MINERνA

NuMI

The MINER*ν*A Experiment

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(For the Collaboration)

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- What is MINER*ν*A?
- MINER*ν*A's goals
- Detector design & R&D status
- Examples of capabilities
  - > Basic neutrino measurements
  - > Aiding oscillation measurements
- Project status

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MINER*v*A *

Main INjector ExpeRiment for ν-A

- MINER*v*A is a compact, fully active neutrino detector designed to study neutrino-nucleus interactions with unprecedented detail
- The detector will be placed in the NuMI beam line upstream of the MINOS Near Detector

* Goddess of wisdom & technical skill

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A collaboration of Particle, Nuclear, and Theoretical physicists

New collaborators welcome & joining

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Physics Goals

- Axial form factor of the nucleon
  - > Yet to be accurately measured over a wide Q^2 range.
- Resonance production in both NC & CC neutrino interactions
  - > Statistically significant measurements with 1-5 GeV neutrinos *
  - > Study of “duality” with neutrinos
- Coherent pion production
  - > Statistically significant measurements of σ or A-dependence
- Nuclear effects
  - > Expect some significant differences for ν-A vs e/μ-A nuclear effects
- Strange Particle Production
  - > Important backgrounds for proton decay
- Parton distribution functions
  - > Measurement of high-x behavior of quarks
- Generalized parton distributions

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Aiding Oscillation Measurements

For mass splitting measurements

> Understanding of relationship between observed energy & incident neutrino energy

- Improved measurement of exclusive cross sections
- Measurement of ν-initiated nuclear effects

For electron appearance

> Much improved measurements of ν-nucleus exclusive cross sections

- Individual final states cross sections (esp. π^0 production)
- Intra-nuclear charge exchange
- Nuclear (A) dependence

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How to Achieve these Objectives?

- We need a detector with
  - > Good tracking resolution
  - > Good momentum resolution
  - > A low momentum threshold
  - > Timing (for strange particle ID)
  - > Particle ID to identify exclusive final states
  - > Variety of targets to study nuclear dependencies
- Lots of neutrinos *!!!*

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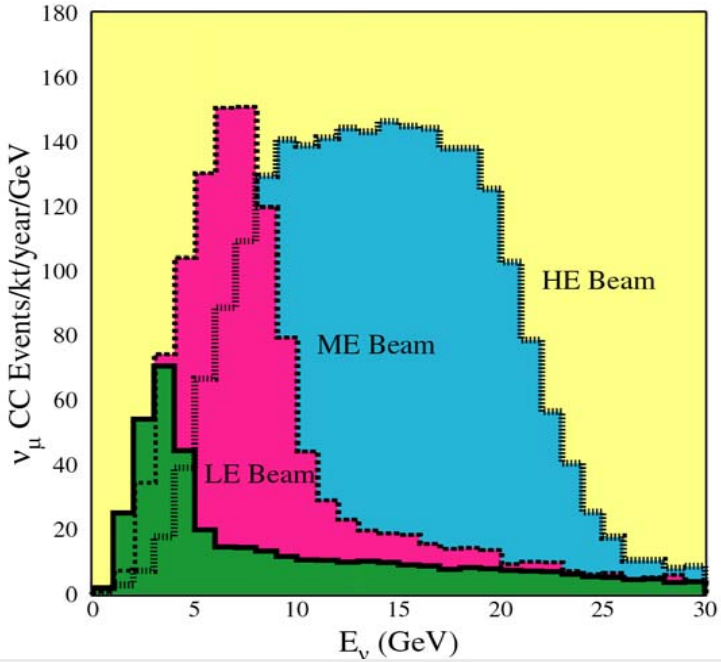
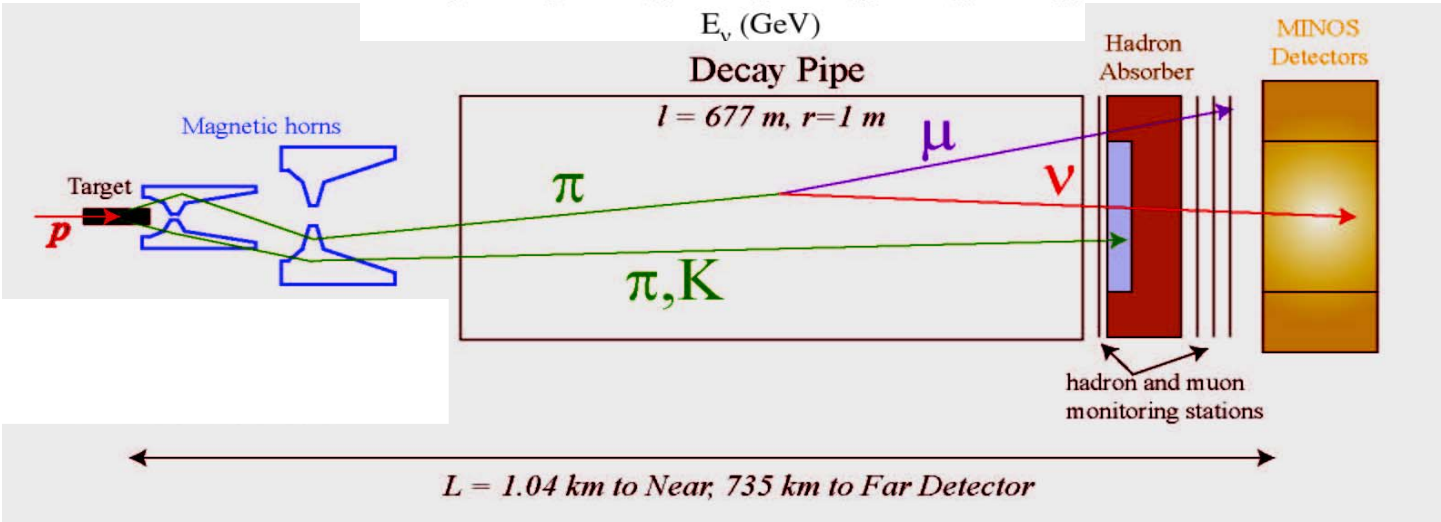
The NuMI Beam: Lots of Neutrinos

ND rates ~ ×10^5 FD



ND rates ~ ×10^5



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MINER*v*A Concept

- MINER*v*A proposes to build a low-risk detector with simple, well-understood technology
- Active core is segmented solid scintillator
  - > Tracking (including low momentum recoil protons)
  - > Particle identification
  - > Few ns timing (track direction, identify stopped $K^{\pm}$)
- Core surrounded by electromagnetic and hadronic calorimeters
  - > Photon (π^0) & hadron energy measurement
- MINOS Near Detector as muon catcher

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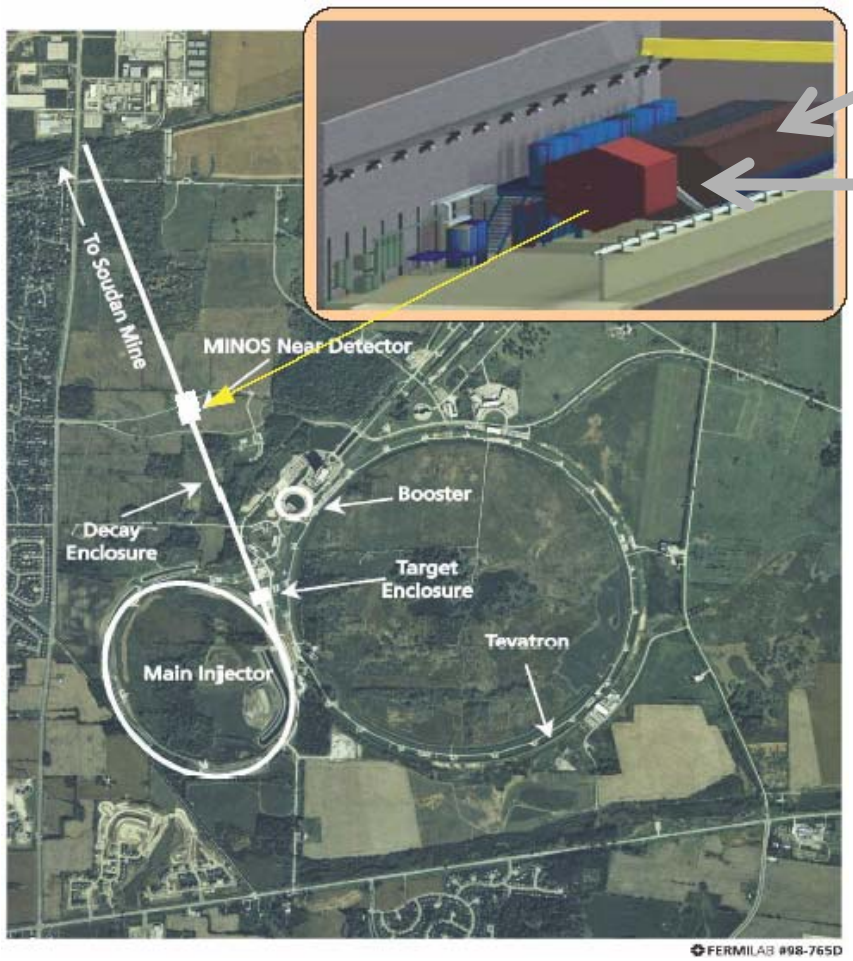
MINER*v*A & MINOS Near Detector



MINOS Near Detector

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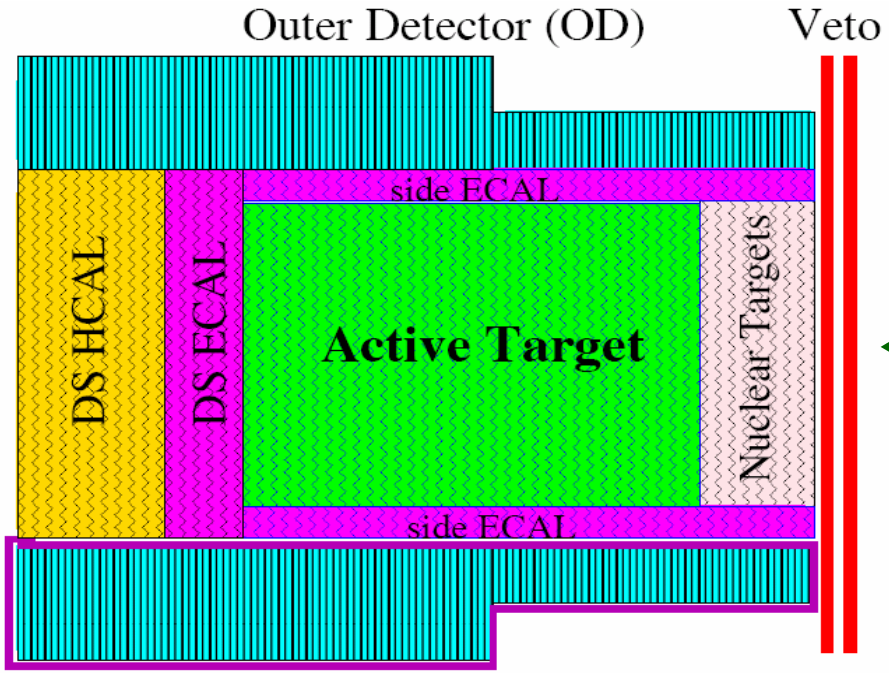
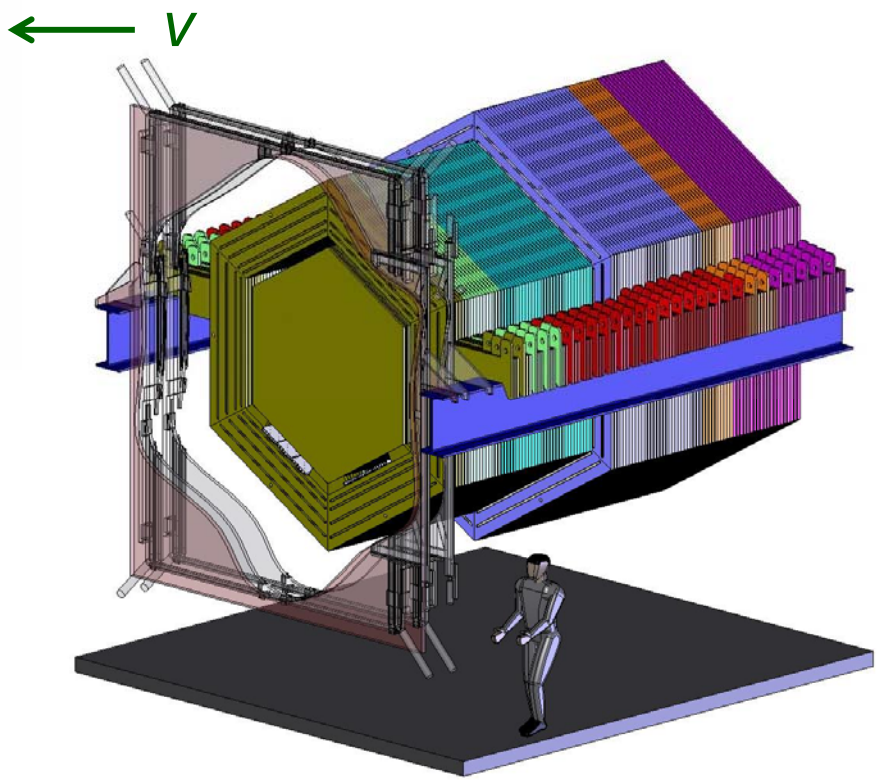
MINERνA Layout



5.87 ton active segmented scintillator target



~1 ton of nuclear targets (C, Fe, Pb) intermingled with the upstream planes

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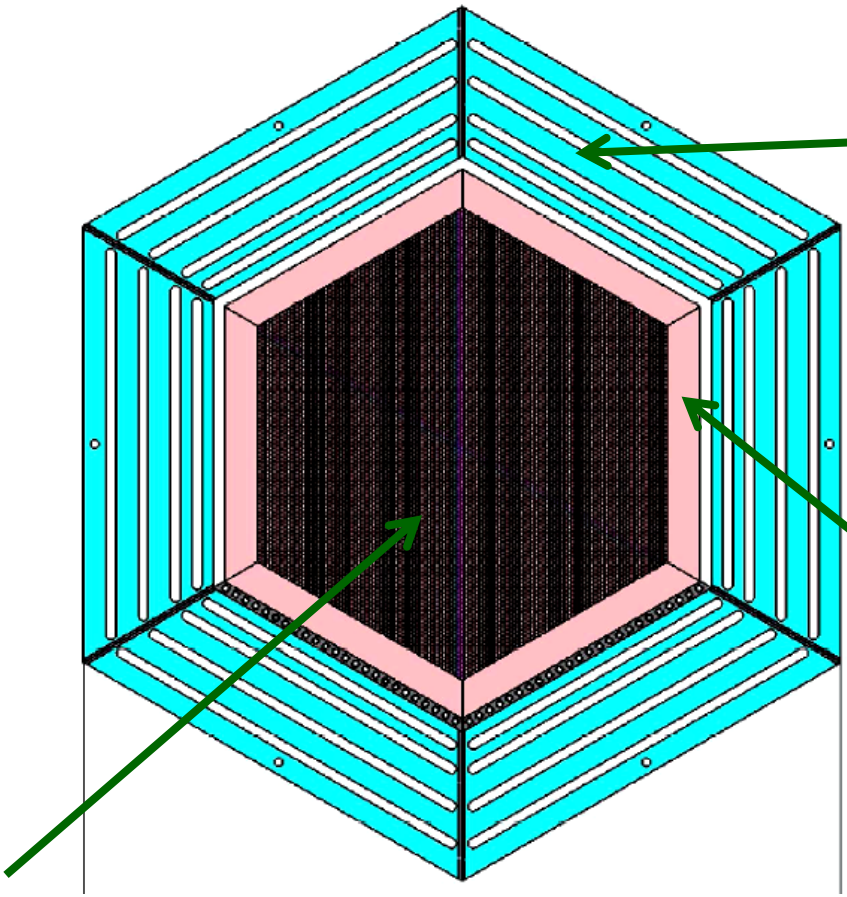
A MINERνA Detector Plane



Layers of iron/scintillator for hadron calorimetry

Lead Sheets for EM calorimetry

Inner Detector – X, U, V planes for stereo view

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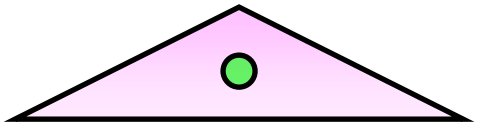
MINERνA Optics

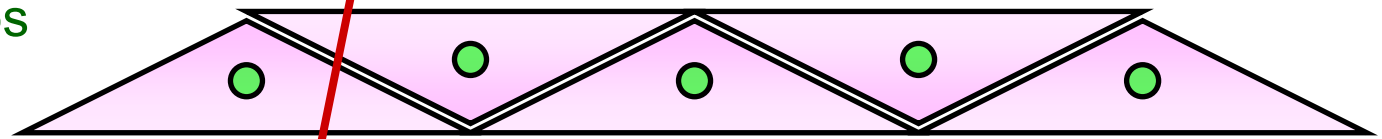


1.7 × 3.3 cm^2 strips

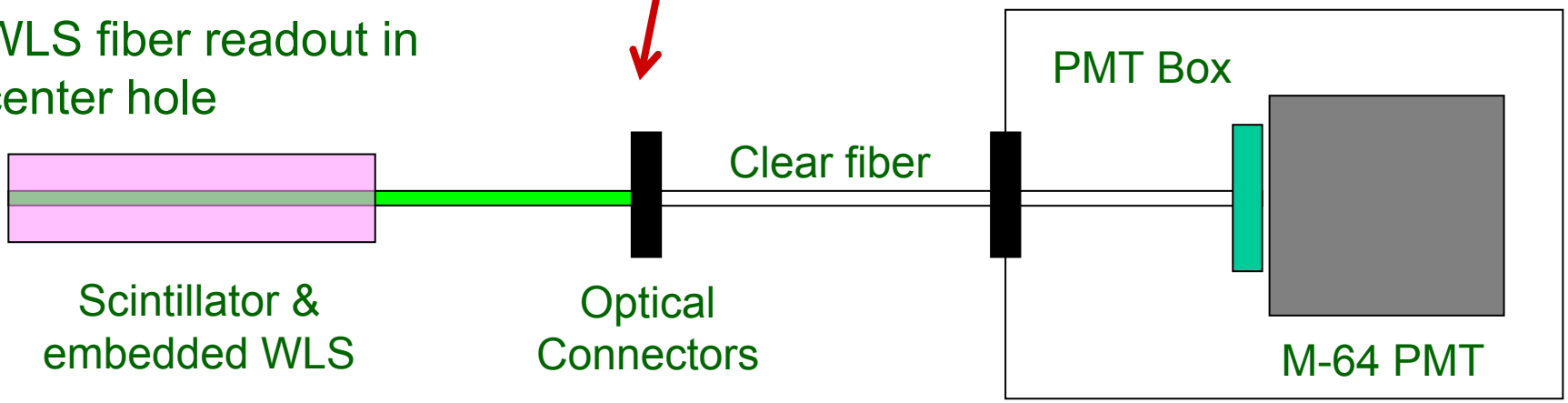
Particle

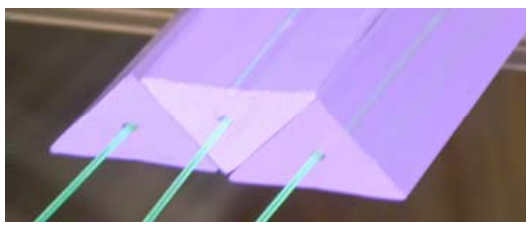
Assembled into 128 strip planes

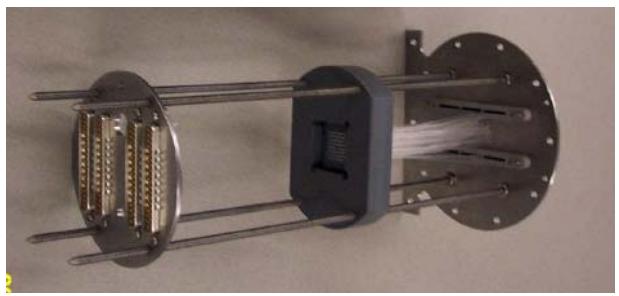
Position by charge sharing



WLS fiber readout in center hole







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Vital Statistics of MINERνA

Number of Channels	30992
Channels in ID+CALS	25088
Channels in OD	5904
Volume of Scintillator (m^3)	22.5
WLS Fiber (km)	90.7
Clear Fiber (km)	41.6
Number of M-64 PMTs	503
Mass of ID (metric tons)	10.8
Mass of OD in ID region (metric tons)	98.0
Mass of CALS, Nuclear Targets (metric tons)	27.2
Mass of OD in CAL region (metric tons)	62.9
Total MINERvA Mass (metric tons)	199
Plastic Region Mass (metric tons)	5.87
Data Rate (bits/spill)	7.9E+6

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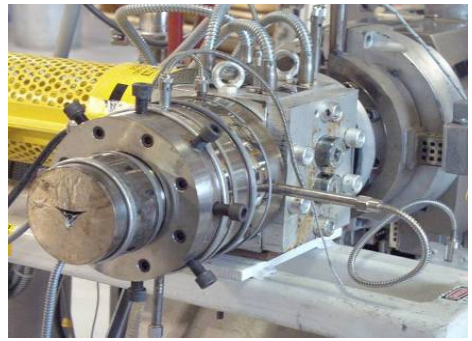
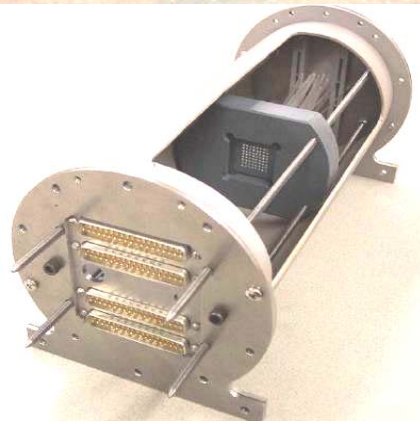
Detector Prototyping

- Summer 05
  - > Refining scintillator extrusion
  - > Developing Co-extruded reflector
  - > First “trapezoid” of OD steel
  - > Prototyping PMT boxes
  - > Prototyping clear fiber cables
  - > Complete detector optimization
  - > 2nd vertical slice test with front-end electronics & DAQ
- Winter 05/06
  - > Full plane prototypes





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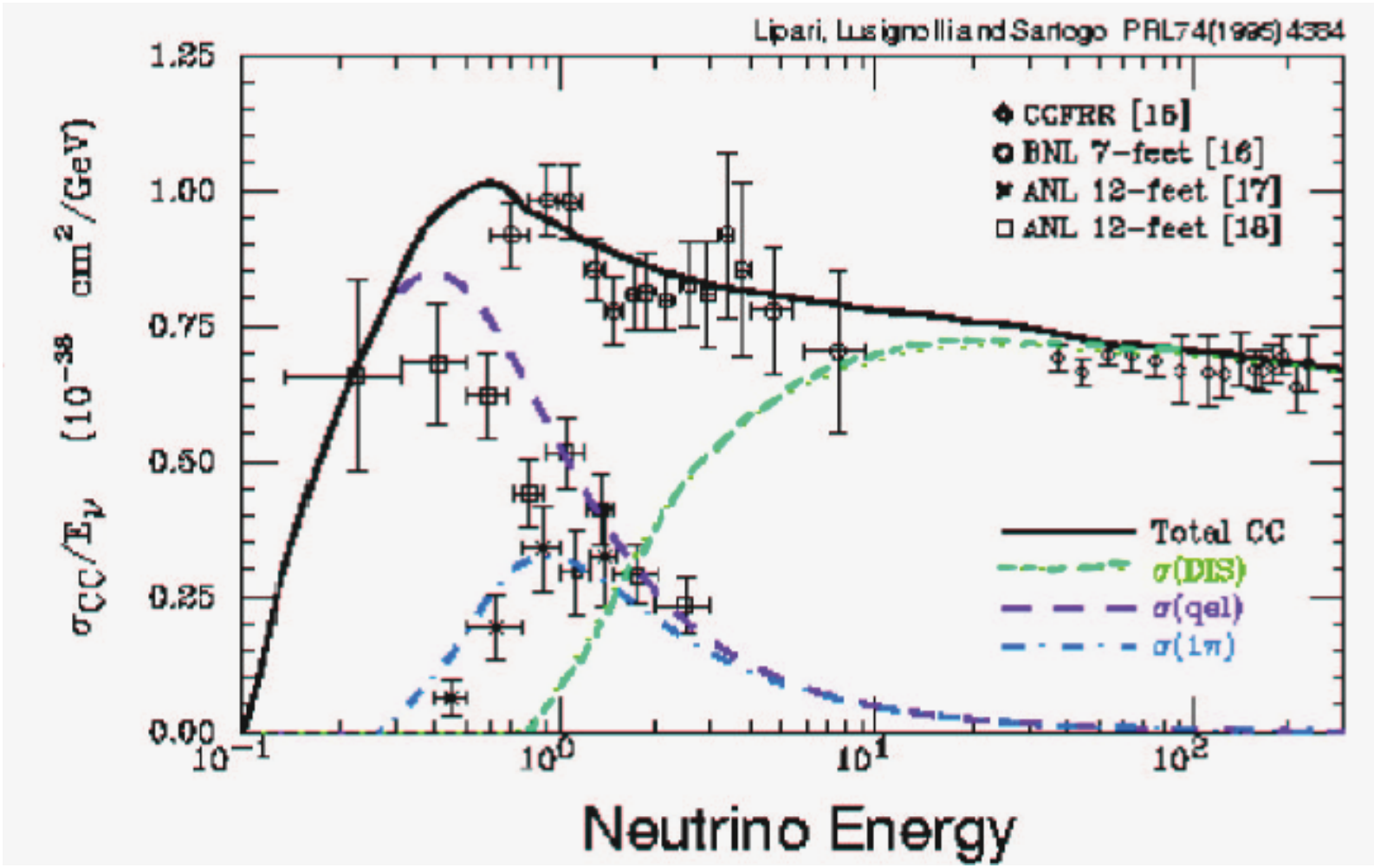
Neutrino-Nucleon Cross Section



NuMI flux (1-20 GeV) ⟷

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Event Yields

16×10^{20} POT in 4 years (mixture of LE, ME, & HE tunes)

- **Fiducial Volumes 3 ton (CH), 0.6 ton C, 1 ton Fe & 1 ton Pb**
- **15 Million total CC events**
- **N.B: POT totals do not reflect changes in post-Tevatron operations**

Expected event yields

Quasi-elastic	**0.8 M events**
Resonance Production	**1.6 M**
Transition: Resonance to DIS	**2.0 M**
DIS and Structure Functions	**4.1 M**
Coherent Pion Production	**85 K (CC) & 37 K (NC)**
Strange & Charm Particle Production	**>230 K fully reco'd**
Generalized Parton Distributions	**~10 K**
Nuclear Effects	**C: 1.4M; Fe: 2.9M; Pb: 2.9M**

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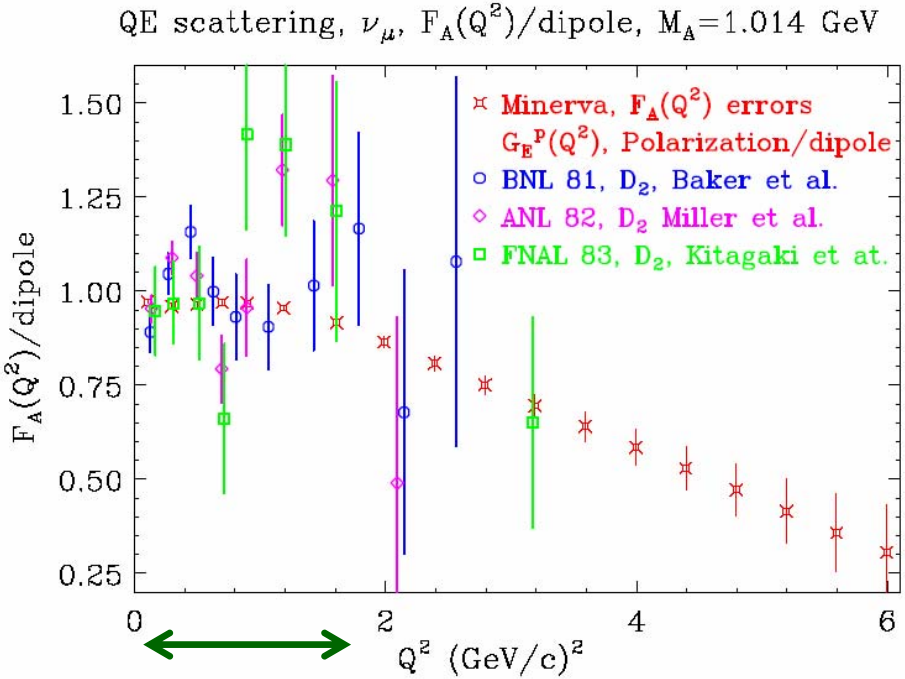
Example Capabilities: Form Factor Measurements

- Vector form factors measured with electrons
- GE/GM ratio varies with Q^2 - a surprise from JLab
- Axial form factor poorly known
- Medium effects for F_A measurement unknown
  - > Will check with C, Fe, & Pb targets

MINER*ν*A Measurement of Axial FF



Expected MiniBooNE & K2K measurements

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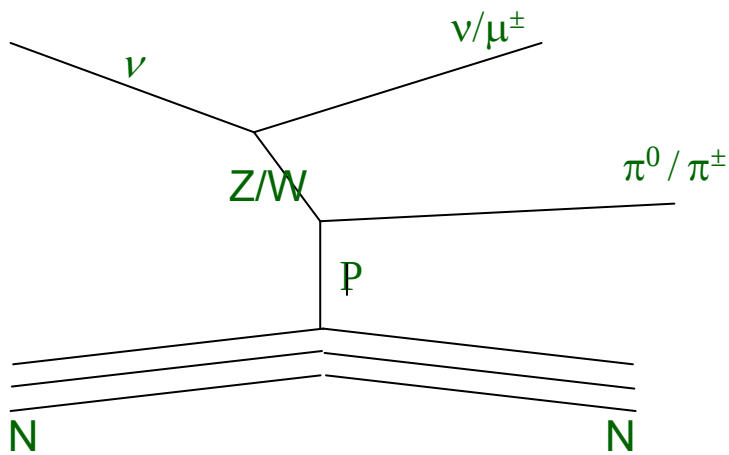
Coherent Pion Production

- Tests understanding of the weak interaction
  - > The cross section can be calculated in various models
- Neutral pion production is a significant background for neutrino oscillations
  - > Asymmetric π^0 showers can be confused with an electron shower



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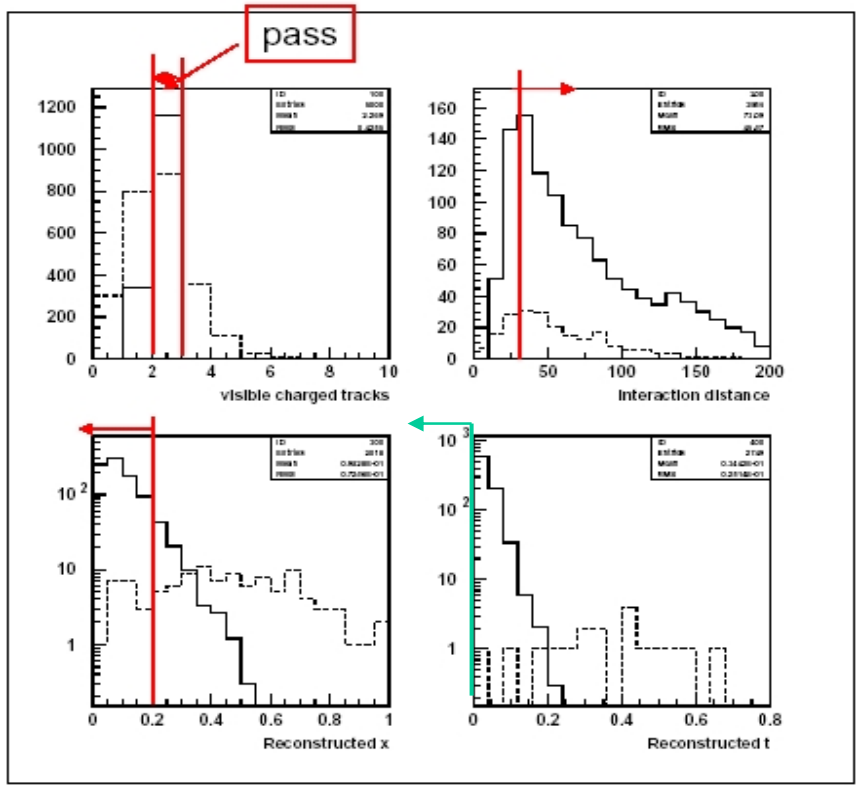
Coherent Pion Production MINERνA's Analysis

- Precision measurement of σ(E) for NC & CC channels
  - > 20k CC / 10k NC (Rein-Seghal model)
  - > Measure A-dependence
- Full analysis, realistic detector simulation & reconstruction
  - > Selection criteria reduces signal by factor of three
  - > Reduces background by factor of 1000



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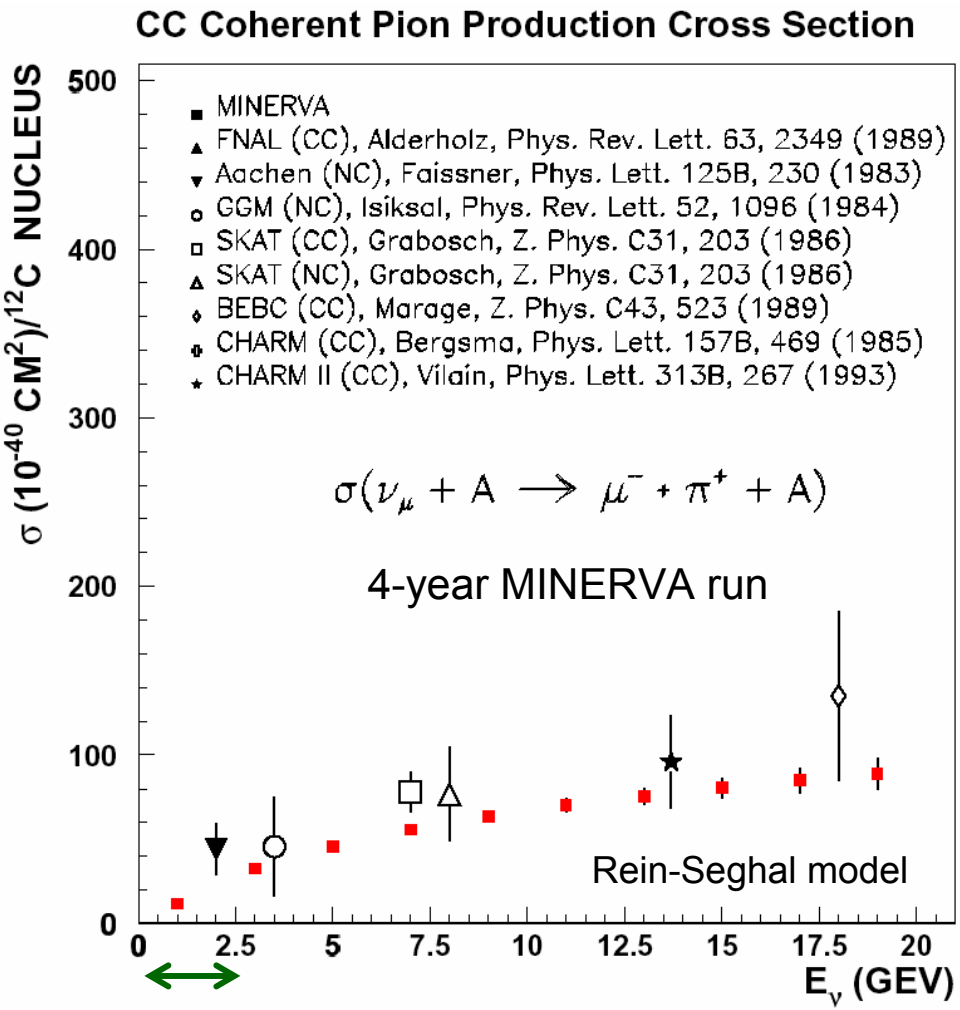
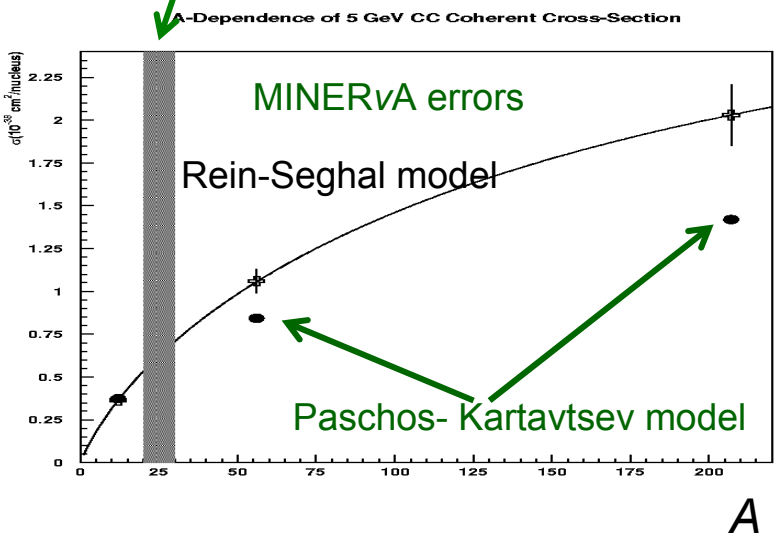
Coherent Pion Production MINERνA's Potential



Expected MiniBooNe & K2K measurements

A-range of current measurements



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

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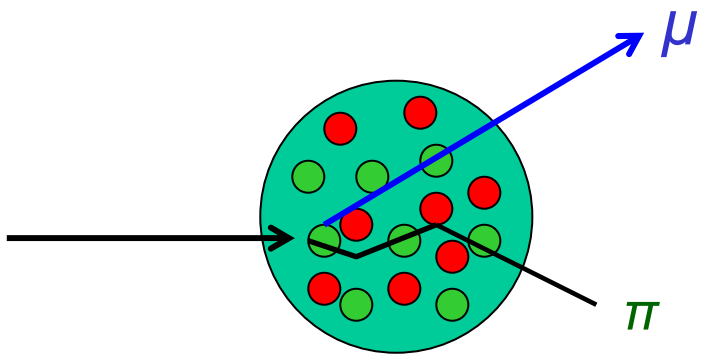
MINERνA & Δm^2 Measurements

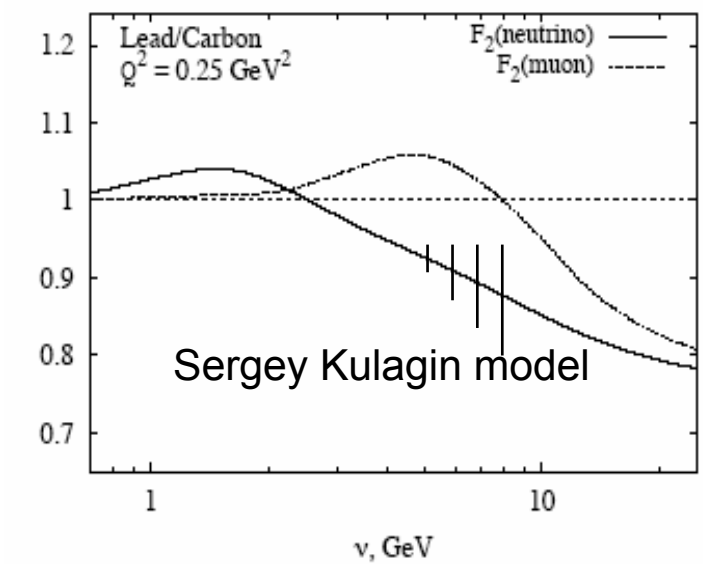
Visible energy ≠ E_ν !

- > Need to understand the relationship between the incoming neutrino energy & the detectable energy
- > π absorption & rescattering
- > Final state rest masses

Studied in charged lepton scattering from deuterium to lead at high energies

- > ν-nuclear corrections predicted to be different





F_2, Pb/C (MINERνA stat. errors)

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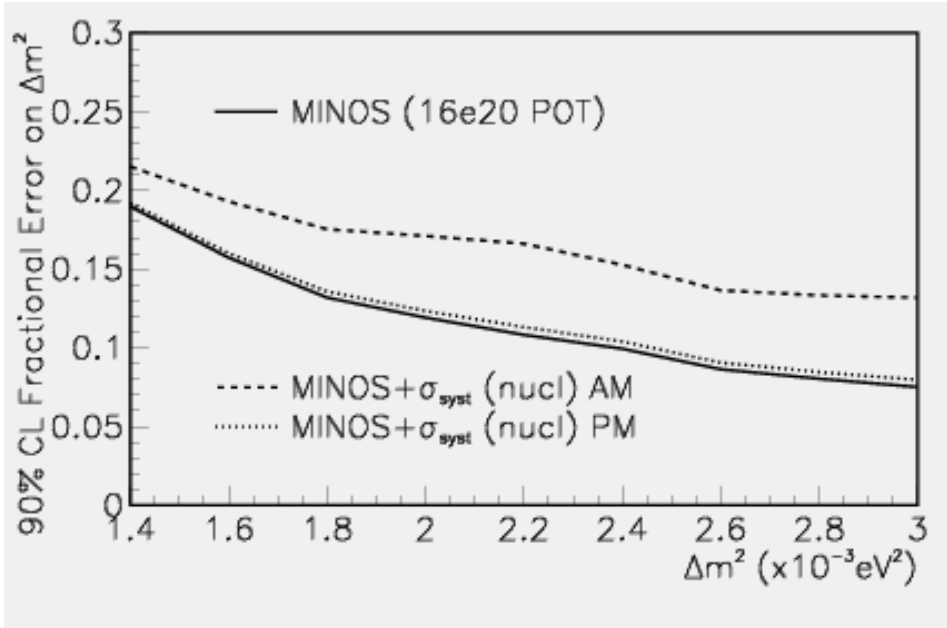
Impact on Δm^2 Measurement

- MINOS statistical errors & systematic errors due to nuclear correction
  - > Shown
    - Pre-MINERvA (AM)
    - Post-MINERvA (PM)
  - > Pion / nucleon absorption
  - > Intra-nuclear scattering effects
  - > Shadowing with neutrinos



- Extrapolation of nuclear effects from Low *A* to high *A* (e.g. C → Fe)

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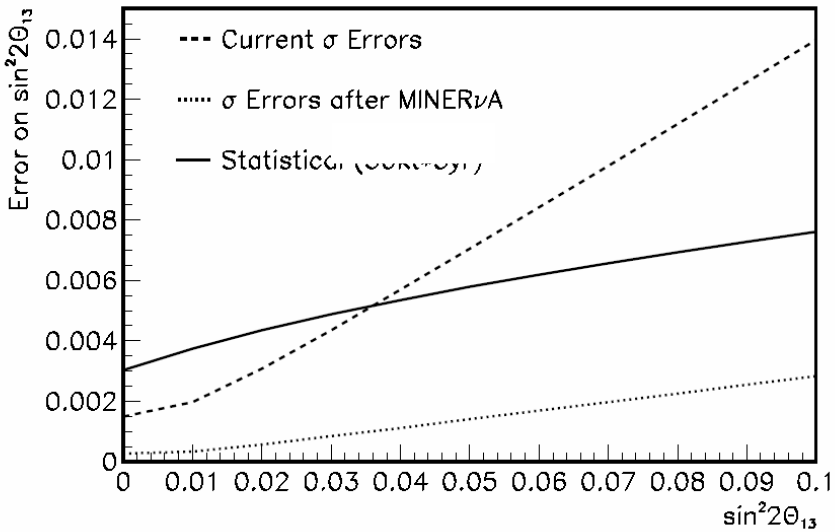
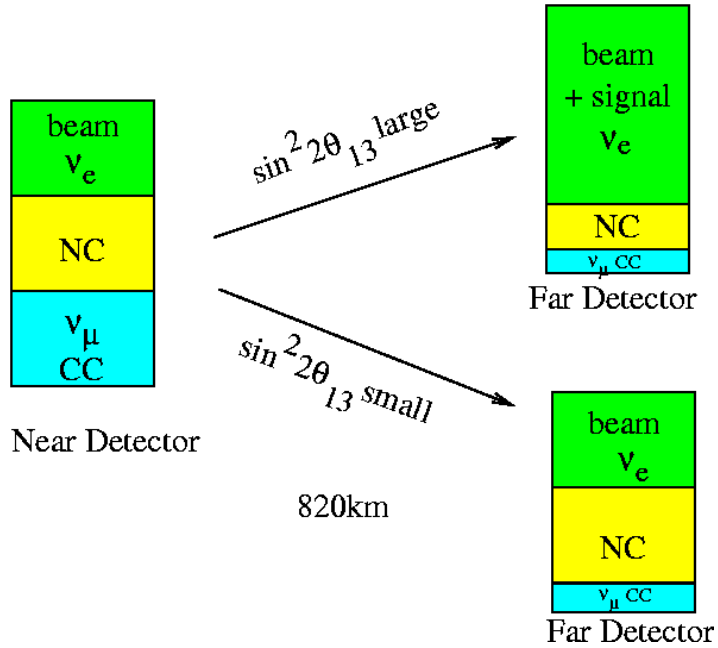
MINERνA & NOνA

Total fractional error in the predictions as a function of reach (NOνA)





Process	QE	RES	COH	DIS
δσ/σ NOW (CC,NC)	20%	40%	100%	20%
δσ/σ after MINERνA (CC,NC)	5%/na	5%/10%	5%/20%	5%/10%

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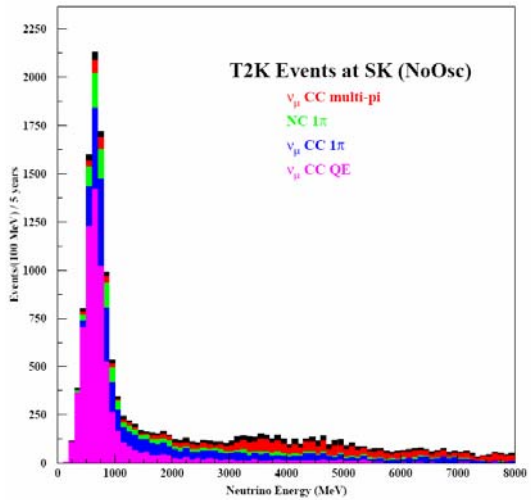
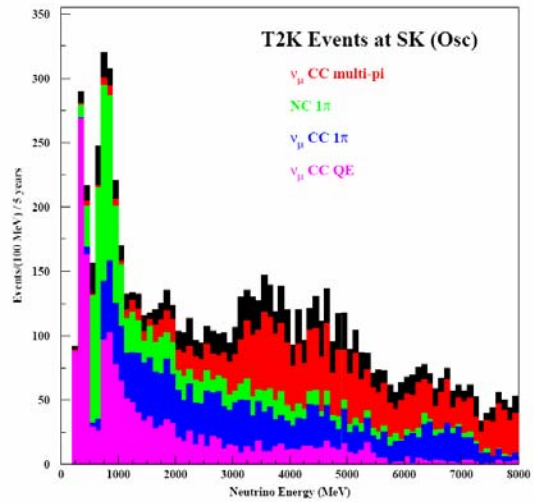
MINER*ν*A & T2K

- T2K's near detector will see different mix of events than the far detector
- To make an accurate prediction one needs
  - > 1 - 4 GeV neutrino cross sections (with energy dependence)
- MINER*ν*A can provide these with low energy NuMI configuration





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Status of MINERvA Project

- Received Stage I approval in April 2004
- Successful 2004 R&D on front-end electronics & scintillator extrusions
- Completed 1st Fermilab Directors Review (Jan. '05)
  - > TDR completed
  - > Detailed costing & schedule completed
- Fermilab requests MINERvA as “Major Item of Equipment” from DOE
  - > MINERvA received 150% of FY05 R&D request
- MINERvA is now has a Fermilab Project Office with experienced project management team established
  - > Goal: project baseline (CD3) this Fall
- Fermilab Project Planning Office schedule includes
  - > Construction starting in late 2006 (FY07)
  - > Commissioning starting end of 2008

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Summary

- MINERvA is unique in worldwide program
  - > The NuMI intensity provides
    - Opportunity for precision neutrino interaction measurements
    - Wide range of neutrino energies
  - > Detector with several different nuclear targets allows 1st study of neutrino nuclear effects
  - > Crucial input to future oscillation measurements
- Project on track
  - > Fermilab requested DoE funding as part of the laboratory's FY07 program
  - > Projected schedule
    - 2006 construction start
    - 2008 commissioning start

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- Visible energy ≠ *ν* energy !
  - > *π* absorption, rescattering
  - > final state rest mass
- Nuclear effects studied in charged lepton scattering, from deuterium to lead, at high energies
- But nuclear corrections may be different between e/μ and *ν* scattering