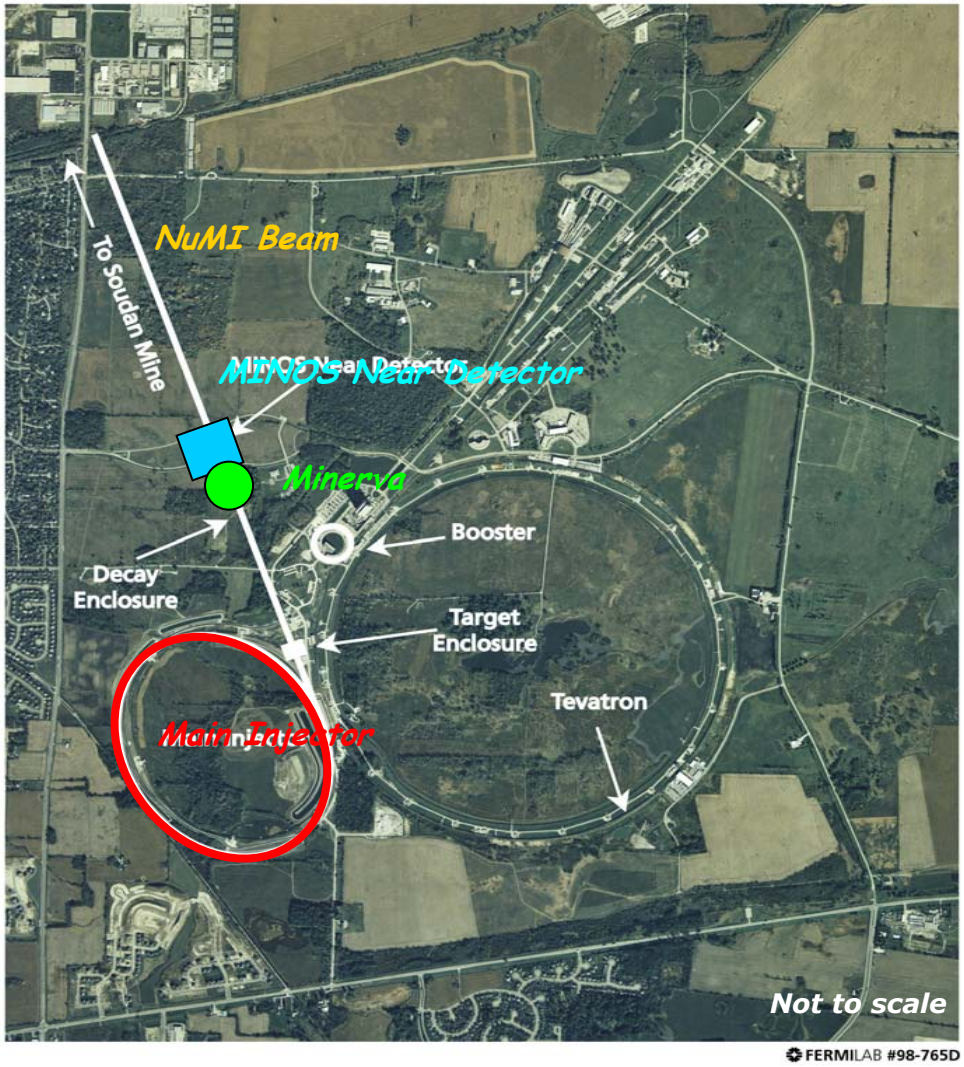
# Minerva (E-938)

**Gabriel Niculescu**
**James Madison University**
**PANIC05 Neutrino Satellite Meeting**




## Goals
## Current Status
## Outlook

# What is Minerνa?

- MINERνA 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) Minerνa?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The College of William and Mary


A collaboration of Particle, Nuclear, and Theoretical physicists

* Co-Spokespersons

\# MINERvA Executive Committee

# Why Minerνa? (I)

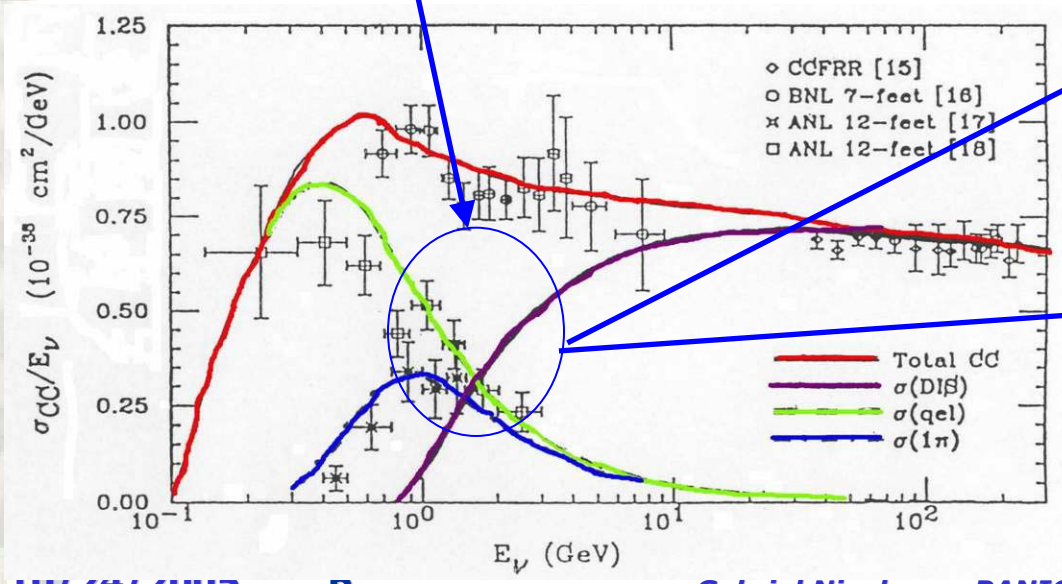
- Inherent interest in the phenomena of low-energy neutrino-nucleus scattering:
  - Axial vector FF
  - Coherent $\pi$ production
  - Resonance & transition (2DIS) data
  - Duality in neutrino scattering
  - Strange particles

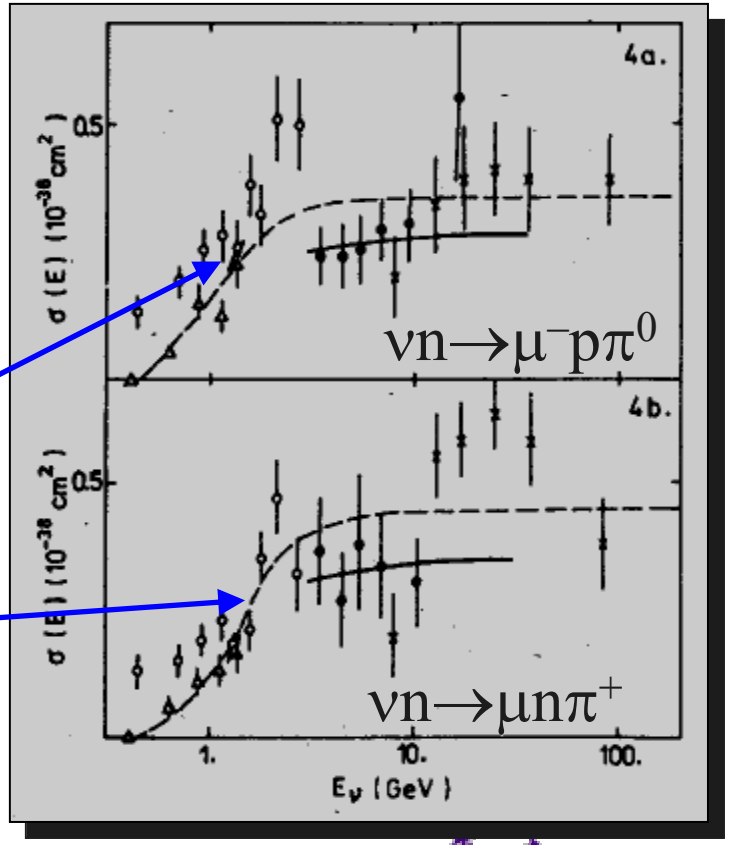
# Why Minerνa? (II)

- "BASF effect": Provide knowledge that will help improve/enhance other neutrino studies (read "oscillations")
  - *mass splitting* ($\Delta m^2$) *measurements in* $\nu_\mu$ *disappearance (Minos)*
    - $E_{vis} \neq E_\nu$ → *ultimate precision in* ($\Delta m^2$)
    - *Measurement of ν-initiated nuclear effects*
  - electron appearance ($\nu_\mu \rightarrow \nu_e$) (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 $\sigma_{total}$ 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 Minerνa?

- 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)

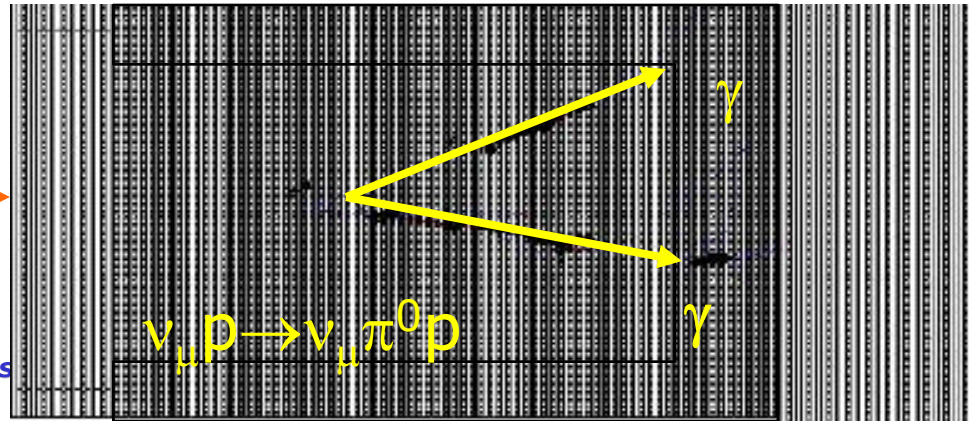
  - …all in an affordable package…

# Minerνa Design

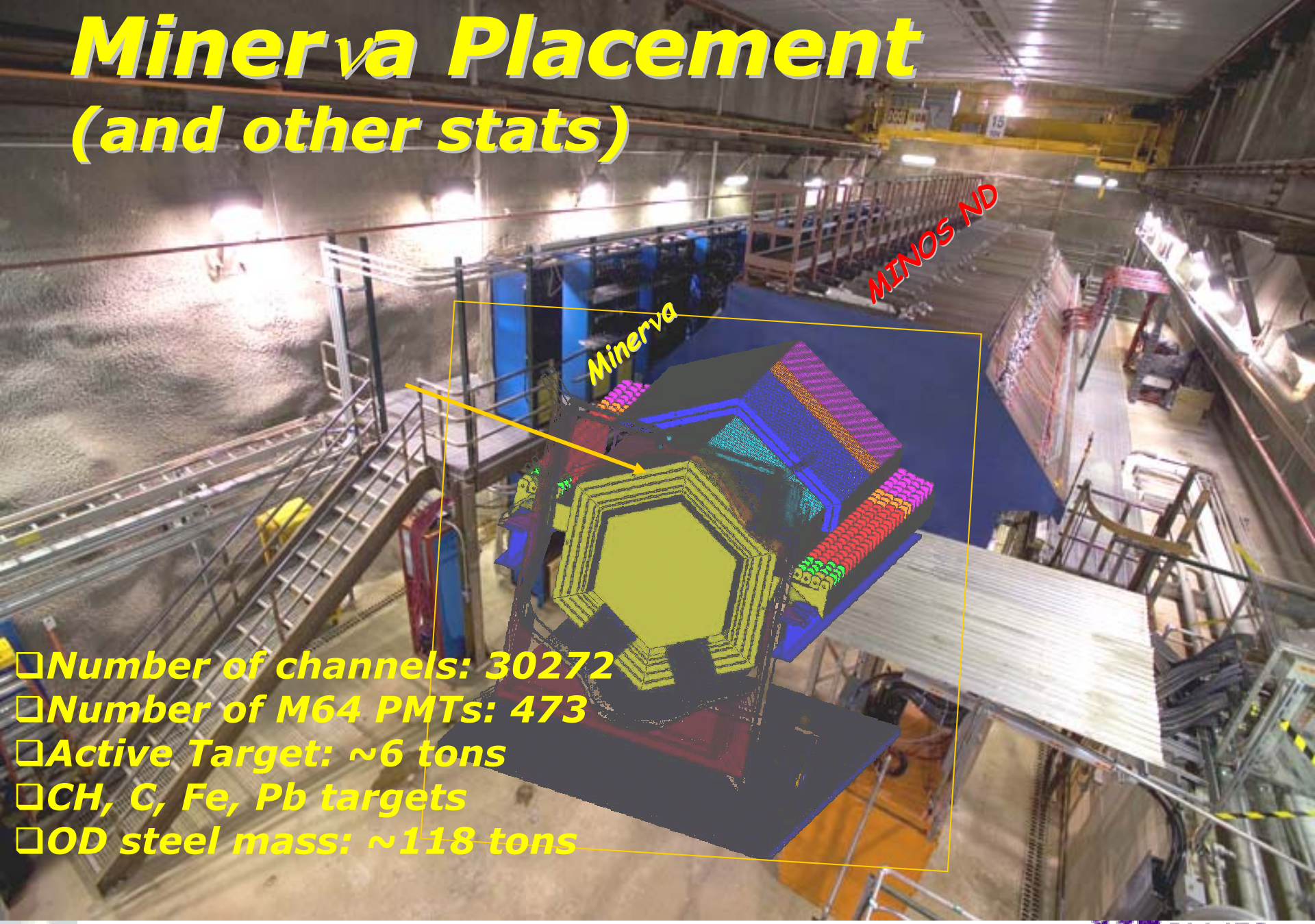
- *low-risk detector with simple, well-understood technology*
- *Segmented solid scintillators – active core*
  - *Tracking (including low momentum)*
  - *PID*
  - *3 ns (RMS) per hit timing (track direction, stopped K±)*
- *Core surrounded by electromagnetic (ECAL) and hadronic calorimeters (HCAL)*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

nuclear targets ECAL

active detector HCAL

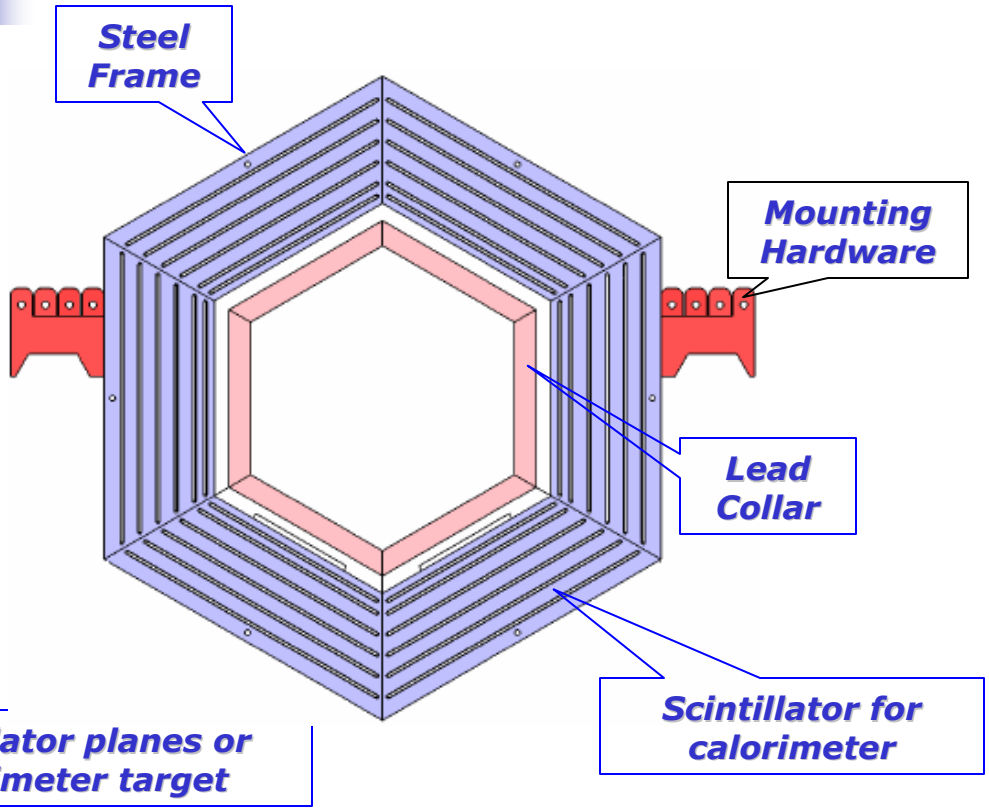


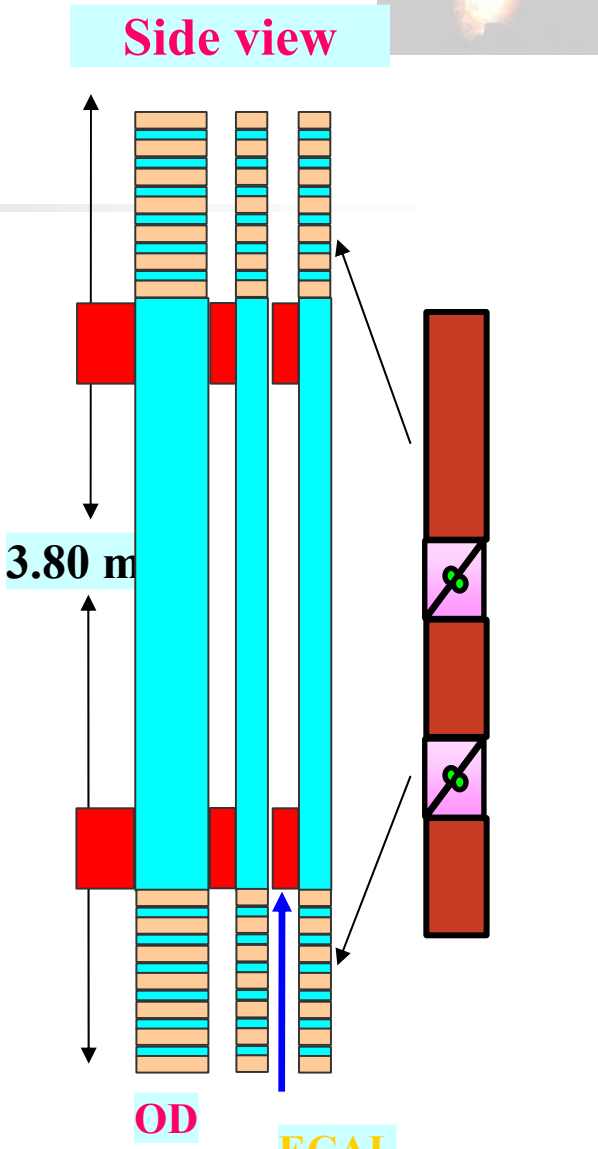
# Minerva Placement (and other stats)



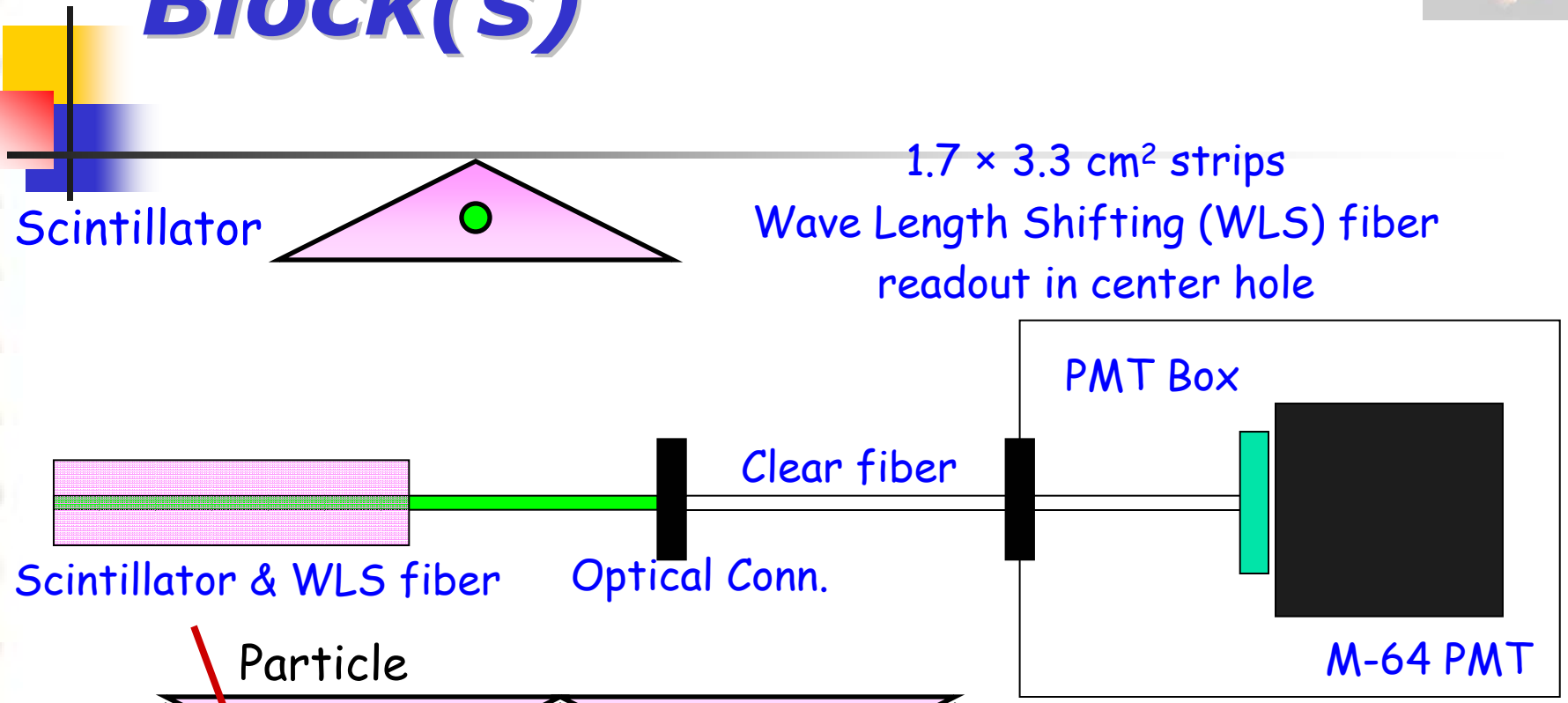

- Number of channels: 30272
- Number of M64 PMTs: 473
- Active Target: ~6 tons
- CH, C, Fe, Pb targets
- OD steel mass: ~118 tons

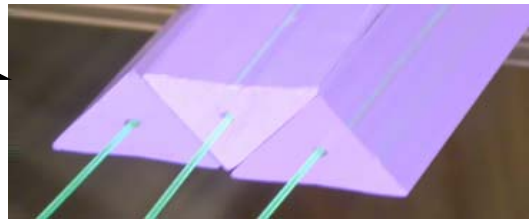
# Minerva Detector Structure



# Minerva Building Block(s)

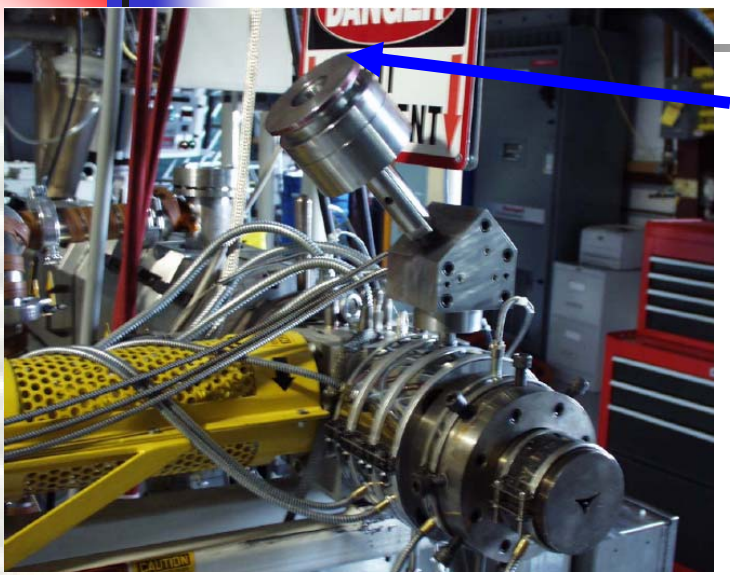


- For the Inner Detector, scintillator is assembled into 128 strip scintillator planes
- Position determined by charge sharing

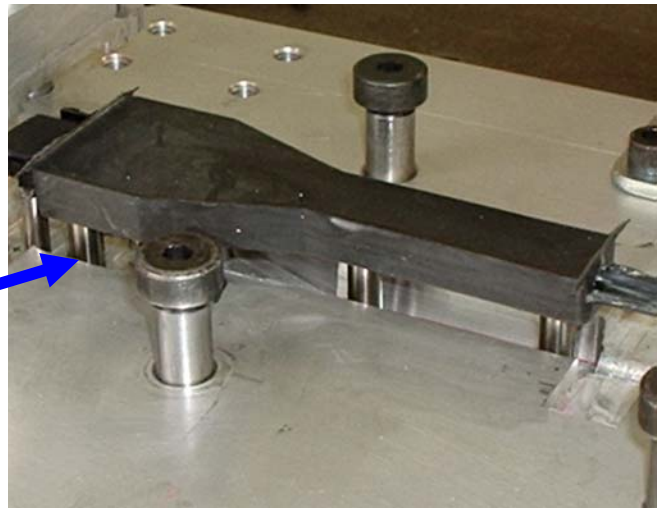
# Minerva R&D Progress:

## Scintillator, Fibers, Connectors

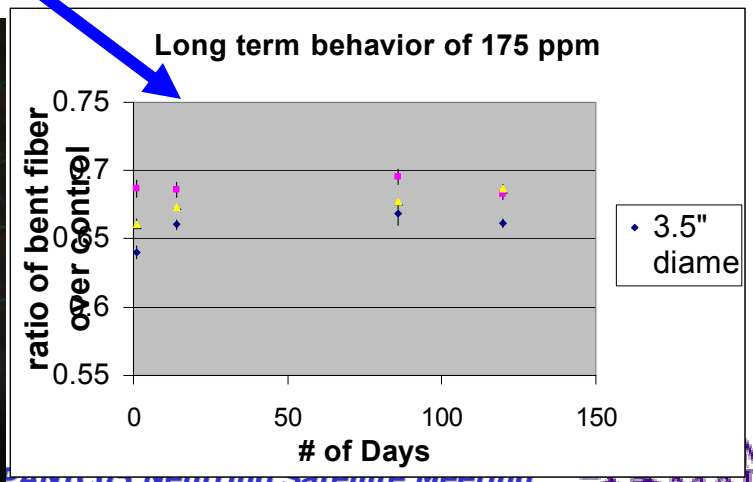


*Co-extruder at NICADD-FNAL:*

*Optical Cable Mold Production Rochester*

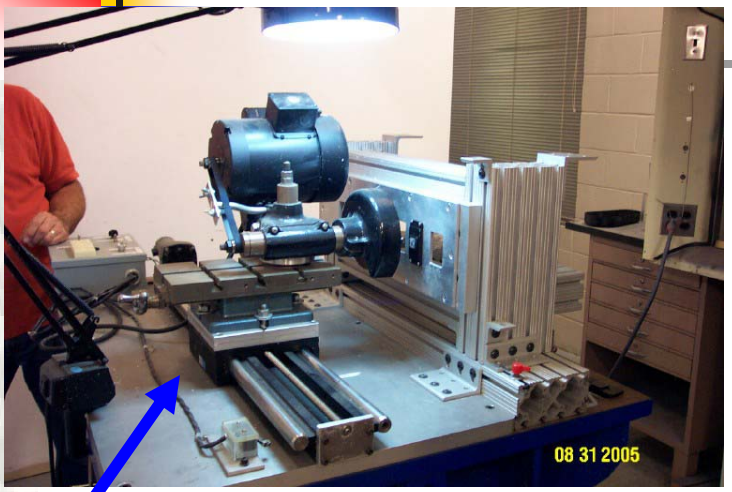


*Fiber Bend Tests Rochester*

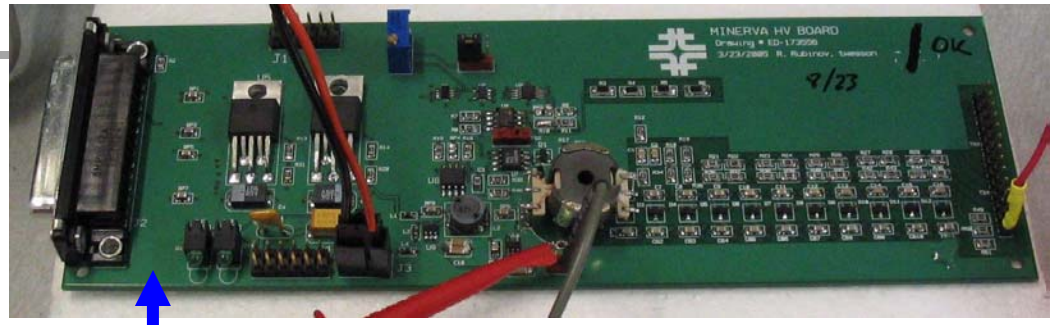


# Minerva R&D Progress:

## PMTs, Boxes, Electronics

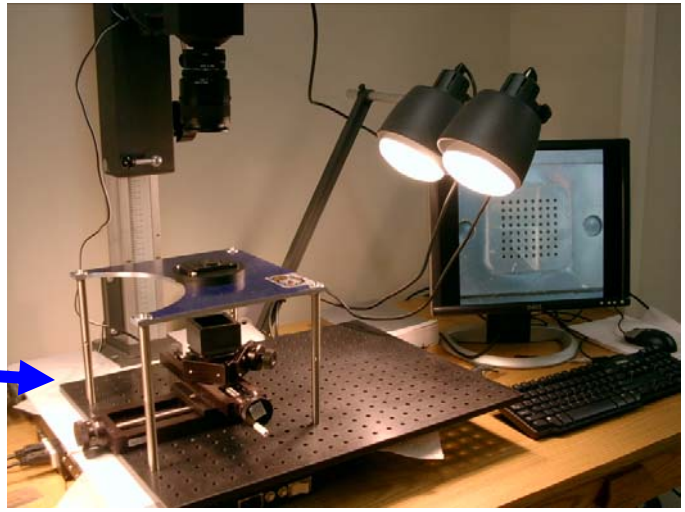


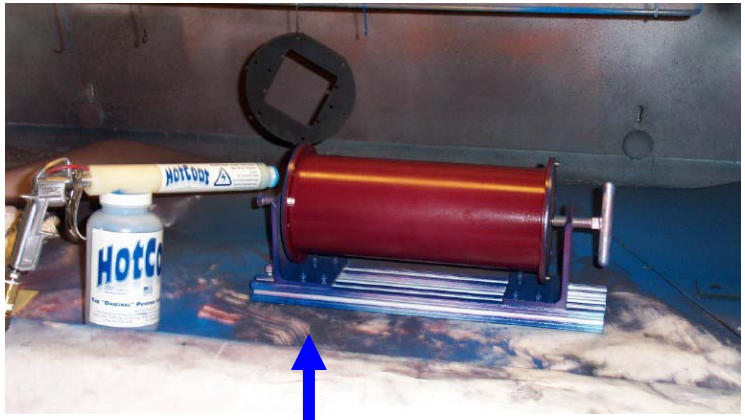

Alignment Piece Factory: Tufts




Cockroft Walton Board: Pittsburgh

PMT Alignment Station: JMU





PMT Box Prototype at Tufts

# Minerνa Event Rates



Fiducial Volume:
3 tons CH, ≈ 0.6 t C, ≈ 1 t Fe and ≈ 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 16.0x10$^{20}$ in LE, ME, and HE NuMI beam configurations over 4 years*

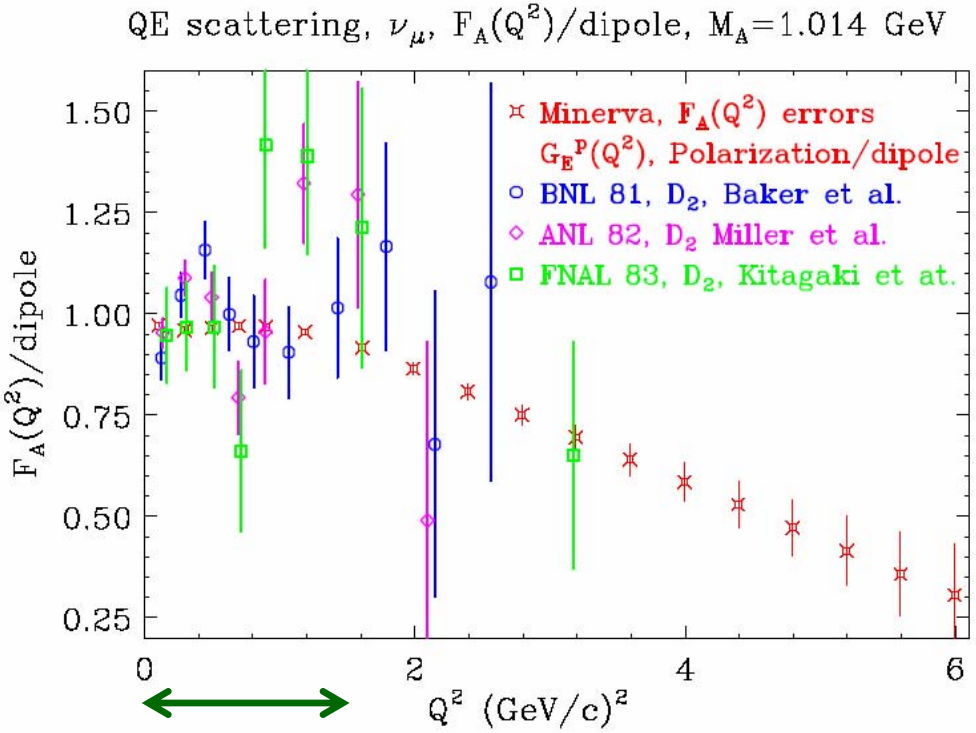
*Main CC Physics Topics (Statistics in CH)*

| | |
|---|---|
| *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* | *> 230 K fully reconstructed* |

# Minerνa & Axial Form Factors

- *Vector form factors measured with electrons*
- *$G_E/G_M$ 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*

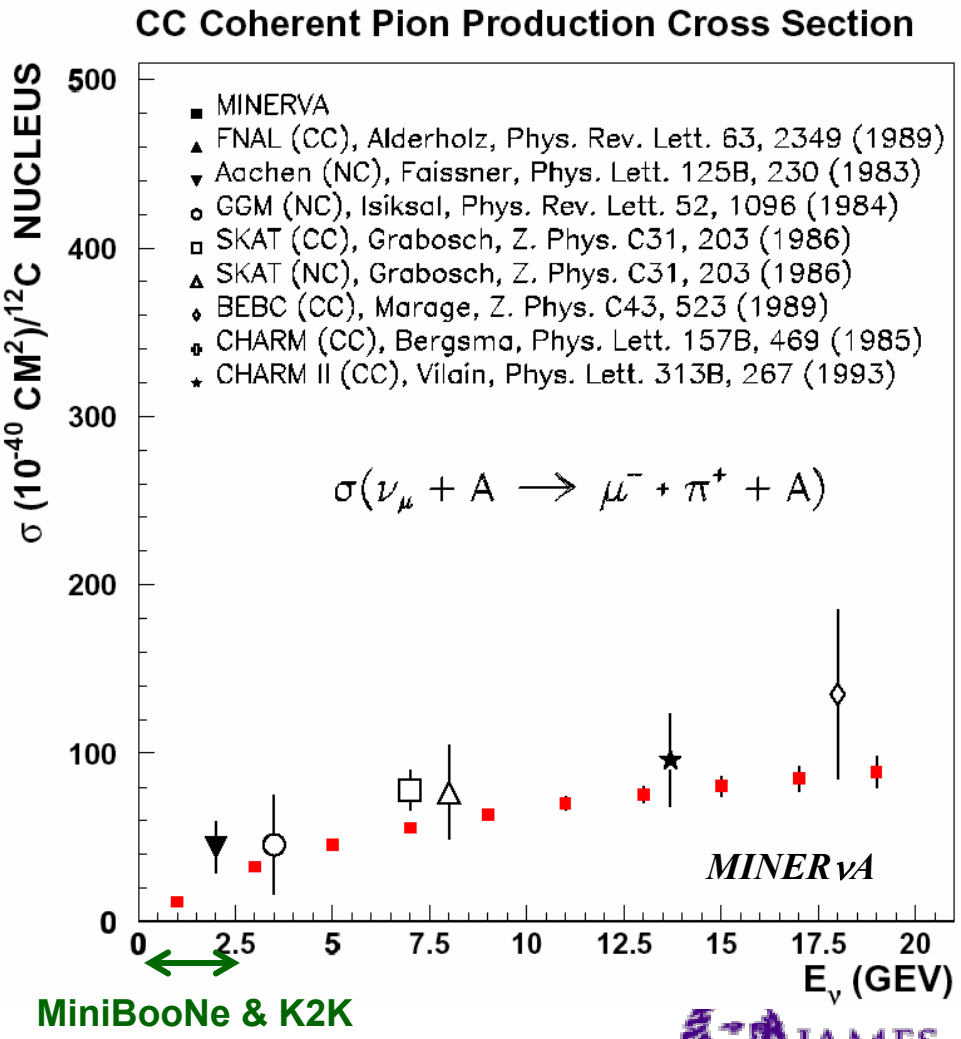
***Projected MINERvA Measurement of Axial FF***




***Range of MiniBooNE & K2K measurements***

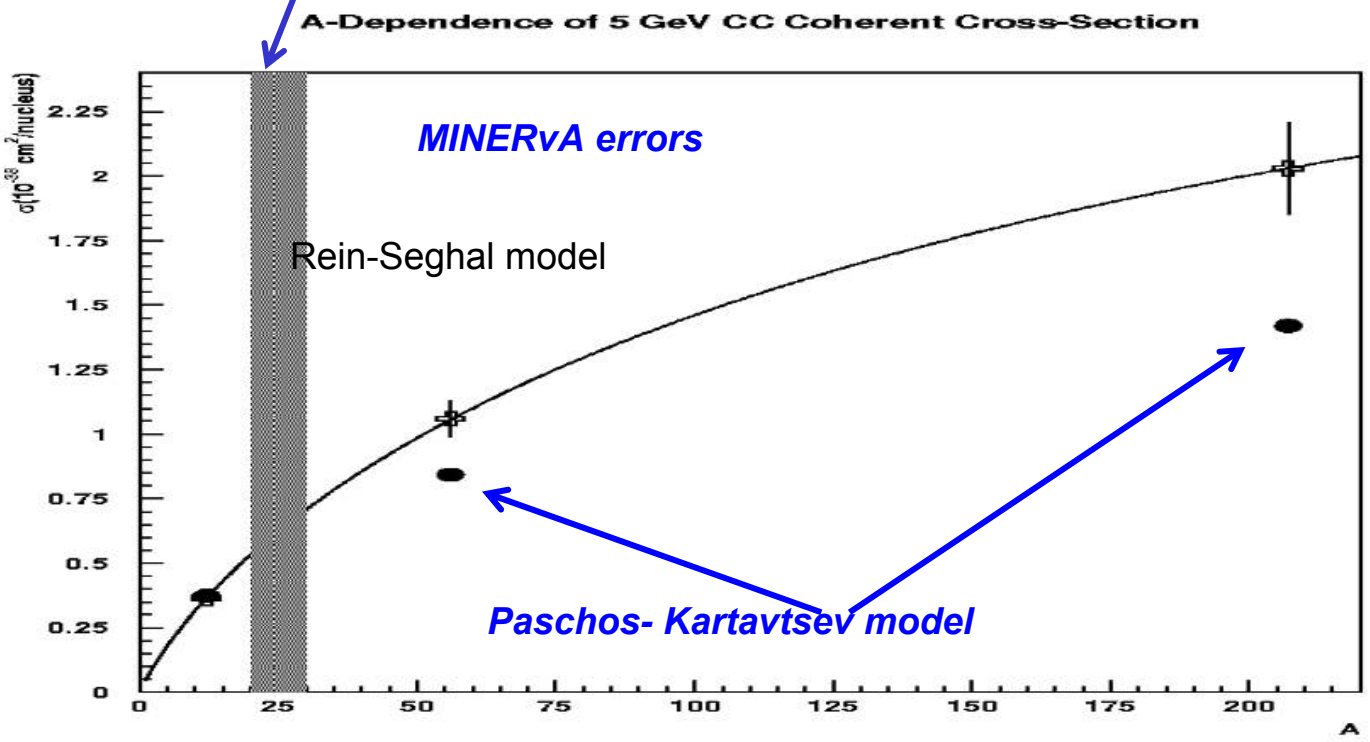
# MinerνA & Coherent Pion Production

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



# Minerνa & Coherent Pion Production (II)

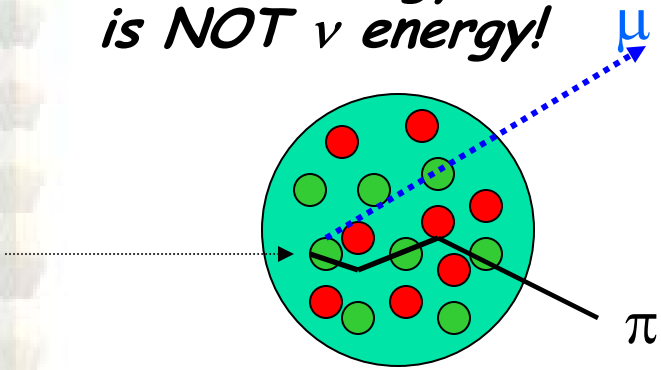
*A-range of current measurements before K2K !*



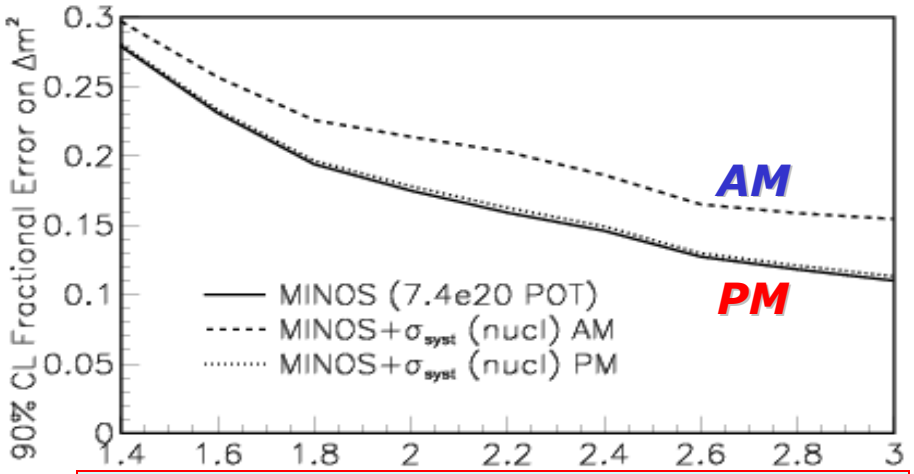

- *…Can also study A-dependence*

# Minerνa's impact... MINOS

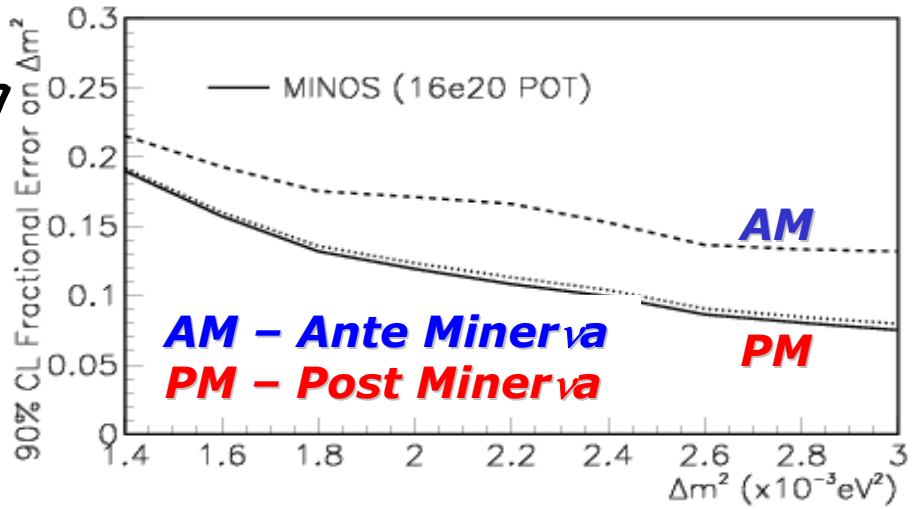
- *Visible Energy in Calorimeter is NOT ν energy!*




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




**(δΔ/Δ) versus Δ, Δ ≡ Δm²**



# OUTLOOK

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