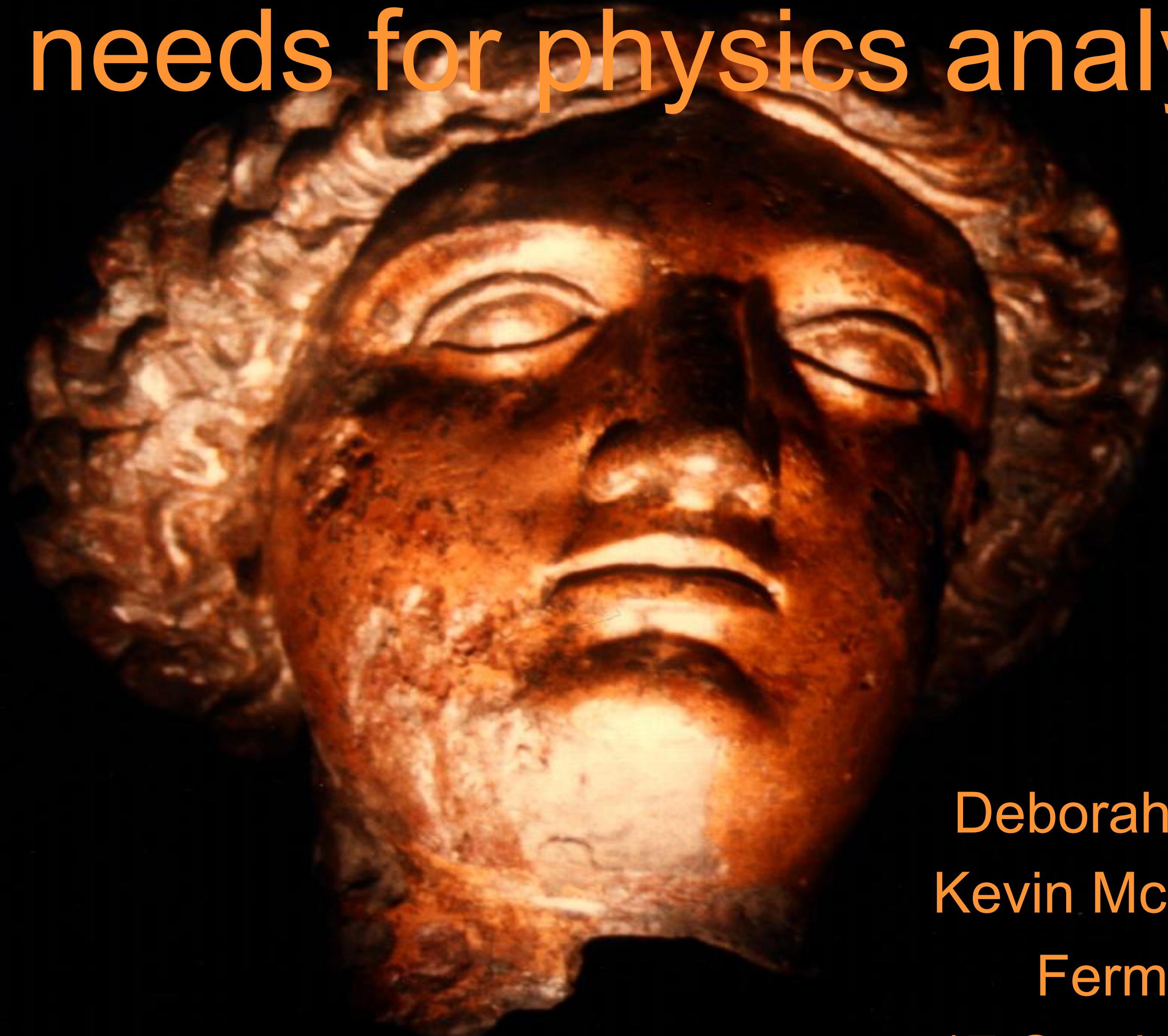
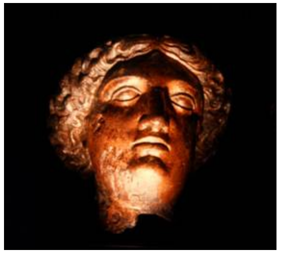
Detector Performance History and needs for physics analyses



Deborah Harris
Kevin McFarland
Fermilab
17 October 2016

Charge Questions



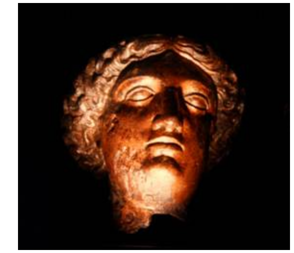
- Question 2: Are the MINOS ND performance and calibration requirements well established for the needs of the MINERvA physics program, and is there a clear plan for achieving these requirements? Leo discussed this already

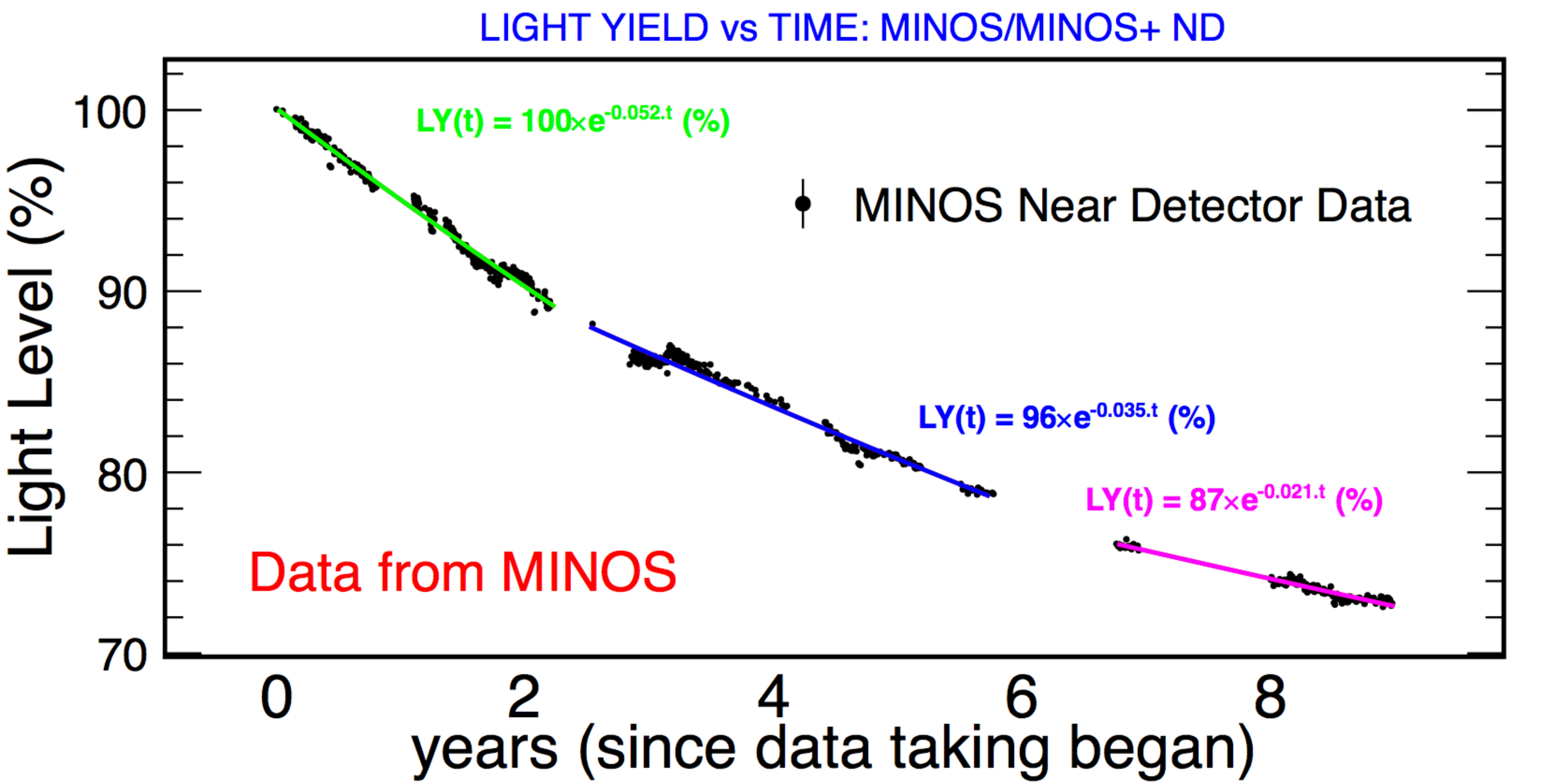
- The performance requirements of MINERvA are much more stringent than for MINOS, so I wanted to talk about those as well in this talk

Outline

- Performance Needs for Physics Analyses
  - Need enough light for tracking (in MINERvA and MINOS)
  - Need enough light for particle identification and calorimetry (less stringent)
  - Need MINOS magnetic field
  - Need to accurately simulate detector acceptance

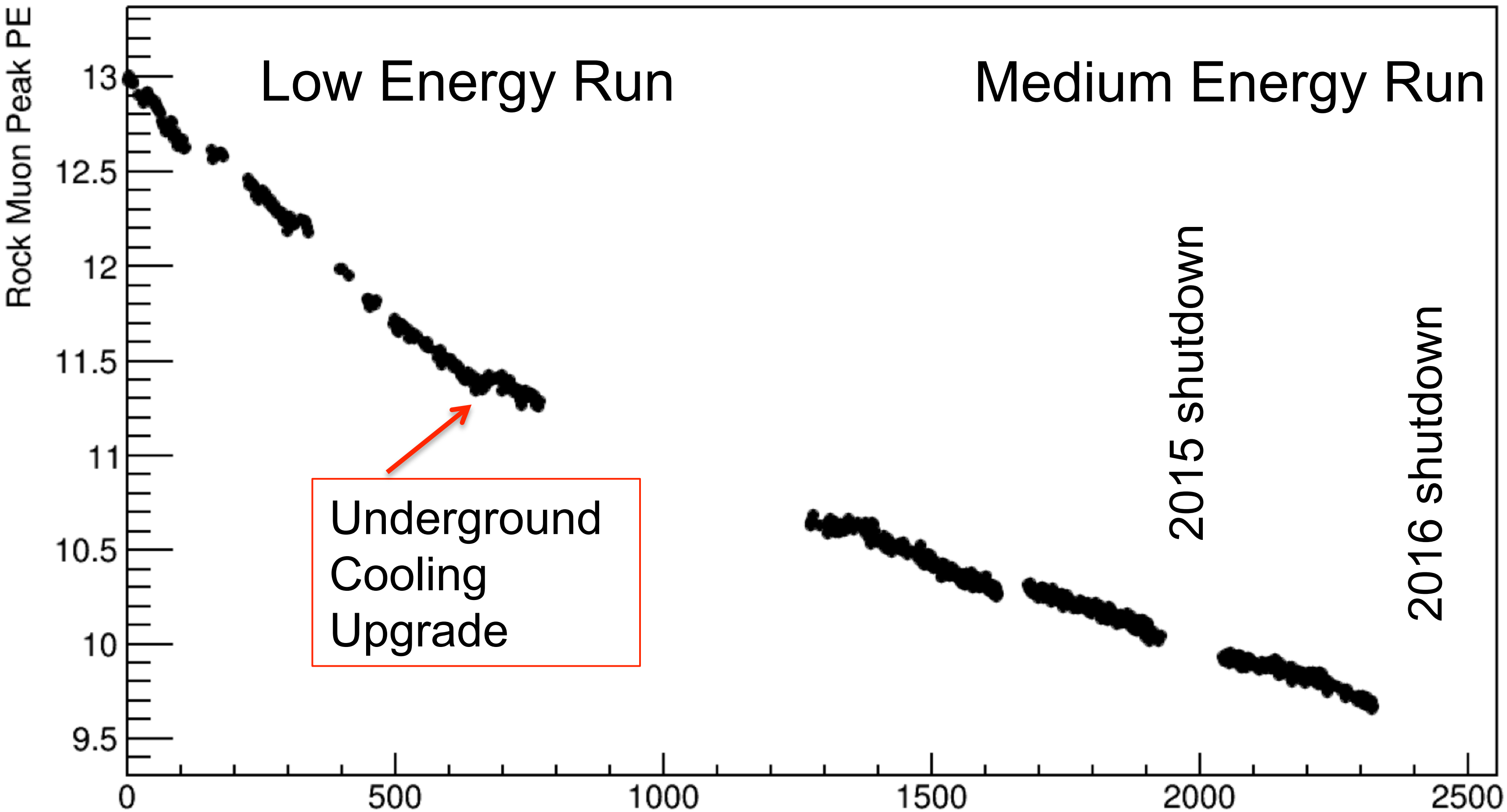
MINOS Light Yield vs Time





100% means 7 Photoelectrons/mip, tracking threshold is 2PE's
Current light level loss: 1.1% per year

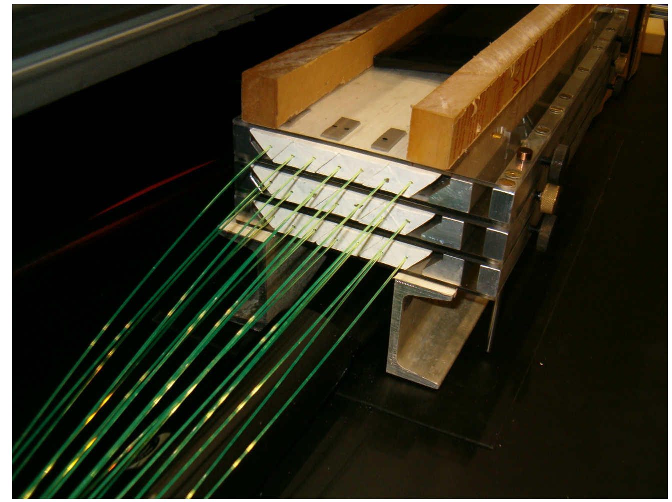
MINERvA Light Yield vs day

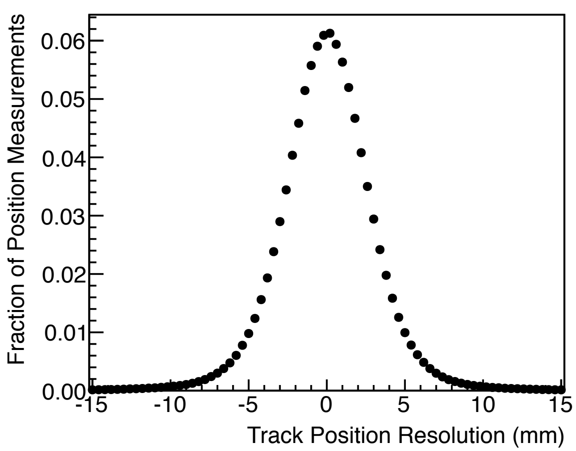


Current Light Loss rate significantly reduced compared to LE run

Light Yield vs Tracking

- In the R&D era, we had a 3-plane vertical slice test
- A systematic study was performed to measure the position resolution of the scintillator planes as a function of light loss (provided by neutral density filters).





Position resolution Degradation for muons: 28% worse for a 37% light loss

Filter	Effective Transmision	Resolution (mm)
0.5	0.43	3.7
0.63	0.59	3.2
0.8	0.75	2.8
1	1	2.5

Light Levels vs time simulated in MC

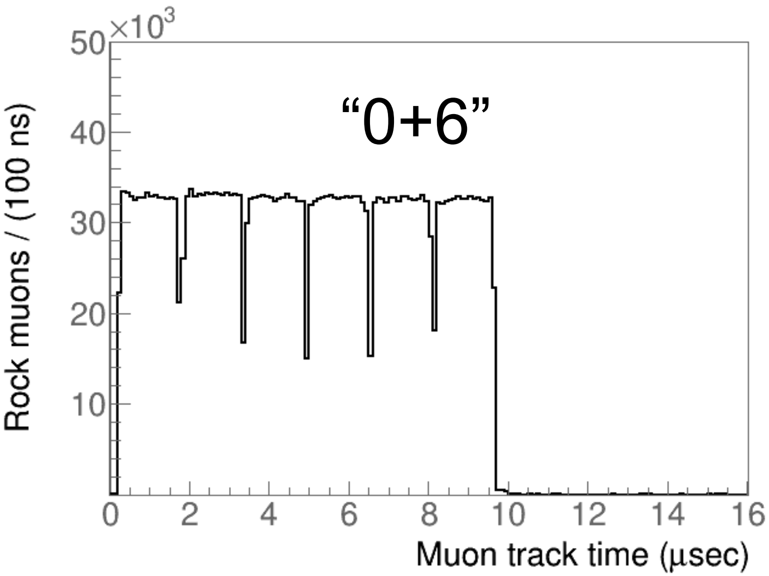
Efficiency Changes from Accidental Activity

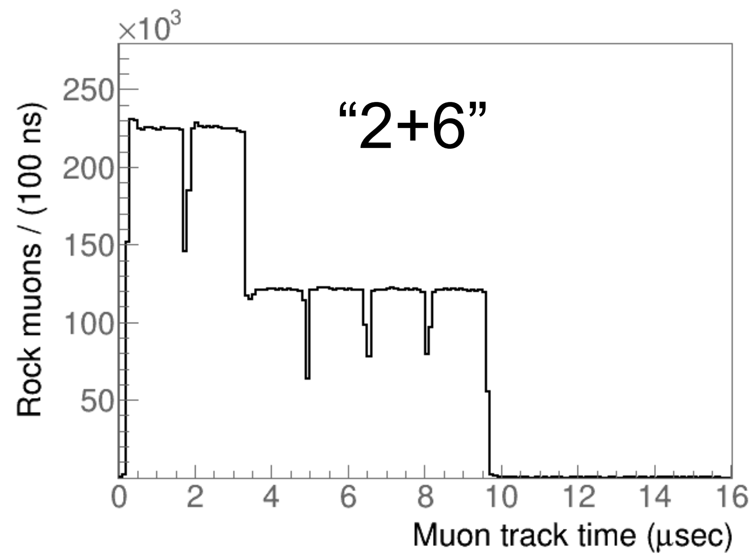
Accidentals in a neutrino experiment?

- MINERvA is affected by accidental activity in several ways
  - Muons from upstream neutrino interactions that overlap with a fiducial event make it hard to match to MINOS muon
  - Preceding activity creates a 200nsec dead time period as signal is read out (this will be reduced in V97)
  - If you are looking for an electron (from π to μ to e decay) you may get one from a different event by accident
- MINOS is affected by accidental activity
  - Tracks get lost or mis-matched between U and V if there is too much activity
  - Far more dense detector means lots more events/spill that can add to confusion

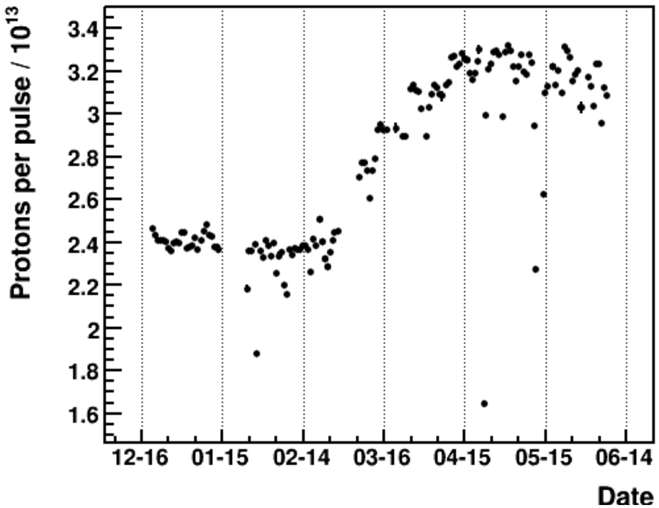
Signatures of Efficiency Loss

- First clue: “Rock Muon Monitoring” plots
  - Muons from upstream interactions 100% correlated with protons on target, should be proportional in perfect detector
  - Checked every day on shift
  - Muon has to travel through all of MINERvA
  - Immediately see several % changes due to slipstacking

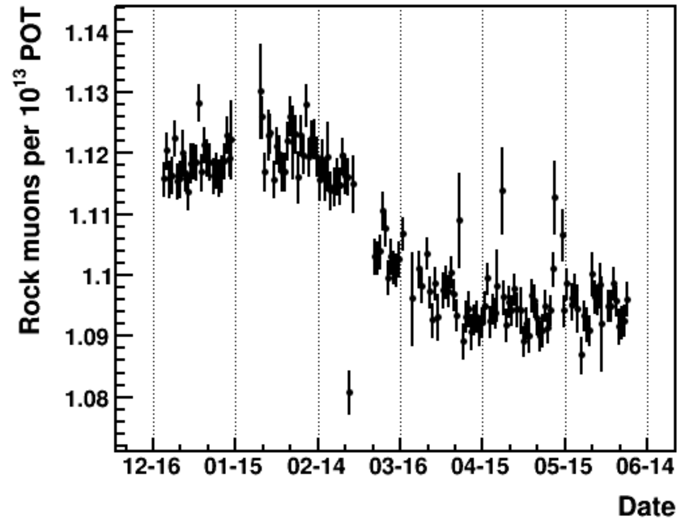




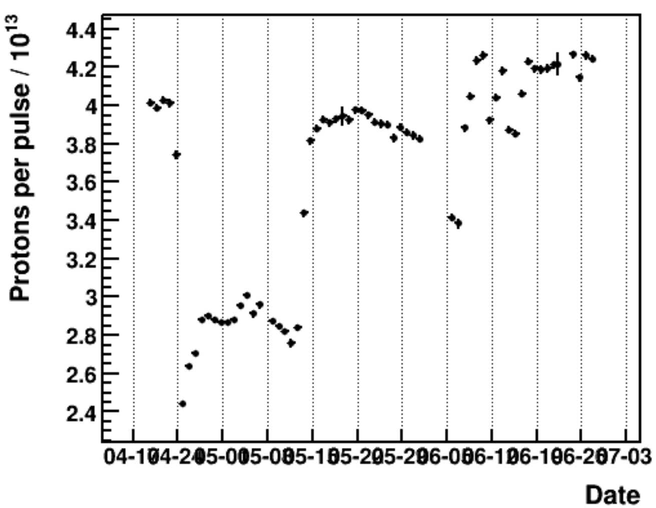
Changes in Slipstacking: Rock Muons



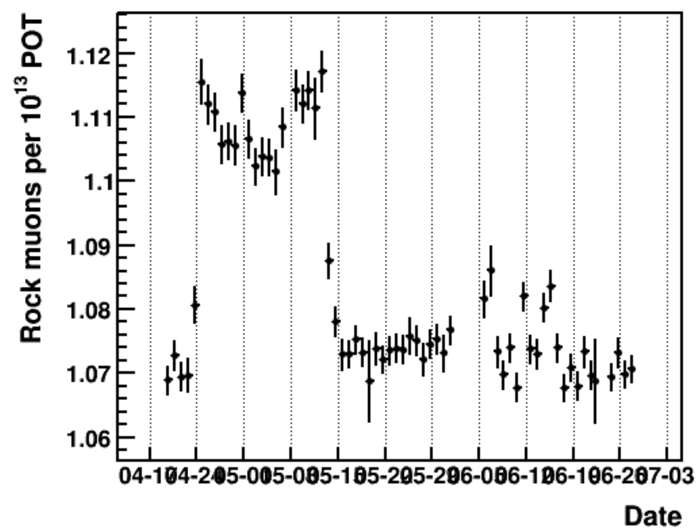
0+6 to 2+6: 3% loss



2015

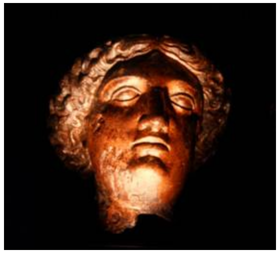


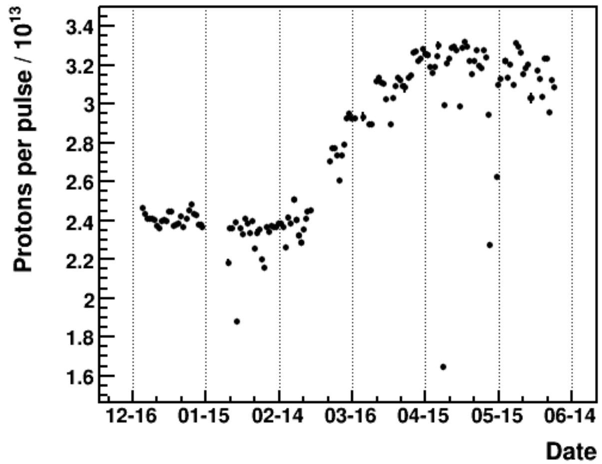
0+6 to 4+6 to 6+6



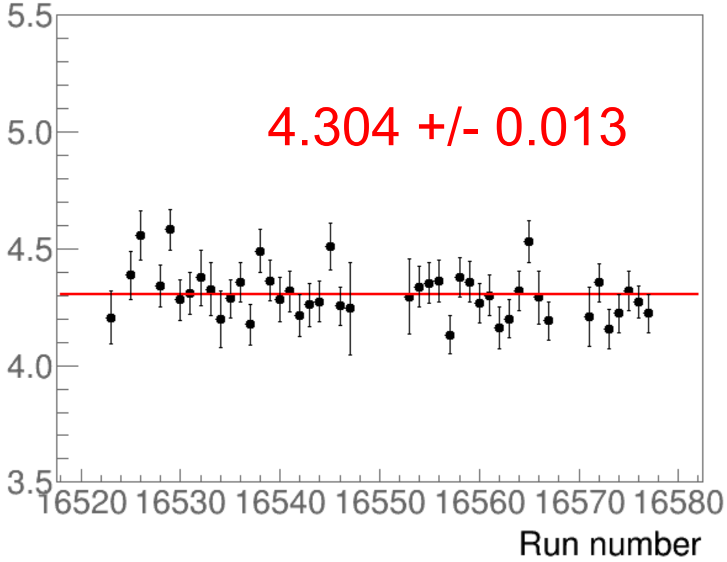
2016

Changes in Slipstacking: e^- from μ decay rates

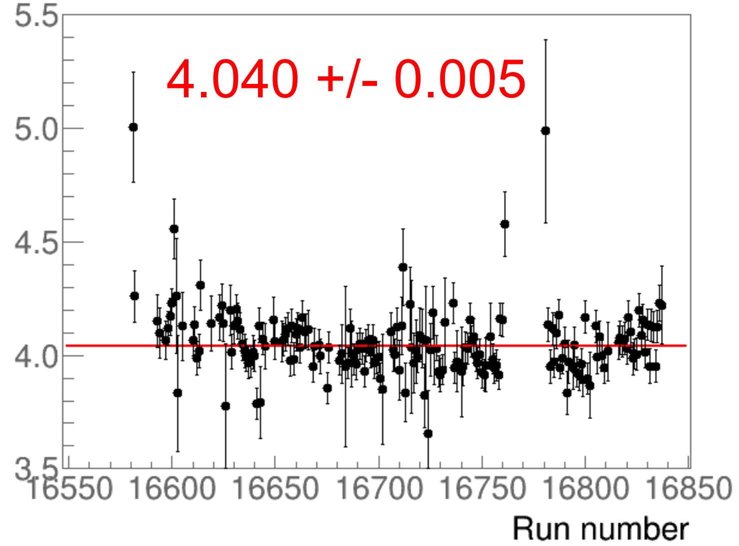




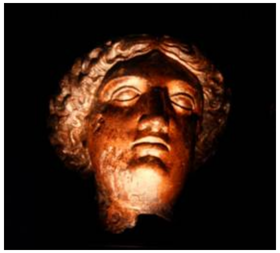
2015

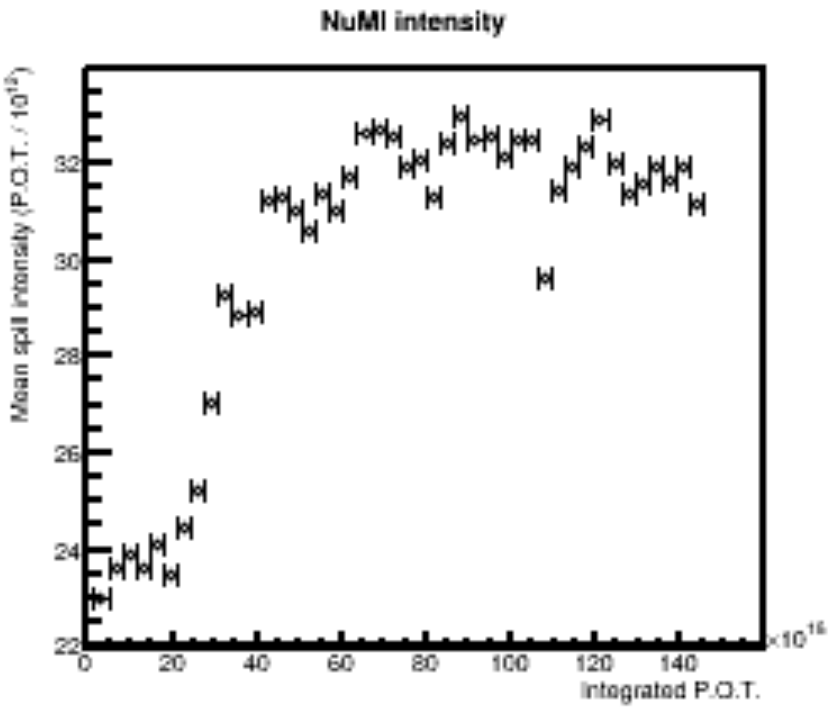


0+6
to
2+6
6.2% loss

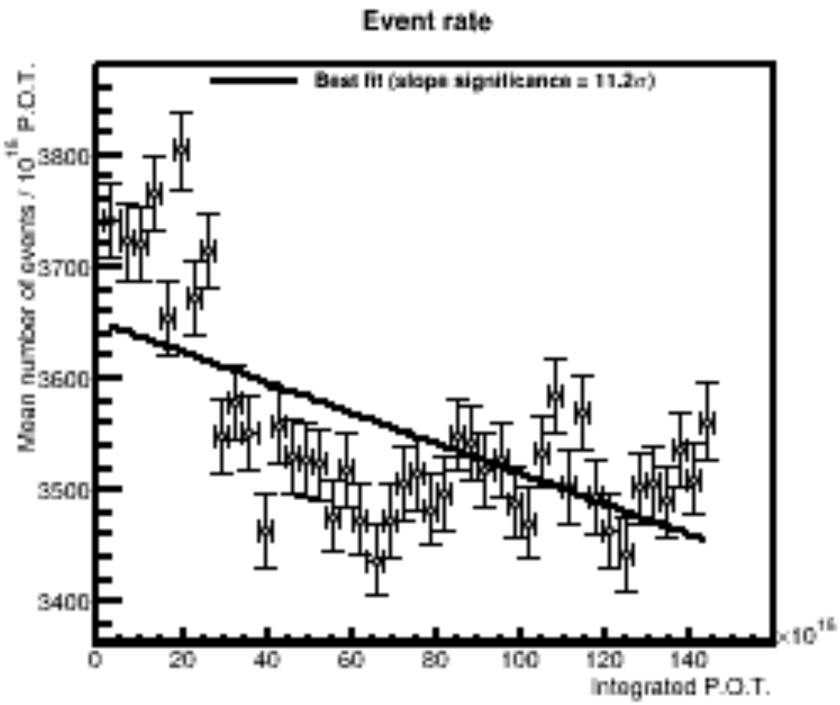


Changes in Slipstacking: ν_μ charged current event rates





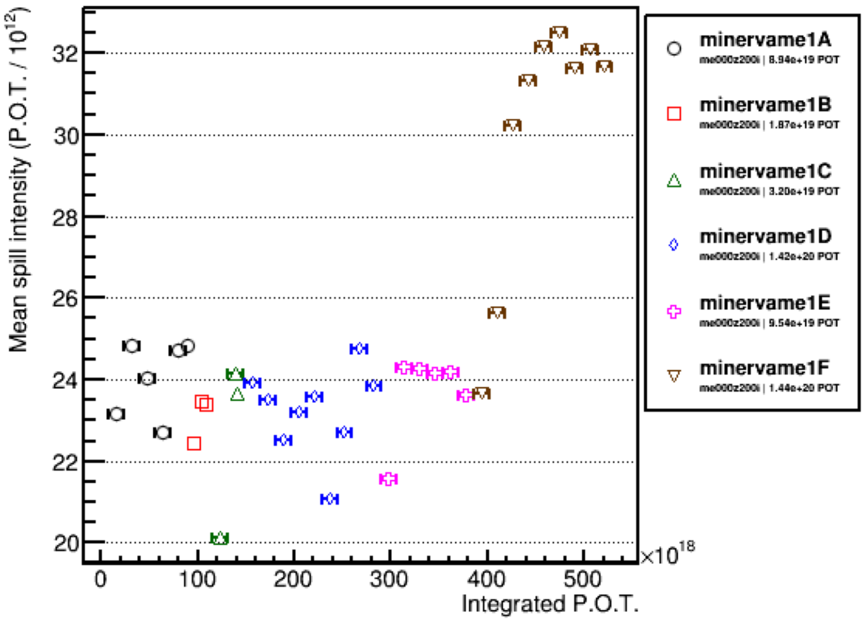
0+6
to
2+6
10%
loss



Note horizontal axis: Integrated POT, not time

Changes in Slipstacking: ν_μ CC: μ and recoil energy

9/2013 6/2015

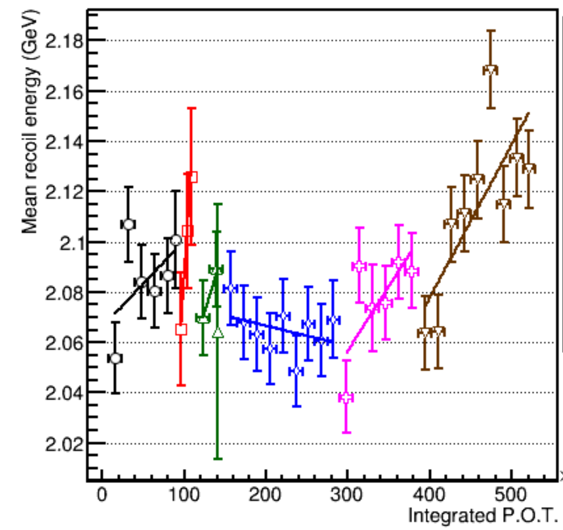


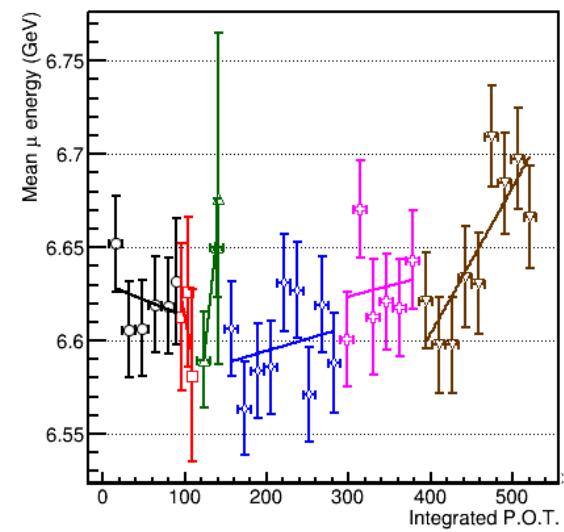
Note horizontal axis!

0+6 for first 4E20

2+6 for next 1E20

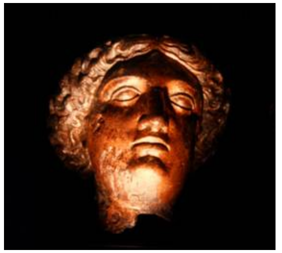
Some Muon and Recoil Energy Dependence





2013 through 2015 Data

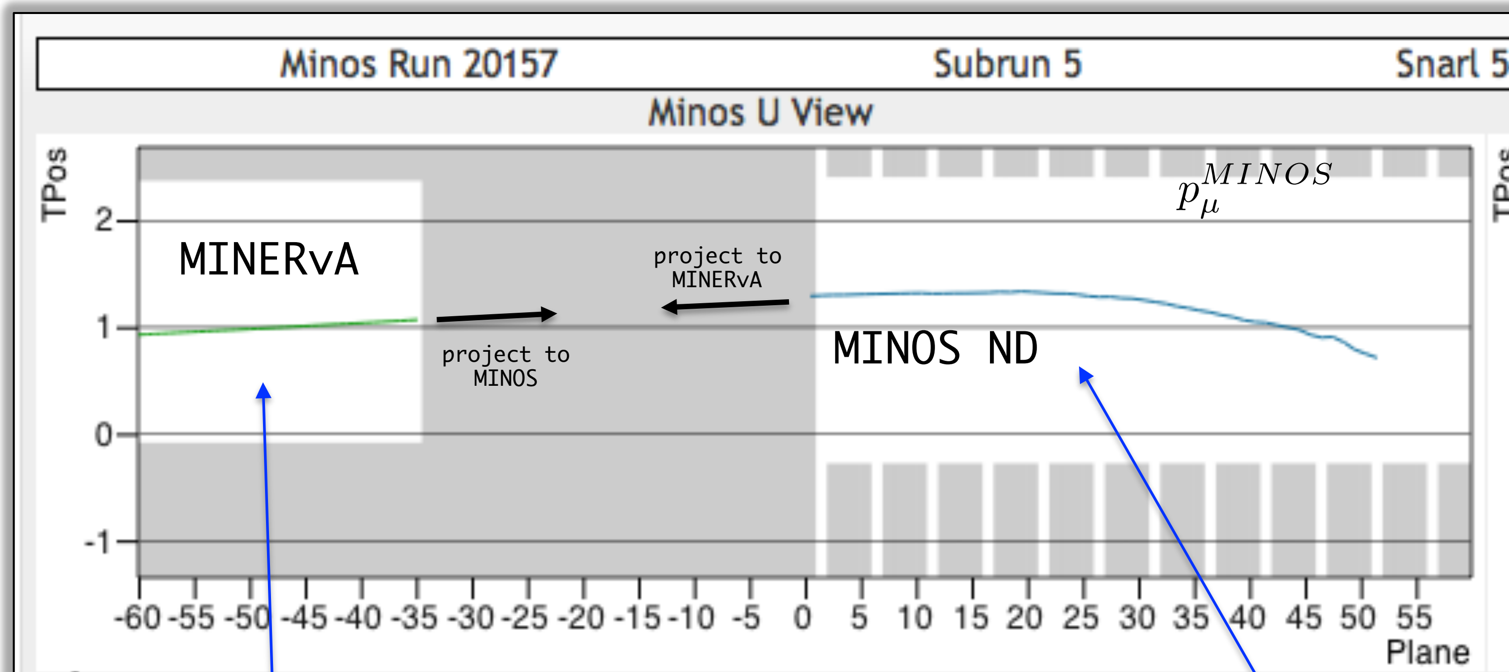
Coping Strategies



- Simulation:
  - Add real data to a MC-generated neutrino event for both MINERvA and MINOS, and THEN do event reconstruction
  - Time dependence is covered if you overlay data events correctly for different run periods
  - Live with inefficiency but make sure you can check with data that you are simulating that correctly
  - We did this for LE, but it was easy because the event rate was low and the protons per booster batch was basically flat for most of our statistics
- Optimize Analysis cuts for a busy detetor
  - We may have to use different analysis cuts for ME if we find that
- Firmware Upgrade:
  - make sure there is less deadtime in the first place

Muon Tracking Efficiency

- Need to check that simulation reproduces efficiency



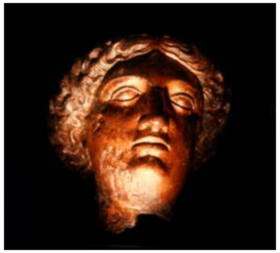
Affected by:

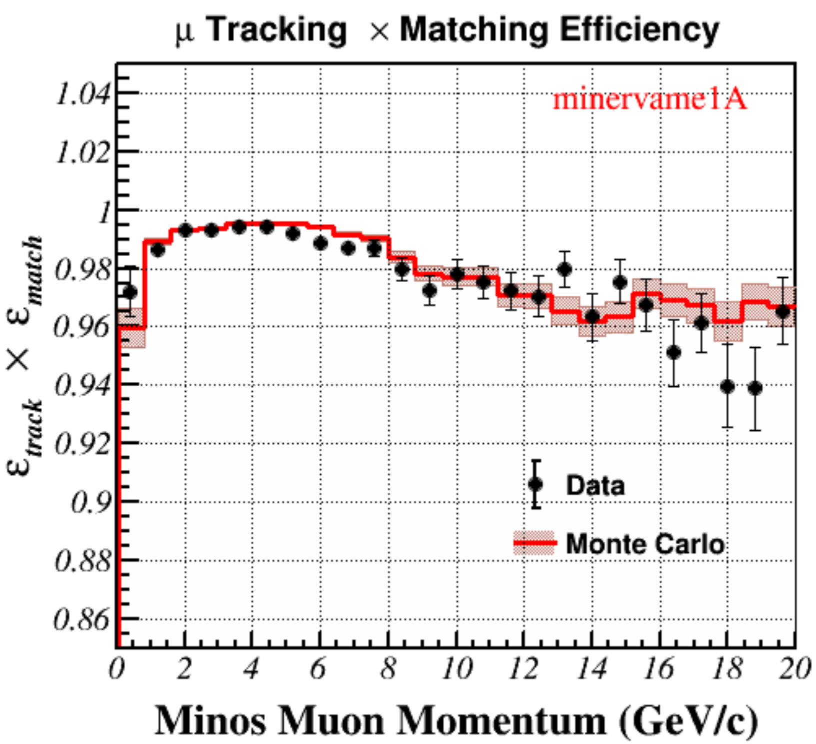
1. pile-up at high intensity
2. dead-time
3. large showers

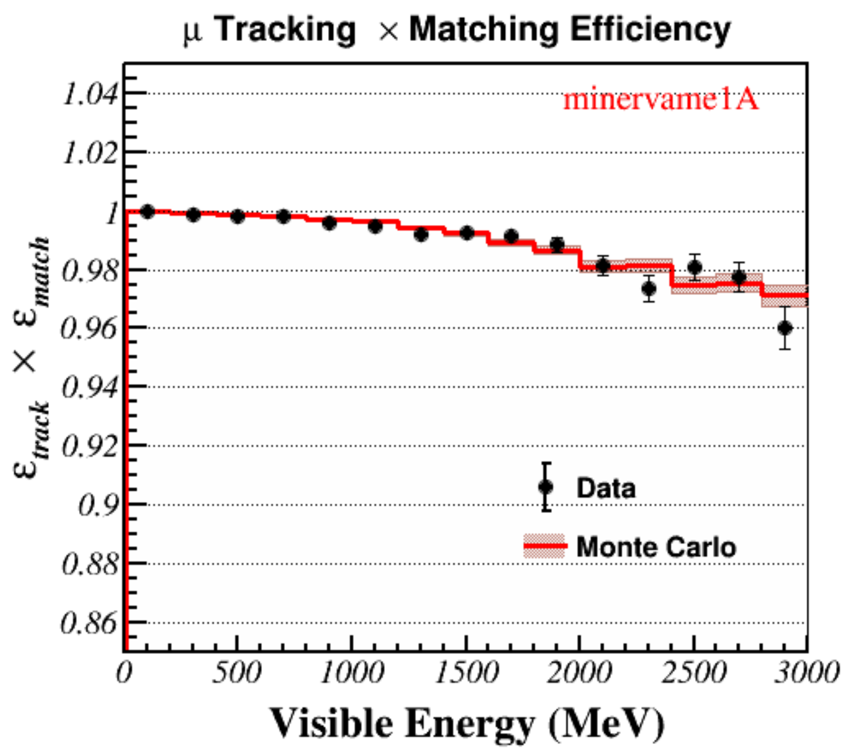
Affected by:

1. pile-up at high intensity, worse for shorter tracks (low energy)

MINERvA Tracking Efficiency (ME)

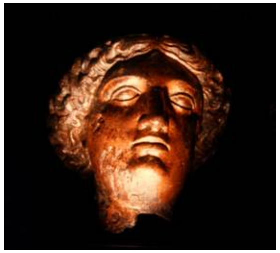


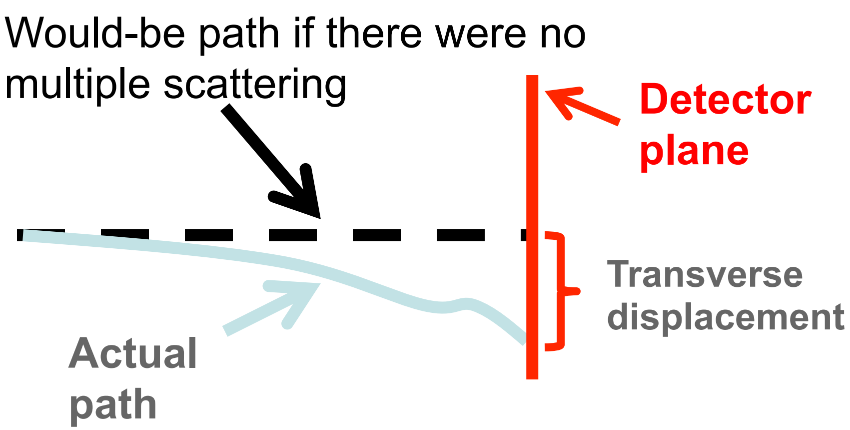


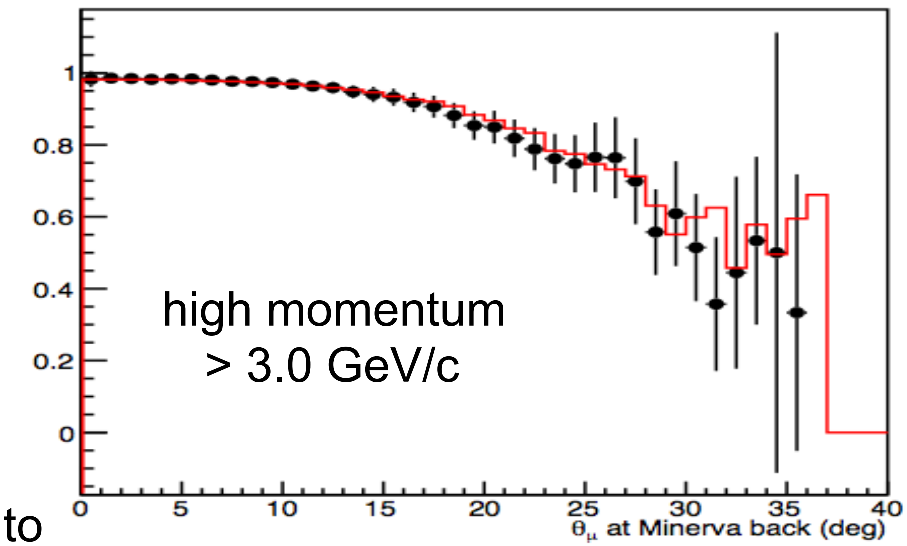


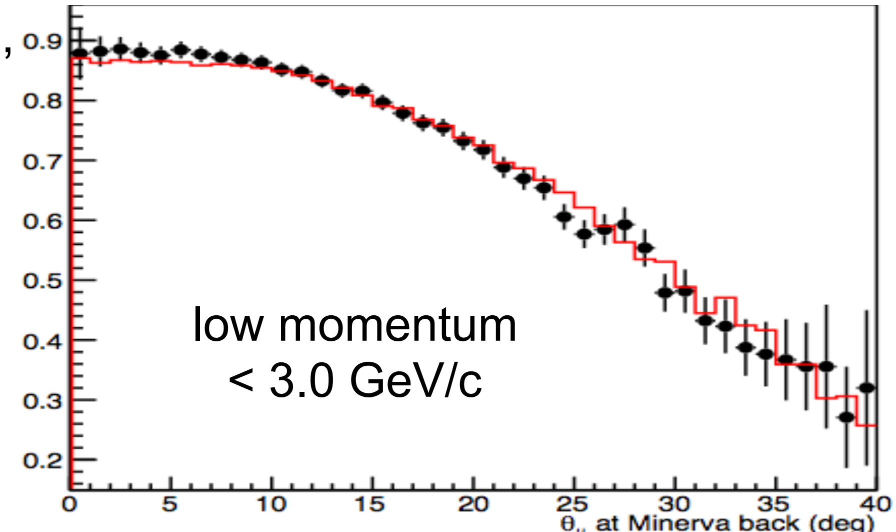
Momentum provided by MINOS Near Detector,
look upstream to see if you can match to a MINERvA track
Agreement between data and MC good to 1%, non-slip-stacked beam

MINOS Tracking Efficiency





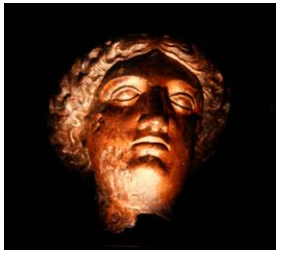




use scattering in MINERvA ECAL+HCAL to split into **high** and **low** momentum samples, correct for data/mc difference

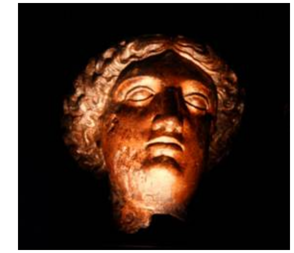
	High p	**Low p**
Data	97.17	81.01
MC	98.01	84.01
Data/MC	**0.991**	**0.964**

Intensity Dependence Summary

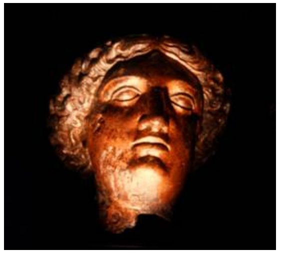


- Different analyses will have different intensity dependences
- Average data overlay is modeling intensity dependence for
  - Tracking from MINOS to MINERvA
  - Tracking from MINERvA to MINOS
- For LE neutrino running and pre-slipstacked ME beam, Data/MC difference is ~3% for μ less than 3GeV
- For LE antineutrino and μ >3GeV events, Data/MC difference is ~1%
- For slipstacked beam, we need a new approach

Adding protons per batch



- Major overhaul of simulation took place over the past few months
- Multi-step process
  – Save the protons per booster batch into the data stream
  – Throw MORE monte carlo neutrino events in the booster batch where there are more protons on target
  – Overlay MORE data events where the data is slipstacked than when the data is not slipstacked
- Have to generate MC versus protons on target, not versus time



Plan for Coping

- New release has intensity dependence simulated correctly
- Will redo earlier tracking studies to see how well we simulate the changes from 0+6 to 2+6
- Will then see how well we simulate antineutrino running accidental activity (2+6 through 6+6)

- After 2016 shutdown: will have to simulate 6+6 neutrinos at high statistics, but with new deadtime model because of v97

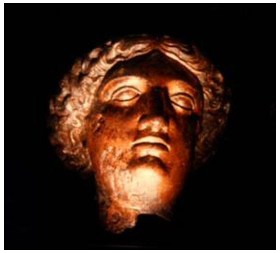
Longer Term Plan

- Will investigate which cuts cause the most intensity-dependence
- Will continue to adjust cuts using new monte carlo to reduce intensity dependence
- May need to change the way we “slice” events in time
- Low Energy Kaon Analysis started some of this work since signal was a delayed track from kaon decay

Summary

- Light levels are adequate in both MINERvA and MINOS Detectors
- Tracking efficiency in ME beam is simulated to 3% (1%) for muons below (above) 3GeV beam before slipstacking started
- New overhaul of simulation now makes it possible to test efficiencies to 2x higher instantaneous intensities (2016 running)

Backup: History of Intensity Dependence Simulation



	Low momenturm muons			High momenturm muons		
	Data	**Simulation**	**Ratio**	**Data**	**Simulation**	**Ratio**
2010 neutrinos	80.2	83.2	**96.3**	97.3	98.2	**99.0**
antineutrinos	82.6	84.8	**97.5**	98.1	98.6	**99.5**
2011-12 neutrinos	80.3	82.5	**97.3**	97.4	98.1	**99.4**

Note: 2010 neutrino running was in TeVatron era, where last booster batch was "cleanup" and had fewer POT than the first 5 batches. We didn't simulate this, but made a correction and assigned a systematic uncertainty