Time Structure of Particle Production in the MERIT High-Intensity Liquid Mercury Target Experiment

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The **MERIT experiment** is a proof-of-principle test of a target system for a high power proton beam to be used as front-end for 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 portion of the MERIT experiment in which separated beam pulses were delivered to a free mercury jet target with time intervals between pulses varying from **2 to 700 μs**. The analysis is based on the responses of particle detectors placed along side and downstream of the target.

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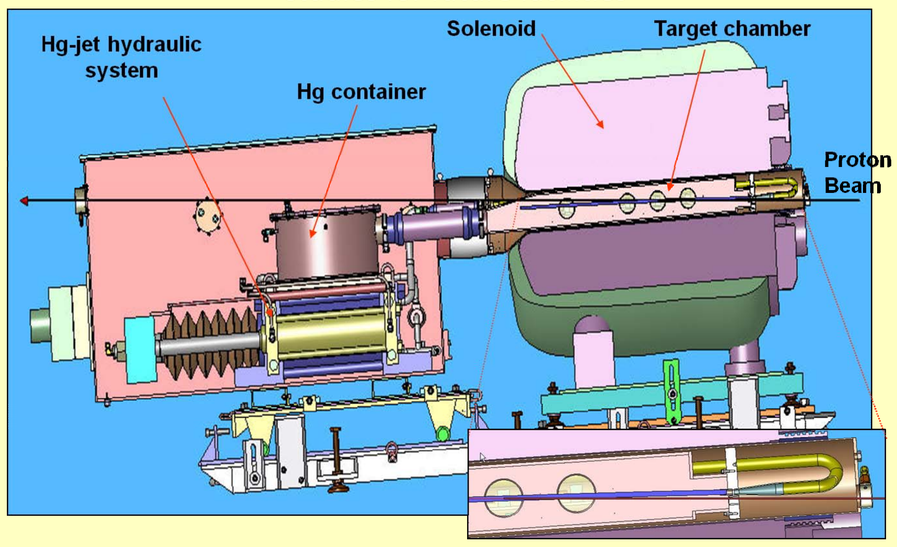
INTRODUCTION

The MERIT experiment represents an important milestone in the R&D program of high-power targetry for a future neutrino factory or muon collider. It combines for the first time a free mercury jet and a focusing/capturing solenoid for secondary pions or muons as proposed in design studies for future facilities



Scientific goals:

- study MHD effects on the mercury jet with nominal target size and velocity
- study jet disruption (cavitation ?) by varying the PS spill structure

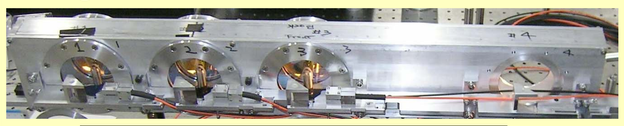
THE TARGET

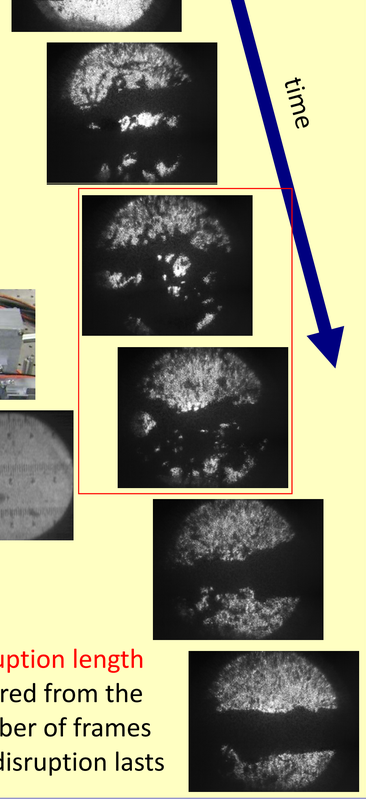
Hg-jet parameters

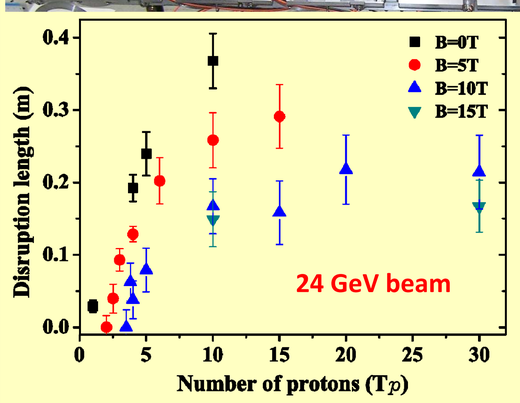
- 1 cm diameter, velocity up to 20 m/s
- Proton beam ↔ solenoid axis 67 mrad
- Proton beam ↔ mercury jet ~50 mrad
- Interaction region ~30 cm

Optical diagnostics

- Observe the mercury-jet / beam interaction using high-speed cameras
- Four locations along the jet inside the magnet bore





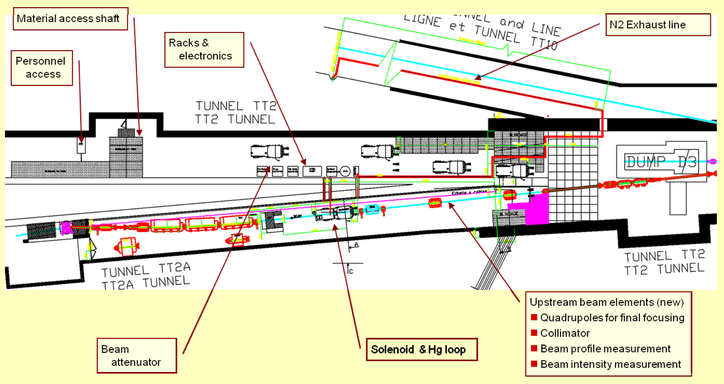


Disruption length inferred from the number of frames the disruption lasts

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



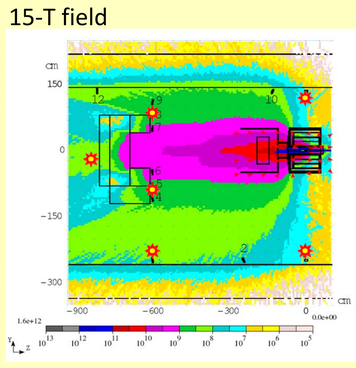
Particle flux detectors

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.

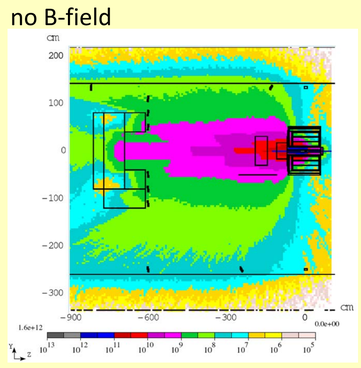
Charged particle flux/cm^2 for 30× 10^{12} pot

MARS simulation

15-T field



no B-field



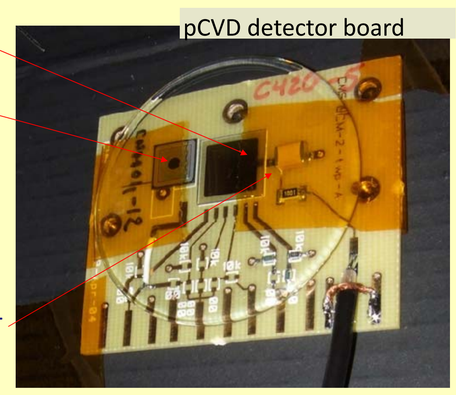
- **6.2× 10^7 particles/bunch (50ns)**
  - signal of 1.6Amps in the pCVD diamond detectors

Detector types

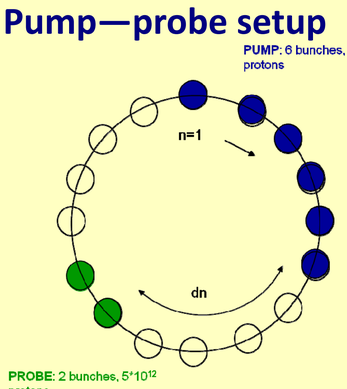
1. **P**olycrystaline **C**hemical **V**apour **D**eposition diamond (**pCVD**)
   - 7.5×7.5 mm^2 active area, 300 μm thick
   - developed as beam loss monitors close to the interaction areas of LHC.
   - ns response, allows clear separation of individual bunches separated by 131 ns

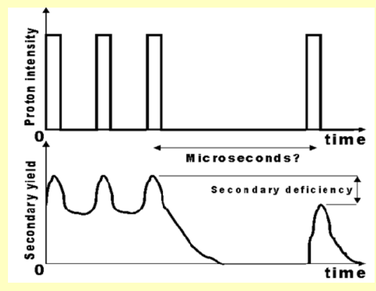
Detector assemblies

Aluminum **C**athode **E**lectron **M**ultiplier (**ACEM**) detectors
- installed as secondary system that could handle high fluxes

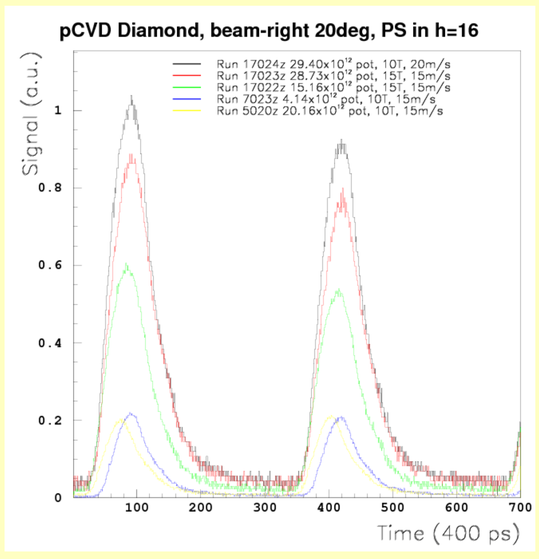


Pump—probe setup



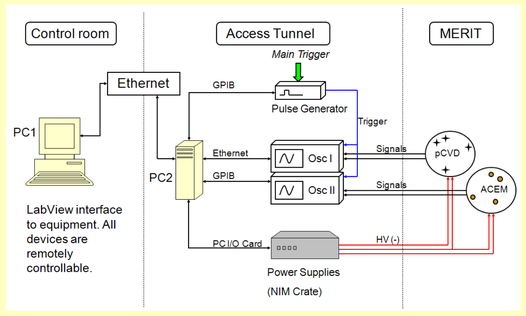


pCVD DETECTOR PERFORMANCE

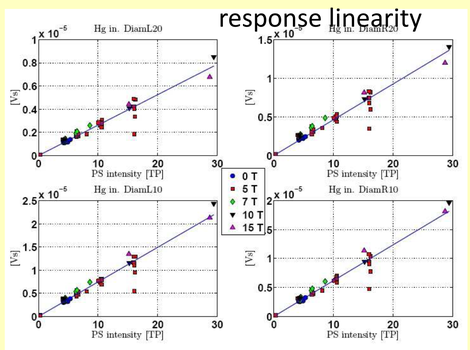


response signal

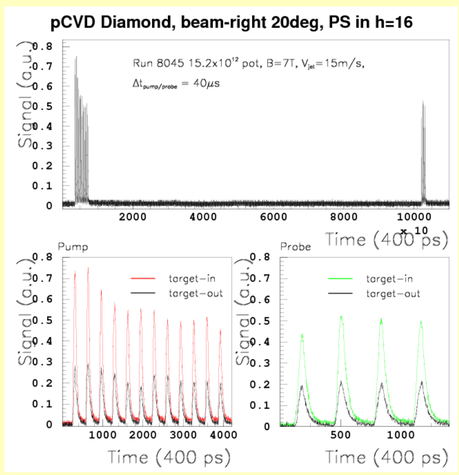
Zoom of two 2 beam bunches in bunch train of 16



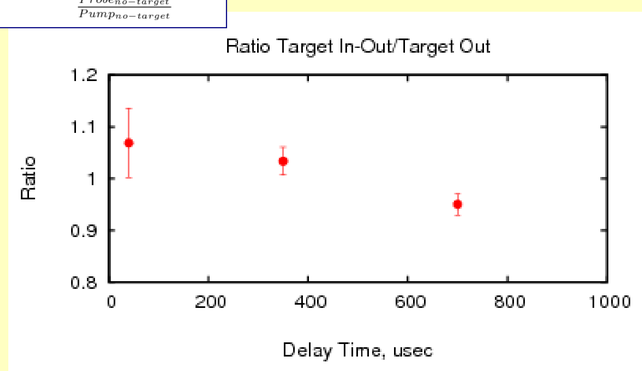
response linearity



THE PUMP-PROBE RESULTS



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



The observed values are consistent with no reduction in particle production for bunches 40 or 350 μs after a first set of bunches, and about 5% reduction for bunches delayed by 700 μs. This indicates that a mercury jet target, although disrupted by intense proton bunches, would remain fully effective in producing pions during a bunch train of up to 300 μs as may be desirable for operation of a **4-MW** proton driver at a Neutrino Factory.