

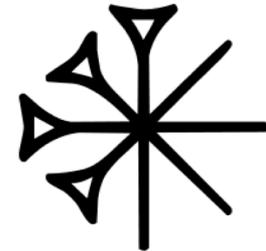


# Accelerator and NuMI Upgrade Status

Paul Derwent  
Associate Project Manager, ANU  
Fermilab



# Context of ANU

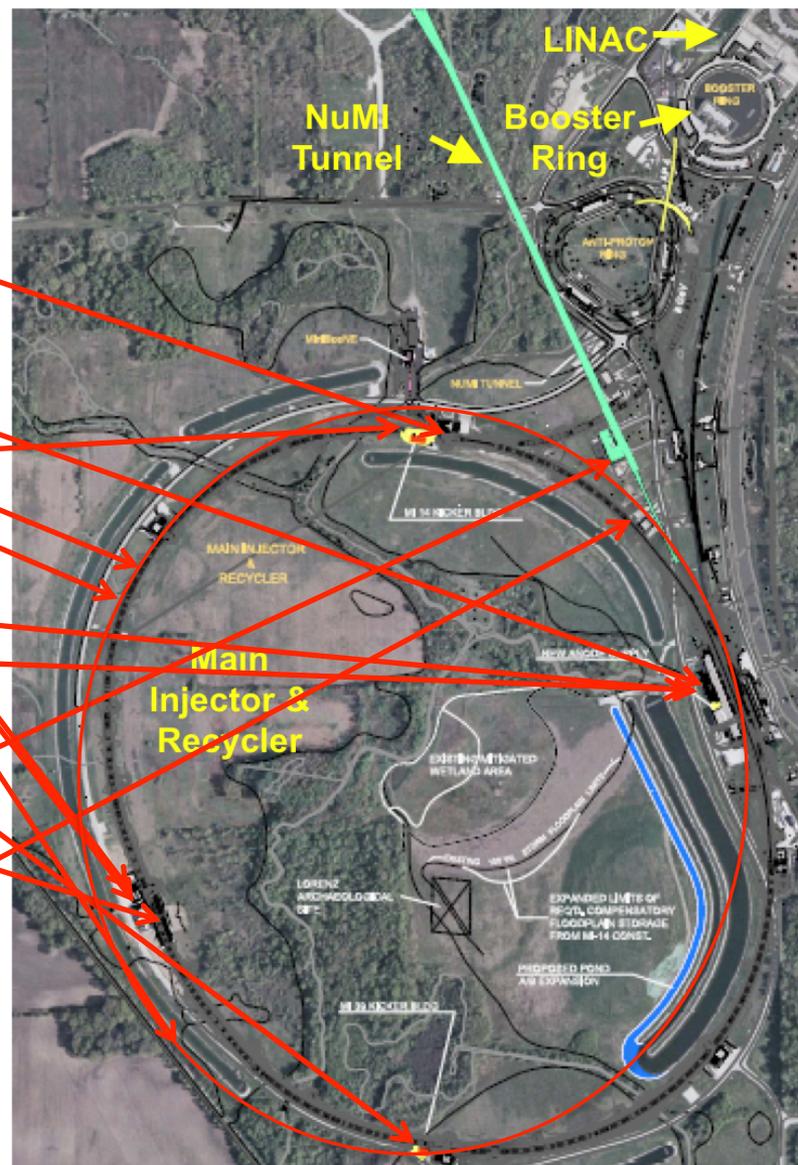


- Changes to the FNAL Accelerator complex to
  - Turn Recycler from pbar to proton ring
    - Injection and extraction lines
    - Associated kickers and instrumentation
    - 53 MHz RF
    - Decommission/remove pbar devices
  - Shorten MI cycle to 1.33 seconds
    - RF upgrades
    - Power Supply upgrades
    - Decommission/remove pbar devices
  - NuMI target station to 700 kW
    - Target & Horns to handle power
    - Configuration to maximize  $\nu$  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  $\nu$  beam configuration (new target, horn, configuration)
  - Cooling & power supply upgrades
- **Beam Physics (WBS 1.0.4 Complete)**
  - 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 Recycler Injection (RKAA 40"), 4 Recycler Abort (RKD 40"), 4 Recycler->MI Transfer line (RKB 60")
- 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



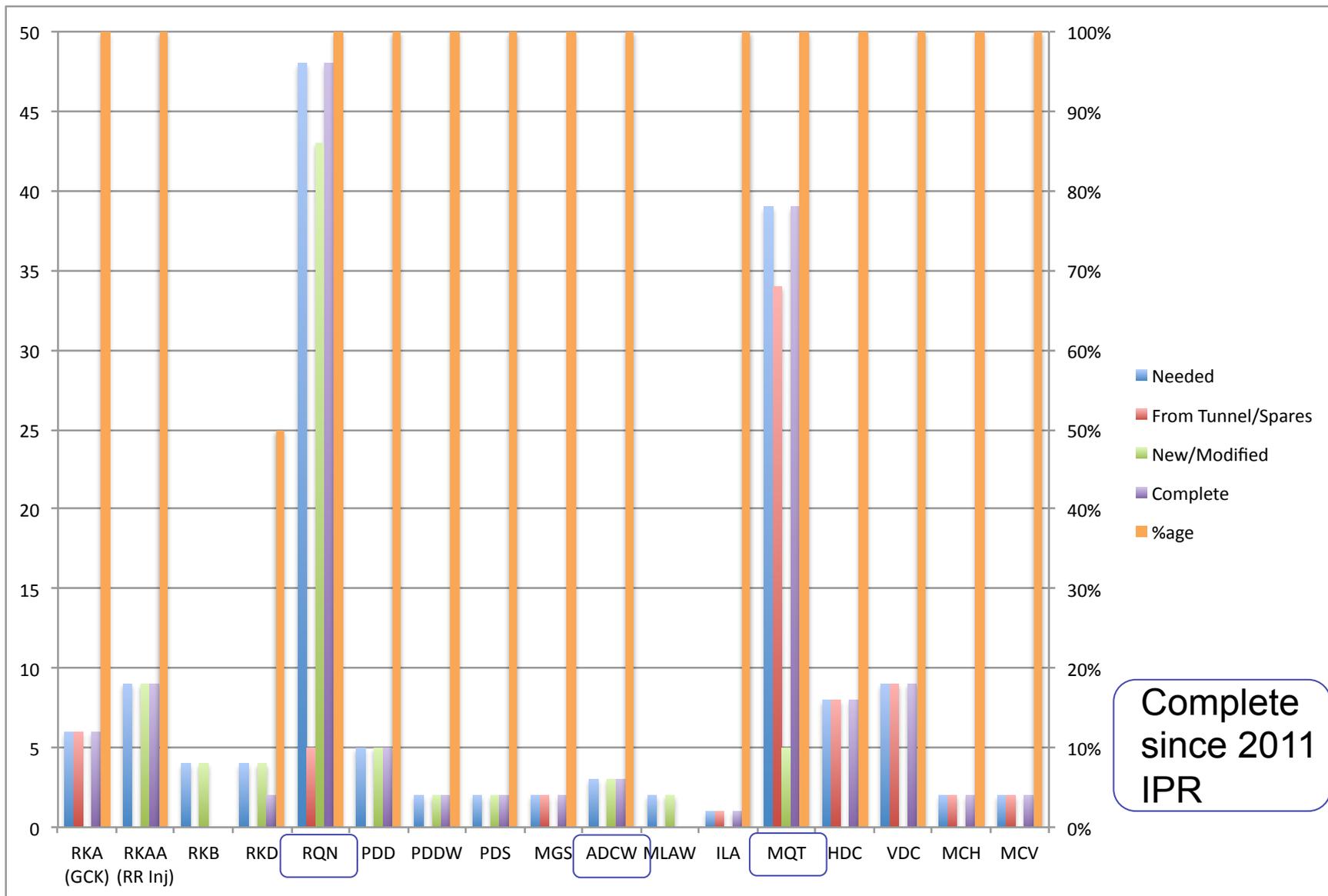


# Technical Progress

- Magnets
  - Finished Permanent Quads (RQN 43 magnets), Powered Quad Trims (MQT 39), Powered Transfer Line Dipoles (ADCW 3) since last August
  - Remaining are kickers RKB (4) RKD (2) and transfer line lambertsons (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



Complete since 2011 IPR



# 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

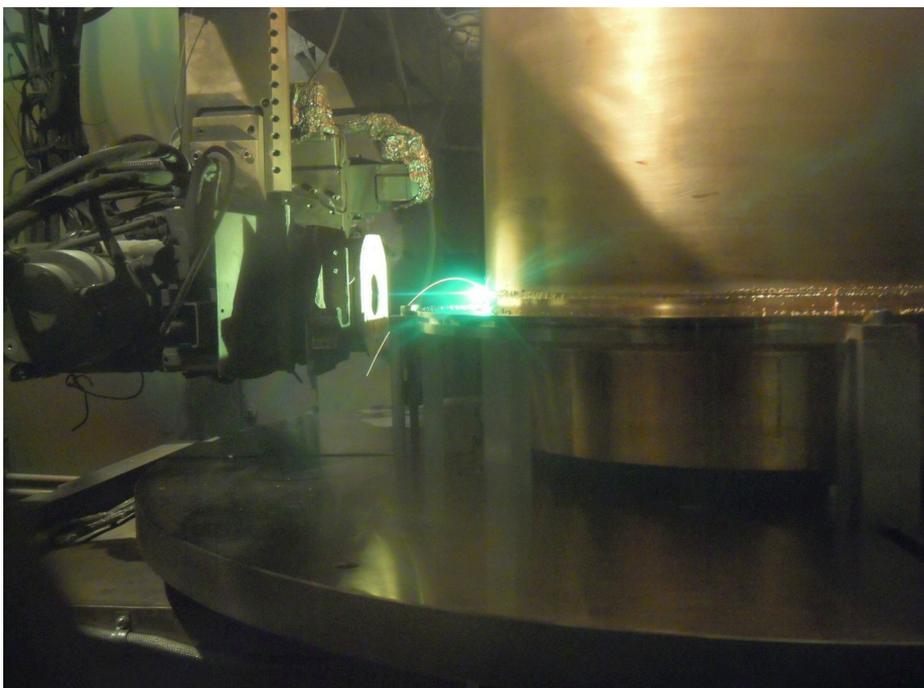
- Girders assembled and staged in MI-8





# RF Cavities

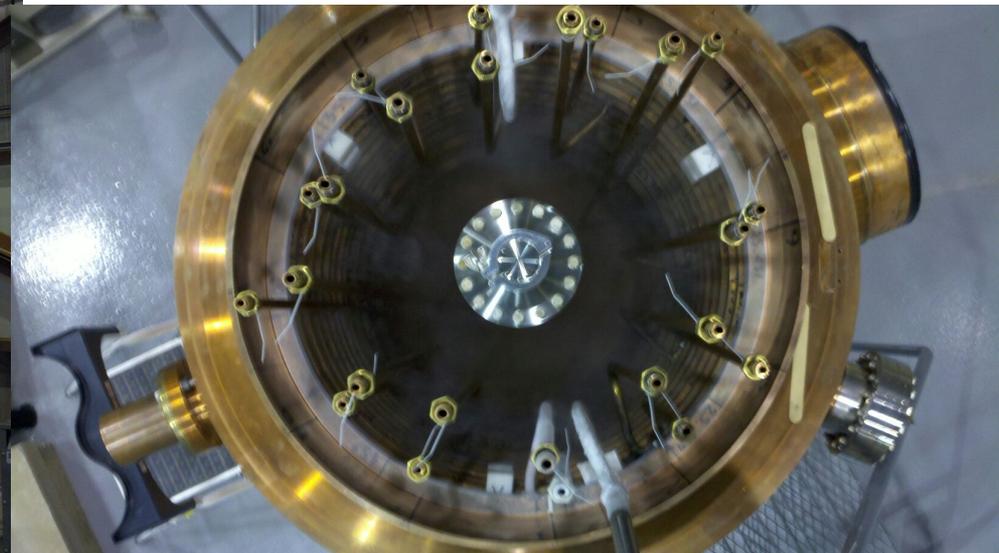
- Building 3 cavities (2+1 hot spare)
  - Setbacks with weld on  $\frac{3}{4}$ " copper
    - Vacuum and RF requirements
    - October 2011 decided on different path
  - Electron beam welding success!
  - 12 inner hoops installed (4/18/12)





# RF Cavity

- Inner hoops are pressure fit:
  - Hoop Outer Diameter  $>$  Cavity Inner Diameter
  - use Liquid  $N_2$  to shrink to fit
  - Pointing toward late fall for installation





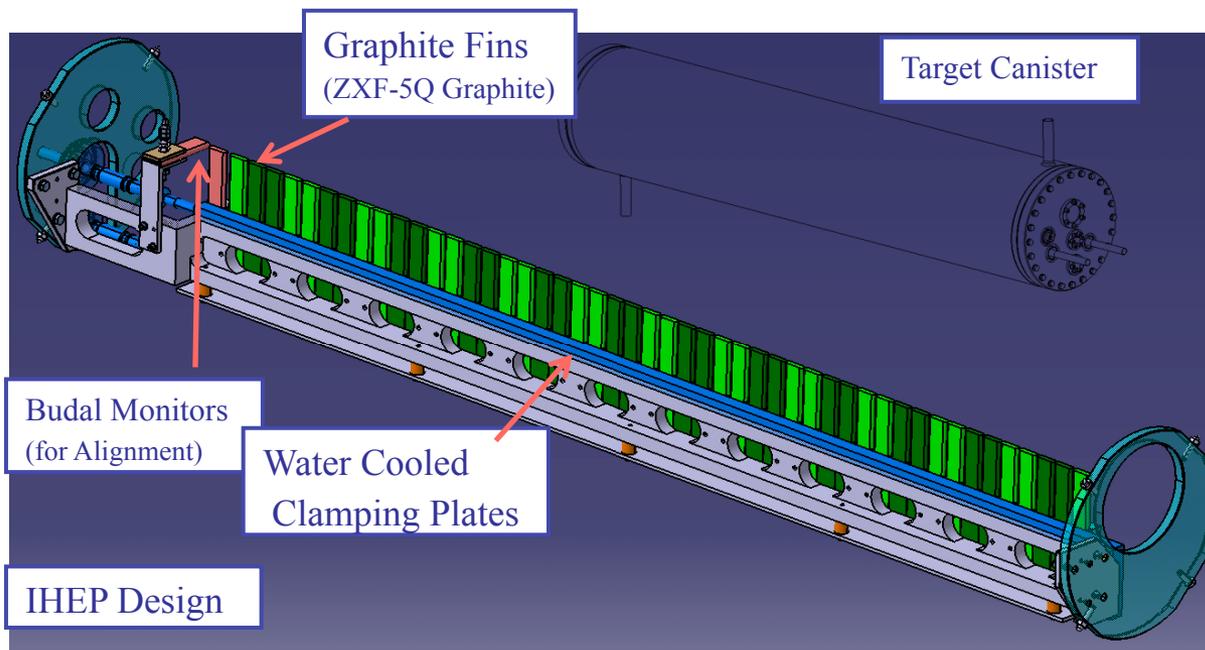
# Technical Progress

- Target Carrier
  - Prototype complete last summer, 2<sup>nd</sup> assembly underway
- Baffles in hand
- Target
  - Additional problematic water system welds, revisited and redesigned
  - 1<sup>st</sup> fabricated at STFC Rutherford Appleton Lab (RAL)
  - Accord with IHEP Protvino to build 2 more (1 on project, 1 off project),
  - Accord with RAL to build more also (off project)



# Target

- Target fabrication in collaboration with RAL





# Target

- Target fabrication in collaboration with RAL



Shipped May 3<sup>rd</sup>!

In customs at O'Hare

Mount on target  
carrier by June 1

Ready for installation  
by August 1



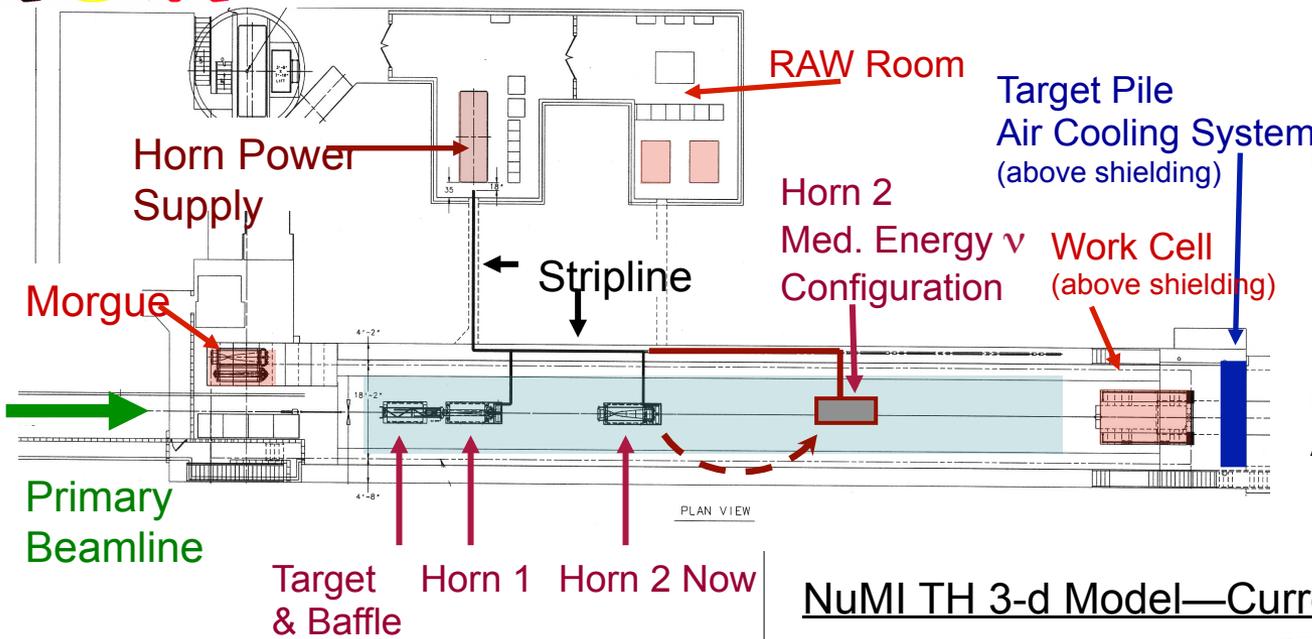
# Installation Shutdown

- 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 to recover  $10^{-10}$  vacuum level
  - 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 from 10 months to 12 months
- Lots of people and equipment traffic!
  - 40+ technicians and engineering staff (Accelerator Division, Technical Division, and Particle Physics Division)
  - 40+ trades (pipefitters, riggers, electricians)
  - 1 equipment access point





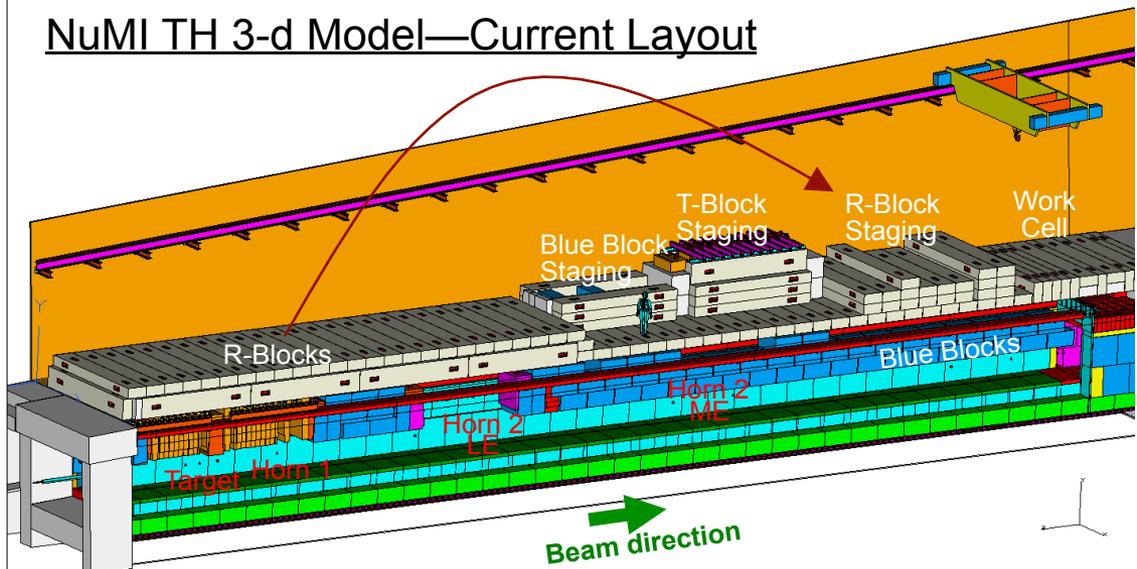
# Target Hall: Scope of work



Utility work associated with upgrades: RAW most significant

Coordinated by Mike Andrews

NuMI TH 3-d Model—Current Layout



Limited space available for Target Hall activities (Horn 2 move, Target & Horn change outs & repairs, Radioactive Component Repair/Removal)



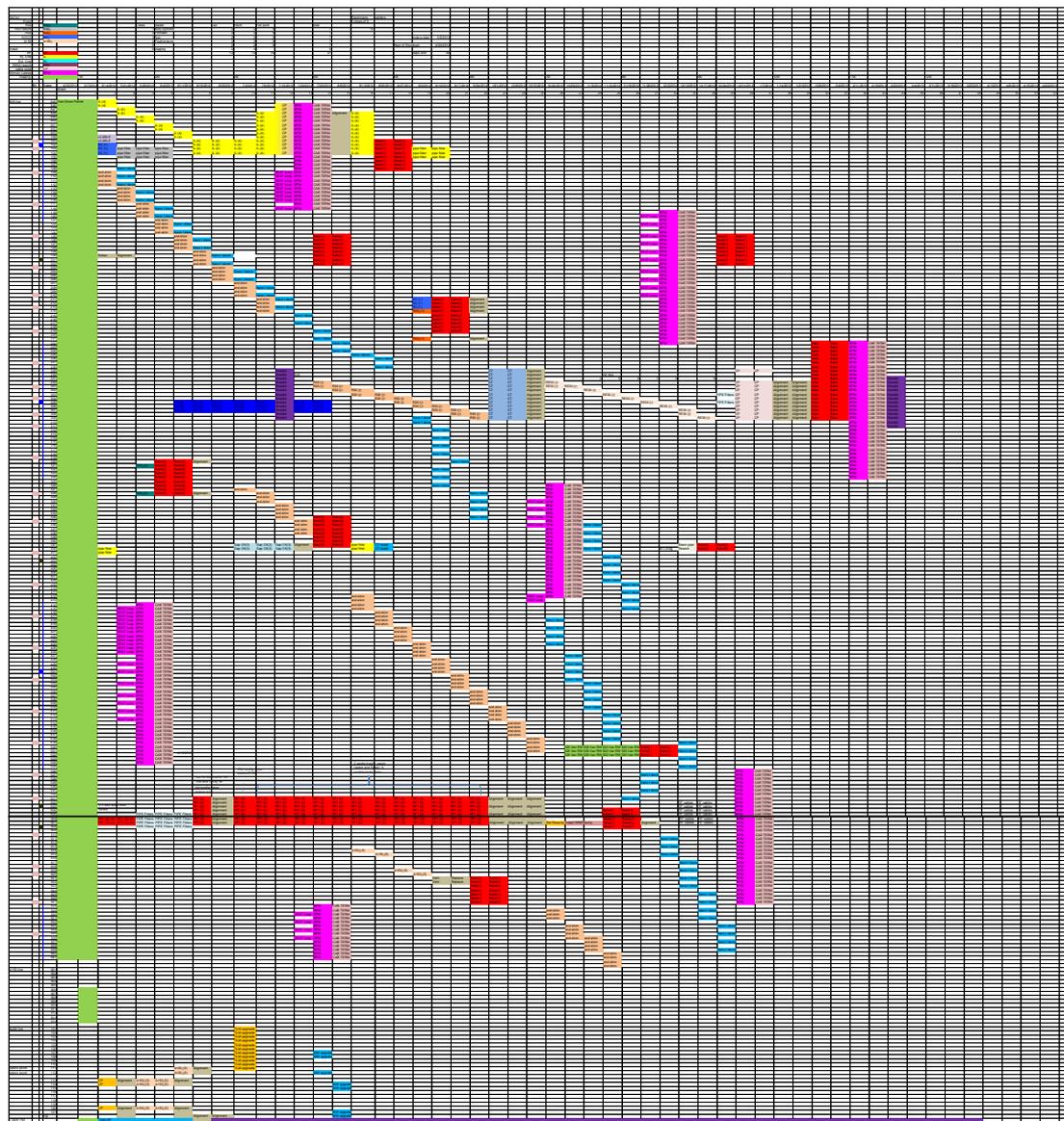
# Off Project Work

- 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 (Proton Improvement Plan)
    - RFQ installation
    - Booster RF cavity upgrade
      - SSRF modulators and PAs
      - Cavity tuners (cooling)
    - Booster magnets
  - Impact available resources
  - Lengthens shutdown from 10 months to 12 months



# Tunnel work schedule (v32)

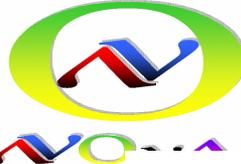
- X axis is time
- Y axis is tunnel location
- Color is type/ location of job
- Text is type of job and crew assigned for job
- Folds in both on project and off project work (maintenance, upgrades for other programs)



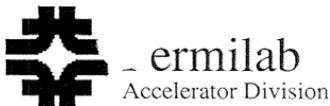


# Shutdown Length

- Driver is the work in MI30 area
  - Removing the Electron Cooling insert
    - Electron line: solenoids, correctors, instrumentation, return line
    - Specialized lattice section
    - ~85 magnets removed
  - Install reworked RR 30 Straight Section
    - FODO lattice and standard instrumentation
      - ~30 magnets
      - Cables, alignment, vacuum leak checking
  - Install RR -> MI transfer line
    - Kickers, lambertsons, quadrupoles, correctors, vacuum system
      - 4 RKB and 1 RKD
      - ~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



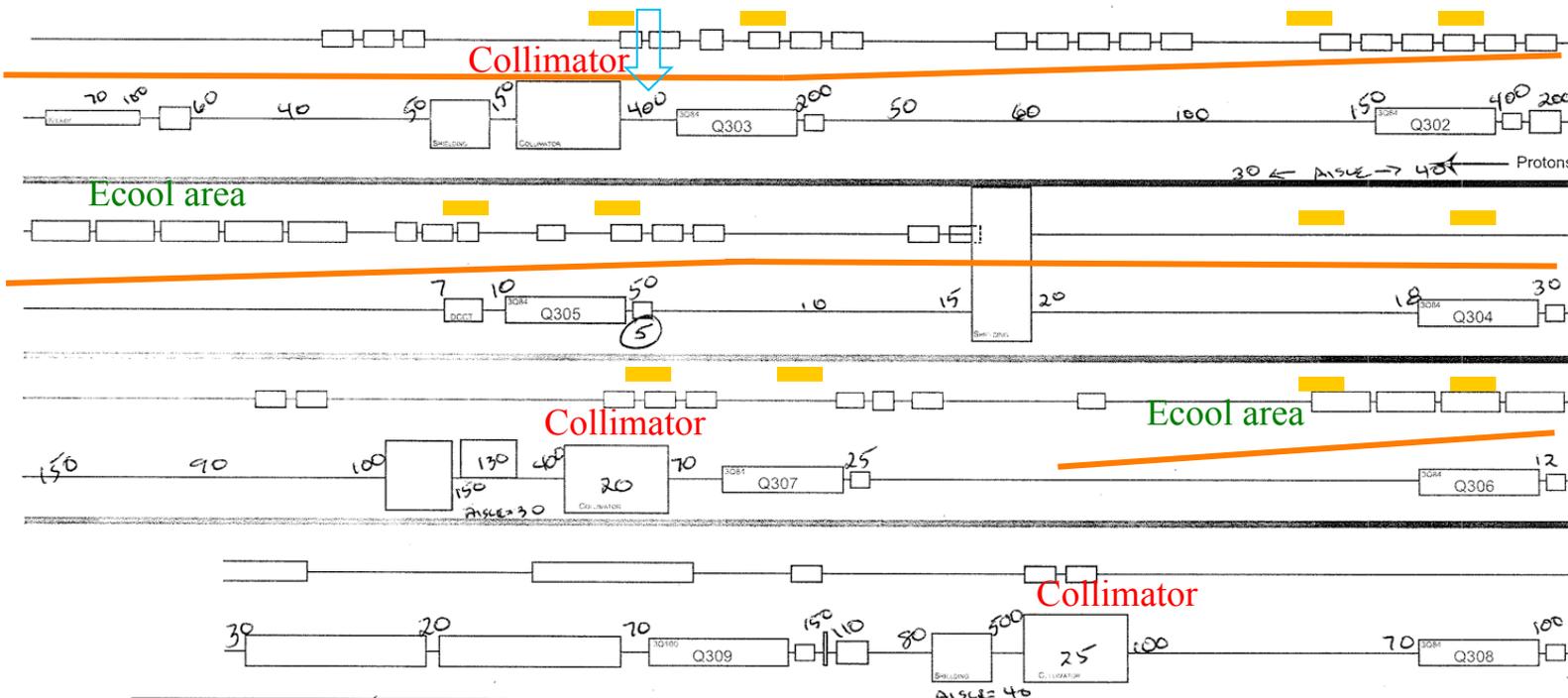
# Initial Rad Survey Completed 32 hours after beam off



DATE: 5/1/12 TIME: \_\_\_\_\_ PURPOSE: \_\_\_\_\_ I. # \_\_\_\_\_

## MI 302-309

New extraction line

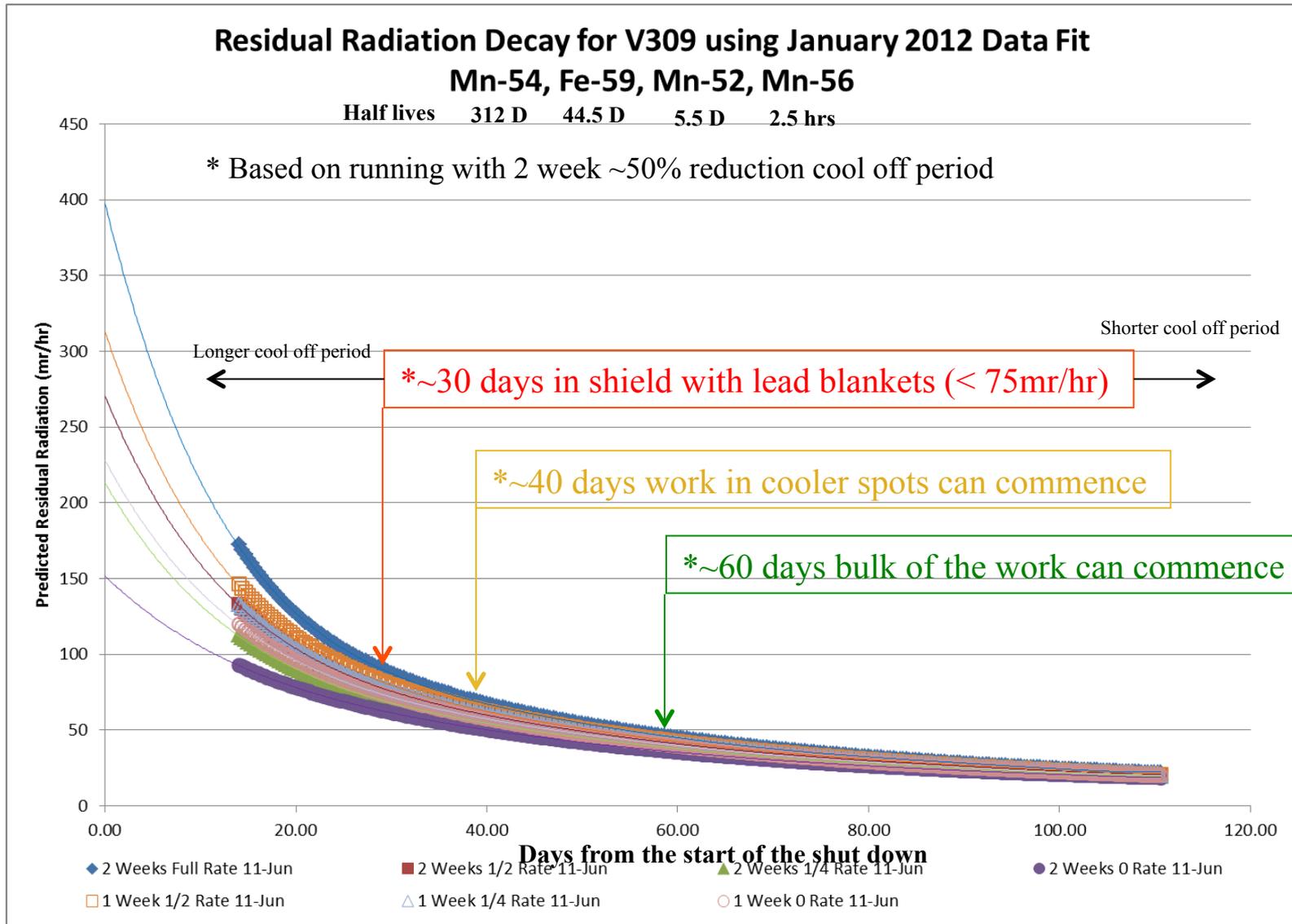


All Dose Rates Below <u>5</u> mR/hr Unless Noted.		Bkgd <u>30</u> cpm	Highest Dose Rate Found <u>500</u> mR/hr at 1 ft.
Inst Type: _____	_____	Wipe # <u>5</u> Reading <u>2</u> ccpm	Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe.  Comments: _____  Surveyed By: _____ Reviewed By: _____
Inst No: _____	_____	_____ ccpm	
Batt/Source Chk: _____	_____	_____ ccpm	
Cal. Due Date: _____	_____	_____ ccpm	
_____	_____	_____ ccpm	
<b>LEGEND</b> Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below * = mR/hr @ contact A = Air Sample    ○ = Wipe    ⊕ = Floor wipe		Beam Off Date: _____ Beam Off Time: _____ Intensity: _____	

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





# RR30 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 RR30
  - Week 7: work commences on e-cool removal
  - Week 12: install temporary shielding
  - RKB kicker last element ready for the line
    - Anticipated first ready in October, last one in December 2012
  - Flexibility with tasks near the end (e.g., BPM cable pulls scheduled after kicker installation, could move earlier)



# 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 Accelerator Division (20), Particle Physics Division (16), and Technical Division (14) technicians and task managers to complete the project work



# Crew Breakdown Information

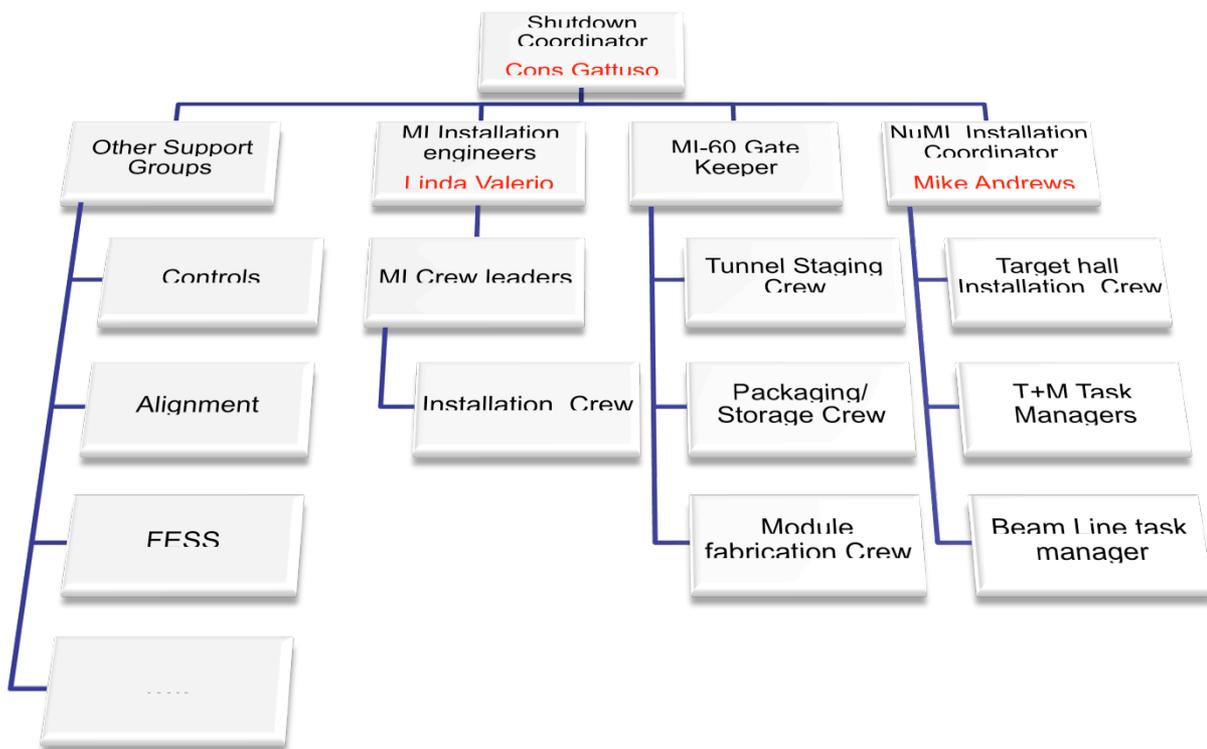
- Had multiple iterations on crew availability
  - Tunnel work schedule now on v32 (in 1 year!)
  - Implemented v16 last fall in OpenPlan
  - Implementing v32 now in OpenPlan

	Leader	Technicians	Riggers	Trades	Total
Crew 1	1	4	3		8
Crew 2	2	3	3		8
Crew 3	1	8	3		12
Crew 4	1	3	3		7
Crew 5	1	6			7
Target Hall	1	11			12
Electricians	1			10	10
Pipefitters	2			22	22
Support		10			
Total	10	35	12	32	99



# Shutdown Coordination

- Dan Johnson, AD Operations Dept Head
  - Complex Coordinator
  - FESS, AD, ComEd, PPD, TD
  - All project work (NOvA, PIP, Maintenance, Power Outages)
- Cons Gattuso, NOvA Shutdown Coordinator
  - All MI tunnel responsibilities
- Mike Andrews NuMI target Hall Coordinator
  - All TH responsibilities





# ANU Milestones

- ANU has 41 milestones remaining
  - Expect to achieve all (but one) of them within the next 12 months

 <b>NOVA Project</b> Milestone Gantt Chart Progress Reporting - thru March 2012 Time Now: 01Apr12 Baseline: LastMonth						Baseline Milestone <span style="color: green;">▼</span>													
						Completed Milestone <span style="color: gold;">★</span>													
						Milestone <span style="color: yellow;">▲</span>													
Activity ID	Milestone Description	Computed Status	Early/Actual Date	Baseline Date	Milestone Level	2012			2013			2014							
						Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1.0 -- ANU Planning, Engineering & Design																			
1.0.3.1.5.1	NuMI Charging PS Upgrade Design Complete	Planned	19Apr12	03Oct11	L.5	▼													
1.0.2.1.6.1	MI 2.5 Mhz Cavities Removal Complete	Planned	12Jun12	21May12	L.5														
1.0.2.1.6.2	MI Decommissioning of A1 Extraction Line Complete	Planned	06Jul12	20Jun12	L.5														
1.0.2.1.6.3	MI Machine Timing Complete	Planned	03Oct12	12Sep12	L.5														









# 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.	<b>Closed.</b> 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

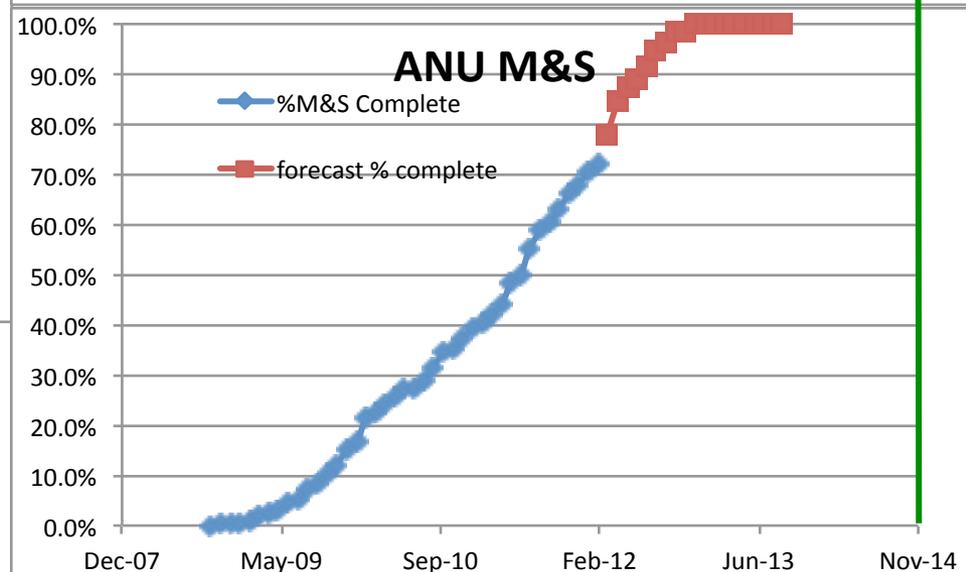
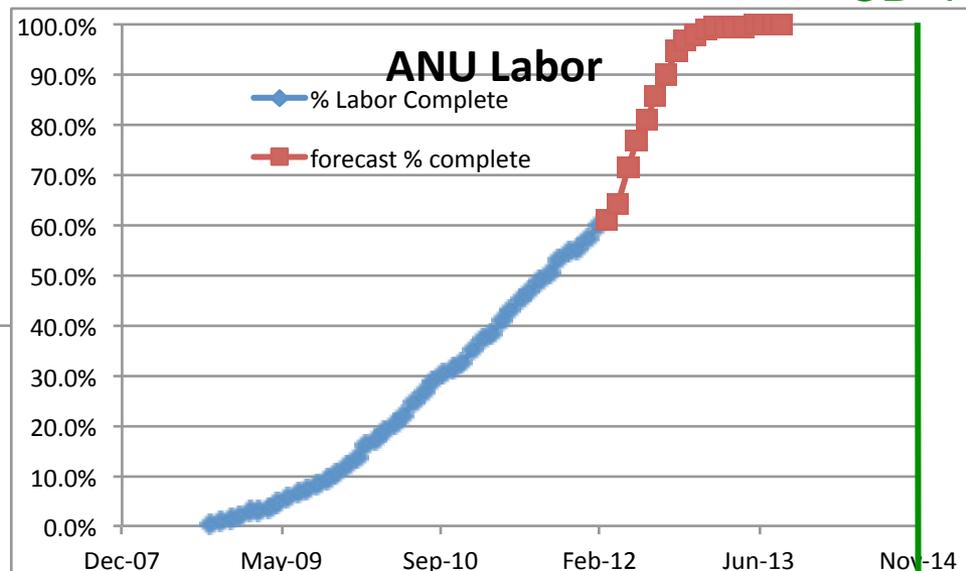
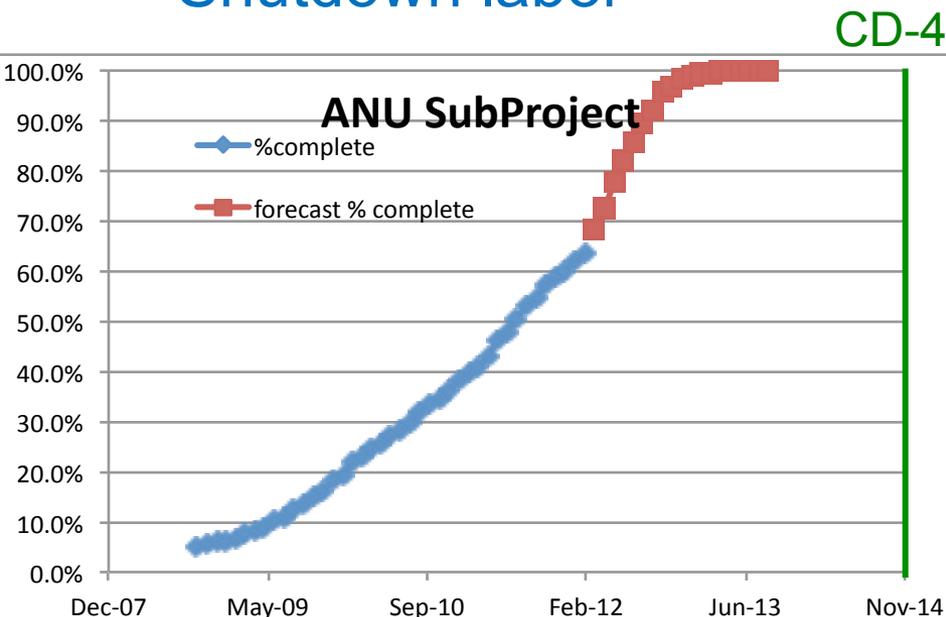
					2012				2013				2014				2015			
					Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
	WBS	Activity Desc.	Total Float	Early Dates																
	1	Research and Development	-11d	03Oct05 19Feb13	[Gantt bar from Q2 2012 to Q1 2013]															
	2	Construction Project	-11d	01Dec06 26Nov14	[Gantt bar from Q2 2012 to Q4 2014]															
	2.0	ANU Construction	-11d	01Dec06 01Oct13	[Gantt bar from Q2 2012 to Q4 2013]															
	2.0.1	Recycler Upgrades	-11d	28Dec07 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.1	Recycler Ring Modifications	-11d	01Oct08 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.1.1	Beam Lines (Transfer, Abort & RR 30 Straight)	-11d	01Oct08 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.1.1.14	Installation	-11d	01Mar10 07May13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.1.1.14.33	RR30 and Extraction Line	-11d	30Jul12 19Mar13	[Gantt bar from Q3 2012 to Q1 2013]															
	2.0.1.1.1.14.37	Sextapole and BPM Cable Pulls	-11d	13Jun12 16Apr13	[Gantt bar from Q3 2012 to Q1 2013]															
	2.0.1.2	Recycler Kicker System	-11d	28Dec07 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.2.3	RKB Magnets	-11d	26Mar09 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.2.3.3	RKB Fabrication, Assembly, Checkout, and Test	-11d	01Dec09 29Jan13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.2.5	RKD Magnets	-11d	01Sep09 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.2.5.1	RKD Magnet Procurement	-11d	30Sep09 28Jun13	[Gantt bar from Q2 2012 to Q3 2013]															
	2.0.1.2.5.2	Beam Abort Kicker Assembly & Checkout/Test	-11d	01Sep09 07Nov12	[Gantt bar from Q2 2012 to Q1 2013]															

- Float with respect to April 1 (11 months)
- RKB and RKD magnet procurement and fabrication



# Forecast % Complete

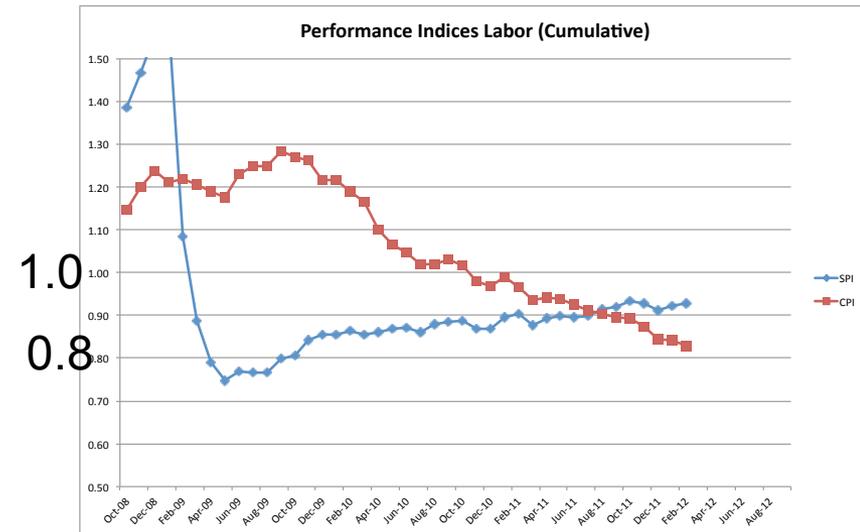
- Using existing schedule, forecast when ANU will be **CD-4** complete
- Change in slope ?
  - Shutdown labor





# Cost Performance

- CPI for ANU : slow decline
  - Labor aspect significant
  - Problems with RF cavities
    - Overall Labor CPI: 81%
    - Labor CPI w/o RF: 85%
- Shutdown work dominated by labor
  - Discussions with Project Manager on possible mitigation
  - Adjust labor estimates for 4 months of effort 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 (after detailed ALARA planning)
  - 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
    - Scheduled Radiation Surveys:
      - Before and after the shielding installation (7 weeks in)
      - Revisit ALARA plan and exposure calculations
      - When major work starts in hottest areas



# Risks and mitigations

- RF cavity fabrication:
  - A year behind schedule (combination of vendor and technical problems) and over budget
  - 1<sup>st</sup> cavity under test after shutdown underway
    - 2 cavities ready for installation: late October
  - 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
  - June 11: RR 30 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)