Common Event Characterization in the RHIC Experiments

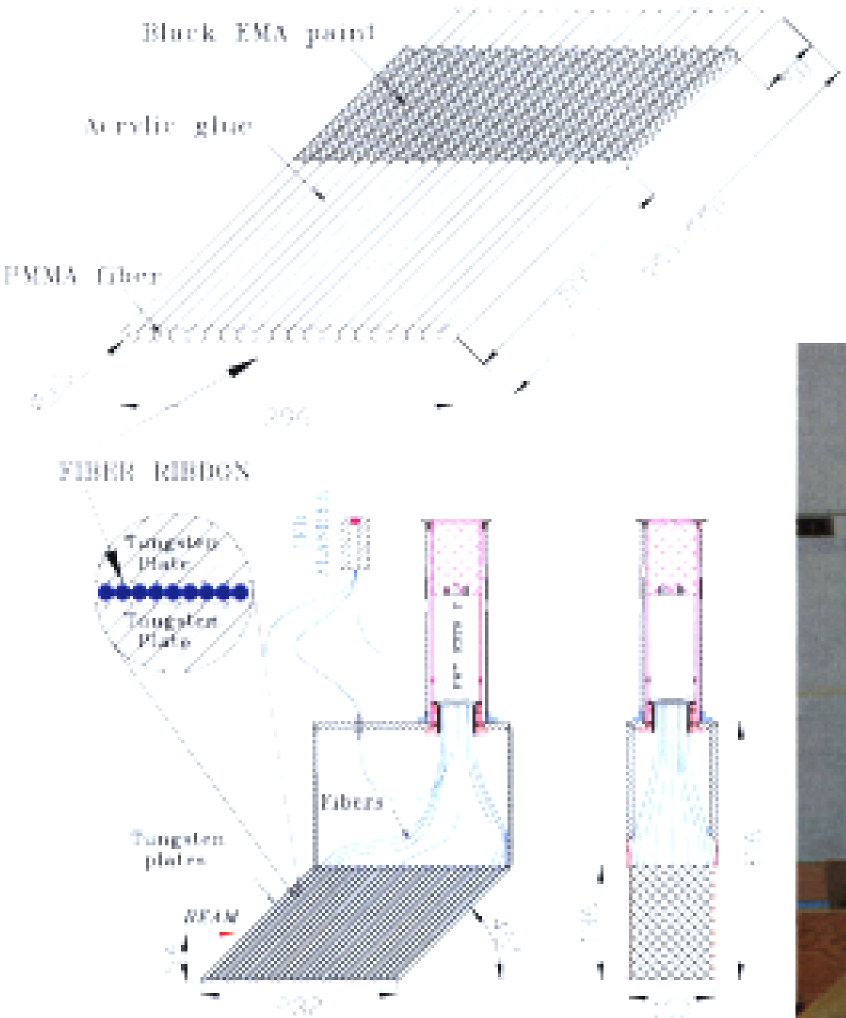
Alexei Denisov , IHEP (Protvino) Russia,
for the PHENIX collaboration

**Related talks:*

S.White, "Calorimetry for Global Event Characterization in PHENIX"

A.Milov et all, "Charged Particle Multiplicity and Transverse Energy in Au+Au Collisions at $\sqrt{s_{nn}} = 130GeV$"

ZDC modules design



Cosmic ray calibration :

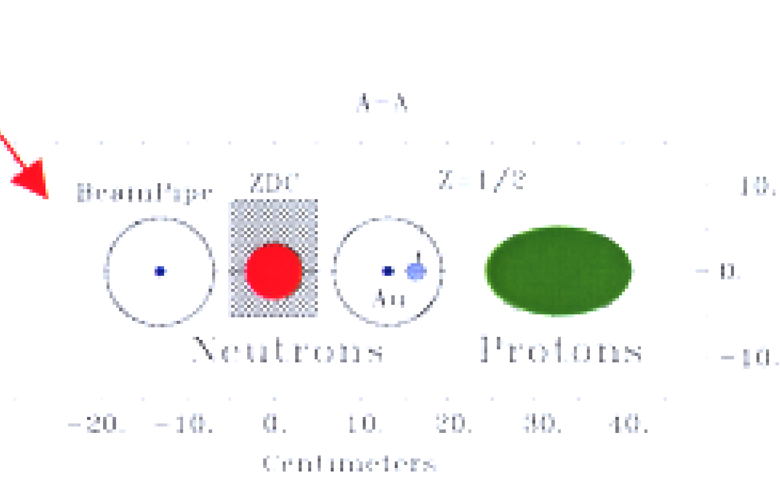
RMS in light yield for the 24 modules is <4%.

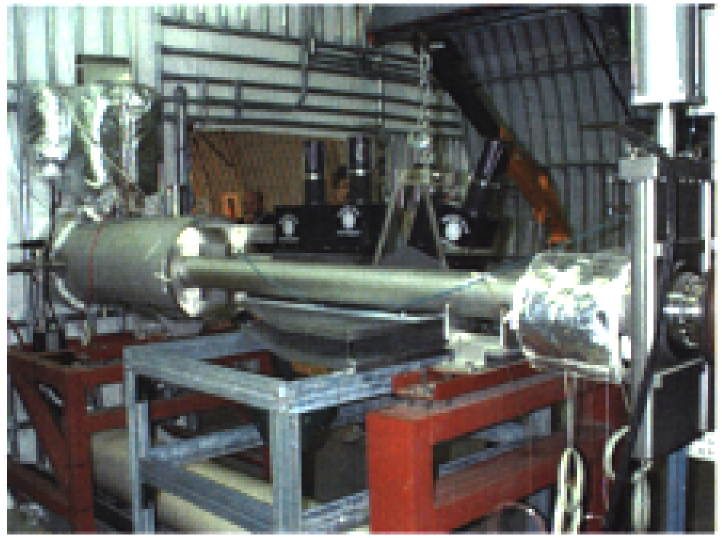
Outline

- Goals of the ZDCs as common & identical detectors for all HI experiments at RHIC:
  - luminosity & collisions parameters monitoring/measurement;
  - consistent normalization of cross sections between experiments;
  - trigger for minimum bias HI events.
- ZDC performance in the RUN 2000:
  - energy, coordinate & time resolution , acceptance ….
- Cross sections :
  - $\sigma_{tot} = \sigma_{geo} + \sigma_{cd}$; $\sigma_{1n,xn}$, $\sigma_{1n,1n}$, $\sigma_{1n,2n}$, … (for CD)
- ZDC performance for centrality characterization.

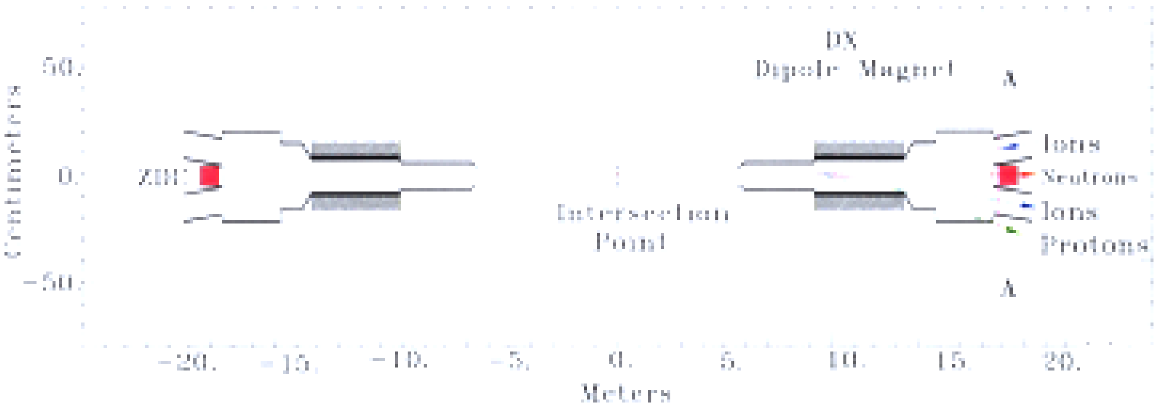
ZDC layout in the RHIC IR's

"Beam-eye" view of the ZDC location





ZDC installation in 1999

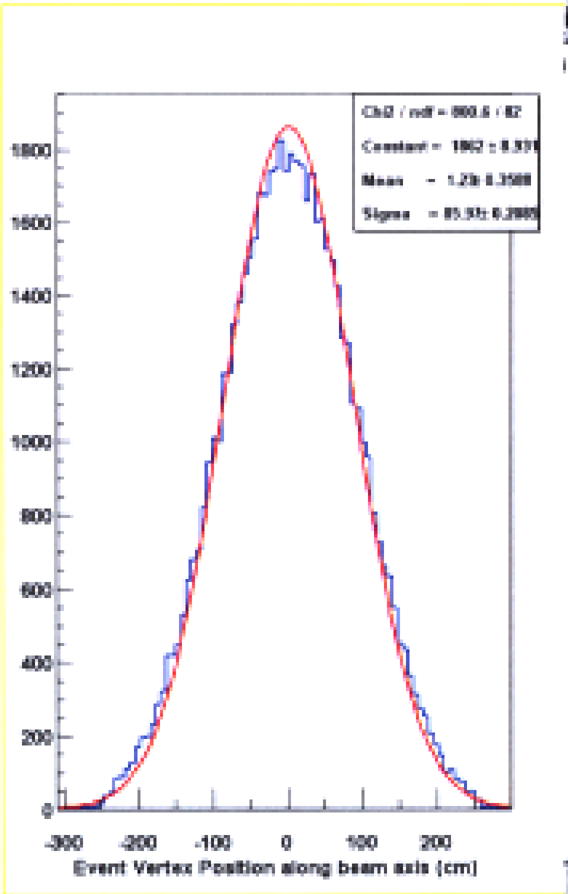


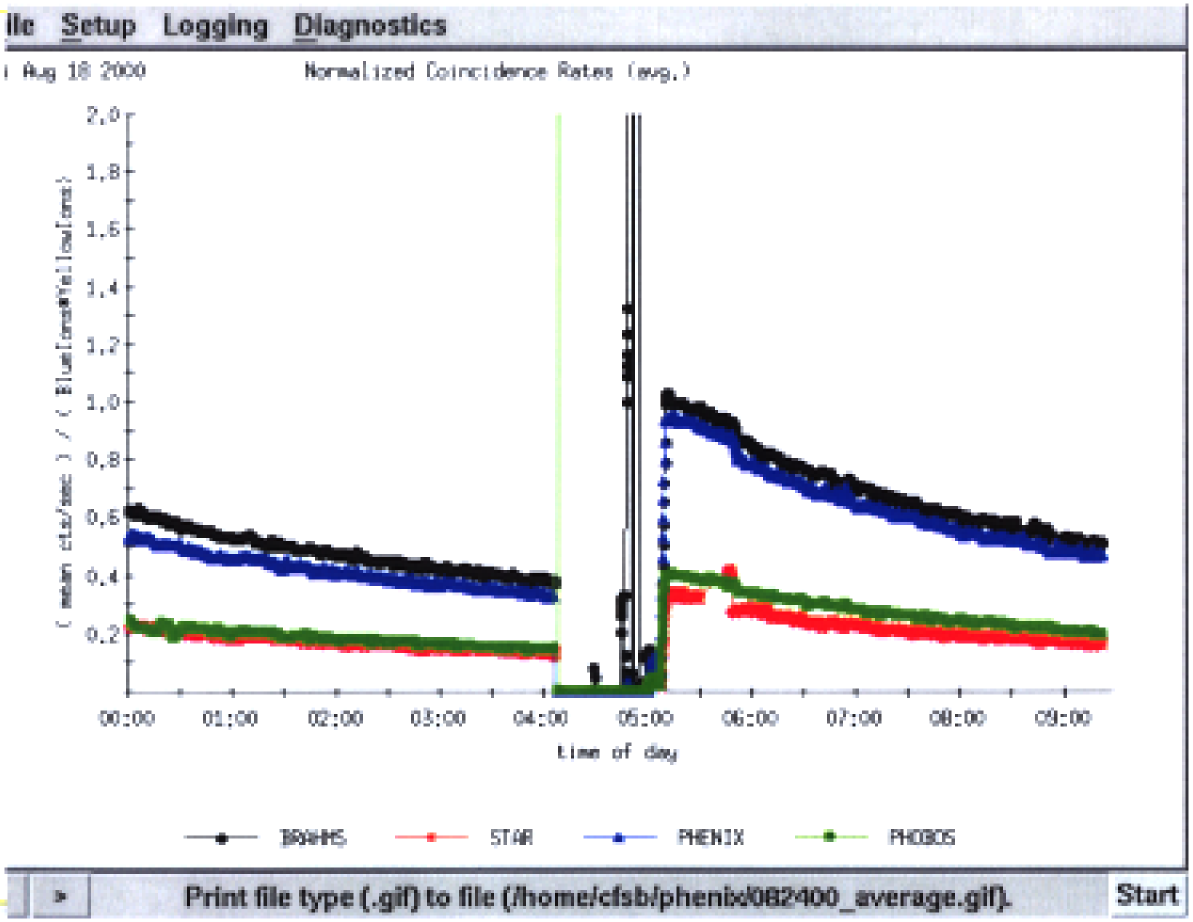
Plane vew of the ZDC layout at RHIC

Luminosity measurements

$$R_{ZDC} = L_{bb} * \sigma_{tot} \ ; \qquad L_{bb} = (N_{au})^2 * N_{bunch} * \nu_{rev} / \{4\pi(\sigma_t)^2\}$$

L_{bb} is derived from machine parameters ==> σ_{tot} measurement.



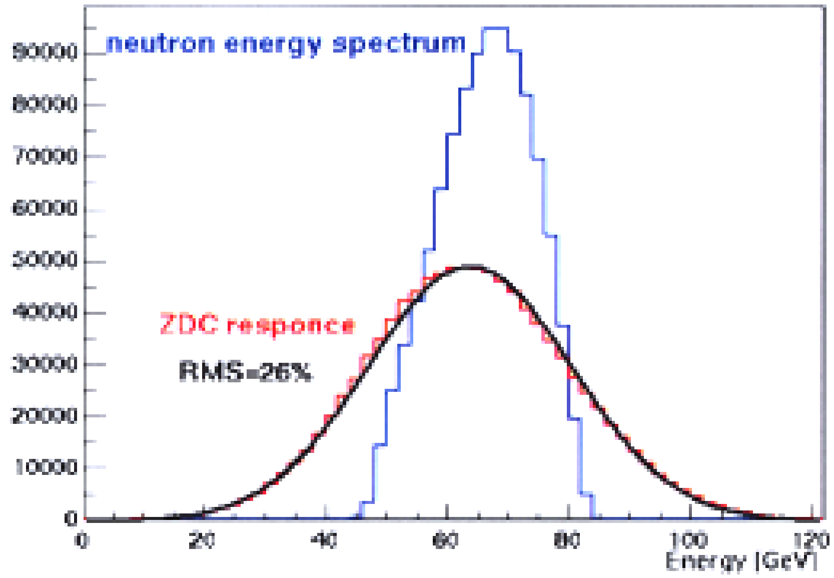


ZDC performance @ $\sqrt{S} = 130GeV$

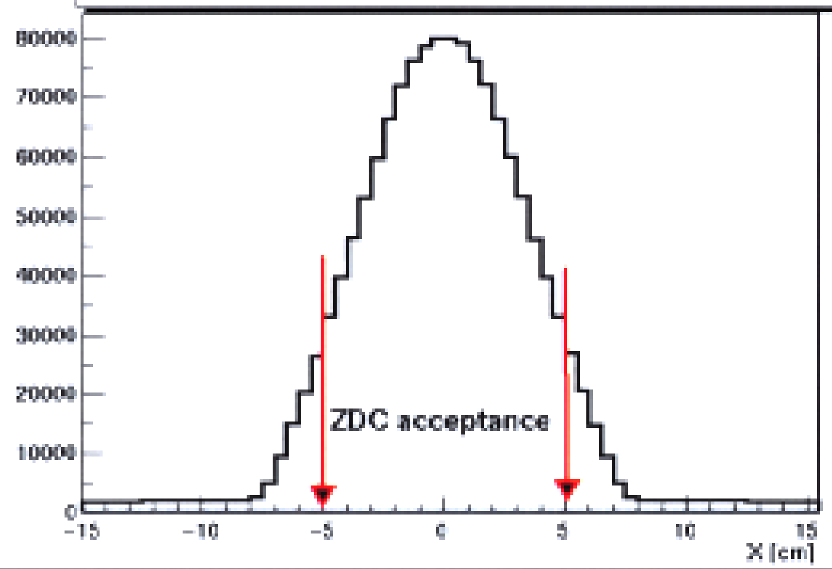
- Energy resolution for 1n is 26% (simulation), 25%(exp.)

- 24% of neutrons out of ZDC acceptance for nuclear events

- ~100% of neutrons from Coulomb Dissociation events in ZDC acceptance



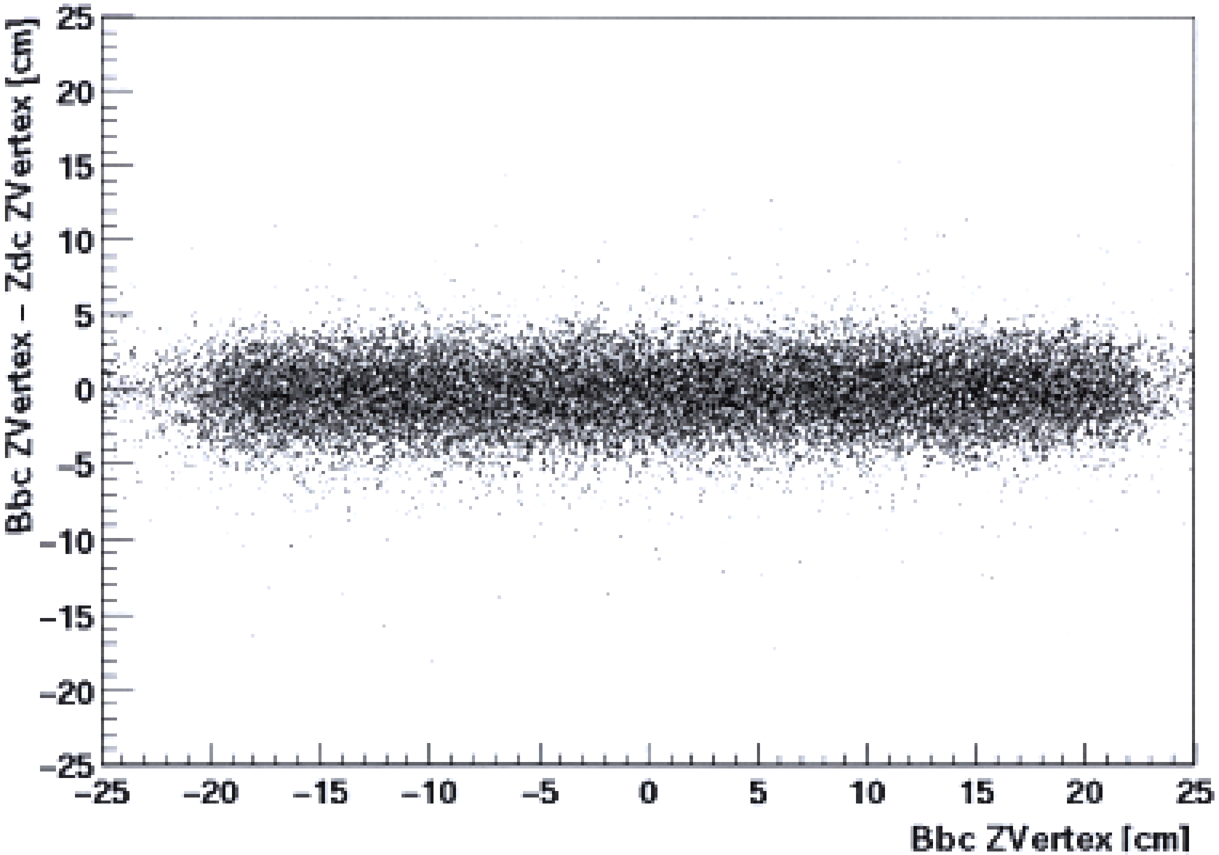
Neutron hits distribution on ZDC front

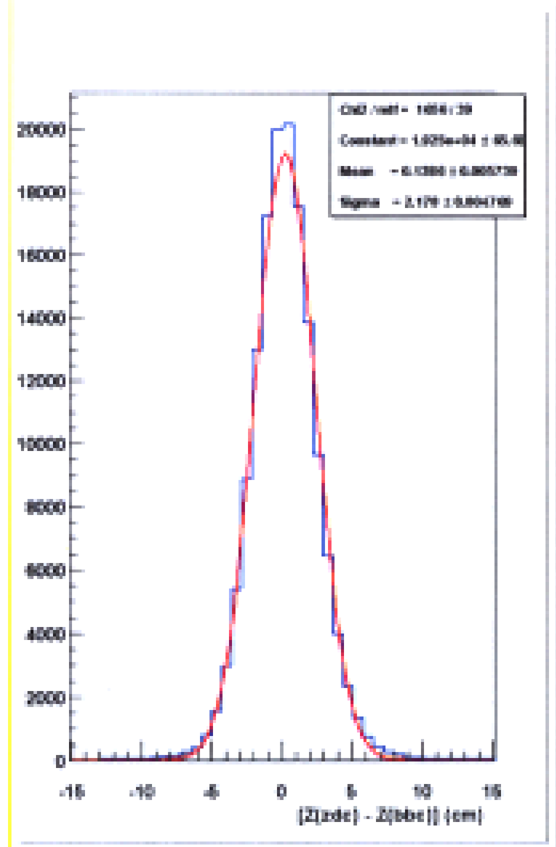


ZDC vertex and time resolution

ZDC vertex resolution $\sigma_Z \approx$ 2cm

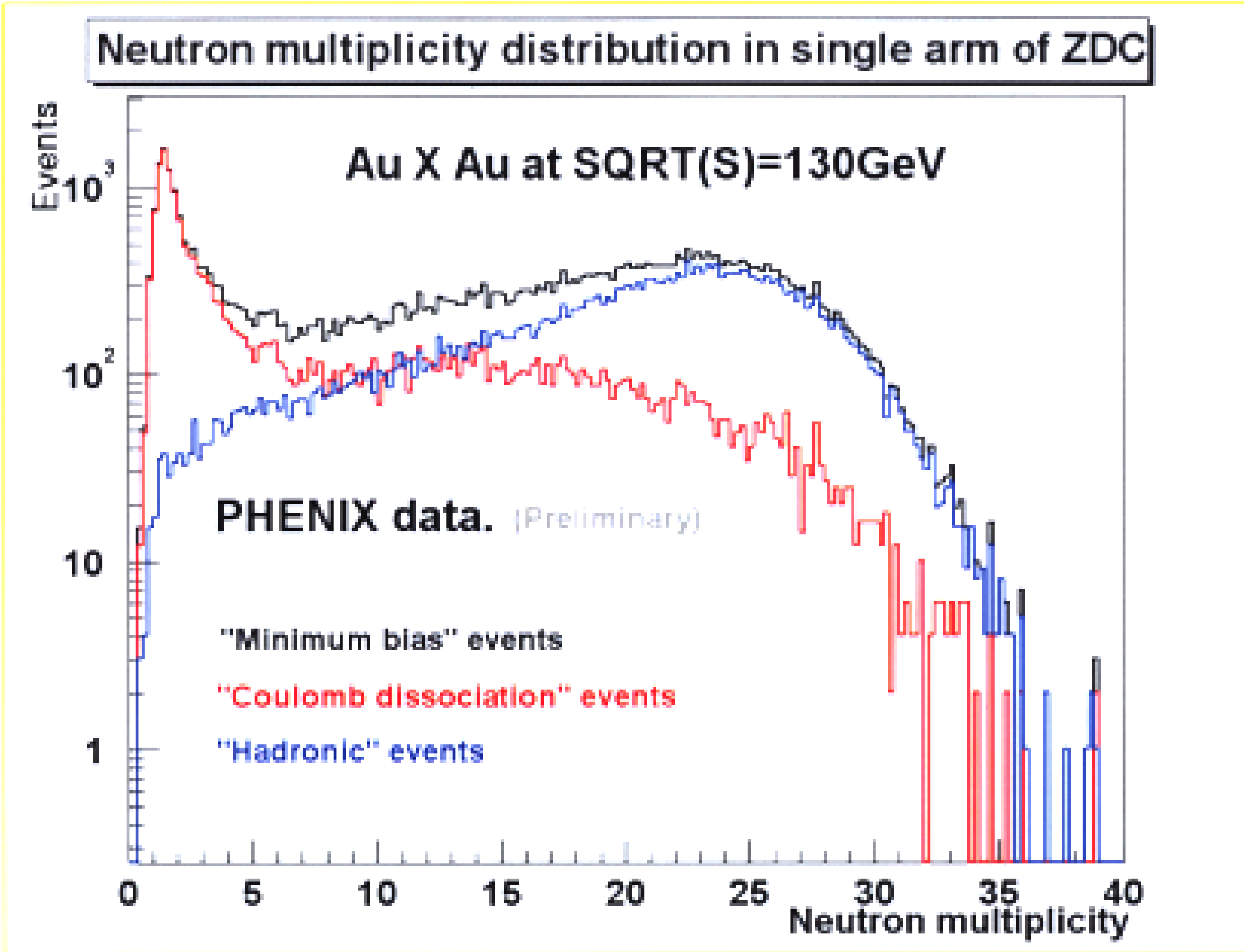
t_0 resolution $\approx$ 120ps





ZDC minimum bias trigger

Fraction of Coulomb Dissociation events ≈ 1/3



Cross Sections (consistency check)

- *Definitions:*

$\sigma_{tot} = \sigma_{cd} + \sigma_{geo}$ - total cross section triggered by ZDC

σ_{cd} - Coulomb Dissociation cross section

σ_{geo} - "geometrical" (nuclear) cross section

- Efficiencies:

$\varepsilon_{bbc} = (92 \pm 2)\%$ (HIJING sim.), $\varepsilon_{bb} = (93 \pm 2)\%$ (JAM sim.)

$\varepsilon_{zdc} = (98 \pm 2)\%$ (conservative), $\varepsilon_{zdc} = (99.5 - 1.5)\%$ (realistic)

- σ_{tot} is derived from luminosity and beam characteristics (underway ?).

Theoretical prediction:

$\sigma_{tot} = (10.7 \pm <0.5)$ b,

$\sigma_{geo} = 7.2$ b (Glauber calculation at $\sigma_{nn} = 40$ mb) ===>

$\sigma_{geo} / \sigma_{tot} = (0.673 \pm <0.034)$

$(N_{bbc} / N_{tot})_{exp} = (0.615 \pm 0.015)$ ==>

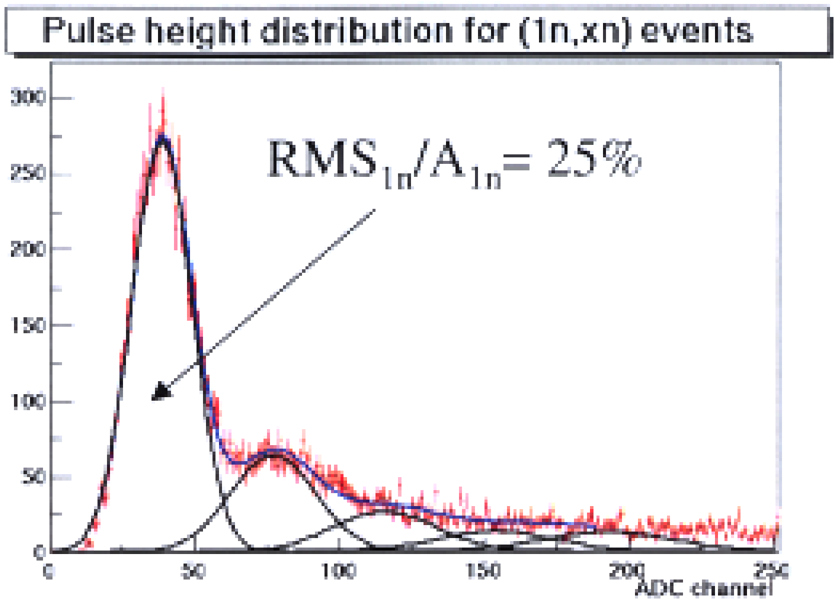
$(\sigma_{geo} / \sigma_{tot})_{exp} = (N_{bbc} / N_{tot})_{exp} / \varepsilon_{bbc} = (0.668 \pm 0.022)$

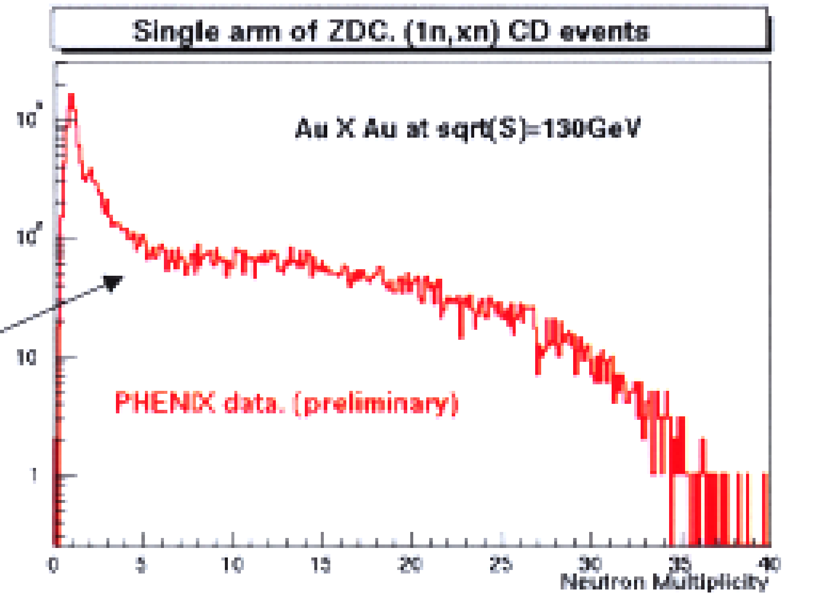
Coulomb Dissociation cross sections

- CD evensts selection:
  $Mult_{bbc1}<2$ OR $Mult_{bbc2}<2$ ==>
  92% of nuclear events removed.
  Bgd shape from low $Mult_{bb}$

- Model:
  $A_{kn} = k^{*} A_{1n}$, $RMS_{kn} = \sqrt{k}^{*} RMS_{1n}$

  A_{kn} defines energy scale.

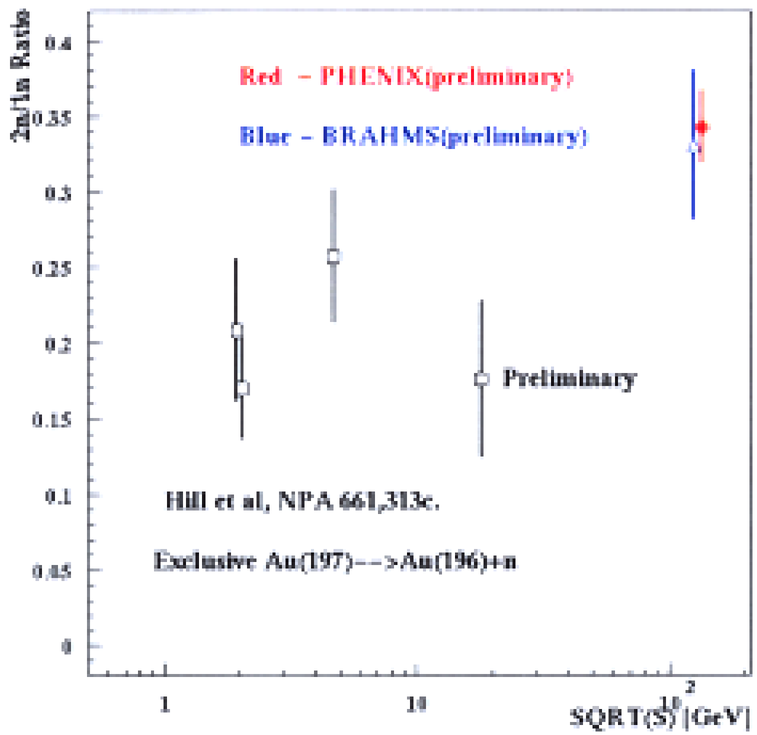




Neutron multiplicity in single arm for pure CD events

Exclusive cross sections for CD

	PHENIX (prelim.)	Calculation
$\sigma_{1n,xn}/\sigma_t$	**(0.124±0.003 ±0.006)**	0.127 ±??
$\sigma_{1n,1n}/\sigma_{1n,xn}$	**(0.350±0.015 ±0.02)**	0.329 ±??
$\sigma_{2n,xn}/\sigma_{1n,xn,}$	**(0.342±0.015 ±0.02)**	------



"Centrality" determination

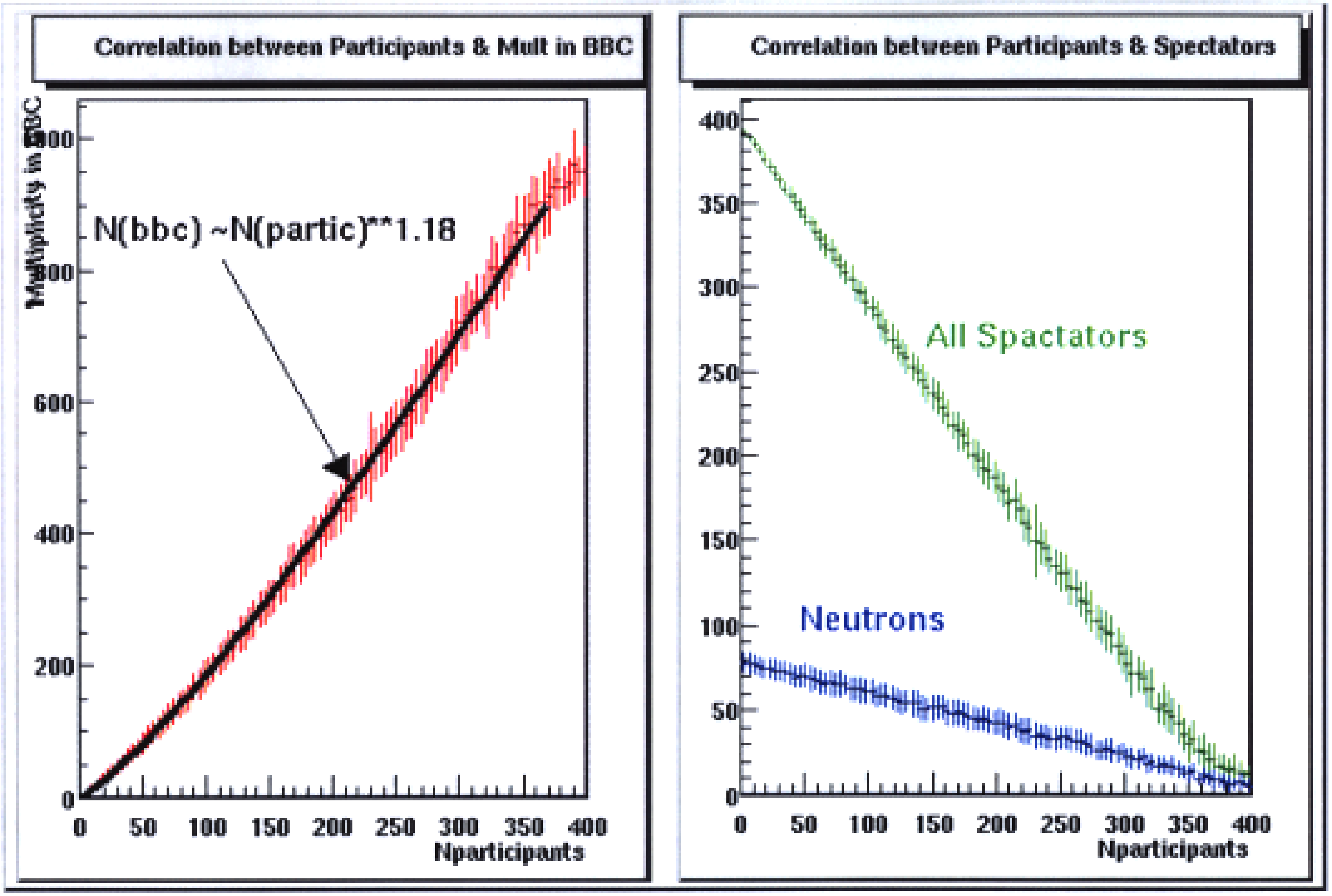
- Direct measurement of $N_{participant}$ via $N_{spectator}$:

$$N_{participant} + E_{spectator}/(m_n * \gamma_{beam}) = A_{beam}$$

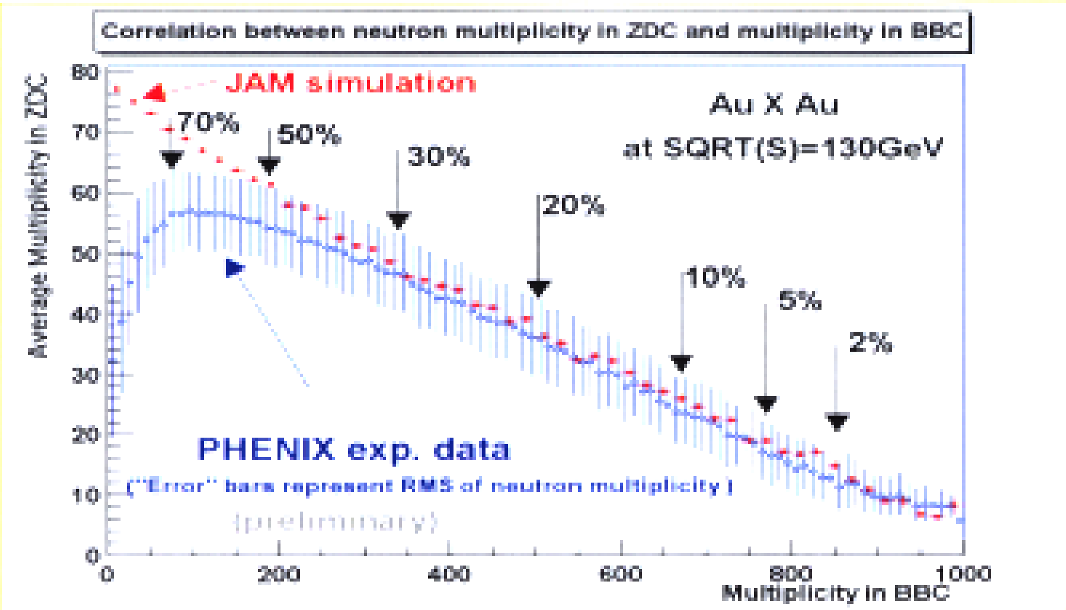
In collider experiments ZDC can measure only part of $E_{spectator}$ ==> large fluctuations + lost of monotonic behavior.

- Using Glauber model, from impact parameter.

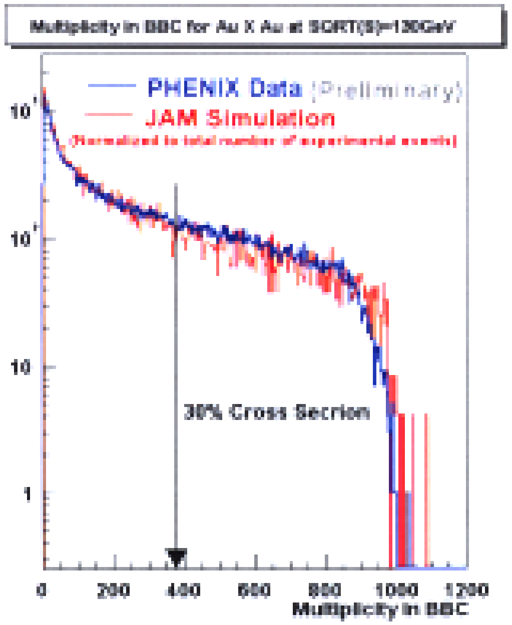
Correlation between $N_{participants}$ & N_{bbc} & Spectators

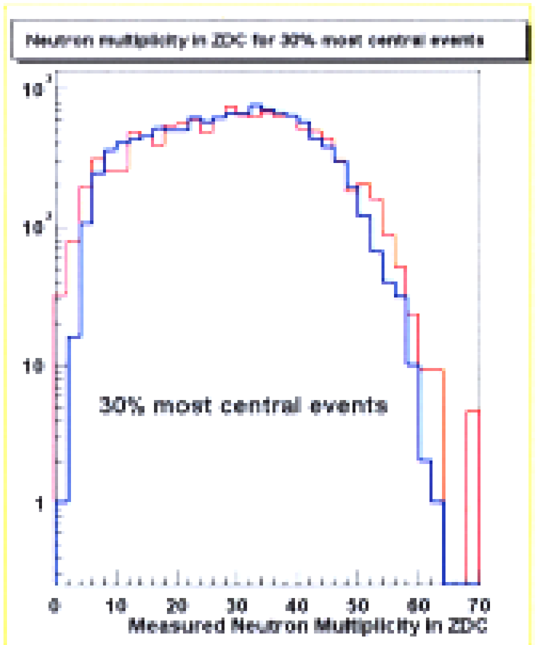


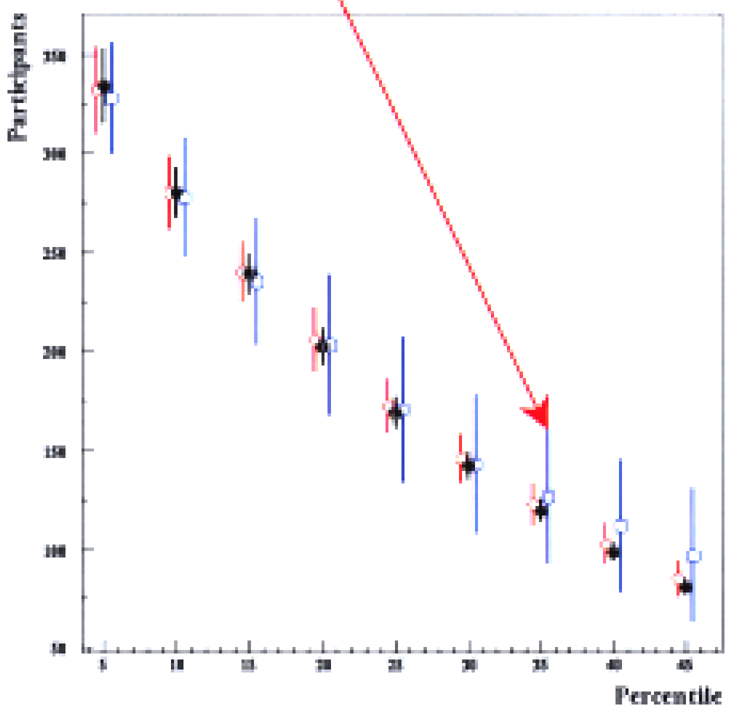
Limitation on centrality selection with ZDC



- ZDC multiplicity is not monotonic function of impact parameter ==> need a cut on peripheral collisions ==> limit on "unbiased" range.







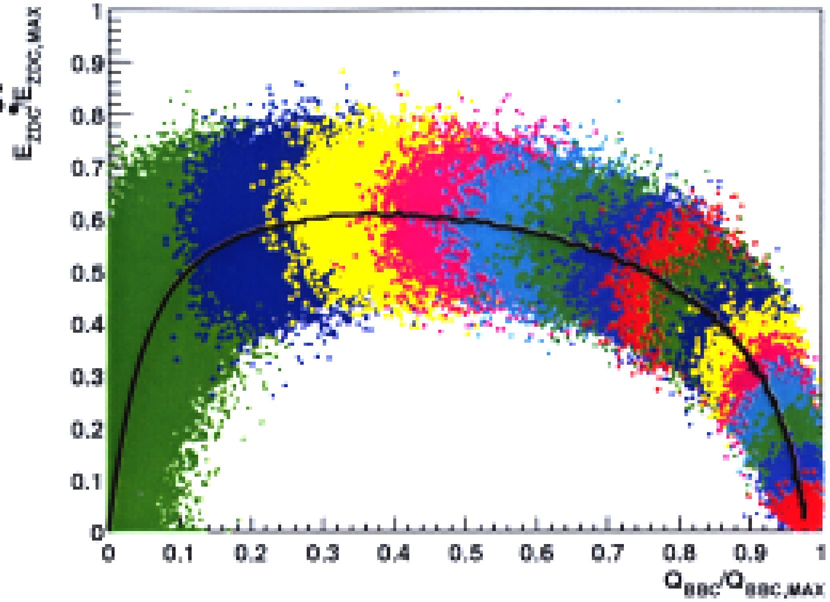
Calculation of N_{part} and N_{coll}

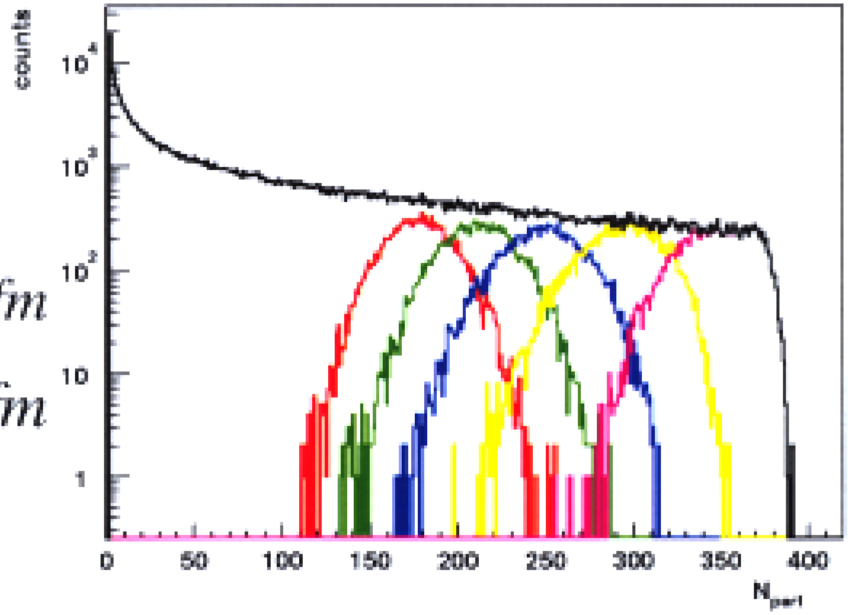
- **Use simulated BBC – ZDC response to define centrality cuts.**
- **Relate them to N_{part} and N_{coll} using Glauber model.**
  - Straight-line nucleon trajectories
  - Constant $\sigma_{NN}=(40 \pm 5)mb.$
  - Woods-Saxon nuclear density:

$$\rho(r) = \rho_o \cdot \frac{1}{1+\exp\left(\frac{r-R}{d}\right)}$$

$$R = 1.19A^{1/3} - 1.61A^{-1/3} = (6.65 \pm 0.03)\,fm$$

$$d = (0.54 \pm 0.01)\,fm$$





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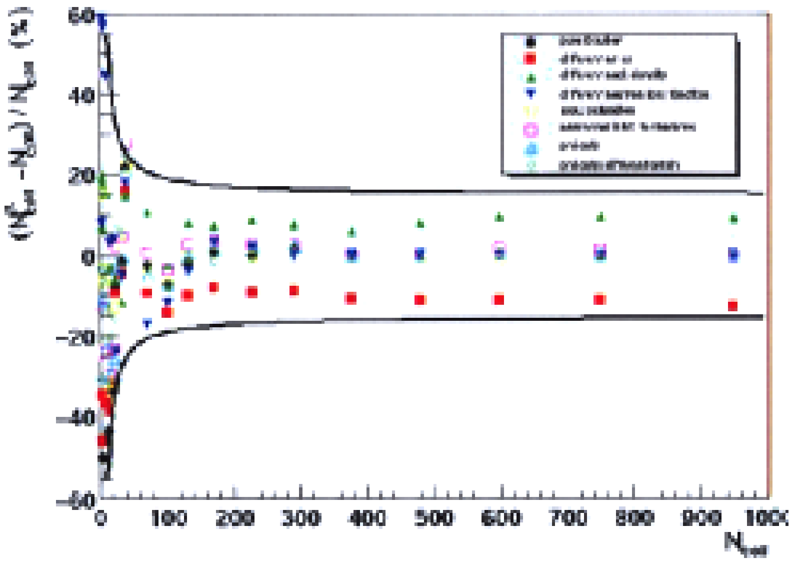
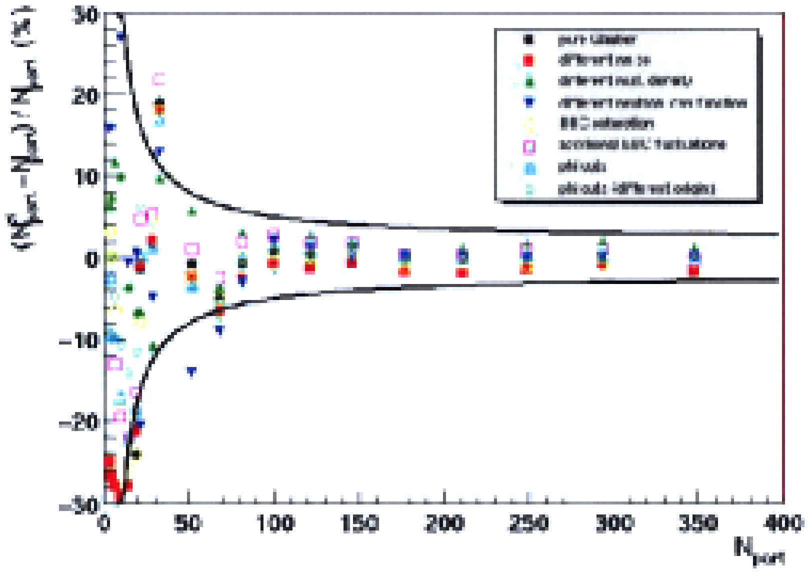
Systematic errors estimation for N_{part} and N_{coll}

Error estimation: N_{coll}



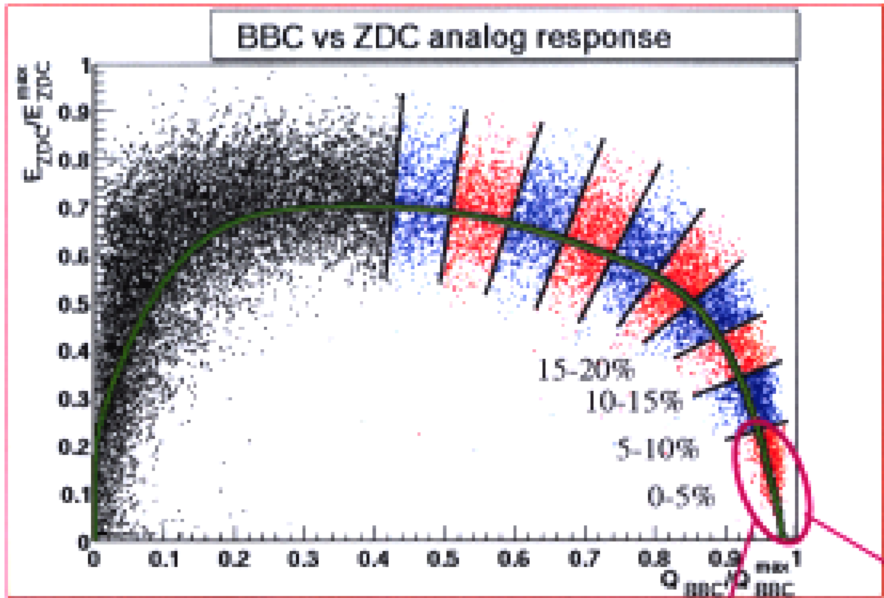
$$rel.\ error(N_{coll})[\%] = 15 + 400 / N_{coll}$$

Error estimation: N_{part}

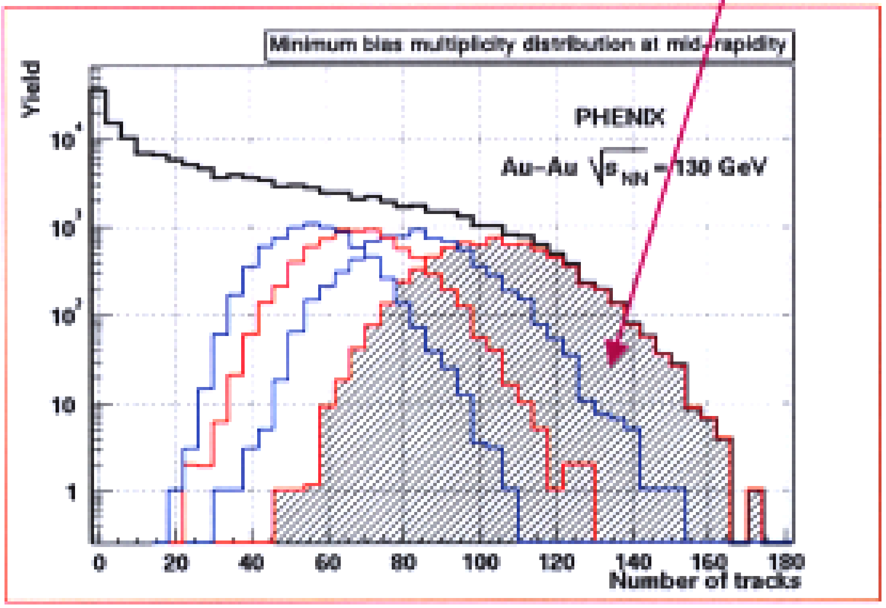


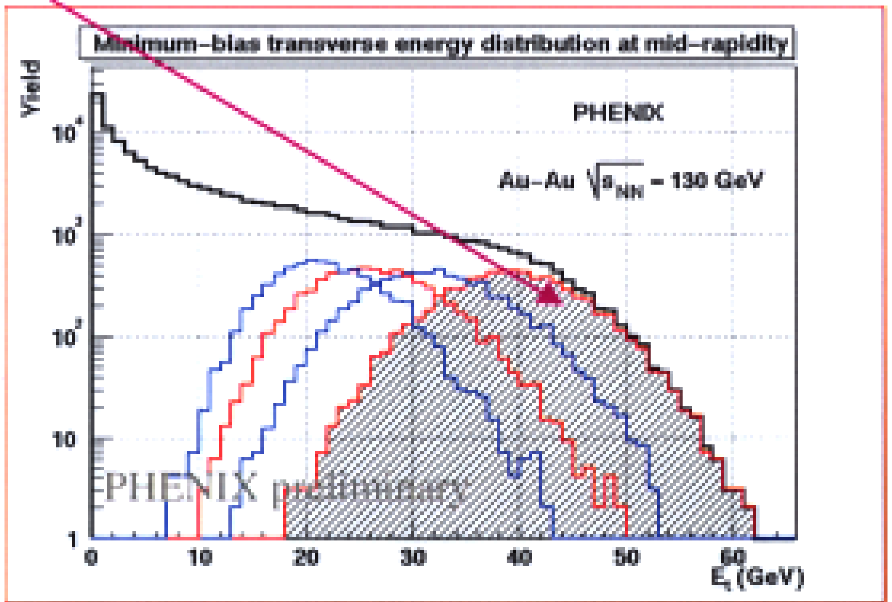
$$rel.\ error(N_{part})[\%] = 2 + 300 / N_{part}$$

Centrality dependence



- Use BBC – ZDC response to define centrality cuts (in 5% bins of σ_{geo})
- Determine $<dN_{ch}/d\eta>$ and $<dE_t/d\eta>$ vs centrality





Conclusions

- ZDCs have been installed and commissioned in all four HI experiments at RHIC;
- ZDC provide highly efficient minimum bias trigger, consistent method for cross sections normalization between experiments, luminosity measurements;
- Geometrical as well as CD cross sections are consistent within ~5%.
- ZDC + BBC provide unbiased method of the centrality characterization.