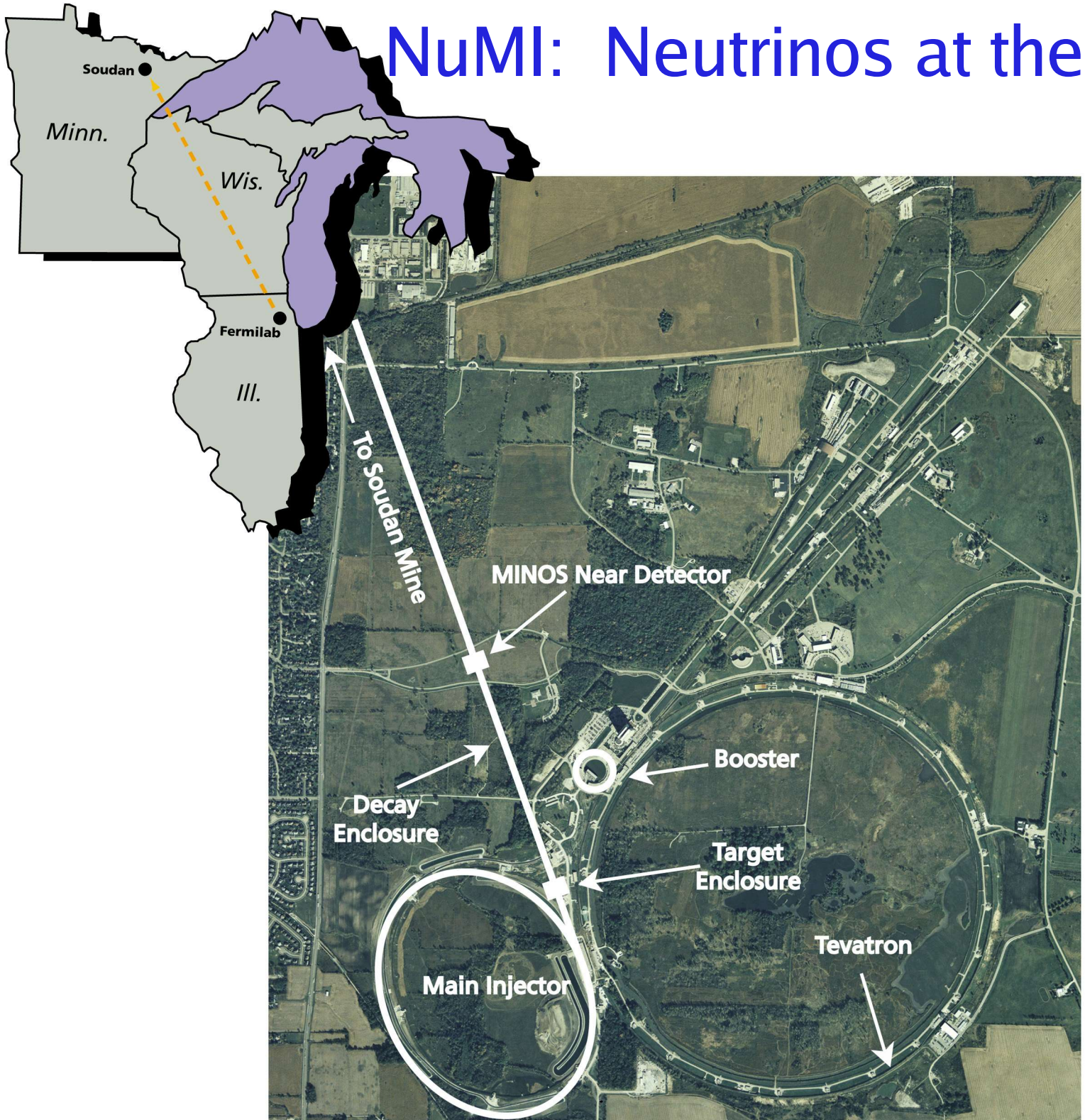
Neutrinos at the Fermilab NuMI beam

MINOS and MINERvA

Rik Gran
University of Minnesota Duluth

for the MINOS and MINERvA collaborations

NuMI: Neutrinos at the Main Injector



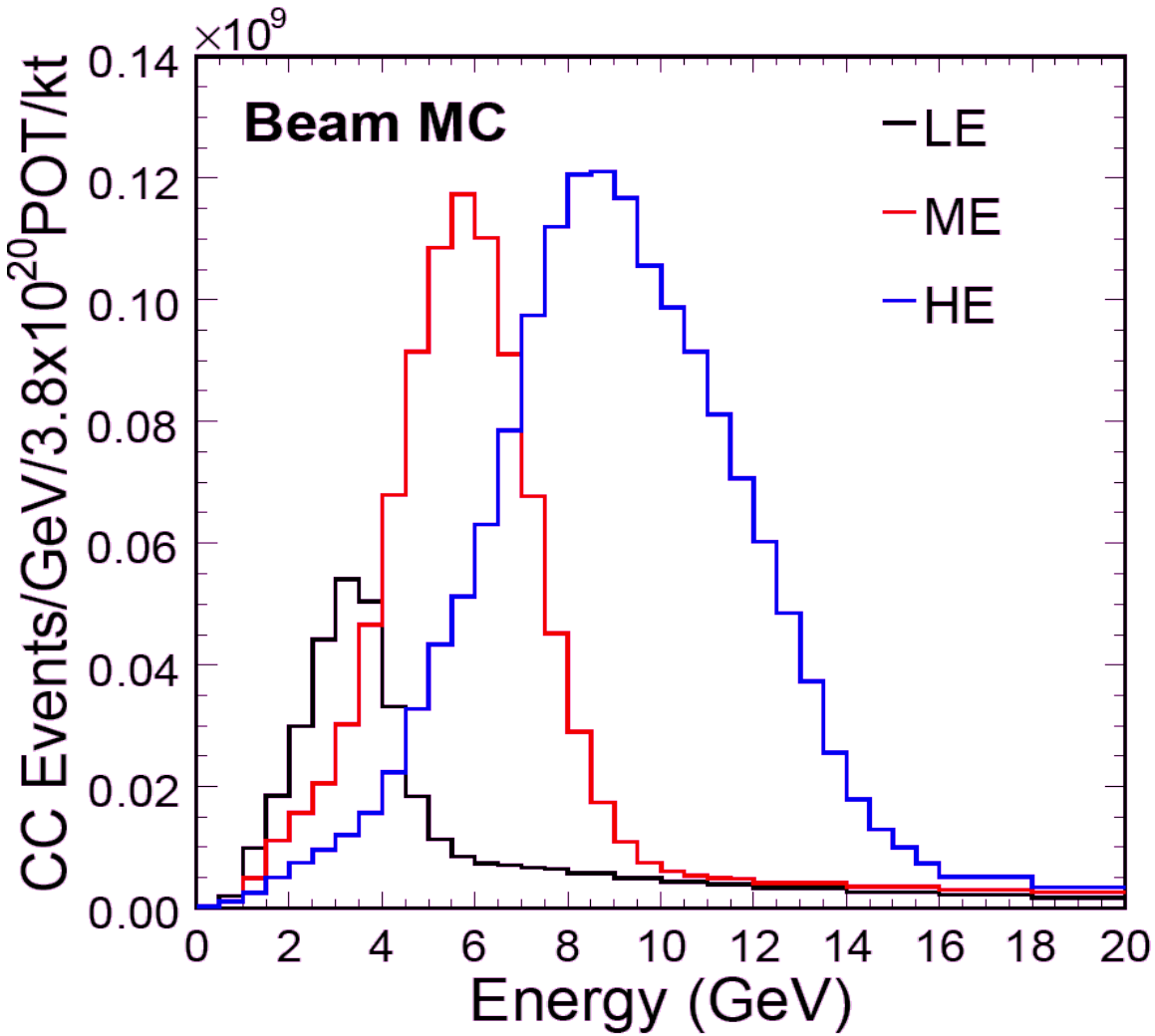
Beamline for

MINOS,

MINERvA,

NOvA

Neutrinos from the NuMI beam

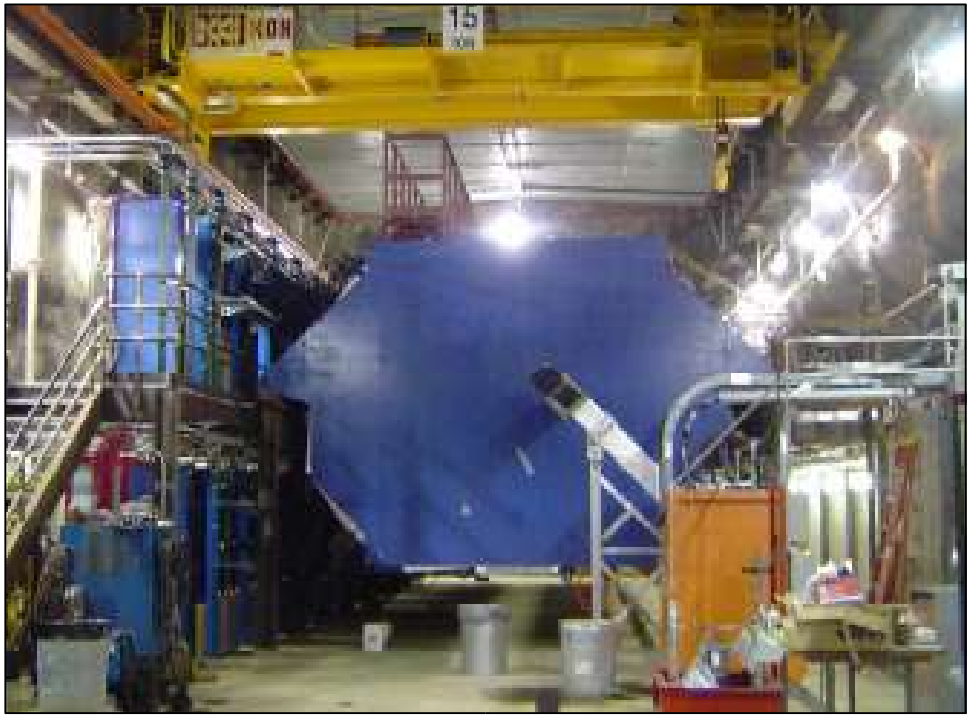


LE beam for MINOS
now through ~2010

ME beam for NOvA
(with intensity upgrade)
years 2010 - 2015

Flux uncertainties ~5% absolute, ~2% bin-to-bin in Enu
(after MIPP hadron production measurement on MINOS target)

MINOS near detector



Event rate in LE beam:
3.5 Million CC events
per 10^{20} protons on target

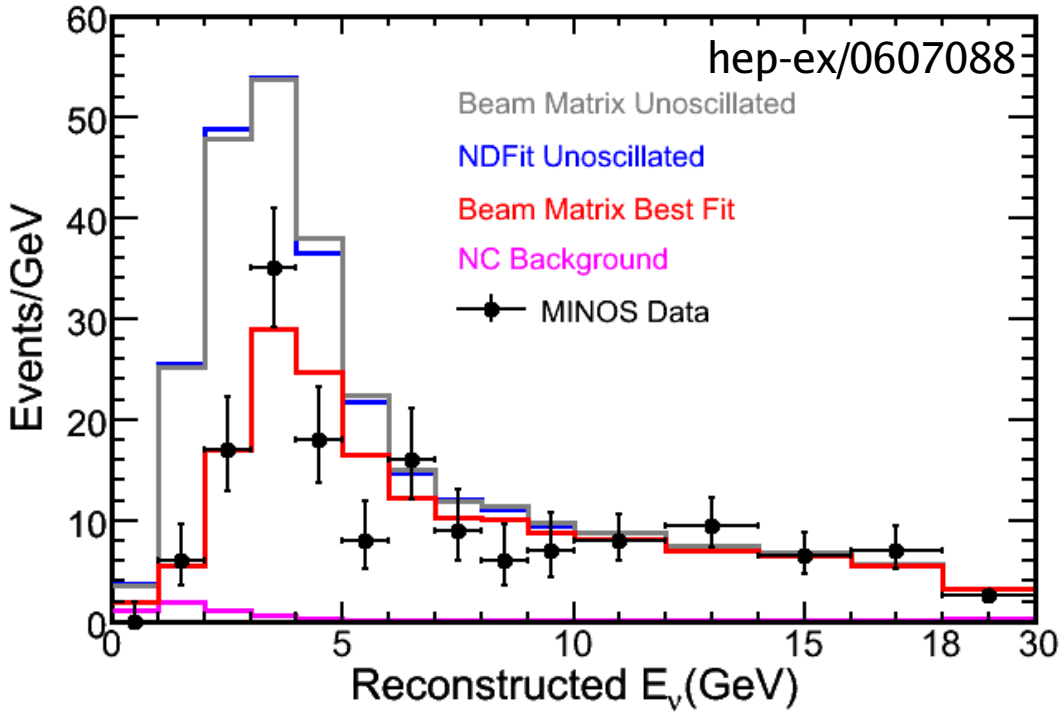
Currently have one year data
1.27×10^{20} POT in LE beam
(MiniBoone, CDF+D0 also get protons)

MINOS Near Detector
1000 tons
$3.8 \times 4.8 \times 15$ m^3
282 steel planes
153 scintillator planes

Expect ~4×10^{20} POT/yr

plus smaller samples for
other beam tunings
to constrain beam errors

MINOS oscillation results and errors



$$\Delta m^2 = 2.74^{+0.44}_{-0.26} \times 10^{-3}\ eV^2$$

$$\sin^2 2\theta = 1.00_{-0.13}$$

Errors are stat. and syst.

Data based on 1.27×10^{20} POT

hep-ex/0607088

Sources of uncertainty	Δm^2 (10^{-3} eV^2)	$\sin^2 2\theta$
NC contamination ±50%	0.09	0.050
Abs. Hadronic Energy Scale ±11%	0.06	0.048
Near/Far normalization ±4%	0.05	0.005
All other systematic uncertainties	0.04	0.011
Statistical Error now	0.36	0.12

MINOS near detector physics studies

Deep Inelastic Cross Sections

F2 structure function

Quasi-elastic interactions

Neutral current interactions

Coherent pion production (CC and NC)

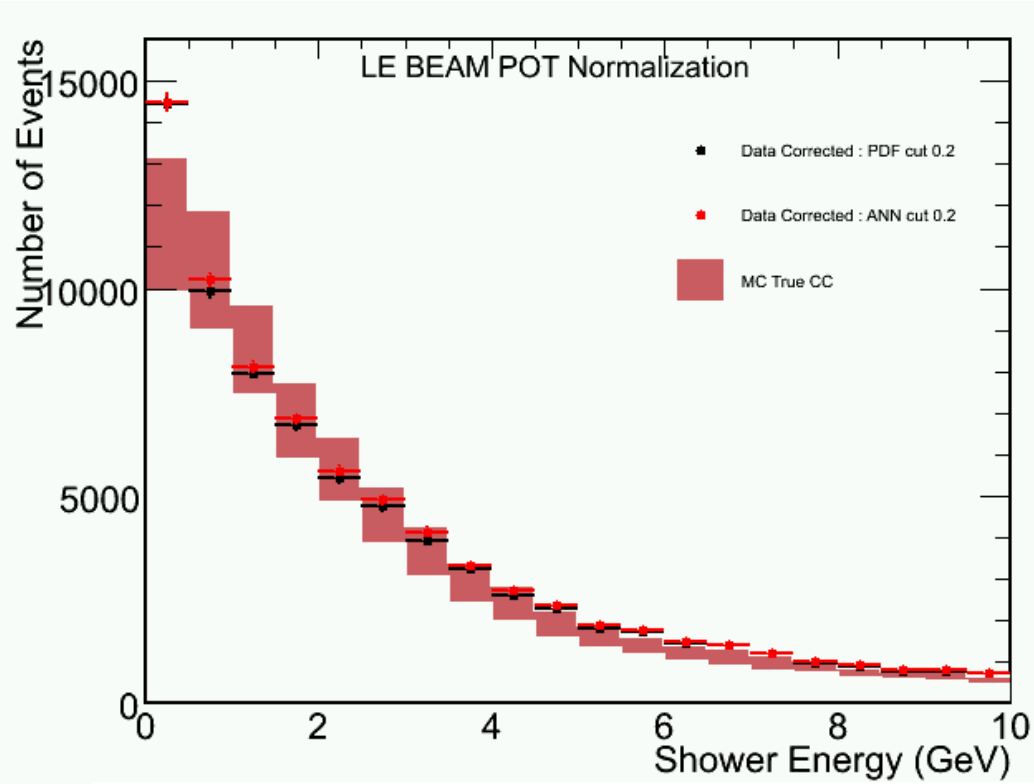
Intranuclear rescattering in Iron

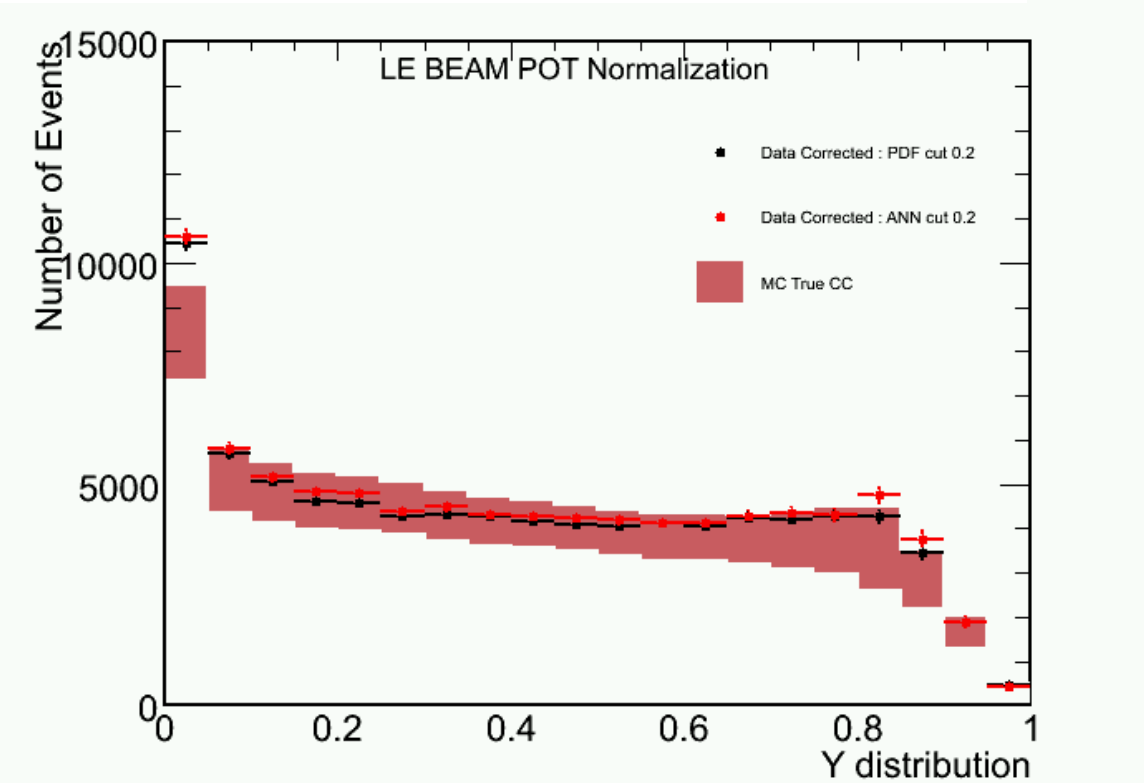
Example: reconstructed hadron energy

Data has more
very-low energy showers

Effort to constrain the effects of
intranuclear rescattering.

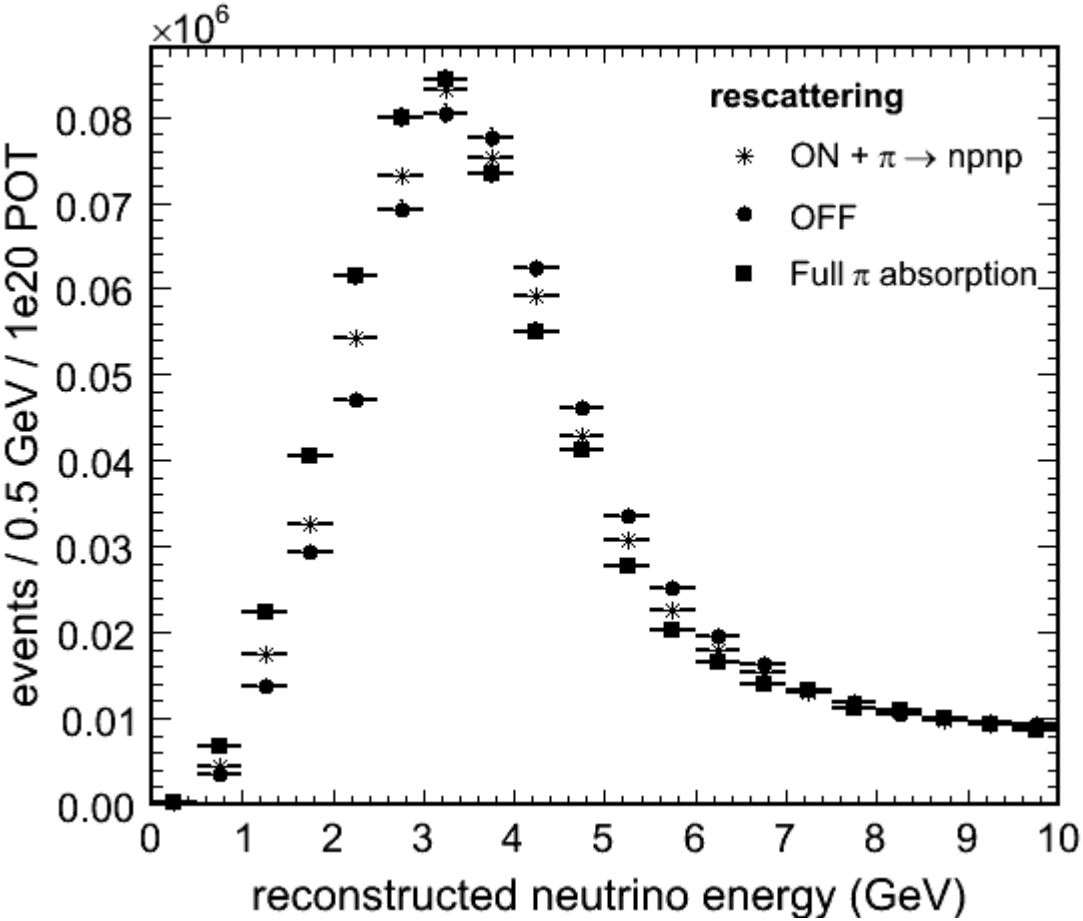
Part of hadronic energy scale
uncertainty





The effect propagates to here
reconstructed y = Ehad/Enu

Example: intranuclear rescattering



Rescattering modifies visible hadronic energy.

In Neugen, rescattering is anchored to ν-D and ν-Ne data comparison of π production.

In-medium cross-sections

Mechanism for pion absorption (how is the energy distributed)

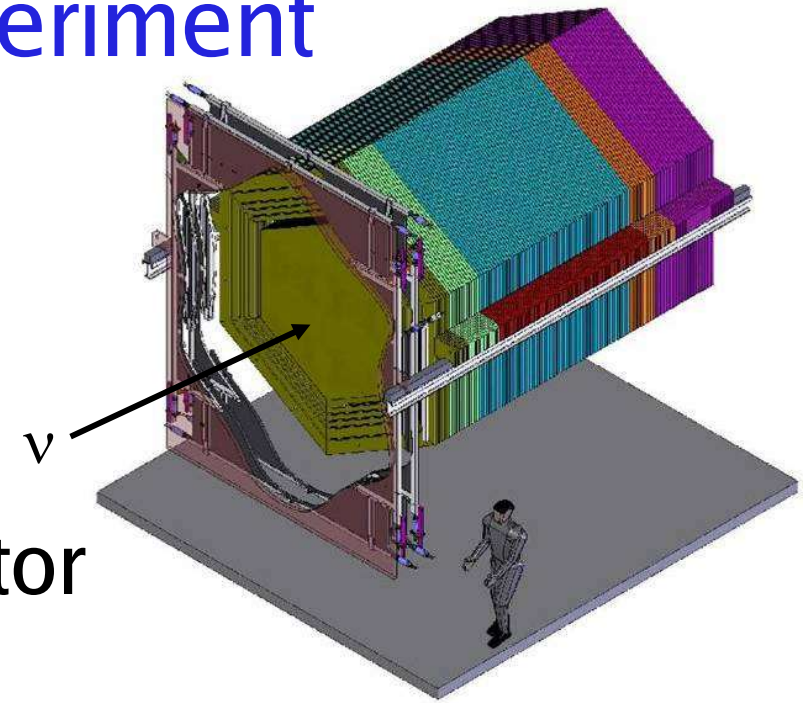
Nuclear excitations

Want reweightable models!!!

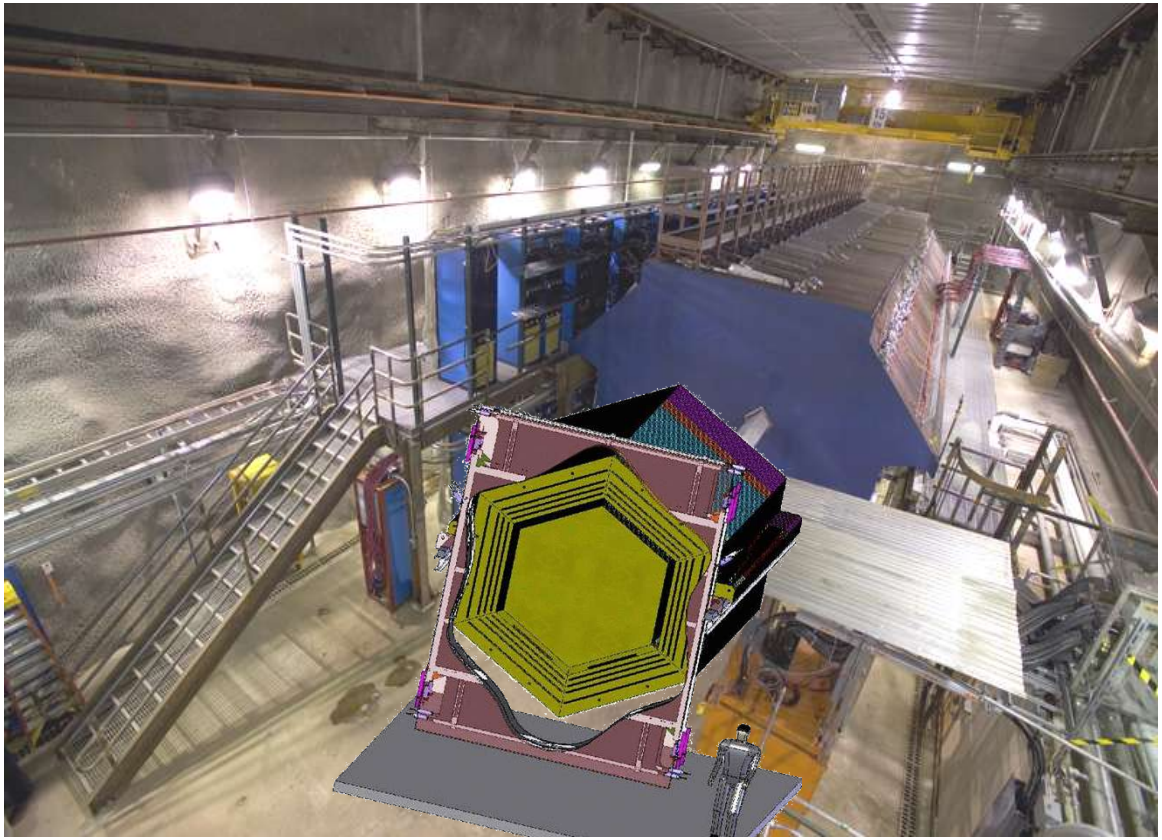
M. Kordosky, hep-ex/0602029

The MINERvA experiment

Fine-grained detector
Tracking and Calorimetry
High Rate



Put in front of MINOS near detector

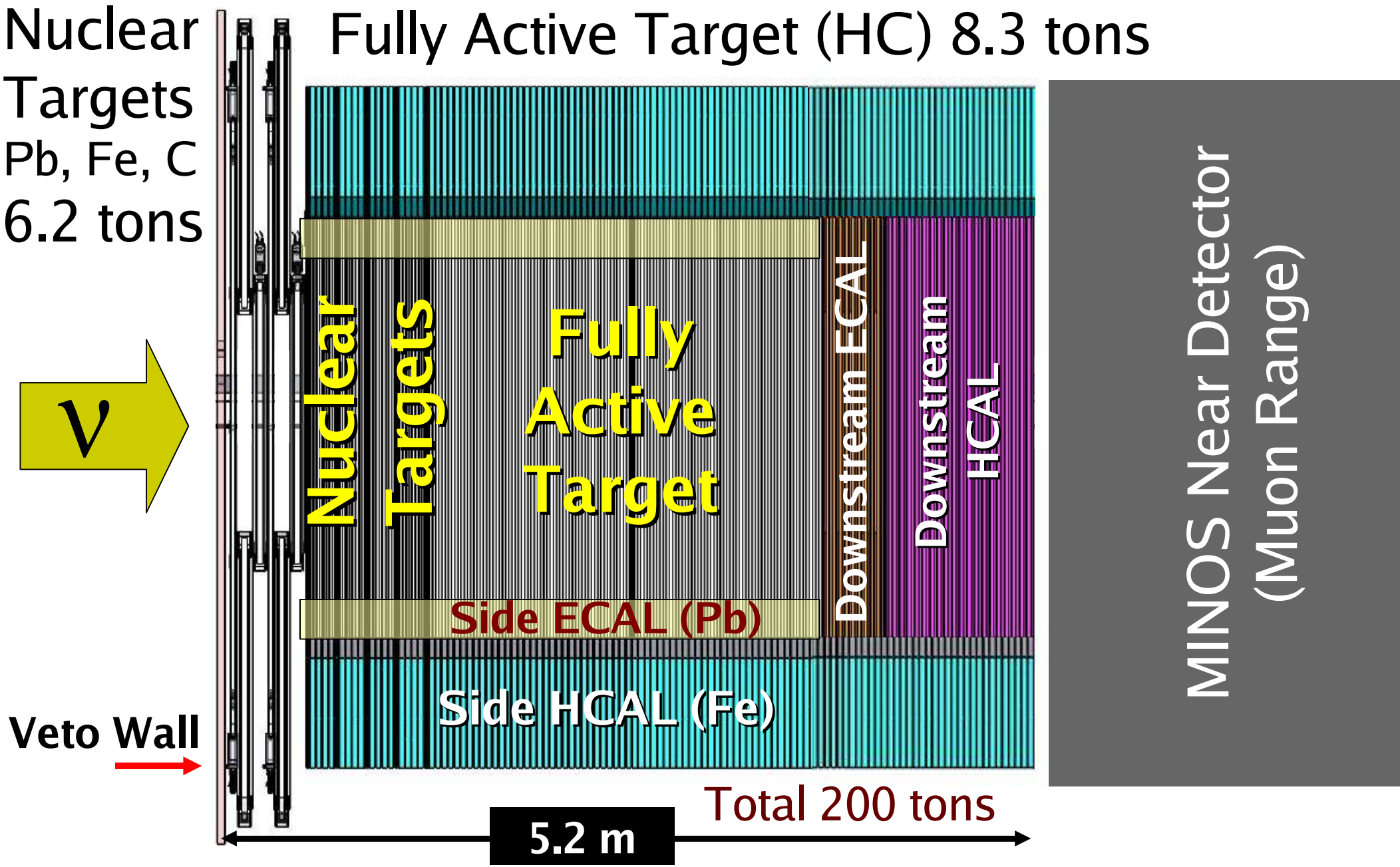


Cross section measurements
Form factor analysis

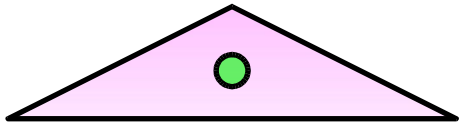
Study of nuclear effects
using integrated
CH, C, Fe, Pb targets

Collaboration includes
HEP and Nuclear folks

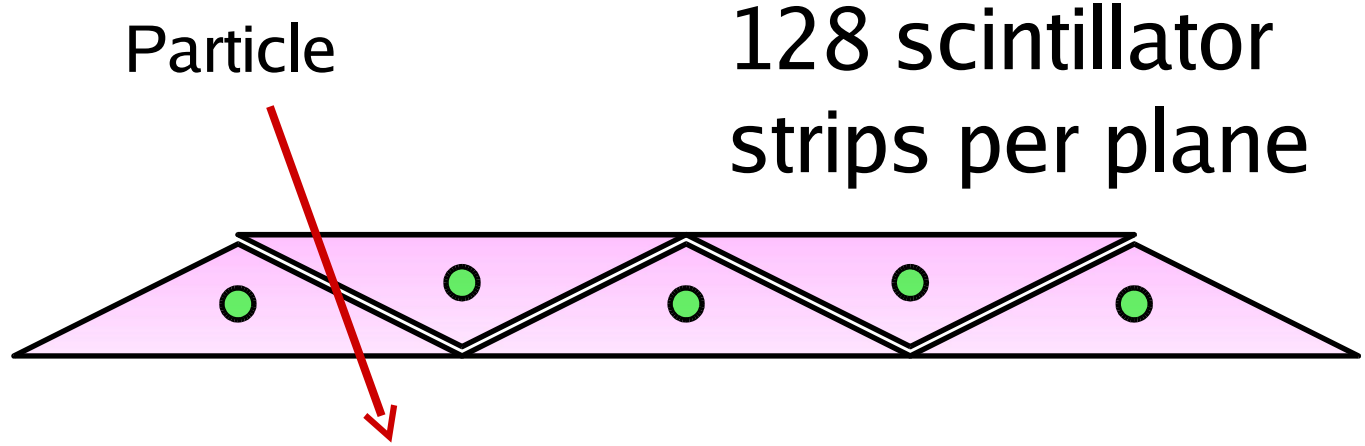
The MINERvA detector



The MINERvA Scintillator

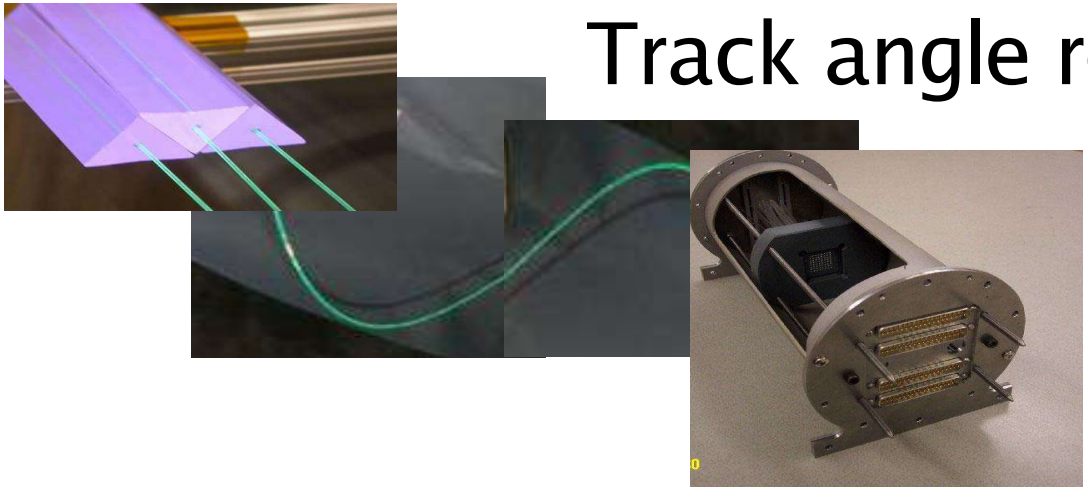


Scintillator
1.7 x 3.3 cm^2
triangle strips



128 scintillator
strips per plane

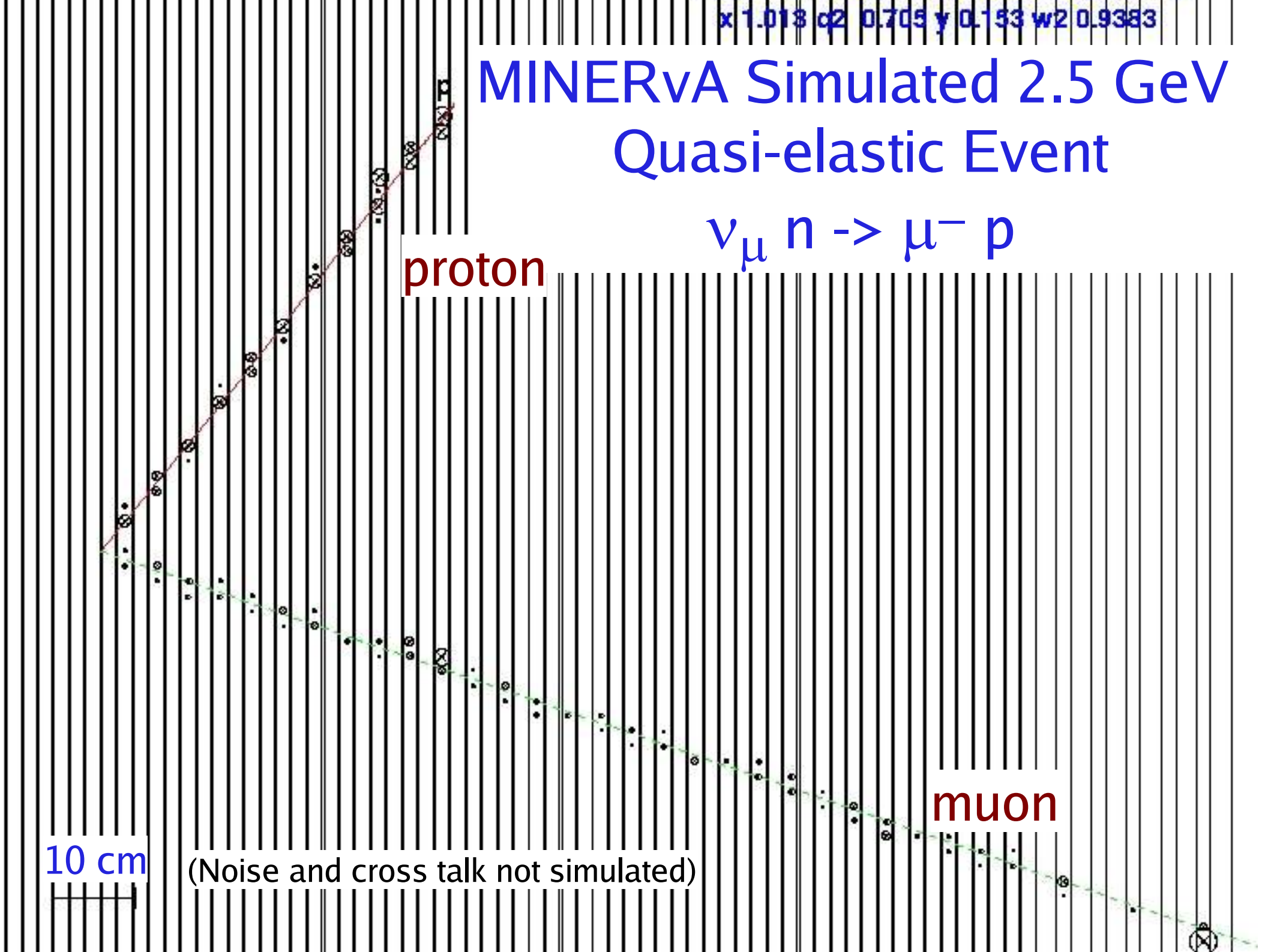
Position determined by charge sharing
Track location resolution ~3 mm
Track angle resolution ~0.5 degrees



Wavelength shifting fiber readout to Hamamatsu 64-anode PMT

MINERvA Simulated 2.5 GeV Quasi-elastic Event

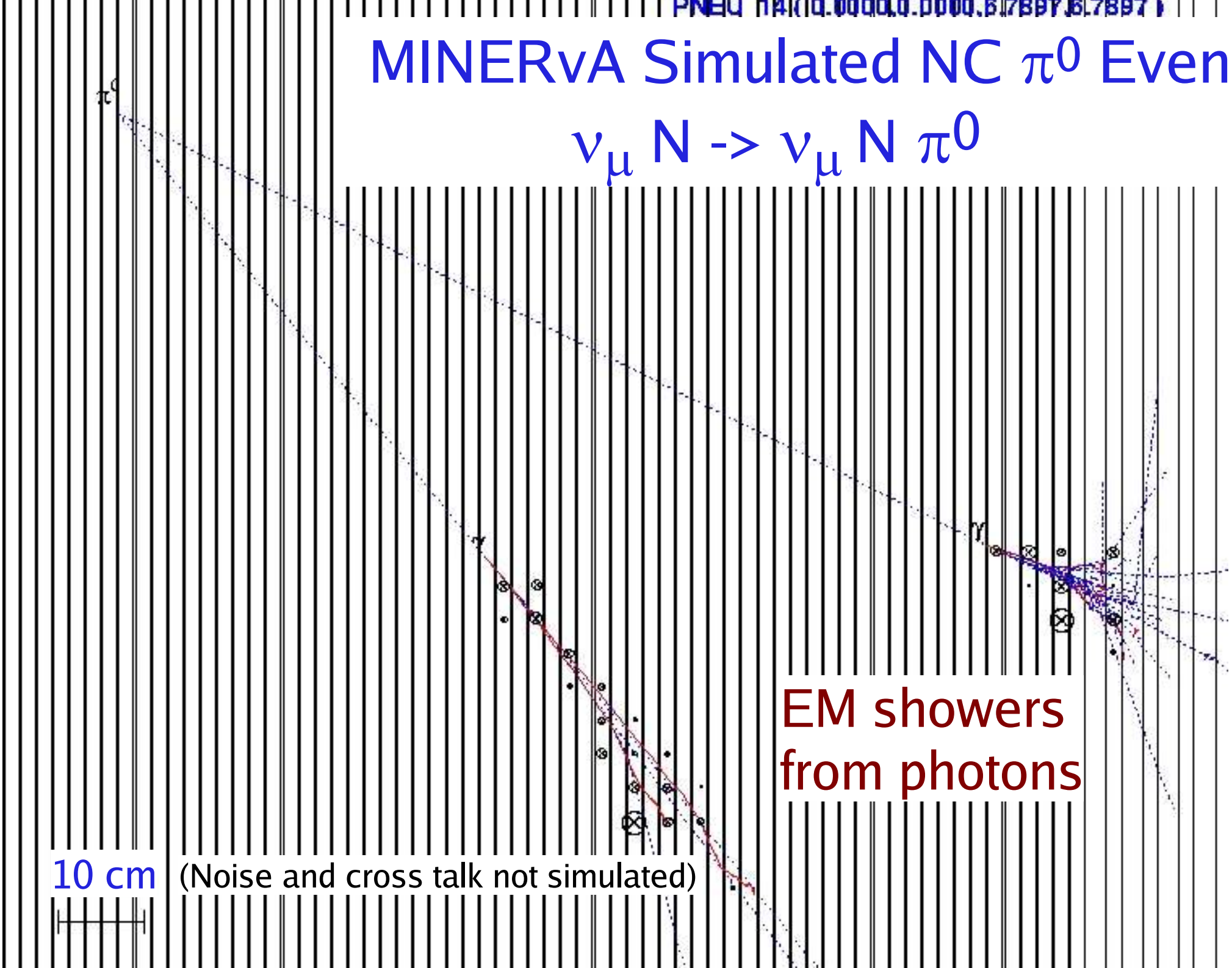
ν_μ n -> μ^- p



(Noise and cross talk not simulated)

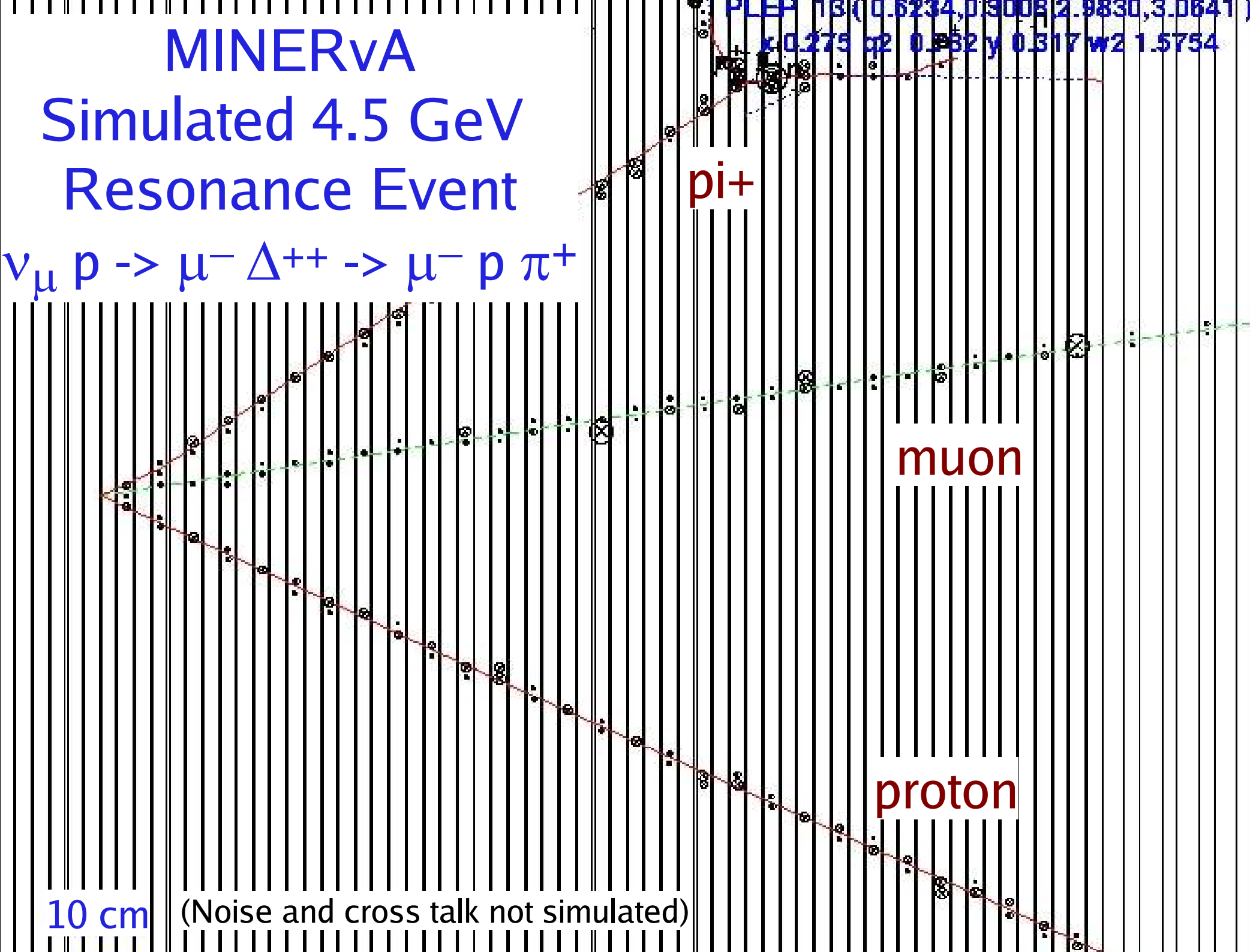
MINERvA Simulated NC π^0 Event

ν_μ N -> ν_μ N π^0



MINERvA
Simulated 4.5 GeV
Resonance Event

ν_μ p -> μ^- Δ^{++} -> μ^- p π^+



(Noise and cross talk not simulated)

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

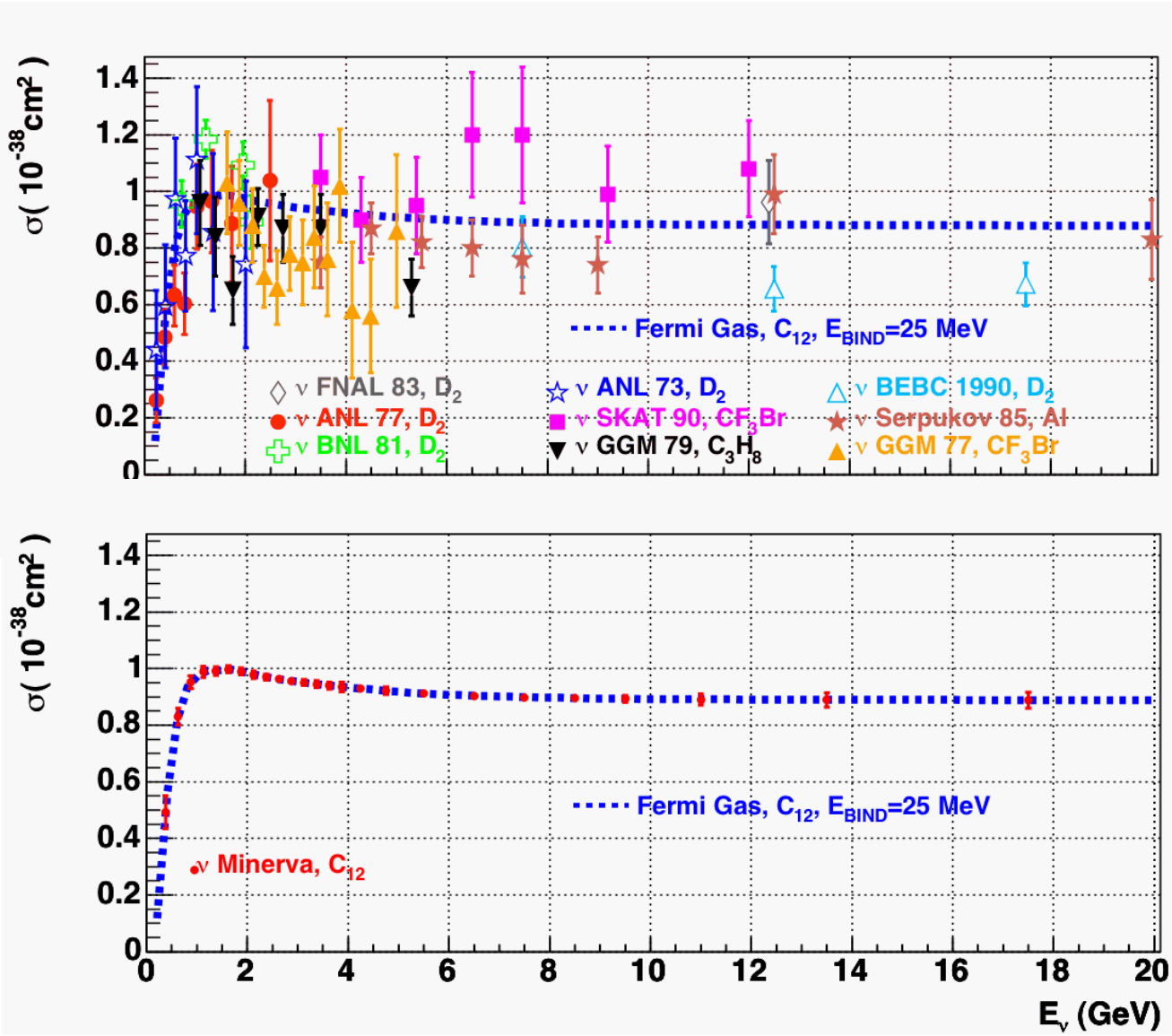
Nuclear effects from comparisons between	C 0.4 M
different nuclear targets	Fe 2.0 M
Polystyrene (CH), Carbon, Iron, Lead	Pb 2.5 M

Statistics assume ~4 years running in NuMI beam

Example: Quasi-elastic Interactions

QE cross section vs. neutrino energy

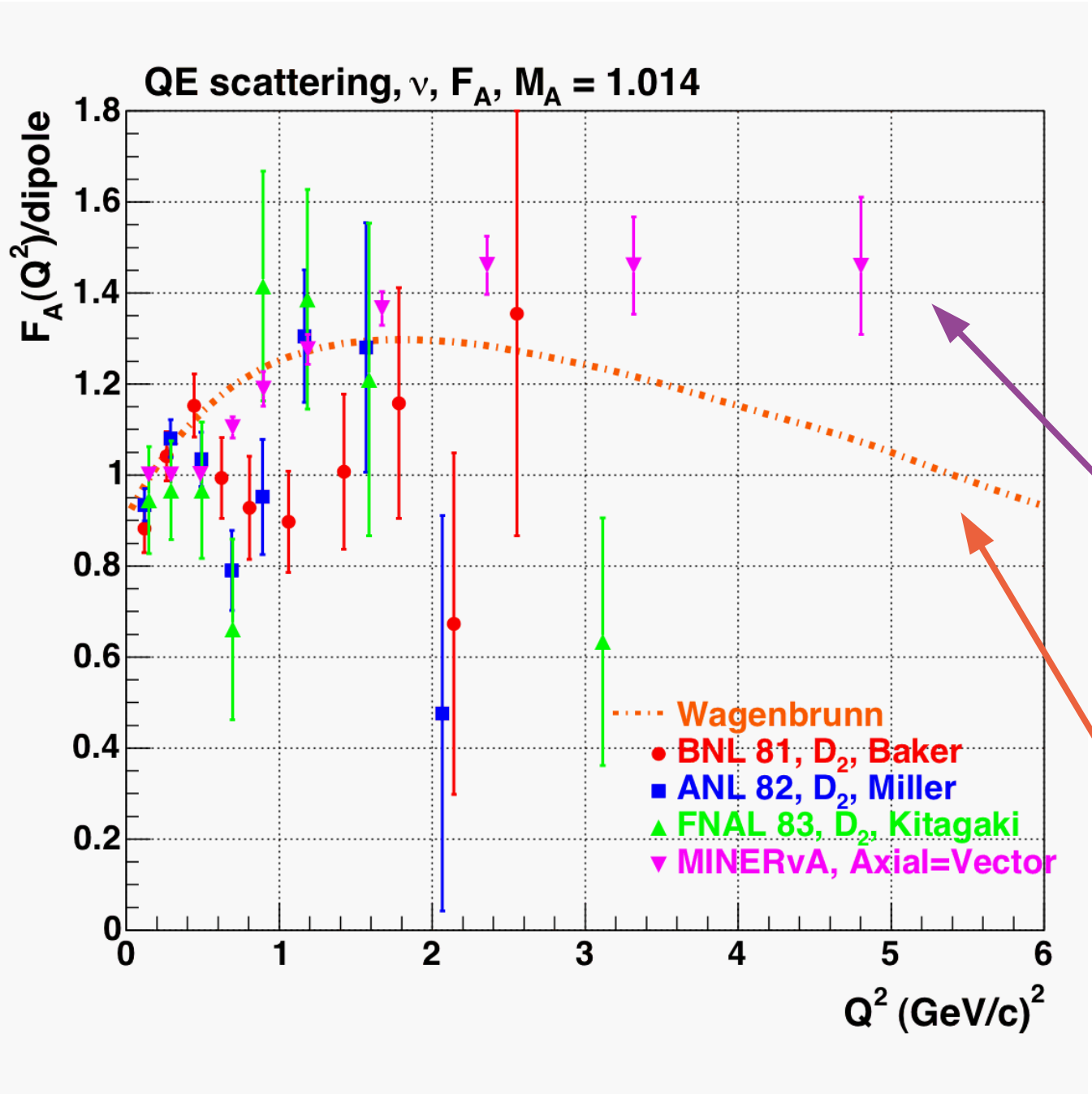
Current measurements



Expected MINERvA result statistical errors only includes purity + efficiency

(not included: flux error ~5%)

Example: Quasi-elastic Axial Form Factor



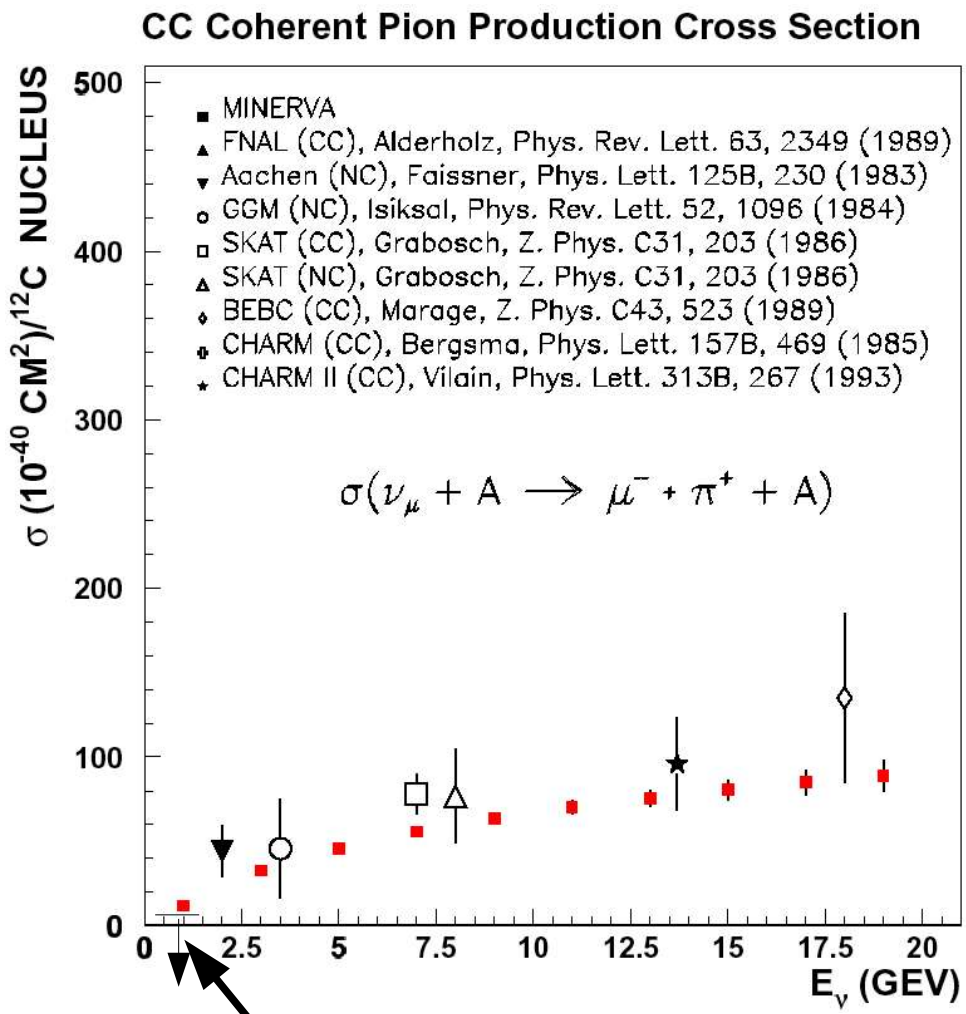
Expected ability to measure high Q^2 behavior and sensitivity to non-dipole F_A form factor

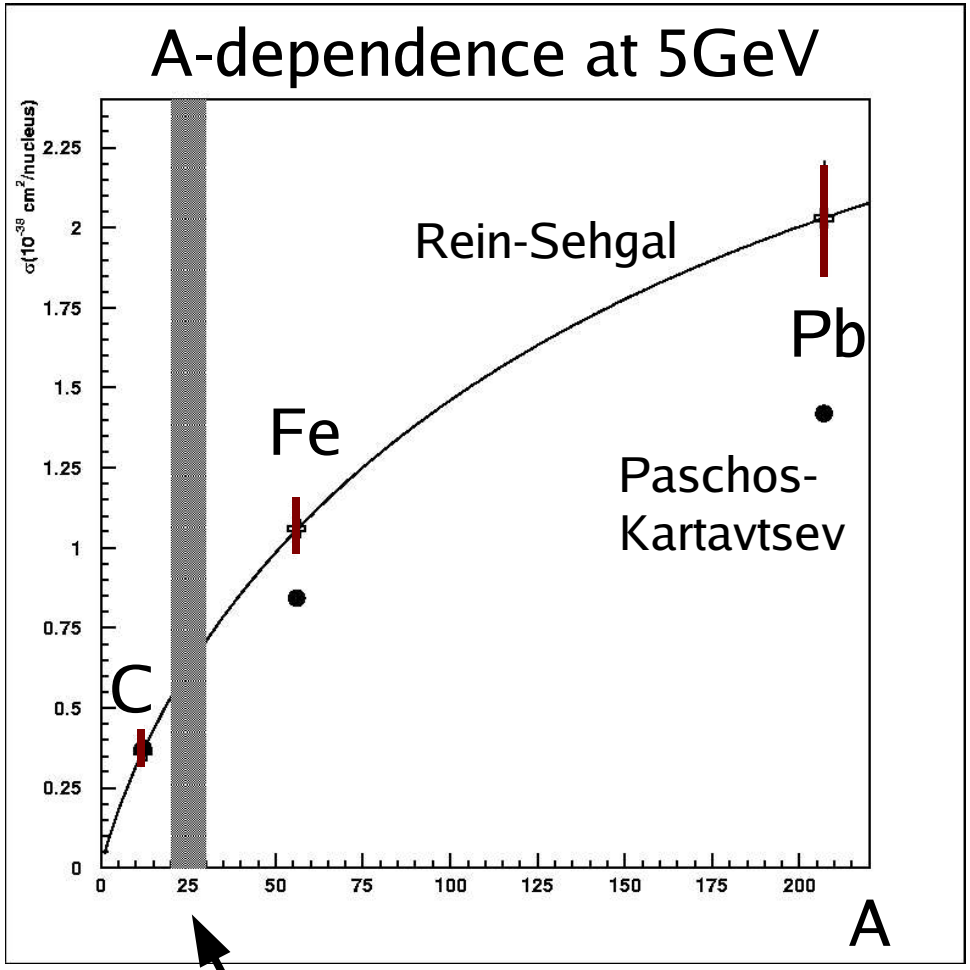
Simulated MINERvA "Axial=Vector" hypothesis (statistical errors only)

Wagenbrunn, et al. hep-ph/0212190

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

MINERvA Status and Timeline

Fall 2006	CD 2 review
2007	Prototype module construction + tests
2008	Full detector construction
2009	Turn on in MINOS LE beam
2010+	Years of running in NOvA ME beam

Strong interest to run in anti-neutrino beam also.

Summary

More high statistics data being analyzed now
Still more available in the upcoming years
from MINOS and MINERvA

From a well-constrained wide-band beam
Multiple nuclear targets
Coarse grained and fine grained tracking detectors