The Mu2e experiment: Target Extinction Monitor

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Mu2e—the experiment

Extinction

- Beam extinction: Fraction of protons arriving at production target **outside** the pulse time window
- Extinction level of $< 10^{-10}$ required

The Need for Extinction

Background (Radiative pion capture only):

$$N(\xi) = (0.0153 \pm 0.0014) + (0.0247 \pm 0.0003) \times \frac{\xi}{10^{-10}}$$

Assuming **no extinction**:

$$N(\xi = 1) \approx 10^{10}$$

Assuming **extinction of 10^{-10}** :

$$N(\xi = 10^{-10}) = (0.0153 \pm 0.0014) + (0.0247 \pm 0.0003)$$

Extinction in 2 Steps

1. Beam formation directs proton pulses to Mu2e production target
 - Extinction factor $\sim 10^{-4}$ or better
2. Oscillating dipoles (“AC dipoles”) in beamline deflects out-of-time beam
 - Extinction factor $\sim 10^{-7}$ or better

AC Dipole Magnet

Hiring Postdoc!
Eric Prebys (prebys@fnal.gov)
 or see
<https://recruit.ucdavis.edu/app/ly/JPF02131>

Measuring Extinction

Extinction requirement $< 10^{-10}$ (95% C.L.)

4×10^7 protons per pulse

$\Rightarrow$ 1 out of time proton per 250 pulses

6×10^{12} proton/s = 150,000 pulses/s

$\Rightarrow$ Extinction measurement time: 10,000 s

$\Rightarrow 6 \times 10^{16}$ protons on target

2.3×10^{10} particles to set limit

$\Rightarrow$ need to count at least $\approx$ **16 particles per pulse**

Mu2e—Target Extinction Monitor

Extinction Monitor Detector

Pixel Telescope System

Pixel Plane

Pixel Plane

Pixel Tracker

- designed for ≈ 25 protons per pulse (safety margin for 16)
- Need highly efficient track reconstruction
- Low fake track reconstruction rate

Figure 5. The distribution of reconstructed momentum of 10000 single protons.

Extinction Monitor Event Display

Extinction Monitor Event Display

Summary

- Mu2e will improve limit on $R_{\mu e}$ by four orders of magnitude
- Extinction requirement $< 10^{-10}$
- Extinction measurement is important to success
- More information: <http://mu2e.fnal.gov>

Mu2e in this session:

- Mu2e Straw Tracker design from Kate Ciampa and Fawzi Abusalma
- Mu2e Calorimeter clustering studies from Emma Castiglia

Now Hiring for Post-doc positions!! Contact:

- **John Finley** (finley@purdue.edu) or **Matthew Jones** (jones105@purdue.edu) or see <https://jobs.physicstoday.org/jobs/11106208/postdoctoral-research-associate>
- **Eric Prebys** (prebys@fnal.gov) or see <https://recruit.ucdavis.edu/apply/JPF02131>

QUESTIONS?

BACKUP SLIDES

Extinction in 2 Steps

Extinction in 2 Steps

Simulation Results

Fraction of DR extracted beam outside of ± 125 ns:	2.1×10^{-5}
In-time beam transmission:	99.5%
Beam line extinction:	$< 5 \times 10^{-8}$
Total extinction:	1.1×10^{-12}
Extinction Requirement:	$< 1.0 \times 10^{-10}$

Almost two order of magnitude margin

Extinction Monitor Pixels

Count 20-50 particles per pulse
Fully efficient for out-of-time particles
Very low false signal background

**Pixel
tracker**

ATLAS FE-I4b pixel readout chip

- 80x336 pixel array (50x250 μm)
- 25 ns timestamp resolution
- 160 (or 320) MBPS data rate
- Radiation hard (up to 300 Mrad)

Muon ID

Expect 95% protons so why identify muons?

- If we observe a non-zero extinction we need to understand if it is real or fake.
- Possible source of background tracks are beam missing the target, creating penetrating muons that sneak up the filter collimators.
- Muon ID will confirm that observed out-of-time tracks are from non-extinct *beam on target* and not other backgrounds.