The High-power Target Experiment at CERN

BENE'04

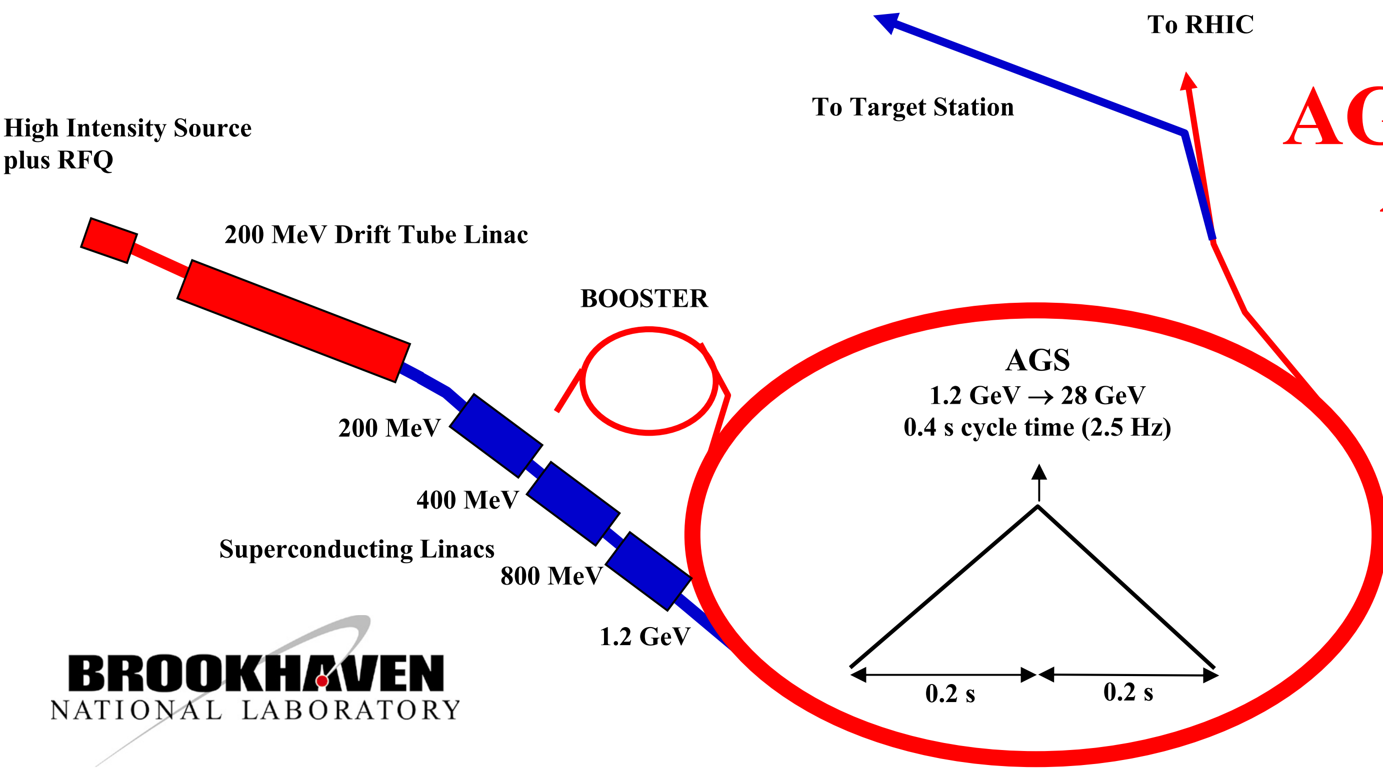
DESY, Hamburg

November 2, 2004

Harold G. Kirk
Brookhaven National Laboratory

Multi-MW New Proton Machines

SNS at 1.2 MW	→	2.0 MW		
JPARC 0.7 MW	→	4.0 MW		
FNAL 0.4 MW	→	1.2 MW	→	2.0 MW
BNL 0.14 MW	→	1.0 MW	→	4.0 MW
SPL				4.0 MW



AGS Upgrade to 1 MW

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High-power Targetry Challenges

High-average power and high-peak power issues

- Thermal management
  - Target melting
  - Target vaporization
- Thermal shock
  - Beam-induced pressure waves
- Radiation
  - Material properties
  - Radioactivity inventory
  - Remote handling

High-Z Materials

Key Properties

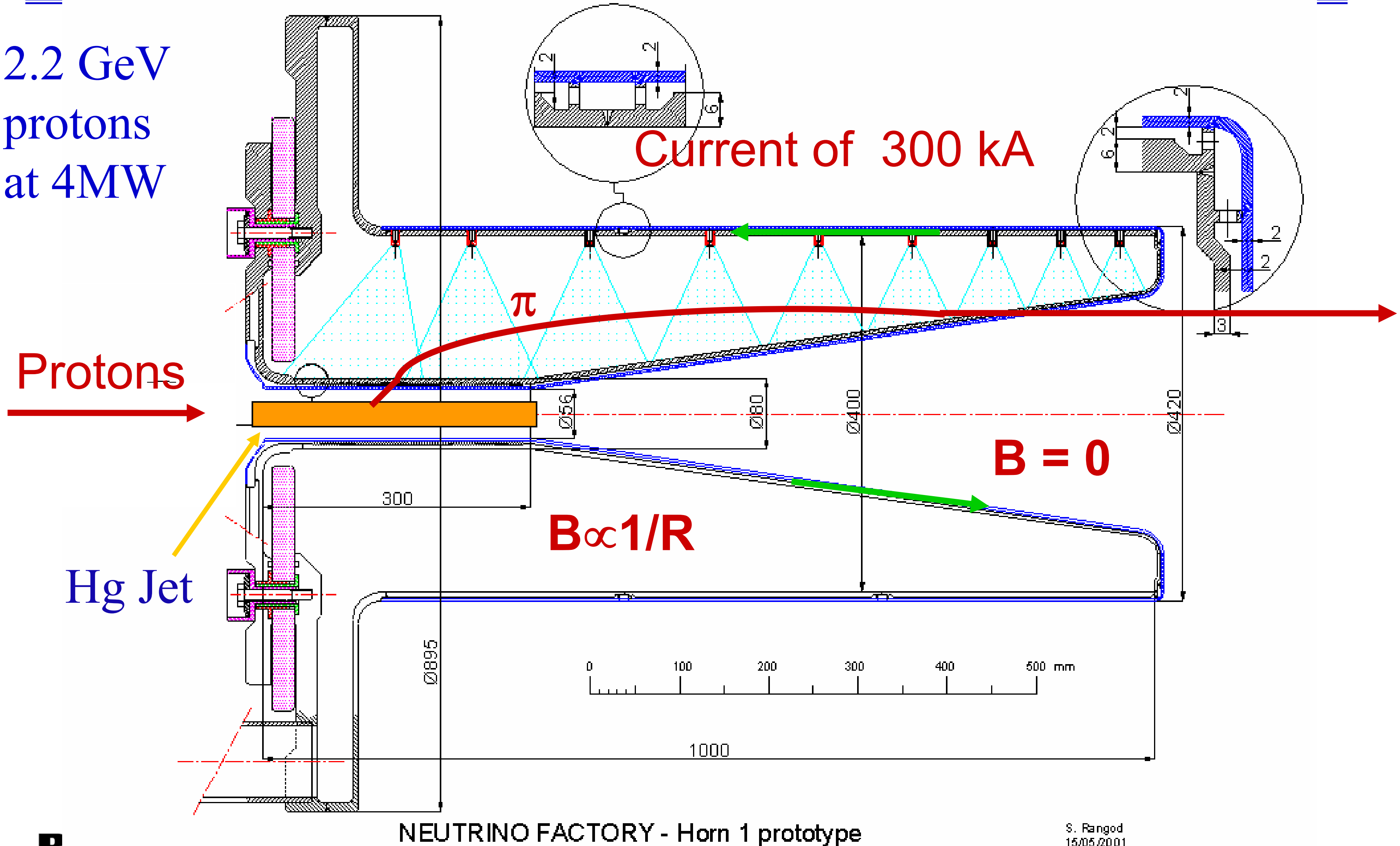
- Copious neutron production
- Maximal soft-pion production
- Both pion signs are collected
- Liquid (Hg) has potential for extension beyond 4 MW

Key Issues

- High pion absorption
- High peak energy deposition
- Jet dynamics in a high-field solenoid
- Target disruption in a high-field solenoid
- Achievement of near-laminar flow for a 20 m/s jet

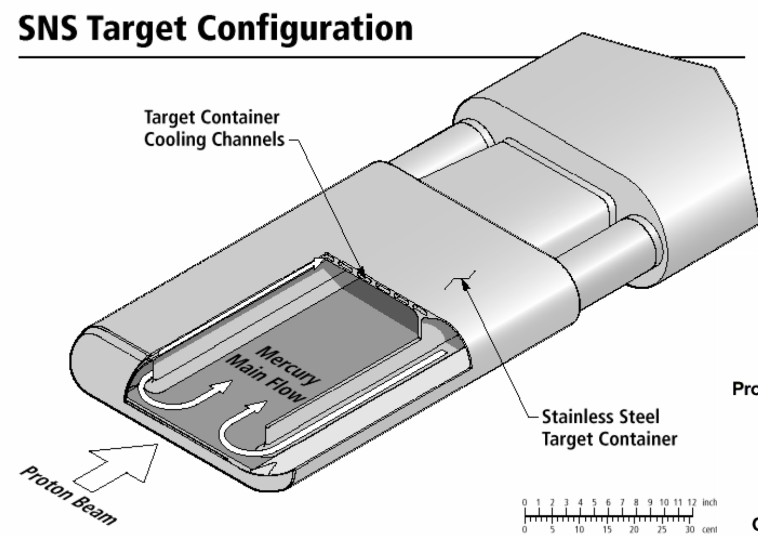
The SPL Neutrino Horn

2.2 GeV protons at 4MW

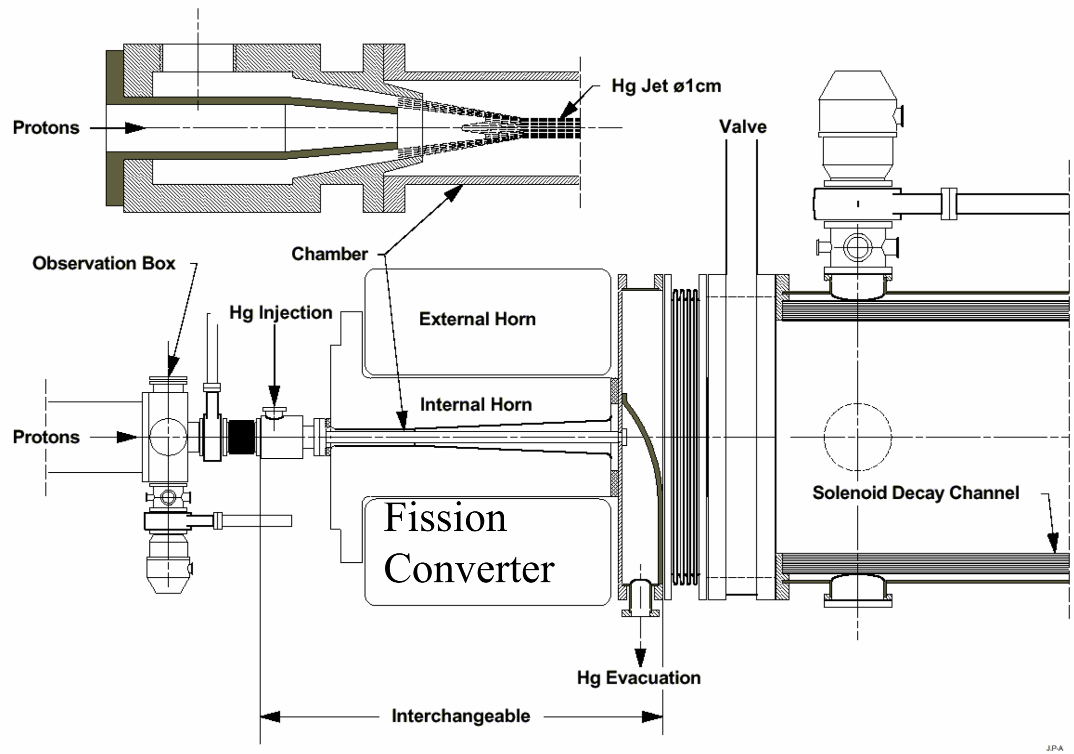


Neutron Production using Hg

SNS Neutron Spallation Target



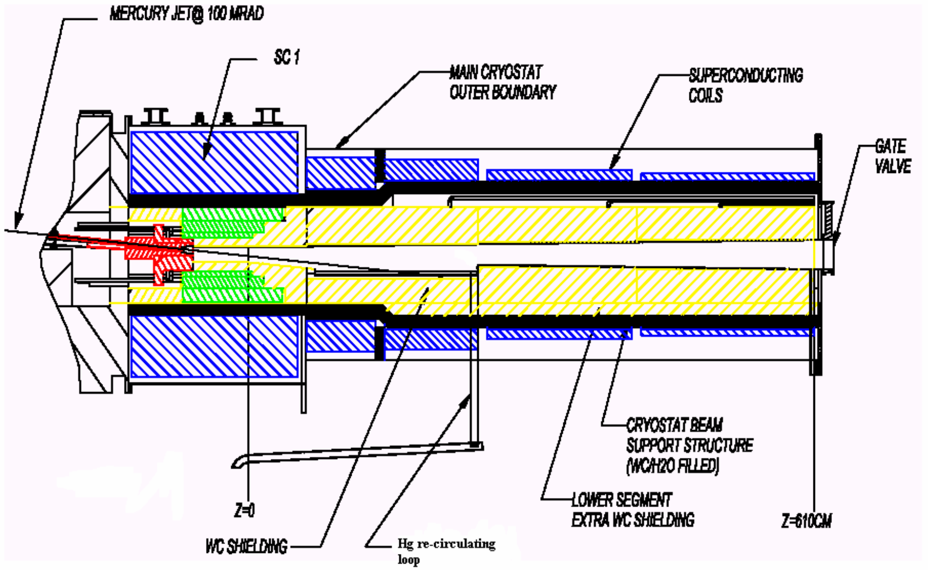
Beta Beams

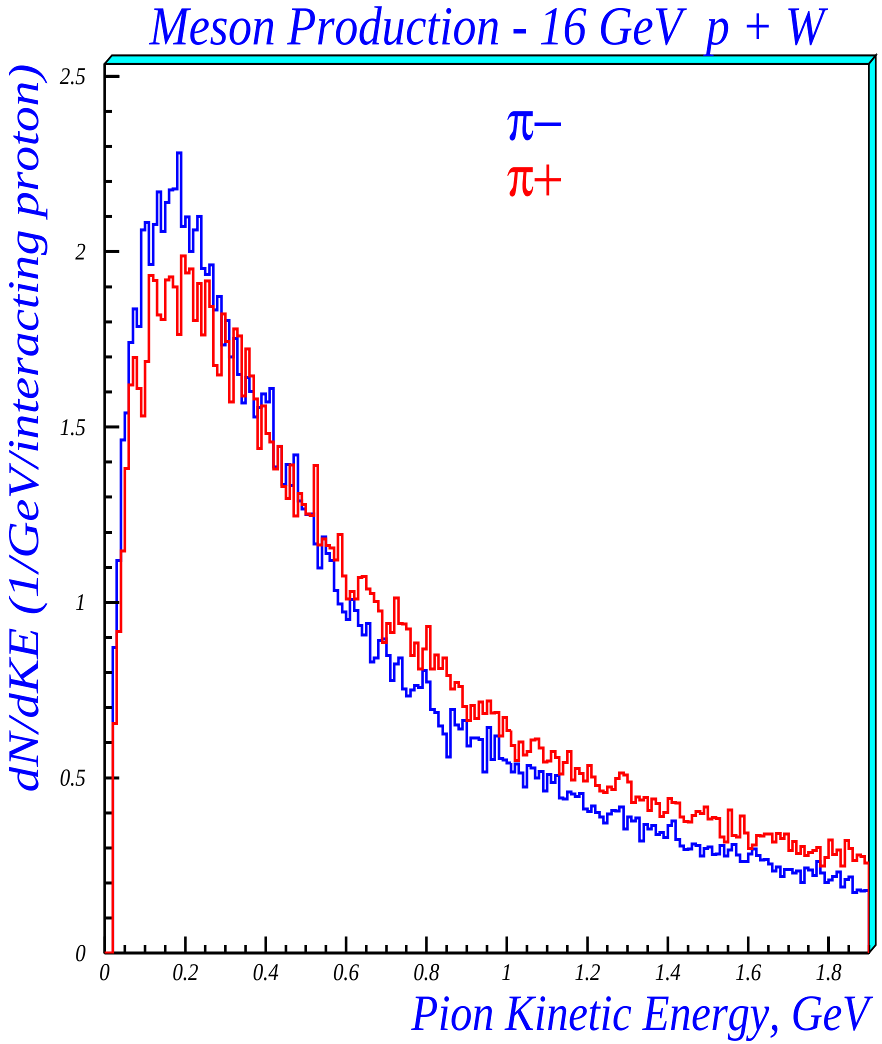


Achieving Intense Muon Beams

Maximize Pion/Muon Production

- Soft Pion Production
- High-Z material
- High Magnetic Field





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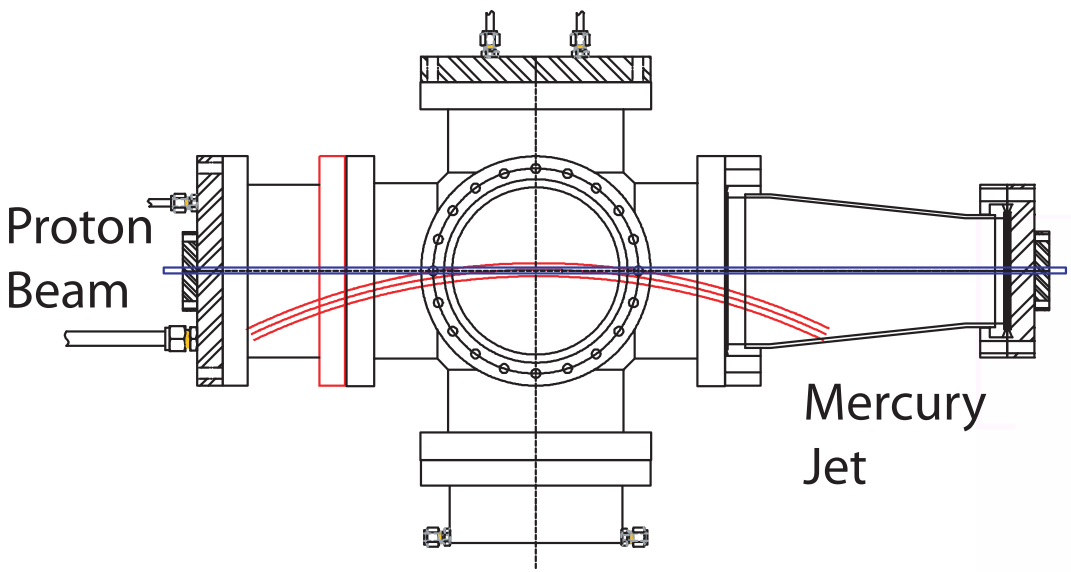
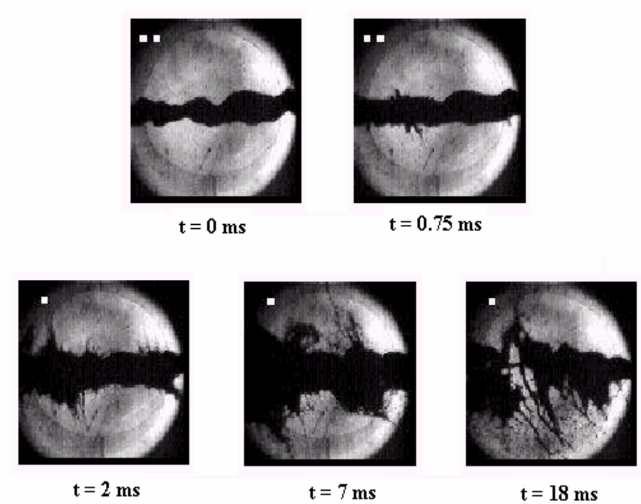
E951 Hg Jet Tests



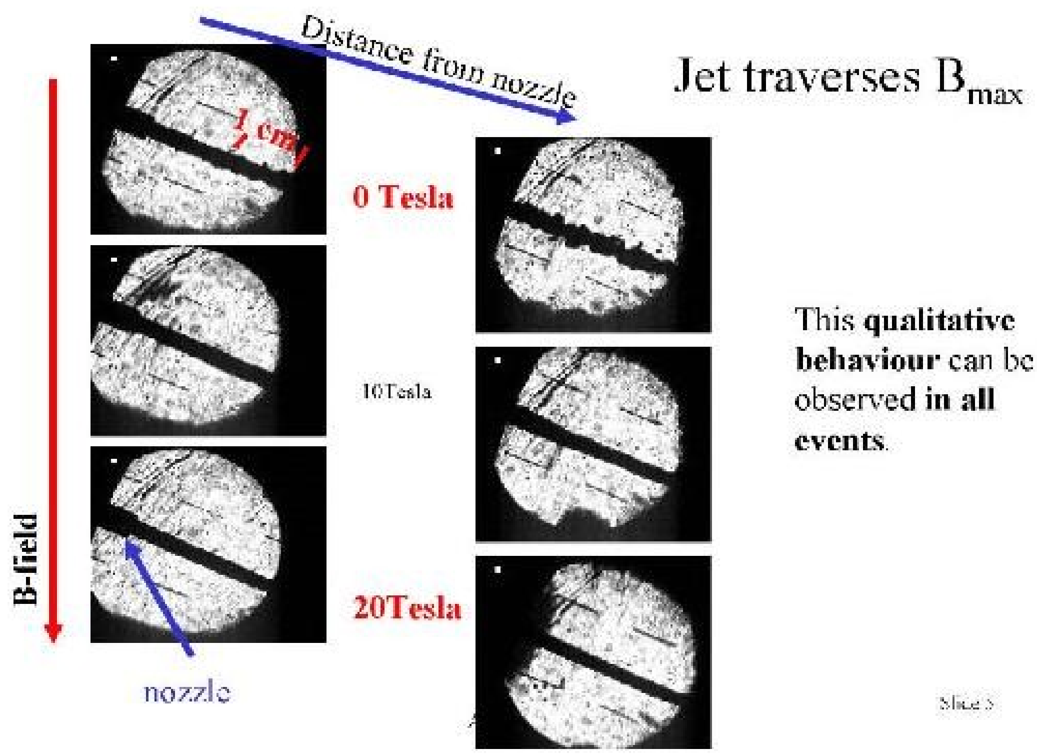
- 1cm diameter Hg Jet
- V = 2.5 m/s
- 24 GeV 4 TP Proton Beam
- <u>No</u> Magnetic Field



Key E951 Results

- Hg jet dispersal proportional to beam intensity
- Hg jet dispersal ~ 10 m/s for 4 TP 24 GeV beam
- Hg jet dispersal velocities ~ ½ times that of "confined thimble" target
- Hg dispersal is largely transverse to the jet axis -- longitudinal propagation of pressure waves is suppressed
- Visible manifestation of jet dispersal delayed 40 μs

CERN/Grenoble Hg Jet Tests



- 4 mm diameter Hg Jet
- v = 12 m/s
- 0, 10, 20T Magnetic Field
- <u>No</u> Proton Beam

A. Fabich, J. Lettry
Nufact'02

Key Jet/Magnetic Field Results

- The Hg jet is stabilized by the 20 T magnetic field
- Minimal jet deflection for 100 mrad angle of entry
- Jet velocity reduced upon entry to the magnetic field

Bringing it all Together

We wish to perform a proof-of-principle test which will include:

- A high-power intense proton beam (16 to 32 TP per pulse)
- A high ($\geq$ 15T) solenoidal field
- A high (> 10m/s) velocity Hg jet
- A ~1cm diameter Hg jet

Experimental goals include:

- Studies of 1cm diameter jet entering a 15T solenoid magnet
- Studies of the Hg jet dispersal provoked by an intense pulse of a proton beam in a high solenoidal field
- Studies of the influence of entry angle on jet performance
- Confirm Neutrino factory/Muon Collider Targetry concept

Proposal to Isolde and nToF Committee

CERN-INTC-2003-033
INTC-I-049
26 April 2004

A Proposal to
the ISOLDE and Neutron Time-of-Flight Experiments
Committee

**Studies of a Target System for
a 4-MW, 24-GeV Proton Beam**

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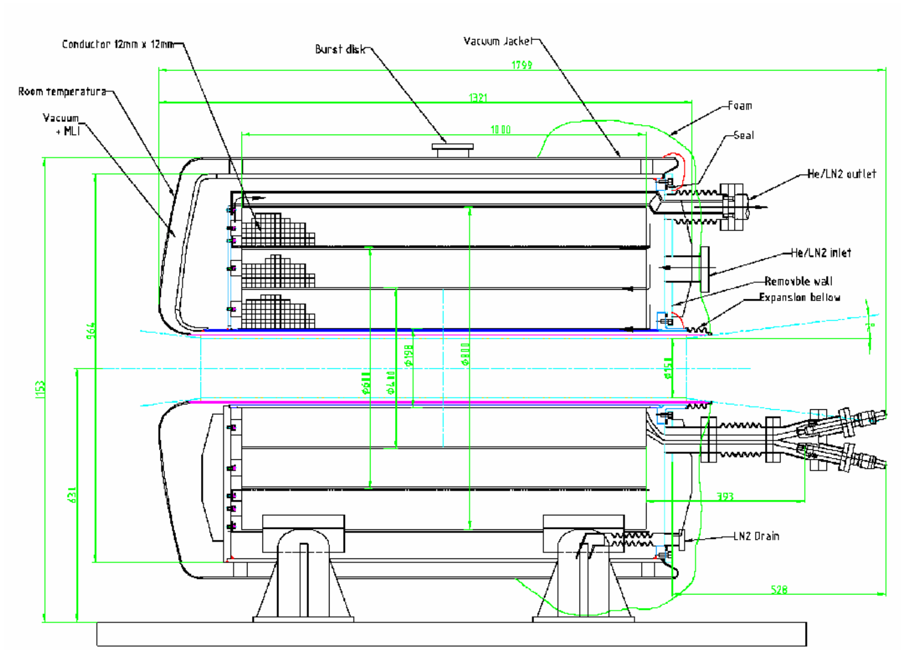
Spokespersons: H.G. Kirk, K.T. McDonald
Local Contact: H. Haseroth

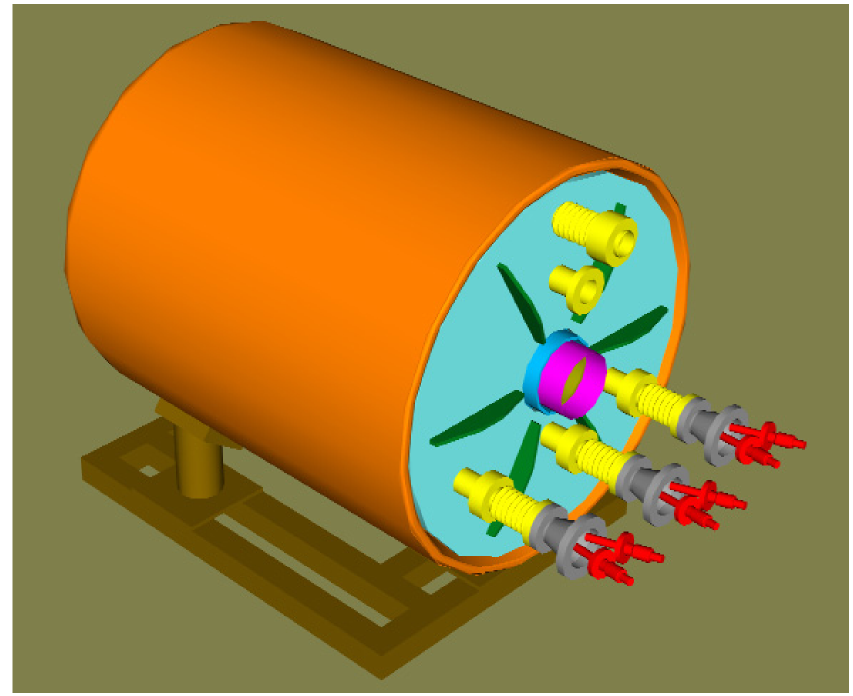
Participating Institutions

1) RAL
2) CERN
3) KEK
4) BNL
5) ORNL
6) Princeton University

Proposal submitted April 26, 2004

High Field Pulsed Solenoid





- 69º K Operation
- 15 T with 4.5 MVA Pulsed Power
- 15 cm warm bore
- 1 m long beam pipe

Peter Titus, MIT

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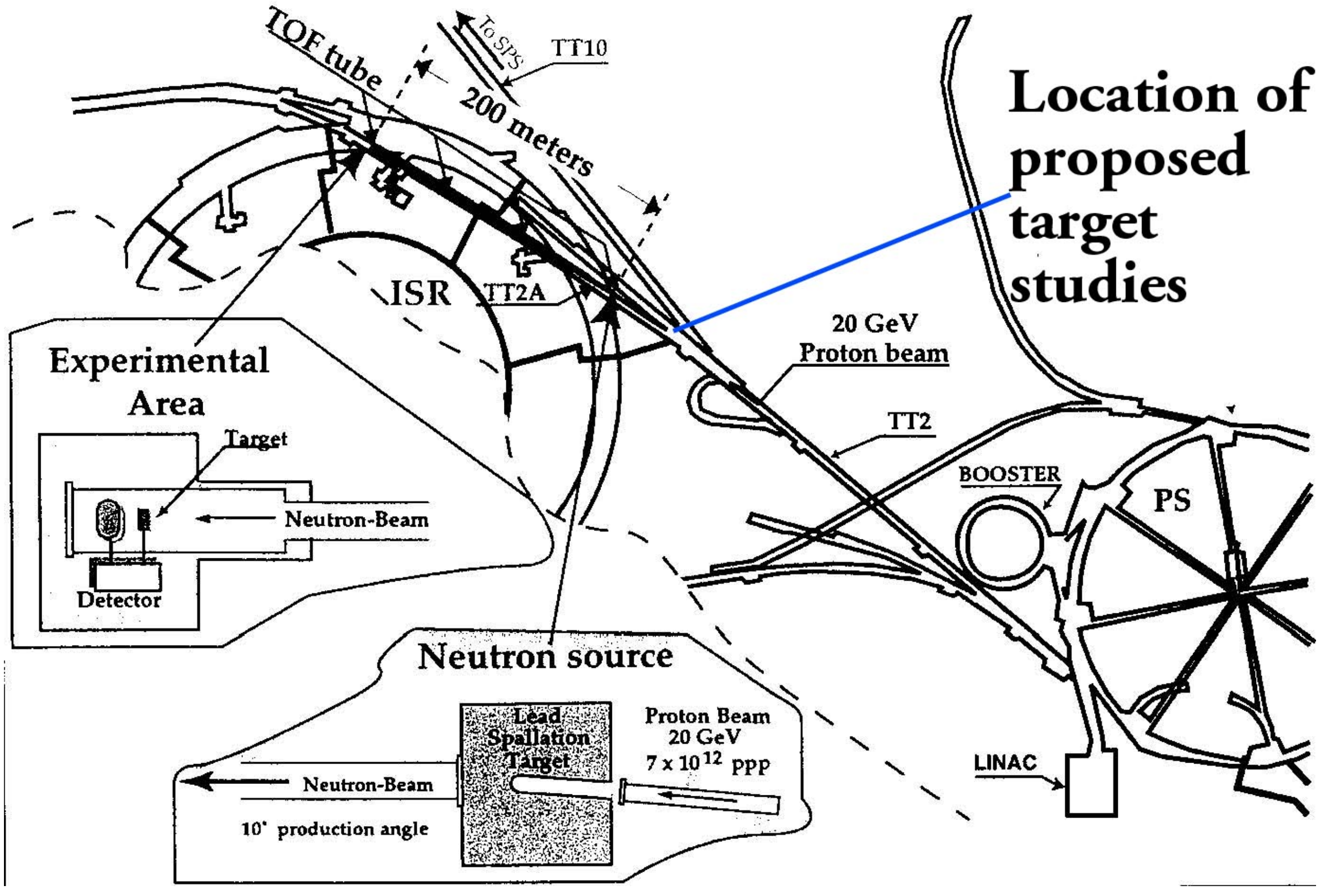
Target Test Site at CERN



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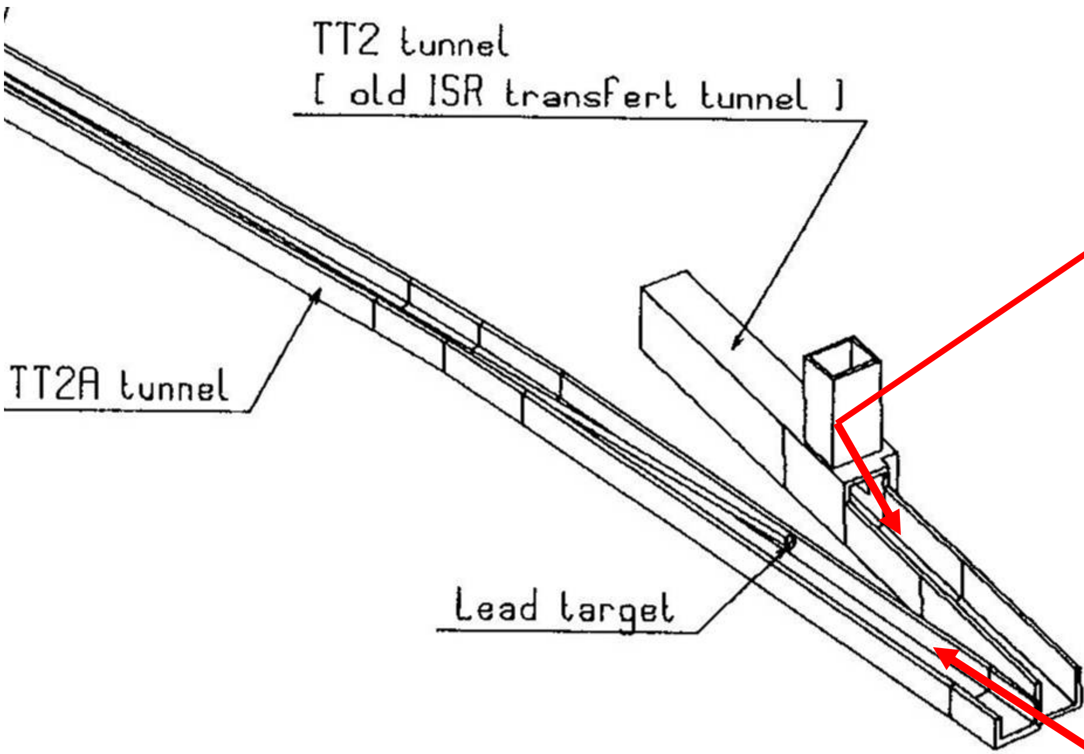
Muon Collaboration

The TT2 Tunnel Complex



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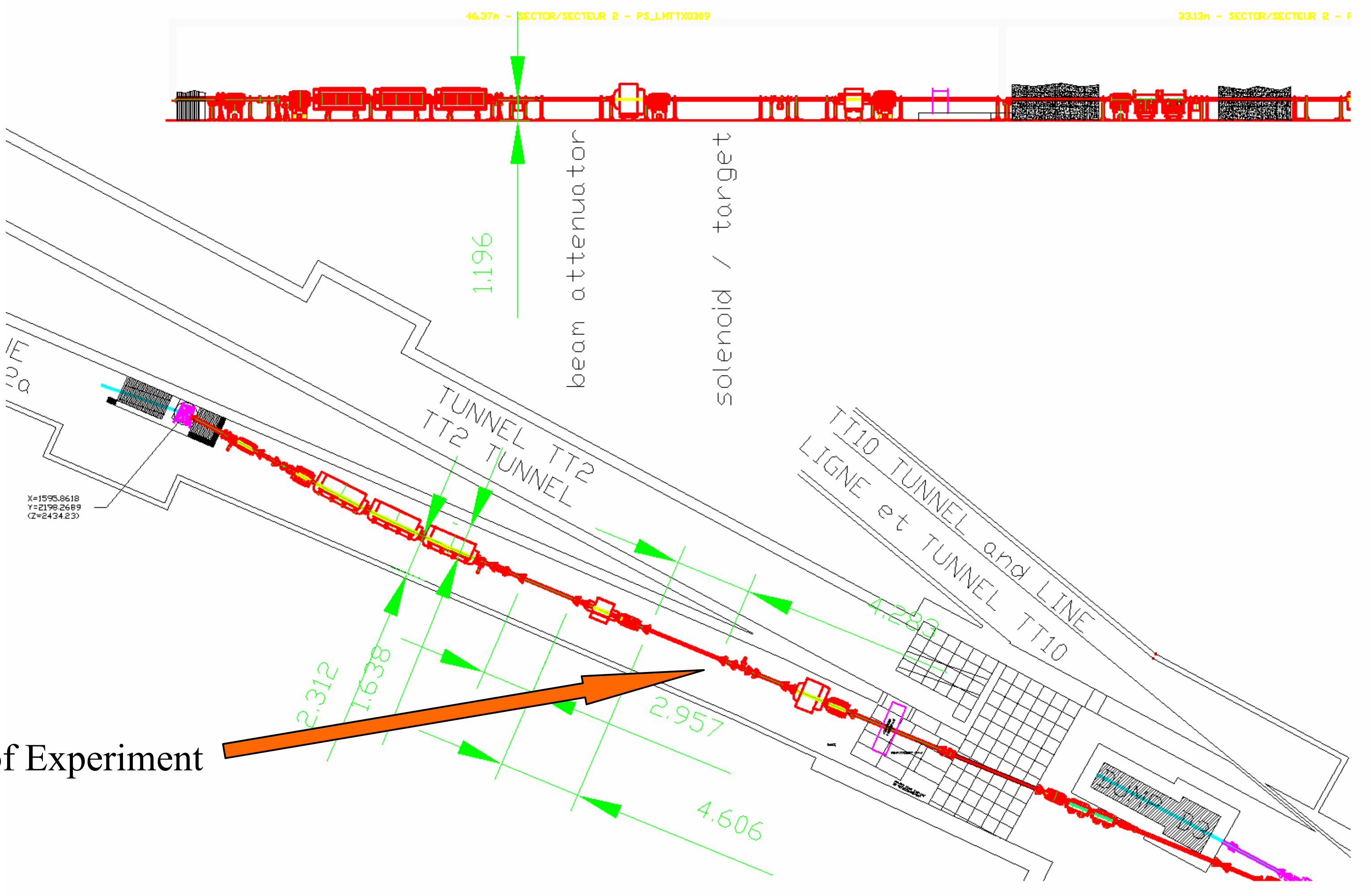
The TT2a Beamline Elements



Location of Experiment

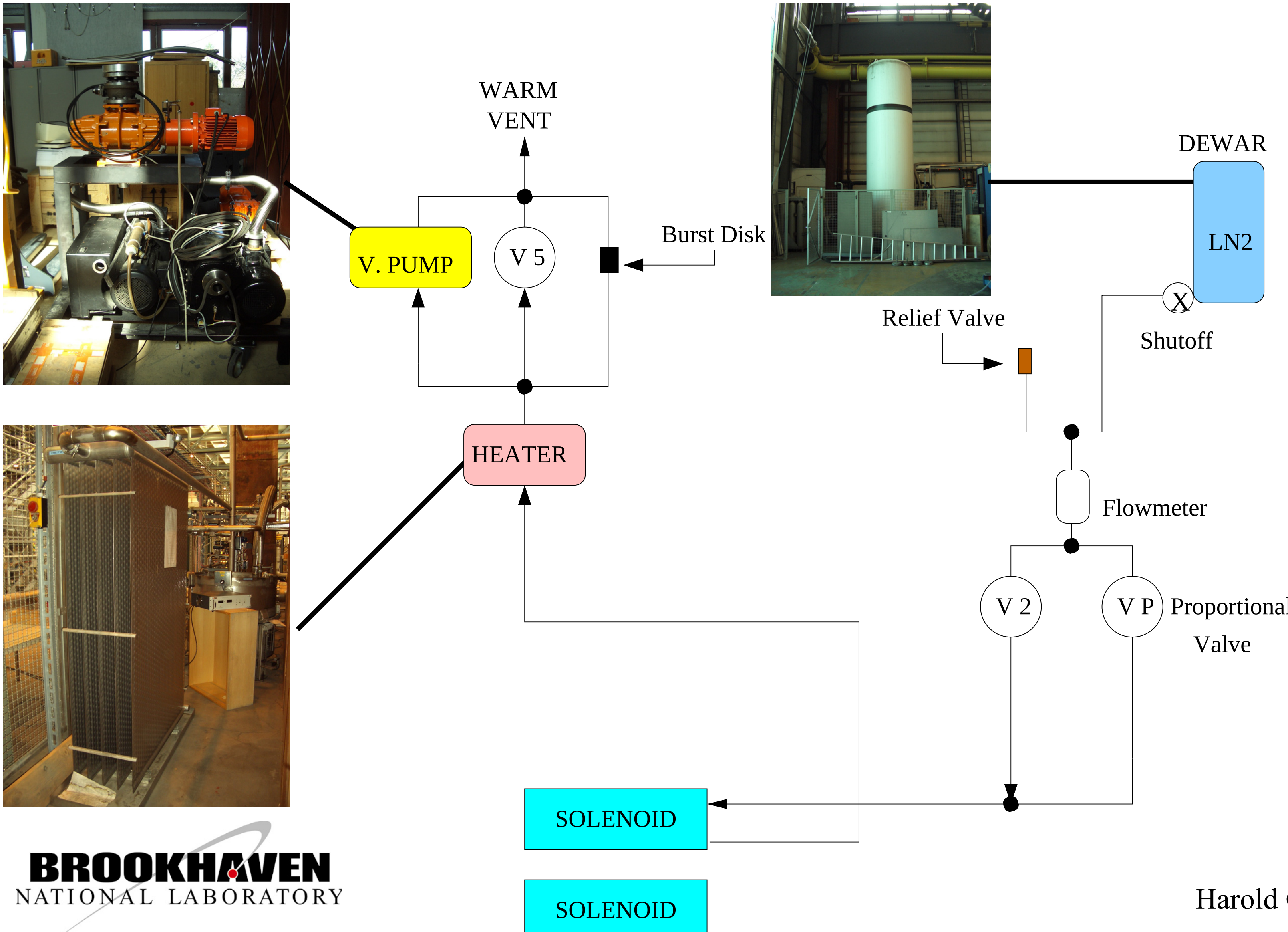
Surface above the ISR

Two 18kV sub-stations

Access Route

One 18kV Sub-station

Cryogenic Flow Scheme



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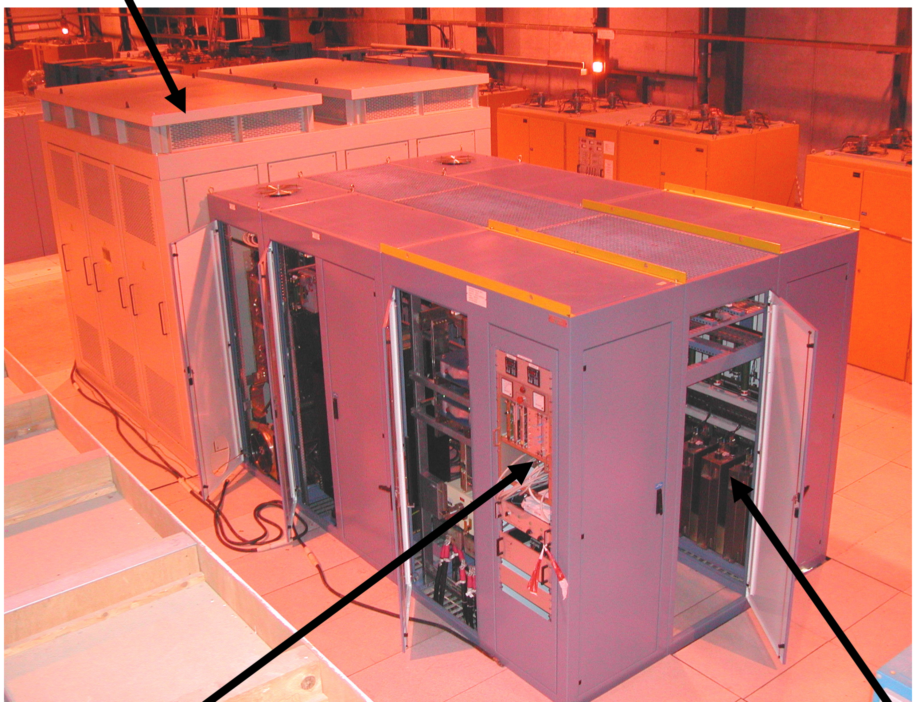
CERN proposed power supply solution type ALICE/LHCb, rated 950V, 6500A

2 x Power transformers in parallel, housed in the same cubicle



High precision current control electronics

2 x rectifier bridges in parallel

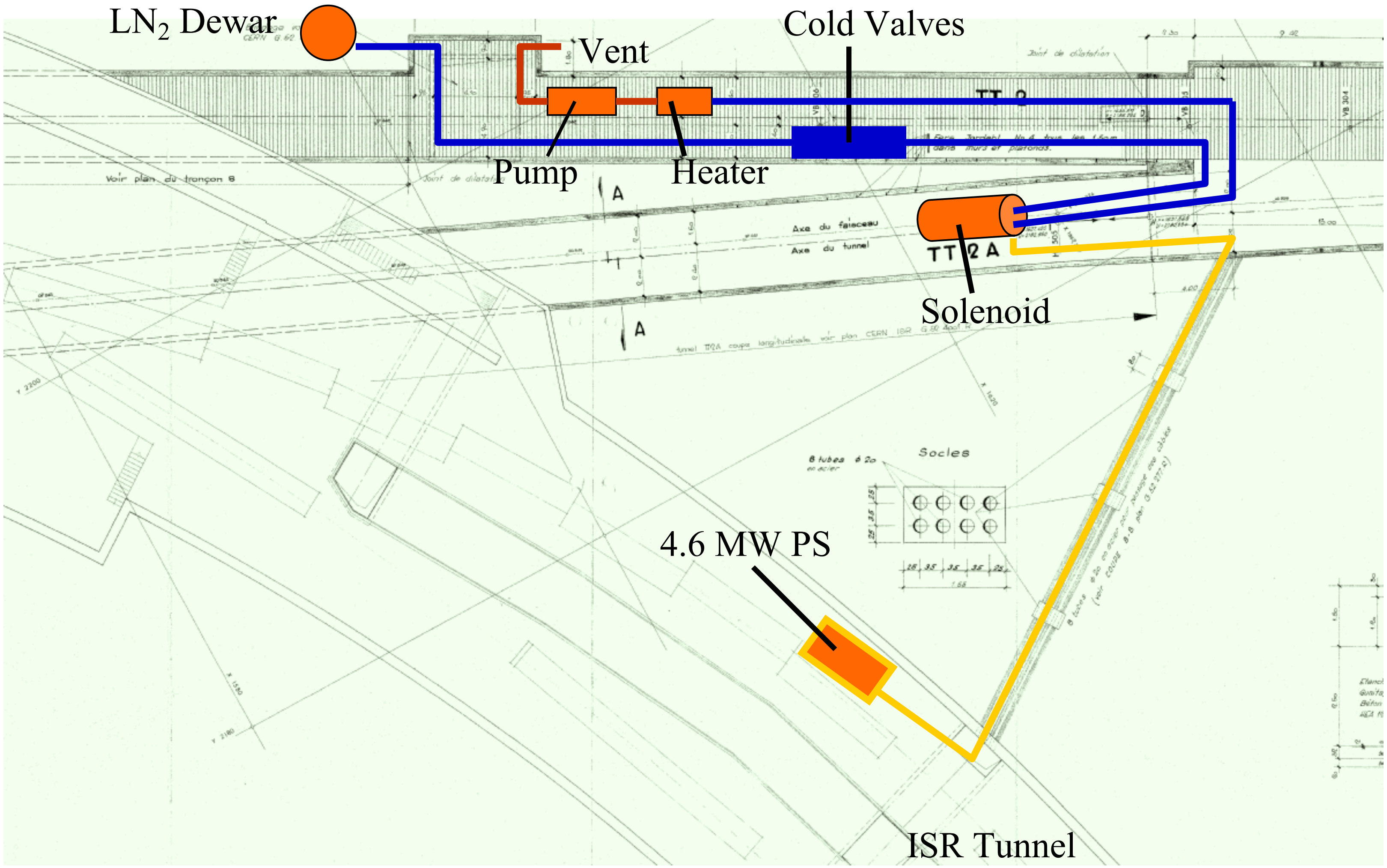
Total DC output ratings:
6500Adc, 950Vdc, 6.7 MW

AC input ratings (per rectifier bridge):
2858Arms, 900Vac (at no load), 4.5 MVA

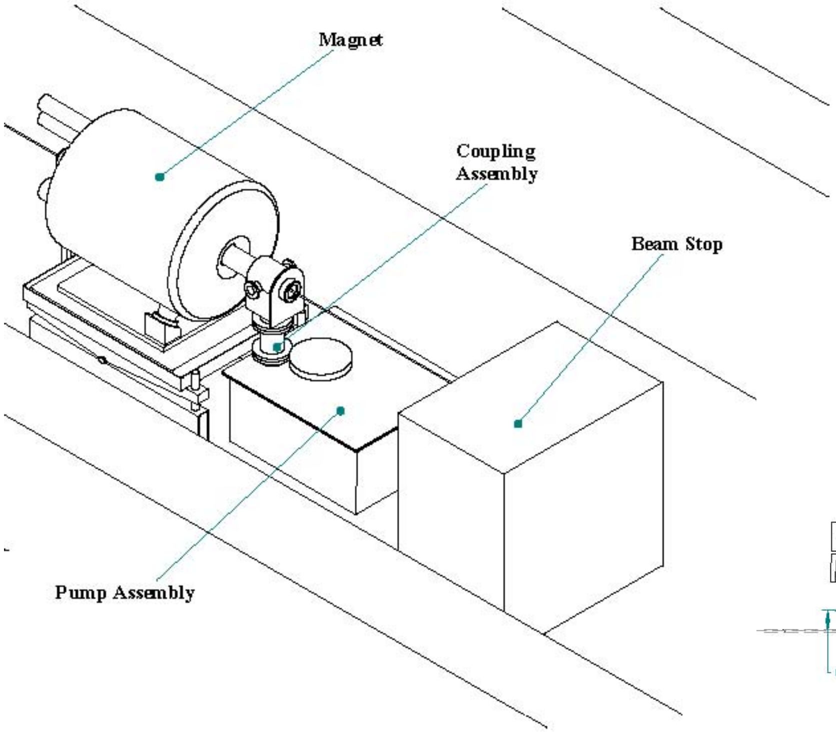
Each power transformer ratings
Primary side: 154Arms, 18kVac
Secondary side: 3080Arms, 900Vac
Nominal power: 4.8 MVA

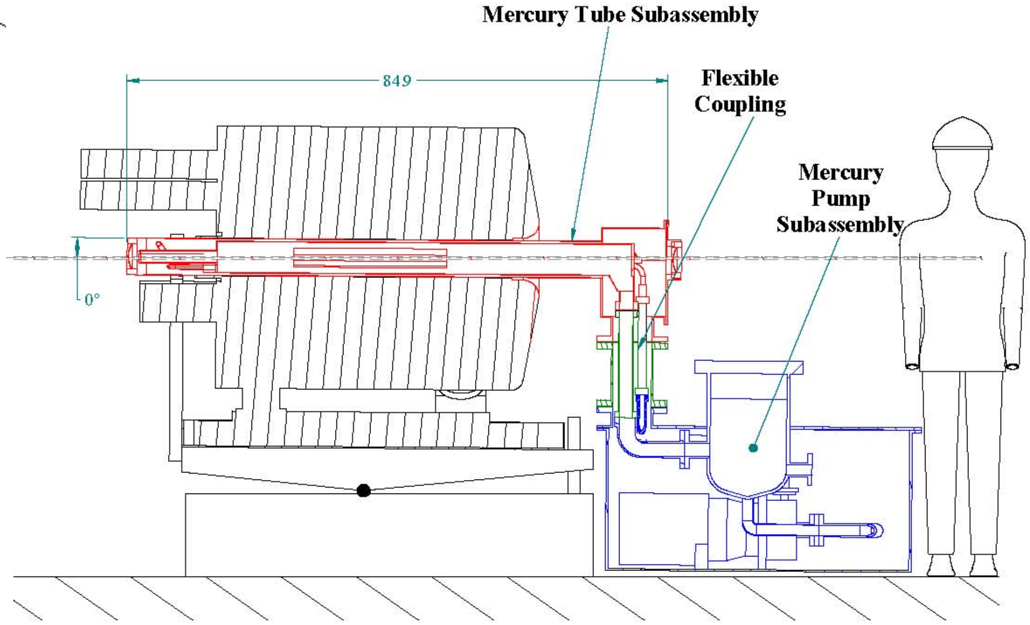
Other
- Air forced cooling;
- Fed by two18 kV lines

Layout of the Experiment



The Experimental Footprint





Run plan for PS beam spills

Our Beam Profile request allows for:

- Varying beam charge intensity from 5 (7) TP to 20 (28) TP
- Studying influence of solenoid field strength on beam dispersal (B_o from 0 to 15T)
- Vary beam/jet overlap
- Study possible cavitation effects by varying PS spill structure—Pump/Probe

Charge	Bucket Structure	Bo	Beam Shift	Number of Shots
4 x 5TP	1-2-3-4	0	0	2
4 x 5TP	1-2-3-4	5	0	2
4 x 5TP	1-2-3-4	10	0	2
4 x 5TP	1-2-3-4	15	0	2
4 x 5TP	1-2-3-4	15	+5mm	2
4 x 5TP	1-2-3-4	15	+2.5mm	2
4 x 5TP	1-2-3-4	15	-2.5mm	2
4 x 5TP	1-2-3-4	15	-5mm	2
1 x 5TP	1	15	0	2
2 x 5TP	1-2	15	0	2
3 x 5TP	1-2-3	15	0	2
4 x 5TP	1-2-3-5	0	0	2
4 x 5TP	1-2-3-5	15	0	2
4 x 5TP	1-2-3-6	0	0	2
4 x 5TP	1-2-3-6	15	0	2
4 x 5TP	1-2-3-7	0	0	2
4 x 5TP	1-2-3-7	15	0	2
4 x 5TP	1-2-3-8	0	0	2
4 x 5TP	1-2-3-8	15	0	2
Total				

High-peak Power Issues

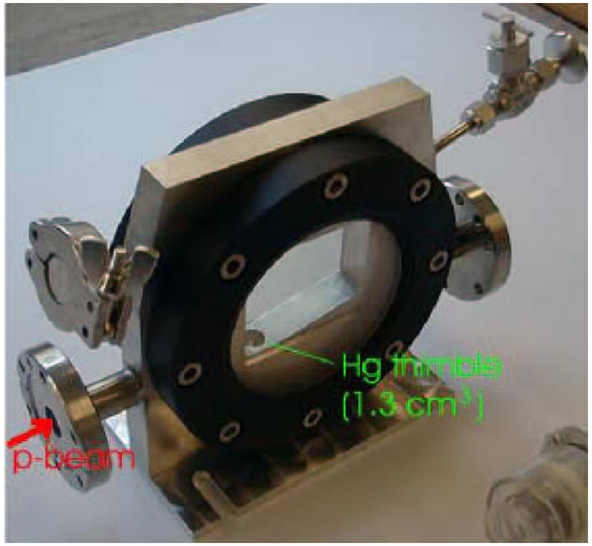
When the energy deposition time frame is on the order off or less than the energy deposition dimensions divided by the speed of sound then pressure waves generation can be an important issue.

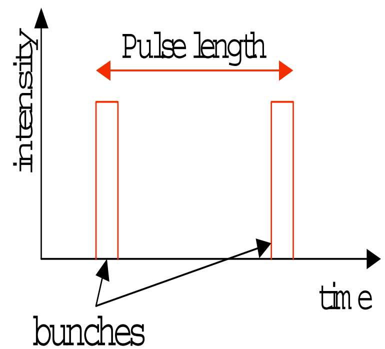
Time frame = beam spot size/speed of sound

Illustration

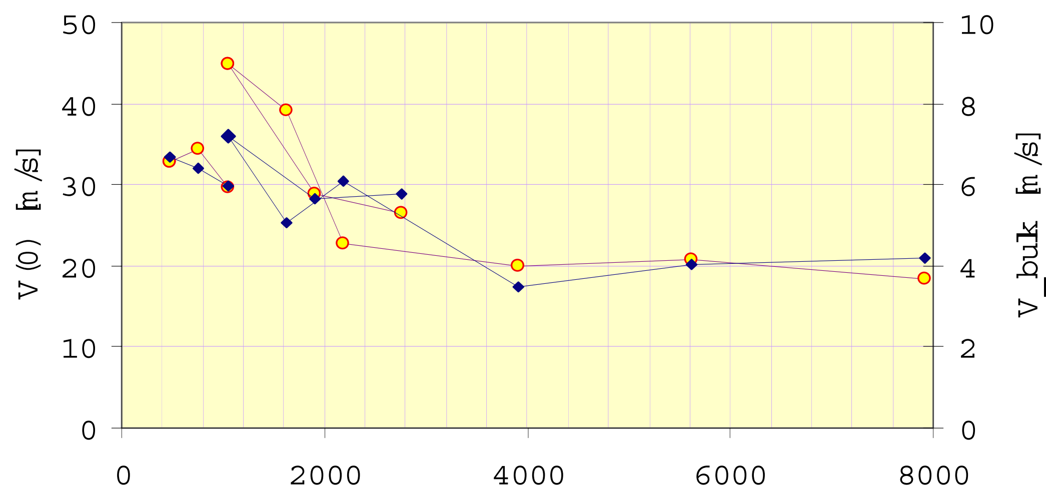
Time frame = 1cm / 5×10^3 m/s = 2 μs

CERN ISOLDE Hg Target Tests





Pulse length



Bunch Separation, ns

Proton beam 5.5 TP per Bunch.

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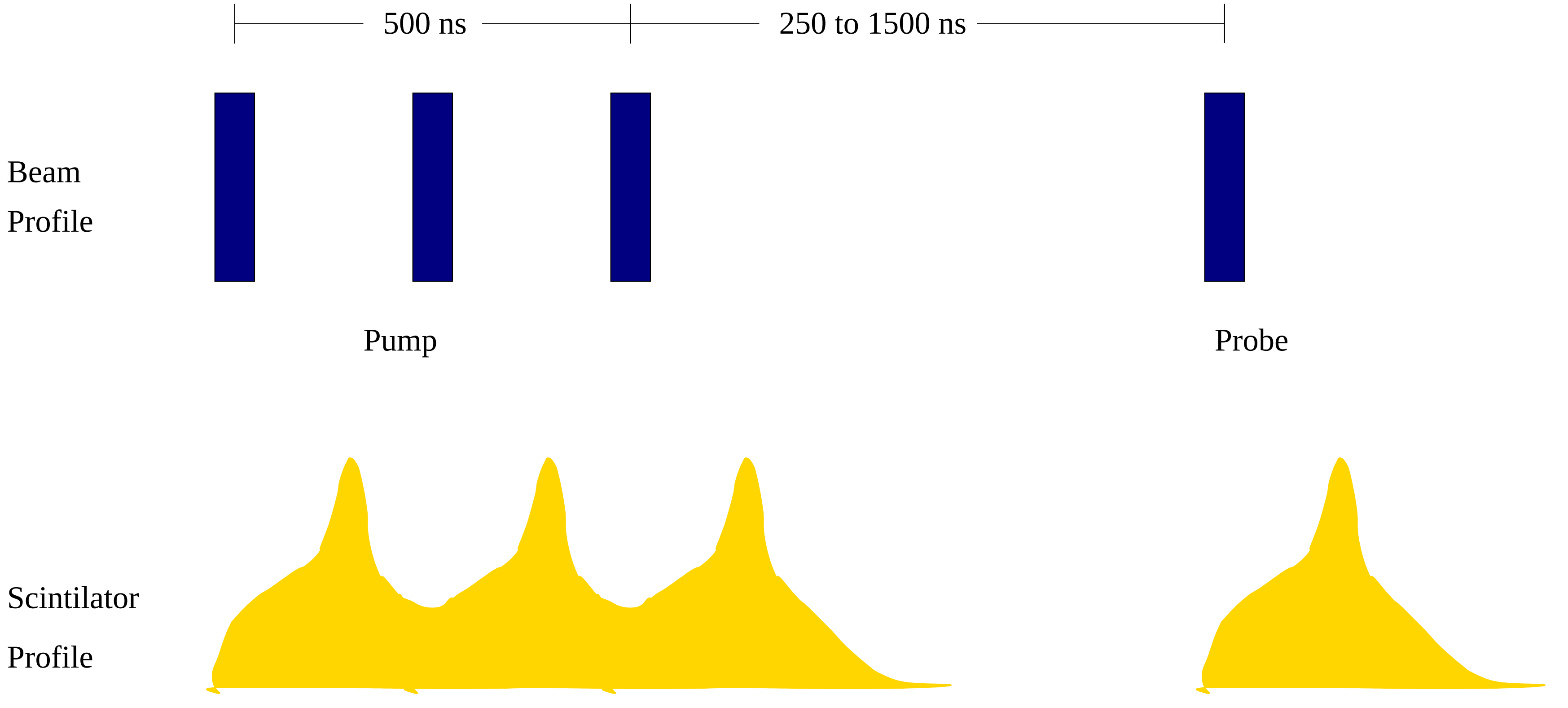
PS Extracted Beam Profile



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The Hg Jet system

More details about the experimental setup including the mercury jet system will be given tomorrow at 11:30 am in the Target and Collection session.