Results of Optical Diagnostics of the MERIT Experiment

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Talk Outline

- Introduction

- Experimental Method
  - Development of optical diagnostics
  - Optics configuration with respect to beam, magnet, and Hg jet
  - Viewports for optical diagnostics
  - Image processing for data analysis

- Experimental Results
  - Hg jet behavior in magnetic field: Jet height, Surface stabilization, Jet trajectory
  - Hg jet interaction with proton beam :
    Jet disruption length with beam intensity and energy,
    B field effect to jet disruption
  - Response of filamentation on jet surface in B field
    B field effect to Hg jet break up, Filament velocity with beam intensity and energy, Time delay of onset of filamentation and Transient response

- Conclusions

Introduction

- The Mercury Intense Target experiment is a proof-of-principle demonstration of a free mercury jet target, contained in a 15T solenoid for maximal collection of secondary pions.

  - Liquid type of High-Z material for higher particle production
  - Avoid the destruction of target due to the beam induced thermal stress
  - Can be recycled

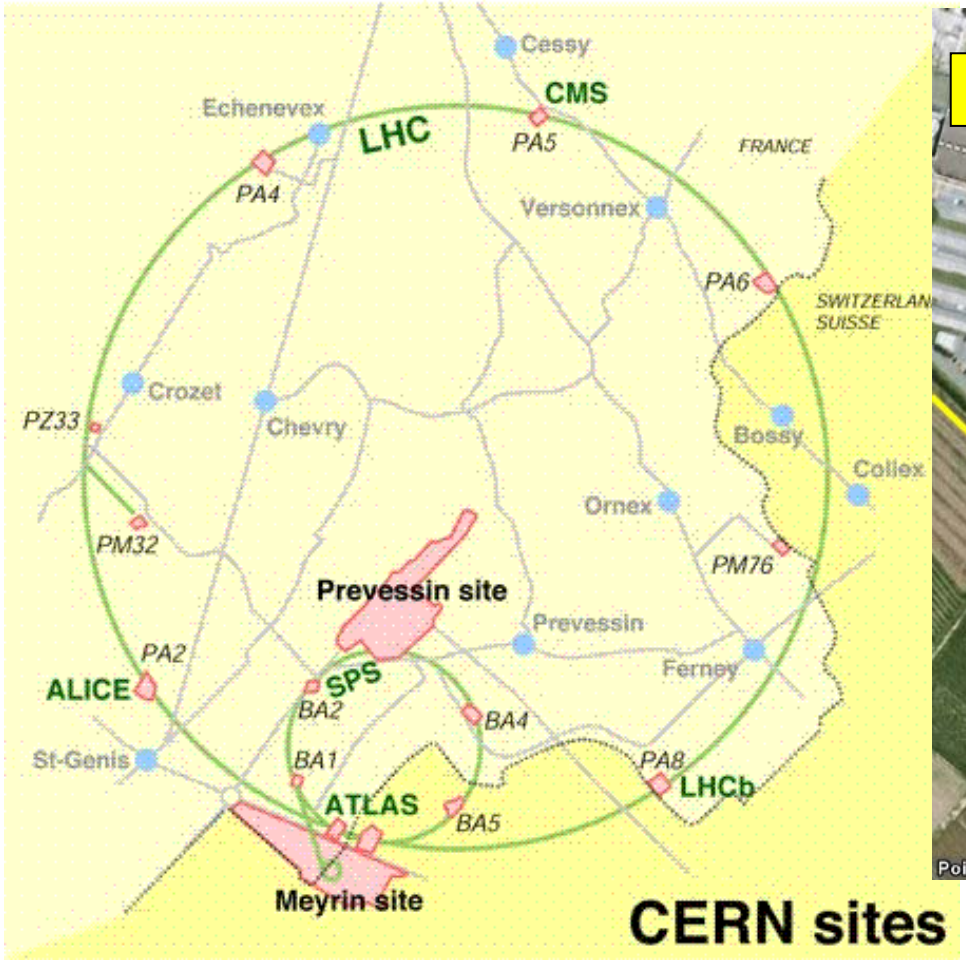
- Issues are Hg jet disruption due to the energy deposition of proton beam and Hg jet distortion in strong magnetic field.

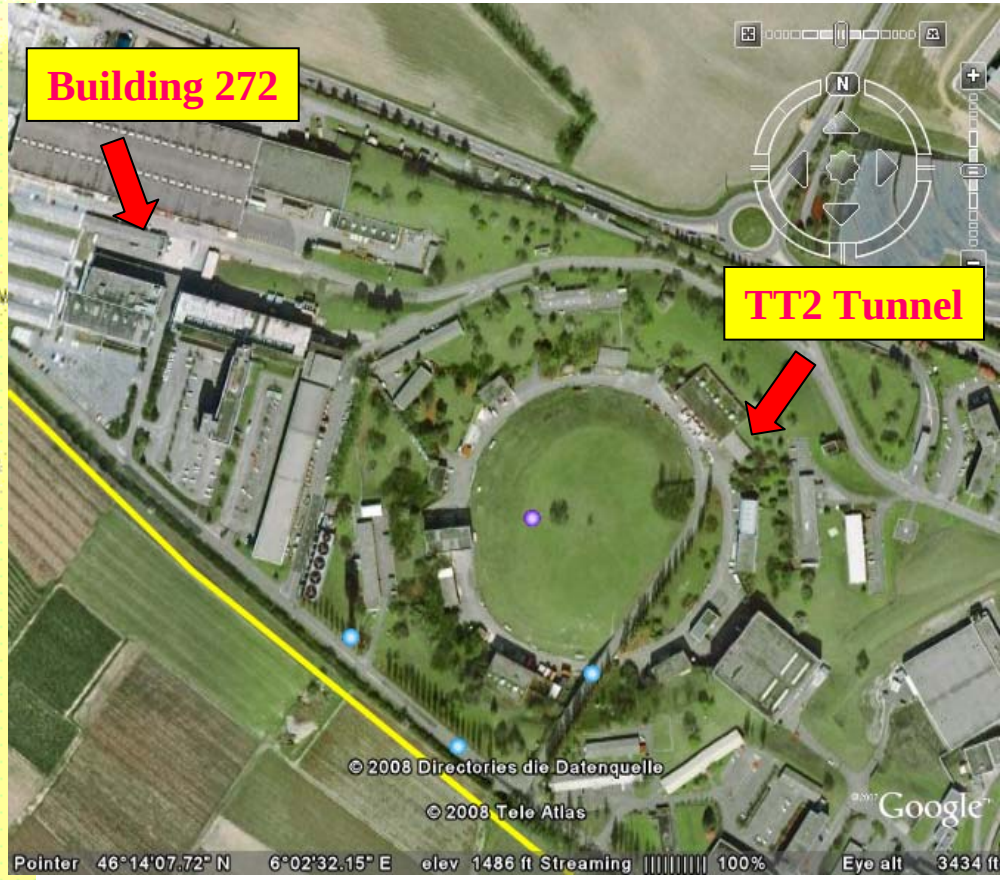
- The Hg jet behavior in magnetic field and the Hg jet interaction with proton beam needs to be investigated experimentally.

- The experimental results provide the Hg jet characteristics in magnetic field with high energy of beam and it will be refered to the simulation code development.

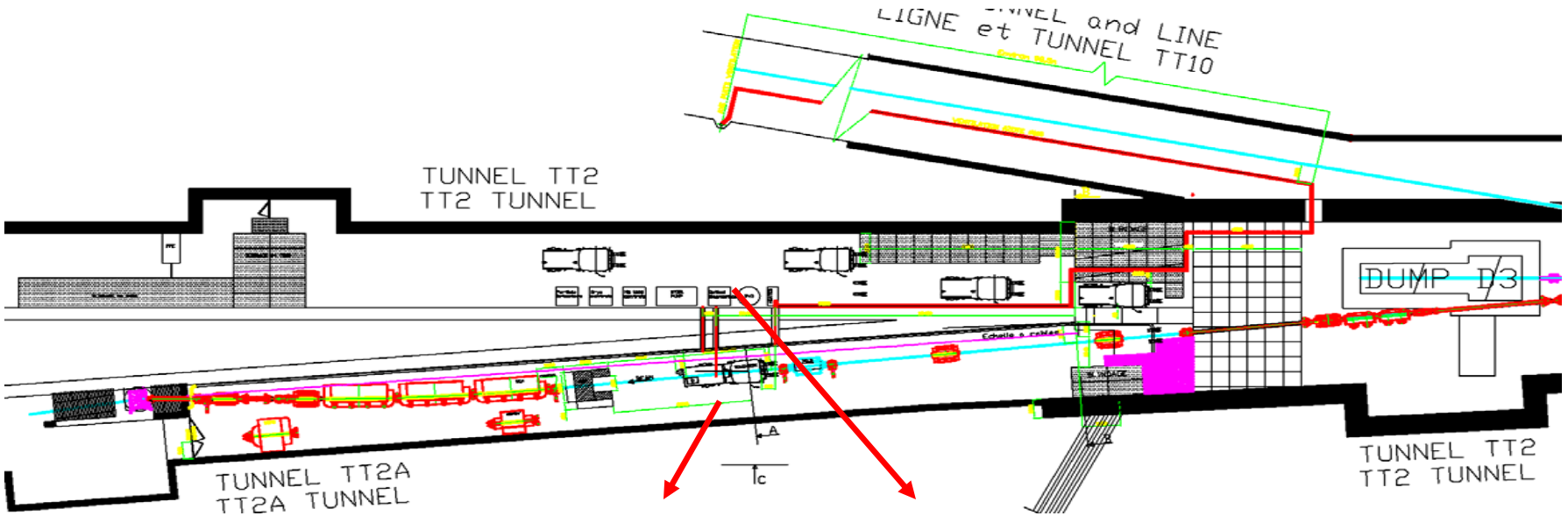
Mercury Intense Target Experiment : October 22, 2007 ~ November 11, 2007

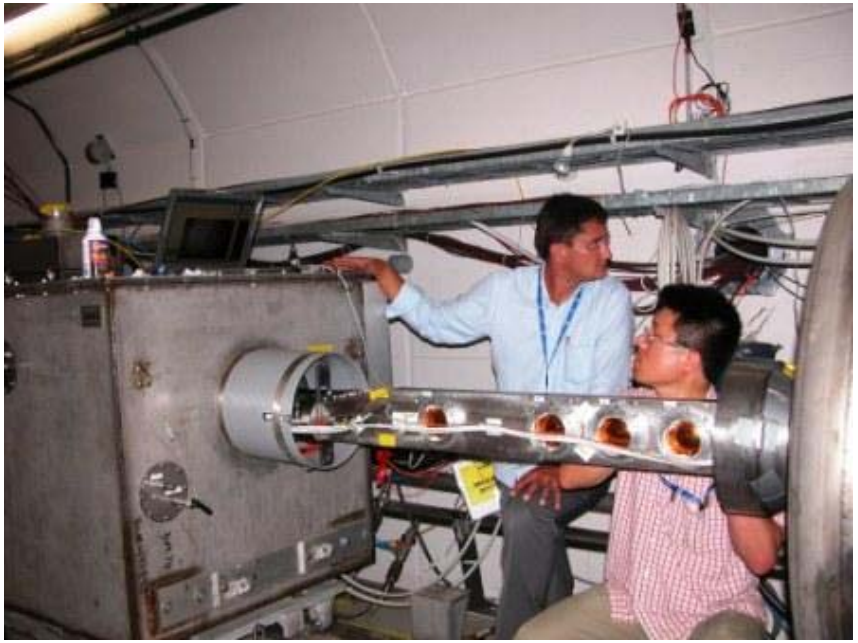
Total 360 of beam shots performed and Images for 227 beam shots collected.
MERIT beam shot summary website,
http://www.hep.princeton.edu/~mcdonald/mumu/target/hkirk/MERIT_Beam_Program_110607.pdf



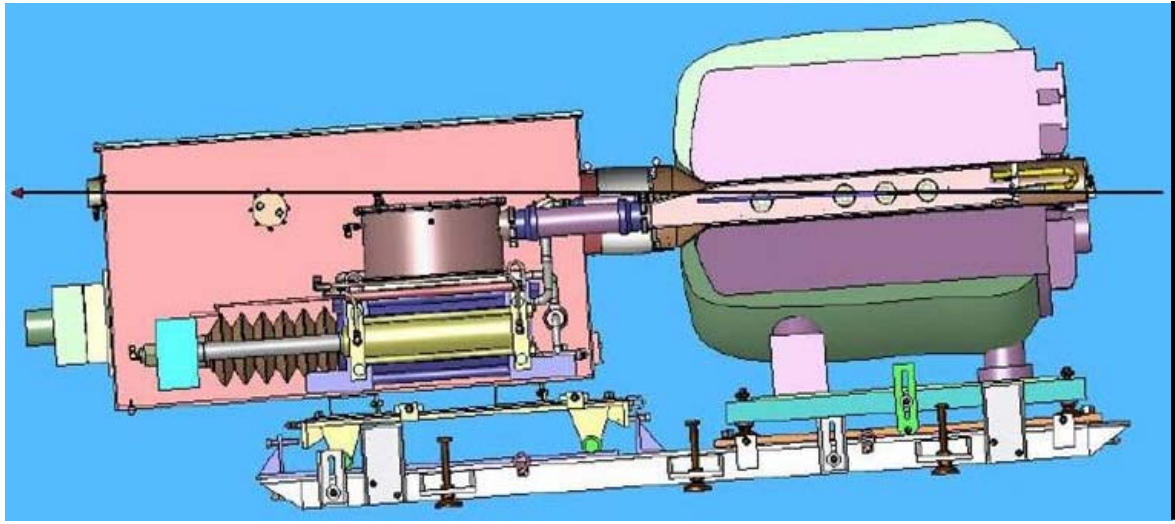


Installation of Optical Diagnostics at CERN Tunnel TT2/TT2A



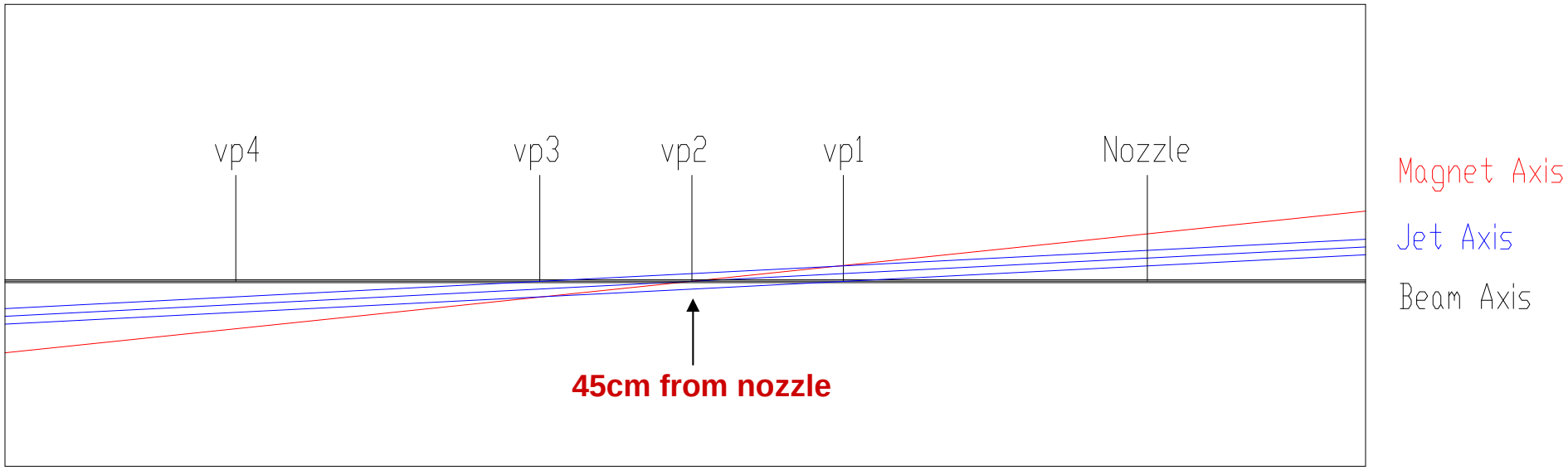


Key Components For An Intense Proton Target Experiment : Proton Beam, 15T Solenoid Magnet, Hg Jet, and Optical Diagnostics

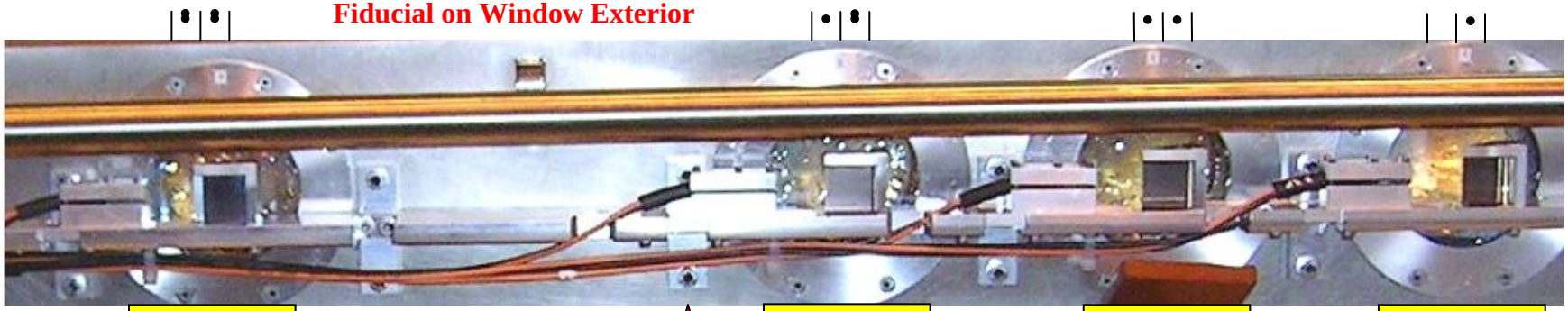


Schematics of configurations of key components:

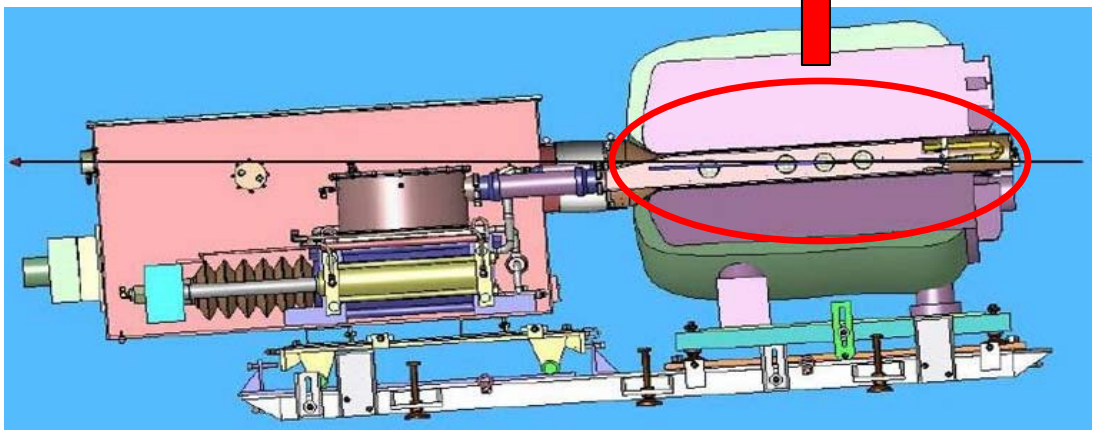
- **Solenoid 67mrad, Jet 34mrad w.r.t Beam**
- **Beam enters at viewport 1 and leaves at viewport 3**
- **Interaction length is 30cm**
- **Viewport 1 =30cm, Viewport 2=45cm, Viewport 3=60, Viewport 4 =90cm apart from nozzle.**
- **Solenoid length = 100cm**
- **Viewport 2 is at center of magnet**

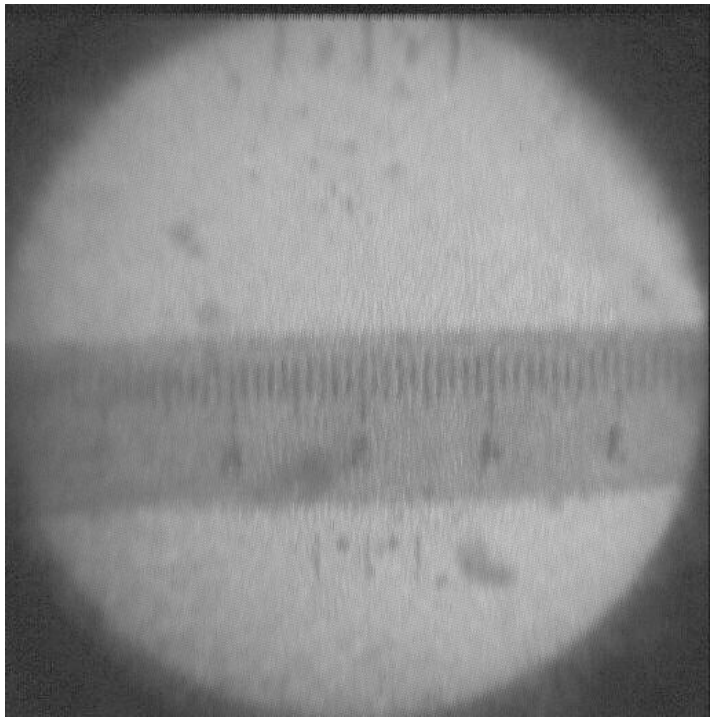


Four Viewports for Optical Diagnostics



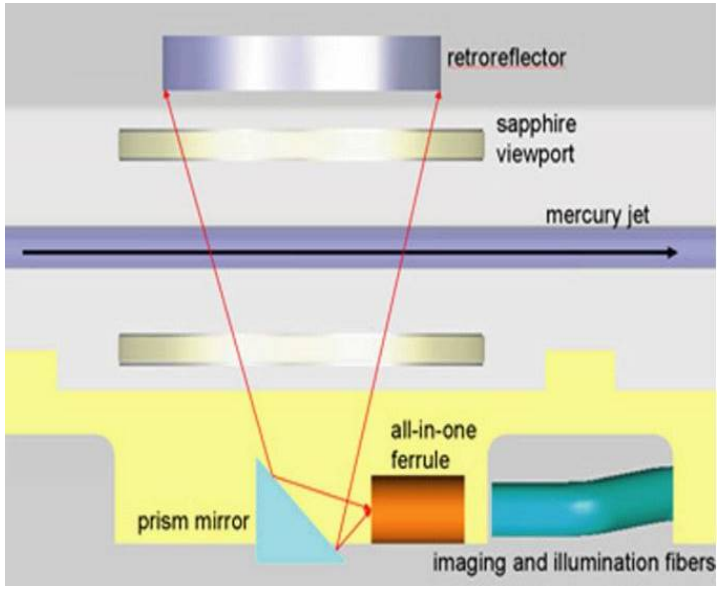
1cm x 0.5cm Fiducials on Front Top and Rear Bottom Window, 0.75'' Apart from Fiducial Center to Center of Window, FOV = 5cm at Midspan





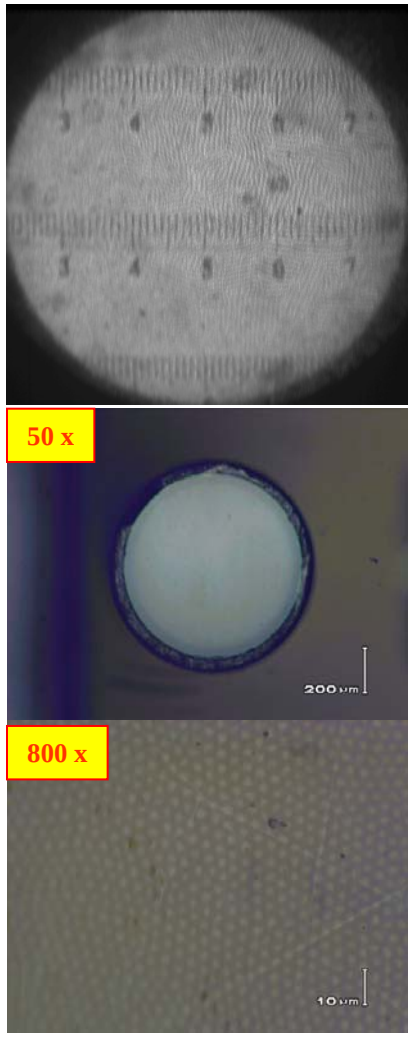
Optics Design and Components

Working Principle : Shadowgraph Method

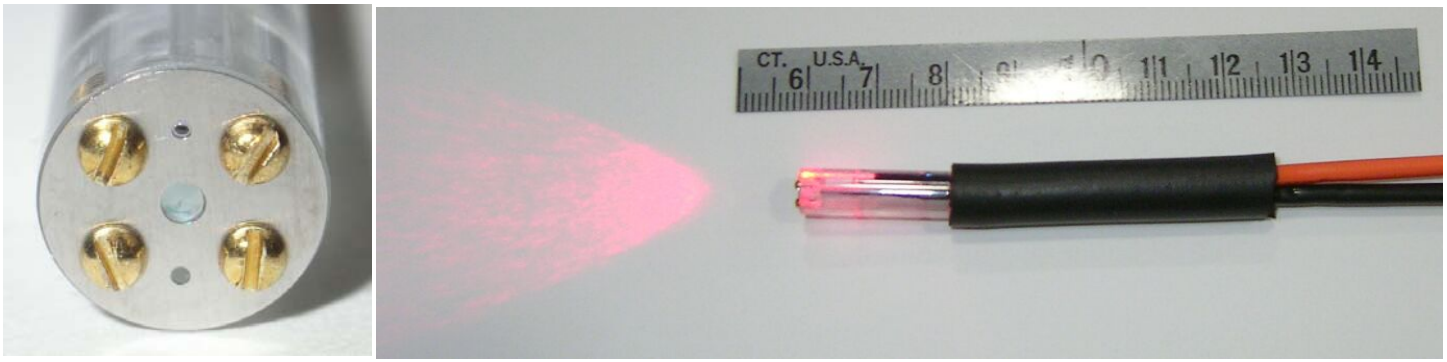


Fiber Patch : Illumination Fiber, 10m, R=4cm Imaging Fiber, SMA

Pixelation From Imaging Fiber To Camera CCD



One Module For Illumination And Imaging : Grin objective lens, Ball lens, Fibers



High Speed Cameras

Viewport 2

SMD 64KIM camera
CCD size: 13.4 x 13.4 mm
Pixels: 960x960
Single frame: 240x240 pixels
57,600 picture elements
Frame rate: 16 frames up to 1 μs/frame
Full well capacity: 220,000 e^-
ADC: 12-bit
Quantum Efficiency: 18%

Used

0.025 ~ 0.25 ms frame rate
0.15 μs exposure
800nm pulsed laser

Viewport 1 &3

FastVision (1,2)
CCD size: 15.4 x 12.3 mm
Pixels: 1280x1024
Single frame: FPGA programable
1.3 M picture elements
Frame rate: 500/s @ full resolution
500k/s @ 1x1280
Responsivity: ~1000 LSB/lux-sec
ADC: 10-bit
Quantum Efficiency: 10%

Used

0.5 ~ 2 ms frame rate
10~15 μs exposure
800nm CW laser

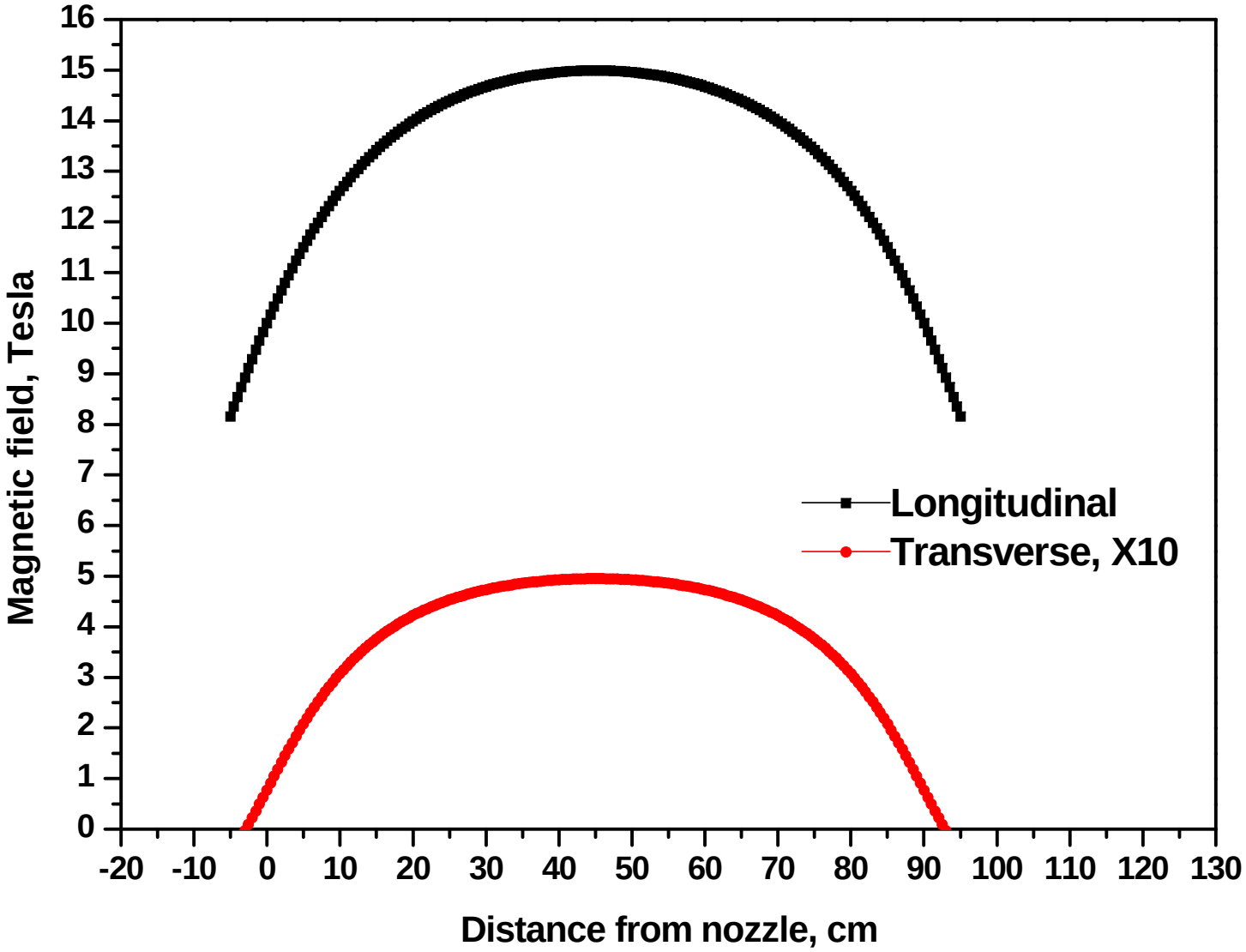
Viewport 1 &3

CERN Olympus Encore PCI 8000S
CCD size: 1/3 inch
Pixels: 650x500
4 kHz recording rate
25 us electronic shutter

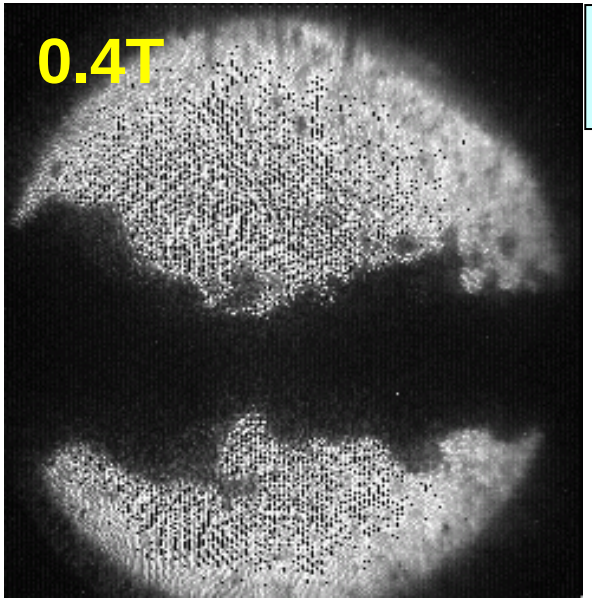
Used

0.5 ~ 2 ms frame rate
60 ~ 100 μs exposure
800nm CW laser

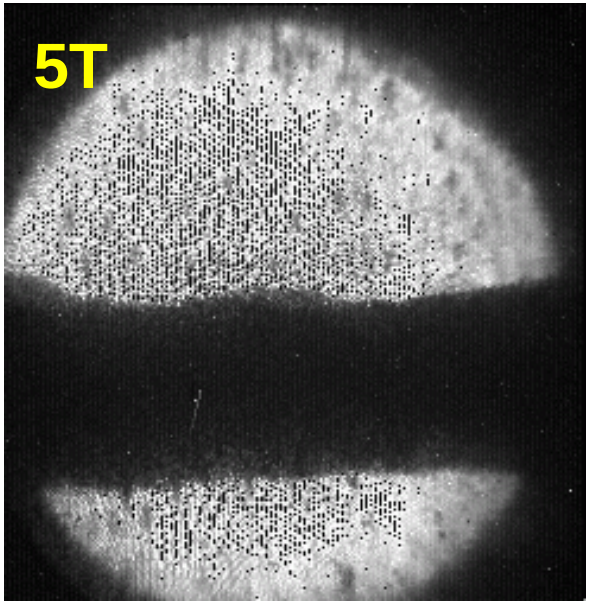
Magnetic Field Map

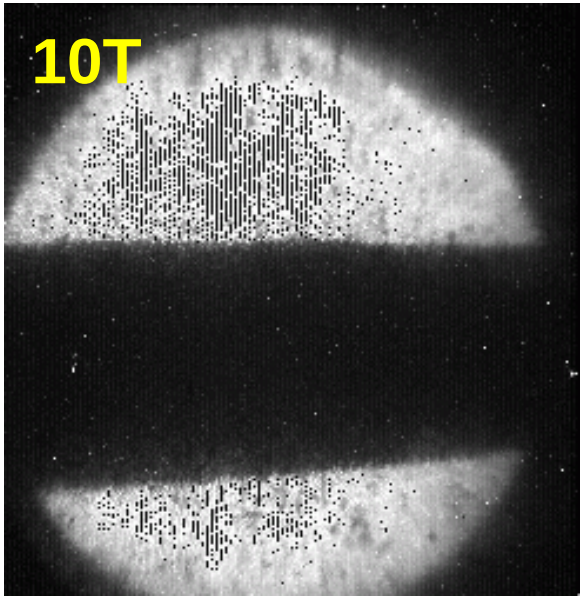


Stabilization of Jet Surface by Magnetic Field



Viewport 2,
V=15m/s





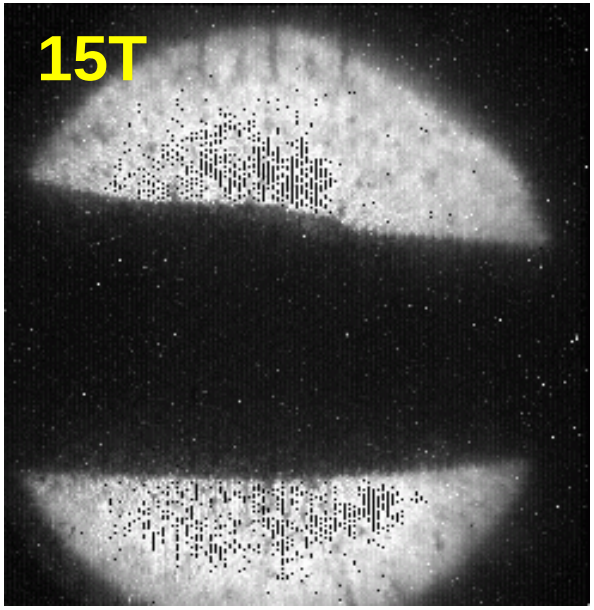
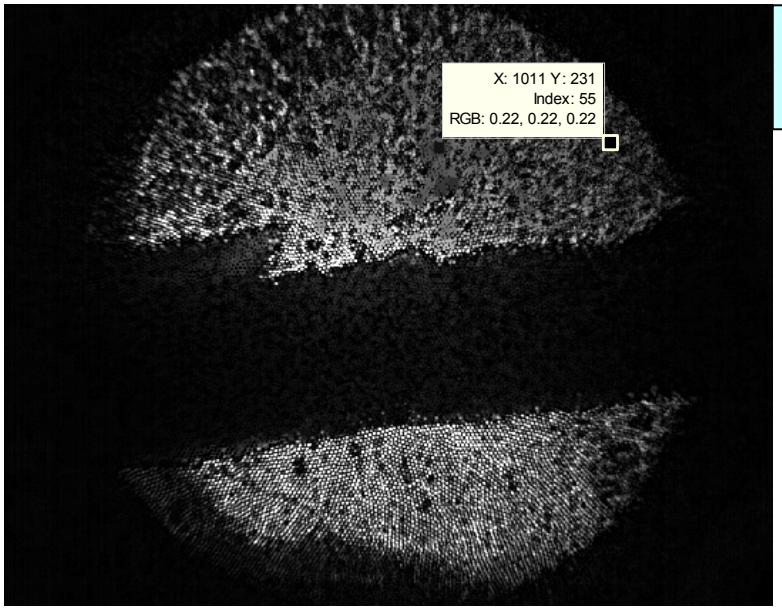
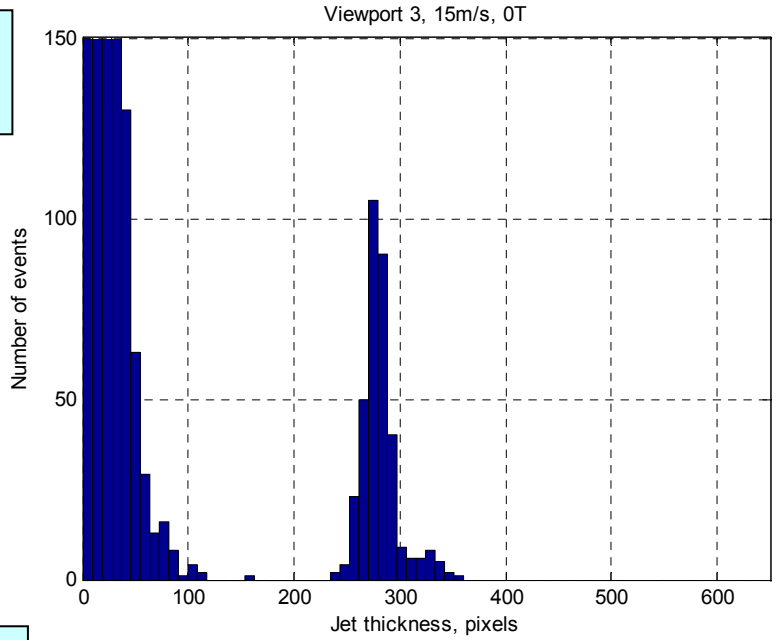
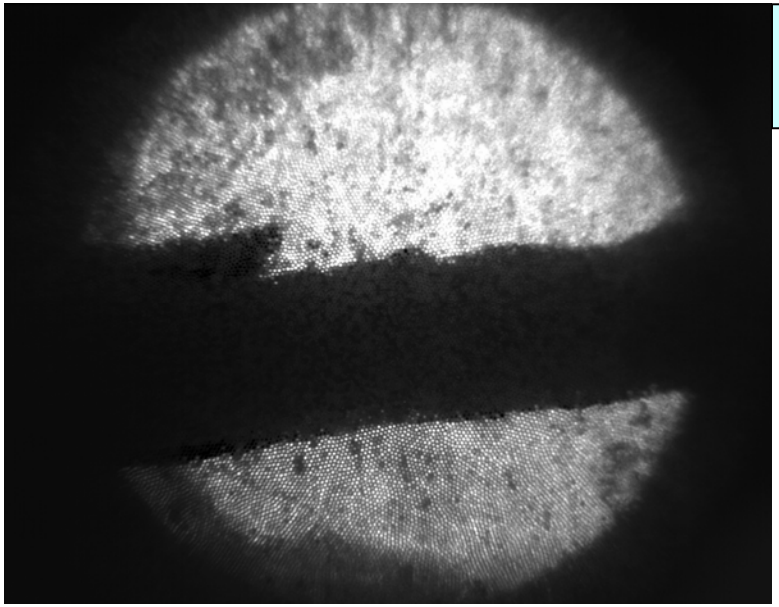


Image Processing Method For Data Analysis

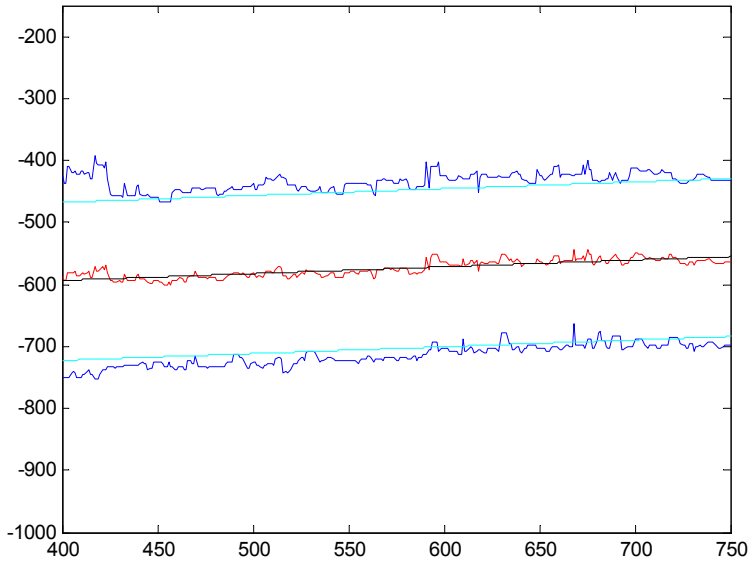


Binary, 1 bit

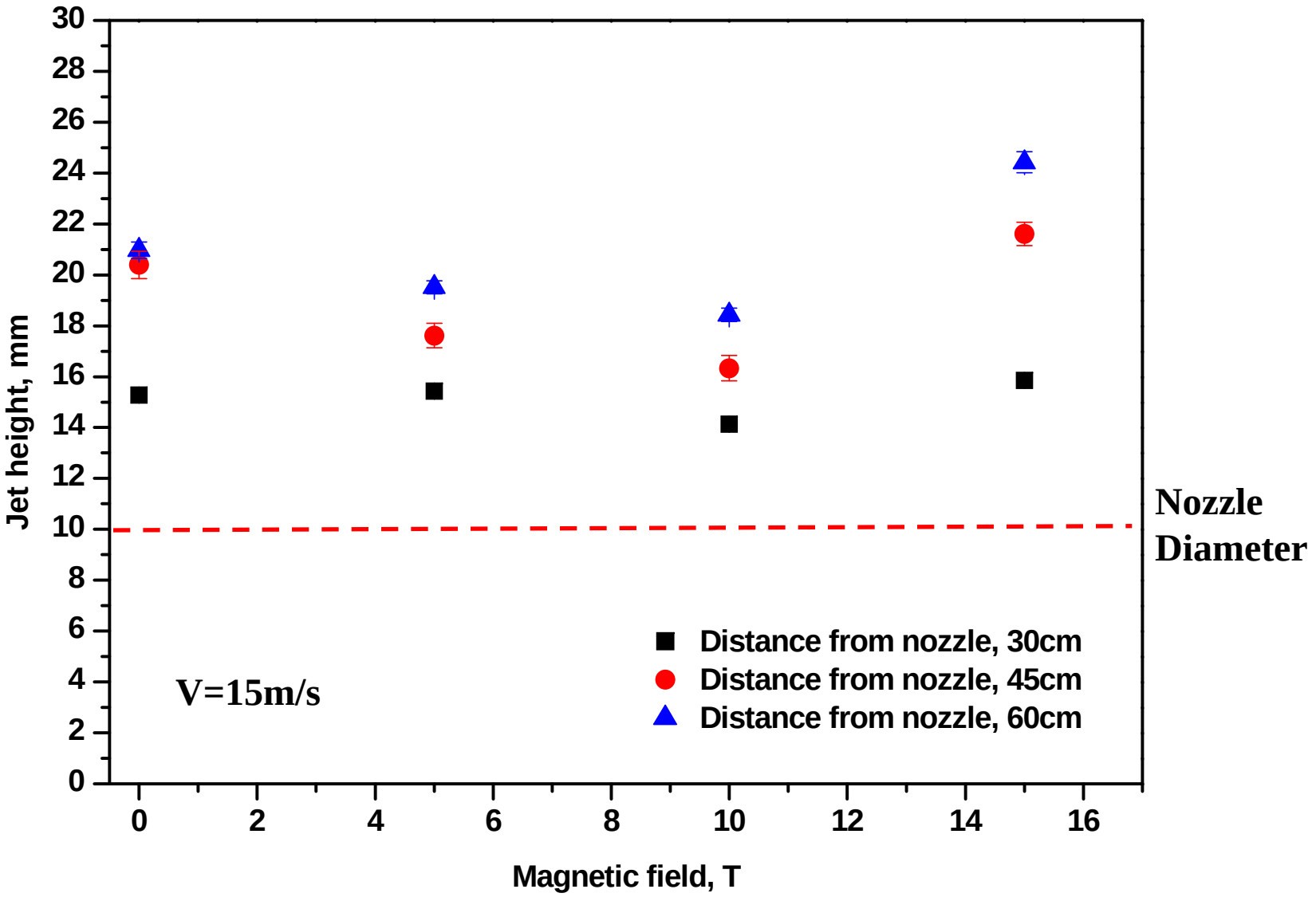




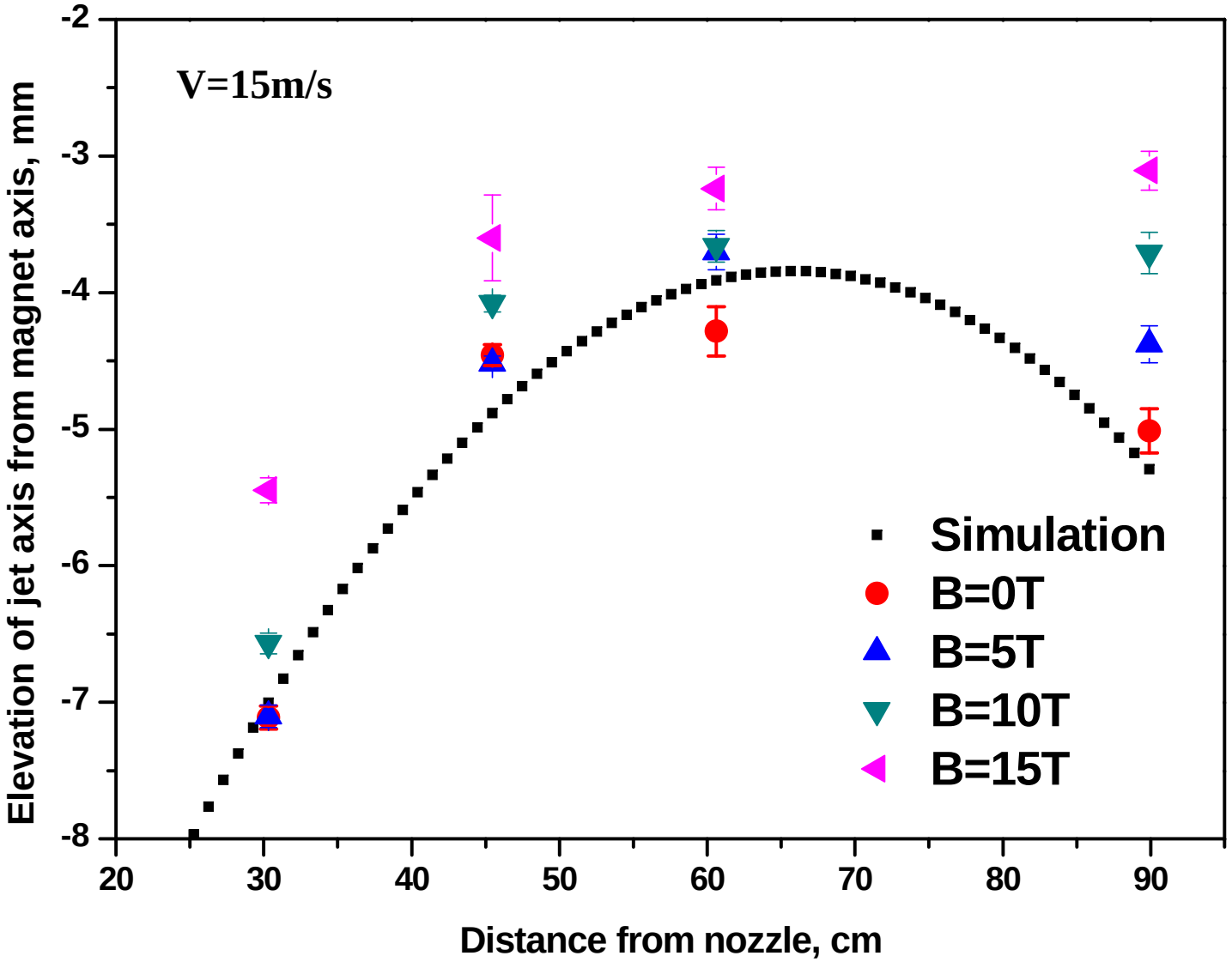
Original, 8 bit



Hg Jet Height vs. Magnetic Field and Distance from Nozzle

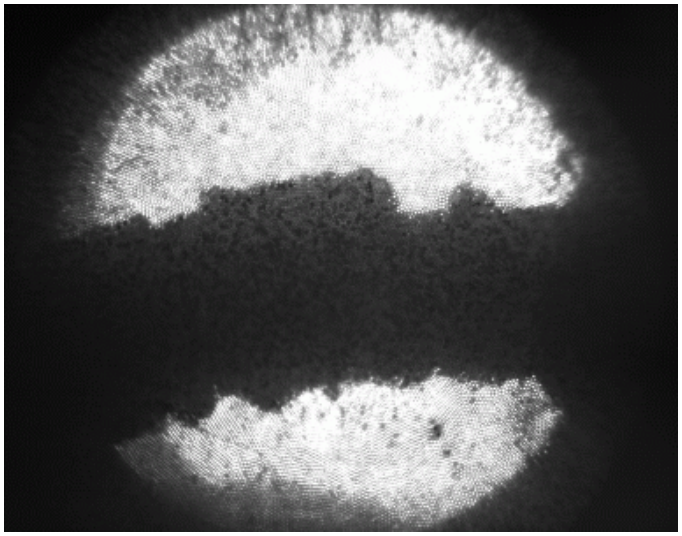
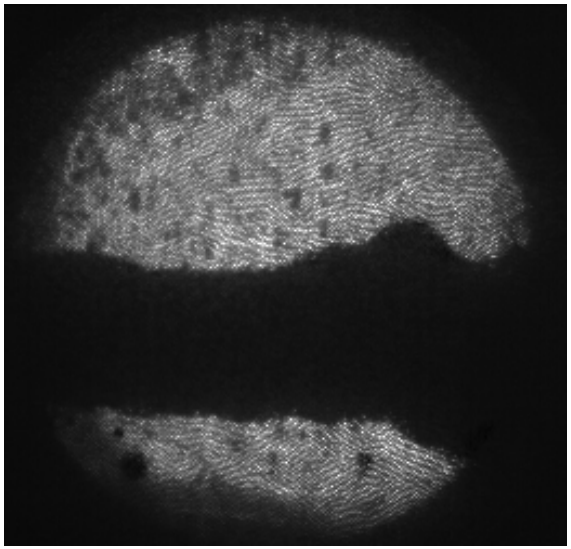
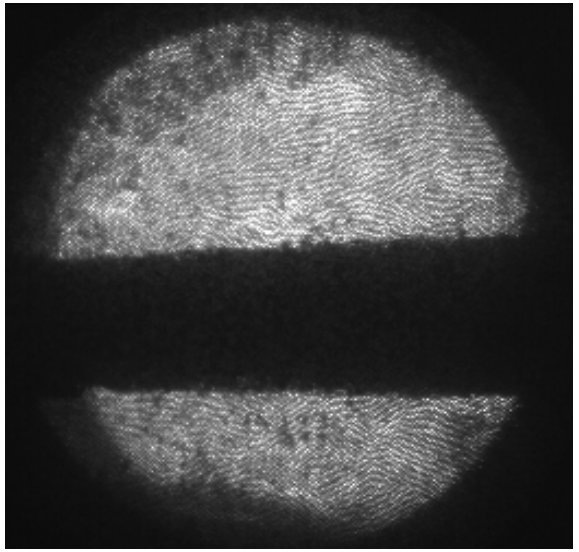


Influence of Magnetic Field and Gravity to Jet Trajectory

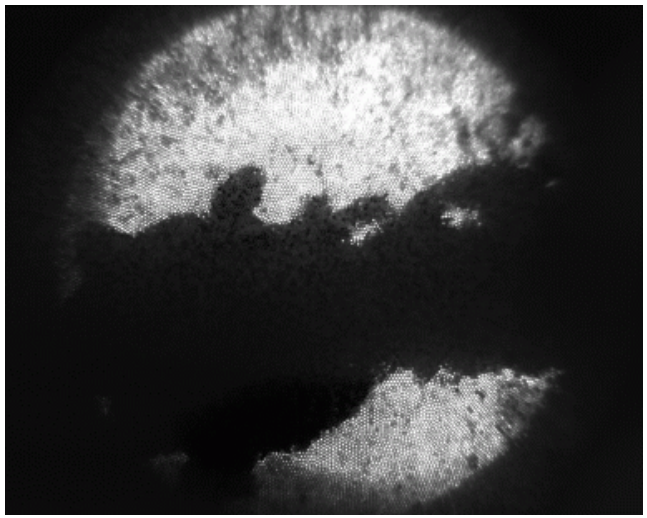
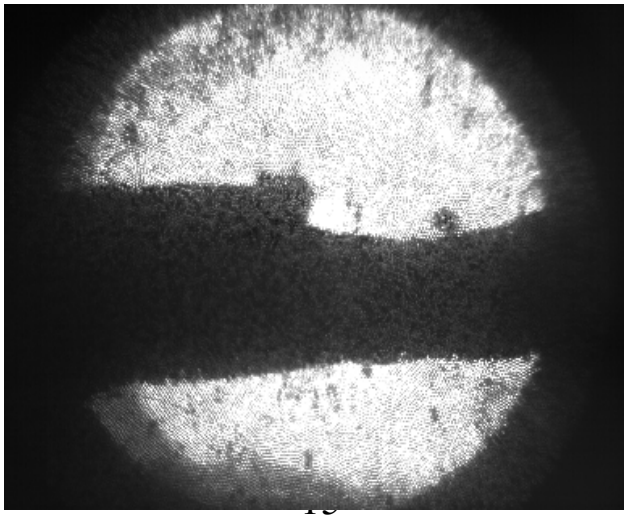
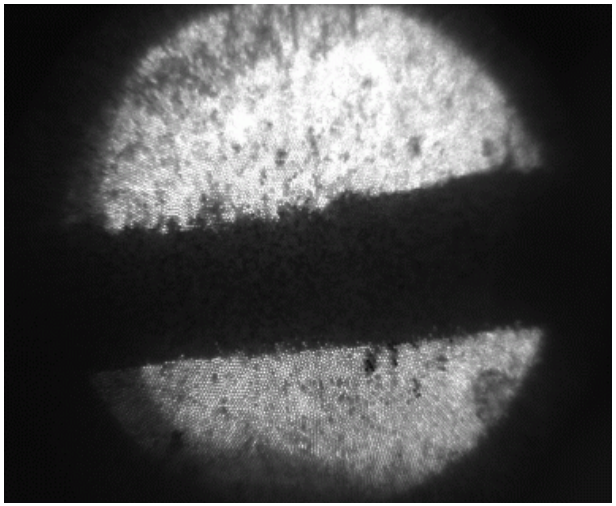


Interaction of Hg Jet With 14 GeV Beam

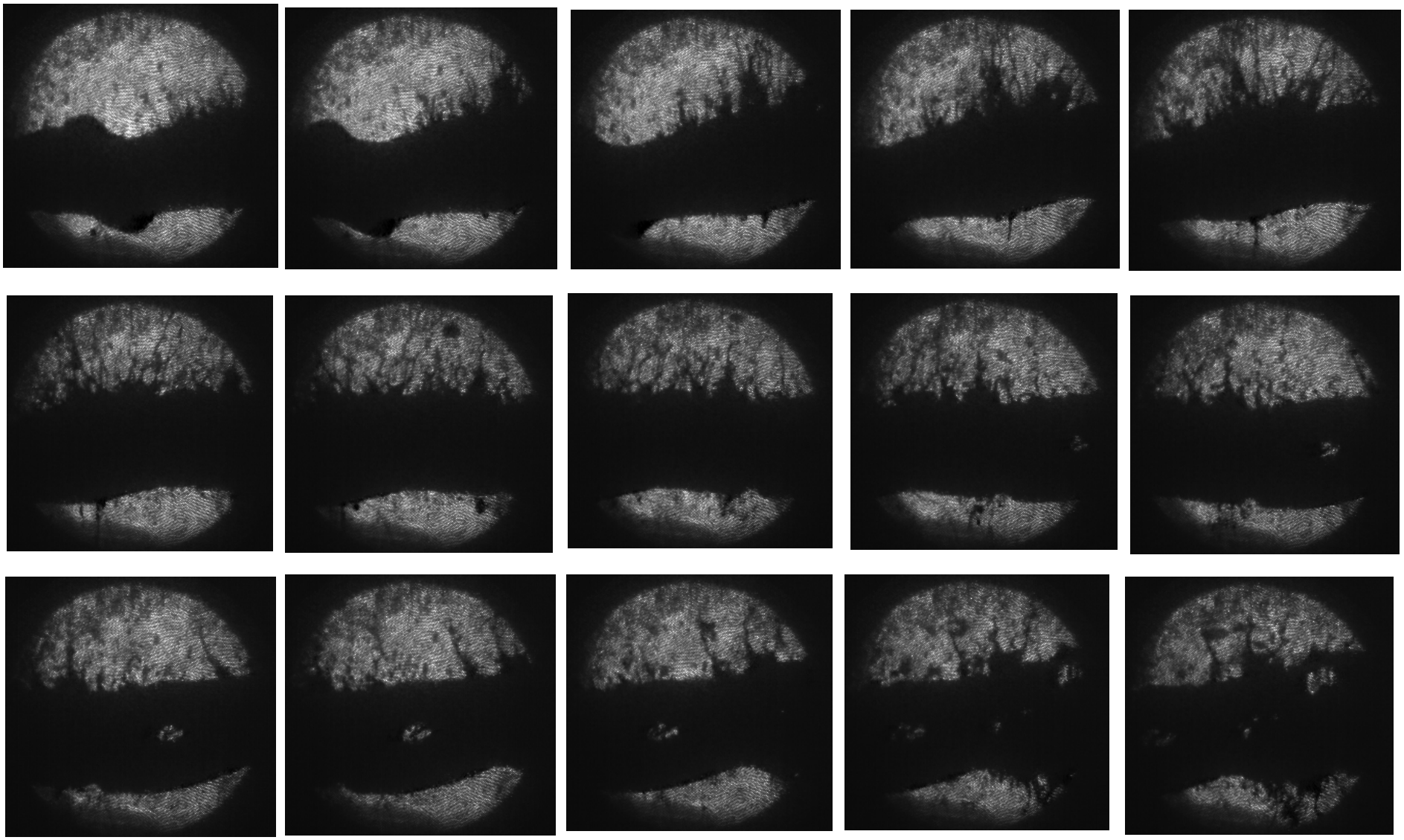
$B = 0\ Tesla, 8\times10^{12}\ protons$ $B = 5\ Tesla, 16\times10^{12}\ protons$ $B = 10\ Tesla, 12\times10^{12}\ protons$

$B = 0\ Tesla, 4\times10^{12}\ protons$ $B = 5\ Tesla, 16\times10^{12}\ protons$ $B = 10\ Tesla, 20\times10^{12}\ protons$

Images Showing Typical Beam/Hg Jet Interaction, B=5T, Protons=16TP, E=14GeV, 2000 FPS, Viewport3



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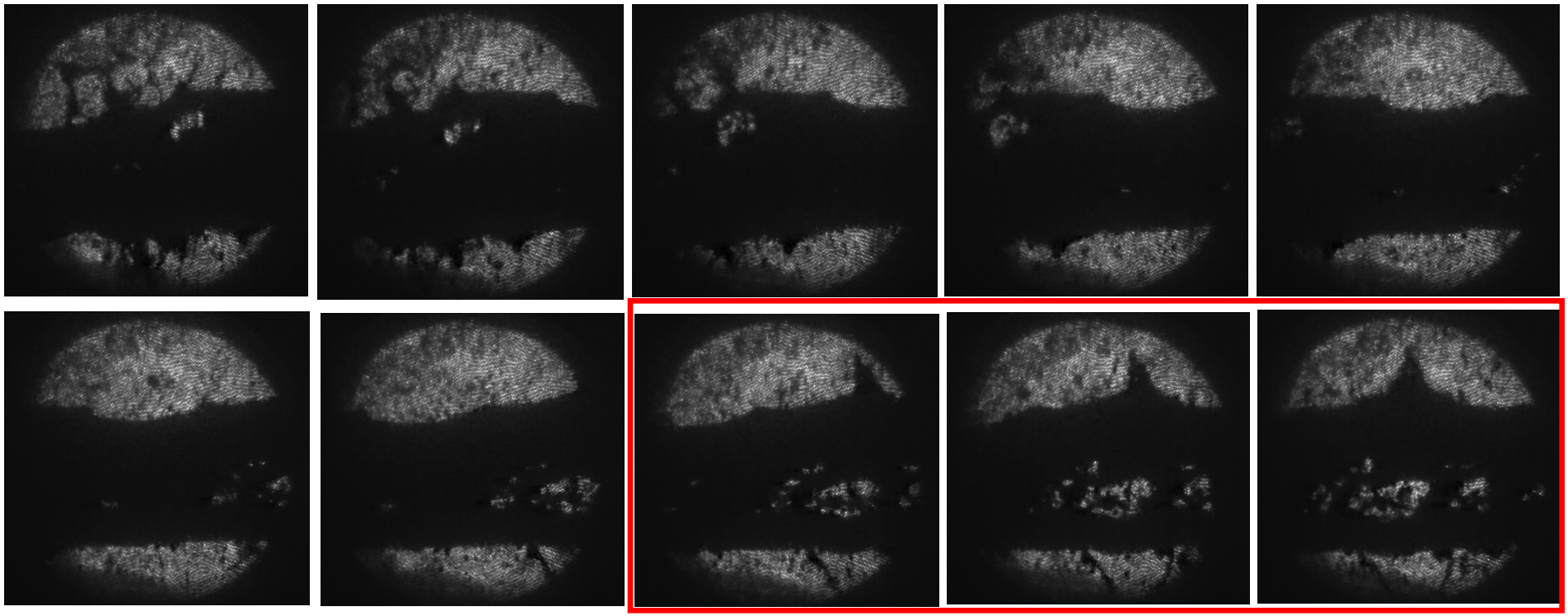
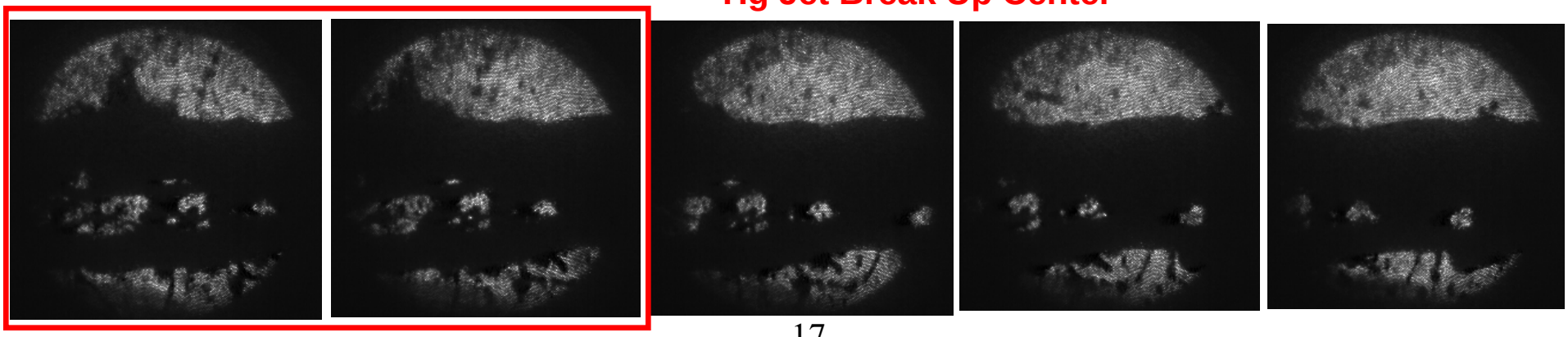
Filament Ends at Top Surface Where Beam Leaves and Filament Begins at Bottom Surface Where Beam Enters



Hg Jet Break Up Center



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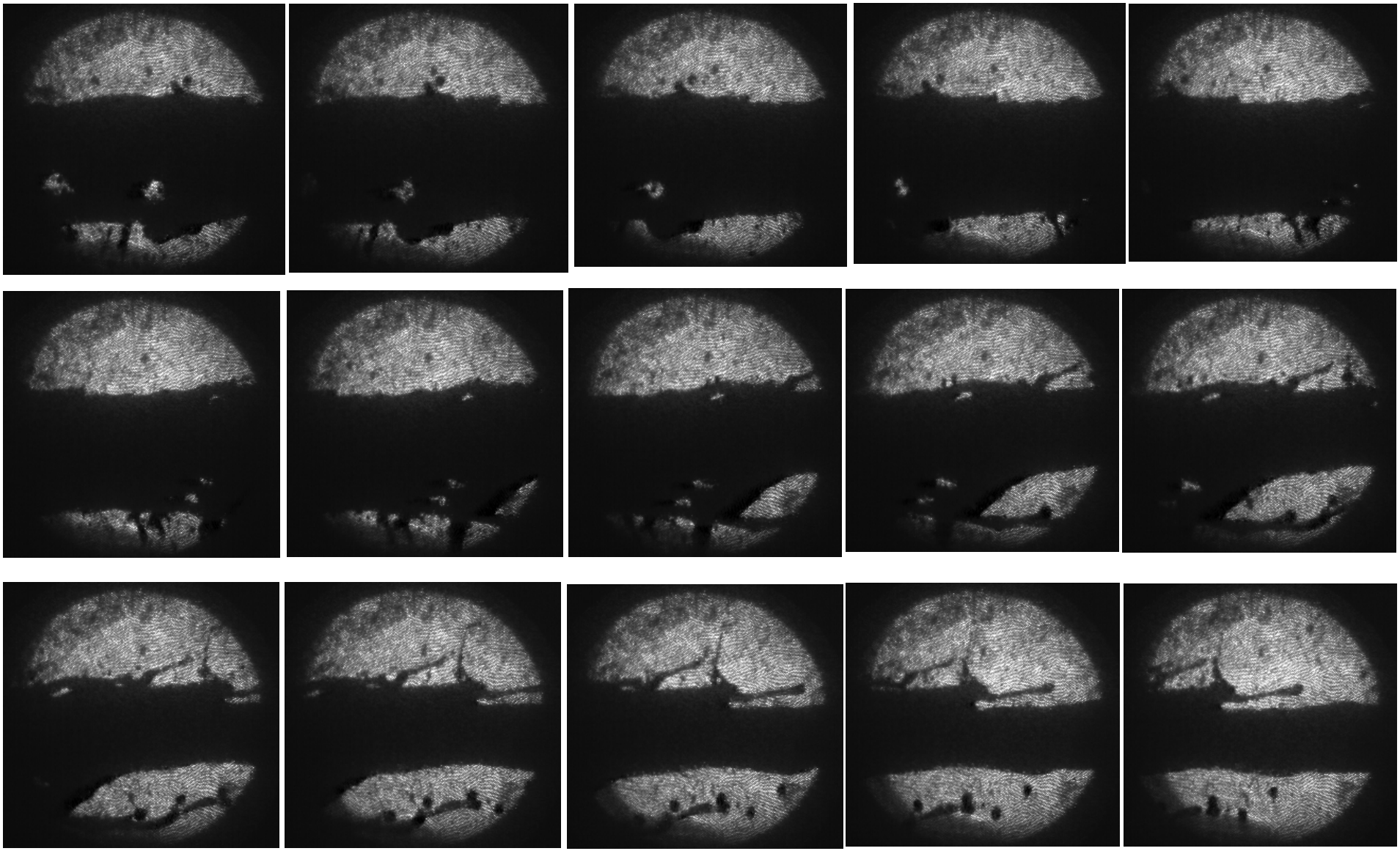
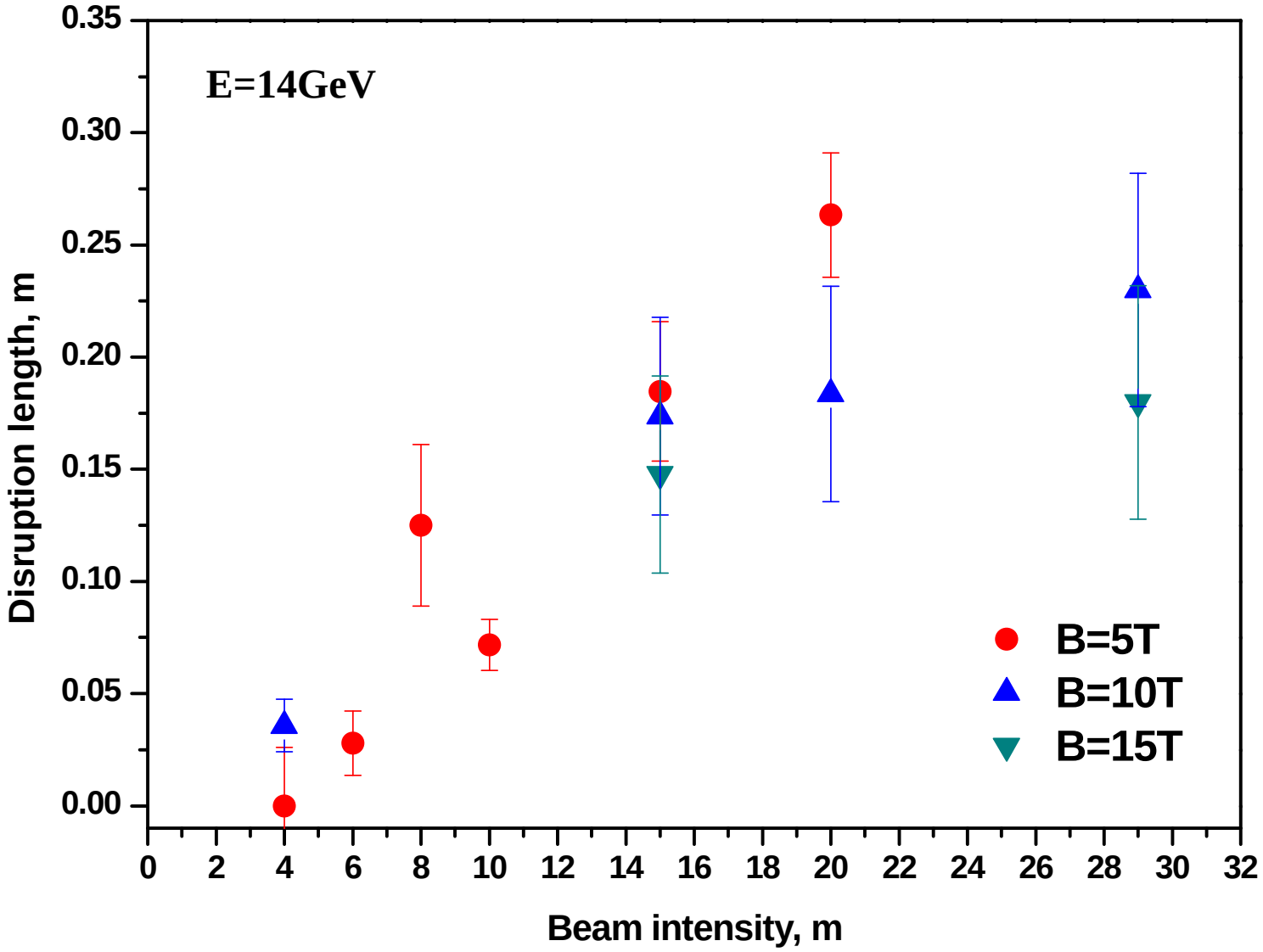
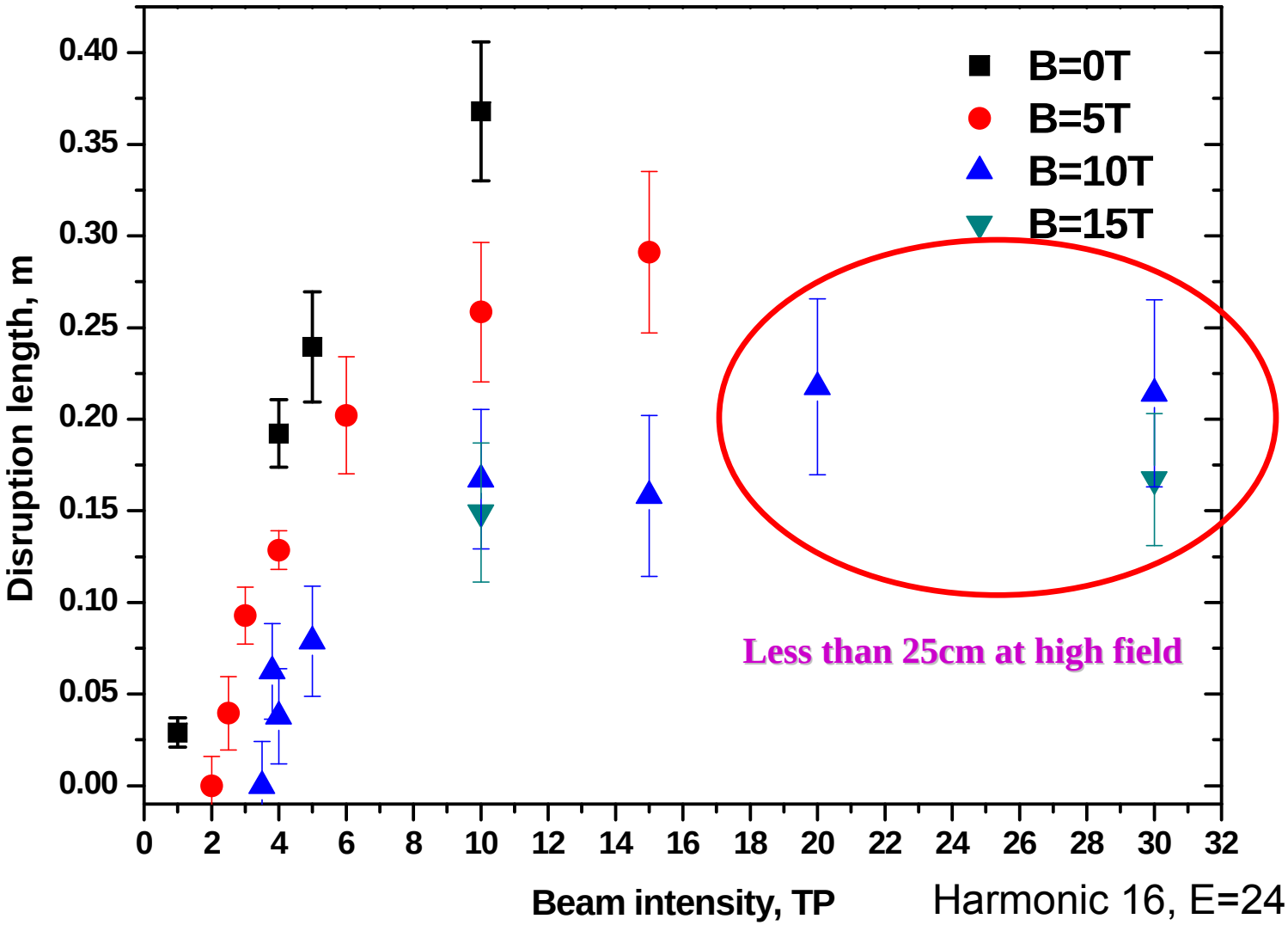
Jet Breakup at Center of Jet Where Maximum Energy Deposition Occurs



Disruption Length Increases with Beam Intensity

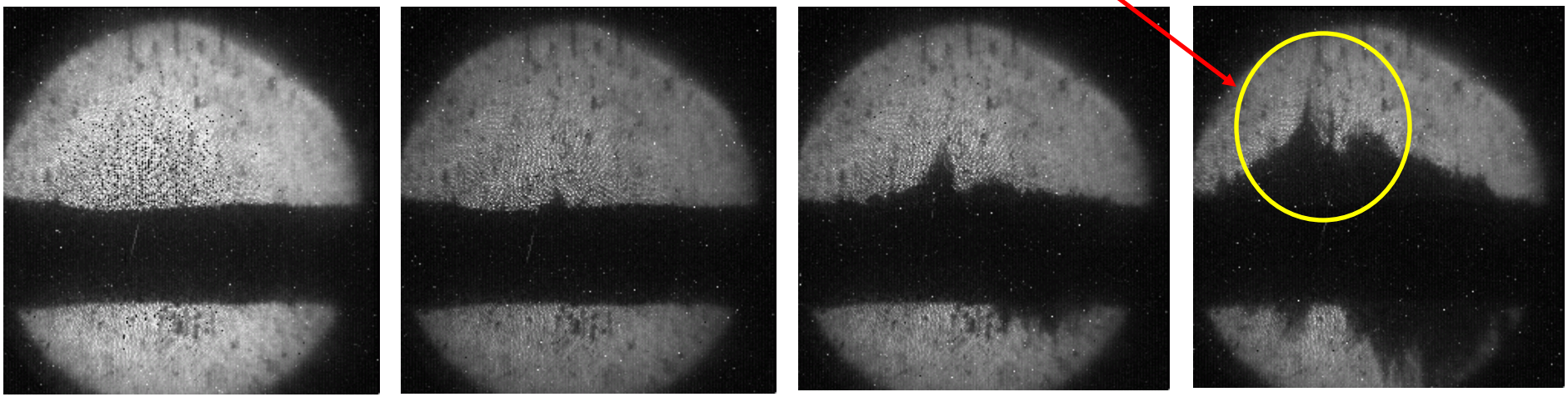


Threshold beam intensity for disruption increases with magnetic field



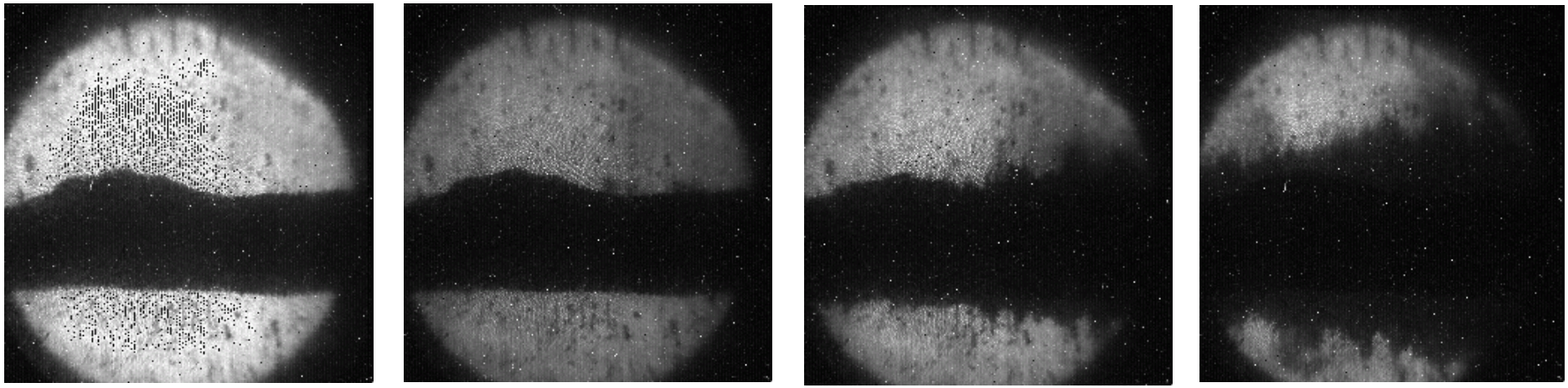
Filamentation Velocity Measurement

10TP, 10T **V = 51 m/s**



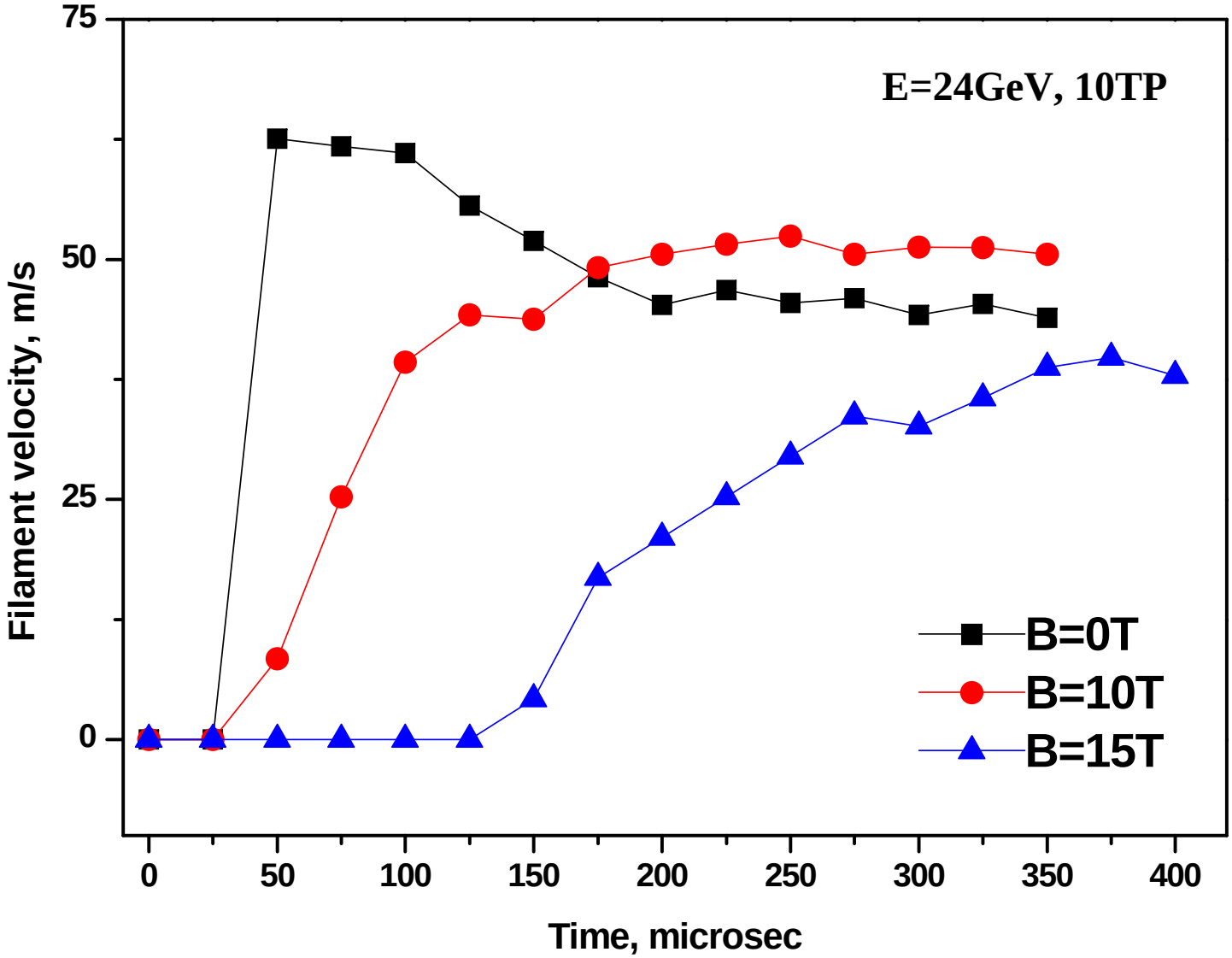
t=0 t=0.075 ms t=0.175 ms t=0.375 ms

20TP, 10T **V = 95 m/s**

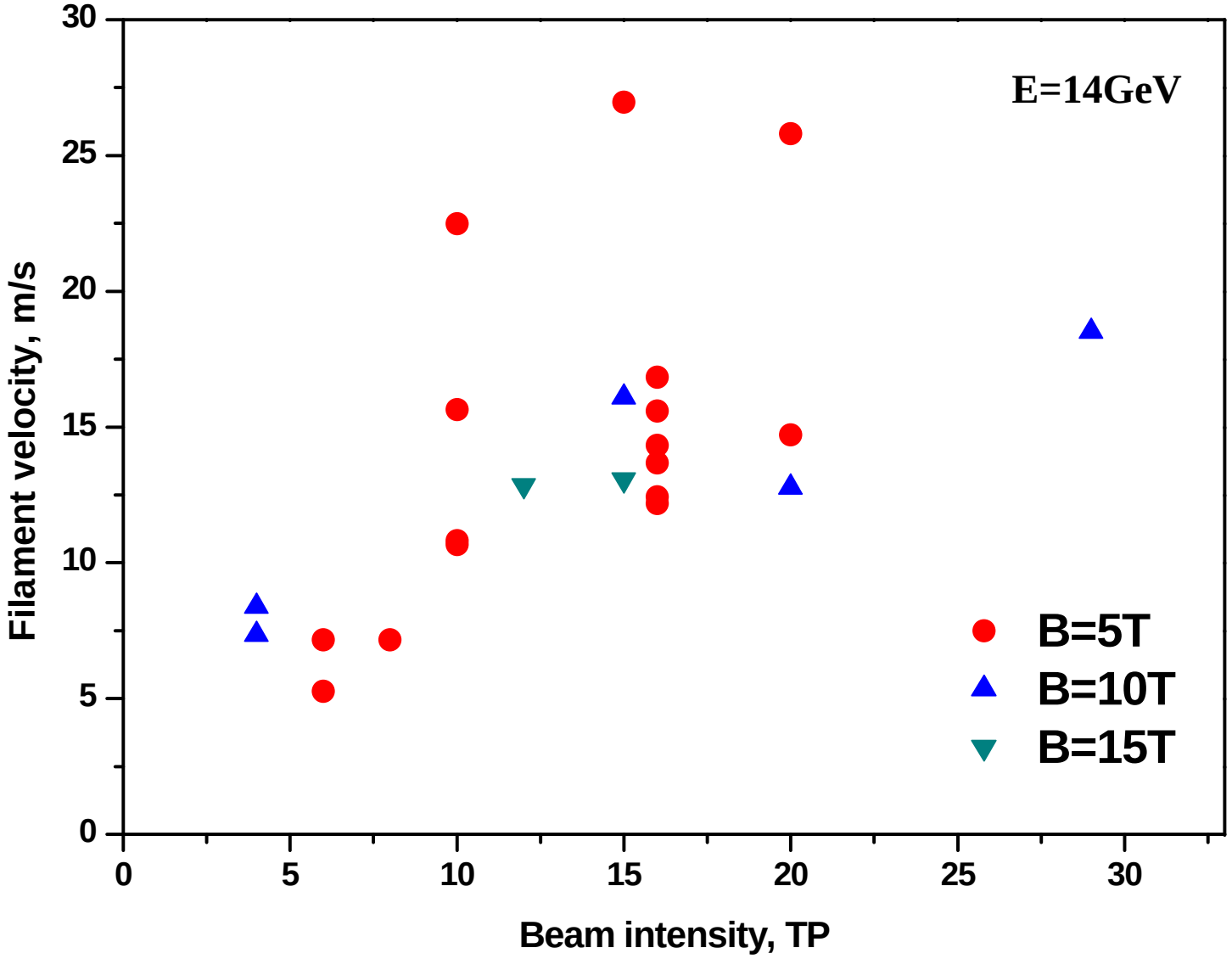


t=0 t=0.050 ms t=0.175 ms t=0.375 ms

Time Delay of Onset of Filamentation



Filamentation Velocity Increases with Beam Intensity and Suppressed By Magnetic Field



Conclusions

1. **An optical imaging system was employed to diagnose the Hg jet in a high power target experiment.**

2. **Experiment ran in the Fall 2007.**

3. **Hg jet properties are influenced by the magnetic field.**
   - **The fluctuations on the jet surface decrease as the magnetic field increases.**
   - **Hg jet height increases slightly with magnetic field.**
   - **The deflection of the jet by gravity is reduced at higher magnetic field.**

4. **Disruption of Hg jet by the proton beam begins at the bottom of jet and ends at the top of jet, which is consistent with the beam trajectory across the jet.**

5. **Hg jet breakup is influenced by the magnetic field.**
   - **The filamentation velocity increases as the beam intensity increases.**
   - **The magnetic field reduces the filamentation velocity.**
   - **Disruption length is suppressed by the magnetic field.**
   - **Onset of filamentation occurs later at higher magnetic field.**

6. **Hg jet breakup is influenced by beam energy and intensity.**
   - **Disruption length increases with both beam energy and intensity.**
   - **The intensity threshold for breakup is lower at higher energy.**