Recent Results from MERIT

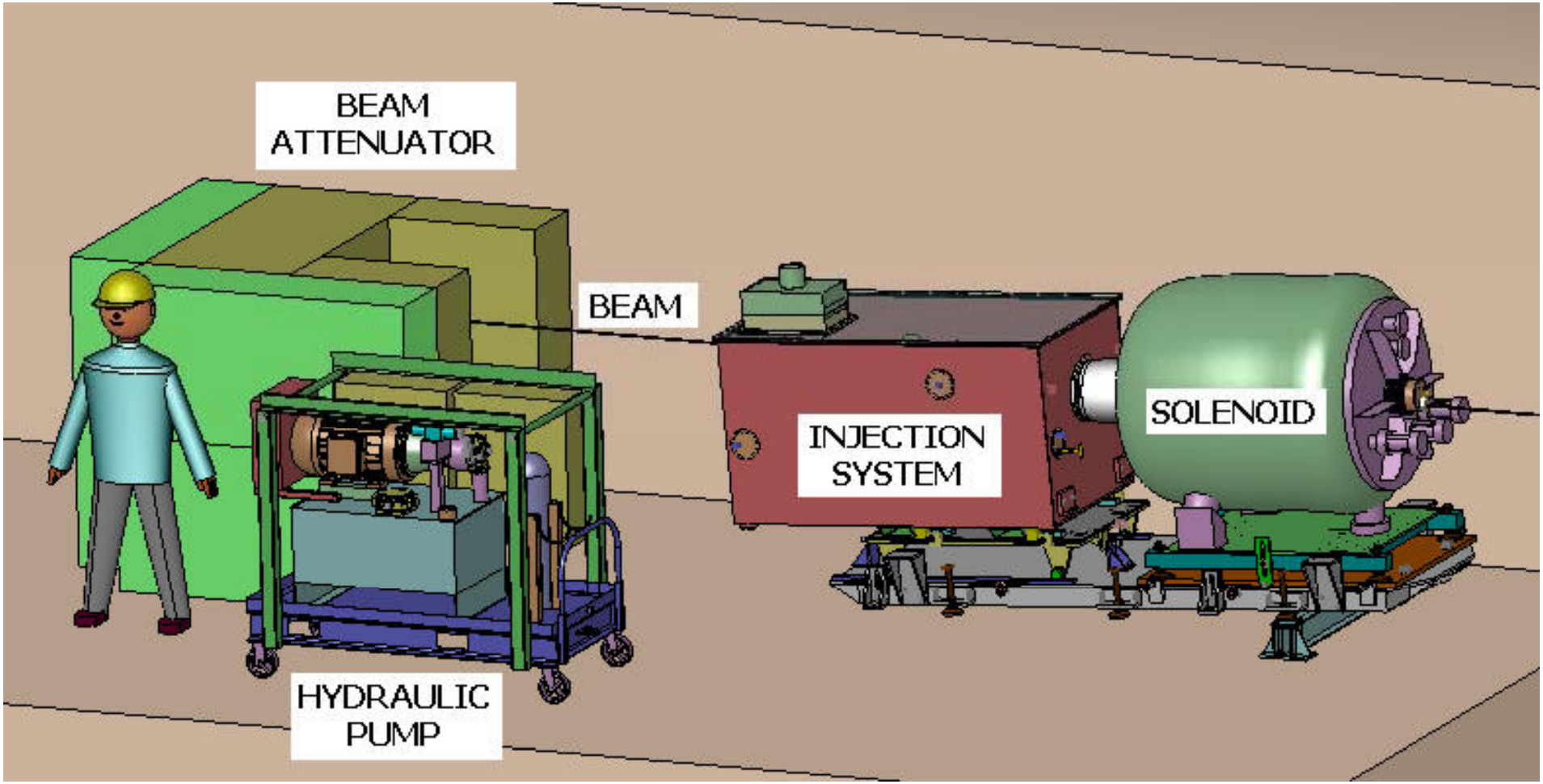
NUFACT09

Illinois Institute of Technology

July 22, 2009

Harold G. Kirk
Brookhaven National Laboratory

The MERIT Experiment



MERcury Intense Target

Experiment ran Oct./Nov. 2007

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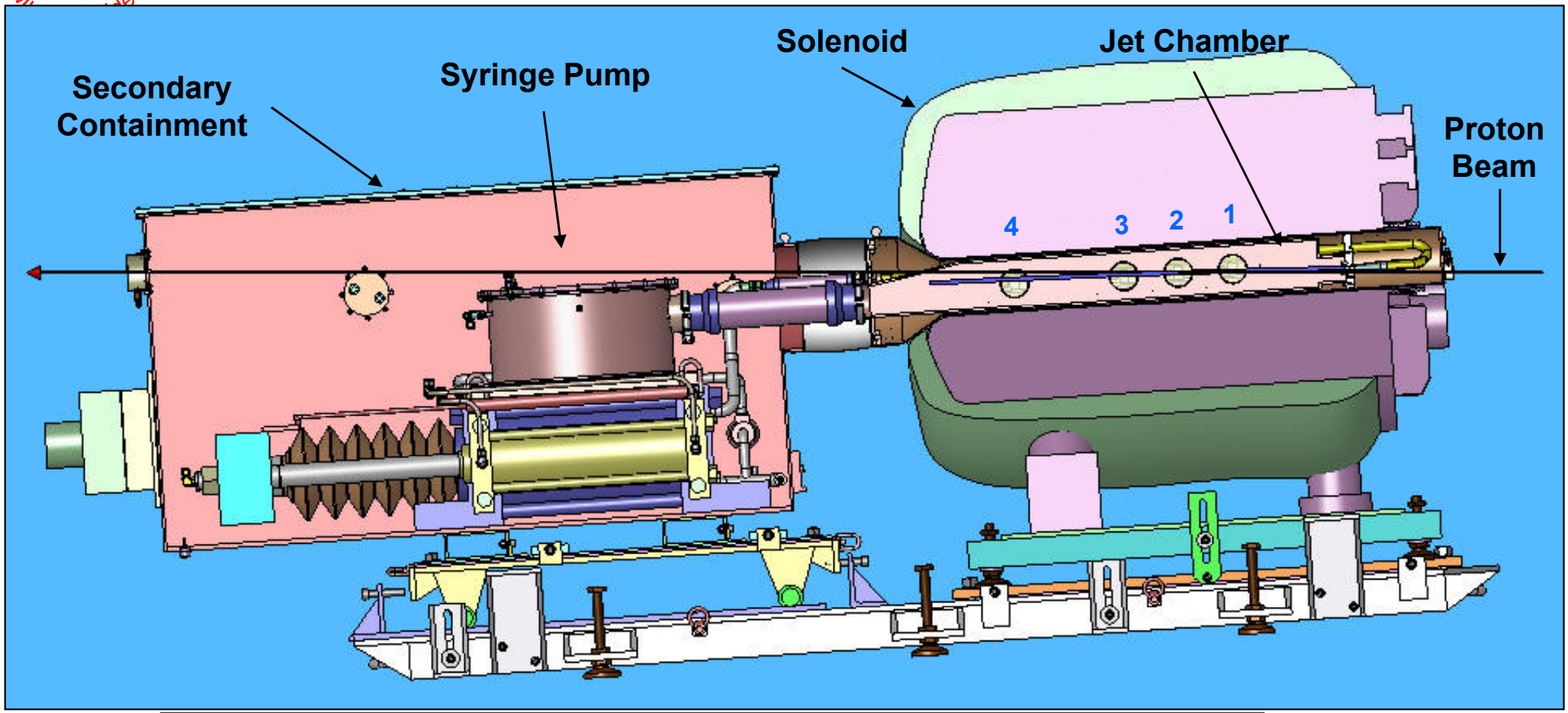
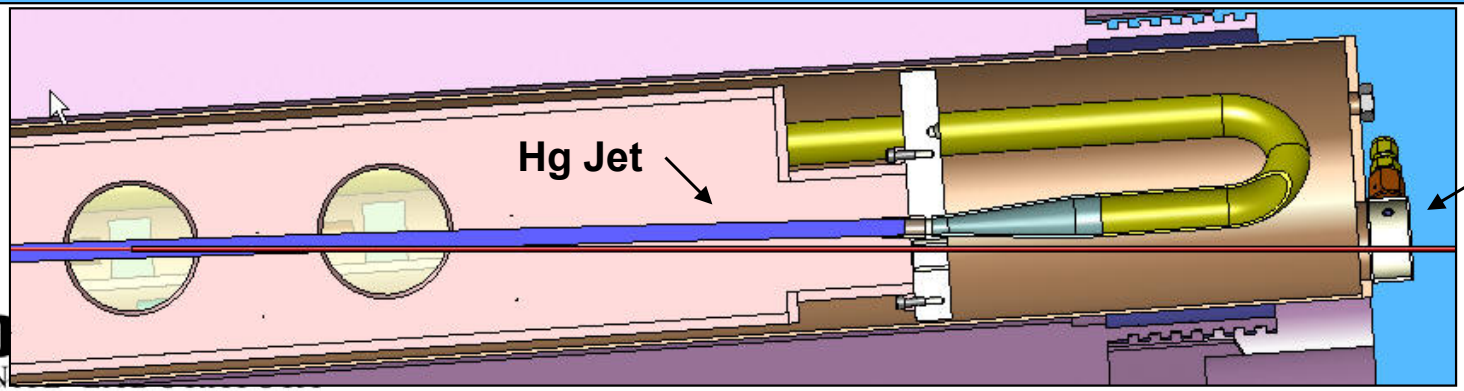
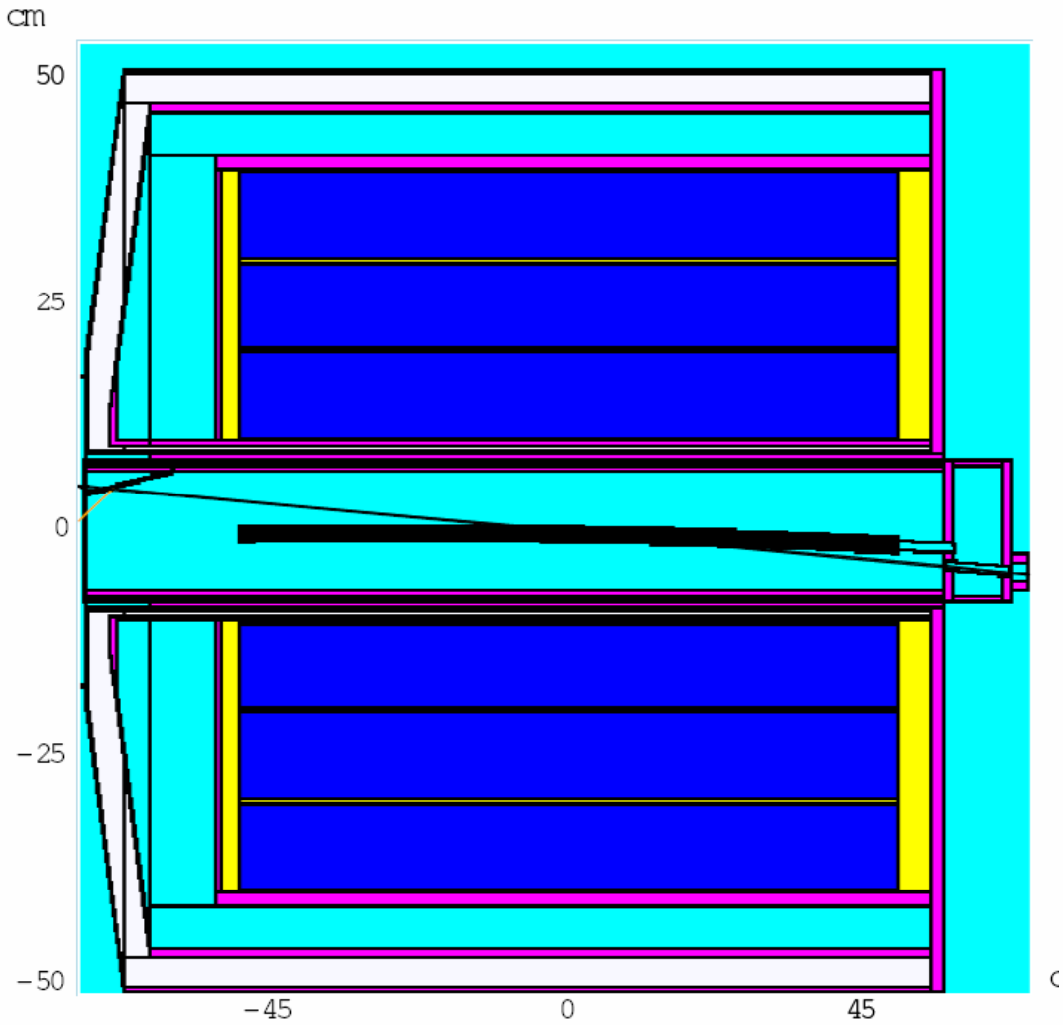
MERIT Experiment at CERN

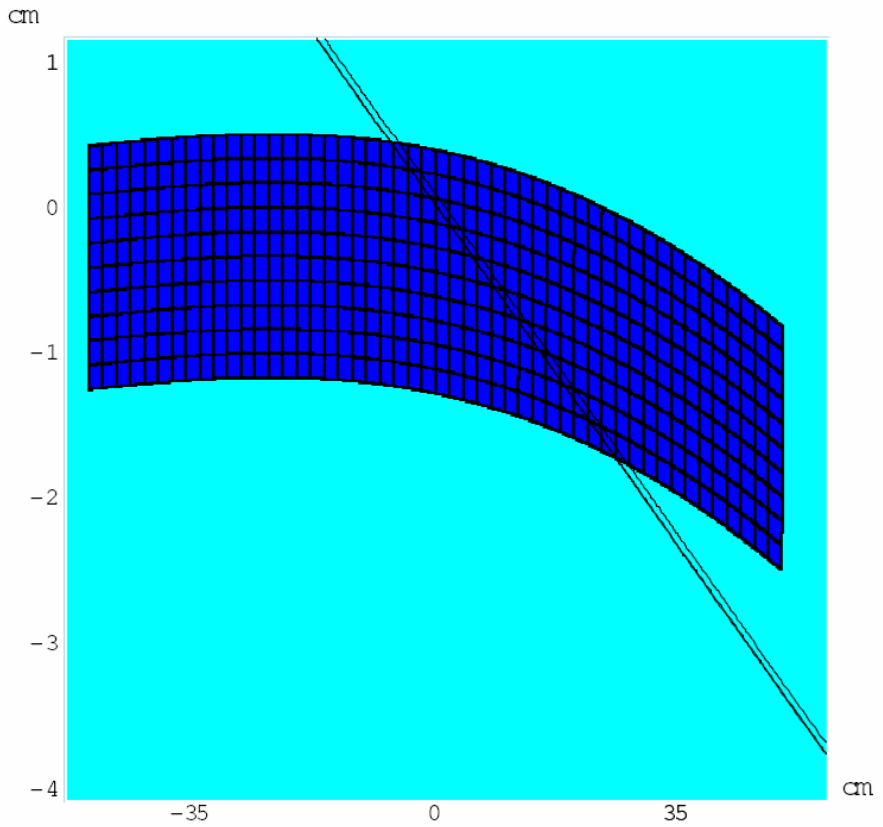




MARS Simulations of MERIT

Sergei Striganov, FNAL





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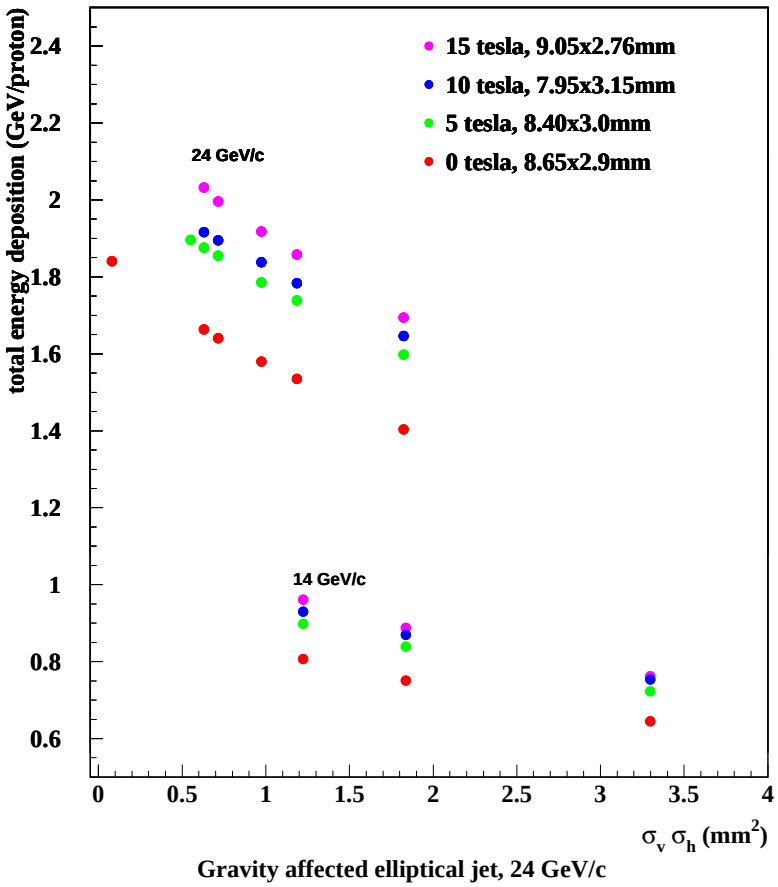
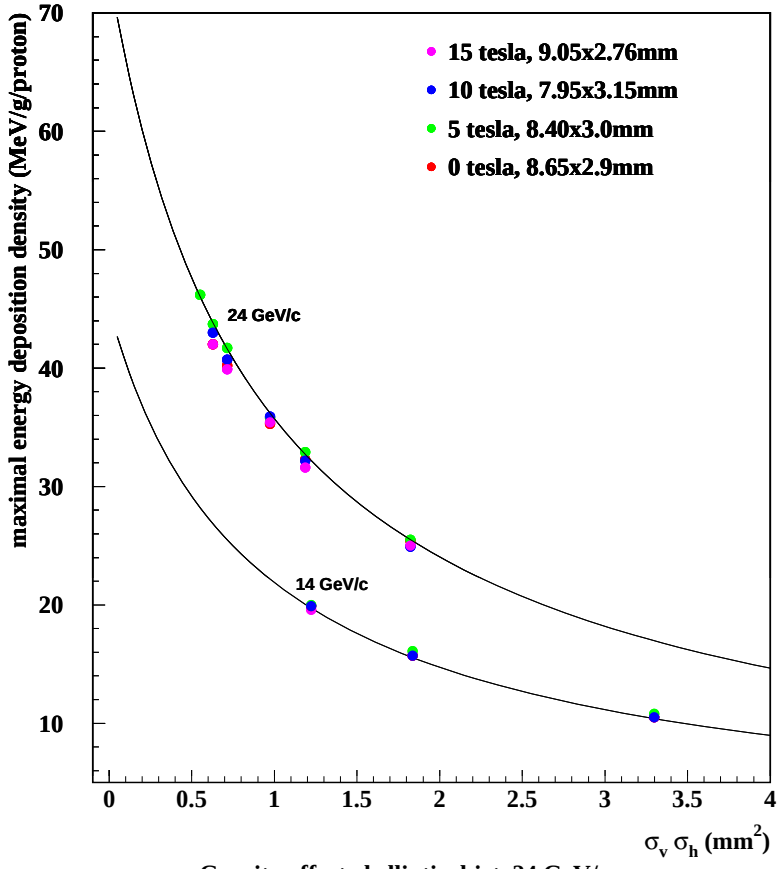
Energy depositions in Hg Jet

Total Energy Deposition



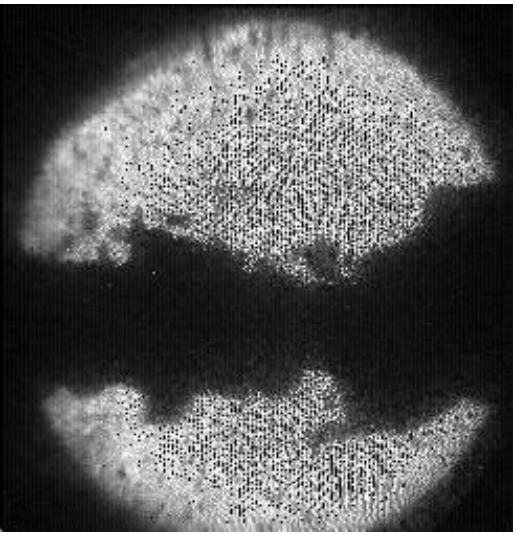
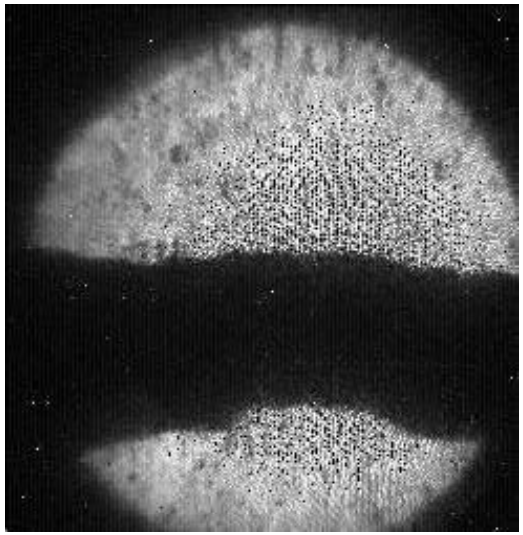
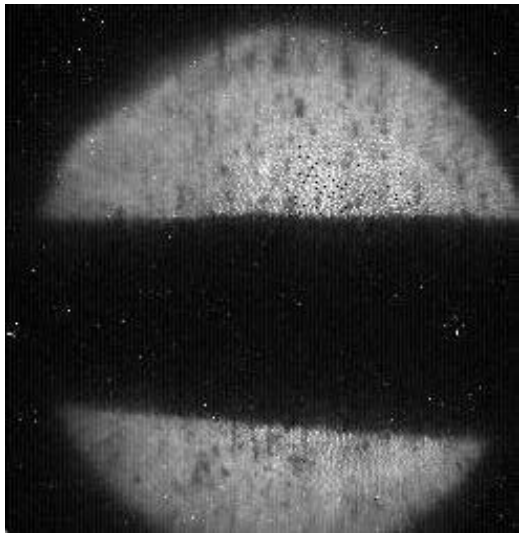
Gravity affected elliptical jet, 24 GeV/c

Peak Energy Deposition



Gravity affected elliptical jet, 24 GeV/c

Stabilization of Jet by High Magnet Field

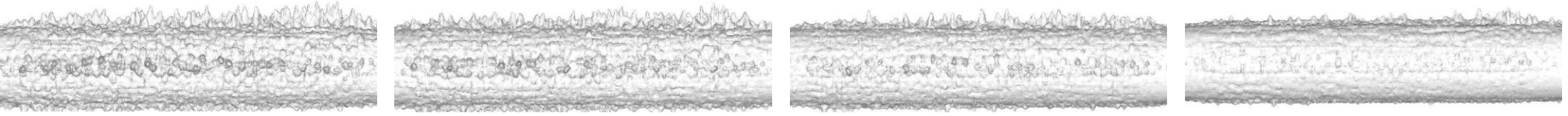





0T 5 T 10 T 15 T

Jet velocities: 15 m/s

Substantial surface perturbations mitigated by high-magnetic field.

MHD simulations (R. Samulyak):



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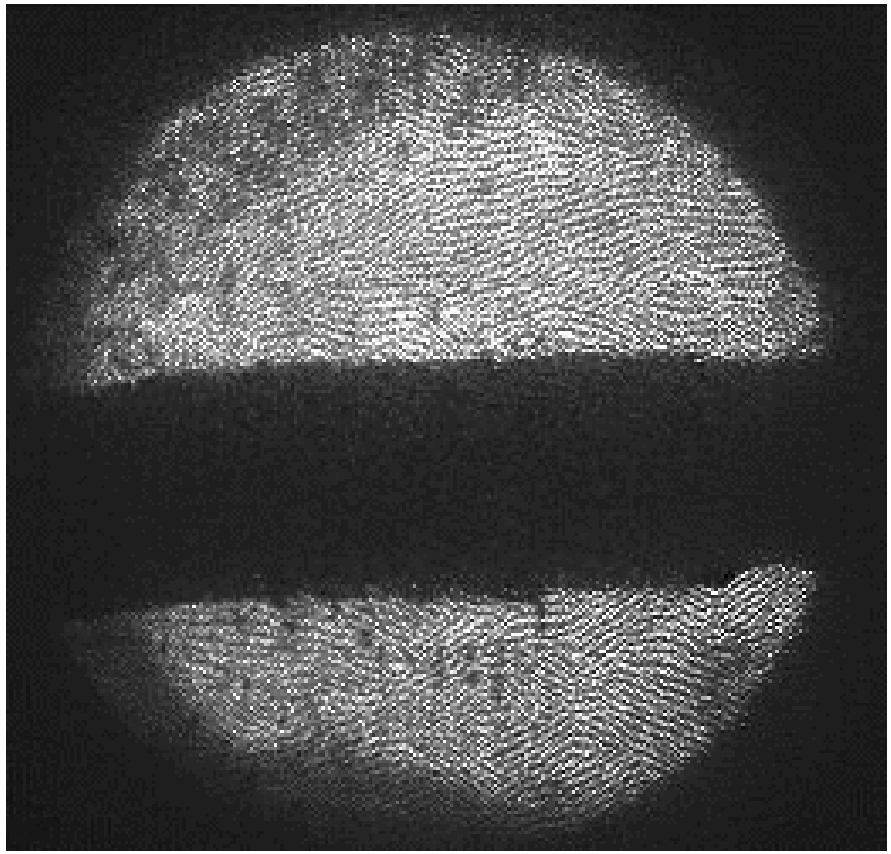
Viewport 3: Disruption Analysis



1 cm

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

Disruption Length =16.5cm

View of Jet/Proton interaction aftermath

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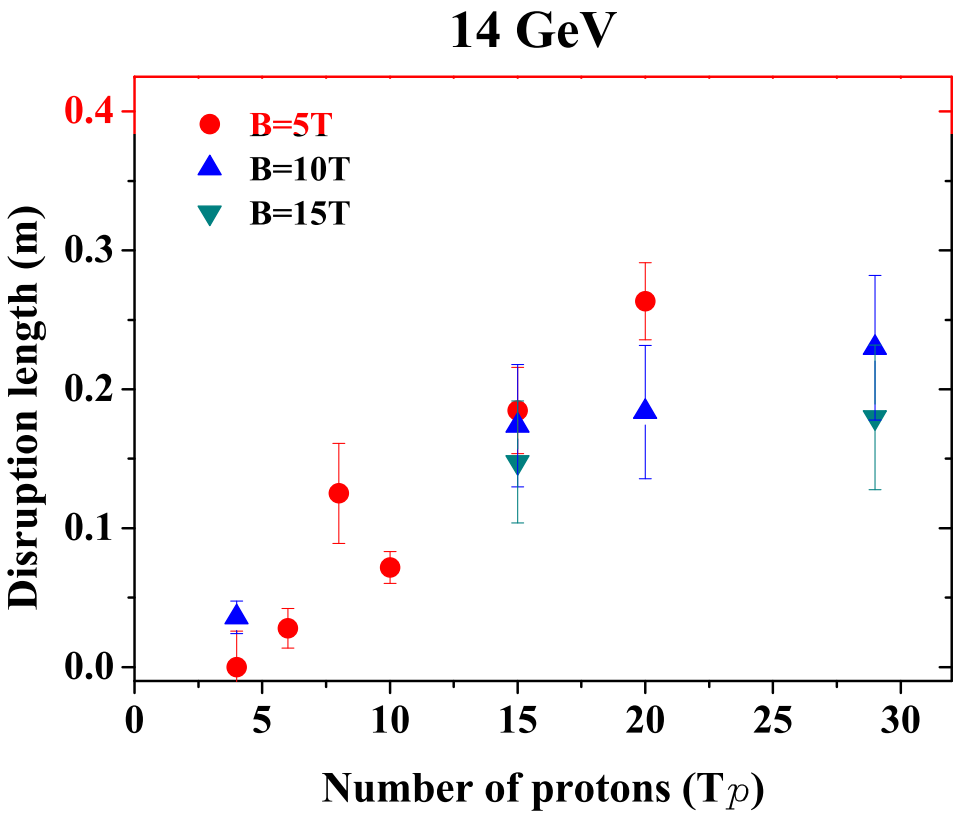
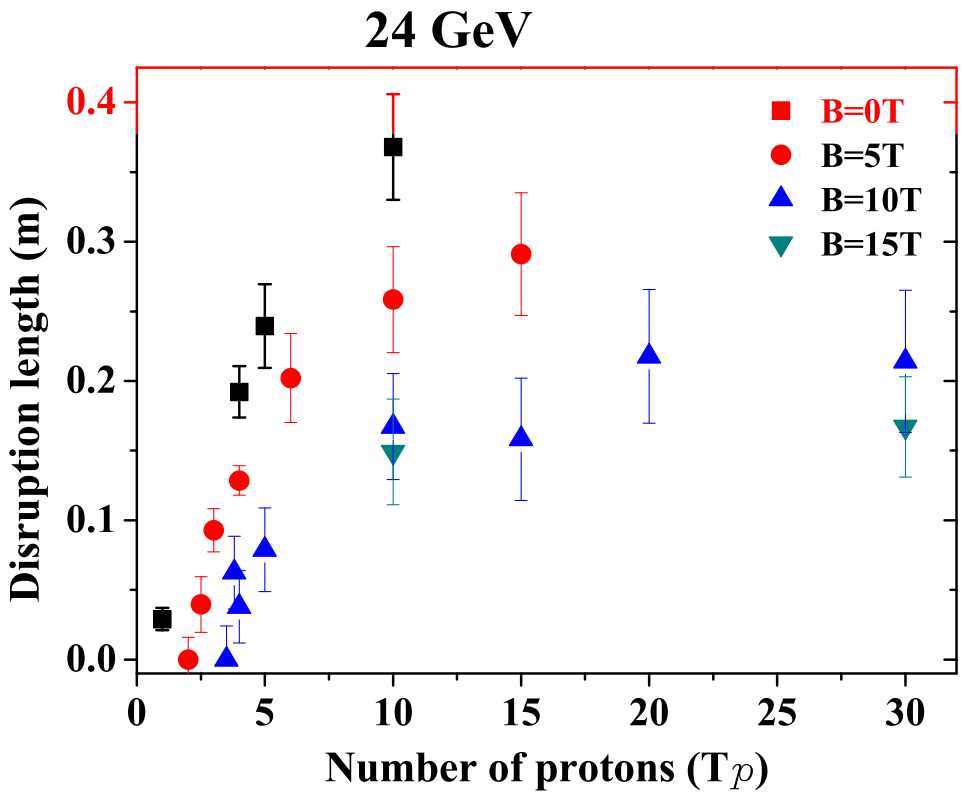
Disruption Analysis





Disruption lengths reduced with higher magnetic fields

Disruption thresholds increased with higher magnetic fields

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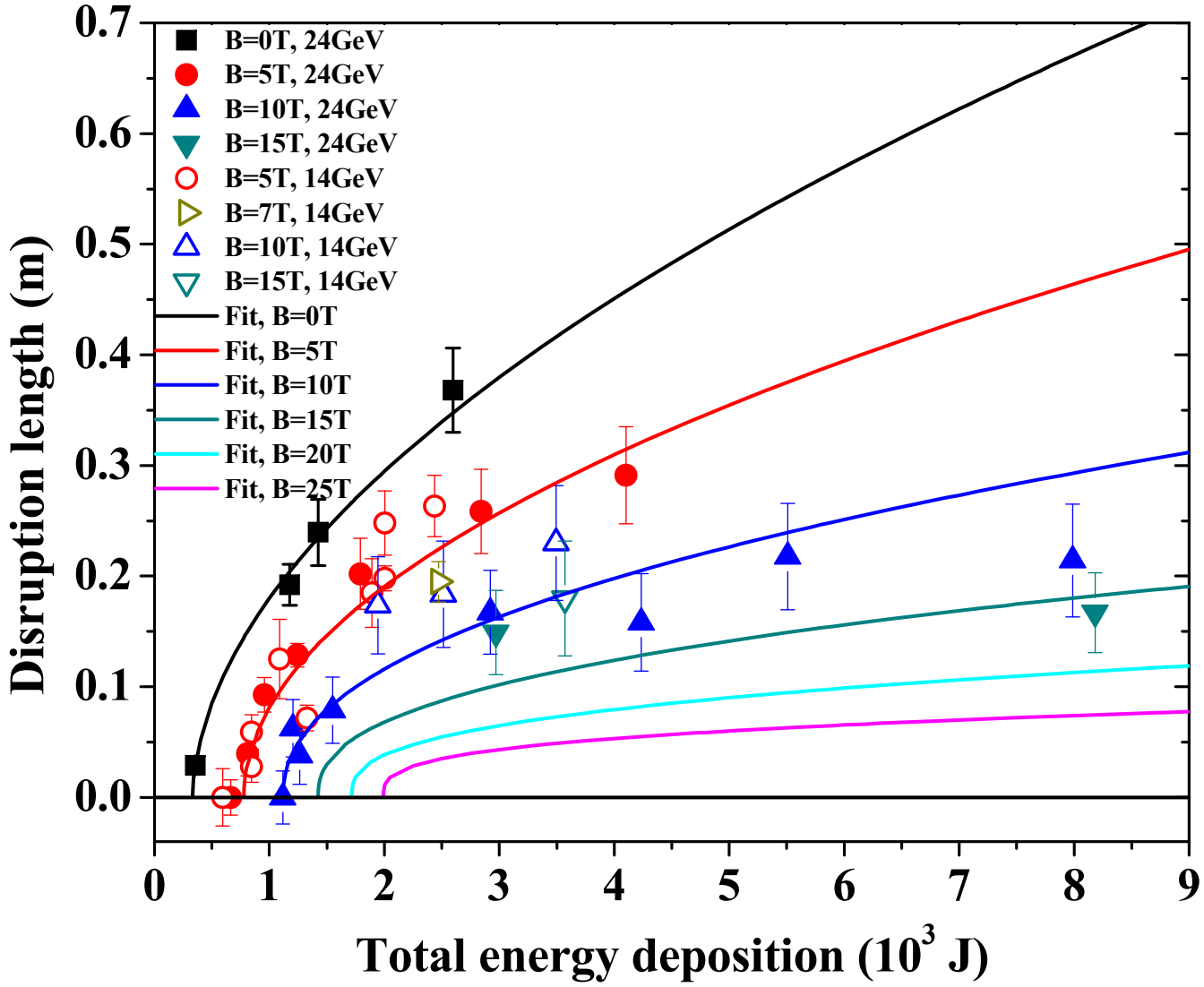
Disruption vs Total Energy Deposition



- 14 and 24 GeV data fitted together
- Clear threshold behavior
- Magnetic field suppression observed
- Extrpolation to 20T and 25T

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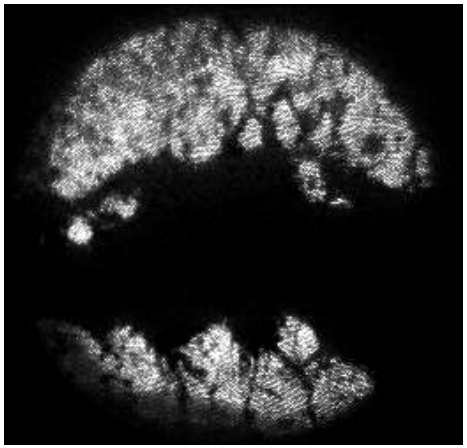
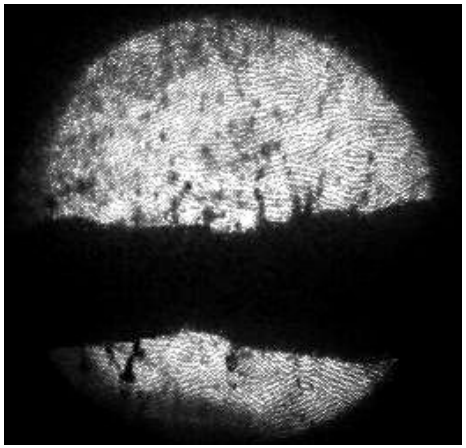
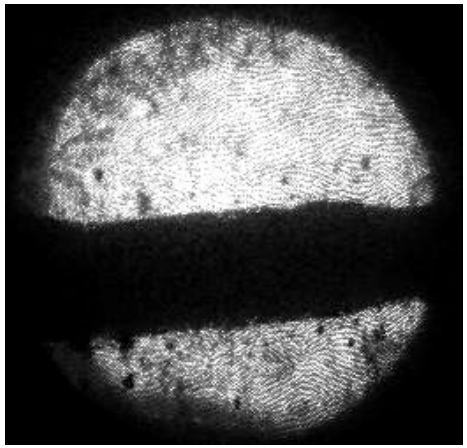
Study with 4 T*p* + 4 T*p* at 14 GeV, 10 T



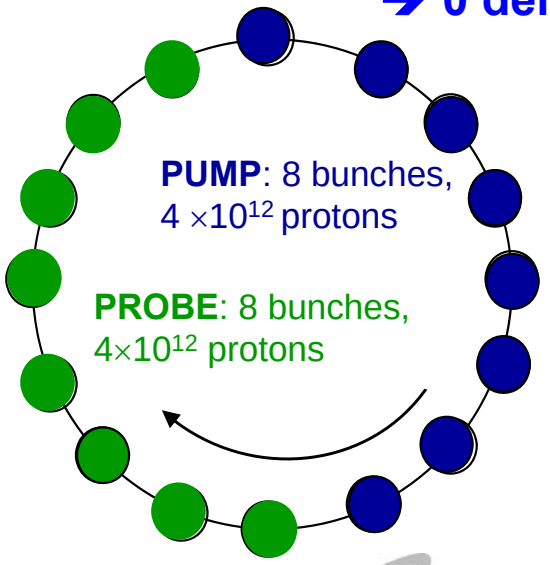
Single-turn extraction
➔ 0 delay, 8 T*p*



4-T*p* probe extracted on subsequent turn
➔ 3.2 μs delay



4-T*p* probe extracted after 2nd full turn
➔ 5.8 μs Delay



Threshold of disruption is > 4 T*p* at 14 Gev, 10 T.

⇒Target supports a 14-GeV, 4-T*p* beam at 172 kHz rep rate without disruption.

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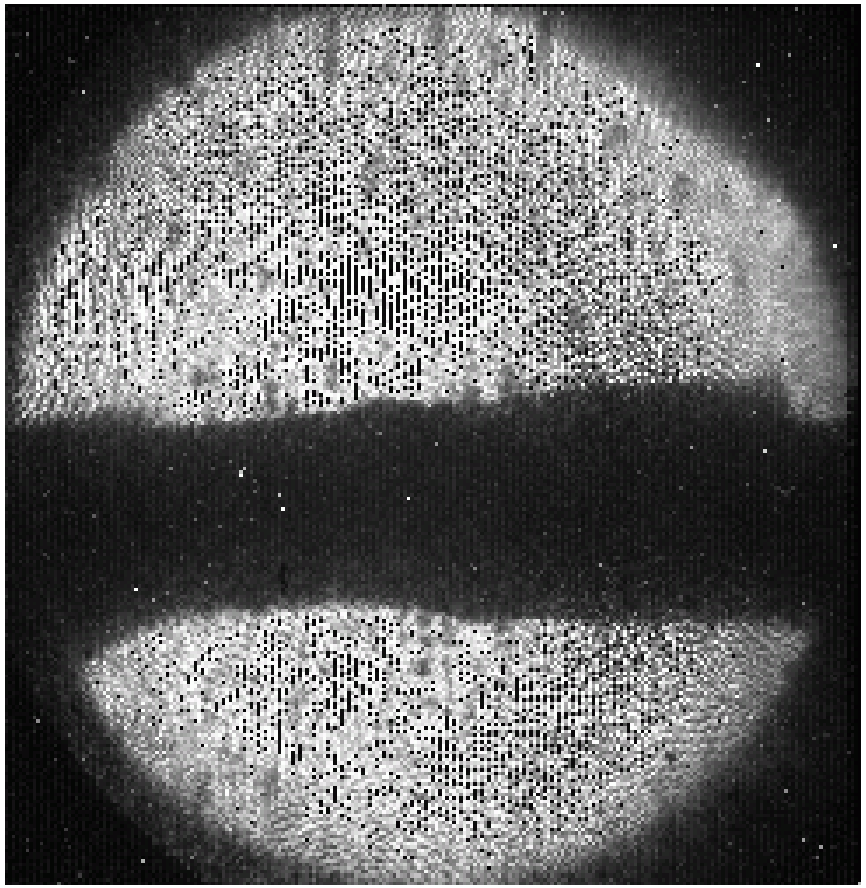
Viewport 2: Velocity Analysis



15 Tp 14GeV Proton Beam

Solenoid Field at 5T

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

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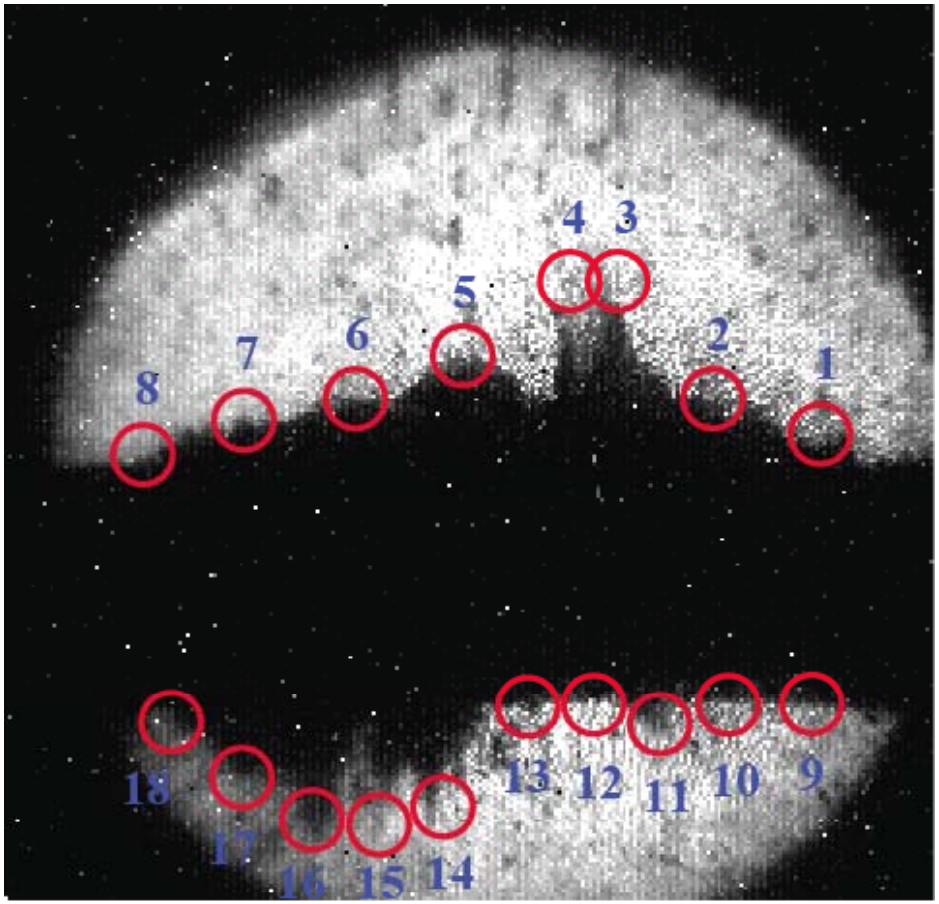
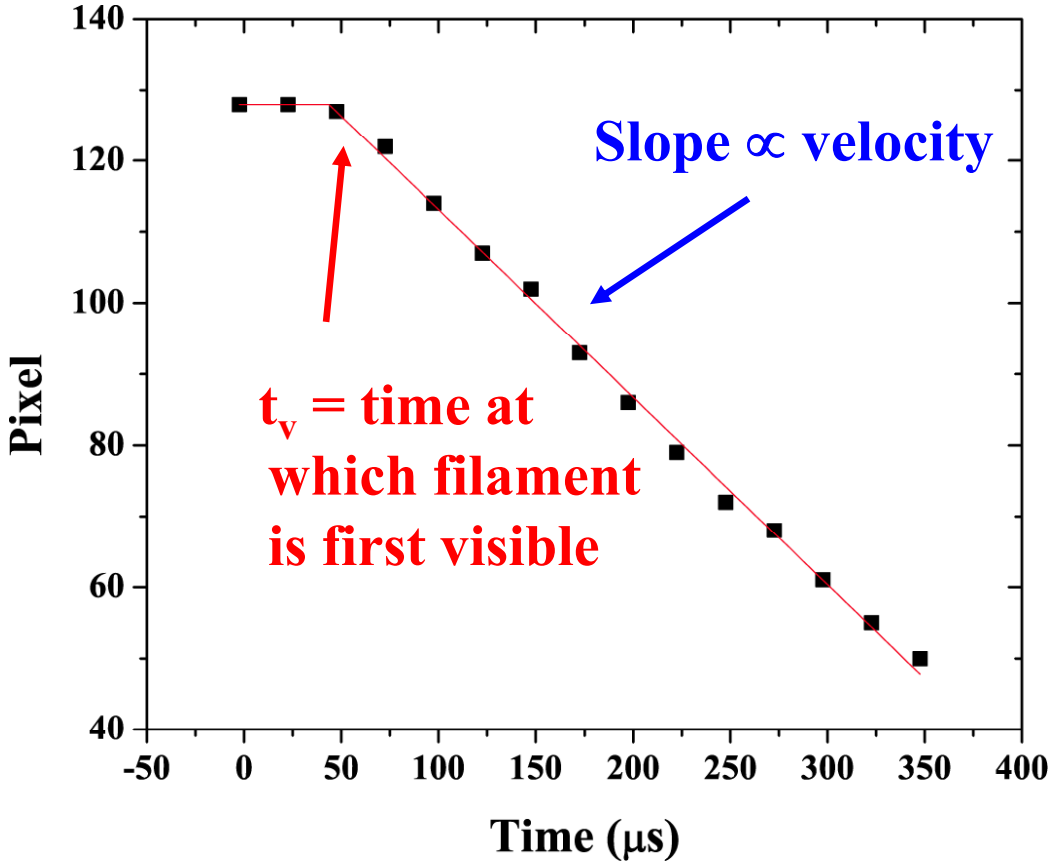
Ejection Velocity Analysis





Study velocity of filaments of ejected mercury using the highest speed camera, at viewport 2, at frame periods of 25, 100 or 500 μs

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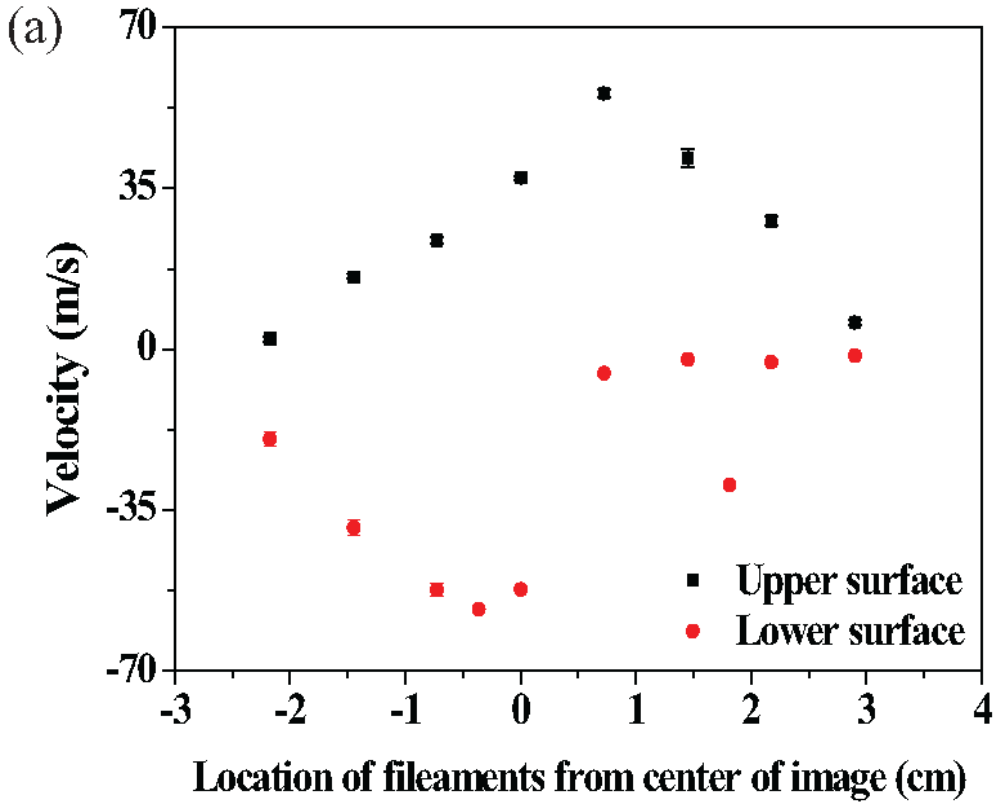
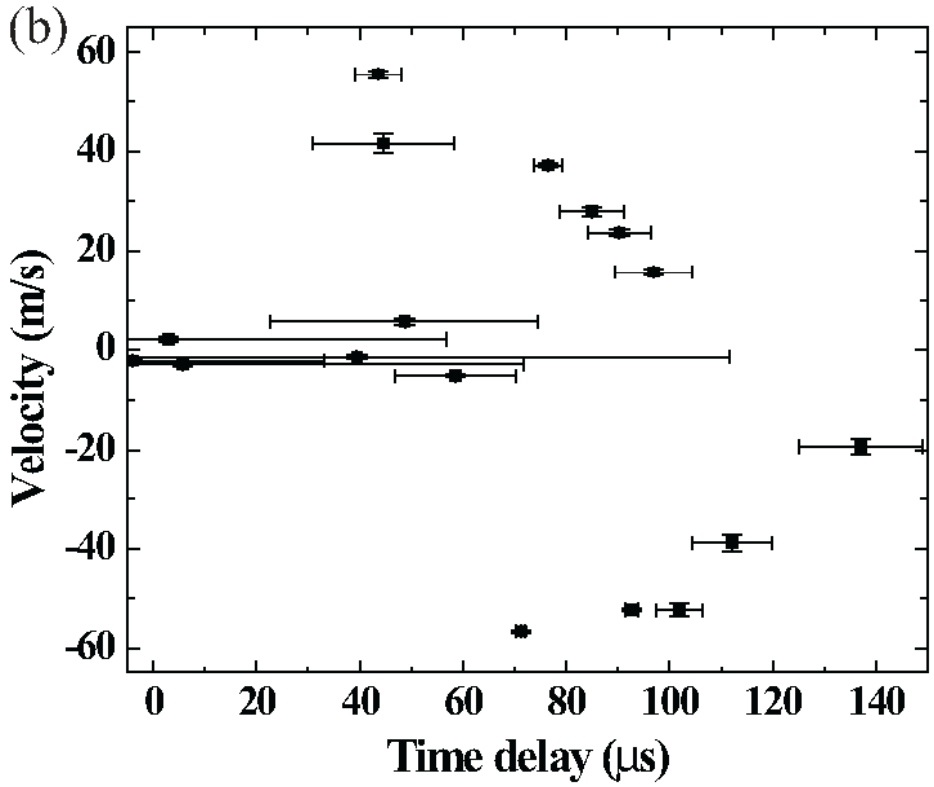
Ejection Velocity Analysis II





Shot 11019: 24-GeV, 10-T*p* Beam, 10-T Field, 25μs/frame:

Peak Velocity—60m/s Time delay ≥ 40μs (agrees with E-951)

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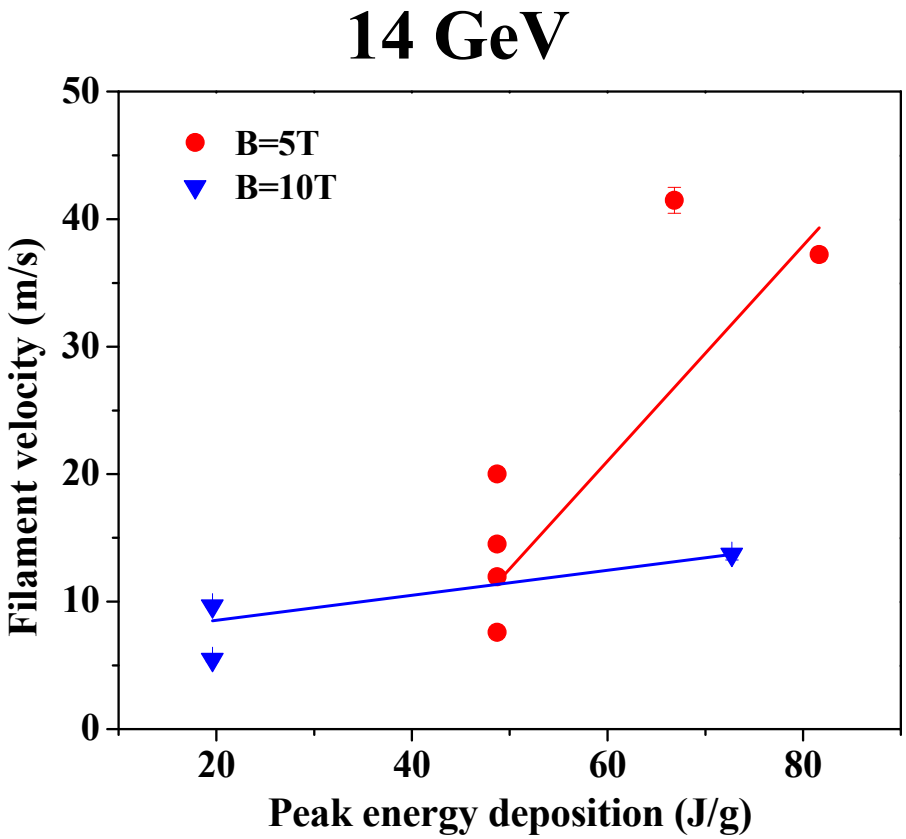
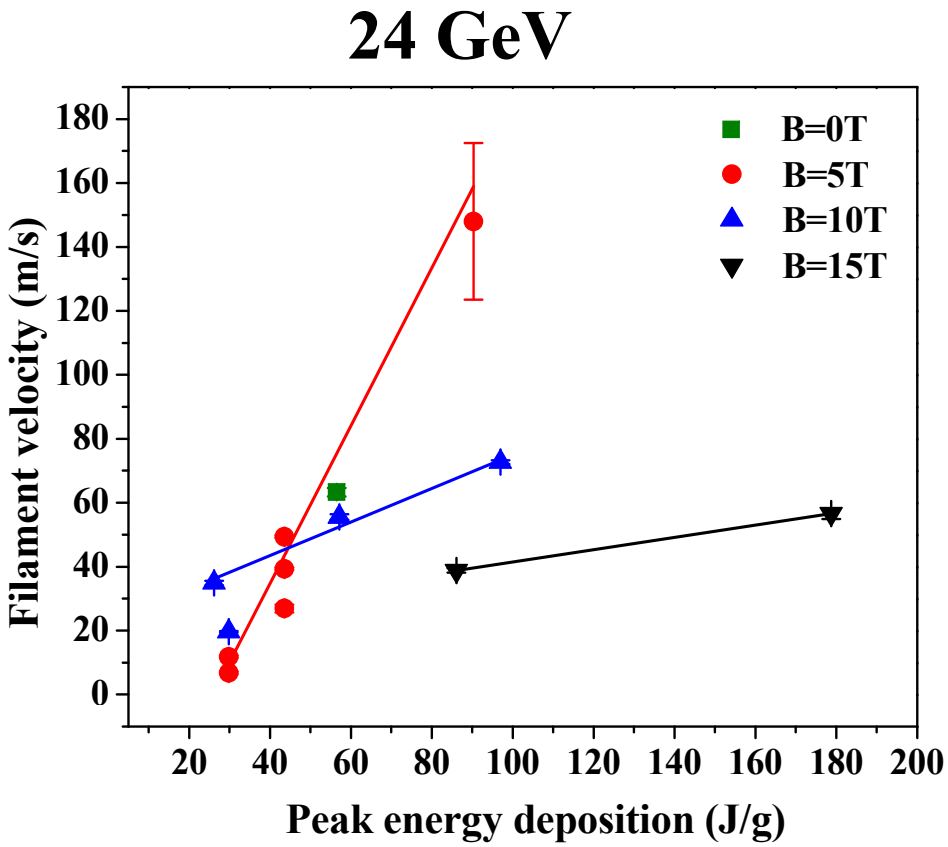
Peak Velocities





Ejection velocities are suppressed by magnetic field

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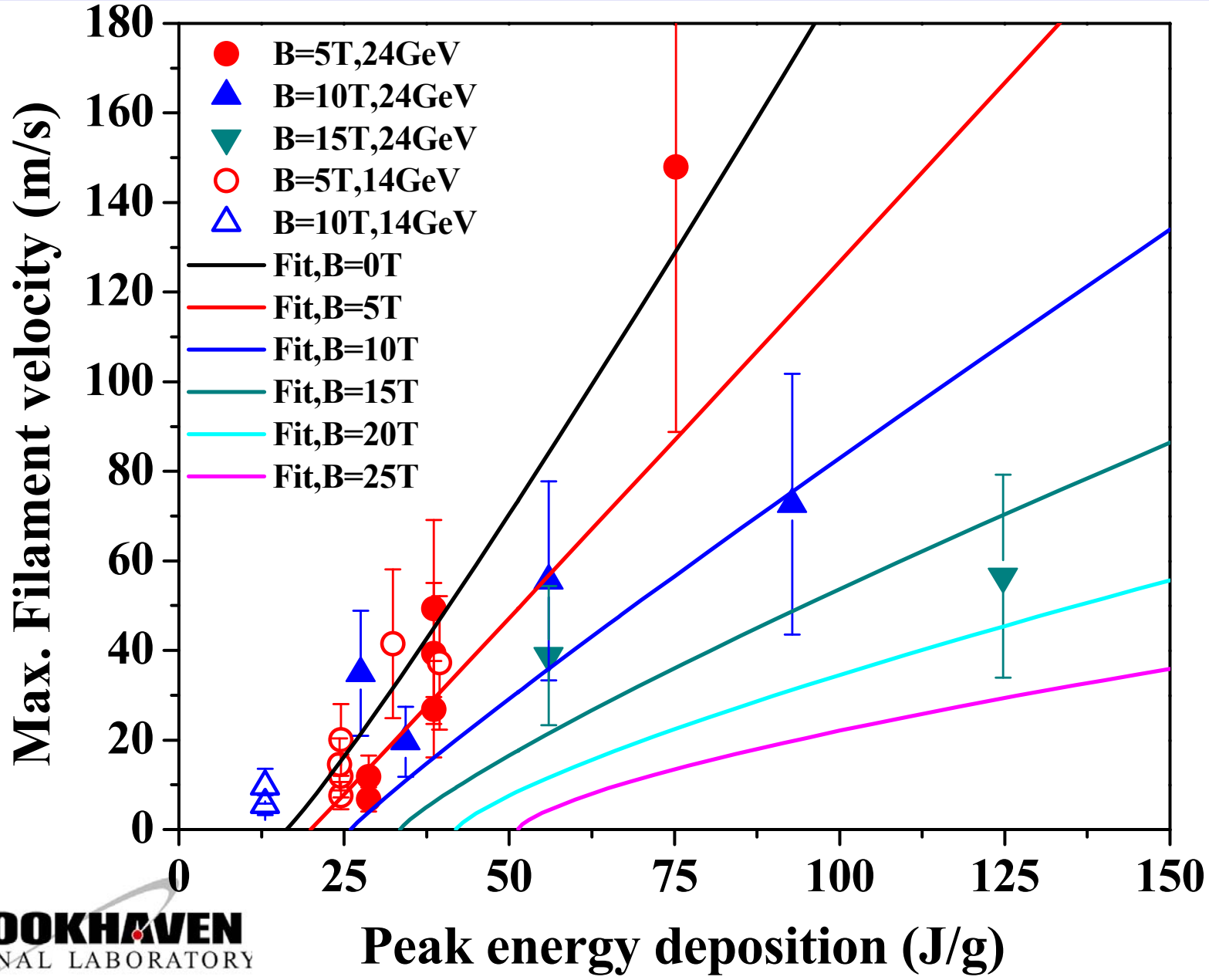
Filament Velocities



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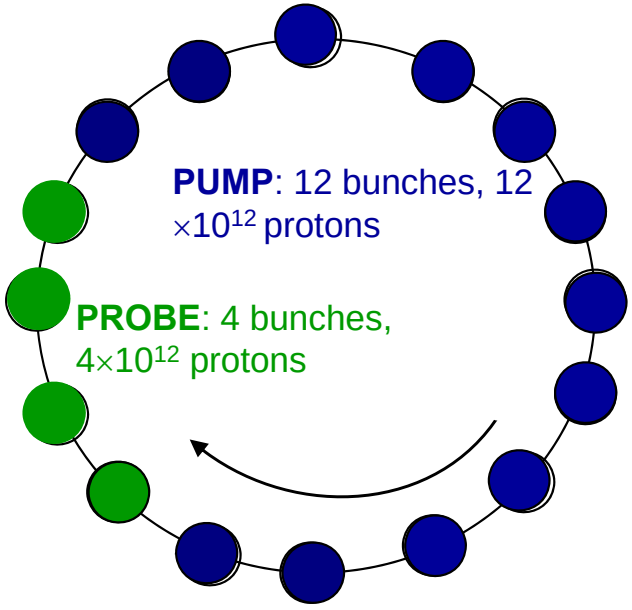
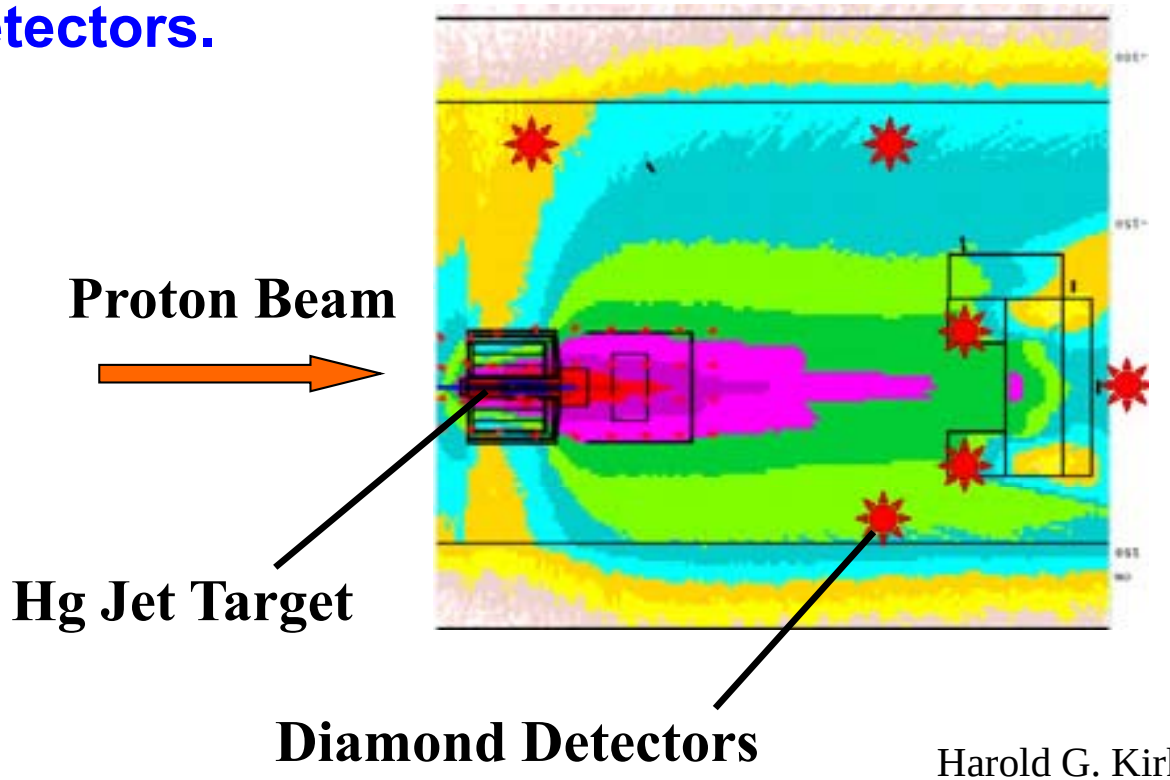
Pump-Probe Studies

Test pion production by trailing bunches after disruption of the mercury jet due to earlier bunches

At 14 GeV, the CERN PS can extract several bunches during one turn (pump), and then the remaining bunches at a later time (probe).

Pion production was monitored for both target-in and target-out events by a set of diamond diode detectors.





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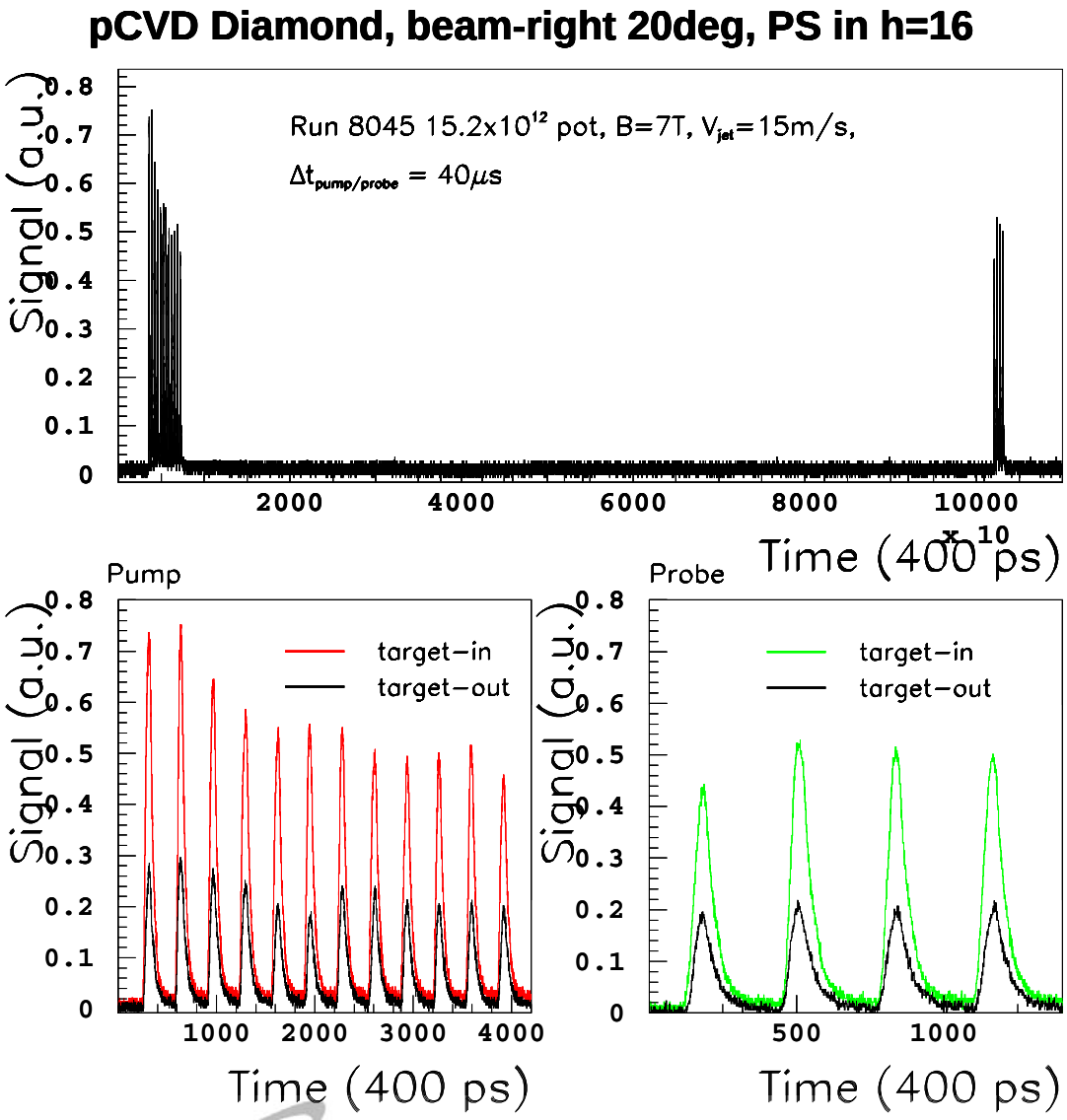
The Diamond Detector Reponses



These detectors showed effects of rapid depletion of the charge stored on the detector electrodes, followed by a slow RC recovery of the charge/voltage.

The beam-current transformer data was used to correct for fluctuations in the number of protons per bunch.

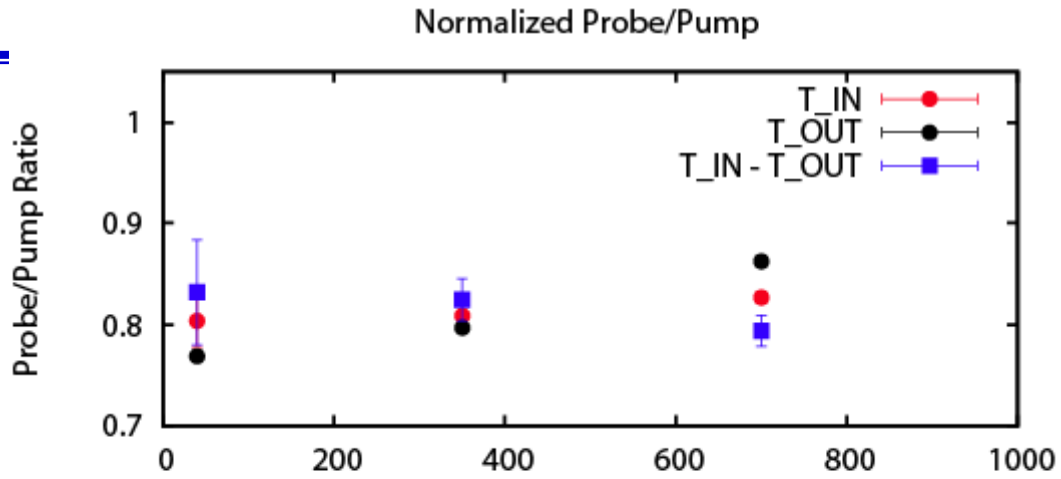
Pump followed by 40μs Probe delay

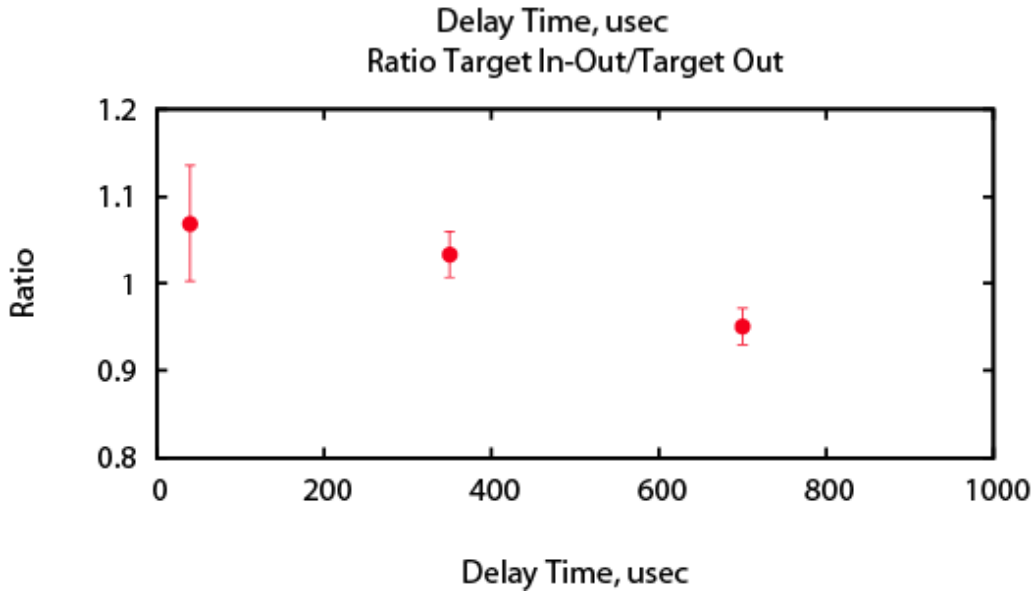
Pump-Probe Data Analysis

Both target-in and target-out data showed smaller signals, relative to the pump bunches, for probe bunches delayed by 40, 350 and 700 μs.

We therefore report a corrected probe/pump ratio:

$$\text{Ratio} = \frac{\text{Probe}_{\text{target in}} - \text{Probe}_{\text{target out}}}{\dfrac{\text{Pump}_{\text{target in}} - \text{Pump}_{\text{target out}}}{\dfrac{\text{Probe}_{\text{target out}}}{\text{Pump}_{\text{target out}}}}}$$





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

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Summary

MERIT experimental results

- **Jet surface instabilities reduced by high-magnetic fields**
- **Proton beam induced Hg jet disruption confined to jet/beam overlap region**
  - **20 m/s operations allows for 70Hz operations**
  - **115kJ pulse containment demonstrated**

    ⟹ **8 MW operations demonstrated**
- **Hg jet disruption mitigated by magnetic field**
- **Hg ejection velocities reduced by magnetic field**
- **Pion production remains viable upto 350μs after previous beam impact**
- **170kHz operations possible for sub-disruption threshold beam intensities**

Post-MERIT

Follow-up: Engineering study of a mercury loop + 20-T capture magnet in the context of the International Design Study for a Neutrino Factory.

- **Splash mitigation in the mercury beam dump.**
- **Possible drain of mercury out upstream end of magnets.**
- **Downstream beam window.**
- **Water-cooled tungsten-carbide shield of superconducting magnets.**
- **HTS fabrication of the superconducting magnets.**
- **Improved nozzle for delivery of Hg jet**