# Targetry Concept for a Neutrino Factory

EMCOG Meeting

CERN

November 18, 2003

Harold G. Kirk
Brookhaven National Laboratory

# Intense Proton Sources

World wide interest in the development of new proton drivers

New physics opportunities 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

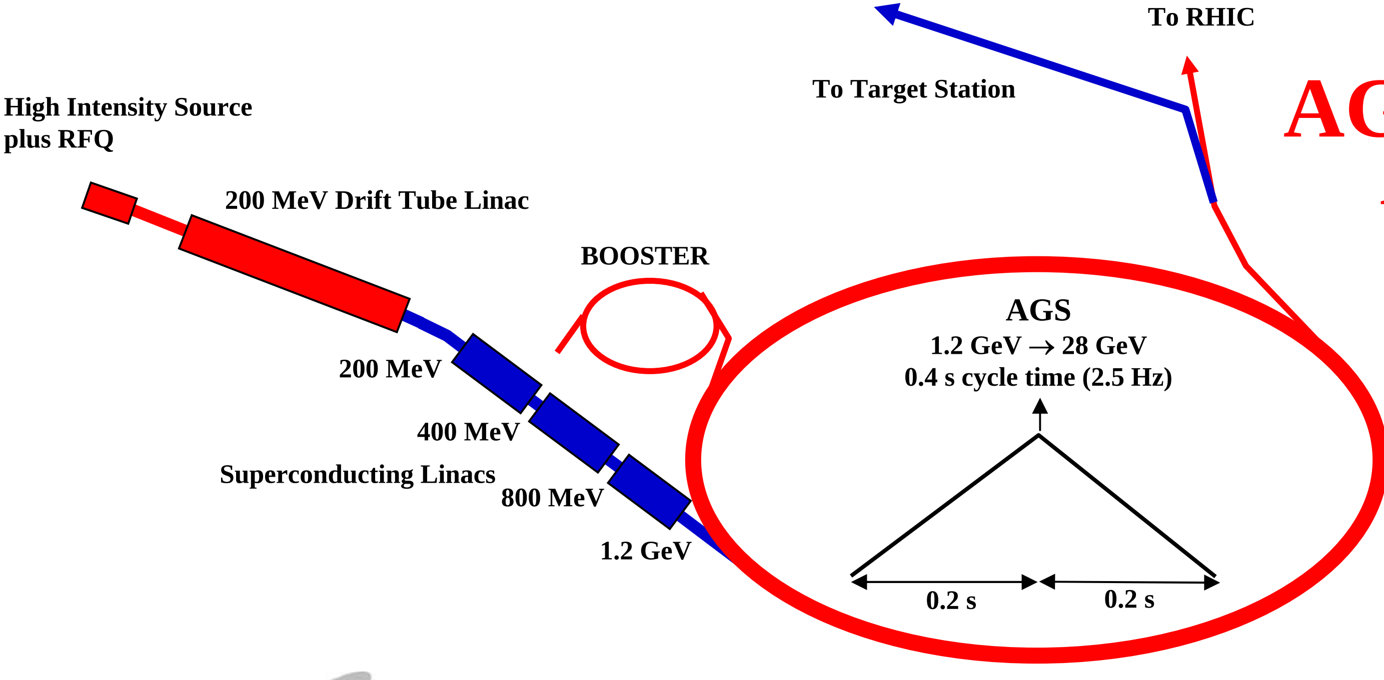
# Multi-MW New Proton Machines

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

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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-power Targetry
# Ronkonkoma, Long Island Sept. 2003

- New physics opportunities are demanding more intense proton drivers.
- 1 MW machines are almost here! 4 MW machines are planned.
- Targets for 1 MW machines exist but are unproven.
- But no convincing solution exists yet for the 4 MW class machines.
- Worldwide R&D efforts to develop targets for these new machines.
- A key workshop concern was the lack of worldwide support facilities where promising new ideas can be tested.

# Neutrino Factory and Muon Collider

## Neutrino Factory

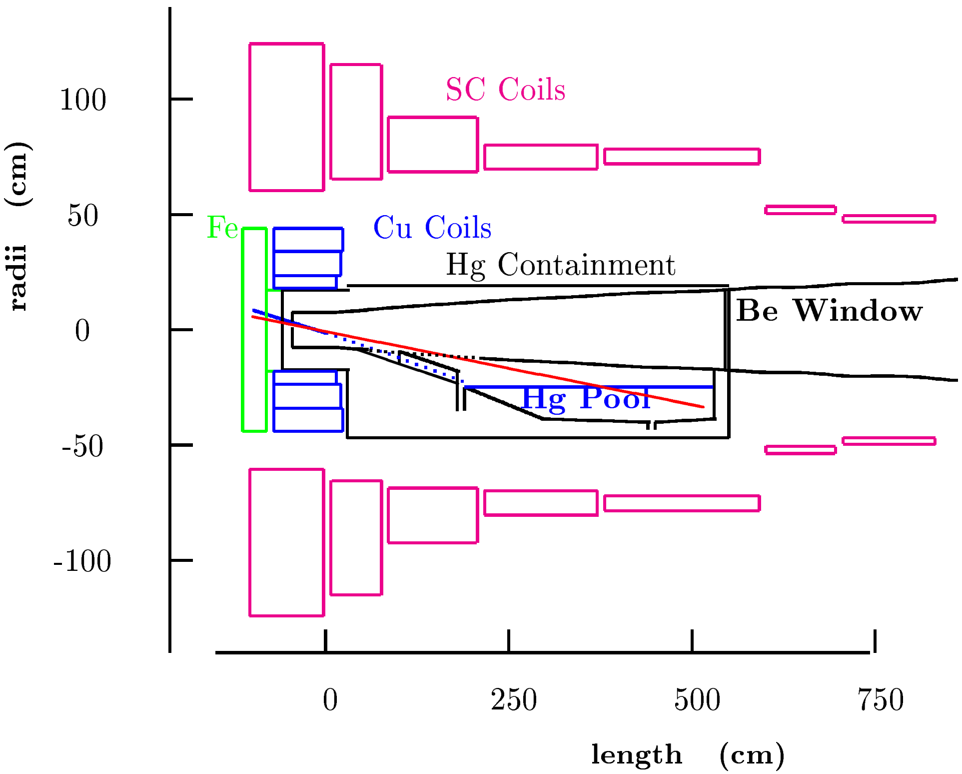
- Key parameter is neutrino flux
- Source strength is pre-eminent issue
- Maximize protons-on-target in order to maximize pions/muons collected

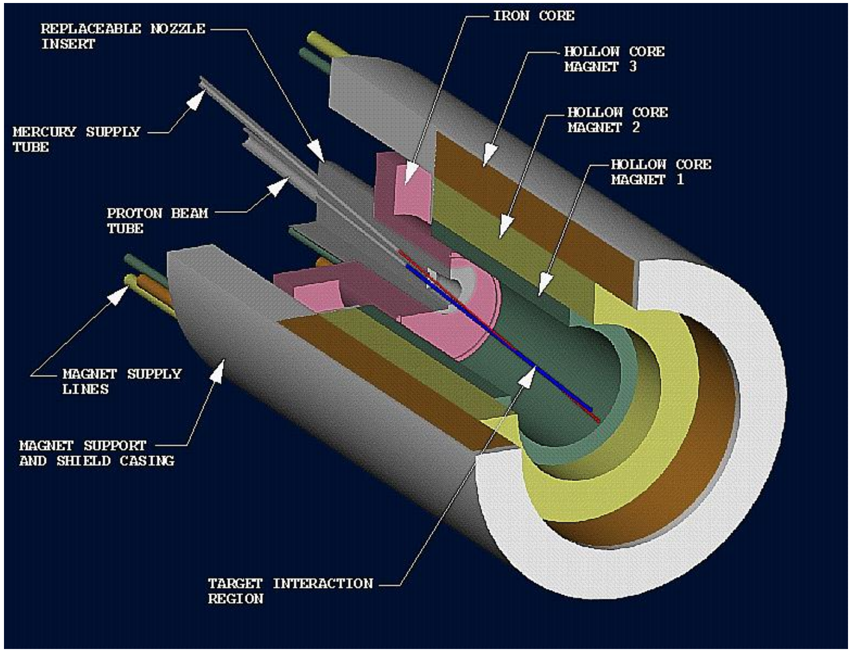
## Muon collider

$$L = \frac{N_1 N_2 f}{A} s^{-1} cm^{-2}$$

- Gain in luminosity proportional to the square of source strength
- Small beam cross-sectional area (beam cooling) is also important

# 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

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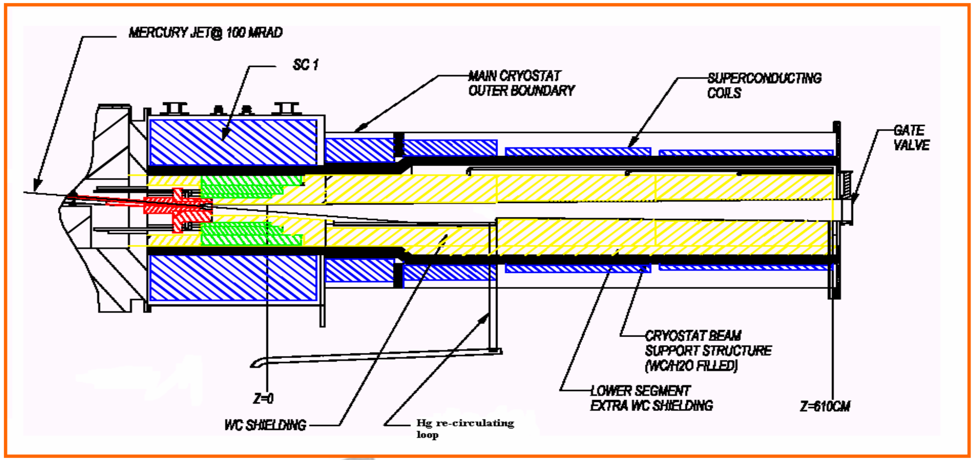
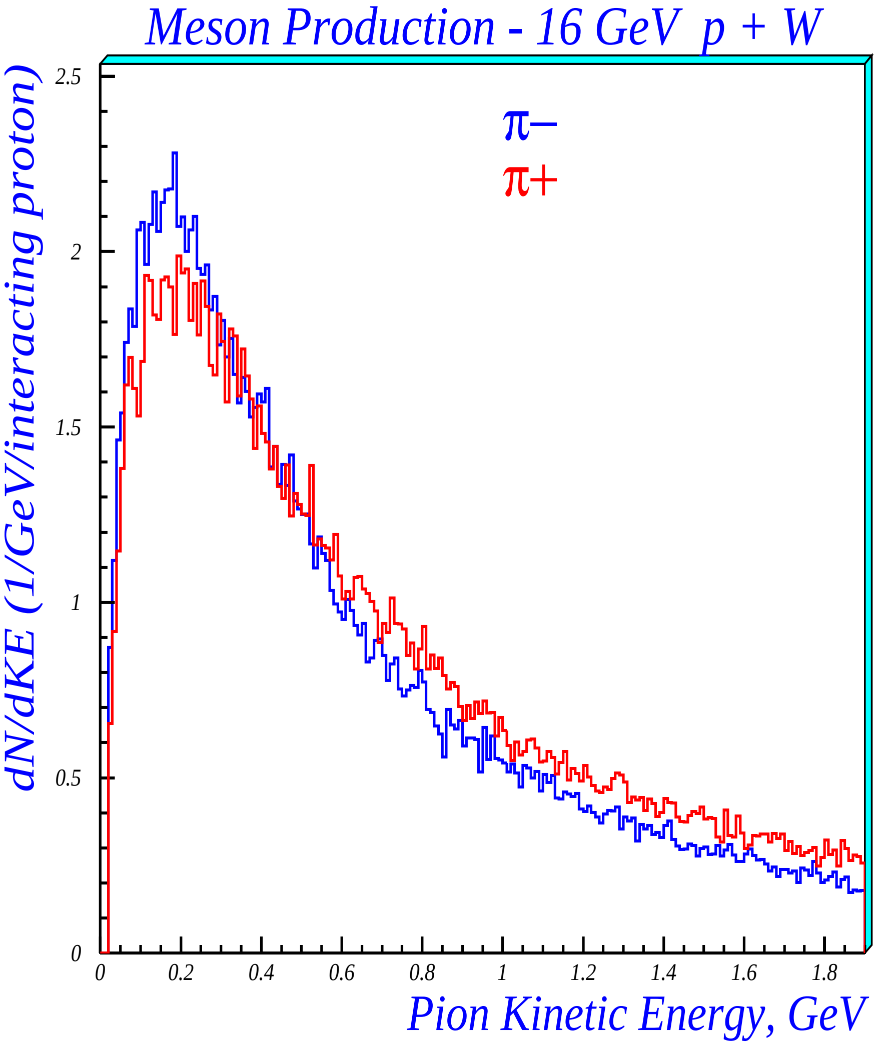
# Achieving Intense Muon Beams

Maximize Pion/Muon Production

- Soft Pion Production
    - Higher Z material
        - High energy deposition
        - Mechanical disruption
- High Magnetic Field

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# High-Z Materials

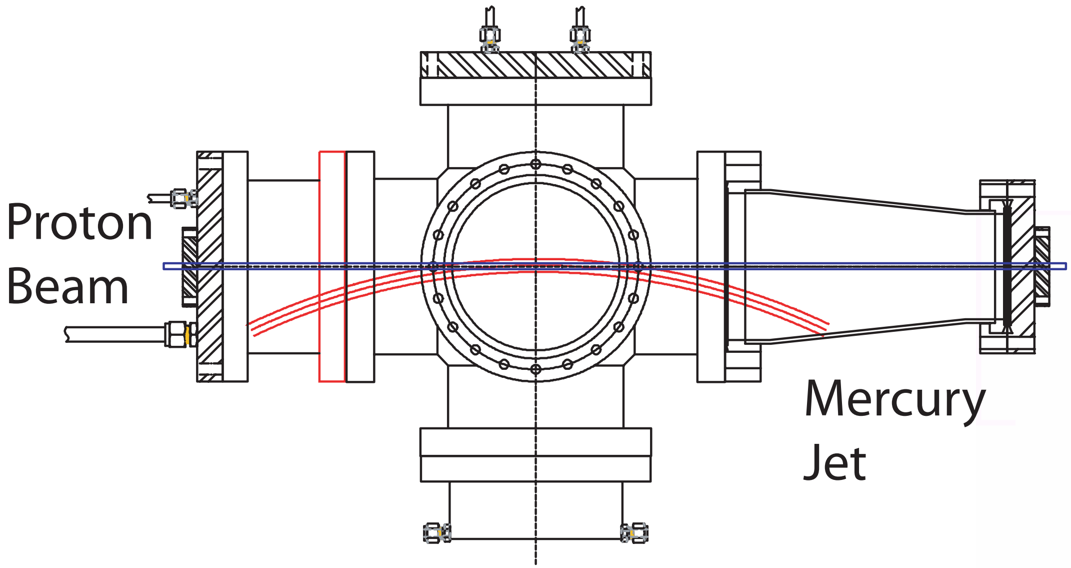
## Key Properties

- Maximal soft-pion production
- High pion absorption
- High peak energy deposition
- Potential for extension beyond 4 MW (liquids)

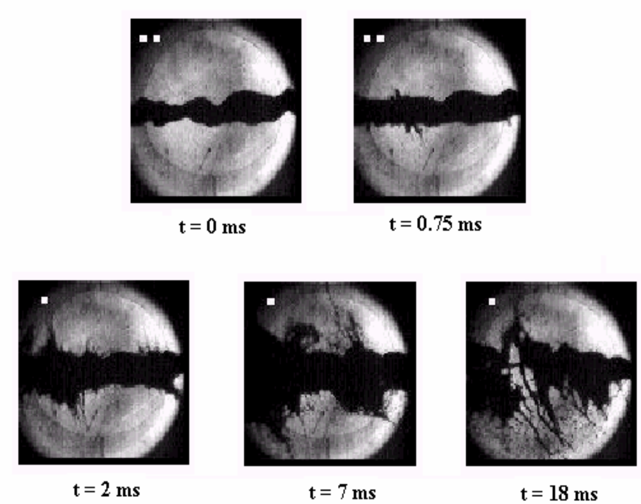
## Key Issues

- Jet dynamics in a high-field solenoid
- Target disruption
- Achievement of near-laminar flow for a 20 m/s jet

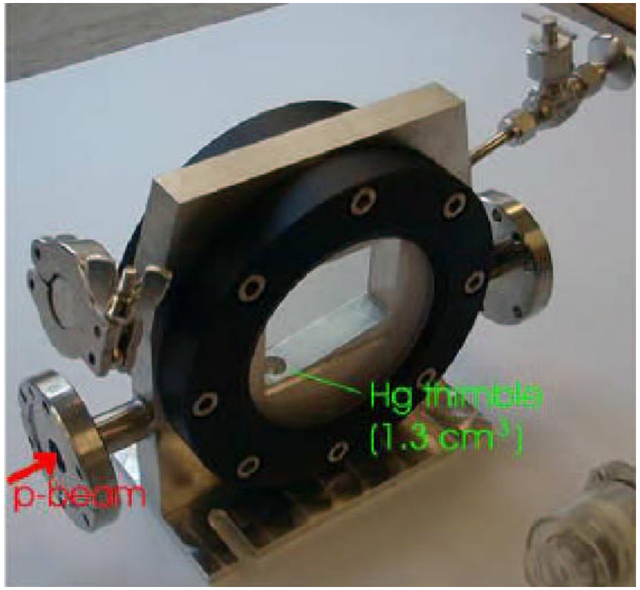
# E951 Hg Jet Tests

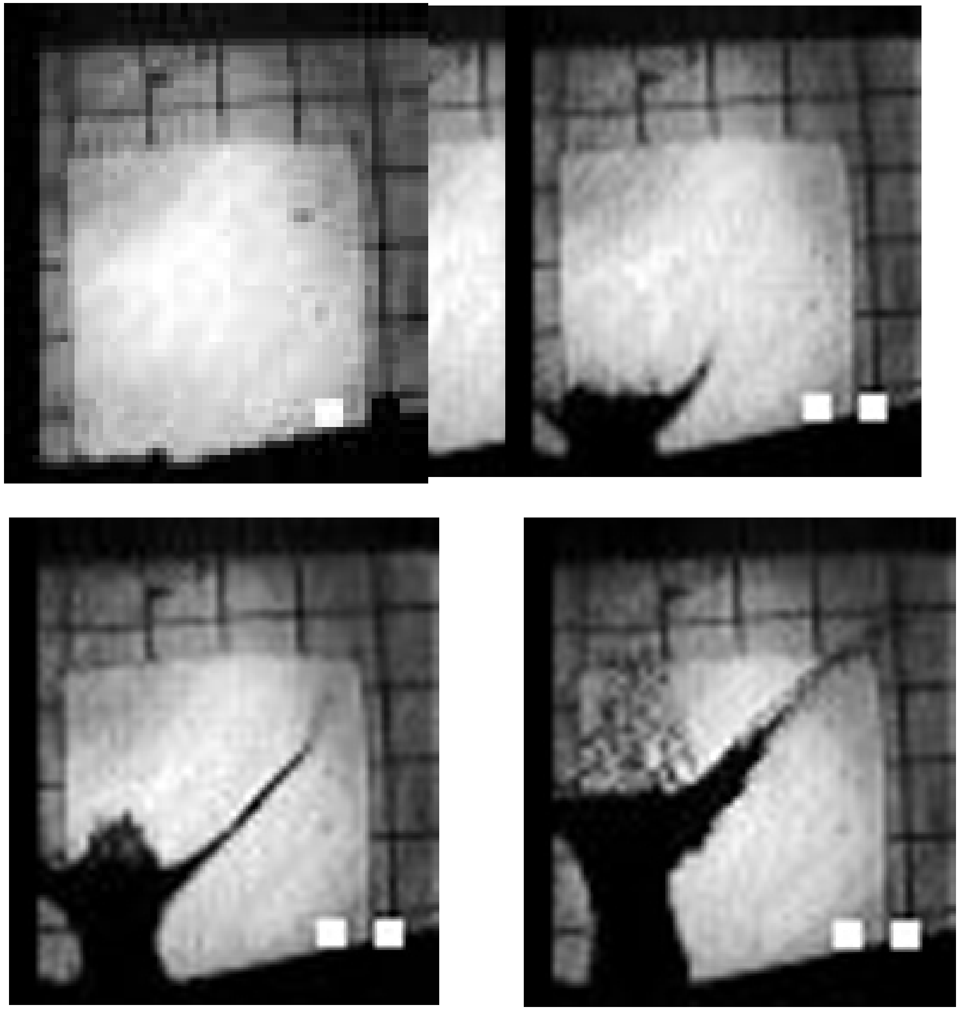



- 1cm diameter Hg Jet
- 24 GeV 4 TP Proton Beam
- **No** Magnetic Field



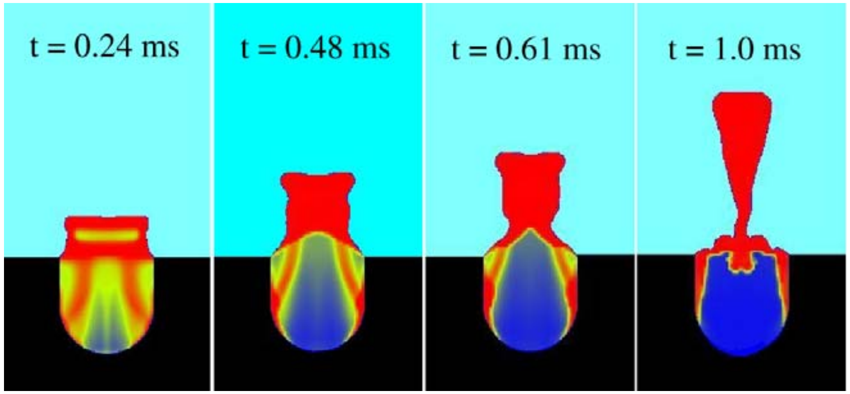
# CERN Passive Hg Thimble Test



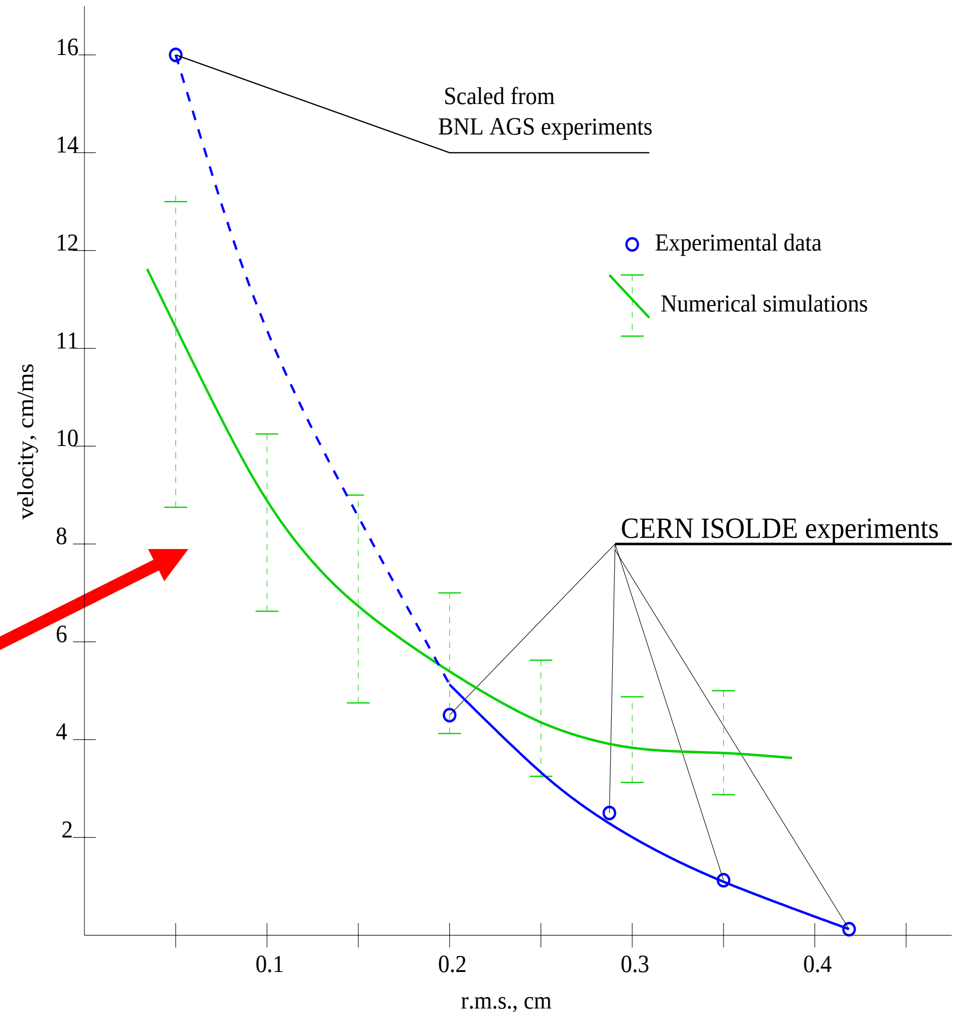



Exposures to a BNL AGS 24 GeV 2 TP beam. T=0, 0.5 , 1.6 and 3.4 ms.

# CERN Hg Thimble Results




Simulations—Prykarpatskyy, BNL




Bulk ejection velocity as a function Of beam spot size. ISOLDE data is 17 TP at 1.4 GeV.

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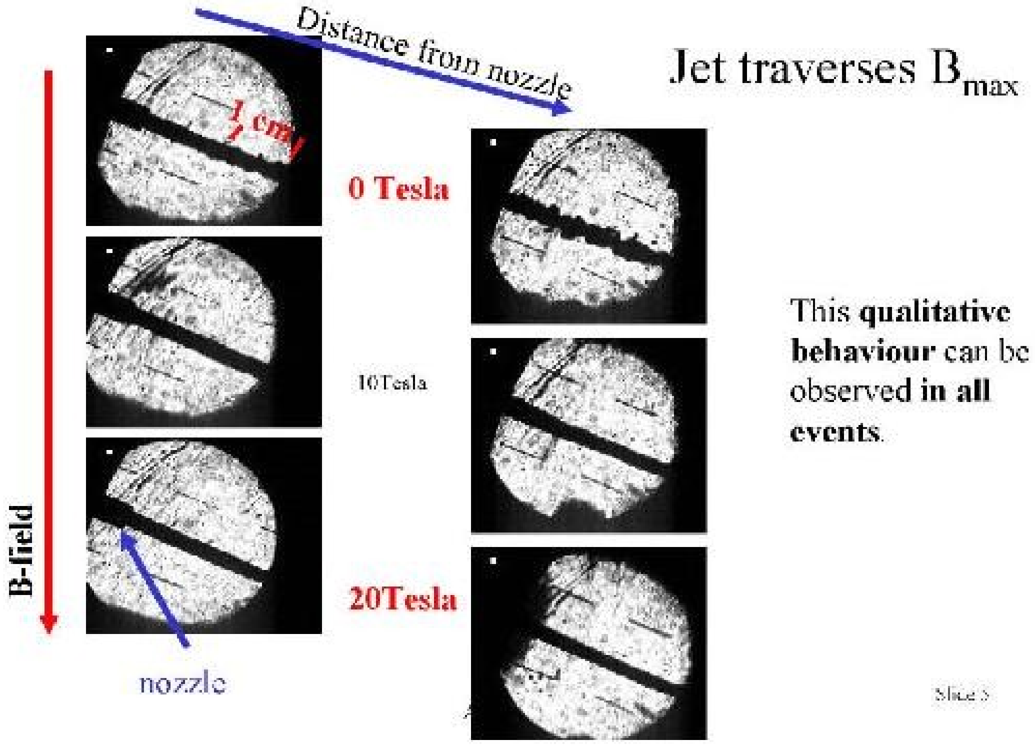
# Key E951 Results

- 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



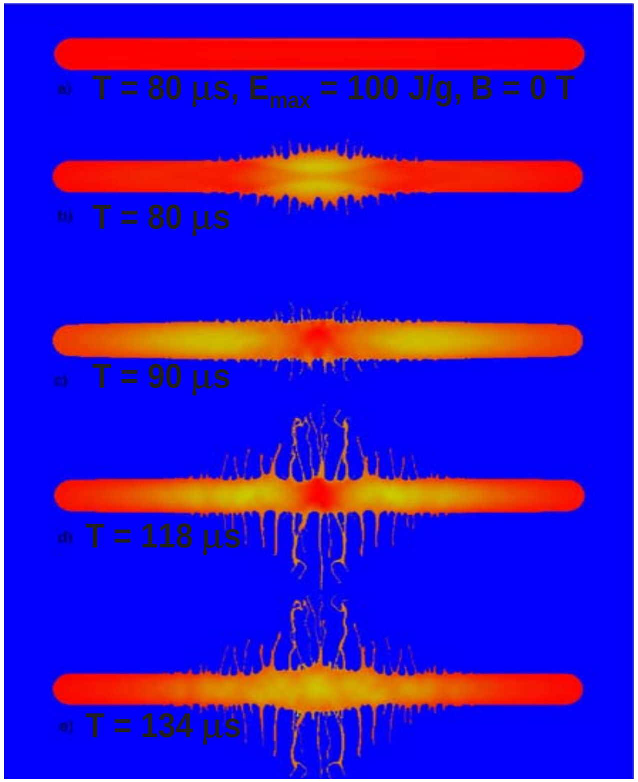

- 4 mm diameter Hg Jet
- v = 12 m/s
- 0, 10, 20T Magnetic Field
- **No** Proton Beam

A. Fabich, J. Lettry
Nufact'02

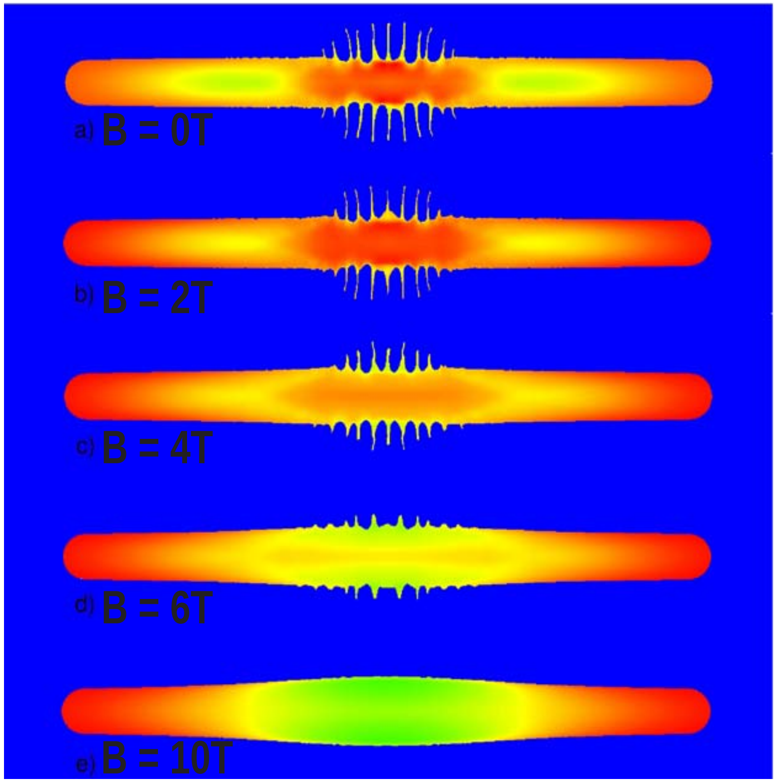
# Key Jet/Magnetic Field Results

- 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

# Simulations at BNL (Samulyak)




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




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

# Bringing it all Together

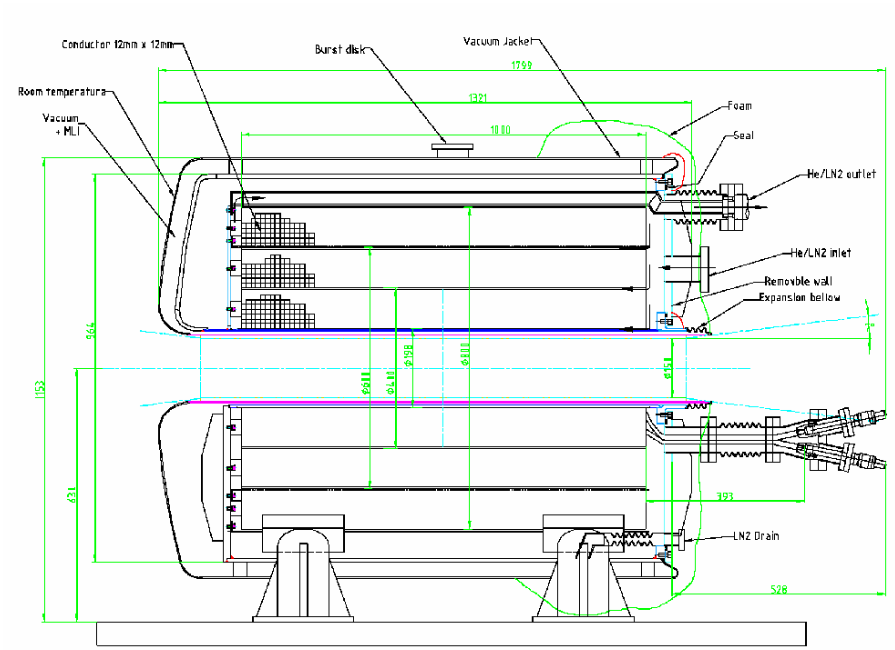
We wish to perform a proof-of-principle test which will include:

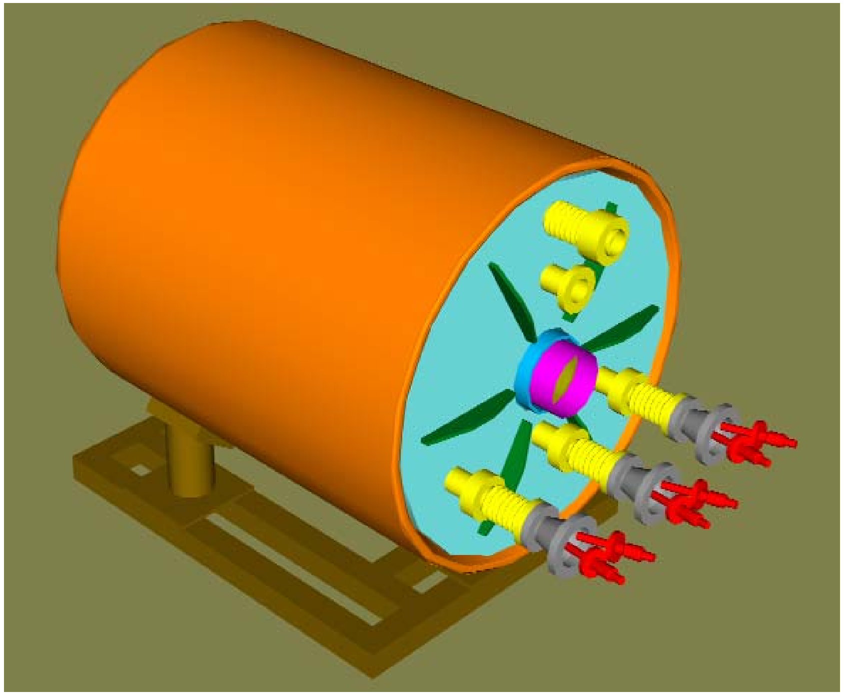
- A high-power intense proton beam (16 to 32 TP per pulse)
- A high (> 15T) solenoidal field
- A high (> 10m/s) velocity Hg jet
- A ~1cm diameter Hg jet

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

# High Field Pulsed Solenoid



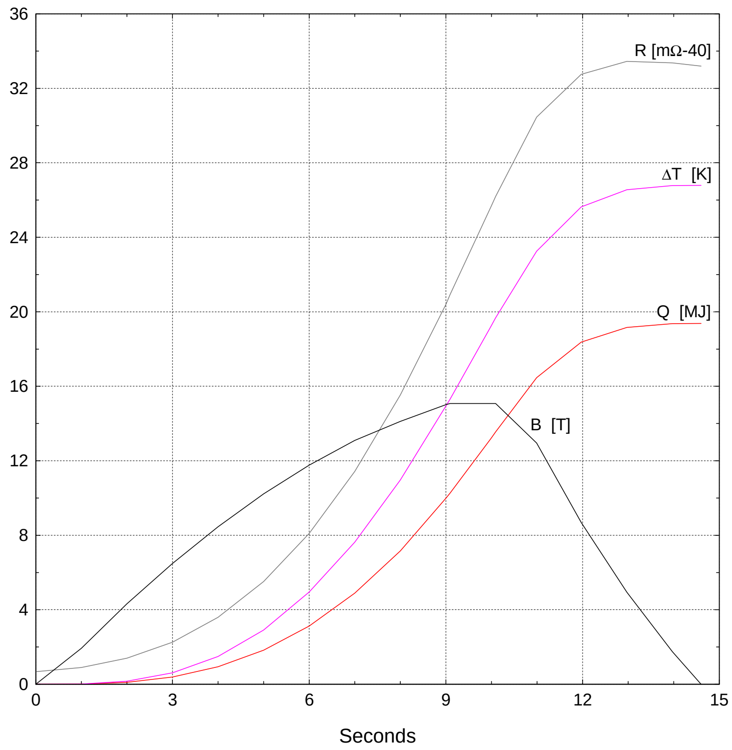
- $70^o$ K Operation
- 15 T with 4.5 MW Pulsed Power
- 15 cm warm bore
- 1 m long beam pipe

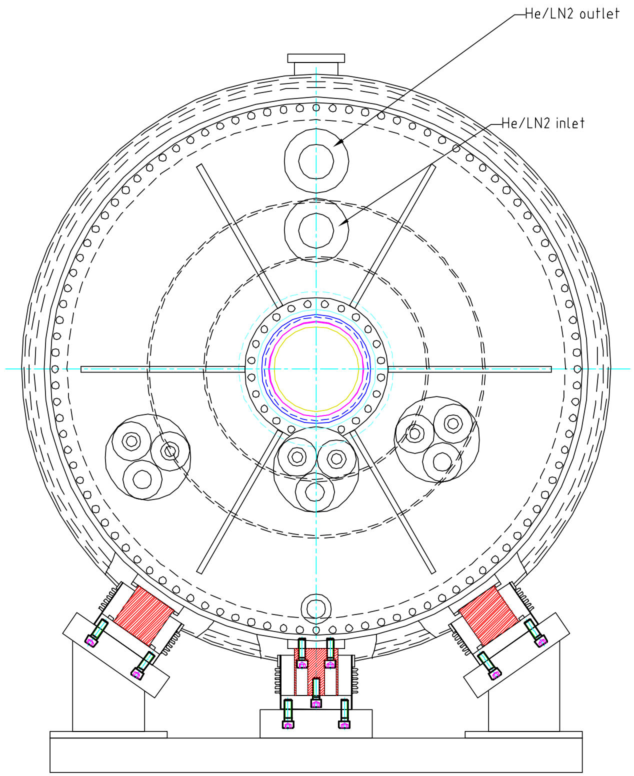
Peter Titus, MIT

Harold G. Kirk

# Pulsed Solenoid Performance

Pulse Coil Cooled to 70 K and Charged to 7200 A at 600 V, then -600 V



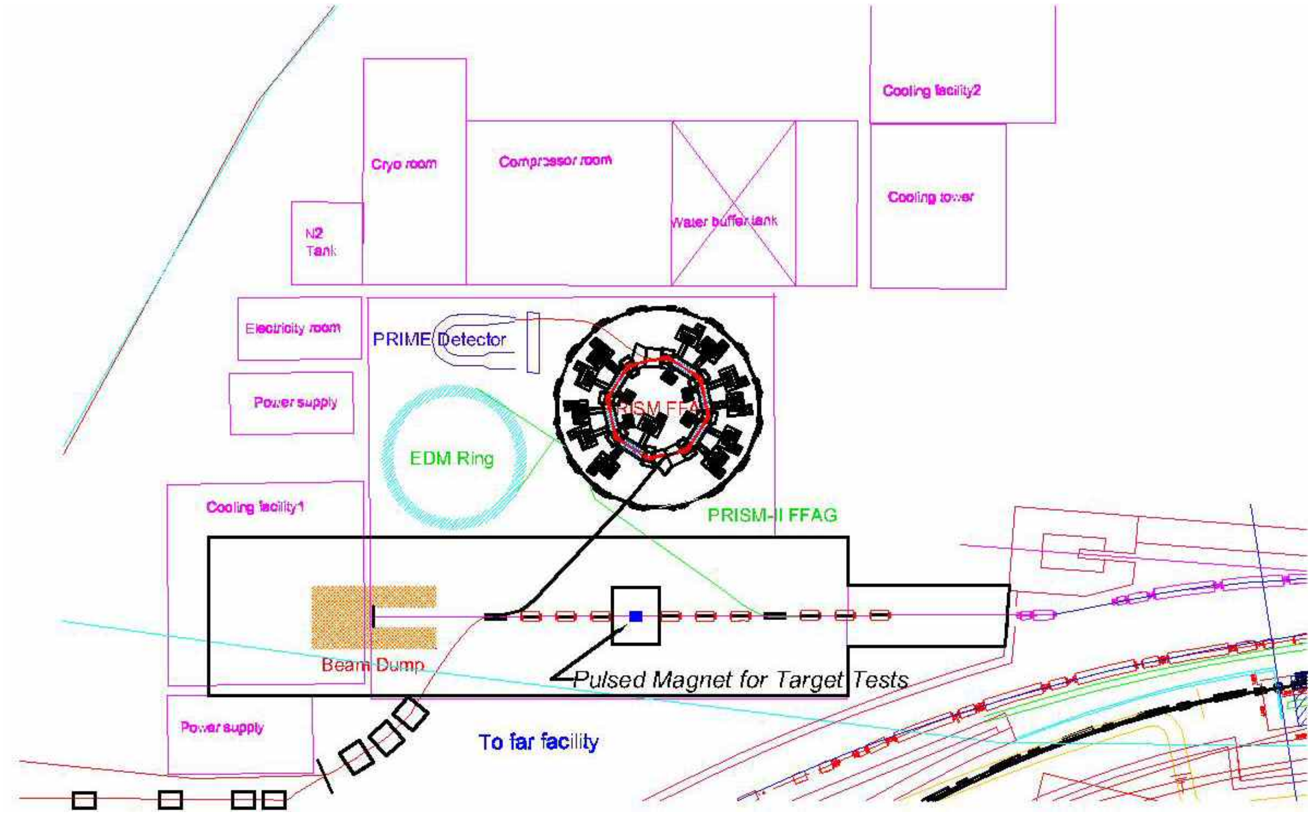

- •5T Peak Field with 2 inner coils; 540 KVA ; 80$^{O}$ K
- •10T Peak Field with 2 inner coils; 2.2 MVA PS; 72$^{O}$ K
- •15T Peak Field with 3 coils; 2.2 MVA PS; 30$^{O}$ K
- •15T Peak Field with 3 coils; 4.4 MVA PS; 70$^{O}$ K

# 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 | 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 |

# Possible Targetry Test at JPARC




Letter of Intent submitted January 21, 2003 – presented June 27, 2003

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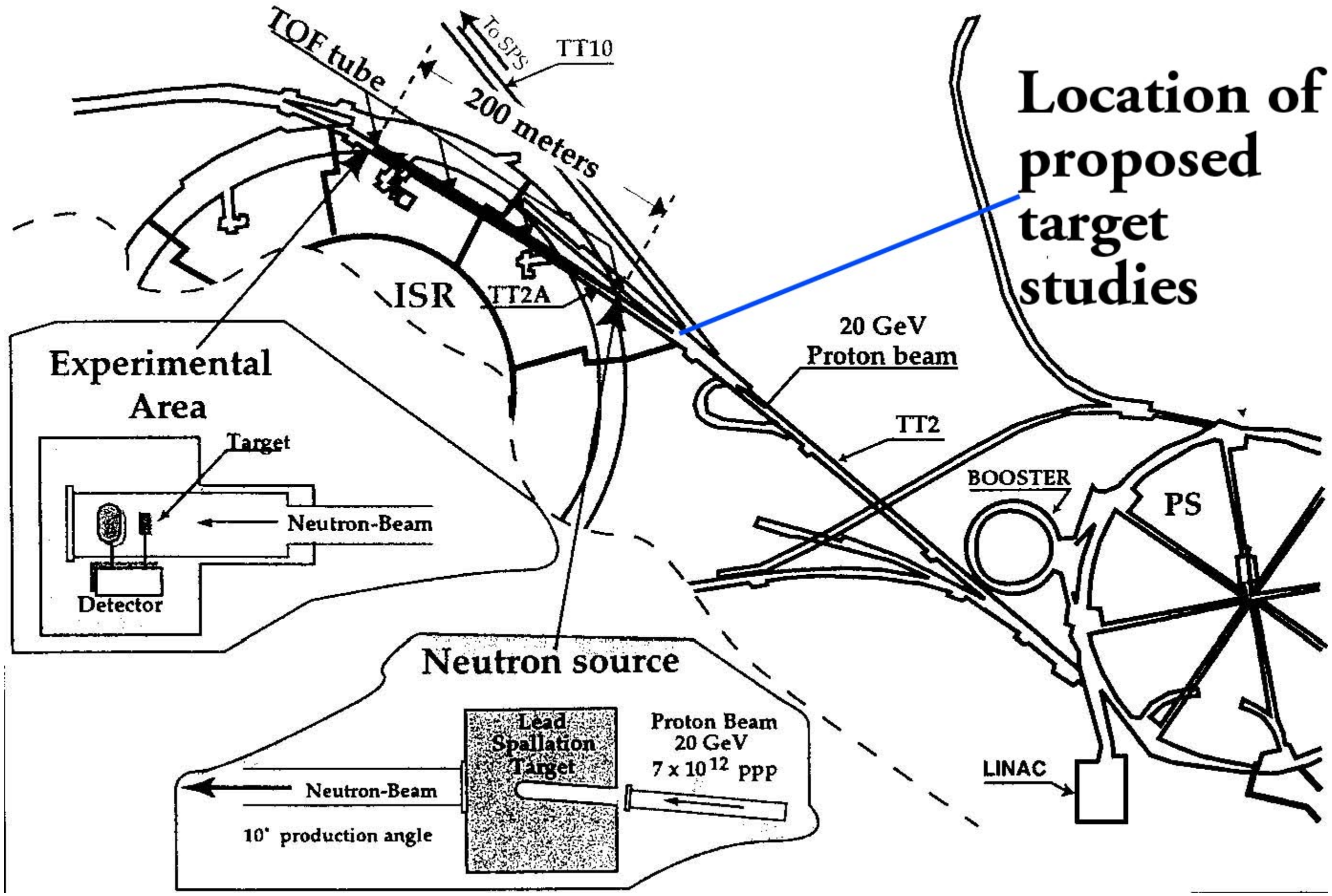
# Target Test Site at CERN



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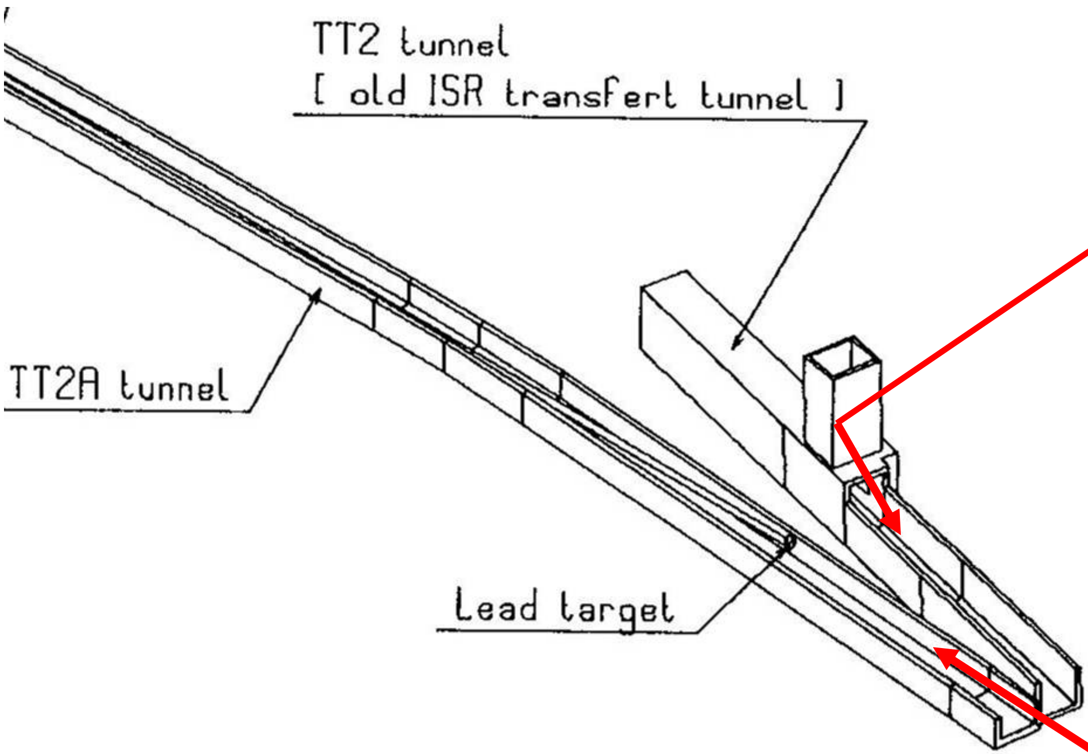
# Possible Experiment Location at CERN

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Letter of Intent to submitted Oct. 23, 2003

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# 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

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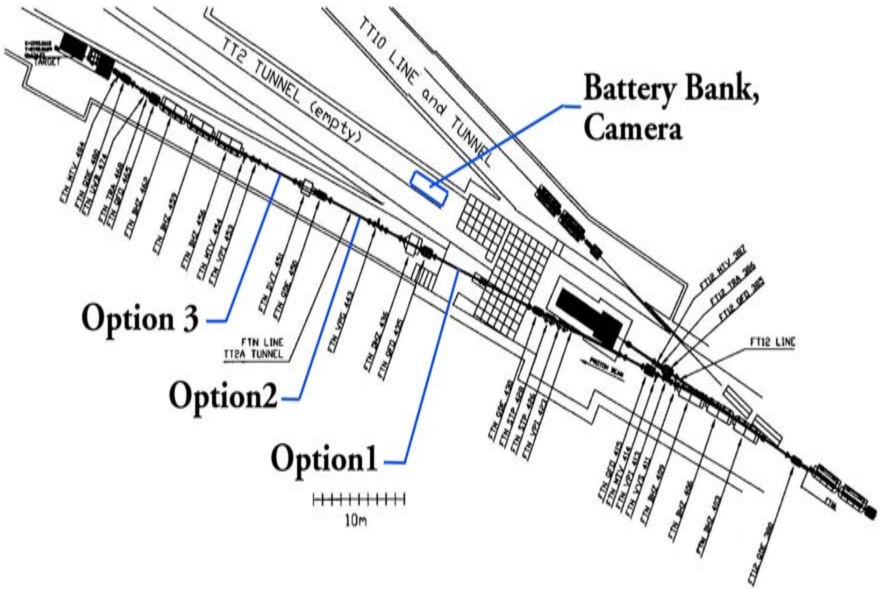
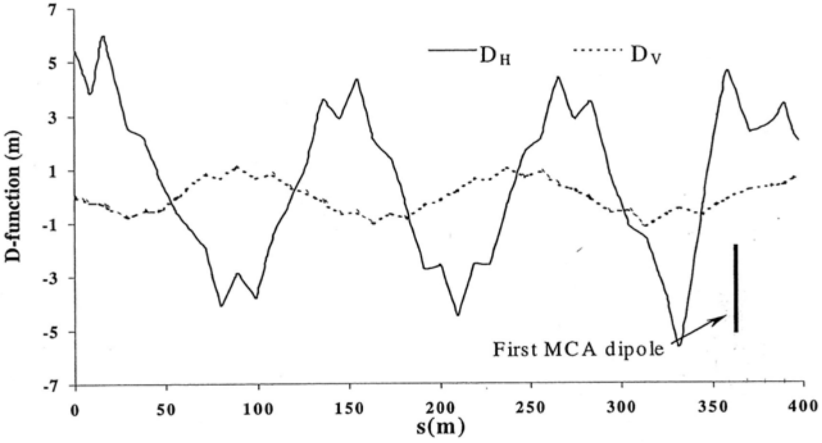
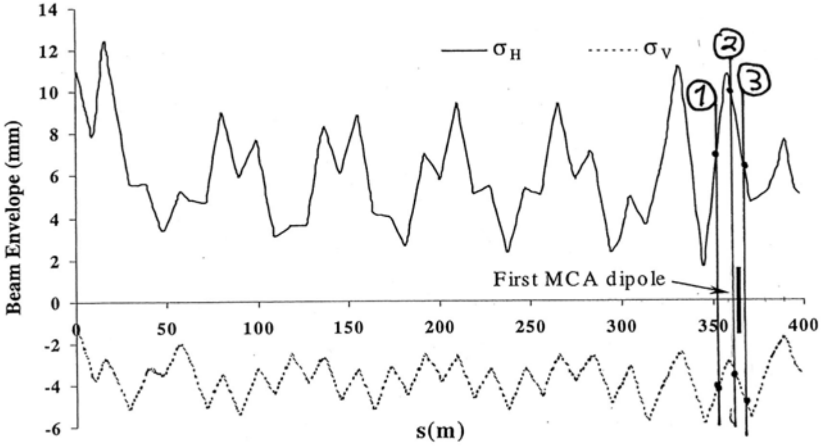
# The TT2a Beam Line



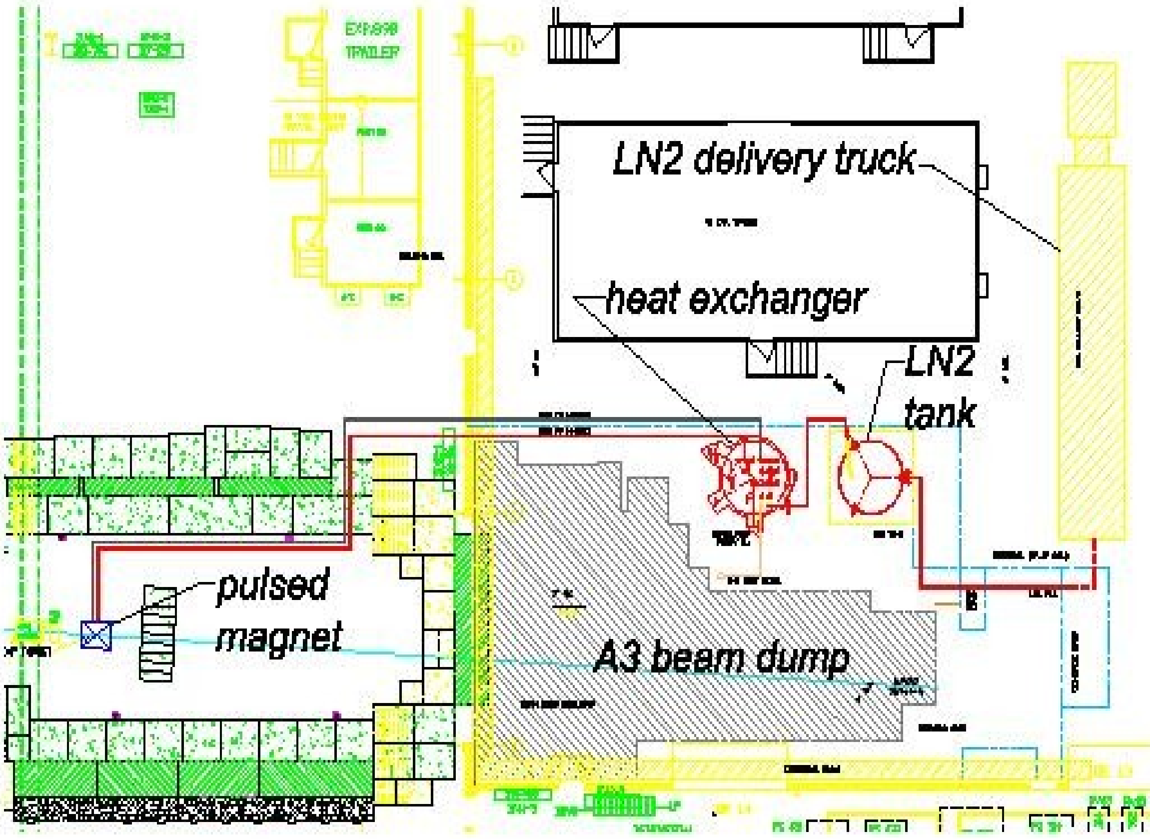



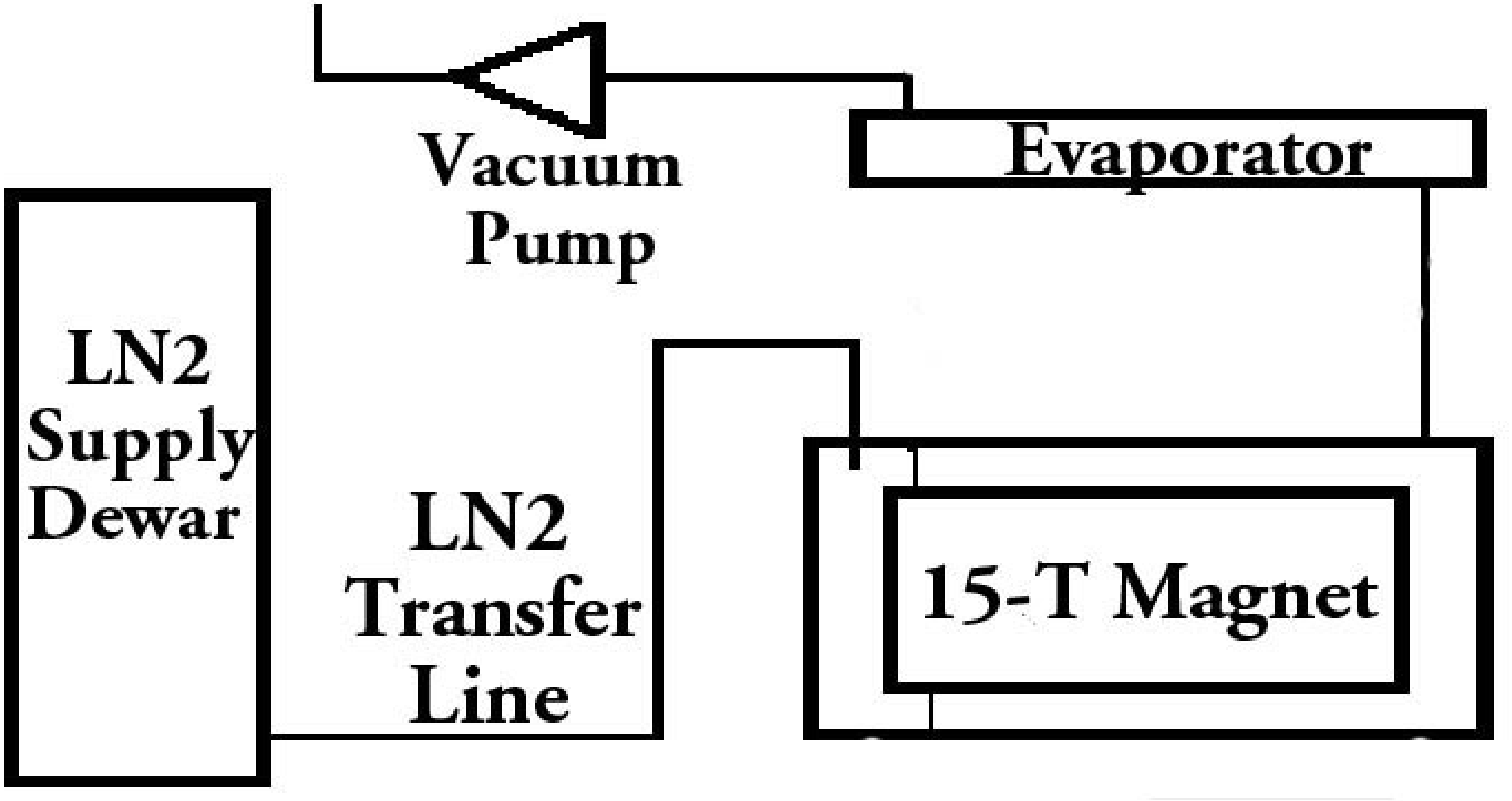

We propose running without longitudinal bunch compression allowing for a reduced beam spot size of ~ 2mm rms radius.

# Original Cryogenic Concept at BNL

- BNL specific solution
- Heat exchanger
- $LH_2$ or $LN_2$ primary cooling
- Circulating gaseous He secondary cooling



# Simplified Cryogenic System



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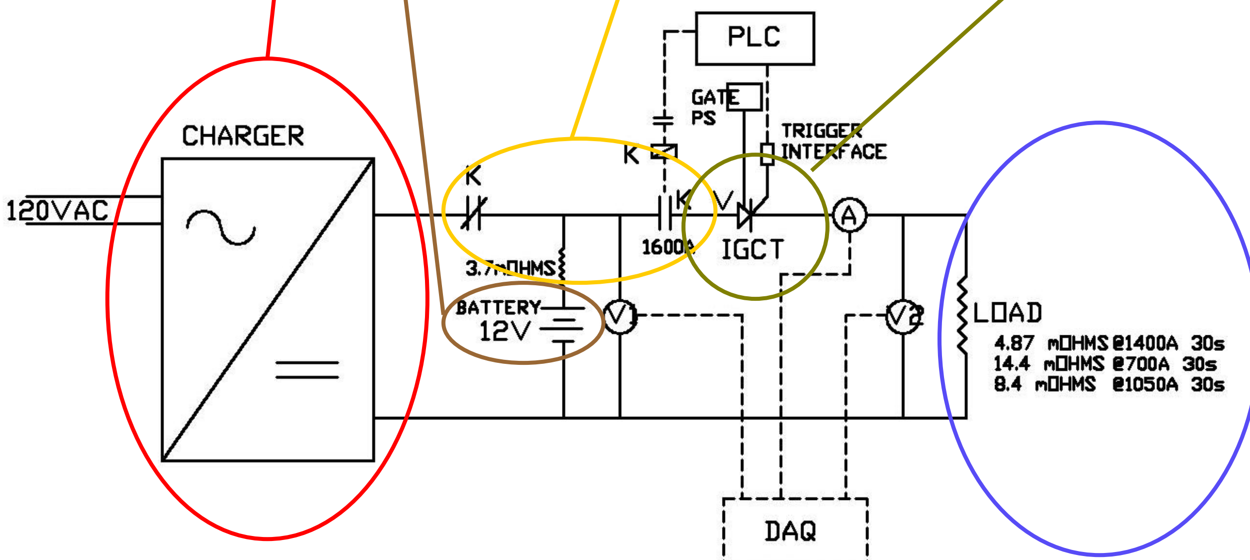
# Battery Power Supply R&D

Battery/Charger
12V 1400A

Mech. Switch
1500V 1600 A

IGCT 600V 4000A




Load

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# Battery Power Supply (Cont)

Mechanical Switch capable
of 4.4 MW Pulsed System

# Pulsed Solenoid Project Cost Profile

## Magnet

| | |
|---|---|
| Fabrication | \$ 410 K |
| Monitoring | \$ 80 K |
| Testing | \$ 90 K |
| Shipping | \$ 15 K |

## Cryogenic System (LN$_2$ without Heat Exchanger)

| | |
|---|---|
| Cryo | \$ 300 K |

## PS (Battery array with switching/charging/bussing)

| | |
|---|---|
| PS System | \$ 460 K |

Total Project Cost \$1355 K