The MINERvA neutrino interaction experiment

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NuFact07
8 August 2007

MINERvA physics goals

Neutrino interaction cross sections
Exclusive final state and differential cross sections
Form factors and structure functions
Nuclear effects

MINERvA detector design

A fully active plastic scintillator inner detector
capable of precision tracking and particle ID
3 nanosecond (RMS) hit timing
Electromagnetic and hadron calorimetry

Integral nuclear target region with Pb, Fe, C, He

the MINERvA collaboration

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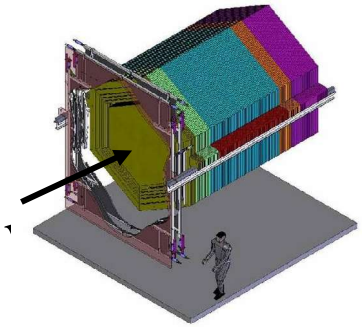
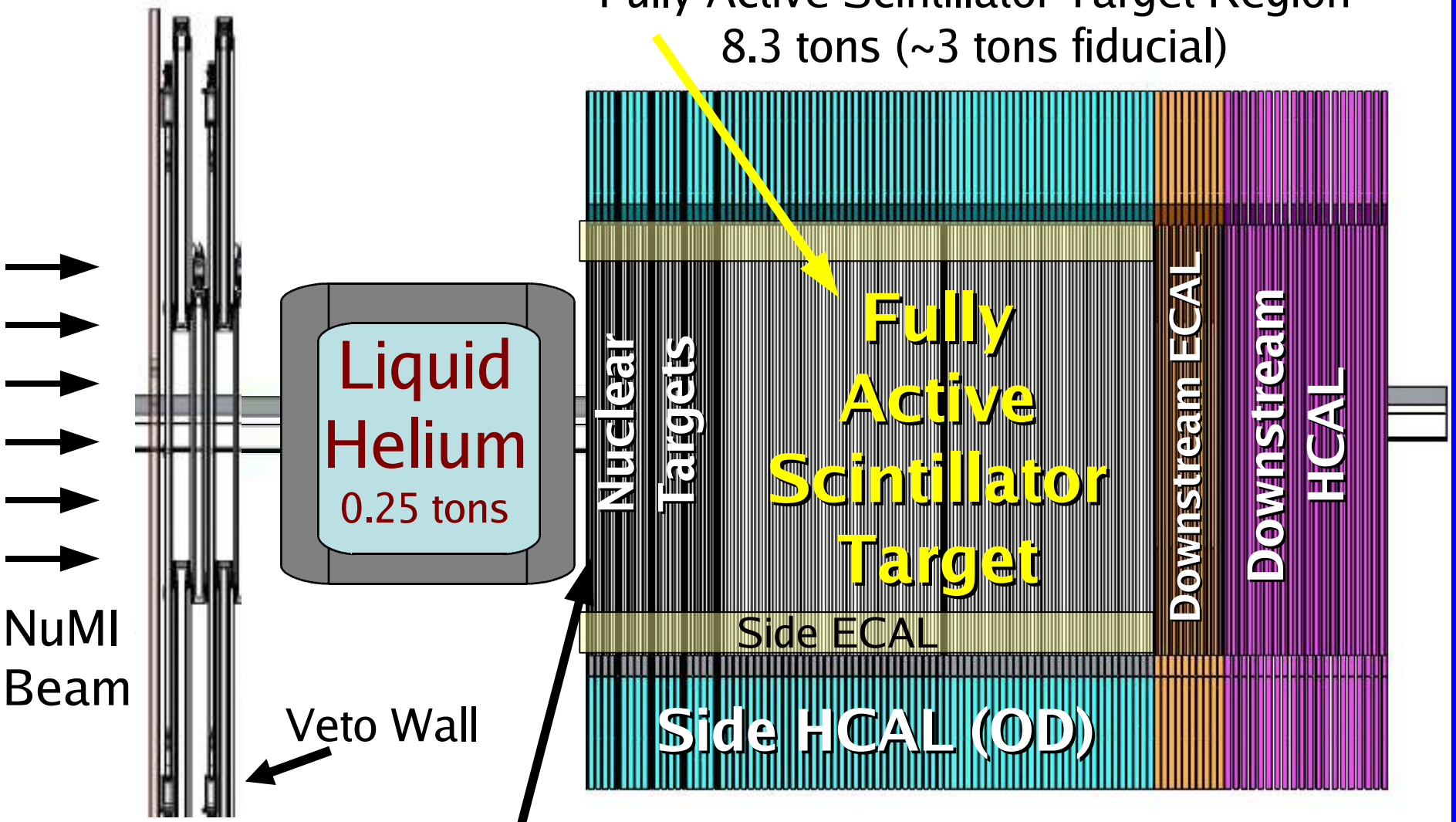
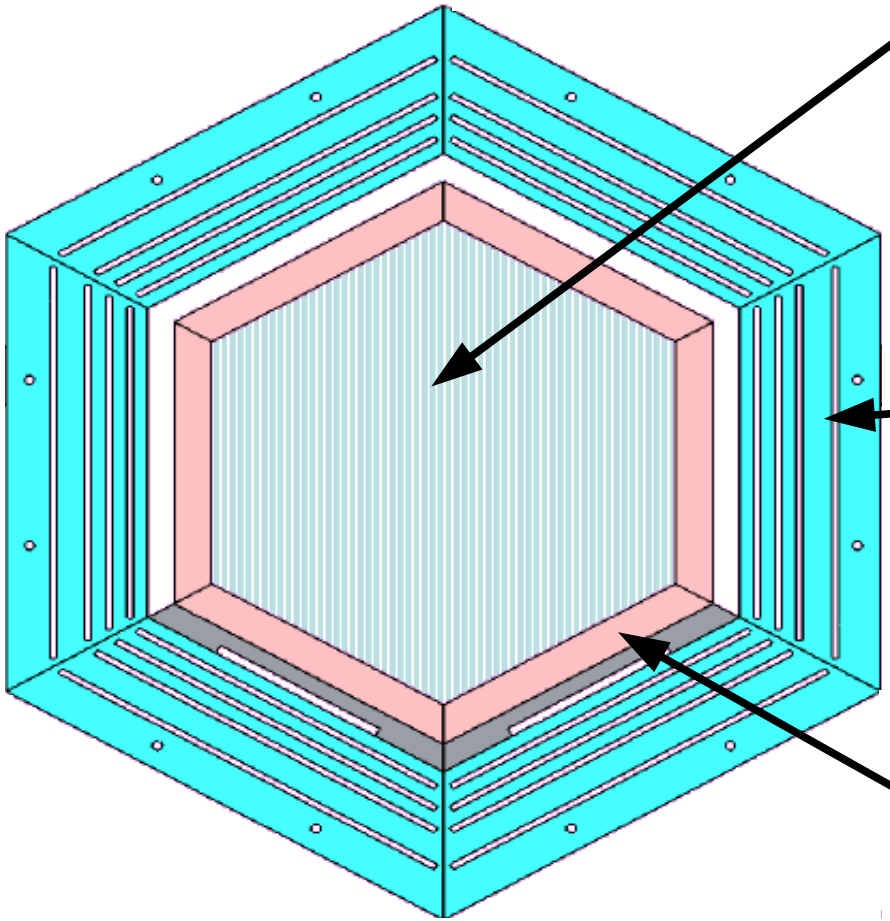
MINERvA detector schematic





MINOS near detector (muon range)

One detector plane



<u>Inner Detector (ID)</u>
Hexagonal UXVX plane sequences for 3D tracking

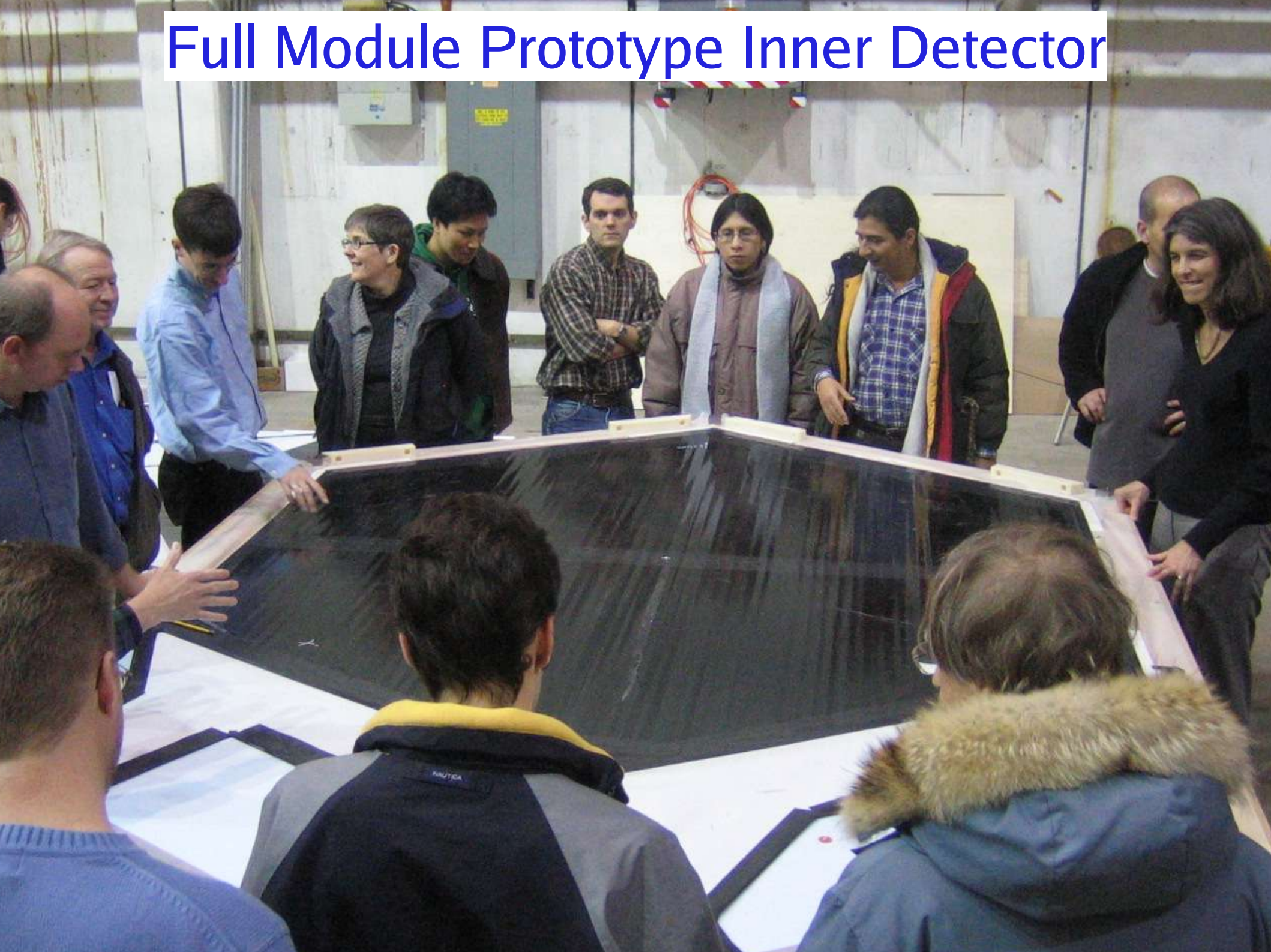
<u>Outer Detector (OD)</u>
'Towers' of iron+scintillator for hadron calorimetry

Side ECAL with lead for EM calorimetry

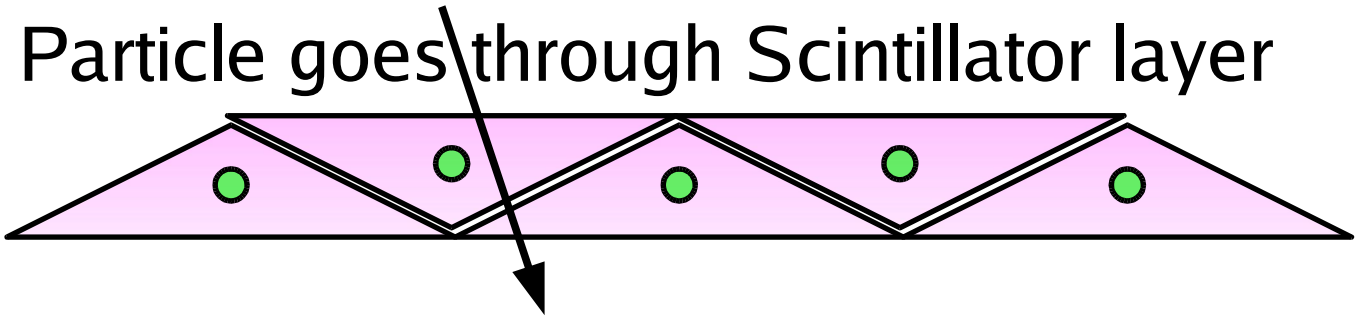
Full Module Prototype Outer Detector Steel

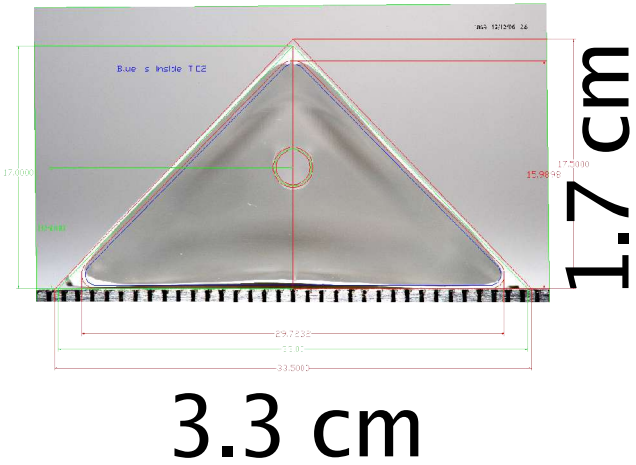
Photos by Bob Flight: 02 March 2007

Full Module Prototype Inner Detector

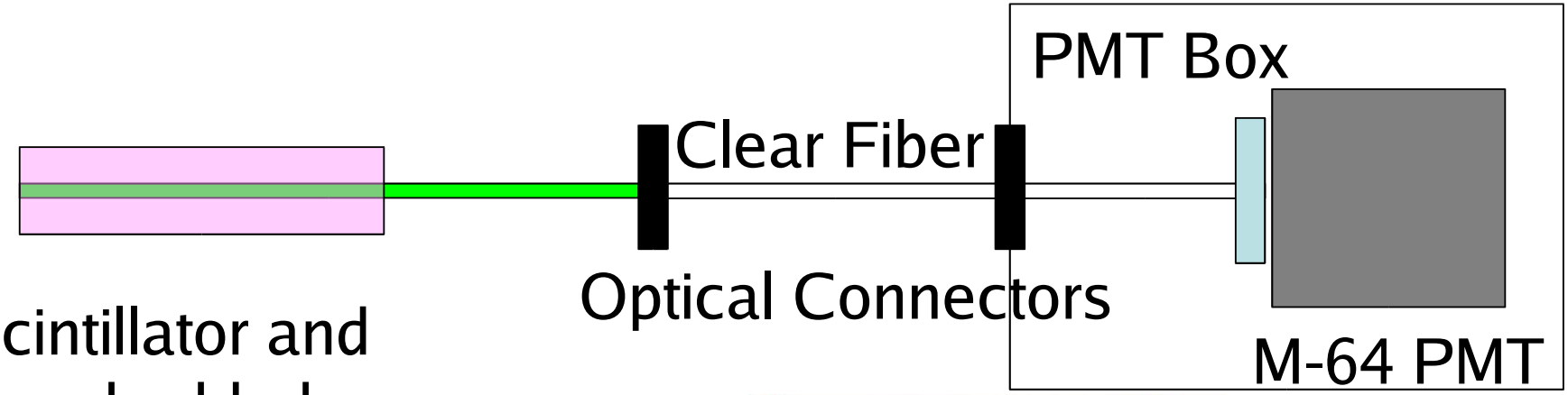


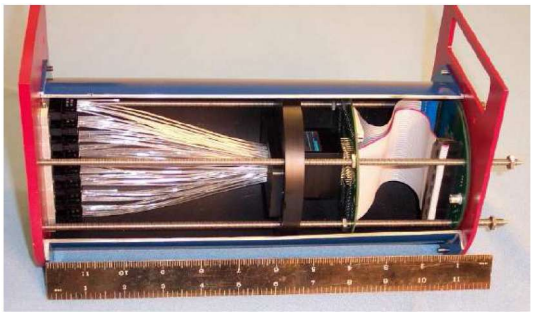
Optical System





Achieved 2.5 mm position resolution using charge sharing and light yield 6.5 pe/MeV

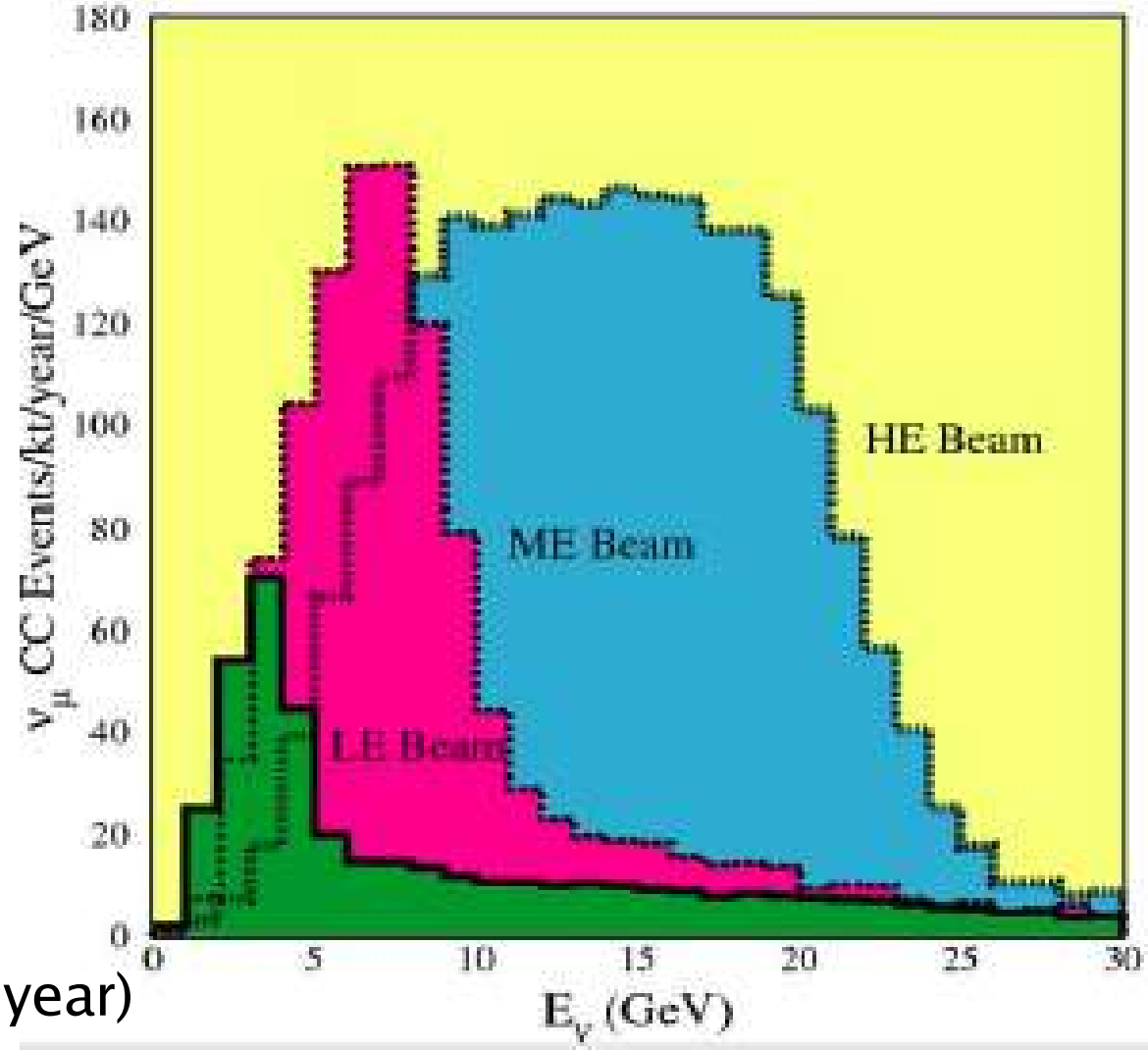




The NuMI beam (expected CC events)

Currently supplying "Low Energy" (LE) beam for MINOS.

Will be similar to this "Medium Energy" (ME) beam for NOvA

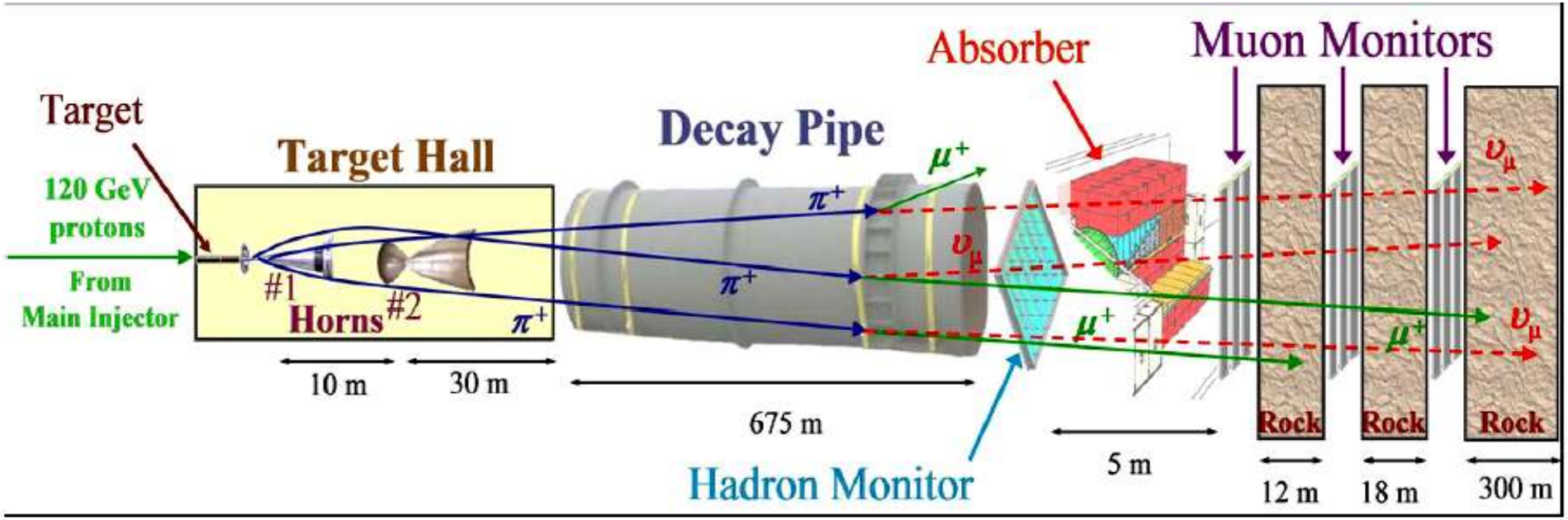


Planning for at least
4 x 10^{20} POT of LE (1 year)
12 x 10^{20} POT of ME (3 years)

Installation and Commissioning in 2009

Affected by both NOvA and Tevatron proton plans

NuMI beam



Important to have constraint on absolute neutrino flux

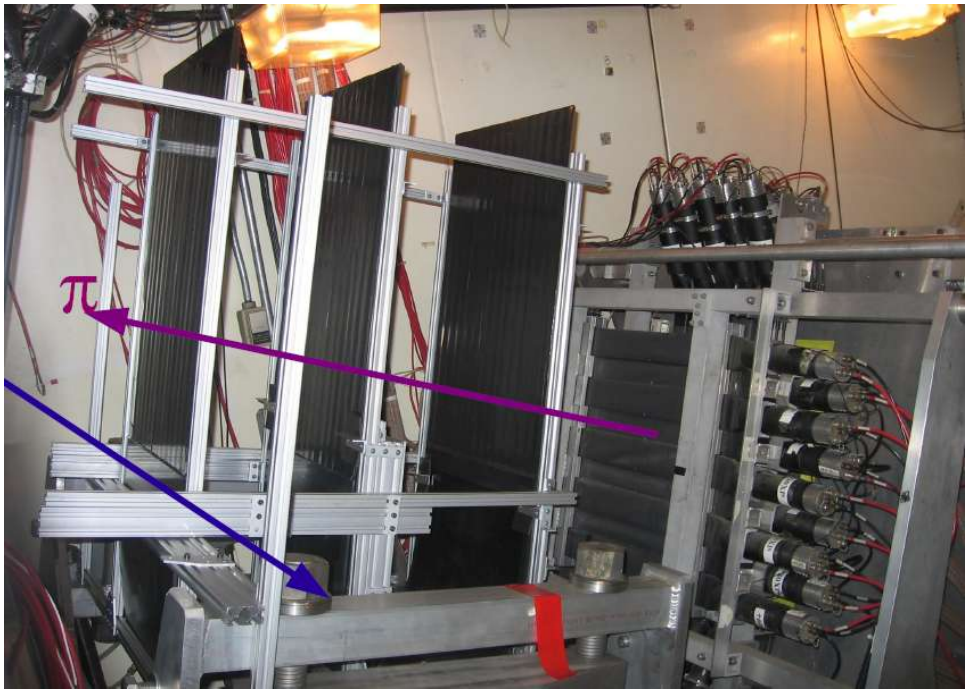
Neutrino data from multiple beam configurations
E-907 (MIPP) hadron spectra off replica target
Improved information from muon monitors

Expect to know flux to ~5% for most of the spectrum

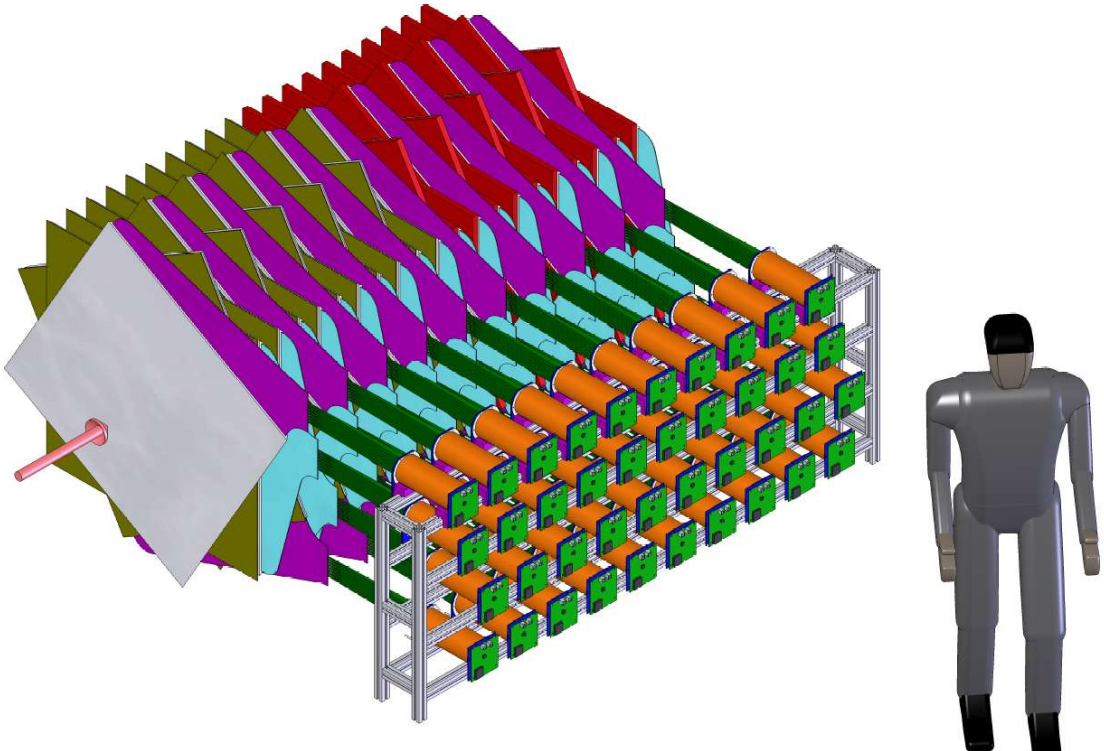
Test beam efforts

Three planes + steel plate
in the SOS spectrometer
at JLAB Hall C.

150 to 450 MeV pions
Data is being analyzed
possible second run this fall



40 plane detector
107 x 107 cm square
removable Fe and Pb
Full UXVX tracking
Run in MTEST Fall 2008
Designing tertiary beam
to get sub GeV pions



Main charged current physics topics

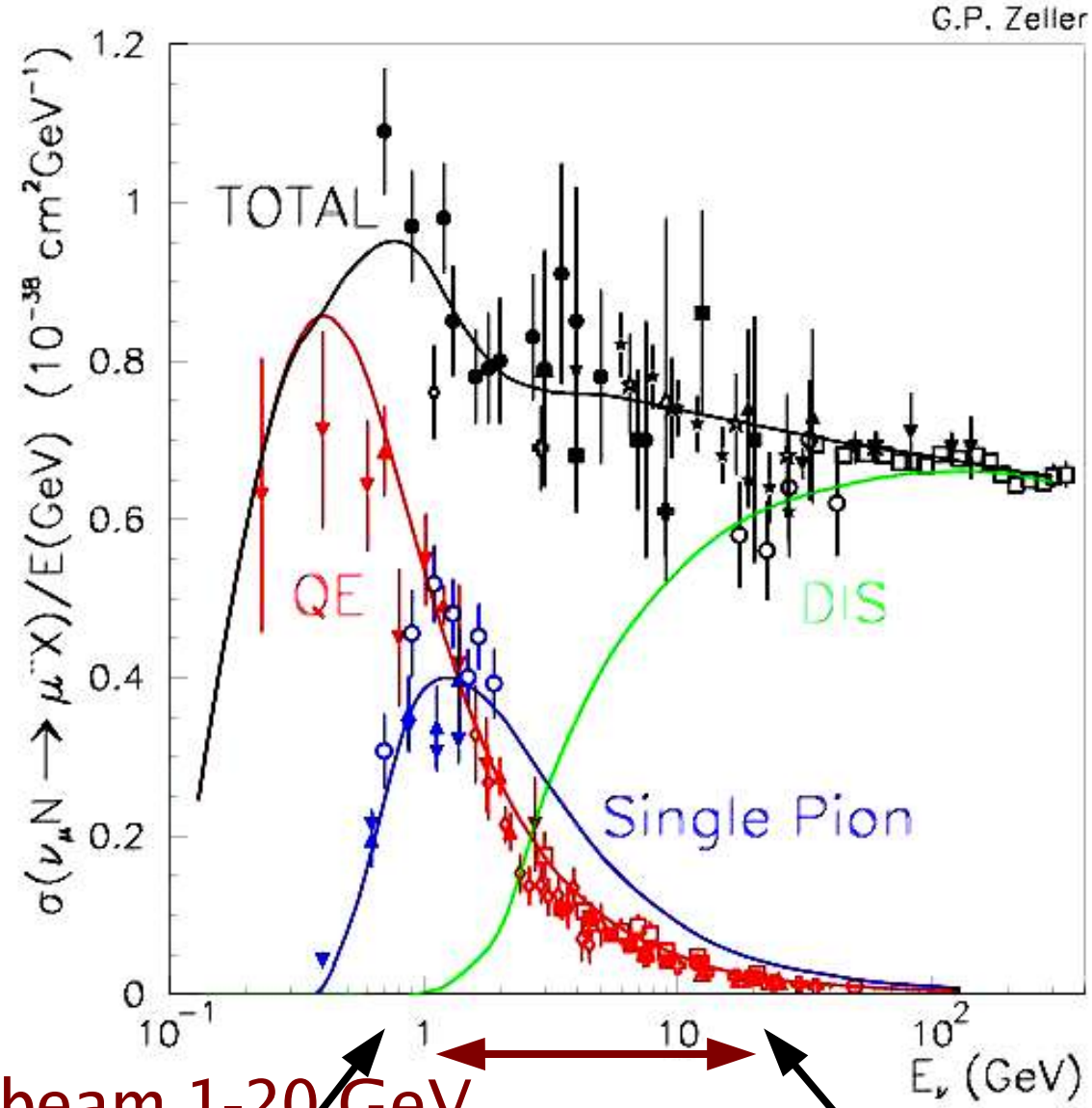
subsamples have roughly a million events each

Quasi-elastic neutrino scattering	0.8 M
Resonance production	1.6 M
Resonance to DIS transition region	2 M
DIS Low Q2 region and structure functions	4.1 M
Coherent Pion Production	CC 85K, NC 37 K
Strange and Charm particle production	230 K

Nuclear effects from comparisons between	C 0.4 M
different nuclear targets	Fe 2.0 M
Polystyrene (CH), Carbon, Iron, Lead, He	Pb 2.5 M
	He 0.6 M

Statistics assume ~4 years running in NuMI beam

Coverage of important neutrino energies



NuMI beam 1-20 GeV

MINOS,NOvA

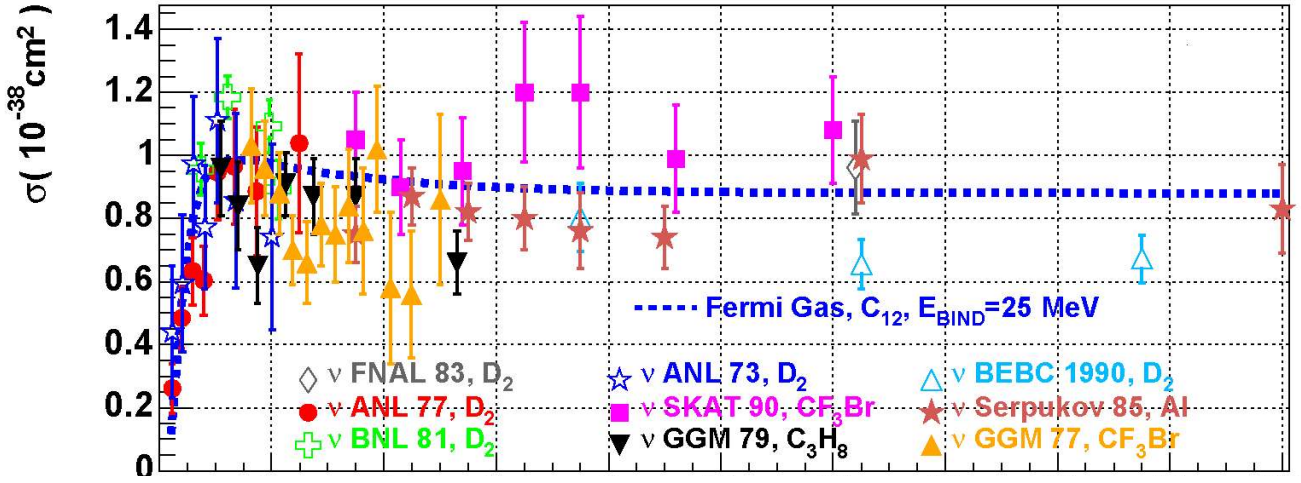
MiniBooNE,T2K

CNGS

Example: Quasi-elastic Interactions

QE cross section vs. neutrino energy

Current measurements

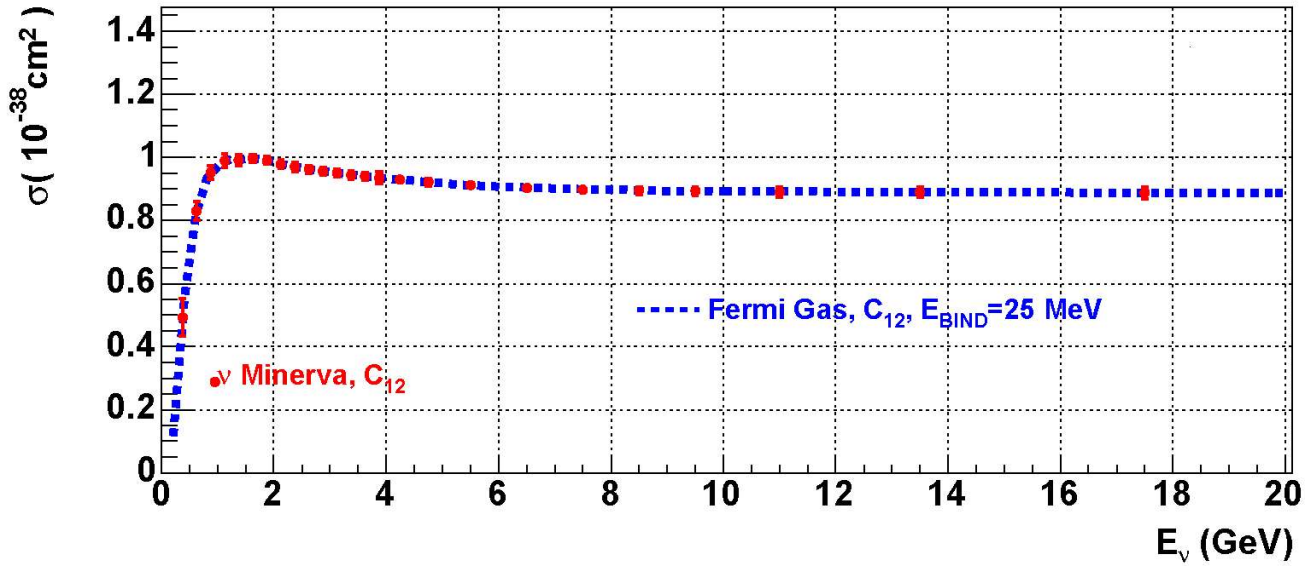


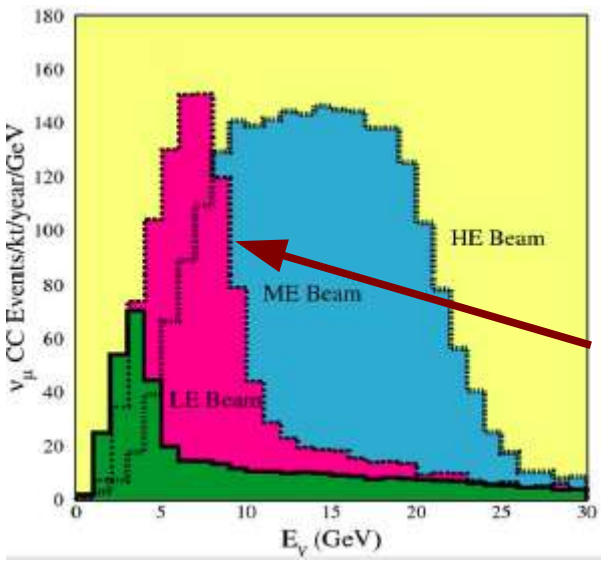
Expected MINERvA result

statistical errors only

includes purity + efficiency

(not included: flux error ~5%)





Will run mostly in ME-like beam + some LE-like

~800,000 QE events in fiducial CH target

plus smaller sub-samples on Pb, Fe, C, He

Simulated Quasi-elastic event strip/plane view

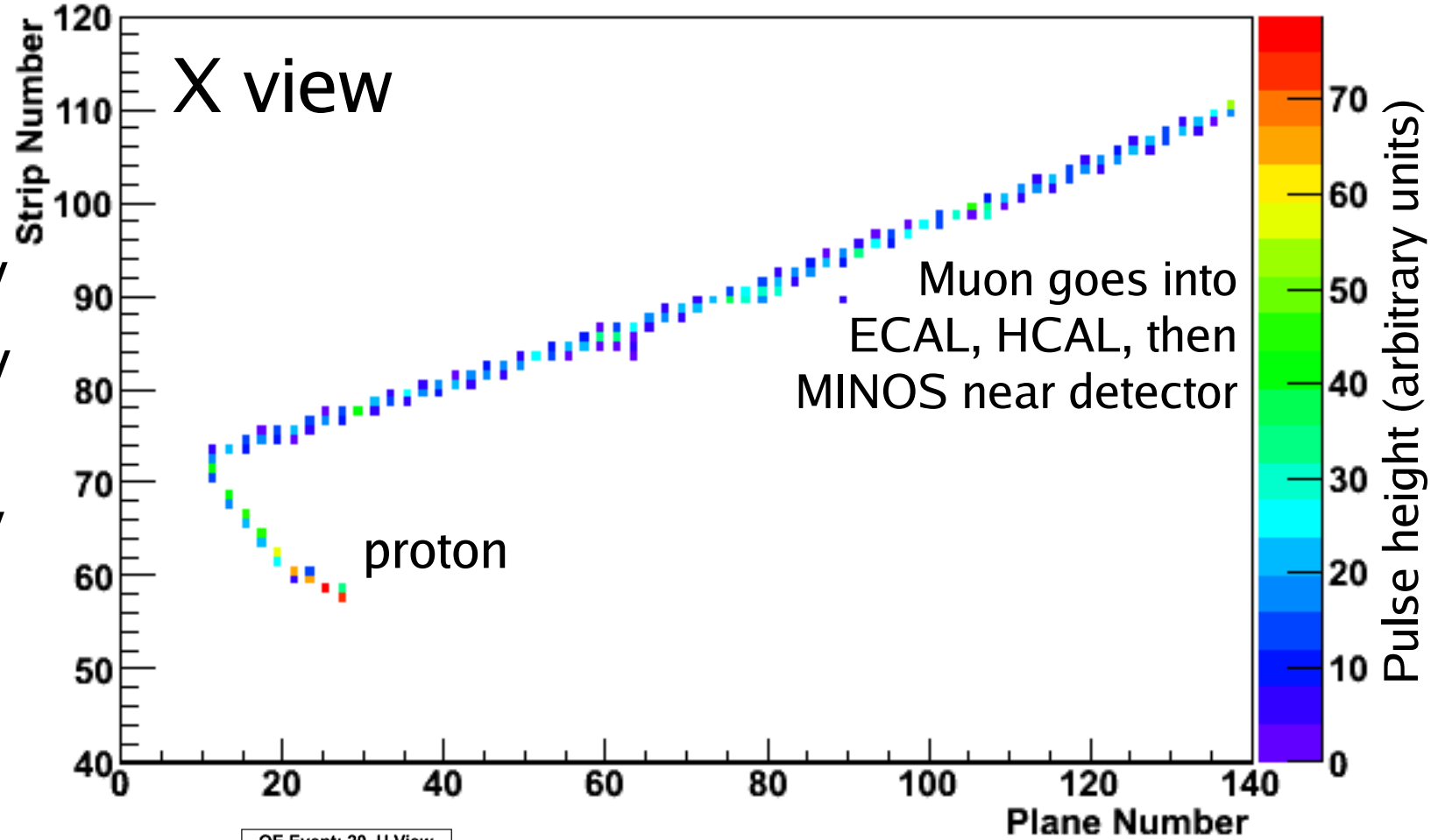
MC truth

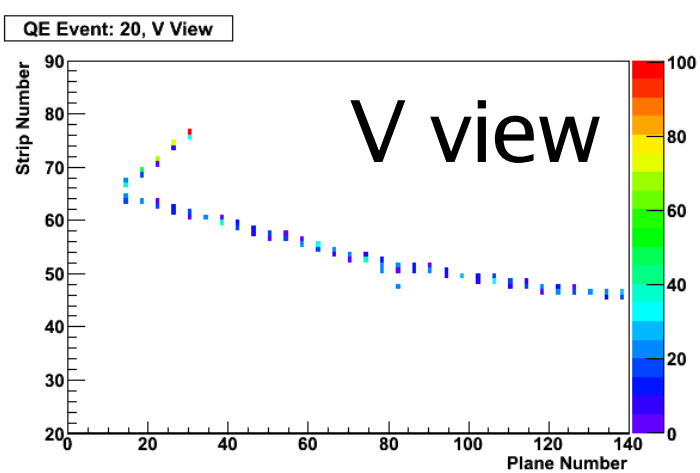
E_ν = 2.93 GeV

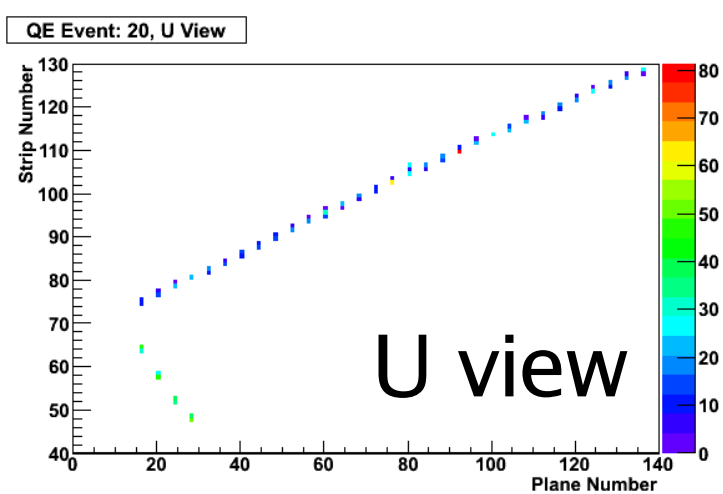
Q^2 = 0.79 GeV

p_μ = 2.51 GeV

p_p = 1.08 GeV

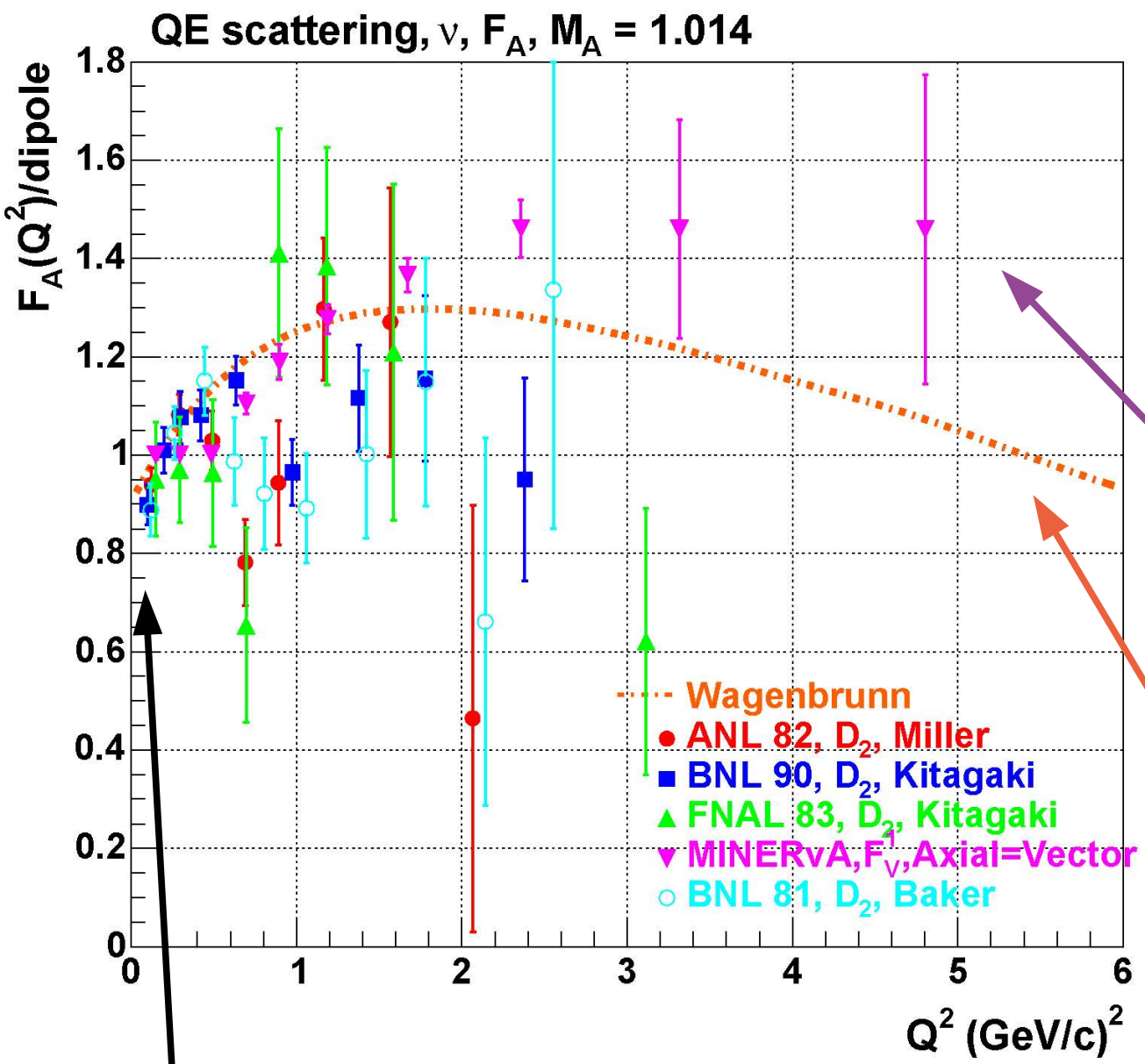






Noise and Crosstalk
Not simulated

Example: Quasi-elastic Axial Form Factor



Expected ability to measure high Q^2 behavior and sensitivity to non-dipole F_A form factor

Simulated MINERvA "Axial=Vector" hypothesis (statistical errors only)

Wagenbrunn, et al. hep-ph/0212190

Also improved measurements at very low Q^2

Simulated CC resonance interaction

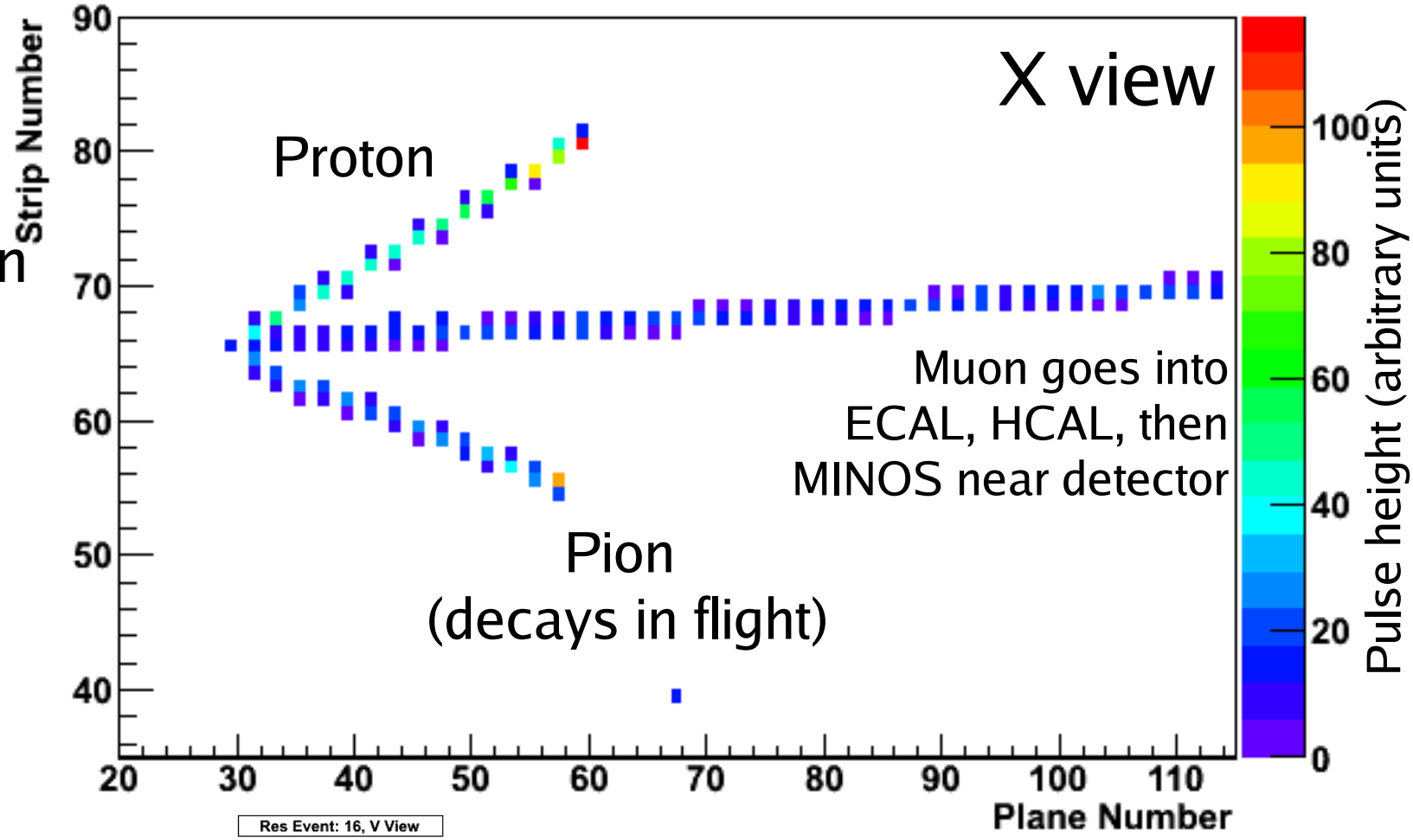
Resonance Production is large fraction of cross section below 5 GeV

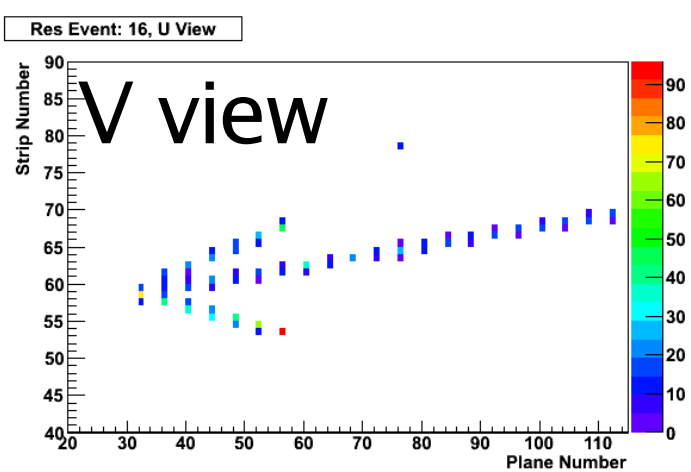
MC truth

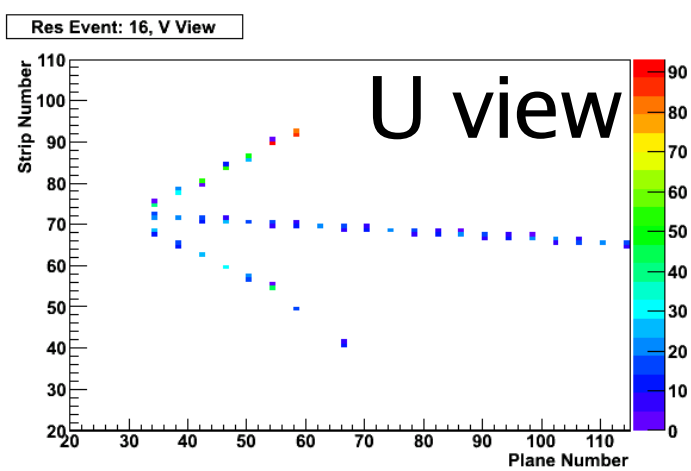
p_μ = 3.60 GeV

p_p = 0.91 GeV

p_π = 0.31 GeV



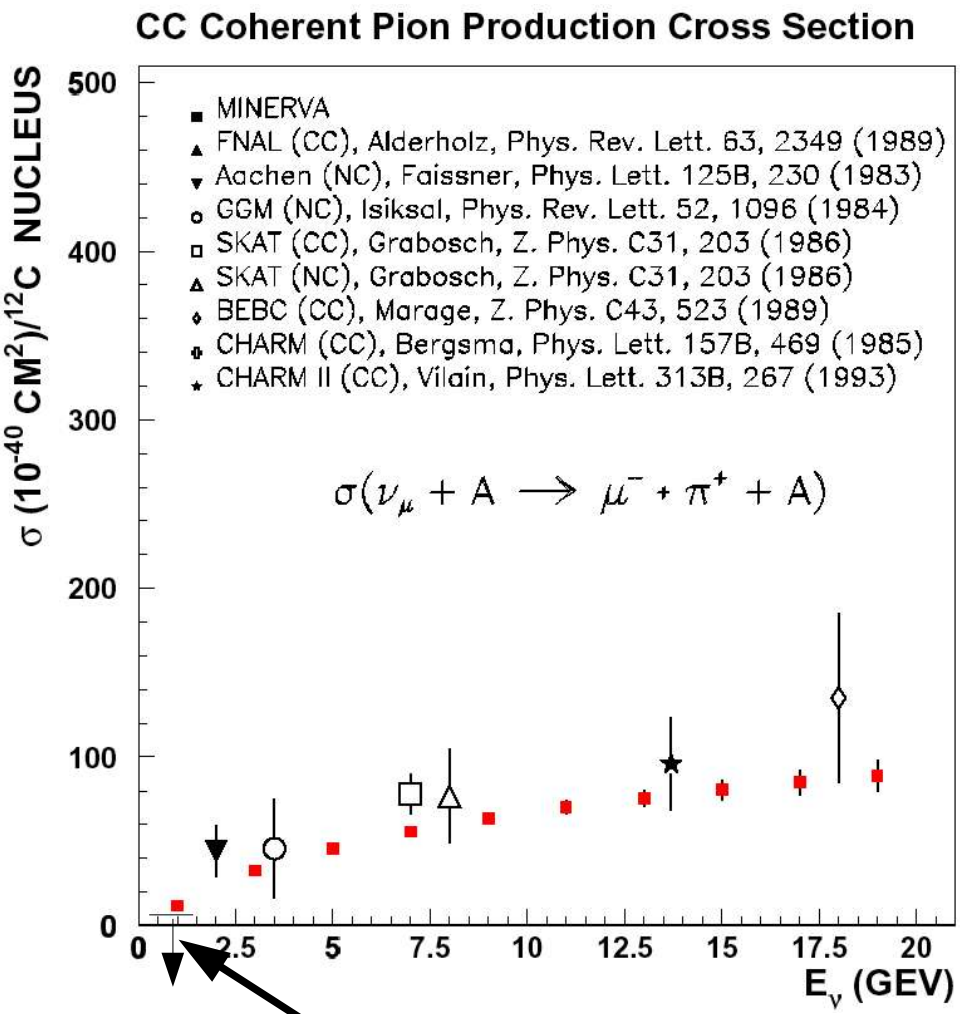


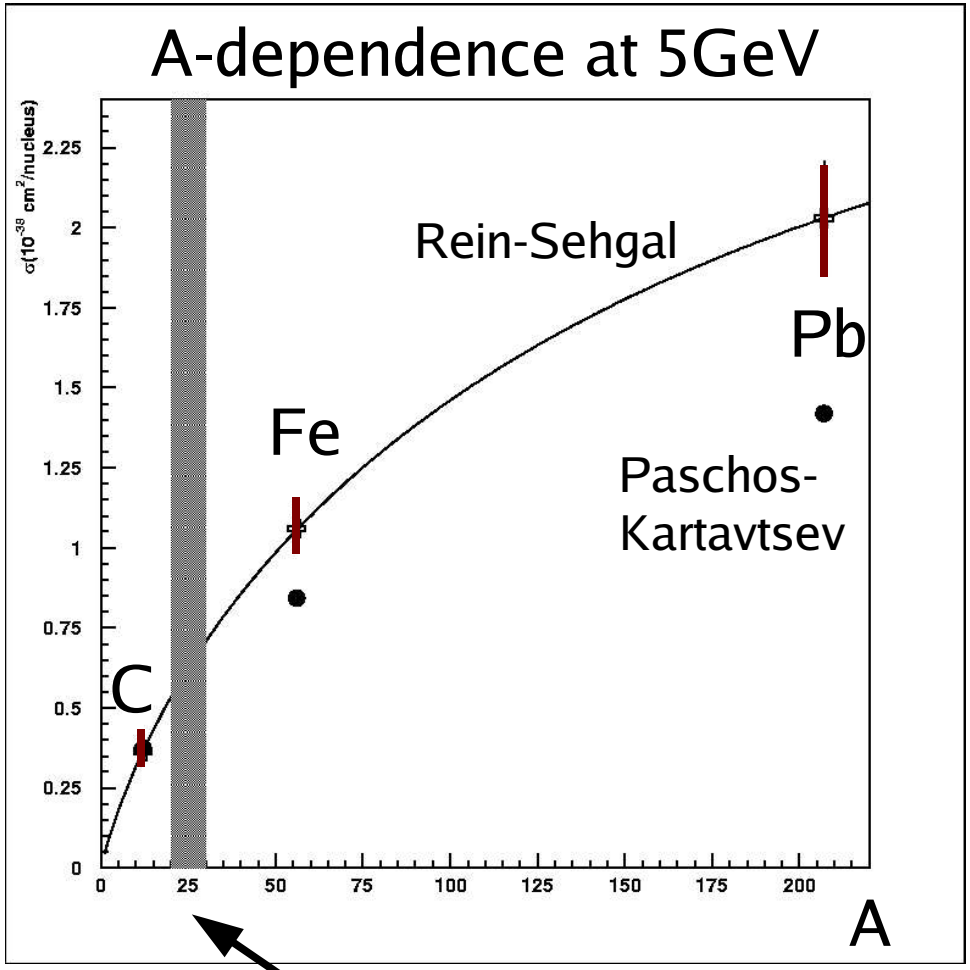


Noise and Crosstalk
Not simulated

Example: CC Coherent Pion Production

Expected MINERvA capabilities in red (statistical errors only)





K2K and MiniBoone Carbon target results will appear down here

Measurements at 5 GeV in shaded region

Resonance and coherent events are background for ν_e appearance

Simulated NC single neutral pion

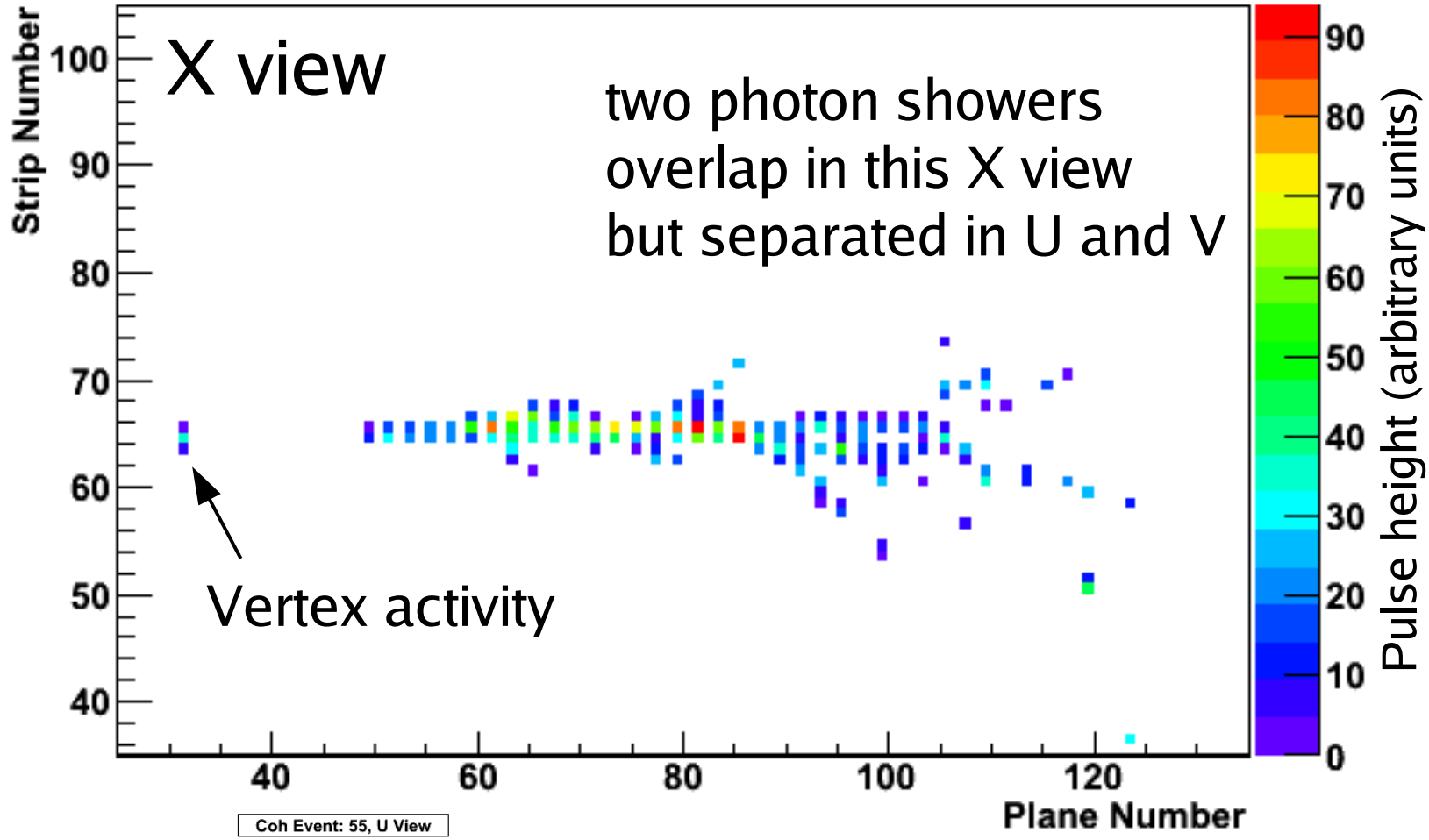
Important background to nu-e apperance

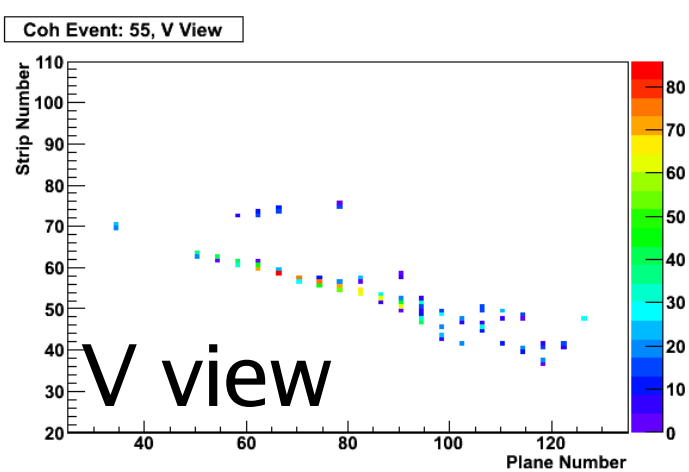
MC truth

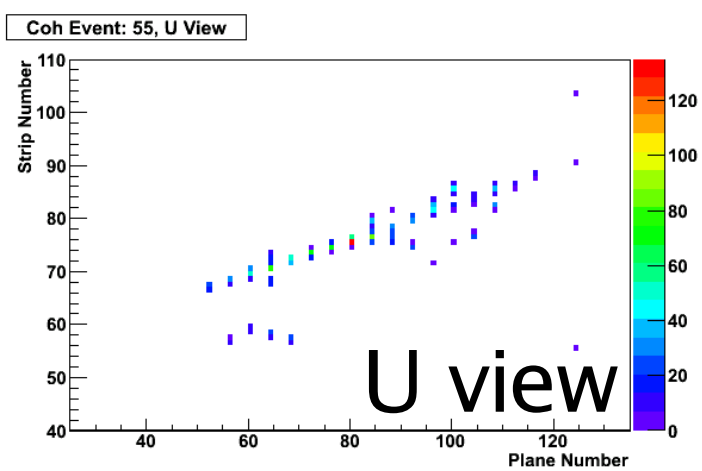
(p_π = 1.4 GeV)

p_γ = 1.3 GeV

p_γ = 0.12 GeV







Noise and Crosstalk
Not simulated

Cross section goals

Constrain charged current channels
quasi-elastic, resonance, coherent, DIS
to ~5% (error on the flux)
for neutrino energies between 1 and 20 GeV

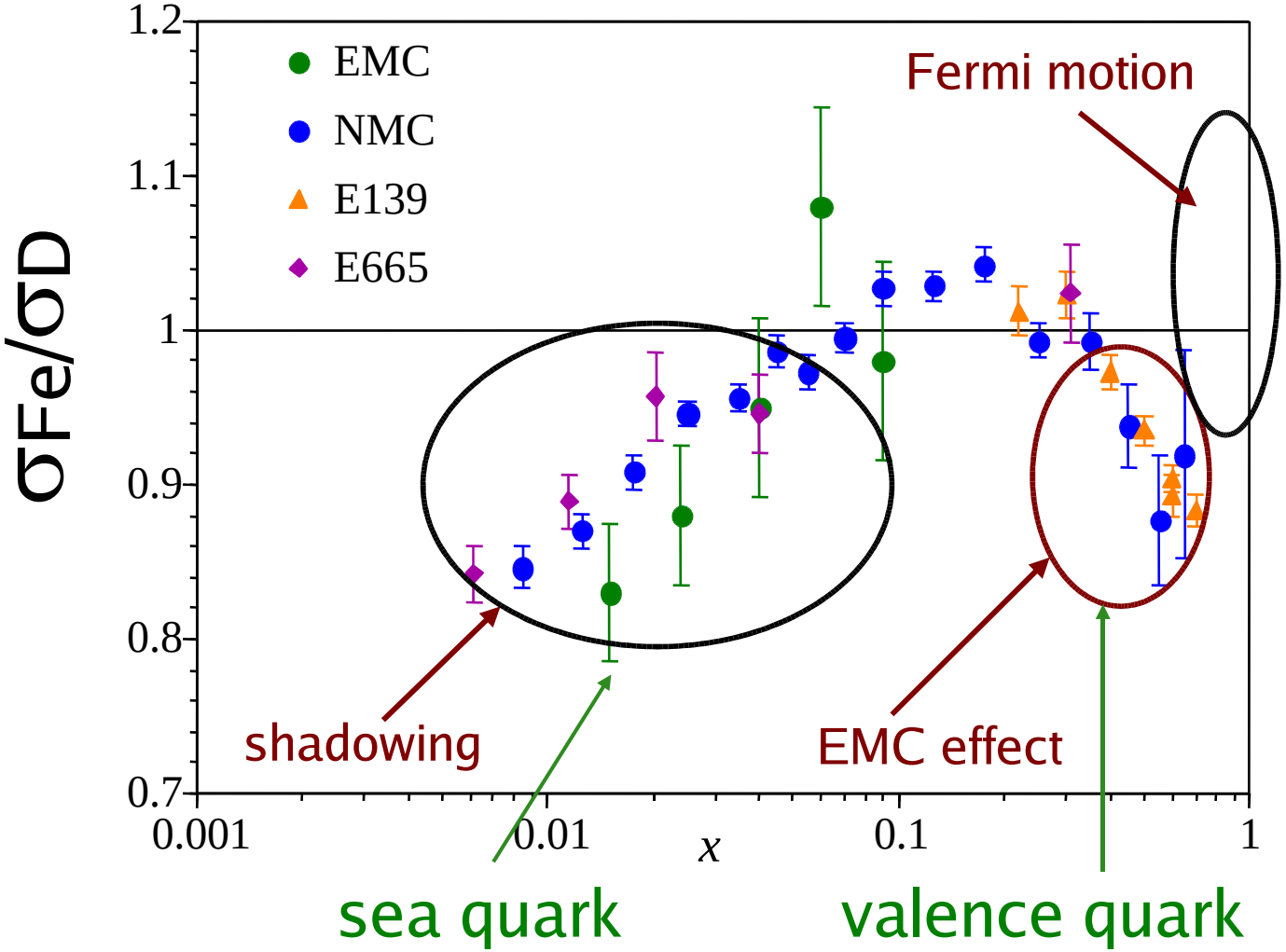
Neutral current channels are more challenging
expect ~10% error on the cross section

Sam Zeller's estimates (FNAL wine and cheese, June 2007)
"Current" uncertainties in absolute cross sections
for $E\nu$ = few GeV and nuclei of interest

QE	15-20%
"Resonance"	20-40%
Coherent	100%

Nuclear effects modify the DIS cross section

Electron and Muon Scattering Data



Expect nuclear effects to be different for neutrinos due to axial-vector currents

Different nuclear effects for valence and sea quarks

JLAB E03-103: These effects hold for resonance events too!

Nuclear effects modify QE, Res cross sections?

K2K and MiniBoone report
QE Q2 shape discrepancy
compared with Deuterium measurements.

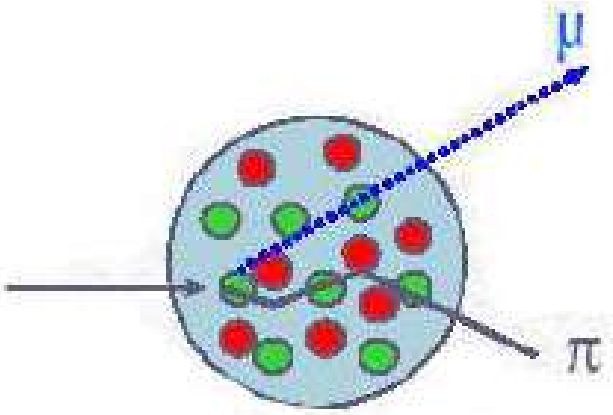
extracted M_A (GeV)	
Deuterium	1.03
K2K-Scifi O	1.20
K2K-SciBar C	1.14
MiniBoone C	1.25
errors near +/-	0.12

Due to nuclear effects?
Systematic uncertainties?
Energy dependent?
Does it affect resonance production?
How are the absolute QE and Res σ affected?

MINERvA spans a wide range of energies
and a wide range of nuclei
with high statistics

Nuclear reinteractions modify final state topology

scattering and energy loss
absorption
charge exchange



for MINOS iron calorimetry
Visible shower energy is among the largest systematics
MINOS estimates 10% error from the combination of hadron multiplicity and final state interactions

for Water Cerenkov kinematic event reconstruction
absorption and charge exchange may be significant

Schedule summary (since NuFact06)

Spring 2007	Received US-DOE CD3a approval
Spring 2007	Full module prototype
Summer 2007	Successful FNAL CD3b review
Summer 2007	Full DAQ system tests
Fall 2007	US-DOE CD3b decision
Spring 2008	Construct Multi-plane Tracking Prototype
Summer 2008	Operate Tracking Prototype with cosmics
Fall 2008	Test beam run in FNAL MTEST beam
2009	Full detector installation
	Neutrinos from MINOS LE beam
2012	Changeover to NOvA ME beam

Summary of MINERvA progress

On track for first data in NuMI beam in 2009

will provide much improved measurements
total cross section
exclusive final state topologies
differential cross sections

high statistics
wide range of energies
wide range of nuclear targets