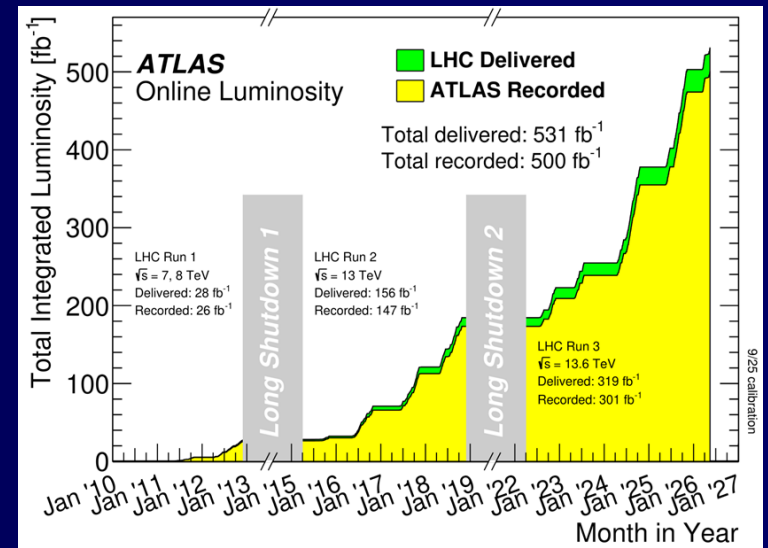
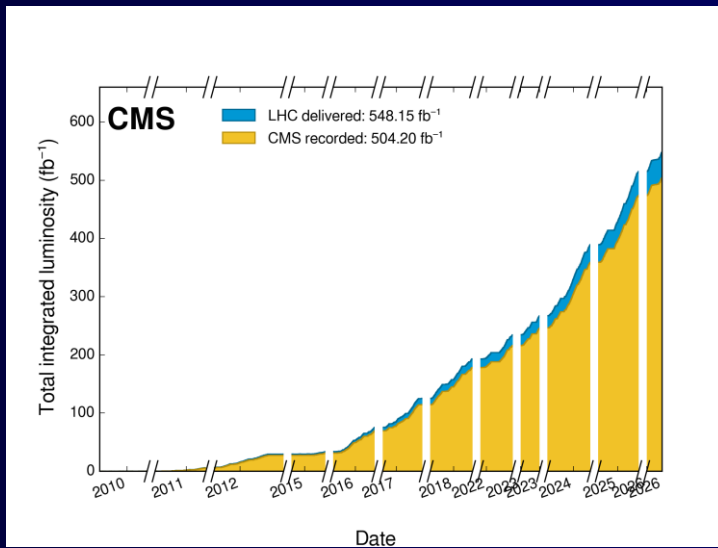


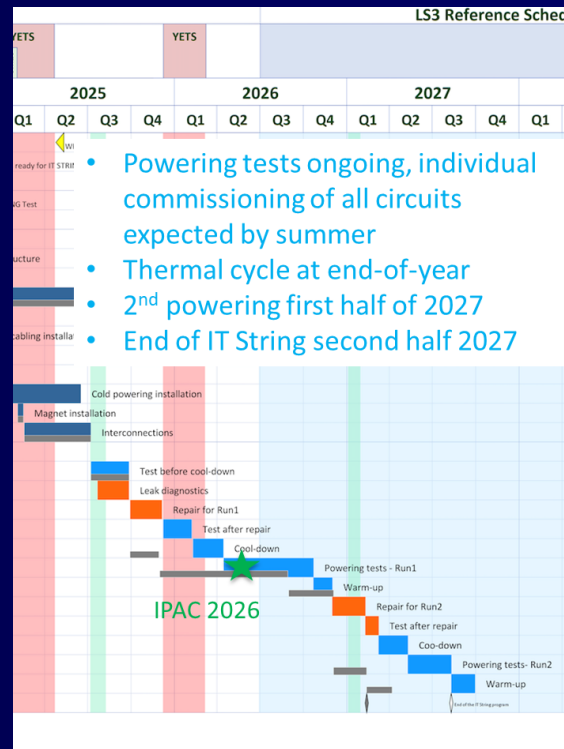
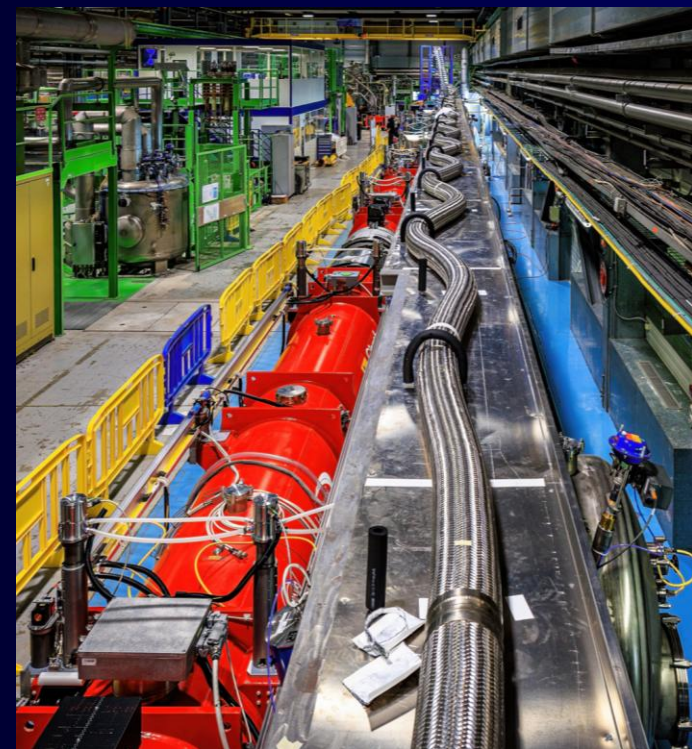
# Update on the HL-LHC in 12 minutes



pp running in LHC Era complete, 0.5 ab<sup>-1</sup> apiece

**S. Nahn, Fermilab**  
(with help from J. Kotcher and G. Apollinari)  
(and apologies to LHCb and ALICE colleagues)

May 21<sup>st</sup>, 2026



IT String Test:  
Vertical Slice test of HL--LHC underway!  
-Cooldown complete  
-Initial powering tests ongoing

<https://string-display.app.cern.ch>

# Why do we do this? P5 report 2023

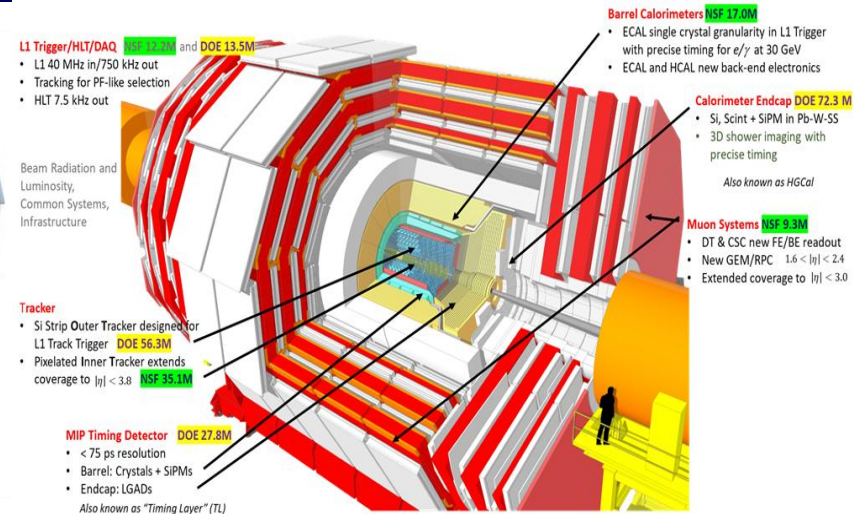
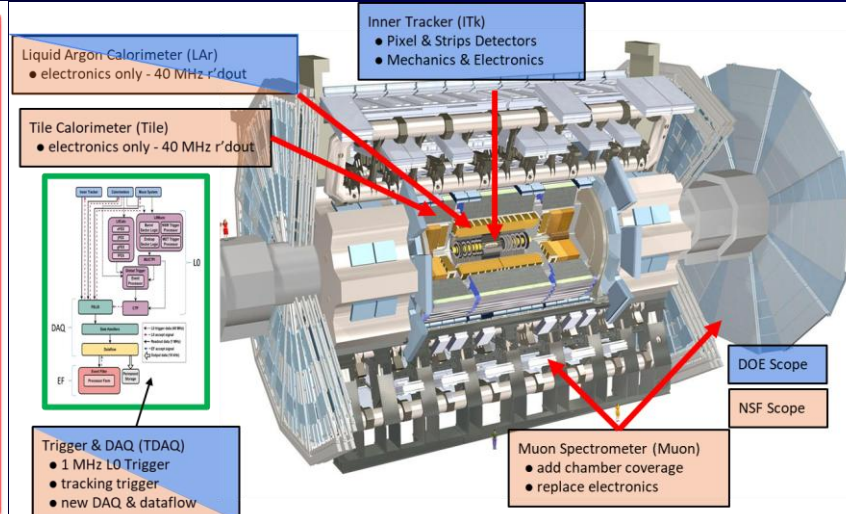
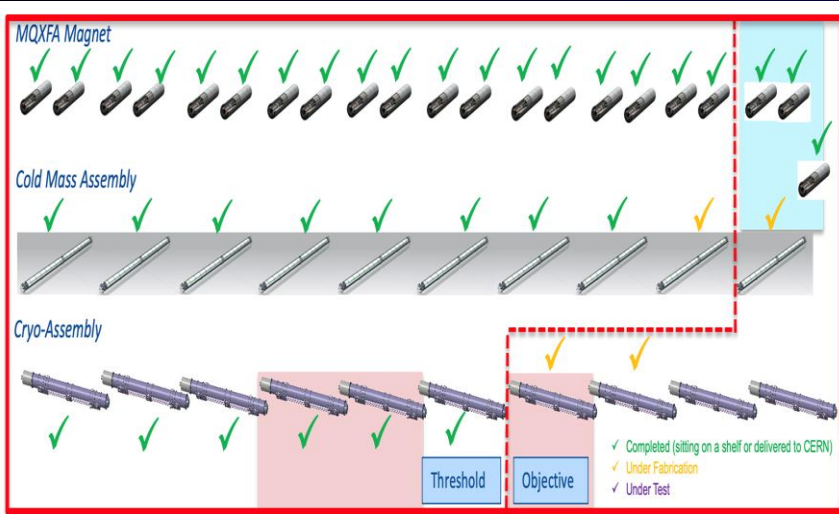
- **Recommendation 1: As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science.**
- **We reaffirm the previous P5 recommendations on major initiatives:**
  - **HL-LHC (including the ATLAS and CMS detectors, as well as the Accelerator Upgrade Project) to start addressing why the Higgs boson condensed in the universe (reveal the secrets of the Higgs boson, section 3.2), to search for direct evidence for new particles (section 5.1), to pursue quantum imprints of new phenomena (section 5.2), and to determine the nature of dark matter (section 4.1).**
  - *... some other stuff here ... ;)*

*From Pathways to Innovation and Discovery in Particle Physics: Report of the 2023 Particle Physics Project Prioritization panel*

**HL LHC covers all of the triangles**



# Brass tacks regarding US Involvement: \$837M (+ Ops, Research)



## • AUP – 93% complete!

- FNAL, BNL, ANL, LBNL + few friends
- DOE Scope \$266M
  - Magnets
  - Cold Mass Assemblies
  - Cryostat Assembly
  - Crab Cavities

## • ATLAS – 75% Complete

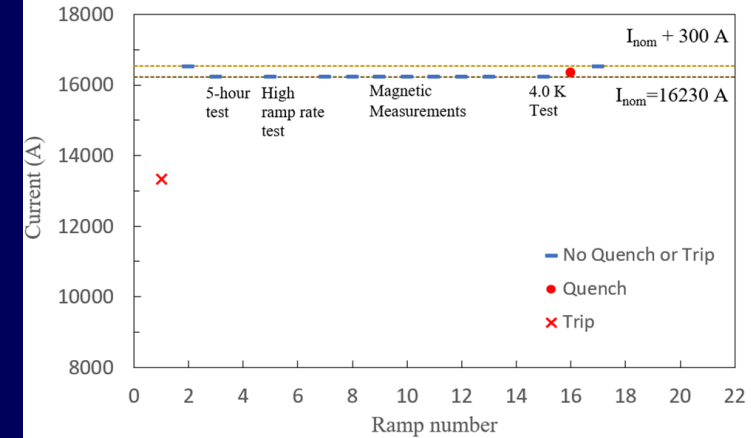
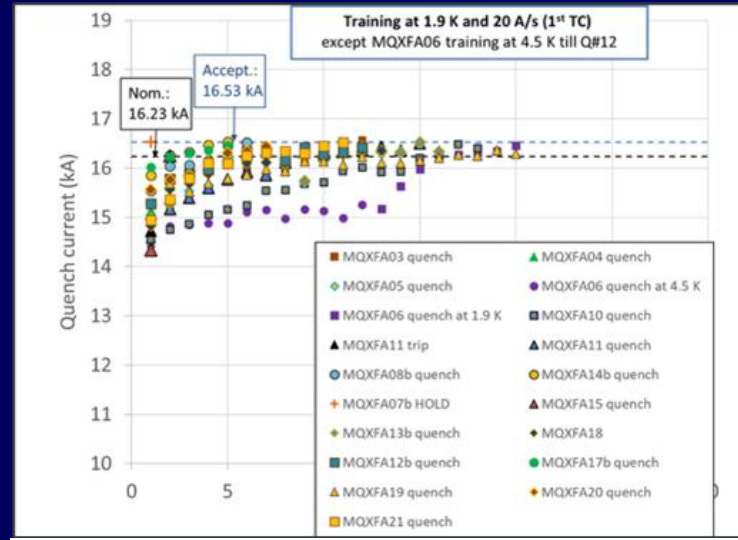
- ANL, BNL, LBNL, SLAC + 33 friends
- DOE Scope \$200M
  - Inner Tracker = {Pixels, Strips, Global Mechanics}, Electronics LAr Calorimeter, DAQ
- NSF Scope \$83M:
  - Electronics for LAr and Tile Calorimeters, Muons, L1 Trigger

## • CMS - 74% Complete

- FNAL + 50 friends
- DOE Scope \$200M:
  - Outer Tracker, MIP Timing Detector, Endcap Calorimeter, L1 Trigger
- NSF Scope \$88M:
  - Inner Tracker, Electronics for Barrel Calorimeter, Muons, L1 Trigger

# AUP rolling along...

- Magnet production **Complete**
- **50% CryoAssemblies at CERN ...**
- **... other 50% in various stages of processing at FNAL**
  - **Most recent Cryoassembly tested (06) reached acceptance current without a quench**
  - **Final Cryoassembly (10) to arrive at CERN in ~ 1 year**
- **Crab Cavities**
  - **Vendor issues with quality in early cavities being overcome by in-house post-fabrication mitigations**
    - **Later cavities quality improved from process improvement**

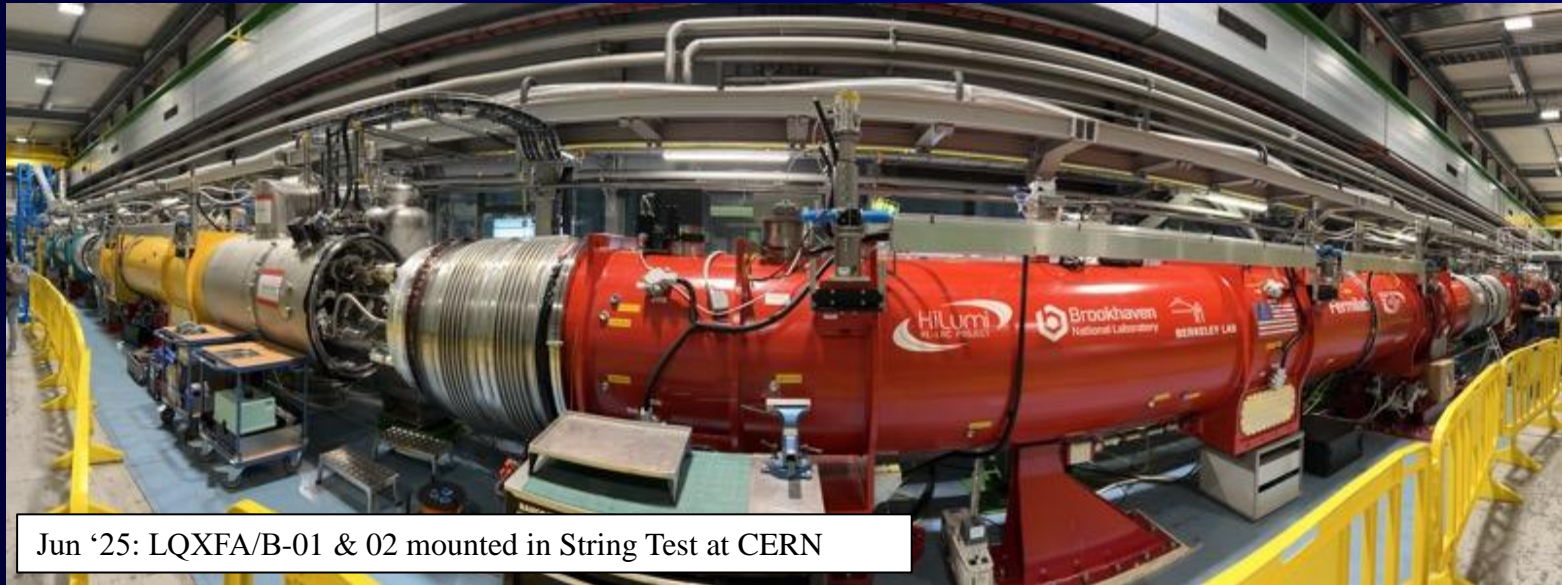


NRPD04 being assembled at ANL

# 50% of CryoAssemblies at CERN ...



Feb '25: LQXFA/B-01 at CERN



Jun '25: LQXFA/B-01 & 02 mounted in String Test at CERN



Aug '25: LQXFA/B-04 at CERN



Oct '25: LQXFA/B-03 at CERN



Nov '25: LQXFA/B-05 at CERN

# ...the “other” 50% at FNAL



Apr '26: Completion of Cryo Test on **LQXFA/B-06** at FNAL



Apr. '26: **LQXFA/B-07** completed and undergoing last Leak-Pressure test before shipment



Apr '26: **CM09** after Longitudinal Welding



Apr. '26: **CM08** Completed at FNAL



Apr. '26: Cryostat for **LQXFA/B-08** ready at FNAL



Apr '26: Last 2 Magnets on Alignment Table for **CM10**

# ATLAS Upgrade

Pixels: R0/1 Ring

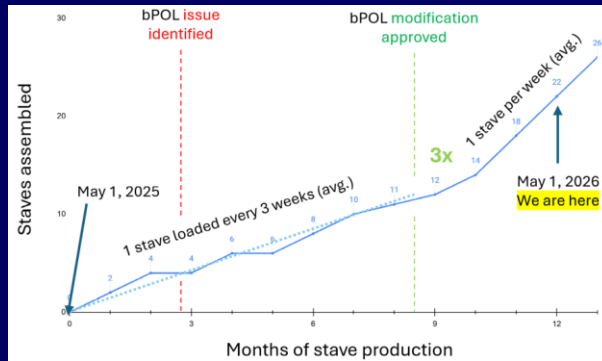


GM: PST at LBNL

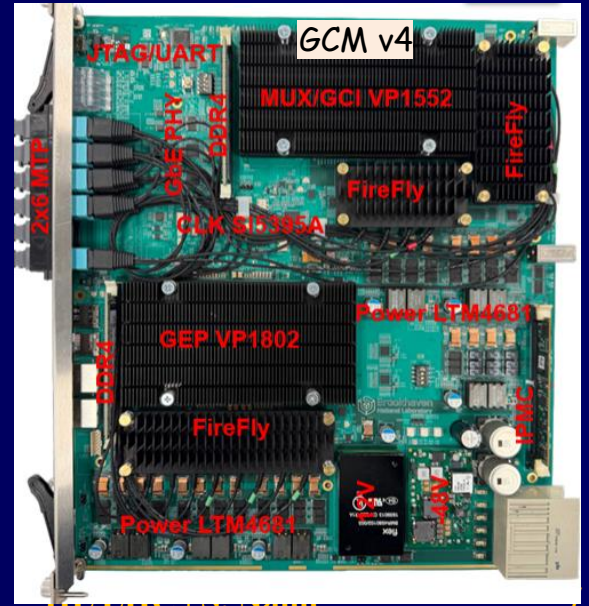


- **Inner Tracker (ITk)**
  - Pixels – 2 inner layers (of 5), Modules/Supports in production
  - Strips – 50% of Barrel, Modules and Staves in production
    - bPOL issue (future slide) mitigated
  - Global Mechanics – **done** (except some rails)
- **Calorimetry (Electronics)**
  - LAr focus is 1% Slice test → FDR in June
  - Tile ~ **done** but for some power supply production
- **Muons**
  - Chamber and ASIC production **done**, Calibration and Trigger electronics starting production
- **Trigger/DAQ**
  - L0 Triggers – in various stages of (pre-)production
  - Global Trigger – GCM v4 final prototype passes QC
    - Firefly issue (future slide) has caused delays
  - FELIX card (DAQ) passed FDR in April, production starts late 2026

Strips: Stave Assembly @ BNL

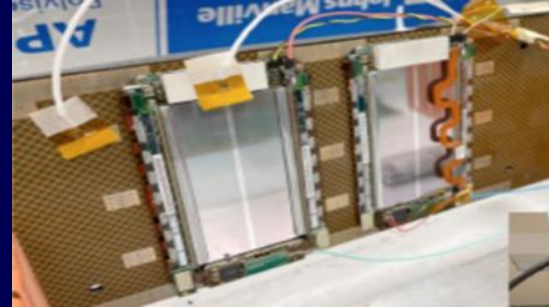
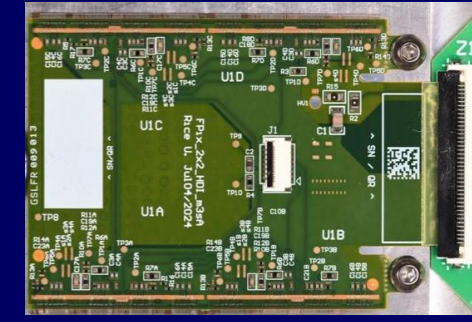


UM Muon Chambers under test at CERN



# CMS Upgrade

- **Tracker**
  - Inner: Modules and Mechanics production in flight
  - Outer: 30% of Modules + central 3 layers production also in flight
    - Building “Partial Modules” due to bPOL issue (next slide)
  - Support tube delivered, repaired
- **MIP Timing Detector**
  - Barrel Layer – Production trays being shipped – **done** this Summer
  - Endcap Layer – ASIC design complete, final System tests next months, production starts end of CY26
- **Calorimeter**
  - Barrel: Front End card and Backend board production imminent
  - Endcap: Electronics and Modules in production, Integration into Cassettes later this year
- **Muons**
  - Electronics and Infrastructure, production underway or **complete**
- **L1 Trigger**
  - Production underway for Muons, imminent for Calo, Correlator, Track
    - Firefly issue has caused delays (next slide)



# The tricky bits (with some but certainly not by a long shot all examples)

- **Both Detectors are showing stress on resources in both Schedule and Cost**
  - **Technical surprises requiring crash R&D/redesign/respin in (early) production**
    - **ATLAS ITk Strips – Cold Noise, then Sensor Cracking – solved (tour d’force!)**
    - **CMS BTL-Tracker Support Tube- Shipping incident, then non-conformity discovered - solved**
    - **Everybody: Critical Component delay → Substantial Standing Army costs**
      - **lpGBT Transceiver uninitialized clock mask – respin, resolved**
      - **bpol12V DCDC converter novel radiation susceptibility – respin, ongoing**
      - **SamTec Firefly 12 channel 25 Gbps Optical component availability – delay, maybe resolved**
  - **Geopolitical surprises**
    - **Scope orphaned from the elapsing of CERN ICAs with Russia, Belarus**
    - **Tariffs - many items come into US, used in fabrication, and sent back**
    - **USD/CHF Exchange Rate – lowest in decades**
- **CERN DG re-iterated LS3 end date → international effort to accelerate assembly**
  - **Difficult to achieve with limited funds**
- **Mitigation: cost reduction (if possible), scope reduction**
  - **Both recently redirected Integration and Installation to Operations, focusing on deliverables completion**
  - **Agencies working with Operations programs to backstop U.S. responsibilities**

# Outlook

- There is a **TON** of work going on to bring the HL LHC era onto the mass shell
  - Way more than I can possibly do justice to
  - **Accelerator Upgrade deliverables deep into production, complete in ~ a year**
    - **Comfortable in terms of cost and schedule**
  - **Detector Upgrades continue to make good progress**
    - **Highly diverse set of deliverables → many relevant timescales**
      - Some deliverables near or at completion, some not quite yet at production, all making progress
      - Last deliverables currently scheduled for late 2028
    - **Time and money running short – may make it, but it isn't going to be easy...**
      - Technical and non-technical bumps in the road encountered, but part and parcel of Big International Science
- **Another production item: Expertise**
  - **Many young scientists learning what is needed to actually build a detector**
    - Essential in case we ever want to do this again....
  - **If you want to hear more details, invite one of them to give a talk!**

# And by the way...

- **Congratulations to Jon on imminent retirement**
  - 34 years in the field at the Tevatron, at LHC, even at funding agencies, enabling a lot of science for a lot of people
  - BNL currently finding someone to take over, but replacement is out of the question



After Project Management

