A Next Generation Muon Facility at FNAL

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I won't be talking about an experiment...

… instead, this is a talk about a proposed *Advanced Muon Facility* (AMF) to support a host of experiments.

- What users could we support?
- What will we build?
- What are the chief technical challenges?
- Where can you get involved?

For more technical details...

A New Charged Lepton Flavor Violation Program at Fermilab

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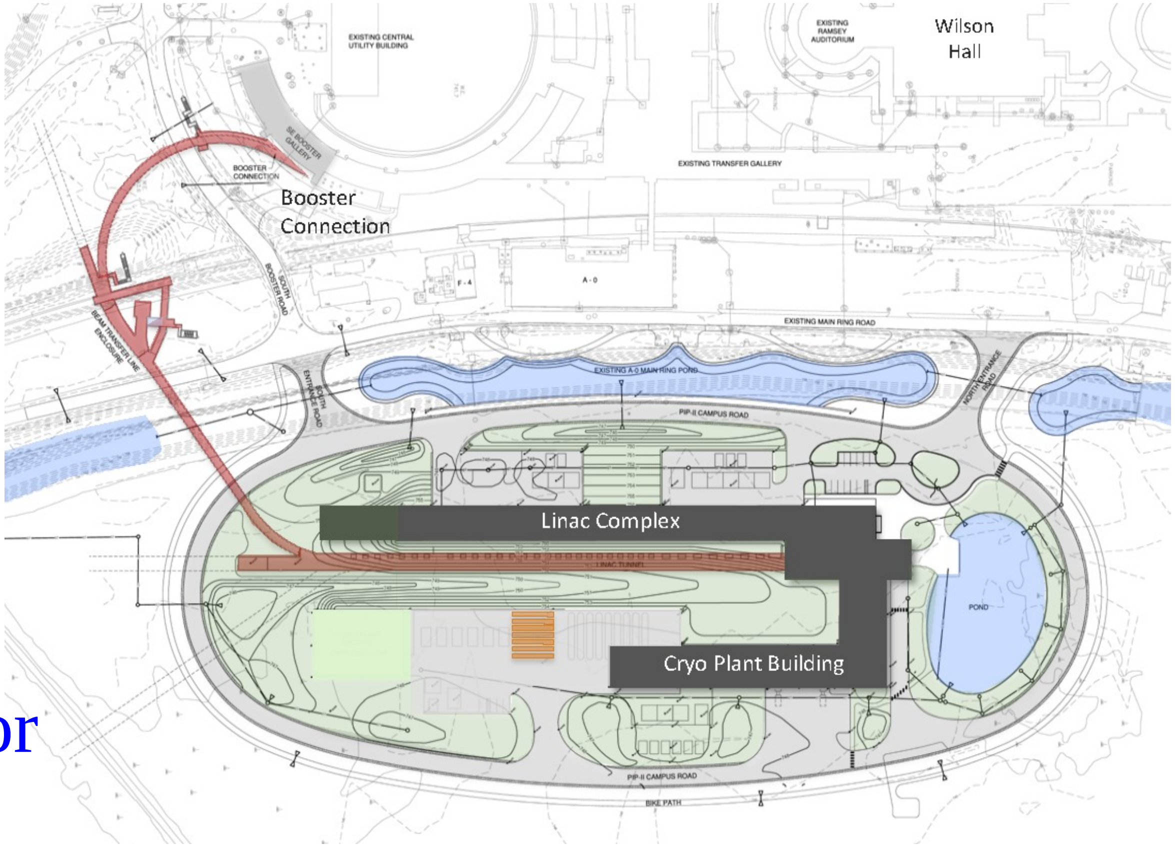
Goals of the AMF

- Utilize the available proton beam enabled by PIP-II that will be unused by LBNF/DUNE
- Provide a flexible facility for future experiments
- Provide muon beams of world-leading intensity for the decades after the current FNAL Muon Campus program (g-2, Mu2e) has run its course
- Build on synergies with the dark matter and muon collider communities

PIP-II is the replacement for the legacy proton source at FNAL

- Under construction
  - CD3!
- 800 MeV H- linac
  - Up to 1.6MW
- LBNF program will only use 1% of the available beam
  - There's ***a lot*** of beam available for other purposes!

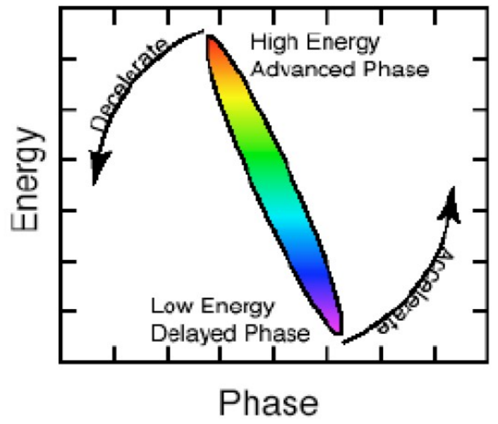


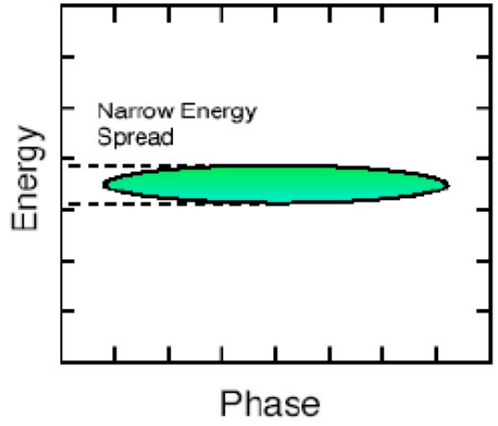
Support for future experiments

- The primary motivation for AMF was CLFV physics:
  - Muon decay experiments
    - mu → 3e, mu → e gamma
    - Factor 100 improvement over MEG-II
  - Muon conversion experiments
    - Factor 100-1000 improvement over Mu2e
    - High-Z targets (very short bunches)
- But there are other possibilities with an intense source!
  - Muonium/Anti-muonium oscillations
  - Muon MDM/EDM source
  - MuSR (industrial users?)
  - Pions/Kaons
- AMF could potentially feed multiple experiments simultaneously!

The Advanced Muon Facility

- Based on the PRISM concept
  - **P**hase **R**otated **I**ntense **S**ource of **M**uons
  - High intensity, short duration proton pulses produce muons with short time duration, but large momentum spread
  - Inject muons into FFA
  - Phase rotation reduces momentum spread
    - Monochromatic muon bunches
    - Eliminate pion contamination
  - Extract beam to experiments

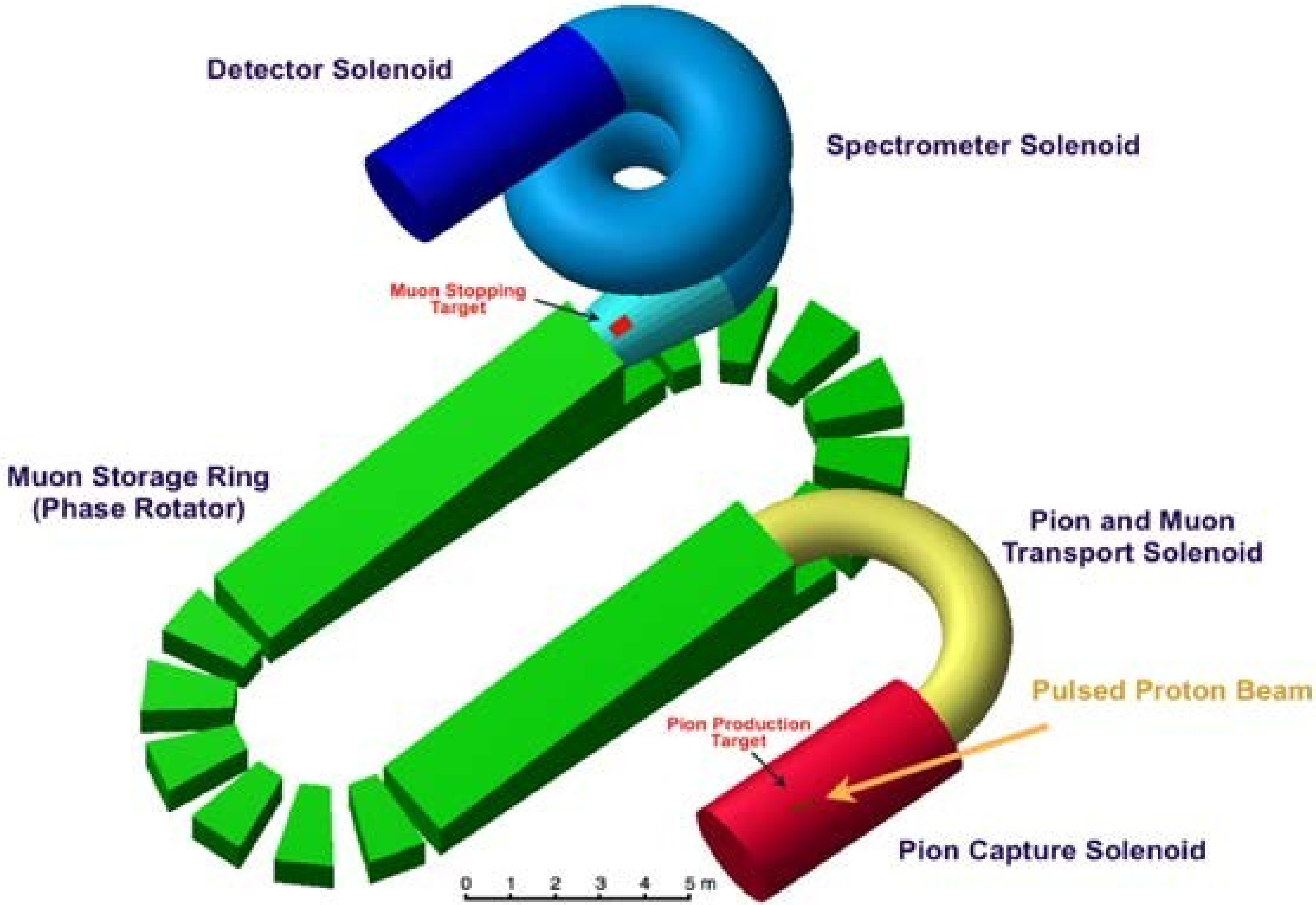




The Advanced Muon Facility

- PIP-II
  - Proton source
- Proton compressor ring
  - Merge proton bunches and compress length
- Production solenoid and target systems
  - House production target
- Muon transport
  - Eliminate LOS from target to experiments
  - Match beam dynamics solenoid $\leftrightarrow$ FFA
- FFA ring
  - Phase rotation $\rightarrow$ monochromator
- Induction linac
  - Reduce bunch energy to minimize target thickness

AMF configured as PRISM/PRIME concept



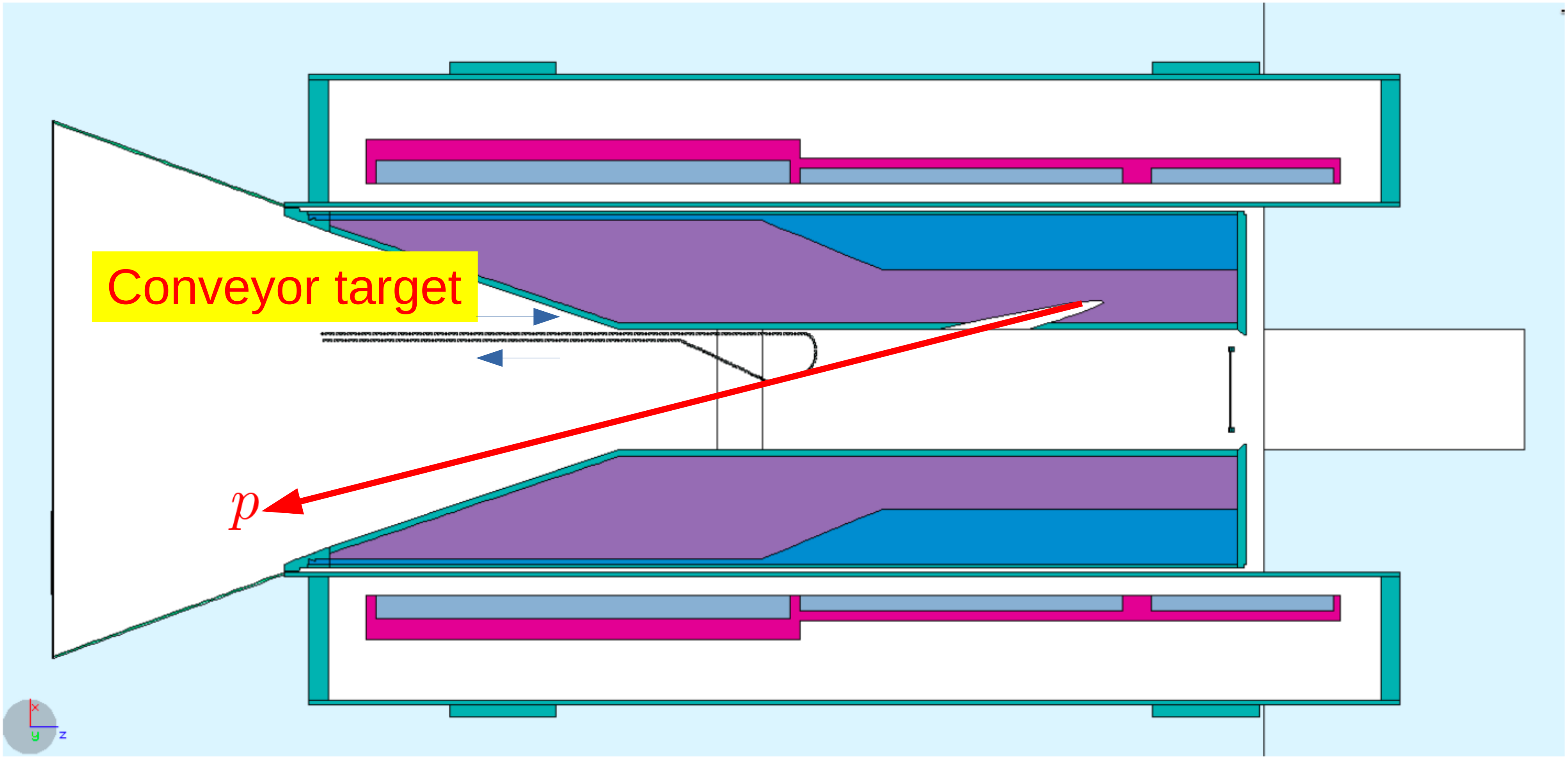
PIP-II, compressor ring, and induction linac not shown

Chief technical challenges

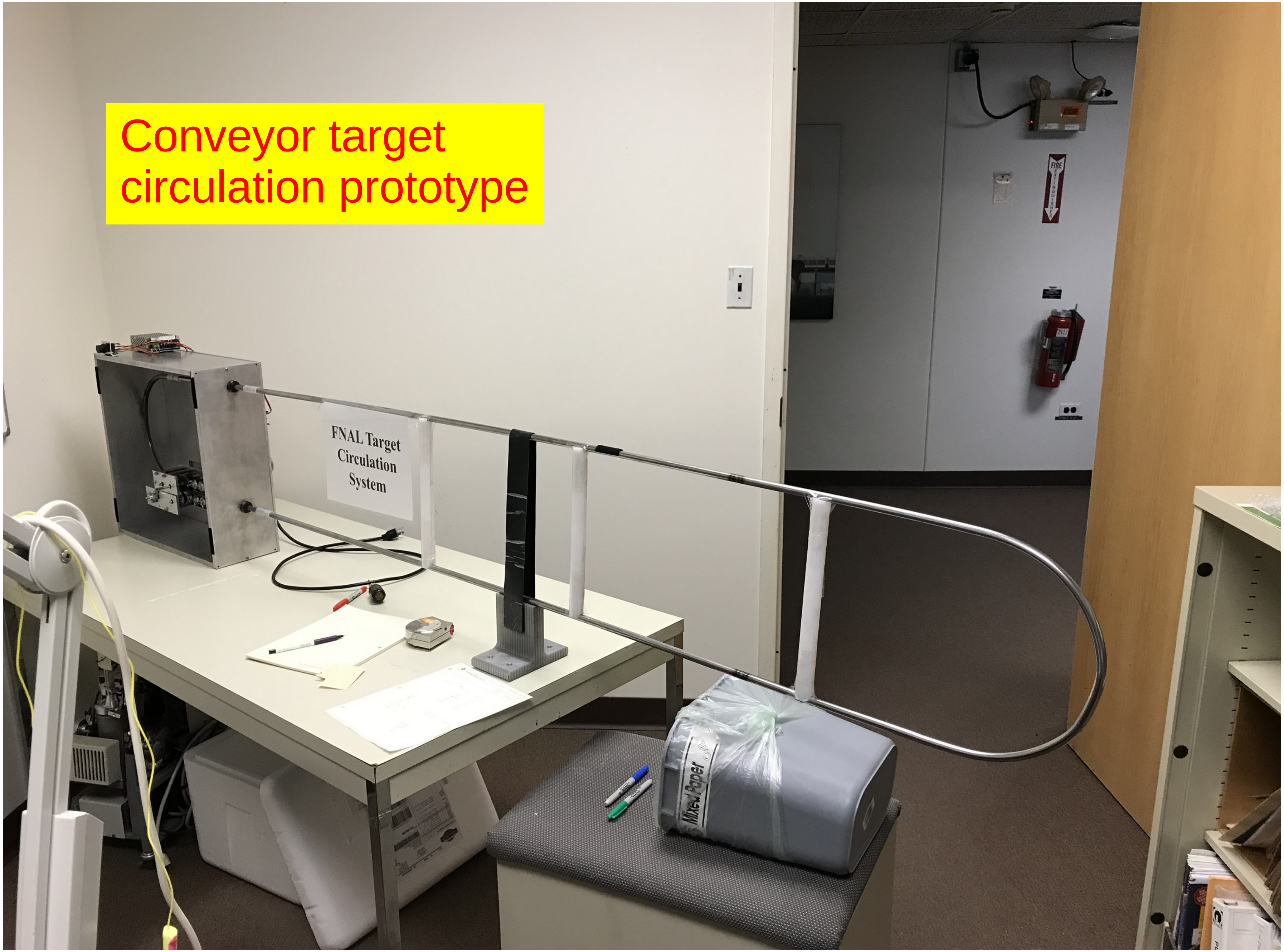
- Compressor ring
  - Kicker rates and rise/fall times limit beam power
    - 100Hz → 1kHz?
- Target and PS
  - Concepts for 100kW targets exist
    - Mu2e-II
  - Compact MW scale targets are R&D effort!

Chief technical challenges: production target

100kW target concept for Mu2e-II

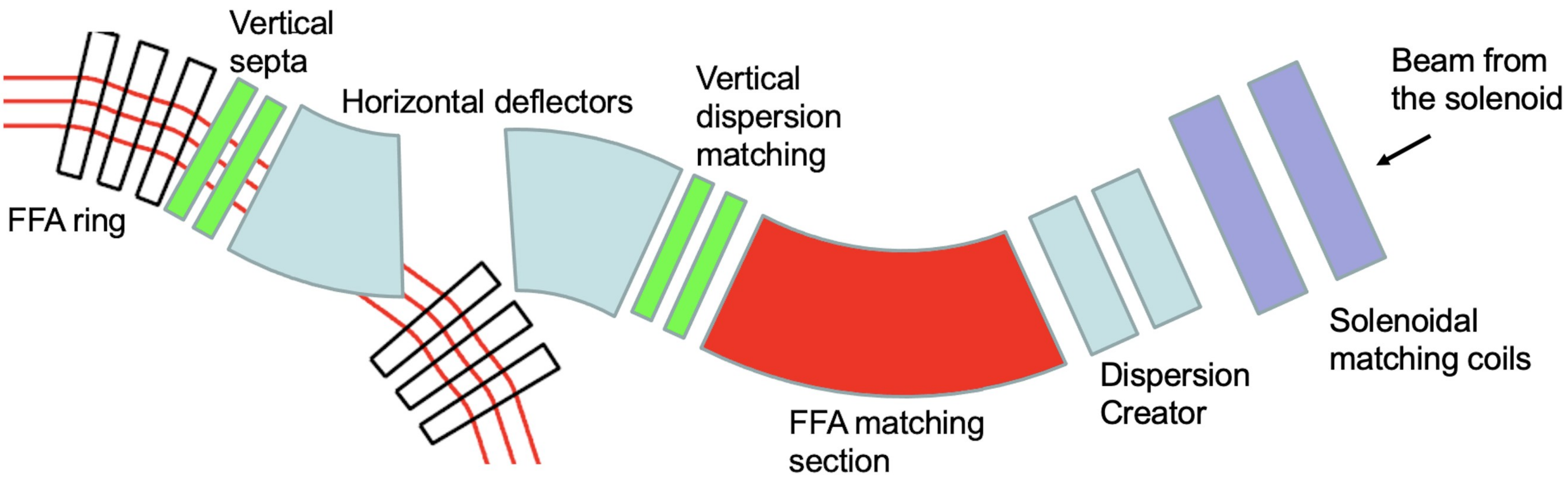


Chief technical challenges: production target



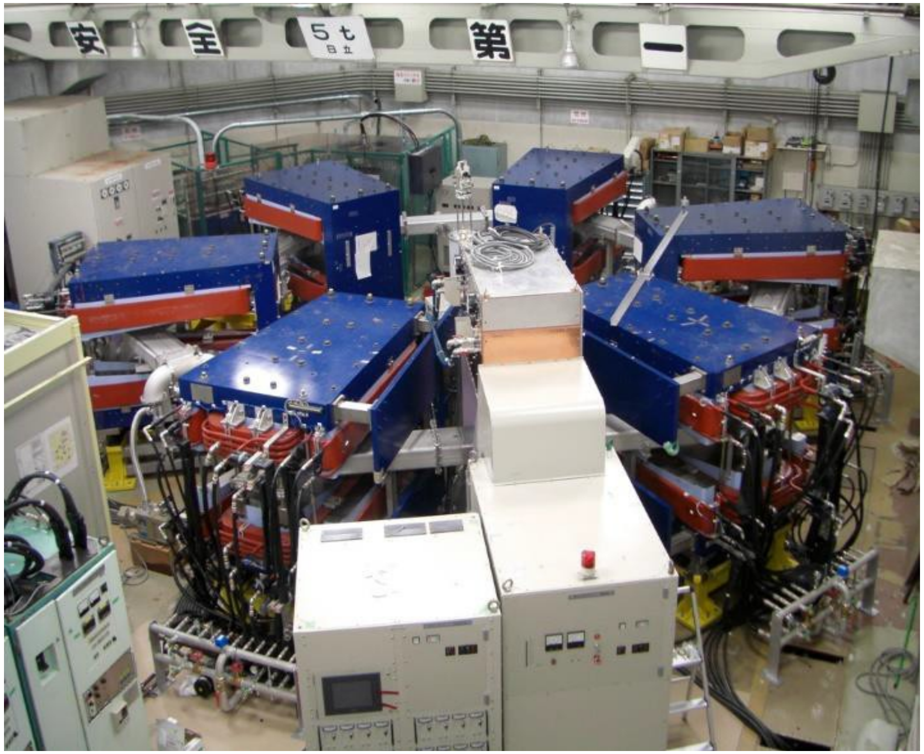
Chief technical challenges

- Muon beam transport
    - Matching between PS and FFA
        - Very different beam dynamics
        - Very large emittances and momentum spread
- FFA
    - Sign switching or both-sign with singlet lattice?
    - Fast injection/extraction kickers



Chief technical challenges: FFA

A 6-cell large-acceptance FFA ring has been demonstrated at Osaka



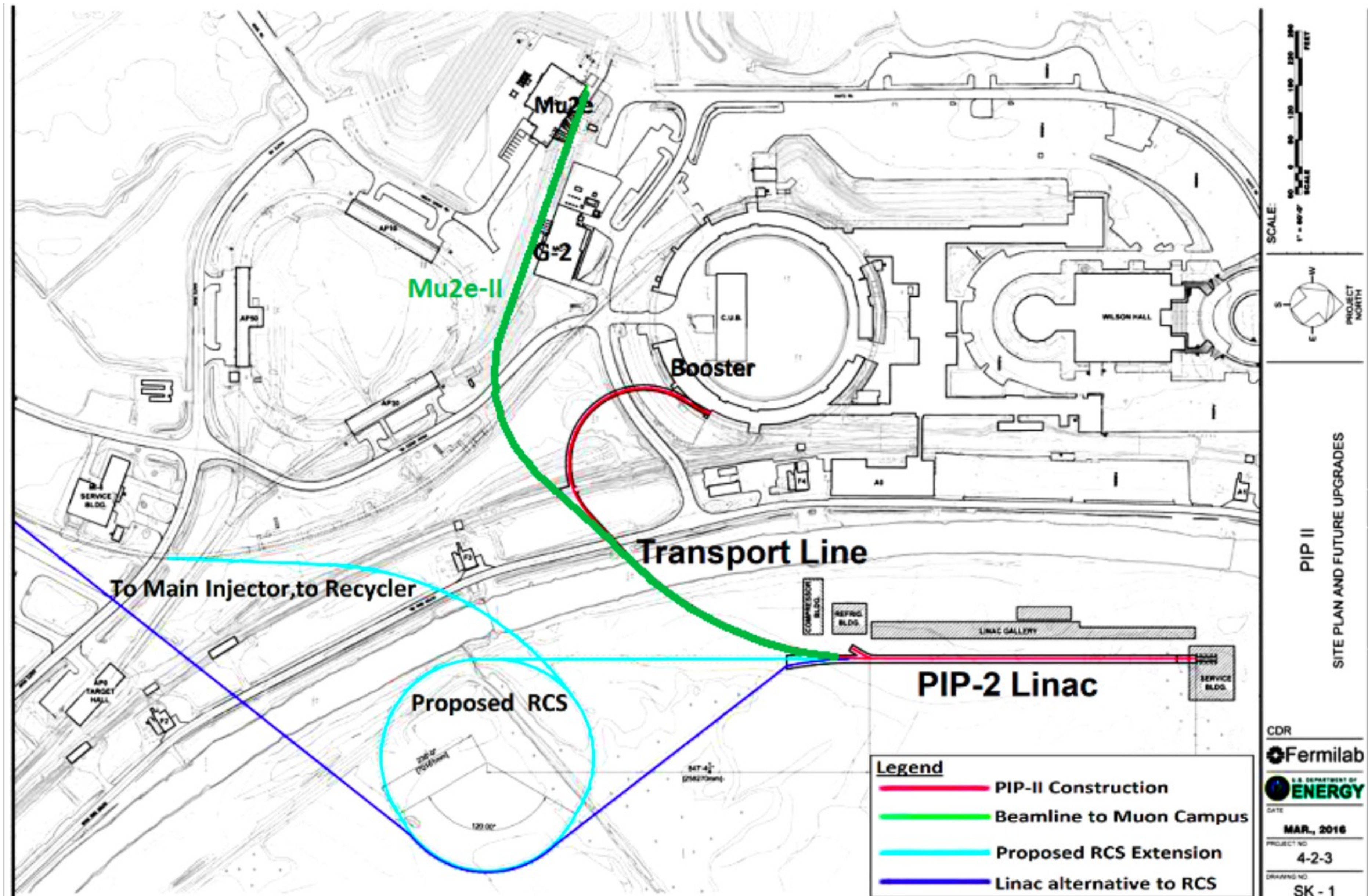
Synergies with other programs

- Dark Matter
    - Accelerator based DM experiments require similar compressor ring to rebunch PIP-II beam
- Muon Collider
    - Very similar production target issues
        - AMF can leverage previous MC R&D and serve as a front-end testbed for future MC development

Summary

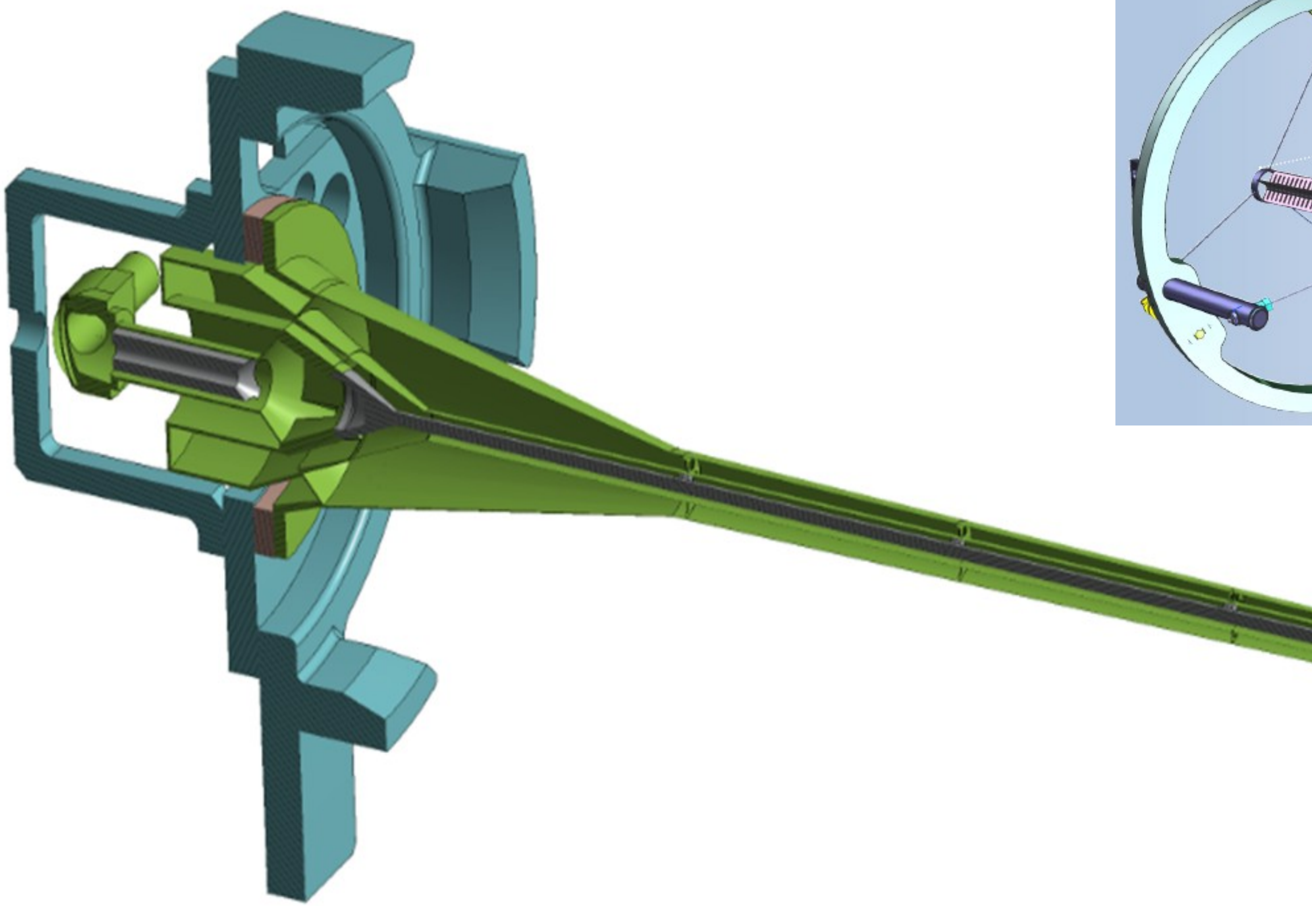
- The AMF proposal provides a concept for a future large-scale, long-term, world-leading muon program at Fermilab
- A first stage of AMF could begin construction following the end of Mu2e operations if R&D starts soon
- There's a lot of room for growth in capabilities in future as technical challenges (kickers, targets, etc) are solved

The AMF concept can adapt to future accelerator complex ideas

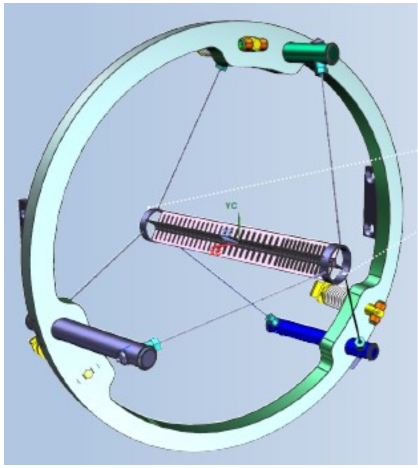


Chief technical challenges: production targets - a rough idea of scale

LBNF Target core
16mm x 1.5m x 25kW

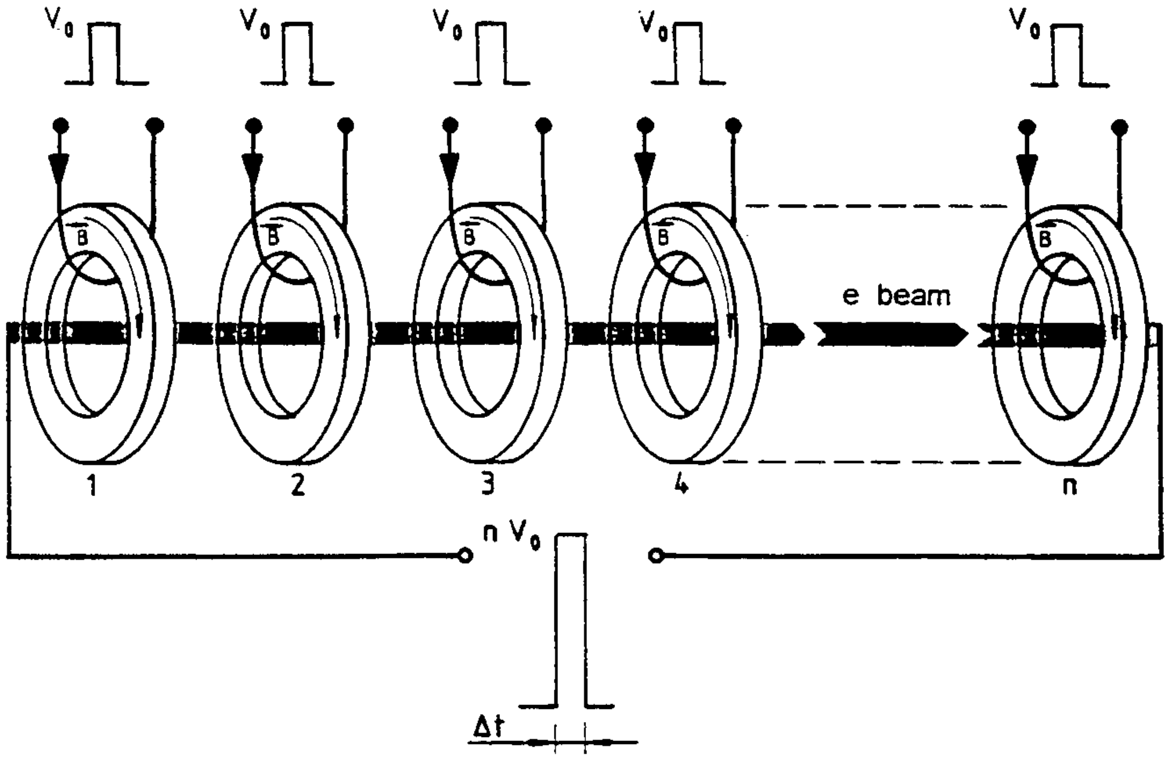


Mu2e Target Core
6.3mm x 220mm x 250kW



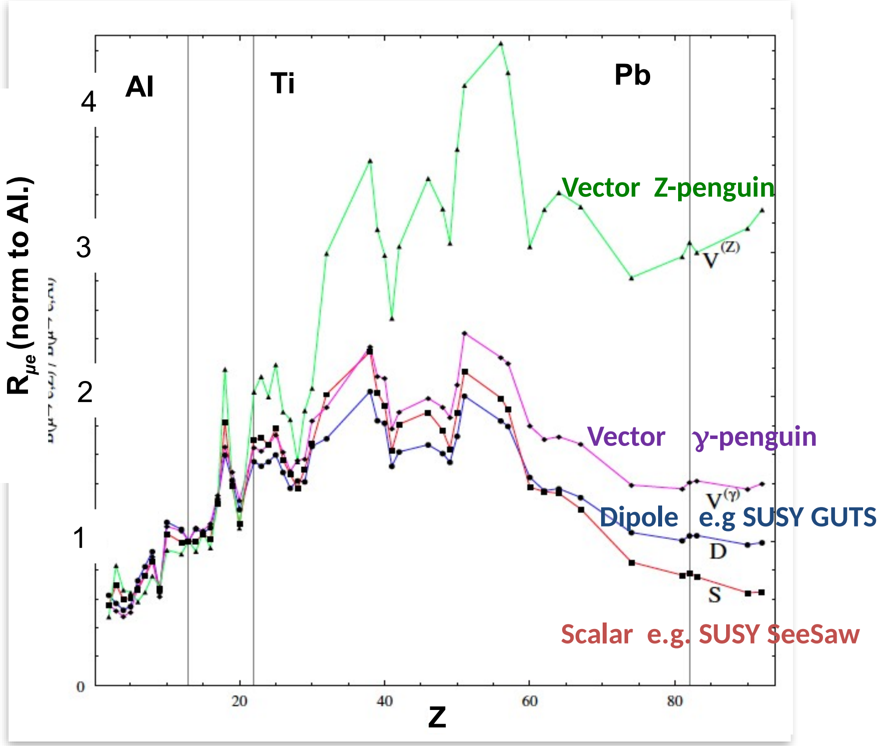
Induction linac

- Experiments need to stop muons in well defined volumes, with minimal material to reduce multiple scattering and dE/dx losses of signal particles
- Momentum from the FFA ~45 MeV/c > surface muon momentum 29.8 MeV/c



Why are narrow pulses so important?

- We want to use high-Z targets, which have very short muon lifetimes



Cirigliano, *et al*, PRD **80**, 013002 (2009)