THE INTERNATIONAL DESIGN STUDY
FOR THE NEUTRINO FACTORY

EUROnu/IDS-NF: Target

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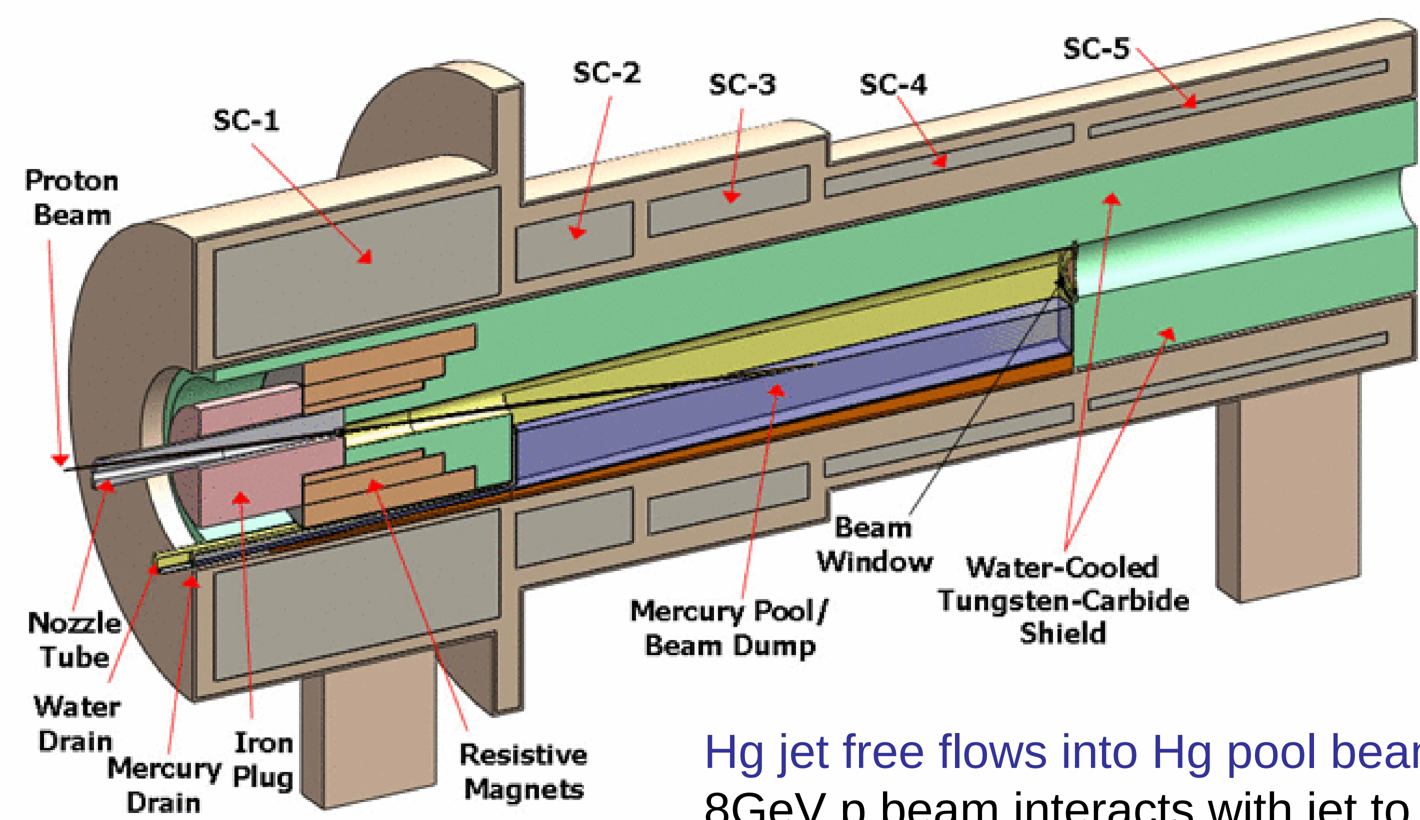
THE UNIVERSITY OF WARWICK

Introduction

- Review of status and plans for Neutrino Factory target work
  - Superbeam target work not part of this presentation (different WP)
- NuFact target baseline: Hg jet
  - Target station layout
  - Energy deposition studies: issues with superconducting coils
  - MERIT experiment results: validates choice of target baseline
  - Particle production simulations (accepted μ yields)
- Alternative target options
  - Powder jet targets: experimental work to demonstrate feasibility
  - Solid targets: measurements of shock/lifetime/strength, preliminary target change design
- Summary

Target Baseline Concept



Hg jet free flows into Hg pool beam dump

8GeV p beam interacts with jet to create π,μ

20 T field to focus π, μ (also stabilises jet)

SC coils (14T), Resistive Magnets (6T)

WC shielding to protect magnets

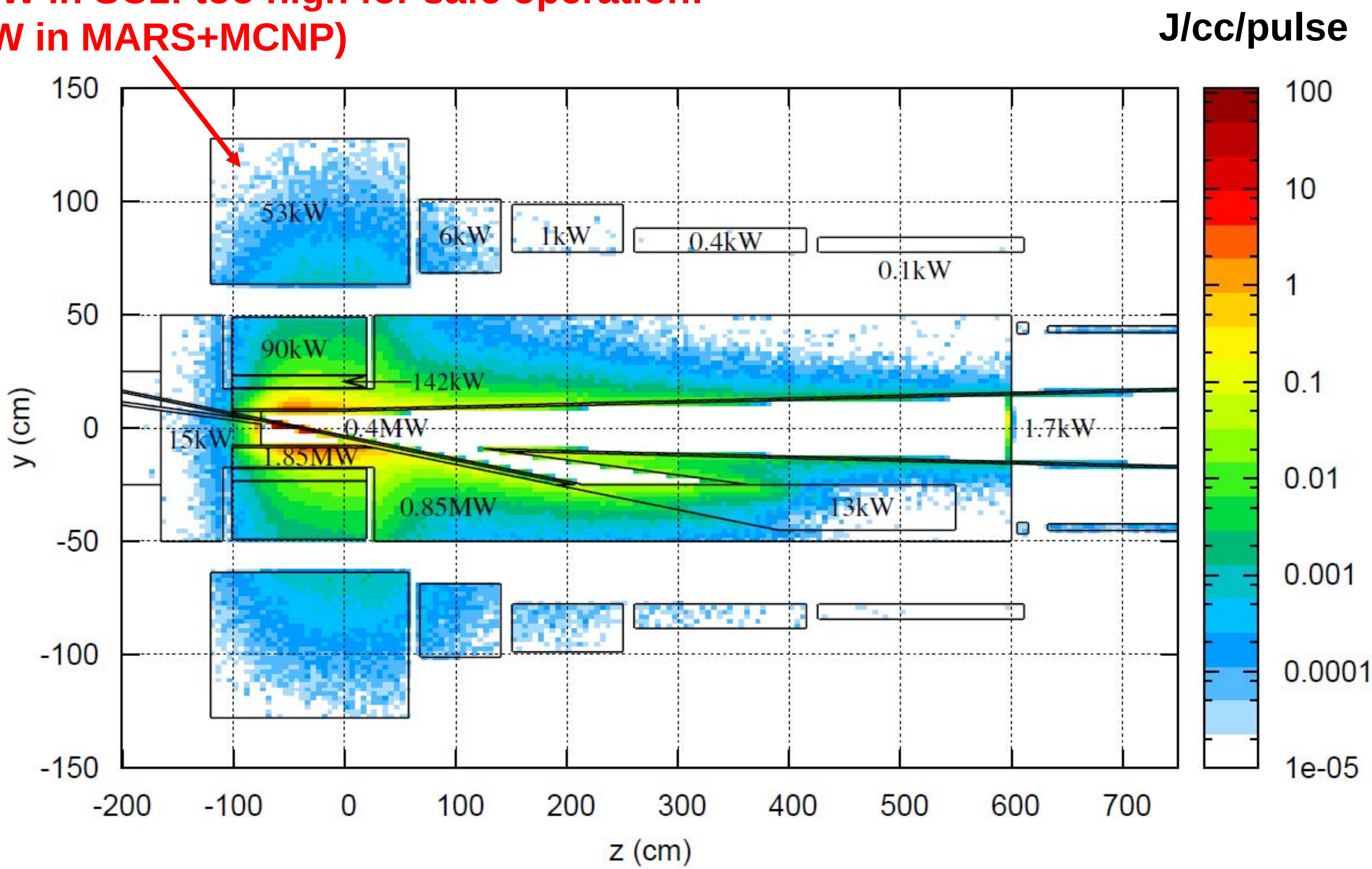
Baseline proton beam parameters:

KE = 8 GeV, 50 Hz rep rate, 3 bunches (240 μs total), bunch width 2±1 ns,

Beam radius = 1.2 mm (rms Gaussian), power = 4 MW (3.125 x 10^{15} protons/sec)

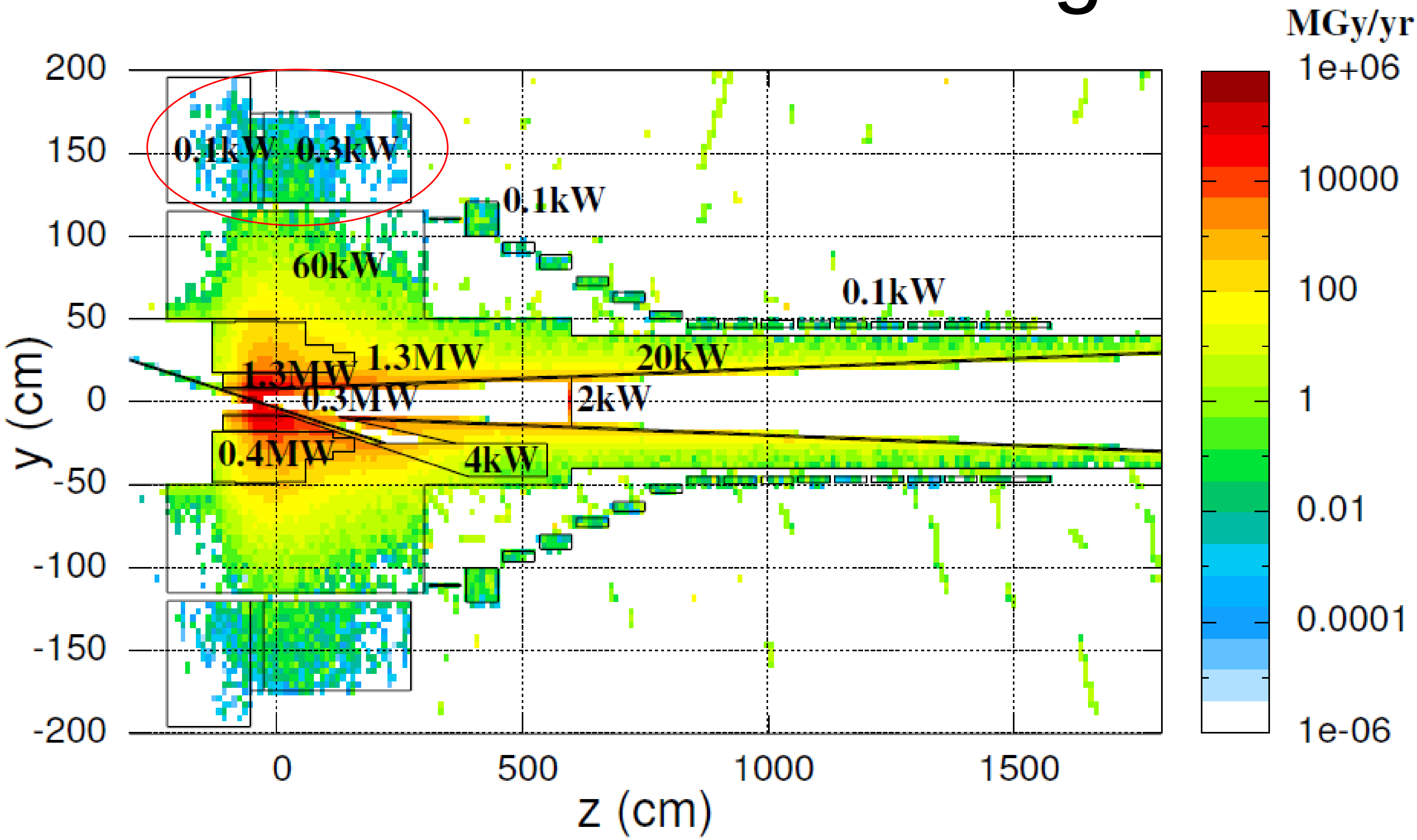
Power Deposition (IDR)

P~53kW in SC1: too high for safe operation!
(~40kW in MARS+MCNP)



FLUKA simulation of energy deposition in IDR geometry
Good agreement when comparing MARS+MNCP (not MARS only)

Increased shielding

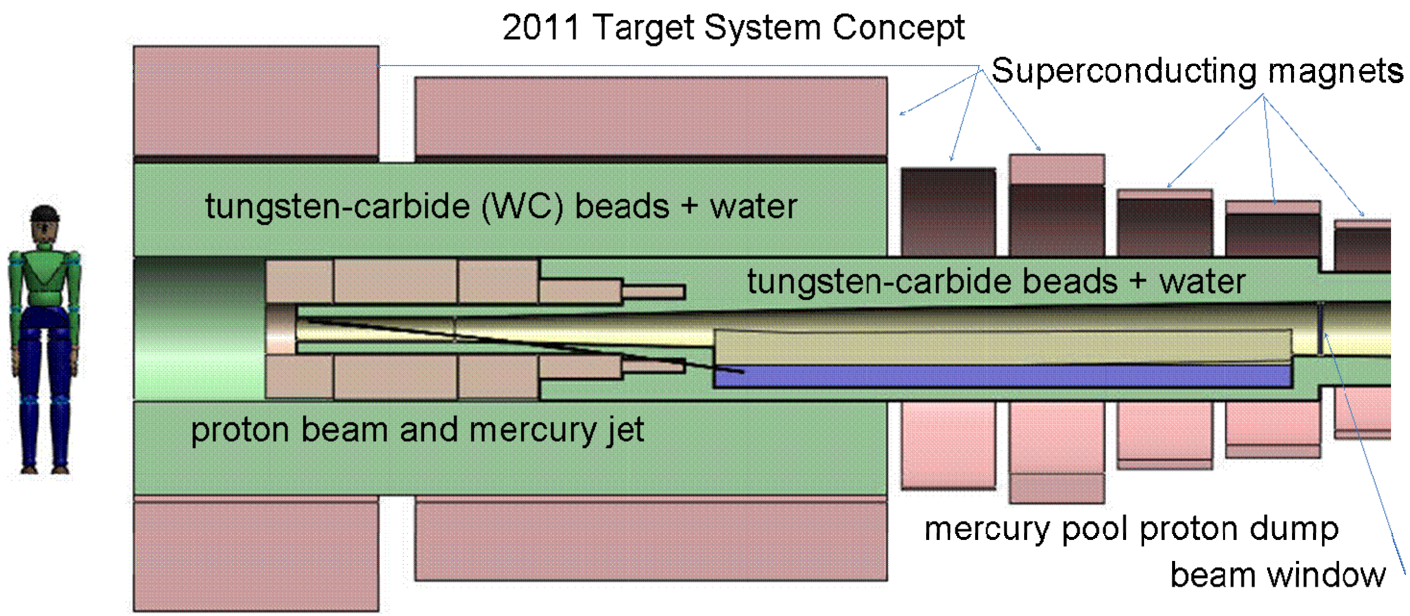


Doubled shielding radius: SC power depositions < 1 kW

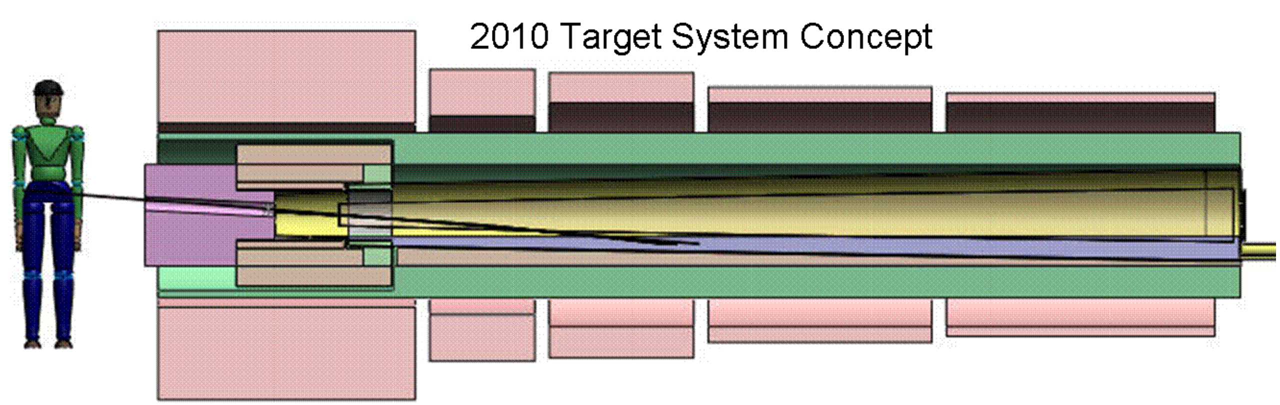
SC peak energy dep < 0.05mW/g (ITER requirement is <0.17mW/g)

Target station design evolution

Energy deposition studies showed that much more shielding was required



LATEST

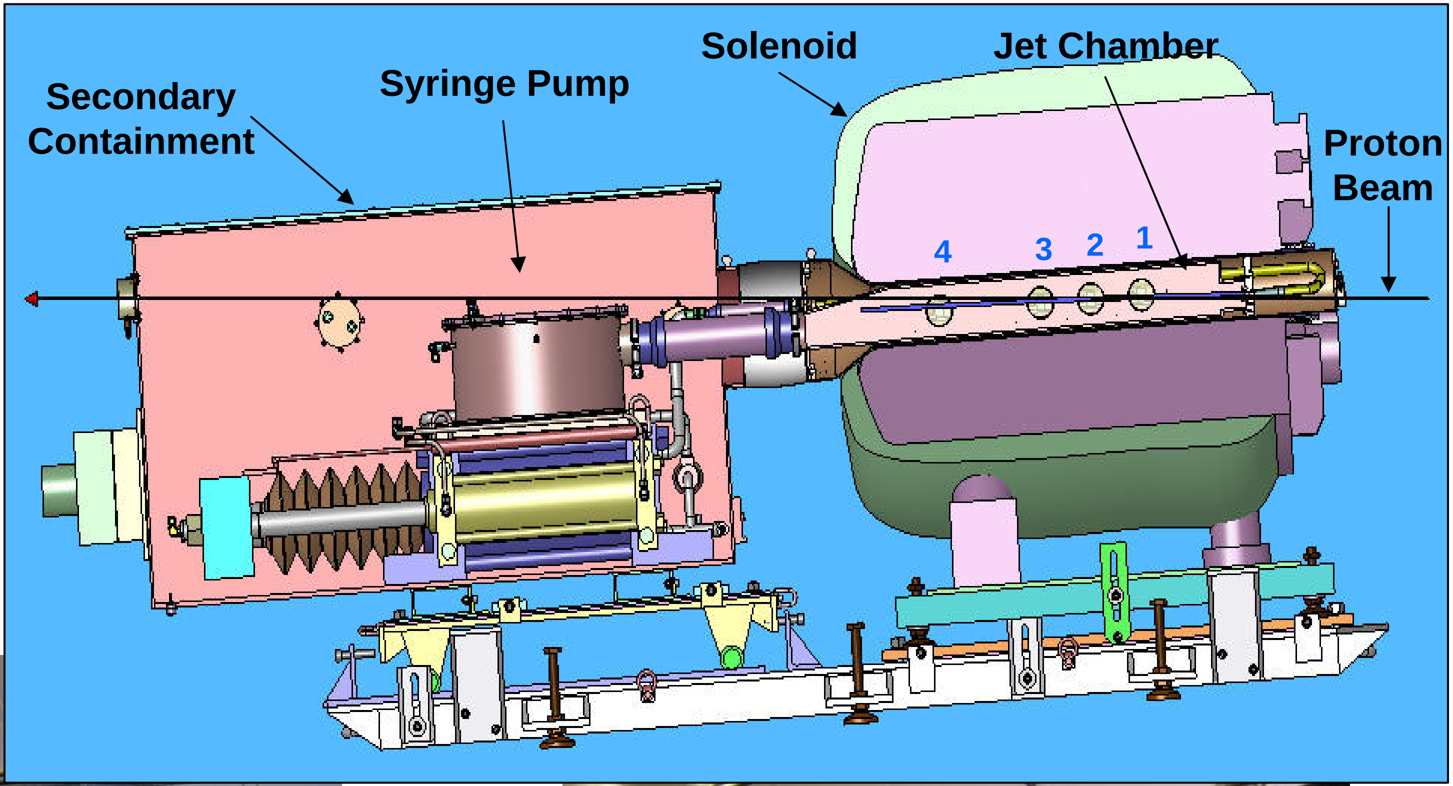


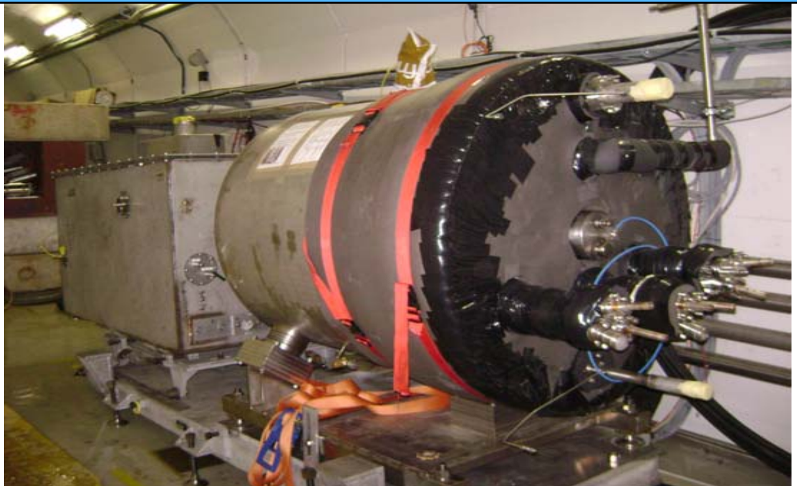
IDR

MERIT Experiment

Proof-of-principle demonstration of a mercury jet target in a strong magnetic field; proton bunches with intensity≡4MW

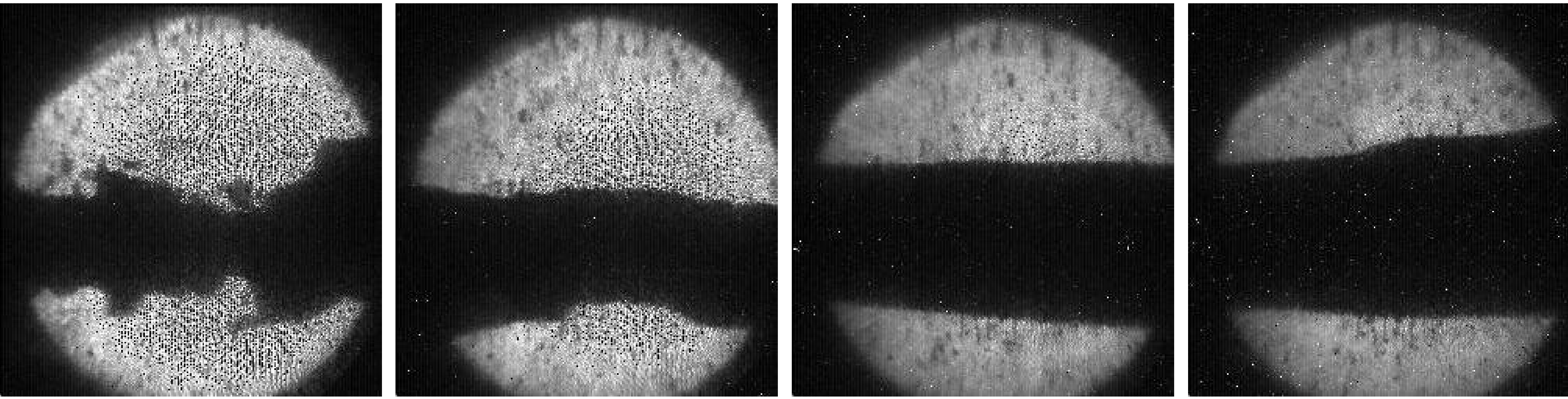
Experiment performed at the CERN TT2a line, Nov '07.





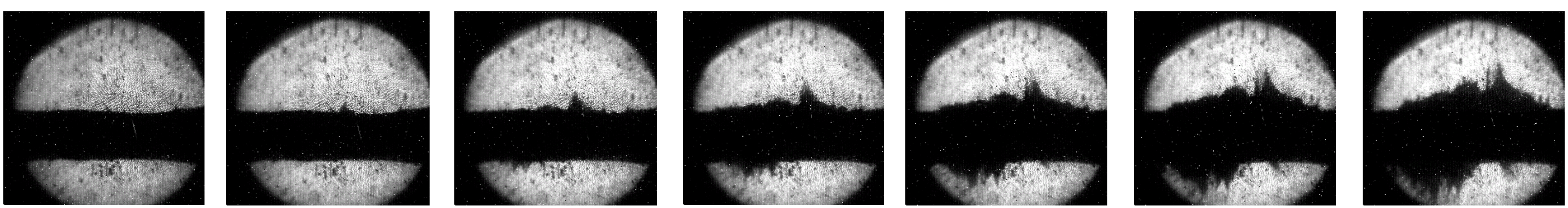
MERIT Results

Stabilisation of Hg jet (v=15m/s) with increasing magnetic field:



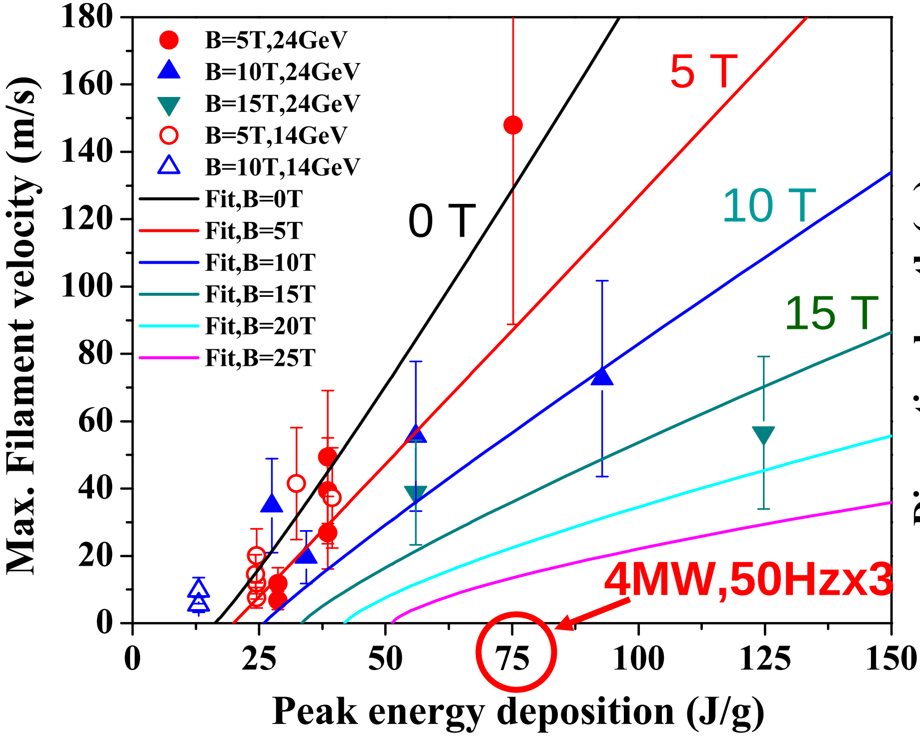
0T 5 T 10 T 15 T

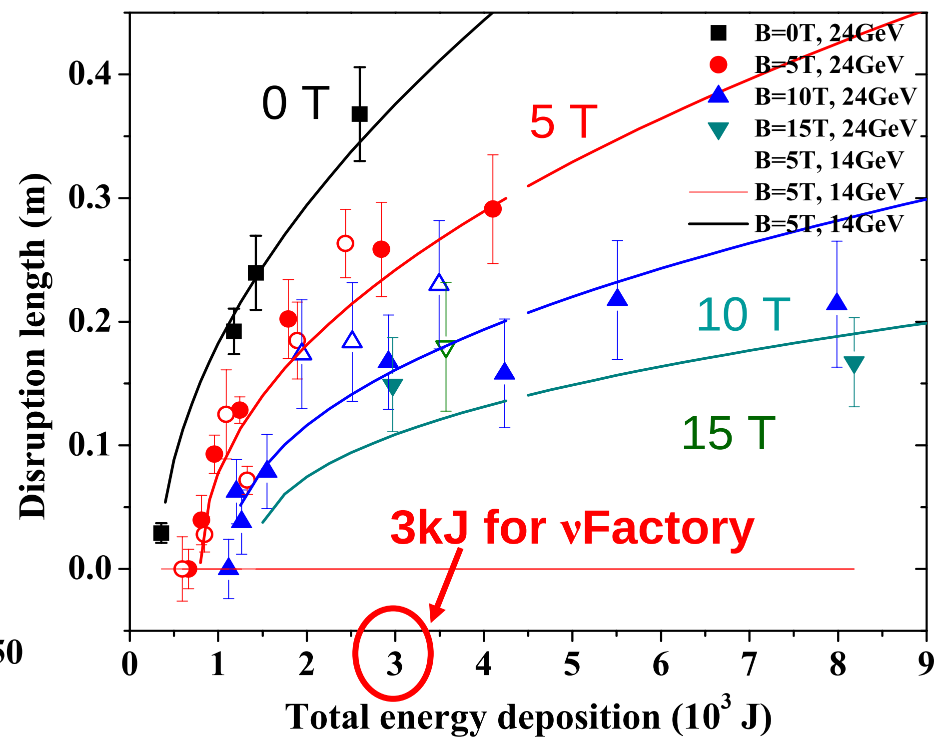
Filament velocities: Measure positions of filaments and track them through time



MERIT Results

Curves are global fits





Filament velocity suppressed by high B field
Filament start time >> transit time of sound across the jet.

Disruption length < region of overlap of jet with proton beam ⇒ does not affect π production
No disruption for pulses of < 2 x10^{12} p in 0 T (< 4 x 10^{12} p in 10 T).
Disruption length shorter at higher B field.

The magnetic field stabilises the liquid metal jet and reduces disruption by the beam

Further Hg jet target studies

Integrated design study of a Hg jet & pool loop + 20 T capture magnet:

•Improved nozzle for mercury jet
•Splash mitigation in the mercury beam dump (see Fig. on right).
•Safe containment/recirculation of mercury jet

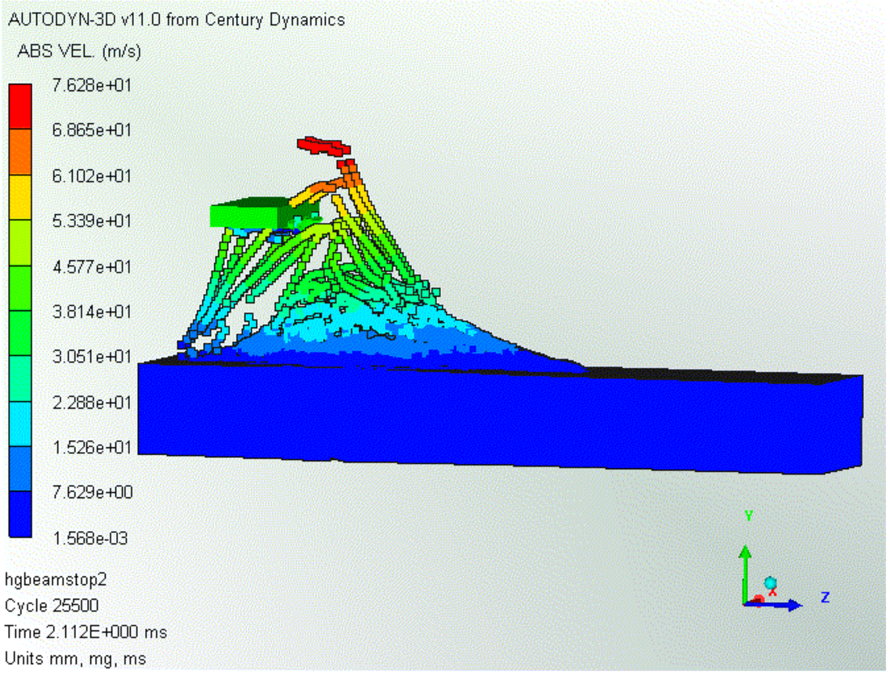
•Downstream (Be?) beam window: high radiation dose expected

•Details of water-cooled tungsten-carbide shield (coolant flow)

•High-T_C fabrication of the superconducting magnets.

•Eliminate the iron plug to improve Hg loop access?

•Optimise geometry to produce best π,μ yields with realistic engineering considerations taken into account

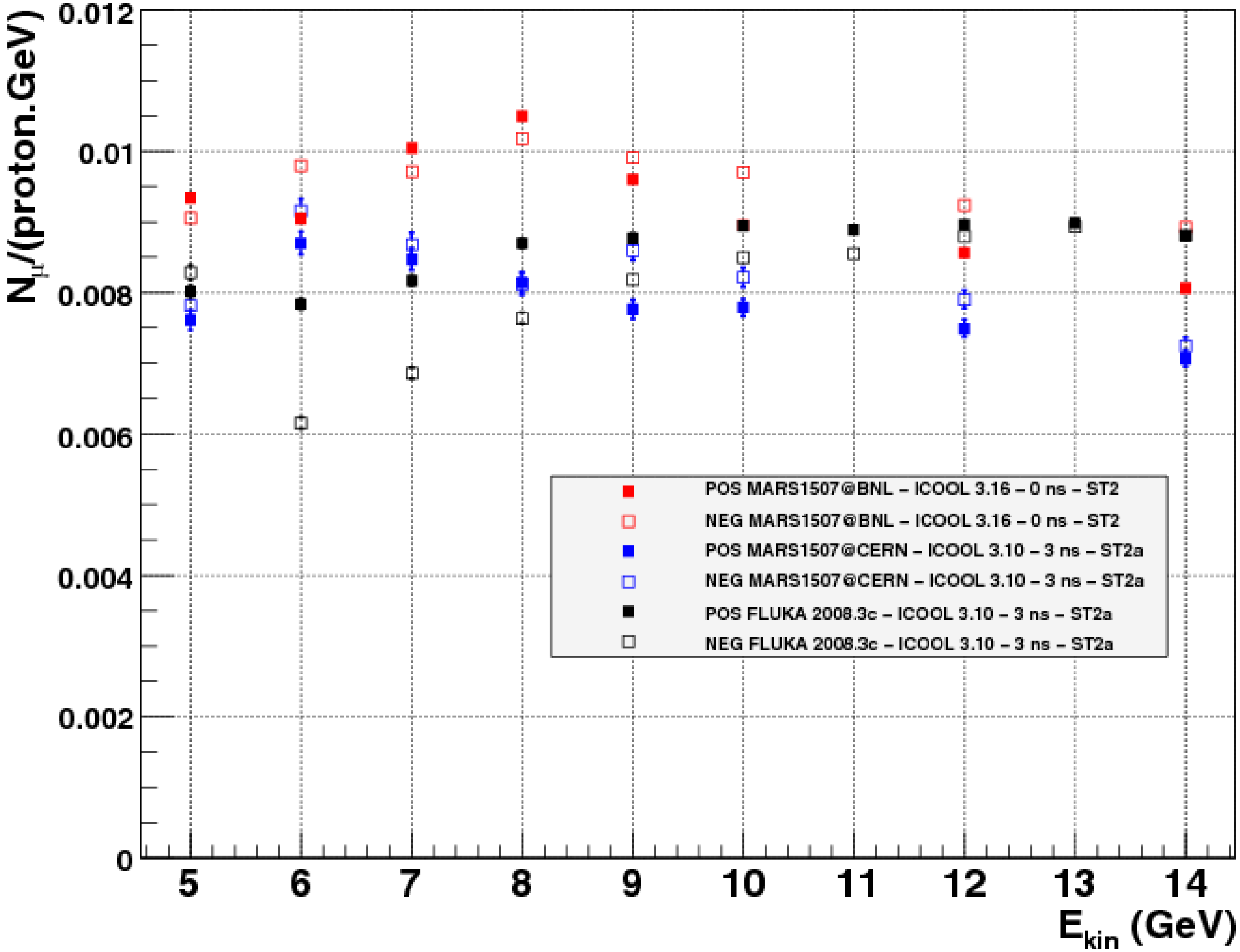


Simulation of Hg pool splash due to 24 GeV proton beam, for no B field failure mode (20×10^{12} p); max v ~75m/s

Continue MHD simulations of the beam-jet interaction in high B field

Particle production – muon yield

MARS & FLUKA simulation results of accepted μ yields for Hg jet target



ICOOL: calculate μ acceptance given π,μ target yields.

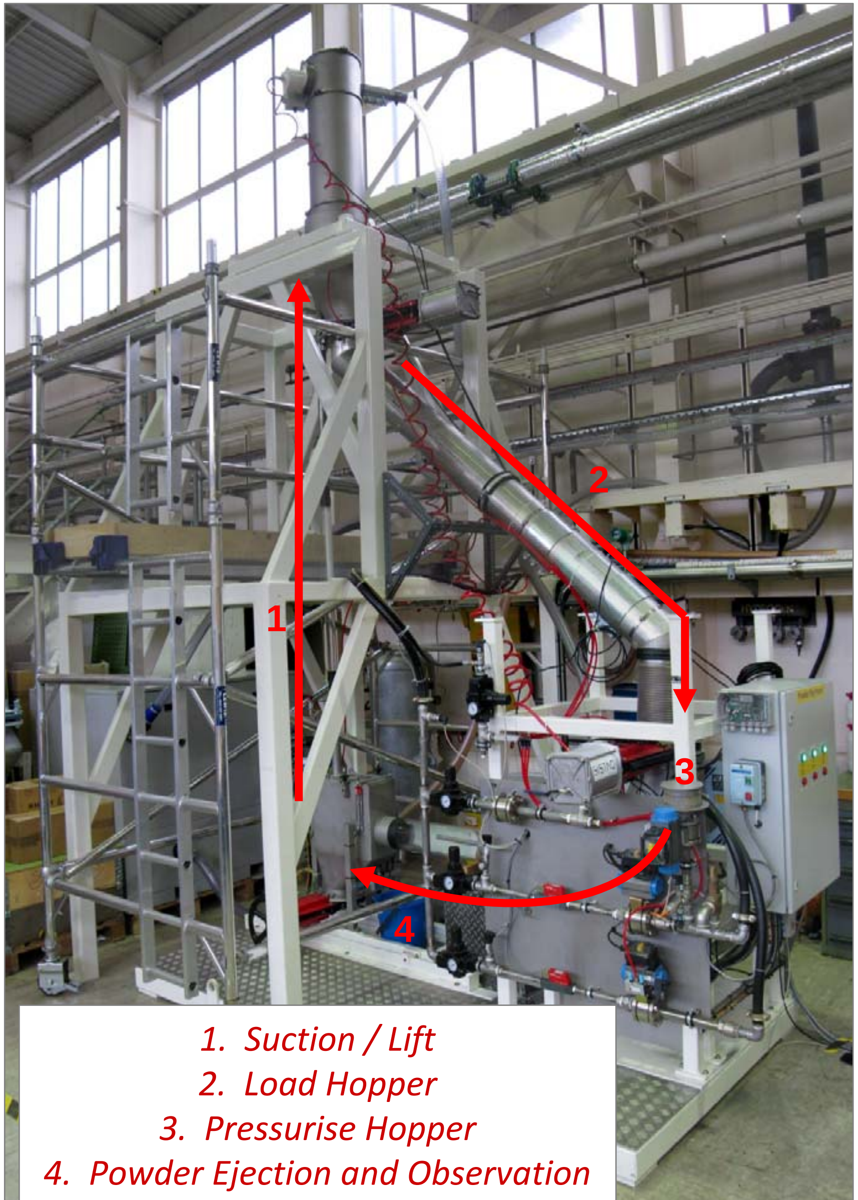
MARS 15.07: 0 ns bunch width

MARS 15.07: 3 ns bunch width

FLUKA 2008.3c: 3 ns bunch width

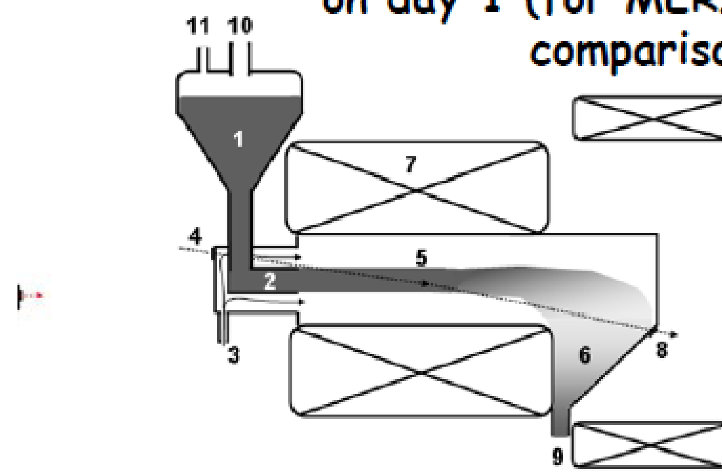
Preliminary studies show MARS results agree with HARP data for KE <10 GeV

Alternative 1: Powder Jet



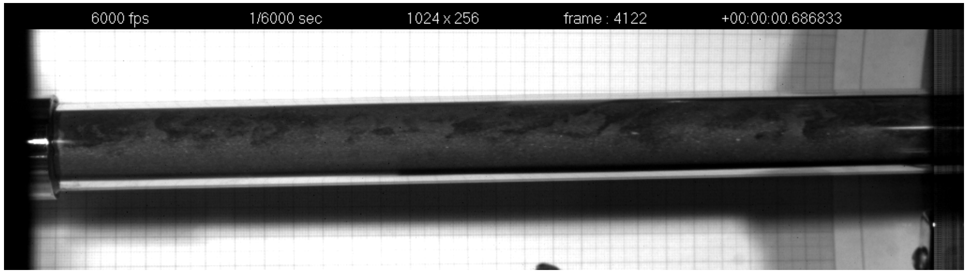
Left: Test rig at RAL
100kg W powder (grain size < 250 μm).
Total ~10,000kg conveyed
($\equiv$20 mins continuous operation).

Neutrino factory target - open jet configuration used in test rig on day 1 (for MERIT comparison)

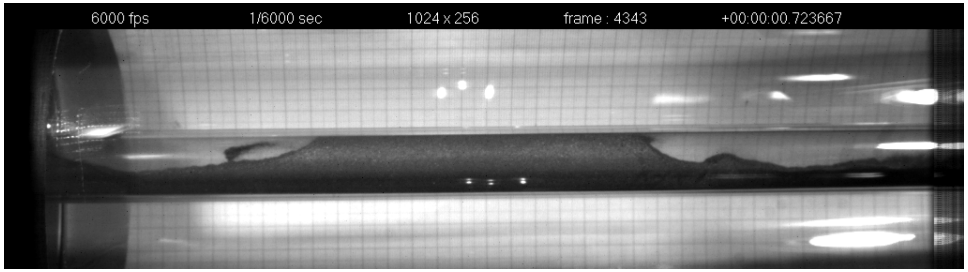


(1) pressurised powder hopper, (2) discharge nozzle, (3) recirculating helium to form coaxial flow around jet, (4) proton beam entry window, (5) open jet interaction region, (6) receiver, (7) pion capture solenoid, (8) beam exit window, (9) powder exit for recirculation, (10) return line for powder to hopper, (11) driver gas line

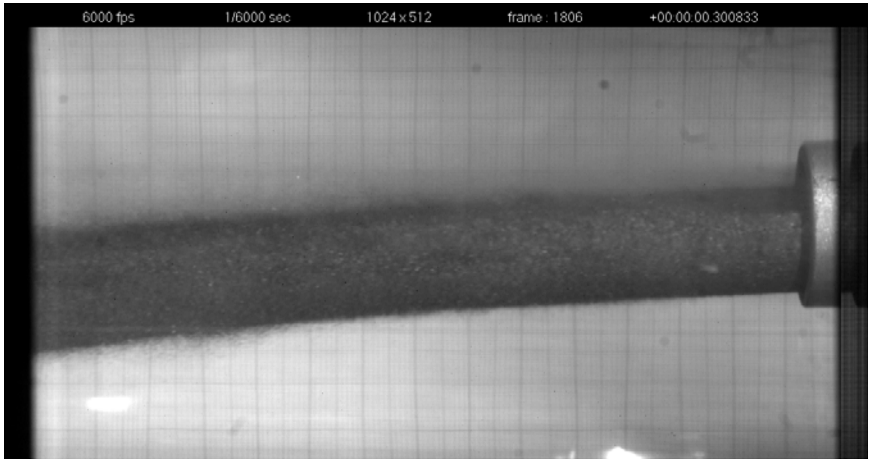
Powder jet flow measurements



Turbulent flow inside container: P~3 bar



Dune flow inside container: P~1.5 bar

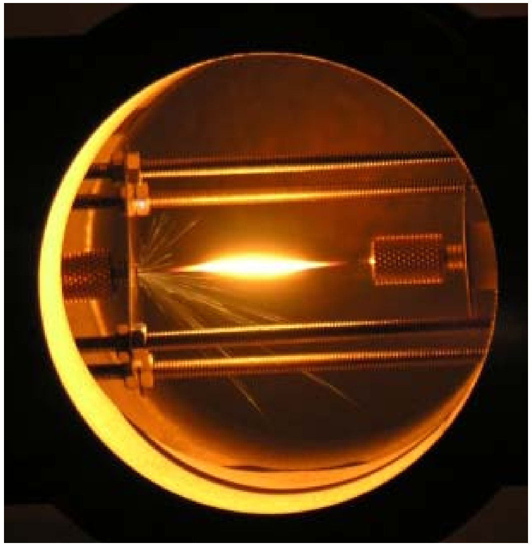


Coherent free flow jet: P~2 bar

Effective density = (42 ±5)% solid W

Alternative 2: Solid Target

- Possible alternative to Hg jet target
  - Many years of experience worldwide using solid targets
  - More safer from toxic point of view (e.g. W less volatile than Hg)
- Issues:
  - Thermal shock: thought that solid target would shatter after first beam pulse
  - Radiation damage may affect target integrity
  - Changing the target reliably in a high B field environment to limit radiation damage/heat load stress

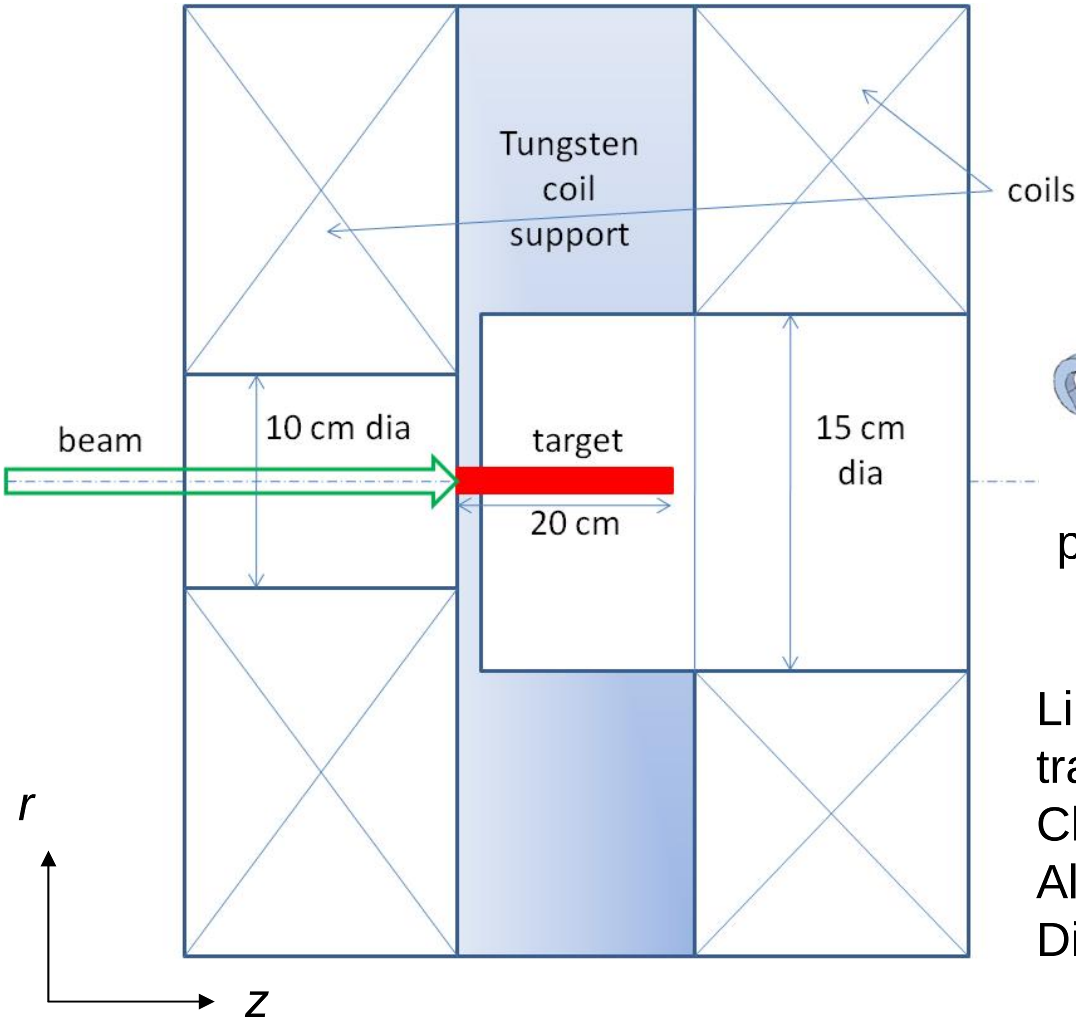


Experimental program at RAL to study shock in solid target: high currents passed through thin W (Ta) wires, results agree with LS-DYNA simulations.

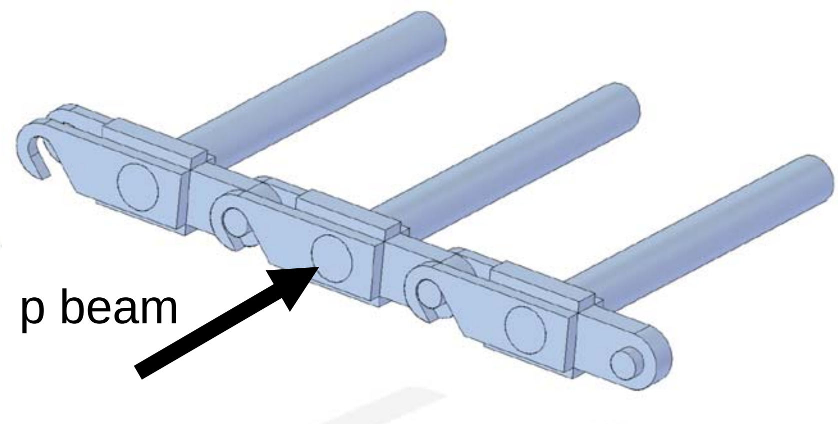
Expected solid target ν Factory lifetime $\geq$ 10 years. Targets should not break: yield strength remains high. Further irradiation studies needed.

Young's modulus results: J. Nucl. Mat. 409, 40 (2011)
Target strength results: accepted for pub in NIM A.

Solid target change



Change targets between beam pulses: 50Hz.



Link target rods on a chain, moving transversely to the beam (z) direction.
Chain speed = 7.5cm*50Hz = 3.75m/s.
All tungsten; use WS_2 for lubricant.
Discussions with manufacturers.

Support Helmholtz coils (large B forces) with additional W shielding inside the “gap”. Engineering designs underway.

Summary

- Baseline Hg jet target station
  - MERIT experiment success: proof-of-principle demonstration
  - Need increased shielding to protect SC magnets from radiation dose
  - Investigating solenoid design options to reduce magnet forces & radiation dose in SC coils
  - Need to optimise geometry for best π,μ production within realistic engineering constraints (shielding, magnets, Hg jet/pool safety)
- Powder jet option
  - Experimental test rig at RAL showing promising results
- Solid target option
  - Shock should not be a problem for tungsten targets; need to check target strength is OK after irradiation
  - Preliminary target change engineering designs underway

- Costing needs to be done for the baseline (and other) options
  - This will be clearer once feasible engineering magnet/shielding/target handling options are narrowed down and identified.