Holographic Synchrotron Radiation Emission Spectroscopy

A concept for a Mu2e-II detector

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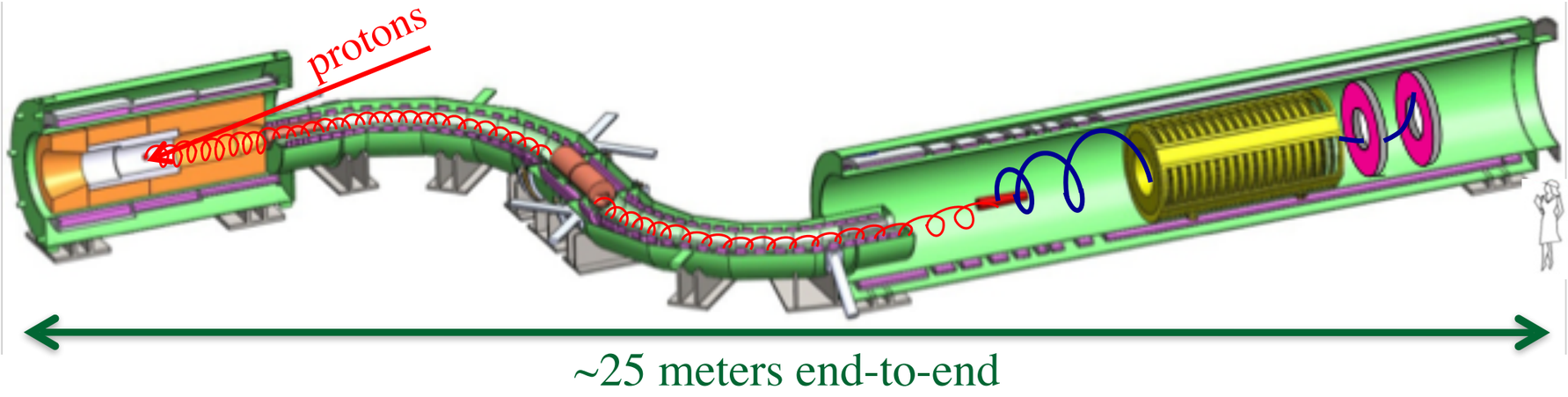
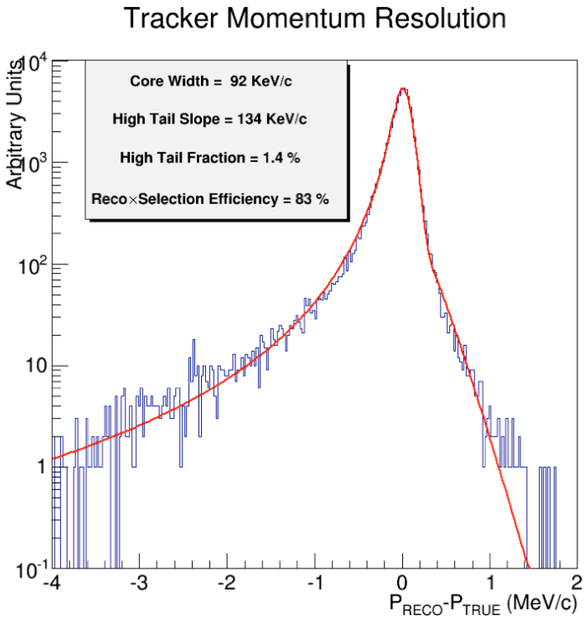
Overview: Mu2e @ FNAL

- Lepton Flavor and Lepton Number Violation search with sensitivity of 3×10^{-17}: $\mu^-\rightarrow e^-$ (and $\mu^-\rightarrow e^+$) conversion
- 4 orders of magnitude improvement over existing limits. First run in 2027
- Signal: ~104 MeV electron (or 92 MeV positron)
- Aim for ~zero background search. Key is the energy resolution of the straw tracker detector



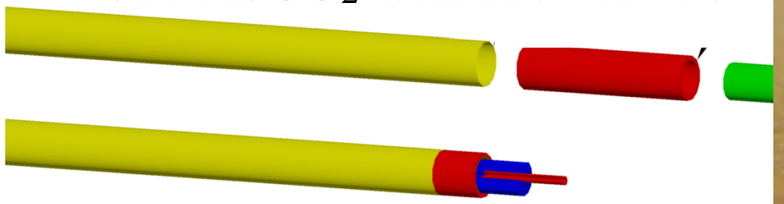


Tracker: Straw Tubes in Vacuum

1 Straws: 5 mm OD; 15μm metaliz

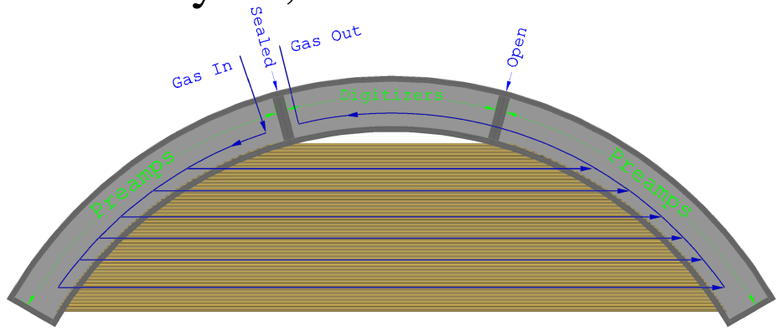
Read out at both ends (time divis

80/20 Ar/CO_2 with HV<1500V

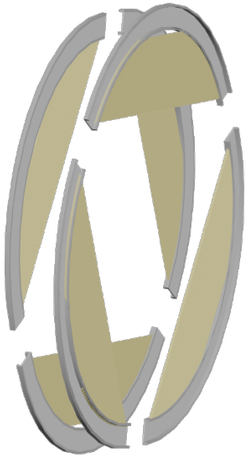


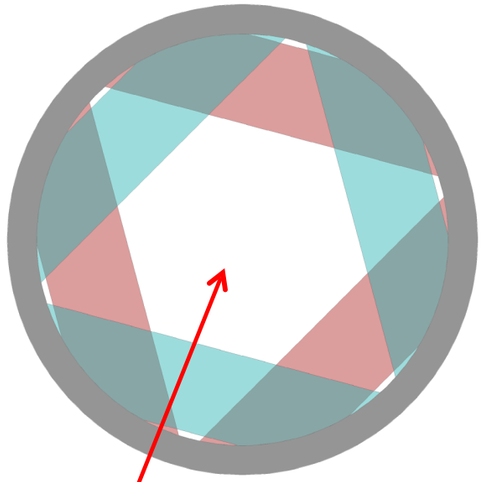
2

Panel: 2 Layers, 48 straws each



3 Plane: 6 panels; self supporting

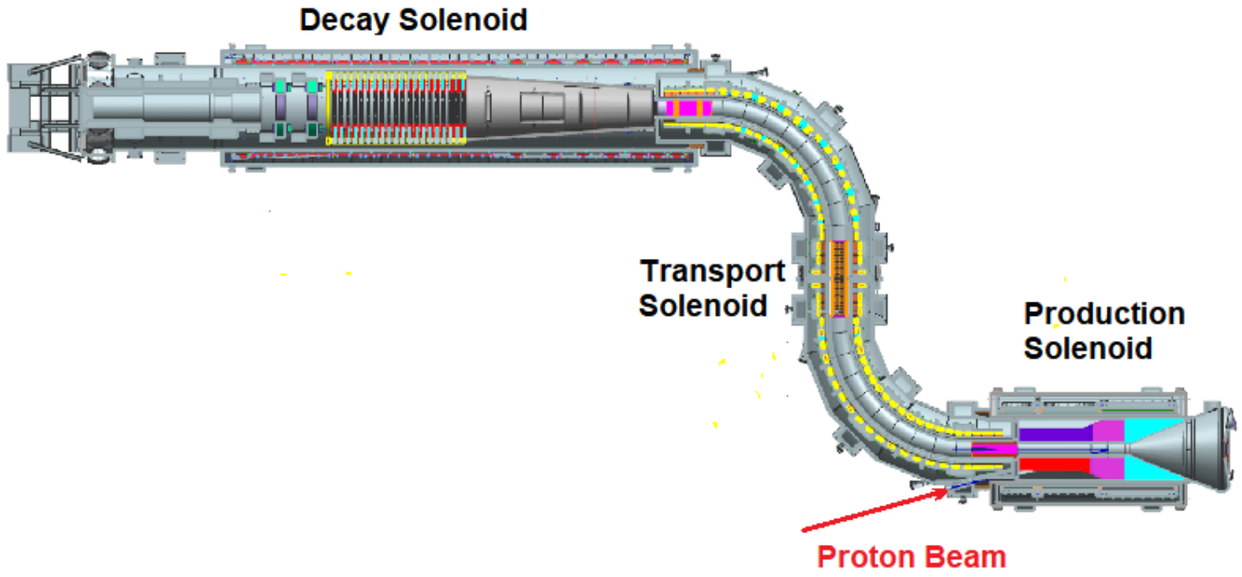


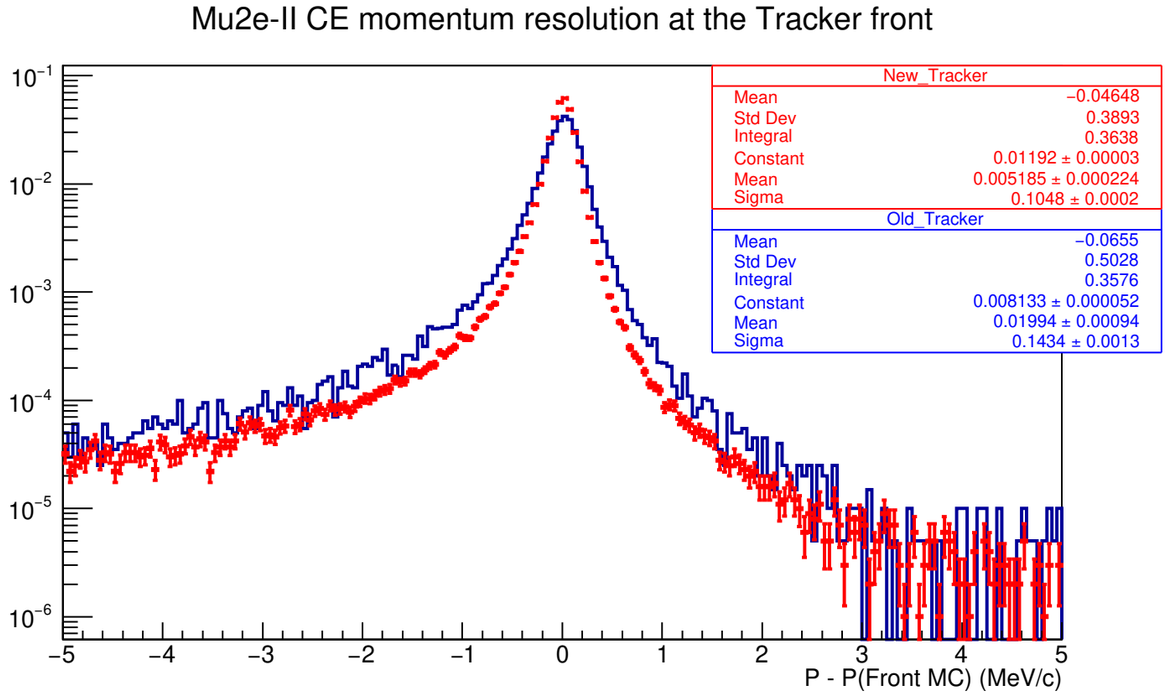


Tracker sits in Vacuum

Mu2e-II

- Aims to improve the sensitivity by another order of magnitude
- Achieve by increasing beam intensity (PIP-II), reducing tracker material budget (by a factor of 2). Hard problem !
- R&D towards implementation endorsed by P5

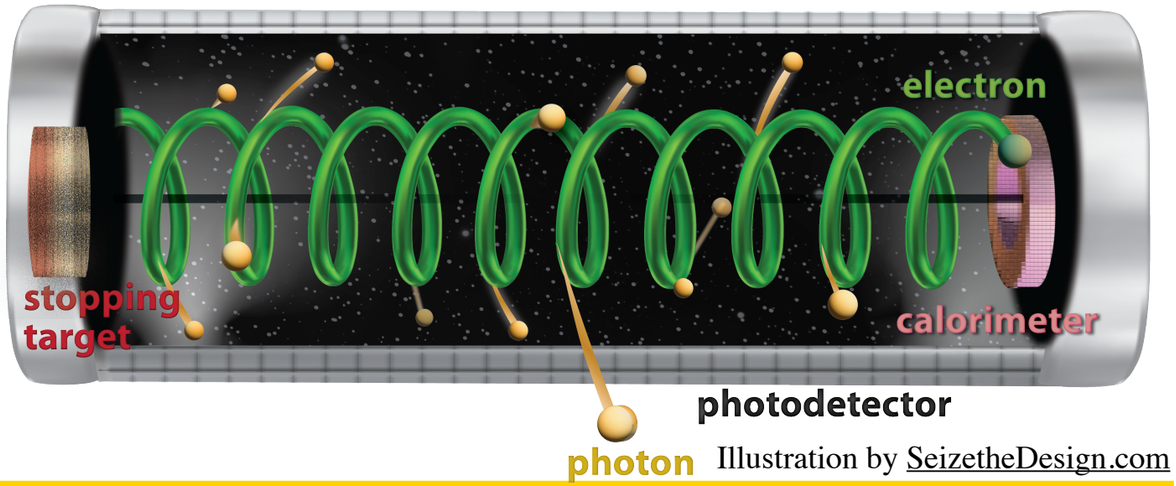




arXiv:2203.07569 [hep-ex]

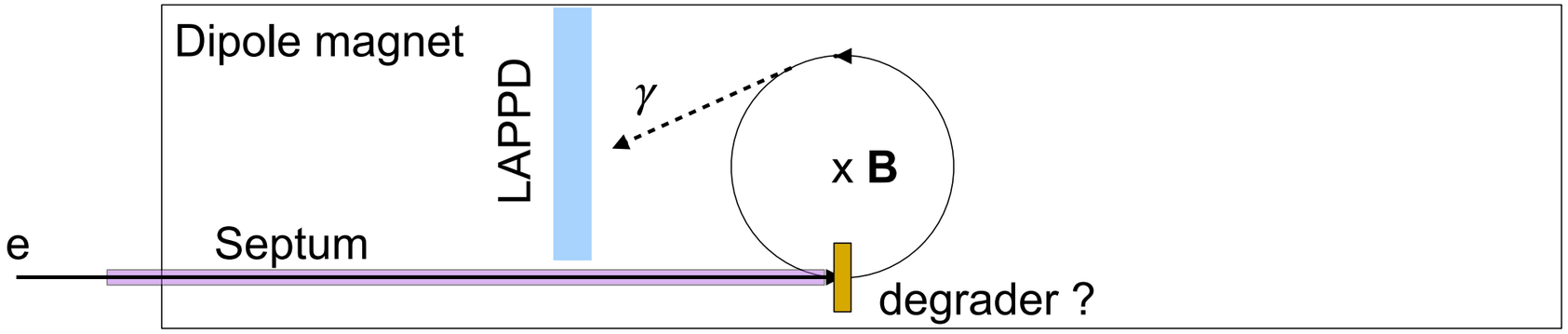
Holographic Synchrotron Radiation Emission Spectroscopy

- Since the material budget limits the resolution of a tracker detector, what about a material-free detector ?
- Enter HSRES: “holographic” reconstruction of the electron trajectories using synchrotron radiation
  - Cutsail, Vonk, Singh, and YGK [arXiv:2409.02878]
- Simulations demonstrate potential 50 keV resolution and high efficiency, exceeding Mu2e-II specs
- Key technology is LAPPD
  - σ(t)~50 psec, σ(x)~3 mm
- Would like a technical demonstration



HSRES Demonstrator Cartoon

- Demonstrate in a “warm” iron magnet, e.g. 18D72 in ESA
- Inject single electrons through a septum inside the gap of the magnet ~perpendicular to the magnetic field
- Electrons spiral in the magnetic field with a period of 3.5 nsec, emitting synchrotron photons towards an LAPPD detector
- Signal is periodic with T=3.5 nsec, with location on the correlated to time
- Demonstrate LAPPD performance in a magnetic field, periodicity of the signal, time resolution, energy spectrum



Requirements for HSRES Demonstrator

- Ideally ~100 MeV “single” electrons
  - Rates of ~few per nsec are acceptable
- ~2T field, will probably need to map the active volume (or use field maps from my thesis :)
- Magnet with a large gap (e.g. 18D72), magnetic septum, beam delivery
- LAPPD readout, mounting, etc.

Type	Dipole
Name	18D72
Length (cm)	182.88
Aperture (cm) x:	15.24
y:	45.72
Pole radius (cm)	
Center x (cm)	1.16
Center y (cm)	-5.17
Center z (cm)	620.75
Pitch (°)	-2.322
Roll (°)	0.017
Yaw (°)	-0.761
$\int Bdl$ (pole, kG-m)	43.105
Bend angle (°)	-3.7
Current (Amps)	2658.8

Questions

- Can LESA produce/deliver ~100 MeV electrons ?
- If not, can one realistically degrade the beam ? (c.f. Tom Markiewicz's talk)
- If not, can this be done in e.g. FFTB ?
- Are ESA magnets available ?
- How does the logistics work (installation, services, etc) ?