Introducing LArIAT (aka T1034)

Jason St. John - University of Cincinnati - for the LArIAT collaboration

March 21st, 2013 - Liquid Argon TPC R&D Workshop - Fermilab

Liquid **Ar**gon TPC
in **a** **T**estbeam

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LArIAT

18 institutions

40+ physicists

New members welcome!

Scientific Goals

Phased program for comprehensive characterization of LArTPC performance for the range of energies relevant to upcoming experiments like MicroBooNE and LBNE

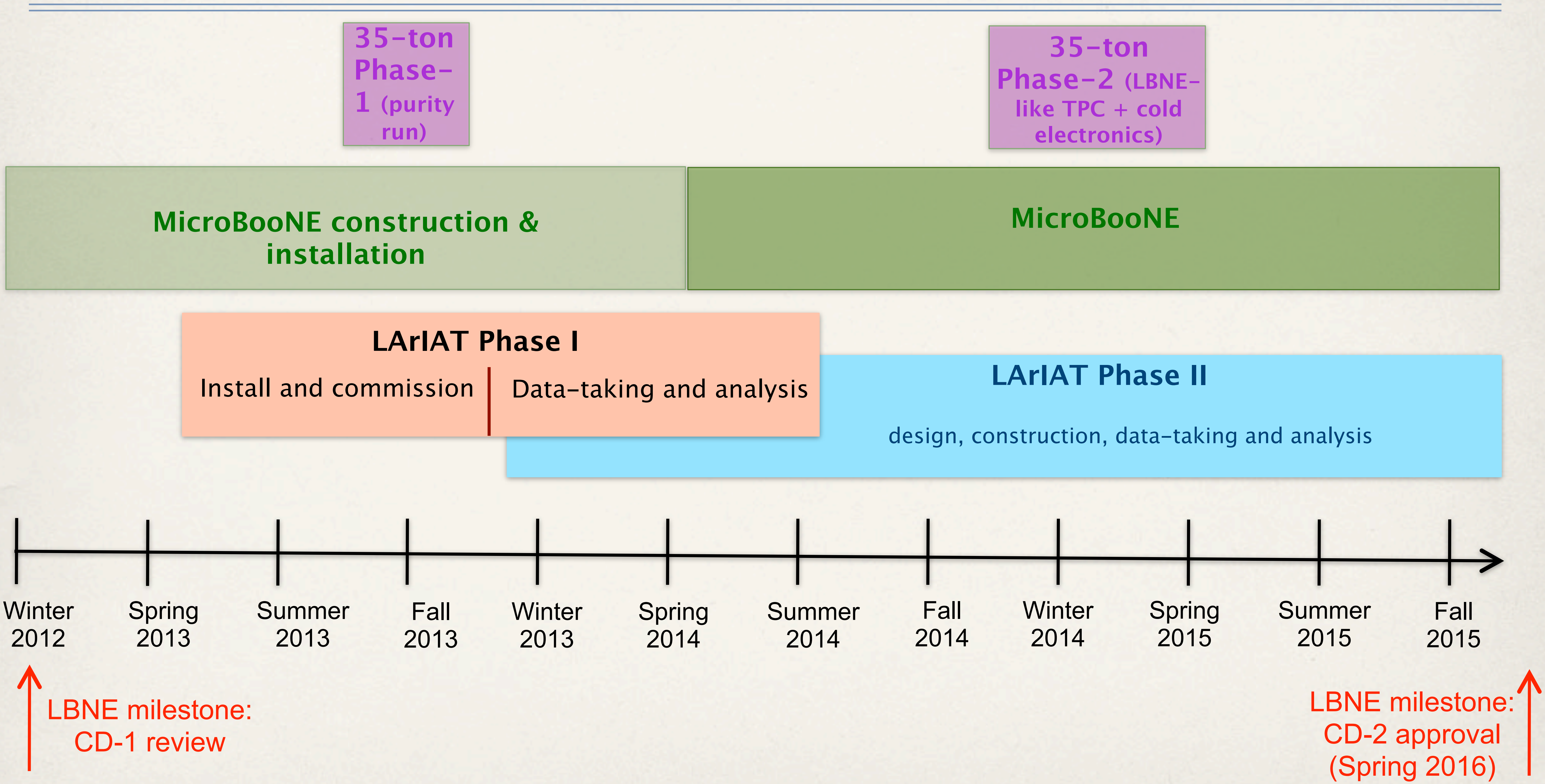
Phase-I: Modified ArgoNeuT detector

Single-track calibration (recombination & charge-to-energy calibration)
Experimental measurement of e/gamma discrimination
Optimization of particle ID methods
Development of criteria for charge sign determination

Phase-II: Larger volume TPC (TBD)

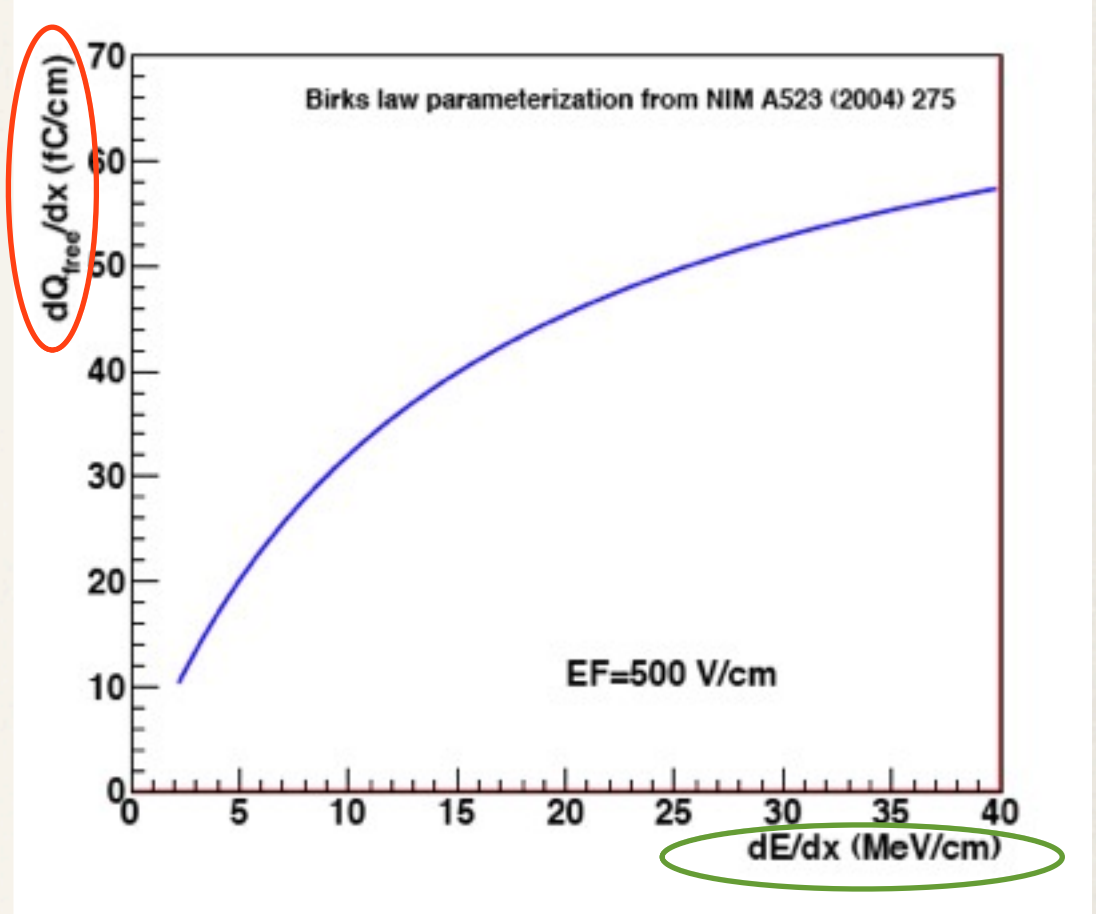
Reconstruction of collective topologies (detected-to-incident energy calibration)
Characterization of EM and hadronic showers
Testing ground for LAr detector subsystems under development for future use (cold electronics, new wire plane designs, study longer drift distances, etc.)

Timeline


35-ton Phase-1 (purity run)
35-ton Phase-2 (LBNE-like TPC + cold electronics)
MicroBooNE construction & installation
MicroBooNE
LArIAT Phase I
Install and commission
Data-taking and analysis
LArIAT Phase II
design, construction, data-taking and analysis
Winter 2012
Spring 2013
Summer 2013
Fall 2013
Winter 2013
Spring 2014
Summer 2014
Fall 2014
Winter 2014
Spring 2015
Summer 2015
Fall 2015
LBNE milestone: CD-1 review
LBNE milestone: CD-2 approval (Spring 2016)

Single Track Calibration

Precisely establish relationship between ionization charge collected at TPC wires and energy deposited in LAr by incident particles of different types and stopping powers.



Below 15 MeV/cm, Birks parameterization well-validated; above ~15-20 MeV/cm data from ICARUS cosmic ray measurements, but sparse and statistically limited.

With 250-2000 MeV beam of particles that penetrate and stop in TPC, can determine calibration for:

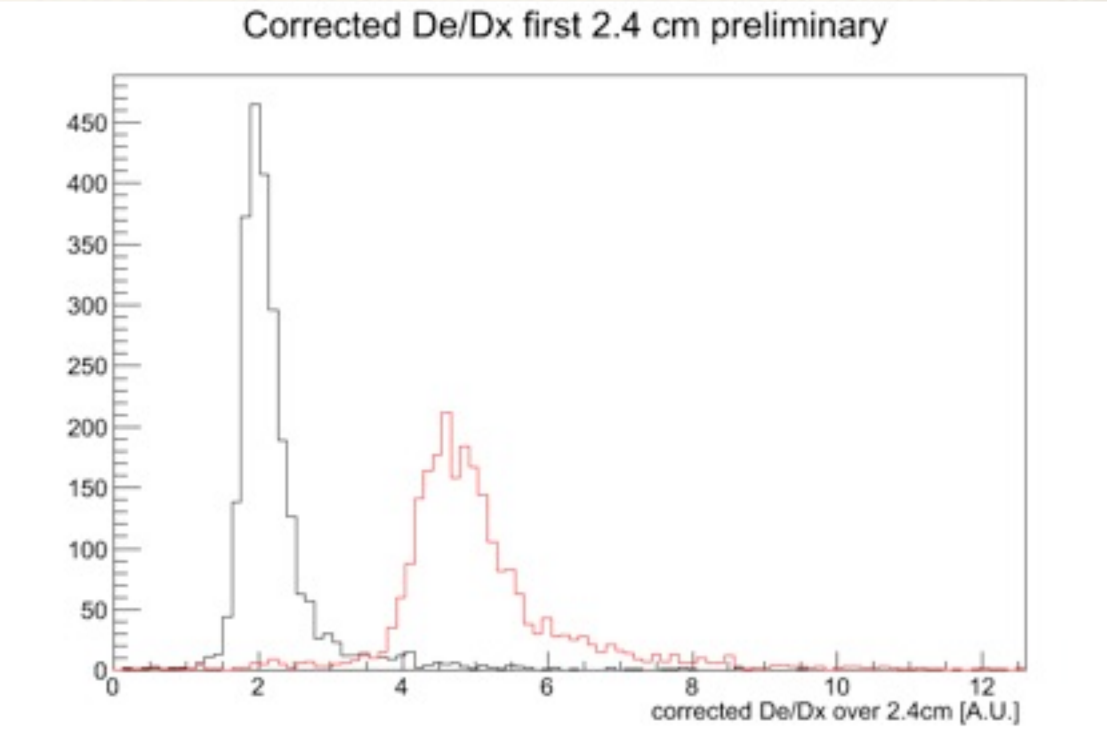
- Extended range of energy deposition (dE/dx)
- Different E field values (~0.3-1.0 kV/cm range, typ. LArTPC operation)
- Different track-to-electric field angles

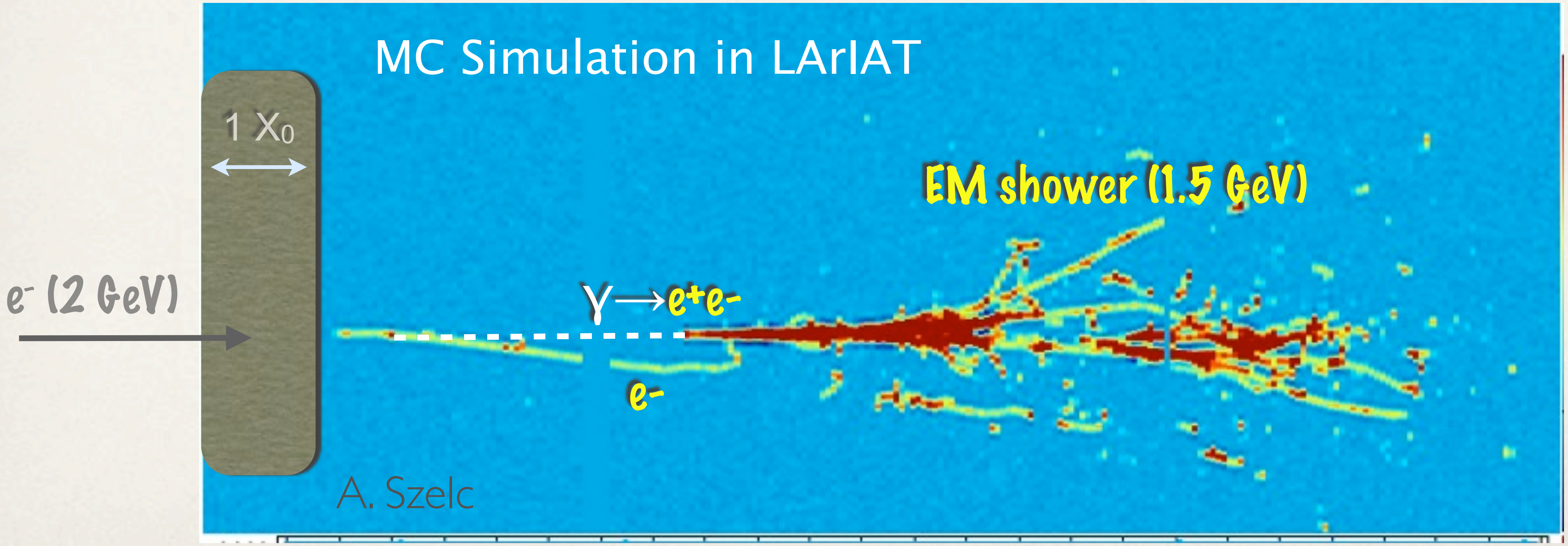
Goal: Provide to MicroBooNE (LArSoft) verification of parameterization or tables of ionization charge vs. energy deposited for each measured setting.

e/γ Shower Separation

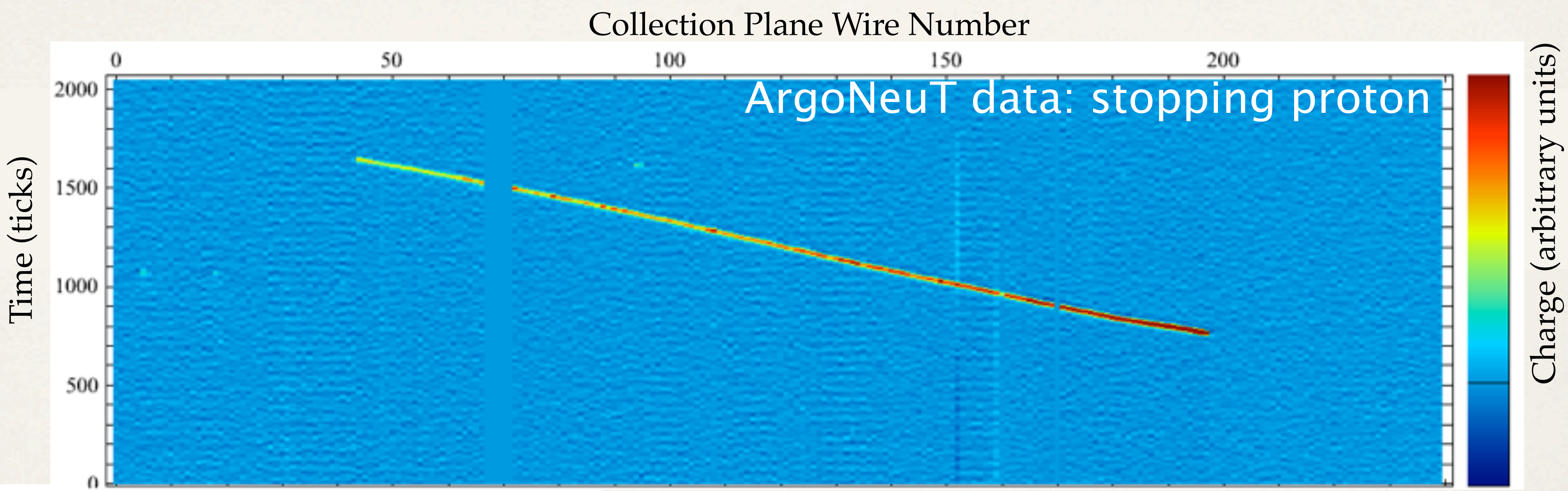
Separation efficiency and sample purity of electron-induced *vs.* photon-induced showers never experimentally measured.

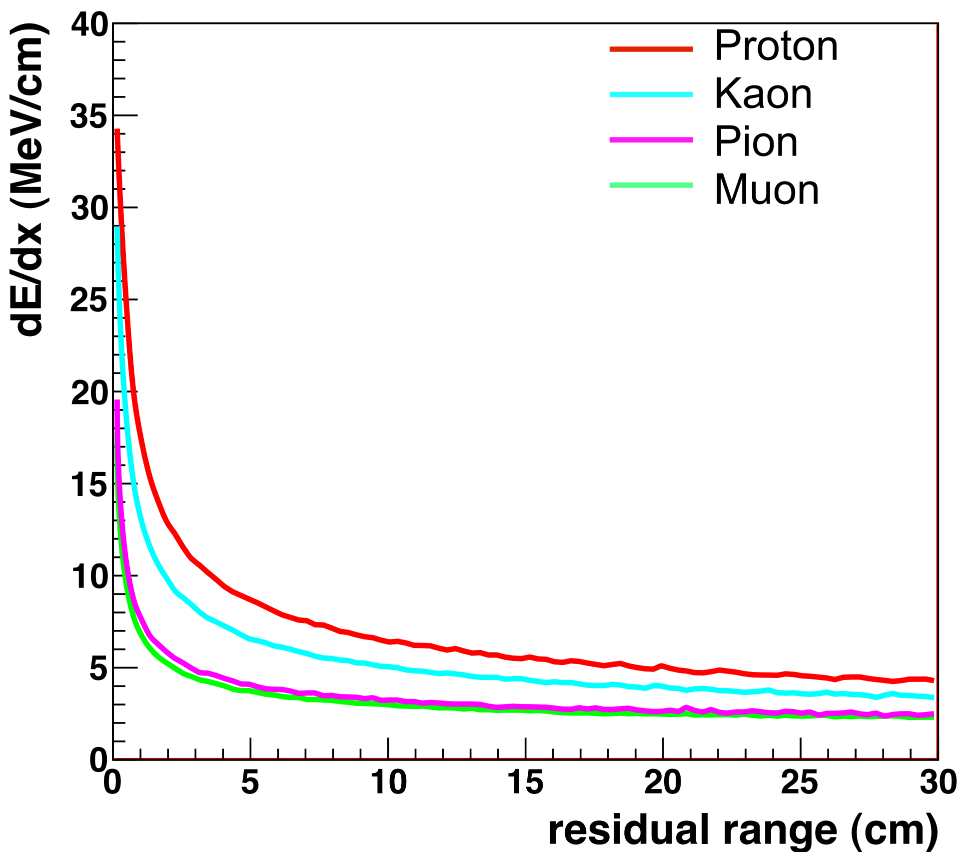
Initial part of shower is relevant for separation (γ converts to e^+e^- pair w/double ionization at shower start).





Optimization of PID Methods





Single track calibration + 3D imaging ⇒ dE/dx vs. residual range

High-statistics test beam data will allow experimental determination of:

Proton ID, p/K separation and purity/rejection factor

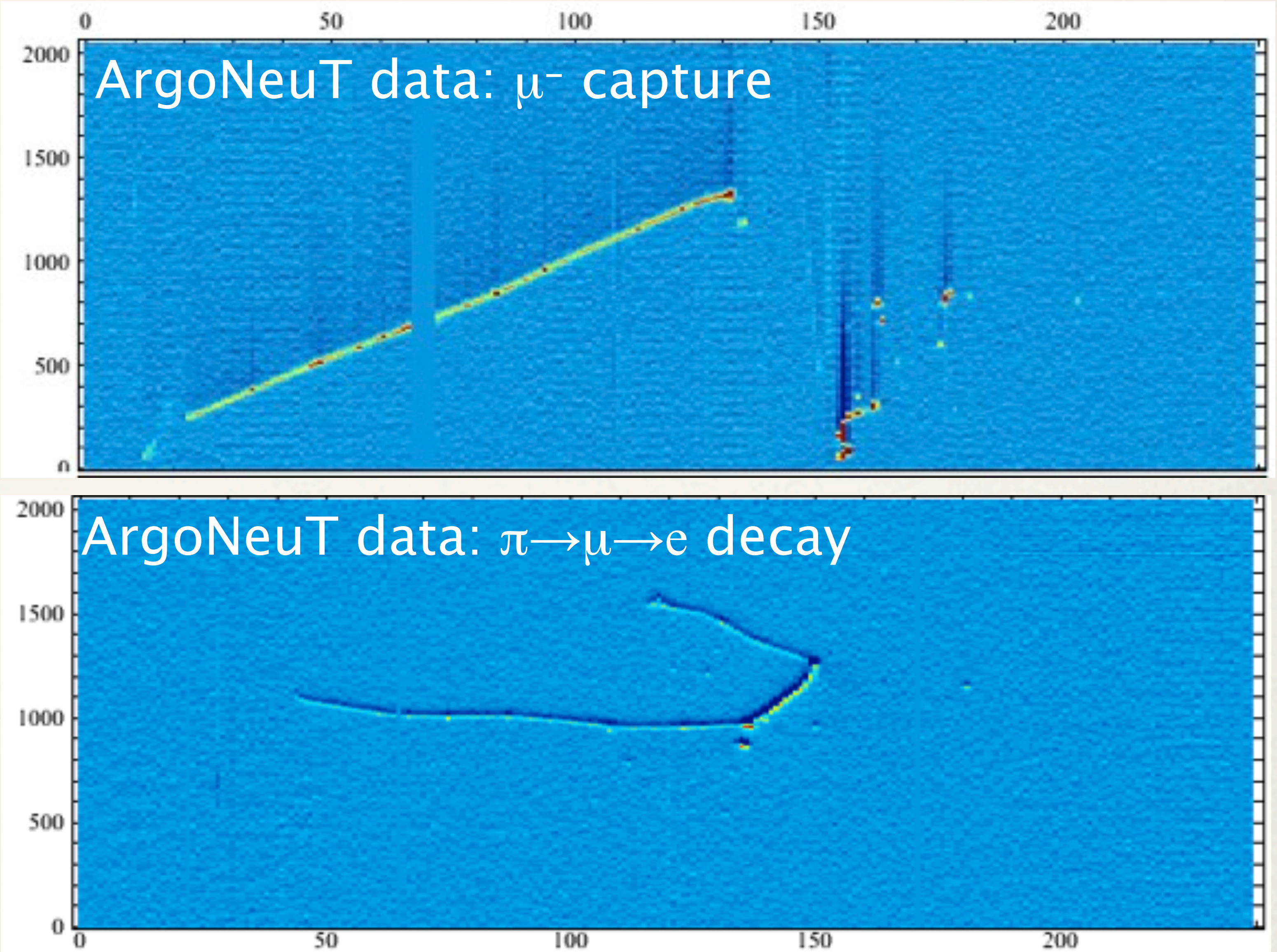
Kaon ID, K/π/μ separation and purity/rejection factor

Charge Sign Determination

Sign selection without magnetic field can be done by statistical analysis based on topological criteria.

- μ^+ only undergo decay
- μ^- capture on nuclei (75%, followed by γ or n emission) or decay (25%)

Systematic study of capture in Ar and LArTPC sign-selection capabilities have not been explored before.



EM & Hadronic Showers

EM energy deposition mechanism is very well understood (MC simulations are very reliable)

However, in LAr, a substantial fraction of the incident energy (~30%, depending on incident energy) goes into soft electrons (< 2 MeV)

How well can the incident energy be reconstructed?

Hadronic showers are more complicated (develop on λ_{int} scale rather than X_0 scale, $\lambda_{int} \sim 5X_0$). Containment more difficult.

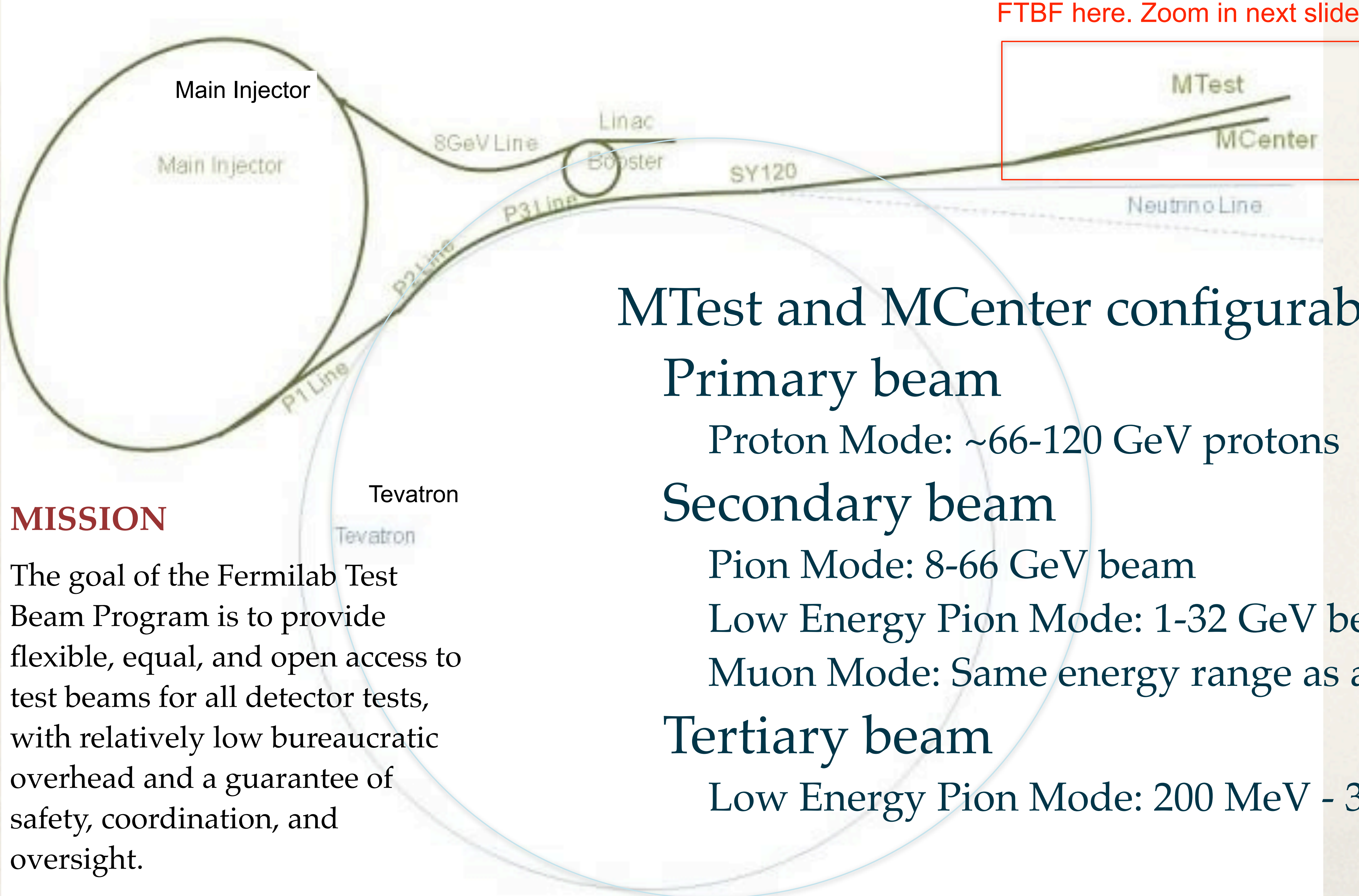
Fraction of energy goes to:

- **EM**: fluctuates and is E-dependent (never measured in LAr)
- **Soft neutrons**: few tens of neutrons per GeV (~10%)
- **Undetectable**: fraction not well known (~10%?)

Need to measure energy-dependent calibration constants for pions

Fermilab Test Beam Facility

http://www-ppd.fnal.gov/MTBF-w/



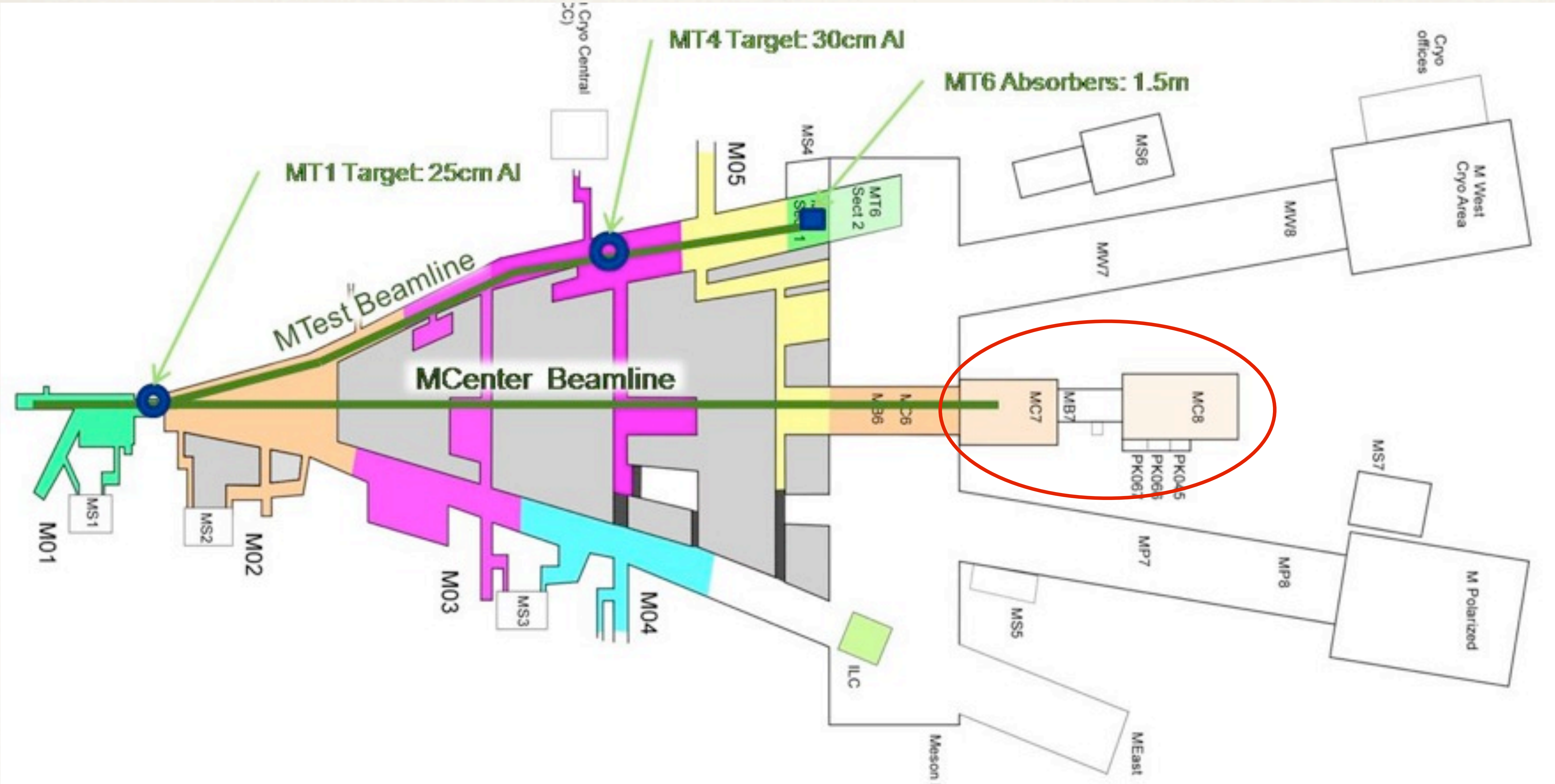
MTest and MCenter configurable for:

- Primary beam
  - Proton Mode: ~66-120 GeV protons
- Secondary beam
  - Pion Mode: 8-66 GeV beam
  - Low Energy Pion Mode: 1-32 GeV beam
  - Muon Mode: Same energy range as above
- Tertiary beam
  - Low Energy Pion Mode: 200 MeV - 3 GeV

MISSION

The goal of the Fermilab Test Beam Program is to provide flexible, equal, and open access to test beams for all detector tests, with relatively low bureaucratic overhead and a guarantee of safety, coordination, and oversight.

Closer Look at FTBF



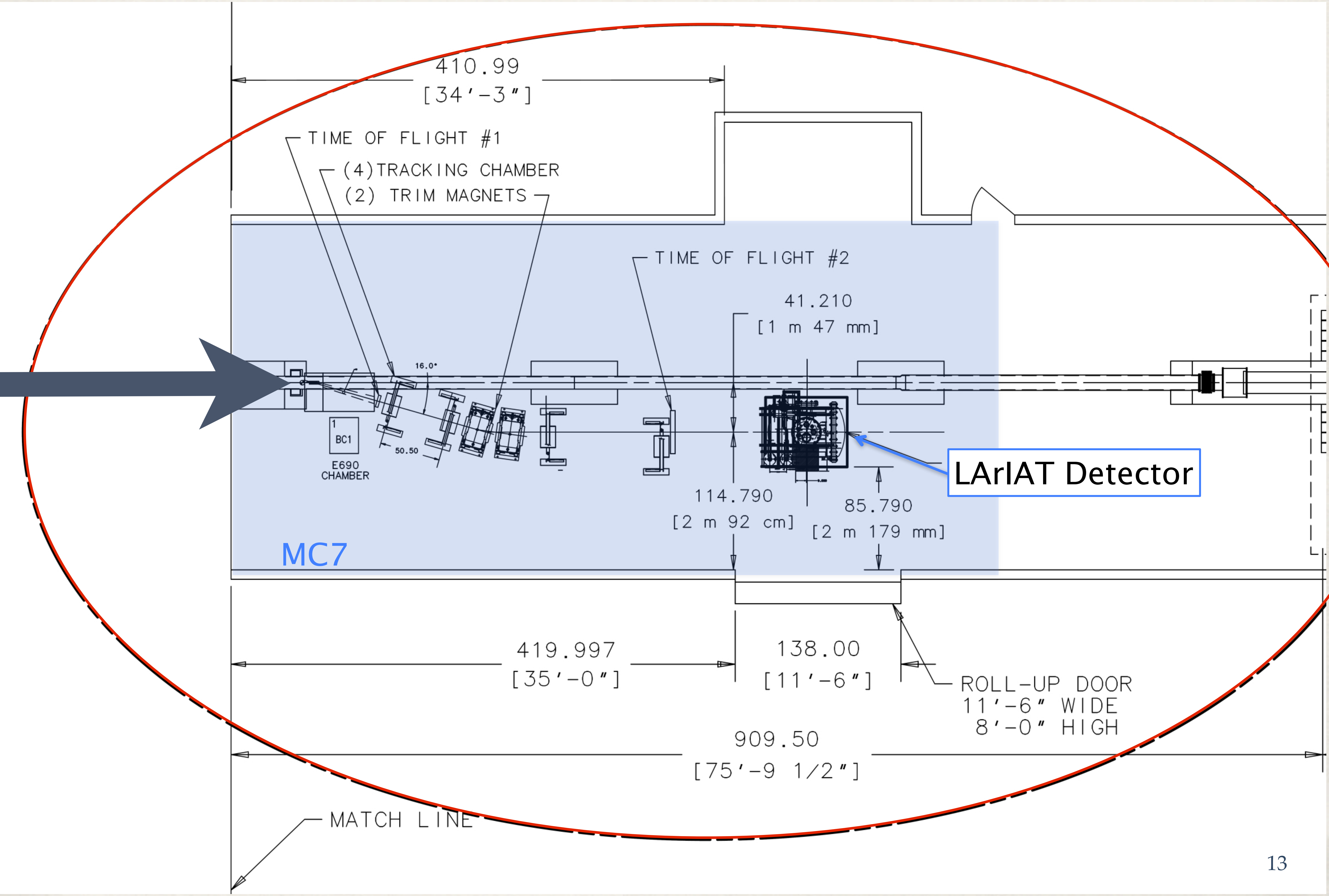
MTest

Continue to use for short-term experiments (few weeks to months)

MCenter

Create a facility for long-term LAr calibration and R&D with "generic" cryogenic plant in MC7/8 that will service upcoming experiments (LArIAT-I and -II) and any future LAr R&D in this beam.

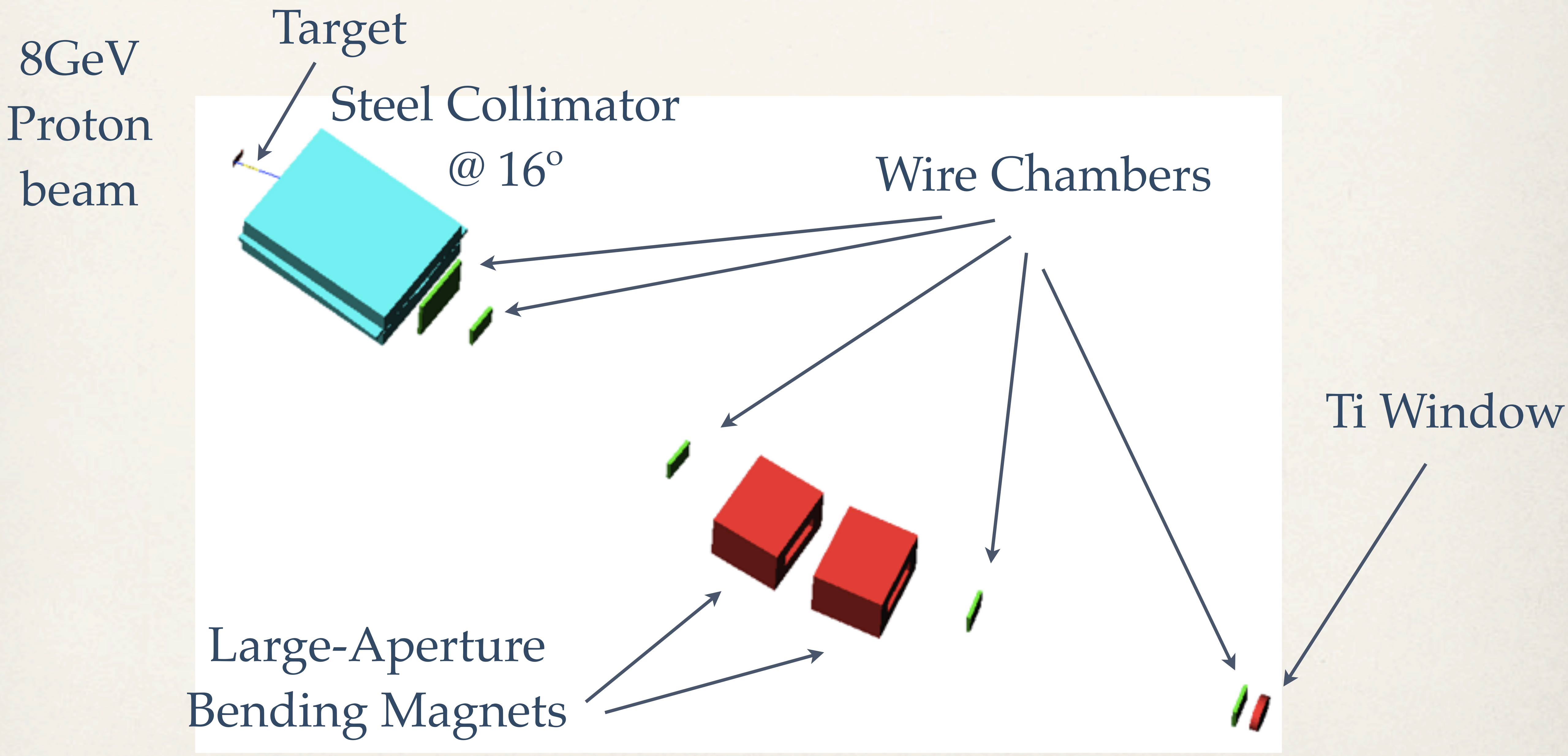
Closer Look at MC7



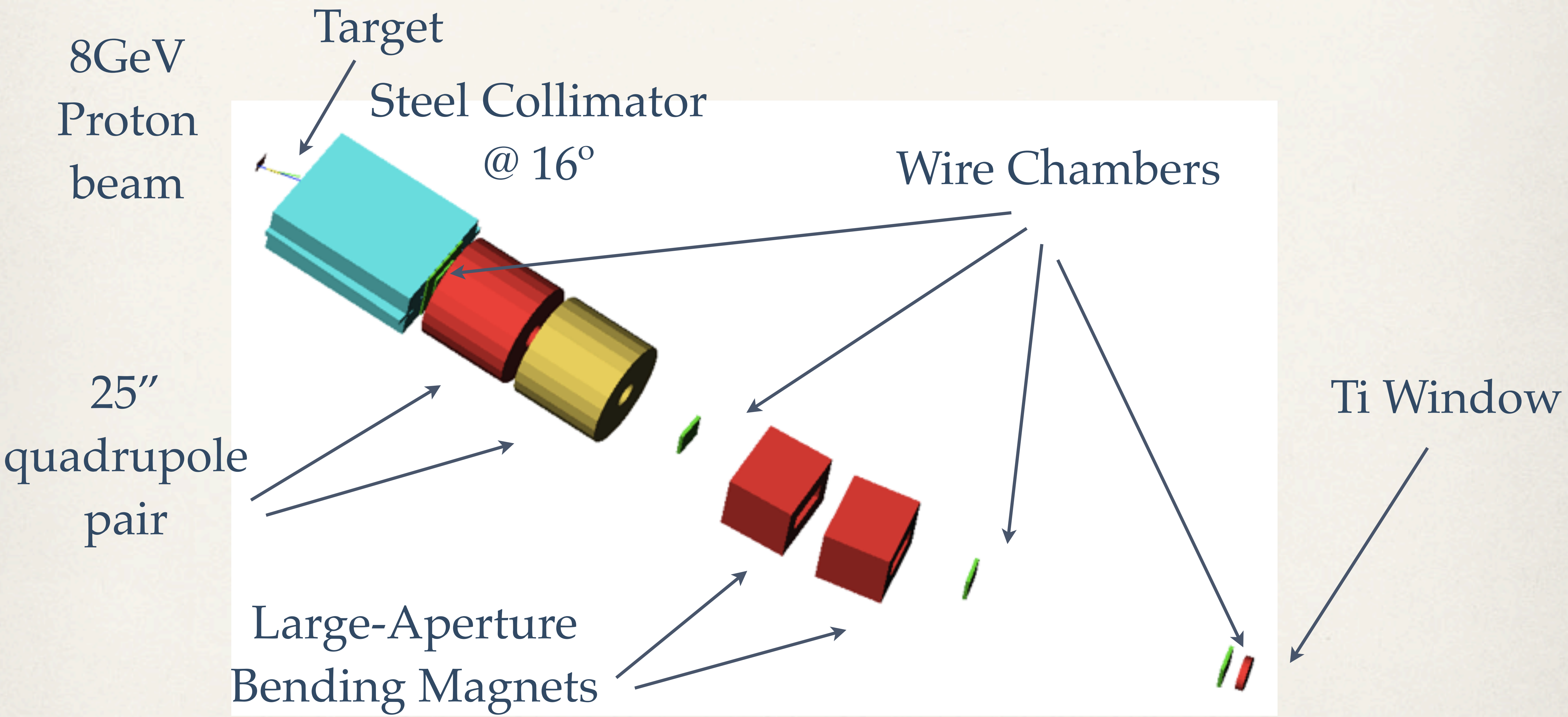
Recent Progress for Phase-1: From Beam to Data

- Beamline layout
- Triggering schemes
- Cryostat preparations
- PMT's and Light Yield
- Readout Electronics
- TPC simulation & Reconstruction

Beam Optics Layout



Beam Optics Layout



Testbeam Triggering

Poss. Inputs

Time of Flight

Cherenkov

Halo veto

PMTs

Punchthrough

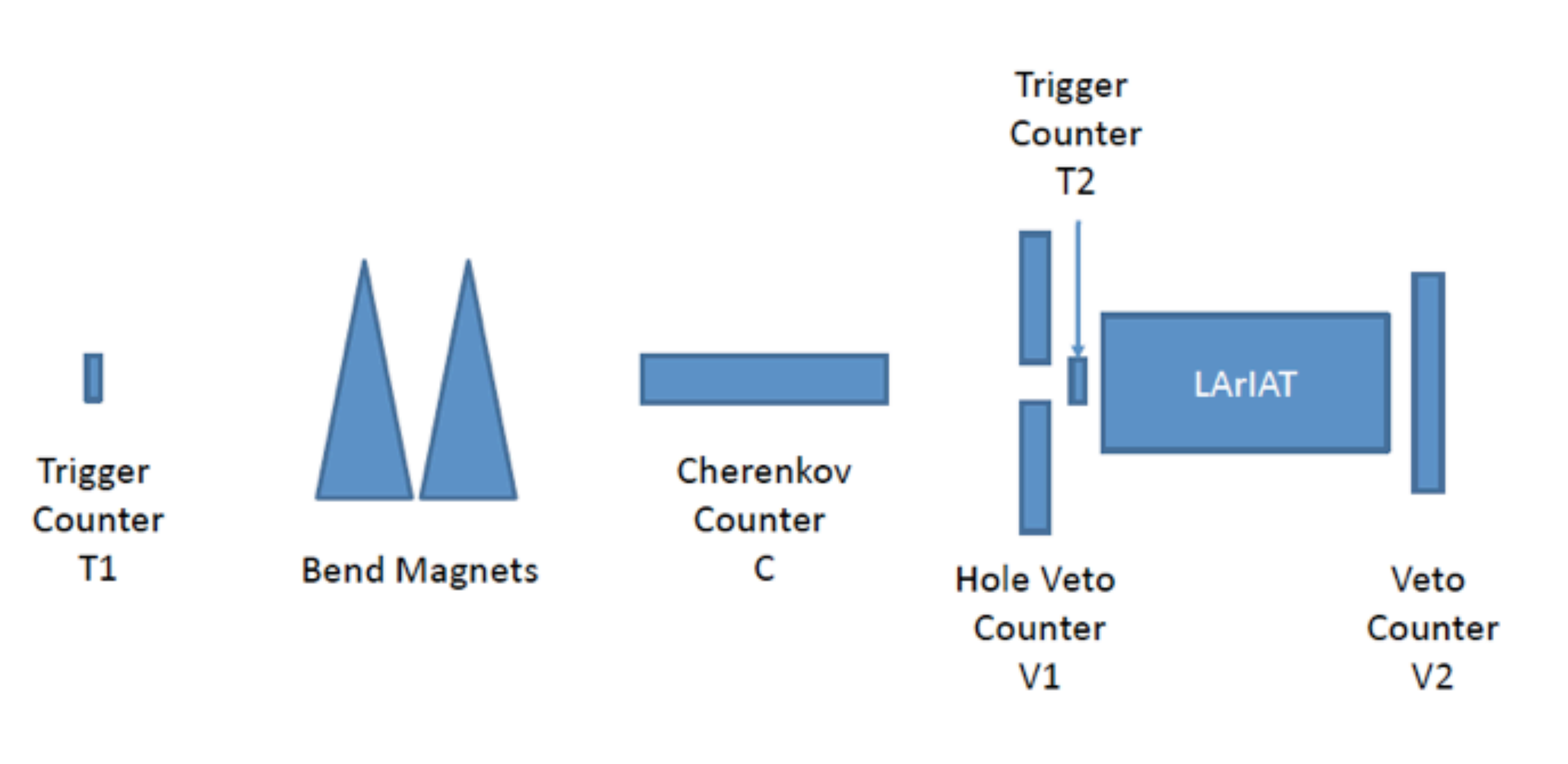
Beamspill

DAQ busy

...

Minerva Testbeam instrumentation and studying/preparing additional:

- Cherenkov electron-tagger
- momentum fit (wire chambers)



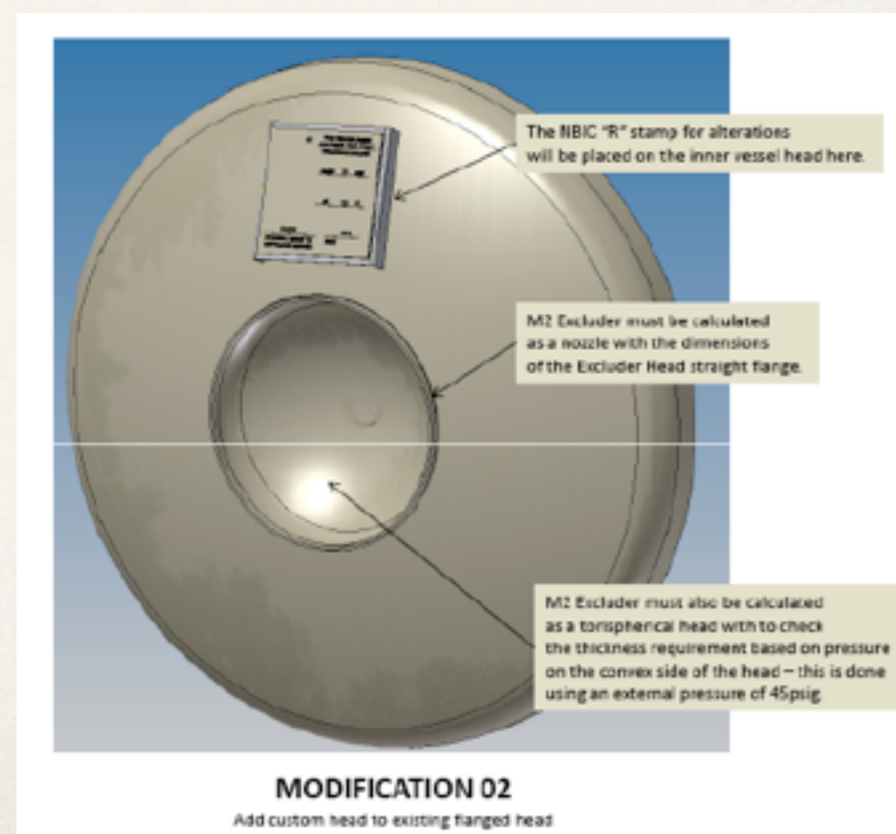
Cryostat Modifications

Work being done at PHPK

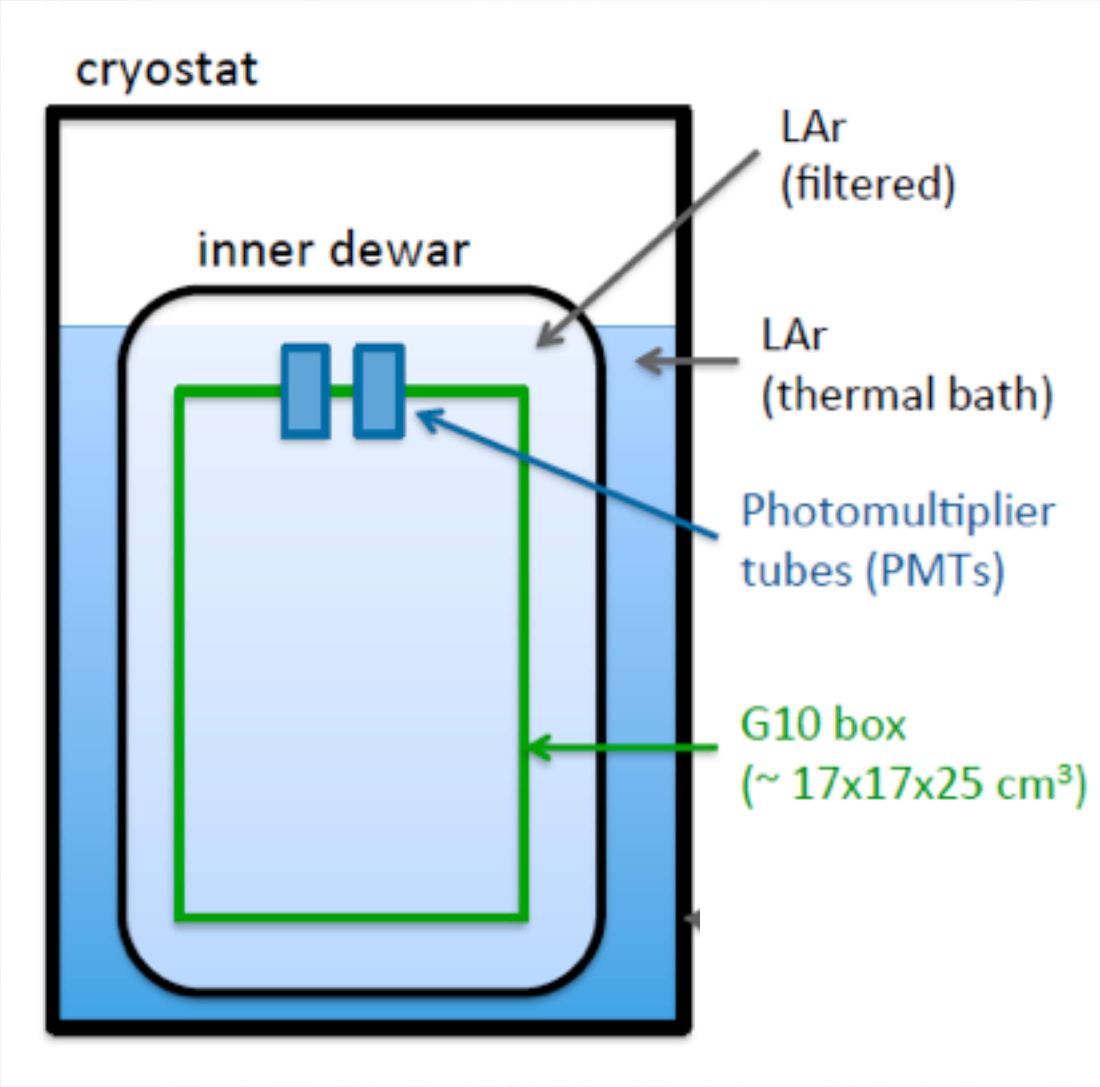
Drainage port: underside

LAr Excluder: upstream side

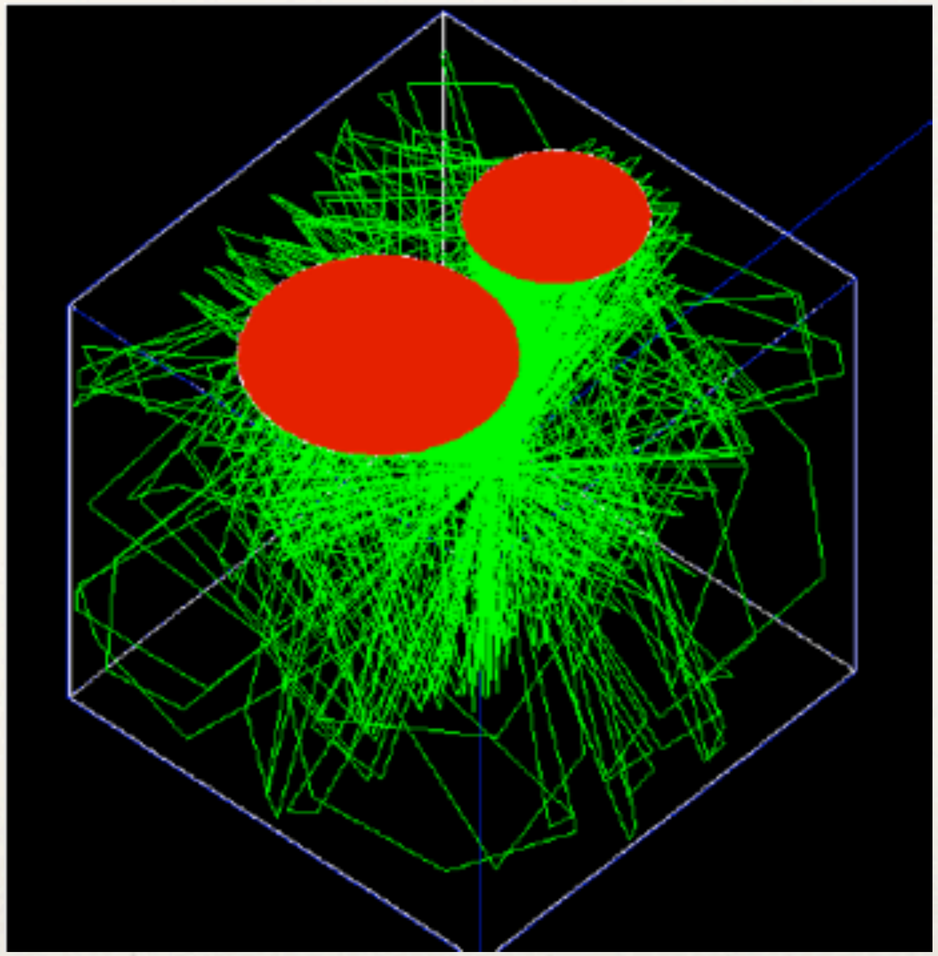
PMT feedthrough: side



Light Readout Tests



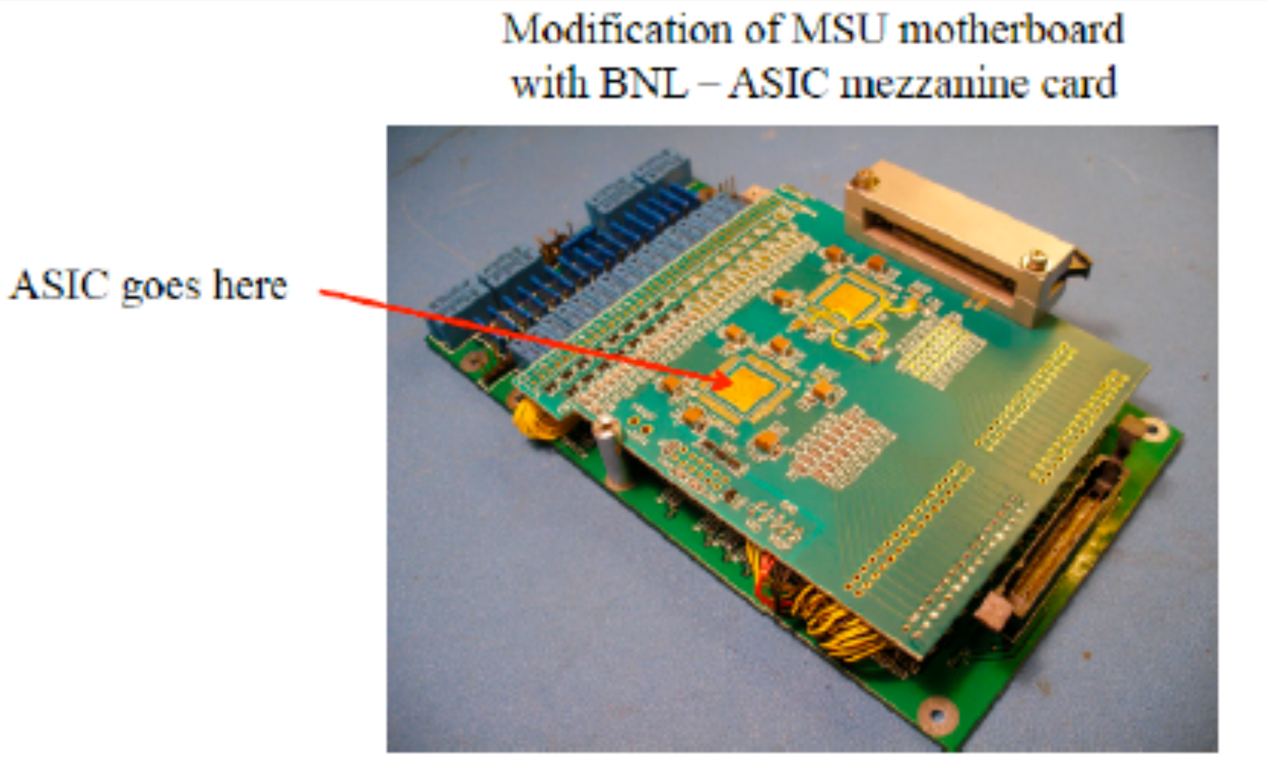
- Submerge-operation teststand
- PMT's delivered, working well
- Optical simulation



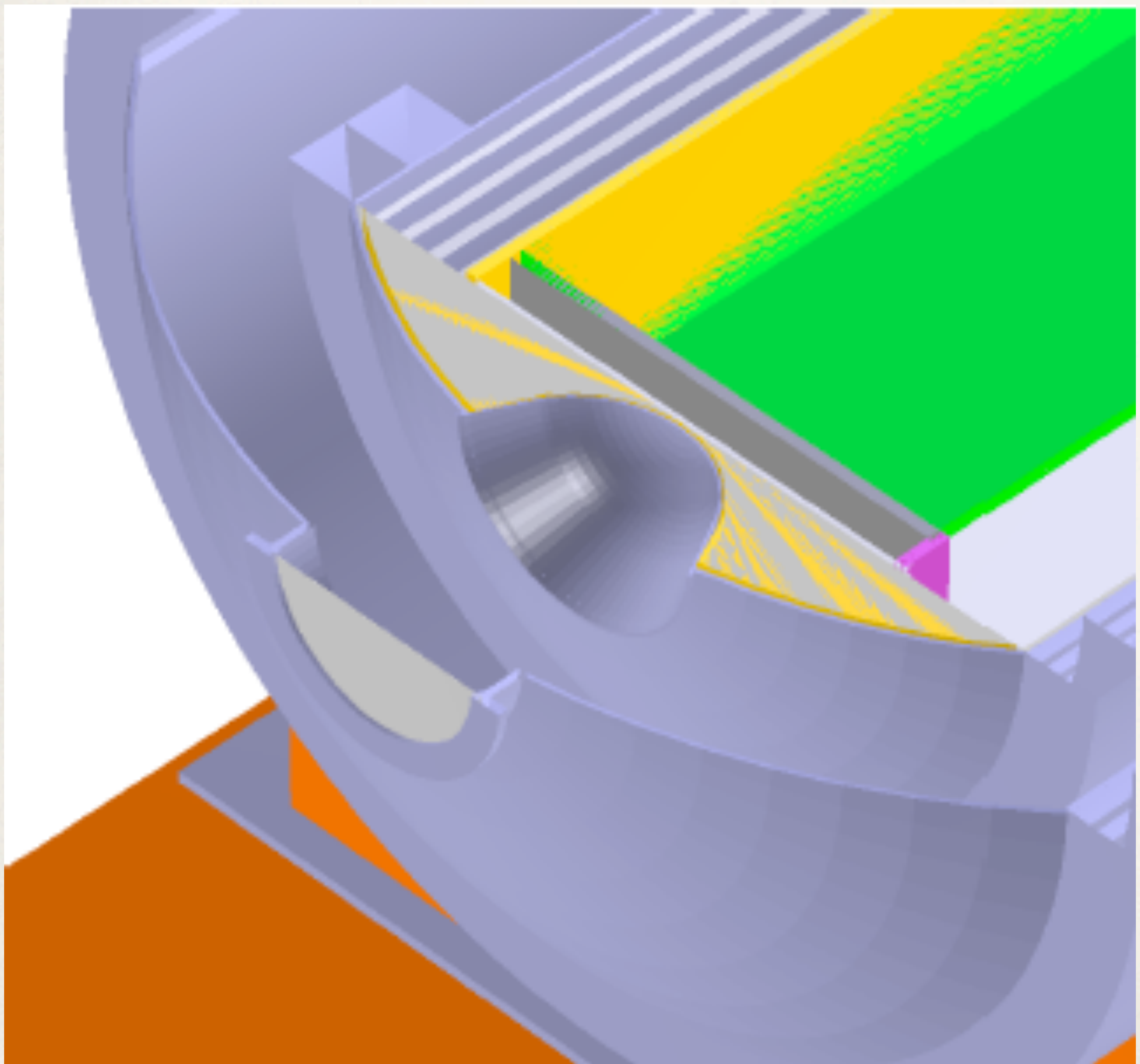
Readout Electronics

LArIAT can re-use Argoneut electronics:
Proven and ready

Improved signal/noise available with MicroBooNE cold electronics (as developed for Long Bo)   [Only funds are lacking]



Simulation & Reconstruction



Modified cryostat geometry now in Geant

⇒ Monte Carlo is Argoneut with this geometry change.

Summary

LArIAT scientific goals:

- Direct/experimental proof of e/γ separation in LArTPCs
- Detailed measurements of recombination factors
  p, K, π, μ PID and accurate calorimetry
- Direct measurement of energy resolutions
  for EM and hadronic showers
- Fine-tuning software for offline analysis

Phase-I effort is well underway

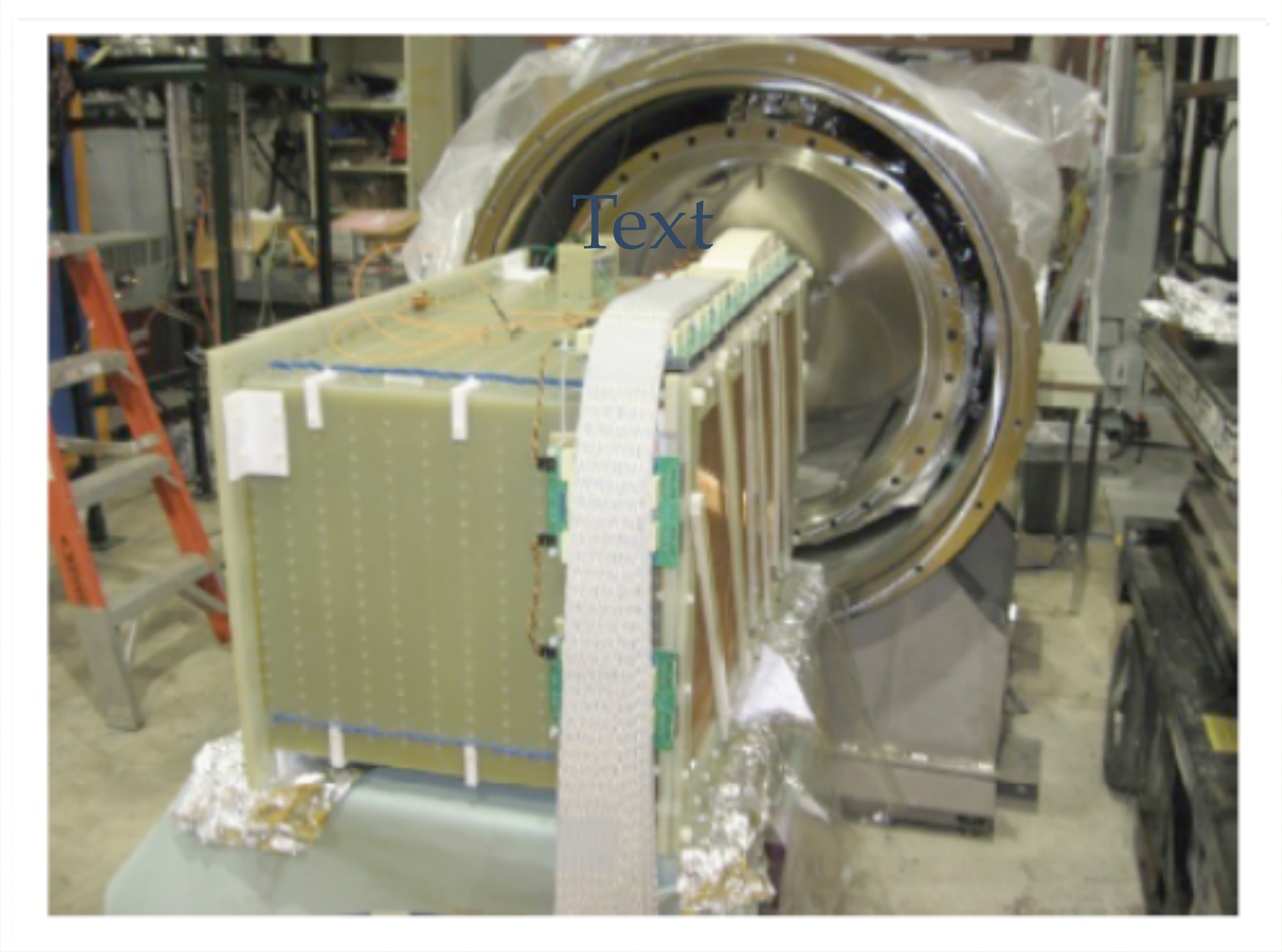
Working hard to be ready for beam startup (Summer 2013)

Phase-II simulation & planning has begun

Plenty of opportunities for new members to contribute!

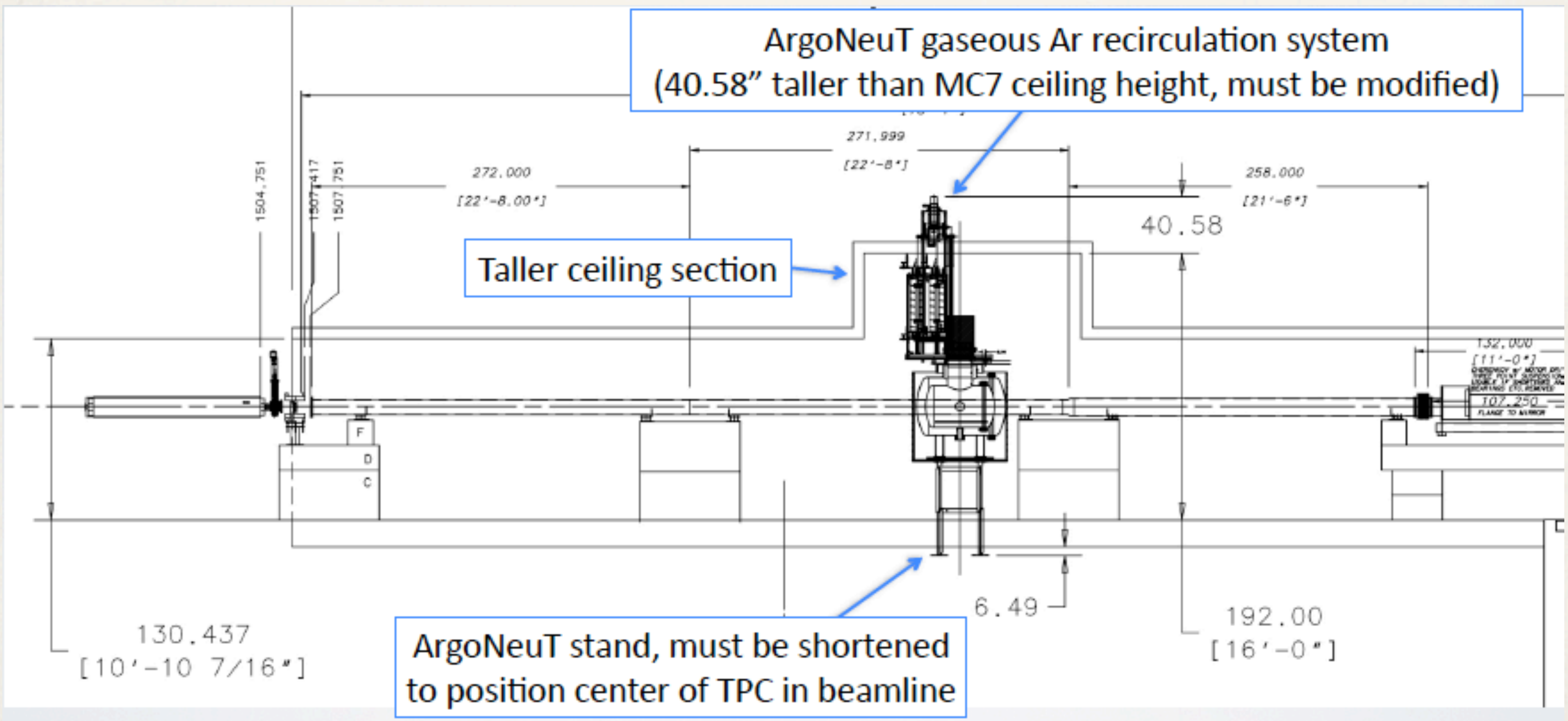
Thank You!

http://intensityfrontier.fnal.gov/lariat.html



Backup Material Follows

Argoneut at MC7



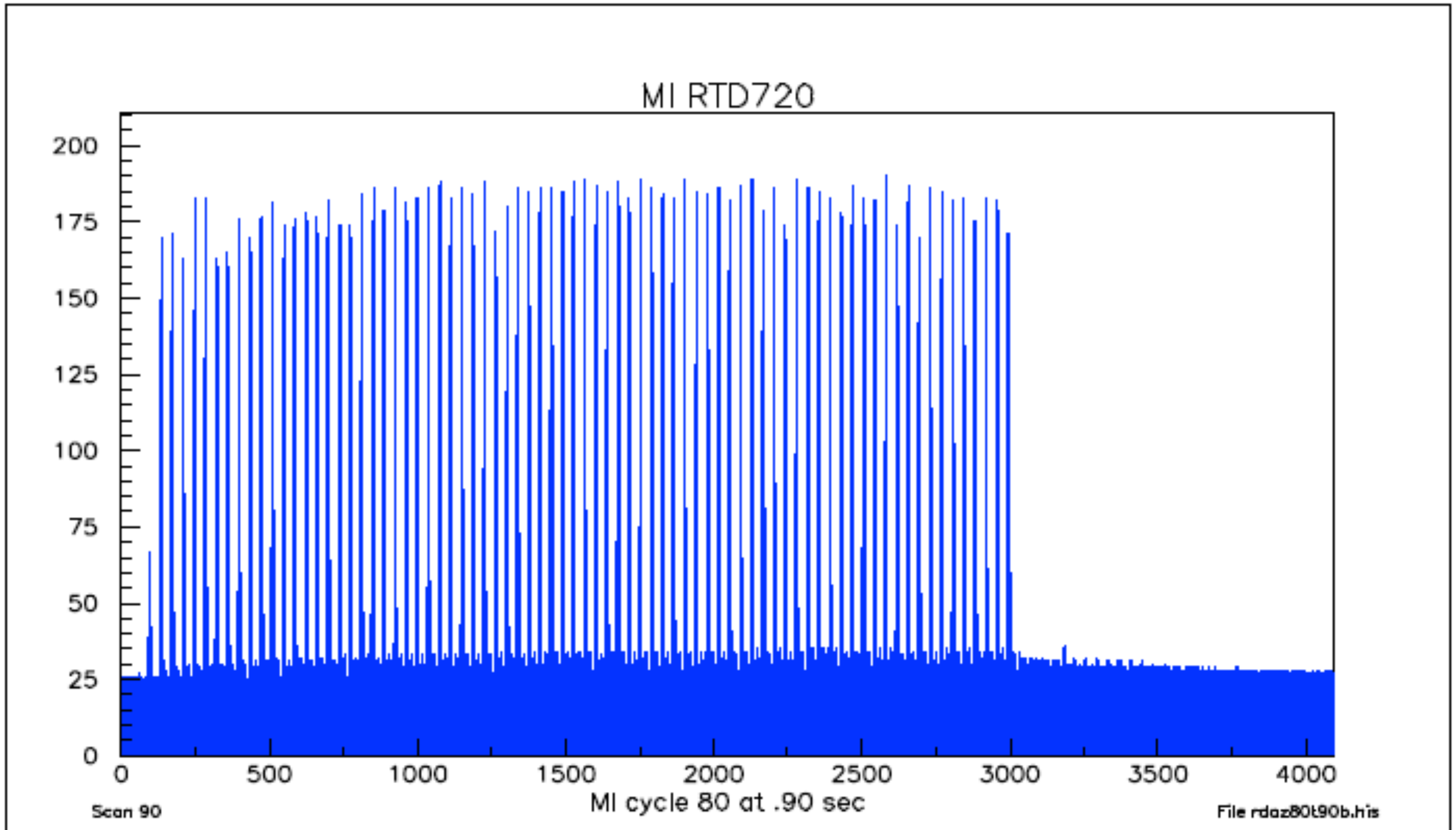
Target and Shielding

Cryogenics and LAr Purification

"Generic" purification system
under discussion/design now.
Plan to be reusable for Phase-II
(and any other future needs)

Detailed Beam Spill Structure

One Batch from the booster in the MI
data from the resistive wall monitor in the MI
this is a set of data during acceleration

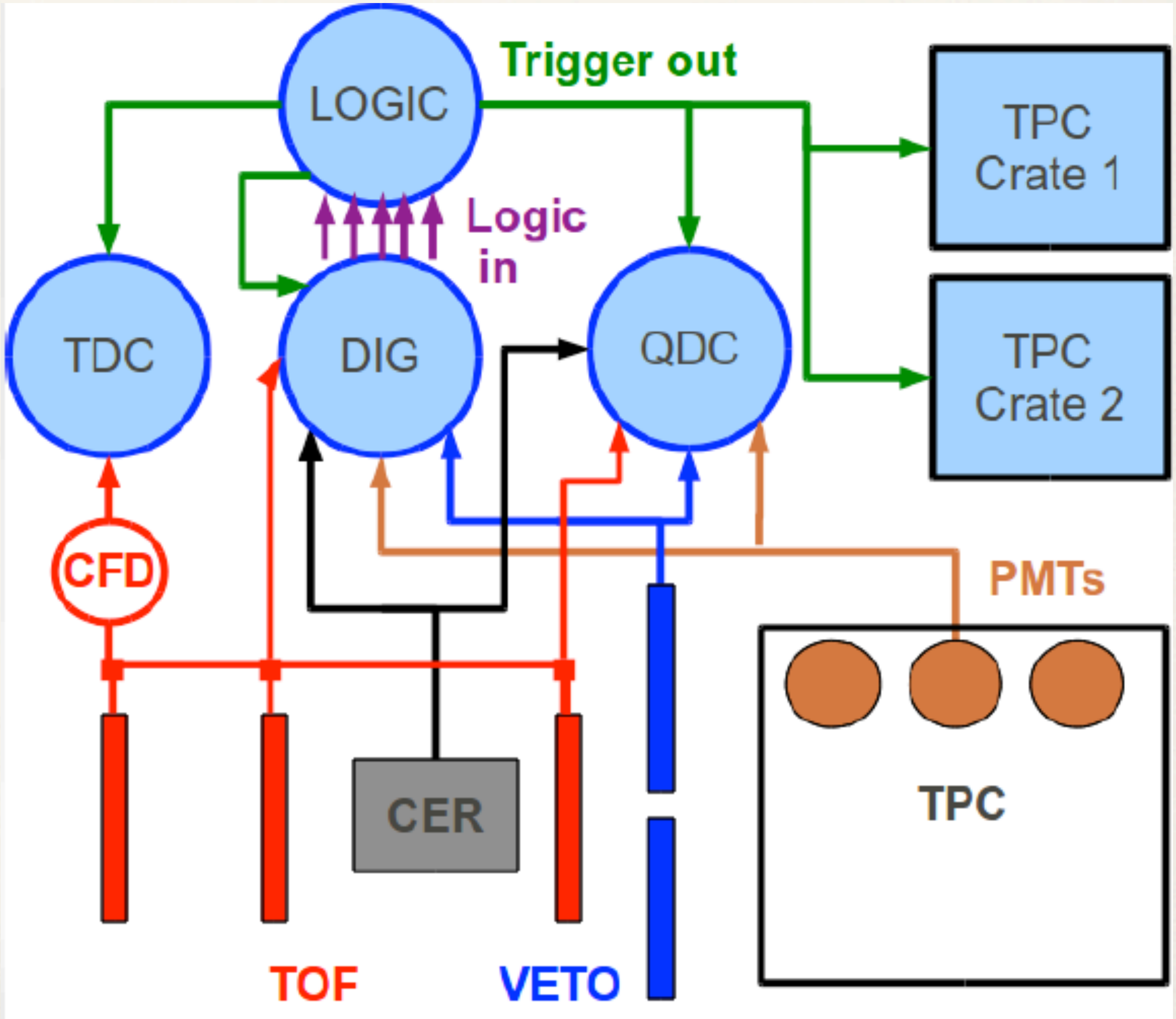


Testbeam Triggering Progress

Existing DAQ crate controllers already accommodate an input signal to trigger on the neutrino beam spill and/or internal PMT signals

Feed information from beam ToF counters, Cherenkov counters, PMTs in vessel, & veto counters into 12-bit digitizer.

Digitizer will discriminate signals by pulse shape, then send fast logic pulses to FPGA-equipped logic module to test for one or more trigger conditions & enable FEM readout



Testbeam Triggering Progress

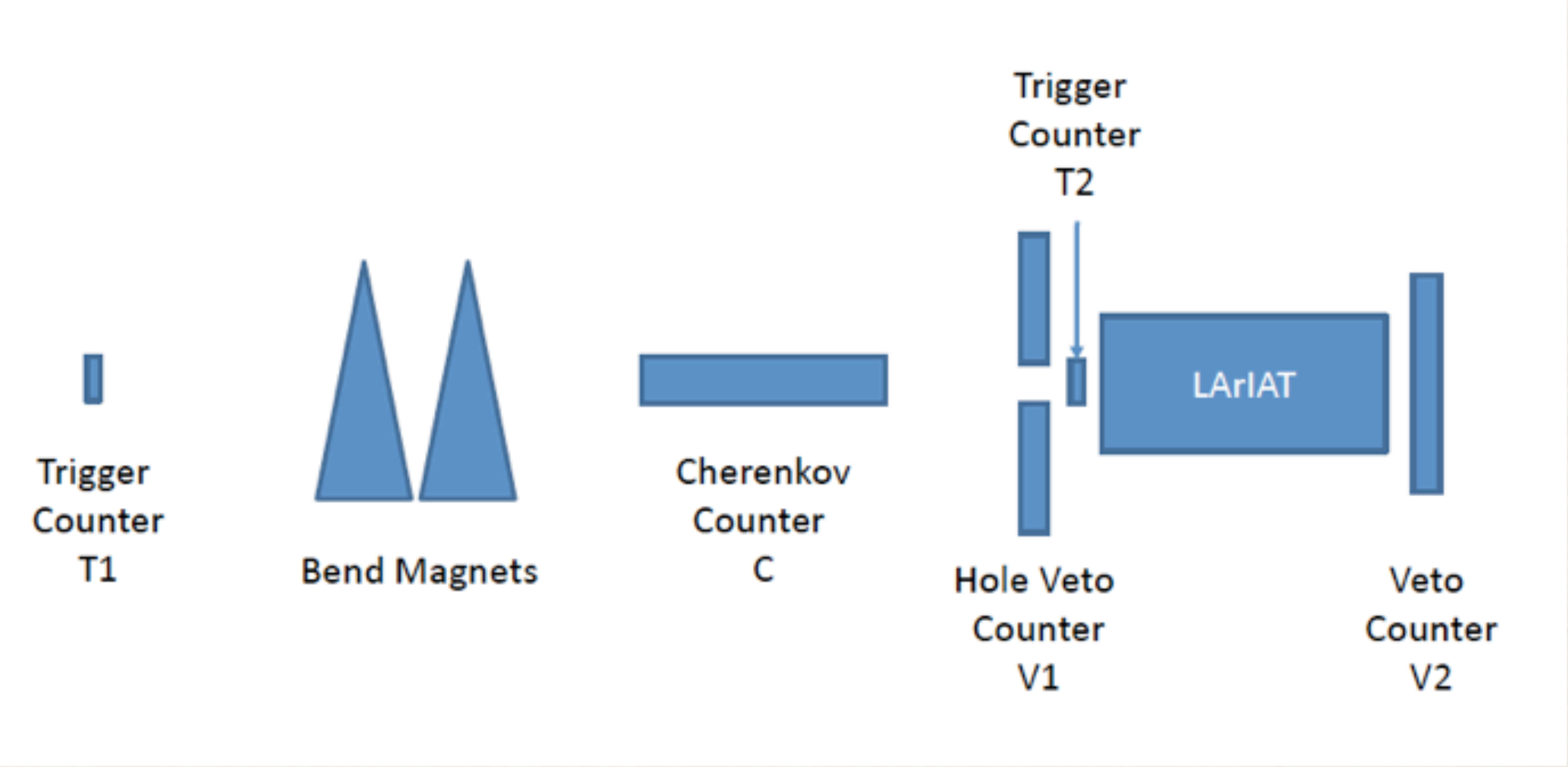
Time of Flight

Cherenkov

Halo veto

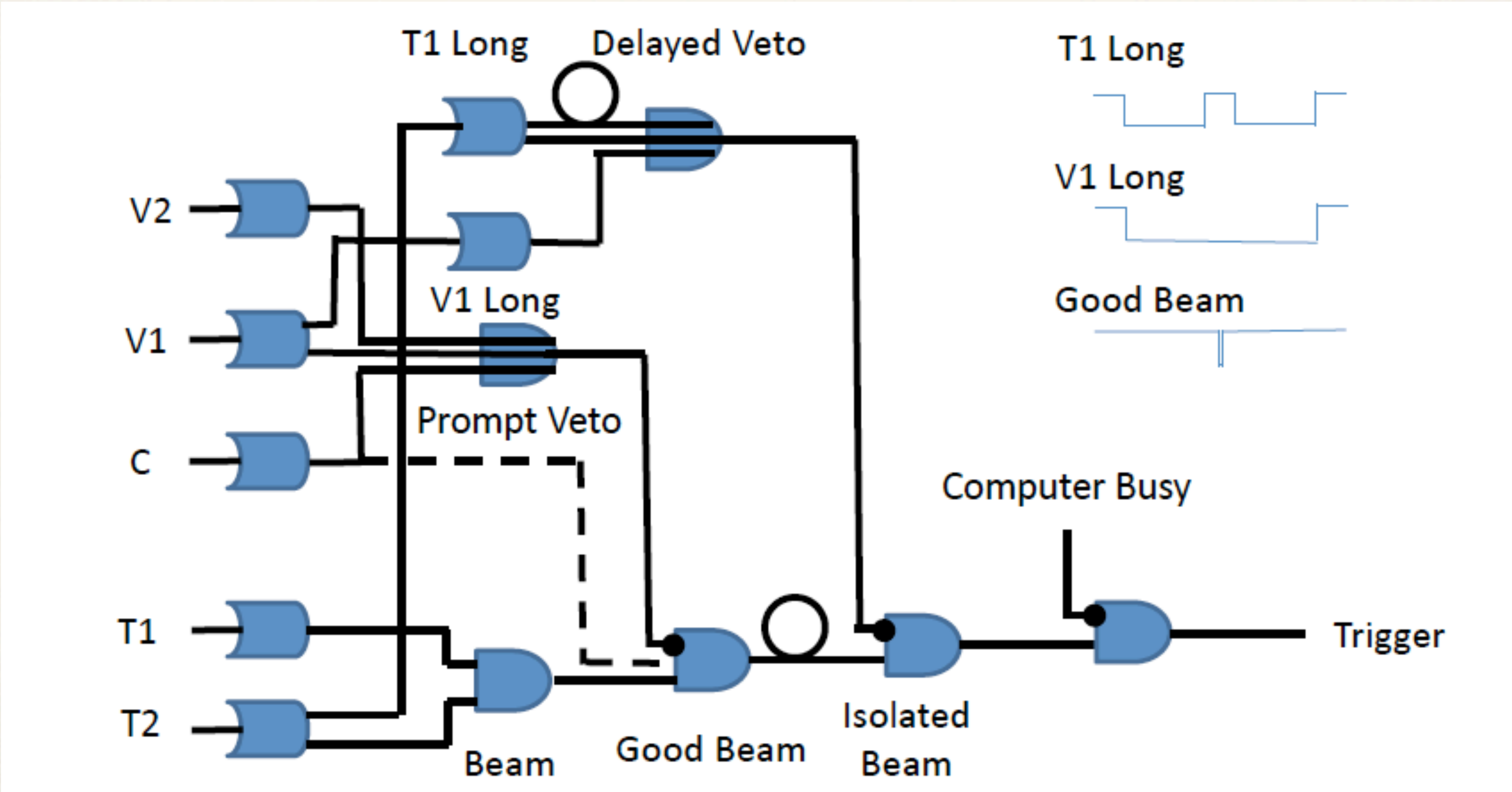
PMTs

Punchthrough

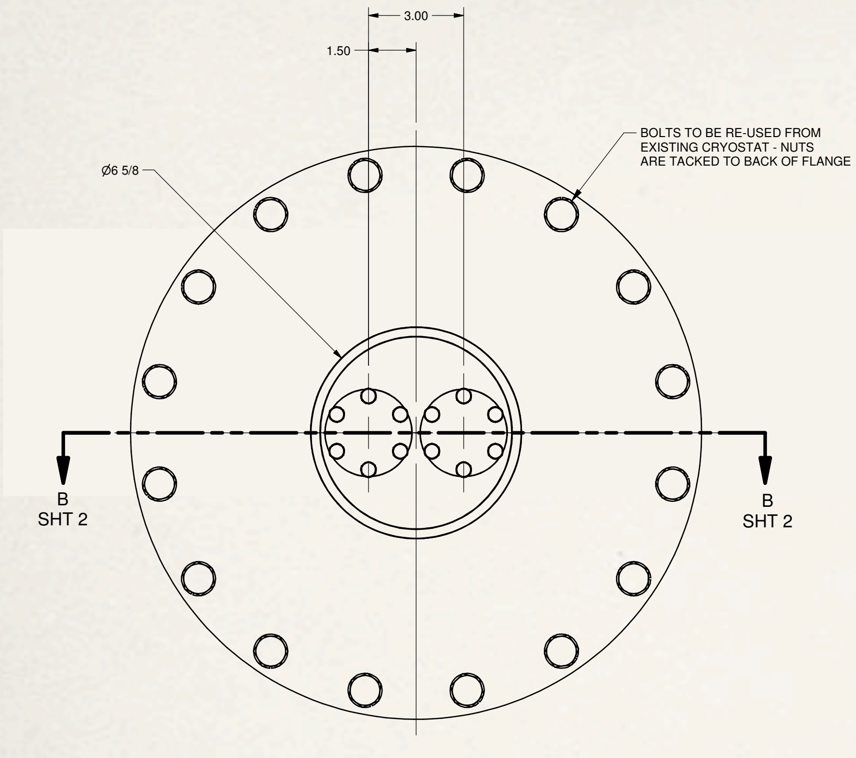


Testbeam Triggering Progress

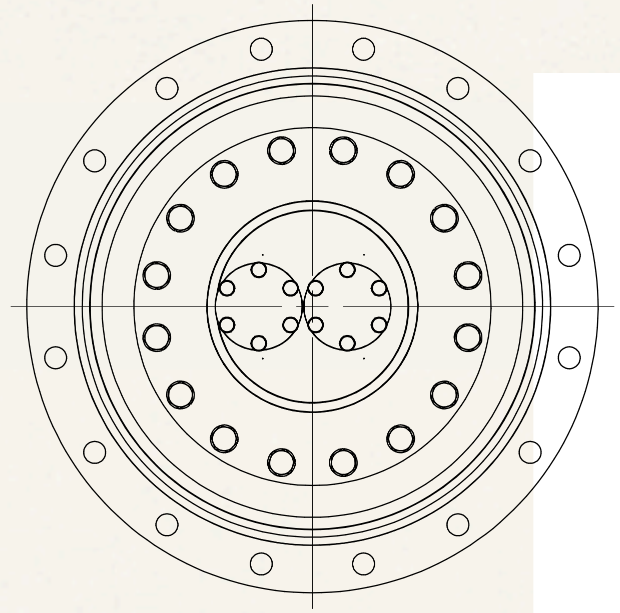
Beamspill, pileup, busy signal



Mod for Scintillation Light Collection

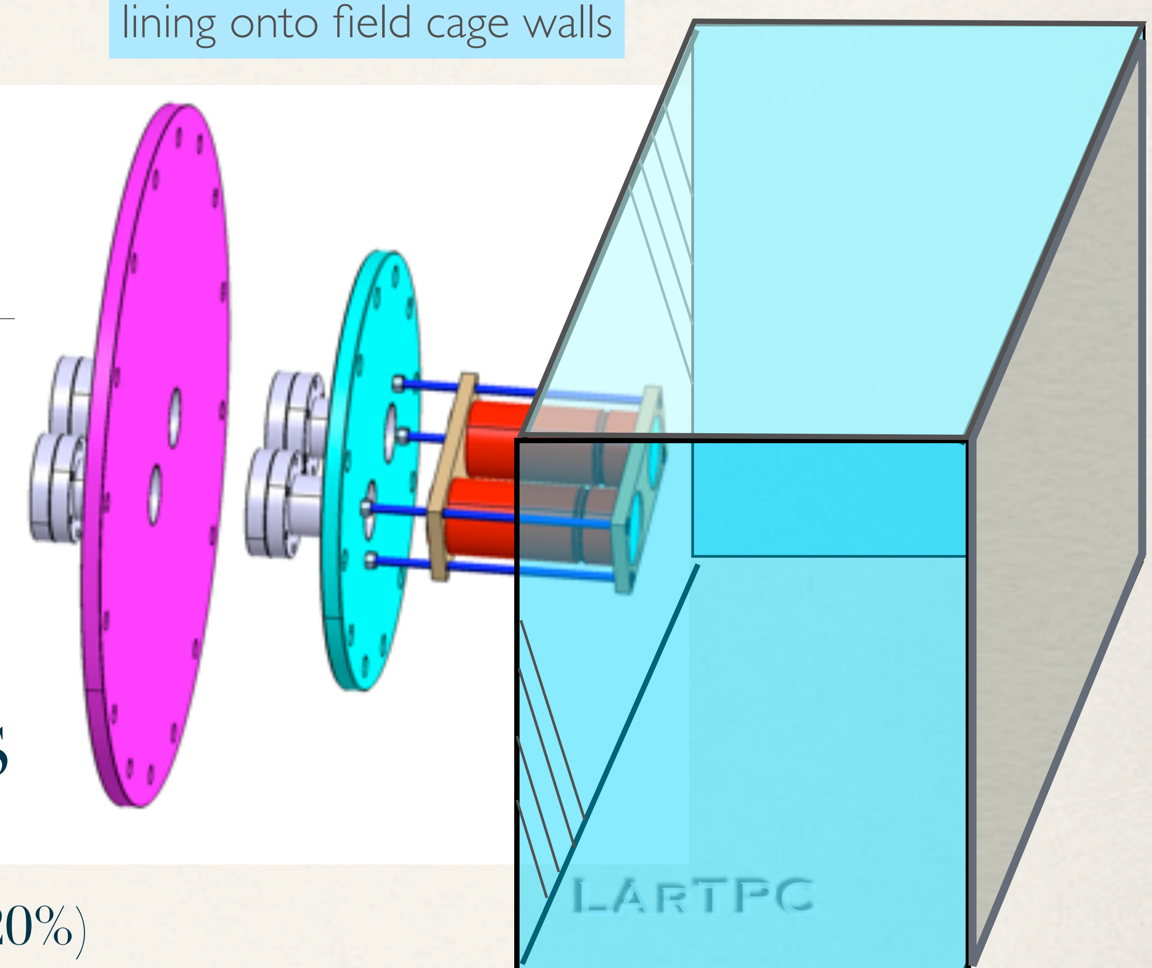


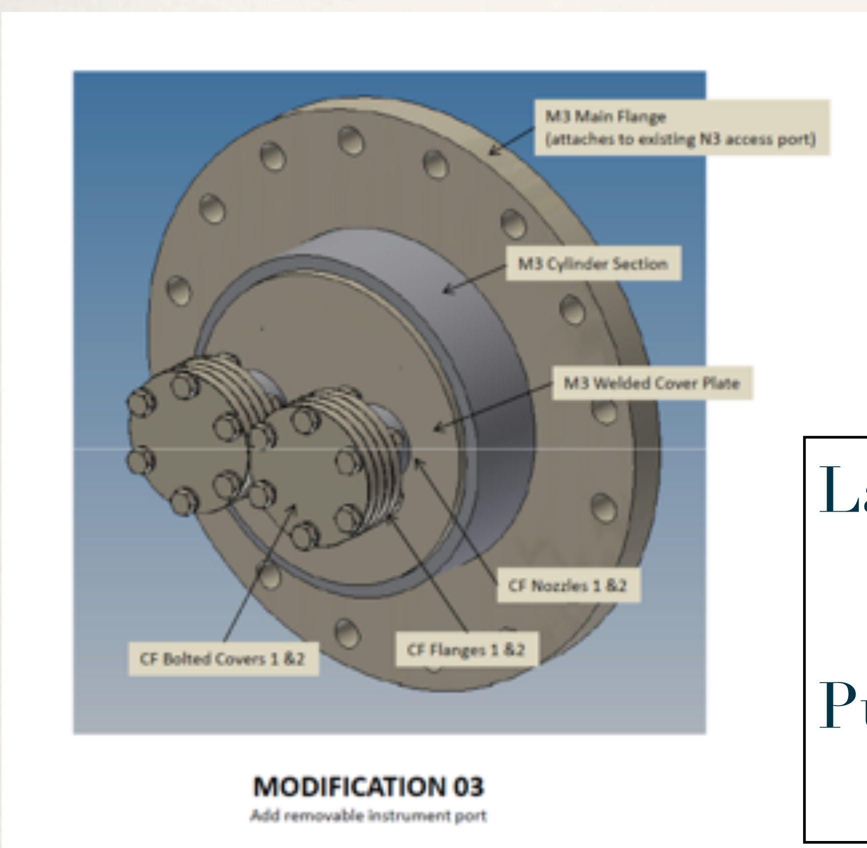
SCINTILLATION CONNECTION PORT - OUTER FLANGE VIEW



SCINTILLATION CONNECTION PORT - INNER FLANGE VIEW

Reflector foil, TPB coated lining onto field cage walls





2 cryogenic PMTS

- one 3" high QE (30%)
- one 2" standard QE (20%)

+ WLS reflector foil lining TPC

CAEN digitizer readout

Large light signal due to reflector foil

Precise calorimetry (although poor position resolution)

Pulse shape discrim of minimum- vs. highly-ionizing particles

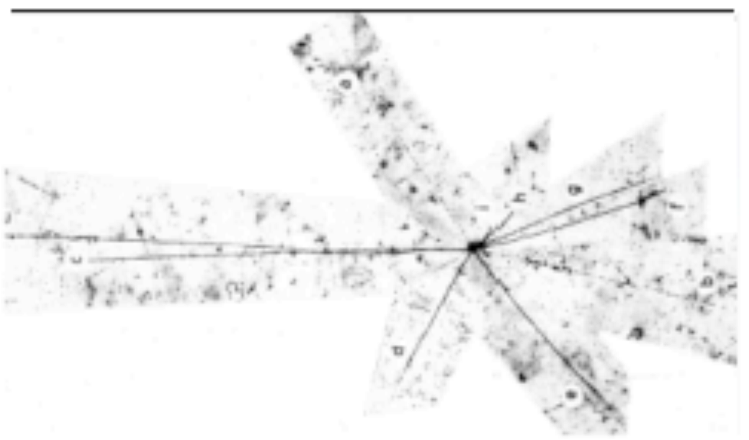
This feature has never been explored with LAr ν detectors

... if available in the test beams... even at very low rate....

low momentum anti_p may allow the first study of hadron star topology from anti_p-p annihilation at rest in Argon (anti-p-Ar reaction).

➤ Characterization of Antiproton Stars in Ar

$\pi^{\pm}$, π^{0}, $K^{\pm}$,... multiplicity in hadron stars can be accurately determined with LAr imaging detector. This information is considered very relevant for ***nnbar-oscillation search*** with future large LArTPC detectors.



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*

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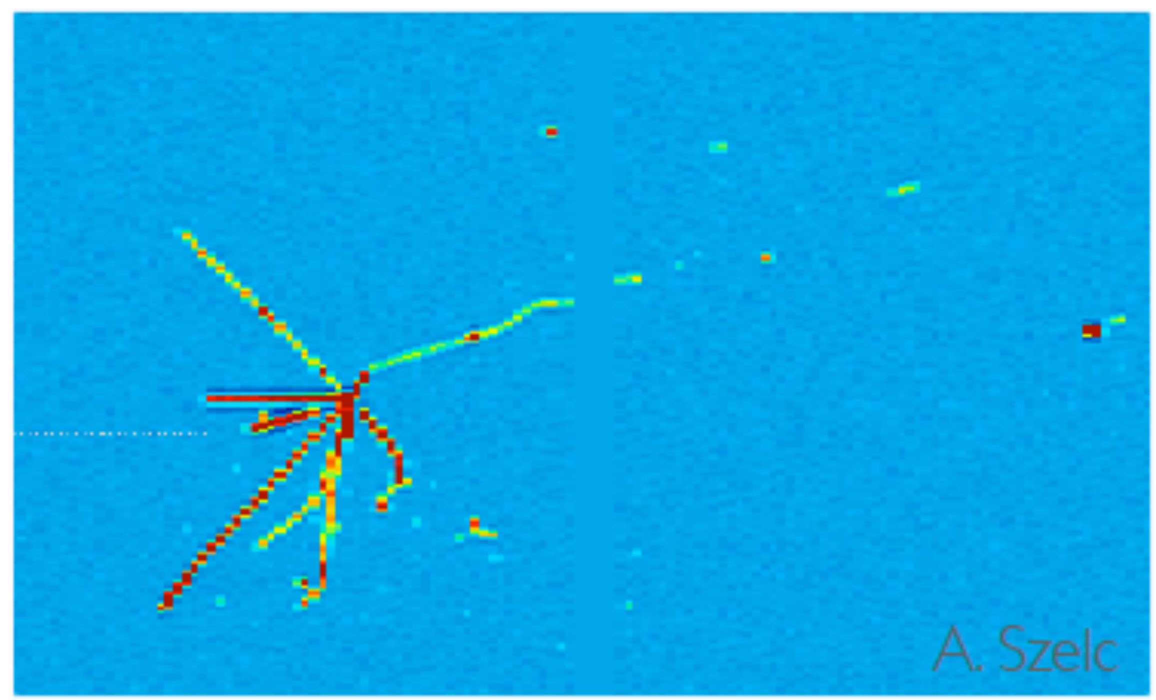

Simulation of Antiproton Star in LAr