The High-Power Target Experiment

INTC Meeting

CERN

May 24, 2004
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

<table>
<thead>
<tr>
<th>Facility</th>
<th>Power 1</th>
<th>Power 2</th>
<th>Power 3</th>
<th>Power 4</th>
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<tbody>
<tr>
<td>SNS</td>
<td>1.2 MW</td>
<td></td>
<td>2.0 MW</td>
<td></td>
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<tr>
<td>JPARC</td>
<td>0.7 MW</td>
<td></td>
<td>4.0 MW</td>
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<tr>
<td>FNAL</td>
<td>0.4 MW</td>
<td>1.2 MW</td>
<td>2.0 MW</td>
<td></td>
</tr>
<tr>
<td>BNL</td>
<td>0.14 MW</td>
<td>1.0 MW</td>
<td>4.0 MW</td>
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</table>

**AGS Upgrade to 1 MW**

- **High Intensity Source** plus RFQ
- **200 MeV Drift Tube Linac**
- **400 MeV Superconducting Linacs**
- **800 MeV Superconducting Linacs**
- **1.2 GeV Superconducting Linacs**

**AGS**
- **1.2 GeV → 28 GeV**
- **0.4 s cycle time (2.5 Hz)**

**To RHIC**

**To Target Station**

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Harold G. Kirk
The SPL Neutrino Horn

2.2 GeV protons at 4MW

Protons

Hg Jet

Current of 300 kA

$B \propto \frac{1}{R}$

$B = 0$

$\pi$
Neutron Production using Hg

SNS Target Configuration

Beta Beams

SNS Neutron Spallation Target

Fission Converter

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

Harold G. Kirk
Achieving Intense Muon Beams

Maximize Pion/Muon Production

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

Harold G. Kirk
E951 Hg Jet Tests

- 1cm diameter Hg Jet
- \( V = 2.5 \text{ m/s} \)
- 24 GeV 4 TP Proton Beam
- **No** Magnetic Field

![Diagram of Proton Beam and Mercury Jet](image)

- \( t = 0 \text{ ms} \)
- \( t = 0.75 \text{ ms} \)
- \( t = 2 \text{ ms} \)
- \( t = 7 \text{ ms} \)
- \( t = 18 \text{ ms} \)
Key E951 Results

- Hg jet dispersal proportional to beam intensity
- Hg jet dispersal $\sim 10 \text{ m/s}$ for 4 TP 24 GeV beam
- Hg jet dispersal velocities $\sim \frac{1}{2}$ 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 $40 \mu \text{s}$
CERN/Grenoble Hg Jet Tests

- 4 mm diameter Hg Jet
- \( v = 12 \text{ m/s} \)
- 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
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 ($> 10\text{m/s}$) velocity Hg jet
- A $\sim 1\text{cm}$ 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

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

Peter Titus, MIT

Harold G. Kirk
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.
Everson Tesla, Inc has been sub-contracted to fabricate the coils.
## Possible Target Test Station Sites

### Accelerator Complex Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BNL AGS</th>
<th>CERN PS</th>
<th>RAL ISIS</th>
<th>LANCE WNR</th>
<th>JPARC RCS</th>
<th>JPARC MR</th>
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<td>24</td>
<td>0.8</td>
<td>0.8</td>
<td>3</td>
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<td>p/bunch, $10^{12}$</td>
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<td>4</td>
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<td>28</td>
<td>42</td>
<td>42</td>
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<td></td>
<td></td>
<td>(7 CNGS)</td>
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<tr>
<td>Bunch/cycle</td>
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<td>2</td>
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<td>p/cycle, $10^{12}$</td>
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<td>20</td>
<td>28</td>
<td>83</td>
<td>300</td>
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<td></td>
<td></td>
<td>(56 CNGS)</td>
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<td>Cycle length, µs</td>
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<td>2.0</td>
<td>0.3</td>
<td>0.25</td>
<td>0.6</td>
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<td>Availability (?)</td>
<td>07</td>
<td>06</td>
<td>06</td>
<td>Now</td>
<td>08</td>
<td>09</td>
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</table>
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. Bennett¹, Luca Bruno², Chris J. Densham¹, Paul V. Drumm¹,
T. Robert Edgecock¹, Tony A. Gabriel⁵, John R. Haines³, Helmut Haseroth²,
Yoshinari Hayato⁴, Steven J. Kuhn⁵, Jacques Lettry², Changguo Lu⁶, Hans Ludewig⁵,
Harold G. Kirk⁵, Kirk T. McDonald⁶, Robert B. Palmer⁵, Yaremch Prykarpatskyy⁵,
Nicholas Simos⁵, Roman V. Samulyak⁵, Peter H. Thieberger⁵, Koji Yoshimura⁴

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

Proposal submitted April 26, 2004
We propose running without longitudinal bunch compression allowing for a reduced beam spot size of \( \sim 2 \text{mm rms radius} \).
The TT2 Tunnel Complex
Surface above the ISR

- Two 18kV sub-stations
- 6000 I Dewar
- Access Route
- One 18kV Sub-station

Harold G. Kirk
CERN proposed power supply solution

type ALICE/LHCb, rated 950V, 6500A

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

**Total DC output ratings:**
6500A(d), 950V(d), 6.7 MW

**AC input ratings**
*(per rectifier bridge):*
2858A(s), 900V(a) (at no load), 4.5 MVA

**Each power transformer ratings**
*Primary side:* 154A(s), 18kV(a)
*Secondary side:* 3080A(s), 900V(a)
*Nominal power:* 4.8 MVA

**Other**
- Air forced cooling;
- Fed by two 18 kV lines

Harold G. Kirk
Layout of the Experiment

LN$_2$ Dewar

Vent

Cold Valves

Pump

Heater

4.6 MW PS

ISR Tunnel

Solenoid

Harold G. Kirk
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 ($B_0$ from 0 to 15T)
- Vary beam/jet overlap
- Study possible cavitation effects by varying PS spill structure—Pump/Probe

<table>
<thead>
<tr>
<th>Charge Structure</th>
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<th>Beam Shift</th>
<th>Number of Shots</th>
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<td>2</td>
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<td>2</td>
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<td>4 x 5TP 1-2-3-4</td>
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<td>2</td>
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<td>4 x 5TP 1-2-3-4</td>
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<td>0</td>
<td>2</td>
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<tr>
<td>4 x 5TP 1-2-3-4</td>
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<td>+5mm</td>
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<tr>
<td>4 x 5TP 1-2-3-4</td>
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<td>+2.5mm</td>
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<td>-2.5mm</td>
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<tr>
<td>4 x 5TP 1-2-3-4</td>
<td>15</td>
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<td>1 x 5TP 1</td>
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<tr>
<td>4 x 5TP 1-2-3-8</td>
<td>15</td>
<td>0</td>
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Total
CERN ISOLDE Hg Target Tests

Proton beam 5.5 TP per Bunch.

Harold G. Kirk
PS Extracted Beam Profile

Beam Profile

Pump

Probe

Scintillator Profile

500 ns

250 to 1500 ns
Optical Diagnostics of Hg Dispersal
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.
# Pulsed Solenoid Project Cost Profile

<table>
<thead>
<tr>
<th>Component</th>
<th>Engineering</th>
<th>Fabrication</th>
<th>Testing</th>
<th>Shipping</th>
<th>Installation</th>
<th>Decommission</th>
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<tr>
<td>Magnet</td>
<td>$350 K</td>
<td>$350 K</td>
<td>$90 K</td>
<td>$15 K</td>
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<tr>
<td>Cryogenics System</td>
<td>(Assume CERN supplied components)</td>
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<td>$45 K</td>
<td>$50 K</td>
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<td>$110 K</td>
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<td>Hg Jet System</td>
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<td>$45 K</td>
<td>$35 K</td>
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<tr>
<td>Support Services</td>
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<td>Data Acquisition</td>
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<table>
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<th>Engineering</th>
<th>Procurement</th>
<th>Installation</th>
<th>Decommission</th>
<th>Contingency</th>
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<tbody>
<tr>
<td>Magnet</td>
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<tr>
<td>Power Supply (CERN Solution)</td>
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<td>$80 K</td>
<td>$20 K</td>
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<tr>
<td>Cryogenics System</td>
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<tr>
<td>Hg Jet System</td>
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<td></td>
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<tr>
<td>Support Services</td>
<td></td>
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</table>
CERN Staff Effort Profile

Pulsed Solenoid
Transport/Install/Remove

1 Man-month

Power Converter
Requisition/Installation/Decommission

9 Man-months

Cryosystem
Design/Installation/Decommission

18 Man-months

Total CERN effort

~ 2.3 Man-Years
## Cost Summary

<table>
<thead>
<tr>
<th>System</th>
<th>Spent Costs</th>
<th>Costs to date</th>
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<td>Magnet System</td>
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<td>Cryogenics</td>
<td>$340 K</td>
<td>$45 K</td>
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<td>Hg Jet System</td>
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<td>Beam Systems</td>
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<td>Support Services</td>
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**Total**          | $2205 K     | $825 K

**Remaining Costs** | $1380K