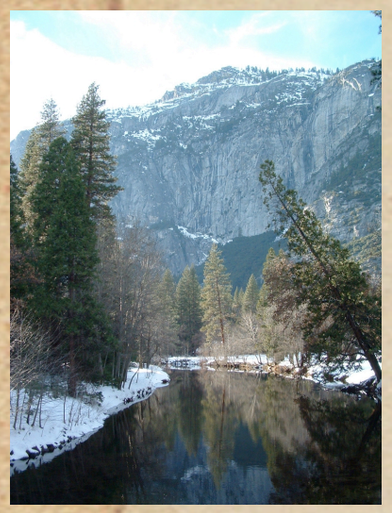
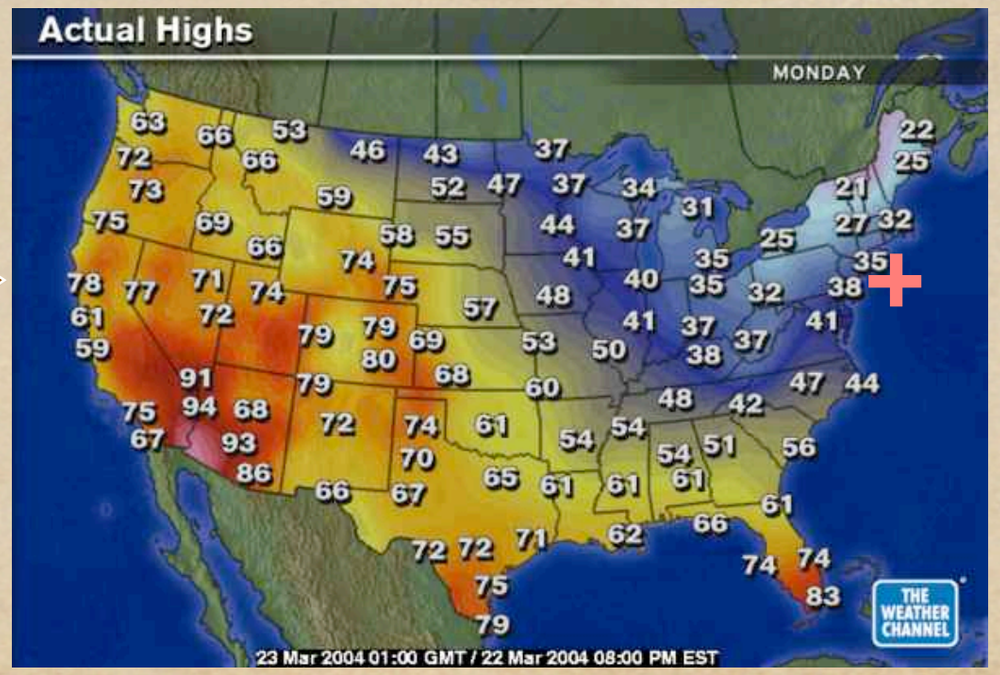
Forward Hadron Calorimeter

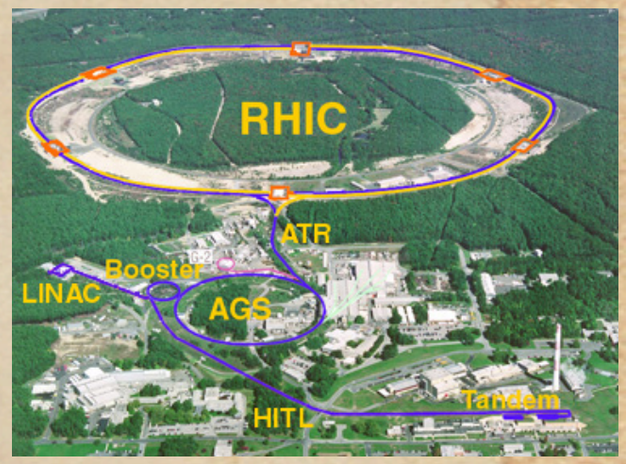
Jason Newby

Lawrence Livermore National Lab



LLNL





The Forward Caliorimeters are:

- Some of the youngest PHENIX detectors
- Two 12-Ton calorimeters placed near the beam pipe, beyond the DX magnets
- Conceived to measure centrality in pA/dA Collisions, but considered for interesting physics in pp and d-d
- Promising Au+Au reaction plane analysis

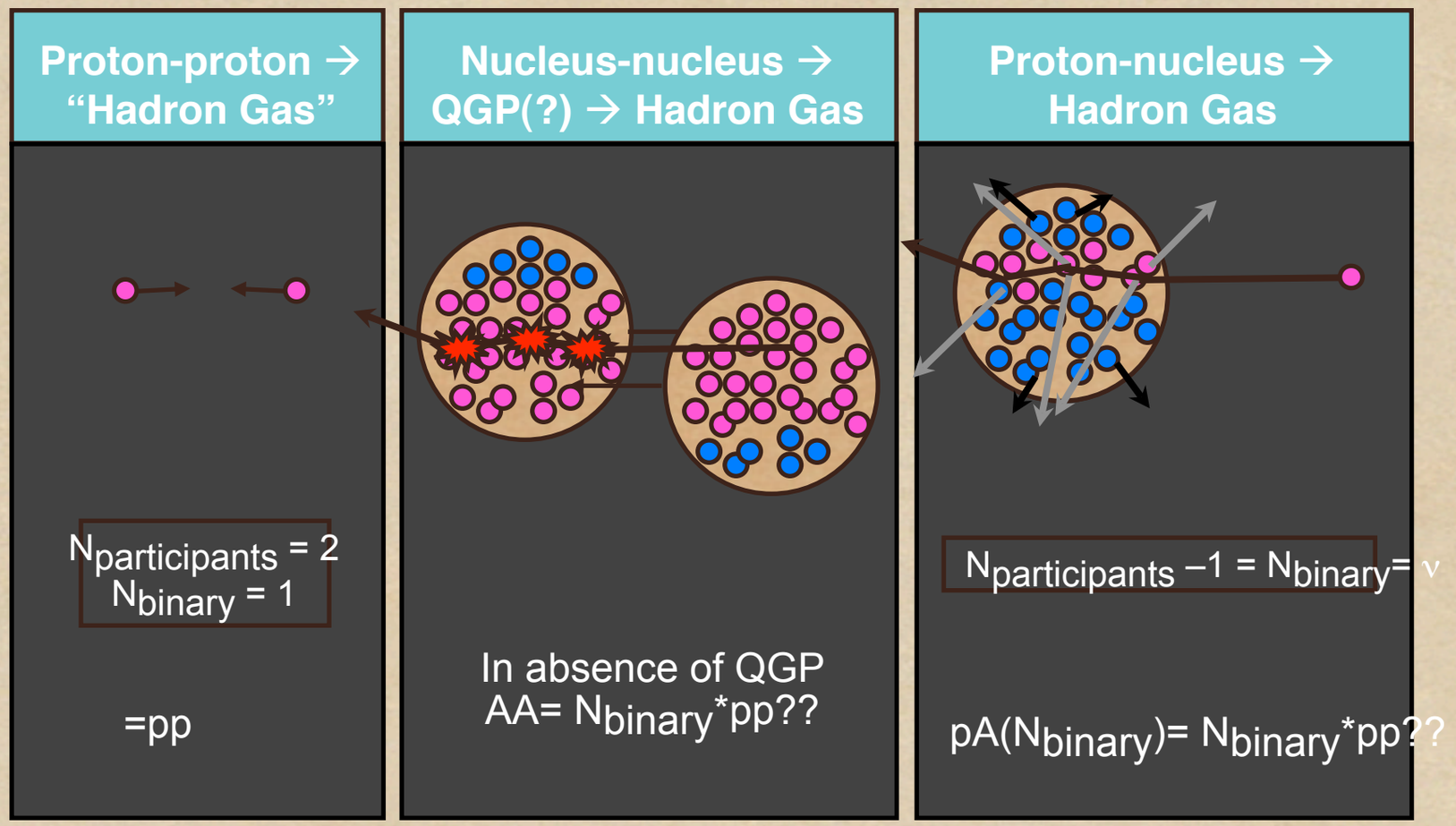
Outline

- Why another Forward calorimeter?
- Calorimeter search
- FCAL testing, assembly, installation
- FCAL Response in dAu
- Ncol extraction from RQMD
- Future...

Why is d-Au centrality so important?

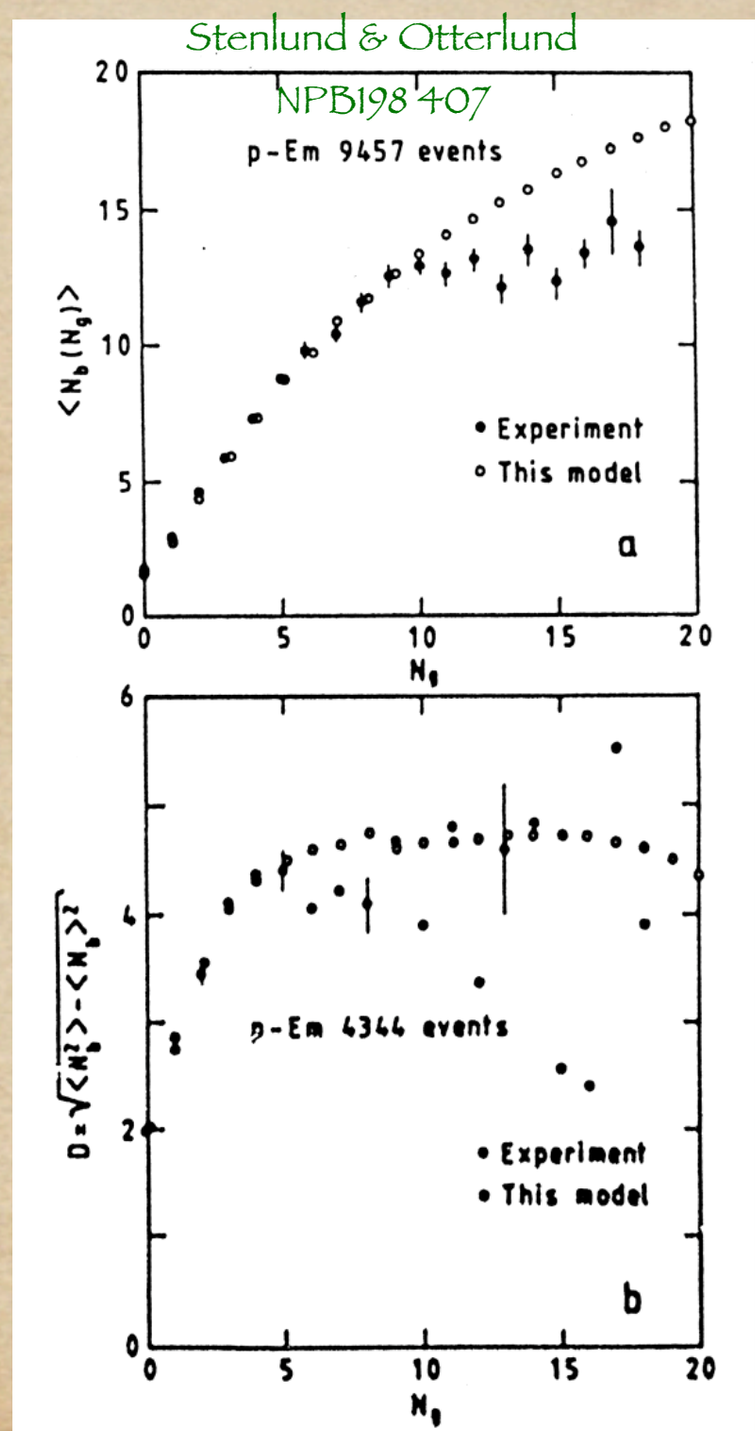
- Separate Initial State Effects Au-Au: CGC!?
- R_dA=σ_dAu(central)/Ncoll/σ_pp
- R_CP=σ_dAu(central)/Ncoll/σ_dA(Periph)/Ncoll
- pions, protons, at mid rapidity
- J/ψ, charged hadrons -2<y<2

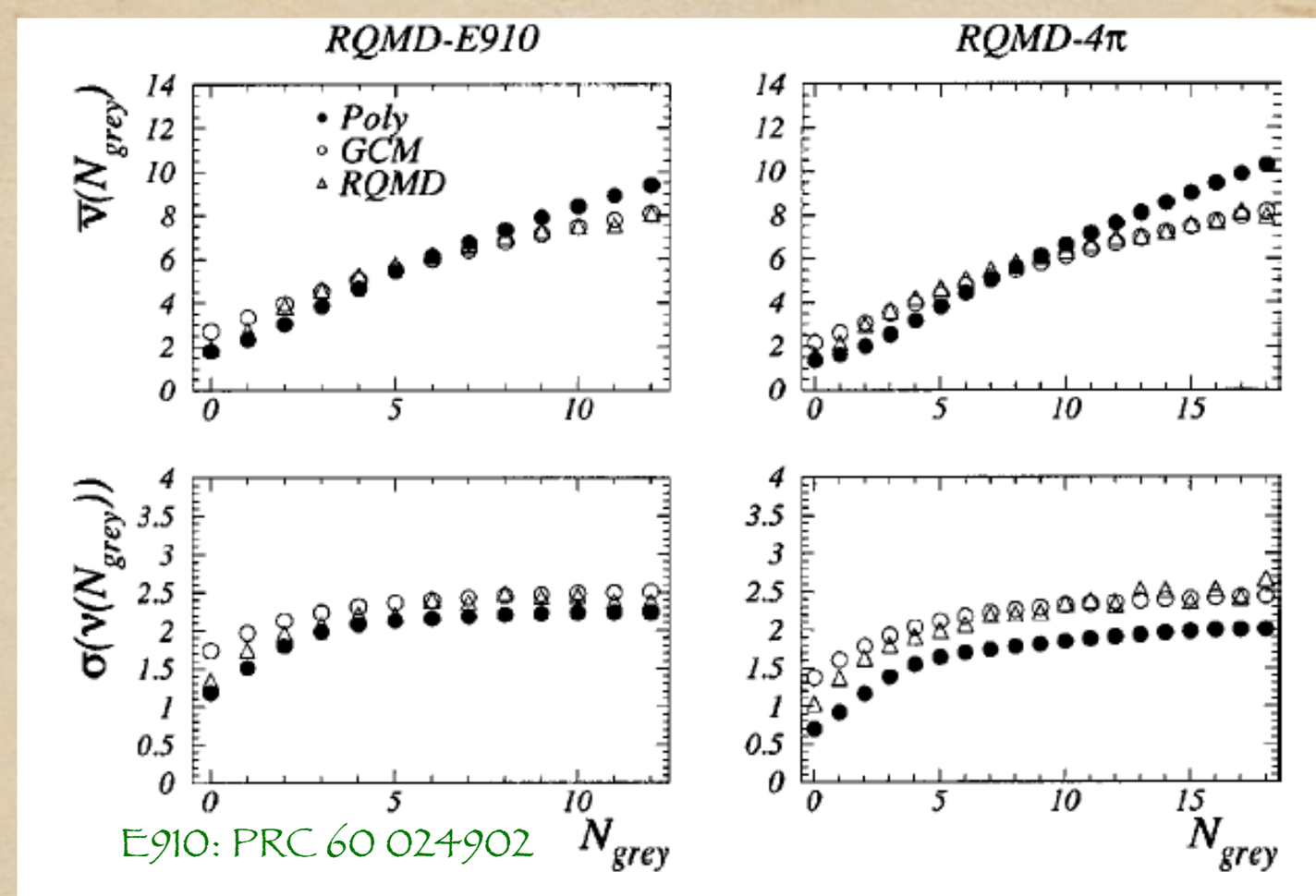
Centrality in p(d)A



Need to measure grey/black nucleons to determine N_{binary}

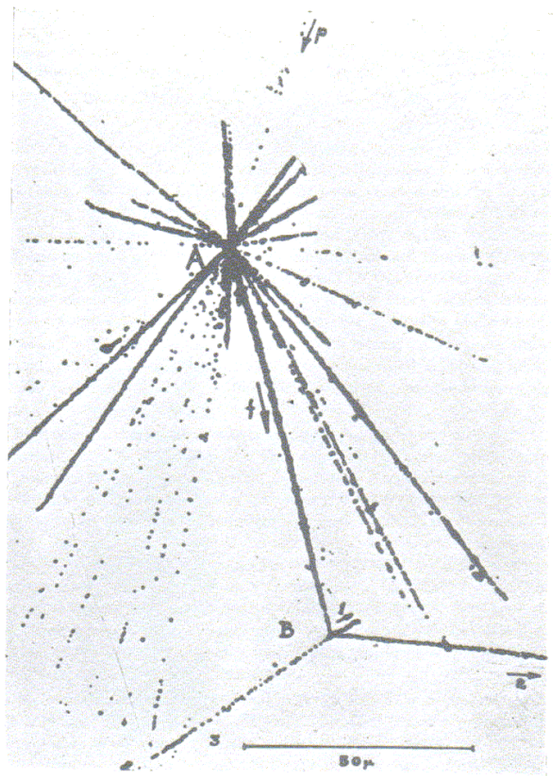
Ngrey/Nblack relation





- Physical picture:
  - N_{grey} directly related to N_{binary}
  - N_{black} related to excitation of nucleus (N_{grey})

Ngrey dependencies



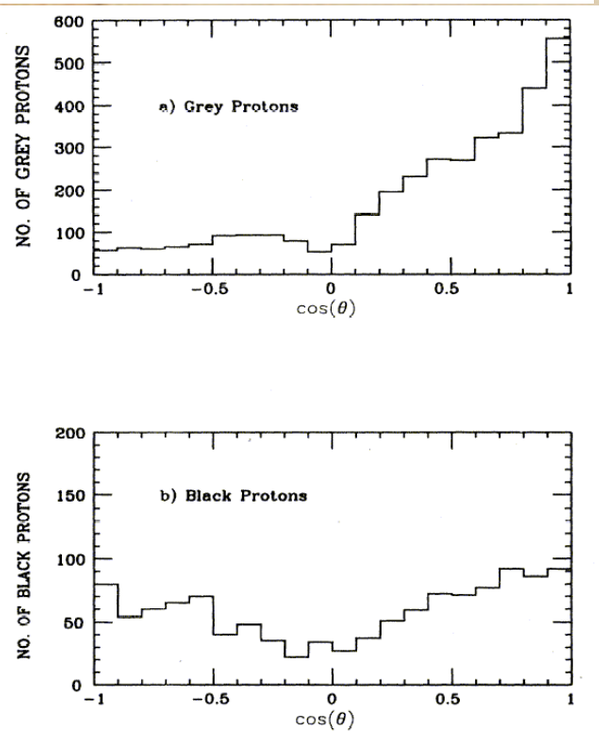


FIG. 2. Angular distribution of identified protons with respect to the beam direction for (a) grey protons with momentum >0.3 GeV/c and (b) black protons with momentum <0.3 GeV/c.

Bubble Spectrometer
D.H. Brick, et al.
PRD39 ('89) 2484

18GeV/c

I. Chemakin, et al.
E910 PRC 60 024902

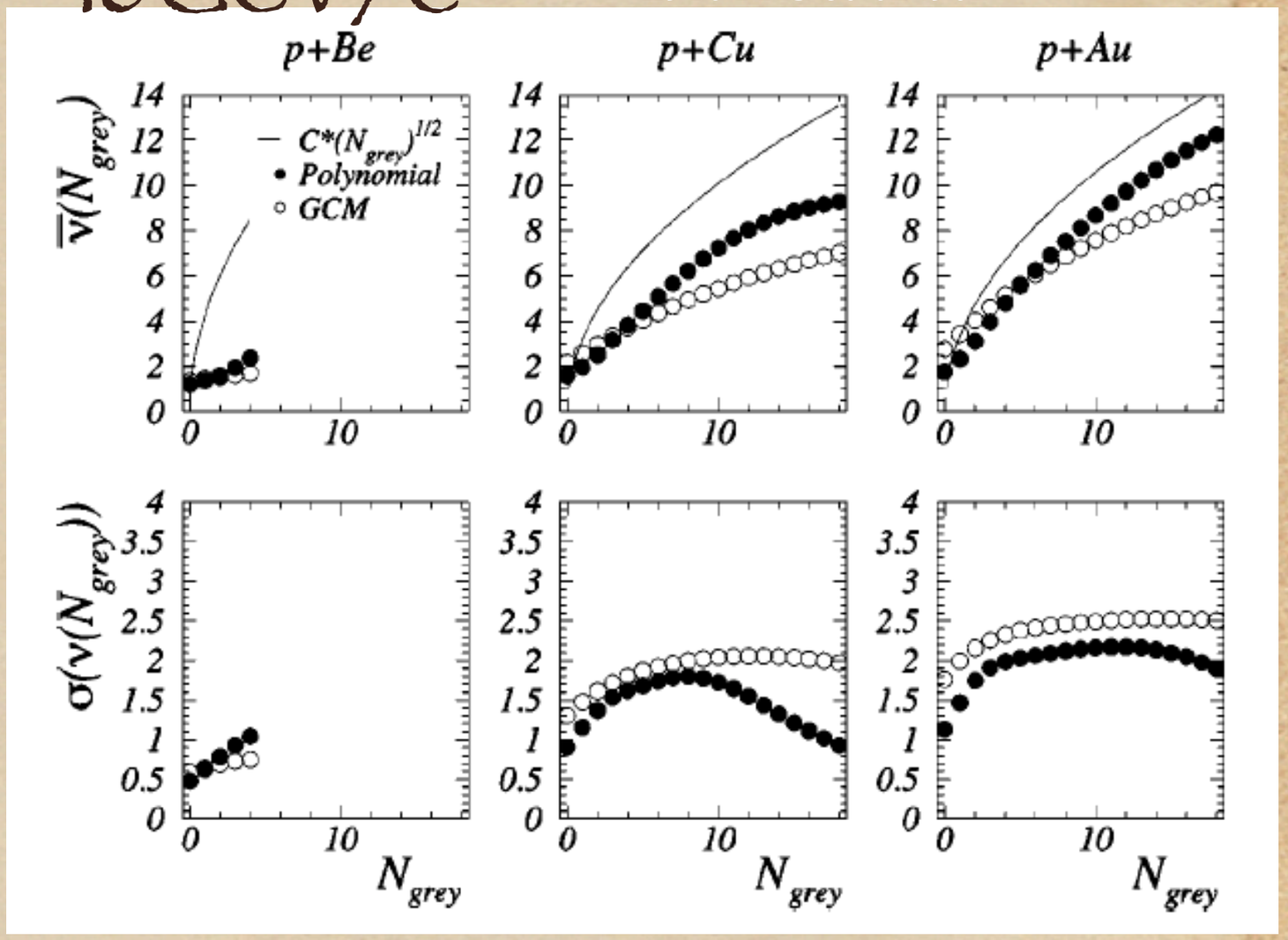


FIG. 12. $\bar{\nu}(N_{\text{grey}})$ and $\sigma[\nu(N_{\text{grey}})]$ generated from the polynomial model (solid circles) and the GCM (open circles), and $\bar{\nu}(N_{\text{grey}})$ according to the $\bar{\nu}^2$ ansatz (solid line) for $p+\text{Be}$, $p+\text{Cu}$, and $p+\text{Au}$.

Previous Uses of Grey Protons

Multiplicity vs N_{binary}
NA5 PRD29
(1984) 2476.

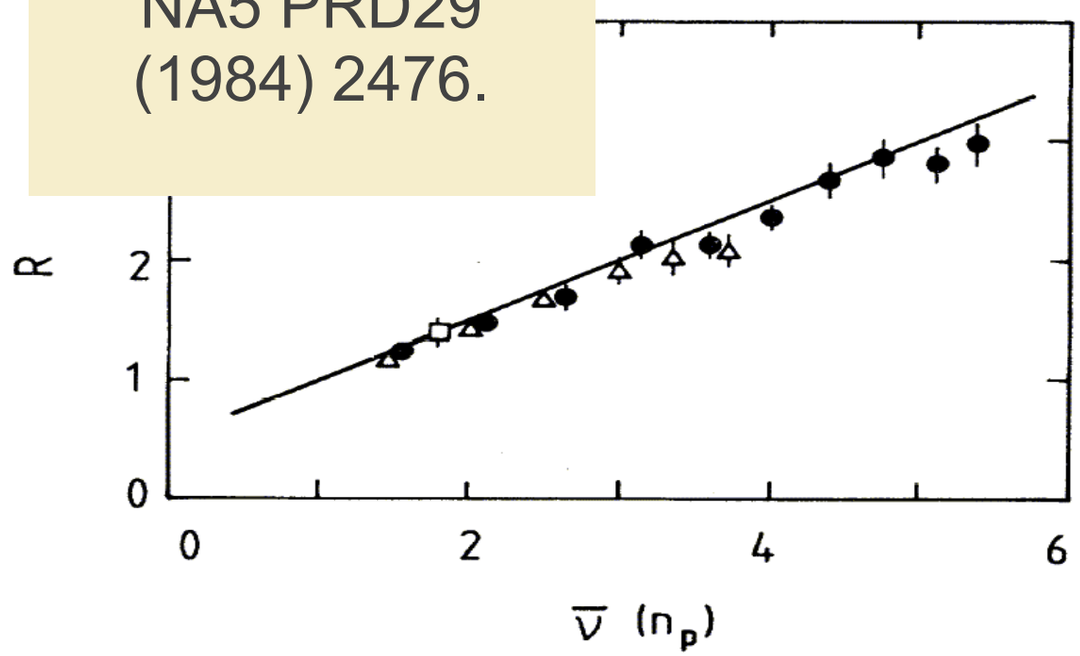
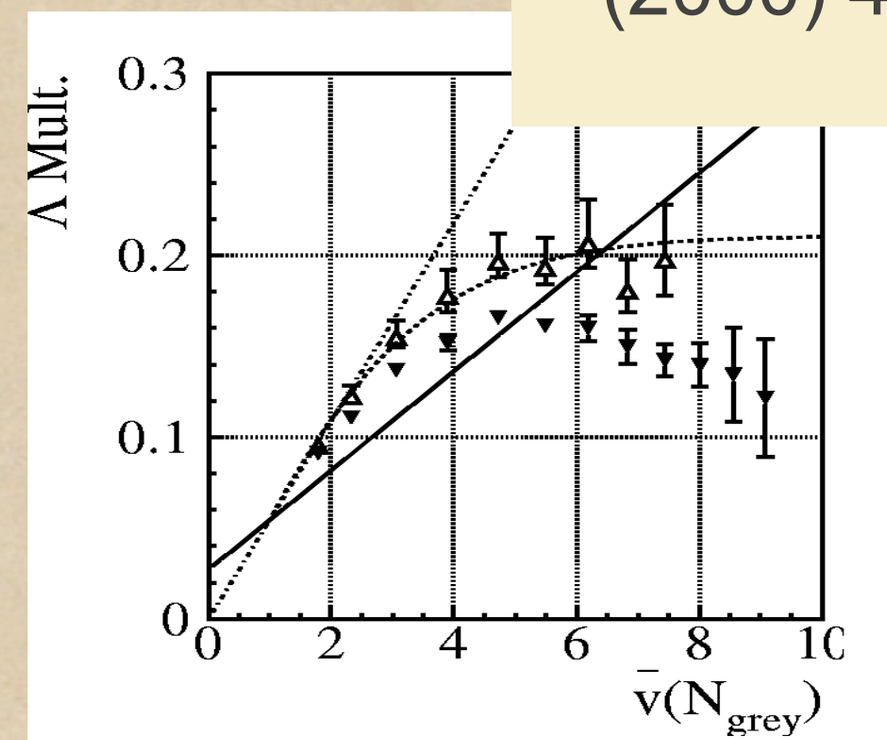


FIG. 4. The ratio $R = \langle n \rangle_{pA} / \langle n \rangle_{pp}$ versus the av
ber $\bar{\nu}(n_p)$ of projectile collisions for pXe (circles),
gles), and pNe (squares) collisions. A line of
$R = 0.5[\bar{\nu}(n_p) + 1]$ is shown for comparison.

Strangeness
E910 PRL85
(2000) 4868



Strangeness
at CERN NA49 PRL85
(2000) 4868

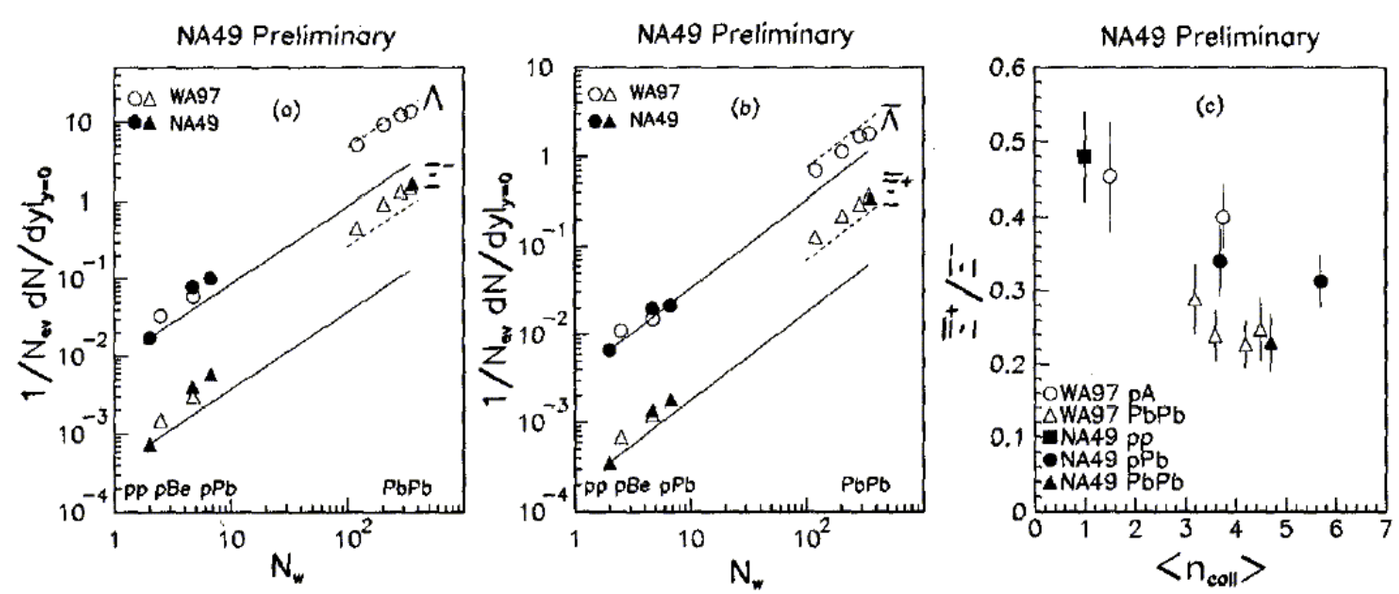
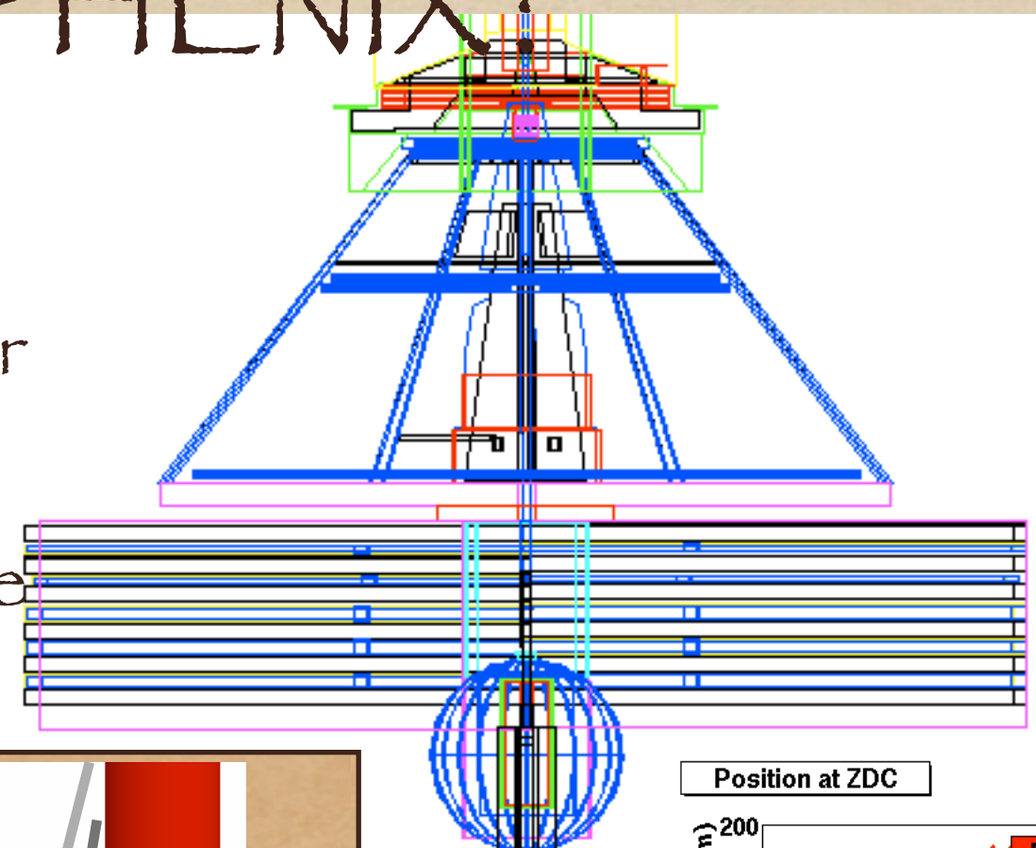
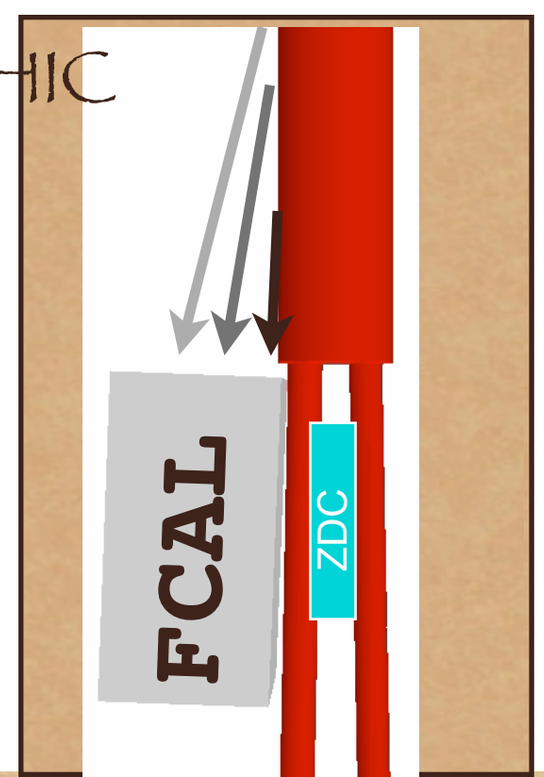


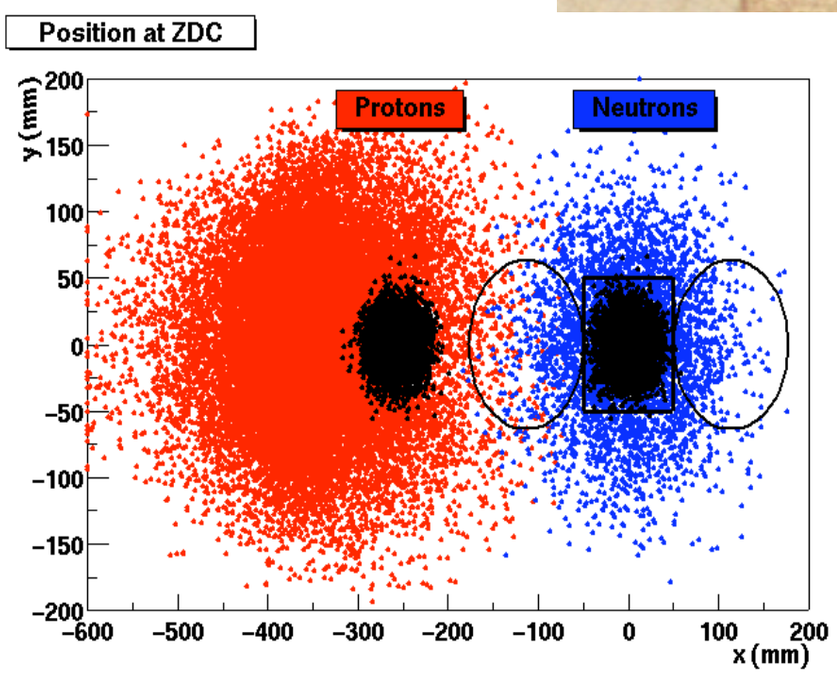
Figure 3. Mid-rapidity yields as a function of number of wounded nucleons for (a) baryons (b) antibaryons (c) $\bar{\Xi}^+/\Xi^-$ ratio at mid-rapidity

How do we measure grey protons in PHENIX?

- Non Trivial:
  - In high energy collider environment, grey particles pass, charge and momentum separated by RHIC DX magnet

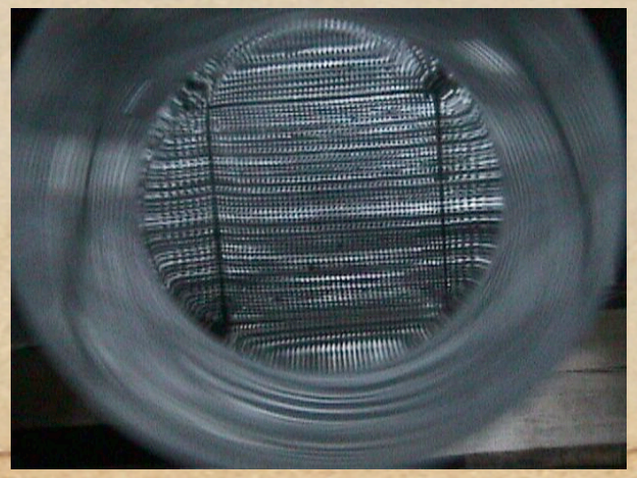






A Calorimeter's Tale: To the scrap yard and back again...

- From E864 experiment
- Younger, spaghetti-style calorimeter
  - 47 x47 Fibers
- Very good energy resolution



$$\partial E / E = 35\% / \sqrt{E} + 3.5\%$$

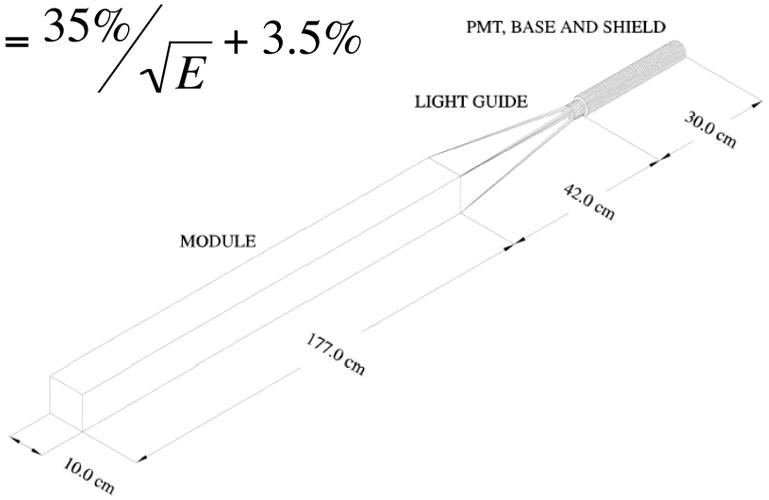
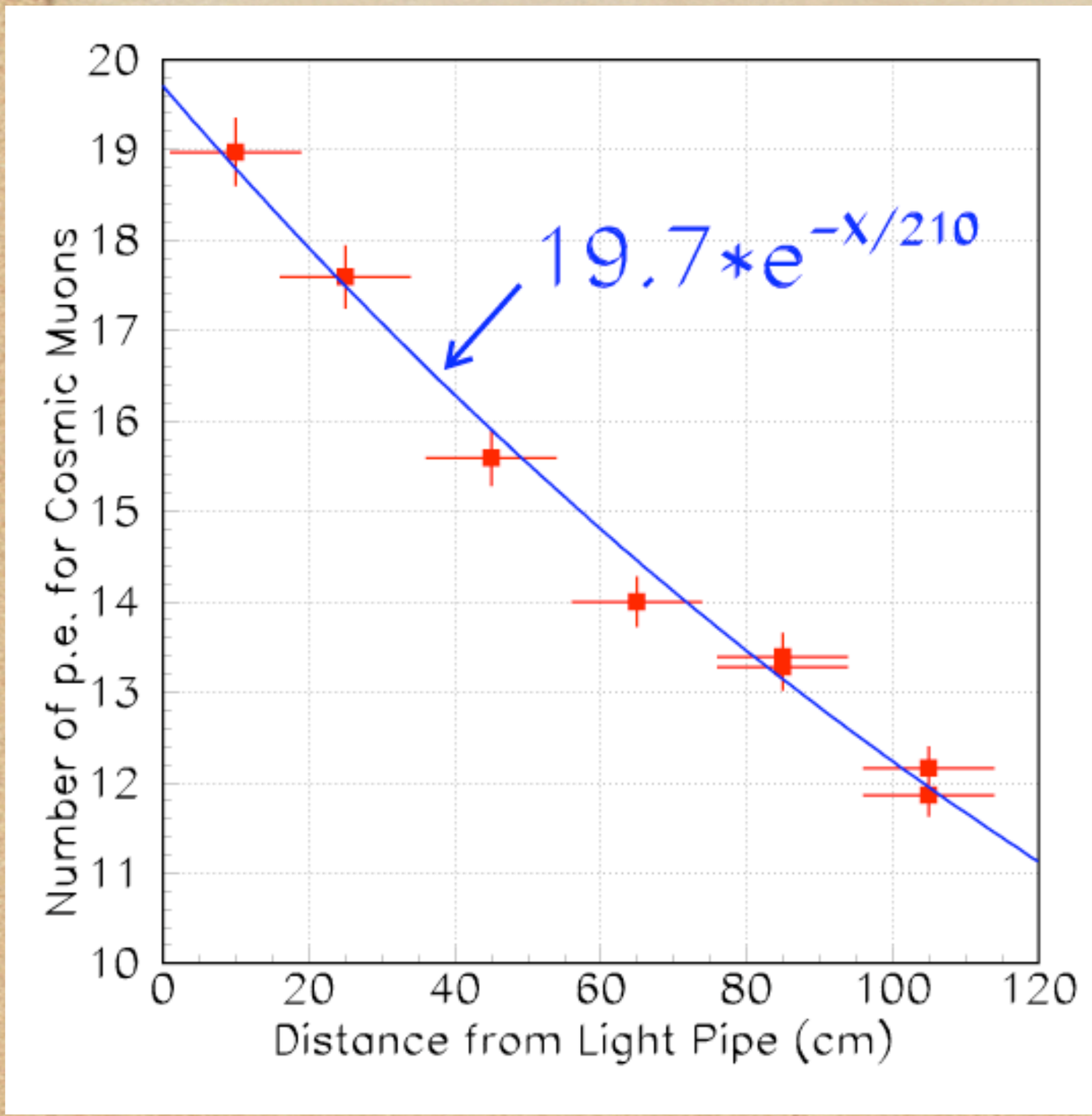


Fig. 3. Calorimeter Tower Layout. Scintillating fibers are imbedded longitudinally in a lead substrate. The light readout proceeds through a tapered lucite light guide with a single photo-multiplier tube per tower.

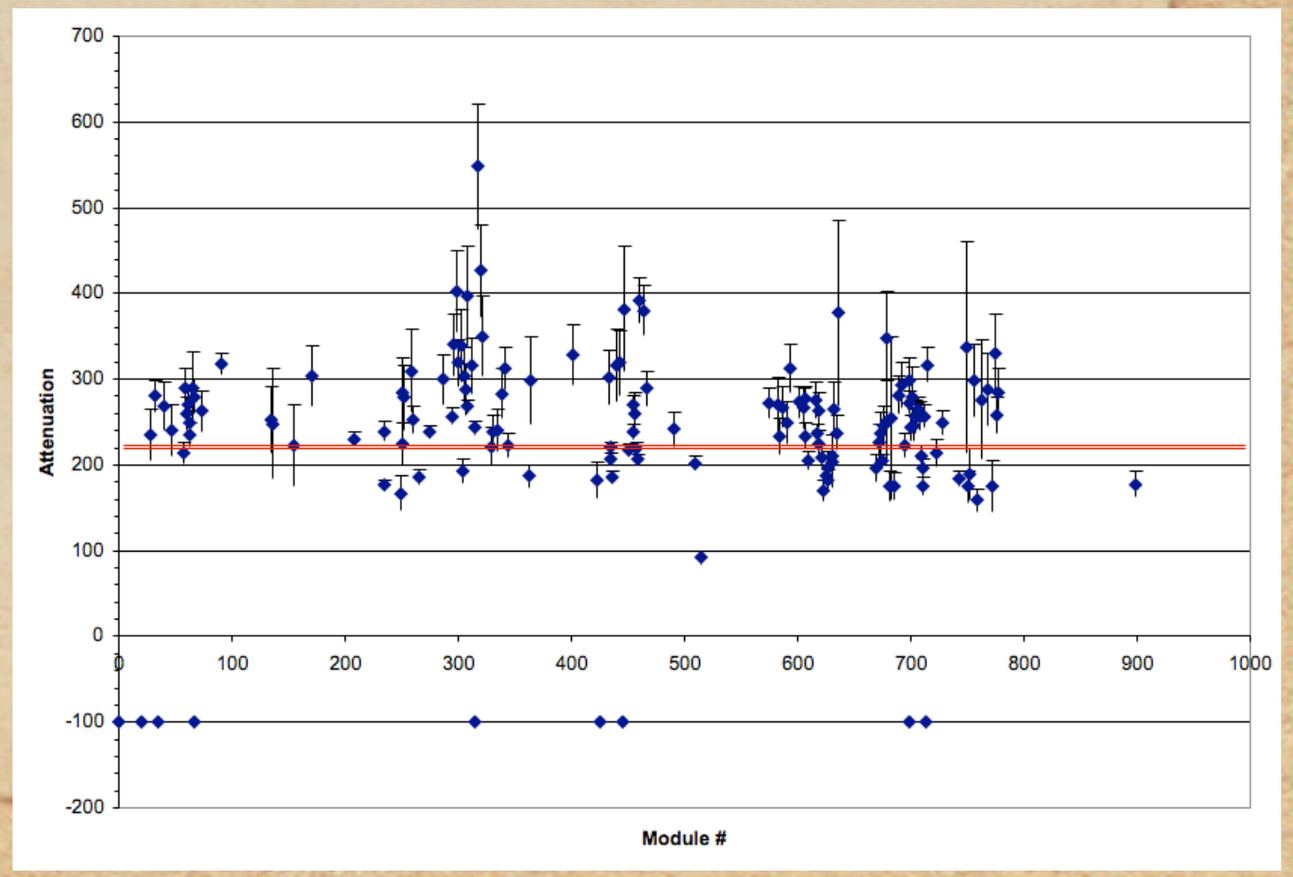
Salvageable? Yes



- Study at Yale by Dick Majka and Gerd Kunde show modules are unscathed after several years outside
  - Attenuation of fibers: 200cm
  - #PE/cosmic ~ 20

Module Test

- Testbench
  - Initial Testing and Setup Nathan Grau and Ray Stantz
- PHENIX and PHOBOS collaborate on module testing



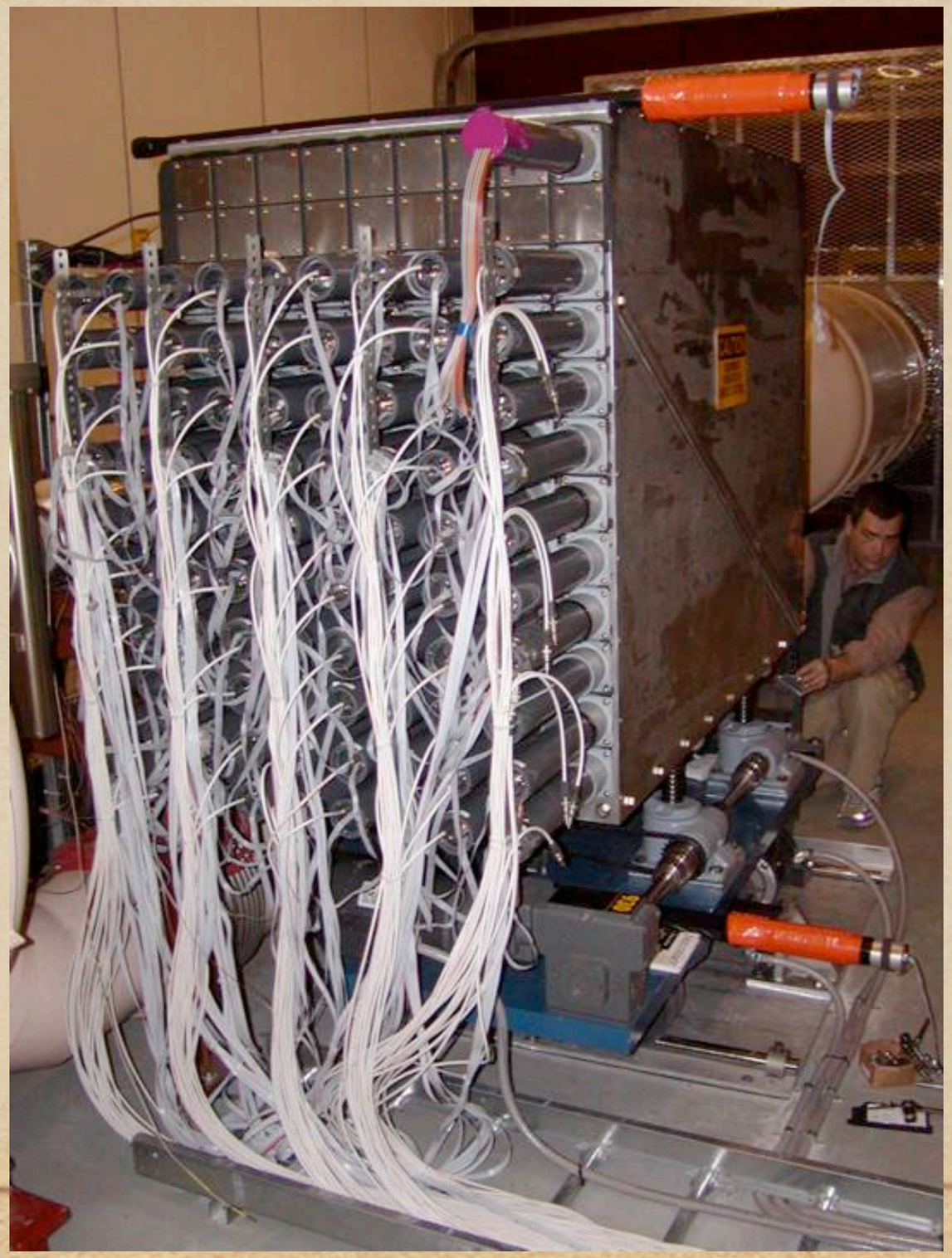
The STAND

- Non trivial
  - Modules have no lifting point
  - 12 Tons of Pb
- To make matters worse:
  - Pb oxide dust found on modules
  - Quick action by BNL safety, PHENIX techs and Pearson's crew get the modules stacked in a couple of weeks

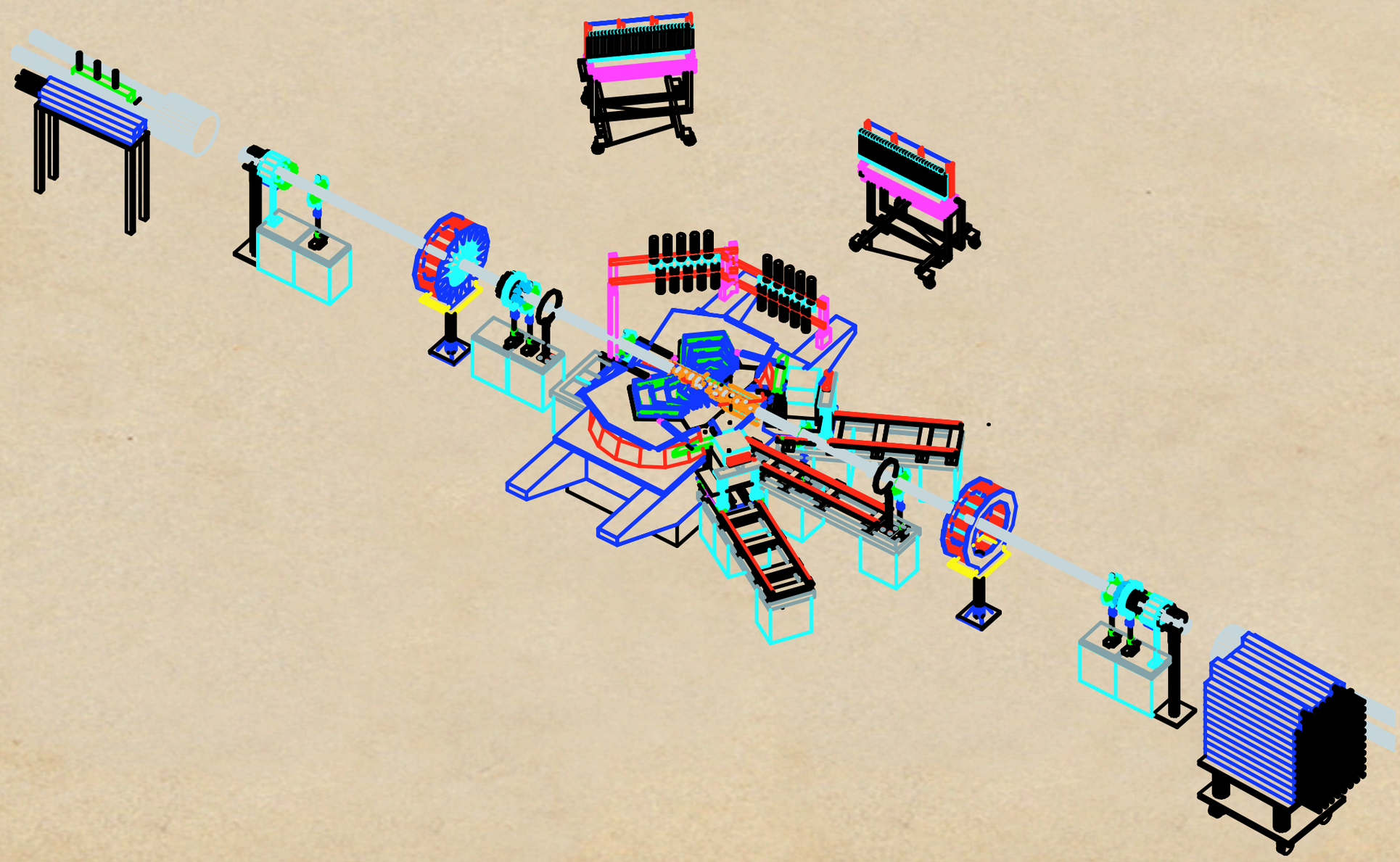
Construction in Duplicate

- Two is better than one.
- RHIC Couldn't promise direction of d-Au
- Tag proton spectator of deuteron
- Au-Au Reaction Plane?

Installation

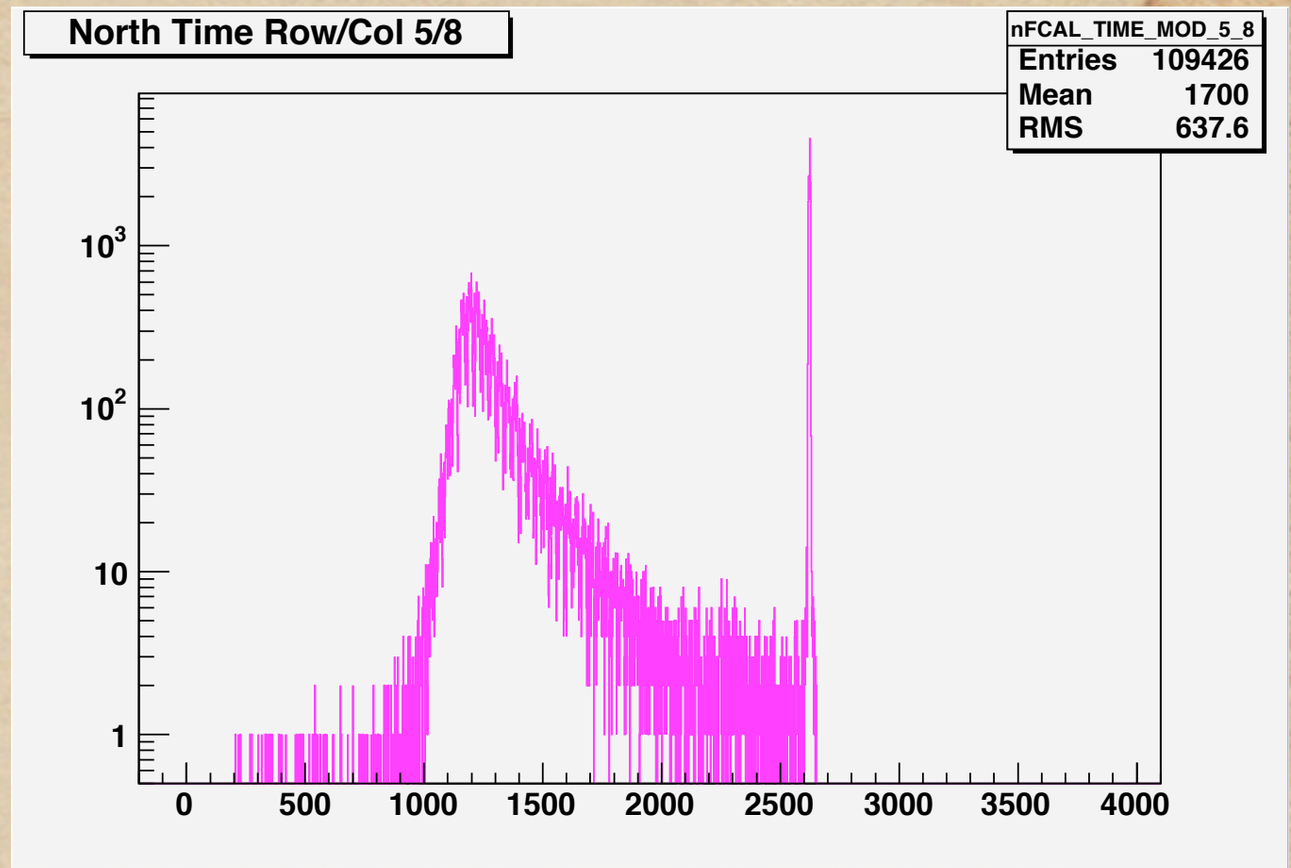


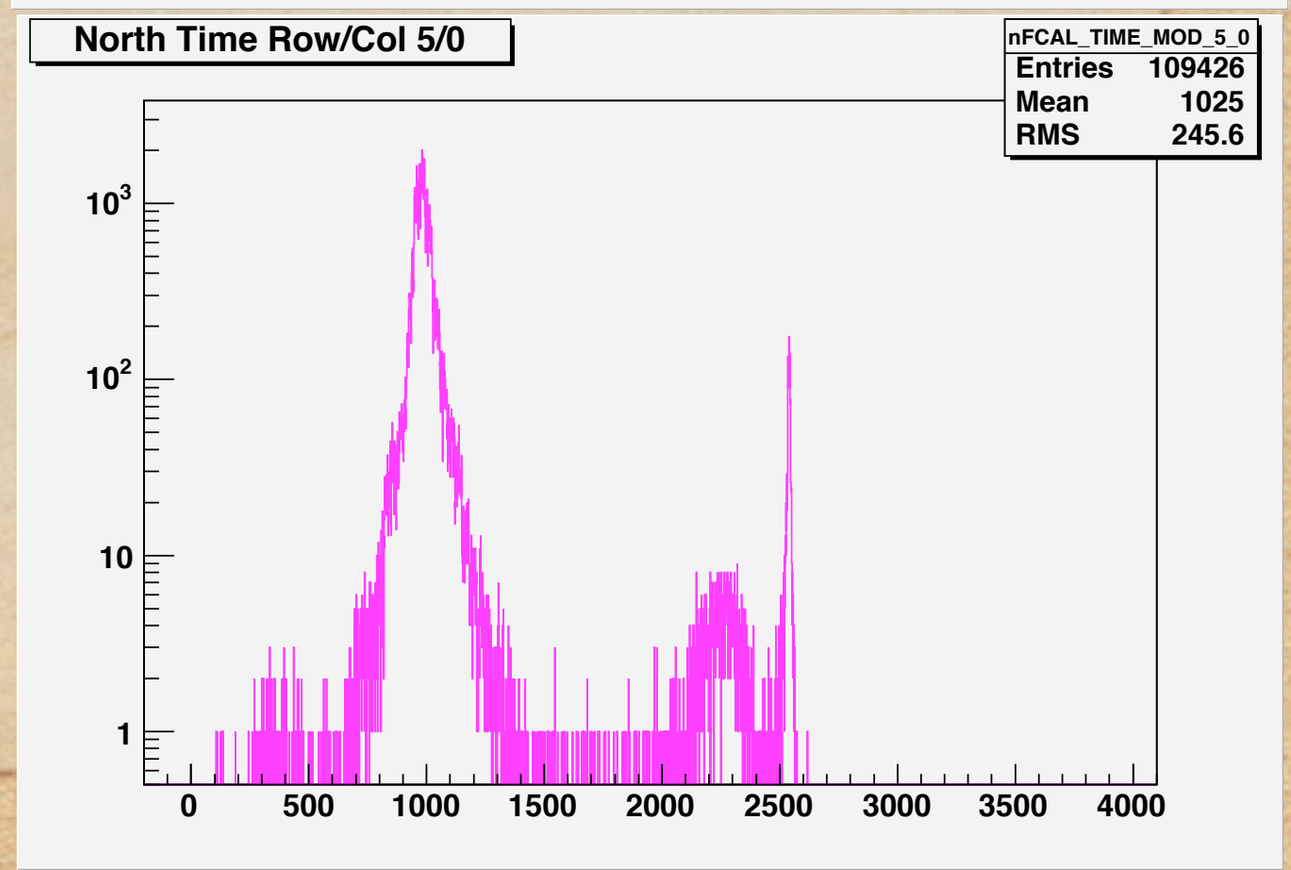
PHOBOS - Installation



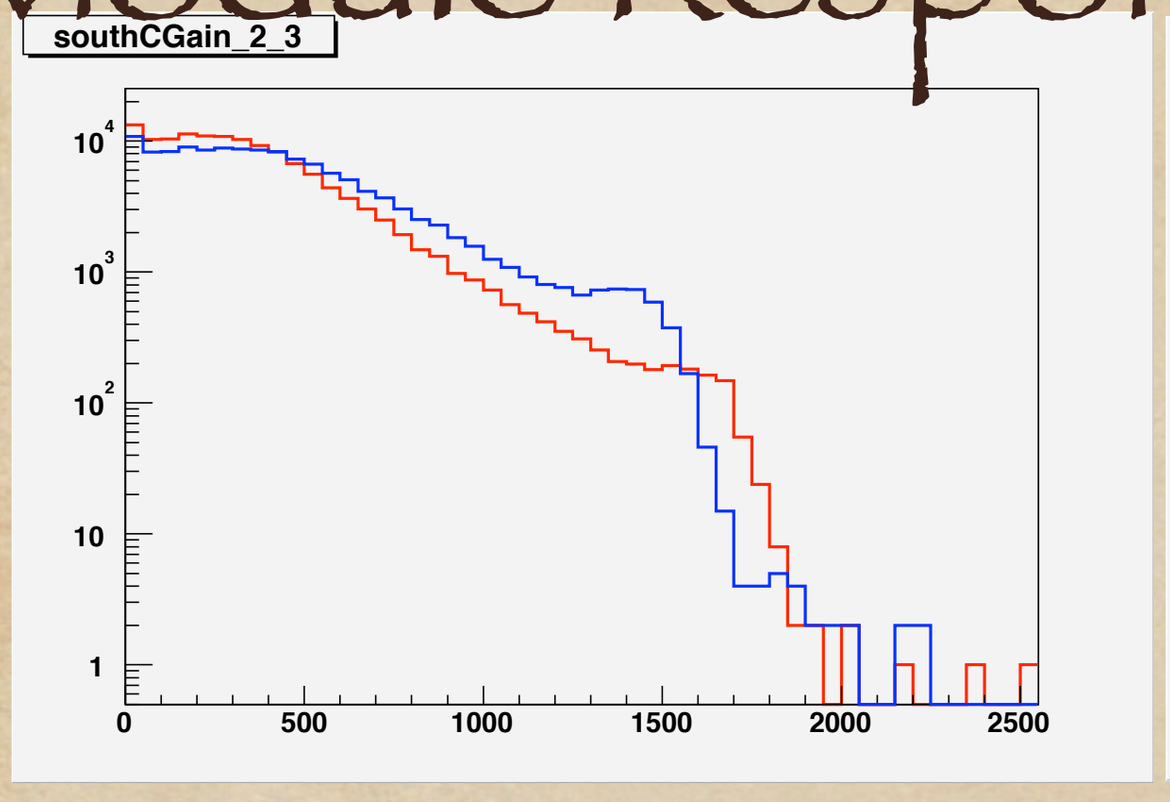
~~EMCAL~~ FCAL Electronics

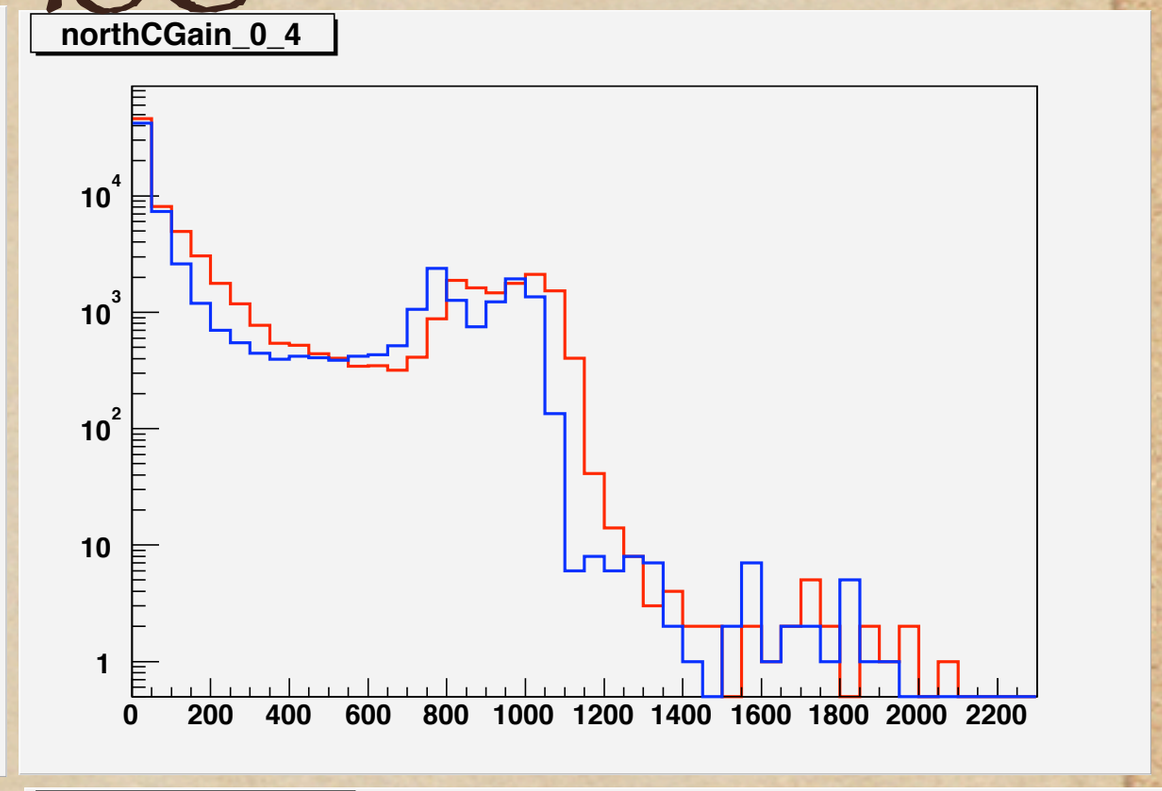
- Post and Pre Samples Separated by 424 ns
- Channels with less occupancy, greater fraction at full scale

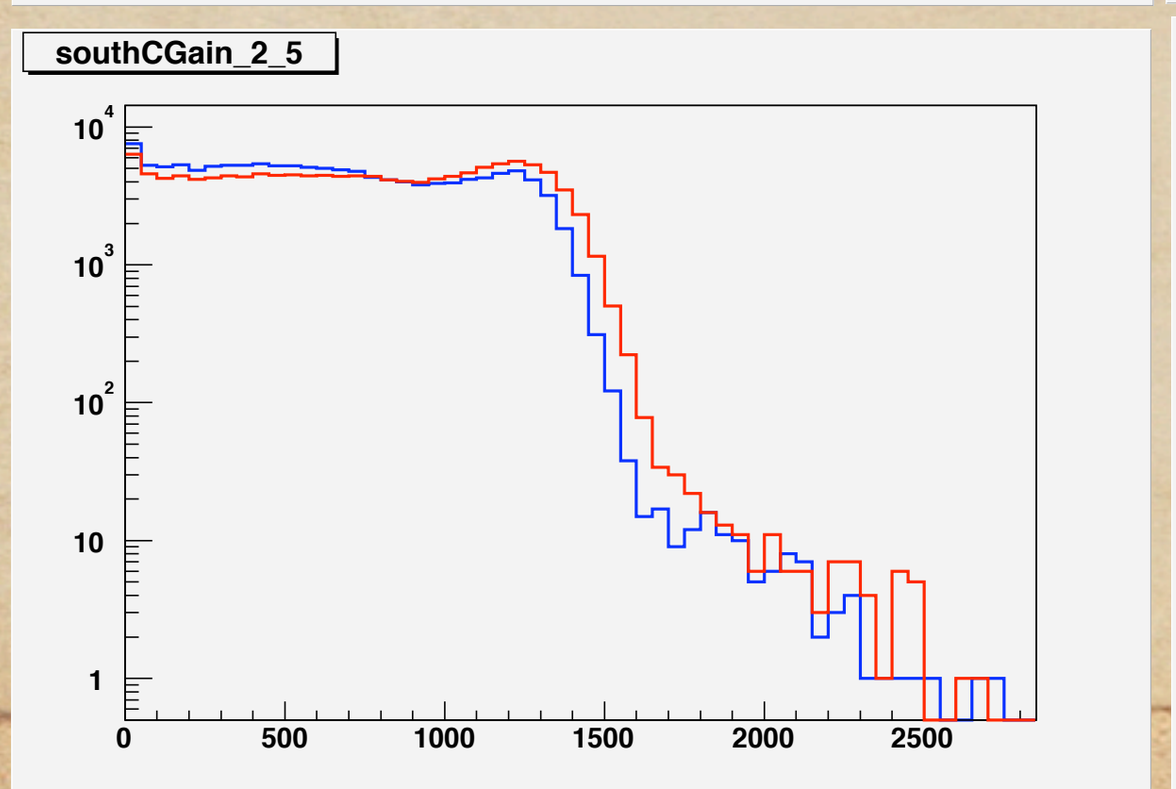


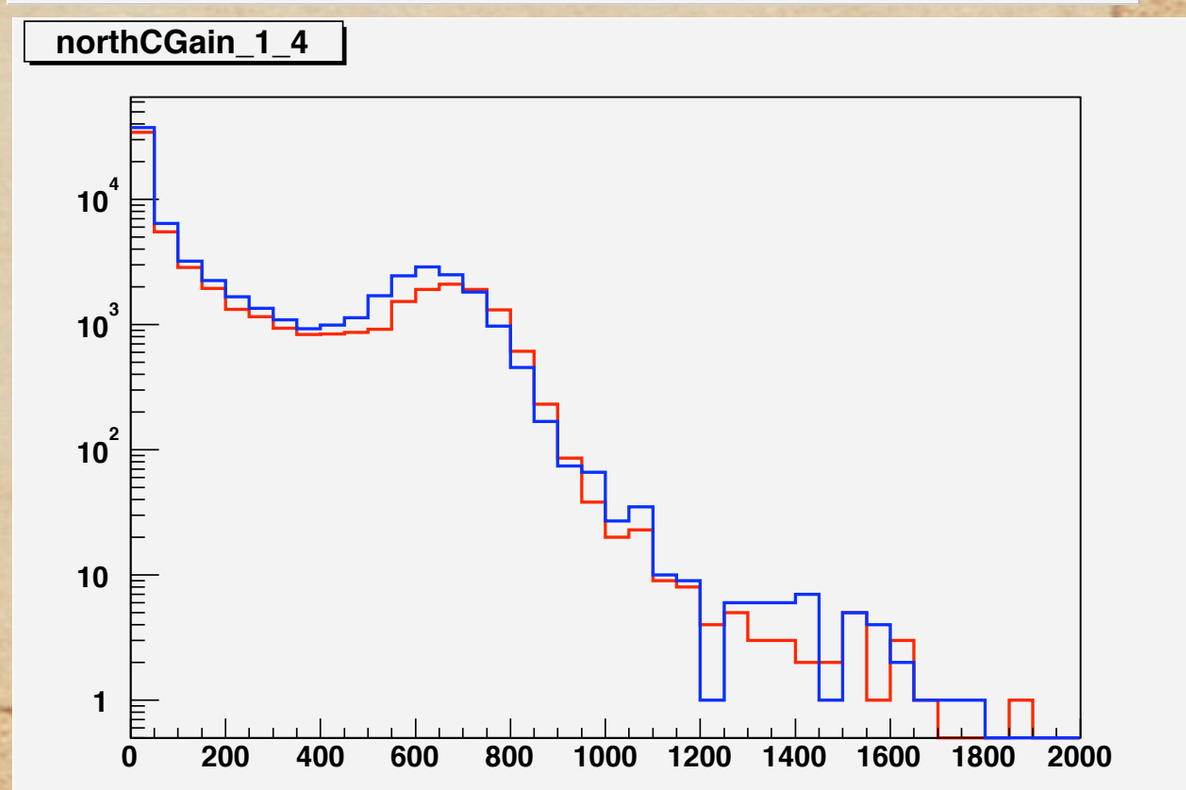


Module Response





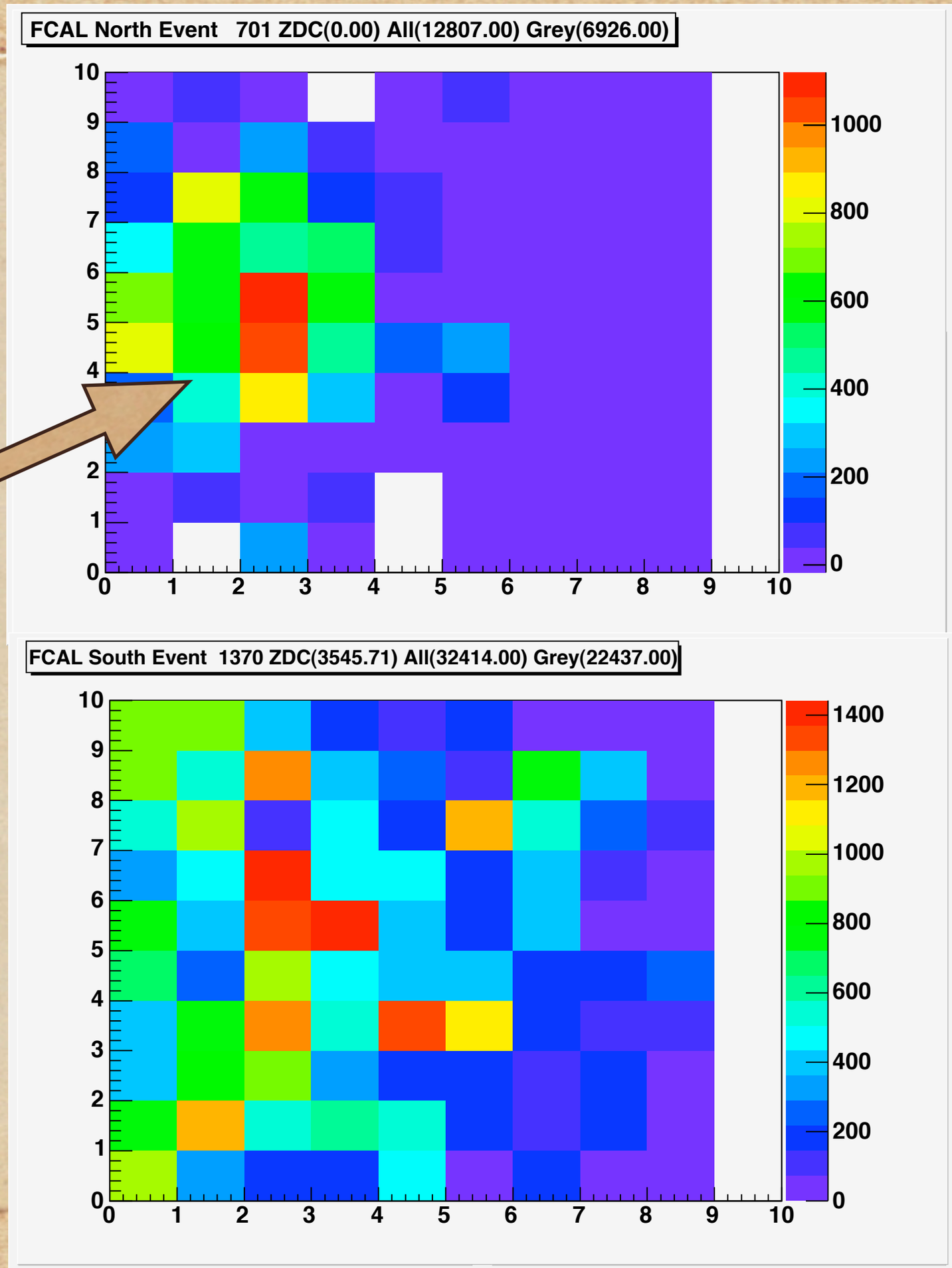


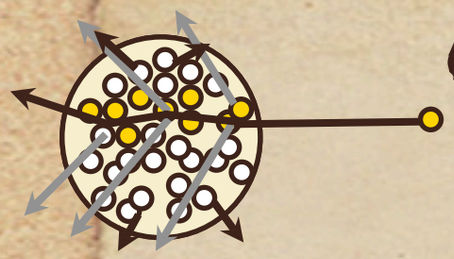


Single d-Au Event

Spectator Proton Peak

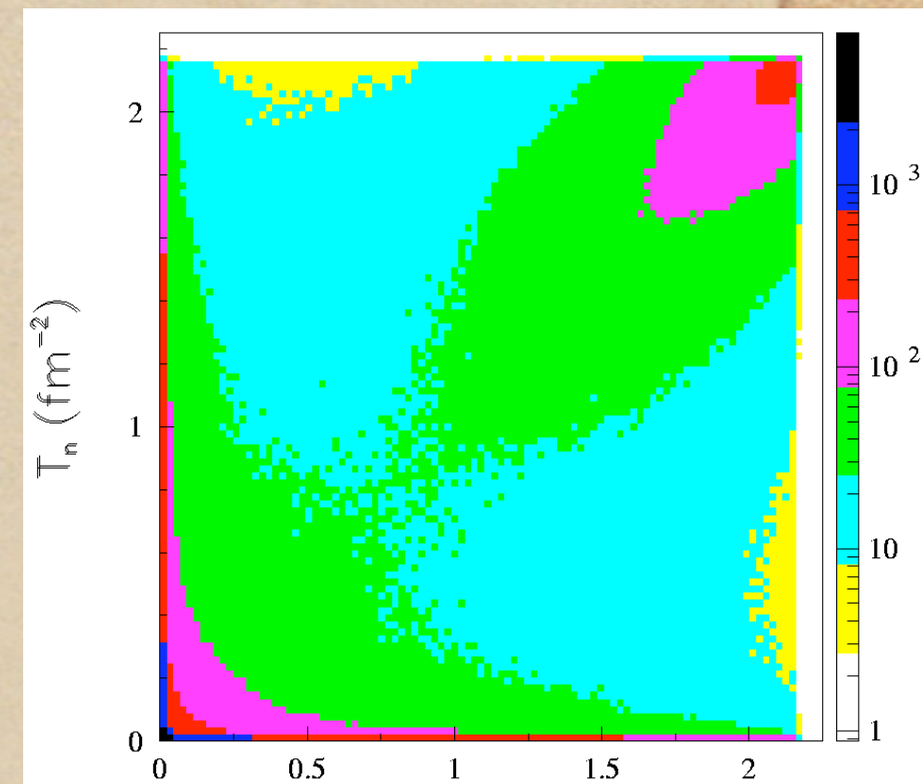
Recoil Protons

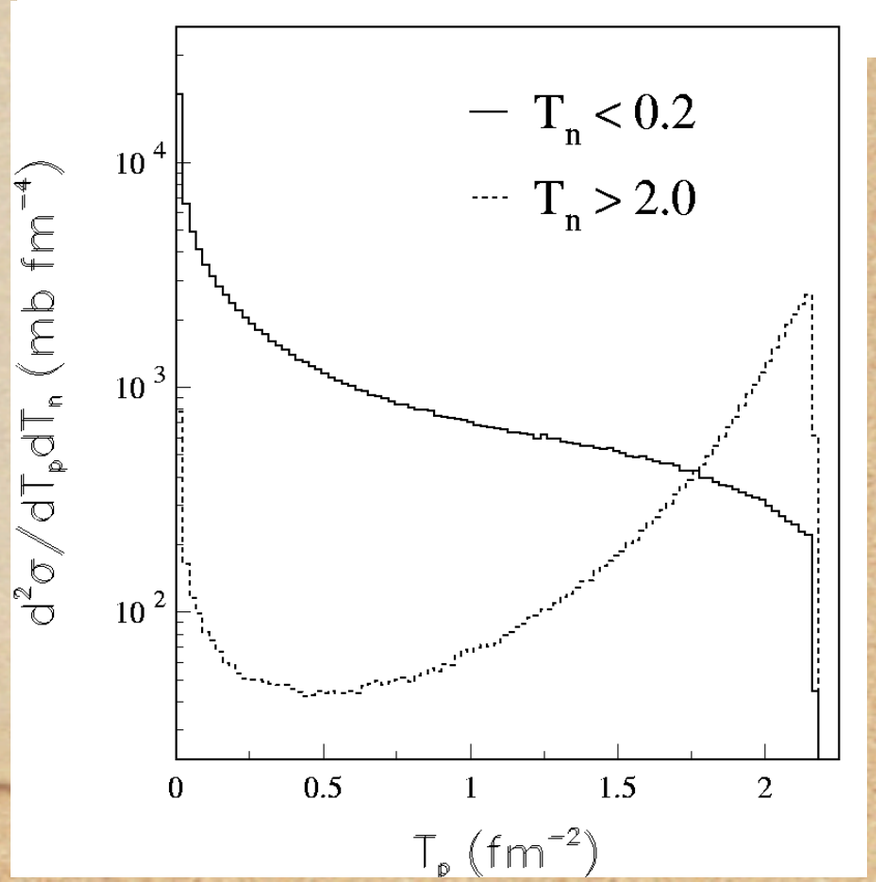




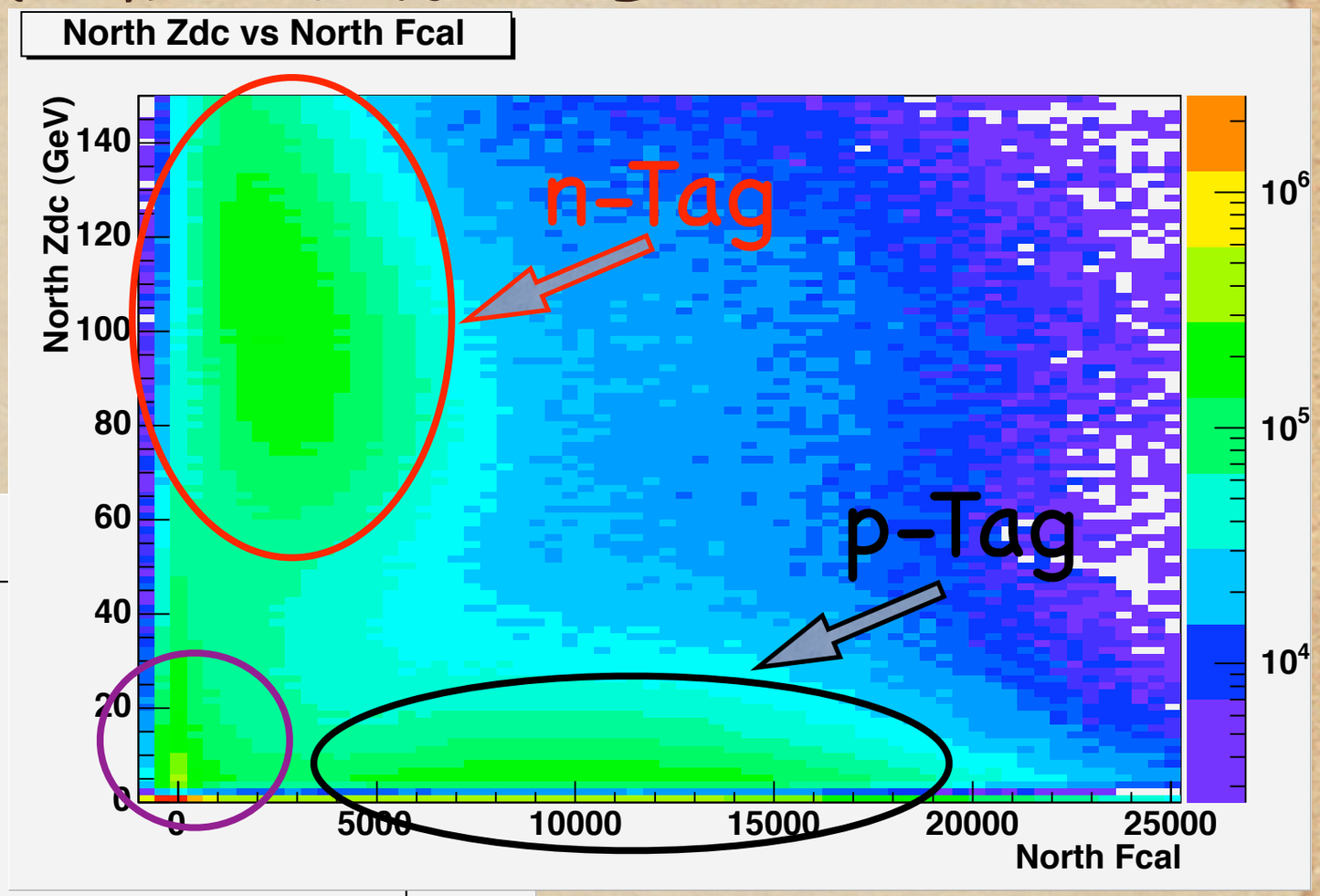
deuteron-Au Collision Geometry

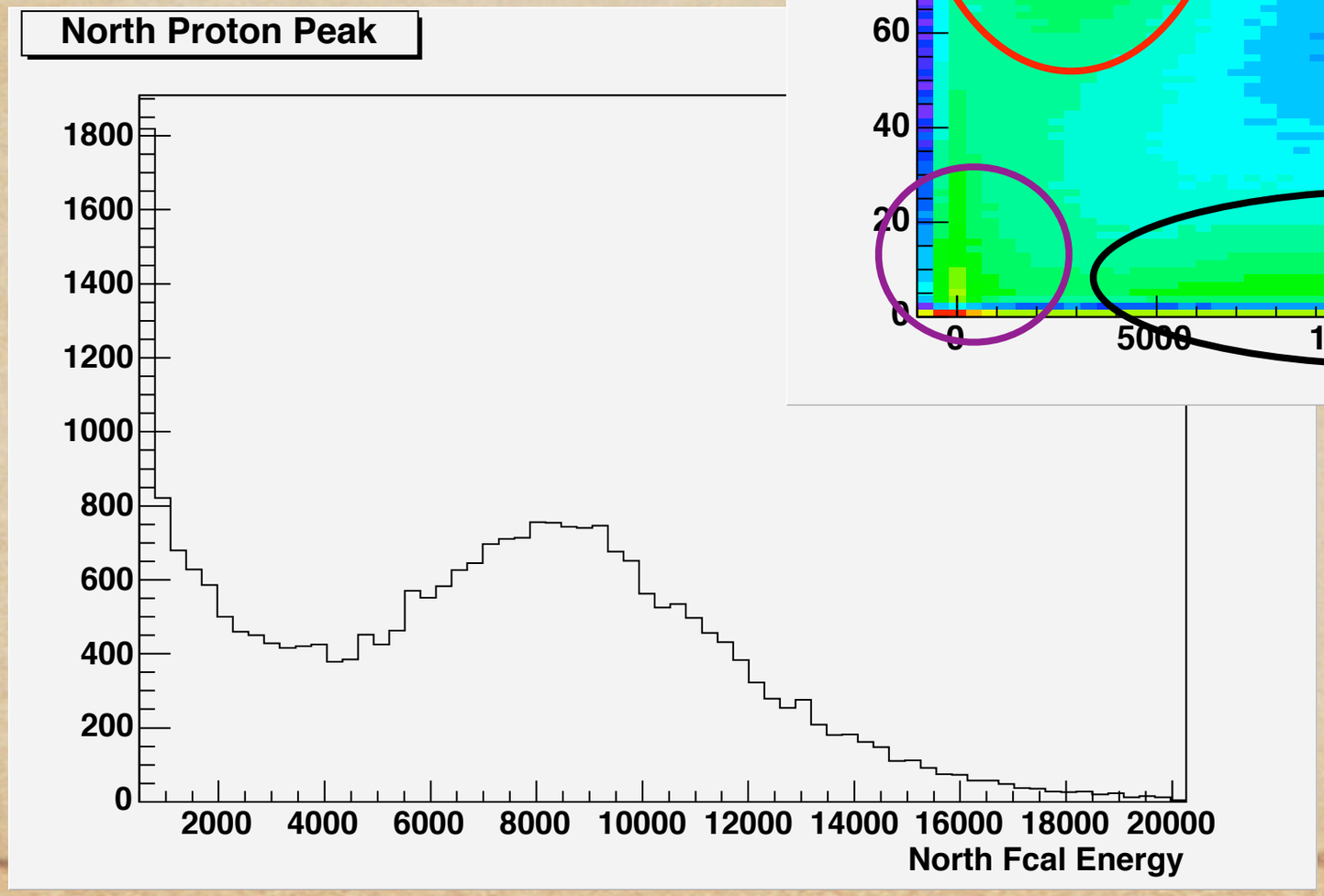
- Deuteron-Au is approximately two independent collisions
- Not exactly true:
  - Brian Cole's study of thickness seen by proton and neutron of deuteron





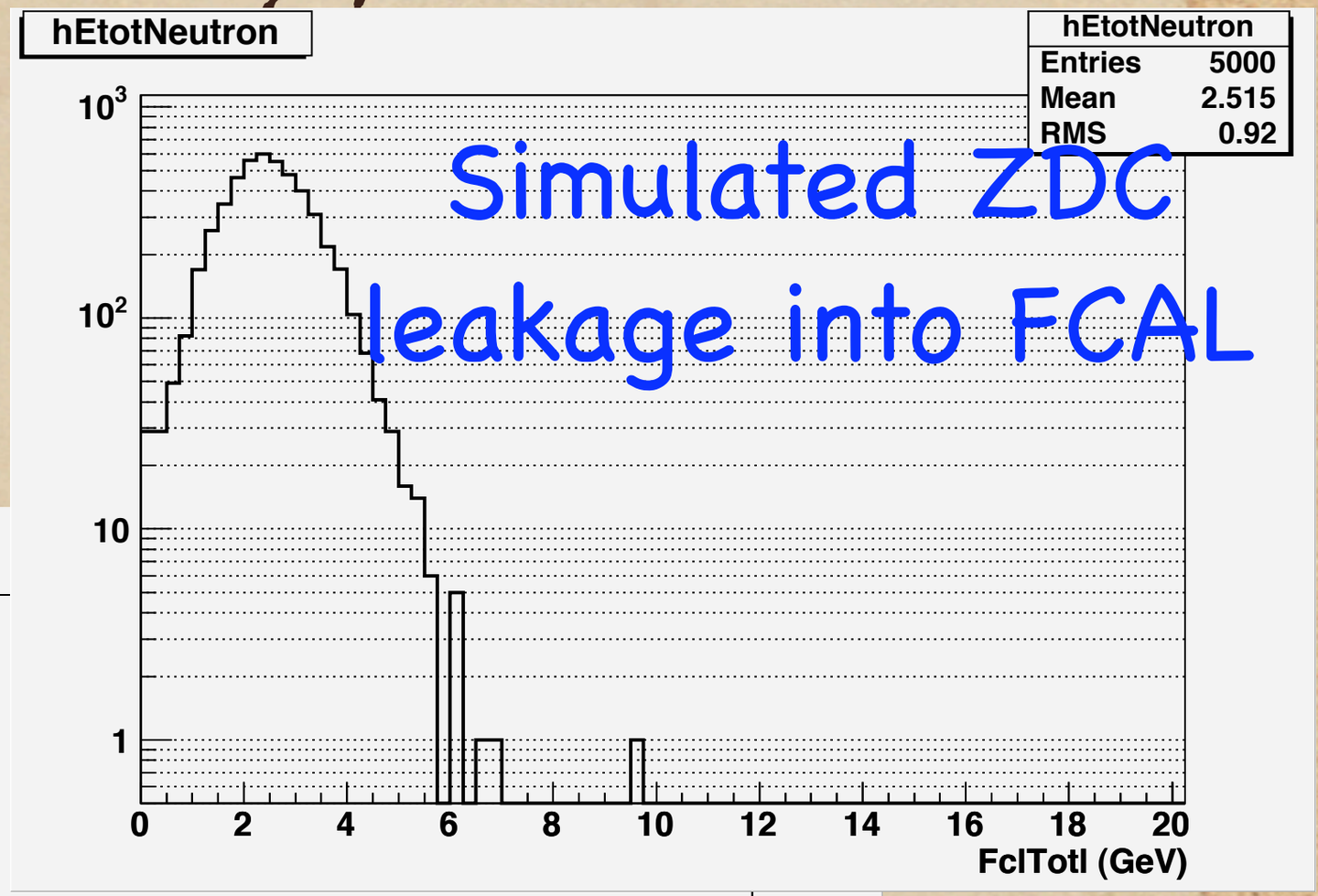
North FCAL-ZDC

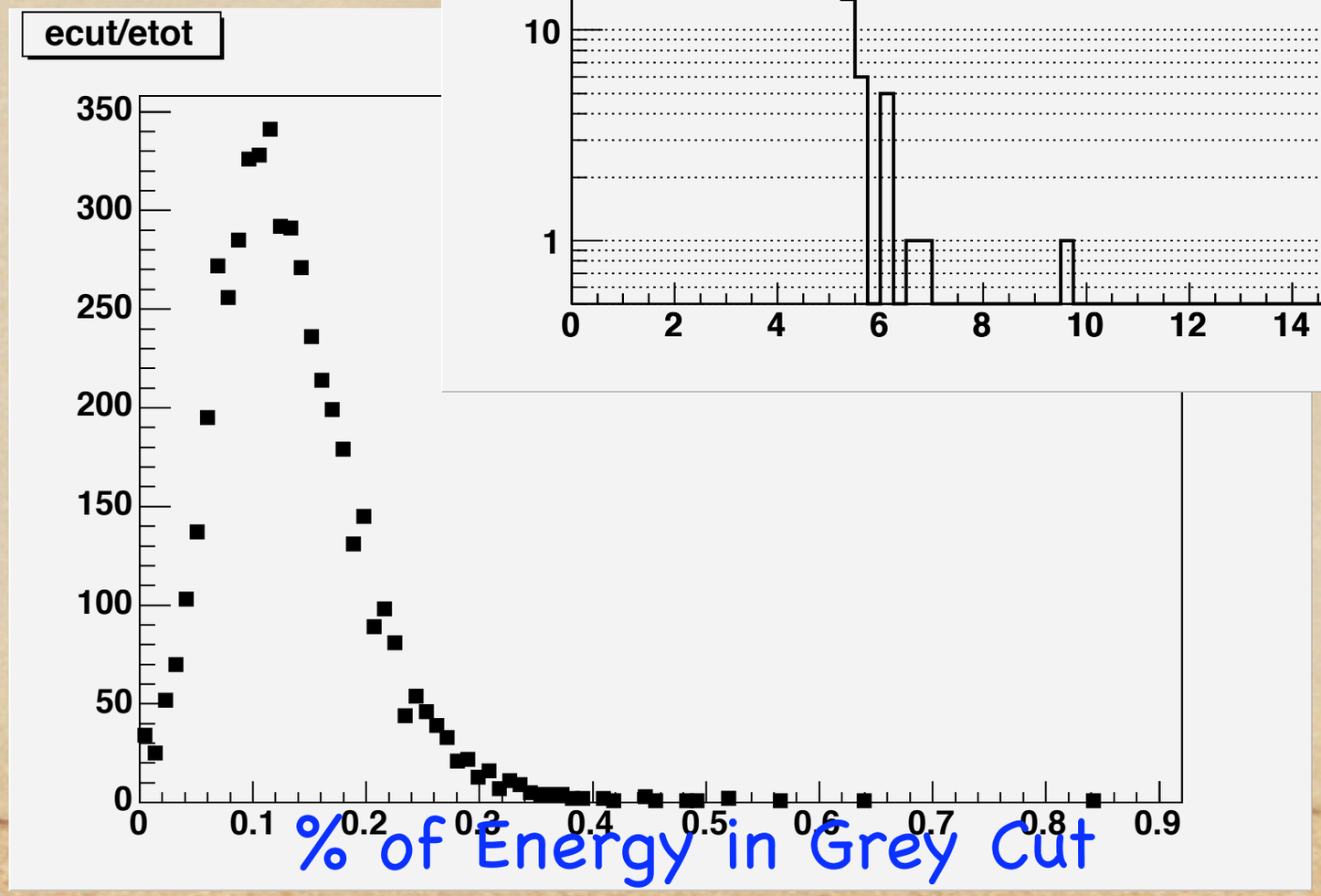




FCAL Backgrounds

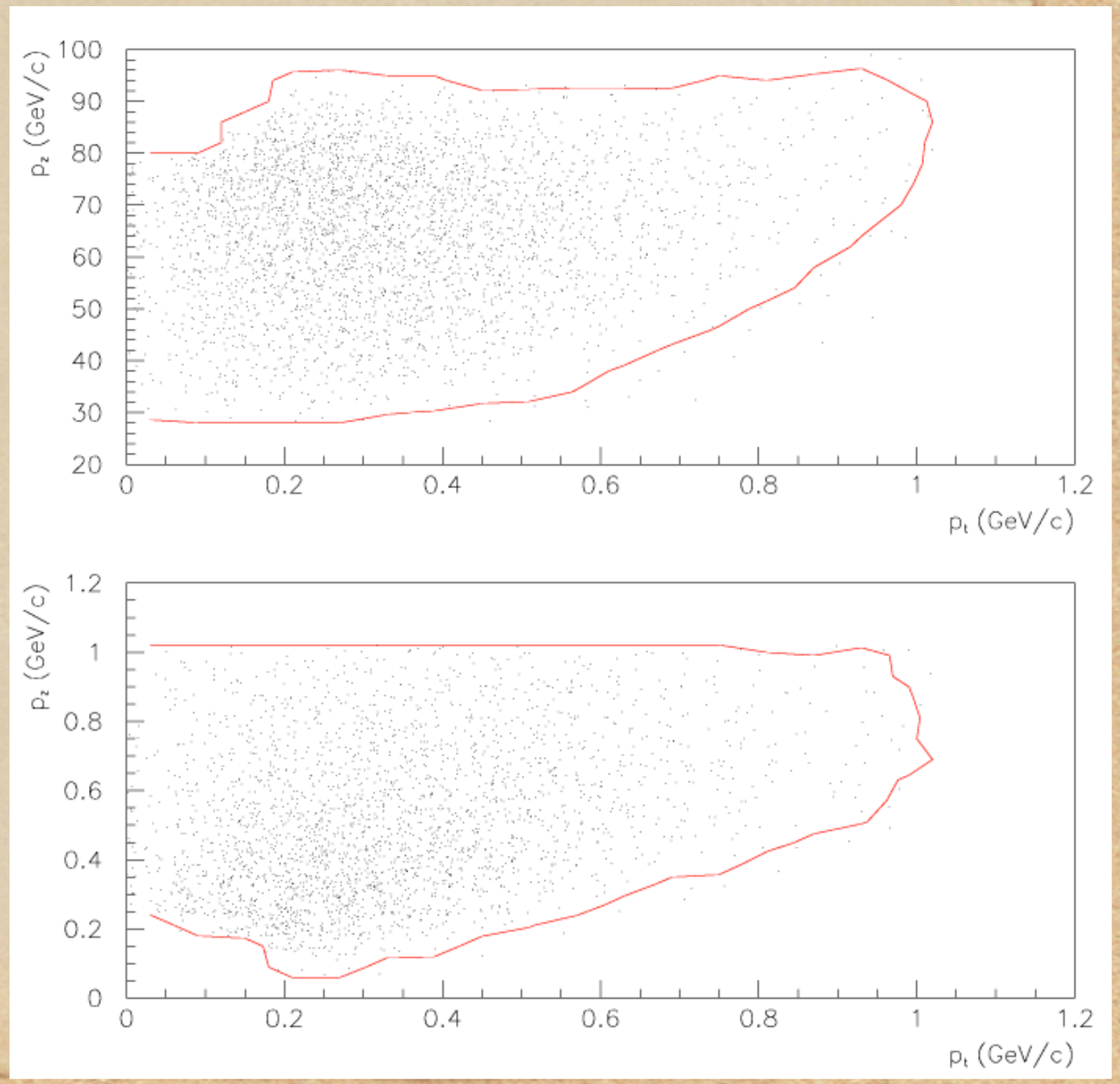
- ZDC leakage
- Forward Particles



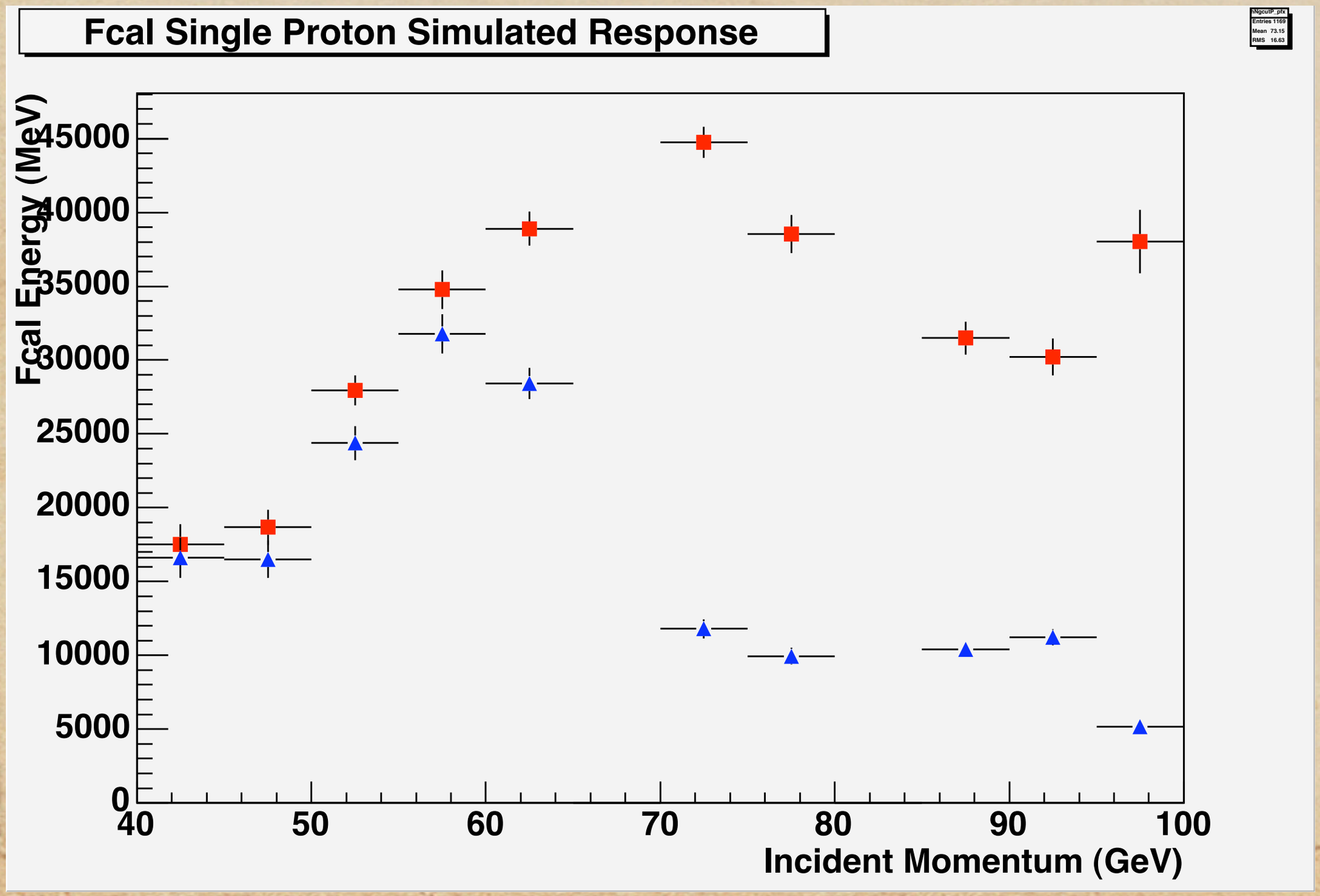


Au Side - Best Guess

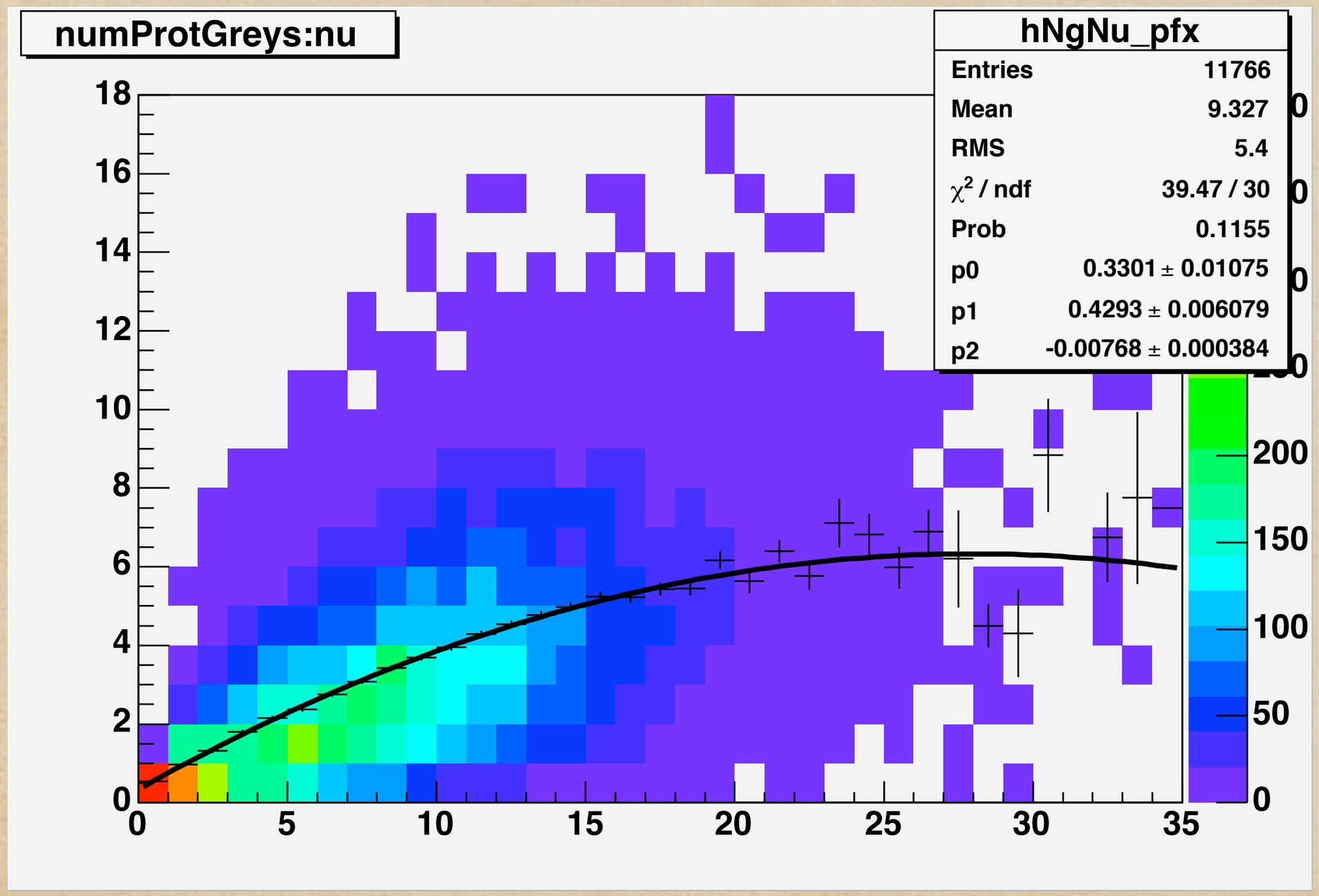
- In Au Frame
  - Recoil neutrons/ protons
  - Evaporative neutrons/protons



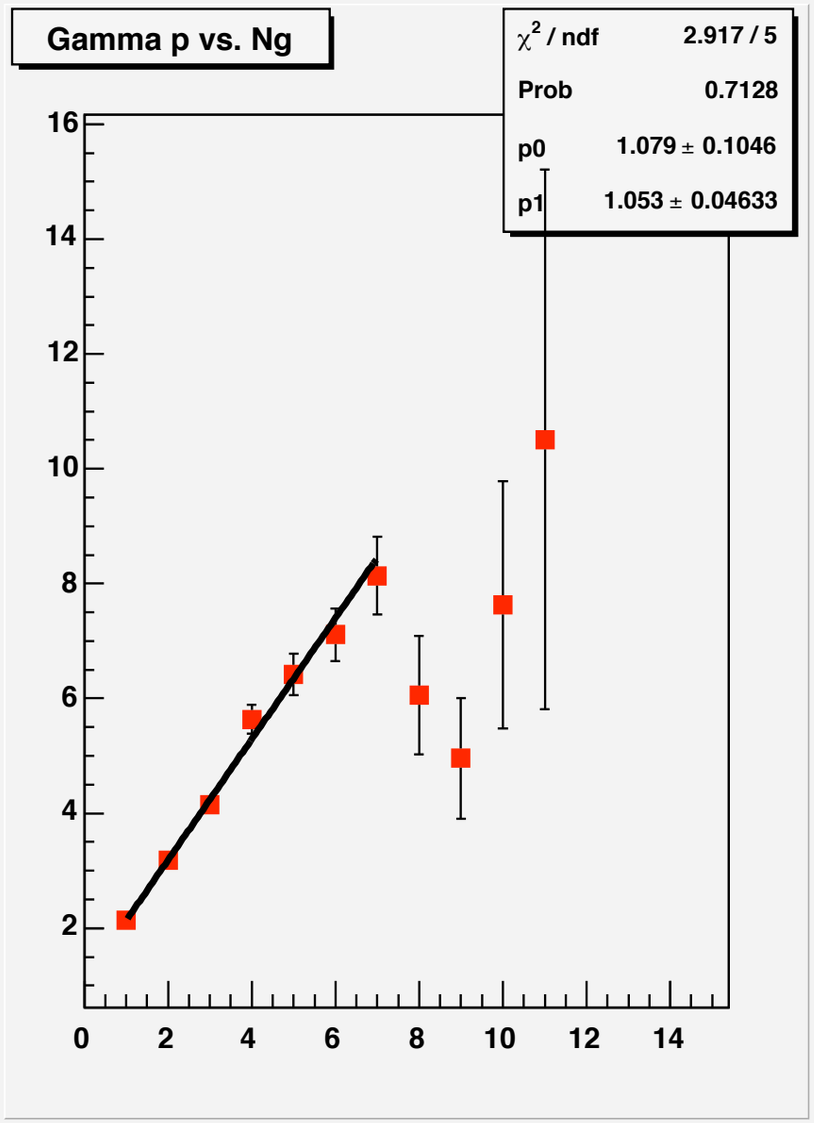
FCAL Acceptance

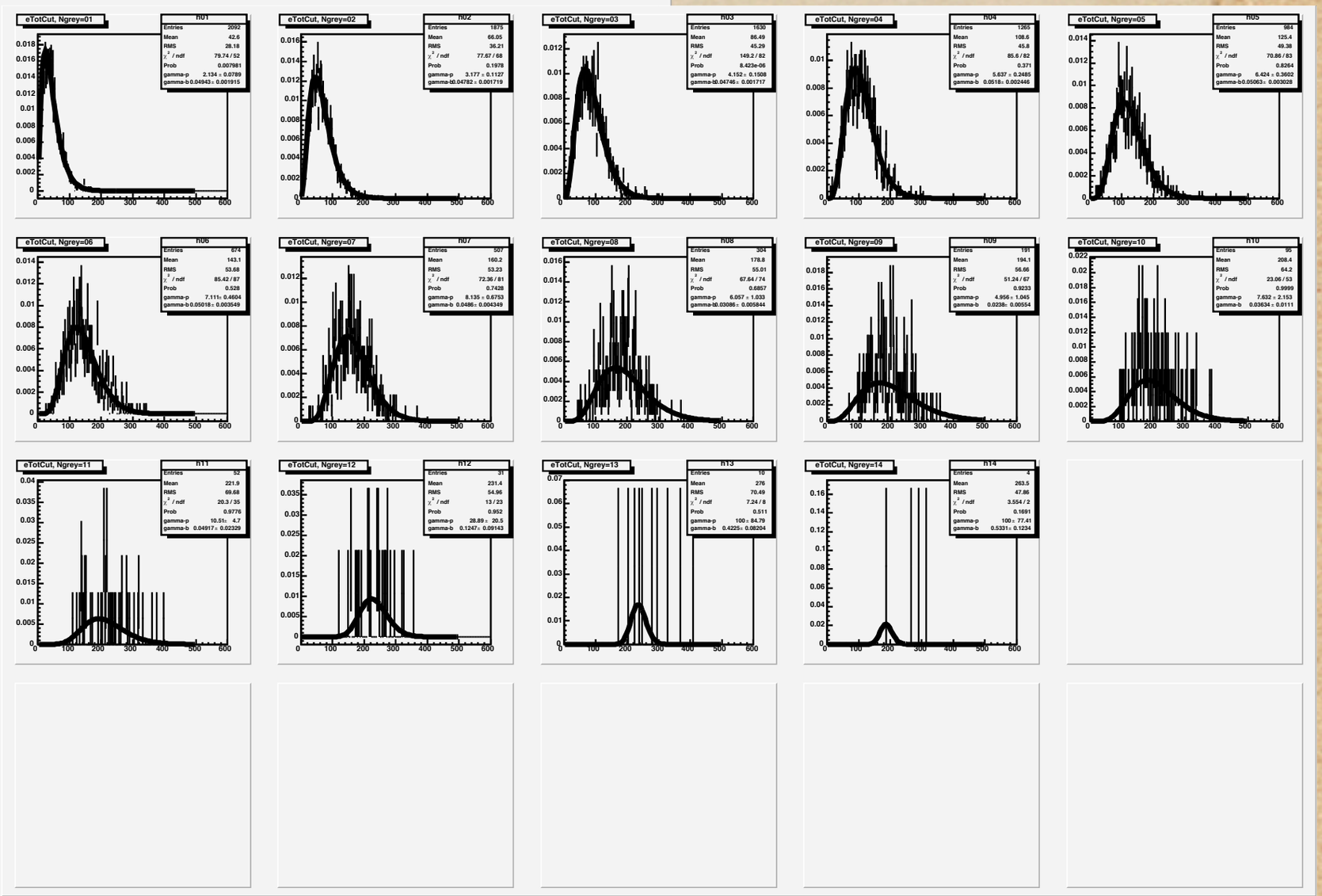


RQMD Simulation for Recoils

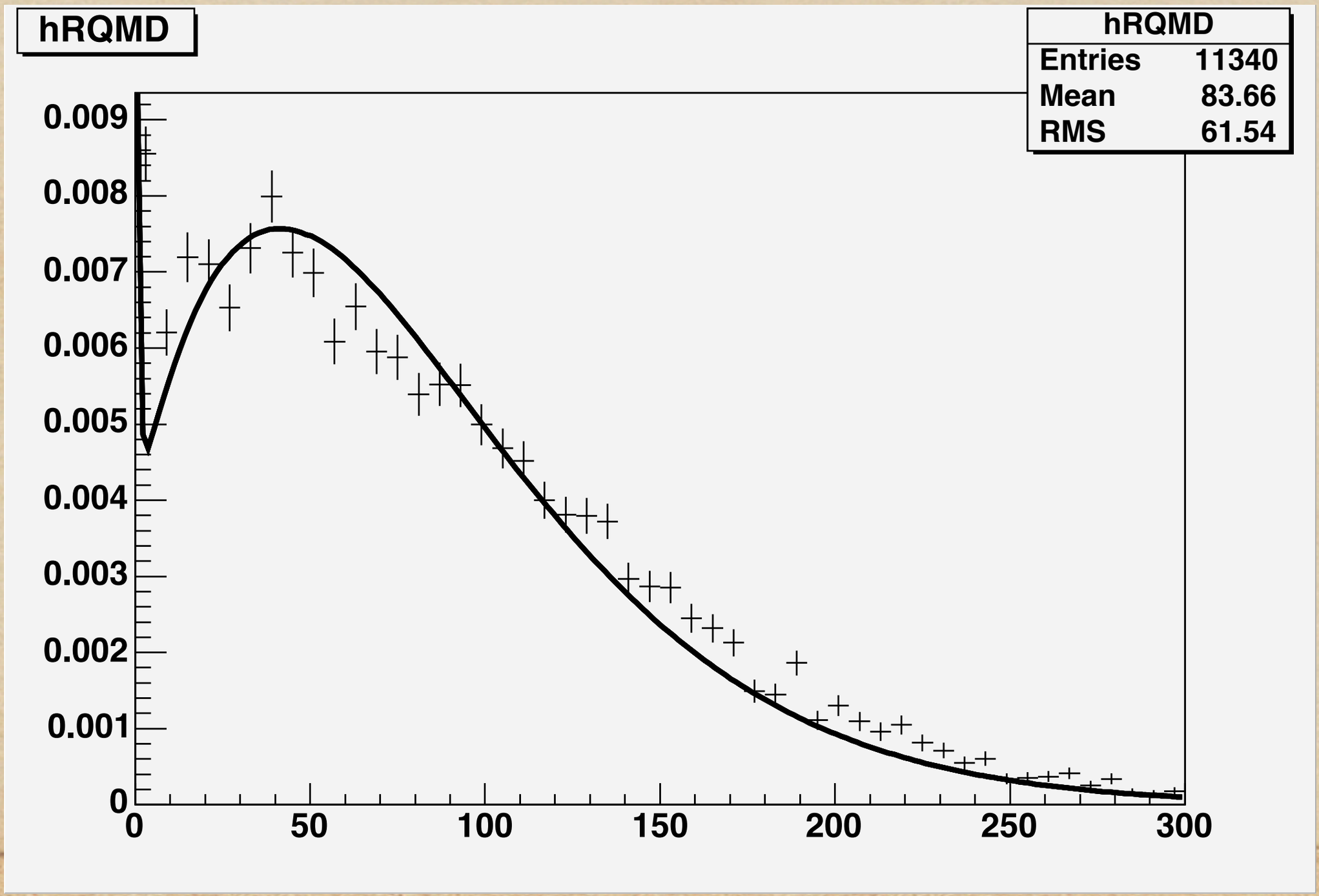


FCAL Simulated Energy Response

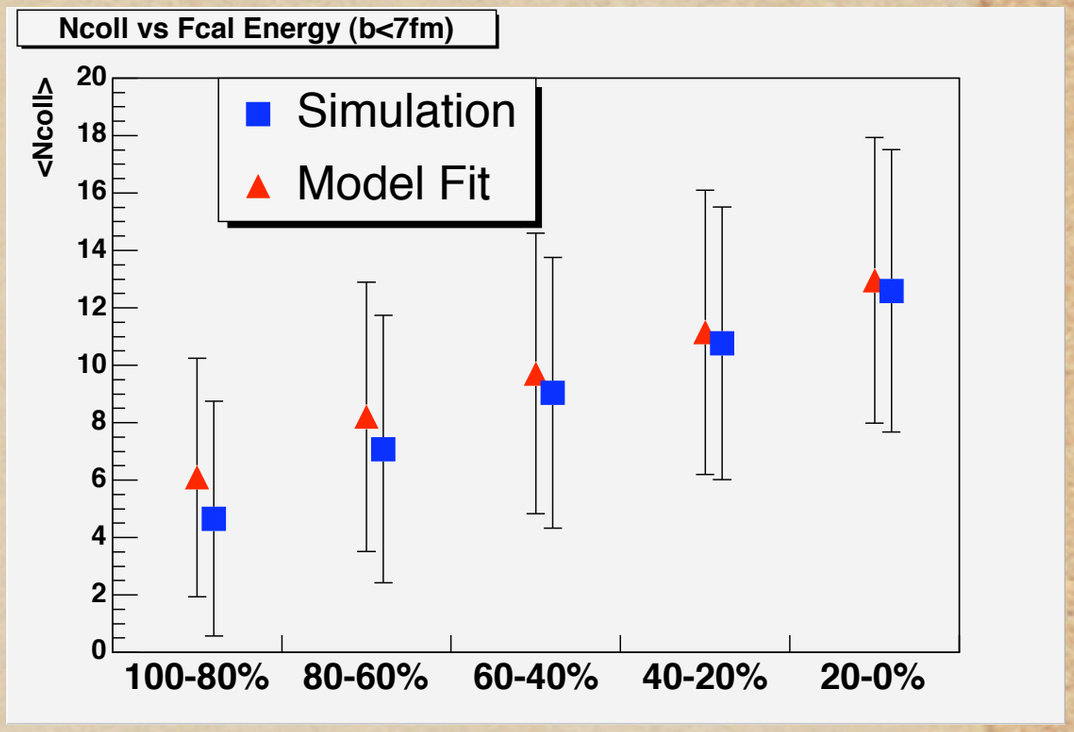


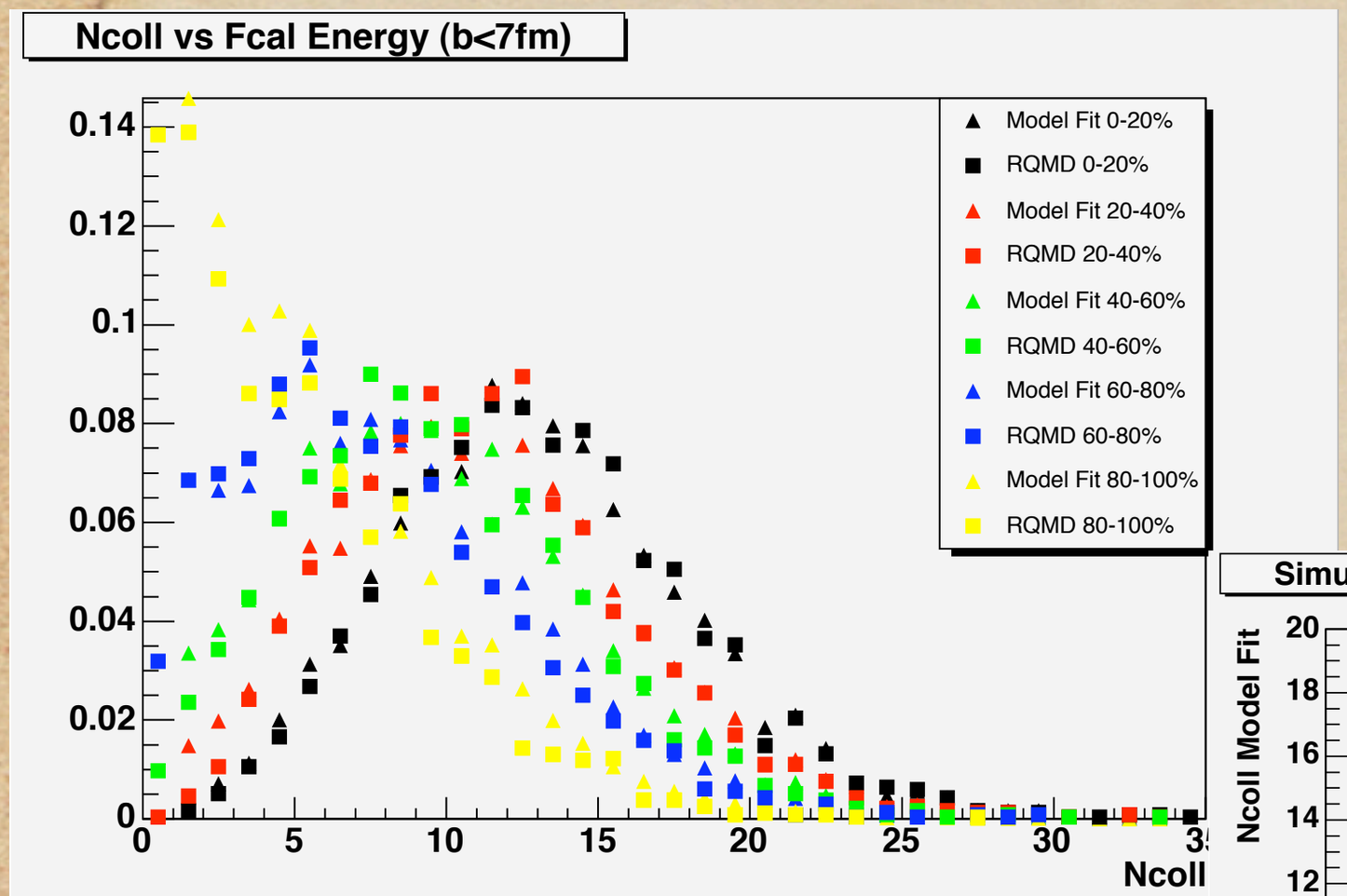


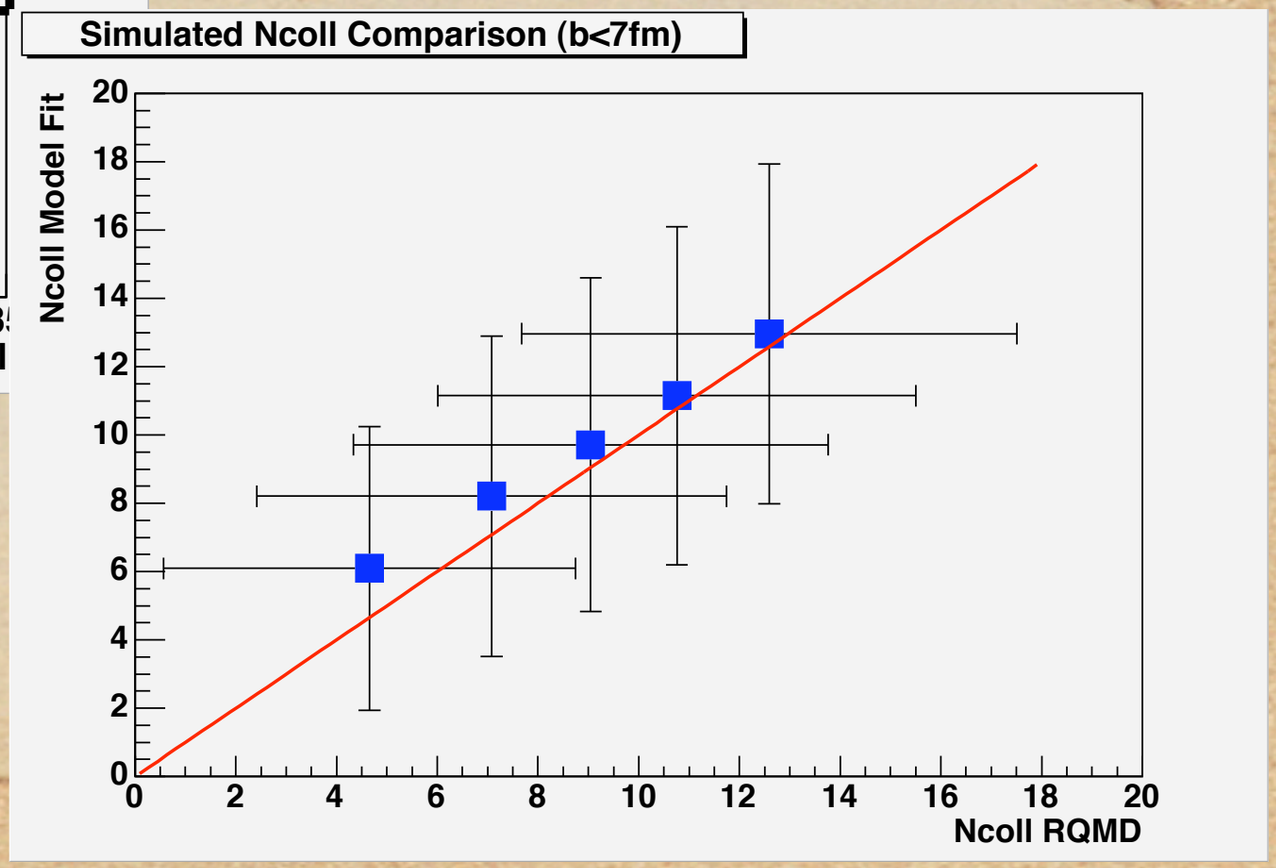
Model Reproduces Energy Distribution



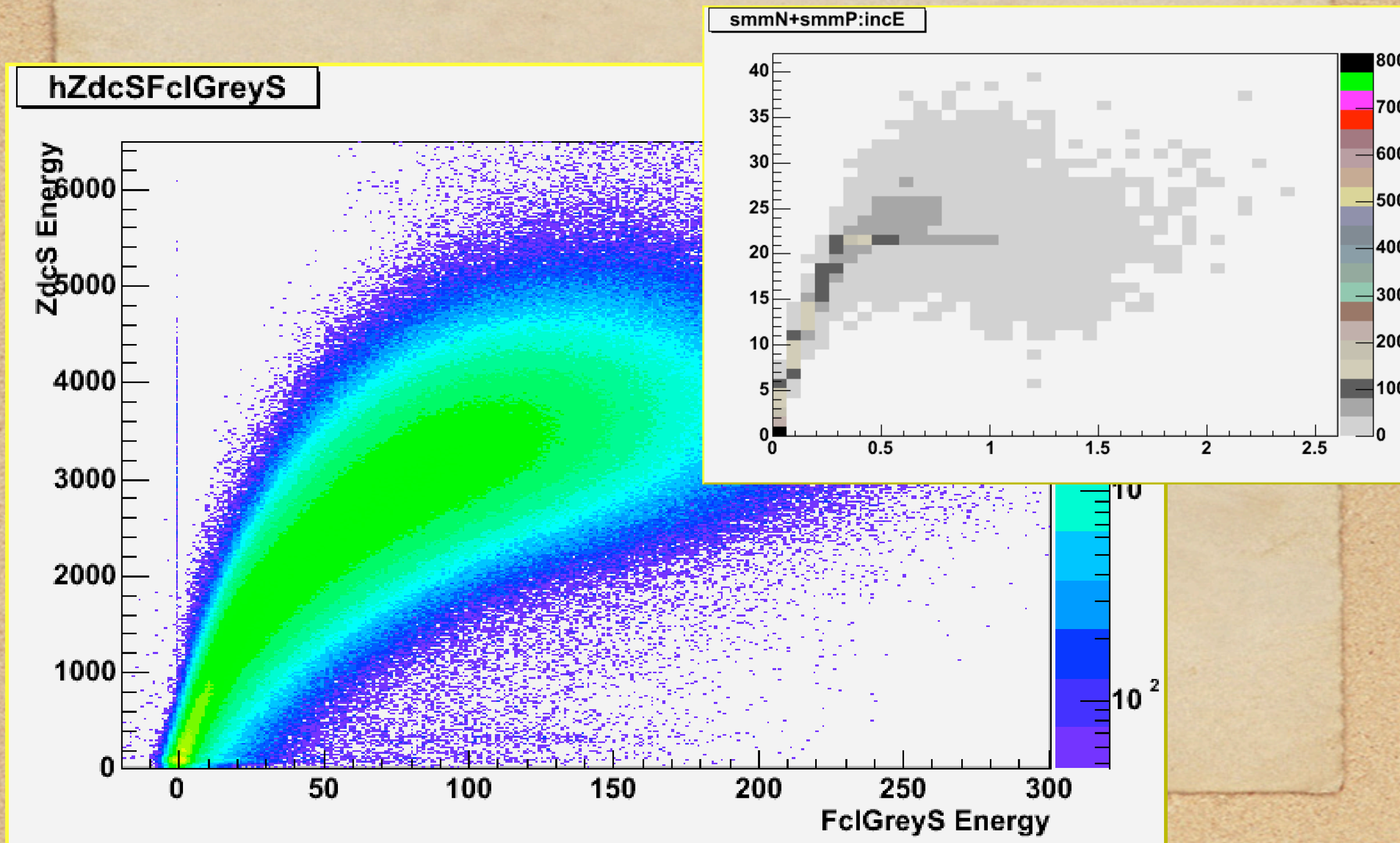
Extract Ncoll



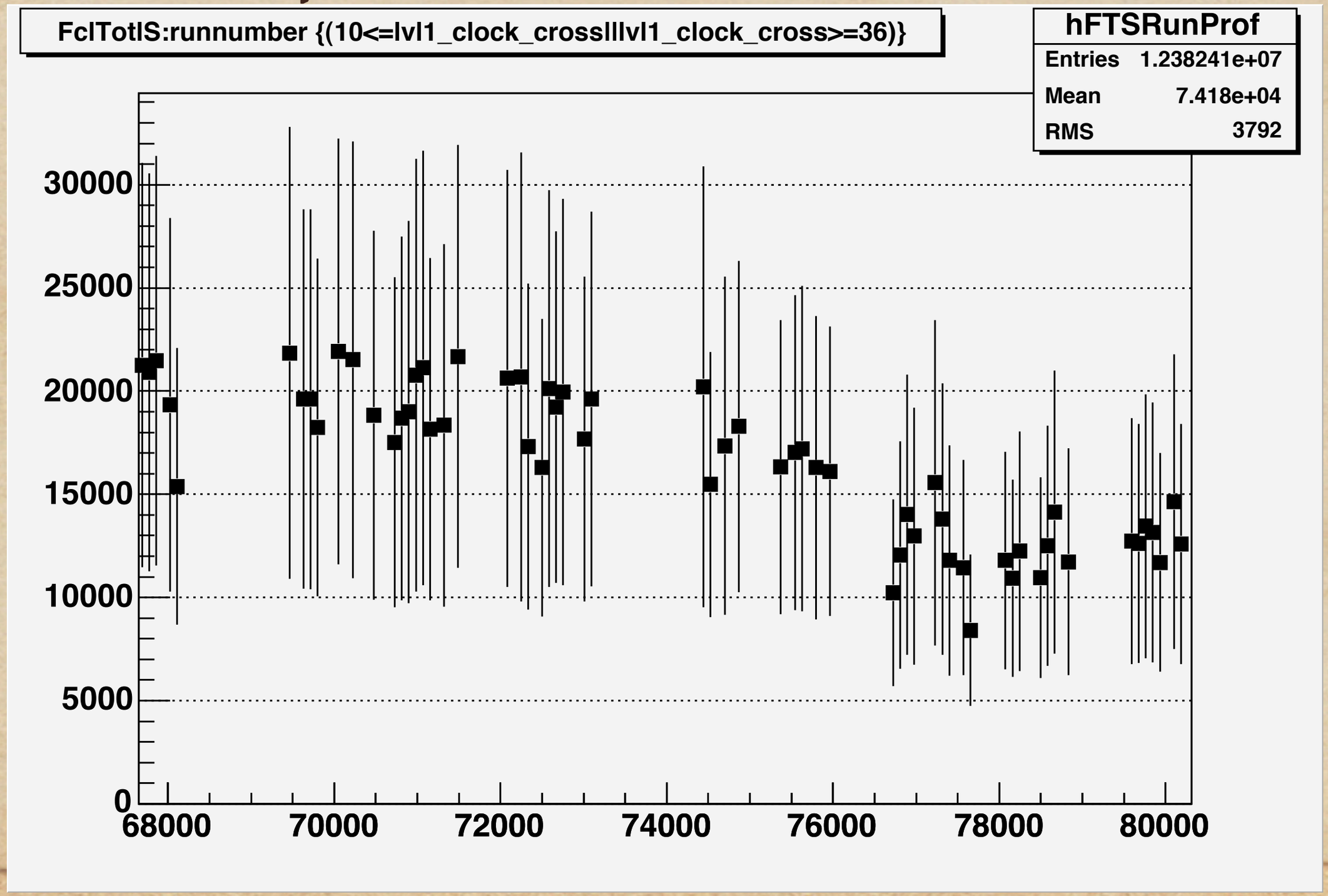




South FCAL-ZDC Correlation

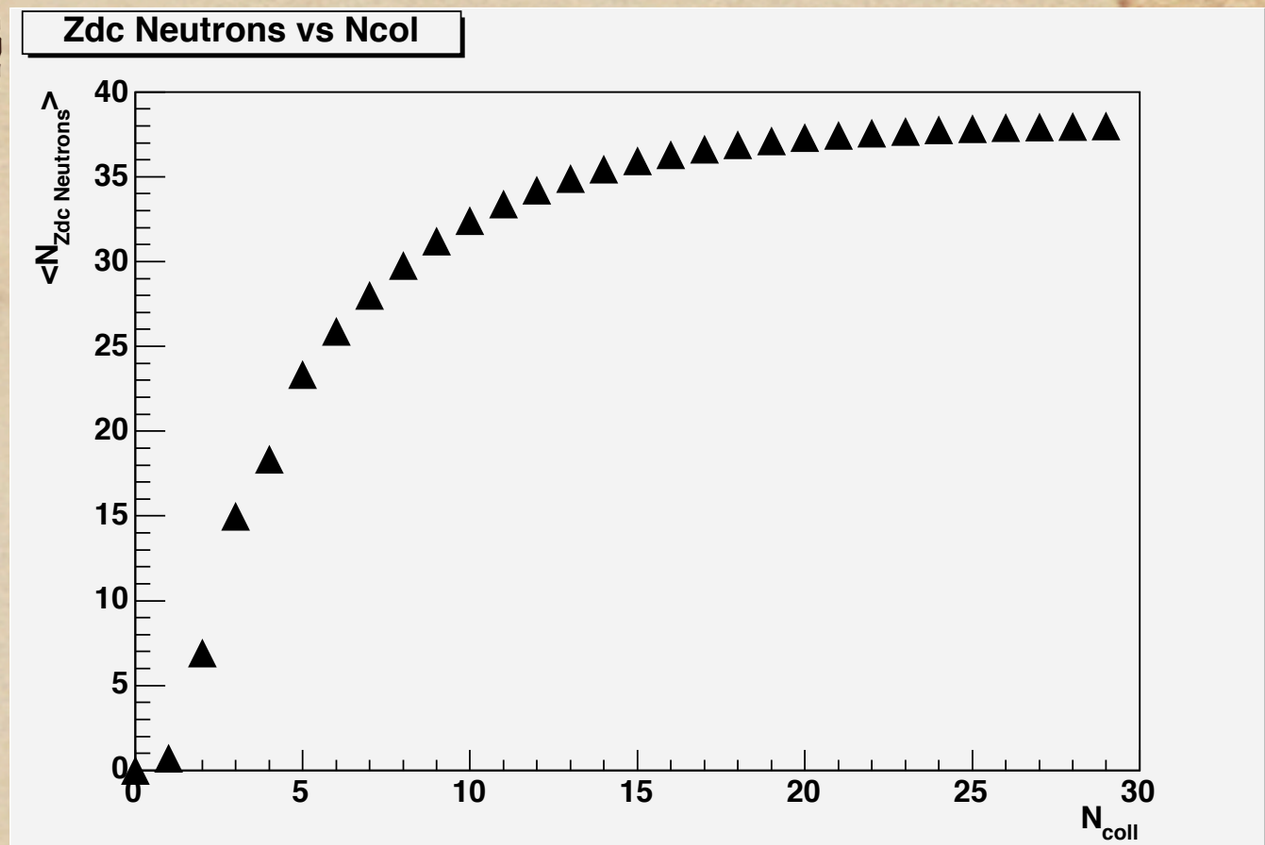


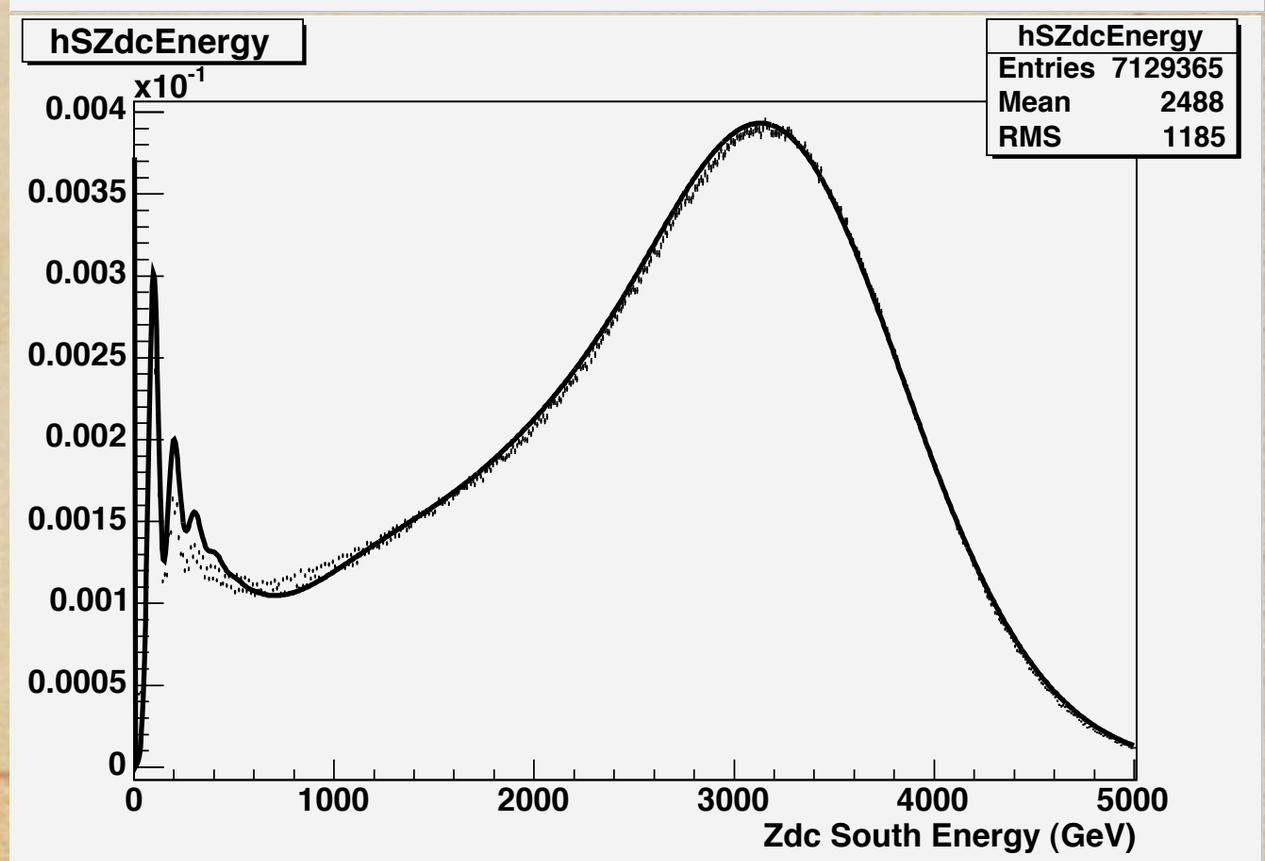
Complications...



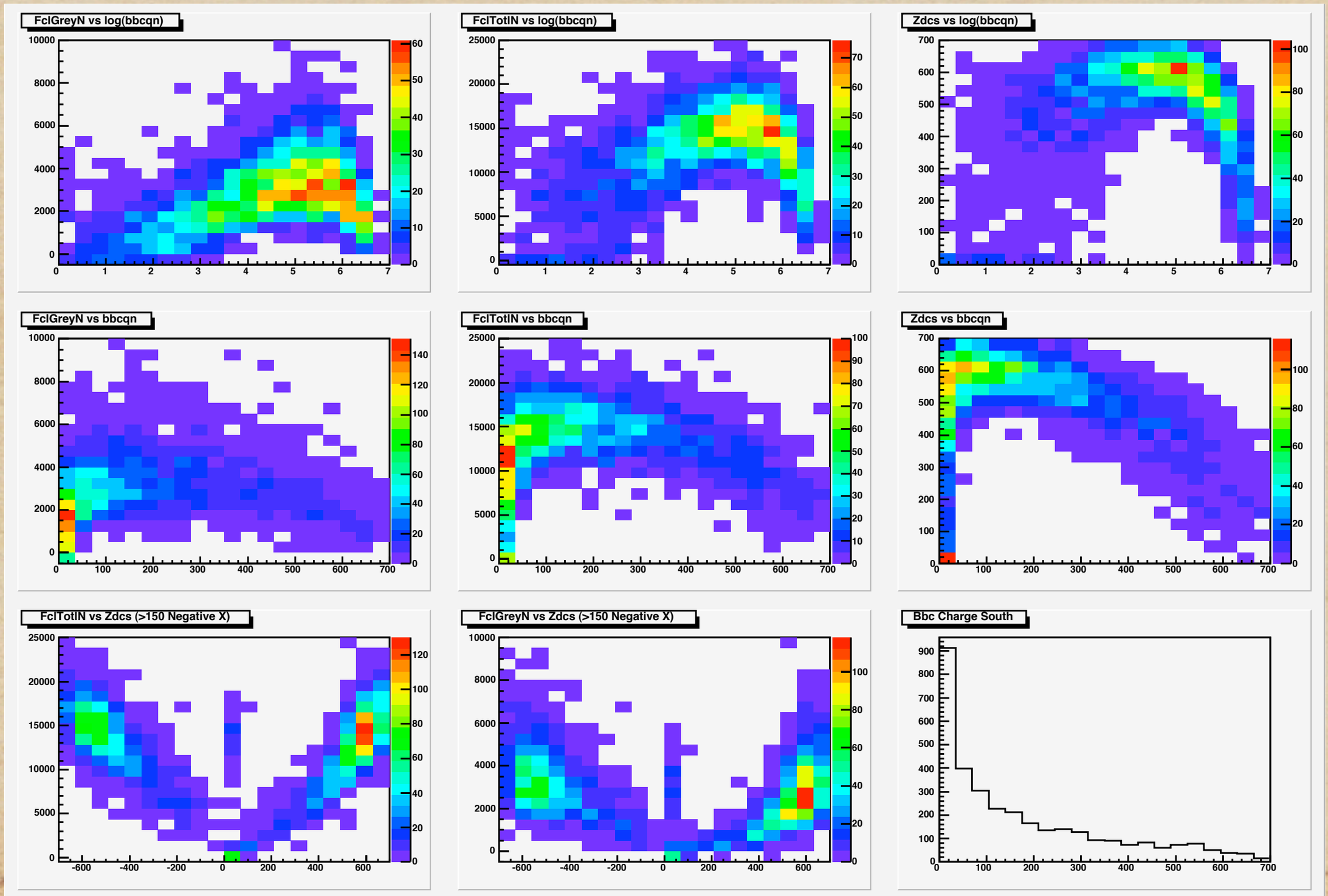
ZDC Energy

- FCAL analysis my require subtraction of ZDC leakage





FCAL in Au+Au


FclGreyN vs log(bbcqn)
FclTotIN vs log(bbcqn)
Zdcs vs log(bbcqn)
FclGreyN vs bbcqn
FclTotIN vs bbcqn
Zdcs vs bbcqn
FclTotIN vs Zdcs (>150 Negative X)
FclGreyN vs Zdcs (>150 Negative X)
Bbc Charge South

FCAL Plans

- d-Au
  - Proton Tagged/Neutron Analyses
  - Centrality Determination
    - Ncol(Ngrey) analysis proceeding
    - Evaporative component from SMM and E900
- Au-Au Reaction plane (Masui, Kaneta,Esumi)