LArIAT:
a TPC to calibrate TPCs
(and much more...)

Roberto Acciarri – FNAL
on behalf of LArIAT collaboration

LAr TPC R&D Workshop – Fermi National Accelerator Laboratory – 08-09 July 2014

Liquid Argon TPC In A Testbeam

Setting up a long-term test facility to calibrate and test LArTPCs and their components using a beam of charged particles

PHASE I

Reuse the ArgoNeuT detector with small modification for:

- *Visible energy calibration*
- *Optimization of particle ID (PID) methods*
- *Experimental determination of e / γ separation*
- *Development of criteria for charge sign determination*
- *Kaon reconstruction*

PHASE II

Build a larger TPC for:

- *Characterization of EM and hadronic showers*
- *Realization of a test station for LAr detector subsystems under development for future use (cold electronics, new wire plane designs, study longer drift distances…)*

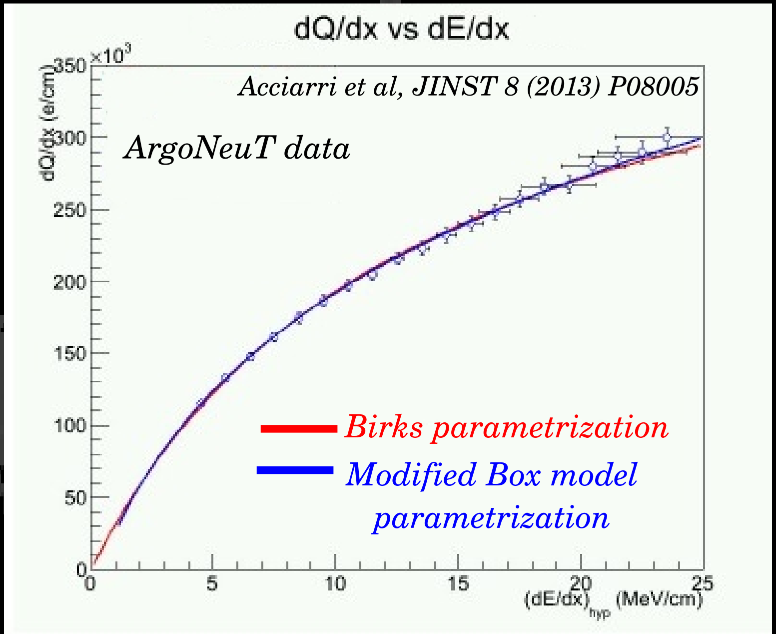
A unique cryogenic/purification facility designed to operate for both phases and to allow future tests of LAr detectors

Visible Energy Calibration

Precisely determine the electron recombination parameters by studying the dQ/dx of single stopping tracks of known energy

WHY?

- *ArgoNeuT data agree with standard parametrization over a large range of dE/dx but rely on protons/deuterons only*
- *Recombination parameters estimated using secondary particle whose nature is established by the parametrization itself*
- *Provide to LAr TPC experiments a verification of the Birks parametrization in a large range of dE/dx for different types of particles*



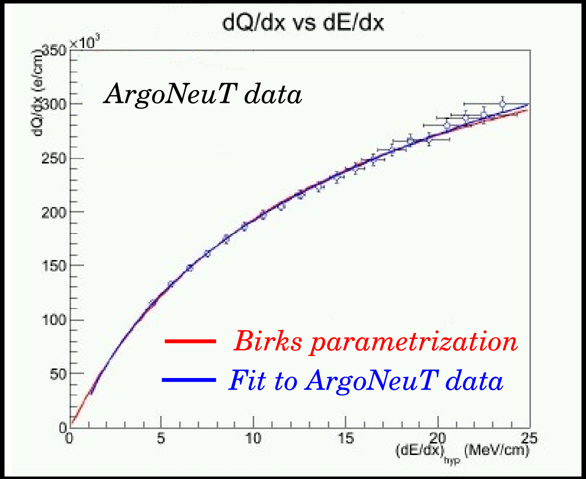
HOW?

Determination of ionization charge collected at TPC wires vs energy deposited in LAr for:

- *Different types of stopping particles (E=0.25-1 GeV - large dE/dx range)*
- *Different E fields (~0.3-1.0 kV/cm)*

PID Methods Optimization

e⁻ recomb. param. in LAr



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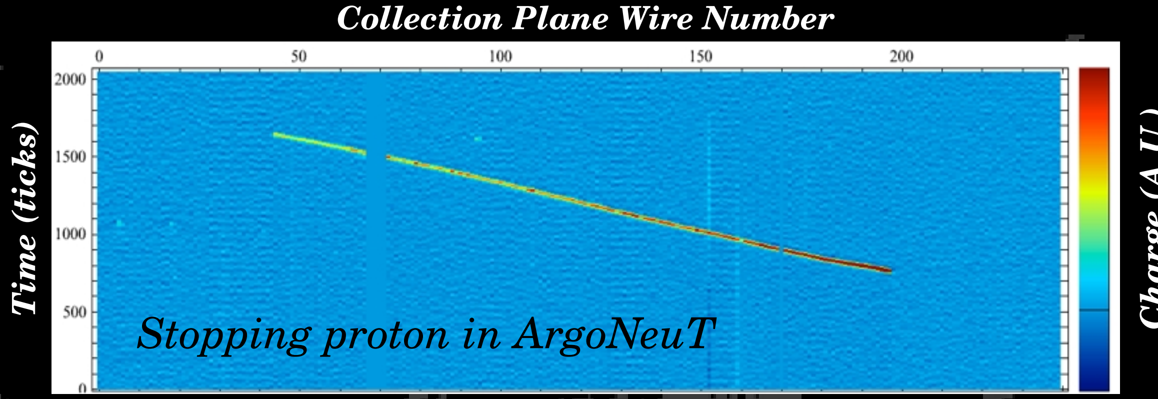
Full 3D imaging



dE/dx vs. Residual Range: Particle Identification

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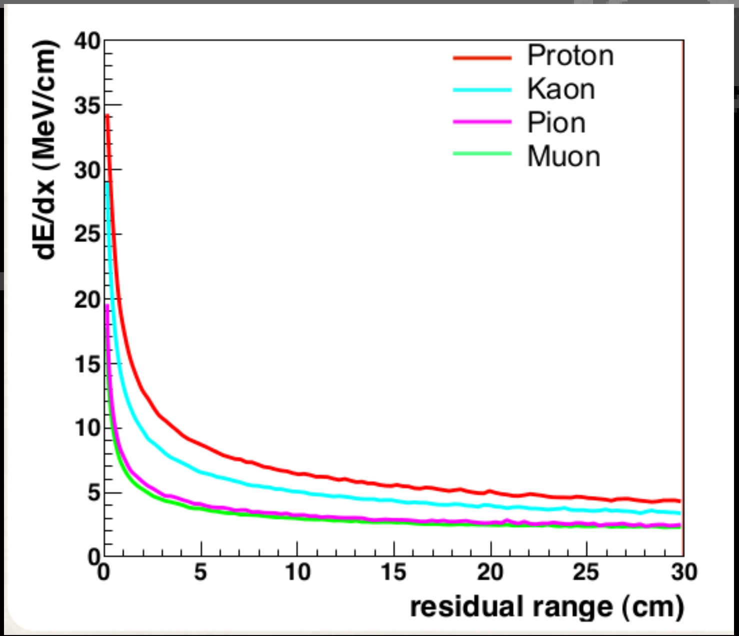


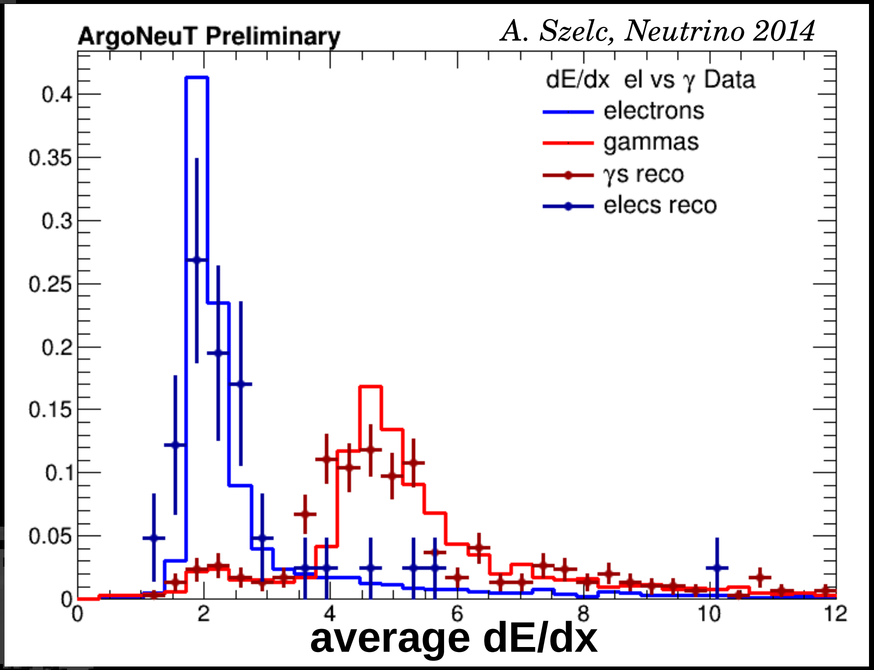
High-statistics test beam data will allow experimental determination of:

- *Proton ID*
- *Kaon ID*
- *P/K separation and purity/rejection factor*
- *K/π/μ separation and purity/rejection factor*

Electron/Gamma Shower Separation

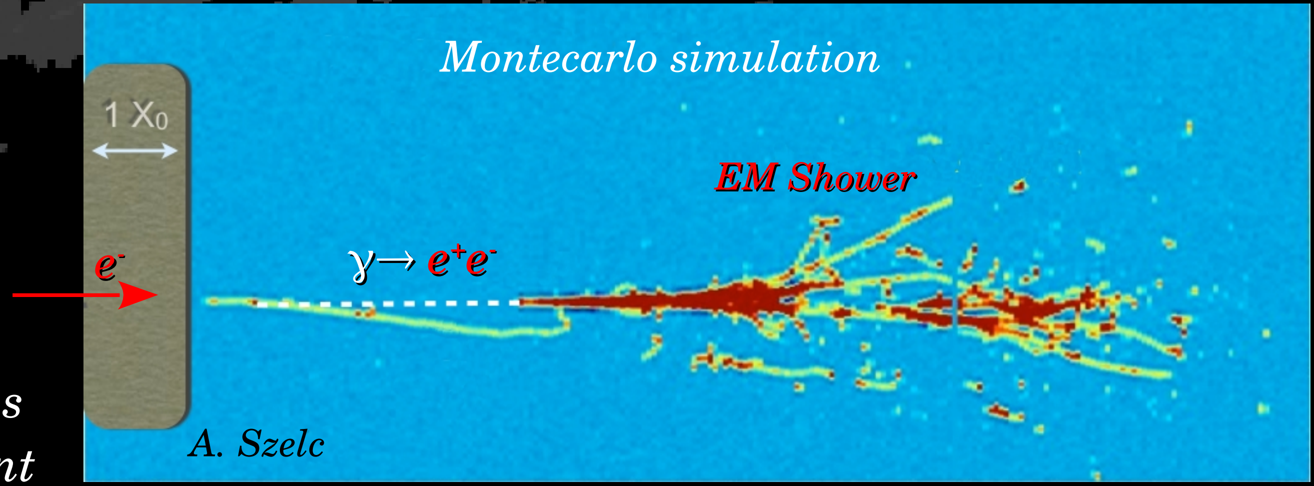
WHY?

- Crucial for discriminating ν_e CC signal from π_0 background coming from NC interactions
- e^-/γ shower separation efficiency and sample purity not yet experimentally measured
- Recently (Neutrino 2014) ArgoNeuT showed the feasibility of such study in LAr



HOW?

- Electrons found in the beam
- Photons generated via brehmsstrahlung in 1 X_0 pre-shower disk.
- Only initial part of the shower is relevant – no need of containment



Muon Sign Determination

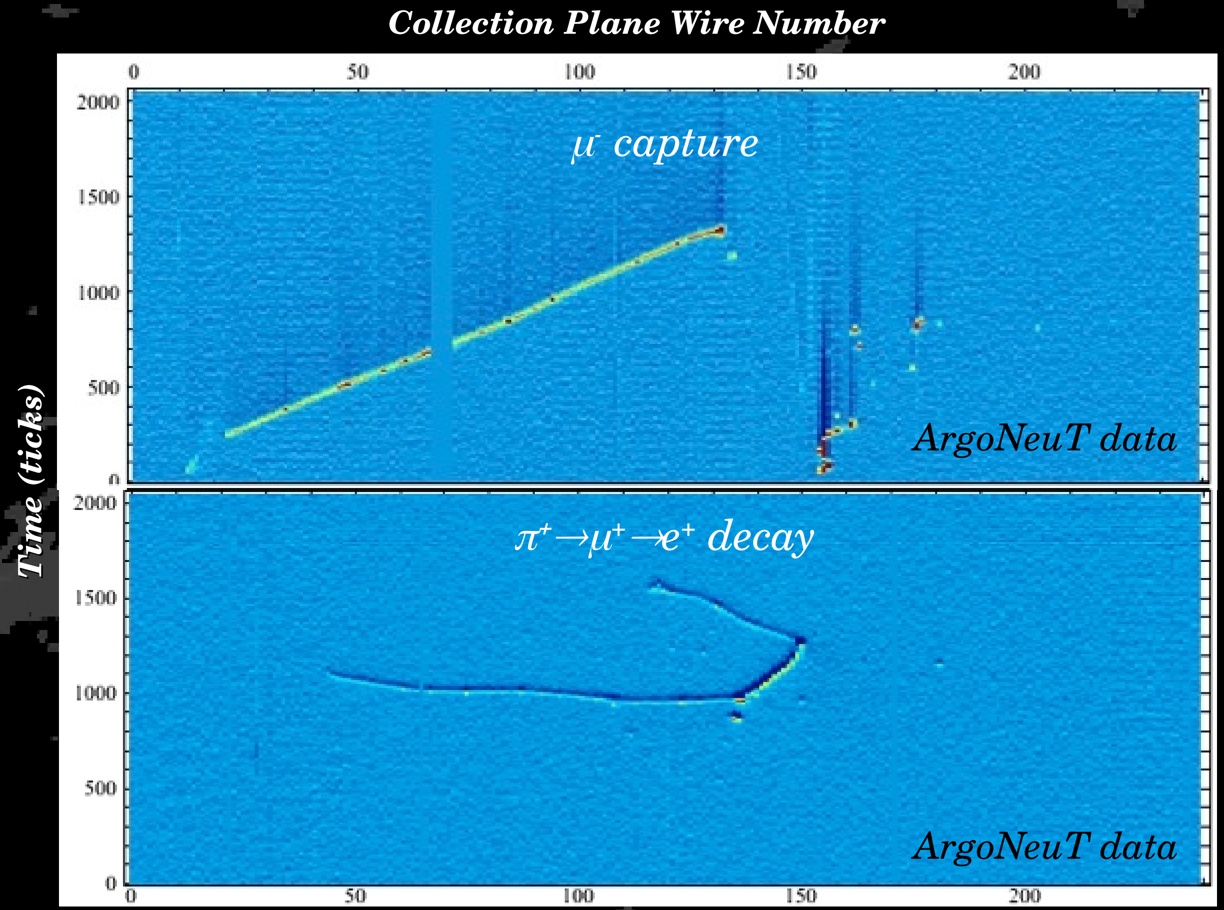
Systematic study of capture in Ar and sign-selection capabilities in LArTPC

WHY?

- ν_μ/ν_μbar discrimination in non-magnetized LarTPC

HOW?

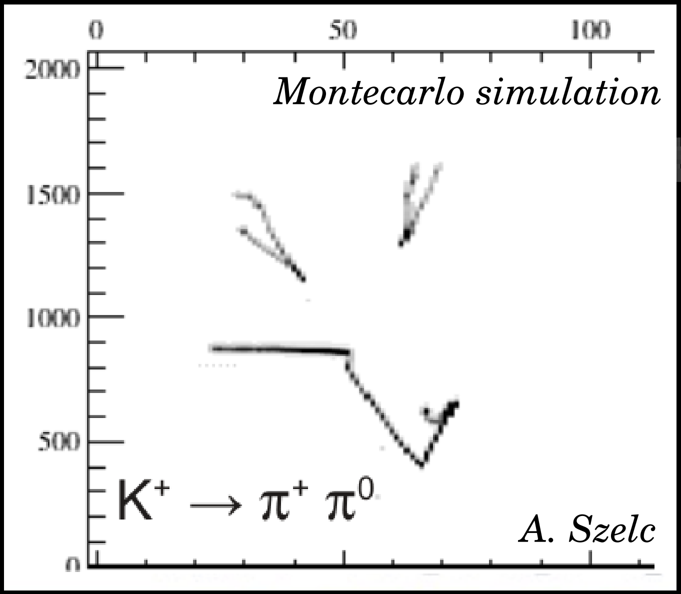
- μ^- undergo both capture on nuclei (76%) and decay (24%)
- μ^+ undergo decay (100%)
- Topological differences can allow for sign determination in absence of magnetic field on a statistical basis



LArIAT will be the first exploring this possibility in a systematic way!

Kaon Reconstruction

Kaon reconstruction and systematic study of decay topologies

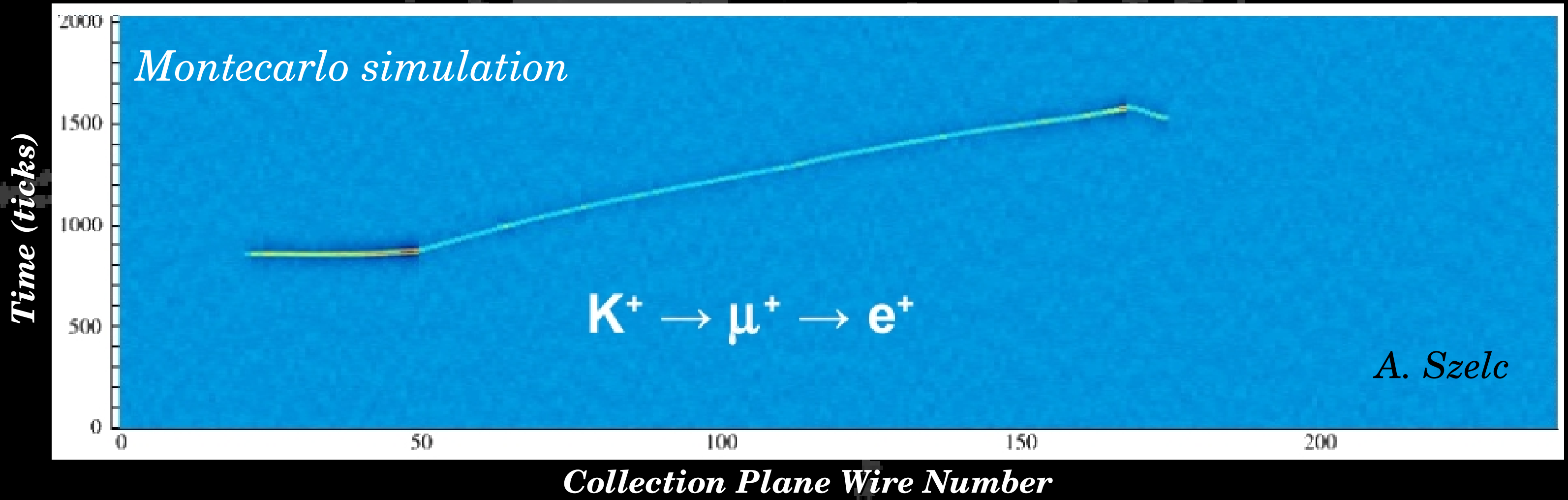


WHY?

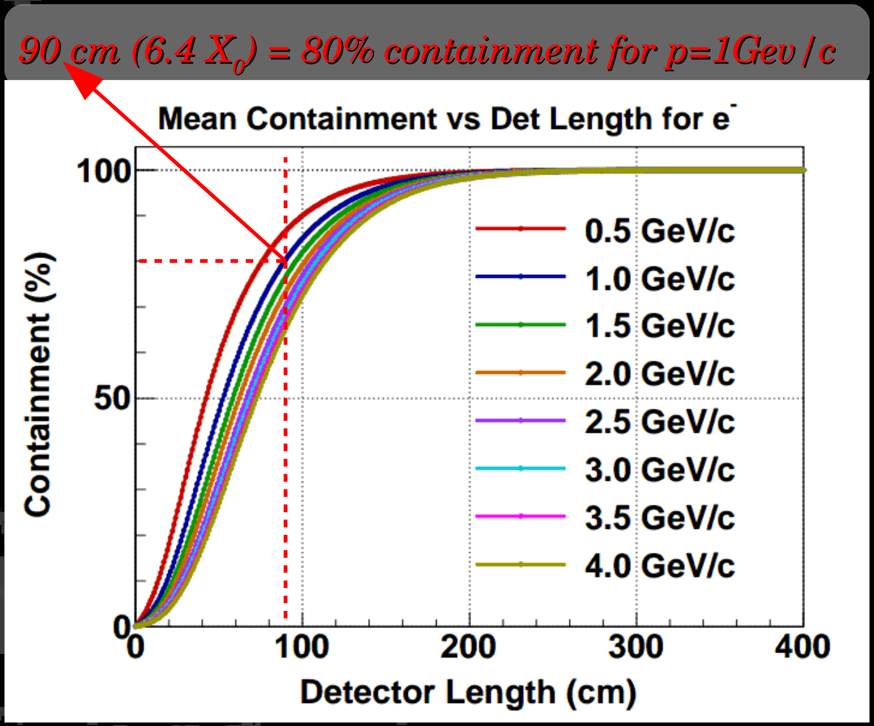
- *Never performed in LAr in a systematic way*
- *Will provide insight into possible proton decay topologies*

HOW?

- *dE/dx vs. residual range allows K/P discrimination*
- *TOF detectors provides K sample and allows test of dE/dx vs. residual range discrimination power*



EM/Hadronic Showers Characterization



EM showers:

- *Energy deposition mechanisms very well understood and reliable MC simulation*
- *~30% deposited energy goes into soft electrons (< 2 MeV)*

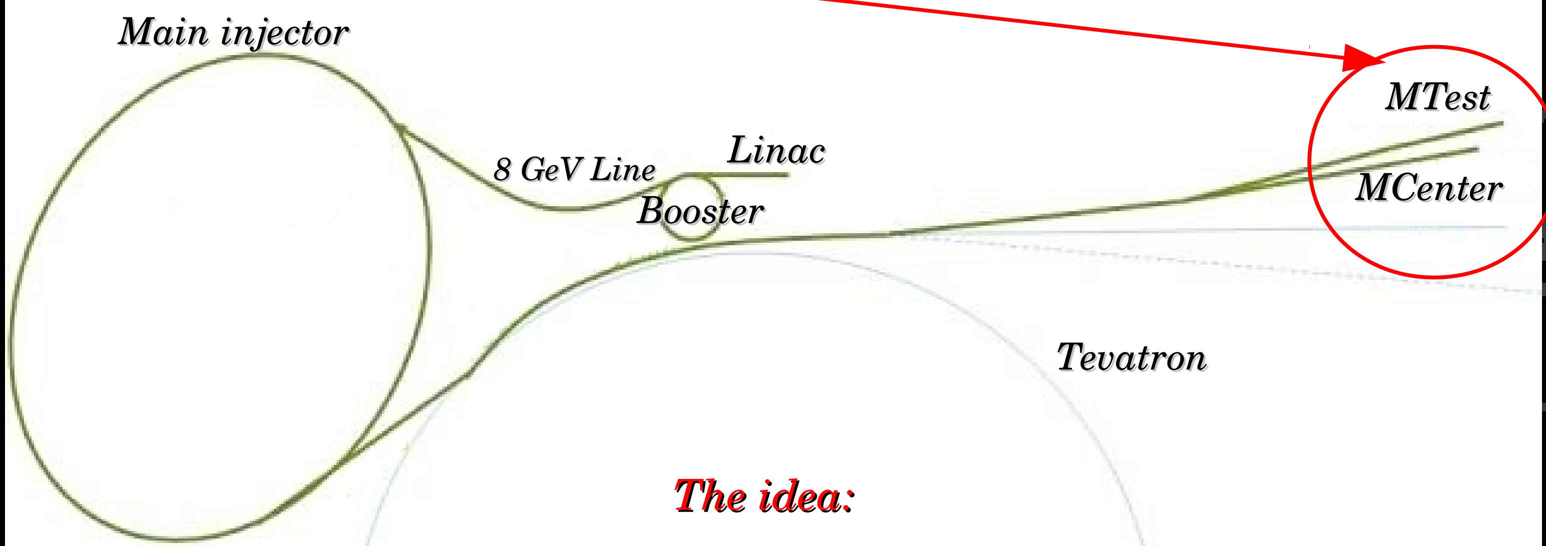
Phase I detector size allows for a first study of energy reconstructed vs. total energy deposited

Hadronic showers:

- *Hard to contain (develop on $\lambda_{int} \simeq 5\, X_0$)*
- *More complicated energy deposition mechanism: energy goes into EM (E dependent), soft neutrons (≃10%) and an undetectable not-well-known fraction*

Characterization of hadronic showers possible with a larger phase 2 detector

Where Everything Happens:
Fermilab Test Beam Facility



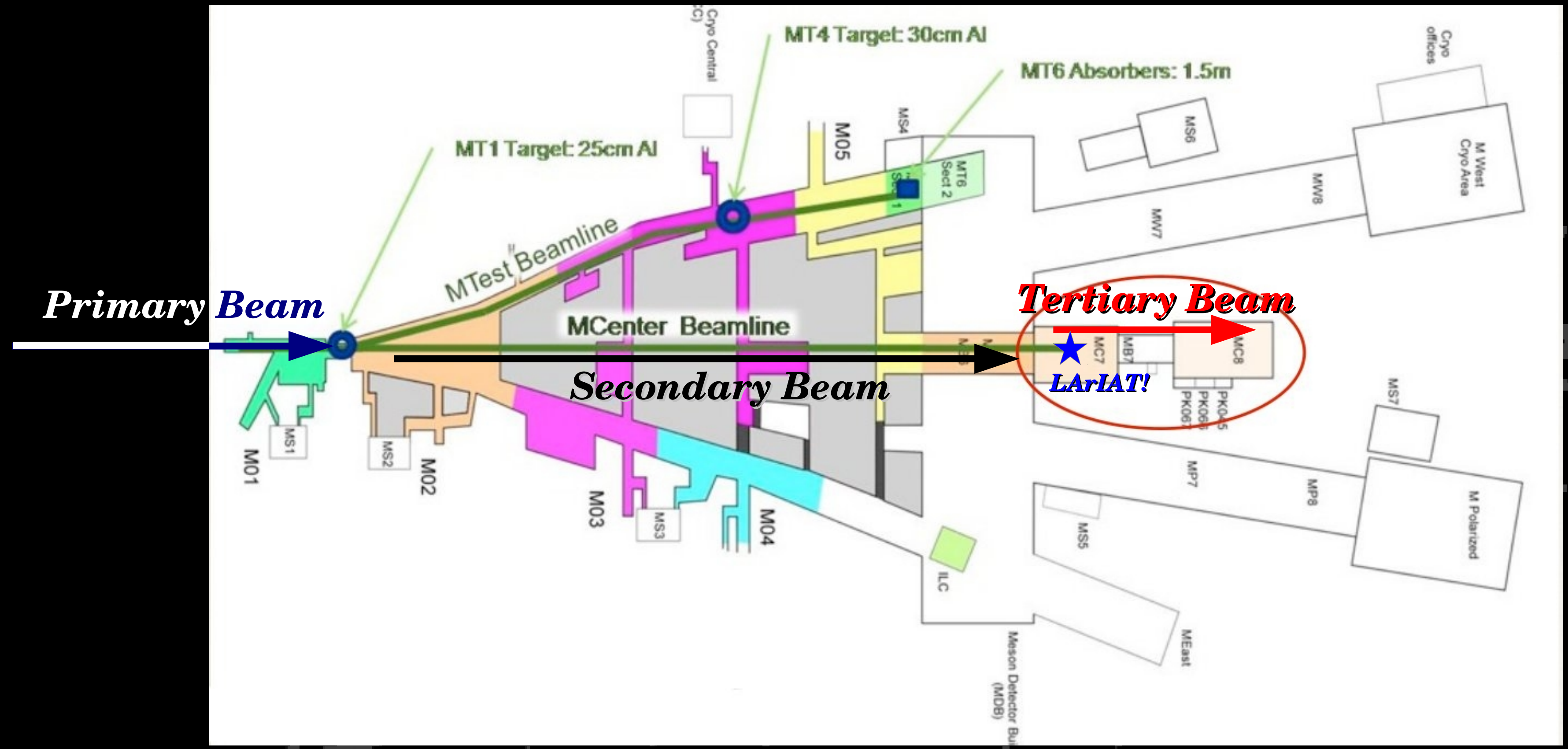
The idea:

Flexible, equal, and open access to test beams for all detector tests, with low bureaucratic overhead and a guarantee of safety, coordination, and oversight

Two facilities:

- ✔ *MTest: hosts short-term tests (1 week – 1 month)*
- ✔ *MCenter: allows long term occupation. Will host LArIAT becoming the facility for long-term LAr calibration and R&D*
- ✔ *Both receive a primary beam of 66-120 GeV protons in 4 sec/min spills*

Fermilab Test Beam Facility



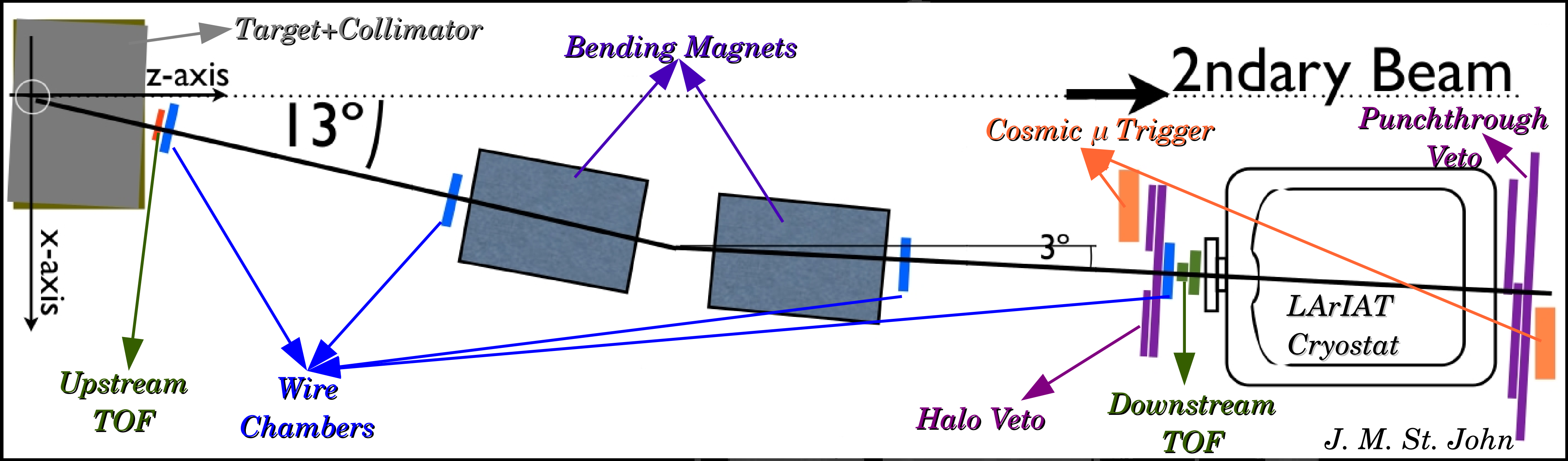
Secondary Beam

- ➢ π mode: 8-80 GeV beam
- ➢ Low energy π mode: 1-32 GeV beam
- ➢ μ / κ / e mode: same energy as low energy π

Tertiary Beam

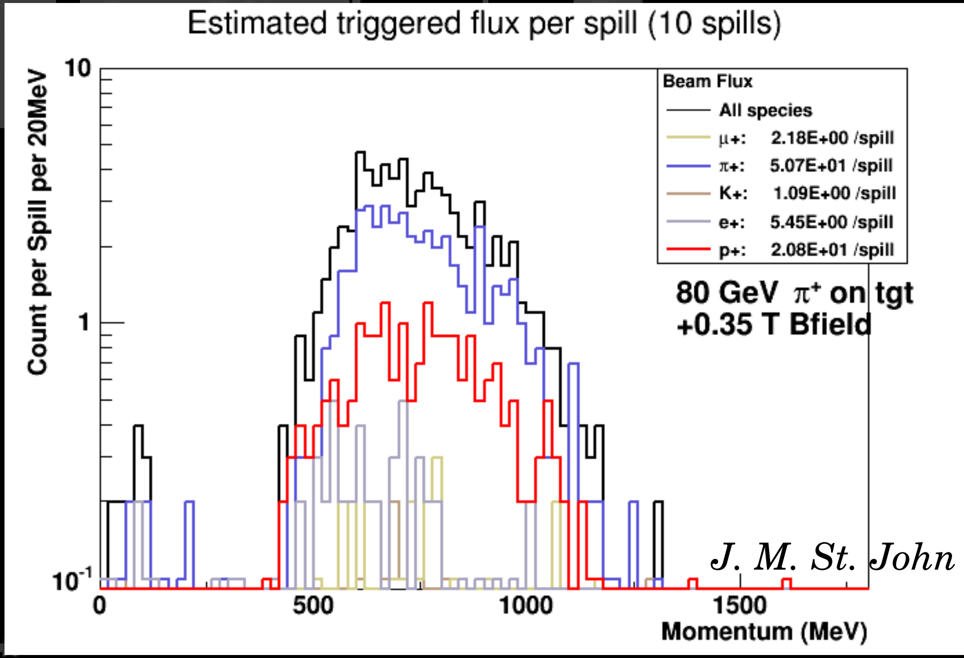
- ➢ Low energy π mode: 0.2-3 GeV beam
- ➢ p,κ,μ,e down to 200 MeV

Tertiary Beam & Beam Detectors Layout



➢ *Particle momentum range and sign @ TPC selected by tuning secondary beam energy and dipole magnetic field (± 0.35 T)*

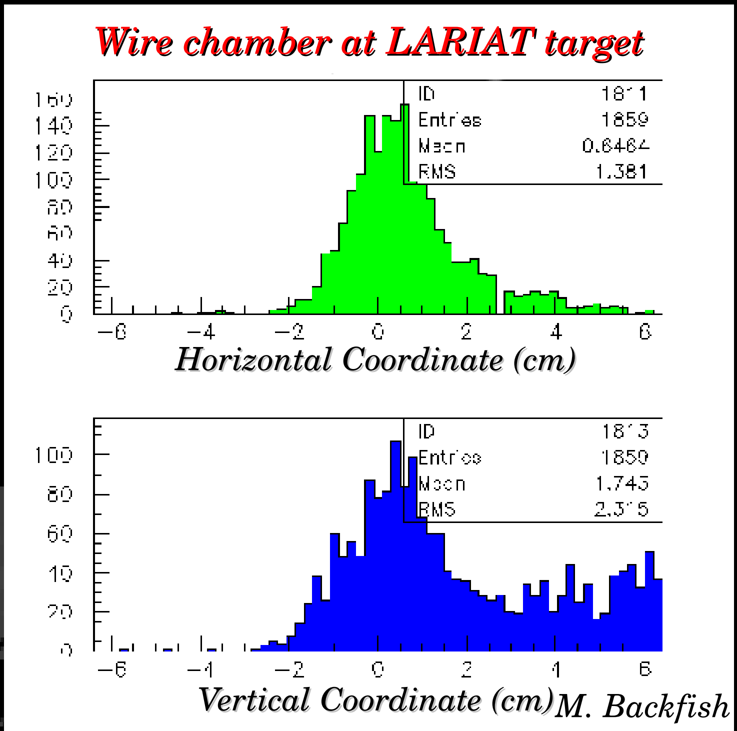
➢ *For $3 \cdot 10^5$ 80 GeV π^+ per spill on target expected 400 particles at cryostat / 70-80 after trigger cuts*



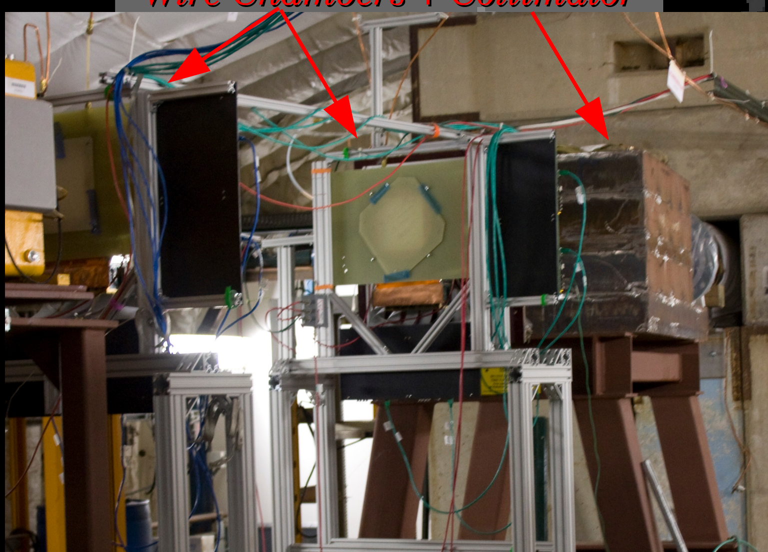
Where We Are

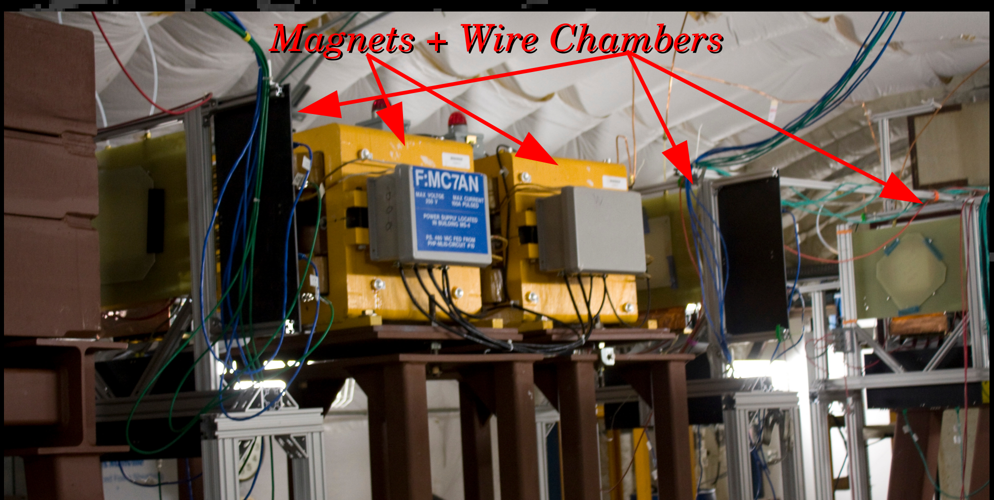
Beam detectors @ MC7

- Secondary beam commissioned!
- Target, Collimator, Wire Chambers, TOF, Magnets installed
- Tertiary beam under commissioning right now



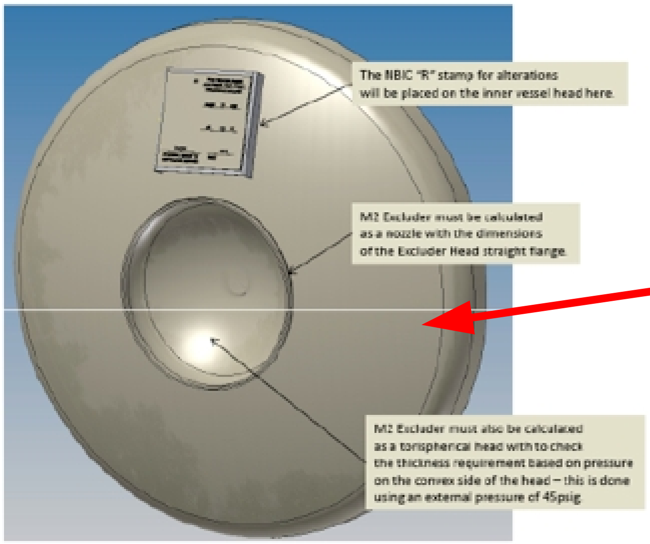
Wire Chambers + Collimator



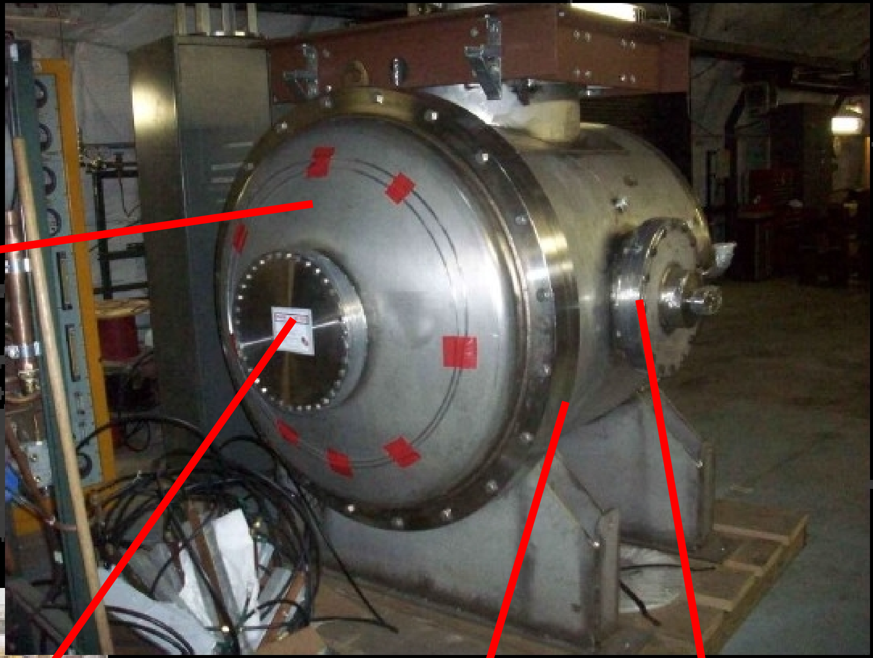


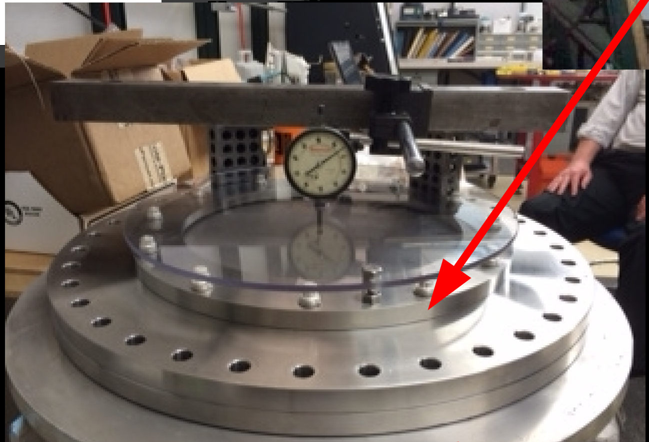
Other Updates: Cryostat

Work on cryostat done by PHPK; realization of a Ti beam window done by the Fermilab engineer and mechanical department



LAr Excluder



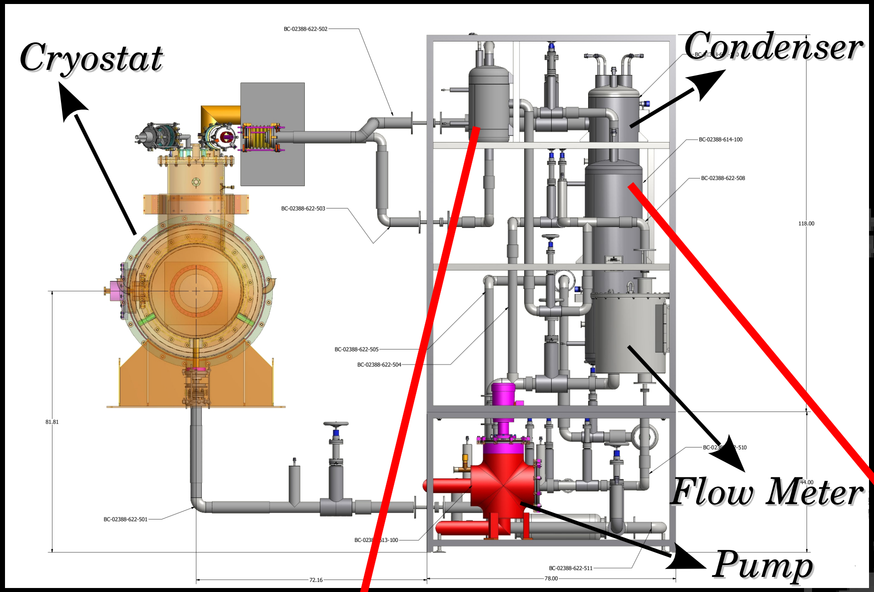


Ti Beam Window

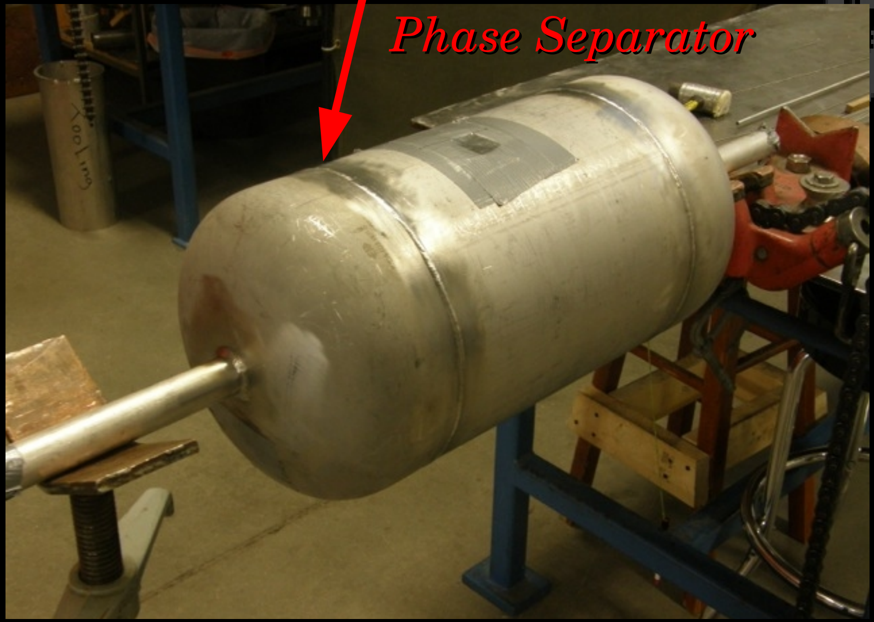
PMT Feedthrough

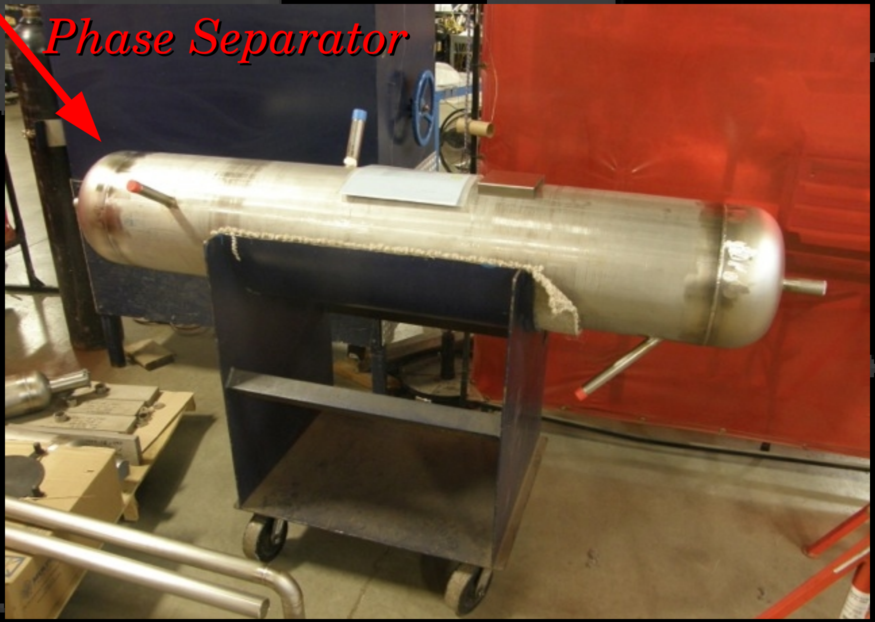
Drainage Port

Other Updates: Cryogenic System



- Work done by EDEN
- First parts arriving soon

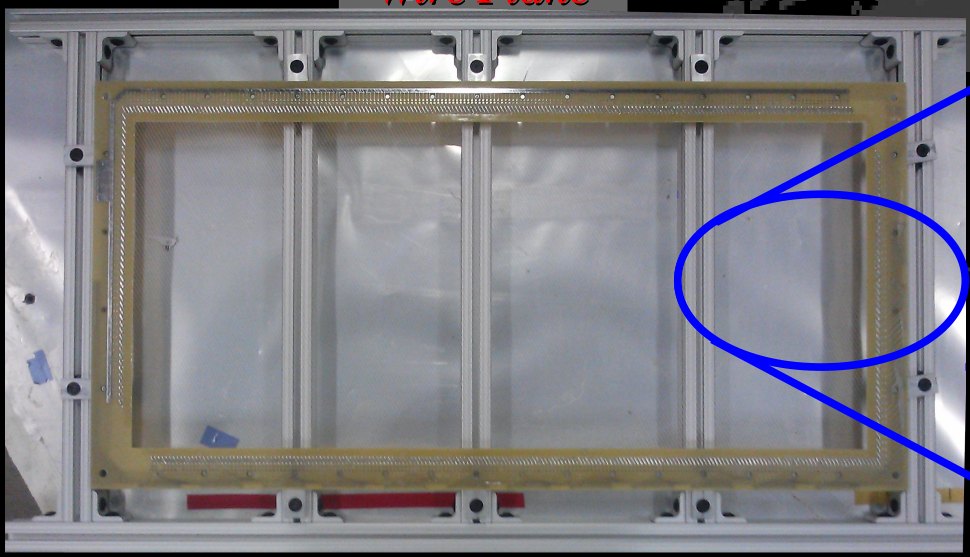


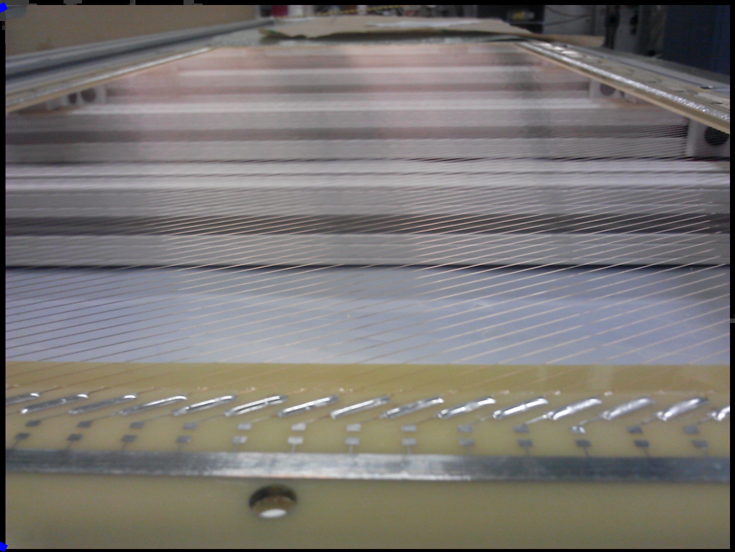


Other Updates: TPC

- ArgoNeuT TPC with new wire, wire frames, resistors
- Cryostat and TPC moved to Lab6 to allow assembling in parallel with beam commissioning and cryo-system work
- Wire mounted on wire frames
- Field cage resistors tested
- TPC assembled by August, in time for an engineering run

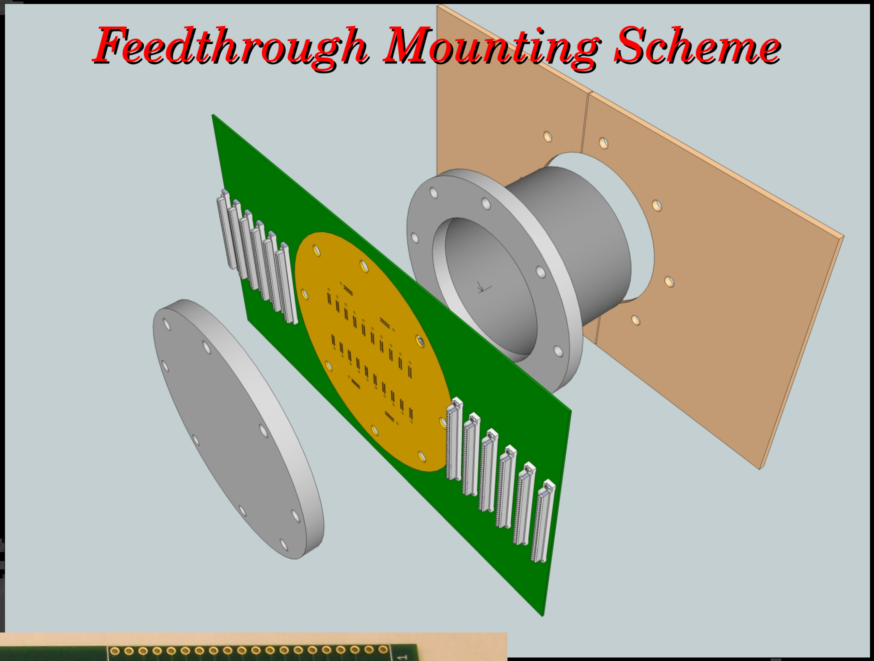
Wire Plane

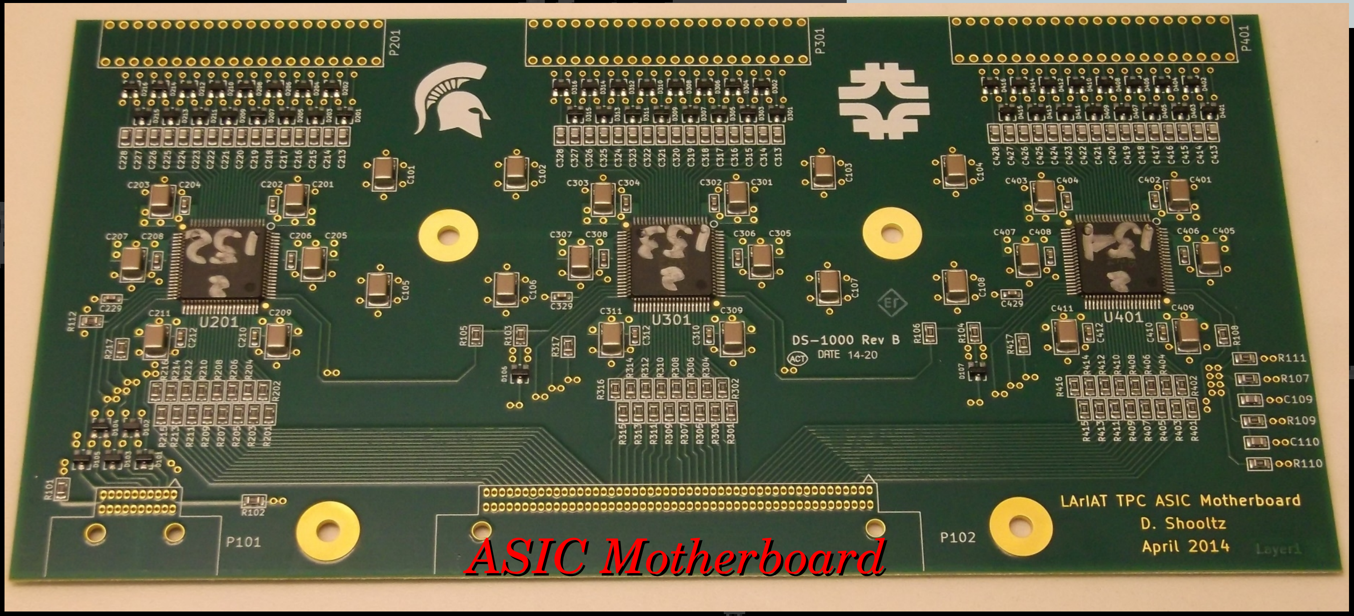




Other Updates: Readout Electronics

- *Replace ArgoNeuT warm electronics with new cold electronic designed and made @ MSU using the same BNL ASIC as is used in MicroBooNE*
- *14 ASIC motherboards realized and being tested now*
- *Feedthrough design finalized and being realized now*



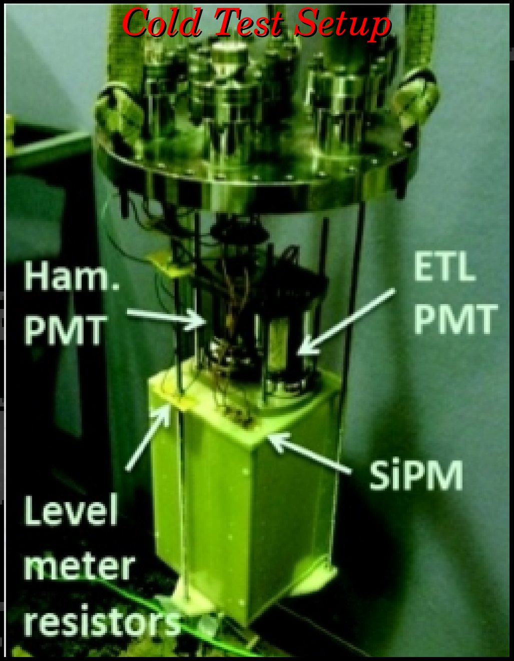


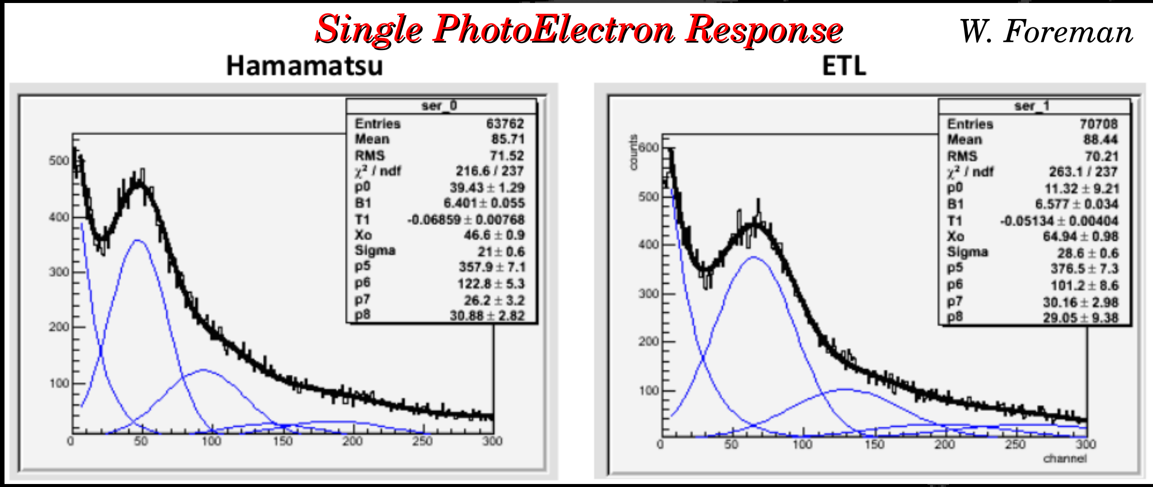
Other Updates: Light Readout

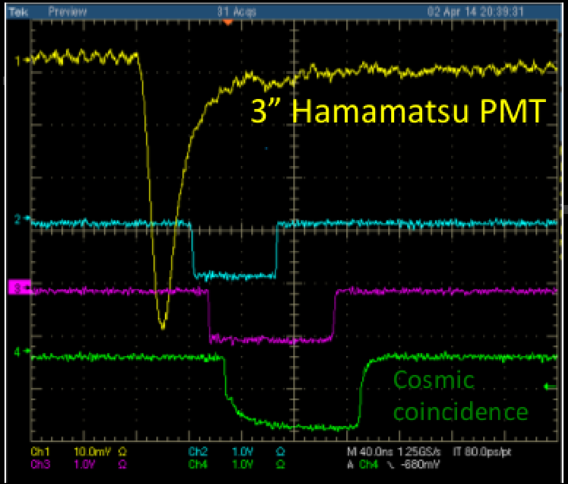
Two PMTs and two SiPM for R&D on light collection and energy reconstruction from charge+light

- *Cold test @ U Chicago: check of devices working conditions, TPB-covered foils and light collection simulation*
- *Test of the mounting procedure of the TPB-covered foils in the TPC*
- *Test of the power supplies at MCenter*

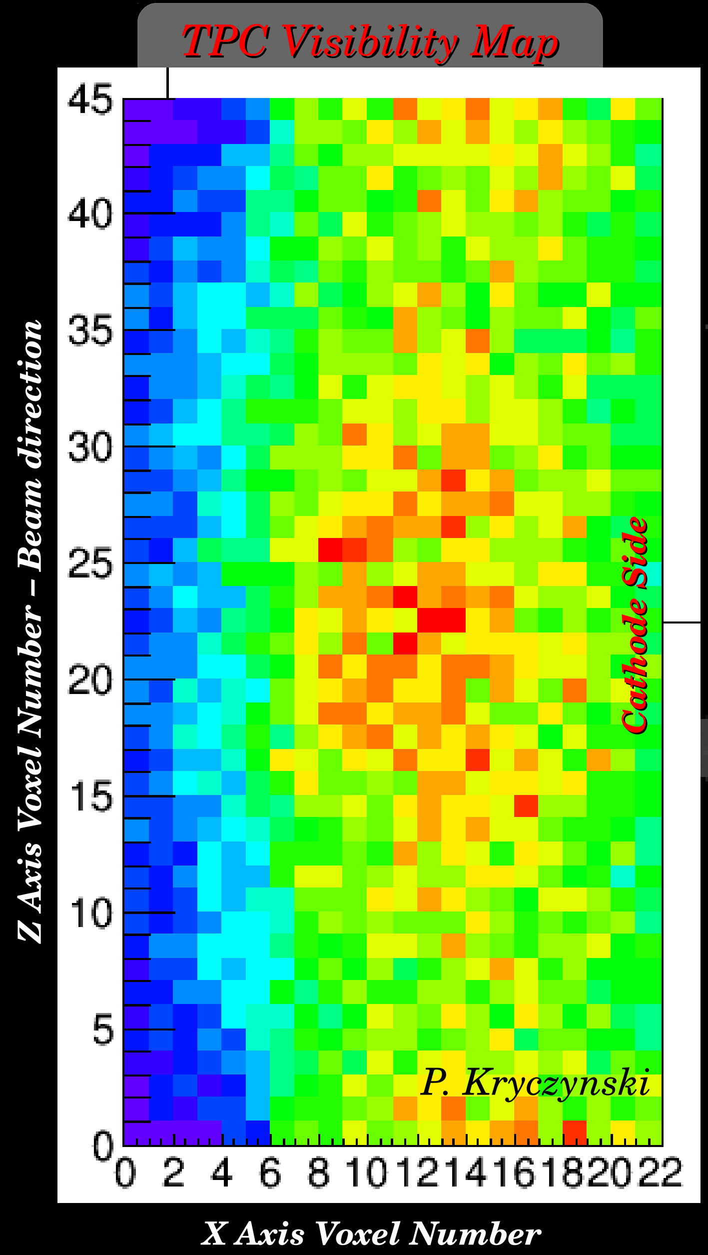
More info in W. Foreman talk!!!



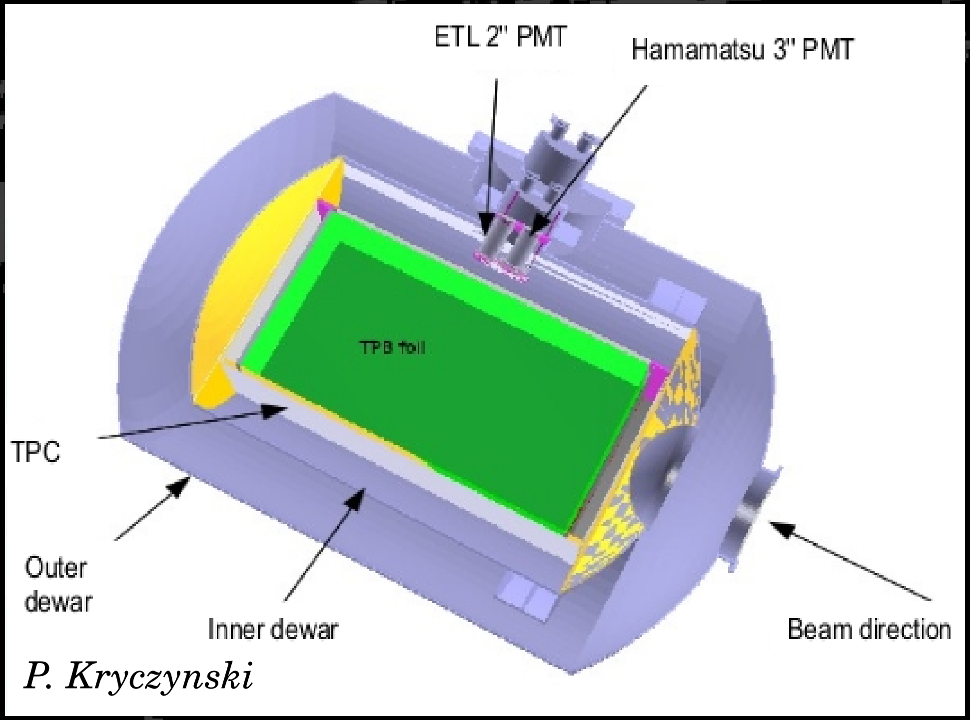




Other Updates: Simulation



- *Cryostat modifications inserted in Geant*
- *MonteCarlo is based on ArgoNeut detector with updated geometry*
- *Light collection system (PMTs+SiPM+TPB) fully simulated and tested*



Other Updates: HV System

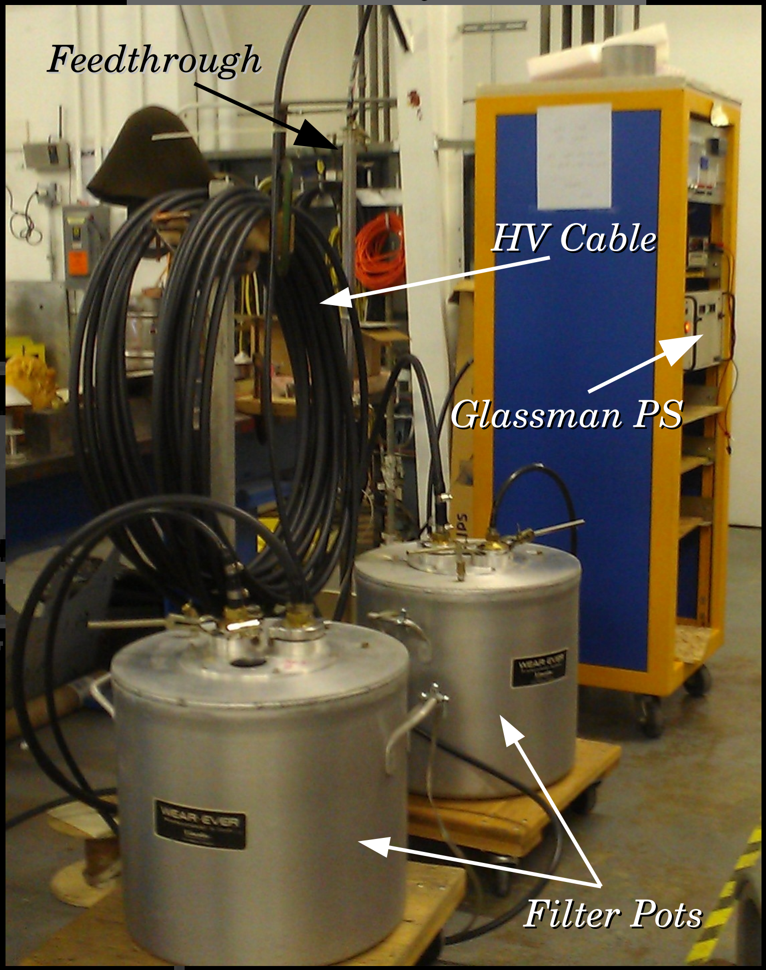
- *HV power supplies for cathode and PMTs controlled remotely via web using a system developed by the Fermilab Accelerator Division (ACNET)*

- *All HV controls and monitors ready*

- *Cathode HV system tested in air. Soon test in LAr*

- *Test of full chain (from HV power supply to readout electronics) + measurement HV-related noise scheduled for the end of July*

Cathode HV system test



Summary

- ***LArIAT scientific goals:***
  - ✔ *Direct/experimental proof of e/γ separation in LarTPCs*
  - ✔ *Detailed measurement of recombination factors p, K, π, μ PID and accurate calorimetry*
  - ✔ *Topological studies for non-magnetic sign determination*
  - ✔ *Kaon reconstruction and decay topology study*
  - ✔ *Direct measurement of energy resolutions for EM and hadronic showers*
  - ✔ *Fine-tuning software for off-line analysis*

- ***Phase I:***
  - ✔ *Commissioning started!*
    - *Secondary beam commissioned*
    - *Tertiary beam and first part beam detectors under commissioning*
  - ✔ *3 months beam shutdown (September-November)*
  - ✔ *Engineering GAr run before/during beam shutdown with full detector*
  - ✔ *First LAr run by the end of the year*

- ***Phase II:***
  - ✔ *Simulation and planning has begun*

Thank you from the 65+ physicists of the 20 institutions forming LArIAT!!!

Argonne Jon Paley

Boston U. Dan Gastler, Ed Kearns

Caltech Ryan Patterson

U. Chicago Will Foreman, Johnny Ho, Dave Schmitz

U. Cincinnati Randy Johnson, Jason St. John

Fermilab Roberto Acciarri, Phil Adamson, Michael Backfish, William Badgett, Bruce Baller, Alan Hahn, Doug Jensen, Hans Jostlein, Tom Junk, Mike Kirby, Tom Kobilarcik, Pawel Kryczynski, Hugh Lippincott, Sarah Lockwitz, Alberto Marchionni, Ko Nishikawa, Jennifer Raaf*, Erik Ramberg, Brian Rebel**, Michelle Stancari, Sam Zeller

Imperial College London Morgan Wascko

KEK Eito Iwai, Takasumi Maruyama

LANL Christopher Mauger

Louisiana State University Flor de Maria Blaszczyk, William Metcalf, Martin Tzanov, Jieun Yoo

U. Manchester Justin Evans, Pawel Guzowski

Michigan State University Carl Bromberg, Dan Edmunds, Dean Shooltz

U. Minnesota, Duluth Rik Gran, Alec Habig, Karl Kaess

U. Pittsburgh Steve Dytman

Syracuse University Jonathan Asaadi, Jessica Esquivel, Mitch Soderberg

U. Texas, Arlington Amir Farbin, Seongtae Park, Timothy Watson, Andy White, Jae Yu

U. Texas, Austin Junting Huang, Karol Lang

University College London Anna Holin, Ryan Nichol, Jenny Thomas

William & Mary Mike Kordosky**, Matthew Stephens, Patricia Vahle

Yale University Flavio Cavanna*, Eric Church, Bonnie Fleming, Elena Gramellini, Ornella Palamara, Andrzej Szelc

** Phase I spokesperson*

*** Phase II spokesperson*

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Backup Slides

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Fermilab Roberto Acciarri, Phil Adamson, Michael Backf[illegible]h, William Badgett, Bruce Baller, Alan Hahn, Doug Je[illegible], Hans Jostlein, Tom Junk, Mike Kirby, T[illegible] Kobilar[illegible] P[illegible], Kryczynski, Hugh Lippincott, Sarah Lock[illegible] er[illegible] Marchionni, Ko Nishikawa, Jennifer R[illegible]af[illegible] R[illegible]berg, Brian Rebel**, Michelle Stancari, [illegible]

Imperial Colle[illegible]don [illegible]

KEK Eito Iw[illegible] T[illegible]um[illegible] [illegible]ama

LANL Christo[illegible]er [illegible]ger

Louisiana Stat[illegible] University Flor de Maria Blaszczyk, William Metcalf, Martin Tzanov, Jieun Yoo

U. Manchester Justi[illegible] Evans, [illegible]

Michigan Sta[illegible] [illegible]berg, Dan Edmunds, Dean S[illegible]z

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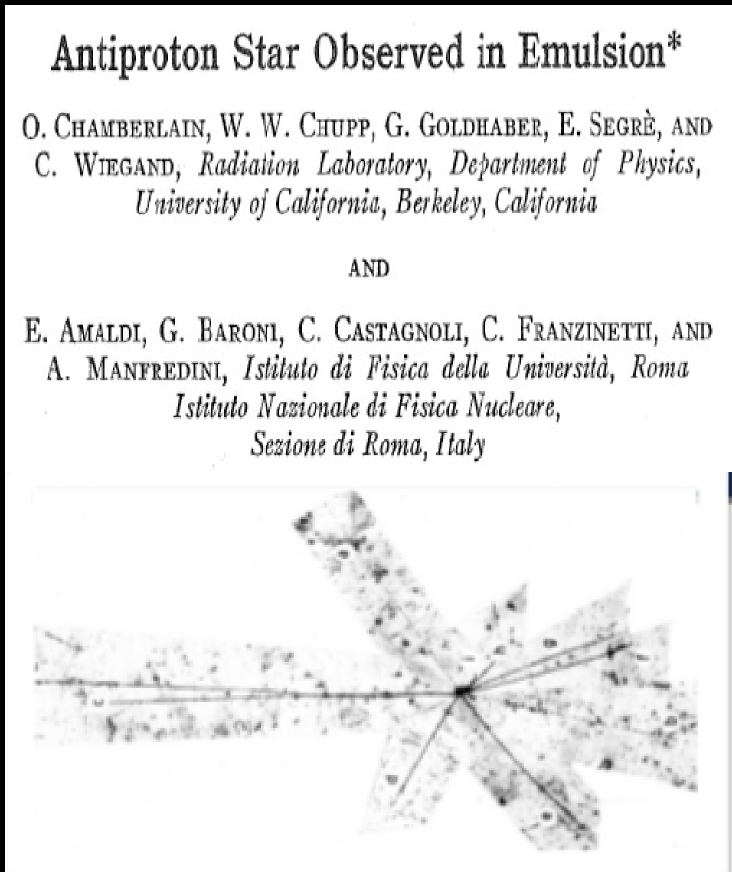
Anti-proton Stars


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*

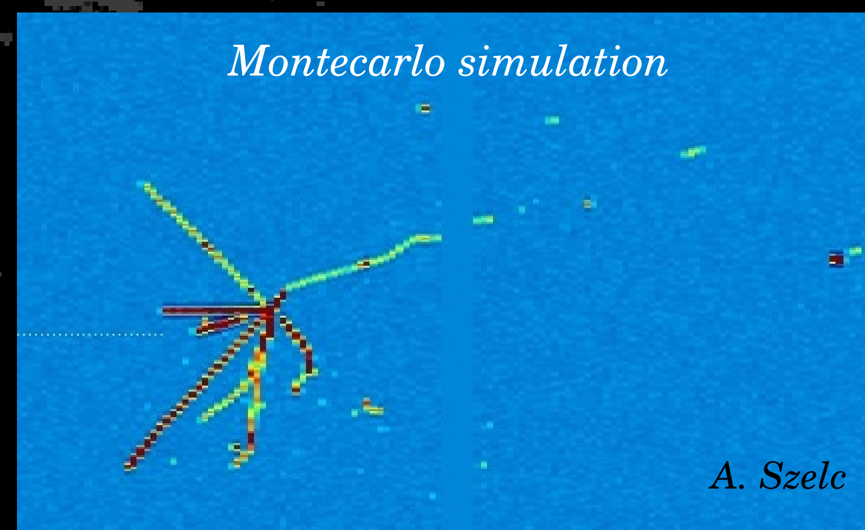
and

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*

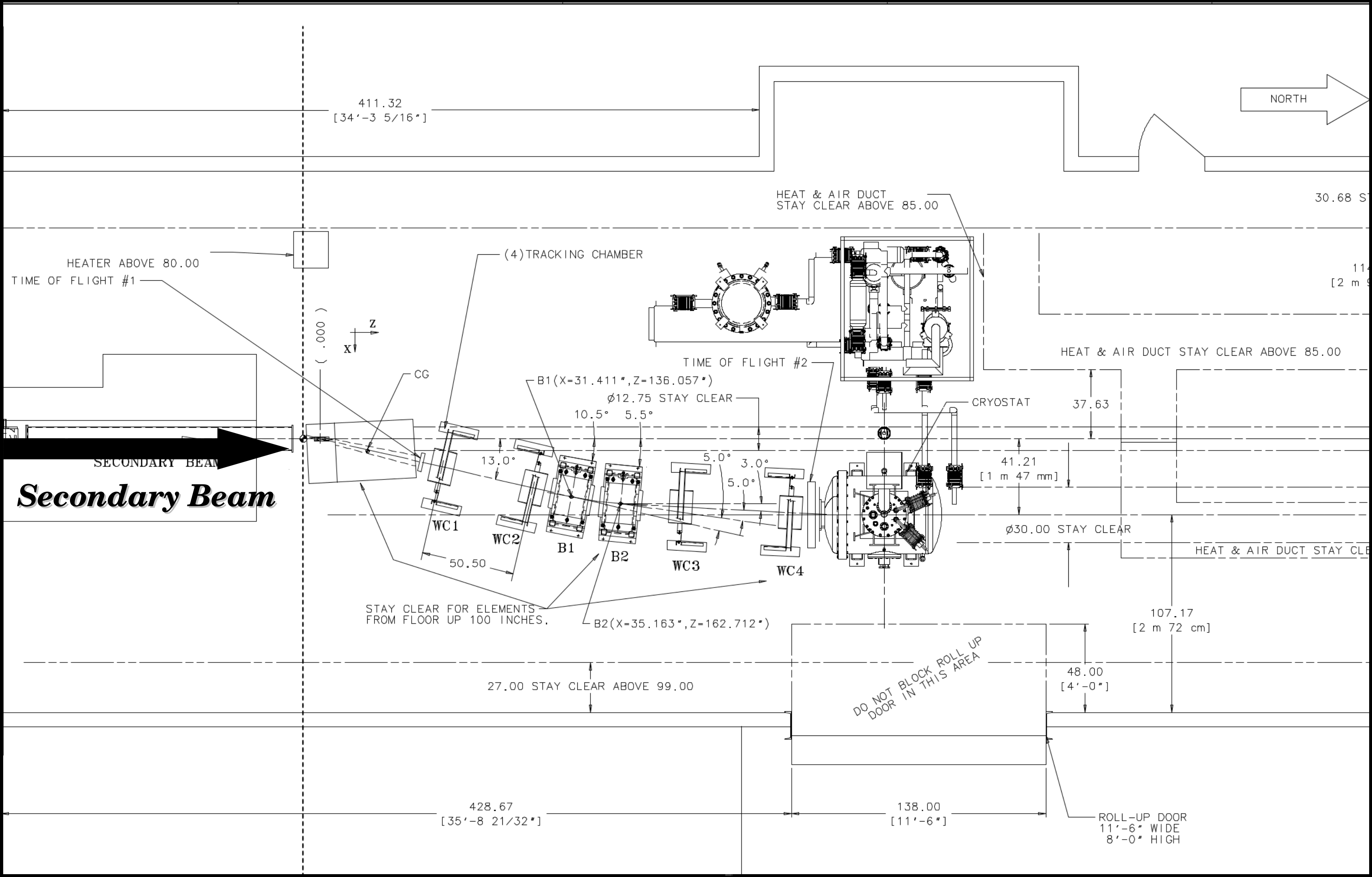
✔ *Low momentum anti-protons in the beam (even at a small rate) will allow the first study of hadron star topology from p-pbar annihilation at rest in Argon*

✔ *LAr imaging detector capabilities permits accurate determination of meson multiplicity*

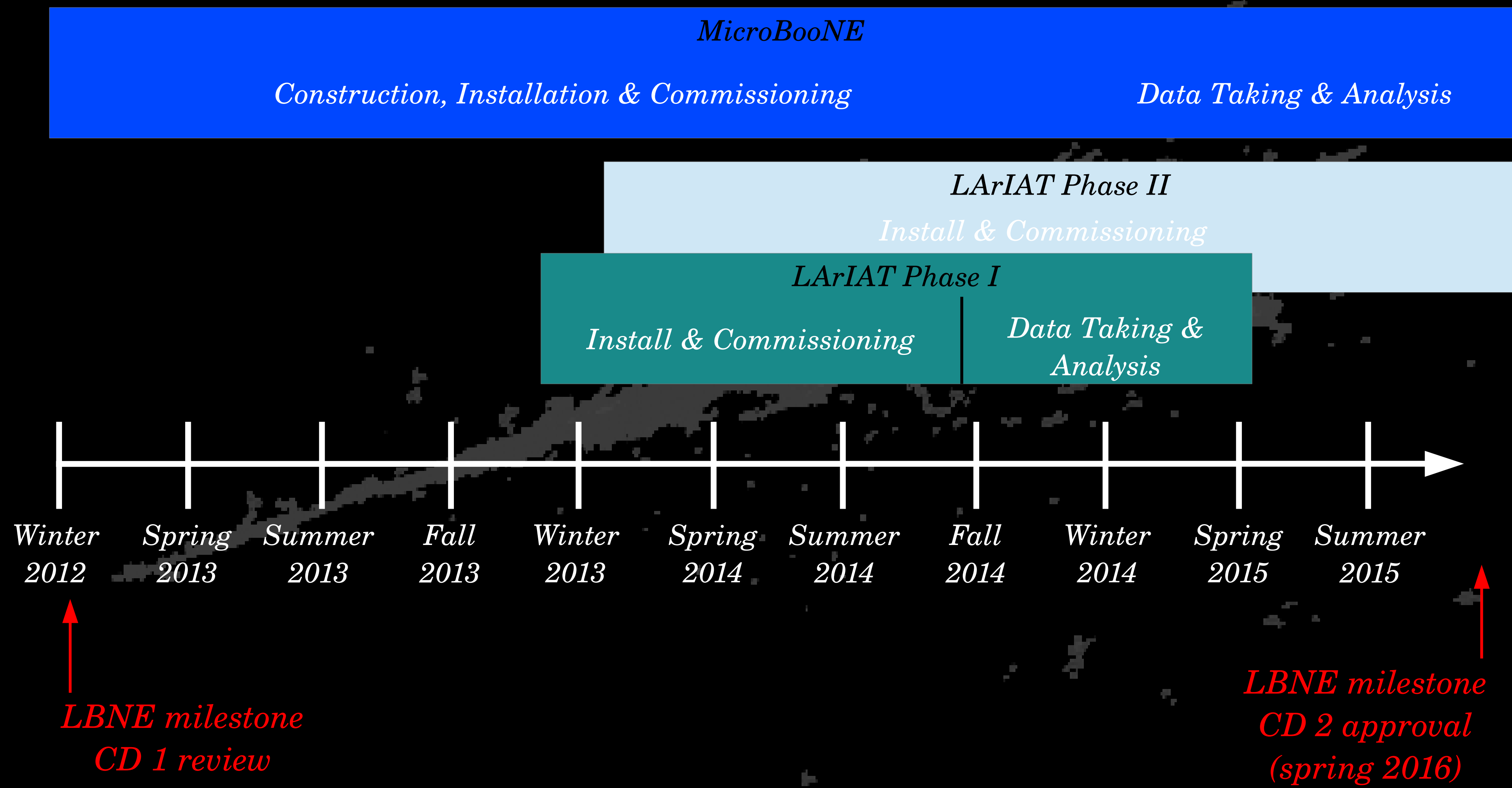
Relevant for n-nbar oscillation searches at future large underground LarTPC detectors.



MC7


411.32
[34'-3 5/16"]
NORTH
30.68 S
HEAT & AIR DUCT
STAY CLEAR ABOVE 85.00
HEATER ABOVE 80.00
TIME OF FLIGHT #1
(4)TRACKING CHAMBER
Z
X
CG
TIME OF FLIGHT #2
B1(X=31.411",Z=136.057")
Ø12.75 STAY CLEAR
10.5° 5.5°
CRYOSTAT
37.63
HEAT & AIR DUCT STAY CLEAR ABOVE 85.00
13.0°
5.0° 3.0°
5.0°
41.21
[1 m 47 mm]
SECONDARY BEAM
Secondary Beam
WC1
WC2
B1
B2
WC3
WC4
Ø30.00 STAY CLEAR
HEAT & AIR DUCT STAY CL
50.50
STAY CLEAR FOR ELEMENTS
FROM FLOOR UP 100 INCHES.
B2(X=35.163",Z=162.712")
107.17
[2 m 72 cm]
DO NOT BLOCK ROLL UP
DOOR IN THIS AREA
48.00
[4'-0"]
27.00 STAY CLEAR ABOVE 99.00
428.67
[35'-8 21/32"]
138.00
[11'-6"]
ROLL-UP DOOR
11'-6" WIDE
8'-0" HIGH

Timeline



MicroBooNE
Construction, Installation & Commissioning
Data Taking & Analysis
LArIAT Phase II
Install & Commissioning
LArIAT Phase I
Install & Commissioning
Data Taking & Analysis
Winter 2012
Spring 2013
Summer 2013
Fall 2013
Winter 2013
Spring 2014
Summer 2014
Fall 2014
Winter 2014
Spring 2015
Summer 2015
LBNE milestone CD 1 review
LBNE milestone CD 2 approval (spring 2016)