High Power Targets

Target Options for a Neutrino Factory

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Objectives for Target Station

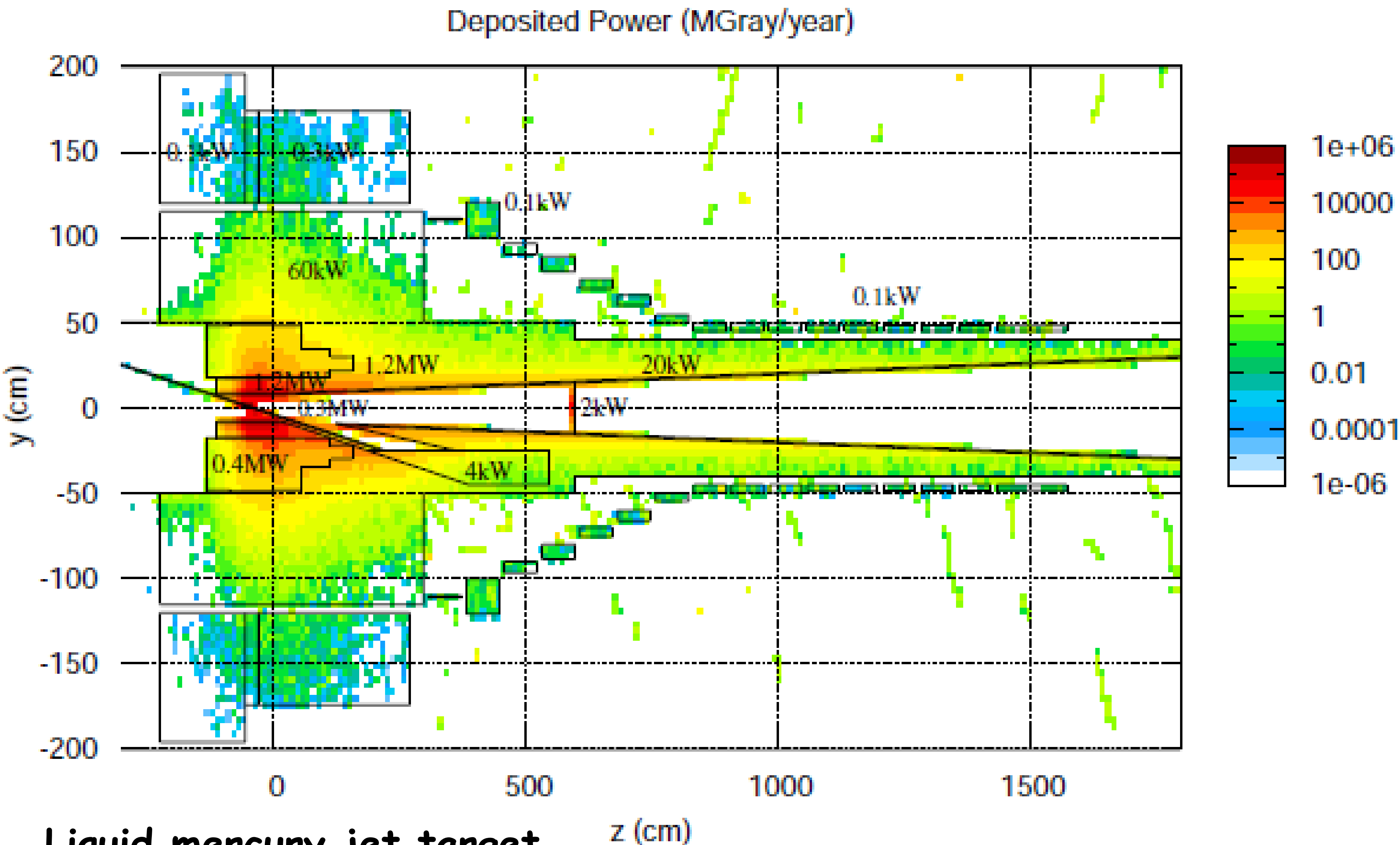
- Target Station is an engineering task
  - With scientific objectives
- Focus on NF (and MC?)
- Objective: maximise useful pion yield per 10^7 s year of operation, over 10 (20?) year lifetime
- Yield = instantaneous yield x reliability
  - Instantaneous yield is most fun to study
    - has received (almost) all attention so far
  - Reliability includes:
    - Mean time between failure
    - Speed of target, (shield, solenoid etc) changeover
    - Difficult (and less fun) to assess

Key target station issues	Candidate/required technologies
1. Target	1a. Liquid Hg jet 1b. Fluidised W powder 1c. Solid W bars 1d. Low Z targets
2. Beam window	Thin low Z windows (beryllium)
3. NC inner solenoid	Conventional copper
4. SC outer solenoid	4a. Nb_3Sn 4b. HTS
5. Solenoid shield	WC
6. Target station engineering	Target integration Remote maintenance Shielding
7. Beam dump	7a Liquid Hg 7b For W bars? 7c W powder?
8. Horn back-up? (2 drivers for 2 signs!)	Conventional neutrino beam horn
9. Safety / environmental	!

NF vs MC?

- Muon Collider requires point-like source
- High Z target material strongly favoured
  - Liquid mercury jet is baseline
  - See Kirk MacDonald plenary talk tomorrow for latest news
- Convenient to regard Neutrino Factory target station as prototype for Muon Collider
- If one decouples NF from MC, does one end up with same answer?
- For a NF, are other options possible/preferable?
- Can the beam size be increased (from 1.2 mm (rms) baseline)?

Heat loads in baseline Target Station (J.Back)



Liquid mercury jet target

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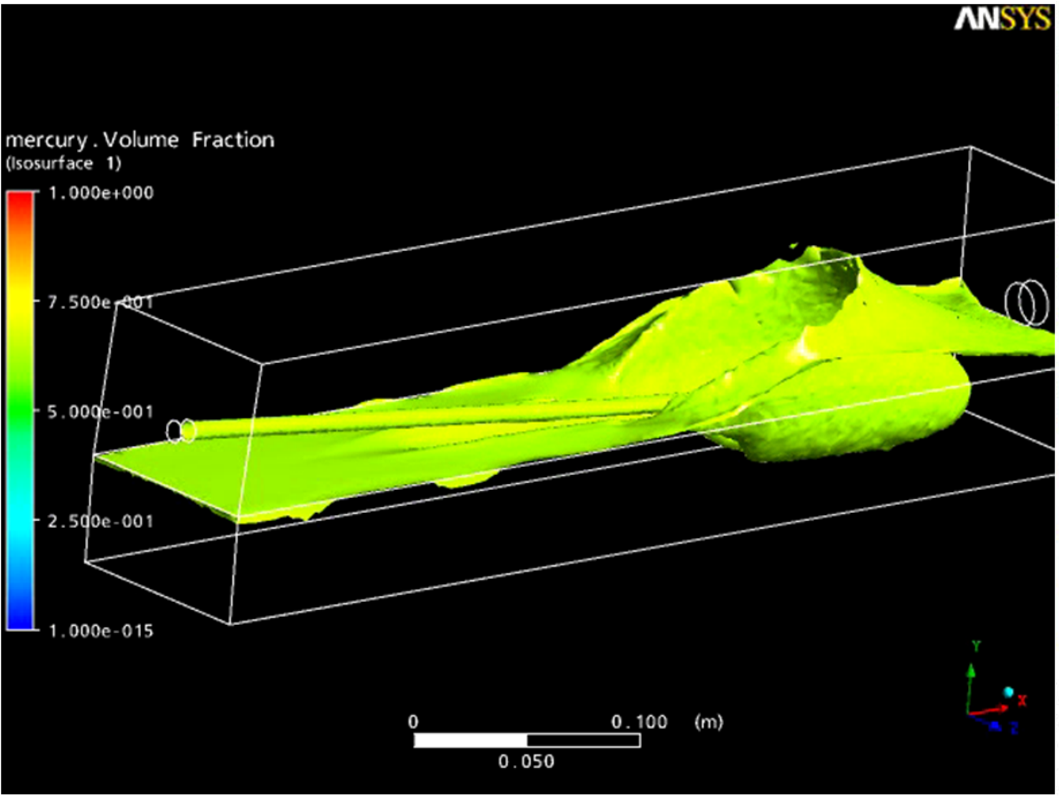
Baseline solenoid system:
Two factors lead to significant technical challenges

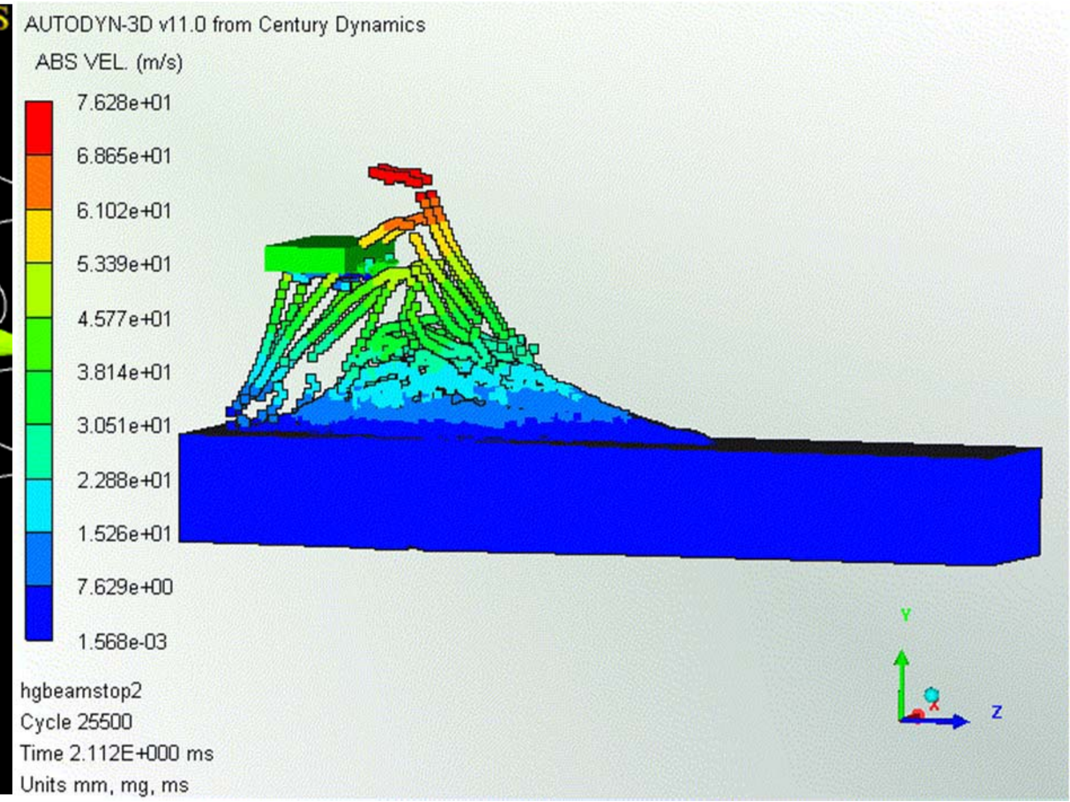
1. Demanding Magnet Parameters - *High field (14 Tesla) in a large bore (1.3 m)*
   - Huge magnetic forces (10,000 Ton)
   - Large stored energy (~600 MJ)
   - Low temperature margin of superconductor
   - Pushing at the limits of present superconductor technology

2. Harsh Radiation Environment – *Heating and material damage Issues*
   - Heat load from 4 MW pulsed proton beam
     - Total Heat load into the cold mass
     - Local Power Density
     - Instantaneous pulsed heating effects
   - Radiation damage to materials
     - Superconductor
     - Stabiliser
     - Turn-to-turn insulation
     - Load Bearing Elements

Plus one or 2 liquid mercury jet challenges



Disruption of beam dump by mercury jet



Disruption of beam dump by non-disrupted proton beam

Tristan Davenne

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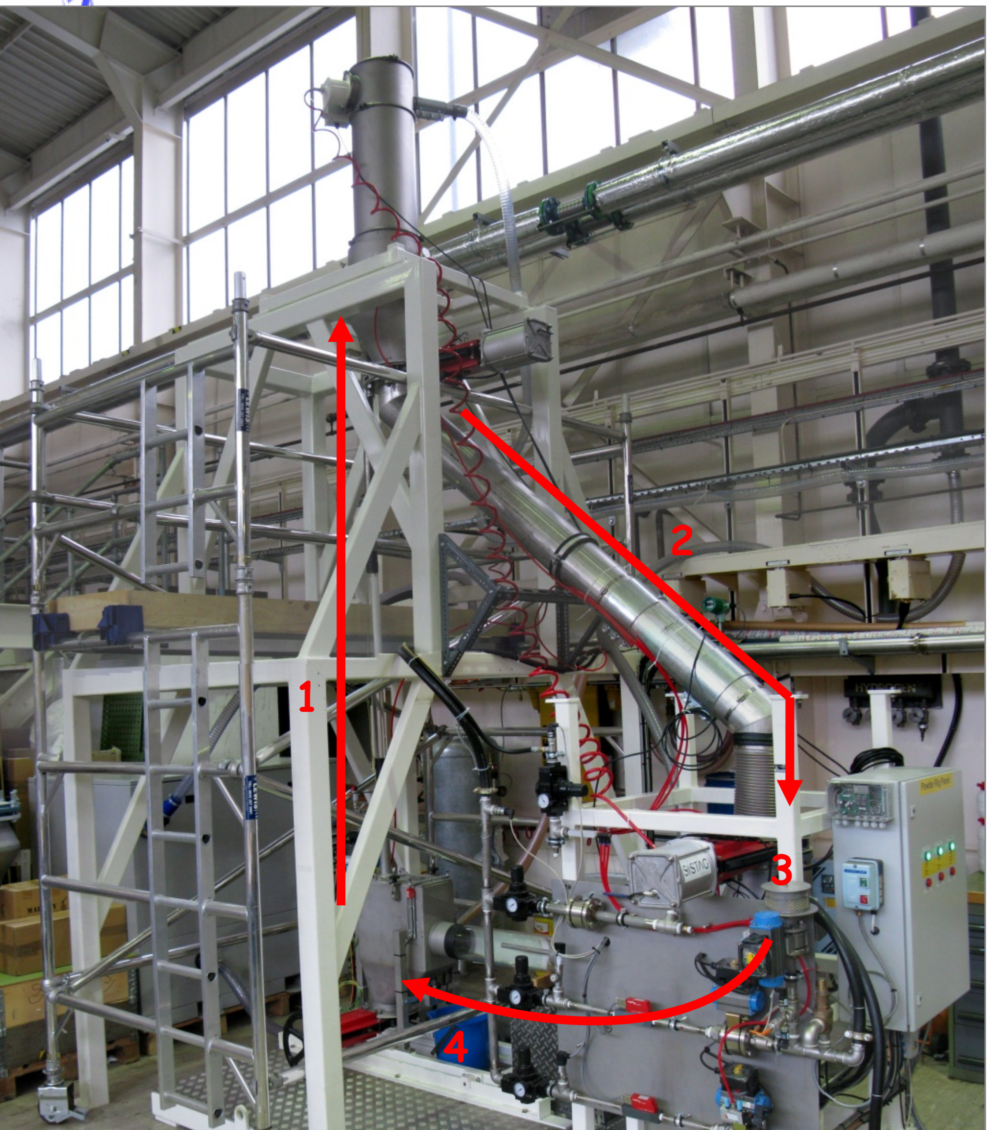
Alternatives to liquid mercury jet?

A few personal comments:

- A neutrino factory will not be built any time soon
- The target station is likely to be the limiting factor in the performance of the facility
- Worth spending time looking at as wide a range of alternatives as possible

High Power Targets

Fluidised tungsten powder: broadly compatible with baseline



1. Suction / Lift
2. Load Hopper
3. Pressurise Hopper
4. Powder Ejection and Observation

- Rig contains 100 kg Tungsten
- Particle size < 250 microns
- Discharge pipe length c.1 m
- Pipe diameter = 2 cm
- Typ. 2-4 bar (net) pneumatic driving pressure (max 10 bar)

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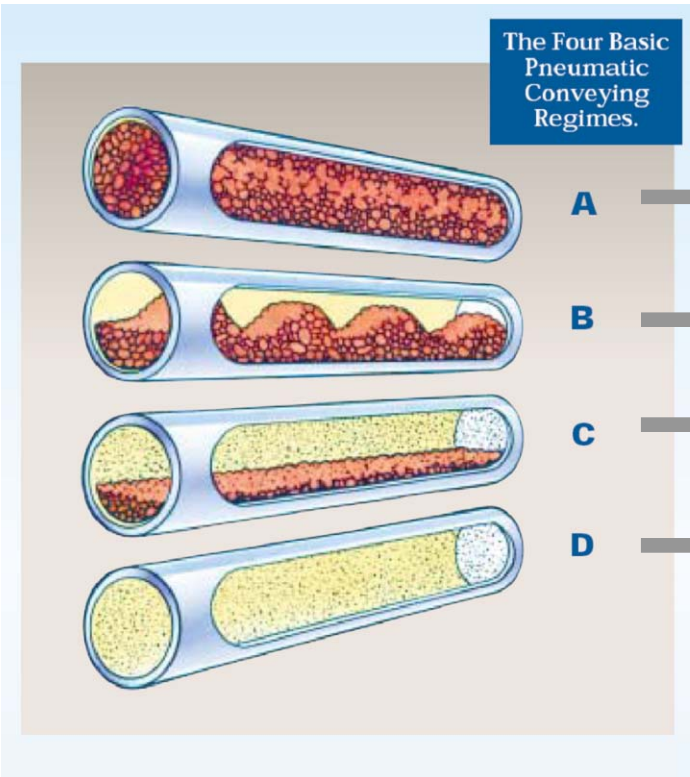
High Power Targets

Pneumatic Conveying Regimes Explored so Far

Low Velocity

Increasing Driver Pressure

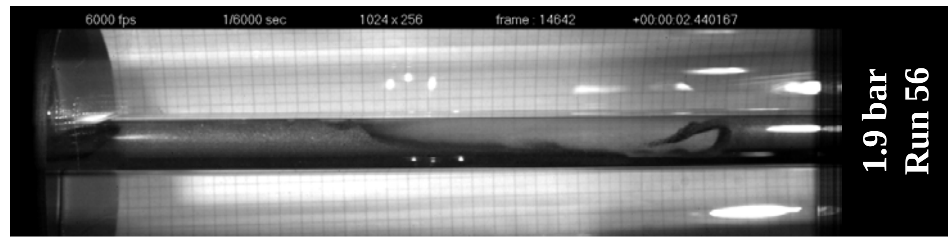
High Velocity



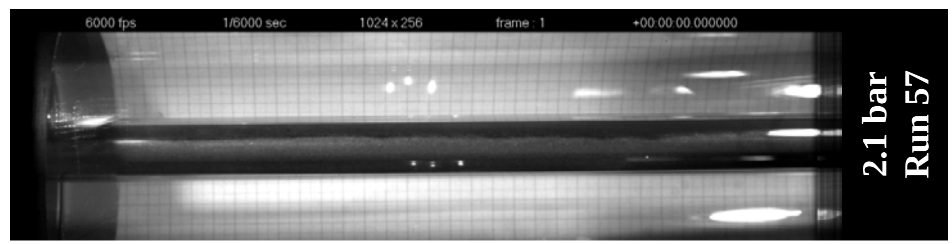
A. Solid Dense Phase

- Pipeline full of material, 50% v/v
- Low velocity
- Not yet achieved in our rig – further work

B. Discontinuous Dense Phase



C. Continuous Dense Phase



D. Lean Phase

- Low fraction of solid material
- High velocity = erosion!
- Used in vacuum recirculation line

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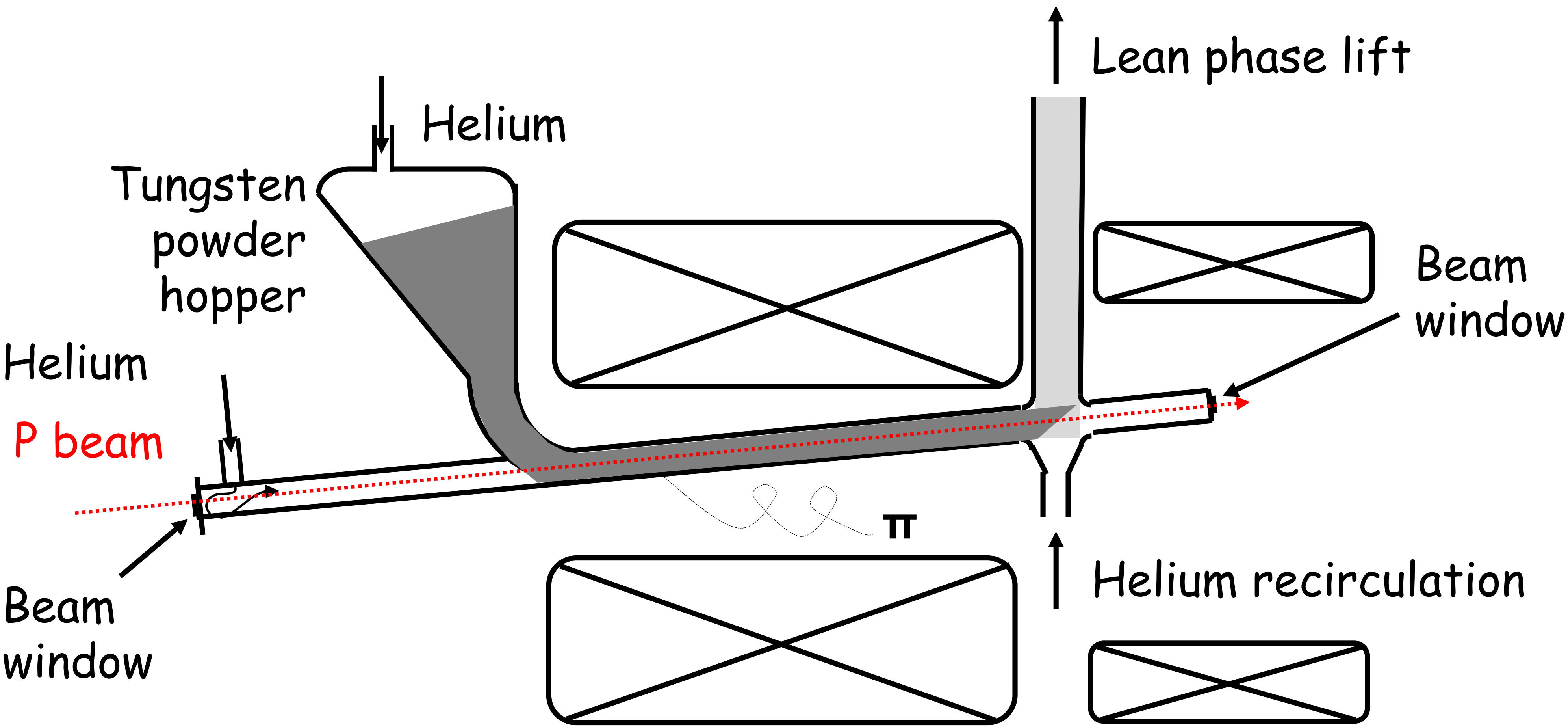
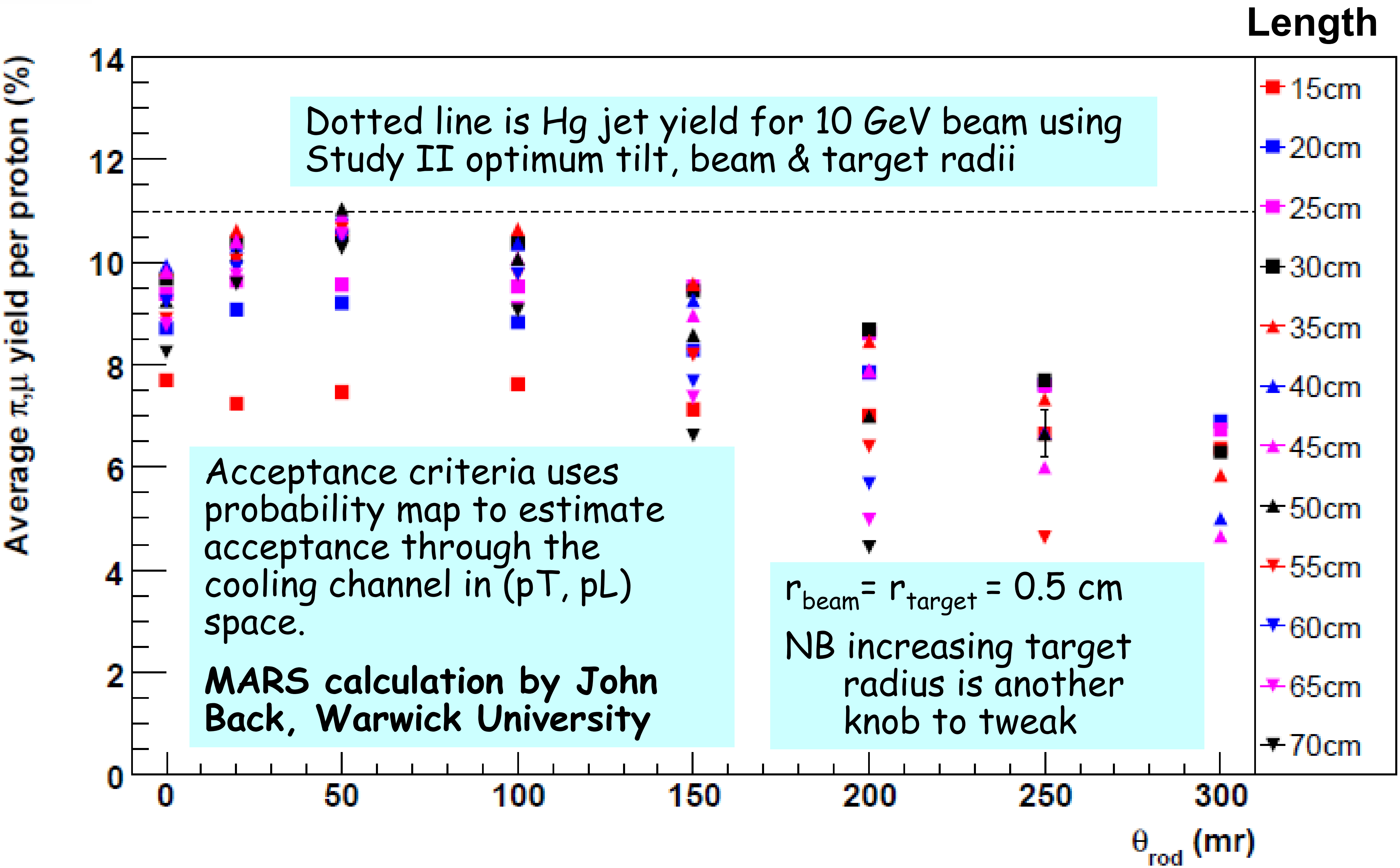
Schematic of implementation as a Neutrino Factory target



NB Alternative configurations possible

Pion+muon production for variable length 50% material fraction W vs 100% Hg



Meson Production at 8GeV (X.Ding)

Target	50% W (9.65 g/cm^3) with optimization*	Hg (13.54 g/cm^3) with optimization
Meson	29069 (pos: 14099 neg: 14970)	28819 (pos: 13613 neg: 15206)

*Target radius: 0.47 cm, target angle: 80mrad, target length: 45cm

HIGH RADIATION TO MATERIALS – HIRADMAT@SPS

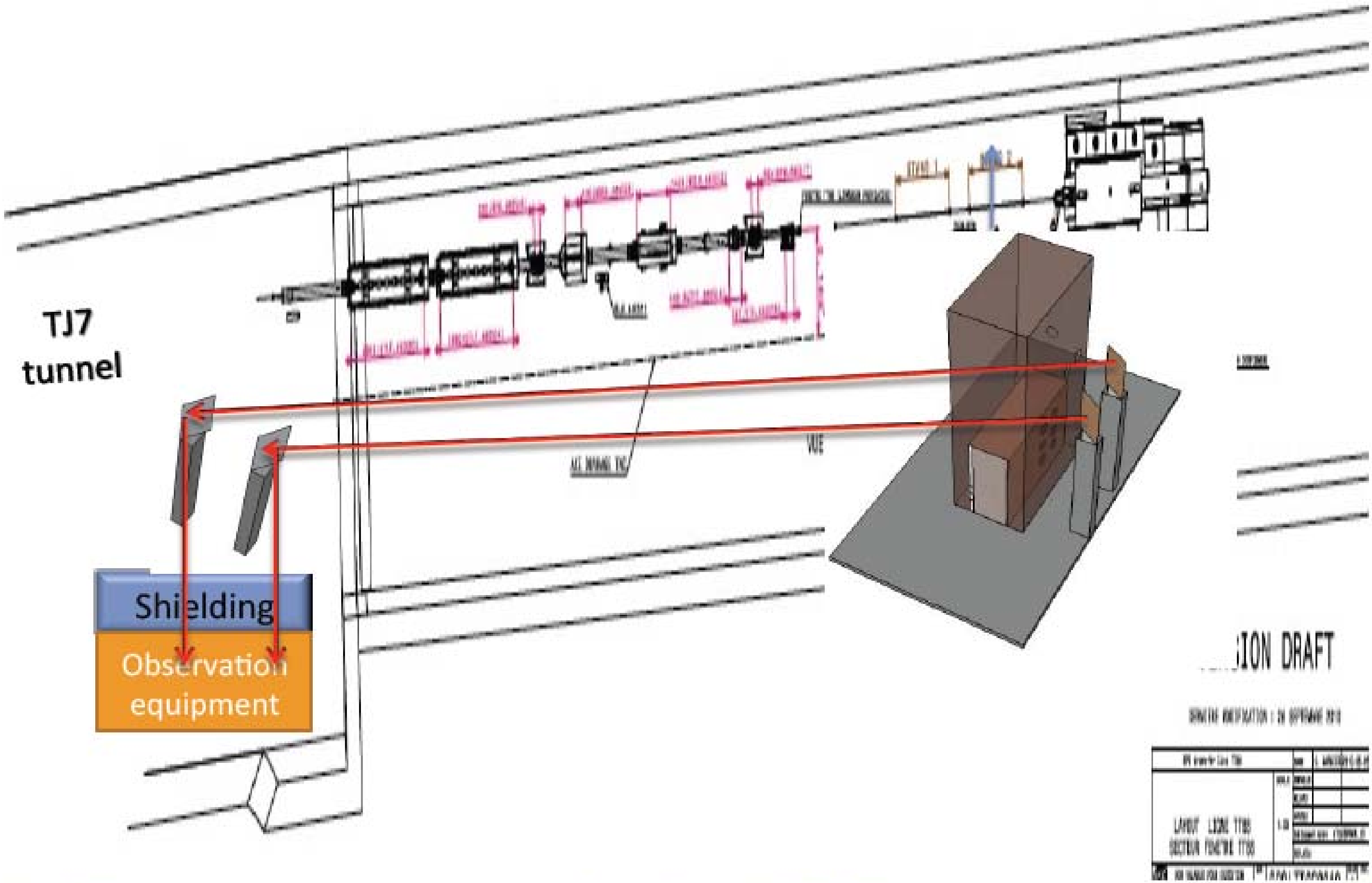
A NEW IRRADIATION FACILITY AT CERN FOR MATERIAL TESTING

Powder 'thimble' test is scheduled to be first ever experiment on HiRadMat this autumn

Ilias Efthymiopoulos, CERN

4th HPTWorkshop - Malmoe , May 6, 2011

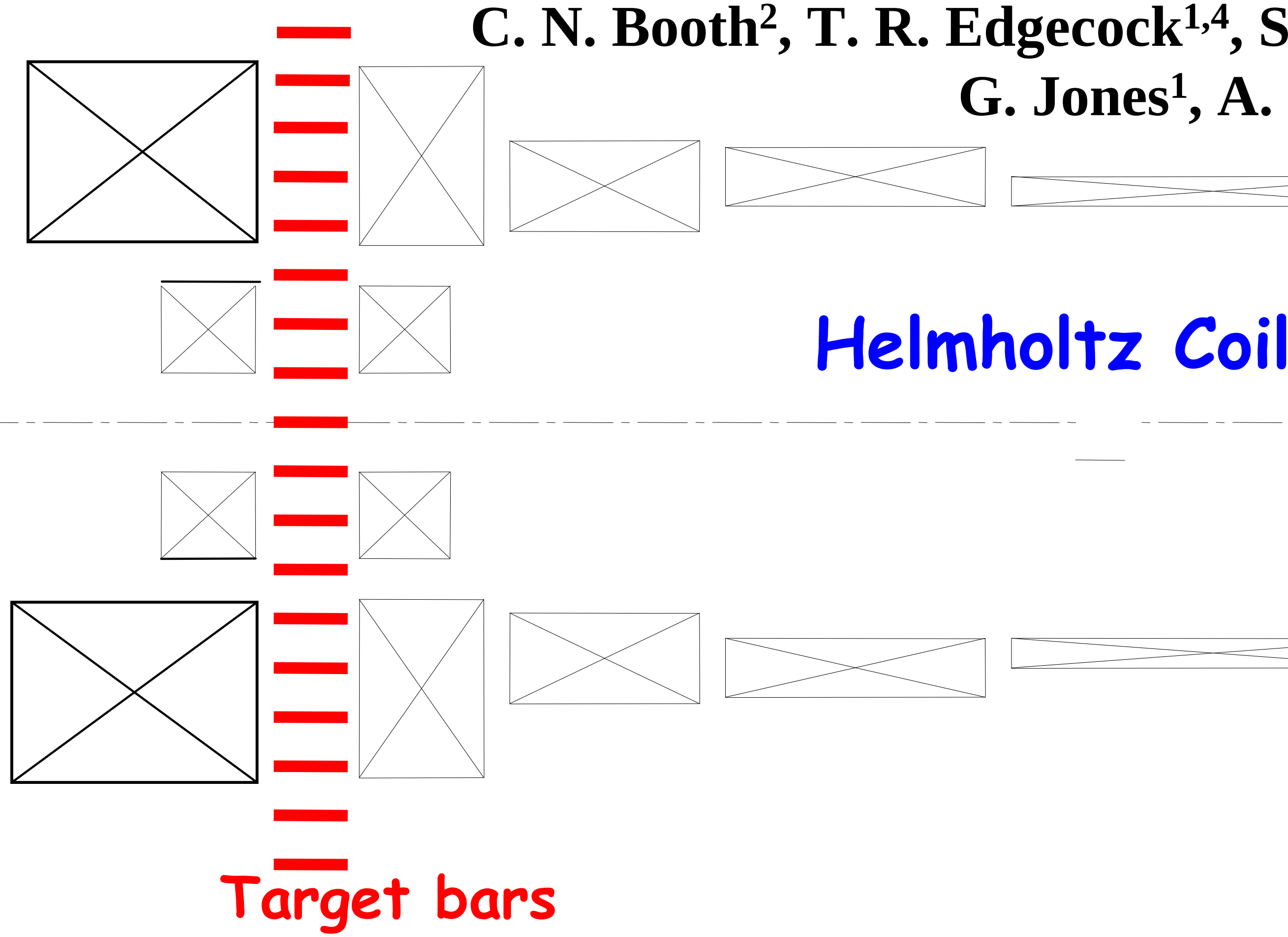
Experimental setup

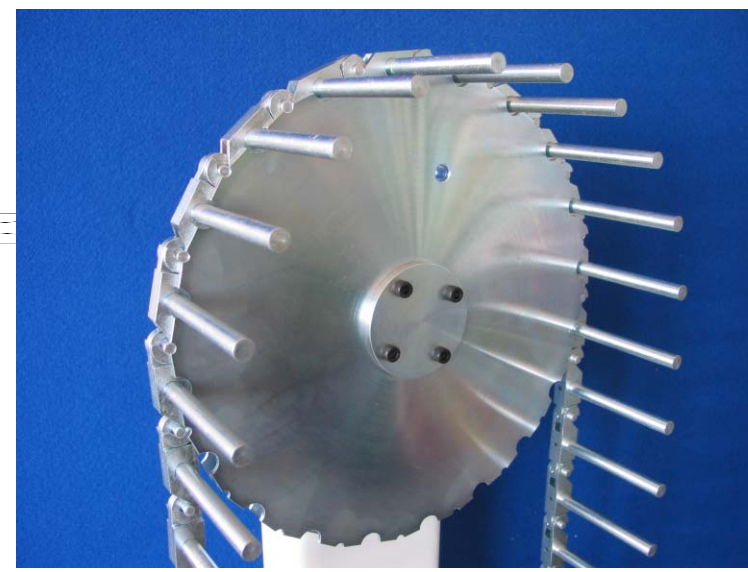


Re-circulating solid tungsten bar ideas

J. R. J. Bennett[1], G. P. Škoro[2], J. J. Back[3], D. W. J. Bellenger[1], C. N. Booth[2], T. R. Edgecock[1,4], S. A. Gray[1], D. M. Jenkins[1], L. G. Jones[1], A. J. McFarland[1], K. J. Rogers[1].

Helmholtz Coil Geometry

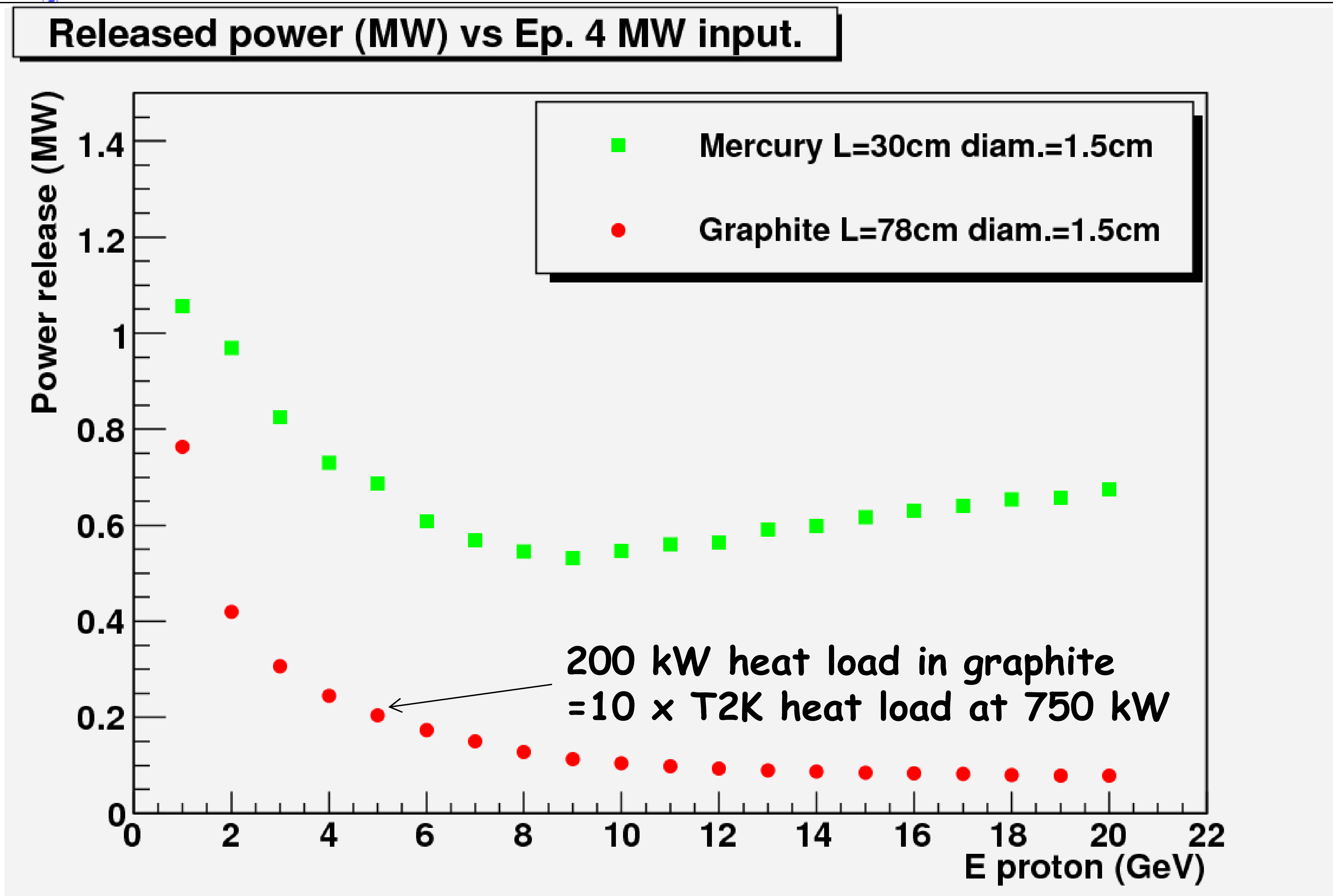




That's enough about heavy metals

- Is a low Z target an attractive option for a Neutrino Factory?

Target material & heat loads (A. Longhin)



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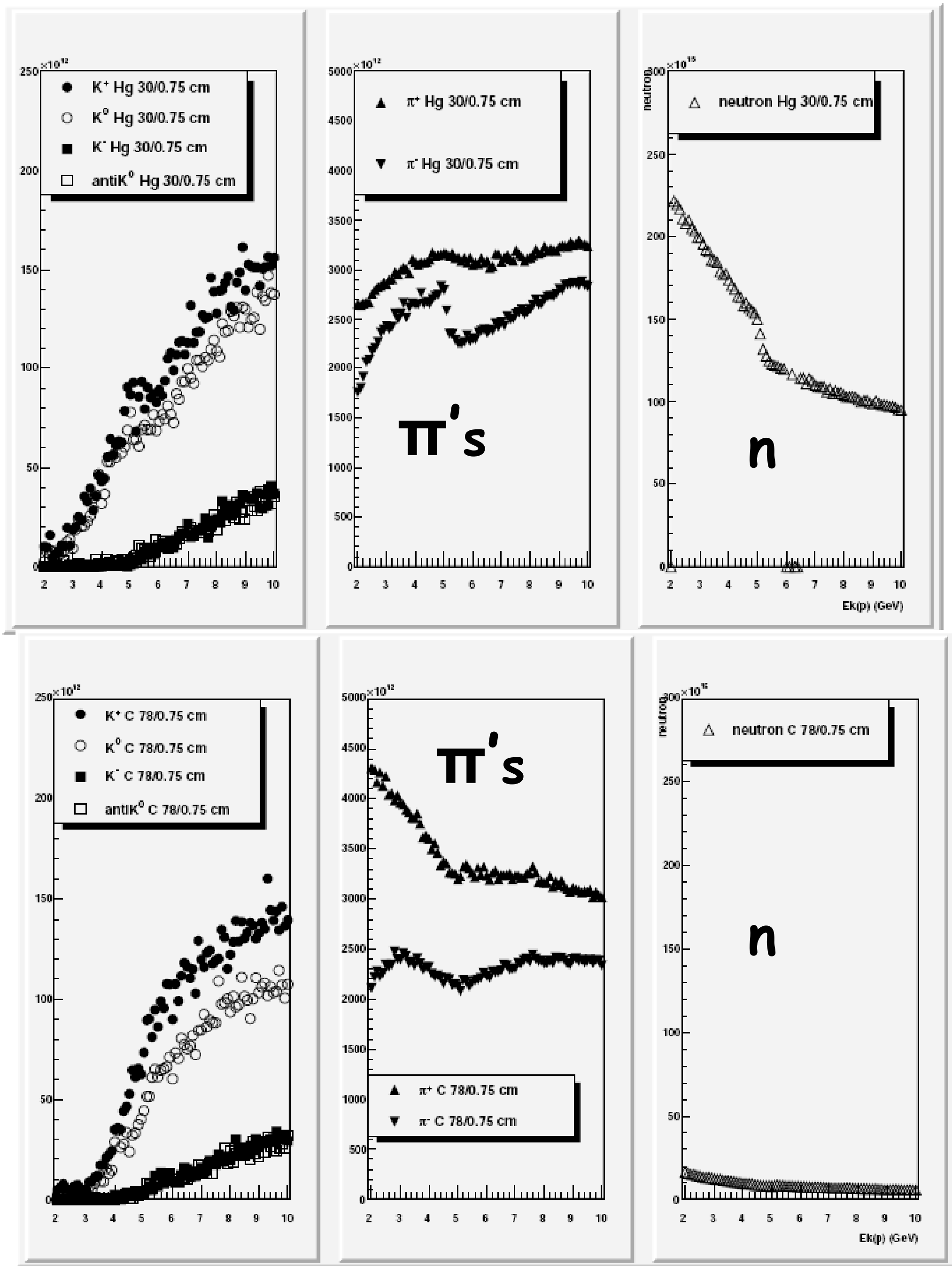
Particle production vs target material

Hg

C



- Proton kinetic energy = 2-10 GeV
- Integrated pion yields comparable for carbon and mercury targets
- Neutron flux for Hg reduced by ~ x15 with C !!

(lower neutron flux => lower heating and radiation damage to solenoid system)

(A. Longhin)

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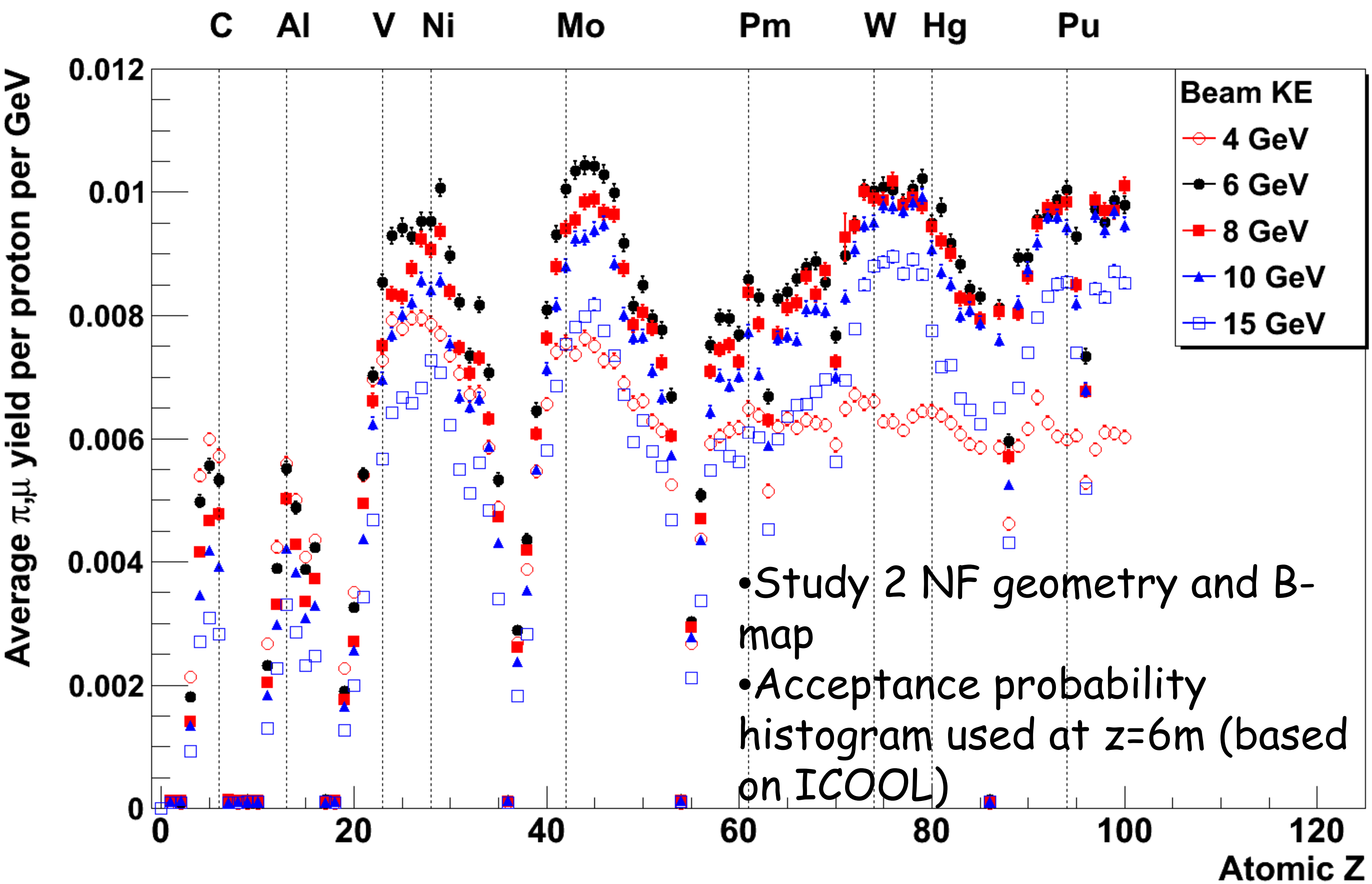
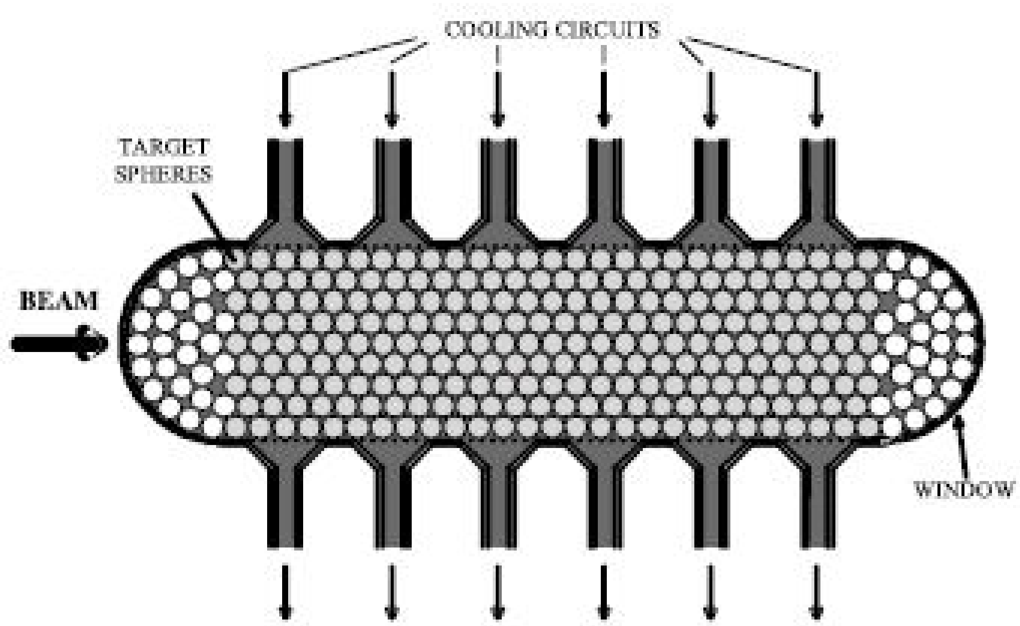
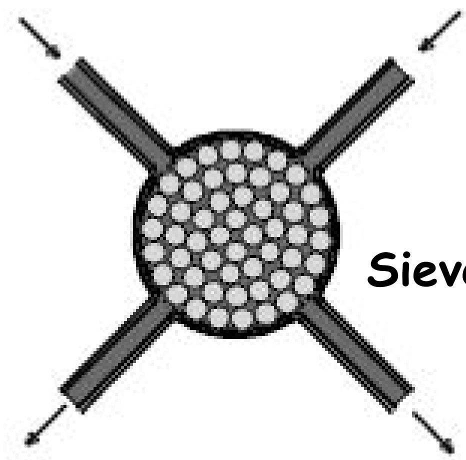
Useful pion/muon yields for different Z's and beam energies (J.Back)



- Study 2 NF geometry and B-map
- Acceptance probability histogram used at z=6m (based on ICOOL)

Packed bed ideas: more attractive for lower Z



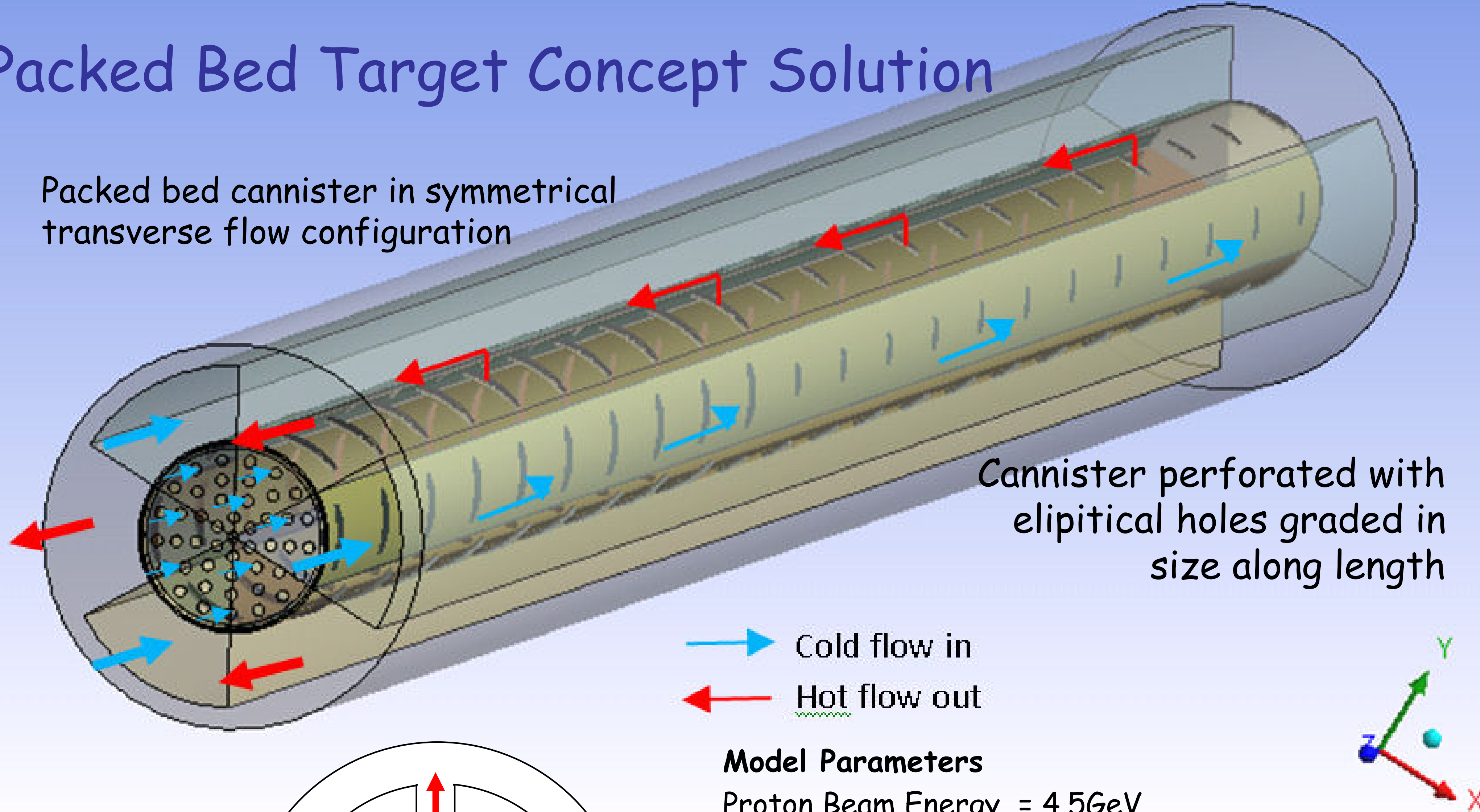


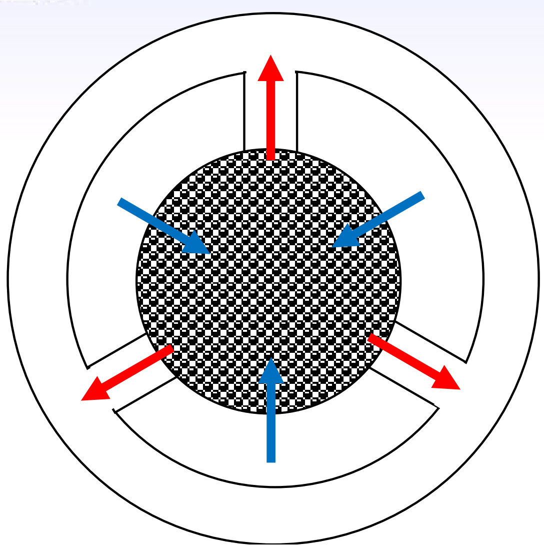
Sievers 2001

Relevant papers:

- A helium gas cooled stationary granular target (Pugnat & Sievers) 2002 [considered for a neutrino factory target with 4MW beam]
- Conceptual Designs for a Spallation Neutron Target Constructed of a Helium-Cooled, Packed Bed of Tungsten Particles (Ammerman et al.) [ATW, 15MW power deposited, 36cm diameter]

Packed Bed Target Concept Solution





Model Parameters

Proton Beam Energy = 4.5GeV

Beam sigma = 4mm

Packed Bed radius = 12mm

Packed Bed Length = 780mm

Packed Bed sphere diameter = 3mm

Packed Bed sphere material : Titanium Alloy

Coolant = Helium at 10 bar pressure

And let's not forget about beam windows

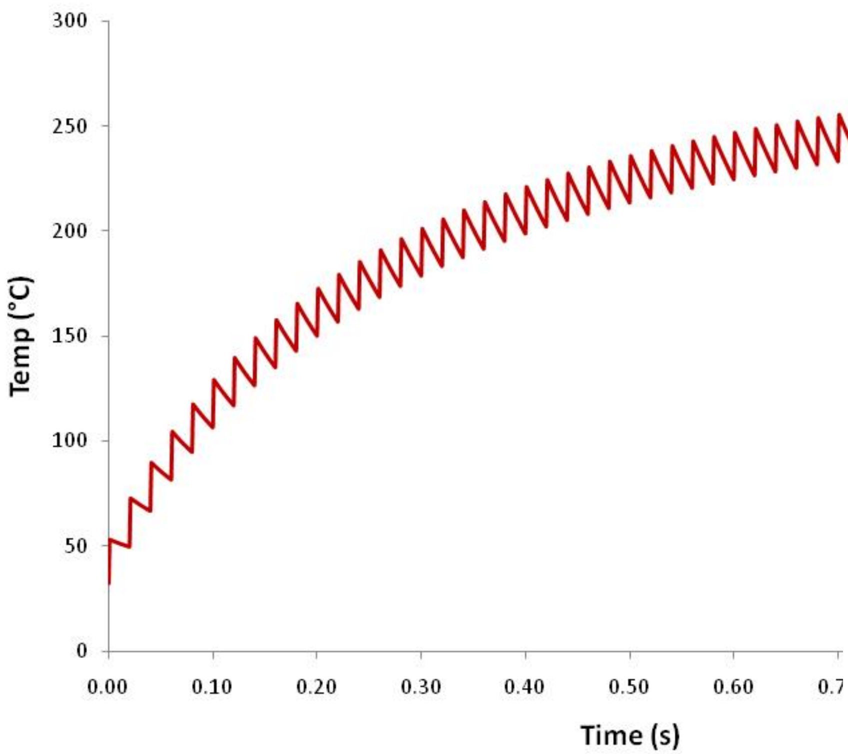
-T2K beam window (M Rooney)

-Double-skinned titanium alloy window, cooled by helium gas

- Installed October 2009

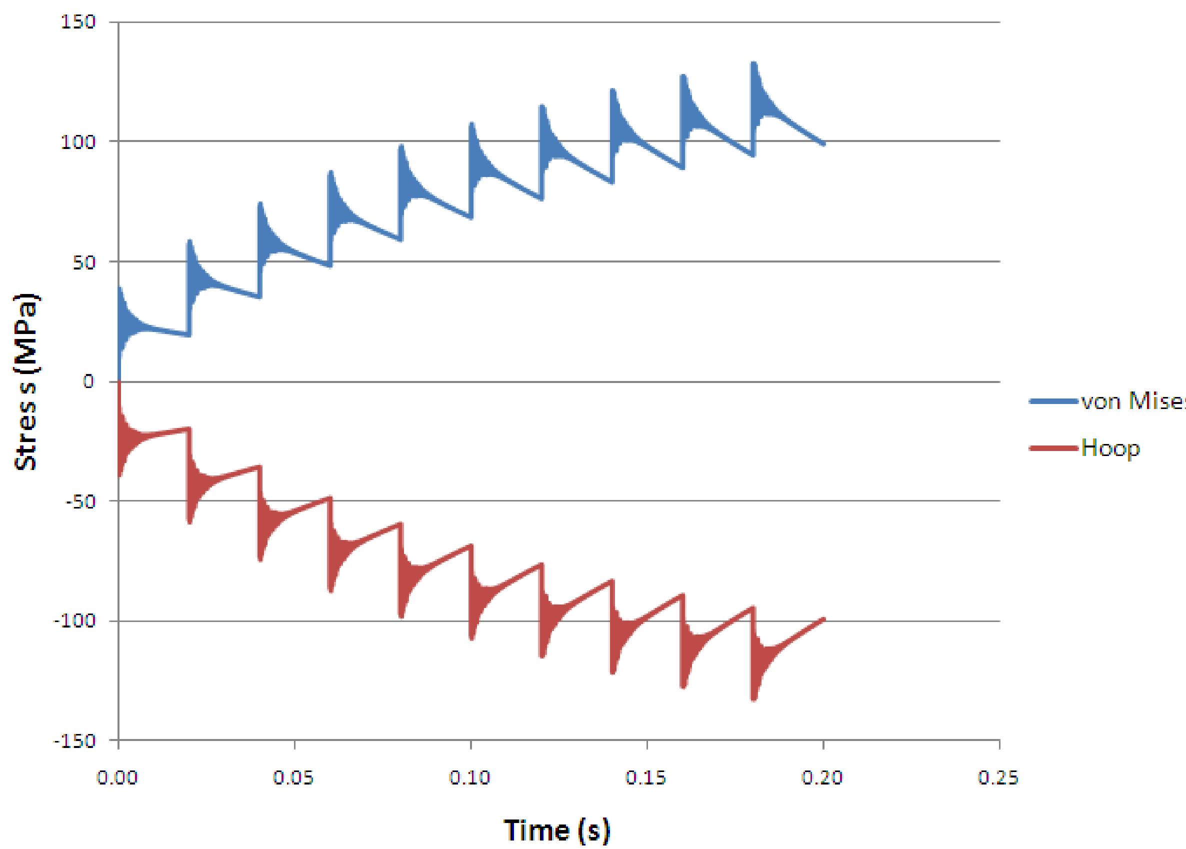
- Designed for 30 GeV, 0.75 MW beam power

4 MW beam window



HP SPL beam parameters

Beam energy:	5 GeV
Protons per pulse:	1.5×10^{14}
Frequency:	50 Hz
Pulse length:	5 microseconds
Beam size:	4 mm (rms)



Yield strength of beryllium @ 260°C is around 200 MPa. This leaves a small safety factor for a beryllium window with these beam parameters.

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A few comments on future programme

- Target technology
  - main focus of NF/MC target station work since Study II (ie last 10 years)
  - at least 1 'champion' of each of 3/4 target technologies
  - Good to have alternatives (provided does not distract from other work that needs to be done – see below)
- Solenoid System
  - Most critical technological issue for NF/MC Target Station?
  - Study 2 baseline appears far from feasible
  - NB 'Brute force' solution with extra shielding:
    - Stored energy α r^2
    - Only very recently receiving any attention
- Activation/handling/safety/environmental issues
  - The other most serious feasibility issue?
  - Nobody working on it?

Cost / Design Issues

- Cost ⇔ technical risk
- Build costs ⇔ running costs?
- Integrated yield ⇔ integrated costs?
- Target Station Design choices depend on grasp of these issues
- May be worth revisiting:
  - Beam energy
  - Target Z
  - Beam size
  - Solenoids vs horns (and 2 proton drivers…)?