CERN Experiment Initiative

H. Haseroth, CERN

CERN experiment initiative

is somehow the wrong name

It was the American Muon Collaboration,
in particular BNL (Harold Kirk) and
Princeton (Kirk McDonald)
making the proposal

Why do I stand here?

Because I looked too late at the agenda of this meeting…

Anyhow I did a little bit already some time ago with the help of Roberto Cappi (now retired) (and I continued a bit…)

But nobody was interested in it until it turned out that it was somewhat difficult to get a beam at BNL…

But let me tell you what I am going to talk about….

General target issues

Funneling

What has been done (centered at Hg)

LOI

Targets:

Difference between a neutron spallation source target and a “neutrino” target (pion escape…)

A neutrino target must be small: 1 to 2 cm in diameter

(For CERN – or a Superbeam - Material must be compatible with horn material)

Targets for MW beams are a must in our field – perhaps except if you are doing funneling…

If you do not want to do funneling: What are the options?

- Solid targets (stationary)
  - Homogenous
  - Structured (e.g. micro spheres)
- Solid targets (moving)

In our experiment we use liquid metal (Hg)
What has been achieved so far?

Try funneling!

B. Autin, F. Meot, A. Verdier

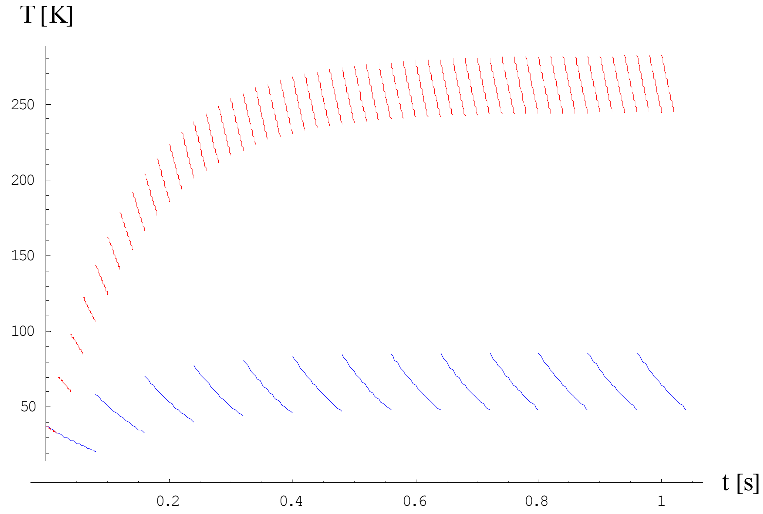
What are the problems?

- Proton beam power: 4 MW
- Target to cope with high power
  (must be a high Z target because of the modest proton energy)
- Horn to be pulsed at: 50 Hz
  (Linac frequency)

•It would be much simpler if we had only 1 MW and e.g. 12.5 Hz

Target dynamics

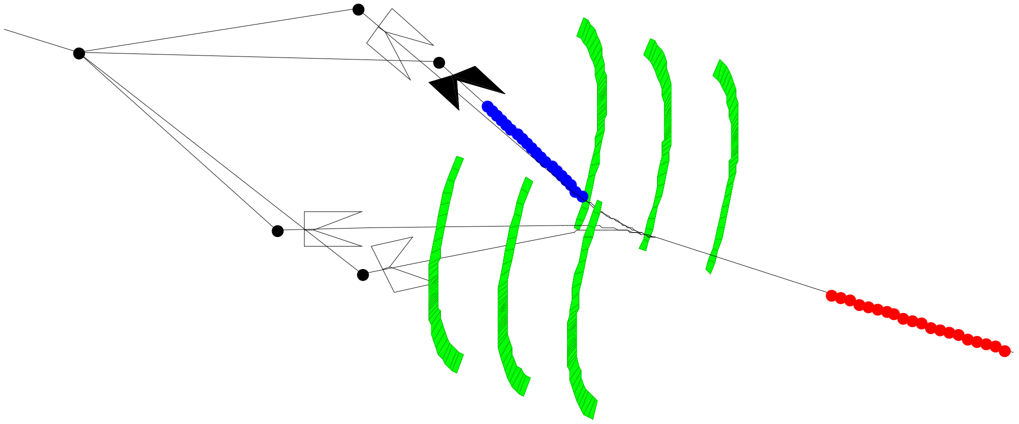
- High repetition frequency f reduces instantaneous energy deposited W at given power P: W = P/f .
- Long pulse heats the spheres adiabatically: no shock.



Without funneling

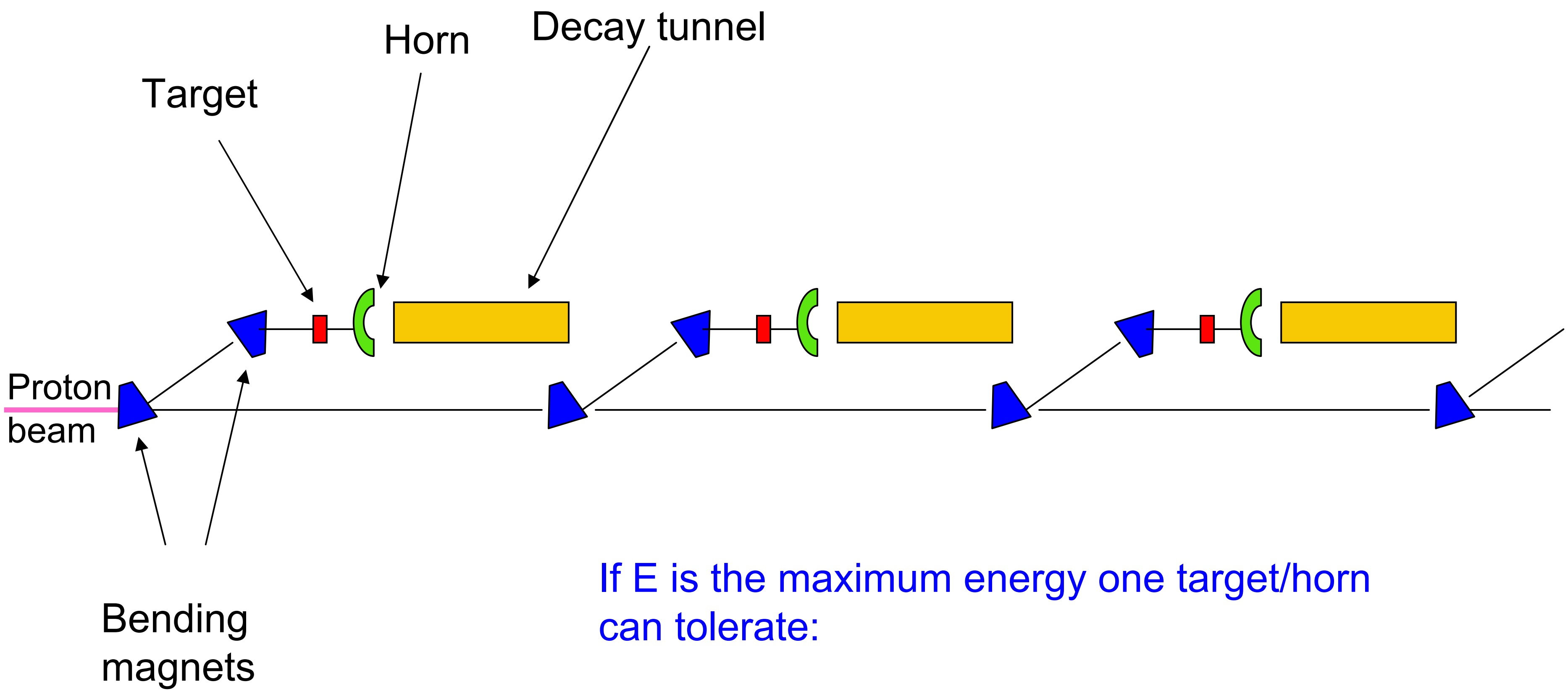
With funneling

Funneling step by step



Funneling maybe a nice idea for a Neutrino Factory, however, you do not need funneling for a superbeam…

Schematic layout

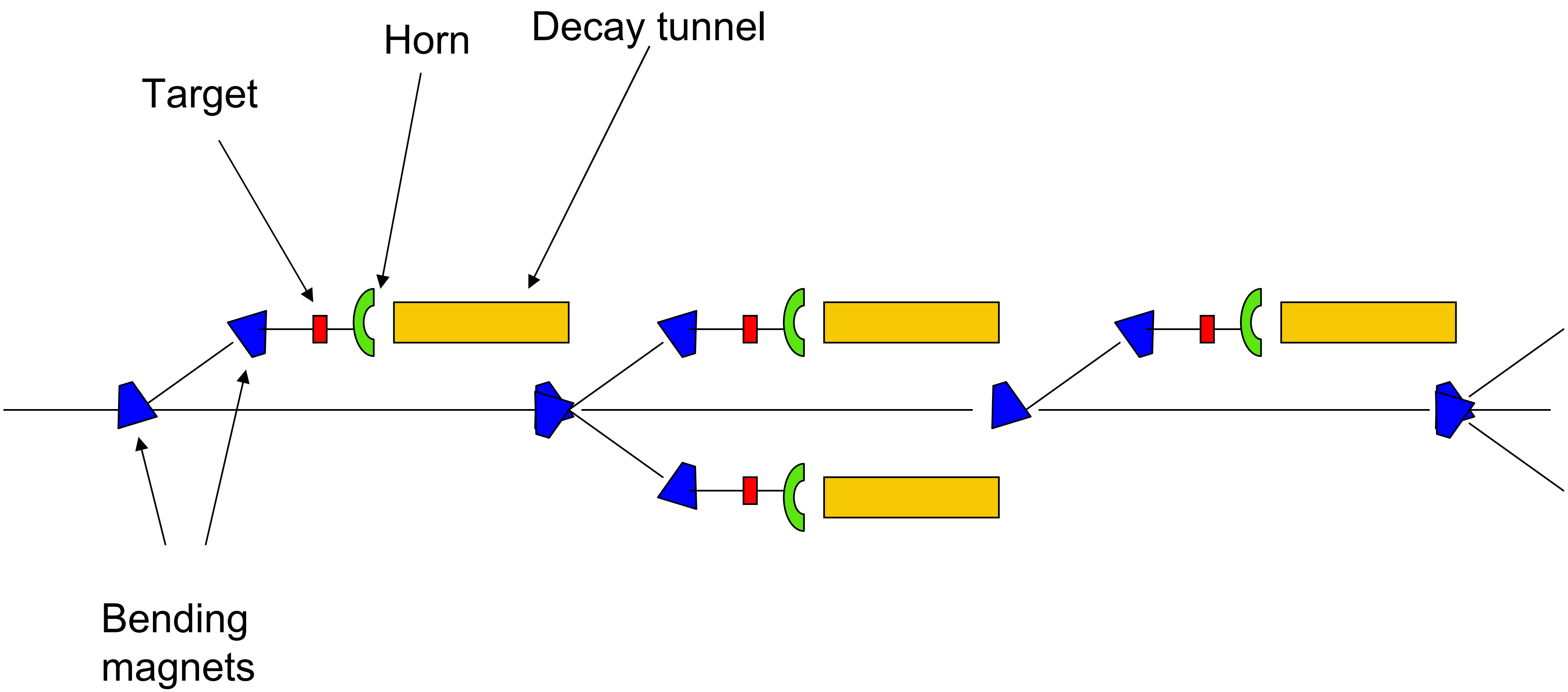


If E is the maximum energy one target/horn can tolerate:

Do this n times to get n $\times$ E

If you think this gets too crowded…

Alternative layout



Of course

this means:

n targets,

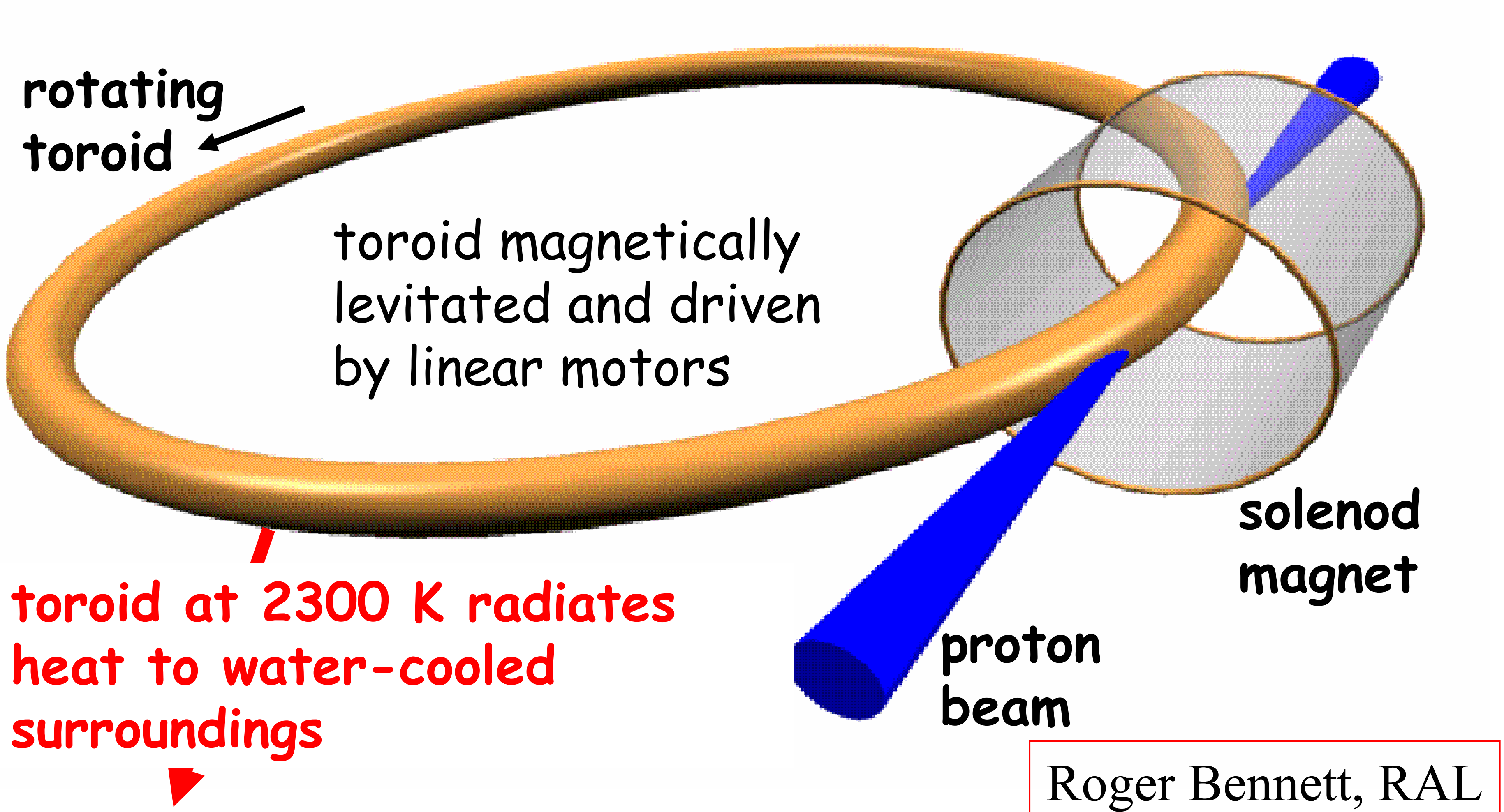
n horns

n power supplies

n target stations with remote handling

but all are identical…

Schematic of a rotating tantalum target



Roger Bennett, RAL

Granular Solid Target

•Advantages for a granular approach

• Reduced sample volume results in reduced sample thermal gradient

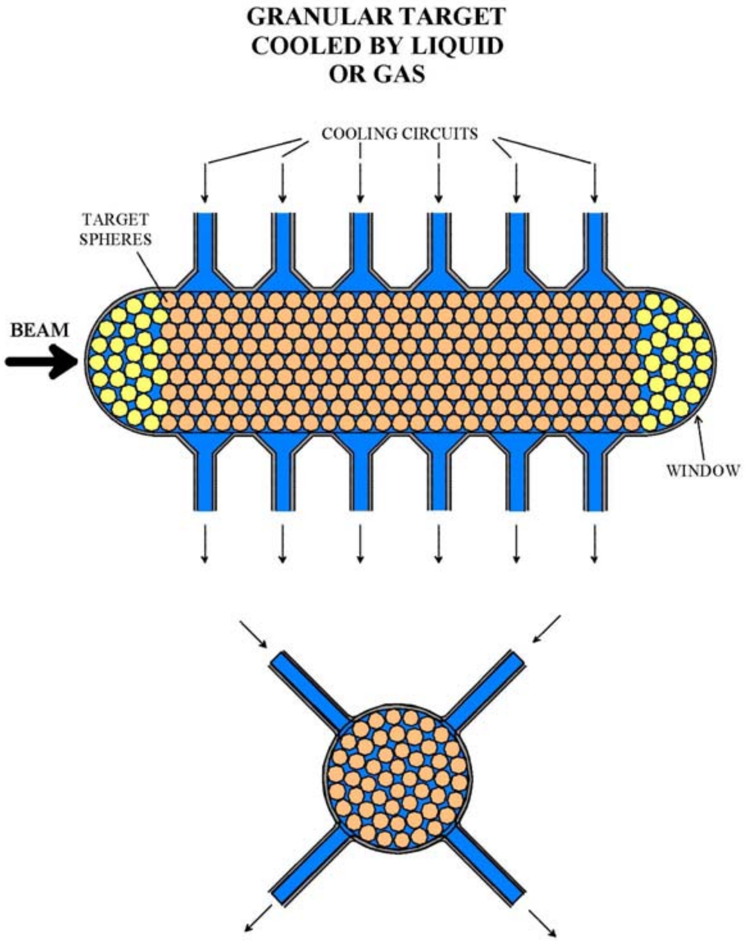
•Large surface/volume ration leads to better heat removal

•Better liquid or gas conduction through the target

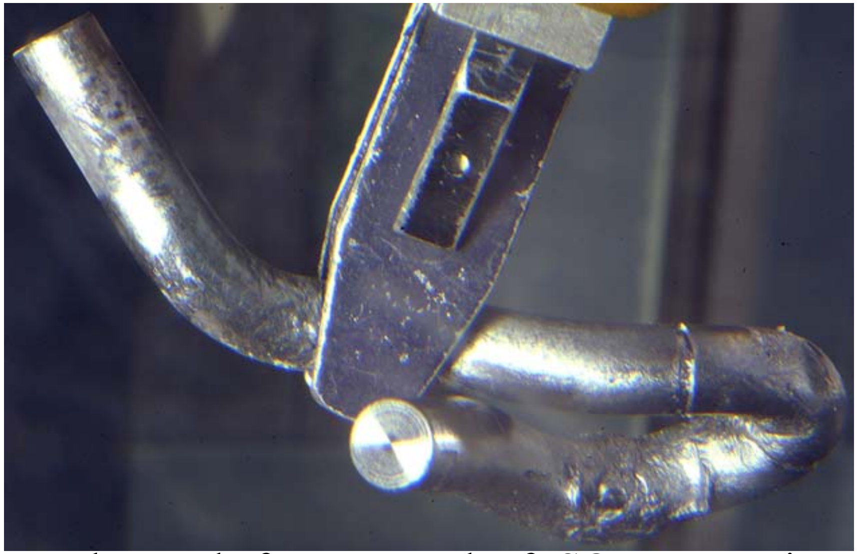
•Simpler stationary solid target approach

•Could utilize high-Z target material

Peter Sievers, CERN

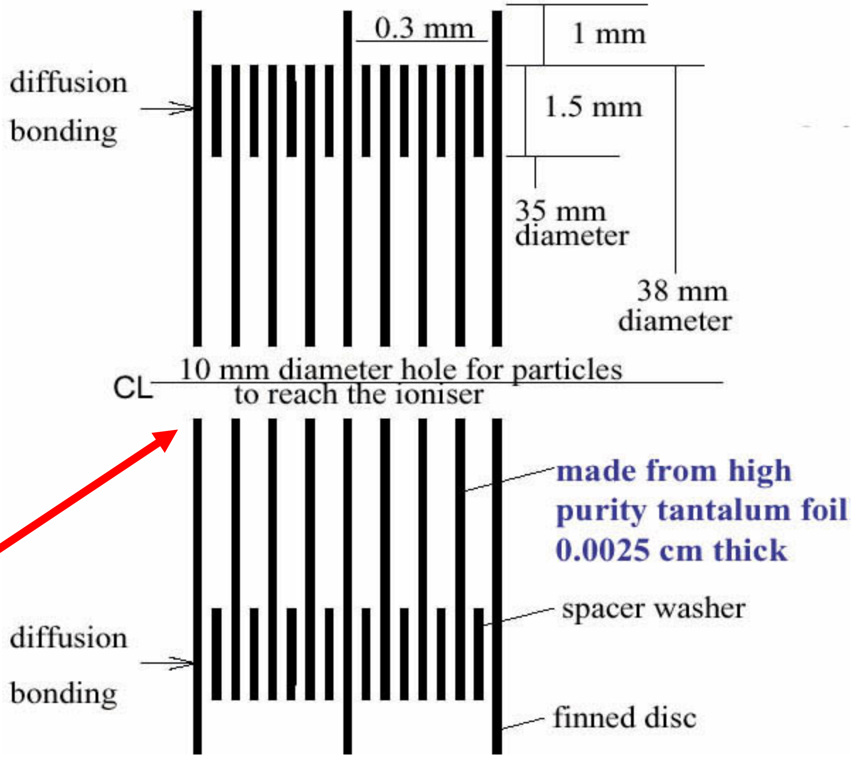


Experience with Tantalum



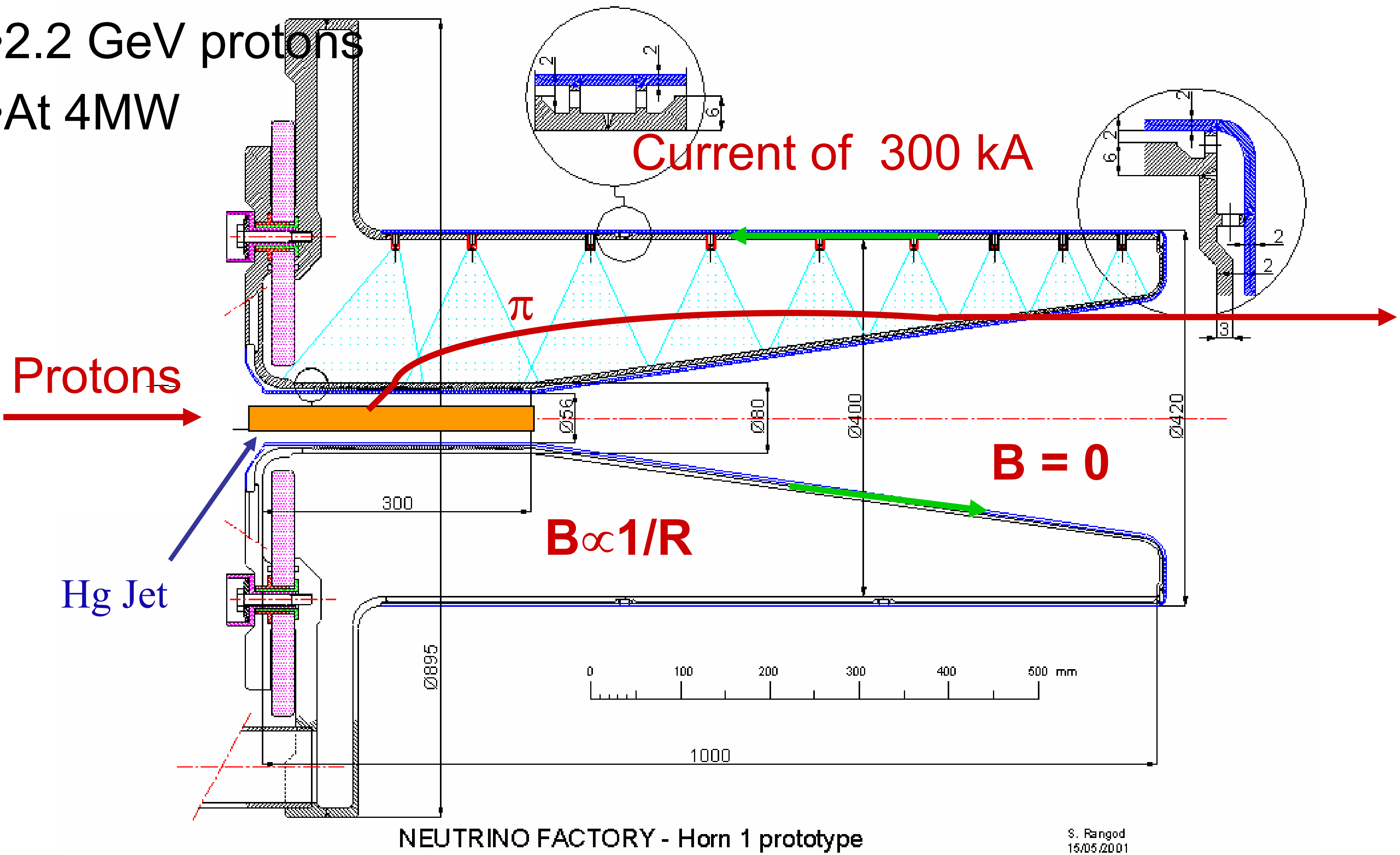
Tantalum rod after one week of ISOLDE running

The radiantly cooled RIST tantalum target

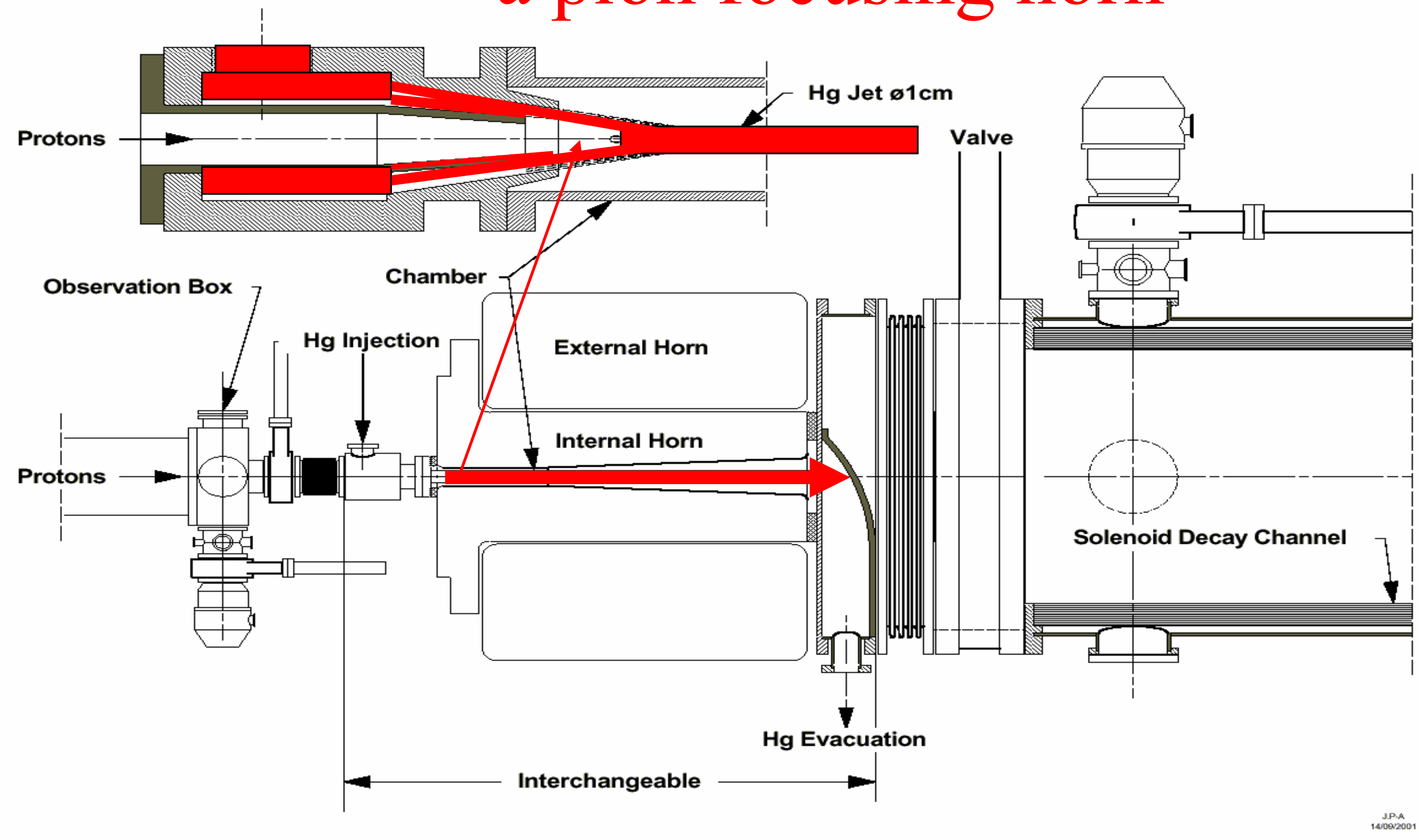


J. Lettry et al.

- 2.2 GeV protons
- At 4MW

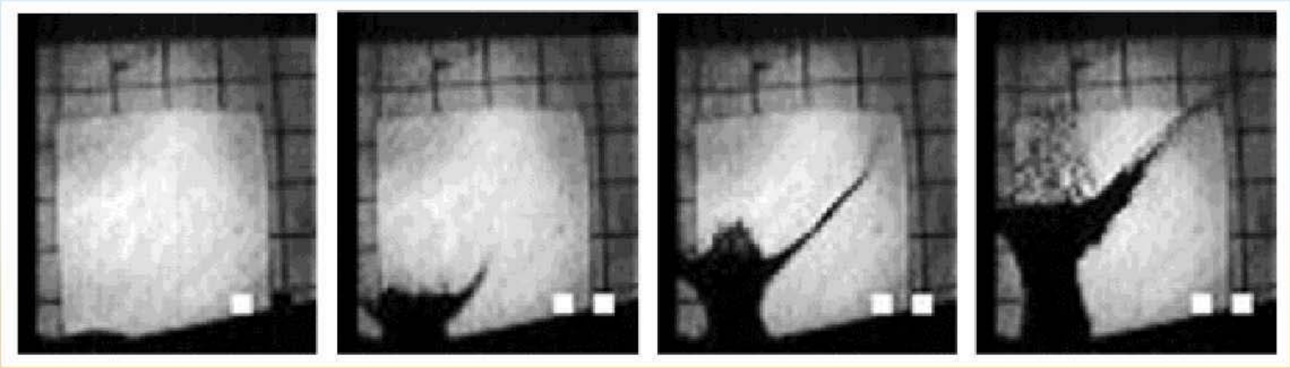


Hg-jet p-converter target with a pion focusing horn



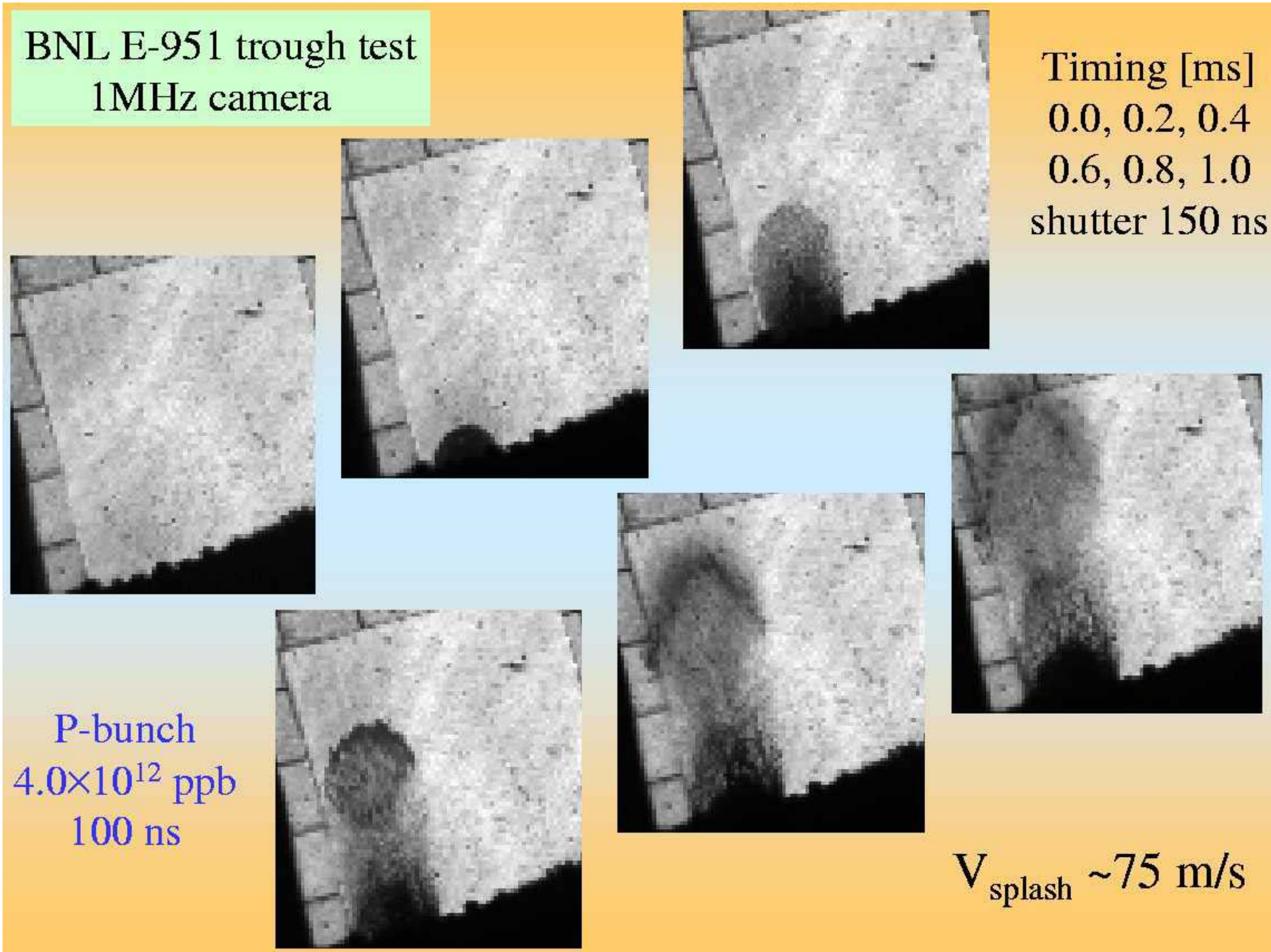
BNL E-951 trough test
8 kHz camera

1^{st} P-bunch
1.8×10^{12} ppb
100 ns



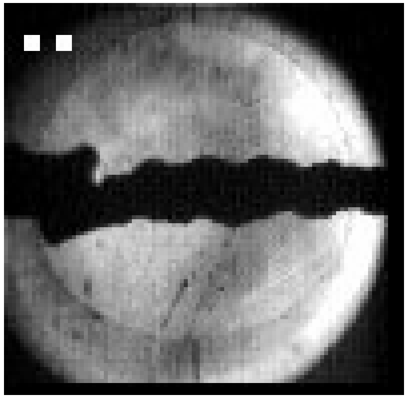
Timing : 0.0, 0.5, 1.6, 3.4 ms, shutter 25 µs

V_{splash} ~20-40 m/s


BNL E-951 trough test
1MHz camera
Timing [ms]
0.0, 0.2, 0.4
0.6, 0.8, 1.0
shutter 150 ns
P-bunch
4.0×10^12 ppb
100 ns
V splash ~75 m/s

Harold G. Kirk

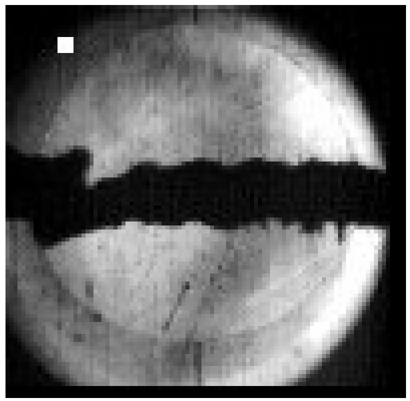
Jet test a BNL E-951



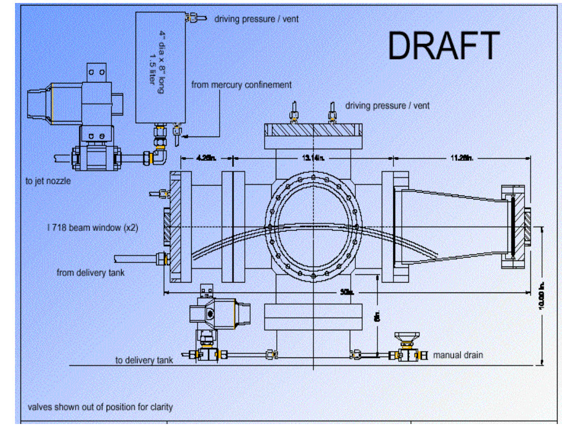
Event #11   25th April 2001

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

Protons ←



- **1cm diameter Hg Jet**
- **24 GeV 4 TP Proton Beam**
- **No Magnetic Field**



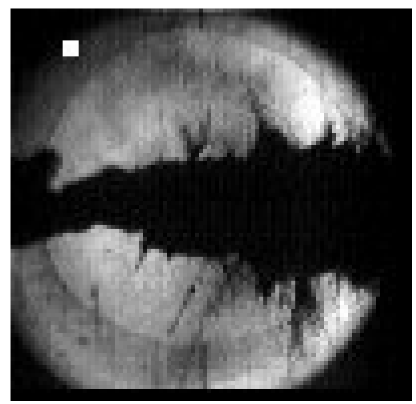
Picture timing [ms]

0.00

0.75

4.50

13.00



P-bunch: 2.7×10^{12} ppb

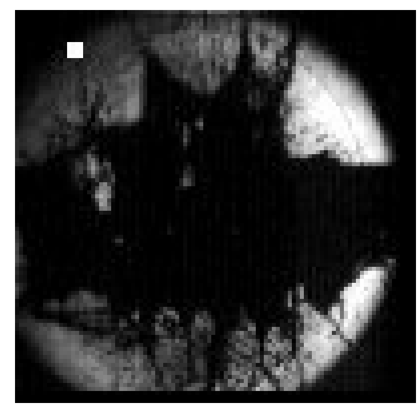
100 ns

t_o = ~ 0.45 ms

Hg- jet : diameter 1.2 cm

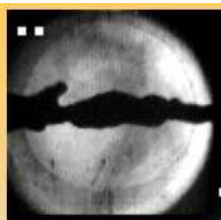
jet-velocity 2.5 m/s

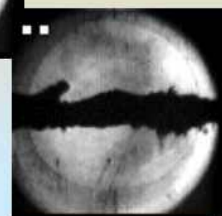
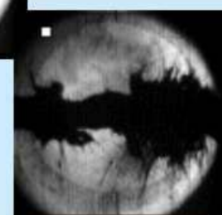
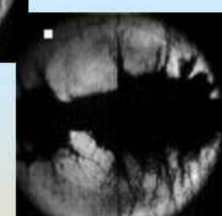
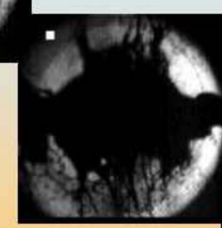
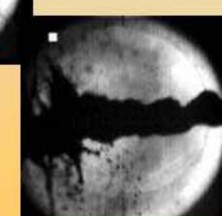
perp. velocity ~ 5 m/s



Jet test at BNL E-951 #4

25th April 2001



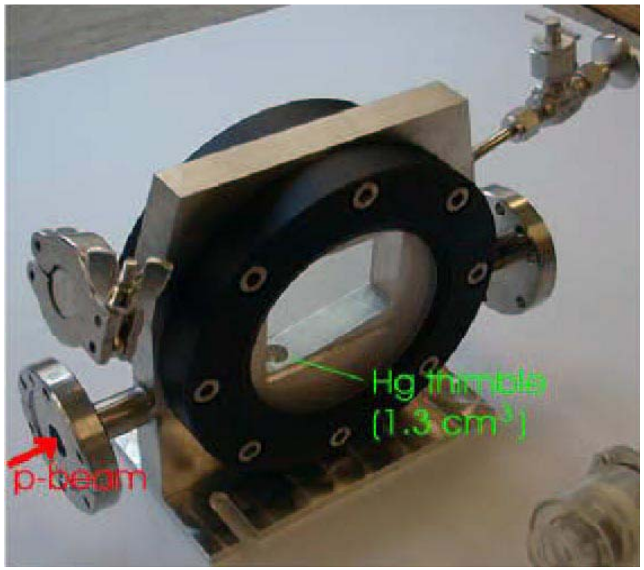






Pictures timing [ms]
0.000
0.250
0.500
0.175
0.425
0.975
3.000

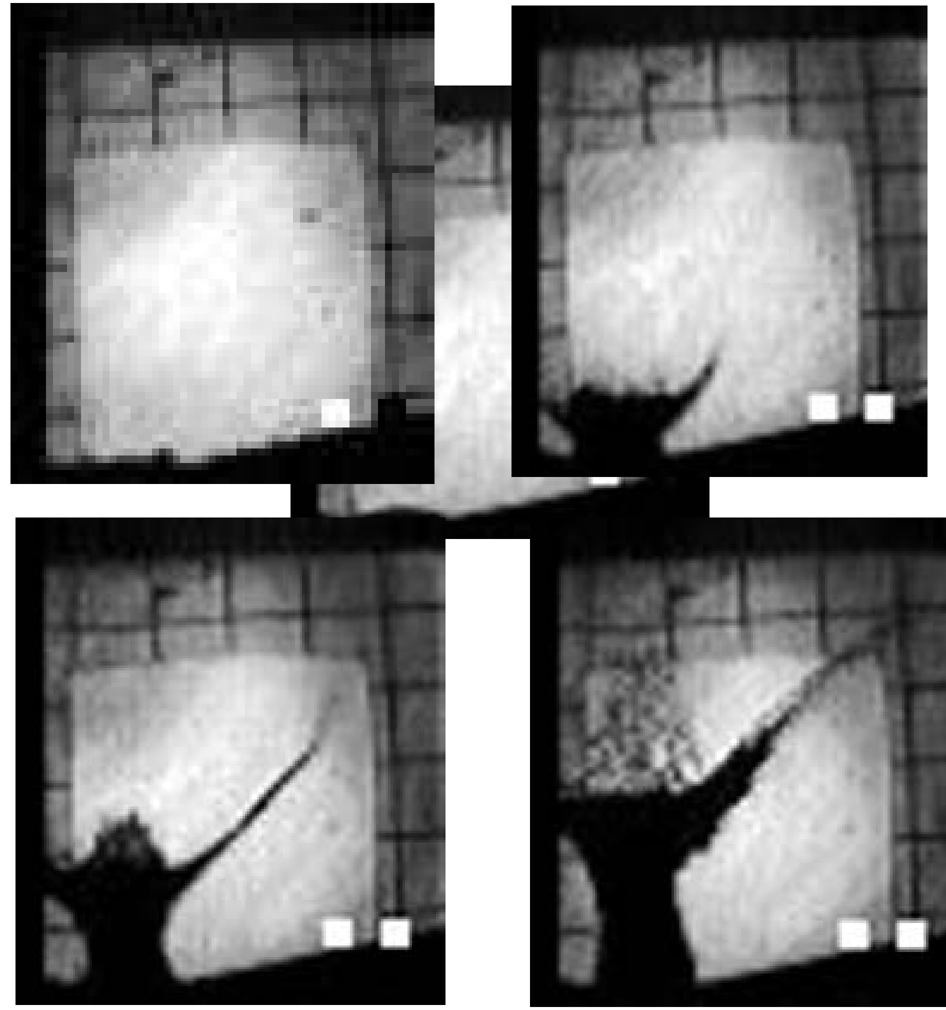
P-bunch: 3.8×10^{12} ppb
100 ns
to = ~ 0.45 ms

Hg- jet : diameter ~ 1cm
jet-velocity ~ 3 m/s
prep. velocity ~ 10 m/s

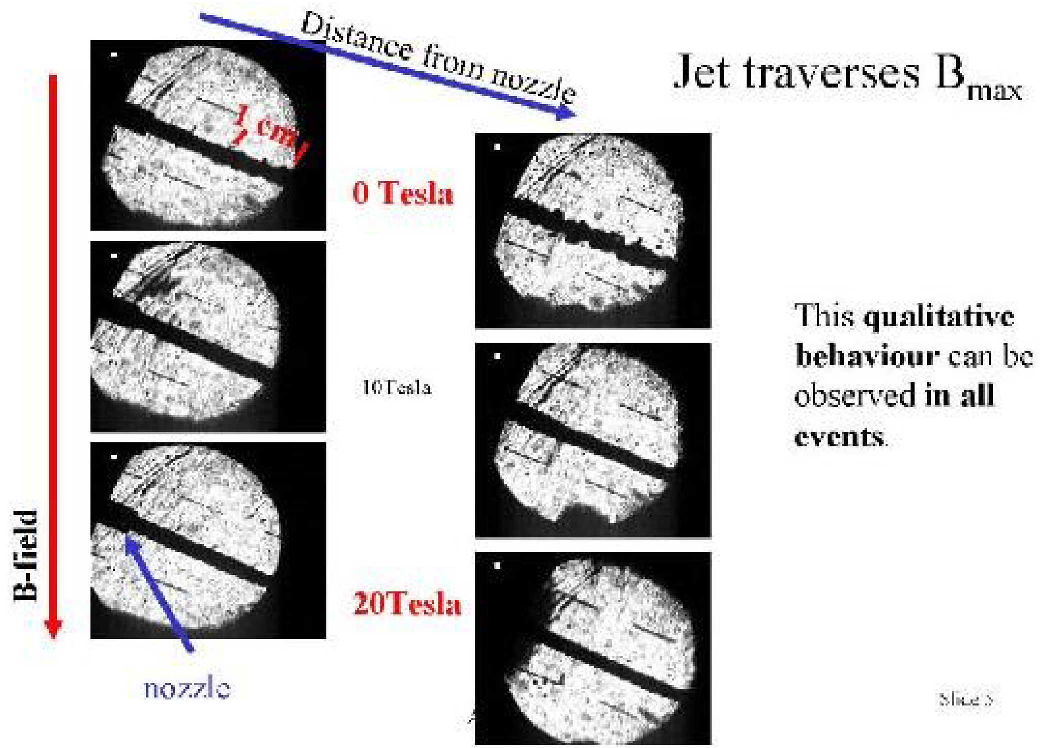
CERN Passive Hg Thimble Test



Exposures to a BNL AGS 24 GeV
2 TP beam. T=0, 0.5 , 1.6 and 3.4 ms.



CERN/Grenoble Hg Jet Tests



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

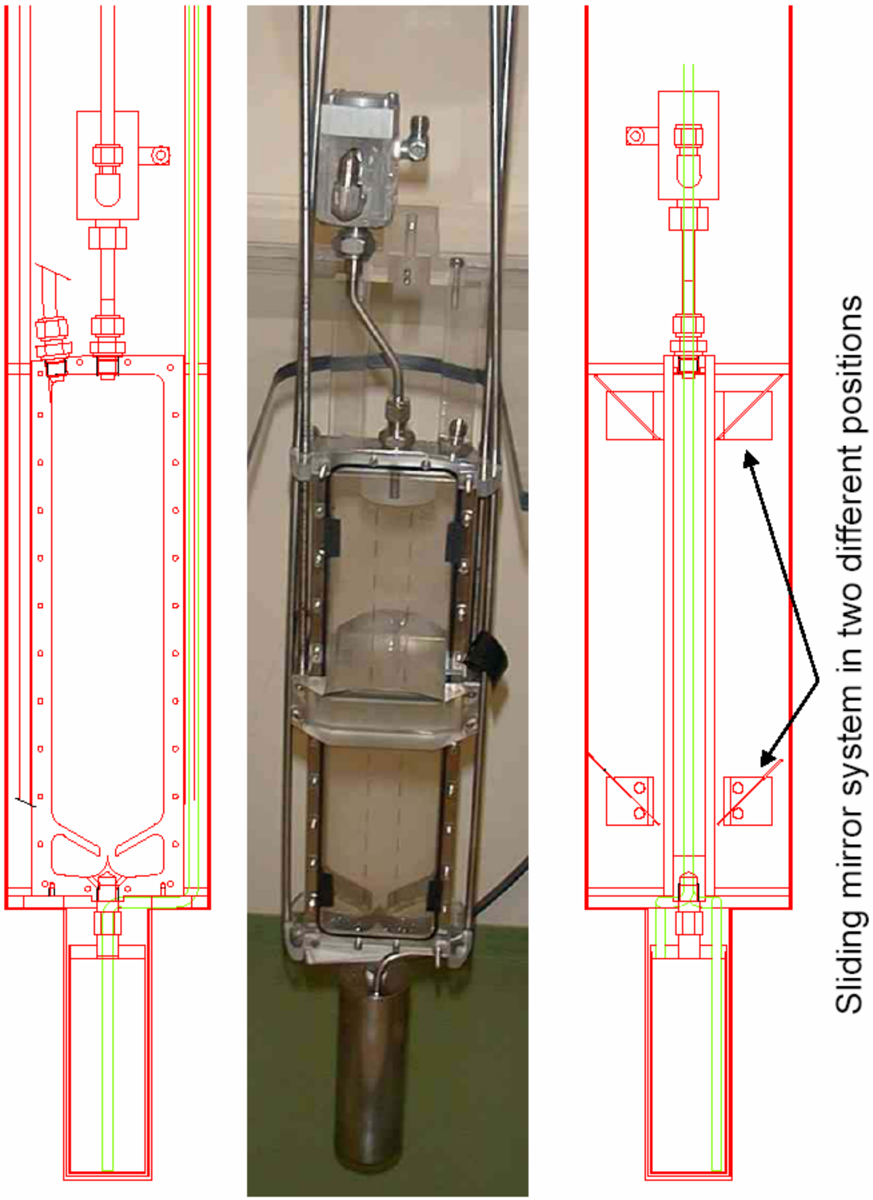
A. Fabich, J. Lettry
Nufact'02

Jet Chamber Version 3 (final)

- GHMFL, M9
- Vertical bore, closed at lower end
- Mercury recuperation by overpressure

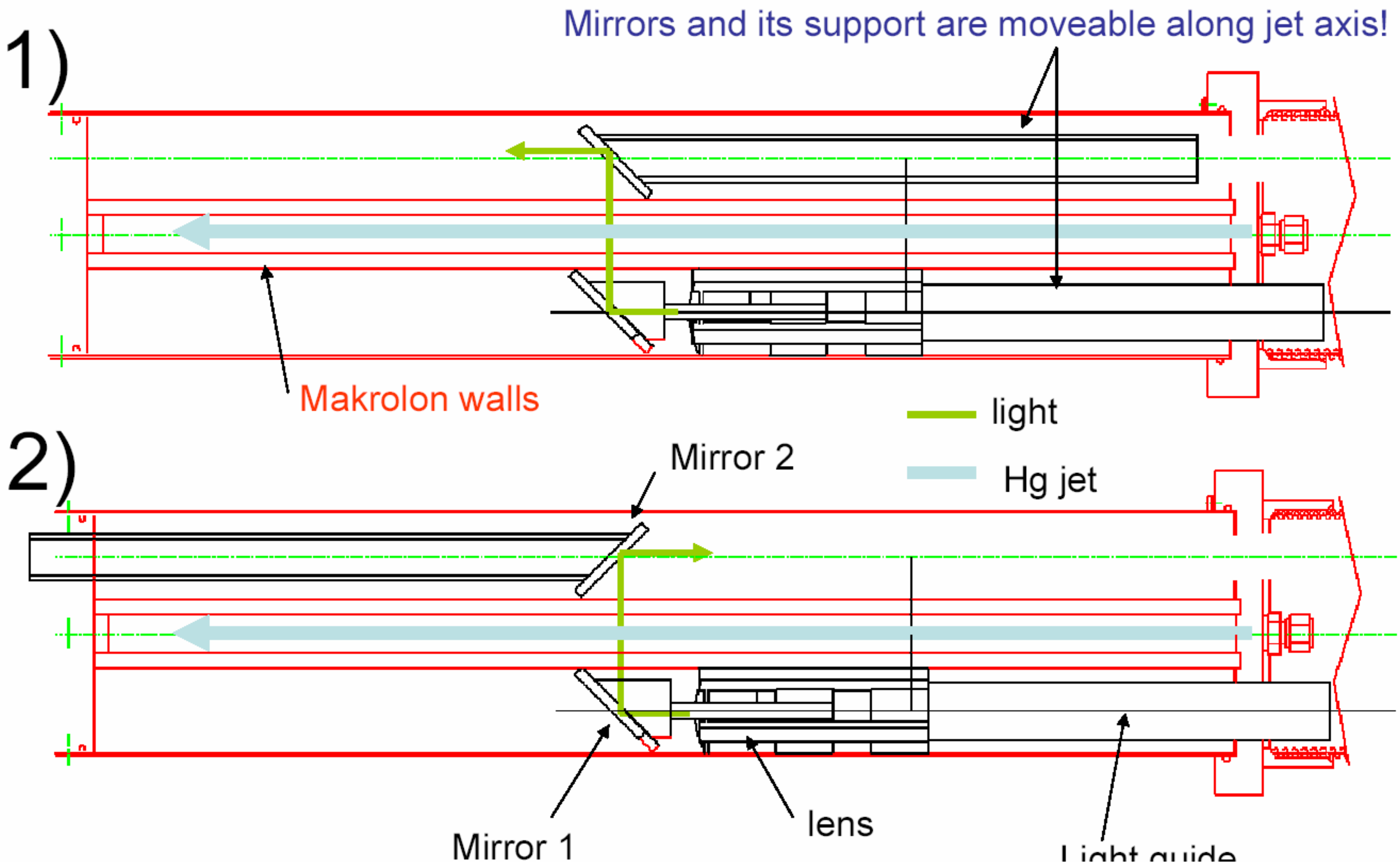
- After gaining experience with this system it fully satisfied the aimed goal for this kind of test!

A. Fabich, J. Lettry



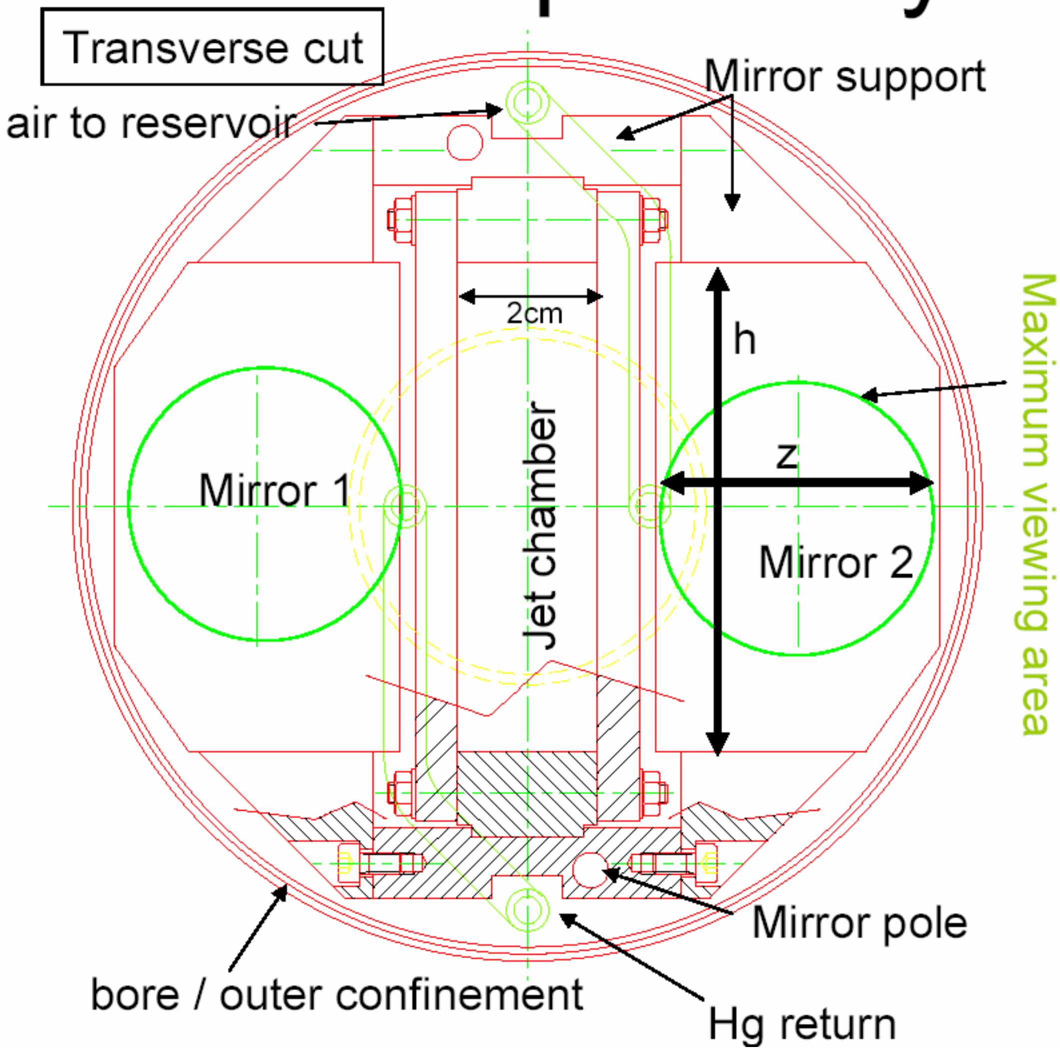
A. Fabich, J. Lettry

Optical system: light path



A. Fabich, J. Lettry

Optical System (2)



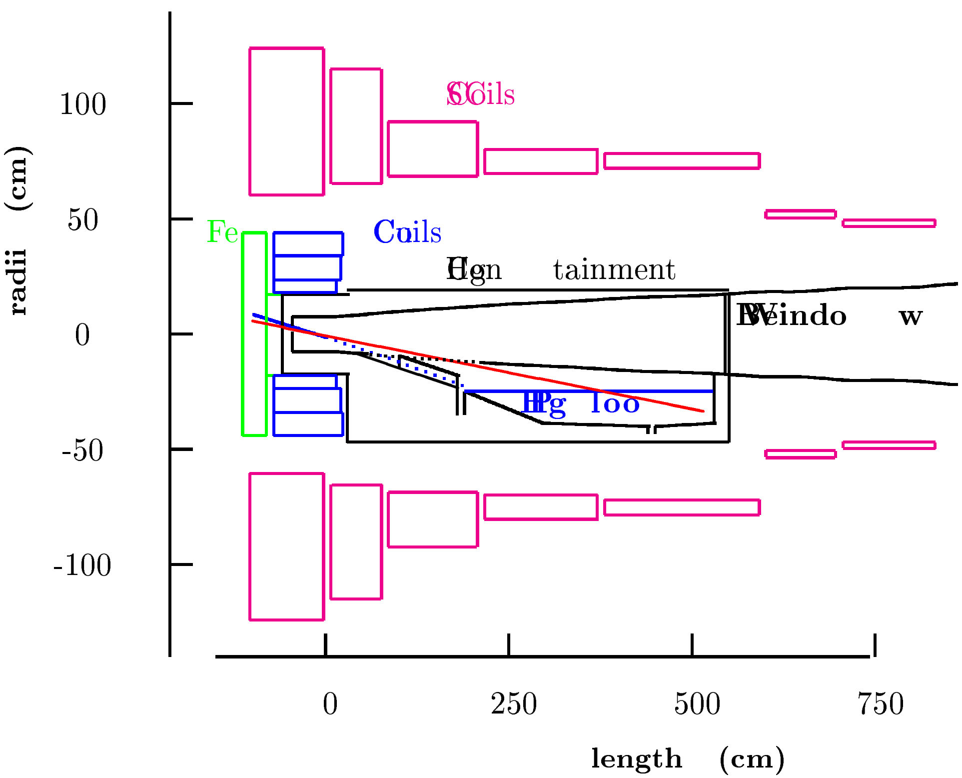
Bore of magnet 13 cm contains:

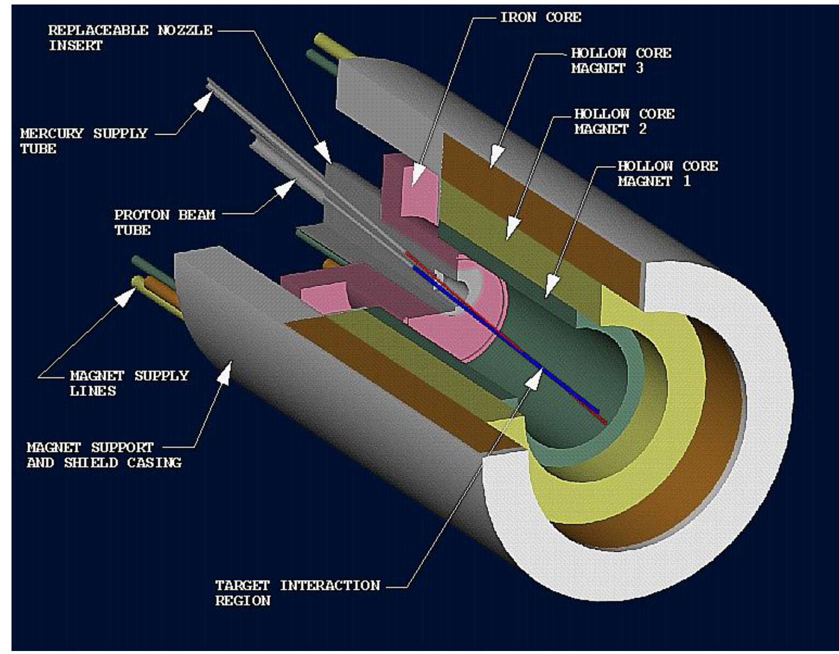
- jet chamber
  - steel frame
  - Makrolon plates
- mirror system
  - support (adjustable in height) around jet chamber
  - 2 mirrors
- mercury recuperation system

The maximum observation along jet is defined by magnet bore minus the width of the jet chamber (minus some safety margins)
- Total area given by h and z

SAFETY MARGINS ~ 1mm

Neutrino Factory Targetry Concept





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

Engineered solution--P. Spampinato, ORNL

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

Key Jet/Magnetic Field Results

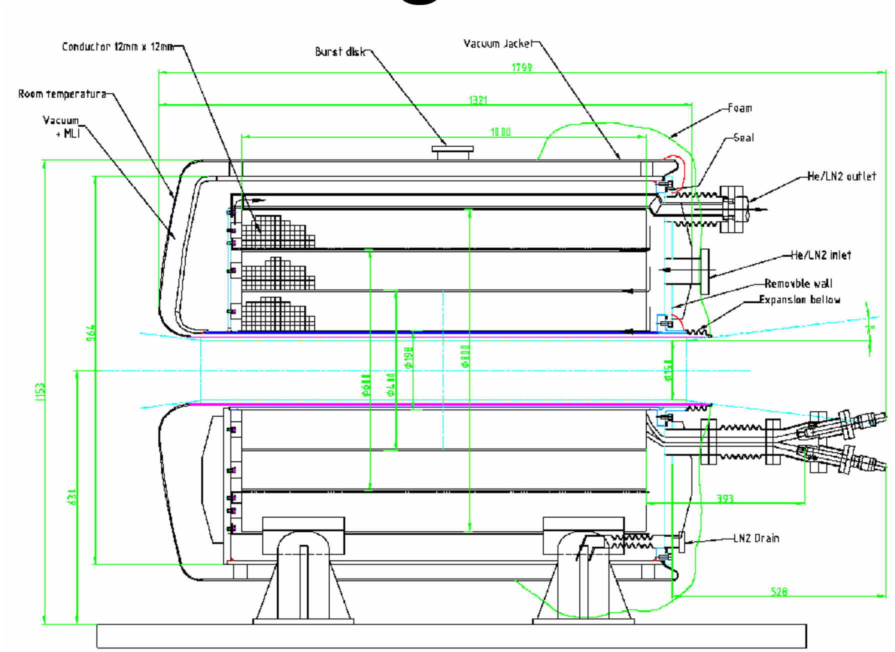
- The Hg jet is stabilized by the 20 T magnetic field
- Minimal jet deflection for 100 mrad angle of entry
- Jet velocity reduced upon entry to the magnetic field

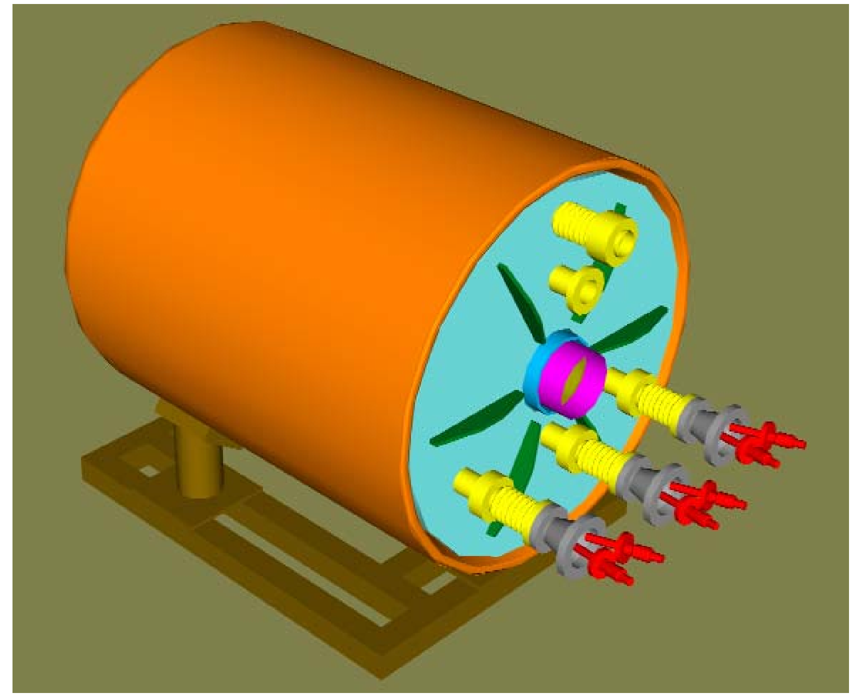
Bringing it all Together

- 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 (> 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

Harold G. Kirk

High Field Pulsed Solenoid





- 70° K Operation
- 15 T with 4.5 MW Pulsed Power
- 15 cm warm bore
- 1 m long beam pipe

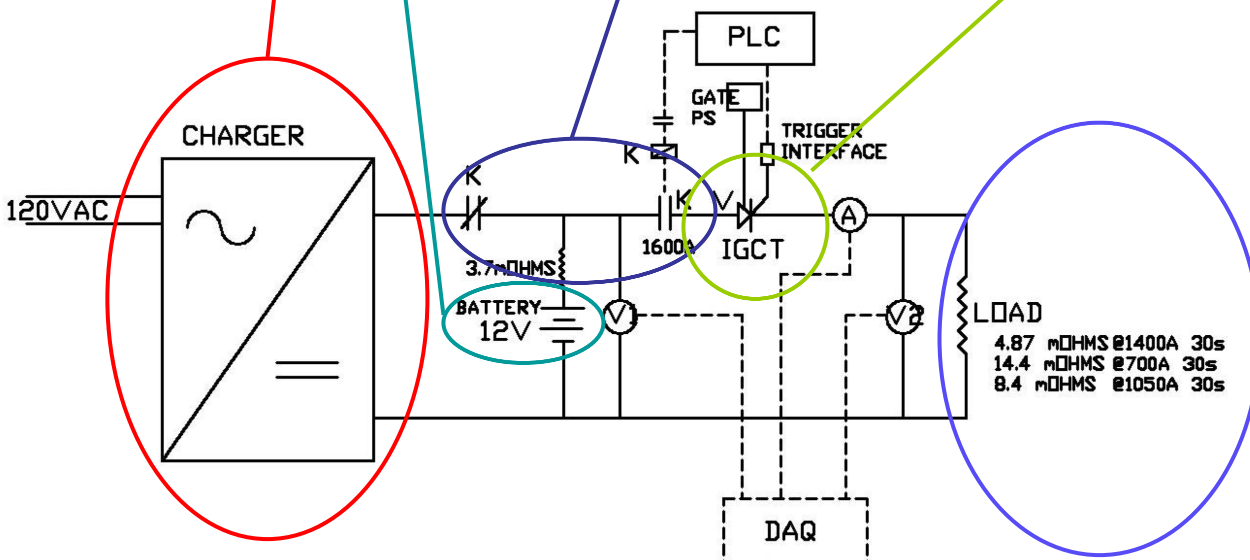
Peter Titus, MIT

Battery Power Supply R&D

Battery/Charger
12V 1400A

Mech. Switch
1500V 1600 A

IGCT 600V 4000A



Load

Battery Power Supply (Cont)

Mechanical Switch capable
of 4.4 MW Pulsed System

Battery Power Supply R&D at BNL

Battery/Charger
12V 1400A

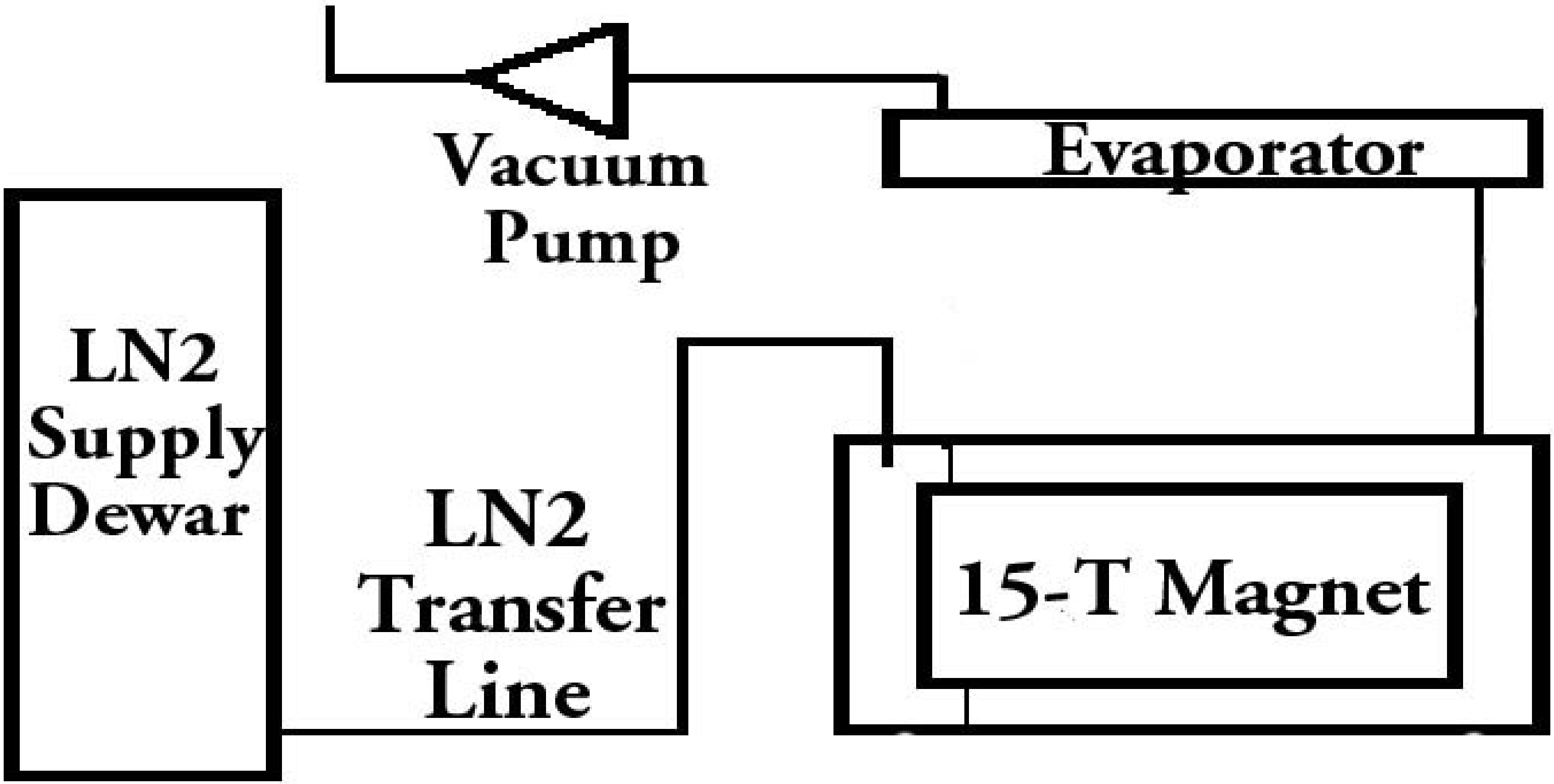
Mech. Switch
1500V 1600 A

Load

IGCT 600V 4000A

Mechanical Switch capable
of 4.4 MW Pulsed System

Simplified Cryogenic System

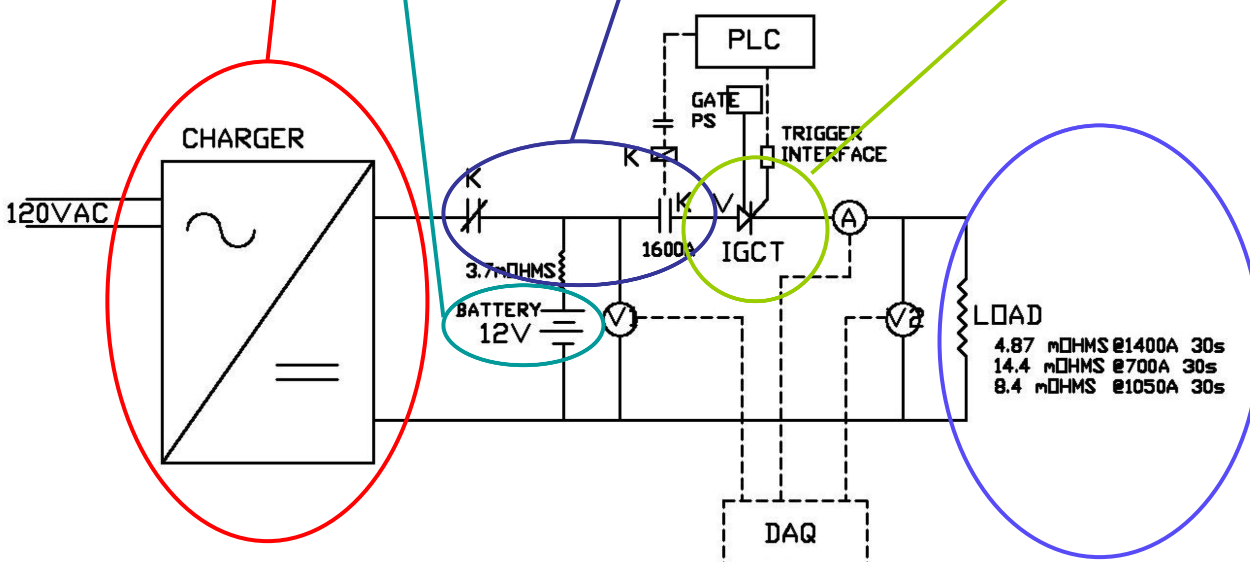


Battery Power Supply R&D

Battery/Charger
12V 1400A

Mech. Switch
1500V 1600 A

IGCT 600V 4000A

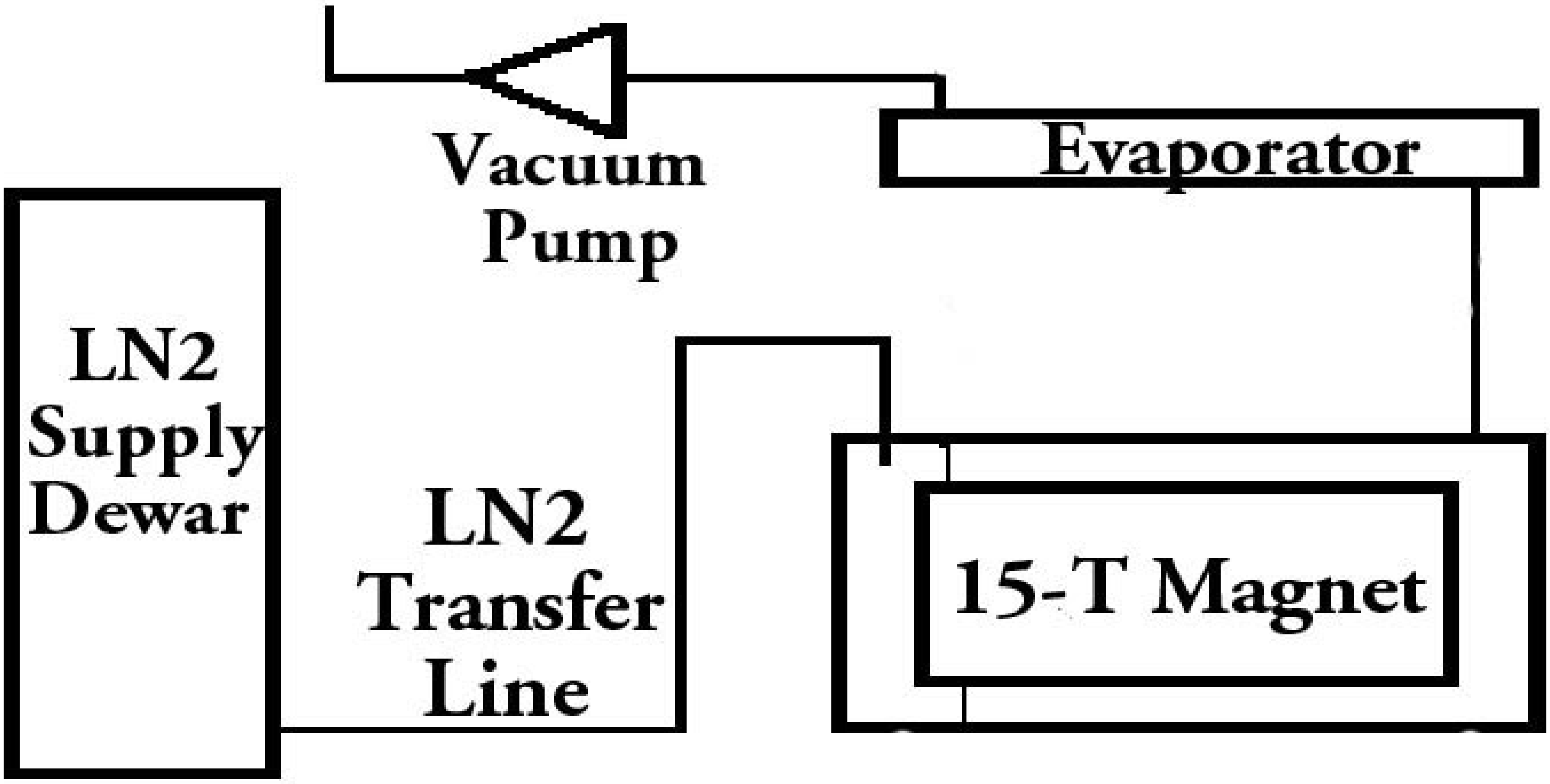


Load

Battery Power Supply (Cont)

Mechanical Switch capable
of 4.4 MW Pulsed System

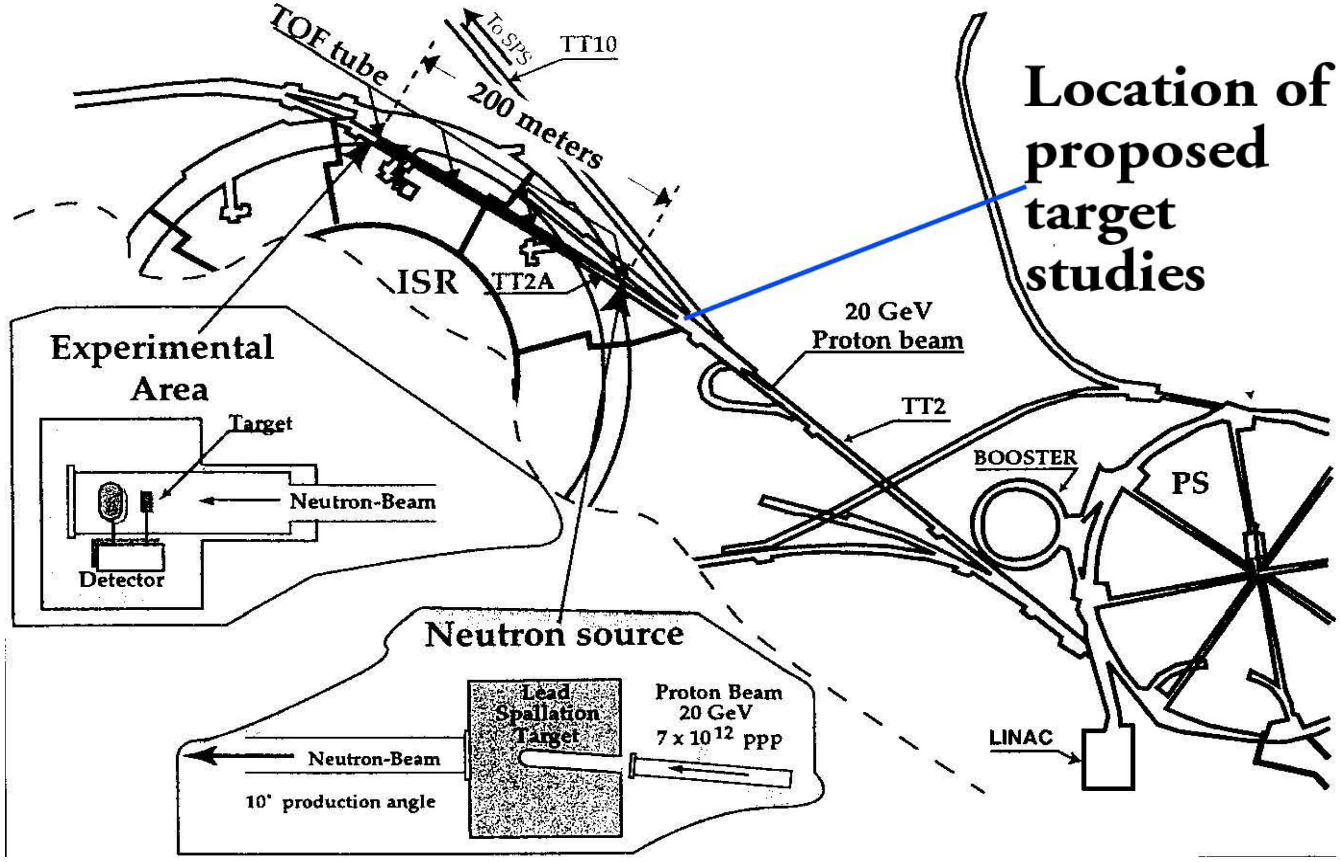
Simplified Cryogenic System

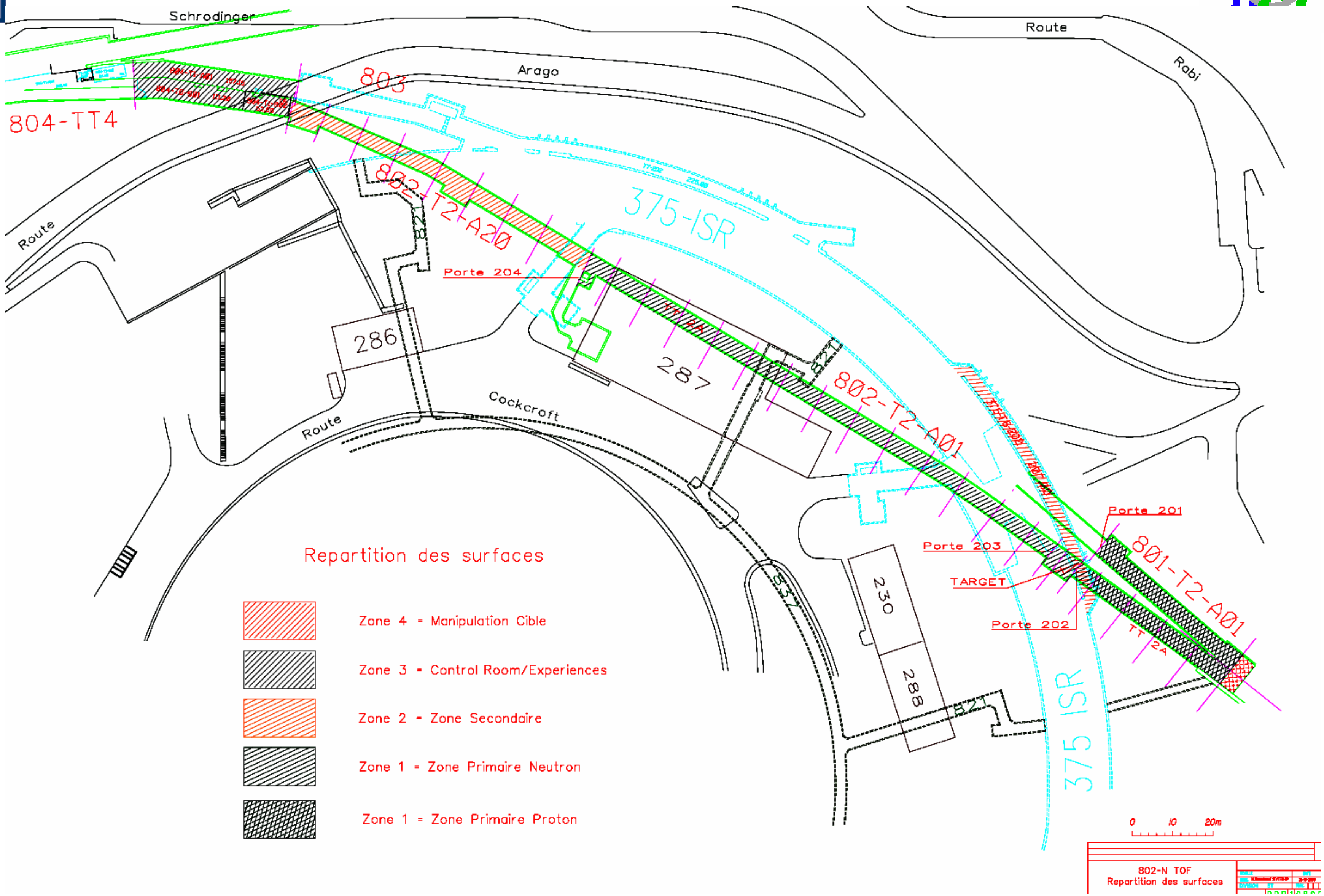


Possible Target Test Station Sites

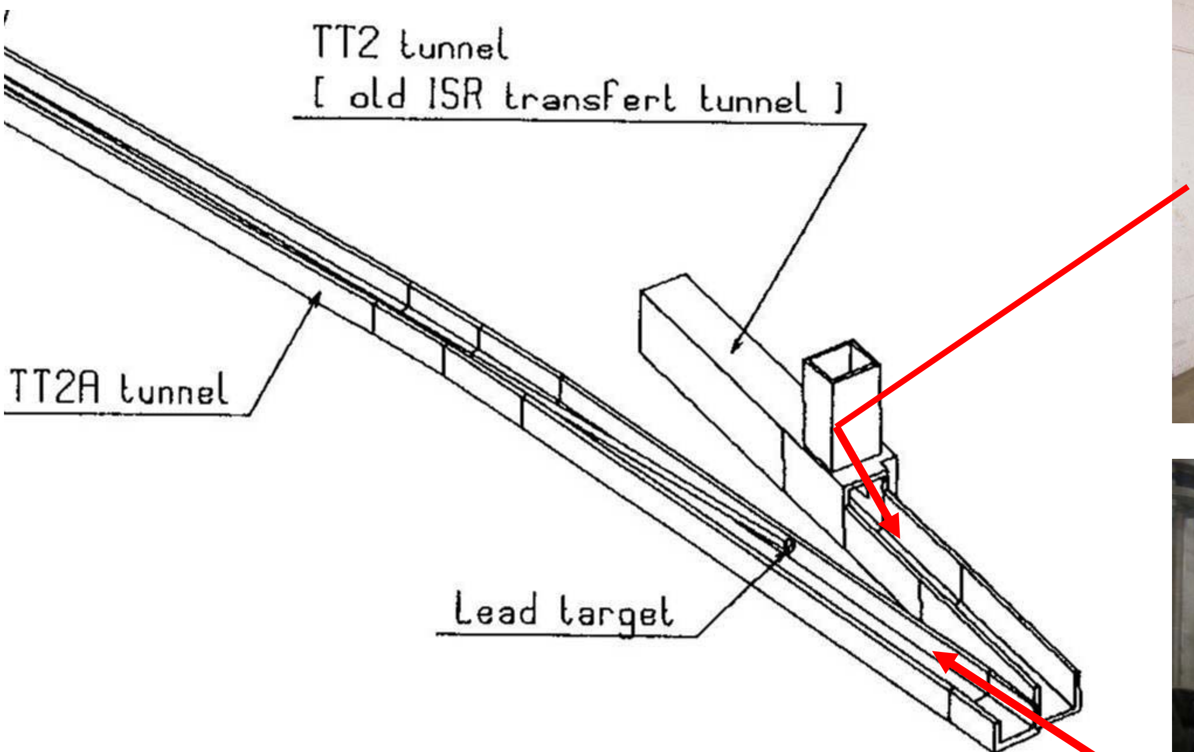
Parameter	BNL AGS	CERN PS	RAL ISIS	LANCE WNR	JPARC RCS	JPARC MR
Proton Energy, GeV	24	24	0.8	0.8	3	50
p/bunch, 10^{12}	6	4	10	28	42	42
Bunch/cycle	12	8	2	1	2	9
p/cycle, 10^{12}	72	32	20	28	83	300
Cycle length, μs	2.2	2.0	0.3	0.25	0.6	4.2
Availability (?)	07	06	06	Now	08	09

Target Test Site at CERN



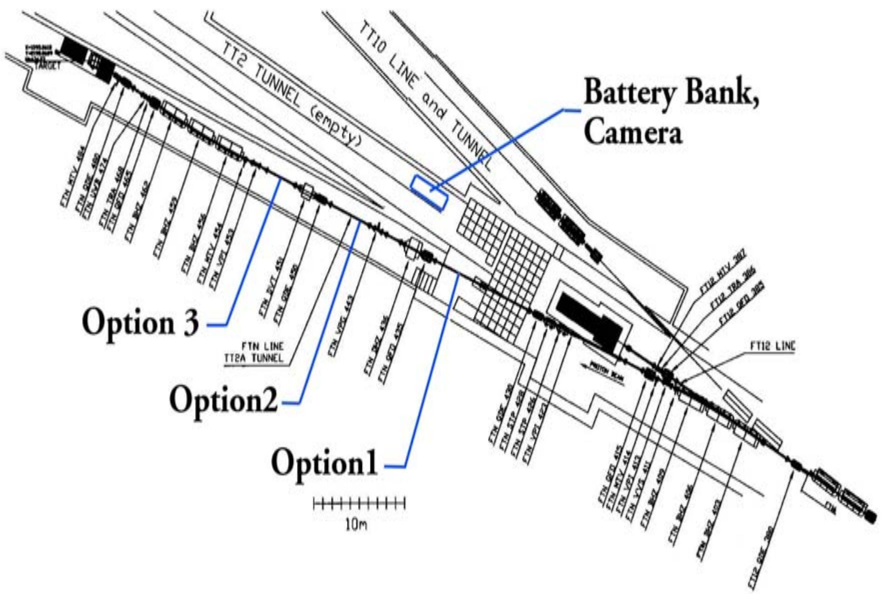

Schrodinger
Arago
803
804-TT4
Route
Rabi
Route
802-T2-A20
375-ISR
Porte 204
286
287
821
Cockcroft
Route
802-T2-A01
801-T2-A01
Porte 201
Porte 203
TARGET
Porte 202
230
288
837
375 ISR
Repartition des surfaces
Zone 4 = Manipulation Cible
Zone 3 - Control Room/Experiences
Zone 2 - Zone Secondaire
Zone 1 = Zone Primaire Neutron
Zone 1 = Zone Primaire Proton
0 10 20m
802-N TOF
Repartition des surfaces

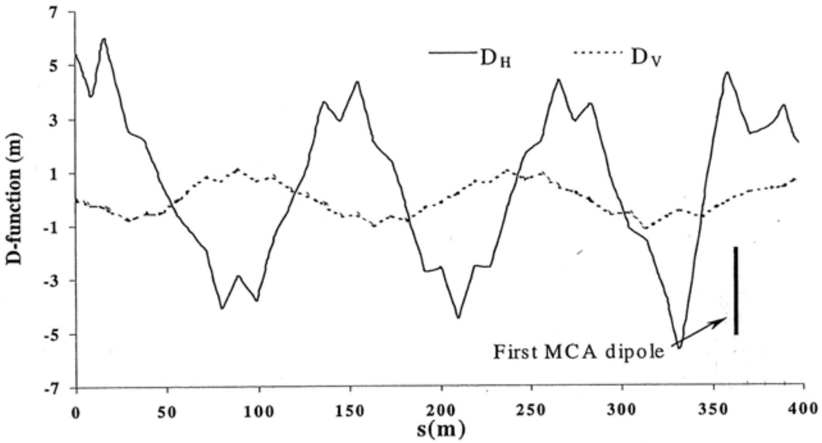
Possible Experiment Location at CERN

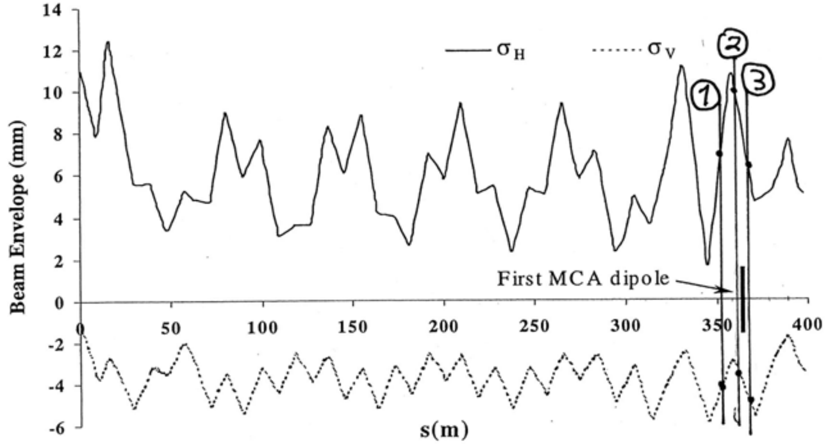


Letter of Intent submitted Oct. 23, 2003

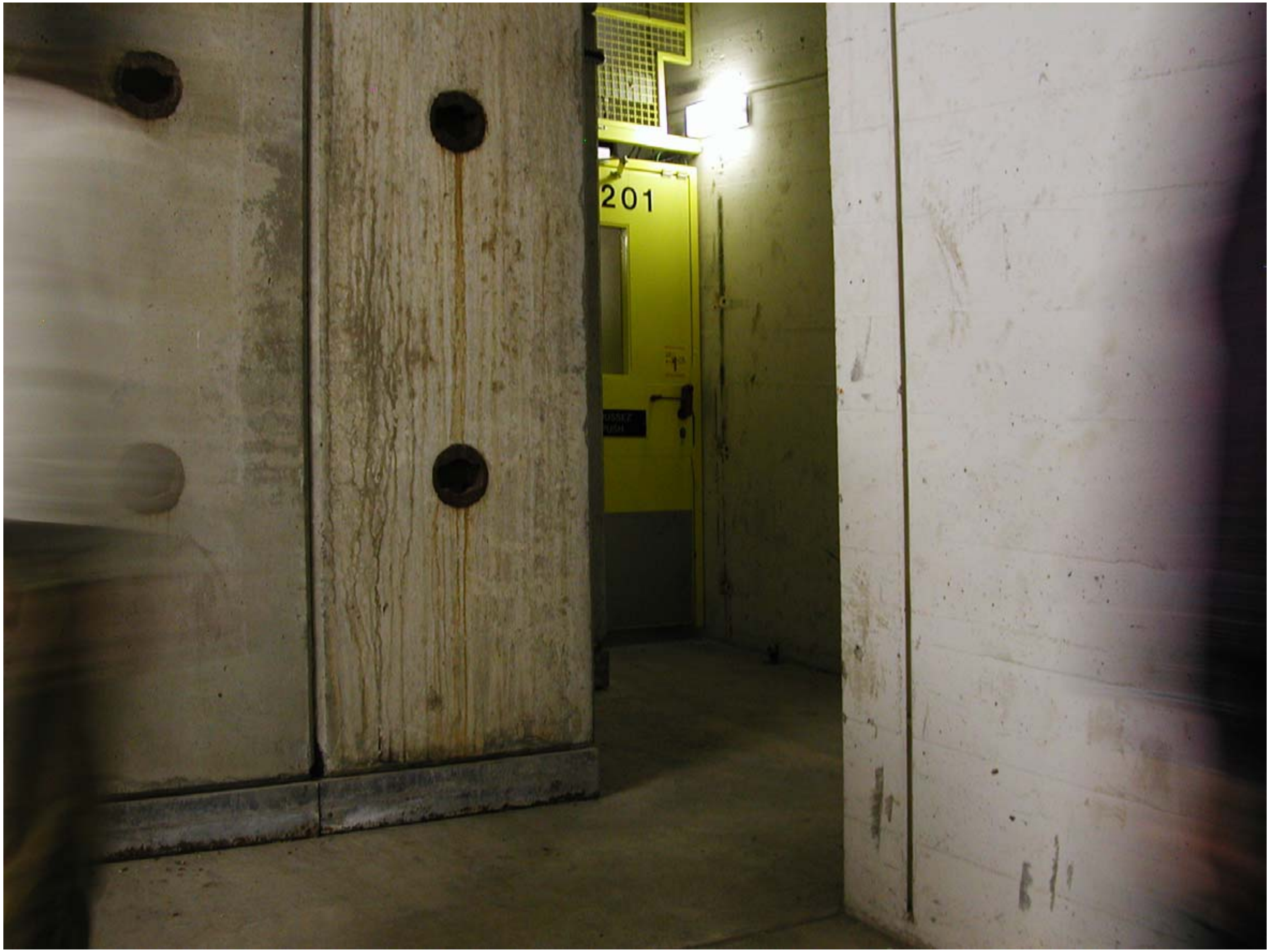
The TT2a Beam Line







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



- Entrance

- Entrance

- Place for batteries (downstream view, slope goes up!)

- Place for batteries (upstream view, slope goes down!)

- Entrance (view upstream)

- Near Entrance (view downstream)

- Beamline (view downstream)

- Entrance (view downstream)

- Entrance (view downstream)

View towards entrance
(upstream)

The radiation people:

- the recommendation of CERN's radiation protection group is to find an alternate position for the planned Hg irradiation than the tunnel TT2a. The reasons are:
- - this tunnel is not ventilated (and thus releases are not monitored) . In case of radioactive Hg spillage we would have incalculable releases into the environment. This is contrary to our operating license.
- - it is impossible to arrange a beam dump behind the Hg set-up. The secondary particle cascade would irradiate and activate beam line elements downstream of the target, creating un-optimised radiation levels for maintenance after the experiments

- Tunnel TT2, upstream of the D3 dump would offer similar beam parameters and significantly better safety conditions for your intended experiment.
- I transmitted this judgement already several weeks ago to Helmut. He mentionned that only "very few" pulses would be required and activation of Hg, air and beam line elements would be "very small" . If these "very small" activation levels could be quantified by you, I am prepared to look again into radiological safety related consequences of the intended irradiations at this specific position.
- For a comprehensive radiological safety study, we would need documented
- estimates (by Monte-Carlo or analytical methods) of:

- - the activation of the Hg target, listing the major contributing isotopes
- - air activation (by isotopes)
- - activation of a "typical" beam line element, e.g. a block of copper in one metre distance form the target. Here, the interesting quantity would be the expected dose equivalent rate at the surface, but we could also do with activation by isotope.
- In the TT2-position, an estimate of the Hg activation alone would be sufficient, as there would be a beam dump behind your setup and the area is ventilated.

The cryogenics people:

- *The reason why I am writing to you is to learn more about the pulsed magnet and in particular about its internal cooling part and the external equipment envisaged. Magnet size and mass, material, cooling channels or "immersed" cooling, temp. gradients limitations, re-cooling temp., speed, lowest temp. desired, cryo equipment, flow scheme, etc.… Even if not yet fully studied all info is appreciated.*

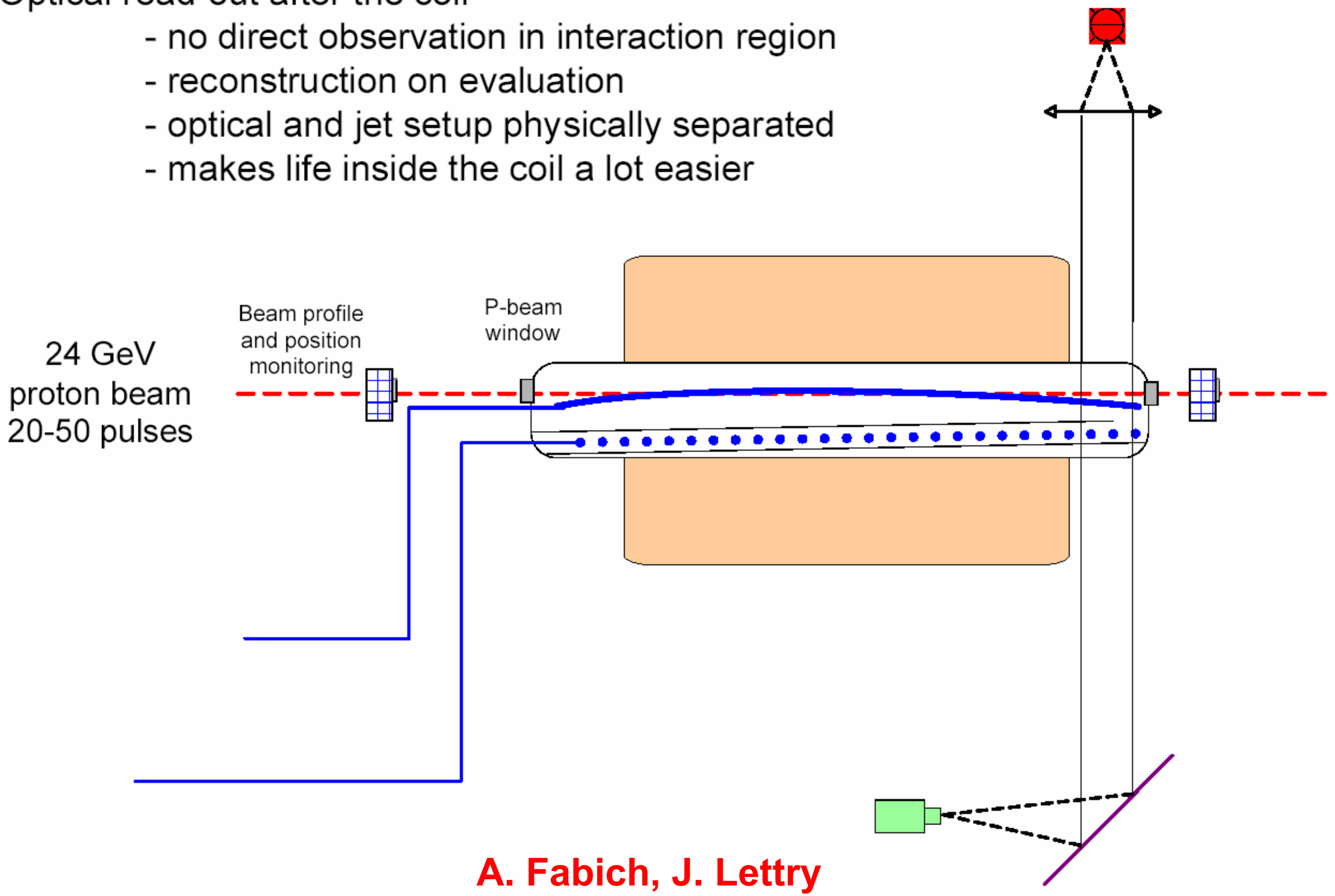
Main Issues towards a design

- Adapt for a jet diameter of 1 cm
  - Mercury flow quasi-continuous?
- If basic CERN principle preserved
  - Optical system inside the bore
    - Two camera systems at the same time? (semi-mirrors)
  - Replace Makrolon by Quartz
- Obey safety issues

Accessibility of bore from two sides makes a lot of things easier.

Optical read-out after the coil

- no direct observation in interaction region
- reconstruction on evaluation
- optical and jet setup physically separated
- makes life inside the coil a lot easier



A. Fabich, J. Lettry

Letter of Intent-- Isolde and nToF Committee

CERN-INTC-2003-033
INTC-I-049
23 October 2003
Updated: 31 Oct 2003

A Letter of Intent 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], Helmut Haseroth[2], Yoshinari Hayato[3], Steven J. Kahn[4],
Jacques Lettry[2], Changguo Lu[5], Hans Ludewig[4], Harold G. Kirk[4],
Kirk T. McDonald[5], Robert B. Palmer[4], Yarema Prykarpatskyy[4],
Nicholas Simos[4], Roman V. Samulyak[4], Peter H. Thieberger[4],
Koji Yoshimura[3]

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

Participating Institutions

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

ISOLDE AND NEUTRON TIME-OF-FLIGHT EXPERIMENTS COMMITTEE

INTC

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The link to the INTC minutes is:

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4. A.O.B.

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The authors of this letter of intent propose to perform proof-of-principle tests of a high-power production target station as needed for a Neutrino Factory or a Muon Collider. The target consists of a free mercury jet situated inside a 15T solenoid and would be installed in the nTOF tunnel. The Committee saw the tests as very useful, but questions regarding the implications for CERN and the nTOF scientific programme would have to be addressed in discussions with the concerned local groups, pending the outcome of an application to the EC. Furthermore, the major effort in machine development needed to deliver 8 PS bunches in one extraction cycle was highlighted. In conclusion, the Committee **welcomed** the physics case and **took note** of the current document.

So far so good…

Thank you!