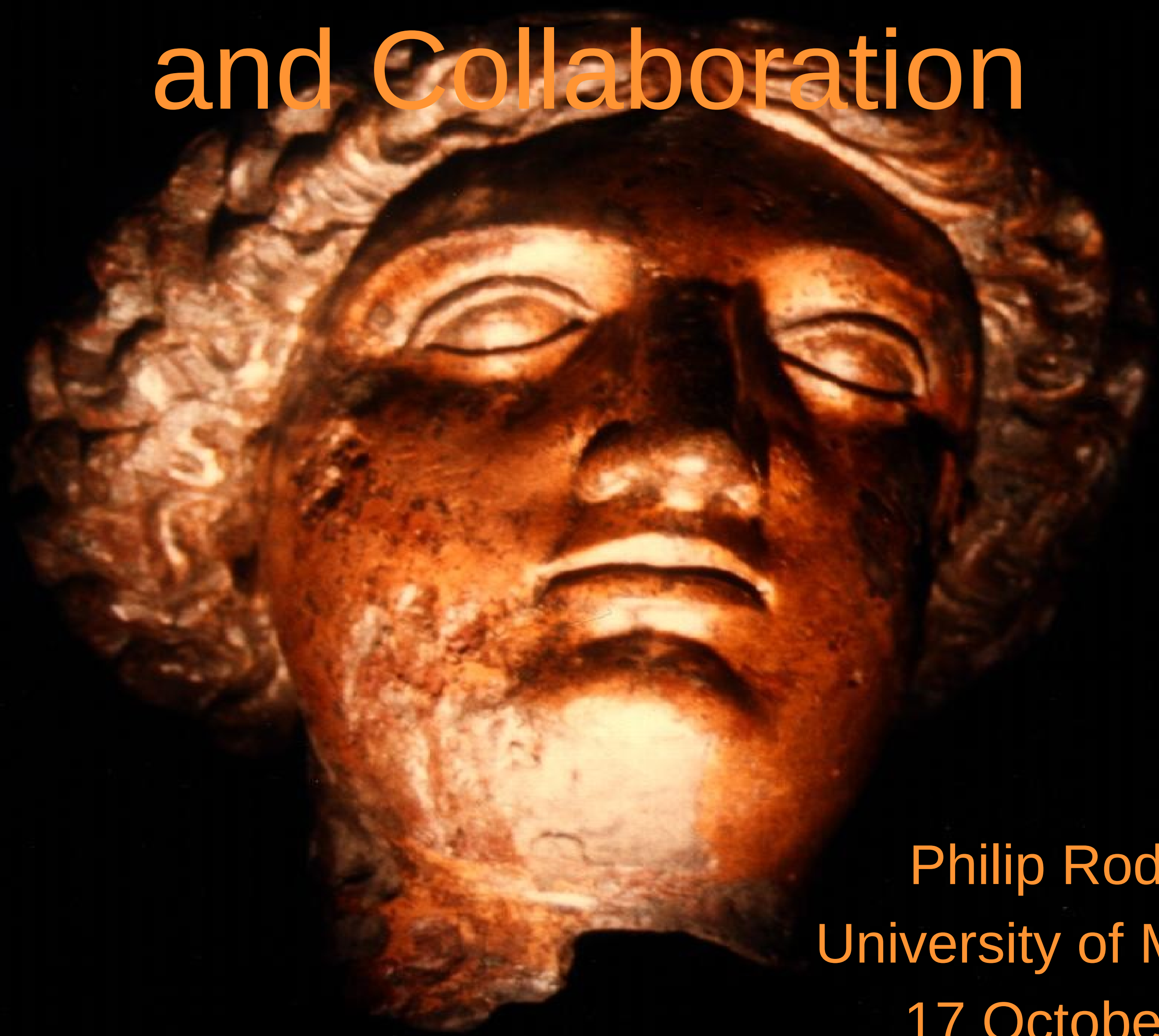
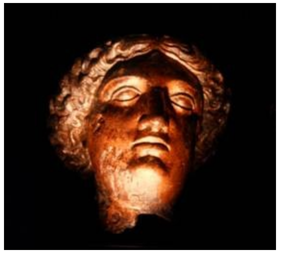
MINERvA Results, Prospects and Collaboration



Philip Rodrigues
University of Mississippi
17 October 2016

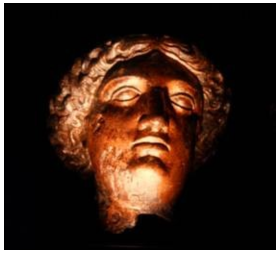
Charge questions



- *Is there a well-understood run plan for FY17, consistent with accelerator schedule and performance?*
- *Are there robust plans for data processing and data analysis? Have adequate resources from the collaboration been identified for data analysis to meet the set goals?*
- *Are there clear goals set for reporting and publishing the results from the experiment in a timely fashion?*

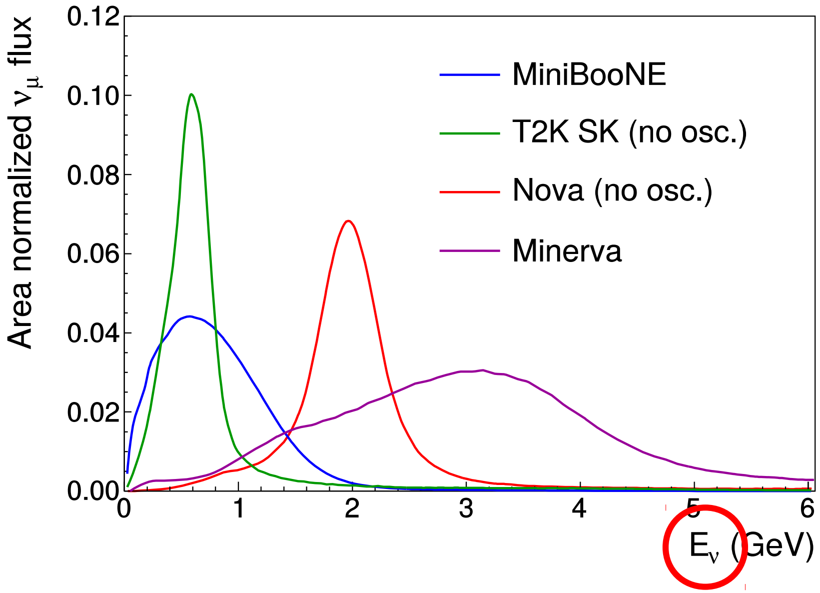
Outline

- The case for MINERvA
- MINERvA low-energy dataset results
  - What it took to get there
- Medium-energy dataset goals
- Run planning
- Resources to meet those goals
- Progress towards meeting those goals

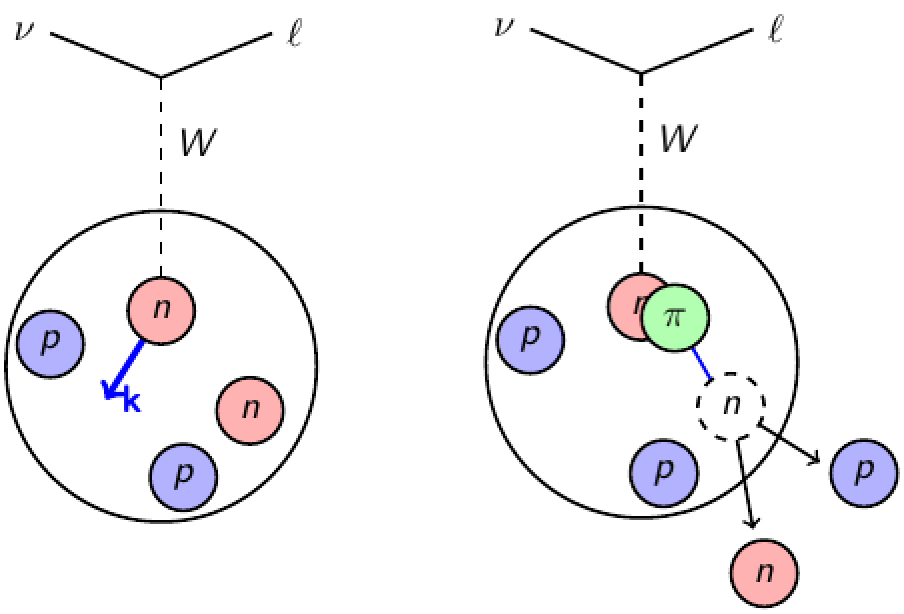


MINERvA Physics Case

- Two reasons we need to know neutrino-nucleus cross sections:
  - To make precise neutrino oscillation measurements
  - To better understand the nucleus



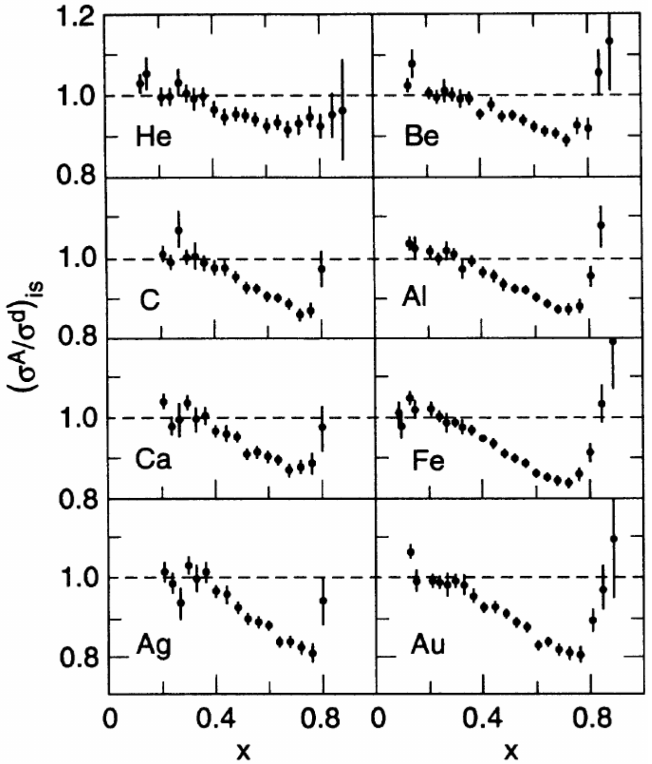
$$P(\nu_\alpha \rightarrow \nu_\beta) \approx 1 - \sin^2 2\theta \sin^2\left(\frac{\Delta m^2 L}{E_\nu}\right)$$



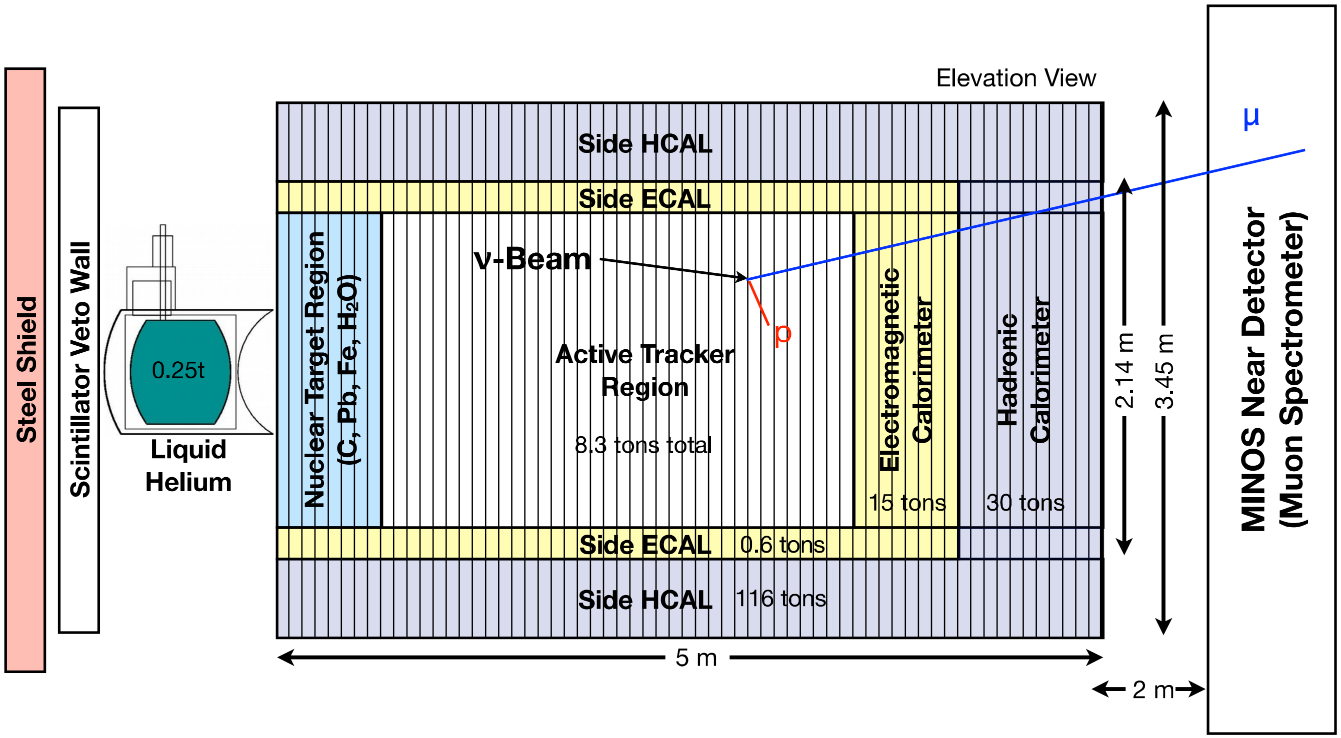
MINERvA Physics Case

- Two reasons we need to know neutrino-nucleus cross sections:
  - To make precise neutrino oscillation measurements
  - To better understand the nucleus

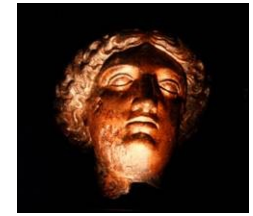
- “EMC effect” in inelastic *electron* scattering still not understood
- Data from neutrinos may discriminate between models
- Need ratios between materials...



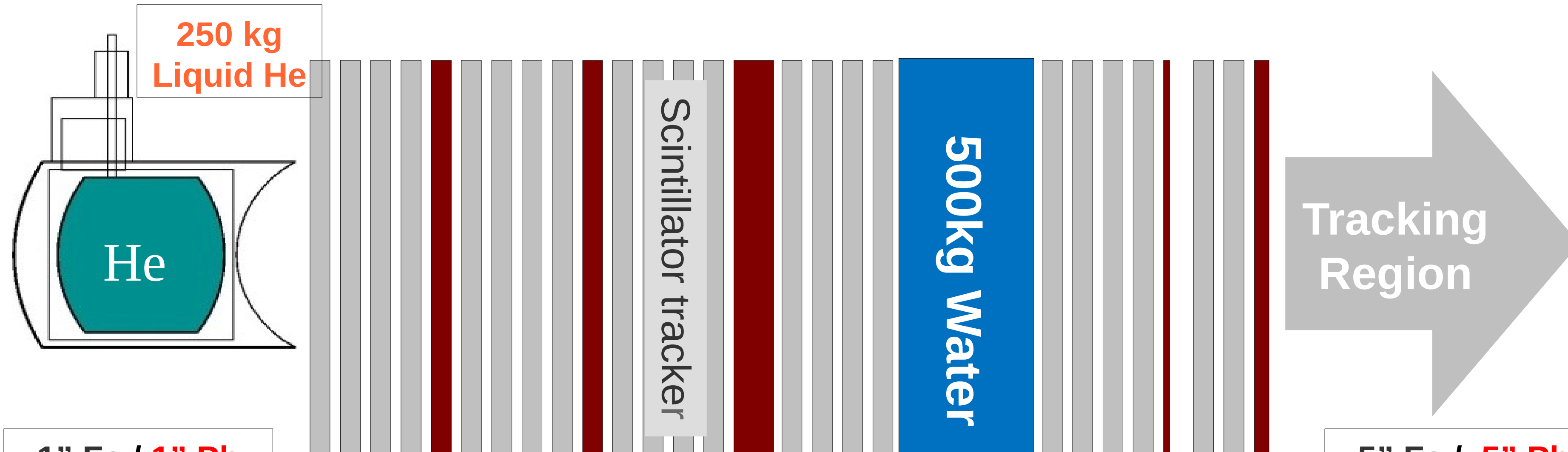
MINERvA Detector



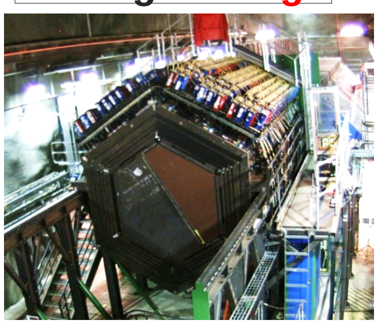
- 32,000 channels. Proven technology: scintillator+PMTs
- Solid targets: CH scintillator, pure carbon, iron, lead
- Liquid targets: Helium, Water
- Muon momentum, charge ID, from MINOS



Nuclear targets

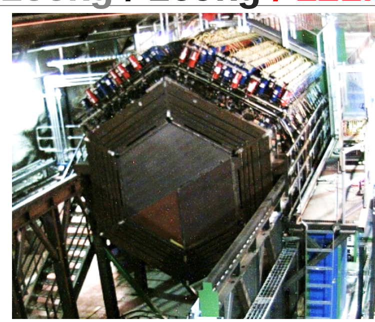


1” Fe / 1” Pb
323kg / 264kg

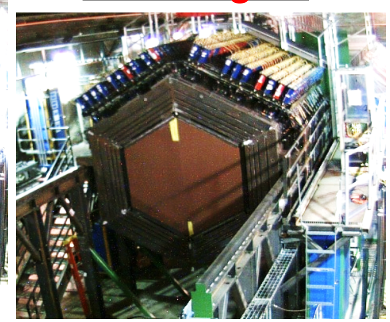


1” Pb / 1” Fe
266kg / 323kg

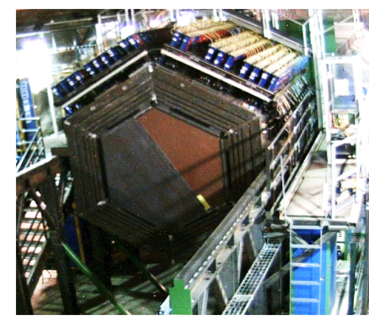
3” C / 1” Fe / 1” Pb
166kg / 169kg / 121kg



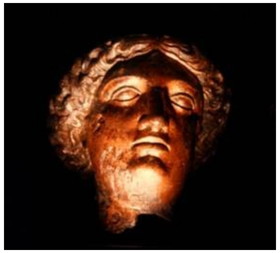
0.3” Pb
228kg



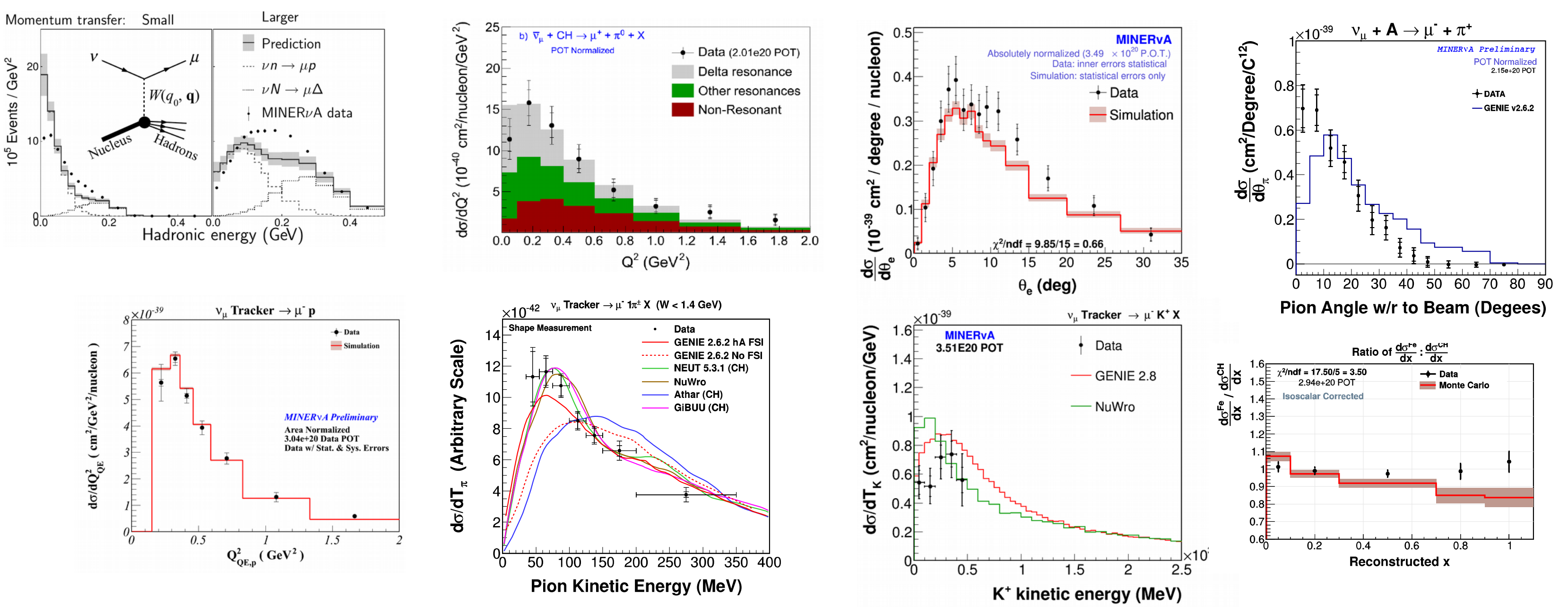
.5” Fe / .5” Pb
161kg/ 135kg



Low-energy dataset results



- Took data in “low-energy” beam tune 2009-2012
- Published 16 cross-section papers: 8 PRL, 7 PRD, 1 PLB
  - 8 of those in the past year!
- 15 W&C talks to date
- Three more papers in collaboration or external review
- Five more LE analyses very close to completion



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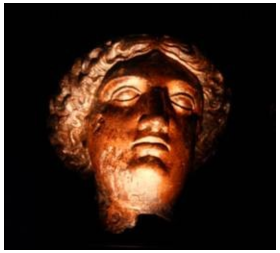

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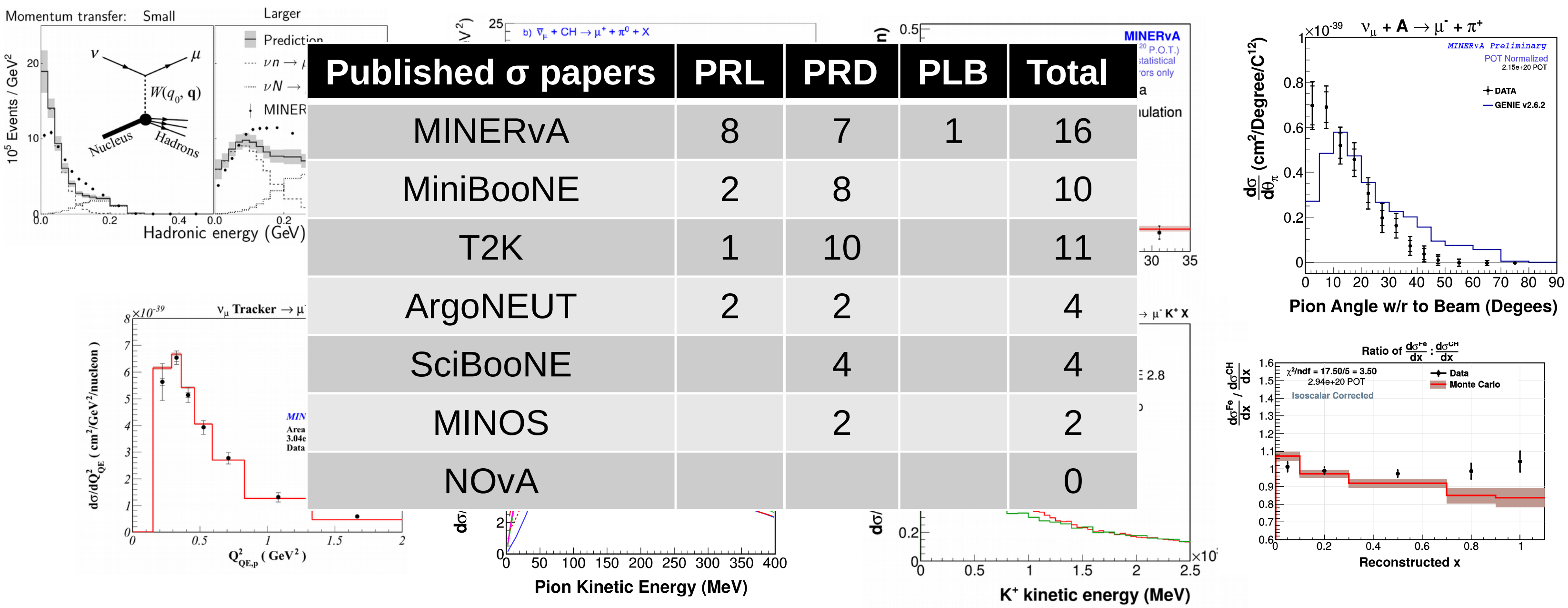
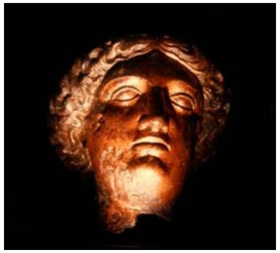


Published σ papers	PRL	PRD	PLB	Total
MINERvA	8	7	1	16
MiniBooNE	2	8		10
T2K	1	10		11
ArgoNEUT	2	2		4
SciBooNE		4		4
MINOS		2		2
NOvA				0

Low-energy dataset results



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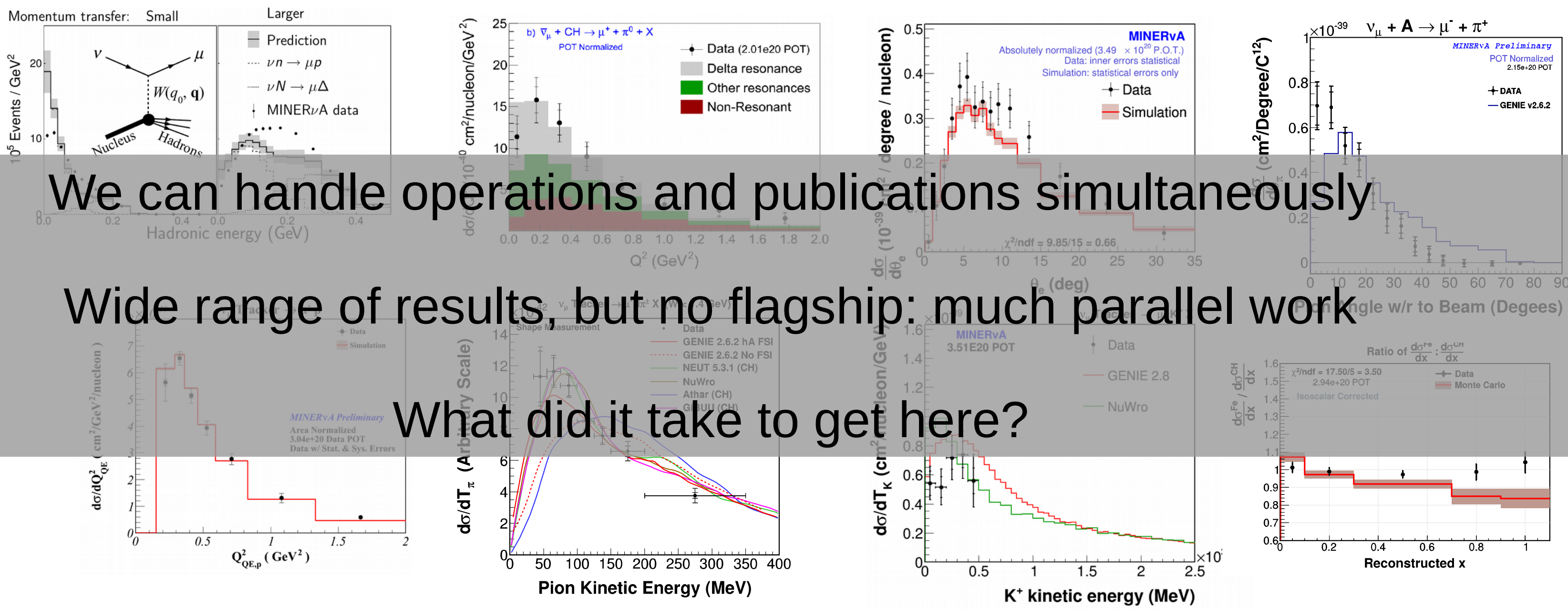
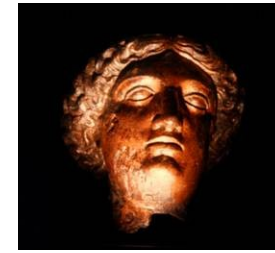


We can handle operations and publications simultaneously

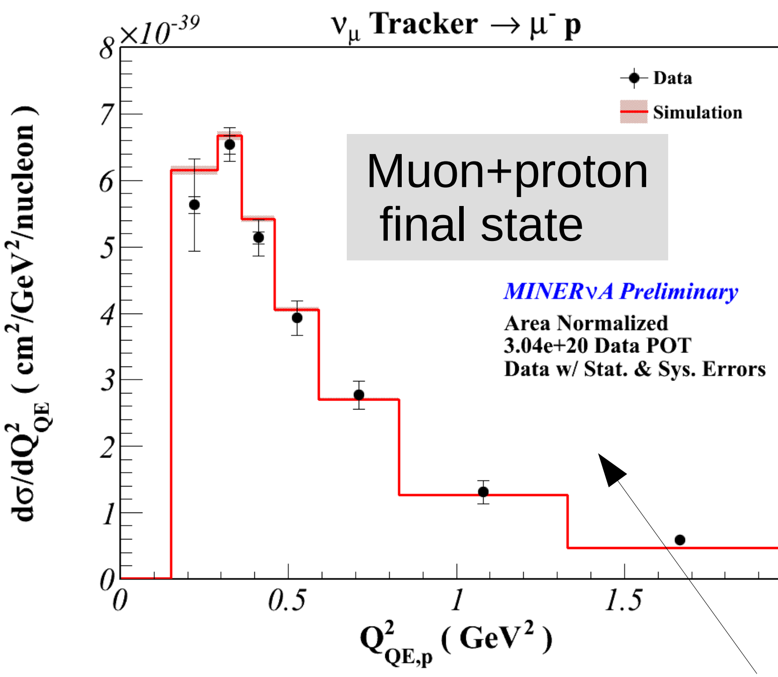
Wide range of results, but no flagship: much parallel work

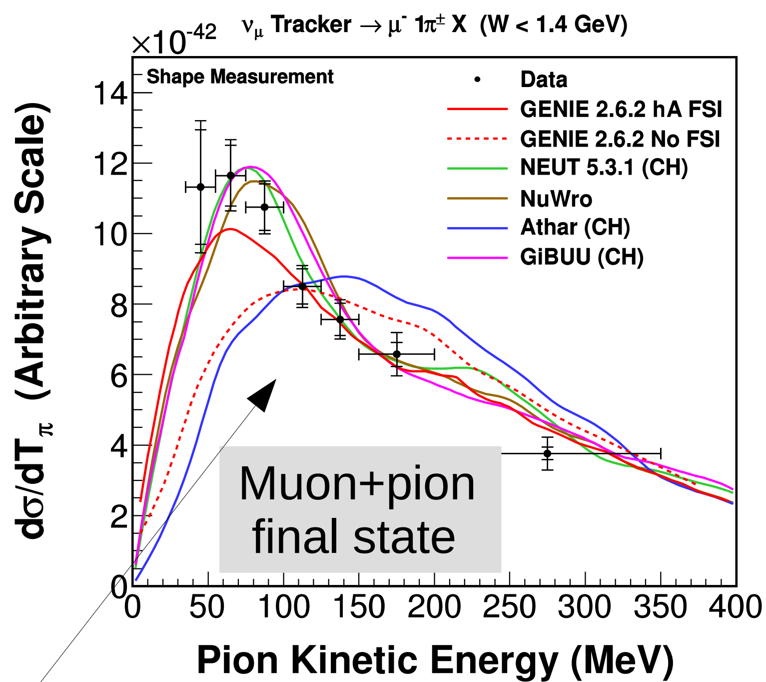
What did it take to get here?

Common analysis techniques



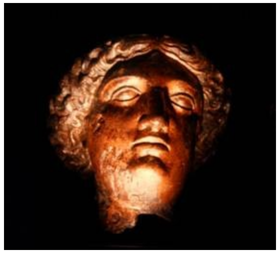
- A wide range of channels, so different reconstruction techniques
- But many common elements
  - Muon ID, background subtraction techniques, pion/proton separation
  - Common systematics framework (more from Trung)
- Publications followed quickly after the first





Same pion/proton separation

LE Testbeam program

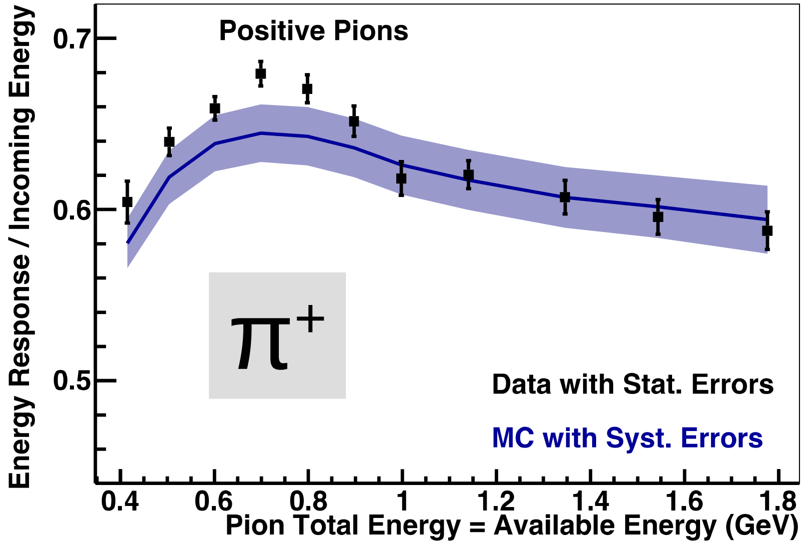


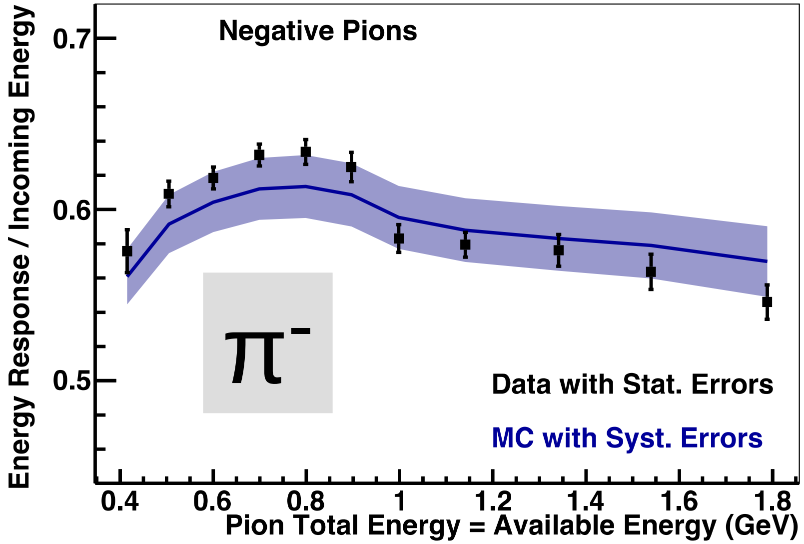
Testbeam I ran in 2010, using a tertiary beam in MTest

Both polarities, $\pi^{\pm}$ and p mostly (few $e^{\pm}$) triggers, < 1.8 GeV,

Two detector configurations

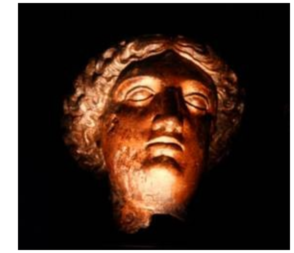
Measured detector response, scintillator saturation, proton range



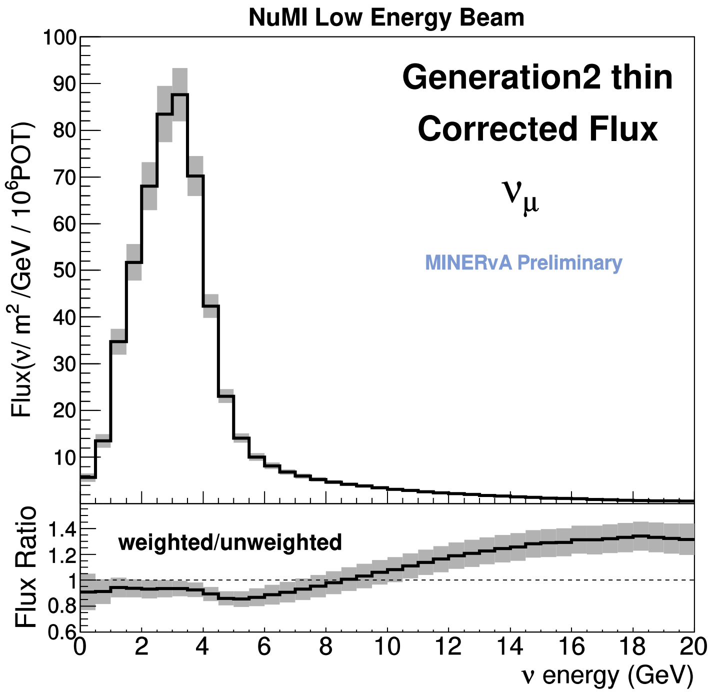


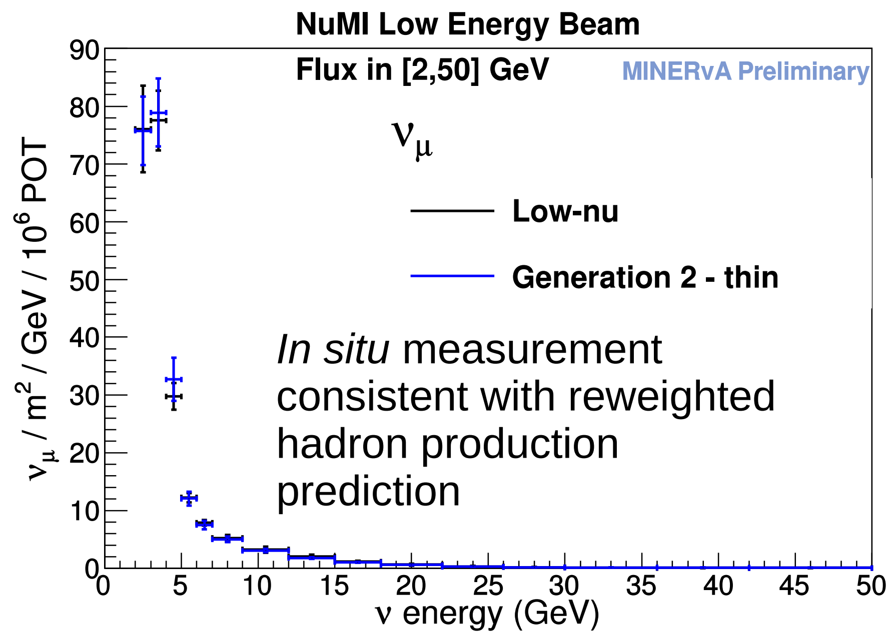
Nucl. Instrum. Meth. A789 (2015) 28-42

Understanding the LE flux



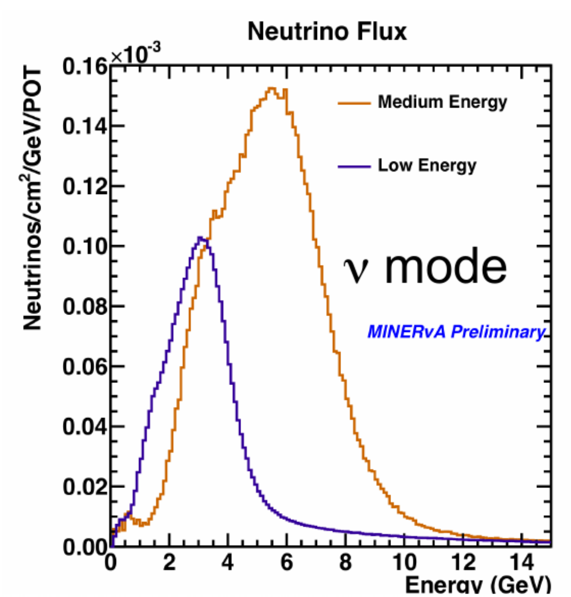
- Dominant flux uncertainties from hadron production
- Multi-FTE-year program through 2015 to understand available data
- Results:
  - Detailed flux prediction, consistent with *in situ* flux measurement
  - We understand hadron production in NuMI
  - Reweighting framework being used by DUNE and NOvA

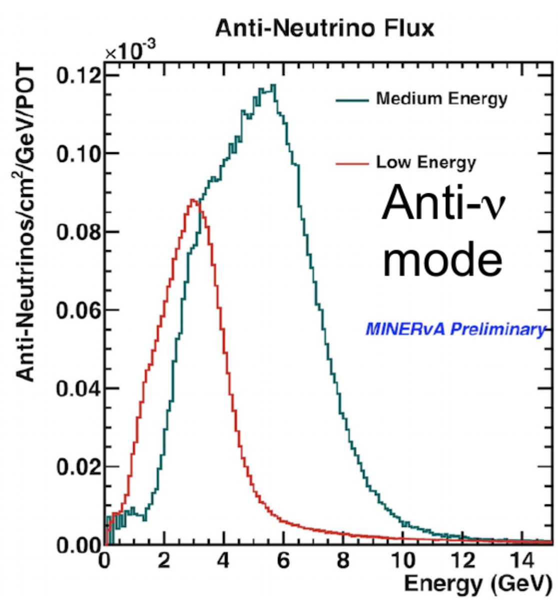




Medium-energy dataset

- ME benefits: higher stats, higher energies
- What this allows us to study:
  - Nuclear effects in DIS neutrino scattering: the EMC effect
  - Nuclear effects in exclusive channels
  - New regions of phase space in exclusive channels

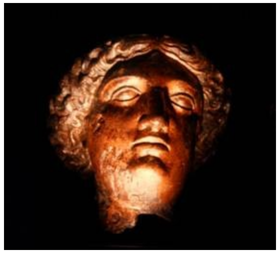




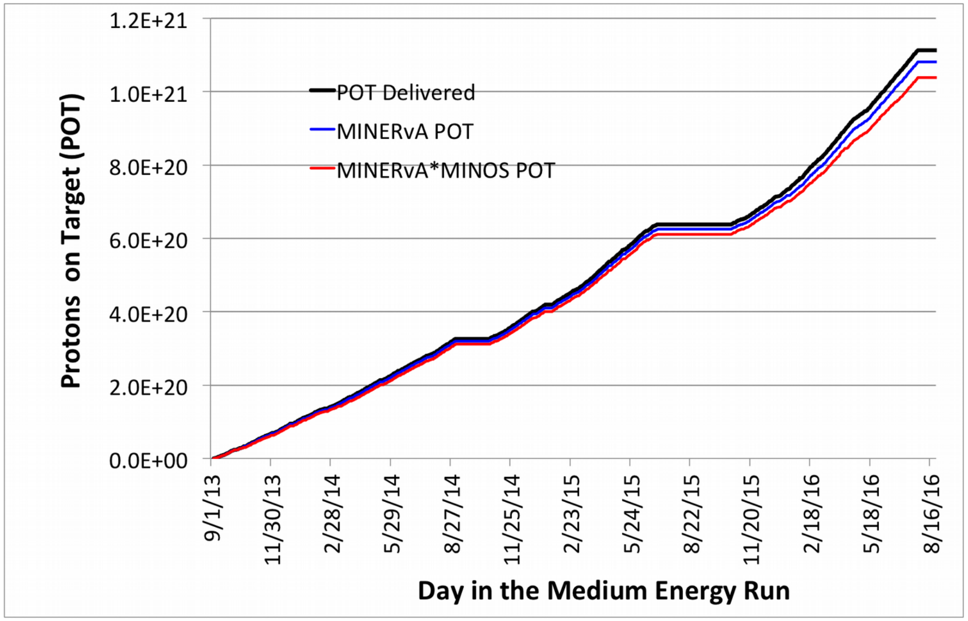
Medium-energy dataset goals

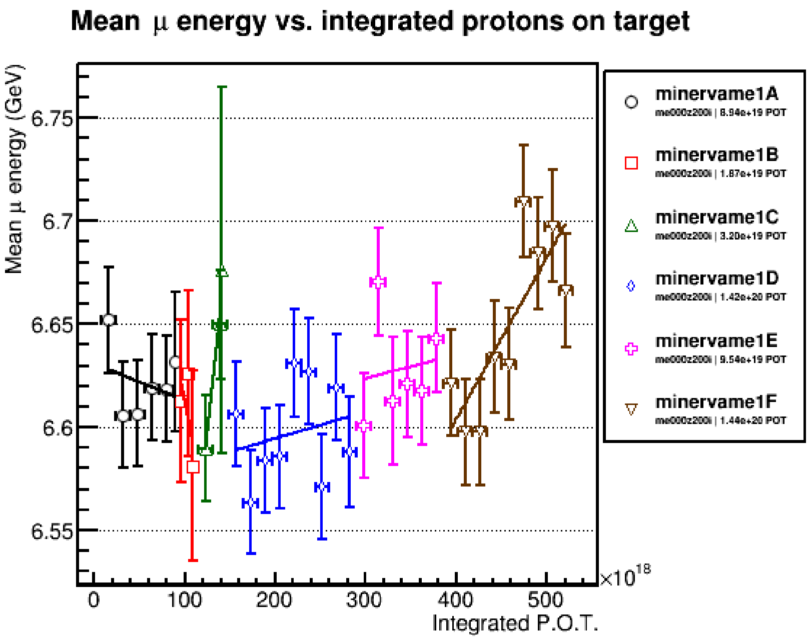
- Measure DIS ratios C/CH, Fe/CH, Pb/CH
- Extend LE analyses to nuclear targets (C, Fe, Pb)
  - Especially statistics-limited analyses: coherent π^+, CC π^0
- Extend the phase-space reach of LE analyses using the ME data

Medium-energy dataset

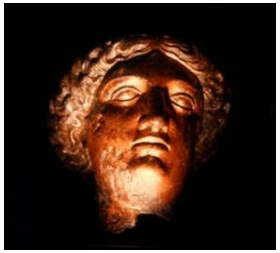


- Started in 2013
- Almost 11e20 pot taken in neutrino mode, 0.7e20 in antineutrino
  - Large changes in protons per pulse over run
- High livetime: 97% MINERvA; 93% MINERvA*MINOS
- Stable running

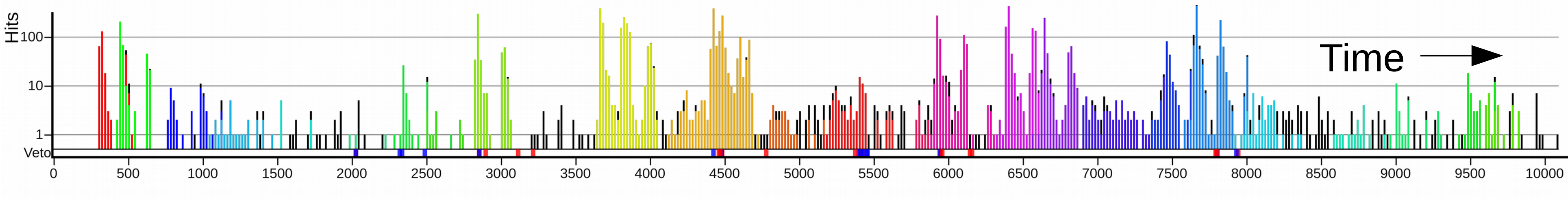


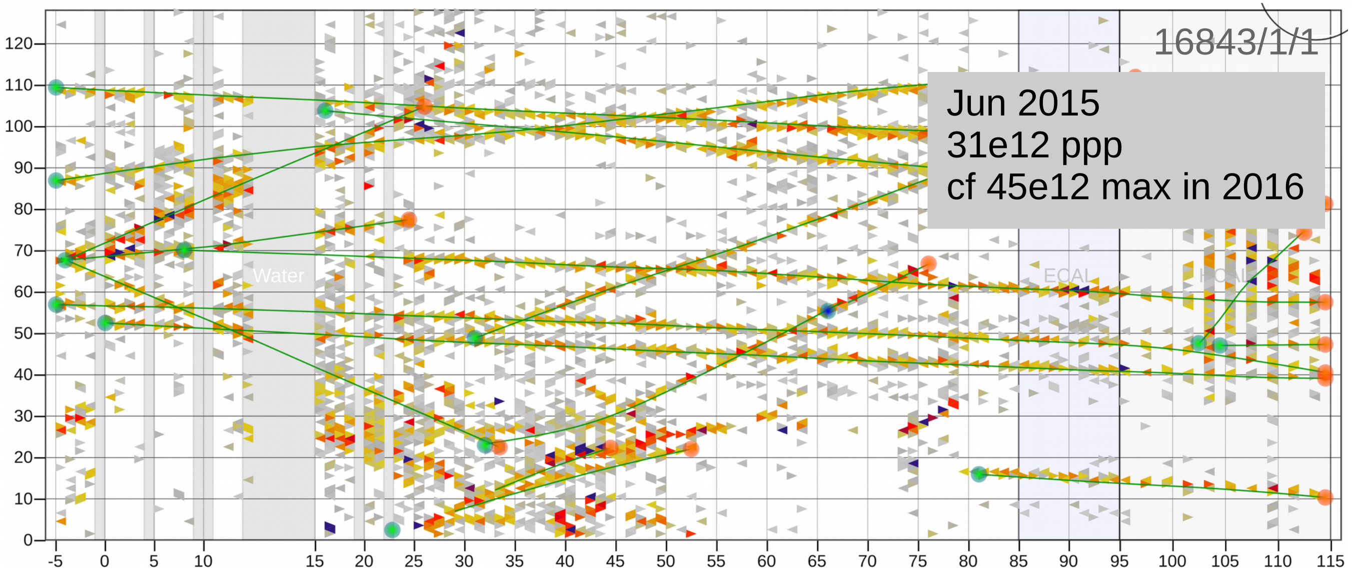


Medium-energy challenges

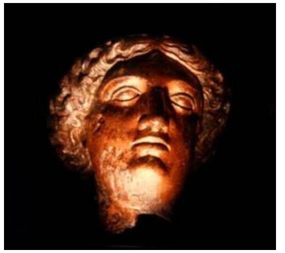


- Higher event rate means more event overlap: need updates to reconstruction
- Backgrounds are different to LE: need updates to analyses
- Understand response of higher-energy hadrons and electrons



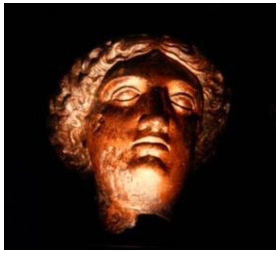


Meeting the ME challenges

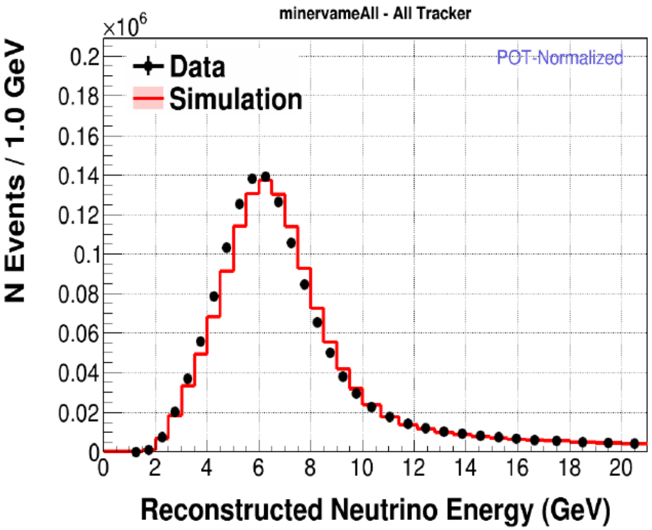


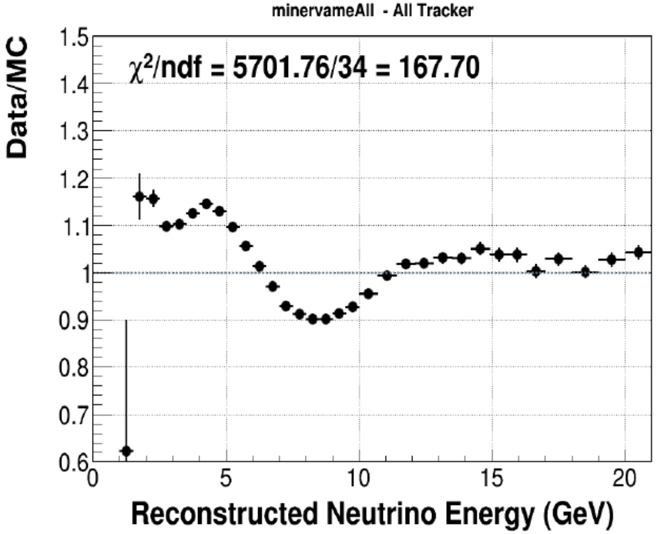
- Well-exercised analysis and systematics infrastructure
  - More on this from Trung
- New simulation of beam intensity variation
  - Expect this is sufficient for first results
  - Use this simulation to re-tune event separation algorithm (“slicer”)
  - More from Debbie
- Analyzers studying cuts, background subtraction in detail
- Testbeam to understand detector response

Another ME challenge: flux?

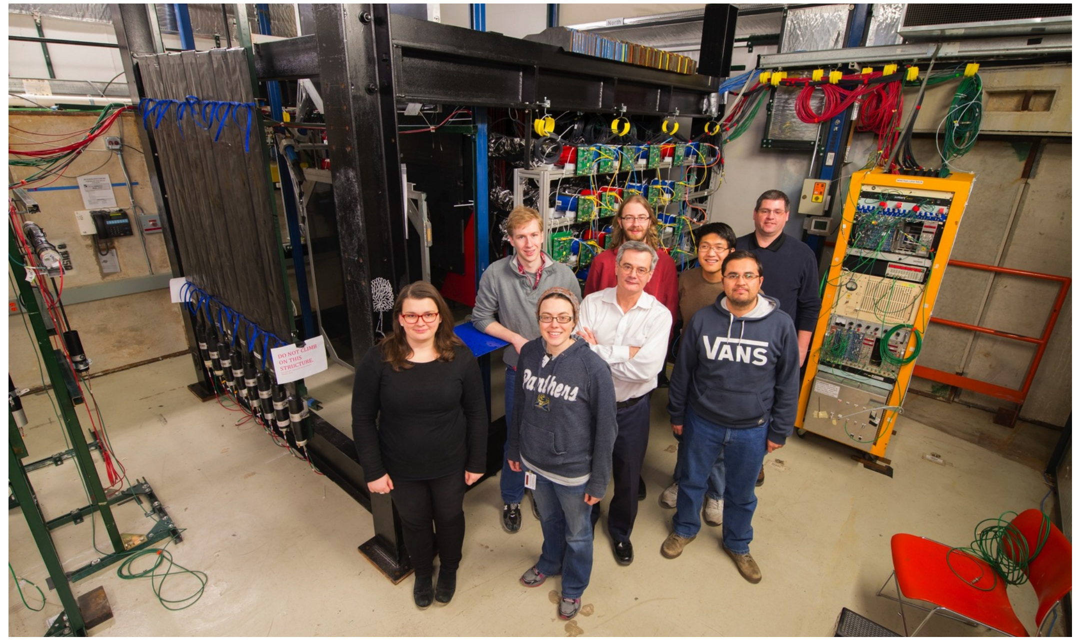


- CC inclusive selection on scintillator suggests flux issue
- Hadron production well studied, so suspect beam focusing
- Must be understood before publishing
- Several lines of inquiry:
  - More detailed study of beam position
  - Understand effect of focusing uncertainties, constraints from NuMI group measurements
  - Pursuing discussions with MINOS+, NOvA
  - Compare to antineutrino data





Testbeam



Ran in higher-energy beam than LE testbeam program.

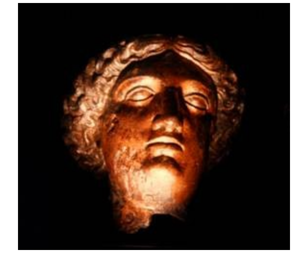
Took electron data

Good data from 6–27 Apr 2015; + 6 days before 2015 shutdown.

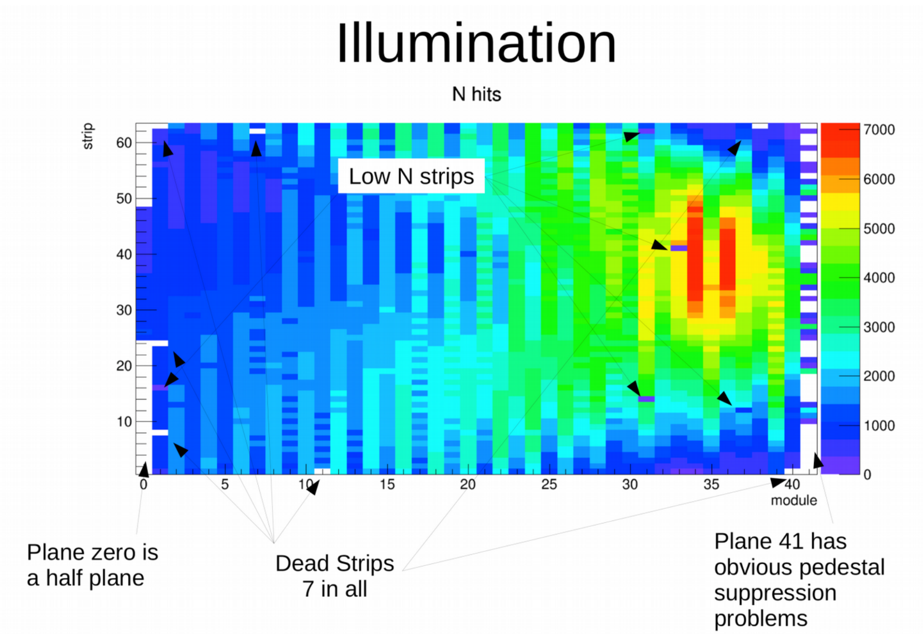
$\pi^{\pm}$, $e^{\pm}$ triggers, ~2 – 8 GeV,
Two detector configurations

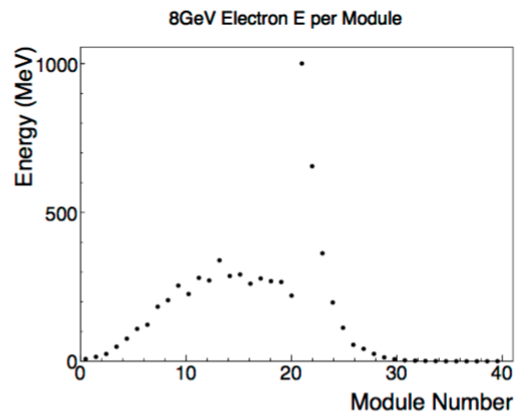
During running, found features in v95 firmware and MTest P_{BEAM}

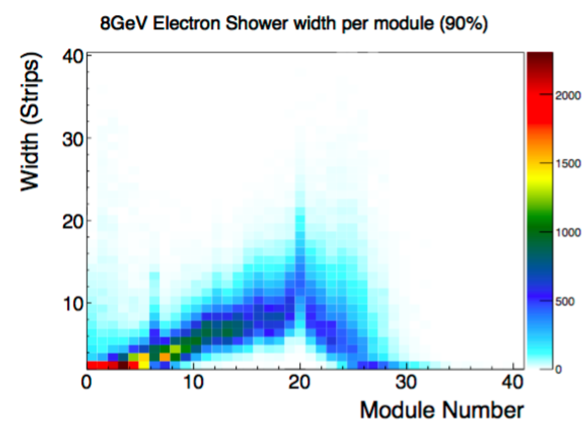
Testbeam



We have a complete calibration pass for the ECAL/HCAL Data
And are starting to look at the electron response & shapes





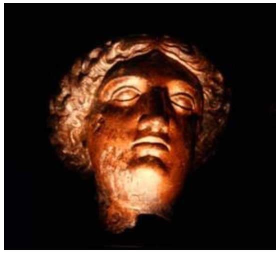


FY17 Run Plan

"Is there a well-understood run plan for FY17, consistent with accelerator schedule and performance?"

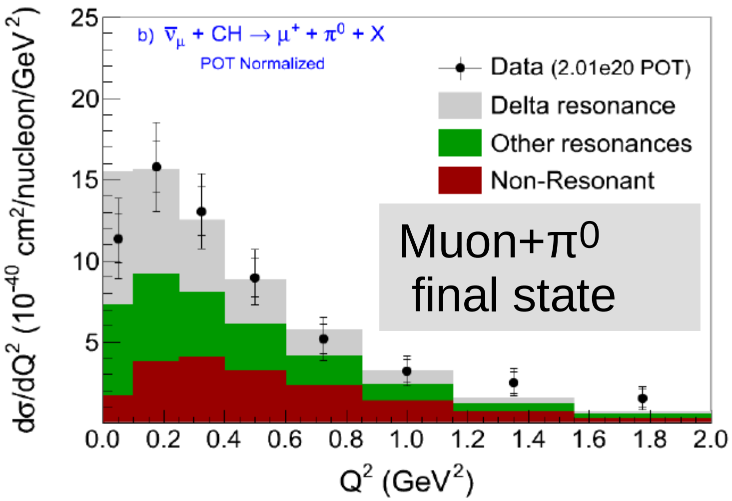
- Beam returns in neutrino mode for 2e20 pot, then switches to antineutrino for rest of FY17
- Assume (3-4)e20 pot of antineutrinos in rest of FY17
- Beyond FY17:
  - MINERvA antineutrinos: request 12e20 pot
  - More neutrino-mode helps some analyses, but prefer antineutrino
  - ME antineutrino data before 2016 shutdown is calibrated.

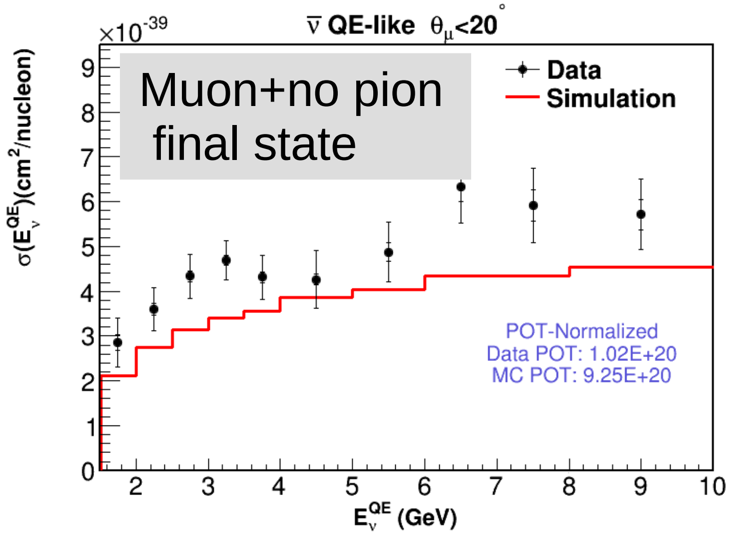
MINERvA antineutrinos



- Successfully analyzed LE antineutrino data

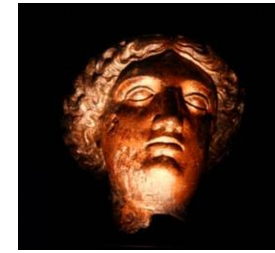
  Phys. Rev. Lett. 111, 022501 (2013); Phys. Lett. B749 130-136 (2015); W&C June 17, 2016





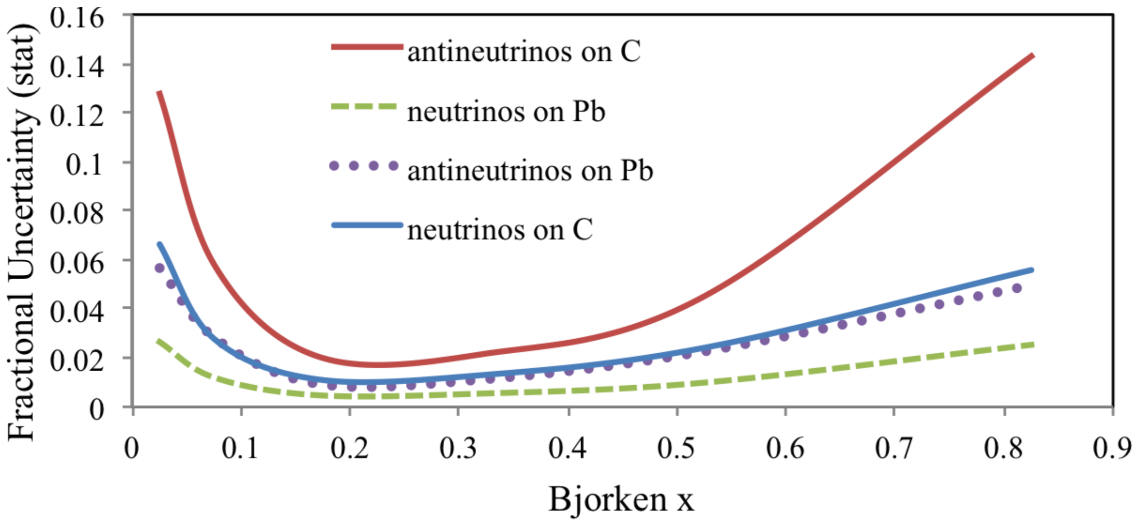
- What do we get from ME antineutrinos?

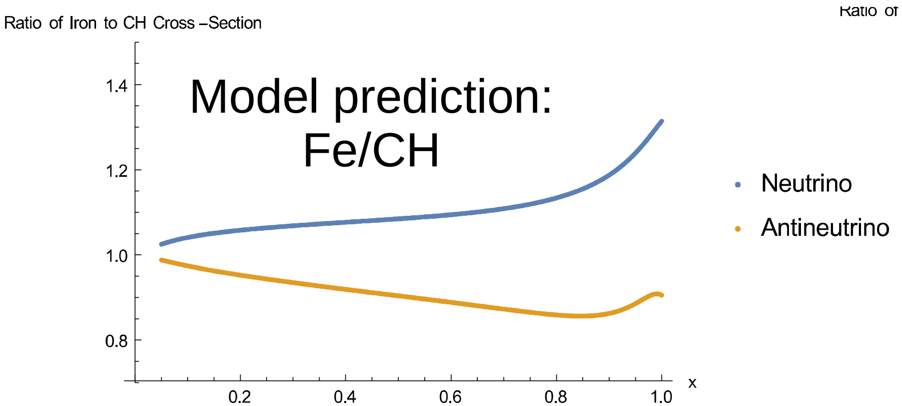
MINERvA ME antineutrinos

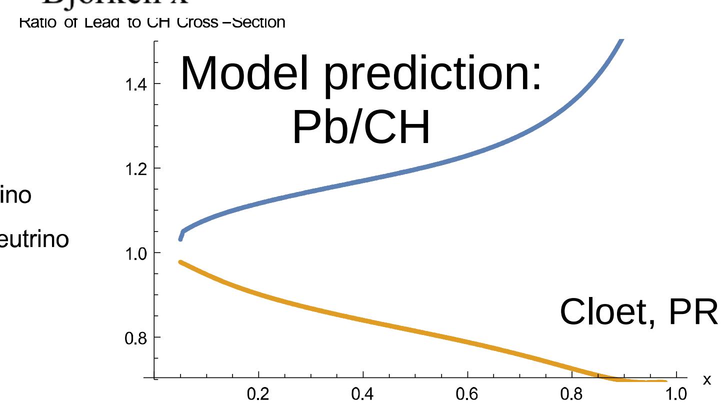


- DIS statistical uncertainties

  (assuming 10E20 neutrino mode, 12E20 in antineutrino mode)





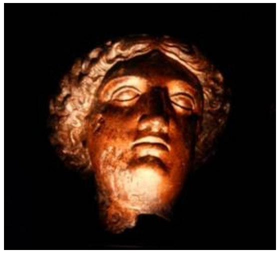


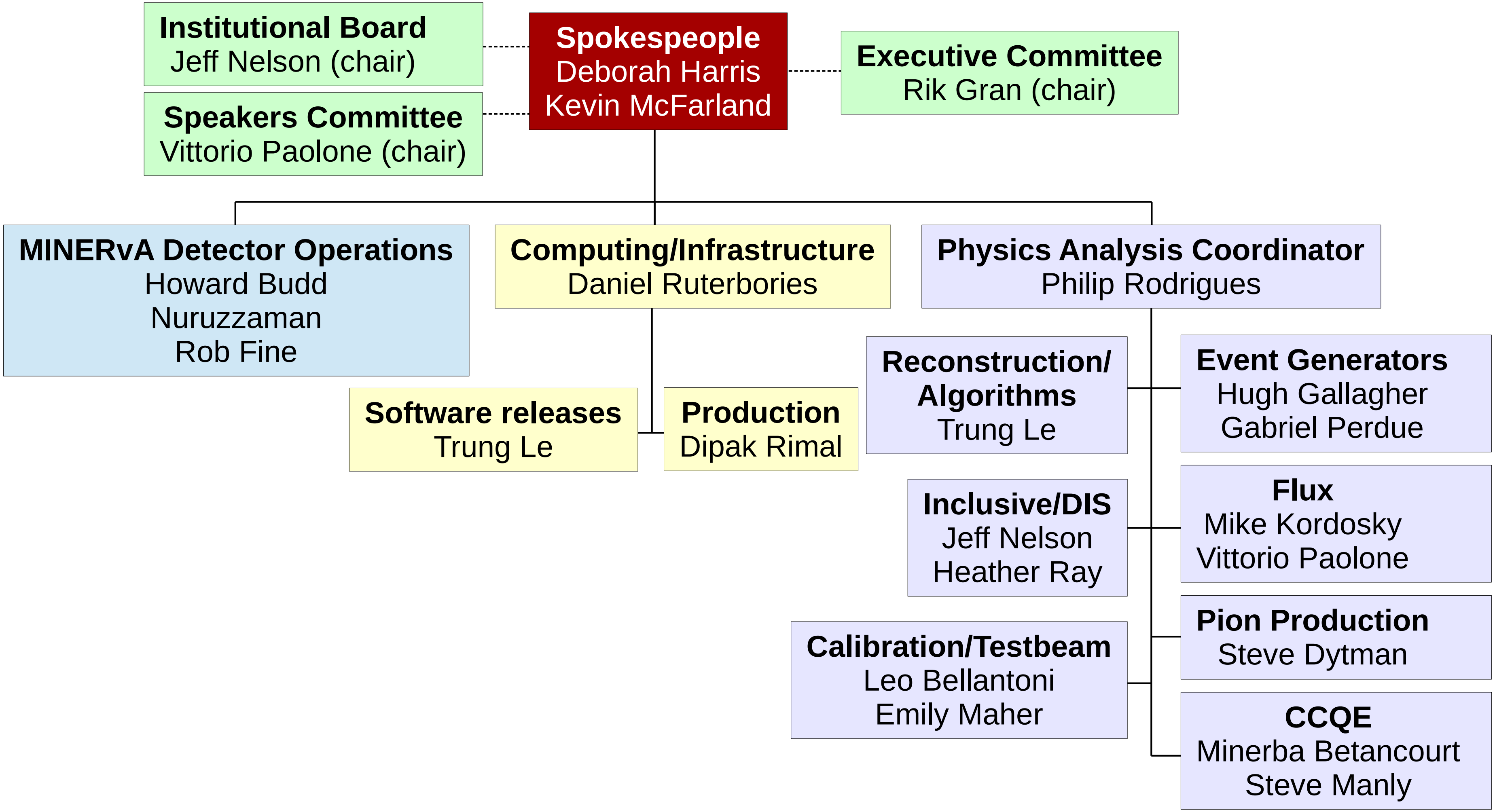
Cloet, PRL 109, 182301

Collaboration resources

- Limited by people, not physics topics
- 62 members from 20 institutions
- New institutions 2016: Oxford, Ole Miss, UPenn

Analysis organization chart





ME Analyses in progress

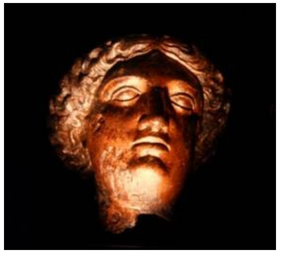
CCQE WG		
“Low-recoil”	R. Gran, A. Lovlein	U. Minn. Duluth
ν_μ CCQE scintillator	M. Carneiro, R. Fine	Oregon State, U. Rochester
ν_μ CCQE targets	J. Kleykamp	U. Rochester

Inclusive/DIS WG		
ν_μ CC on helium	C. Nguyen	U. Florida
ν_μ CC inclusive targets	D. Rimal	U. Florida
ν_μ CC DIS targets	A. Norrick, M. Wospakrik	William & Mary, U. Florida

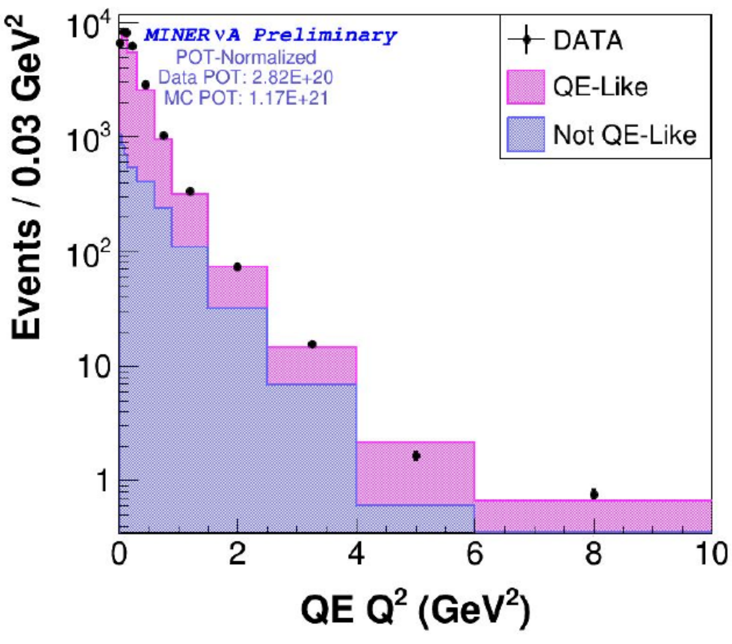
Pion WG		
ν_μ CC coherent π^+	M. A. Ramirez	U. Guanajuato
ν_μ CC π^+ targets	A. Bercellie	U. Rochester
ν_μ CC π^+ scintillator	B. Messerly	Pittsburgh
ν_μ CC π^0 scintillator	R. Galindo, G. Díaz	USM, U. Rochester
ν-e scattering (flux constraint)	E. Valencia	William & Mary

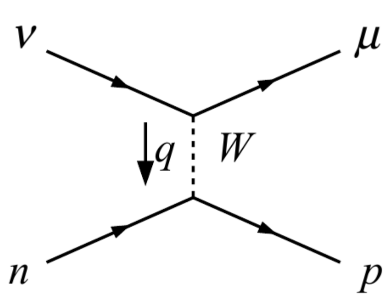
(Plus some new students deciding on projects)

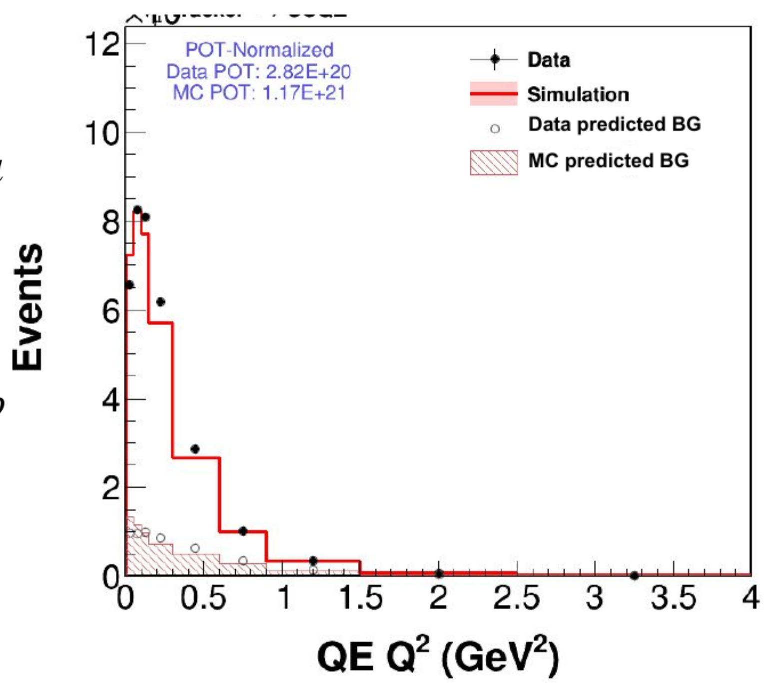
ME Analysis status: ν_μ CCQE



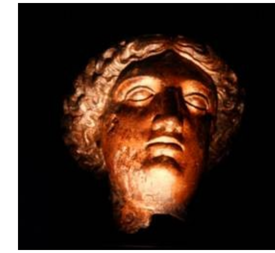
- Select events with a muon/muon+proton and small extra energy
- Higher Q^2 reach: test models in a region not tested before
- Analysis well advanced: selection and background tuning in place



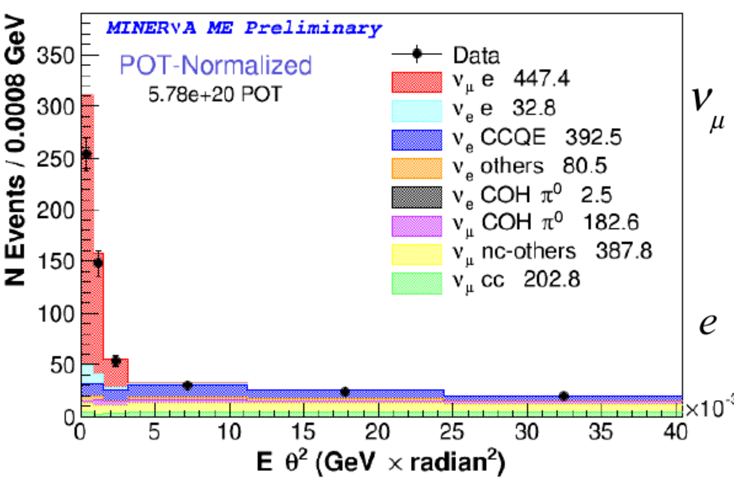


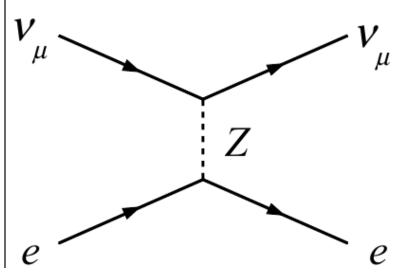


ME Analysis status: ν-electron

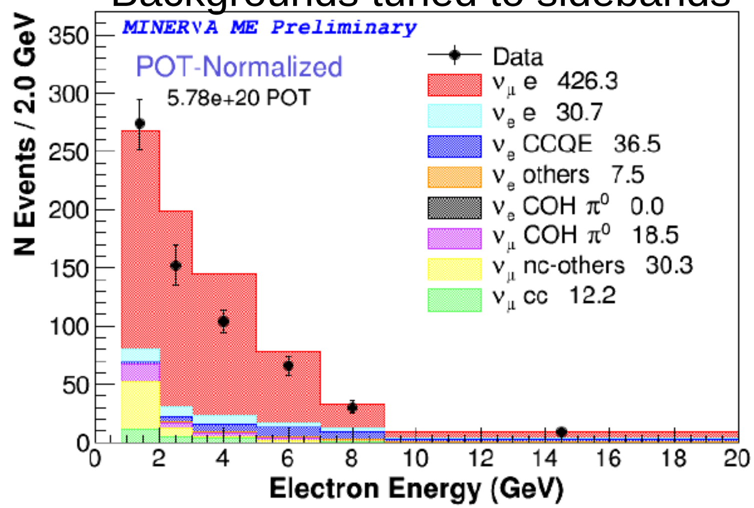


- ν-electron scattering a standard candle for flux measurements
- Successful MINERvA measurement in LE, stats-limited ~15%
  - Phys. Rev. D 93, 112007 (2016)
- Expect O(1000) events in ME, stat/syst similar ~5%
- Analysis in ME well advanced

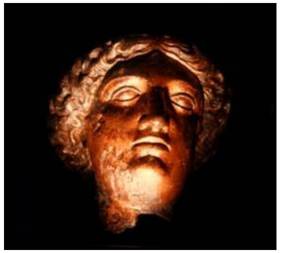




Backgrounds tuned to sidebands



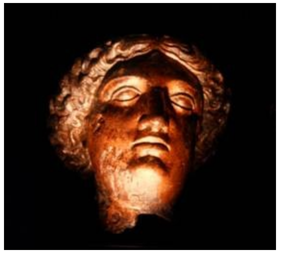
Roadmap to ME publications



- Calibrate data taken to date ✓
- Simulate beam intensity variation
  - Use this simulation to understand intensity systematics. Update reconstruction
- Better understand apparent flux discrepancy
- Validate detector response with testbeam data

- Much of this happens in parallel
- First analyses early 2017:
  - ν_μ CCQE already stats-limited without full dataset
  - Flux constraint from ν-e scattering will pave the way for other analyses

Conclusions



- MINERvA has a strong record of publishing papers while taking data
- Our model: work on analyses in parallel, not serially
- We have a definite run plan:
  - Take 2e20 pot neutrinos, and plan for antineutrinos afterwards, aiming for 12e20 antineutrinos
- ME goals: study nuclear dependence at higher precision, in more channels
- Clear roadmap towards publication
  - Critical steps: simulate beam intensity dependence, understand flux
- Collaboration is healthy, personnel are assigned to analyses

Backup slides follow

Bjorken x	0-0.1	0.1-0.3	0.3-0.7	0.7-0.9	>0.9
Carbon	7	14	11	3	7
Iron	36	71	56	11	36
Lead	39	84	67	13	39
Scintillator	307	663	490	95	307

- Full simulation on Medium Energy event sample, using cuts and reconstruction techniques from Low Energy analysis