FERMILAB-SLIDES-18-082-E

The Mu2e experiment:
Target Extinction Monitor

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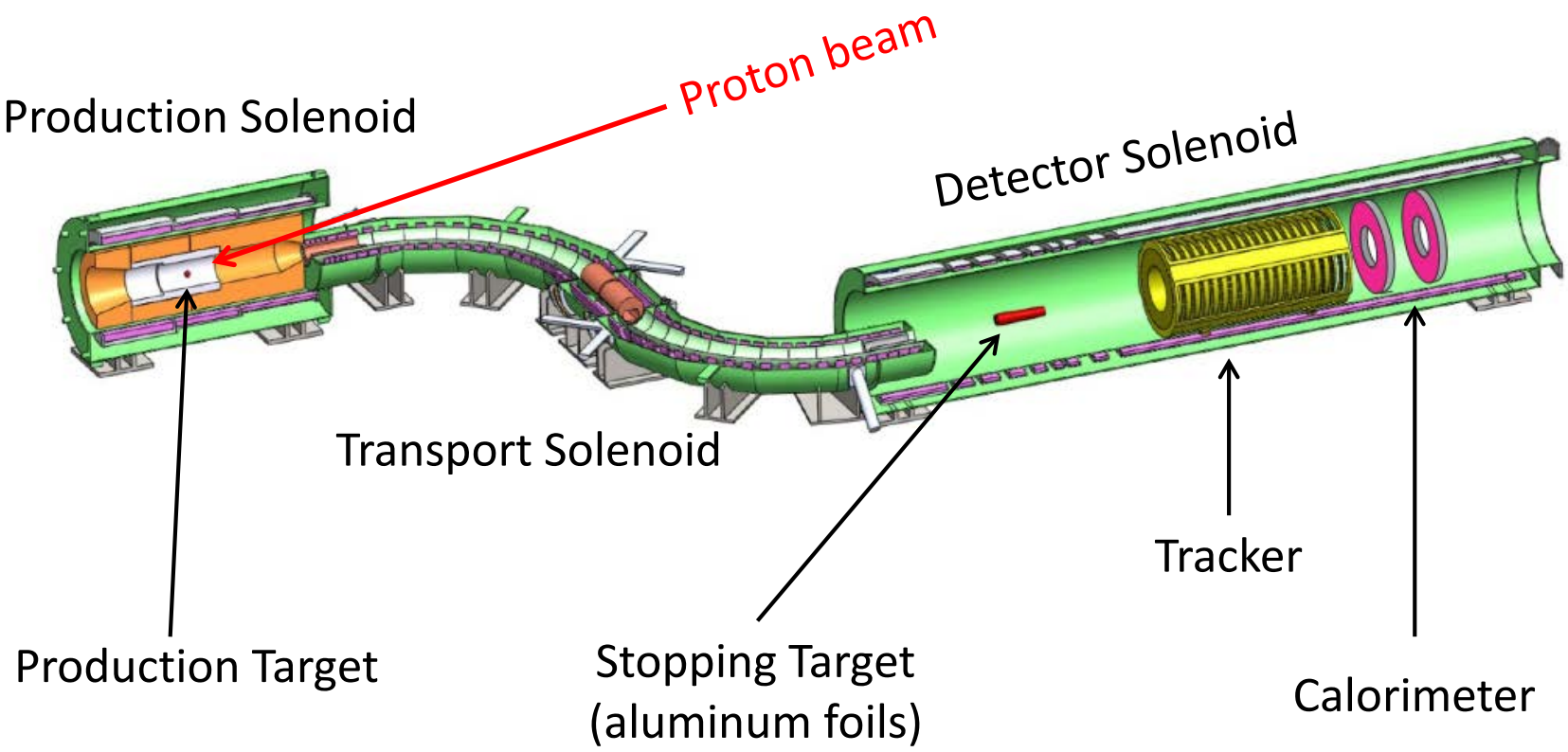
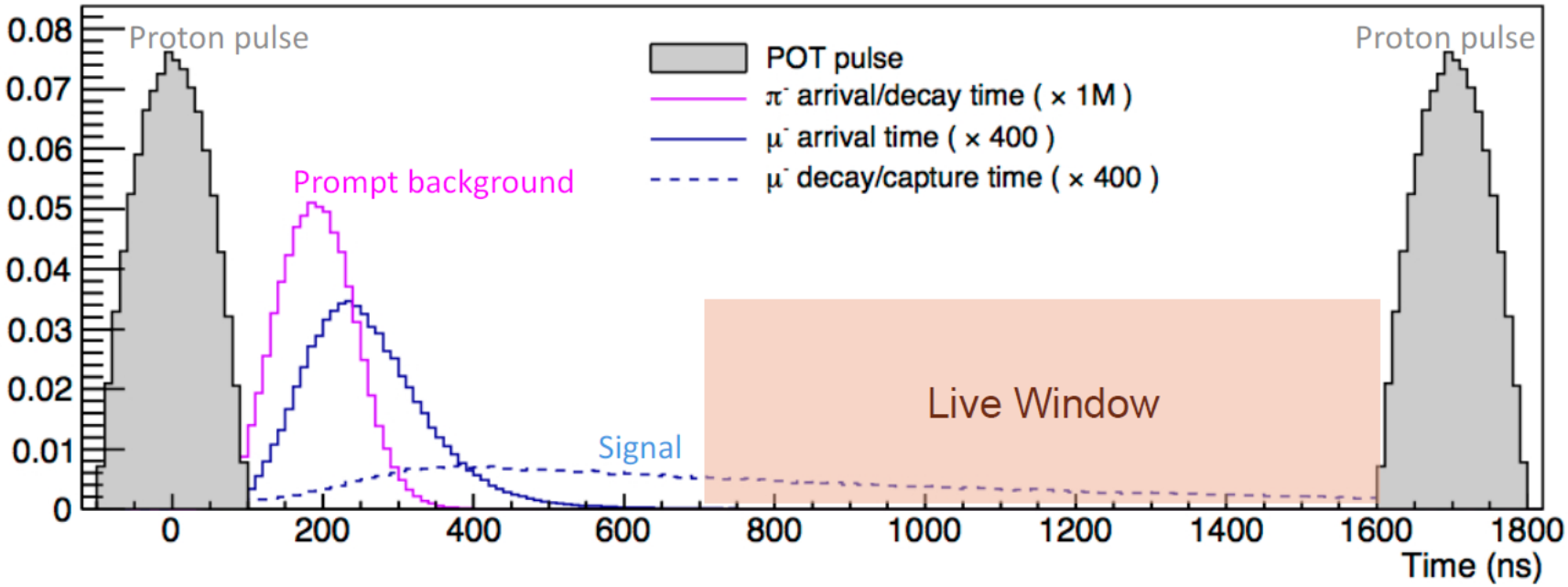
Mu2e—the experiment



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):

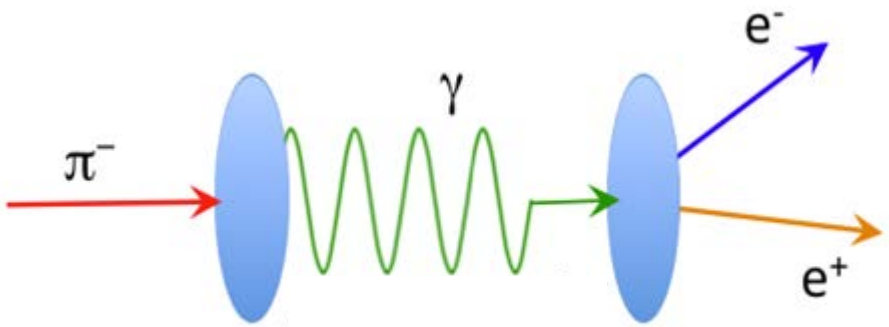
$$N(\xi) = (0.0153 \pm 0.0014) + (0.0247 \pm 0.0003) \times \frac{\xi}{10^{-10}}$$

Assuming ***no extinction***:

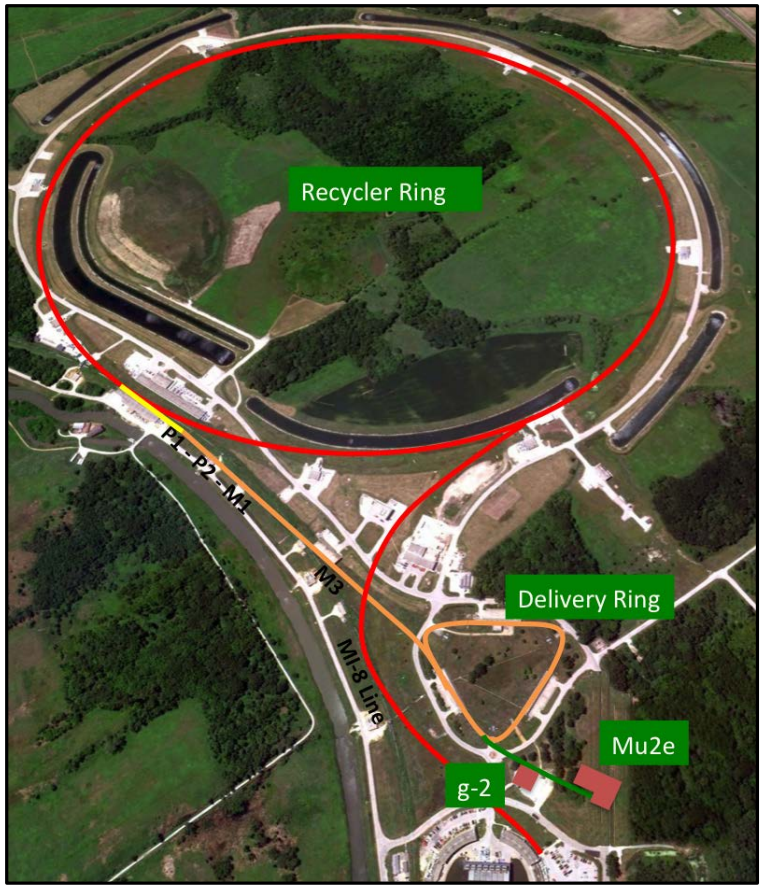
$$N(\xi = 1) \approx 10^{10}$$

Assuming ***extinction of*** $\mathbf{10^{-10}}$:

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

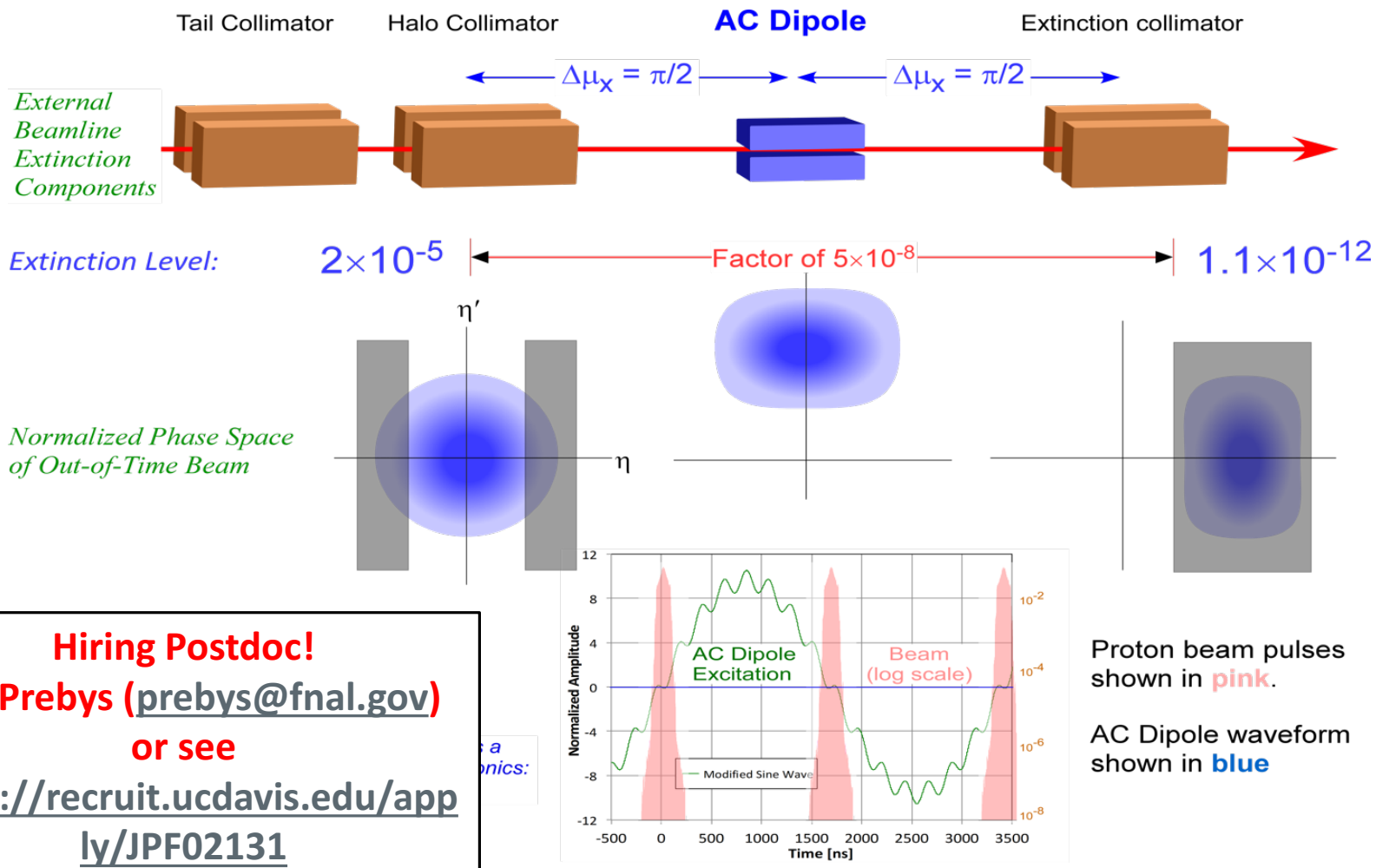


Extinction in 2 Steps



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



Proton beam pulses shown in pink.

AC Dipole waveform shown in blue

Hiring Postdoc!
Eric Prebys (prebys@fnal.gov)
or see
https://recruit.ucdavis.edu/apply/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

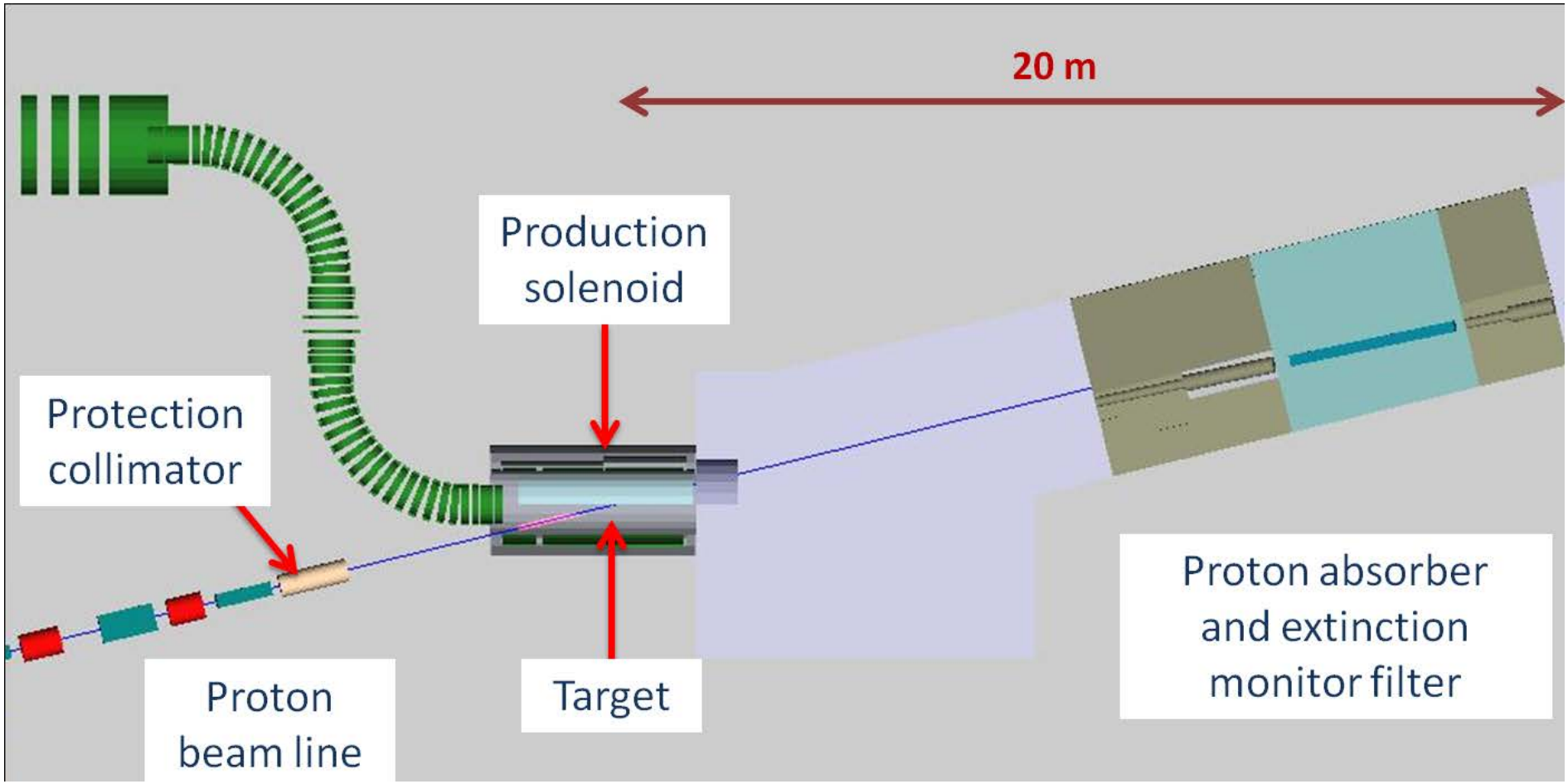
$\Rightarrow$ Extinction measurement time: $10{,}000$ s

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

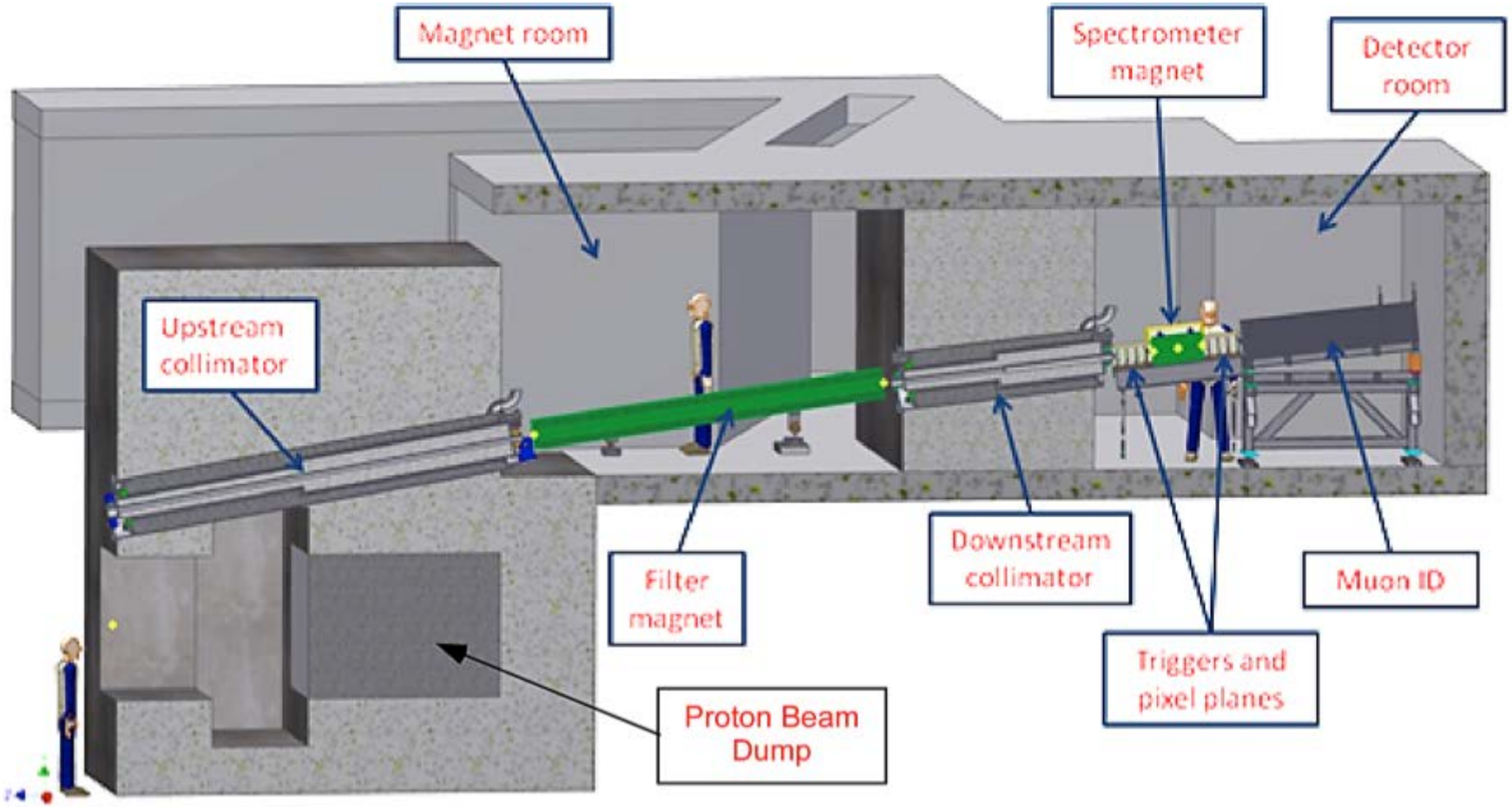
2.3×10^{10} particles to set limit

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

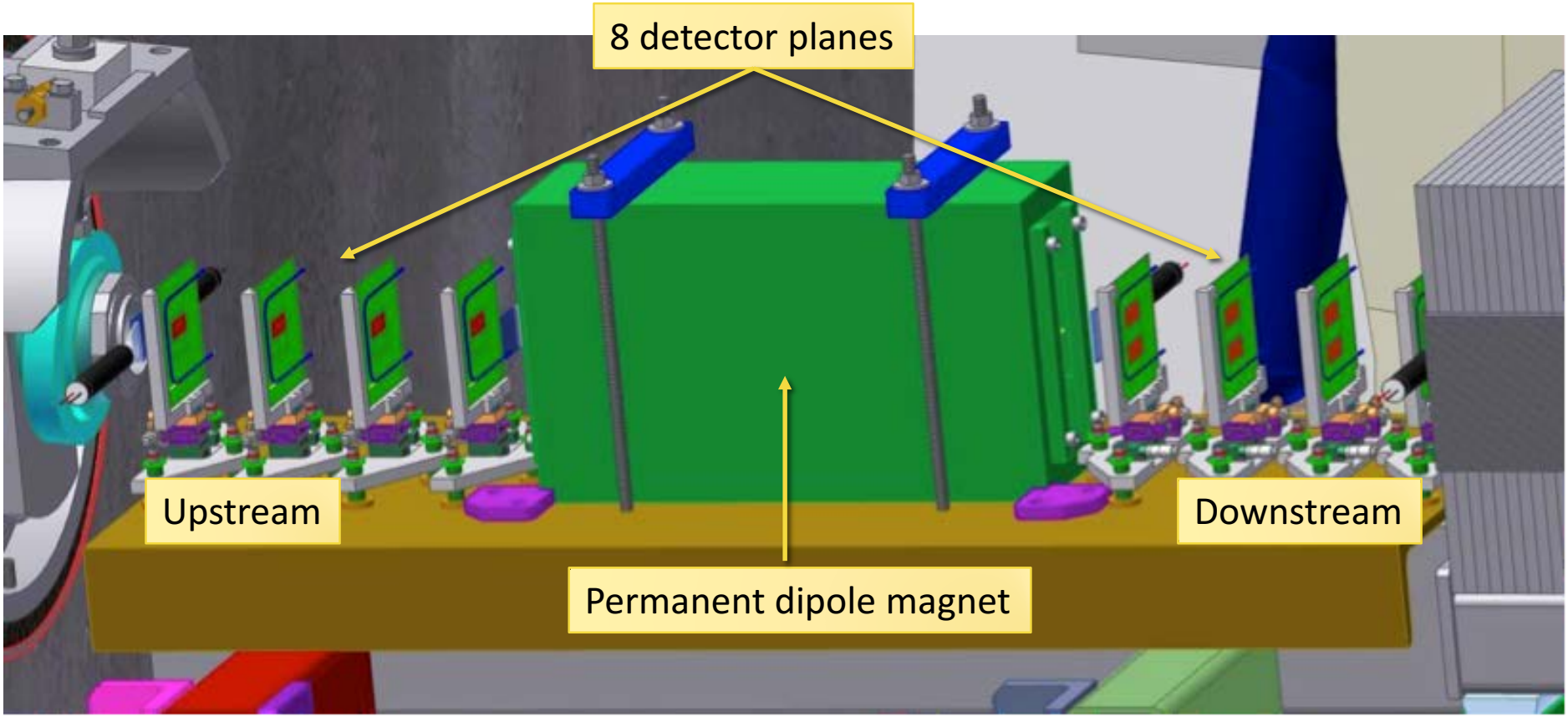
Mu2e—Target Extinction Monitor



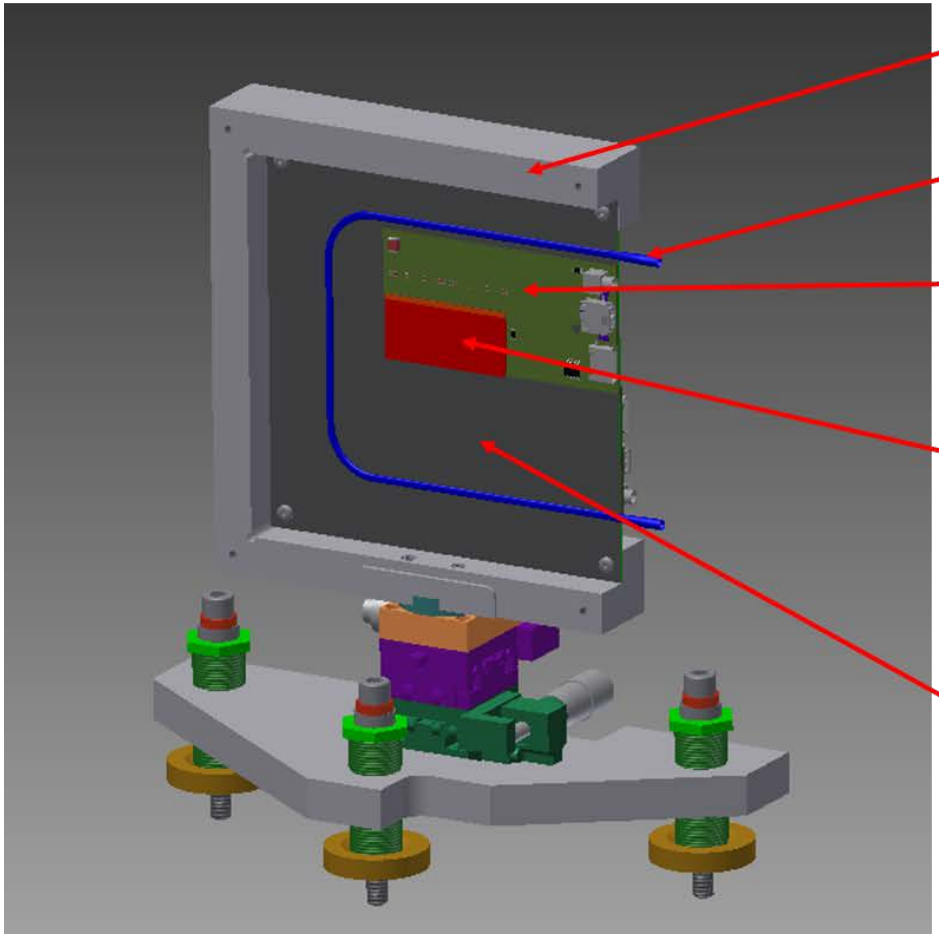
Extinction Monitor Detector



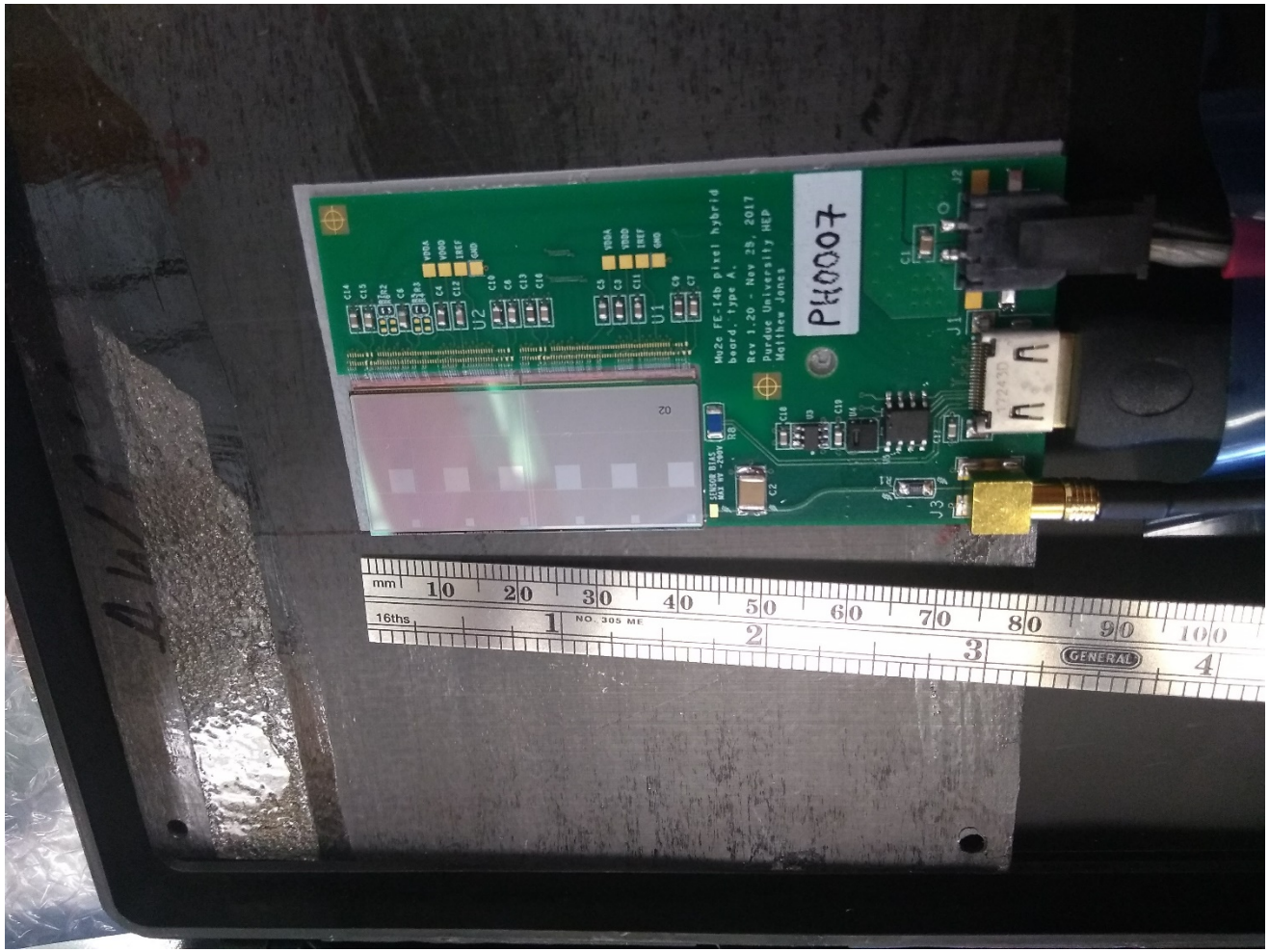
Pixel Telescope System



Pixel Plane


Bracket
Cooling tube
Pixel “hybrid” board
Bump-bonded sensor/readout chip module
TPG sheet
(heat speader)

Pixel Plane


PH0007
Mu2e FE-I4b pixel hybrid board, type A.
Rev 1.20 - Nov 28, 2017
Purdue University HEP
Matthew Jones
mm
16ths
GENERAL

Pixel Tracker

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

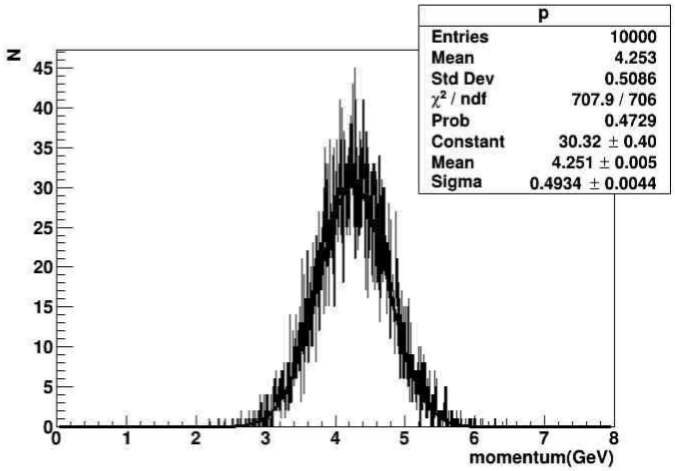
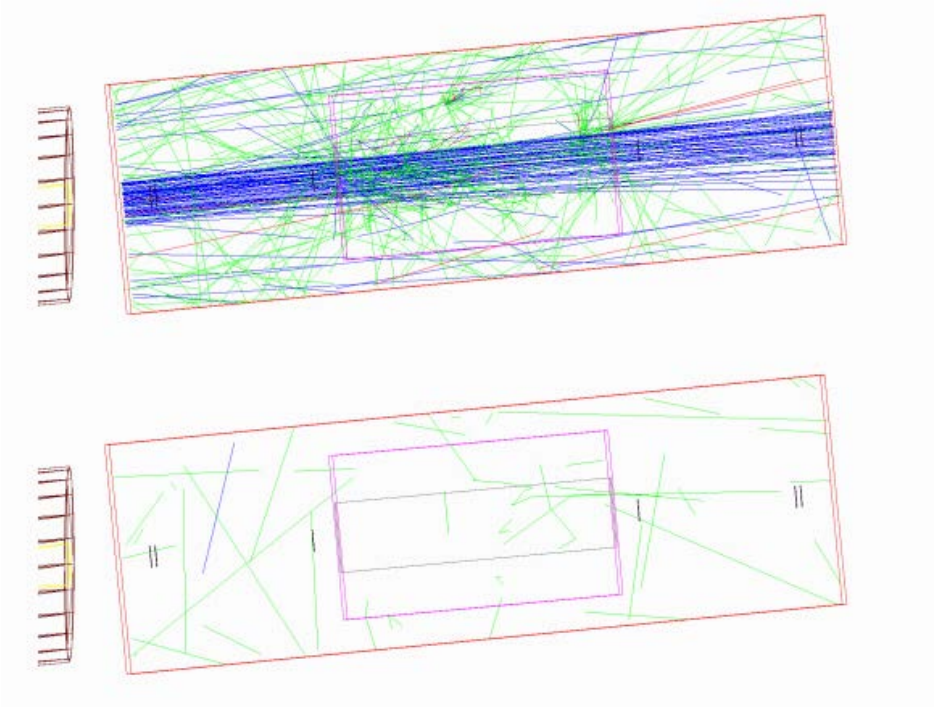
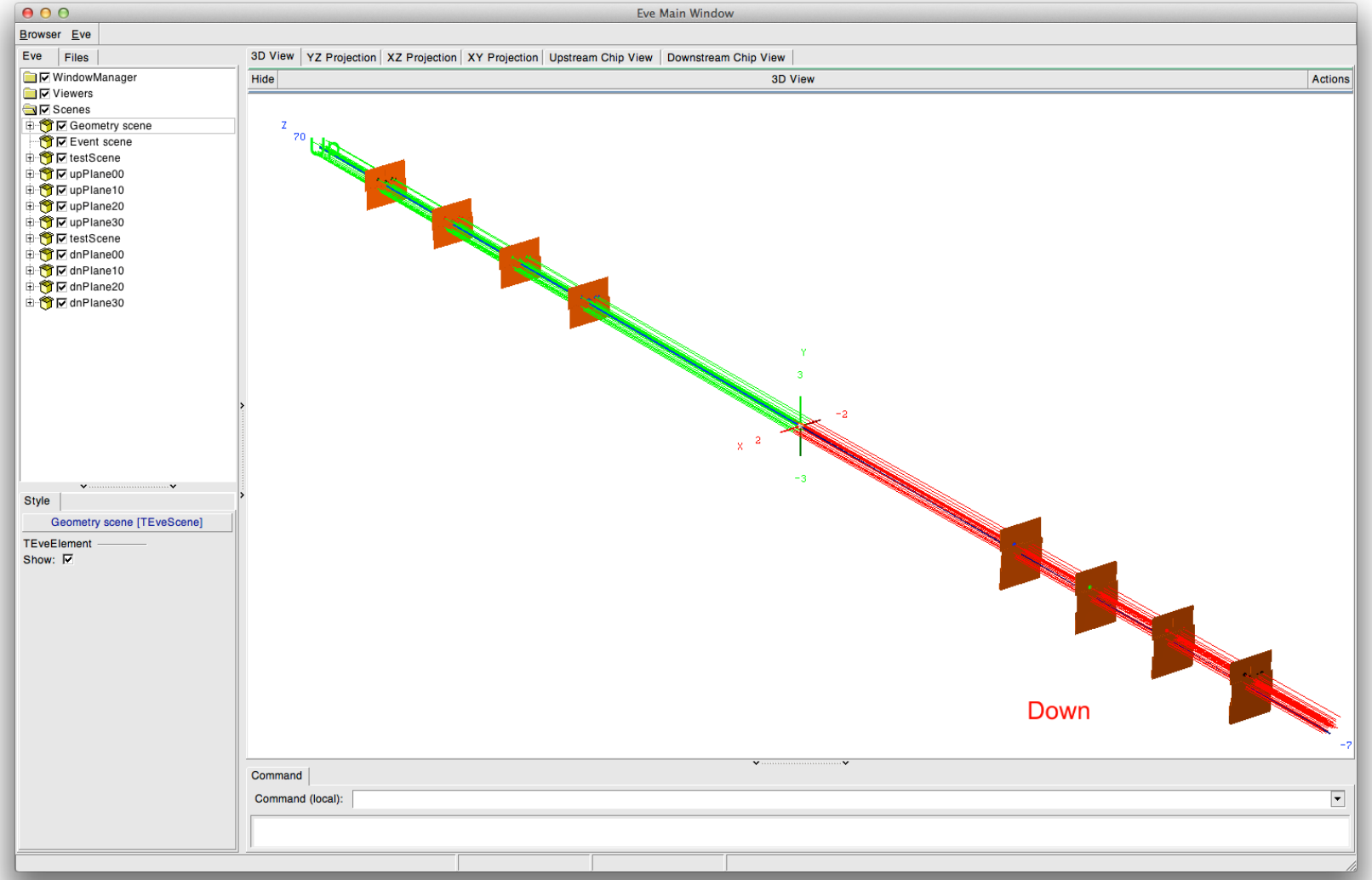


Figure 5. The distribution of reconstructed momentum of 10000 single protons.



Extinction Monitor Event Display



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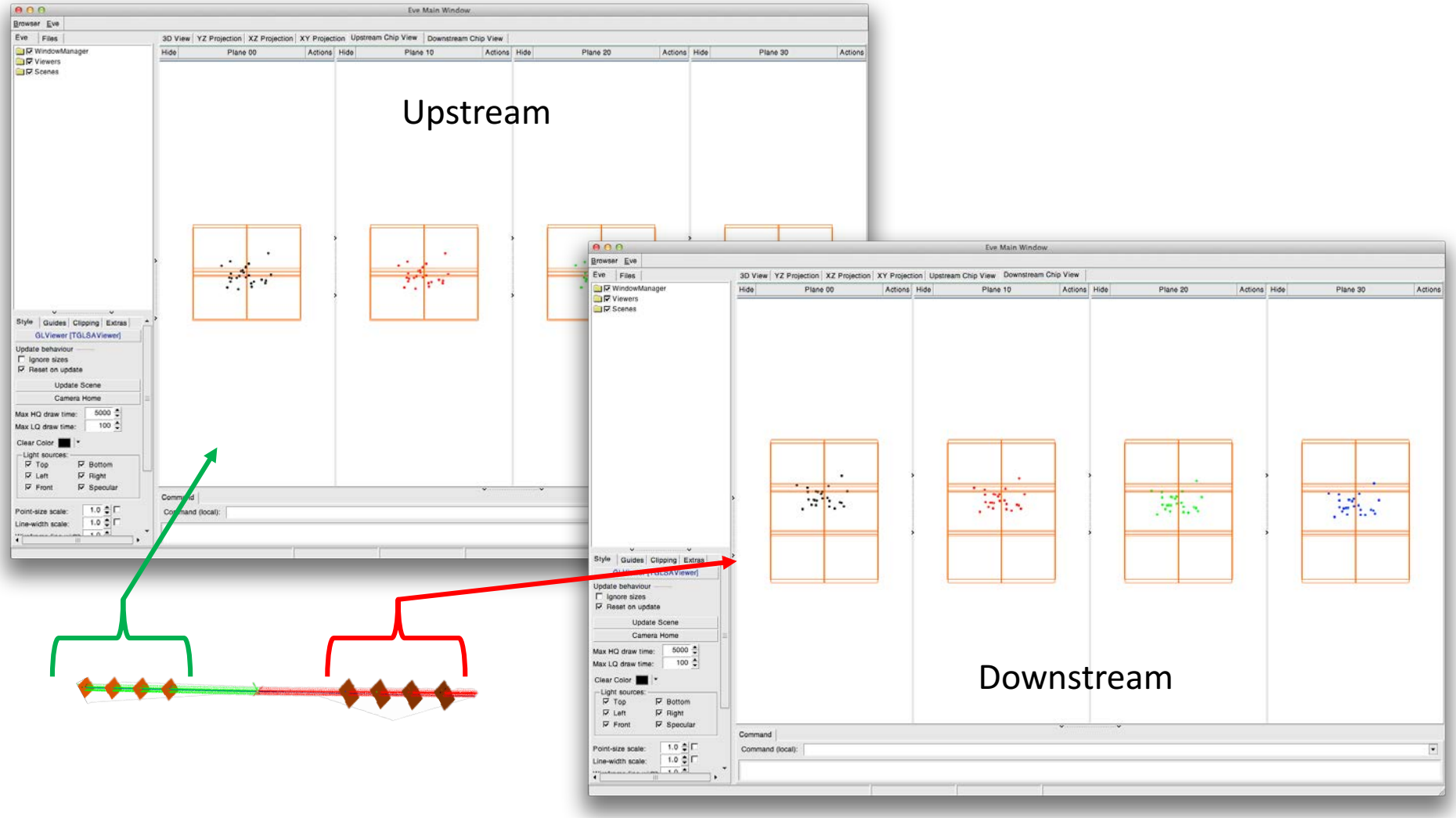


Summary

- 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

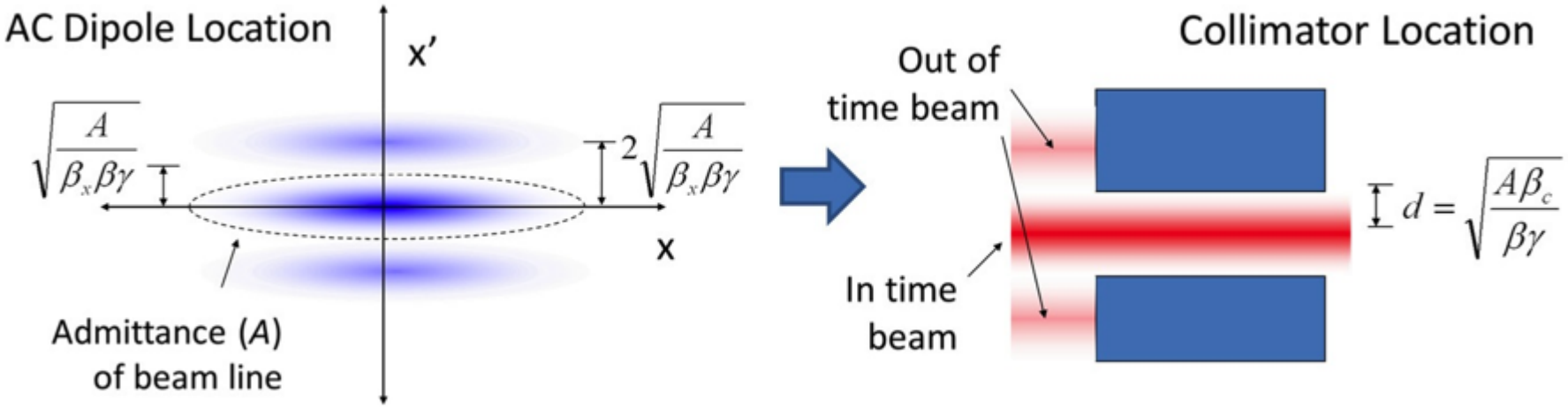
Now Hiring for Post-doc positions!! Contact:

- **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**

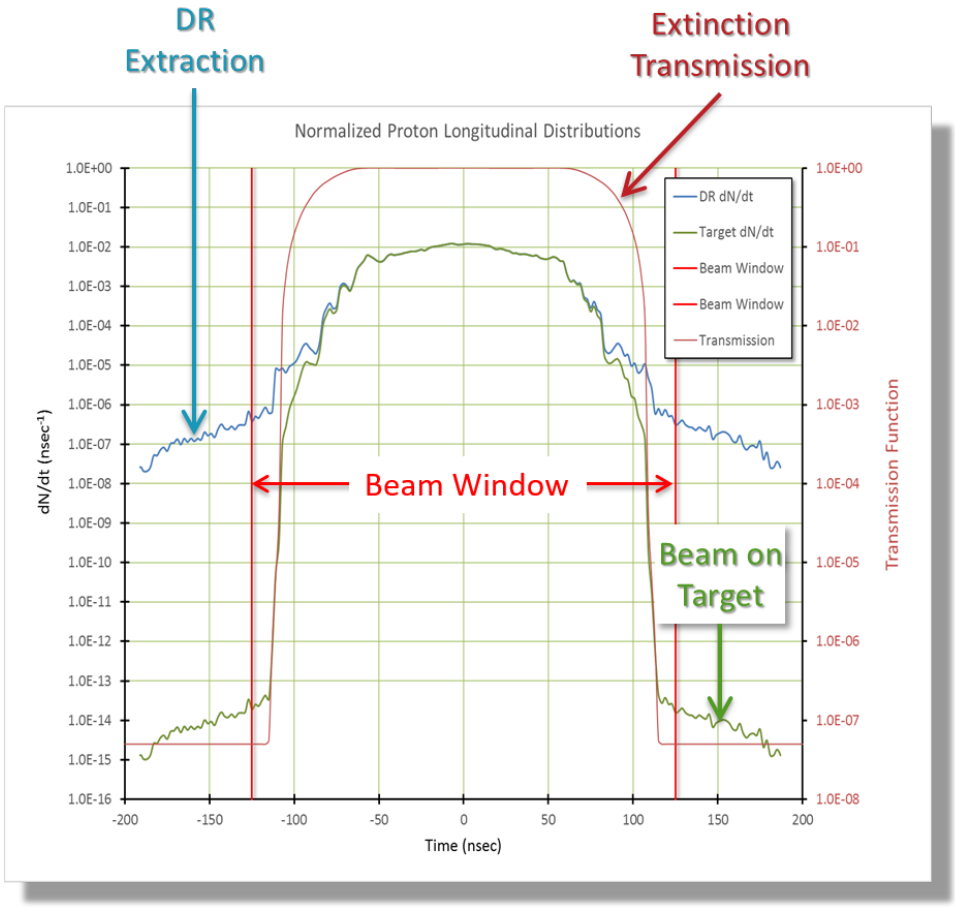
QUESTIONS?

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:	$<5\times10^{-8}$
Total extinction:	1.1×10^{-12}
Extinction Requirement:	$<1.0\times10^{-10}$

Almost two order of magnitude margin

Extinction Monitor Pixels

Count 20-50 particles per pulse

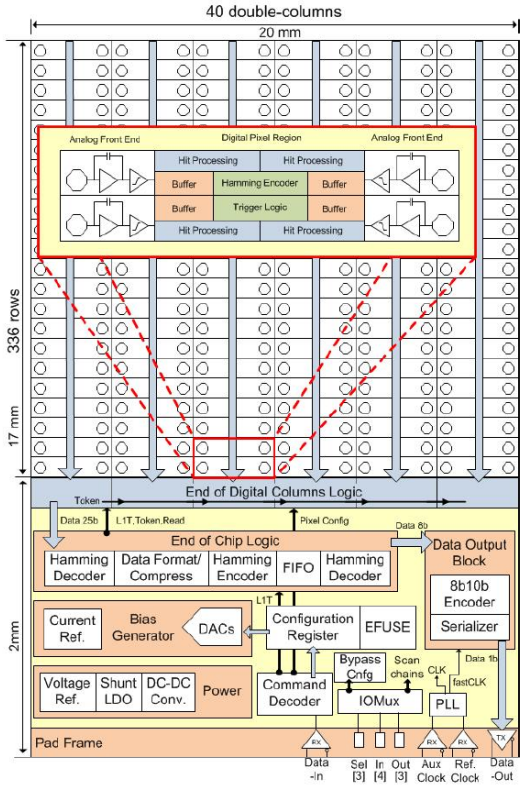
Fully efficient for out-of-time particles

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.