The Fermilab Muon Campus
The Experiments, Projects, and Status

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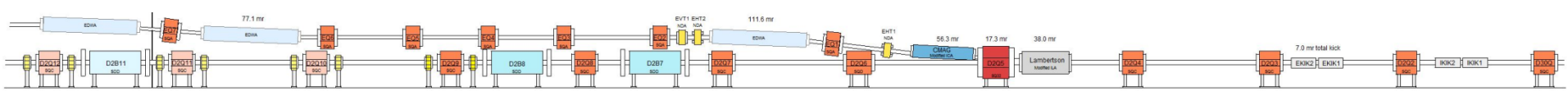
Outline

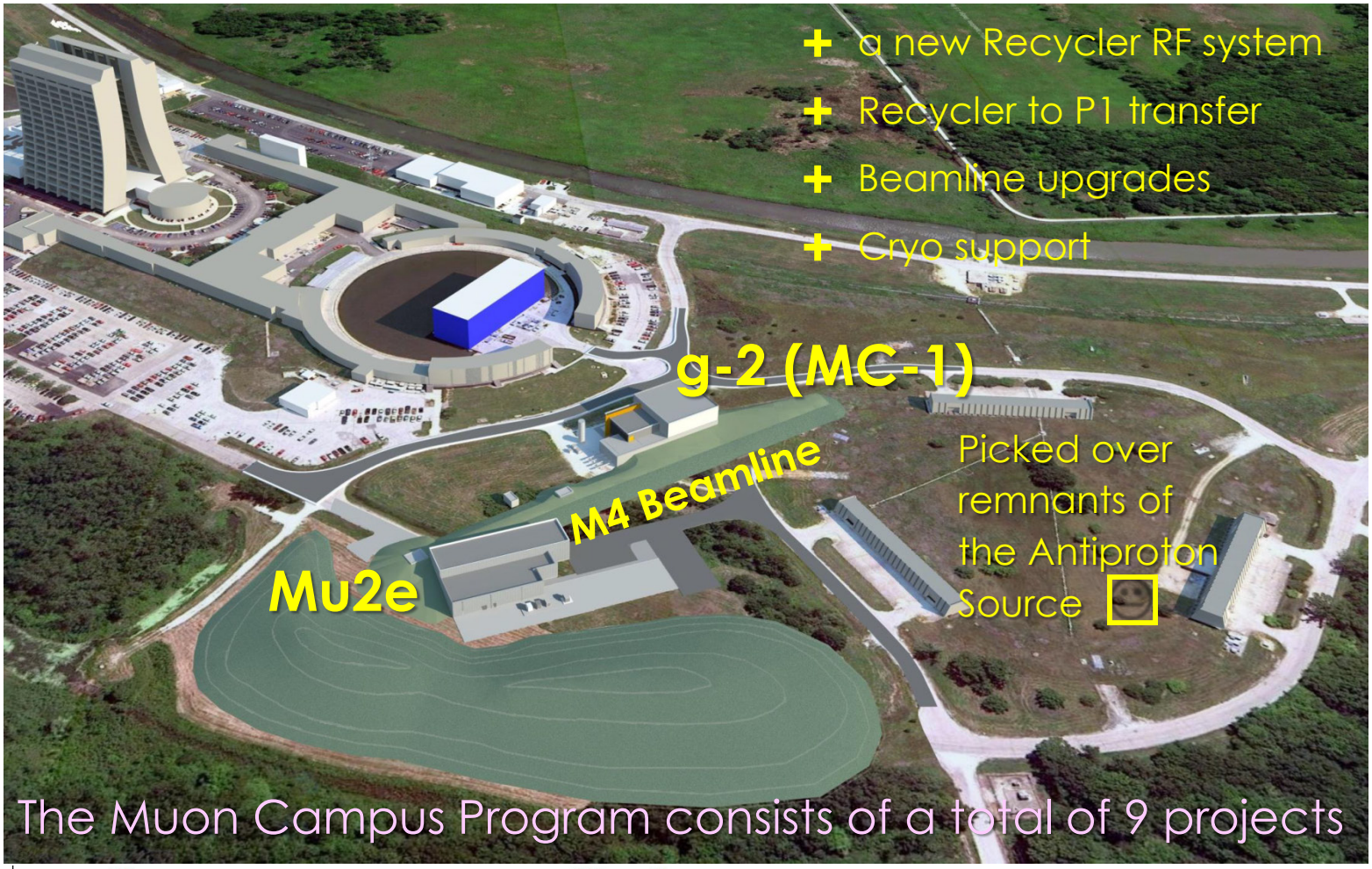
1. The Experiments
   - Muon g-2
   - Mu2e

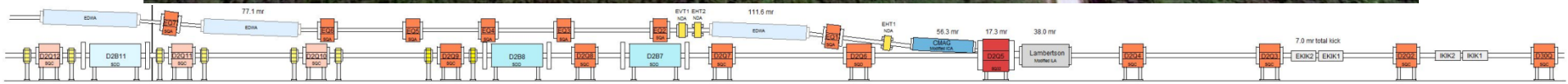
   - What's measured
   - Why it matters
   - How it's measured

2. The Projects
   - DOE 413.3b Projects: Muon g-2 and Mu2e
   - Muon Campus AIPs and GPPs



The Muon Campus

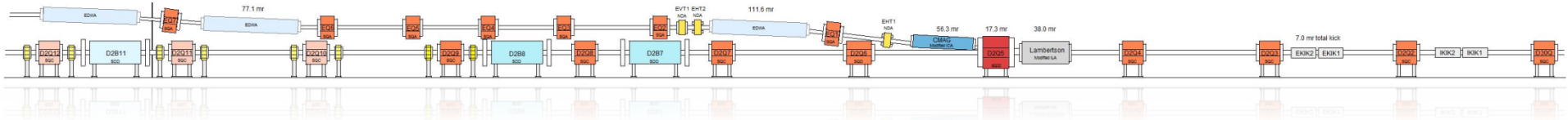




The Experiments

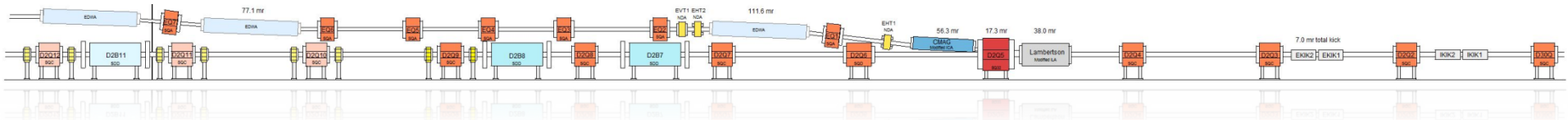
Muon g-2

Mu2e



The Muon g-2 Experiment

- What it measures
- Why it matters
- How it measures it

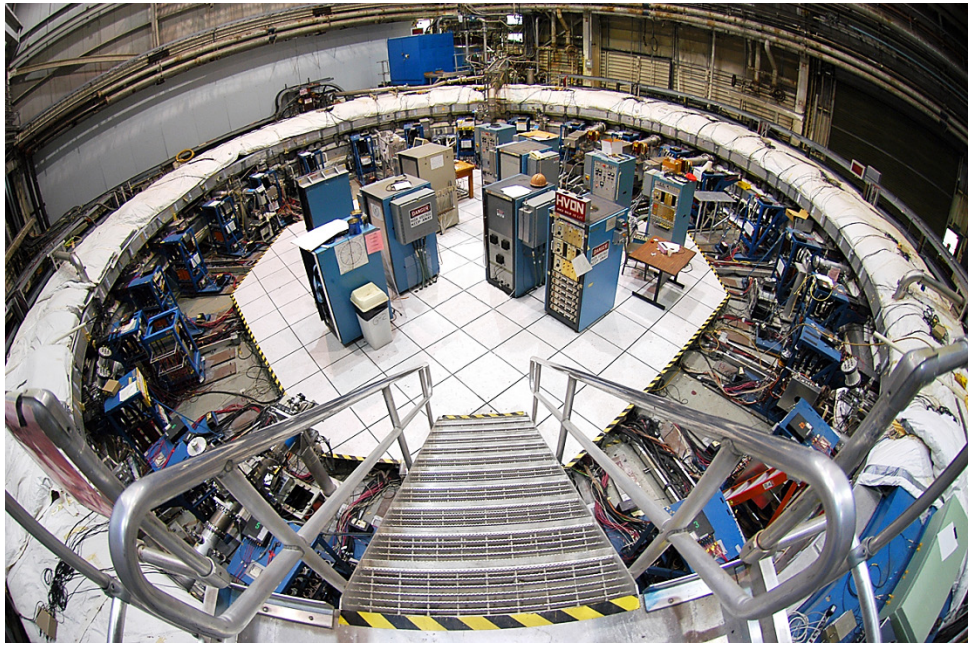


Historical Background

The Muon g-2 experiment has an impressive pedigree:

- Three CERN experiments (~1961 – 1979)
- BNL Experiment E821 (1984 – 2000)

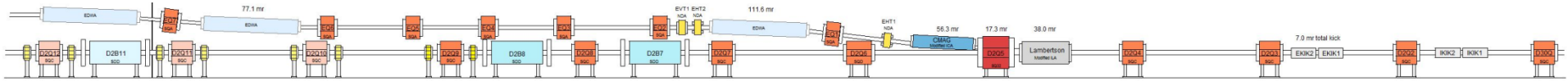
The Fermilab g-2 experiment inherits the principle apparatus of BNL E821.



BNL Experiment E821 muon storage ring

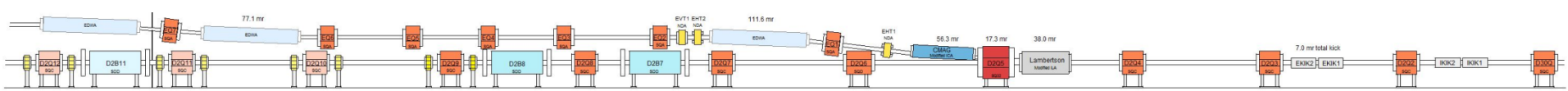
This ring was transported to Fermilab during the summer of 2013.

The ring now resides in the MC-1 building of the Fermilab Muon Campus.

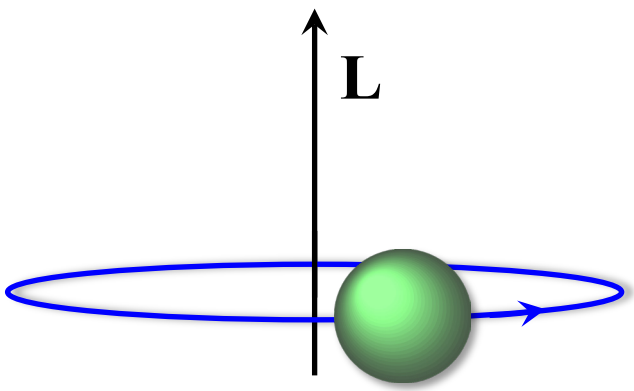


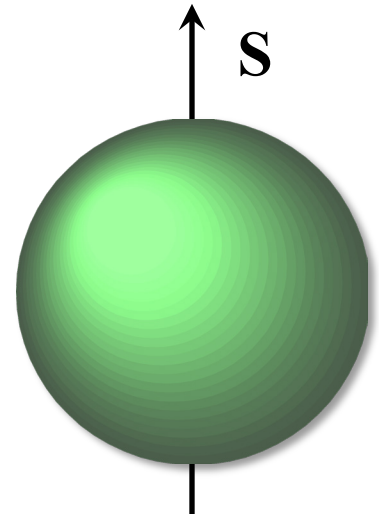
Muon g-2: What it measures

- The Muon g-2 experiment measures the anomalous magnetic moment of the muon, usually written a_μ
- a_μ is defined as: $a_\mu = \frac{g-2}{2}$
- g is the gyromagnetic ratio of the muon – *This is the "g" in "g-2"*
- The gyromagnetic ratio is the ratio of the magnetic moment of a particle due to its spin to that of a classical particle of the same charge and angular momentum



The Gyromagnetic Ratio, g





<u>Note</u>: real muons probably don't look like green spheres

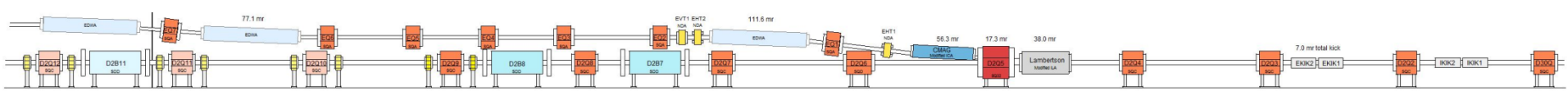
Magnetic Moment ($\boldsymbol{\mu}$) of a classical muon (mass m_μ) with charge e and angular momentum $\mathbf{L}$:

$$\boldsymbol{\mu} = \frac{e}{2m_\mu c}\mathbf{L}$$

Magnetic Moment of a real muon with intrinsic spin angular momentum $\mathbf{S}$:

$$\boldsymbol{\mu} = g\frac{e}{2m_\mu c}\mathbf{S}$$

The factor g is a quantum effect – and it's not small

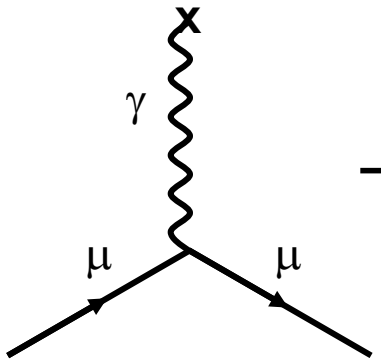


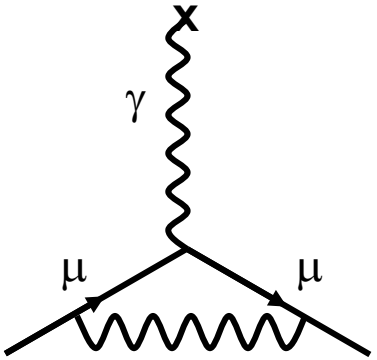
The Value of *g* *(Part 1)*

$$g = 2\left(1 + \frac{\alpha}{2\pi} + \ldots\right)$$

Dirac Equation

1st Order QED
"Schwinger term"

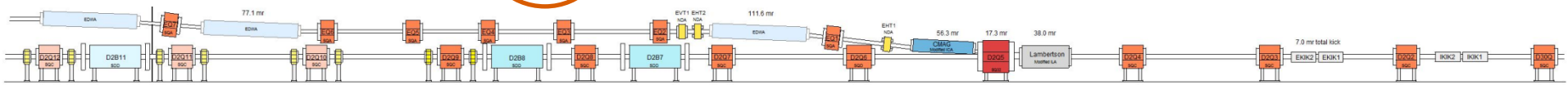
$=$ 

$+$ 

$+ \ldots$

Part subtracted in the definition of a_μ

$= 2 + 0.00232 + \ldots$



The Value of *g (Part 2)*

There are many more processes that contribute to the magnetic moment of the muon:

+ Higher order QED

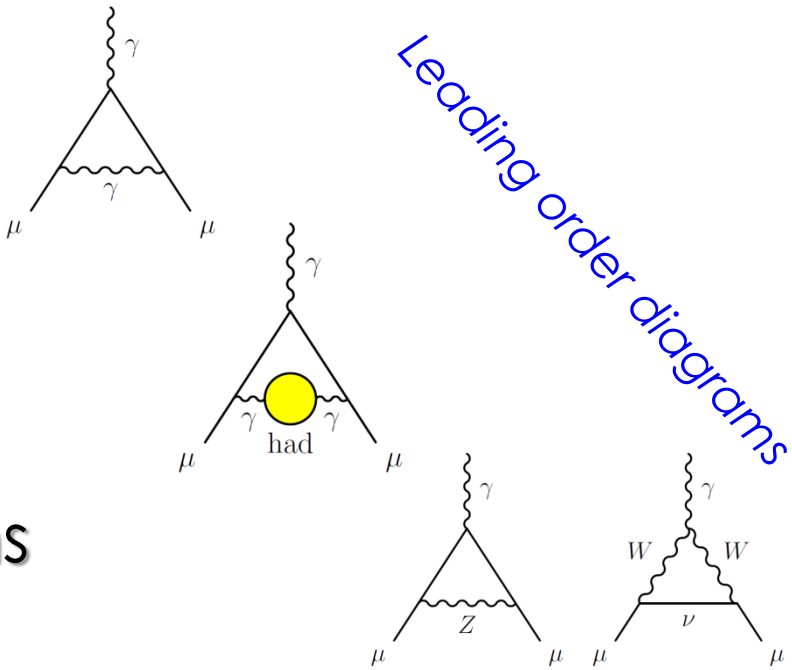
  g_{QED} = 0.00 233 169 437 90(16)

+ Hadronic interactions

  g_{Had} = 0.00 000 013 872(85)

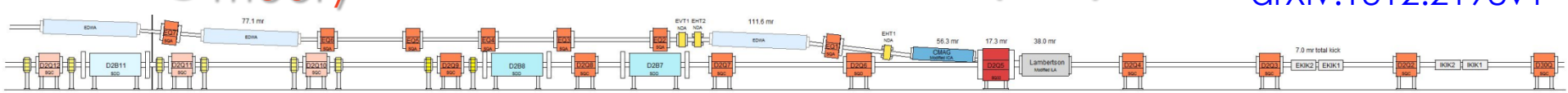
+ Electro-weak contributions

  g_{EW} = 0.00 000 000 307(2)



= g_{Theory} = 2.00 233 183 630(99)

T. Blum et.al
arXiv:1312.2198v1



A Hint of New Physics

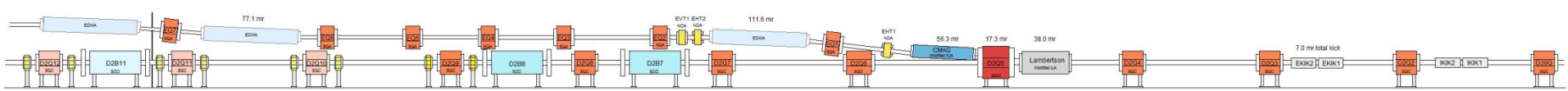
The difference between the calculated value of g (g_{Theory}) and the measured value (g_{Meas}) suggests the possibility of new physics.

$$g_{Theory} = 2.00\ 233\ 183\ 630(99)$$

$$g_{Meas} = 2.00\ 233\ 184\ 178(126)$$

This is a statistically interesting difference.

What other physics must be added to make $g_{Theory} = g_{Meas}$?



Discrepancy between Theory and Experiment

Recall: $a_\mu = \frac{g-2}{2}$

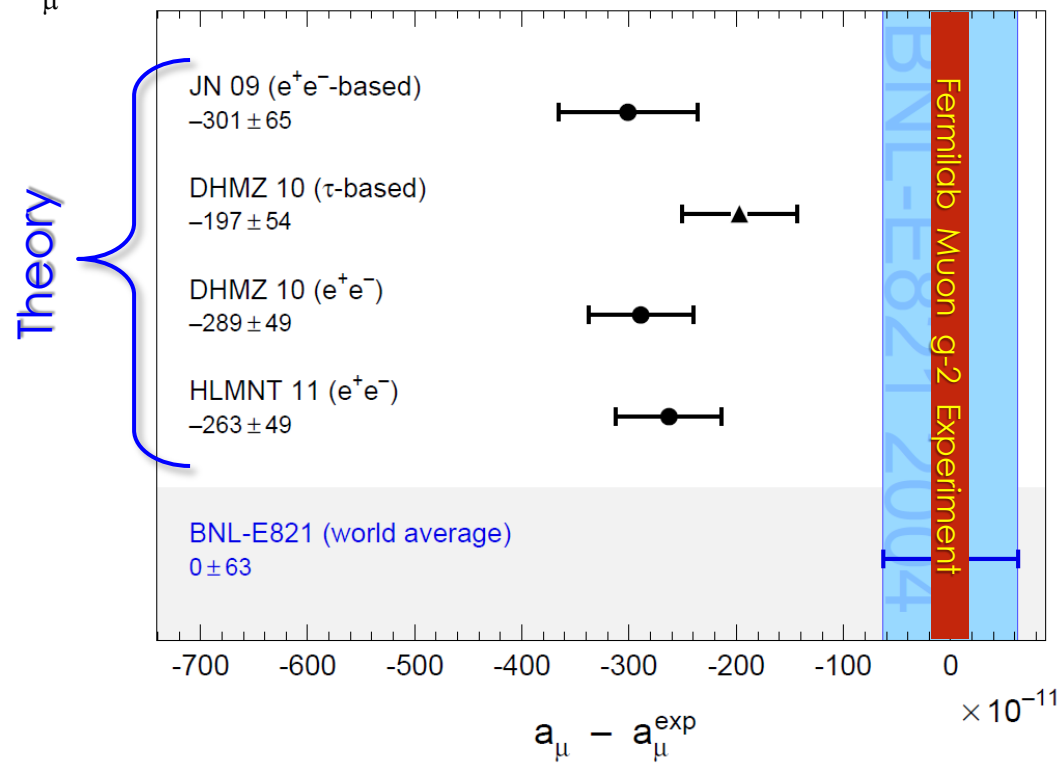
$$a_\mu^{Meas} - a_\mu^{Theory} = 274(80)\times 10^{-11}$$

Presently there is a 3σ discrepancy between theory and experiment.

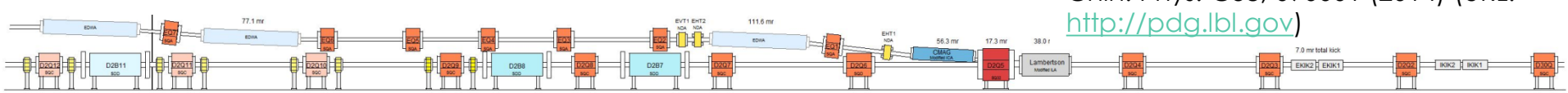
The Fermilab Muon g-2 Experiment will reduce this discrepancy to 5σ.

The goal of the Muon g-2 Experiment is to reduce the uncertainty in Δa_μ from 80×10^{-11} to 16×10^{-11}.

Comparison of theoretical calculations of a_μ with BNL-E821 Measurement

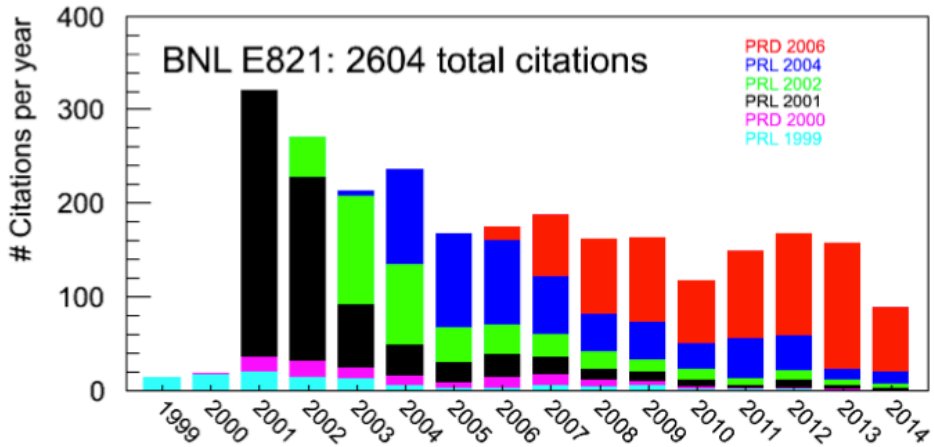


K.A. Olive et al. (Particle Data Group), Chin. Phys. C38, 090001 (2014) (URL: http://pdg.lbl.gov)



The Significance of the Muon g-2 Experiment

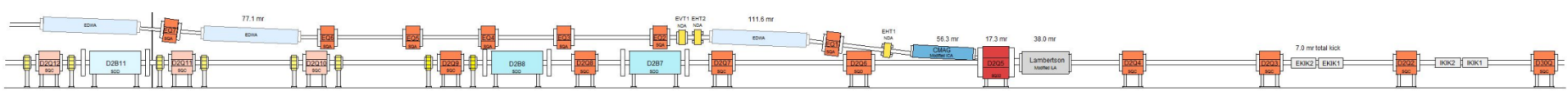
It is important to emphasize that the significance of the Muon g-2 experiment is greater than the mere measurement of the value of a_μ.



The particle physics community recognizes this measurement as a very sensitive probe of physics beyond the Standard Model.

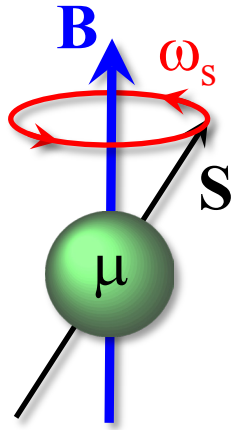
The BNL E821 experiment remains one of the most cited results in particle physics

- Applicability to a wide range of theoretical work



Measuring g-2

- Capture polarized muons in the uniform magnetic field of a cyclotron



- Two motions:
  1) Larmor precession of the muon spin

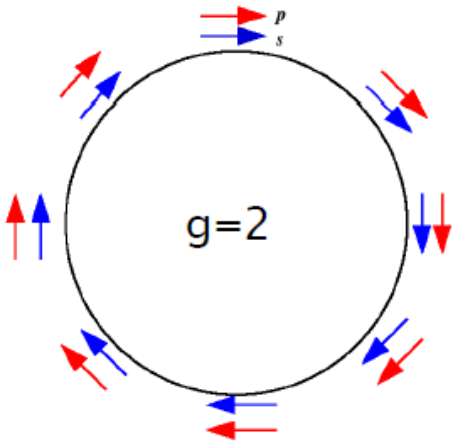
$$\omega_s = g\frac{eB}{2m_\mu c}$$

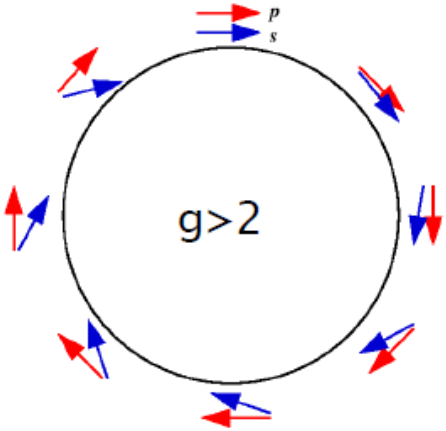
  2) Cyclotron rotation of the muon momentum

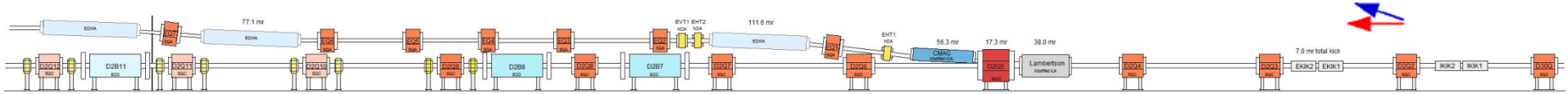
$$\omega_c = \frac{eB}{m_\mu c}$$

- The difference ($\omega_a \equiv \omega_s - \omega_c$) is proportional to g-2

$$\omega_a = \omega_s - \omega_c = \left(\frac{g-2}{2}\right)\frac{eB}{m_\mu c} = a_\mu \frac{eB}{m_\mu c}$$

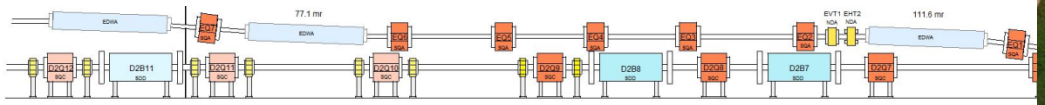


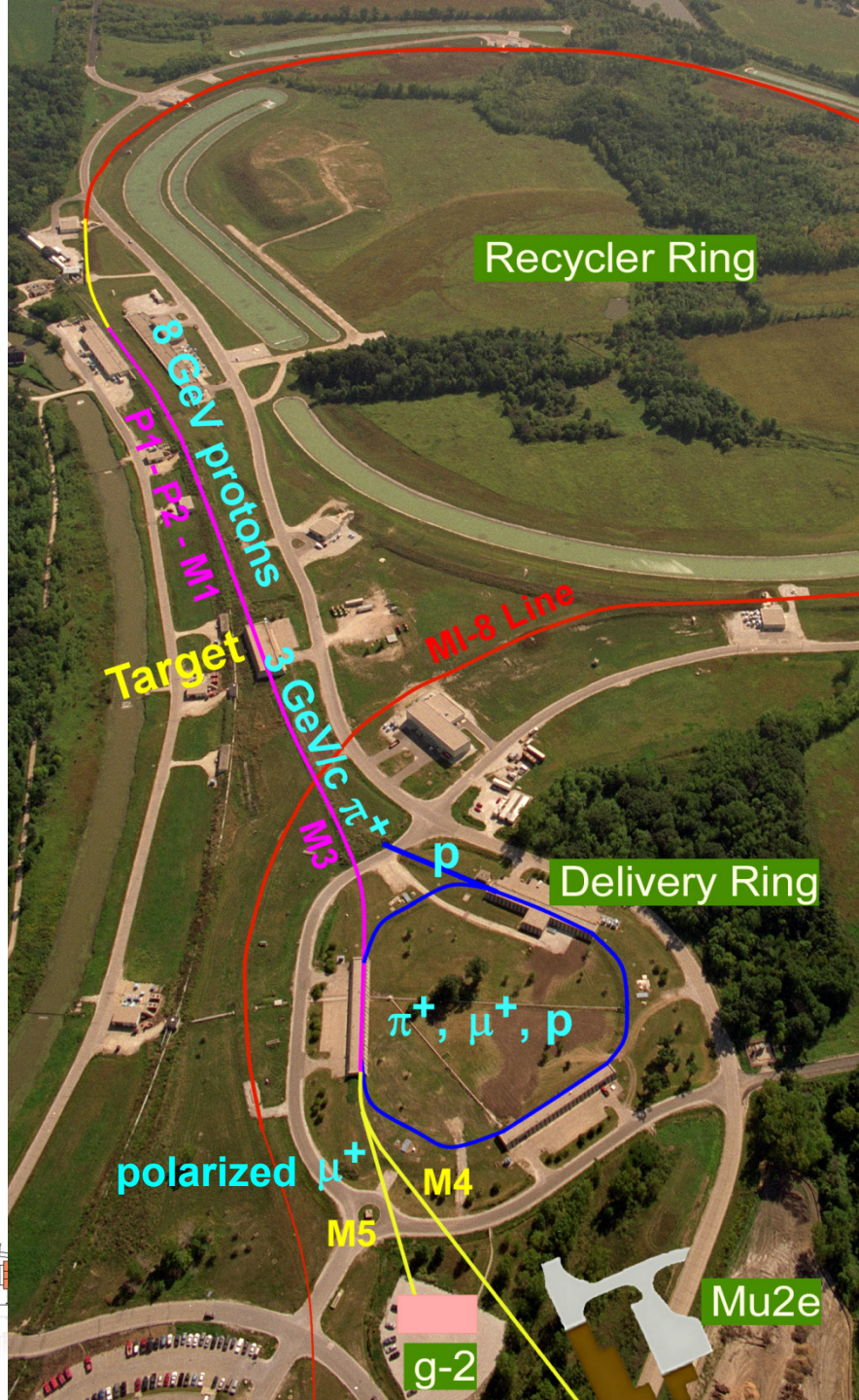




The Muon Beam

- 8 GeV protons from the Recycler Ring are targeted on the former Antiproton production target at AP0 producing many pions
- The beamlines downstream of the target transport 3.1 GeV/c secondaries. The muon beam is derived from the decay of the pions in this secondary beam
- 97% of these muons will be polarized along the momentum vector of the muon (this is a very fortuitous consequence of the V-A nature of pion weak decay)
- The secondary beam circulates in the Delivery Ring for ~4 turns (6.8μs) – pions decay, protons slip in time relative to μ^+ beam.
- Protons aborted prior to extraction
- Polarized μ^+ beam extracted into M5 beamline to g-2 ring.





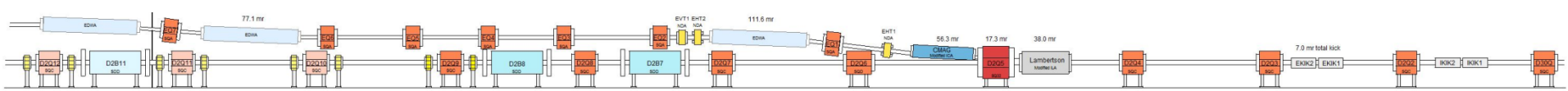
Why 3.1 GeV/c?

- Muon beam focusing in the g-2 ring is accomplished by electrostatic quadrupoles. The electric field from these quadrupoles affects the muon spin precession frequency:

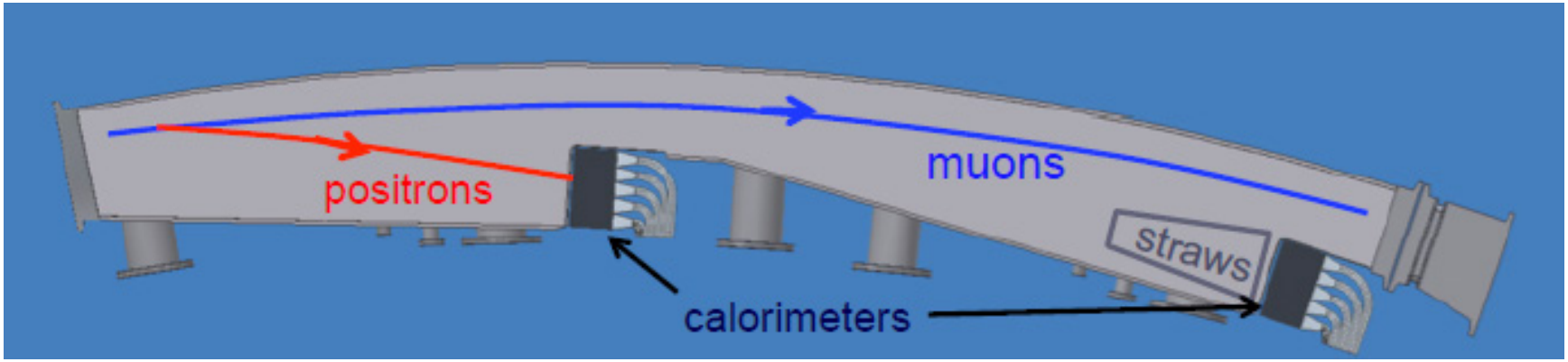
$$\boldsymbol{\omega}_{\mathbf{a}} = \frac{e}{m_\mu}\left[a_\mu \mathbf{B} - \cancel{\left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\boldsymbol{\beta}\times\mathbf{E}}\right]$$

- Choosing $\gamma = 29.3$ ($p = 3.09$ GeV/c) nulls out the $\boldsymbol{\beta}\times\mathbf{E}$ term

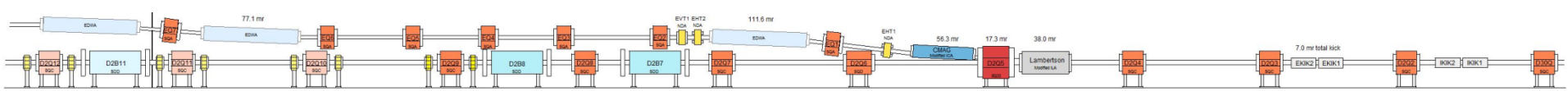
note: $a_\mu = 0.0011659$



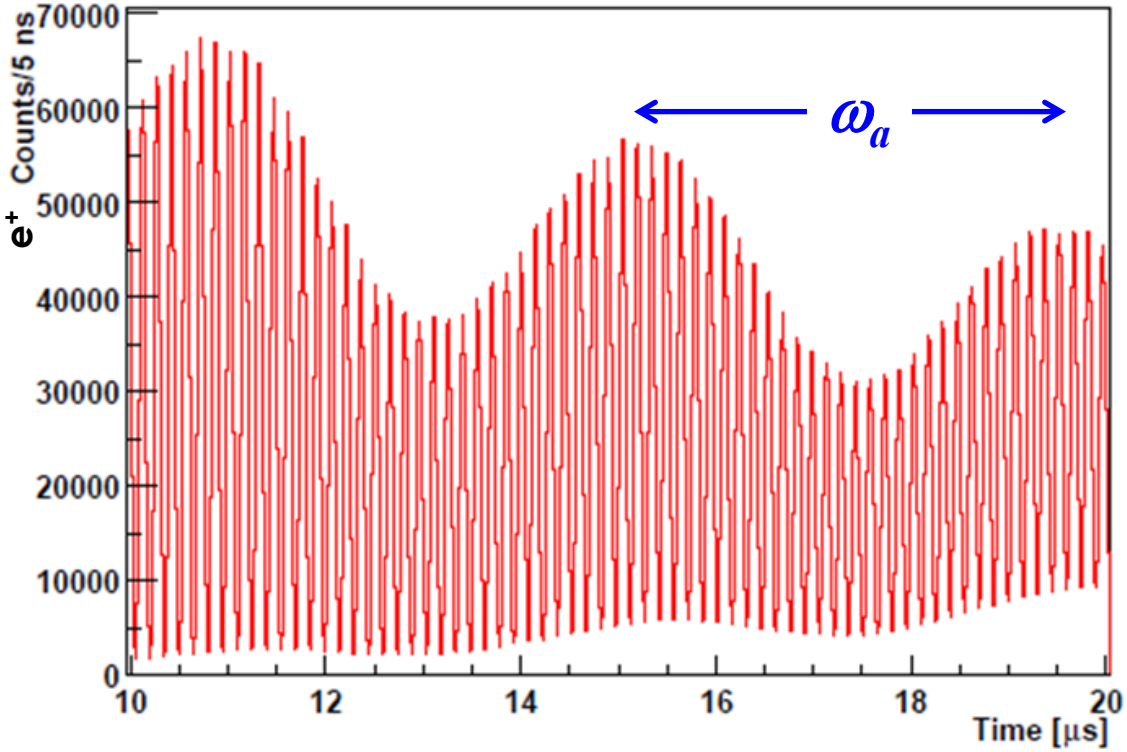
Measuring ω_a



- The muons circulating in the muon storage ring decay with a 2.2 μs half life. $\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$
- 24 detector stations situated around the inside of the muon storage ring detect the decay positrons.
- The direction of the resulting positron correlated with the direction of the muon spin – Therefore, the number of positrons counted in each detector is modulated at frequency ω_a.



Measuring ω_a



e^+ counts at a single detector station vs. time after injection into the muon ring.

Bennett et.al Phys. Rev. D73 (2006)

The raw data has two frequency components:

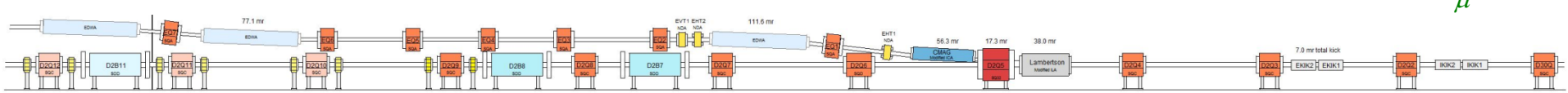
- Muon spin precession frequency, ω_s
- Cyclotron frequency, ω_c

The beat frequency is the difference $\omega_a = \omega_s - \omega_c$

which is proportional to the desired result

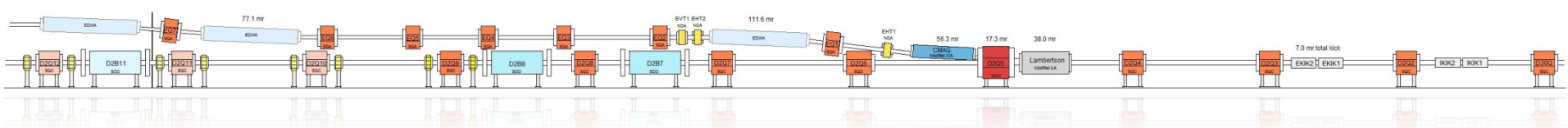
$$\omega_a = a_\mu \frac{eB}{m_\mu c}$$

The precise value of the magnetic field in the muon storage ring is also essential to the determination of a_μ.



The Mu2e Experiment

- What it measures
- Why it matters
- How it measures it

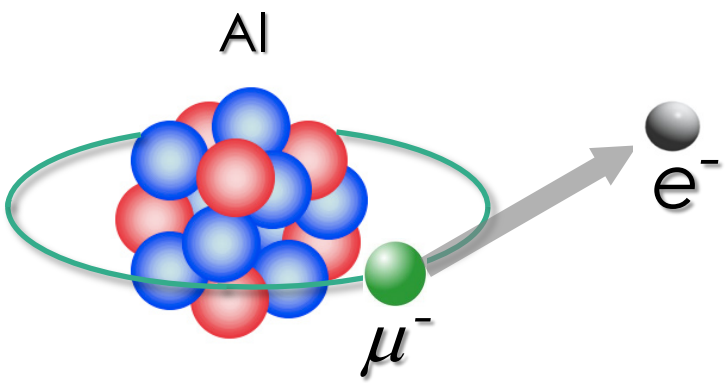


Charged Lepton Flavor Violation

- The Mu2e experiment endeavors to detect Charged Lepton Flavor Violation (CLFV)

- What is CLFV?

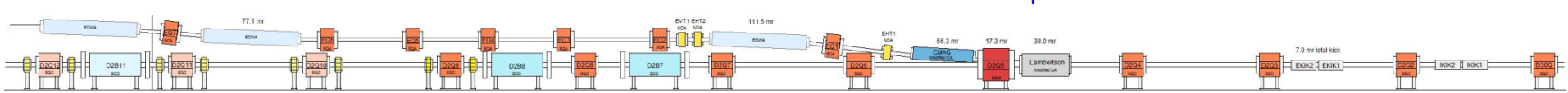
  CLFV is a process involving charged leptons (e, μ, τ) that violates the conservation of the number of leptons of each flavor



$$\mu^- N \rightarrow e^- N$$

L_μ:	1	0
L_e:	0	1

Both L_μ and L_e are not conserved in this process



Muon Decay

Ordinary muon decay conserves lepton flavor and total lepton number:

$$\mu^- \rightarrow e^- \; \bar{\nu}_e \; \nu_\mu$$

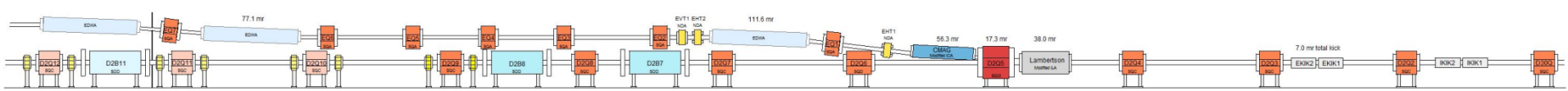
L_μ:	1	0	0	1
L_e:	0	1	-1	0

Mu2e is looking for a neutrinoless final state.

Lepton Number initial and final state values are Equal

L_μ = 1 *Muon number conserved*

L_e = 0 *Electron number conserved*

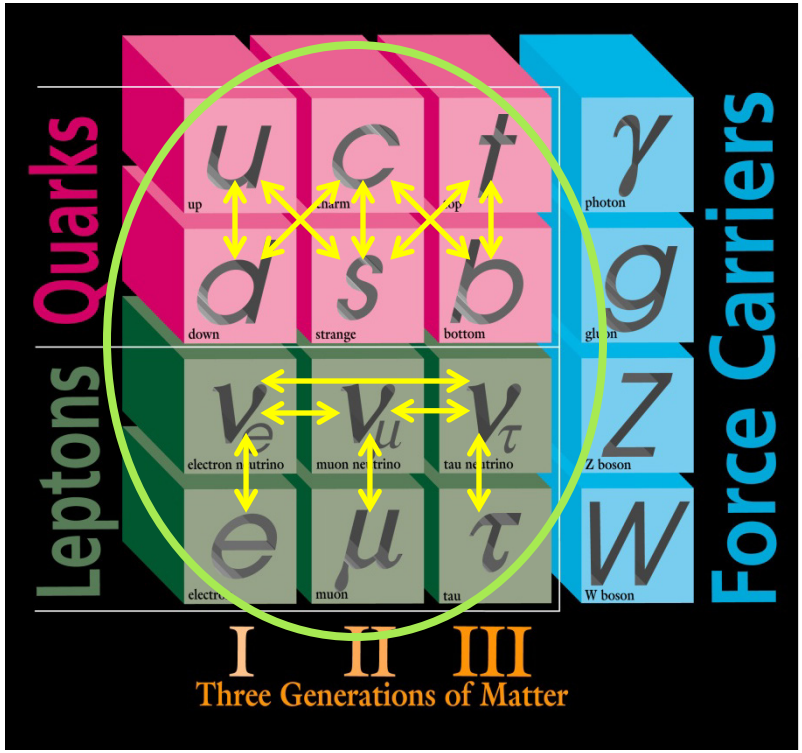


Flavor Changing Processes

A large variety of quark flavor changing processes have been observed and understood in terms of the Standard Model.

The CKM (Cabbibo-Kobayashi-Maskawa) matrix gives the quark flavor couplings:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

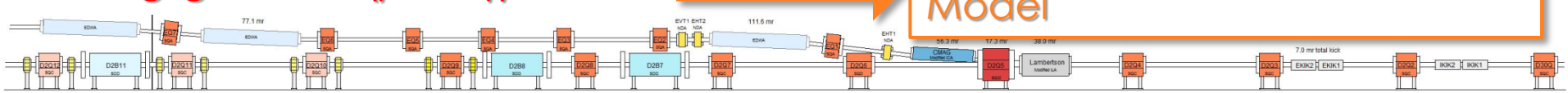


Lepton sector flavor changing processes observed to be more limited

- Weak decay: $\ell^{\pm} \rightarrow W^{\pm}\, \nu$
- Neutrino Oscillations

NOTE: The Standard Model does predict $e \leftrightarrow \mu \leftrightarrow \tau$ mixing, but the rates are negligible. $BR(\mu \rightarrow e\,\gamma) \lesssim 10^{-54}$

Any detection of $\mu^- \rightarrow e^-$ is an unambiguous indication of physics beyond the Standard Model



What Mu2e Measures

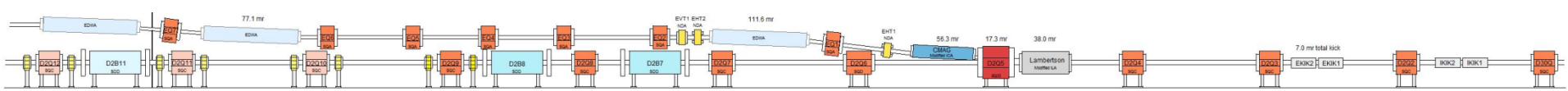
The Mu2e experiment will measure the ratio of the number muon captures in aluminum that produce a conversion electron to the number of those that are captured in the ordinary way. This ratio is called "$R_{\mu e}$"

$$R_{\mu e} = \frac{\Gamma\left(\mu^- + (A,Z) \rightarrow e^- + (A,Z)\right)}{\Gamma\left(\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)\right)}$$

Rate of $\mu \rightarrow e$ conversion

Rate of μ capture and beta-decay

The goal of Mu2e is to measure $R_{\mu e}$ with a single event sensitivity of 2.87×10^{-17}



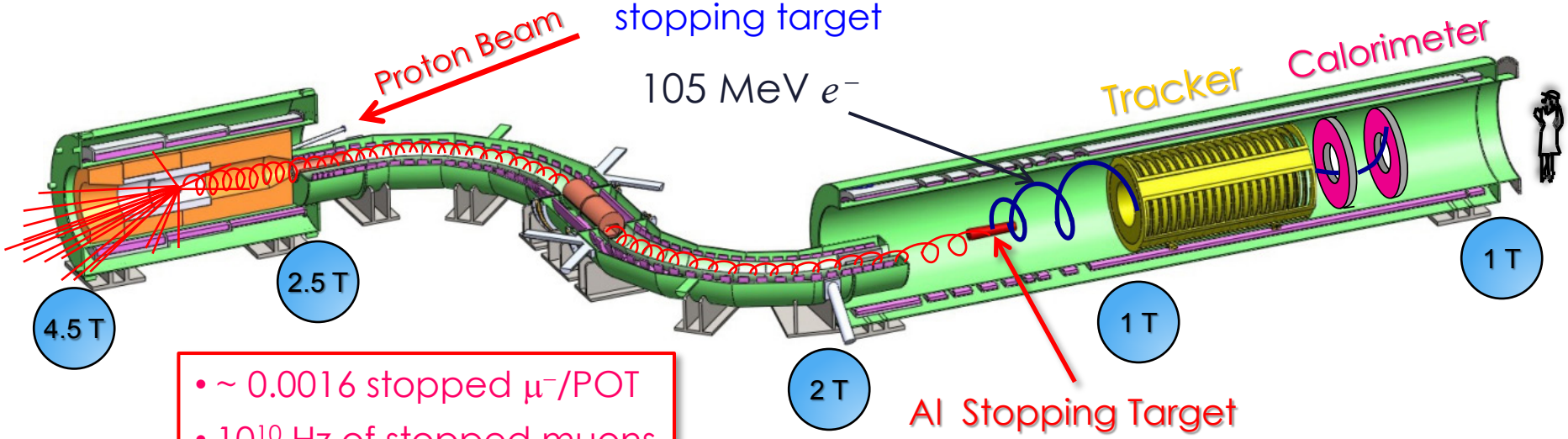
Mu2e Apparatus

The Mu2e apparatus consists of three superconducting solenoids joined together to make a continuous whole

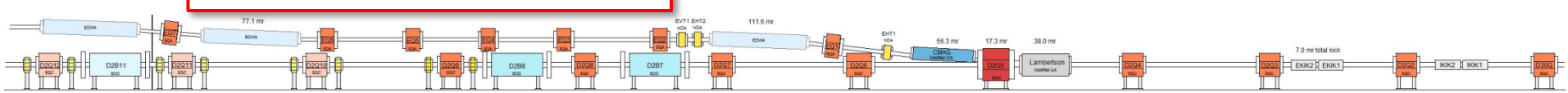
Production Solenoid
- Contains proton target
- Magnetic mirror – reflects secondaries back toward transport solenoid

Transport Solenoid
- Collimation
- Momentum and charge selection
- Transport to stopping target

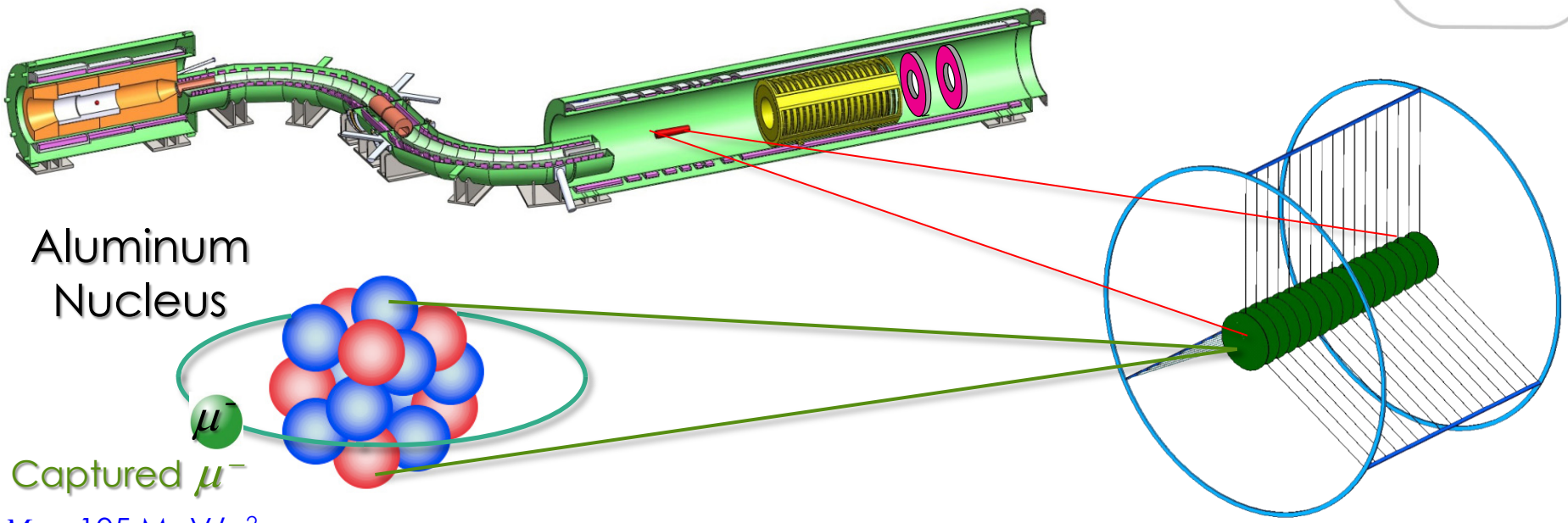
Detector Solenoid
- Contains stopping target
- Tracker (straws)
- Calorimeter (BaF_2 crystals)



- ~ 0.0016 stopped μ^-/POT
- 10^{10} Hz of stopped muons



Stopping Muons



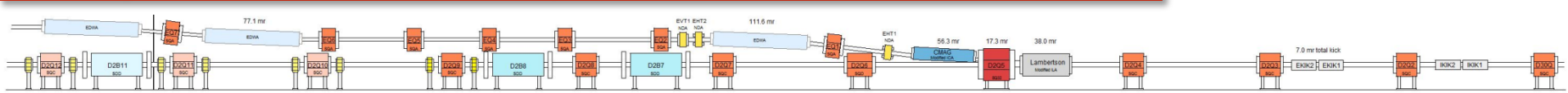
M_μ = 105 MeV/c^2

- A muon that is stopped in the Mu2e target is captured into an atomic orbital state of an aluminum nucleus
- The muon quickly (≲ psec) radiates photons (x-rays*) and drops to the 1S state where its wave-function overlaps the nucleus

* A target monitor counts these x-rays

Mu2e muon stopping target

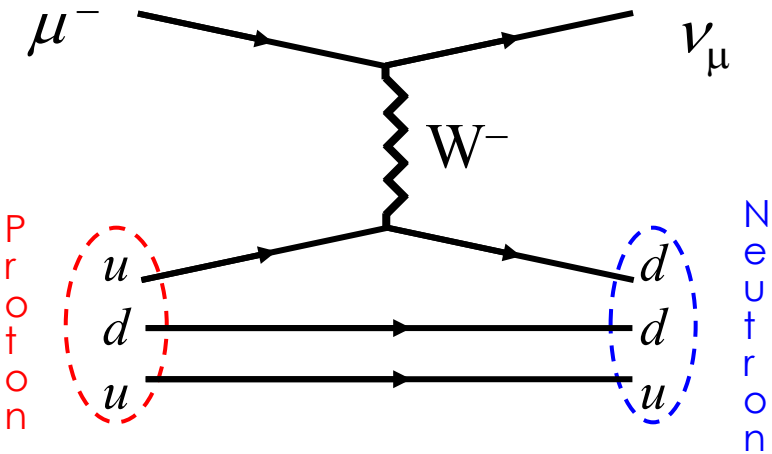
- 17 Al 200 μm foil disks
- Disk radii decrease from 83 mm to 65 mm in downstream direction



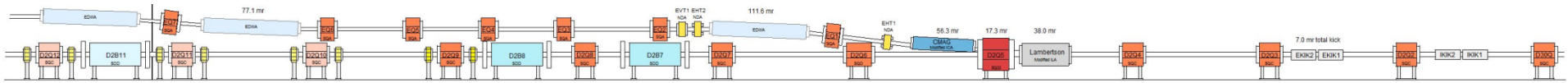
Muon Interactions with Matter

Once in the 1S state, the muon does one of three things:

1. Nuclear capture:
   μ^- N(A, Z) $\rightarrow$ ν_μ N(A, Z–1)
   $\Rightarrow$ Normalization (denominator in $R_{\mu e}$)
2. Decay in orbit (DIO)
   $\mu^- \rightarrow e^- \ \bar{\nu}_e \ \nu_\mu$
   $\Rightarrow$ Background
3. Convert to an electron
   μ^-N$(A, Z) \rightarrow e^-$N(A, Z)
   $\Rightarrow$ Signal



Nuclear Capture of a μ^- by a proton in an Aluminum nucleus

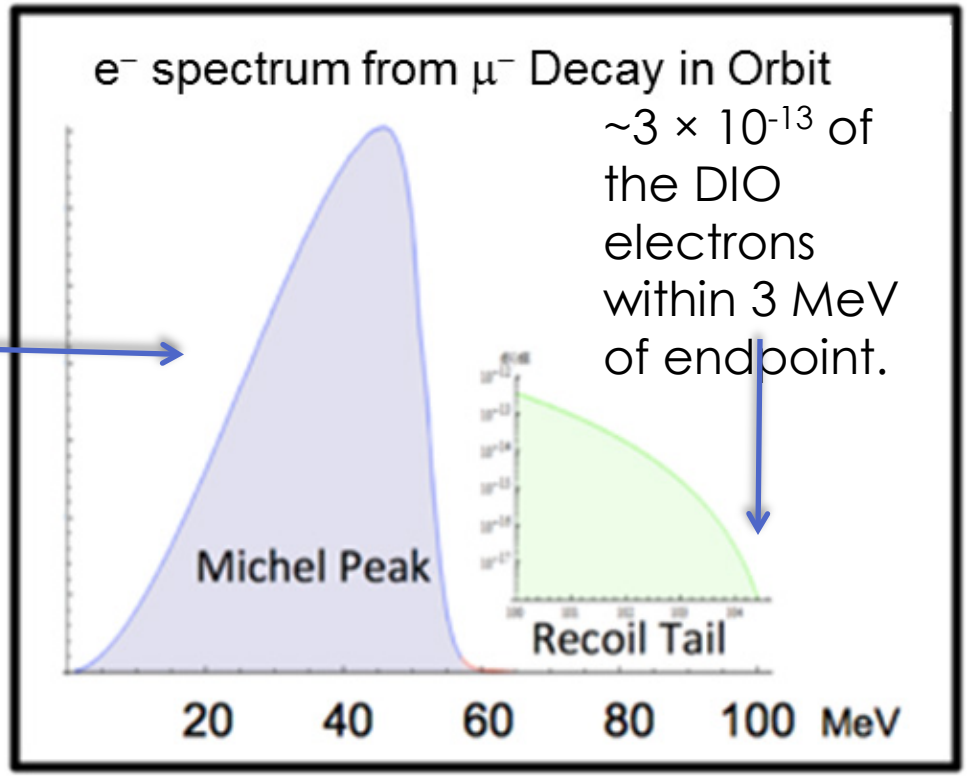


Reducing the Primary Background

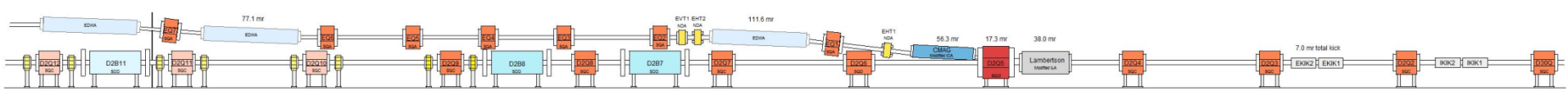
The primary background: electrons from muon DIO

$$\mu^- \rightarrow e^- \; \bar{\nu}_e \, \nu_\mu$$

- electron energy is given by the Michel spectrum
- can produce a very small number of electrons with energy very close to 105 MeV

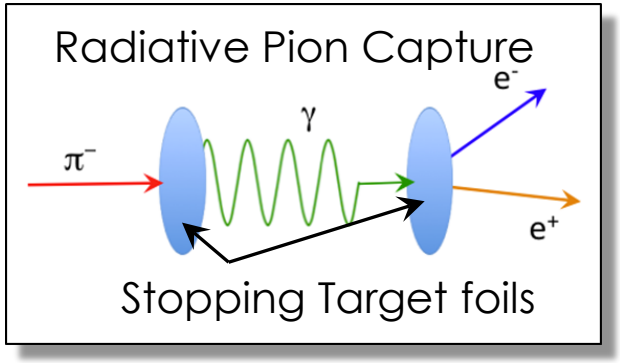


This background is reduced by a detector (the Mu2e Calorimeter) with very good energy resolution ~120 keV out of 105 MeV (0.1%).



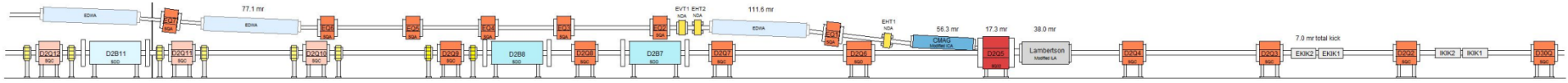
Other Processes that Produce 105 MeV electrons

- Radiative Pion Capture (RPC)
  - POT → π^-
  - π^- survives long enough to get to stopping target
  - π^- capture into pionic atom
  - $\pi^- + Al \rightarrow \gamma + Mg$
    ↳ $e^+ e^-$
  - this process can produce a 105 MeV electron that would be indistinguishable from a conversion electron



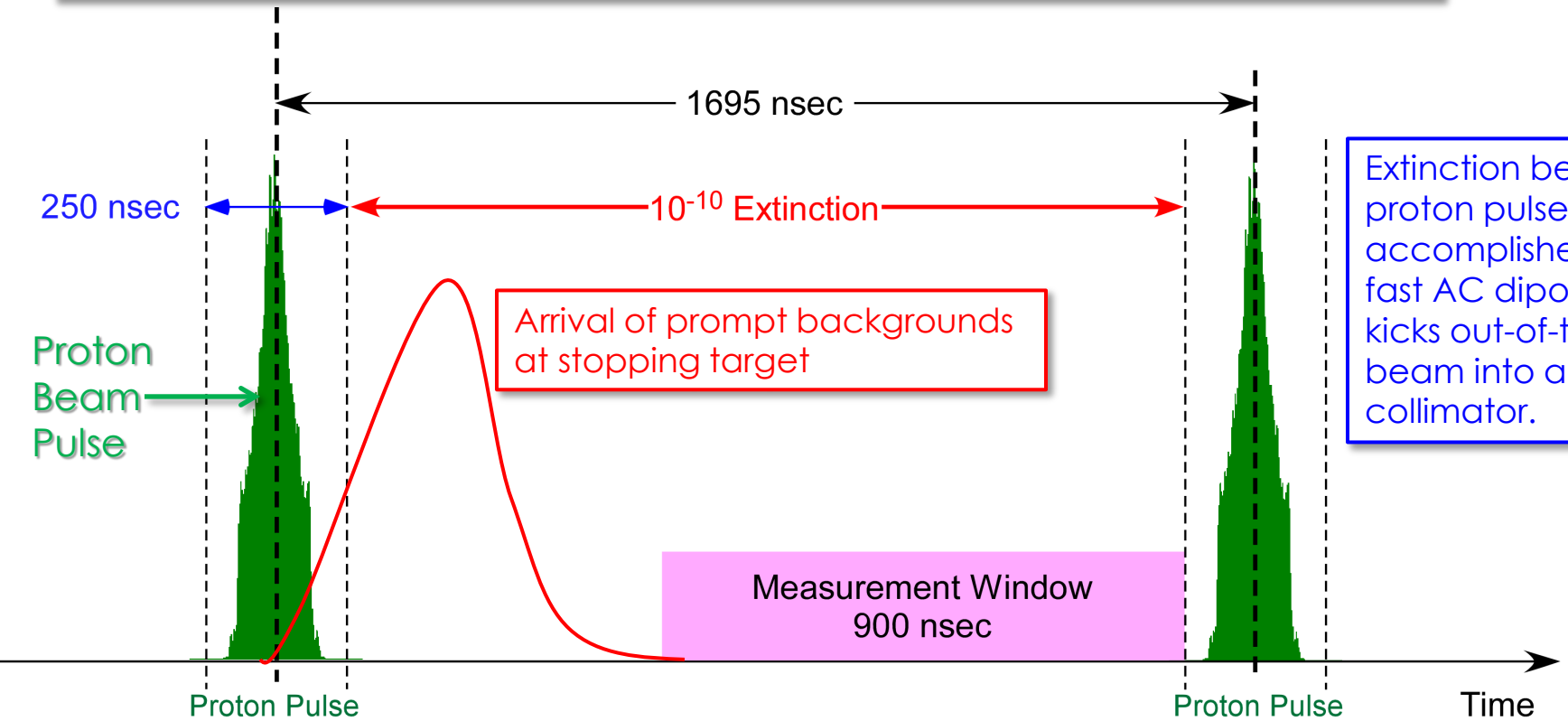
- In-flight muon decay
  - POT → $\pi^- \rightarrow \bar{\nu}_\mu \mu^-$ (>77 MeV/c),
  - $\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$ → ~105 MeV electron
- In-flight pion decays in the Detector Solenoid
  - POT → $\pi^- \rightarrow e^- \bar{\nu}_e$ → ~105 MeV electron
- High energy electrons
  - POT → $\pi^0 \rightarrow \gamma\gamma$ → electrons (formed in PS and transported to DS)

These processes have one thing in common: <u>they are prompt</u> – they happen very soon after any hits the proton target

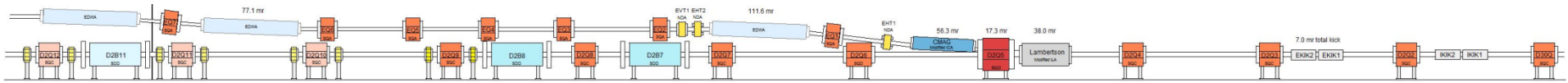


Reducing Prompt Backgrounds

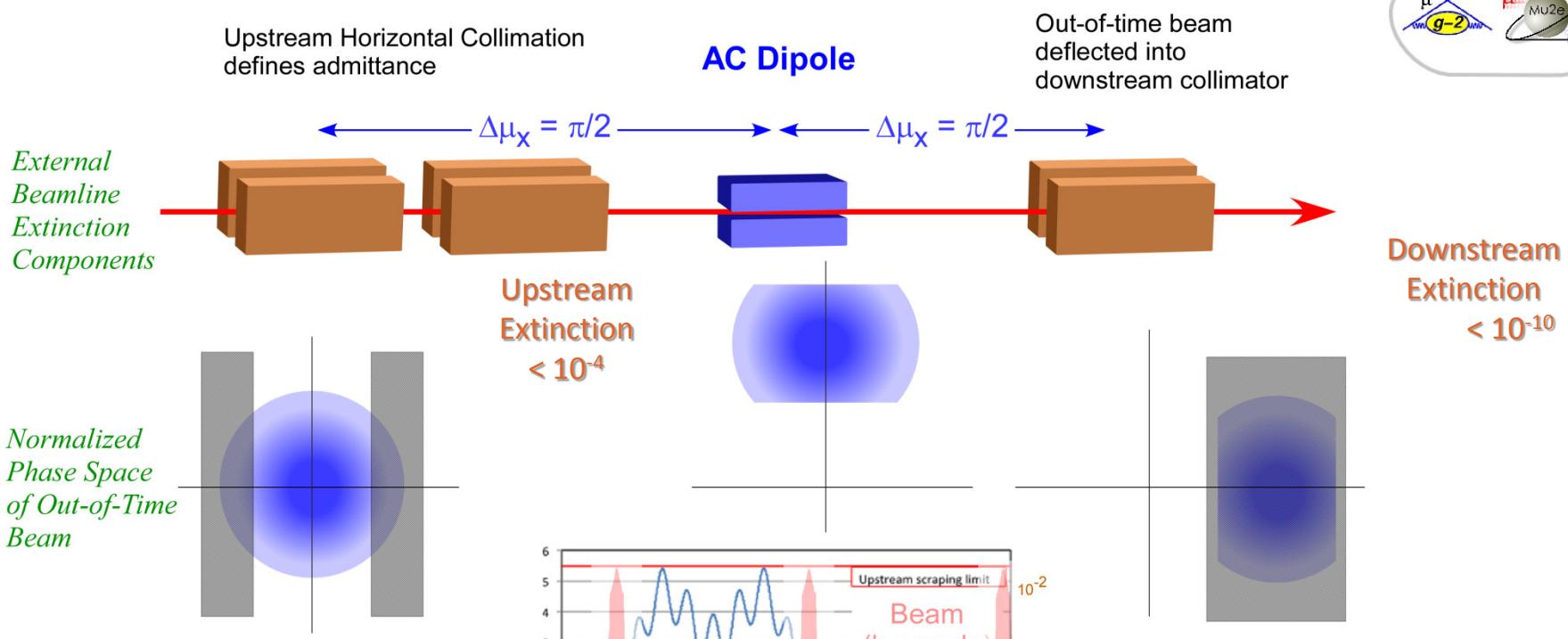
Pulsed beam, a long delayed search window, and extinction of beam between pulses reduces prompt backgrounds.

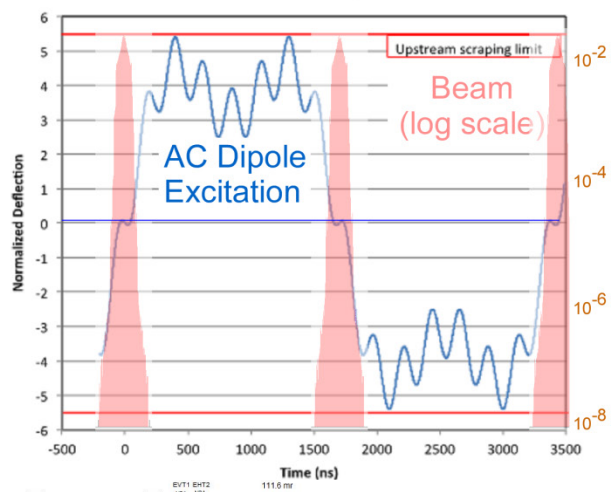


Extinction between proton pulses is accomplished by a fast AC dipole that kicks out-of-time beam into a collimator.



Out-of-time Beam Extinction



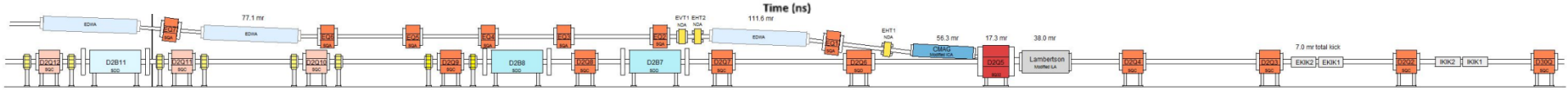


Proton beam pulses shown in pink.

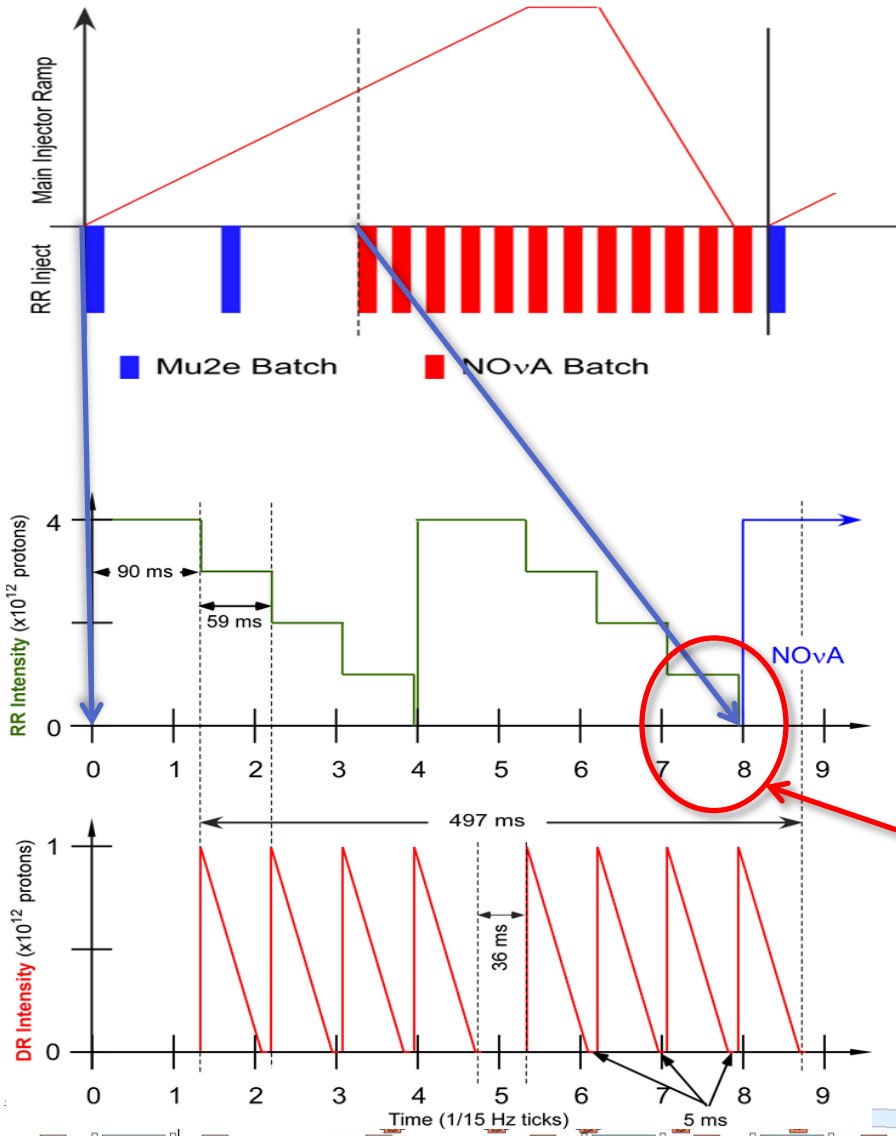
AC Dipole waveform shown in **blue**

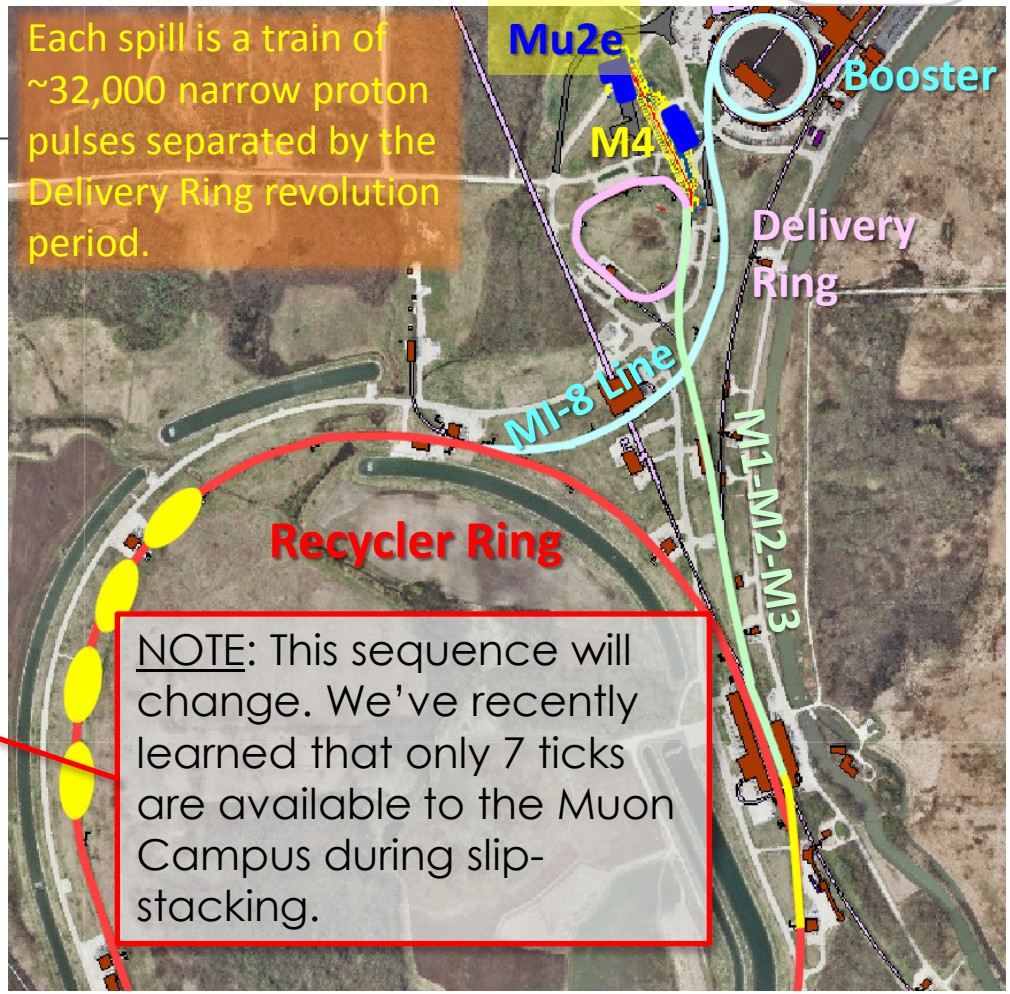
AC Dipole Excitation

The AC Dipole excitation is a superposition of three harmonics: 300 kHz, 900 kHz, and 4.5 MHz.

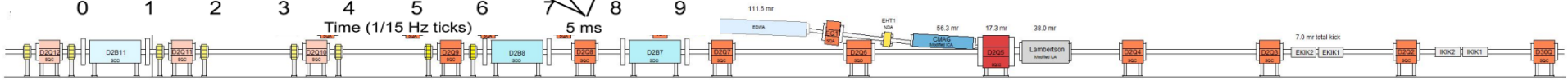


Proton Beam Delivery to Mu2e





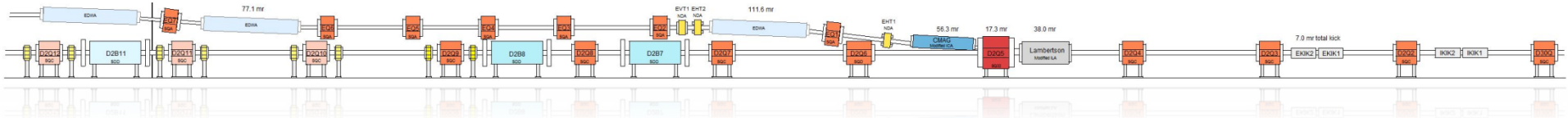
NOTE: This sequence will change. We've recently learned that only 7 ticks are available to the Muon Campus during slip-stacking.



THE PROJECTS

DOE Order 413.3b Projects

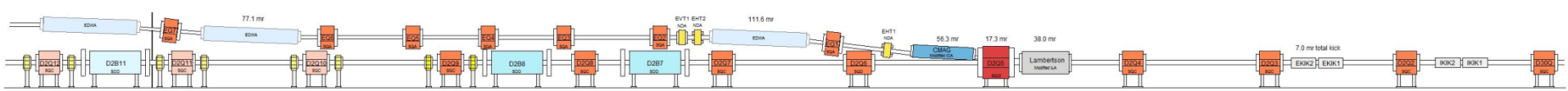
AIPs & GPPs



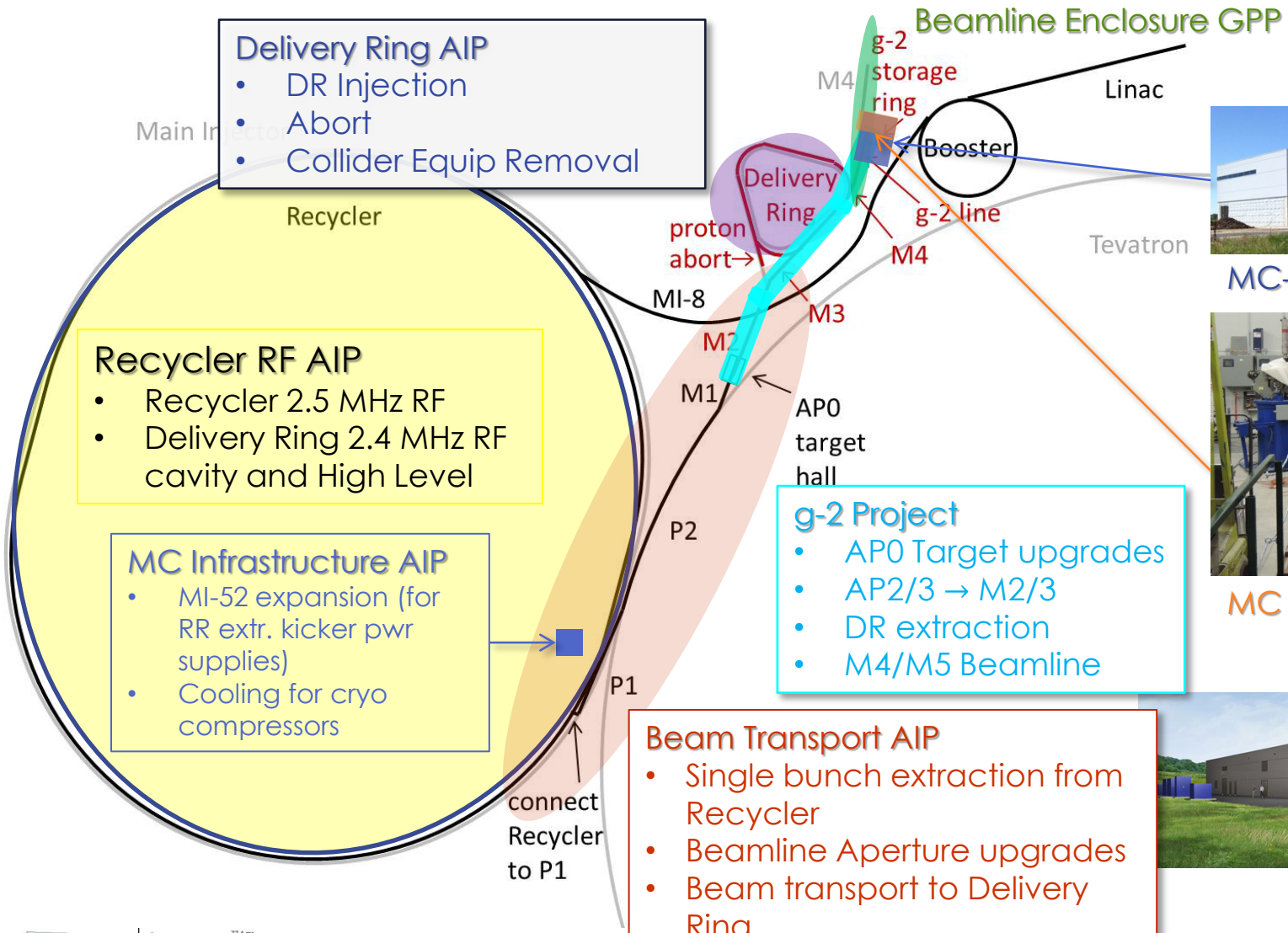
413 Projects, AIPs, GPPs

Building the Muon Campus requires the following projects:

1. DOE 413 Projects
   - Muon g-2
   - Mu2e
2. AIPs (Accelerator Improvement Projects)
   - Recycler RF
   - Beam Transport
   - MC Cryo Plant
   - Delivery Ring
3. GPPs (General Plant Projects)
   - MC-1 Building
   - Beamline Enclosure
   - MC Infrastructure Upgrade



Scope of Muon Campus Projects



Delivery Ring AIP
- DR Injection
- Abort
- Collider Equip Removal

Recycler RF AIP
- Recycler 2.5 MHz RF
- Delivery Ring 2.4 MHz RF cavity and High Level

MC Infrastructure AIP
- MI-52 expansion (for RR extr. kicker pwr supplies)
- Cooling for cryo compressors

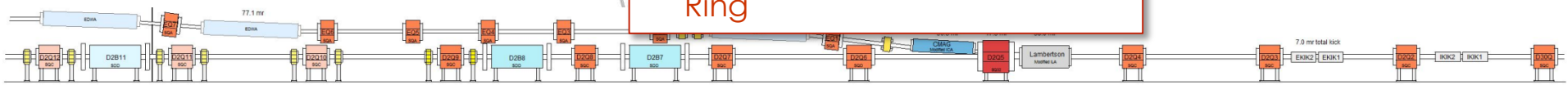
g-2 Project
- AP0 Target upgrades
- AP2/3 → M2/3
- DR extraction
- M4/M5 Beamline

Beam Transport AIP
- Single bunch extraction from Recycler
- Beamline Aperture upgrades
- Beam transport to Delivery Ring

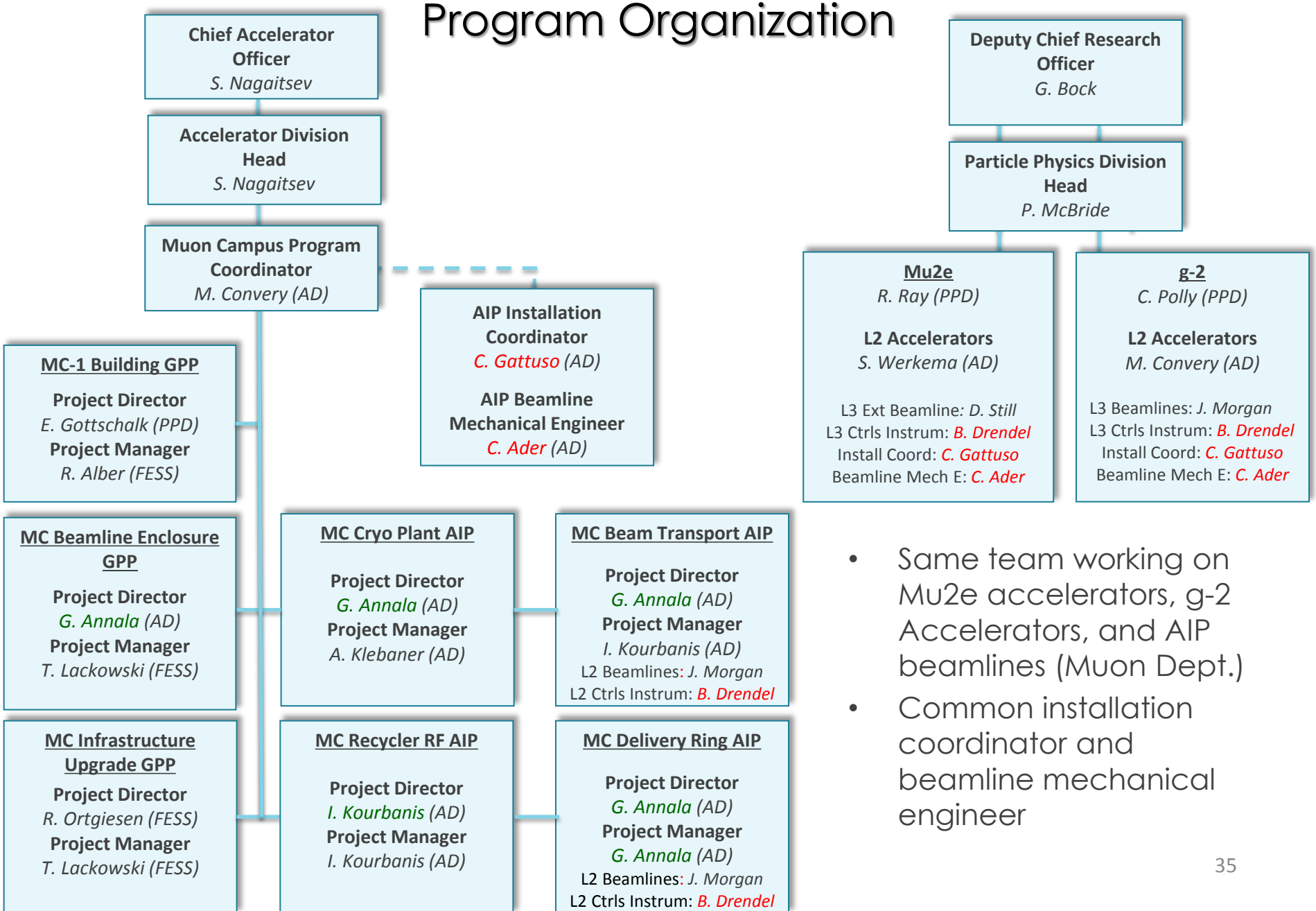
MC-1 Building GPP

MC Cryo AIP

Mu2e



Muon Campus Program Organization



- Same team working on Mu2e accelerators, g-2 Accelerators, and AIP beamlines (Muon Dept.)
- Common installation coordinator and beamline mechanical engineer

Why Would We Do This to Ourselves?

Advantages

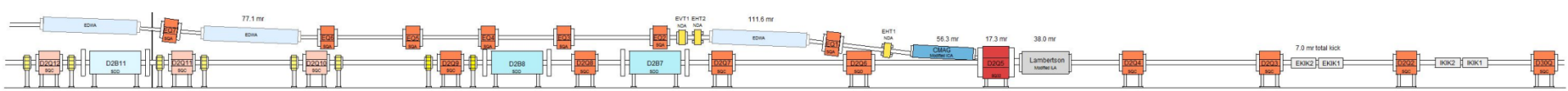
- Exploits the common requirements of Mu2e and g-2. Integrated planning to meet these requirements reduces the combined cost of these two projects
- Scheduling: moving scope that must be accomplished early to AIPs allows implementation to begin before CD-3 for either project –
  - Muon Campus construction is underway now and neither Mu2e or g-2 have CD-3.
  - Without this scheduling flexibility the g-2 run would start later (1 – 2 years) which would delay the start of the Mu2e run

Why many AIPs?

- Collect common scope
- Keep AIP and GPP TPCs below the $10M maximum

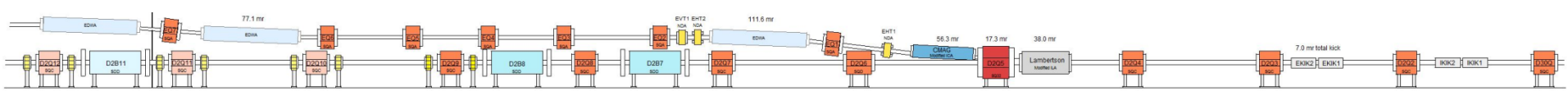
Risk

- Complicated interdependence … a setback in one project may affect the others



THE G-2 PROJECT

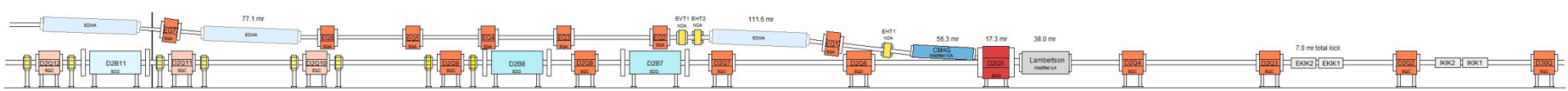
- Scope
- Accelerator Upgrades
- Status



Muon g-2 Scope (Level 2 Sub-projects)

1. **Project Management** – Chris Polly (PPD)
2. **Accelerator upgrades** – Mary Convery (AD/Muon)
3. **Muon Storage Ring** – Hogan Nguyen (PPD)
4. **Detectors** – Branden Casey (PPD)
5. **BNL E821 Equipment transfer** – Hogan Nguyen (FNAL PPD), Bill Morse (BNL)

I'll focus only on the g-2 Accelerator Upgrades



g-2 Accelerator Organization

476.2
Accelerator
M. Convery
(FNAL)

476.2.1
Project
Management
M. Convery
(FNAL)

476.2.2
Target Station
D. Still
(FNAL)

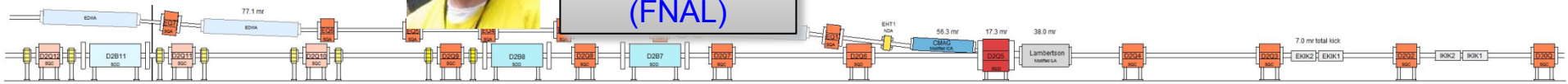
476.2.3
Beamlines
J. Morgan
(FNAL)

476.2.4
Controls &
Instrument.
B.Drendel
(FNAL)

Installation
Coordinator
C. Gattuso
(FNAL)

Beamline
Mechanical
Engineer
C. Ader
(FNAL)

Mary Convery



Muon g-2 Target Station

Reuse:

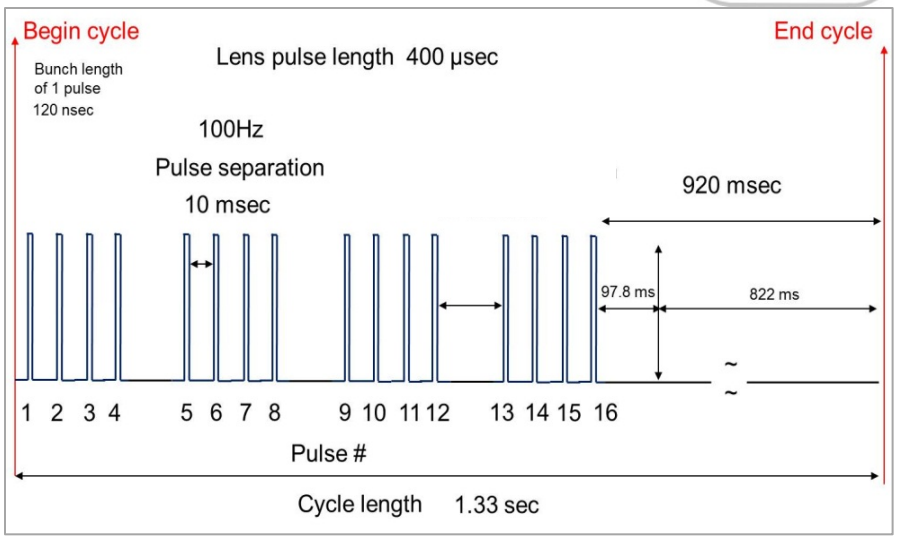
- Pbar target
- Li Lens
- Pulsed dipole magnet

New:

- Pulsed Power Supplies

Replace:

- Target dump

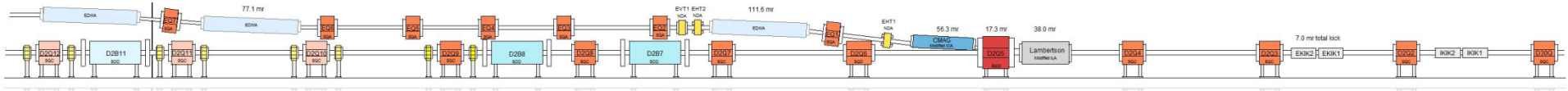


g-2 average 12Hz pulse scenario

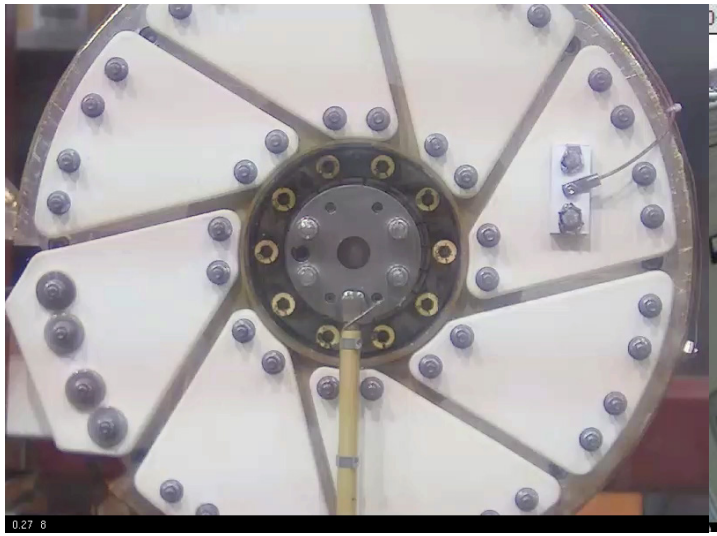
Significant repetition rate increase from Collider era:

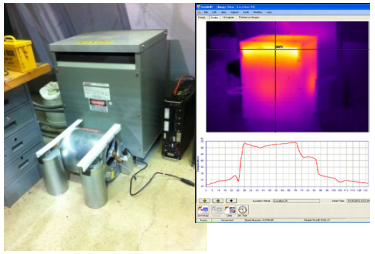
Collider Era rep. rate:
1/2.2 sec = 0.45 Hz

Muon g-2 rep. rates:
Average: 12 Hz (16 pulses/1.33s)
Peak: 100 Hz



Lens 12 Hz Pulse Testing

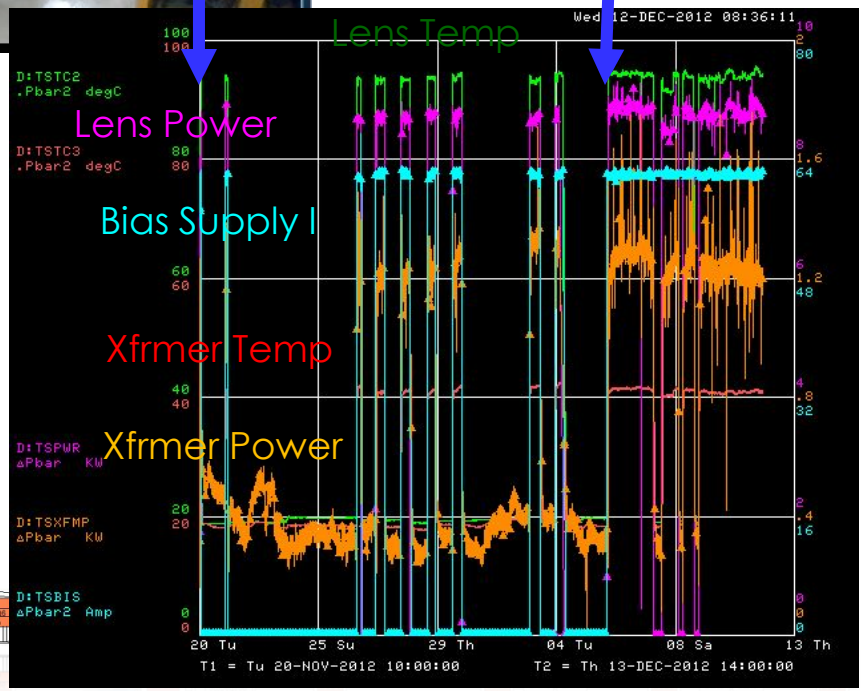




July 6, 2012 - Assess/modify firing circuit of Lens test power supply to run at 12Hz.

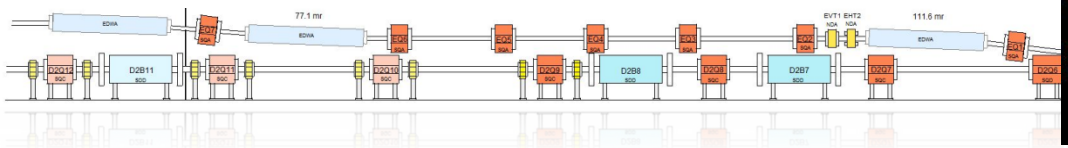
Nov 20,2012

Dec 6,2012

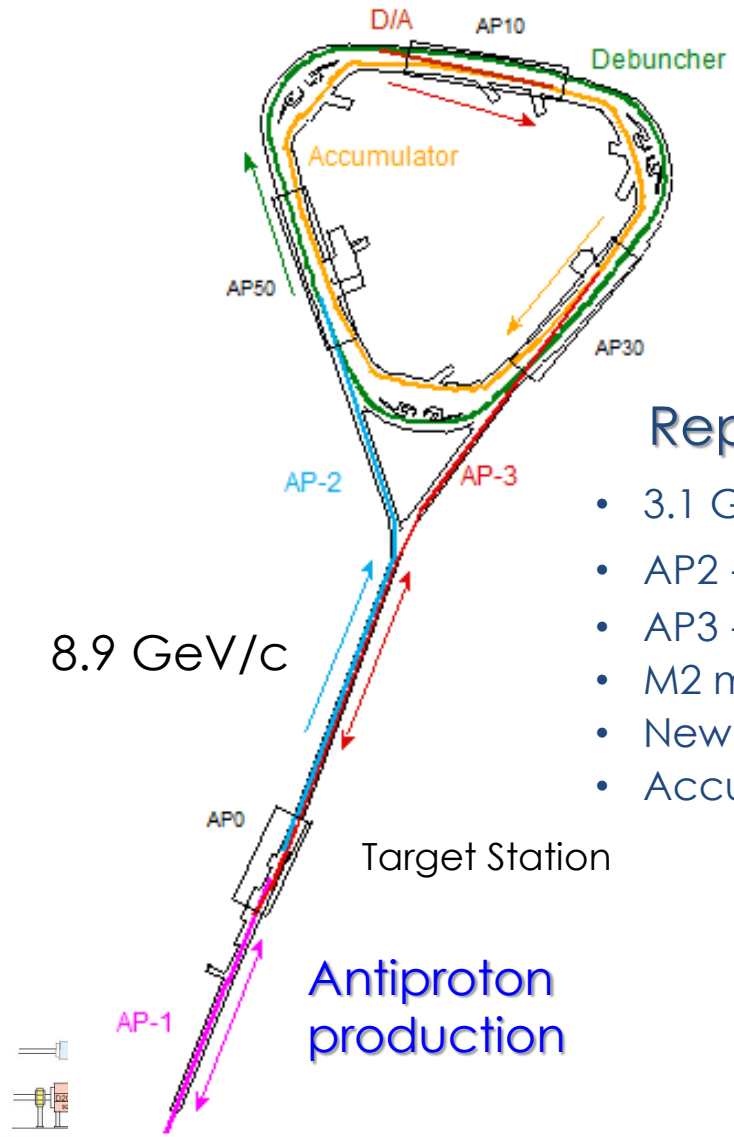


- On Nov 20, 2012 lens running at 12Hz at 19.25kA (g-2 operating current)
- Pulses to date = 80M at 19.25kA (155kA secondary peak) at 12Hz for 3 months without a lens problem!

Dean Still

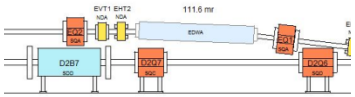


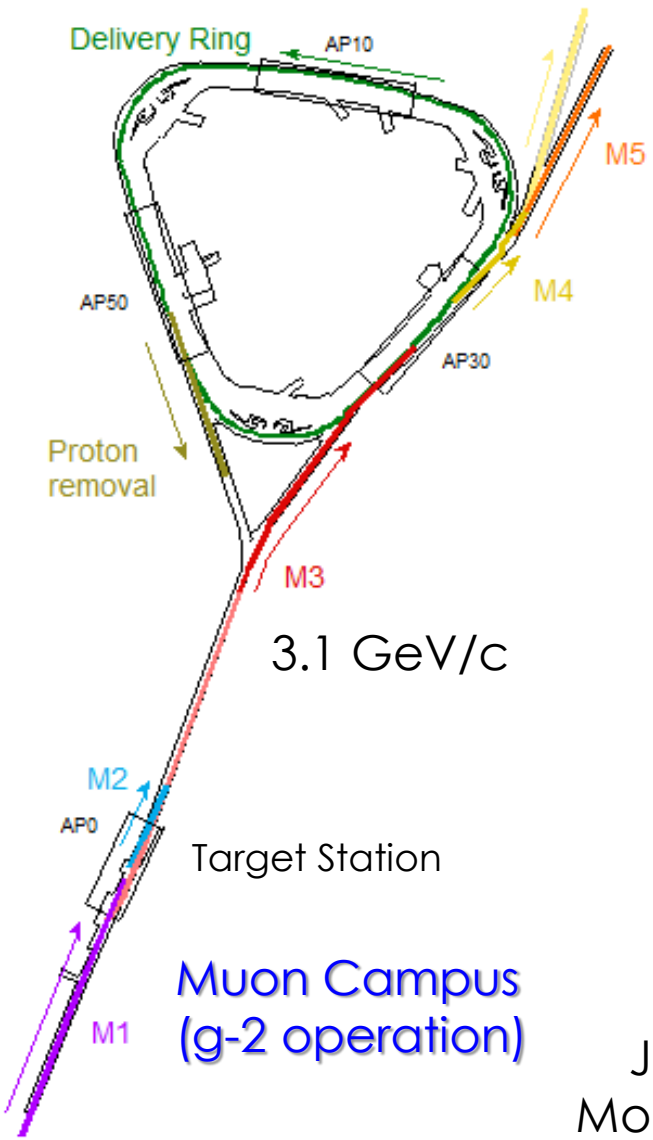
Muon Campus Beamline Overview



Repurposing Pbar

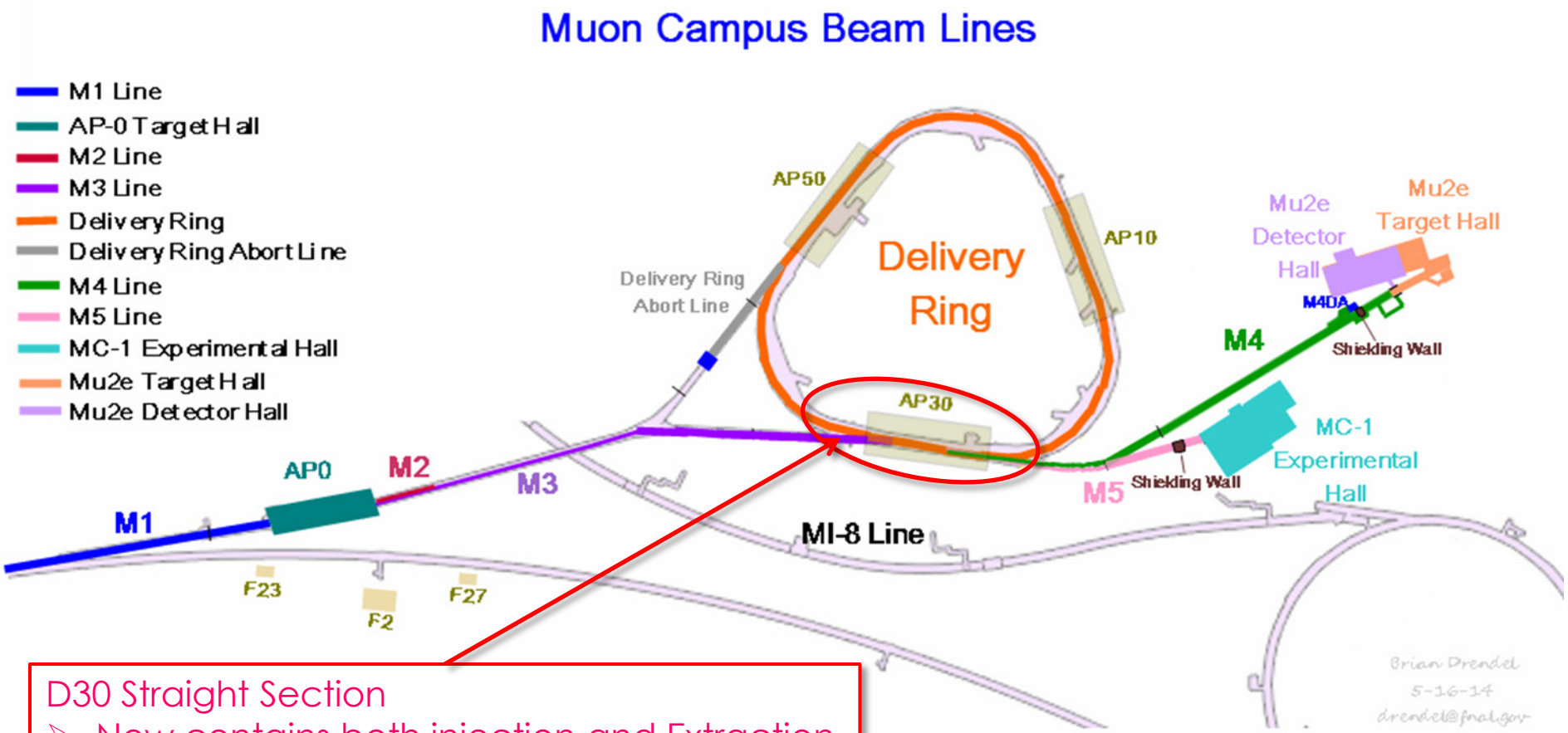
- 3.1 GeV/c secondaries
- AP2 → M2
- AP3 → M3
- M2 merges into M3
- New abort and dump
- Accumulator …





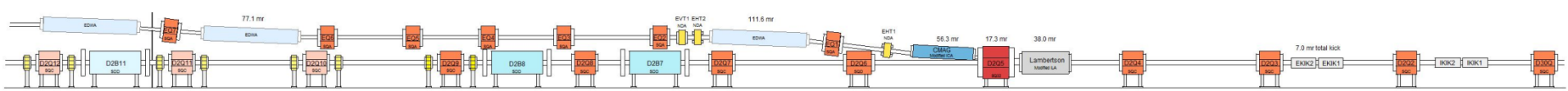
Jim Morgan

Muon Campus Beamline Overview



D30 Straight Section

- Now contains both injection and Extraction

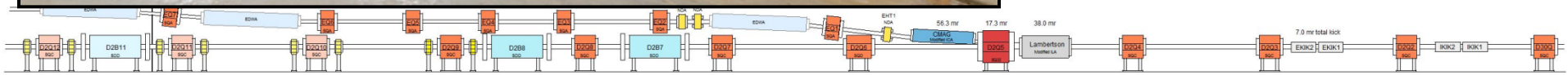


D30 Reconfiguration

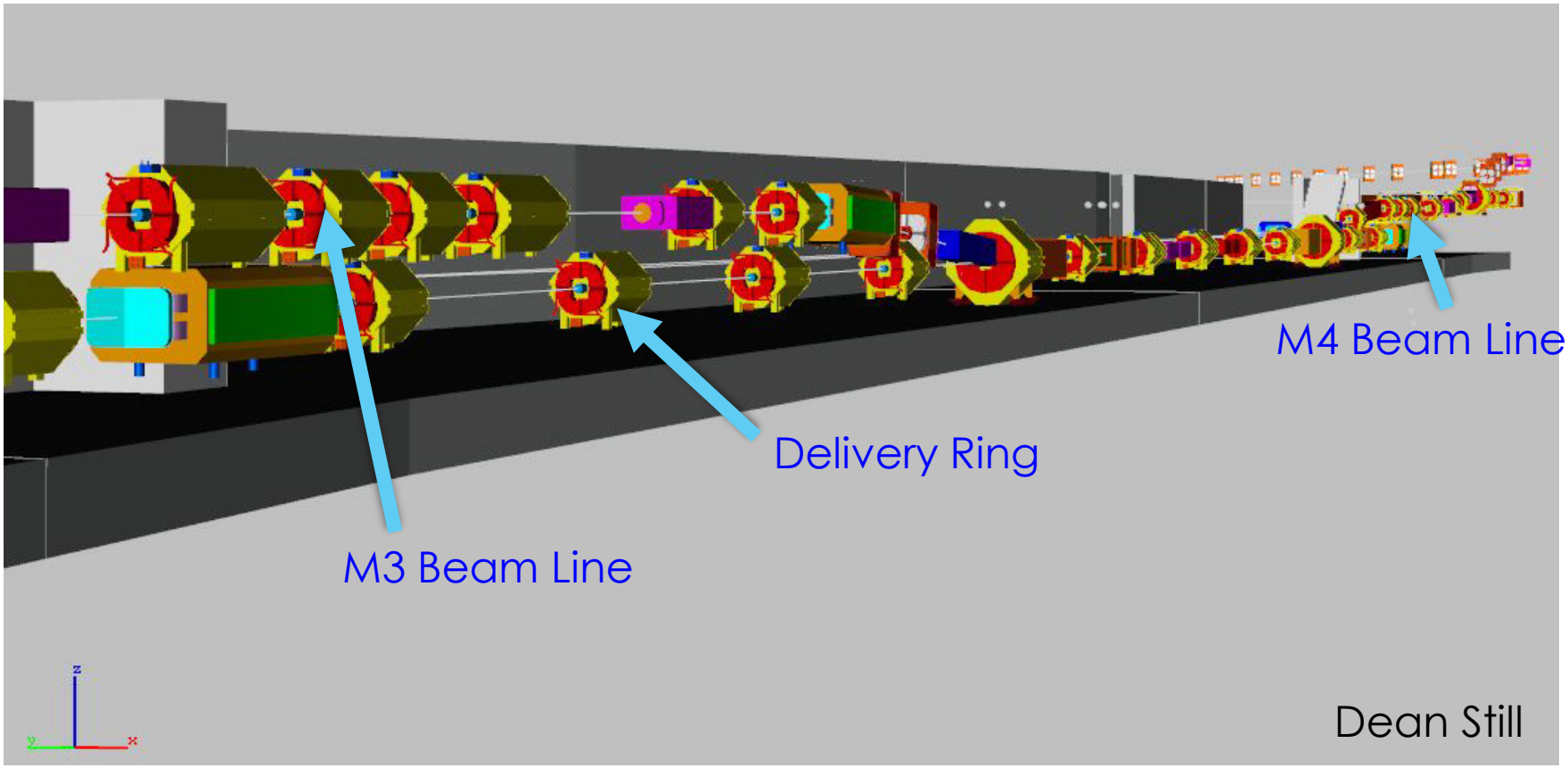
D30 Straight section reconfiguration

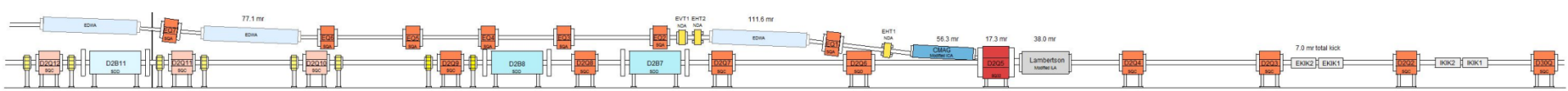
- Collider equipment permanently removed
- Reroute cable-trays, LCW plumbing, electrical bus work to accommodate new installation
- Complicated choreography of magnet movements

Dean Still

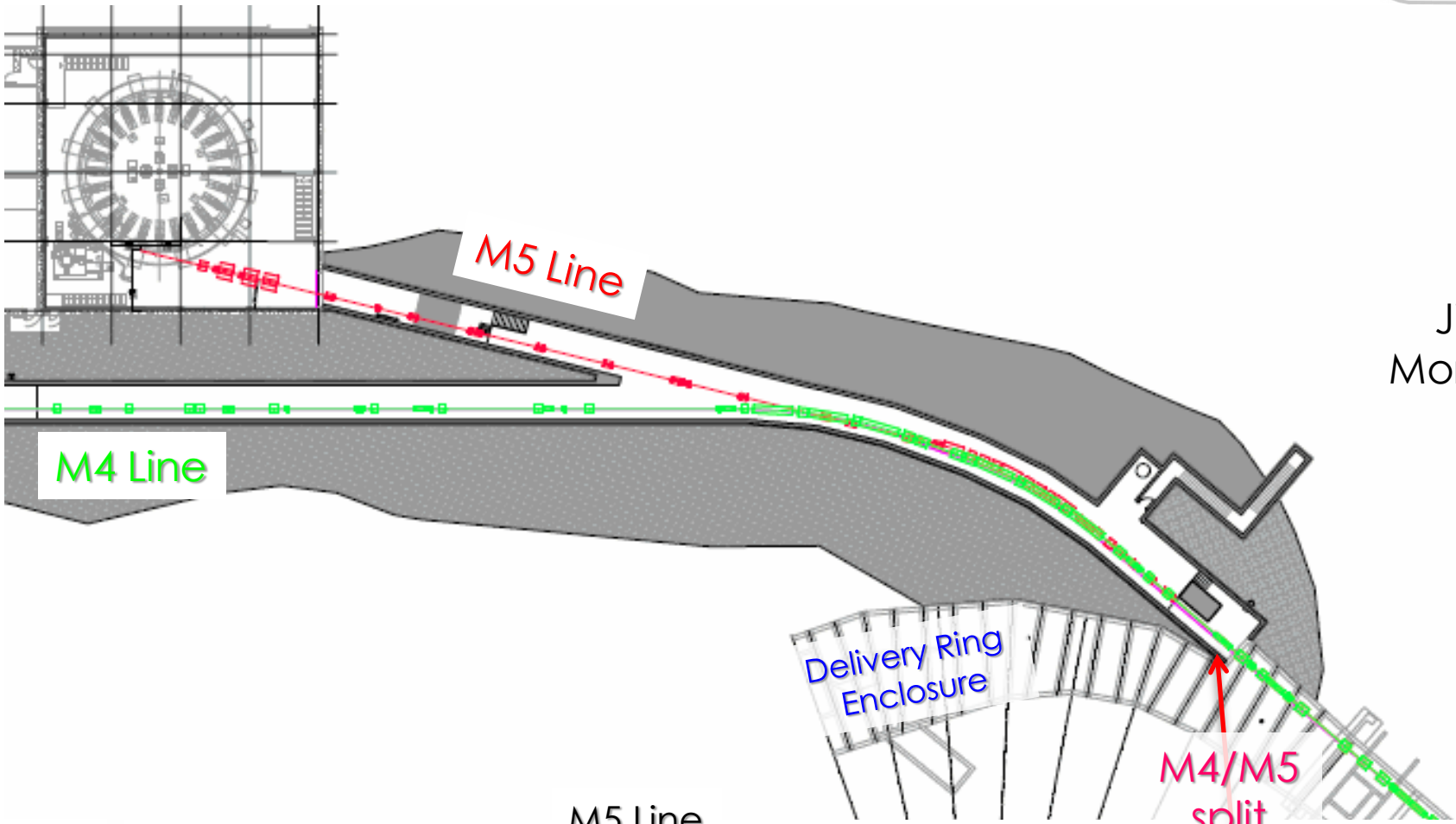


D30 Straight Section Reconfigured

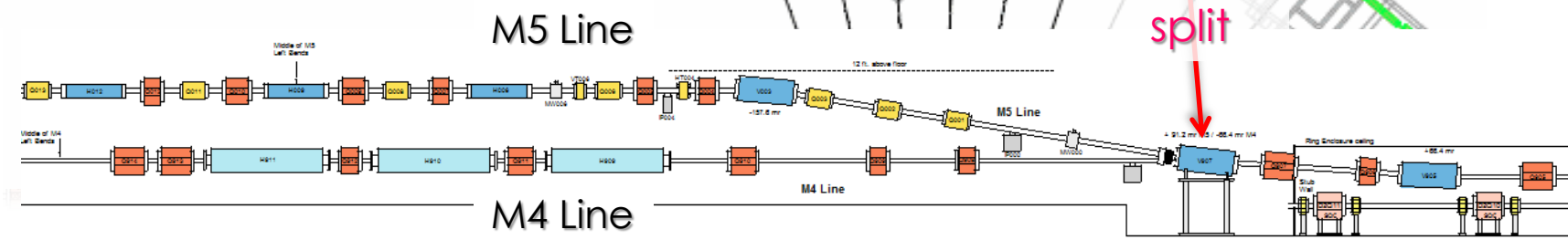




Beamline Design – M4&M5 Lines

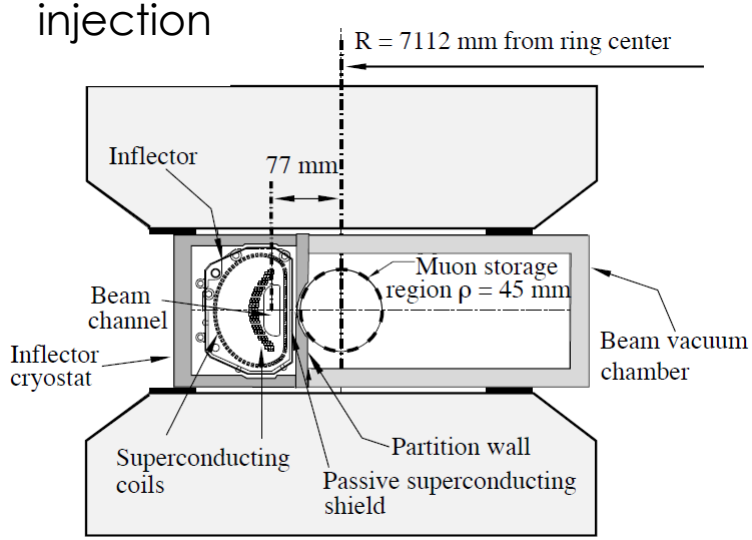


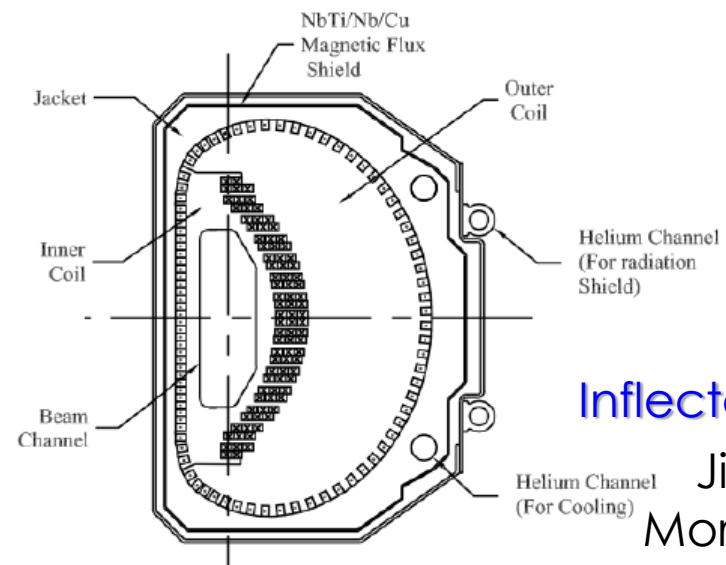
Jim
Morgan



Muon Ring Injection

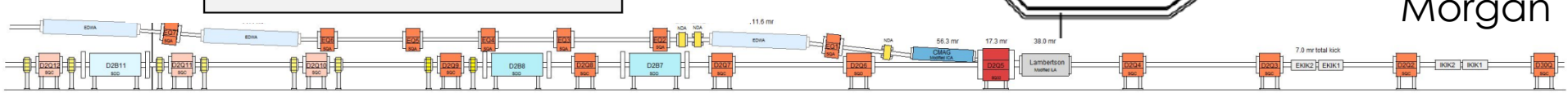
- Injection into g-2 Storage Ring occurs through an inflector
- An inflector is essentially a septum-like cryogenic magnet which cancels the main Storage Ring dipole field to allow tangential injection into the Ring
- Inflector is 1.72 m long
  - The Inflector crosses the fringe field creating a complicated field profile, trajectory and fringe field focusing effects
  - With only an 18 mm horizontal opening, the Inflector is the limiting aperture for injection





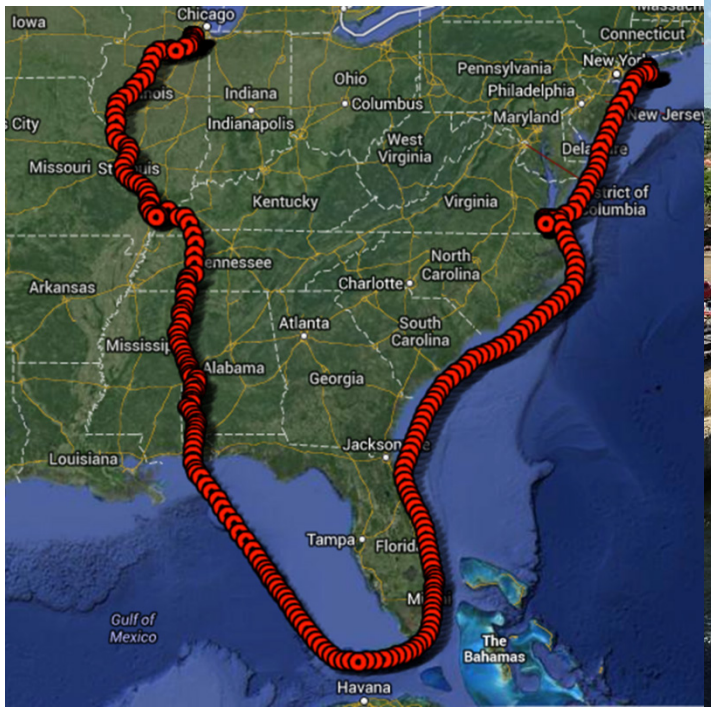
Inflector

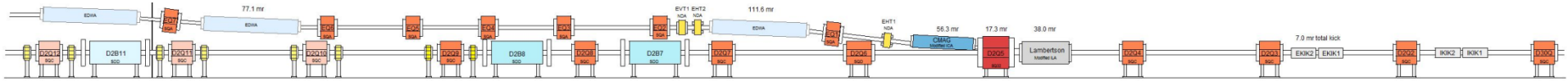
Jim Morgan



Muon g-2 Status

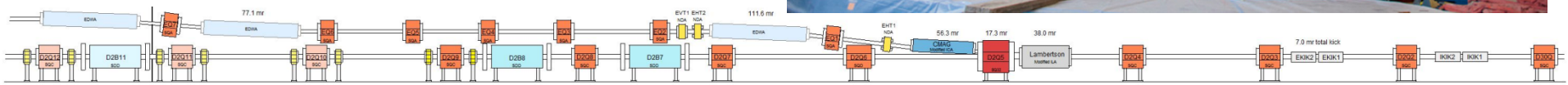
Storage Ring and Detectors have been disassembled (to the extent possible) and transported to Fermilab – to much public fanfare.



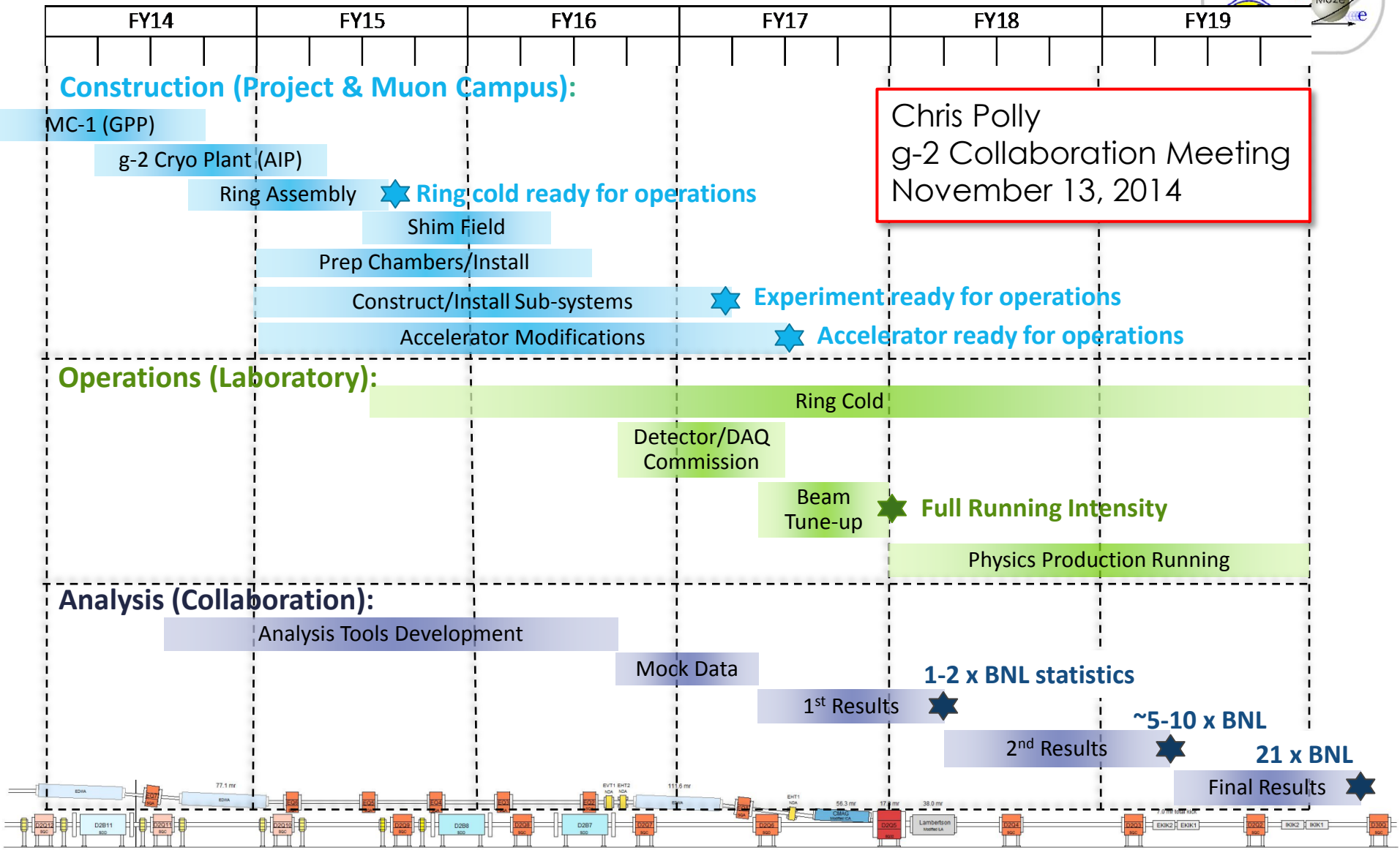


Muon g-2 Status

- MC-1 Building is complete and is the new home of the g-2 muon storage ring
- DOE CD-2/3 Review held June 17-19, 2014
- Must demonstrate ring cooldown prior to CD-2
  - *Expect complete by March – May 2015*
- Seeking OHEP approval to start Accelerator upgrades ~December 2015



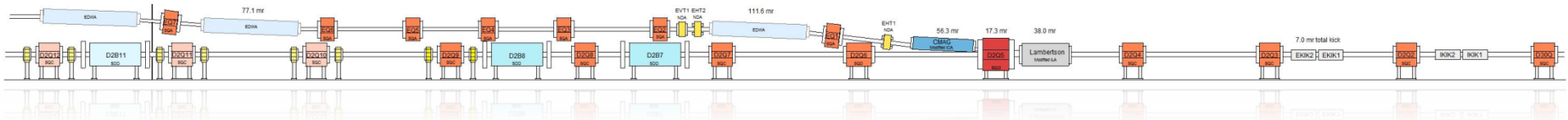
Muon g-2 Schedule



Chris Polly
g-2 Collaboration Meeting
November 13, 2014

The Mu2e Project

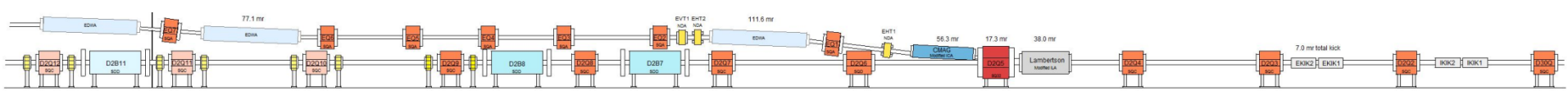
- Scope
- Accelerator Upgrades
- Status



Mu2e Scope (Level 2 Sub-projects)

1. Project Management – Ron Ray (PPD)
2. Accelerator Systems – Steve Werkema (AD)
3. Conventional Construction – Tom Lackowski (FESS)
4. Solenoids – Mike Lamm (TD)
5. Muon Beamline – George Ginther (TD)
6. Tracker – Aseet Mukherjee (PPD)
7. Calorimeter – Stefano Miscetti (INFN Frascati)
8. Cosmic Ray Veto – Craig Dukes (Univ. of Virginia)
9. Trigger and DAQ – Mark Bowden (CD)

Again, I'll focus only on the Mu2e Accelerator Upgrades



Mu2e Accelerator Upgrades

475.2
Accelerator Systems
S. Werkema (FNAL)

475.2.1 Project Management
L3 – S. Werkema
CAM - S. Werkema

475.2.3 Instrumentation & Controls
L3 – B. Drendel
CAM - B. Drendel

475.2.4 Radiation Safety
L3 – T. Leveling
CAM - T. Leveling

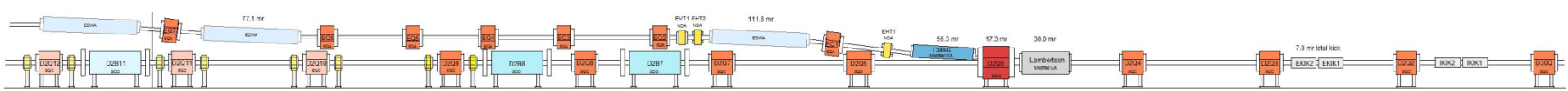
475.2.5 Resonant Extraction
L3 – V. Nagaslaev
CAM – V. Nagaslaev

475.2.6 Delivery Ring RF
L3 – J. Dey
CAM – J. Dey

475.2.7 External Beamline
L3 – D. Still
CAM – D. Still

475.2.8 Extinction
L3 – E. Prebys
CAM – E. Prebys

475.2.9 Target Station
L3 – R. Coleman
CAM – R. Coleman



Mu2e Scope Overview

Extinction Monitor

Target Station

External (M4) Beamline

Out-of-time Extinction

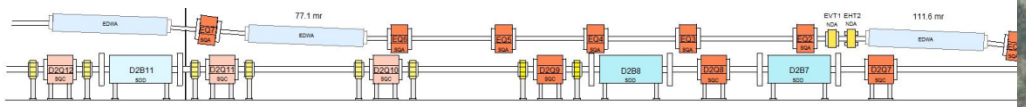
Instrumentation & Controls

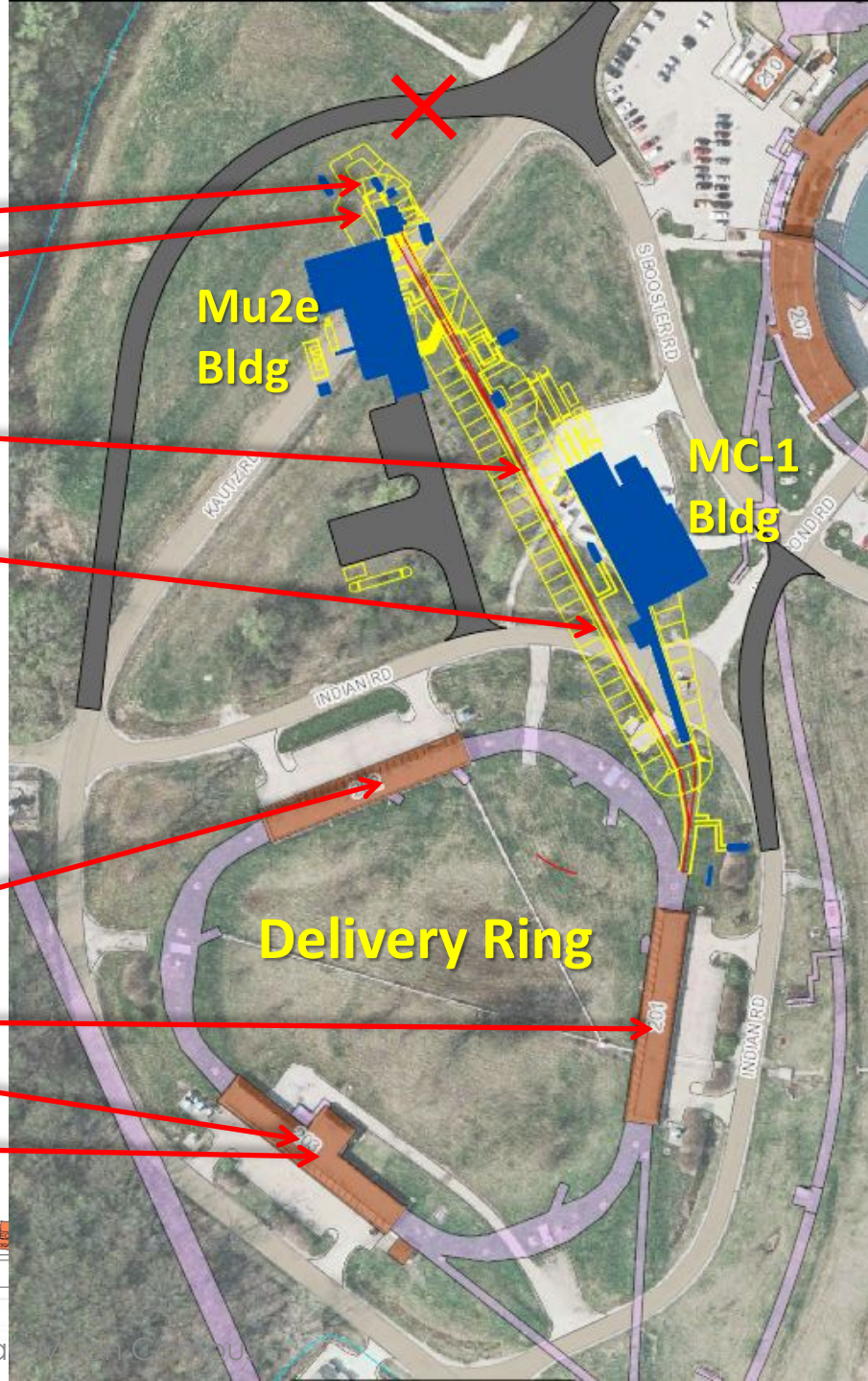
Radiation Safety

Everywhere

Resonant Extraction

Delivery Ring RF

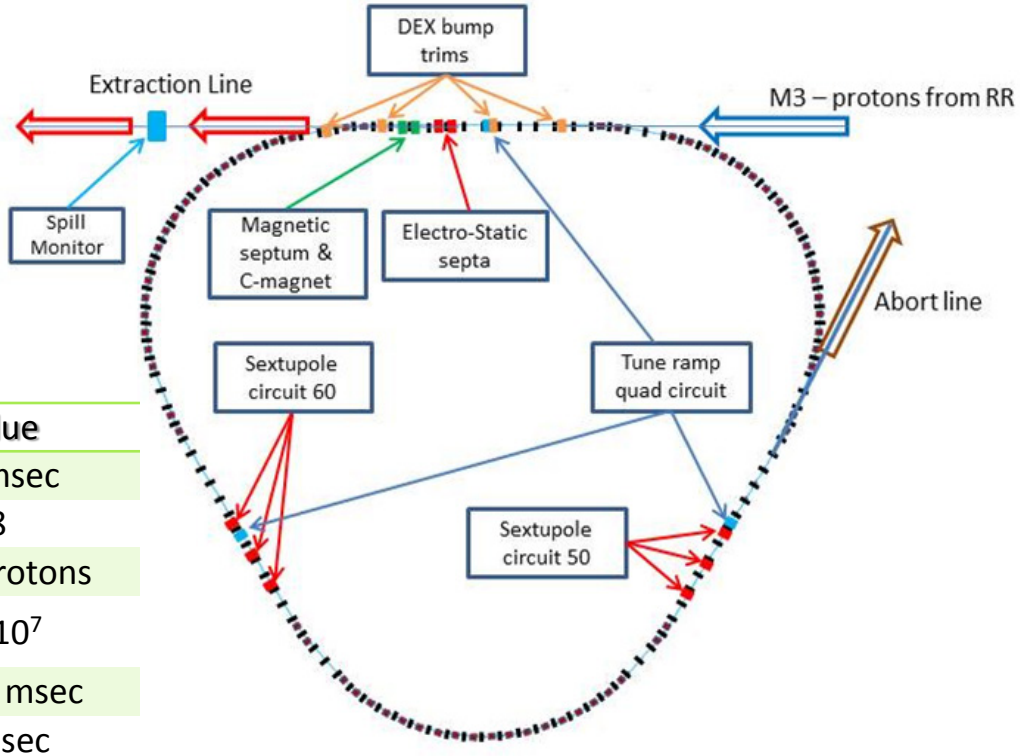




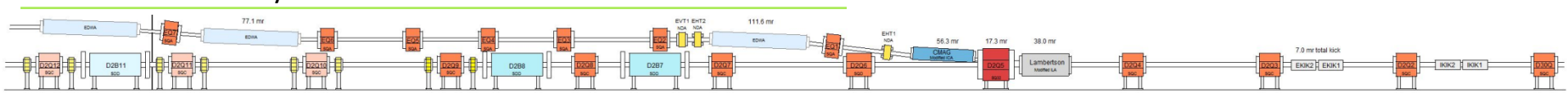
Delivery Ring Resonant Extraction

The Mu2e project will install a Resonant Extraction System in the Delivery Ring.

- Two Electro-static septum modules
- Two families of harmonic sextupole magnets (6 magnets total)
- Three horizontal tune ramp quadrupole magnets
- RF-knockout based spill feedback and cont
- Spill monitoring

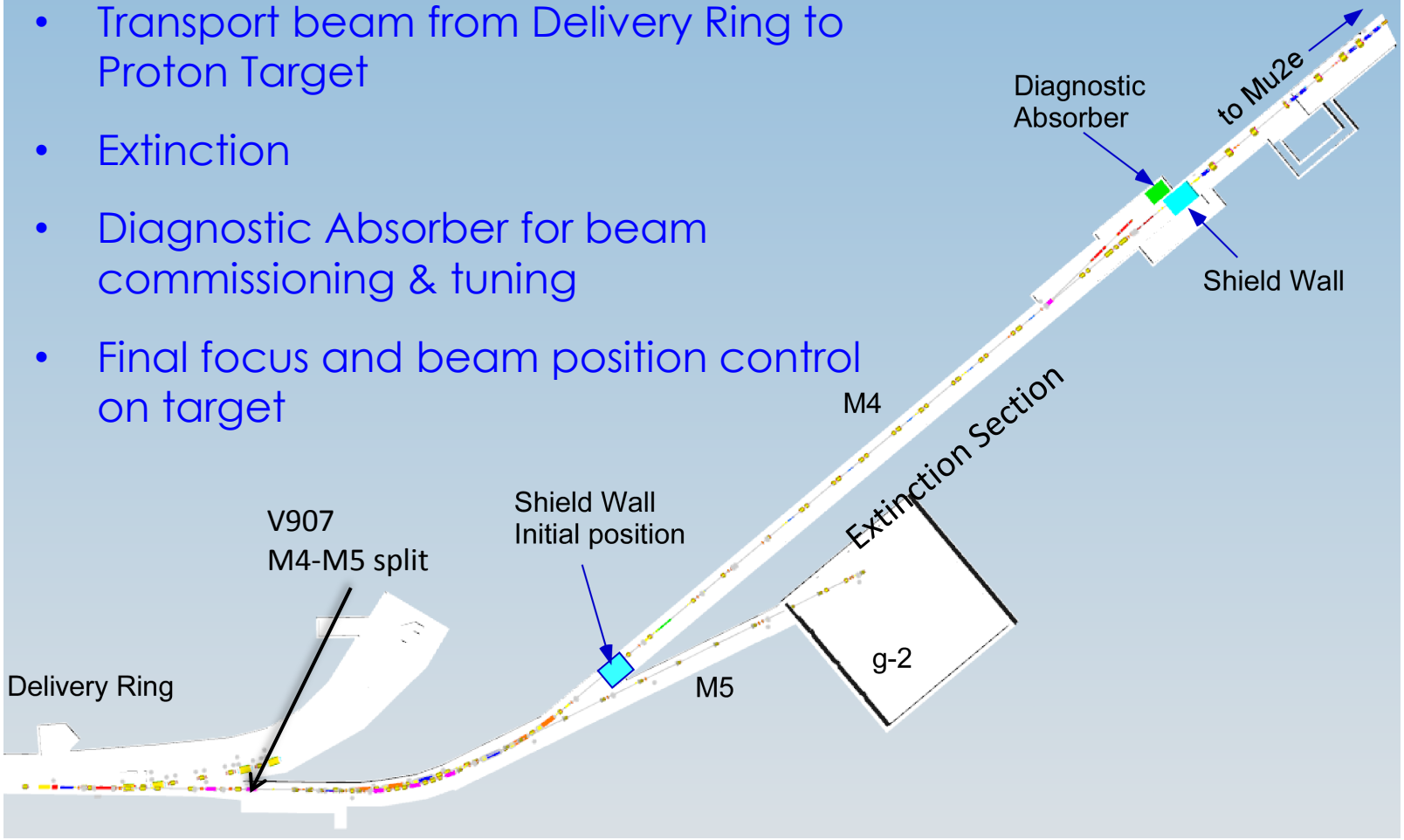


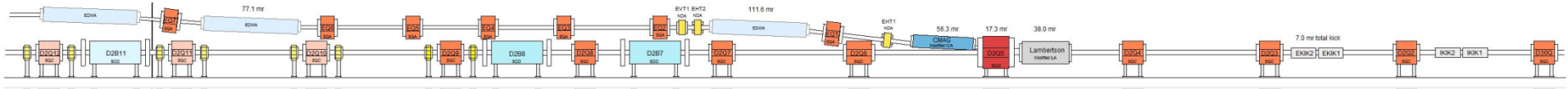
Parameter	Value
Spill duration	54 msec
Number of spills in a supercycle	8
Integrated spill intensity	10^{12} protons
Number of protons extracted per pulse (turn)	3×10^{7}
Time between pulses	1.695 msec
Reset time between spills	5 msec
Spill rate variations	< 50%
Extraction time duty factor	32%



External (M4) Beamline

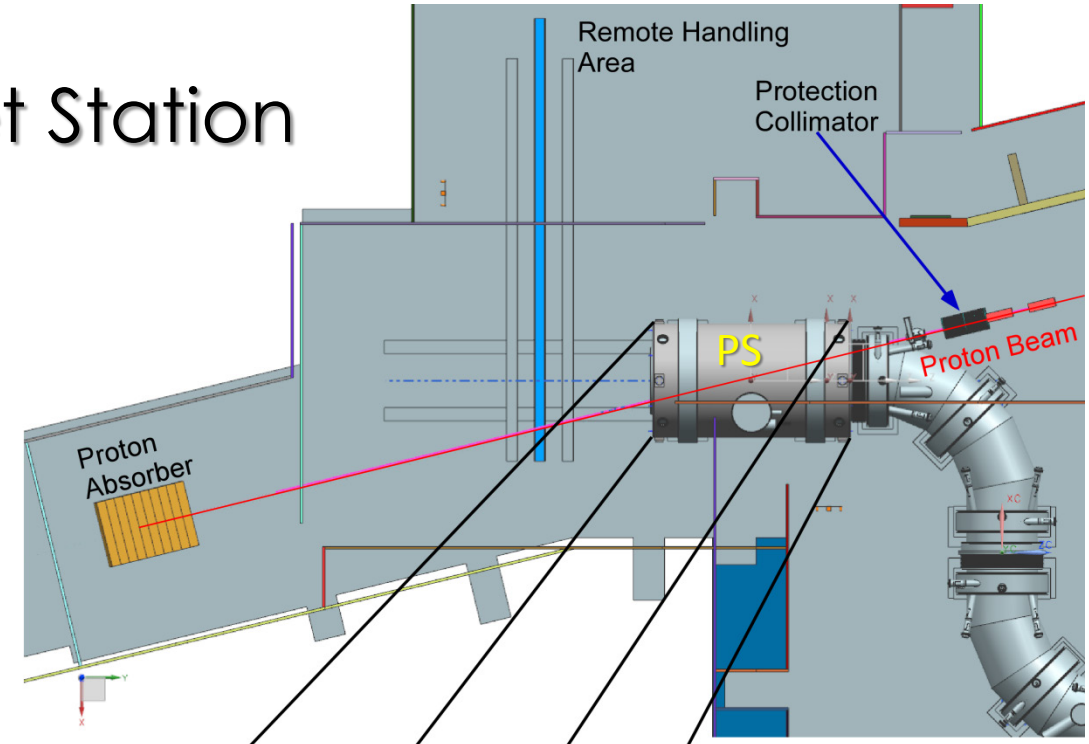
- Transport beam from Delivery Ring to Proton Target
- Extinction
- Diagnostic Absorber for beam commissioning & tuning
- Final focus and beam position control on target

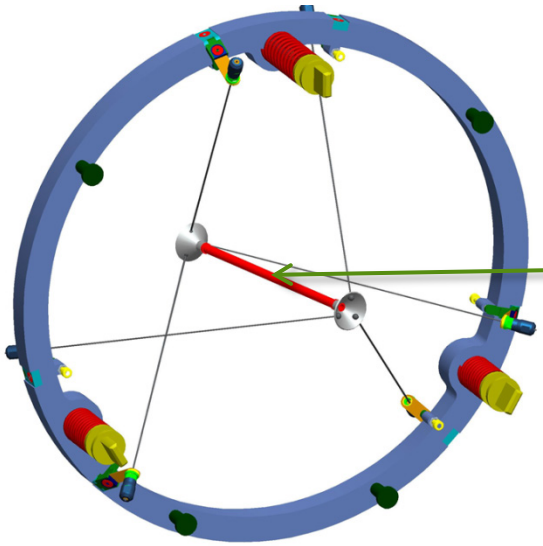


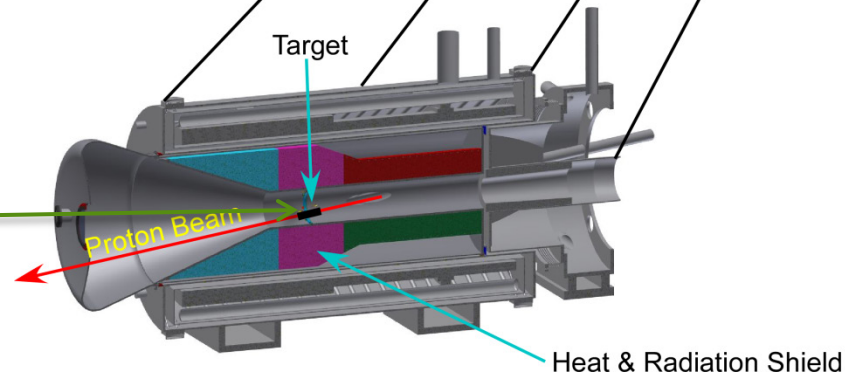


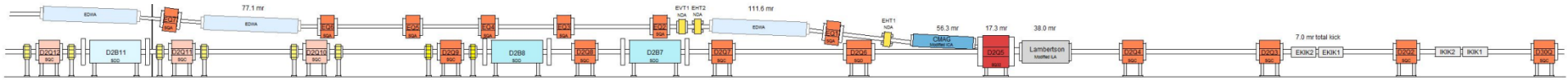
Mu2e Proton Target Station

- Target – located inside the Production Solenoid (PS)
- Heat & Radiation Shield (HRS)
- Proton Absorber (aka dump)
- Protection Collimator



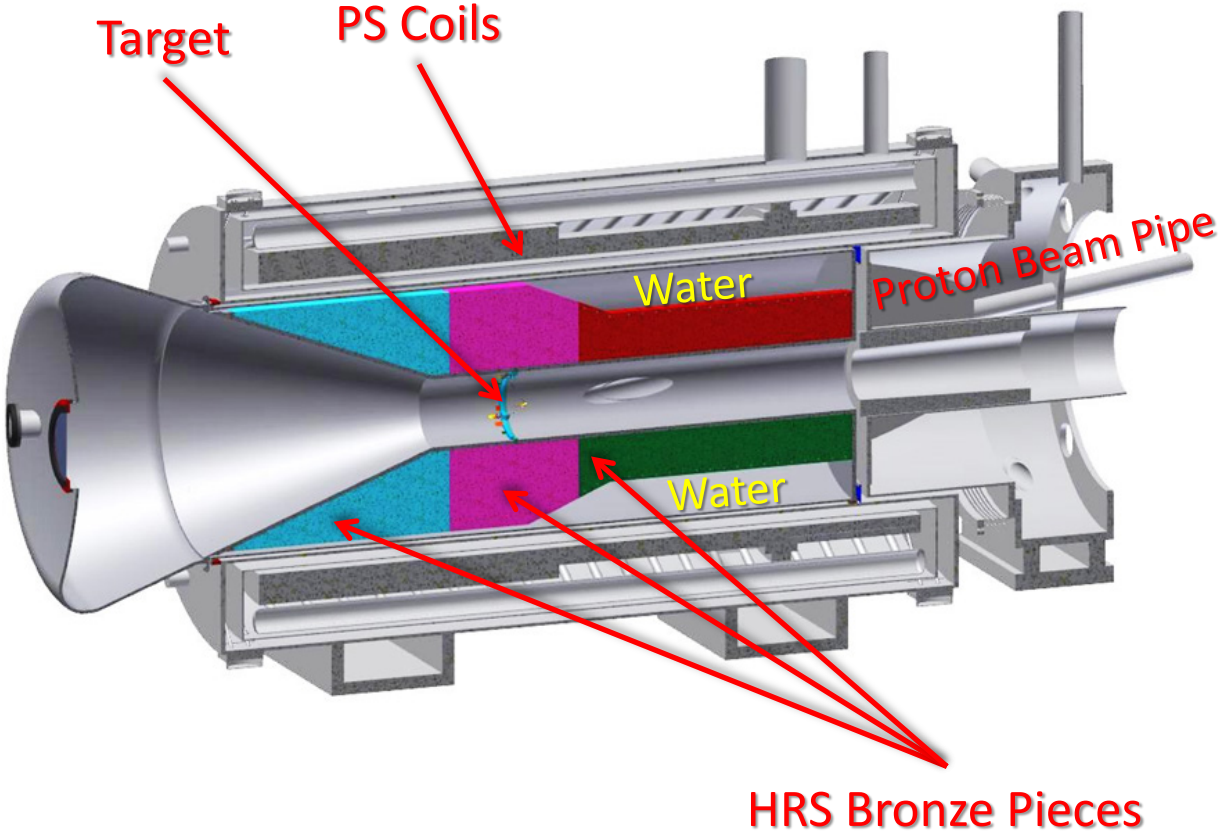


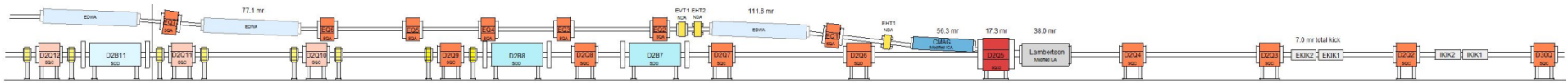




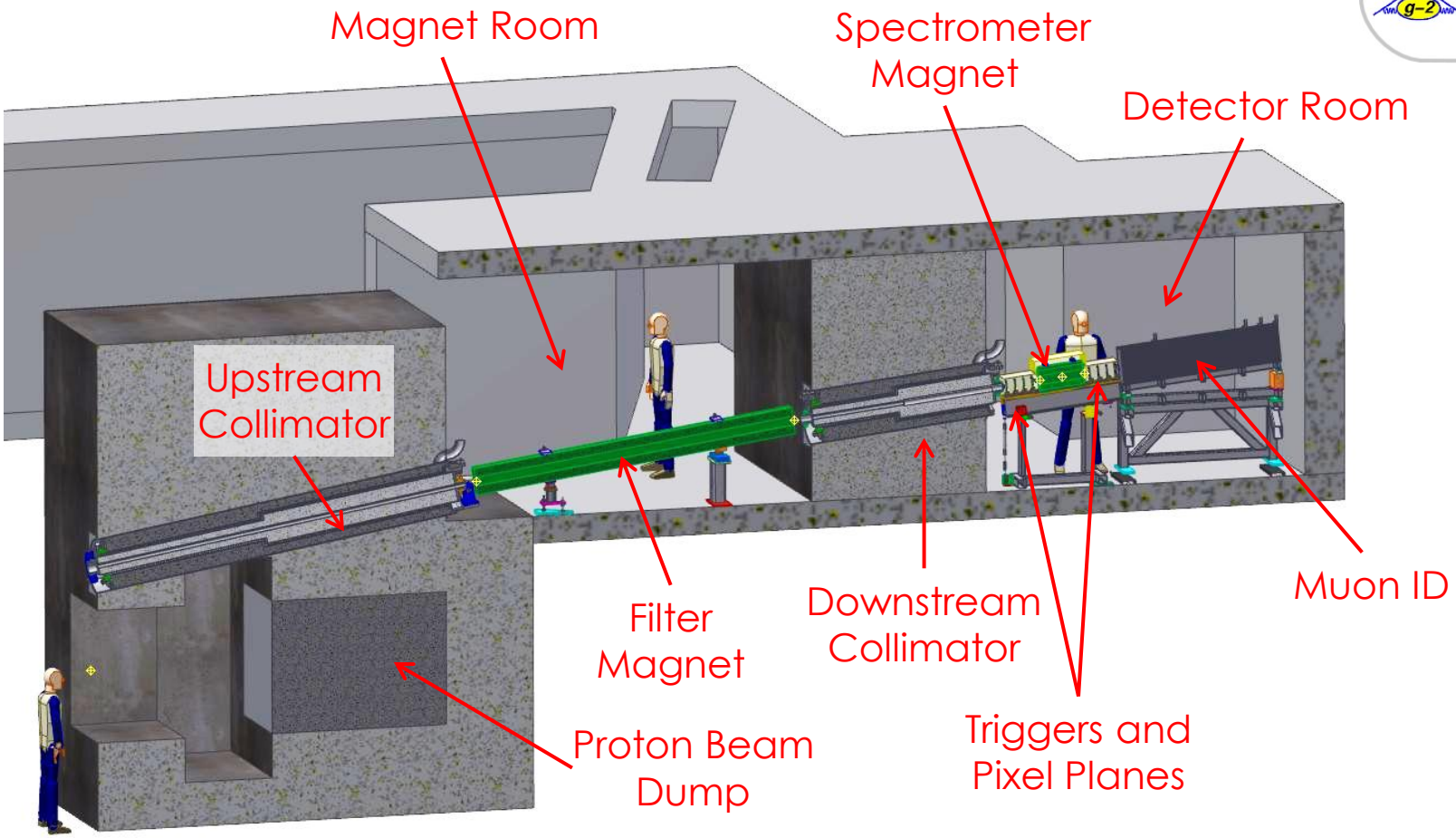
PS Heat and Radiation Shield

- Limit Production Solenoid (PS) and Transport Solenoid (TS) thermal exposure from heat radiated from target to acceptable levels
- Limit radiation dose and radiation damage to the PS and TS superconducting coils to acceptable levels
- Constraints on HRS design:
  - PS field quality
  - Quench induced eddy currents
  - Muon yield

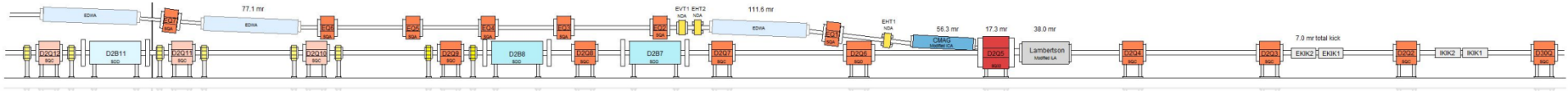




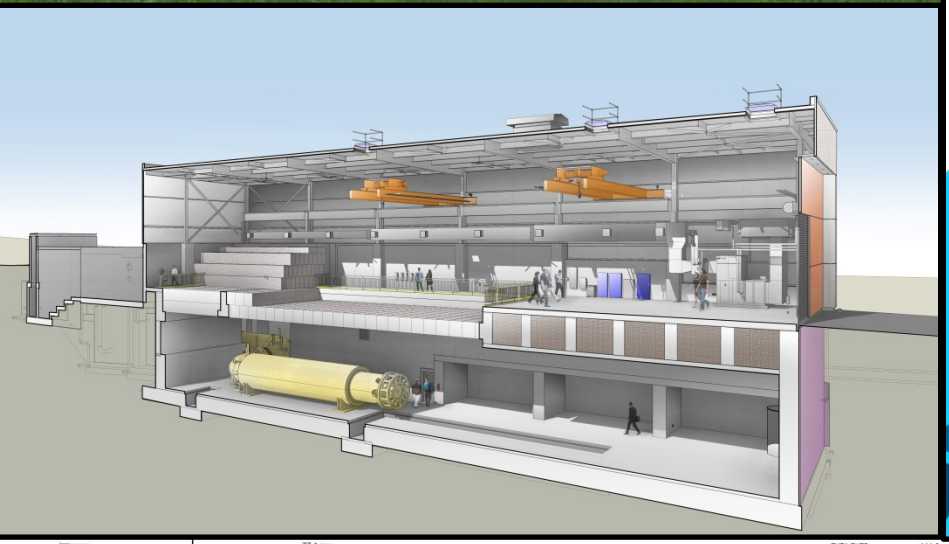
Mu2e Extinction Monitor

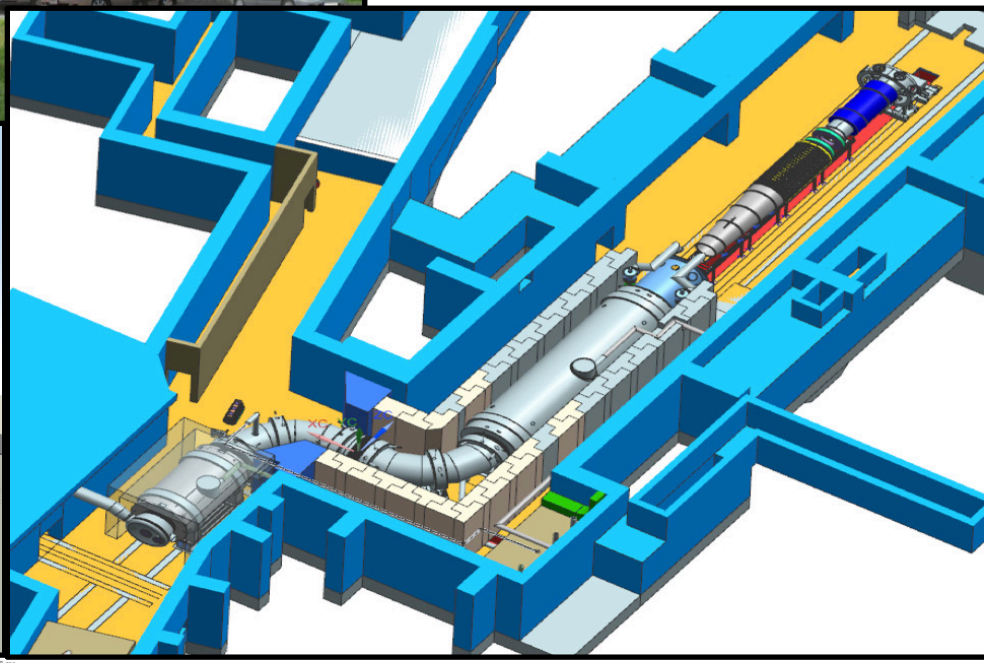


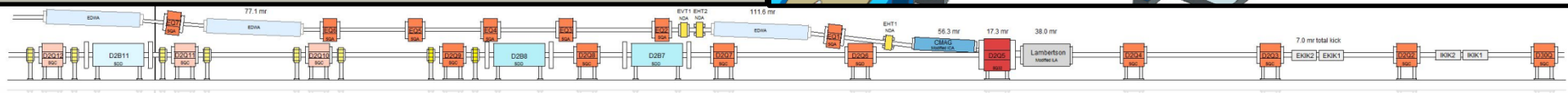
The extinction monitor design is a momentum-selecting filter consisting of collimators and a permanent dipole magnet, a magnetic spectrometer, and a range stack.



The Mu2e Building



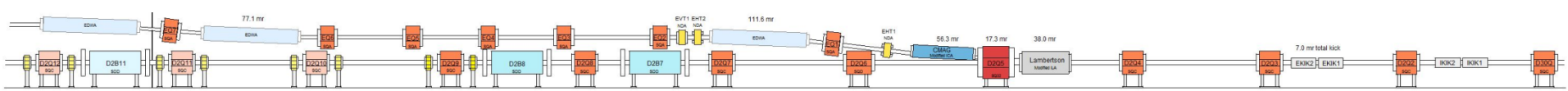




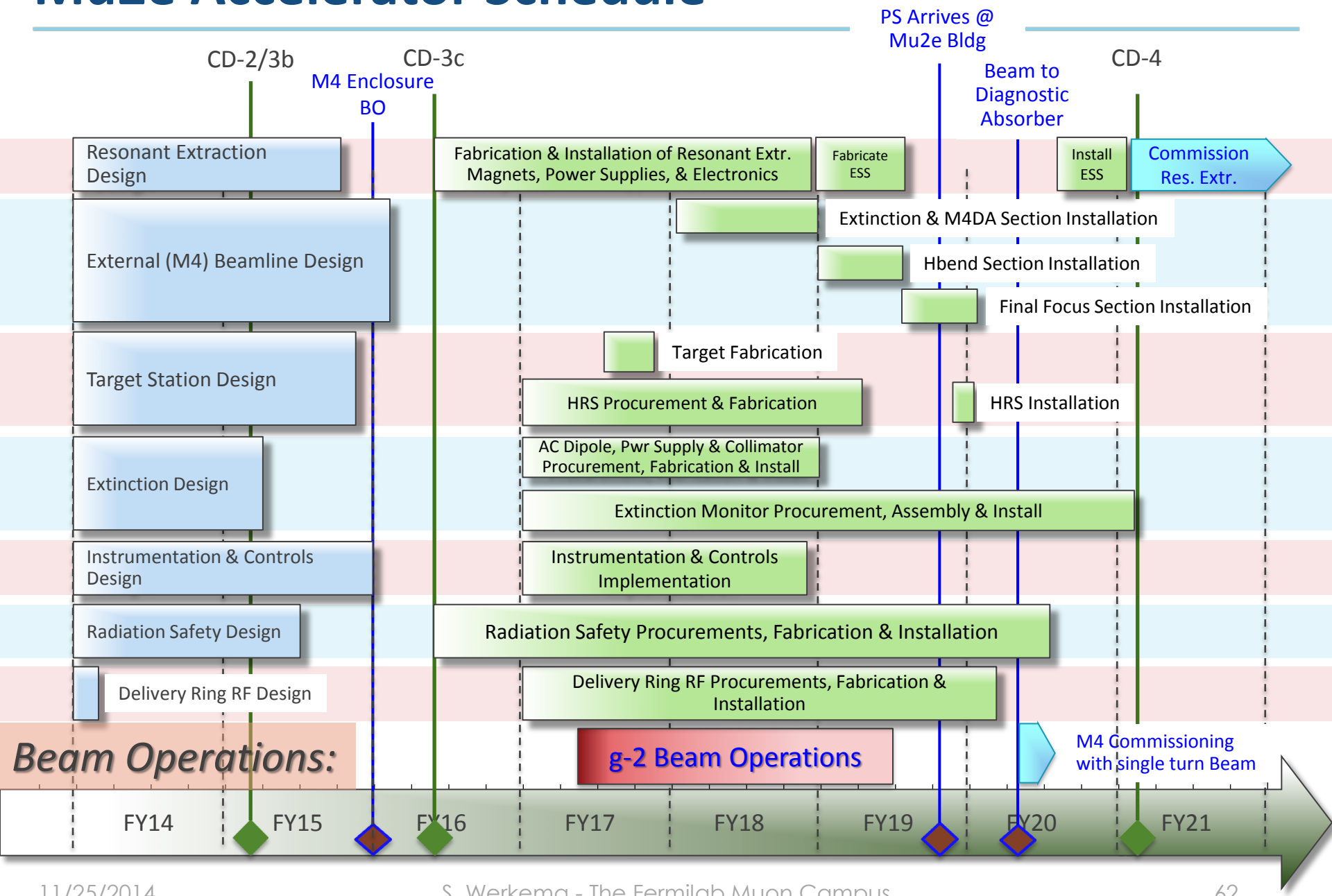
Mu2e Status

- Received CD-3a in July 2014 for long-lead solenoid super-conductor
- CD-2/3b Review held October 21-24, 2014

  Request CD-3b for:
  - Detector Hall Civil construction
  - Construction of Transport Solenoid Modules
- Expect CD-2/3b in ~January 2015
- Expect CD-3c review for remainder of Mu2e project in late calendar year 2015



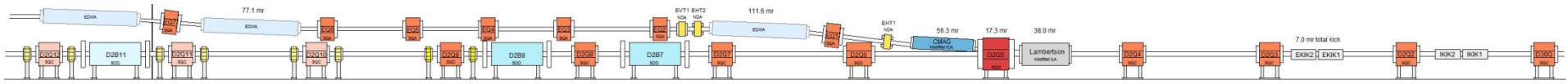
Mu2e Accelerator Schedule



AIPs & GPPs

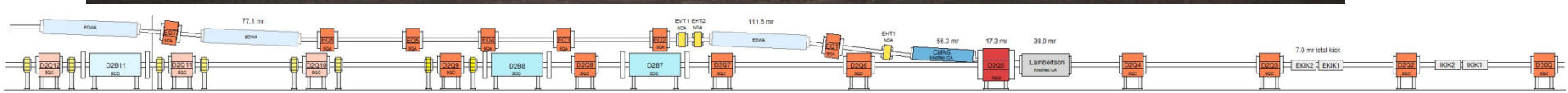
Recycler RF AIP
Beam Transport AIP
Delivery Ring AIP
Cryo AIP

MC-1 GPP
MC Beam Enclosure GPP
MC Infrastructure GPP



MC-1 Building GPP

- Building is complete
- g-2 muon storage ring in place – reassembly activities in progress

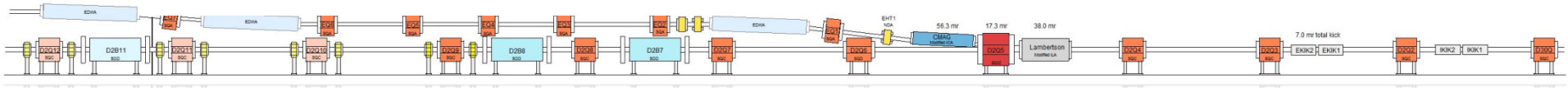


Beamline Enclosure GPP

Tunnel will break ground calendar 2014

- Contract finalized early November 2014

Expect Beneficial Occupancy October 2015

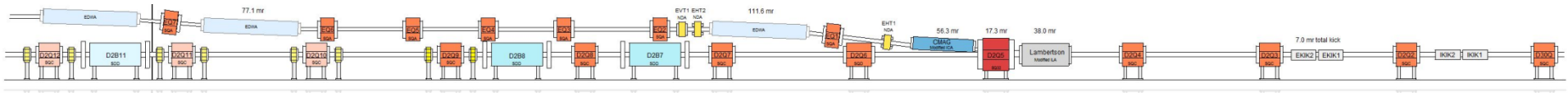


Cryo AIP

Refrigeration plant for Muon g-2 and Mu2e. Primarily located in MC-1 building

- LHe circulated
- g-2 Acceptance tests in March 2015

Project complete September 2017

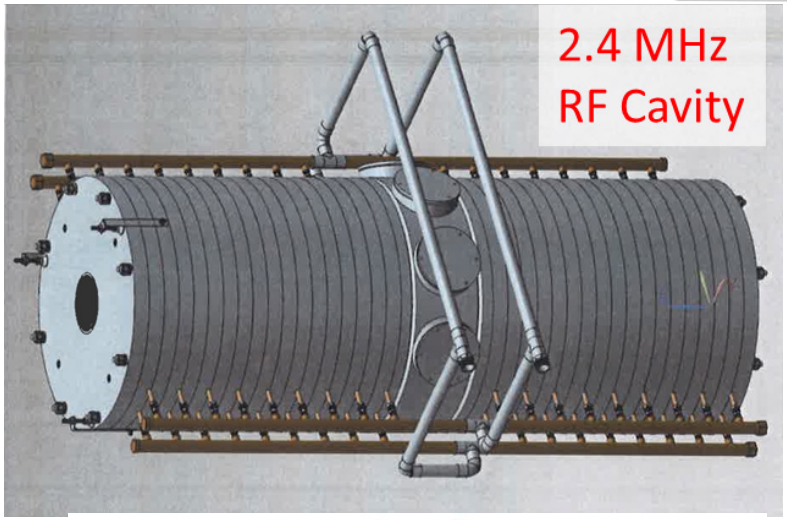


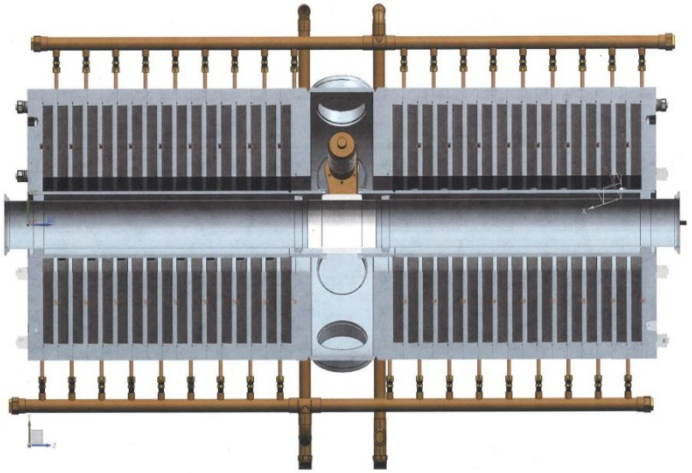
Recycler RF AIP

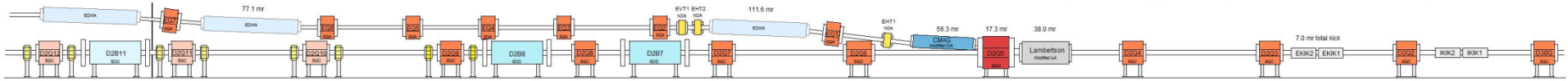
2.5 MHz bunch formation RF for Muon g-2 and Mu2e.

- Recycler Low Level, High Level, and seven 2.5 MHz cavities
- Delivery Ring High Level and one 2.5 MHz cavity

Project completion: October 2016





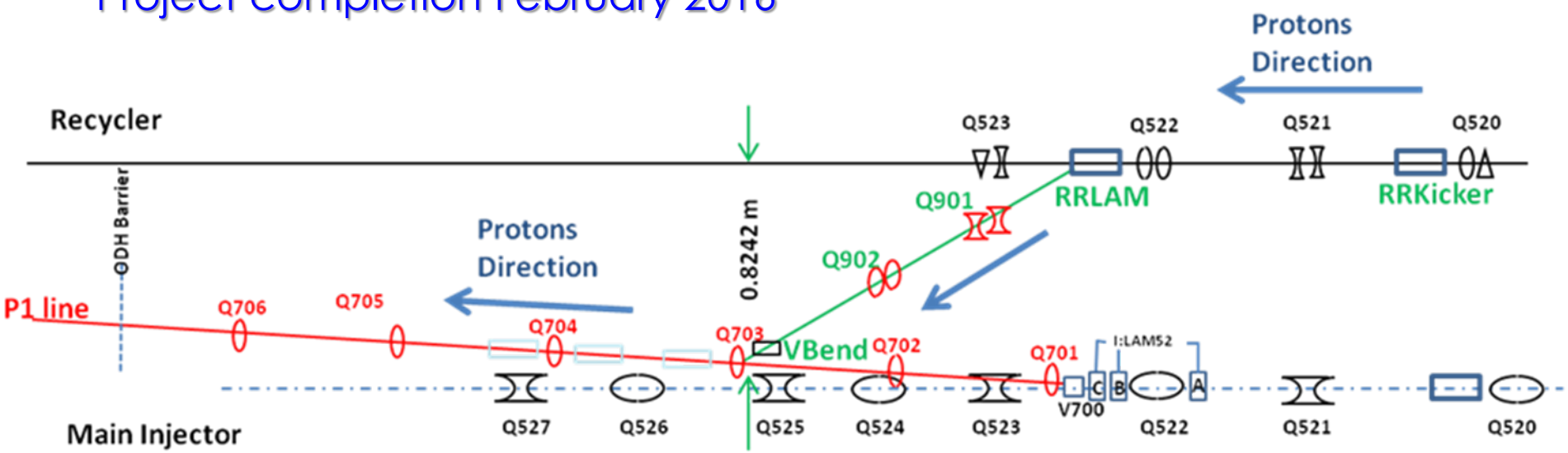


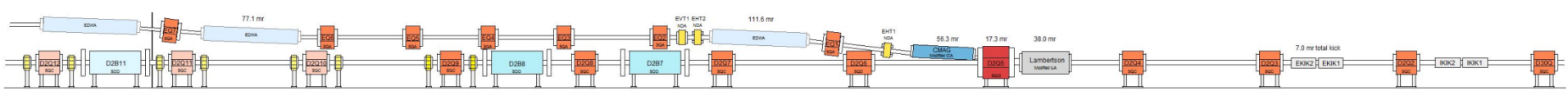
Beam Transport AIP

Extraction from Recycler to P1 beamline.

- Recycler extraction devices (kicker, Lambertson)
- Beamline stub from Recycler to P1
- P1/P2/M1 aperture improvements

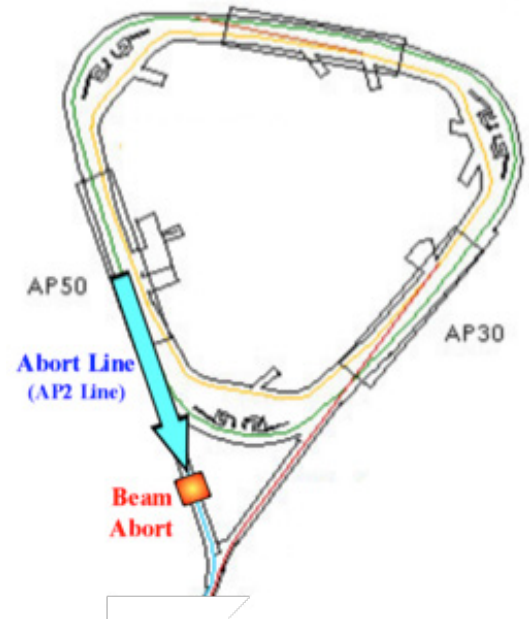
Project completion February 2016



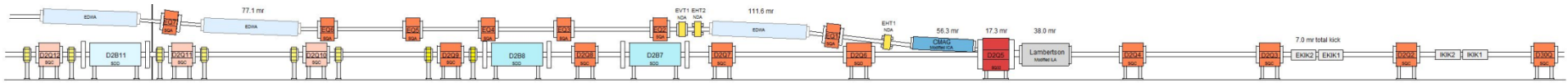


Delivery Ring AIP

- Delivery Ring Abort
  - proton removal for g-2
  - cleanup abort after resonant extraction for Mu2e
- Collider equipment removal
- Electrical Infrastructure
- Re-route controls around external beamline enclosure

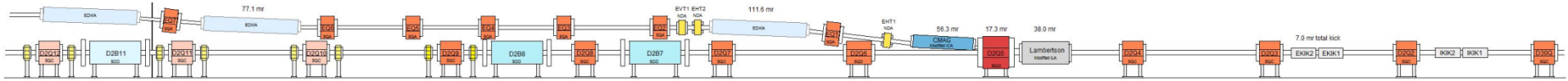


Project Complete December 2016



Wrapping up

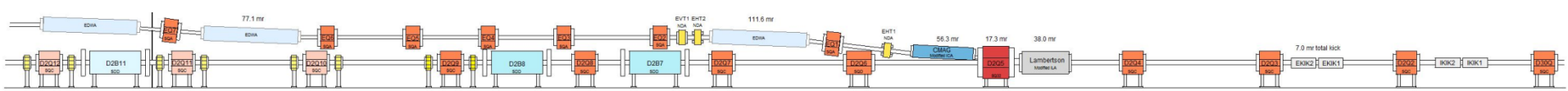
- Costs
- Conclusions



Muon Campus Program Cost

Project	Total Project Cost ($M)	Accelerator Costs ($M)
Muon g-2 Project	46.4	22.2
Mu2e Project	271.0	50.2
Recycler RF AIP	9.7	9.7
Beam Transport AIP	6.2	6.2
Delivery Ring AIP	9.3	9.3
Cryo AIP	9.7	9.7
MC-1 Building GPP	9.0	
Beam Enclosure GPP	9.7	
MC Infrastructure GPP	1.0	1.0
Total	372.0	108.3

All costs are base cost + estimate uncertainty (contingency)

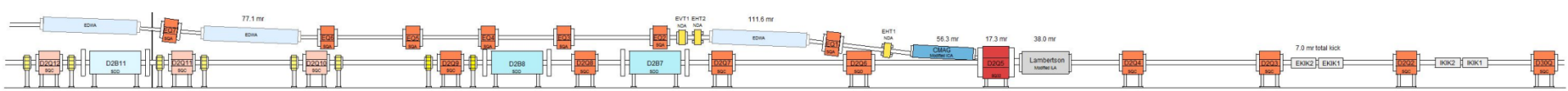


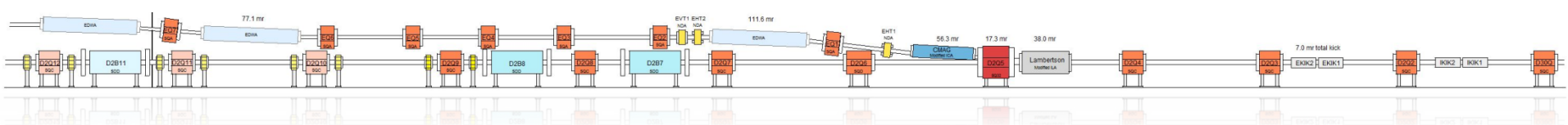
Lessons Learned: Cost Estimating is IMPORTANT

Project Proposal	Proposal Accelerator Costs	Baseline Accelerator Cost Estimate
Muon g-2 (April 2010)	$9.3 M	$22.2 M
Mu2e (October 2008)	$17.1 M	$50.2 M
Other Accelerator Costs (AIPs)	$0.0 M	$35.9 M
Total:	$26.4 M	$108.3 M

The proposals for both projects greatly underestimated the cost of the necessary Fermilab accelerator upgrades.

These initial low estimates have the effect of biasing future expectations – there is a lot of pressure on those constructing baseline costs estimates to make the costs lower to meet these expectations.



Conclusions

- The Muon Campus program plans to launch two experiments in the next 7 years – Muon g-2 and Mu2e
- Both of these experiments will probe the possibility of physics beyond the Standard Model
- The projects that will accomplish this are a significant undertaking for Fermilab – $372 M, more than a quarter of which are accelerator upgrades
- These projects are already underway with significant developments coming in the near future.