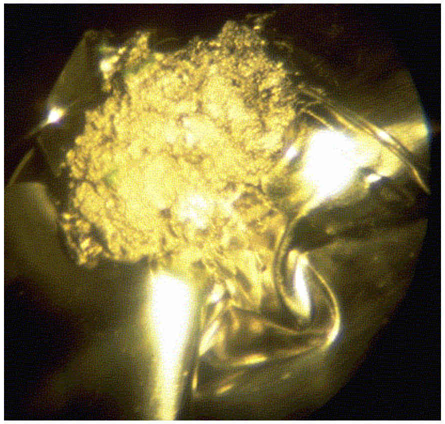
MERIT Scientific goals and importance

BNL, CERN, KEK
MIT, ORNL,
Princeton
University, RAL

- High power pulsed targets
  - Introduction
  - Beyond solid targets
  - Pion collection
  - Preliminary experiments
- MERIT (n-ToF-011)
  - Experimental setup
  - Scientific goals
- Conclusion and outlook

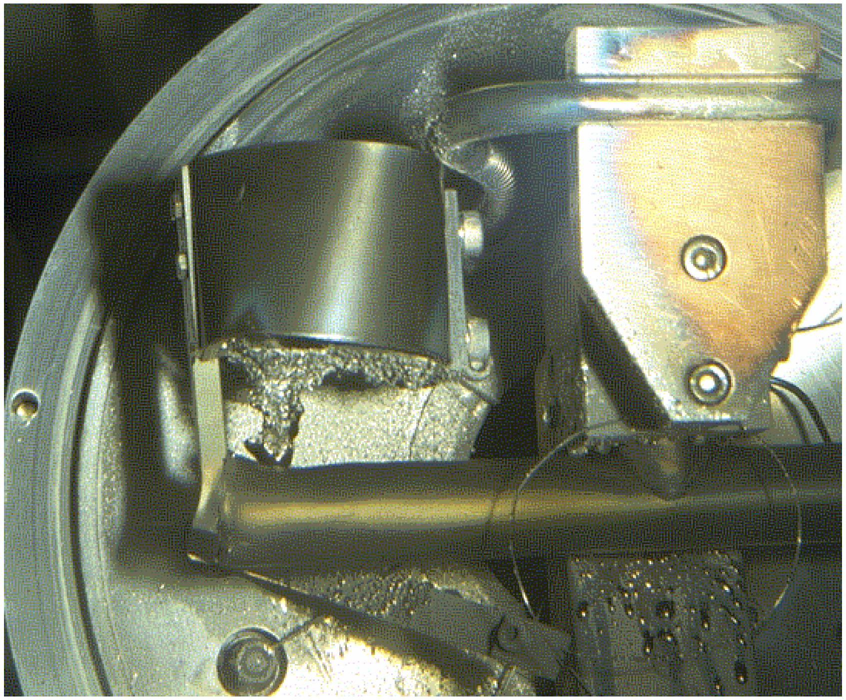
Why are we discussing liquid targets ?

Stress induced plastic deformation

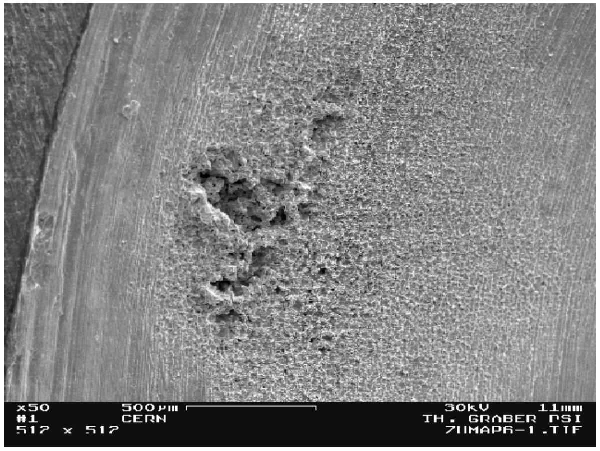


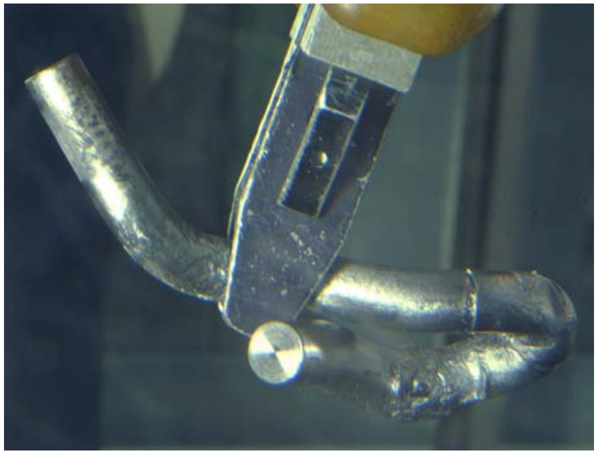
CERN-PS-booster 30 Tp (1 GeV)
on ISOLDE targets:

Shock induced rupture of confinement



Targetry related Issues or new technologies to be established





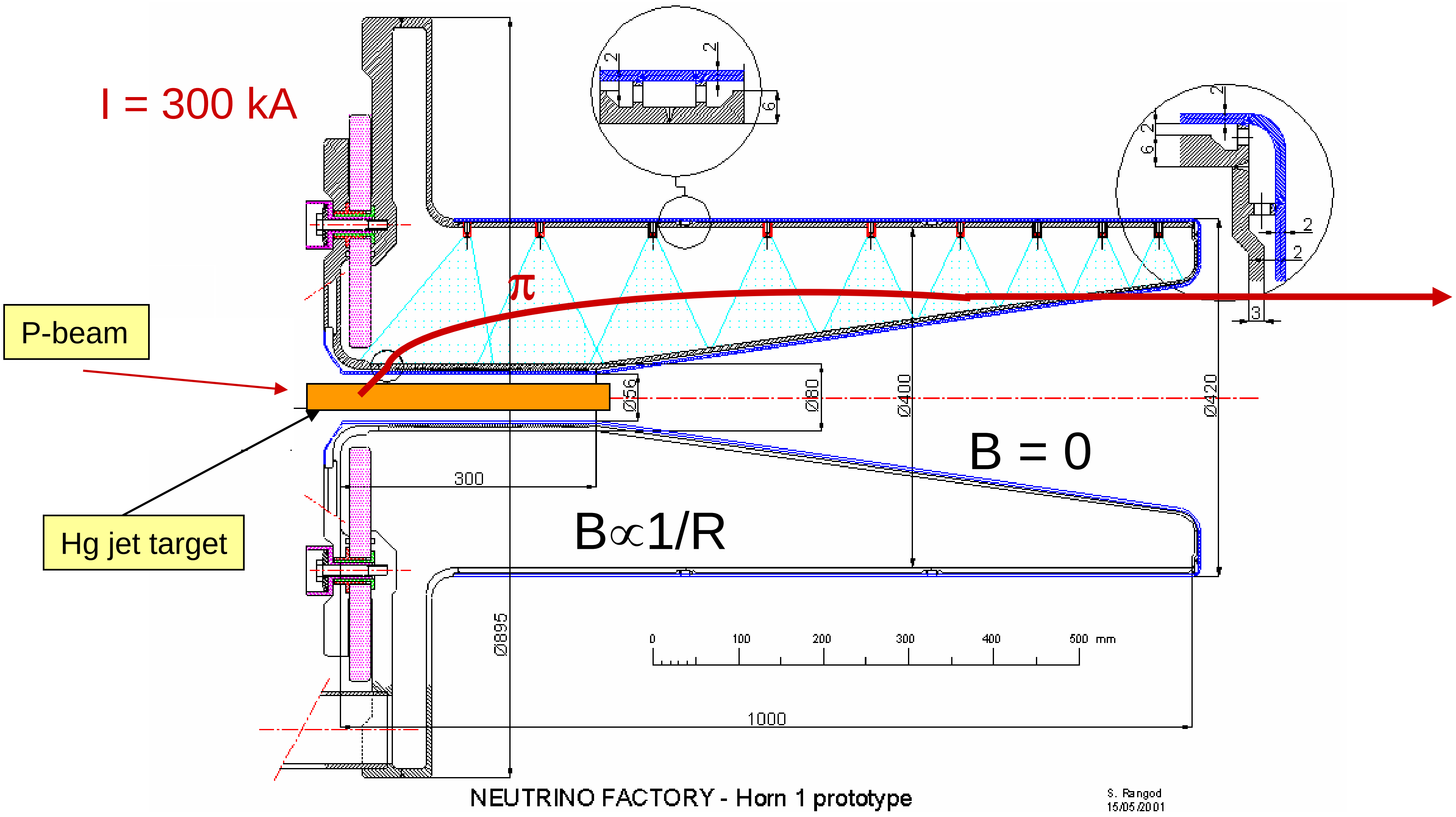
- Molten metal targets
  - Hight pressure high velocity molten metal fluid dynamics
    - Cavitation in the piping
    - Corrosion
    - Recuperation of high velocity splashes
  - Purification of the molten metal circuits
  - Phase transition
  - MHD of molten metal jets
- Solid targets
  - Effect of radiogenic chemical impurities on material properties
  - High velocity mechanics under vacuum
  - Compaction of Ta-beads
- Component reliability or life time vs. exchange time
  - Horns
  - 20 T magnets
- Simulation codes
  - Detailled Energy deposition
  - Shock transport elastic-plastic
  - 3d-Shocks in liquids with MHD
- Optical measurement techniques in high radiation environment
- Activation of components, inventory of specific activities vs. time
  - Radioactive waste handling
  - Internal transport, intermediate storage
  - End disposal
- *Experimental areas dedicated to target tests (highest radiotoxicity)*

MW target: Heat flow enhanced by mass flow

- He-cooling forced convection
  - Ta-beads (< 1MW / unit)
- New material for each proton pulse (20-40 kg/s)
  - Chain saw, bullets,
  - Levitating rings (*Radiation cooling*)
  - Molten metal Jets (*Molten metal convection in remote heat exchanger*)

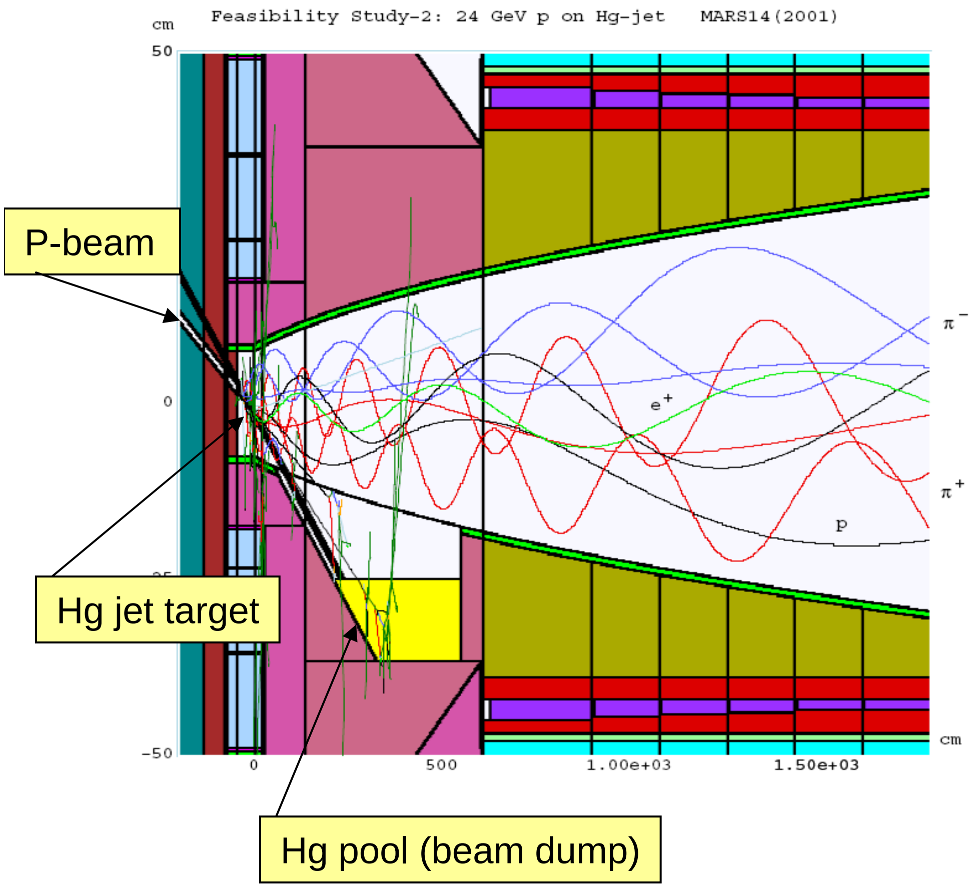
Molten metal jets were proposed to:
a) Avoid deformation of solids or high speed mechanics under vacuum
b) Reduce the effects of modification of the material constants with irradiation
c) Attempt to increase the power density of the beam beyond any solid.

Pion capture with a magnetic Horn (SPL 2.2 GeV)



Pion capture via 20 T magnetic field (BNL 24 GeV p)

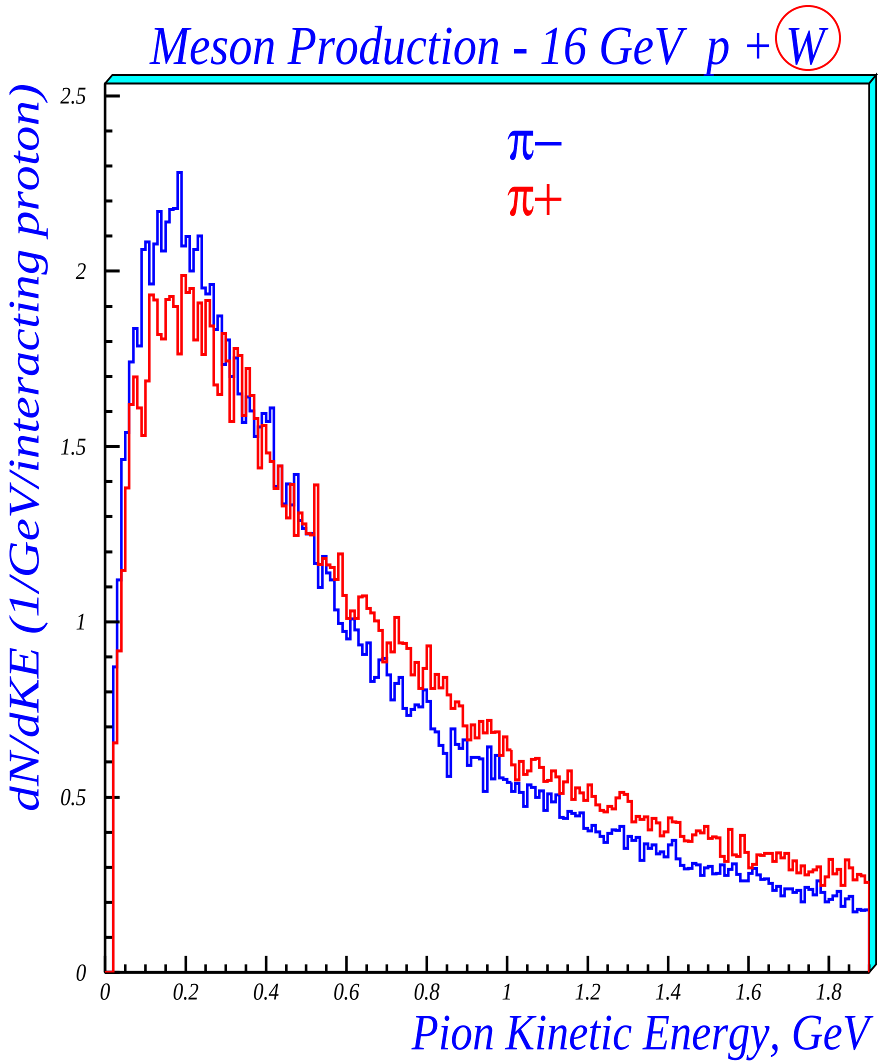
- Maximize Pion/Muon Production
  - Soft-pion Production
  - High Z materials
  - High Magnetic Field
  - Hg jet tilted with respect to solenoid and to p-beam axis



P-beam

Hg jet target

Hg pool (beam dump)



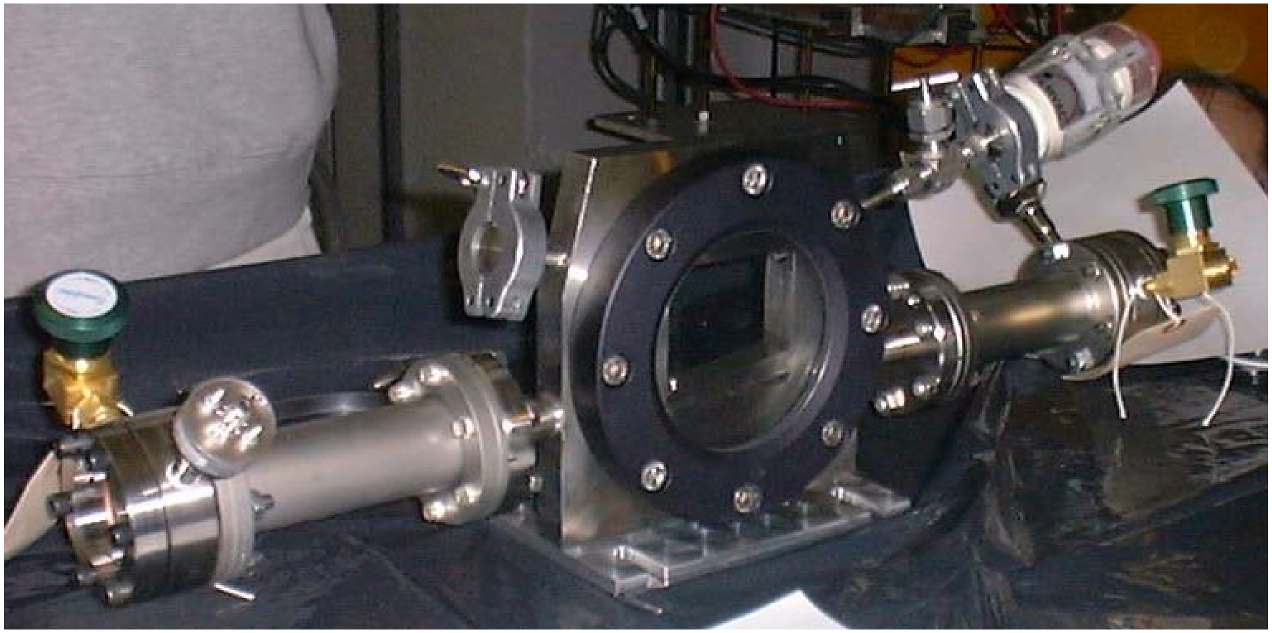
Needs for nufact benchmarks and simulation, Issues

- Molten metal jet targets
  - Observation of shock waves
  - Observation of Magneto-hydrodynamics effects
  - Pressure waves or Cavitation induced surface disruption ?
  - Simulation (shocks, cavitation and MHD)
- Shock effect of the hadronic shower on surrounding material
- Collecting ~50 m/s splashes

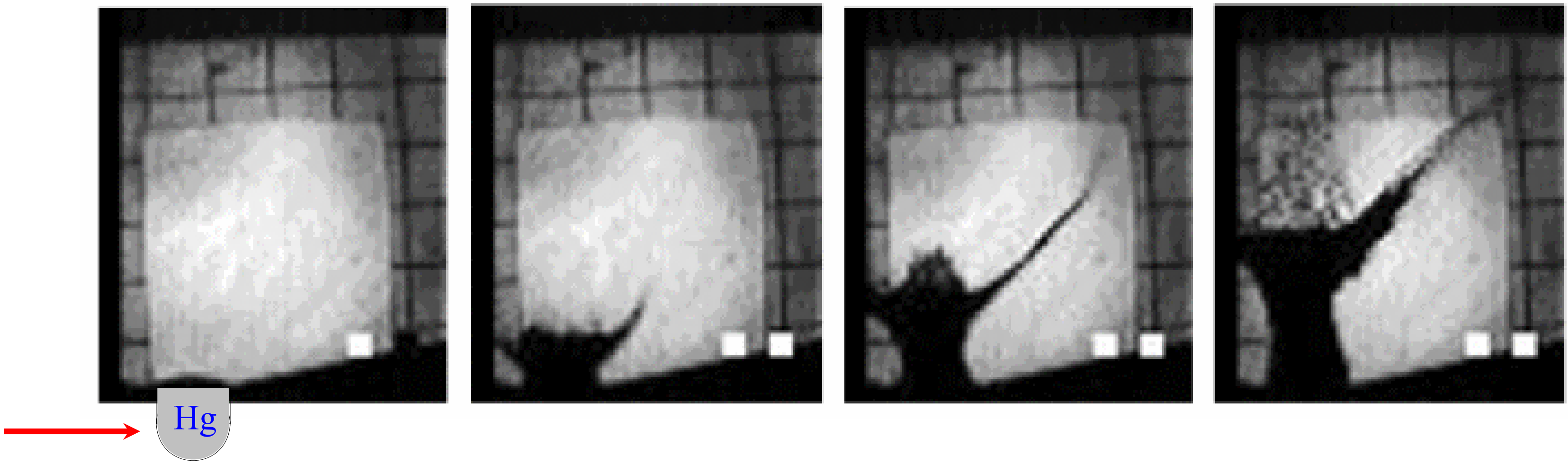
A. Fabich, J. Lettry, H. Kirk, K. Mc Donald, T. Tsang

BNL-CERN thimble test

1st P-bunch
1.8×10^{12} ppb
dt: 100 ns



24GeV p^+



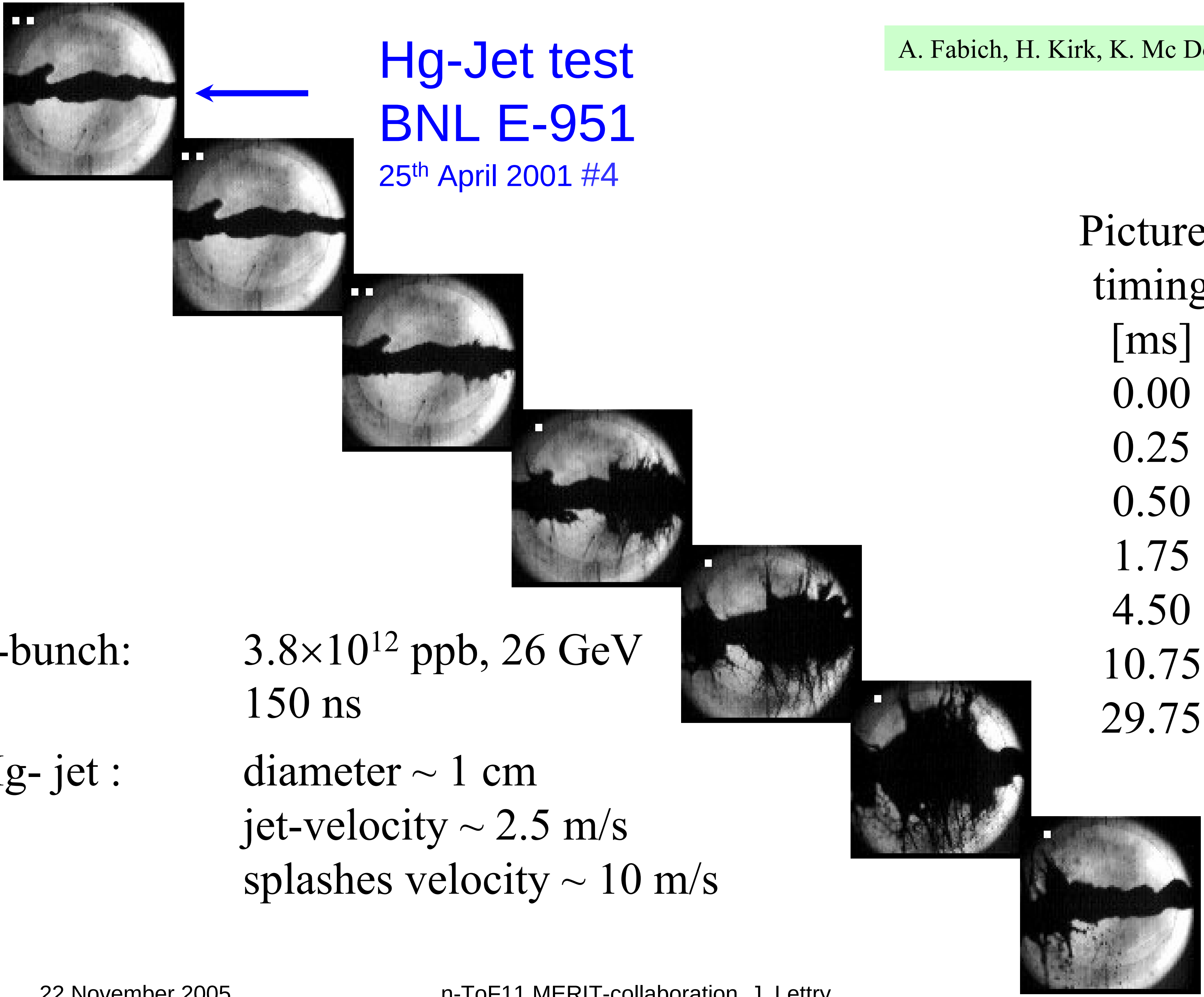
Timing : 0.0, 0.5, 1.6, 3.4 ms, shutter 25 µs

V_{splash} ~20-40 m/s

Hg-Jet test
BNL E-951

25th April 2001 #4

A. Fabich, H. Kirk, K. Mc Donald



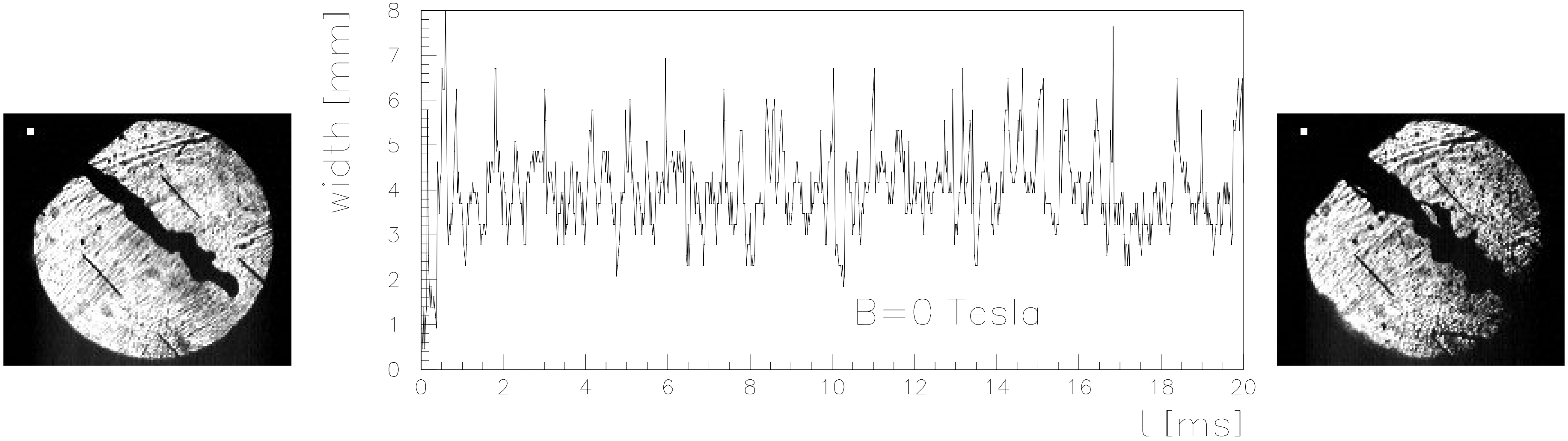
Pictures
timing
[ms]
0.00
0.25
0.50
1.75
4.50
10.75
29.75

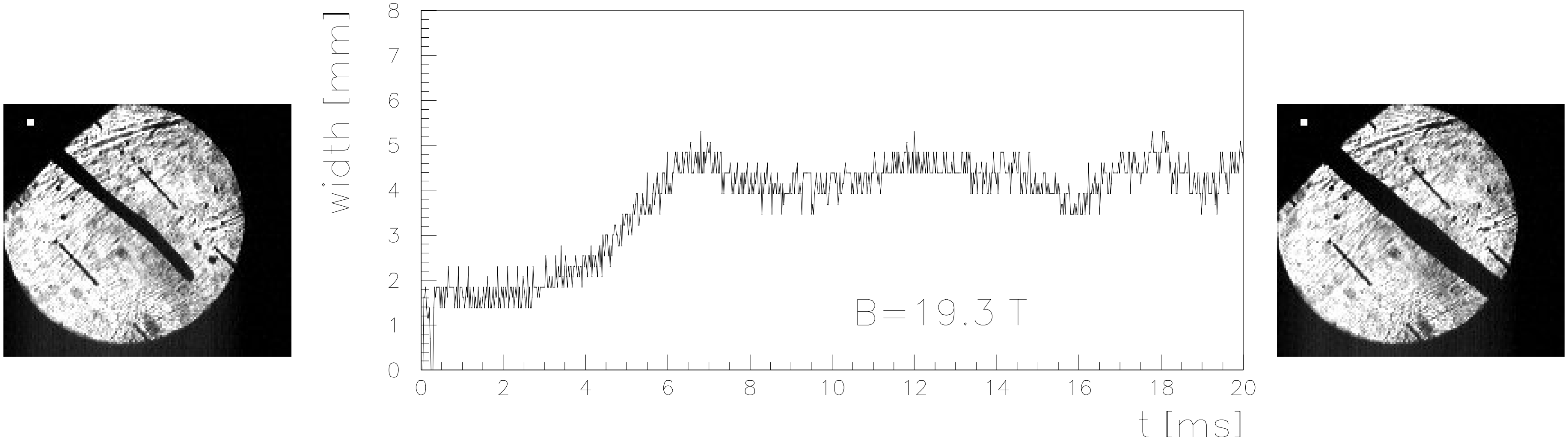
p-bunch:	3.8×10^{12} ppb, 26 GeV 150 ns
Hg- jet :	diameter ~ 1 cm jet-velocity ~ 2.5 m/s splashes velocity ~ 10 m/s

MHD damping of the instabilities of a Hg-jet

Ref: A. Fabich
PhD. thesis TUV

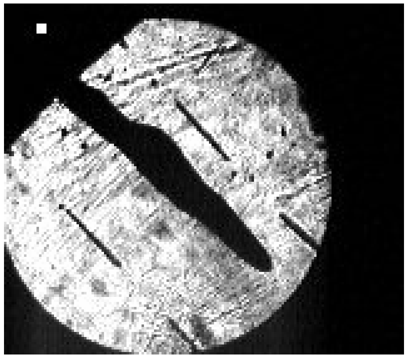
The radius is measured at a fixed position, the jet velocity is 11 m/s

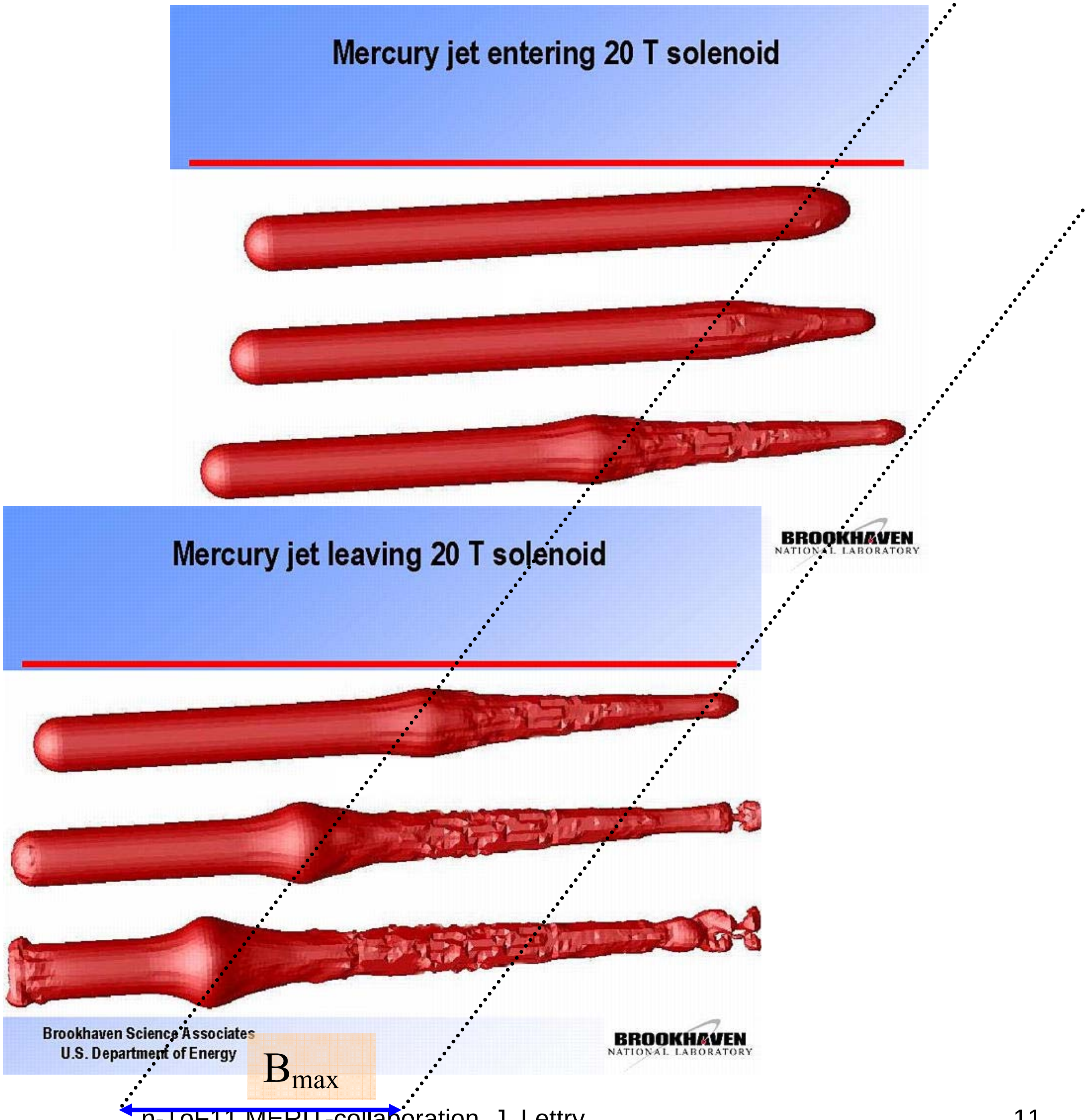




Simulation:
R. Samulyak BNL

10 T

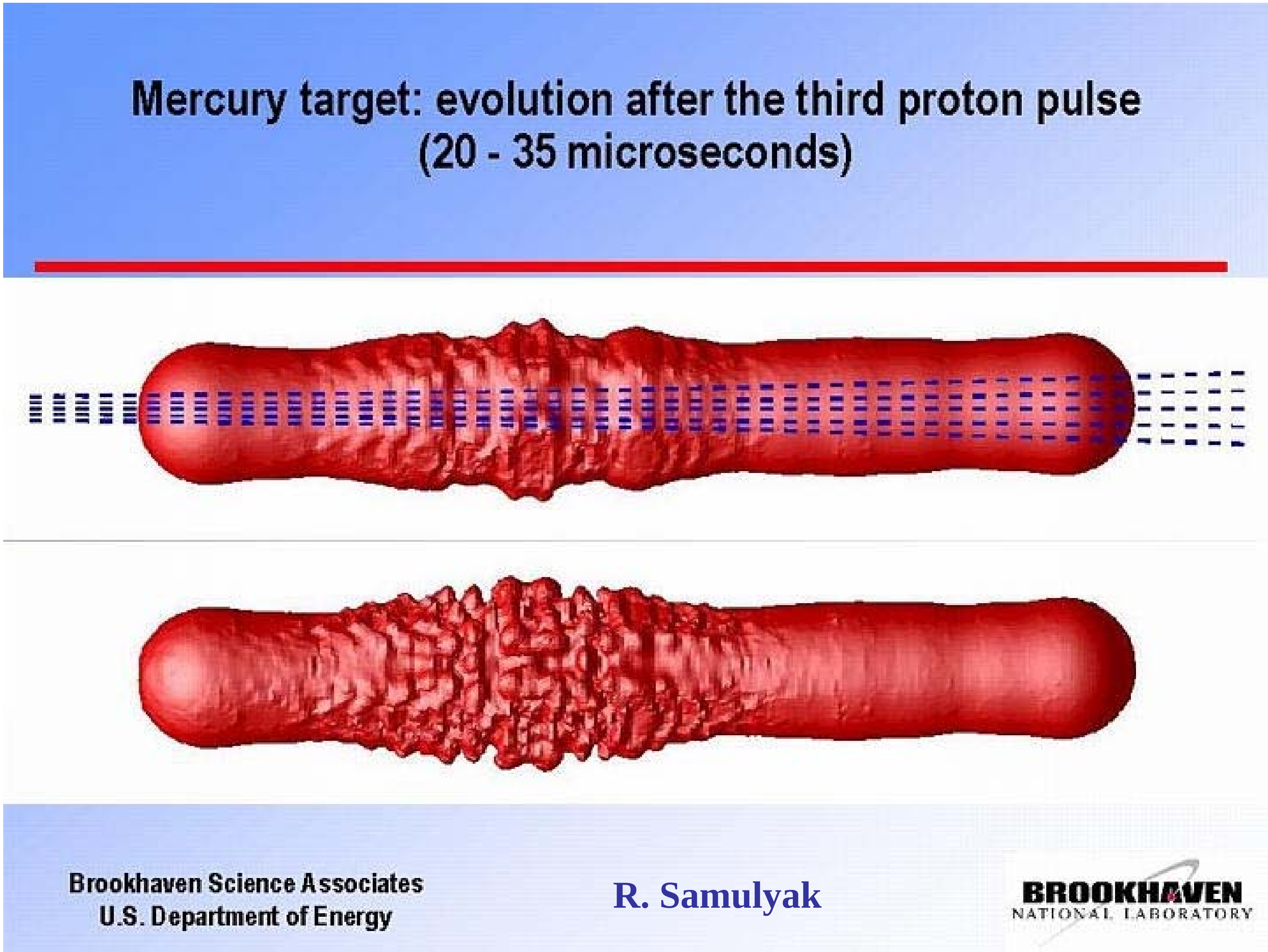




Mercury jet entering 20 T solenoid

Mercury jet leaving 20 T solenoid

Brookhaven Science Associates
U.S. Department of Energy



Mercury target: evolution after the third proton pulse (20 - 35 microseconds)

Brookhaven Science Associates
U.S. Department of Energy

R. Samulyak

BROOKHAVEN
NATIONAL LABORATORY

Water jet ripples generated by a 8 mJ Laser cavitation bubble (~50 μs after collapse)

Ref: E. Robert
Dipl. thesis EPFL

Most of the experimental data was gained via high speed optical methods.
bis repetita for MERIT

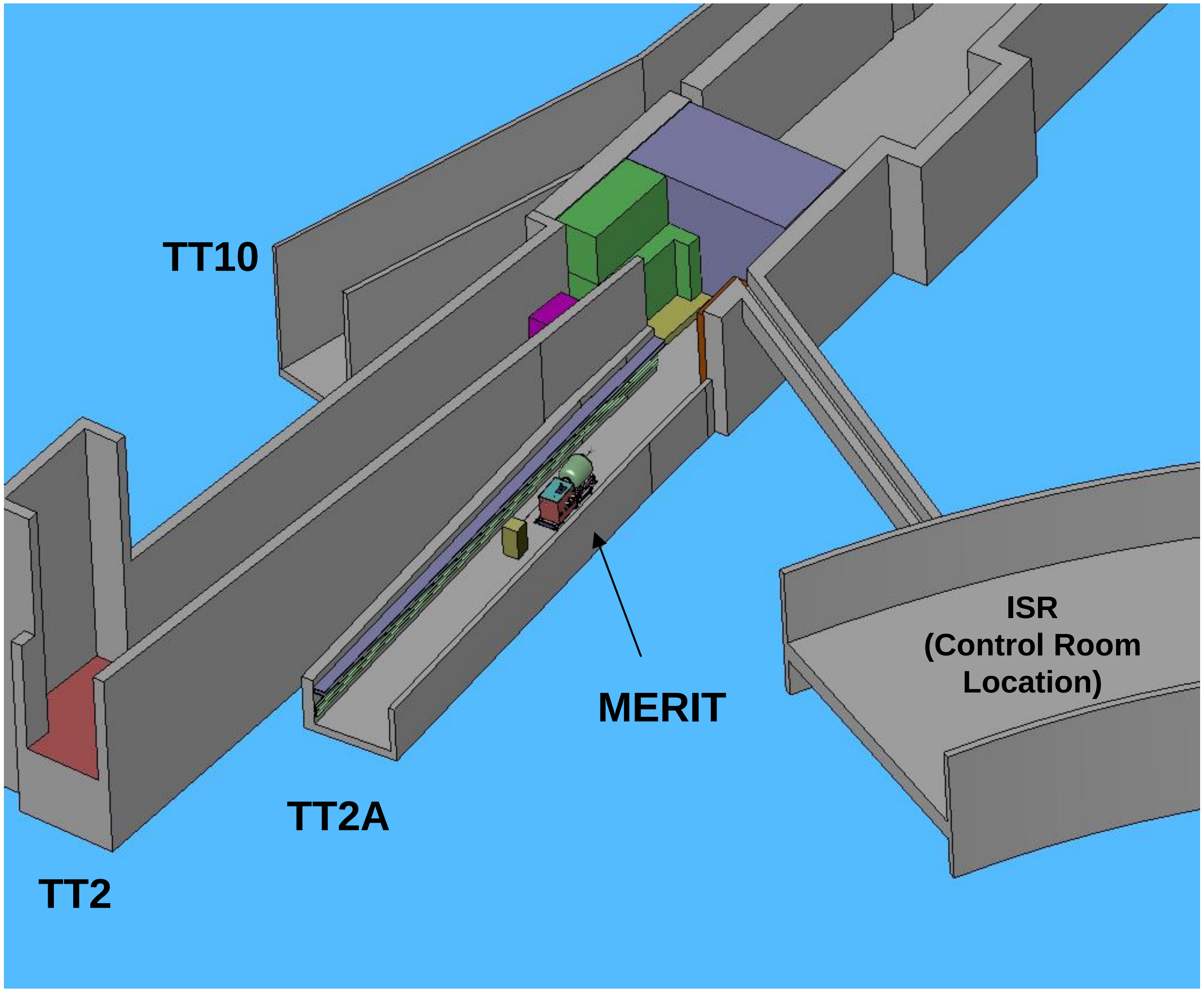
The MERIT Experiment do closely match the nominal parameters of the ν-factory

- 24 GeV Proton beam
- Up to 28 x 10^{12} Protons (TP) per 2 μs spill
- Proton beam spot with r $\leq$ 1.5 mm rms
- 1 cm diameter Hg Jet
- Hg Jet/Proton beam off solenoid axis
  - Hg Jet 100 mrad
  - Proton beam 67 mrad
- Test 50 Hz operations
  - 20 m/s Hg Jet
  - 2 spills separated by 20 ms

Peak Energy Deposition

- Neutrino Factories
  - Hg target; 1 MW 24 GeV proton beam; 15 Hz
    - 1cm diameter Hg jet ; 1.5mm x 1.5mm beam spot 100 J/g
  - Hg target; 4 MW 2.2 GeV proton beam; 50 Hz
    - 2cm diameter Hg jet; 3mm x 3mm beam spot 180 J/g
- E951
  - Hg target; 4 TP 24 GeV proton beam;
    - σ_y=0.3mm x σ_x=0.9mm rms beam spot 80 J/g
- CERN PS (projected)
  - Hg target; 28 TP 24 GeV proton beam
    - 1.2mm x 1.2 mm rms beam spot 180 J/g

MERIT location: In the transfer tunnel between the PS-complex and the n-ToF target



Cryogenics

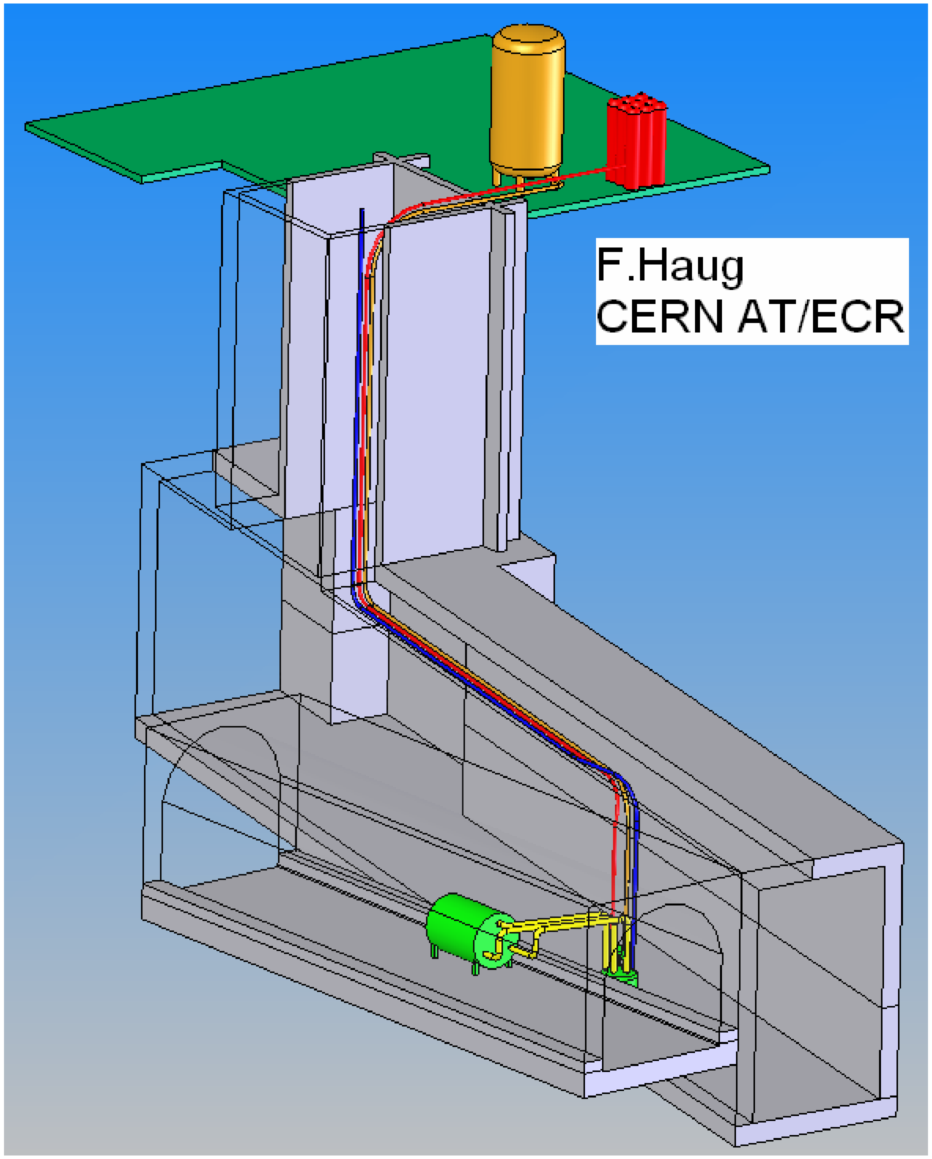
LN_2 and N_2 gas stored on the surface.

Cold valve box in the TT2 tunnel.

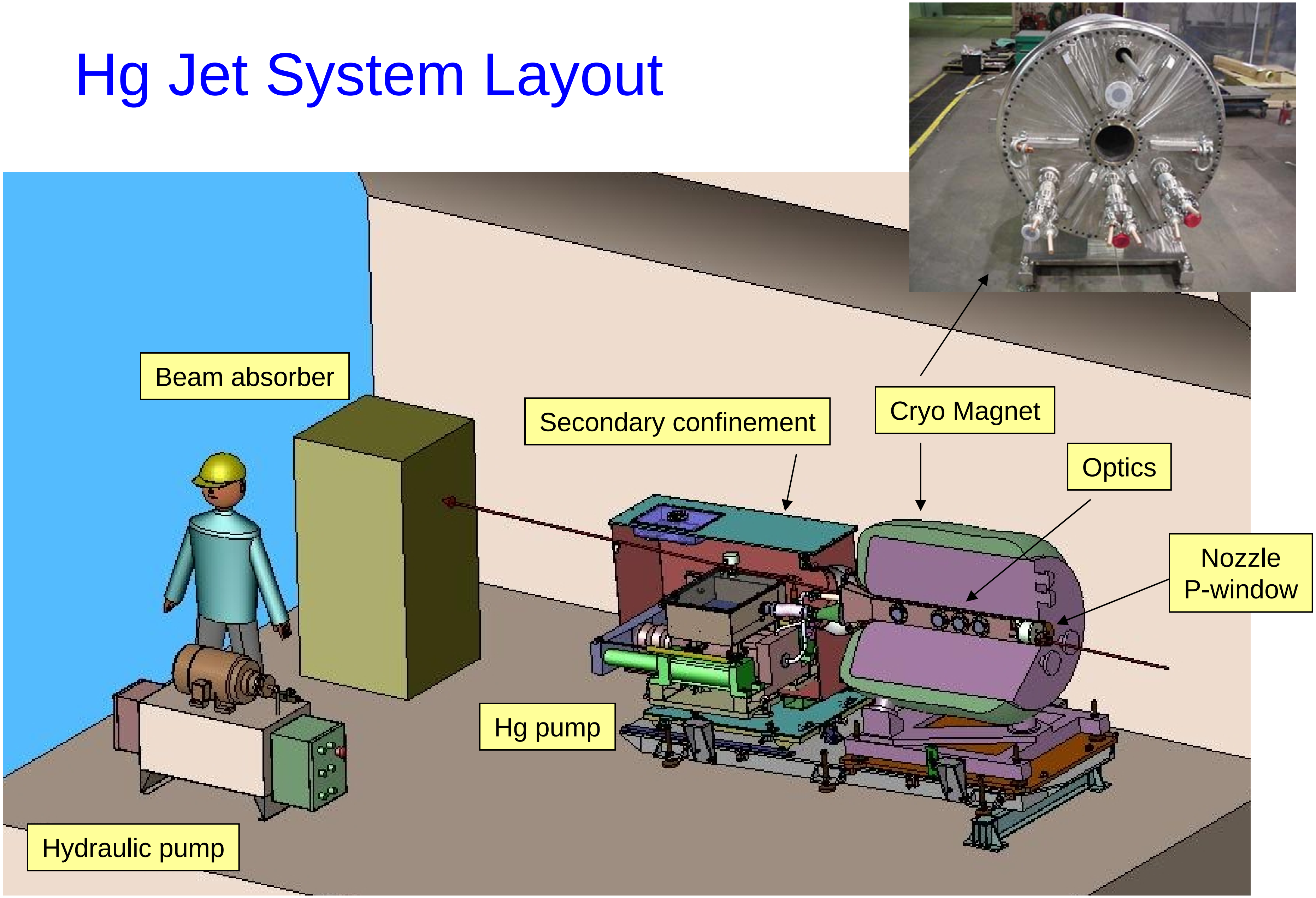
Exhaust gas vented into TT10 tunnel through filtration system.

~ 150 liters of LN_2 per Magnet pulse.

Magnet flushed with N_2 prior to each pulse, to minimize activation of N_2.



Hg Jet System Layout



Beam absorber

Secondary confinement

Cryo Magnet

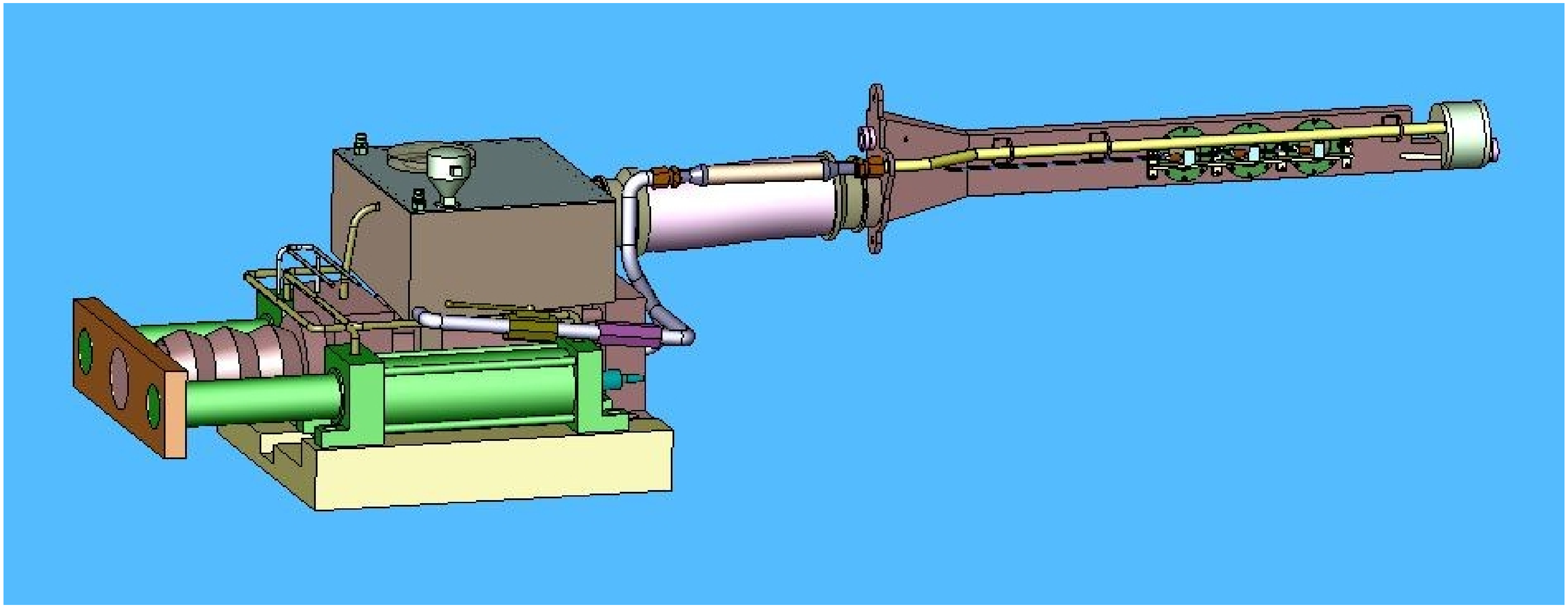
Optics

Nozzle
P-window

Hg pump

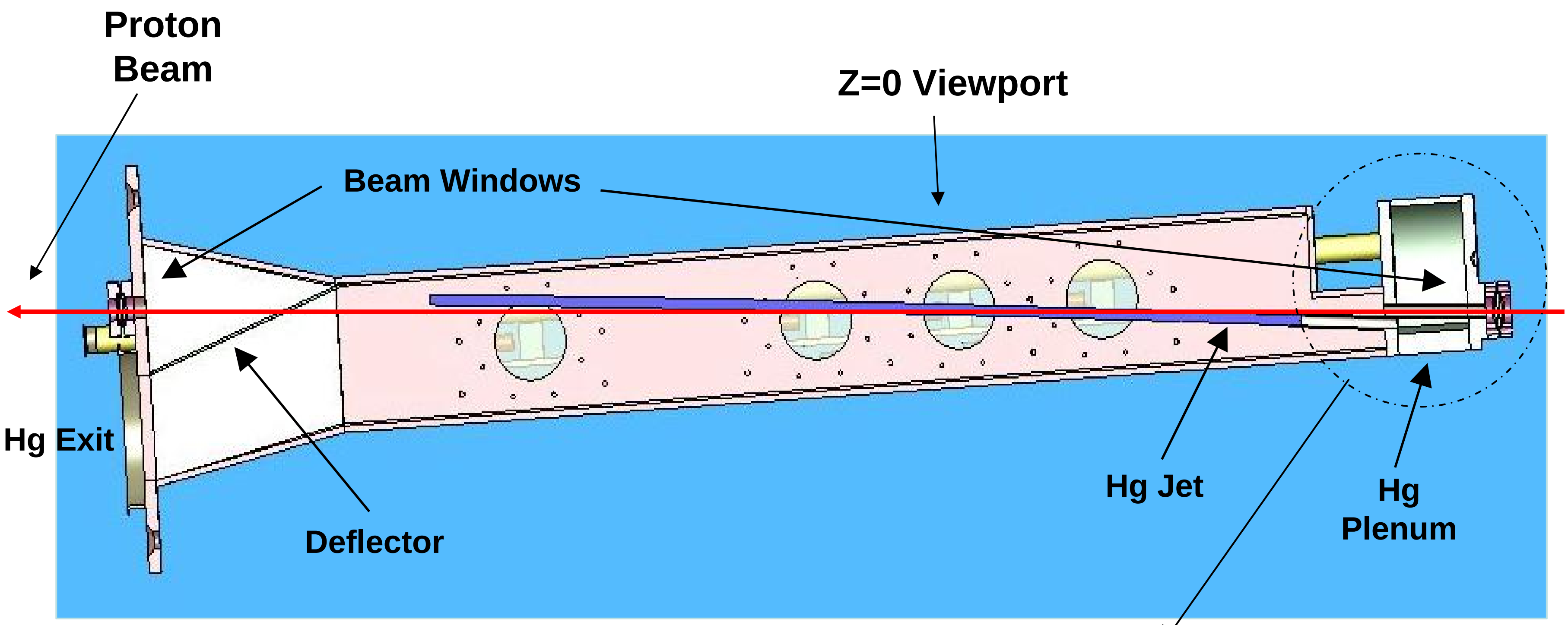
Hydraulic pump

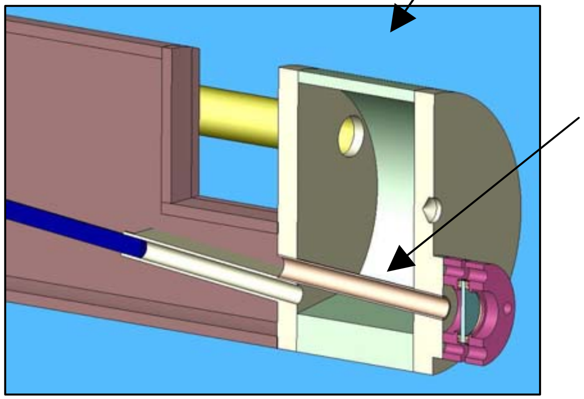
The Hg Jet primary confinement



Snout inserted into 15 T cryo-magnet.
Mercury inventory ~ 20 liters.
Hydraulic system can deliver up to 1000 psi, to propel mercury at ~ 20 m/s

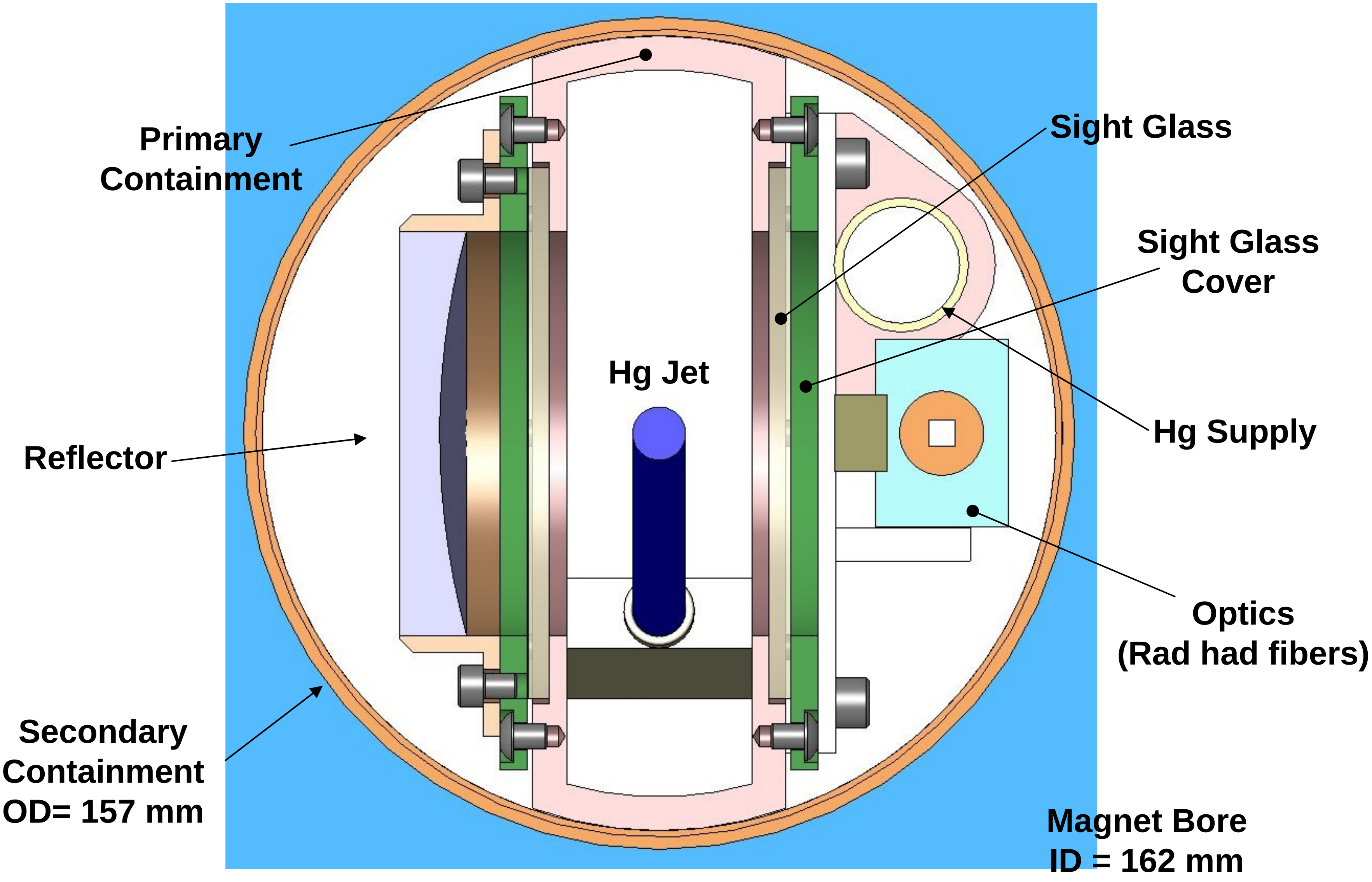
Observation chamber





Nozzle under R&D

Data acquisition 1: Hg-Jet shadow recorded via fiber optics high speed photography



Primary Containment

Sight Glass

Sight Glass Cover

Reflector

Hg Jet

Hg Supply

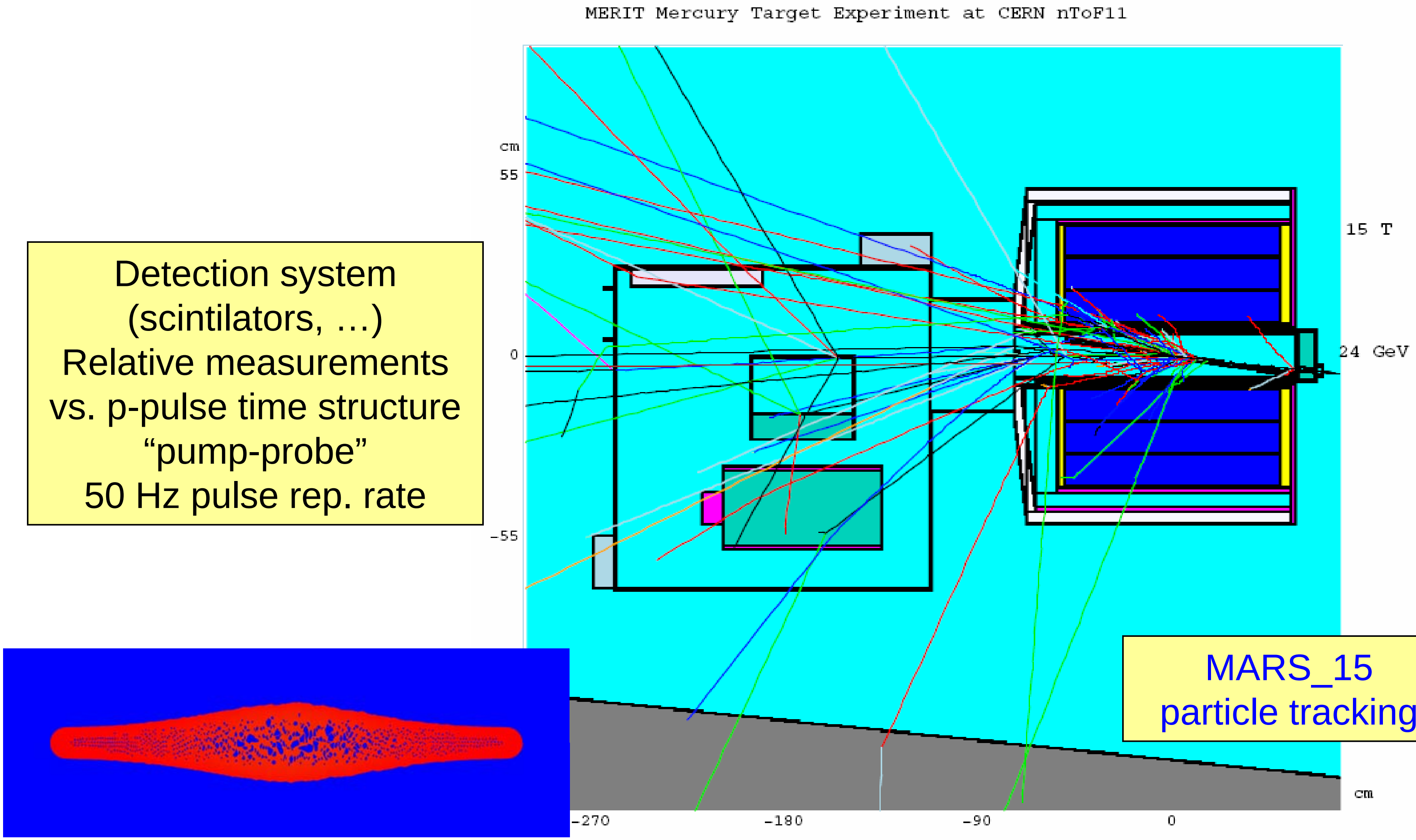
Optics (Rad had fibers)

Secondary Containment OD= 157 mm

Magnet Bore ID = 162 mm

Data acquisition 2: time structure of high energy particle flux

Detection system
(scintilators, …)
Relative measurements
vs. p-pulse time structure
“pump-probe”
50 Hz pulse rep. rate



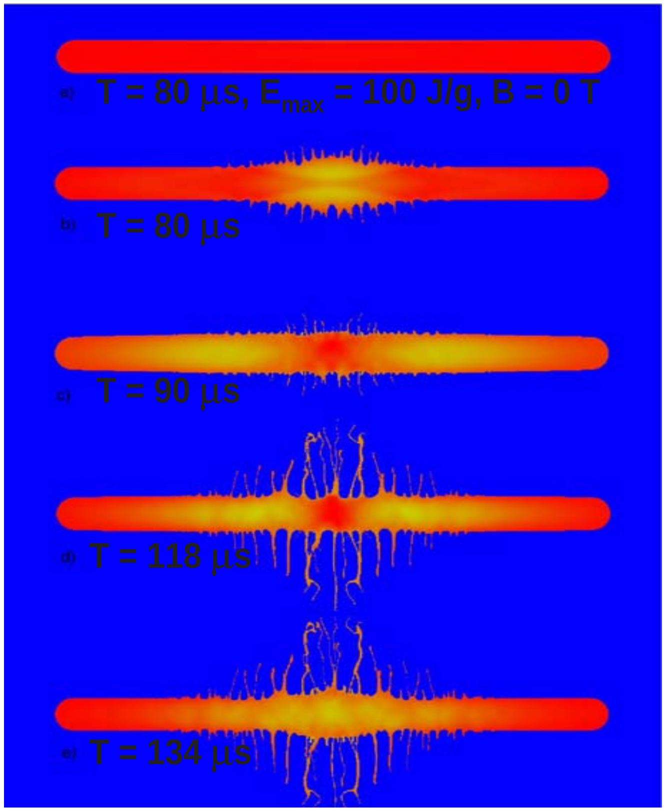
MARS_15
particle tracking

PS complex MDs required to prepare beam settings

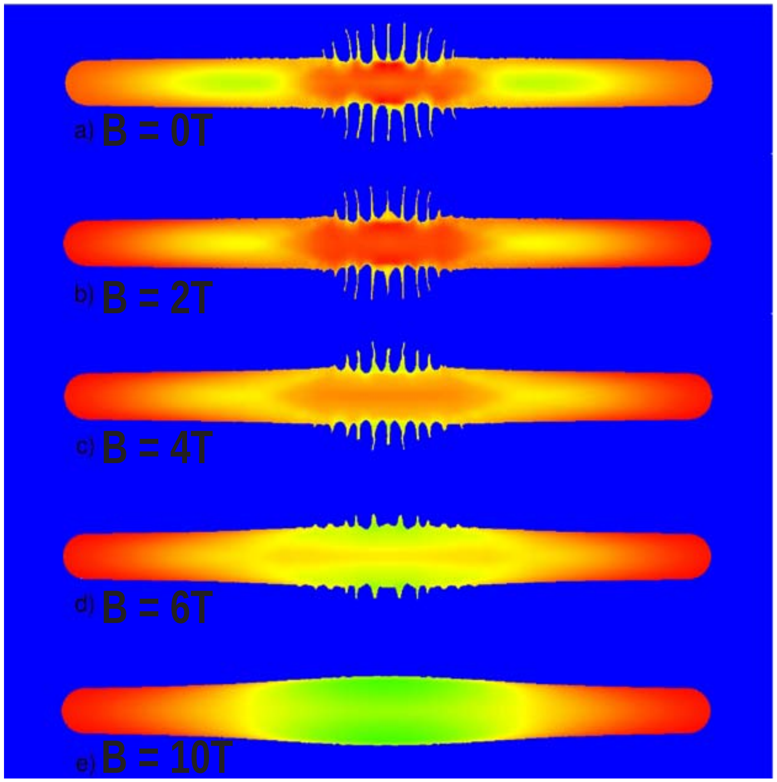
- Numerous different beam tuning and timing
  - Variation of:
    - Intensity, energy
    - Beam position on target
    - Beam spot size
    - Pump-probe method
- Hint to reach high Intensity
  - Consider running PS in harmonic 16
    - increases intensity to $5*10^{12}$ p^+ per 1/8 of PS (< 40 Tp)
- 50 Hz operation
  - Operate at 14 GeV/c only (Kicker could, but not the septum)
  - Like pump-probe method, but extend bunch-to- bunch distance extensively (milliseconds)

MHD + shock Simulations
BNL (Samulyak)

Gaussian energy deposition profile
Peaked at 100 J/g. Times run from
0 to 124 μs, B = 0 T



Jet dispersal at t = 100 μs with magnetic
Field varying from 0 to 10 Tesla



Axial symmetric splashes suppressed by MHD forces

MERIT will:

- **Produce benchmarks for Neutrino Factory targetry design tools**
  - Study MHD of the Hg jet with nominal size and velocity
  - Study the origin of jet disruption by varying PS spill structure *“Pump / Probe”*
- **Validate the Neutrino Factory targetry concept**
  - Effects of single beam pulses with realistic proton energy, timing, intensity and energy density
  - Influence of solenoid field strength on Hg jet dispersal (MHD shock damping)
  - Information on the 50 Hz operations scenario by recording 2 pulses at 20 ms interval.
- **Define potential issues and open the path to engineering study**
- ***Set a milestone towards 1-4 MW pion production targets***
- *First beam expected April 2007*

Thanks to all contributors