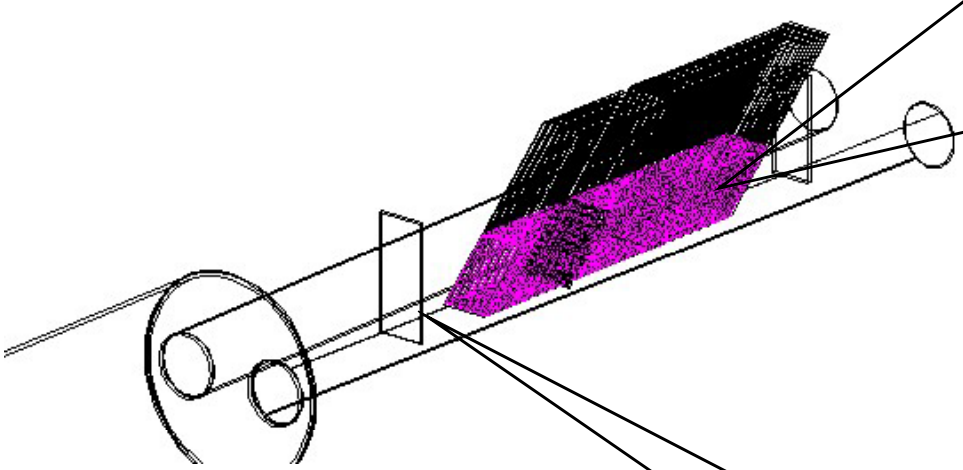
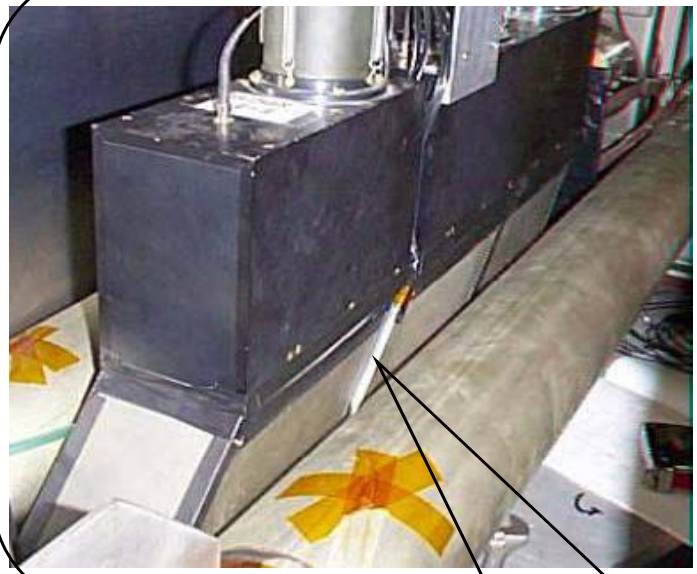
Forward neutron pPPG

2008/05/07

Manabu Togawa

ZDC system





ZDC

10*10cm
→ 2.8 mrad

1 module
$1.7\lambda_I$ $50X_0$

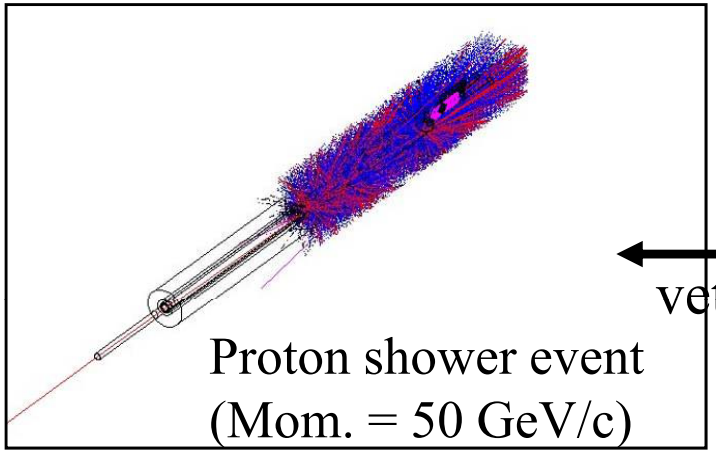
3 module
$5.1\lambda_I$ $150X_0$

SMD

Decision of the neutron position by hadron showers generated in the 1st module.

Charge veto

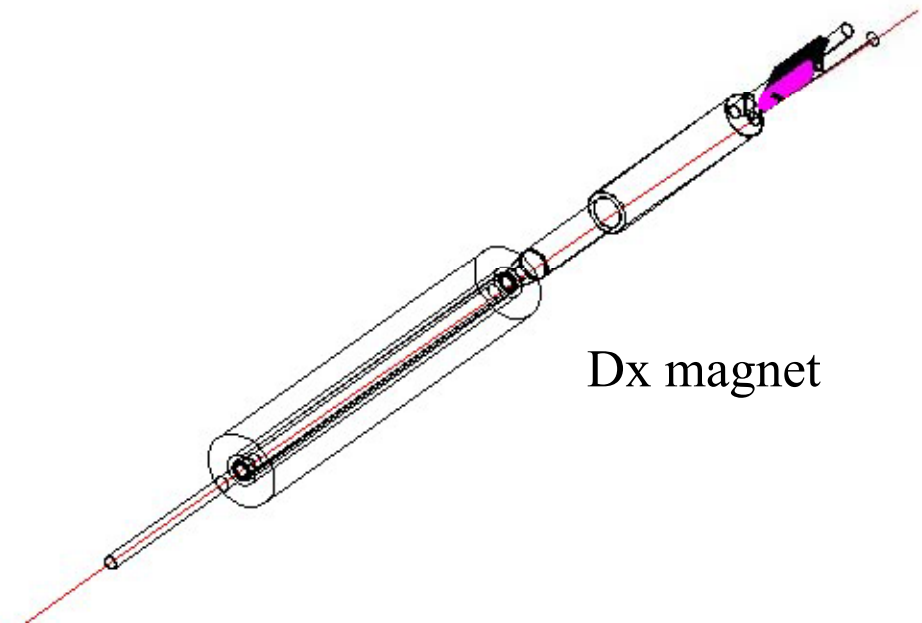
veto



Proton shower event
(Mom. = 50 GeV/c)

Simulation

- Prepared by GEANT3 with GEISHA
  - This set well reproduced the test experiment @ CERN (100 and 160 GeV/*c* proton beams).
    - C. Adler et al., Nucl. Instr. And Meth. A470, 488 (01)
    - ZDC only (Test module : $2.0\lambda_I$, and 4 modules in series)
  - Including beam pipe, any materials from PISA.



Event generators

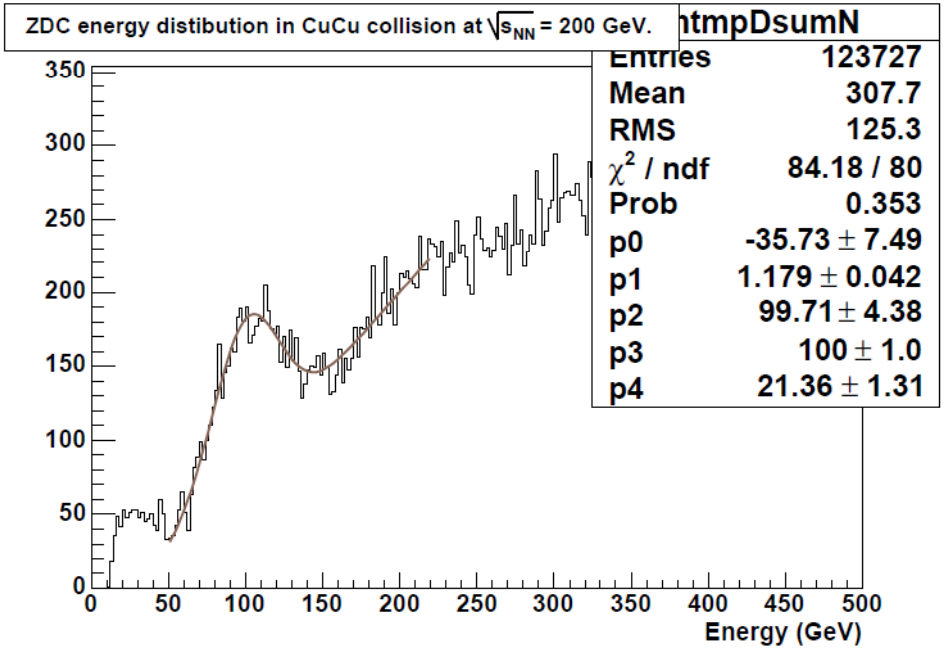
- Single neutron generator
  - Input p_T shape : $A*\exp(-4.8 \pm 0.3\ p_T)$ for $0.3<x_F<0.7$ @ ISR
  - Input x_F shape : decided by cross section analysis.

  → Response for neutron, detector efficiency…
- Pythia (v.6220)
  - Investigation for the background.
    - K/n and p/n ratios.
    - Basically studied for single input case.

Energy resolution.

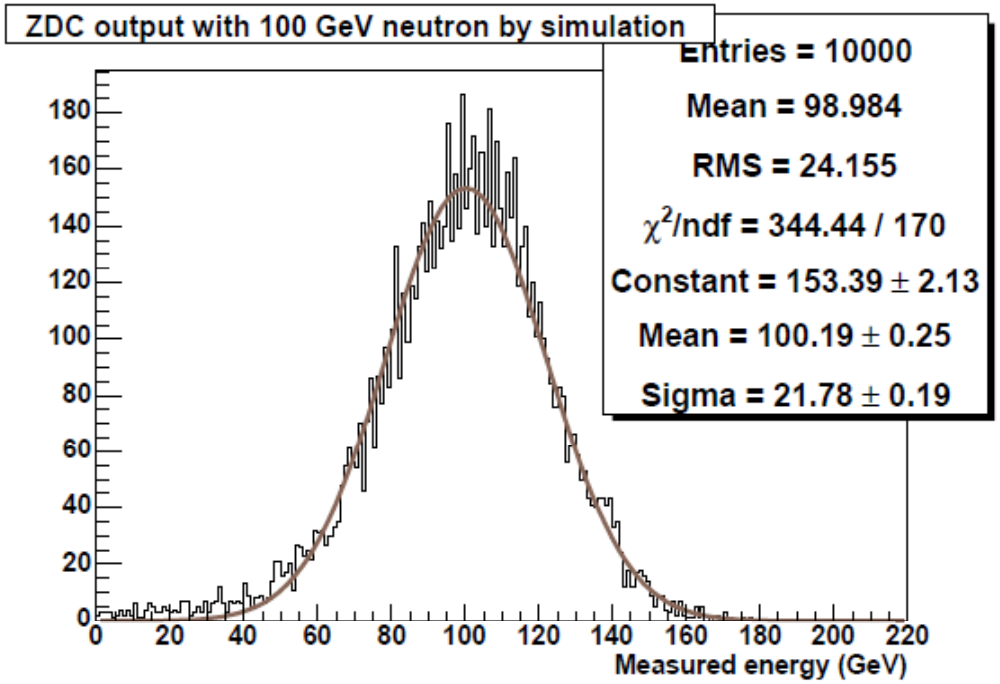
* 100 GeV neutron was put to the center of ZDC same as CuCu data.

Energy calibration was done by one n peak



Real data

Res. 21.36±1.31

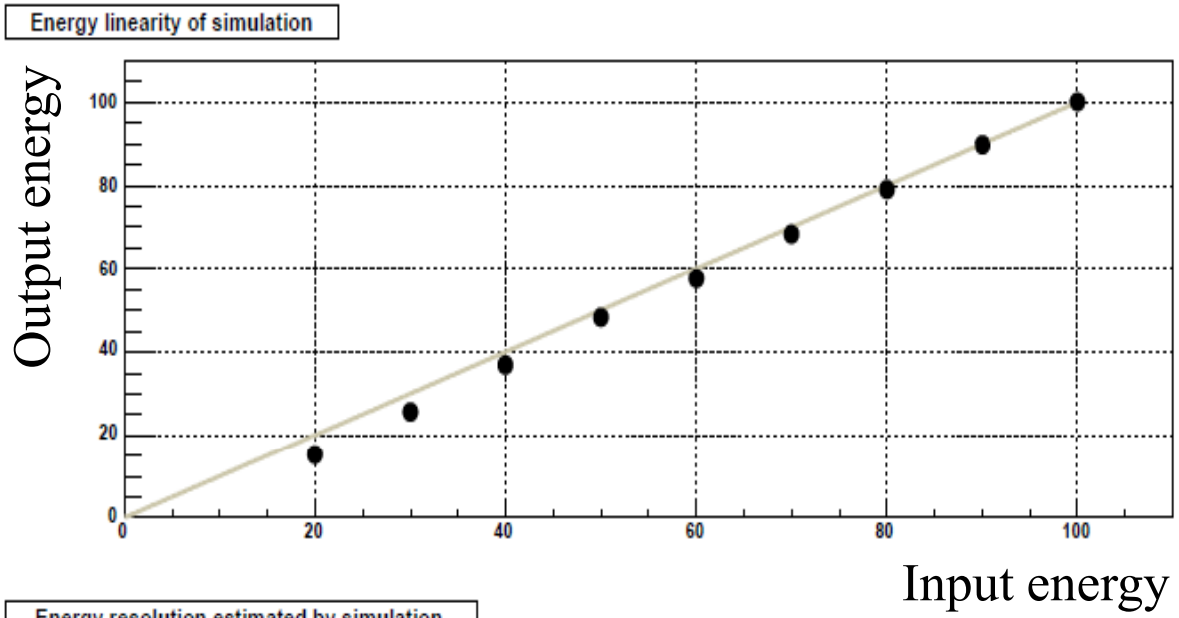


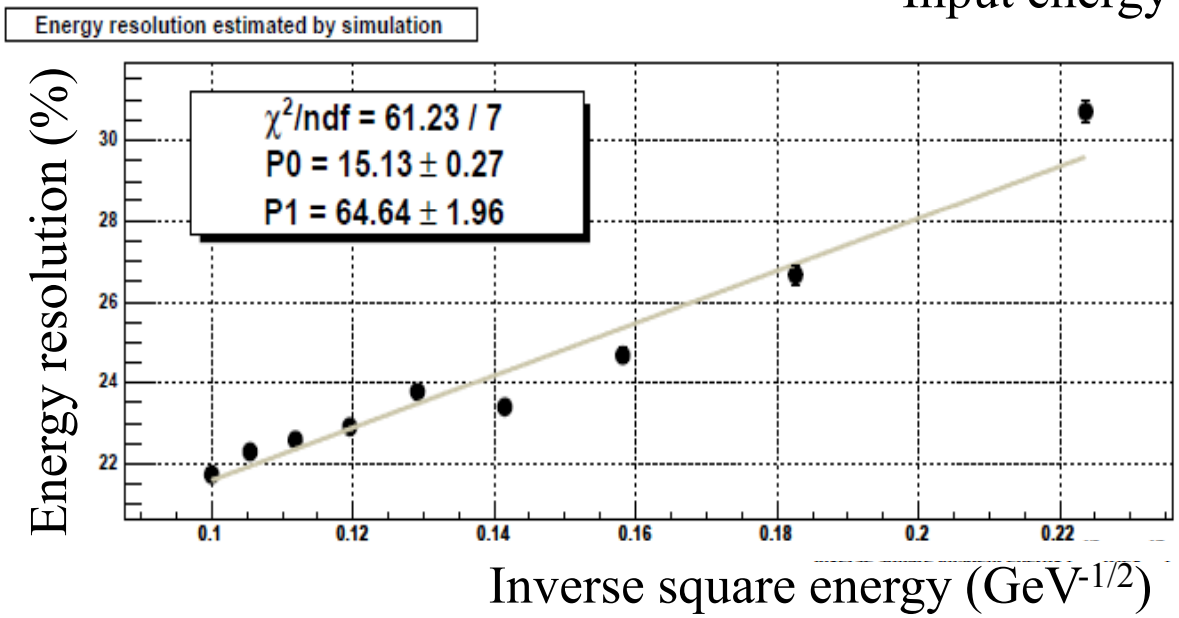
Simulation

Res. 21.78±0.19

Consistent btw real and simulation data. for 100 GeV n

Energy resolution below 100 GeV

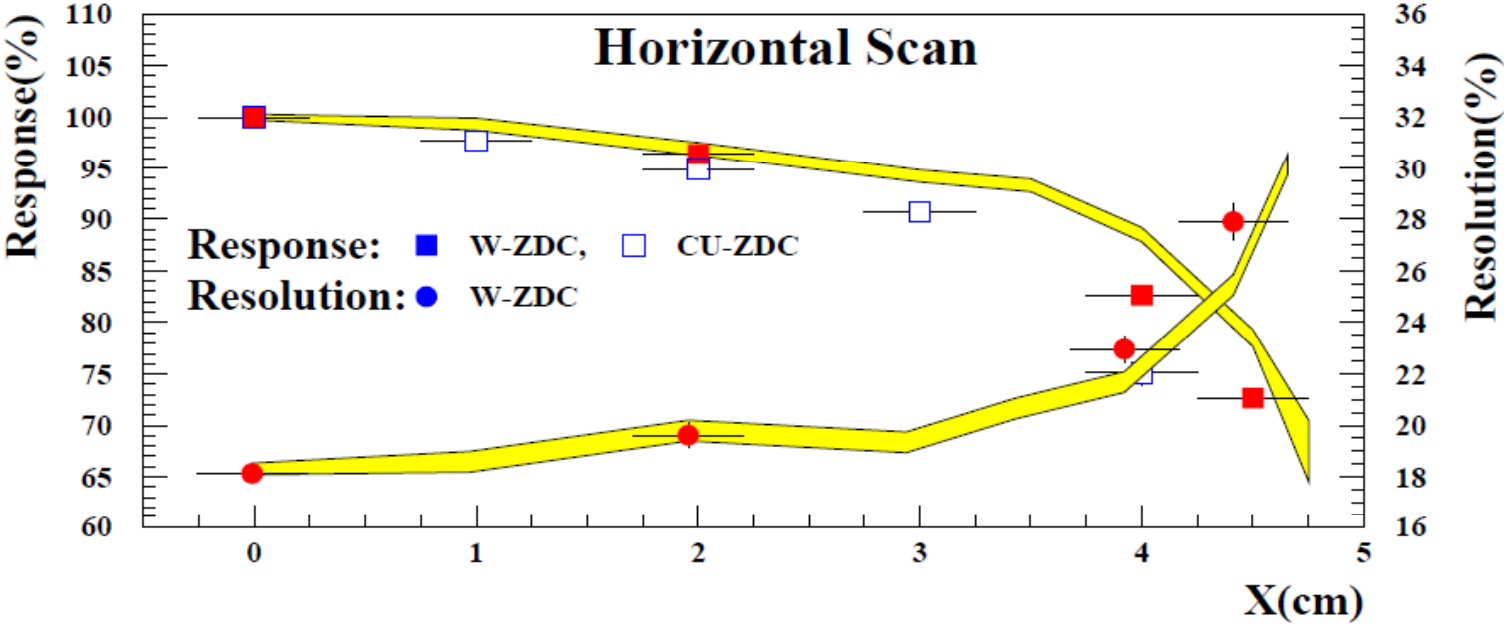


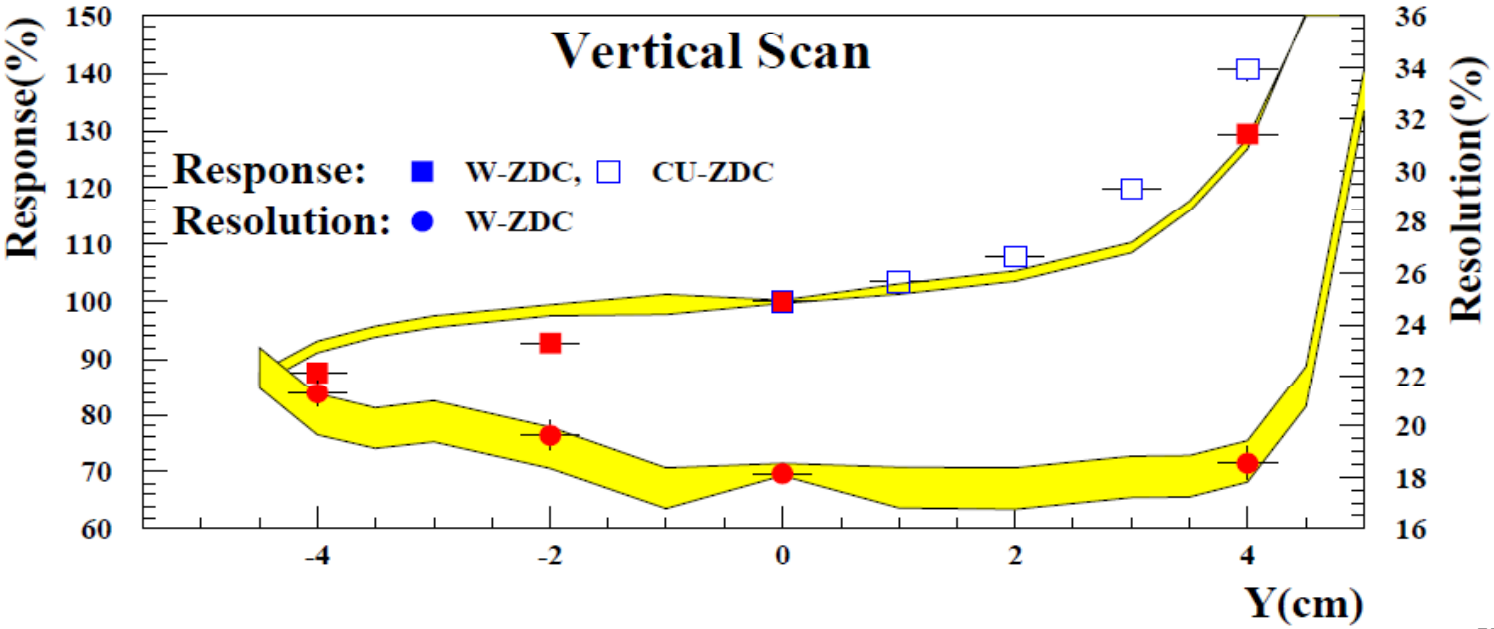


- Non-linearity
  - e.g. 20 GeV input → 15 GeV out.
  - Corrected by energy unfolding.
  - Added as systematics diff. btw linear case.
- Resolution

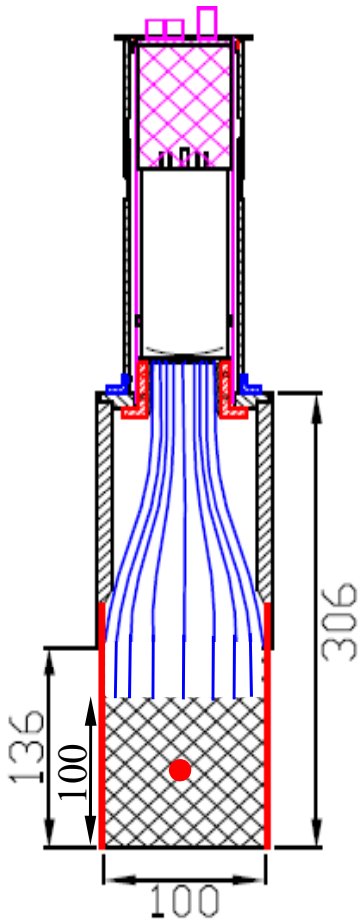
$$\frac{\Delta E}{E} = \frac{64.6}{\sqrt{E\ (\mathrm{GeV})}} + 15.1\ (\%)$$

Edge effect for energy measurement (Test ZDC)





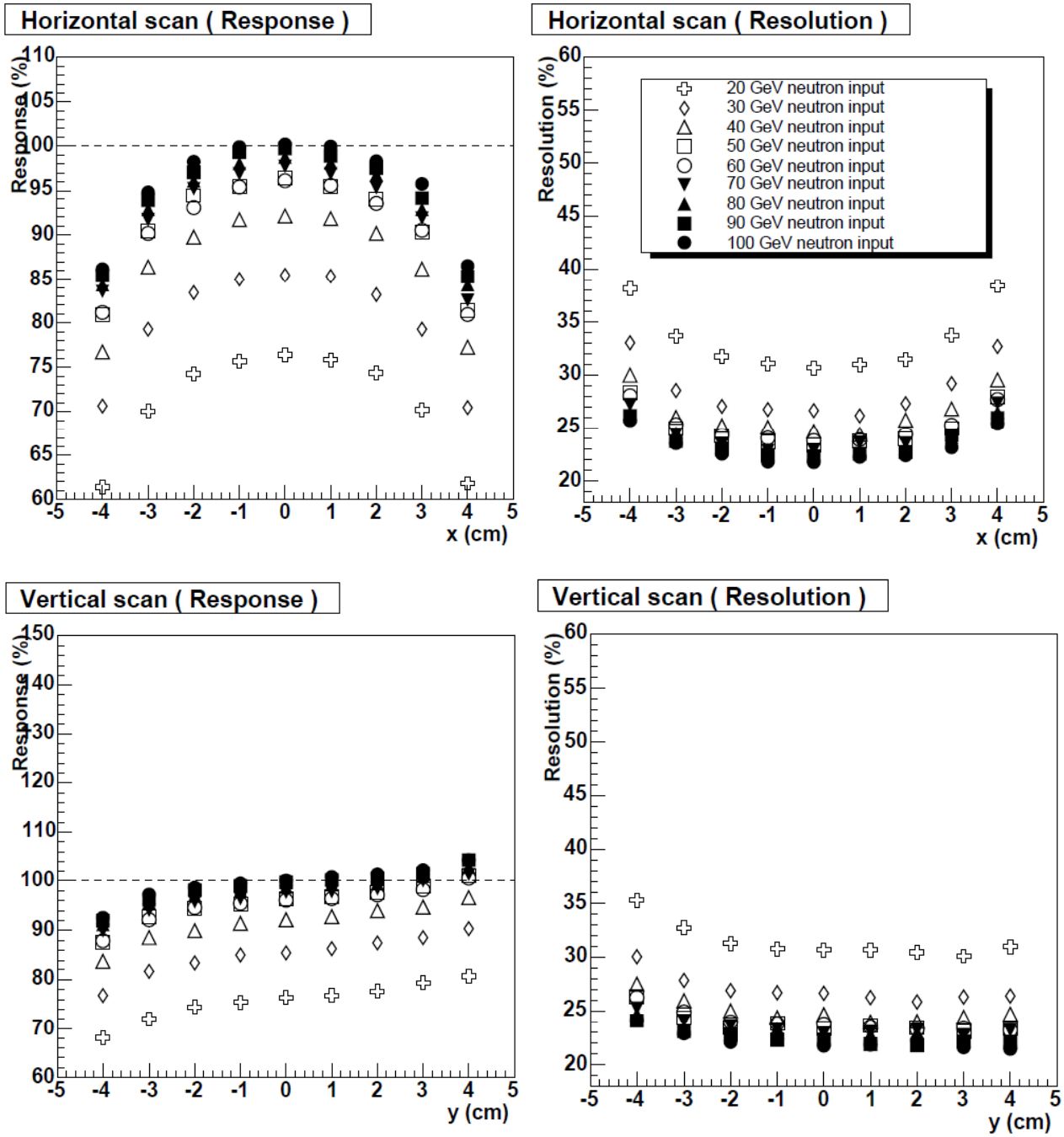
Test module



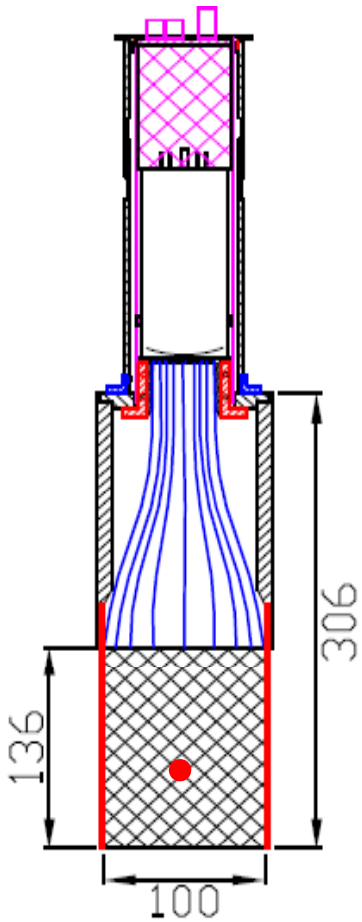
Measured by 100 GeV/c proton @ CERN.

C. Adler et al., Nucl. Instr. And Meth. A470, 488 (01)

Edge effect for energy measurement (ZDC)

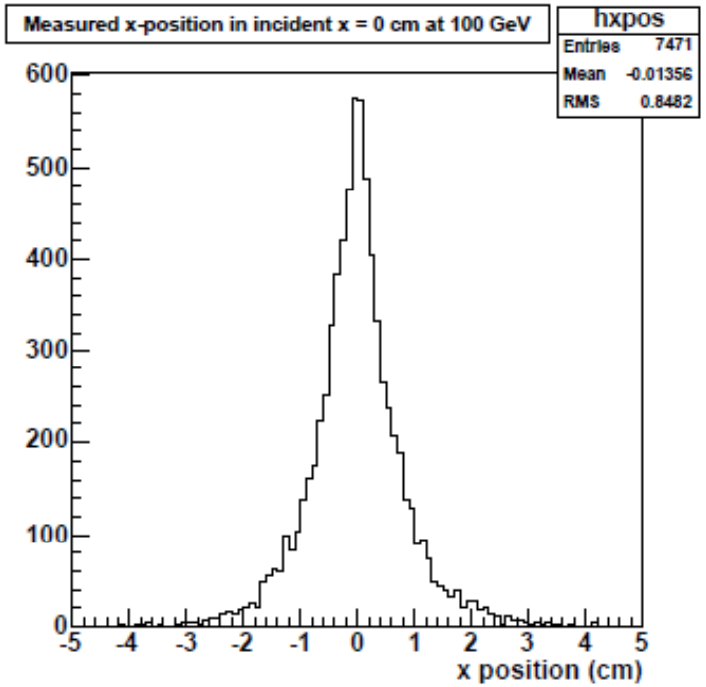


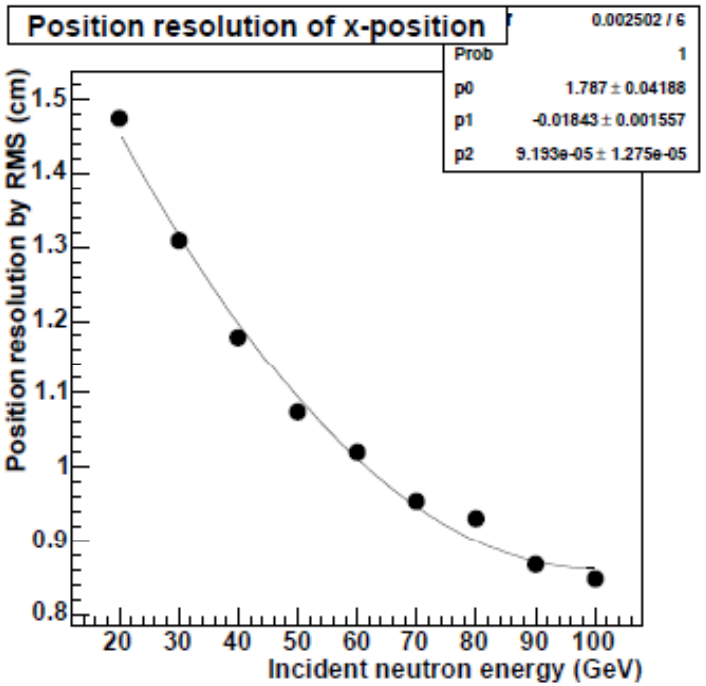
ZDC



Energy response is 95~100% within ±3 cm

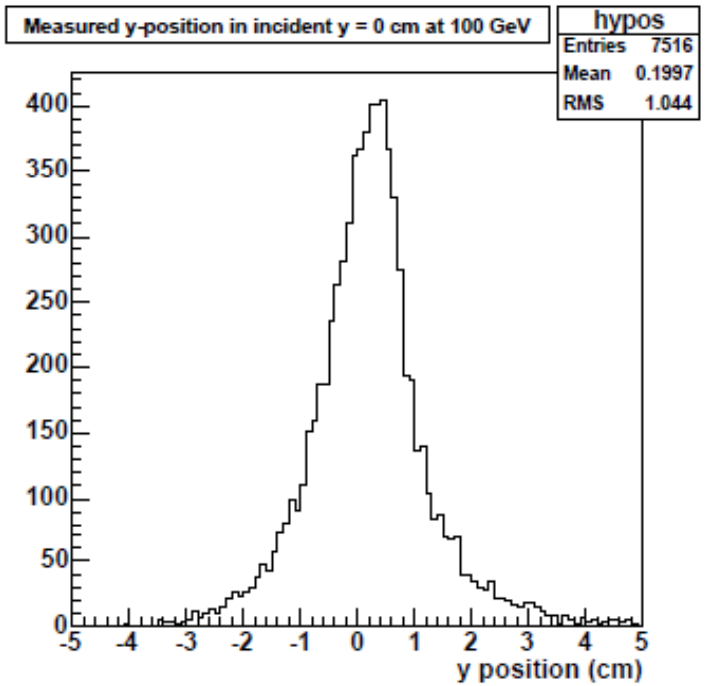
Position resolution.

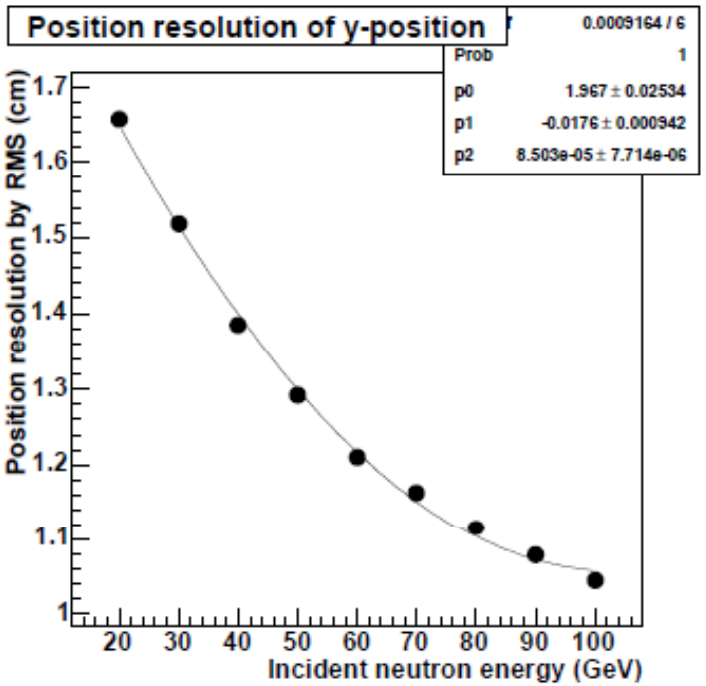




Centroid method

$$x, y = \frac{\sum_i^N ene(i) \cdot pos(i)}{\sum_i^N ene(i)},$$



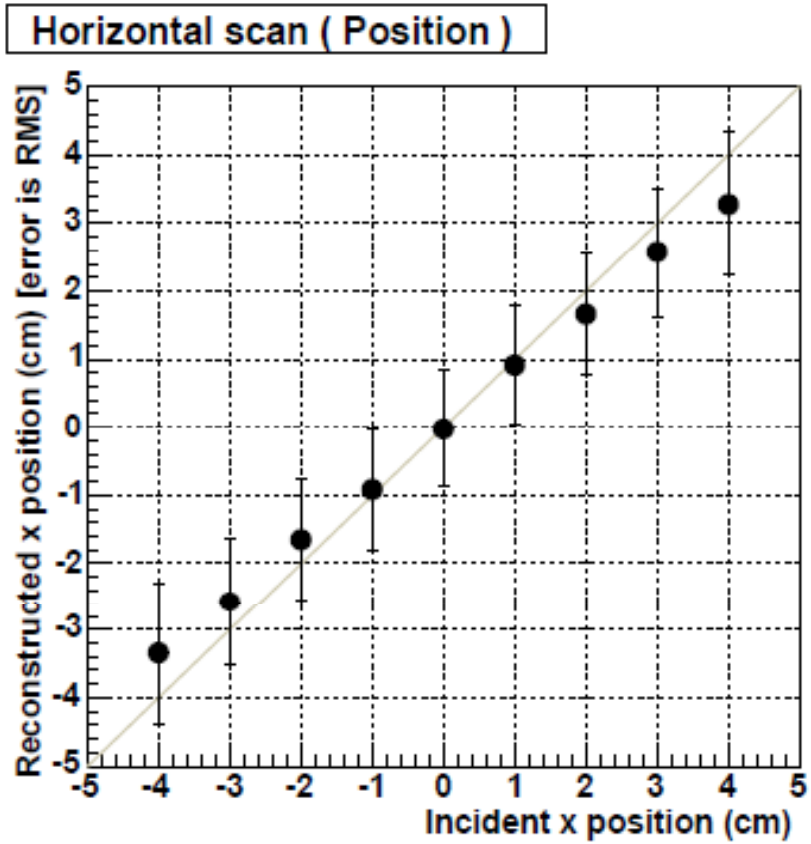


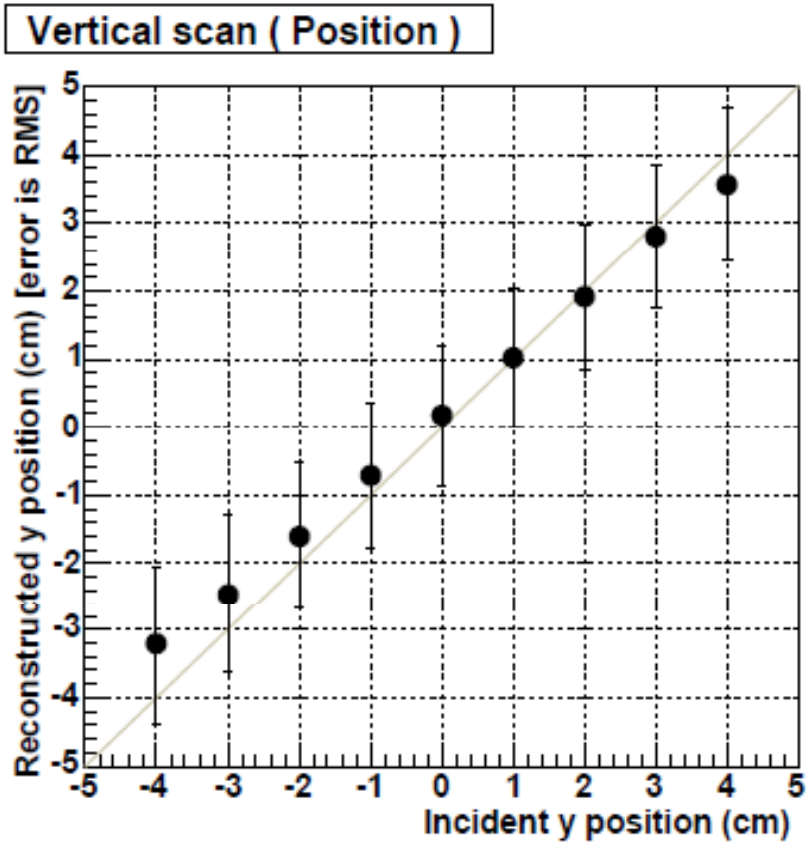
1.0 cm @ 100 GeV

~

1.5 cm @ 20 GeV

Edge effect of position resolution





- Calculated position is shifted to the center due to the hadron shower leakage.
  - Corrected based on this result.
- Off set is found in y due to the asymmetric structure of ZDC.

Reliability of the position resolution estimated by simulation

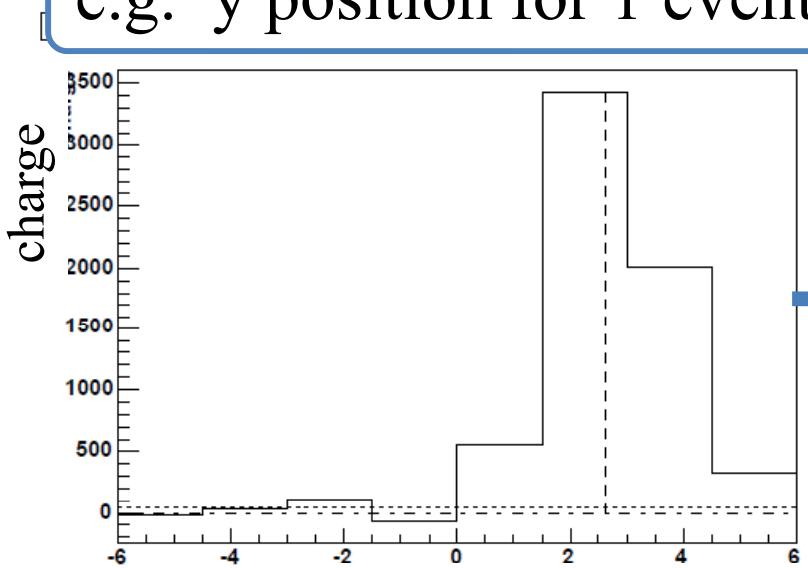
- Comparison of the hadron shower shape at SMD
  - SS (Shower shape) → Shower width in x-y plane
    - f_i^{Charge} was plotted as a center of the position decided by C.M.

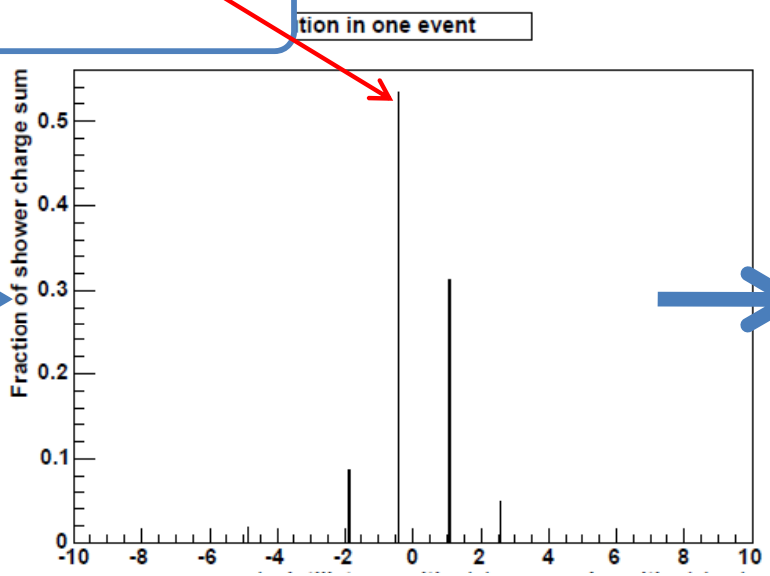
$$f_i^{\text{Charge}} = \frac{C_i}{\sum_N C_i}$$

N : SMD multiplicity
The number of sintillators above threshold

  - PF (Peak Fraction) → Shower height
    - The largest f_i^{Charge} velue

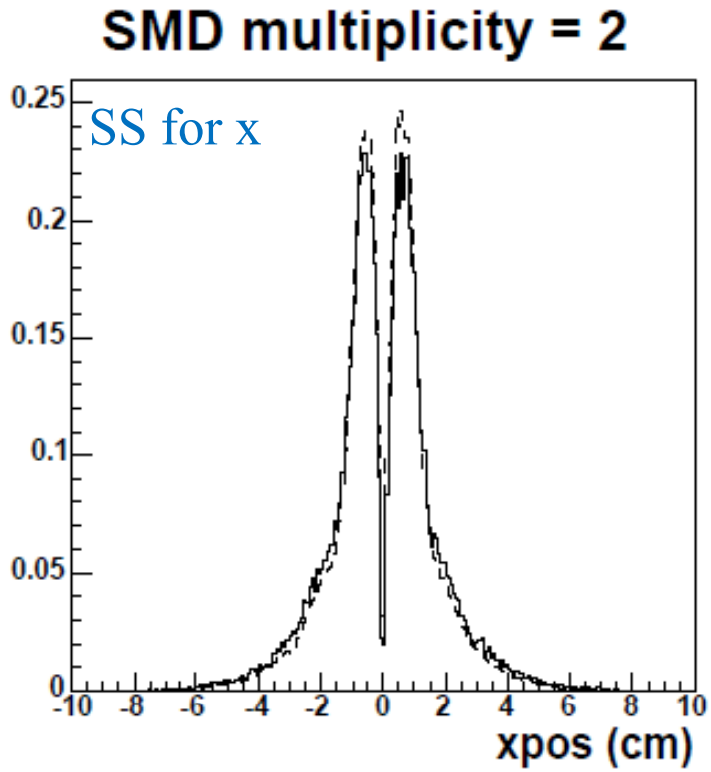
e.g. y position for 1 event

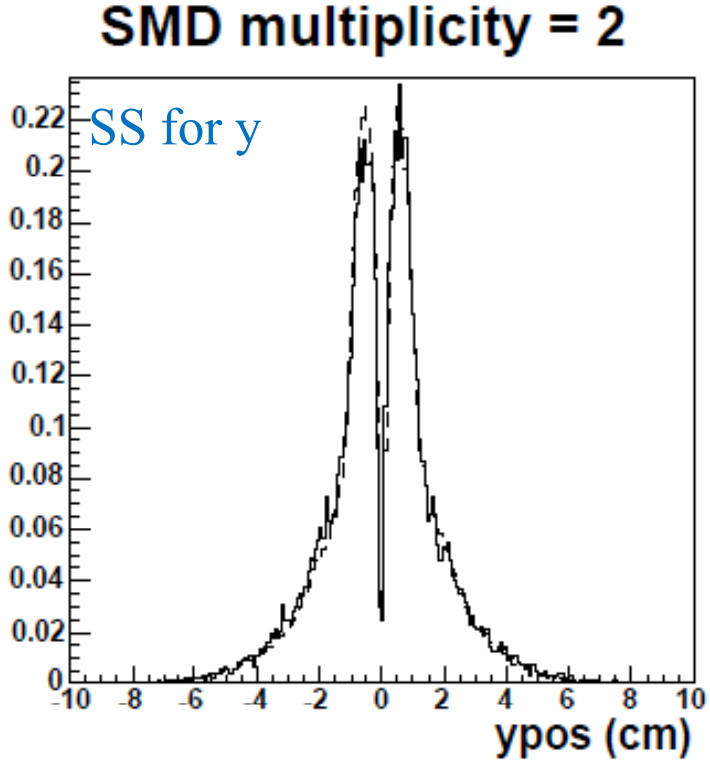


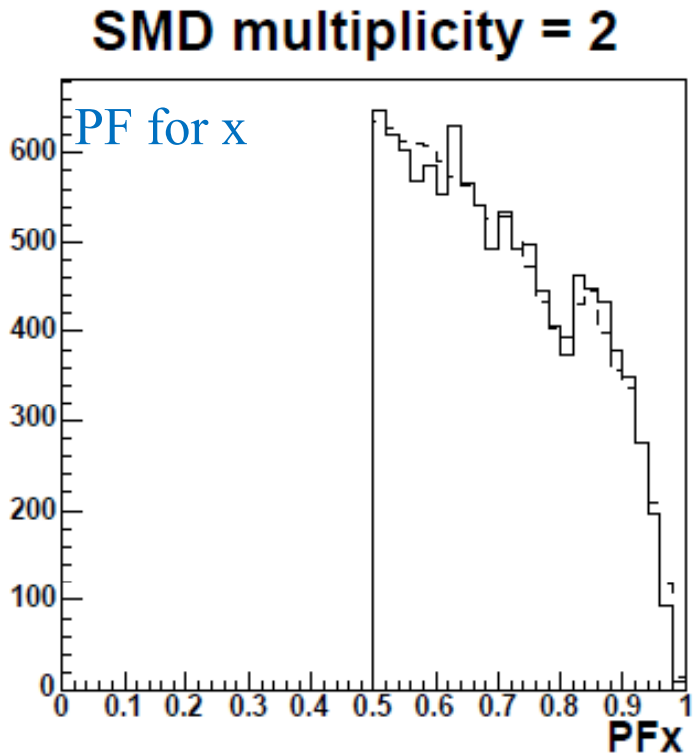


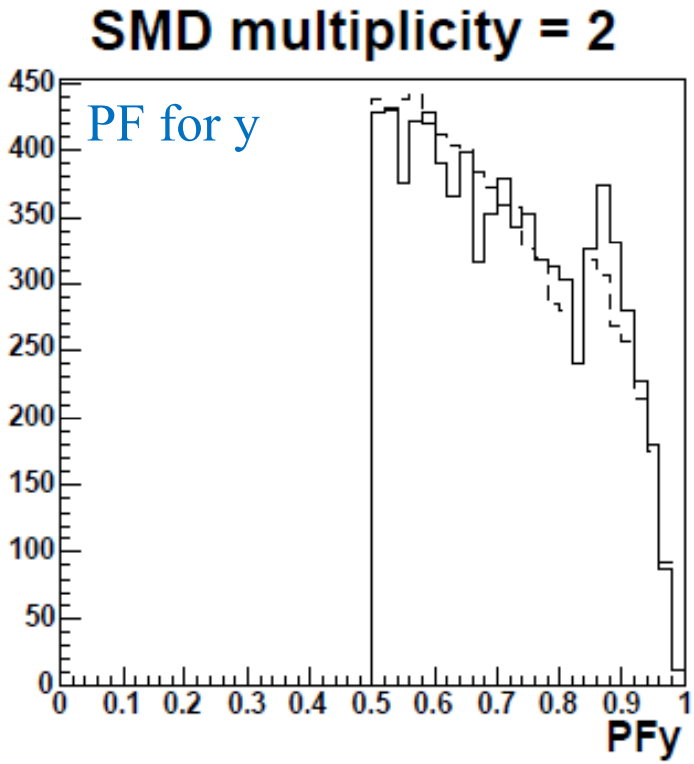
SS and PF were evaluated in high stats.

SS and PF @Mult.=2 (r<4 cm)





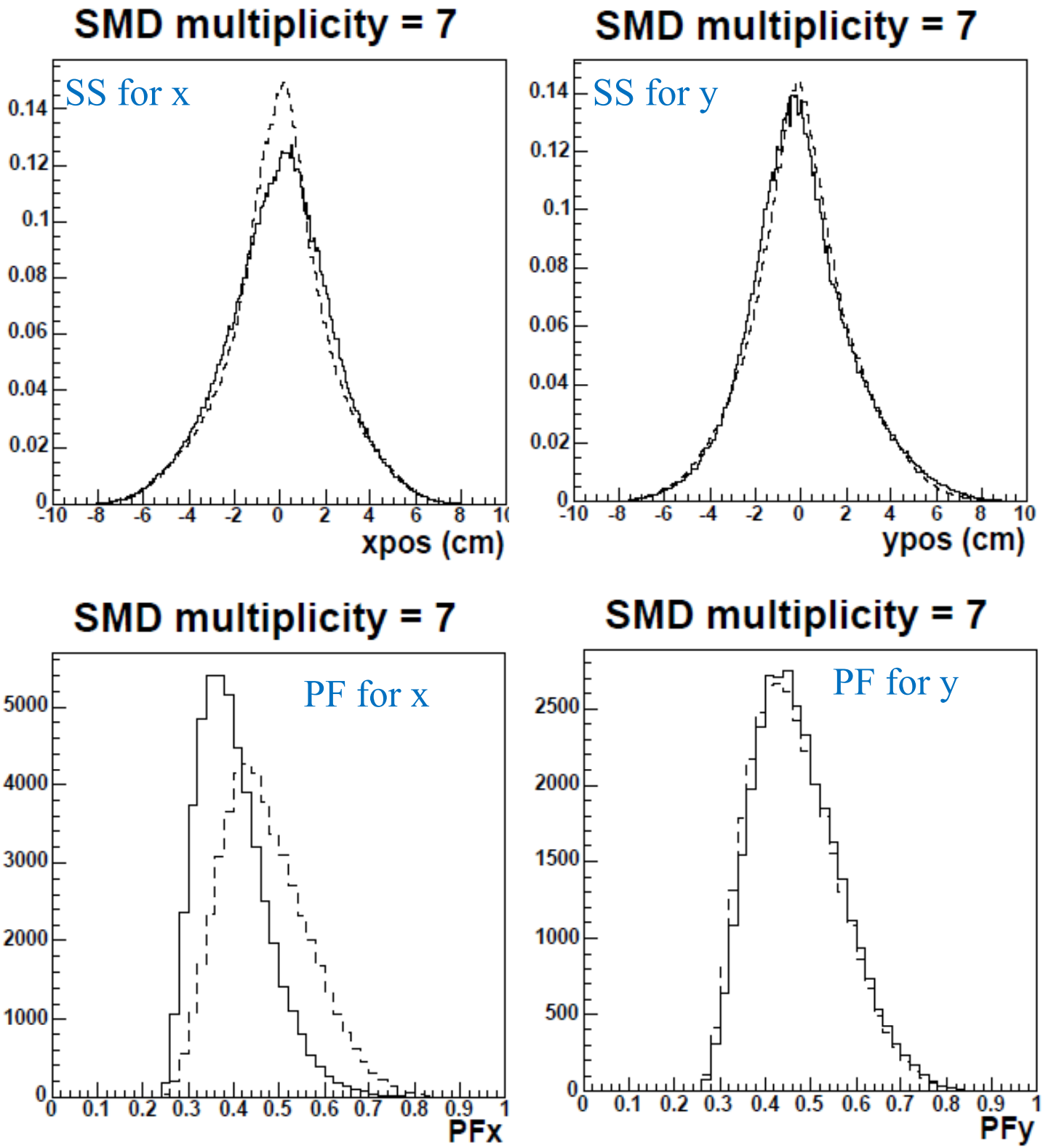




Real data

Simulation

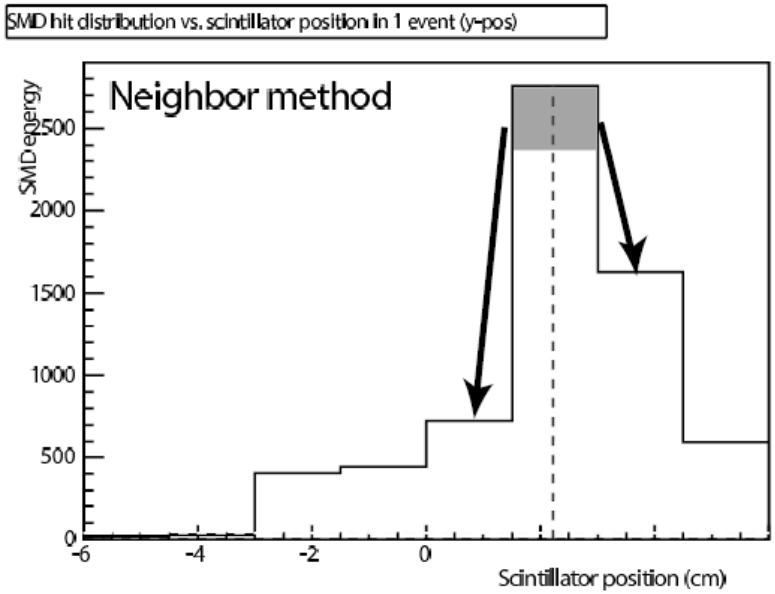
SS and PF @Mult.=7 (r<4 cm)



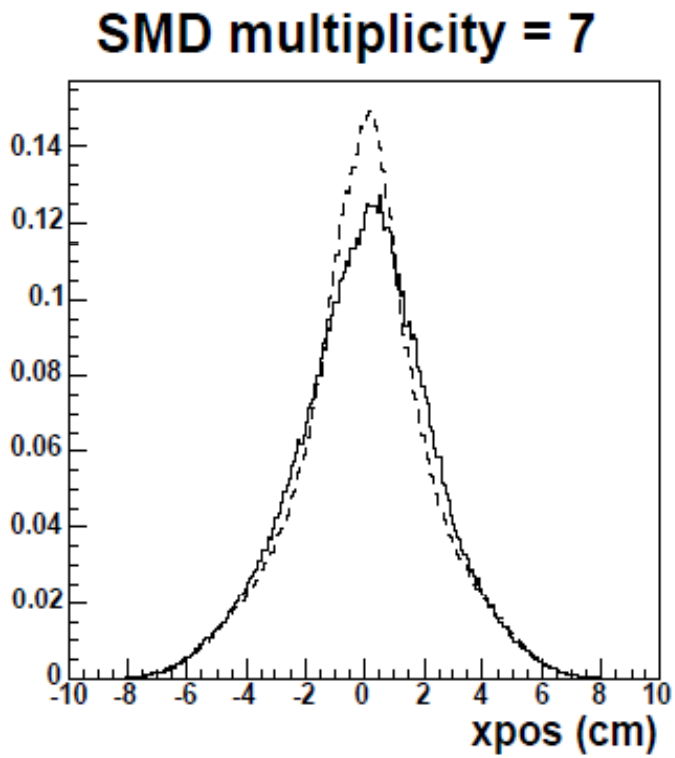
Real data

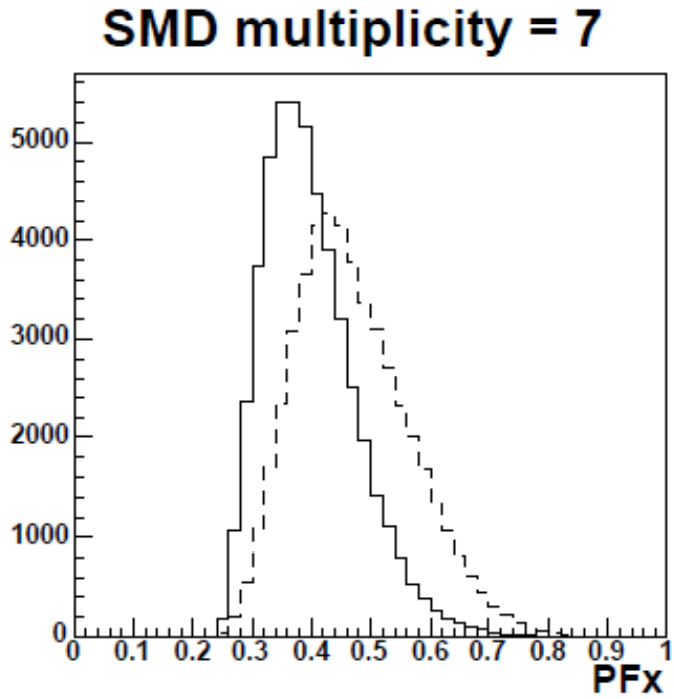
Simulation

Smearing

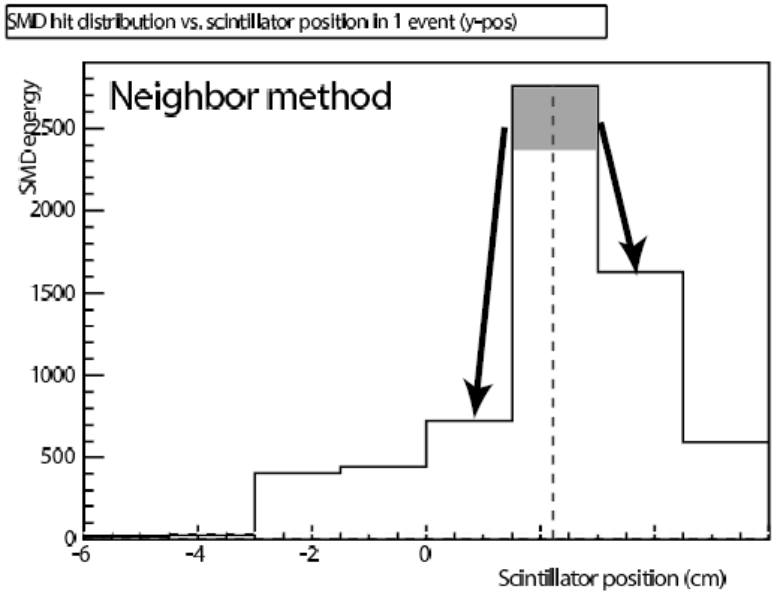


- Mismatch of the hadron shower in x-direction.
  - Simulation is narrower

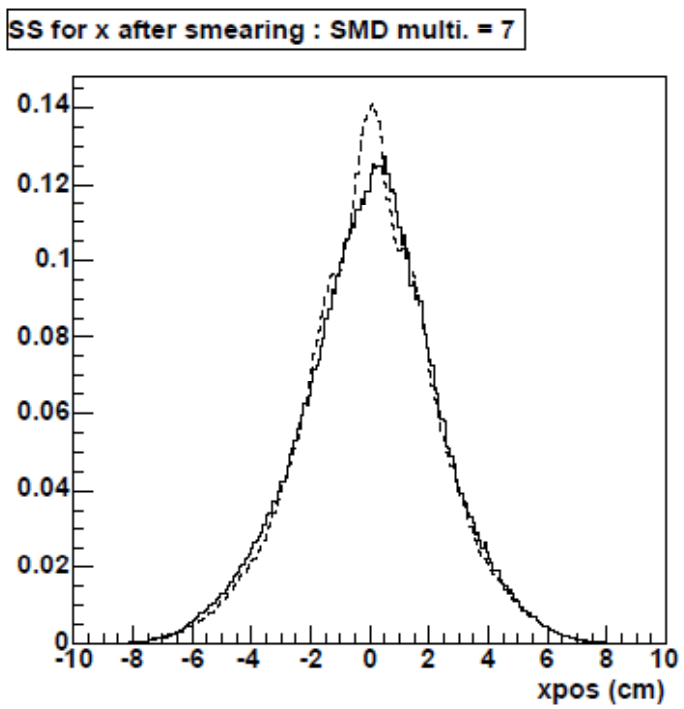


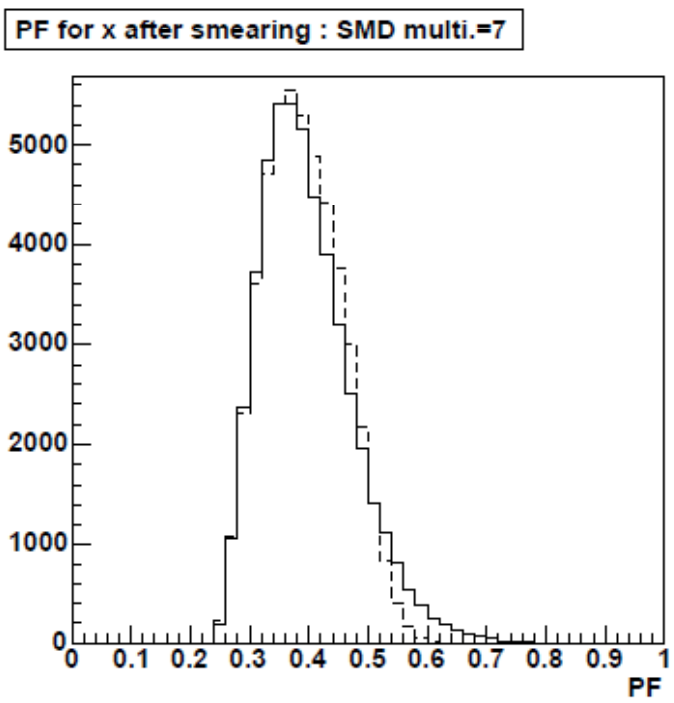


Smearing

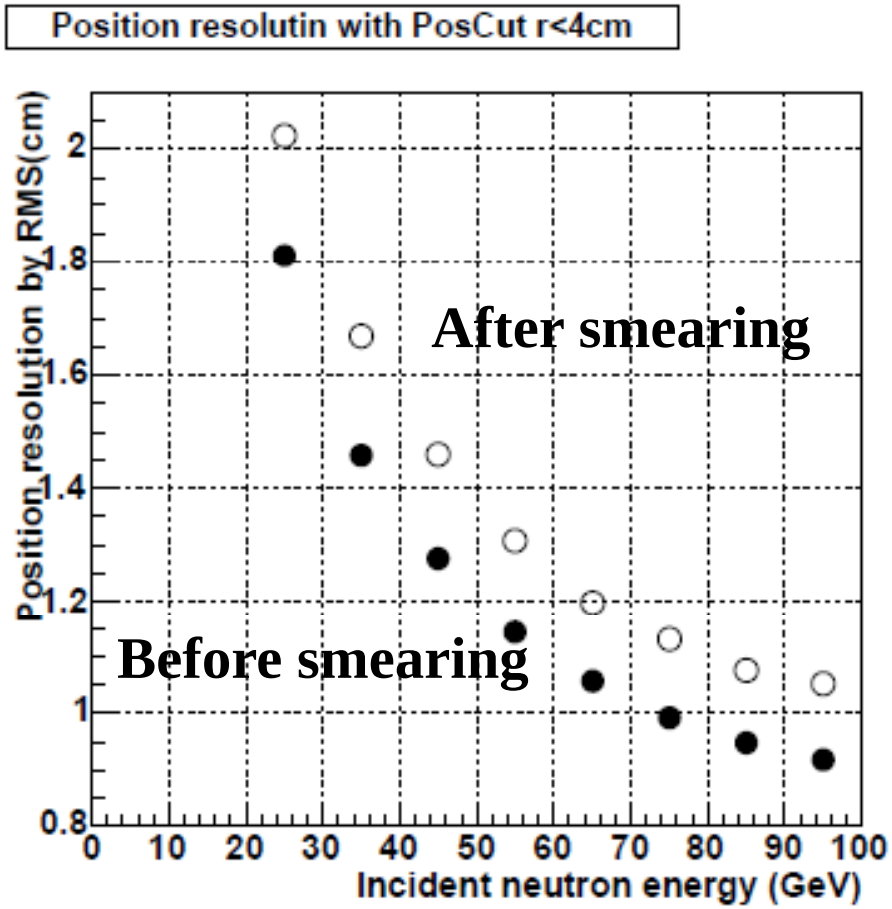


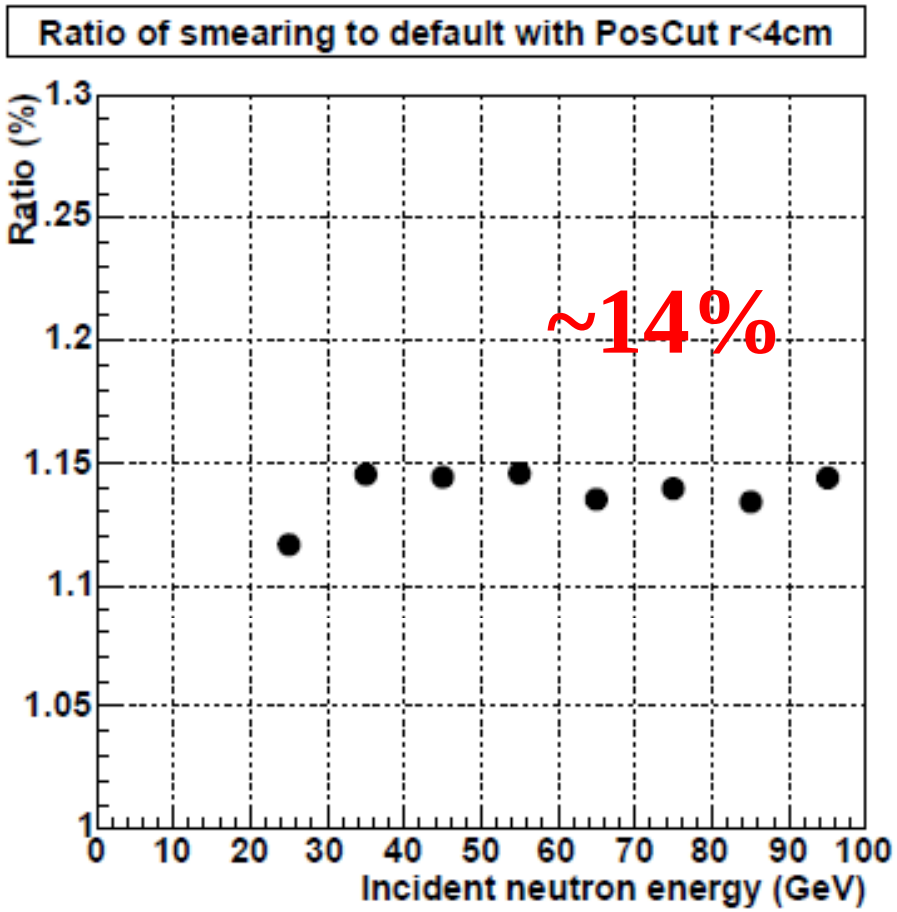
- Mismatch of the hadron shower in x-direction.
  - Simulation is narrower
    - → Shower smearing (f=0.28)





How is the resolution changed.





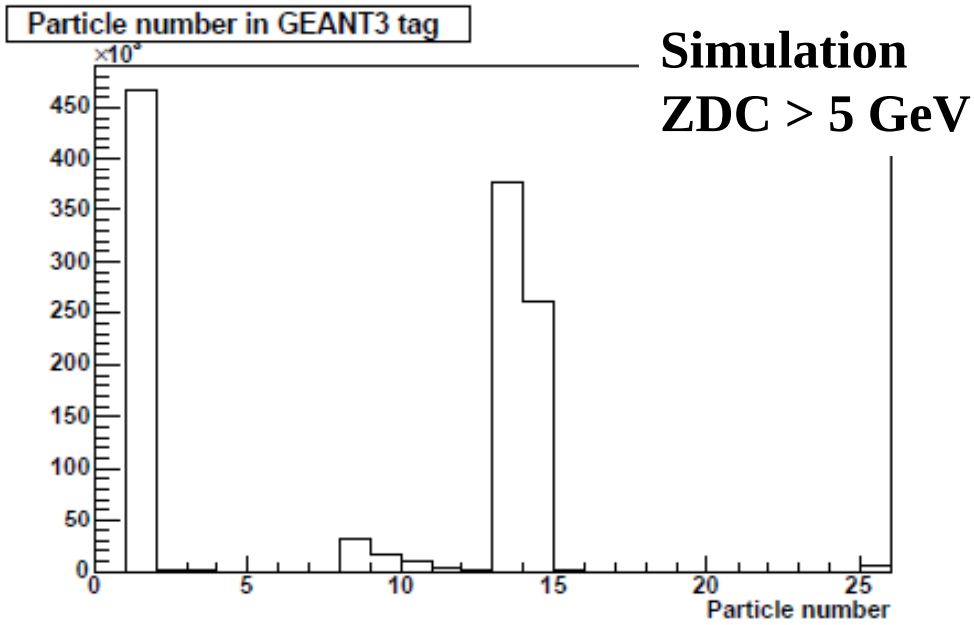
- Increasing 14% with energy independent.
  - Added as systematic error for position resolutions both x and y as maximum.

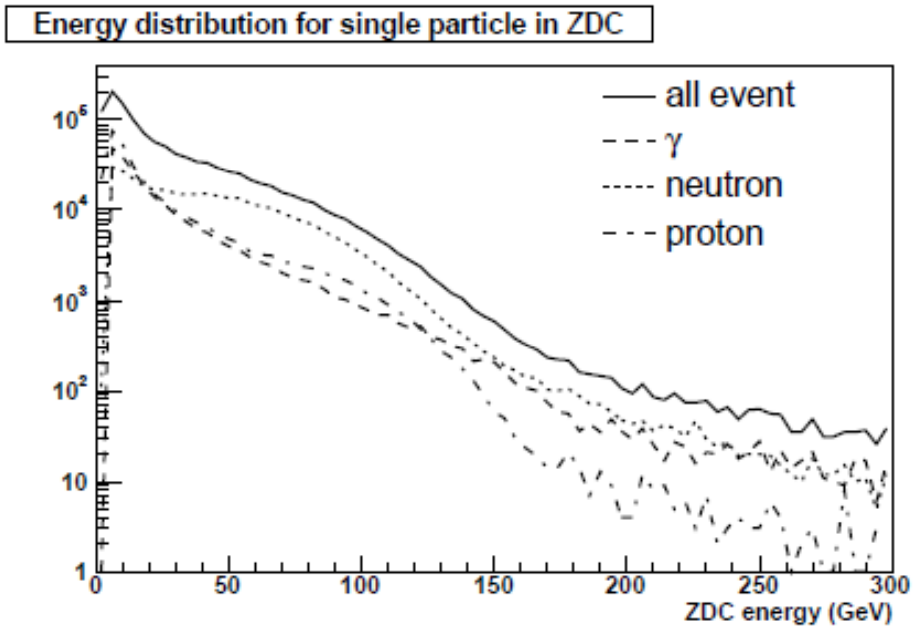
Neutron identification

Studied by GEANT3+Pythia(v.6220)

- Main BG in data samples are photon and proton.
  - Common : distributed in lower energy ← E>20 GeV
  - γ : will stop at ZDC 1 module (50 X_0) ← SMD hit requirement
  - proton : hadron shower generated by DX magnet, beam pipe hit

    ← Charge veto (below 1 MIP)





Background after neutron ID

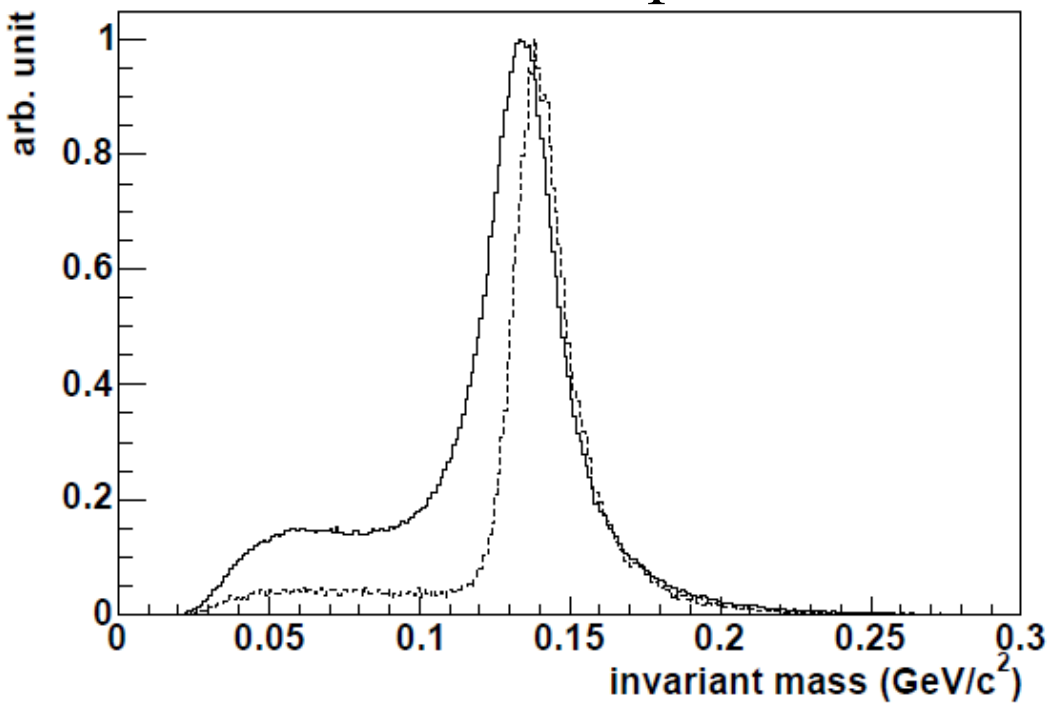
- Main BG
  - K_L^0 : fraction in the neutron measurement less than 4% for x_F>0.4@Pythia
    - This estimation is consistent with the ISR measurement

      In my doctoral thesis, it was not considered as well as IP12 paper.
  - proton : Same amount of K_L^0. But real data has larger fraction of charge counter. (1.5 times higher)
    - Pythia generator is wrong?
    - Other consideration is materials around ZDC has not been installed in simulation properly. In my doctoral thesis, it was added as systematic uncertainty (no correction).

2 particles in 1 event

- 2366 event in 35567 event after nID cut
  - After the acceptance cut, it will be ~6%
- Almost n+γ event (not from same parents)
  - n is from "string, Δ^0,Λ^0, Δ^+, Δ^-" (red is main)
  - γ of from π^0
- This estimation seems to be reliable
  - IP12 p0 mass spectrum can be understandable with pythia+GEANT
  - In my thesis, it was added as a systematic error. (No correction)

IP12 π^0 mass spectra



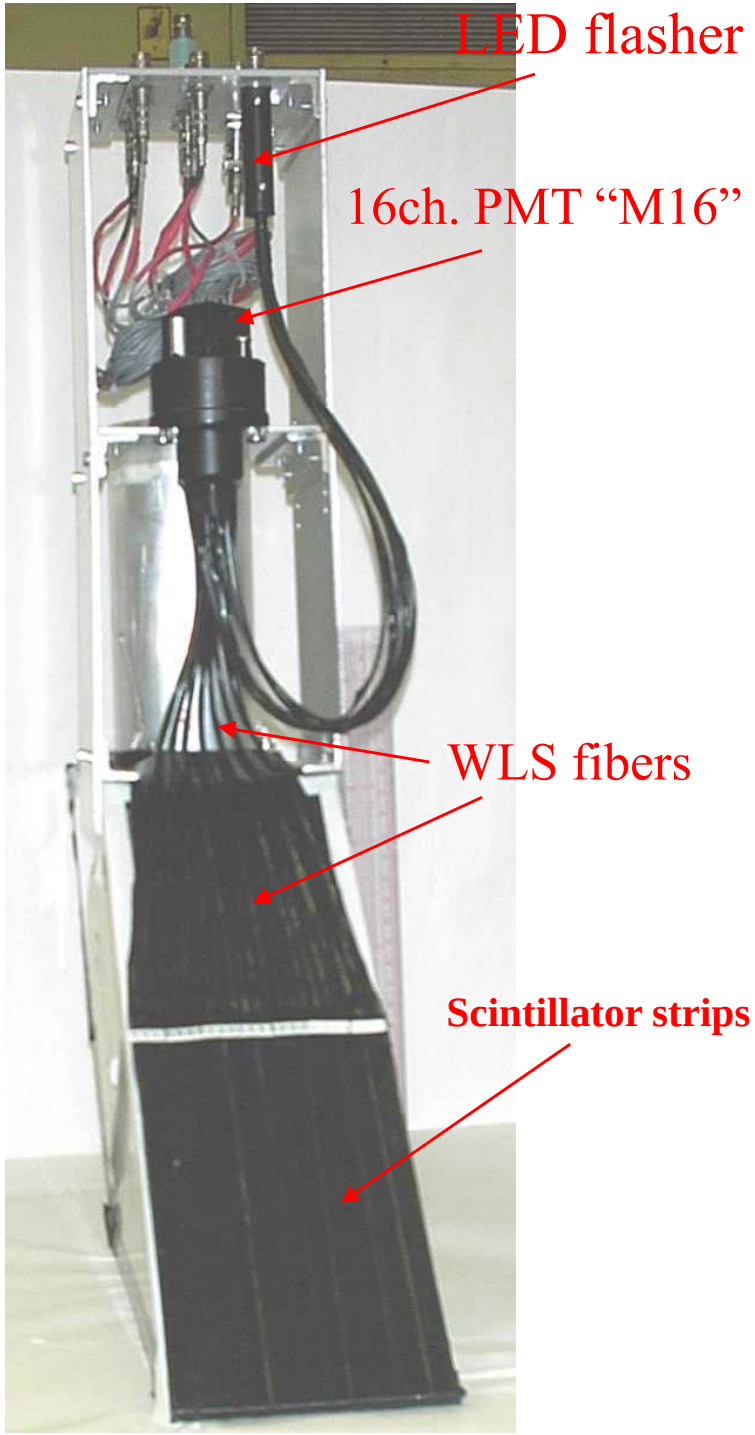
Summary

- Basically we can understand ZDC/SMD response and BG by simulation with not so much systematic.
- More details are in my thesis
  - I will ask to publish department.

backup

Shower Maximum Detector (SMD)

- SMD is an X-Y scintillator strip hodoscope inserted between 1st and 2nd ZDC modules. This location corresponds (approximately) to hadronic shower maximum position. The X-coordinate (horizontal) is sampled by 7 scintillator strips of 15mm width, while the Y-coordinate (vertical) is sampled by 8 strips of 20mm width, tilted by 45 degree.The active area covered by SMD is 105mm X 110mm (horizontal X vertical). Scintillation light is delivered to multichannel PMT "M16" by WLS fibers.
- The SMD position resolution depends on energy deposited in the scintillator and varies from ~10mm at small number of charged particles crossing the SMD to <3mm when number of particles exceed 100. For comparison, the spread of neutrons due to of nucleon Fermi motion is about 2.2cm at 100GeV.



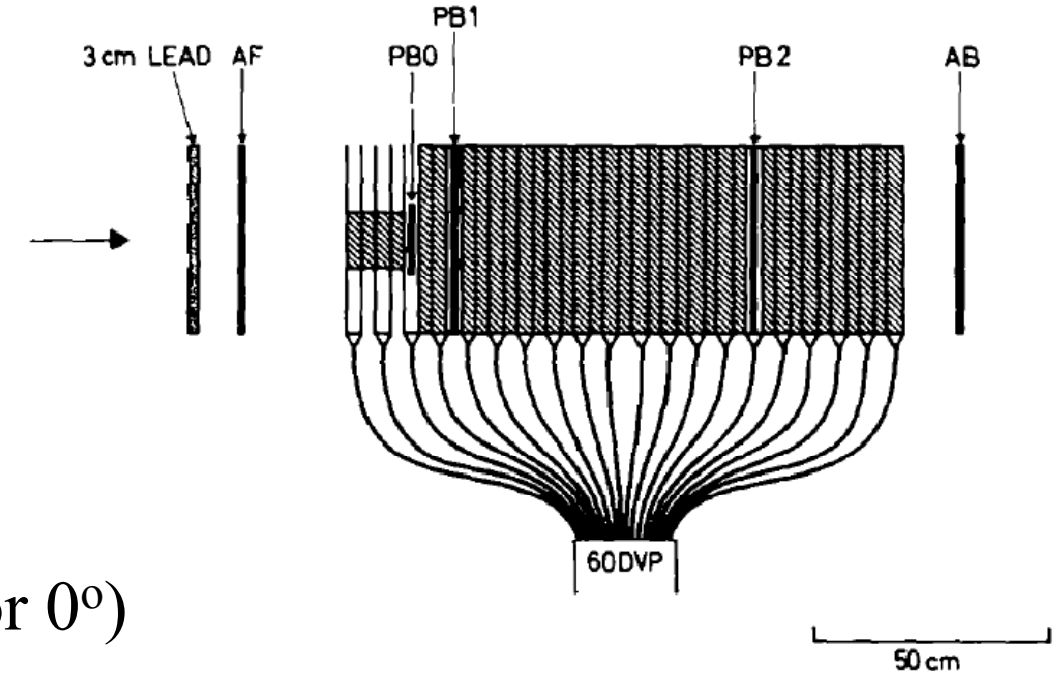
ISR experiment

- sqrt(s)=30~63 GeV
- STAC

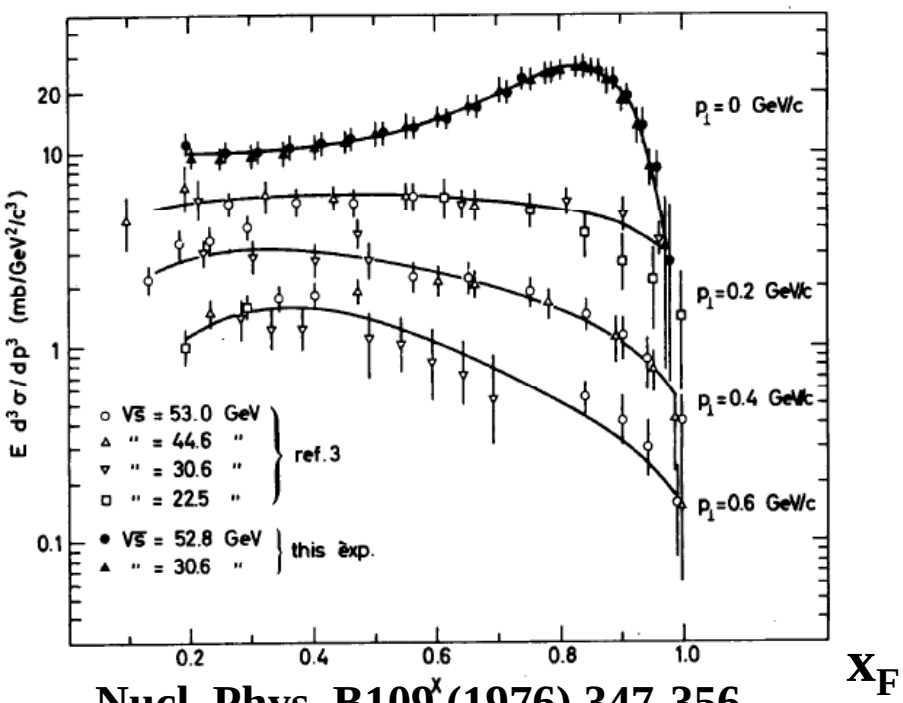
  40*40*80 cm^3 (iron) $5.5l_I$

  res. 26%@20GeV 19%@30GeV
- They were placed in

  0°,20°,66°,119°,(±1) mrad (56m for 0°)

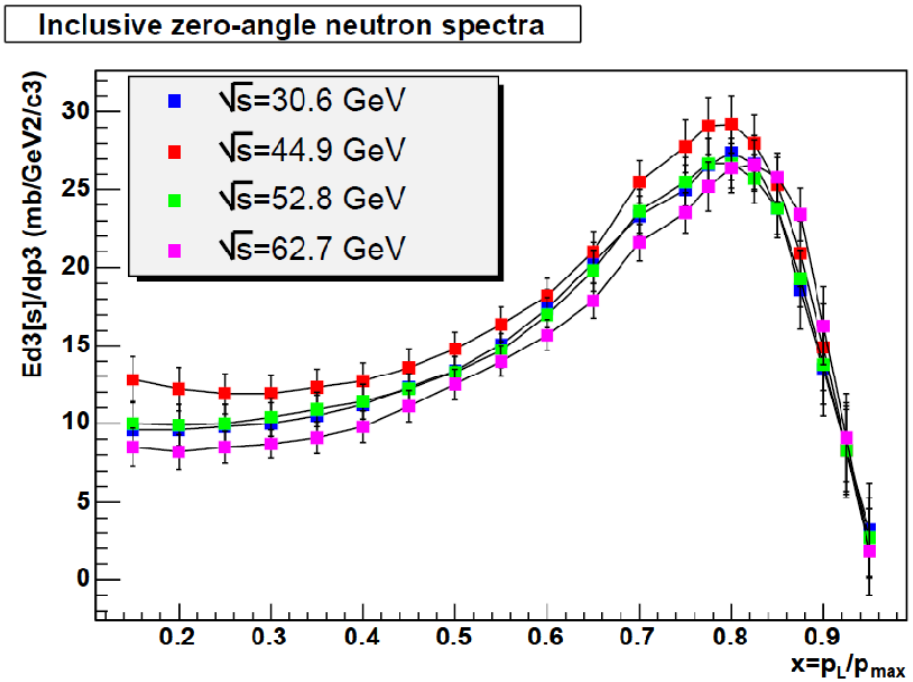


Forward peak

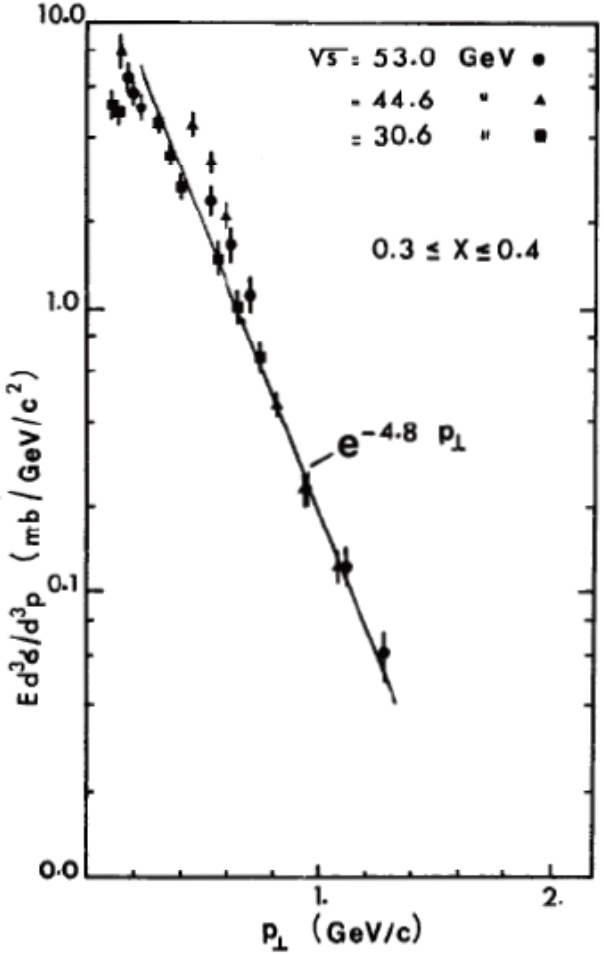


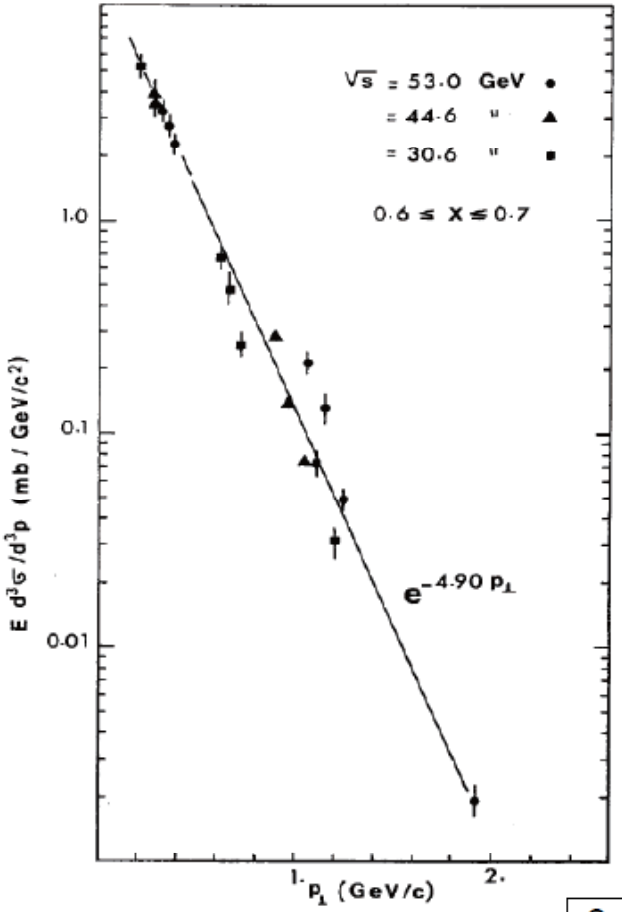
Nucl. Phys. B109 (1976) 347-356

x_F scaling



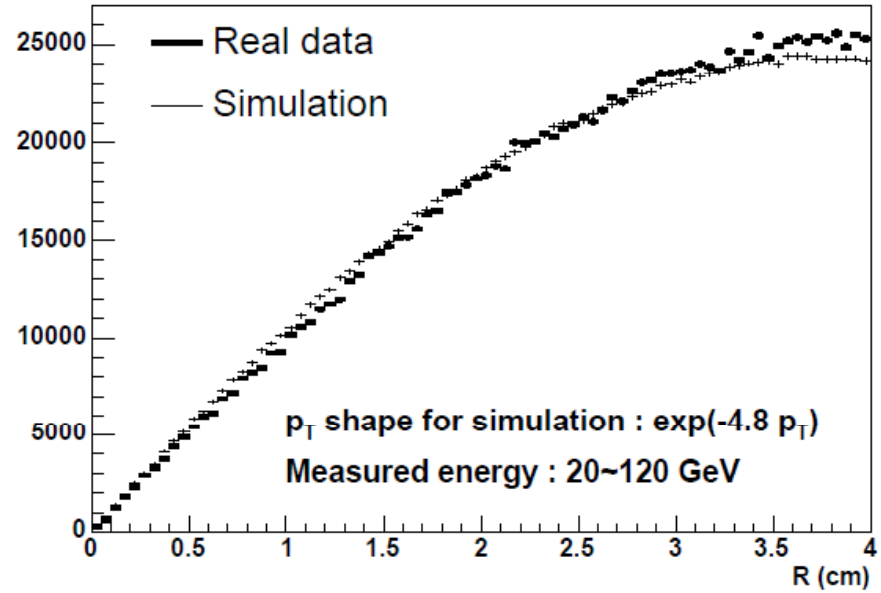
ISR p_T shape



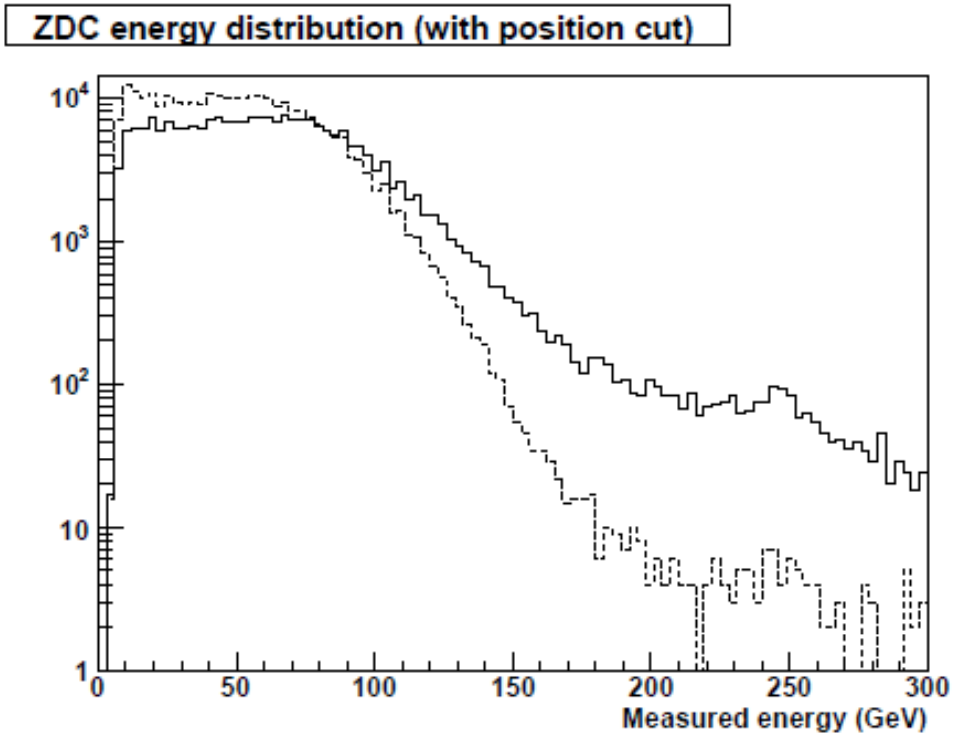


$$p_T = E_n \sin\theta_n = E_n \frac{r}{\sqrt{r^2 + d^2}} \sim E_n \frac{r}{d},$$

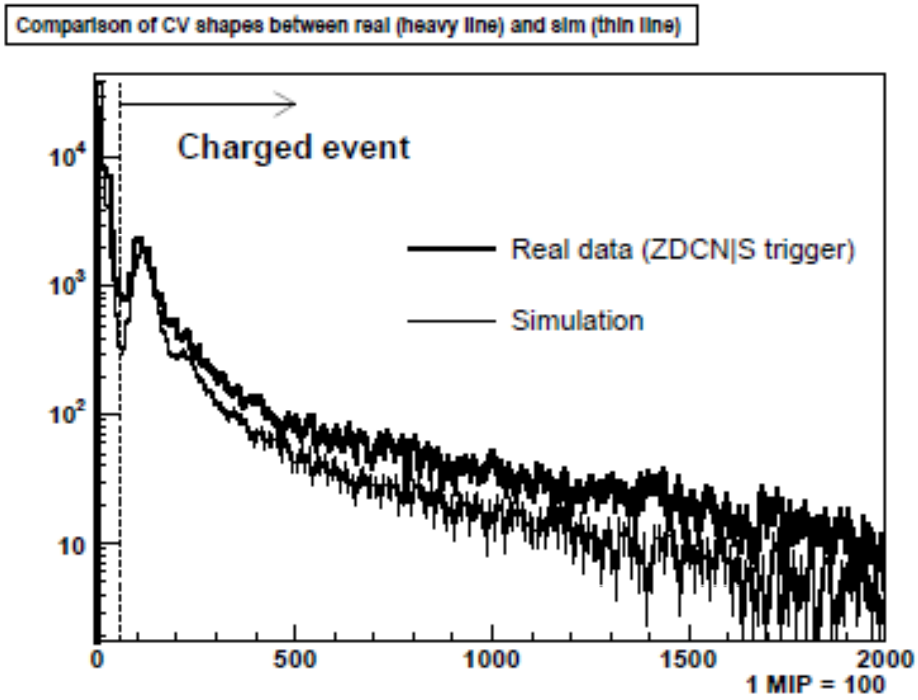
Comparison of radii distributions btw real and sim

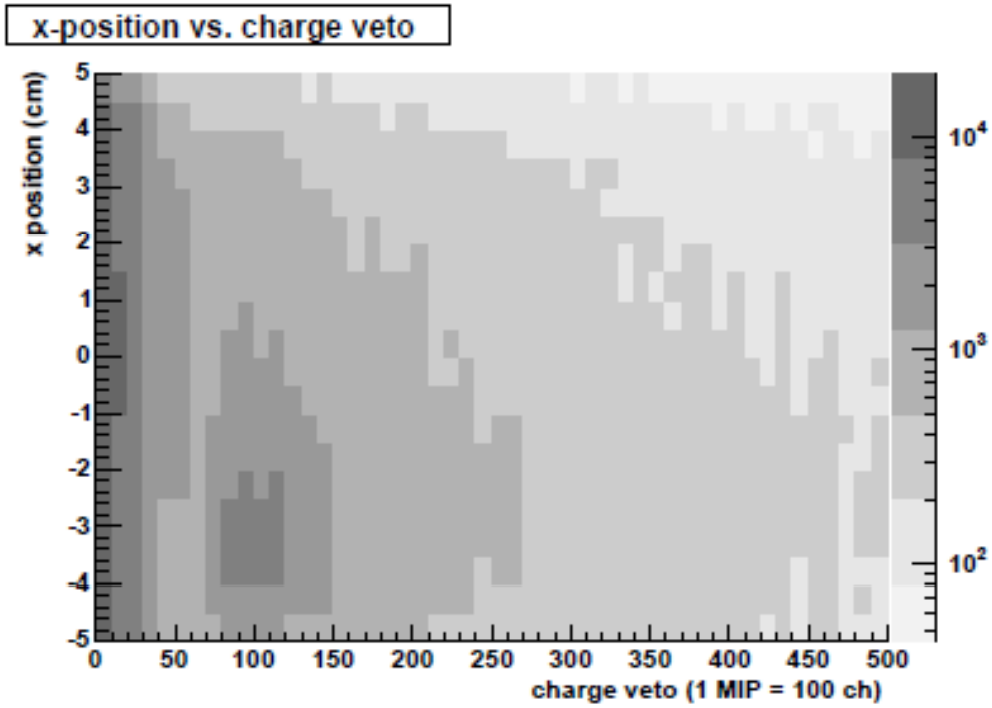


Energy distribution with y cut.



Proton shower event.





https://www.phenix.bnl.gov/WWW/publish/togawa/localpol/counter/xpos_counter/xpos_counter.html