Muon Collaboration

The High-Power Target Experiment

NUFACT'04

Osaka, Japan

July 27, 2004

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk
Brookhaven National Laboratory

Intense Proton Sources

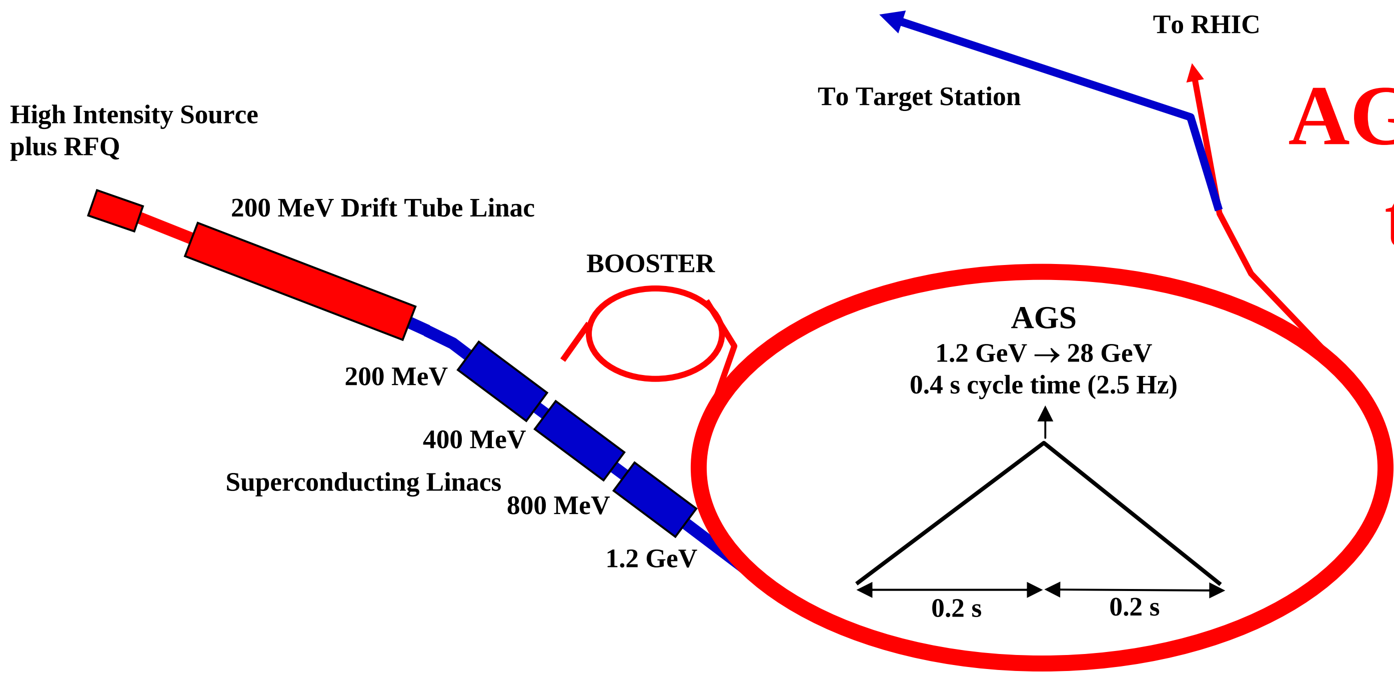
World wide interest in the development of new MW-class proton drivers

New physics opportunities utilizing intense secondary beams are presenting themselves

- Neutron Sources
  - European Spallation Source
  - US Spallation Neutron Source
  - Japanese Neutron Source
- Kaons
  - RSVP at BNL
  - KAMI at FNAL
- Muons
  - MECO and g-2 at BNL
  - SINDRUM at PSI
  - EDM at JPARC
  - Muon Collider
- Neutrinos
  - Superbeams
  - Neutrino Factories
  - Beta-beams

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



AGS Upgrade to 1 MW

Harold G. Kirk

High-power Targetry Challenges

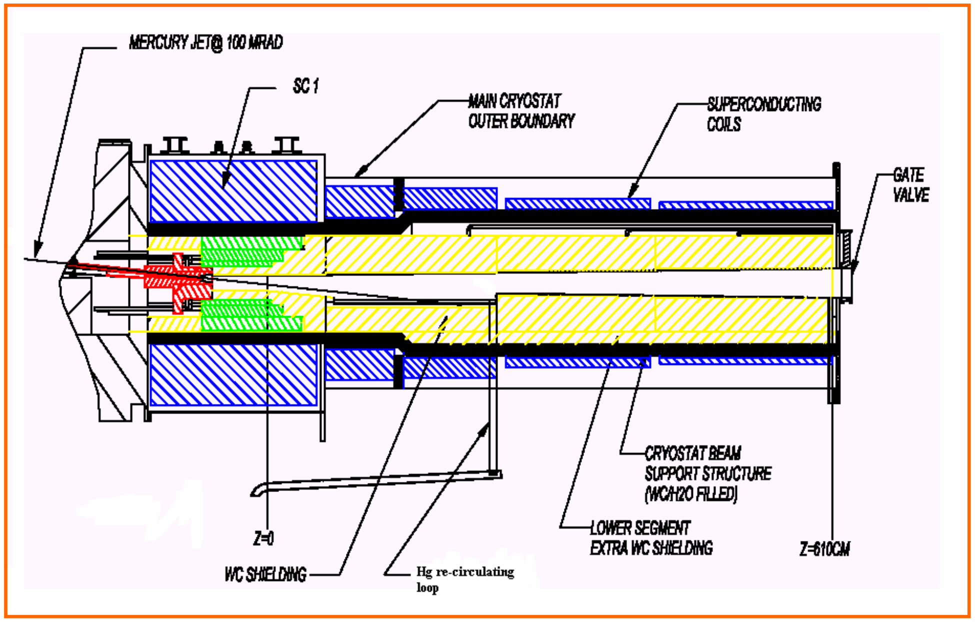
High-average power and high-peak power issues

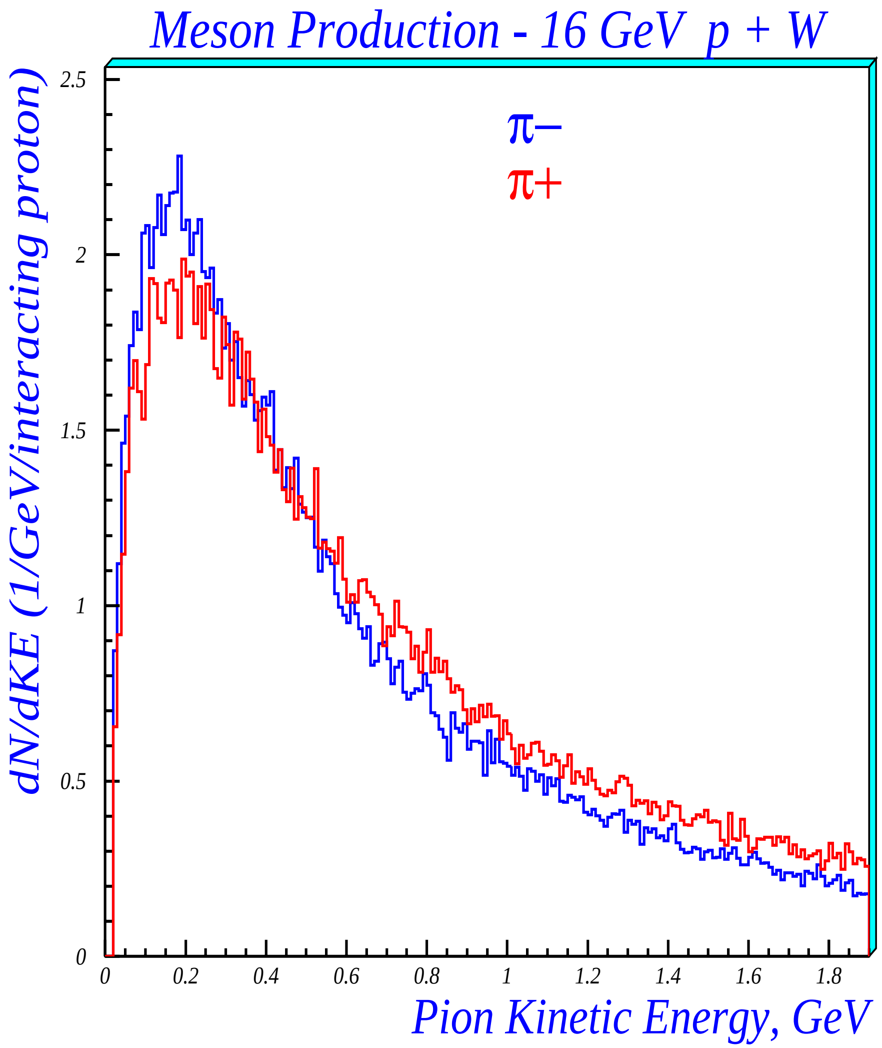
- Thermal management
  - Target melting
  - Target vaporization
- Thermal shock
  - Beam-induced pressure waves
- Radiation
  - Material properties
  - Radioactivity inventory
  - Remote handling

Achieving Intense Muon Beams

Maximize Pion/Muon Production

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





Harold G. Kirk

High-Z Materials

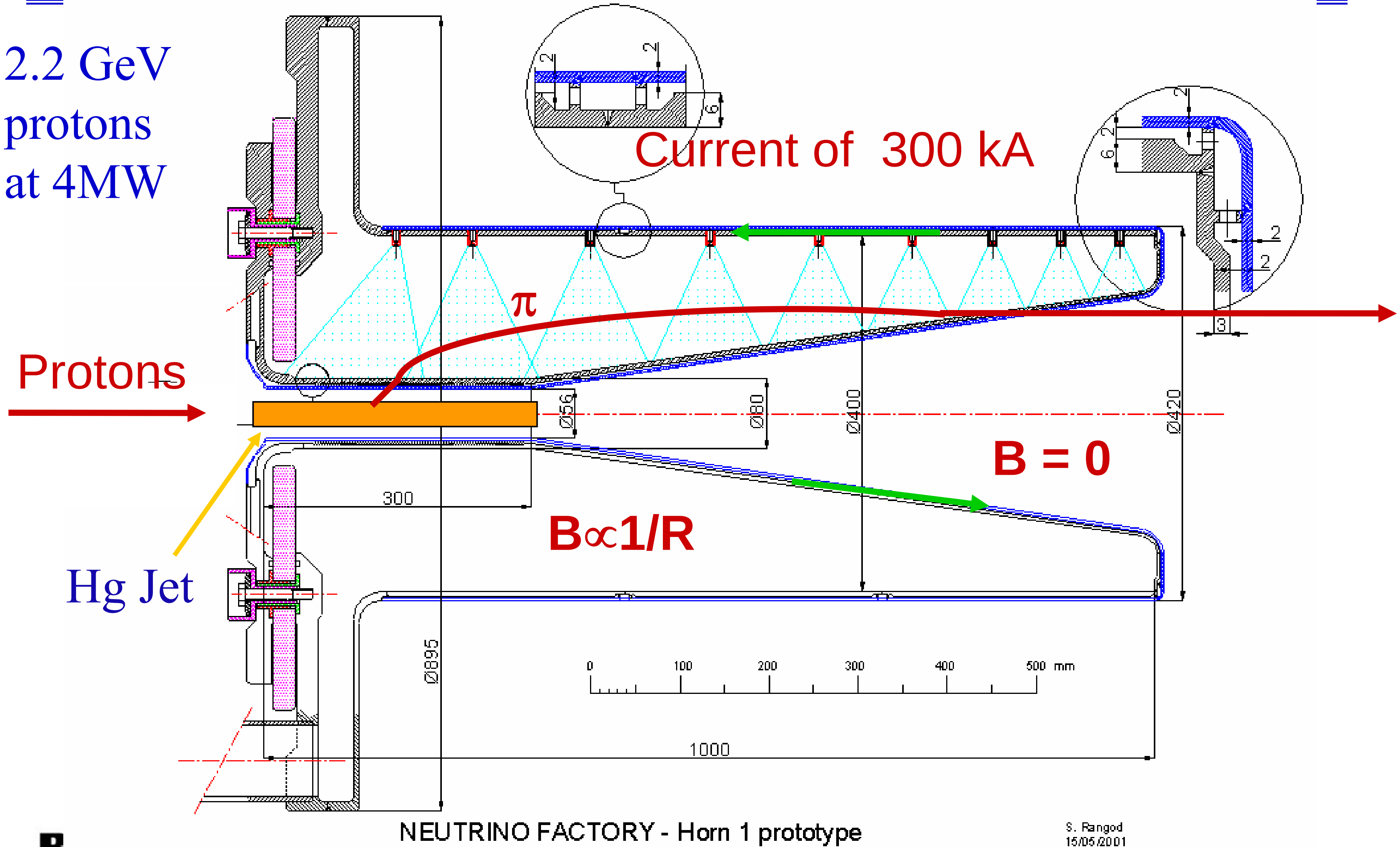
Key Properties

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

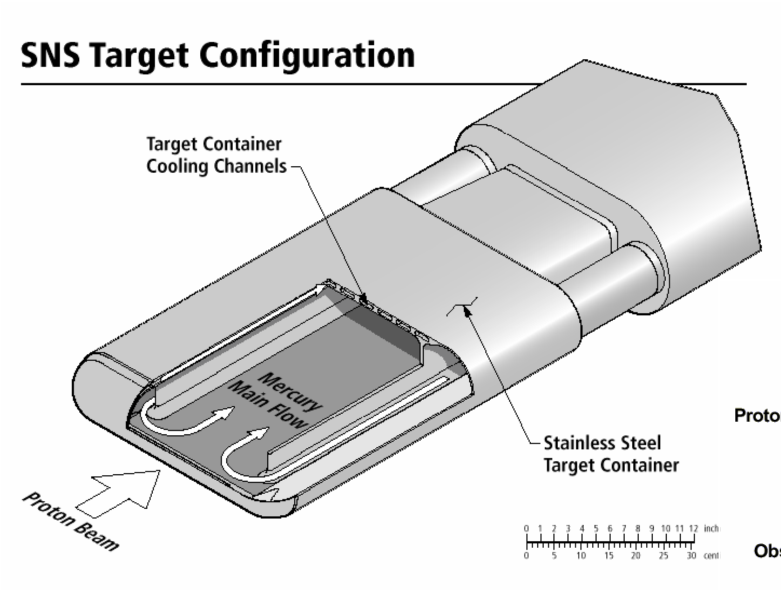
Key Issues

- 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

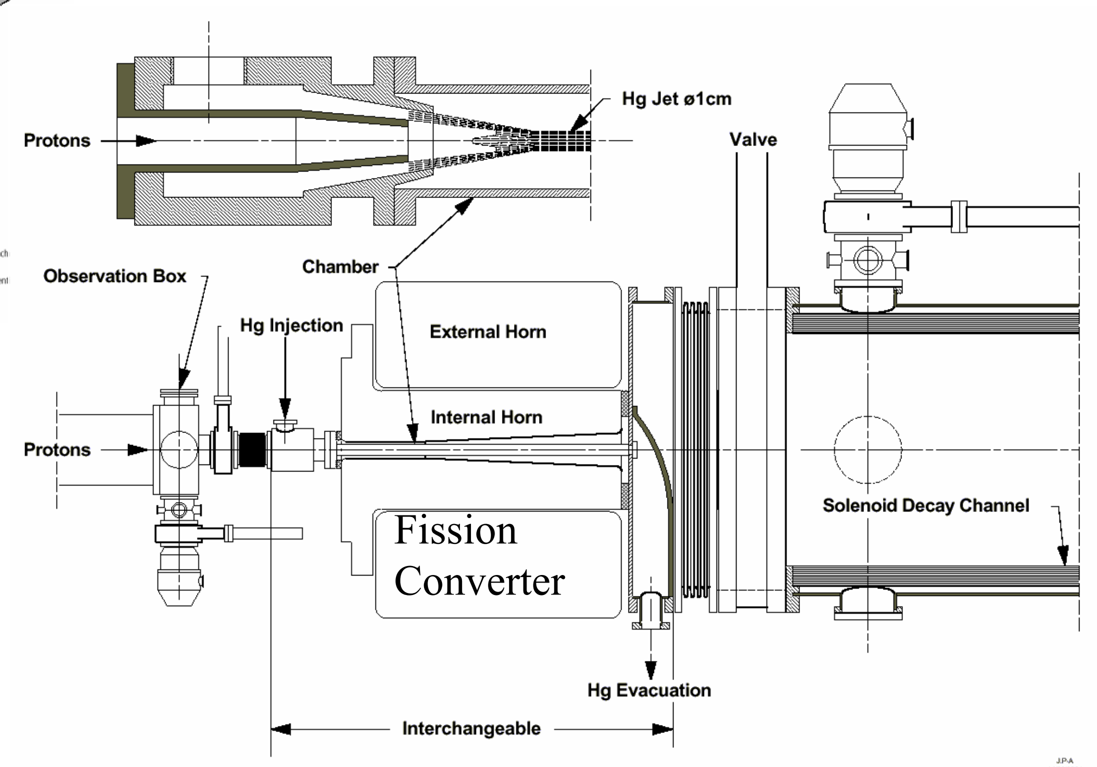


Neutron Production using Hg



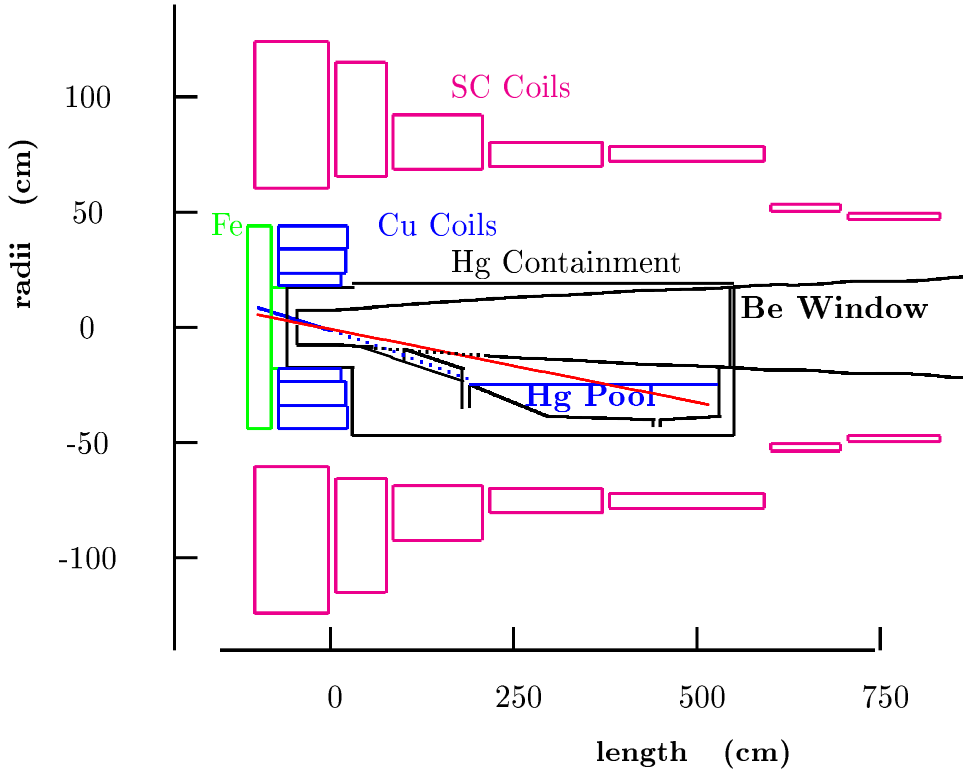
SNS Neutron
Spallation Target

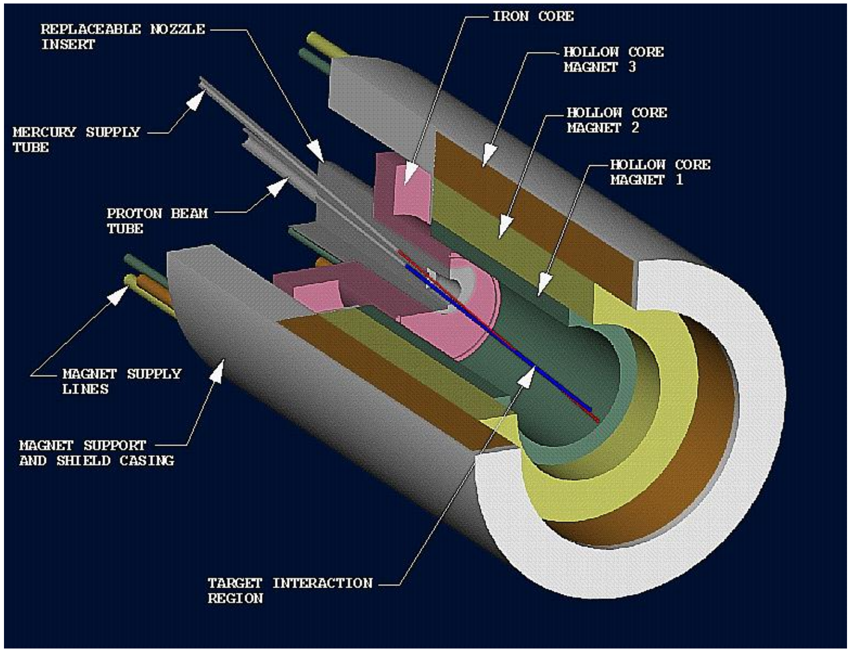
Beta Beams



Harold G. Kirk

Neutrino Factory Targetry Concept





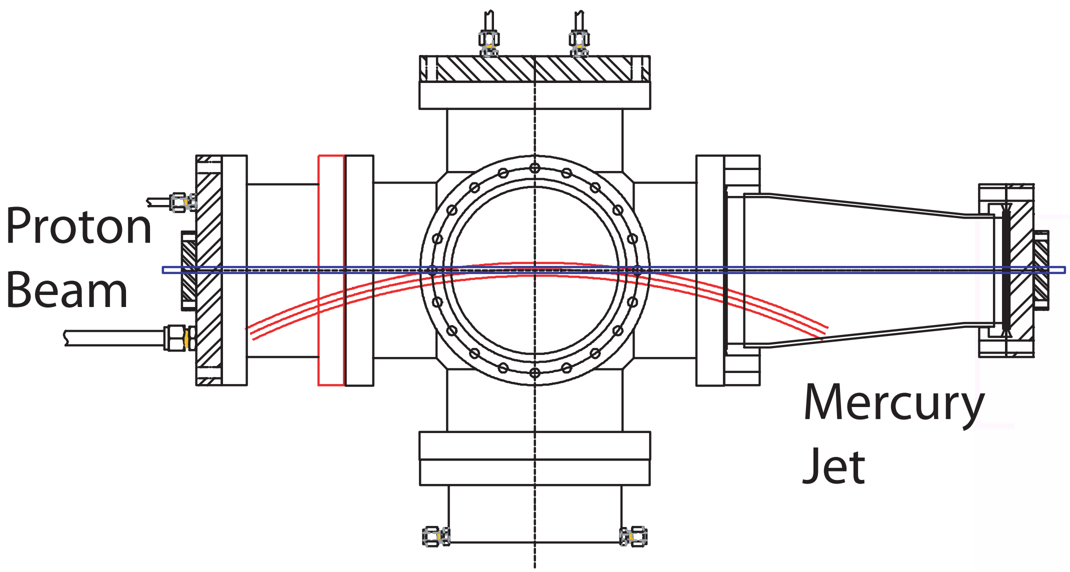
Capture low P_T pions in a high-field solenoid
Use Hg jet tilted with respect to solenoid axis
Use Hg pool as beam dump

Engineered solution--P. Spampinato, ORNL

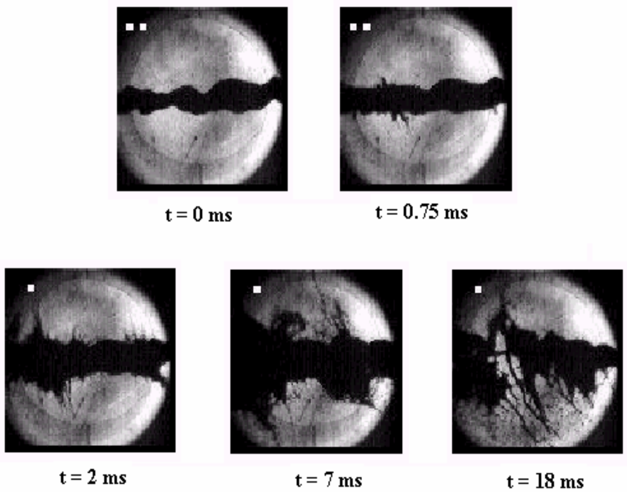
BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

E951 Hg Jet Tests



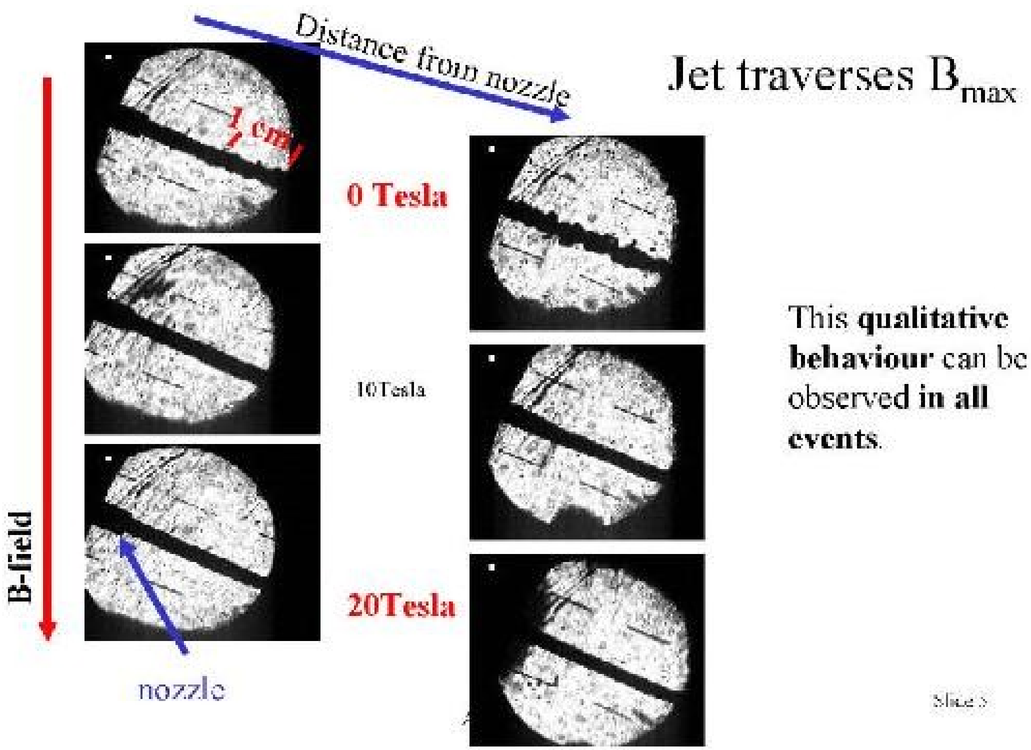
- 1cm diameter Hg Jet
- V = 2.5 m/s
- 24 GeV 4 TP Proton Beam
- <u>No</u> Magnetic Field



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:

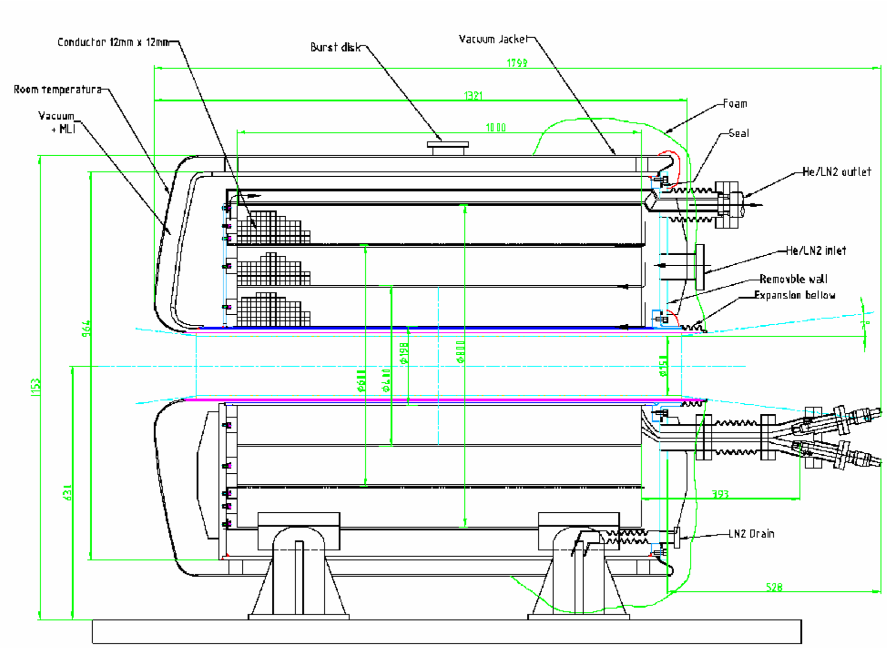
- A high-power intense proton beam (16 to 32 TP per pulse)
- A high ($\geq$ 15T) solenoidal field
- A high (> 10m/s) velocity Hg jet
- A ~1cm diameter Hg jet

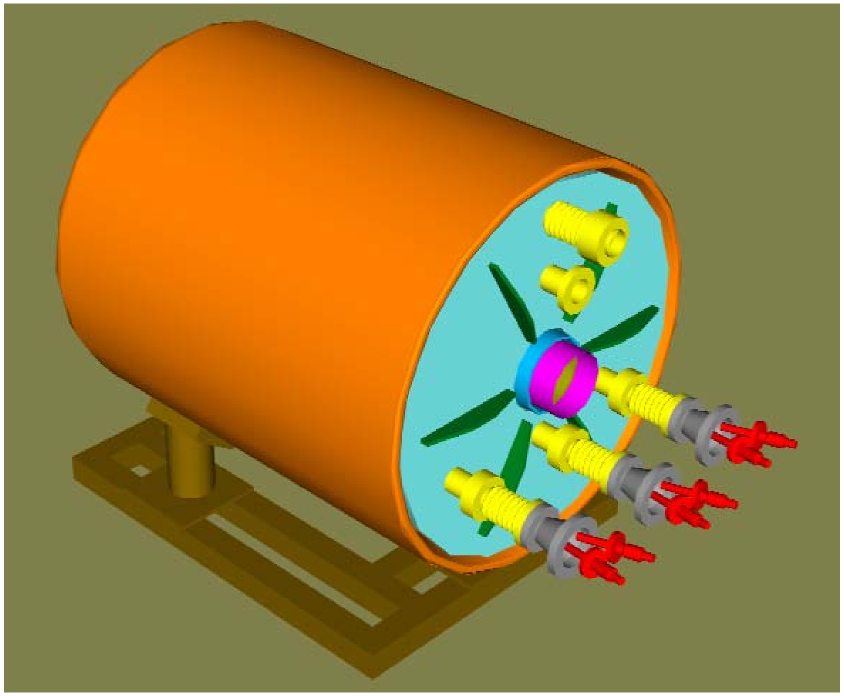
Experimental goals include:

- 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

Muon Collaboration

High Field Pulsed Solenoid





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

Peter Titus, MIT

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

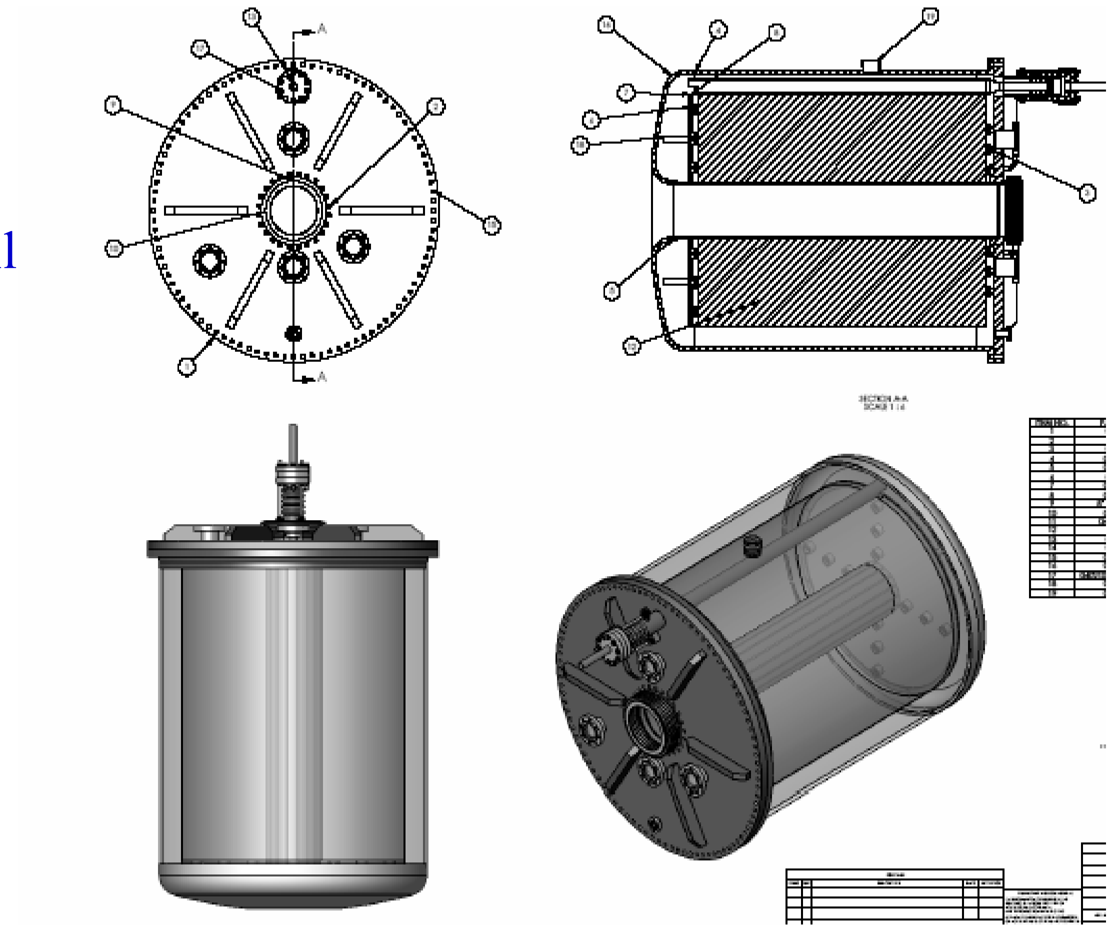
Fabrication Contract has been Awarded

CVIP has been awarded the contract for the pulsed solenoid.

They are responsible for the cryostat and integration of the coil package into the cryostat.

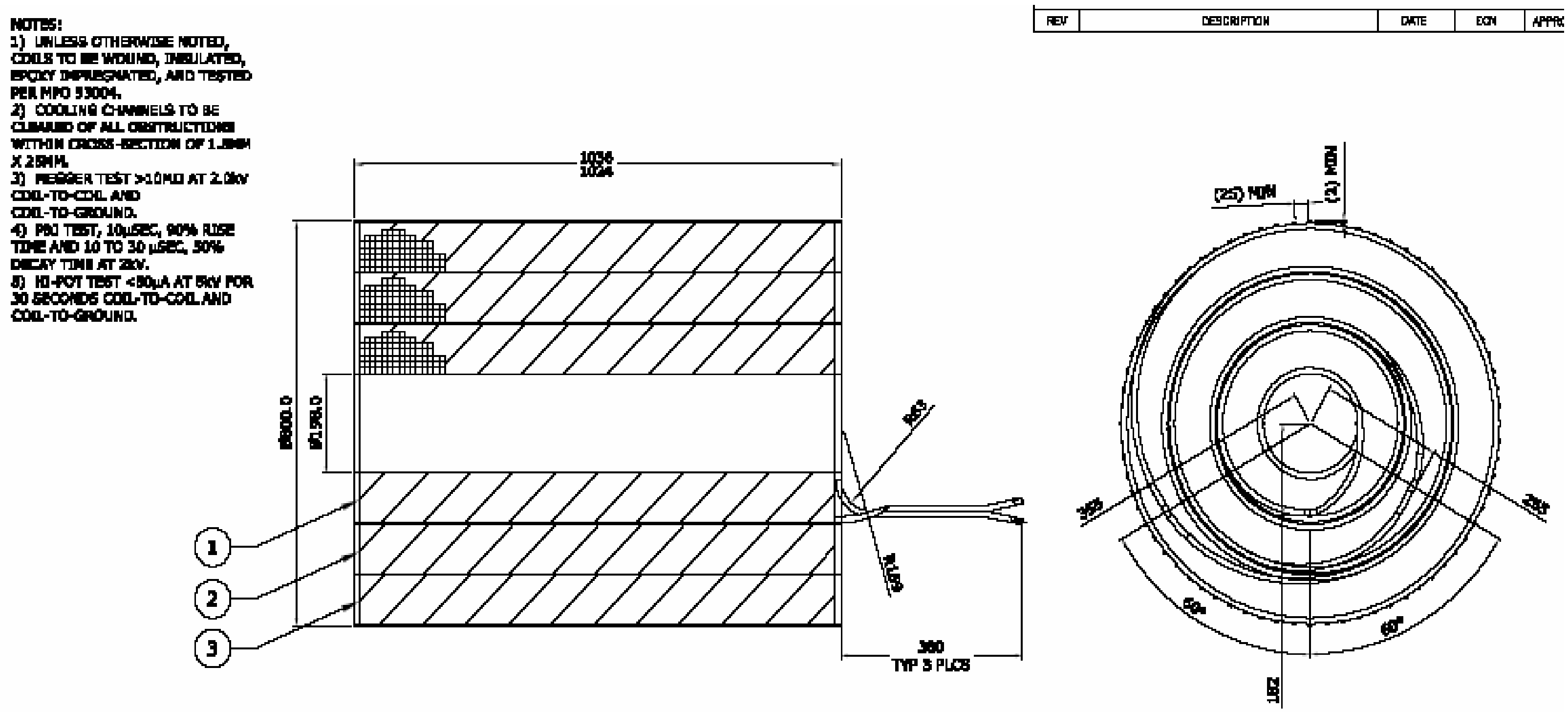
We are now receiving build-to-print drawings from CVIP for approval.

Scheduled delivery is Nov. 2004



Coil Fabrication

Everson-Tesla, Inc has been sub-contracted to fabricate the coils



BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

Possible Target Test Station Sites

Accelerator Complex Parameters:

Parameter	BNL AGS	CERN PS	RAL ISIS	LANCE WNR	JPARC RCS	JPARC MR
Proton Energy, GeV	24	24	0.8	0.8	3	50
p/bunch, 10^{12}	6	4 (7 CNGS)	10	28	42	42
Bunch/cycle	12	8	2	1	2	9
p/cycle, 10^{12}	72	28 (56 CNGS)	20	28	83	300
Cycle length, μs	2.2	2.0	0.3	0.25	0.6	4.2
Availability (?)	07	06	06	Now	08	09

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

J. Roger J. Bennett[1], Luca Bruno[2], Chris J. Densham[1], Paul V. Drumm[1],
T. Robert Edgecock[1], Tony A. Gabriel[3], John R. Haines[3], Helmut Haseroth[2],
Yoshinari Hayato[4], Steven J. Kahn[5], Jacques Lettry[2], Changguo Lu[6], Hans Ludewig[5],
Harold G. Kirk[5], Kirk T. McDonald[6], Robert B. Palmer[5], Yarema Prykarpatskyy[5],
Nicholas Simos[5], Roman V. Samulyak[5], Peter H. Thieberger[5], Koji Yoshimura[4]

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

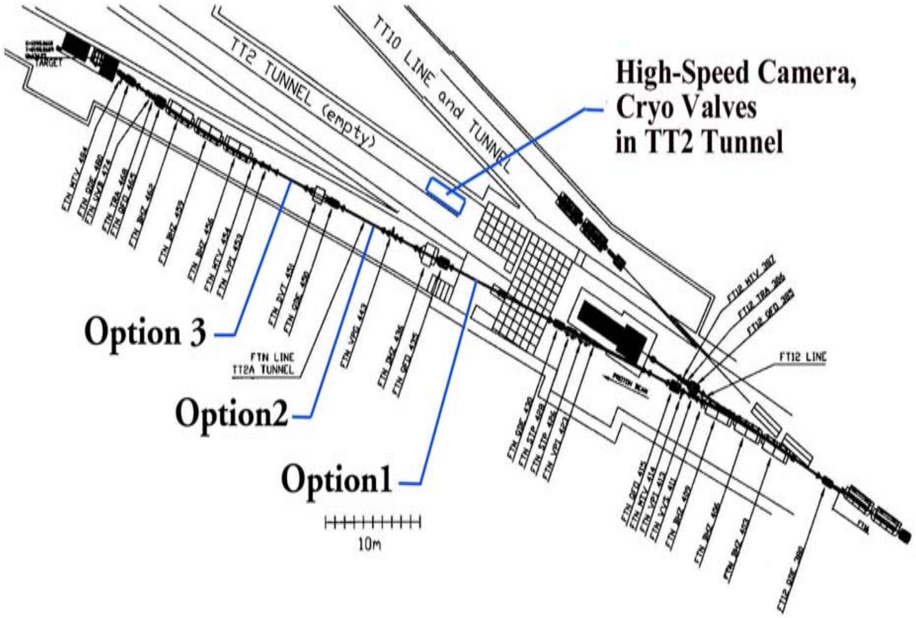
Participating Institutions

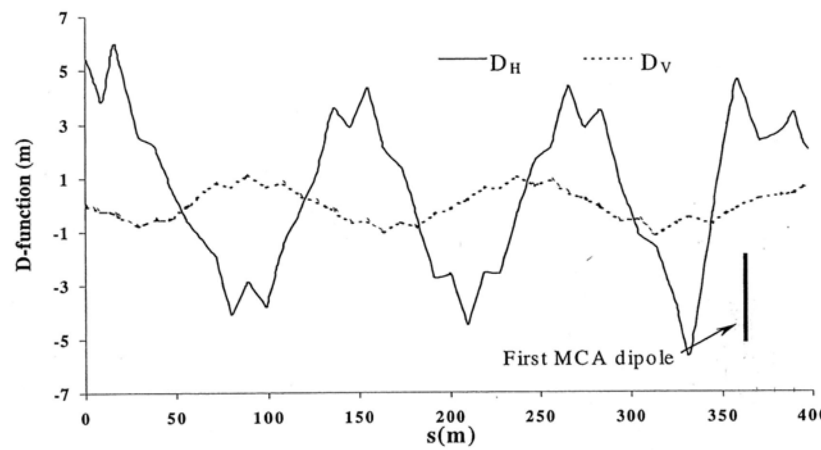
1) RAL
2) CERN
3) KEK
4) BNL
5) ORNL
6) Princeton University

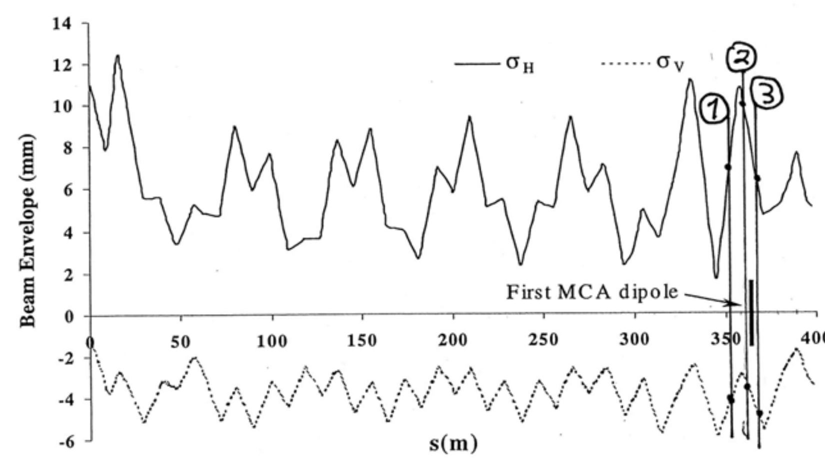
Proposal submitted April 26, 2004

Harold G. Kirk

The TT2a Beam Line

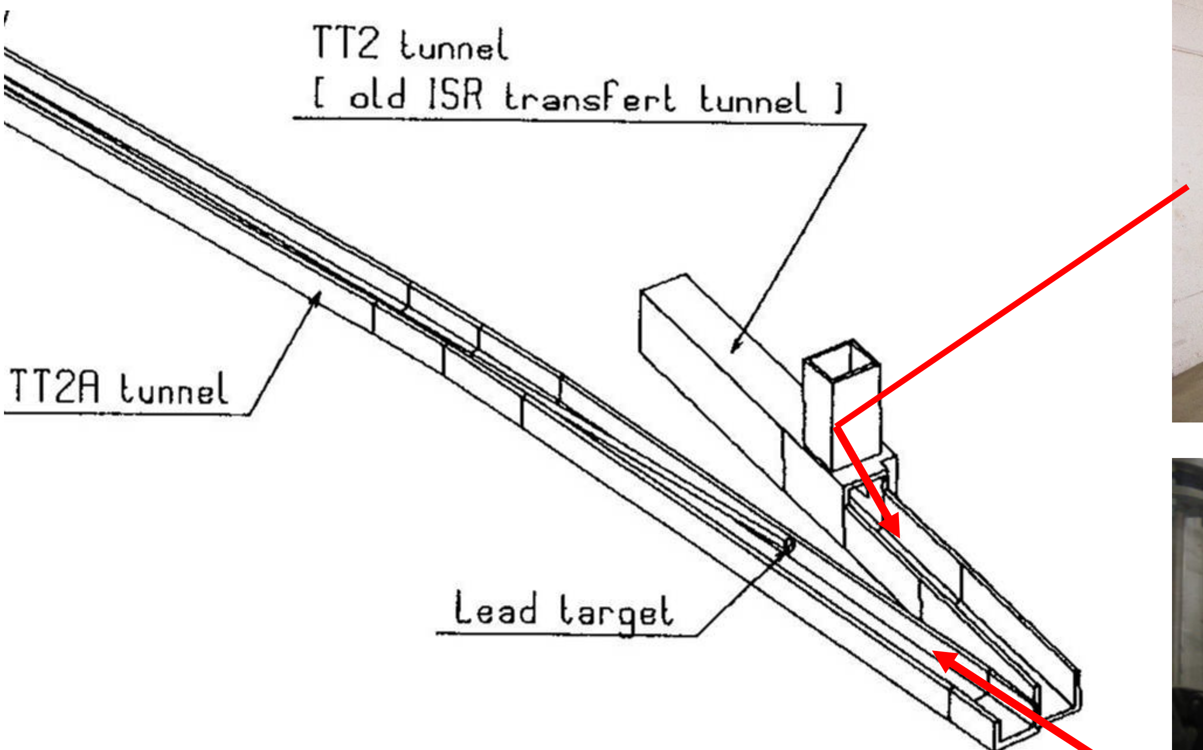






We propose running without longitudinal bunch compression allowing for a reduced beam spot size of ~ 2mm rms radius.

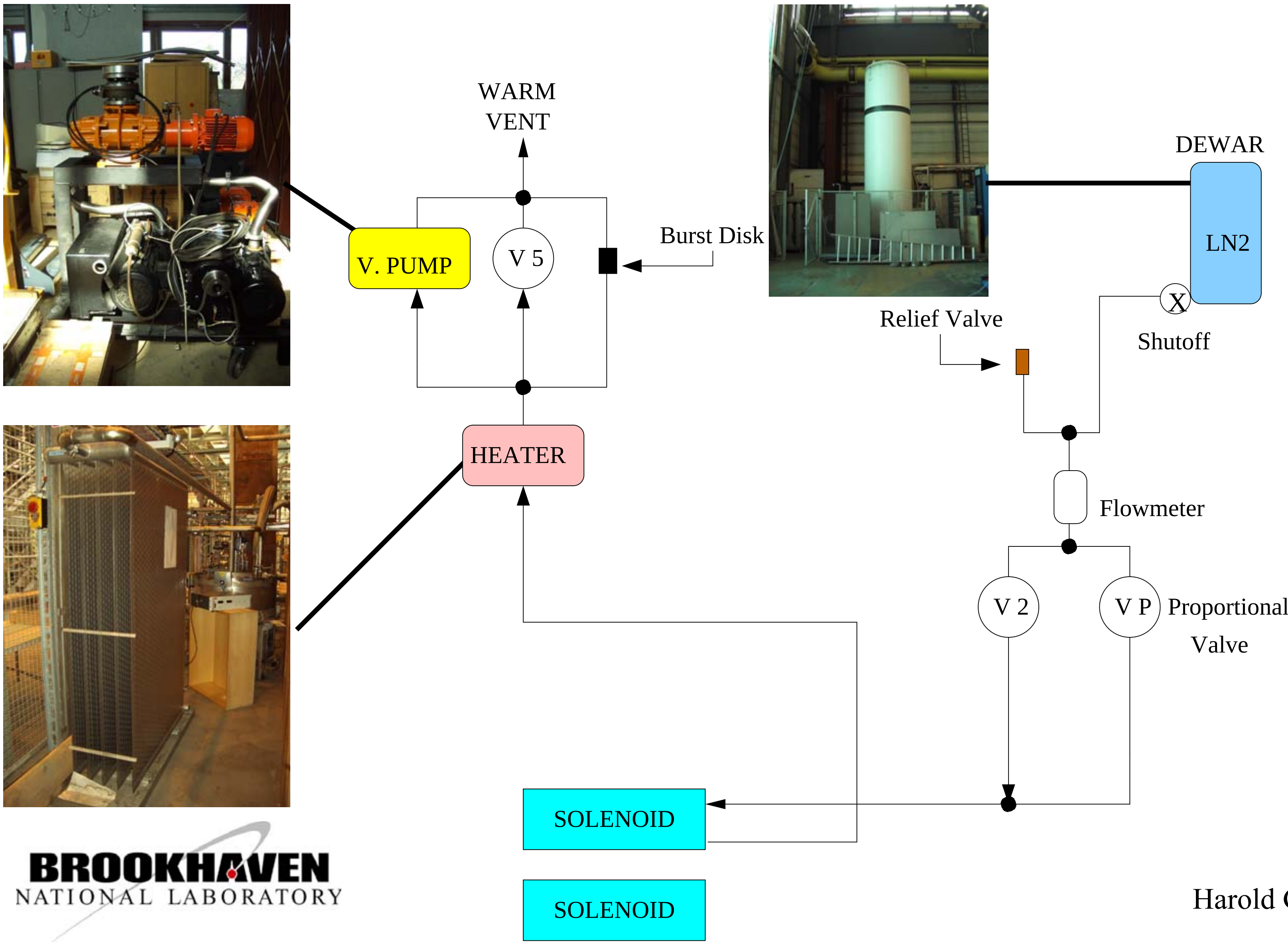
The TT2 Tunnel Complex



Harold G. Kirk

Muon Collaboration

Cryogenic Flow Scheme

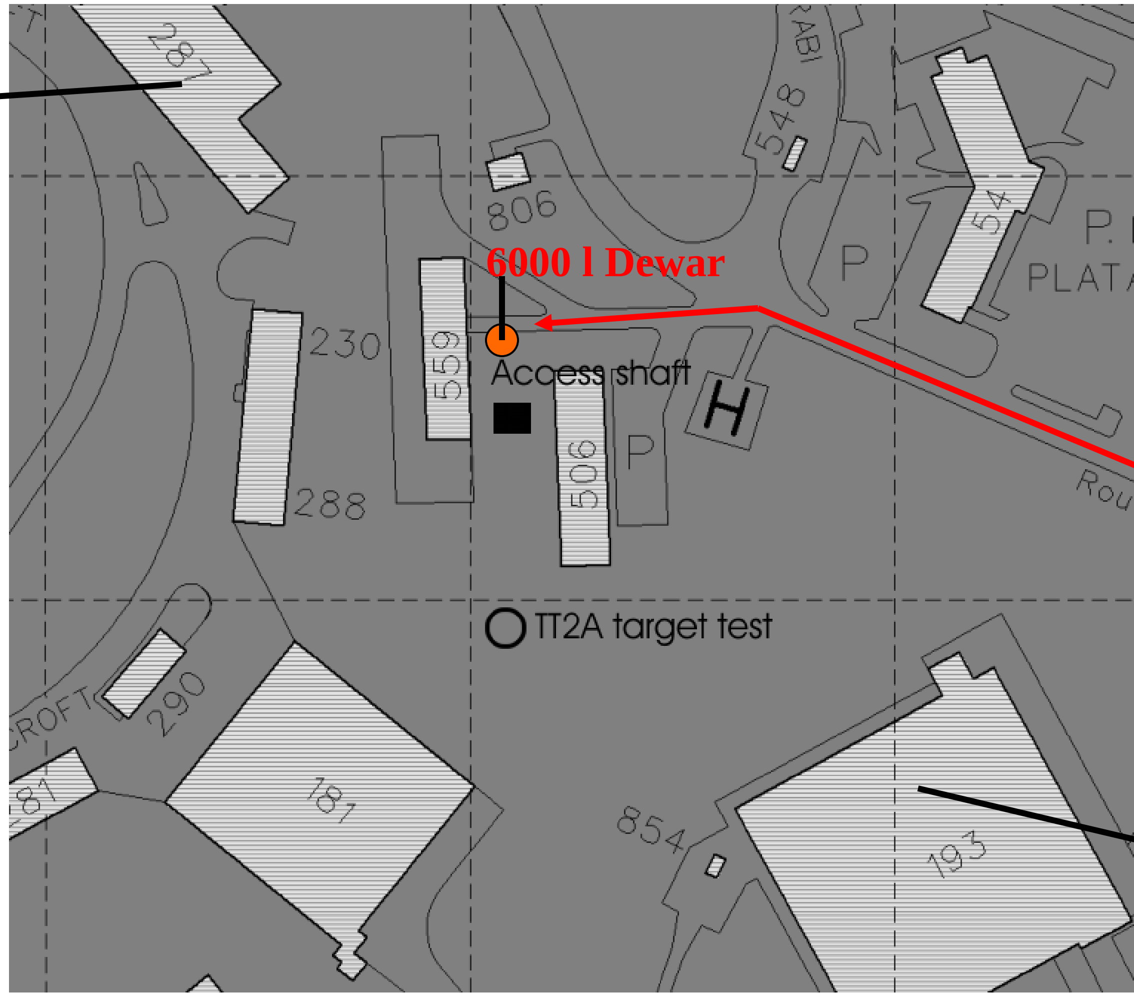


BROOKHAVEN
NATIONAL LABORATORY

Harold G. Kirk

Surface above the ISR

Two 18kV sub-stations

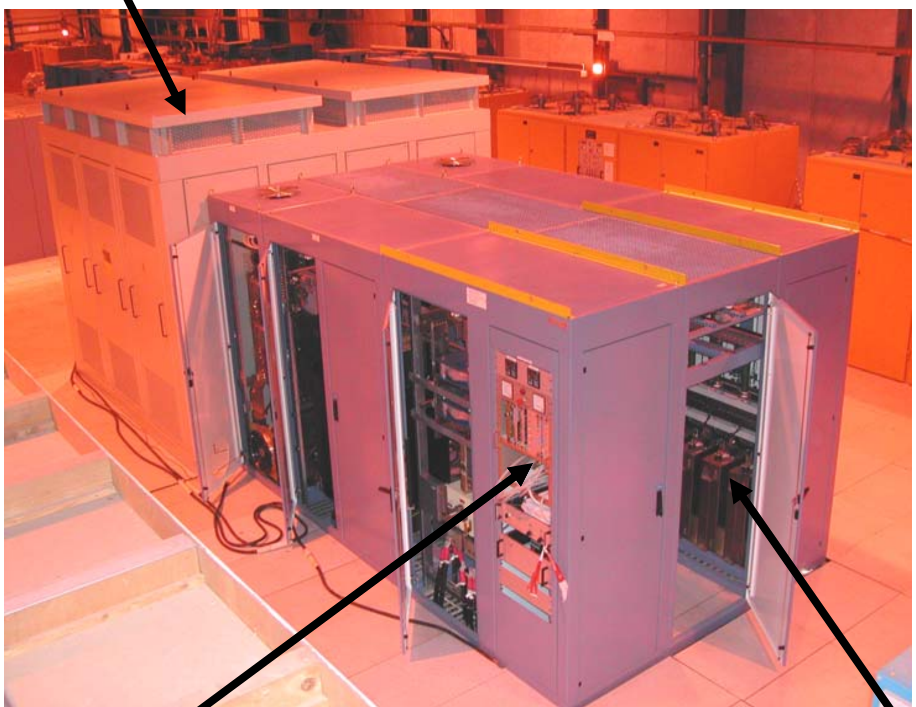


Access Route

One 18kV Sub-station

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

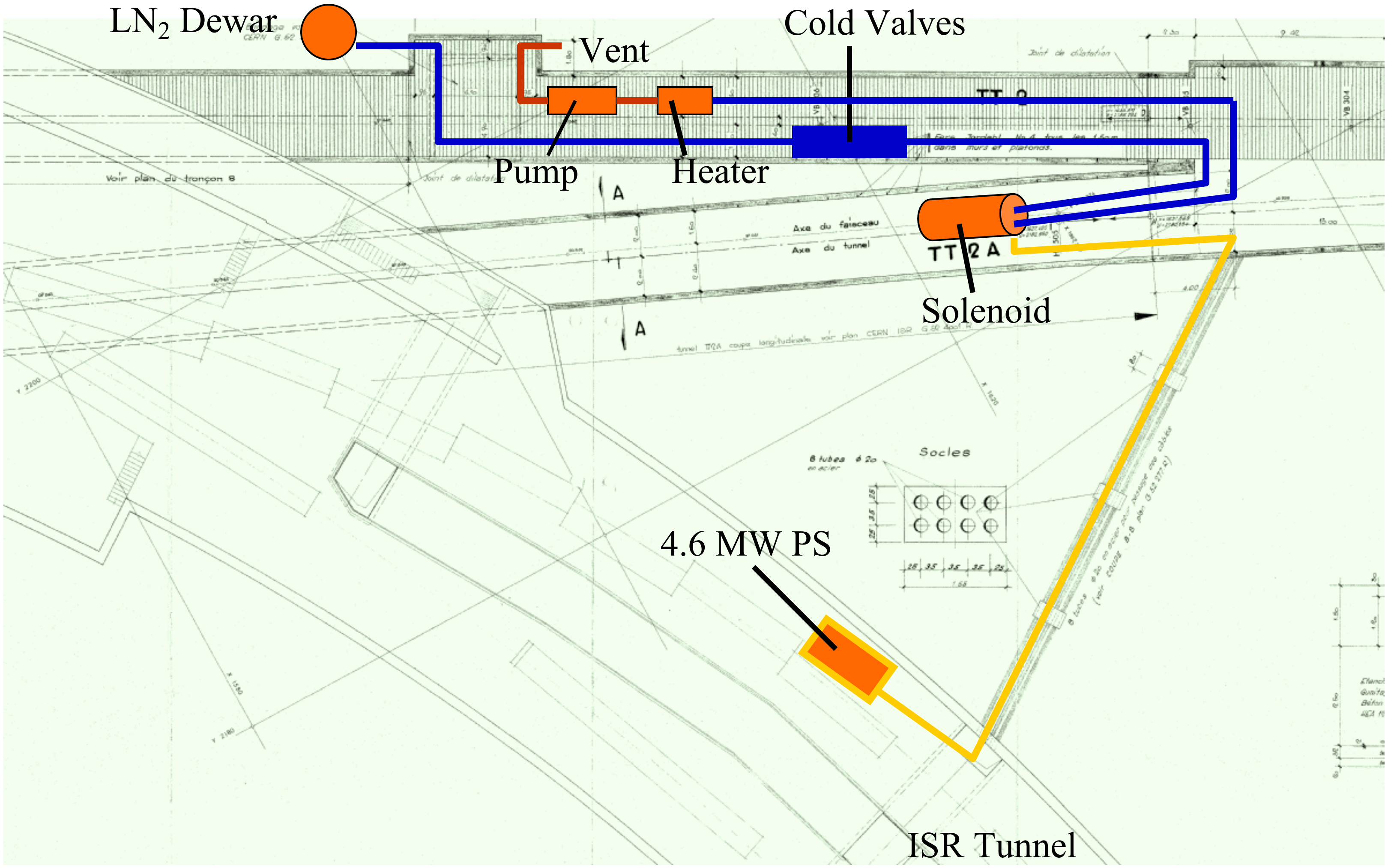
Total DC output ratings:
6500Adc, 950Vdc, 6.7 MW

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



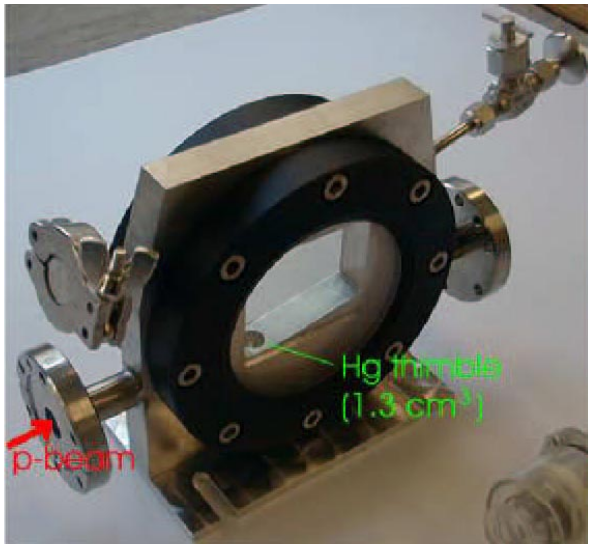
Run plan for PS beam spills

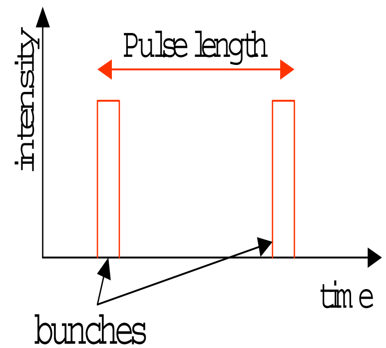
Our Beam Profile request allows for:

- 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				38

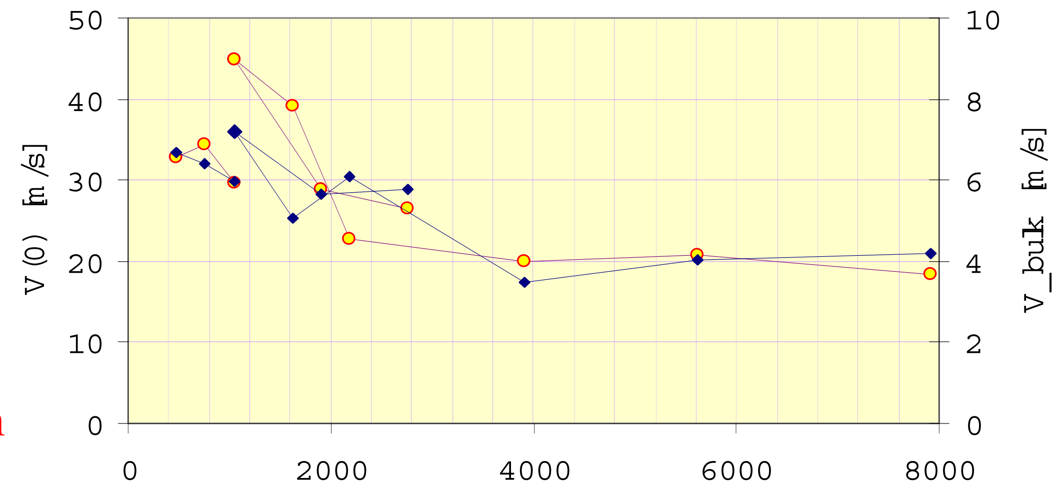
CERN ISOLDE Hg Target Tests





Pulse length

Velocities (pulse length)



Bunch Separation, ns

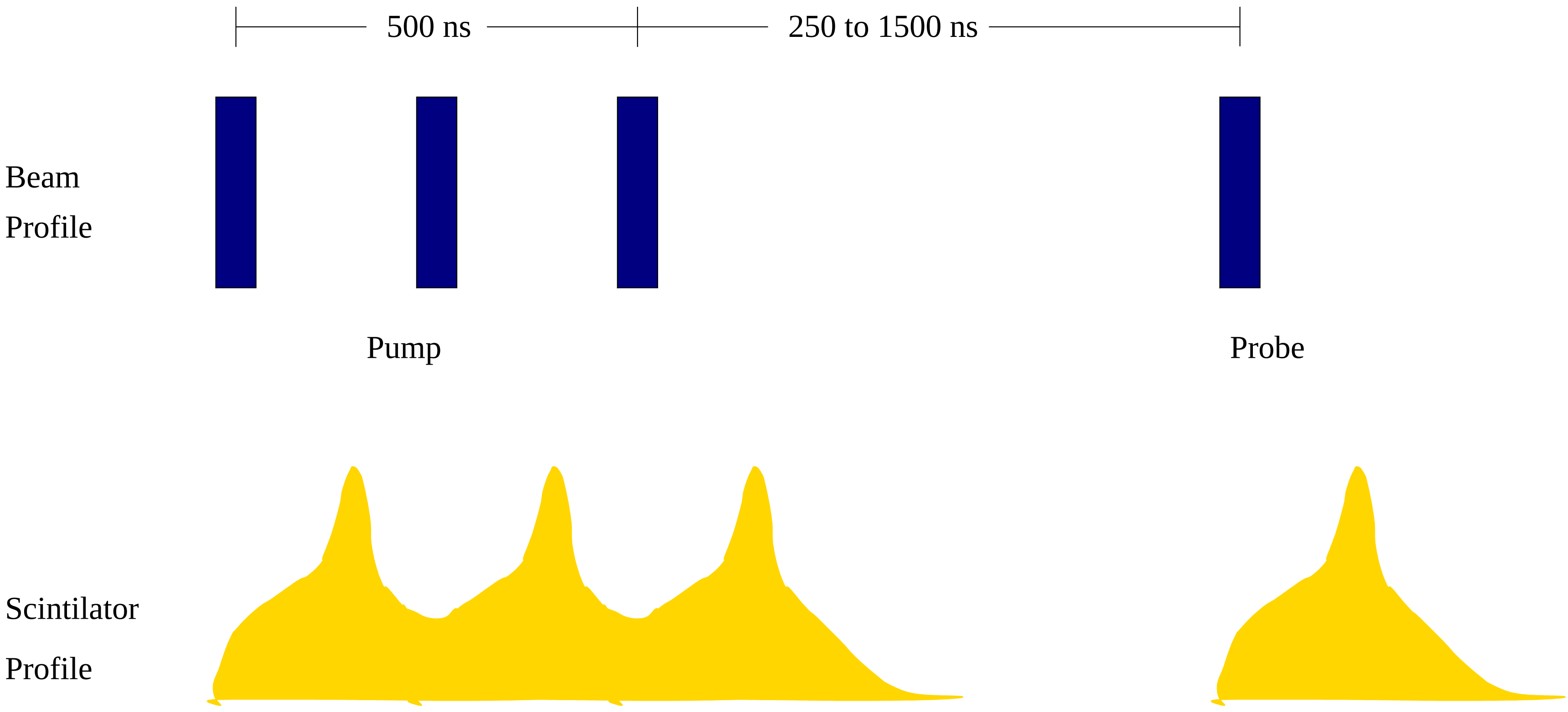
Proton beam 5.5 TP per Bunch.

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

Muon Collaboration

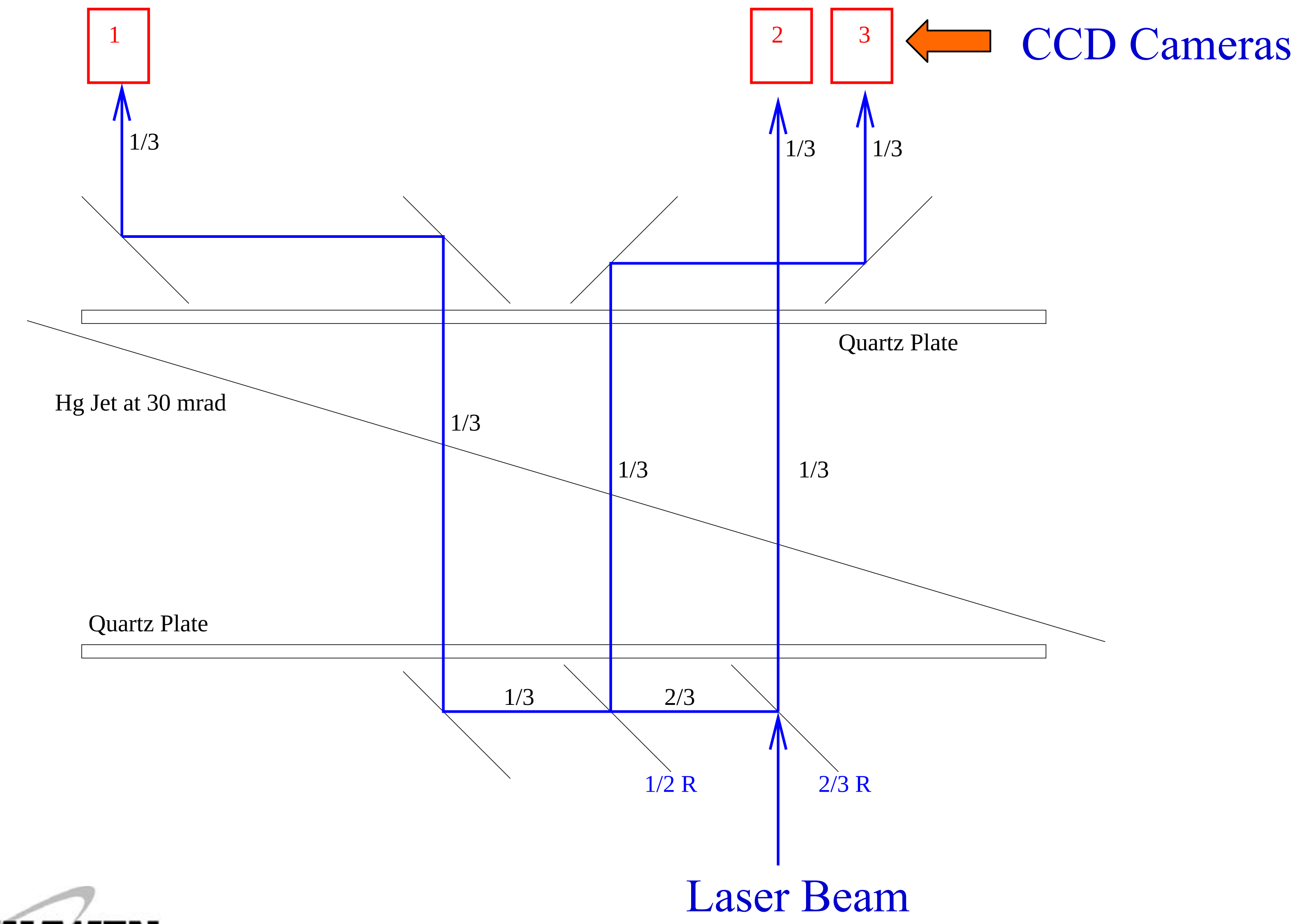
PS Extracted Beam Profile



BROOKHAVEN
NATIONAL LABORATORY

Harold G. Kirk

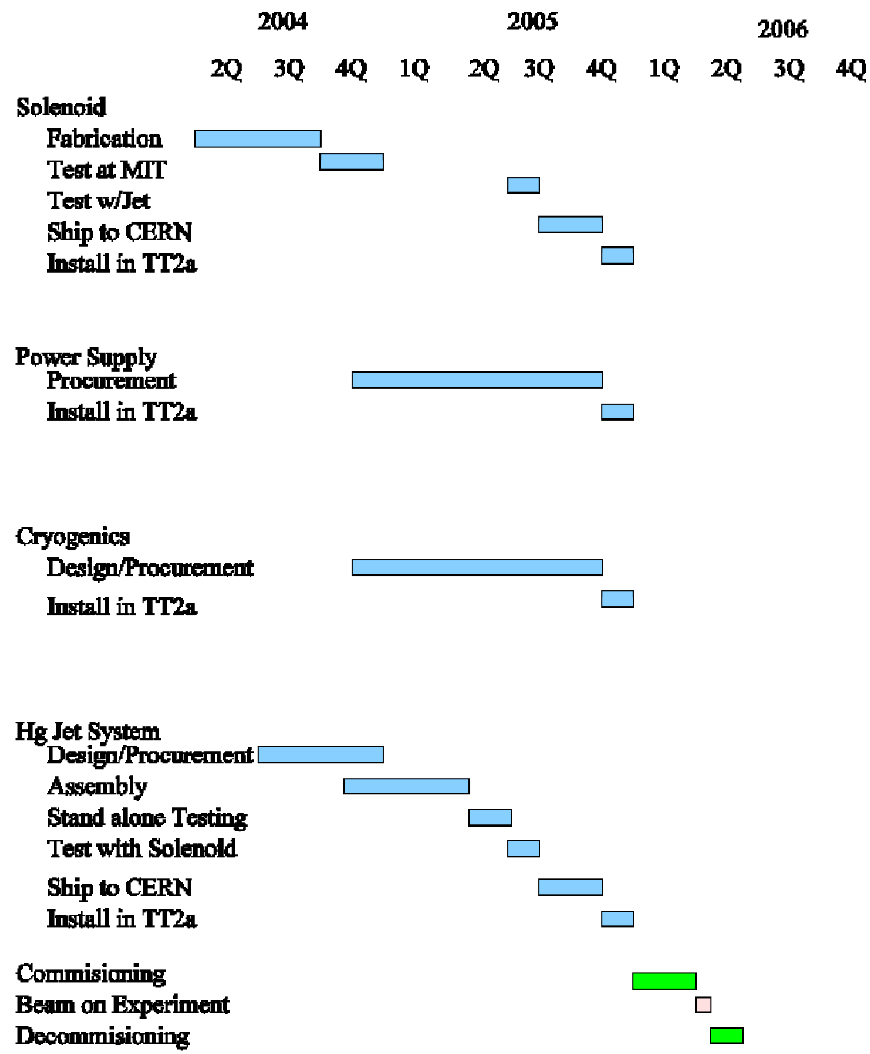
Optical Diagnostics of Hg Dispersal



Experiment Schedule

Key to plan is the scheduled shutdown of PS/SPS operations for 2005. We have an excellent opportunity to install the experiment and commission the experiment before the April 2006 resumption of PS operations.

- Installation 4th Q 2005
- Commissioning 1st Q 2006
- Beam on target April 2006
- Equipment removal end of April, 2006
- nTOF resumes May 2006.



Harold G. Kirk

Muon Collaboration

Pulsed Solenoid Project Cost Profile

Magnet		
Engineering	$ 350 K	$ 350 K
Fabrication	$ 410 K	$ 410 K
Testing	$ 90 K	
Shipping	$ 15 K	
Installation	$ 20 K	
Decommission	$ 25 K	

Power Supply (CERN Solution)		
Engineering	$ 70 K	$ 20 K
Procurement	$ 300 K	
Installation	$ 80 K	
Decommission	$ 20 K	
Contingency	$ 70 K	

Beam Diagnostics	
Beam Profile	$ 40 K
Beam Dump	$ 25 K
Scintillators	$ 10 K

Cryogenics System

(Assume CERN supplied components)

Engineering	$ 90 K	$ 45 K
Procurements	$ 50 K	
Control System	$ 40 K	
Installation	$110 K	
Decommission	$ 10 K	
Contingency	$ 40 K	

Hg Jet System	
Engineering	$ 30 K
Procurements	$ 45 K
Optical System	$ 35 K
Decommission	$20 K
Contingency	$ 20 K

Support Services	
Data Acquisition	$ 30 K
Project Management	$150 K

BROOKHAVEN NATIONAL LABORATORY

Harold G. Kirk

Cost Summary

	System Costs	Spent to date
Magnet System	$ 910 K	$ 760 K
Power Supply	$ 540 K	$ 20 K
Cryogenics	$ 340 K	$ 45 K
Hg Jet System	$ 150 K	
Beam Systems	$ 75 K	
Support Services	$ 190 K	
Total	$ 2205 K	$ 825 K

→ Remaining Costs $ 1380K