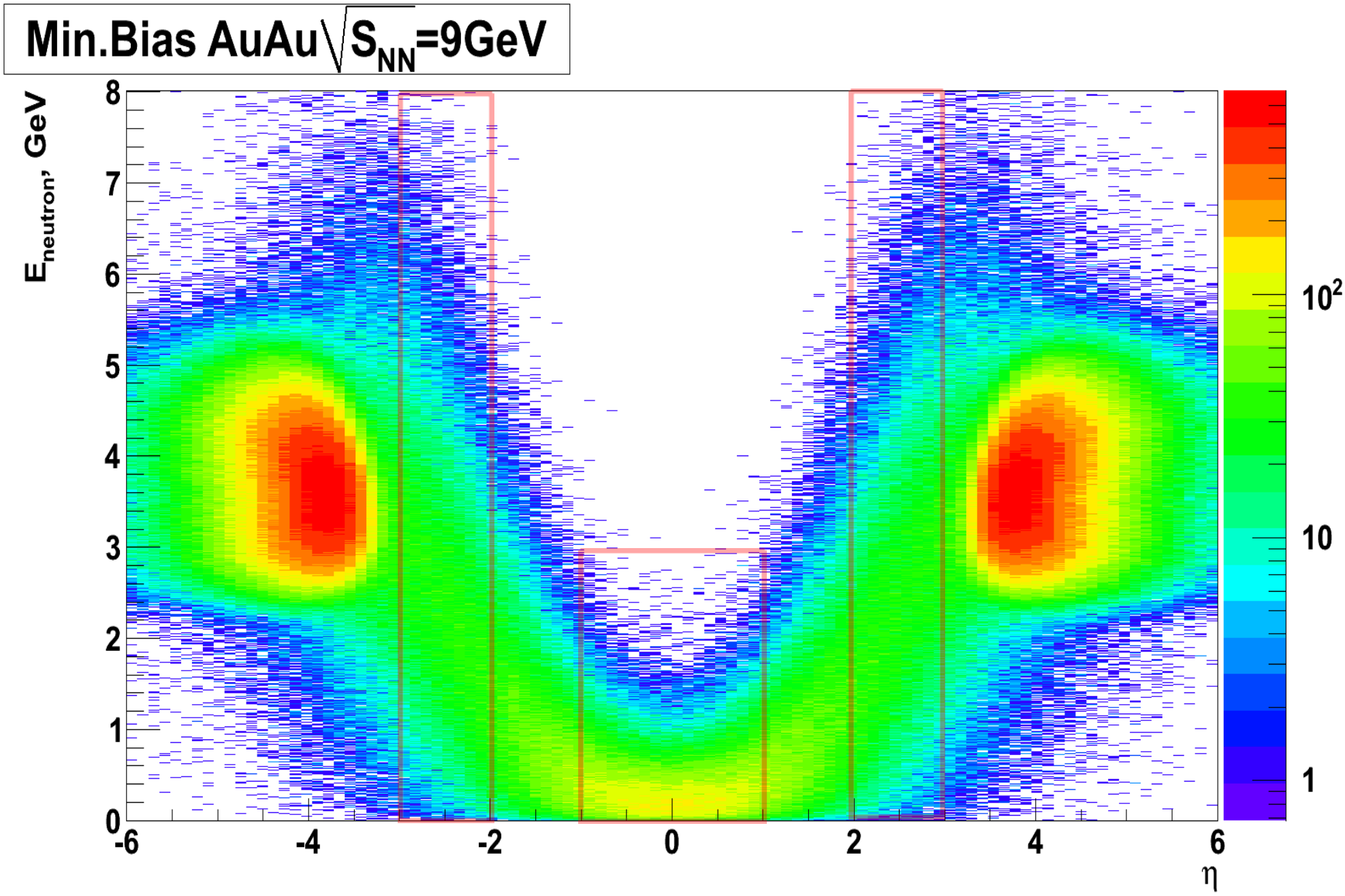
- MPD ROOT (from svn) simulations (Fedora 12 OS in ITEP)
- Standard geometry (Cave,Pipe,Magnet,Sts,Tpc,Tof,eTof,Strow,Cpc,Zdc)
- Switch off Fsa package (forward spectrometer)
- $|\eta|<1$: Ndet package (form svn)
- $2<|\eta|<3$: Land package (new)
- $|\eta|>3$: MC tracks only
- 10^4 UrQMD Min. Bias AuAu $\sqrt{s} = 9$ GeV events
- Hand made neutron asymmetry with respect to RP

UrQMD 2.3

Pseudorapidity (UrQMD)

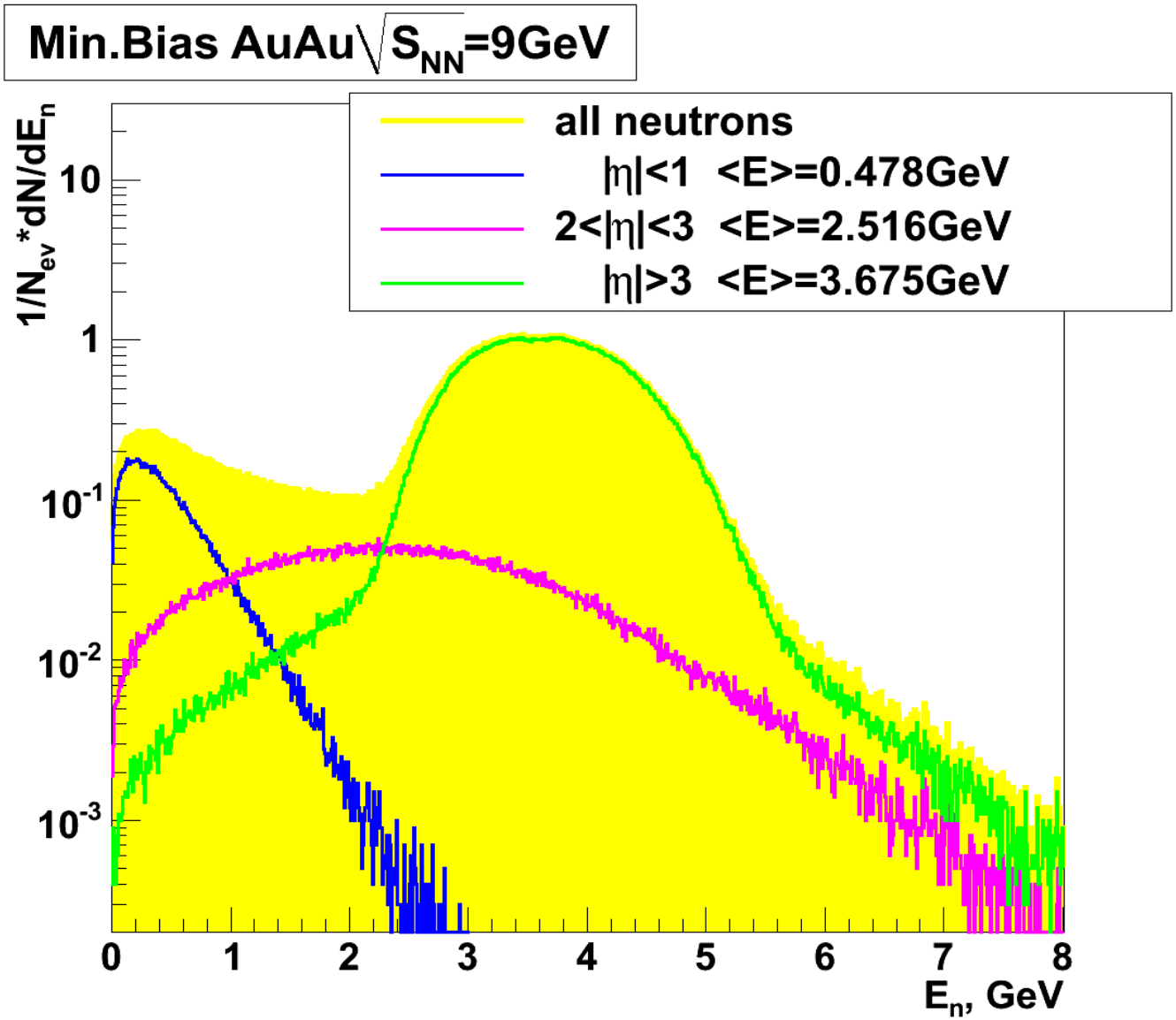


Neutron energy vs Pseudorapidity (UrQMD)



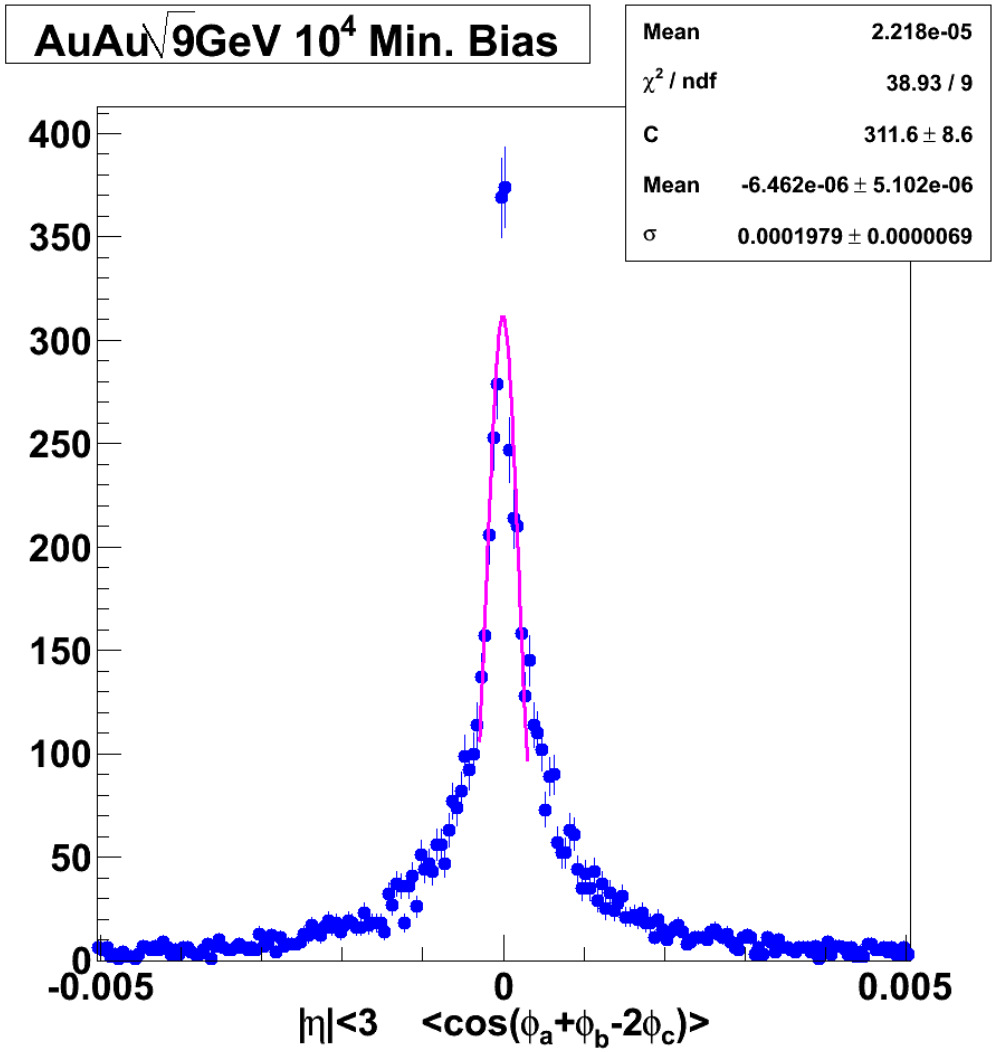
Neutron spectra (UrQMD)

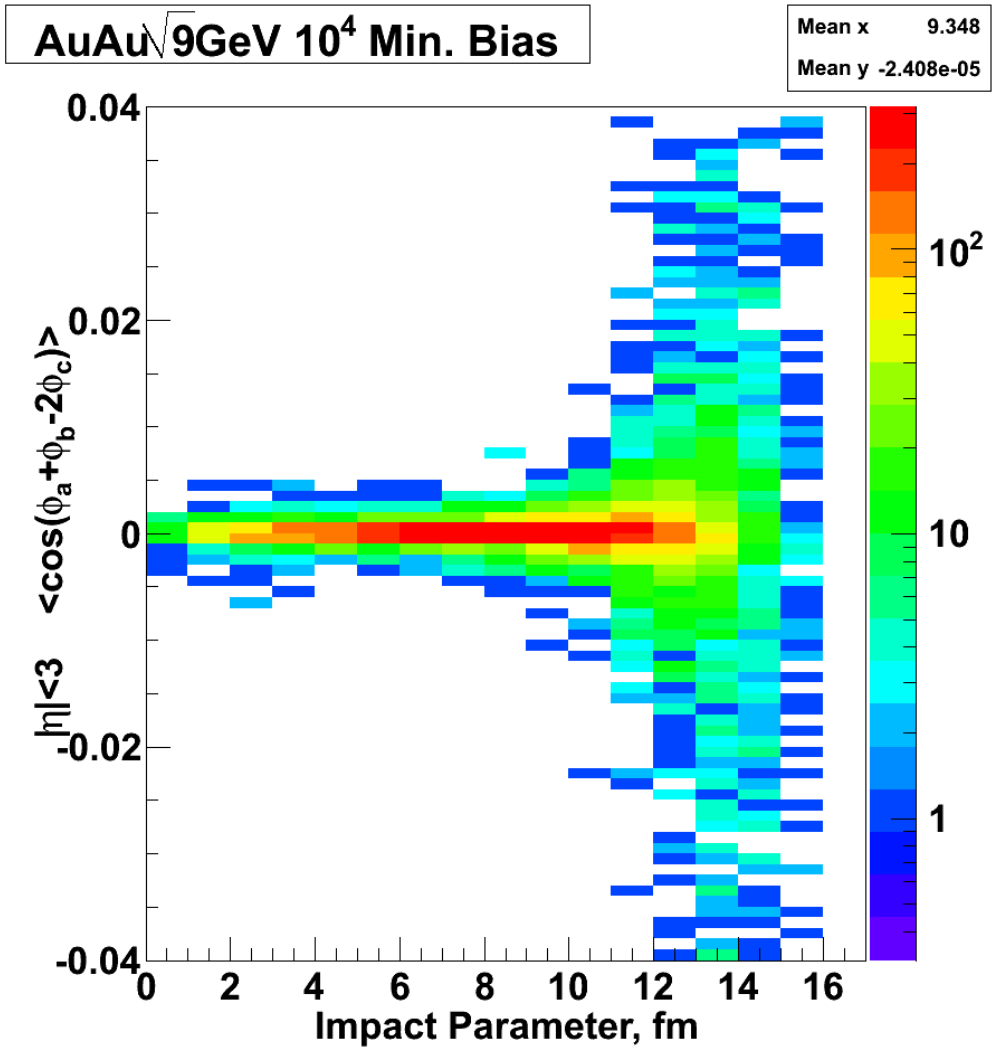
About 28 MC neutrons per event at $|\eta|<1$ and $2<|\eta|<3$
(efficiency and cuts is not included)



Asymmetry in UrQMD

$$\langle \cos(\varphi_a + \varphi_b - 2\varphi_c) \rangle$$



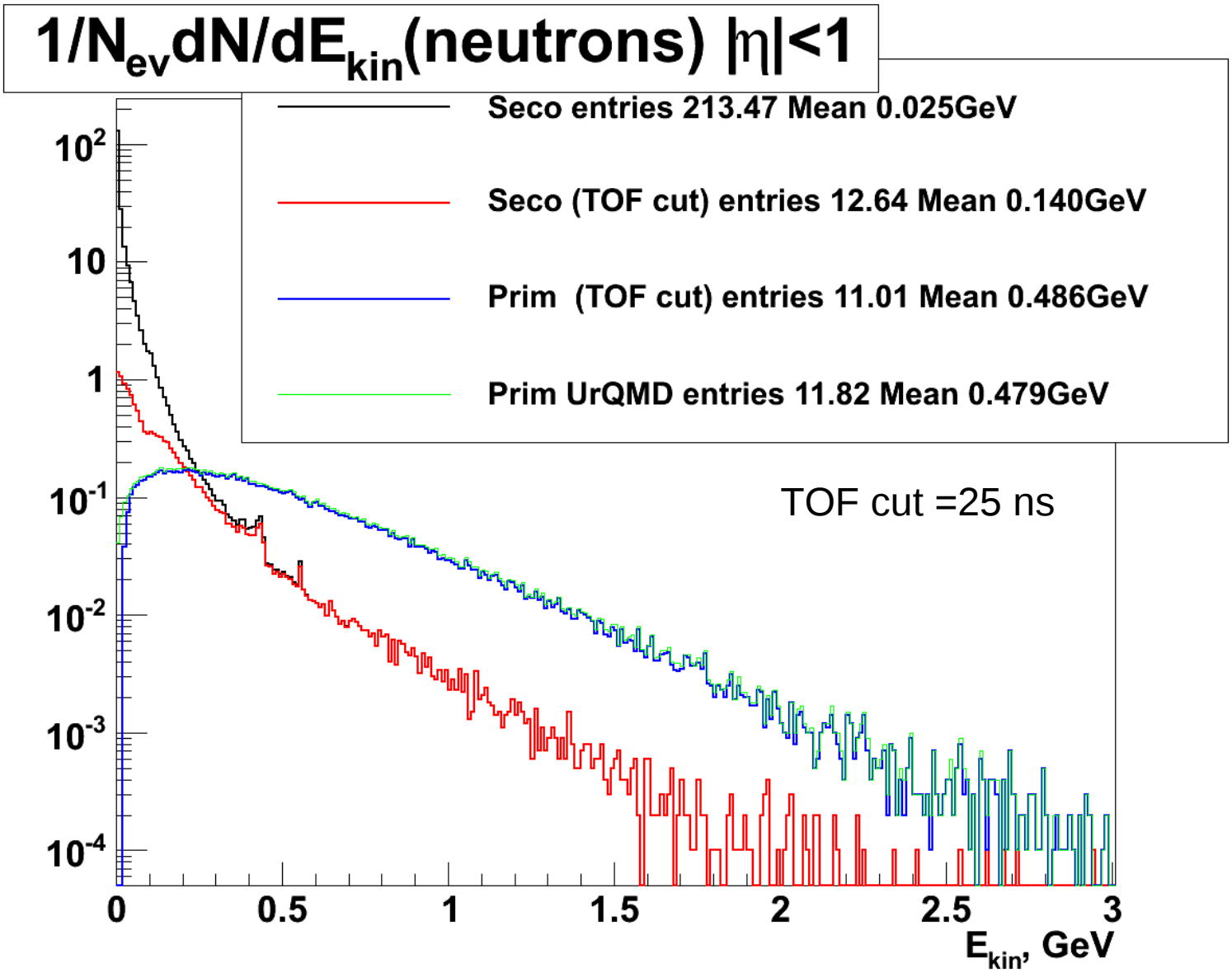


Asymmetry in UrQMD is zero ($\varphi_a + \varphi_b$ $|\eta|<3$ and φ_c $|\eta|>3$)

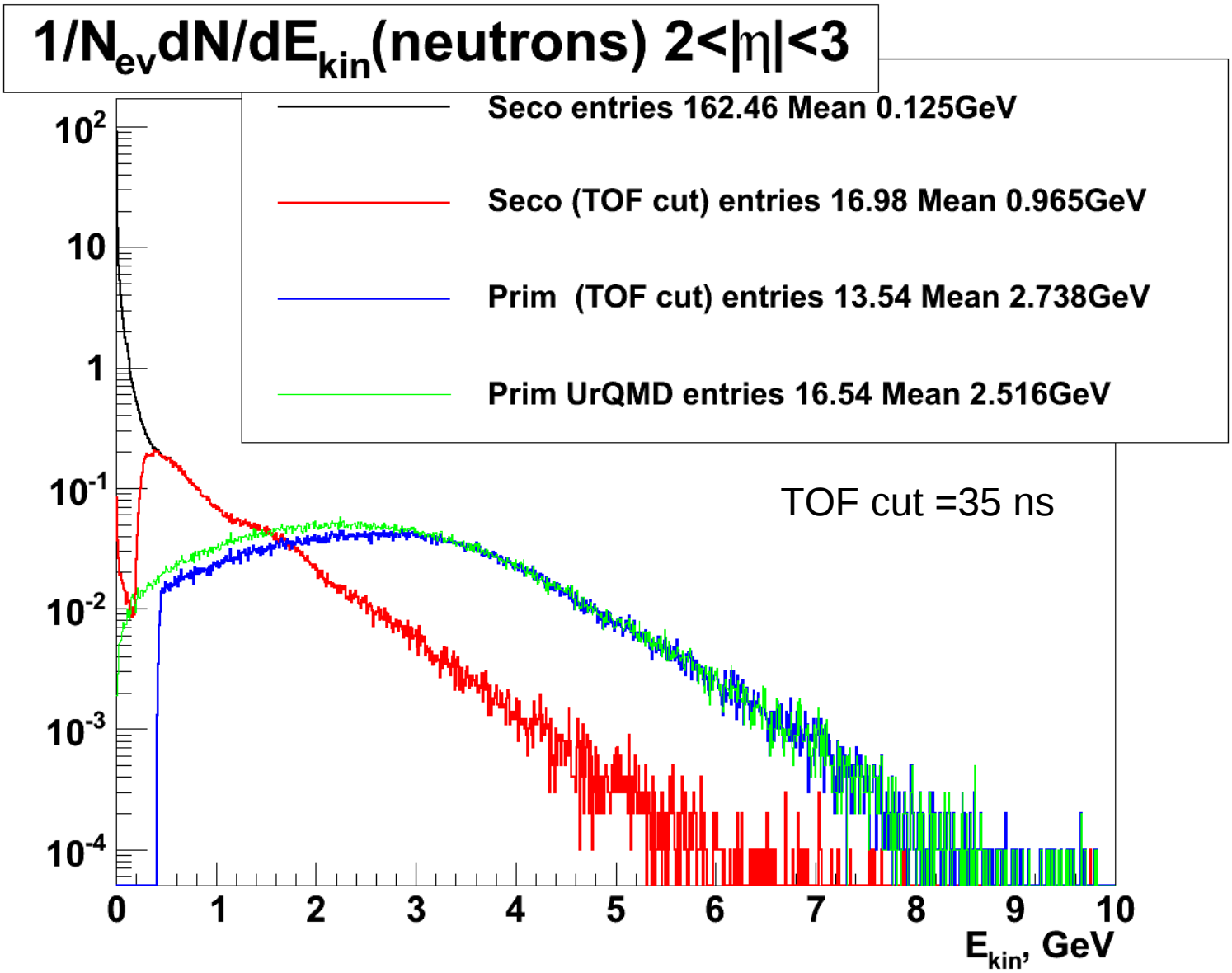
High impact parameter (low neutron multiplicity) region could be a problem.

UrQMD + GEANT3

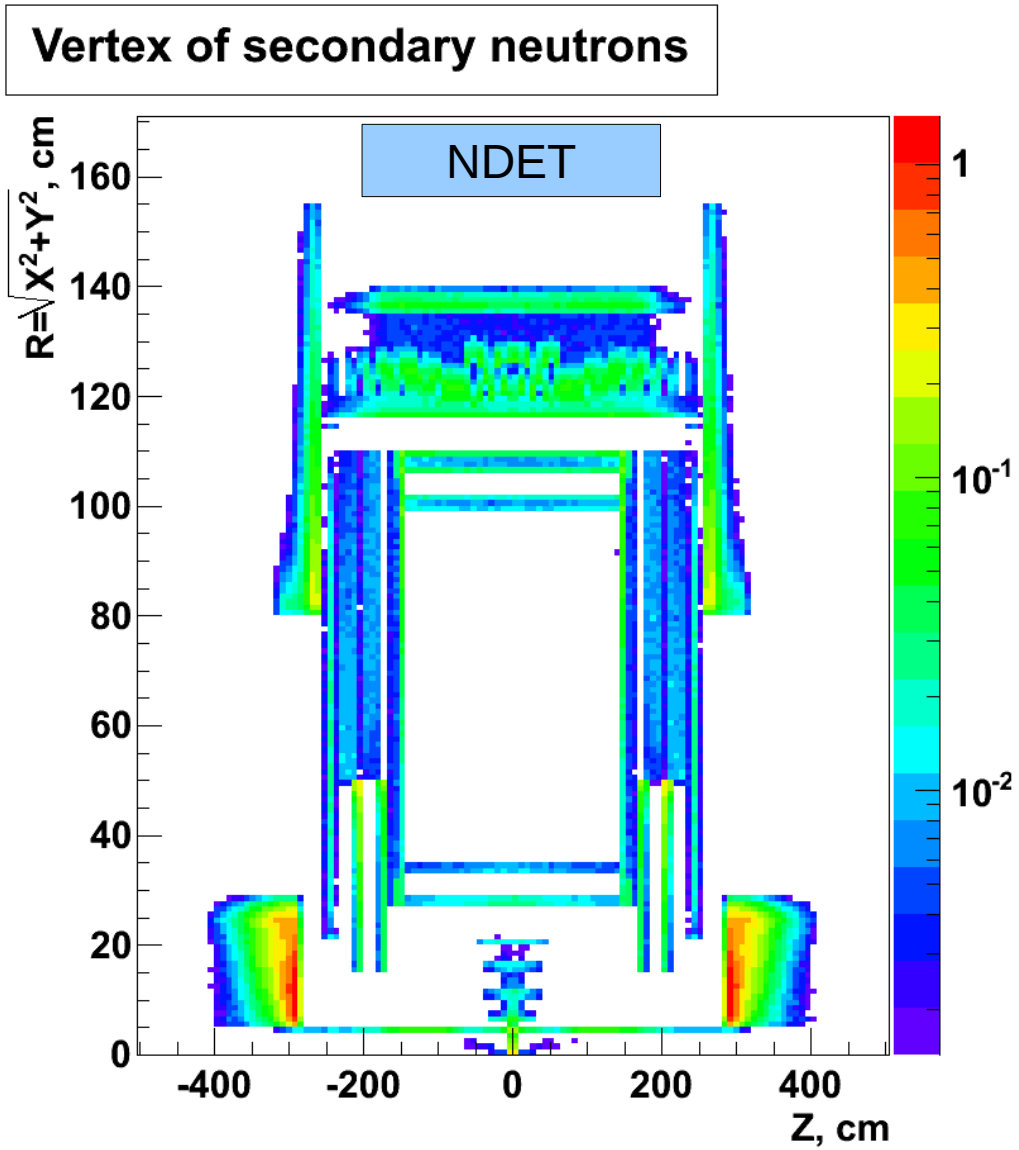
Neutron spectra at |eta|<1

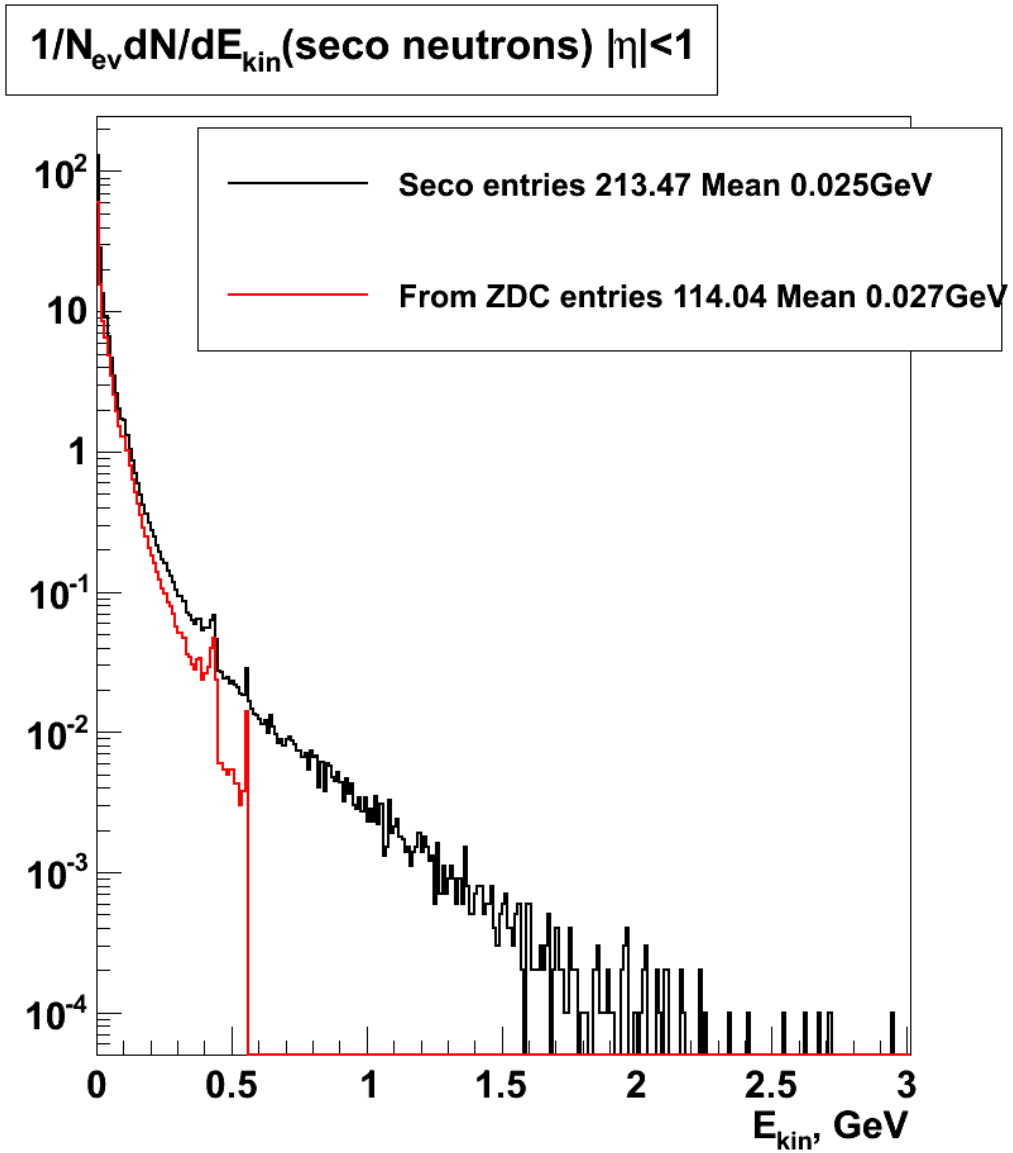


Neutron spectra at 2<|eta|<3

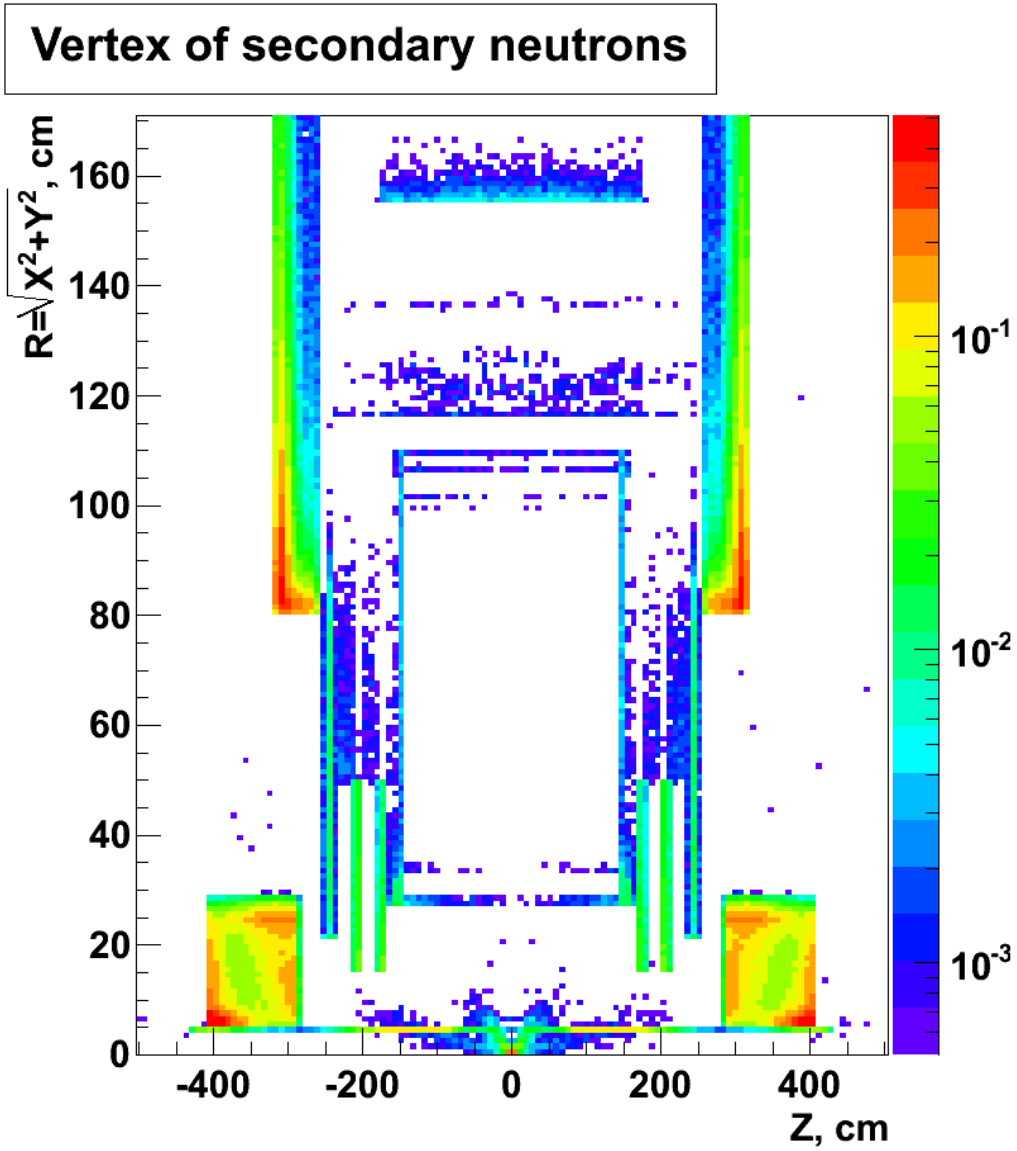


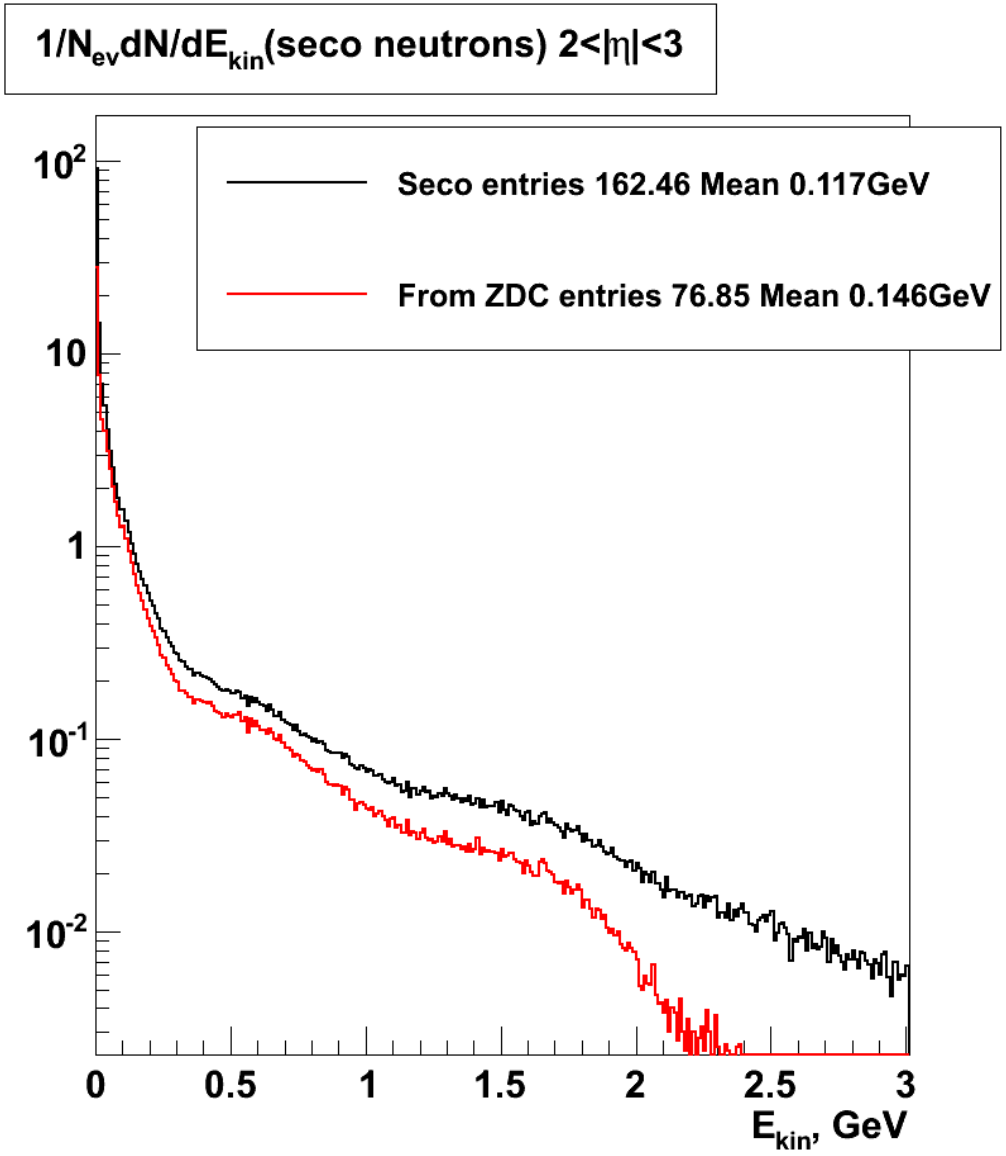
Sources of seco neutrons |eta|<1





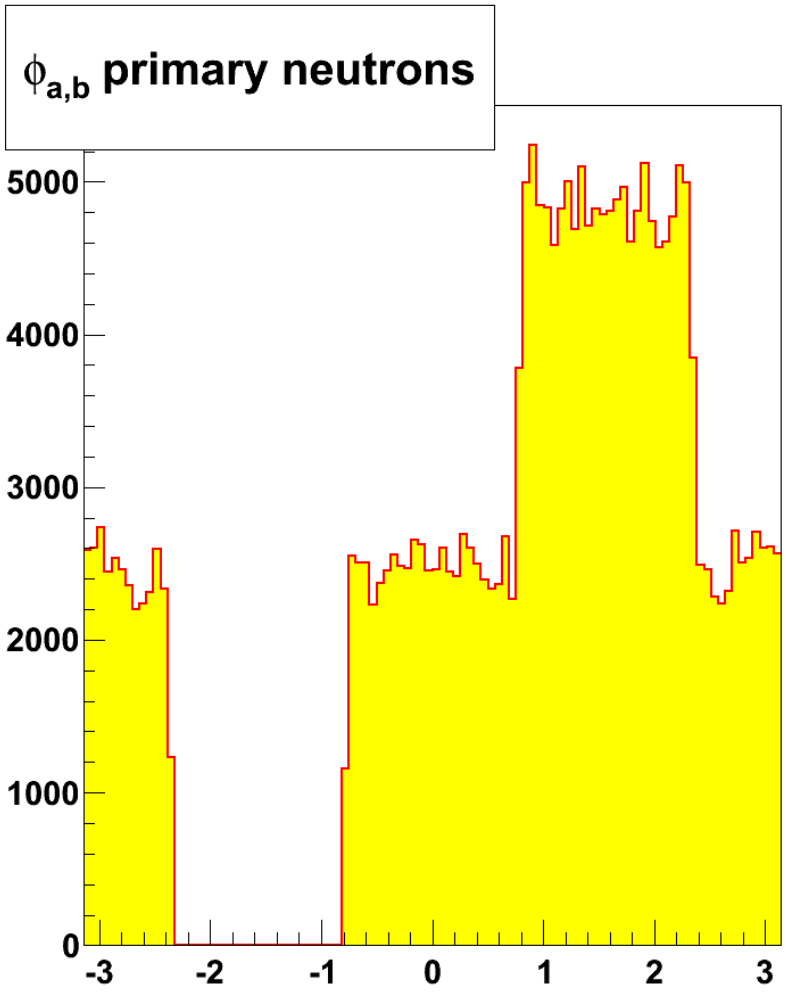
Sources of seco neut 2<|eta|<3(with ZDC)

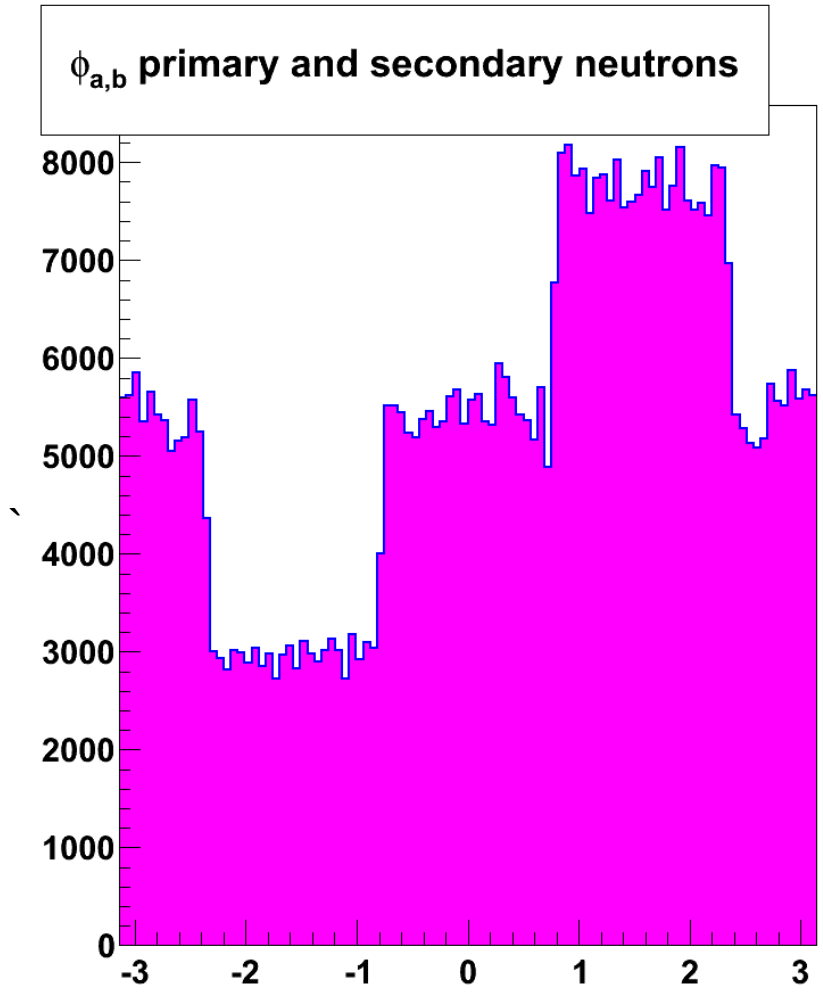




Hand Made Asymmetry

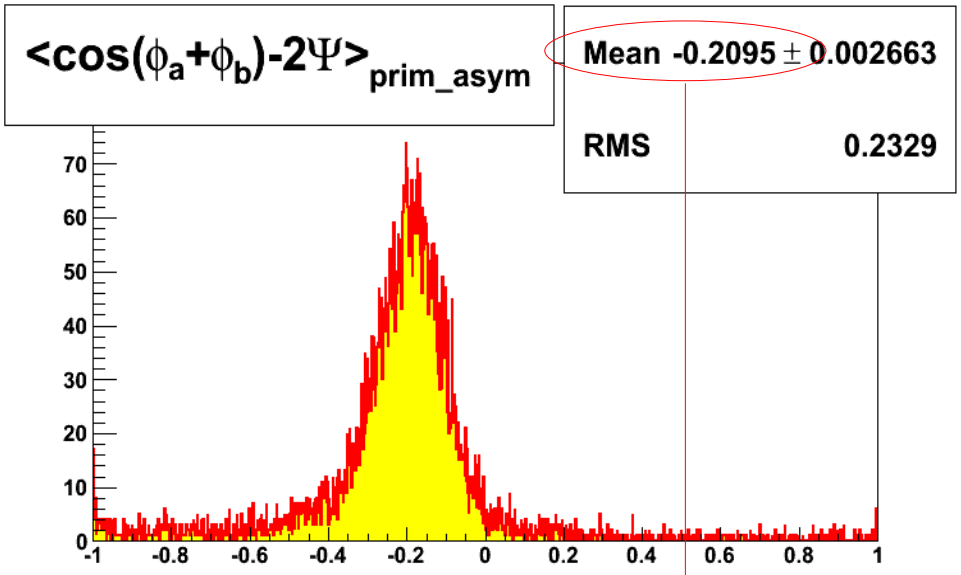
φ_c from MC neutrons $|\eta|>3$, $v_{2,c}=0.1$

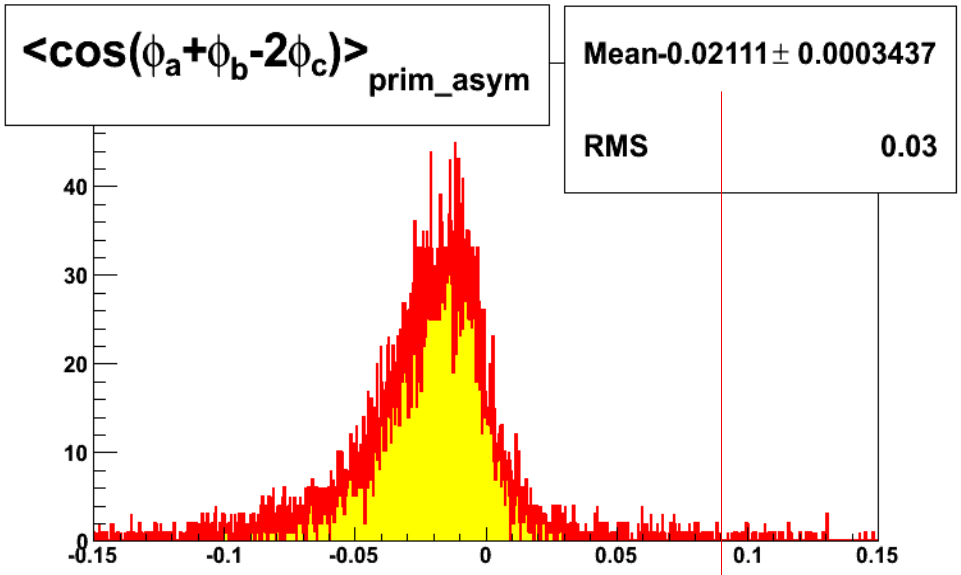


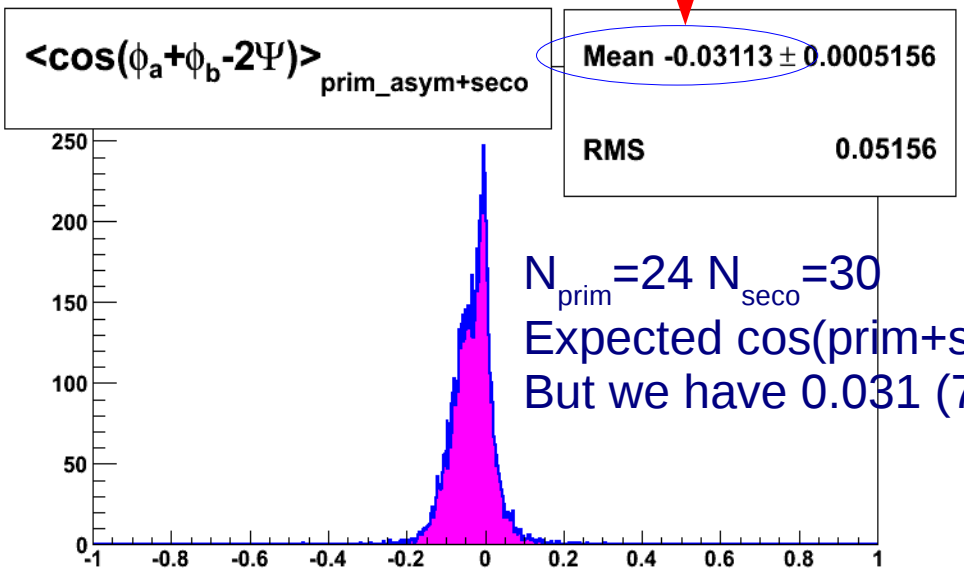


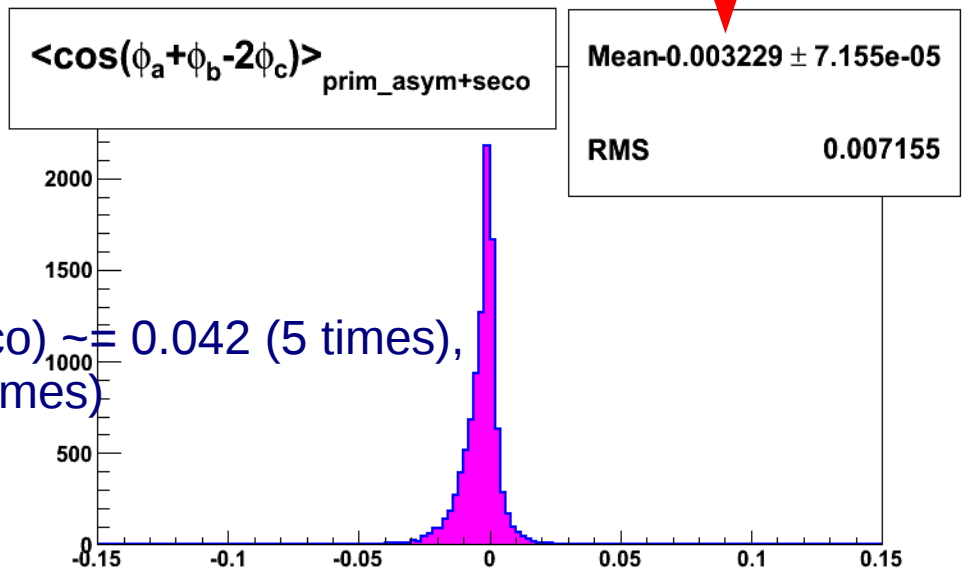
Asymmetry with MPD

$\langle\cos(\varphi_a + \varphi_b - 2\Psi_{RP})\rangle = \langle\cos(\varphi_a + \varphi_b - 2\varphi_c)\rangle / v_{2,c}$, $\Psi_{RP}=0$, $v_{2,c}=0.1$







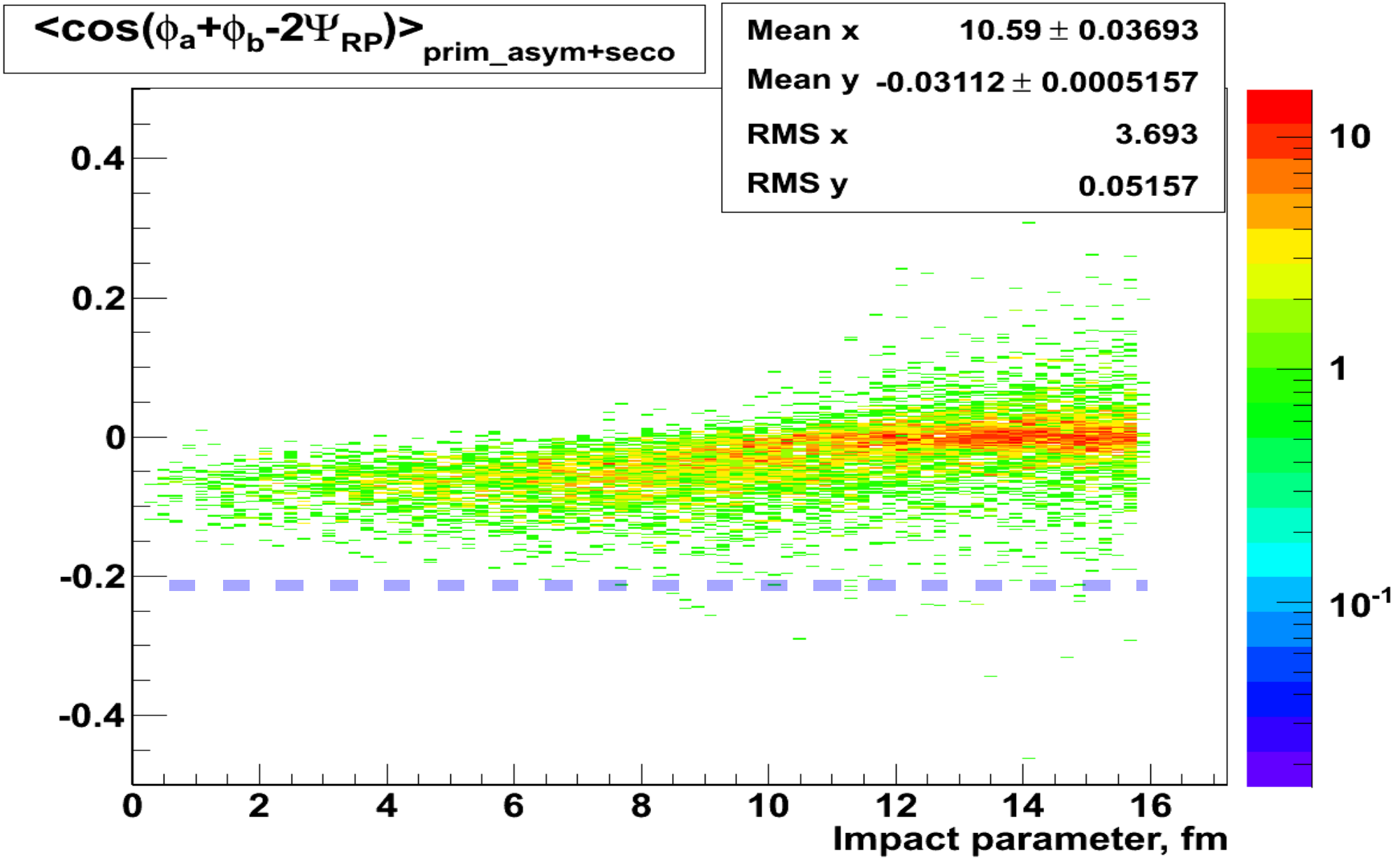


$N_{prim}=24$ $N_{seco}=30$

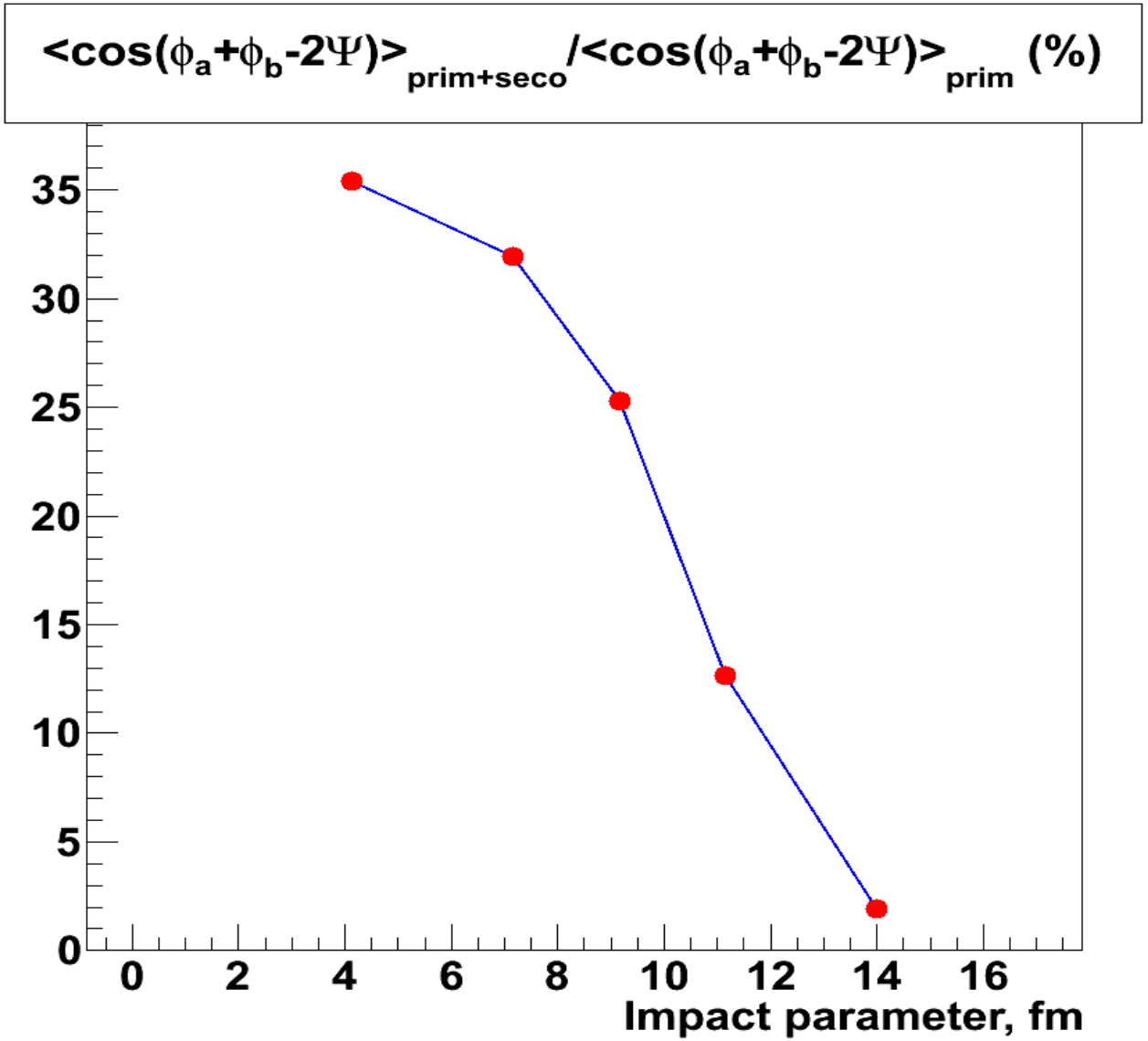
Expected cos(prim+seco) ~= 0.042 (5 times),

But we have 0.031 (7 times)

Asymmetry vs impact parameter

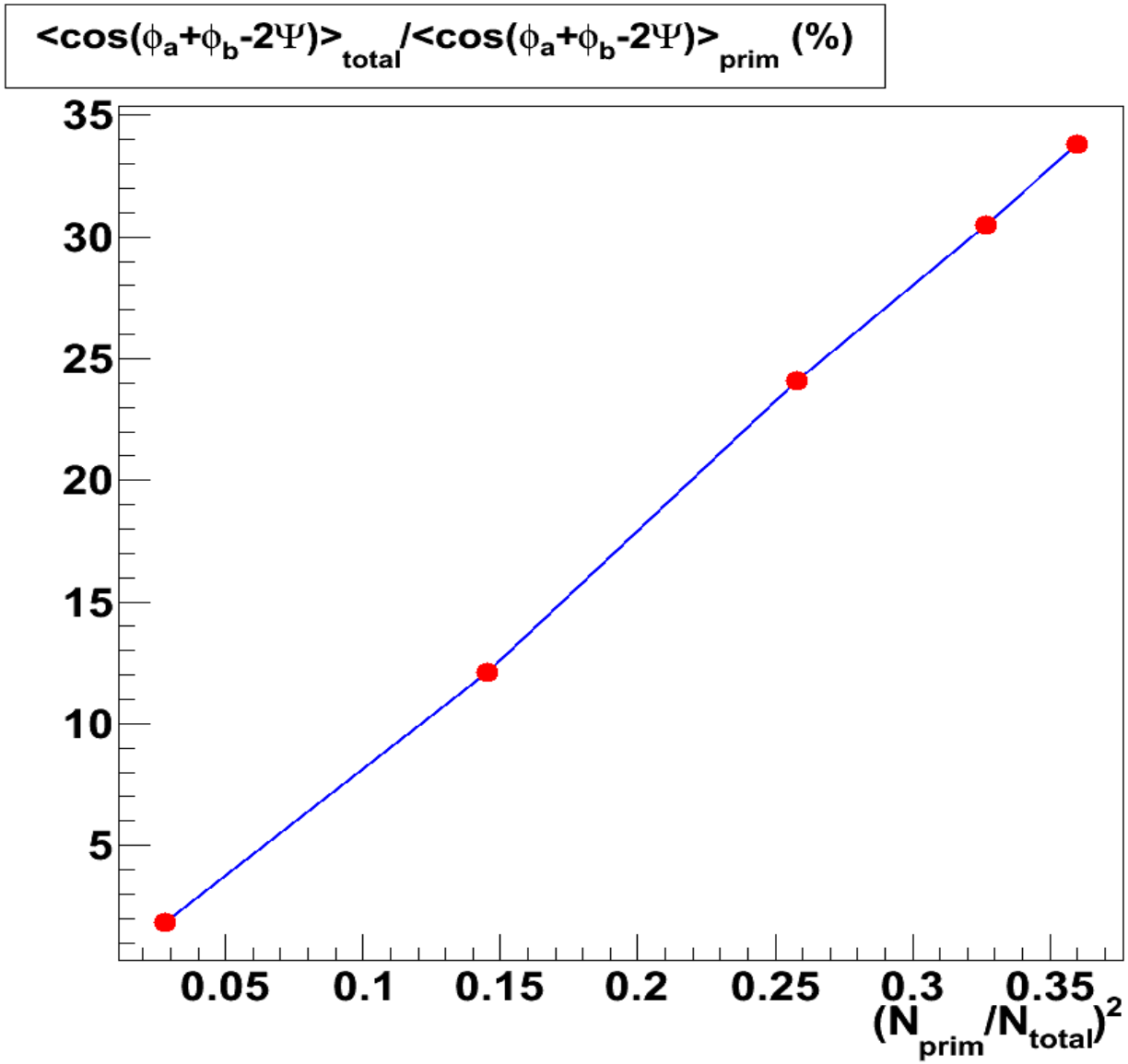


Signal/Background vs Impact parameter



Signal/Background vs Nseco

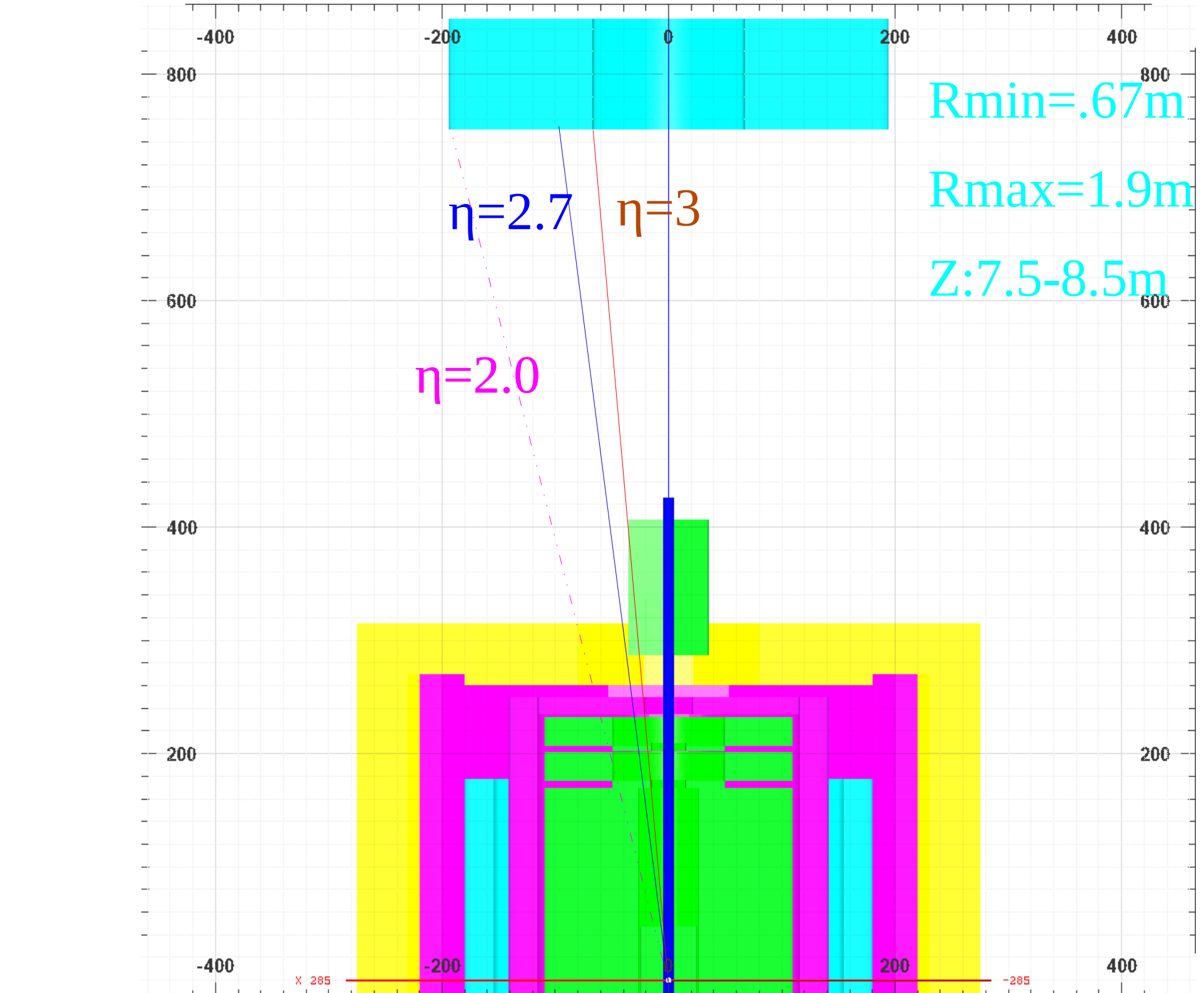
$$\langle\cos(\varphi_a + \varphi_b - 2\Psi_{RP})\rangle_{total} / \langle\cos(\varphi_a + \varphi_b - 2\Psi_{RP})\rangle_{prim} \sim (N_{prim}/N_{total})^2$$



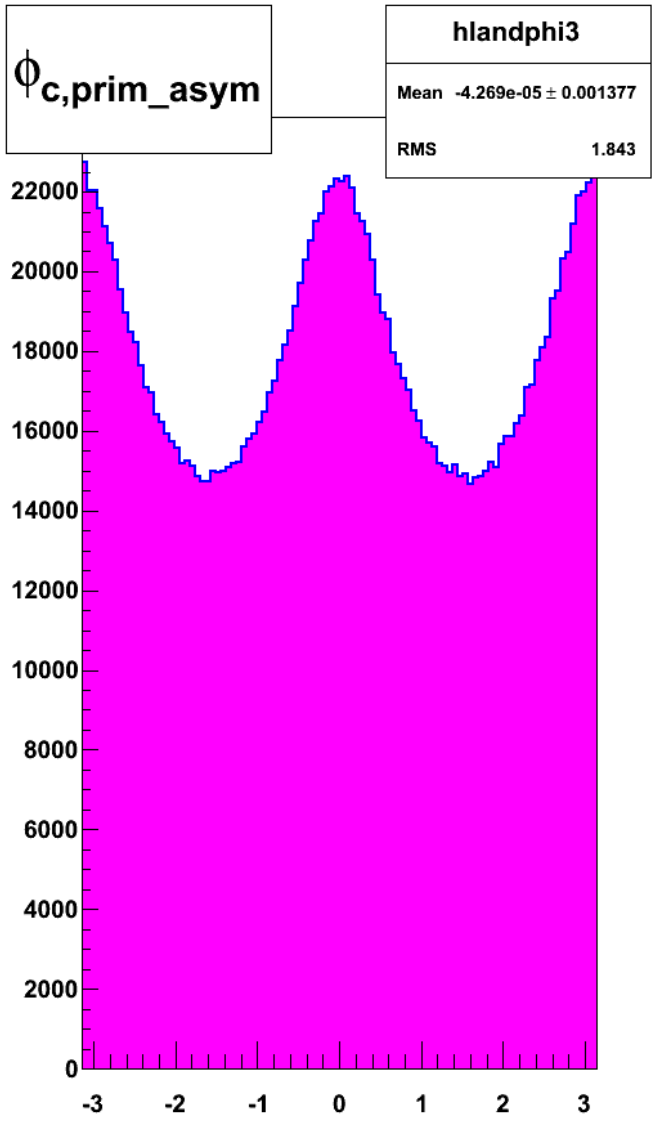
Conclusions

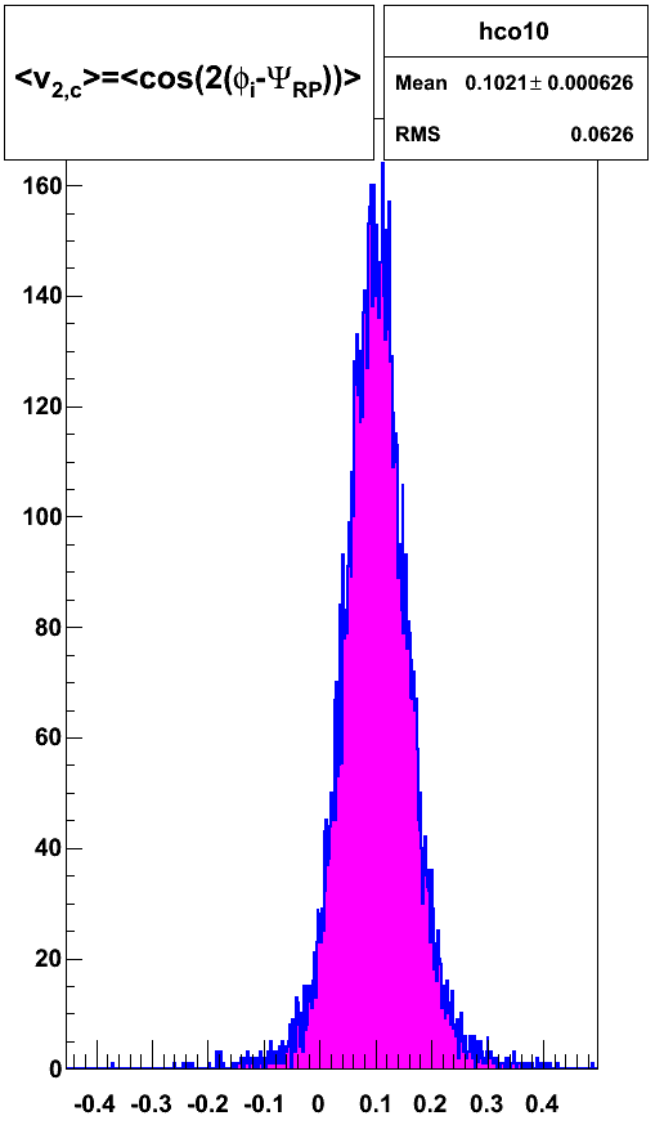
- There is no neutron asymmetry in UrQMD. We have to introduce some asymmetry.
- There are about 11+13 primary neutrons and 13+17 secondary neutrons ($|\eta|<3$) per event
- 3-particle correlator decreases ~7 times due to secondary neutrons for current geometry
- Background depends on centrality and the effect goes down in proportional to square of backrgound

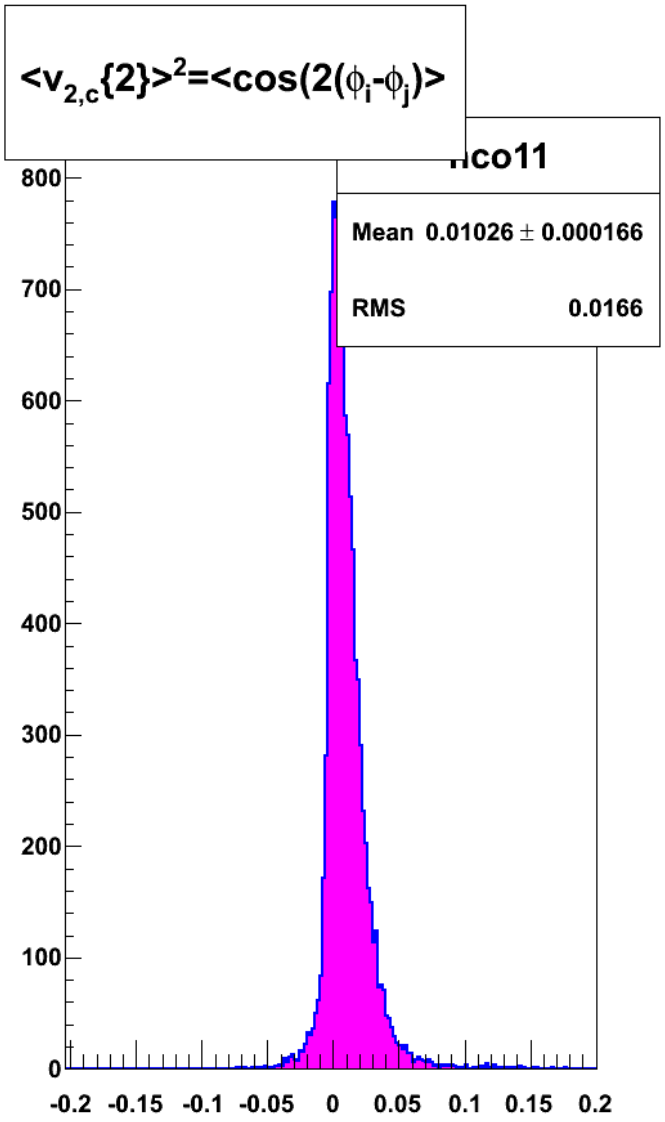
Thank you for your attention!

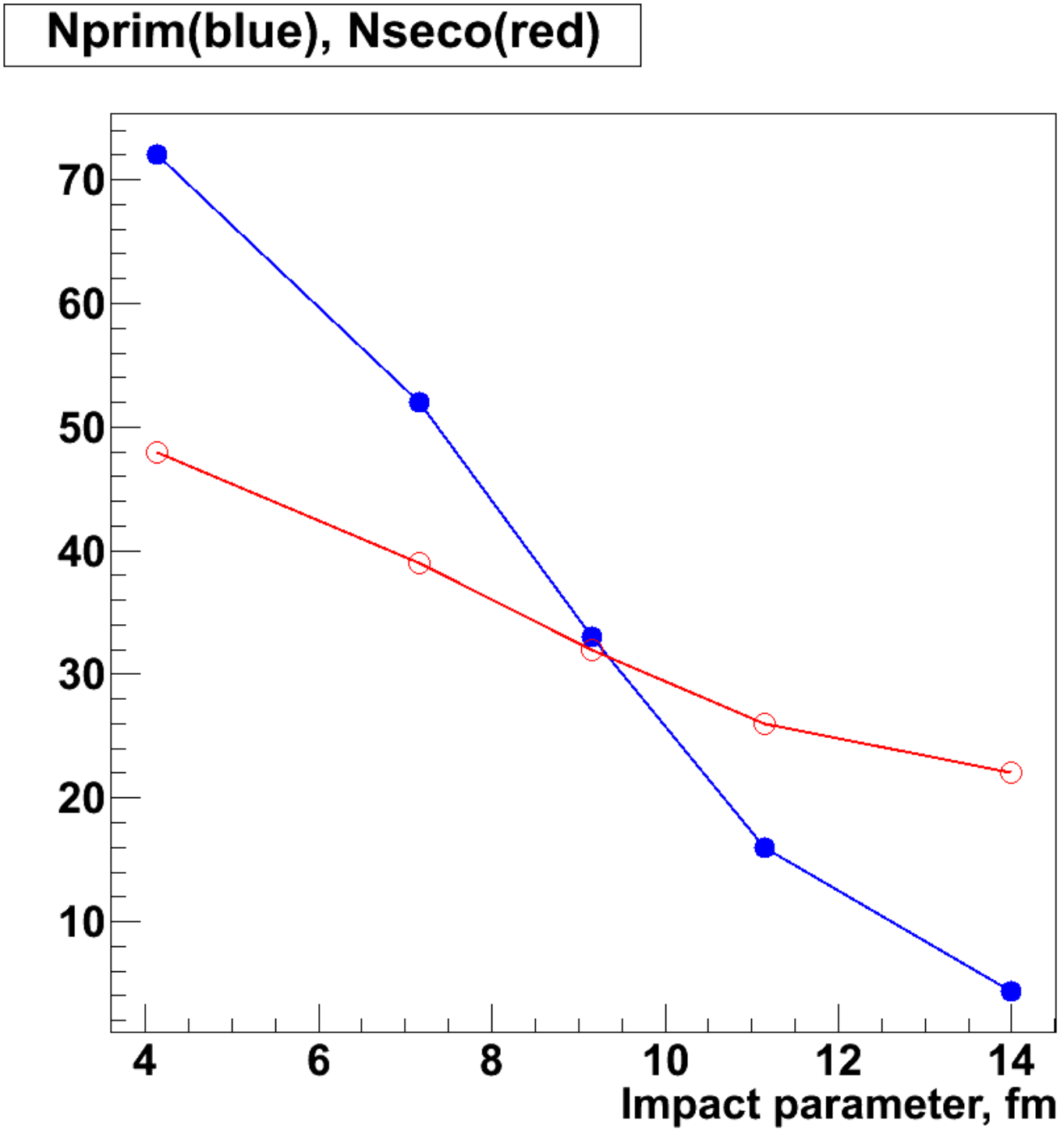

-400
-200
0
200
400
800
600
400
200
-400
-200
200
400
Rmin=.67m
Rmax=1.9m
Z:7.5-8.5m
η=2.7
η=3
η=2.0
X 285
-285

Hand made v2,c

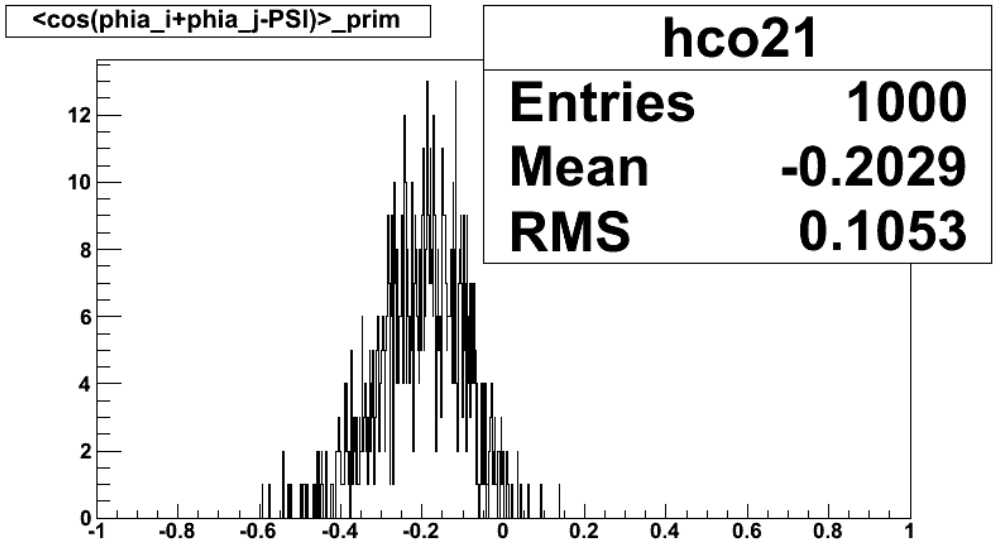


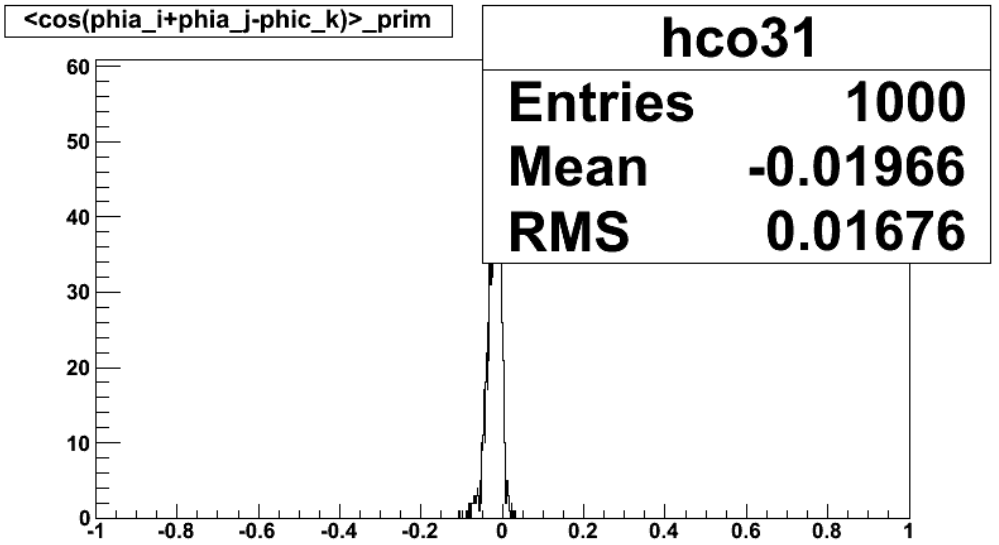


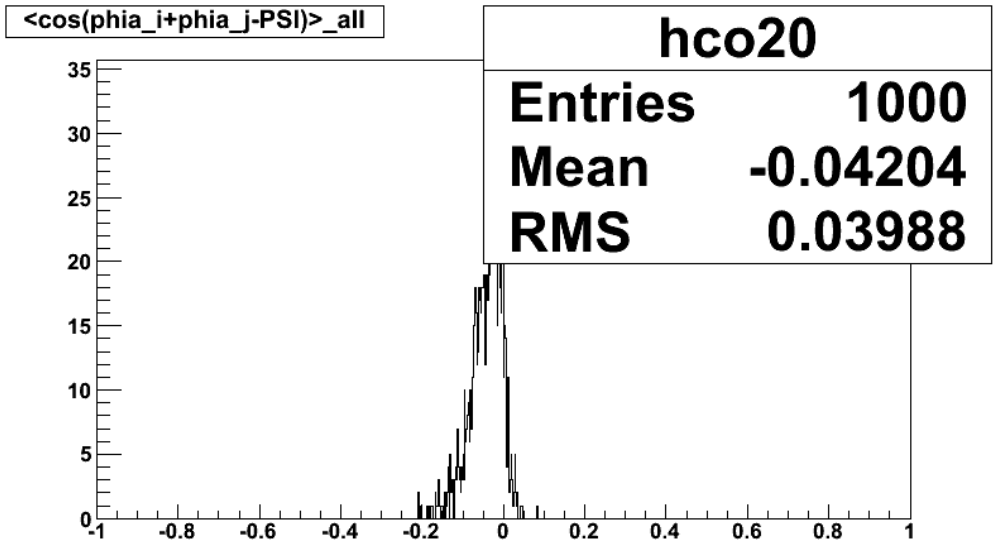


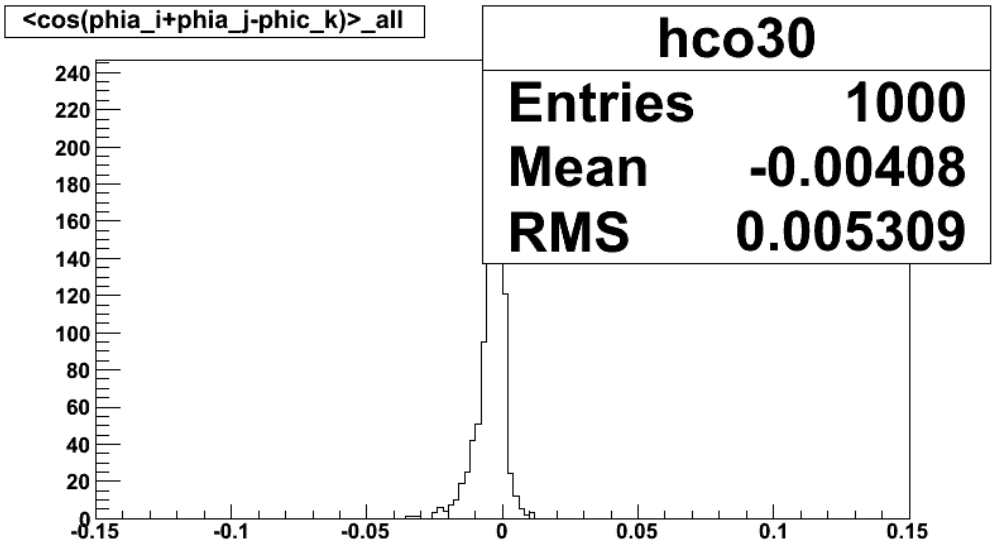

Nprim(blue), Nseco(red)
70
60
50
40
30
20
10
4
6
8
10
12
14
Impact parameter, fm

Simple simulation. N_{prim}=24, N_{seco}=30 hand made asymmetry, v2,c=0.1

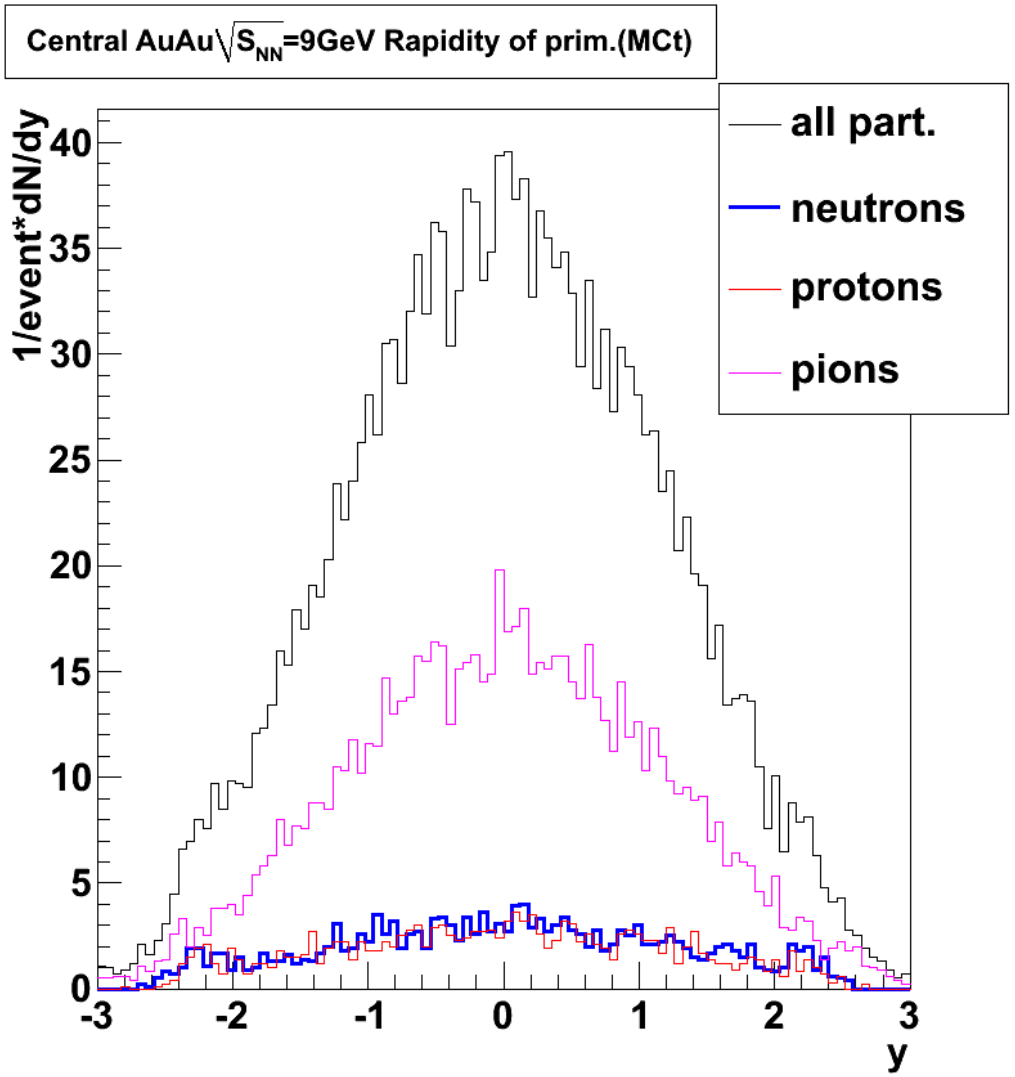


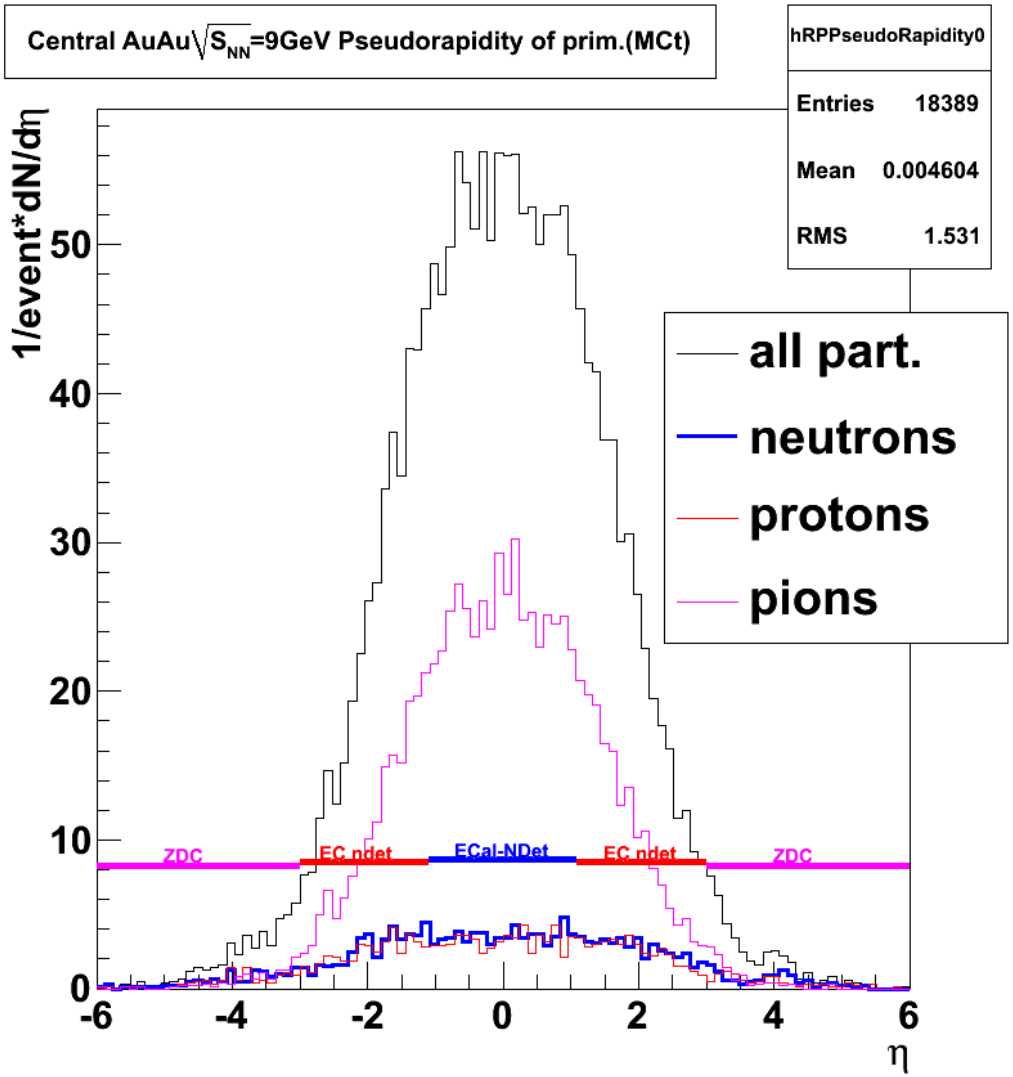




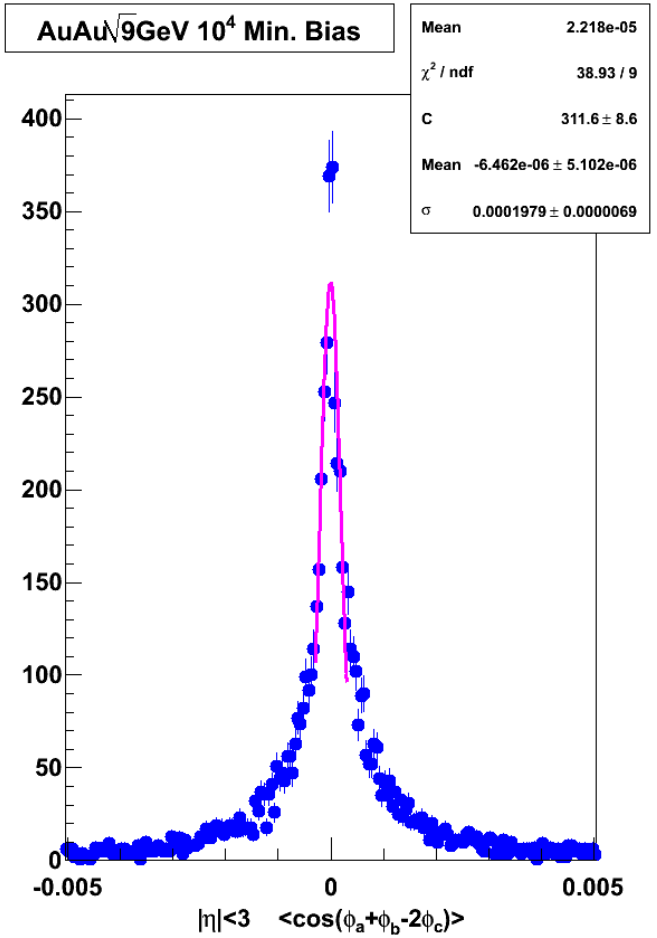


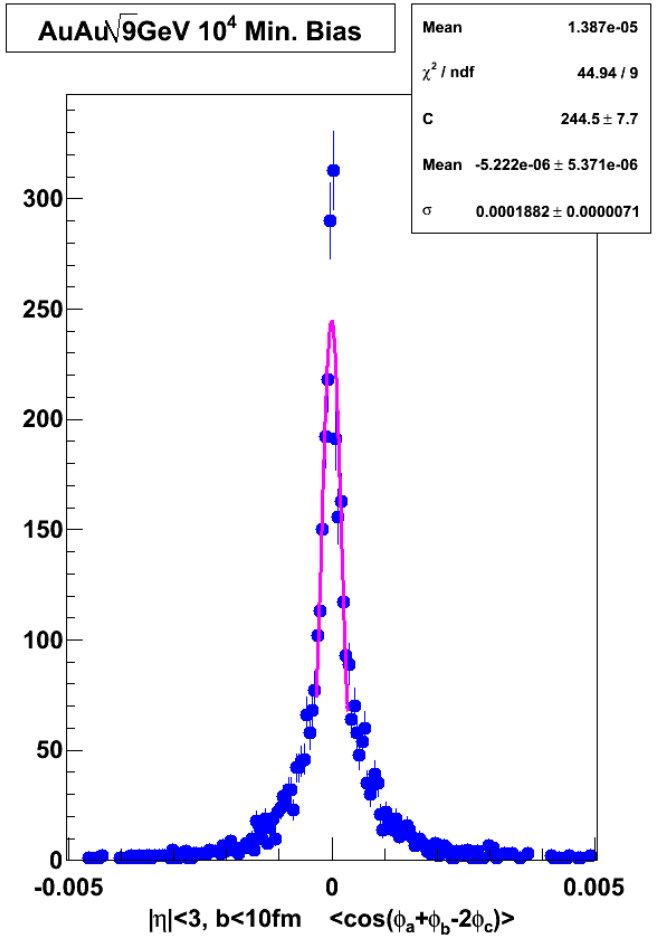
Rapidity Central AuAu 9 GeV

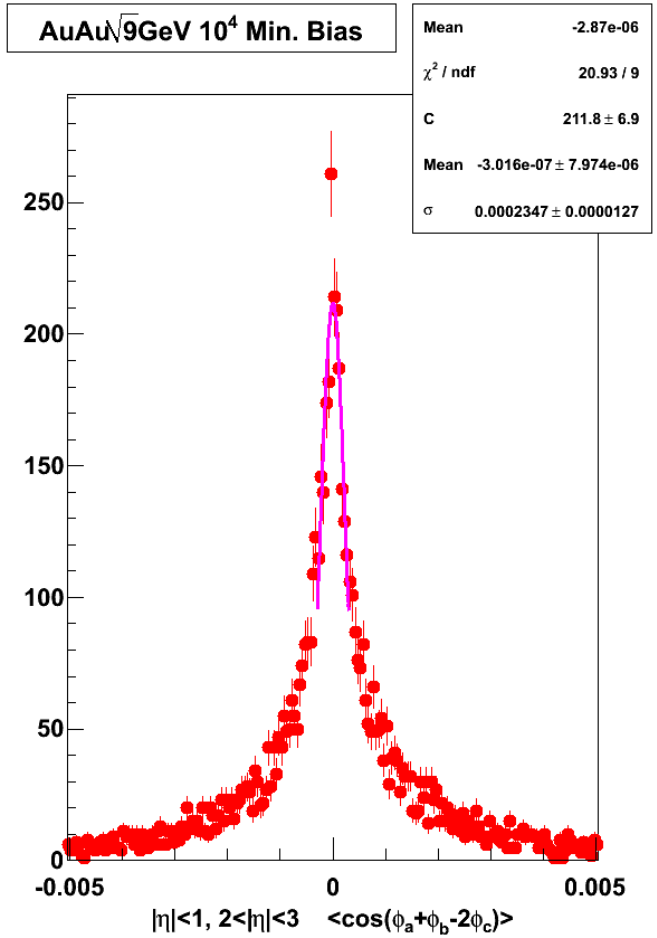




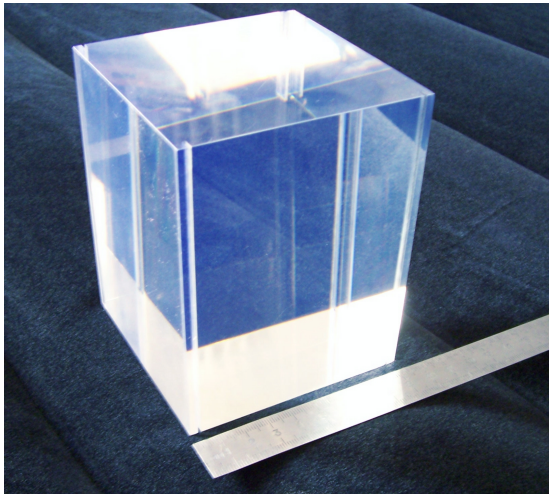
Asymmetry in UrQMD







Position sensitive neutron detector (Ndet in ITEP)



Plastic: Scintillator 96x96x128 mm^3

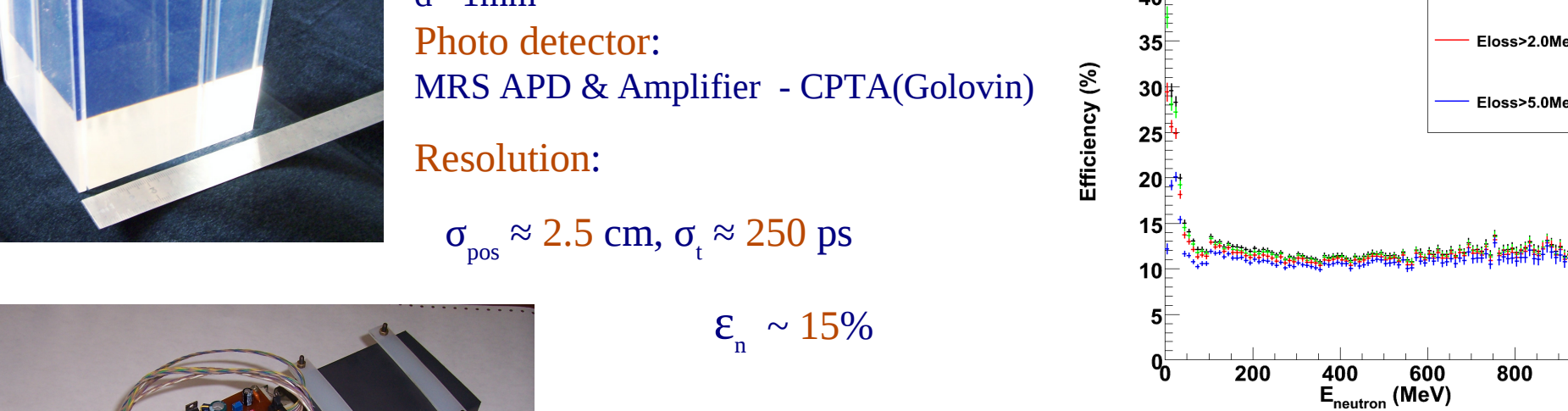
Fiber: KYRARAY,Y-11, wavelength shift, d =1mm

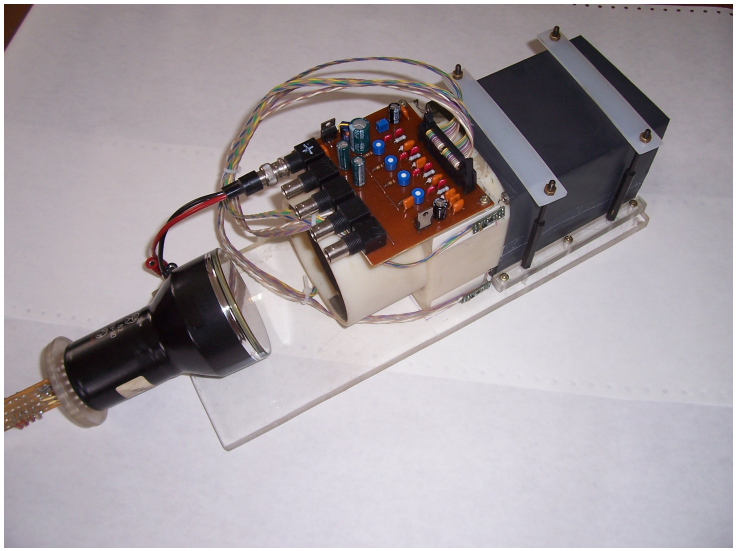
Photo detector:
MRS APD & Amplifier - CPTA(Golovin)

Resolution:

$\sigma_{pos} \approx 2.5$ cm, $\sigma_t \approx 250$ ps

$\varepsilon_n \sim 15\%$





- Array for FLINT experiment 6x6=36
- Array for NICA(tube r=155cm and width 15 cm) about 3000 neutron detectors