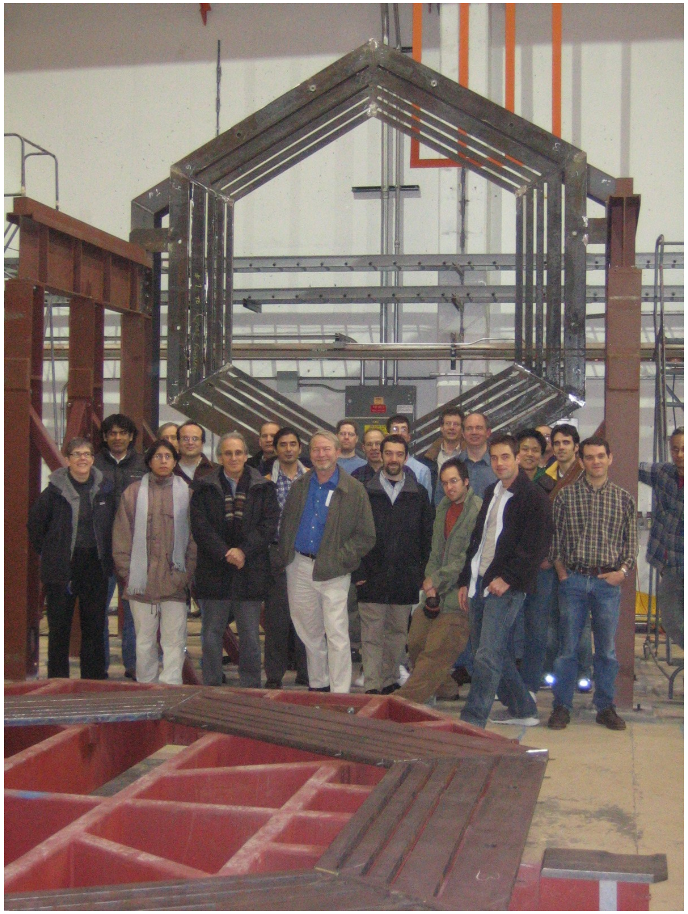
MINERvA

High Precision Neutrino Scattering at the Main Injector

Mike Kordosky

William and Mary

MINERvA Introduction



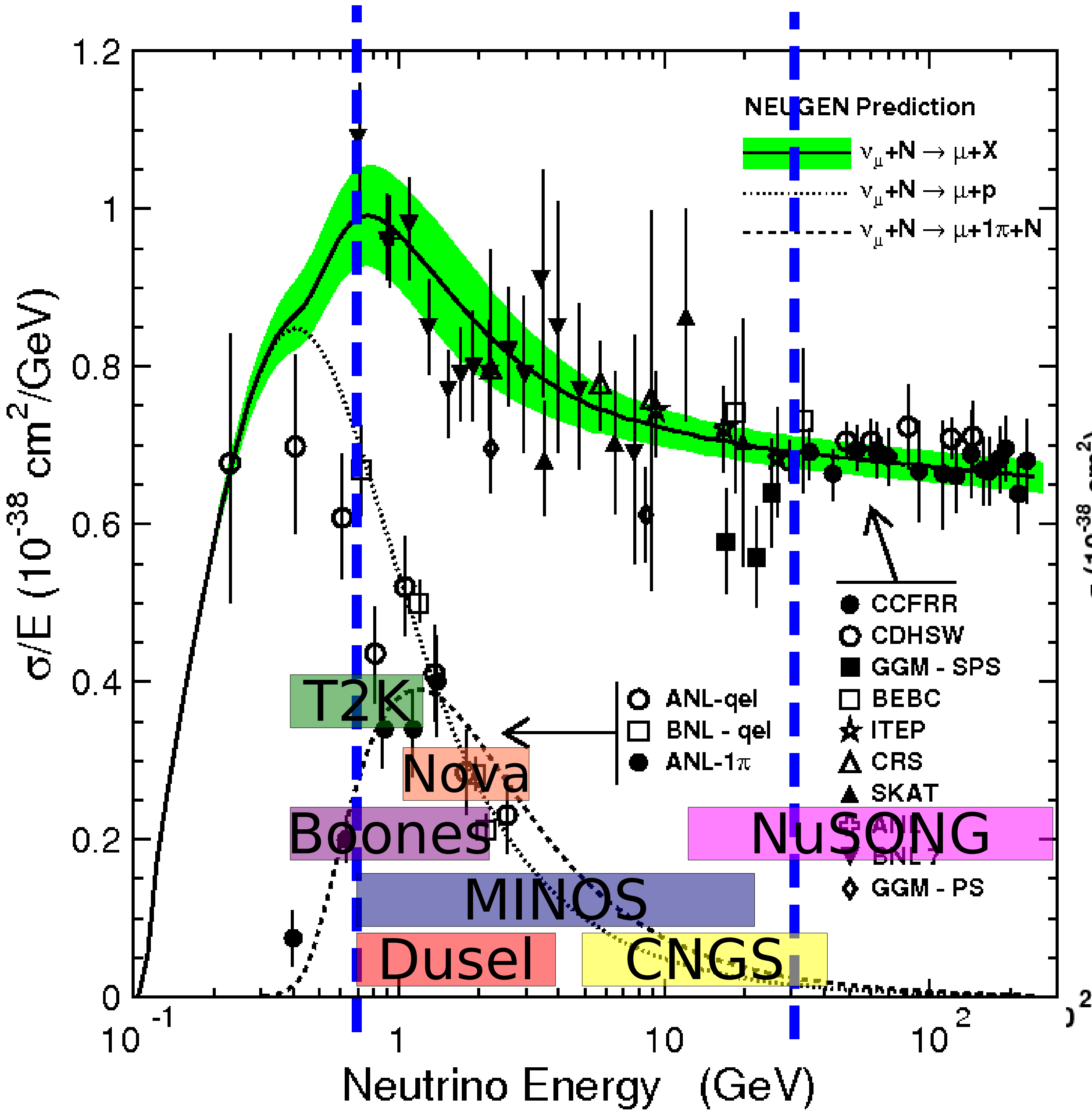
- MINERvA: precision ν scattering @ NuMI
- Highly segmented fully active scintillator tracking chamber, surrounded by ECAL, HCAL
  - Fully reconstruced exculsive final states
- Emphasis on tried and true technology
- Nuclear targets for A dependence
- Upstream of MINOS (muon spectrometer)

Motivation for MINERvA

- Entering a precision era in neutrino physics
- Our tool: ν scattering on nuclei @ few GeV
  - Knowledge anchored to bubble chamber data
  - Nuclear targets add significant complication
  - Exclusive final states important
- APS Multi-Divisional Study on the Physics of Neutrinos:

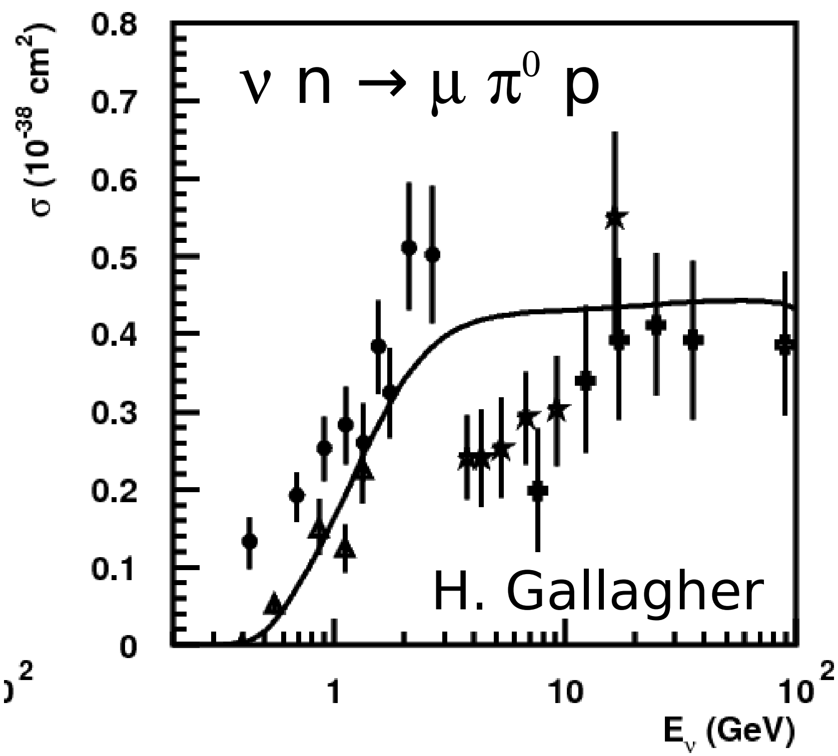
"*determination of the neutrino reaction and production cross sections required for a precise understanding of neutrino-oscillation physics and the neutrino astronomy of astrophysical and cosmological sources.* ***Our broad and exacting program of neutrino physics is built upon precise knowledge of how neutrinos interact with matter.***"

Energy Coverage



Estimated Cross section uncertainties

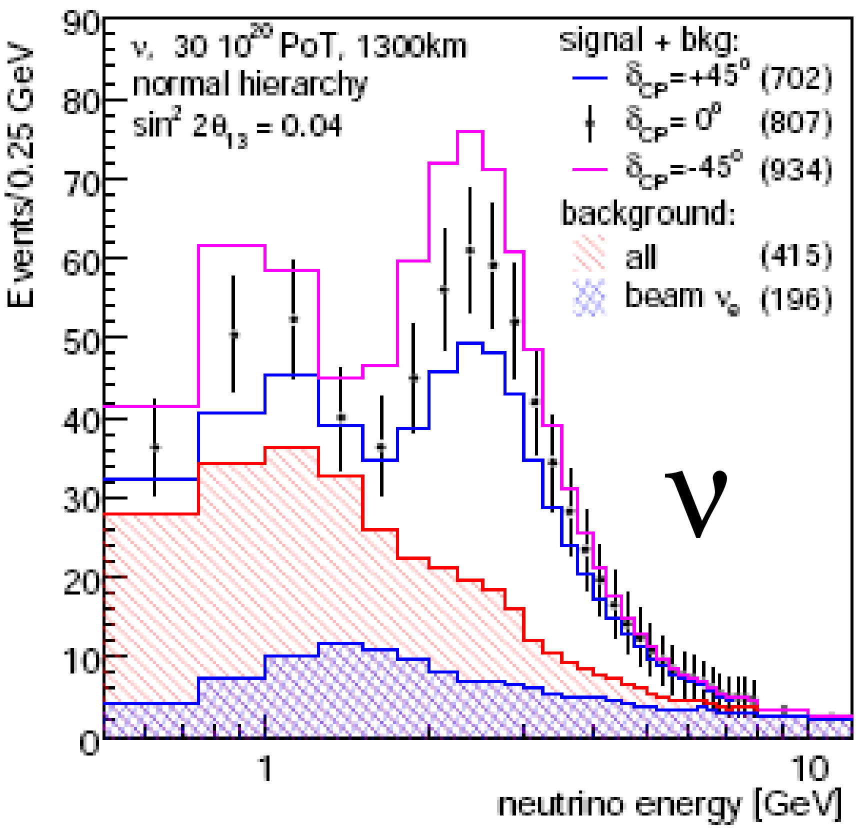
Process	Current	After MINERνA
QE	20%	5%
Res	40%	5/10%(CC/NC)
DIS	20%	5%
Coh	100%	20%

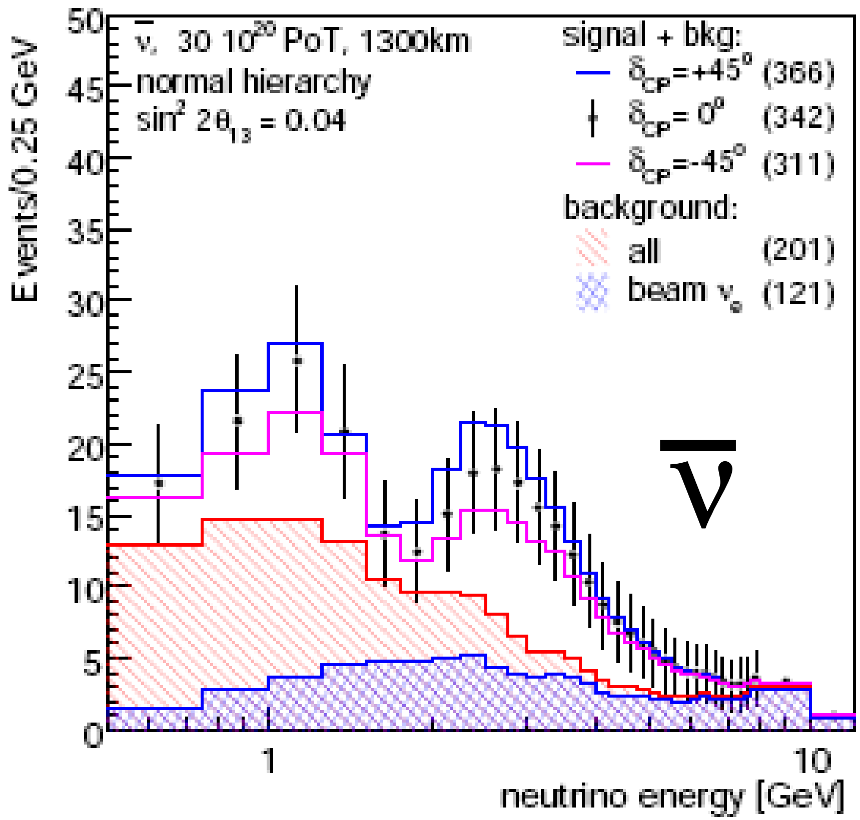


Example: DUSEL

300kt Water Cerenkov

arXiv: 0705.4396





Backgrounds from NC π^0 production feed down

Study above assumes 5% knowledge of background

Basic cross-sections have large uncertainties (30-100%)

Note: MiniBoone coherent / all π^0 = 19.5 +/- 2.7% @ 1 GeV

arXiv: 0803.3423

MINERvA Institutions

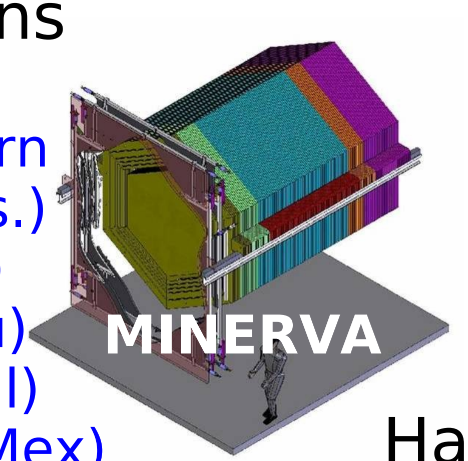
Tufts
William & Mary
FNAL
Duluth
Texas
Athens

NOVA

MINOS

Pitt

Northwestern
MCLA (Mass.)
UNI (Peru)
PUCP (Peru)
CBPF (Brazil)
Guanajuato (Mex)



Dortmund
INR, Moscow

Theory

Jefferson Lab

Hampton
James Madison
Rutgers

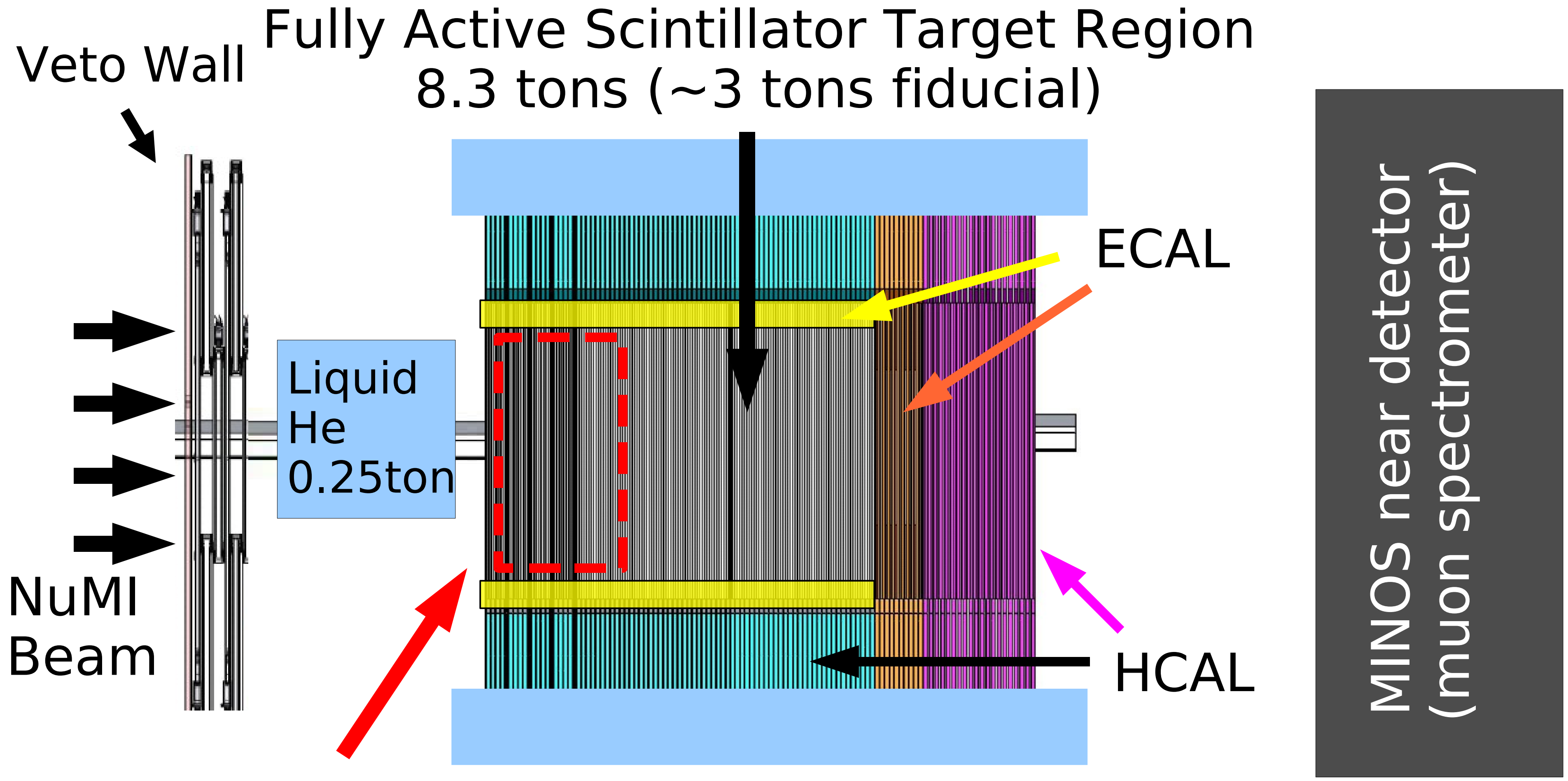
Irvine

T2K

Rochester

Nuclear

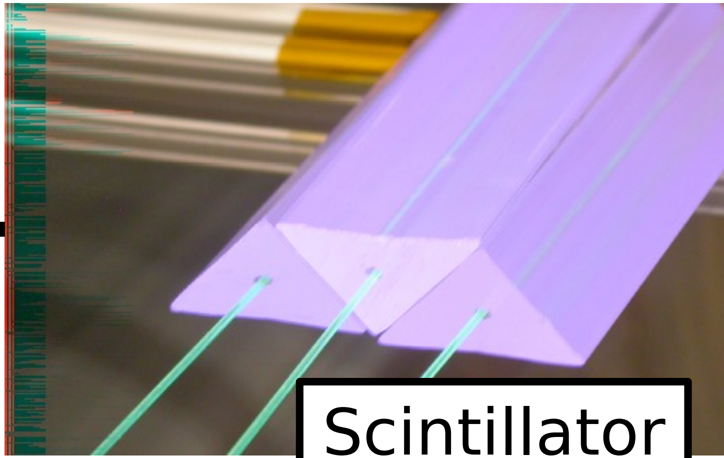
MINERvA Detector



Nuclear Target Region with Pb, Fe, C
6.2 tons (including 40% Scintillator)

Detector Components

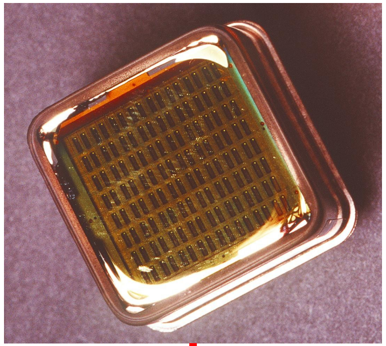
Scintillator Plane



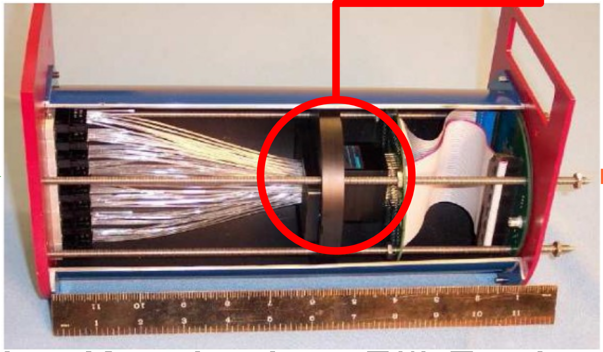
Scintillator Strips and WLS

Clear Optical Fibers

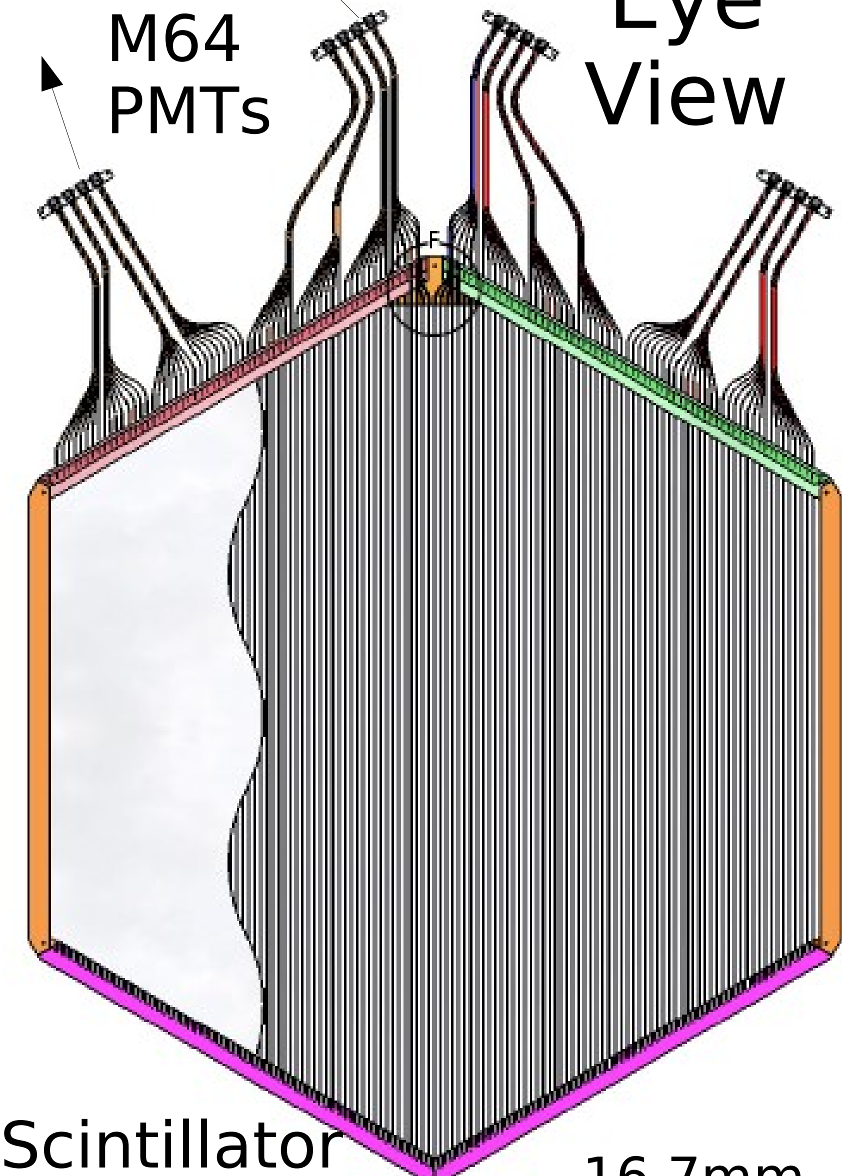
64 Anode PMT

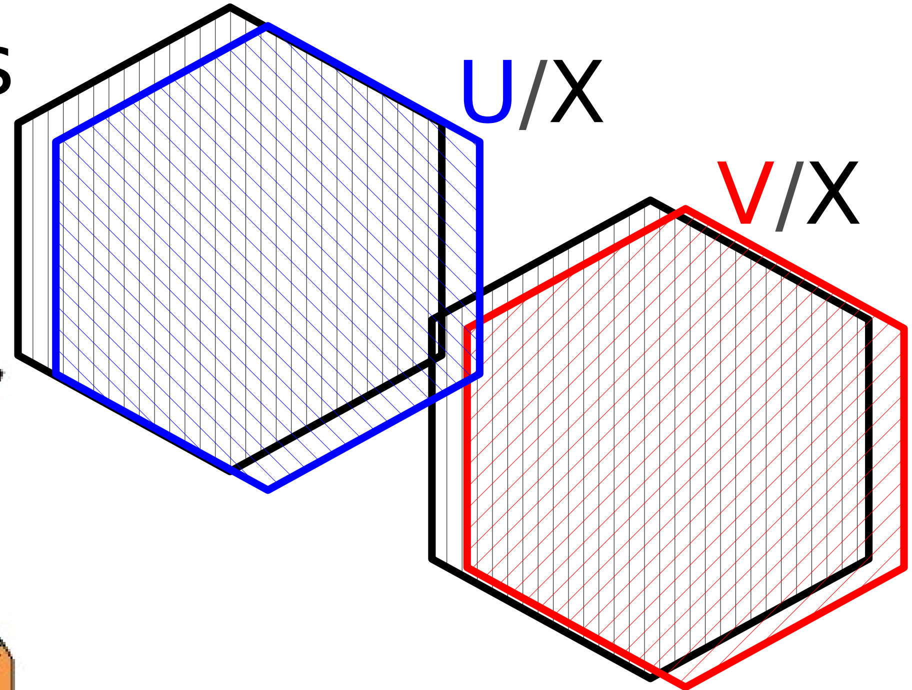


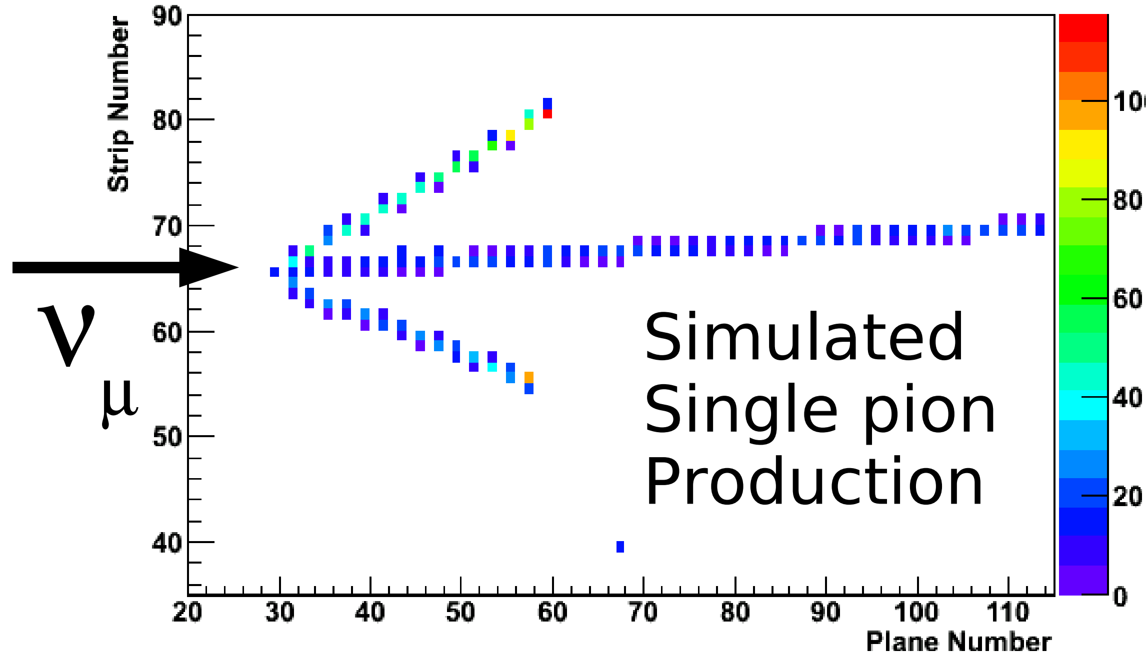
PMT Box & ODU

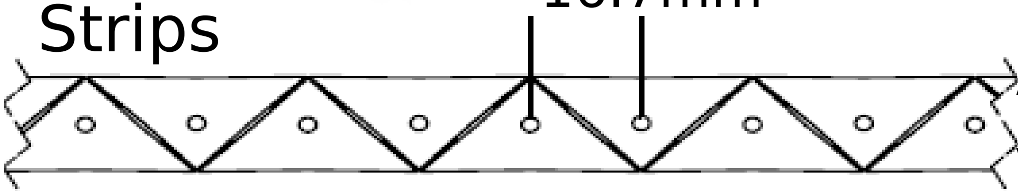


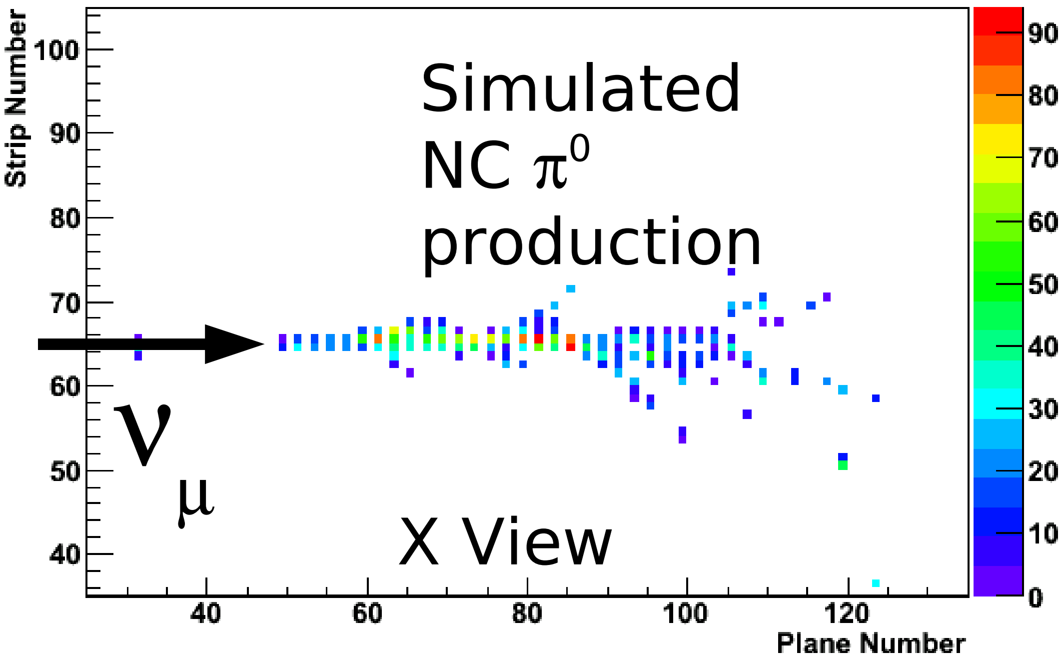
Trip-t ASIC

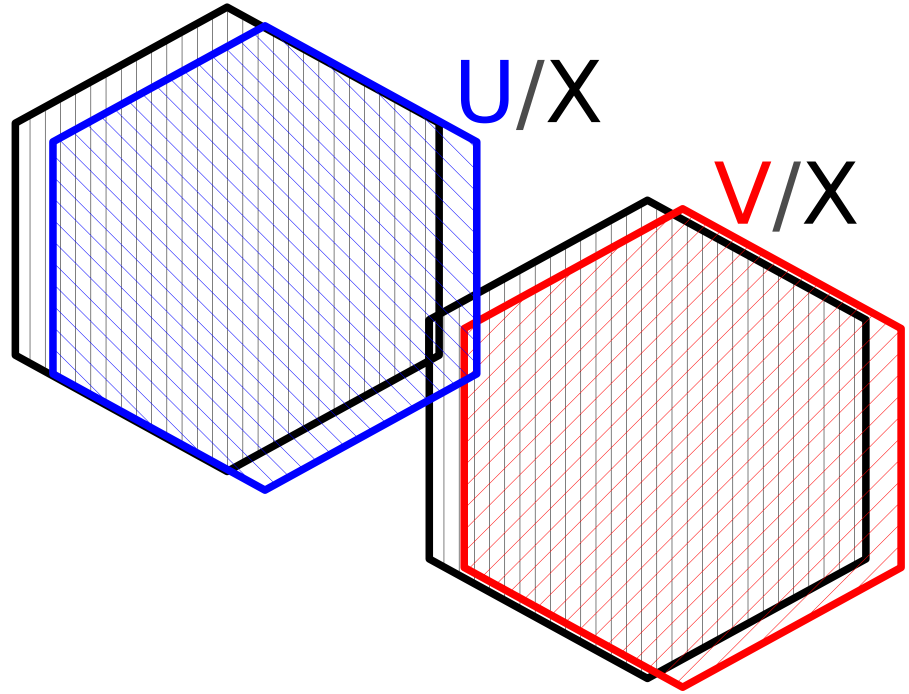

To
M64
PMTs
Scintillator
Strips


Beam's
Eye
View
U/X
V/X

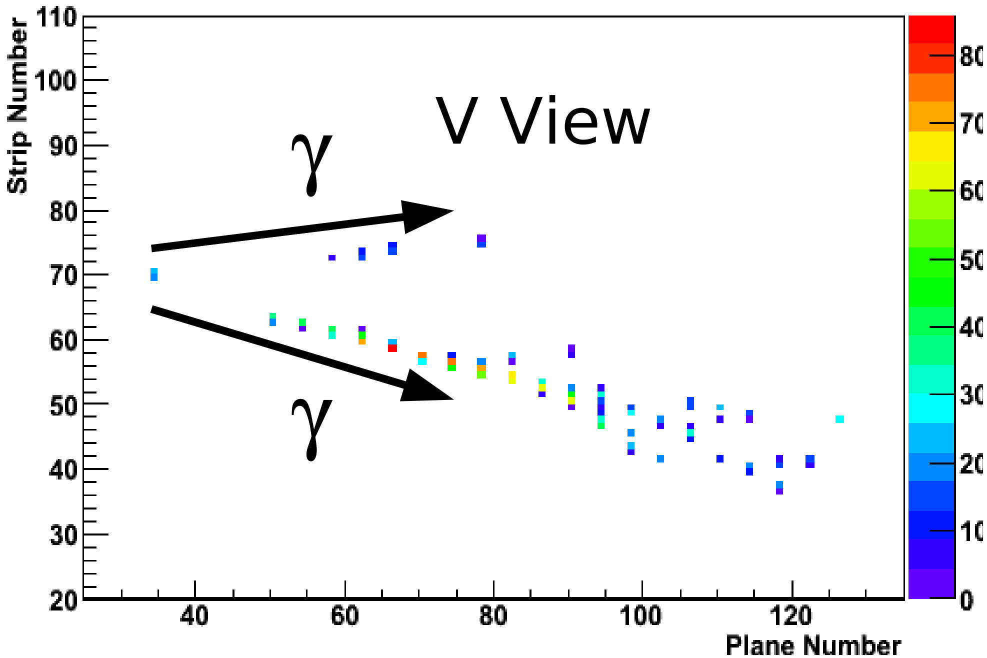

ν_μ
Strip Number
Plane Number
Simulated
Single pion
Production

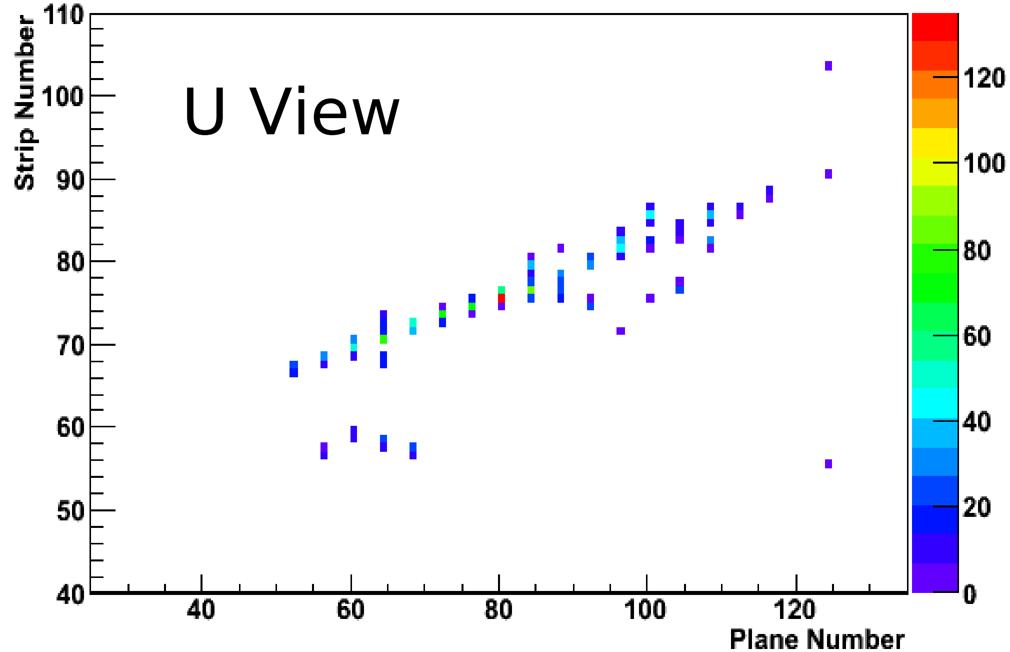

16.7mm
17mm





3D event reconstruction

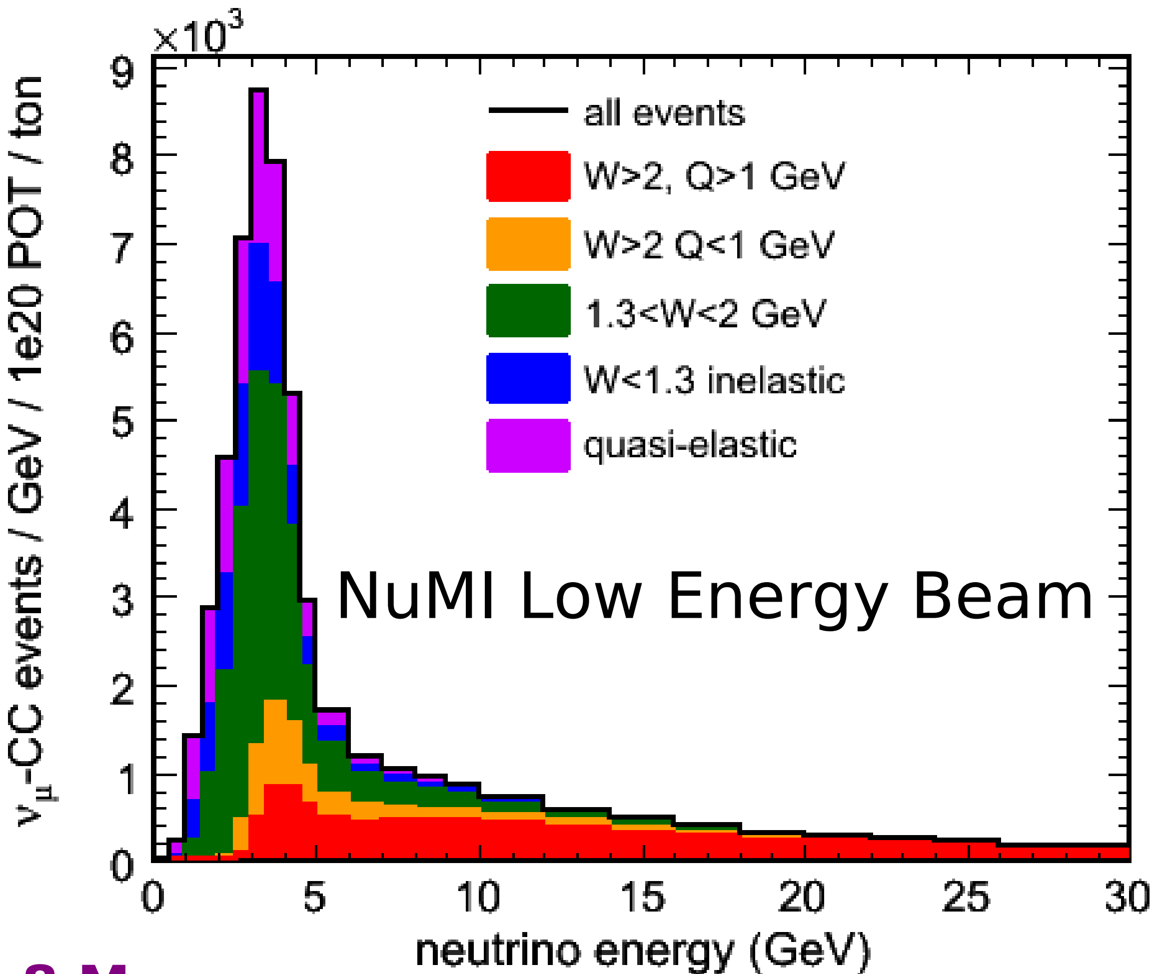




Event Yields

- Assume 4yr run
  4e20 POT LE beam
  12e20 POT ME beam

- Yield: ~14M events



Quasi-elastic	**0.8 M**
Resonance production	**1.7 M**
Resonance to DIS transition region	**2.1 M**
DIS Low Q^2 region and structure functions	**4.3 M**
Coherent Pion Production	**CC 89k, NC 44k**
charm / strange production	**230 k**

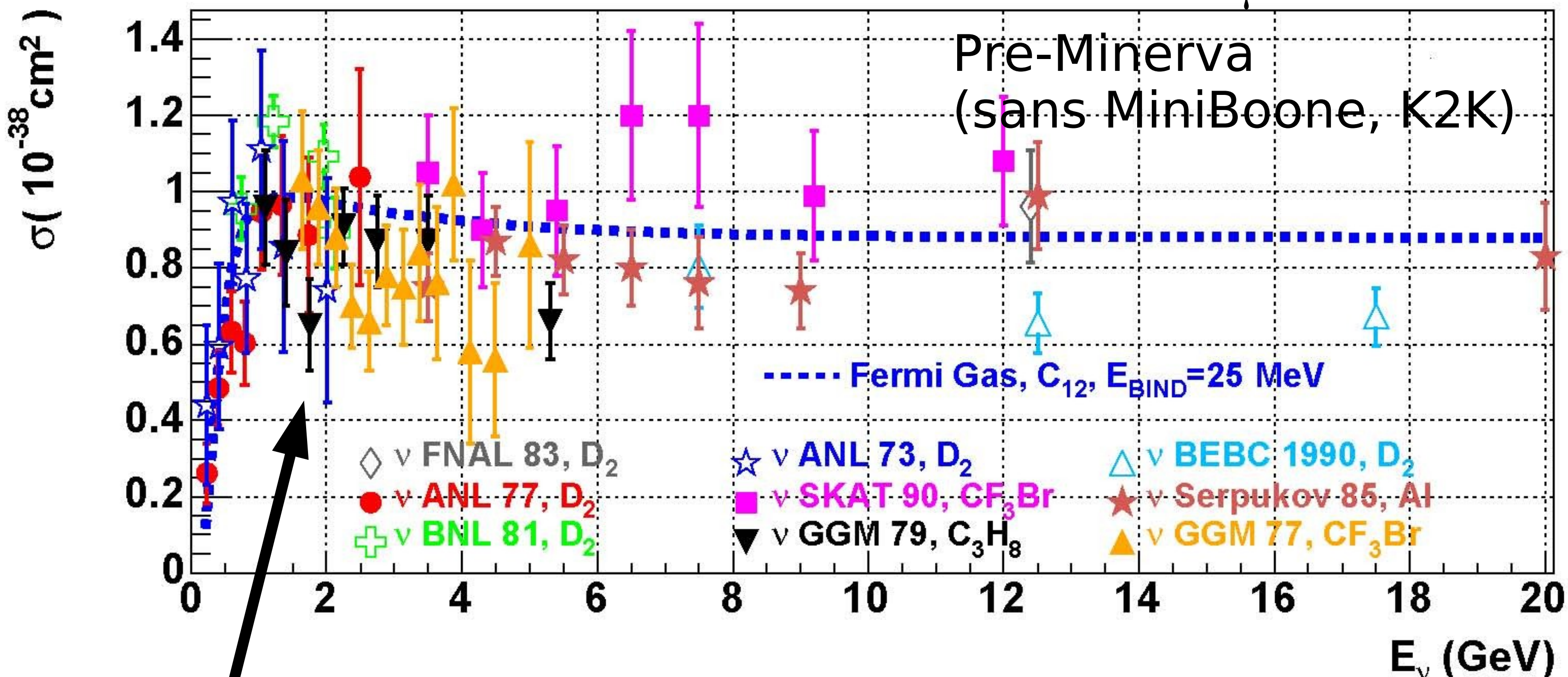
Nuclear Targets

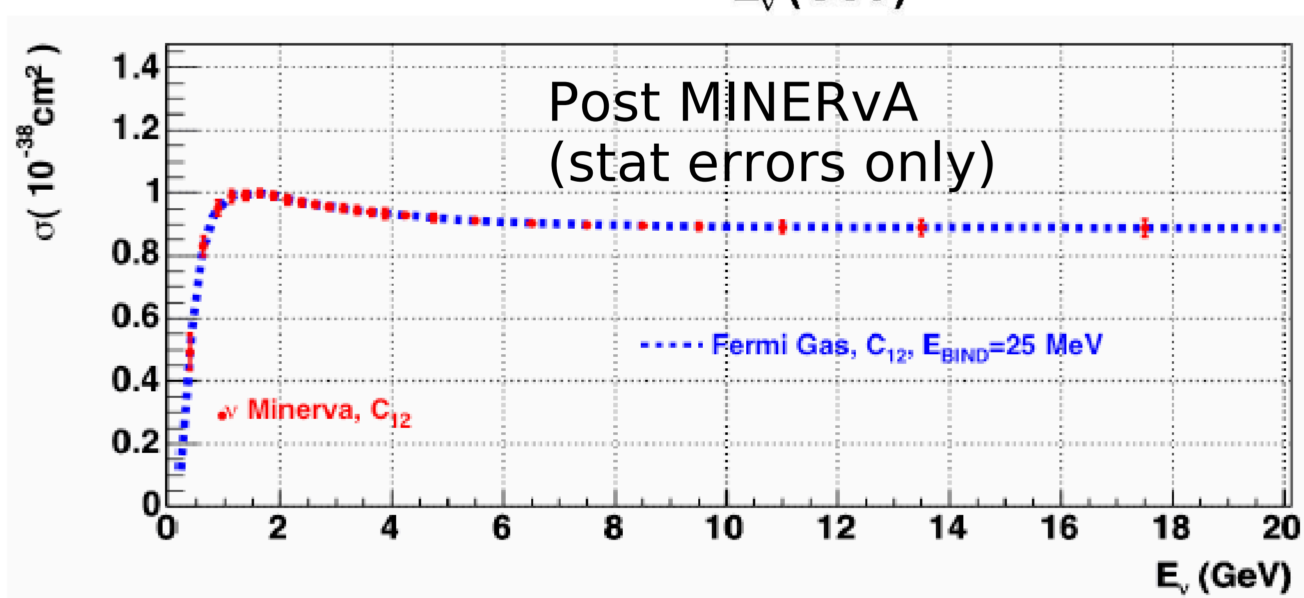
He	0.6M
C	0.4M
Fe	2.0M
Pb	2.5M

Physics Example

Quasi-elastic

$\nu_\mu + n \rightarrow \mu + p$





“Best understood” channel
~ 15% uncertainty

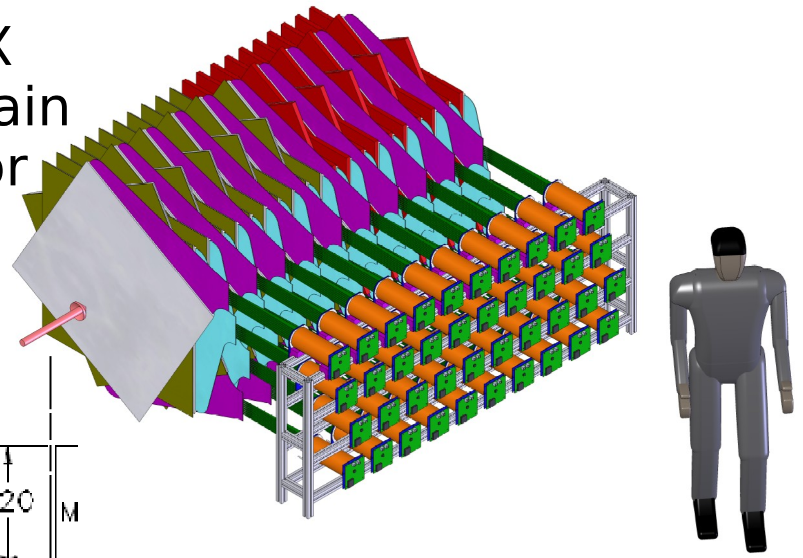
Current Status

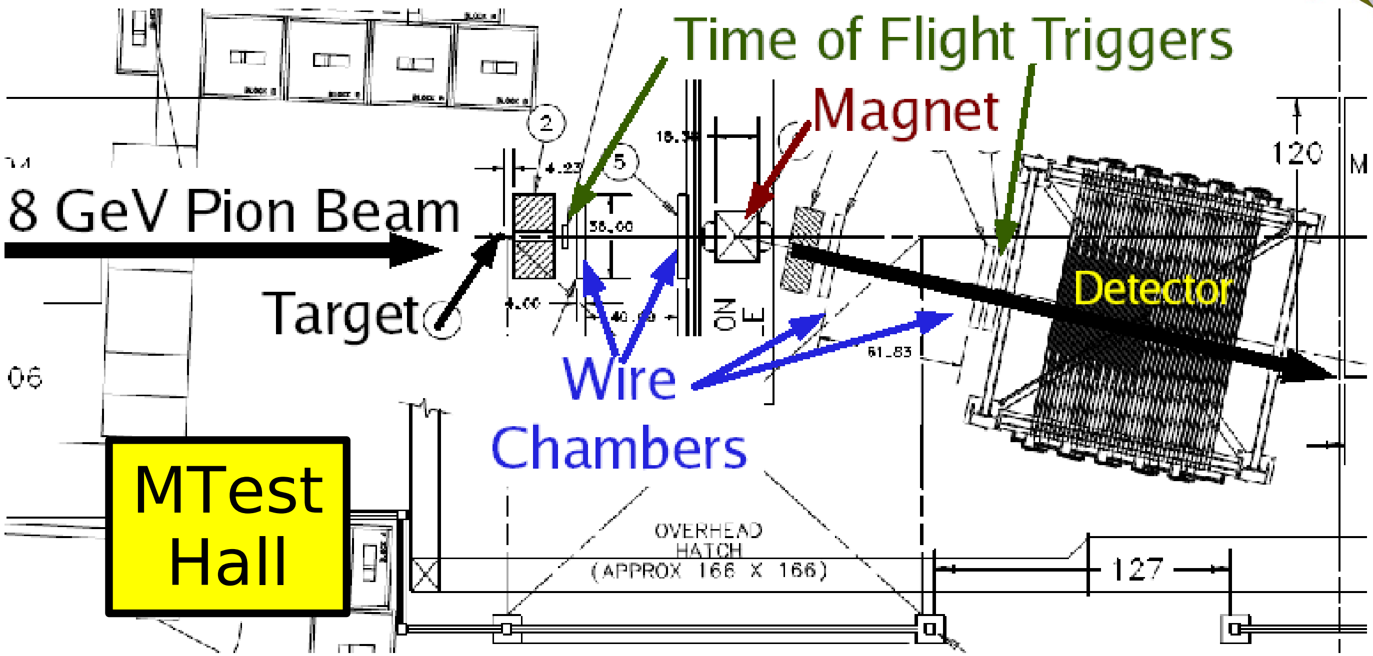
- Obtained CD 3b in Nov 2007 and currently under construction
- Building MINERvA tracking prototype (20 modules) for advanced system integration, cosmic rays
  - If detector performs well, perhaps NuMI running (autumn 08)
- Test beam detector under construction for operation in Mtest (fall 08).
  - Benchmark energy scale, tune MC
- Installation/commissioning: end 2009

Backups

Test Beam Detector

U/X V/X
as in main
Detector

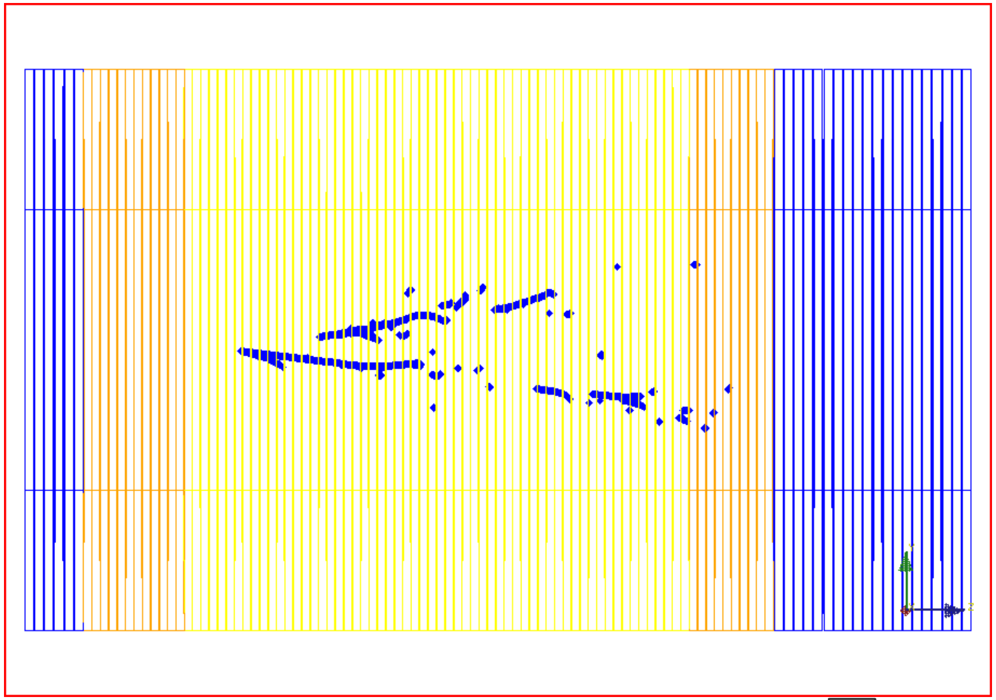




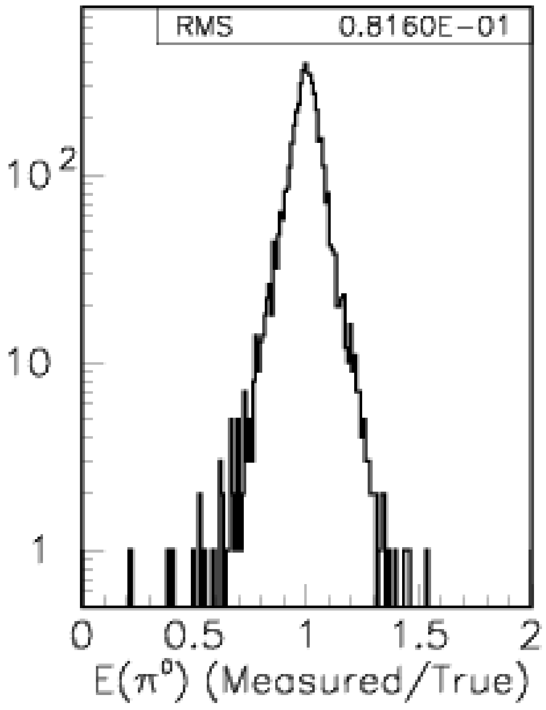
Test Beam Det.
Nuclear Targets
LI system
funded by NSF

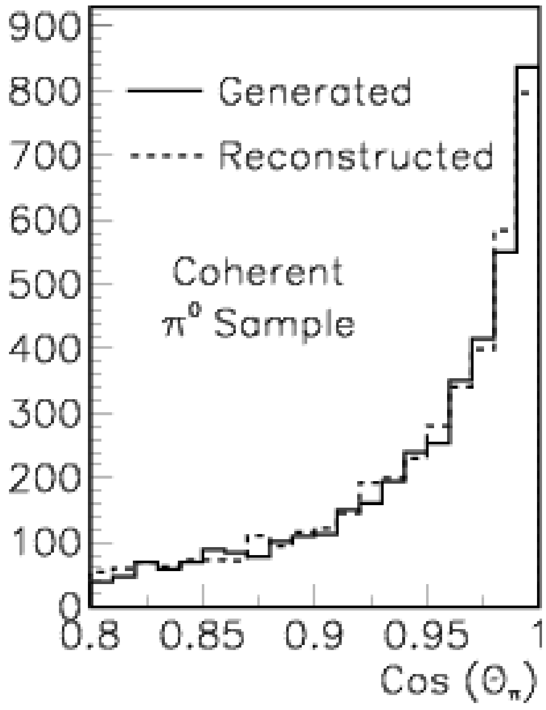
- Scaled down version of MINERvA
- Benchmark detector response to single particles
- To be operated in MTest Hall, fall 2008
- New tertiary beam to get down to 200 MeV/c
- Reconfigurable Sci, Fe, Pb modules
  to emulate different detector sections

Neutral Pions



- Photons cleanly identified and tracked
  - π^0 energy res.: 6%/√E (GeV)
- For coherent pion production, the angular distribution is dominated by physics not resolution

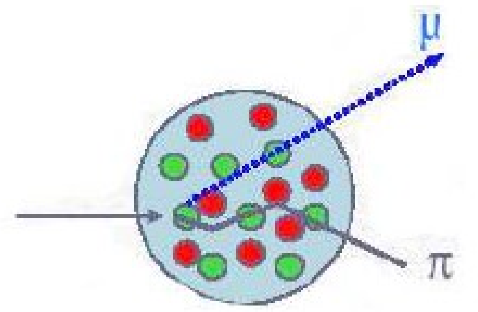




MINERvA and Oscillations- How much is the improvement: Nuclear Effects on MINOS

Final State Interactions

- Intranuclear rescattering
- Energy loss and/or absorption
- Change in direction

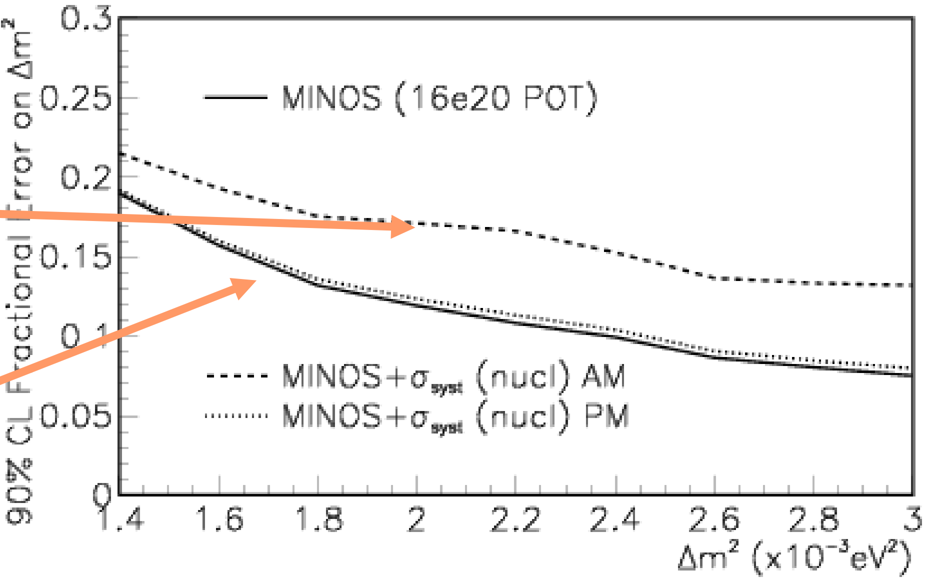


Before MINERν A

$\sigma_{stat} \sim \sigma_{syst}$ (rescattering only)

After MINERν A:

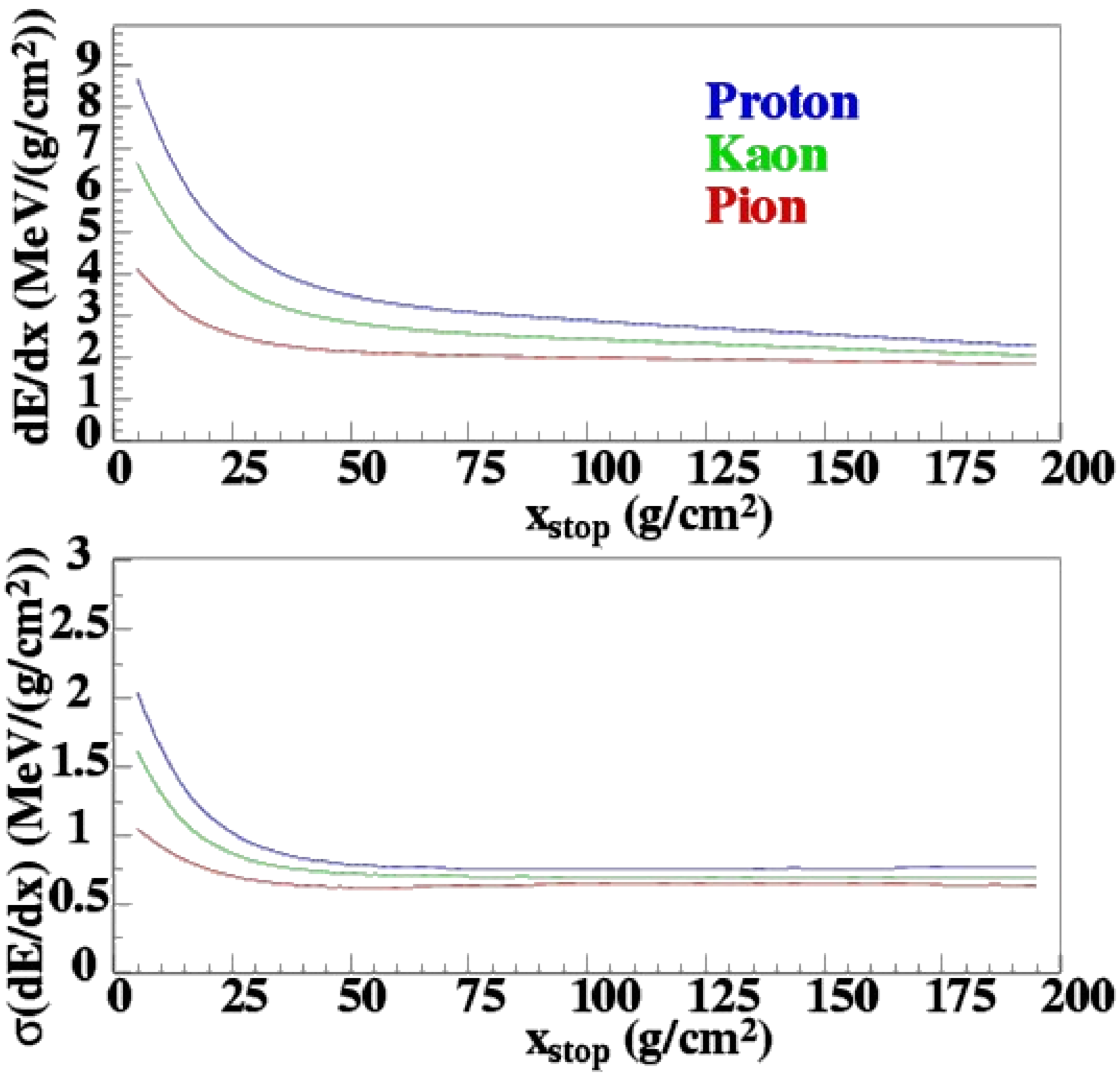
$\sigma_{stat} >> \sigma_{syst}$ (rescattering only)



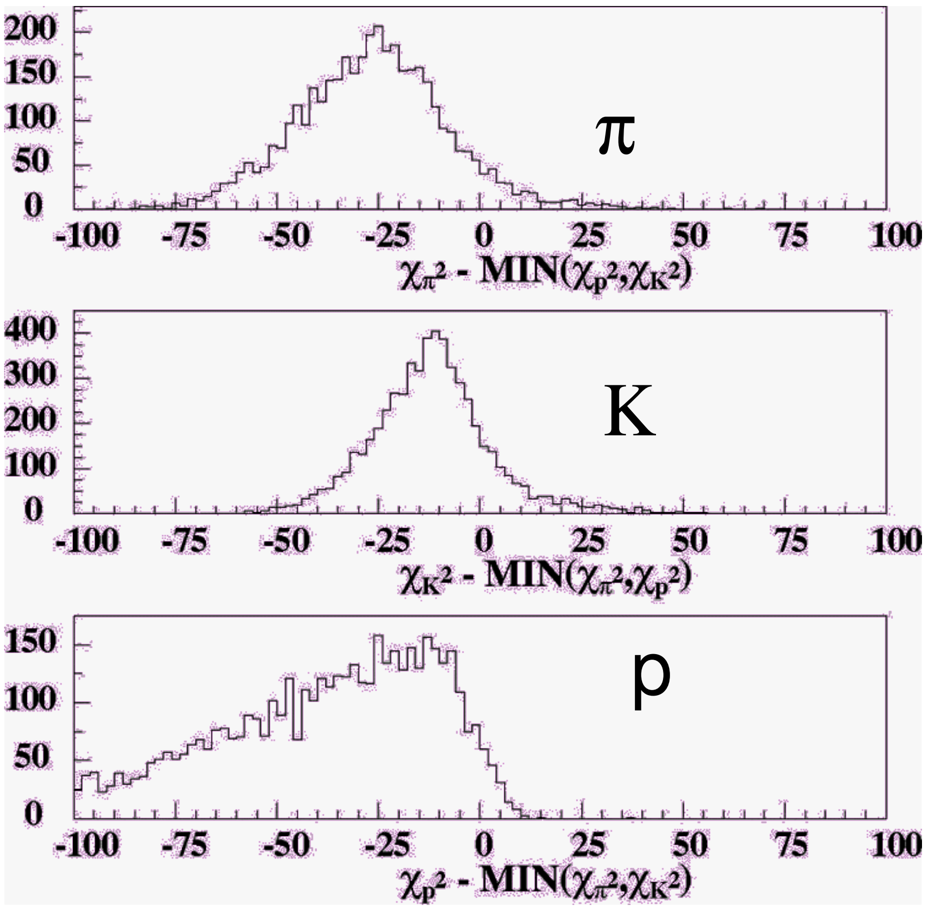
MINERvA: measurements with high-A targets and high-statistics

Particle Identification

- Particle ID by dE/dx in strips and endpoint activity

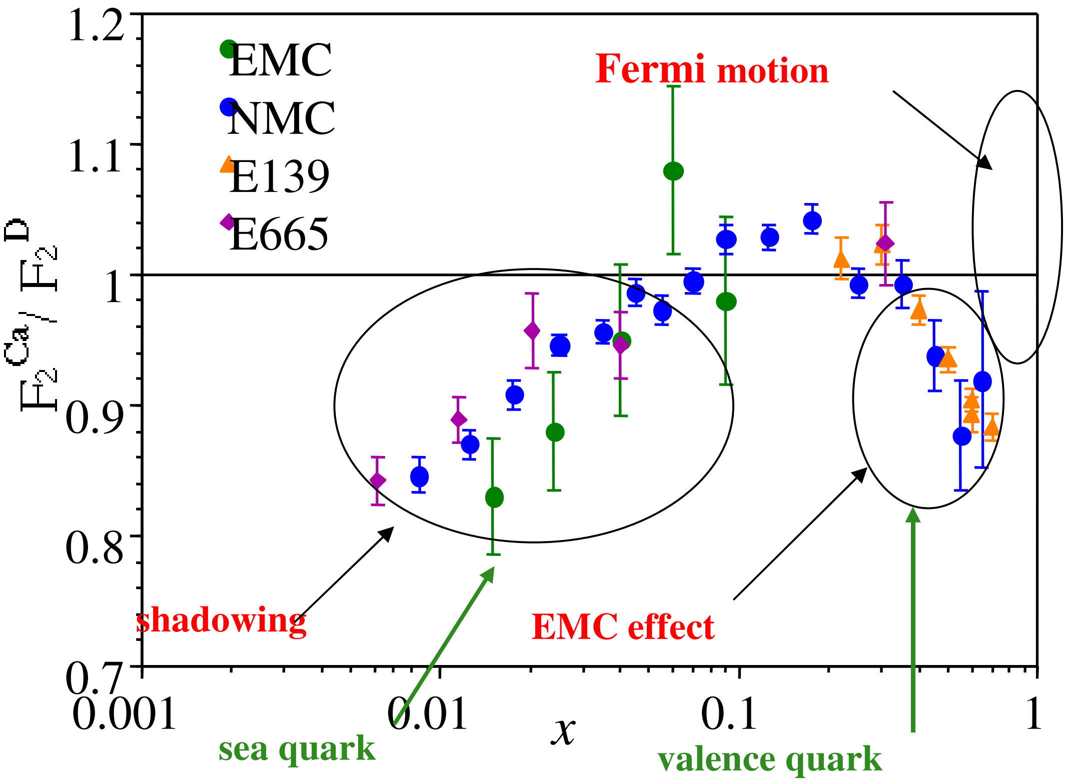


X^2 differences between right and best wrong hypothesis



A-dependence in ν scattering

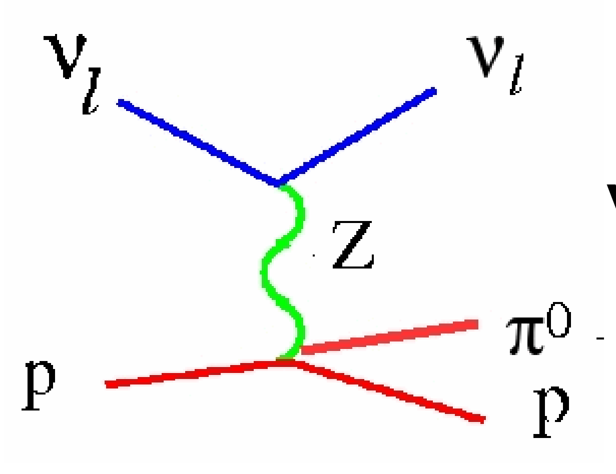
- A dependence observed in e/μ DIS
- Could be different for neutrinos
  - Presence of axial-vector current.
  - Different nuclear effects for valence and sea
  - leads to different shadowing for xF_3 compared to F_2.



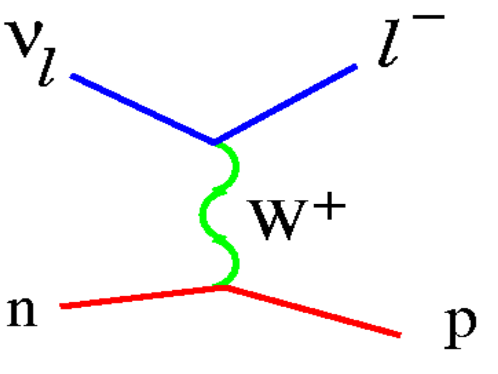
If we understand at 10-20 GeV
Will that help at 100 GeV?
Comparing with JLAB will help.

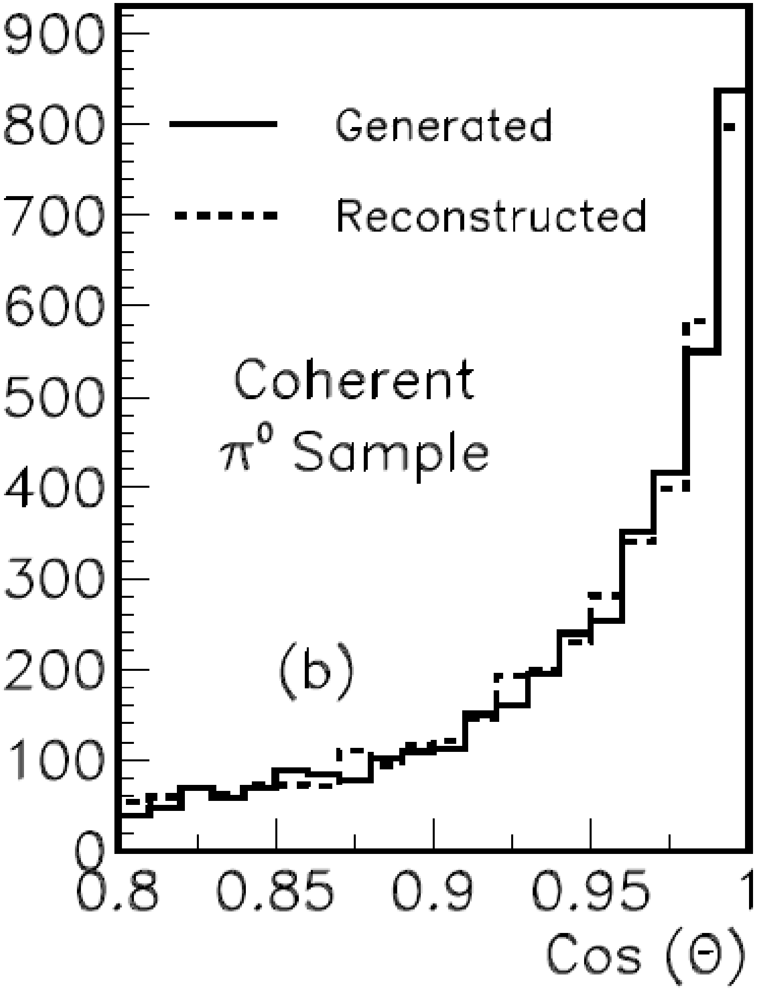
Low energy inclusive and exclusive cross sections for neutrino oscillations

- Example: π^0 NC important for oscillation experiments

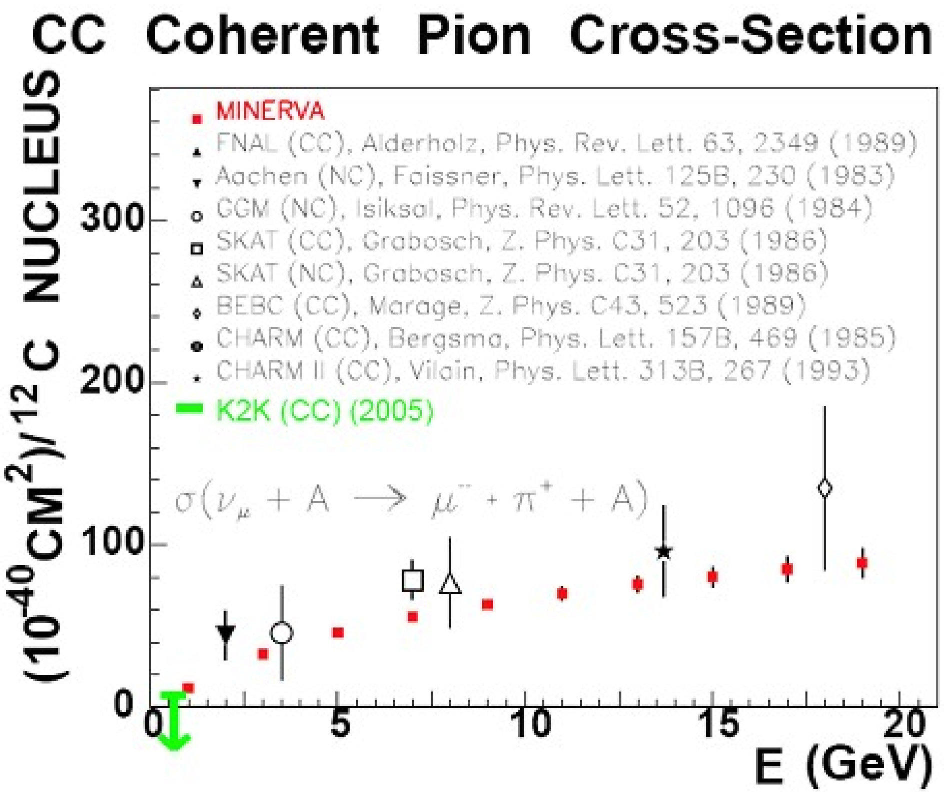


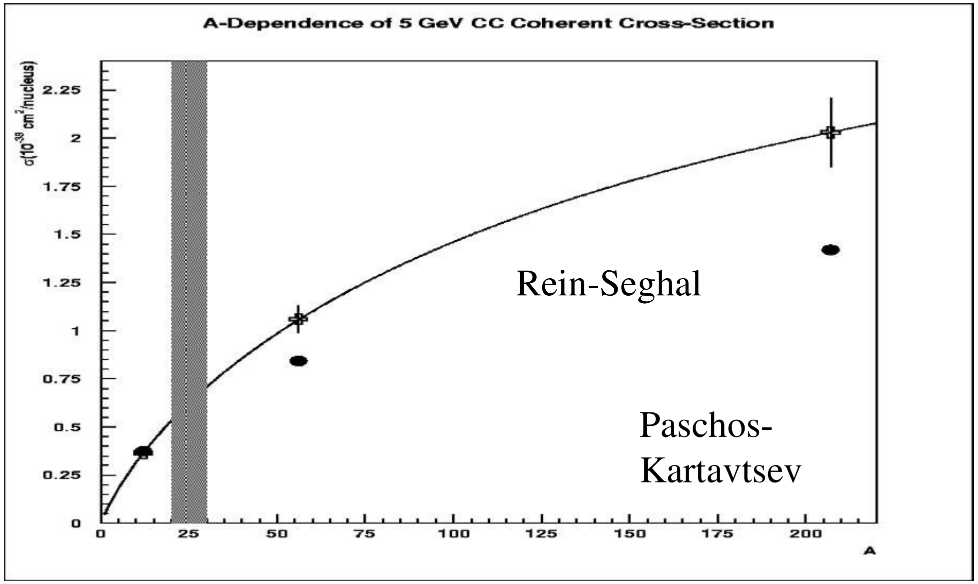
VS.



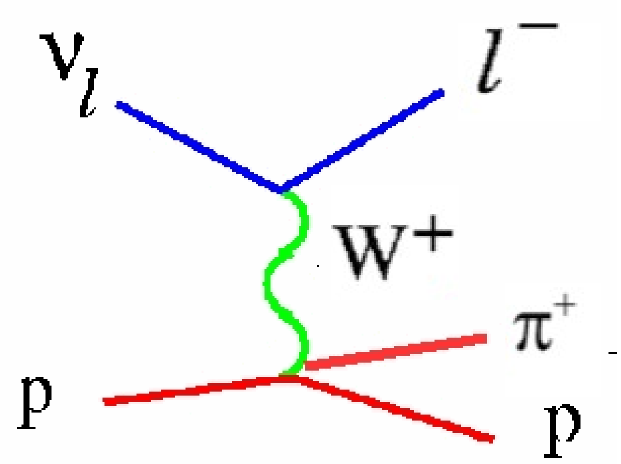


Coherent Pion Production



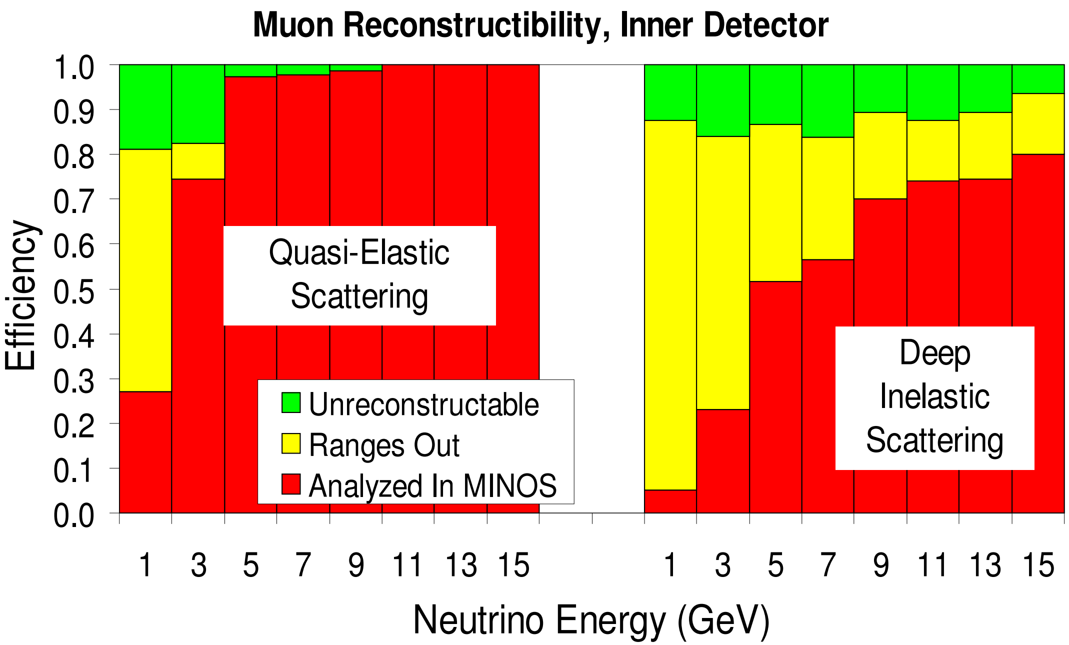


MINERν A's nuclear targets allow the first measurement of the A-dependence of σ_{coh} across a wide A range

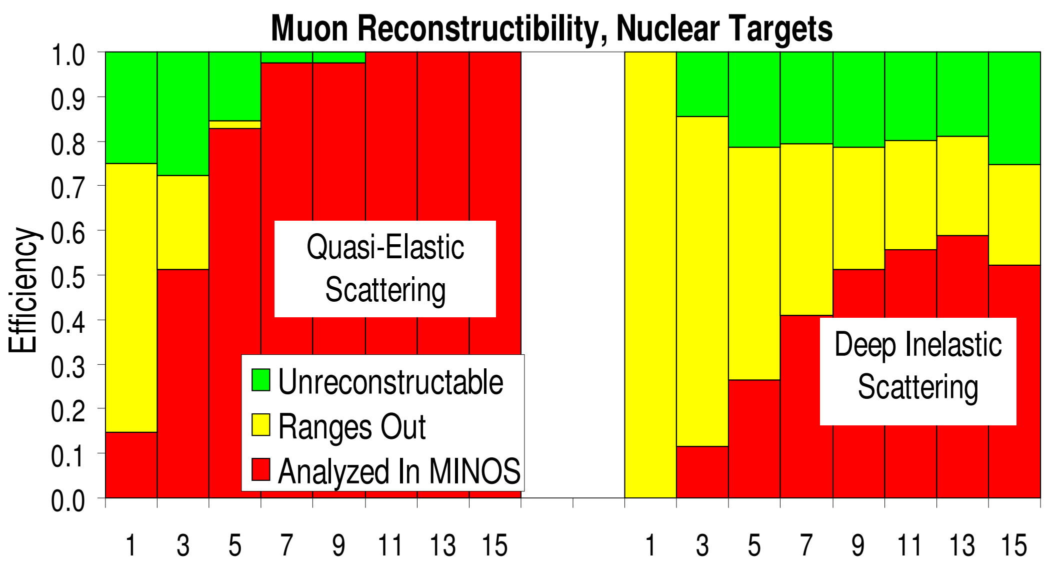


Muon Acceptance Study

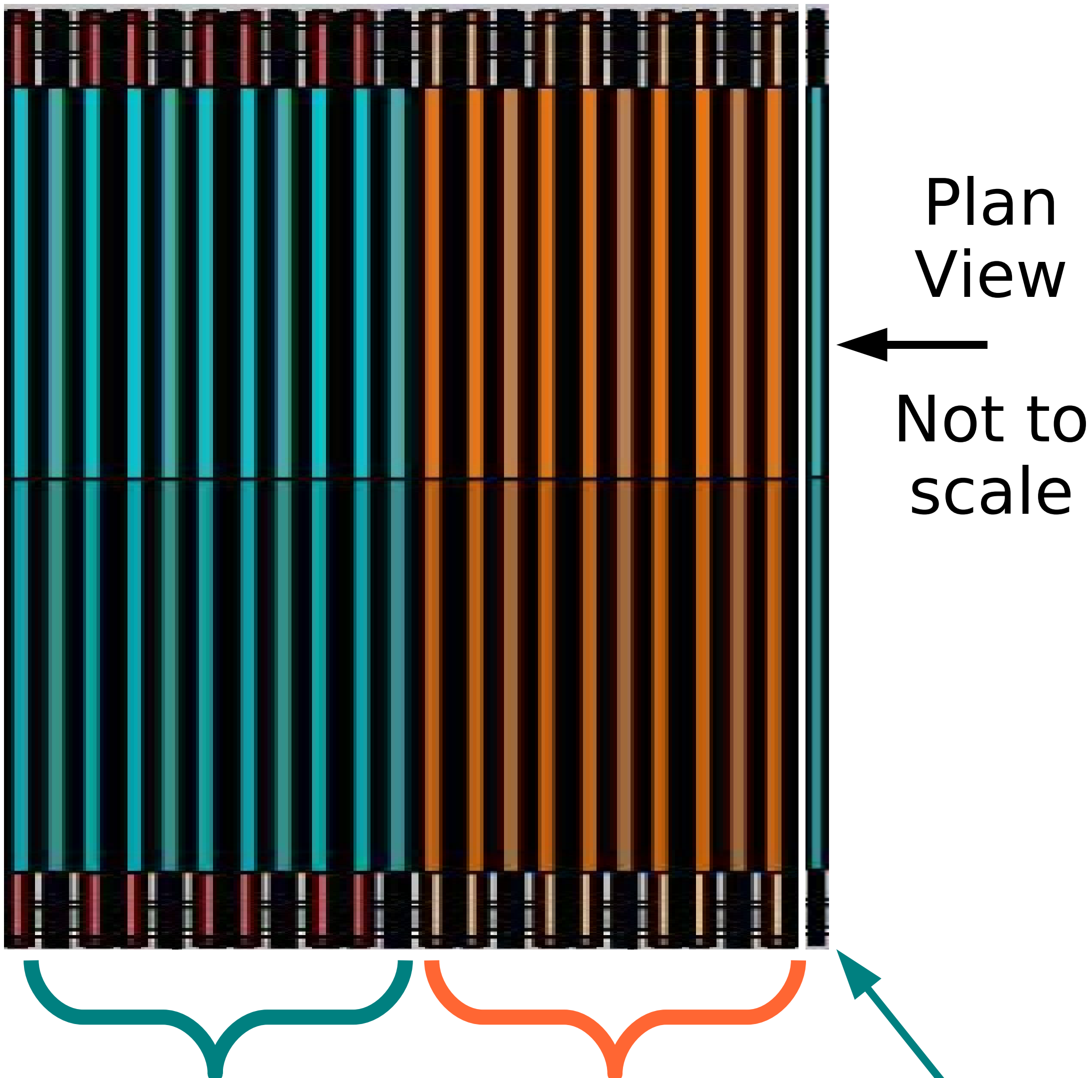
- Fiducial Volume Cuts: radius<75cm
- Look at acceptance for muon
  - Active Target (>50cm from DS ECAL)
  - Nuclear Target Region

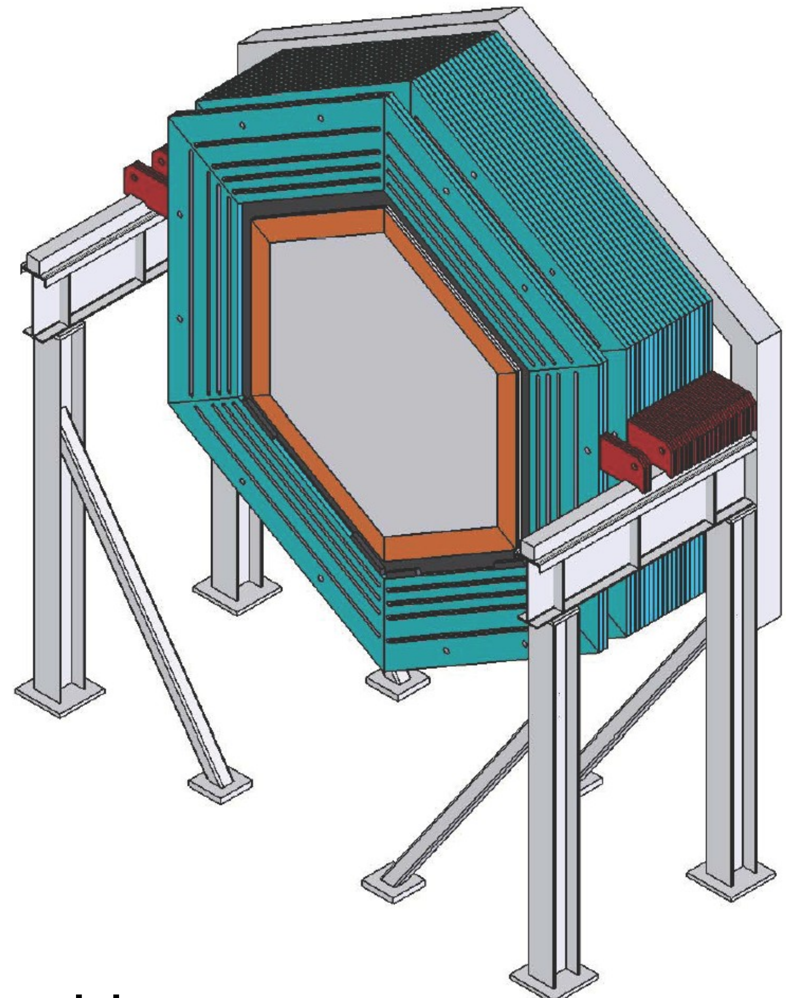


- In kinematic extrema of interest:
  - High x DIS: (x>.7)
    - Analyzed in MINOS: >90% active TGT, >80% nucl target
    - Remainder escape the sides
  - High Q^2 Quasi-Elastic:
    - Analyzed in MINOS: >99% active TGT, >86% nucl. target

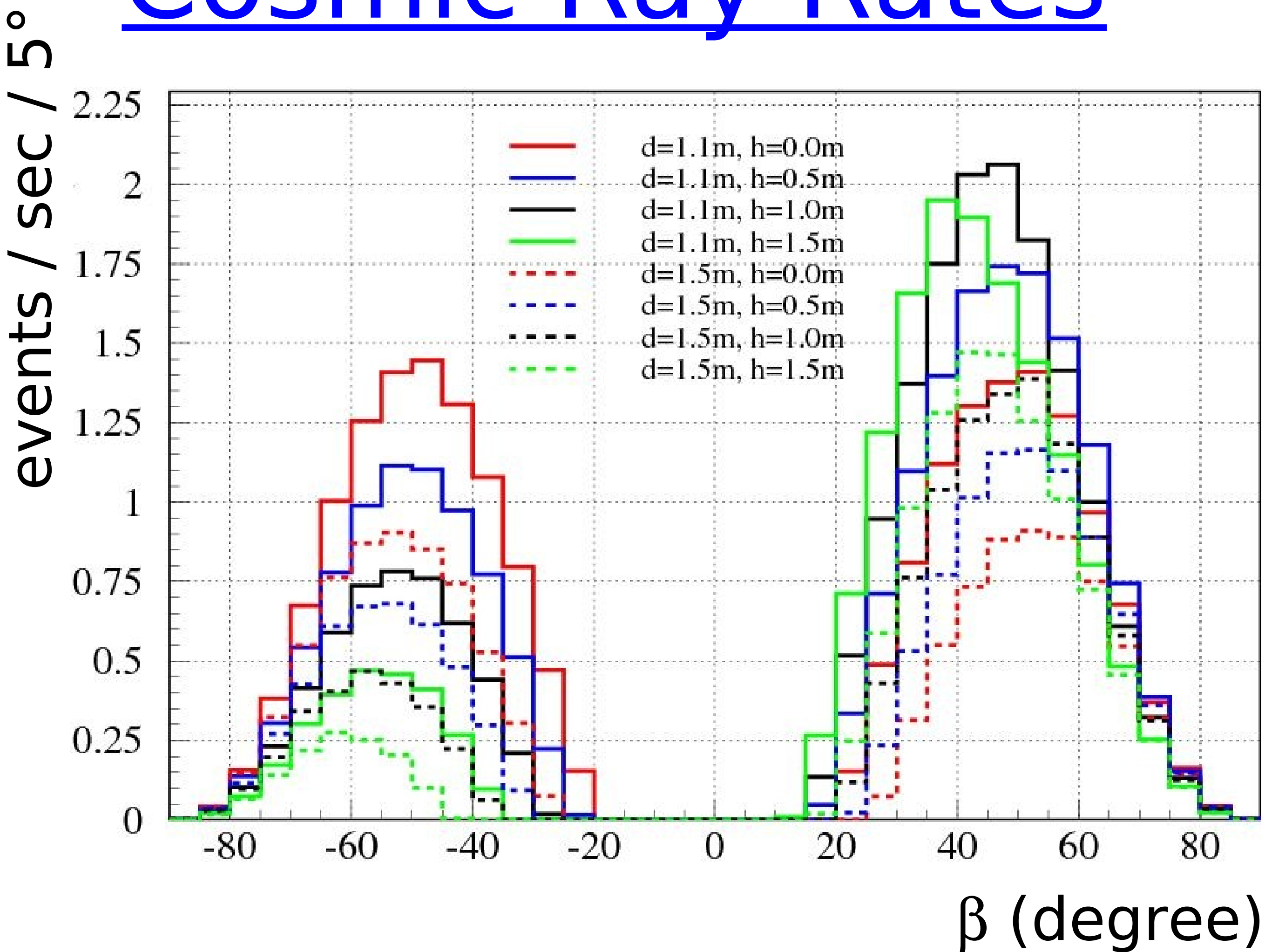


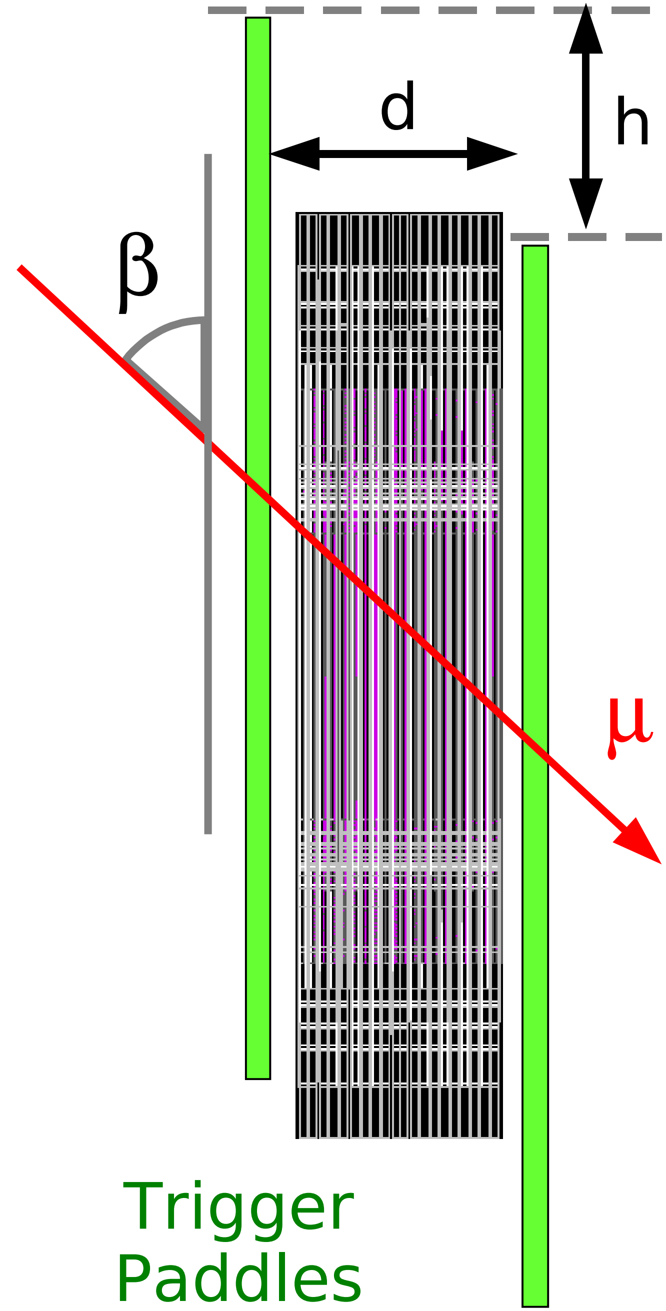
Tracking Prototype

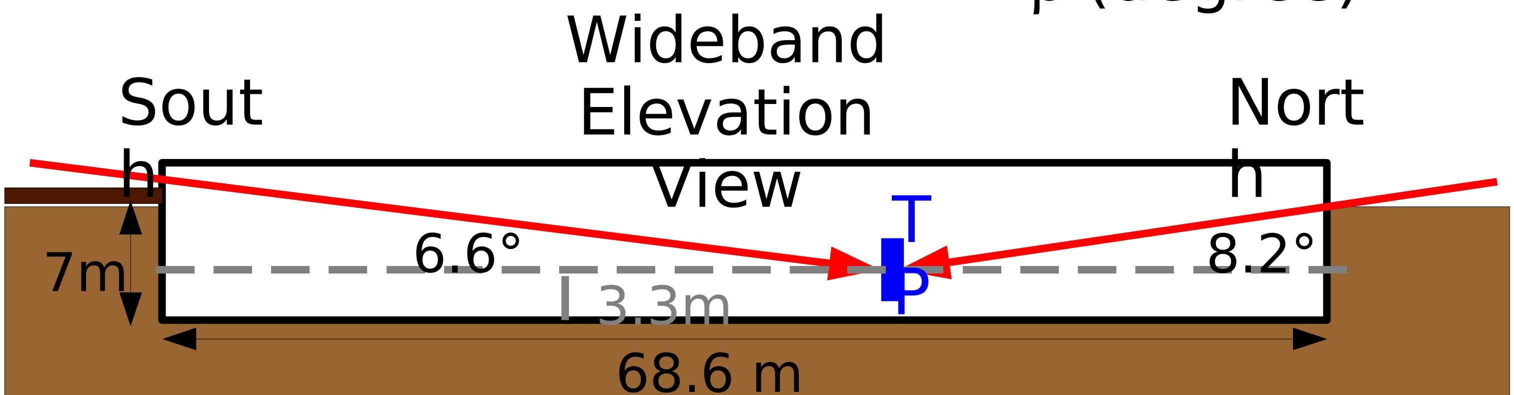




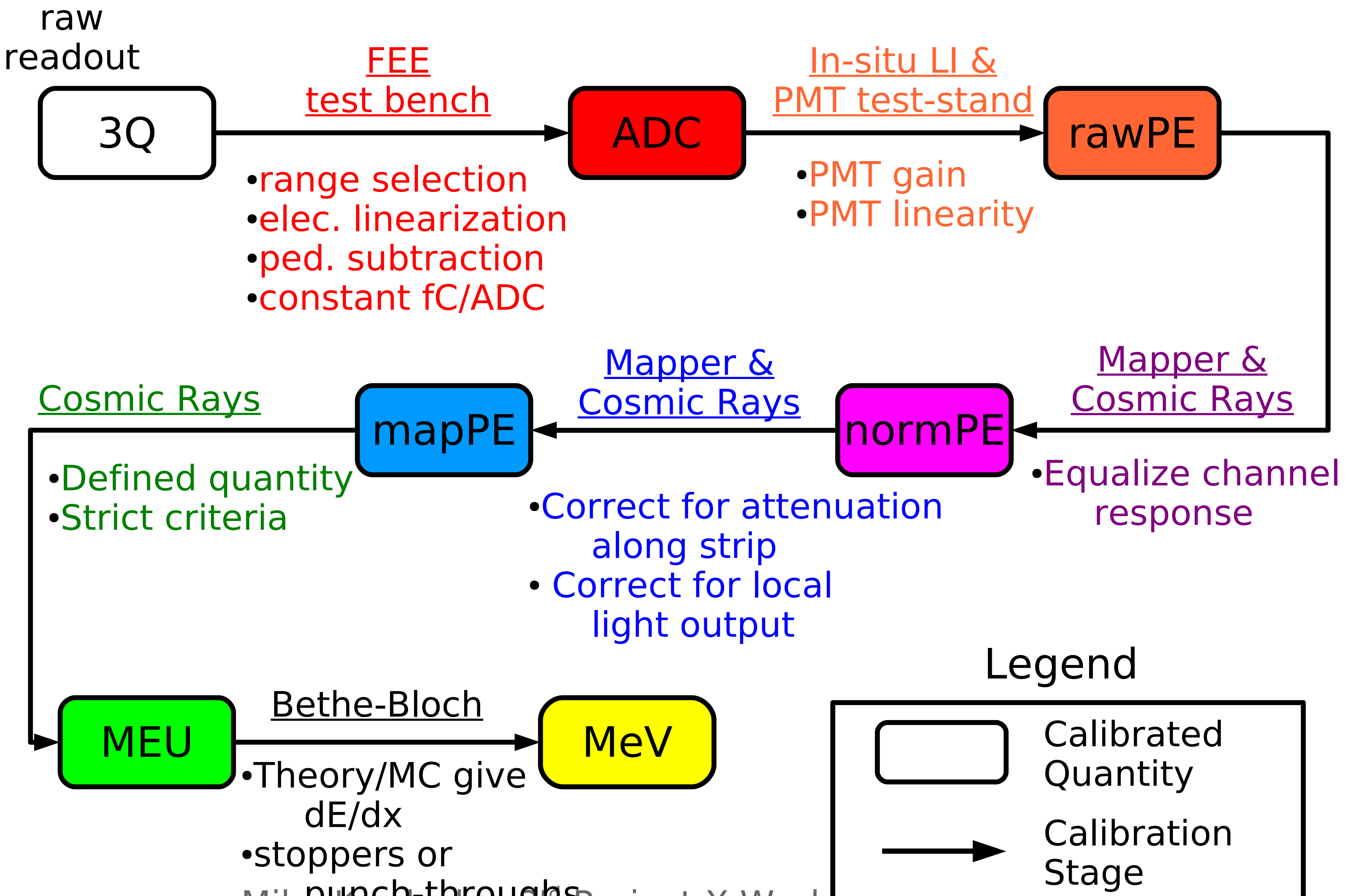
Cosmic Ray Rates



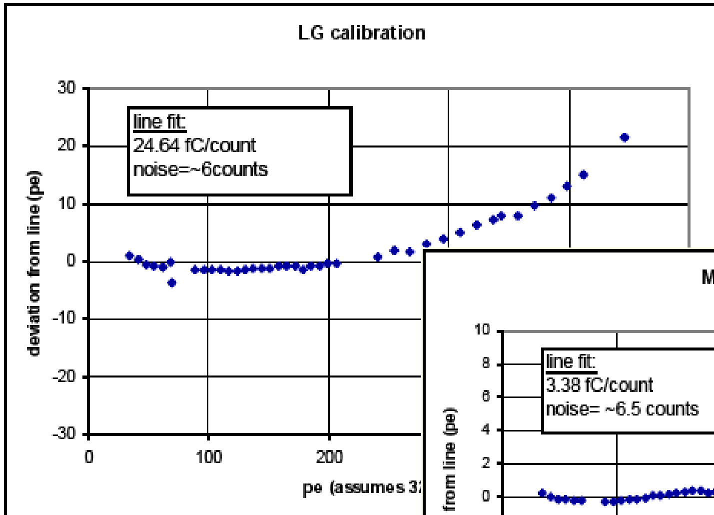


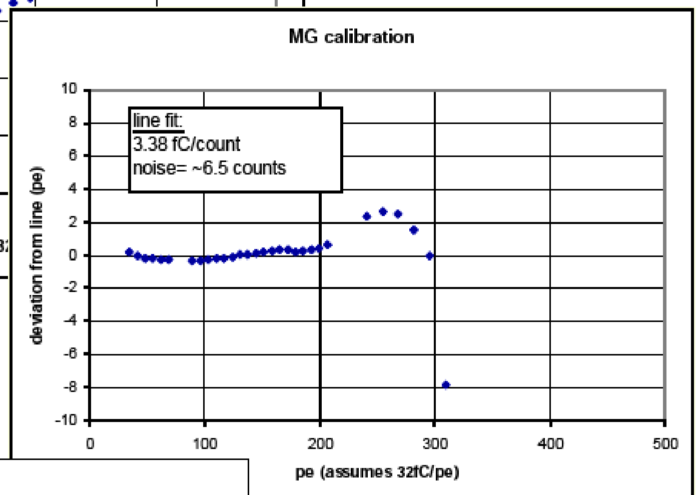


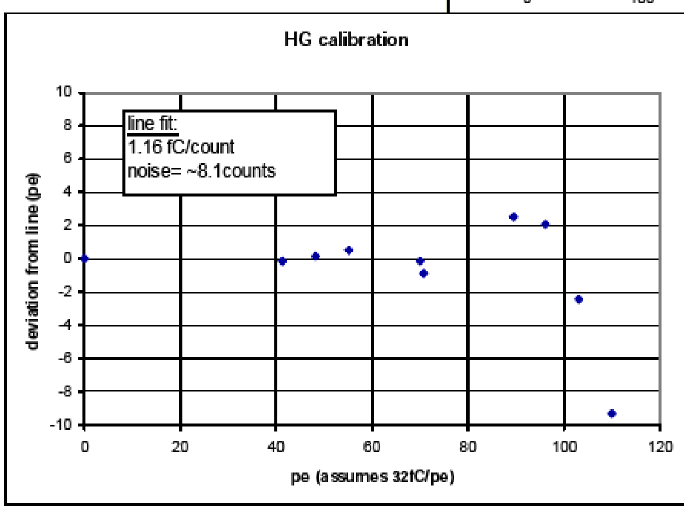
Calibration Scheme



Electronics Gain, Linearity



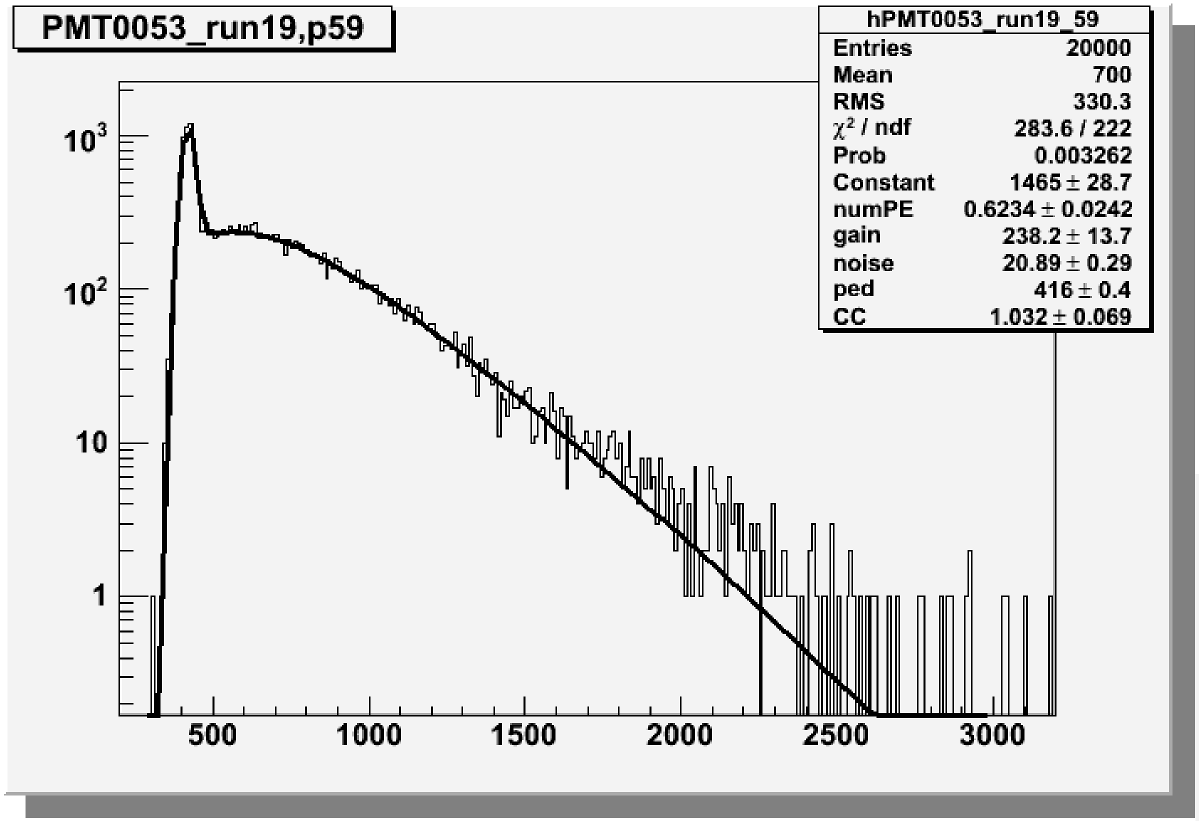




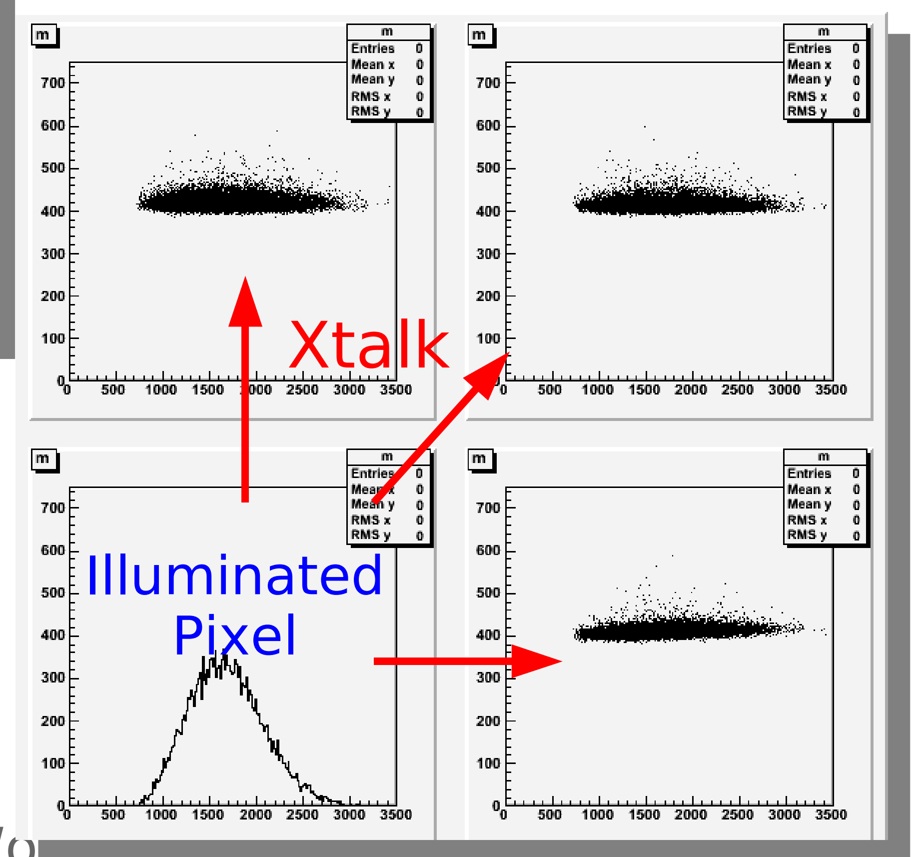
Trip-t chip
& FEB

- Three Trip-t gain channels
  - high, medium and low gain
- Bench testing for linearity, range selection
- Relative gain in-situ
- Absolute gain rolled in w/ PMT

PMT Gain and Xtalk



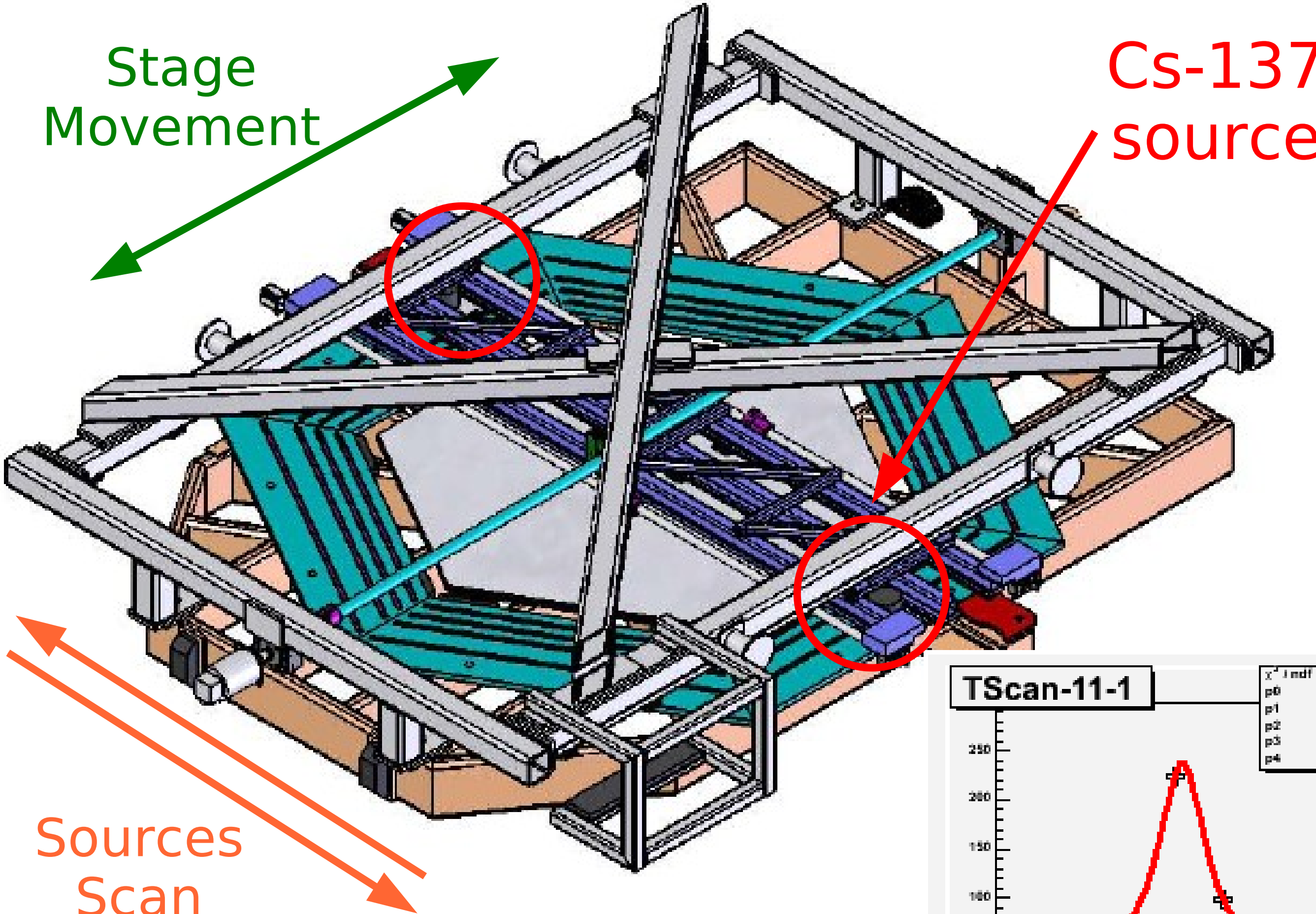
PMT Cross-Talk



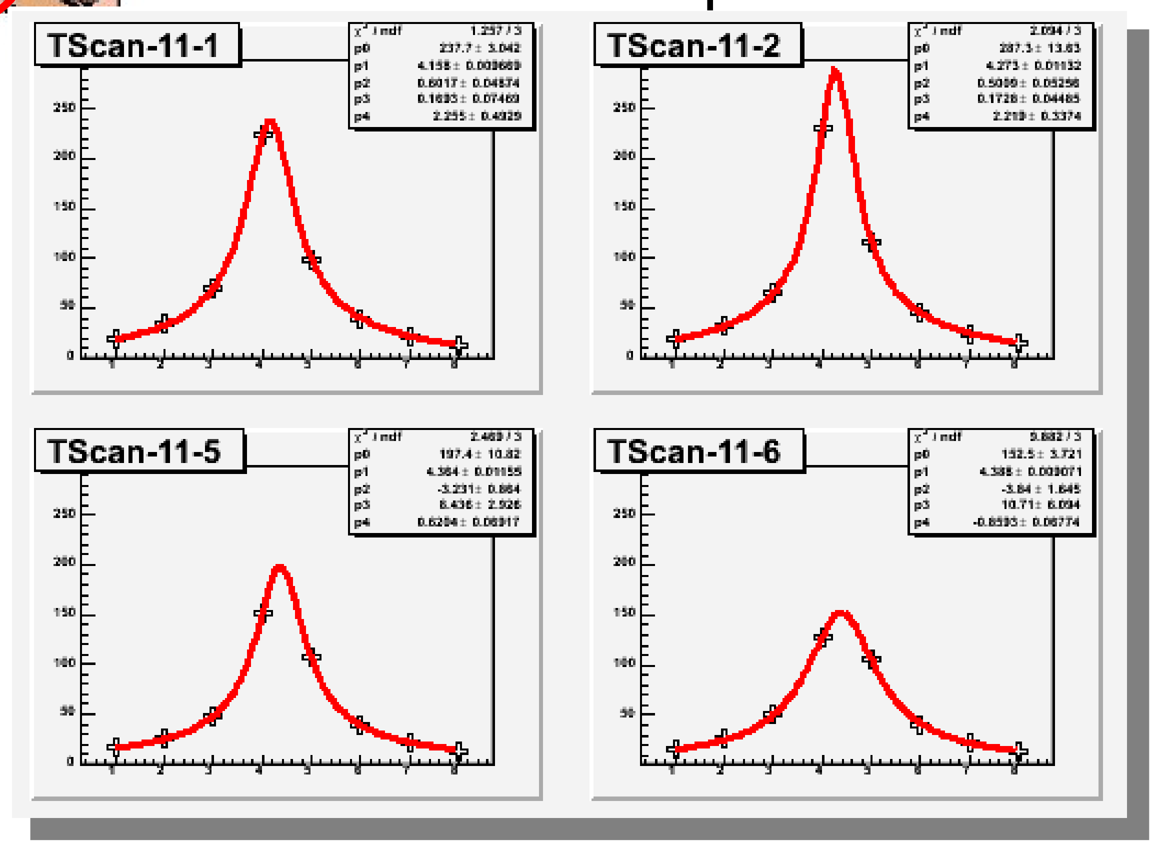
PMT gains from 1PE peak

- Test stands
- In situ Light Injection

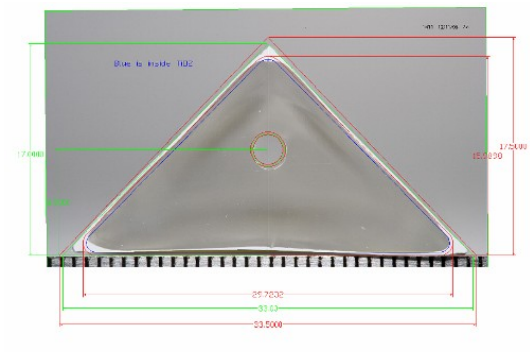
Module Mapper

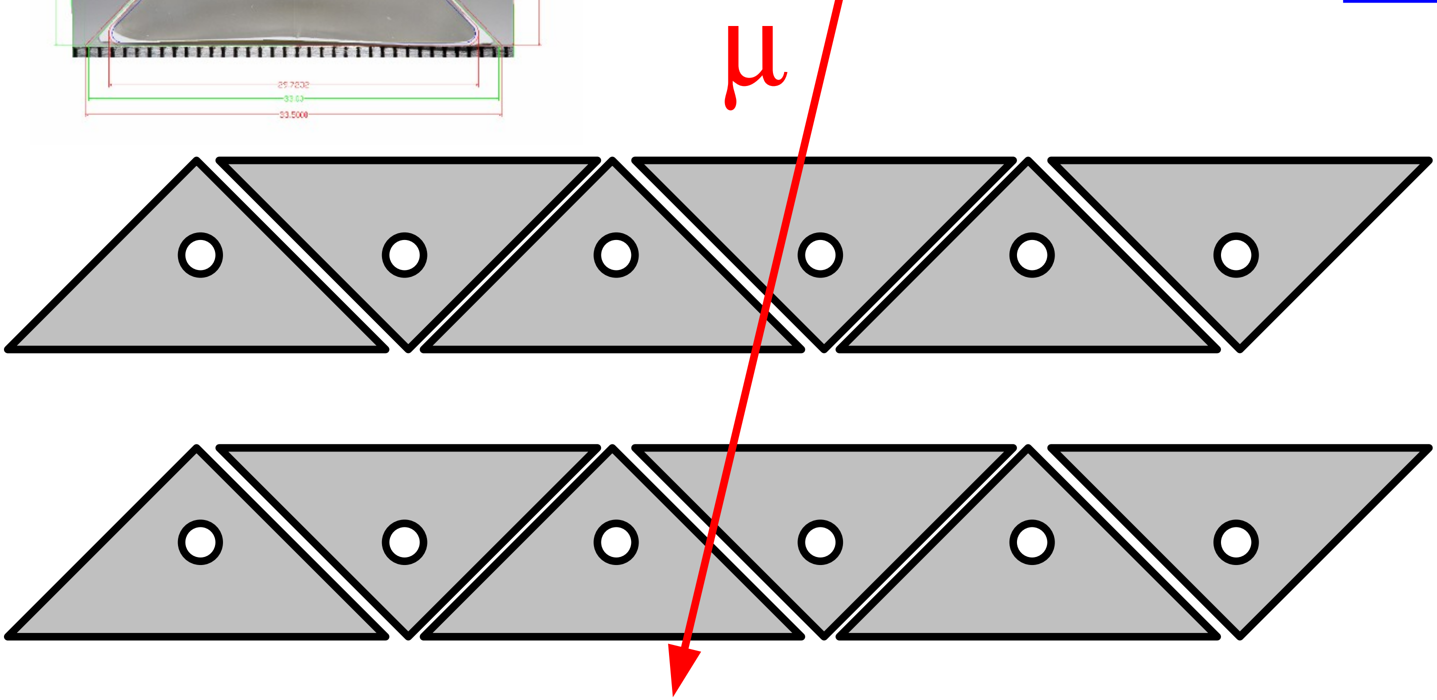


- Fiber position
- Relative strip response
- Attenuation along strip



Tracking and Light Output



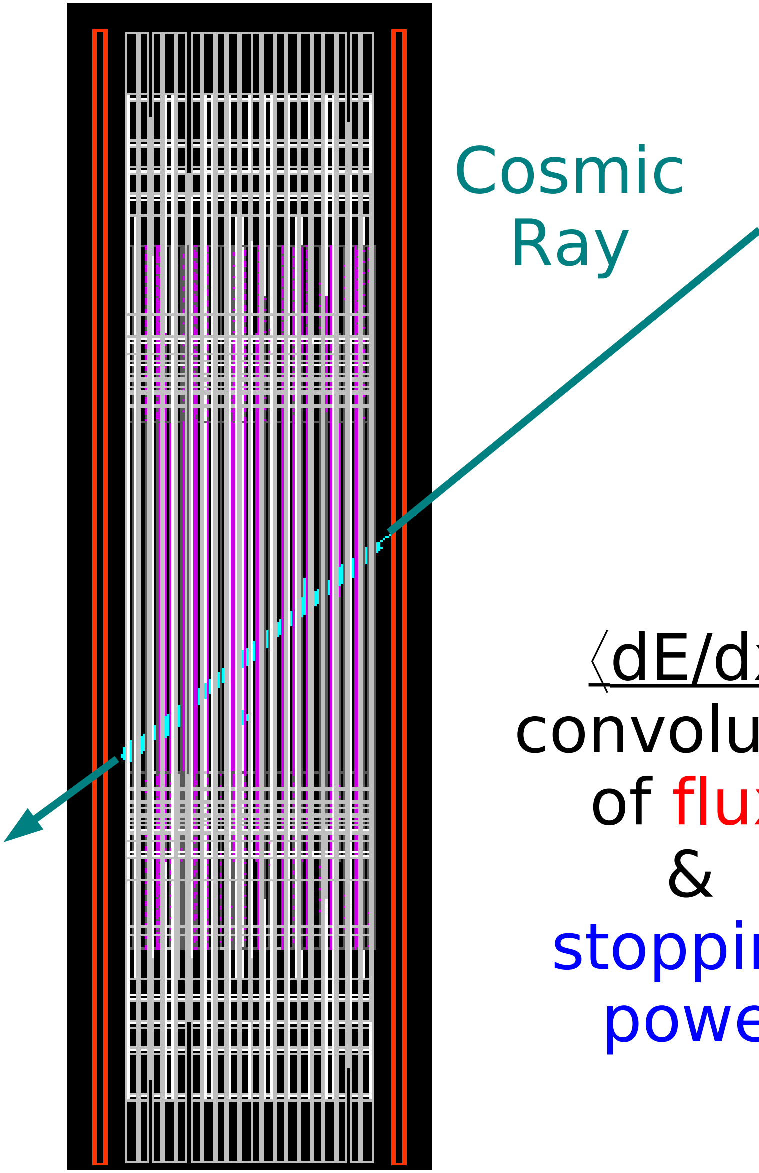


This is likely to be the most challenging calibration task

- Signal depends on light output, path-length, muon energy
- Reconstructed position depends on light-sharing, which depends on relative light output and alignments
- Alignments and relative light output from cosmics, mapper

Implies Iteration

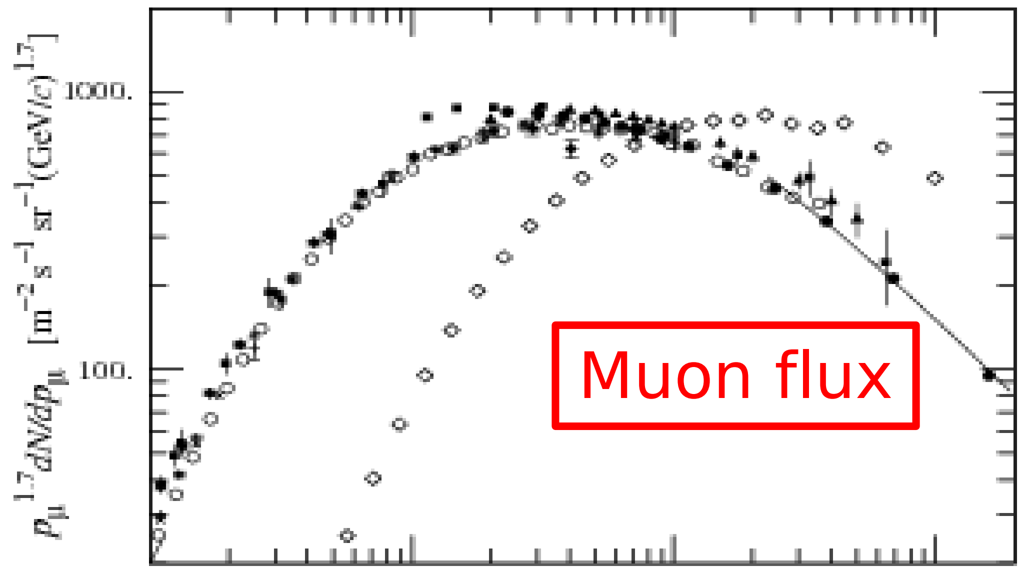
Absolute Scale

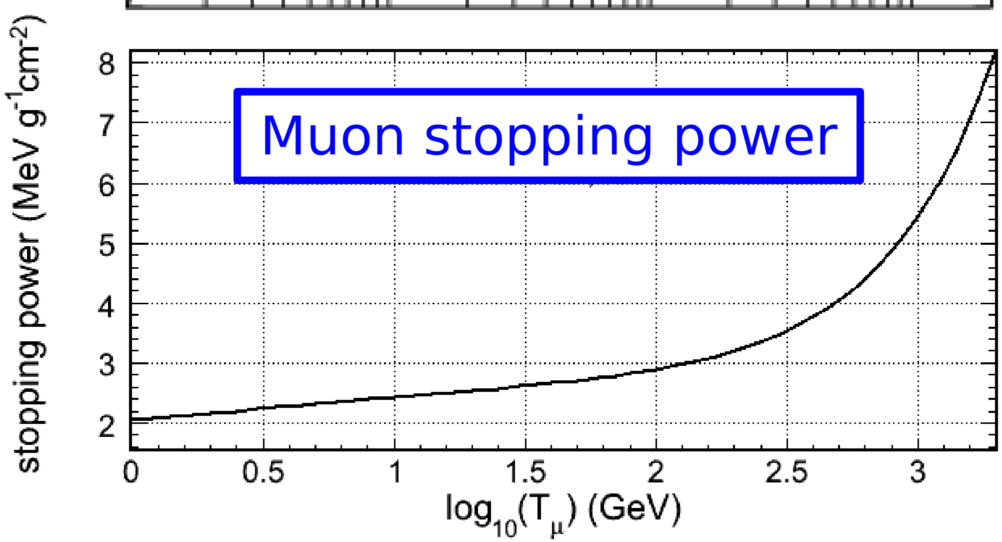


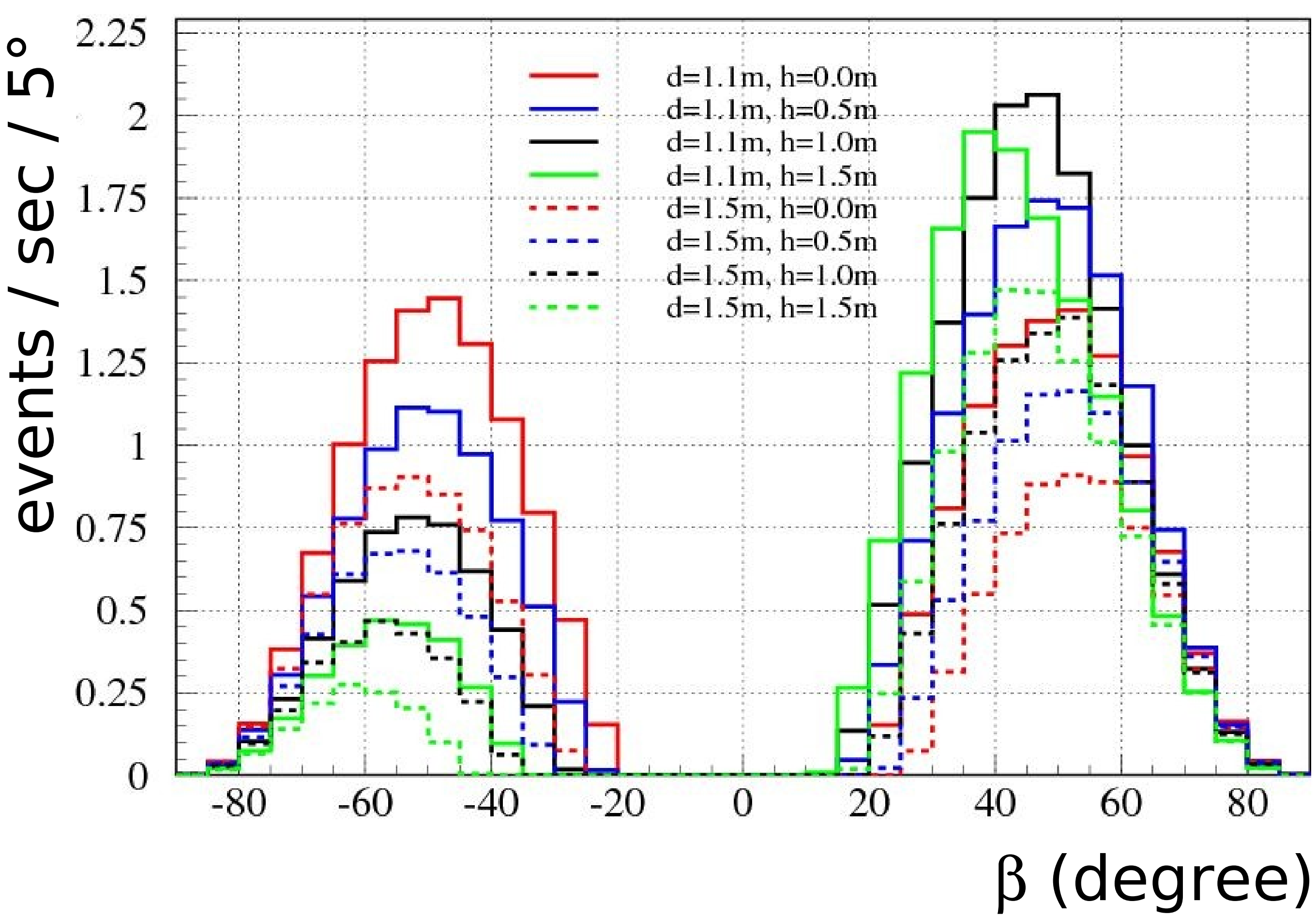
Cosmic Ray

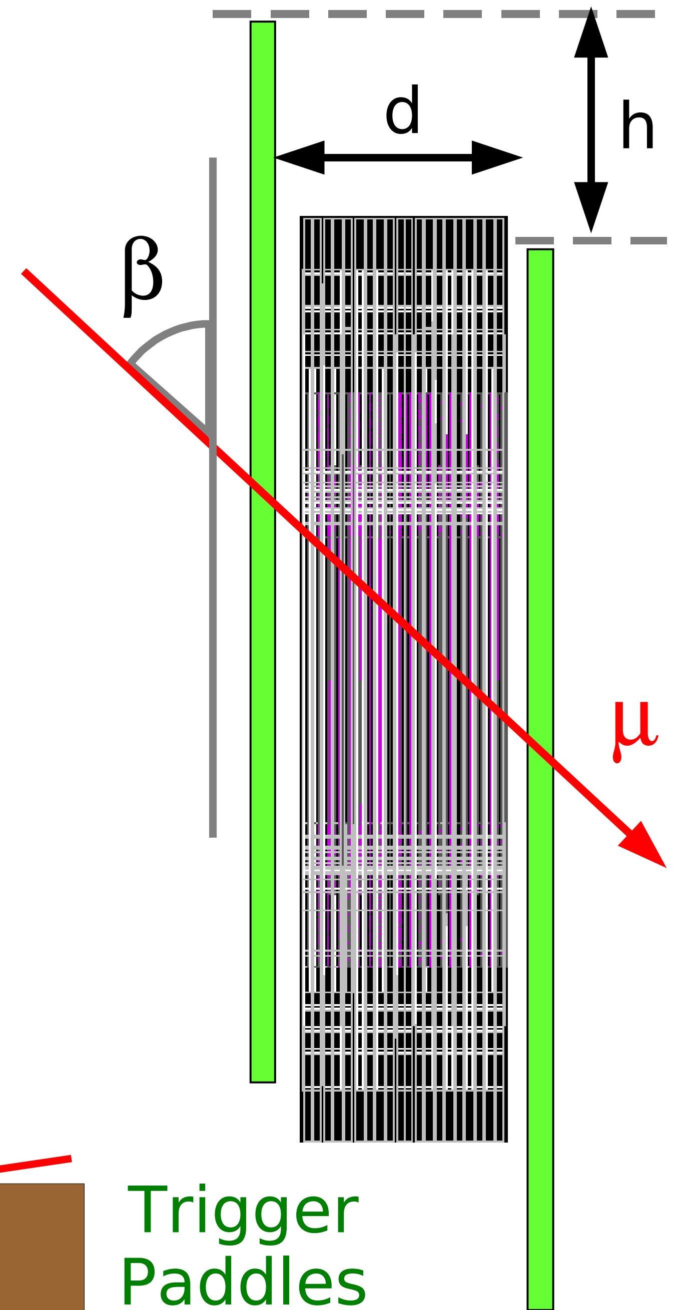
- MeV energy loss / MEU
- Via average signal/plane for through-going muons

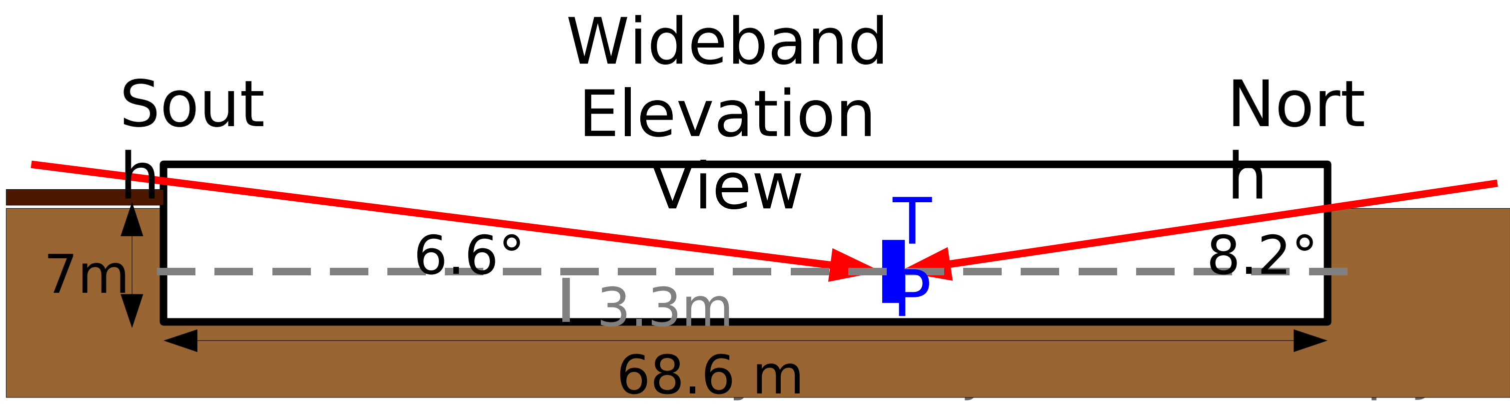
⟨dE/dx⟩
convolution
of flux
&
stopping
power



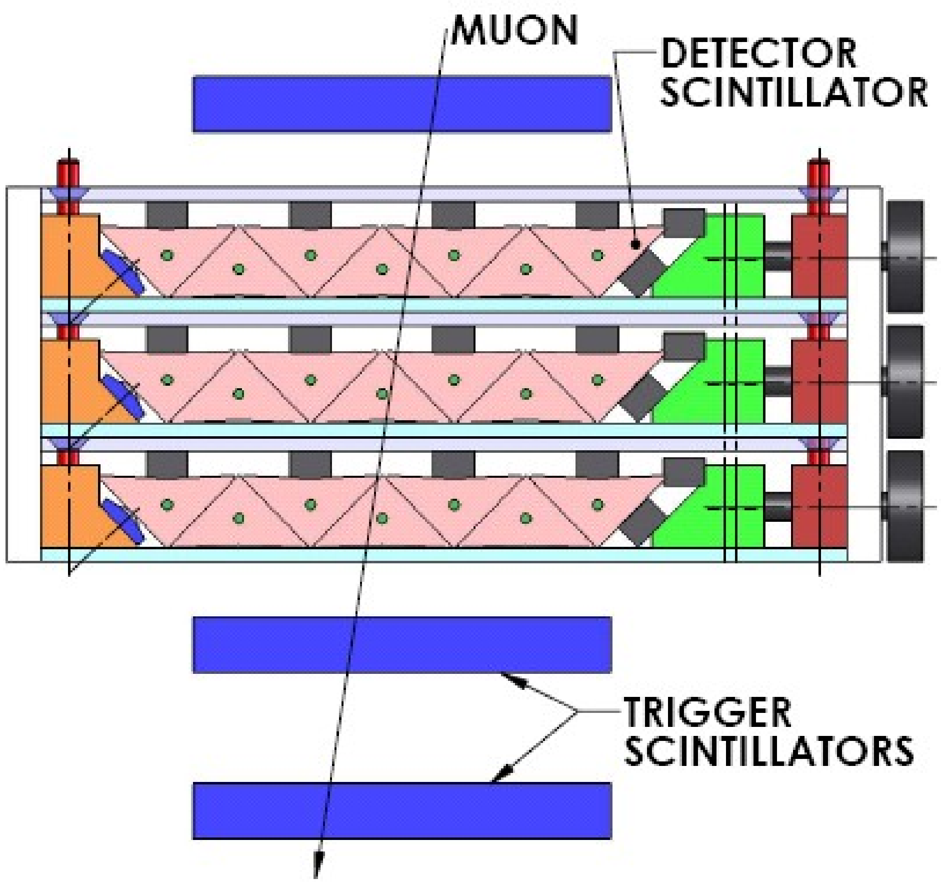



events / sec / 5°
d=1.1m, h=0.0m
d=1.1m, h=0.5m
d=1.1m, h=1.0m
d=1.1m, h=1.5m
d=1.5m, h=0.0m
d=1.5m, h=0.5m
d=1.5m, h=1.0m
d=1.5m, h=1.5m
β (degree)

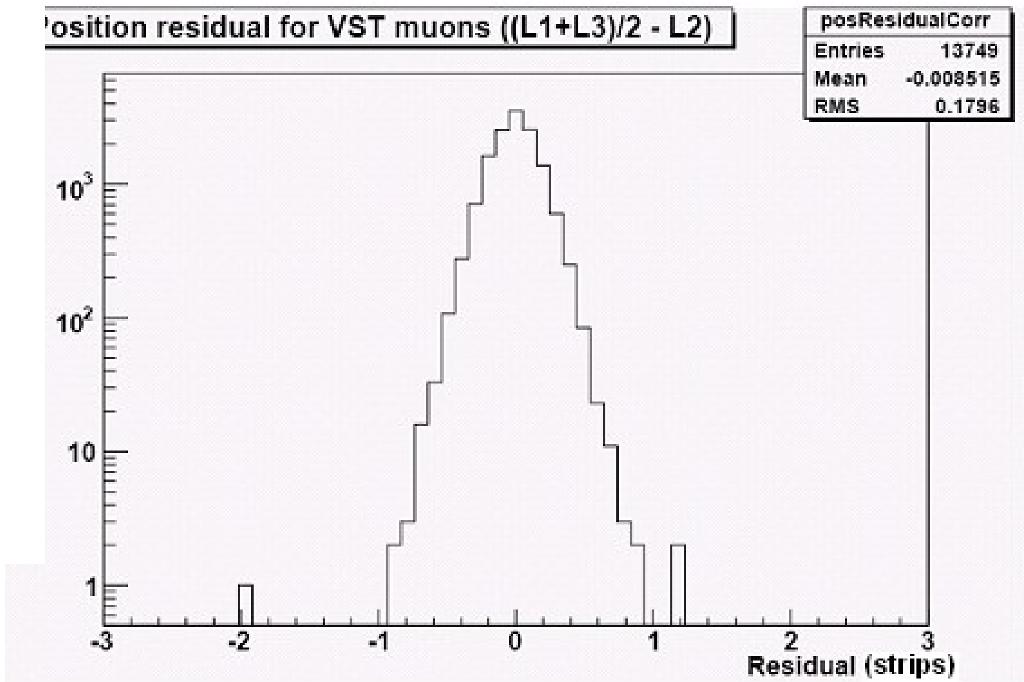

d
h
β
μ
Trigger
Paddles


Wideband
Elevation
View
Sout
h
Nort
h
7m
6.6°
8.2°
T
B
3.3m
68.6 m

Position Resolution

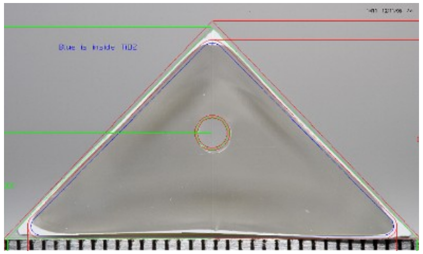


Vertical Slice Test

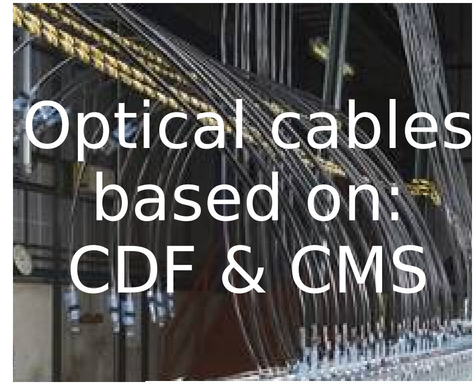


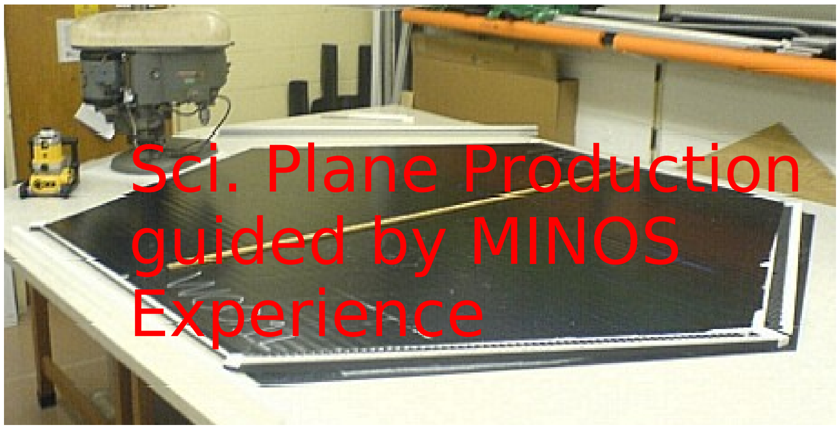
- Position resolution = 2.5 mm
- Distance between the center of strips is 1.7 cm

Synergy?



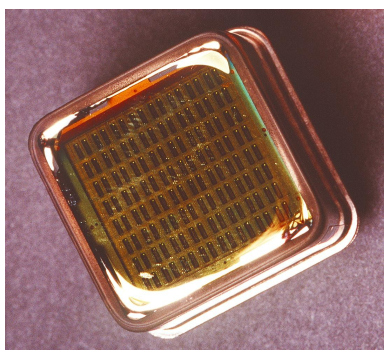
Sci. Bars from FNAL Extrusion Facility
→ Now also used by T2K



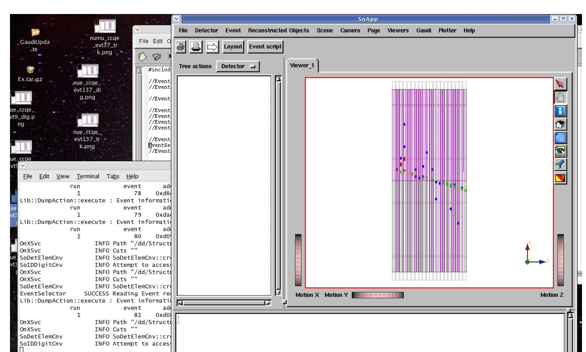


Trip-t ASIC originally designed for DZero
→ used by T2K

M64 PMTs used by MINOS

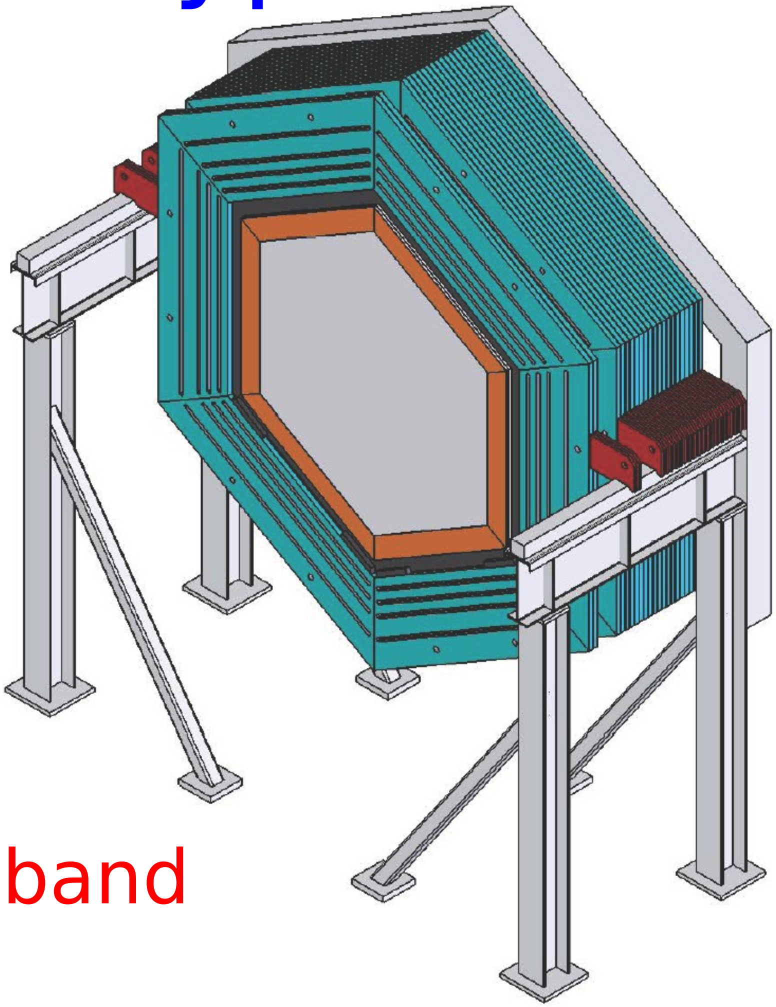


Light Injection Hardware Design From MINOS



Offline software (GAUDI) also used by LHCb & ATLAS

Tracking Prototype



- Comprehensive test of
  - detector design
  - component production
  - detector assembly
  - component integration
  - calibration chain
  - event reconstruction
  - Simulations
- Commissioning now in Wideband
  - Led by university groups
  - **Twenty-three** students coming to the lab this summer

Now Playing at Wideband Hall