FNAL-T1034

LArIAT

CERN-LAr1_ND Meeting

CERN

Feb.16-17, 2014

FLAVIO CAVANNA
YALE UNIVERSITY
AND U.OF L'AQUILA/INFN

ORIGIN OF THE LARIAT EFFORT

Integrated Plan for LArTPC neutrino detectors in the US

Prepared for the FNAL Director's Review of LArTPC R&D Planning
LArTPC Planning Group, B. Baller and B. Fleming, Editors
November 18, 2009

most of the indicated LArR&D items in the list successfully accomplished in the meantime!!

1 LBNE and LAr Science and Project Goals

Experimental results from the last decade have revolutionized n
first conclusive evidence that neutrinos oscillate and have mass
ago. While this seminal discovery has answered many questions
even more. Particularly interesting is the question of CP Viol
neutrinos and anti-neutrinos oscillate at the same rate? The ans
neutrinos are the key to our matter dominated universe.

Long baseline neutrino oscillation searches are proposed
ences. Moreover, these experiments are the only ones that can si
unknown in the 3x3 neutrino mixing matrix, a CP violating ph
the neutrino mass eigenstates.

The US particle physics community is developing idea
baseline oscillation experiments beyond NOνA. To be sensitive to

In summary form, the plan consists of the following pre-existing components:

- The Materials Test Stand program, now in operation at Fermilab, addressing questions pertaining to maintenance of argon purity
- Exisiting electronics test stands at FNAL and BNL
- The Liquid Argon Purity Demonstrator (LAPD) now being assembled at Fermilab
- The ArgoNeuT prototype LArTPC, now running in the NuMI beam
- The MicroBooNE experiment, proposed as a physics experiment that will advance our understanding of the LArTPC technology, now completing its conceptual design phase.
- A software development effort that is well integrated across present and planned LArTPC detectors.

e are proposing to add to these efforts the following:

- A membrane cryostat mechanical prototype to evaluate and gain expertise with this technology.
- An installation and integration prototype, to understand issues pertaining to detector assembly, particularly in an underground environment.
- A $\sim$ 5% scale electronics systems test to understand system-wide issues as well as individual component reliability.
- A calibration test stand that would consist of a small TPC to be exposed to a test beam for calibration studies, relevant for evaluation of physics sensitivities.

and discussed again
at LBNE Integrated Plan – May 2010
and
at LBNE/LAr Working Group mtg
June 2/3 2011

Feb. 2012 – formed Collaboration

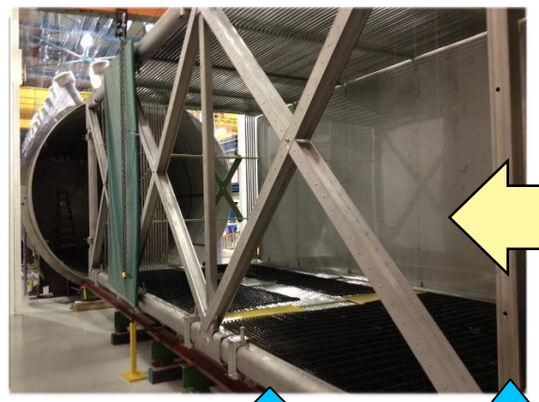
Financial Support in FY 2013
(DoE/FNAL and Yale)

WORKING TOWARD LBNE

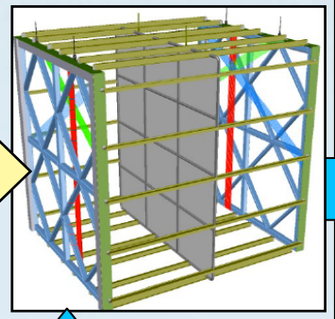
Physics

Argoneut

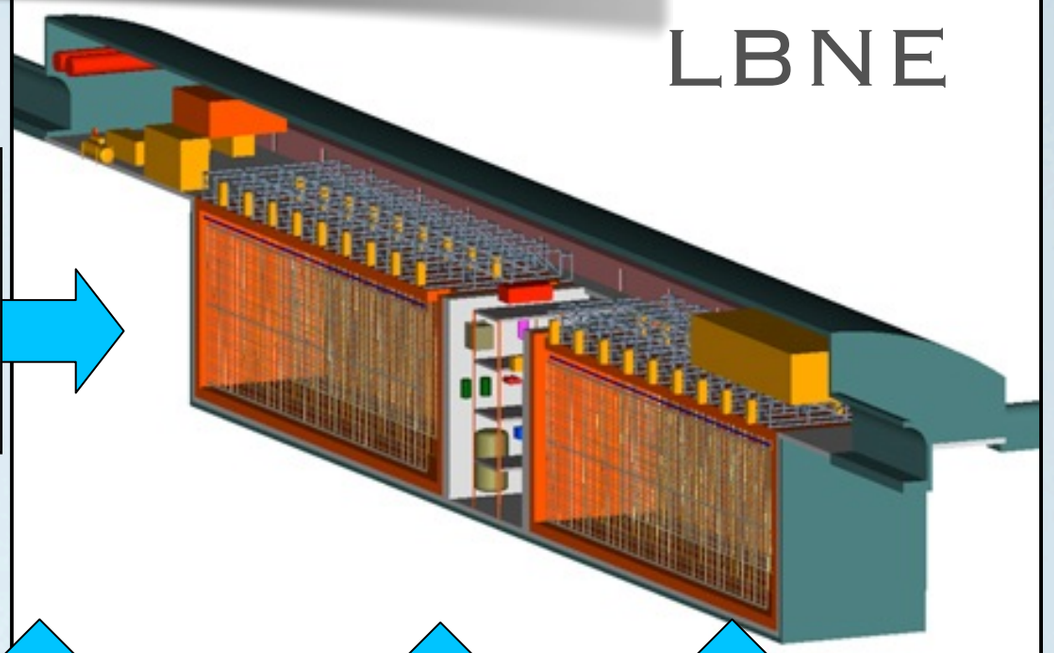
MicroBooNE



LAr1-ND



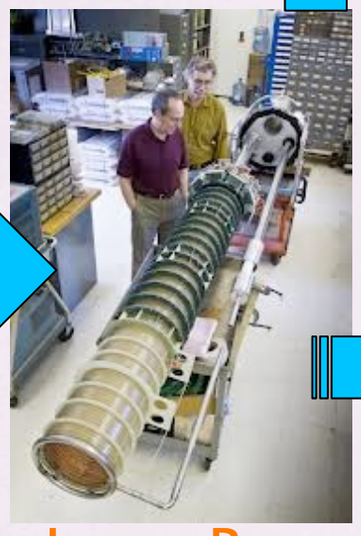
LBNE



R&D

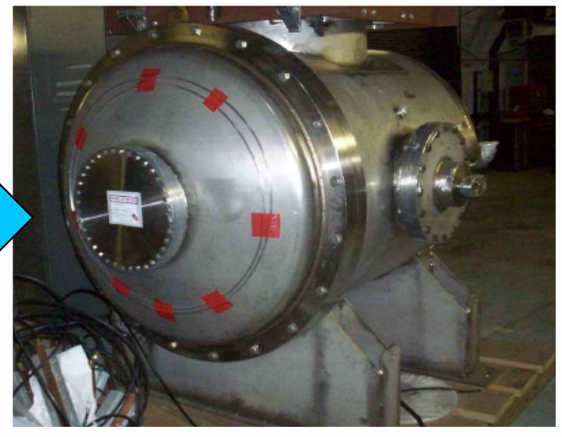
Bo

Electronics, readout, cold elec.



Long Bo (LAPD)

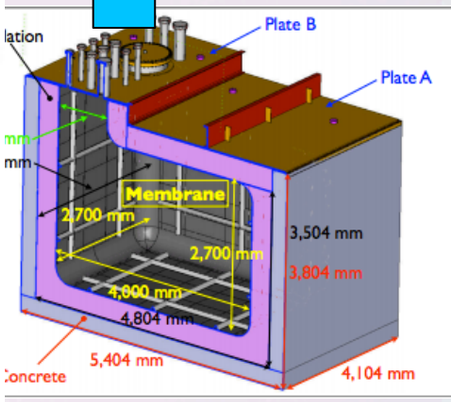
HV,cold elec.,purity



LARIAT

Complementary R&D programs

Location: LANL
Purpose: LArTPC calibration
Operational: 2014

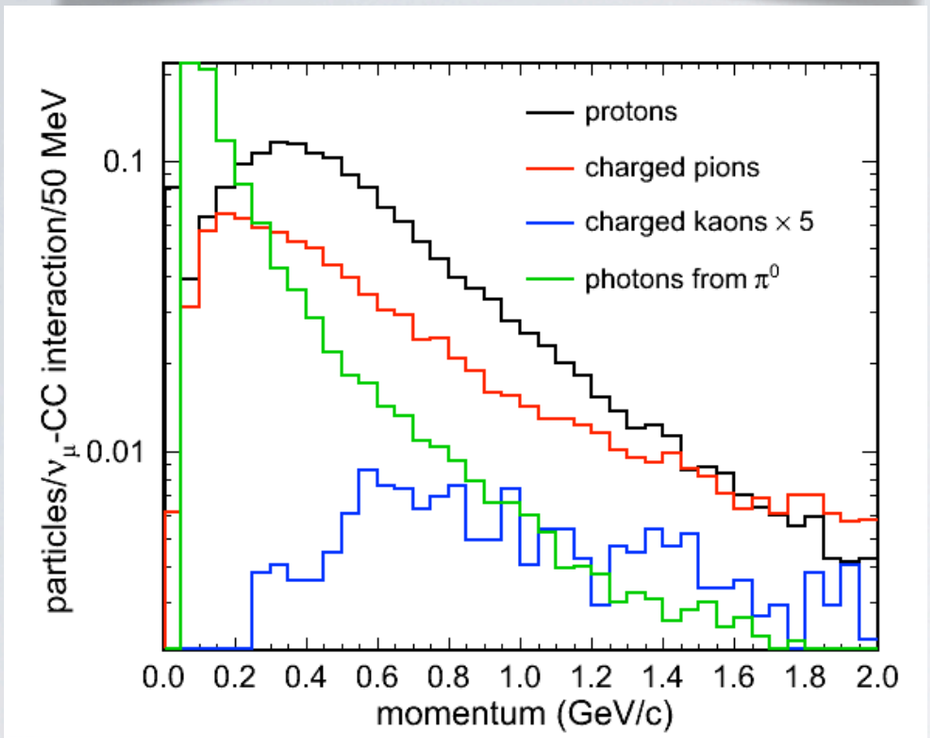


35T MEMBRANE CRYOSTAT

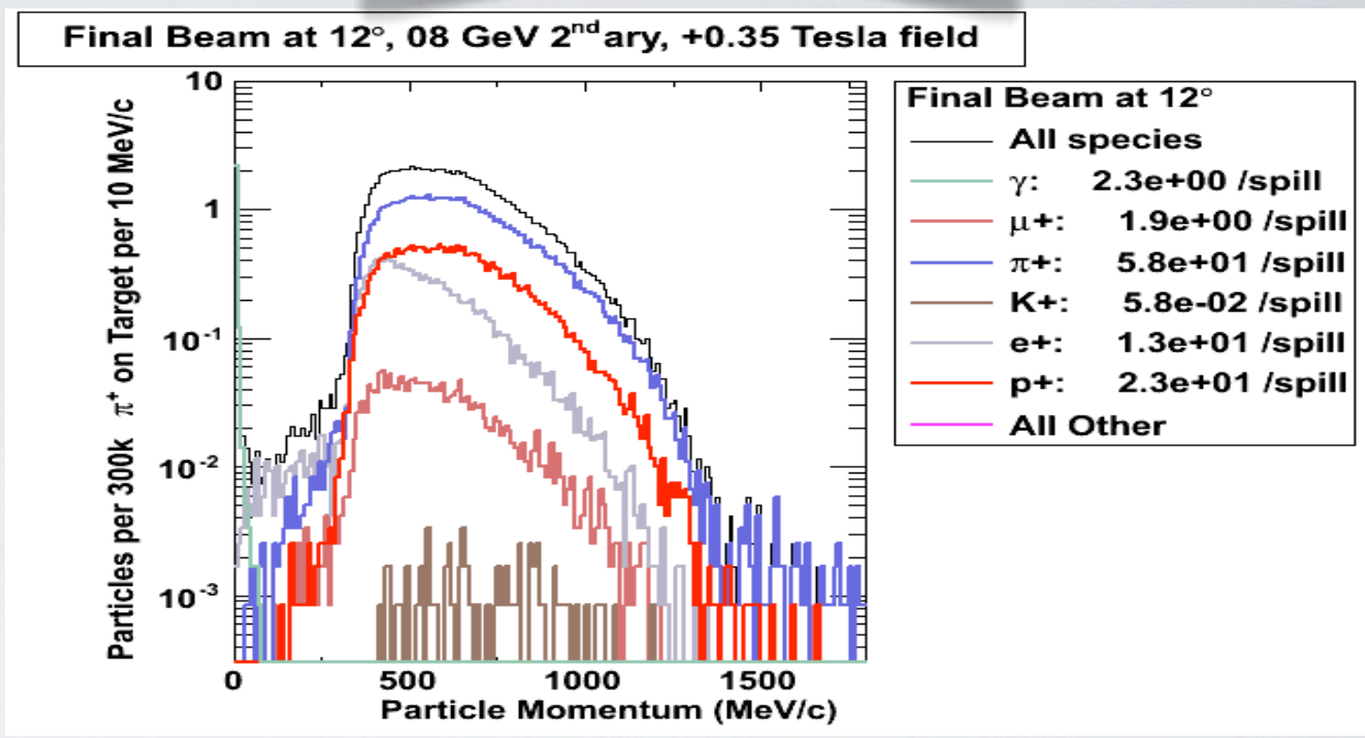
purity test &

TPC prototype

Motivation



Method



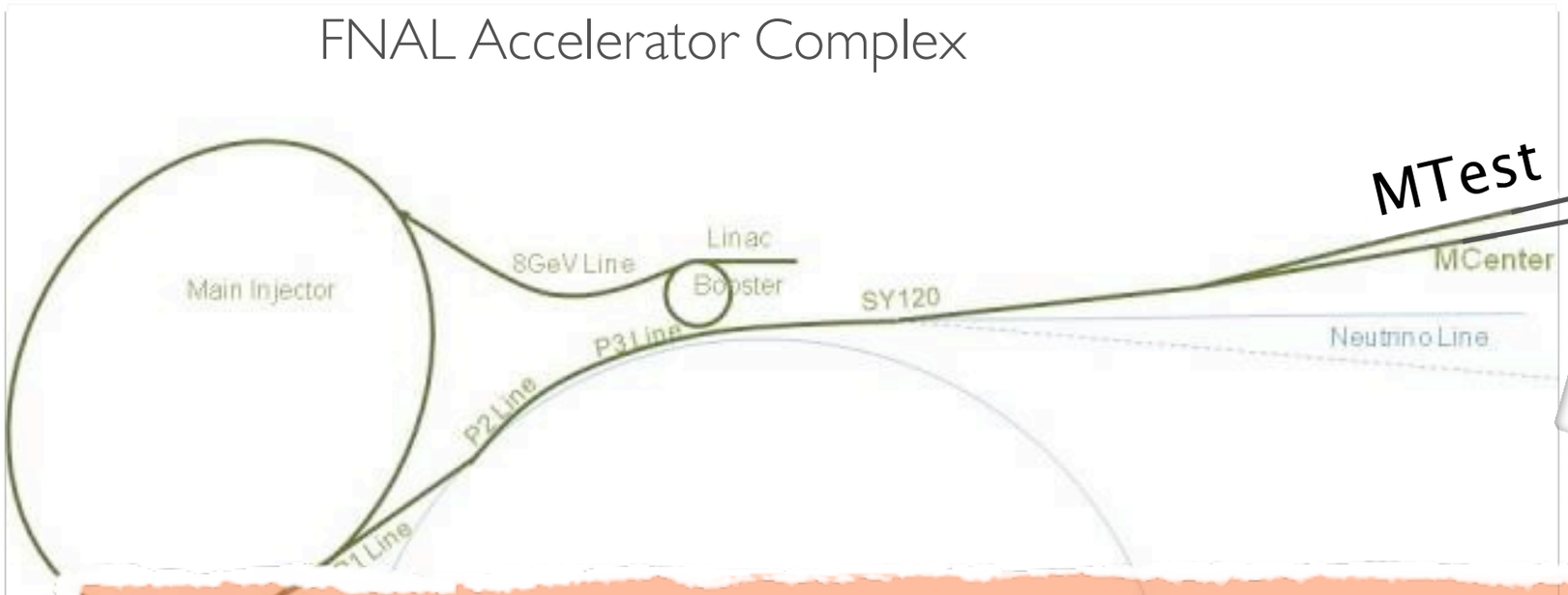
NuMI LE on-axis Beam

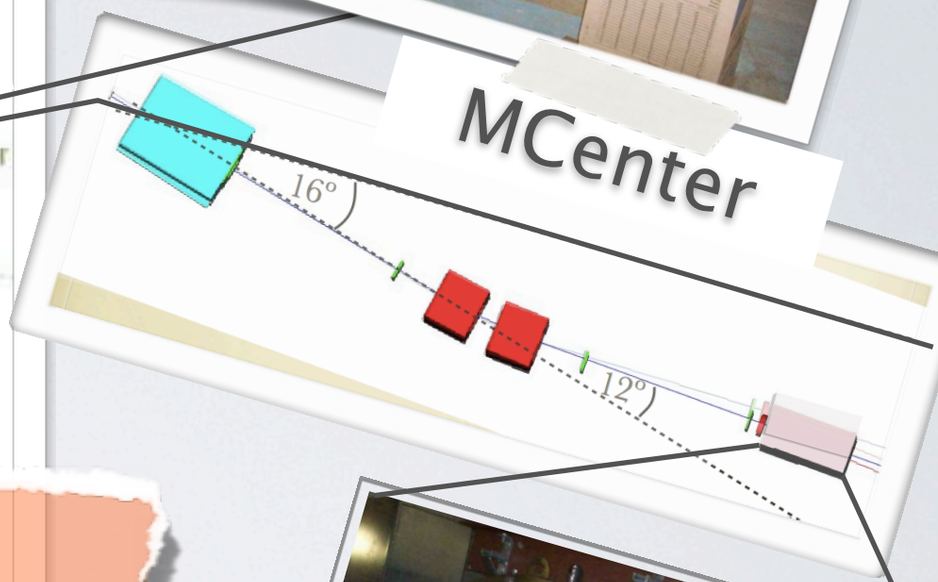
Study in LArTPC
Particles emerging
from **ν** Interactions
(in the energy range
relevant for uB &LBNE)

LArIAT Test Beam

Study in LArTPC
Particles emerging from
the LArIAT dedicated
Tertiary Beam
at FTBF (MCentral)

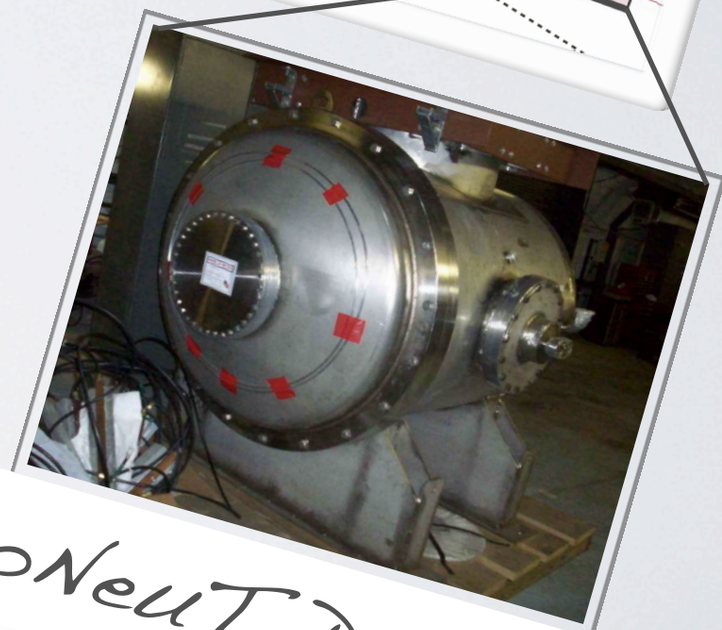
BASIC CONCEPT:
A (SEMI-PERMANENT) LAR FACILITY AT FTBF





A **fully operational TB/cryo-Facility** will allow for any future test of different components in experimental conditions

(e.g. different designs for TPC, Light Det. system, Electronics)



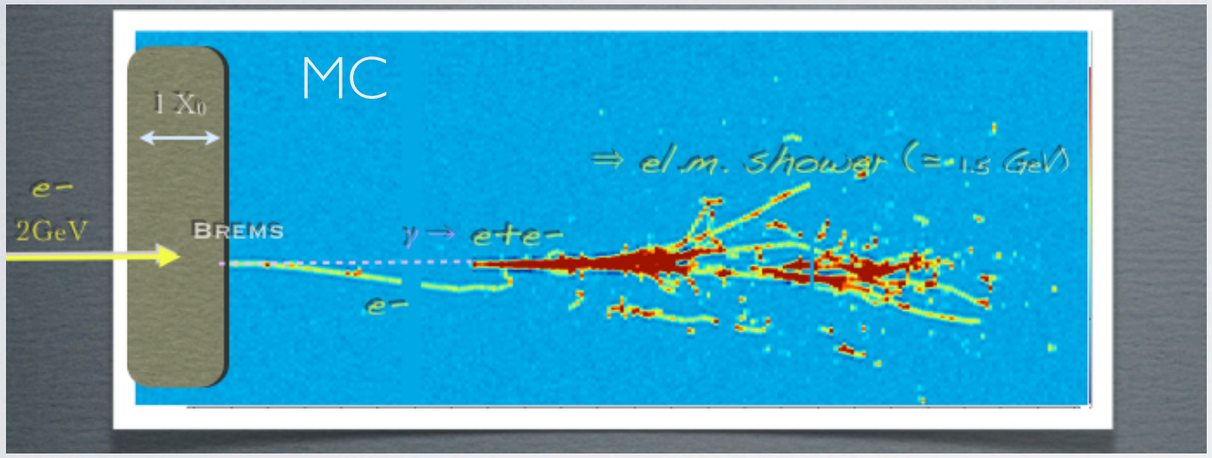
ArgoNeuT Detector

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/c - 2 GeV/c
(p,K,π,μ,e)

PARTICLE IDENTIFICATION

e vs γ shower discrimination



Bremsstrahlung from upstream radiator plate

Tagged with incoming electron PID in beamline
+ deviated track + gap.

- Experimental confirmation for the separation efficiencies (MC determined) - key feature of LArTPC tech

- Enable ultimate development and most reliable **separation criteria/algorithms** in the LArSoft off-line reconstruction code

- Support measurement of the low-energy elm evt. excess from MiniBooNE - primary goal of MicroBooNE,
and of the CP violating phase from oscillation into electron (anti)neutrinos (LBNE goal)

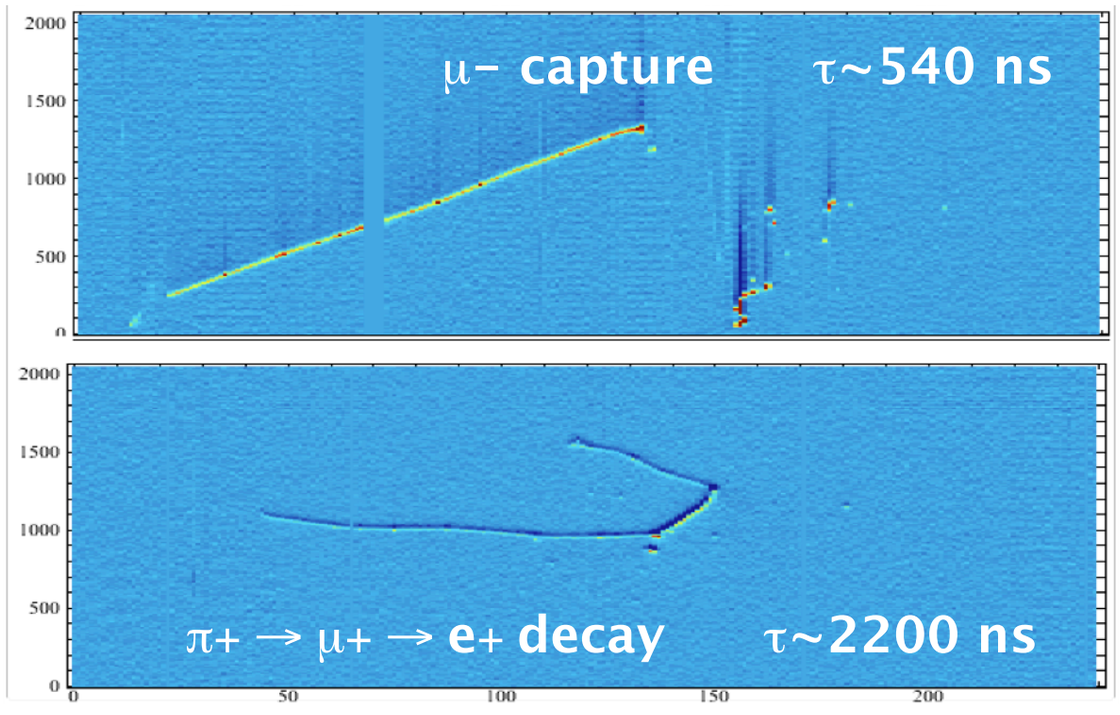
Muon sign determination (w/out magnetic field)

Timing and pattern recognition

- Explore a LArTPC feature never (systematically) considered (decay vs capture in LAr)

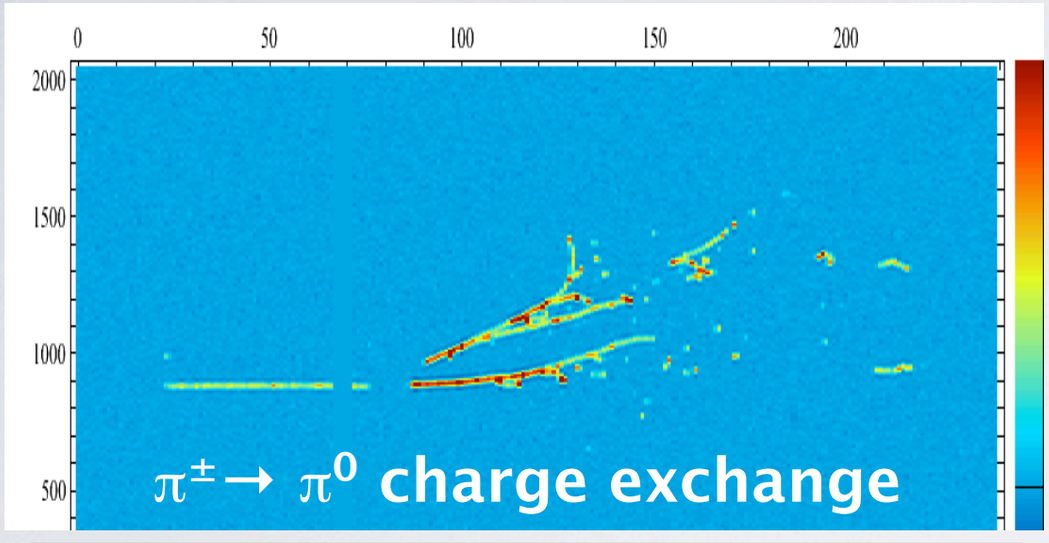
- Constrain the capability to charge-ID the primary lepton in muon neutrino CC interactions of particular interest for CP violation with LBNE

ArgoNeuT Data



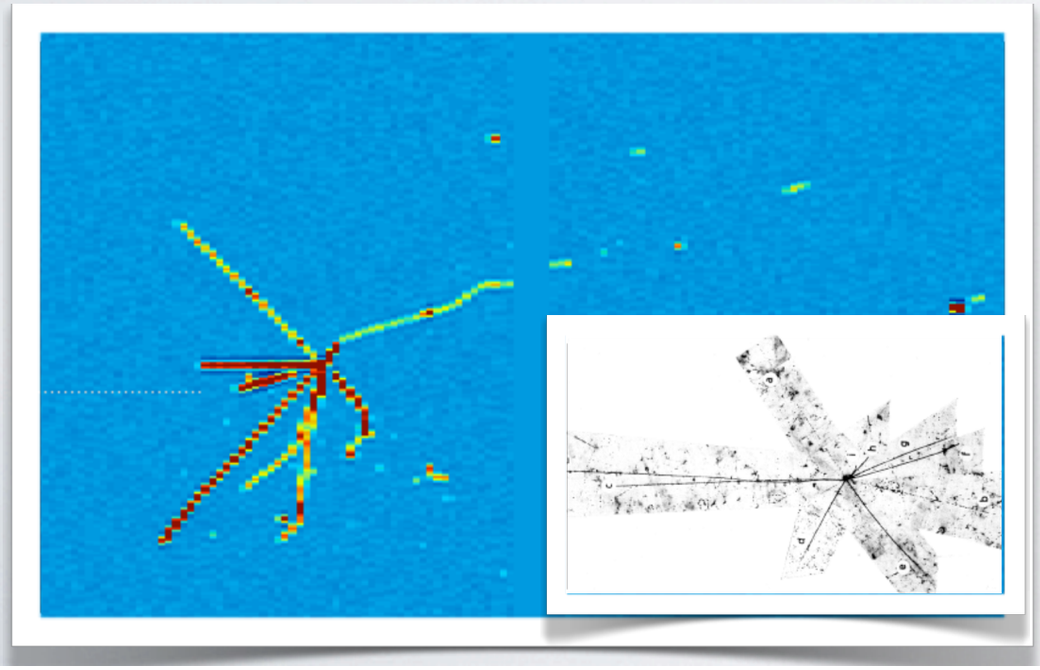
PARTICLE IDENTIFICATION

Study of Nuclear Effects



- Study/constrain the features of the most dangerous background in ν-Oscillation physics

Simulation of Antiproton Star in LAr

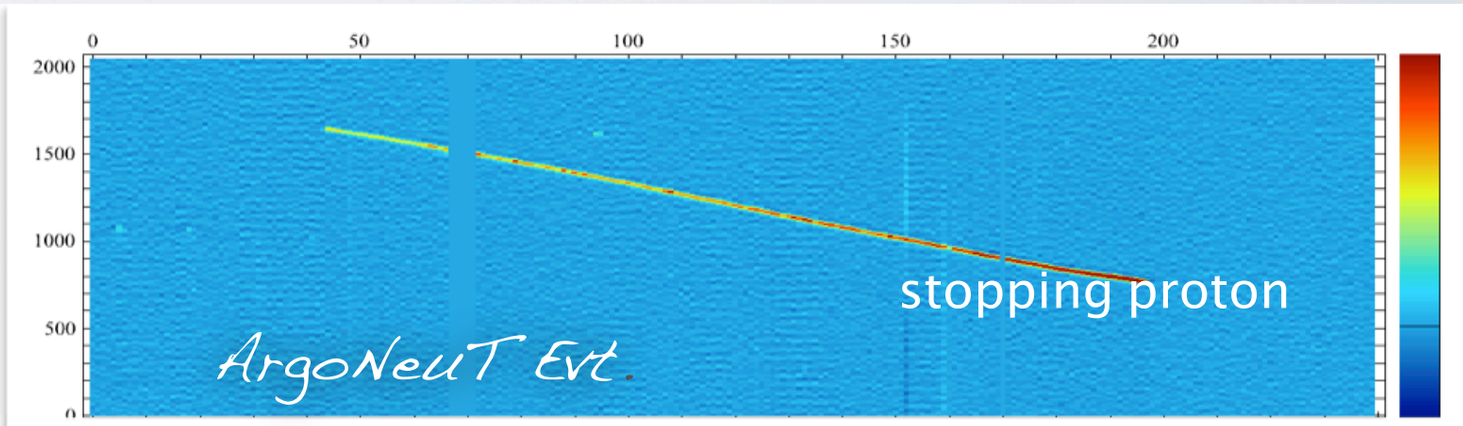


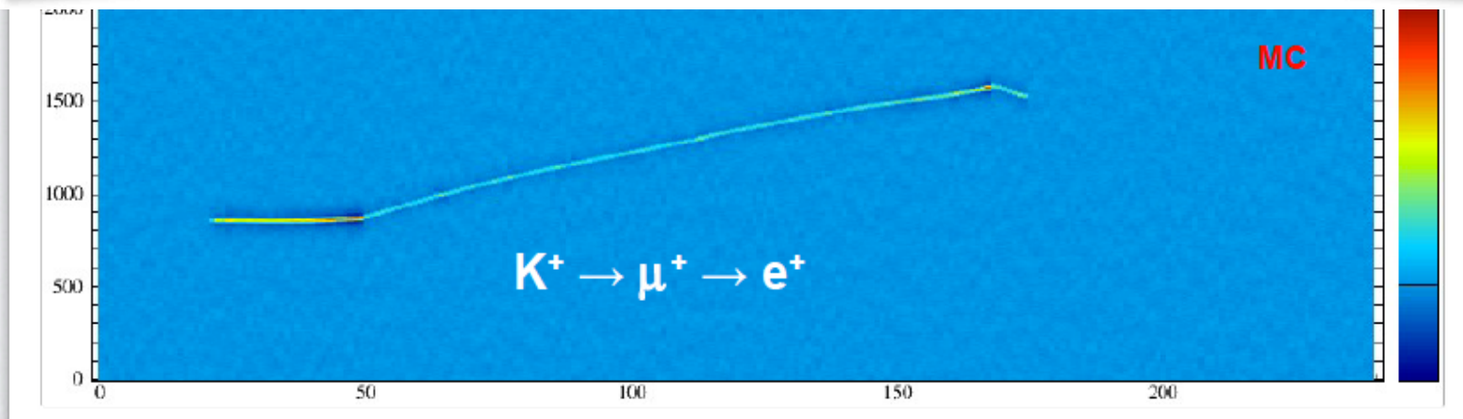
Kaon discrimination

Study recombination along stopping tracks:

- Kaon to proton separation
- Kaon to pion separation

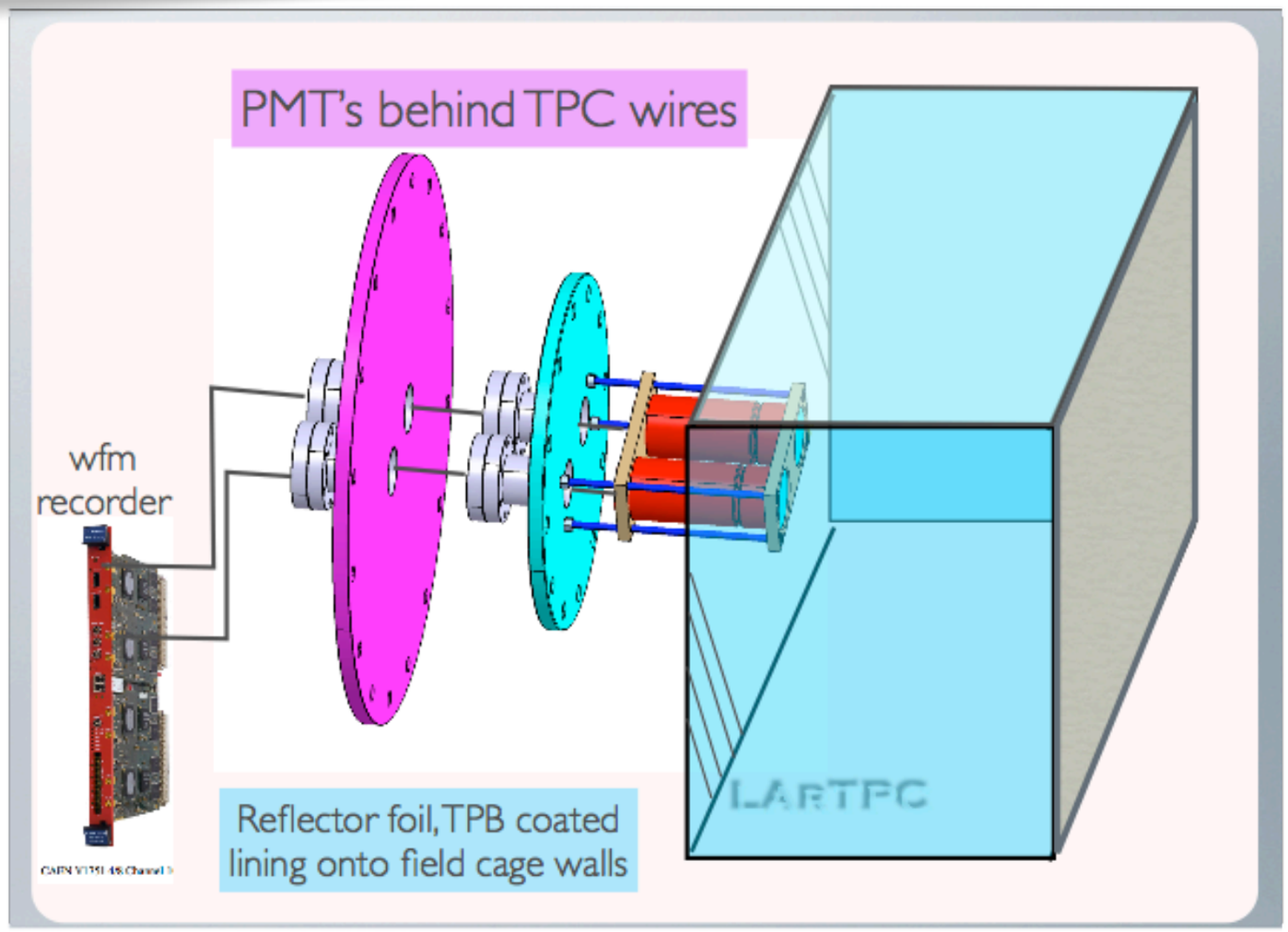
p-decay (LBNE UG)





Antiproton annihilation (relevant for n-nbar oscillations)

Development of a new concept in LAr Scintillation Light Collection



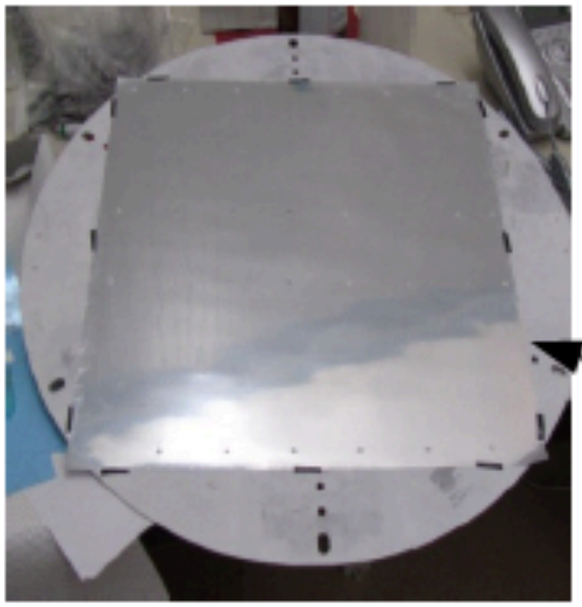
To enhance efficiency of light collection one has to increase the detector active surface.
This can be achieved by increasing the n. of PMTs (expensive) OR by adding a reflector coated by wl.s. on the boundary of the detector volume.
Scintillation VUV photons thus are wl.shifted when hitting the TPB and then reflected from the mirror surface beneath multiple times up to collection at the PMT

Relate energy deposited

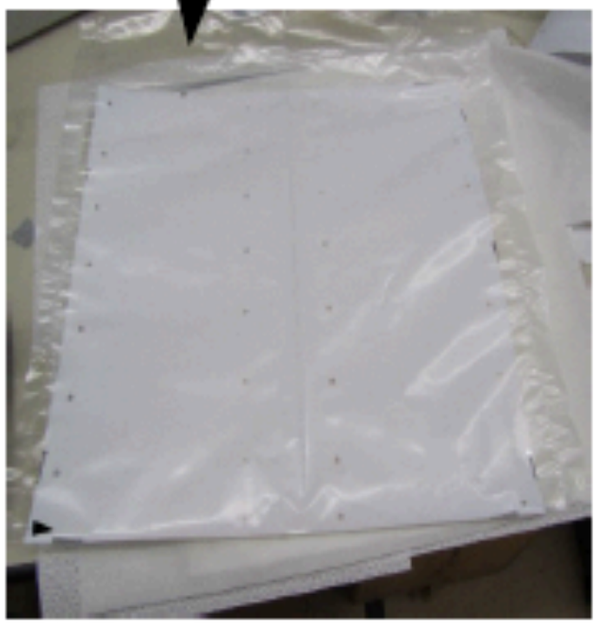
into CHARGE AND LIGHT

for an improved calorimetric energy resolution

Development of a new concept in LAr Scintillation Light Collection



Applying TPB to the reflective foil that will line the inside of the LArIAT TPC



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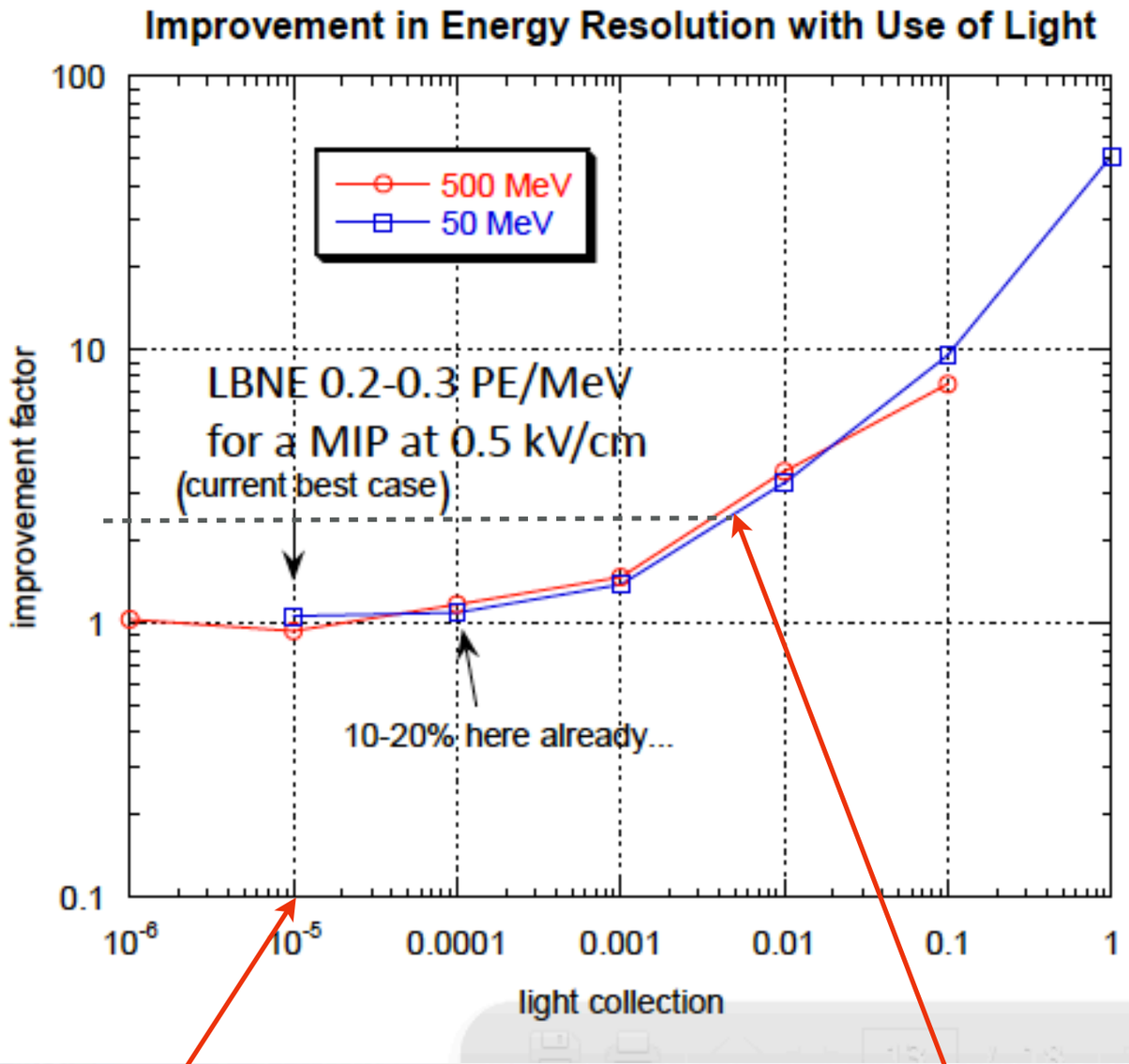
Scintillation VUV photons thus are wl.shifted when hitting the TPB and then reflected from the mirror surface beneath multiple times up to collection at the PMT

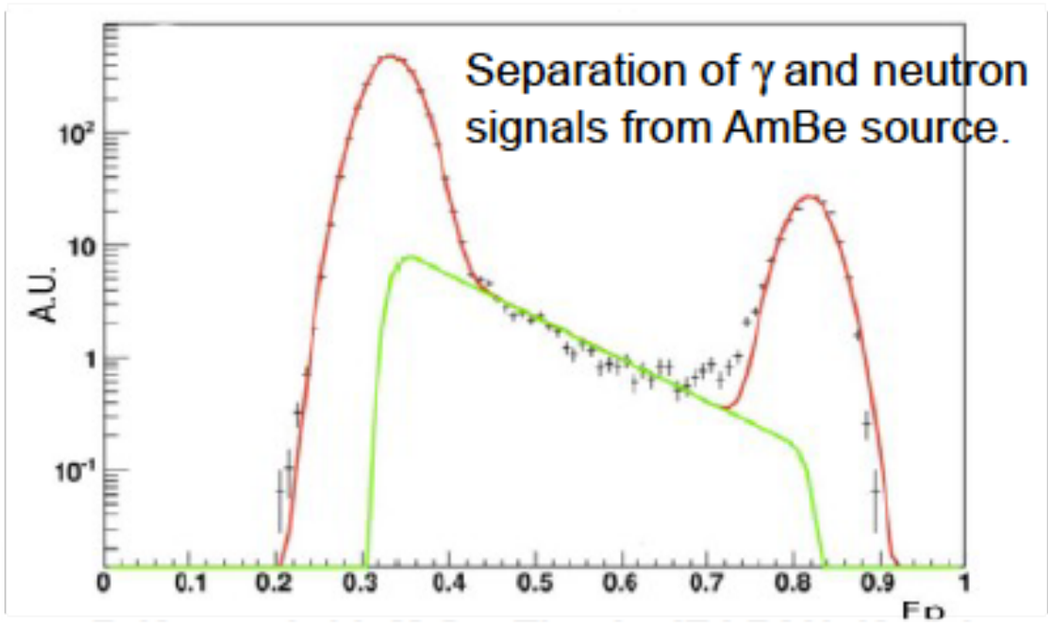
Matthew Szydagis, UC Davis

FNAL, Software Workshop, Thursday 3-21-13

Energy Resolution



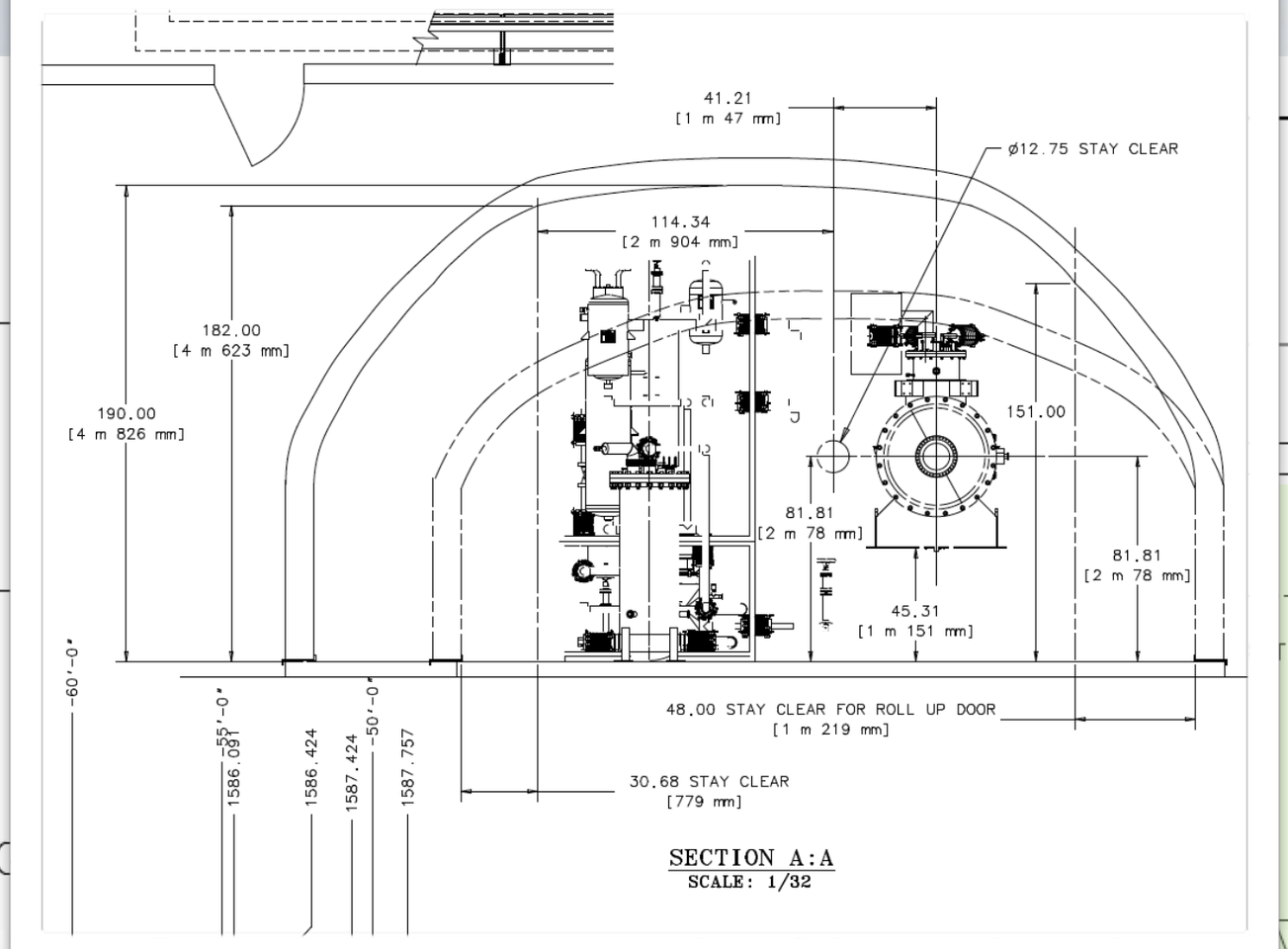
	LC (frac)	CY [%]	LY [%]	comb [%]	opt [%]	<-- with	improv
500 MeV	1.00E-06	0.33	79.32	0	0.32	0.001	1.0313
	1.00E-05	0.31	9.07	3.28	0.33	0.1	0.93939
	1.00E-04	0.34	3.96	1.19	0.29	900	1.1724
	0.001	0.34	1.2	0.33	0.23	300	1.4783
	0.01	0.36	0.72	0.12	0.1	90	3.6
	0.1	0.27	0.48	0.037	0.036	11	7.5
50 MeV	1.00E-06	0.98	100				
	1.00E-05	1.21	29.01	10.96	1.14	0	1.0614
	1.00E-04	1.01	9.95	3.51	0.92	900	1.0978
	0.001	0.93	3.8	1.11	0.67	300	1.3881
	0.01	1.11	2.39	0.37	0.34	90	3.2647
	0.1	1.05	2.18	0.11	0.11	10	9.5455
	1	0.97	1.91	0.019	0.019	1	51.053



0.2 PE/MeV ≃ 10 ppm of the available light

~100 PE/MeV ≈ 1% of the available light

➪ factor >2 improvement in energy resolution



SECTION A:A
SCALE: 1/32

Cryo-Purification system

TRACKING CHAMBER

TIME OF FLIGHT #2

B1(X=31.411",Z=136.057")

Ø12.75 STAY CLEAR

CRYOSTAT

10.5° 5.5°

13.0°

5.0° 3.0°

5.0°

41.21
[1 m 47 mm]

SECONDARY BEAM

WC1 WC2 B1 B2 WC3 WC4

Ø30.00 STAY CL

LArIAT Enclosure

Tertiary BeamLine

LAr Detector

STAY CLEAR FOR
FROM FLOOR UP 100

3",Z=162.712")

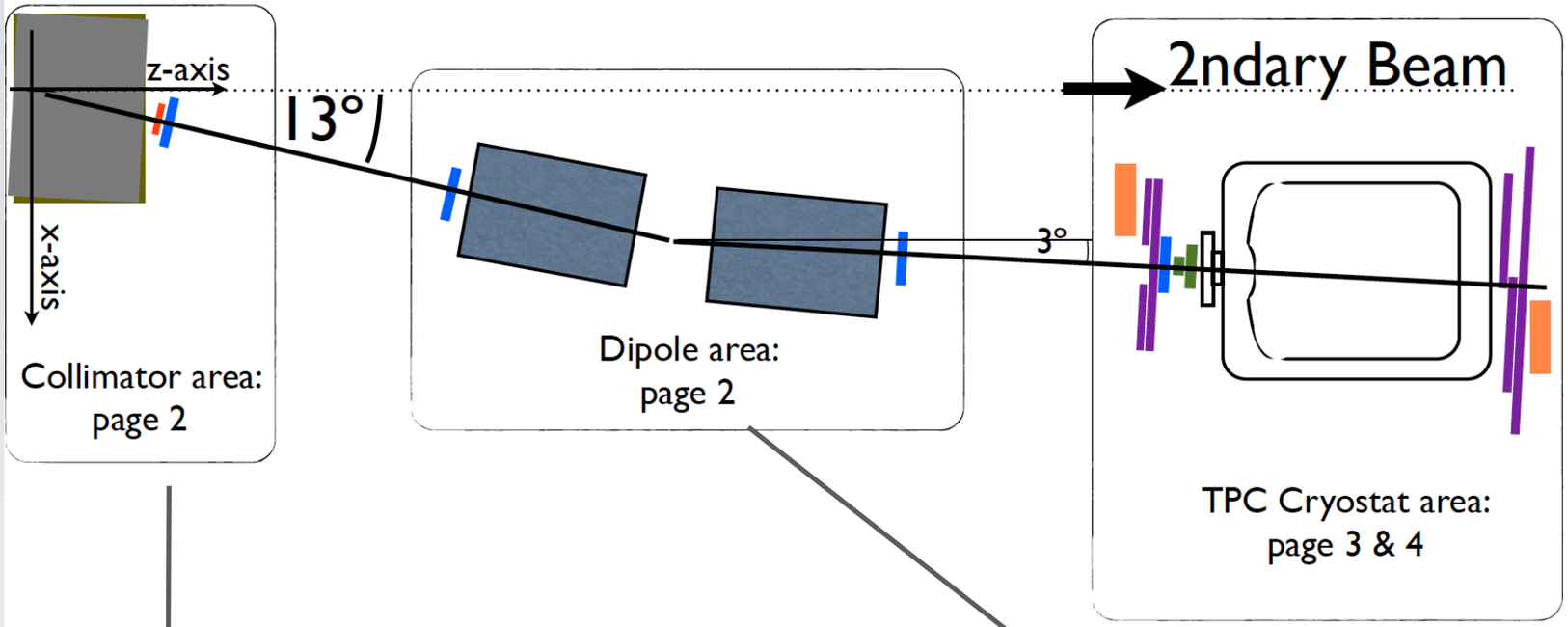
27.00 STAY CLEAR ABOVE 99.00

DO NOT BLOCK ROLL
DOOR IN THIS AREA

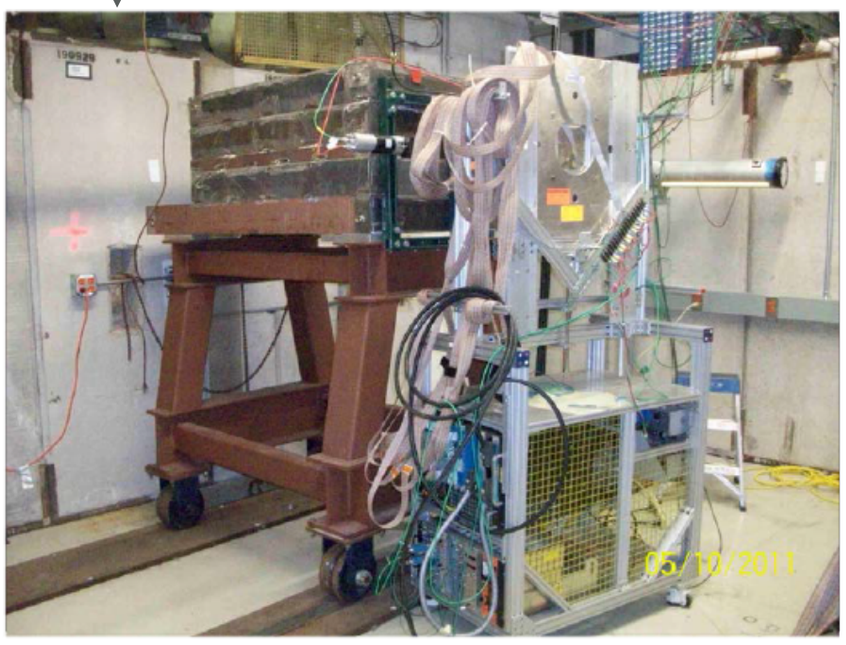
48.00
[4'-0"]

LAriaT Tertiary Beamline Instruments

US TOF paddle
DS TOF crossed paddles
Wire Chambers 1,2,3,4
Halo Veto paddles
Punchthrough paddles
Cosmic Finders



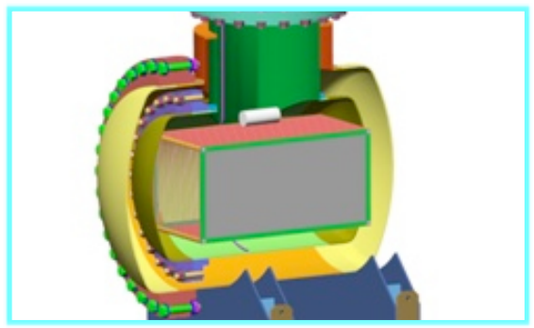
Block diagrams for beamline layout and use in mechanical support design

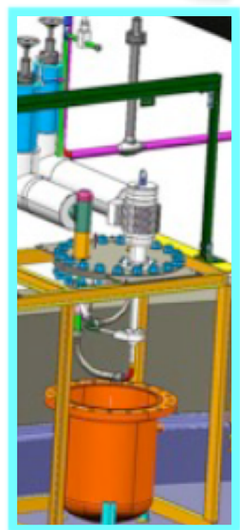


in red the “stay clear” zones (secondary and tertiary beams)

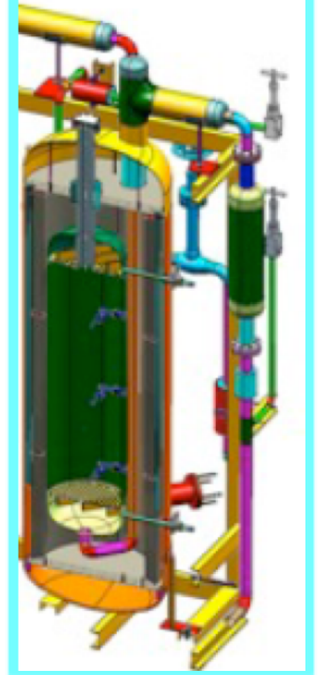
FTBF-LAr Facility:

Cryogenic & Purification System & flexible LArTPC DAQ system





LAr Pump



Filter

NOTE 1 PIPING TERMINATES IN A 1 INCH MALE SWAGELOK VCR FITTING OUTSIDE THE
NOTE 2 PIPING TERMINATES IN A 1/2 INCH MALE SWAGELOK VCR FITTING OUTSIDE
NOTE 3 PIPING TERMINATES IN A 1/4 INCH MALE SWAGELOK VCR FITTING OUTSIDE
NOTE 4 PIPING TERMINATES IN A 3/4 INCH MALE SWAGELOK VCR FITTING OUTSIDE
NOTE 5 DIELECTRIC BREAK FLANGES ON BOTH ARGON PIPING AND VACUUM JACKET.
NOTE 6 KF40 FITTING ATTACHED TO VACUUM JACKET.

UNLESS OTHERWISE SPECIFIED	ORIGINATOR	T.TOPE	03-APR-2013
	DRAWN	J.CATALANELLO	03-APR-2013
± ± ±	CHECKED		
1. BREAK ALL SHARP EDGES MAX.	APPROVED		
2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON	USED ON		
4. MAX. ALL MACH. SURFACES	MATERIAL		
5. DRAWING UNITS:			

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MECHANICAL/COOLING SYSTEMS
LIQUID ARGON TEST BEAM
FLOW SCHEMATIC

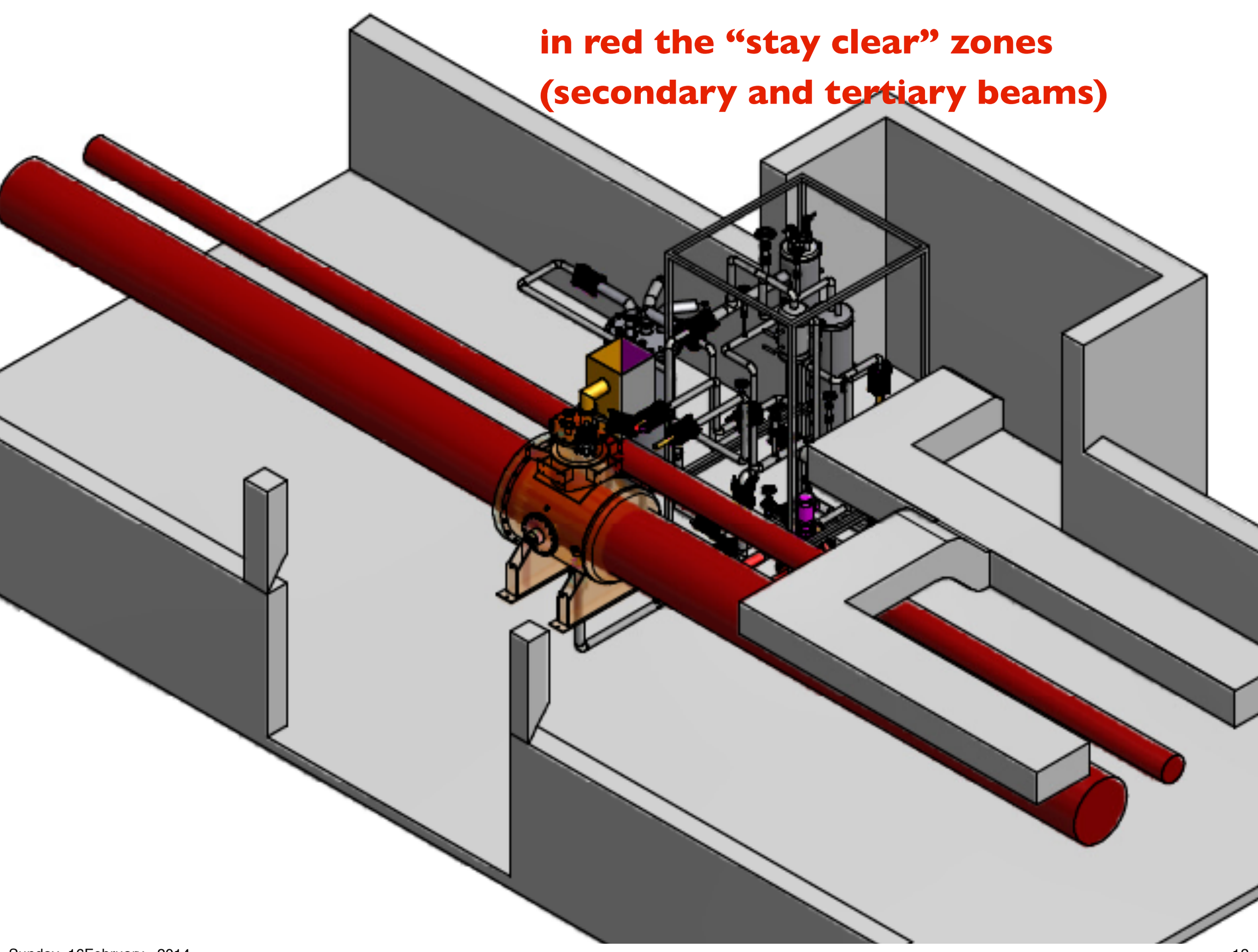
SCALE	DRAWING NUMBER	SHEET	REV
NONE	9212.100-MD-493666	1 OF 1	

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

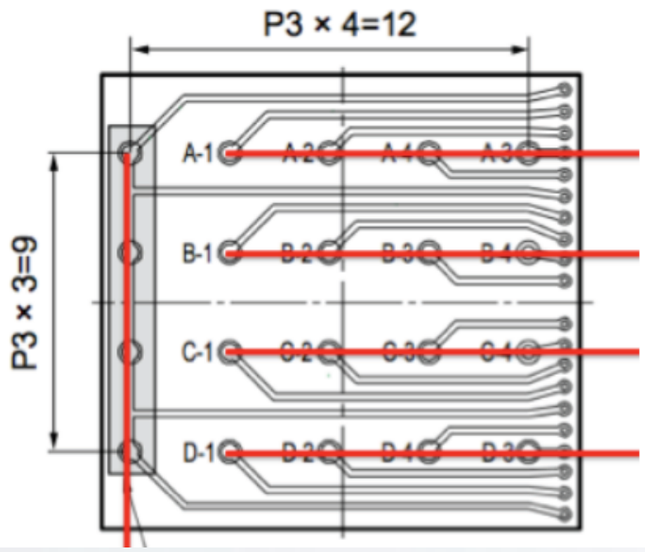
Components

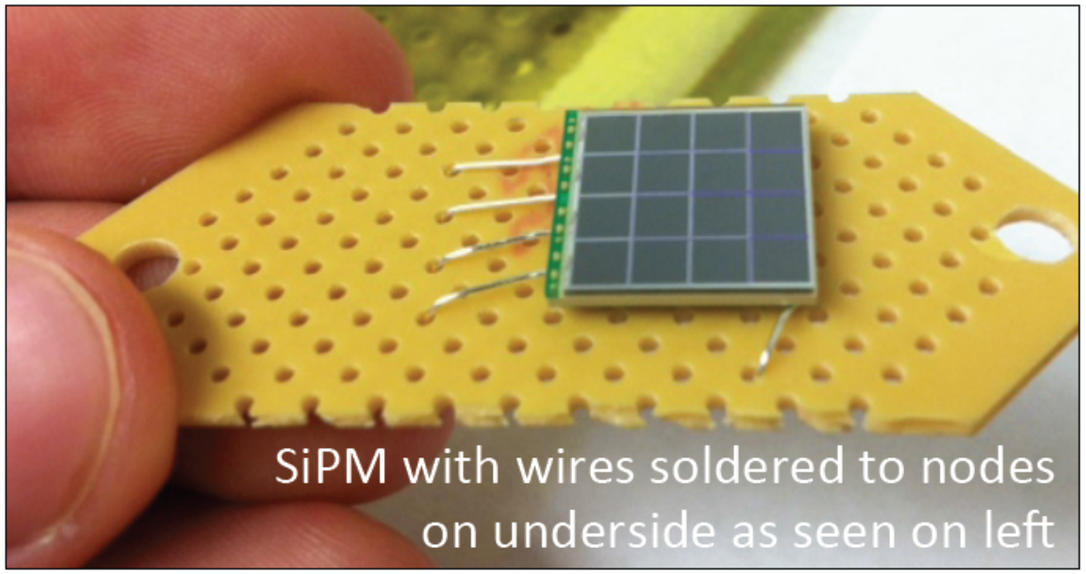
already available

in red the “stay clear” zones
(secondary and tertiary beams)



Mounting the SiPM

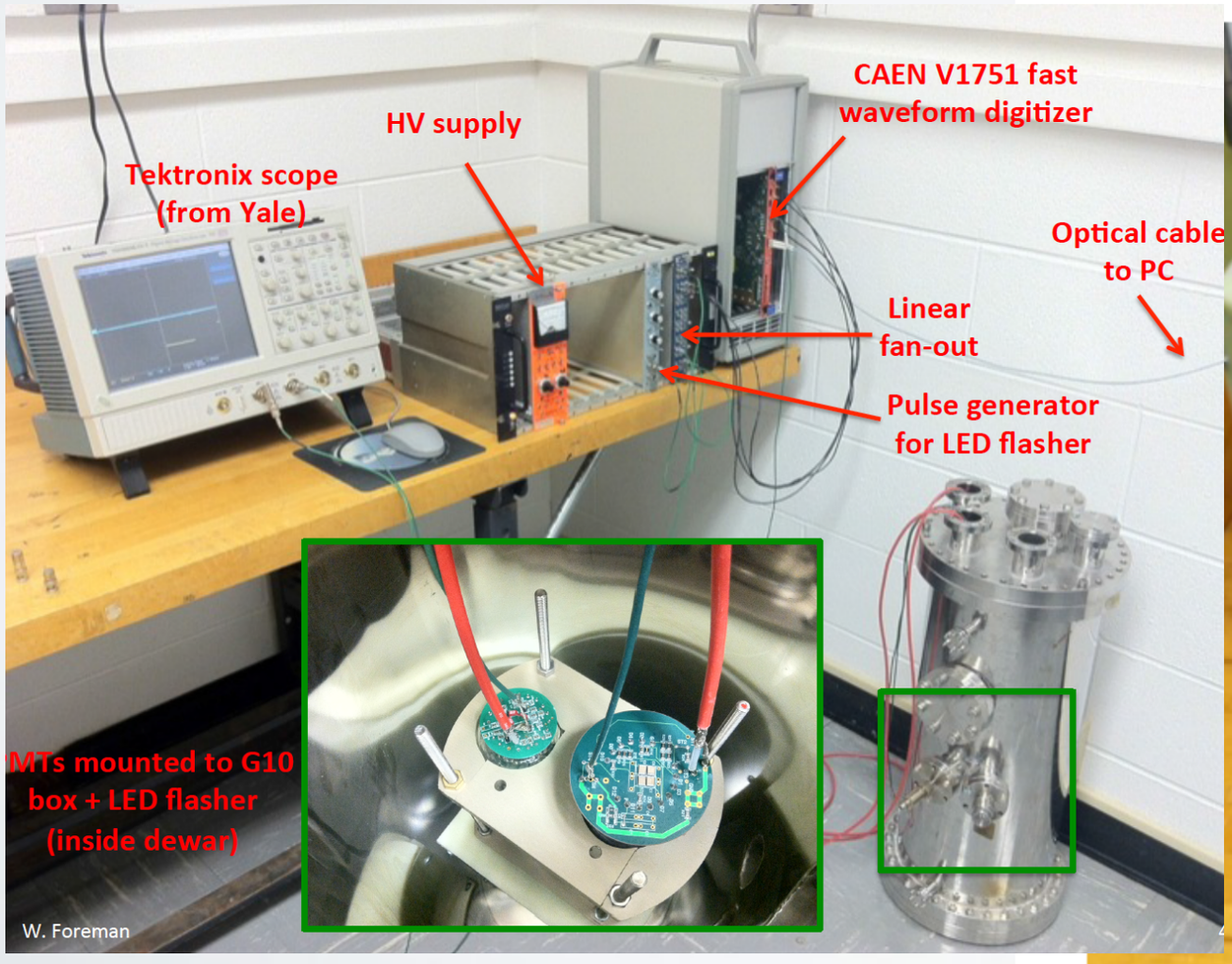


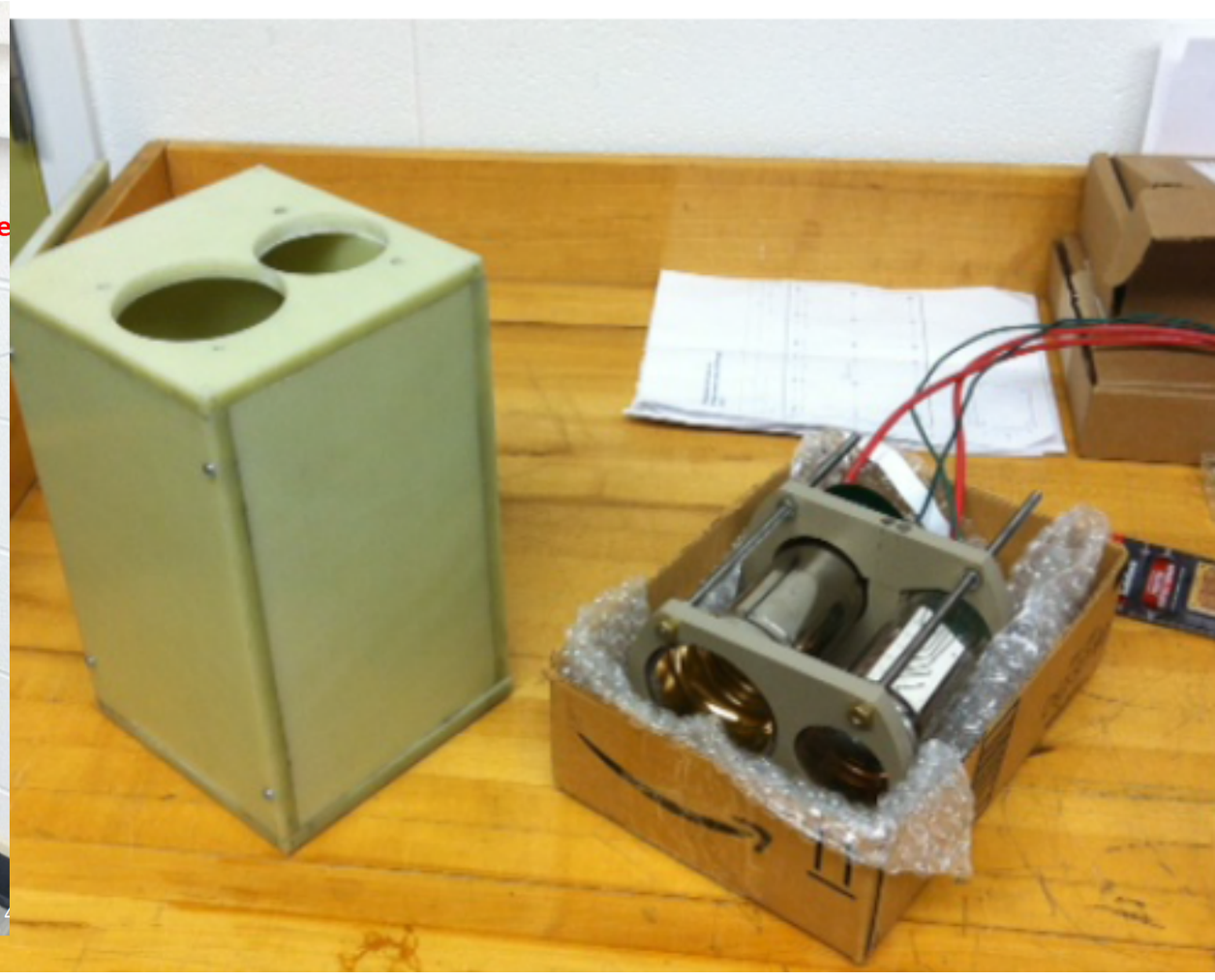


The LArIAT
Scintillation Light System

- Yale + UoChicago

(test stand at U. of Chicago)



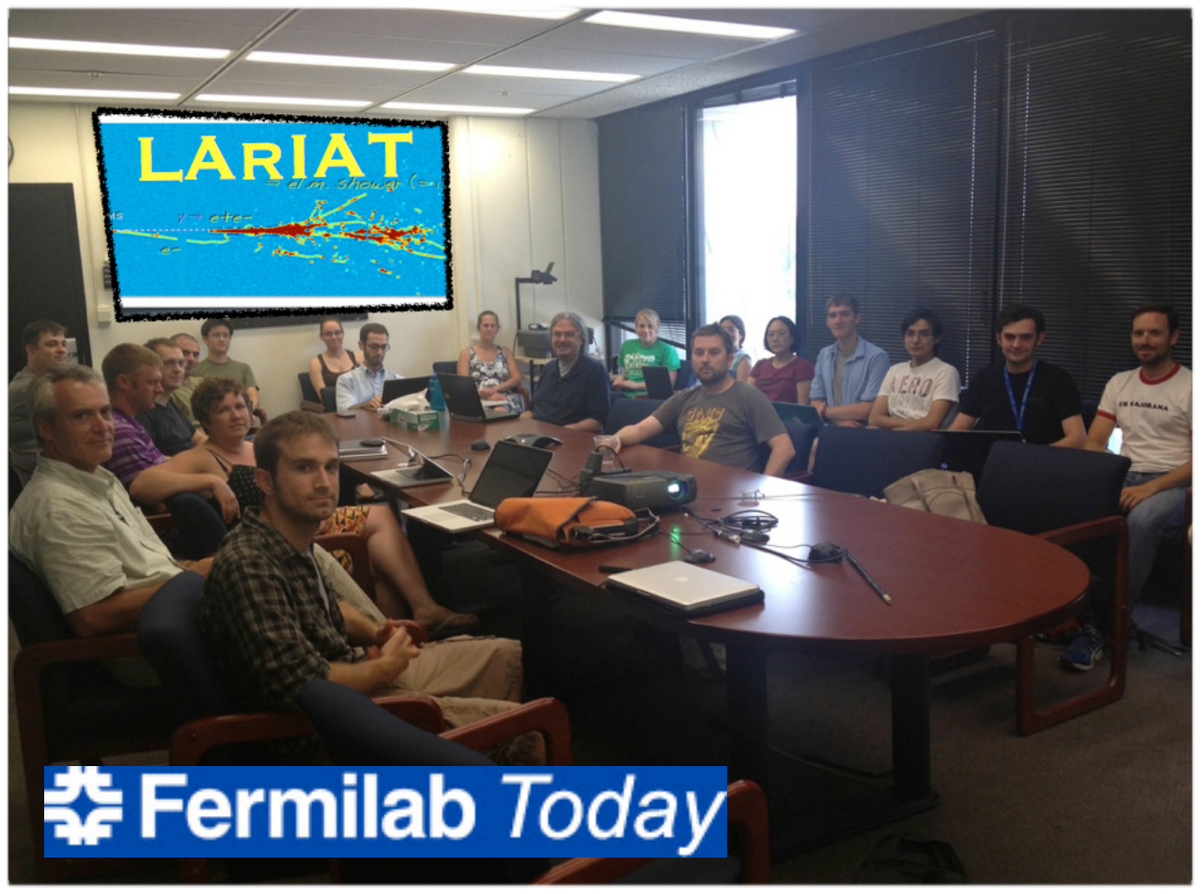


THE COLLABORATION

- 65 Collaborators
- 3 US national labs
- 12 US universities
- 5 foreign institutions
- *and 20+ students in summer*

new groups are in the process to join

Argonne	J. Paley
Boston U.	E. Kearns, D. Gastler and R. Linehan
Caltech	R. Patterson
Chicago	W. Foreman, J. Ho, D. Schmitz
Cincinnati	R. Johnson, J. St John
Fermilab	R. Acciarri, P. Adamson, M. Backfish, W. Badgett,B. Baller, A. Hahn, D. Jensen, T. Junk, M. Kirby, T. Kobilarcizk, P. Kryczynski, H. Lippincot, A. Marchionni, K. Nishikawa, J. Raaf*, E. Ramberg, B. Rebel, M. Stancari, G. Zeller
Imperial Col. London	M. Wascko
KEK (just joined)	T. Maruyama, E. Iwai, S. Kunori
Los Alamos	C. Mauger
Louisiana State	F. Blazsczyk, W. Metcalf, A. Olivier, M. Tzanov
Manchester	J. Evans, P. Guzowski
Michigan State	C. Bromberg, D. Edmunds, D. Shoo
Minnesota – Duluth	R. Gran, A. Habig, K. Kaess
Syracuse	J. Asaadi, M. Soderberg, J. Esquivel
Texas – Arlington	A. Farbin, S. Park, J. Yu
Texas – Austin	J. Huang, K. Lang
University Col. London	R. Nichol, A. Holin, J. Thomas
William and Mary	M. Kordosky, M. Stephens, P. Vahle
Yale	F. Cavanna*, E. Church, B. Fleming, E. Gramellini, O. Palamara, A. Szelc



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

* elected spokespersons

Structure of the Collaboration

RUN COORDINATOR

MC7 Coordinator

Tertiary **B**eam Operation Manager

Cryo/**P**urif. Operation Manager

TB Task Grp.

- Magnets
- Pwr.Supply & Cooling
- Target & Collimators
- Shield
- Geometry
- Survey
- Liaison w/FTBF

CP Task Grp.

- Cryo-plant
- Filters
- Gas Analyzers
- SlowCtrl (P,T,lev)

Ctrl Room

Trigger/DAQ Coordinator

Beam **Det**ectors Operation Manager

BDet Task Grp.

- FTBF-counters
- Veto-counters
- Cherenkov
- CRμ-counters

LAr Detector

(inside cryostat) Operation Manager

(outside cryostat) Operation Manager

LArDet. Task Grp. 1

- TPC
- Cold Electronics
- Scint.Light System
- Det. Calibration

LArDet. Task Grp. 2

- HV
- LV
- Cabling
- DAQ

R&D's at FNAL (+μB): Timeline

we're here

LAPD + LongBO

LArIAT I Construction & Installation

LArIAT I Data Taking

LArIAT II Cryostat&TPC Design, Construction and Installation

LArIAT II Data Taking

Summer 2013 | Winter 2013 | Summer 2014 | Winter 2014 | Summer 2015 | Winter 2015 | Summer 2016 | Winter 2016 | Summer 2017

CAPTAIN Installation & Data Taking

LBNE 35T Prototype Phase I

TPC Construction and Installation

LBNE 35T Prototype Phase 2

LBNE CD2 Review

MicroBooNe Construction & Installation

MicroBooNe Data Taking

SUMMARY

- FNAL review (Dec.12-Jan.13) concluded:
  "a very worthwhile investment"
- LARIAT is a well established, major component of the LAr R&D program in US
- Wide support in the LAr community
- Well aligned with MicroBooNE and LBNE
- Strong support from FNAL permitted the realization of the LAr Facility at FTBF *(ready for Phase-1 and Phase-2)*
  - *LAr* Cryogenic/Purification System
  - New flexible DAQ system for LArTPC
- DOE/Yale funding & Significant in-kind contributions from Labs and University Groups permitted detector realization (Phase-1)

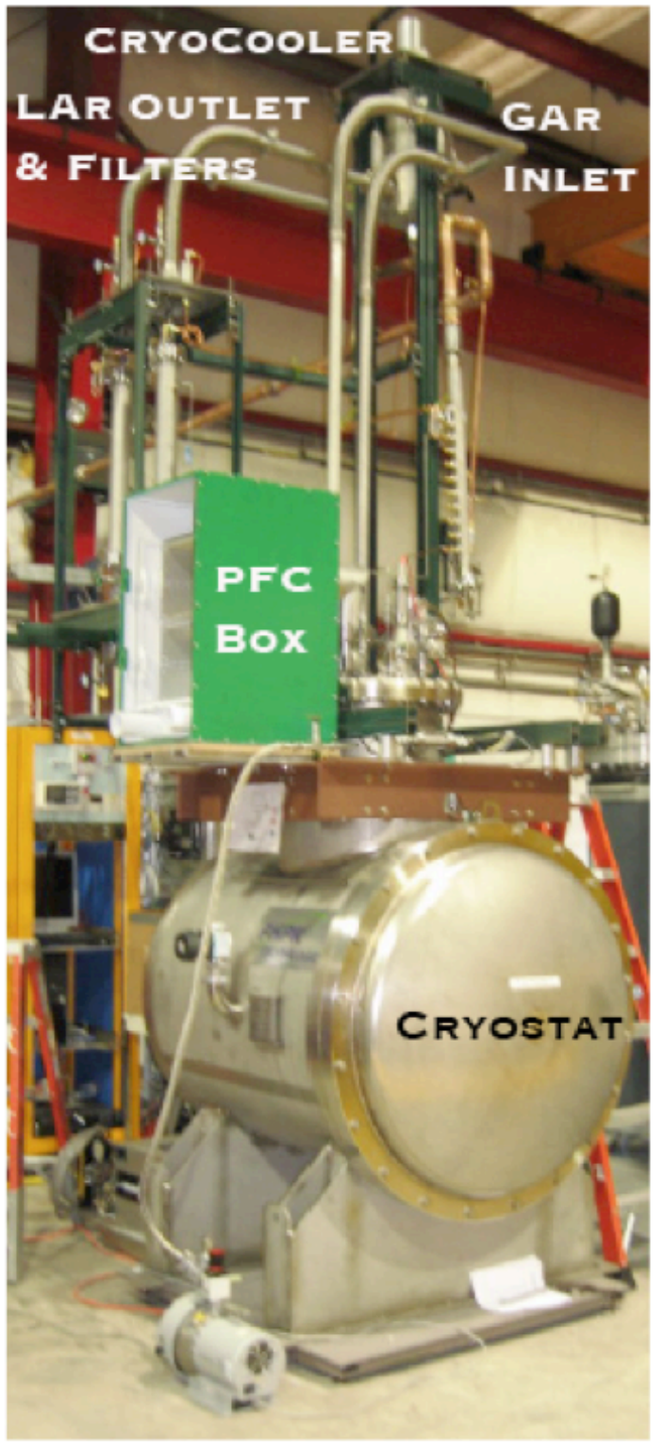
CONCLUSIONS

- LARIAT will create a new cadre of experimenters with deep experience in LArTPC technology: Training of (young) physicists during extended beam operation and real data analysis is an invaluable add-on in view of future Short & Long Baseline/Underground LArTPC experiments
- Short Term: Augments investment in MicroBooNE
  - Controlled testbeam conditions buttress MicroBooNE findings
- Longer Term: LBNE will profit from higher confidence in the estimate of signal to background separation from MC simulations, and later on from data analysis
- Data and conclusions available to global LArTPC community
- International – worldwide – collaboration *(few new grp.s are welcome..)*

Long history of test beam exposures prior to major experiments shows this is the right thing to do.

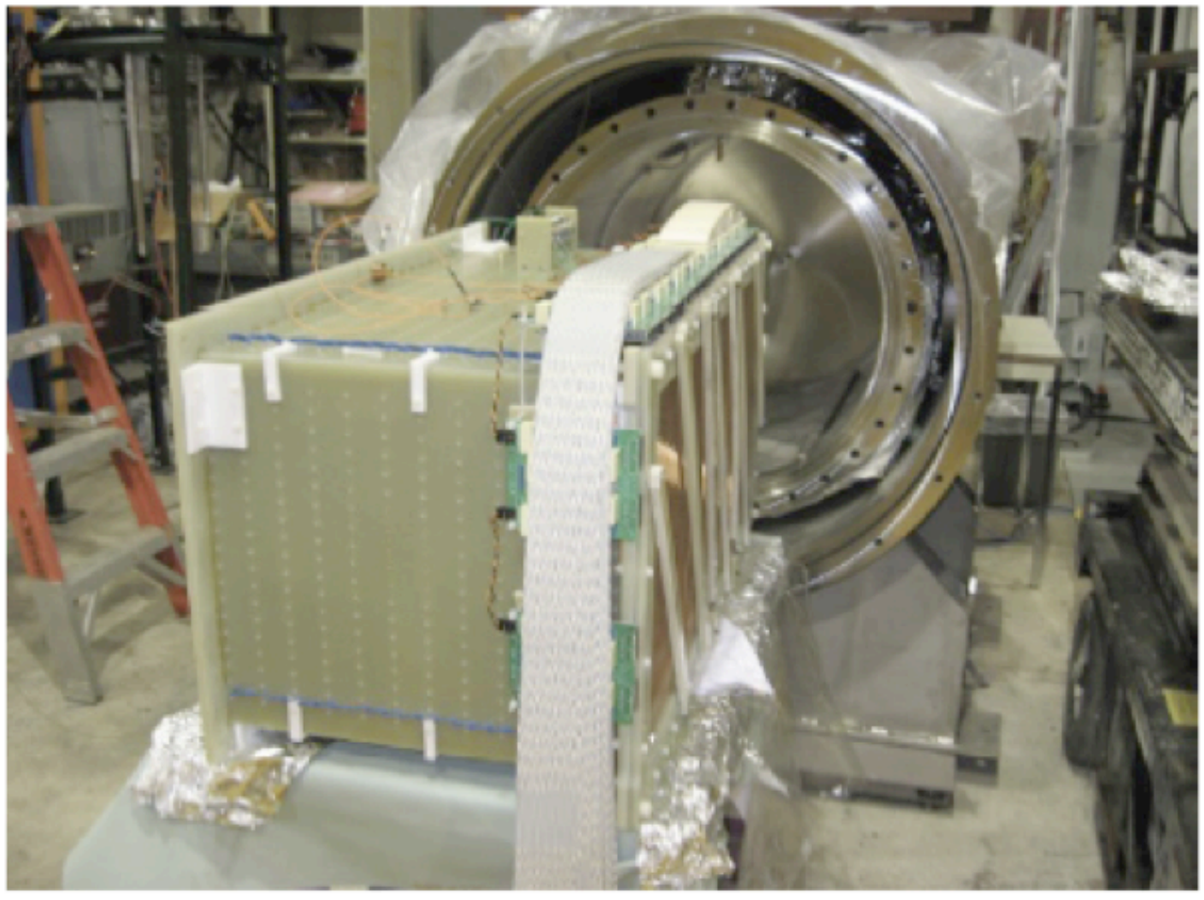
BACKUP SLIDES

LAR TPC

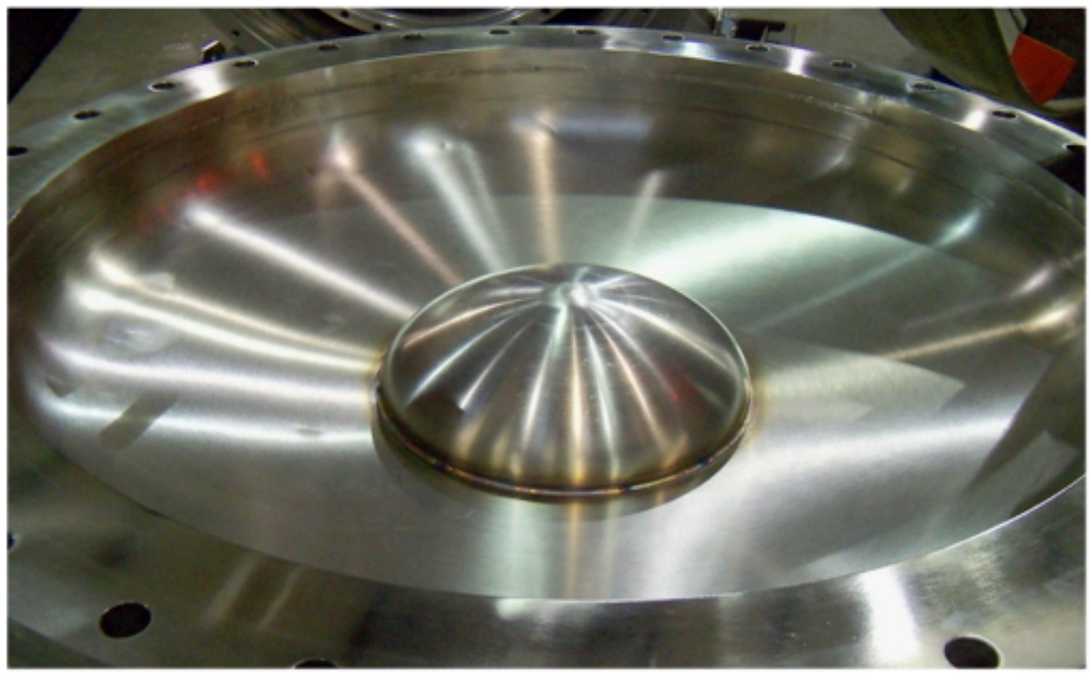


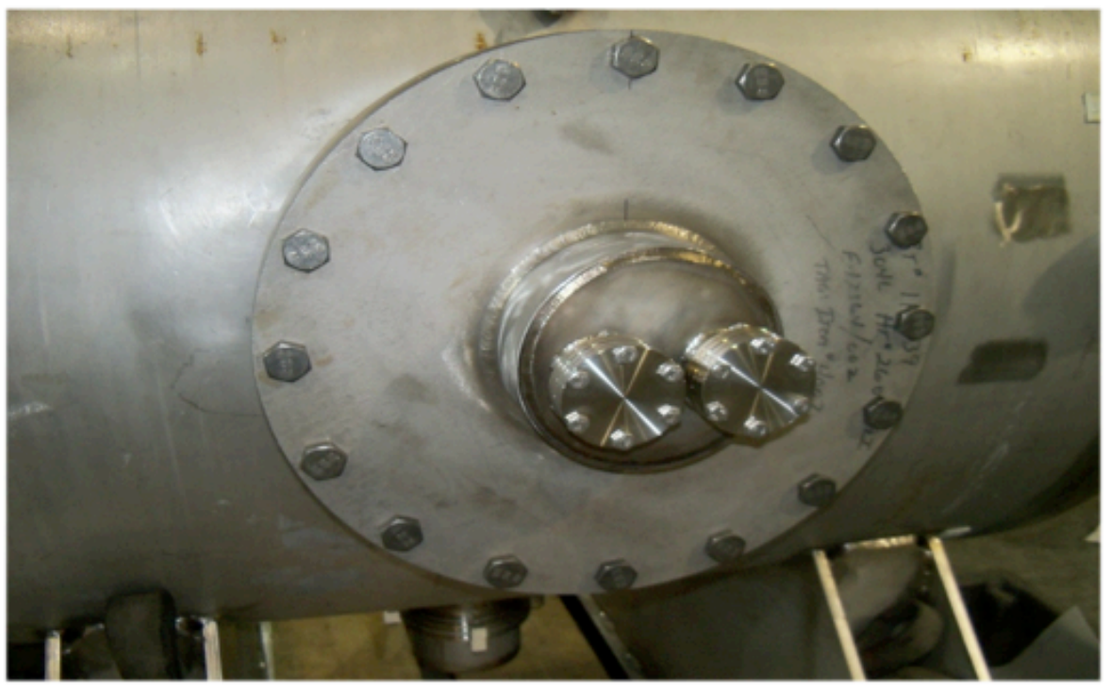
Capitalize on ArgoNeuT
effort and infrastructure

Leverages initial investment

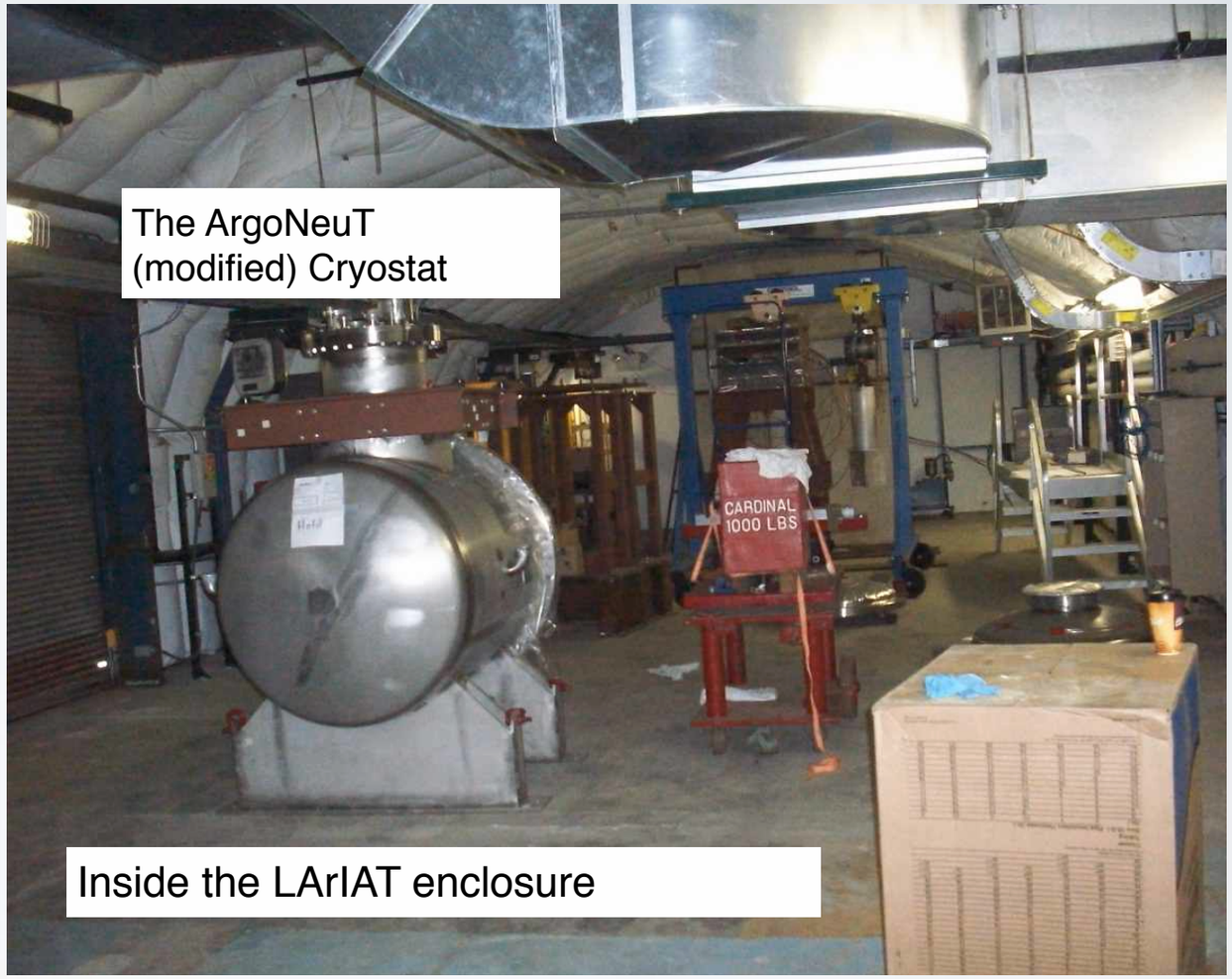


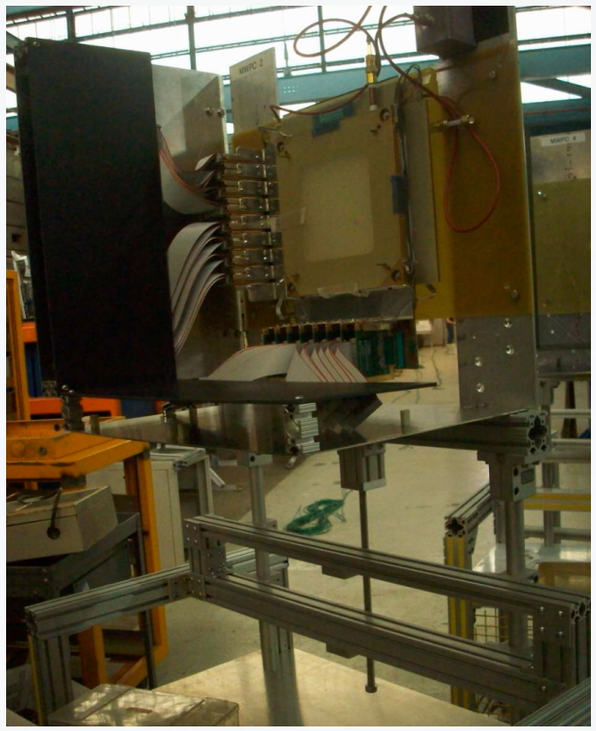
CRYOSTAT MODIFICATIONS





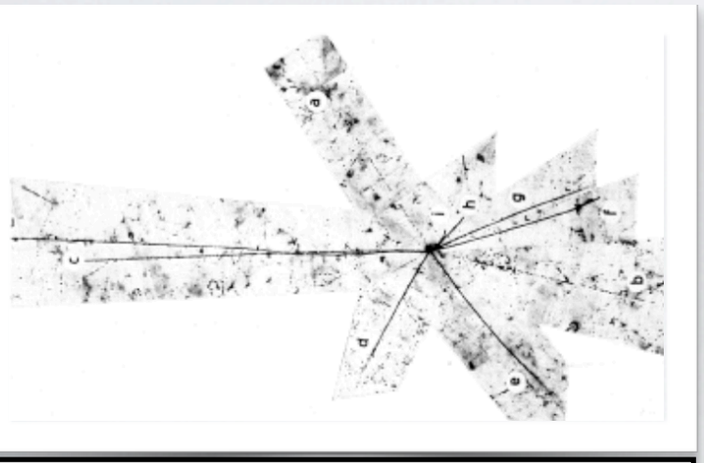
FTBF (Meson Hall at FNAL)





STUDY NUCLEAR EFFECTS

- Nuclear effects are always an unknown for neutrino experiments
- Study fixed q^2 (t) transfer to nucleus by:
  - Elastic scattering
  - Quasielastic scattering
  - Antiproton annihilation (n-nbar oscillation - LBNE UnderGround)



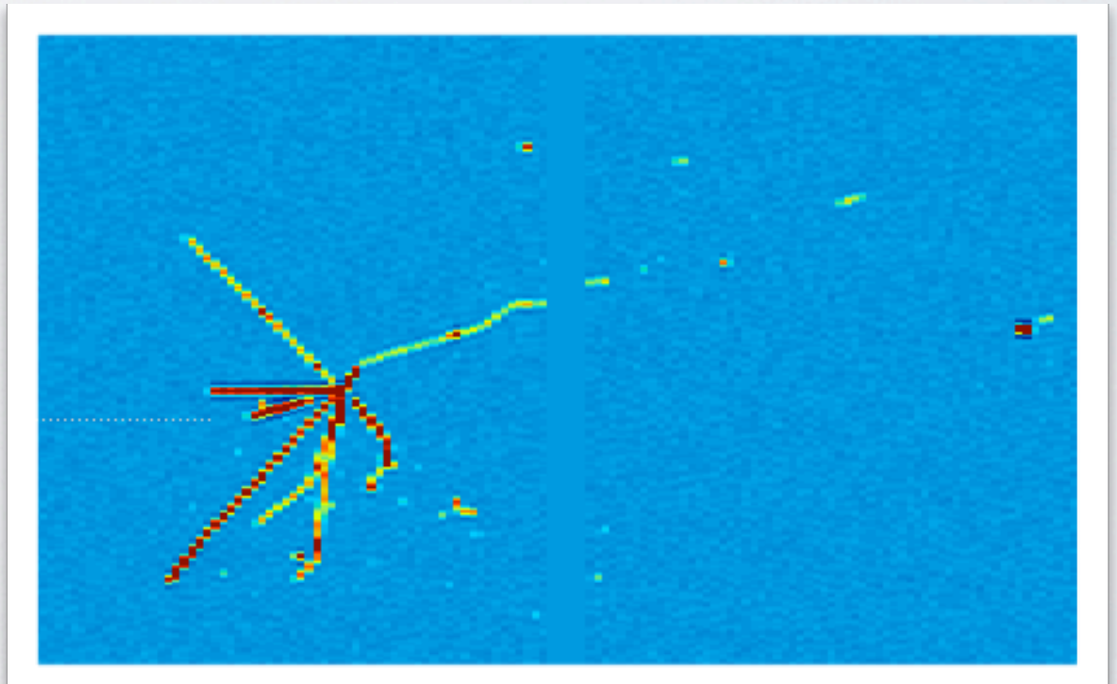
Antiproton Star Observed in Emulsion*

O. Chamberlain, W. W. Chupp, G. Goldhaber, E. Segrè, and C. Wiegand, *Radiation Laboratory, Department of Physics, University of California, Berkeley, California*

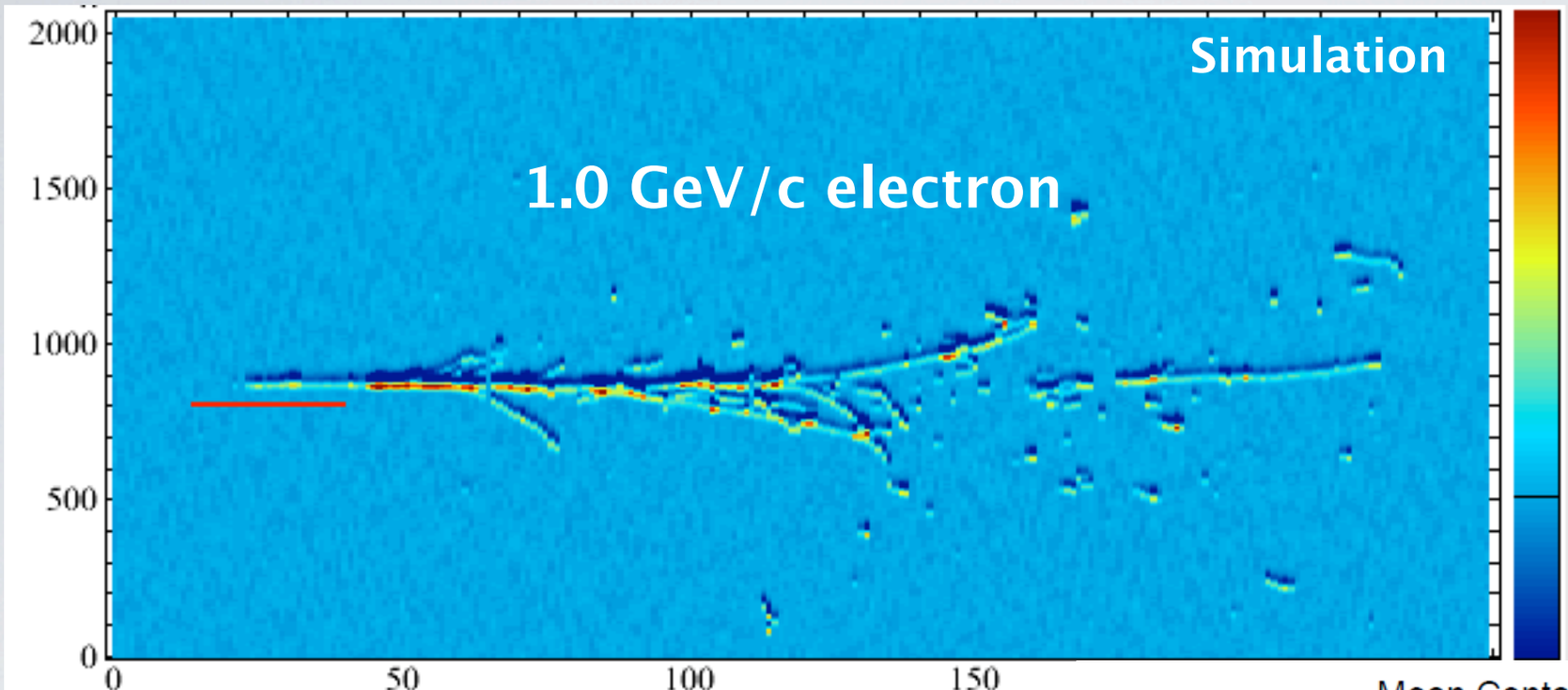
AND

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

Simulation of Antiproton Star in LAr

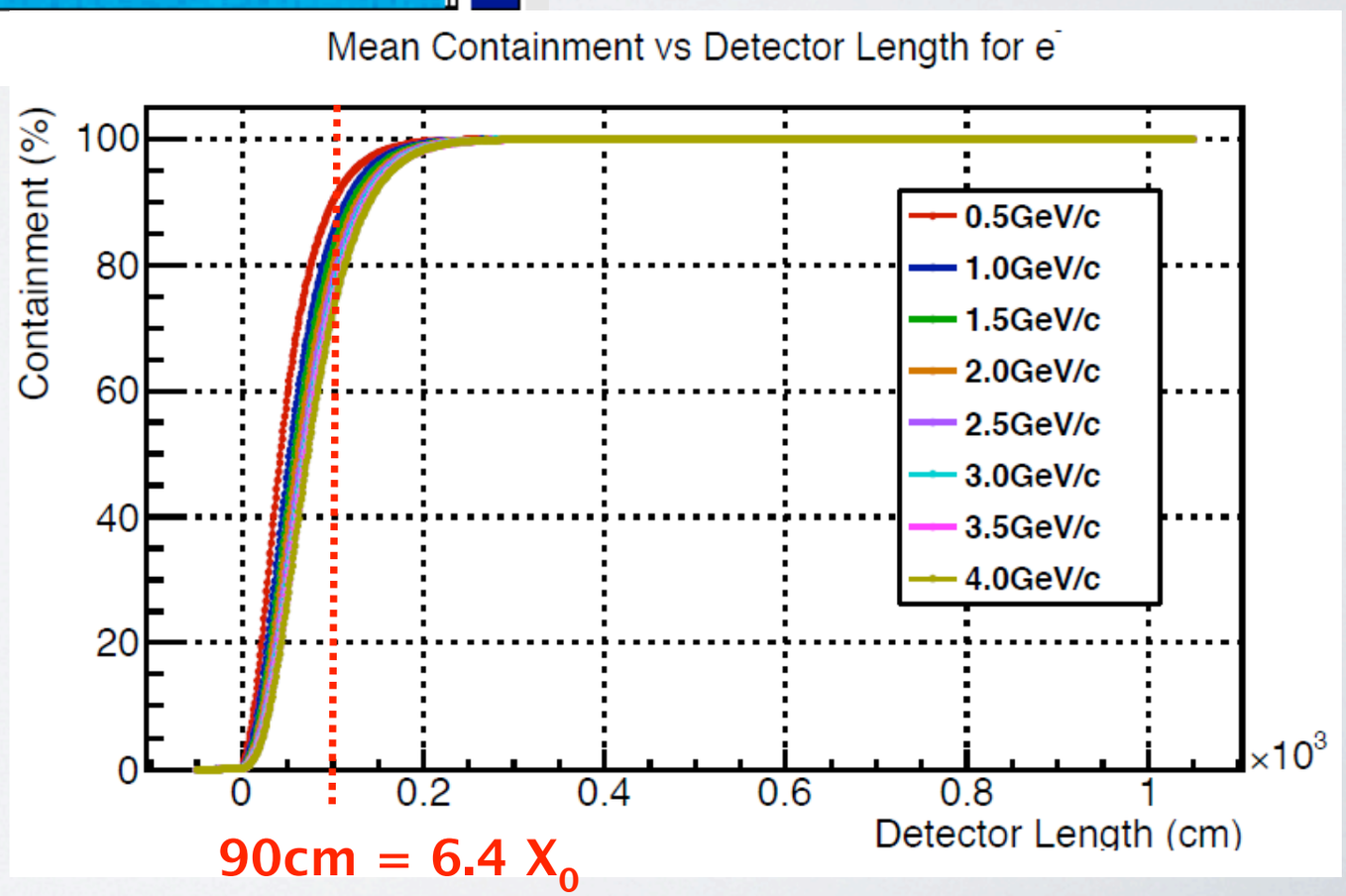


ENERGY MEASUREMENTS

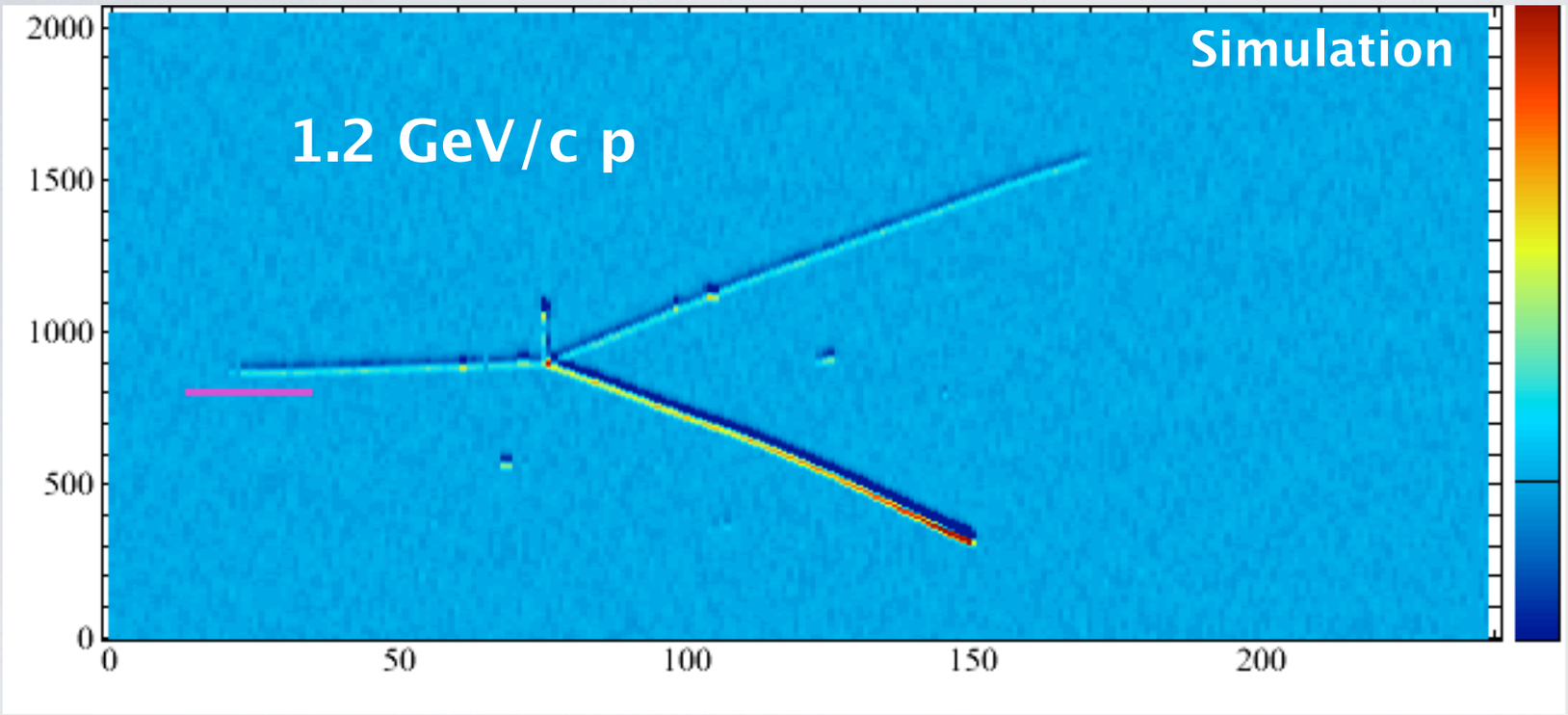


Benchmark MC

<u>Electrons</u>
~85% containment
for p <1 GeV/c
<u>Stopping range</u>
protons p<1 GeV/c



HADRONIC INTERACTIONS



- $\sigma_{REACTION}$ seems doable.
- Motivation: FSI, reco. syst., calorimetry (study shower beginning)
- Naively, poor containment. Can one do better by incorporating topology? EM fraction?

PION CONTAINMENT