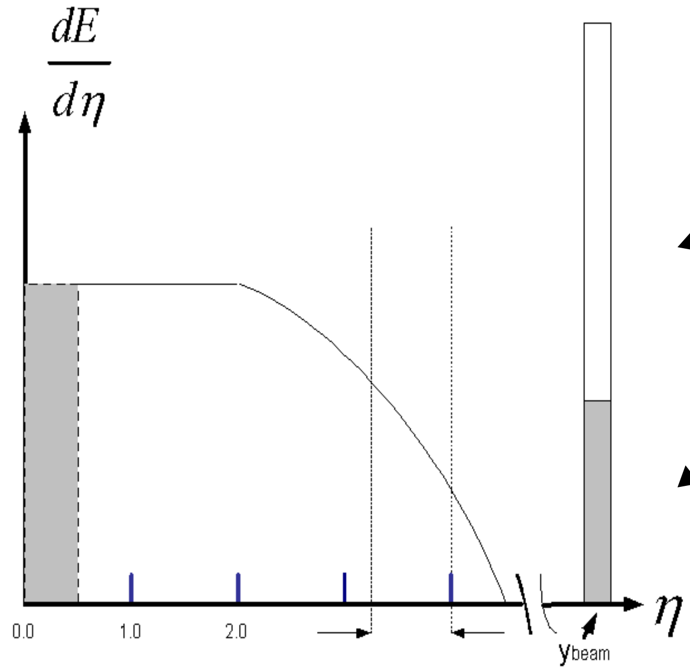
Calorimetry for Global Event Characterization in PHENIX

Sebastian White, Brookhaven Nat'l Lab,
for the PHENIX collaboration

- PHENIX $\frac{dE_t}{dh}\left(h=0\right)$ vs.participant#
- EMCal Design and Performance
- Forward Detectors and Collision Geometry
- Results

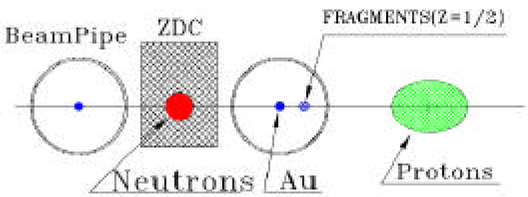
*See also: G.David,A.Milov,A.Denisov and
A. Bazilevsky, H.Torii (poster)

Energy Flow in a Heavy Ion Collision



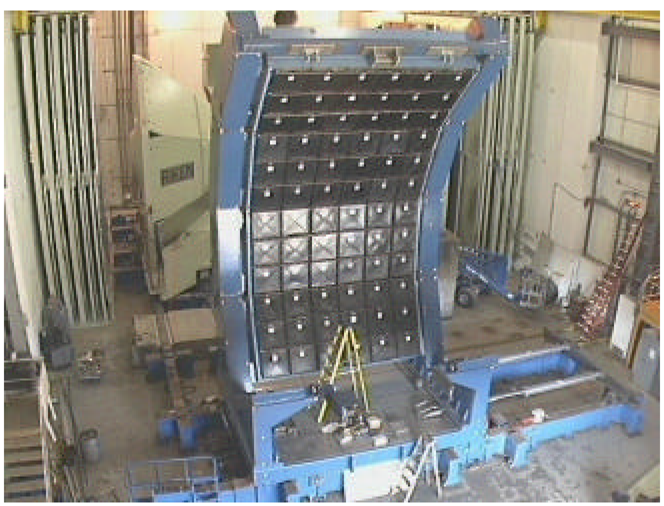
Forward, spectator Energy
charged, neutral

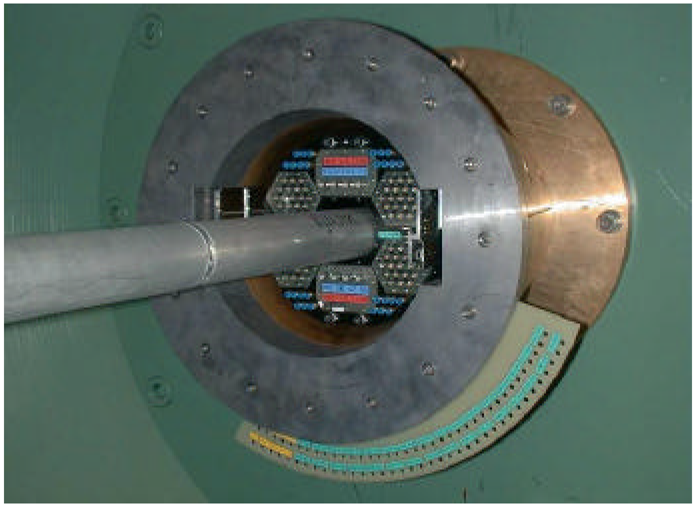
Zero Degree Calorimeter



Beam-Beam
Counters

EMCal





Definitions:

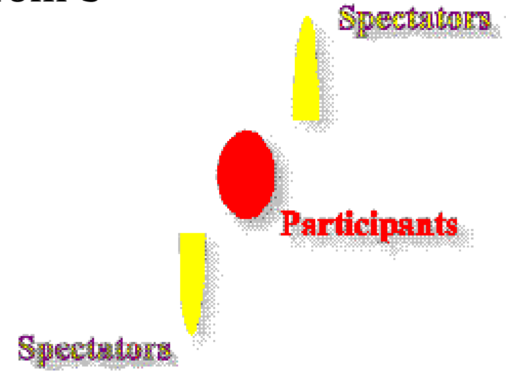
$E_t^i = \sin(\theta^i) * (E_{kin}^i + m^i)$ π, K…

(E_{kin}^i) baryons

$N_{participant}$:

“direct” 1) $N_{part} + E_{spectator} / (m_n * \gamma_{beam}) = A_{beam}$

Glauber Model 2) $pb'^2 = \int_0^{E'_f} \frac{ds}{dE_f} dE_f$,calculate $N_{participant}$ from b’



Physical Limitations:

- Finite Coverage ($\frac{p}{4}, |h| \leq 0.38$) -> E_t fluctuations from acceptance
- Backgrounds, Hadron Response -> net correction of 17%
- Detectable “Spectator”Neutron Fraction ~{1/2:0}

E_t produced is related to energy density ~ $\dfrac{dE_t}{dh} \Big/ Volume$

How does it increase from SPS to RHIC?

Naïve extrapolation;

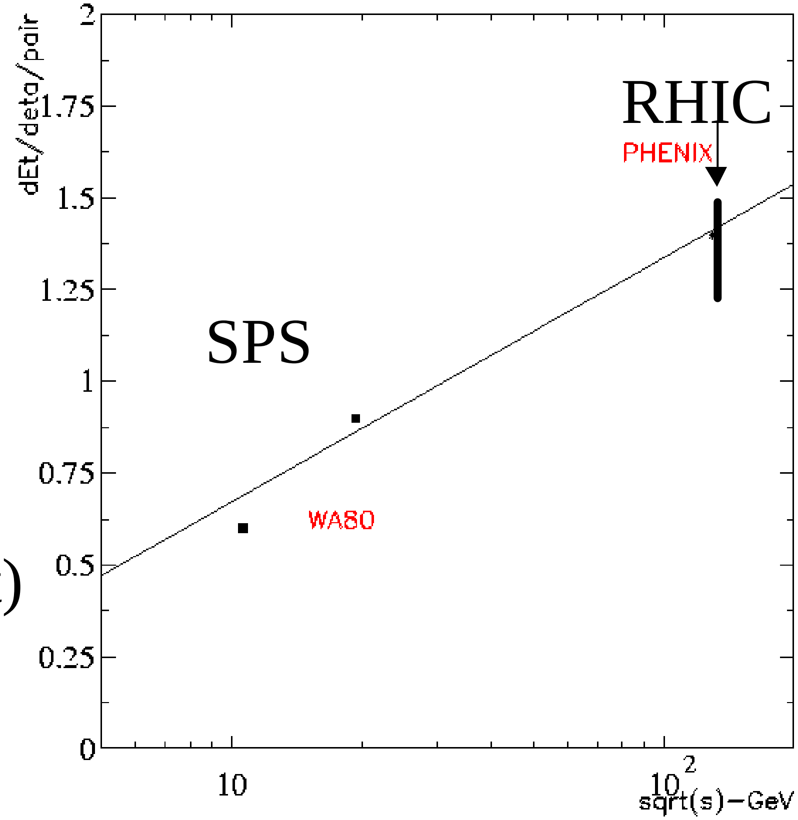
$$\frac{dE_t}{dh} = \left.\frac{dN_{ch}}{dh}\right|_{pp} *1.5* < E_{trk}^{t} > *(N_{part}/2)$$

$0.01+0.22*\ln(s)$

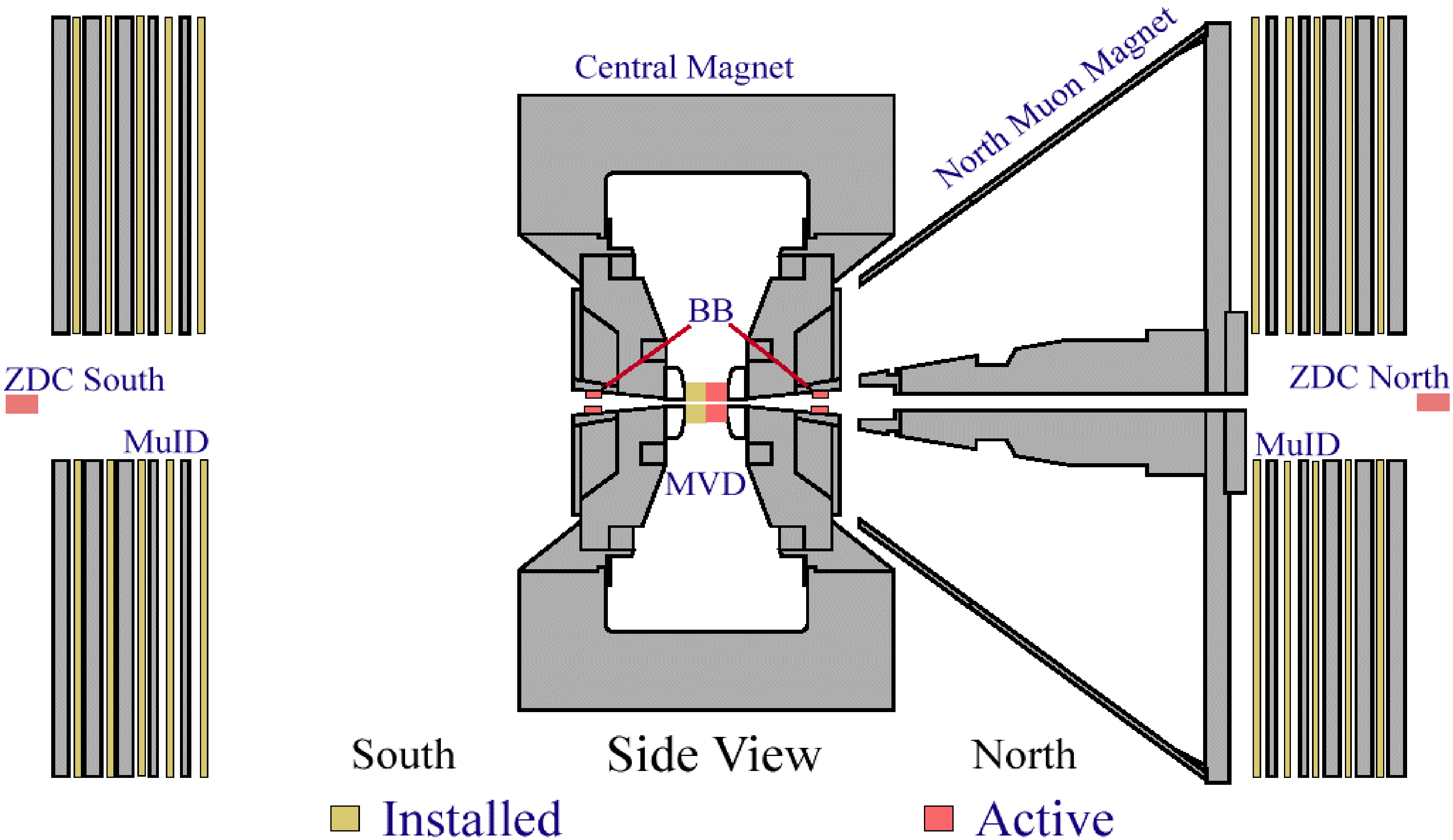
$(A - N_{spectator})$

$\cong 0.5 GeV$ (assume constant)

Is it proportional to $N_{participant}$?



PHENIX-Setup: Side View

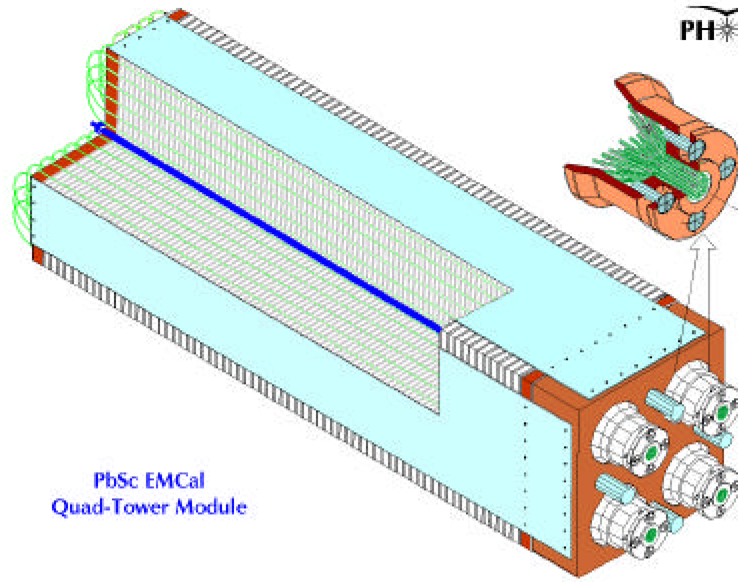


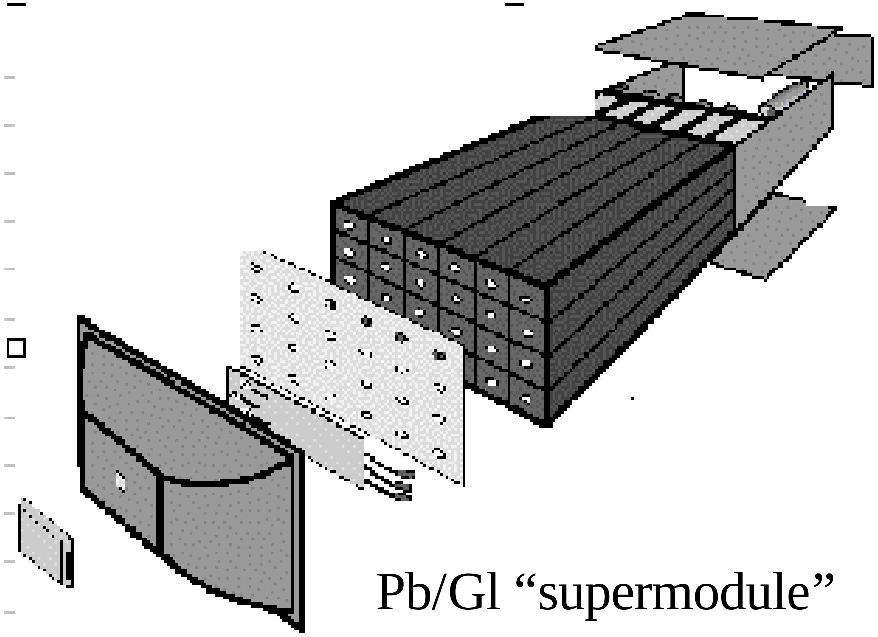
Phenix EM Calorimeter Parameters

- Pb-scintillator sampling calorimeter (PbSc)
  - WLS fiber readout
  - 66 layers of Pb 1.5mm + Sc 4mm
  - laser monitoring system
  - 1 super-module = 12 x 12 towers
  - 1 module = 2x2 towers
- Lead glass calorimeter (PbGl)from WA98
  - LED monitoring system
  - 1 super-module = 4 x 6 towers

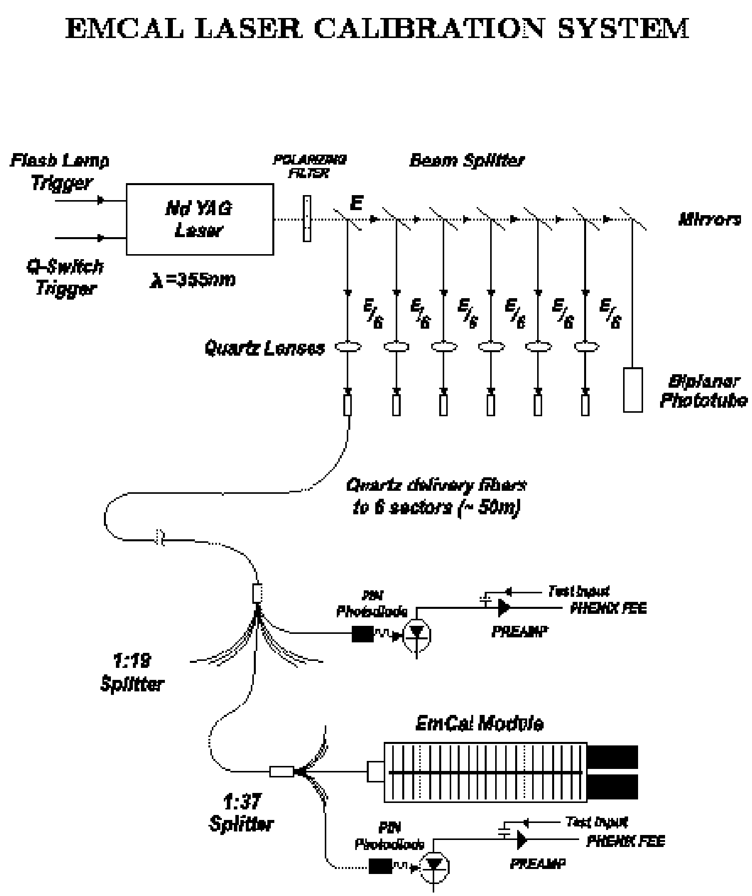
	PbSc	PbGl
Size(cm x cm)	5.535 x 5.535	4.0 x 4.0
Depth(cm)	37.5	40
Number of towers	15552	9216
Sampling fraction	~ 20%	100%
η cov.	0.7	0.7
ϕ cov.	90+45deg	45deg
η/mod	0.011	0.008
ϕ/mod	0.011	0.008
X_0	18	14.4
Molière Radius	~ 3cm	3.68cm

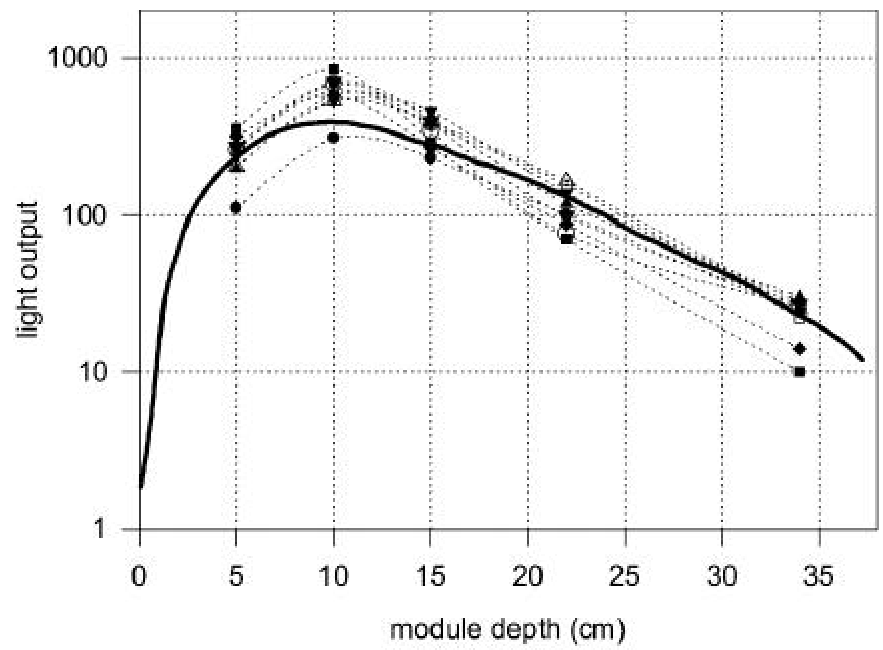
Pb/Sc “module”

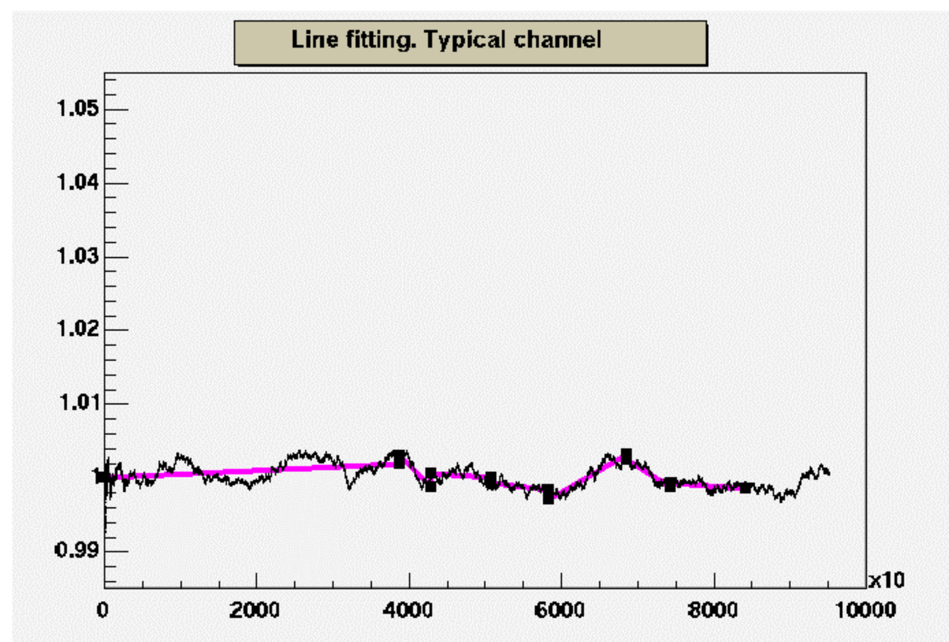


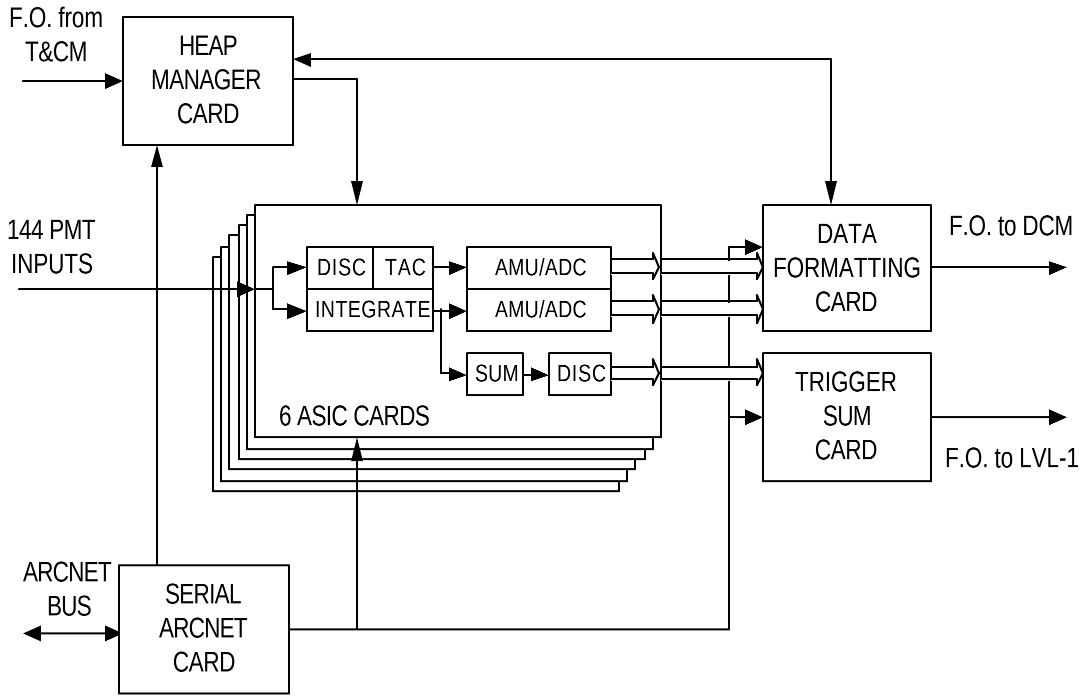


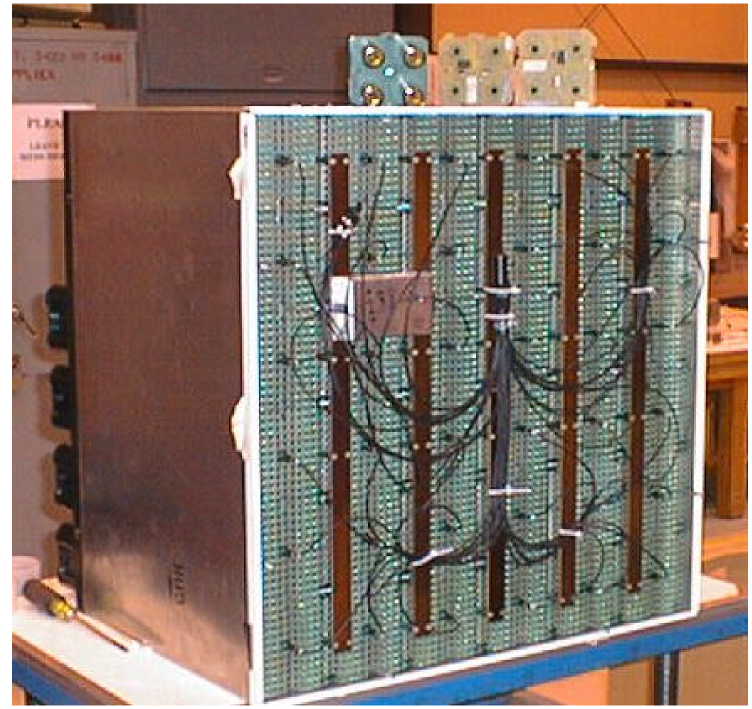
Pb/Gl “supermodule”

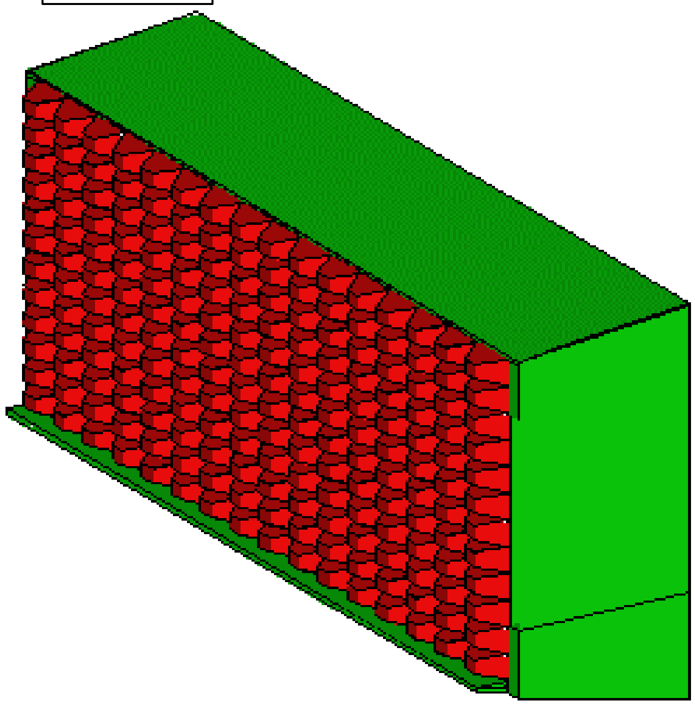

EMCAL LASER CALIBRATION SYSTEM
Flash Lamp Trigger
Q-Switch Trigger
Nd YAG Laser
λ=355nm
POLARIZING FILTER
Beam Splitter
E
Mirrors
E/6
Quartz Lenses
Biplanar Phototube
Quartz delivery fibers to 6 sectors (~ 50m)
PIN Photodiode
Test Input
PHENIX FEE
PREAMP
1:19 Splitter
EmCal Module
1:37 Splitter


light output
module depth (cm)
1000
100
10
1
0
5
10
15
20
25
30
35


Line fitting. Typical channel
1.05
1.04
1.03
1.02
1.01
0.99
0
2000
4000
6000
8000
10000
x10


F.O. from T&CM
HEAP MANAGER CARD
144 PMT INPUTS
DISC
TAC
INTEGRATE
AMU/ADC
AMU/ADC
SUM
DISC
6 ASIC CARDS
DATA FORMATTING CARD
F.O. to DCM
TRIGGER SUM CARD
F.O. to LVL-1
ARCNET BUS
SERIAL ARCNET CARD



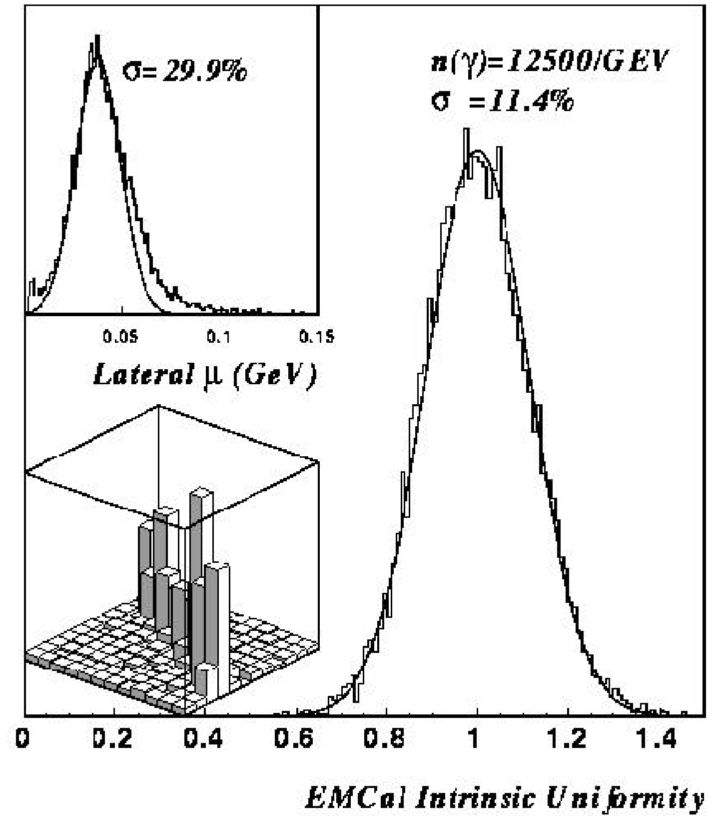


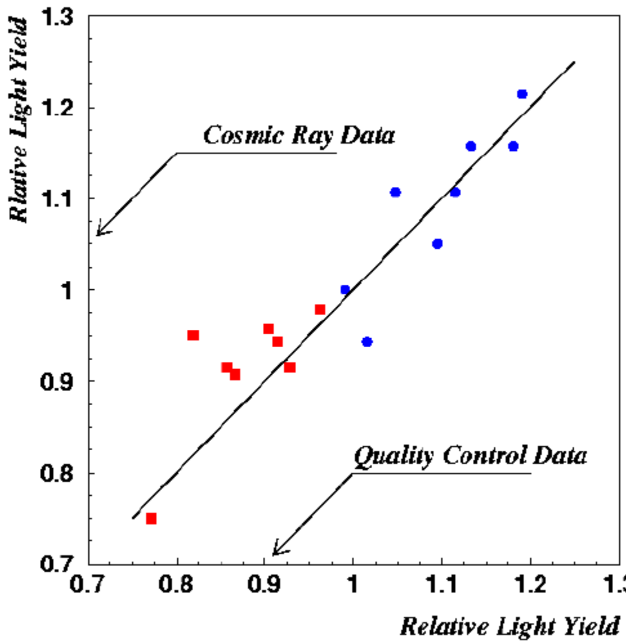
Production control and precalibration (to 5%)

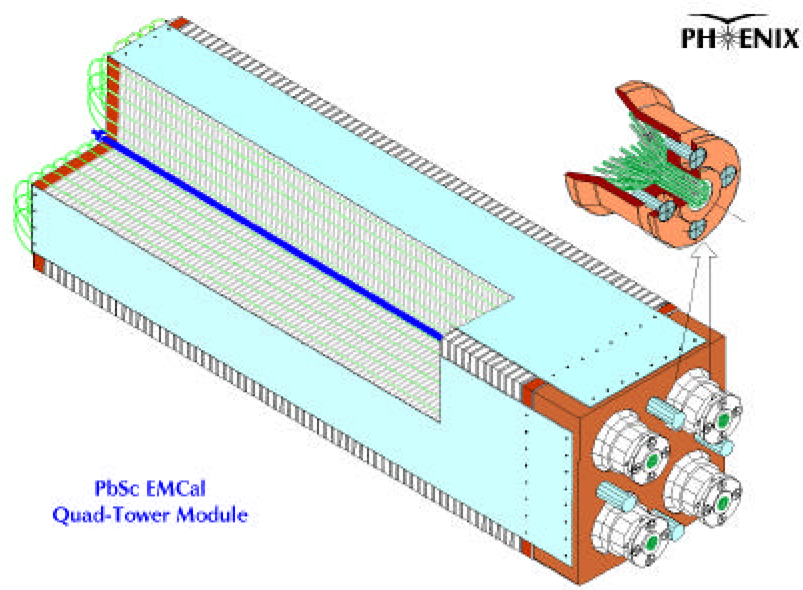
Energy Scale from beam tests

1GeV e^- :μ_{Trans}: μ_{long}

=1GeV: 38 MeV: 280 MeV

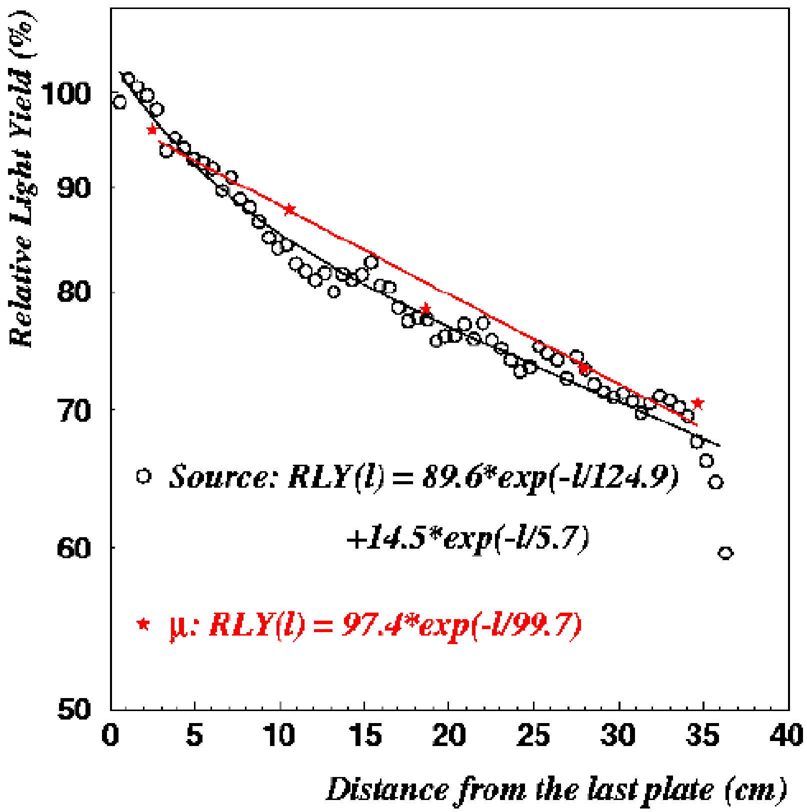




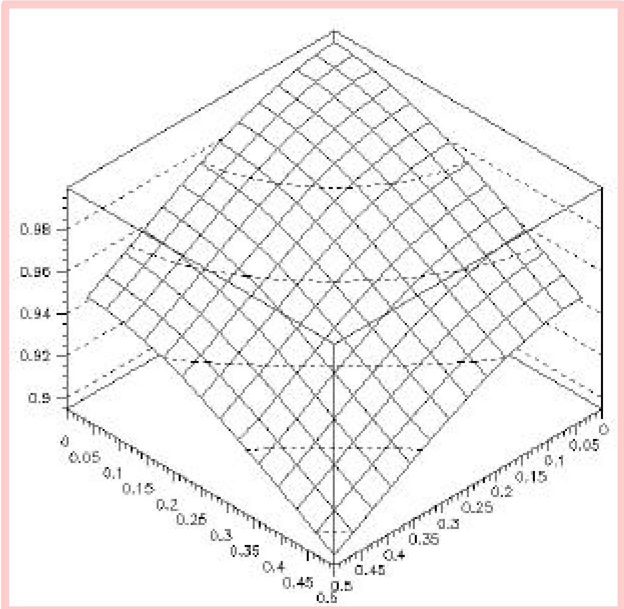


Internal timing/light yield uniformity of Calorimeter

- EM Shower distributed within several modules
- uniformity of response affects ultimate t and Energy resolution
- signal(in fiber) and shower velocity partially cancel
- signal attenuation partially compensates shower depth



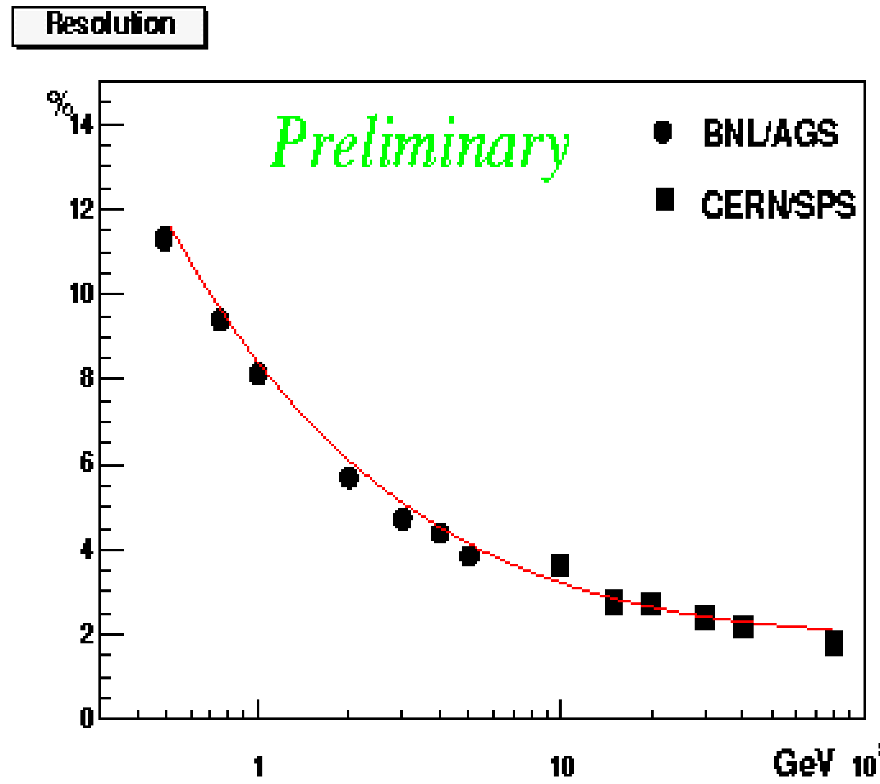
Transverse Uniformity



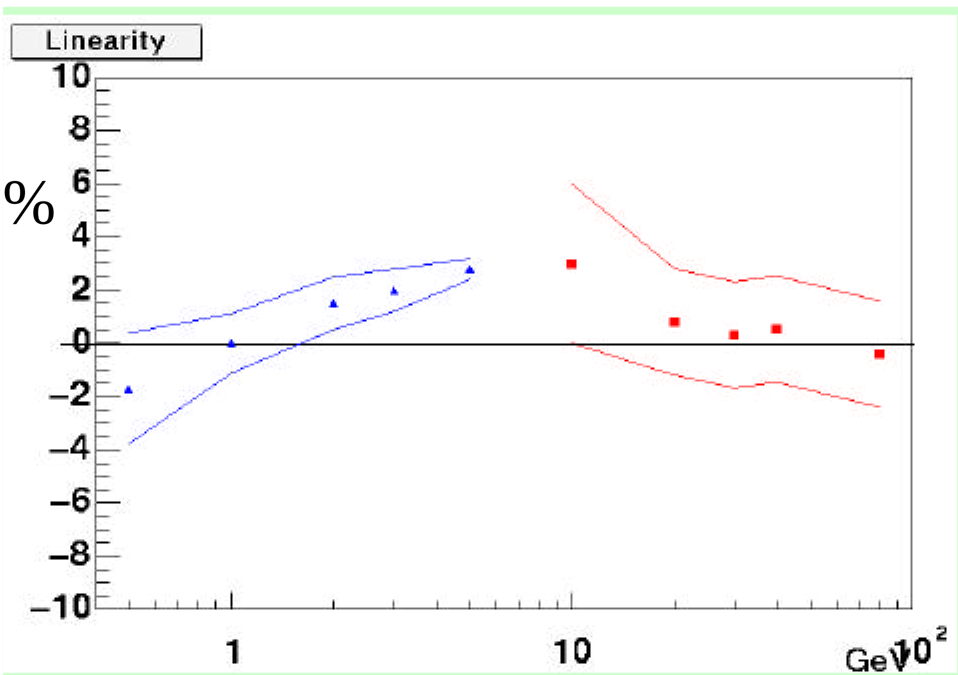
Pb/Sc Linearity, resolution

Stochastic, constant term :

$$\frac{s}{E} \approx \frac{8.2\%}{\sqrt{E(GeV)}} \oplus 1.9\%$$



$(E_{EMCal} - E_{beam}) / E_{beam}$



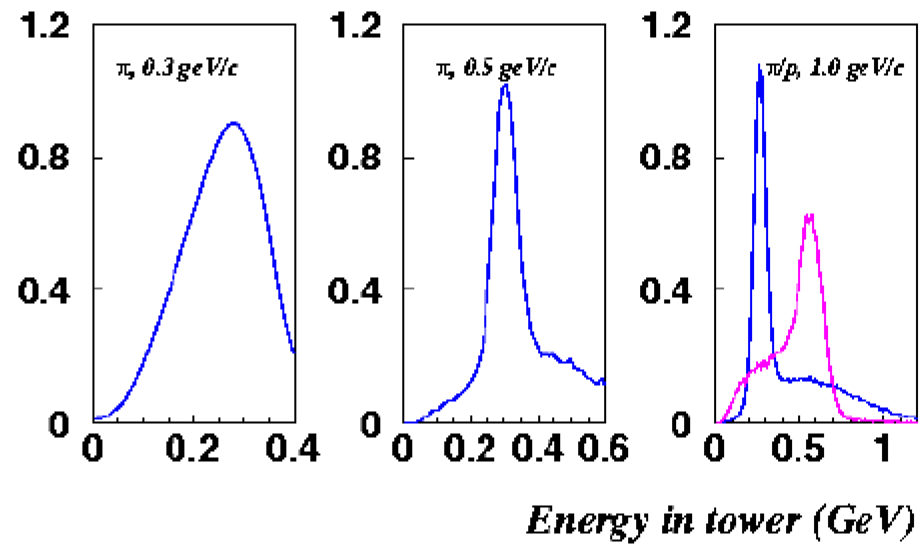
Testbeams at BNL,Cern

$$Linearity = \frac{Eemc - Ebeam}{Ebeam}\%$$

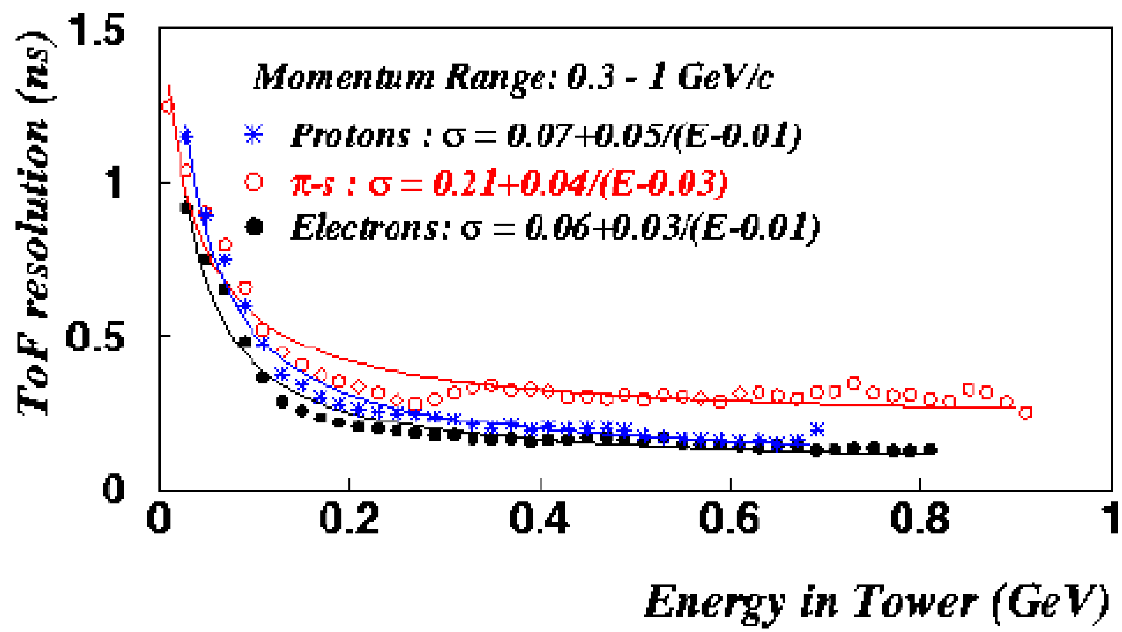
•Et measurement is corrected for hadron response of the EMCal.

•On average this is a factor of 0.8.

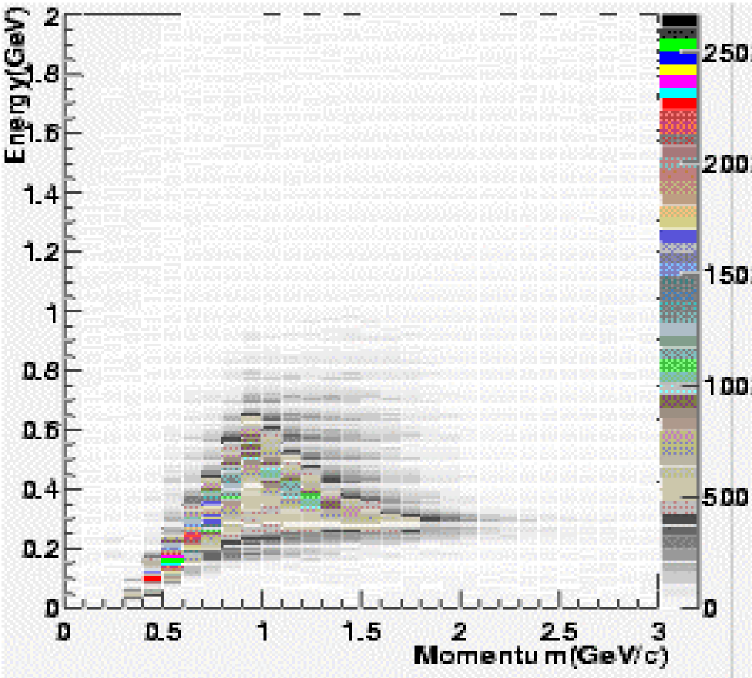
•Calorimeter timing in principle a tool for particle id.



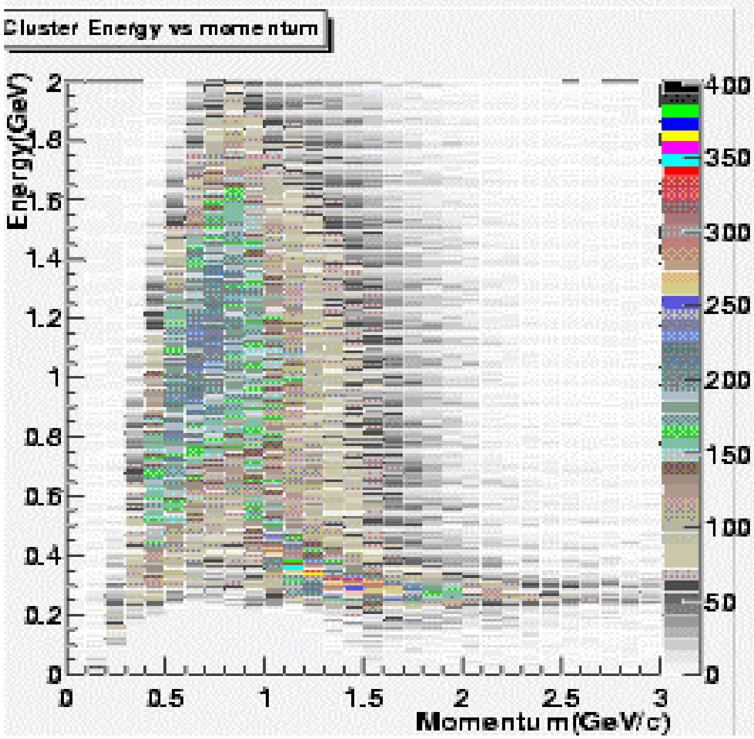
Intrinsic Resolution (testbeam)



Response to identified hadrons, RHIC data

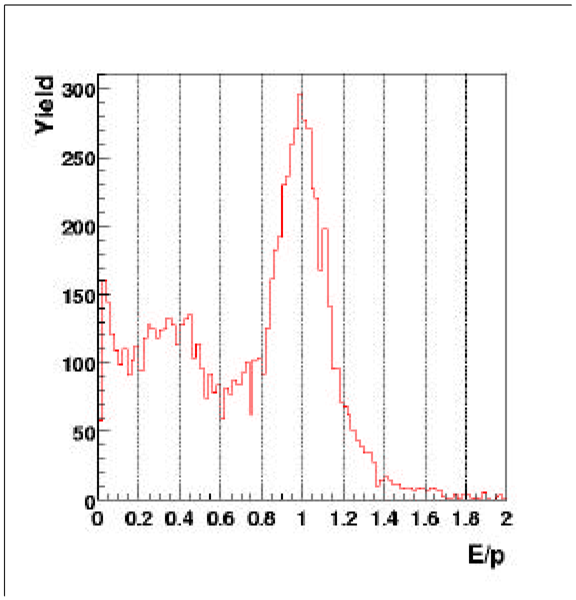


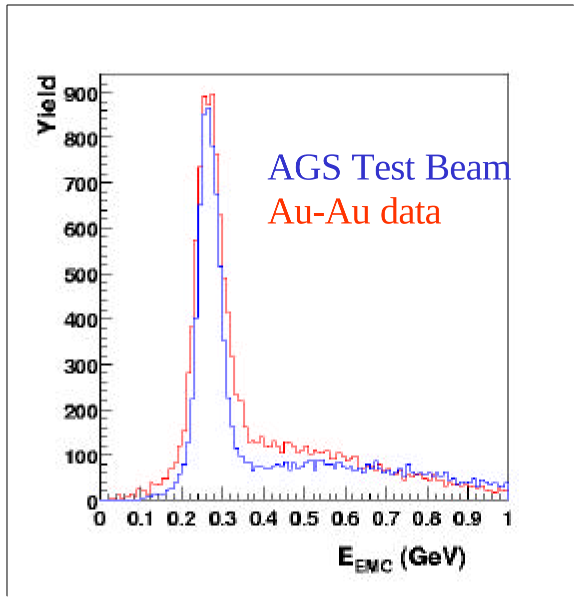
Identified protons: EMC energy vs. momentum

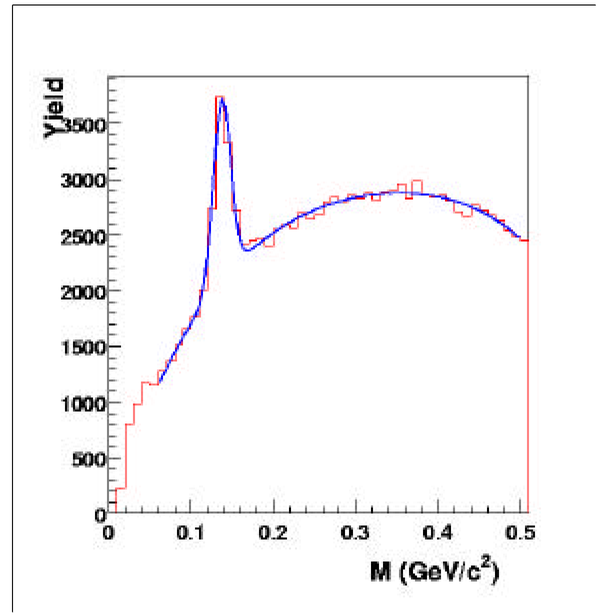


antiprotons

EMCal global energy calibration





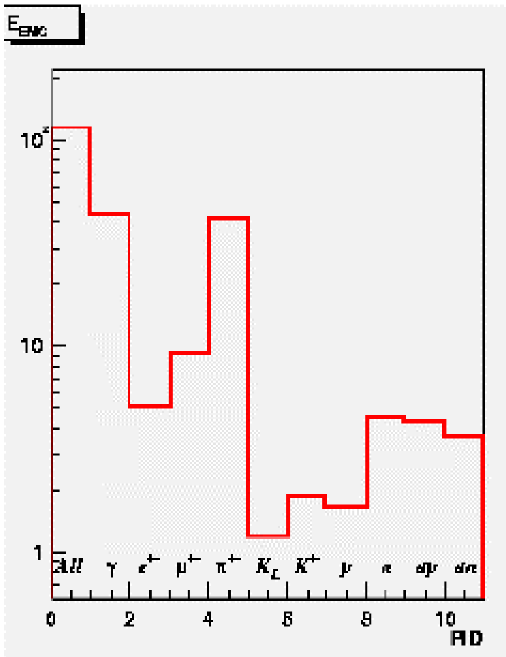


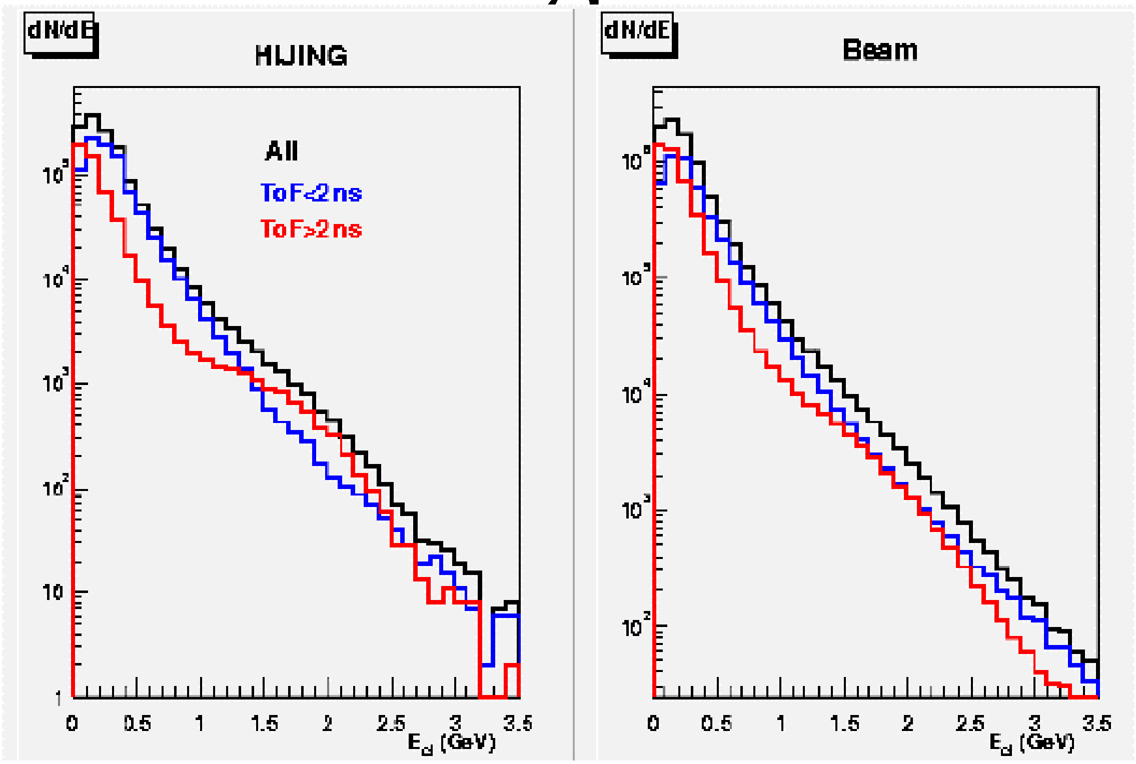
E/p matching
for electron enriched sample (with RICH): p>0.5 GeV/c

MIP peak position
for 1 GeV/c charged tracks (mostly pions):
Within 1% from Test Beam results

p**0's**
p_t>2 GeV, asym<0.8
m=136.7 MeV/c^2

Particles contributing to Et

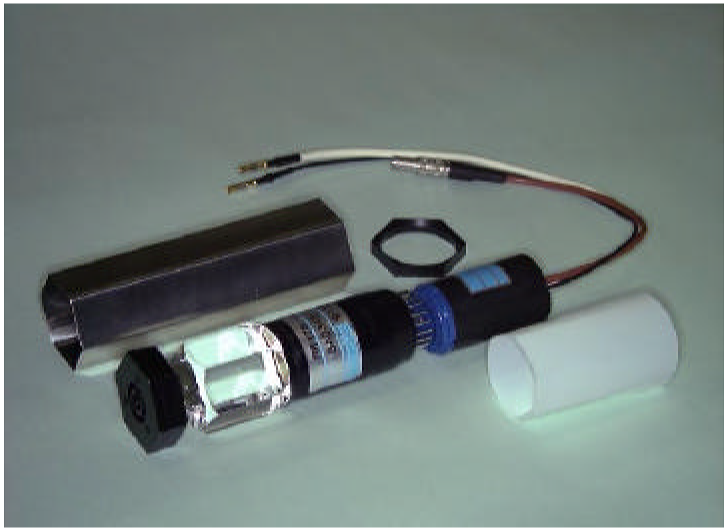


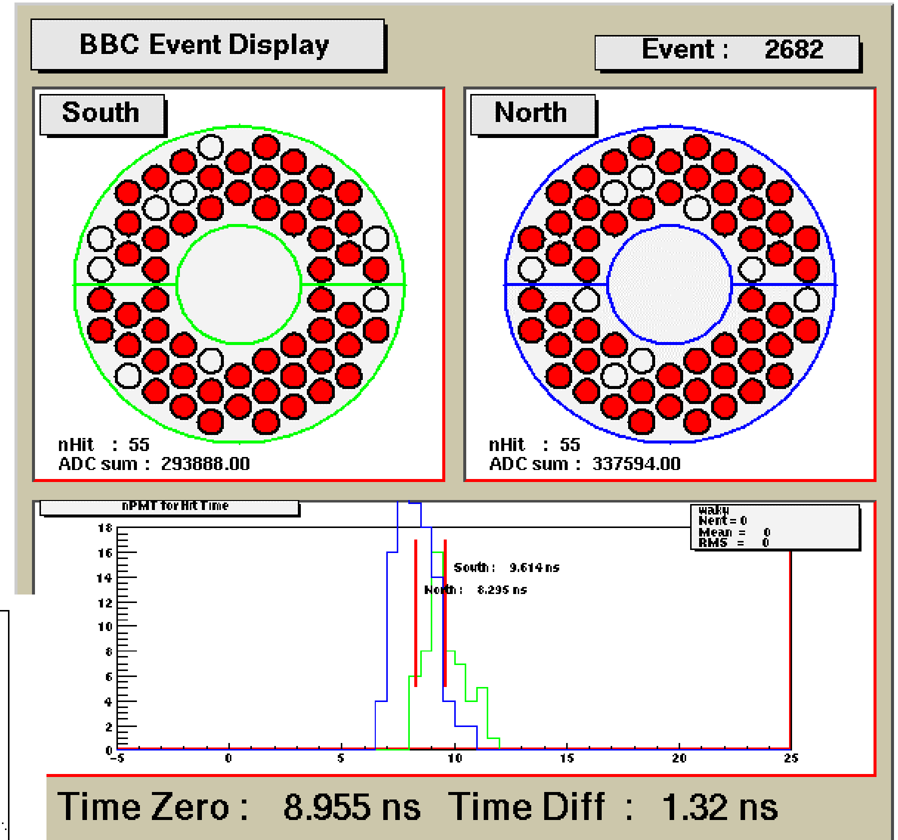


Simulation: geant particle id vs. energy deposit

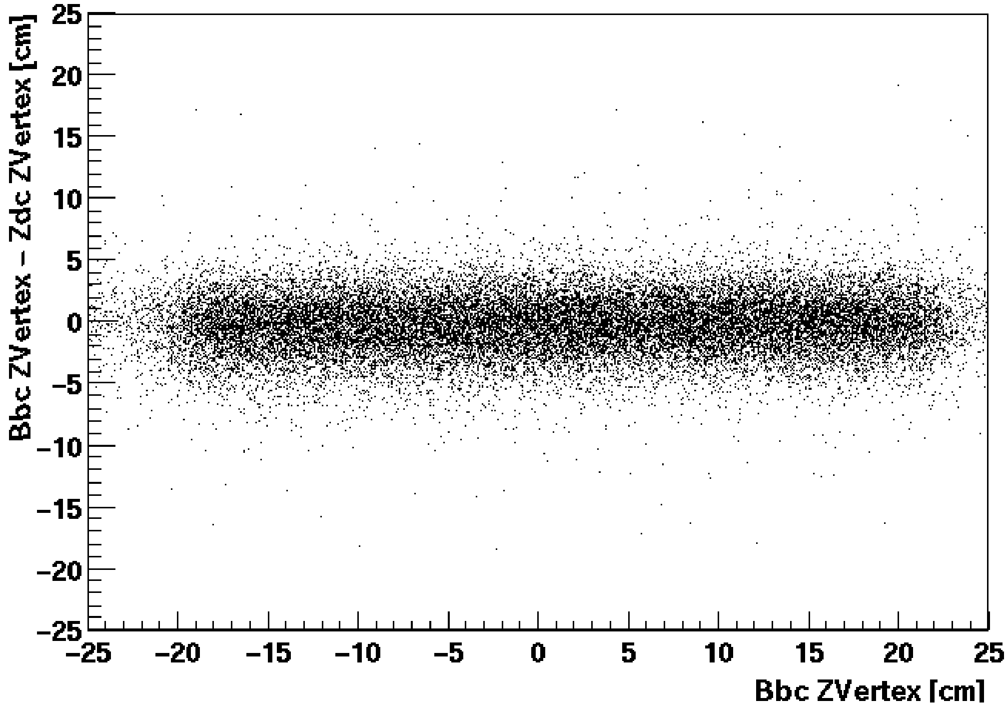
Simulation & Data: Cluster Energy distribution from fast(π^0,π^{+-}) and slow(baryons) particles

Beam Beam Counter



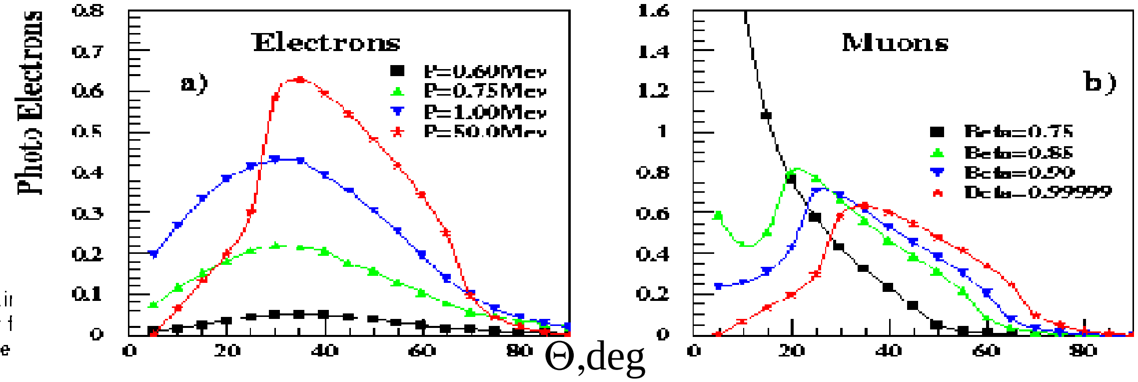


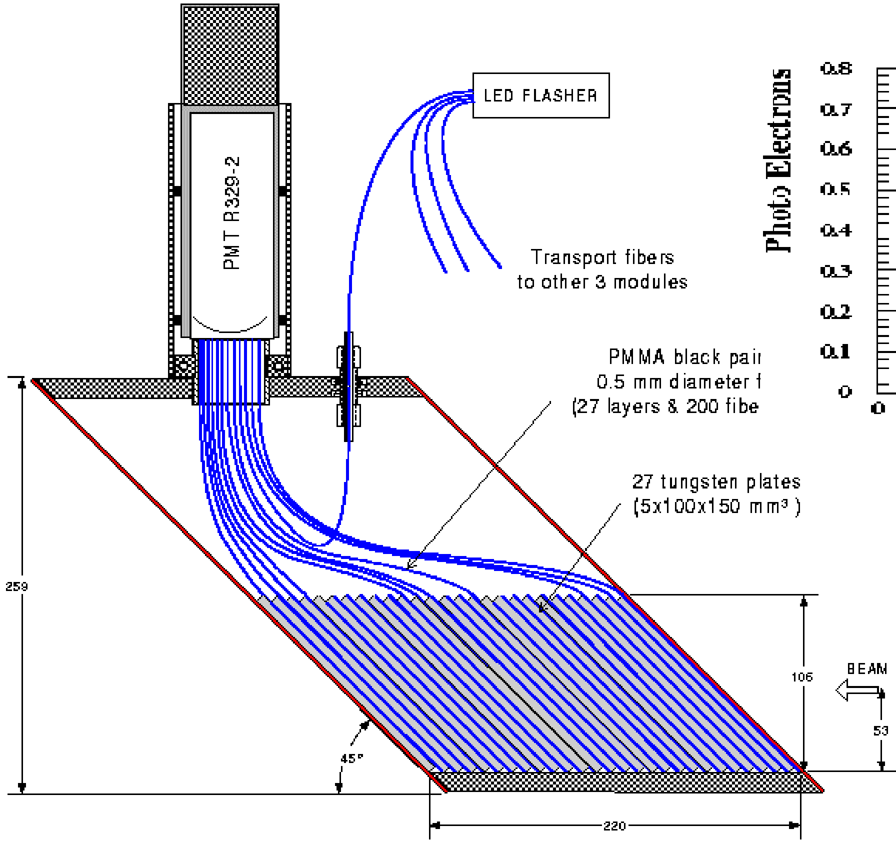
BBC event Display, t_0, Zvtx (~ δt)

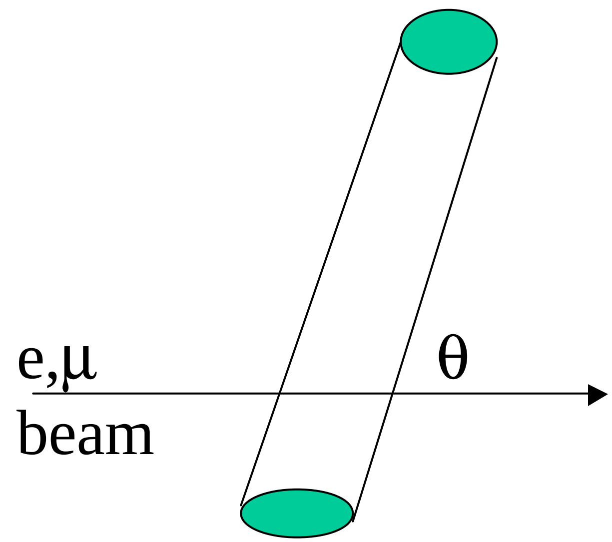


δ_{vertex}(cms) , σ~2 cm
BBC vs. ZDC

Fiber response vs. angle

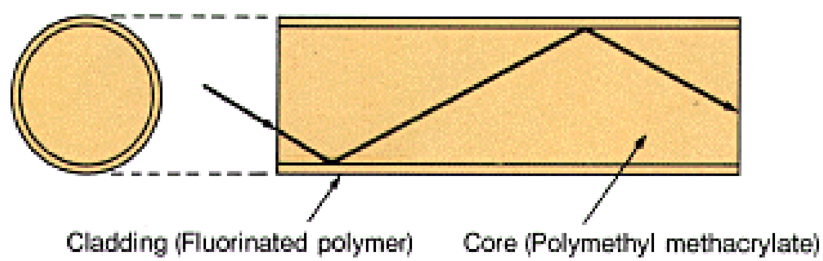






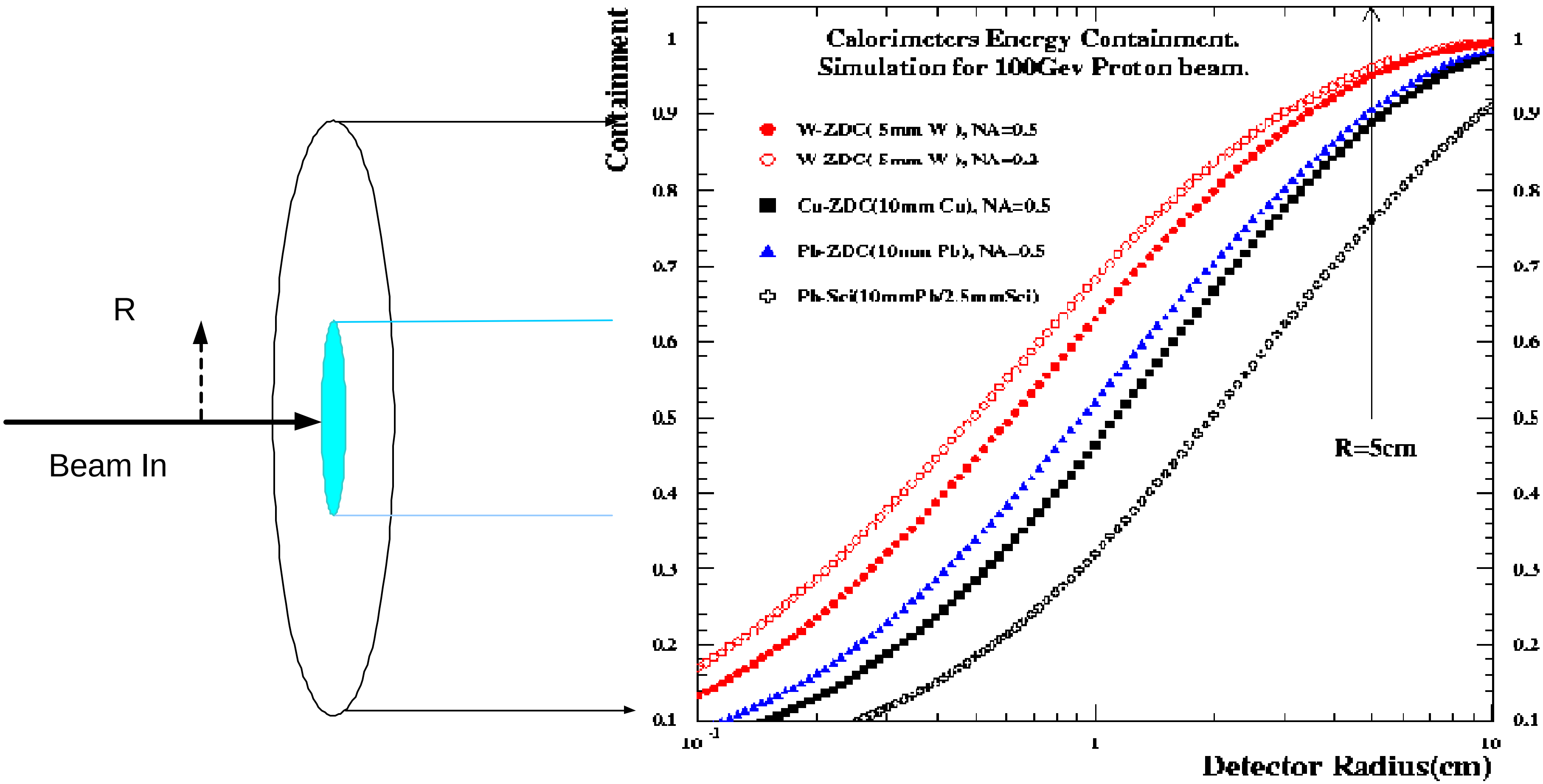
ZDC Calorimeter construction:

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

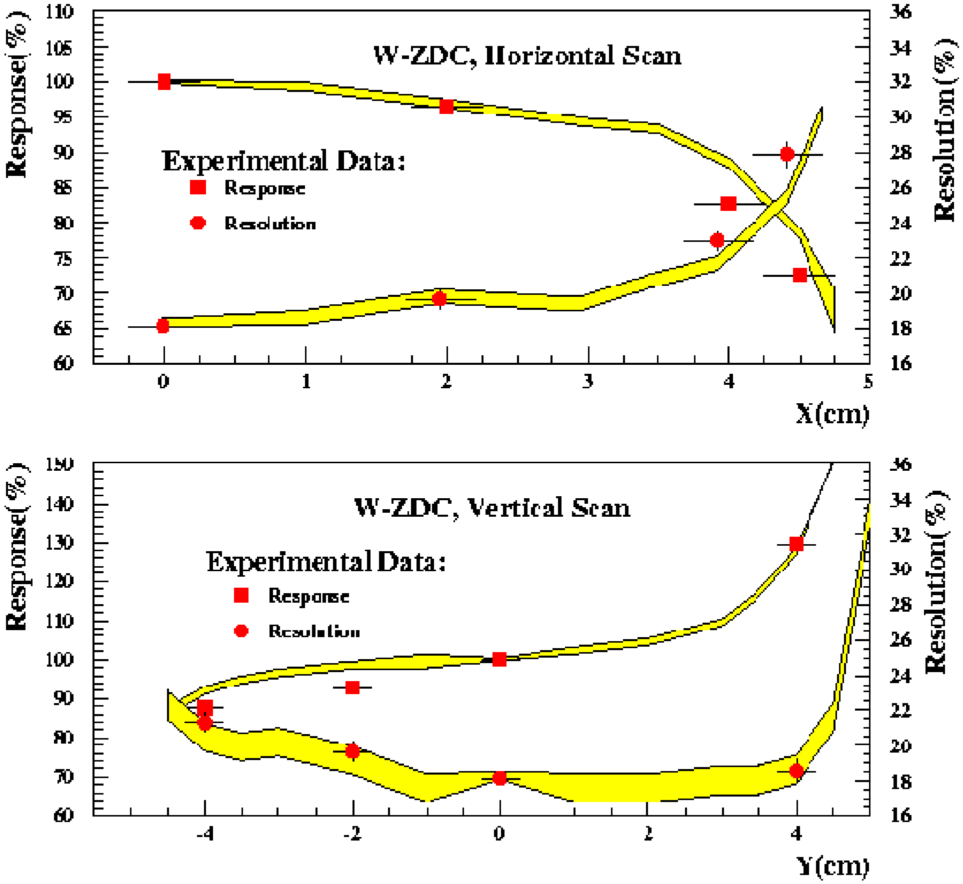


Zero Degree Calorimetry:
Effective Shower Size Scintillator vs. ZCAl

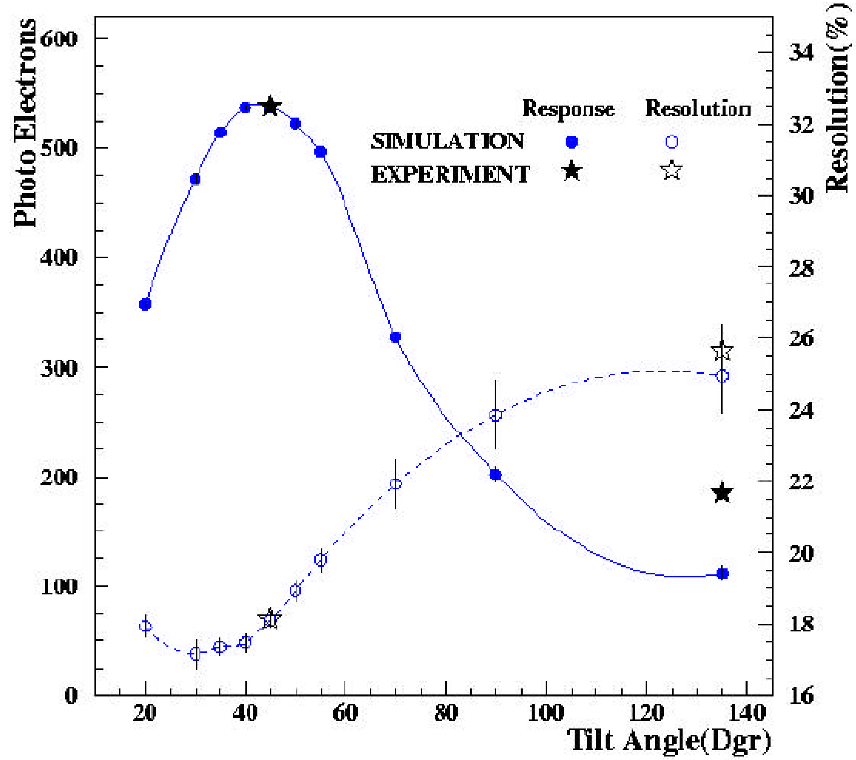
$$Containment \equiv Signal(r < R)/Total$$



Testbeam Measurements (100 GeV p)

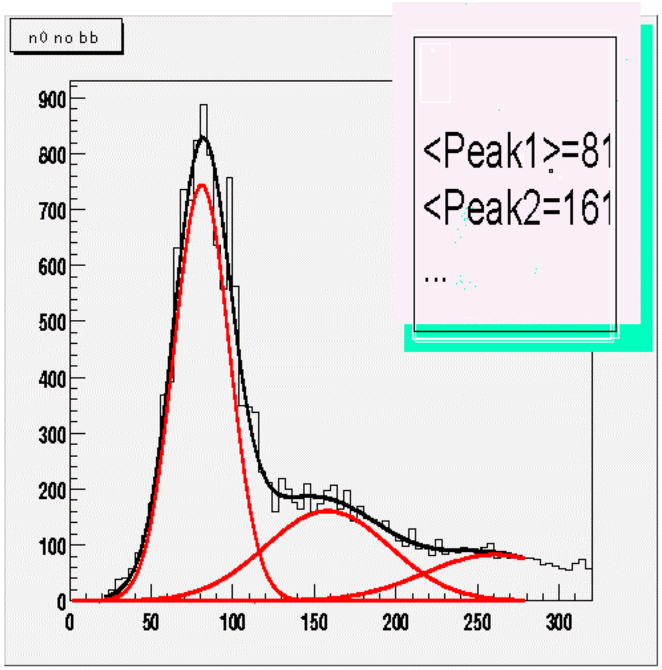


Response uniformity

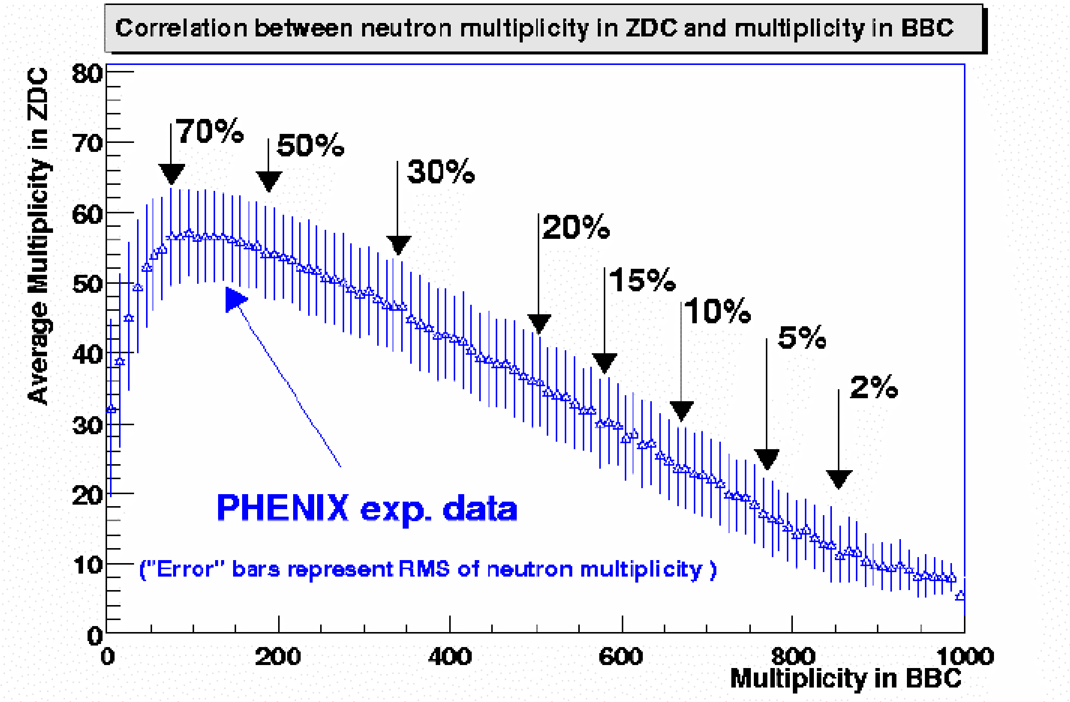


Directional response

ZDC Energy/Multiplicity Scale: Determination of Participant

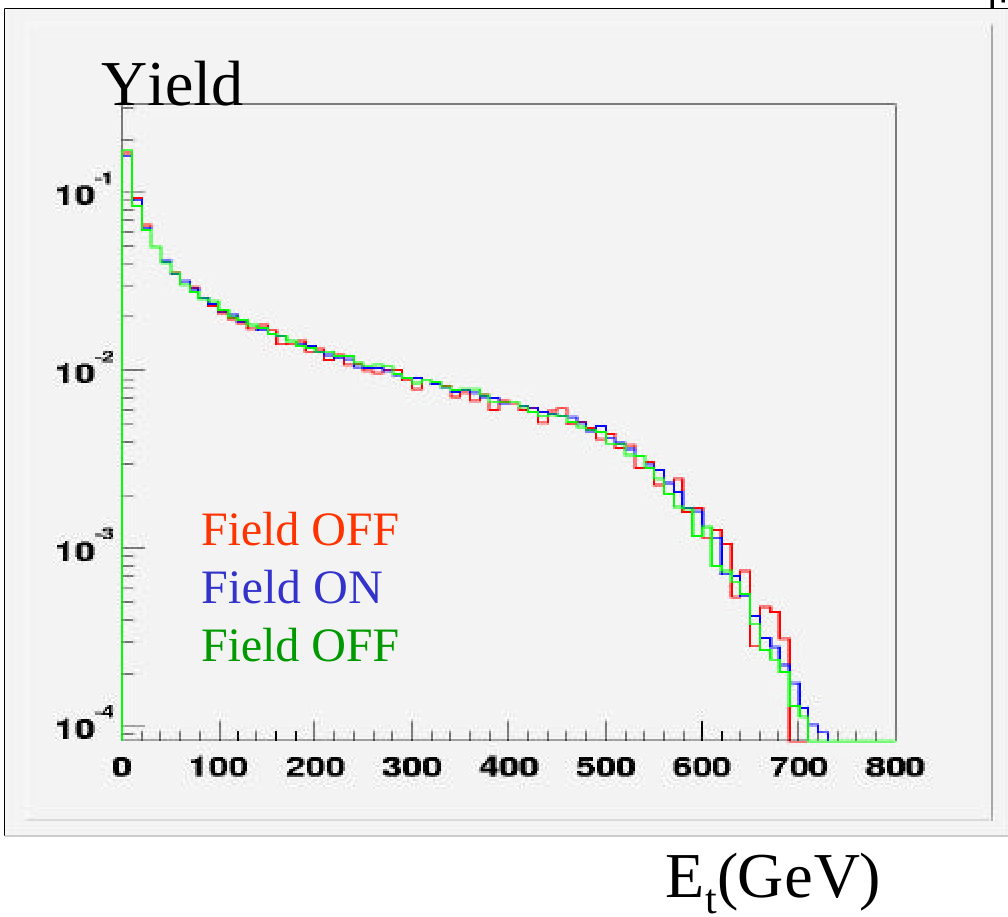


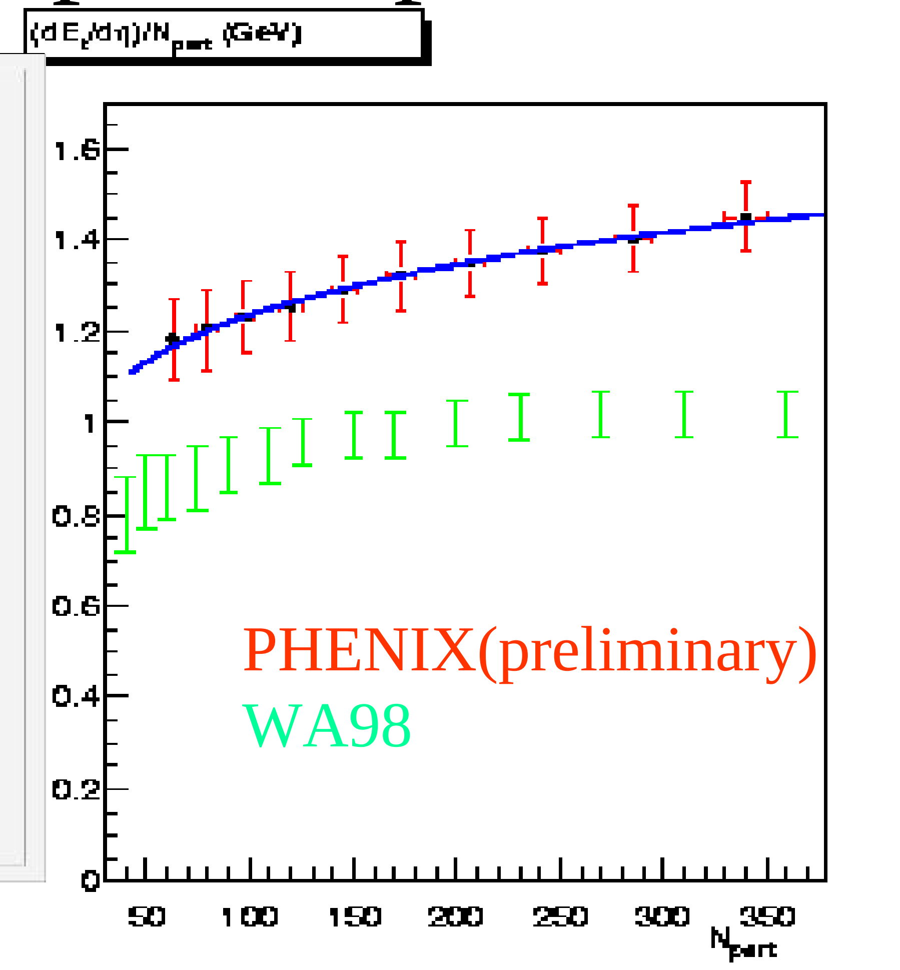
Fit to distribution of 1,2..
65 GeV neutron peaks
σ/E~ 25%



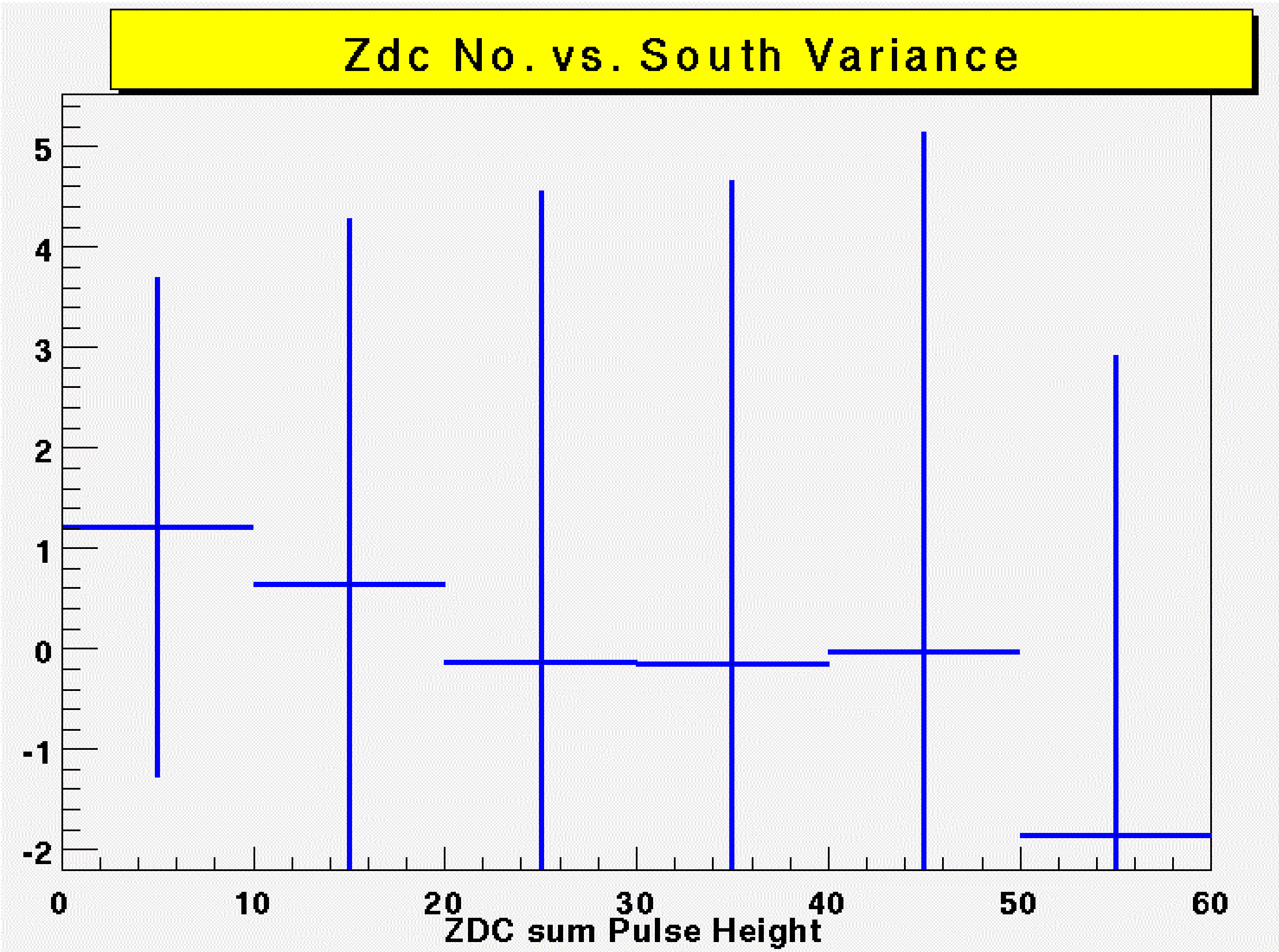
ZDC/BBC multiplicities vs. Centrality determined from cross sections

dE$_t$/dη and participant dependence





$$\frac{dE_t}{dh}\Big|_{h=0} \sim N_{part}^{a}$$,α=1.13+/-0.05



2 ZDC’s measure same multiplicity to Δ/<> ~ 10%

Conclusions

- EMCal energy scale determined to 2%
- Et/event scale to +/- 4%
- BBC , ZDC measure global properties of events(z_{vert},t_0,Centrality)
- $dE_t/d\eta$ increases by ~50% from SPS to RHIC
- clear departure from linear $N_{participant}$ dependence seen