

# Radiation, thermal, and mechanical studies toward the design of a pion-production target for Mu2e-II

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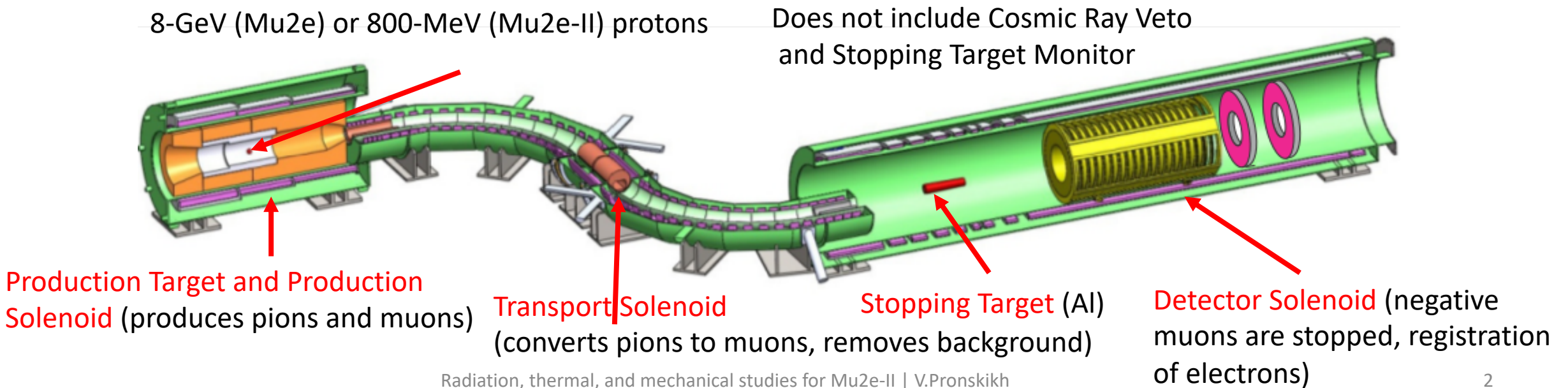
On behalf of the Mu2e-II collaboration

APS DPF Meeting

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# The Mu2e experiment and its upgrade Mu2e-II

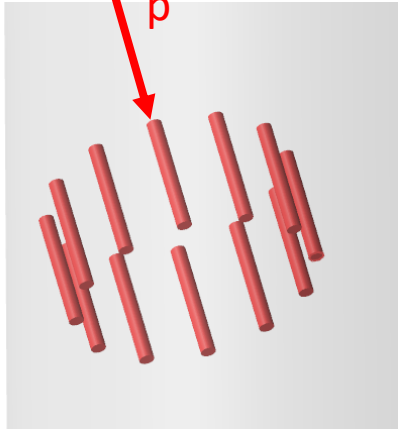
- The Mu2e experiment at Fermilab will search for evidence of charged lepton flavor violation by observing the conversion of a negative muon into an electron in the Coulomb field of a nucleus without emission of neutrinos. It will probe effective new-physics mass scales in the  $10^3$ - $10^4$  TeV range.
- The Mu2e-II improved sensitivity would be enabled by the PIP-II accelerator upgrade project, which is a 250-meter-long linac capable of accelerating a 2 mA proton beam to a kinetic energy of 800 MeV corresponding to 1.6 MW of power (Mu2e-II is planning to use 100 kW).



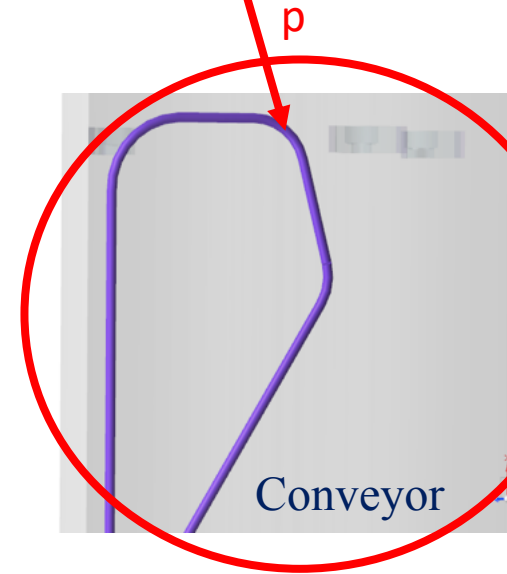
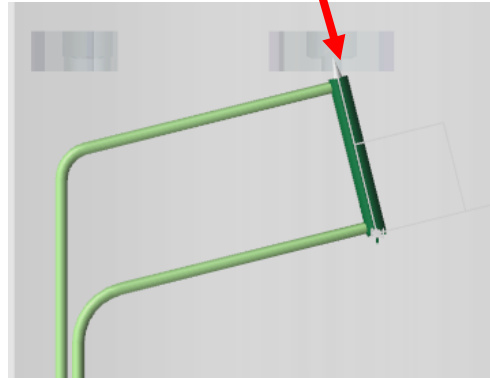
# Prioritizing designs under consideration

- Constraint: compatibility with the current HRS design (inner bore=20 (25) cm)

Rotating Elements



Fixed Granular Target



**Pros:** small space required; two-phase ammonia could be used for both cooling and moving elements inside conveyor; radiation damage can be distributed; **Cons:** technical complexity (prototyping needed)

**Pros:** radiation damage can be distributed over many rods

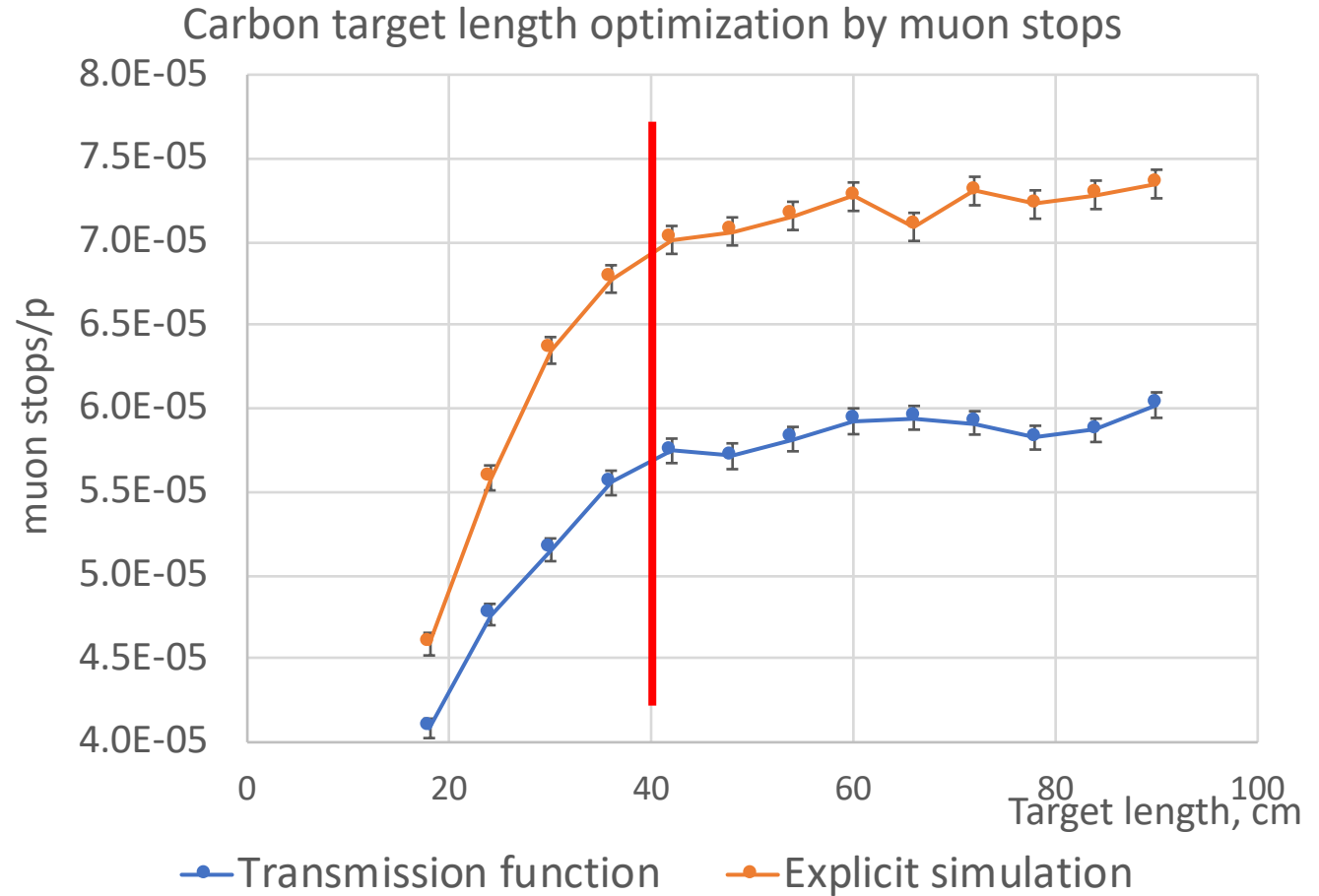
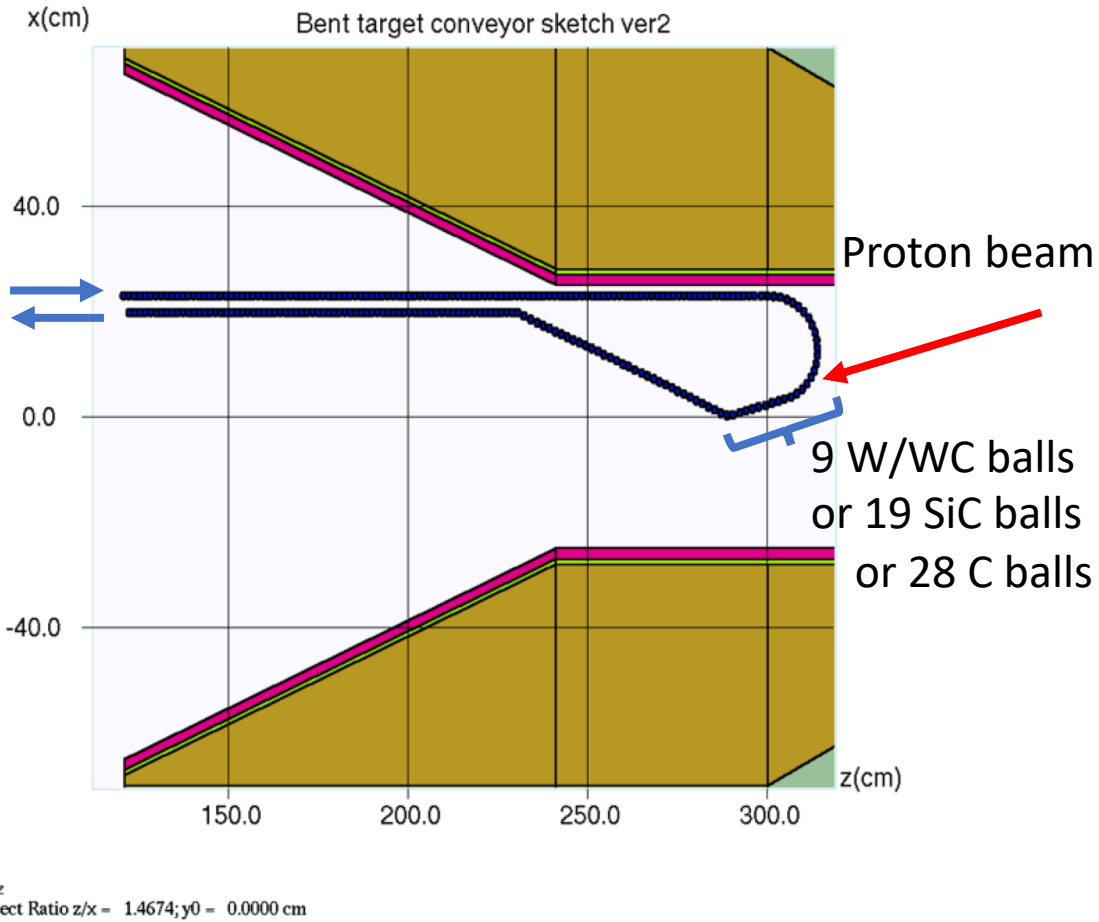
**Cons:** its hardware would require a significant space inside the bore (complicates cooling and muon flow)

**Pros:** small space required  
**Cons:** peak DPA (MARS15) >300/yr; gas cooling cannot be performed efficiently

Target will be placed in the inner bore of Heat and Radiation Shield



# Conveyor target length optimization

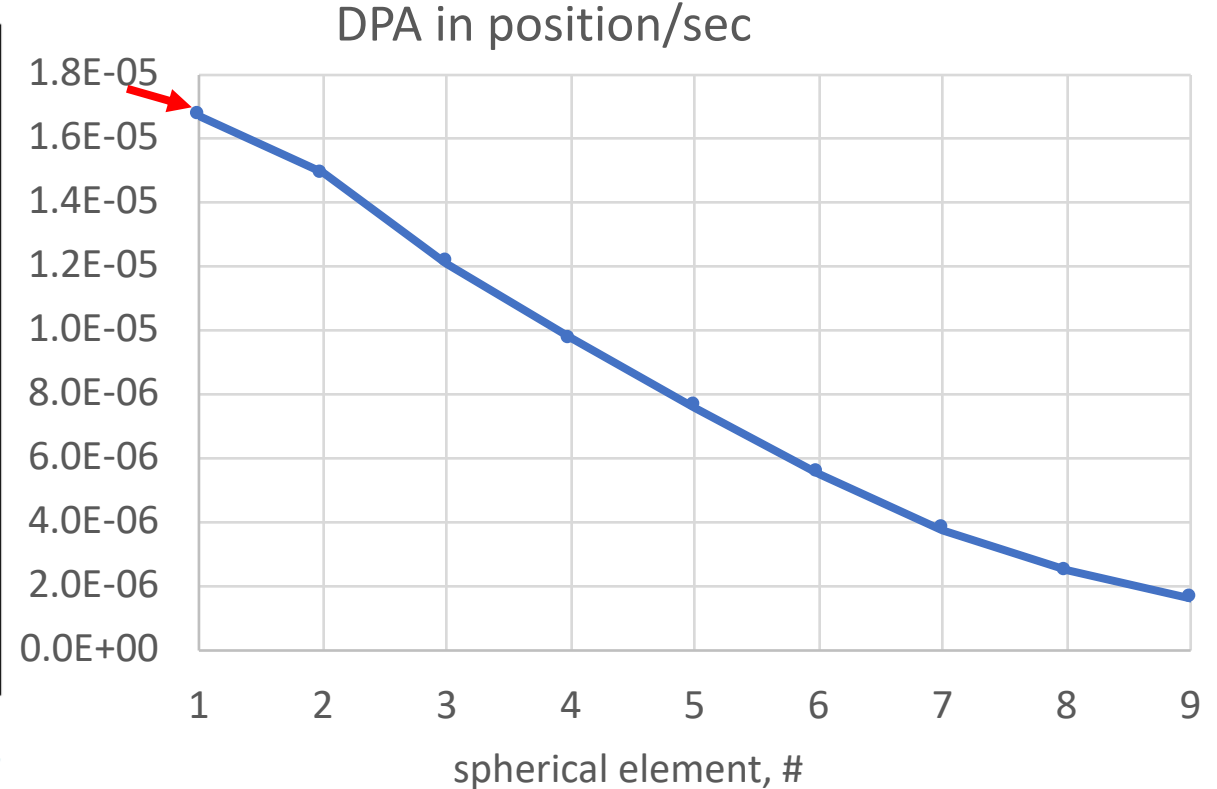
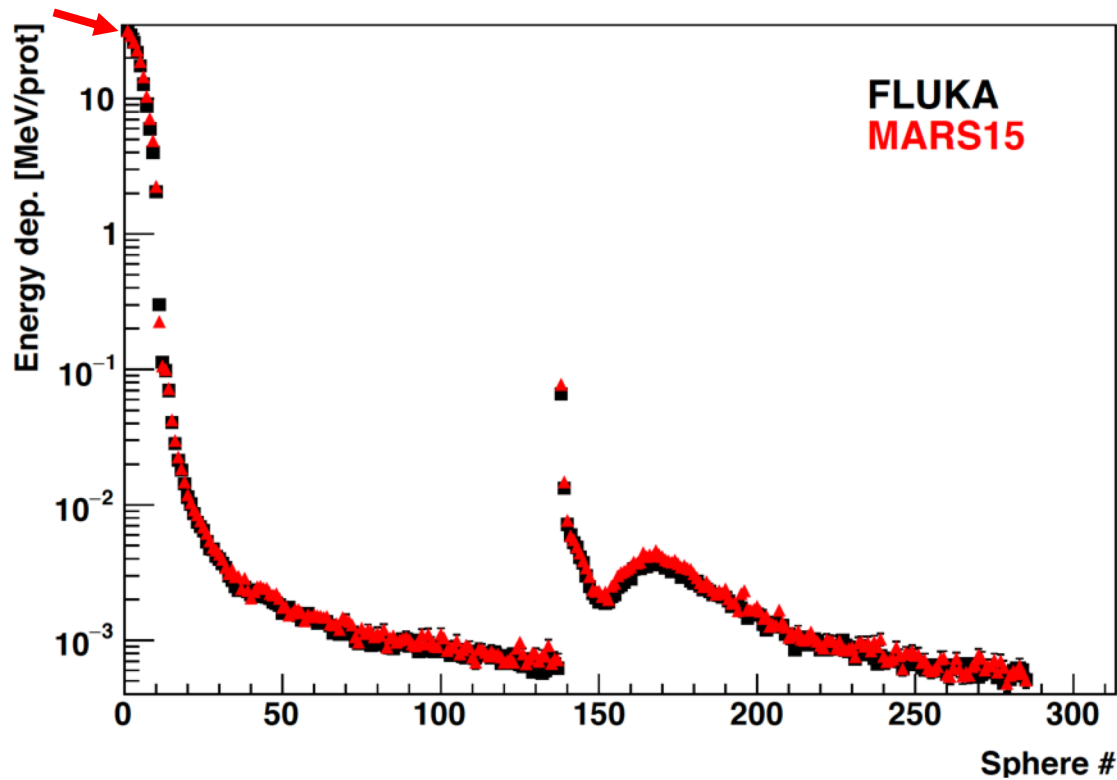


DPA limit assumed  $\leq 10$

Rball=0.5-0.75 cm;  $\sigma = 0.1$  cm

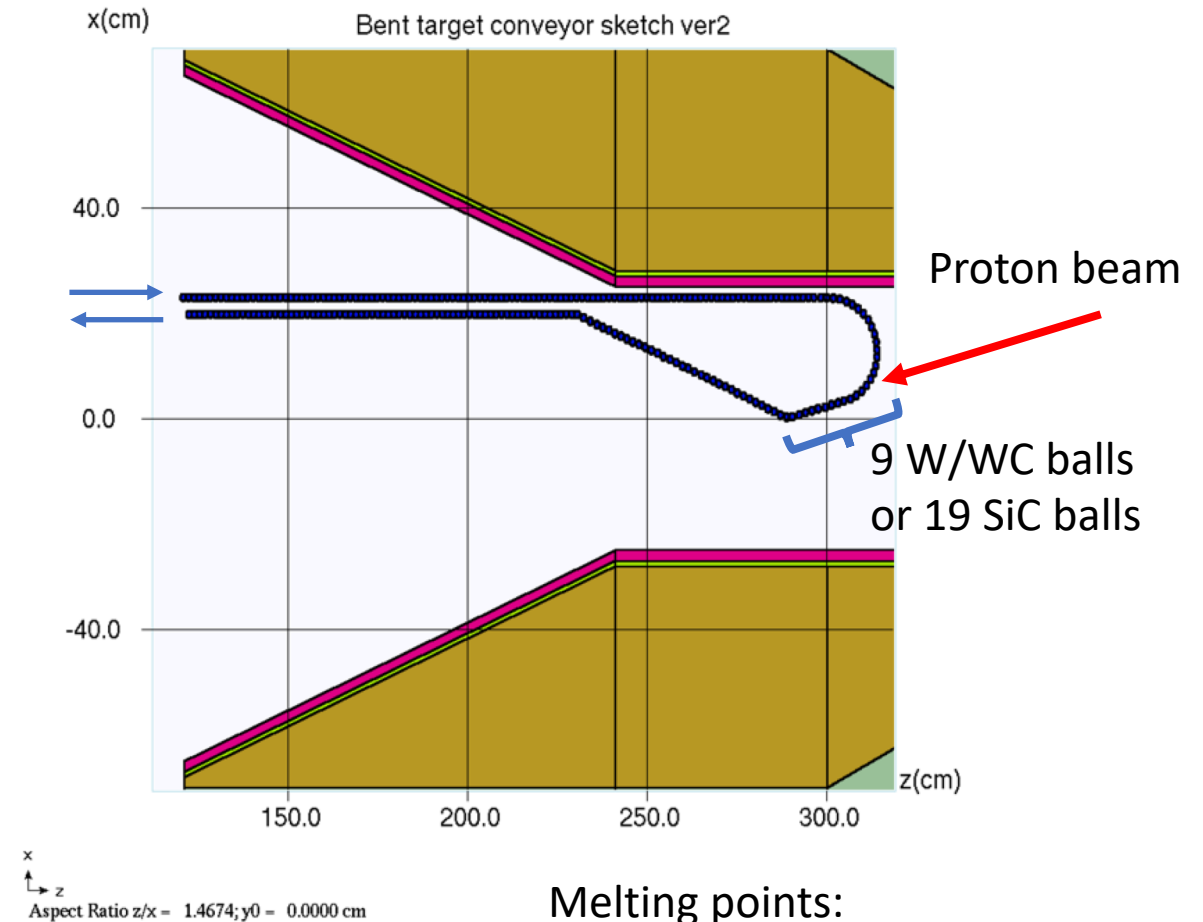
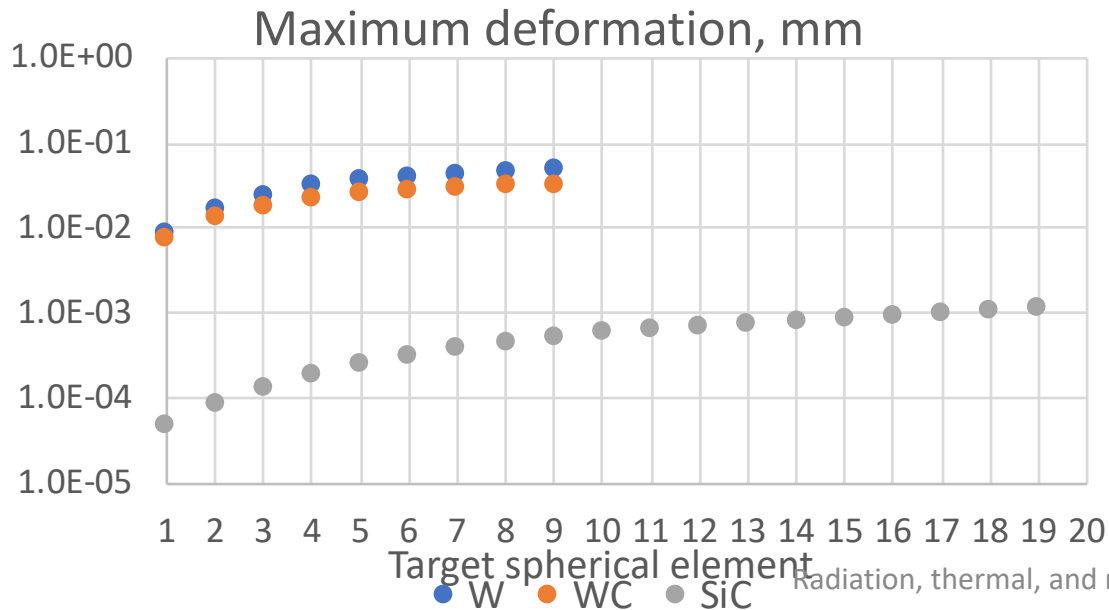
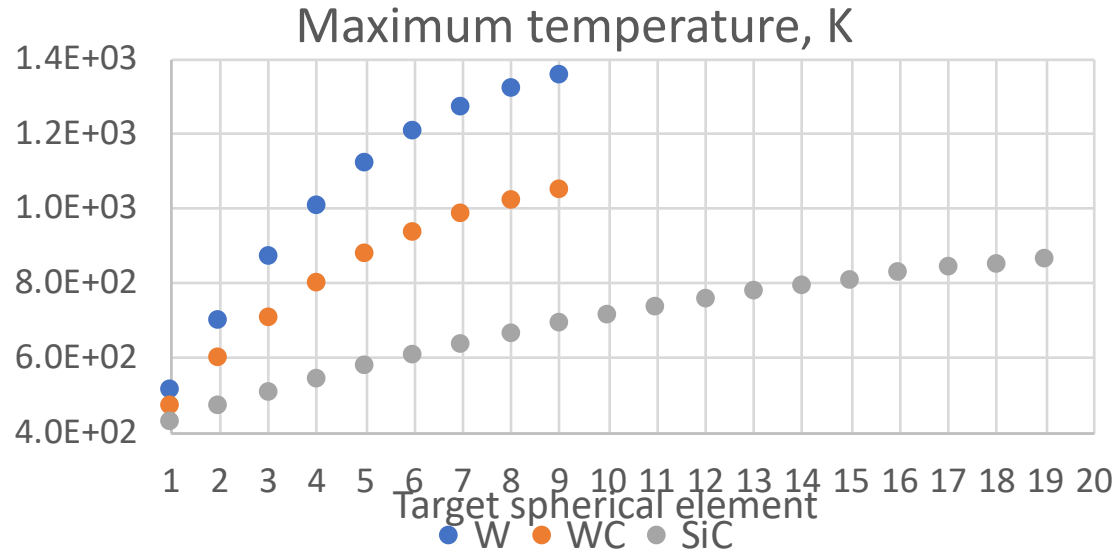
Based on muon stopping rate studies with MARS15 and G4beamline optimal target lengths were determined to be: 28 balls (C target), 9 balls (W and WC targets), 19 balls (SiC); MoGRCF was studied. Agreement between transmission and explicit allows saving computation time.

# Edep and radiation damage for a W target



- MARS15/FLUKA data agreement is better than 20% for energy deposition.
- Total Edep = 31.8 kW; peak DPA (Nordlund) = 330 DPA/yr; min balls required (DPA) = 150/yr
- Motion speed of spherical elements in conveyor is 10 cm/sec
- (1.35 sec for an element to pass the beam). **More spherical elements are required by thermal analysis**

# Thermal and mechanical analyses (no cooling)



Melting points:  
 3422 C for W  
 2870 C for WC  
 2730 C for SiC

# Summary and future plans

- The conveyor bent target (C or W) is the primary candidate for prototyping
- Lengths, shapes, angles, positions for the target elements have been optimized assuming Mu2e baseline beam shape
- We found that energy deposition imposes more constraints on number of target elements in the system (requires more elements) than radiation damage (DPA)
- Thermal and mechanical conservative analysis indicates that WC is better than W
- Cross-comparisons of MARS15 with FLUKA and G4bl are being carried out; for energy deposition the codes agree better than to 20%
- Currently we are considering primarily a two-phase (ammonia) cooling

	Tungsten/WC	Lower-density bent (Carbon)
Rotated	Requires a large hardware in HRS	Too large to fit HRS
Fixed granular	DPA is too high	DPA is high; lower pion production
Conveyor	Thermal and mechanical analyses are ongoing; currently looks feasible	Lower pion production; thermal analysis is ongoing; currently looks feasible

Thank you for your attention!

# Scope of LDRD (Laboratory-Driven R&D)

- Project for the **PIP-II era**: proton current on the Mu2e target could be higher by as much as a factor of 100 compared to the baseline Mu2e (**~x10 improvement** in the single event sensitivity).
- There is no Mu2e upgrade target concept close to satisfying the new requirements (for a **100-kW 800-MeV** proton beam). (We are aware of a 50-kW target prototype designed for MECO and PRISM at Irvine CA: MECO Production Target Development”, J.L.Popp, AIP V.721, p.321, 2003.)
- We are developing a **conceptual design using the MARS15 and G4beamline Monte-Carlo codes, Mathematica** and utilize the most favorable aspects of the **granular, “conveyor”, and rotating cylindrical targets**. We are simulating the **overall target pion production performance and durability at beam induced pulsed energy deposition spikes**, thermal stress, radiation damage, muon stopping rates, residual activation and radiation loads.
- The project is aimed at the **design of the prototype** of the Mu2e-II pion-production target for the **100-kW 800-MeV** proton beam and its mechanical tests.
- **Deliverables:**
- **Mid-2020 – Mid-2021**: the **plausible design** for the Mu2e-II target.
- **Mid-2021 – Mid-2022**: designed, printed, and tested. Conclusions regarding **feasibility** to be drawn.