ZDC Performance and Simulation

Mickey Chiu
Columbia University

RHIC Topical Workshop:
Estimating Npart and Ncoll

Outline

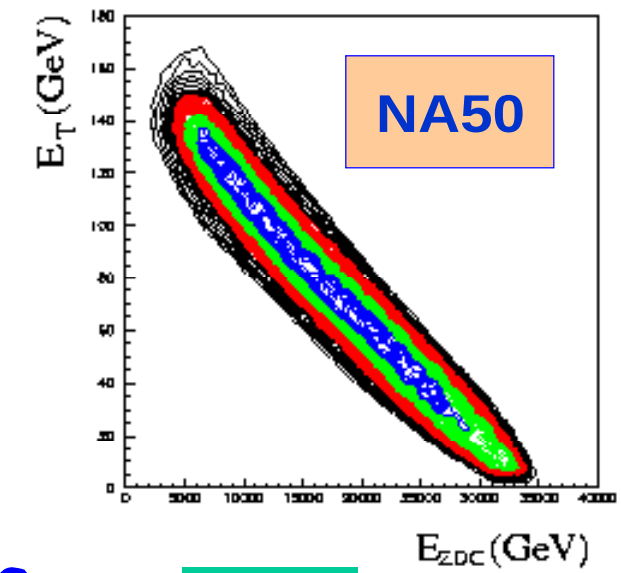
- Goals of the ZDCs as common & identical detectors for all HI experiments at RHIC:
  - luminosity & collisions parameters monitoring/measurement;
  - consistent normalization of cross sections between experiments;
  - trigger for minimum bias HI events.
- ZDC performance in the RUN 2000:
  - energy, 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.

Determining N_{PART}

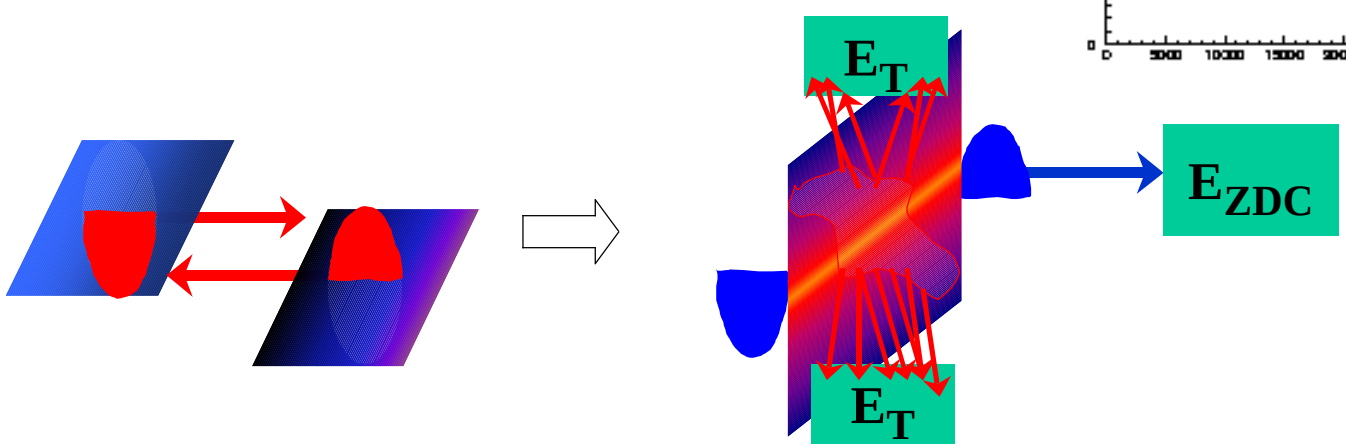
Best approach *(for fixed target!):*

- Directly measure in a "zero degree calorimeter"

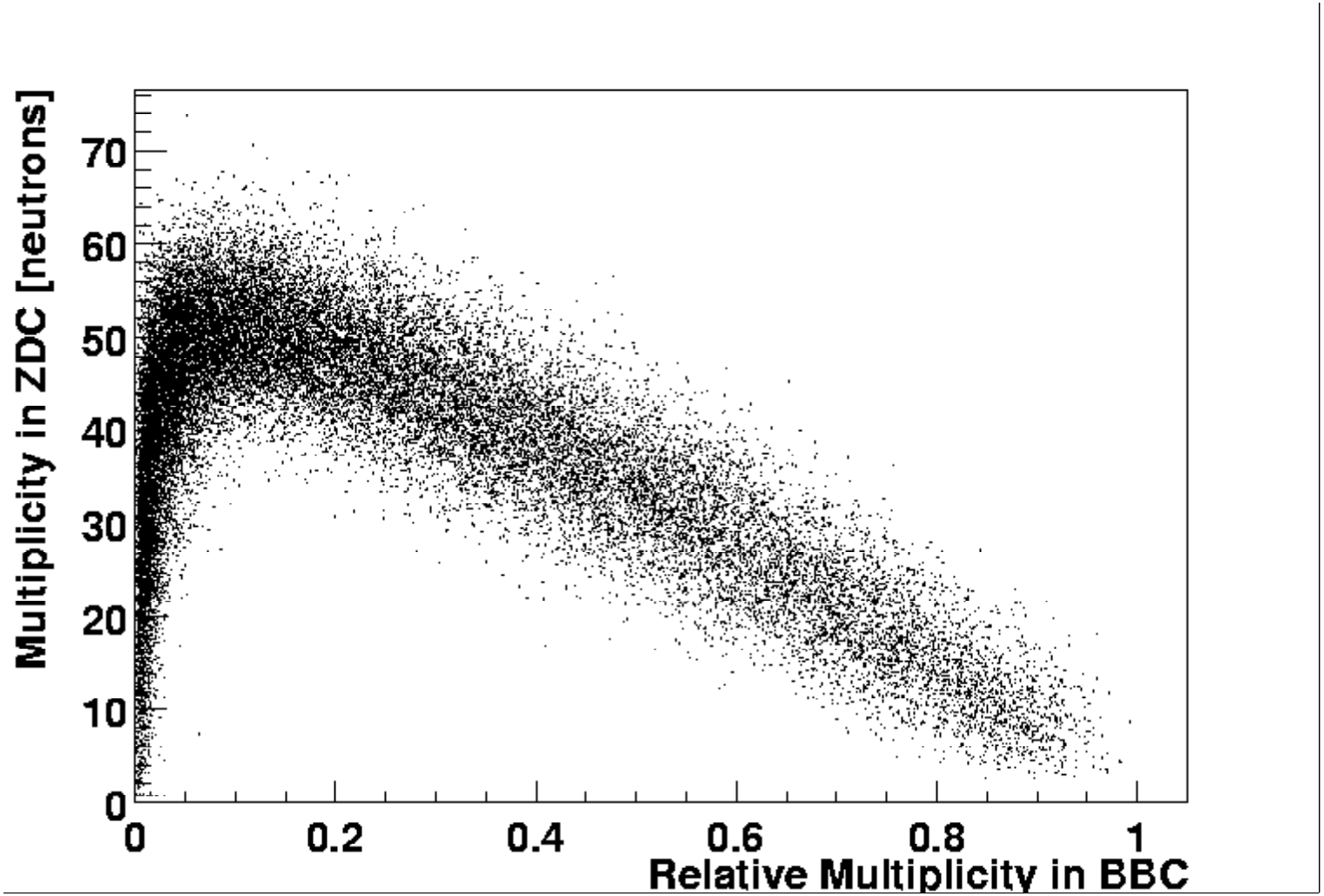
$$N_{PART} \approx 2 \times \left[A - \frac{E_{ZDC}}{E_{PerNucleon}} \right]$$ (for A+A collisions)



- Strongly (anti)-correlated with produced transverse energy:



PHENIX BBC-ZDC Correlation



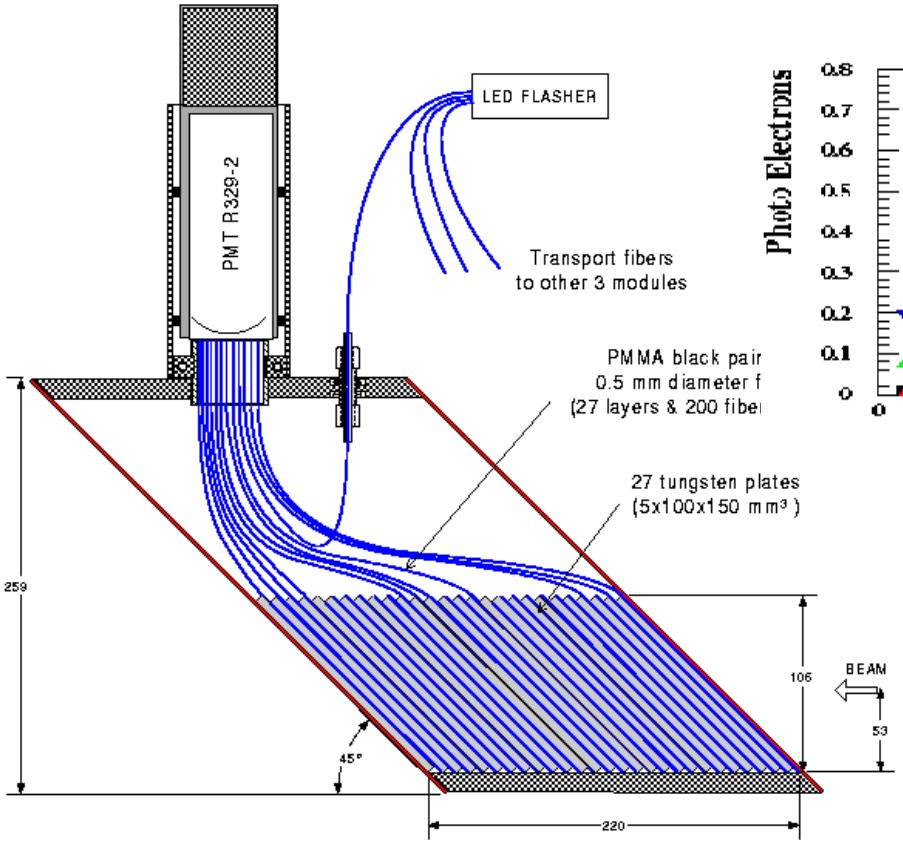
"Centrality" determination

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

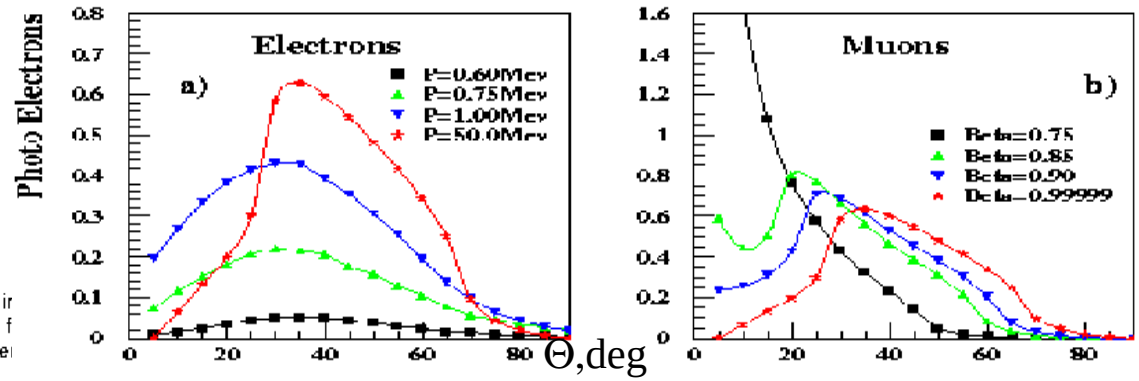
$$N_{participant} + E_{spectator}/(m_n * \gamma_{beam}) = A_{beam}$$

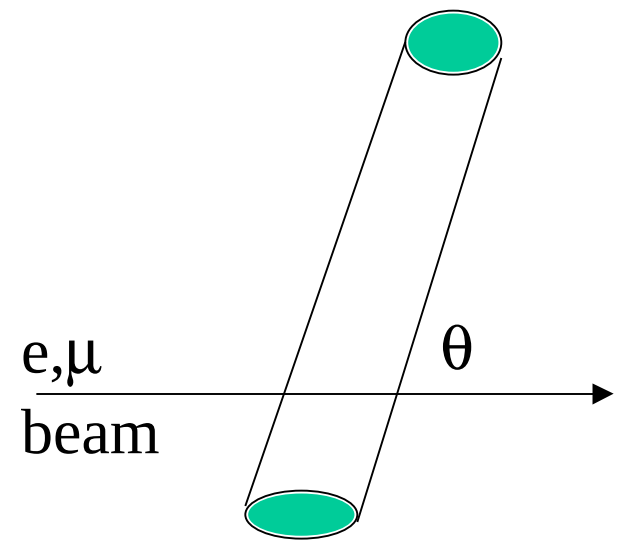
In collider experiments ZDC can measure only part of $E_{spectator}$ ==> large fluctuations + lost of monotonic behavior.

• Using Glauber model, from impact parameter.



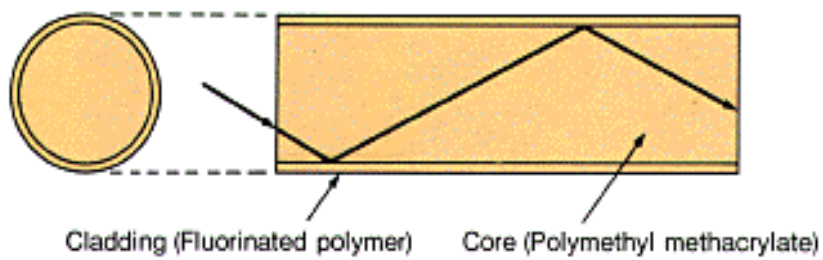
Fiber response vs. angle





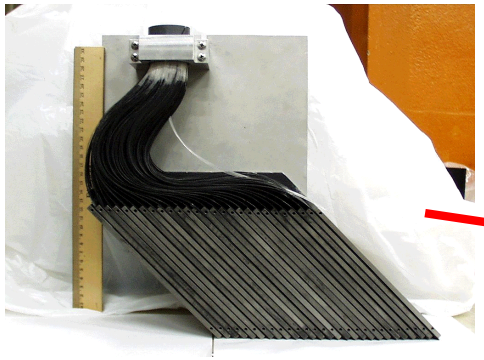
ZDC Calorimeter construction:

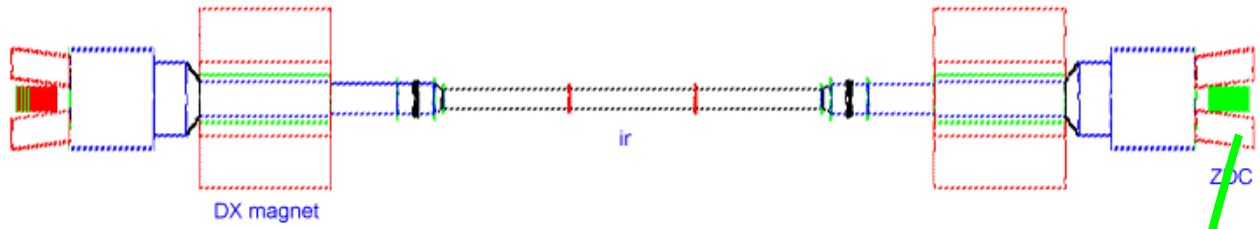
- Tungsten absorber/ fiber (C)sampling
- 2 Lint/module, 3 modules total
- C sampling filters shower secondaries
- Uniform response vs. impact point



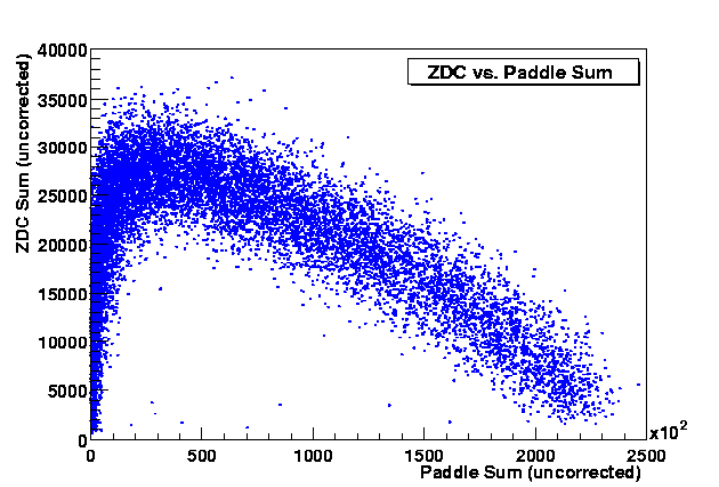
RHIC ZDC's

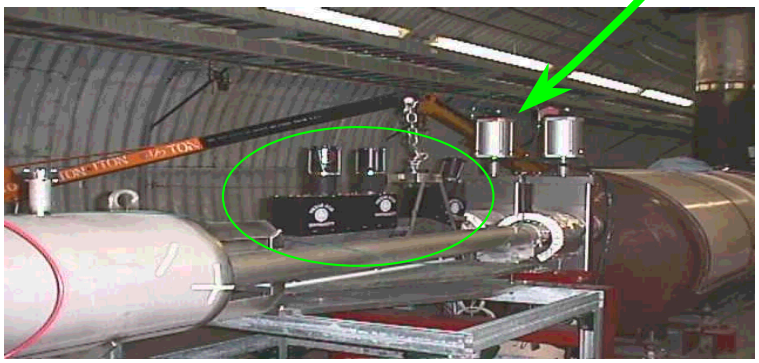
- ZDC ≡ Zero Degree Calorimeter
- Goals:
  - Uniform luminosity monitoring at all 4 intersections
  - Uniform event characterization by all 4 experiments





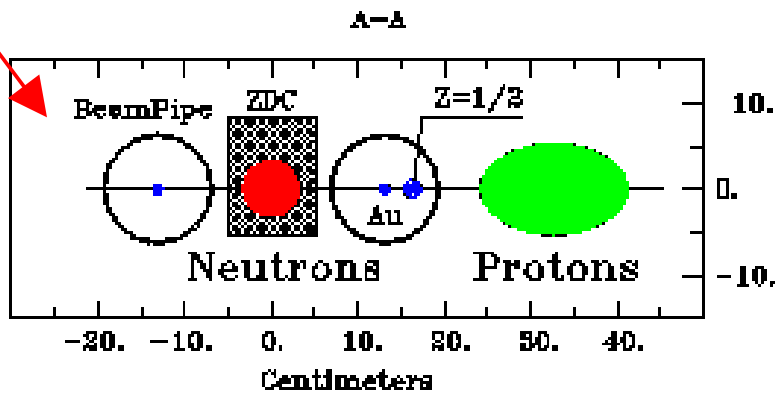
-
  - Correlated Forward-Backward Dissociation
  - **σ_{tot} = 11.0 Barns (+/- few %)**



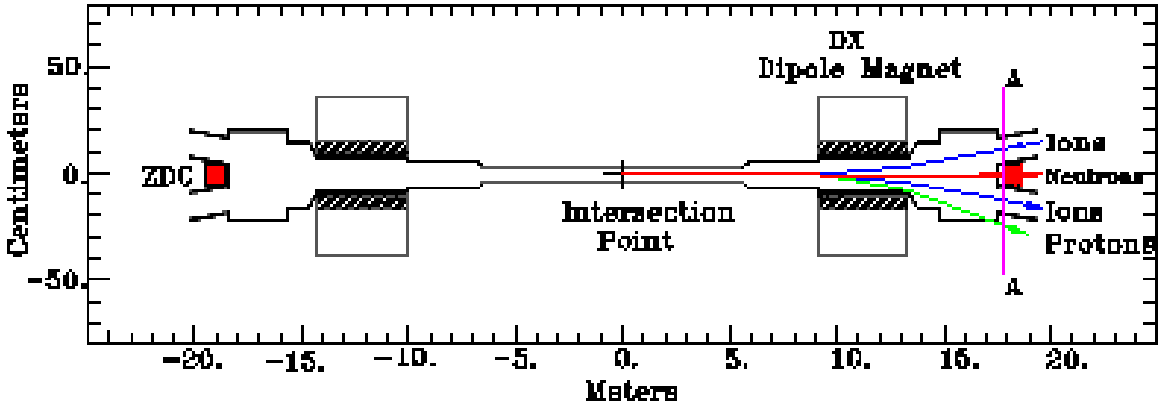


ZDC layout in the RHIC IR's

"Beam-eye" view of the ZDC location

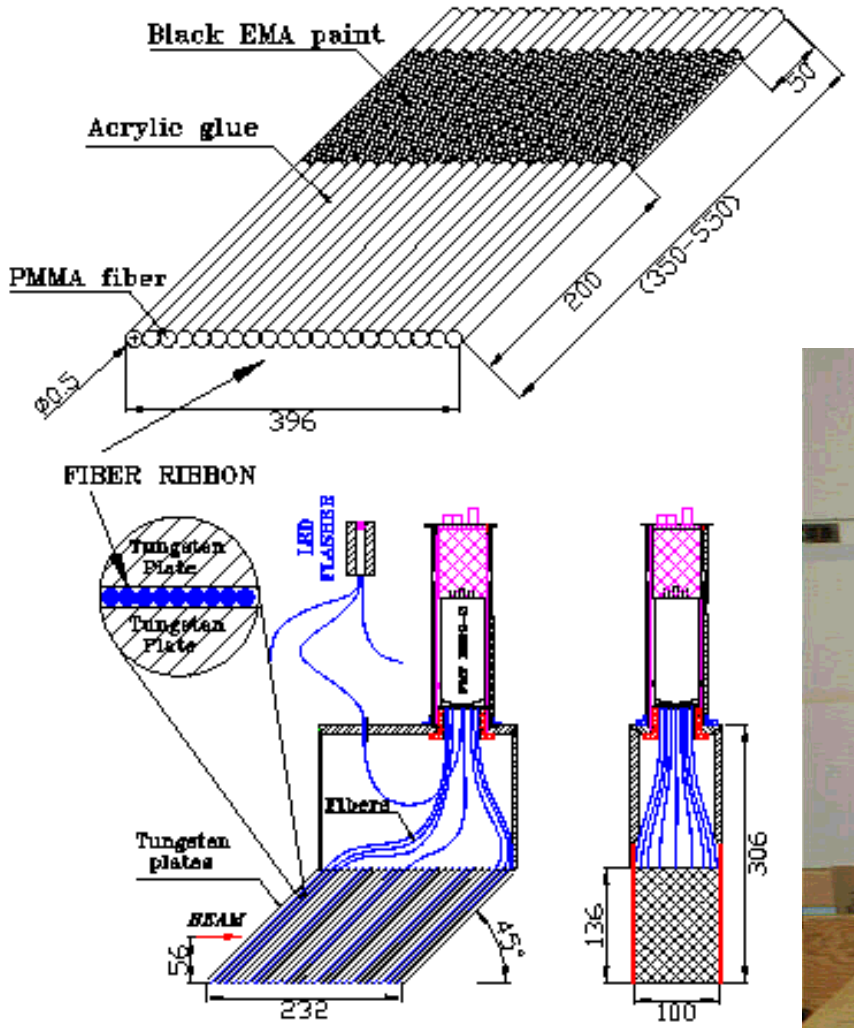


ZDC installation in 1999



Plane vew of the ZDC layout at RHIC

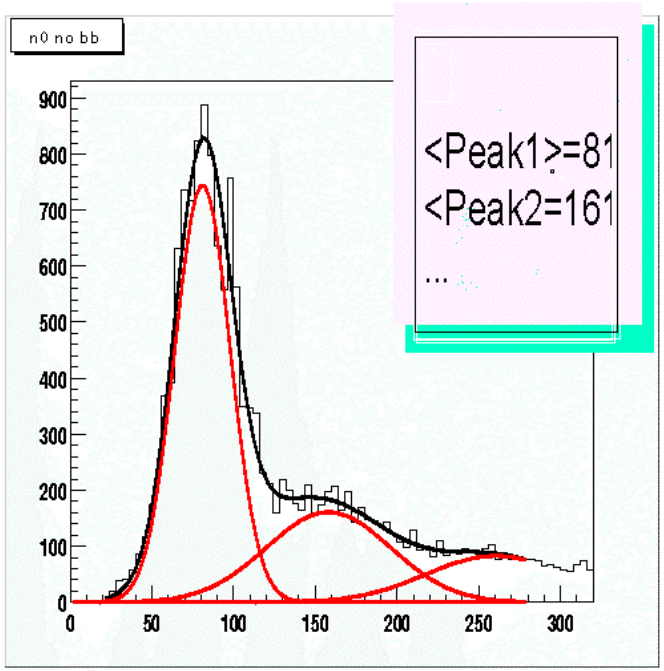
ZDC modules design



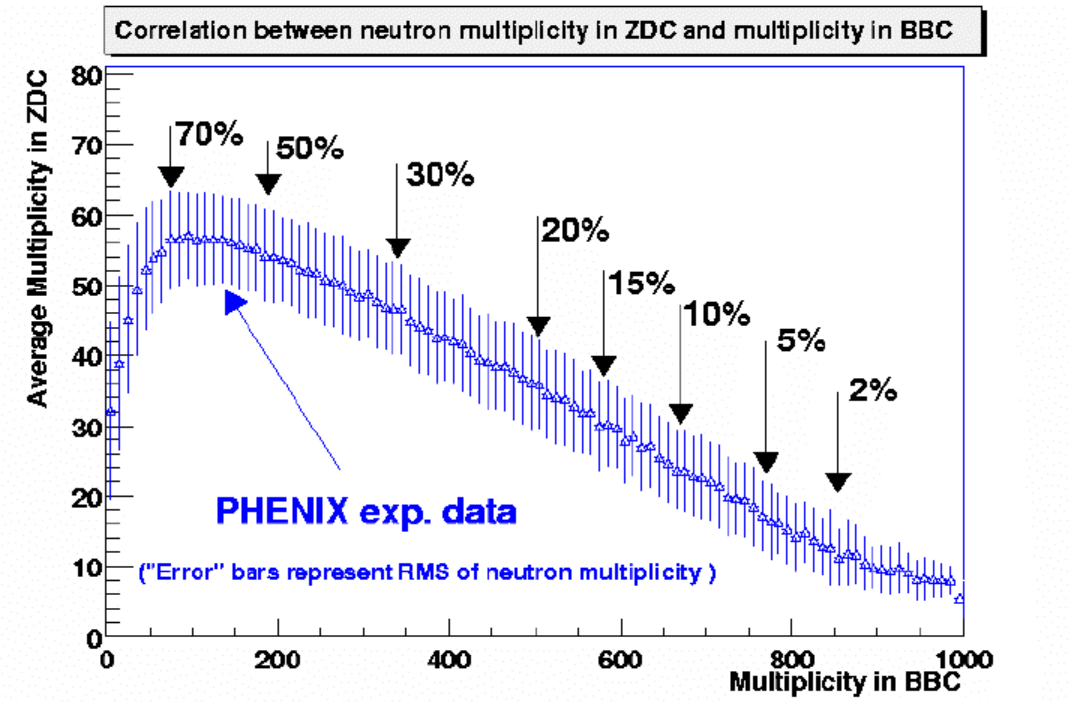
Cosmic ray calibration :

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

ZDC Energy/Multiplicity Scale: Determination of Participant



Fit to distribution of 1,2..
65 GeV neutron peaks
$\sigma/E \sim 25\%$

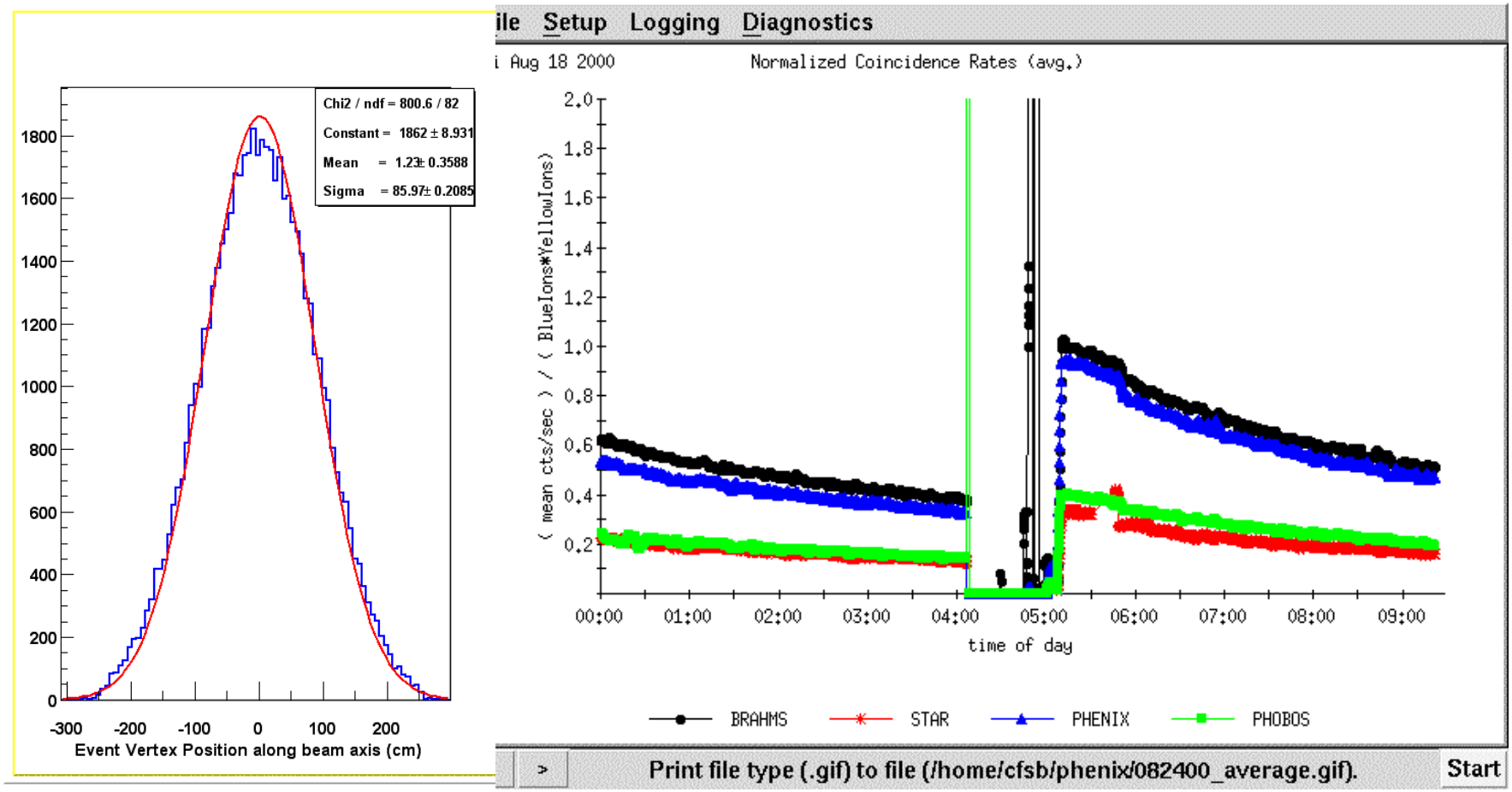


ZDC/BBC multiplicities vs. Centrality determined from cross sections

Luminosity measurements

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

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

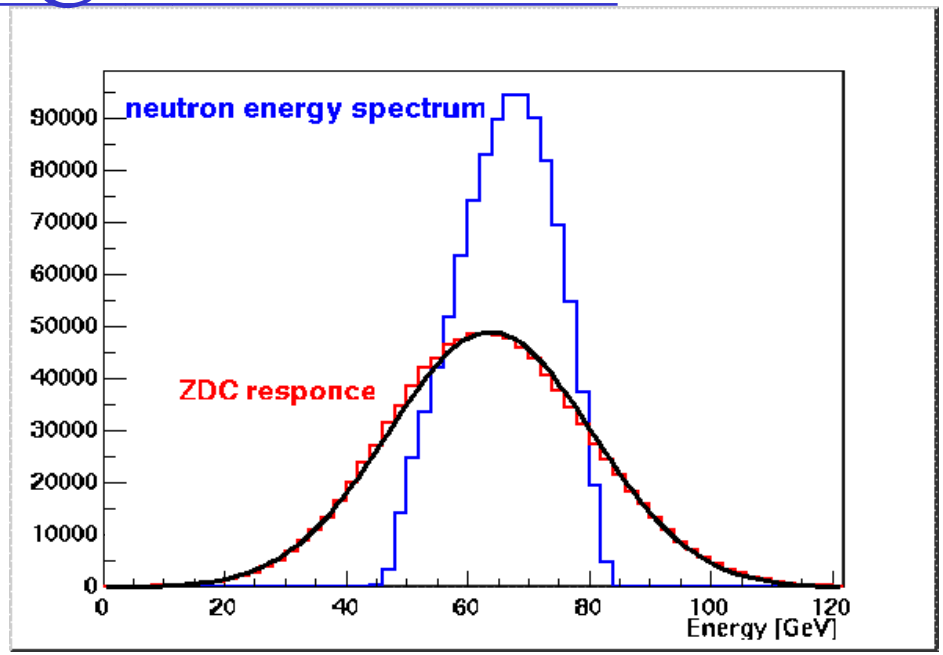


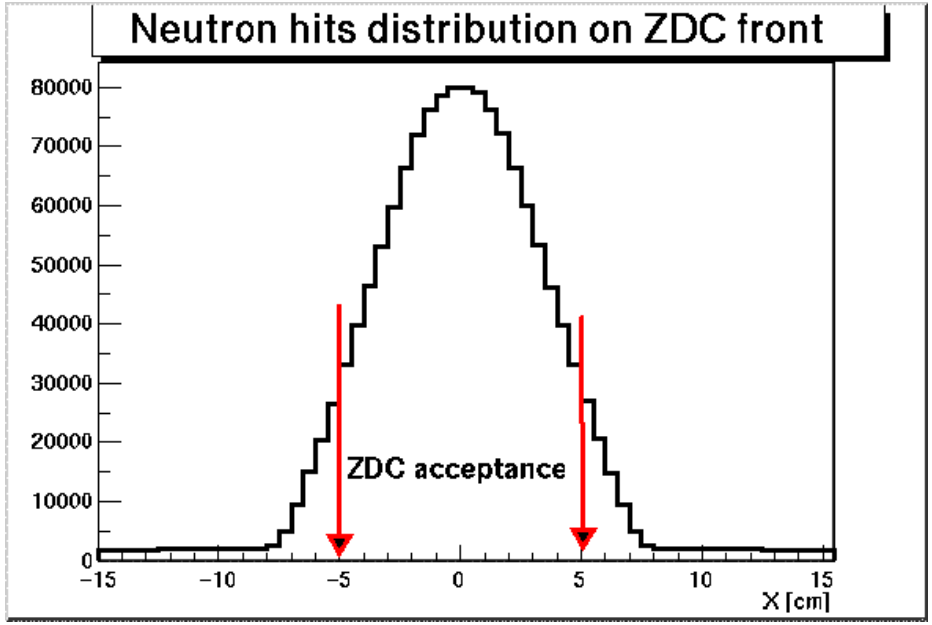
ZDC performance @ √ S = 130GeV

- **Energy resolution for 1n is 21% (simulation)**

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

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

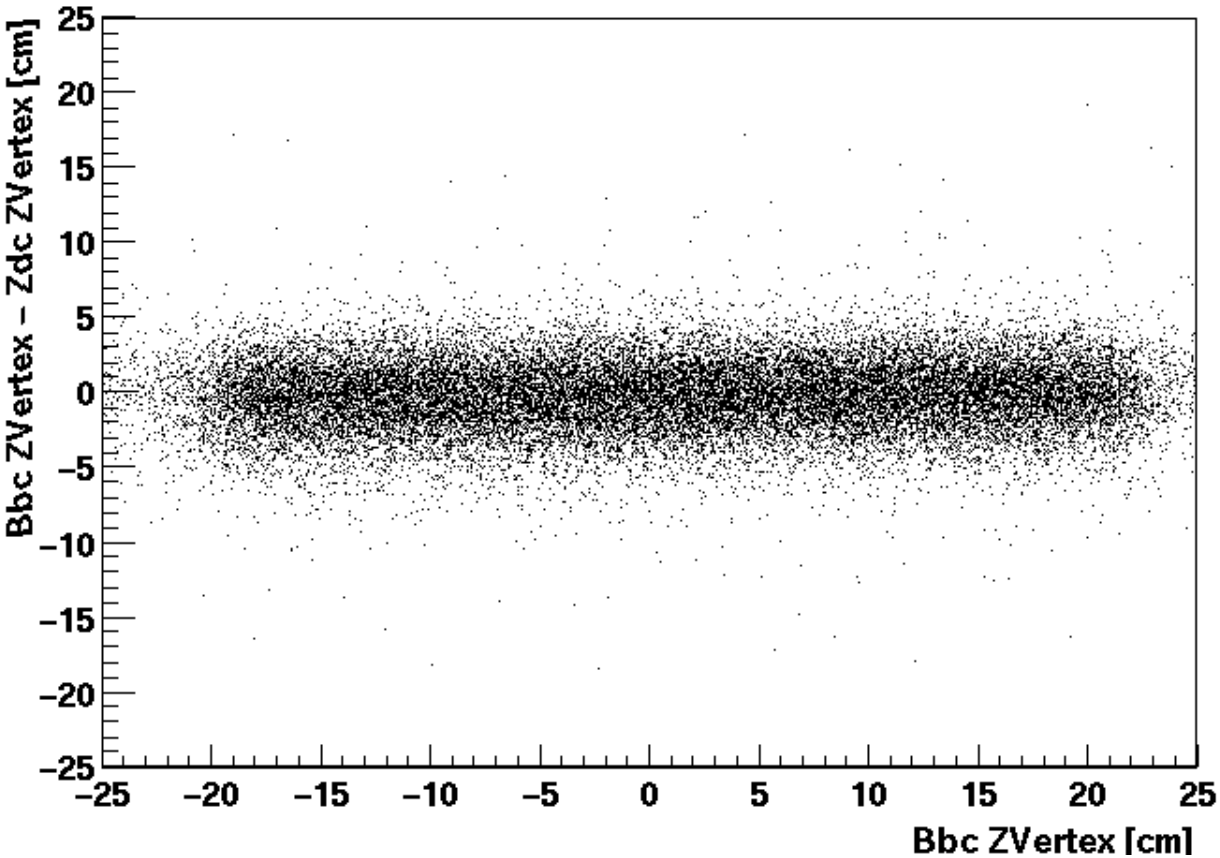


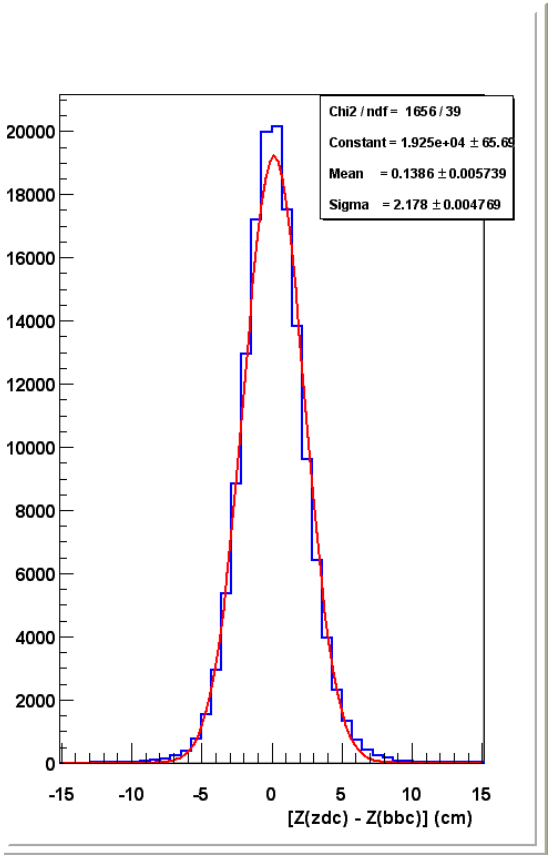


ZDC vertex and time resolution

ZDC vertex resolution $\sigma_Z \approx$ 2cm

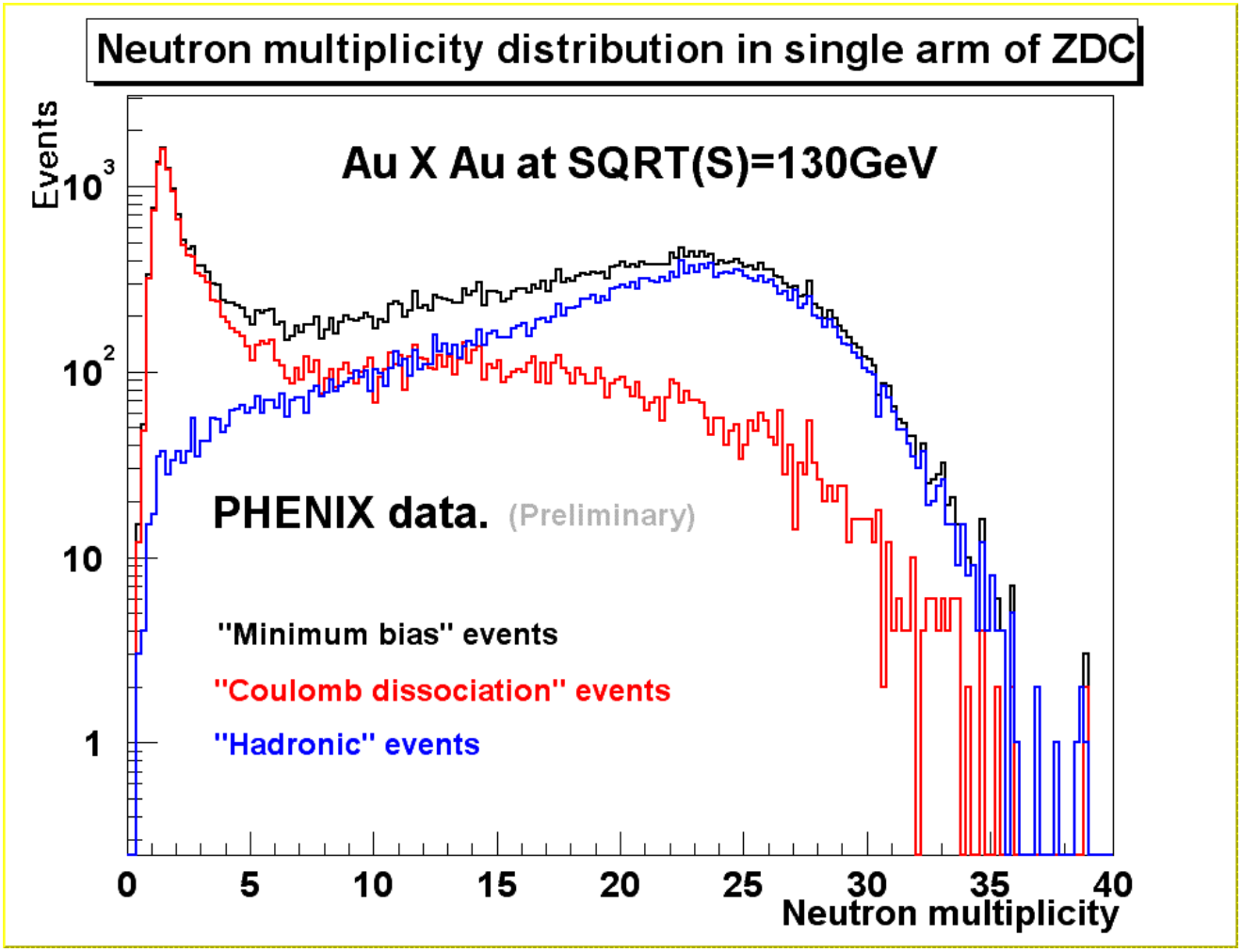
t_0 resolution ≈ 120ps





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,

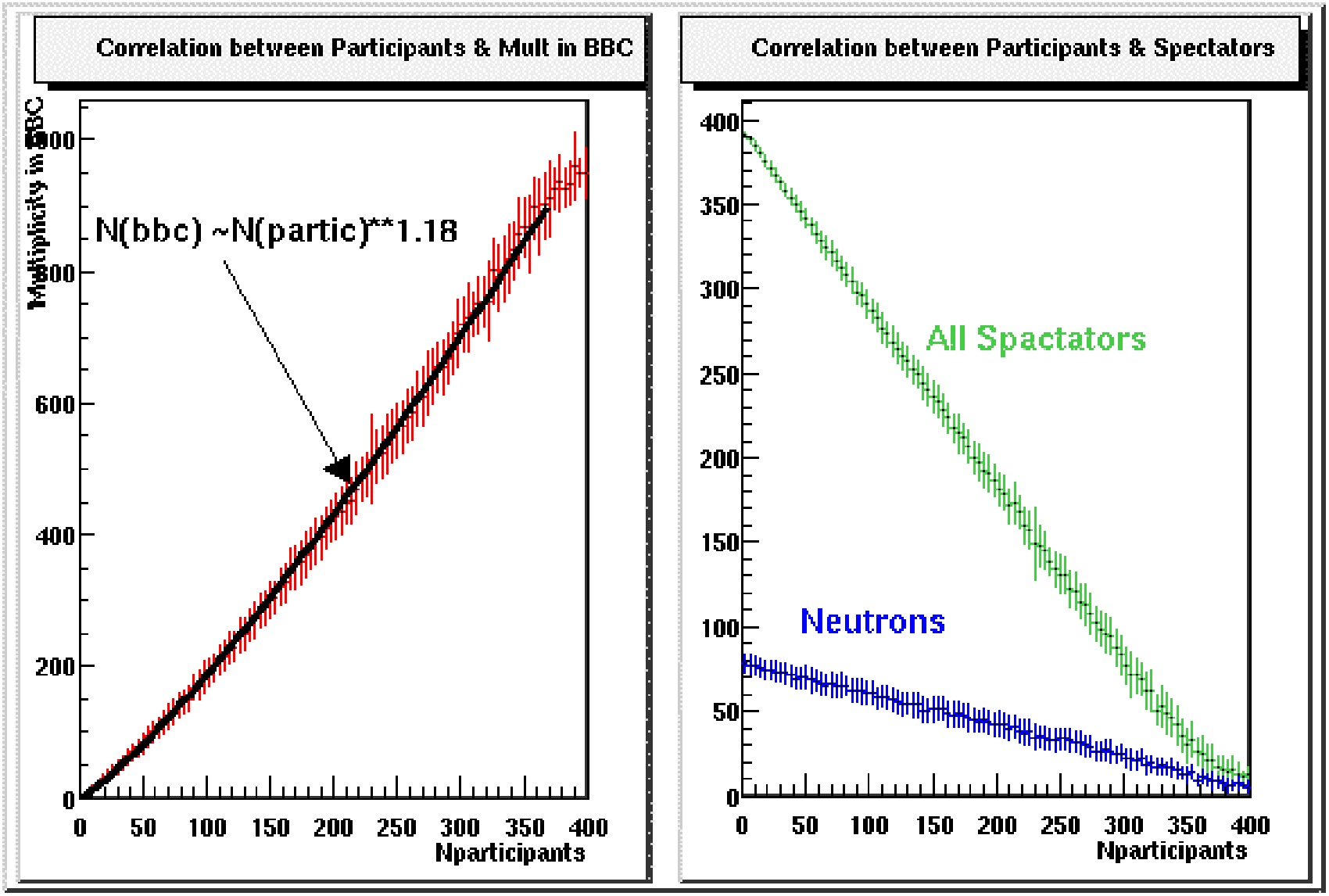
σ_{geo}=7.2 b (Glauber calculation at σ_{nn} =40 mb) ===>

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

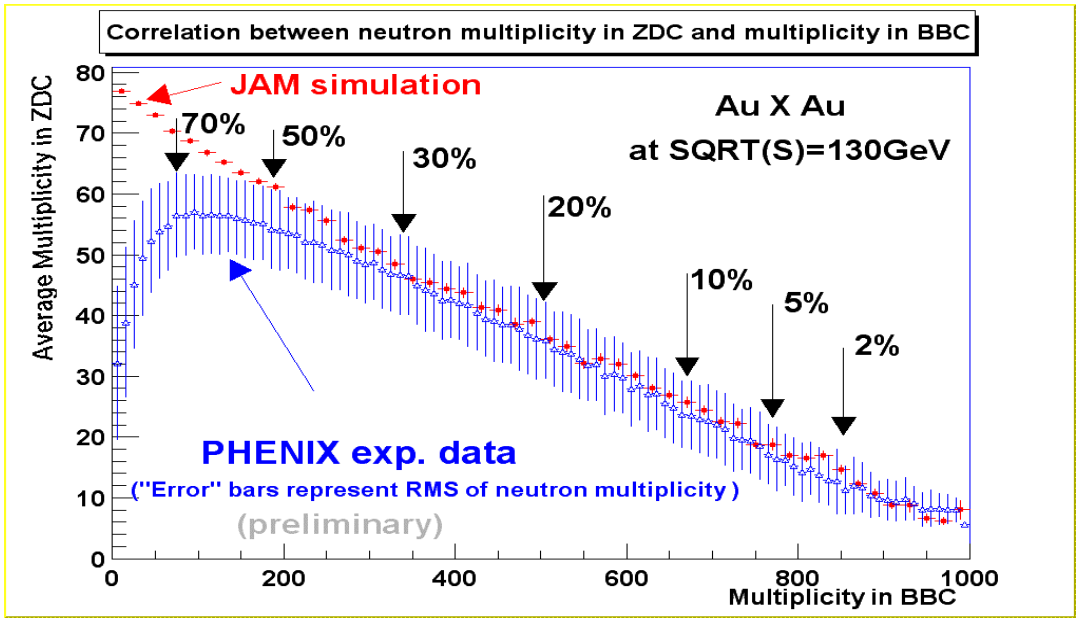
$(N_{bbc}/ N_{tot})_{exp} = (0.615 \pm 0.015)$ ==>

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

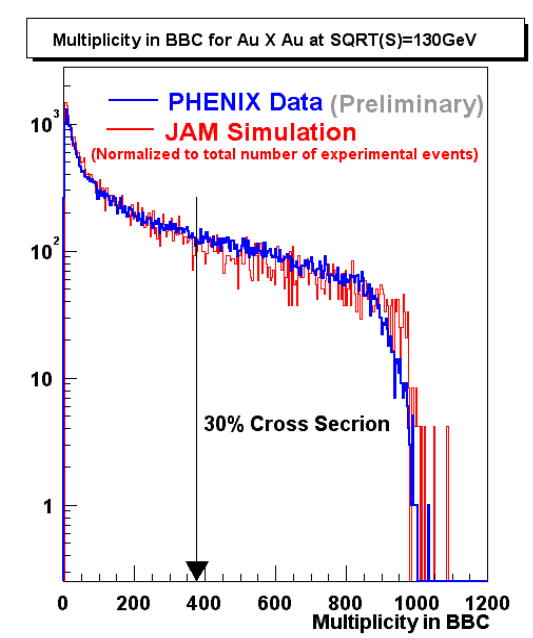
Correlation between $N_{participants}$ & N_{bbc} & Spectators

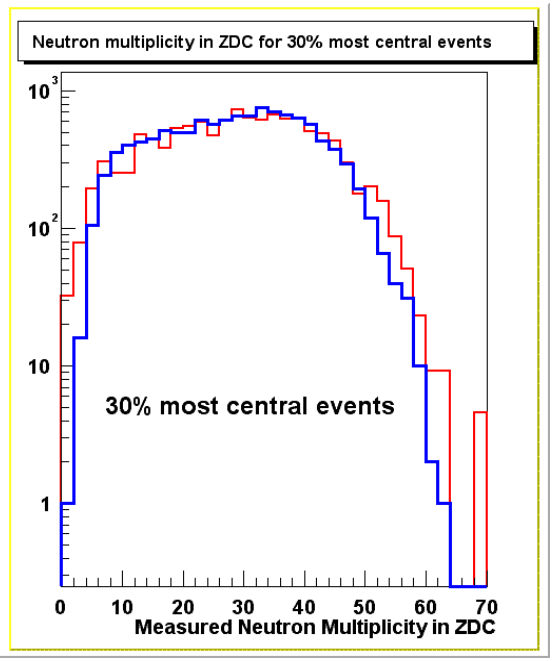


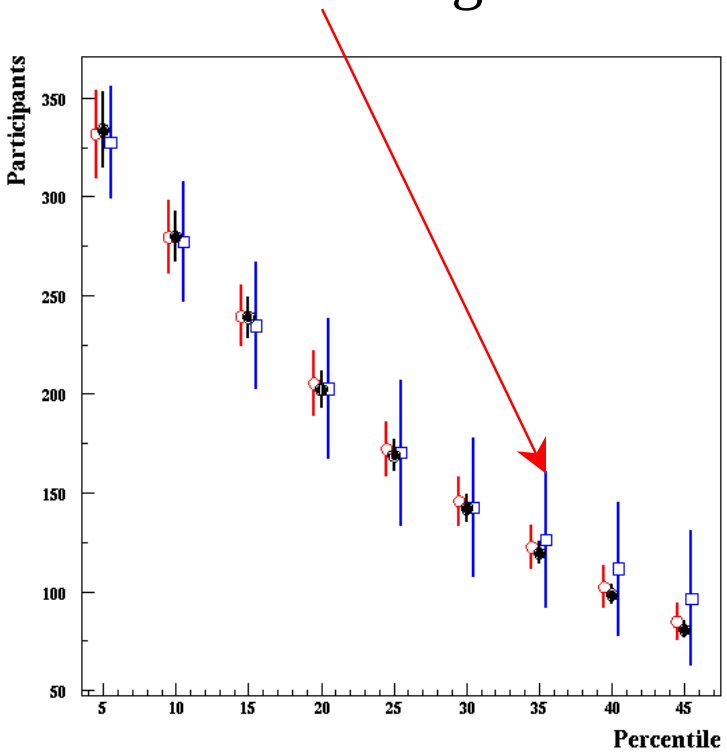
Limitation on centrality selection with ZDC



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







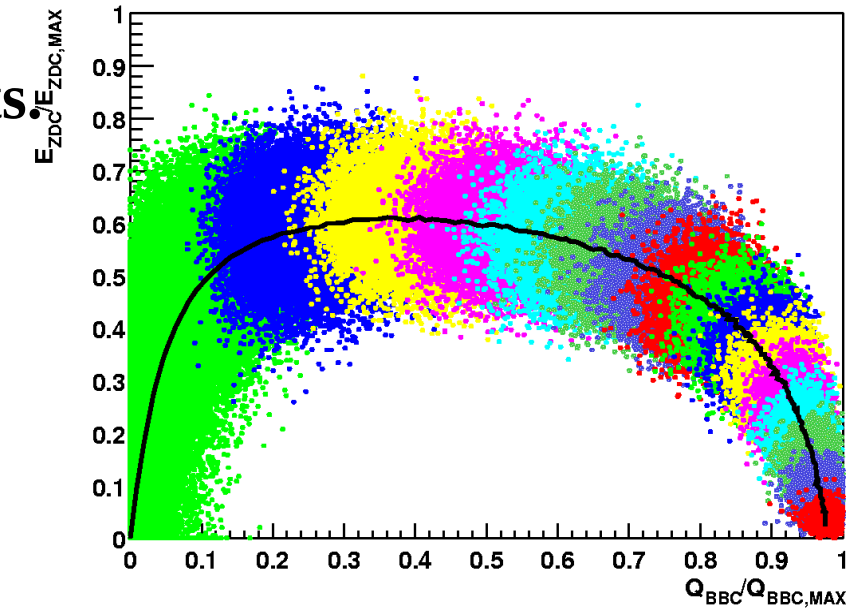
Calculation of N_{part} and N_{coll}

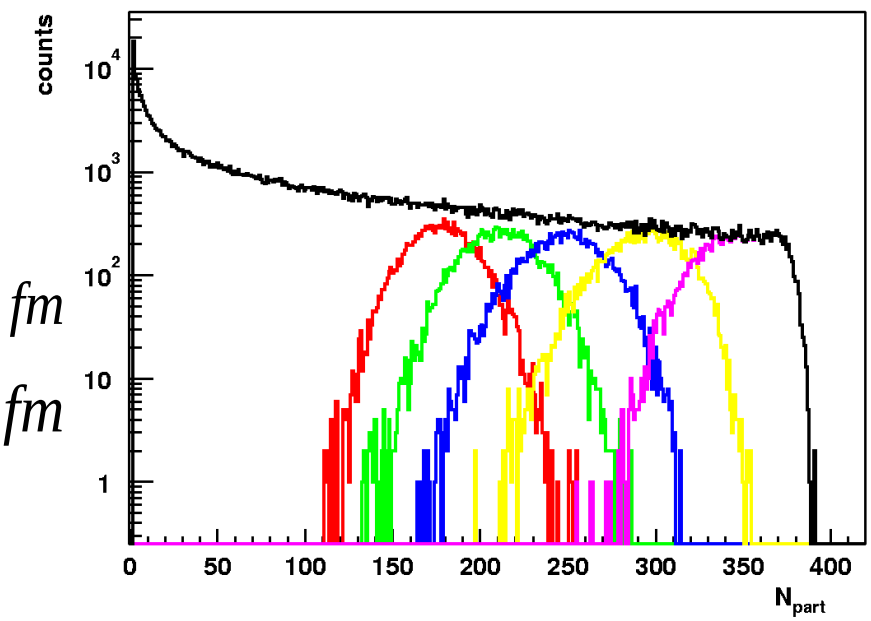
- **Use simulated BBC – ZDC response to define centrality cuts.**
- **Relate them to N_{part} and N_{coll} using Glauber model.**
  - Straight-line nucleon trajectories
  - Constant $\sigma_{NN}=(40 \pm 5)mb$.
  - Woods-Saxon nuclear density:

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

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

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





Parametrization from data at the SPS

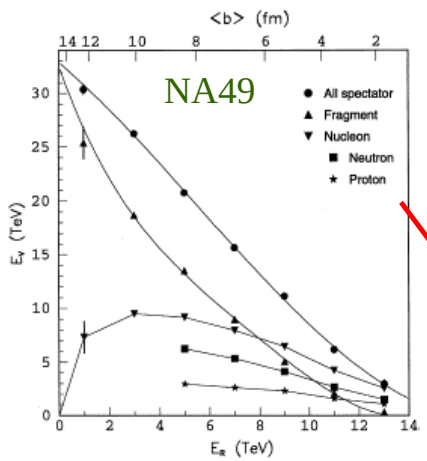
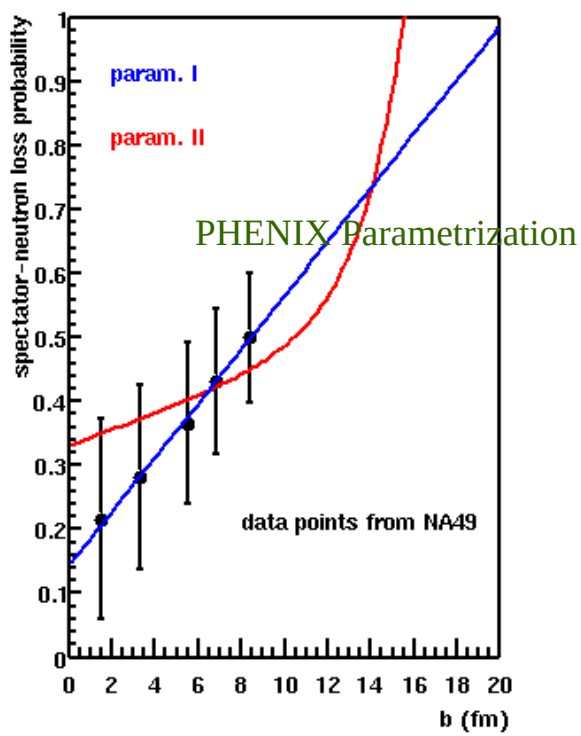
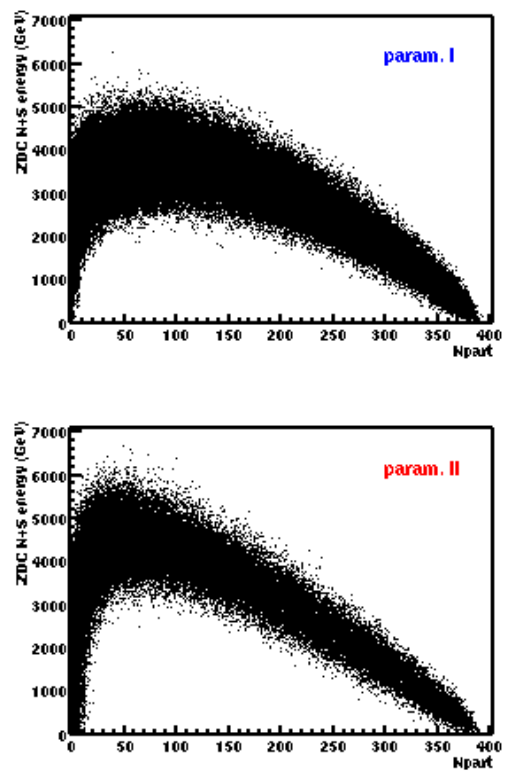


Fig. 6. Corrected forward-going energy of various species as a function of E_R. The average impact parameter scale is shown at the top. The symbols are the data points. The statistical error bars are smaller than the symbols themselves. There is an estimated systematic uncertainty of 20%. The curves through "All spectator" and "Fragment" data points are the results of polynomial fits. The polygons joining the nucleon data points are straight lines to guide the eye





- NA49 Measured Forward Energy for nucleons and fragments
- Compared to Venus Simulation to get impact parameter
- Limited to b < 8
- 20% systematic error

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 + Some Other Detector can provide an unbiased method of the centrality characterization.
- Simulations are poor and almost non-existent.