Targetry session summary

Vitaly Pronskikh
Fermilab
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Muon program at Fermilab workshop, Pasadena, CA

The talks we heard

	Intro — *269, Lauritsen*	*Kevin Lynch* — 08:30 - 08:35
	What we know and do not know about tungsten in accelerator environments — *269, Lauritsen*	*Yong Joong Lee* — 08:35 - 09:05
09:00	**Granular tungsten target R&D at RAL** — *269, Lauritsen*	*Dan Wilcox* — 09:05 - 09:35
	HPT R&D — *269, Lauritsen*	*Frederique Pellemoine* — 09:35 - 10:00
10:00	**Muon Collider, fluidized targets** — *269, Lauritsen*	*Carlo Carelli* — 10:00 - 10:30
11:00	**Mu2e talk**	*Michael Hedges* — 11:00 - 11:30
	Mu2e-II LDRD	*David Neuffer* — 11:30 - 12:00
12:00	**Discussion**	*Everyone* — 12:00 - 12:30

K.Lynch (Introduction)

We clearly need lots of muons for these experiments!

- Mu2e
  - Radiatively cooled tungsten target in vacuum and high field
  - 8 GeV, 8 kW proton beam
    - 700 W power deposition
    - 200 ns pulse length
    - ~200 kHz (30% duty factor)
- Mu2e-II
  - Actively cooled …. something
  - 800 MeV, 100 kW beam
    - 25 kW power deposition in tungsten
    - 100 ns pulse length
    - ~ 200 kHz (95% duty factor)
- AMF
  - No idea! Similar to muon collider parameters
  - 800 MeV – 8 GeV, 1MW beam
    - 1 kHz pulse rate (100 % duty factor)
    - ~10 ns pulse length
- Compare to LBNF
  - Long graphite target
  - 120 GeV, 1.2(2.4) MW beam
    - 1 Hz
    - ~10mu s pulse length

We have a target for Mu2e,

Concepts for Mu2e-II,

No idea how to build AMF target,

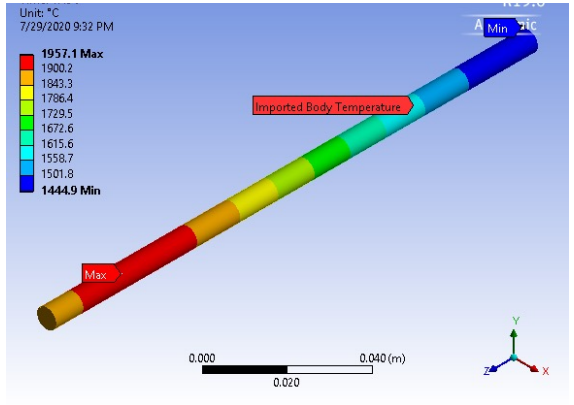
The regime is difficult for materials,

What synergies with MuC and other projects are possible?

Y.J.Lee Tungsten in accelerator environments

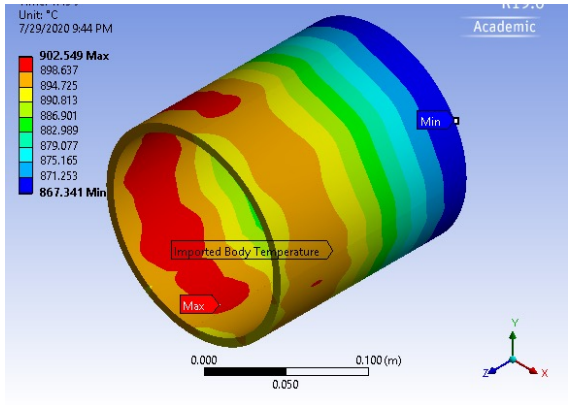
Excellent review of tungsten properties

Mu2e



TDR

1957.1 C (1130 C M.Hedges)
16.1 MPa
(principal stress)

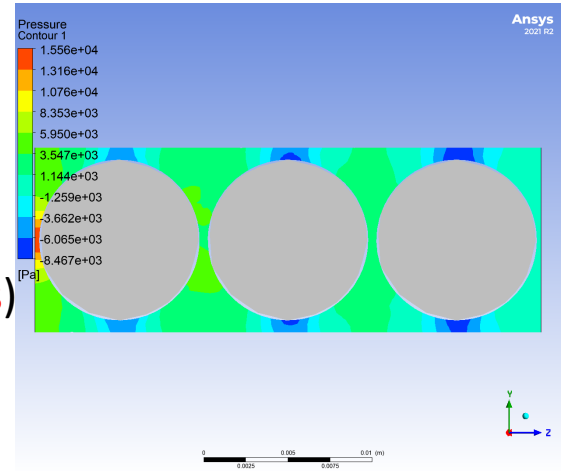


Hollow
Cylinder

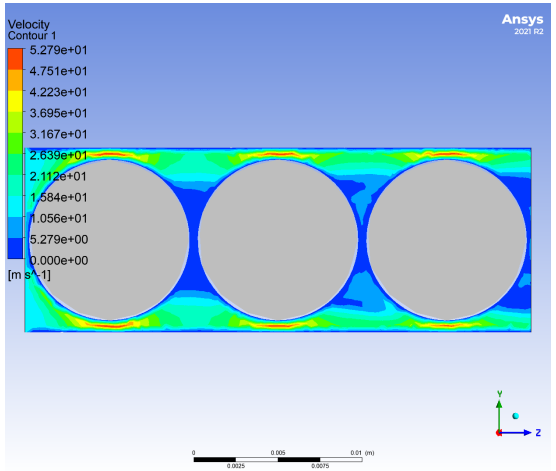
903 C
8.3 MPa
10% loss in muons

OD 15 cm, wall thickness 6.3 mm, 16 cm long

Mu2e-II conveyor



Pressure drop 16 bar (standing)

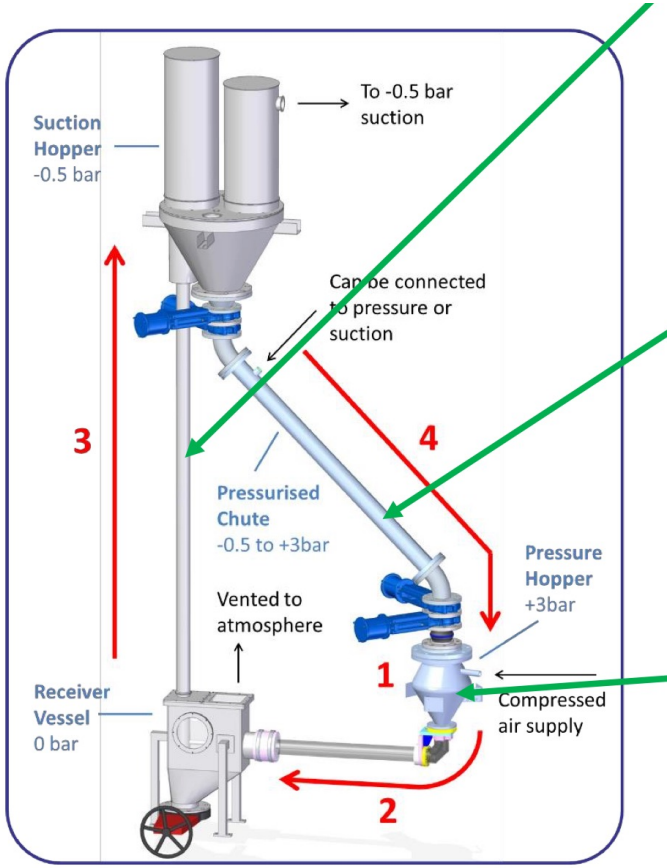


Pressure drop 3.8 bar (moving half the flow speed)

- Lack of data on embrittlement, hardening, diffusivity in tungsten
- We need to continue and expand this collaboration!

Dan Wilcox: Fluidized Tungsten Powder as a Muon Production Target

- Advantages:
  - Can withstand extremely high energy density
  - Fluidised powder handling technology is well-established in industry
  - Lower eruption velocity than liquid mercury, and no cavitation damage
- Challenges:
  - More R+D required to mitigate erosion of containment during long term operation
  - Tungsten is much more dense than materials handled in industry; existing flow equations and plant designs may need to be modified
  - Diagnostics and process control must be developed to ensure reliable long-term operation
- These challenges can be addressed with cost effective off-line testing



Tests at HiRadMat in 2012 and 2015

K.Lynch ft F.Pellemoine: “HPT R&D”, FNAL plans and needs

Tools to Support R&D Program

- High energy beam irradiation
  - Highly activated material

→ Need to develop PIE: hot cells and specific characterization equipment

  - High energy **p** Low dpa rate **p** long irradiation time (order of months) **p** Expensive
- Alternative radiation damage and thermal shock method
  - Low-energy ion irradiation
    - Lower cost, high dose rate without activating the specimen
    - Few heavy ion irradiation facilities around the world
  - Electron beam for thermal shock

No target concept for AMF!

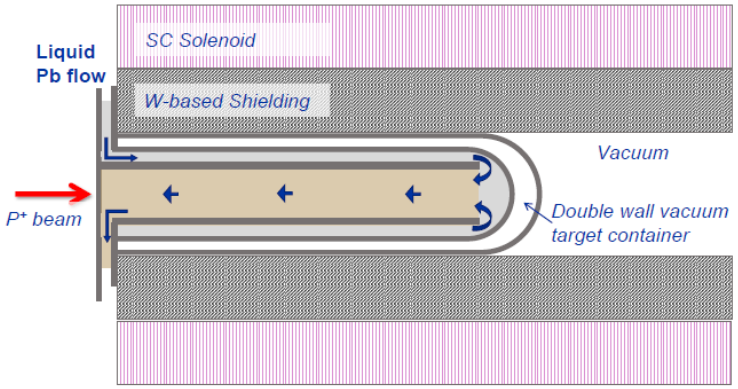
→ Need more development of such facilities with higher intensity

- Ab initio and molecular dynamics (MD) modeling
  - still not yet mature enough to model atomistic changes to micro-structural evolution to macro-properties of real-world materials. Prediction of fundamental response of various material classes to irradiation helps steer material choices and experiment design for future irradiation studies
    - Modeling of He gas bubbles in Beryllium and of novel material radiation behavior (HEAs)

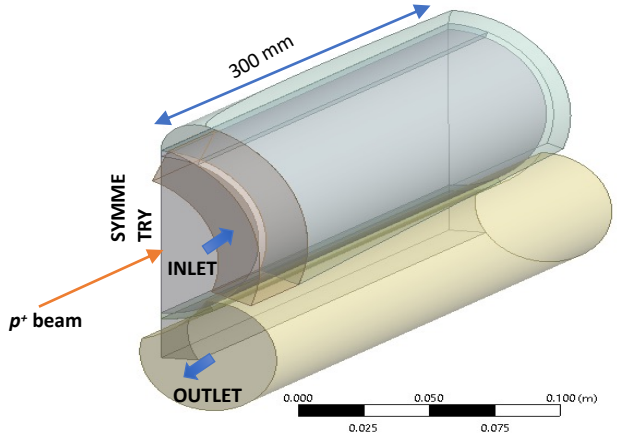
→ Need to develop this expertise at FNAL

C.Carelli: Liquid Heavy Metal applications for particle accelerators

MuC option 1



MuC option 2
Lead curtain



MuC option 3
Liquid jet (SNS)

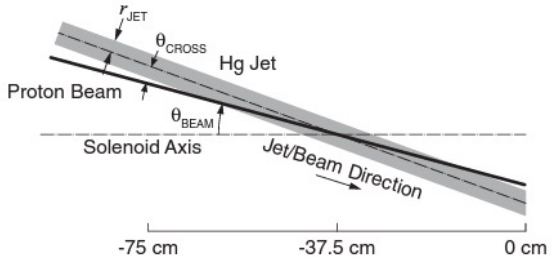


FIG. 3. The mercury jet target geometry. The proton beam and mercury jet cross at $z = -37.5$ cm.

Issues expected: cavitation, fatigue, shockwave, MHD, stability etc. A lot of R&D is required.

Also (my considerations): 1) pion yield compared to tungsten,
2) secondary neutrons (shielding), 3) mixed wastes?

Michael Hedges: Mu2e target

Without testing, we are flying blind

Idea: place target at Fermilab "AP0"

- 8 GeV protons
- Skeleton test plan somewhat outlined already, needs work in implementation
    - Expose target to beam, steady-state temp, take measurements, validate sims

Complications:

- No resonant extraction (more severe thermal shock than Mu2e)
- Spot sizes (beam sigma) slightly different
- Facility available, but still needs plenty of work before starting

No showstoppers, but need to start soon

Mu2e "Hayman" production target is in-hand

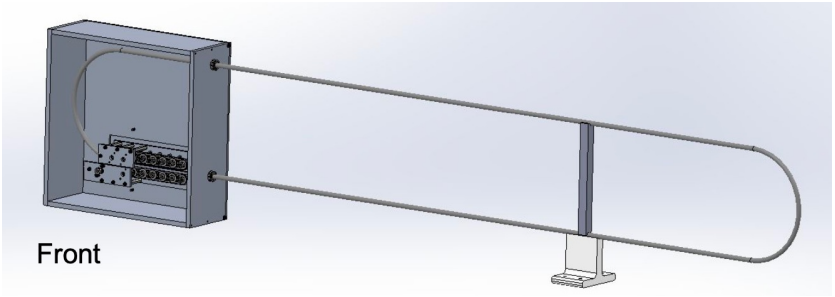
- Mu2e Run 1 scheduled for ~2026 ($\leq$ 1 year long, ~0.5x beam intensity)

Can we get testing facility setup at AP0 after g-2 finishes?

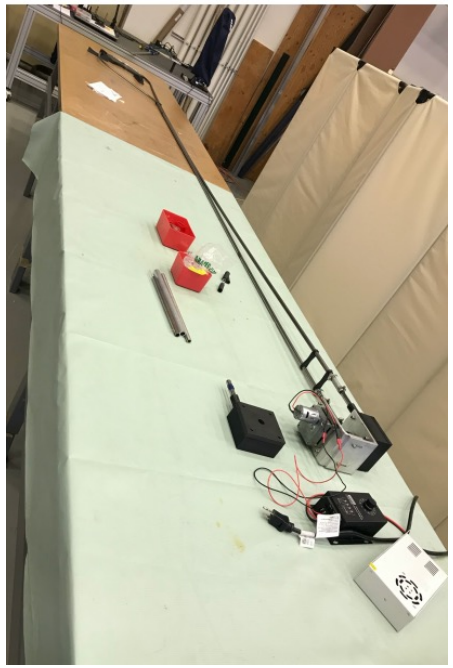
- Test whether expected performance degradations (e.g. thermal stresses, oxidation, creep) within tolerances

D.Neuffer: “Mu2e-II pion-production target LDRD

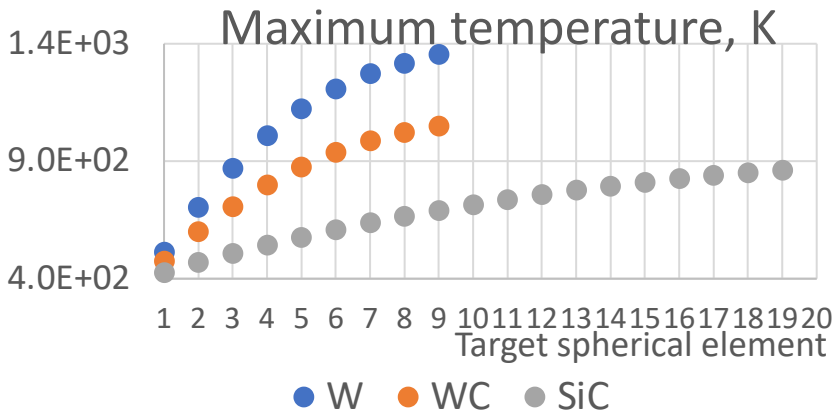
Prototype I. Fully operational



Prototype II. Partially operational



- LDRD funding is complete; need funding for further development
- Prototypes show promise, but not at level of final design
  - Steel spheres, not W/WC or C/SiC
  - Long-term mechanical reliability
  - Lifetime of confining tube
- Next steps
  - Study target configurations in simulation
  - Next prototype
- Build prototype that could be inserted into Mu2e solenoid ?



Which temperature should we compare To? Melting point ? Annealing?

Hoping to collaborate with ORNL

Simulation consistency: DPA, muon yield

Take-aways

- A lot of new and relevant information on target material properties.
- New collaborations are being formed with target experts.
- Fermilab and its collaborations (Radiate, HiRadMat) show great promise and provide resources for radiation tests.
- Advanced target concepts for future muon experiments were presented: fluidized powder (RAL), liquid metal (ENEA), conveyor (FNAL).
- Projects are in full steam worldwide but no plausible ideas regarding AMF target yet !