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MINERvA Detector: Status Report

November 8th, 2010

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OUTLINE

- The MINERva Collaboration
- The MINERvA Detector
- The MINERvA Motivations
- The Test Beam Facility
- Current Status
- Conclusions

The MINERvA Collaboration

At present-day, the MINERvA Collaboration is constituted by ca. 80 nuclear and particle physicists from 21 institutions in the United States, Brazil, Chile, Greece, Peru, Russia Mexico.

The MINERvA Detector

GOALS:

- ν-A interaction cross sections (broad range of A)
- Exclusive final state and differential cross sections
- Exclusive final states and inclusive scattering.
- Form factors and structure functions
- Nuclear effects on the ν-A interactions

MINERvA´s Timeline

SUMMARY:

November 2009:

- **MINERvA starts taking data with 55% of the detector and some nuclear targets.**

January - March 2010:

- **Install remaining detector**
- **Start taking neutrino data**

November 2010:

- **Start antineutrino data**

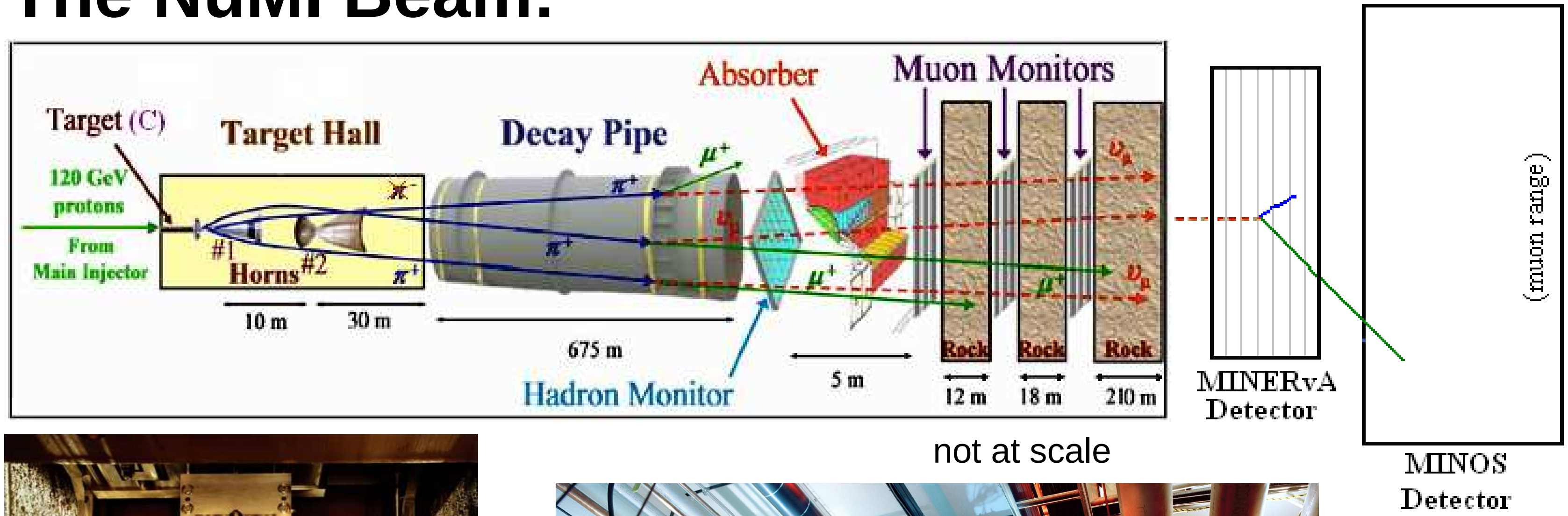
MINERvA´s Timeline (cont.)

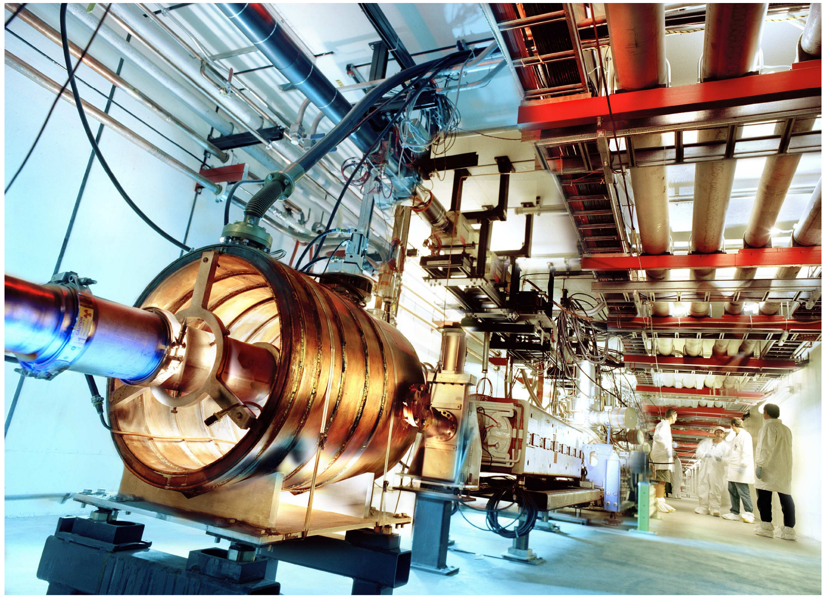
2010 and beyond:

- **Data acquisition for:**
  - **LE configuration (3 GeV)**
  - **ME configuration (8 GeV)**
  - **ν and anti-ν**
  - **All targets (H_2O, He, C, Fe, Pb)**
- **Special runs to understand the flux**
- **Cross-section experiments**
- **MC Simulations for experimental data**
- **Data processing, validation, etc.**

The MINERvA Detector

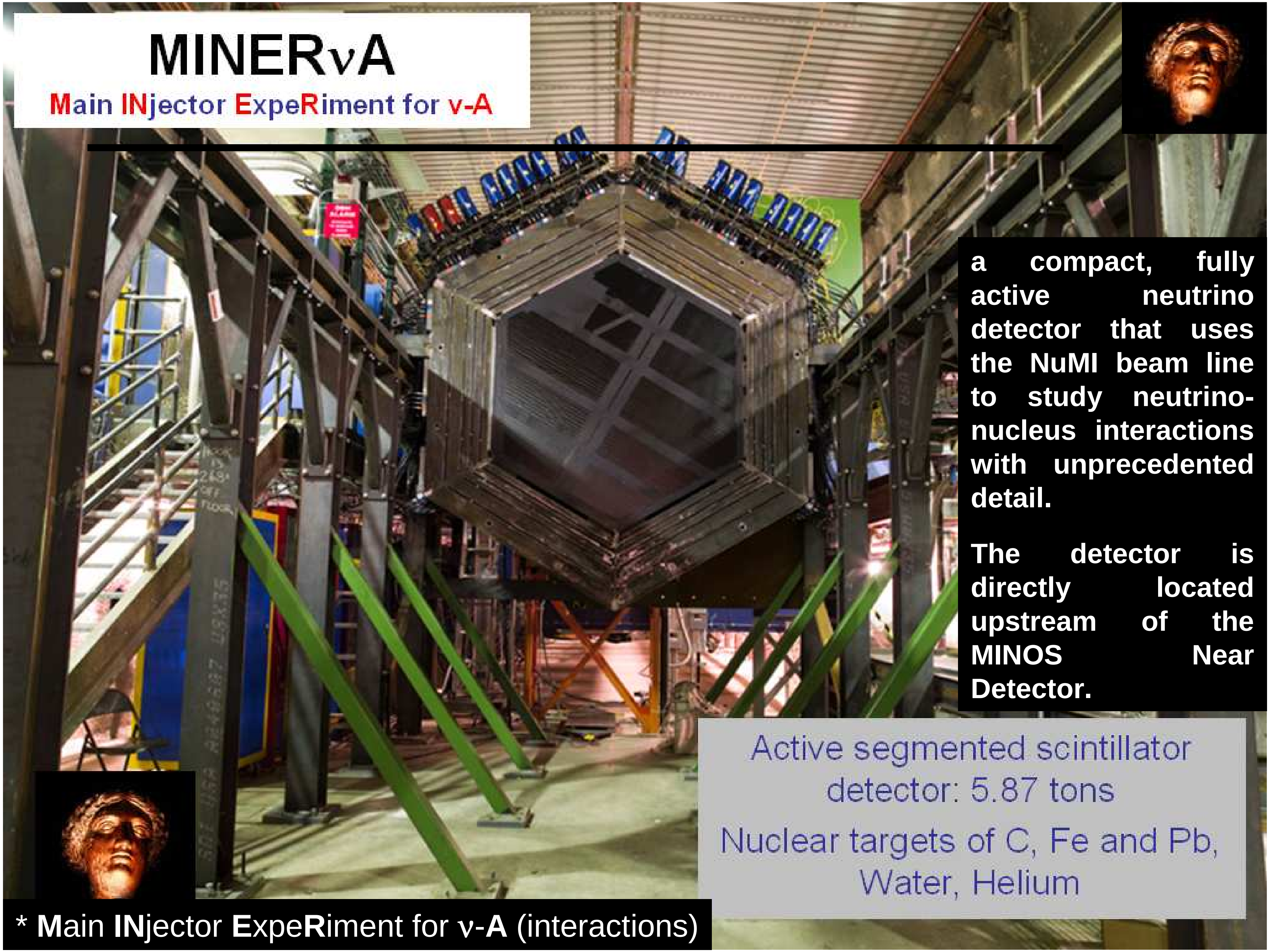
The NuMI Beam:





MINERνA

Main INjector ExpeRiment for ν-A



a compact, fully active neutrino detector that uses the NuMI beam line to study neutrino-nucleus interactions with unprecedented detail.

The detector is directly located upstream of the MINOS Near Detector.

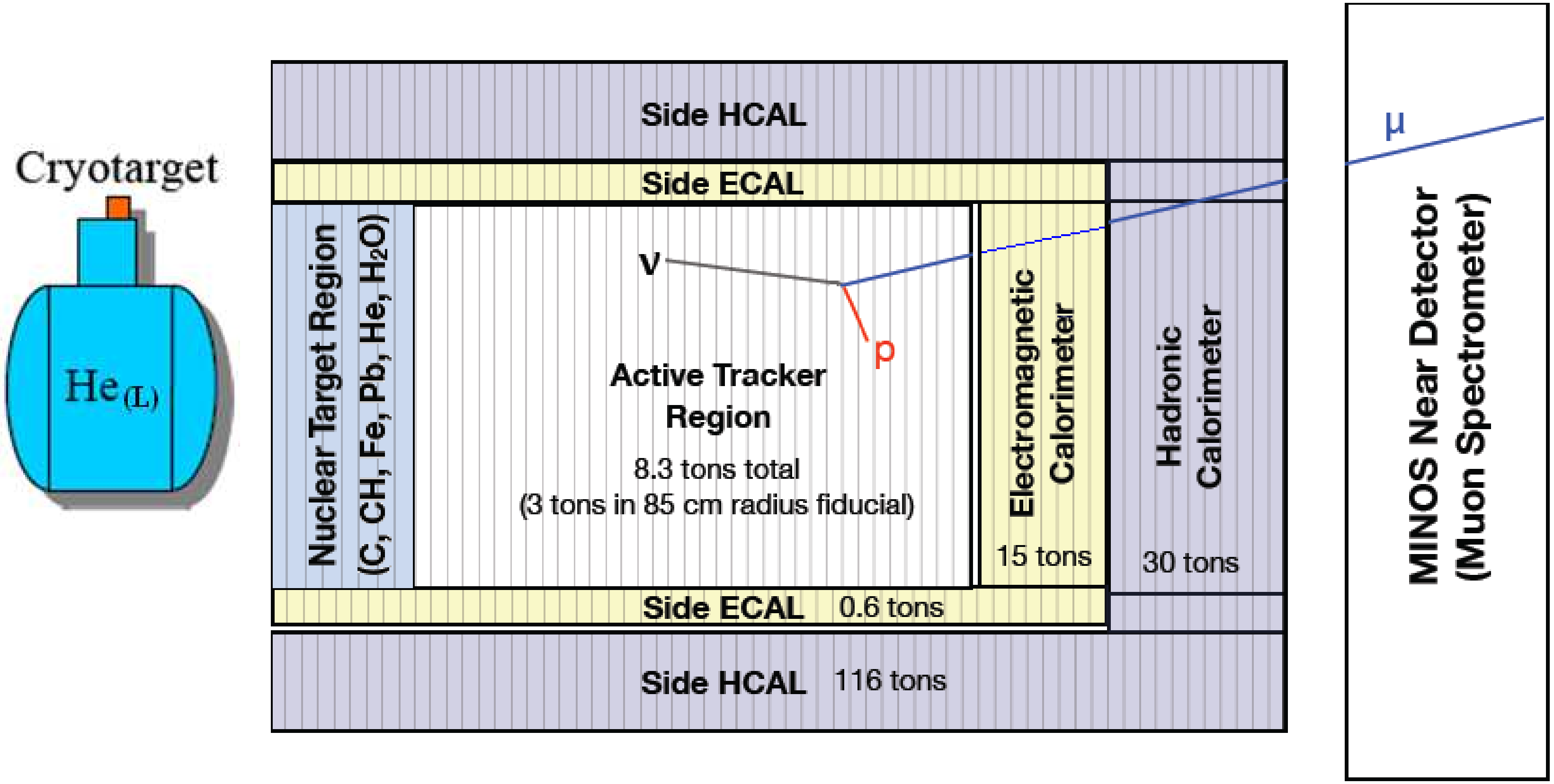
Active segmented scintillator detector: 5.87 tons

Nuclear targets of C, Fe and Pb, Water, Helium

* **M**ain **IN**jector **E**xpe**R**iment for ν-**A** (interactions)

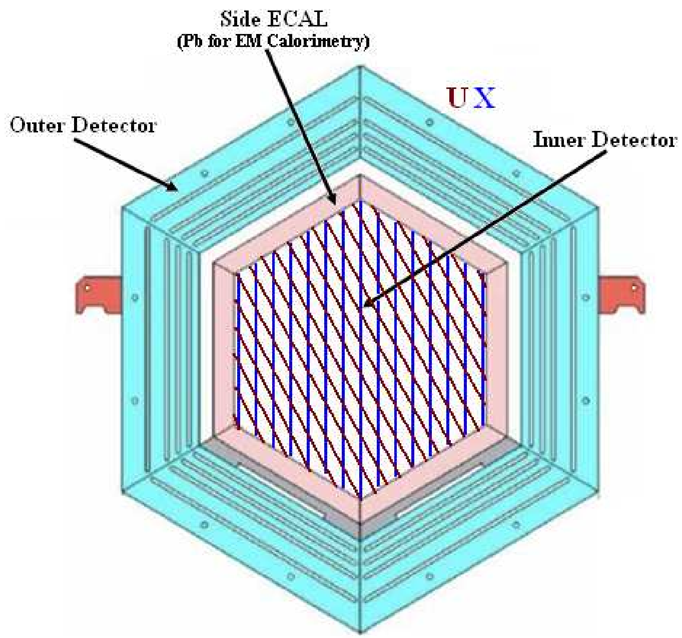
The MINERvA Detector (cont.)

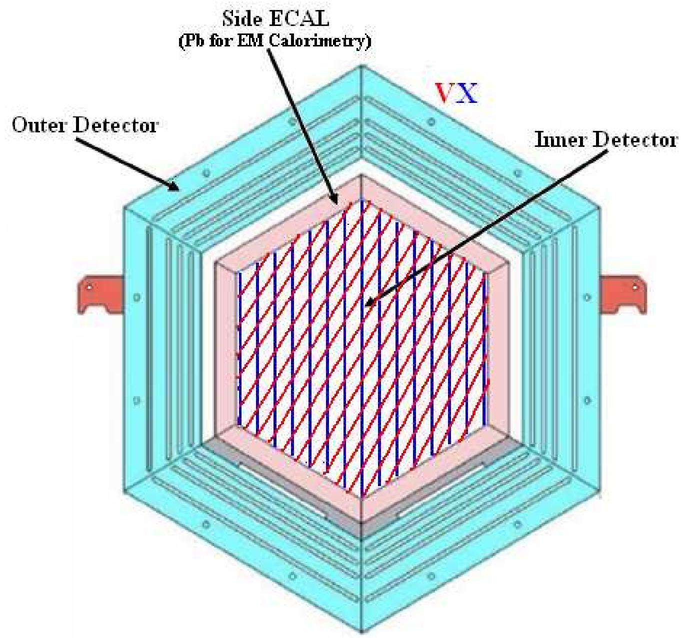
Main Components:



The MINERvA Detector (cont.)

The modules:





UX and VX configuration of the scintillator strips for stereoscopic 3D tracking

The MINERvA Detector (cont.)

The modules:

the real thing
(120 modules)

done !

The MINERvA Detector (cont.)

The NuMI Beam Characteristics:

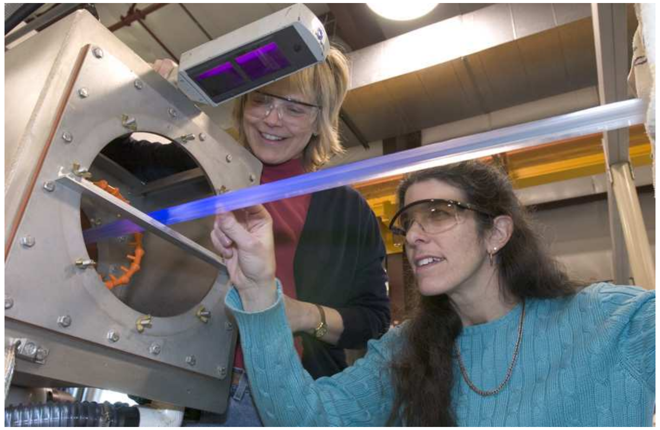
- **Adjustable beam energy of the NuMI ν beam (broad range ν_E):**
  Via target positioning relative to the focusing horns: Peak energy at 3, 8 and 12 GeV for the LE, ME and HE configurations, resp.

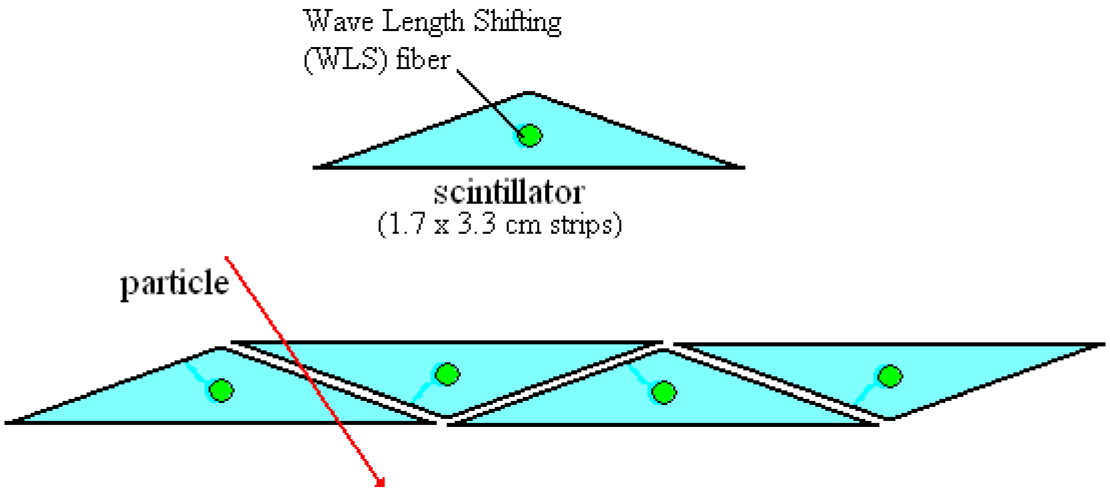
- **NuMI p+ beam intensity:**
  $\sim <35\times10^{12}>$ P.O.T. per spill at 120 GeV

- **NuMI p+ beam power:**
  300-350 kW at $\sim$0.5 Hz.

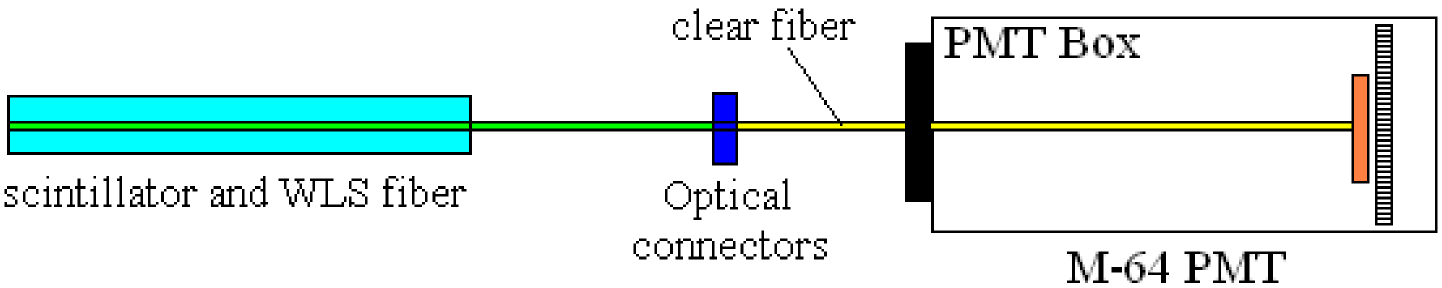
The MINERvA Detector (cont.)

The Optics:





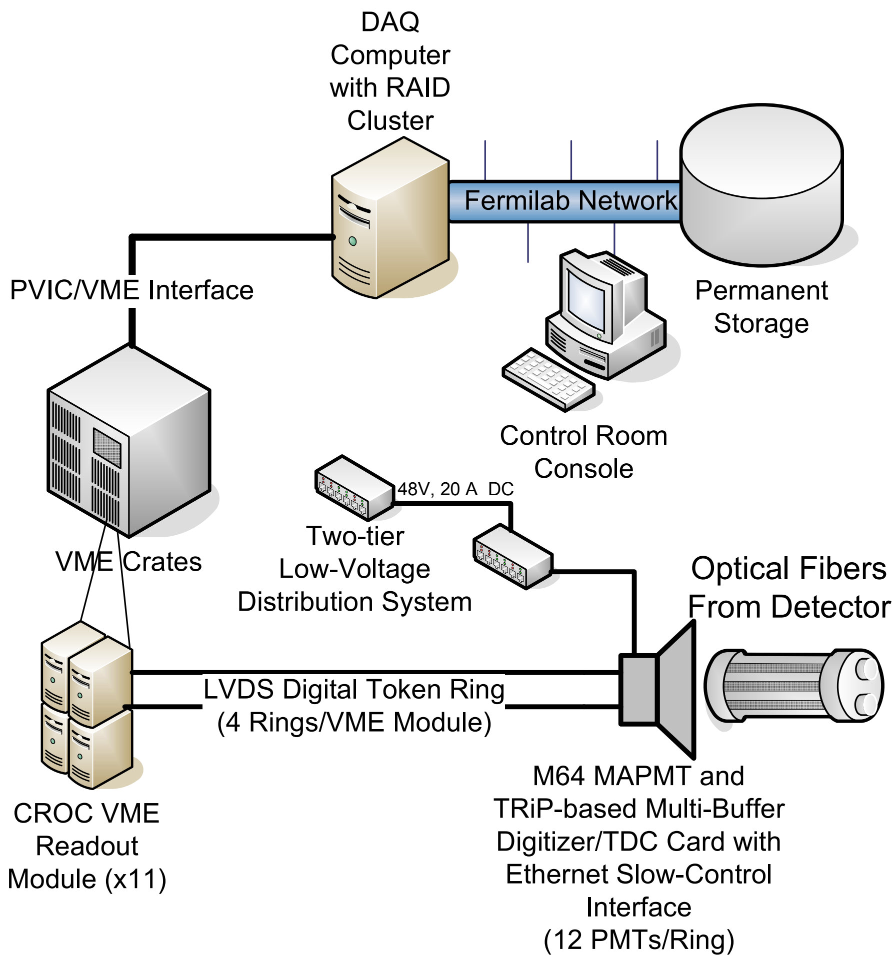
Each scintillator plane of the inner detector contains 128 strips



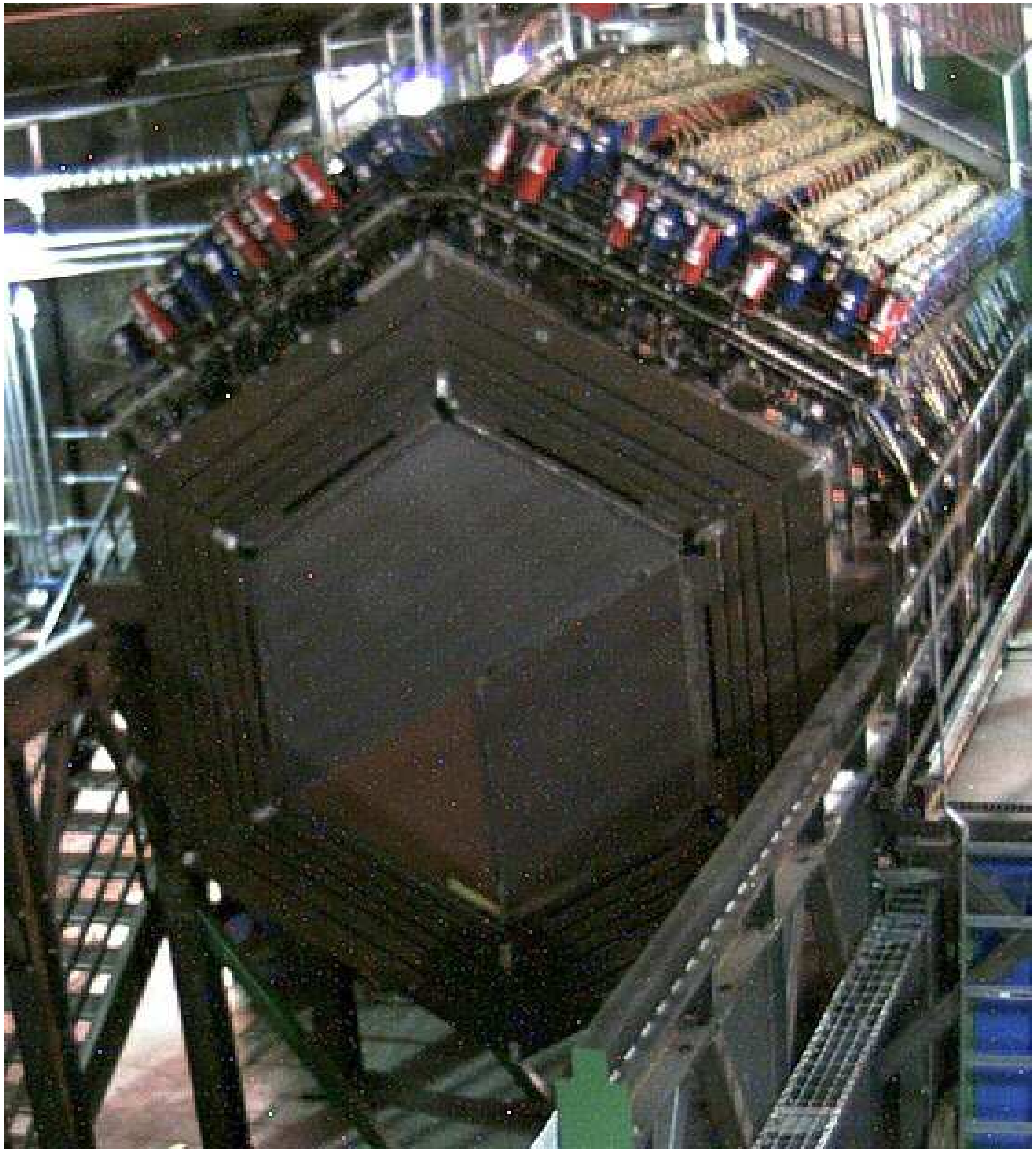
The MINERvA Electronics)

The Electronics:

- **Front End Boards**
- **FEBs and DAQ**
- **Power and rack protection**



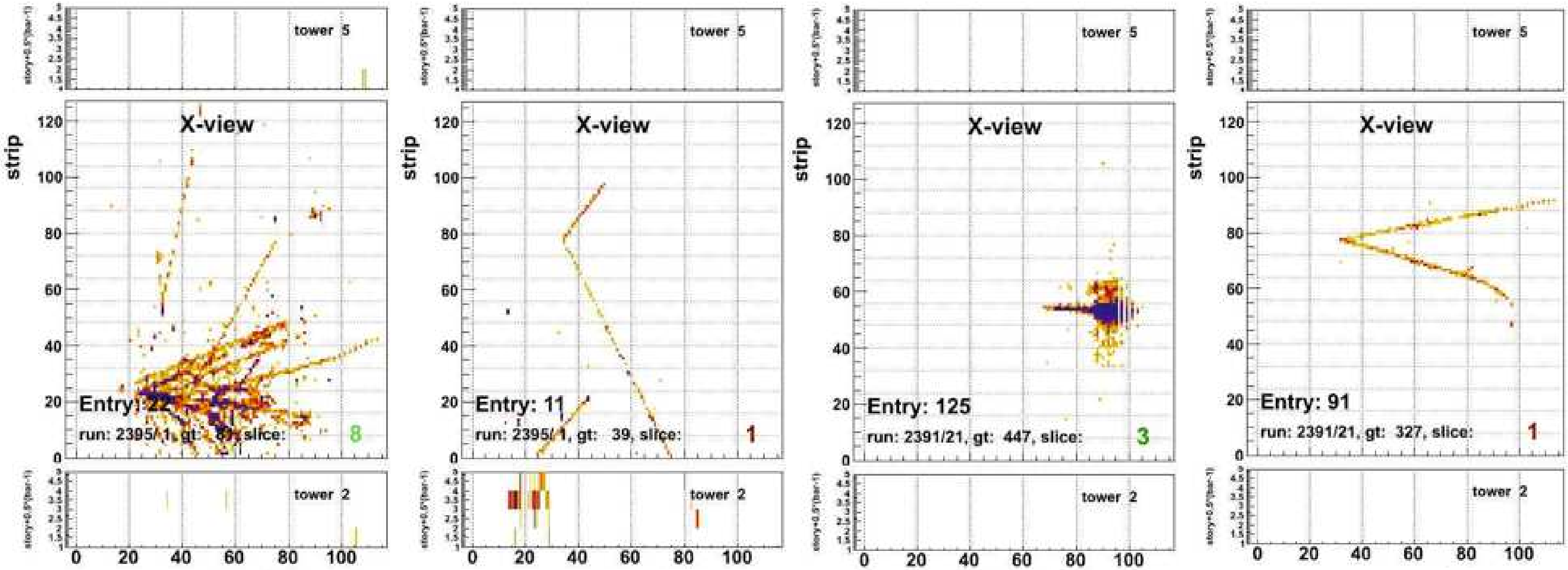
The MINERvA Detector (cont.)



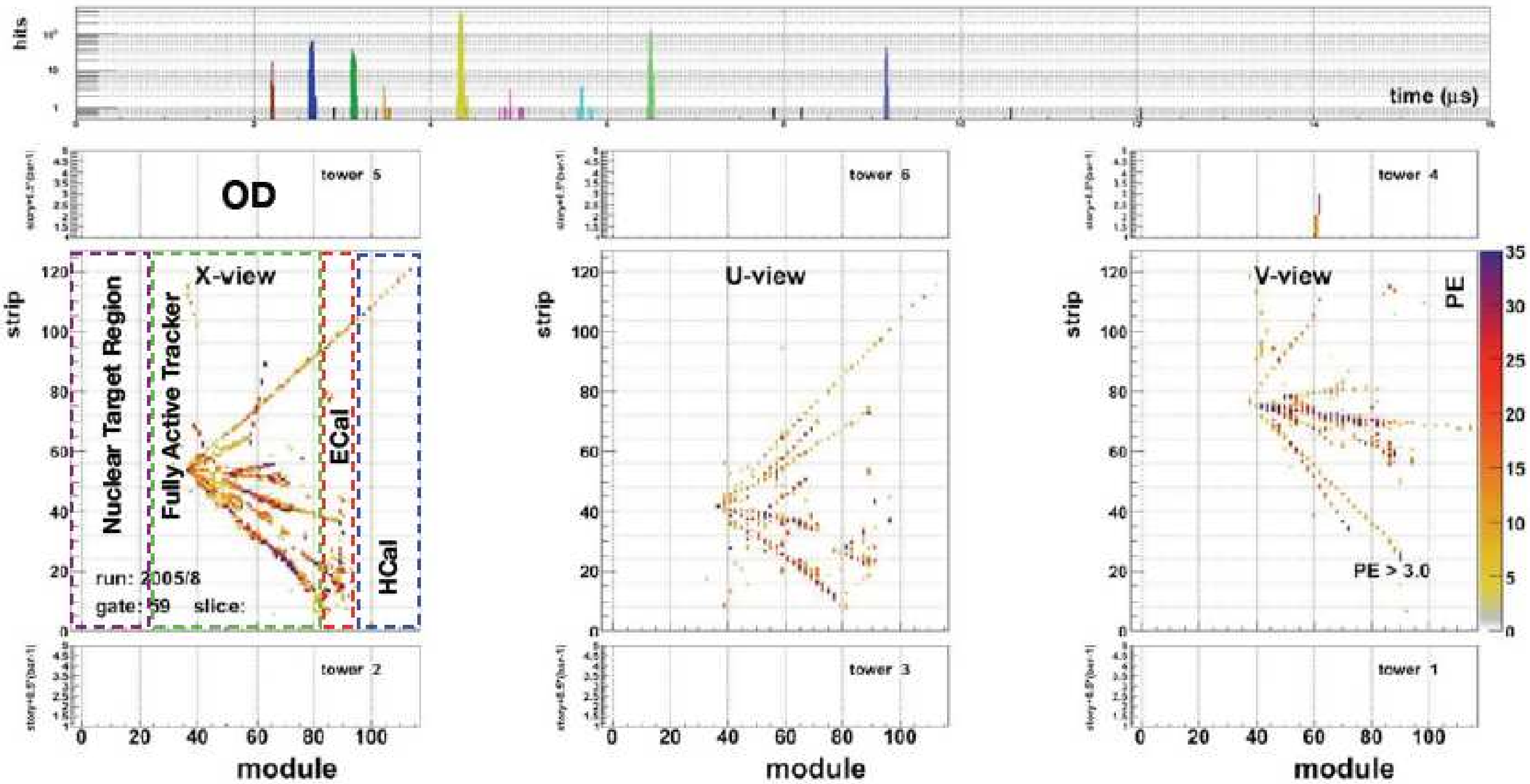
Spatial resolution:
~ 3 mm
Time resolution:
~ 4 ns
Nuclear targets (broad A):
He, C, H_2O, Fe, Pb
(nuclear effects on ν interactions absent in free standing nucleons)
dσ/dE measurements:
QE, DIS, sπ
Recorded POT*:
1.37×10^{20} neutrinos
$0,9\times10^{20}$ anti-neutrinos

* as of October 18, 2010

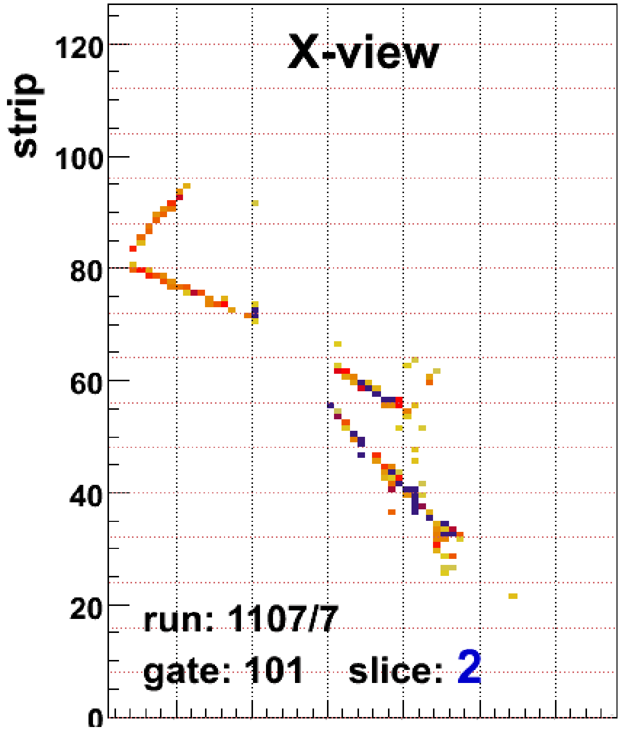
MINERvA Full Detector Events

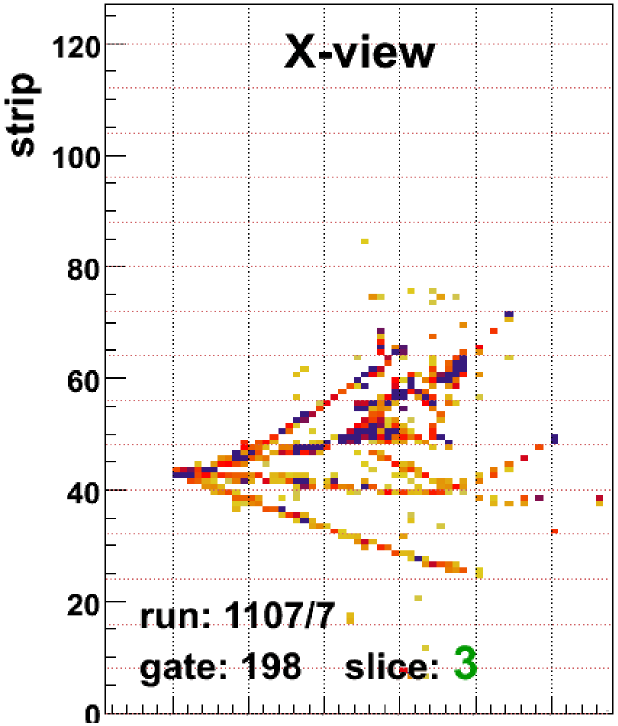


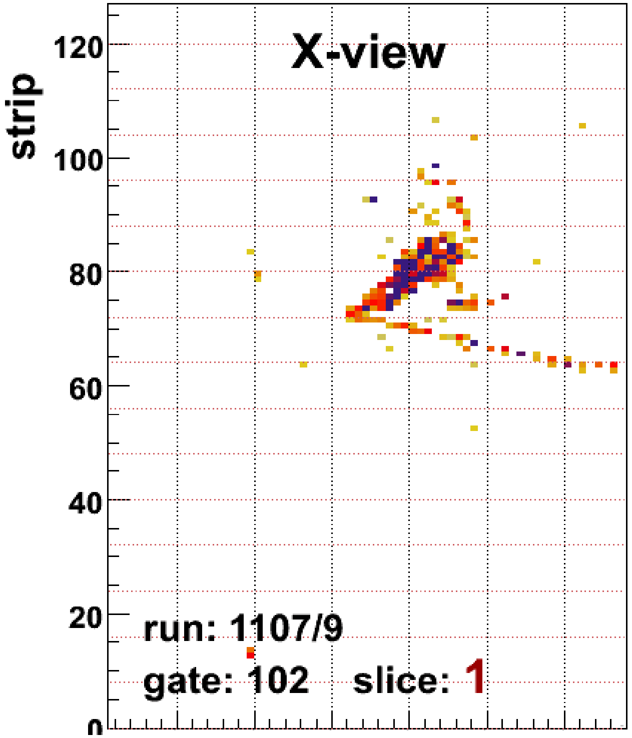
MINERvA Full Detector Events



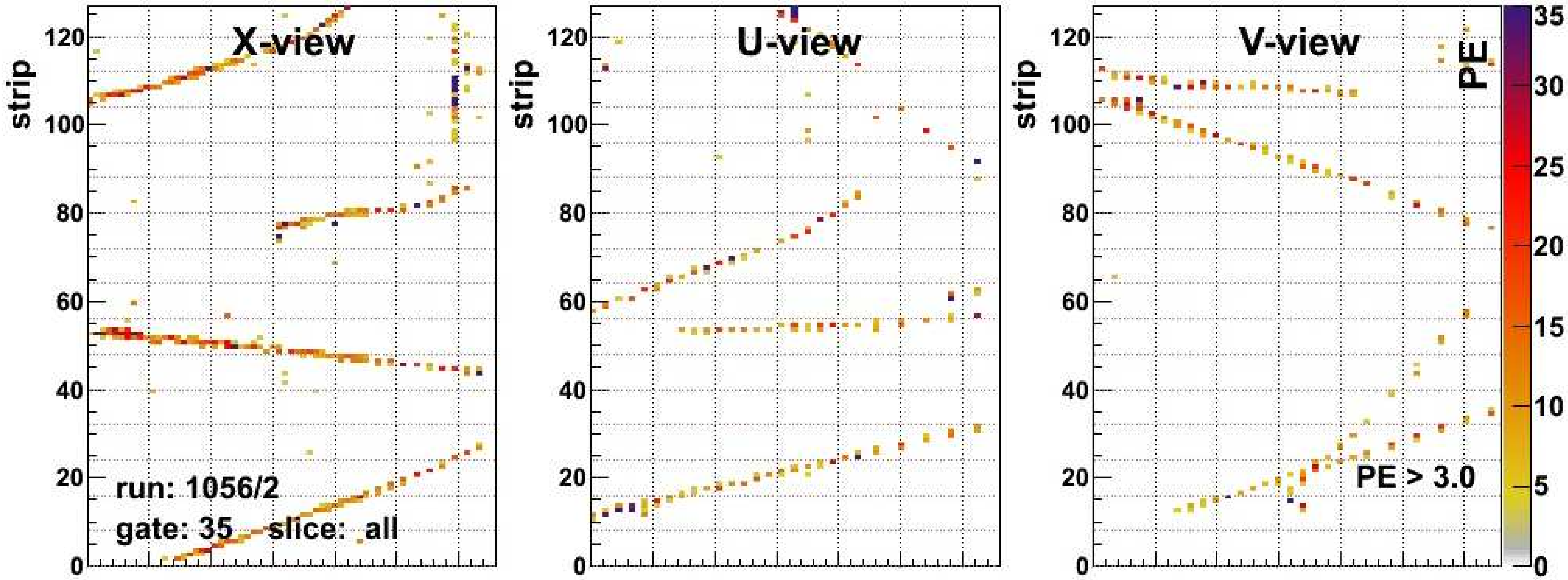
MINERvA Full Detector Events







MINERvA Full Detector Events



MINERvA Motivations

MINOS*

MiniBooNE*

NOvA*

current and next generation of experiments need MINERvA data to get the most of their far detectors !!!

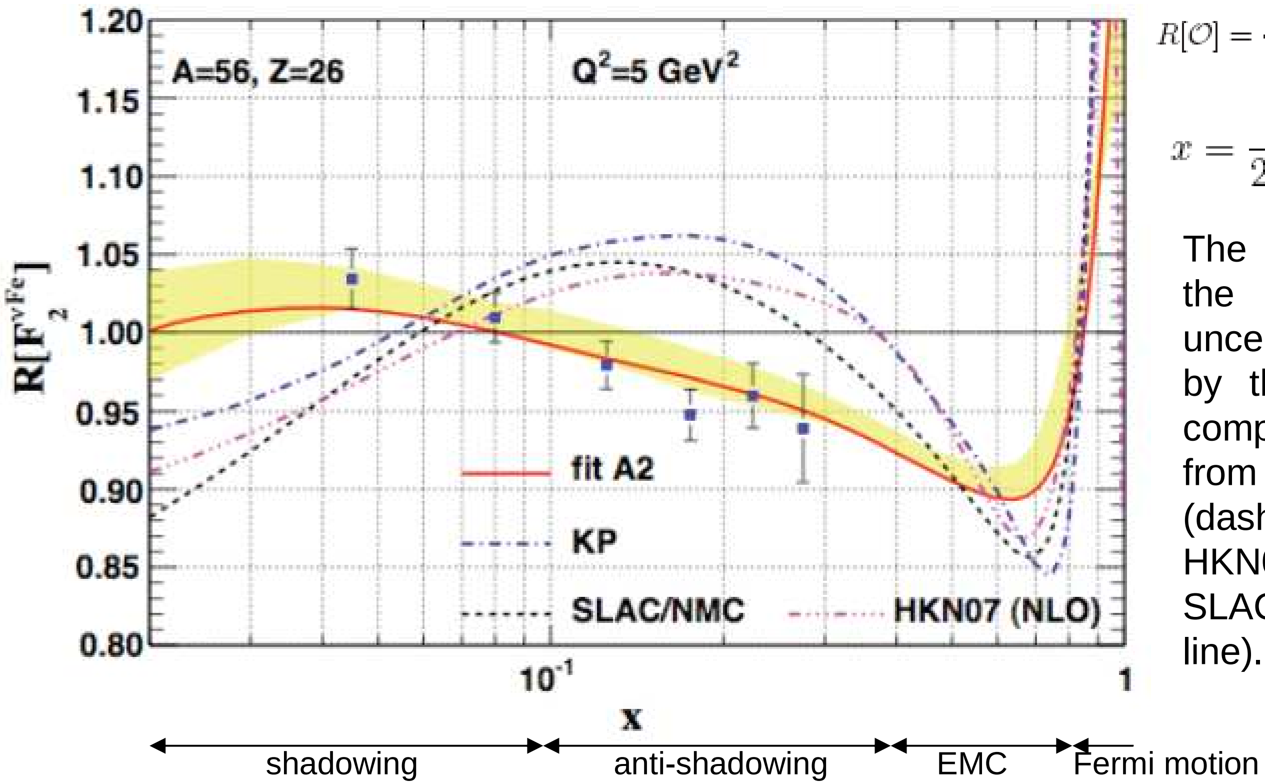
* **M**ain **I**njector **N**eutrino **O**scillation **S**earch

* **M**ini **B**ooster **N**eutrino **E**xperiment

* **N**uMI **O**ff-axis $\mathbf{v}_e$ **A**ppearance experiment

MINERvA Motivations

cross sections: the ν-Fe scattering



$$R[\mathcal{O}] = \frac{\mathcal{O}[\mathrm{NPDF}]}{\mathcal{O}[\mathrm{free}]}$$

$$x = \frac{Q^2}{2P \cdot q} = \frac{Q^2}{2M\nu}.$$

The solid curve shows the result of the analysis of NuTeV data; the uncertainty from the fit is represented by the shaded (yellow) band. For comparison, the correction factor from the Kulagin–Petti model (dashed-dot line) is shown, HKN07(dashed-dotted line), and the SLAC/NMC parameterization (dashed line).

Nuclear Correction Factor vs. Bjorken scaling variable

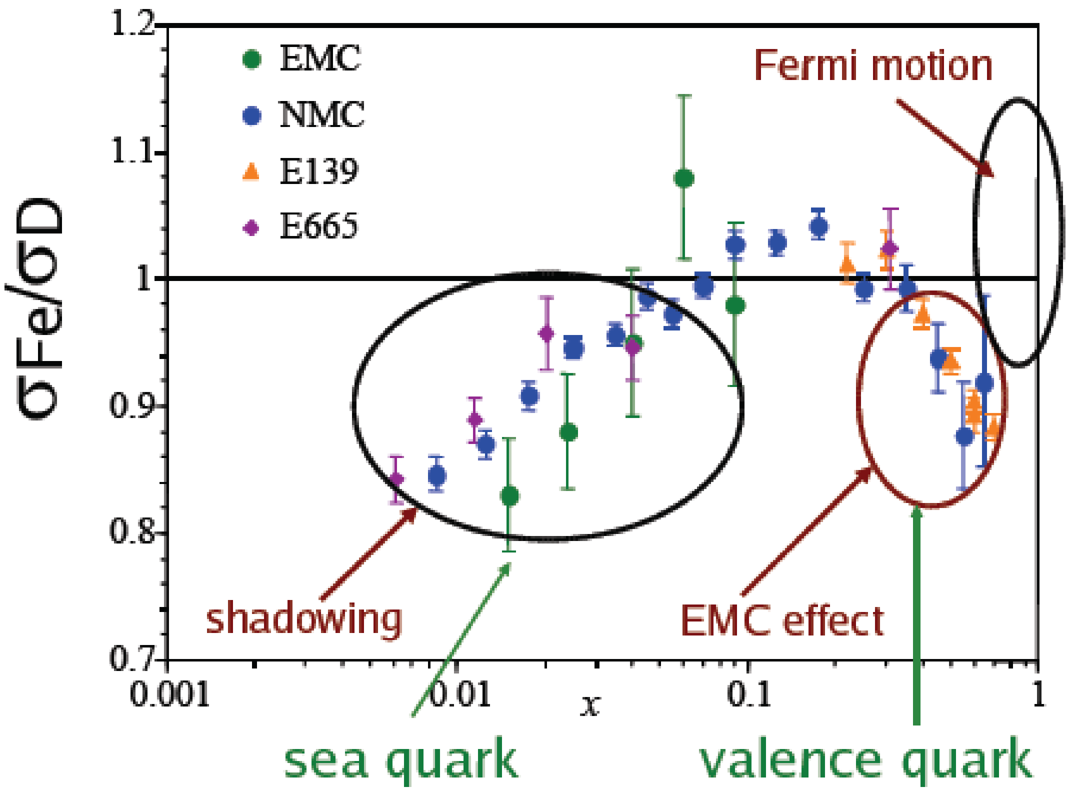
charged current correction factors

$\overset{?}{\neq}$

neutral current correction factors

MINERvA Motivations

DIS cross section: $f_{(\text{nuclear effects})}$



electron and muon scattering data

Cross sections goals:

Constrain charged current channels, Quasi-elastic, resonance, coherent, DIS, to ca. 5% for neutrino energies in the range 1 – 20 GeV.

The MINERvA Motivations

Main CC Physics Topics:

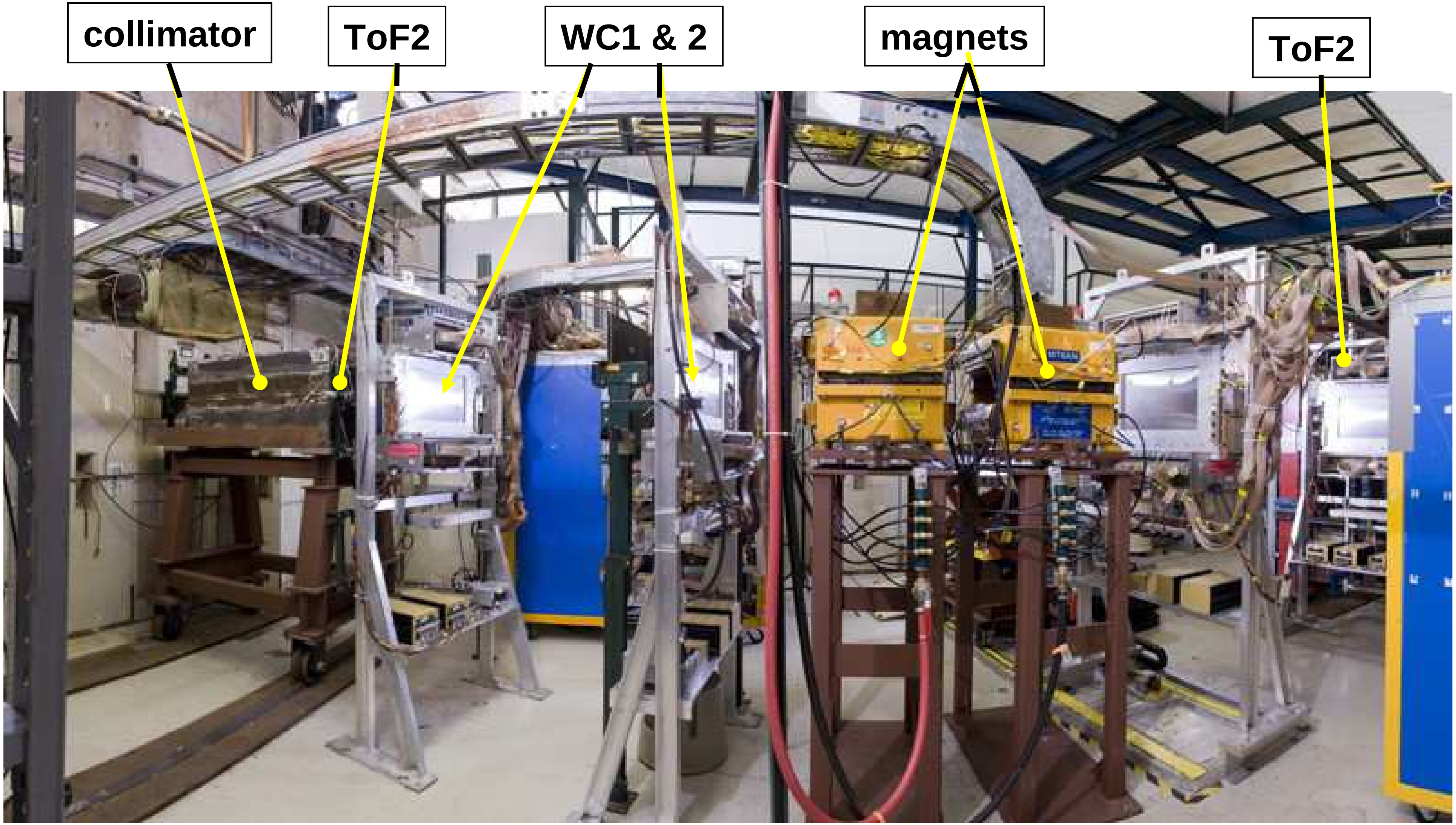
- **Quasi-elastic neutrino scattering**
- **Resonance production**
- **Resonance to DIS transition region**
- **DIS Low Q^2 region and structure functions**
- **Coherent Pion Production**
- **Strange and Charm particle production**
- **Nuclear effects from comparisons between different nuclear targets: Polystyrene (CH), Carbon, Iron, Lead, He**

The MINERvA Test Beam Facility

- **Provides hadronic response calibration (ratio of π/μ).**
- **Consists of 40 planes in XU/XV stereoscopic orientation using the same scintillator and absorber geometry.**
- **Configuration can be adjusted**

- 16 GeV pion beam on a Cu target produces tertiary pion beam from 400 MeV to 1.2 GeV.
- Four wire chambers, two dipole magnets, and time-of-flight system for triggering.

The MINERvA Test Beam Facility



Conclusions

Accumulated:

1.37×10^{20} POT for neutrino
0.90×10^{20} POT for antineutrino

The goal:

$4.9x10^{20}$ in LE mode.
$12x10^{20}$ in ME mode.

We are doing: {
high statistics
wide range of energies
wide range of nuclear targets

New Understanding of Neutrino Interactions is just around the corner !!!

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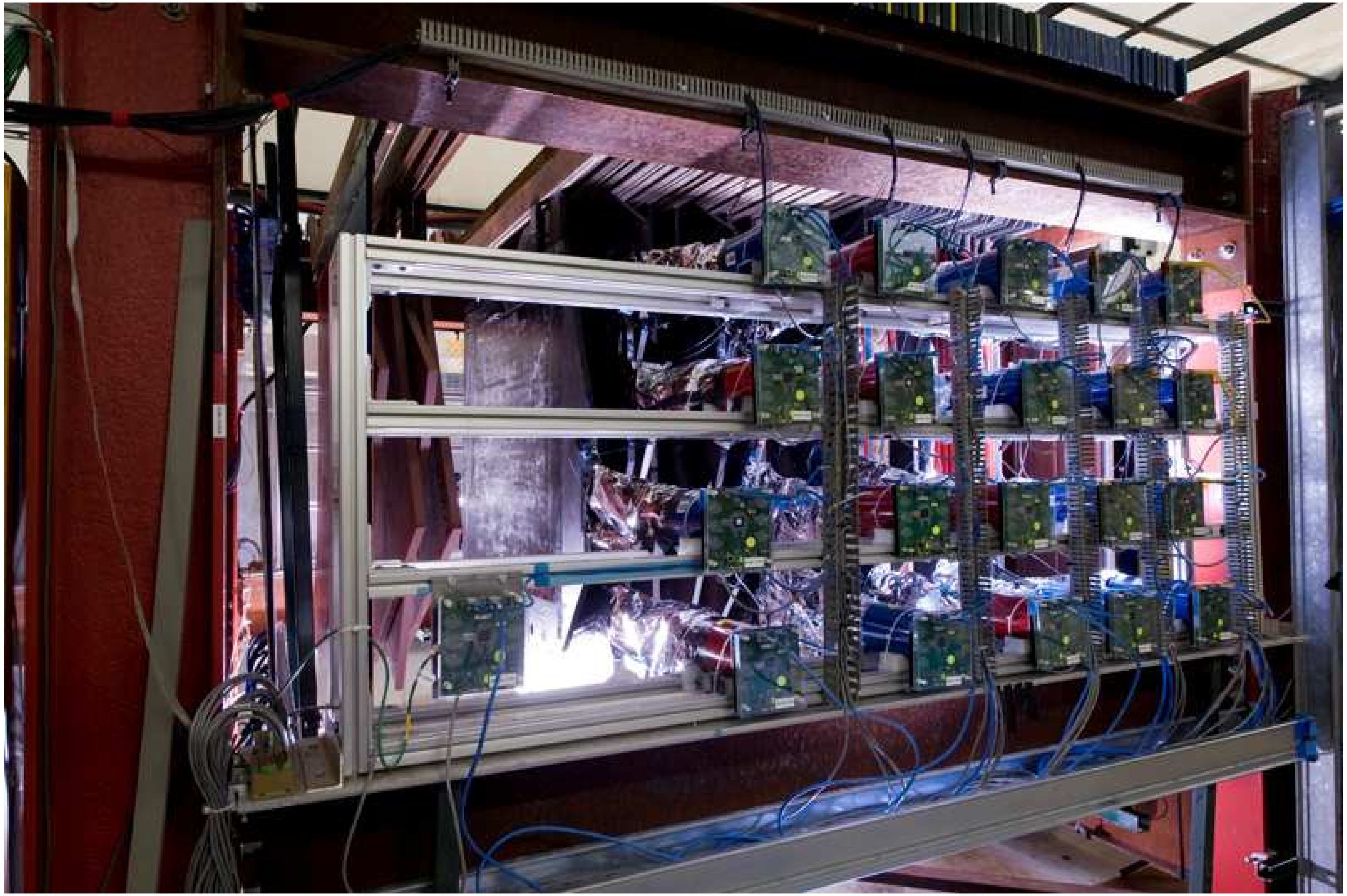
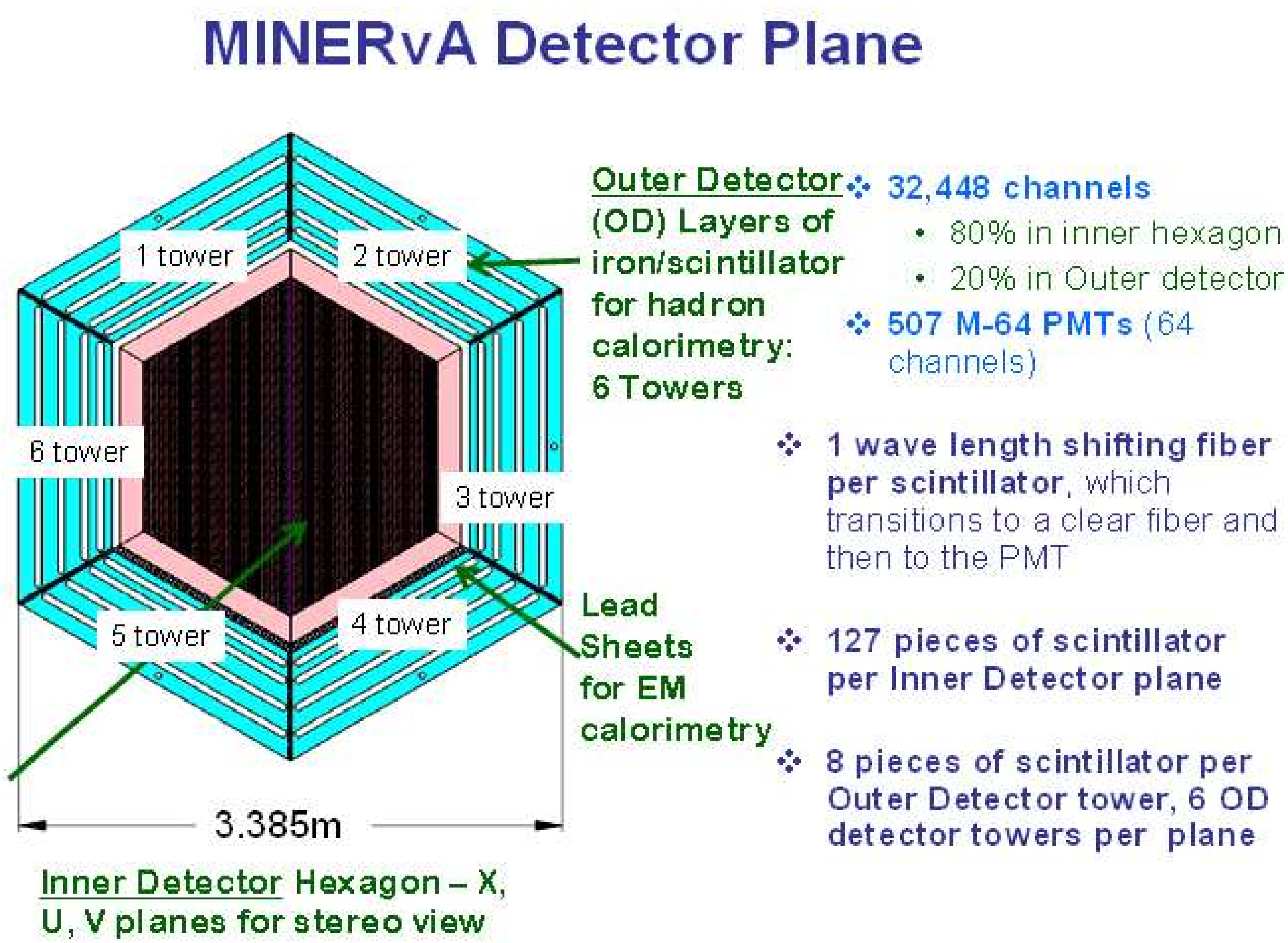
The MINERvA Test Beam Facility

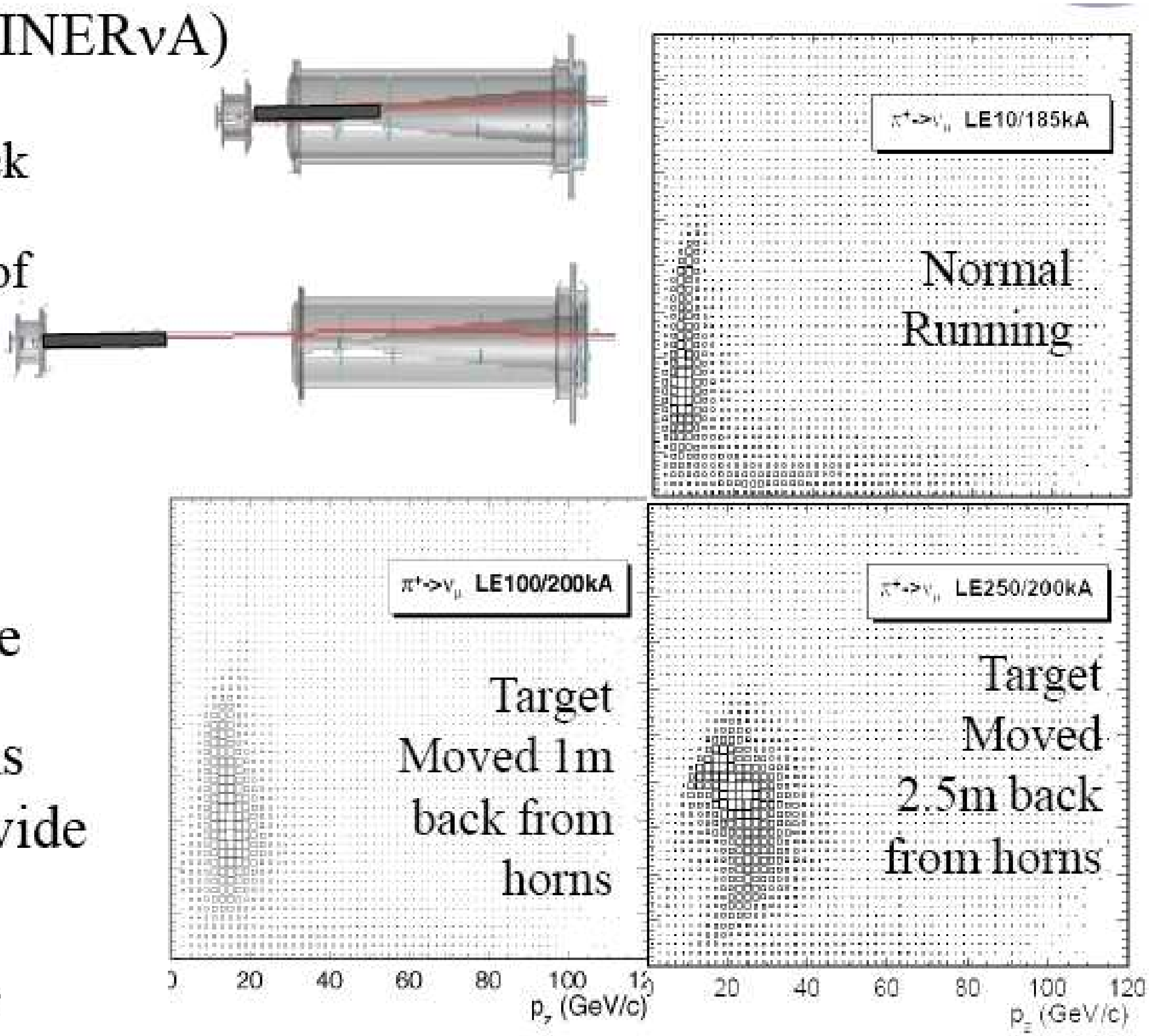


The MINERvA Detector Plane



Understanding the Flux

- NuMI Beamline (MINERνA) can vary
  - Horn current (p_T kick supplied to π's)
  - Target Position (x_F of focused particles)
- Plots show (x_F ,p_T) of π^+ contributing to neutrino flux.
- Minerva will acquire data from total of 8 beam configurations
- Muon monitors provide independent check
- To see more: S. Kopp talk, L. Loiacono Poster



Physics Goals

Nuclear Effects (C, Fe and Pb targets)

- Final-state intra-nuclear interactions. Measure multiplicities and E_{vis} off C, Fe and Pb.
- Measure NC/CC as a function of E_H off C, Fe and Pb.
- Measure shadowing, anti-shadowing and EMC-effect as well as flavor-dependent nuclear effects and extract nuclear parton distributions.

MINERνA and Oscillation Physics

- MINERνA measurements enable greater precision in measure of Δm, $\sin^2\theta_{23}$ in MINOS
- MINERνA measurements important for θ_{13} in MINOS and off-axis experiments
- MINERνA measurements as foundation for measurement of possible CP and CPT violations in the ν–sector

σ_T and Structure Functions (2.8 M total /1.2 M DIS events)

- Precision measurement of low-energy total and partial cross-sections
- Understand resonance-DIS transition region - duality studies with neutrinos
- Detailed study of high-x_{Bj} region: extract pdf's and leading exponentials over 1.2M DIS events

Strange and Charm Particle Production (> 60 K **fully** reconstructed exclusive events) -

- Exclusive channel $\sigma(E_\nu)$ precision measurements - importance for nucleon decay background studies.
- Statistics sufficient to reignite theorists attempt for a predictive phenomenology
- Exclusive charm production channels at charm threshold to constrain m_c

Generalized Parton Distributions (few K events)

- Provide unique combinations of GPDs, not accessible in electron scattering (e.g. C-odd, or valence-only GPDs), to map out a precise 3-dimensional image of the nucleon. MINERνA would expect a few K signature events in 4 years.
- Provide better constraints on nucleon (nuclear) GPDs, leading to a more definitive determination of the orbital angular momentum carried by quarks and gluons in the nucleon (nucleus)
- provide constraints on axial form factors, including transition nucleon --> N* form factors