A SOLENOID CAPTURE SYSTEM FOR A MUON COLLIDER

(TUP265, PAC11)

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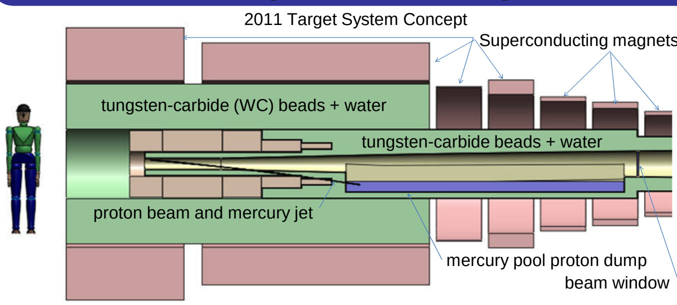
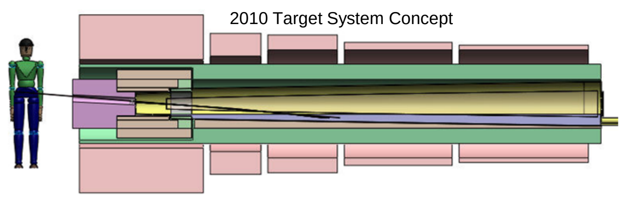
The concept for a muon-production system for a muon collider (or neutrino factory) calls for an intense 4-MW-class proton beam impinging upon a free-flowing mercury jet immersed in a 20-T solenoid field. While the principle of a liquid-metal jet target inside a 20-T solenoid has been validated by the **MERIT experiment** for beam pulses equivalent to 4-MW beam power at 50 Hz, substantial effort is still required to turn this concept into a viable engineering design.

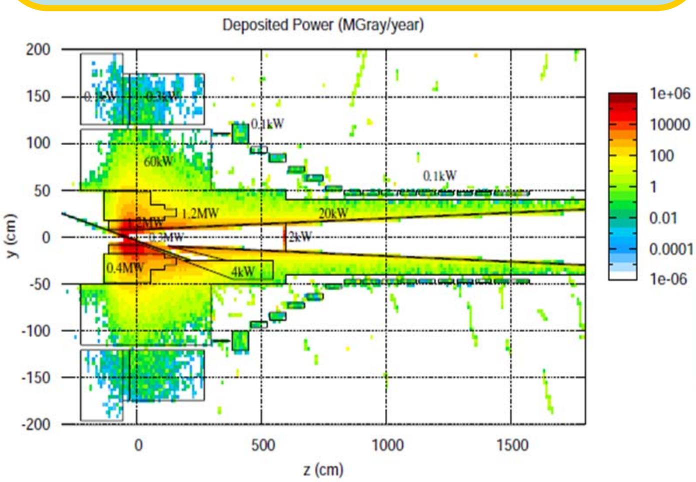




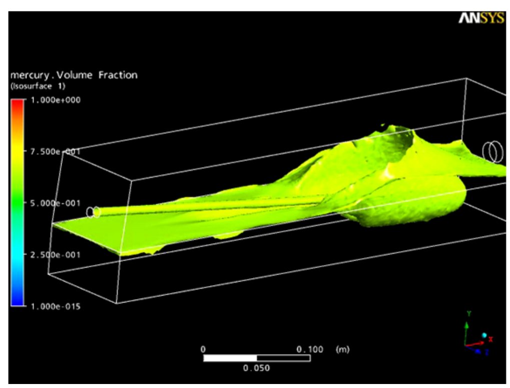
Present concept (top) of a continuous mercury jet target for an intense proton beam. The jet beam is tilted by ~ 70 mrad and with respect to a 20-T solenoid magnet that conducts low-momentum pions into a decay channel. To obtain a 10-year lifetime of the superconducting magnets against radiation damage, a substantial shield of WC beads + water is envisaged. This leads to a much more massive configuration that previously considered (bottom), and a stored magnetic energy of ≈ 4 GJ.

Item	Neutrino Factory IDS / Muon Collider (MC)	Comments
Beam Power	4 MW	No existing target system will survive at this power
E_p	8 GeV	π yield for fixed beam power peaks at ~ 8 GeV
Rep Rate	50 Hz (15 Hz, MC)	Lower rep rate could be favorable
Bunch width	2 ± 1 ns	Very challenging for proton driver
Bunches/pulse	3 (1, MC)	3-ns bunches easier if 3 bunches per pulse
Bunch spacing (MC)	~ 120 μs	Disruption of liquid target takes longer than 200 μs
Beam dump	< 5 m from target	Very challenging for target system
π Capture system	20-T Solenoid	High field solenoid "cools" rms emittance
Stored energy	4 GJ	Quench-protection system a significant challenge
π Capture energy	40 < T_π < 300 MeV	Much lower energy than for ν Superbeams
Target geometry	Free liquid jet	Moving target, replaced every pulse
Target velocity	20 m/s	Target moves by 50 cm ~ 3 int. lengths per pulse
Target material	Hg	High-Z favored; could also be Pb-Bi eutectic
Target radius	4 mm	Proton beam σ_r = 0.3 of target radius = 1.2 mm
Beam angle	≈ 97 mrad	Thin target at angle to capture axis maximizes π's
Beam-jet angle	≈ 27 mrad	Beam/jet angle ≈ 27 mrad, ⇒ 2 int. lengths
Dump material	Hg	Hg pool serves as dump and jet collector
Magnet shield	WC beads + water	Shield must dissipate 2.4 MW

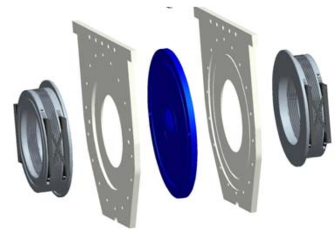
Above: Baseline Parameters for the target system.



Above: Power deposition in the superconducting magnets and the tungsten-carbide + water shield inside them, according to a FLUKA simulation Approximately 2.4 MW must be dissipated in the shield. Some 800 kW flows out of the target system into the downstream beam-transport elements. See also TUP179.



Above: A major challenge is incorporation of the proton beam dump inside the superconducting magnet cryostat. The mercury collection pool can serve as this dump, but the 3-kW mechanical power of the mercury jet will disrupt the pool, unless mitigated by a splash suppressor.



Above : The downstream Be window of the mercury-containment vessel intercepts ≈ 1 kW of power, and must be suitably cooled (and replaceable).