MERcury Intense Target (MERIT) Experiment – or nTOF-11

Experiment overview & Safety Issues

Contact persons:
Ilias Efthymiopoulos
Adrian Fabich

AB Safety Committee Meeting
CERN – January 25, 2006
Outline

Overview

☐ Introduction
☐ The Experimental setup
☐ Safety Issues
  ■ Mercury loop
  ■ Radiation
  ■ Cryogenics
  ■ Solenoid – power supply
  ■ Access
  ■ Installation

☐ Schedule
☐ Next steps wrt safety
The MERIT Experiment (1/2)

We propose to perform a proof-of-principle test of a target station suitable for a Neutrino Factory or Muon Collider source using a 24-GeV proton beam incident on a target consisting of a free mercury jet that is inside a 15-T capture solenoid magnet.

Proposal submitted to INTC – May 2004
Experiment approved as nTOF-11 → MERIT

Target

☐ 1-cm diameter Hg jet, \( v \cong 20 \text{m/s} \)
☐ PS Proton beam: 24 GeV/c
  ■ 4 bunches of \( 7 \times 10^{12} \) protons each (max), spaced between 0.5÷2 usec
  ■ \(~100\) (HI) pulses in total
☐ Meson collection using a 15-T solenoid

From previous tests @ CERN + BNL

Recovery
The Experimental Setup (1/2)

- Located in the TT2A tunnel upstream of the nTOF target
- **Data taking**: two-weeks at the PS startup in 2007 – second slot later as reserve
The Experimental Setup (1/2)
The Experimental Setup (2/2)

Hg loop - Target volume

- The beam hits the jet at z=0 position at an angle of 33 mrad

- Hg jet at 100 mrad angle with magnet axis

- Proton beam at 67 mrad angle with the magnet axis
Safety issues

- Several safety aspects discussed with SC experts
  - No show-stopper found
  - Decisions on few items still to be finalized

- Memos on:
  - http://proj-hiptarget.web.cern.ch

- Items to include:
  - ISIEC form
  - Beam Authorization Form

NEW

SAFETY

- 3rd Feb. Safety Review - Announcement
- General safety hearing, March 04, minutes
- General safety hearing, December 2003, minutes

presentation Activation Tunnel (HK)

- LIST OF SAFETY PERSONS CONCERNED

SAFETY CONTACT PERSON FOR ALL MATTERS:

<table>
<thead>
<tr>
<th></th>
<th>Responsible</th>
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<tr>
<td>DSO of AB</td>
<td>Paolo CENNINI</td>
<td>16 4625</td>
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<tr>
<td>FGSO of PH</td>
<td>Olav ULLALAND</td>
<td>16 33 42</td>
</tr>
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<td>General Safety</td>
<td>Bruno PICHLER</td>
<td>16 0889</td>
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<td>Thomas OTTO</td>
<td>16 0648</td>
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<td>Gas and Chemicals</td>
<td>Jonathan GULLEY</td>
<td>16 0890</td>
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<td>Electricity</td>
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<td>Fritz SZONCSO</td>
<td>16 4030</td>
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<td>Fire</td>
<td>Fabio CORSANEGO</td>
<td>16 4548</td>
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<td>Material</td>
<td>(material also J. Gulley)</td>
<td>16 0638</td>
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<td>Mechanical safety</td>
<td>Alberto DESIRELLI</td>
<td>16 0784</td>
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<td>Cryogenics</td>
<td>Maurizio BONA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gunnar LINDELL</td>
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</table>
Safety issues (2/8)

Mercury Handling

- Keep volume to strict minimum
- All operation by experts – ORNL
- All mercury comes from US and goes back to US (ORNL)
- Primary / Secondary container configuration
- No break of the primary container whatsoever during the lifetime of the experiment at CERN
- All measures for personnel protection will be taken

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1. Efthymiopoulos CERN

January 31, 2006

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**memorandum**

**FROM:** J. Galley (SC-GS)

**TO:** A. Fabish (AB/ATB)

**CC:** F. Cerasi (AB/ATB), T. Oto (SC-RP), B. Pieler (SC-GS), B. Trant (SC-GS)

**Subject:** Proposed use of mercury at CERN in the Experiment T14

**Date:** January 31, 2006

This memorandum outlines some guidelines and preliminary remarks with respect to the proposed use of mercury in the T14 experiment at CERN.

1. The amount of mercury employed in the experiment should be kept to a minimum.
2. On arrival at CERN the mercury will be stored in a dedicated place (e.g., Chemical Laboratory V1-03).
3. Use the type of container recommended by the manufacturer. Inspect containers not leaks before handling. Secondary protective containers must be used when this material is being carried. Label containers and keep them tightly closed when not in use. Use corrosion-resistant transfer equipment when dispensing.
4. A safe means of filling the system should be provided (e.g., by vacuum pump).
5. The leak-tightness of the closed system used for the experiment must be verified before operation and after any intervention on the system which may affect the leak-tightness.
6. Mercury monitoring devices which continuously measure the concentration of mercury in the surrounding air are to be employed at strategic points (inside and outside of the cabinment that will enclose the apparatus) to give an early warning of a leak or loss of containment. All mercury monitors must be calibrated according to the manufacturer’s instructions and given an alarm sufficiently below the exposure limits (e.g., VME = 0.05 mg/m³, VLE = 0.4 mg/m³). Any alarm generated must be promptly dealt with.
7. Appropriate personal protective equipment, e.g., (lab coat, coverall, gloves, visor, safety goggles, boot, full-face respiratory equipment) must be made available for all persons who will come into contact with mercury during an intervention on the system or during an emergency. N.B. The maximum requirements for PPE shall be based on the measured concentration of mercury in the system. In the event of the requirements not being met, the T14 experiment is also deemed necessary. The type of gloves and the mercury vapour cartridge used in the respiratory protection must be specified. Cartridges and gloves must be kept outside of the immediate area where the mercury is used and must be changed on a regular basis. Respiratory protection is to be used only for work of short duration (e.g., filling, replacement of filters) or in case of an emergency.

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1. VME = valeur moyenne d’exposition.
2. VLE = valeur limite d’exposition calculée sur une courte durée.

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The original memorandum contains several guidelines and preliminary remarks with respect to the proposed use of mercury in the T14 experiment at CERN.
Safety issues (3/8)

Solenoid and Cryogenics

- Safety review foreseen on February 3rd

**Reviewers:**

- Cryogenic experts:
  - Goran Perinic
  - Vladislav Benda

- Cryogenics safety:
  - Gunnar Lindell

- Mechanical Safety:
  - Benoit Delille
  - Andrea Astone

**Key issue:** exhaust line to TT10

Documentation:

1. Please provide P&ID’s (Pipe & Instrumentation Diagram) for all the equipments, including date, version and drawing number.
2. Please provide a PFD (Process Flow Diagram) for all the different modes (filling, quenching, warming up etc).
3. Please provide a list of all safety valves, their positions and their settings for all cryogenic equipment in this project.
4. The pressure vessels (magnet and dewar) and its accessories shall be conform to Directive 97/15/EC (CE declaration plus manufacturing documents such as material certificates, welding procedure specification, method of welding, certification of welder, pressure tests etc). Please contact F. Jéquier (SC/CGS) directly in this matter.
5. Please provide the documentation for the safety valves as indicated in the Directive 97/15/EC. Safety valves are category IV.
6. Please provide the calculations for sizing the safety valves.
7. The dewar shall be conform with the applicable cryogenic standard (depending on size).
8. The cryogenic vessels shall be conform with EN13846
9. Complete documentation shall be provided for the instrumentation (manufacturer, model, operating range, maintenance etc)
10. Please provide implementation drawings of the dewar, the transfer line and the magnet.

Pressure build up

11. Please assure that there are safety valves wherever cold gas/liquid could be trapped. vessels & pipes between valves.
12. Please show that no liquid can be trapped in the valve when operating it (ball values and gate valves).

Comments from CERN’s Safety Commission concerning:

- Supply of LHe from a dewar installed outside between building 339 and 300.
- LHe transfer line from the dewar to the magnet is TT1A.
- The magnet will contain 30 to 300 litres of LHe (still not defined).
Safety issues (4/8)

Solenoid and Cryogenics – Exhaust line to TT10

- Release of LN2 gas (through a heat exchanger) during the cooling down of the magnet
  - ~200 lt of LN2; ~1 lt activated – remnant from previous fill

- TT10 is the only ventilated tunnel close to the experiment
  - ~27'000 m³/h flow
  - Release near bat 806

MERIT

- ~4400 m³/h
- Wait few min before refilling to reduce radiation levels
Recuperate the power supply used for the SPS extraction to the West Area

“pulsed” mode: 7kA / 30 min ; 5MW

Installed in bat 193

Cabling to TT2A during 2005-2006 shutdown – AB/PO & TS/EL
Safety issues (6/8)

Power supply

- Recuperate the power supply used for the SPS extraction to the West Area
- “pulsed” mode: 7kA / 30 min ; 5MW
- Installed in bat 193 - cabling to TT2A ongoing (AB/PO & TS/EL)
- Interlock → see later
Safety issues (7/8)

General safety

- Magnetic field
  - Nearby objects (Hg container) in non-magnetic material

- Electrical safety – solenoid
  - Connections to power cables should be protected

- Interlock – access

  - **Experiment:**
    - No access with magnet ON
    - Veto to power supply from cryogenics system

  - **Area:**
    - No access while handling the mercury – only specialists
      - Minimize at any time the number of people in TT2A tunnel
    - Request to modify the access to TT2/TT2A
      - Can be accessed even if beam is present in TT10 (M.Silari, T.Otto)
      - Install “normal” door, i.e. without request for RP people
        - n-TOF activated filter already dismounted
Safety issues (8/8)

Radiation environment

- Radiation issues should be considered for the components of the experiment.
- Absorbed and residual doses within limits.

MARS Simulations

S. Striganov – FNAL

MEMORANDUM

20 September 2004

To: P. Cennini, DSO AB
cc: H. Haseroth, AB-ABP; A. Fabich, AB-ATB; Ch. Hill, FSO AB

From: Th. Otto, SC-RP

Conc.: Ventilation issues for Proposal INTC-P-186

Proposal INTC-P-186 (CERN-INTC-2004-016) foresees to install a Target system for a 4 MW, 24-GeV Proton Beam in transfer tunnel TT2a, upstream from the n-TOF target. An experimental campaign with not more than $3 \times 10^{15}$ protons from the PS on a mercury jet target is foreseen.

In principle, a target area should be equipped with a filtered and monitored ventilation system in order to reduce and to account for releases of radioactive air and aerosols into the environment.

The amount of radioactive air and aerosol produced by the the limited total beam intensity of the experiment proposed will not contribute significantly to the total releases from CERN. This circumstance allows to exceptionally deviate from the general principle.

The operation of the experiment proposed in INTC-P-186 for not more than $3 \times 10^{15}$ protons on target from the PS without filtered and monitored ventilation in transfer tunnel TT2a is authorised.

Th. Otto

Radiation Protection PS accelerator complex

January 31, 2006
## Schedule – project milestones

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
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<tbody>
<tr>
<td>Magnet testing at MIT</td>
<td>Oct- Dec 2005</td>
</tr>
<tr>
<td>Hg loop and nozzle tests at Princeton</td>
<td>Oct – Dec 2005</td>
</tr>
<tr>
<td>Hg target loop system test at ORNL</td>
<td>April – June 2006</td>
</tr>
<tr>
<td>Integration tests at MIT</td>
<td>Aug – Sept 2006</td>
</tr>
<tr>
<td>Shipment to CERN</td>
<td>Nov 2006</td>
</tr>
<tr>
<td>Installation preparation at CERN</td>
<td></td>
</tr>
<tr>
<td>Shutdown 2005-2006: basic infrastructure</td>
<td></td>
</tr>
<tr>
<td>Shutdown 2006-2007: experiment setup</td>
<td></td>
</tr>
<tr>
<td><strong>Experiment – data taking</strong></td>
<td>PS startup in 2007 (April?)</td>
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</table>
Next steps wrt Safety

Beam Acceptance Form (BAF)

† Seen as the complement/continuation of the ISIEC form

ISIEC: the experiment describes the safety issues & risks

BAF: filled during/after the safety visit to experiment or as the installation advances

† Approved by the safety officers – can be done in EDMS/EDH?

Note:

"BAF exists in other labs (i.e. Berkeley) for all experiments or tests in order to get beam"

At CERN:

† I ask (as EA) all users to call a safety visit before they start

† It is done, but no feedback and no "official" document is filled to authorize the experiment – maybe I am wrong?

However:

"I will be the first to refuse that the beam should be used as a handle to impose safety in our areas"

change name to:

Safety Acceptance Form for Exp. at CERN

This is a proposal not only for MERIT but for all experiments & tests at CERN

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(5) LIFTING AND HANDLING

Weight of heaviest single piece to install? BNL solenoid with baseplate, ~5.5 tons

Specially designed handling equipment? CERN standards: 170 ton crane, turtle, jacks

For what noise weight?

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(6) VACUUM TANK, PRESSURE TANK, CRYO TANK

<table>
<thead>
<tr>
<th>Tank</th>
<th>Abs. pressure</th>
<th>Volume</th>
<th>Weakest point(s) of well</th>
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<tr>
<td>DN2600w</td>
<td>2 bar</td>
<td>6000 liter</td>
<td>standard equipment</td>
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<tr>
<td>cryostat</td>
<td>15 bar</td>
<td>120 liter</td>
<td>with supply lines</td>
</tr>
<tr>
<td>Hg loop</td>
<td>200 bar</td>
<td>open system, beam windows</td>
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</tbody>
</table>

(7) IONIZING RADIATION

Beam intensity, radioact. Source(s), depleted uranium, etc.

PS proton beam, 24 GeV, 4.10^13 protons/pulse; see also EDMSesees

(8) NON-IONIZING RADIATION

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Power</th>
<th>Field</th>
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<tbody>
<tr>
<td>BNL solenoid</td>
<td>5 MW</td>
<td>15 T pulsec</td>
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</table>

(9) OTHER HAZARDS (or remarks):

CDH fire, access interlocks...

see memos at EDMS/AB9603, 097550, 097857, 097860

(10) RISK ANALYSIS

CDH not yet done, see also above

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PLEASE RETURN THIS FORM TO THE DSO OF THE PH DEPARTMENT

2/2
Backup Slides
Cryogenics (1/2)

- LN2 dewar
- LN2 transfer line
- N2 gas bottles and N2 heat exchanger
- GN2 gas line
- Solenoid
- Transfer lines
- Proximity cryogenics: CVB and Heat Exchanger
- Warm gas exhaust line to TT10
ONLY warm N2 gas to TT10
~ 120’000 lt every 30 min
- slightly radioactive: <600lt
Exit location in TT10 still to be decided
- Interplay between radiation and ODH risks
- ODH detector has to be installed in TT10 and TT2

Exhaust line to TT10
- Use existing tubes to pass the exhaust line through the shielding wall
- No concrete drilling
Solenoid power supply (1/2)

Installation of DC cables

- Installation of DC cables

- Activity started will be completed gradually during the 2005-2006 shutdown

- C.Martins & A.Beuret – AB/PO

- PS control (LEIR standard) – AB/CO (?)

- Need to be extended to TT2A and pass through the shielding wall

- 3 x 400 mm² Al cables per polarity – reduce thermal load

- K.Kahle & M.Gaidon (TS/EL)

- Power supply interlocks:
  - Cryogenics system – danger to damage the solenoid
  - Access door – magnetic field (personnel safety)

Bat.193 – AD hall

MERIT Experiment
Other installation issues (1/1)

Experimental control room
- Use area in ISR tunnel (~40 m²) presently occupied by AT group
  - Should not be a problem, but needs to become official
  - Systems to install:
    - Cryogenics and Hg-loop control
    - DAQ and diagnostics for the experiment

FTN beam line modifications
- Liberate the space for the installation of the experiment
  - Remove few magnets and open the vacuum
- Install a new quadrupole for beam focusing onto the target
  - Magnet + power supply to specify
- Beam instrumentation to observe the beam spot at the target
  - Install a wire chamber (SEM-grid) for beam profile measurement
  - TV screen to measure the beam spot – poor man’s solution
Summary

Key installation issues for 2005-2006 shutdown

- Power supply
  - Installation in bat.193 and AC cell outside
  - DC cables to TT2A
- Cryogenics
  - Exhaust line to TT10
- General installation
  - Remove the beam elements and vacuum
  - Prepare transport tools
  - Install the beam attenuator (dump)
  - Drilling between TT2A and TT2
    - Passage of cables and fiber optics for the target diagnostics
  - Interlocks – access safety

Concentrate cabling activities in **March ’06**

Installation “slot” with access to PS & SPS transfer tunnels?

Next report to ABIC: in about two months ??
The MERIT Experiment (2/2)

- The experiment will be located in the TT2A tunnel upstream of the nTOF target
- Data taking: two-weeks at the PS startup in 2007 – second slot later as reserve

V. Graves - ORNL
Specialties of the experiment (1/6)

**Hg loop - Primary containment**

- Hg delivered to the nozzle using a hydraulically-actuated piston
- Required flow: 1.57 lt/s
- Mercury inventory: ~23 lt

- Piston velocity: 3.0 cm/s
- Hg jet duration of 12s
- Drive cylinders: 15-cm diam, 45 lt/min, 30 MPa (300 bar)

V. Graves - ORNL
Specialties of the experiment (2/6)

**Hg loop - The secondary containment**

- No break of the primary container during the experiment
- All connections through the secondary containment
- Note: fringe field of the solenoid not negligible at all !!!
  - \( \sim 0.9 \text{T at 0.5 m distance from the solenoid} \)

![Diagram of the experiment setup](image)
Specialties of the experiment (4/6)

**Solenoid**
- 15-T field
- Pulsed: 1/30min
- LN2 cooled (80K) between pulses
- Ready for tests at MIT

*Assembled Solenoid - MIT*

*P. Titus - MIT*
Specialties of the experiment (5/6)

Cryogenics

- Collaboration between RAL & CERN
- Provide LN2 to cool the solenoid at 80 K
- Readout and control from AT/ECR group – CERN standard
General Layout (1/1)

- Beam elements to remove – vacuum break
- Proximity Cryogenics
- Exhaust line (N2-gas) to TT10
- To surface dewar

Beam Attenuator
Experimental setup