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Review of Target Developments in Europe

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1. Target Specification
2. Targets Developments - so far
3. Proposed Target Developments

Specification

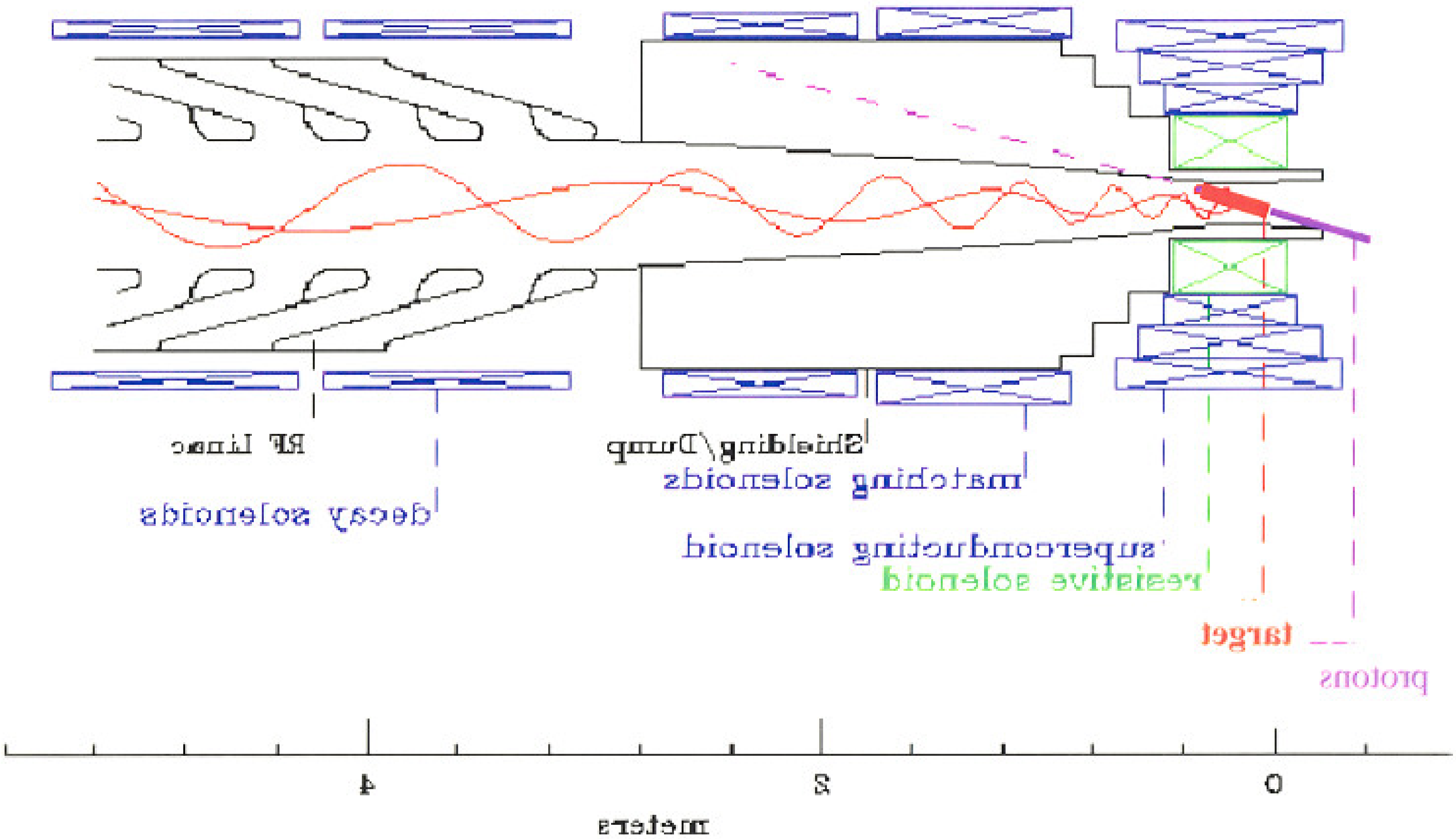
Proton Beam

• pulsed	10-50 Hz
• energy	2-30 GeV
• average power	~4 MW

Target

2 cm diameter, 20 cm long.

• mean power dissipation	1 MW
• pulse length	1-2 μs
• pulse repetition rate	10-50 Hz
• energy dissipated/pulse	20 kJ (50 Hz)
• energy density	0.3 kJ/cm^3 (50 Hz)



Typical Schematic Arrangement of a Neutrino Factory Target

Design Considerations

Need to know

- Beam current density profile and target geometry
- Power density distribution within the target

Apply thermal calculations

Cooling, Stresses including Pulsed Effects, Temperatures

Radiation Effects

Shielding, Activity, Remote Handling, Beam Dump,

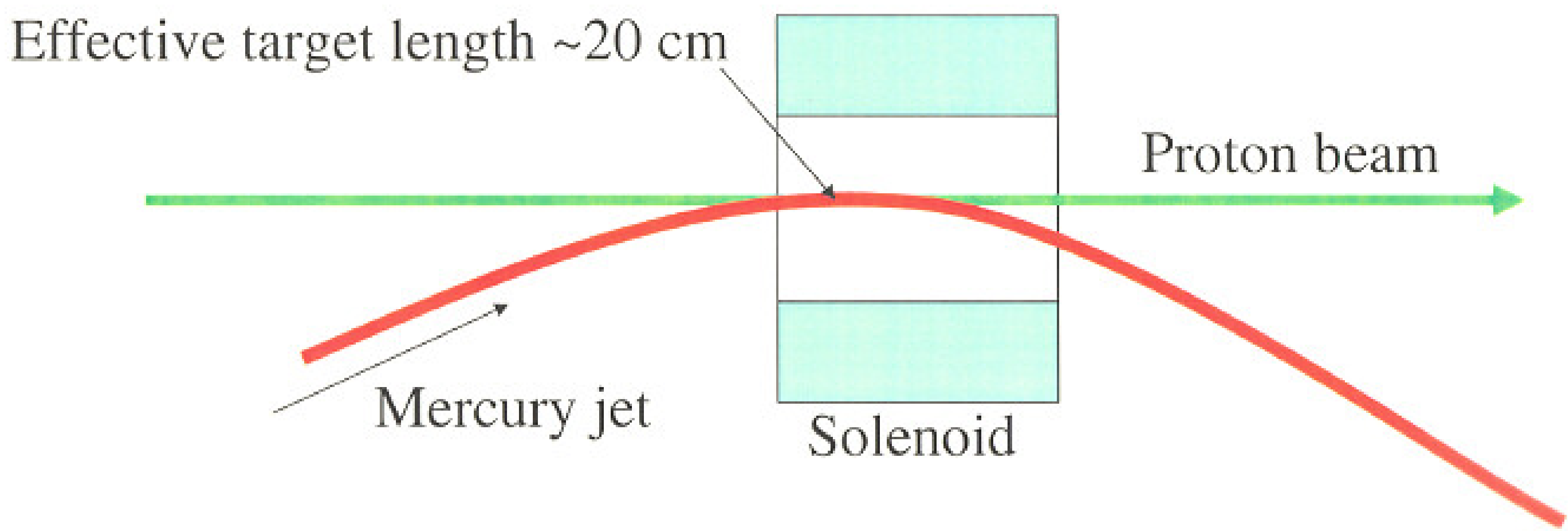
Radiation Damage, Maintenance, Target Changes, Disposal

Magnet

Magnetic field, sc magnet (heat and radiation), Forces, Induced Currents

Target Developments – so far

1. Mercury Jets
2. Contained Flowing Mercury
3. Granulated Targets
4. Solid targets
5. Solid Rotating Ring



Schematic diagram of the mercury jet target

The Mercury Jet

Proposed for the USA and by CERN

- The jet breaks up when the beam hits it, but the beam has interacted with the jet before it has time to break up. So no problem. Tests show that the "next jet" is not prevented from appearing in time. Jet velocity ~30 m/s.
- No power limit?
- The jet hits the walls and they must take the heat and the effect of the mercury hitting the walls. Not thought to be a problem.
- The mercury is condensed and recycled. It can also be distilled so removing some of the radioactive isotopes formed in the jet.
- Easy to remove the "target" by draining out.
- Interaction of the jet with the magnetic field of the solenoid is not a problem.
- A mercury pool in the target chamber can serve as the beam dump.

- Handling the mercury is hazardous. If the mercury escapes - severe hazard. Messy!
- Need windows between the other parts of machine.

- There has been considerable success with the developments of mercury jet targets.
- Further tests at full flow (in the solenoid) and with full proton beam power is required.
- The outlook is good.

Tests at BNL and CERN

- Calculations of injecting into a magnetic field showed small perturbations.
- The field provides damping of the motion in the jet. Tests at Grenoble (CERN) show this.
- Tests with a proton beam at BNL showed that the jet broke up.

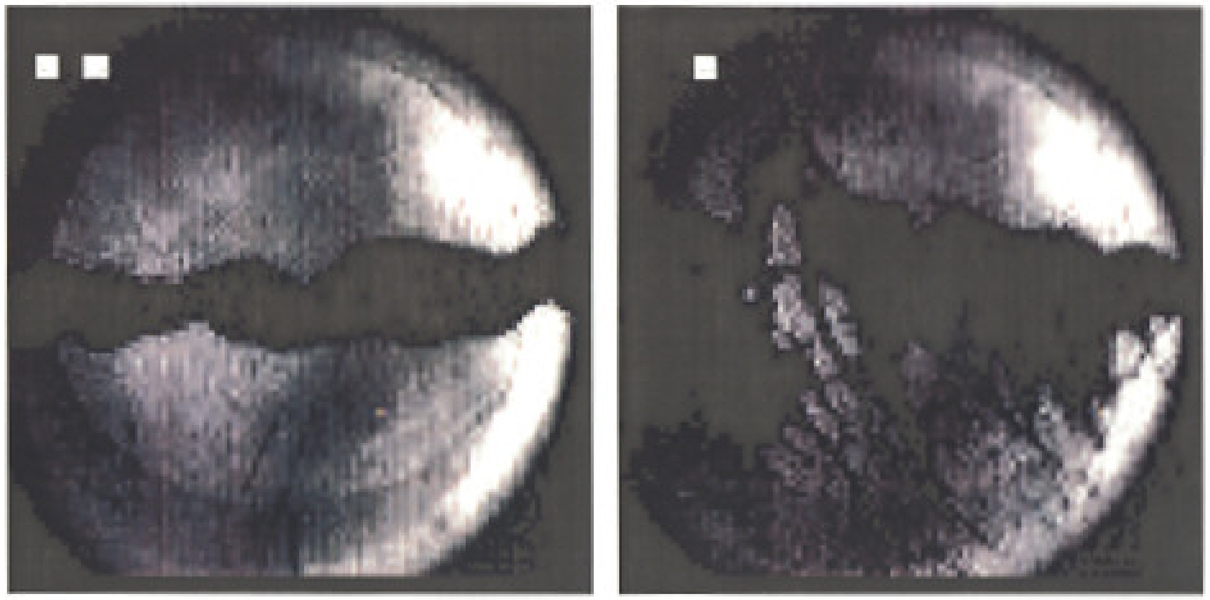
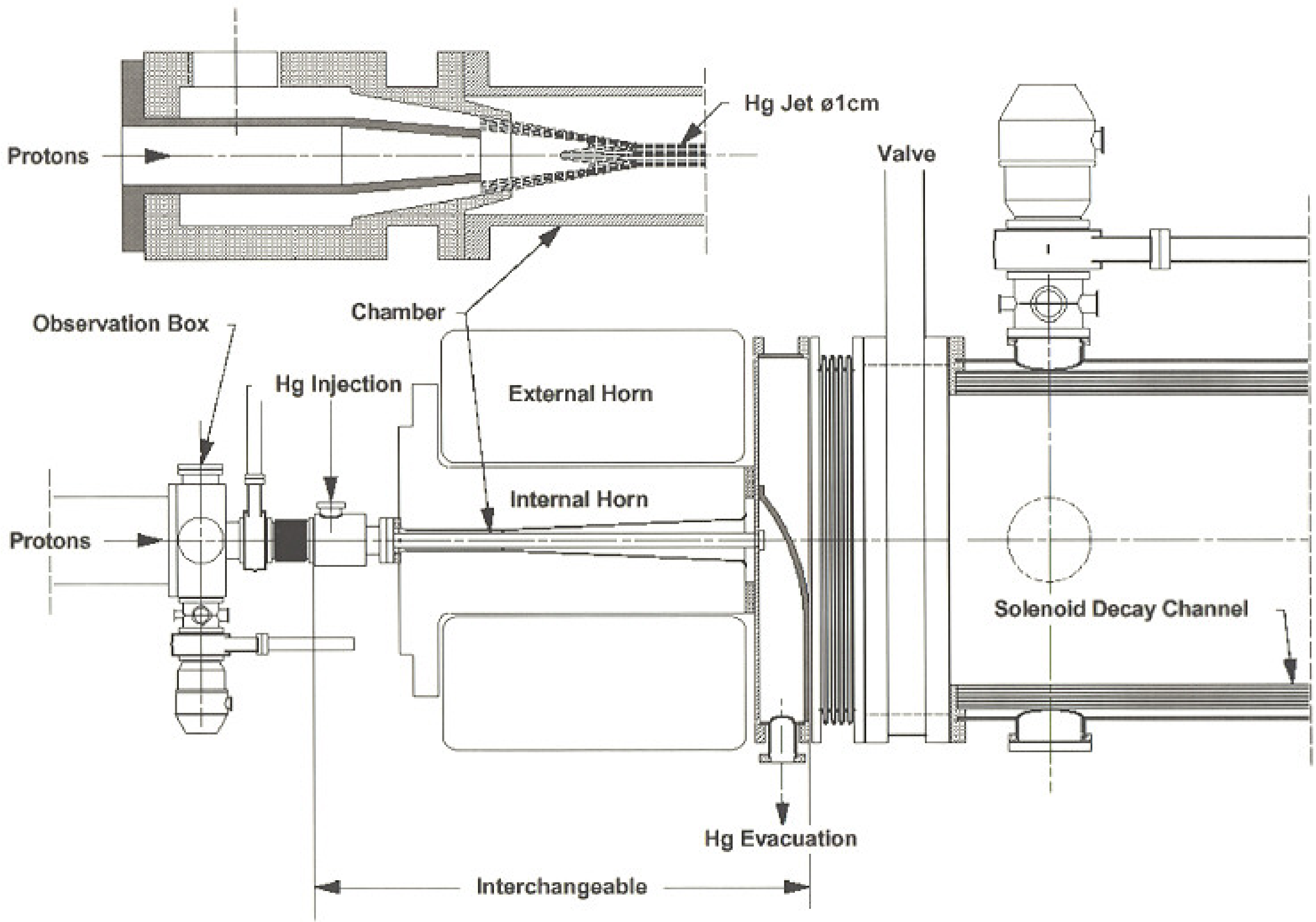
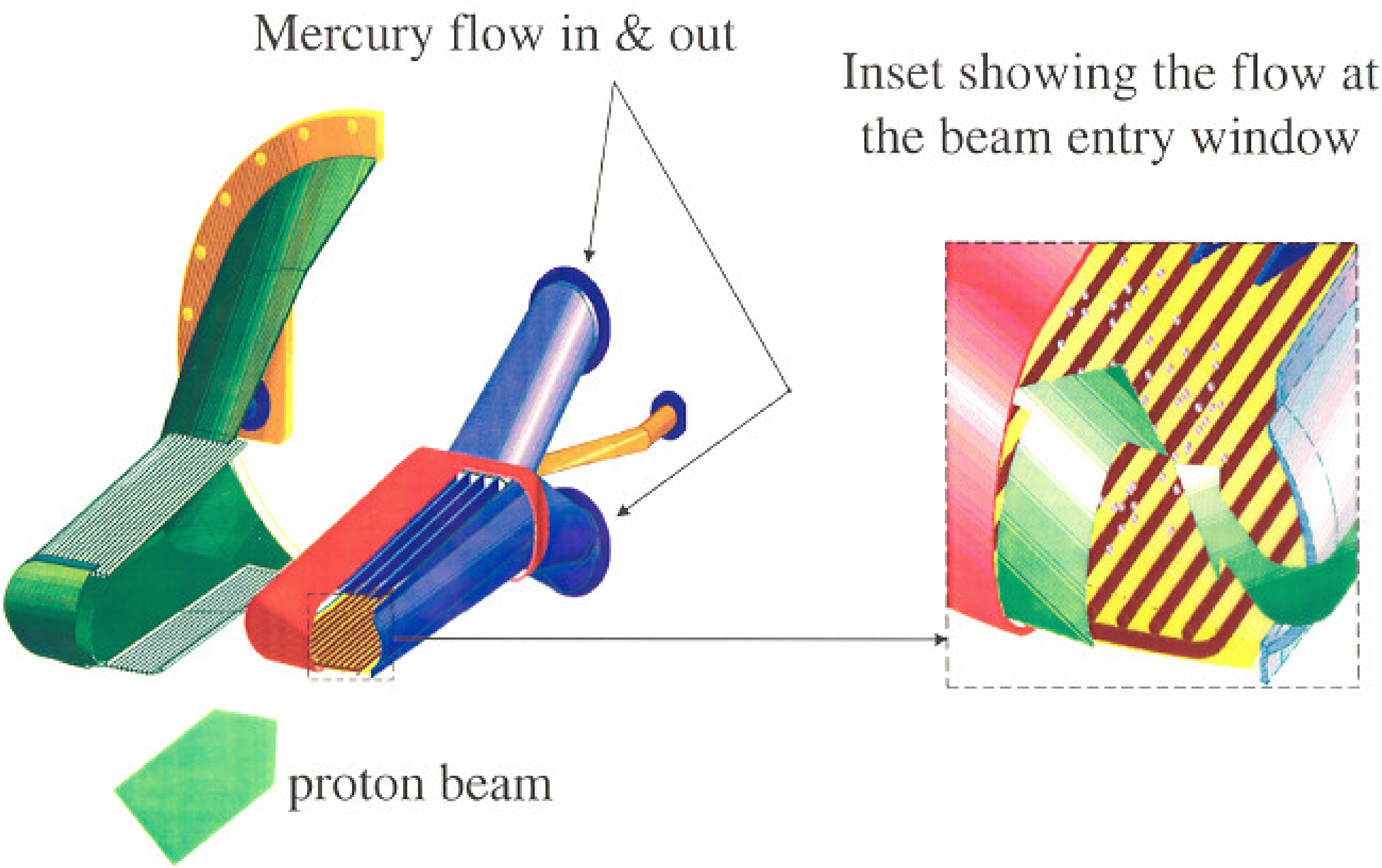


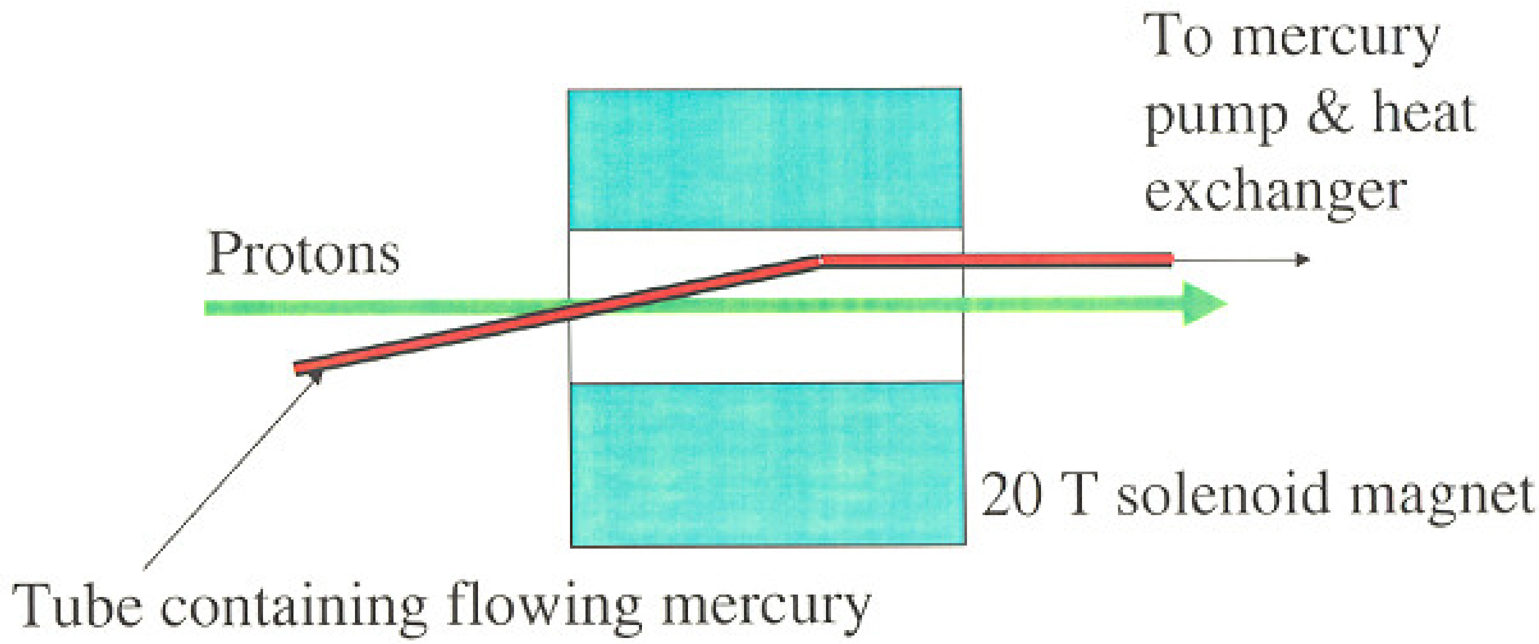
Figure 3.7: Breakup of a 1-cm-diameter mercury jet in a 24-GeV proton beam (BNL E951).



Recent schematic of the CERN Target



Exploded views of the ESS Target



Schematic diagram of the contained flowing mercury target

Solid Metal Spheres in Flowing Coolant

P. Sievers, CERN

Small spheres (2 mm dia.) of heavy metal are cooled by the flowing water, liquid metal or helium gas coolant.

The small spheres can be shown not to suffer from shock stress (pulses longer than ~3 μs)and therefore be mechanically stable.

GRANULAR TARGET COOLED BY LIQUID

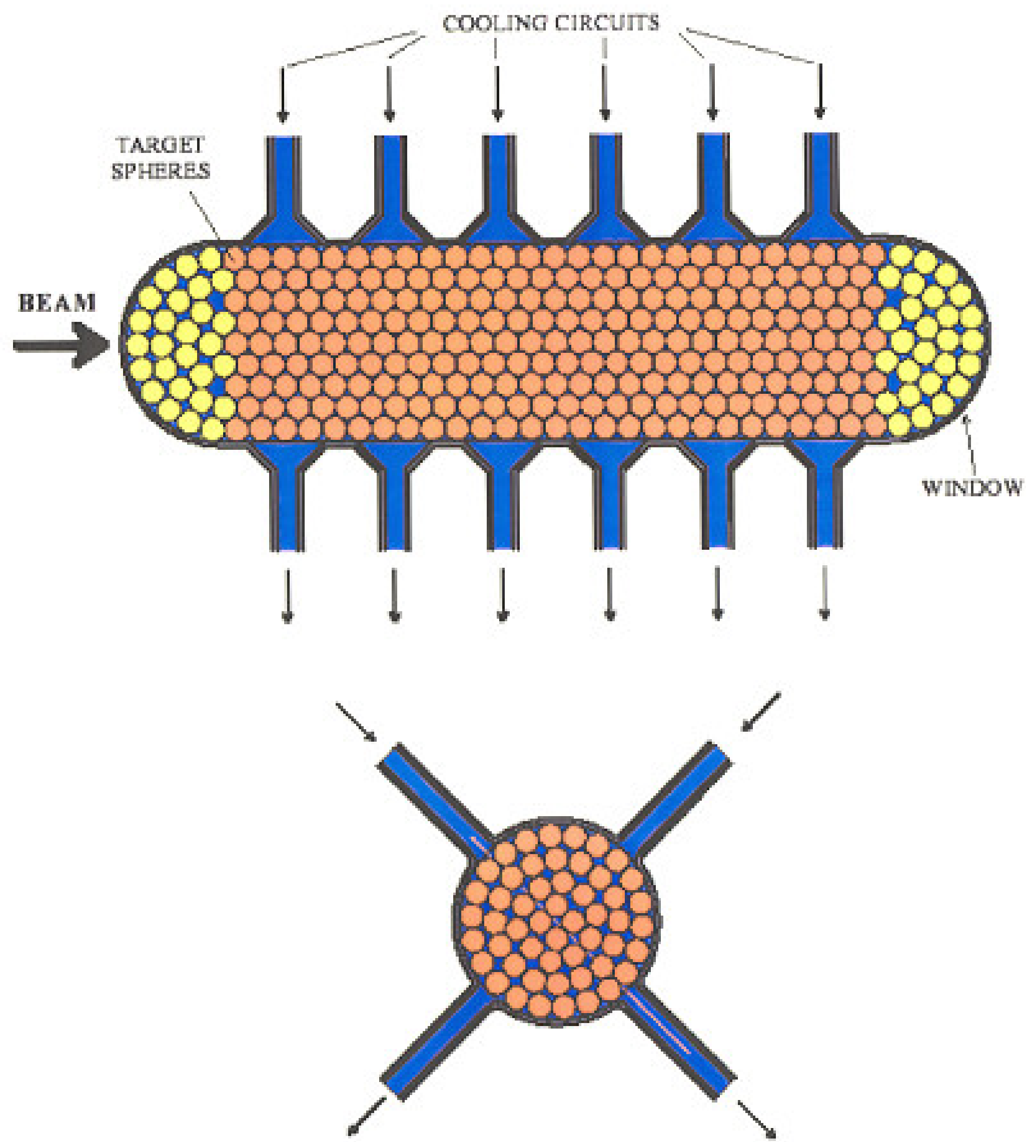
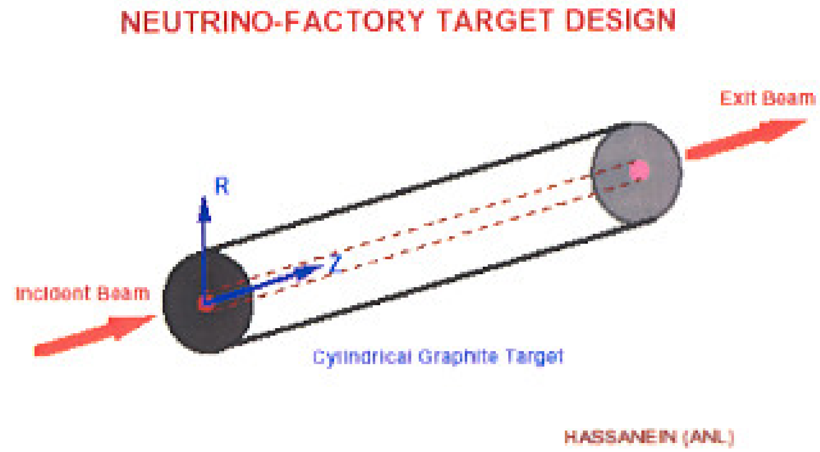


Fig. 1 : Principle lay-out of a liquid cooled, granular target. Tantalum spheres with a diameter of about 2mm are confined in a Titanium container and cooled by water (or possibly liquid metal) traversing the voids between the spheres.

Some tests have been successfully completed and the use of several targets with horn collectors appears promising.

The system looks good.

A Carbon Target is Feasible at 1-MW Beam Power

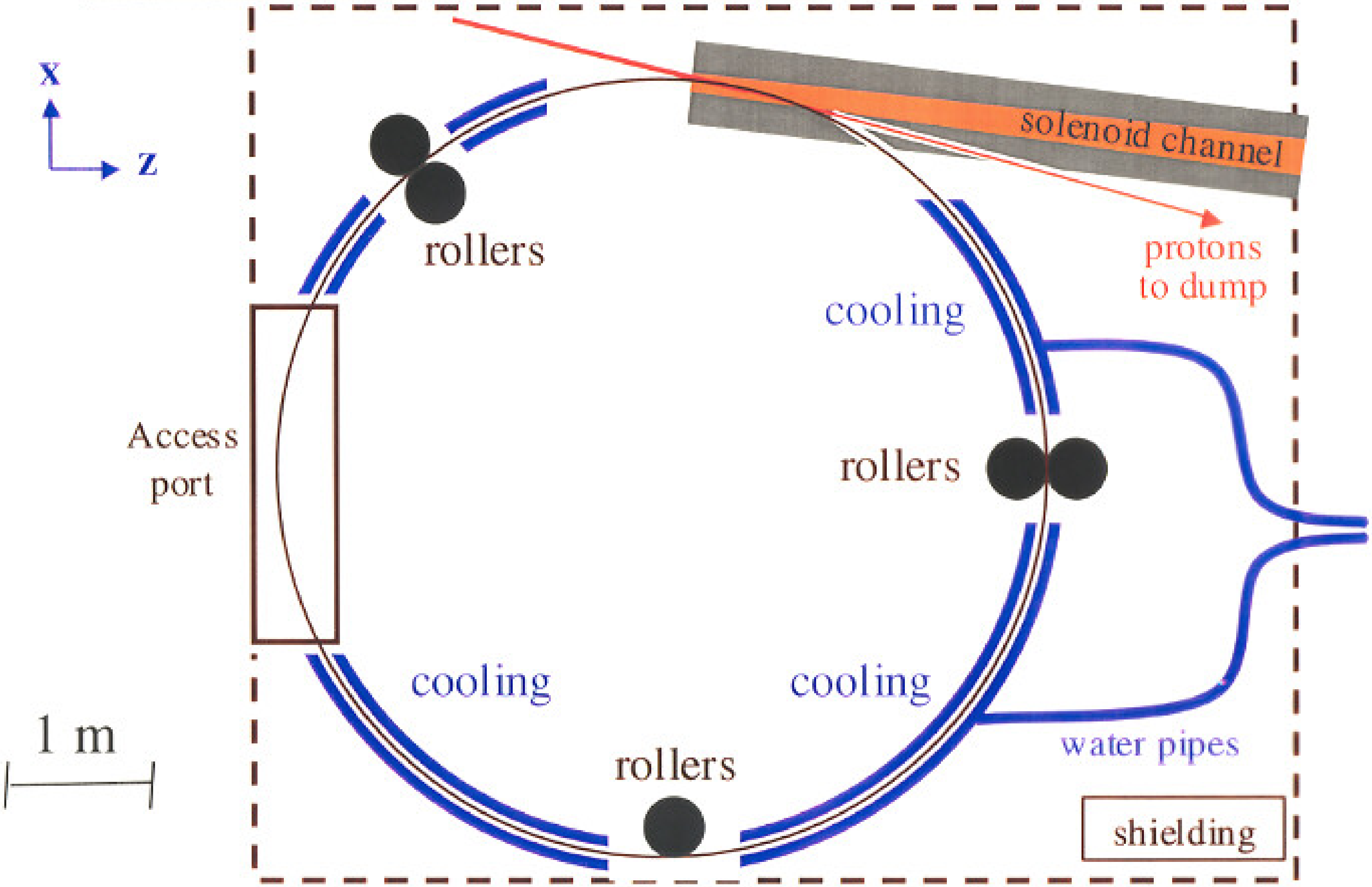


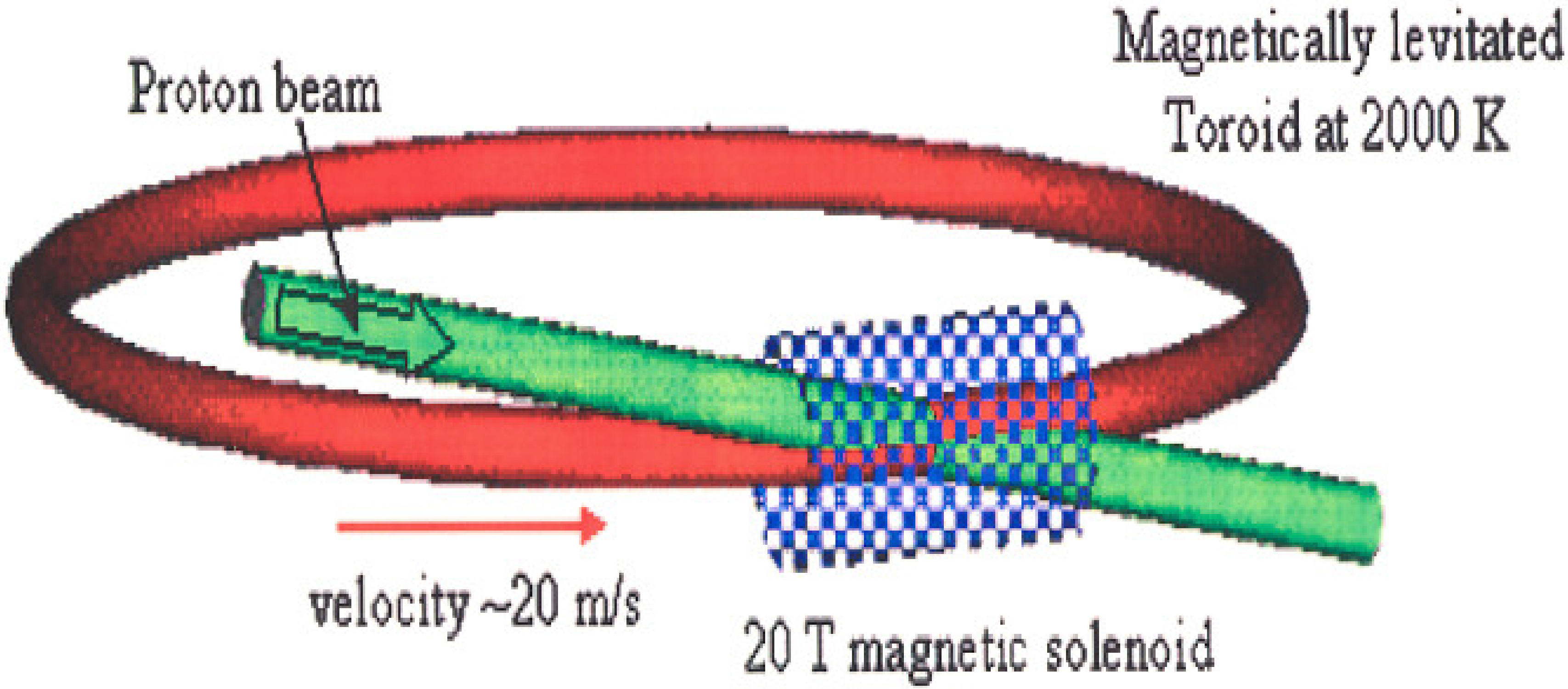
A carbon-carbon composite with near-zero thermal expansion is largely immune to beam-induced pressure waves.

Sublimation of carbon is negligible in a helium atmosphere.

Radiation damage is limiting factor: $\approx$ 12 weeks at 1 MW.

Plan View of Targetry Setup





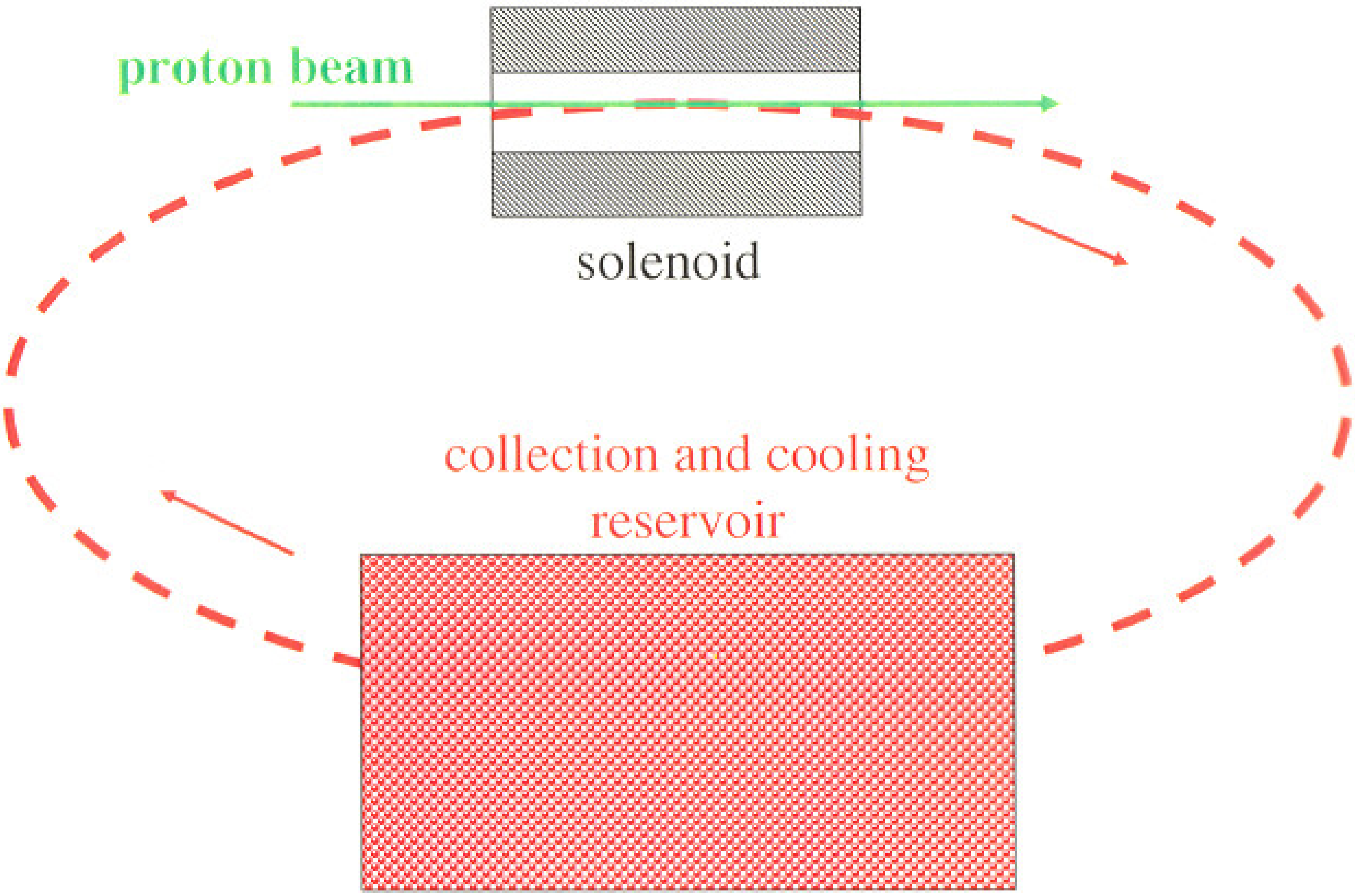
Schematic diagram of the radiation-cooled rotating toroid

A Cu-Ni Rotating Band Target (BNL and FNAL)

Radiation Cooled Rotating Toroid, Magnetically Levitated (RAL)

- TOROID OPERATES AT 2000-2500 K
- RADIATION COOLED
- ROTATES IN A VACUUM
- VACUUM CHAMBER WALLS WATER COOLED
- NO WINDOWS
- SHOCK? Pbar target OK. SLAC target OK. Tests at Lawrence Livermore and RAL using electron beam simulation indicate no problem. Tantalum is a good material long term in proton beams – ISIS target, RAL.

Levitated target bars are projected through the solenoid and guided to and from the holding reservoir where they are allowed to cool.



Conclusions

- We have a number of possible solutions.
- None have been tested at full beam or lifetime (problem!).
- Other problems only partly addressed.
- **Lots to do!!**

Proposed Target Developments in EUROPE

Continue with present lines of study

1. Molten Metal Jets
2. Flowing Contained Molten Metal
3. Helium Cooled Solid Spheres
4. Moving Solid Targets or Rotating Band
5. New Ideas?

The BIG

BUT

1. No Money

2. ESGARD; Applications to the EU, Framework 6

Applied for EU Network (Outcome mid July - ?)

Will apply for EU Design Study

(Closing date 4 March 2004)

3. RAL; PPARC (possibly ~£1M?)
EPSRC (bid for £5M)

Places to do High Power Proton Beam Tests:

ISOLDE, CERN

ISIS, RAL

Have indicted to the managements that we want to do tests.