The MERIT High-Power Target Experiment

Muon Collider Design Workshop

BNL

December 3-7, 2007

Harold G. Kirk
Brookhaven National Laboratory

The Collaborating Institutions

U.S.

- **Brookhaven National Laboratory**
- **Fermi National Accelerator Laboratory**
- **Oak Ridge National Laboratory**
- **Princeton**

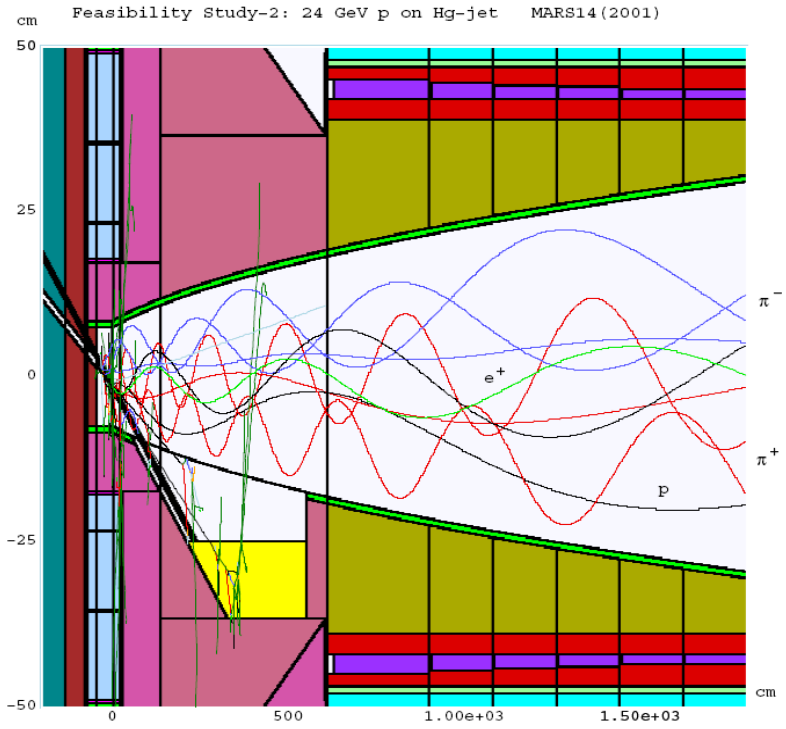
Europe

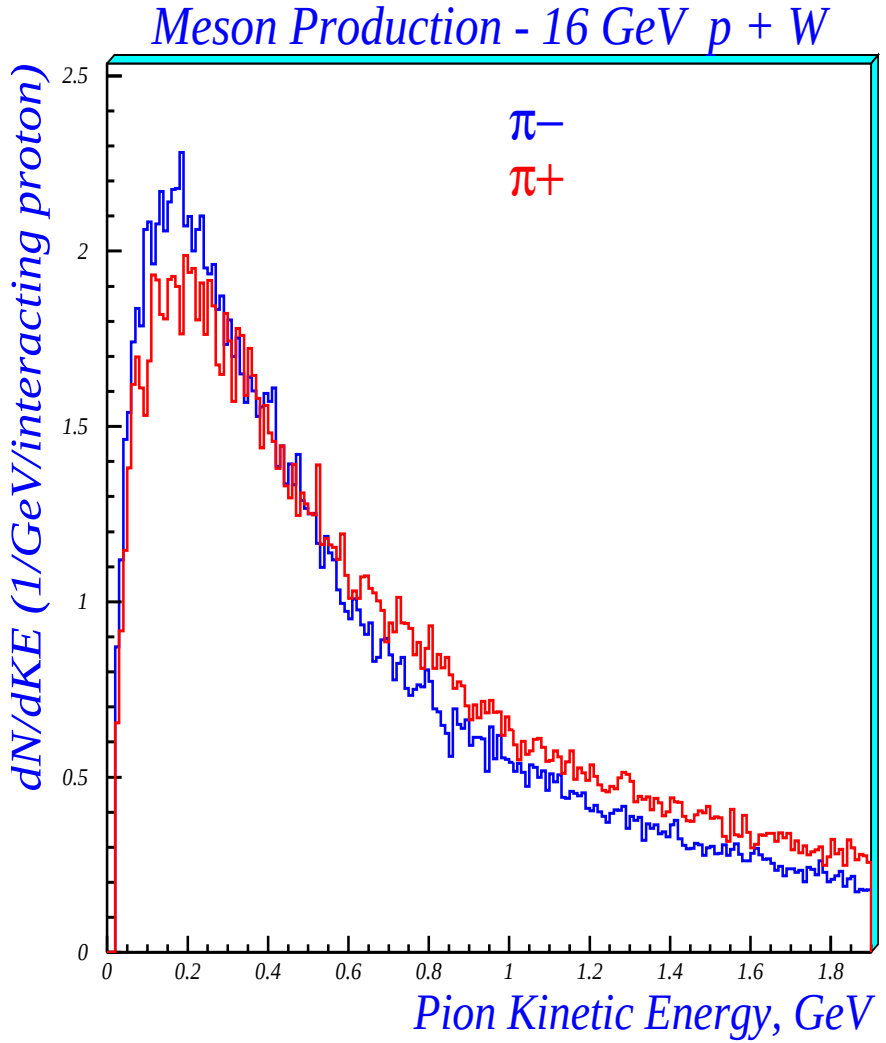
- **CERN**
- **Rutherford Appleton Laboratory**

The Neutrino Factory Target Concept

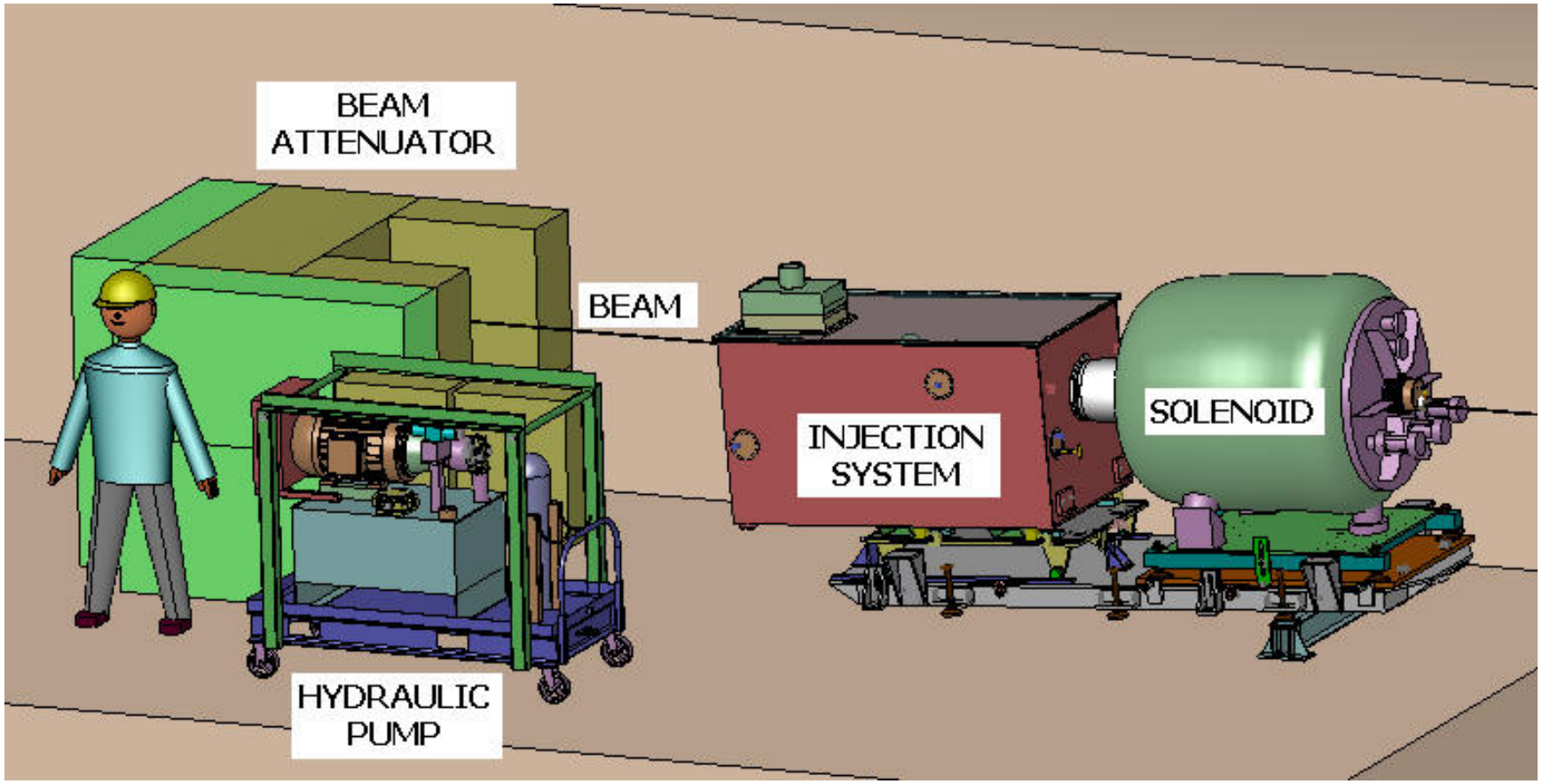
Maximize Pion/Muon Production

- Soft-pion Production
- High-Z materials
- High Magnetic Field





The MERIT Experiment



MERcury Intense Target

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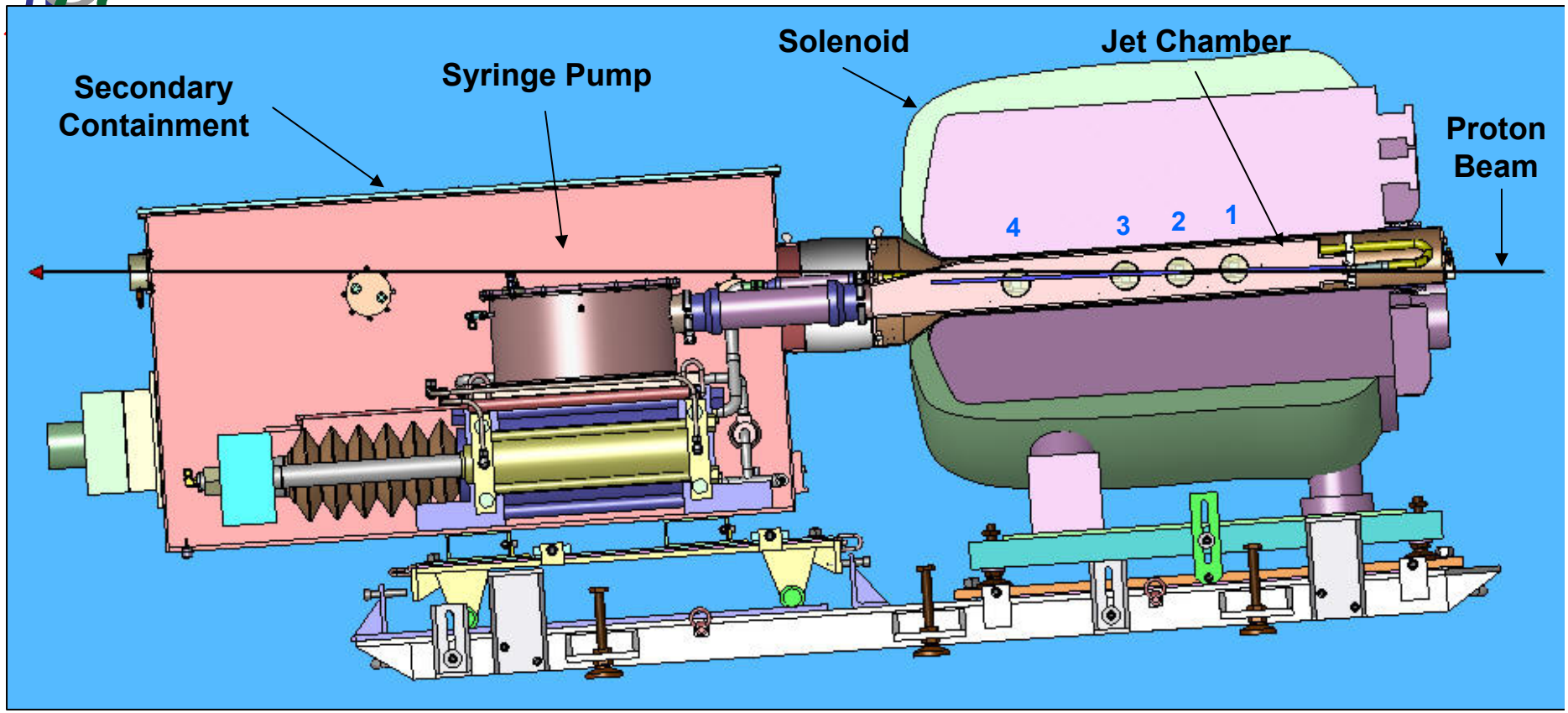
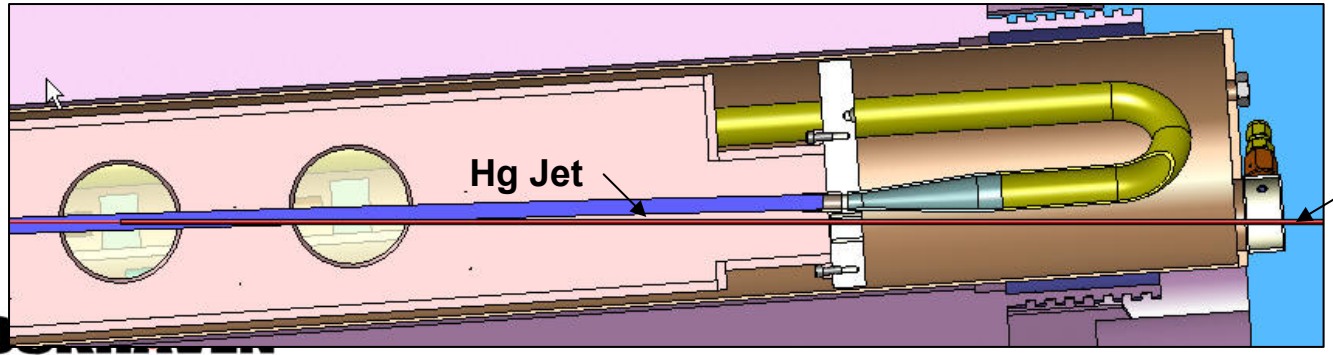
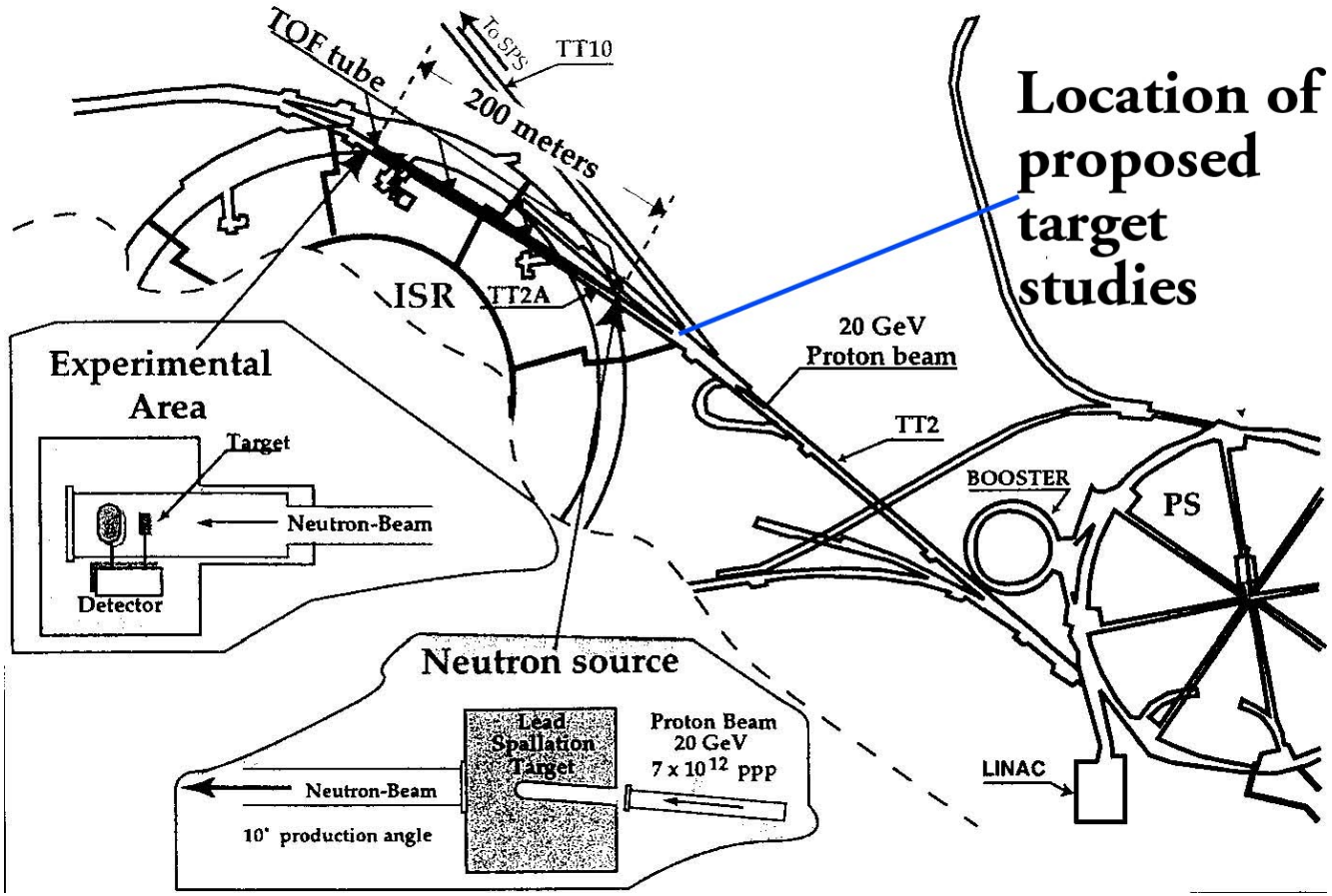
Sectional view of the MERIT Experiment





Site of experiment at CERN



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Profile of the Experiment

- 14 and 24 GeV proton beam
- Up to 30 x 10^{12} protons (TP) per 2.5μs spill
- Proton beam spot with r ≤ 1.5 mm rms
- 1cm diameter Hg Jet
- Hg Jet/proton beam off solenoid axis
  - Hg Jet 33 mrad
  - Proton beam 67 mrad
- Test 50 Hz operations
  - 20 m/s Hg Jet

Proton Beam Characteristics

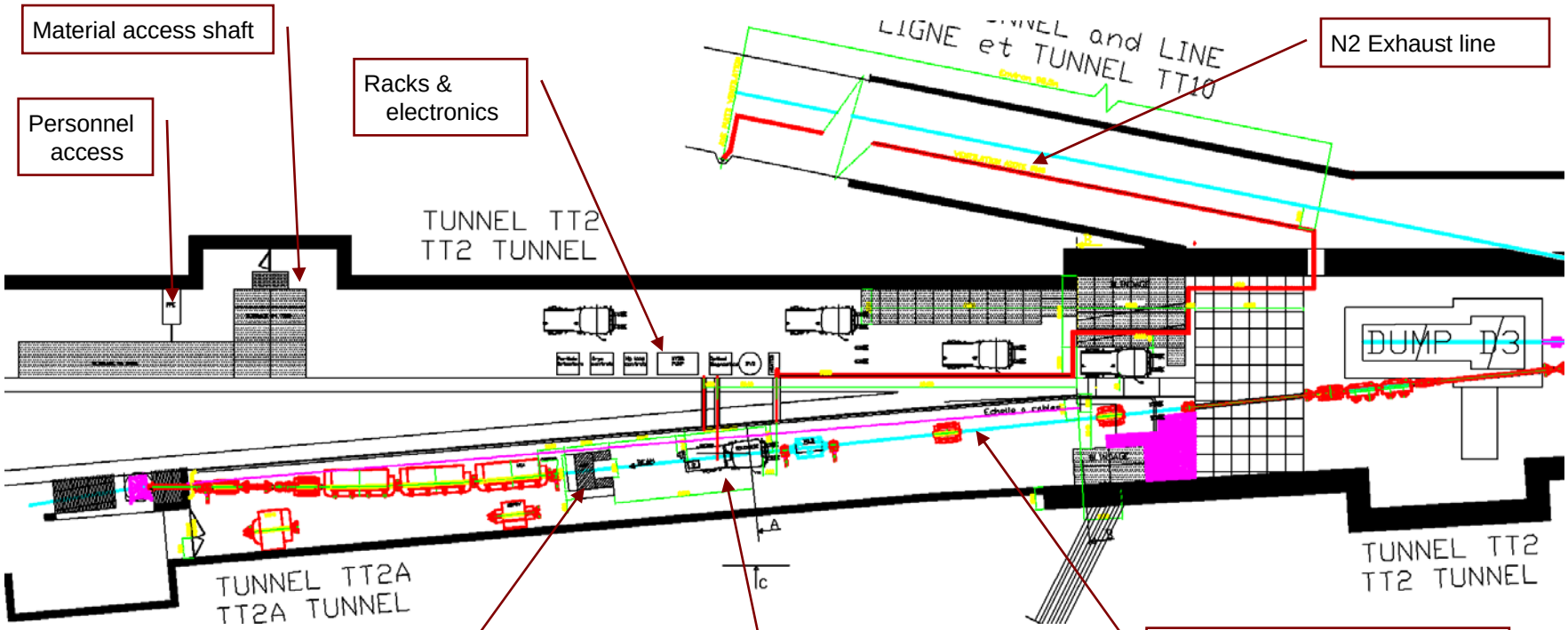
- PS was run in a harmonic 4, 8, and 16 mode
- We can fill any of the rf buckets with sub-bunches at our discretion.
- Total PS fill can contain up to 30 TP.
- Fast extraction can accommodate entire 2.5 μs PS fill.
- Single turn extraction at 24 GeV
- Partial/multiple extraction possible at 14 GeV
- First Beam on Target October 17 2007

Run plan for the CERN PS beam

The PS Beam Profile allows for:

- **Varying beam charge intensity from 1 TP to 30 TP.**
- **Studying influence of solenoid field strength on jet dispersal (vary B_z from 0 to 15T).**
- **Study possible cavitation effects by varying PS spill structure (Pump/Probe)**

MERIT Experiment in the TT2a Area



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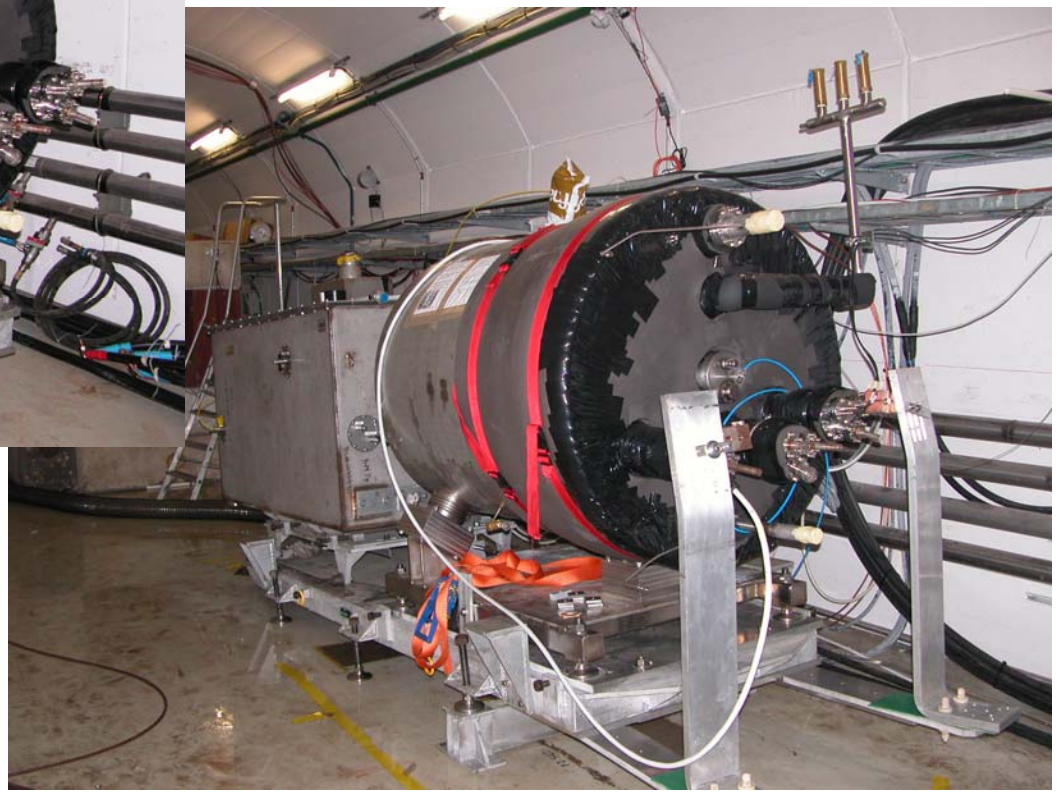
Installed in the CERN TT2a Line

Before Mating



After Mating and Tilting

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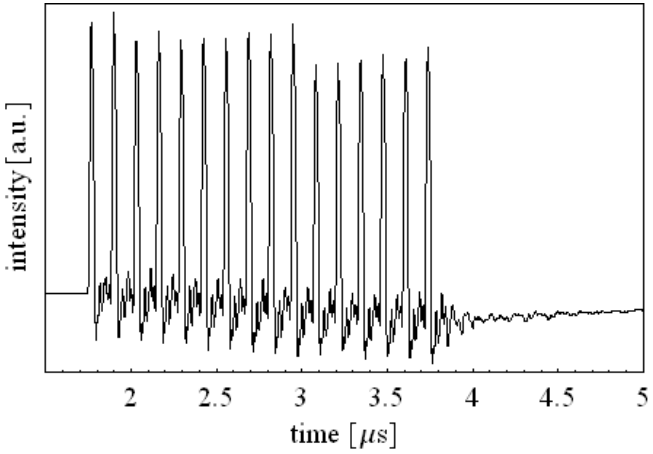
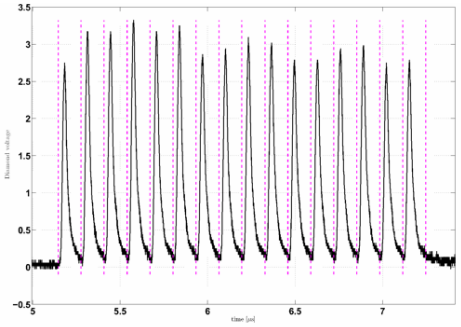
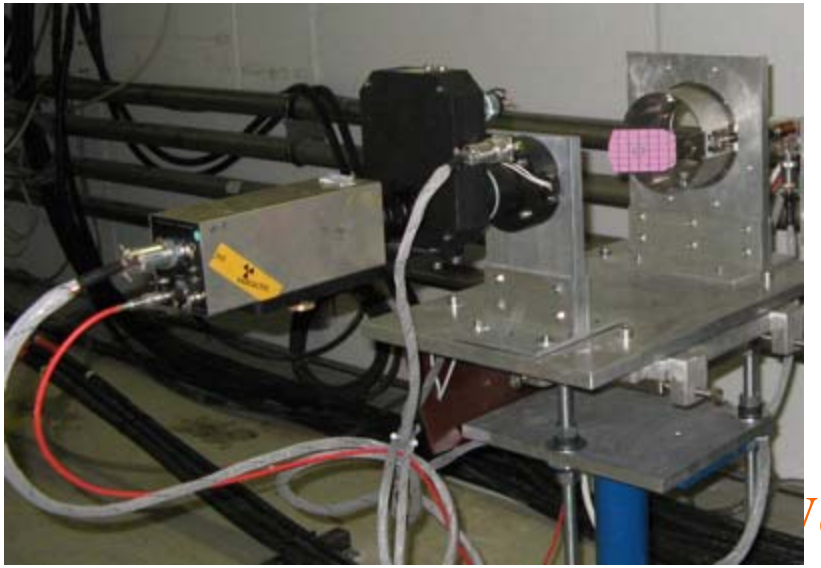
Beam instrumentation

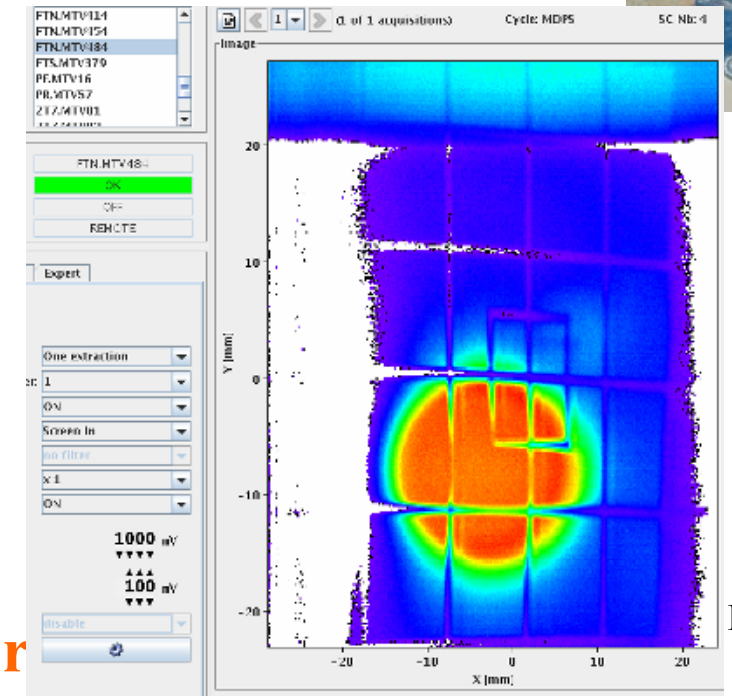
Beam current transformer: 500 MHz sampling!



Particle detector response:







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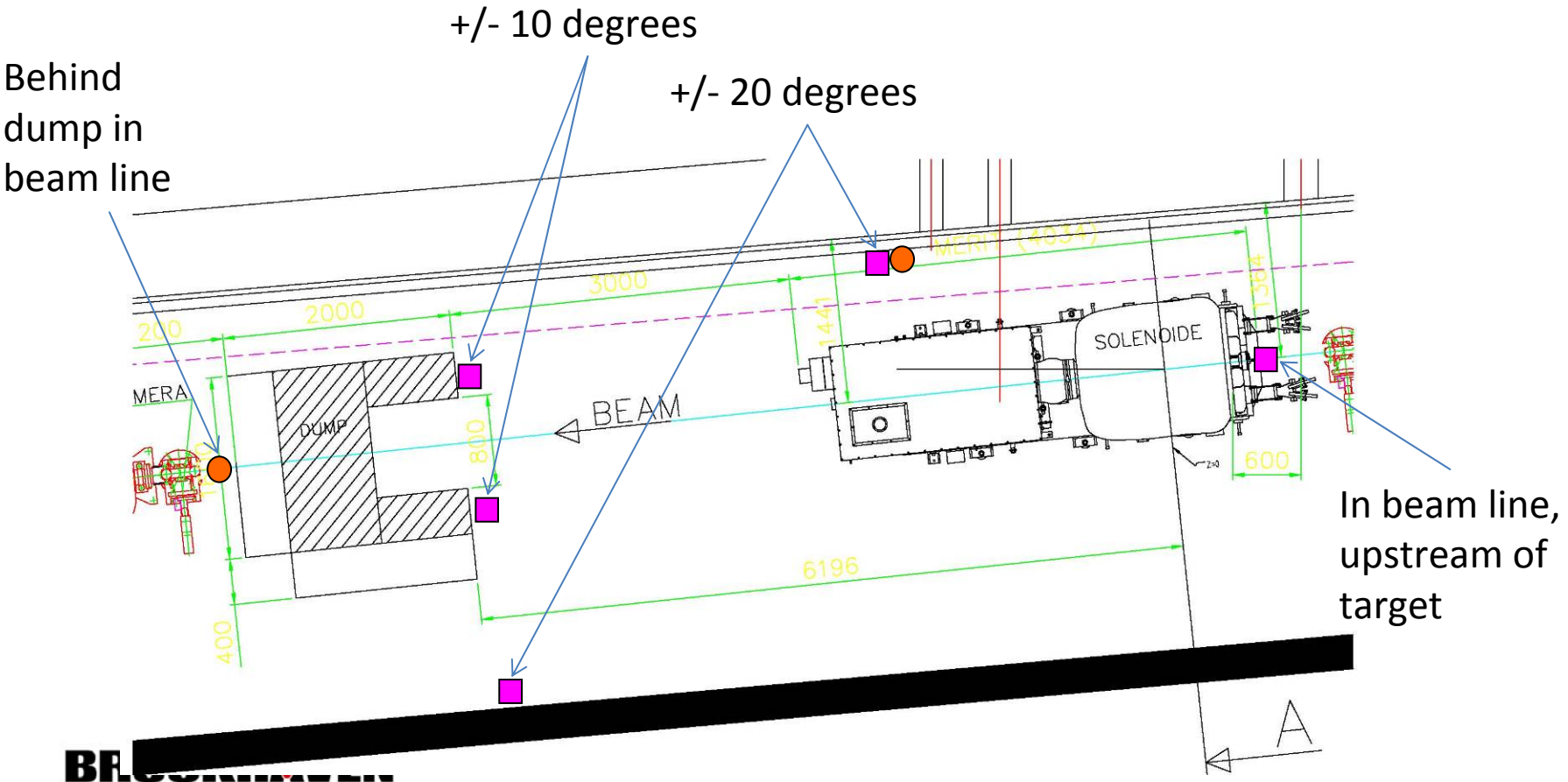
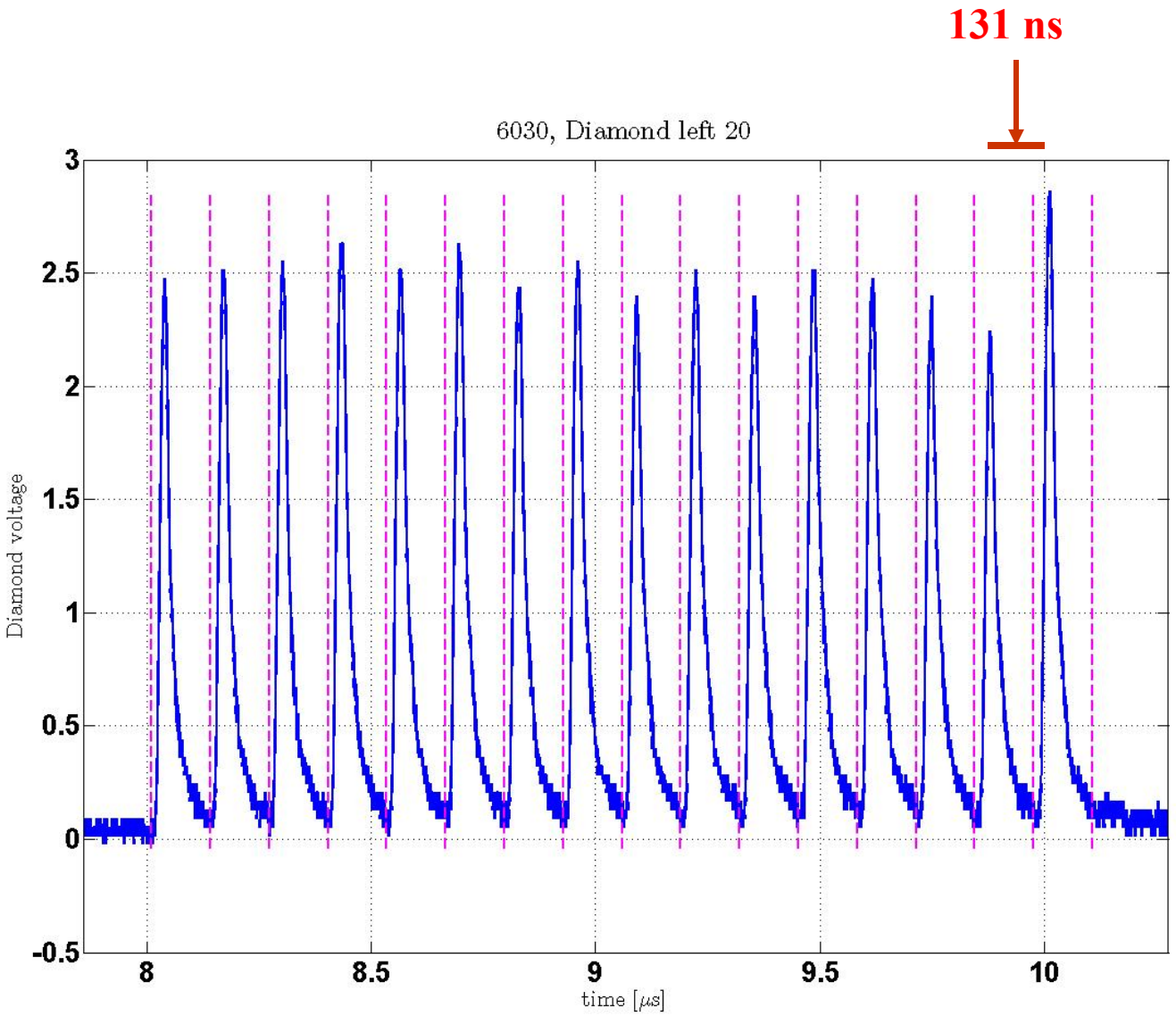
The Pump/Probe Detectors

- ACEM (Aluminum Cathode Electron Multiplier)
- Diamond

M. Palm, CERN - AB/ATB/EA



Diamond Left 20^0 Response



Oct. 29, 2007
14 GeV
4TP
10T Field
15m/s Hg Jet

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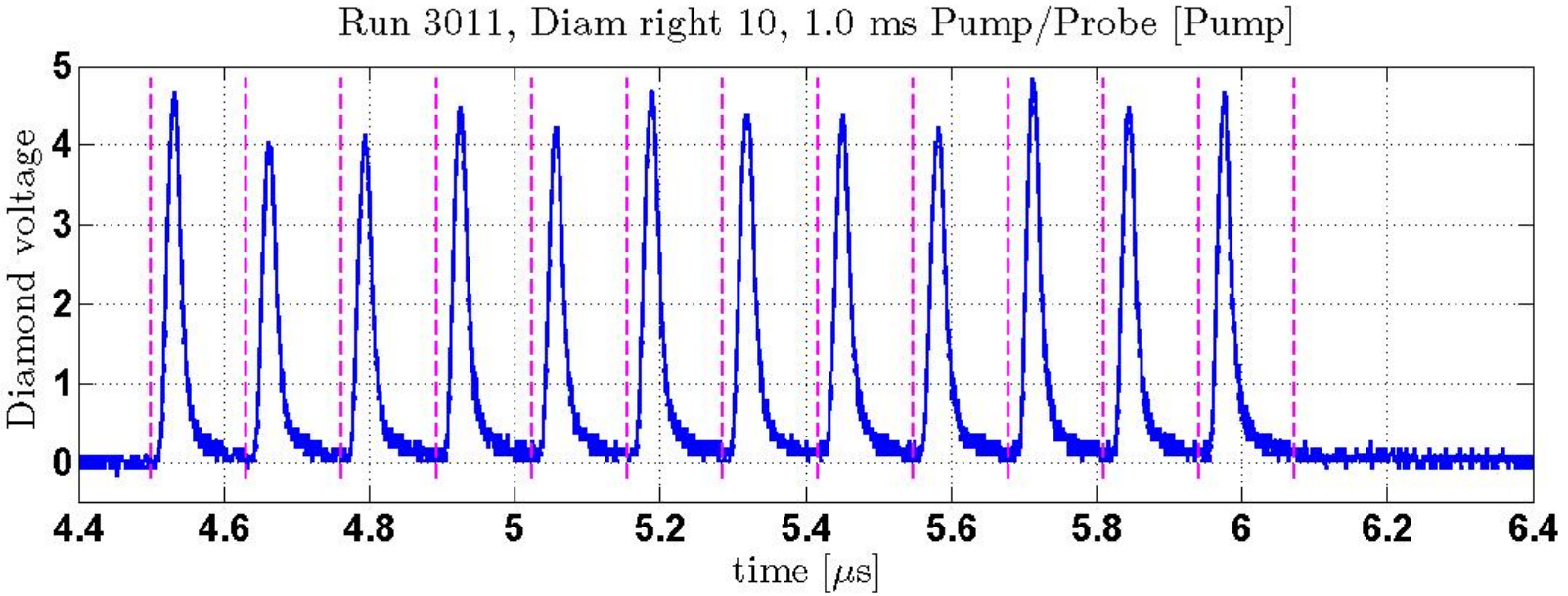
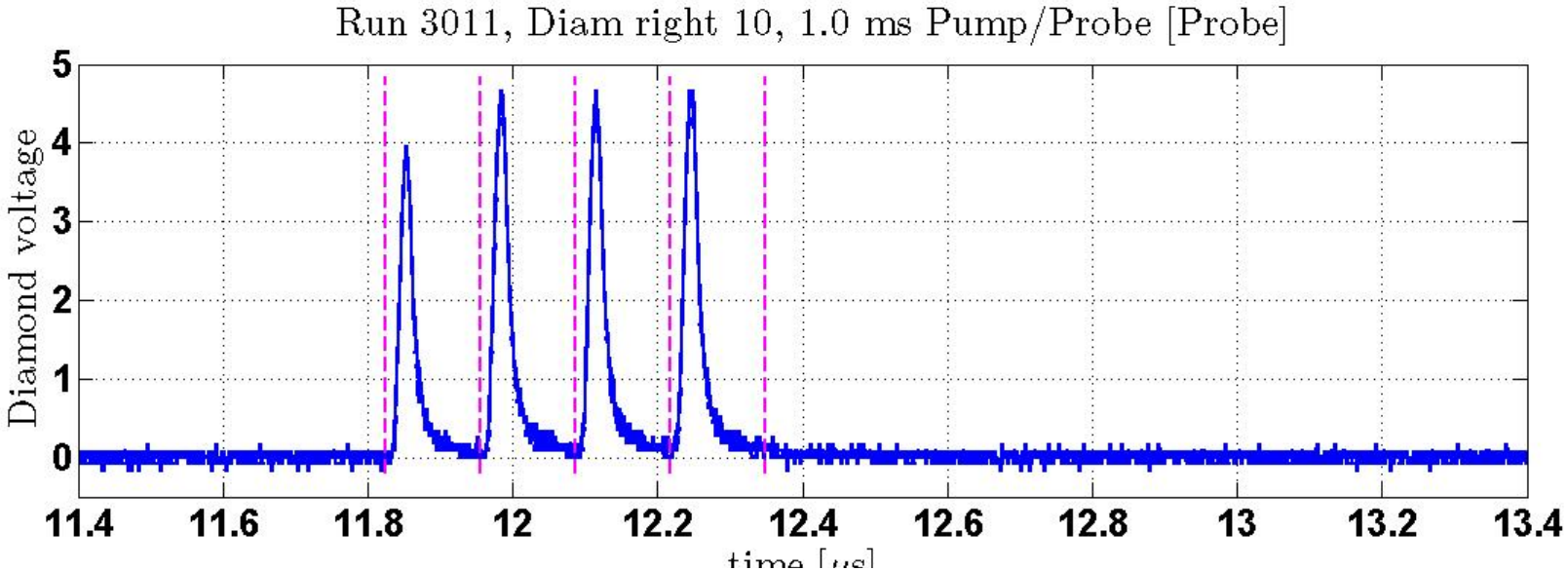
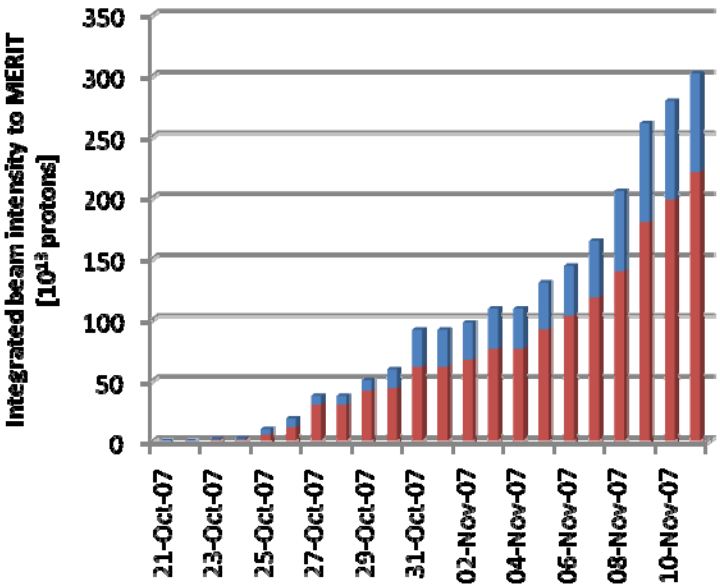
A 3T Pump Pulse and a 1TP Probe Pulse with 1ms delay

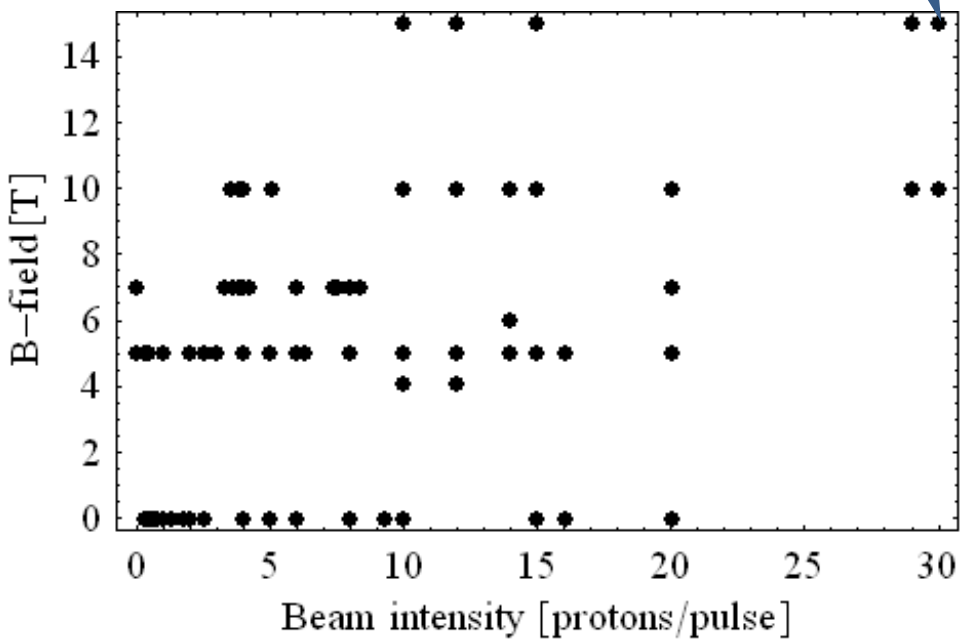




MERIT Beam Shots



- 30 x 10^{12} protons/pulse!!!
- 24 GeV
- 115kJ !!! a PS record



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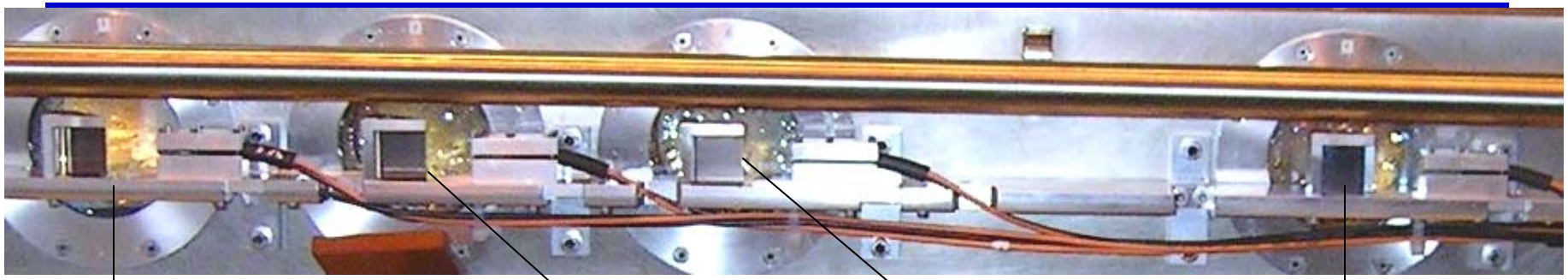
The Optical Diagnostic Cameras

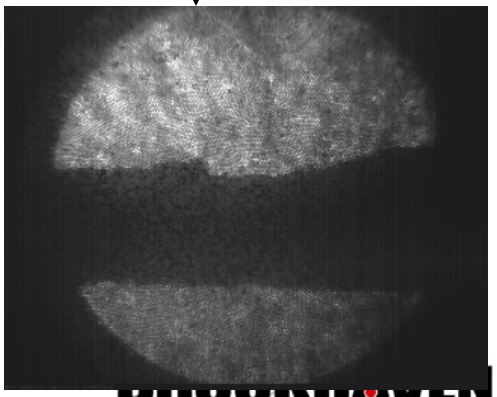


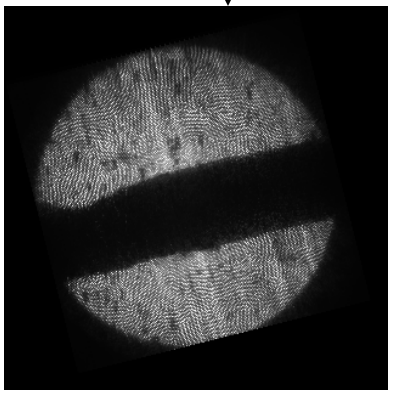
FastVision 1

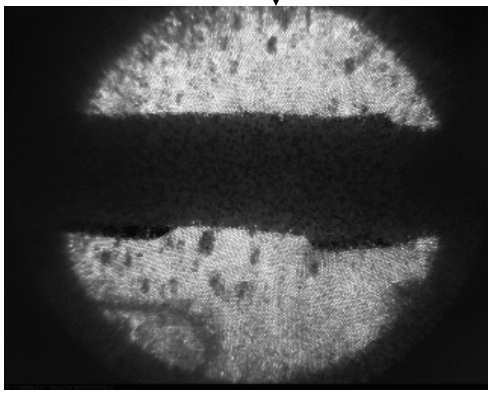
SMD

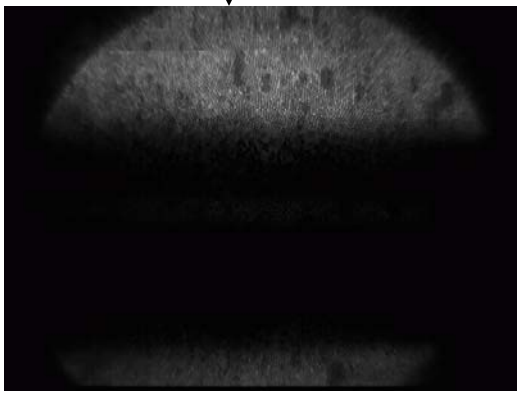
FastVision 2

video camera









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20 m/s Hg jet, 7 Tesla field

0.1 ms/frame

2 ms/frame

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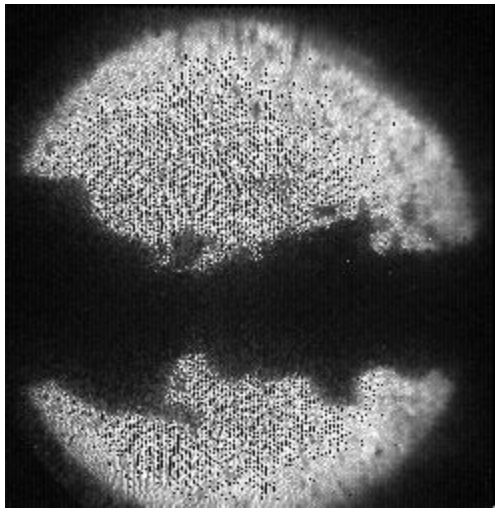
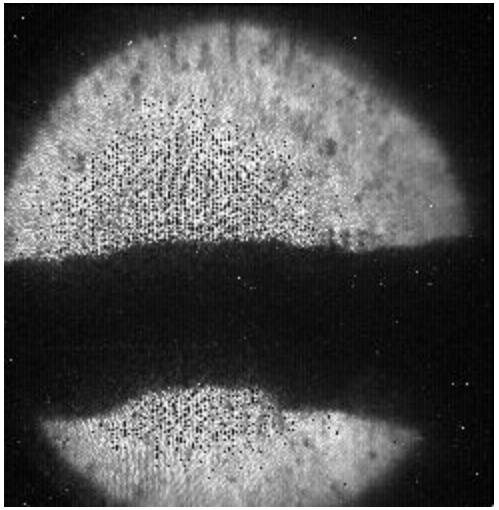
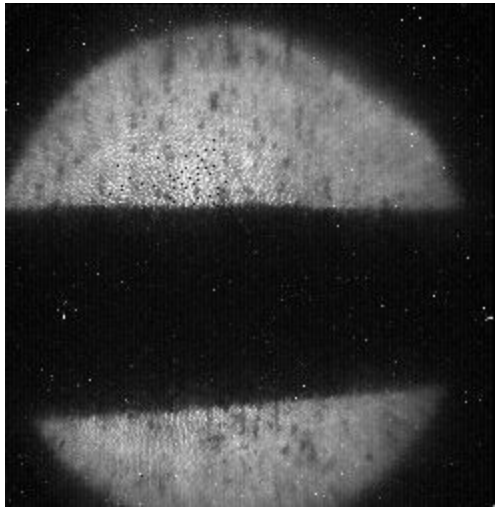
Influence of Magnetic Field



Jet Velocity is 15m/s



0T **5T**



10T **15T**

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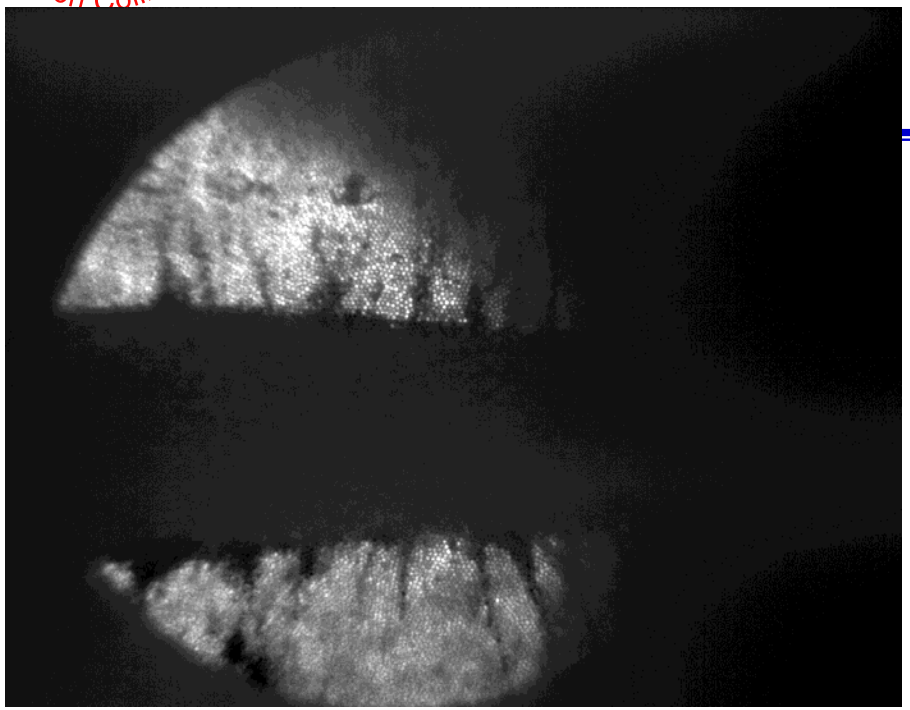
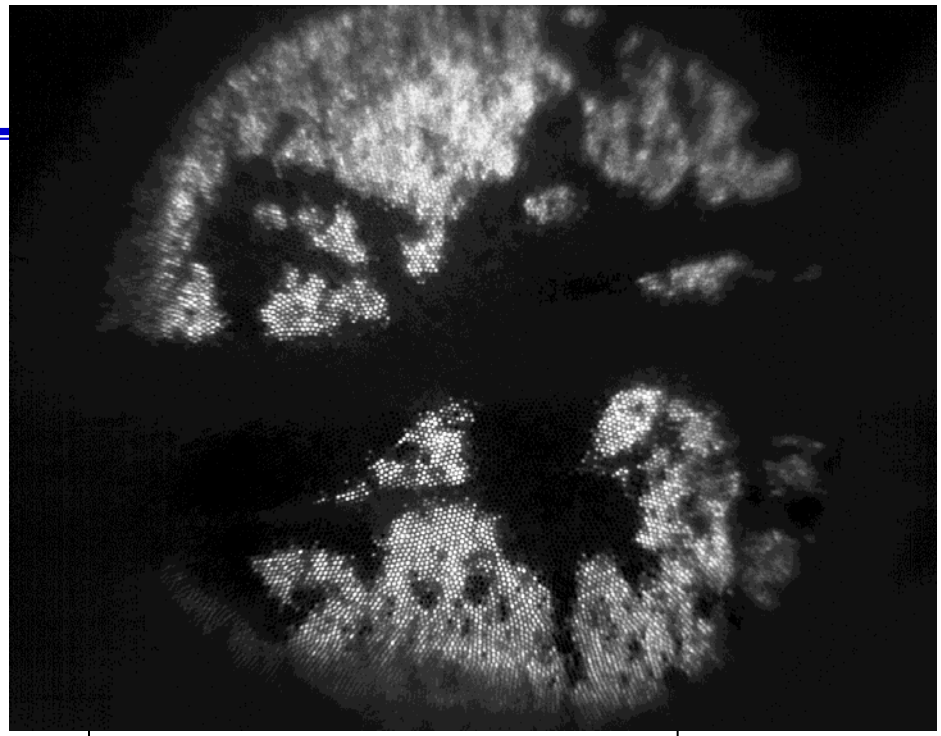
14 GeV Proton Beam on Hg Jet with Magnetic Field

Viewport 1 at 2ms



Viewport 3 at 26ms



October 26, 2007
Beam Pulse at 8:39pm
Central European Daylight Time

Hg Jet 15m/s
Solenoid Field 5T
Proton Intensity 10TP

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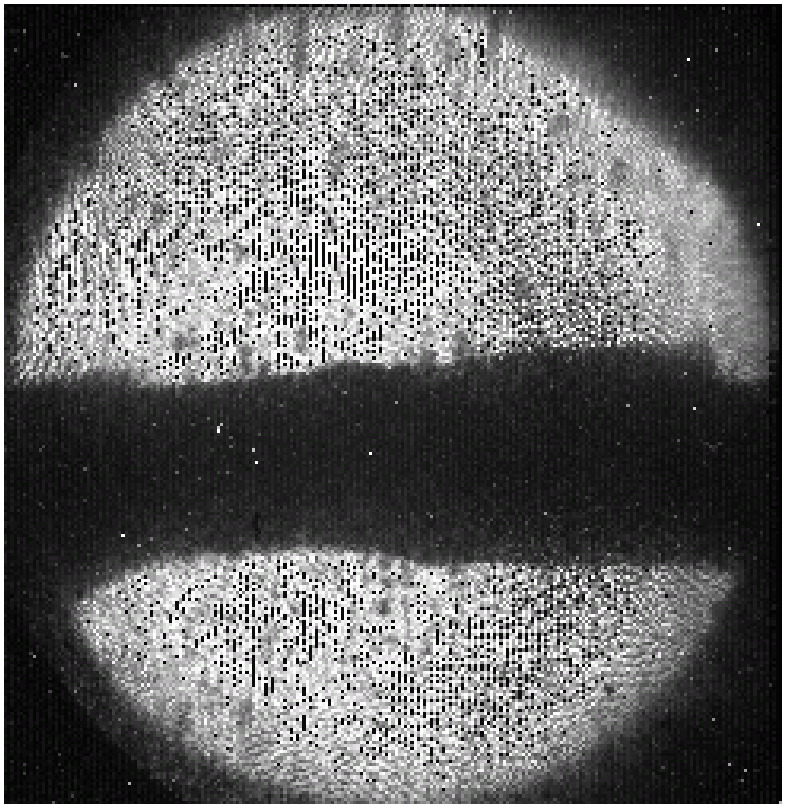
15TP 14GeV Proton Beam

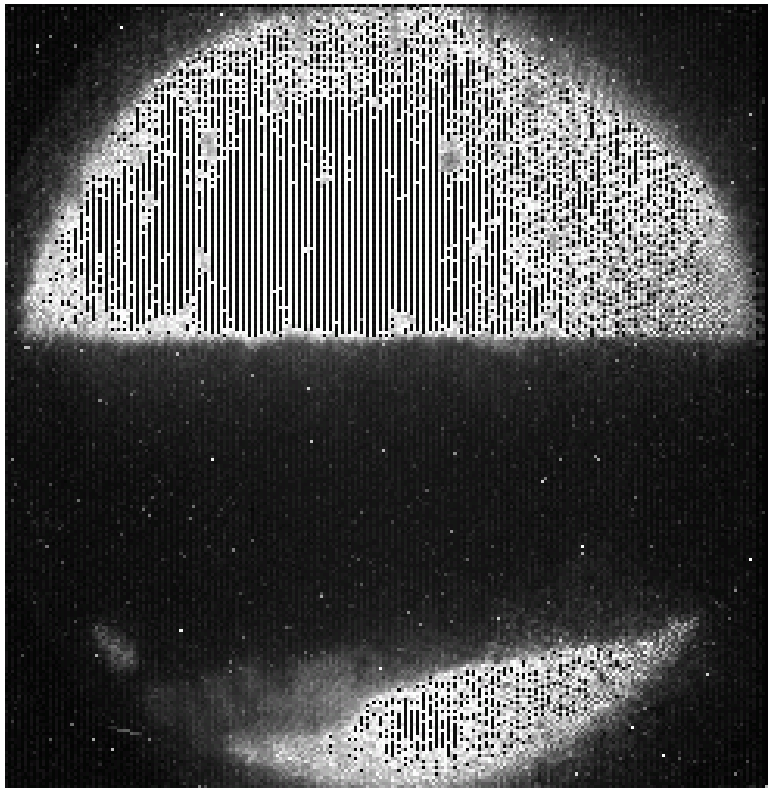


Oct. 27, 2007
Solenoid Field at 5T

Viewport 2

Beam 5016, Hg 15m/s, 100μs/frame, Total 1.6ms

20TP 14GeV Proton Beam

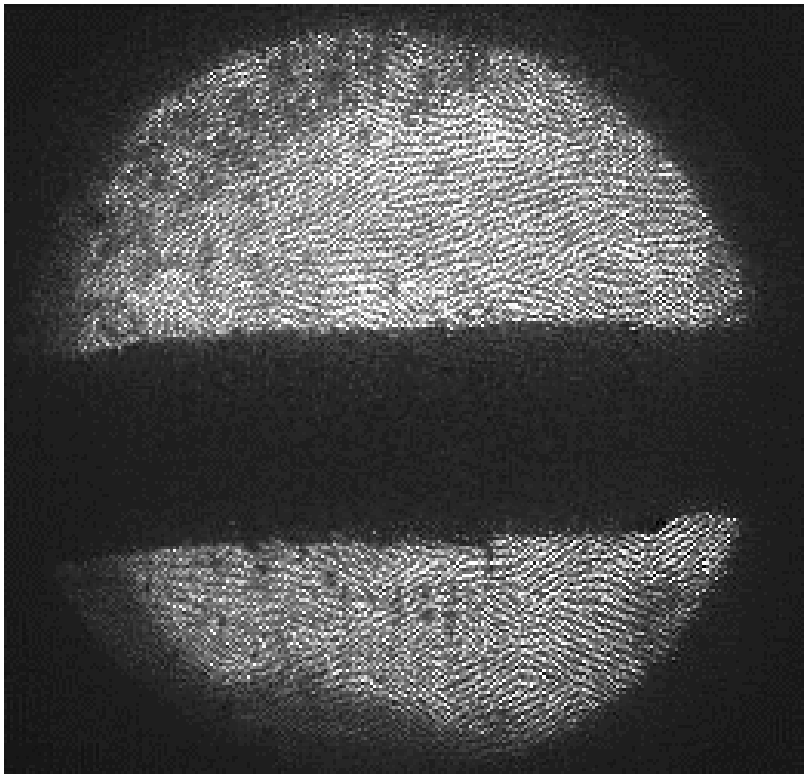


Oct. 27, 2007
Solenoid Field at 10T

Viewport 2

Beam 5020, Hg 15m/s, 100μs/frame, Total 1.6ms

Viewport 3: Jet/proton interaction



1 cm

Shot 16014
- 14 GeV
- 12×10^{12} protons/pulse
- B-field 10 T
- 500μs/frame

Disruption Length =16.5cm

The 24 GeV 30TP shot

Beam pulse energy = 115kJ

B-field = 15T

Jet Velocity = 20 m/s

Disruption Length = 28 cm

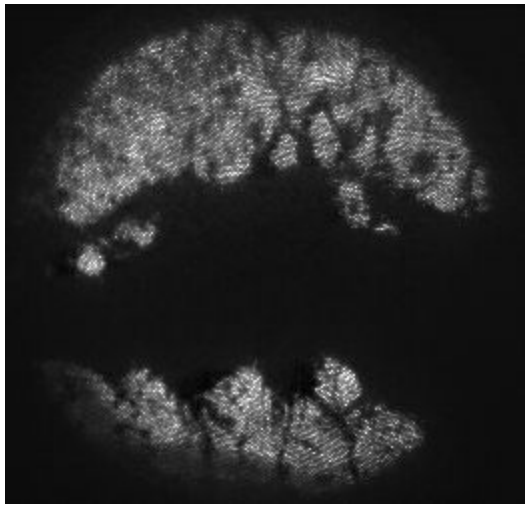
We will replace the 28cm disruption length (2 interaction lengths)

Then the jet transport time is 28cm/20m/s = 14ms

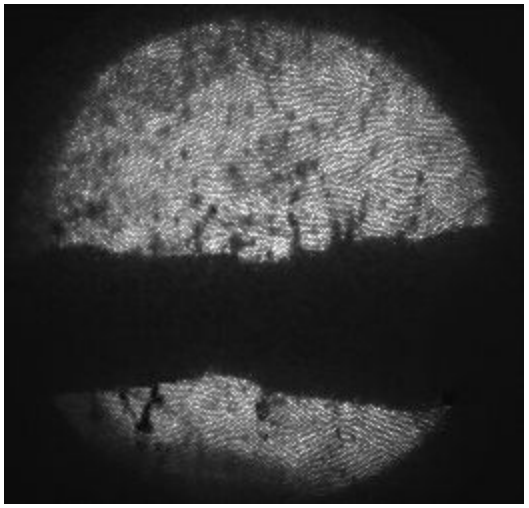
➔Rep rate of 70Hz

➔Proton beam power at that rate is 115kJ *70 = 8MW

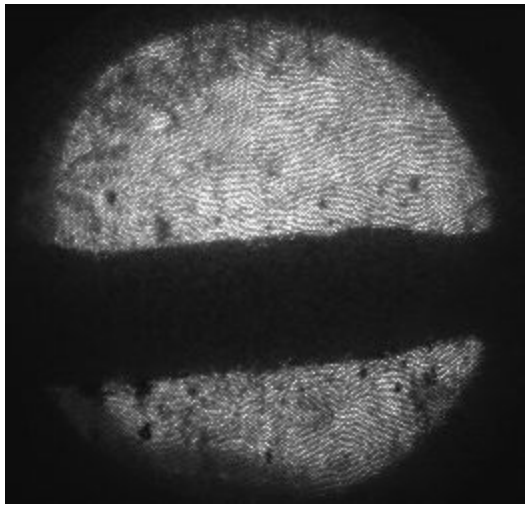
4TP + 4TP Delay Study at 14 GeV



Single Turn Extraction
➔ 0 Delay



4TP Probe extracted on subsequent turn
➔ 3.2 μs Delay



4TP Probe extracted after 2nd full turn
➔ 5.8 μs Delay

Target supports 14 GeV 4TP beam at 172kHz rep rate without disruption

Data Analysis Pipeline

- Disruption threshold based on proton beam characteristics
  - Intensity variations
  - Proton beam harmonic structure
- Disruption threshold based on solenoid field strength
- Pump/probe studies
  - 15TP pump + 5TP probe with delays 2 to 700μs
  - 24 GeV pump/probe studies with delays < 2μs
- Magnetodynamic studies
  - disruption (filamentation) velocities
  - quadruple distortions
- Proton beam spot size analysis

The MERIT Bottom Line

The Neutrino Factory/Muon Collider target concept has been validated for 4MW 50Hz operations.