MINERvA User Experience and Suggestions for Evolving the Facility

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on behalf of the MINERvA collaboration

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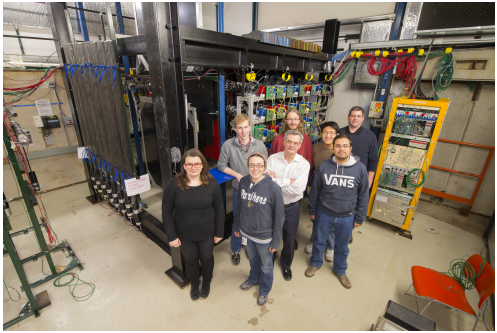
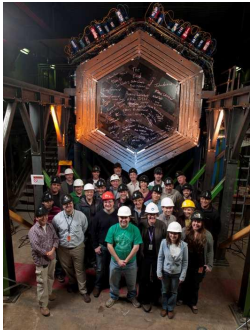
Why should you care?

- MINERvA is not the average user of FTBF
  - We installed a large detector
  - We utilized many resources that FTBF had to offer for a long time
  - We are local to Fermilab
- MINERvA is one of FTBF's best customers!
  - In 2010 we ran in a tertiary beam, $400 MeV < p_{beam} < 2 GeV$ [arXiv:1501.06431]
  - In 2015, we ran in the secondary beam, $2 GeV < p_{beam} < 8 GeV$
  - We have a lot of experience using the facility and a lot of data that have helped us to better understand the available beam

What scale of experiment, you ask?





- MINERvA TB (MINERvA) itself:
  - Ran (runs) at Fermilab in the MTest (NuMI) beamline
  - A fine-grained scintillator tracking detector with $\sim 3,000$ ($\sim 30,000$) channels
  - 42 (507) multi-channel PMTs with associated mounting, power, and readout
  - 32 (20) steel planes measuring $\sim$1m x $\sim$1m x 2.54cm ($\sim$2m x $\sim$2m x 2.54cm)
  - 20 (20) Pb sheets measuring $\sim$1m x $\sim$1m x $\sim$2mm ($\sim$2m x $\sim$2m x $\sim$2mm)

What scale of experiment, you ask?

- Auxiliary systems, specific to use on the surface in a hadron beam:
  - ToF for PID and momentum measurement - 2 stations, 104m apart
  - Cosmic tagging system - 20 channels, $4m^2$ coverage
  - Veto, to reject multi-particle events - 14 channels, $1m^2$ coverage
  - Motorized $\frac{1}{4}$"-thick Pb sheet upstream to reduce $e^{\pm}$ contamination for hadron running
  - Cherenkov, for $e^{\pm}$ ID [FACILITY]
  - MWPCs, for external tracking [FACILITY]
  - Pb glass calorimeter for beam studies [FACILITY]
  - He pipes, to reduce scattering at low momenta [FACILITY]
- Miscellaneous other needs
  - The Fermilab alignment group to make precise measurements *in-situ*
  - Crane operators and mechanical technicians during installation, reconfiguration, and deinstallation of our detector
  - 4 computers, 10 monitors, 1 VME crate, 3 CAMAC crate, 8 NIM crates

Gee, Rob, that sounds like a lot of resources... What did you get out of it?

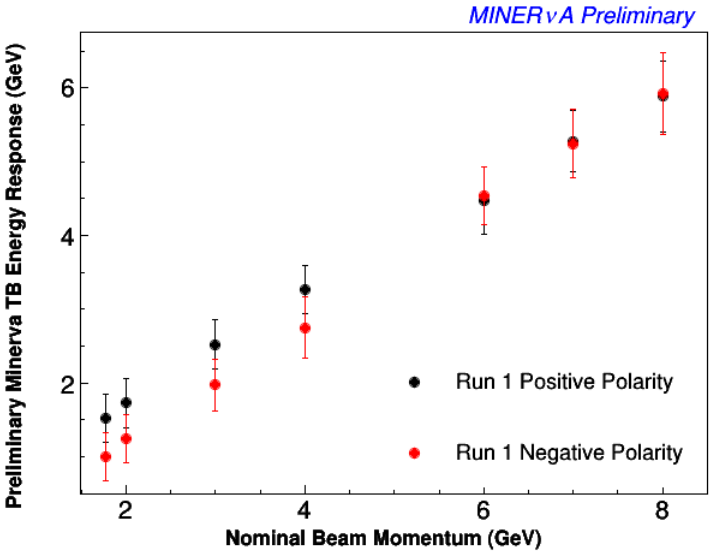
- Self-improvement, for one!
  - This type of work provides excellent hands-on experience for students
  - FTBF, in particular, facilitates this aspect of the experience through their dedicated staff (more on that later)
- We collected several large data sets
  - We ran at nominal beam momenta of ± 1.77, ± 2.00, ± 3.00, ± 4.00, ± 5.00, ± 6.00, ± 7.00, ± 8.00, ± 9.00, ± 10.00, ± 16.00, $+120$ GeV
  - Two primary modes of running:
    - "electron mode" - trigger on electrons
    - "pion mode" - suppress electrons using Pb sheet upstream, then veto electrons using Cherenkov
  - Target number of analyzable events at each beam configuration: $\sim$1,000
  - Total number of events recorded: $\sim$300,000 in "electrons", $\sim$900,000 in "pions"

Wow, that sounds like a lot of work!

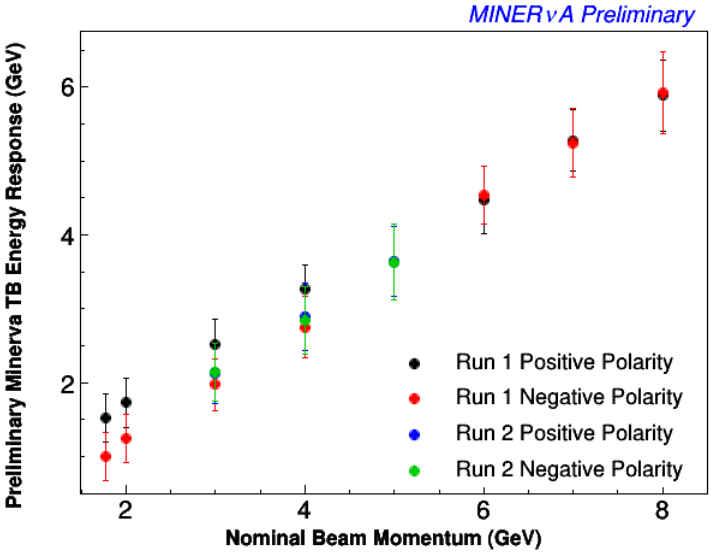
- Yes. And now we've got *analyze* all that data
- But, you should be aware that it's possible to mount such an operation at FTBF, and that there's an excellent support system in place to help you

Well, it sounds like you've got a lot of experience, Rob. Any tips for me?

- Know what you want, know what you *expect*, and plan ahead
- The facilities are constantly evolving.
  - Maybe last time you came in, temperature variation was an issue, but insulation has since been installed in the enclosure
  - Maybe last time you came in, Fermilab had a resident scintillator expert, but he's since retired
- If a particular aspect of the beam that you expect is important to your analysis plans, have a plan to **prove** its what you need
  - In many cases, the facility has done this
  - Sometimes, you'll need input from previous users - what we knew about beam composition at low momenta came from CALICE
  - Sometimes, you'll be the *first* user (in a while) with a particular need - knowing the momentum of our low energy beam *precisely* is critical to our analysis



We expect the energy response (vertical axis) in our calorimeter to be the same for e^+ and e^-



With the help of AD, we came to a better understanding of the delivered beam

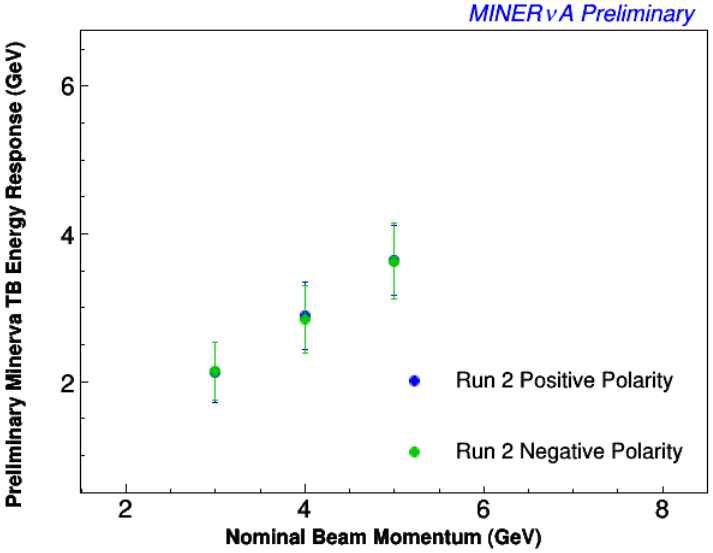
Ideas for evolving the facility

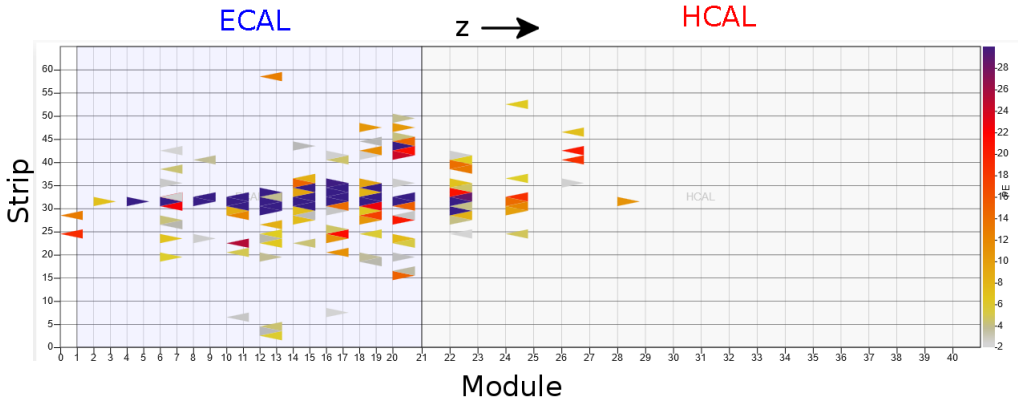
- Continue to improve understanding of the secondary beam - momentum, particle composition, spatial and temporal distributions of particles
- Support an inventory of (working) well-understood scintillator counters - these are a versatile tool and we hadn't realized we'd want to use so many
- Develop a spectrometer as a permanent fixture in the beamline for direct measurement of beam momentum
  - If that's not in the cards soon, we can recommend specs for a ToF-based momentum measurement system
- A unified facility DAQ
  - Collect output of all facility systems into a data file with user-selectable fields (inner Cherenkov, MWPC 1 only, etc.)
  - Build in functionality to use facility hardware (Pb glass, scintillator counters, etc.) as LEGO bricks

Special thanks to, and explicit recommendation of:

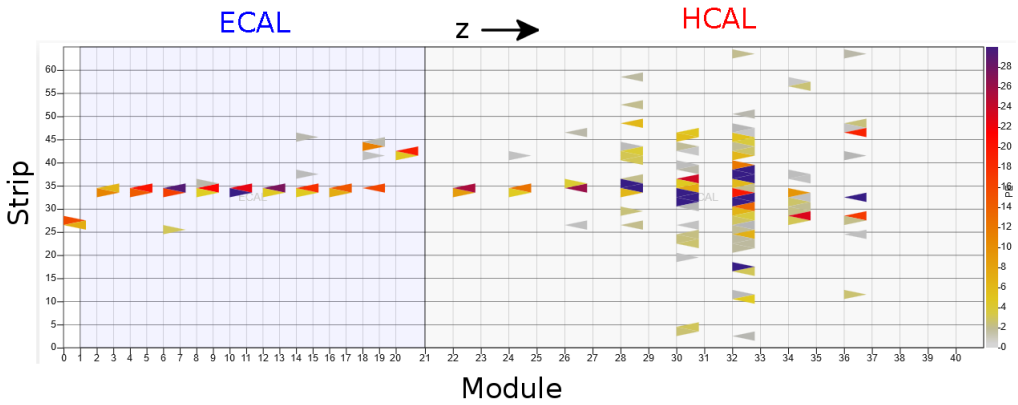
- **Michael Backfish**, "AD external beams engineering physicist", has worked very closely with us to try to understand and characterize the low-momentum beam delivered to MTest
- **Todd Nebel**, the technical coordinator for FTBF, has a keen logistical intuition, and has been very patient with us students
- **Geoff Savage**, the FTBF DAQ specialist, has really good ideas and asks really good questions
- **PREP** is an excellent resource for stock electronics needs (NIM, CAMAC, etc.)
- We received professional and efficient support in the way of surveys by the alignment group and the time and expertise of mechanical technicians

BACKUP

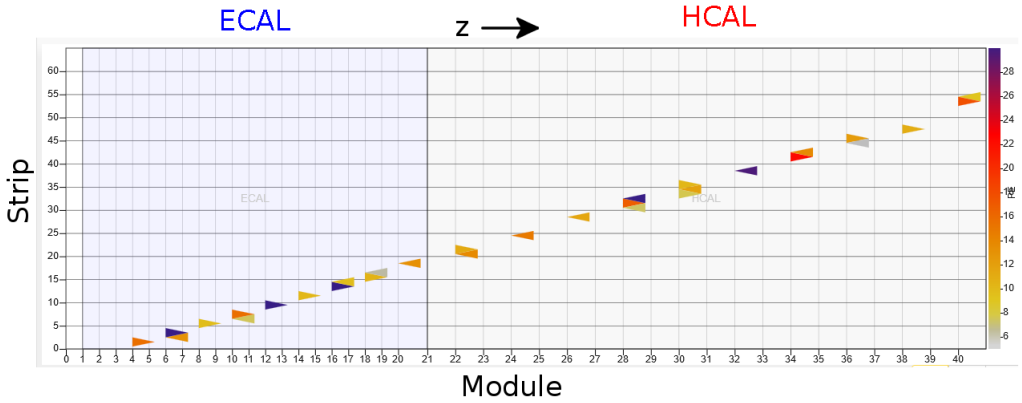

MINERvA Preliminary
Preliminary Minerva TB Energy Response (GeV)
6
4
2
2
4
6
8
Nominal Beam Momentum (GeV)
Run 2 Positive Polarity
Run 2 Negative Polarity



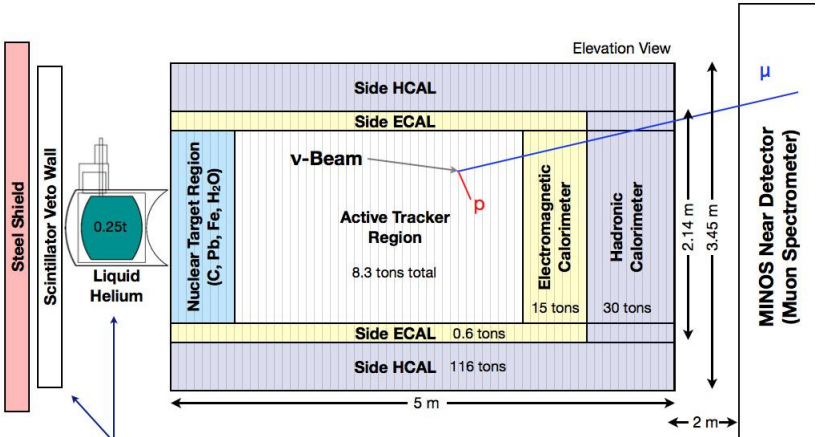
8 GeV e^+ shower



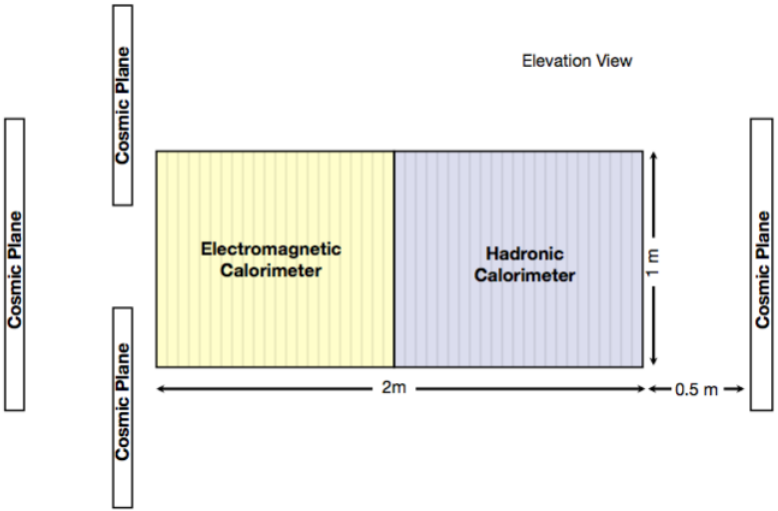
8 GeV π^+ shower



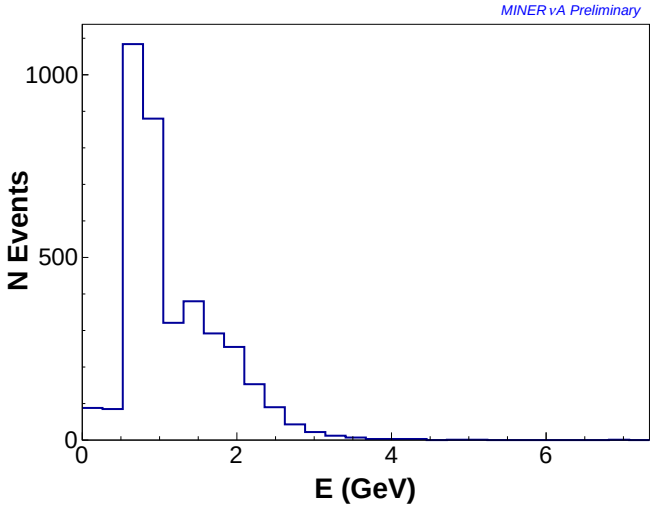
cosmic muon



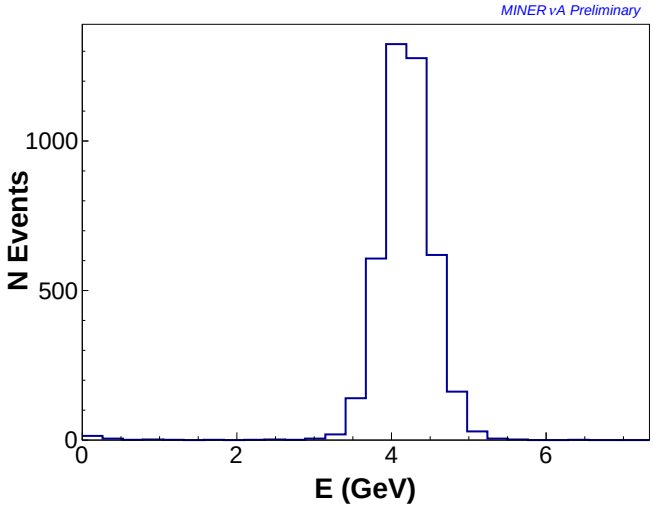
MINERvA detector: side view



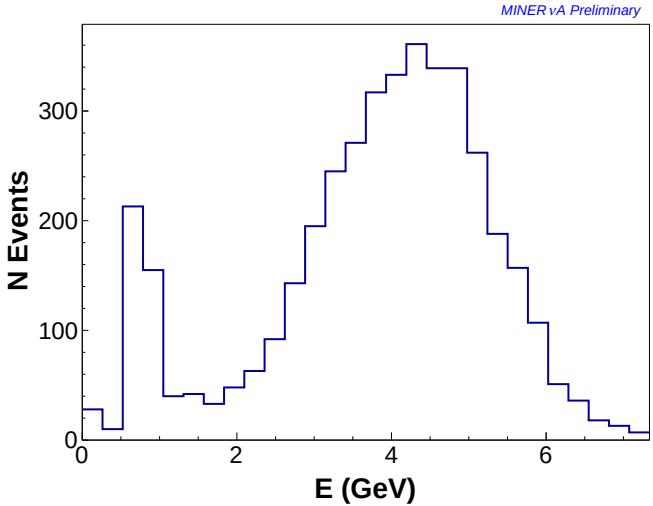
MINERvA Test Beam detector: side view



3 GeV π^+ sample



6 GeV e^+ sample



8 GeV π^+ sample