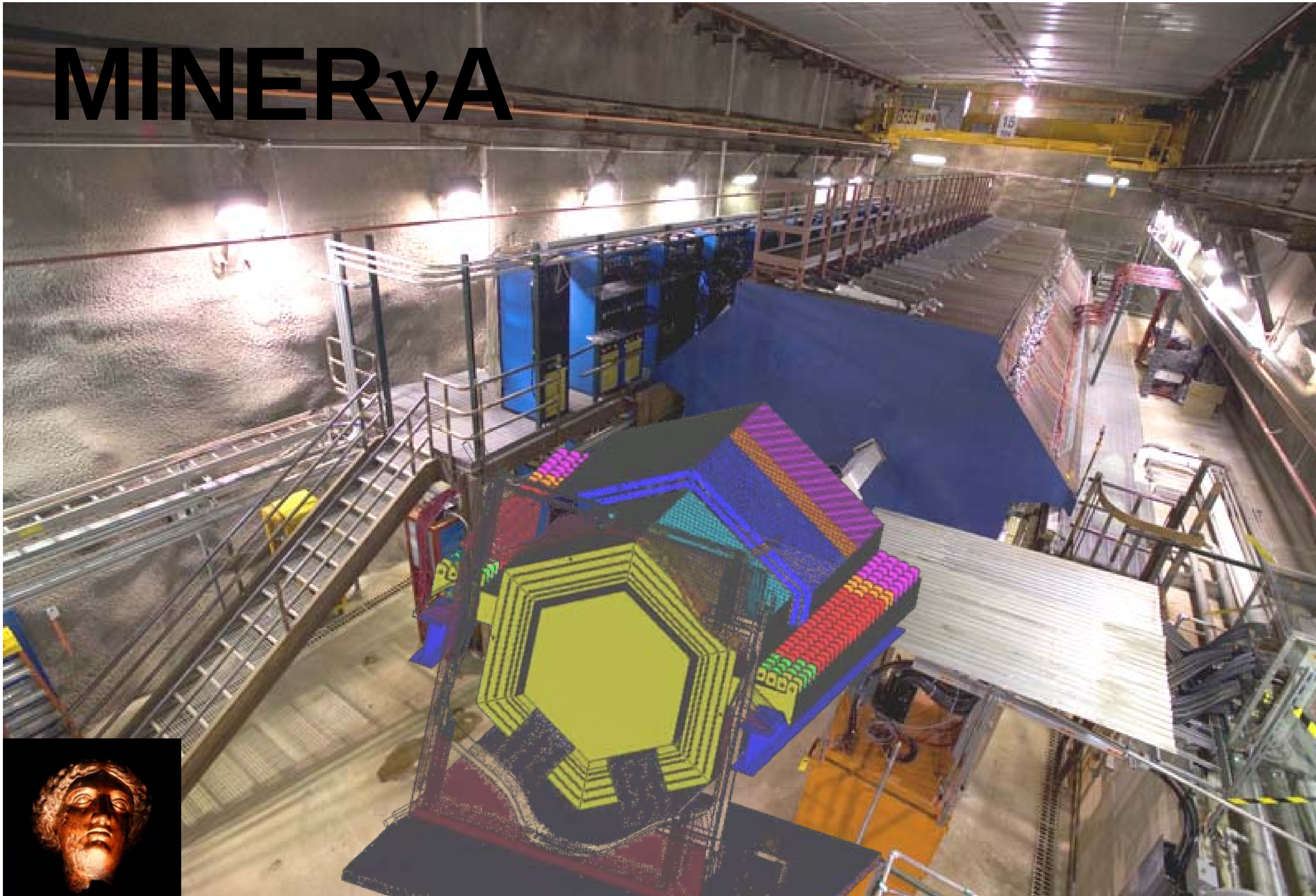
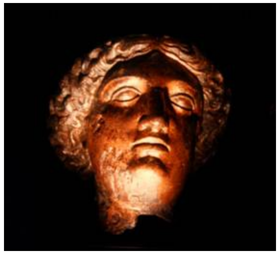
MINERνA



Deborah Harris   Fermilab

WIN05, Δελφοι

The MINERνA Collaboration



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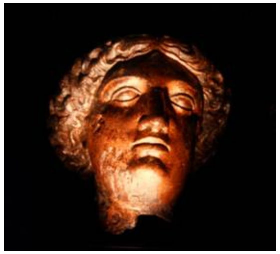
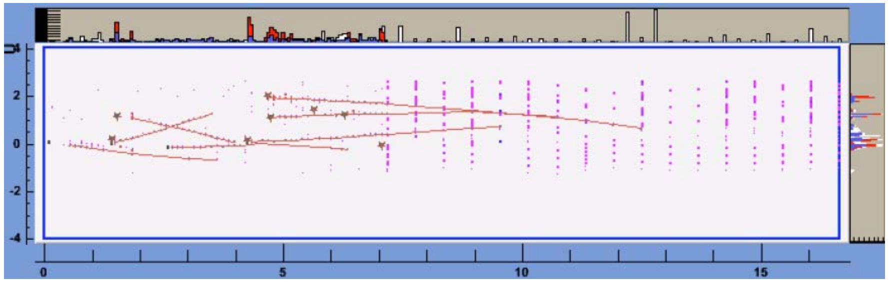
We are entering a new era…

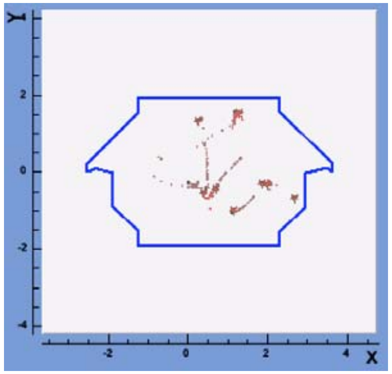
- Oscillation experiments are requiring
  - precision
  - long distances
- New Very Intense Beamlines are here!
  - NuMI at Fermilab: has achieved 150kWatts, designed for 400kWatts
  - CNGS under construction, 120kWatt
  - T2K has goal of 750kWatts

With new era, new Opportunities



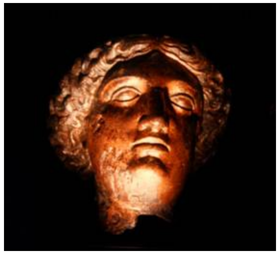
- Extremely intense beam means near detectors see huge event rates





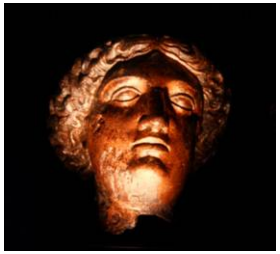
- Example: NuMI low energy beam, get ~million events per ton-year in near hall
- MIPP measurements of NuMI target mean that ν flux will be better predicted than ever before
- Perfect opportunity for precision ν interaction studies

Why measure ν interactions precisely?

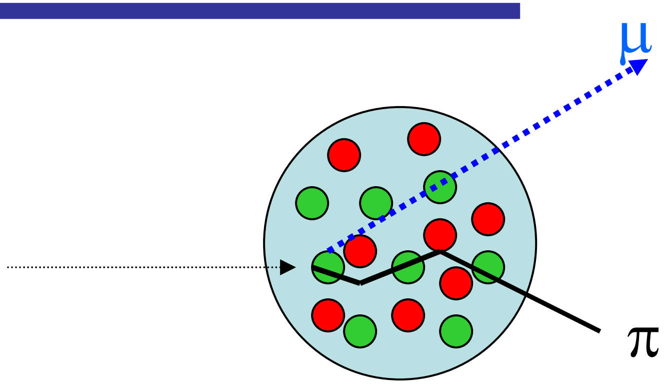


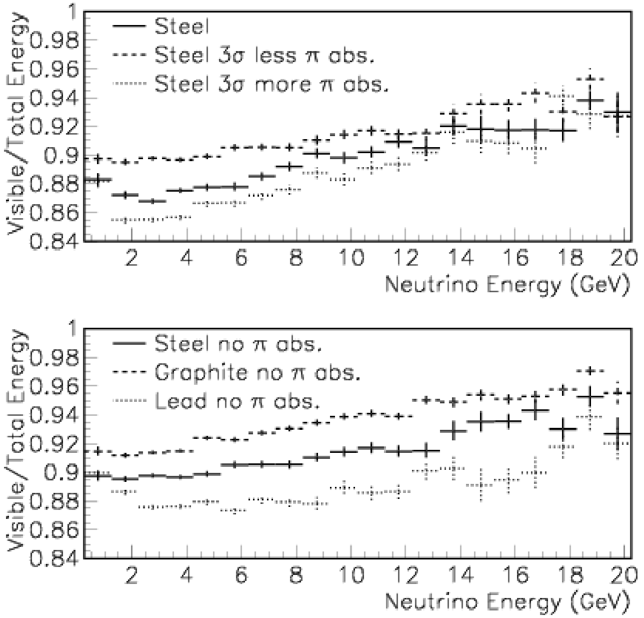
- Precise Oscillation measurements need it
  - Ultimate precision in Δm^2 from disappearance
  - Accurate background predictions for appearance
  - Translating from events above bkgd to appearance probability!
- New precise Jefferson Lab measurements of electron scattering are inspiring nuclear physicists to consider neutrinos
  - Vector versus axial vector form factors
  - Nuclear effects: are they the same or different for neutrinos?

How MINOS will use MINERνA

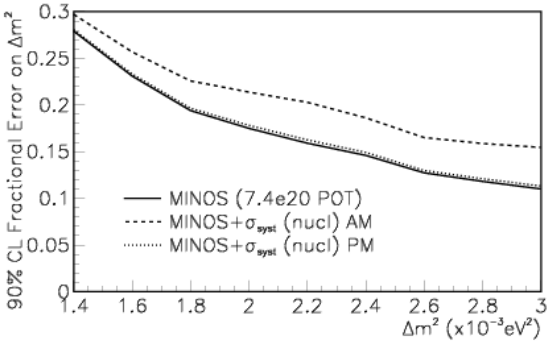


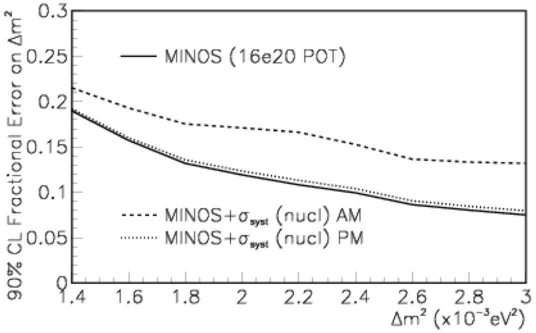
- Visible Energy in Calorimeter is NOT ν energy!
  - π absorption, rescattering
  - final state rest mass



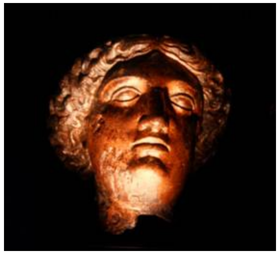


Nuclear Effects Studied in Charged Lepton Scattering, from Deuterium to Lead, at High energies, but nuclear corrections may be different between e/μ and ν scattering

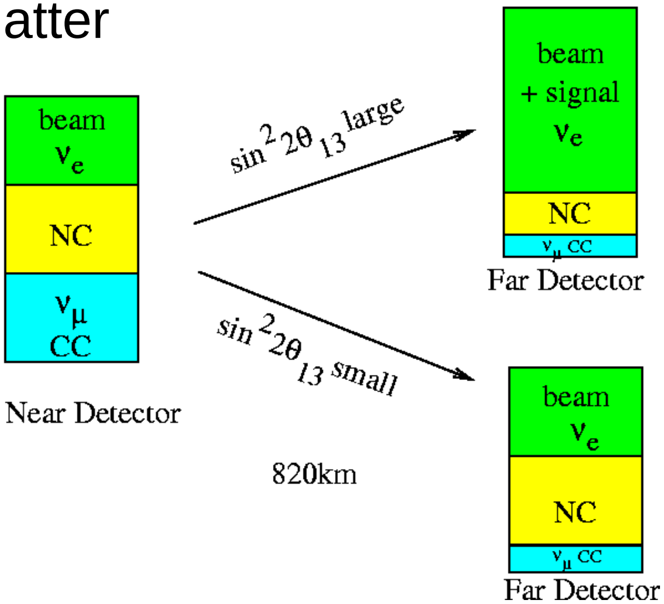


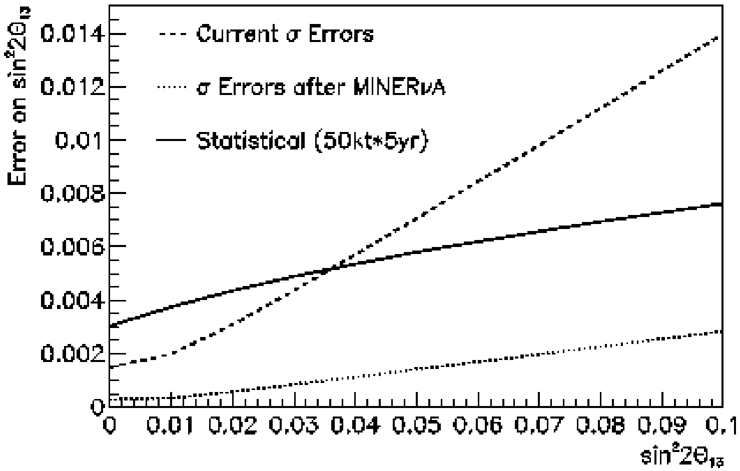


How NOνA will use MINERνA Measurements



Near and Far fluxes will have different compositions no matter how much $\nu_\mu \rightarrow \nu_e$

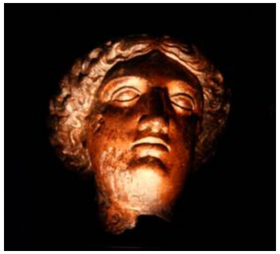


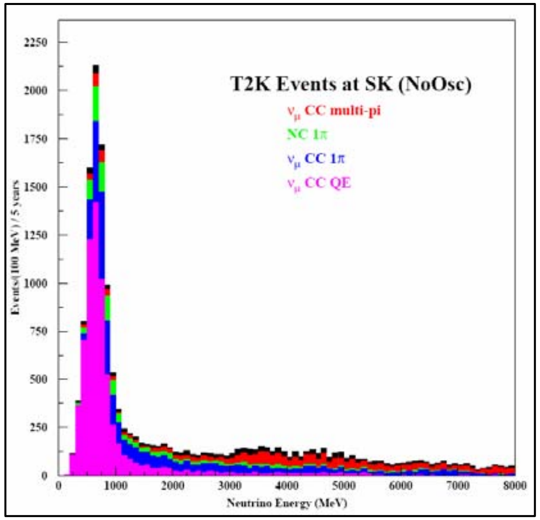


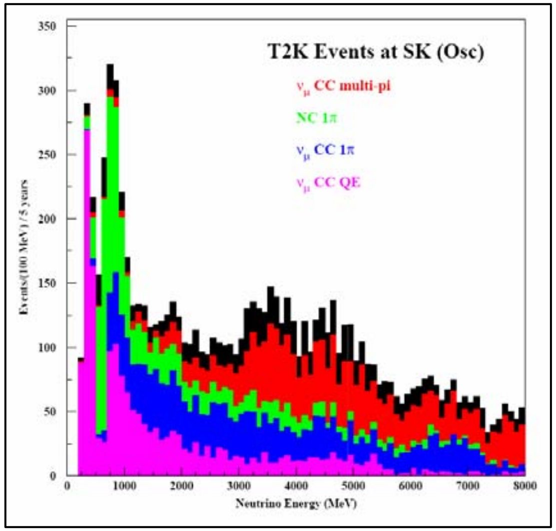
Process	QE	RES	COH	DIS
$\delta\sigma/\sigma$ NOW (CC,NC)	20%	40%	100%	20%
$\delta\sigma/\sigma$ after MINERνA (CC/NC)	5%/na	5%/10%	5%/20%	5%/10%

Without MINERνA, NOνA risks being limited by cross section uncertainties

How will T2K use MINERvA measurements







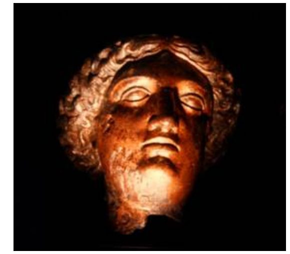
Note that as in NOvA, T2K's near detector will be a very different mix of events than the far detector.

To make accurate prediction, need

- 1 - 4 GeV neutrino cross sections
- Energy Dependence of cross sections

MINERvA can provide these with NuMI beamline Low Energy running!

What about Near Detectors?

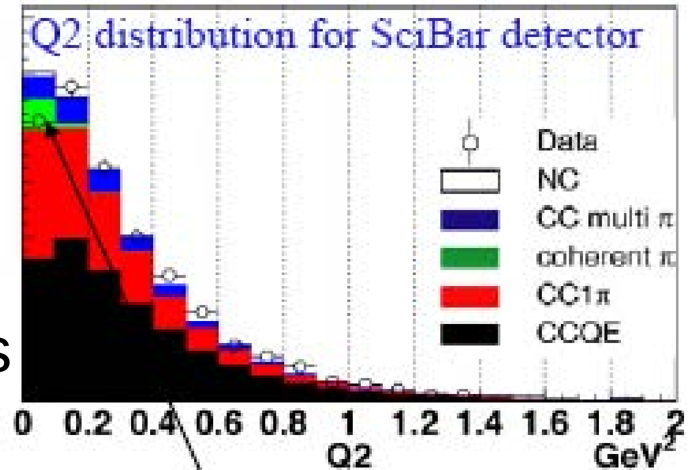


- MINOS Near Detector:
  - Can’t test nuclear effect models with only one nucleus!
- NOvA and T2K Near Detectors:
  - Can’t measure energy dependence with only one energy
  - If near design is same as far, can’t separate backgrounds any better near than far

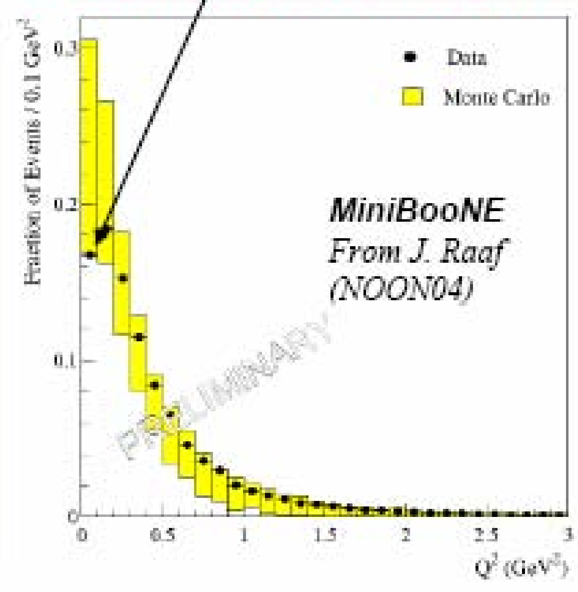
MINERvA design solves all three of these problems

MINERνA and Cross-Sections

- High Q^2 axial form factor of nucleon
  (complements high Q^2 vector FF, hot at JLab)
- coherent cross-sections vs. energy
  (exploit resolution, containing detector)
- differential dists. of exclusive final states
  (multi-purpose containing detector, high stats)
- A-dependence of:
  - low Q^2 elastic (K2K/MiniBooNE "low Q^2 problem"?)
  - exclusive final states (nuclear re-interactions)
  - deep inelastic scattering (F_2^ν, xF_3^ν)



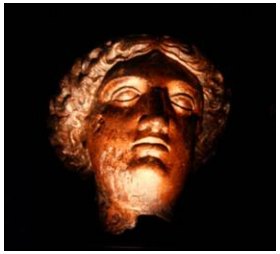
Larger than expected rollover at low Q²

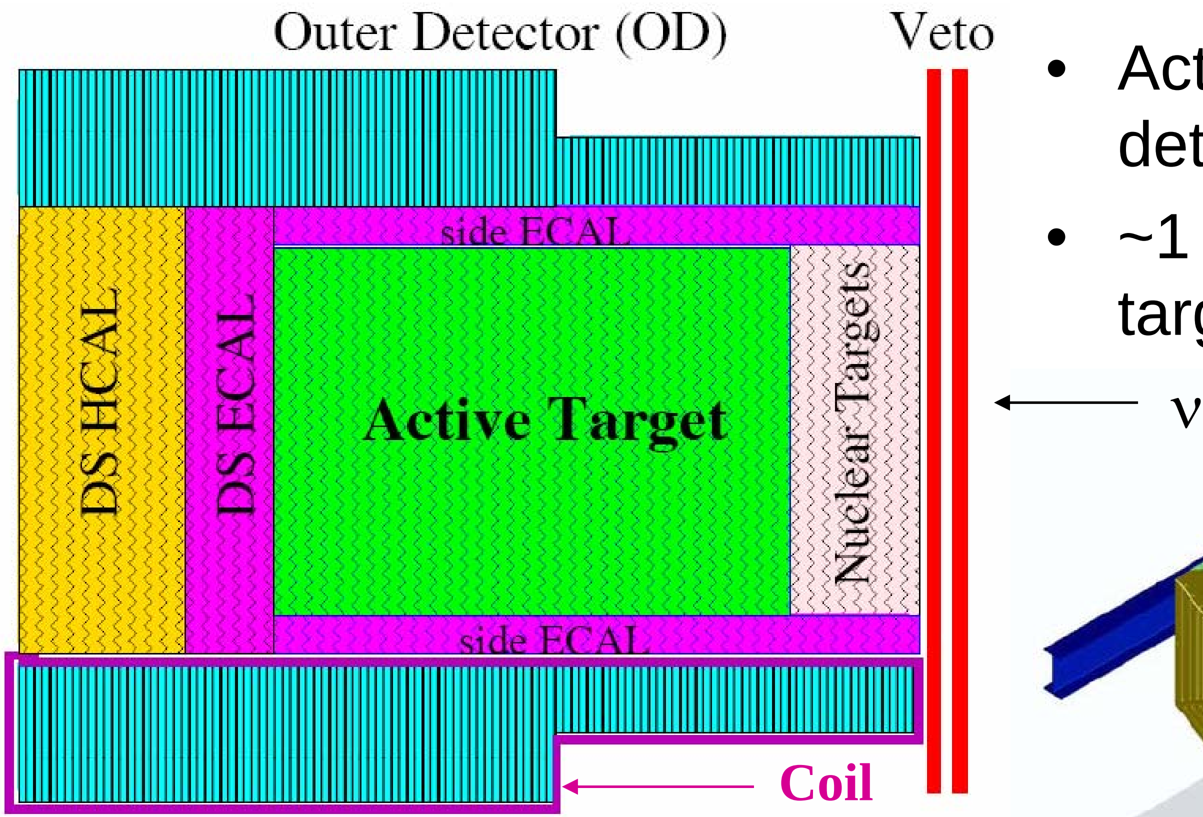


Detector Design

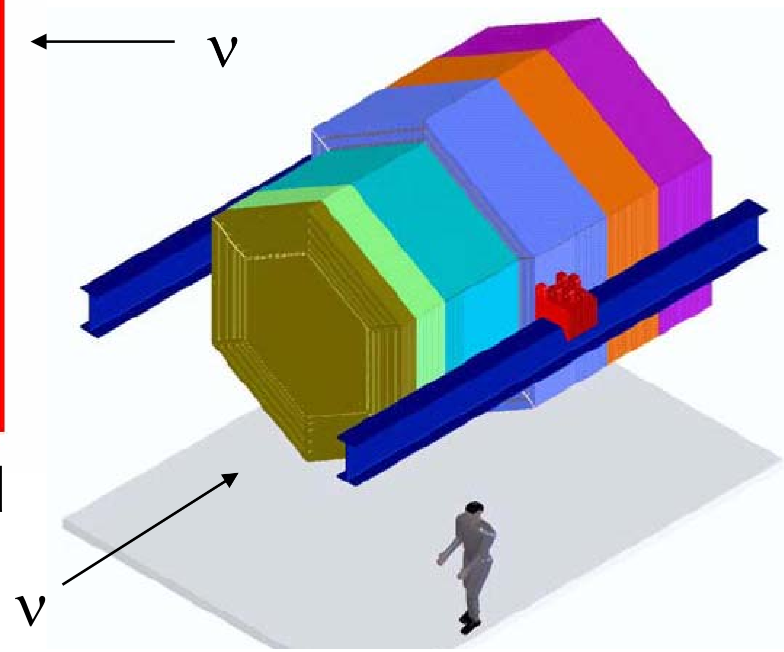
- MINERνA proposes to build a low-risk detector with simple, well-understood technology
- Active core is segmented solid scintillator (K2K SciBar)
  - tracking (including low momentum recoil protons)
  - particle identification
  - few ns timing (track direction, identify stopped $K^{\pm}$)
- Surrounded by electromagnetic and then hadronic calorimeters
  - photon (π^0) and hadron ($\pi^{\pm}$) energy measurement
  - magnetized for charge, momentum measurement of escaping muons at wide angles

Basic Detector Geometry





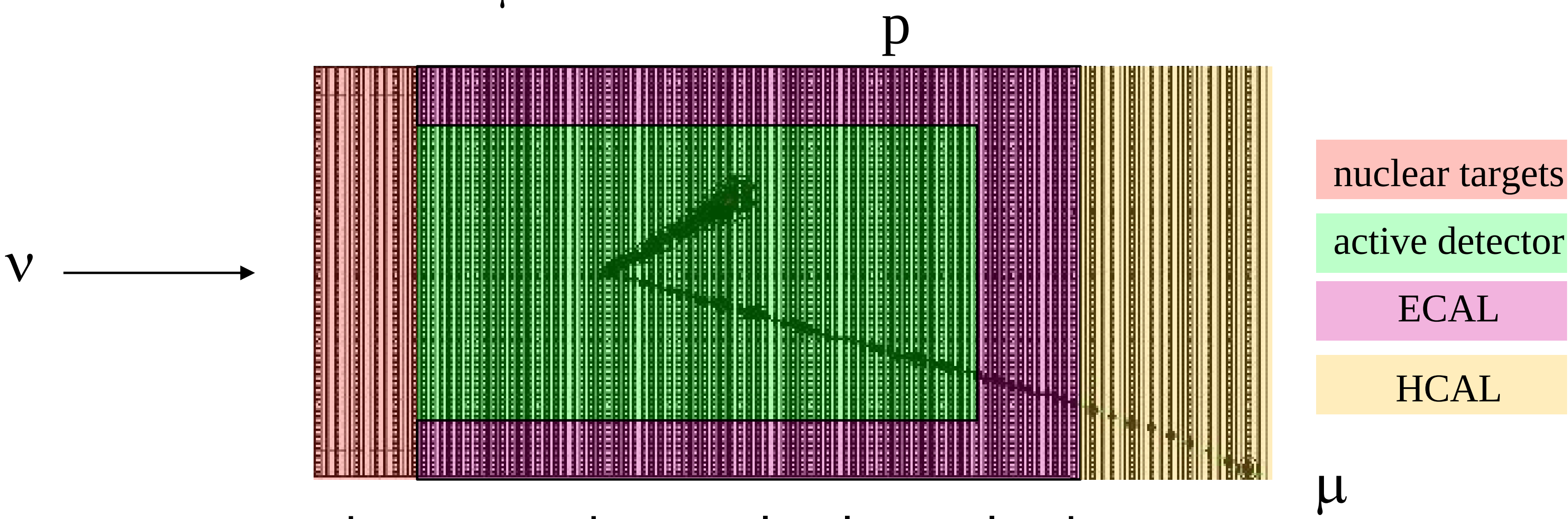
- Active segmented scint. detector 5.87 tons
- ~1 ton of US nuclear target planes (C, Fe, Pb)



- DS Cals, Nucl. Targets just add absorber to scintillator planes
- Magnetized OD (HCAL) frames

Example Events

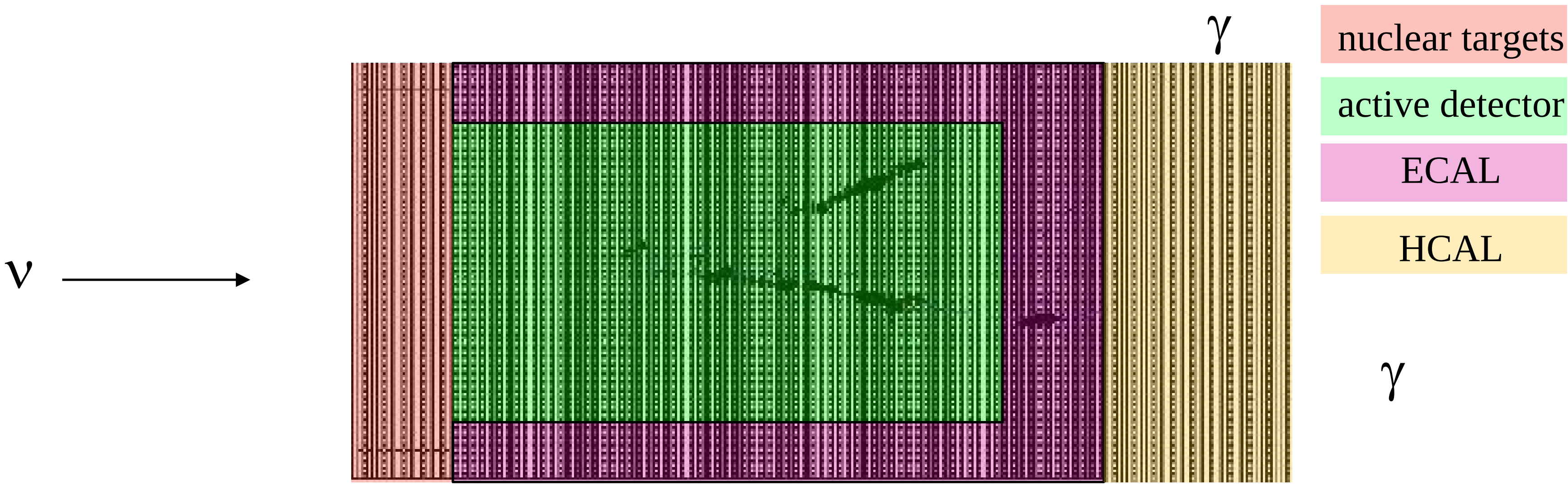
- Quasi-elastic $\nu_\mu n \rightarrow \mu^- p$



  - proton and muon tracks are clearly resolved
  - observed energy deposit is shown as size of hit; can clearly see larger proton dE/dx
  - precise determination of vertex and measurement of Q^2 from tracking

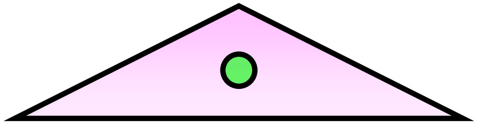
Example Events (cont'd)

- π^0 Production



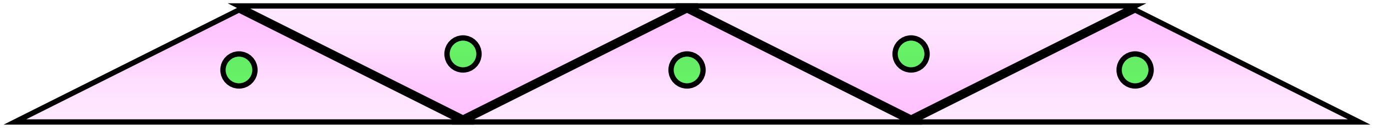
  – two photons clearly resolved (tracked). can find vertex.
  – some photons shower in ID,
    some in side ECAL (Pb absorber) region
  – photon energy resolution is ~6%/sqrt(E) (average)

Extruded Scintillator and Optics

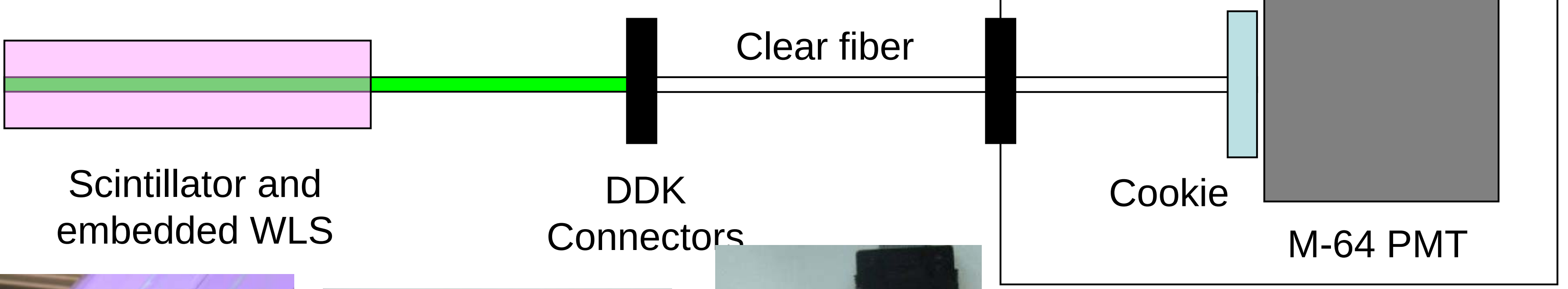


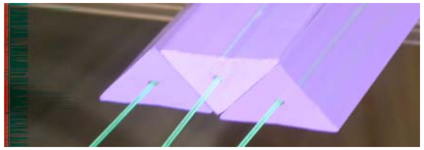
Basic element: 1.7x3.3cm triangular strips.
1.2mm WLS fiber readout in center hole

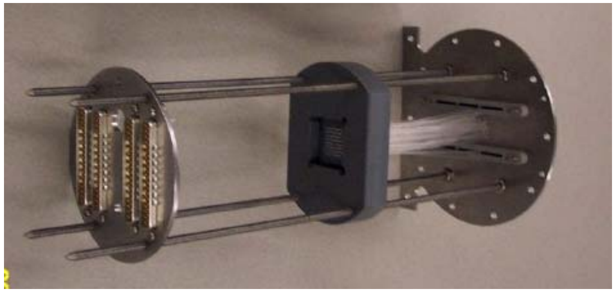
Assemble into planes



- MINERνA optical system

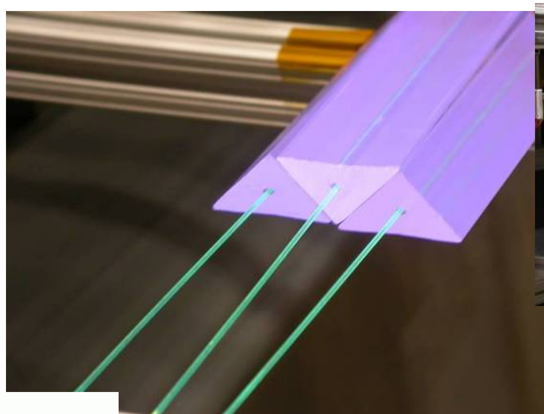


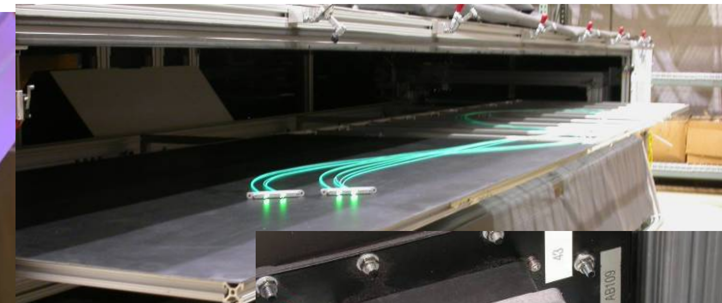


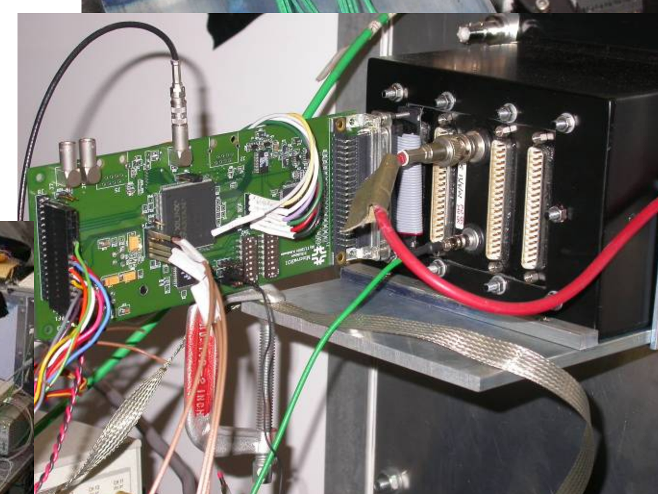


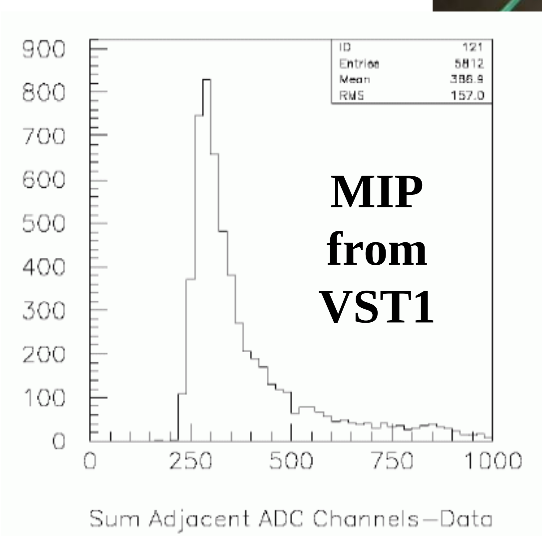
Vertical Slice Test (VST1)

VST1 array, electronics and DAQ





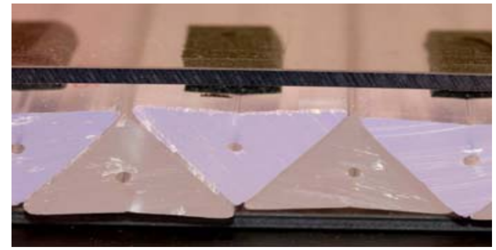


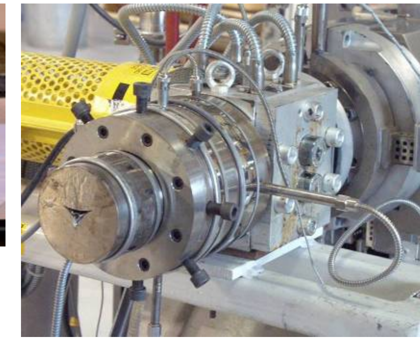


8 PE/MIP per doublet

Current Prototyping

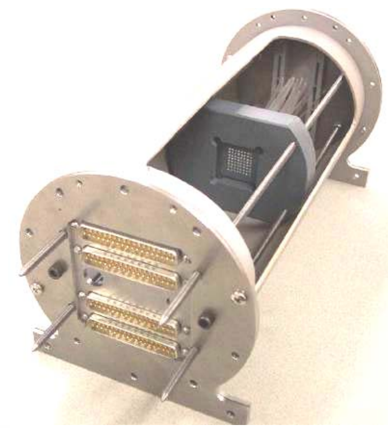
- Refining scint. extrusion





- First “trapezoid” of OD steel

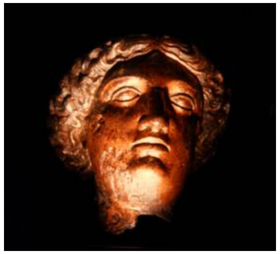
- Prototype PMT box



- Prototype clear fiber cables in progress

- 2nd Prototype front-end and prototype readout electronics

MINERνA statistics and running



Assume 9×10^{20} POT: **7.0×10^{20} in LE ν beam, 1.2×10^{20} in sME ν beam and 0.8×10^{20} in sHE ν beam**

ν_μ Event Rates per fiducial ton

Process	CC	NC
Quasi-elastic	103 K	42 K
Resonance	196 K	70 K
Transition	210 K	65 K
DIS	420 K	125 K
Coherent	8.4 K	4.2 K
TOTAL	**940 K**	**305 K**

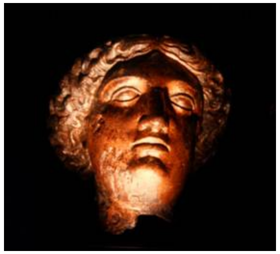
Typical Fiducial Volume =
3-5 tons CH, 0.6 ton C, ≈ 1 ton Fe and ≈ 1 ton Pb

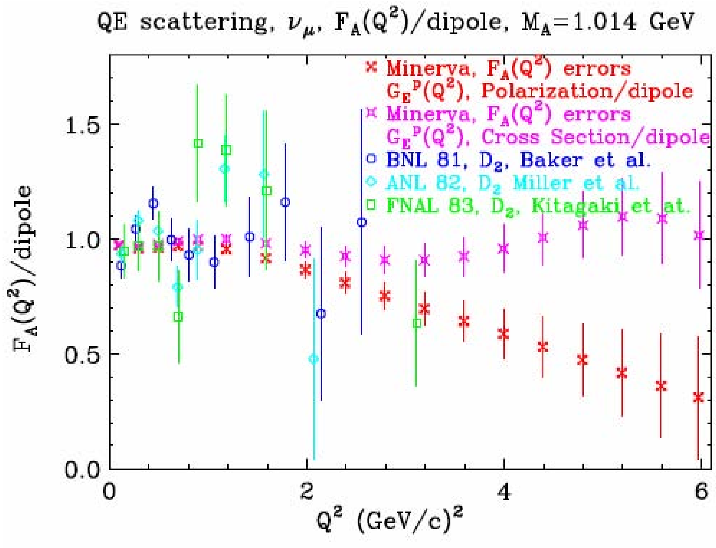
3 - 4.5 M events in CH
0.5 M events in C
1 M events in Fe
1 M events in Pb

Main Physics Topics with Expected Produced Statistics

- **Quasi-elastic** - ν+n --> μ^-+p - 300 K events off 3 tons CH
- **Resonance Production** - e.g. ν+N ---> ν /μ^-+Δ 600 K total, 450K 1π
- **Coherent Pion Production** - ν+A --> ν /μ^-+A + π, 25 K CC / 12.5 K NC
- **Nuclear Effects** - C: 0.6M events, Fe: 1M and Pb: 1 M
- **σ_T and Structure Functions** - 2.8 M total /1.2 M DIS events
- **Strange and Charm Particle Production** - (> 60 K **fully** reconstructed)

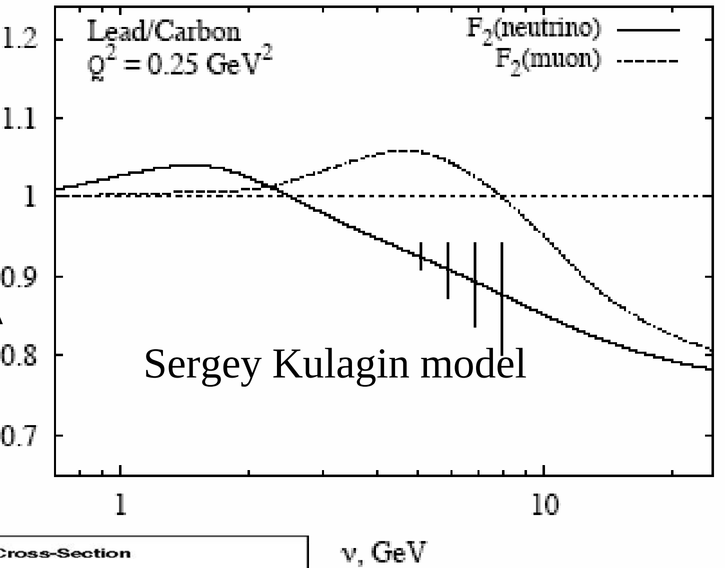
Sample Expected Results

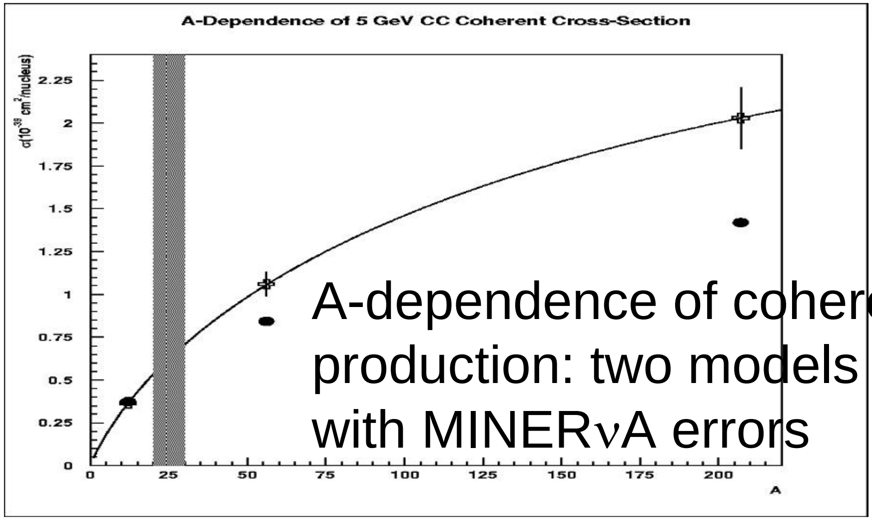




Axial Form Factor at high Q^2: two models with MINERνA errors

F2, Pb/C, with MINERνA errors





A-dependence of coherent pion production: two models with MINERνA errors

MINERνA Schedule

- April 2004 – Stage I approval from FNAL PAC
- October 2004 – Complete first Vertical Slice Test with MINERvA extrusions, WLS fiber and Front-End electronics
- January 2005 – First Project Director's ('Temple') Review
- Summer 2005 – Second Vertical Slice Test
- End CY 2005 – Projected Date for MINERvA Project Baseline Review
- October 2006 – Start of Construction
- Summer 2008 – MINERvA Installation and Commissioning in NuMI Near Hall

Summary

- NuMI provides opportunity to break new ground on precision neutrino interaction measurements
- MINERvA is unique in worldwide program:
  - On-axis near detector allows energy dependence measurements
  - Detector with several different nuclear targets allows first glance at neutrino nuclear effects!
- On track technically to build and use detector
  - R&D and prototyping progressing
- For more, see http://www.pas.rochester.edu/minerva