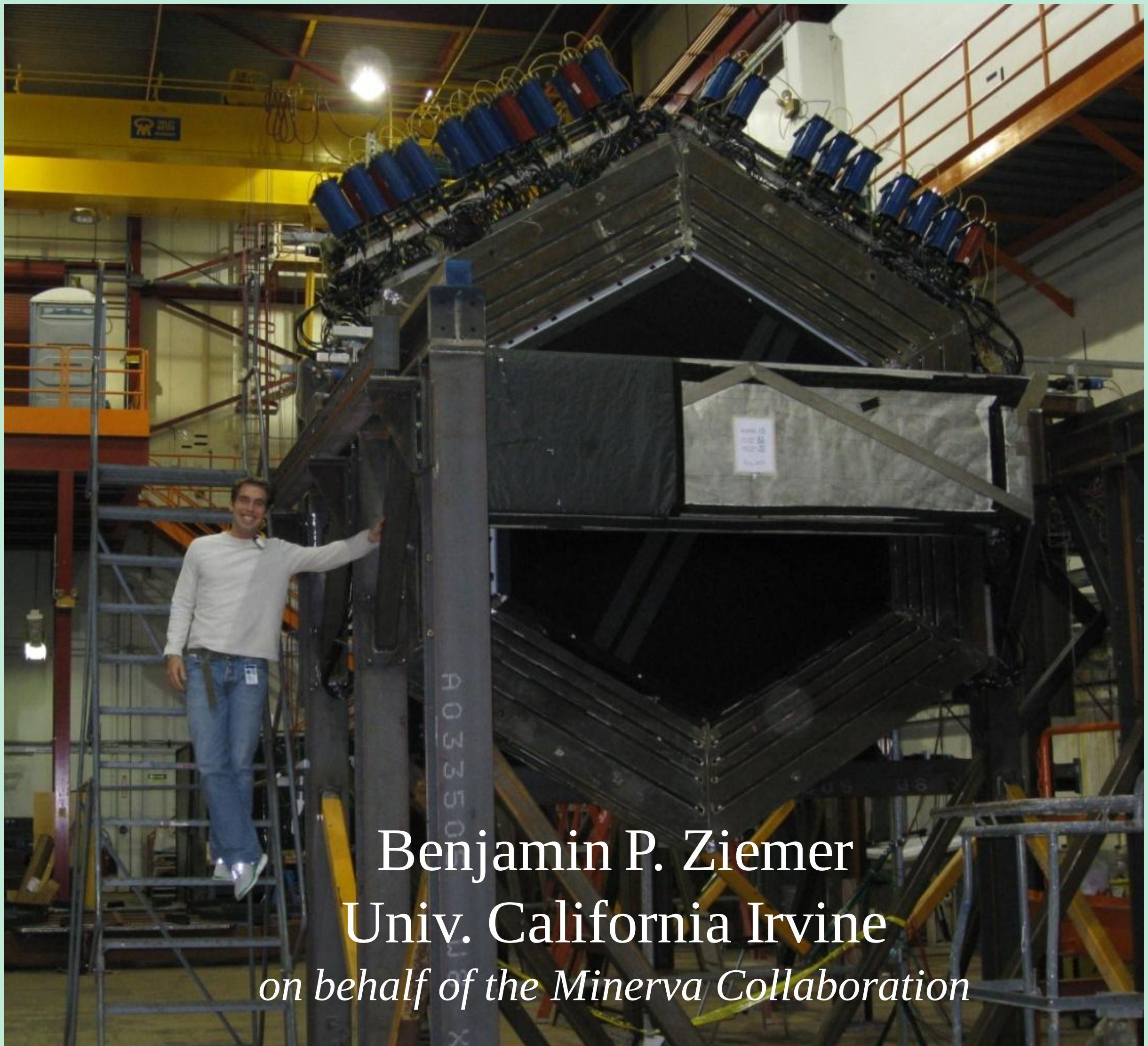
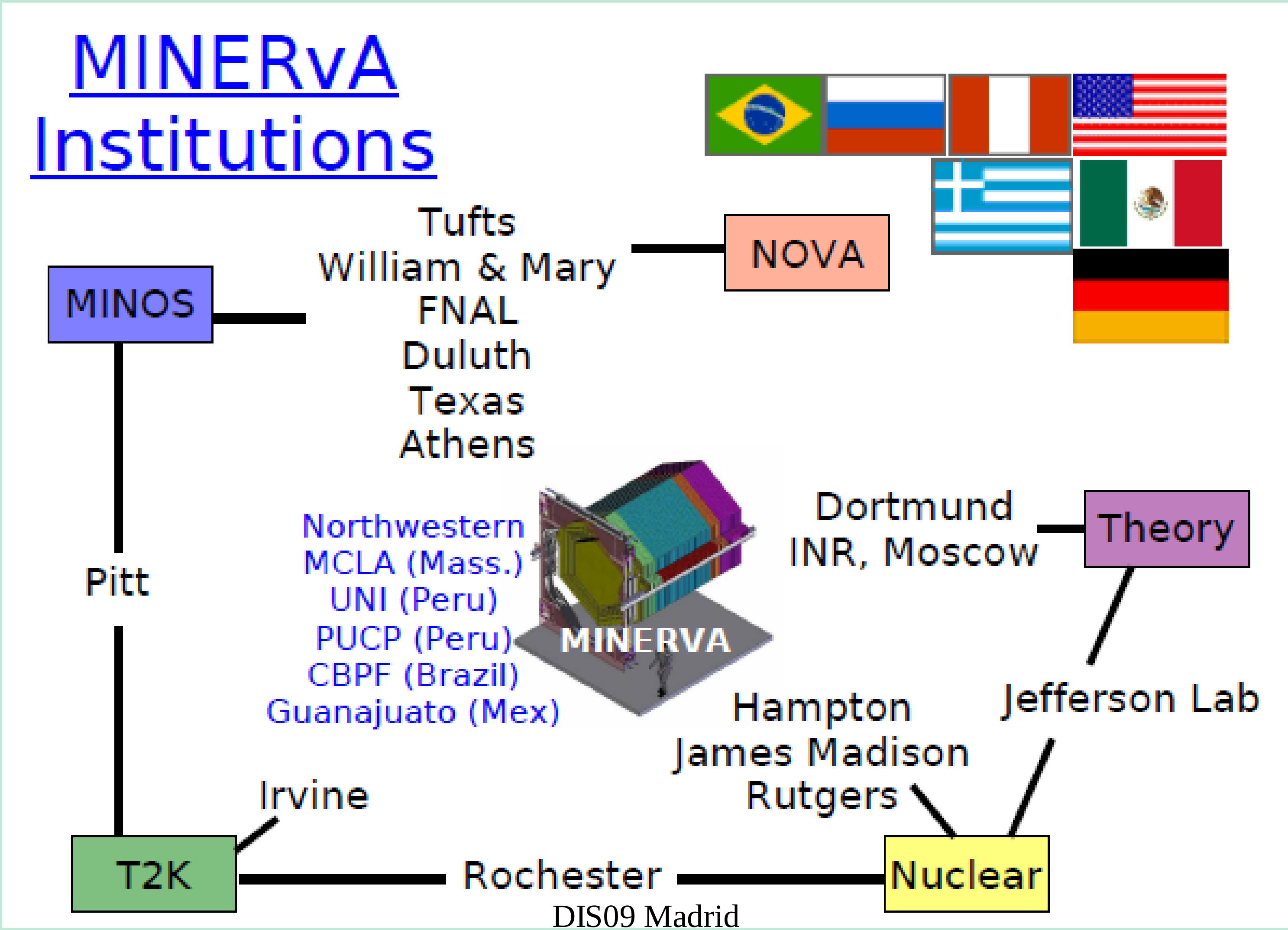
MINERνA: νN Scattering



Benjamin P. Ziemer
Univ. California Irvine
on behalf of the Minerva Collaboration

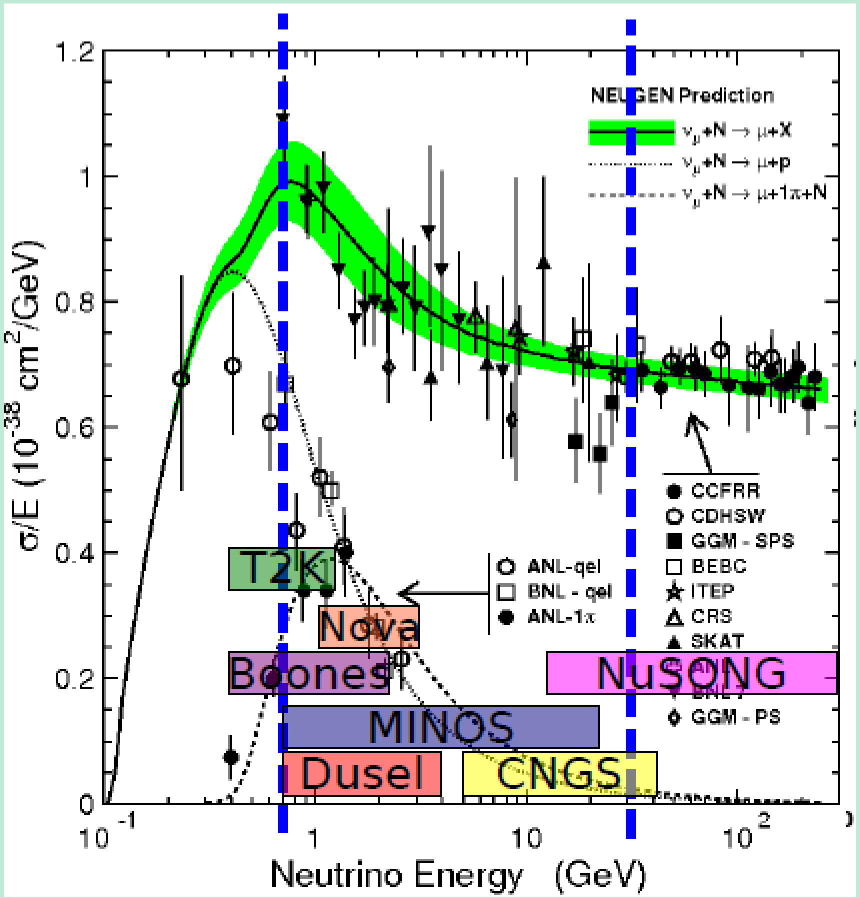
MINERνA

MINERνA Collaboration



MINERνA Physics Goals

(non-exclusive list)



(oscillation friendly plot)

Minerva will make precise measurements of neutrino cross-sections in a wide range of energies relevant to many oscillation experiments.

These measurements will be exclusive and inclusive channels:

$\nu n \rightarrow \mu p$, $\nu N \rightarrow \nu N'$, $\nu N \rightarrow \mu X$, etc.

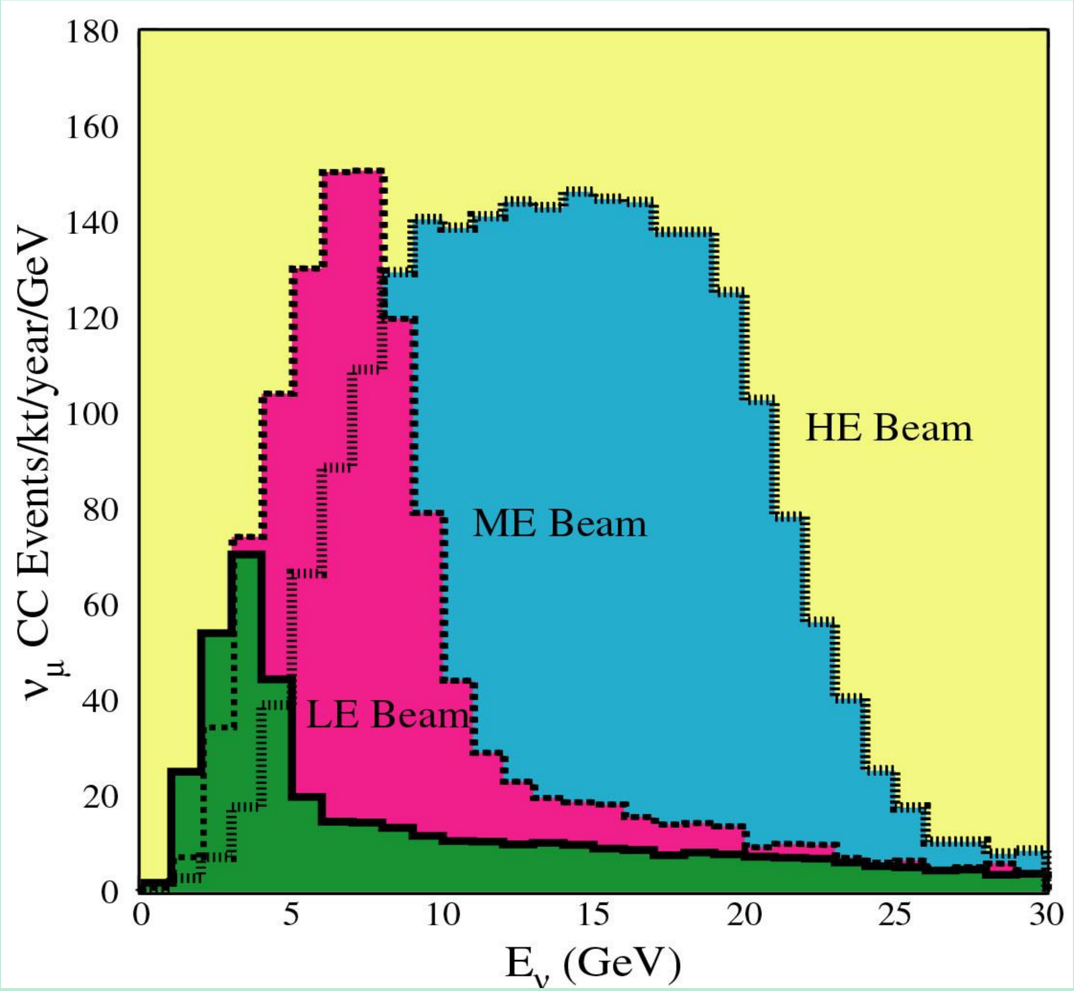
The A dependence of the cross section will be extracted with Minerva's nuclear targets. A detailed study of nuclear effects will be done with data taken from these targets.

NuMI Beam at FNAL

Intense neutrino beam with broad energy range

MINERvA will use mixture of LE, ME, HE beam

Anti-neutrino running possible by changing horn currents



MINERνA Event Rates

Assuming 4.0x10^{20} in LE and 12.0x10^{20} ME NuMI beam configurations in current run plan

Fiducial Volume = 3 tons CH, 0.2t He, 0.15t C, 0.7t Fe and 0.85t Pb

Expected CC event samples:

9.0 M ν events in 3 tons of CH

0.6 M ν events in He

0.4 M ν events in C

2.0 M ν events in Fe

2.5 M ν events in Pb

Main CC Physics Topics (Statistics in CH) - 9 Million total CC events

❑ Quasi-elastic	0.8 M events
❑ Resonance Production	1.7 M total
❑ Transition: Resonance to DIS	2.1 M events
❑ DIS, Structure Funcs. and high-x PDFs	4.3 M DIS events
❑ Coherent Pion Production	89 K CC / 44 K NC
❑ Strange and Charm Particle Production	> 240 K fully reconstructed events
❑ Generalized Parton Distributions	order 10 K events
❑ Nuclear Effects	He: 0.6 M, C: 0.4 M, Fe: 2.0 M and Pb: 2.5 M

MINERνA Detector

MINERνA Detector

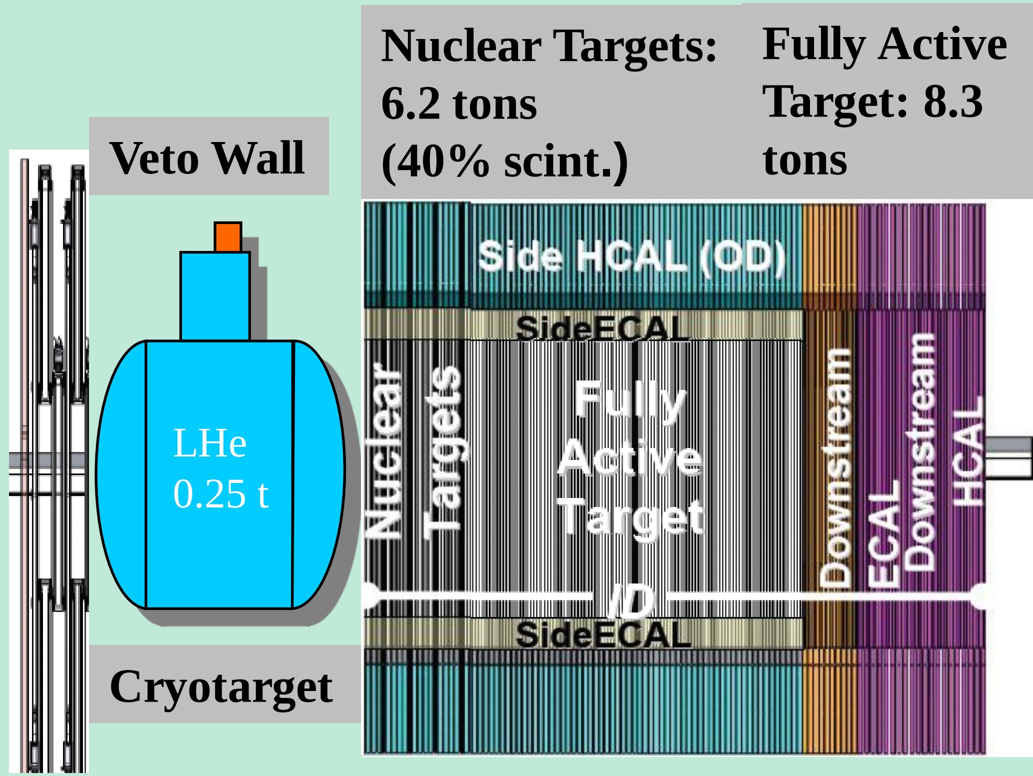
Basic element of MINERνA is ~2m across hexagonal scintillator plane in a steel frame - three different orientations to aid reconstruction

Nuclear Targets (see next slide)

Fully active scintillator tracker region

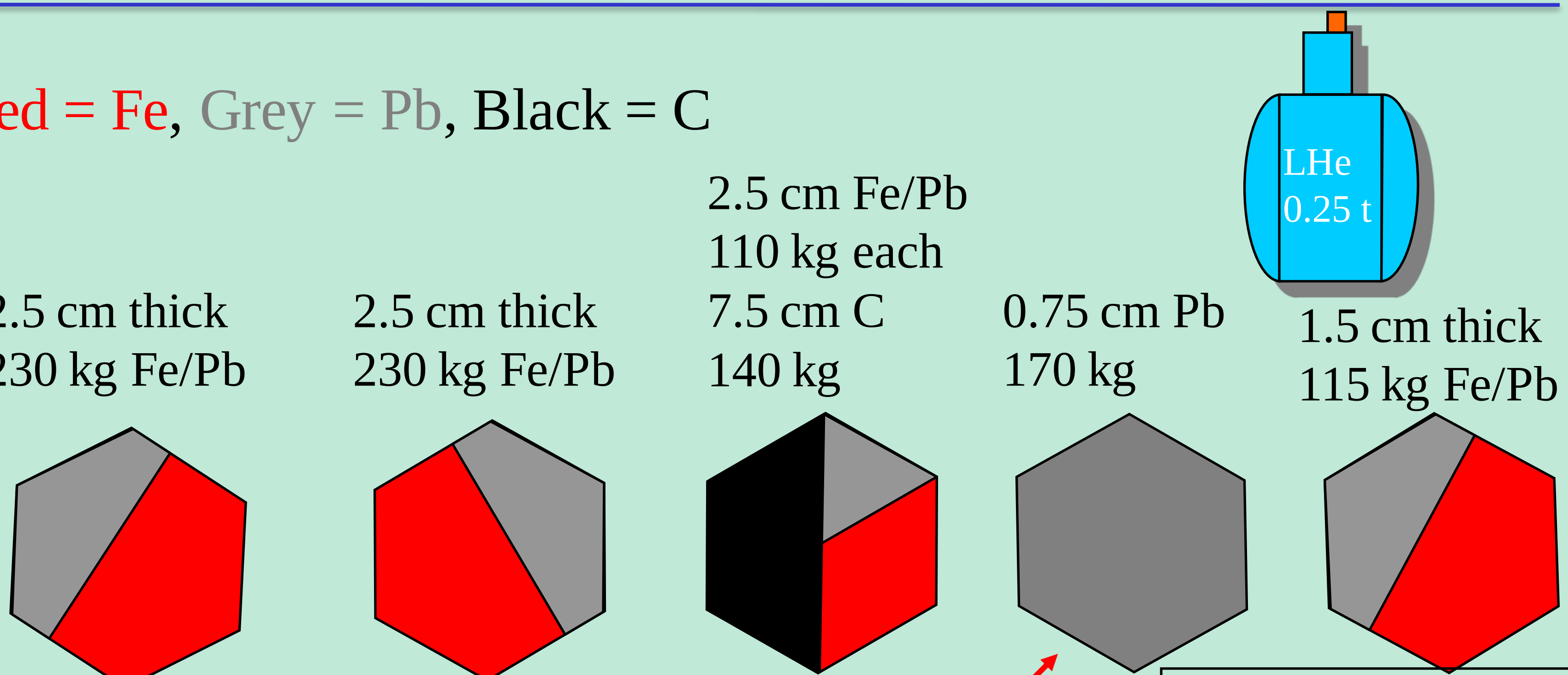
Side and down-stream calorimeters

MINOS Near Detector will measure the momentum of exiting muons



MINERνA Nuclear Targets

Red = Fe, Grey = Pb, Black = C

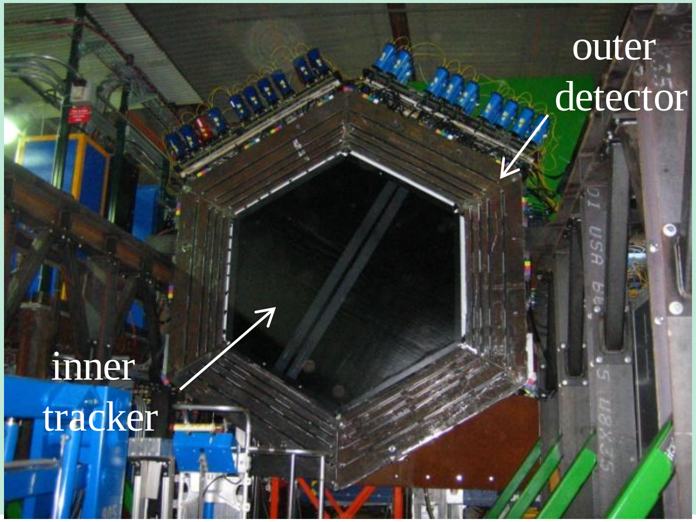


Comparison of He/Pb/C/Fe with same detector geometry

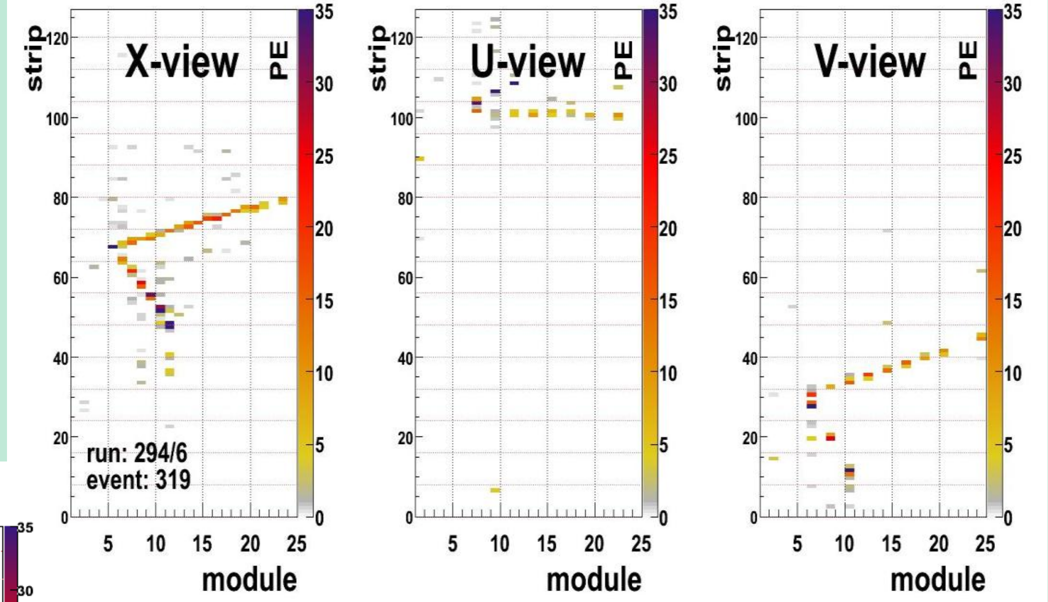
Thin Pb target also serves to insure good photon detection efficiency

Thin targets for low energy particle emission studies

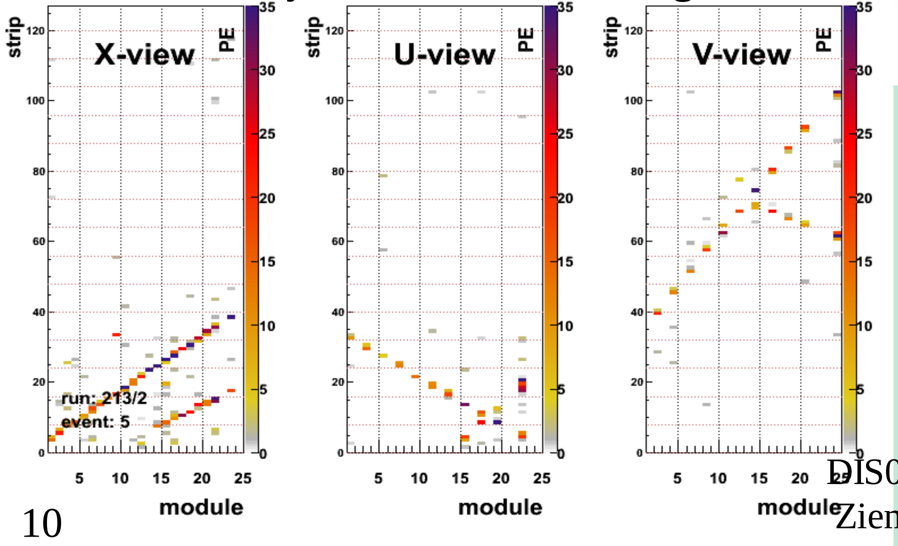
MINERνA Tracking Prototype



TP neutrino event (4/24) in NuMi Hall



TP cosmic ray tracks taken above ground



The Tracking Prototype served as a test of Minerva's subsystems. It was constructed above ground and took CR data. ***Mid-April*** it was moved underground and is taking neutrino events as we speak.

http://minervacam.fnal.gov/

MINERνA Reconstruction

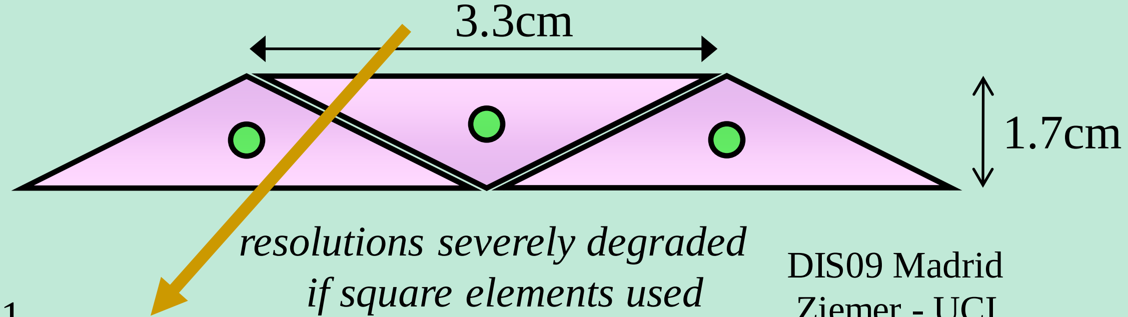
Reconstruction must be able to handle many event topologies:

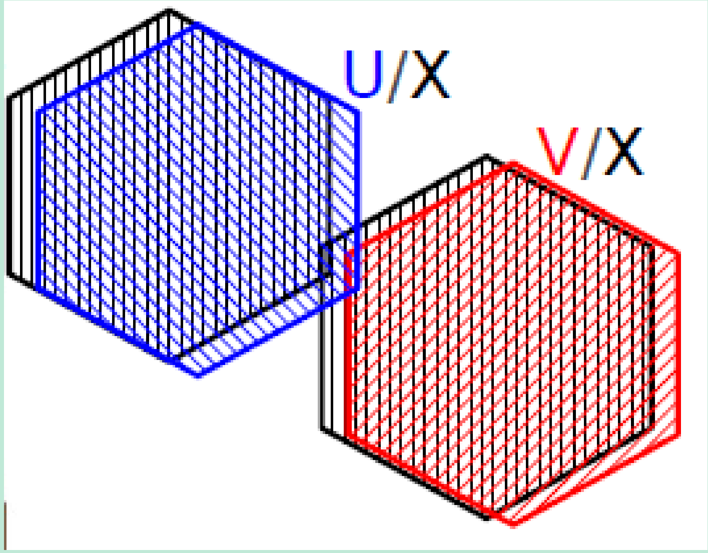
- short tracks, high multiplicities, accurately measure EM/hadronic showers

Detector performance and resolutions impact physics extracted:

- 3mm coordinate, 4-6mm vertex, <1º angular resolutions
- $\Delta E_{EM}/E_{EM} = 1\% + 2.7\%/\sqrt{E}$ ($5\%/\sqrt{E}$), $\Delta e_h/E_h = 4\% + 18\%/\sqrt{E}$ ($23\%/\sqrt{E}$)
- $\Delta P_\mu/P_\mu = 5\%$ (stopping), ~12-13% (MINOS)
- 85%, 90%, 95% of stopping K,π, and p correctly identified via dE/dx
- Around Δ(1232), $W_{res} \sim 0.1$GeV and $Q^2_{res} \sim 0.2$ (GeV/c)^2

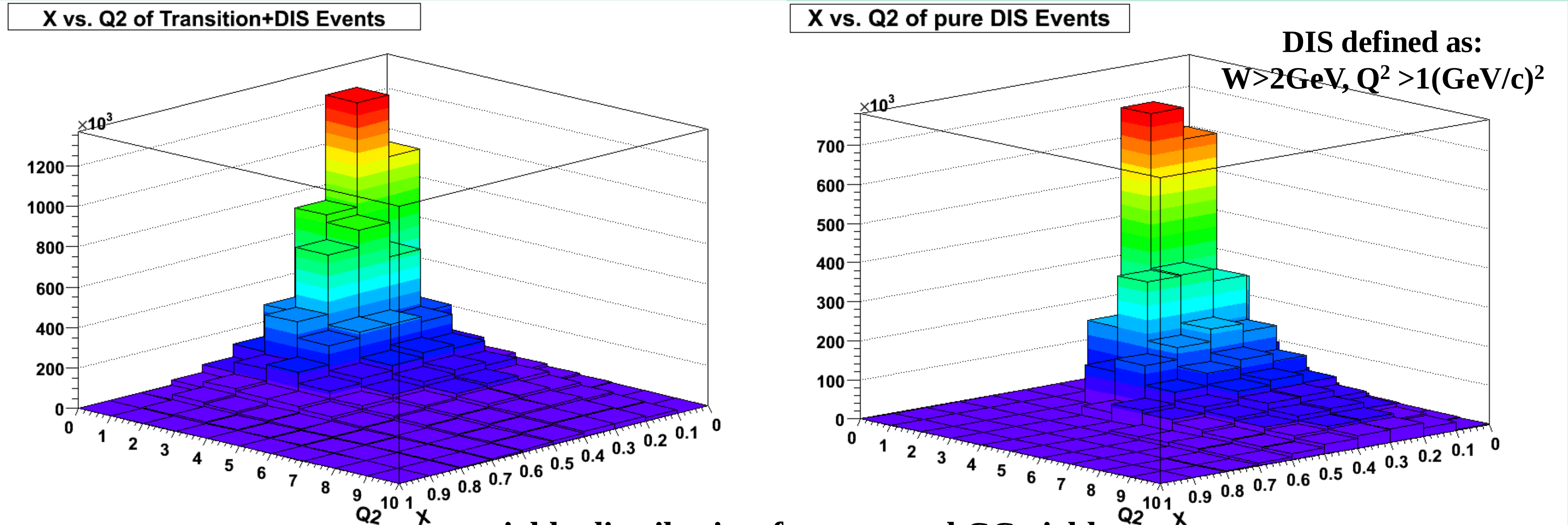
Initial tracking has approx. 99% efficiency and track based alignment using CR sample is underway.





MINERνA and DIS

MINERνA ‘DIS’ Coverage

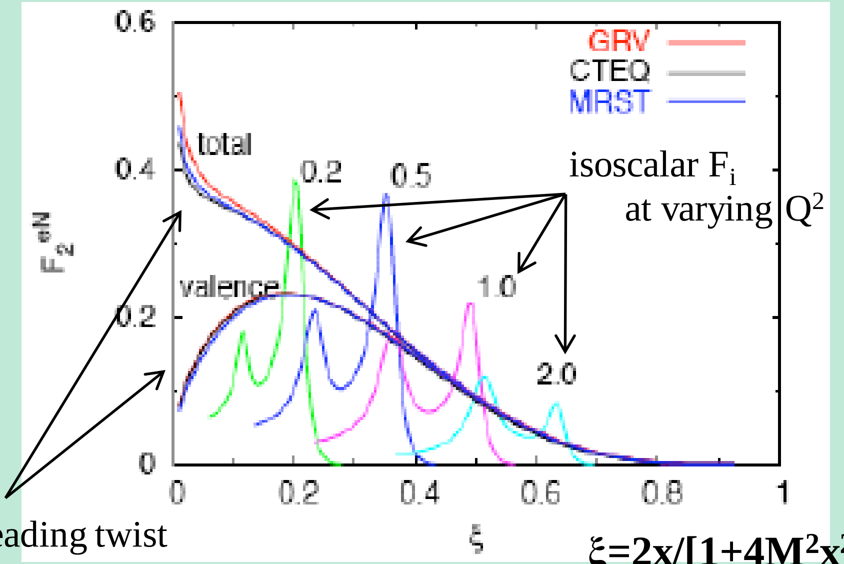


variable distribution for expected CC yield

• Minerva will collect **6M** events in carbon in the transition (not-so-deep DIS) and DIS region plus an additional **6.5M** events in the four nuclear targets.

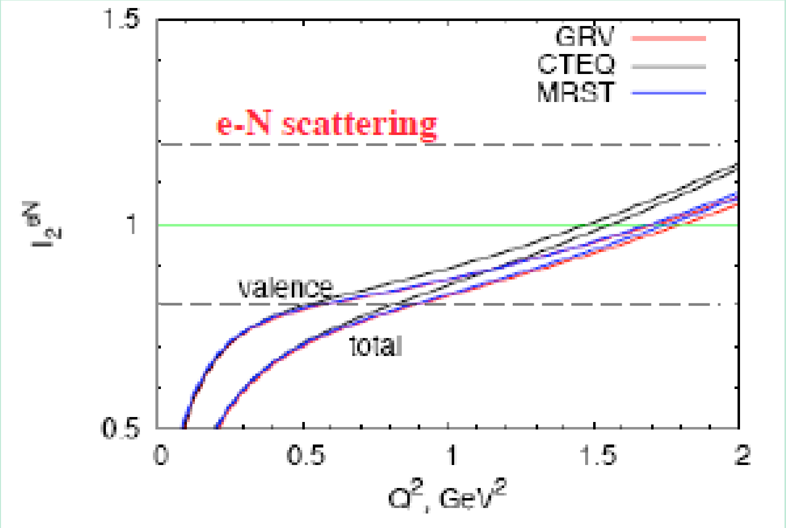
• Different specific studies will focus on various regions of variable space, but Minerva will increase the existing neutrino data set available to the community.

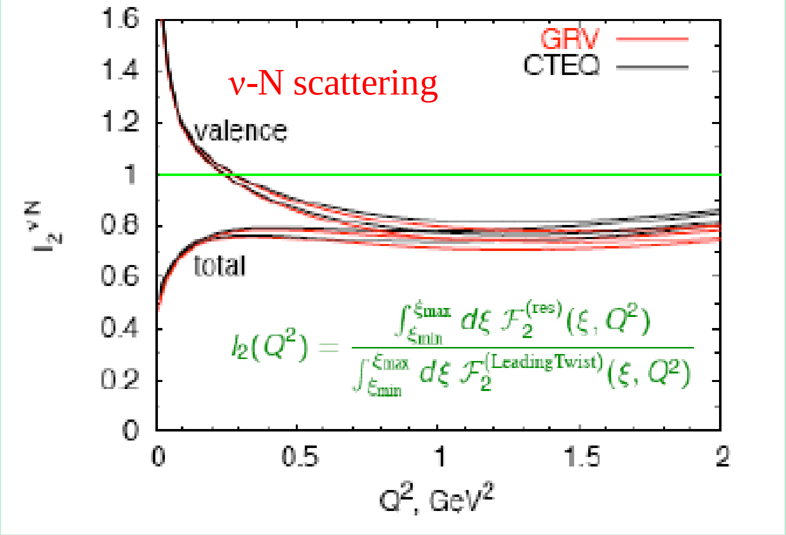
Quark-Hadron Duality



leading twist
parameterization

$\xi = 2x/[1+4M^2x^2/Q^2]^{1/2}$





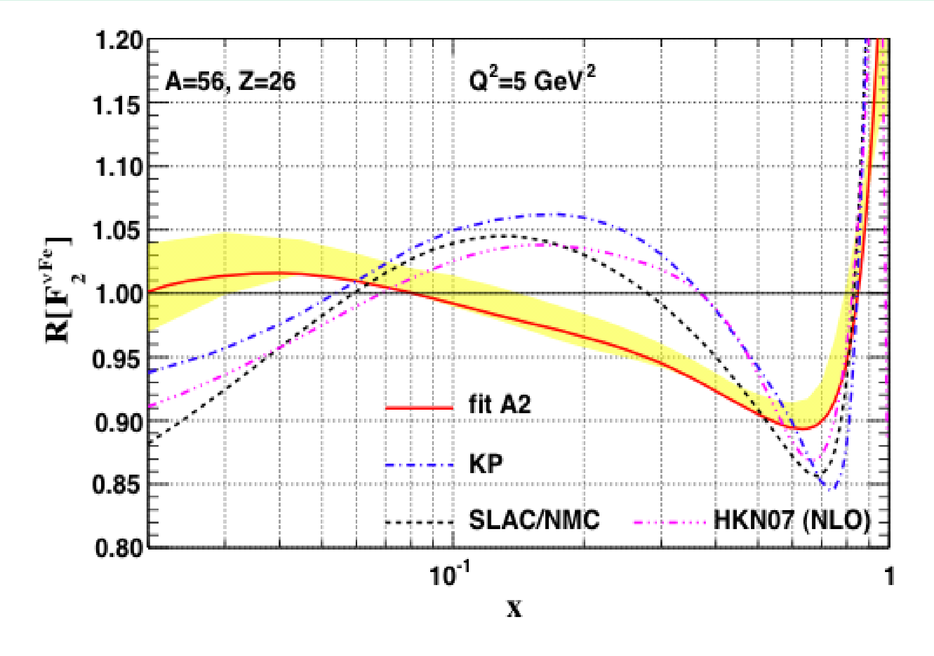
Averages of the resonance form factors appear to be ‘dual’ to the leading twist structure functions. The quotient of the ξ integral of these two quantities yields to what degree duality holds. Theoretically, neutrino duality seems to hold better than charged leptons, but depends on the axial form factor model.

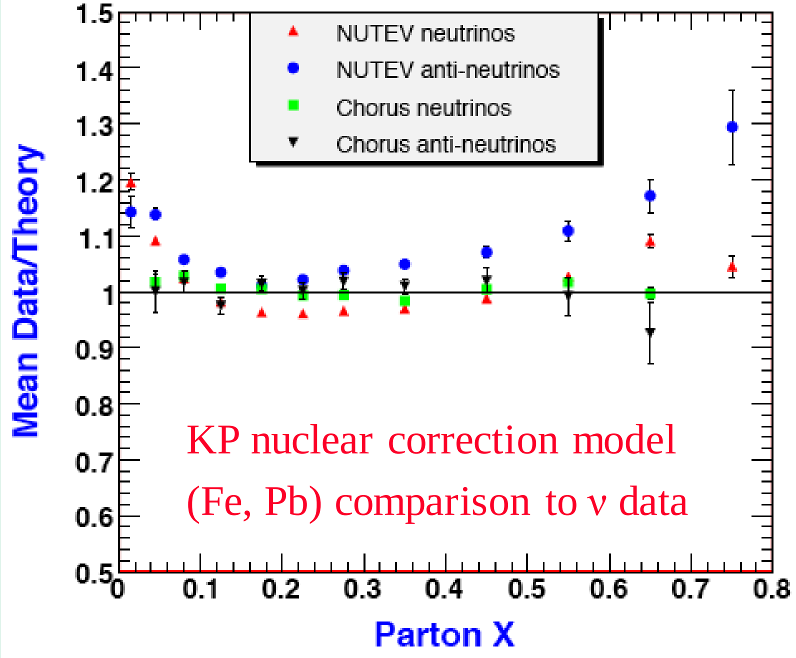
DIS09 Madrid
Ziemer - UCI

Lalakulich, et.al. Phys.Rev.C75,015202

Neutrino Nuclear Effects

(modified interaction probabilities)





These effects are relatively well understood for electrons and muons, but a detailed study has not been done for neutrinos. Presence of the axial vector current and flavor specificity obscure neutrino nuclear effects.

Minerva will take data across a wide range of targets with the same beam. Precision tracking will allow extraction of nuclear correction factors and new models to be tested.

Morfin, et.al hep-ph/0710.4897

Morfin, et.al.,Phys.Rev.D75:054030,2007

Neutrino Nuclear Effects

(final state interactions)

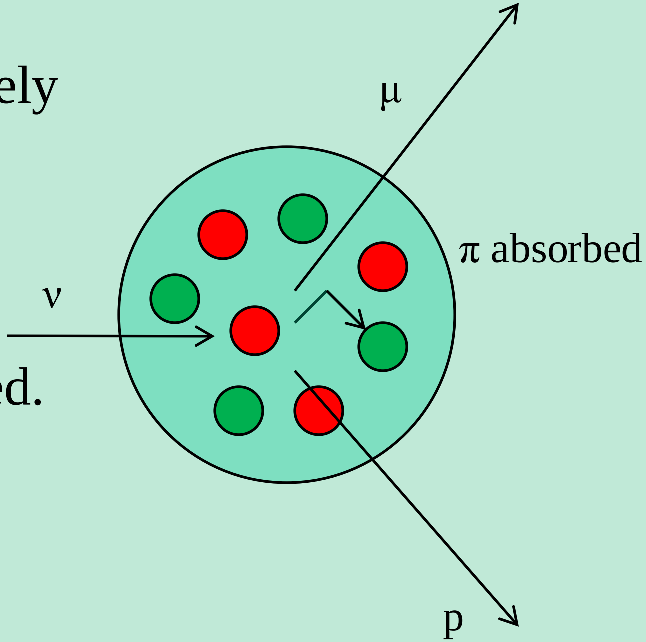
• Particles that are produced in heavy nuclei have a probability of being altered upon exiting. This is especially true in the range of energies used in current oscillation experiments.

• Pions produced with NuMI neutrinos are most likely to undergo final state interactions. These can be:

- o elastic or inelastic scattering
- o full absorption
- o charge exchange

Any of these effects alters the signal that is extracted.

- o change angular distributions
- o change measured multiplicities
- o alter energy measured



• MINERνA will measure FSI by measuring track multiplicities and hadron shower energies as a function of the struck target.

Conclusions

• MINERνA Tracking Prototype is collecting data right now and will run until the shutdown. The full MINERνA detector is scheduled for completion in April 2010.

• We will reduce the error on many neutrino measurements with a combination of a large data set, fine-grained detector and much hard work. These measurements will then aid the broader physics community.

<u>DIS Conclusions</u>

MINERνA will measure:

- cross sections in the transition region to test quark-hadron duality
- structure function ratios for combinations of nuclear targets
- FSI via nuclear target multiplicities and hadron shower energies

Thank you again.

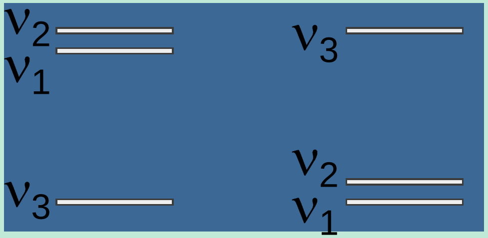
Backup Slides

Neutrino Open Questions

Is the neutrino mass hierarchy ‘normal’ or ‘inverted’?

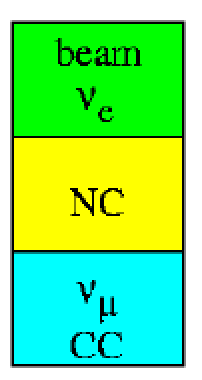
Is there a $\nu_\mu \rightarrow \nu_e$ conversion?

Does CP Violation exist in the neutrino sector? Can we ever measure it?

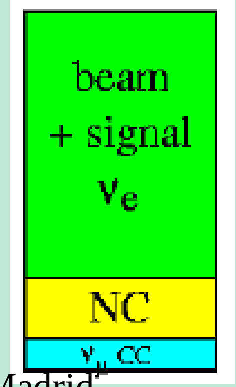


Inverted Normal

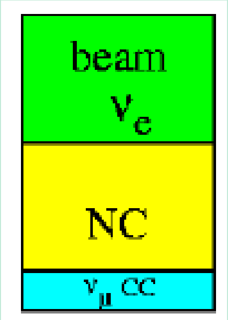
One of the biggest systematic uncertainties comes from neutrino cross-sections – most existing knowledge is from early bubble chamber data.



$\nu_\mu \rightarrow \nu_e$?



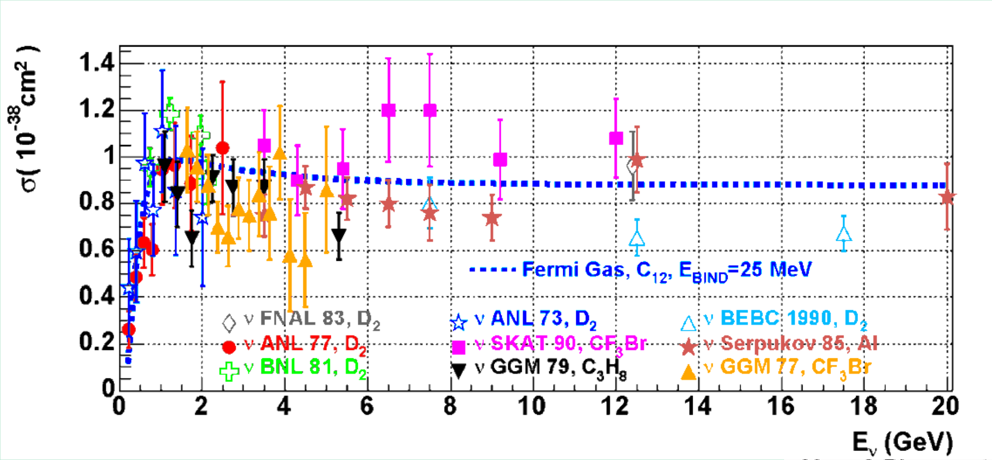
vs.



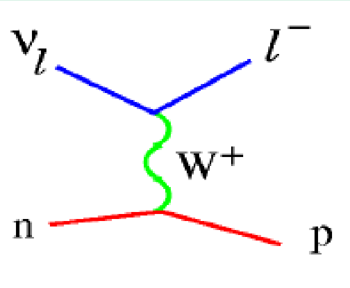
near detector

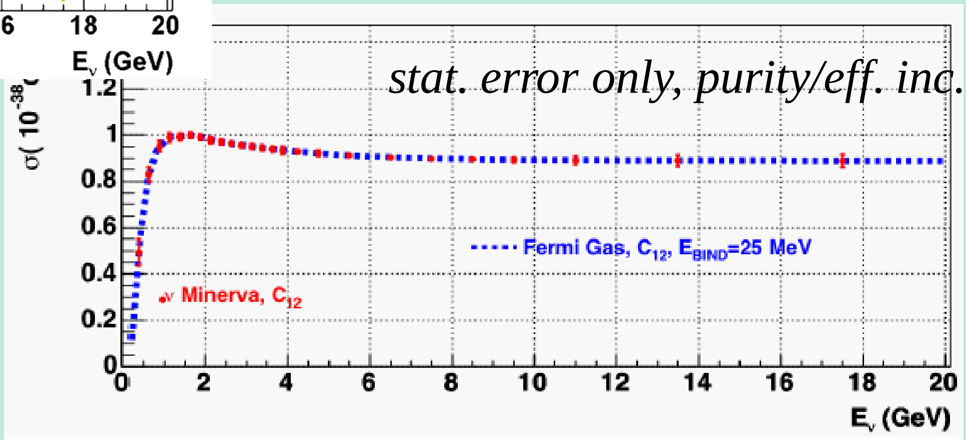
far detector

MINERνA Physics: Quasi-elastic



pre-Minerva



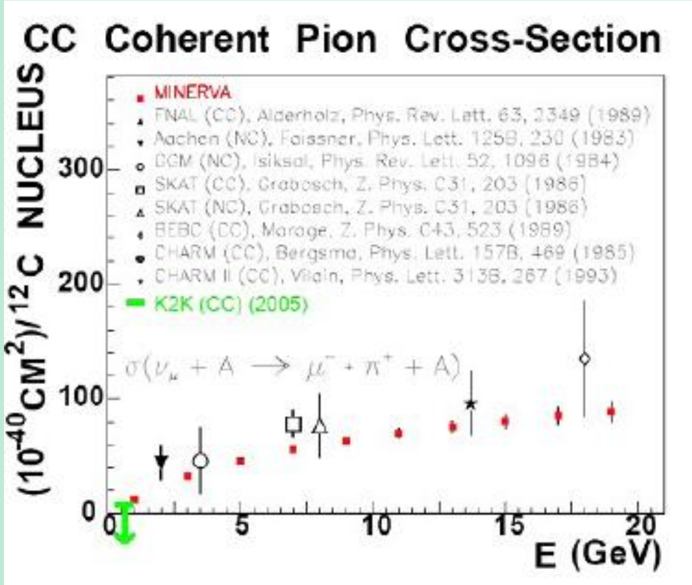


post-Minerva

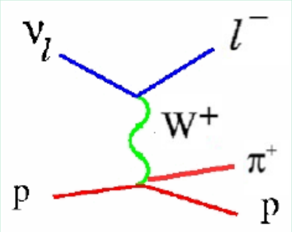
The quasi-elastic channel is used in many oscillation experiments. Currently, the cross section is known to about 10-15%*. Minerva will collect roughly 1M CCQE events in a 4yr run. Precision extraction of this cross section will aid many current and future neutrino experiments.

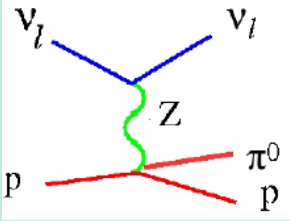
*G.Zeller NuINT07

MINERvA Physics: CC/NC Pion



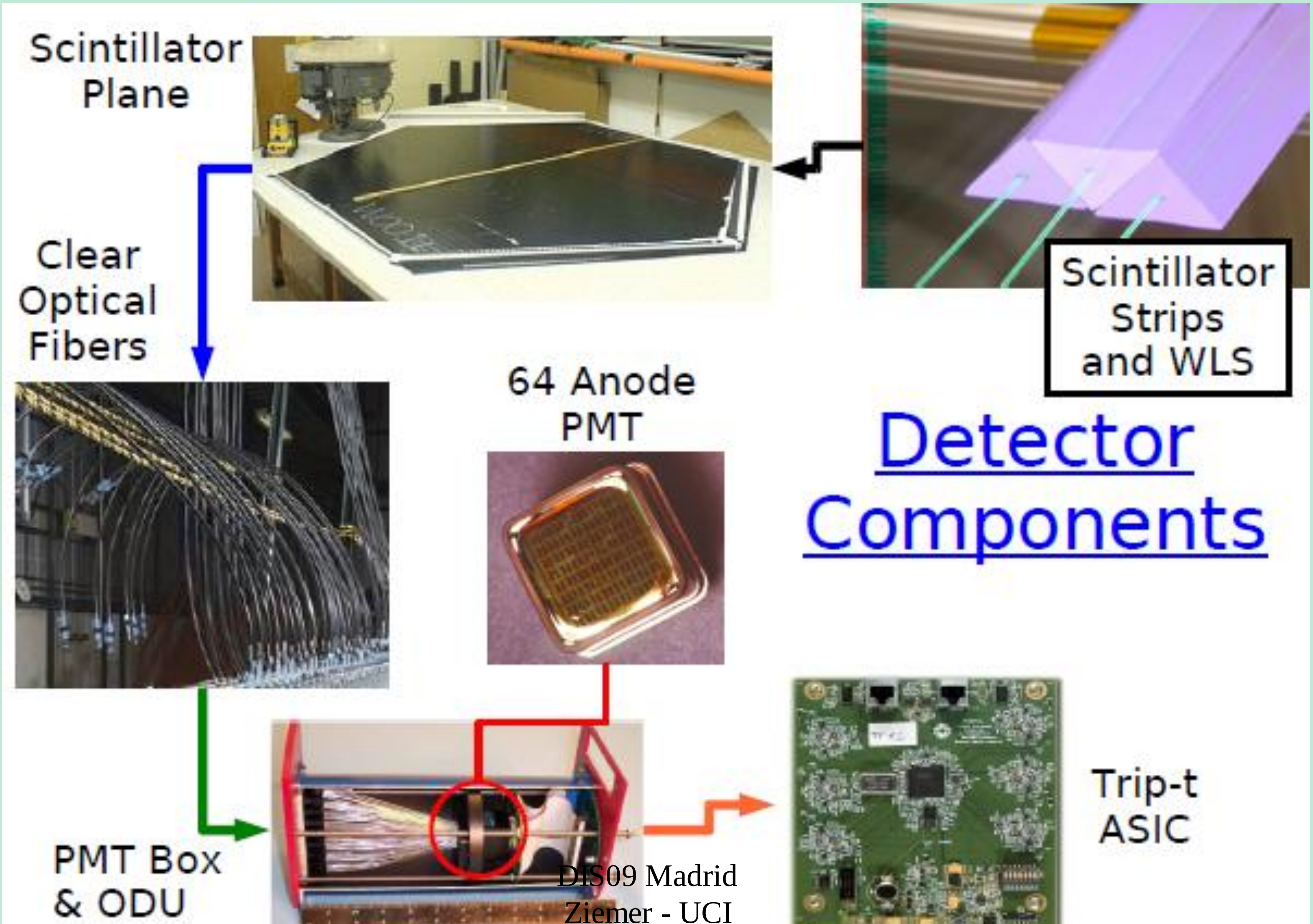
CC/NC pion production is another important channel. This channel is a background to oscillation experiments.





Current uncertainty in the various CC/NC pion channels is around 10-50%*. Minerva will collect 1.7M CC pion events and a coherent sample of 80K/40K CC/NC. This data will be able to address the current CC coherent pion results and their discrepancy with current models.

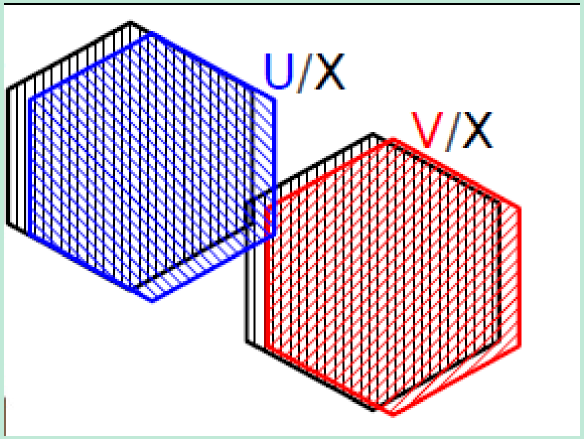
Detector Technology

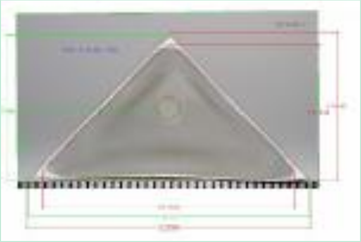


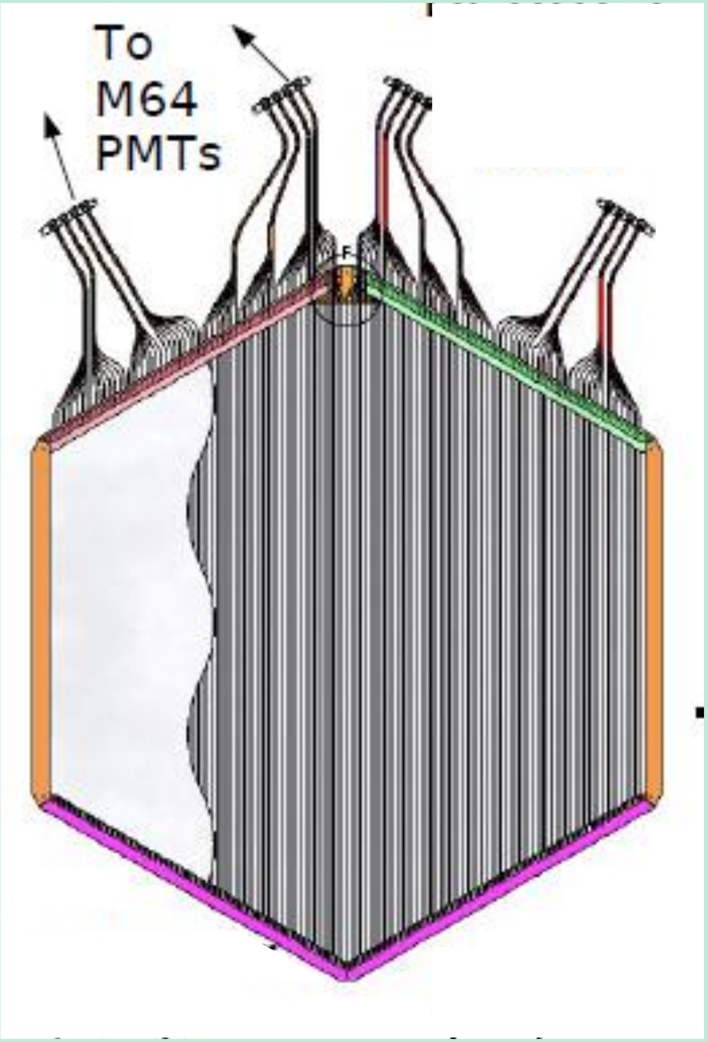
MINERνA Scintillator Planes

The basic element of Minerva is the scintillating plane. Different regions of the detector have absorbers or targets flanking these planes.

Successive planes are rotated by ±60° to aid in 3D reconstruction.







MINERνA Motivation

APS Multi-Divisional Study of the Physics of Neutrinos (2003)

“ . . 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.”

Particle Physics Project Prioritization Panel Report (2008)

“The panel recommends world-class neutrino program as a core component of the US program . . . ”

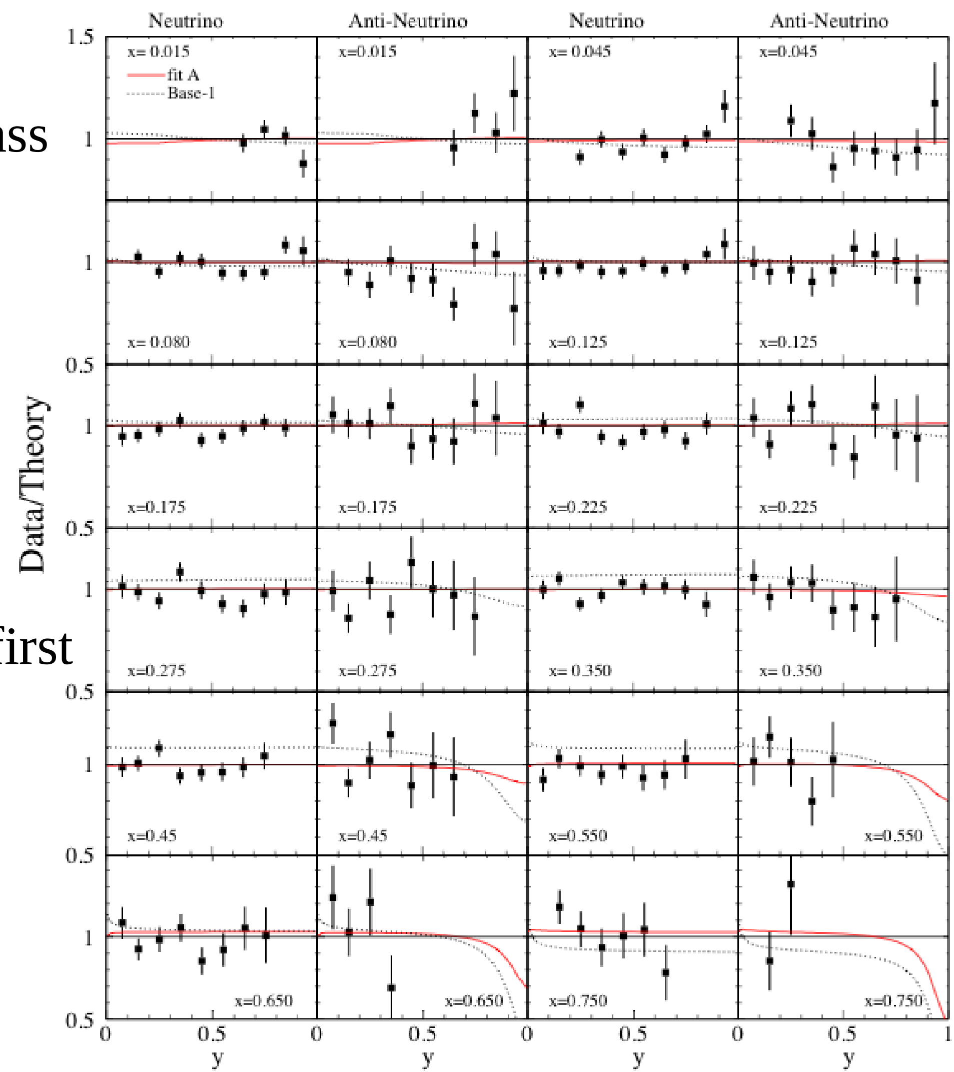
Sample NuTeV Data vs Theory

Use ACOT - heavy quark mass Effects - in NLO QCD.

Q > 2.0 GeV, W > 3.5 GeV

Use same reference fit as in first publication

Double-differential cross sections



DIS09 Madrid (E=245 GeV)

Ziemer - UCI

Morfin, et.al hep-ph/0710.4897