A TARGET MAGNET SYSTEM FOR A MUON COLLIDER AND NEUTRINO FACTORY

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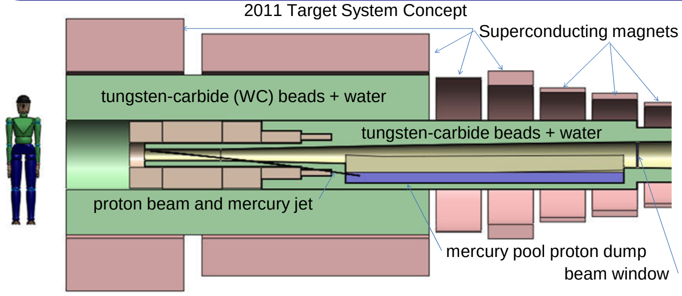
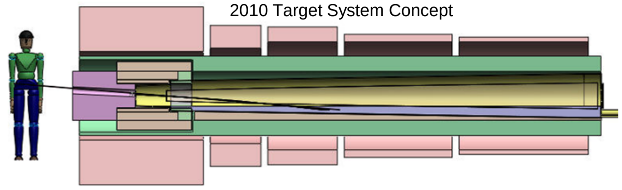
The concept for a muon-production system for a Muon Collider (or Neutrino Factory) calls for an intense 4-MW-class proton beam impinging upon a free-flowing mercury jet immersed in a 20-T solenoid field. The target system calls for a solenoidal magnetic field that tapers from 20 T to 1.5 T over 15 m. The magnet system includes both superconducting (SC) coils and resistive ones. A set of nineteen large-bore, helium-cooled, cable-in-conduit SC coils contributes ~ 75% of the peak field. Within the bore of the SC magnet is a 12-MW water-cooled resistive magnet of copper hollow conductor insulated with ceramic (MgO) for radiation resistance. Vessels filled with tungsten-carbide pellets (~ 60% by volume, cooled by water) attenuate the radiation issuing from the 4-MW proton beam impacting the mercury-jet target.

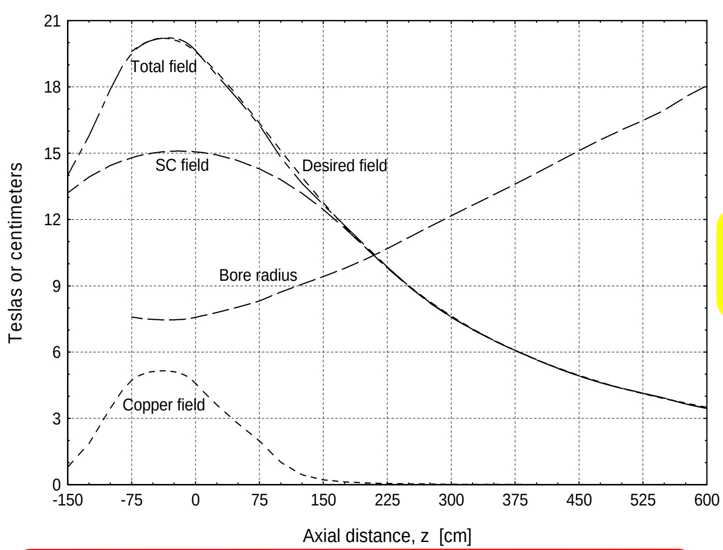




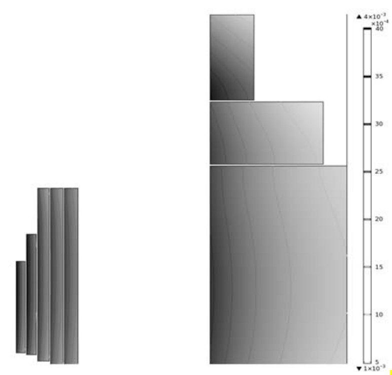
Present concept (top) of a continuous mercury jet target for an intense proton beam. The jet beam is tilted by ~ 70 mrad and with respect to a 20-T solenoid magnet that conducts low-momentum pions into a decay channel. To obtain a 10-year lifetime of the superconducting magnets against radiation damage, 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	$40 < T_\pi < 300$ 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

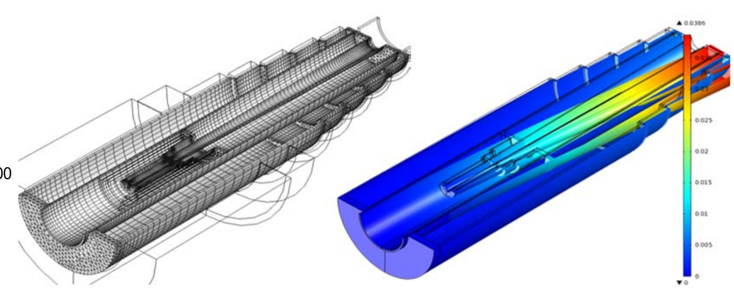
Above: Baseline Parameters for the target system.



Above: On-axis field profiles of resistive, superconducting and all magnets, and bore-tube radius $r = 7.5\,(B/20\mathrm{T})^{-1/2}$ cm.



Above: Hoop strain ε_θ in resistive coils and SC coils #1-3. In all coils The maximum ε_θ is ~0.4%; in SC coil #1 it is 0.36%, implying a hoop stress of 720 MPa in the CICC conduit.



Above: Deformation δ, magnified 20-fold, of the W-C shielding vessel When fixed only at its upstream end; δ_{max} = 39 mm