



# Director's report

Joe Lykken

51<sup>st</sup> Annual Users Meeting

June 20, 2018

# The P5 Plan is working and is strongly supported in Washington

## High Energy Physics – DOE Budget

- FY2015: \$766M
- FY2016: \$795M
- FY2017: \$825M
- **FY2018: \$908M**
- **FY2019 outlook is very favorable**

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## Building for Discovery

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

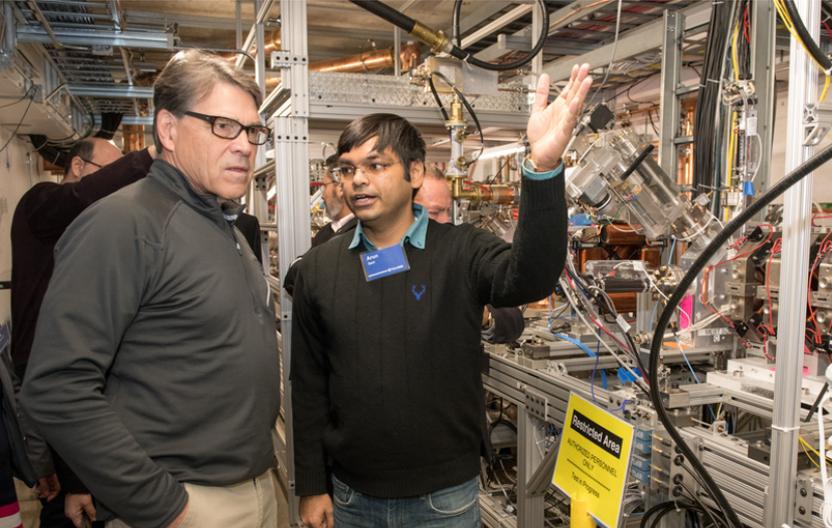
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# Washington Summary

- Strong support from DOE Office of Science and HEP
- White House OSTP has highlighted DUNE as a key project
- Recognition of project by DOE Leadership - Secretary Perry, Deputy Secretary Brouillette, Under Secretary Dabbar, DD SC Steve Binkley, Joe McBrearty DD Field Operations, Mike Weis, Head of FSO, and AD OHEP Jim Siegrist, etc etc
- Congressional support strong
  - Letters of support from Senators from IL, SD, CT, WI, MN
  - House support includes IL, SD, MN, TX, ...
- Lewis-Burke (Leland Cogliani) and your Washington visits have done a remarkable job – **Thank You**

# DOE Secretary Perry visits Fermilab



# Paul Dabbar, DOE Under Secretary for Science, visits Fermilab



Paul Dabbar (center) at a visit last fall to the Fermi National Accelerator Laboratory in Batavia, Illinois REIDAR HAHN/FERMILAB

## Undersecretary Paul Dabbar paints broad vision for Department of Energy science

By [Adrian Cho](#) | Jun. 13, 2018 , 12:50 PM

# PIP-II project moving ahead

- Successful Independent Project Review (CD-1)– Dec '17
- **FY18 Budget = \$25.1M (full funding) and a budget line item**
- First time a U.S. lab will have built a major accelerator project in the U.S. with international partners
  - Major partners at Dec '17 review: India, UK, France, Italy
- Aim is 1.2 MW of beam power day one for DUNE 2026



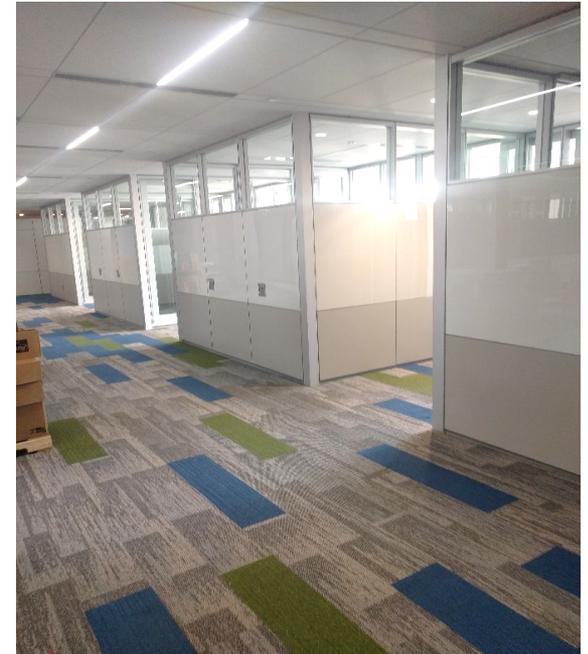
# Integrated Engineering Research Center

- Fermilab has a Campus Master Plan that positions the 6,800-acre campus to support the international DUNE experiment + LBNF + PIP-II.
- The Integrated Engineering Research Center (IERC) will provide state-of-the-art laboratories, engineering and technical spaces within a collaborative environment that will host scientists and engineers from around the world at Fermilab.
- IERC building is funded at \$20M in U.S. FY18 Budget



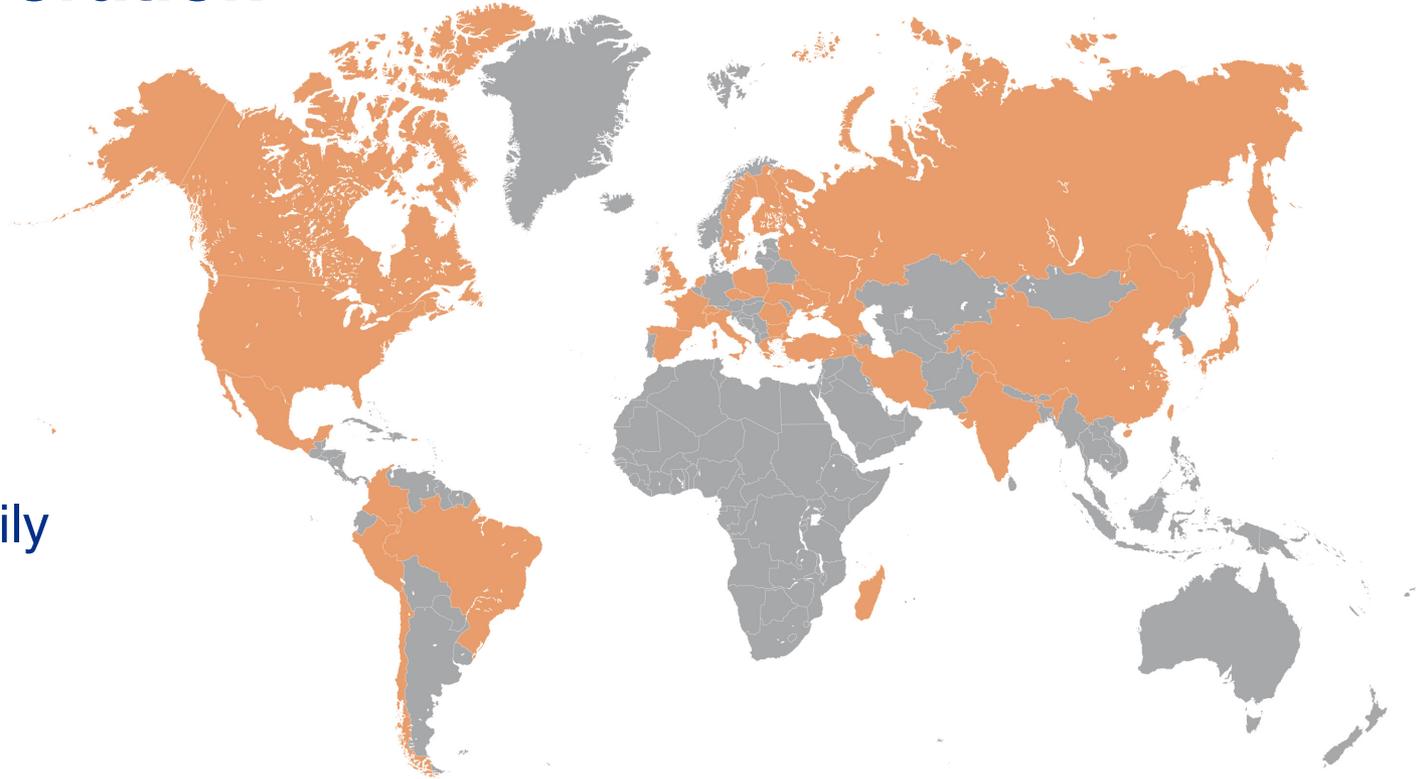
# Wilson Hall Renovation – 13<sup>th</sup> Floor

- Setting a new standard for state-of-the-art, well-organized space in Wilson Hall, the renovated 13th floor will become the hub for the neutrino community - Neutrino Division HQ, LBNF and DUNE
- Sustainability features include LED lights, heat reflecting window shades, hydropowered self-generating faucets, upgraded lighting and mechanical controls, and daylight harvesting



# DUNE collaboration

1,078 scientists  
from 175 institutes  
in 32 countries  
and growing steadily



# Her Excellency Julie Payette, Governor General of Canada

New partnership  
between Fermilab and  
York University in  
Toronto in support of  
DUNE



First stop on her first official visit to the U.S.

# U.S. – India Sign Agreement for Neutrino Physics Collaboration

Annex – II signed to advance cutting-edge neutrino science projects

“The LBNF/DUNE project hosted by Fermilab in collaboration with our international partners is an important priority for the Department, the Administration, and America’s leadership in science,” said Secretary of Energy Rick Perry.

## U.S. Department of Energy and Indian Department of Atomic Energy Sign Agreement for Neutrino Physics Collaboration

APRIL 16, 2018

Home » U.S. Department of Energy and Indian Department of Atomic Energy Sign Agreement for Neutrino Physics Collaboration



NEW DELHI, INDIA-- Today, U.S. Secretary of Energy Rick Perry and India's Atomic Energy Secretary Dr. Sekhar Basu signed an agreement to expand the two countries' collaboration on world-leading science and technology projects. It opens the way for jointly advancing cutting-edge neutrino science projects underway in both countries: the Long-Baseline Neutrino Facility (LBNF) with the international Deep Underground Neutrino Experiment (DUNE) hosted at the U.S. Department of Energy's (DOE's) Fermilab, and the India-based Neutrino Observatory (INO).

# ProtoDUNE-SP at CERN is on schedule



# New Fermilab Leadership

- Lia Meringa – PIP-II Project Director
- Liz Sexton-Kennedy – Chief Information Officer
- Josh Frieman – head of Particle Physics Division
- Patrick Weber – head of South Dakota Services Division



# Leadership in International CMS

- Joel Butler rotates off as CMS Spokesperson on Sept 1, 2018
- Patty McBride selected as new CMS Deputy Spokesperson
- Patty is also Nigel Lockyer liaison to CERN and the European community



Joel Butler  
Fermilab



Patricia McBride  
Fermilab

# SBN: ICARUS and SBND

## Recent ICARUS progress

- Welding of vessel doors – now
- Rig detector vessels into the building July 9

## Early 2019

- ICARUS LAr fill and transition to commissioning



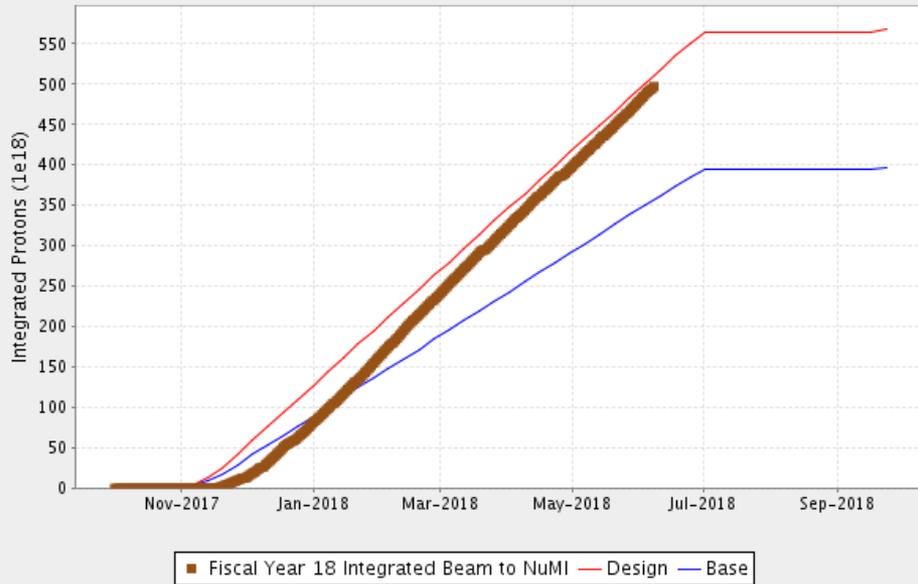
## Coming in 2019:

- SBND start cryostat and detector installation

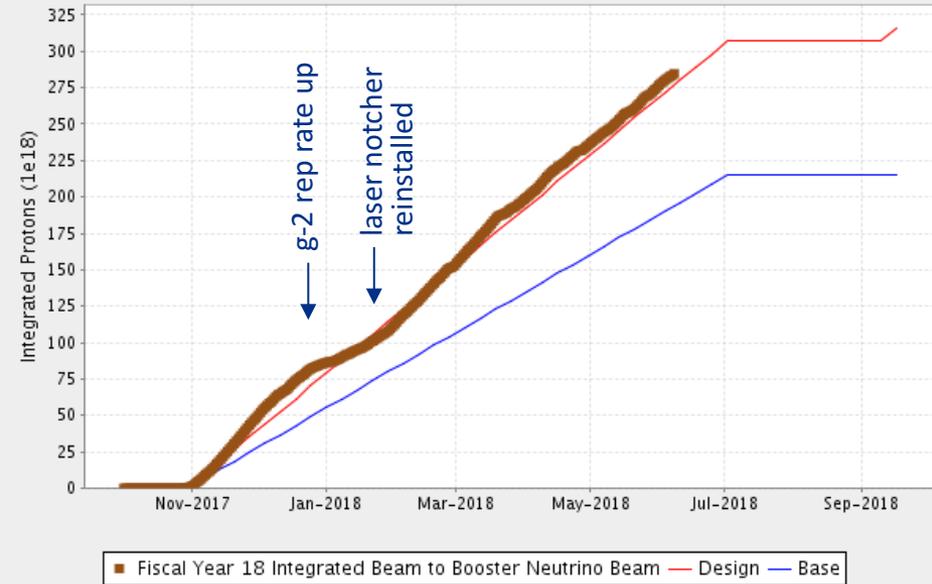


# FY18 Fermilab accelerator performance for HEP

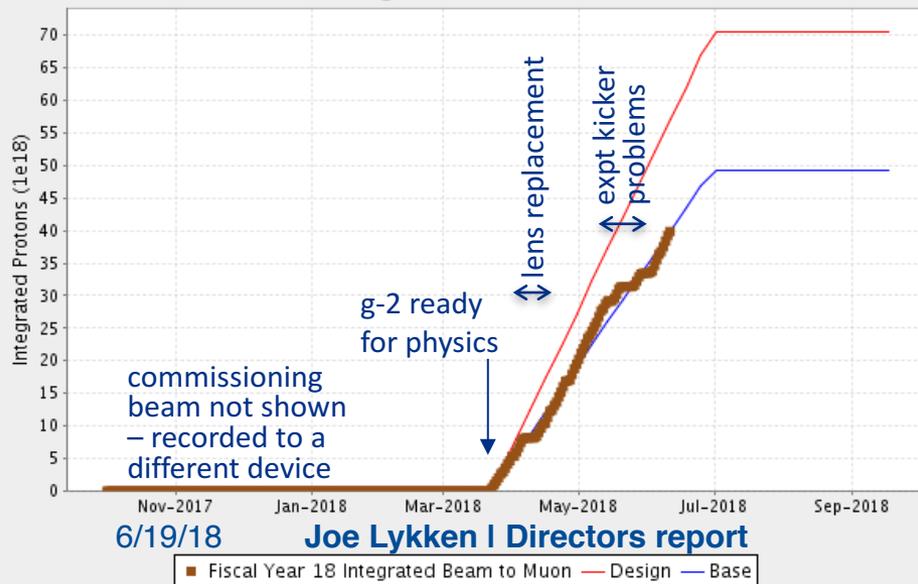
## FY18 Integrated Beam to NuMI



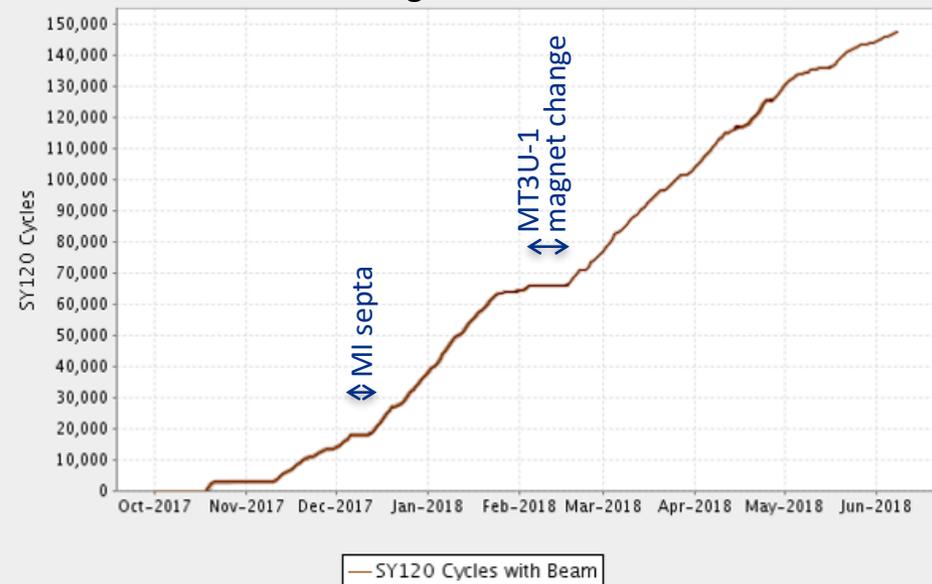
## FY18 Integrated Beam to Booster Neutrino Beam



## FY18 Integrated Beam to Muon

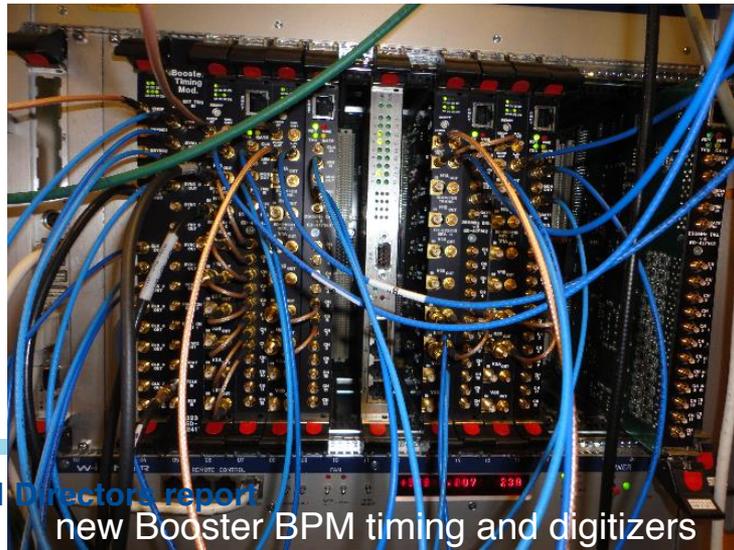
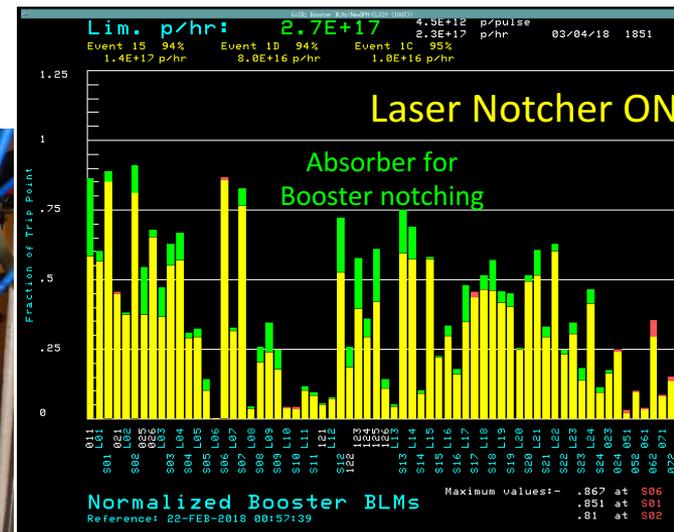
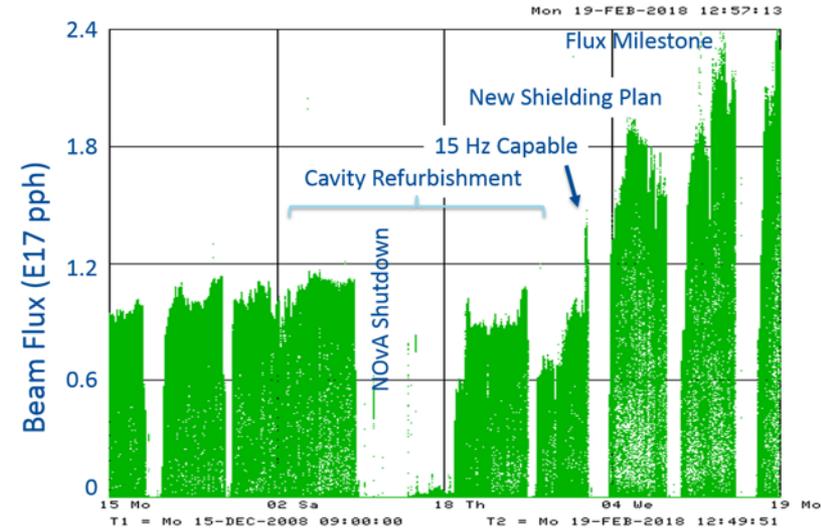


## FY18 Integrated Beam to SY120



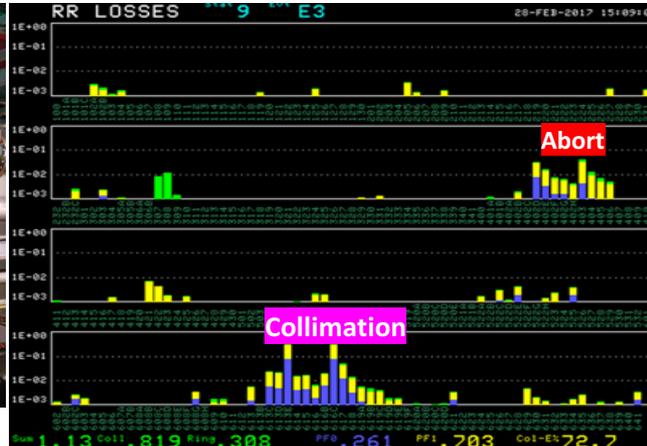
# Proton Improvement Plan will complete this summer!

- Running 2.4 E17 protons per hour
- Laser notcher was last critical piece
- Complete Marx modulator installation
- BPM upgrades
- Install prototype replacement cavity (20-Hz capable)

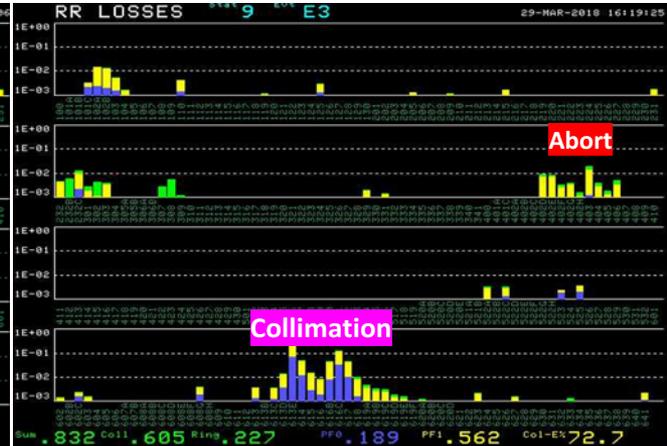


# NuMI integrated beam and beam power

- Made aperture improvements in Recycler last shutdown to reduce losses



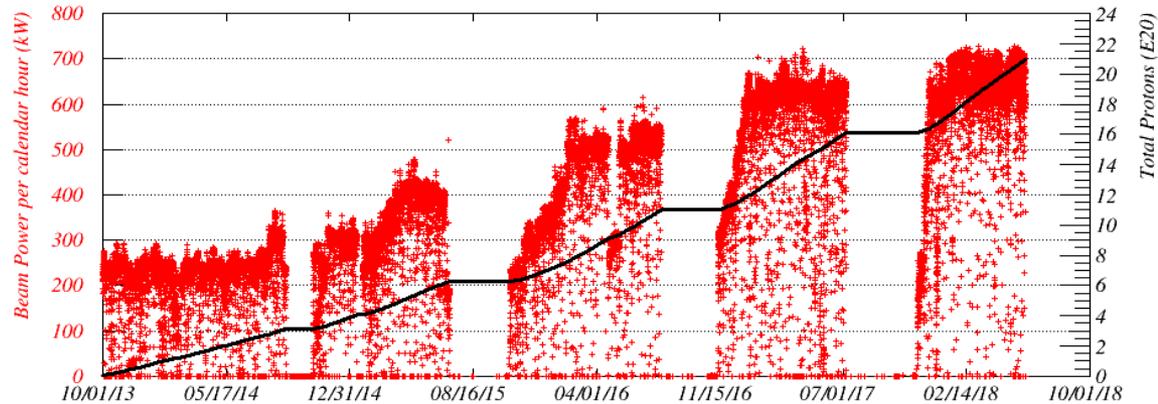
BEFORE



AFTER

Replaced the Recycler Lambertson with an MLAW and the RR beam pipe with MI beam pipe

- Delivered 21 E20 p to NuMI target since 2013
- Averaging 0.73 E20/mo
- 85% uptime recent years
- Short shutdowns help keep NOvA competitive
- New shielding assessment approved for up to 1.5 MW!



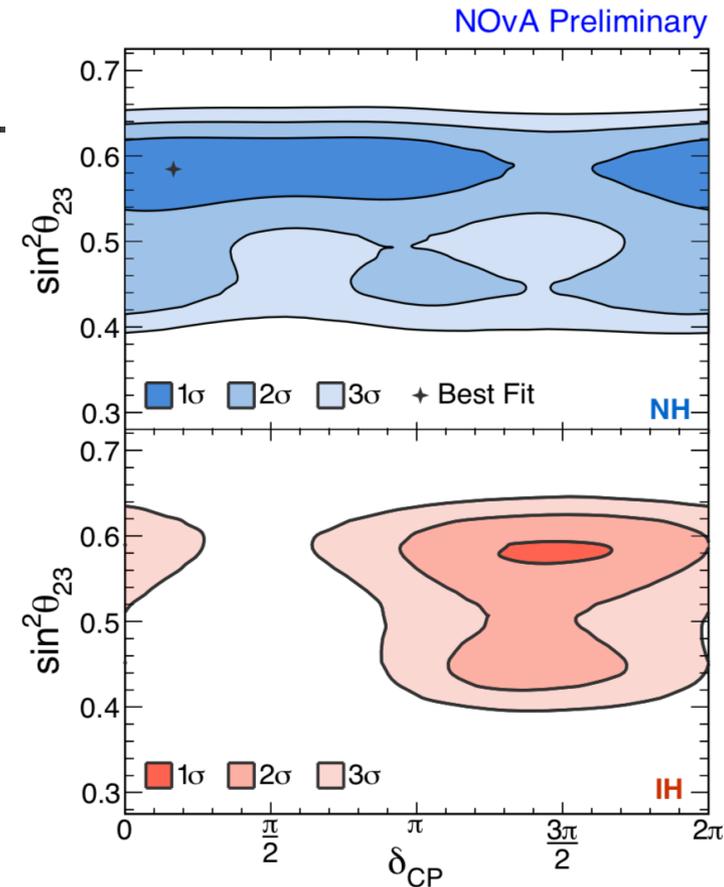
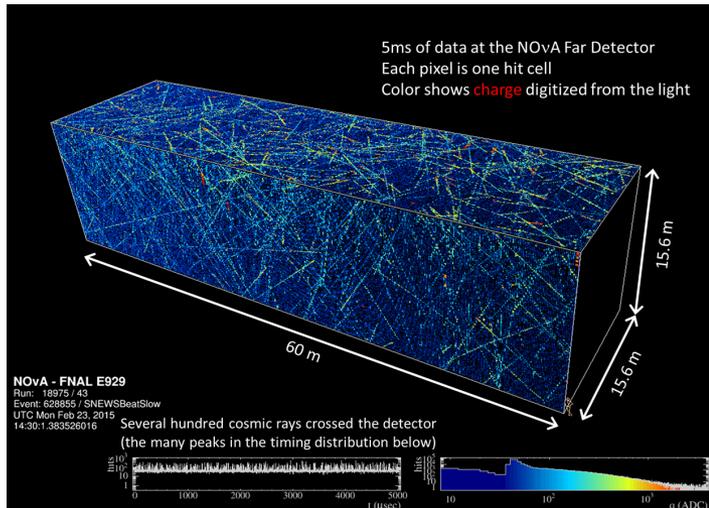
# NOvA

## New co-spokesperson Patricia Vahle

- Many thanks to Mark Messier (*Indiana*), who has stepped down after 12 years of outstanding service to NOvA!
- Tricia joins Peter Shanahan (*Fermilab*)..



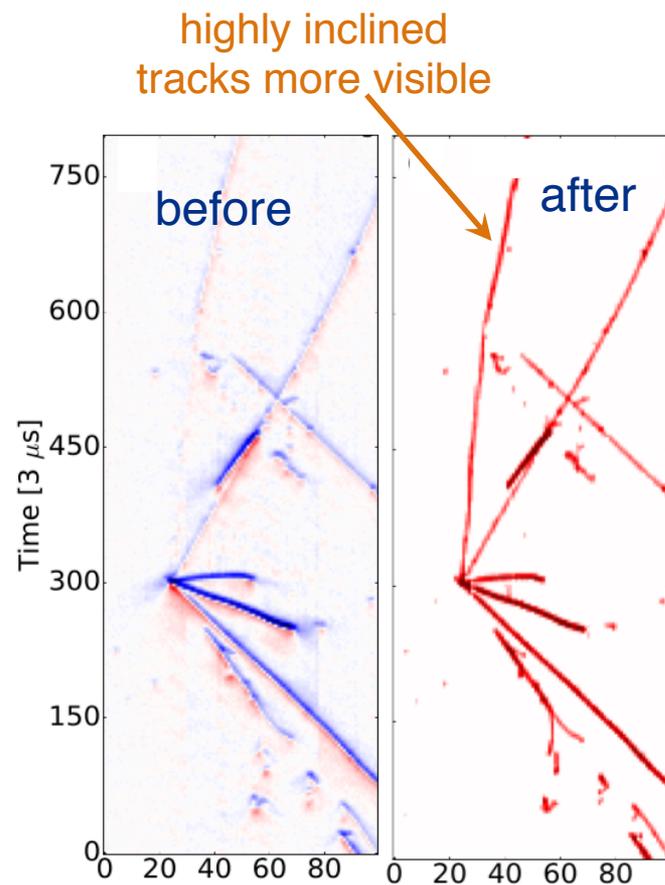
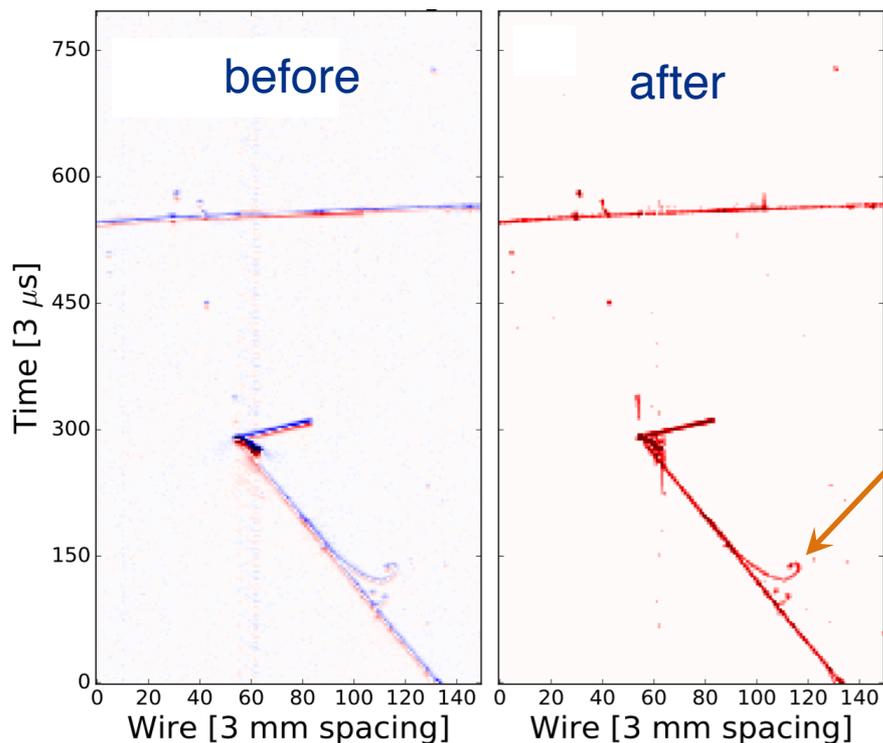
## Impressive new results presented at Neutrino 2018



# MicroBooNE

Physics results + first set of comprehensive papers on extracting improved signals from single-phase liquid argon TPC detectors

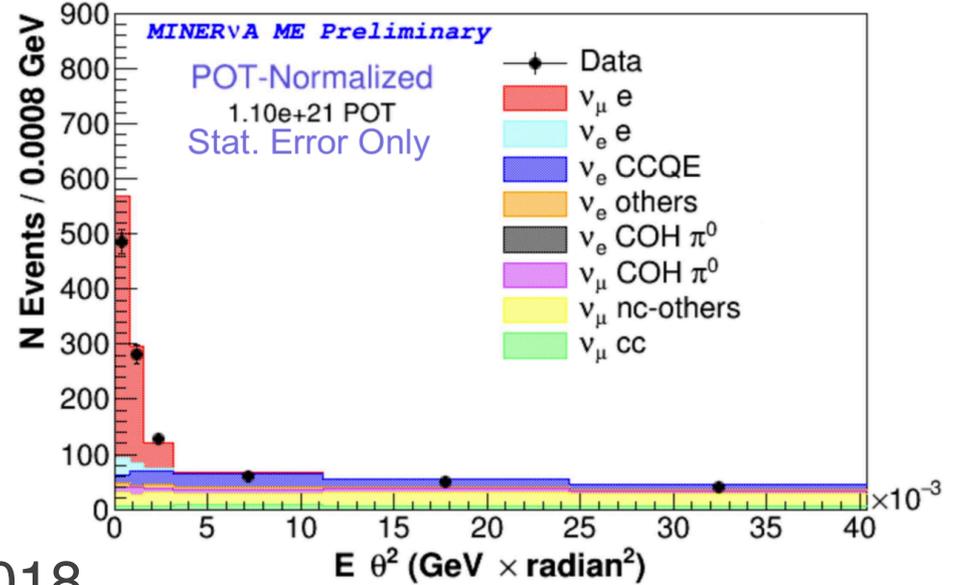
(<http://arxiv.org/abs/1804.02583>)  
(<http://arxiv.org/abs/1802.08709>)



# MINERvA



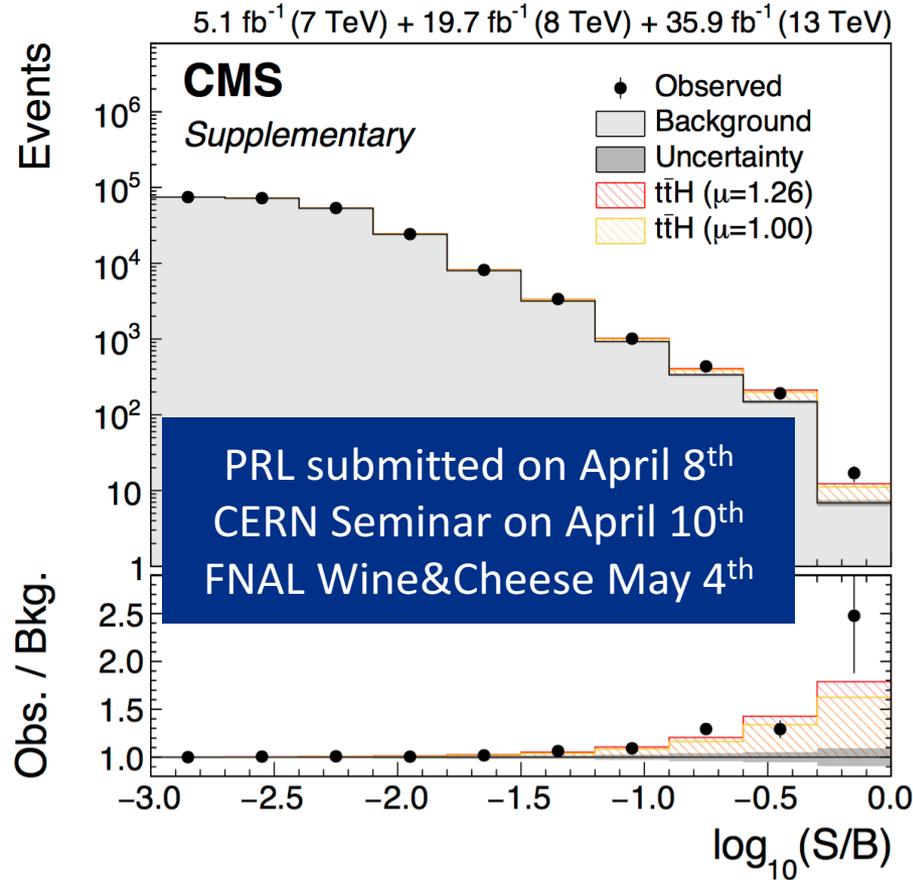
## First Medium Energy Result



Teaser of first medium energy results presented at Neutrino 2018



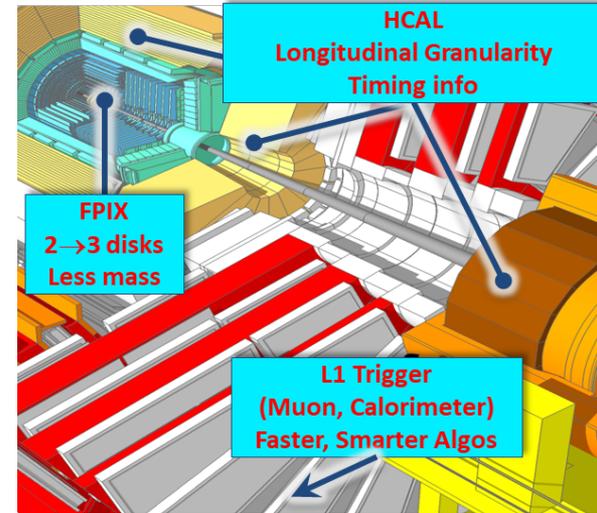
# CMS makes a historical step in the understanding of the Higgs boson



- **First observation of the associated production of Higgs bosons and top quarks**
- Search based on 7, 8, 13 TeV datasets
  - Significant contributions from FNAL RAs, Caterina Vernieri and Satoshi Hasegawa
- Observed excess of 5.2 standard deviations
- Normalized signal strength  $1.26^{+0.31}_{-0.26}$

# CMS Phase 1 Upgrade is nearing completion

- **Forward Pixel Detector** - Done, now in Operations
- **L1 Trigger** - Done, now in Operations
- **Hadron Calorimetry Electronics**, including latest of the QIE ASIC dynasty
  - Backend Readout - Done, now in Operations
  - Forward and Endcap Front-end - Done, now in Operations
  - Barrel portion will complete by end of 2018



Happy Andrew Whitbeck at the HCAL electronics burn-in installation



6/19/18

Joe Lykken / Directors report

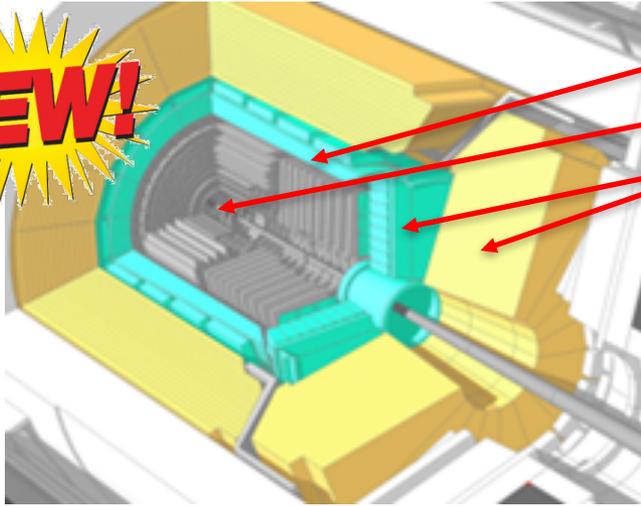
Lou Del Monte and Nadja Strobbe testing QIE11 ASICs



Aram Apyan safely working on installation

# HL-LHC CMS Upgrade picking up steam

**NEW!**



**Timing Layer** – 4D tracking!

**Outer Tracker** – Track Trigger capabilities!

**Calorimeter Endcap** – Imaging jets!

**L1 Trigger** – Track/Calorimetry correlation at L1!

R&D on all of the above (and more) ongoing

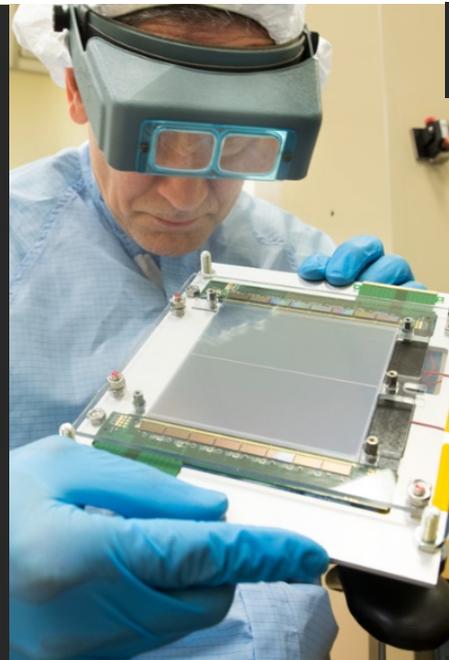
- Spans facilities such as SiDet, Testbeam, Irradiation facility, ASIC design, carbon fiber fabrication...



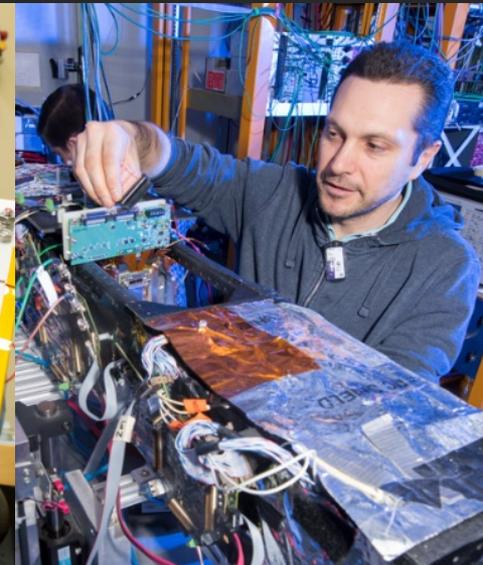
Texas Tech students Sonaina Undleeb and Kamal Lamichhane , with Zoltan Gecse and Maral Alyari testing the prototype Endcap cassette at SiDet

[Joe Lykken | Directors report](#)

Bert Gonzales with prototype Outer Tracker Module at SiDet

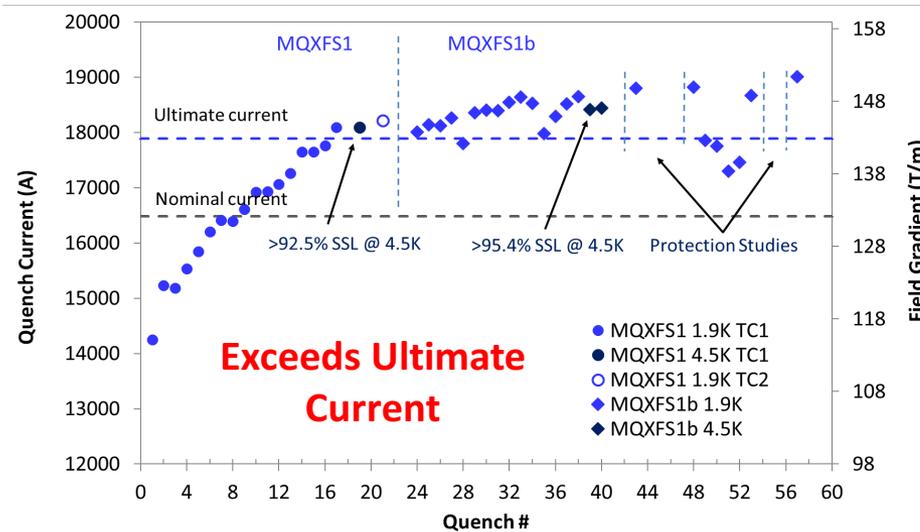


Lorenzo Uplegger preparing for Tracker Module testing at FTBF



# HL-LHC AUP project

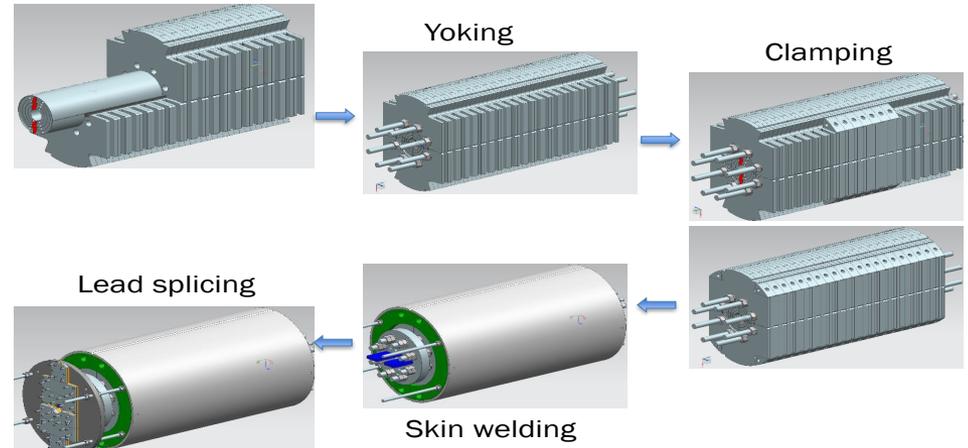
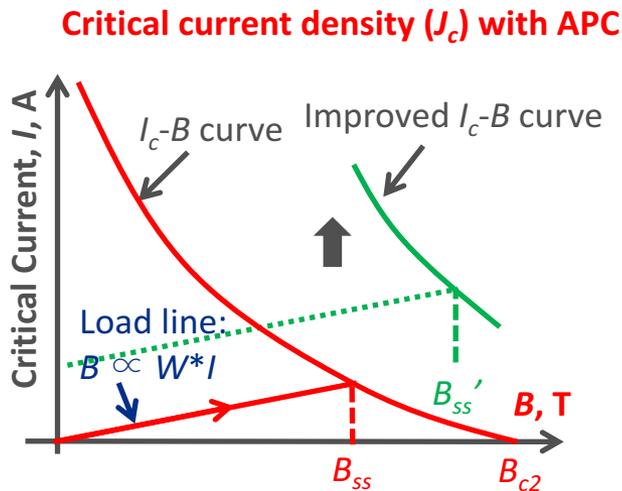
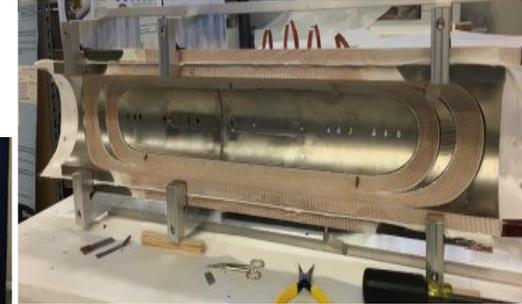
- The project is building half of the large aperture interaction region quadrupole for High-Lumi LHC upgrade
- The magnets are built on the state-of-art Nb<sub>3</sub>Sn superconductor - first time application in accelerators
- Projects passed CD1/2a review, preparing for CD2/3b. Production is ramping up.



# Nb<sub>3</sub>Sn conductor R&D and 15 T dipole for future accelerators

- Nb<sub>3</sub>Sn wires with Artificial Pinning Centers (APC) – Fermilab LDRD
  - Increasing 2-3 times  $J_c$
- High-heat capacity ( $C_p$ ) Nb<sub>3</sub>Sn wire R&D
  - Improving quench training
- These R&Ds are establishing FNAL leadership in the Nb<sub>3</sub>Sn conductor R&D field!

- 15 T dipoles step to 16 T HE-LHC or FCC dipole
- Magnet production is progressing well!
- Magnet test - planned in October 2018!



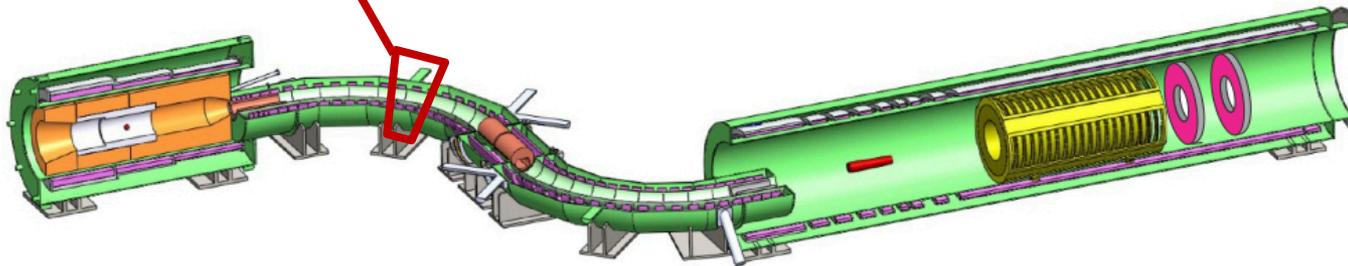
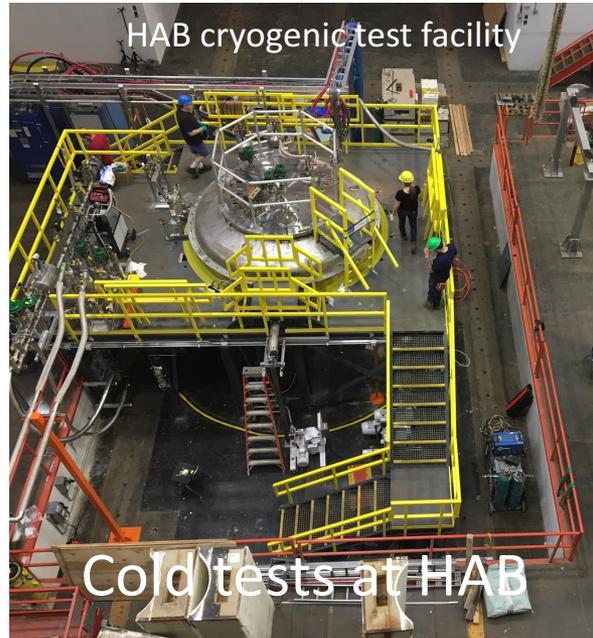
# Muon g-2 commissioning → physics data



Collecting  $\sim 1.5 \times$  BNL before shutdown → 1<sup>st</sup> physics results in FY19

# Mu2e: First unit of Transport Solenoid (TS) has arrived!

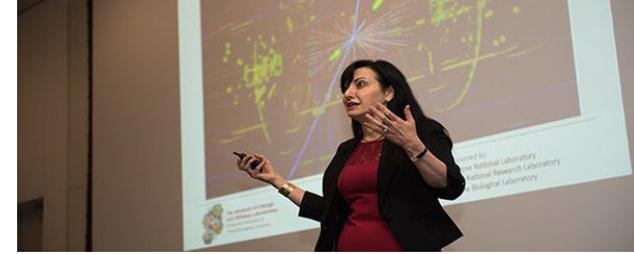
- First TS Unit has arrived at FNAL and is being tested
- A new unit will arrive every 6 to 8 weeks



# Leadership in Theory



Ruth Van de Water and Distinguished Scholar Aida El-Khadra leading the Muon g-2 Theory Initiative



Marcela Carena AAAS Fellow

Stephen Parke co-coordinator of Neutrino Physics Center



Andreas Kronfeld succeeds Paul Mackenzie as spokesperson of USQCD



Pedro Machado, new Associate Scientist

HL/HE LHC Meeting

4-6 April 2018  
Fermilab  
US/Central time zone

Wed 04/04 Thu 05/04 **Fri 06/04** All days

Print PDF Full screen **Detailed view** Filter

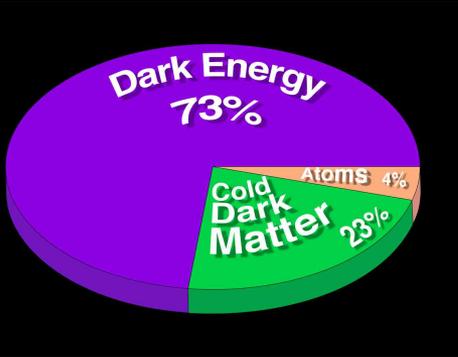
BSM Flavour Higgs + Flavour Plenary

09:00	<b>TH perspective on Higgs and Flavour</b> Emmanuel STAMOU IARC First Floor Lecture Hall, Fermilab 09:00 - 09:23	<b>SUSY at HL/HE-LHC</b> Prof. Howard BAER IARC I/W/B First Floor, Fermilab 09:00 - 09:23
	<b>TH perspective on CP violation in Higgs Couplings (tau, H)</b> Adam MARTIN IARC First Floor Lecture Hall, Fermilab 09:23 - 09:46	<b>Search for SUSY strong production at ATLAS at HL-LHC (p)</b> Iacopo VIVARELLI IARC I/W/B First Floor, Fermilab 09:23 - 09:45
	<b>EXP prospects for charm tagging and the Higgs</b> Dr. Daniel CRAIK IARC First Floor Lecture Hall, Fermilab 09:46 - 10:08	<b>CMS strong SUSY</b> Prof. Kenichi HATAKEYAMA IARC I/W/B First Floor, Fermilab 09:45 - 10:07
10:00	<b>EXP prospects for Higgs and CPV</b> Ms. Isabel OJALVO IARC First Floor Lecture Hall, Fermilab 10:08 - 10:30	<b>Search on vectorlike fermions in heavy Higgs cascade at HL/HE-LHC</b> Dr. Seodong SHIN IARC I/W/B First Floor, Fermilab 10:07 - 10:30

Launch of the Neutrino Theory Network, Fermilab meeting on HL/HE LHC, etc etc



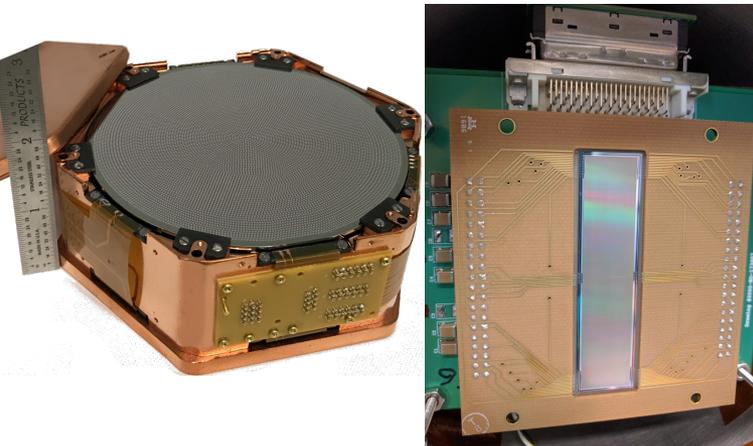
# The Dark Universe @ Fermilab



The Dark Energy Survey measuring 300 million galaxies



World-leading experiments attempting to detect dark matter



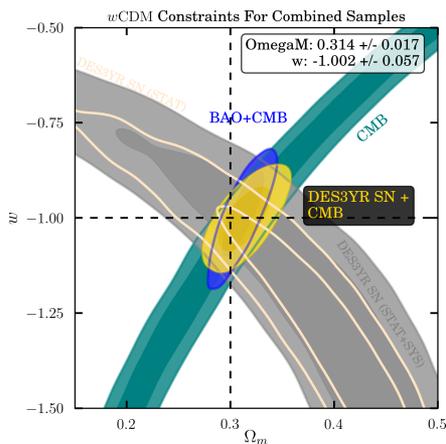
Developing new technologies to detect dark matter



Looking at the cosmos from the South Pole

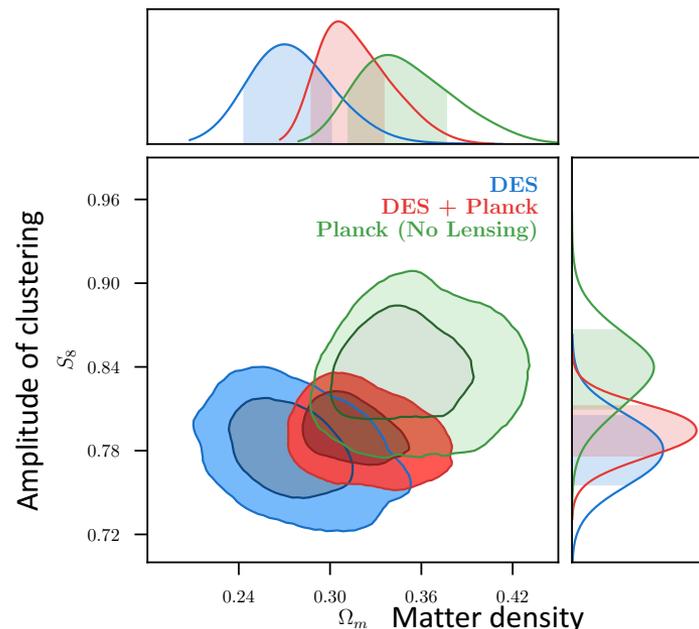
# Dark Energy Survey

- Probing Dark Energy via survey of 300 million galaxies and ~2500 supernovae, using Fermilab-built Dark Energy Camera on Blanco telescope in Chile
- Over 150 papers submitted, including: most distant supernova; new Milky Way dwarf satellites to constrain dark matter; expansion rate from LIGO follow-up.
- **2019:** Cosmology results from first 3 years of data, all dark energy probes.



Preliminary cosmology results from first 3 years of DES Supernova survey

DES Year 1: cosmology from galaxy clustering and weak lensing (DES 2017). Consistent with Planck CMB within  $\Lambda$ CDM. Combined constraints on dark energy with Planck, BAO, SN:  
 $w = -1.00^{+0.04}_{-0.05}$ .



# News from Core Computing

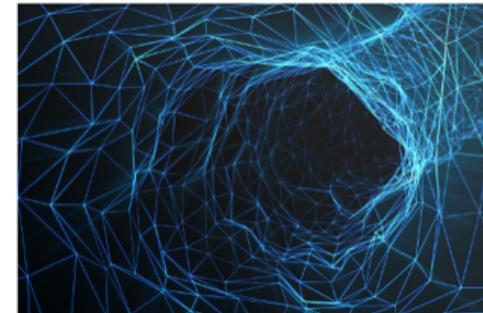


- Improving international collaboration to support Fermilab as international host lab for LBNF/DUNE:
  - Bringing a 3rd 100Gb WAN connection online
  - Maintaining open science in the face of **constant cyber threats**
  - Federated Identity; eduroam works all around the world and Fermilab's service is excellent
  - Continuing to roll out the site firewall, moving to a more secure "default deny" posture. **Science traffic unaffected**

# News from Scientific Computing

HEP community decadal survey: "A Roadmap for HEP Software and Computing R&D for the 2020s" [1]

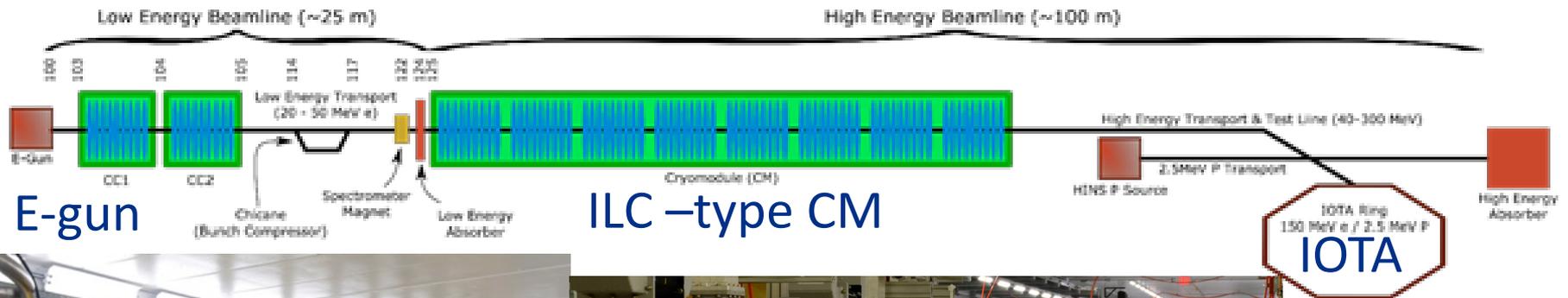
- Many in SCD participated and signed this paper
- SciDAC projects (HEP partnerships with Advanced Scientific Computing Research, ASCR) making progress toward important plan elements
- HEPCloud is rolling out!
- Now to “Beyond Moore’s Law Computing” - Fermilab can do quantum computing.



[1] arXiv: <https://arxiv.org/abs/1712.06982>

# Fermilab Accelerator Science Thrust

## Fermilab Accelerator Science & Technology (FAST) Facility



**FAST Electron Linac commissioned in 2017**

Dec. 2017 – achieved the ILC design goal for a CM, 250 MeV

- While commissioning the FAST linac, also conducted several experiments: (1) Flat beam transformations (with NIU) and (2) HOM effects on beam quality (with LANL, CEA-Saclay)

# The IOTA ring is under construction

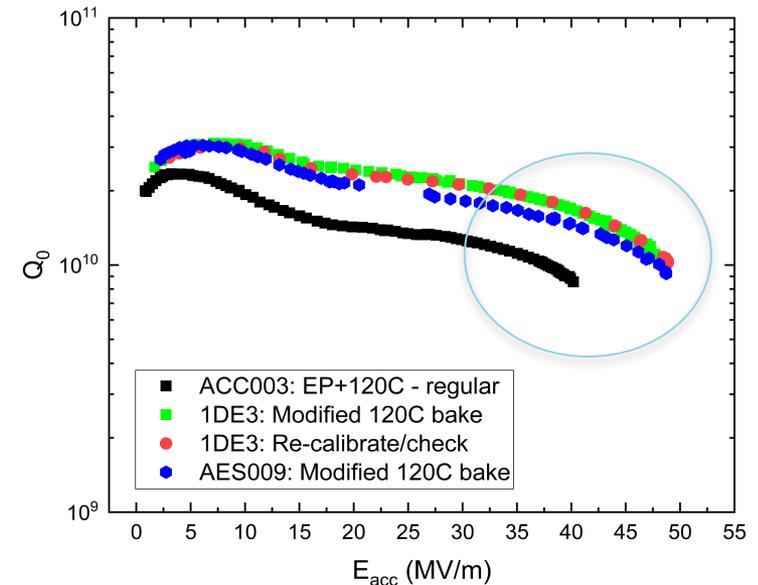


- First IOTA beam is expected in Sep 2018:
  - Two experiments in nonlinear beam dynamics are planned
- Also, a collaboration-driven experiments with FAST electron linac will continue in 2018
- Our overall goal is to establish a National User Facility at FAST for research in Accelerator Science and Technology
  - Complements the FACET-II User Facility at SLAC

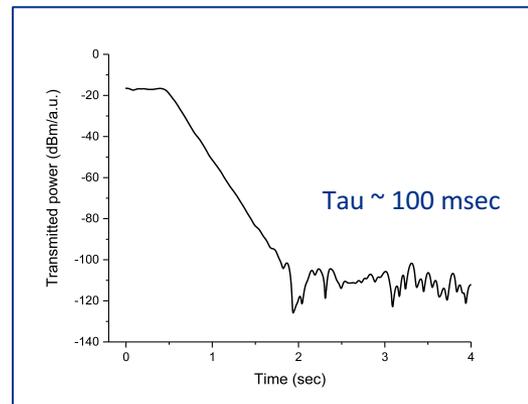
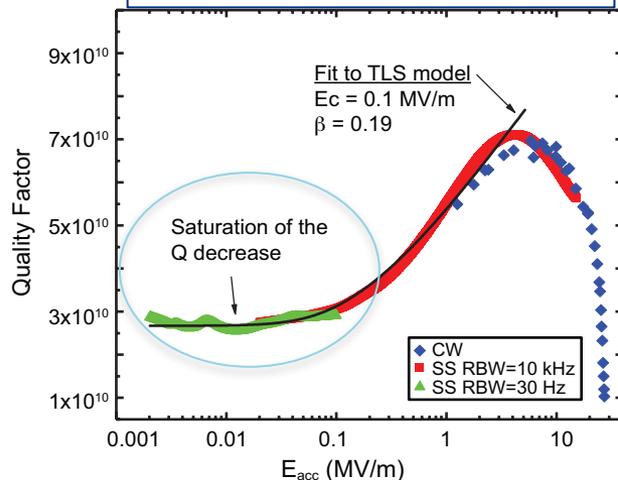
# SRF R&D Breakthroughs

- High Q now at high gradient
  - Modified 120°C baking (*new discovery*)
  - 49 MV/m (210 mT) – record gradient for ILC cavities**
- Ultralow temperature/field physics uncovered
  - Solved the low field Q slope
  - Opened up the potential of SRF for QIS and fundamental physics experiments
  - Supported by the new *Ultralow Temperature Facility*

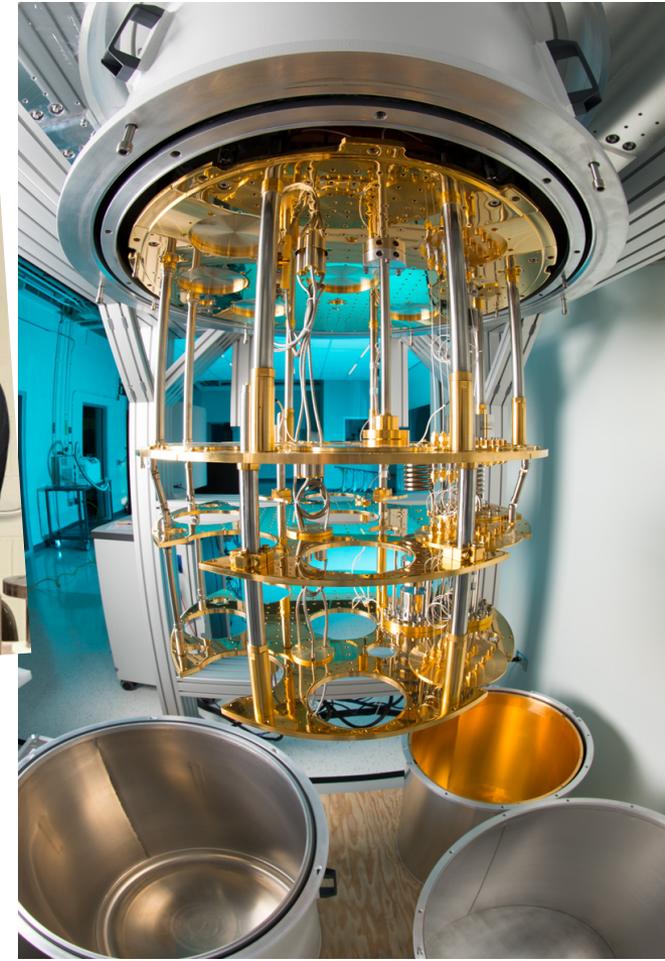
A. Grassellino et al, publication in preparation



A. Romanenko and D. I. Schuster, *Phys. Rev. Lett.* **119**, 264801 (2017)



# SRF cavities for quantum computers



**NIST**



THE UNIVERSITY  
of  
**WISCONSIN**  
MADISON

 **Fermilab**

# Quantum computing for problems in HEP

arXiv.org > quant-ph > arXiv:1802.07347

Search or Article  
(Help | Advanced Search)

Quantum Physics

## Electron-Phonon Systems on a Universal Quantum Computer

Alexandru Macridin, Panagiotis Spentzouris, James Amundson, Roni Harnik

(Submitted on 20 Feb 2018)

We present an algorithm that extends existing quantum algorithms for simulating fermion systems in quantum chemistry and condensed matter physics to include phonons. The phonon degrees of freedom are represented with exponential accuracy on a truncated Hilbert space with a size that increases linearly with the cutoff of the maximum phonon number. The additional number of qubits required by the presence of phonons scales linearly with the size of the system. The additional circuit depth is constant for systems with finite-range electron-phonon and phonon-phonon interactions and linear for long-range electron-phonon interactions. Our algorithm for a Holstein polaron problem was implemented on an Atos Quantum Learning Machine (QLM) quantum simulator employing the Quantum Phase Estimation method. The energy and the phonon number distribution of the polaron state agree with exact diagonalization results for weak, intermediate and strong electron-phonon coupling regimes.

Subjects: **Quantum Physics (quant-ph)**; Strongly Correlated Electrons (cond-mat.str-el)  
Cite as: [arXiv:1802.07347](https://arxiv.org/abs/1802.07347) [quant-ph]  
(or [arXiv:1802.07347v1](https://arxiv.org/abs/1802.07347v1) [quant-ph] for this version)

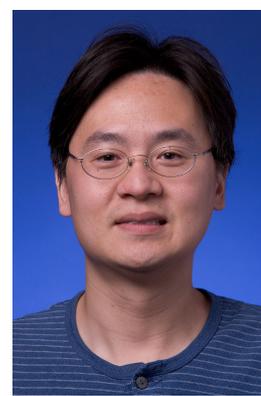
### Submission history

From: Alexandru Macridin [[view email](#)]  
[v1] Tue, 20 Feb 2018 21:49:00 GMT (72kb)

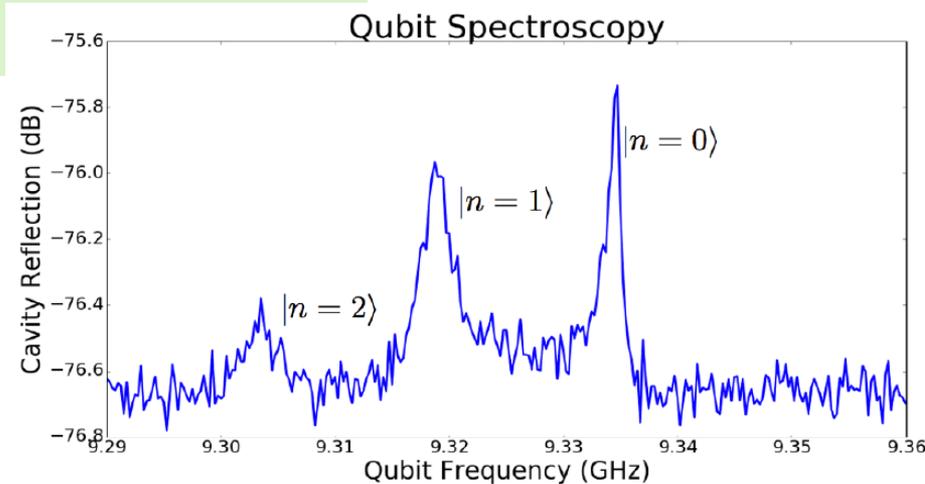


# Quantum technology for axion dark matter detection

Develop superconducting qubit-based single microwave photon detectors to enable a next generation dark matter axion search.

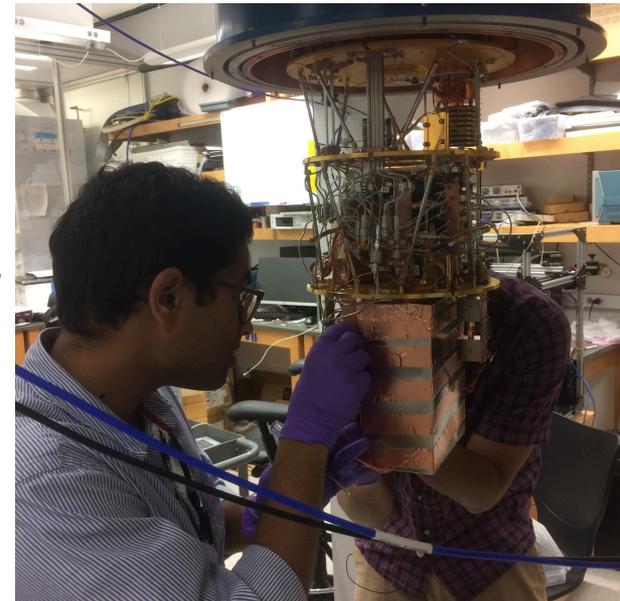


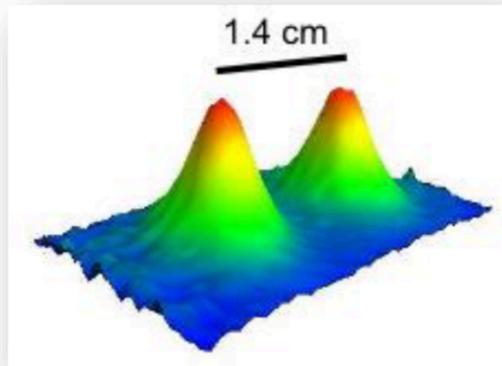
Aaron Chou, David Schuster (UC), Daniel Bowring



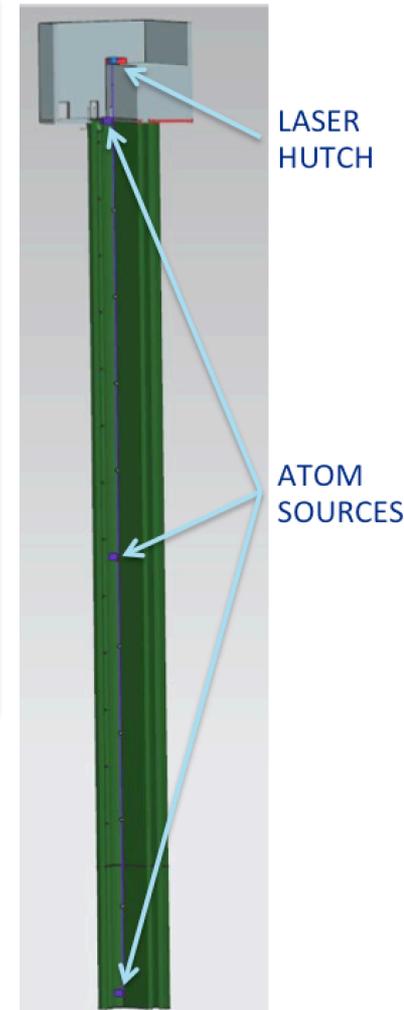
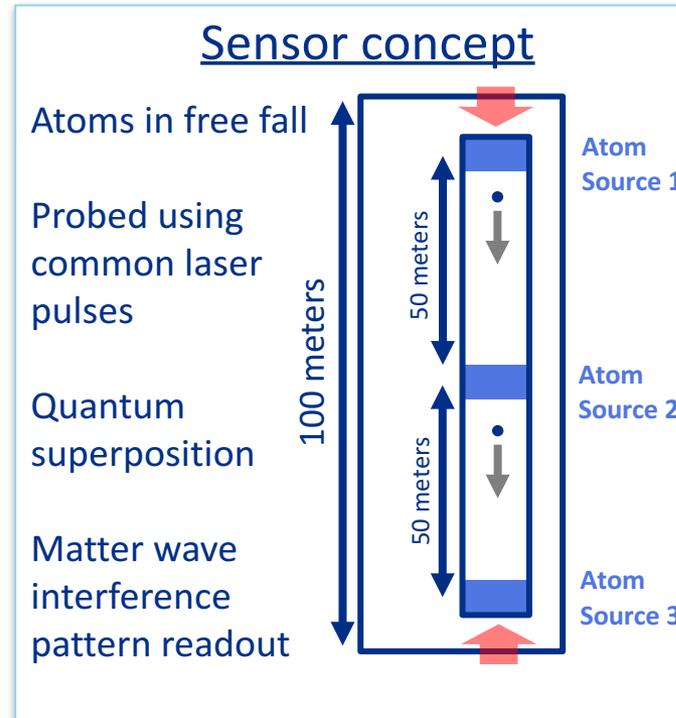
New Fermilab test stand will incorporate magnet into a dilution refrigerator to simulate the extreme environment of a dark matter axion experiment.

Grad student Akash Dixit installing a prototype detector in a 10 mK test stand in the Schuster Lab.





*Wavepacket separation at apex (this data 50 nK)*



**CAD model of detector in 100-meter MINOS shaft at Fermilab**



## Quantum initiative

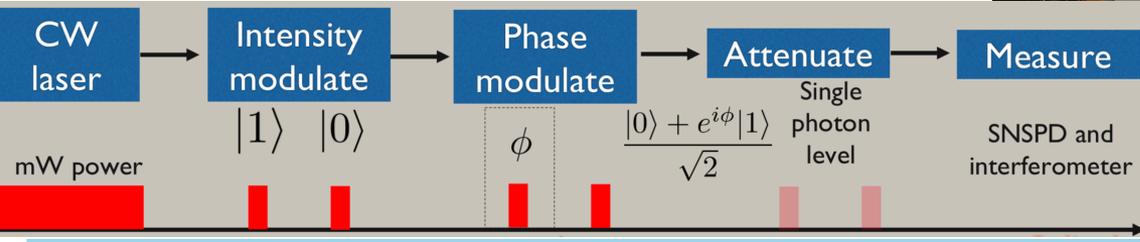
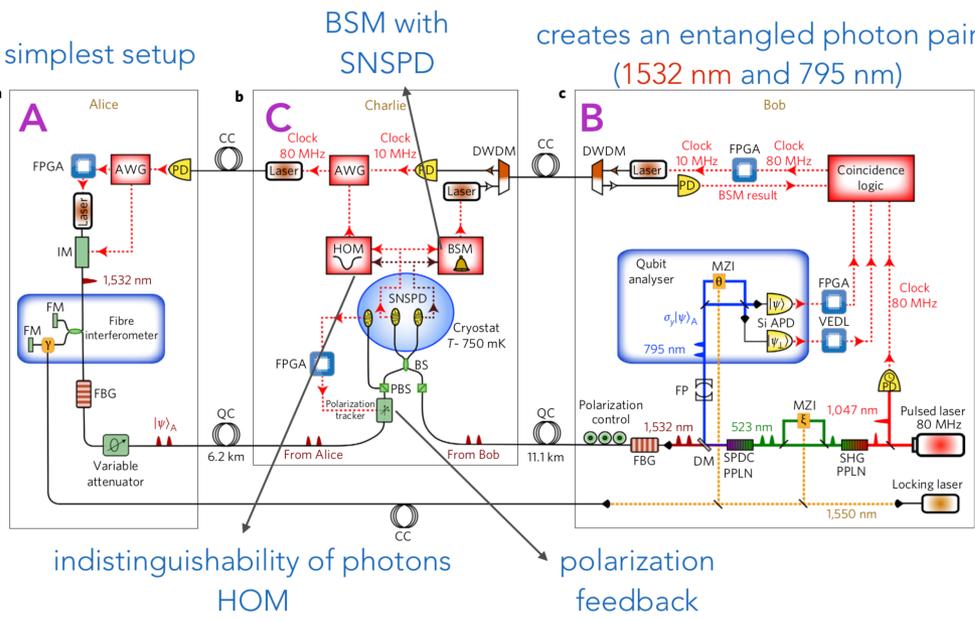
Atom matter waves in superposition separated by up to 10 meters  
 Entangled atom source for increased sensitivity

## Fundamental physics applications

Time-dependent signals from ultra-light dark matter  
 Gravity waves

# Fermilab quantum teleportation experiment (FQNET)

- Teleport photonic qubits over commercial fiber
- Establish a quantum network facility connecting Fermilab and Argonne



# Fermilab Community Standards

- Fermilab's success depends on how we treat and contribute to one another in positive, respectful manner
- With input from the UEC, SAC, EAC, EAG, WDRS, Chiefs, and numerous other groups across the community, a **“Statement of Community Standards”** has been developed
- The goal is that no matter who you are or where you are from, you can count on a basic level of decency and respect when you work in the Fermilab community...and situations where this isn't happening will be examined and corrected
- See the policy on Fermilab Policies webpage

# Summary:

## Fermilab is an great place to be

