The MERIT High-Intensity Liquid Mercury Target Experiment at CERN PS

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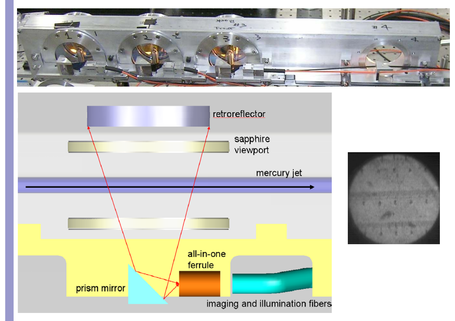
Abstract: The MERIT experiment is a proof-of-principle test of a target system for a free mercury jet inside a high-field solenoid magnet foreseen as front-end target system in a pulsed high-power **4MW** proton beam, like in a Neutrino Factory or a Muon Collider. The experiment took data in autumn 2007 with the fast-extracted beam from the CERN Proton Synchrotron (PS) to a maximum intensity of **30×10^{12} protons per pulse**. We report results from the experiment which validate the target concept.

OPTICAL DIAGNOSTICS

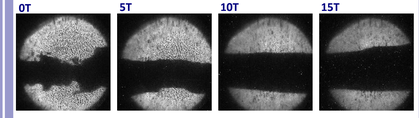
- The Hg jet was viewed as it streamed by viewports 1, 2, 3, and 4. The jet and beam axis overlapped at viewport 2, while the aftermath of the interaction was viewed at viewports 3 and 4.

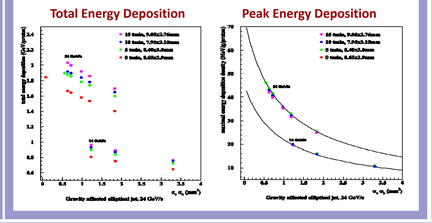


Hg-JET

- 1 cm diameter, velocity up to 20 m/s
- Proton beam ↔ solenoid axis 67 mrad
- Proton beam ↔ mercury jet ~50 mrad
- Interaction region ~30 cm

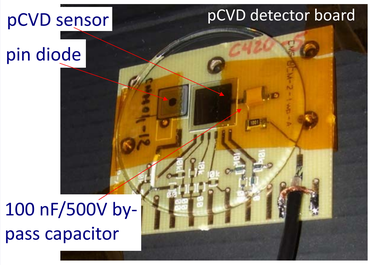
Hg-jet stabilization with magnetic field



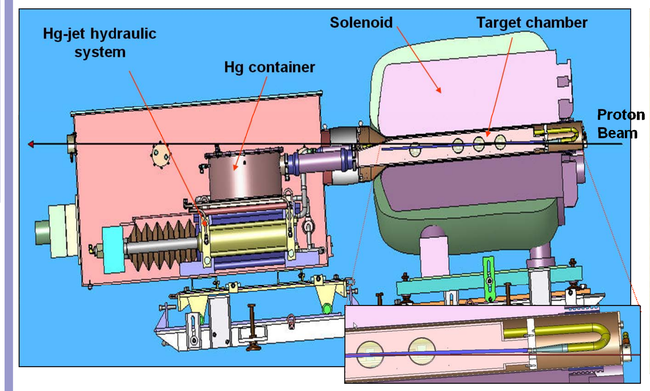


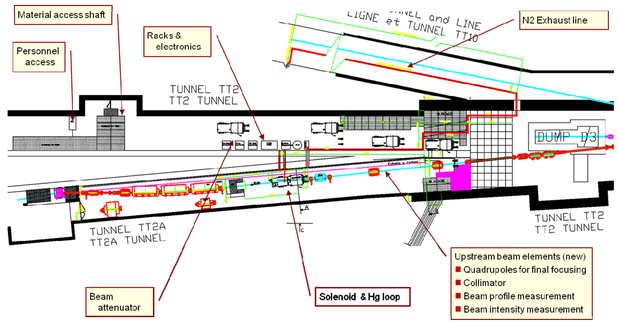
FLUX DETECTORS

- Measure the flux of charged particles produced at the target for each bunch to probe material vaporization and cavitation formation in the target due to the sudden energy deposition at the impact with the high-intensity beam.



THE EXPERIMENTAL SETUP



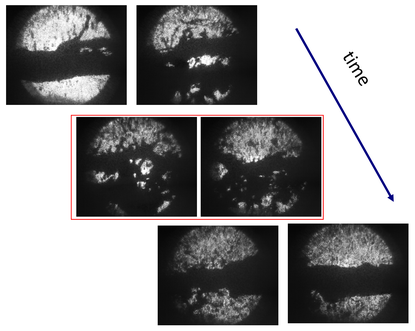


Beam Parameters

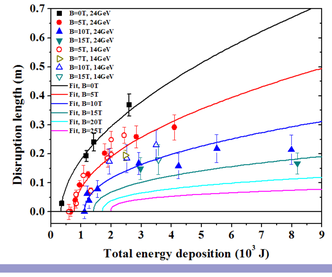
- 24(14) GeV/c proton beam extracted from PS
- max. Intensity : 30×10^{12} protons/pulse
  - 115 kJ of beam power—**an PS machine record**
- beam spot size: 6(12) mm^2 for 24(14) GeV/c beam
- 160 J/gr max. energy deposition at the target
- 100 high-intensity pulses, 10^{15} protons in total
- PS configured to produce **pump/probe** bunch trains to study the timing of the target disruption
  - variable pulse length: 0.131 to 700 μs and harmonic configuration (8 or 16) of the PS

EXPERIMENTAL RESULTS

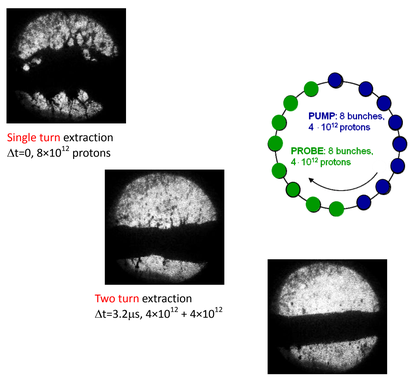
Interaction example : 14GeV/c, 5T, 16×10^{12} protons



Disruption length inferred from the number of frames the disruption lasts

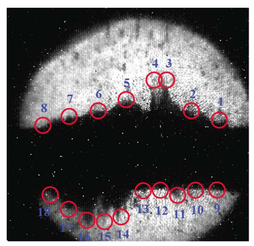


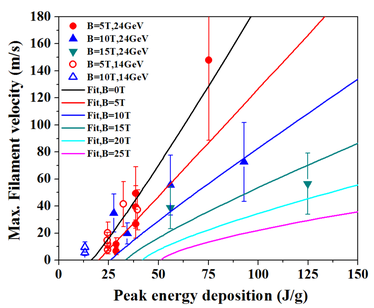
Pulse structure study: 14GeV/c, 10T, two batches of 4×10^{12} protons each, at variable time delay



- Threshold of disruption is > 4×10^{12} at 14 Gev, 10 T.
- Target supports a 14-GeV, 4×10^{12} beam at **172 kHz rep rate** without disruption.

Ejection velocity analysis: study the velocity of filaments of ejected mercury using the highest speed camera, at viewport #2, at frame periods of 25, 100 or 500 μs

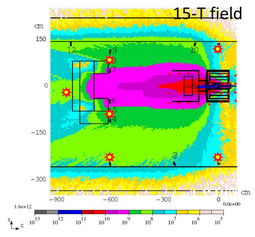




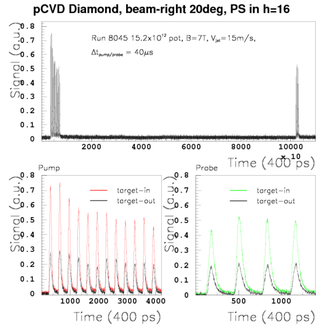
Pump-probe studies:

- test pion production by trailing bunches after disruption of the Hg-jet due to earlier bunches
- At 14 GeV/c, the CERN PS can extract several bunches during one tun (**pump**) and then the remaining bunches at a later time (**probe**)

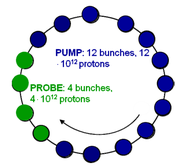
Charged particle flux/cm^2 for 30×10^{12} pot



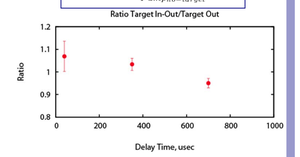
pCVD Diamond, beam-right 20deg, PS in h=16



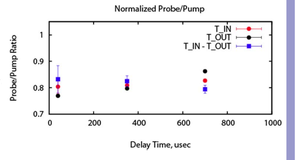
- Both target-in and target-out data showed smaller signals, relative to the pump bunches, for probe bunches delayed by 40, 350, and 700 us.
- The corrected probe/pump ratio was used



$$Ratio = \frac{\frac{Probe_{target} - Probe_{no-target}}{Pump_{target} - Pump_{no-target}}}{\frac{Probe_{no-target}}{Pump_{no-target}}}$$



- Results are consistent with no loss of pion production for bunch delays of 40 and 350 μs, and a 5% loss (2.5s-efect) of pion production for bunches delayed by 700μs



Summary — MERIT Experimental Results

- Jet surface instabilities are reduced by high-magnetic fields
- Proton beam induced Hg-jet disruption confirmed to jet/beam overlap region
- 20 m/s operations allows for 70 Hz beam rep.rate
- 115 kJ pulse containment demonstrated
  - **8MW operations** demonstrated
- Hg-jet disruption mitigated by magnetic field
- Hg-jet velocities reduced by magnetic field
- Pion production remains viable up to 350 μs after previous beam impact
- **170kHz operations** possible for sub-disruption threshold beam intensities