MINERνA II:
Detector,
Project
and Conclusions

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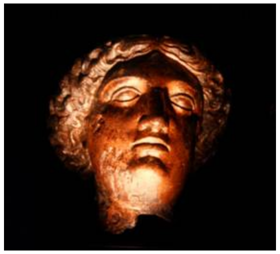
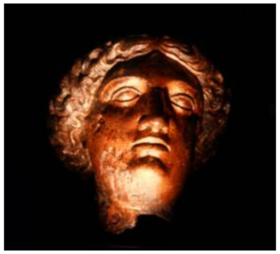
FNAL PAC
12 December 2003

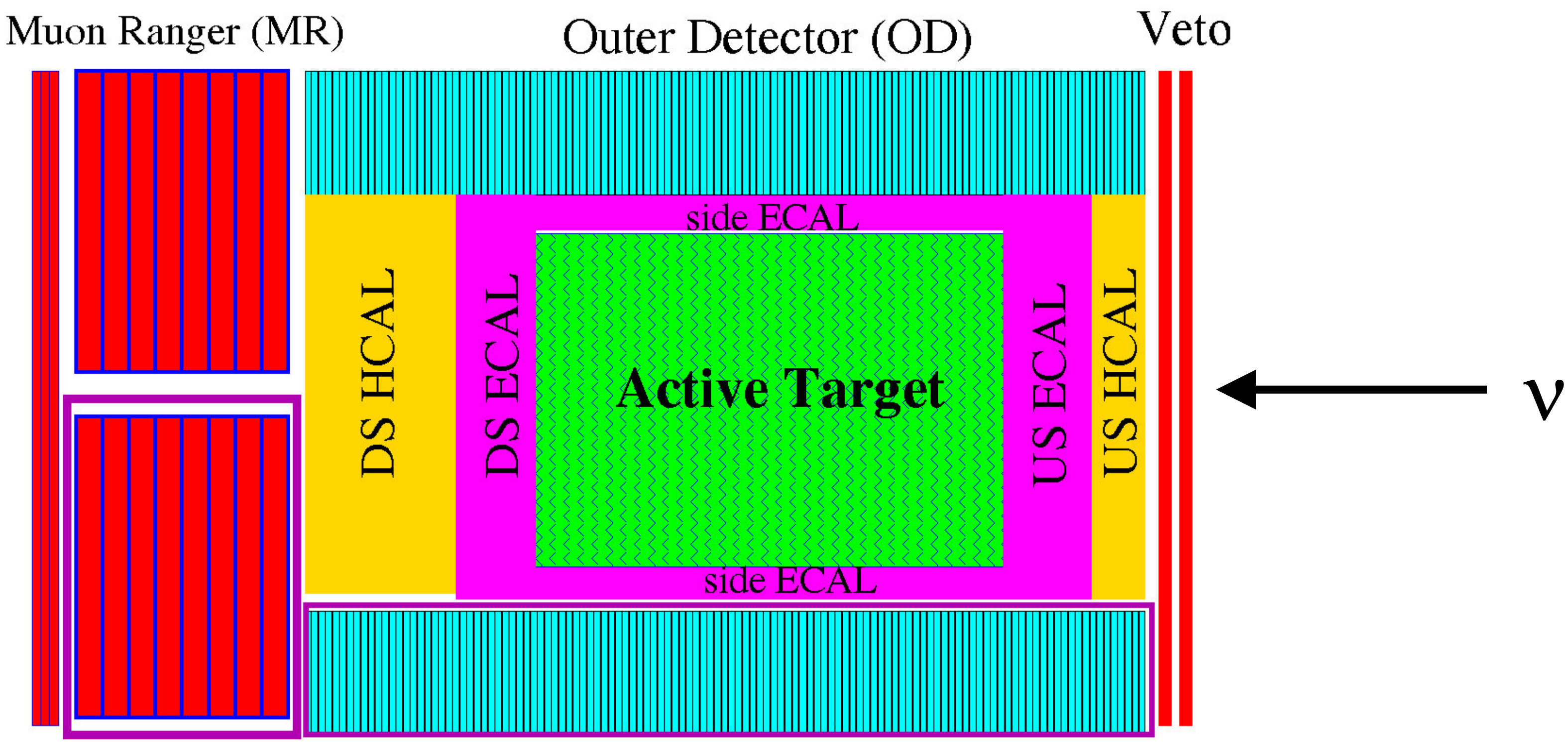
Goals of MINERνA Require…



- Identification and separation of exclusive final states
  - Quasi-elastic $\nu_\mu n \rightarrow \mu^- p$, $\nu_e n \rightarrow e^- p$
  - Single π^0, $\pi^\pm$ final states
  - Muon and electron energy measurement
- Must observe recoil protons
  - Important for $\nu n \rightarrow \mu^- p$, $\nu n \rightarrow \mu^- p \pi^0$, etc.
- π^0 , μ^- reconstruction. Hadronic energy
  - Adds a lot of mass. B-field for charge
- Nuclear targets (high A, Fe of interest for MINOS)

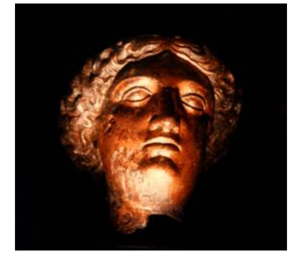
Detector Overview

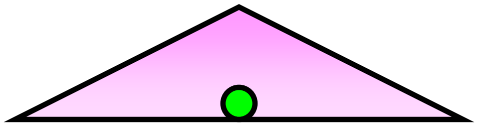




- Active target, surrounded by calorimeters
  - upstream calorimeters are Pb, Fe targets
- Magnetized side and downstream tracker/calorimeter

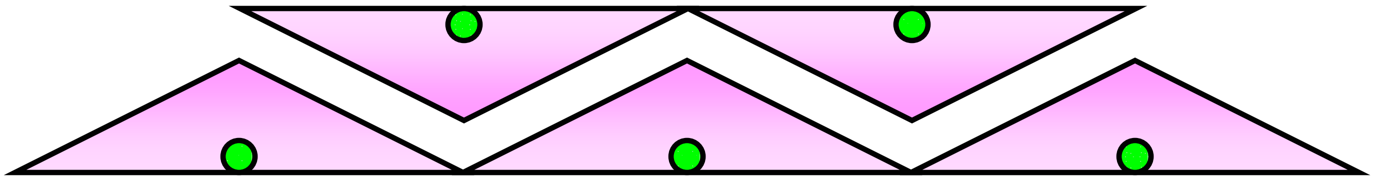
Fully-Active Target: Extruded Scintillator



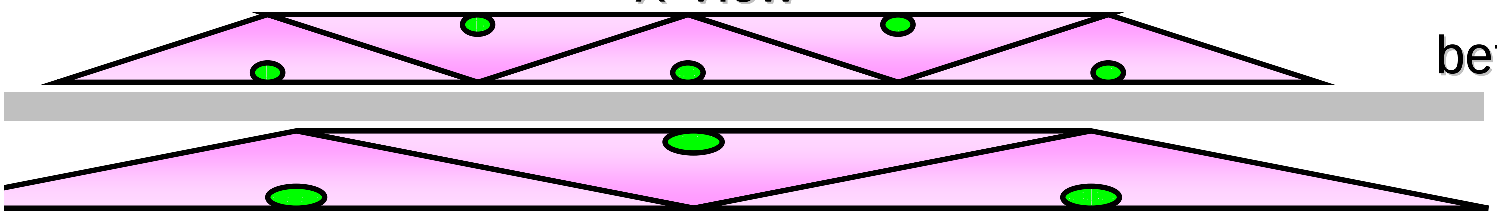


Basic element: 1.7x3.3cm triangular strips.
1.2mm WLS fiber readout in grove at bottom

Assemble into planes



X-View

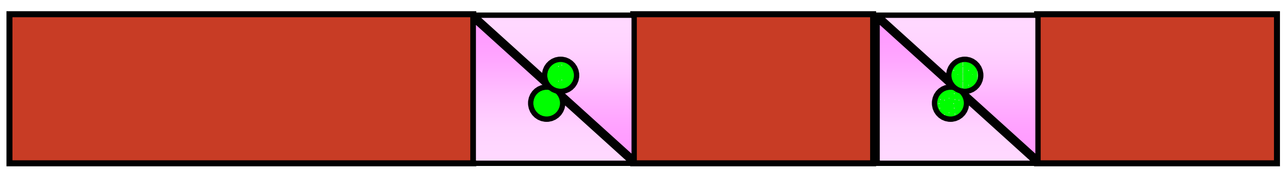


U/V-View

Absorbers between planes

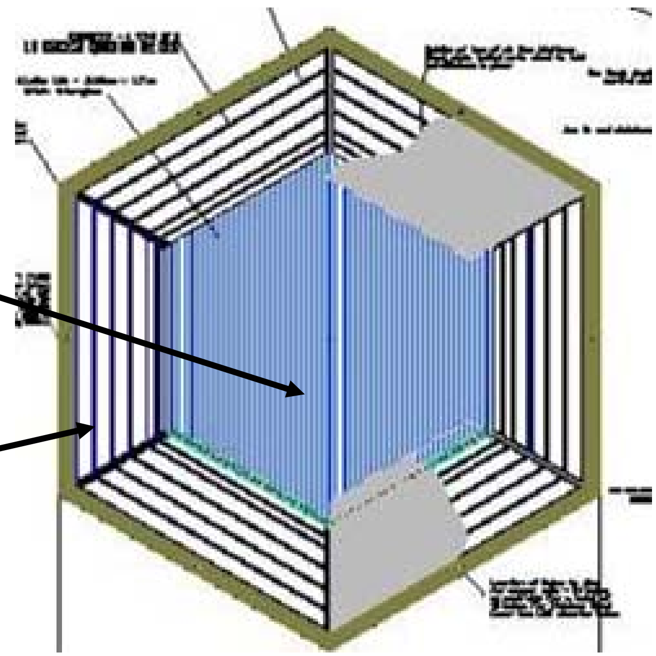
e.g., E- or H-CAL, nuclear targets

Or replace strips with absorber (outer detector)



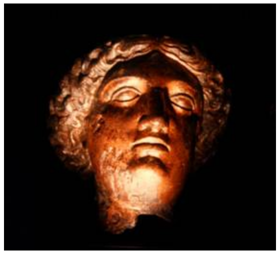
Active Target Module

- Planes of strips are hexagonal
  - rotate 60º to get U,V views
  - X+U+X+V make a module

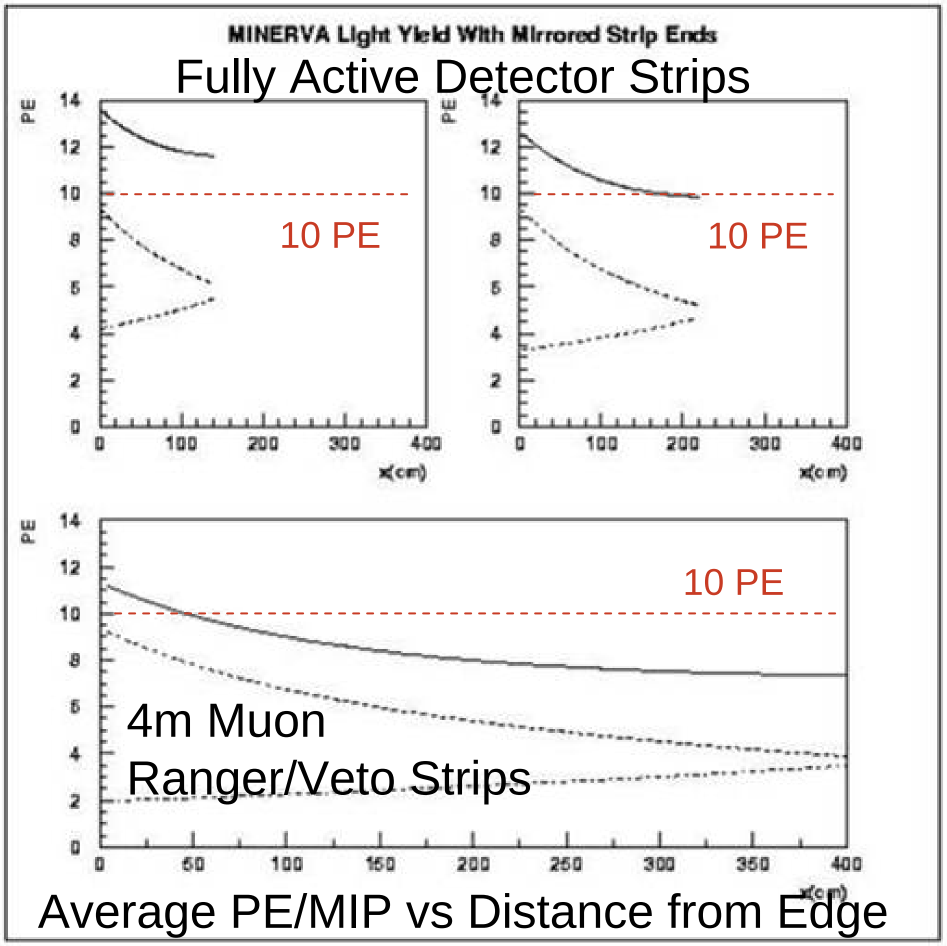


- More on construction, calorimeters later

Light Yield

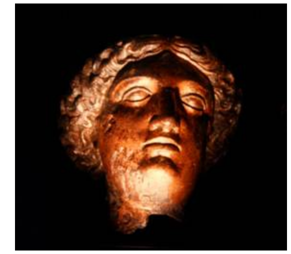


- Critical question: does light yield allow for low quantum efficiency photosensor?
- Study: use MINOS light MC, *normalized to MINOS results*, MINERνA strips
- Sufficient light, even for single-ended fiber readout, with MAPMT Quantum Efficiencies…

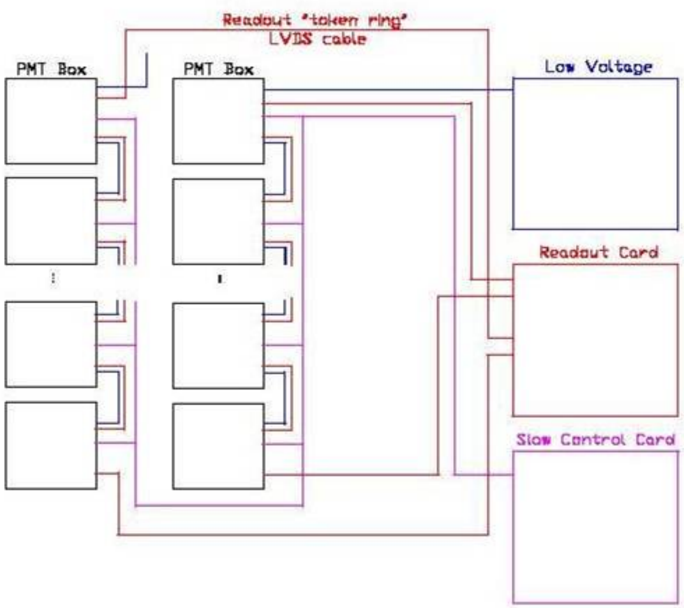


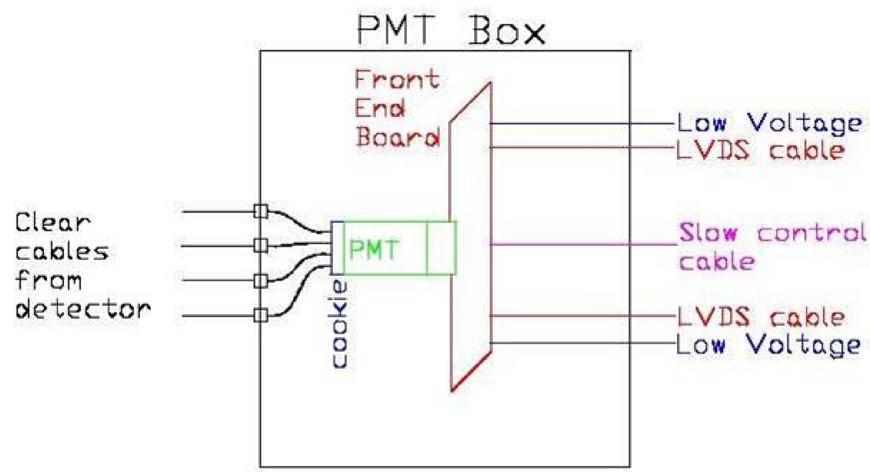
Electronics

(photosensors, electronics are cost drivers)



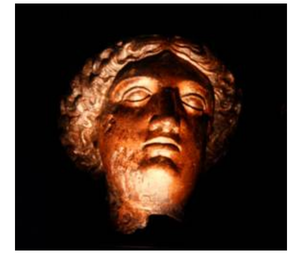
- FE Readout Based on existing TRiP ASIC
  - builds on FNAL investment. cost effective.
  - chips from this submission are “free” (no user currently)
  - ADC (dual range) plus few ns resolution timing

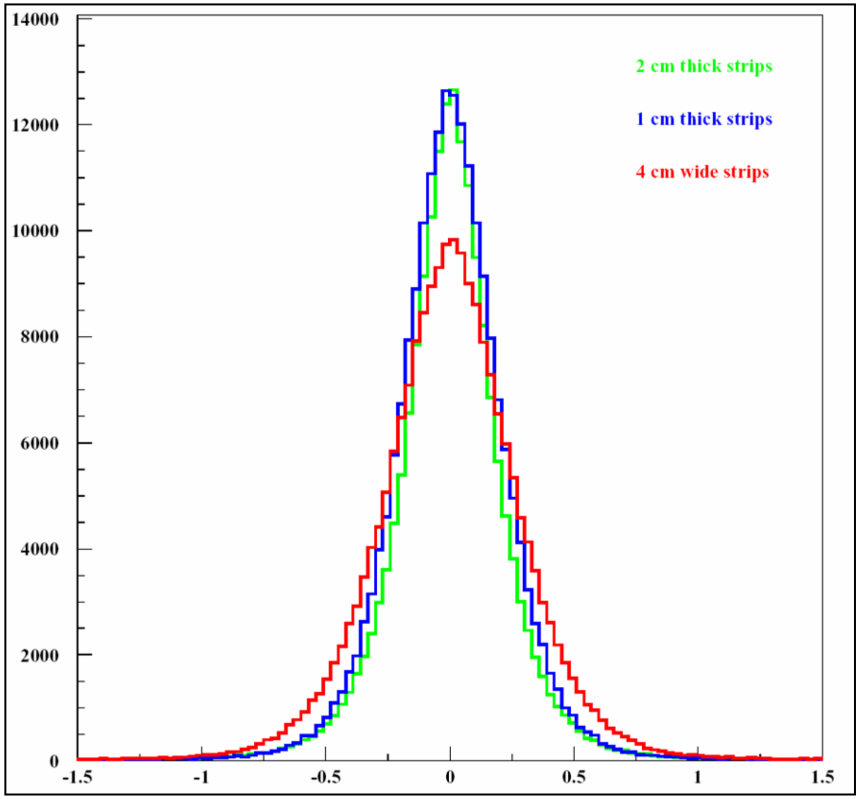




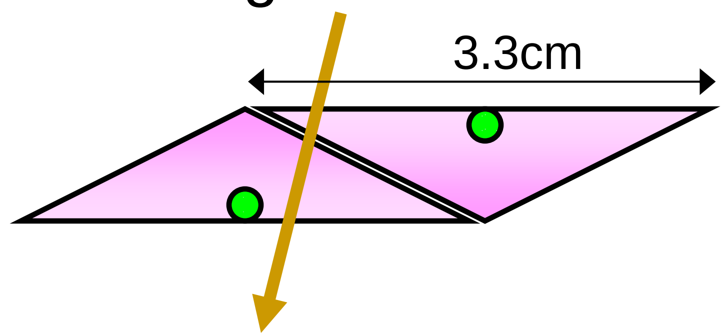
readout scheme by P. Rubinov, FNAL

Tracking in Active Target



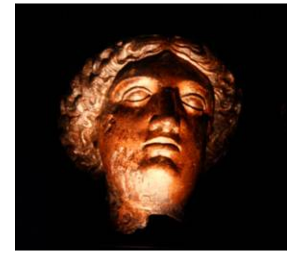


- Coordinate resolution from triangular geometry is excellent
  - ~2-3 mm in transverse direction from light sharing

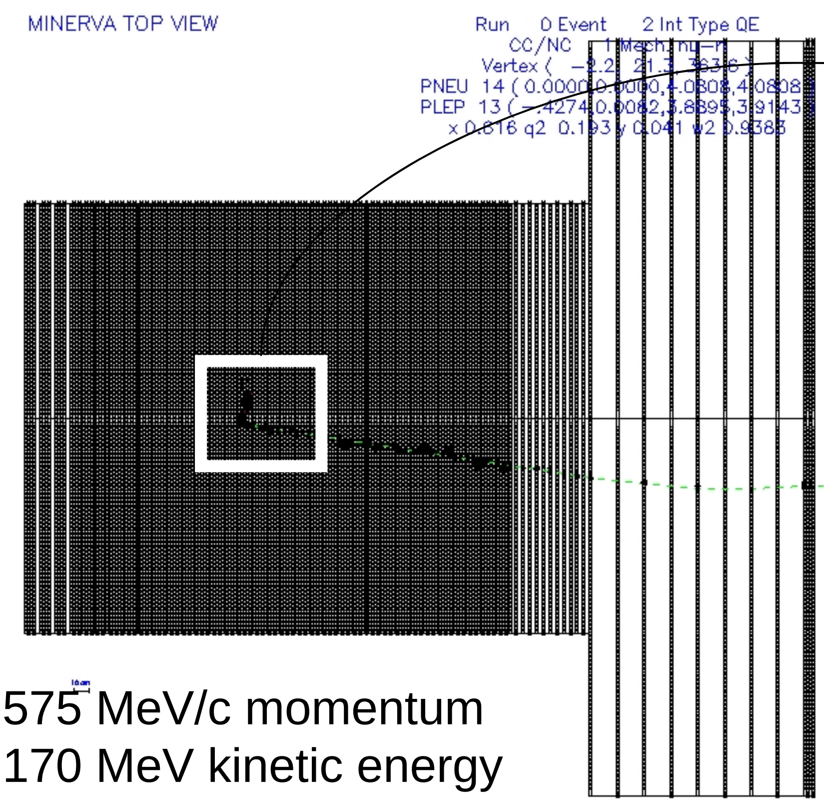


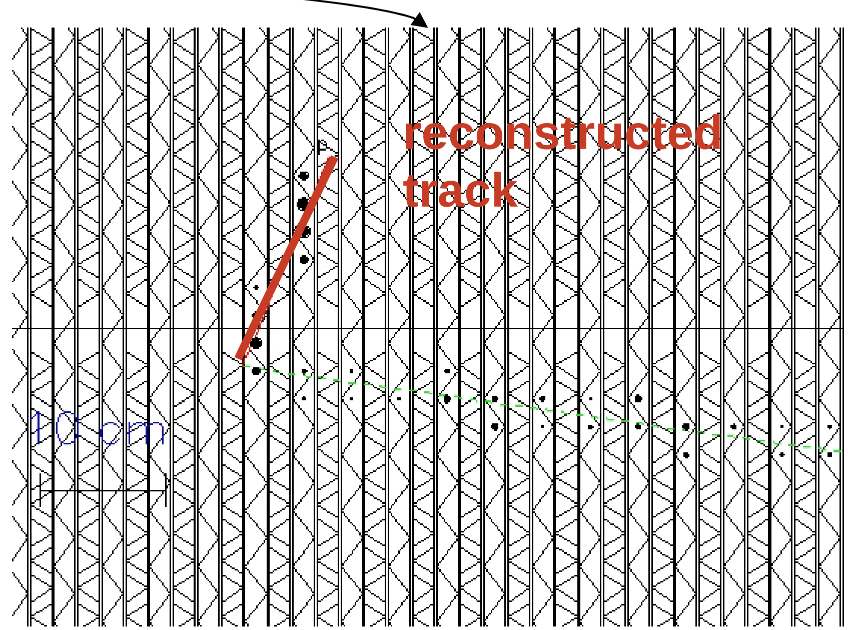
- technique pioneered by D0 upgrade pre-shower detector

Proton Reconstruction



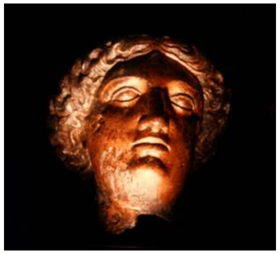
- Reminder: proton tracks from quasi-elastic events are typically short. Want sensitivity to p_p~500 MeV



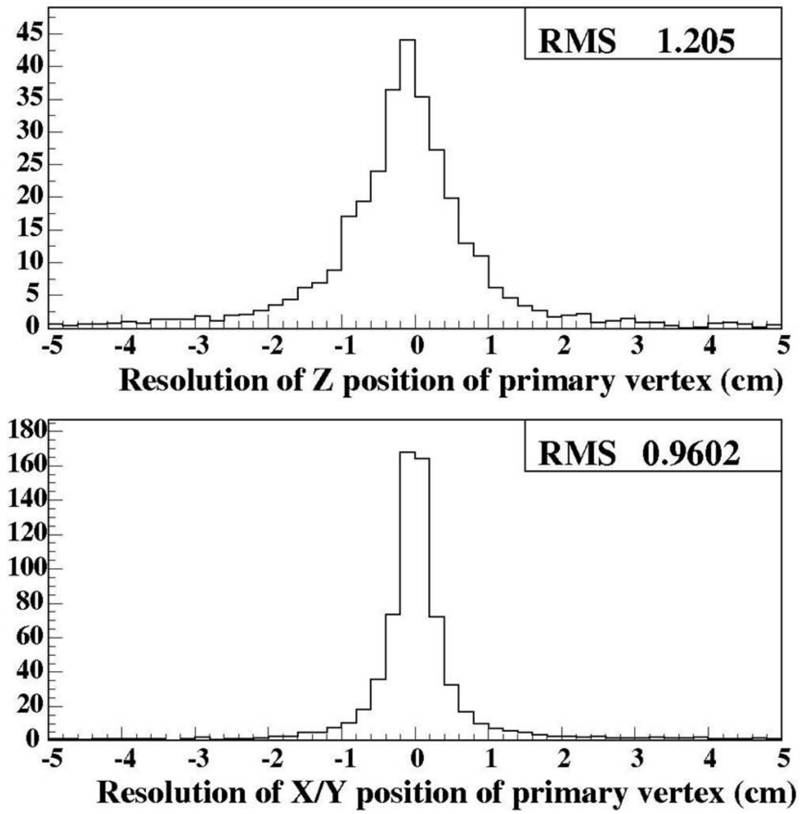


575 MeV/c momentum
170 MeV kinetic energy

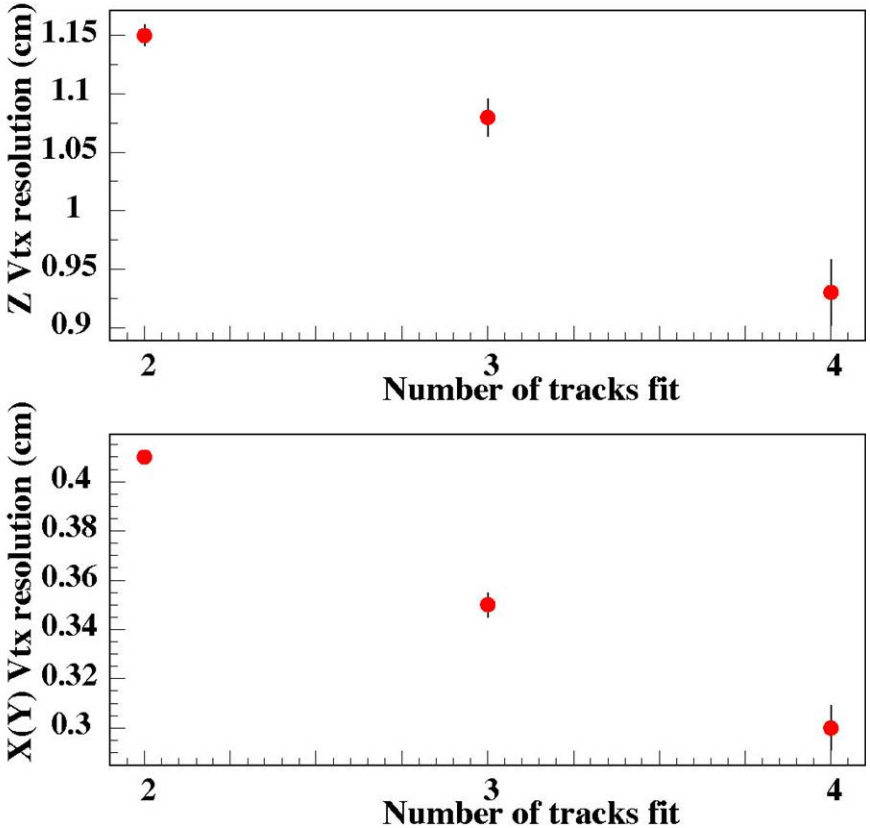
Performance: Vertex Reconstruction



- Excellent tracking resolution
  (results from full GEANT MC, Kalman filter track fitter)

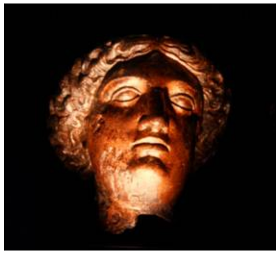


Two-track vertex resolution

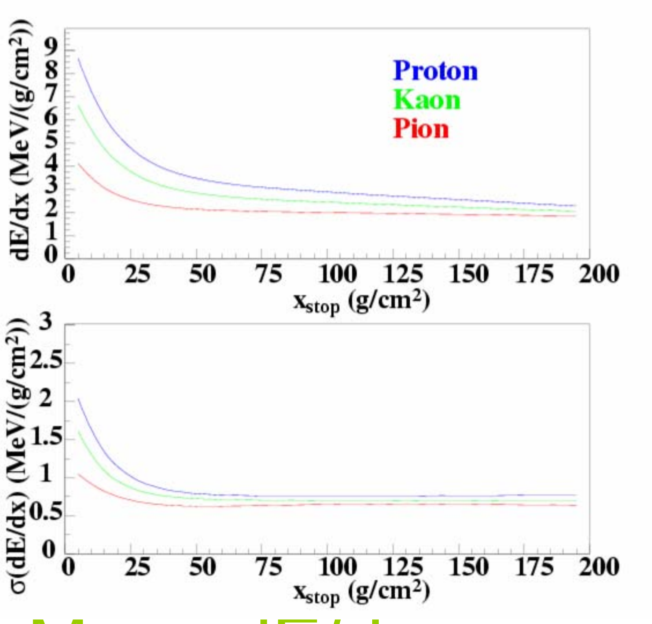


Resolution vs. multiplicity

Performance: Particle Identification

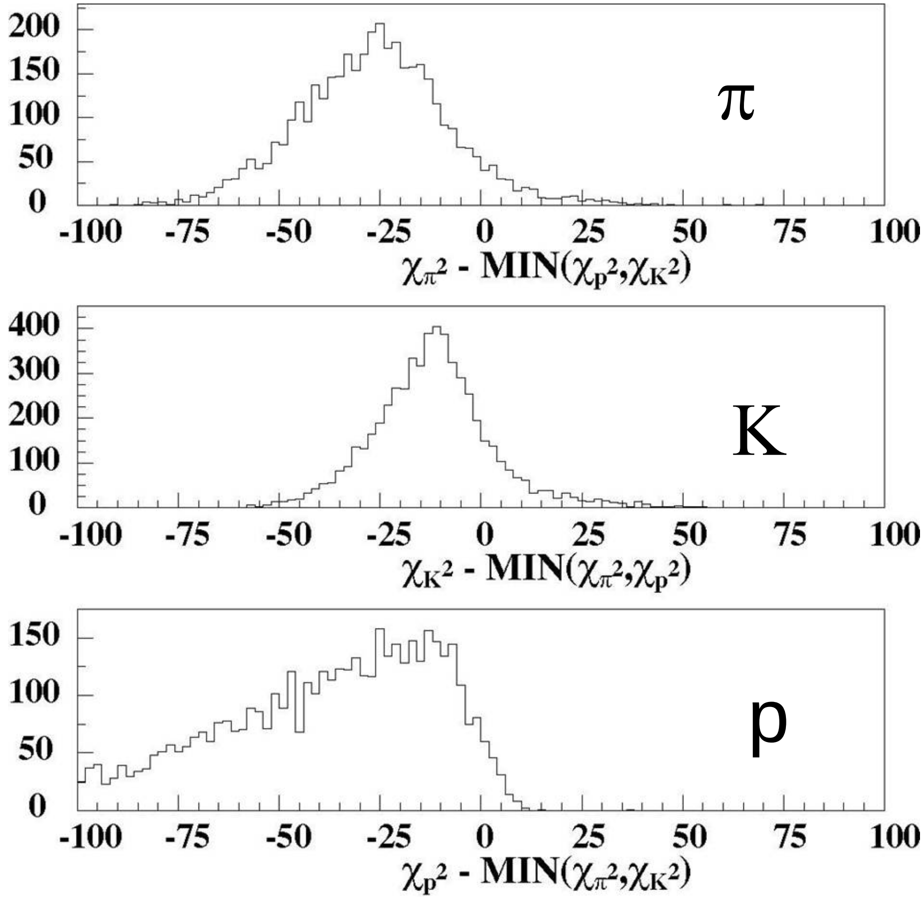


- Particle ID by dE/dx in strips

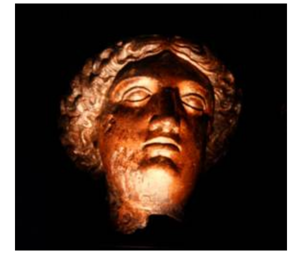


- Many dE/dx samples for good discrimination

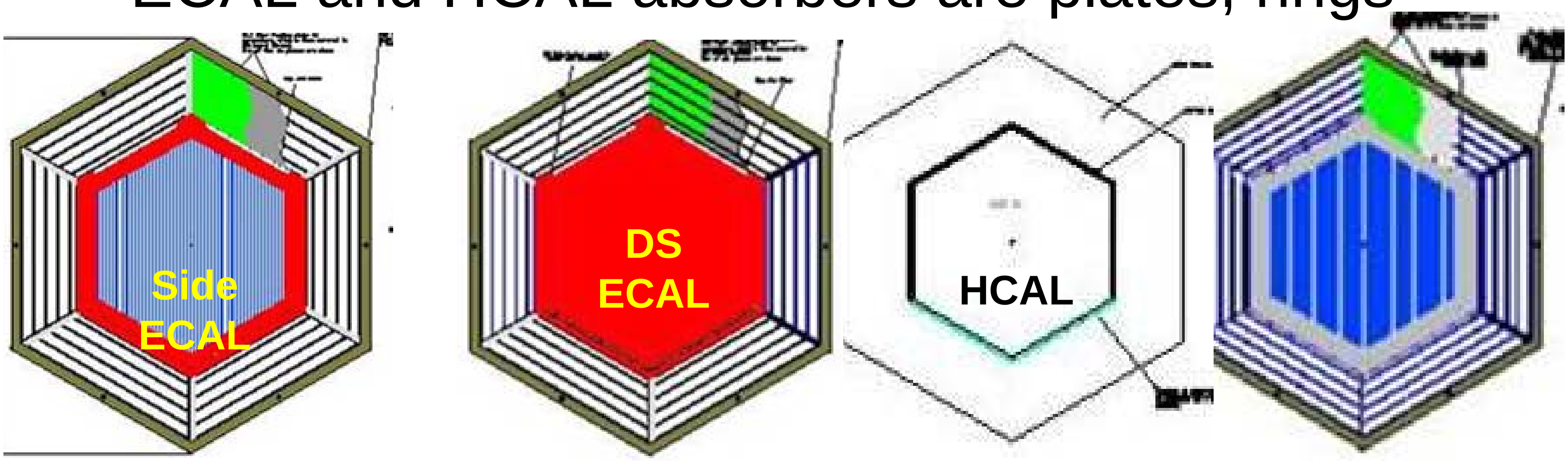
Chi2 differences between right and best wrong hypothesis



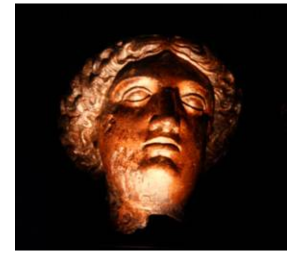
Calorimeters



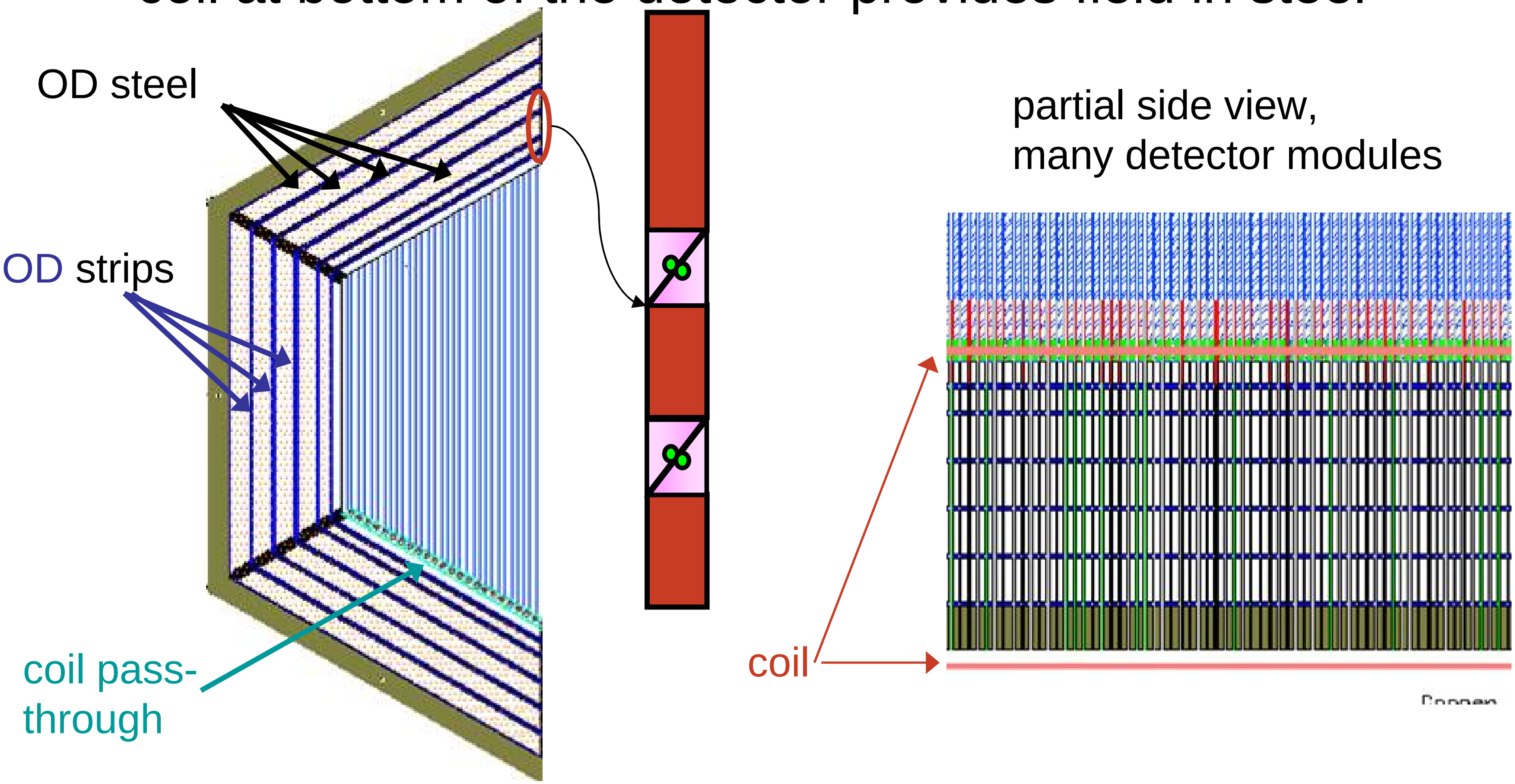
- Three types of calorimeters in MINERνA
  - ECAL: between each sampling plane, 1/16” Pb laminated with 10mil stainless (X_0/3)
  - HCAL: between each sampling plane, 1” steel (λ_0/6)
  - OD: 4” and 2” steel between radial sampling layers
- ECAL and HCAL absorbers are plates, rings



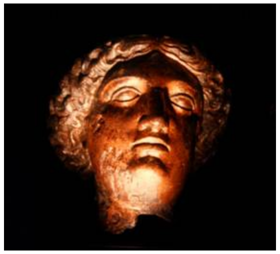
Calorimeters (cont’d)

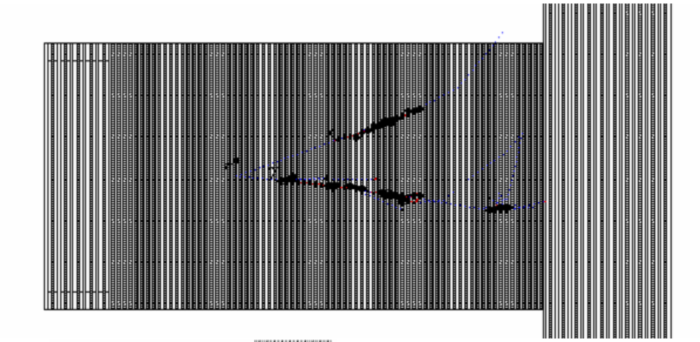


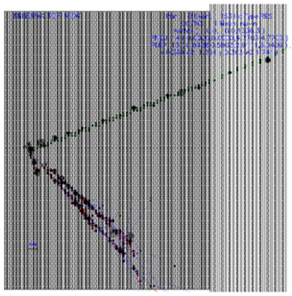
- OD: 4” and 2” steel between radial sampling layers
  - coil at bottom of the detector provides field in steel



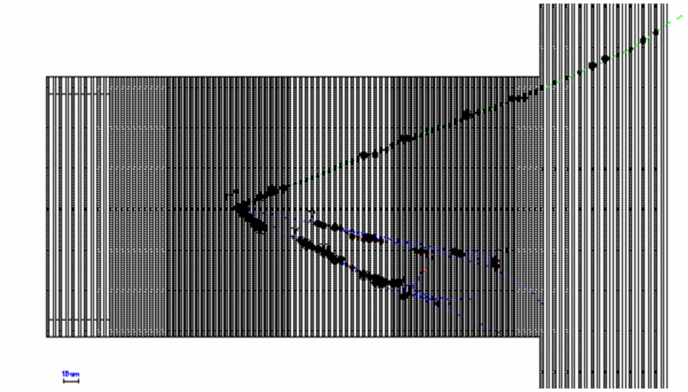
Performance: π^0 Energy and Angle Reconstruction



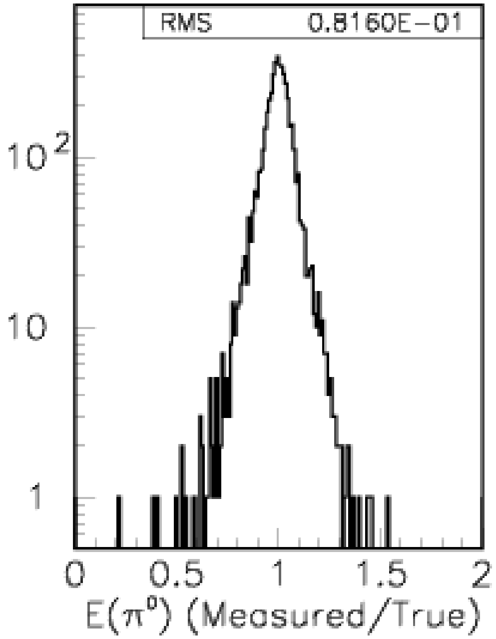


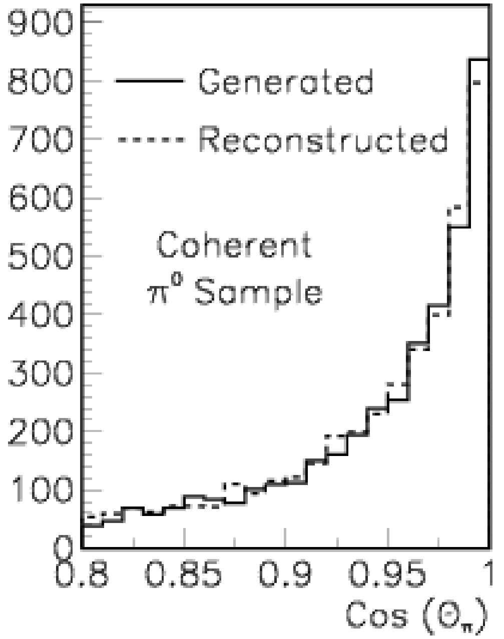


Coherent, resonance events with π^0

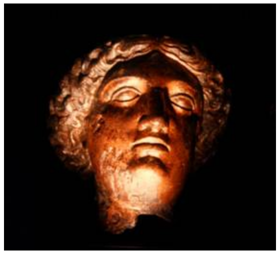


- π^0's cleanly identified
- π^0 energy resolution $\frac{RMS(E_\pi)}{E_\pi} = \frac{5.5\%}{\sqrt{E_\pi(GeV)}}$
- π^0 angular resolution better than smearing from physics

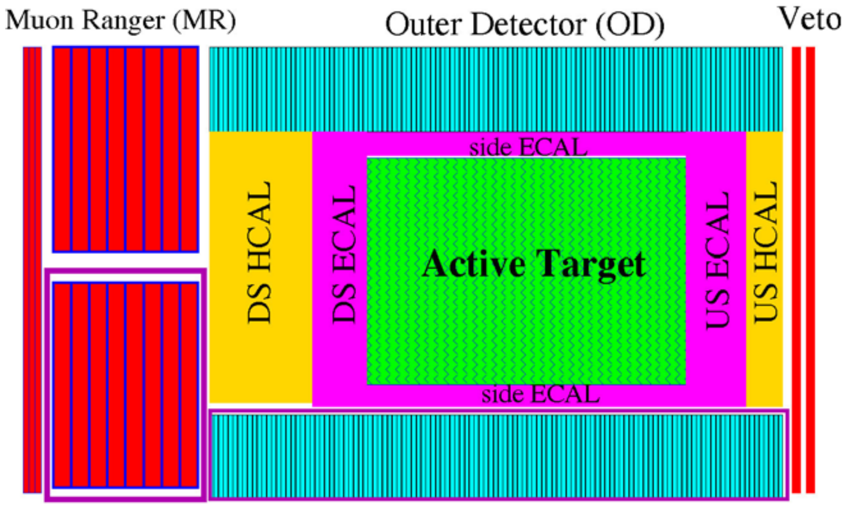




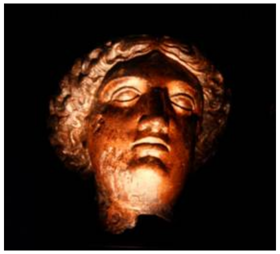
Modular Design



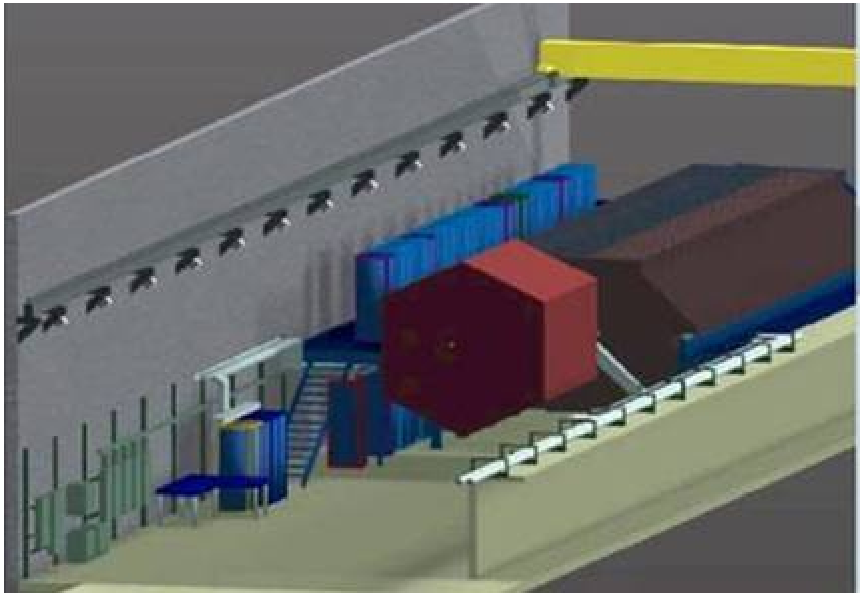
- a necessary part of installation in NuMI near hall is that detector should be constructed in thin modules
  - each module consists of *four planes* of active inner detector, absorbers and outer detector
- flexibility in design
  - MINERνA can run stand-alone
  - or can use MINOS as long muon catcher

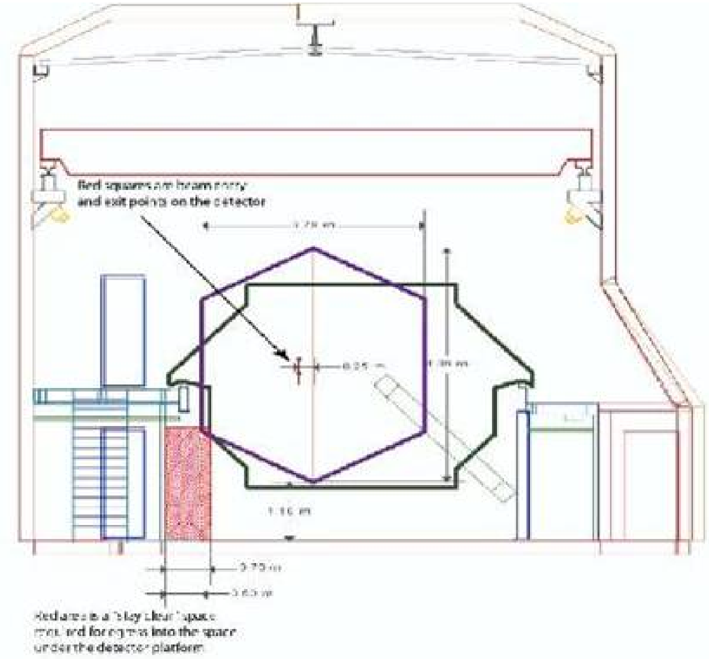


Location in NuMI Near Hall

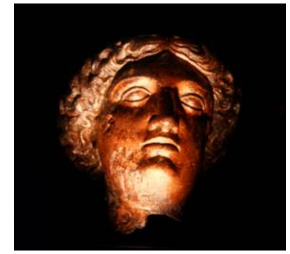


- MINERνA preferred initial running is without muon ranger, as close to MINOS as possible
  - if this is not possible, we can run initially stand-alone elsewhere in the hall





Detector Cost Summary

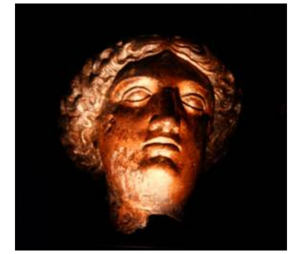


- Costs are primarily scaled from experience of MINERνA collaborators on CMS HCAL, MINOS
- $2.55M equipment (no F&A)
- $1.41M labor, EDIA
- $1.54M contingency (39% avg.)

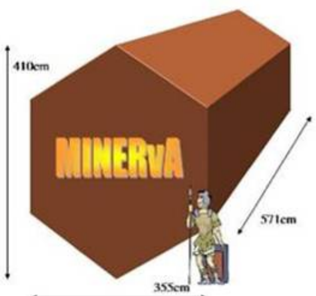
	Cost (kUSD)			
Sub-Project	M&S (no F&A)	SWF (w/ F&A)	EDIA (w/ F&A)	Contingency (%)
Extruded Scintillator	151	12	30	78 (40%)
Fiber and Glue	262	n/a	n/a	52 (20%)
WLS Fiber Prep.	50	104	16	85 (50%)
Optical Cables	77	162	11	100 (40%)
Absorbers	310	67	32	122 (30%)
Module Assembly	11	473	53	268 (50%)
Photosensors	772	n/a	25	159 (20%)
MAPMT Testing	6	45	n/a	26 (50%)
PMT Box and Optics	278	95	51	212 (50%)
Electronics and DAQ	628	33	206	435 (50%)
Totals	2545	990	423	1537 (39%)

- Schedule: estimate ~23 months from project start
  - module assembly, PMT box most uncertain sub-projects

Construction Model



- Our goal is to fund as much of detector as possible from University program funds and infrastructure programs



Module Assembly (Rochester/FNAL)

Optical Cables (Rochester)

PMT Boxes (Tufts, Rutgers)

Absorbers (Rutgers)

Extruded Scint. (NIU/FNAL)

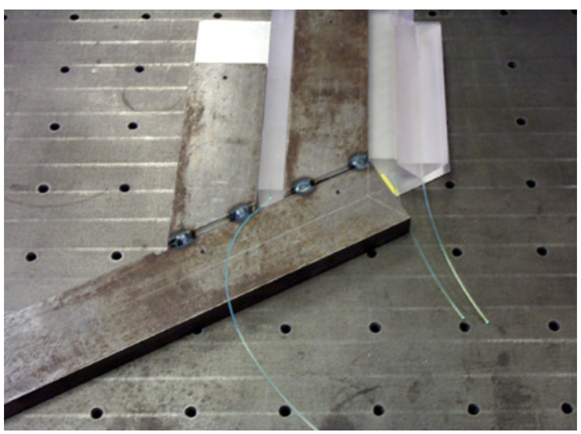
Readout Electronics (Pittsburgh)

DAQ/Slow (Irvine)

PMTs, WLS Fibers, FE Electronics (Hampton)

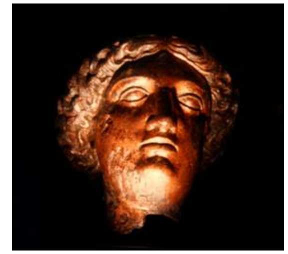
MINERνA Design Status

- Working to improve our understanding of project
  - PMT Box construction schedule and module assembly procedure and schedule are most pressing
- Preliminary EDIA has begun
  - absorbers, fiber routing, FE electronics
- Prototypes of several systems in early spring
  - TRiP FE Readout (PPD, MINOS support for vertical slice test)
  - OD module (Rochester)

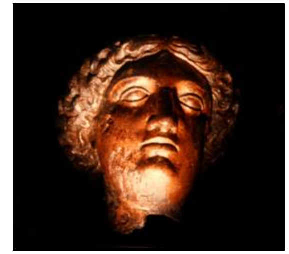


Ray Teng, Rochester Nuclear Physics Group Mech. Technician with OD prototype

Needs from the Laboratory



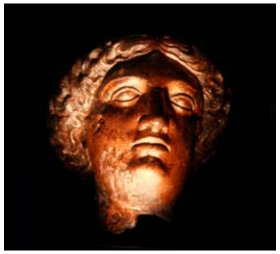
- EDIA
  - TRiP FE Readout can be most effectively designed here (common design elements with D0 boards)
  - Critical safety systems: detector stand, magnet coil, low voltage distribution to electronics
- Staging area
  - Detector assembly
  - Physicist desks and counting room
- Installation
  - Rigging detector modules down shaft and into place
  - Utilities and outfitting for near hall site



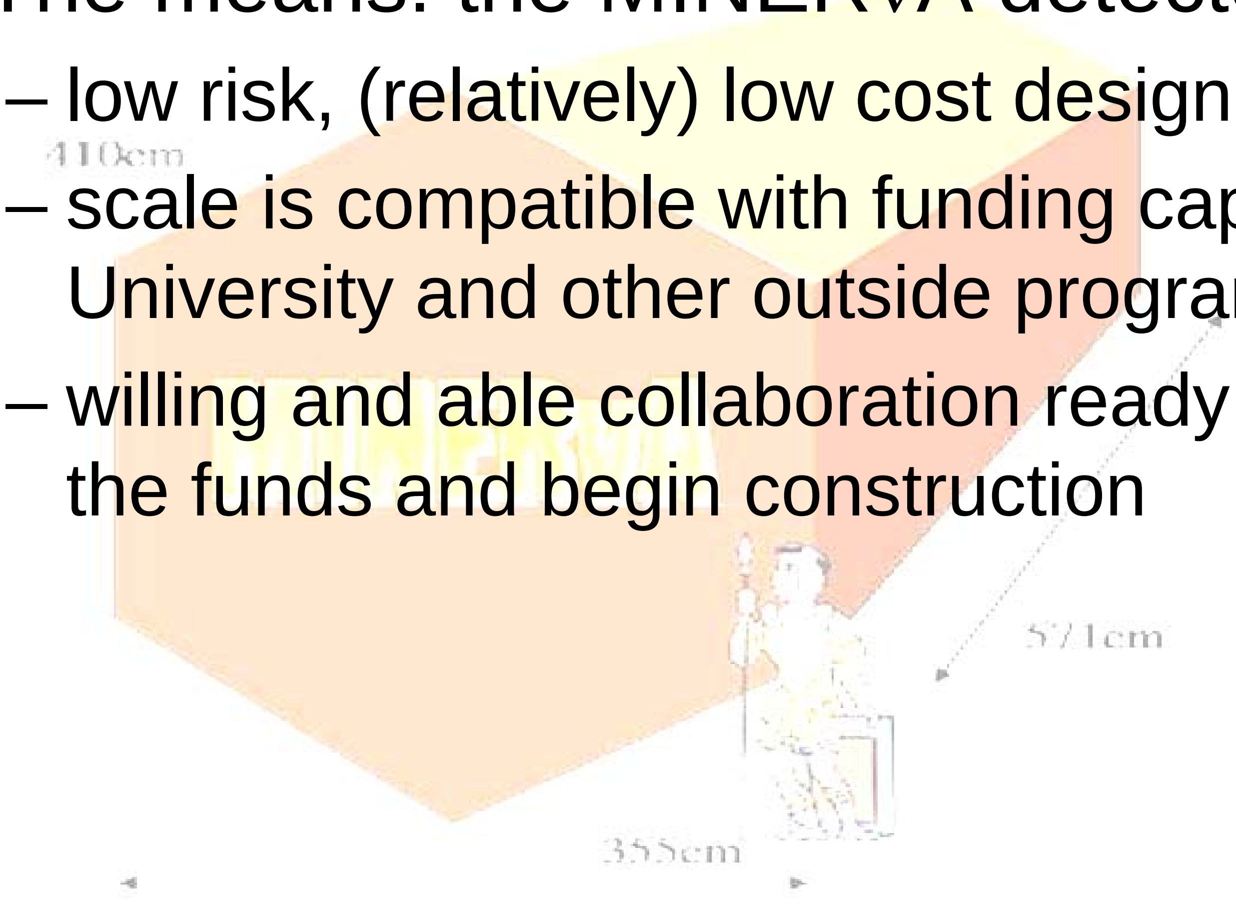
Summary

- The opportunity: NuMI
  - NuMI is at the intensity frontier of neutrino physics for the latter half of the decade and beyond
  - Spacious near detector hall is *terra firma* for parasitic near detector experiments
    - happy to run with beam driven by MINOS
  - Opens a new field: “JLab of neutrinos”
    - *Rich physics program in its own right and support for oscillation program*

Summary (cont'd)



- The means: the MINERνA detector
  - low risk, (relatively) low cost design
  - scale is compatible with funding capability of University and other outside programs
  - willing and able collaboration ready to seek the funds and begin construction



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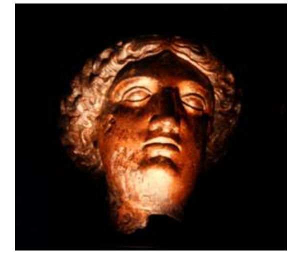
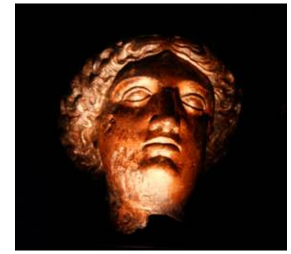


- Our request to the PAC and Laboratory:
  - we seek timely approval of MINERνA's proposed physics program

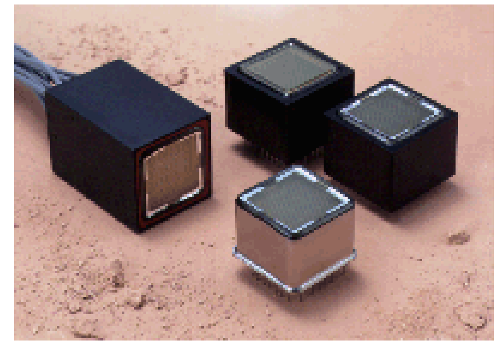
- With physics approval, we can begin the business of making this a reality
  - funding
  - complete design
  - begin this partnership between nuclear and particle physics

Backup Slides

Choice of Photosensors



- Photosensors are the first cost driver.
  - we took great care to evaluate options before choosing MAPMTs



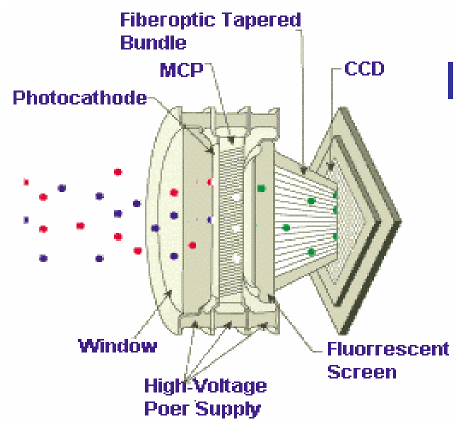
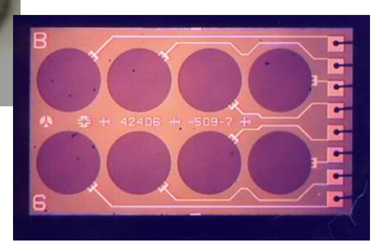


Image Intensifiers with CCD readout

- large cost savings relative to MAPMT for sensor
- CCD readout dramatically inexpensive
- but… concerns about dynamic range, mean time to failure, and *no timing*

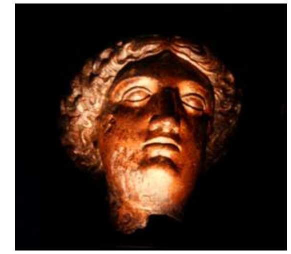
APDs. High Q.E.!

- low gain. Noisy.
- need to cool
- electronics is a challenge if we want to run soon



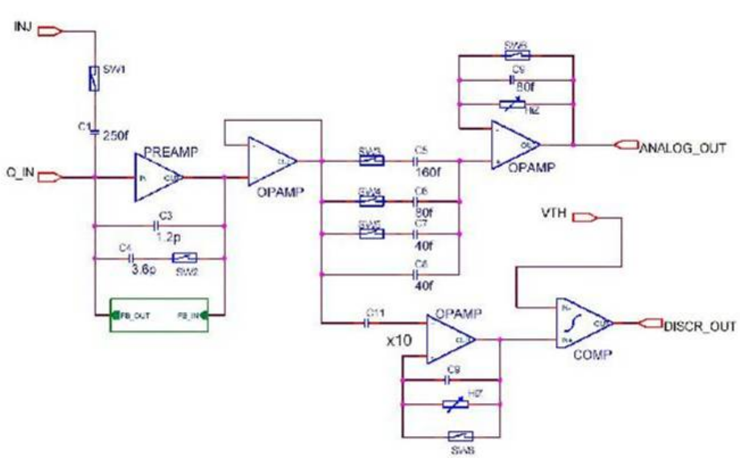
VLPCs. High Q.E.! Sexy!

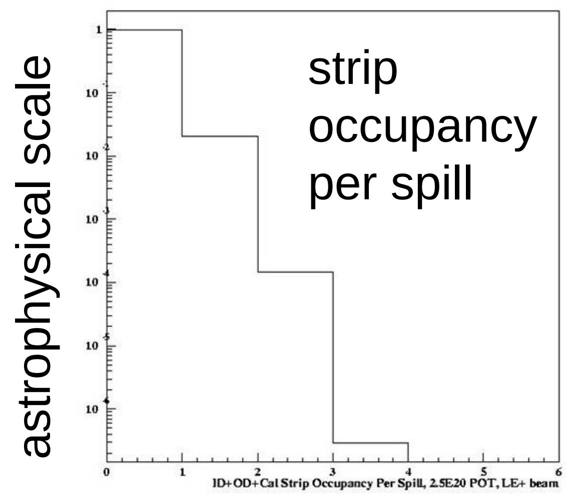
- high performance
- but cryogenic, $$$
- we conclude this isn't a worth the trouble and cost



Electronics (cont'd)

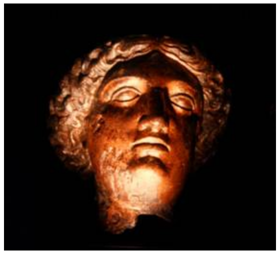
- TRiP ASIC provides sample and hold functionality in time slices
  - initial operation, planning to integrate ADC over spill

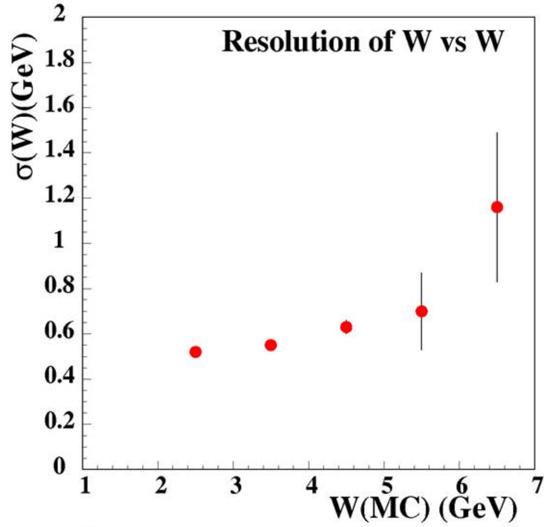


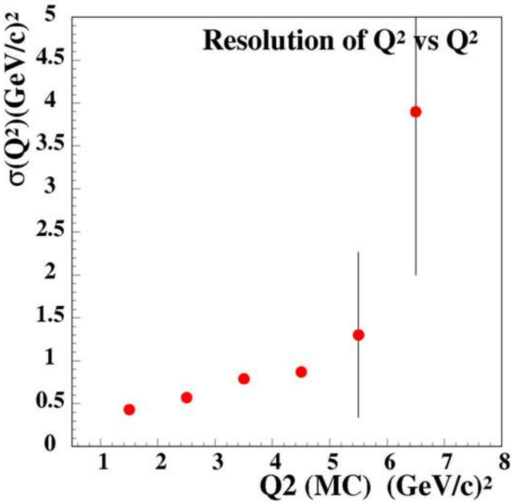


  - could divide into sub-spills later if rates are higher
  - each time over threshold also recorded in spill

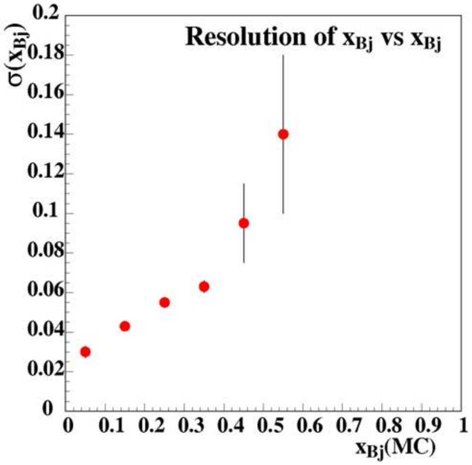
Performance: DIS Kinematics Reconstruction

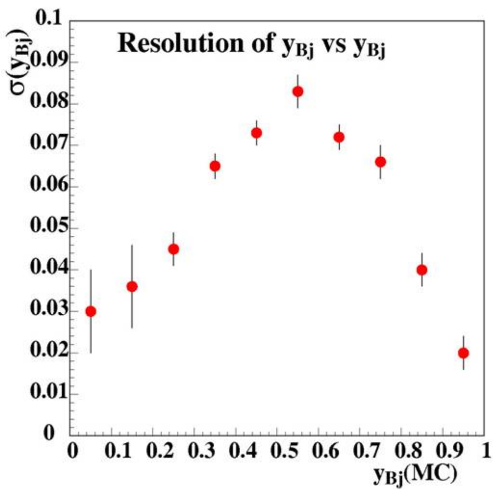




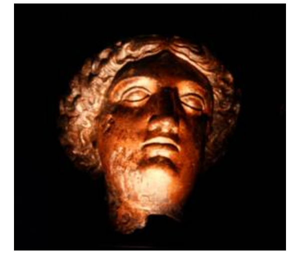


- inclusive reconstruction shown
- W resolution to separate resonance from DIS independent of exclusive reconstruction
- Q^2 resolution for form factor measurements
- x resolution for valence/sea
- y resolution for quark/antiquark



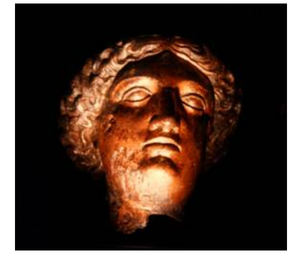


Costing Methodology



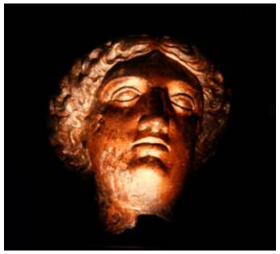
- most of our costs could be scaled from similar construction products in MINOS or CMS HCAL where *MINERνA collaborators have hands-on experience*
  - FE electronics boards. TRiP bottoms-up costs were significantly lower than analogous MINOS board costs. Used MINOS
  - PMT box costs scaled from MINOS 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



- Schedule estimates are tentative
  - assembly schedule is more difficult to scale from past projects than M&S costs
- Module assembly
  - 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
  - a labor intensive “craft” component. Scaled from MINOS. Accurate?
- 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

Schedule (cont'd)



- Current model for module construction
  - needs fast start from Rutgers on initial absorbers.
  - then dominated by assembly (Rochester at FNAL)