Accelerator and NuMI Upgrade Status

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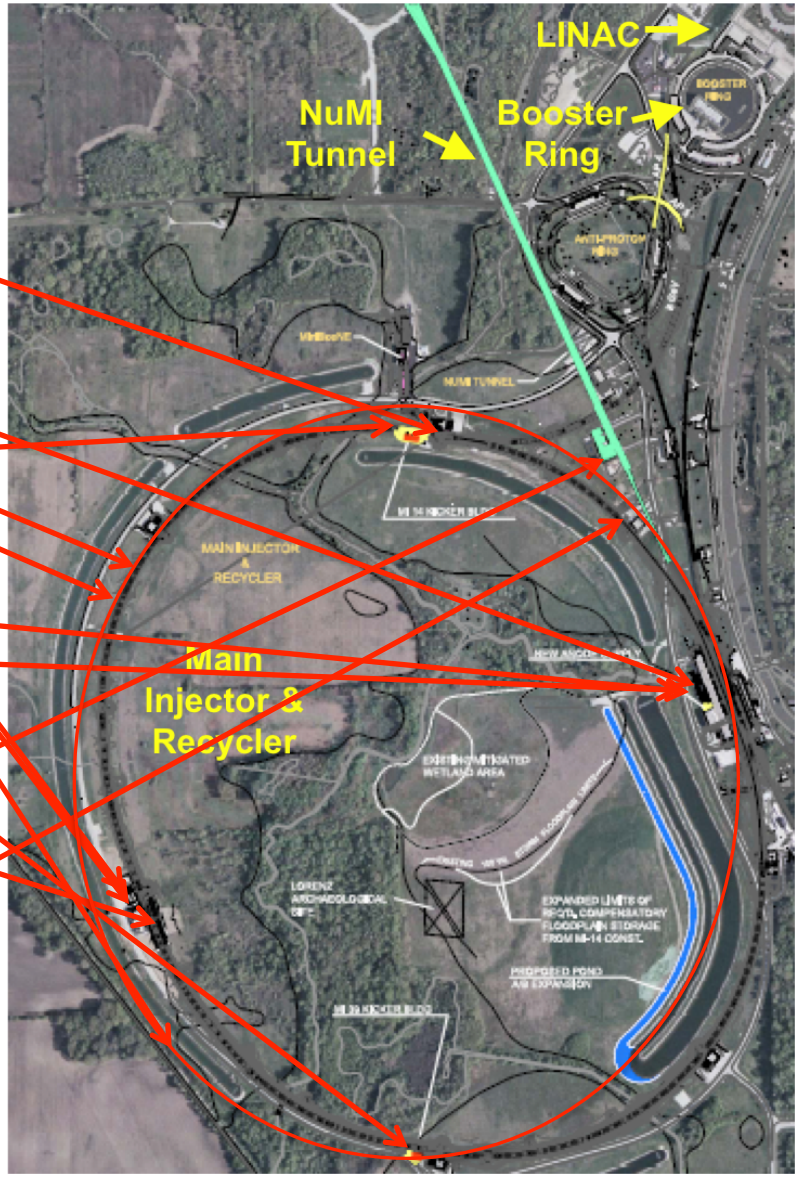
Context of ANU

- Changes to the FNAL Accelerator complex to
  - Turn Recycler from pbar to proton ring
    - Injection and extraction lines
    - Associated kickers and instrumentation
    - 53 MHz RF
    - Decommission/remove pbar devices
  - Shorten MI cycle to 1.33 seconds
    - RF upgrades
    - Power Supply upgrades
    - Decommission/remove pbar devices
  - NuMI target station to 700 kW
    - Target & Horns to handle power
    - Configuration to maximize ν flux
  - Installation and Hardware commissioning

Accelerator and NuMI Upgrades

- Recycler Ring, RR (WBS x.0.1)
  - New injection line into RR
  - New extraction line from RR
  - New 53 MHz RF system
  - Instrumentation Upgrades
  - New abort kickers
  - Decommissioning of pbar components
- Main Injector (WBS x.0.2)
  - Two 53 MHz cavities
  - Quad Power Supply Upgrade
  - Low Level RF System
- NuMI (WBS x.0.3)
  - Change to medium energy ν beam configuration (new target, horn, configuration)
  - Cooling & power supply upgrades
- Beam Physics (WBS 1.0.4)
  - Beam Simulations & Evaluation of Proton Plan



Technical Progress

- Beam tubes
- Need minimum 4 60” and 11 40” brazed, coated, and flanged ceramic beam tubes

Length	Brazed	Coated	Flanged	Installed
40”	25	16	11	10
60”	9	3	1	0

  - Have enough in hand to install 7 RKAA (short), 4 RKD (short), 4 RKB (long)
  - Have installed 2 in the RKAA spare magnets also

- Major risk item identified in 2006, will finally retire the brazing risk!

Beam tubes

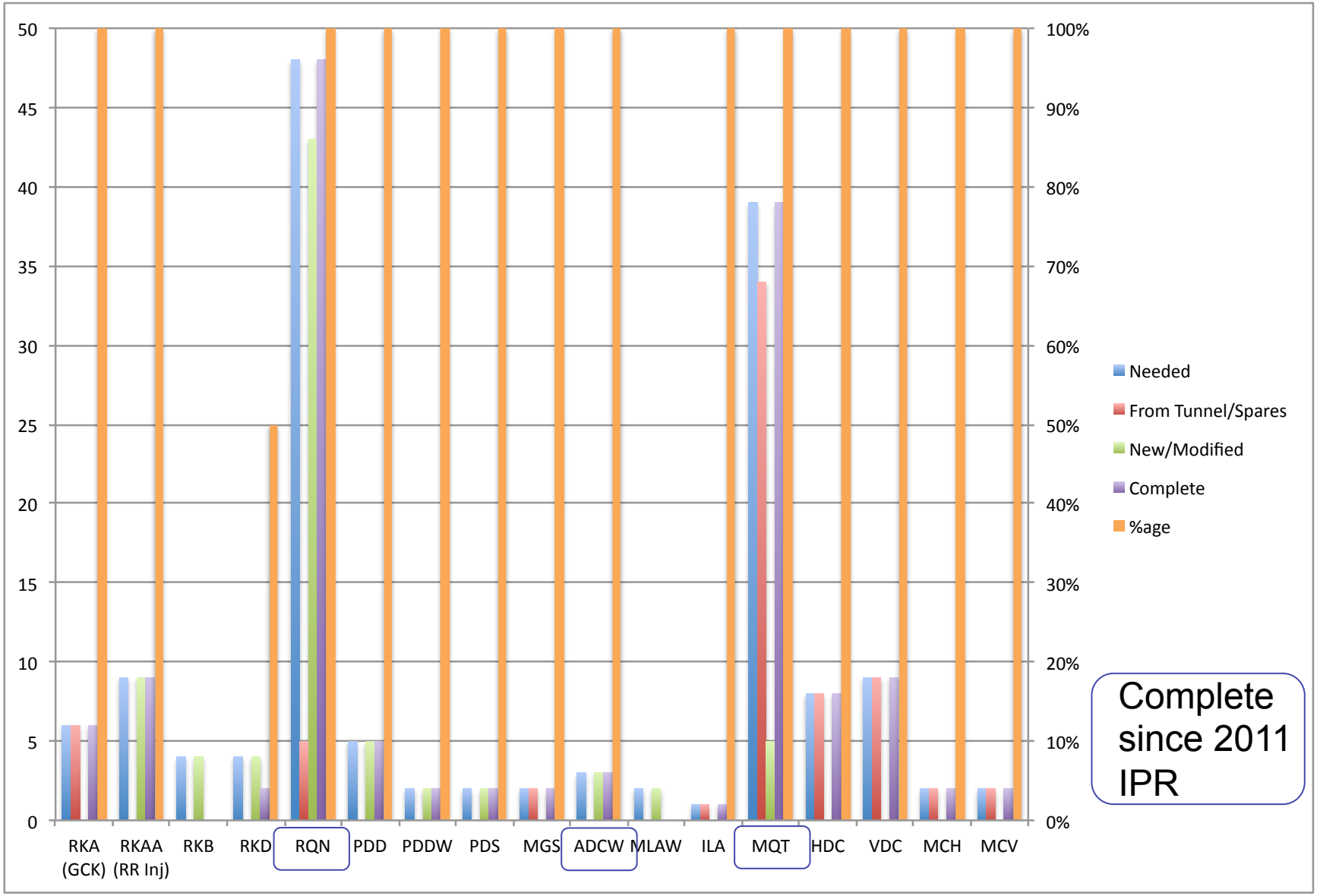
- Problems
  - Shipping: damage to long tubes
  - Repaired and acceptable
- Progress
  - Coating: low conductivity surface to prevent ion buildup
  - Welding: bellowed flange for installation
  - Installation in magnets

Technical Progress

- Magnets
  - Finished RQN, MQT, ADCW since last August
  - Remaining RKB (4) RKD (2) MLAW (2)

- End shim design:
  - RR uses permanent magnets, edge fields contribute to higher order components – affect tune and chromaticity
  - Want to change base chromaticity for slip stacking in RR
  - Lost art, so in summer 2010 Dan called his congressman for assistance
  - Complete design and going out for manufacturing

Magnet Status May 2012



Technical Progress

- Girder assembly and installation
  - For radiation considerations (ALARA), minimize tunnel assembly time
  - Where possible, magnet and instrumentation assembly and alignment on a girder, then install the girder

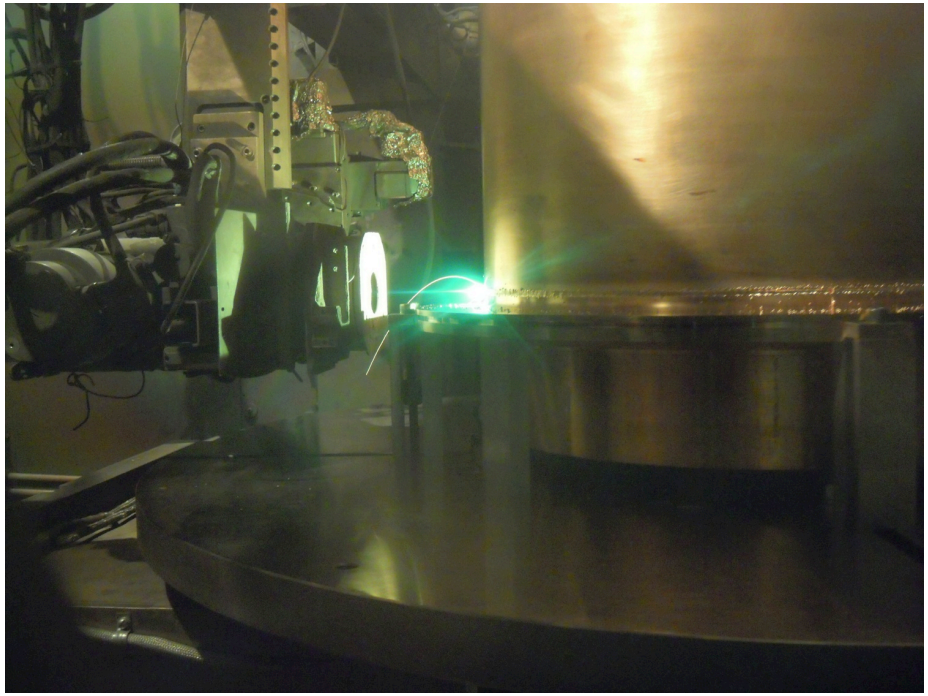
Area	# Required	# Complete
Injection Line	11	8
Extraction Line	9	4
RR 30 Straight	16	13

Technical Progress

- Girders assembled and staged in MI-8

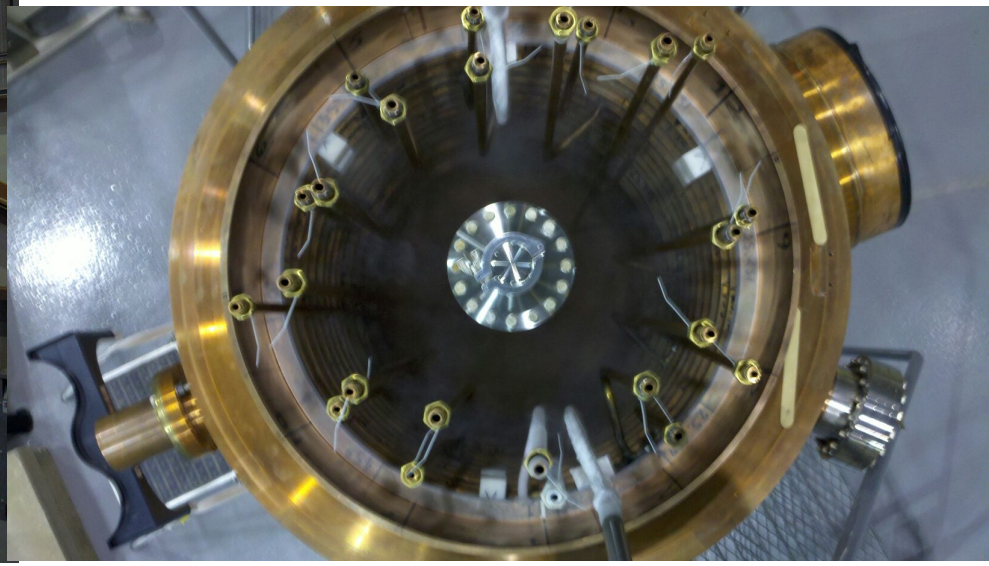
RF Cavities

- Building 3 cavities (2+1 hot spare)
  - Setbacks with weld on ¾” copper
    - Vacuum and RF requirements
    - October 2011 decided on different path
    - Electron beam welding success!
    - 12 inner hoops installed (4/18/12)



RF Cavity

- Inner hoops are pressure fit:
  - Hoop OD > Cavity ID
  - use L N_2 to shrink

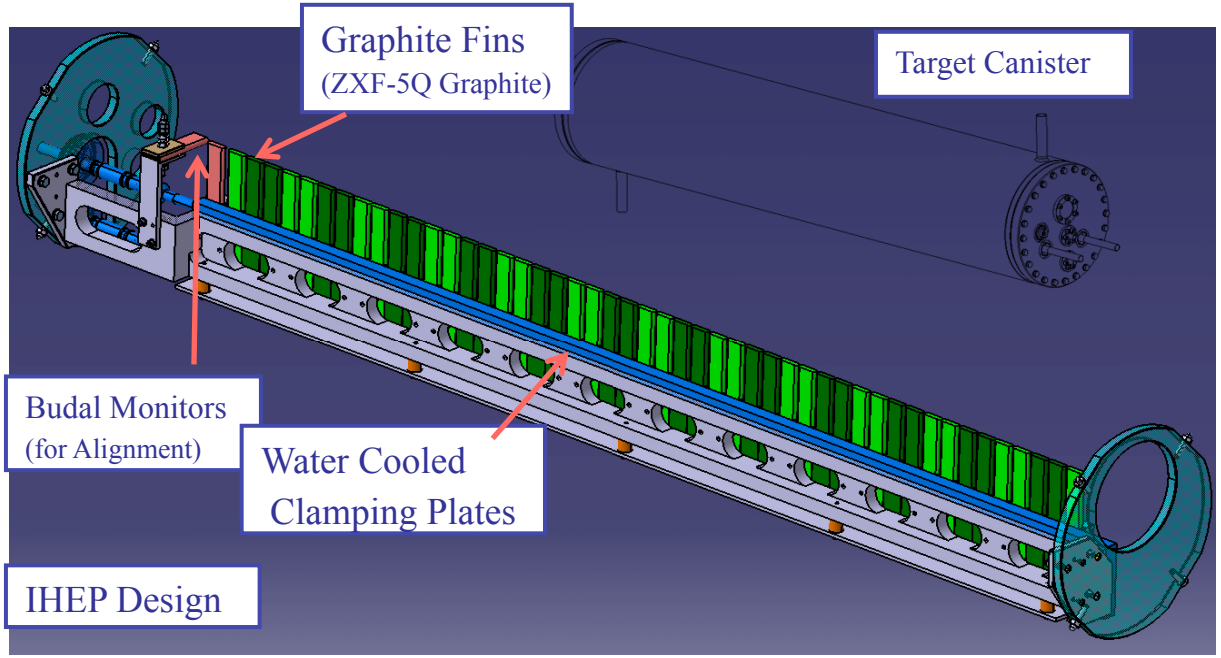


Technical Progress

- Target Carrier
  - Prototype complete last summer
- Baffles in hand
- Target
  - Additional problematic water system welds, revisited and redesigned
  - 1st fabricated at RAL, delivery in May
  - Accord with IHEP to build 2 more (1 on project, 1 off project),
  - AD will continue to work with RAL to build more

Target

- Target fabrication in collaboration with STFC Rutherford Appleton Laboratory (UK)



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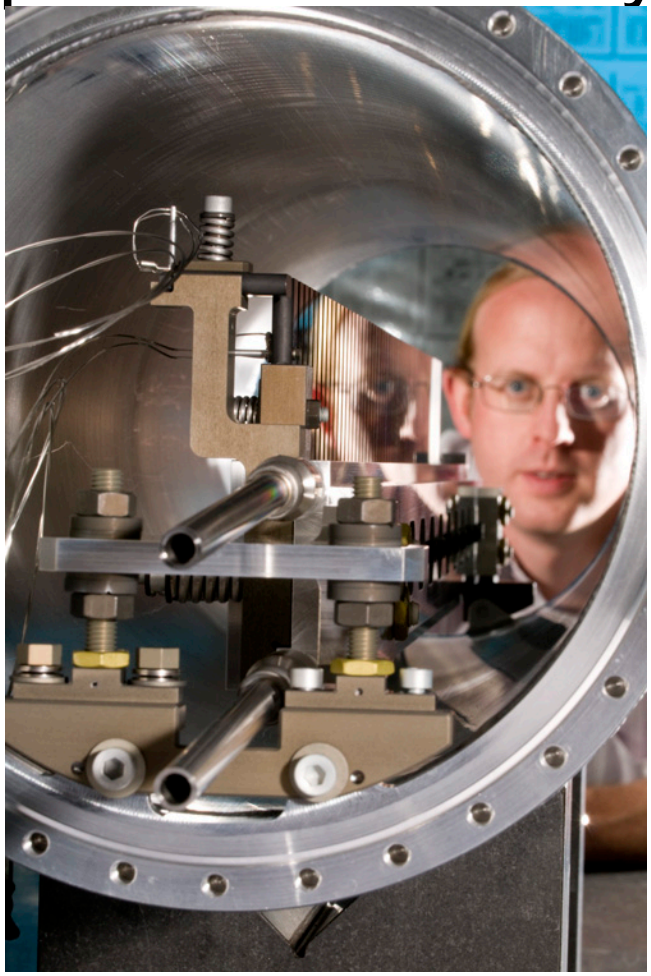


Shipping in 1st week of May

Installation Shutdown

- 12 months to change over to new mode of operations
  - Removing all pbar hardware
    - About 100 magnets, 8 cooling tanks, 2 beamlines, diagnostics for storage rings
  - Installing more than 150 magnets (dipoles, quads, trims, kickers, lambertsons)
  - Pulling nearly 400,000 feet of cable (including 300,000 ft of 3/8” heliax)
    - 2 cables to every BPM in the Recycler
  - 5 RF cavities (2 to MI, 3 to RR)
  - Opening 11 RR vacuum sectors – all of which require baking
  - Alignment of new components and areas where components are removed
  - 1 target carrier, 1 new horn
  - Moving Horn 2 and rearranging the shielding
  - Maintenance and upgrades for other programs extend the length
- Lots of people and equipment traffic!
  - 40+ technicians and engineering staff (AD, TD, and PPD)
  - 40+ trades (pipefitters, riggers, electricians)
  - 1 equipment access point

We do listen to Washington

Program Goals and Funding

HEP balances the scientific priorities of the research community with the constraints of the facilities, tools, and resources available. Research facilities for high energy physics generally require significant investments over many years and the coordinated efforts of international teams of scientists and engineers to realize accelerators and detectors that push the frontiers of energy, intensity, and cosmic exploration.

HEP, with input from the scientific community, has developed a long-range plan which maintains a leadership role for the U.S. within this global context. The plan shifts focus from the operation of the facilities built in the 1990s to the design and construction of new research facilities and instruments, while maintaining a world-leading scientific program and supporting advanced technology R&D for the future. This strategic plan positions the Nation to play a role at all three frontiers of particle physics. Proposed FY 2013 investments will develop capabilities for future accelerator-based experimental research facilities.

The Energy Frontier: The Tevatron Collider at Fermilab completed operations in 2011. Its record-breaking performance in data delivery resulted in a dataset that will continue to be mined for significant discoveries during the first few years of Large Hadron Collider (LHC) operations at CERN. In FY 2013, HEP will support the

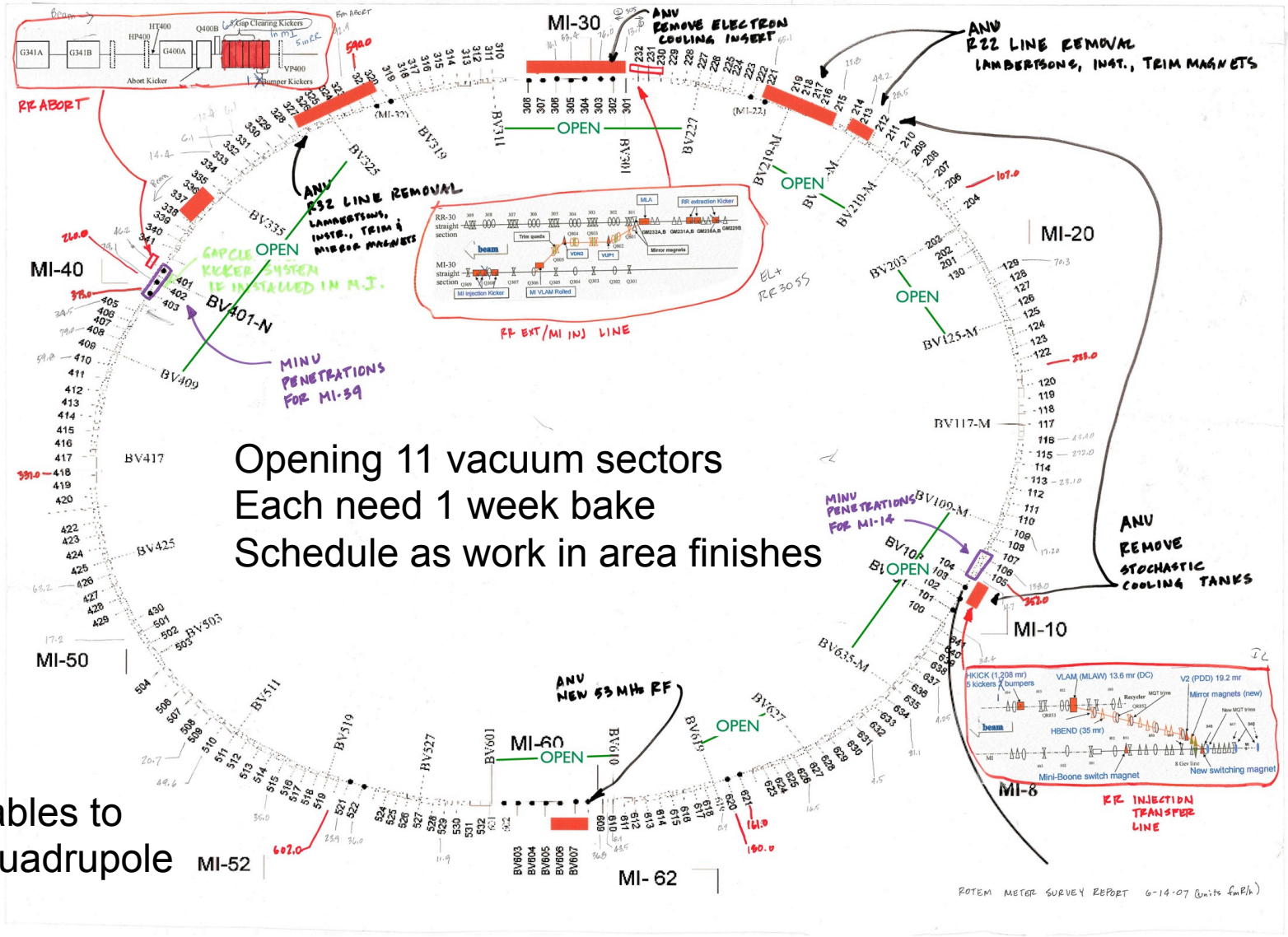
are analyzed.

The Intensity Frontier: The Neutrinos at the Main Injector (NuMI) beamline at Fermilab will operate in its current configuration through mid-FY 2012 for ongoing neutrino experiments and then will shut down for a year-long upgrade to enhance the beam power from approximately 400 to 700 kW for the NuMI Off-Axis Neutrino Appearance (NOvA) experiment. The NOvA project, currently under fabrication, will be in full operation in 2014 to enable key measurements of neutrino properties. In FY 2012, engineering and design funding is provided for the Long Baseline Neutrino Experiment (LBNE) and the Muon to Electron Conversion Experiment (Mu2e).

The HEP program has been developing the LBNE project, with the Homestake mine in South Dakota as a possible site for a far detector. The National Science Foundation was a potential partner in development and operations of the LBNE far detector but has chosen not to participate. Since DOE would now be responsible for the full development, operation, and maintenance of the Homestake site, the estimated costs associated with the LBNE far detector have risen significantly. The Office of Science is undertaking a thorough review of the costs and alternatives to LBNE and expects to make decisions concerning a future intensity frontier project in 2012.

Science/High Energy Physics Page 206 FY 2013 Congressional Budget

Installation: Scope of Work



Opening 11 vacuum sectors
Each need 1 week bake
Schedule as work in area finishes

BPM cables to every quadrupole

Off Project Work

- MI Tunnel Work
  - Feeder maintenance
    - Pulsed power
    - Service Building
  - IPM installation in the MI 10 region
  - MI RF
    - Vacuum Repairs
    - RF repairs (up to 6 Cavities will be repaired)
    - Replace Microwave pickups
  - Aperture improvements
    - MI 40/52 Lamberstons locations
  - General Vacuum Maintenance
    - Leak repairs
    - Cable replacement due to rad damage
  - Primary Collimator replacement @Q230
  - Mask installation @Q308

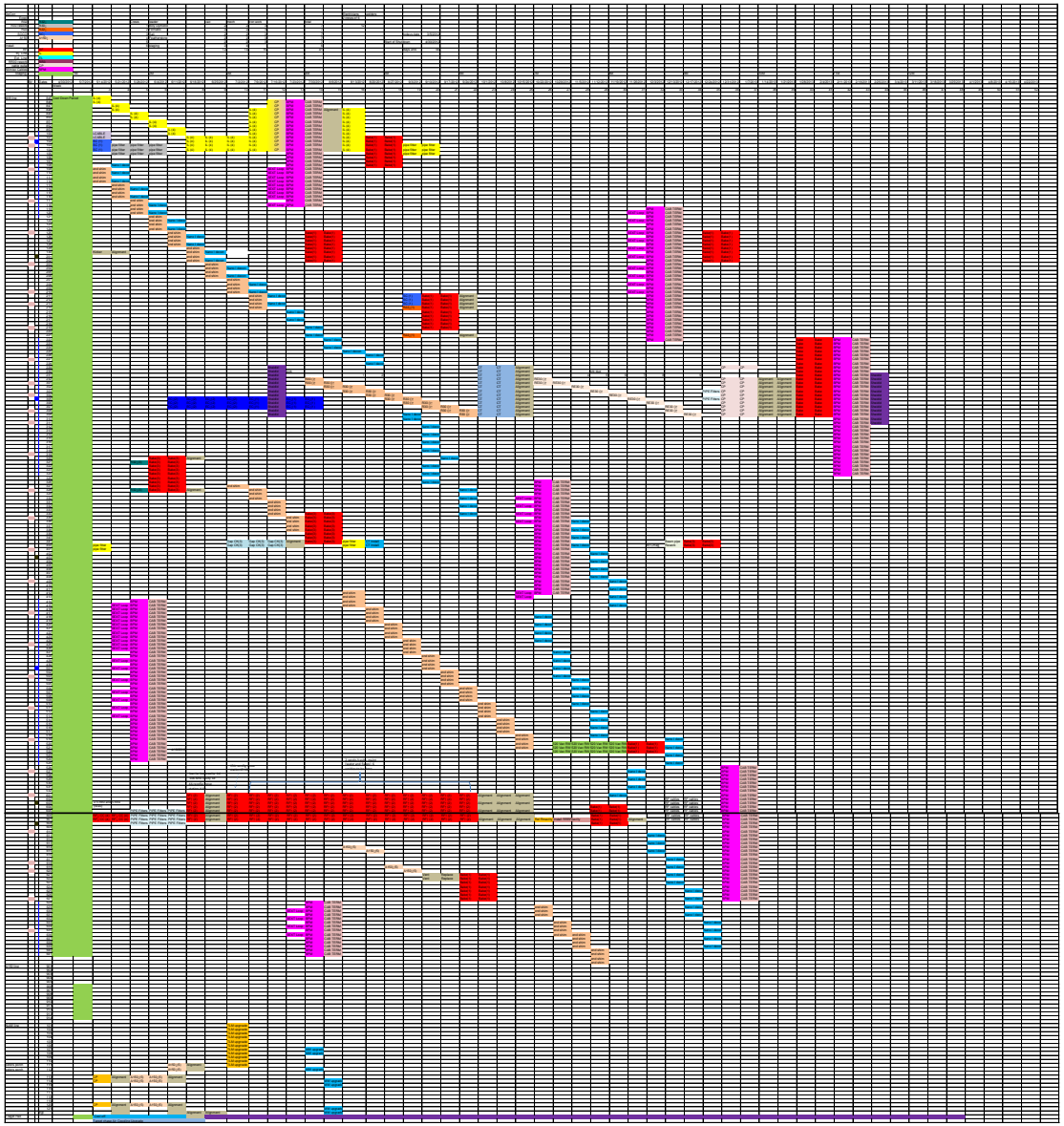
- Rest of the Complex (PIP)
  - RFQ installation
  - Booster RF cavity upgrade
    - SSRF modulators and PAs
    - Cavity tuners (cooling)
  - Booster magnets

- Impact available resources
  - STILL working on this one
  - Adds about 2 months to length of MI tunnel effort

Tunnel work schedule

- X axis is time
- Y axis is tunnel location
- Color is type/ location of job
- Text is type of job and crew assigned for job

- Folds in both on project and off project work (maintenance, upgrades for other programs)



Shutdown Length

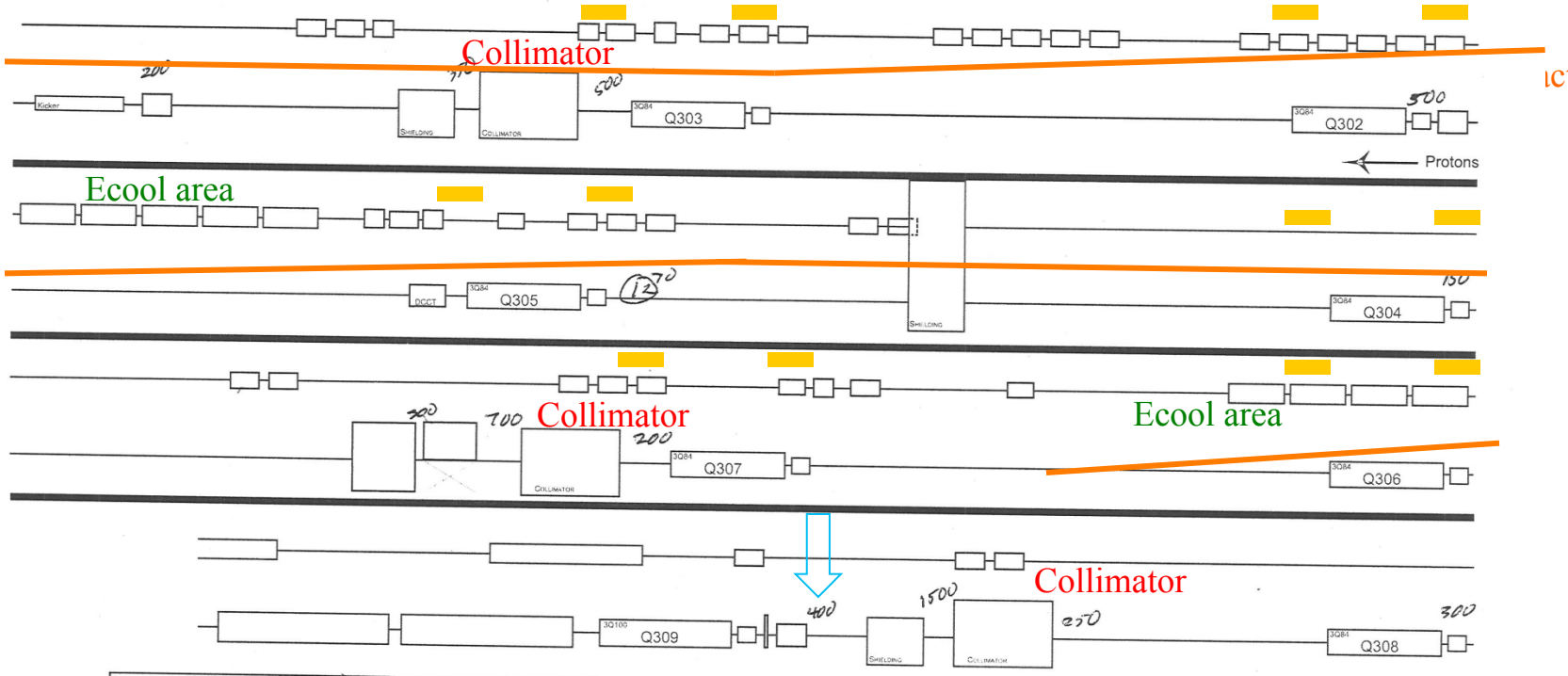
- Driver is the work in MI30 area
  - Removing the Electron Cooling insert
    - Ecool section: solenoids, correctors, instrumentation, return line
    - Specialized lattice section
    - ~85 magnets removed
  - Install reworked RR 30 Straight Section
    - FODO lattice and standard RR instrumentation
      - ~30 magnets
      - Cables, alignment, vacuum leak checking
  - Install RR -> MI transfer line
    - Kickers, lambertsons, quadrupoles, correctors, vacuum system
      - 4 RKD and 1 RKB
      - ~20 magnets
      - Cables, alignment, vacuum leak checking
  - Primary Collimator Replacement @ Q230 (off project)
  - Q308 Mask Replacement (off project)
  - And it is the hottest area in the tunnel

Rad Survey Completed for MI Q403 Change Out

Fermilab
Accelerator Division

DATE 1/31/12 | TIME: | PURPOSE: | RWP:

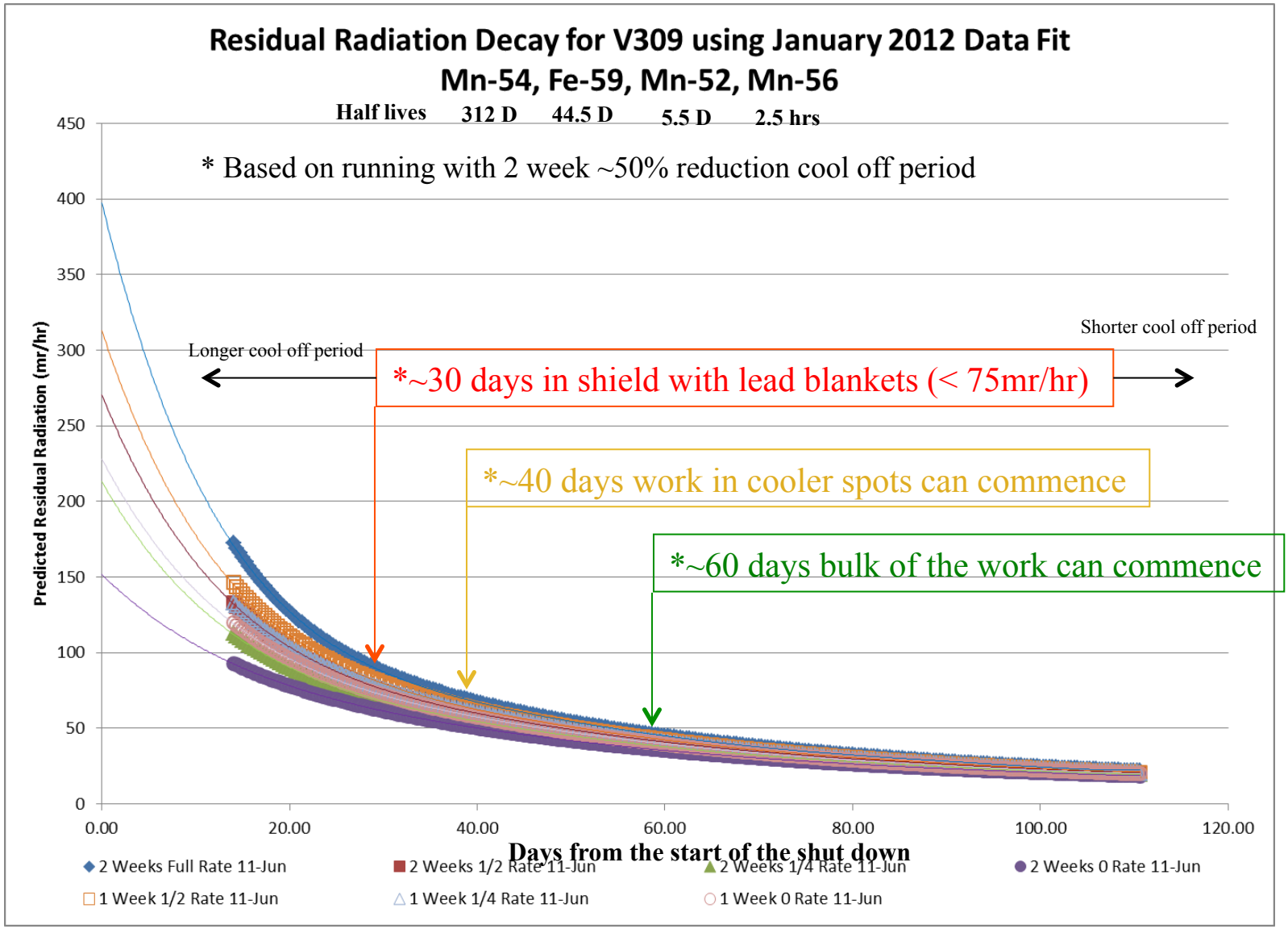
MI 302-309



All Dose Rates Below 20 mR/hr Unless Noted.	Bkgd 30 cpm	Highest Dose Rate Found 1500 mR/hr at 1 ft.
Inst Type: Inst No: Batt/Source Chk: Cal. Due Date:	Wipe # / Reading: 12 / 0 ccpm	Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe.
LEGEND Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below * = mR/hr @ contact A = Air Sample ◯ = Wipe (F) = Floor wipe	Beam Off Date: Beam Off Time: Intensity:	Comments: Surveyed By: White / Fulgham Reviewed By:

Created 11/28/07 ☑ This survey is part of the Main Injector survey package. See attached cover sheet for surveyor, instrument, and review information.

Example of Residual Radiation Level near 309 location



30 Straight Section

- Original Installation plan assumed reduced intensity running leading up to shutdown
  - Lab decided not to reduce intensity
  - Additional two weeks before can start in 30
  - Week 7: work commences on e-cool removal
  - Week 12: install temporary shielding
  - RKB kicker last element ready for the line
    - Anticipated ready in NEED TO PUT IN DATE

Installation Shutdown

- Pbar beam to Recycler went off in October
  - Took advantage of access opportunities to get a jump on decommissioning where appropriate
- Proton beam to Recycler went off March 14
  - Began decommissioning activities in the Service Buildings the next day
  - Reconfiguring power supplies, BPM electronics hardware, installing new hardware

Shutdown Resources

- Requisitions for the T&M labor:
  - Due to competition for pipefitting/welders, offering 60 hour weeks
    - ~10% cost increase
    - ~50% schedule decrease
- Committed technician pool
  - Drawing on AD (20), PPD (16), and TD (14) technicians and task managers to complete the project work

Crew Breakdown Information

- From Cons' Proton PMG talk

- Had multiple iterations on crew availability
  - Tunnel work schedule now on v32 (in 1 year!)
  - Implemented v16 last fall in OP
  - Implement v32 this month in OP

NOvA response to IPR recommendations

	Reviewer Out-brief words	NOvA response
Aug 2011 IPR	The NOvA project should insure that the development of the installation schedule includes contingency planning if ceramic beam tubes are delayed.	**Closed**. This is included in our installation planning by scheduling these tasks as late as possible. From the 22 Nov 2011 PMG, we are confident that we now have enough tubes in hand for all of the various fallback scenarios we have envisioned.

Further update: We have in hand enough beam tubes to carry out the planned installation of 7 RKAA magnets, 4 RKD magnets and 4 RKB magnets. Installation is still scheduled as late as possible for the RKB and RKD magnets, which are awaiting completion.

Is ANU on the Critical Path?

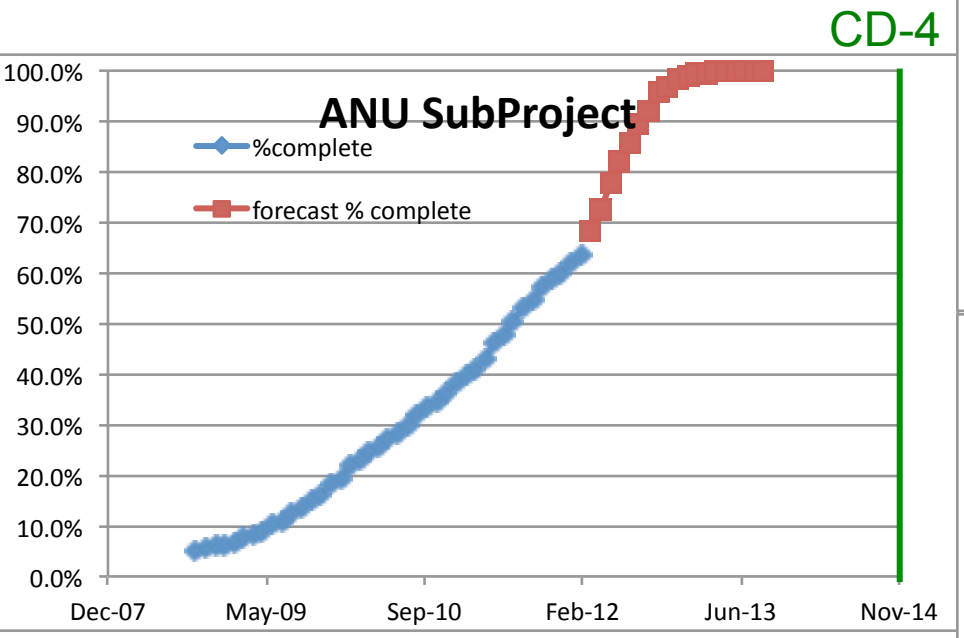
- ANU is not directly on the project critical path
  - 400+ days of float from “Accelerator shutdown complete” to CD-4
  - All planned ANU activities complete: Sep 30 2013
    - Last task: As-built documentation
  - Coupled to “Neutrino Detected” milestones in each superblock – commissioning and operations a laboratory responsibility
- Internal critical path considerations:
  - Fabrication and installation of 3 RF cavities
  - Fabrication and installation of kicker magnets (RKB/RKD)

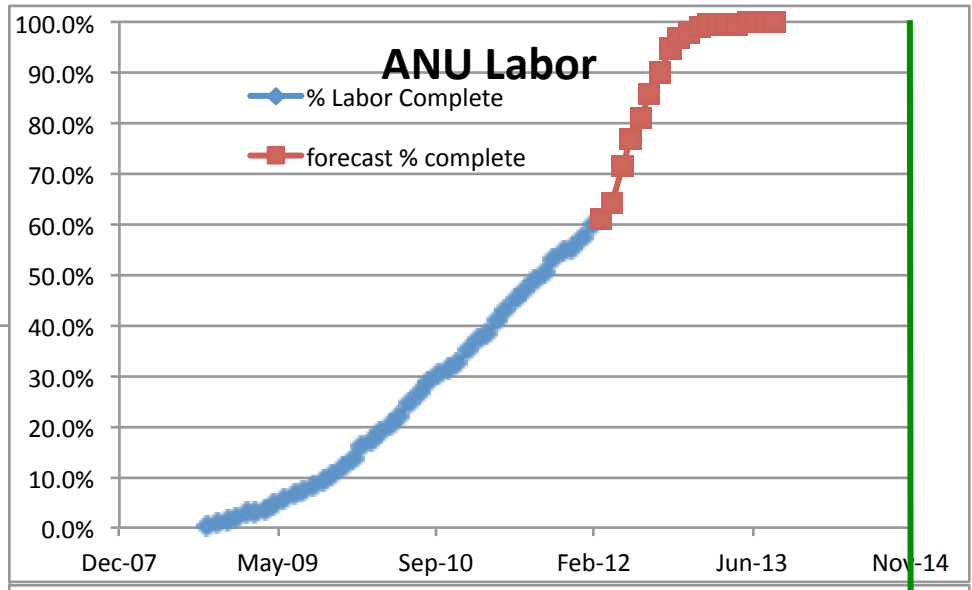
ANU Critical Path

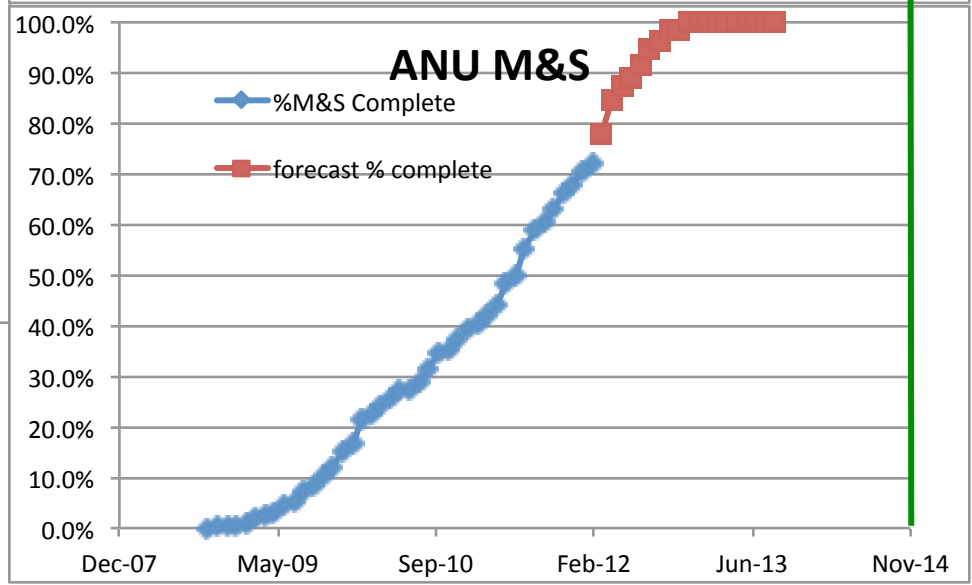
- Will get it out of OpenPlan

Forecast % Complete

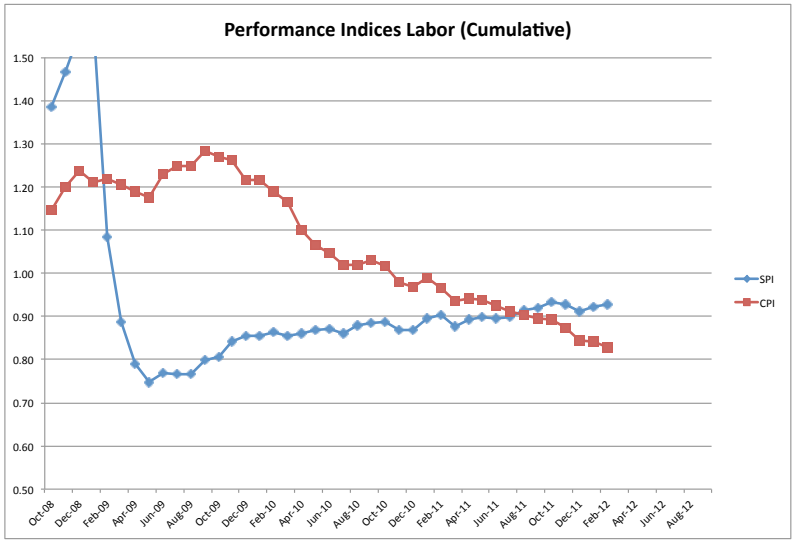
- Using existing schedule, forecast when ANU will be complete CD-4
- Labor jump is shutdown







Cost Performance



- CPI for ANU : slow decline
  - Labor aspect significant
  - Problems with RF cavities
    - 4% contribution
- Shutdown work dominated by labor
  - Discussions with Project Manager on possible mitigation
  - Adjust labor estimates for the first 3 months of the shutdown up by ~15% (moving from assigned contingency to budget)
    - Better match recent performance metrics
    - CR 487 adjusted 118 tasks
  - Revisit in July based on shutdown performance

Risks and mitigations

- Radiation exposure:
  - Significant work in hot areas
    - Estimate ~13R to workers
  - Slow down and shuffle crews around
    - Cost and schedule implications
  - Mitigate with
    - careful planning (e.g., girder assembly upstairs)
    - Local shielding
    - Detailed investigation of losses and isotopes and half lives

Risks and mitigations

- RF cavity fabrication:
  - A year behind schedule (combination of vendor and technical problems) and over budget
  - 1st cavity under test after shutdown underway
  - Mitigation:
    - Fallback to install 2 MI RF cavities in RR
    - Impact on final performance (~15% lower beam power)
  - Impact on CD-4 Accelerator parameters
    - Cost and schedule implications

Risks and mitigations

- Until we have all beam tubes installed in all magnets, I will still worry!
  - Have enough in hand to meet the plan
    - Cost and schedule implications if any break during processing steps
- Complicated installation
  - Cost and schedule implications
  - Prototyped where possible (Magnet stand in 2011)
  - Using accepted Fermilab techniques and protocols

Summary

- Accelerator Changeover Shutdown :
  - April 30: beam off
  - May 14: tunnel work commences
  - Have taken advantage of opportunities to do early work
- RF cavities and Kickers still the ANU critical path (not on project critical path at this time)
- A few outstanding components to be completed but have adjusted installation schedule to allow float for these components
- 12 months to complete all the work (10 months if only ANU work)