LArIAT

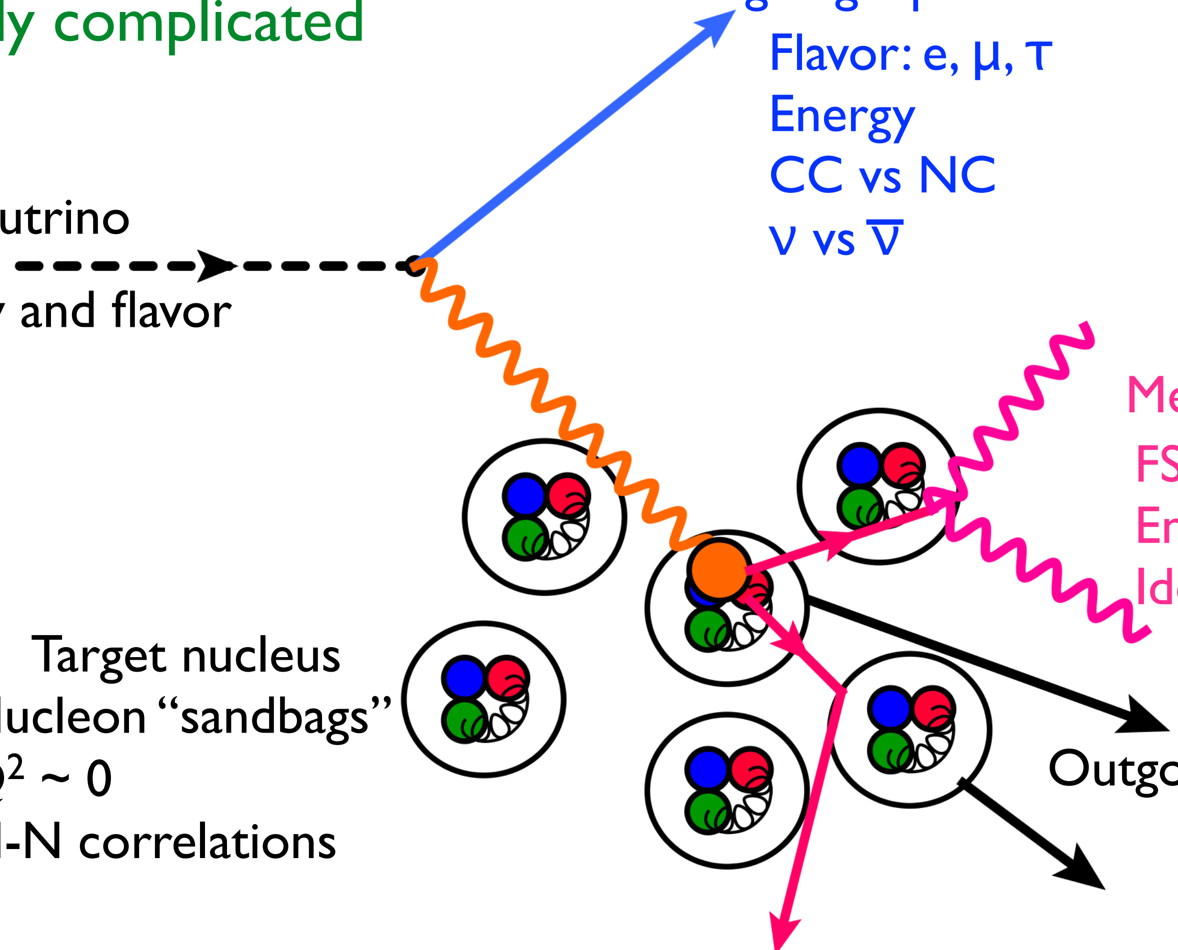
Liquid Argon In A Test Beam
Fermilab T-1034

Brian Rebel

October 29, 2014

Making Good Experiments Great

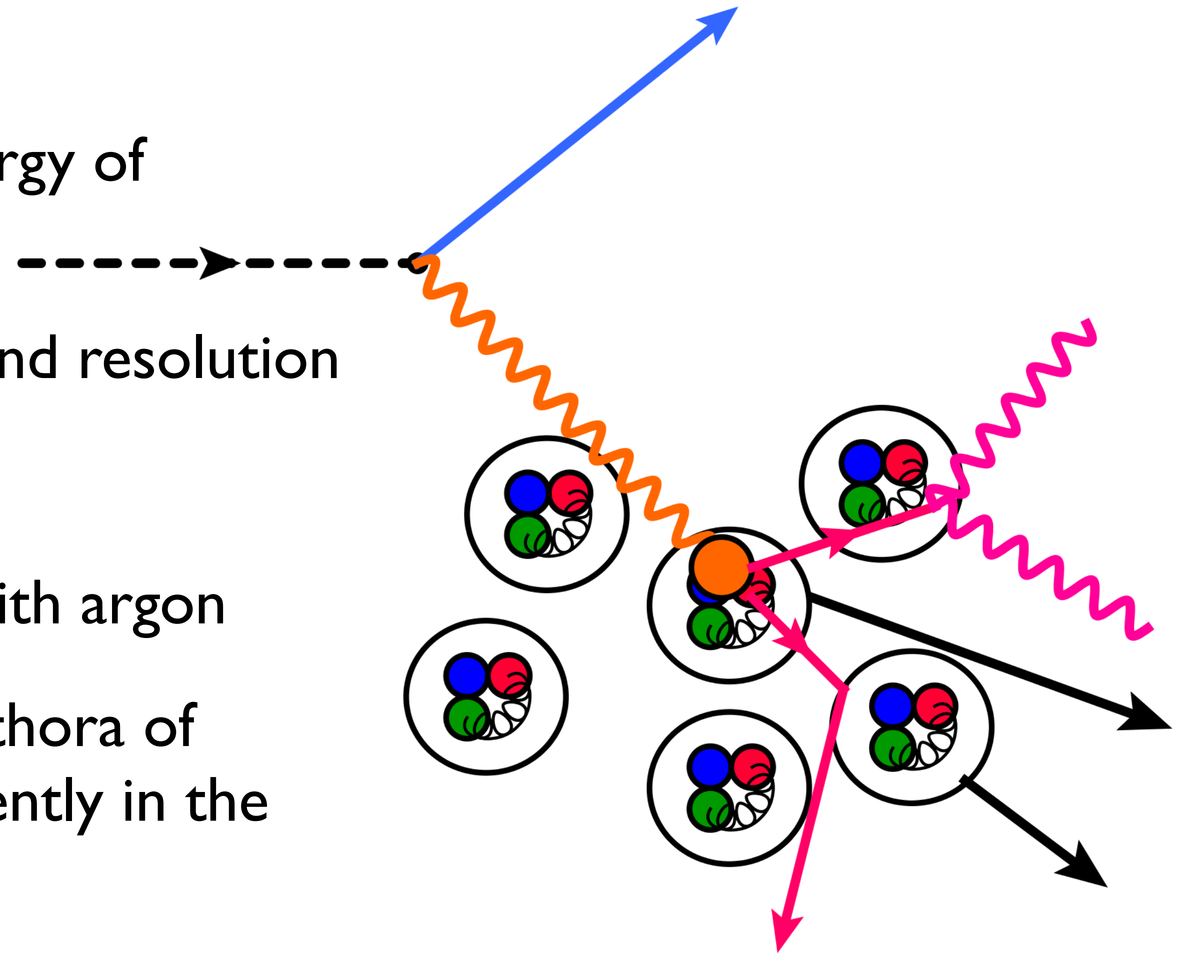
Neutrino interactions are surprisingly complicated



Give your experiment an edge by understanding the Final State Particles

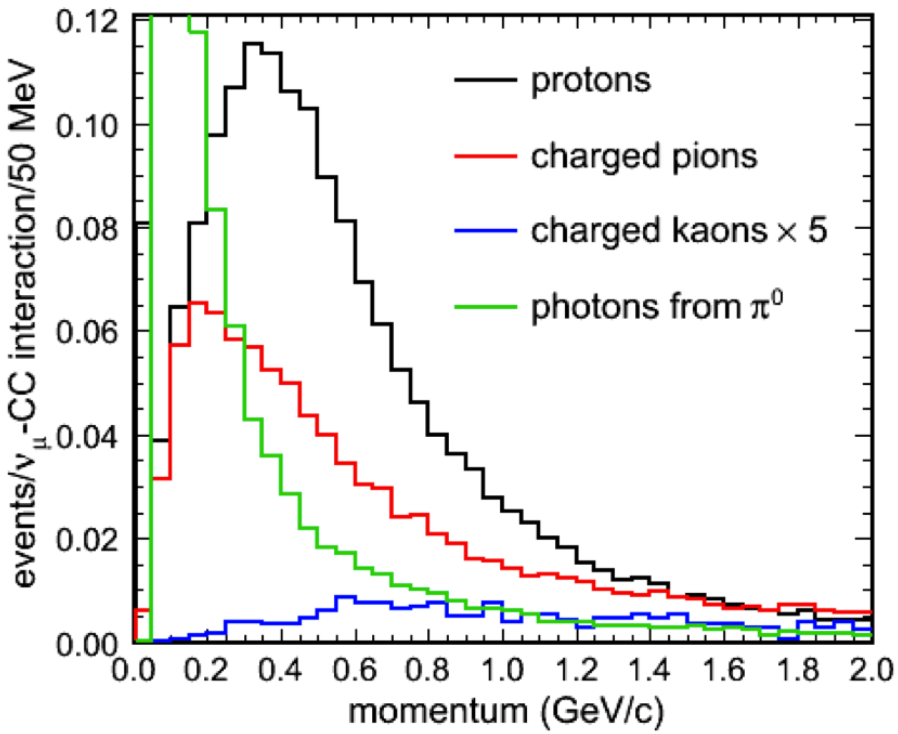
Studying Final State Particles with LArIAT

- Calibrate the visible energy of interactions
- Calorimetric response and resolution
- Event reconstruction
- Hadronic interactions with argon
- Provide input to the plethora of LArTPC detectors currently in the works
- First time a fine-grained LArTPC exposed to a beam of known particles and momenta

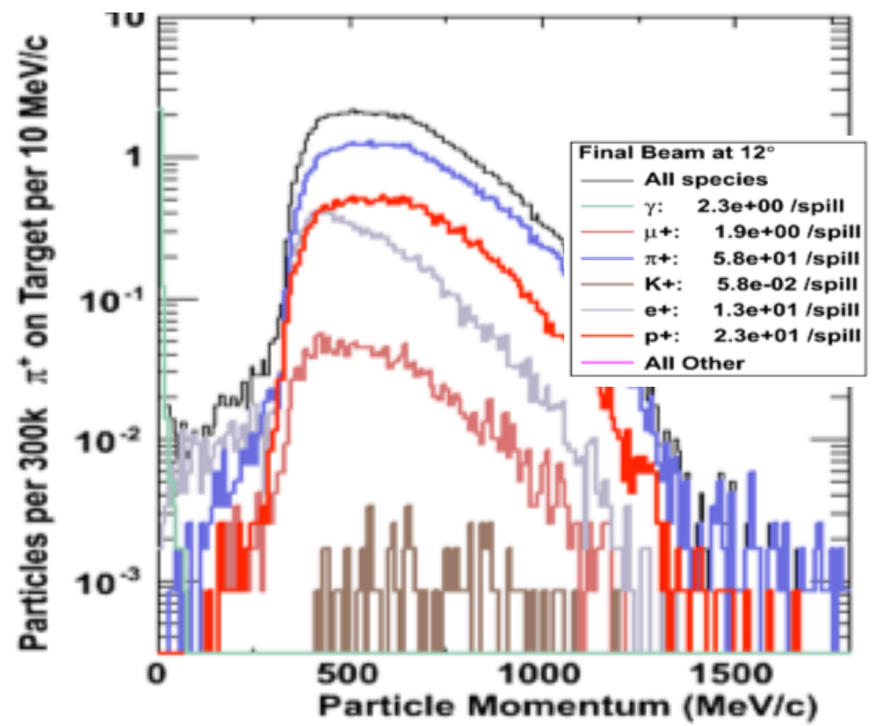


Studying Final State Particles with LArIAT

NuMI LE On-axis Beam

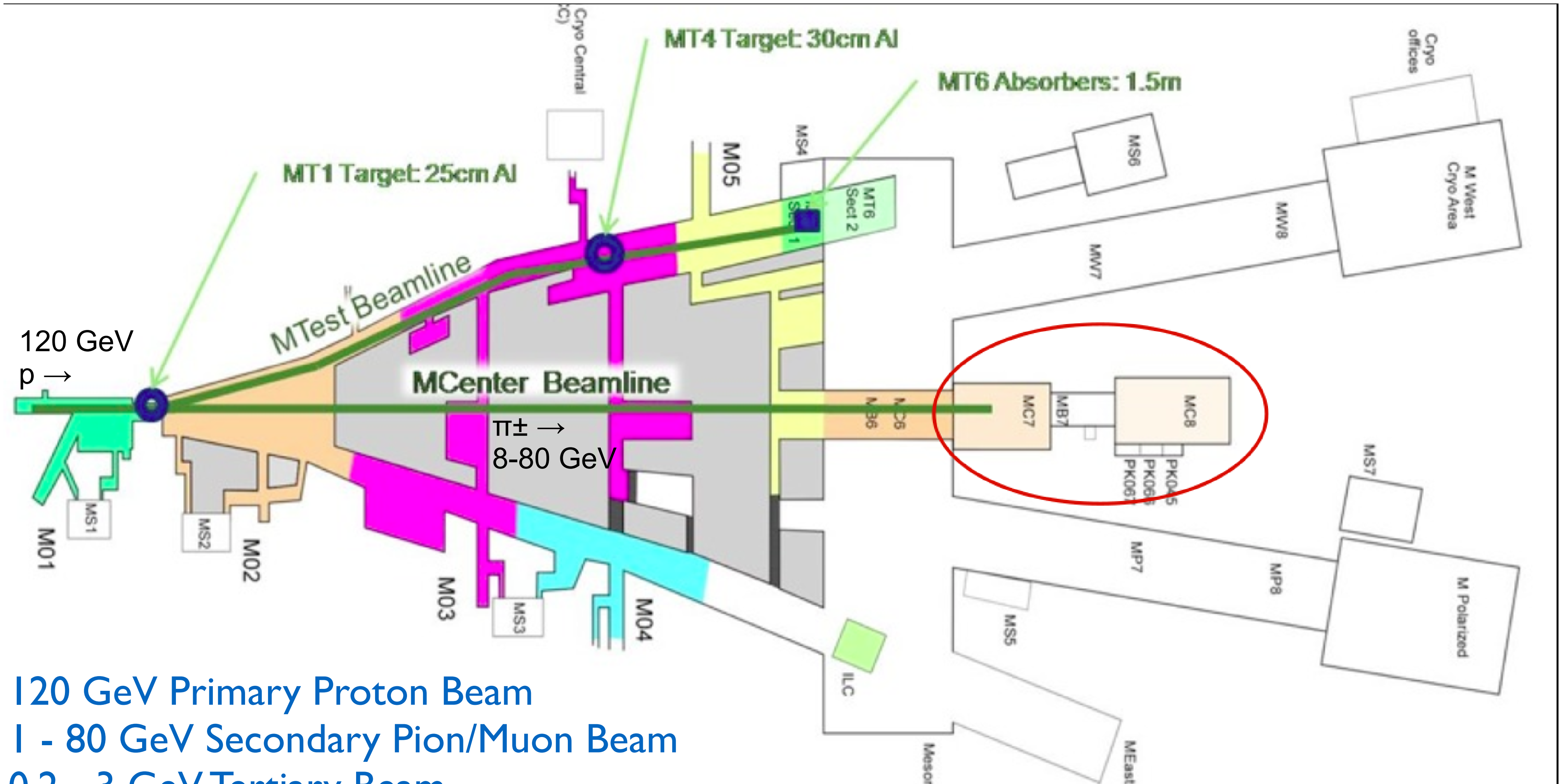


LArIAT Beam



- Particles produced in LArIAT beam are same species and similar momentum range as those produced in neutrino interactions from NuMI and Booster beams
- Momentum spread is tunable to adjust relative fractions of different species
- Ideal for producing results relevant to MicroBooNE, LBNE and SBM

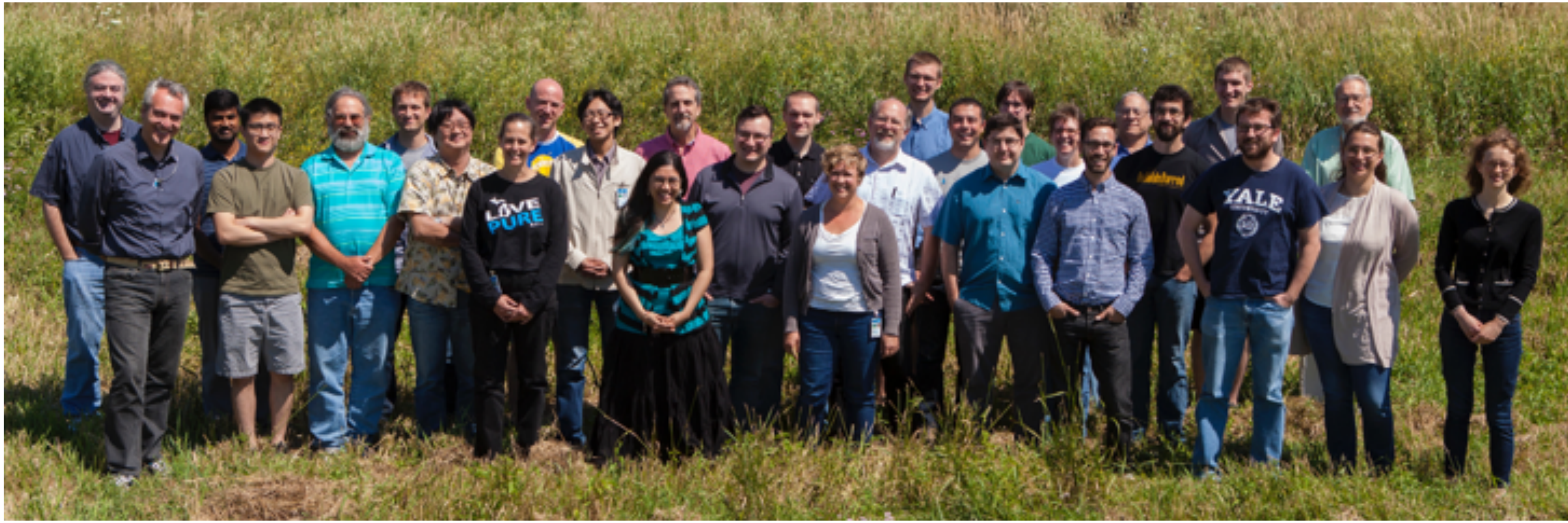
FTBF MCenter Beamline



120 GeV Primary Proton Beam
1 - 80 GeV Secondary Pion/Muon Beam
0.2 - 3 GeV Tertiary Beam

MC7 available for long term experiments
Expect LArIAT to run for *years*

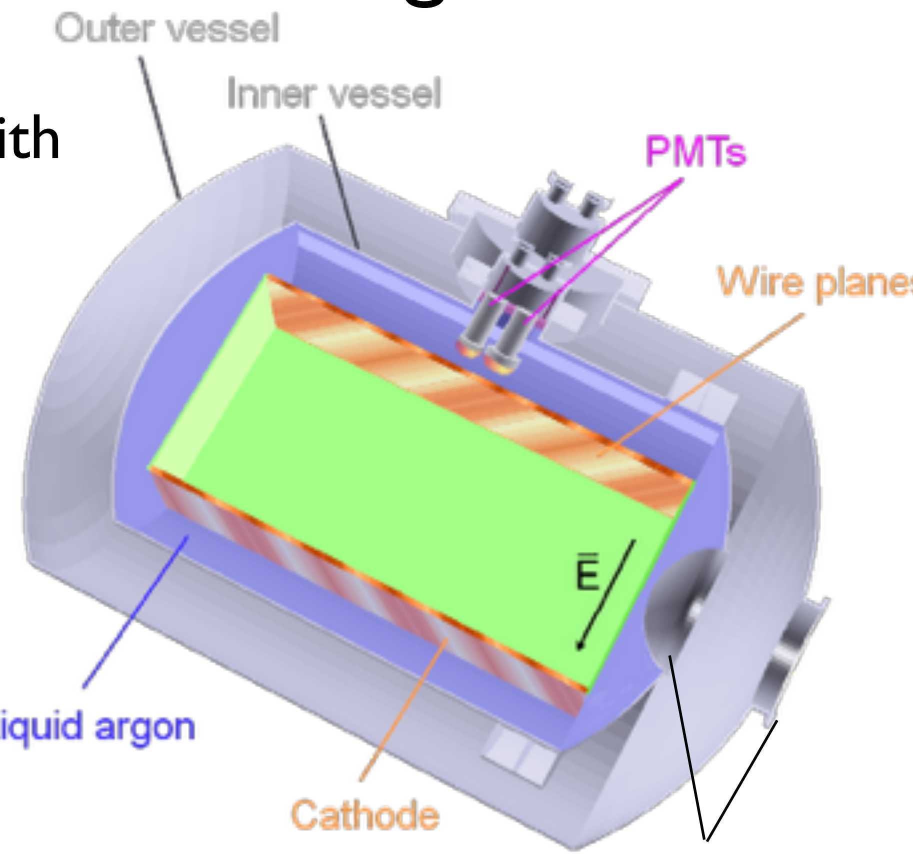
The LArIAT Collaboration

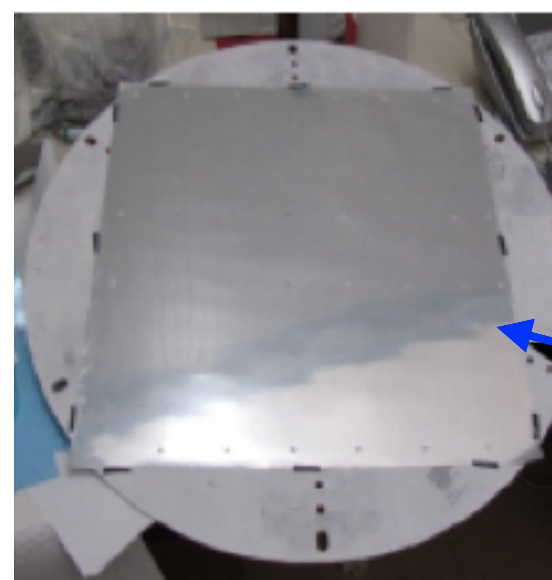


- Broad community interest in LArIAT:
  - 20 institutions; 16 US, 3 UK, 1 Japanese
  - 67 collaborators; 11 gradstudents, 8 postdocs, 48 senior scientists
  - Perfect opportunity for students and postdocs to build and run an experiment, not to mention gain experience with LArTPCs
  - Drawing foreign institutions into collaboration and can be seen as a gateway to US neutrino program

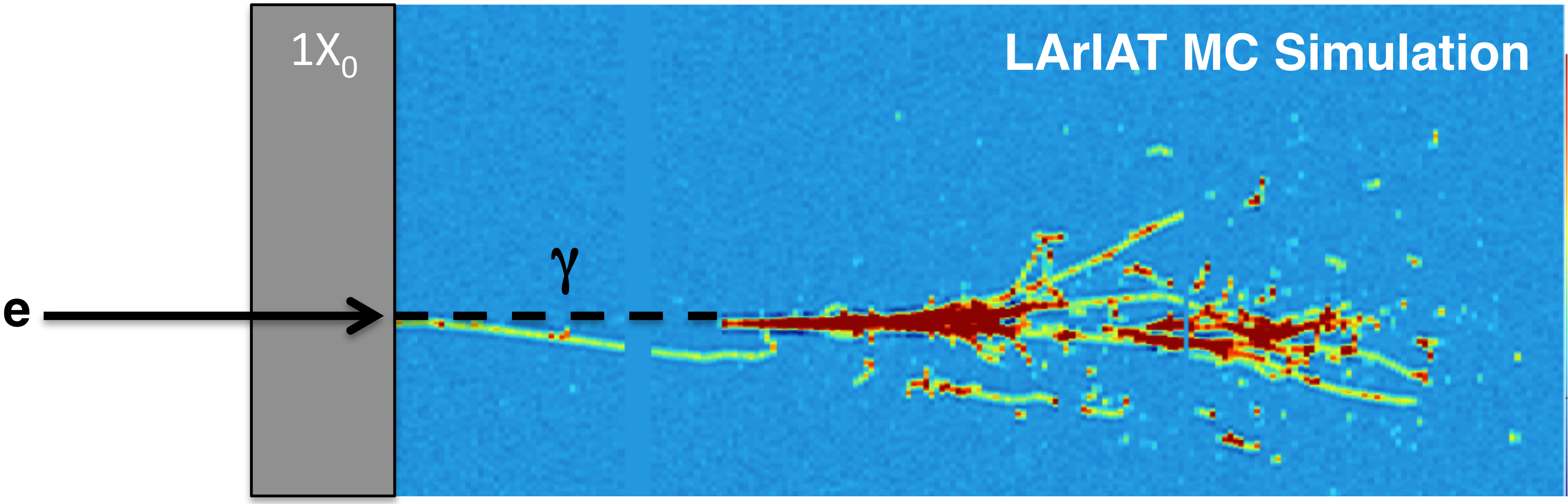
LArIAT - A Comprehensive Program

- Initial phase reuses ArgoNeuT cryostat with modifications to enable
  - Studies of light collection and reconstruction to improve calibration
  - Experimentally measure ability to distinguish electrons from photons
  - Optimize particle identification
- Second phase will use a larger TPC -
  - At least 2m x 2m x 3m
  - Full characterization of hadronic and electromagnetic showers
  - Testing ground for future detector system development
  - Detected to incident energy calibration



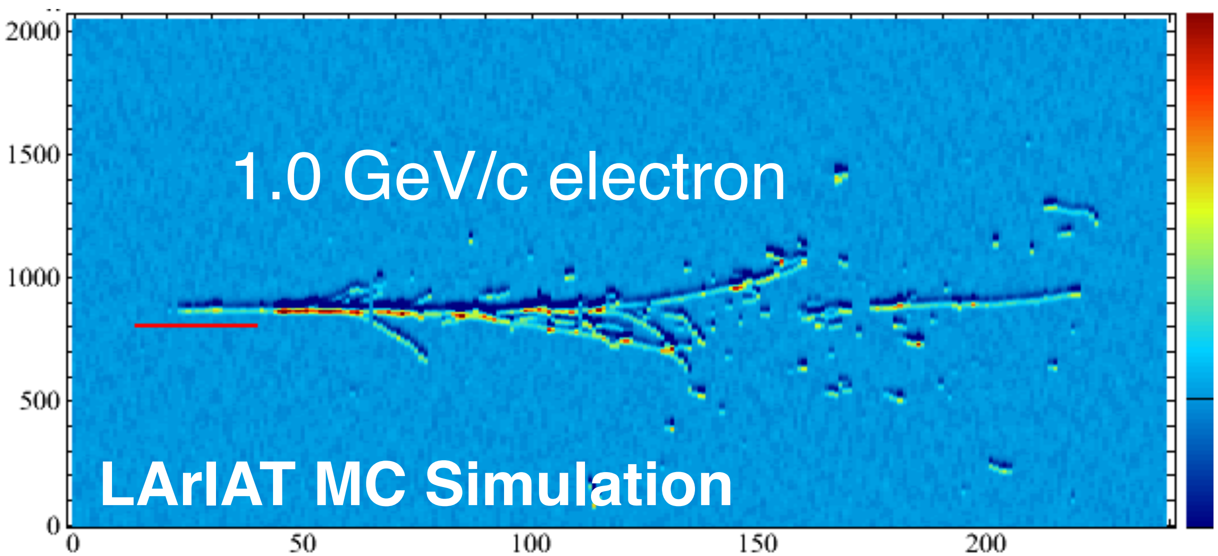


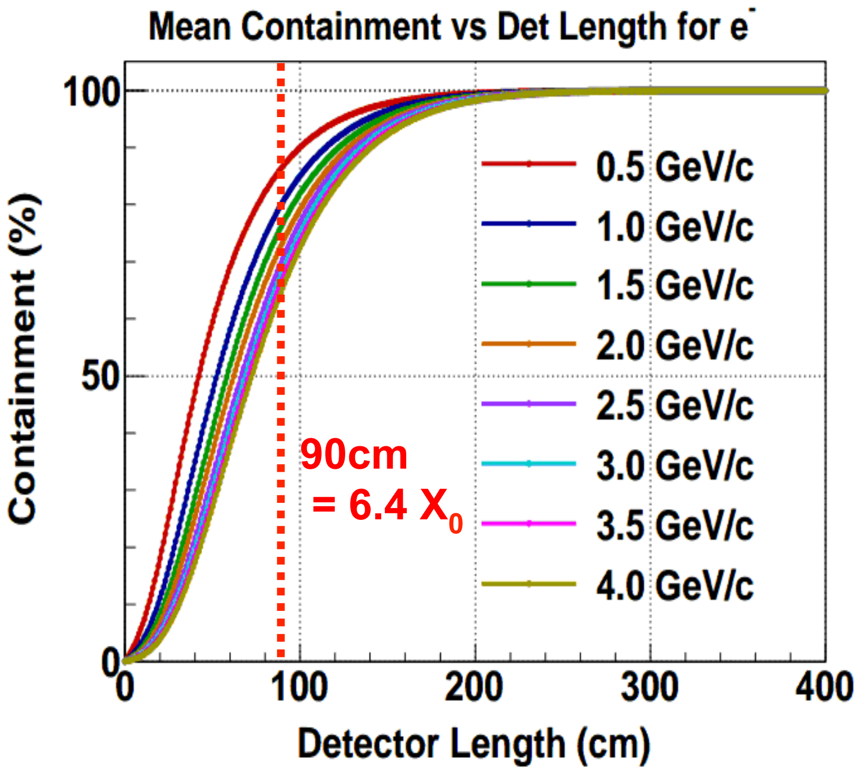
Electron/Photon Discrimination



- Key aspect of LArTPCs that makes them attractive for neutrino oscillation experiments - excellent separation between electrons from CC interactions and photons from NC interactions with neutral pions
- Separation has not been determined experimentally using beams of known species and momentum
- Basic idea is to look at the total charge in the initial few centimeters before the shower develops
- LArIAT analyzers will develop algorithms for discrimination that will be used by others

EM Shower Development

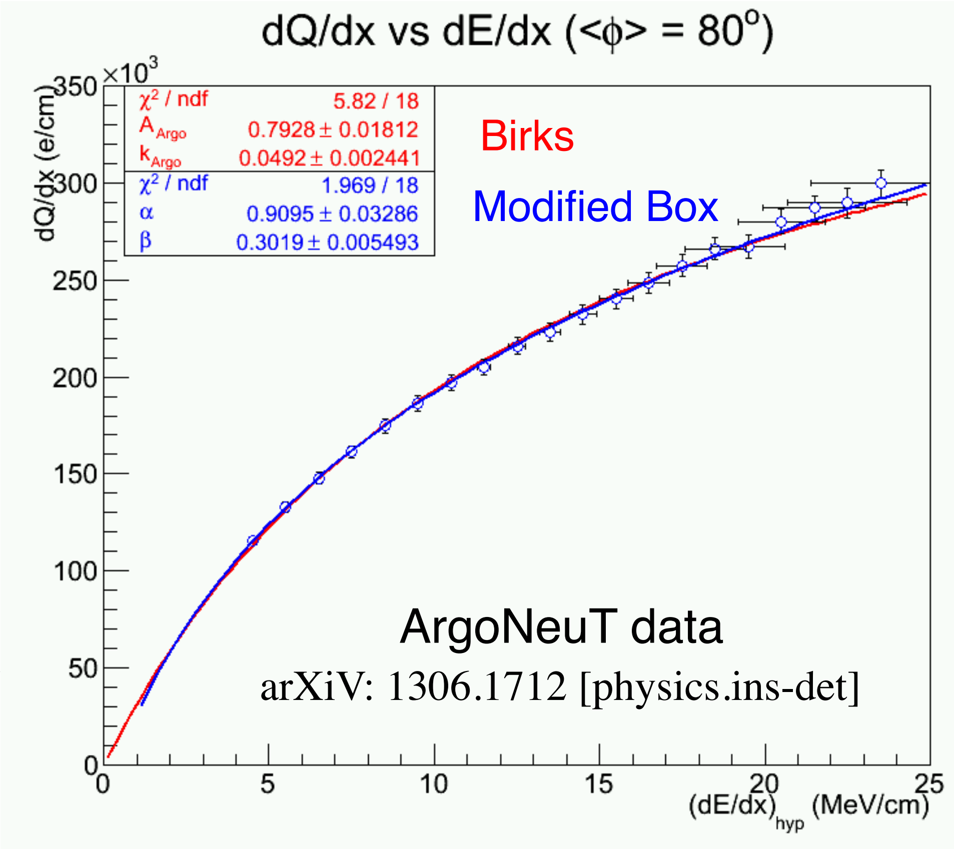


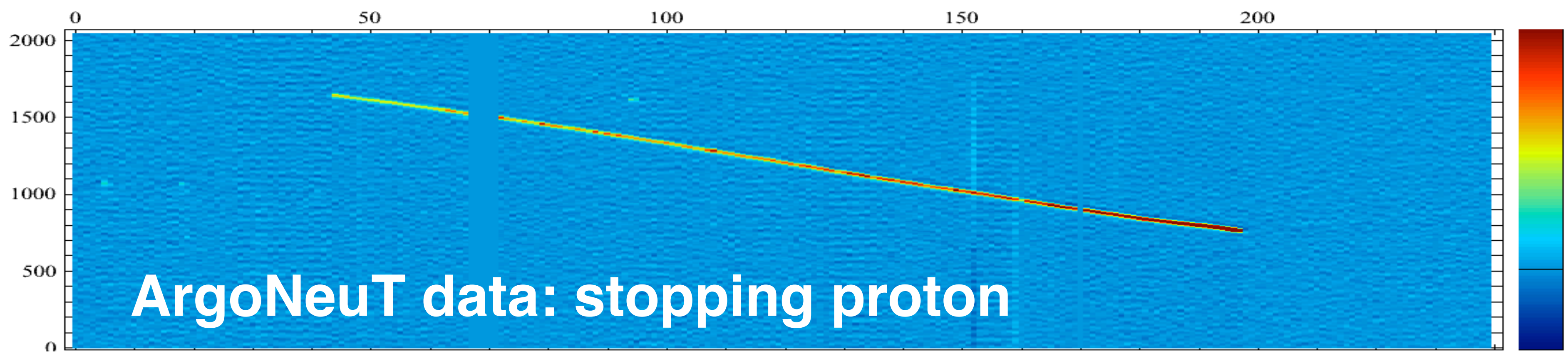


- The initial phase cryostat will contain about 80% of the shower for electrons with $p < 1$ GeV/c
- Sufficient argon in the initial phase to stop protons with $p < 1$ GeV/c as well
- The second phase cryostat will have full containment for EM showers
- The data taken with LArIAT will be used to improve simulations and will benefit all LArTPC detectors

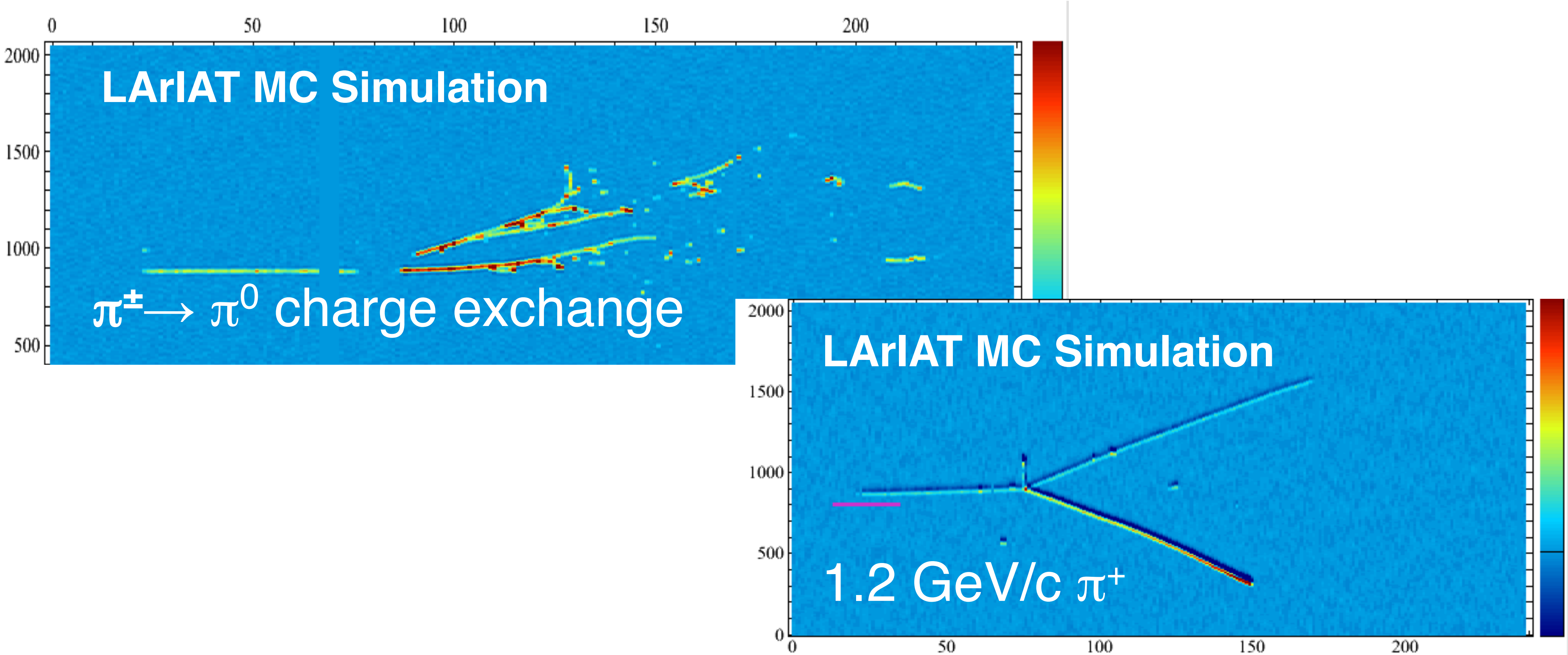
Visible Energy Calibration

- Improve resolution of energy deposited using both the collected charge and light
- New technique of TPB coated foils to maximize light collection
- dE/dx is critical for measuring energy of the particles and species
- Depends on electron-ion recombination
- Determine recombination parameters for various ranges of dE/dx, electric field magnitudes and track to field angles



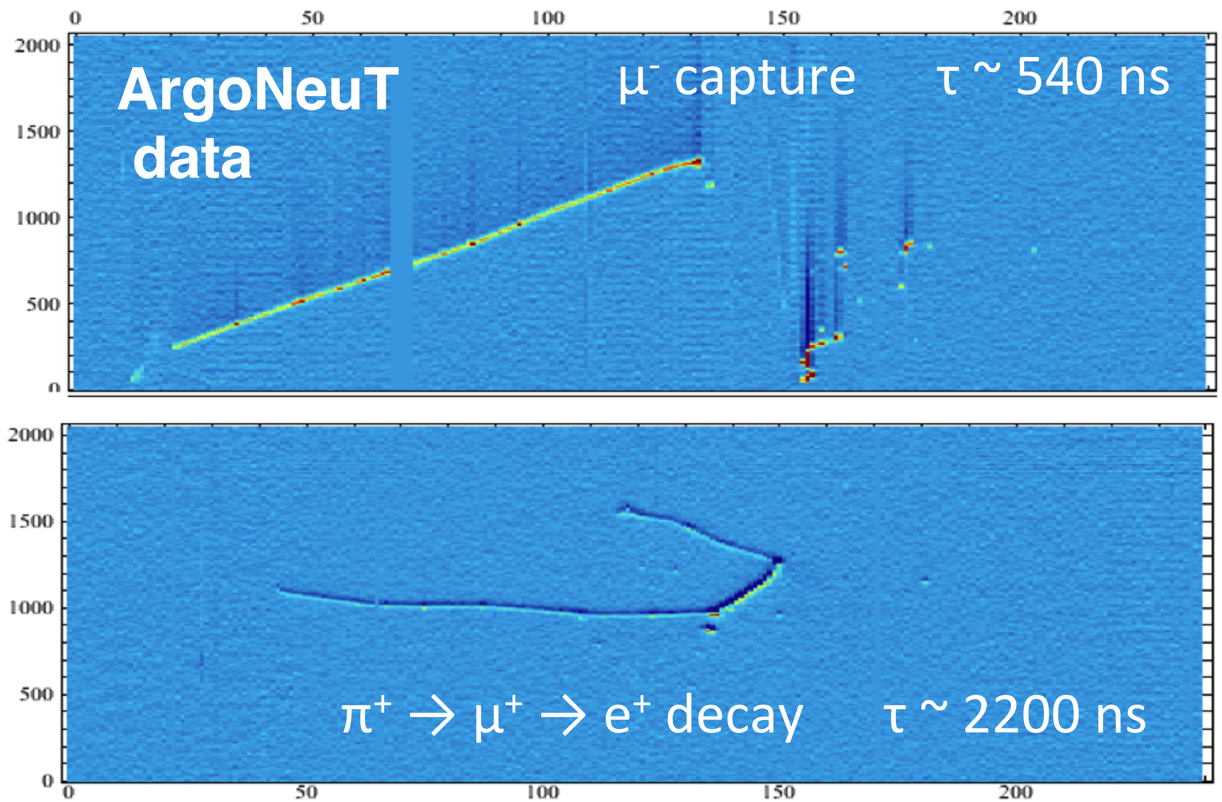


Nuclear Effects and FSI



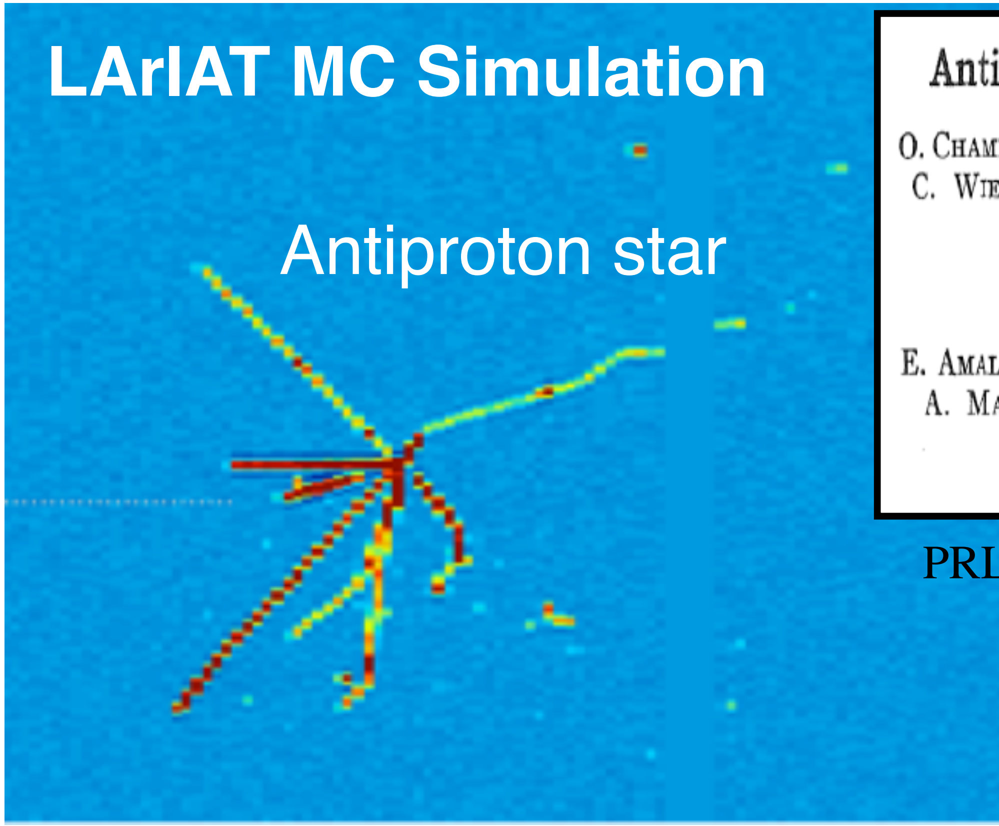
- Provide data to tune hadron-nucleus interactions for neutrino generators
- Study reconstruction performance and systematic uncertainties
- Use pion charge exchange to provide a standard candle to calibration EM shower energy resolution
- Provide important inputs and constrain backgrounds to neutrino oscillation analyses

Muon Charge Determination



- Exploit the position resolution of the LArTPC to discriminate between muon capture and decay
- μ- capture 76% of the time and decay 24%, μ+ only decay
- Use the identification of these processes to statistically study charge sign without a magnetic field
- Benefit LBN and SBN programs by constraining charge of ν_μ CC interactions

Study Anti-proton Interactions



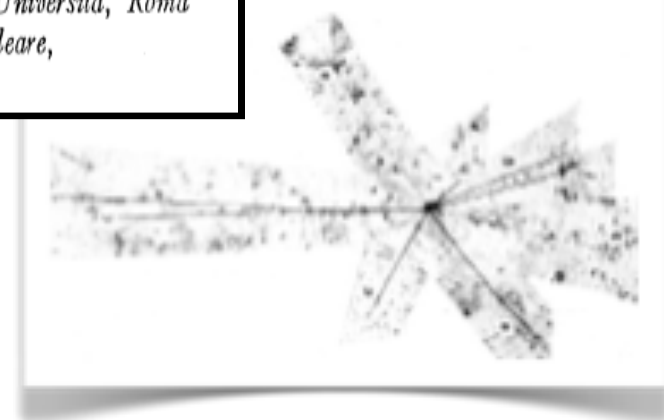
Antiproton Star Observed in Emulsion*

O. CHAMBERLAIN, W. W. CHUPP, G. GOLDHABER, E. SEGRÈ, AND C. WIEGAND, *Radiation Laboratory, Department of Physics, University of California, Berkeley, California*

AND

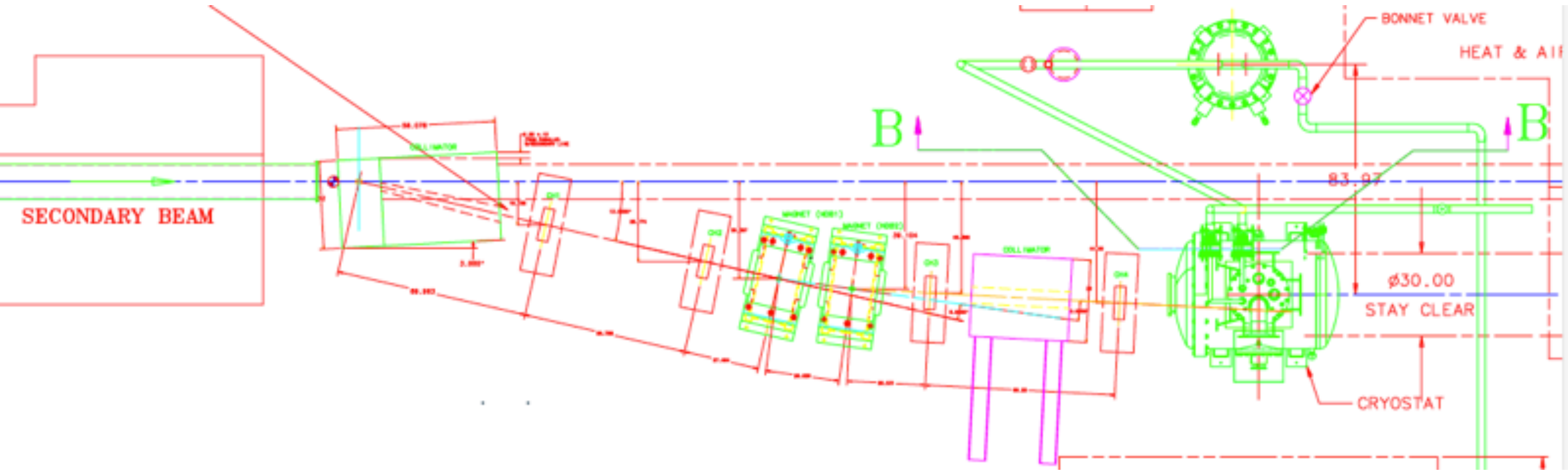
E. AMALDI, G. BARONI, C. CASTAGNOLI, C. FRANZINETTI, AND A. MANFREDINI, *Istituto di Fisica della Università, Roma Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italy*

PRL 101, 909 (1956)

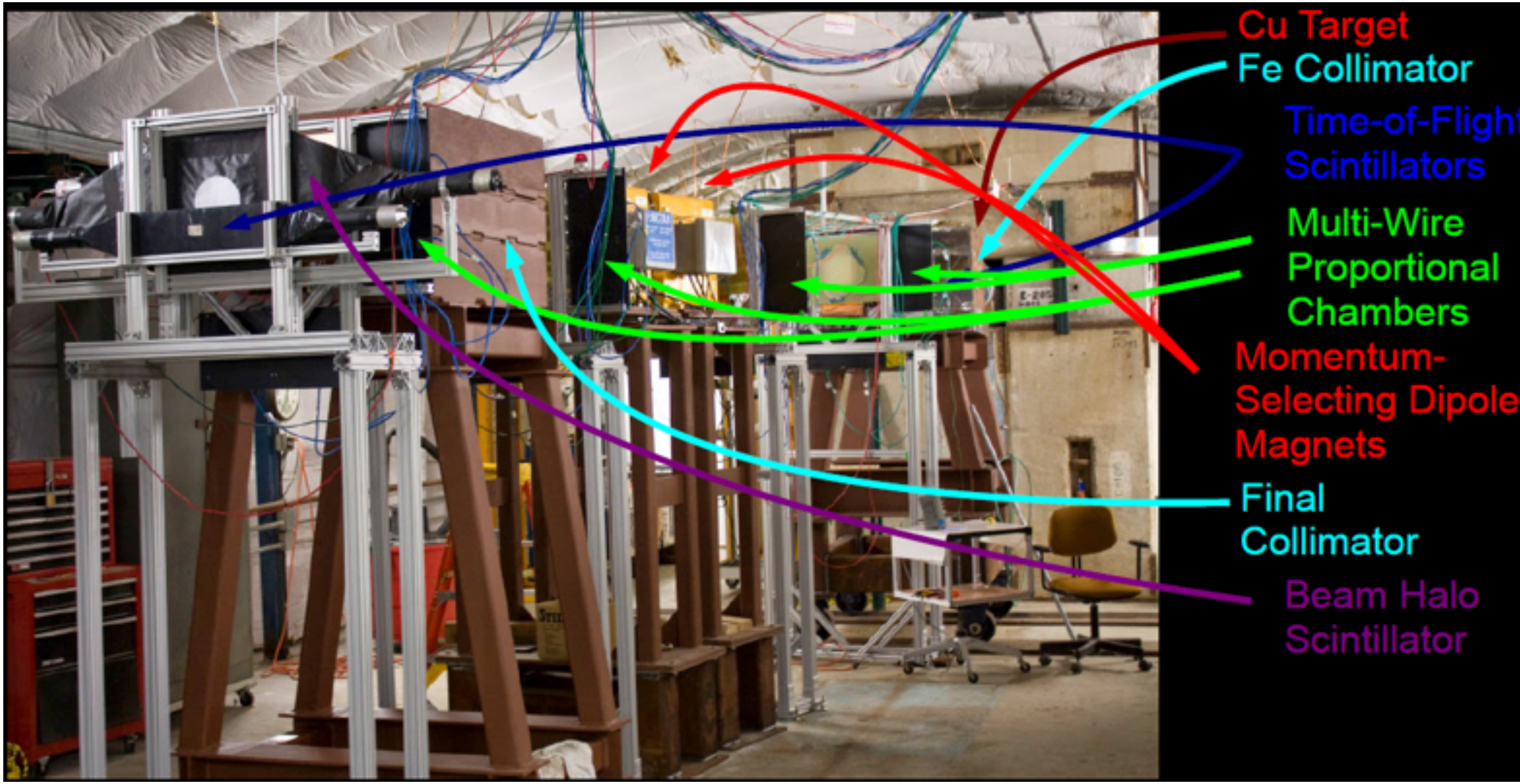


- Sufficient low momentum anti-protons in the beam to study hadron star topology from p-$\bar{p}$ annihilation at rest
- Very important for baryon number violation studies
- Directly measure hadron multiplicity

From Vision to Reality



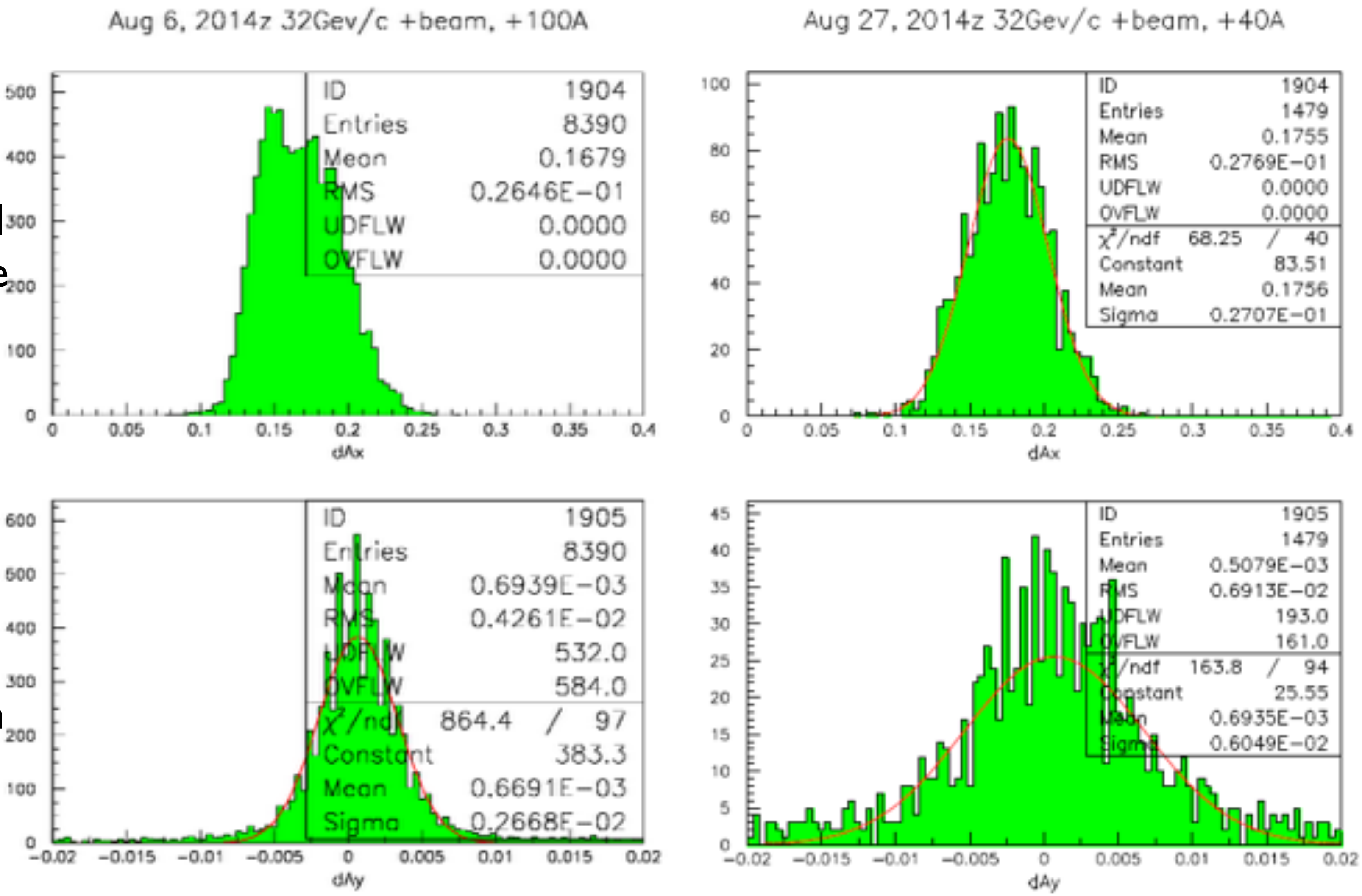
From Vision to Reality



Commissioning Run Summer 2014

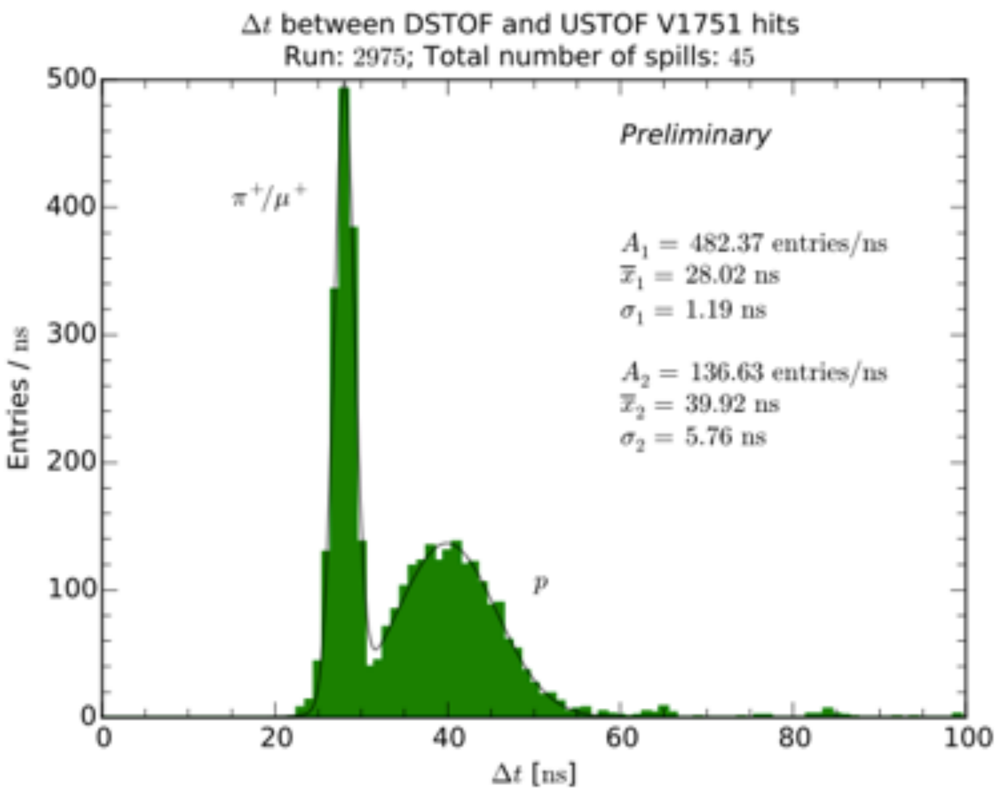
Horizontal Bend Angle

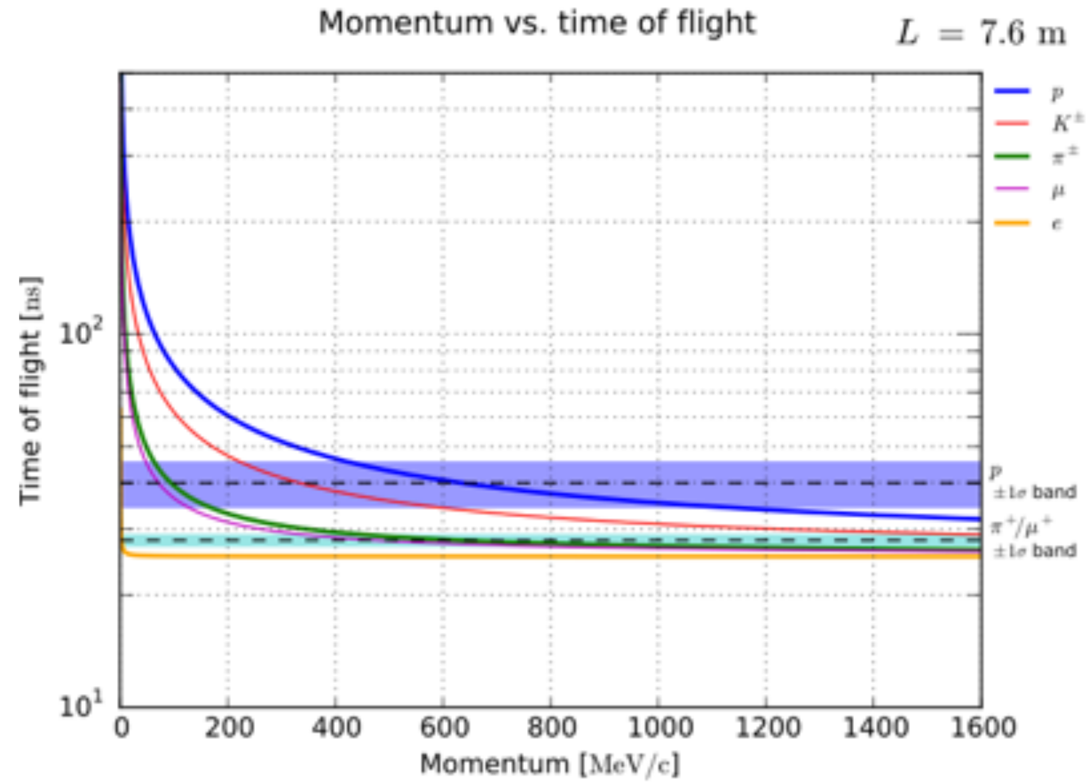
Vertical Angle Resolution



- First beam experiment to use artdaq for DAQ - great support from SCD
- Preliminary momentum reconstruction using wire chambers
  - Resolution when magnets run at 100 A is 1.6%
  - Resolution when magnets run at 40 A is 3.4%

Commissioning Run Summer 2014

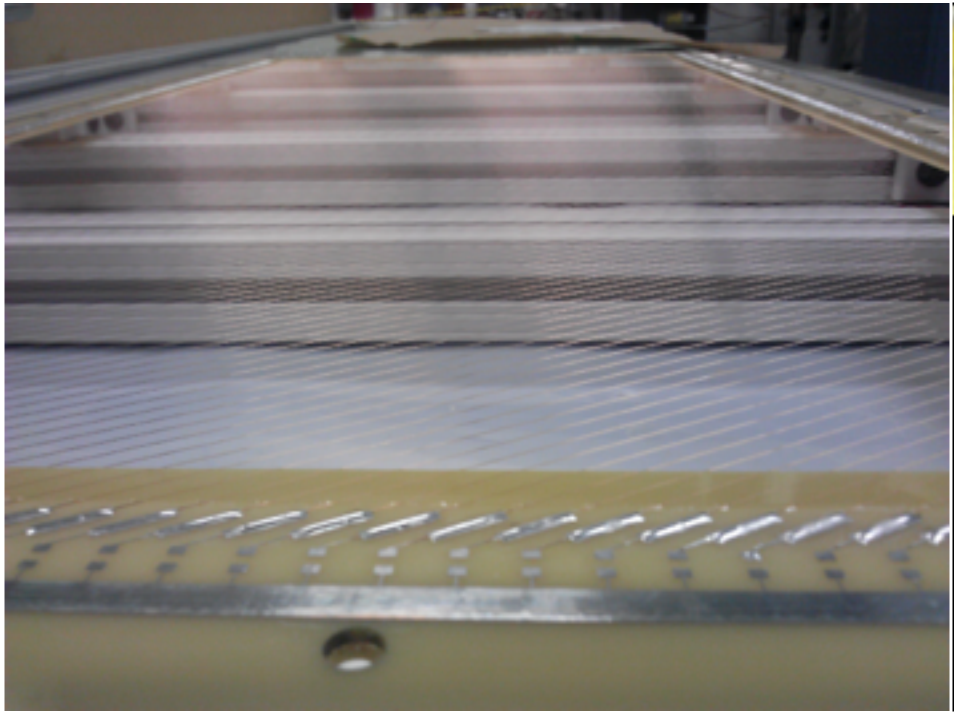


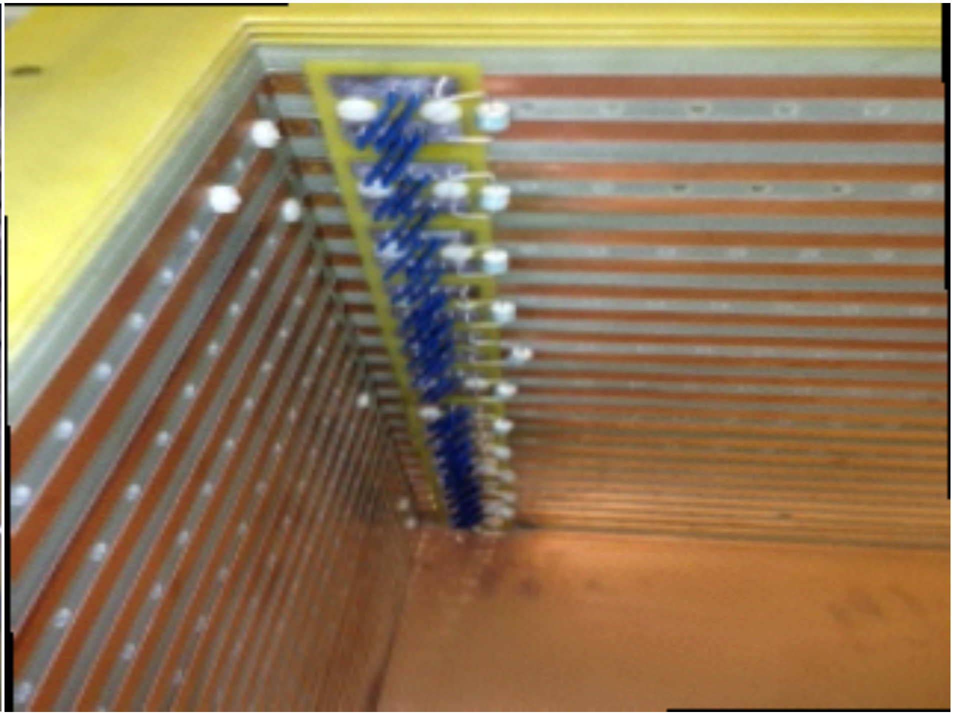


- Took advantage of summer running to understand the auxiliary detectors
- Plots above show the performance of the time of flight system
- Discrimination of protons and pions/muons
- Monte Carlo studies show that we are discriminating in the region of 400 MeV/c < p < 1000 MeV/c

Plan Coming Together

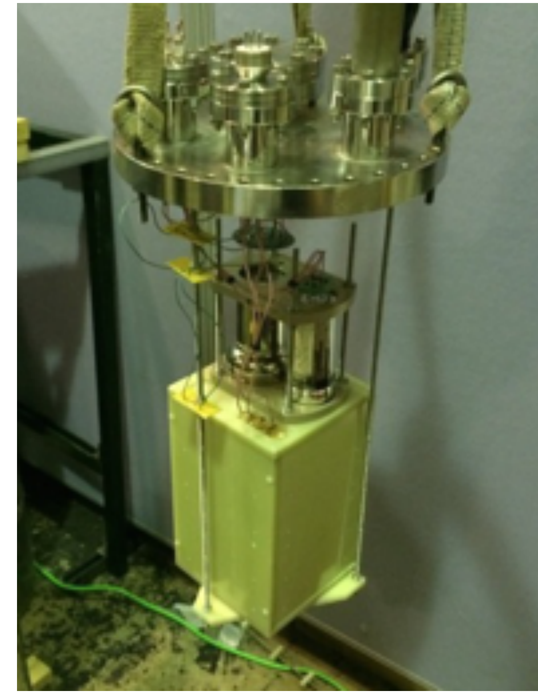
- Photo detectors ready to go after tests at U Chicago, reflectors made at Yale, simulations from Fermilab
- Syracuse built the TPC, Fermilab strung the wires, BU built the wire plane boards and bias voltage filter cards
- Full group effort to get the TPC ready and inserted into the cryostat

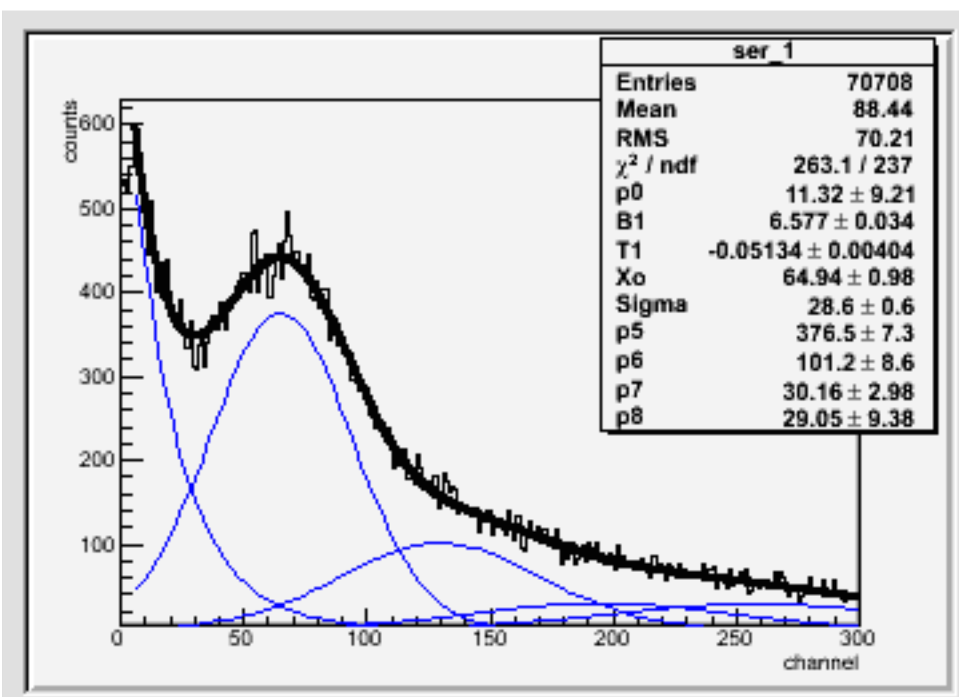


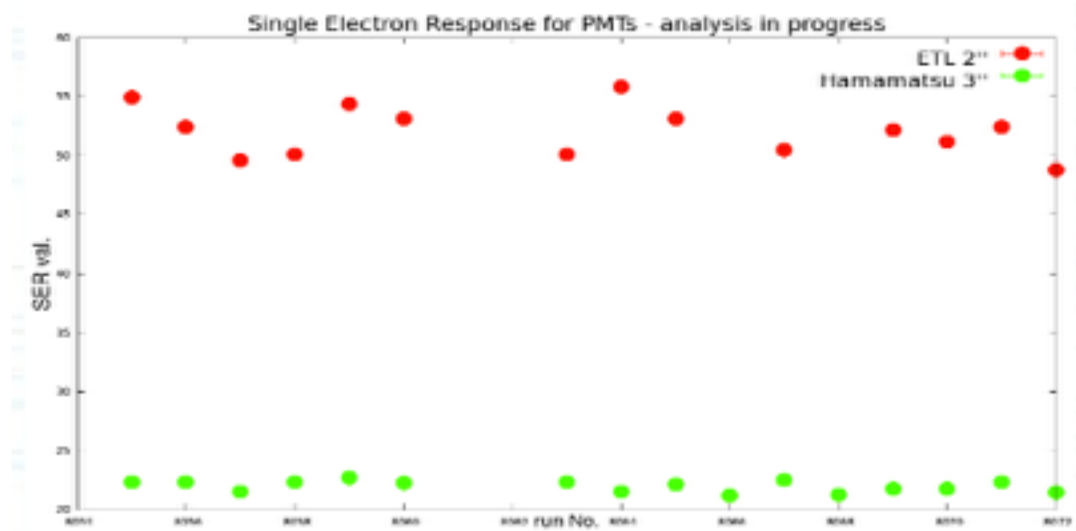


Light Collection System Tests

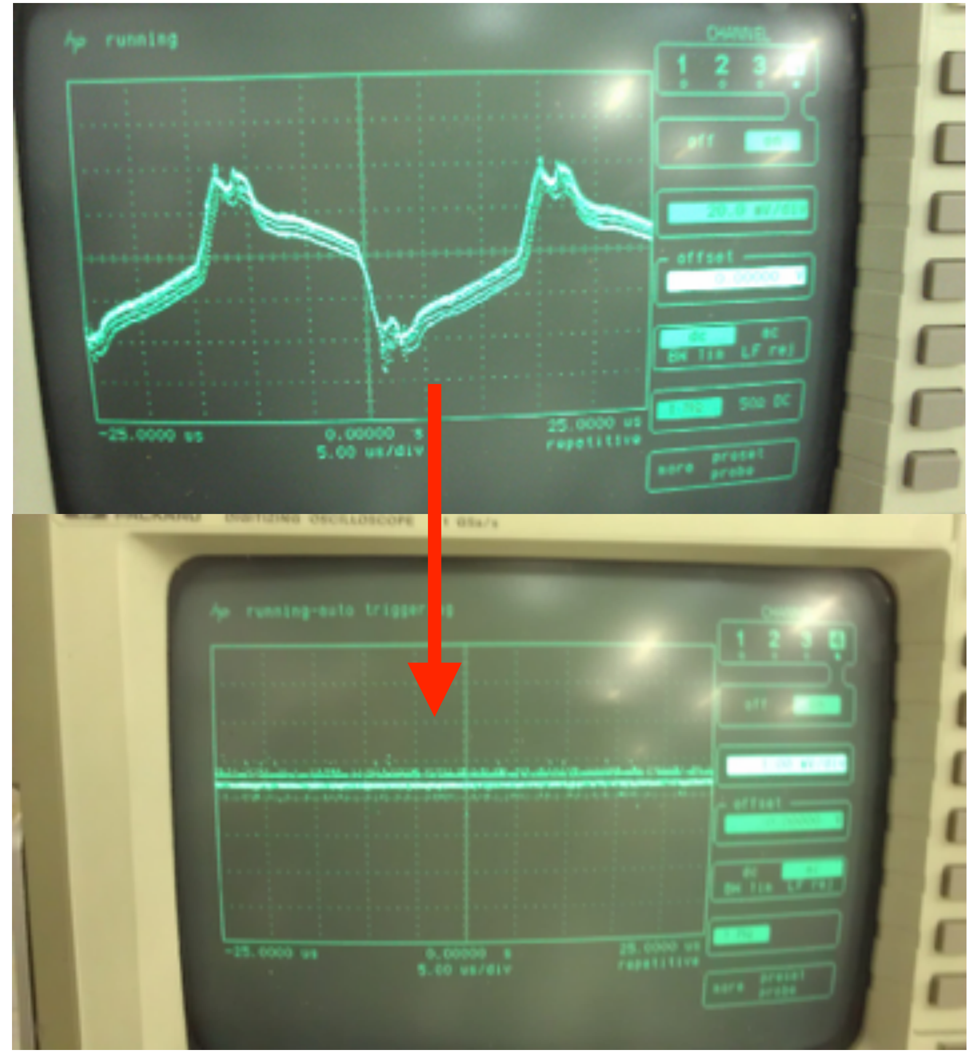
- PMTs were mounted on a mock TPC
- Tested PMT response as well as feed throughs
- Measured the single PE response to understand gain and stability
- Also using SiPMs as light collection devices





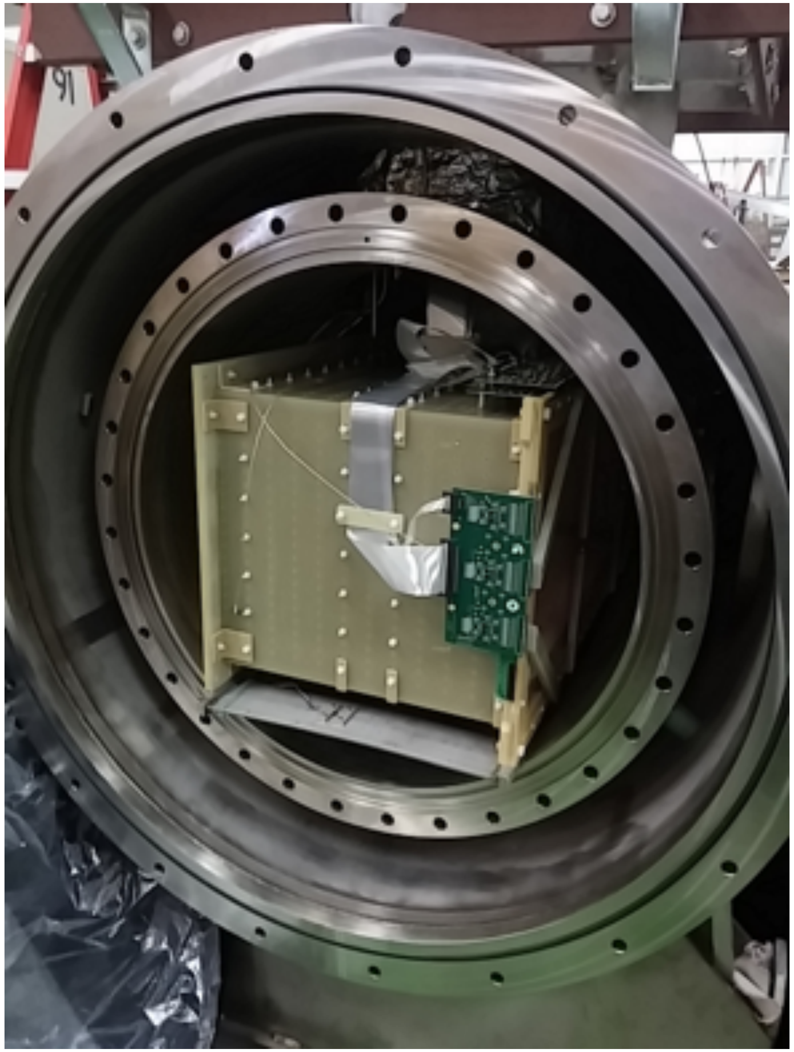


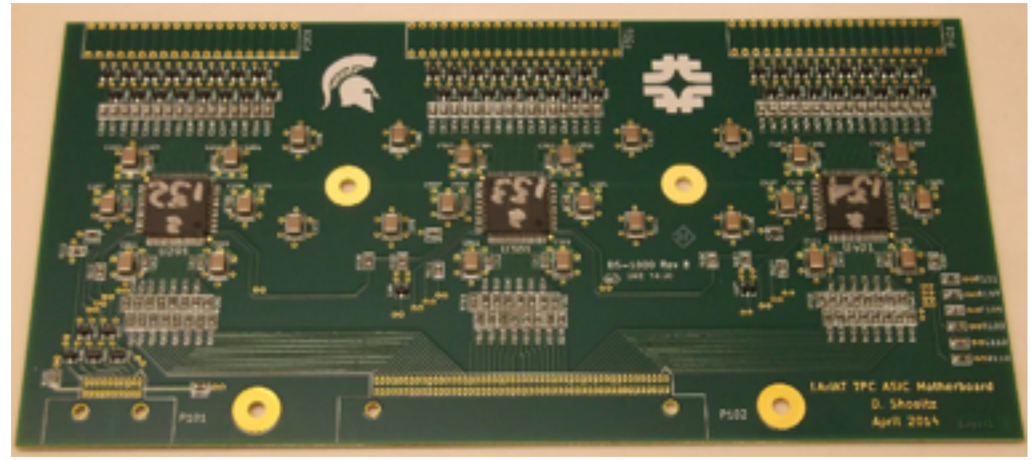
Plan Coming Together

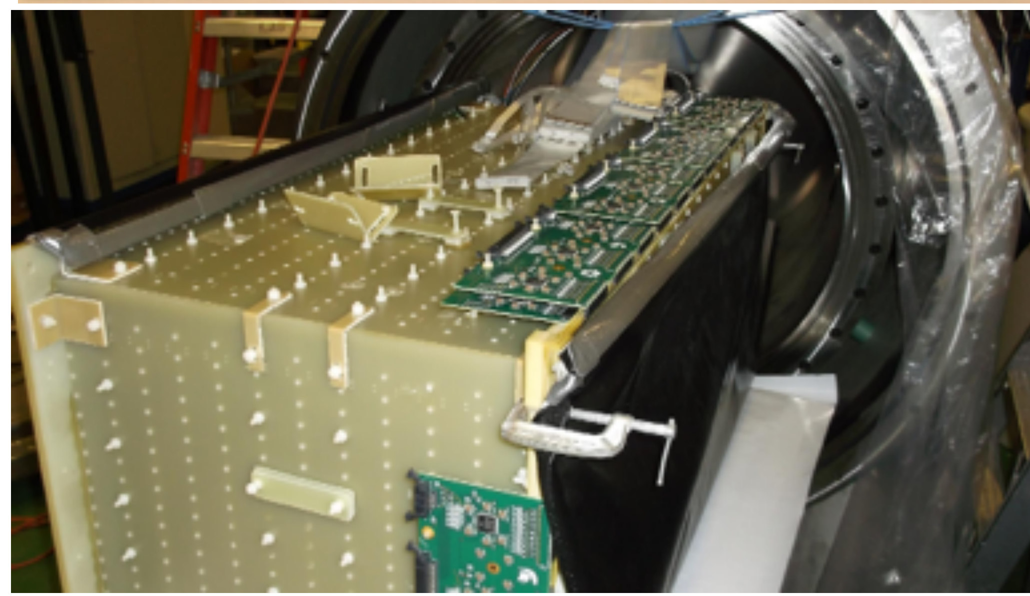


- HV system ready to deploy, multiple filter pots to ensure very low ripple - < 0.2 mV peak to peak - LSU postdoc brought it together
- Reached -40 kV in air without incident, need only -25 kV

Plan Coming Together

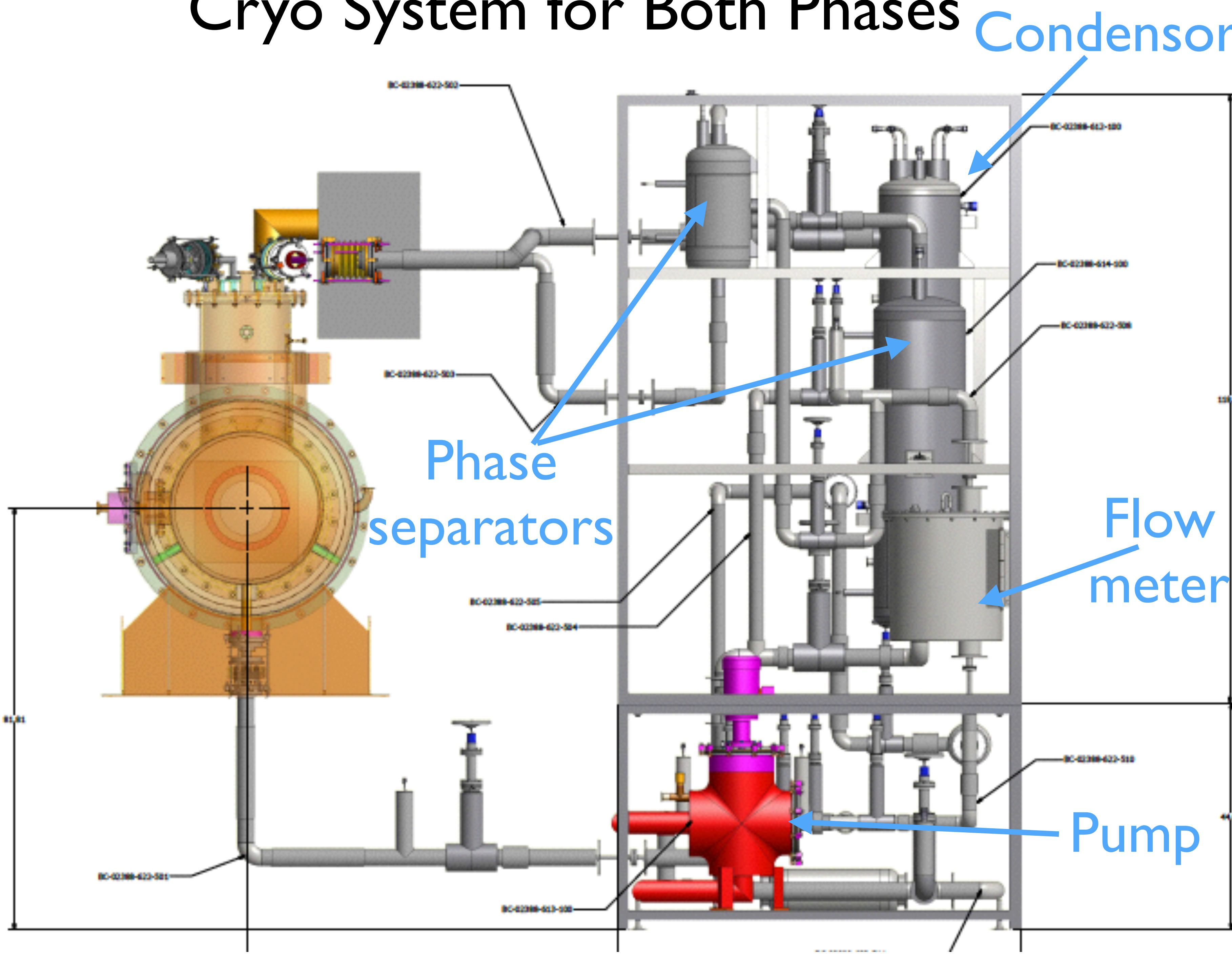






- Cold electronics built by MSU using MicroBooNE/LBNE ASIC and installed on the TPC
- ASICs are in the liquid, remaining electronics are outside the cryostat

Cryo System for Both Phases

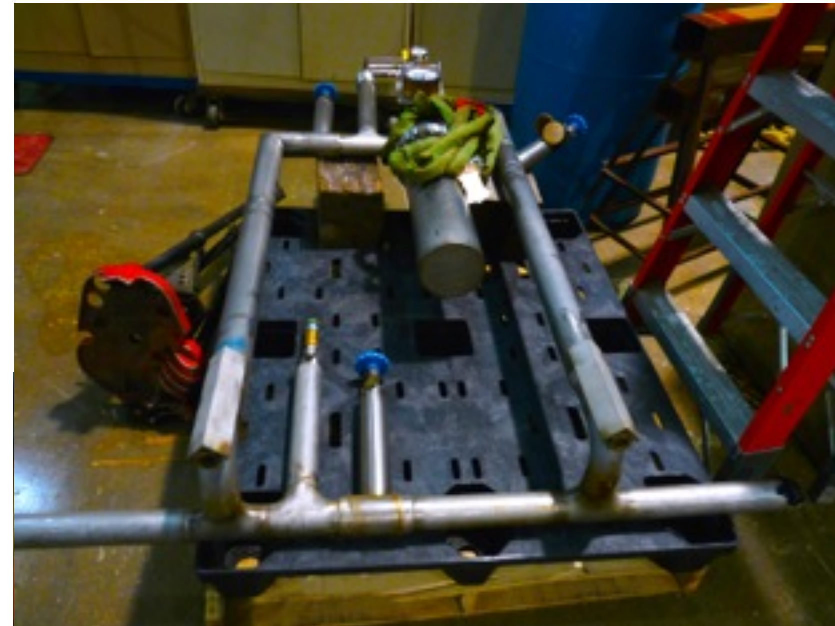


Cryo System for Both Phases

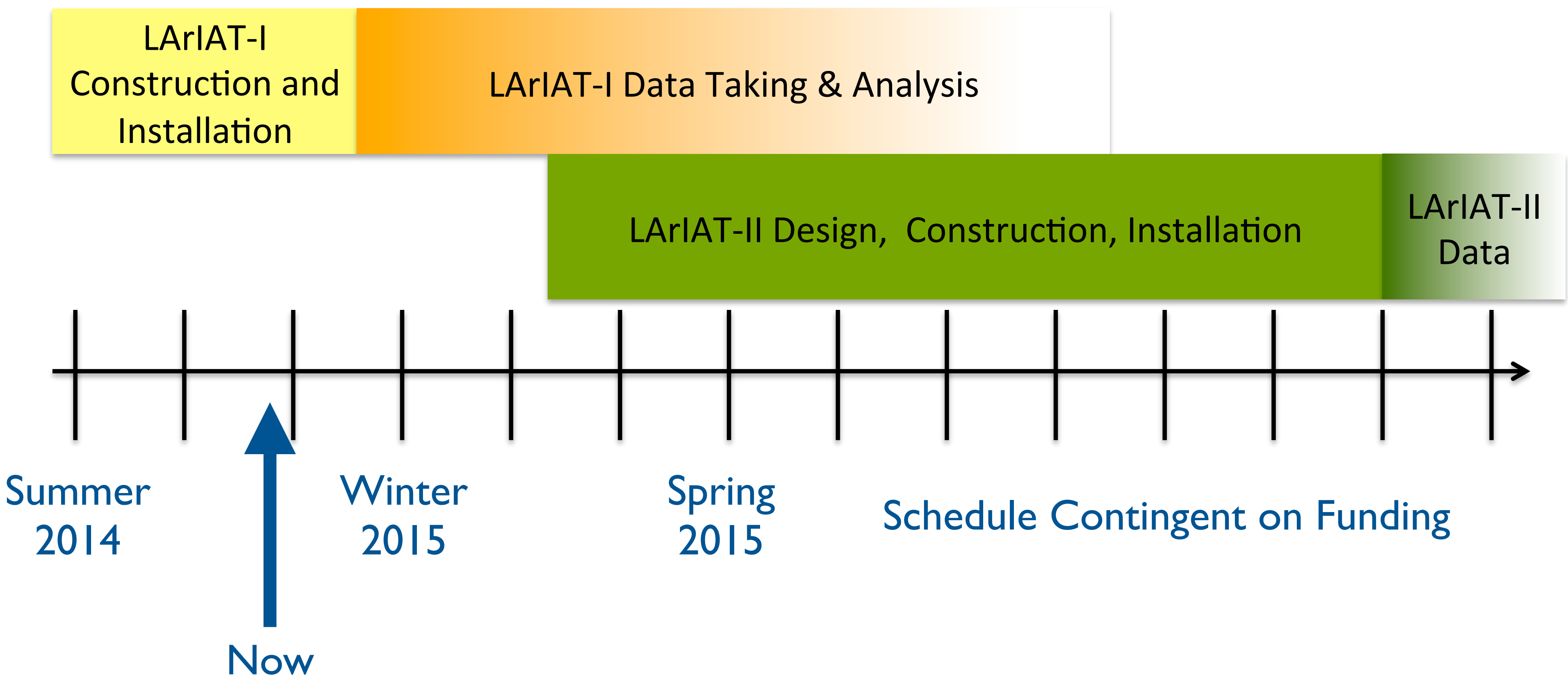
- System ordered from Eden Cryogenics after bid process, delivery in December
- Well oversized for initial phase allows use in second phase
- Filter skid for second phase based on MicroBooNE design

Data Taking Before Cryo Delivery

- Want to be ready as close to when beam returns as possible
- Recycling spare filter vessel from LAPD for smaller volume of Phase 1 running
- Recycling pieces from D0 for particulate filter
- Plan is to continually bring argon into the system from an external dewar, through filter, and boil it out of the cryostat
- No recirculation, but allows data taking with the TPC to start much sooner



LArIAT Long Term Plan



Conclusions

- LArIAT is an integral part of the liquid argon TPC detector development program - more details at

  http://arxiv.org/pdf/1406.5560.pdf

- Results from LArIAT will be useful for both the SBN and LBN program
- LArIAT is also an ideal location to test new ideas for the technology because of its size
- Test runs during the Summer 2014 were successful demonstrations of the DAQ and auxiliary detectors
- Running with the TPC will start very soon
- Look for first results next year