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Mu2e-II LDRD target design: an update

January 31, 2023

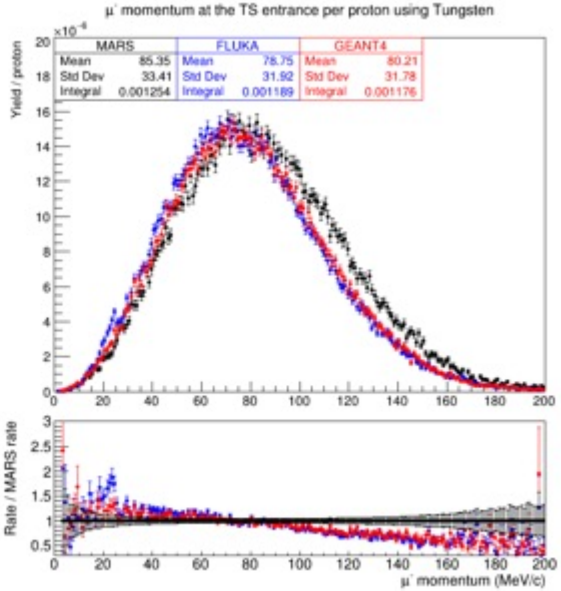
Scope of LDRD (Laboratory-Driven R&D)

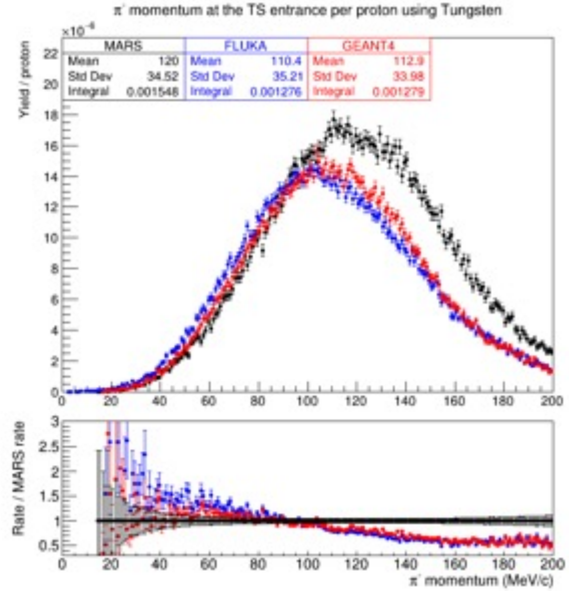
- There is no Mu2e upgrade target concept close to satisfying the new requirements (for a 100-kW 800-MeV proton beam). (A 50-kW target prototype was designed for MECO and PRISM at Irvine CA: MECO Production Target Development", J.L.Popp, AIP V.721, p.321, 2003.) (High energy density, DPA)
- We are developing a conceptual design using the MARS15, FLUKA, and G4beamline Monte-Carlo codes, and Mathematica
- 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:

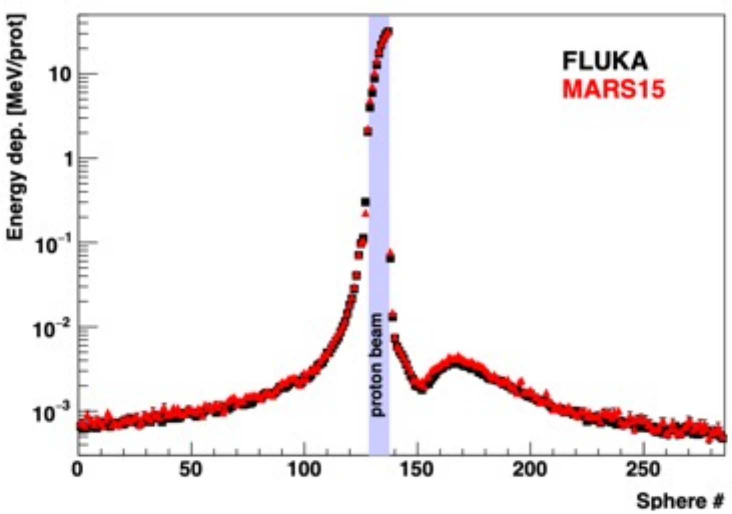
- Mid-2020 – Mid-2021: the plausible design for the Mu2e-II target.
- Mid-2021 – Mid-2022: designed, built, and tested. Conclusions regarding feasibility to be drawn. First prototype version built and tested.
- **Mid-2022 – March 2023: Second version of prototype. Designed, fabricated, tested. Conclusions drawn and next steps proposed.**

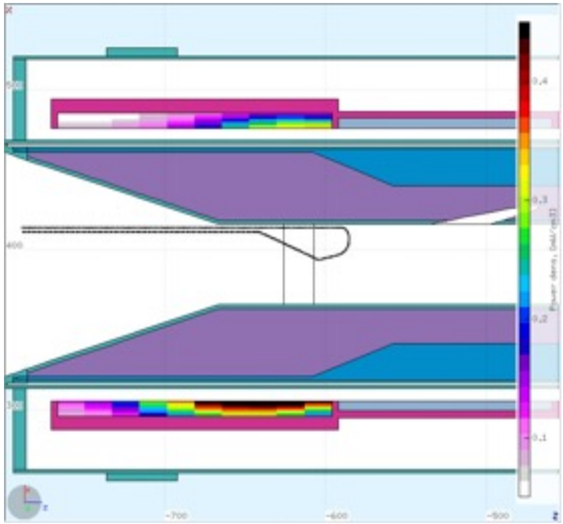
Simulations with several codes of **π-/μ-** and heatload





Excellent or very good agreement between codes.



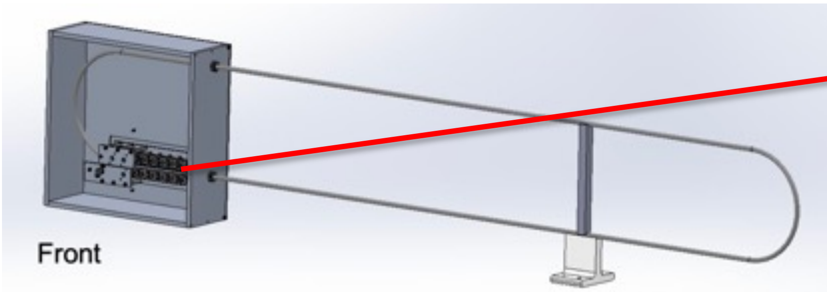


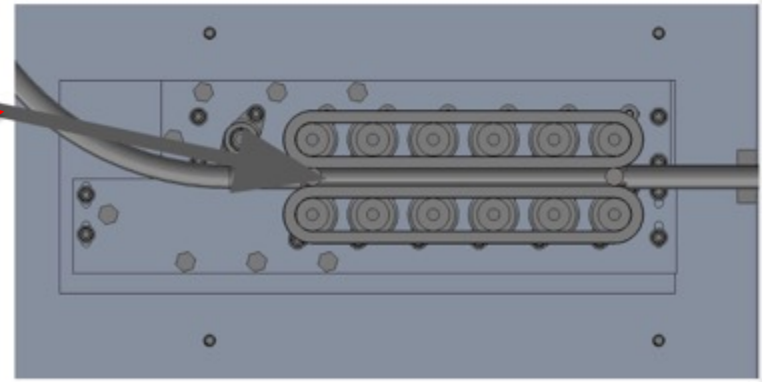
Peak power density in the PS1 coil is 0.138 mW/g.

Total heatload in the W target ~32 kW.

A. Ferrari, M. MacKenzie, S. E. Müller, V. Pronskikh and R. Rachamin, SATIF-15, September 2022.

First prototype design





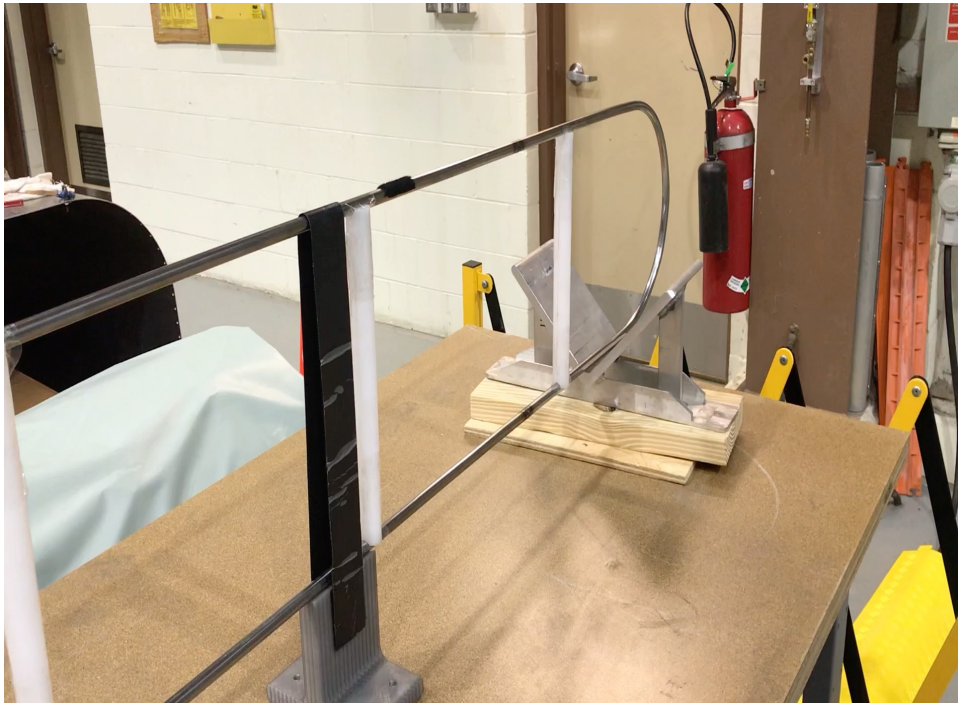
The engineering was done by Euclid
Requisition processed September 2021
Delivered to Fermilab December 2022
Mechanical tests started January 2022

First design:

- circulates Steel balls R=0.5 cm
- U-turn R=15 cm; L = 245 cm.
- Racetrack shape (no beam straight section)
- Tubing slightly larger than the balls (tolerance)
- Variable velocity
- Sealable design (for future vacuum to avoid oxidation in air)
- Track actuated from two sides in gearbox
- Track is gripped in drivetrain

Mechanical tests of the first prototype at Fermilab

Test at 12.3 cm/s



The prototype despite many simplifications does the job

- Demonstrated a stable operation at 8 cm/s, 12 cm/s, and 16 cm/s

all regimes (the initial design required 10 cm/s)

- After ~1 hour of integrated operation we saw that the traveling belt crumbles (may not be reliable for high temperatures and long-duration regimes)
- Some rollers slip and do not turn

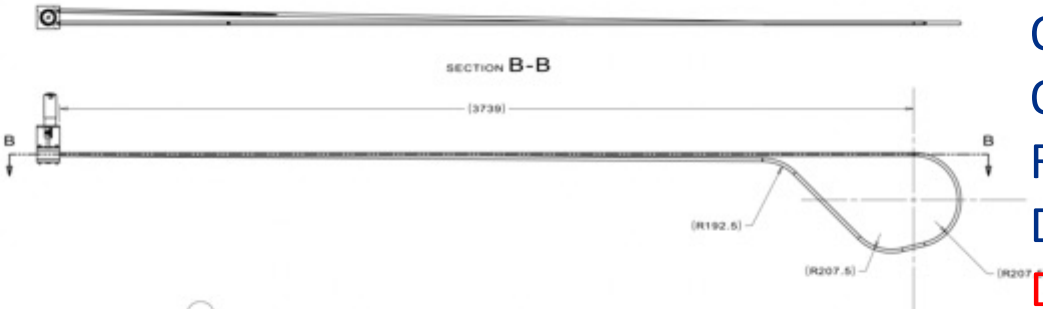
- In general, long-term uniform movement of the balls in the tubing can be ensured. The design is generally feasible.
- The design required several improvements that can be done within the current LDRD scope.

Second version of the prototype

Fabricate using the design provided a sprocket-driven sphere drive mechanism to mechanically drive the spheres at velocity of 2 to 10 cm per second.

The shape of the tubing should be more realistic than a racetrack with a U-turn. It should include a ~10-cm-long straight section (beam interaction region) on the reverse flow from the U-turn at an angle ~16° to the inlet pipe followed by a piping connecting with the outlet tubing at an angle ~27° with it.

Second phase (time permitting). The tubing design should be hermetic (gas-tight) to make a provision to use gas as a complementary to the sprocket one sphere-moving means. Air circulation should be designed such that the majority of the air flows thru the long path.



Quote from Euclid: $12,100.

Quote #: Fermi-008-2022.

Requisition: September 28, 2022.

Delivery: 6~8 weeks ARO.

Delivered: beginning of January, 2023

Designed at Fermilab, fabricated at Euclid Techlabs, LLC

The second prototype being tested. January 2023

Fermilab

Takeaways

- The first version of prototype was received and mechanically tested in 2022. Advantages (the device is functioning as intended) and disadvantages (traversing belt is crumbling and is not suitable for high-temperature and radiation conditions) have been identified.
- The directions for further improvements have been identified: a sprocket mechanism, a realistic shape (with a straight beam interaction region); possibly, a hermetic tubing.
- The design for the second version prototype has been made. Vendor has been selected (Euclid), the prototype has been manufactured and delivered.
- Comparisons of simulations with several codes have been performed for particle fluxes and energy deposition. Good to excellent agreement has been found.
- Results reported at ICHEP (2022), NuFact (2022), SATIF-15 (2022). Proceedings have been published, a journal paper are in preparation.
- Working parameters: 10 cm/s speed of the conveyor is required to keep the temperature within the safety margins (to avoid deformation) for a 100-kW 800-MeV beam