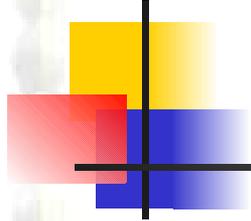


Minerva (E-938)

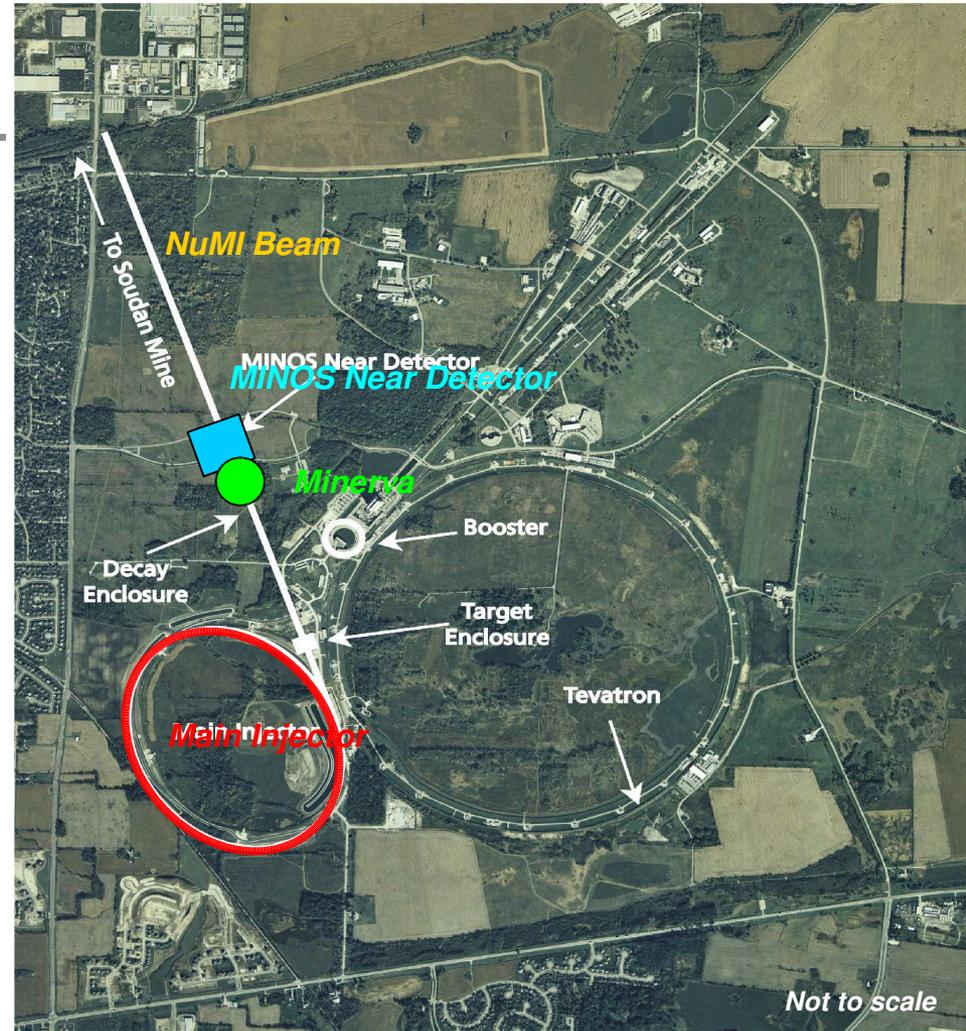


Gabriel Niculescu
James Madison University
PANIC05 Neutrino Satellite
Meeting

Goals

Current Status

Outlook



FERMILAB #98-765D

What is Minerva?



- + MINERvA is a compact, fully active neutrino detector designed to study neutrino-nucleus interactions in detail at high statistics***
- + Uniquely positioned (NuMI near Hall) to provide critical input for the world neutrino oscillation program (“neutrino engineering”...)***
- + Proton structure & nuclear effects in axial current (“JLab mid-west”)***
- + Fruitful HEP-NP collaboration***

Who is *(in)* Minerva?



D. Drakoulakos, P. Stamoulis, G. Tzanakos, M. Zois
University of Athens, Greece

D. Casper#, J. Dunmore, C. Regis, B. Ziemer
University of California, Irvine

E. Paschos
University of Dortmund

D. Boehnlein, D. A. Harris#, N. Grossman, J. Kilmer, M. Kostin, J.G. Morfin*, A. Pla-Dalmau, P. Rubinov, P. Shanahan, P. Spentzouris
Fermi National Accelerator Laboratory

I. Albayrak, M.E. Christy, C.E. Keppel, V. Tvaskis
Hampton University

R. Burnstein, O. Kamaev, N. Solomey
Illinois Institute of Technology

S. Kulagin
Institute for Nuclear Research, Russia

I. Niculescu. G. Niculescu
James Madison University

G. Blazey, M.A.C. Cummings, V. Rykalin
Northern Illinois University

W.K. Brooks, A. Bruell, R. Ent, D. Gaskell, W. Melnitchouk, S. Wood
Jefferson Lab

* Co-Spokespersons

MINERvA Executive Committee

L. Aliaga, J.L. Bazo, A. Gago,
Pontificia Universidad Catolica del Peru

S. Boyd, S. Dytman, M.-S. Kim, D. Naples, V. Paolone
University of Pittsburgh

A. Bodek, R. Bradford, H. Budd, J. Chvojka, P. de Barbaro, R. Flight, S. Manly, K. McFarland*, J. Park, W. Sakumoto, J. Steinman
University of Rochester

R. Gilman, C. Glasshausser, X. Jiang, G. Kumbartzki, R. Ransome#, E. Schulte
Rutgers University

A. Chakravorty
Saint Xavier University

D. Cherdack, H. Gallagher, T. Kafka, W.A. Mann, W. Oliver
Tufts University

R. Ochoa, O. Pereyra, J. Solano
Universidad Nacional de Ingenieria. Lima, Peru

J.K. Nelson#, F.X. Yumiceva
The College of William and Mary

A collaboration of Particle, Nuclear, and Theoretical physicists

Why Minerva? (I)



- + Inherent interest in the phenomena of low-energy neutrino-nucleus scattering:***
 - + Axial vector FF***
 - + Coherent π production***
 - + Resonance & transition (2DIS) data***
 - + Duality in neutrino scattering***
 - + Strange particles***

Why Minerva? (II)

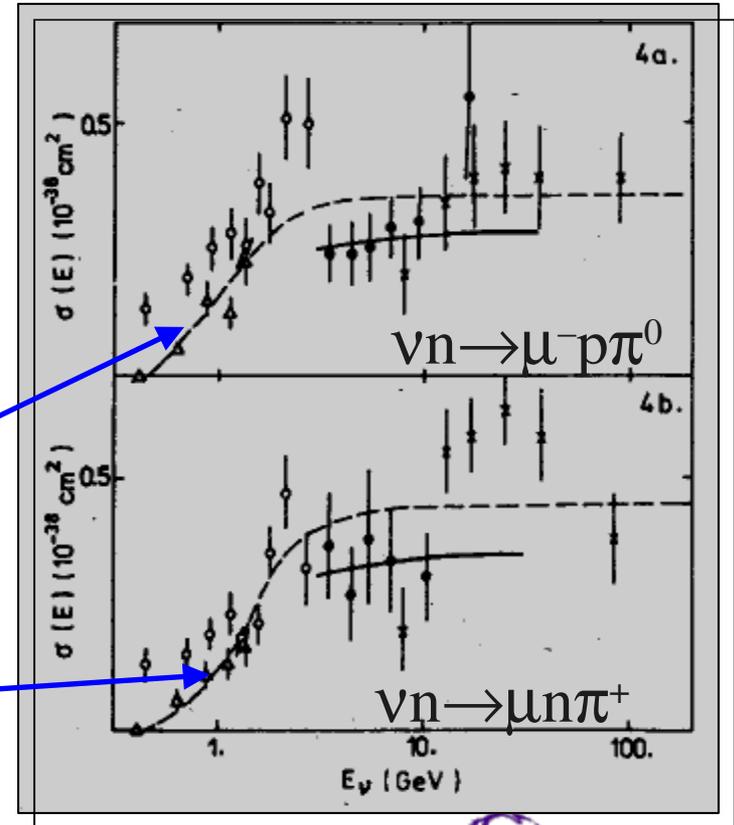
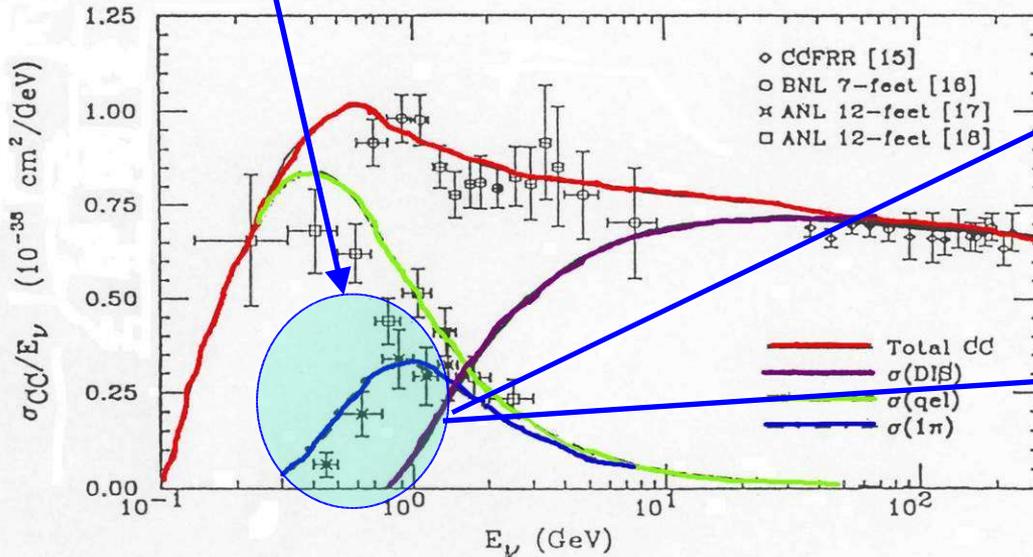


- ✦ **“BASF effect”**: Provide knowledge that will help improve/enhance other neutrino studies (read “oscillations”)
 - ✦ **mass splitting** (Δm^2) measurements in **disappearance (Minos)**
 - ✦ $E_{vis} \neq E_\nu \rightarrow$ ultimate precision in (Δm^2)
 - ✦ Measurement of ν -initiated nuclear effects
 - ✦ **electron appearance** ($\nu_\mu \rightarrow e$) (**Nova**)
 - ✦ Better background estimates
 - ✦ Intra-nuclear charge exchange
 - ✦ A-dependence

Why do we need to know more about neutrino cross-sections?



- ✦ In the few GeV neutrino energy (relevant for osc. expt's)...
 - ✦ Errors on σ_{total} are large
 - ✦ A-dependence data - scarce
 - ✦ Understanding of backgrounds needs differential cross-sections on target
 - ✦ Theoretically difficult region: transition from elastic to DIS



Goals for Minerva?



- + ***Axial form factor of the nucleon***
- + ***Resonance production in both NC & CC neutrino interactions***
- + ***Coherent pion production***
- + ***Nuclear effects***
- + ***Strange Particle Production***
- + ***Parton distribution functions (PDFs)***
- + ***Generalized parton distributions (GPDs)***

Requirements for Minerva

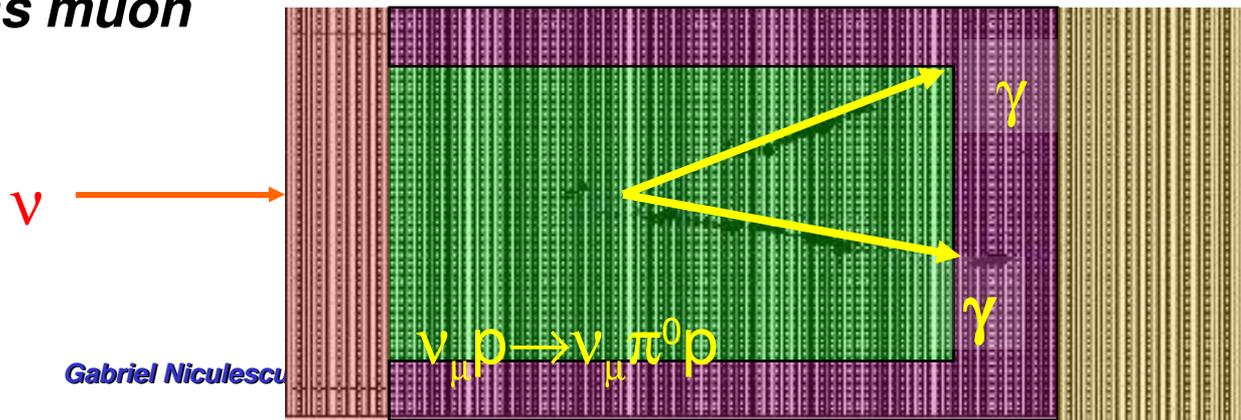


- + Intense neutrino beam (NuMI)***
- + Improved systematics in Neutrino Flux (MIPP)***
- + Variety of targets (A-dependence)***
- + Detector with:***
 - + Good tracking resolution***
 - + Good momentum resolution***
 - + Timing (strange particles)***
 - + Particle ID (exclusive final states)***
- + ...all in an affordable package...***

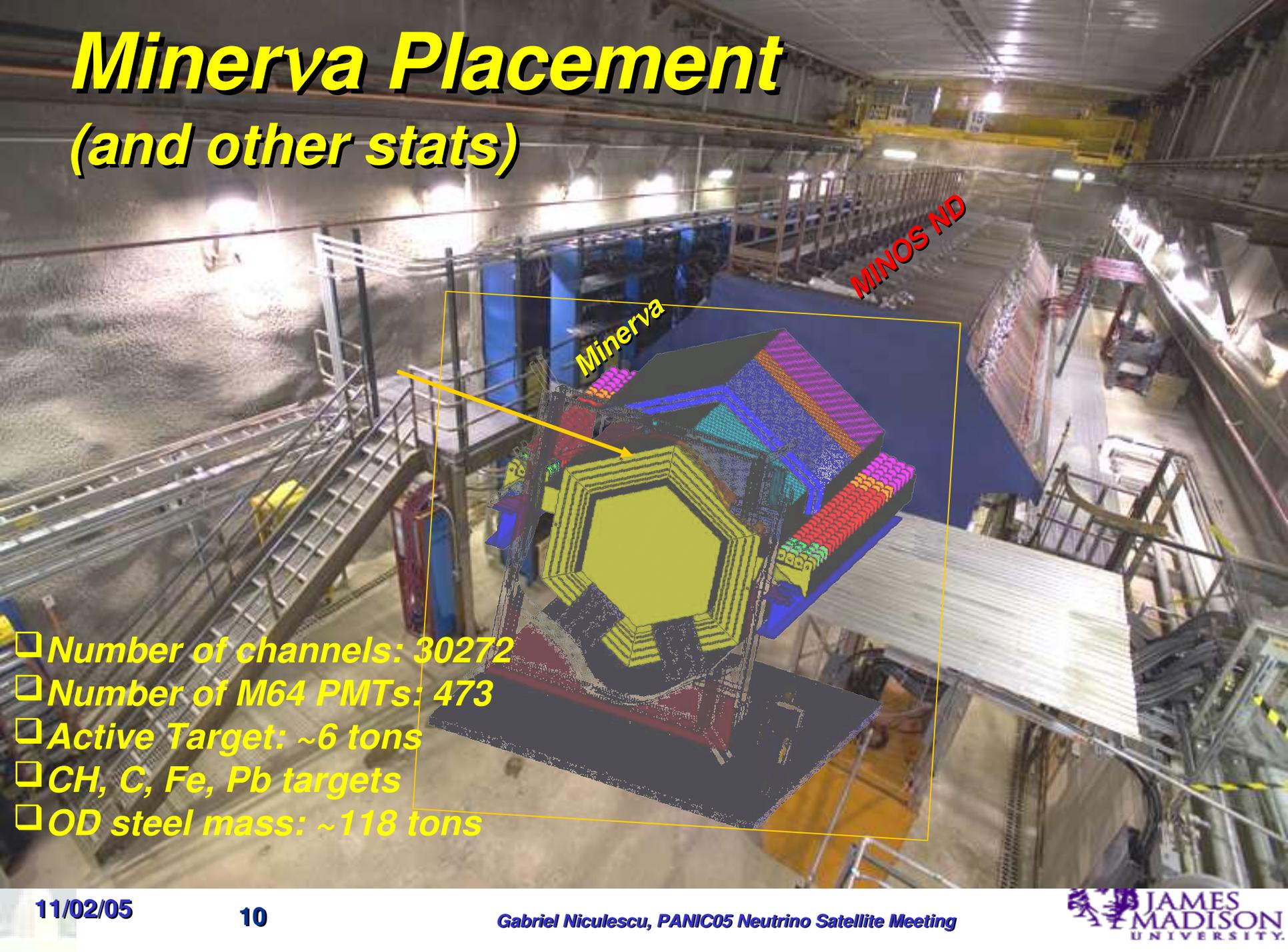
Minerva Design



- ✦ **low-risk detector with simple, well-understood technology**
- ✦ **Segmented solid scintillators – active core**
 - ✦ **Tracking (including low momentum)**
 - ✦ **PID**
 - ✦ **3 ns (RMS) per hit timing (track direction, stopped K^\pm)**
- ✦ **Core surrounded by electromagnetic (ECAL) and hadronic calorimeters (HCAL)**
 - ✦ **Photon (π^0) & hadron energy measurement**
- ✦ **MINOS Near Detector as muon spectrometer**

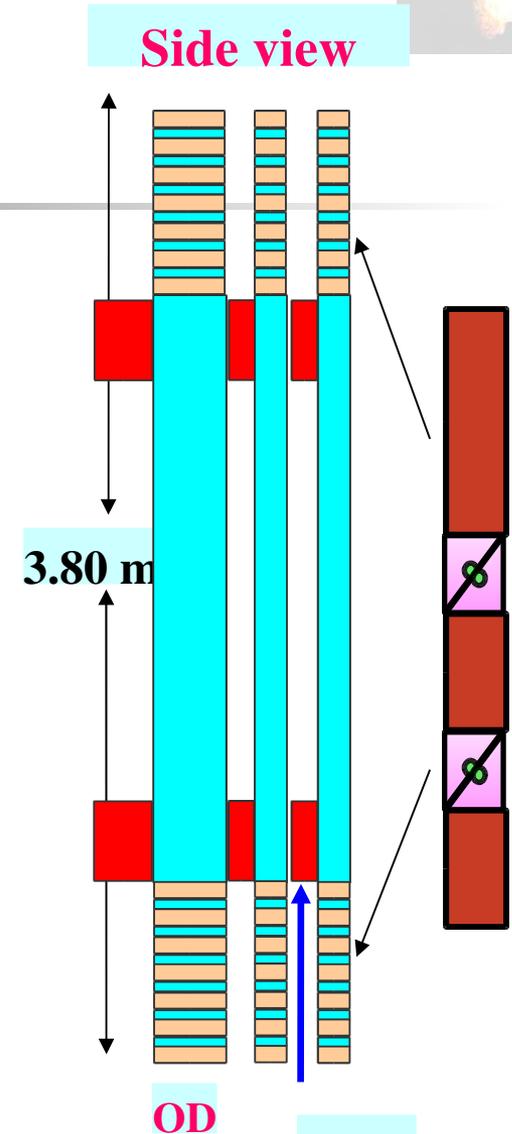
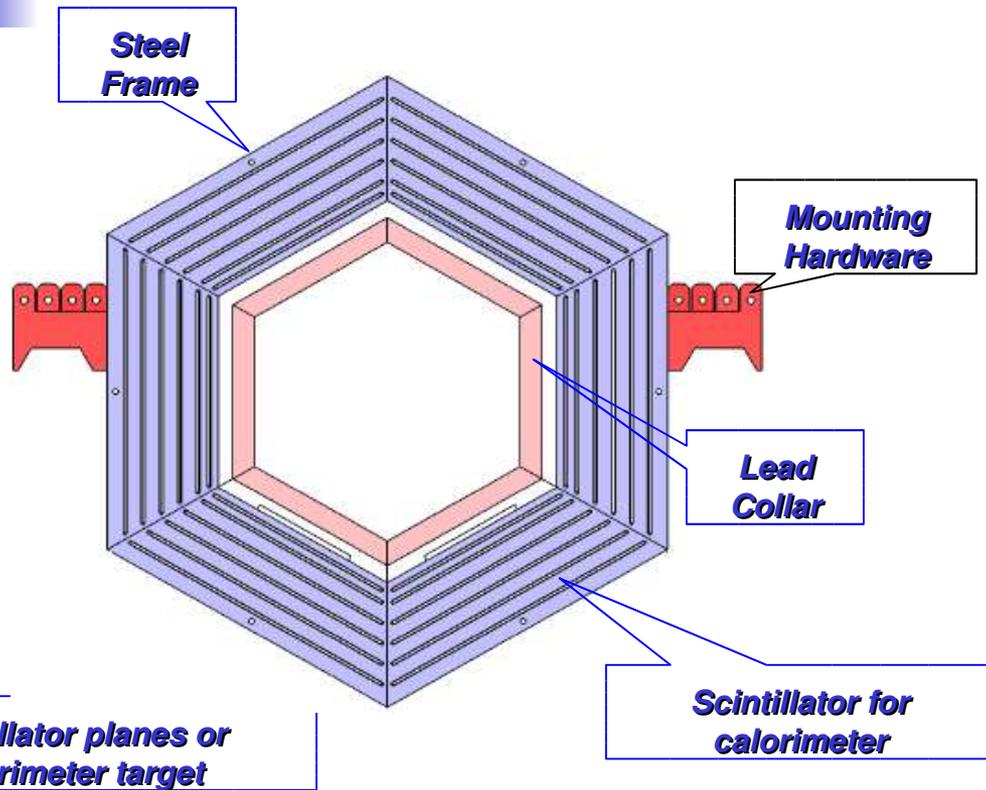


Minerva Placement (and other stats)



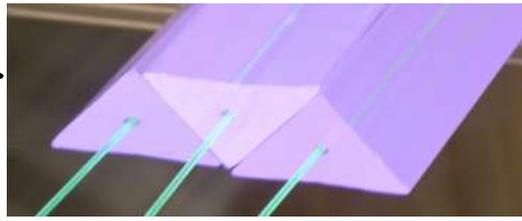
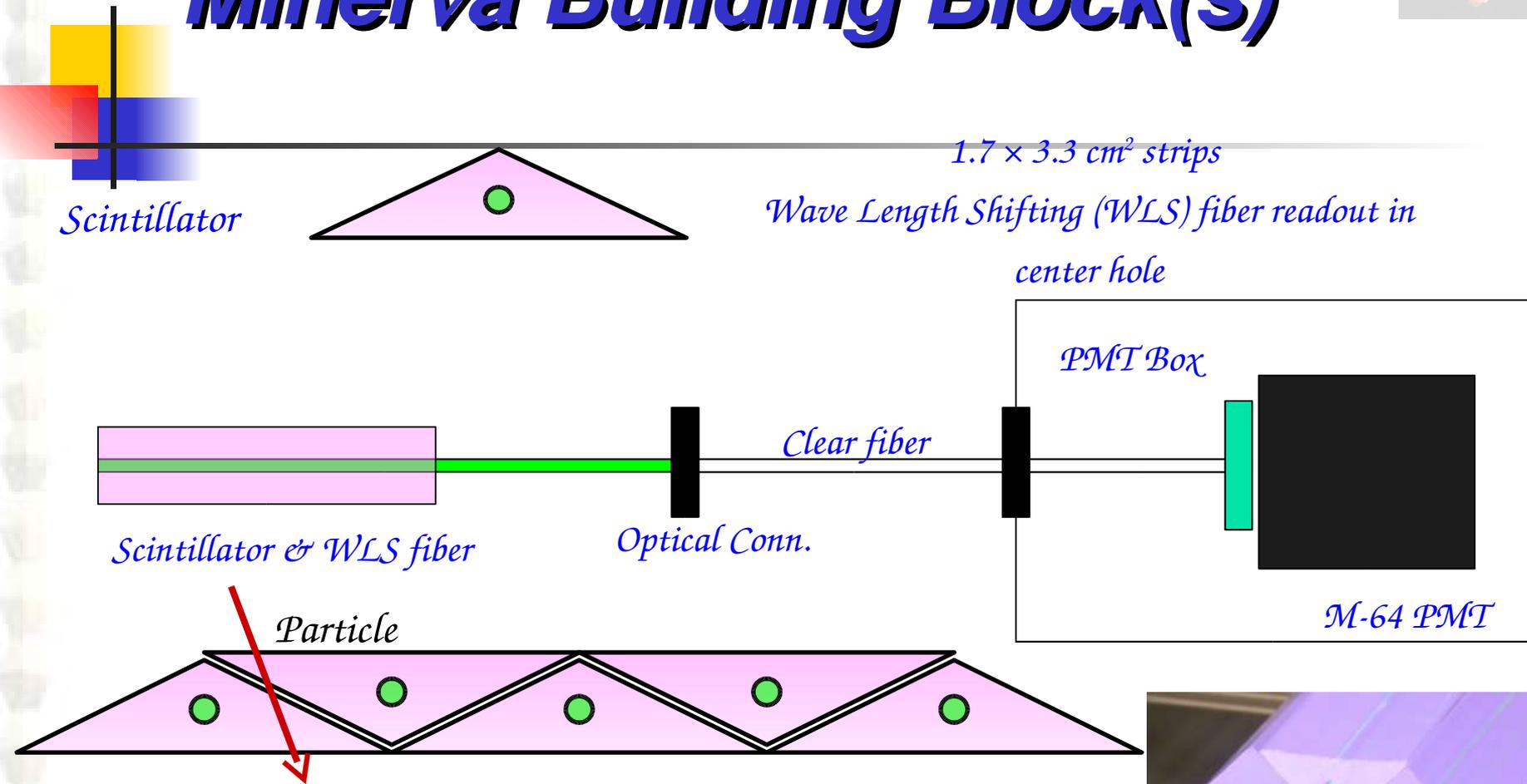
- ❑ Number of channels: 30272
- ❑ Number of M64 PMTs: 473
- ❑ Active Target: ~6 tons
- ❑ CH, C, Fe, Pb targets
- ❑ OD steel mass: ~118 tons

Minerva Detector Structure





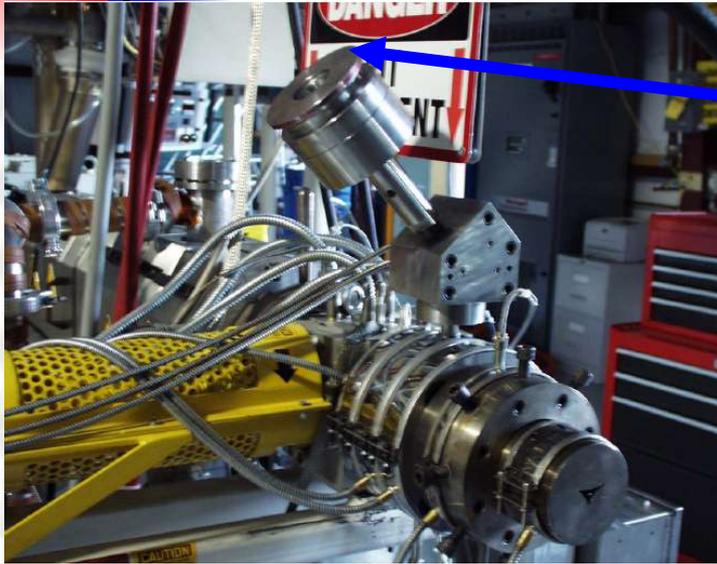
Minerva Building Block(s)



- For the Inner Detector, scintillator is assembled into 128 strip scintillator planes
- Position determined by charge sharing

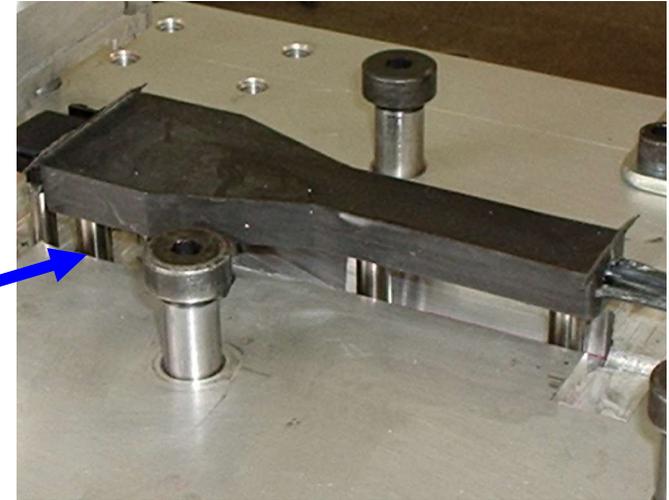
Minerva R&D Progress:

Scintillator, Fibers, Connectors

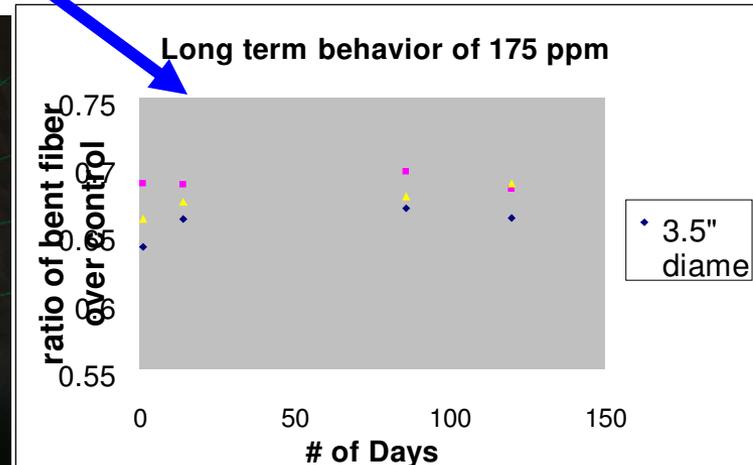


Co-extruder
at NICADD-
FNAL:

Optical Cable
Mold Production
Rochester

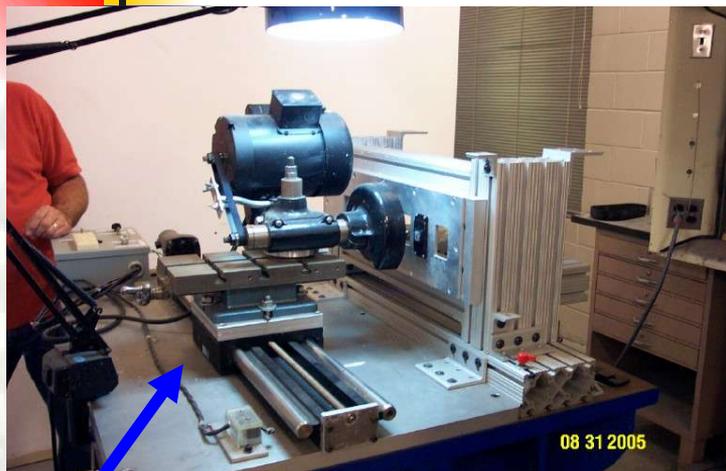


Fiber Bend Tests
Rochester

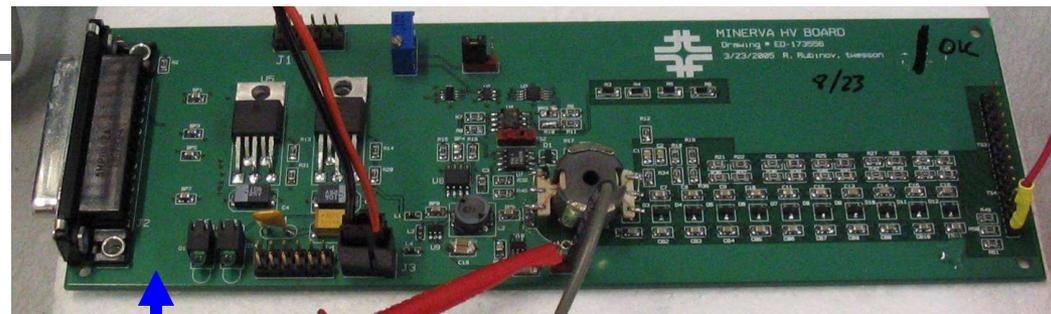


Minerva R&D Progress:

PMTs, Boxes, Electronics

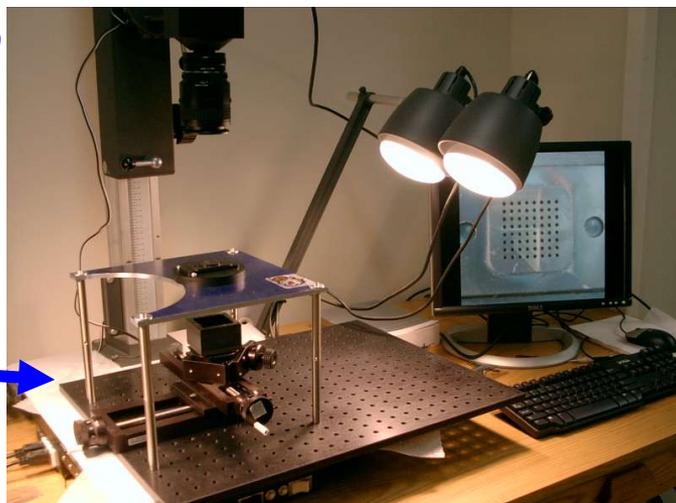


08 31 2005



Cockroft Walton Board: Pittsburgh

**Alignment Piece
Factory: Tufts**



**PMT Alignment
Station: JMU**



PMT Box Prototype at Tufts

11/02/05

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Minerva Event Rates



Fiducial Volume:

3 tons CH, \approx 0.6 t C, \approx 1 t Fe and \approx 1 t Pb

Expected CC event samples:

8.6 M n events in CH

1.4 M n events in C

2.9 M n events in Fe

2.9 M n events in Pb

**Assumes 16.0×10^{20} in
LE, ME, and HE NuMI
beam configurations
over 4 years**

Main CC Physics Topics (Statistics in CH)

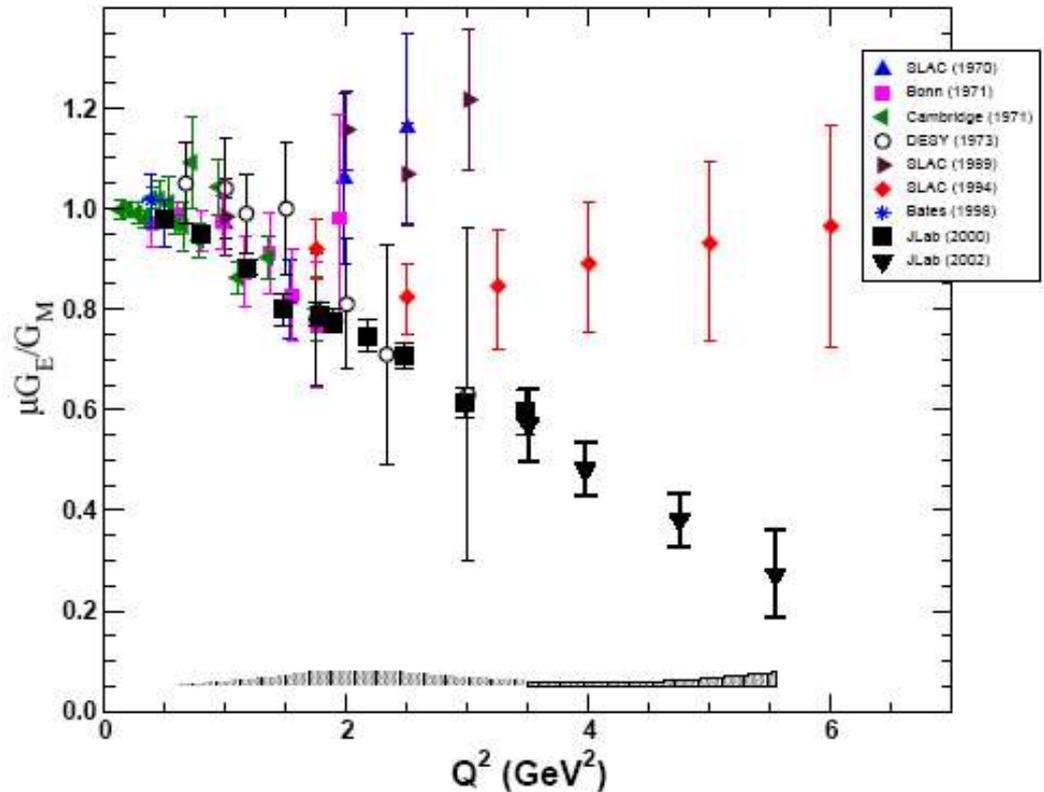
Quasi-elastic	0.8 M events
Resonance Production	1.6 M total
Transition: Resonance to DIS	2 M events
DIS, Structure Funcs. and high-x PDFs	4.1 M DIS events
Coherent Pion Production	85 K CC / 37 K NC
Strange and Charm Particle Production reconstructed	> 230 K fully



Minerva & Axial Form Factors

- + Vector form factors measured with electro
- + G_E/G_M ratio varies with Q^2 - a surprise from JLab
- + Axial form factor poorly known
- + Medium effects for F_A ?
 - + check with C, Fe, & Pb targets

Proton G_E/G_M

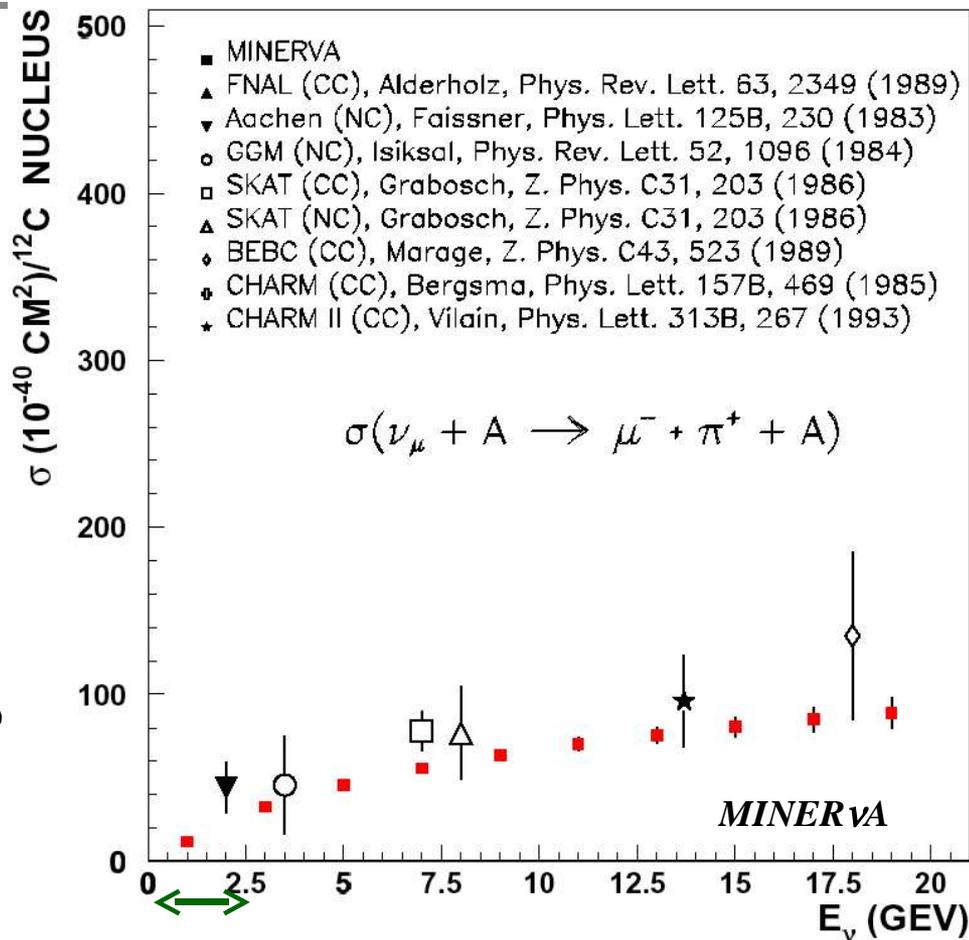


Minerva & Coherent Pion Production



- + **small energy transfer to the nucleus, forward going π .**
- + **data cannot discriminate between models.**
- + **MINERvA: 30-40% det. Eff. (5-25k events)**
- + **Can also study A-dependence**

CC Coherent Pion Production Cross Section

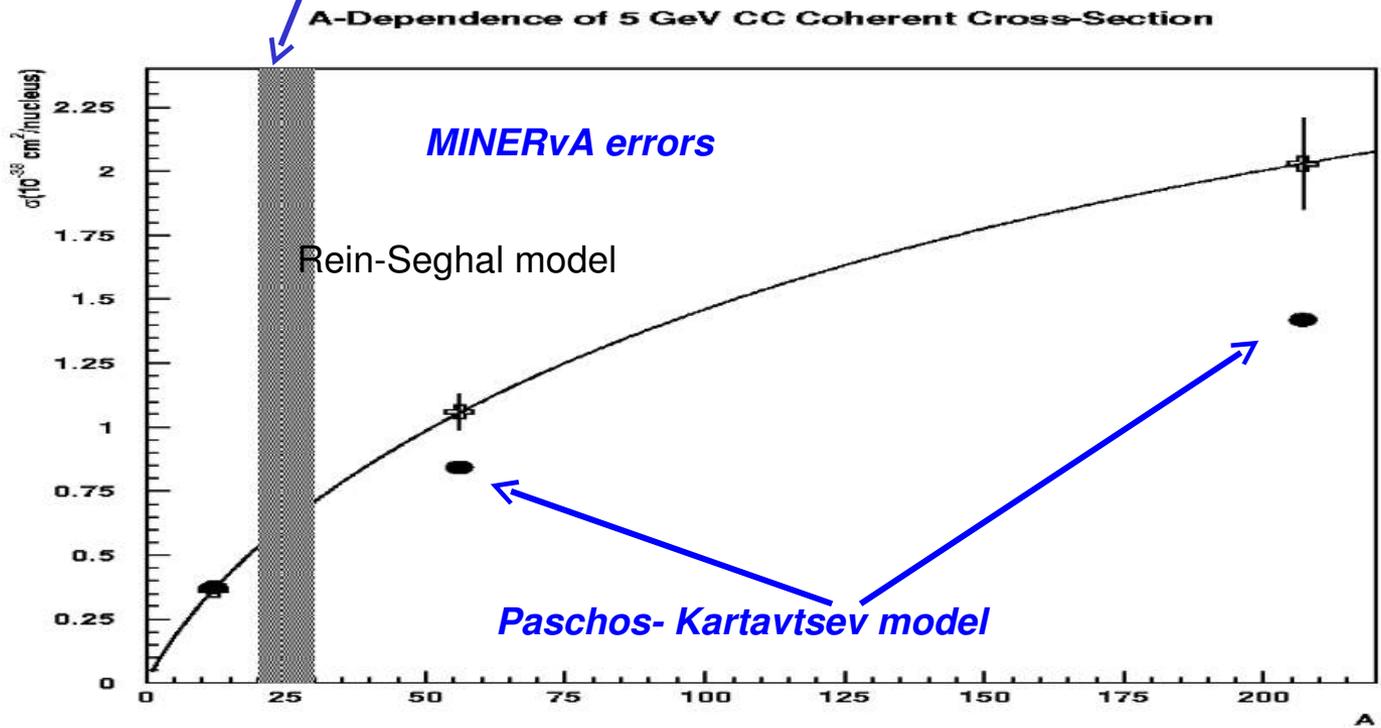


MiniBooNe & K2K



Minerva & Coherent Pion Production (II)

A-range of current measurements before K2K !



... Can also study A-dependence

A

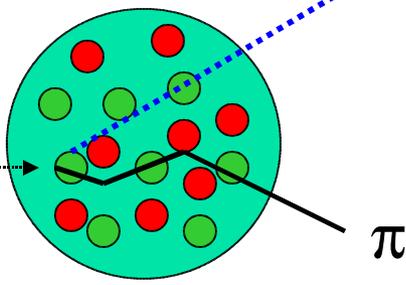




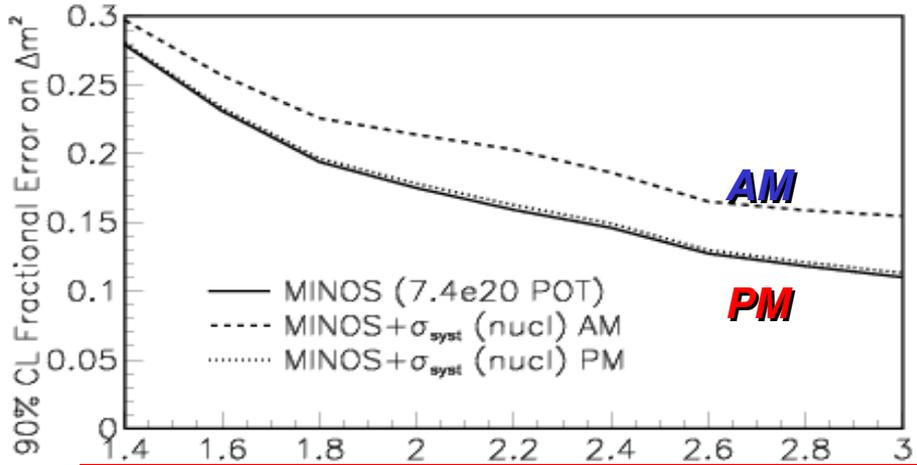
Minerva's impact...

MINOS

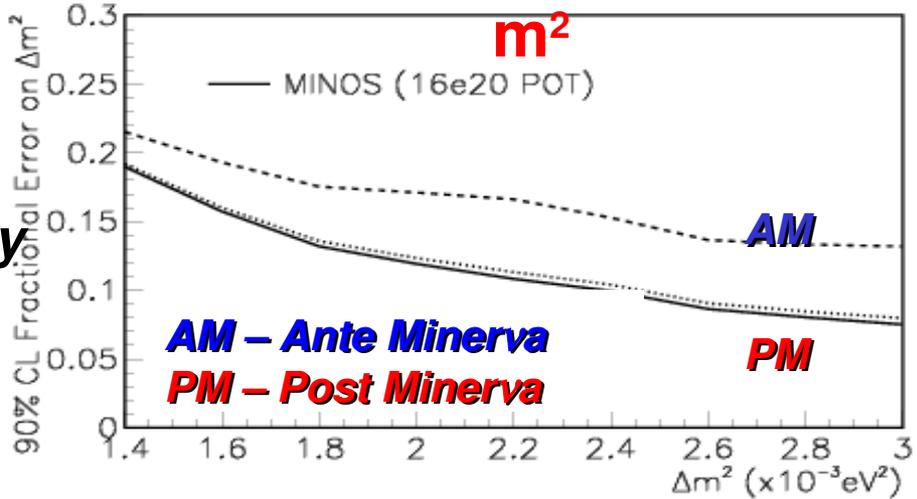
Visible Energy in Calorimeter is NOT ν energy!



- π absorption, rescattering
- final state rest mass
- nuclear Effects studied only w/ Charged Lepton Scattering, from Deuterium to Lead, at High energies



(/) versus , ≡

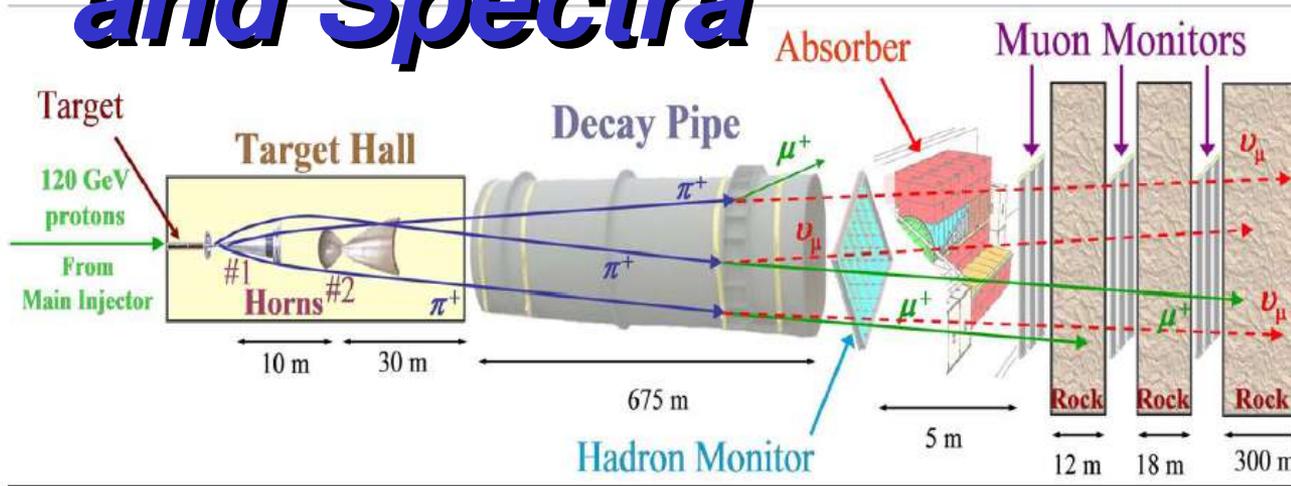




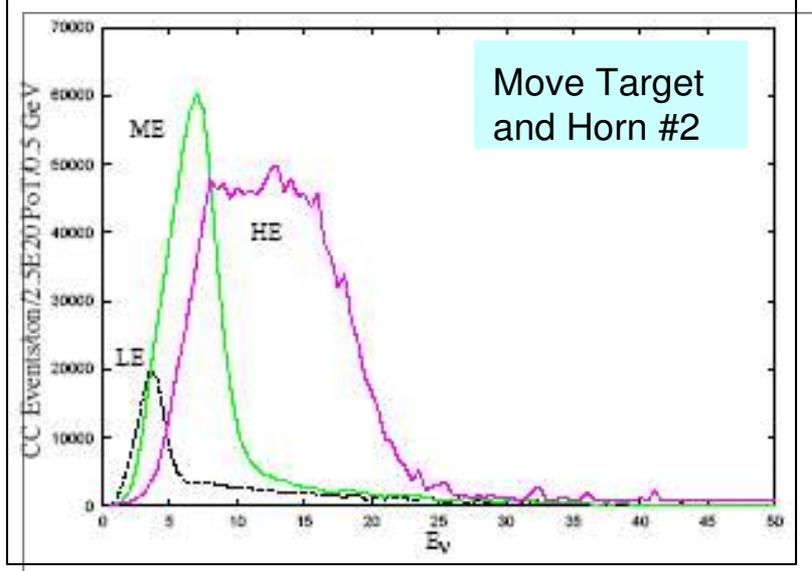
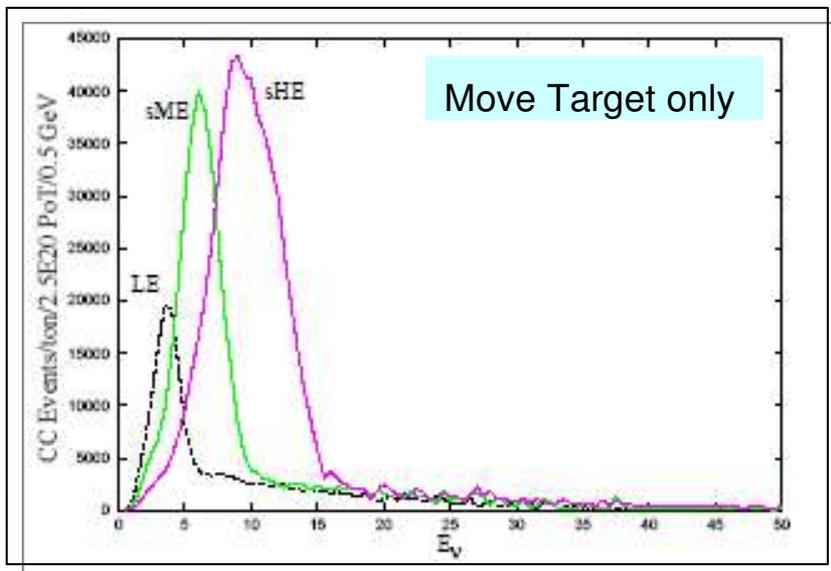
OUTLOOK

- ✦ ***Minerva is poised to test ν -A models over a wide range of energies***
 - ✦ ***NuMI beamline:***
 - ✦ ***tunable 1 – 20 GeV***
 - ✦ ***precisely known neutrino flux***
- ✦ ***The MINER ν A detector – optimized for both inclusive and exclusive reactions***
- ✦ ***... is being built as we speak!***
 - ✦ ***first signal - summer '08***
 - ✦ ***begin operations – end 'of 08***

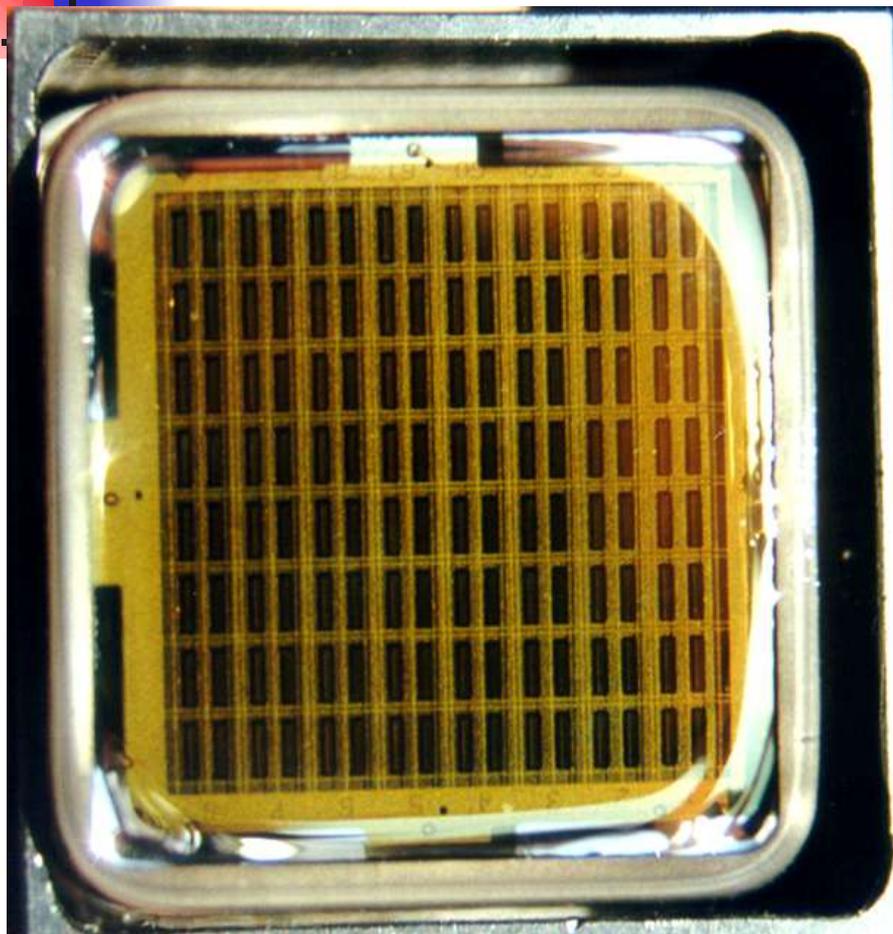
Neutrino Horns and Spectra



- 120 GeV primary Main Injector beam
- 675 meter decay pipe for p decay
- Target readily movable in beam direction
- 2-horn beam adjusts for variable energy range



Hamamatsu M64

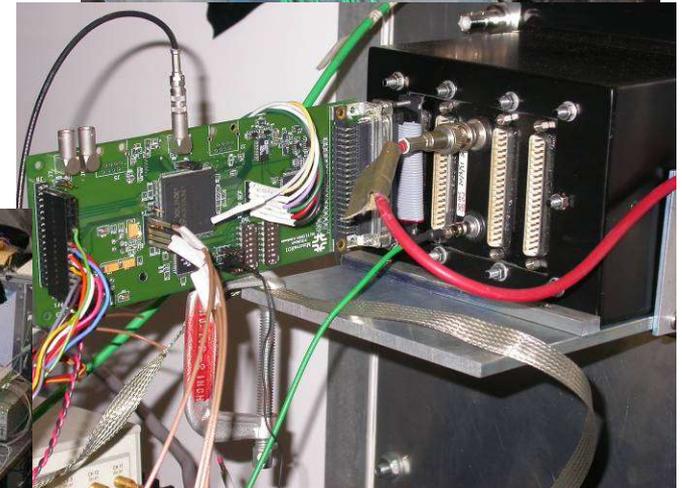
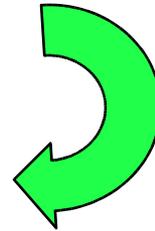
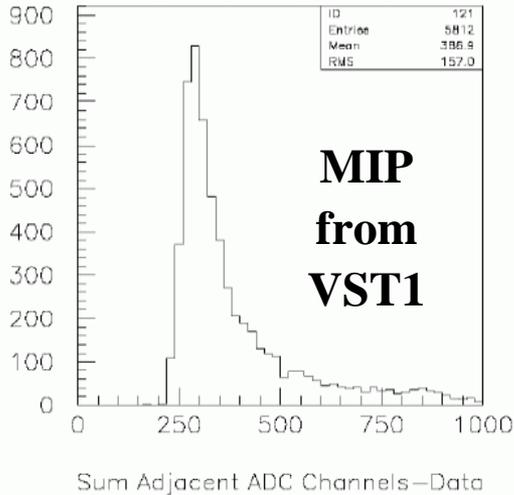
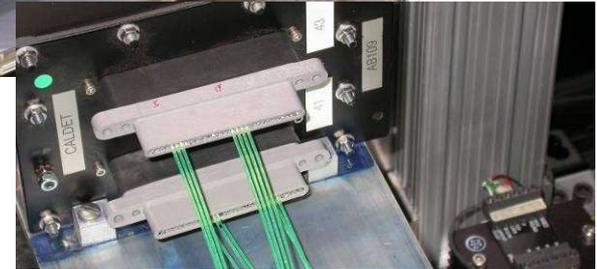
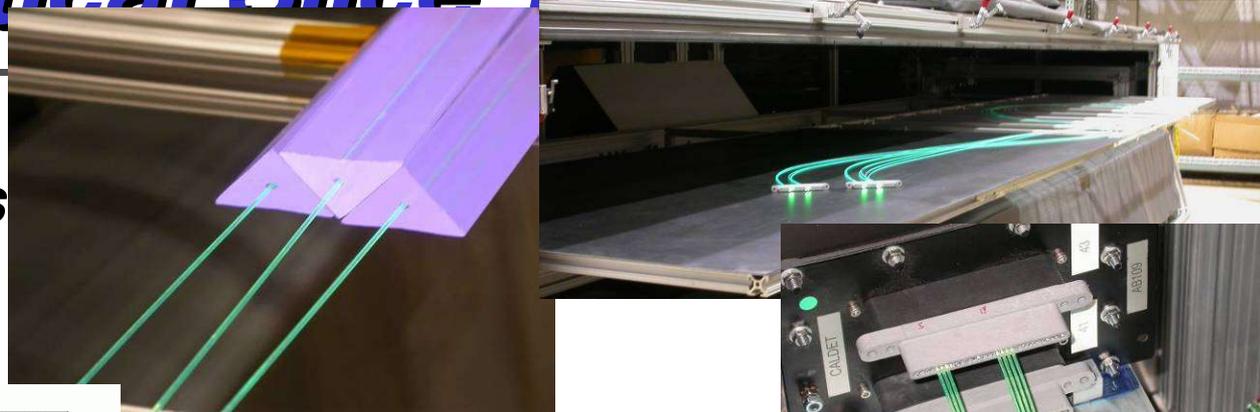


- + Weight: **28 gr**
- + 64 pixels, 8 X 8 array
- + pixel: 2 x 2 mm²
- + Photocathode: **bialkali**
- + Spectral response:
300 - 650 nm
- + QE (520 nm): **>12.5%**
- + Cross-talk: ~ **10%**
- + Anode Pulse Rise Time:
~0.83 nsec
- + TTS: **0.3 nsec**
- + Uniformity: **1:3**



Vertical Slice Test (VST1)

**VST1 array,
electronics
and DAQ**



**8 PE/MIP per
doublet**

11/02/05

23



Oscillation Measurements and Neutrino Interaction Uncertainties

MINOS

✦ Current Generation's Primary Goal:

- ✦ Precise Δm^2 measurement from ν_μ disappearance measurements vs. neutrino energy
- ✦ Biggest systematic concern: how do you know you're really measuring the energy correctly?

✦ Next Generation's Primary Goal:

- ✦ Search for $\nu_\mu \rightarrow \nu_e$ transitions at one neutrino energy
- ✦ Biggest systematic concern:

NOvA, T2K

- ✦ Predicting Background accurately
- ✦ At first, claiming discovery based on an excess above background!
- ✦ Later, precision measurements with neutrinos and anti-neutrinos

✦ Next Generation's "guaranteed" measurement

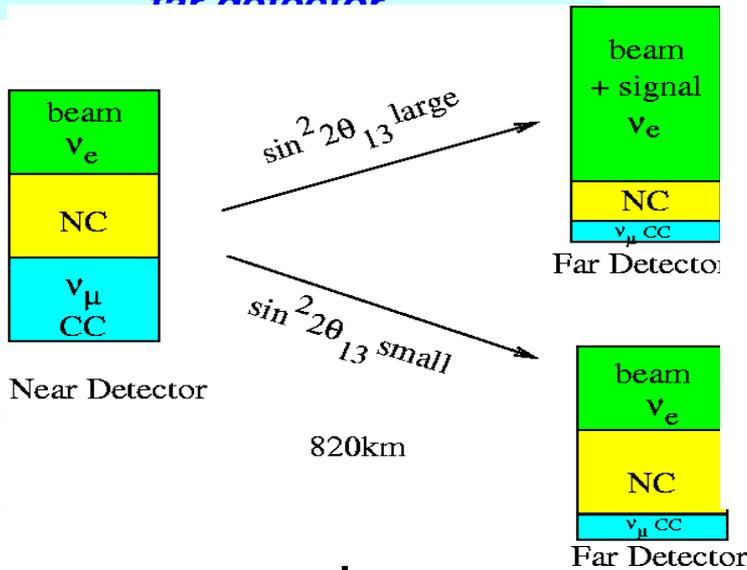
- ✦ More precise Δm^2 measurement, if you can understand the backgrounds in narrow band beam



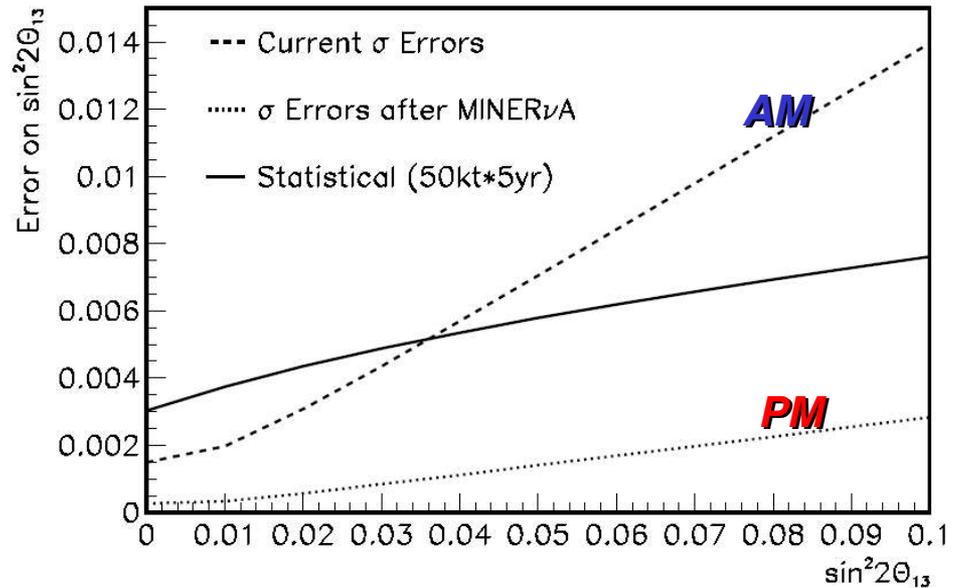
Minerva's impact...

Nova

- NOvA's near detector will see different mix of events than the far detector



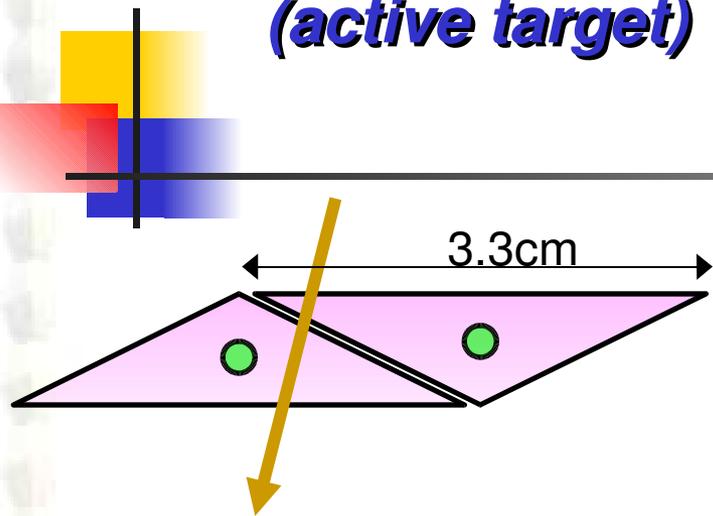
Total fractional error in the predictions as a function of reach (NOvA)



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

Minerva Resolution

(active target)



technique pioneered by D0 upgrade pre-shower detector

Triangular extrusion

$\sigma \sim 3$ mm (transverse direction)

Better than rectangular geometry

Need long. Segmentation for z-vertex determination

