ENHANCING PROTON EXTRACTION FOR THE MU2E EXPERIMENT

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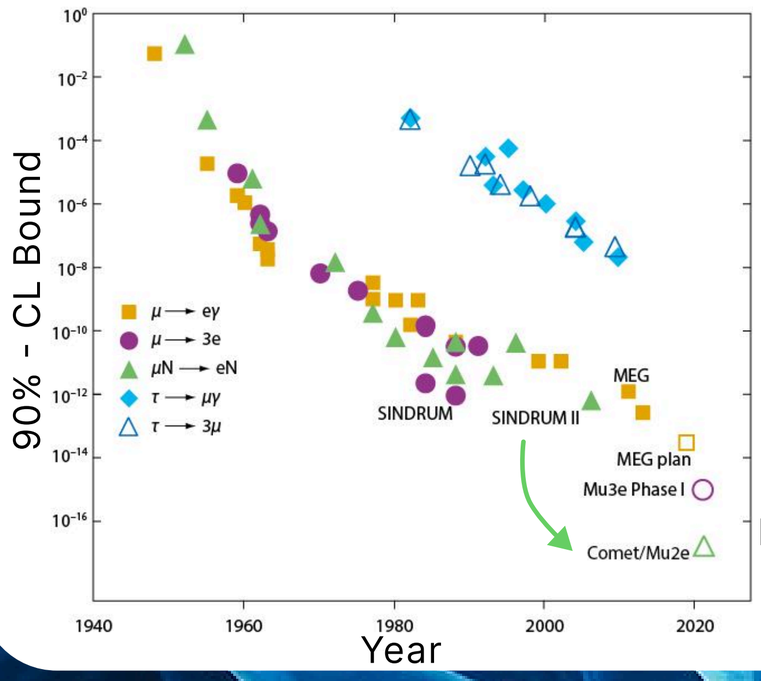
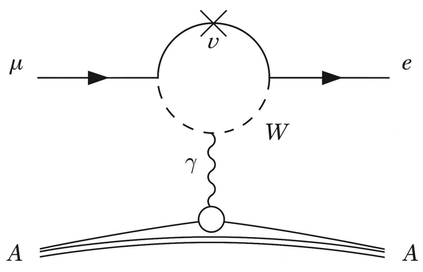
On behalf of the Mu2e Collaboration

Mu2e Physics goal



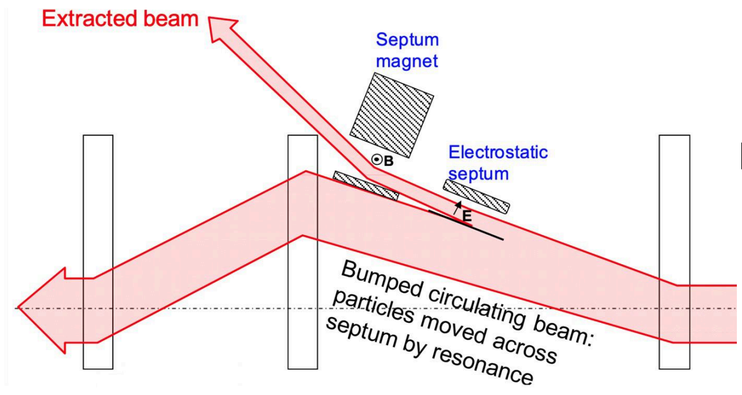
Search for neutrinoless muon-to-electron conversion as a signature of new physics beyond SM



Improvement of current single event sensitivity by a factor 10^4

Mu2e requirements

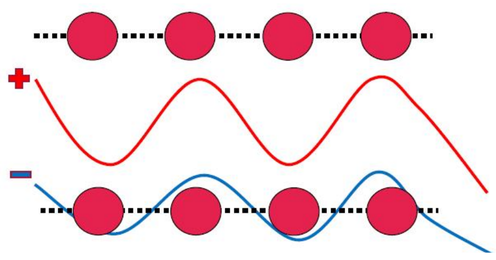
1. High statistics: highest intensity muon beam in the world
2. High background rejection: **pulsed proton beam structure to reject Radiative Pion Capture**
3. High detector precision



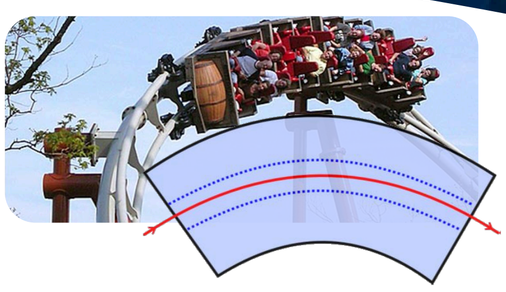
The pulsed proton beam is extracted via resonant extraction. Issue: a fraction of the beam interacts with the septum material, causing about 1.5% of beam losses and unwanted radiation damage. **[1]**

Septum shadowing with bent crystals

1. **Channeling**: particles aligned with atomic planes are bound to oscillate in the atomic potential well. Channeling works very well with **positively charged** particles such as protons.



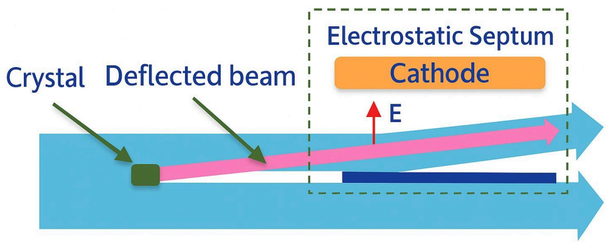
2. In a **bent crystal** channeled particles **follow the curvature** of the lattice plane which acts as a sort of wave-guide.



Energy (GeV)	Deflection (μrad)	Size (mm)	Equivalent dipole (T)	
6500	50	4	271	LHC
8	300-600	3	2.65-5.30	
8	300-600	2	4-8	Mu2e
2000	14000	70	1333	

[2]

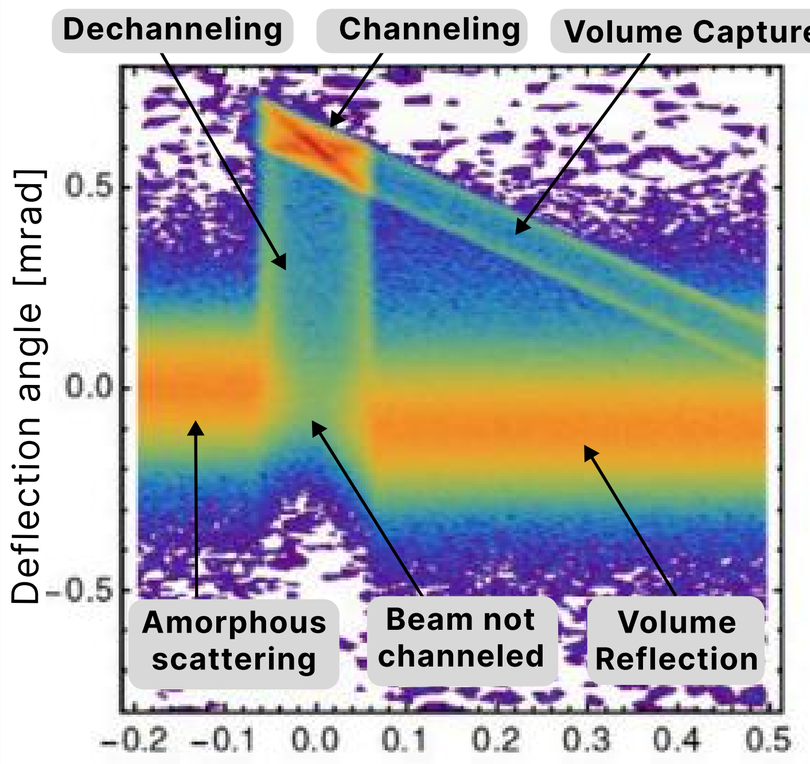
3. Idea: implement an optimized bent crystal upstream of the electrostatic septum to **reduce particle loss**.



4. A large steering power can be obtained in **few millimeters of crystal**, equivalent to that of **hundreds of Tesla** magnetic dipole. This technology is already implemented into LHC.

Simulations

GEANT4 Simulation – Bent Crystal PDF



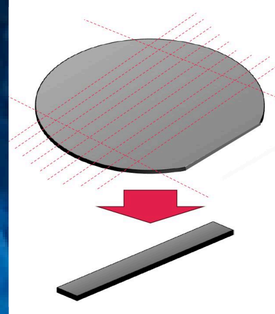
Simulations of a silicon-oriented bent crystal with a 600 μrad bending angle and 3 mm thickness, using Fermilab Delivery Ring beam parameters

A preliminary beam loss reduction of a factor 3 is estimated for a beam with 40 μrad angular divergence.

[2-3]

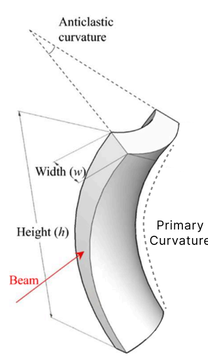
Silicon bent crystal realization

1. Cutting



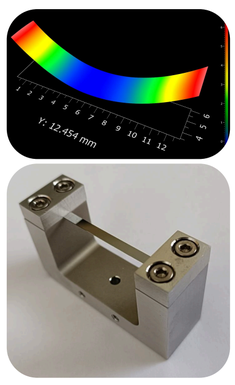
Parallelepiped-shaped samples were obtained with micrometric precision using dicing blades bonded with micro-diamonds.

2. Crystal bending scheme



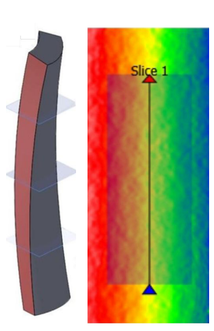
A holder forces the crystal into arched position.
A very uniform secondary anticlastic curvature appear as elastic reaction of silicon.

3. Curvature characterization



A 2D measure of surface profile is achieved with nanometric precision with interferometric profilometer

4. Torsion Characterization



Torsion <10μrad/mm is required for good steering efficiency.
The optical characterization estimates ~5μrad/mm.

5. First beam test scheduled in August 2025 at CERN H8

References:
[1] Mu2e Collaboration, Universe 2023, 9(1), 54.
DOI: 10.3390/universe9010054
[2] V. Nagaslaev, et al., Nucl. Instr. Meth. A, 1058 (2024) 168892.
DOI: 10.1016/j.nima.2023.168892
[3] S. Miscetti, et al., Nucl. Instr. Meth. A, 1073 (2025) 170257.
DOI: 10.1016/j.nima.2025.170257

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