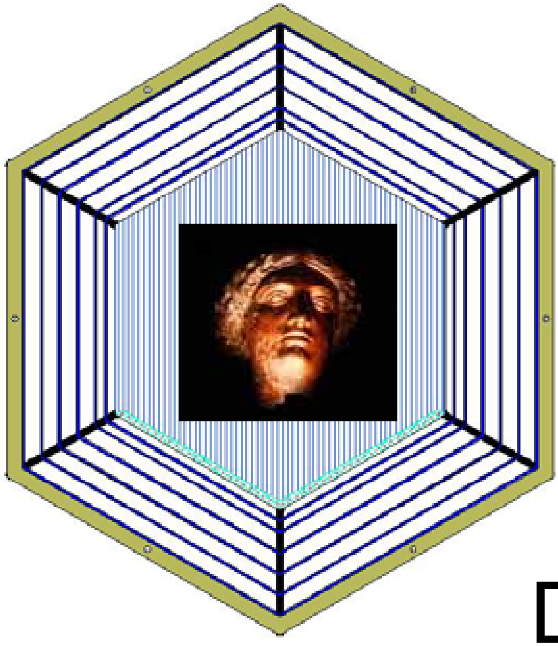
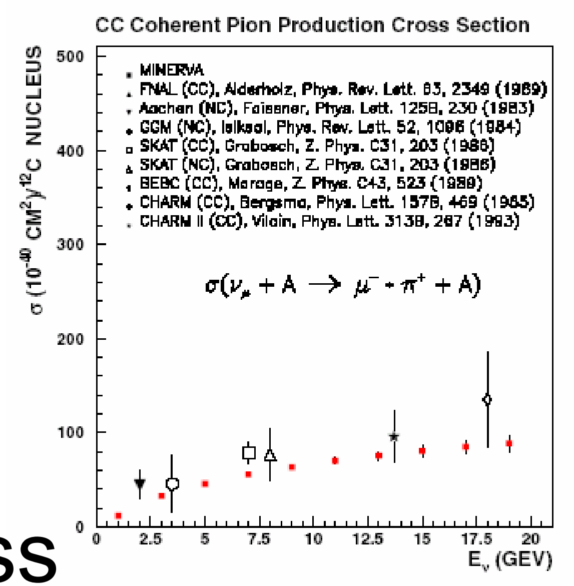


MINERνA



Introduction, Detector Progress and MRI Proposal

Kevin McFarland
University of Rochester
FNAL PAC Meeting
2 April 2004

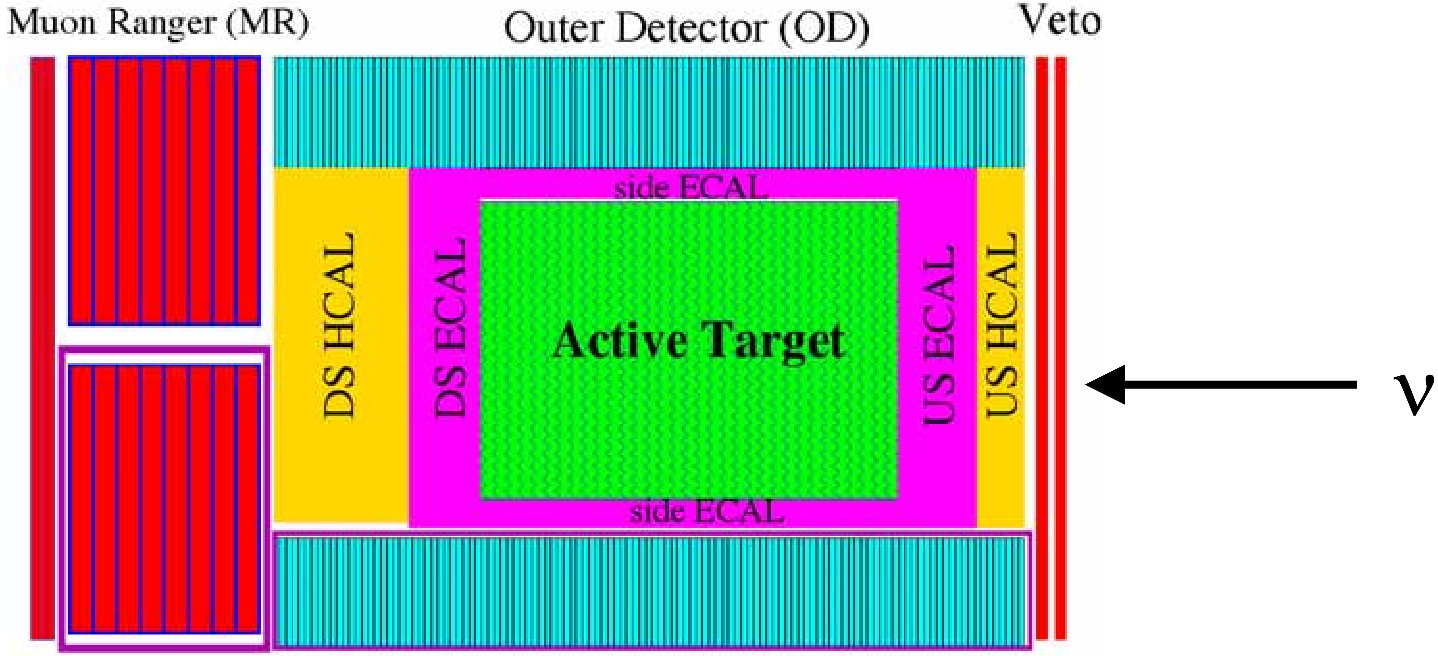
The Opportunities

- The NuMI beam and its Near Hall
  - *at the intensity frontier of neutrino physics for the latter half of the decade, possibly beyond*
- The need to understand GeV neutrino interactions for oscillation experiments
  - *and rich physics mine in its own right. "JLab West"*
- A community of nuclear and particle physics groups excited about making the measurements
  - *many users new to FNAL*
- Capable University groups willing to start building

Essence of the MINERνA Detector

- Must reconstruct exclusive final states
  - high granularity for charged tracking, particle ID, low momentum thresholds,
    - e.g. $\nu_\mu n \to \mu^- p$
- But also must contain
  - electromagnetic showers (π^0, $e^\pm$)
  - high momentum hadrons ($\pi^\pm$, p, etc.)
  - $\mu^\pm$ from CC (enough to measure momentum)
- Nuclear targets (high A, Fe of interest for MINOS)

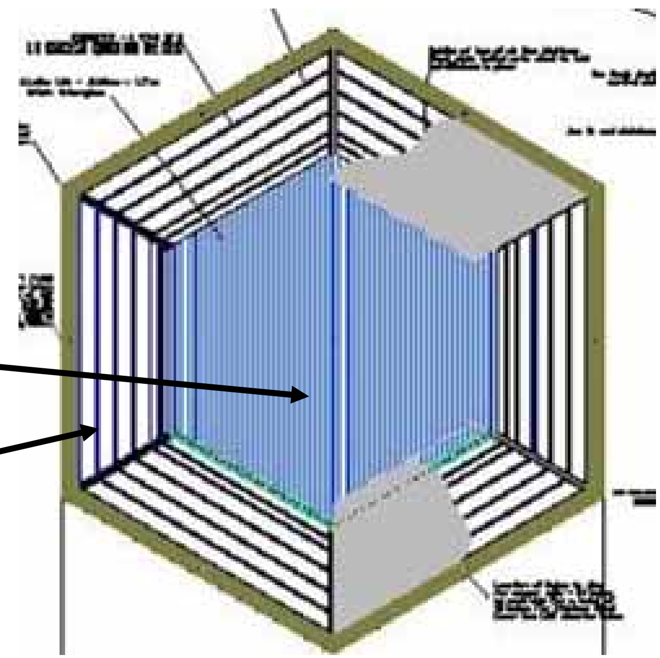
Detector Overview



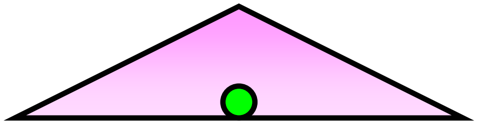
- "Chewy center": active target (5t total, >3t fiducial)
- "Crunchy shell": surrounded by calorimeters
  - upstream calorimeters are Pb, Fe targets (~1t each)
  - magnetized side and downstream tracker/calorimeter

Active Target Module

- Planes of strips are hexagonal
  - inner detector: active scintillator strip tracker
  - outer detector: frame, HCAL, spectrometer
  - XUXV planes → module
    - atom of construction and installation

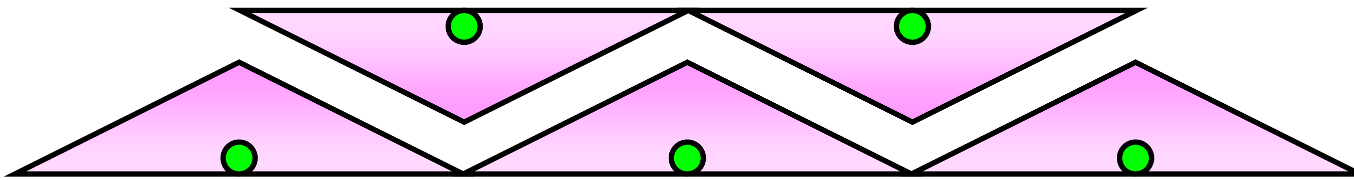


Fully-Active Target: Extruded Scintillator and Optics

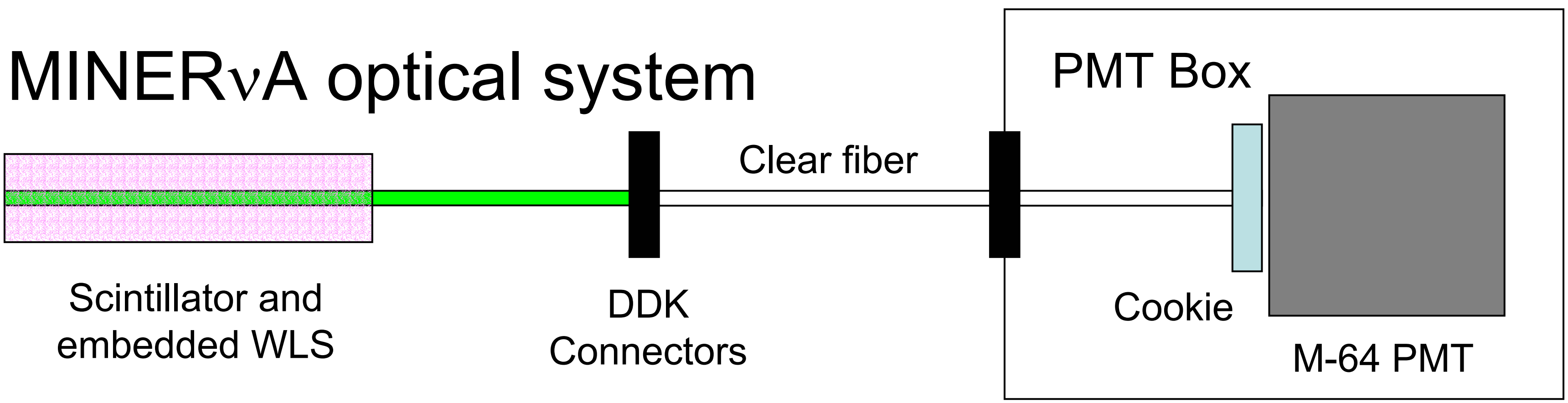


Basic element: 1.7x3.3cm triangular strips. 1.2mm WLS fiber readout in groove at bottom

Assemble into planes



- MINERνA optical system



- Key questions: light, PMT box design, clear cables, connectors, extrusion, fiber placement

Optical System Development

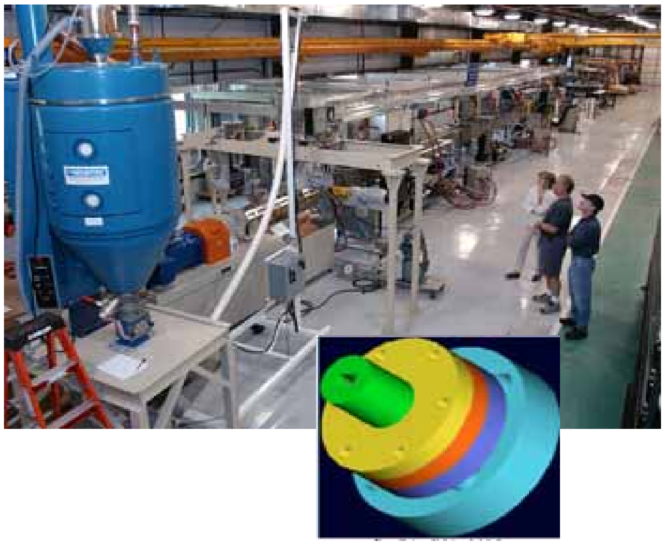
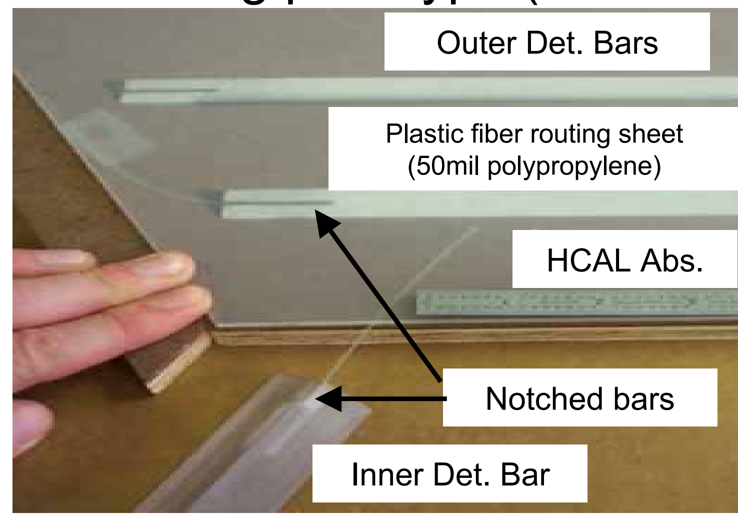


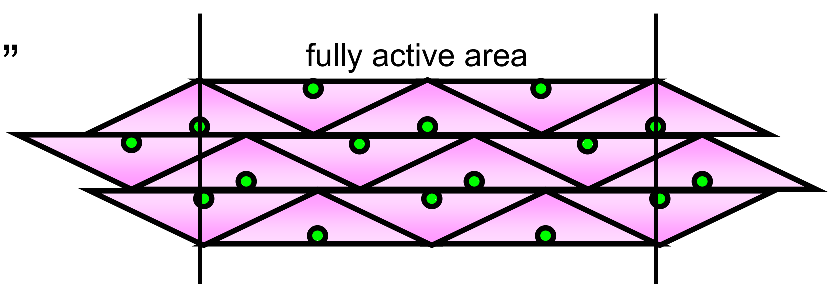
photo courtesy *Northern Today*

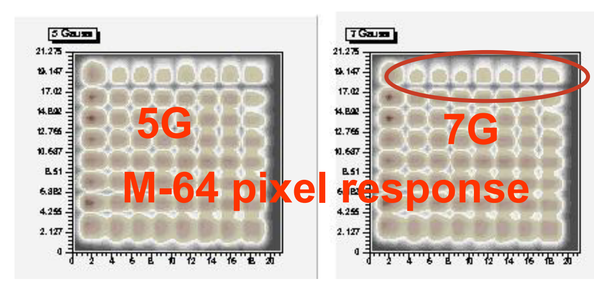
Lab 5 Production extrusion facility, die simulation (NIU/FNAL)

Fiber routing prototype (Rochester)



“Vertical slice” test detector construction (Hampton)

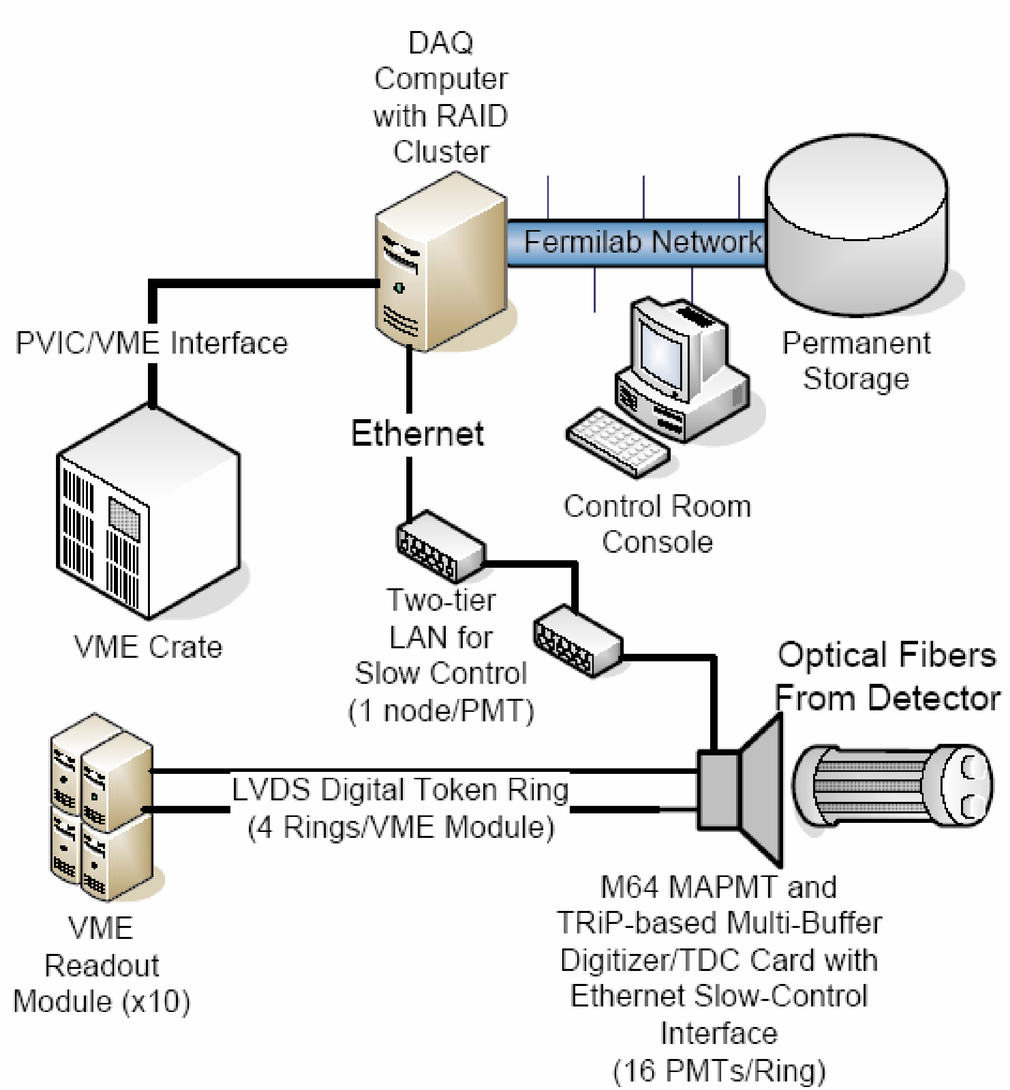




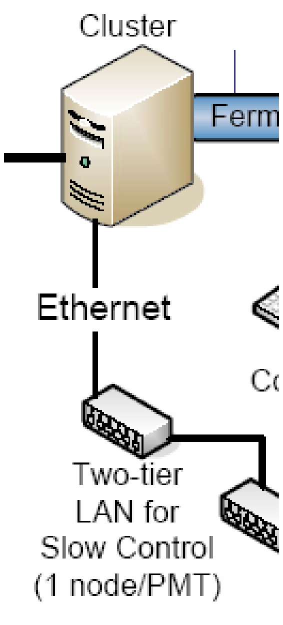
Sweating the fringe fields inside the PMT box (Tufts)

Electronics/DAQ System

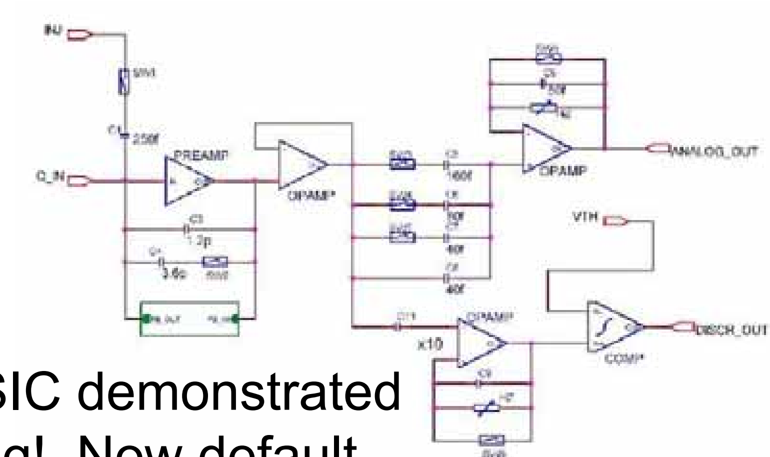
- Data rate is modest
  - 100 kBytes/spill
  - but many sources! (~37000 channels)
- Front-end board based on existing TriP ASIC
  - sample and hold in up to four time slices
  - few ns TDC, 2 range ADC
- Token Ring readout scheme to VME board
  - existing design
- VME/PVIC to logger PC
  - archive/online by network



Electronics/DAQ Progress



Re-specified slow controls
- change from MIL-1553
- to less costly Ethernet solution (Irvine/FNAL)

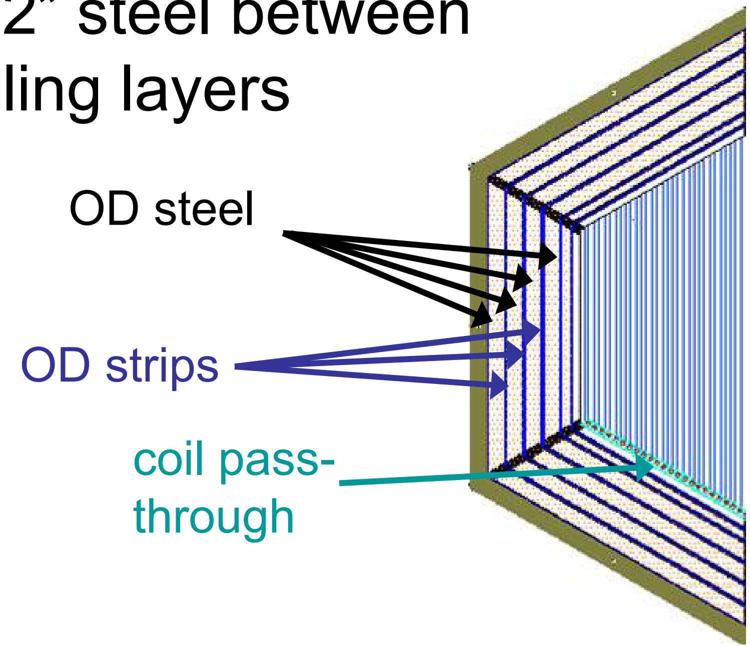


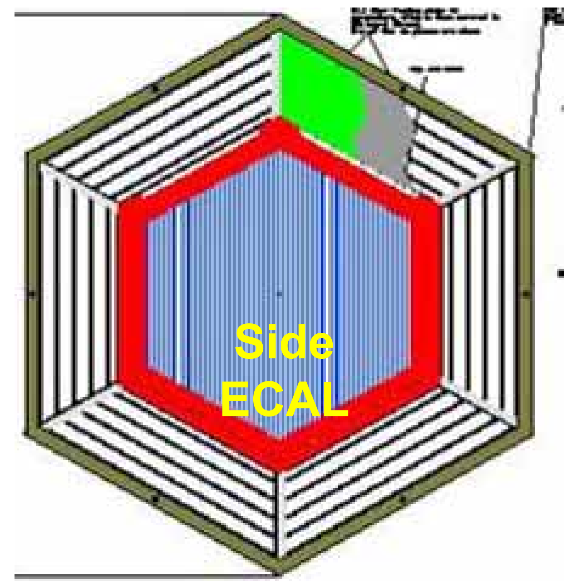
TriP ASIC demonstrated buffering! Now default readout scheme (FNAL)

- Progress on Summer Vertical slice test
  - test of charge digitization, buffering for readout and timing on front-end
  - circuit design complete (April); produced boards (May) (FNAL/Rochester)
  - input will be MAPMTs in MINOS MUX box
    - can test complete slice including a mini-detector (summer ’04)

Mechanical Systems

- ECAL and HCAL absorbers are plates, rings
- OD: 4” and 2” steel between radial sampling layers



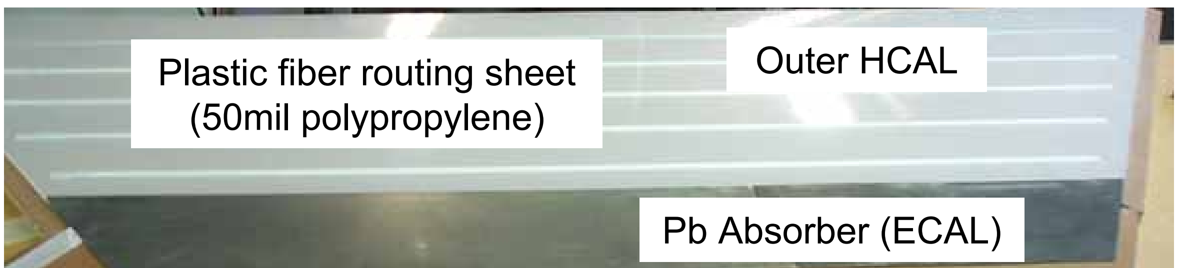


- Assembly:
  - OD frame is support; hold strips and fibers in place (Al retainers)
  - “layer cake” construction of planes into a single module

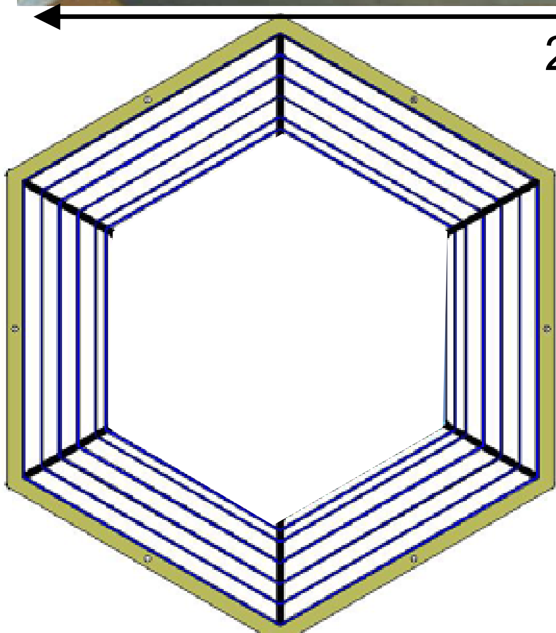
Mechanical Progress

"Hanging ECAL test" (Rochester)

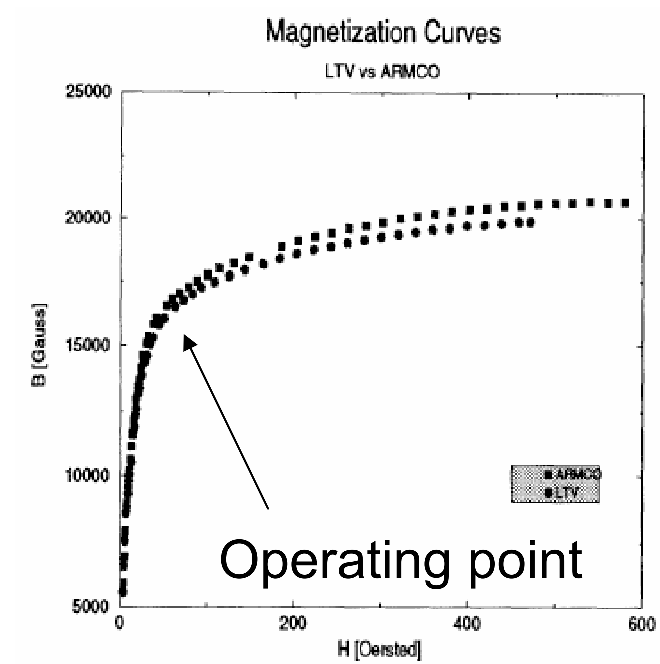
attempting to use harder Pb alloys to reduce cost of ECAL, reduce attachments to OD



2 meters



Beginning FEA of structural properties of OD as frame. Also study OD assembly techniques. (FNAL, Rochester, Rutgers)



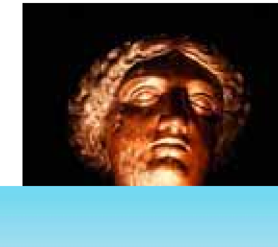
Identified potential vendors for steel with acceptable B-H. This week! (Rutgers)

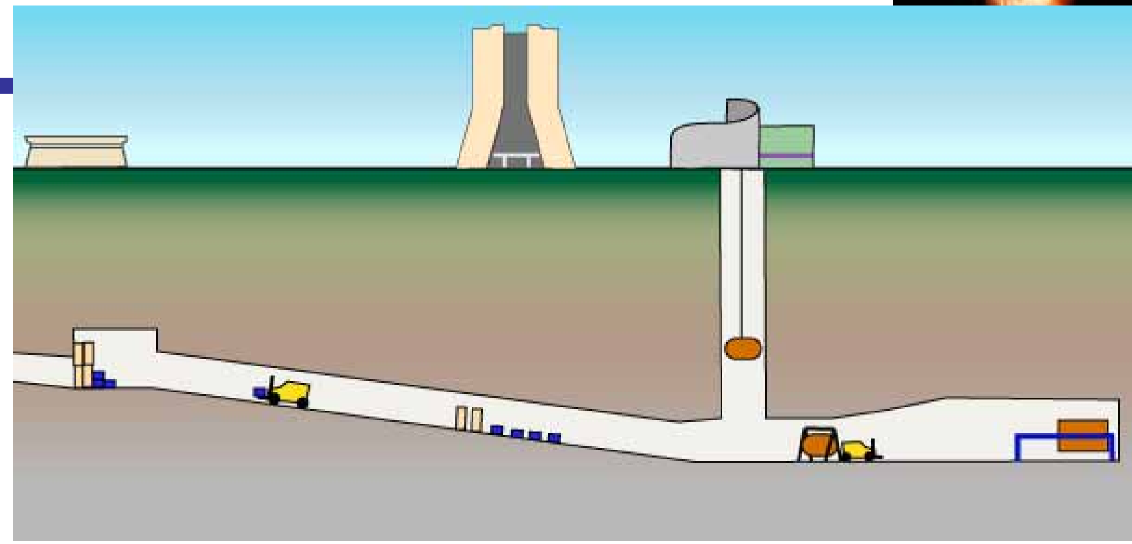
The Unique Roles of FNAL in MINERνA

- Proposed beam use is parasitic
- But… “detector project” as proposed also has places where only FNAL can contribute
  - EDIA for Front-End board (TriP-based design builds on work on D0 electronics)
  - Critical safety items
    - magnet coil and its power supply and cooling
    - detector stand. LV supply and distribution
  - Utilities and installation
  - Safety and oversight of on-site activities
  - Space!

impact!

E.g., Model for Installation Procedure





Similar to MINOS Near Detector:

- Assemble "modules" on surface
  - Mostly University Technicians, Fermilab oversight and space.
  - 6 months prototyping
  - 12 months assembly
- Install final stand in MINOS
- Bring modules down the shaft using strongback and cart: max load 5.3 tons
  - 2 "modules" a day for most of detector
  - 1 "module" plus 6 Fe planes/day for μ ranger
  - Physicists commission after each layer installed
- Low voltage, coil, and coil power supply installed by Fermilab folks

Detector Region	Modules	Tons per module	Time to install (days)
Inner Detector	30	3.6	15
US ECAL	6	3.8	3
US HCAL	4	3.9	2
DS ECAL	5	4	3
DS HCAL	5	5.3	5
Muon Ranger	3+18 Fe Planes	3.6	3
Total			31

FNAL Impact Summary

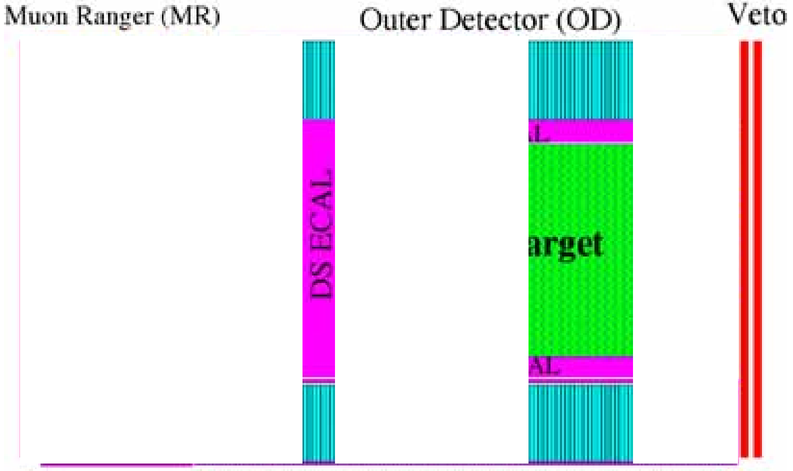
Item	**Design**	**Fabrication**	**Installation**
Installation Strongback	2mos, 22k	2wks, 12.5k	n/a
Transport Cart	n/a	n/i	2k
Detector Stand+Bookend+Drip	5 wks, 21k	68k	3 wks 73k
Detector	59k (installation plan)	1.5yr, 95k	7wks 85k
Magnet Coil and Cooling	n/i	n/i	6 wks 70k
Electronics (inc. Trip Chip)	1yr, 130k	n/i	(2k FNAL)
Magnet Power Supply	n/a	Already built	12k+22k
Quiet Power (low voltage supply)	3 mos, 33k	bought	24k+8k
Alignment	n/a	3.5k	7k
Safety Review/Inspection/Managm.	1 mo, 11k	14k	104k
Total	**272k**	**193k**	**415k**

Design work: engineers, Fabrication: welders, machinists Installation: Riggers

- Impact review (29 March) concluded, in part, need to add 40% contingency

MRI Submission

- A consortium of MINERvA US Universities submitted an MRI proposal this January
  - Hampton, IIT, Irvine, James Madison, NIU, Pittsburgh, Rochester, Rutgers, Tufts
- Funds all construction costs except FNAL “Unique roles”
- Proposal is to construct only a fraction of MINERvA (limited by $2M MRI cap + University contributions)
  - modules could run standalone with MINOS as both HCAL and muon catcher
  - MRI does fund all EDIA, startup items needed for detector factories



MRI Status

- It is out for review.
  - Expect a decision by summer.
- It is abundantly clear that we will not receive MRI funding to build this detector if there is not a commitment to the experiment by FNAL.
- If it has this commitment, we believe the physics program gives us an excellent chance of success…

The MINERνA Experiment: Physics Topics

Jorge G. Morfín

Fermilab

MINERνA will have the statistics to cover a wide variety of important ν physics topics

Assume 9×10^{20} POT: 7**.0x**10^{20} **in LE ν beam, 1.2x**10^{20} **in sME ν beam and 0.8x**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

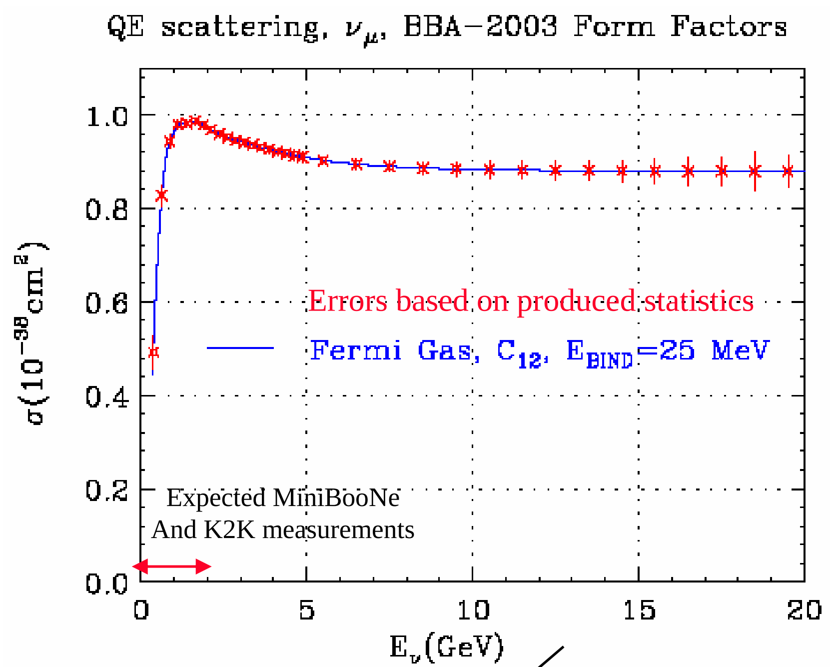
Main Physics Topics with Expected Produced Statistics

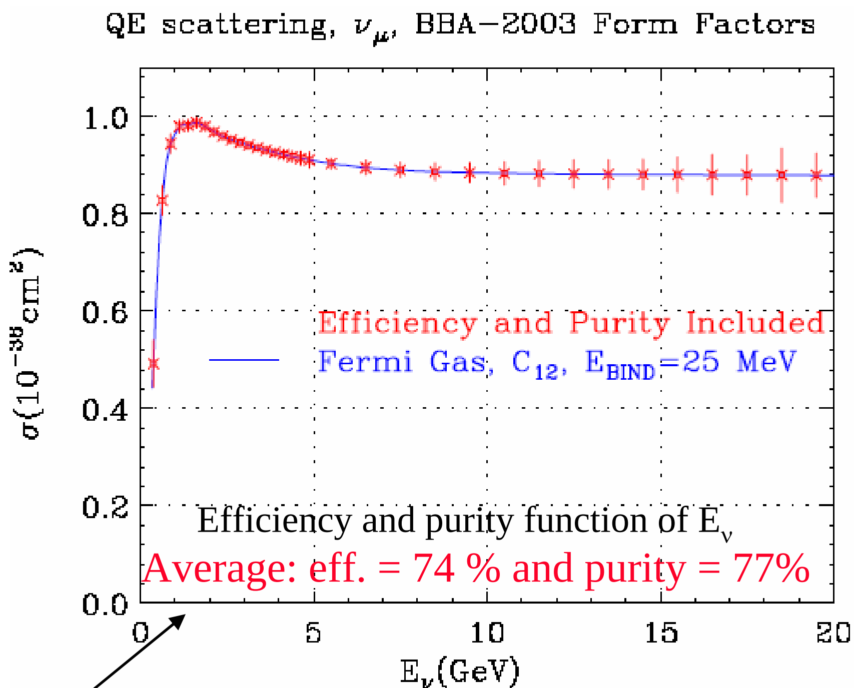
- **Quasi-elastic** - ν+n --> μ^-+p - 300 K events off 3 tons CH
- **Resonance Production** - e.g. ν+N ---> ν /μ^-+Δ 600 K total, 450K 1π
- **Coherent Pion Production** - ν+A --> ν /μ^-+A + π, 25 K CC / 12.5 K NC
- **Nuclear Effects** - C: 0.6M events, Fe: 1M and Pb: 1 M
- σ_T and Structure Functions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

Quasi-elastic ν Scattering

MINERνA: 300 K events off CH and over 100 K off of Fe and Pb produced

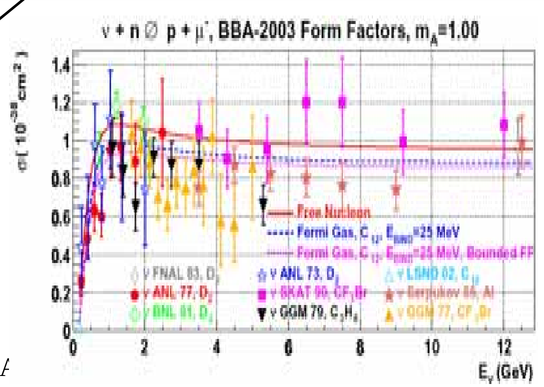
H. Budd and K. McFarland



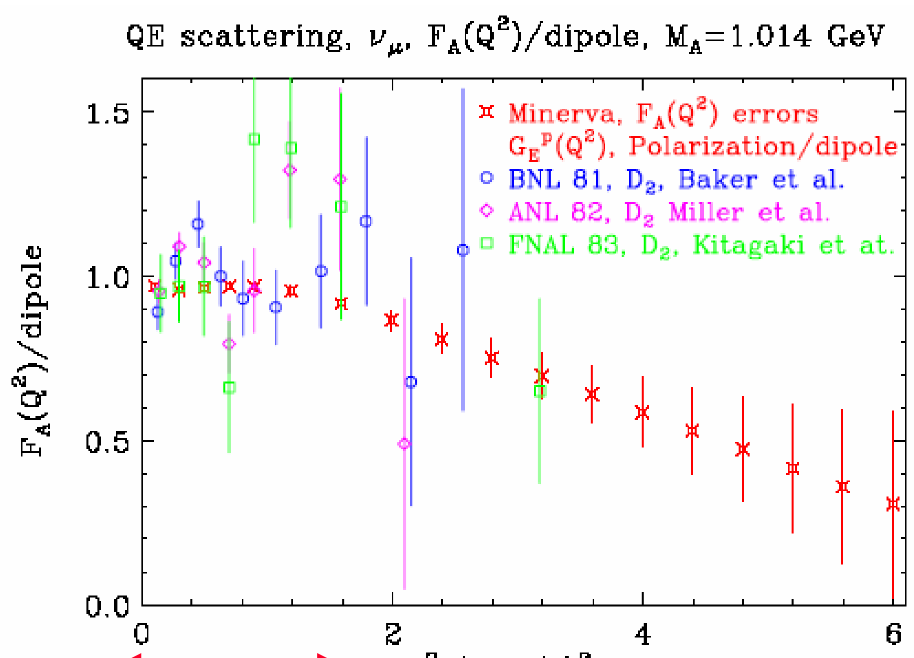


Include Selection Criteria

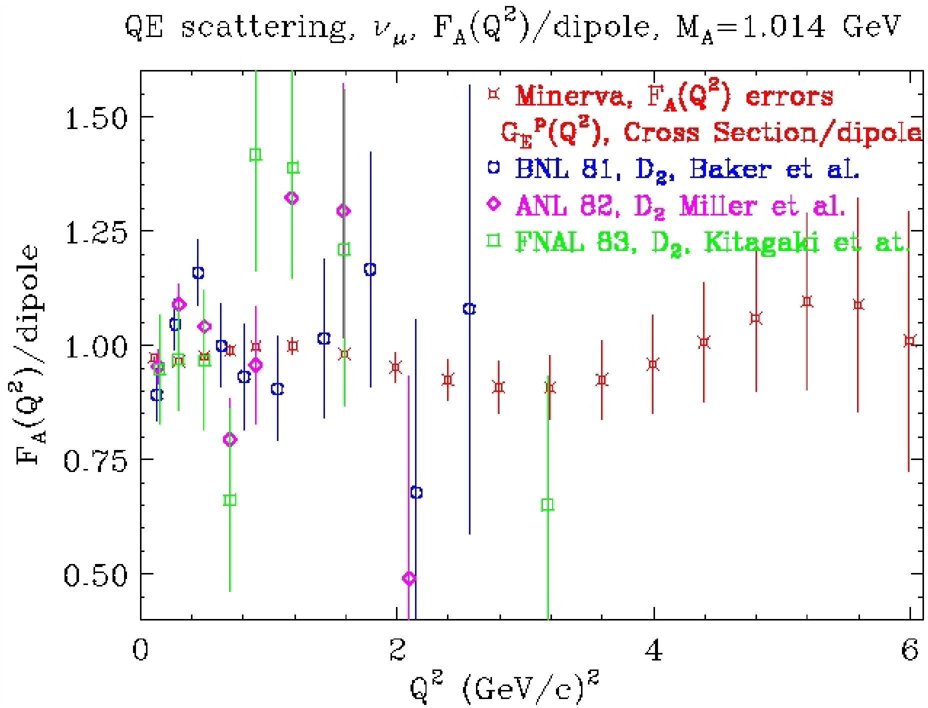
- 1 or 2 tracks for $Q^2 < 1$ GeV^2 and 2 tracks for $Q^2 > 1$ GeV^2
- 1 long non-interacting track consistent with muon
- Q^2_μ - 2Mν / error < 2.0 (x_{Bj} consistent with 1.0)
- Q^2-dependent missing p_T cut
- minimal number of hits in event not associated with μ or p



Extraction of F_A with Selected Sample



Expected MiniBooNe and K2K measurements



Note that, even with the larger errors of the selected sample, MINERνA will have the statistics and Q^2 range to distinguish between the two different suggested Q^2 behaviors.

Coherent Pion Production

MINERνA: 25 K CC / 13 K NC: CH and 25 K (50K) CC / 13 K (25K)NC: Fe (Pb)

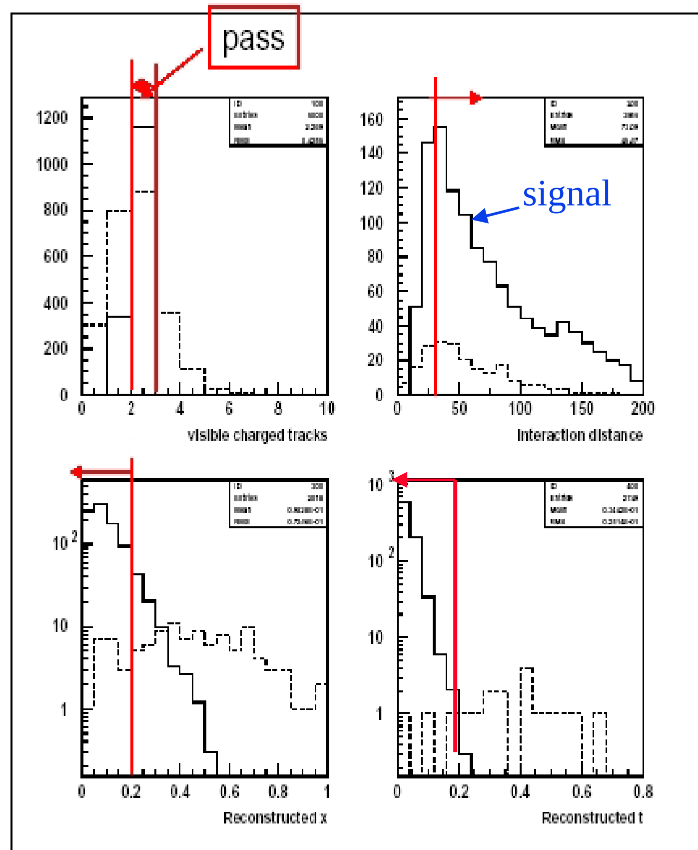
H. Gallagher

Selection criteria reduce the signal by a factor of three - while reducing the background by a factor of ≈ 1000.

	Signal	Background
	5000	10000
2 Visible Charged Tracks	3856	3693
π^0/n <500 MeV	3124	3360
Track separation	2420	500
x<0.2	2223	100
t<0.2	2223	19
p_π> 600 MeV	1721	12
Fudge factor factor	(0.65)	-
Normalized	5004	4400

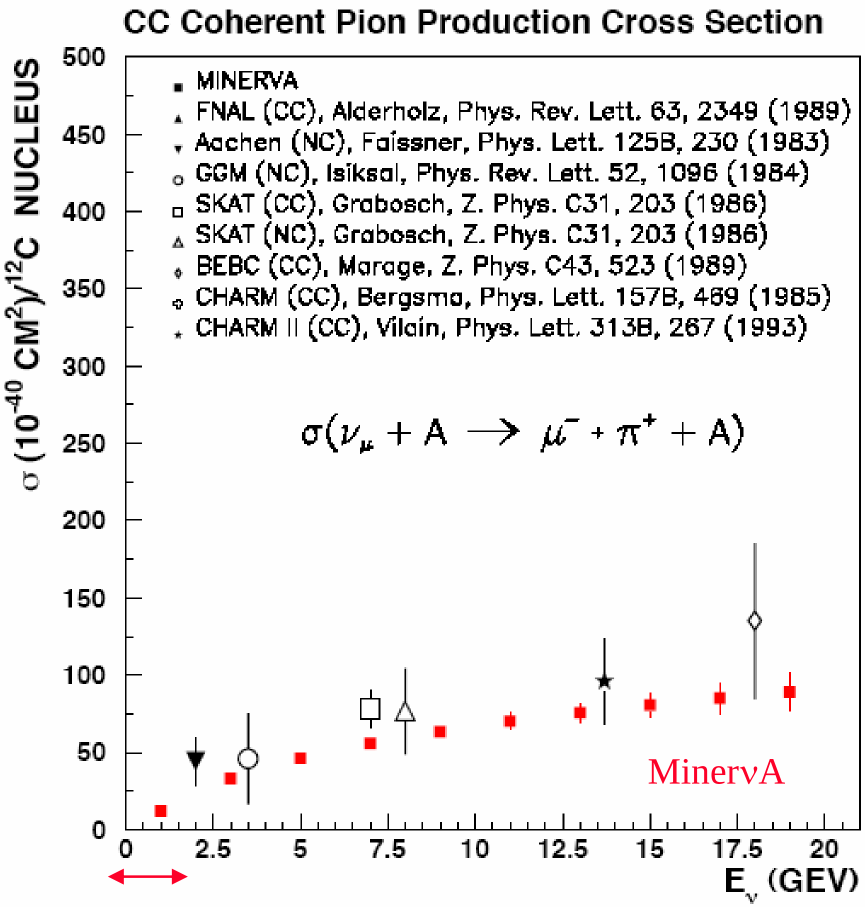
Resulting sample is ≈ 5 K CC coherent events

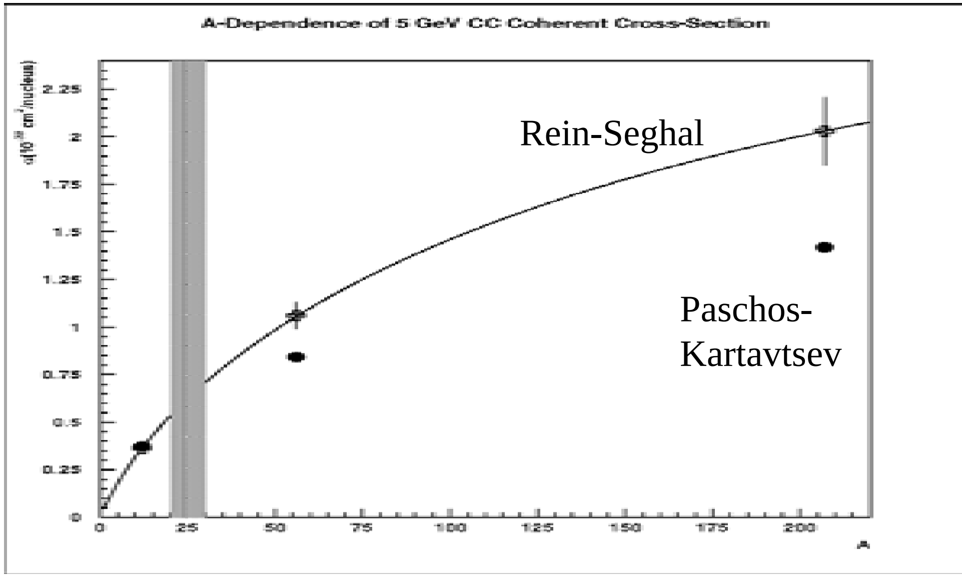
Selection criteria discussed at previous meeting



Expected MINERνA Results - Coherent π Production

Errors now include estimated background subtraction





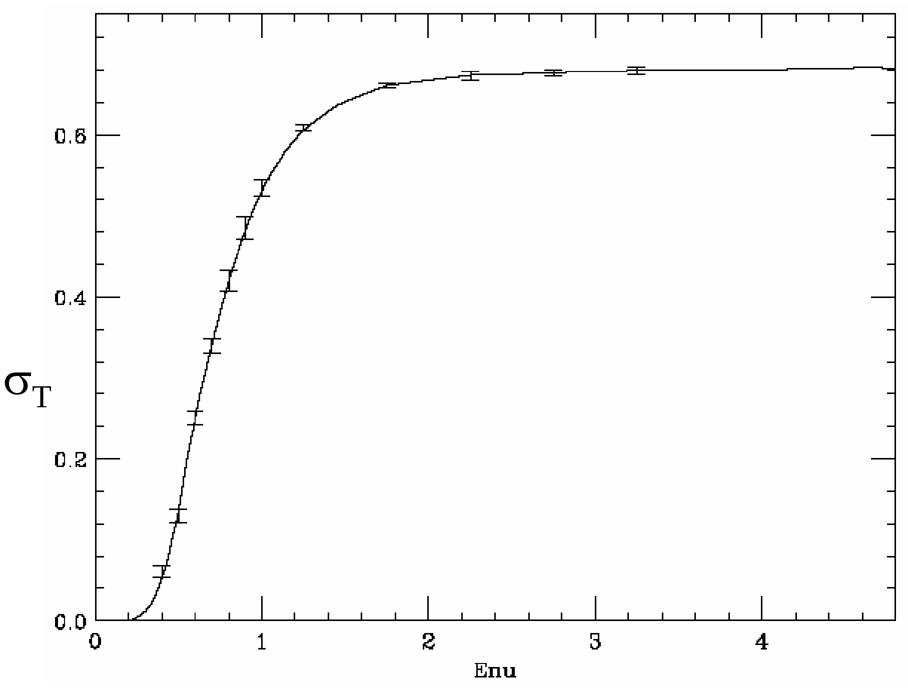
Expected MiniBooNe and K2K measurements

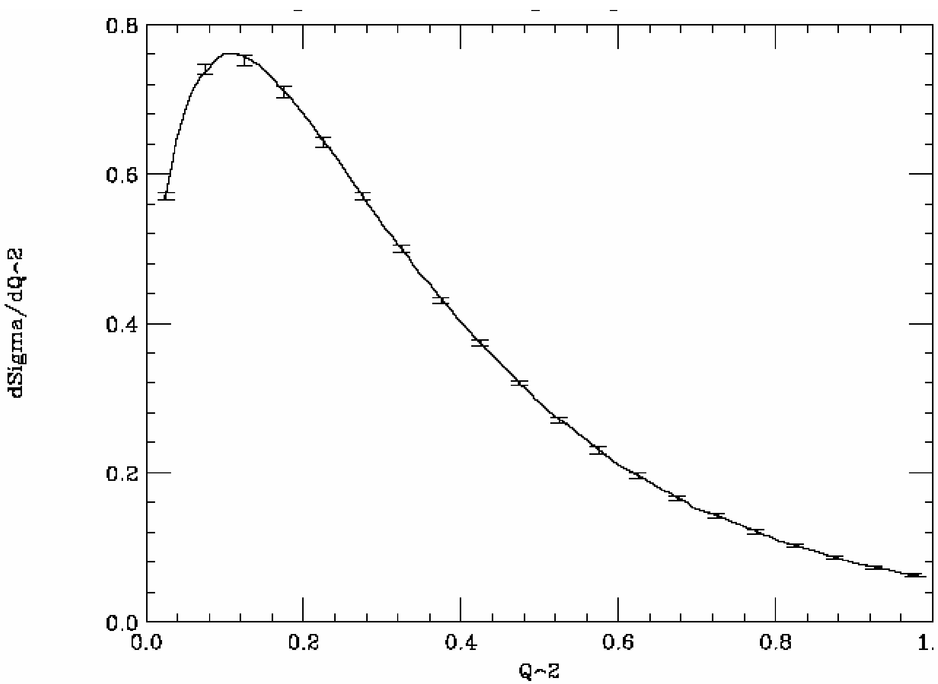
Resonance Production - Δ

S. Wood and M. Paschos

Total Cross-section and $d\sigma/dQ^2$ for the Δ^{++} assuming 50% detection efficiency

Errors are statistical only: 175K Δ^{++}

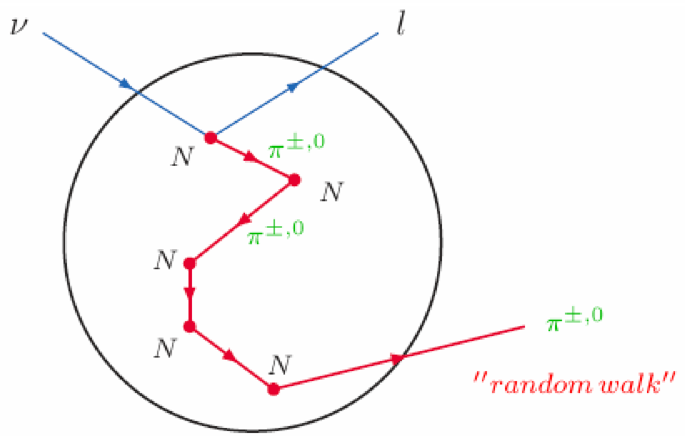




Resonance Production - Nuclear Effects

Adler, Nusinov, Paschos model (1974)

1. single pion production in νN scattering
   $\rightarrow$ Pauli Principle, Fermi motion
2. multiple scattering of pions
   $\rightarrow$ Charge exchange, absorption, Pauli Principle

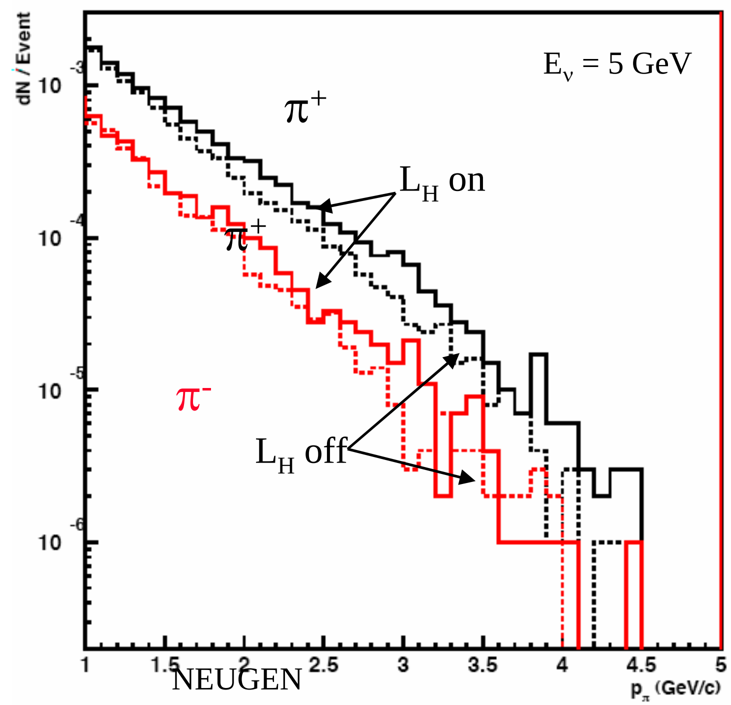


- charge exchange matrix M for isoscalar targets
  ($M = M^T, \sum_j M_{ij} = A_p, M_{+0} = M_{-0} \rightarrow$ 3 param. A_p, d, c)

$$M = A_p \begin{pmatrix} 1-c-d & d & c \\ d & 1-2d & d \\ c & d & 1-c-d \end{pmatrix}$$

- π^+ cross section is largely reduced (up to 40%) $\leftrightarrow$ charge exchange M
- π^0 cross sections is slightly increased by the nuclear corrections

One obvious omission, this model does not include
hadron formation length corrections

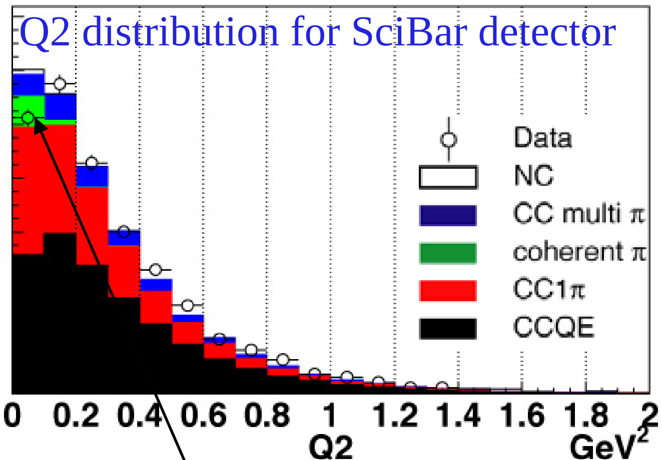


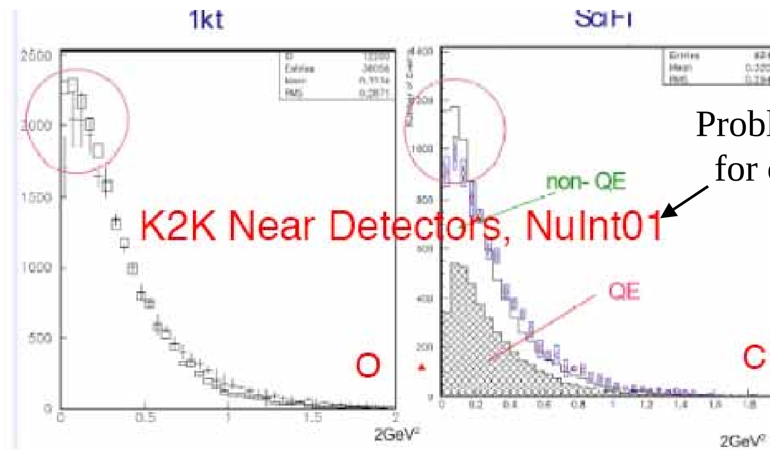
MINERνA can measure L_H off of C, Fe and Pb

Nuclear Effects

MINERνA: 2.8 M events off CH, 600 K off C and 1 M events off of Fe and Pb

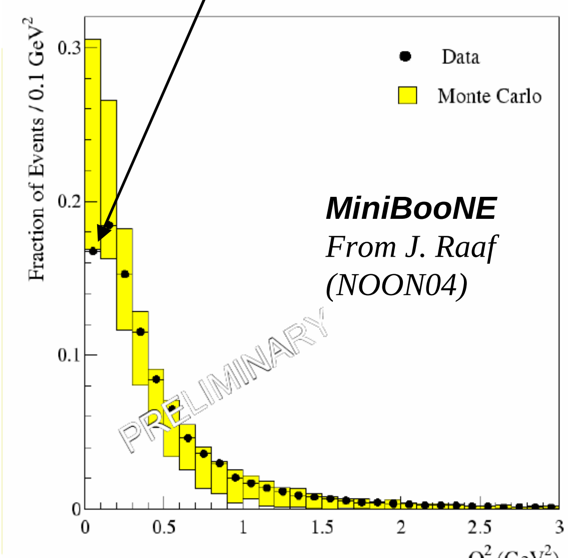
S. Boyd, JGM, R. Ransome





Problem has existed for over two years

Larger than expected rollover at low Q^2



All "known" nuclear effects taken into account:
Pauli suppression, Fermi Motion, Final State Interactions
They have **not included** low-ν shadowing that is only allowed with axial-vector (Boris Kopeliovich at NuInt04)

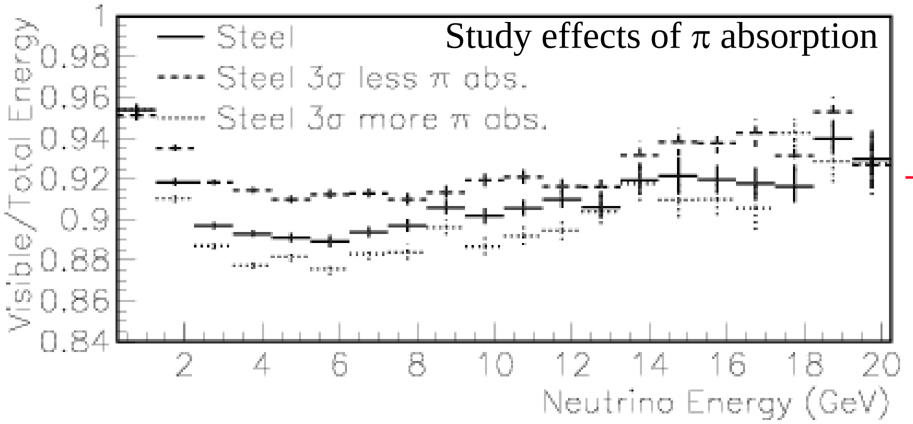
$L_c = 2\nu / (m_\pi^2 + Q^2) \geq R_A$ **(not** m_A^2**)**

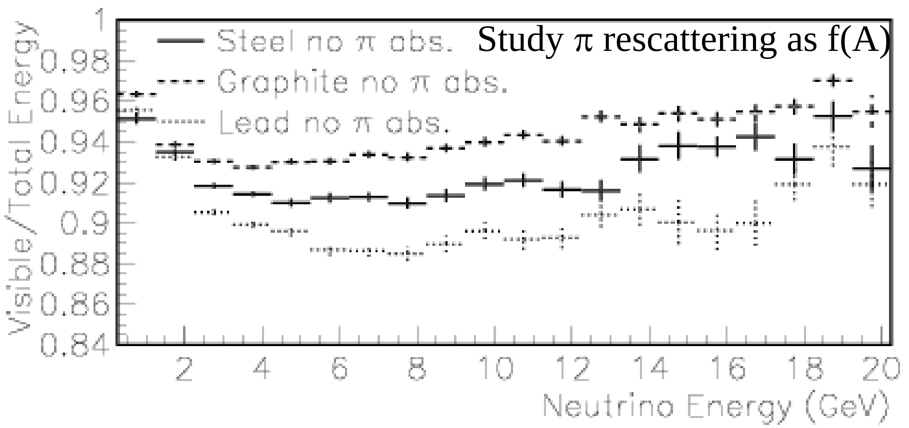
L_c **100 times shorter with** m_π **allowing low ν-low** Q^2 **shadowing**

ONLY MEASURABLE VIA NEUTRINO - NUCLEUS INTERACTIONS! **MINERνA WILL MEASURE THIS ACROSS A WIDE ν AND Q^2 RANGE WITH C : Fe : Pb**

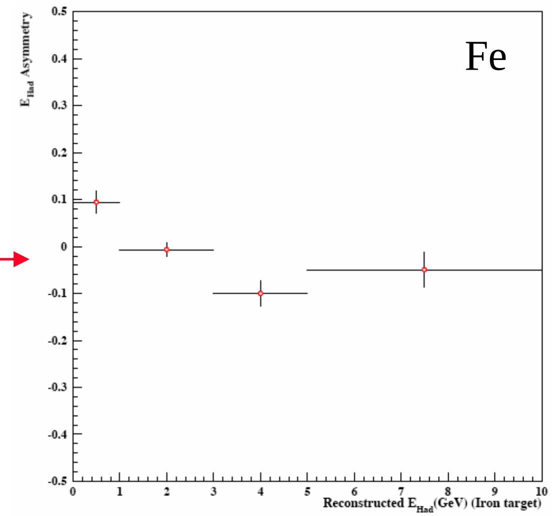
Example: MINERνA Sensitivity to Nuclear Effects

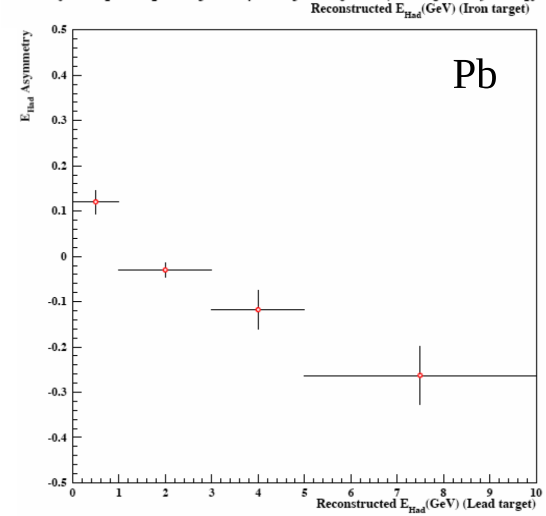
Use NEUGEN Monte Carlo model to study
π intranuclear scattering and absorption
D. Harris





E_{Had} (+3σ) - E_{Had} (-3σ)} / E_{Had} (-3σ)





If we take the projected MINERνA results, how could it improve Neutrino Oscillation Experiments?

Deborah Harris

Fermilab

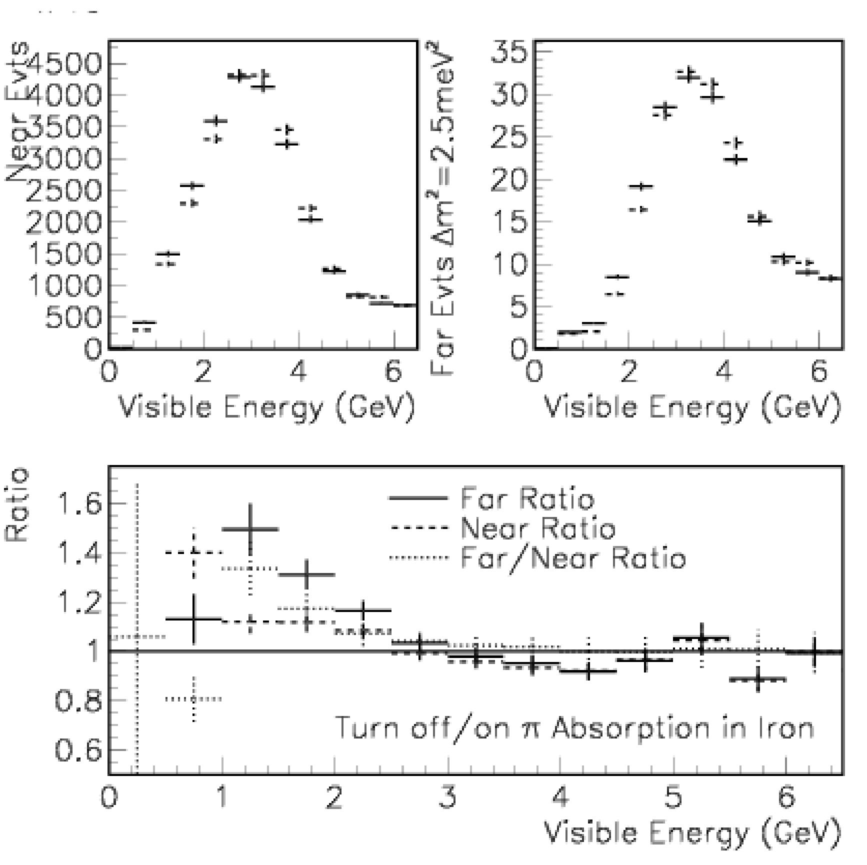
Challenges of Oscillation Measurements

- MINOS measurement of Δm^2
  - need a wide band beam to do this
  - need to understand the relationship between the incoming neutrino energy and the visible energy in the detector
- NOνA search for $\nu_\mu \to \nu_e$
  - Must have accurate prediction for backgrounds
  - Once a signal is seen, it's extracting a probability
- NOνA precision measurement of $\sin^2 2\theta_{23}$
  - Have to predict NC background

How Nuclear Effects enter Δm^2 Analyses

Measurement of Δm^2 (e.g.MINOS)

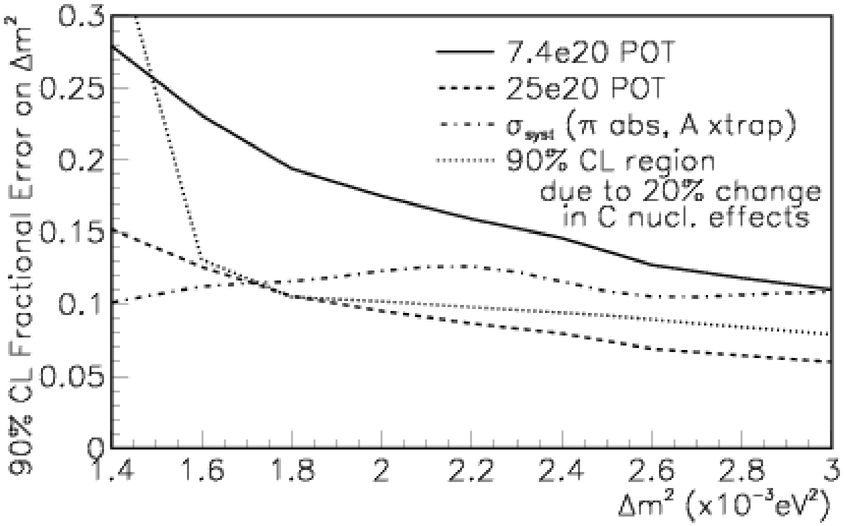
- Need to understand the relationship between the incoming neutrino energy and the visible energy in the detector
  - Improve understanding of pion and nucleon absorption
  - Understand intra-nuclear scattering effects
  - Understand how to extrapolate these effects from one A to another
  - Improve measurement of pion production cross-sections
  - Understand low-ν shadowing with neutrinos

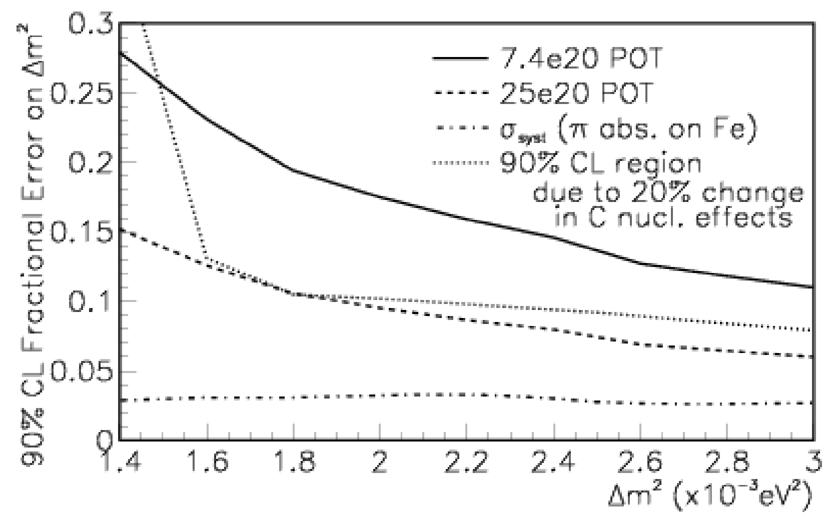


How Nuclear Effects enter MINOS Δm^2 Measurement

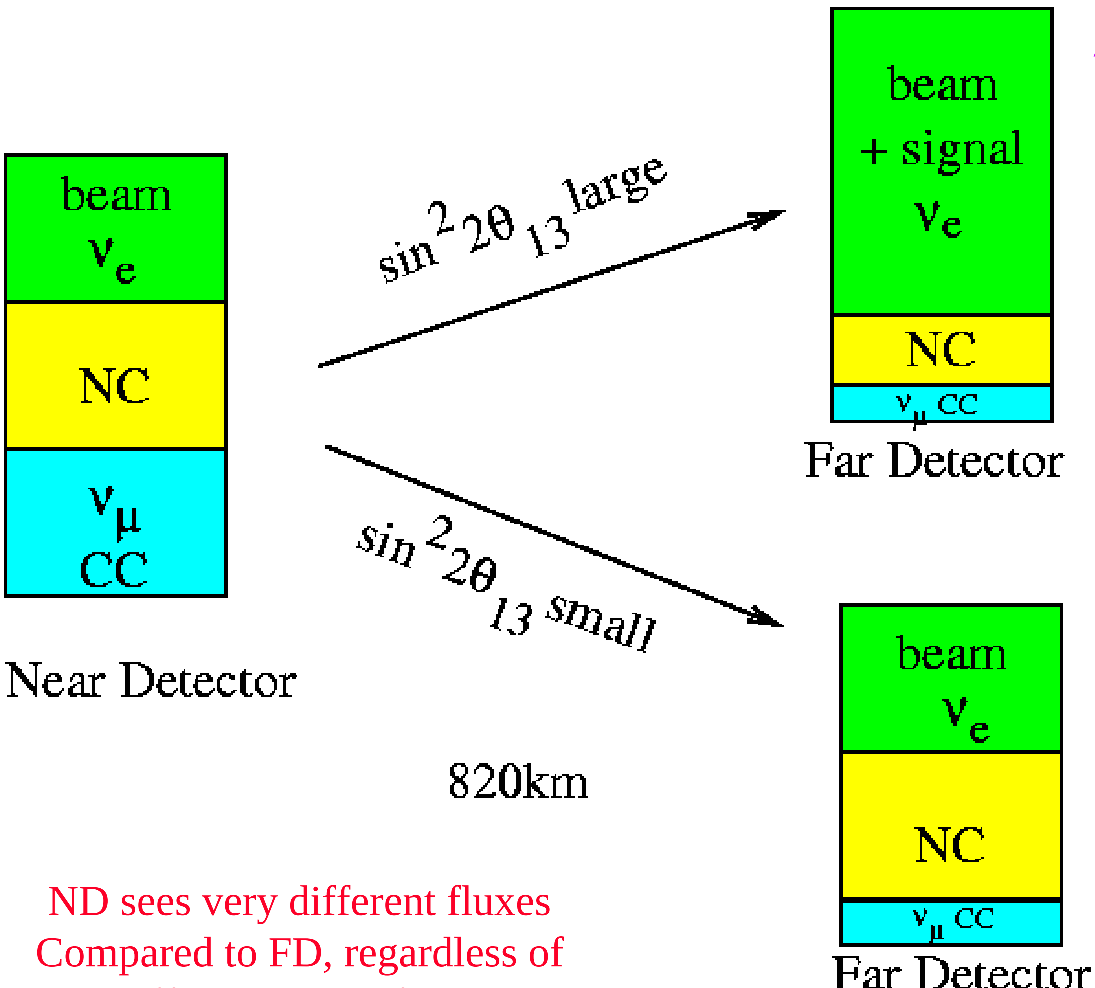
Before MINERνA:
pion absorption measured on Neon
All nuclear effects extrapolated from low A

After MINERνA:
pion absorption and rescattering measured on steel,
No extrapolation necessary!





Measuring $\nu_\mu \rightarrow \nu_e$ at NOνA



Assuming 50kton,
5 years at 4×10^{20} POT, $\Delta m^2=2.5\times10^{-3}eV^2$

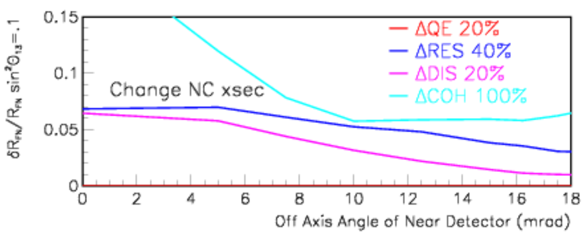
Process	**Events**	QE	RES	COH	DIS
$\delta\sigma/\sigma$		20%	40%	100%	20%
Signal ν_e	**175 At $\sin^2 2\theta_{13}$ =0.1**	55%	35%	n/i	10%
NC	**15.4**	0	50%	20%	30%
ν_μCC	**3.6**	0	65%	n/i	35%
Beam ν_e	**19.1**	50%	40%	n/i	10%

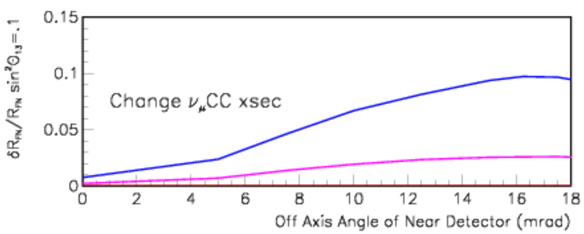
For large $\sin^2 2\theta_{13}$, statistical=8%
For small $\sin^2 2\theta_{13}$, statistical=16%

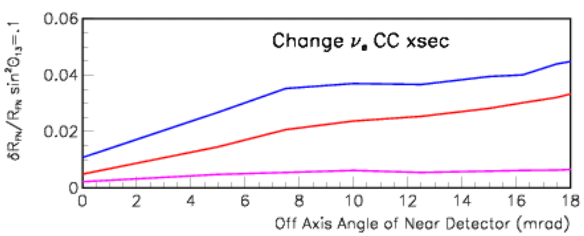
ND sees very different fluxes
Compared to FD, regardless of
Off axis angle of ND!

How MINERνA Would Help NovA: Once a Signal is seen…

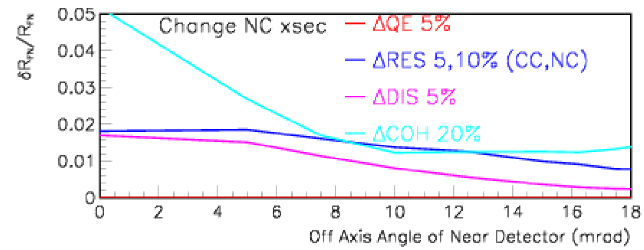
Assume Energy Dependence Perfectly known….vary σ levels

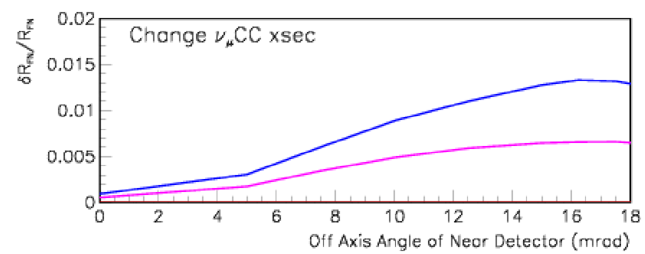


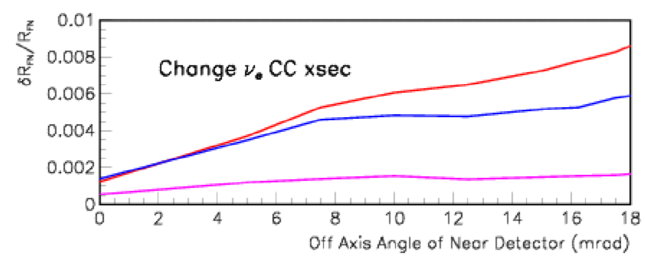




Same study, but with MINERνA precision







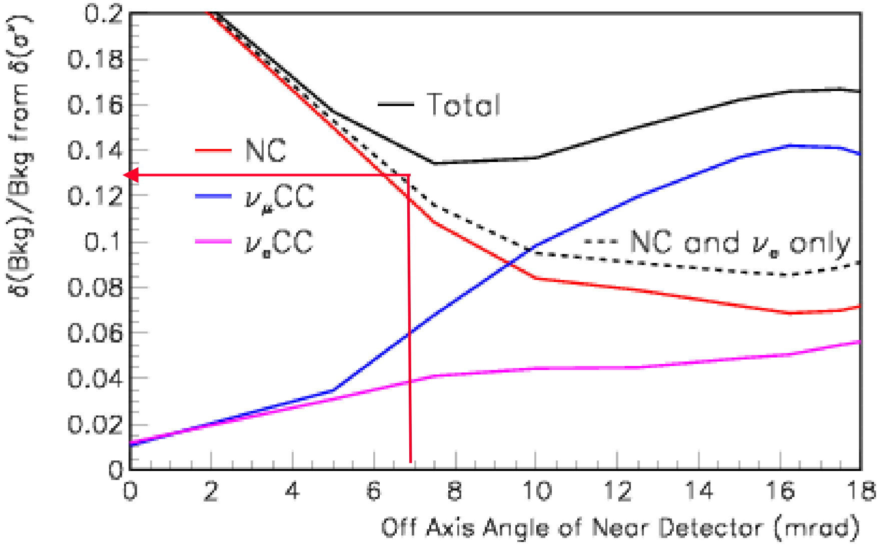
Regardless of NOνA Near Detector Location, large errors in extrapolation To far detector….

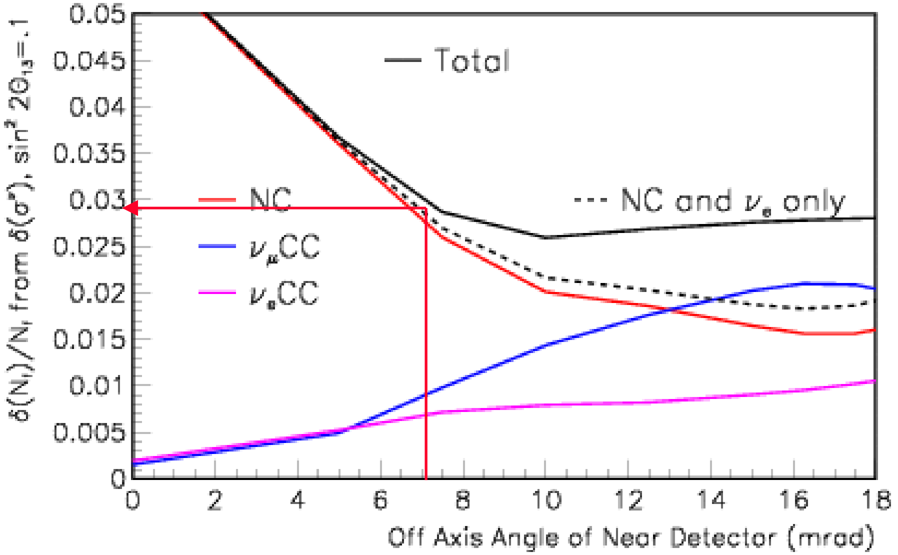
How MINERνA Would Help NOνA: Once a Signal is seen…

Total fractional error in the predictions as a function of Near Detector off-axis Angle

Current Accuracy of Cross-sections
ΔQE = 20%
ΔRES = 40%
ΔDIS = 20%
ΔCOH = 100%

With MINERνA Measurements of σ
ΔQE = 5%
ΔRES = 5, 10% (CC, NC)
ΔDIS = 5%
ΔCOH = 20%





Without MINERνA measurements of σ,
oscillation probability measurement could be limited by systematics!

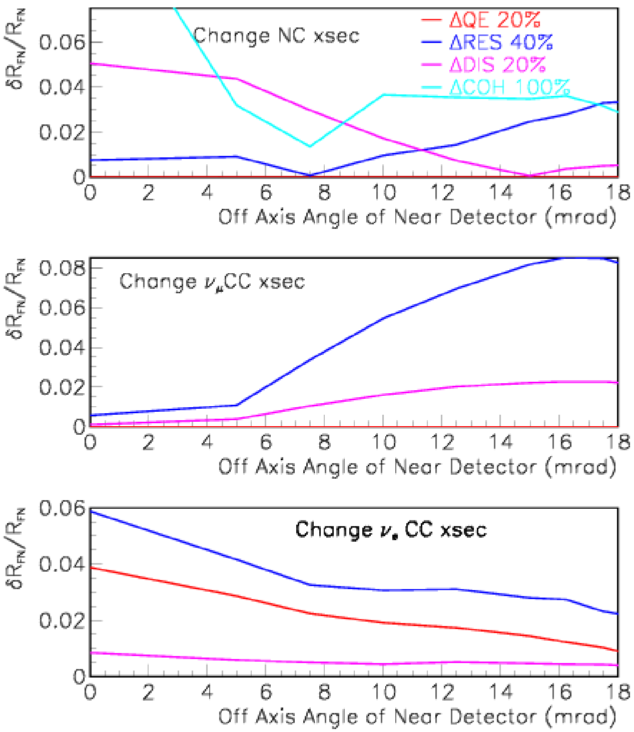
Summary

- MINERνA brings together the expertise of the HEP and NP communities to address the challenges of low-energy ν-A physics.
- MINERνA will accumulate significantly more events in important exclusive channels across a wide E_ν range than currently available.
- MINERνA will enable a systematic study of nuclear effects in ν-A interactions, known to be different than well-studied e-A channels.
- MINERνA results will dramatically improve the systematic errors of current and future neutrino oscillation experiments.

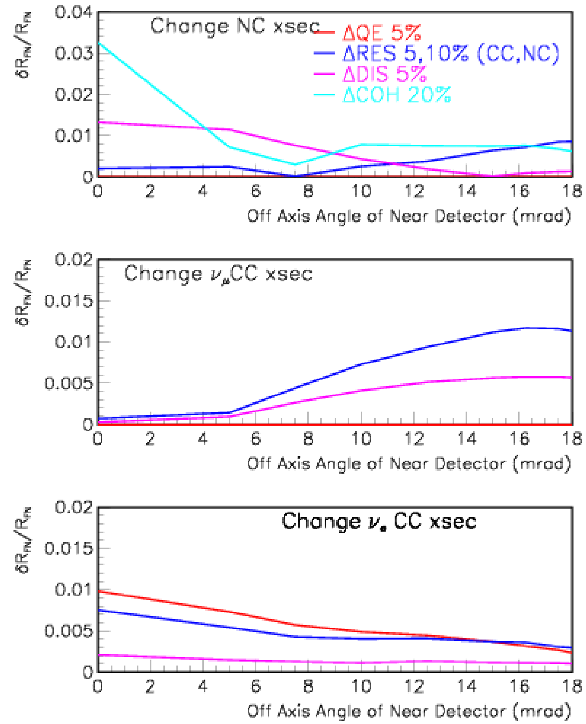
Backup Slides

How MINERνA Helps NovA Background Predictions

Assume Energy Dependence Perfectly known….vary σ levels



Same study, but with MINERνA precision



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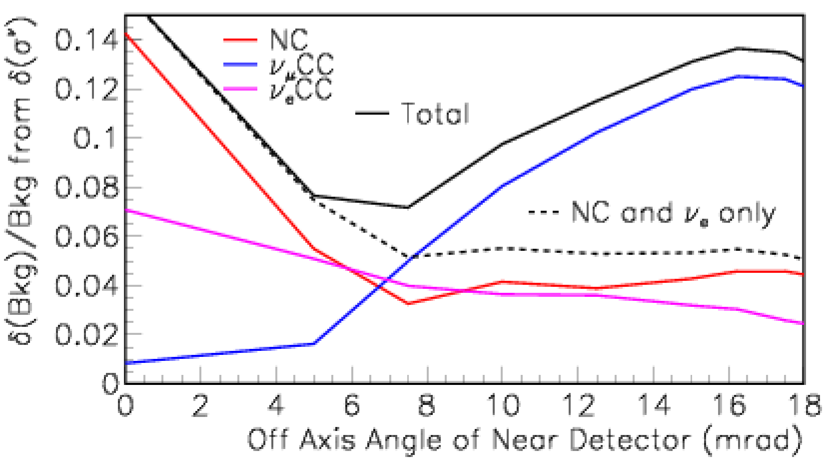
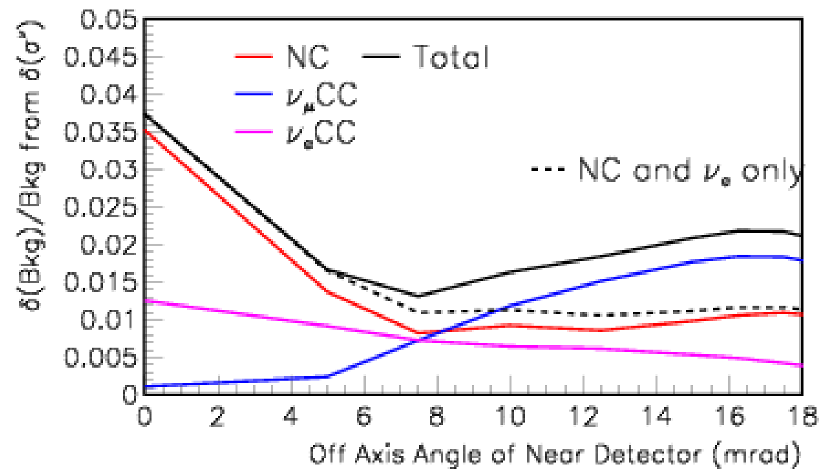




With MINERνA measurements of σ,
decrease fractional error on background prediction again by a factor of FOUR

Strange and Charm Particle Production

- Theory: Initial attempts at a predictive phenomenology stalled in the 70's due to lack of constraining data.
- MINERνA will focus on exclusive channel strange particle production - fully reconstructed events (small fraction of total events) but still.
- **Important for background calculations of nucleon decay experiments**
- With extended ν running could study single hyperon production to greatly extend form factor analyses
- New measurements of charm production near threshold which will improve the determination of the charm-quark effective mass.

Existing Strange Particle Production

Gargamelle-PS - **15** Λ events. FNAL - ≈ 100 events

ZGS - 7 events BNL - 8 events

Larger NOMAD **inclusive** sample expected

MINERνA Exclusive States

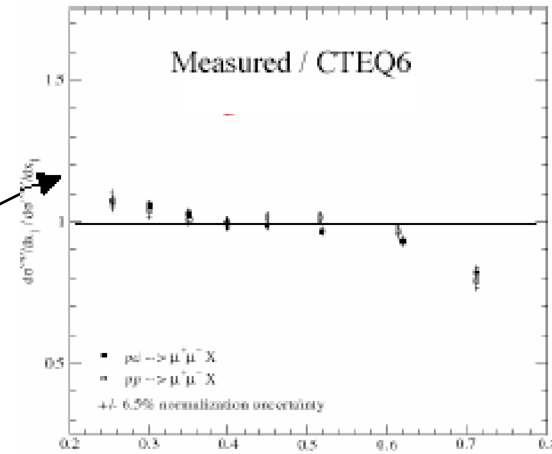
100x earlier samples

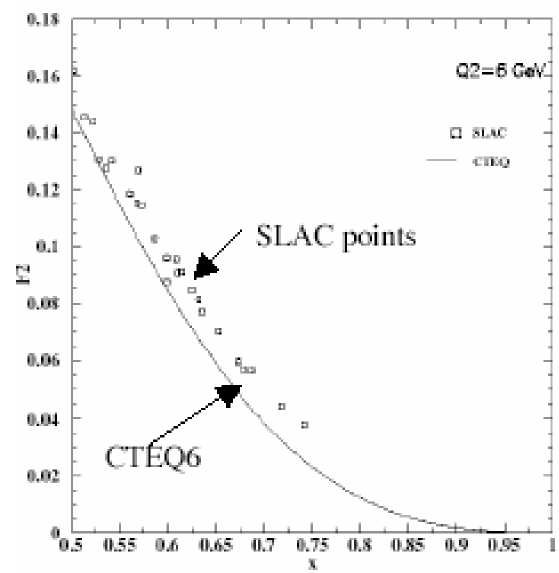
3 tons and 4 years

$\Delta S = 0$	
$\mu^- K^+ \Lambda^0$	10.5 K
$\mu^- \pi^0 K^+ \Lambda^0$	9.5 K
$\mu^- \pi^+ K^0 \Lambda^0$	6.5 K
$\mu^- K^- K^+ p$	5.0 K
$\mu^- K^0 K^+ \pi^0 p$	1.5 K
$\Delta S = 1$	
$\mu^- K^+ p$	16.0 K
$\mu^- K^0 p$	2.5 K
$\mu^- \pi^+ K^{0n}$	2.0 K
$\Delta S = 0$ - Neutral Current	
$\nu K^+ \Lambda^0$	3.5 K
$\nu K^0 \Lambda^0$	1.0 K
$\nu K^0 \Lambda^0$	3.0 K

High-x_{Bj} Parton Distribution Functions

- The particular case of what is happening at high- x_{Bj} is currently a bit of controversial with indications that current global results are not correct
- Drell-Yan production results (E-866) may indicate that high-x_{Bj} (valence) quarks OVERESTIMATED.
- A Jlab analysis of Jlab and SLAC high x DIS indicate high-x_{Bj} quarks UNDERESTIMATED
- CTEQ / MINERνA working group to investigate high - x_{Bj} region.
- MINERνA will have over 1.2 M DIS events to study high - x_{Bj} Close examination of the non-PQCD and pQCD transition region, in context of quark-hadron duality, with axial-vector probe.

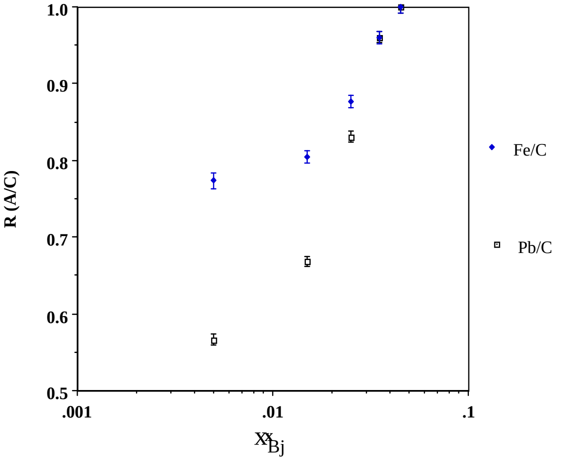




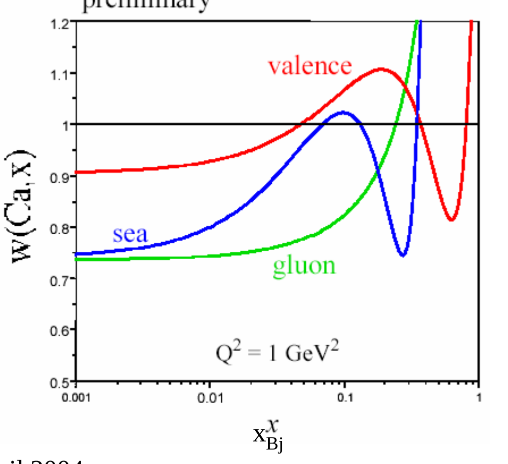
Nuclear Effects

- **Modified Interaction Probabilities**
  - Shadowing Region ($x_{Bj} < 0.1$): Expect a difference in comparison to e/μ - nucleus results due to axial-vector current and quark-flavor dependent nuclear effects.
  - EMC-effect ($0.2 < x_{Bj} < 0.7$): depends on explanation of the effect
  - Fermi Motion Effect ($x_{Bj} > 0.7$): should be the same as e-nucleus scattering
  - With sufficient $\bar{\nu}$: measure flavor dependent effects.
- NC/CC off C, Fe and Pb
  - Over 100 K CC and 30 K NC with $E_H > 5$ GeV on Fe and Pb, times 3 for Carbon.

S. Kulagin prediction for shadowing region

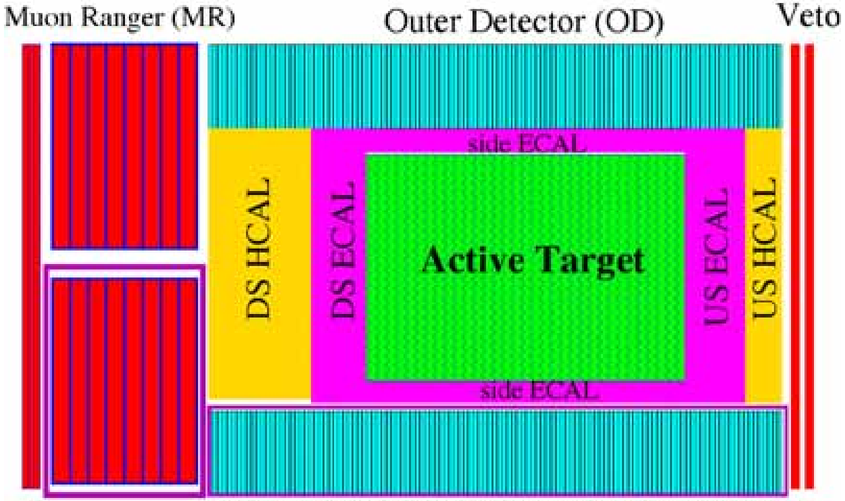


Kumano fit for flavor-dependent effects



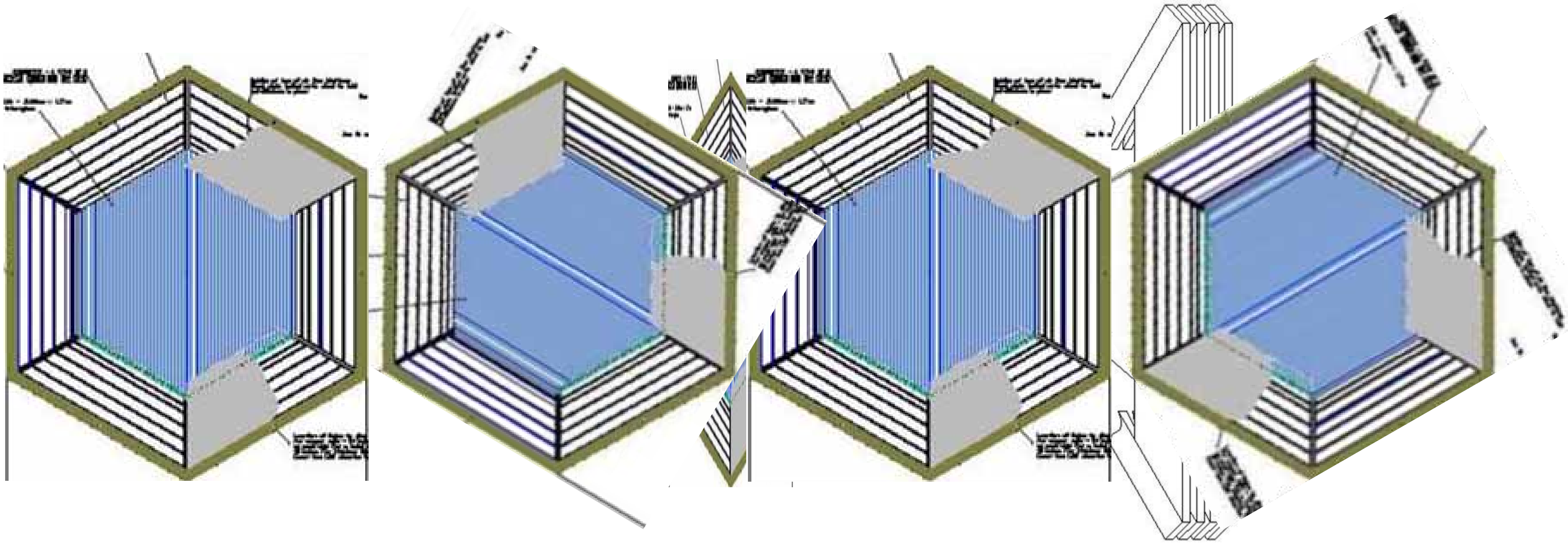
Modular Design

- a necessary part of installation in NuMI near hall is that detector should be constructed in thin modules
  - each module consists of *four planes* of active inner detector, absorbers and outer detector
- flexibility in design
  - MINERνA can run stand-alone
  - or can use MINOS as long muon catcher



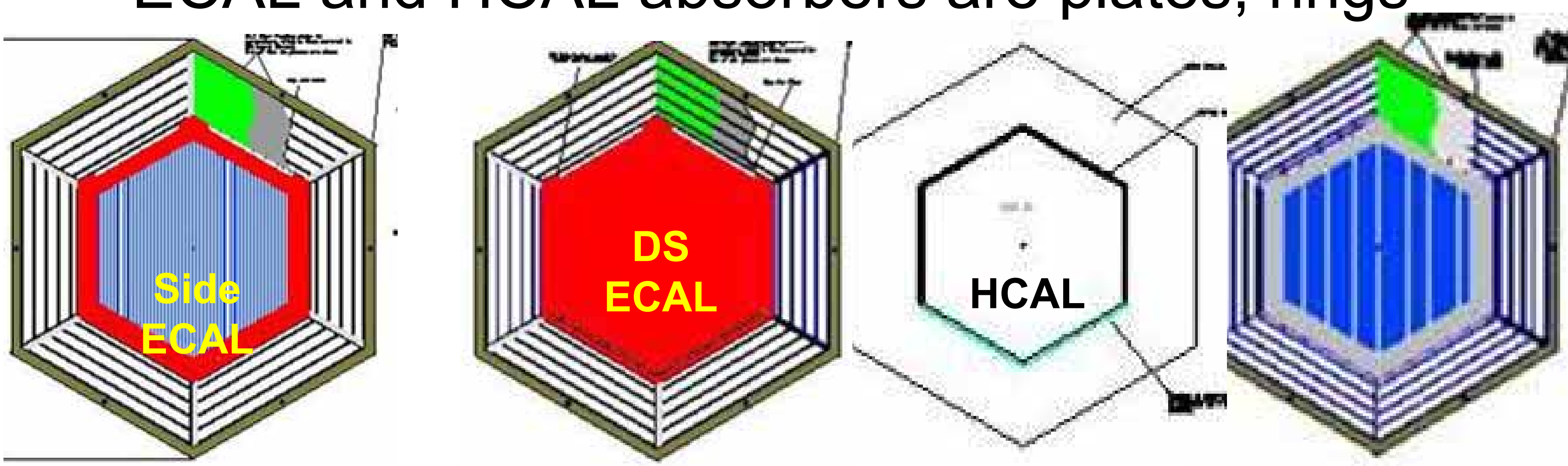
Active Target Module

- Rotate 60º to get U,V views
  - X+U+X+V make a module, bolted together
  - module is unit of construction and installation



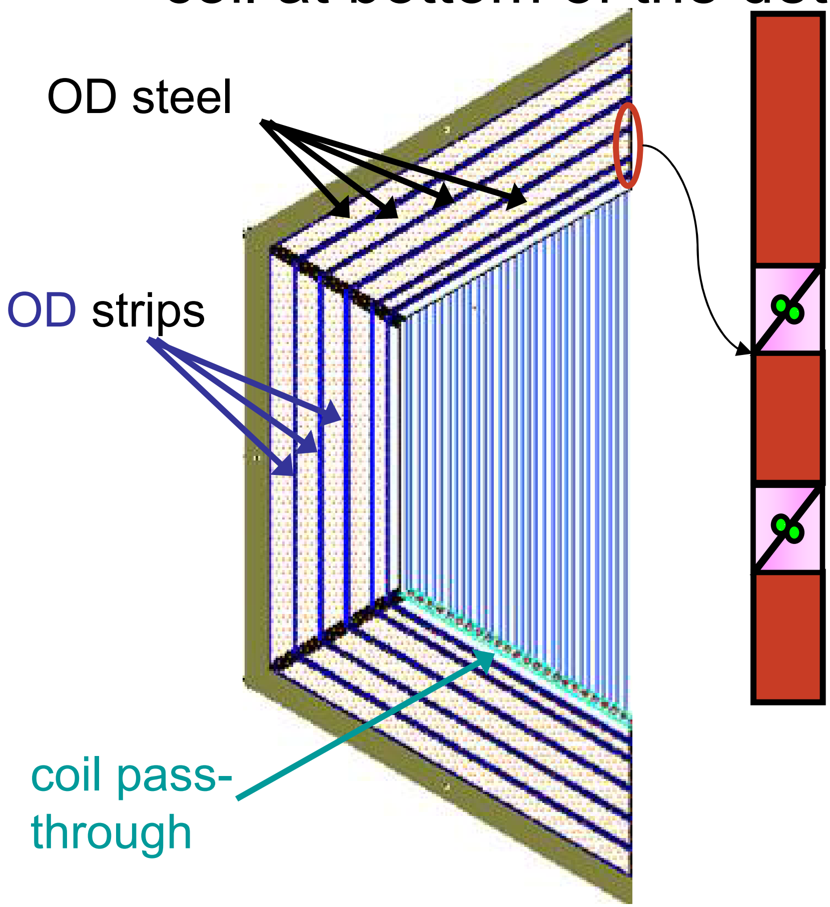
Calorimeters

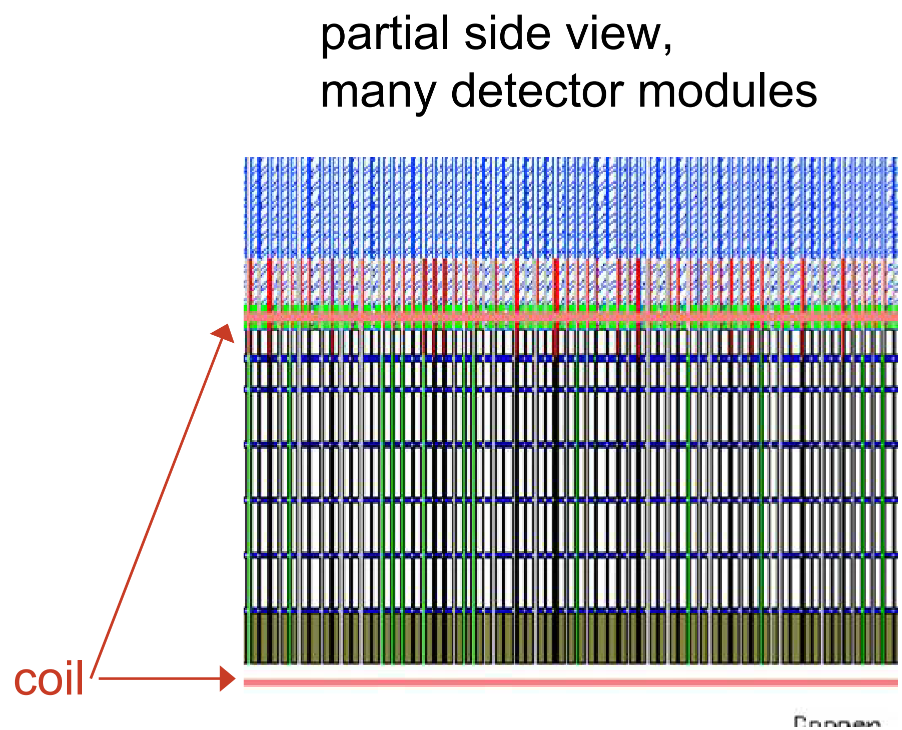
- Three types of calorimeters in MINERνA
  - ECAL: between each sampling plane, 1/16” Pb laminated with 10mil stainless ($X_0/3$)
  - HCAL: between each sampling plane, 1” steel ($\lambda_0/6$)
  - OD: 4” and 2” steel between radial sampling layers
- ECAL and HCAL absorbers are plates, rings



Calorimeters (cont'd)

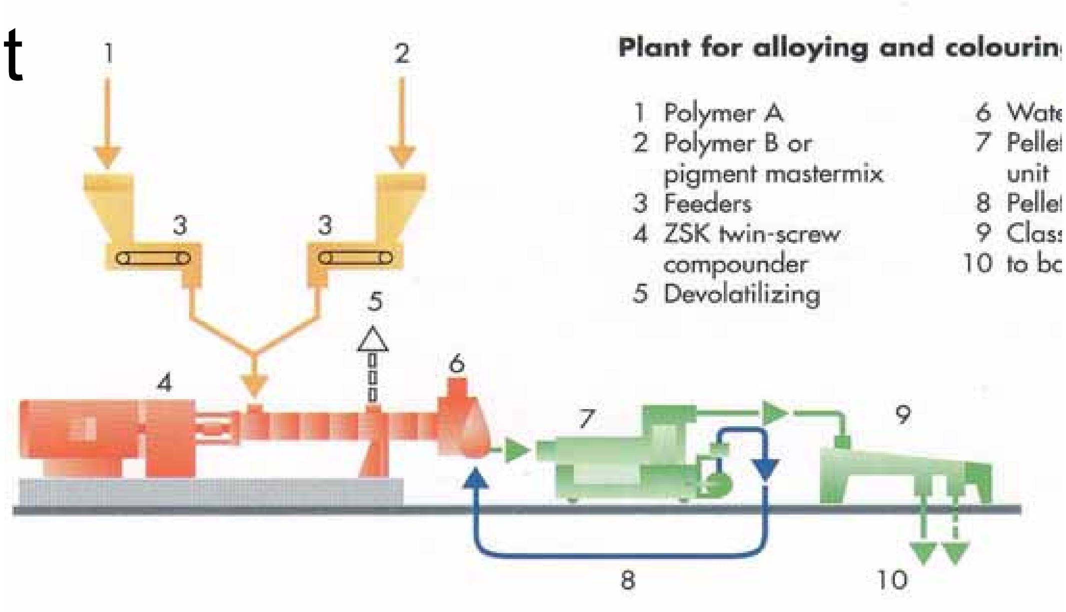
- OD: 4" and 2" steel between radial sampling layers
  - coil at bottom of the detector provides field in steel





Extruding Scintillator

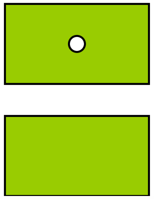
- Process is inline continuous extrusion
  - improvement over batch processing (MINOS)



- Tremendous capacity at Lab 5
  - the 18 tons of MINERνA in < 2 months, including startup and shutdown time

Extruding Scintillator (cont'd)

- Design of the die in order to achieve the desired scintillator profile
  - collaboration with NIU Mech. E. department (Kostic and Kim)



e 16: Exploded view of whole die (Full shade model)

2x1cm rect. die developed at NIU for Lab 5

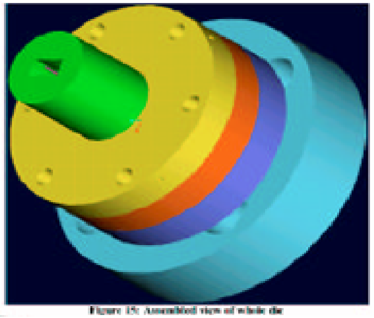
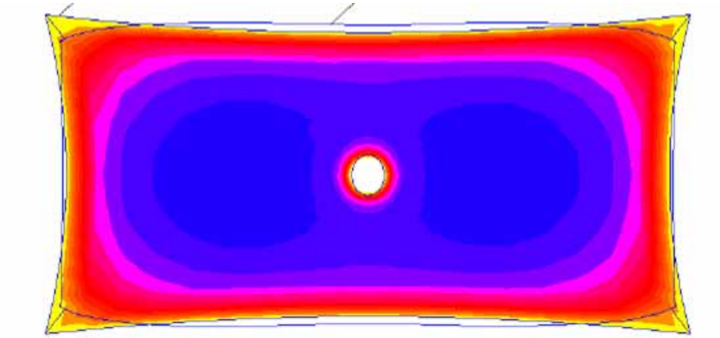


Figure 15: Assembled view of whole die

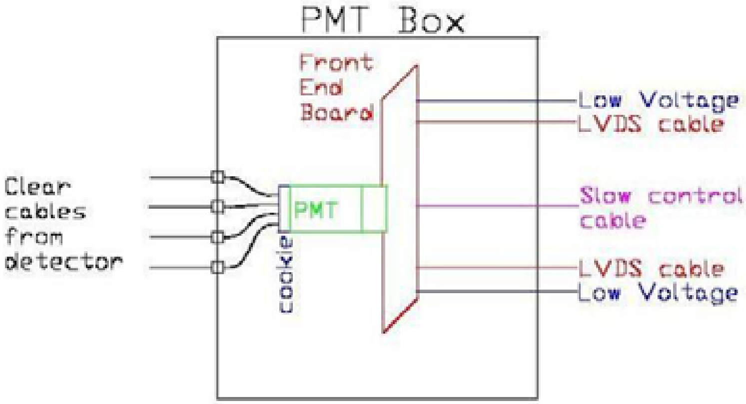
simulation of performance (design tool)

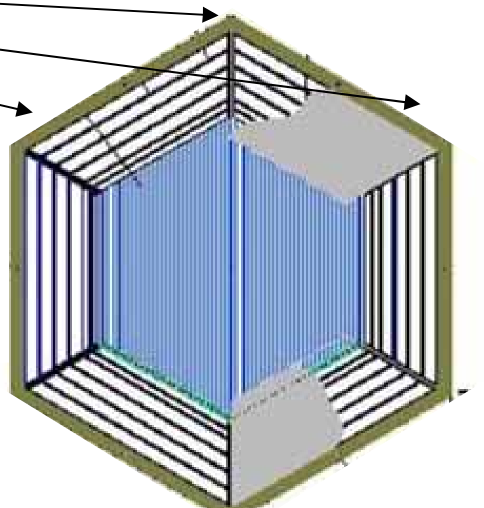


Die cross section and Extrudate Profile

PMT Boxes

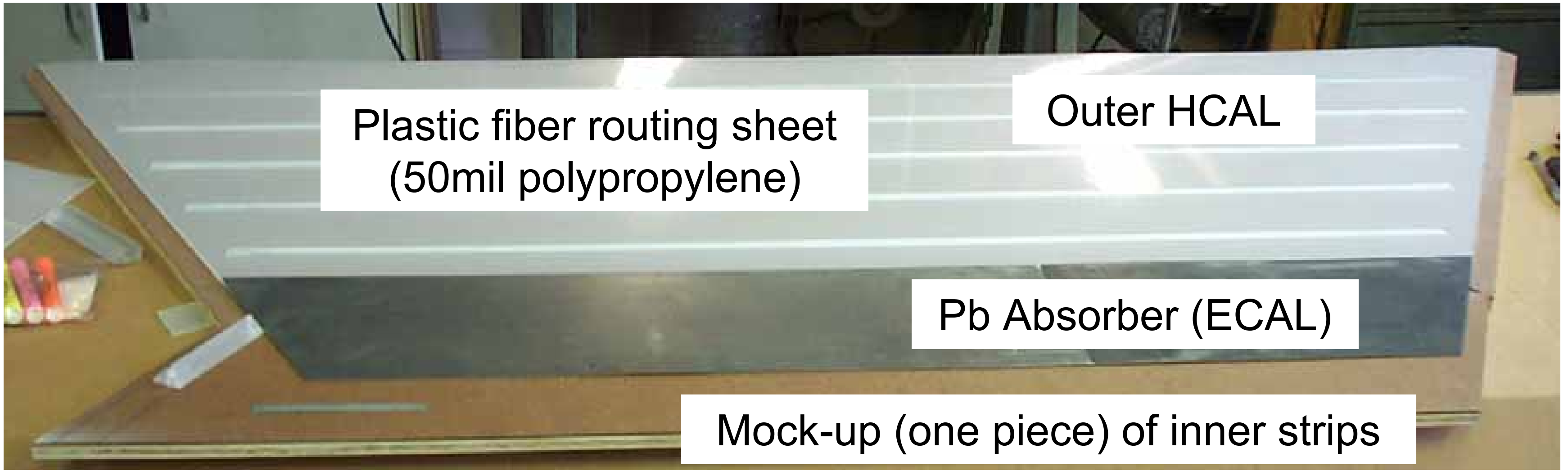
- Design is similar to MINOS MUX boxes
  - but no MUX!
- Mount on detector
  - minimizes clear fiber length





Fiber Routing

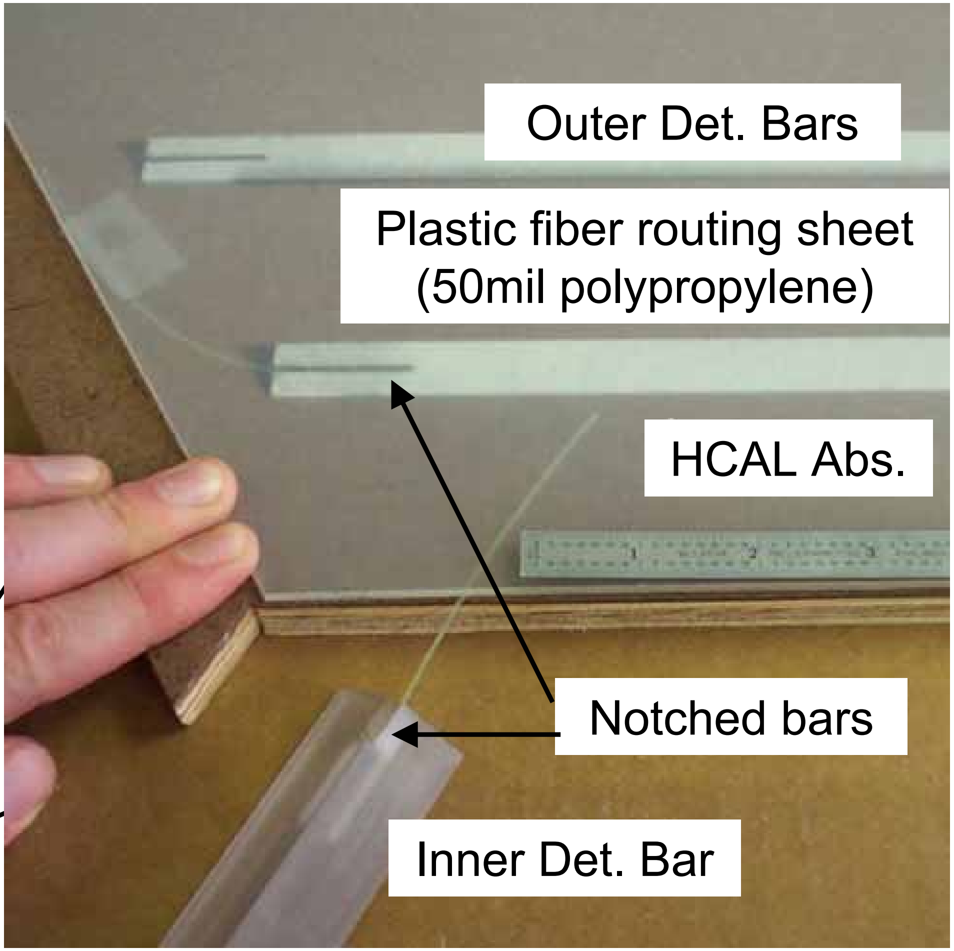
- Downside of design: getting fibers from inner detector to outside is complicated
  - built a 1/6 hexagon prototype to study (Rochester)



2 meters

Fiber Routing (cont'd)

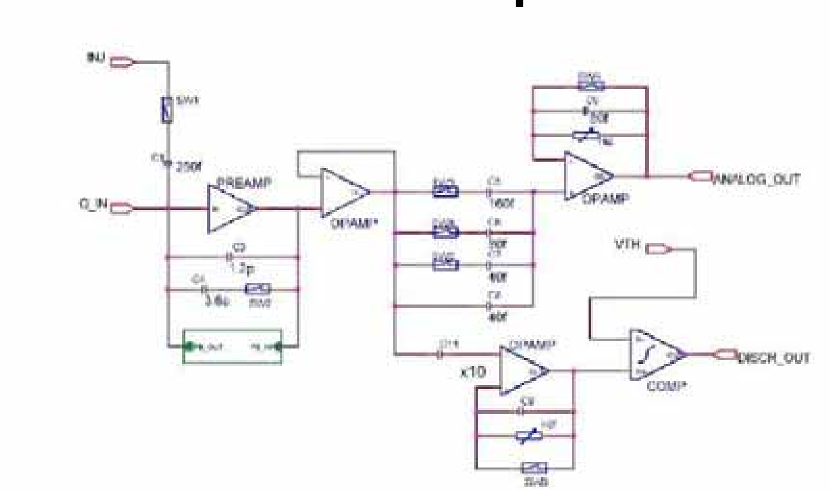
- Fibers are not infinitely flexible
  - but must route outer and inner detector fibers around the absorber/frame

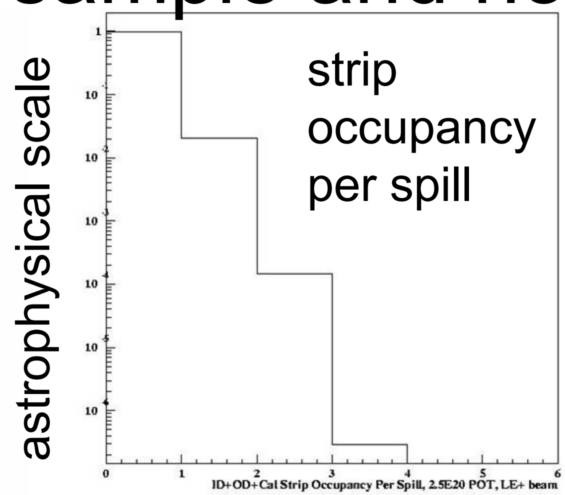


fibers must bend up (out of plane) and to outside of detector

Front-End Electronics

- FE Readout Based on existing TriP ASIC
  - builds on FNAL work. existing submission “free”.
  - ADC (dual range) plus few ns resolution timing
- TriP ASIC provides sample and hold slices





  - four-sample mode works on bench; this is our default
  - each time over threshold also recorded in spill

Electronics / Vertical Slice Test

Phase 1: Testing the TriP Chip

Test board being designed by P. Rubinov (PPD/EE); piggy back on D0 work

Reads out 16 channels of a MINOS M64 in a spare MINOS PMT box (coming from MINOS CalDet)

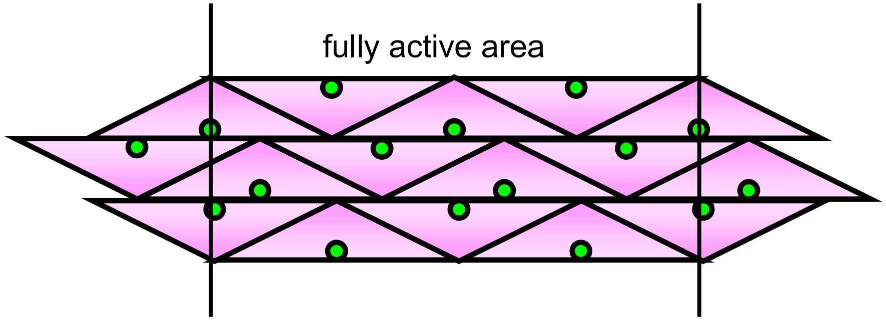
Questions:

1. Noise and signal when integrating over 10 μs.
2. Test self-triggering and external triggering mode for storing charge.
3. Test the dynamic range (2 TriP Channels / PMT channel)
4. Procedure to get timing from the TriP chip.

Early summer

Phase 2: Test our full system

Build a small tracking array in the new muon lab using strips and fibers of the proposed design and the readout system from Phase 1.
Use CR and β sources.



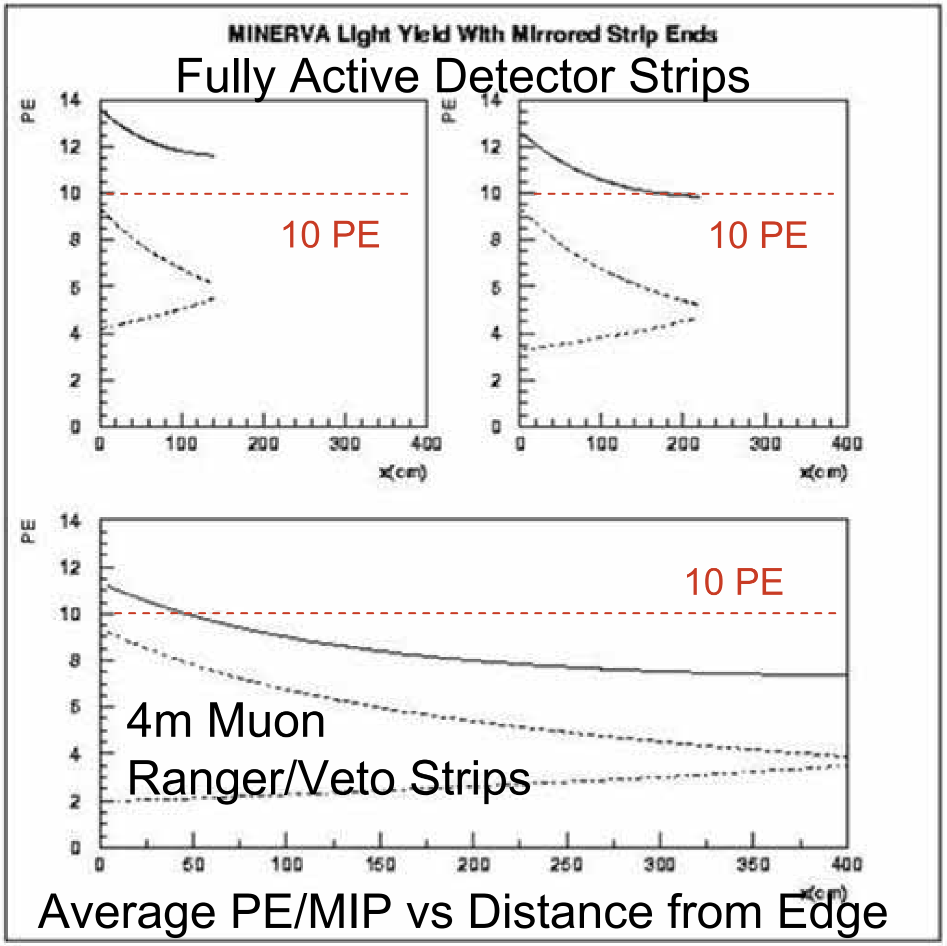
Questions:

1. Light yield – does it match our expectations?
2. Spatial resolution via light sharing in a plane
3. Timing
4. Uniformity

Late summer

Light Yield

- Critical question:
  does light yield allow for low quantum efficiency photosensor?
- Study: use MINOS light MC, *normalized to MINOS results*, MINERνA strips
- Need roughly 5-7 PEs for reconstruction
- Must mirror fibers!

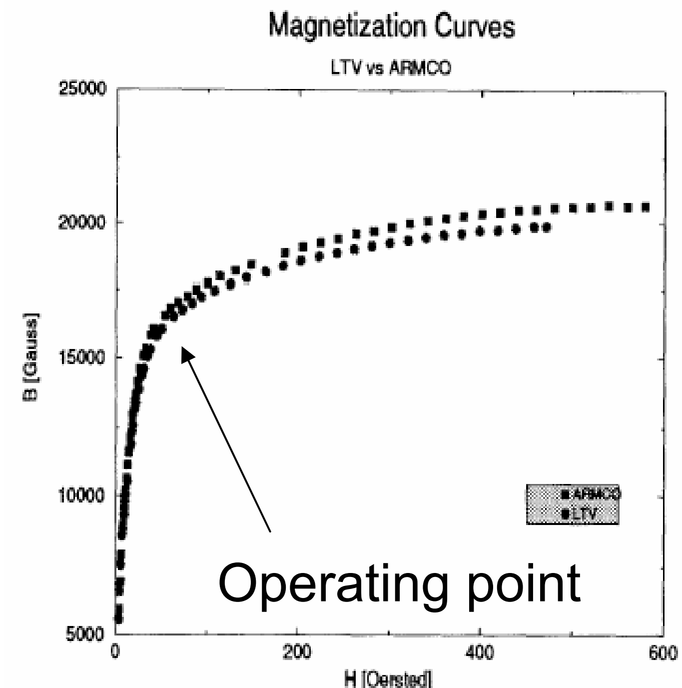


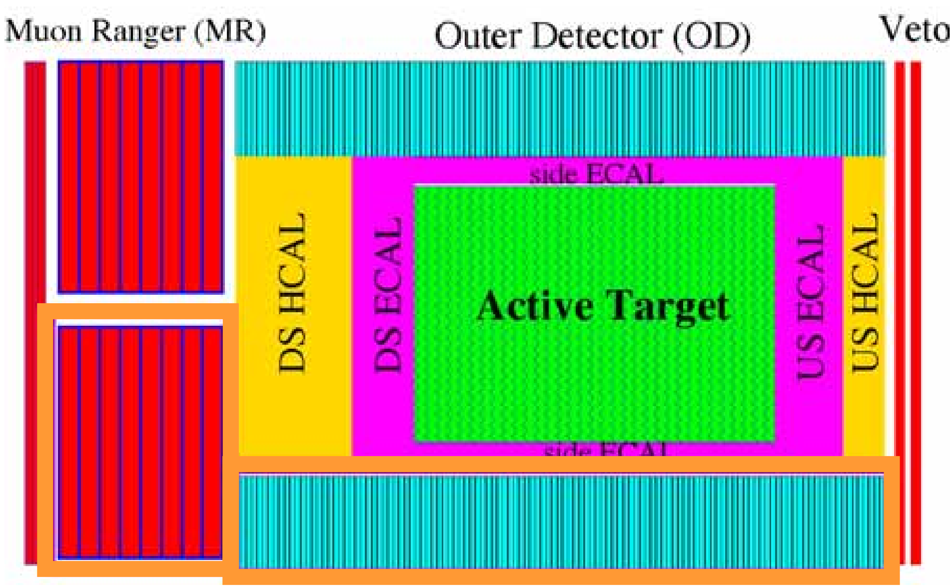
Fiber Processing

- Mirrors are clearly necessary
  – Lab 7 vacuum deposition facility (E. Hahn)
- Fibers (WLS, clear) bundled in connectors
  – working with DDK to develop an analog to MCP-10x series used in CDF plug upgrade
  – polishing also most effectively done at FNAL
- MRI proposal included costs for contracting FNAL effort through Universities

Magnet Coil

- Design: using ARMCO specialty steel (MINOS)
  - B of 1.6T, H ~ 30 Gauss

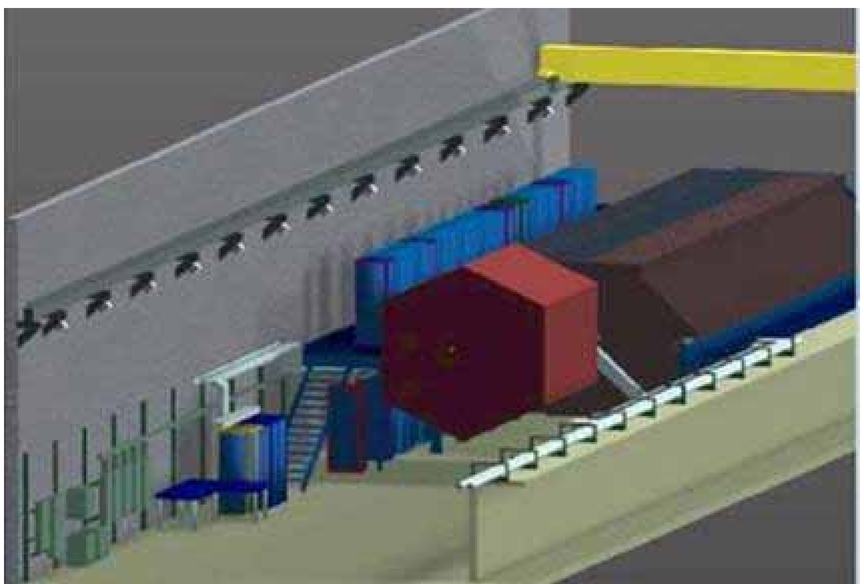


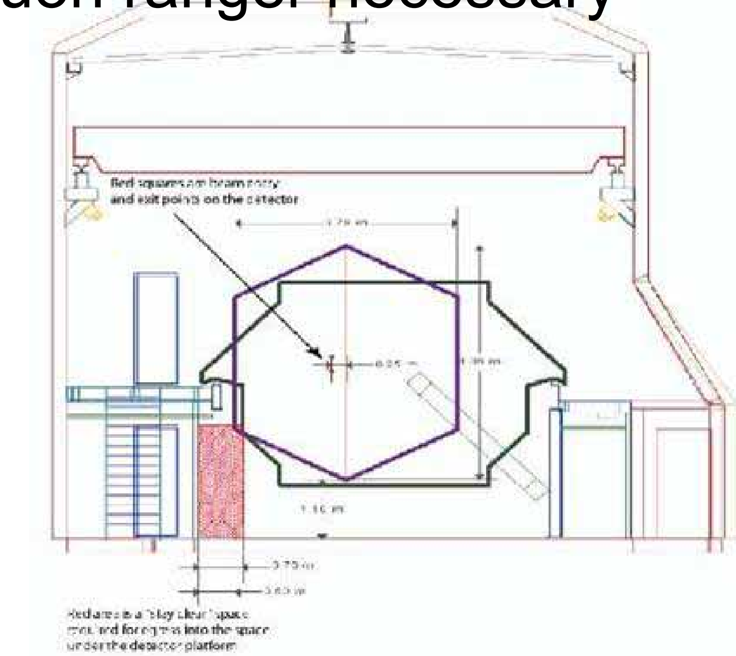


- 48 turn coils
  - 700 Amps in OD
  - 1200 Amps in MR
  - Assume $1cm^2$ wire (with hole for cooling)

Location in NuMI Near Hall

- MINERνA preferred initial running is as close to MINOS as possible
  - if this is not possible, we can run initially stand-alone elsewhere in the hall with muon ranger necessary





Utilities

- Quiet Power
  (3kW draw, add 175kVA transformer)
- Magnet Coil Power (240kW PEI supply)
- Cooling (c.f., MINOS 120kW)
  - Magnet coil heat loss expected: 30kW
  - Magnet power supply 10kW
  - Electronics: Rack 2kW, PMT boxes: 4kW

Summary of Design Tasks

Task	Division	Personnel	Time	Cost (k$)
Installation Procedure	PPD PPD	Mech. Eng. Drafting	4 months 2 months	45 14
Detector Stand for Near Hall (incl. Bookend and Drip protection)	PPD	Engineer Draftsman	5 weeks 5 weeks	13 8
Strongback for module transport	PPD	Mech. Eng. Drafting	1 month 1 month	11 7
Review of Module Assembly procedure	PPD	Mech. Eng.	1 month	11
Low Voltage System (5kW)	PPD	Elec. Eng.	3 months	33
TriP-chip front-end board	PPD	Elec. Eng.	12 months	130
Total				272

Fabrication

Modules would be assembled on site (NMS)

Task	Division	Personnel	Time	Cost (k$)
Detector Stand for Near Hall (incl. Bookend and Drip protection) Detector Stands Material (≈ 16 tons)	PPD	See table 4	See statement table 4	52 16
Installation Strongback Fabrication Strongback Material	PPD	Technicians	2 weeks	11 1.5
Strongback safety oversight	ES&H	Engineer	2 days	1
Module Assembly Prototyping	PPD	Safety oversight Welder Crane Operator	0.1FTEx 6 months 0.2FTEx 6 months 0.2FTE x 6 months	13 15 8
Module Assembly	PPD	Same at prototype	12 months	72
Internal Alignment	PPD	Survery Crew	1 week	3.5
Total				193

Installation Summary

Task	Division	Personnel	Time	Cost (k$)
Installation Manager	PPD	1 engineer	4 months	44
Bookend	PPD	2+1 Riggers	2 days	4
Transport Cart	PPD	2+1Riggers	1 day	2
Detector Stand	PPD	See Impact table 4	Table 4	52
Module Installation	PPD	2 + 1 riggers 2 technicians	7 weeks 7 weeks	77 22
Electronics rack	PPD	1 rigger	0.5day	0.7
PMT Boxes down shaft	PPD	1 rigger	0.5 day	0.7
PMT Boxes on Detector	Experimenters			-
Magnet Coil and Cooling	PPD	4 tech crew	6 weeks	70
Refurbish Magnet PS	PPD	Techs, riggers	1 week	22
Install Magnet PS	PPD	2 tech crew, riggers	1 week	12
Quiet Power Panel Boards Install M&S	PPD	Techs & electricians (2)	2-4 weeks	24 8
Accelerator Controls/GPS	AD			-
Possible Readout Platform Mod. M&S	PPD PPD	4 techs	3 days	1.2 8.7
Survey	PPD	Survey crew (3)	2 weeks	7
Safety Reviews	PPD	6 Safety officers (engineers)	1 week	60
Total				415

Detector Cost Summary

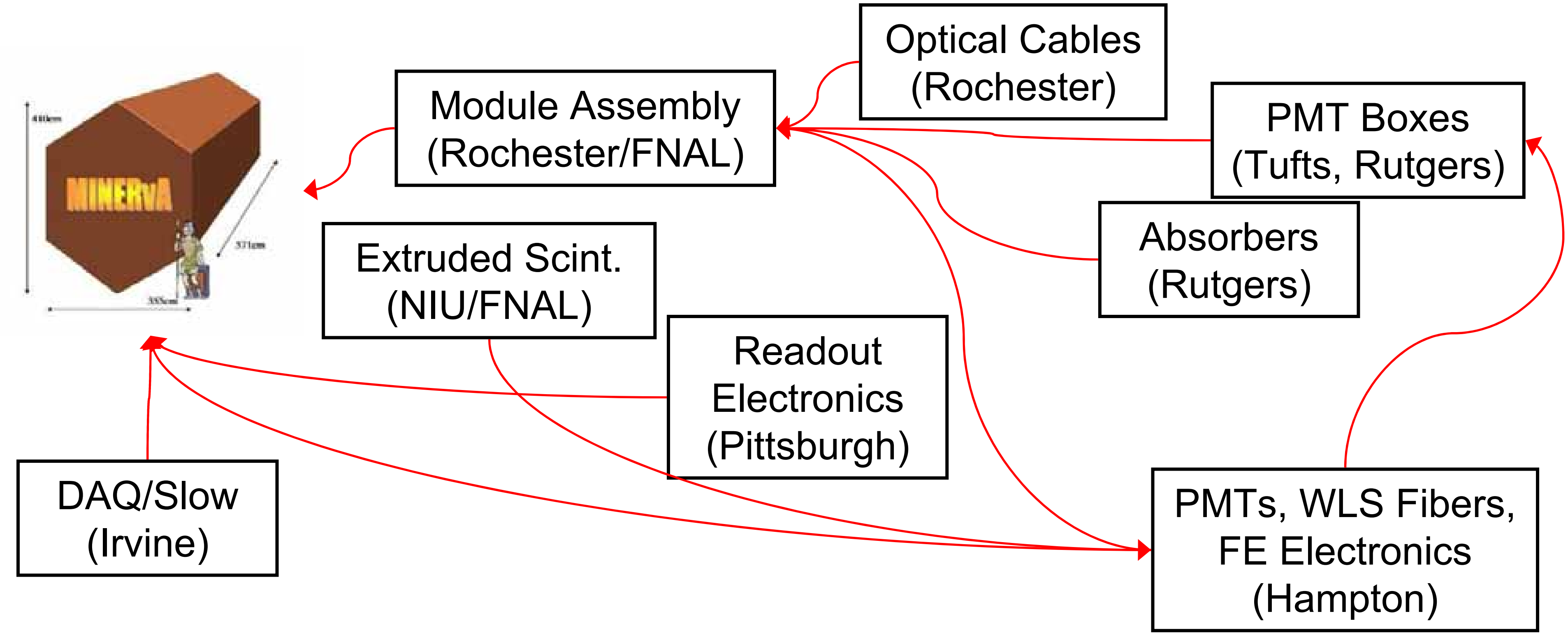
- Costs are primarily scaled from experience of MINERνA collaborators on CMS HCAL, MINOS
- $2.55M equipment (no F&A)
- $1.41M labor, EDIA
- $1.54M contingency (39% avg.)

	Cost (kUSD)			
Sub-Project	M&S (no F&A)	SWF (w/ F&A)	EDIA (w/ F&A)	Contingency (%)
Extruded Scintillator	151	12	30	78 (40%)
Fiber and Glue	262	n/a	n/a	52 (20%)
WLS Fiber Prep.	50	104	16	85 (50%)
Optical Cables	77	162	11	100 (40%)
Absorbers	310	67	32	122 (30%)
Module Assembly	11	473	53	268 (50%)
[redacted]				
MAPMT Testing	6	45	n/a	26 (50%)
PMT Box and Optics	278	95	51	212 (50%)
[redacted]				
Totals	2545	990	423	1537 (39%)

- Full project costs not updated since proposal
  - MRI exercise was consistent with this costing (ex: steel)

Construction Model

- Our goal is that detector construction be managed and carried out by University collaborators

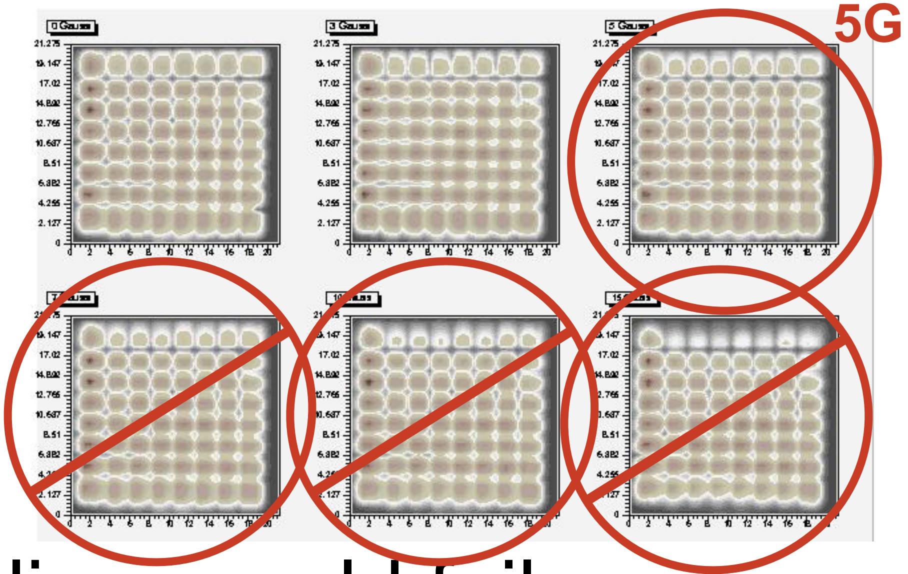


Known Technical Risks

- Light Yields
  - we are not swimming in light
  - problem may be exacerbated by need to use center hole with air coupling
  - *larger diameter fiber*
- Steel
  - have not located a vendor for MINOS quality magnetic steel
  - global steel costs have “gone mad”
  - *it’s just $$$, but may be significant*

Known Technical Risks (cont'd)

- Fringe Field at PMT
  - need to keep field at PMT to <5 Gauss
  - *increase shielding for optical boxes. $$$*



- TriP multiple time slices could fail
  - *fallback is to integrate over spill. Survivable.*

Schedule

- Schedule for MRI detector: ~20 months from start
  - MRI schedule is our only schedule exercise with “contingency”
- Scaling to full detector…
  - schedule dominated by module assembly
  - we believe that stretches from six months to twelve months
    - with larger crew
  - PMT boxes may also vie for critical path

Costing Methodology

- most of our costs could be scaled from similar construction products in MINOS or CMS HCAL where *MINERνA collaborators have hands-on experience*
  - FE electronics boards. TRiP bottoms-up costs were significantly lower than analogous MINOS board costs. Used MINOS
  - PMT box costs scaled from MINOS far MUX boxes
  - MINOS costs for most electronics infrastructure, LV, slow
  - Optical cable, connectors, fiber mirroring from CMS HCAL
  - Gluing, extrusion costs from MINOS
  - Absorber costs based on preliminary sketches from Rutgers machine shop
  - Fiber, MAPMTs quoted from vendors (Kurary, Hamamatsu)
- Contingency: 40-50%
  - except Rutgers shop (30%) and vendor quotes (20%)

Schedule Comments

- Schedule estimates are still tentative
  - assembly schedule is more difficult to scale from past projects than M&S costs
- Module assembly is most uncertainty
  - estimate ~6 months of prototyping and one year of assembly
  - need to improve model for assembly procedure
  - this is focus of EDIA work at Rochester
- PMT boxes
  - Tufts group has scaled from MINOS; should be OK.
- FE electronics
  - scaling from D0 TriP project is probably accurate. Need EDIA and prototyping now (underway, FNAL PPD/Rochester)
- Only obvious resource limit in critical path is ability to expend money at the start of the project for fixed costs and absorber M&S
  - and, of course, the flow of cash…