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Mu2e Project Overview

Steve Werkema – Mu2e Accelerator Systems L2 Manager

Mu2e Remote Handling Review

3 March 2015

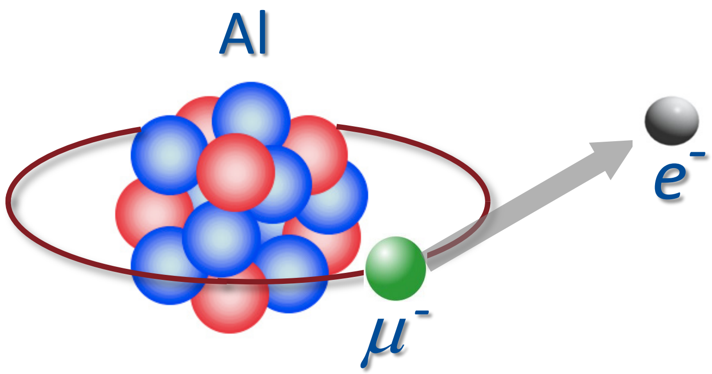
Outline

- The Mu2e Experiment
- The Muon Campus
- The Mu2e Project Accelerator Systems
- Schedule

The Mu2e Experiment

Charged Lepton Flavor Violation

- The Mu2e experiment endeavors to detect Charged Lepton Flavor Violation (CLFV)
- CLFV is a process involving charged leptons (e, μ, τ)that violates the conservation of the number of leptons of each flavor



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

	$\mu^- N$	$e^- N$
L_μ:	1	0
L_e:	0	1

Both L_μ and L_e are not conserved in this process

Note: Ordinary muon decay is not CLFV

	μ^- →	e^-	$\bar{\nu}_e$	ν_μ
L_μ:	1	0	0	1
L_e:	0	1	-1	0

If this is observed, it is evidence 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 "$R_{\mu e}$"

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

← *Rate of CLFV* $\mu \rightarrow e$ conversion

← μ capture rate

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

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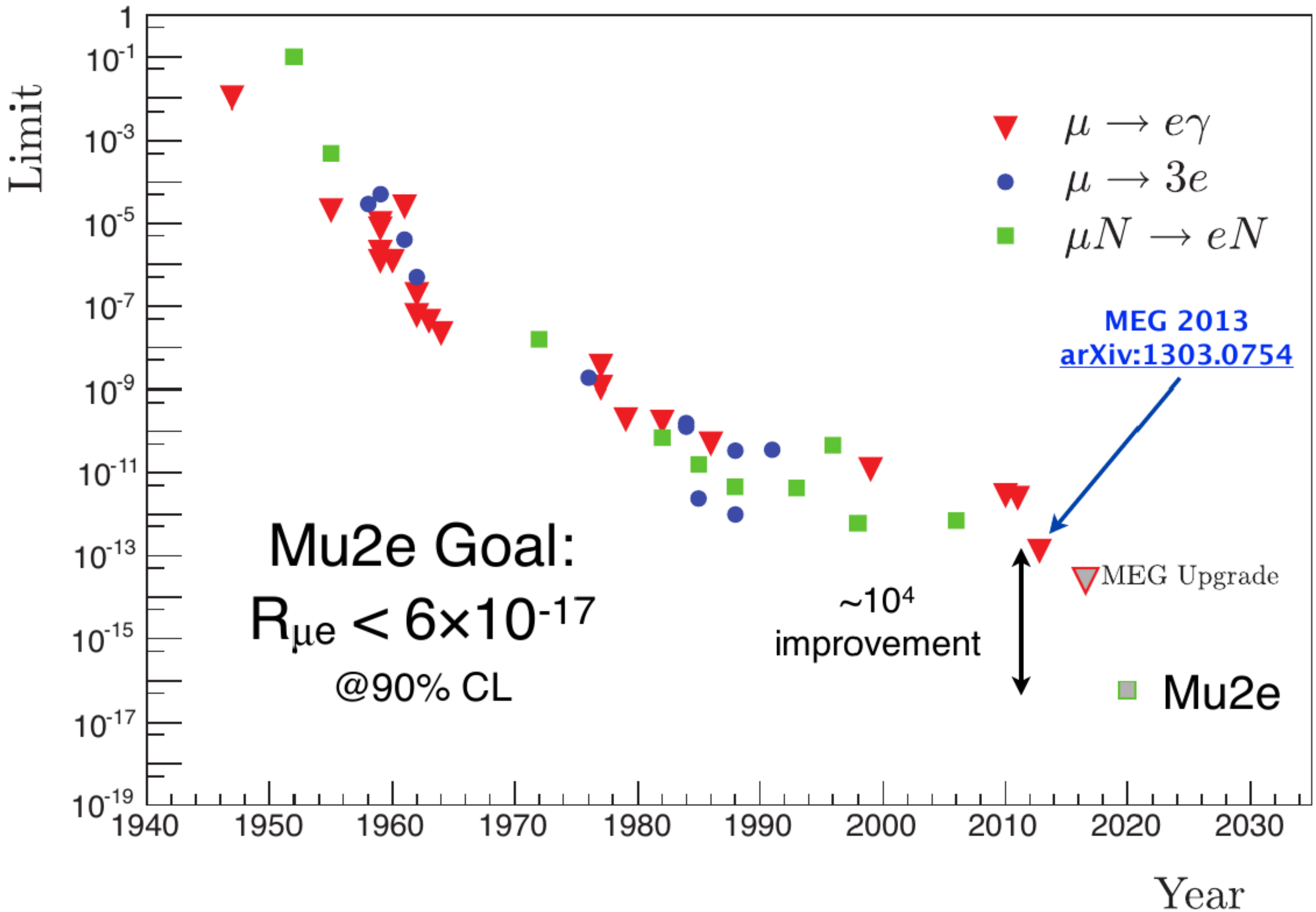
Results of Previous CLFV Searches



In Case You've Missed the Significance of this …

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Mu2e Apparatus

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

Production Solenoid

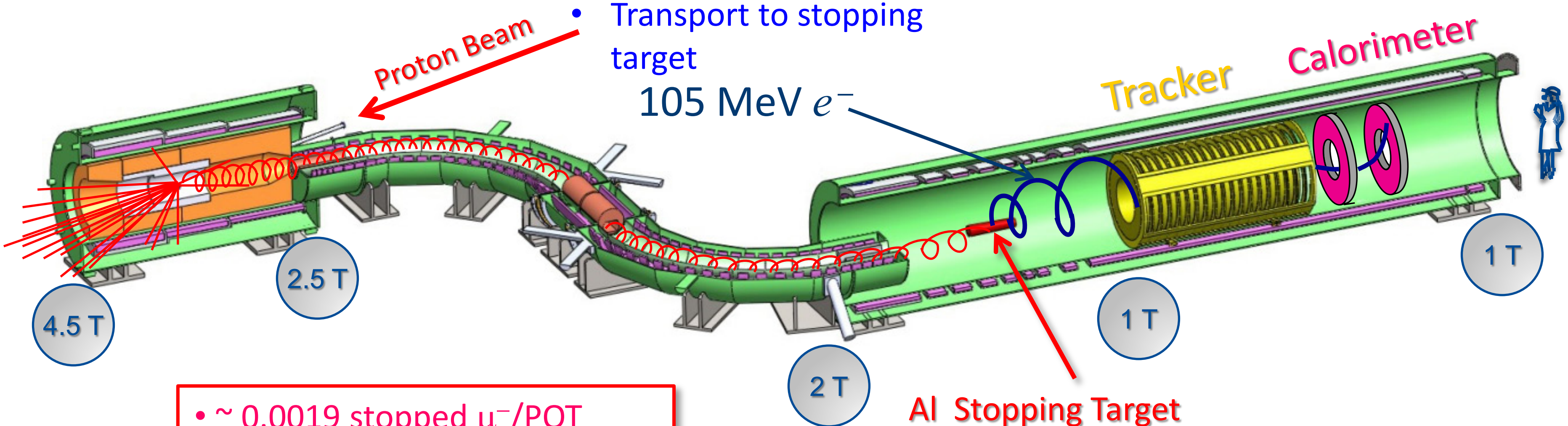
- Contains proton target
- Magnetic mirror – reflects secondaries back toward transport solenoid

Transport Solenoid

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

Detector Solenoid

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



- ~ 0.0019 stopped μ^-/POT
- 10^{10} Hz of stopped muons

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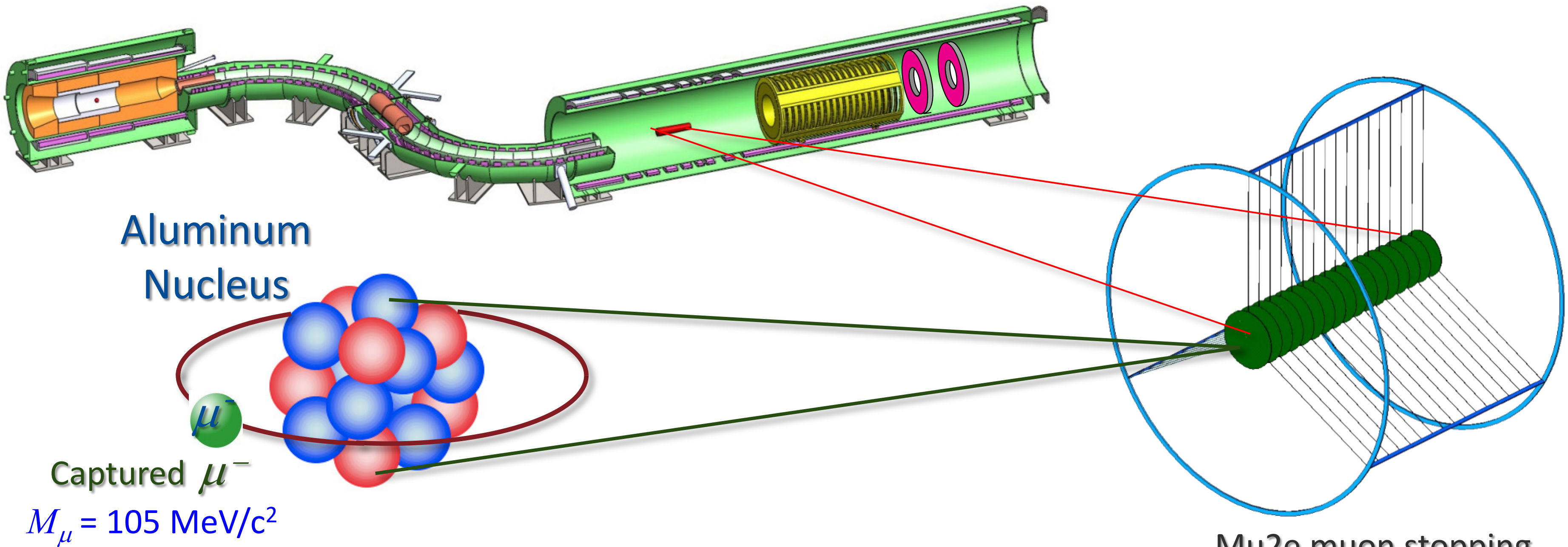
Stopping Muons



- 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 (final target monitor concept is not yet settled)

Mu2e muon stopping target

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

The Muon Campus

The Muon Campus

DOE Projects, AIPs, GPPs

Building the Muon Campus requires the following projects:

1. DOE 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

Muon Campus Upgrades Required for the Mu2e Experiment but not on the Mu2e Project

Accelerator Upgrade	Project
MI-8 beamline to Recycler Ring Injection	NOvA Project
Recycler Ring 2.5 MHz RF system	Recycler RF AIP
Delivery Ring 2.4 MHz RF Cavities and HL Amps & Cooling	Recycler RF AIP
Single bunch extraction from Recycler Ring	Beam Transport AIP
Beamline aperture upgrades	Beam Transport AIP
AP1, AP2, AP3 to M1, M2, M3 conversion & upgrade	Beam Transport AIP
Beam transport instrumentation & infrastructure	Beam Transport AIP
Beam transport controls	Delivery Ring AIP
Delivery Ring Injection	Delivery Ring AIP
Delivery Ring Abort	Delivery Ring AIP
Delivery Ring infrastructure	Delivery Ring AIP
Delivery Ring Controls and Instrumentation	Delivery Ring AIP
D30 straight section reconfiguration	g-2 Project
Delivery Ring Extraction (except ESS)	g-2 Project
Extraction line (M4) to M5 split	g-2 Project
M4 beamline enclosure	MC Beamline Enclosure GPP

M4 Beamline construction

- Looking west from AP30
- Foreground building is MC-1 (g-2 building)

M4 Beamline construction

- Looking south east at location where M4 line exits Delivery Ring enclosure
- Foreground building is AP30

The Mu2e Project Accelerator Systems

Mu2e Accelerator Systems Scope Overview

475.02.08.03 Extinction Monitor

475.02.09 Target Station

475.02.07 External (M4) Beamline

475.02.08.02 Extinction

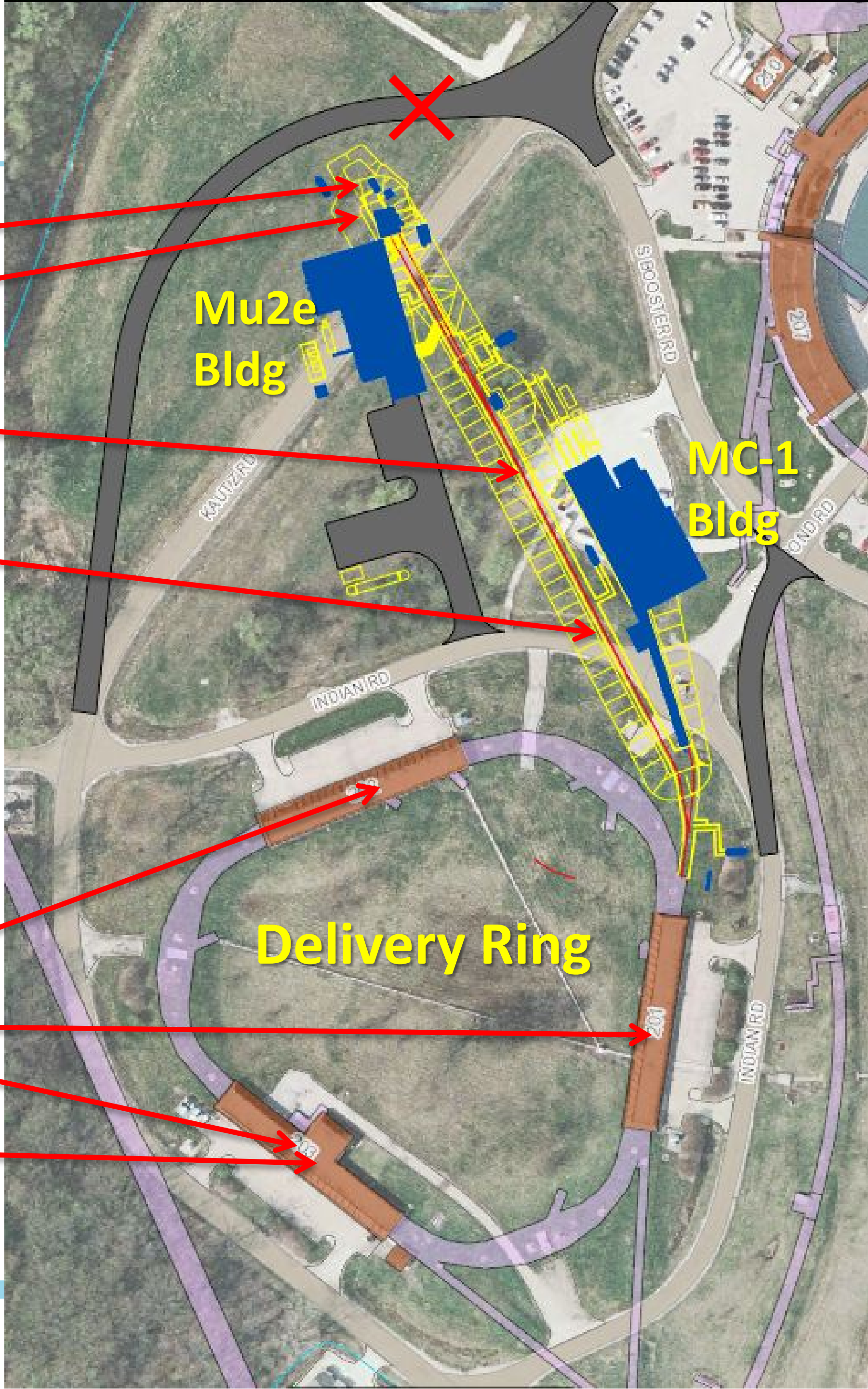
475.02.03 Instrumentation & Controls

475.02.04 Radiation Safety

Everywhere

475.02.05 Resonant Extraction

475.02.06 Delivery Ring RF

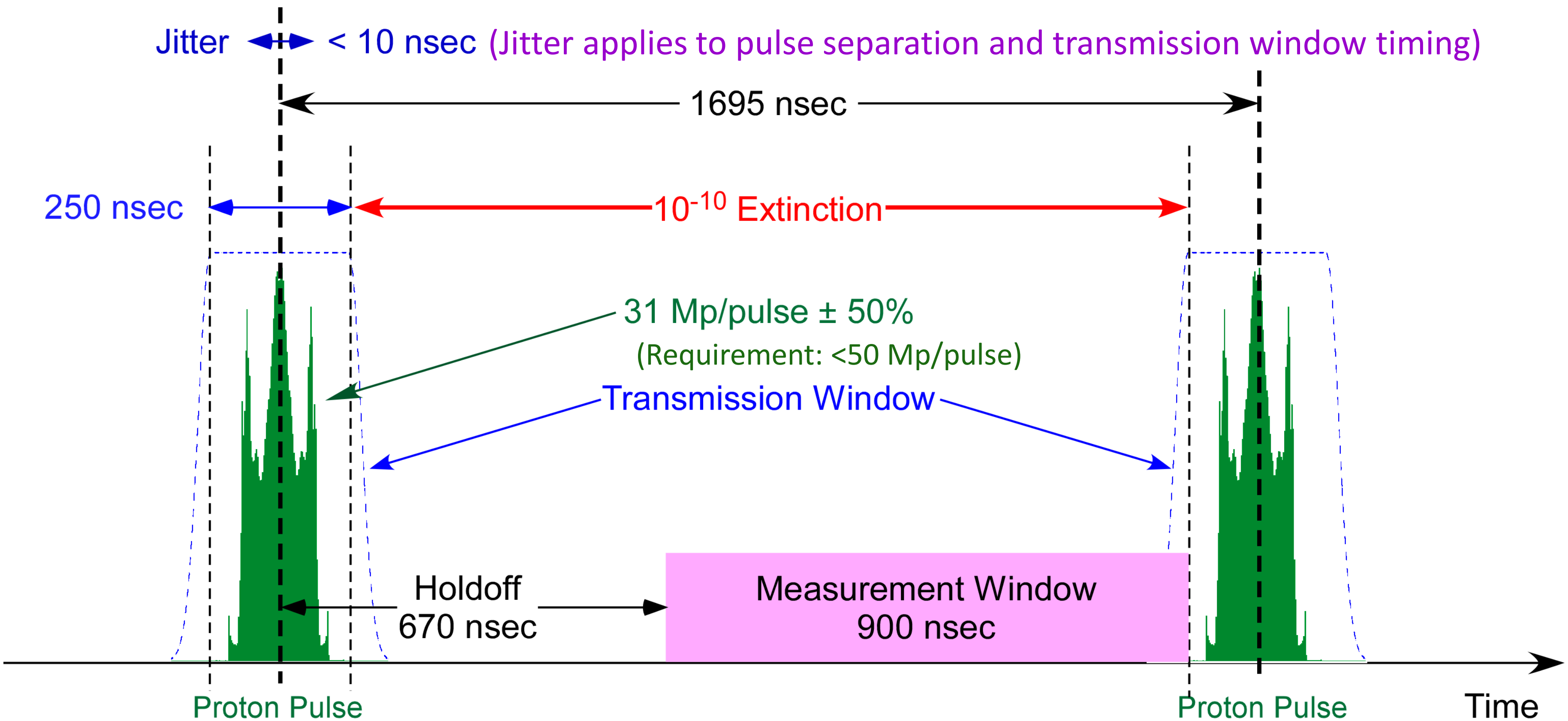


Proton Beam Requirements

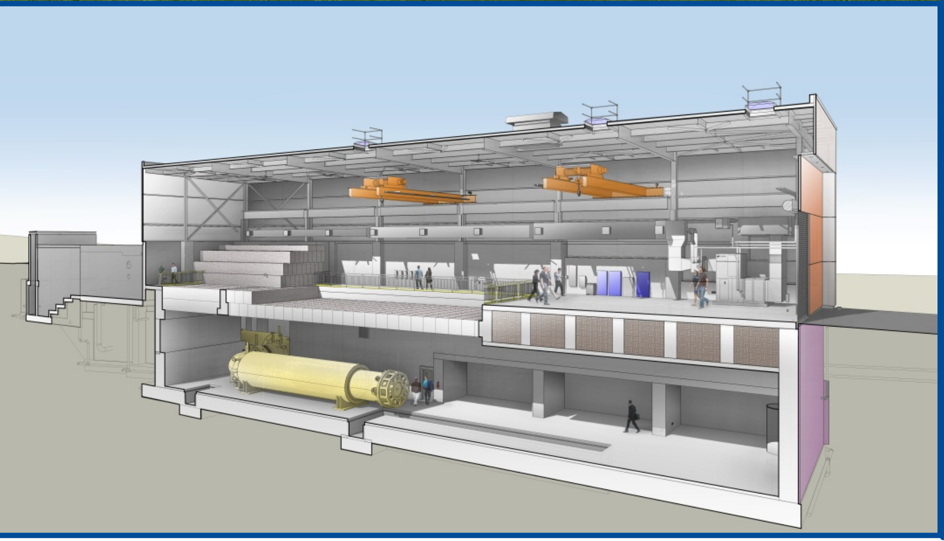
	Parameter	Design Value	Requirement	Unit
3-4 year run	Total protons on target	3.6×10^{20}	3.6×10^{20}	protons
Time Structure	Time between beam pulses	1695	> 864	nsec
	Maximum variation in pulse separation	< 1	10	nsec
	Spill duration	54	> 20	msec
	Beamline Transmission Window	230	250	nsec
	Transmission Window Jitter (rms)	5	<10	nsec
	Out-of-time extinction factor	10^{-10}	$\leq 10^{-10}$	
Intensity	Average proton intensity per pulse	3.1×10^{7}	$< 5.0\times10^{7}$	protons/ pulse
	Maximum Pulse to Pulse intensity variation	50	50	%
Beam Size	Target rms spot size	1	0.5 – 1.5	mm
	Target rms beam divergence	0.5	< 4.0	mrad

Proton Beam & Extinction Requirements

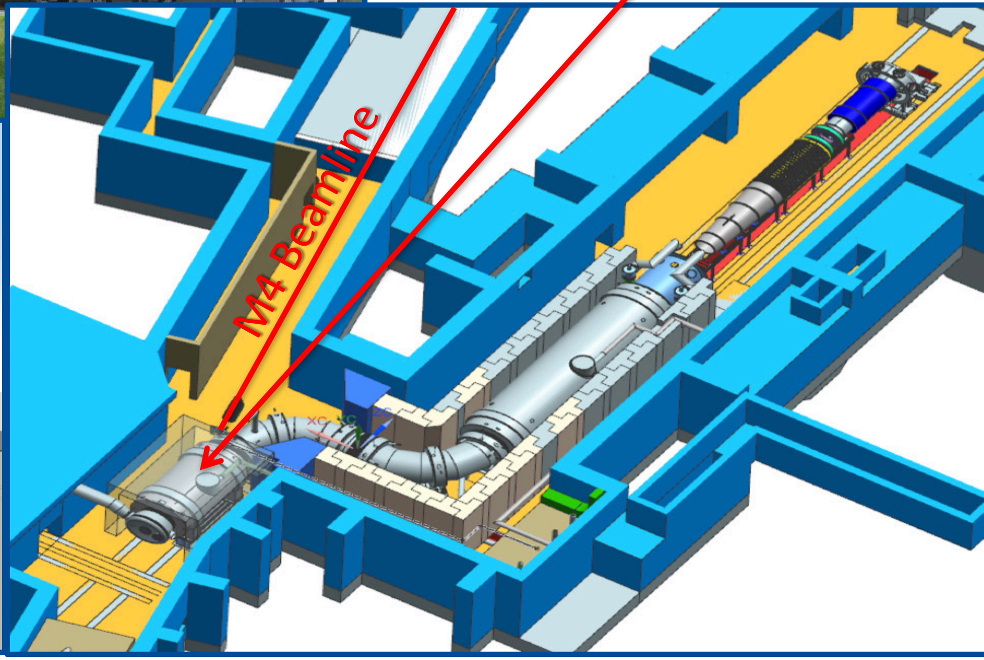
Two successive proton pulses on the Mu2e target (out of ~30,000 per spill)



The Mu2e Building

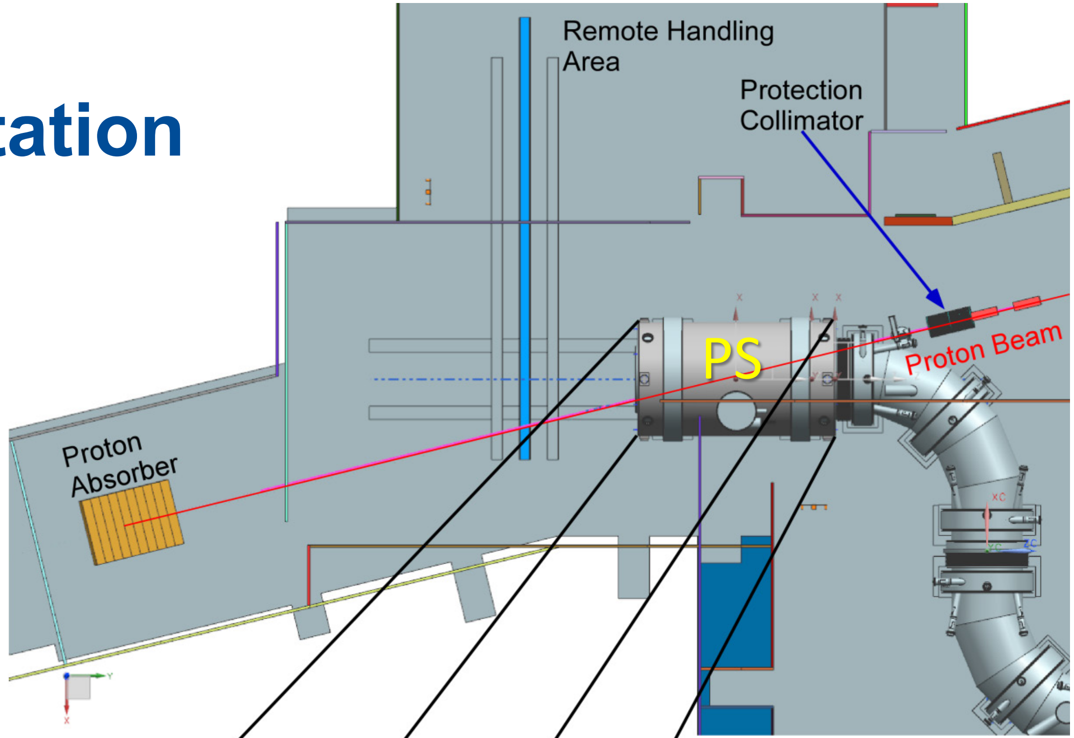


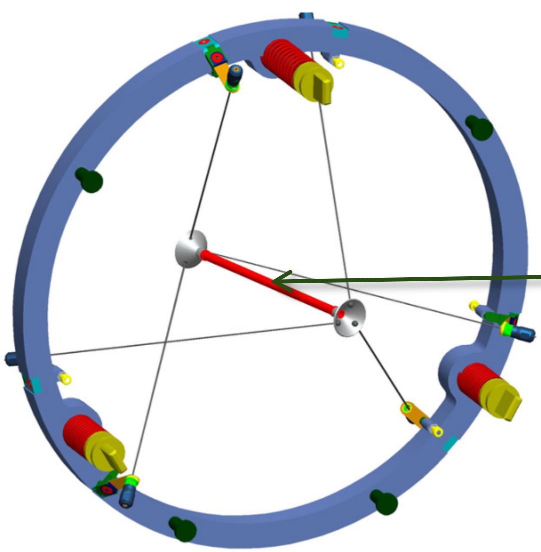
Proton Target
lives here

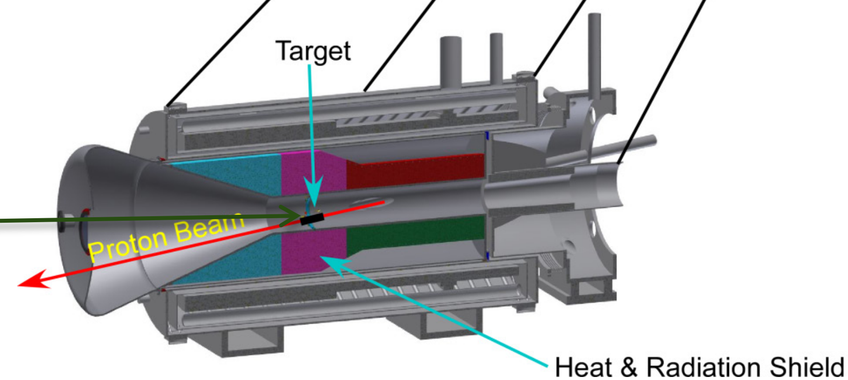


Mu2e Proton Target Station

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



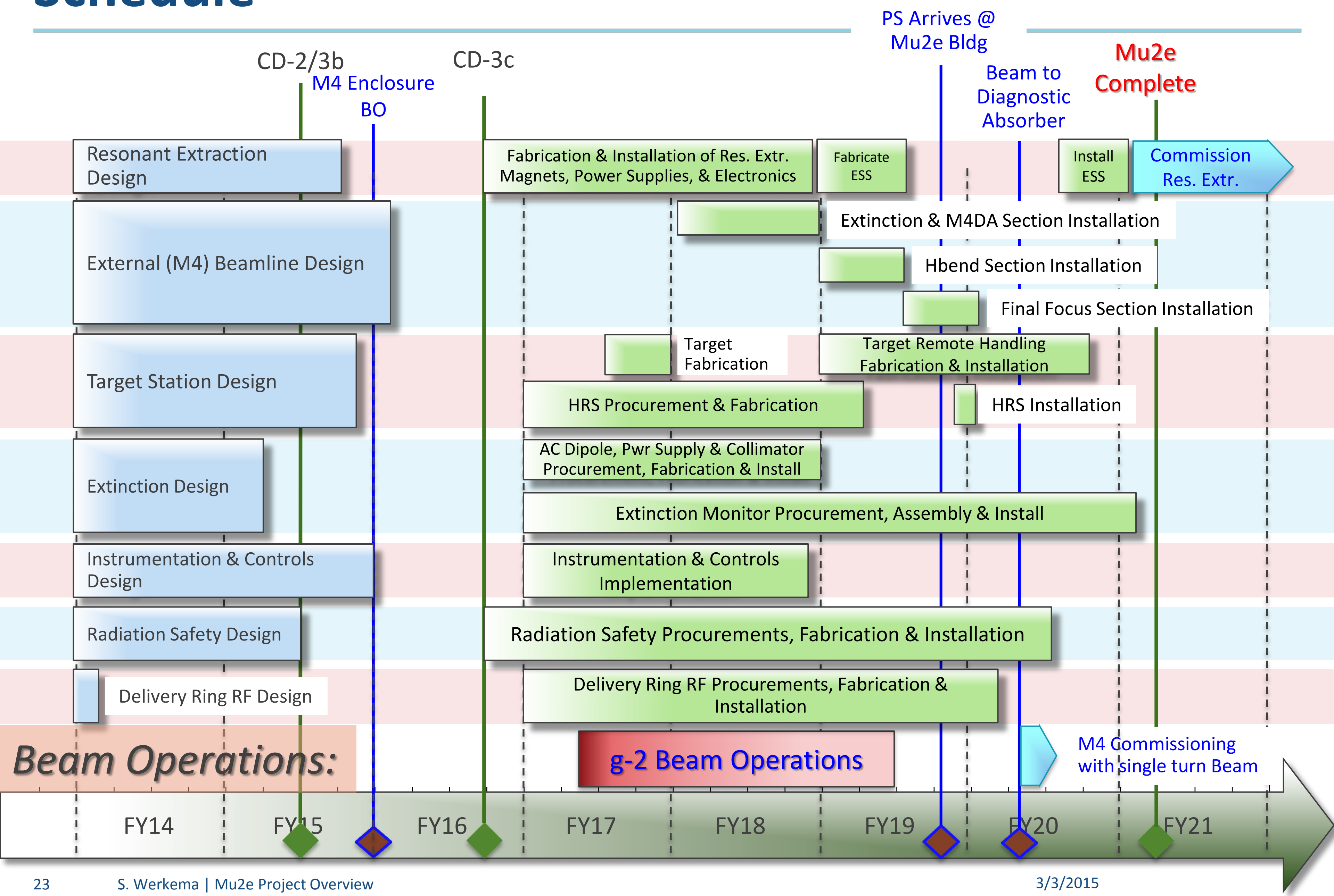




Details in talk by Rick Coleman

Schedule

Schedule



PS Arrives @ Mu2e Bldg
CD-2/3b
M4 Enclosure BO
CD-3c
Beam to Diagnostic Absorber
Mu2e Complete
Resonant Extraction Design
Fabrication & Installation of Res. Extr. Magnets, Power Supplies, & Electronics
Fabricate ESS
Install ESS
Commission Res. Extr.
External (M4) Beamline Design
Extinction & M4DA Section Installation
Hbend Section Installation
Final Focus Section Installation
Target Station Design
Target Fabrication
Target Remote Handling Fabrication & Installation
HRS Procurement & Fabrication
HRS Installation
Extinction Design
AC Dipole, Pwr Supply & Collimator Procurement, Fabrication & Install
Extinction Monitor Procurement, Assembly & Install
Instrumentation & Controls Design
Instrumentation & Controls Implementation
Radiation Safety Design
Radiation Safety Procurements, Fabrication & Installation
Delivery Ring RF Design
Delivery Ring RF Procurements, Fabrication & Installation
Beam Operations:
g-2 Beam Operations
M4 Commissioning with single turn Beam
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

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)

Schedule for Today

~~Project Overview~~	~~Steve Werkema~~	~~8:15-8:40~~
Target Hall Overview	Rick Coleman	8:40-9:10
Remote Handling - Overview	Ryan Schultz	9:10-9:30
MARS analysis, Radiation maps	Vitaly Pronskikh	9:30-9:50
Radiological Issues	Tony Leveling	9:50-10:15
Break		10:15-10:30
Remote Handling - Horizontal Scheme	Mike Campbell	10:30-11:15
Discussion		11:15-12:00
Lunch		12:00-1:00
Remote Handling – Overhead Scheme	Mike Campbell	1:00-1:45
Discussion		1:45-2:20
Break		2:20-2:30
Comparisons: Mechanical, Risks, Costs	Ryan Schultz	2:30-3:00
Discussion		3:00-3:30
Reviewers meet	Reviewers	3:30-5:00
Reviewers submit questions to coordinator	Reviewers	5:00

➤ *Tornado Drill*