Fermilab

Operated by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Fermilab Report

Nigel Lockyer

HEPAP

06 April 2015

Science is happening

- LHC Run 2 starts in June, CMS detector ready to go
- NOvA, MINERvA, MINOS+ all running well
- MicroBooNE almost ready to fill
- g-2 SC magnet powers up soon
- SuperCDMS taking data with lower energy thresholds
- DAMIC upgrading, DarkSide-50 filling with “underground” LAr from Fermilab
- SeaQuest results expected this month
- Theory group supporting LHC, neutrinos, lattice…
- Several Tevatron analyses wrapping up
- **World’s best spin-dep. dark matter limit from PICO-2L!**
- **Holometer gravity wave results!**
- **And the Dark Energy Survey made a discovery!!**

DOE Institutional Review of Fermilab, Feb 10-13

Quotes from the closeout:

- Lab is aligned very well to P5 priorities & following P5 recommendations
- There is palpable excitement for the recent positive developments in securing international support for the long baseline neutrino program
- The Laboratory is much more focused than in previous years
- Fermilab has long been the focal point for high energy physics in the United States. The lab should strive to maintain this role
- The Lab has made significant progress in the design of PIP-II. This will maintain FNAL leadership in intense beams for the coming decades

P5 plan for US HEP in a nutshell

- Continue our commitment and leading roles in the LHC
- Build a neutrino program that will attract the world community
- Continue leading efforts in dark matter, cosmic surveys & CMB
- Invest in the accelerator and detector technologies that we will need in the future

It is a feature of this plan that the major components reinforce each other

Fermilab is “Building for Discovery”

- NOvA CD-4 Sept 2014 ✔
- CMS phase 1 upgrades CD-2/3 ESAAB Nov 2014 ✔
- MicroBooNE CD-4 received Dec 2014 ✔
- Utility SLI baselined Dec 2014 ✔
- Mu2e CD-2/3b received Mar 2015 ✔
- Muon g-2 CD-2/3 expected late spring 2015
- LBNF/DUNE CD-1 refresh, CD-2a/3a both in 2015
- PIP-II CD-0 review scheduled for June 2015
- SuperCDMS SNOLAB, CD-2 hoped for by end of 2015
- CMS HL-LHC pre-CD-0 but projectized management of R&D
- HL-LHC accelerator is pre-CD-0 but international CRADA with CERN to purchase Nb_3SN magnet conductor
- + LCLS-II + DESI + SLI projects

List limited to US projects with significant FNAL involvement in project management

P5 top priorities: Neutrinos

Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

Recommendation 13: Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest-priority large project in its timeframe.

- A big commitment by the US HEP community
- Basically asks Fermilab to do for neutrinos what CERN did for the Higgs, involving the worldwide community

P5 neutrino mandate for Fermilab

- Encourage formation of a new international collaboration to build large liquid argon detectors deep underground
- Provide a > 1 megaWatt neutrino beam for LBNF (PIP-II)
- Develop a short baseline neutrino program that advances liquid argon R&D

  The short baseline program should be coherent with both LBNF and non-Fermilab based neutrino efforts

European strategy

- Highest priority is exploitation of the LHC including luminosity upgrades
- Support at CERN for European involvement in neutrino experiments in the US

- **Combination strengthens the US-European partnership for HEP**
- **Note the strong CERN-Fermilab partnership is key here**

A Global Neutrino Collaboration is Born

- Jan 14-16: interim IB Chair Sergio Bertolucci presented the LOI of the new international proto-collaboration at the Fermilab PAC meeting

- Jan 22-23: First meeting of the proto-collaboration (at FNAL)
  - approved Memorandum of Collaboration
  - Launched governance working group
  - Established Experiment-Facility Interface Group (EFIG)

- March 6: IB announces elected spokespeople

- March 13: IB announces winner of the naming contest for the new experiment…

DUNE @ LBNF

DUNE is the acronym for the
Deep Underground Neutrino Experiment
(Deep Underground Nucleon decay Experiment)
(Deep Underground superNova Experiment)

Spokesperson:
André Rubbia
ETH

Spokesperson:
Mark Thomson
Cambridge

Interim Technical Coordinator:
Eric James
Fermilab

A growing global science collaboration:

- **720 members**
- **142 institutions**
- **24 countries**

LBNC

- Recommended by the Fermilab PAC as a new committee focused on DUNE/LBNF
- Modeled after the LHCC at CERN
- To review the scientific, technical and managerial decisions/preparations of the experiment
- Meets as needed, reports to the Fermilab director
- Phone meetings already, first face-to-face meeting April 19 at Fermilab

  - Chair: David MacFarlane (SLAC)
  - Ursula Bassler (IN2P3)
  - Francesca Di Lodovico (Queen Mary)
  - Patrick Huber (Virginia Tech)
  - Mike Lindgren (FNAL)
  - Naba Mondal (TIFR)
  - Tsuyoshi Nakaya (Kyoto)
  - Dave Nygren (UT Arlington)
  - Stephen Pordes (FNAL)
  - Kem Robinson (LBNL)
  - Nigel Smith (SNOLAB)
  - Dave Wark (Oxford)

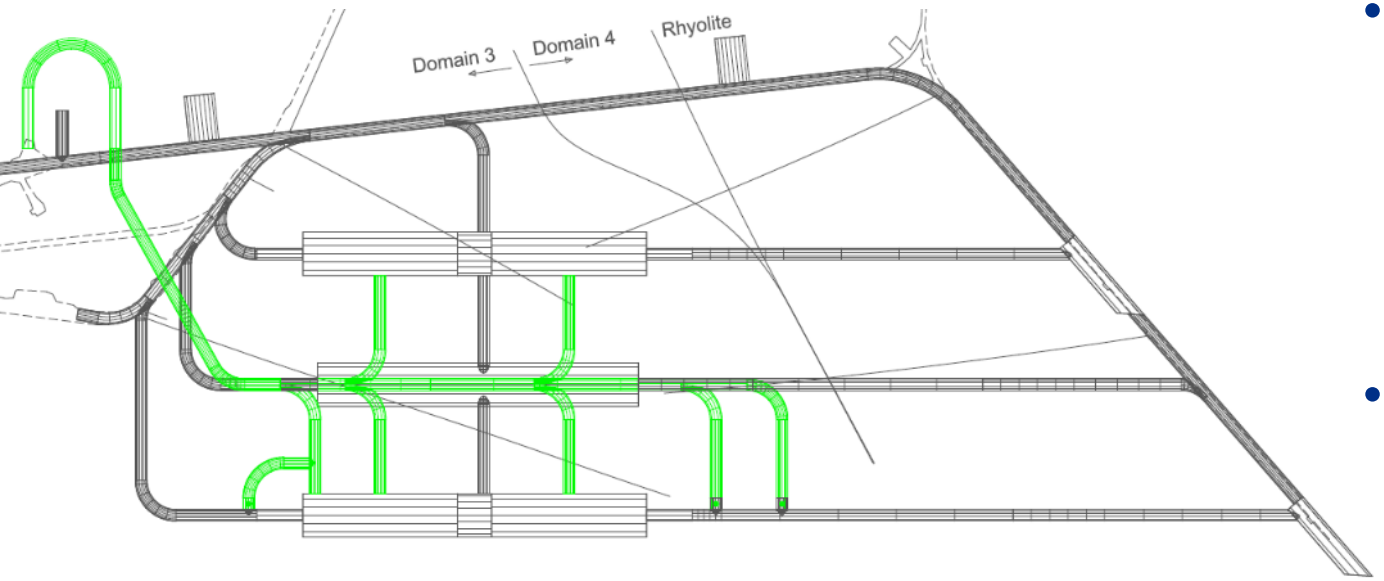
EFIG = Experiment Facility Interface Group for LBNF

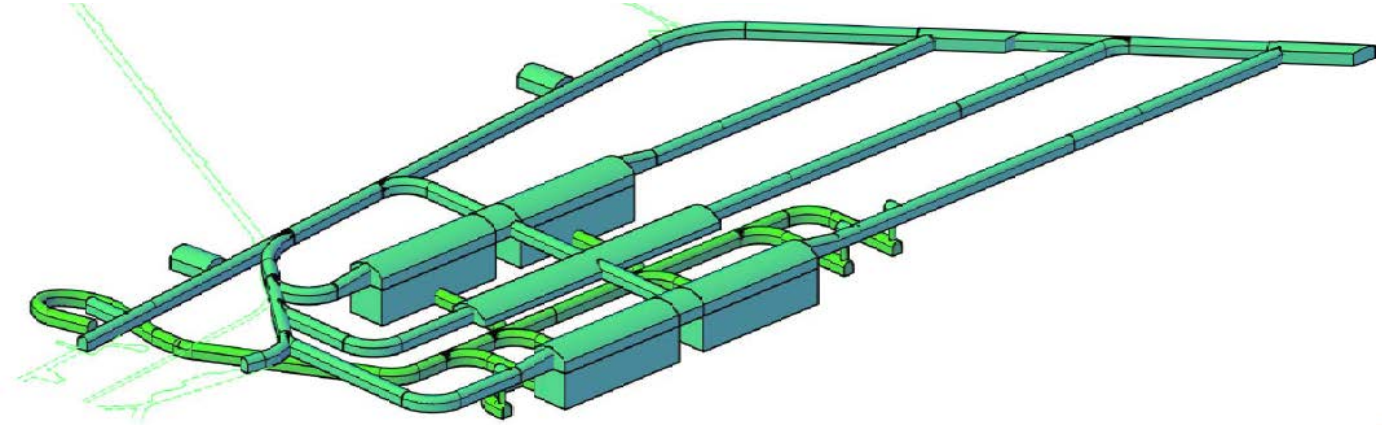
- This group is the regular interface between the LBNF facility project and the DUNE experimental collaboration
- Meeting since January for high-level critical path design choices, in consultation with engineering teams from Fermilab, CERN, and SDSTA
- Chair is Joe Lykken (representing Nigel Lockyer), Mike Lindgren (FNAL Chief Project Officer) and Pepin Carolan (DOE) ex officio
- DUNE spokespeople André Rubbia and Mark Thomson, and interim Technical Coordinator Eric James
- Jim Strait and Elaine McCluskey from the LBNF project
- Marzio Nessi (CERN), David Lissauer and Jim Stewart (BNL)
- Mike Headley from SDSTA

Ross shaft rehab

- South Dakota legislature just appropriated another $4M
- Working two 12 hour shifts/day in order to be done by 2017
- Also need a waste rock handling system on the surface (~$10M)

Cavern configuration for LBNF

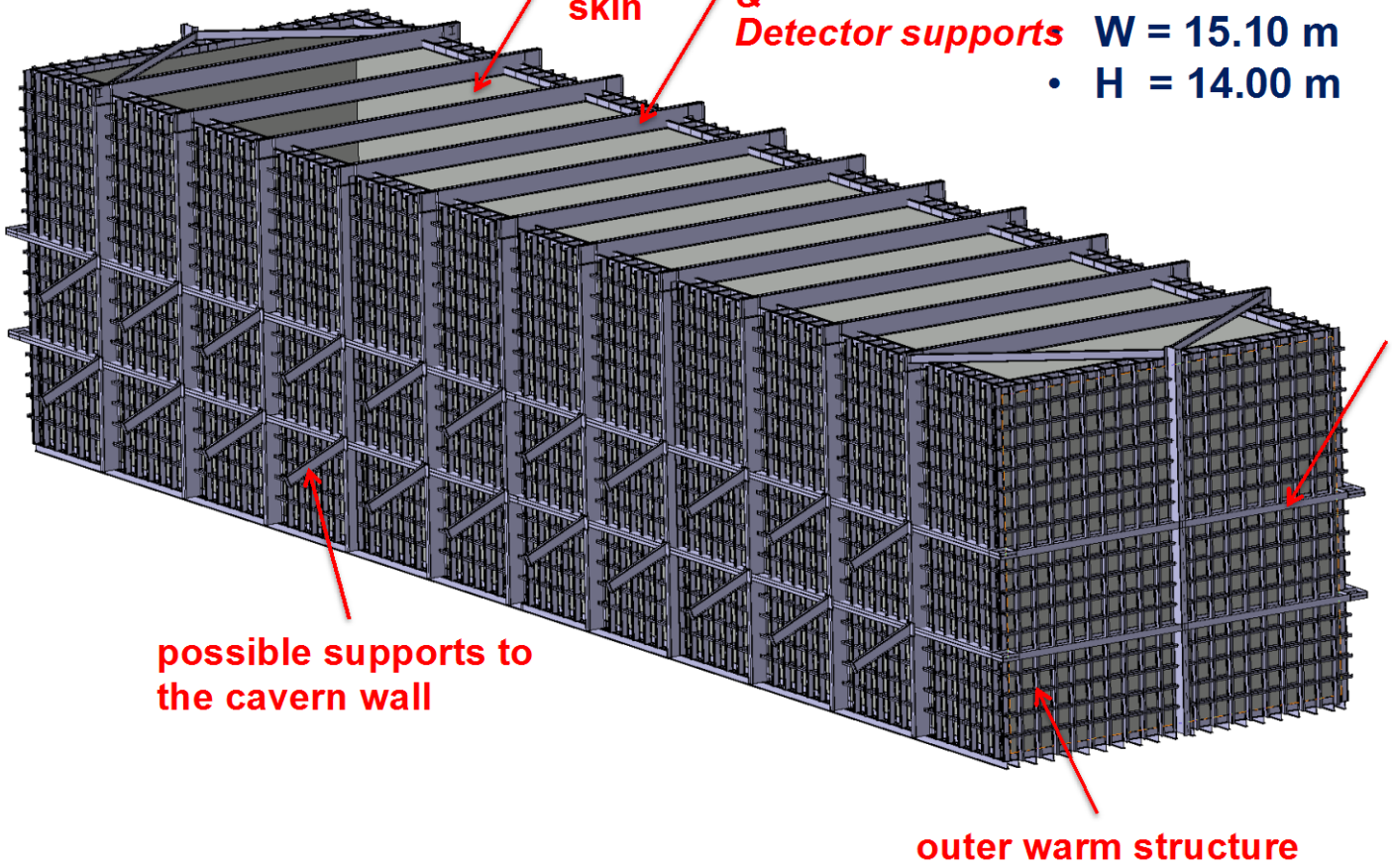




- Two parallel caverns each have two 10 kt detector pits with a laydown space in between
- The CF utilities and cryogenics are in a separate parallel chamber, thus no conflict with cryostat & detector laydown

Steel-supported cryostat design for LBNF

4 LBNF Cryostats extrapolation



Inner dimension (liquid +gas):

- **L = 62.00 m**
- **W = 15.10 m**
- **H = 14.00 m**

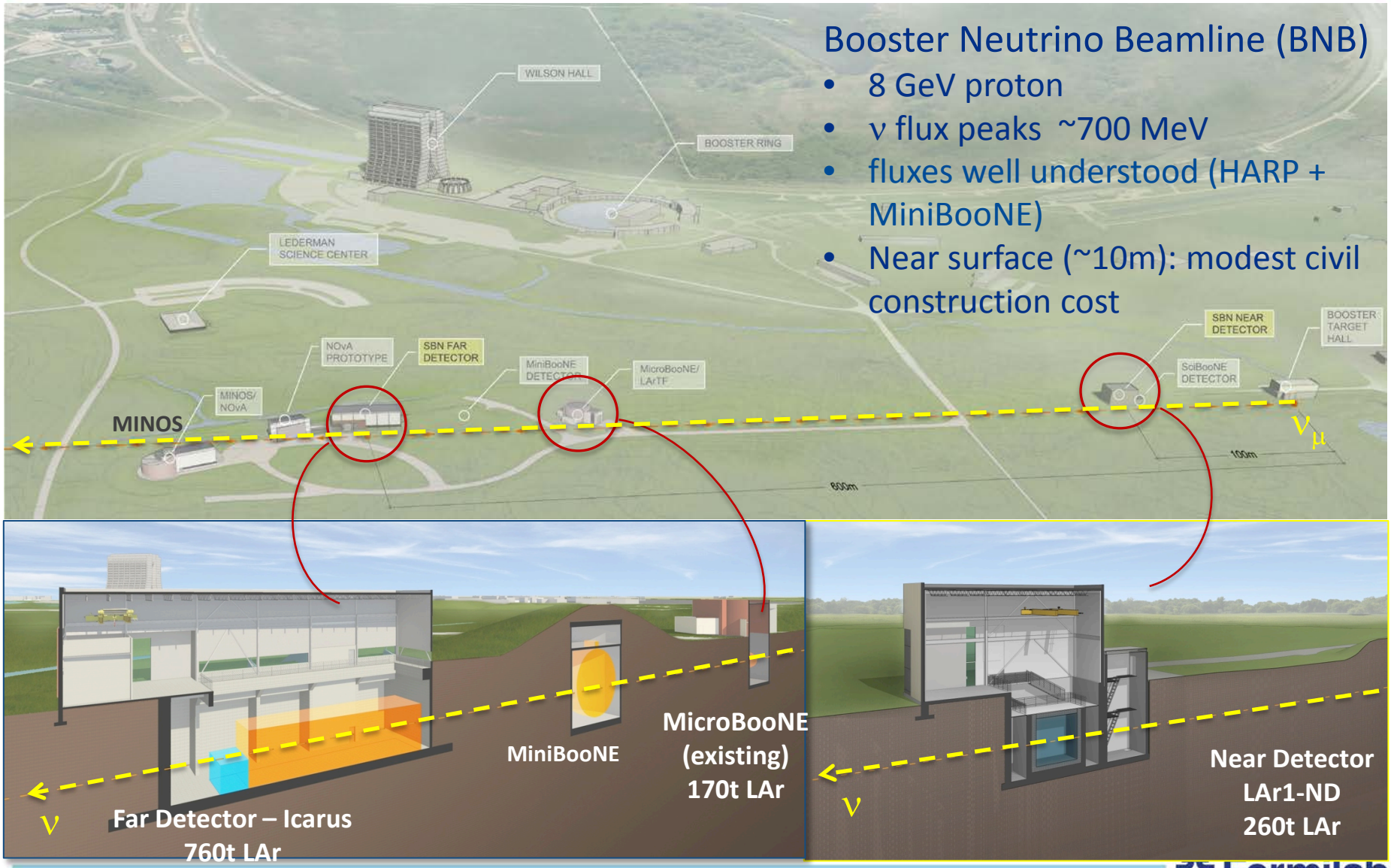
LAr = 17'432 tons (95% liquid)

CD-1-R Internal Milestones

18 March	**DUNE Technical Coordinator Named**
24 March	**Task Force Conveners Named**
31 March	**CD-1 Document Scope Defined**
15 April	Zeroth-order Draft of CD-1-R Documents
16-18 April	First DUNE Collaboration Meeting
19 April	First full LBNC Meeting
5 May	First CD-1-R draft for review by project office
19 May	CD-1-R documents posted for Director's Review
2-3 June	Director's Review
22-23 June	Fermilab PAC
6-8 July	DOE CD-1 Review

November 1st week CD2a/CD3a……construction start FY17 goal

One SBN Program - Three LAr-TPC Detectors



Booster Neutrino Beamline (BNB)

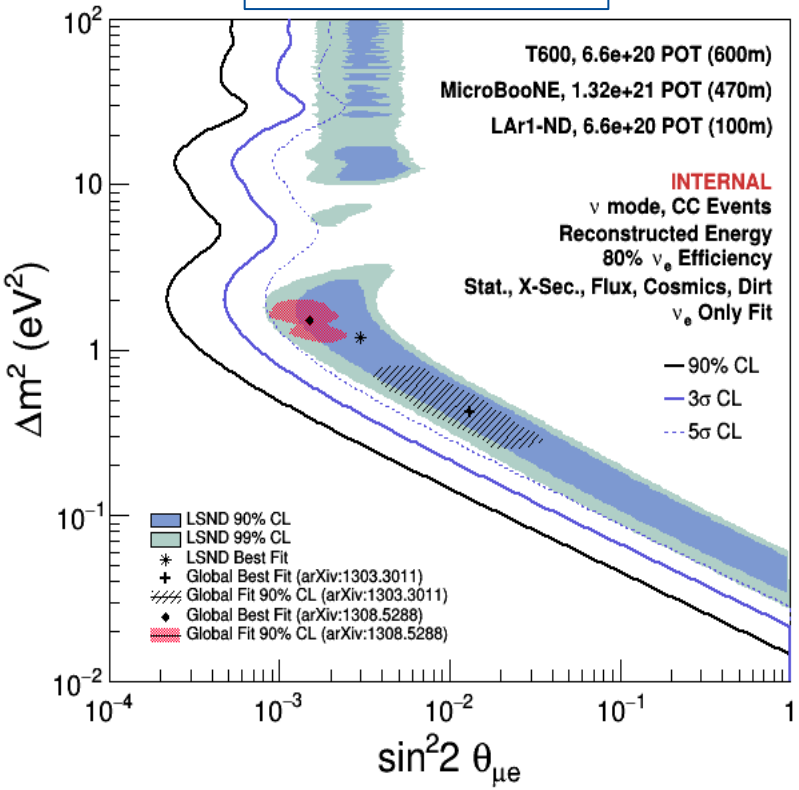
- 8 GeV proton
- ν flux peaks ~700 MeV
- fluxes well understood (HARP + MiniBooNE)
- Near surface (~10m): modest civil construction cost

Projected Sterile ν Sensitivity for 3+1 Scenario

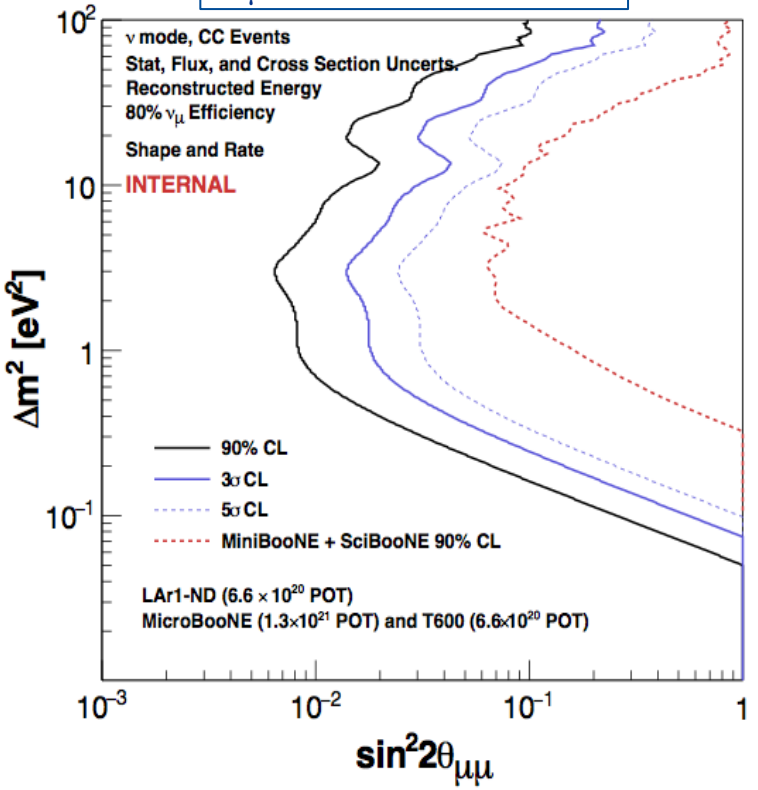
A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam

- Presented at Jan 2015 PAC
- Granted Stage 1 approval
- Request stage 2 at June PAC

ν_e Appearance



ν_μ Disappearance



SBN Far Detector: ICARUS-T600

- ICARUS-WA104 collaboration: refurbish at CERN w/new cryostats and electronics, upgraded light detection
  - ✓ Move from Gran Sasso to CERN Dec 2014
  - ✓ Refurbishing started

  Schedule: TPCs delivered to FNAL in new cryostats when new building is available, currently foreseen as early 2017
- For surface operation need improved cosmic rejection:
  - Improved light detection, external cosmic tagger system
- CERN-INFN collaborative effort to refurbishment:
  - MOU signed covering all work up to shipment to Fermilab
- CERN leadership on cryogenics

First TPC leaving LNGS

First TPC in Cleanroom at CERN

SBN Near Detector: LAr1-ND

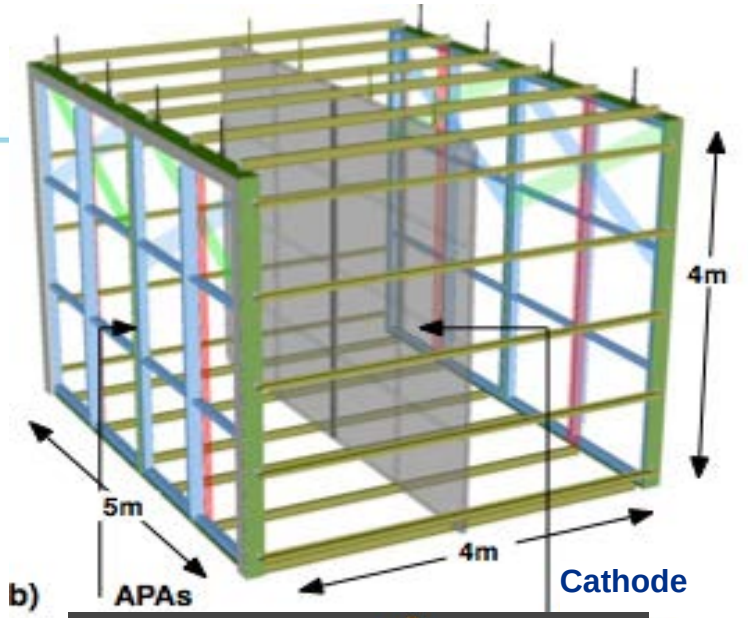
- Build on experience from ICARUS, MicroBooNE, LBNE 35ton prototype, and based LBNE designs
- Opportunity for prototyping DUNE designs or developing alternative system designs
  - e.g. test-bed for light collection concepts
- International collaborative efforts on detector:

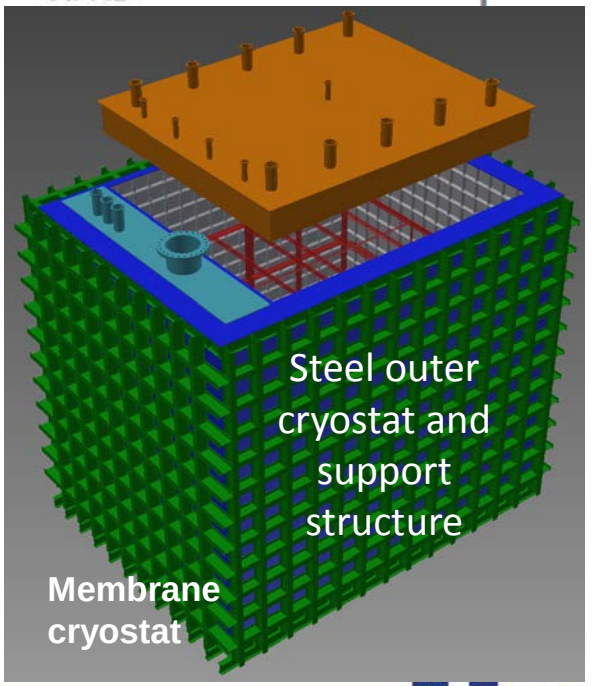
  TPC: Five universities (US NSF + UK STFC)

  TPC Electronics: BNL (DOE) + Columbia (NSF requested)

  Laser calibration: Bern (SNSF, AEC)

  Cosmic Tagger: Bern
- CERN + Fermilab collaborating on cryostat and cryogenics
  - Establish teams for LBNF infrastructure
- Installation in 2017

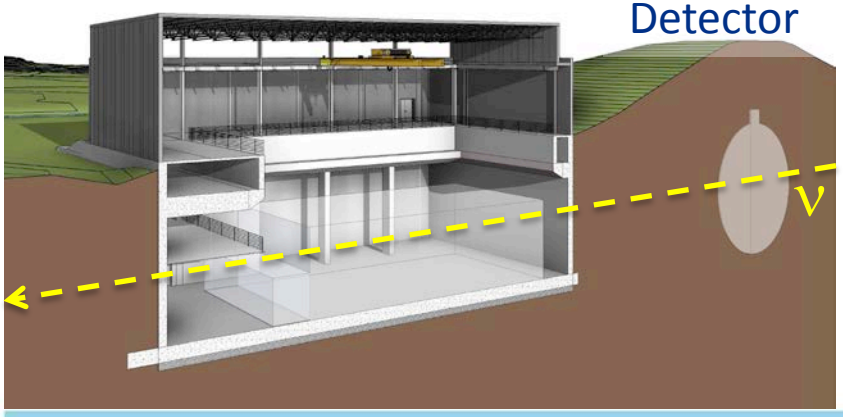


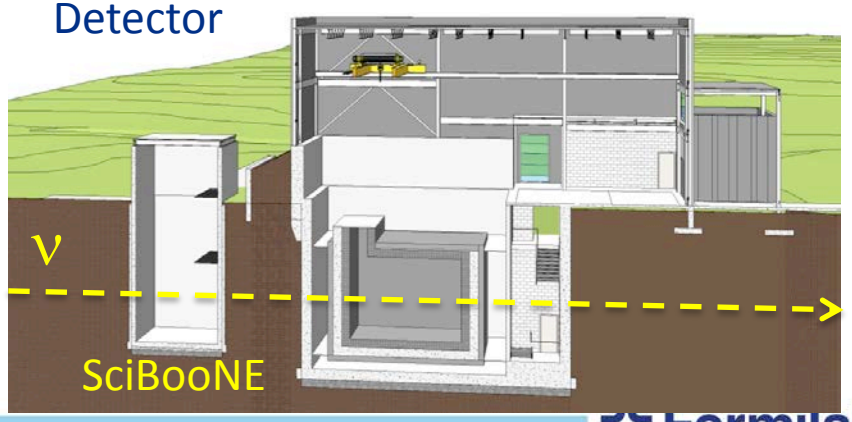


New Detector Buildings

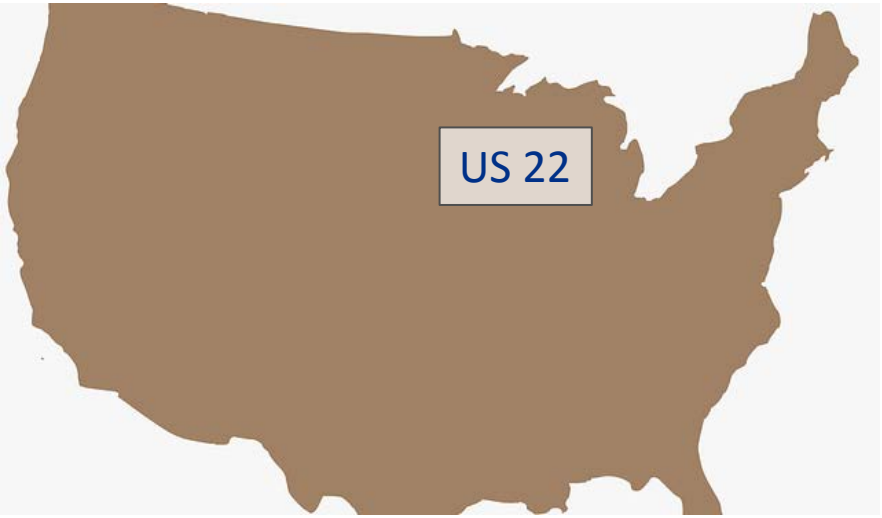
- Funded as GPP projects
- Current status:
  - Far detector: construction bidding
  - Near detector: 60% design completion

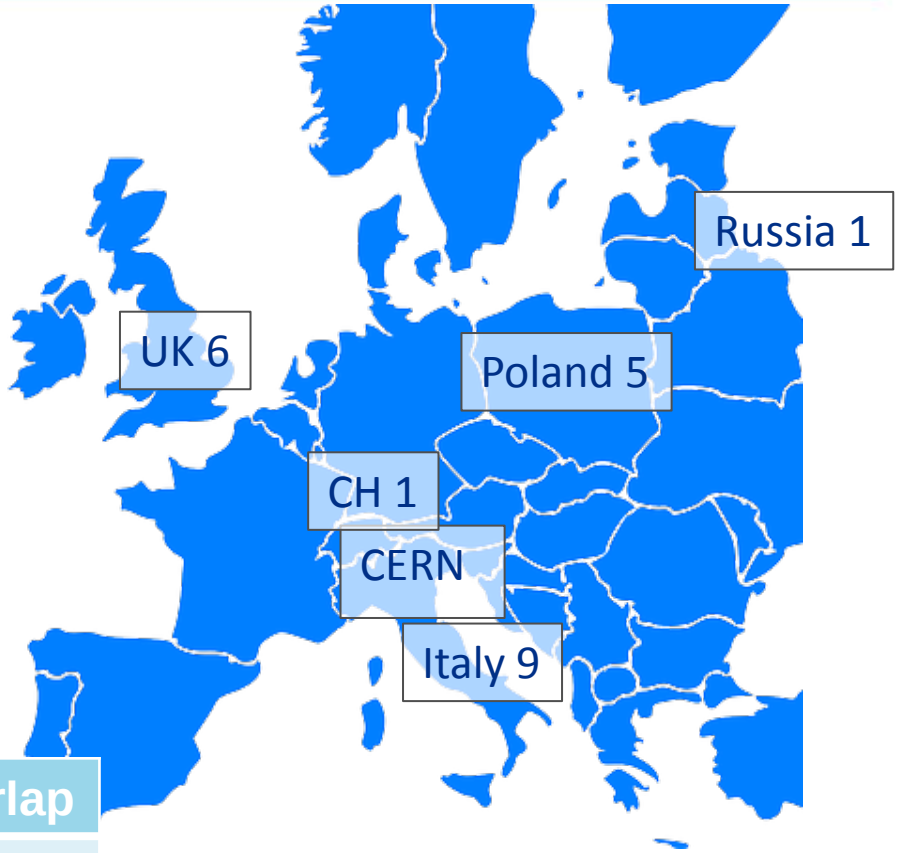
	Far	Near
Design Complete	Mar 2015	May 2015
Construction Start	May 2015	Aug 2015
Beneficial Occ.	Nov 2016	Sept 2016





SBN Institutions and Authors





Collaboration	Authors	Overlap
ICARUS-WA104	57	6
LAr1-ND	108	59
MicroBooNE	118	
All SBN (excl overlaps)	**218**	

Institutions	SBN	SBN-DUNE Overlap
US	22	20
Non-US	23	19

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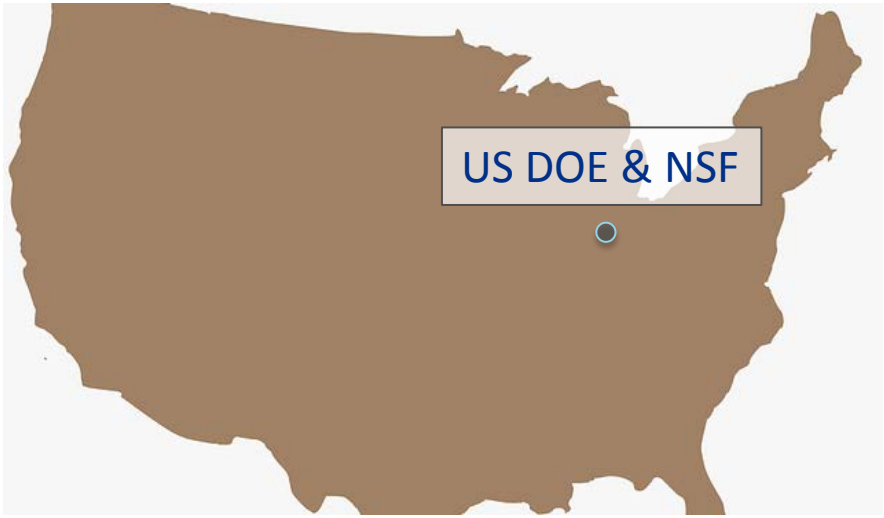
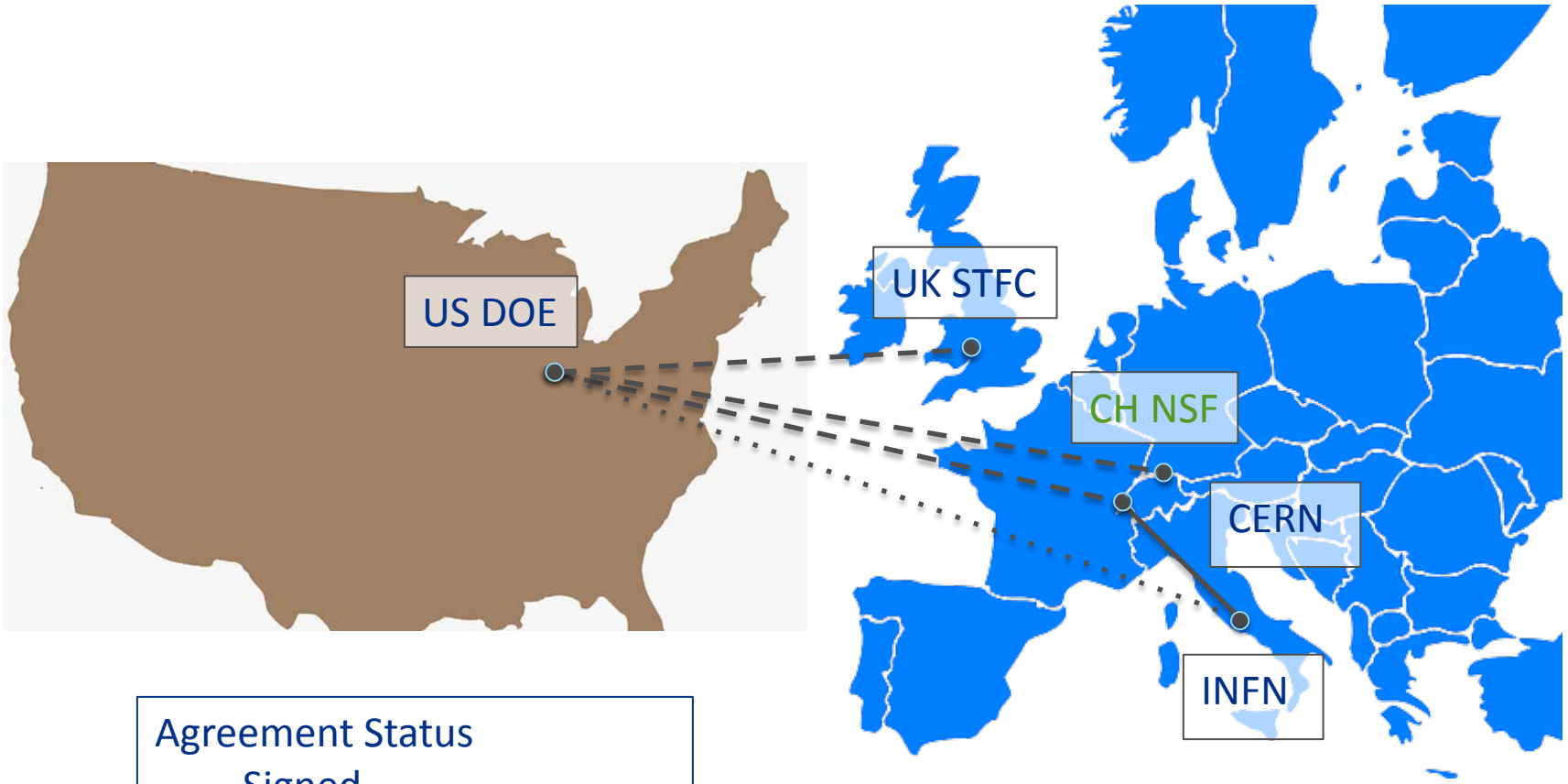
Main SBN Funding Sources



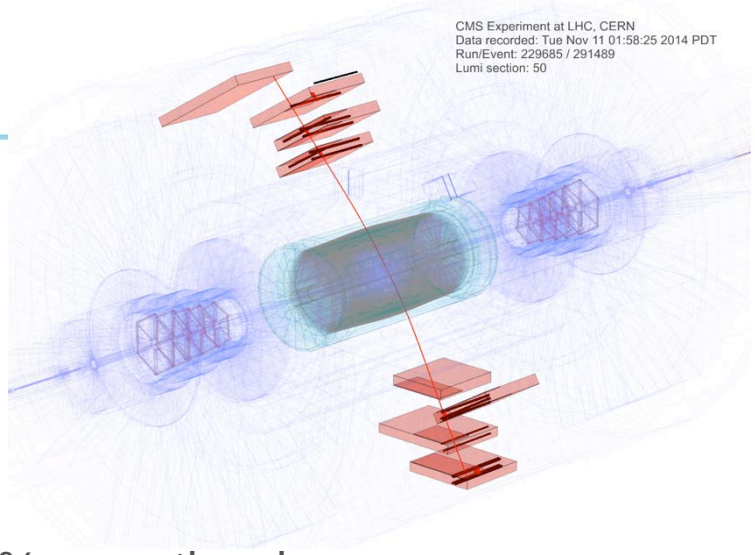
Main SBN International Agreements



SBN Conclusions

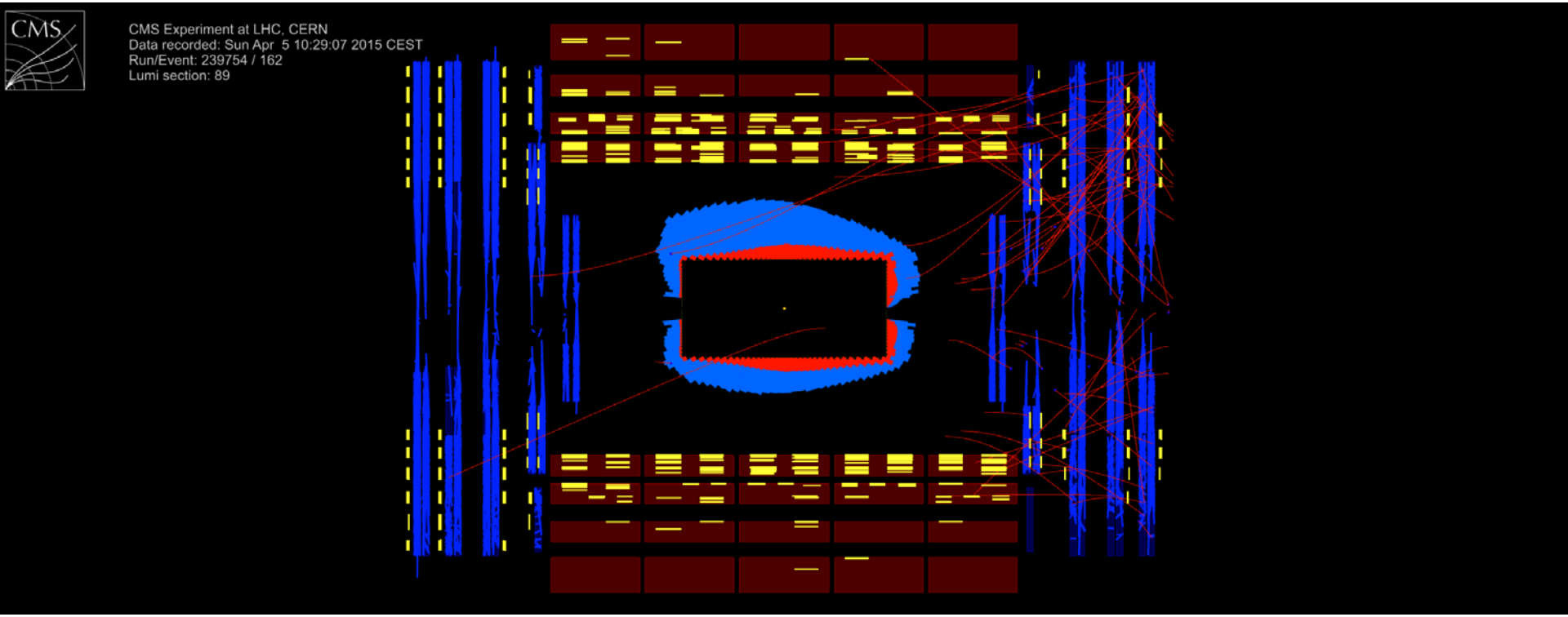
- The BNB is a unique facility providing an excellent base for a diverse neutrino physics program.
- The second generation of BNB physics is about to start with the operation of MicroBooNE.
- The three detector SBN program can make a definitive statement on the LSND and MiniBooNE anomalies with the potential for a ground breaking discovery in neutrino physics.
- This program brings together LAr-TPC detectors developed by leading teams of scientists and engineers from Europe and the US representing a tremendous scientific and R&D opportunity toward the future LBN program.
- We are moving forward aggressively to prepare the near and far detectors and required infrastructure for operation with beam by 2018.
  - SBN Program reviewed by Fermilab PAC – January 2015
  - Technical, cost and schedule reviews foreseen during 2015

CMS Status



- **First beams in LHC!**
  - First collisions ~2 months later
- **CMS is ready for Run 2**
  - FNAL involved in extensive detector repairs and improvements during shutdown
    - FPIX: repaired to recover channels - now >99% operational
    - HCAL: improved photodetectors installed in accessible subdetectors
    - ME4/2: machined new panels
  - Ongoing improvements in computing
    - multithreading implemented for reconstruction to control memory consumption
    - CERN↔FNAL Transfer rates tested extensively for Run 2 data volume
- **Phase 1 Upgrades on track - CD-3 approved**
  - FPIX: 1st sensors received, testing 1st production high-density interconnects
  - HCAL: 1st batches of QIE10, QIE11 tested with robotic chip tester
  - Trigger: Stage-1 calorimeter trigger hardware, firmware operating at CERN

First beam Splash at CMS…..run-II beginning



LHC Upgrades: High Priority!

Recommendation 10: Complete the LHC phase-1 upgrades and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.

US HEP community (P5) report June 2014

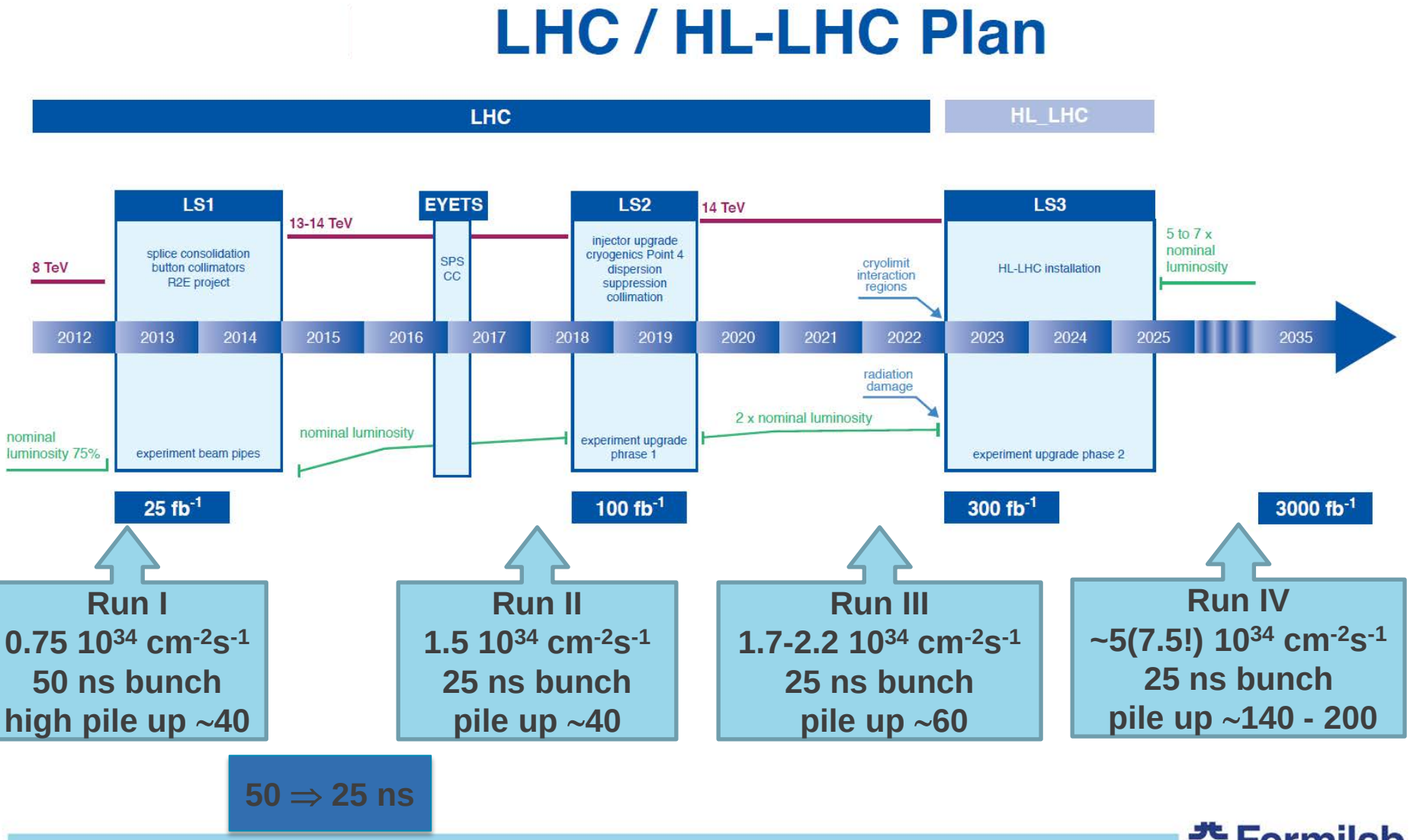
The European Strategy for Particle Physics Update 2013

High-priority large-scale scientific activities

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

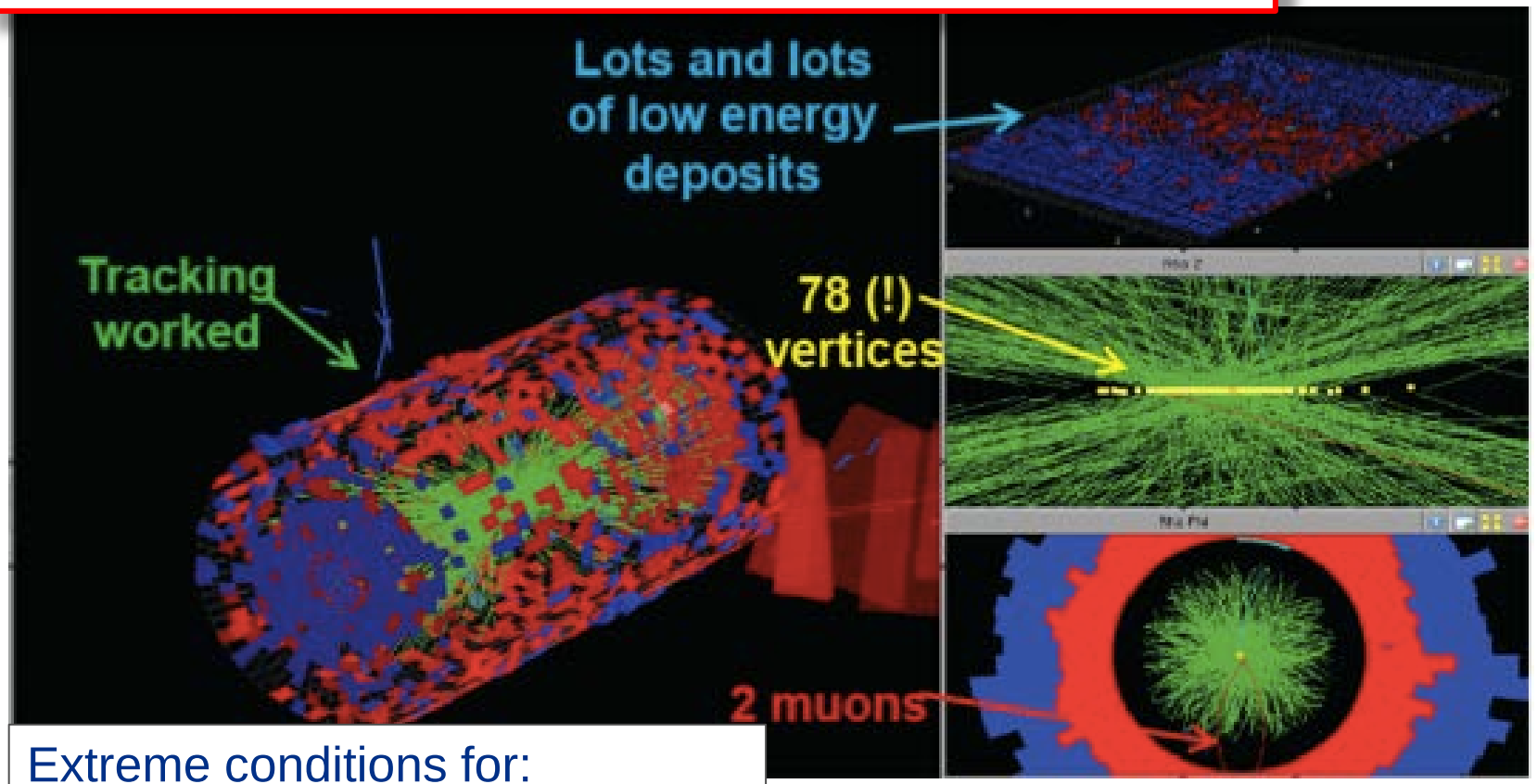
c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

LHC Upgrades: Timeline towards HL-LHC



CMS Upgrades for HL-LHC: High pileup!

Real event from Run 1 during LHC special high pileup running



Extreme conditions for:

- radiation
- pileup
- Trigger / DAQ
- Data handling

Note: HL-LHC pileup ~ 140-200 !

USCMS HL-LHC upgrades: Main areas of work in a nutshell

- Replacing endcap calorimeters
  - Two designs being actively pursued / decision end of April
    - US is embedded in both options
- Replace tracker
  - Increase tracker eta coverage, less material / L1 track trigger
    - US mainly in Forward Pixels, L1 track trigger, parts of outer tracker
- Muon chambers
  - Longevity studies on current chambers / increased muon coverage with new chambers
    - US keeps responsibility for part of the endcap muon system / electronics upgrades
- Trigger / DAQ: US has critical roles in both trigger / DAQ
- Computing
  - Reconstruct / analyze larger event rate, complexity, size
    - US leads much of this effort

LARP and the High Luminosity LHC Upgrade

- Major goal: Design the next generation interaction region quads for the LHC.
- The original IR quads, which Fermilab built, will reach their end of life due to radiation damage in perhaps ten years.
- Increased luminosity demands large aperture quadrupoles at comparable gradients.
  - Larger aperture leads to much higher magnetic fields at the coils.
  - NbTi will not meet the needs.
- LARP focus is therefore Nb_3Sn IR quadrupole magnets.
  - Builds on the development of the Nb_3Sn strand and cable technology from the HFM program
- A series of smaller aperture Nb3Sn model quadrupole magnets have been constructed.
- The next three years will see
  - Full aperture model quadrupoles constructed and tested.
  - Long quadrupole models constructed and tested.

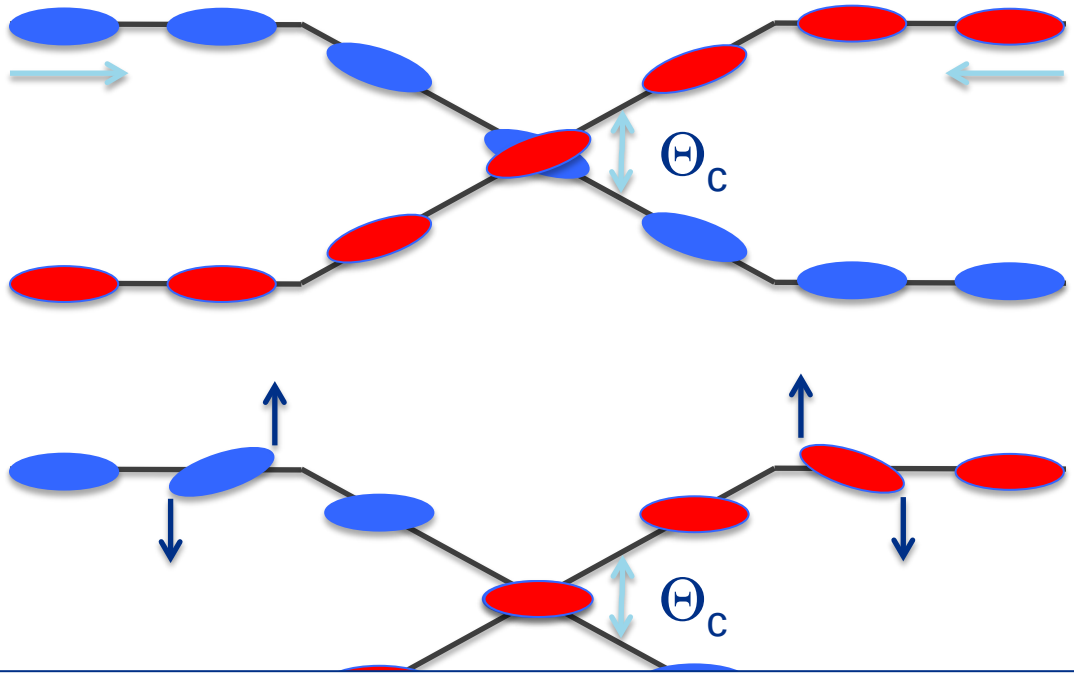
QXF (HL-LHC 150 mm Quads) Achievements and Plans

- Short model program: **2014-2016**
  - **First SQXF coil test (Mirror struct.) ready for testing at FNAL**
  - **First short magnet (SQXF) ready for assembly at LBL in May '15**
  - Goals: 2 (LARP) + 3 (CERN) short models
- Long model program: **2015-2018**
  - **Practice Long Coil winding started in April 2015**
  - First LQXF coil test (Mirror structure) in Dec. 2015
  - First model test in Oct. 2016 (LARP) and July 2017 (CERN)
  - 3 (LARP) + 2 (CERN) models in total
- Series production: **2018-2022**

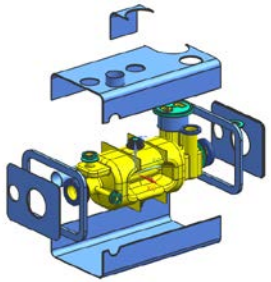
LARP has brought Nb_3Sn to Readiness for Accelerator Applications

Crab Cavities

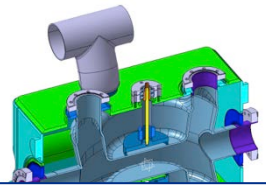
- Larger Crossing angle (~300 μrad in HL-LHC vs. ~150 μrad in LHC) calls for a correction of individual bunches orientation
- Cavities parts for SPS Test in FY18 manufactured at company (Niowave) and assembled at Jefferson Lab



RFD Option

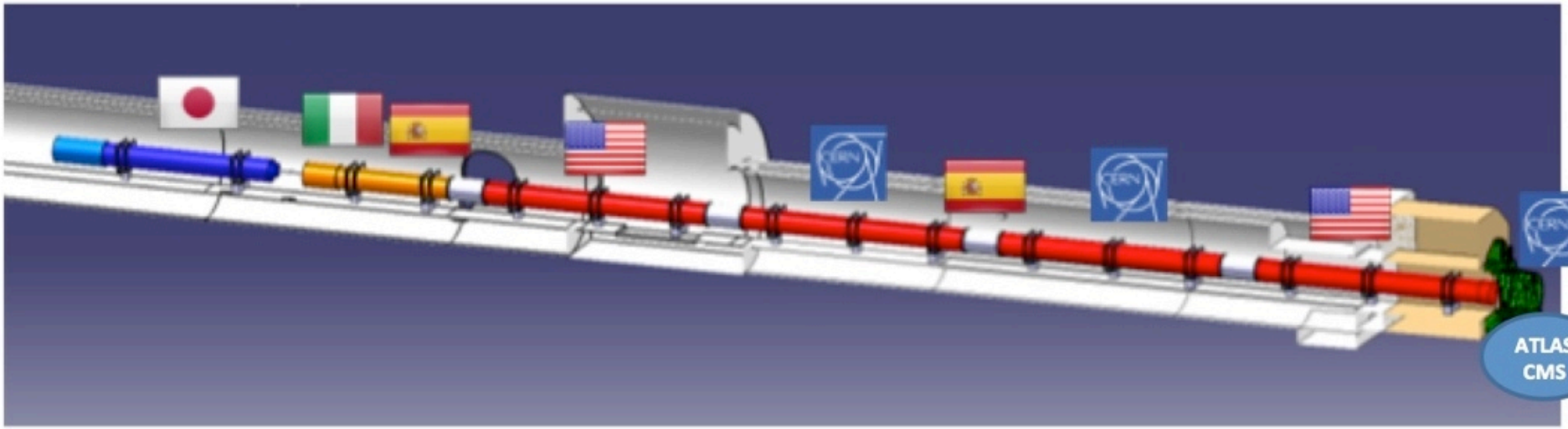


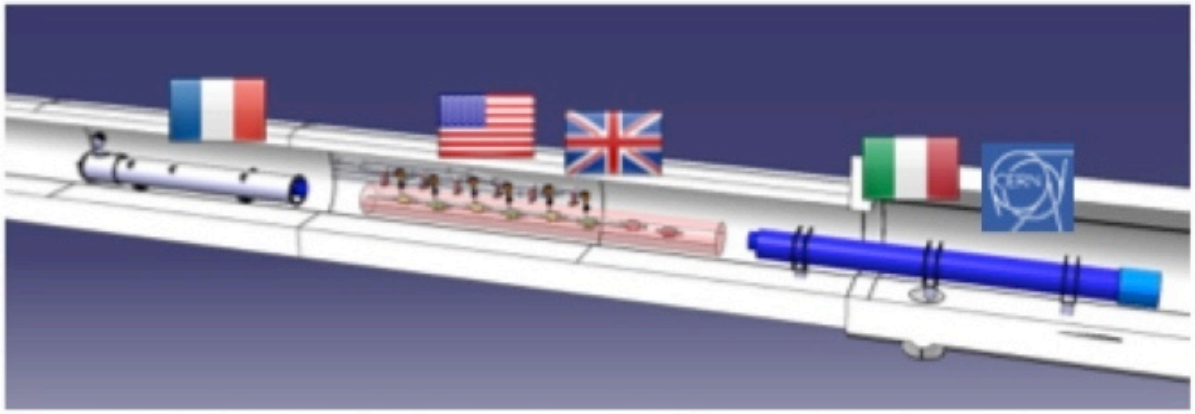
DQW Option



LARP has been instrumental in bringing the Crab Cavities solution into the baseline of HL-LHC

US-HiLumi: in-kind contribution ‘25-’35





CC : R&D, Design and in-kind **USA**

CC : R&D and Design **UK**

Q1-Q3 : R&D, Design, Prototypes and in-kind **USA**

D1 : R&D, Design, Prototypes and in-kind **JP**

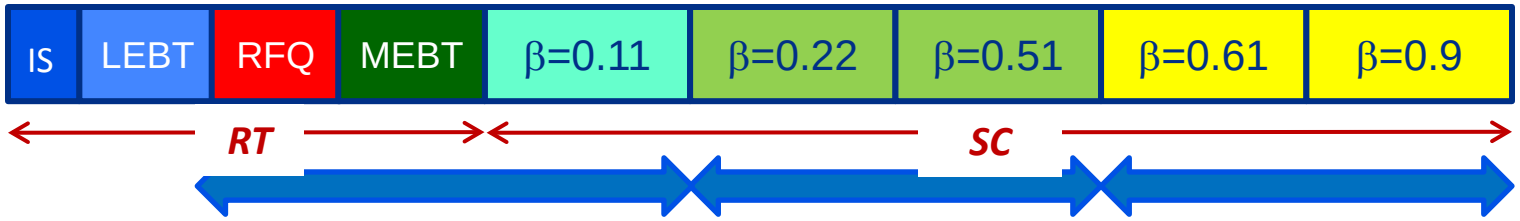
MCBX : Design and Prototype **ES**

HO Correctors: Design and Prototypes **IT**

Q4 : Design and Prototype **FR**

Proton Improvement Plan-II (PIP-II) - 1.2 MW beam

Structures under development



ANL -Half Wave

Spokes

Medium-Beta Elliptical Cavities

India Collaboration…is working extremely well

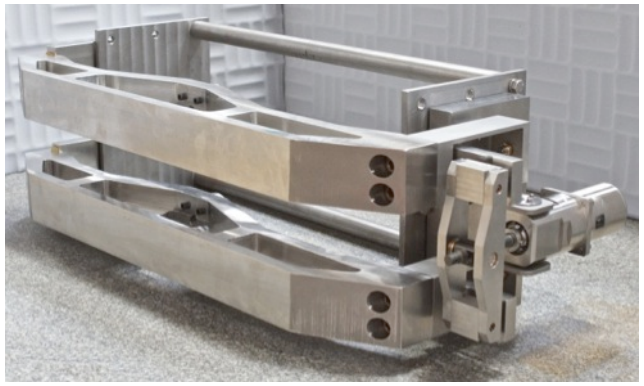
- Annex I signed ($200M)
- Recent Siegrist/Lockyer trip to BARC
- We concluded India is in great shape with top engineers involved and world-class infrastructure installed & being used
- R&D deliverables being established with BARC director
  - Four India labs: VECC, IUAC, RRCAT, BARC
  - Two months we should be able to sign
- Strategy: build each type of dressed cavity (4) and one prototype of each cryomodule (2)…. and test
- Work well underway in India & Fermilab to reduce risk by end of FY18 for PIP-II

SSR1 development

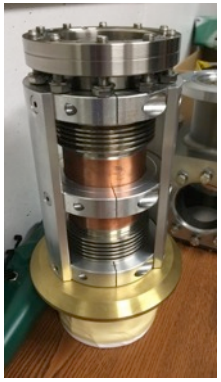
First SSR1 prototype with prototype tuner for HINS (2010)

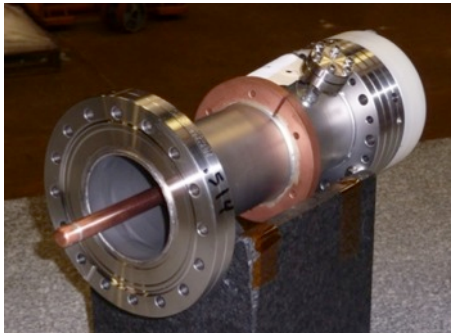
First production SSR1

First jacketed SSR1 for PXIE (2013)



Double-Lever tuner prototype

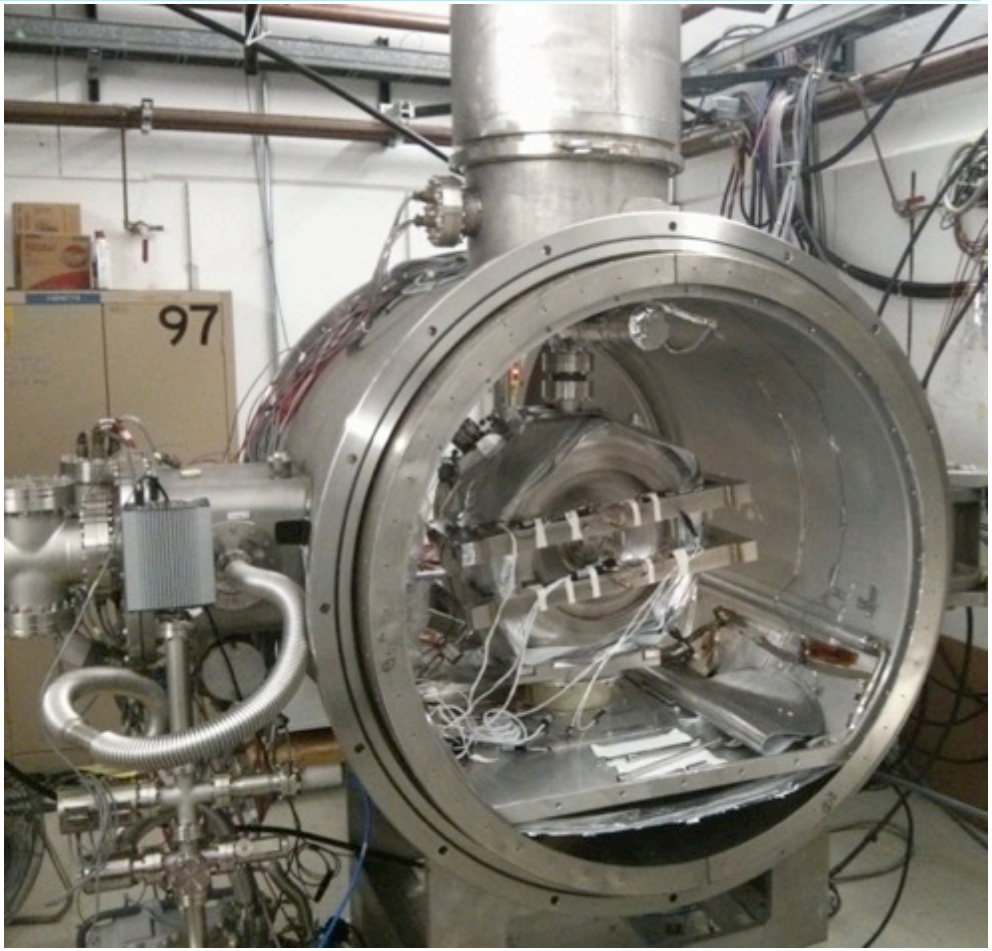




Prototype Power Coupler

Spoke Test-Cryostat (STC)

A. Hocker, A. Sukhanov

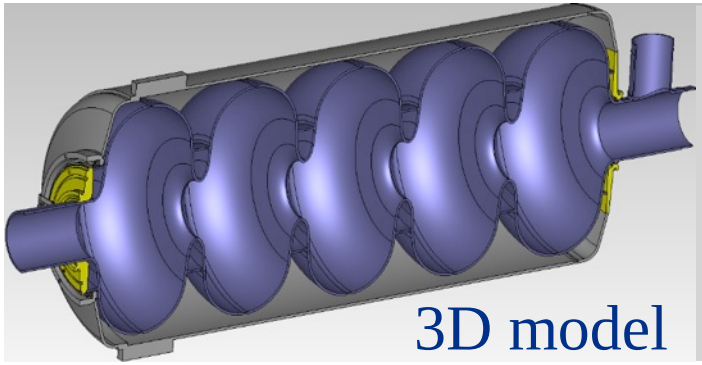


India ships first SSR1 cavity in June! Excellent progress

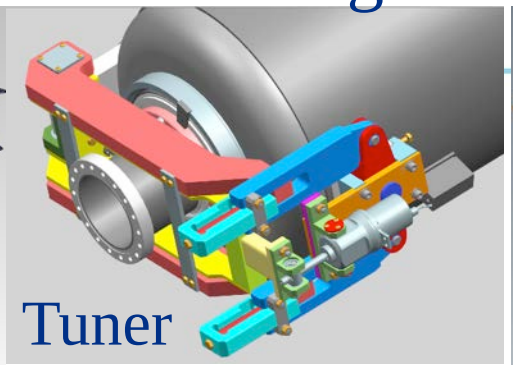
Design of SSR2, low beta 650 and high beta 650 underway

High beta 650 CM design underway

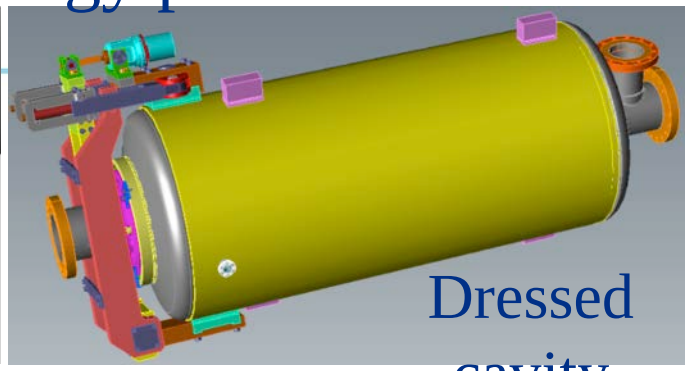
R&D for 650 MHz SRF for high energy part of PIP-II



3D model

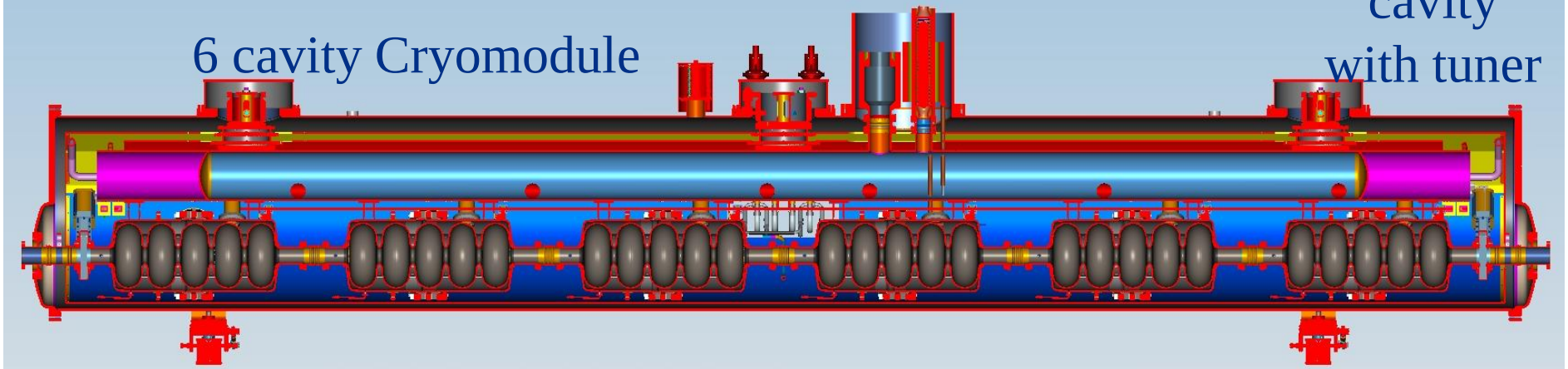


Tuner



Dressed cavity with tuner

6 cavity Cryomodule



Design

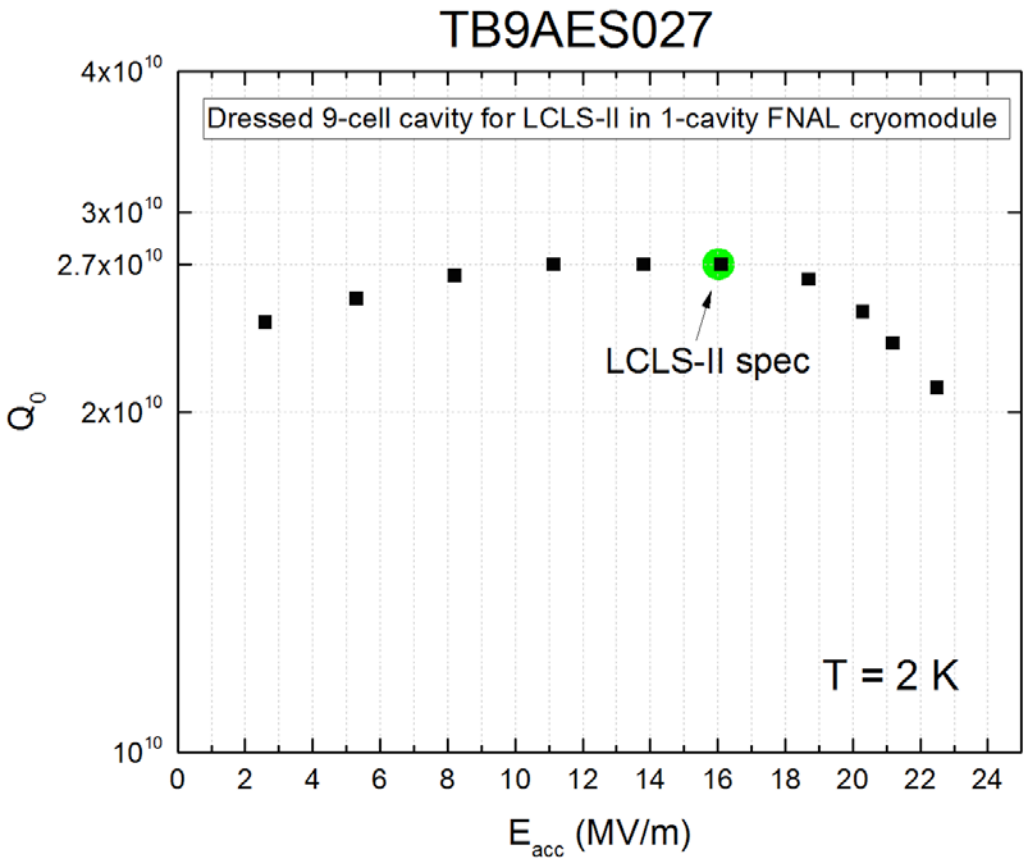
&

Production

1-cell cavity

5-cell cavity

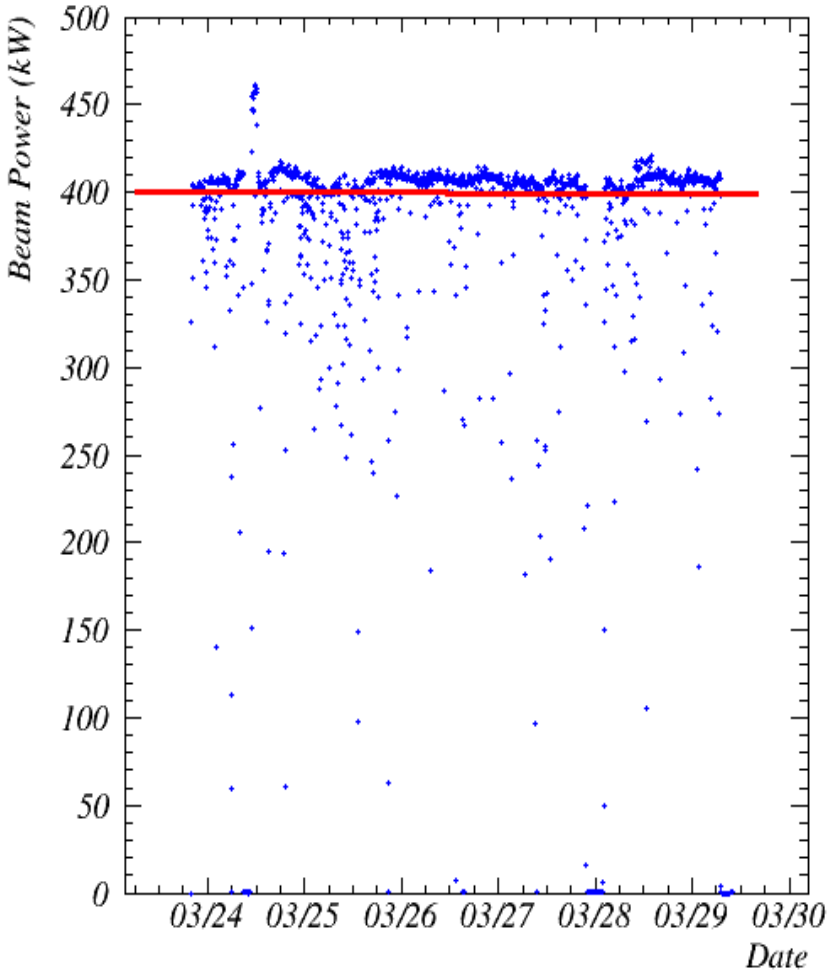
HTS Test Result…meets LCLS-II spec….amazing



Focused R&D to raise Q0
Flux exclusive important
Cool down rate key

1.3 GHz technology

Record Power to the NuMI experiments



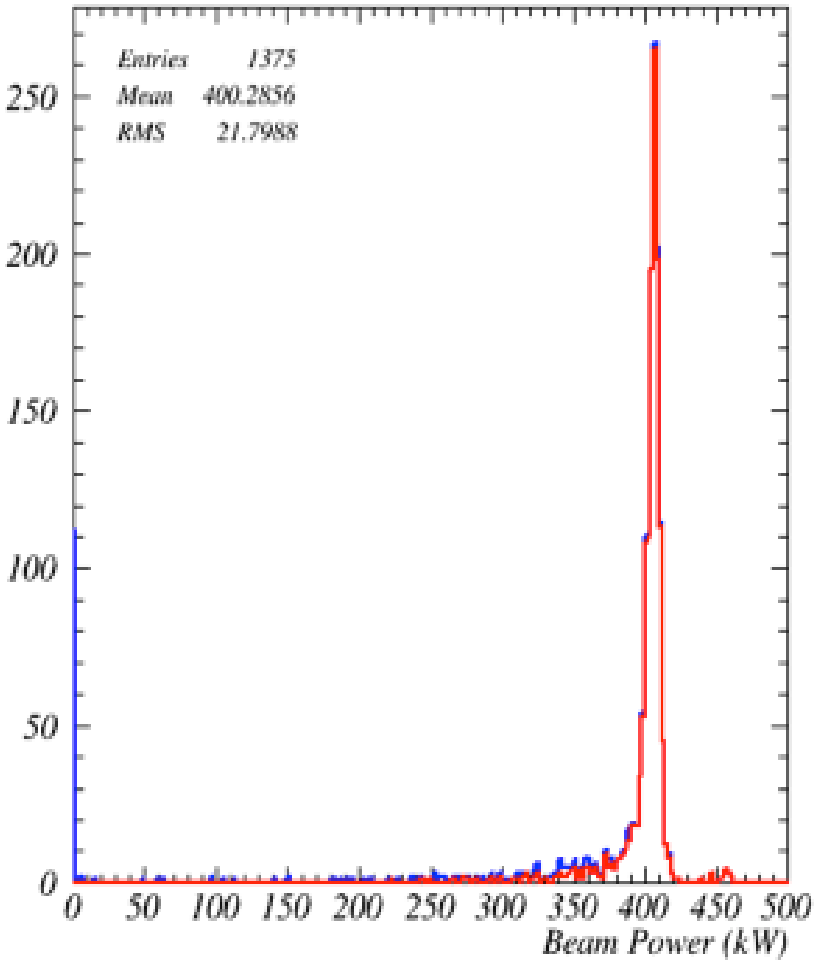
NuMI Accomplishments

- Beam operated to NuMI experiments using the Main Injector and Recycler (1.33 second ramp).

Tuesday, March 24th – record beam was delivered to the NuMI target at 408.8 kW for one hour in conjunction with switchyard operation.

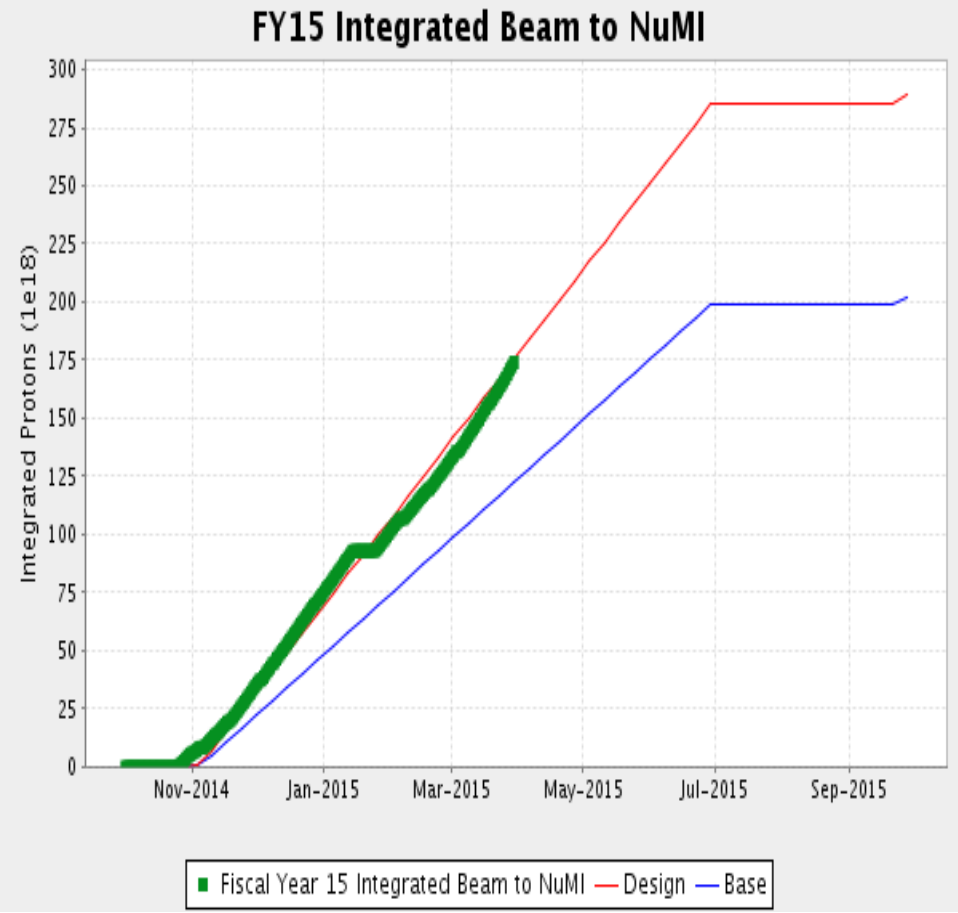
Wednesday, March 25th – record beam was delivered to the NuMI target at 453 kW for one hour without switchyard operation.

Meeting the Goals



- **Beam Power Metric Achieved**
  - **Beam Power Metric**: "achieve an average beam power of 400kW for at least one week of at least 100 hours sometime during the year"
- This was accomplished in the past week with 114.6 hours of live beam time with an average power of 400.3 kW
- Routinely running in the 390 – 400kW range.

Delivering the beam



Fiscal Year Beam Delivery

- On pace to exceed the Design goal for the year.
- July is the upcoming Summer Muon Campus installation and Accelerator maintenance period.

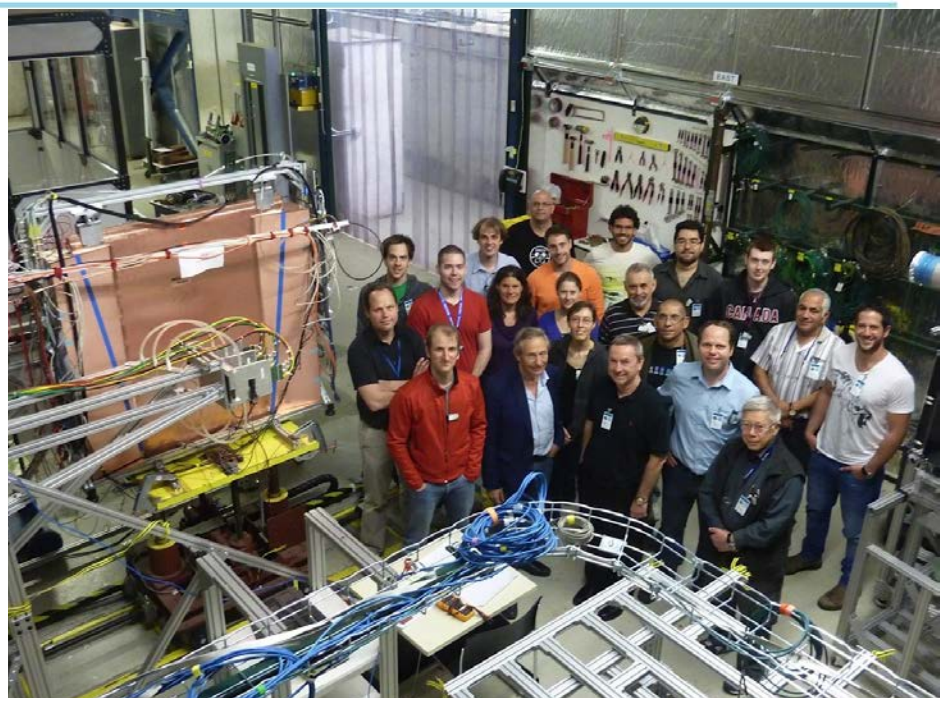
First Beam at ASTA/IOTA…..tested with ILC parameters

On Friday morning, March 27 first beam was delivered. We were able to deliver a 20 MeV electron beam from the IOTA-Injector photocathode, through a 1 m long SRF booster cavity CC2, and all the way to the beam dump, in front of the SRF Cryomodule 2.

Test beam facility…successful and oversubscribed

MTest Beamline

- T997 MInerva
- T1015 DRC in Glasses
- T1058 Secondary Emission Calorimeter
- T1041 CMS Forward Calorimetry
- T1043 Mu2e CRV
- T992 Radiation-hard Sensors for the SLHC
- T1042 Muon g-2 straw tracker
- T1018 Spacordion Tungsten Fiber Calorimeter
- T994 JASMIN
- T979 Fast Timing with Cerenkov Detectors



MCenter Beamline

- T1034 LAriaT
- T1059 Optical TPC

New beamline (MCenter) is up & running

Peter Wittich Cornell Chairs TB “PAC”

Test beam users in FY14:

- 233 collaborators
- 13 experiments
- 67 institutions
- 13 countries

Current Fermilab hosted accelerator experiments

- Accelerators have never been operating better
- Experiment up-times are high.

Experiment	Beam	POT Request	POT Delivered	
MiniBooNE-DM	BNB	1.5E20	1.9E20	completed FY14
MINOS+	NuMI - ME	18E20	4.8E20	27%
MINERvA	NuMI - ME	6E20 (ν) 12E20(νbar)	4.8E20 (ν)	80% (ν)
NOvA	NuMI - ME	36E20	2.5E20	7%
MicroBooNE	BNB	6.6E20	N/A	starting soon
SeaQuest	SY120	5E18	7.0E17	14%

+ Test Beams: 19 experiments

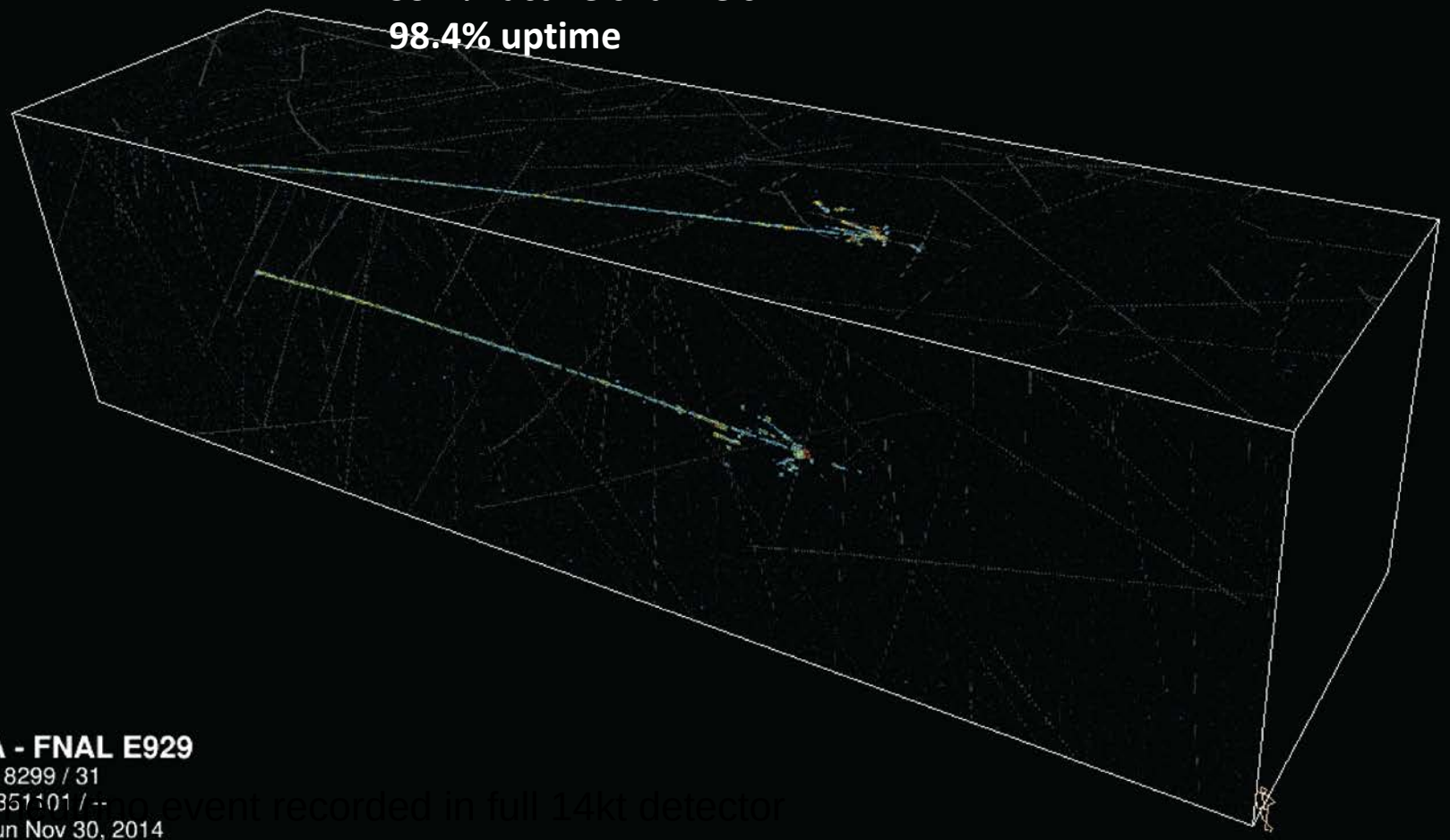
NOvA Project received ‘Secretary’s Award of Excellence’

Pepin Carolan, DOE/FSO named Federal Project Director of the year

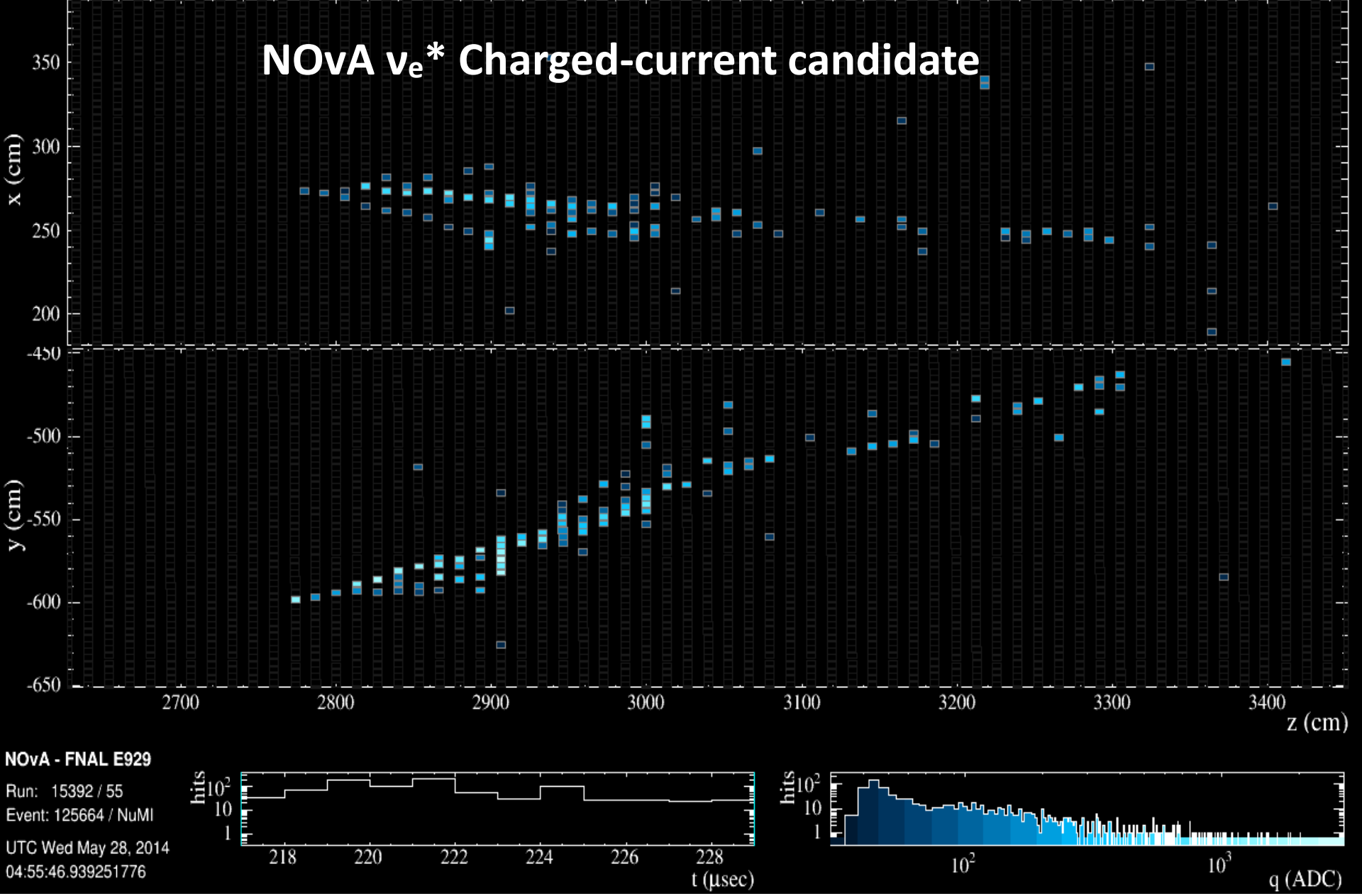
NOvA Far detector

99.7% active channels

98.4% uptime

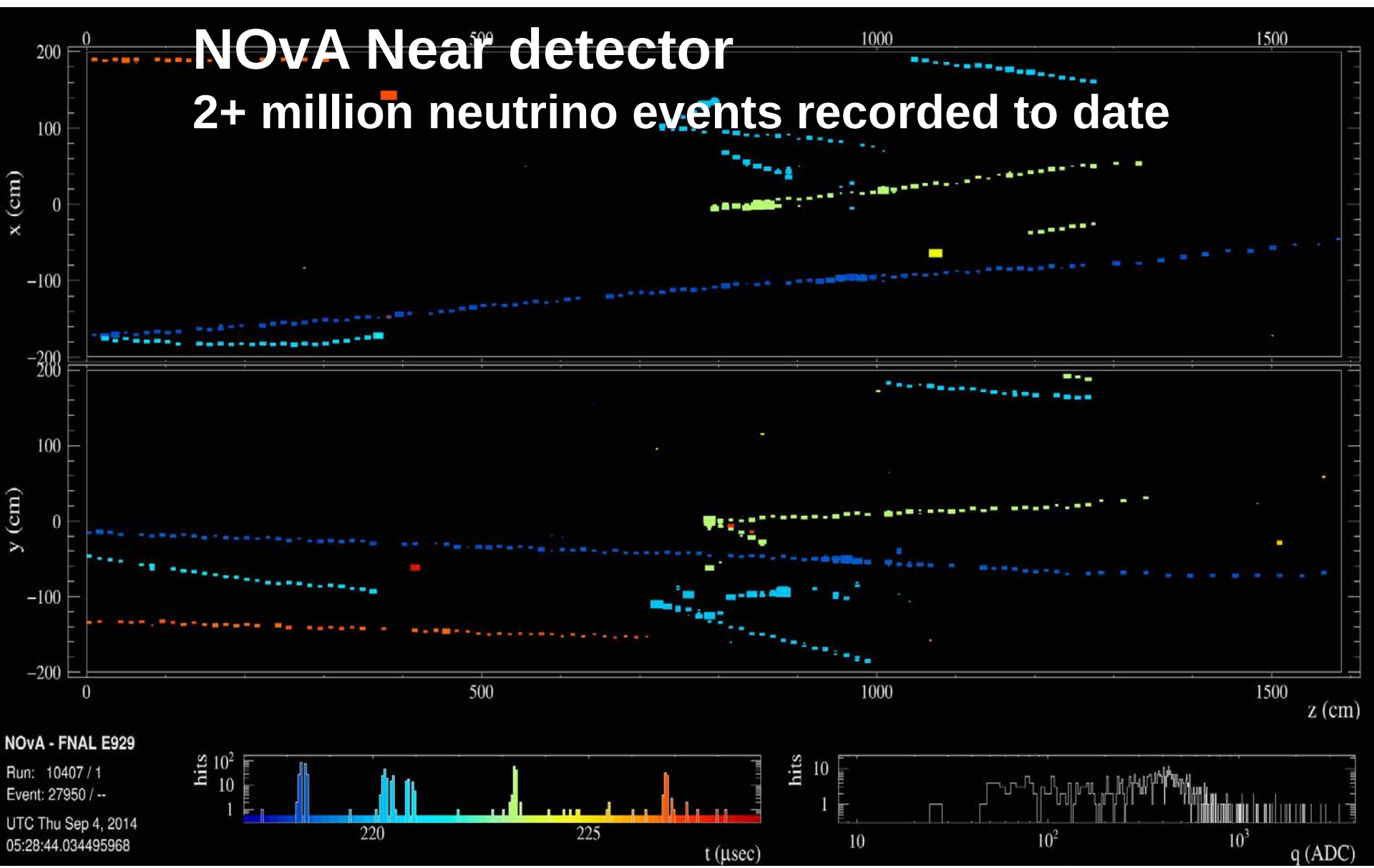


Typical event recorded in full 14kt detector

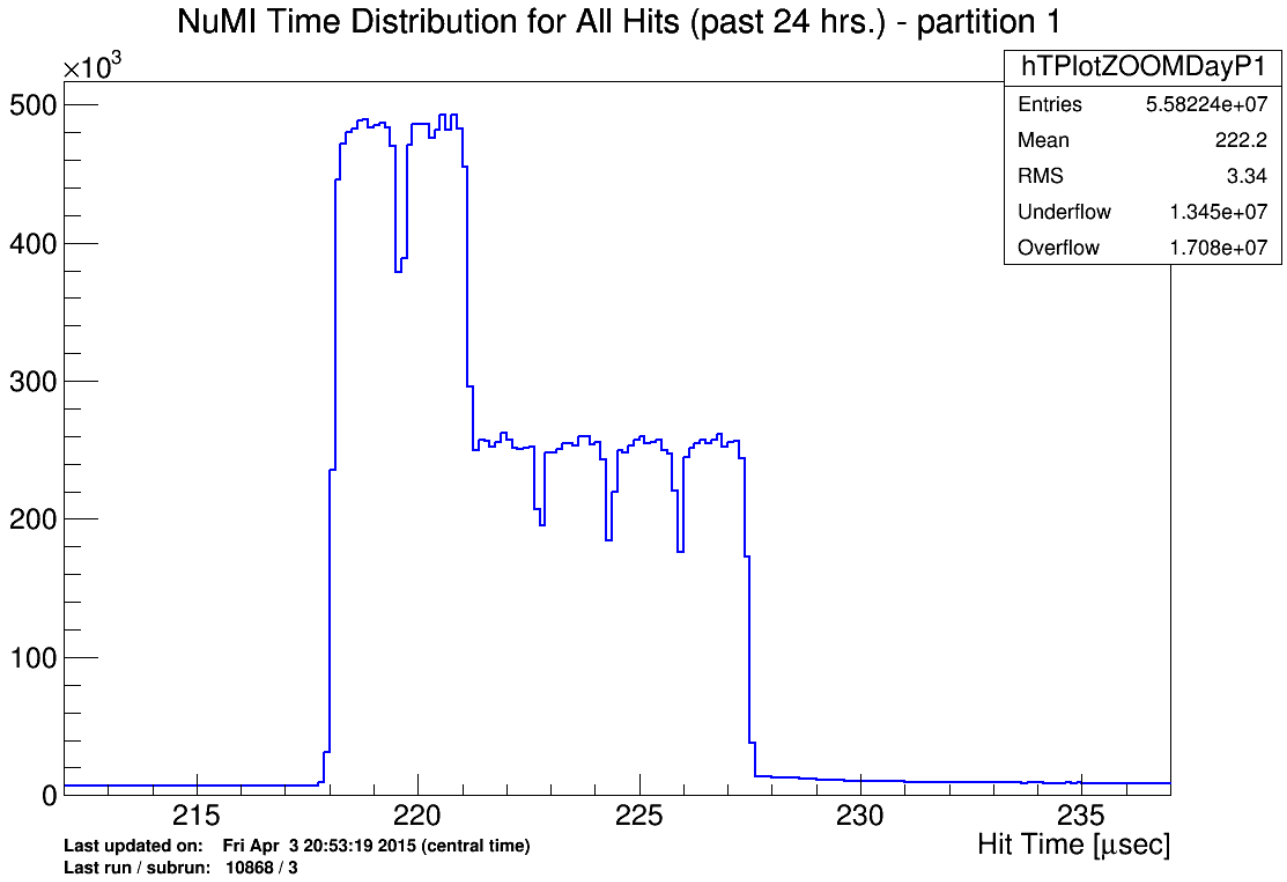

NOvA νe* Charged-current candidate
x (cm)
y (cm)
z (cm)
NOvA - FNAL E929
Run: 15392 / 55
Event: 125664 / NuMI
UTC Wed May 28, 2014
04:55:46.939251776
hits
t (μsec)
q (ADC)

NOvA Near detector

2+ million neutrino events recorded to date



Record NuMI Intensity…slip stacking in recycler

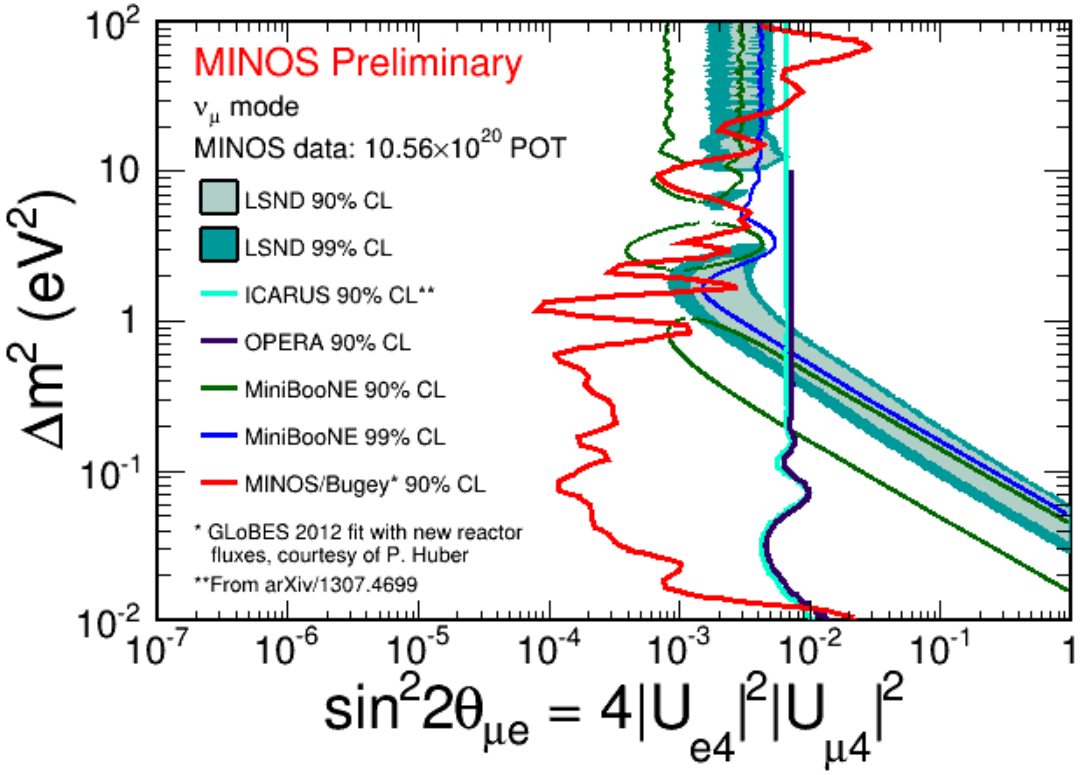


- Histogram shows in spill activity in the NOvA near detector. 6 accelerator bunches are clearly seen.
- "Slip stacking" is working for the first 2 of 6 bunches enabling 400 kW operation.
- Expect to enable slip stacking for remaining 4 bringing intensity to 500 kW this year.

Fermilab

MINOS/MINOS+

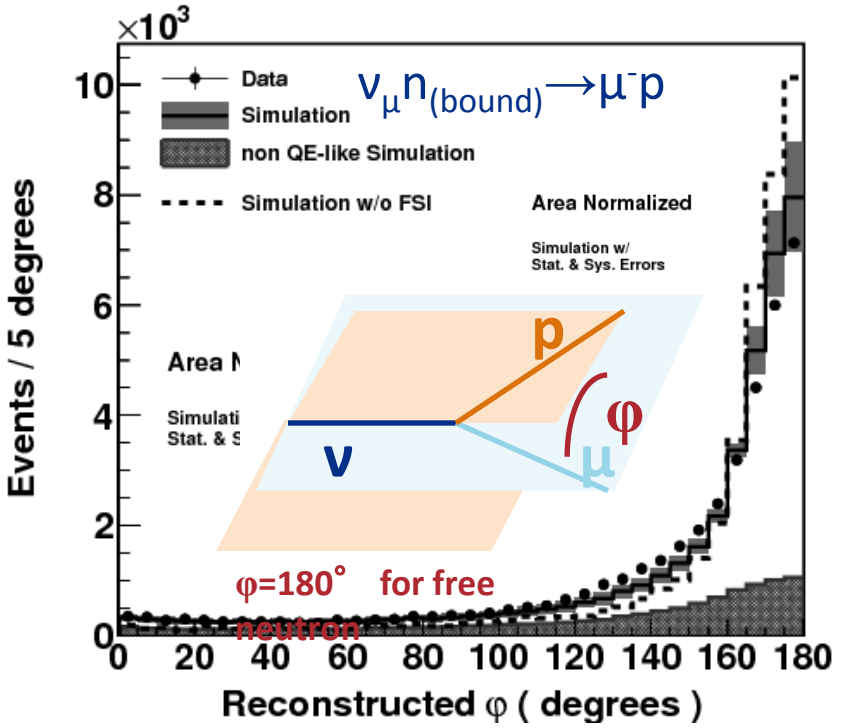
- MINOS/MINOS+ continues exploiting MINOS data and will be soon combining results with MINOS+. The MINOS/MINOS+ experiments are sensitive to several exotic oscillations channels, including sterile neutrinos.



Combining MINOS NC and CC disappearance data with ν_e disappearance data from the Bugey Reactor gives combined limits that can be compared to MiniBooNE, LSND, ICARUS, and OPERA results

MINERvA

- MINERvA's measurement of $\nu_\mu n_{(bound)} \rightarrow \mu^- p$ (Phys Rev D91 071301) directly probes nuclear dynamics in signal reaction for oscillation experiments. Current models are in qualitative, but not quantitative, agreement.



Phi is the angle between the neutrino-muon and neutrino-proton planes. If the original neutron that is struck is free and at rest, then phi is always 180 degrees. Clearly there is more happening inside the nucleus than that and these data are the first to measure this reaction from the final state proton side.

MicroBooNE

- detector has been fully installed in the Booster neutrino beamline

- CD-4 granted in Dec
- Booster horn is currently being replaced
- detector commissioning is in full swing
- taking some time to investigate some new noisy wires (~1% of the TPC)
- initial cool-down will likely start next week

LArIAT (Liquid Argon In A Testbeam)

Repurposed 550-ℓ ArgoNeuT LArTPC detector with modifications for operation in Fermilab Test Beam Facility charged particle tertiary beam (~200 MeV – 2 GeV).


LArIAT TPC


MCenter Tertiary Beam (looking upstream)

Goals Characterize LArTPC performance in the range of energies relevant to upcoming SBN and LBN experiments for neutrino physics and for proton decay searches.

- Study energy resolution improvement by combining information from scintillation light and ionization charge signals
- Experimentally measure e-γ separation
- Develop criteria for charge sign determination
- Optimize pion and kaon ID capabilities

arXiv:1406.5560 [physics.ins-det]

Muon Program

P5:

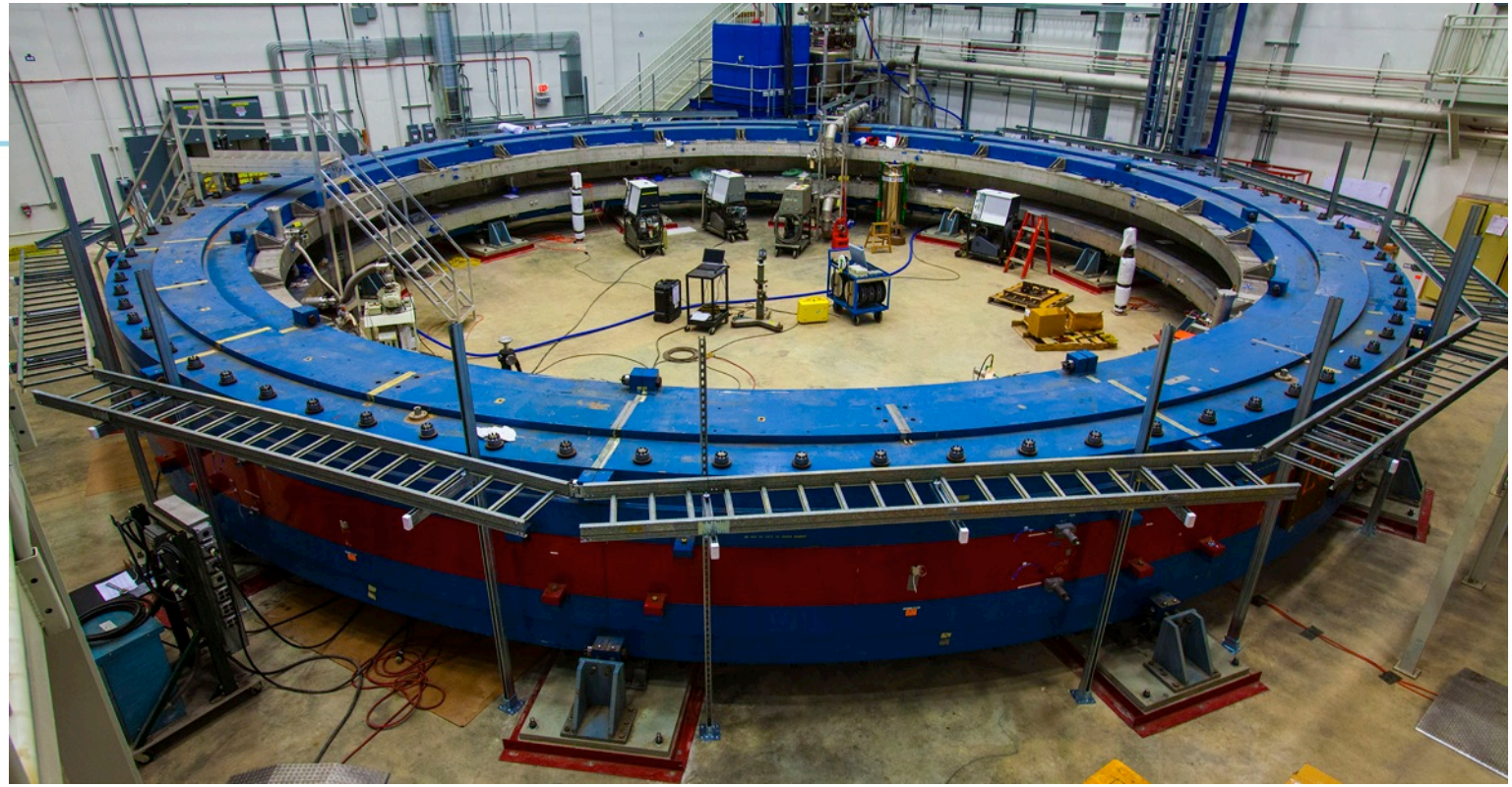
Recommendation 22: Complete the Mu2e and muon g-2 projects.

Our response

Muon Campus

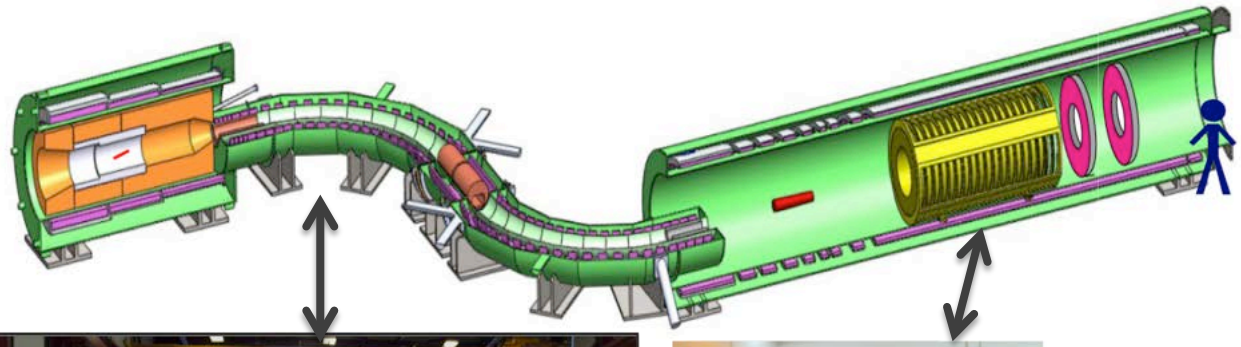
- New user facility with bright μ source
- Already hosts 300 users from 50 international institutions
- Designed a common solution for g-2 and Mu2e
- First generation experiments enabled by PIP, second generation experiments rely on PIP-II

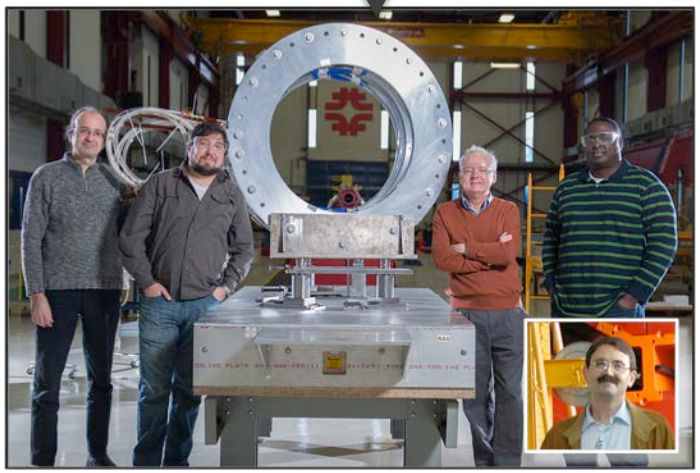
Muon g-2

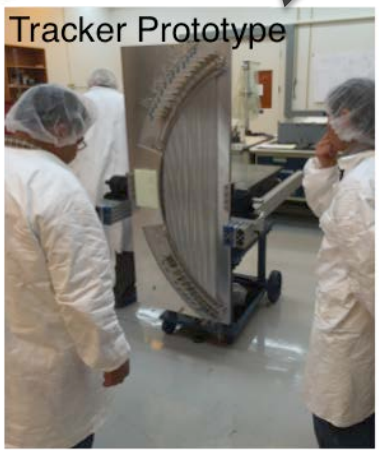


- Magnet reassembly complete
- First pump down / cool down / power up cycle begins today
- Field measurements start this spring, CD2/3 this summer, first beam in 23 months
- Will have a BNL size data set in 2017 and 20x BNL stats by 2019

Mu2e

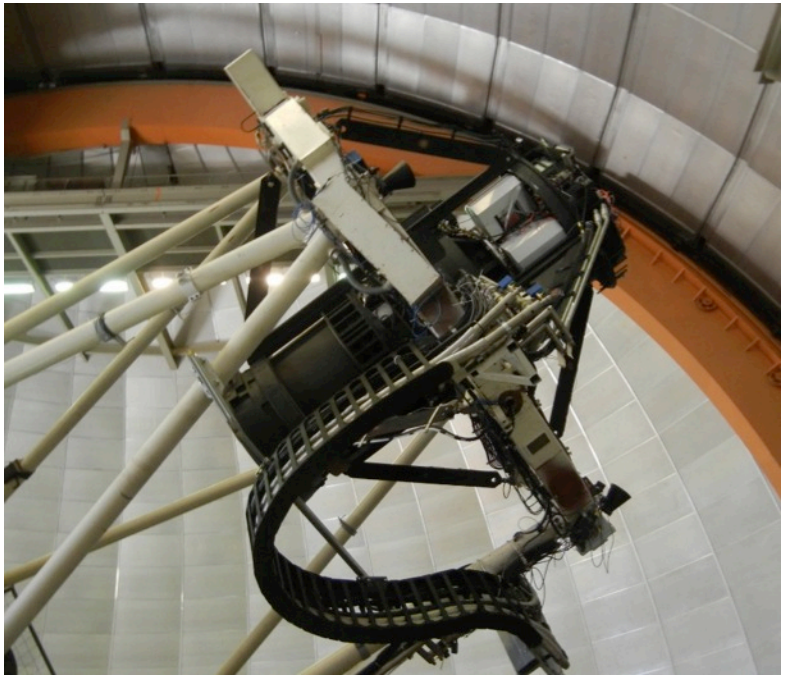






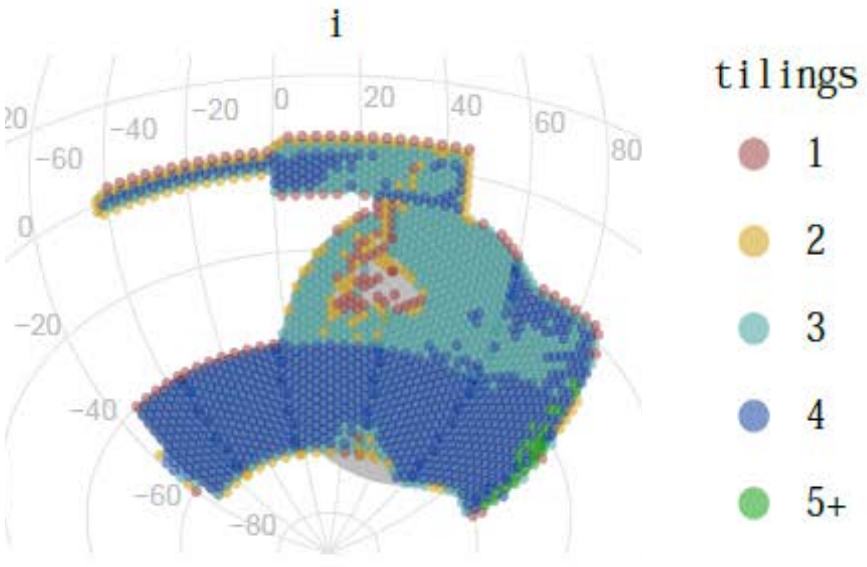
- CD2/3b granted March 4, solenoid procurement underway
- Prototypes for the transport solenoid, tracker, calorimeter and cosmic ray veto systems have been constructed
- Ground breaking for new experimental hall April 18
- Engineering measurements ongoing at PSI (ALCAP), first beam expected 2020

Dark Energy Survey Status



- Dark Energy Camera on the Blanco 4m Telescope in Chile.
- During season 2 the camera and telescope had 99.4% combined reliability (uptime).

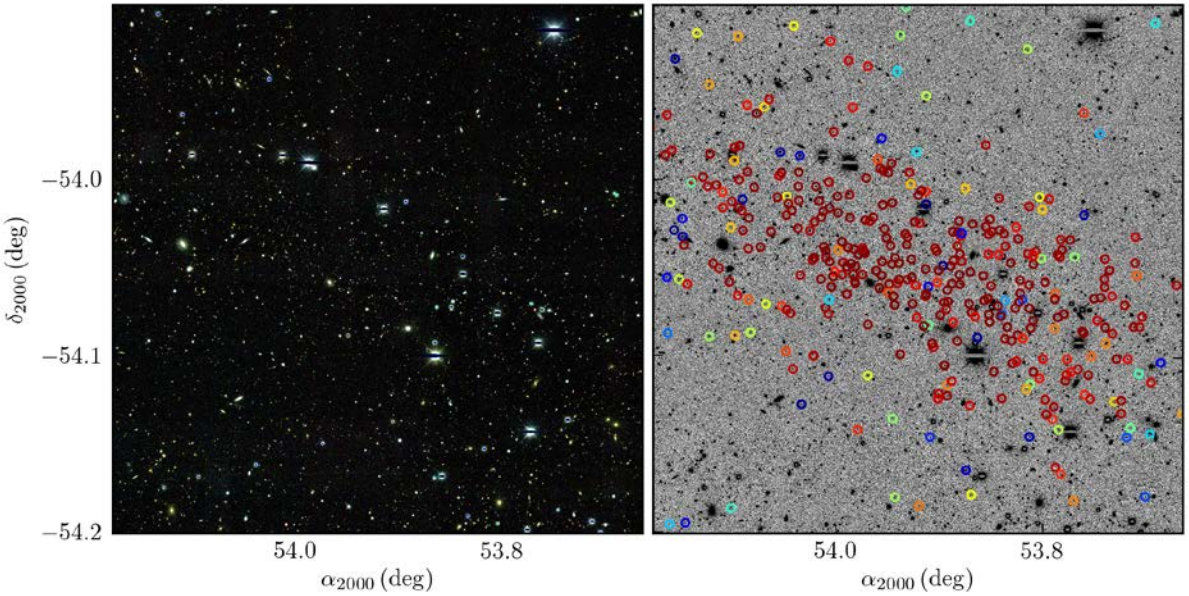
- DES just finished observing season 2 (out of 5) in mid-February.



i-band filter completion map after 2nd year. Goal after 5 seasons is 10 tilings in each field in all 5 filters. Completed 90%.

Dark Energy Survey Science Results

- DES has 9 papers published with 5 more submitted and 9 others in collaboration-wide review.
- Hot off the Presses: 8 New Milky Way Satellite “Dwarf” Galaxies discovered by DES in 1st year data (arXiv:1503.02632). No associated γ-ray excess seen in Fermi/LAT data (arXiv:1503.02584).



Left: cutout of DES image and Right: the stars from one of the dwarf galaxies

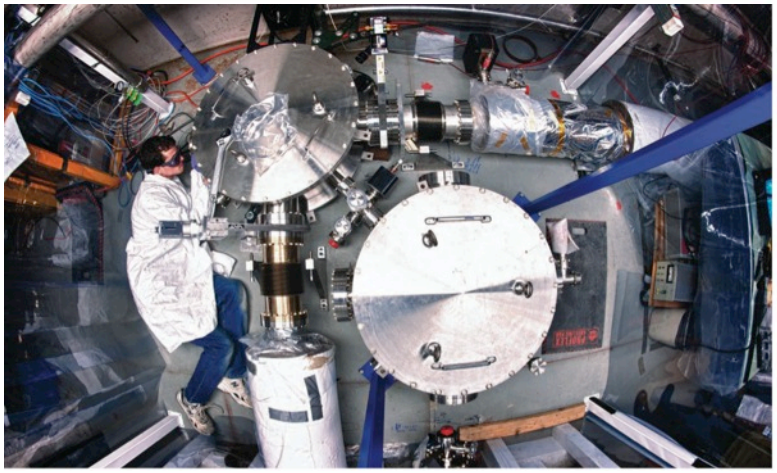
Plus:
So many abstracts
In April 2015 APS Meeting (Baltimore) the organizers created a special session just for DES

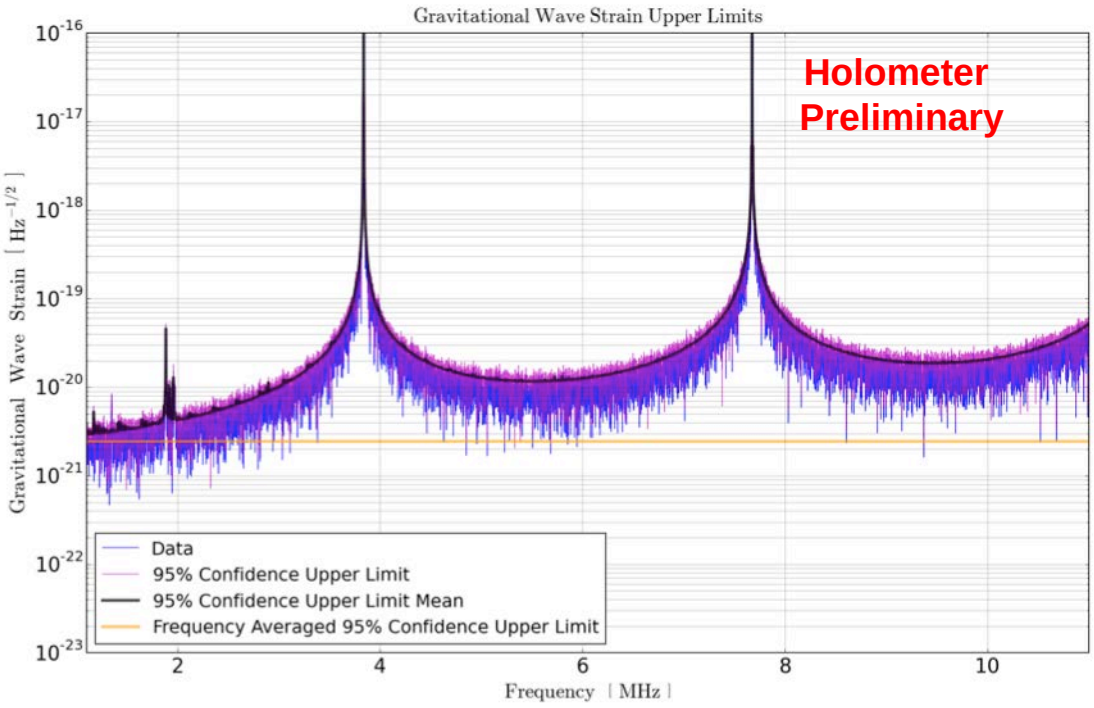
http://www.fnal.gov/pub/presspass/press_releases/2015/DES-Dwarf-Galaxies-20150310.html

http://meetings.aps.org/Meeting/APR15/Session/Y2

Holometer first results

- Holometer funded through DOE Early Career program in 2011 (A. Chou Fermilab)
- Operations began in 2014
- Cross-correlate the outputs of two 40 meter, high-power laser interferometers to average down uncorrelated noise



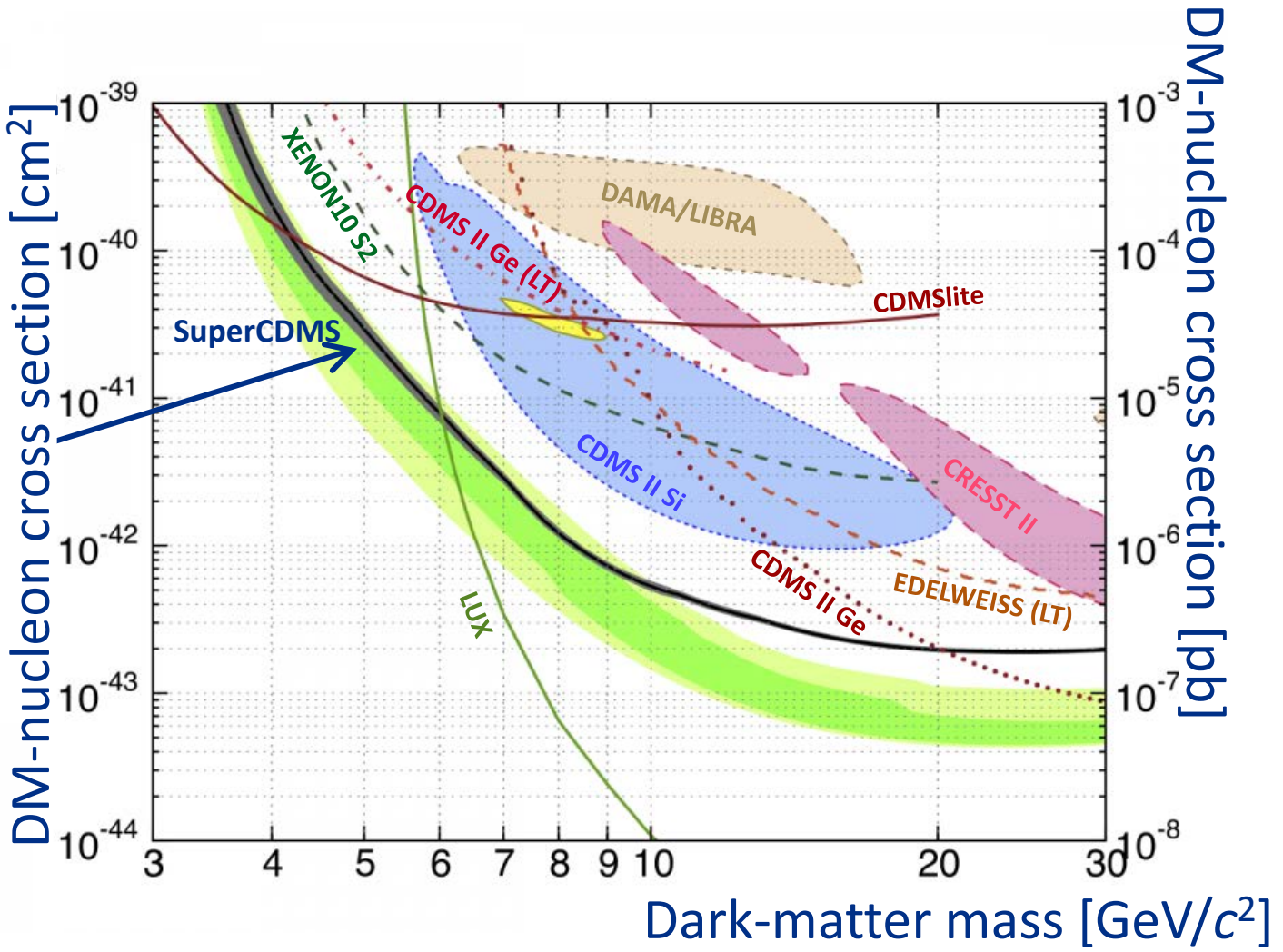


- Initial data with position sensitivity of ~ 10^{-19} m/rtHz already gives world-leading sensitivity to MHz gravitational waves
- Results on Planck-suppressed holographic noise at 10^{-20} m/rtHz are expected later in 2015

Fermilab

SuperCDMS (Cryogenic Dark Matter Search)

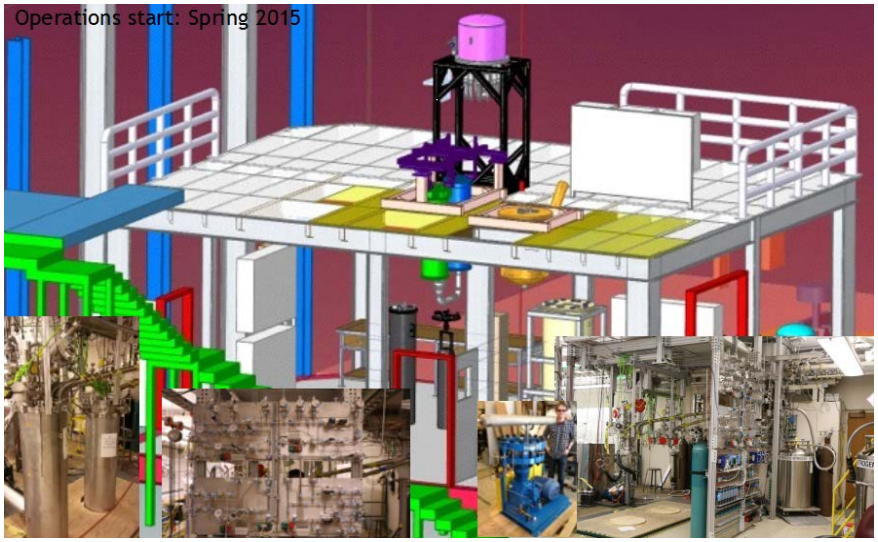
- Best low-mass WIMP dark matter sensitivity
- Recent results from Soudan



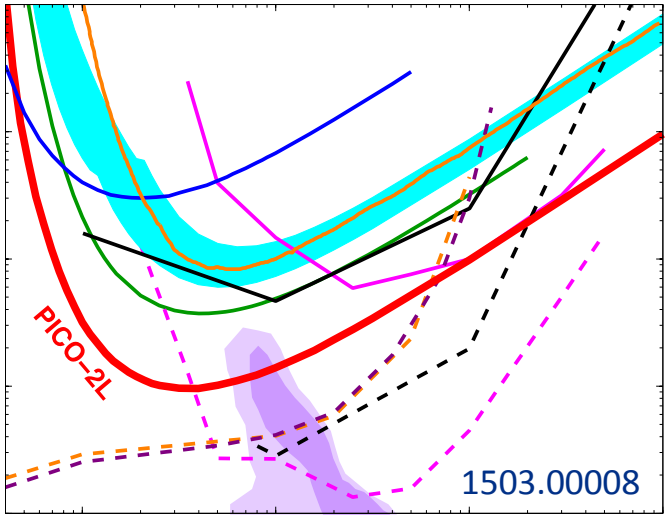
Fermilab

Fermilab role in LZ and PICO

LZ system test at SLAC (spring 2015)



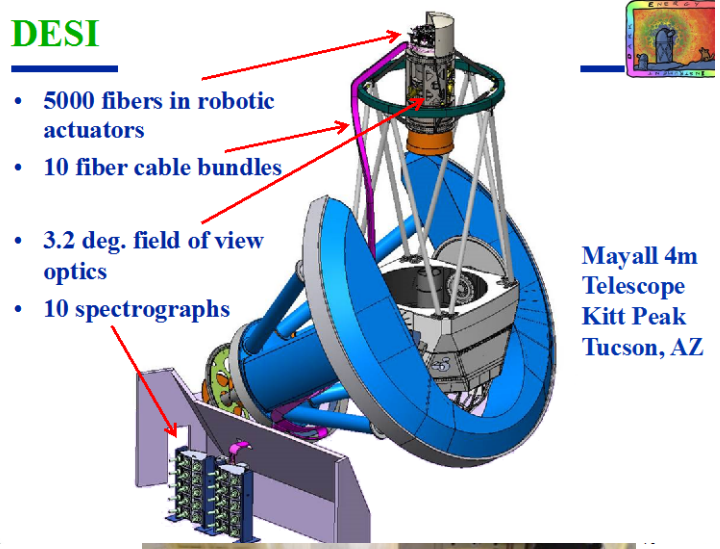
- **LZ - Process Controls**
  - Builds on experience with MicroBooNE, NoVA, other Fermilab experiments
  - Filling urgent short term need of system test at SLAC (testing HV, Kr purification)
  - System test development applicable to full detector

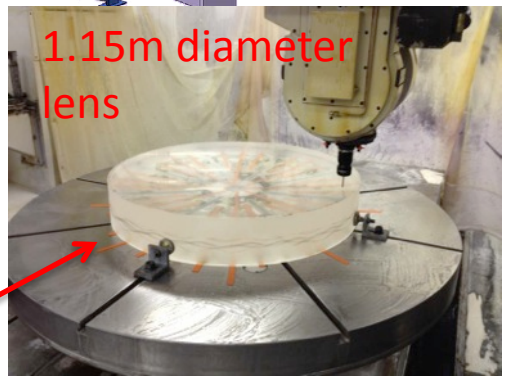


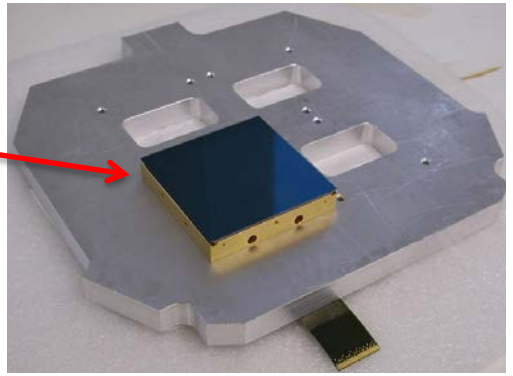
- **PICO Operations and R&D**
  - PICO-2L (C_3F_8) most sensitive direct detection experiment for **spin dependent** WIMP-proton couplings
  - First PICO-60 CF_3I results expected this spring
  - Continuing R&D to understand background sources (test chambers, engineering runs of SNOLAB detectors)
  - Increasing participation from external collaborators

Dark Energy Spectrographic Instrument (DESI)

- Stage 4 DE project to measure the cosmic distance scale to better than 0.3% over nearly the entire age of the Universe, constrain neutrino masses and inflation.
- CD-1 approval March 2015
- CD2/3a review July 2015
- On-sky commissioning 2019
- Strong support (financial, scientific, engineering/technical) from many institutions and private funds are jump starting the project.
- All lens Blanks delivered, polishing started
- CCD packaging: March ’15 CCD prototypes
- Purchase of **new CMM** for lens cell alignment
- Broad international collaboration still forming
- DESI collaboration meeting at Fermilab May ‘15

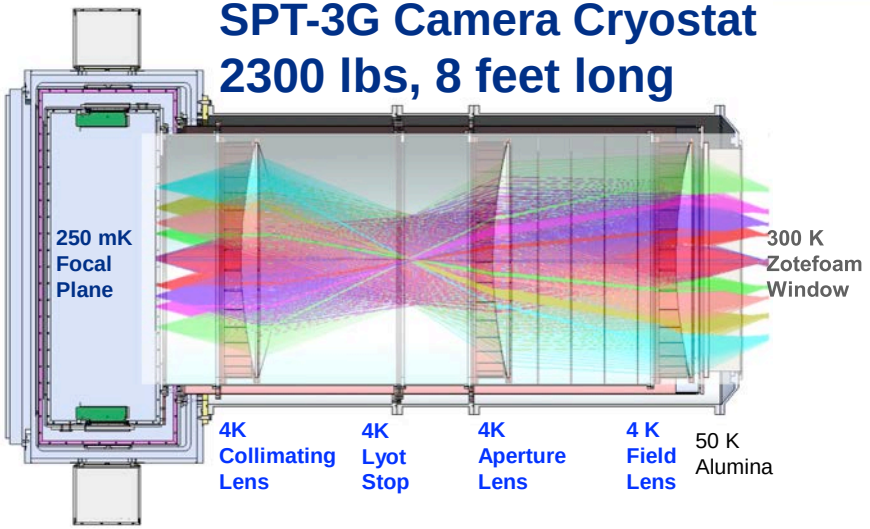


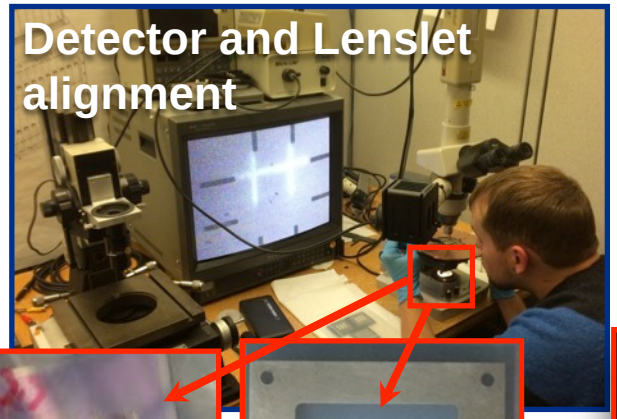


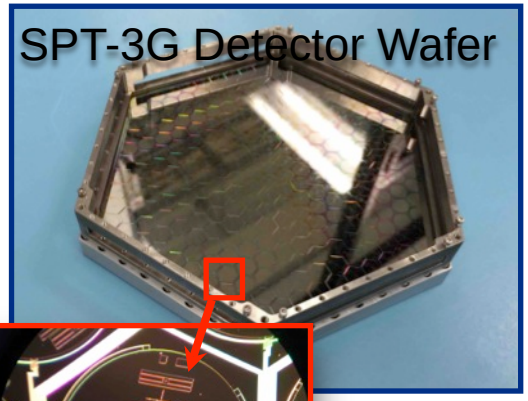


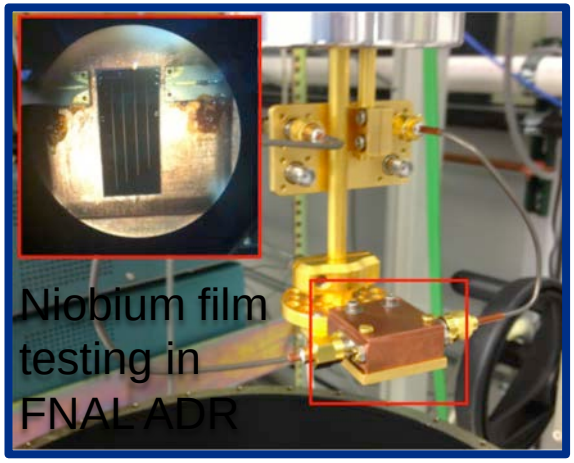
Fermilab Roles for CMB

- **SPT-3G Camera:** Design and fabrication of cryostat, integration with focal plane.
- **Detector Module Assembly:** Packaging detector wafers for SPT-3G (wire-bonding, wafer alignment)
- **Detector Development:** Sub-Kelvin cryostats to characterize TES detectors and superconducting films; microwave simulation of detectors.









Summary

- P5 implementation is on schedule
- Neutrino program launching ahead of schedule
  - International partnerships have come together in DUNE
- LHC program is strong
  - Physics, upgrades, high field magnet program, crabs,computing
- Muon campus on track…g-2 starts 2017
- Cosmic programs strong & diverse…DES making discoveries
- Ongoing experiments & accelerator performance excellent
- HEP R&D in SRF technology impacting LCLS-II