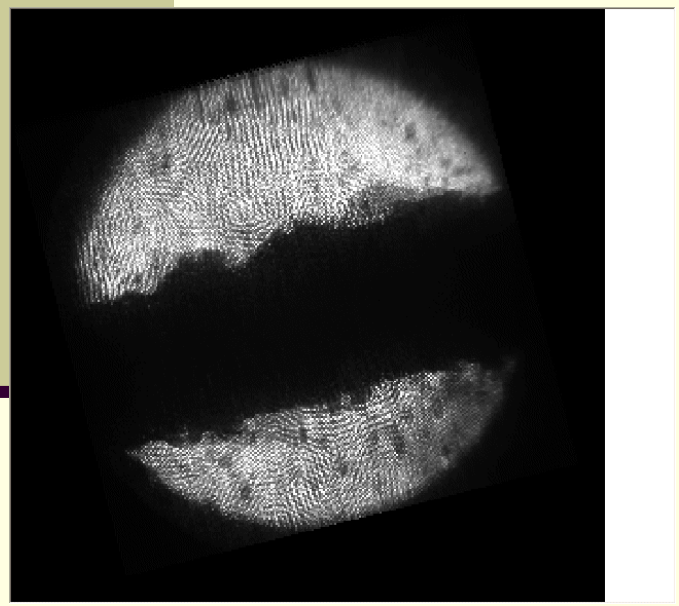
The MERcury Intense Target Experiment – or nTOF11



20m/sec Hg jet achieved on February 14, 2007
MERIT Collaboration – ORNL test setup

I. Efthymiopoulos – CERN, AB Dept.

(for the MERIT collaboration)

MUTAC Review
BNL – April 18, 2007

Outline

- Reminder: scientific goals & layout of the experiment
- Schedule
- Construction of experimental components
  - Solenoid & Hg loop
    - MIT combined tests → Van Graves's talk
  - Cryogenics
- Activities at CERN
- Safety
- Beam issues & particle detectors

The MERIT experiment

*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

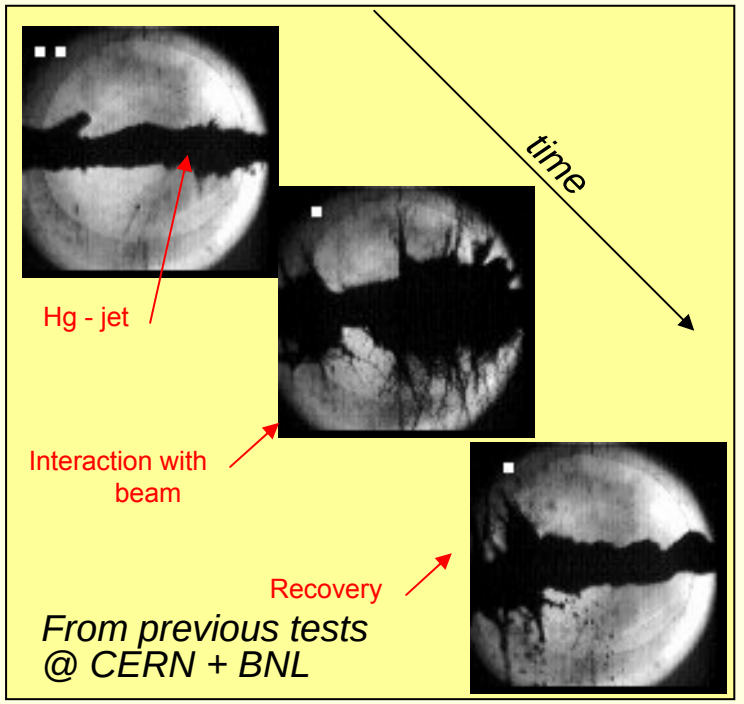
Experiment approved as **nTOF11**

Participating Institutes

- BNL, MIT, ORNL, Princeton University
- KEK
- CERN, RAL

Spokespersons

- H. Kirk (BNL), K. McDonald (Princeton Univ.)



MERIT Experiment – Profile

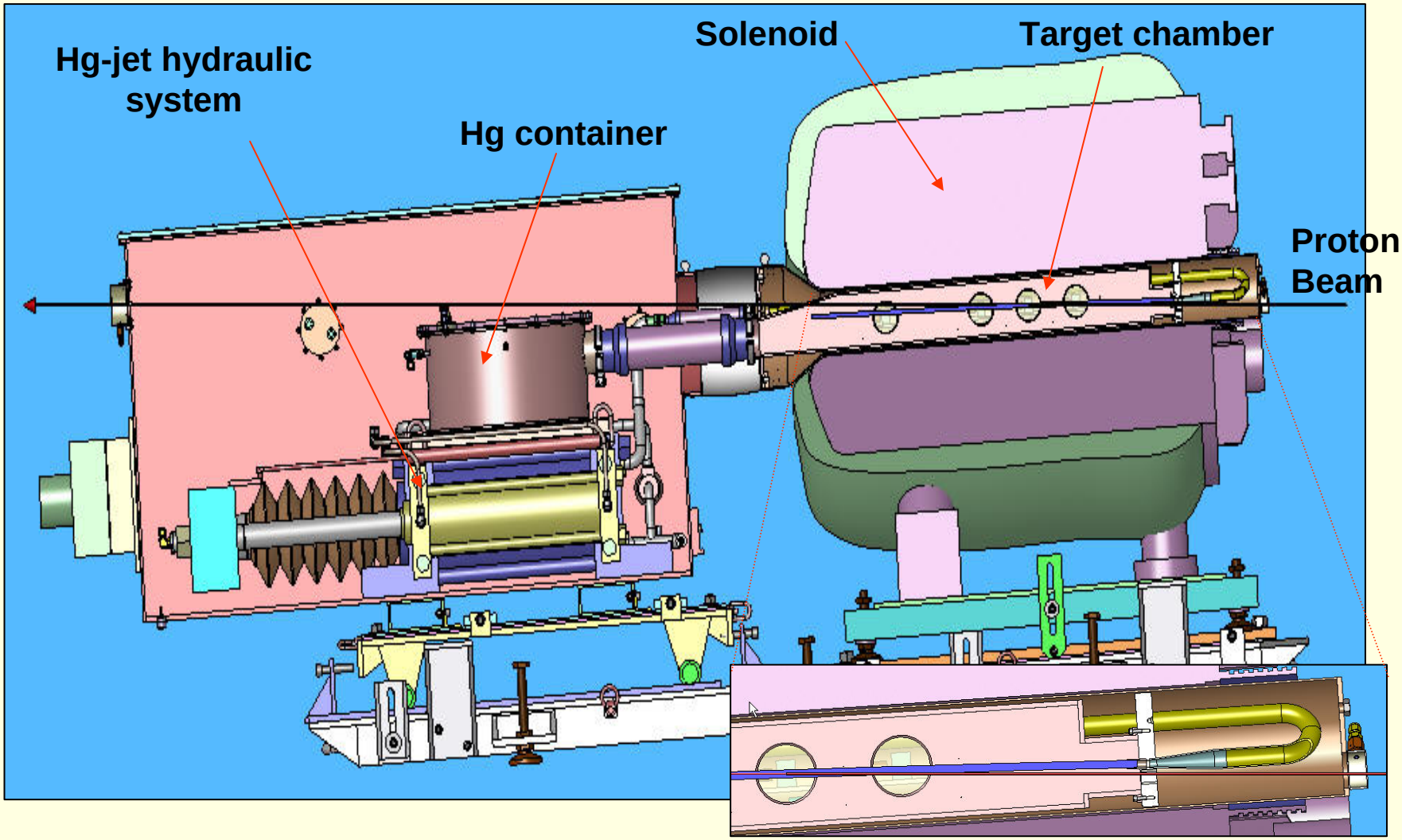
Target

- 1-cm diameter **Hg jet,** jet velocity ≅ **20m/s**
- Hg jet/proton beam configuration:
  - Hg-jet ↔ solenoid axis = 33 mrad
  - proton beam ↔ Hg-jet axis = 67 mrad
  - beam ↔ Hg-jet interaction length = ~30cm (2 λ_I)

Proton beam

- 24(14) GeV/c extracted from PS
  - Max. intensity **3 × 10^{13} protons/pulse**
  - Beam spot r≤ 1.2 mm rms
  - Variable pulse length 0.134 ÷ 500 μsec
  - **~100** high-intensity pulses
  - 3 × 10^{15} protons on target in total (radiation limit)

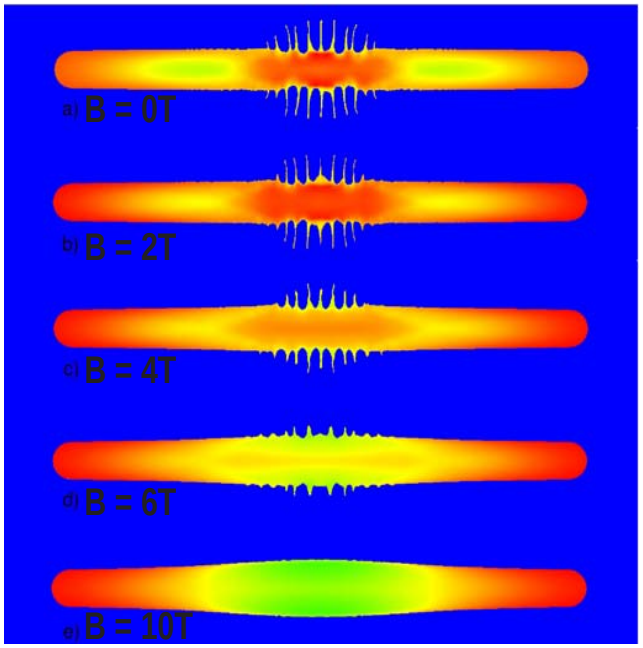
MERIT Experiment – Target & Solenoid



MERIT Experiment – Scientific Goals

Important milestone towards the production of 1-4MW pion production targets

1. Study MHD effects on Hg-jet with



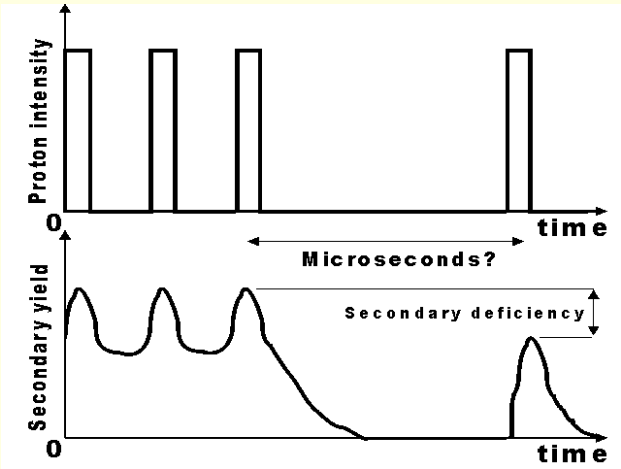
R.Samulyak-BNL

Jet dispersal at t=100μs with magnetic field varying from 0 to 10 Tesla

2. Study jet disruption (cavitation?) by varying the PS spill structure

MERIT: 180 J/g

- 28TP@24GeV protons
- 1cm diam. Hg-jet
- 1.2×1.2 mm² beam size rms



MERIT Experiment – Layout

Build.180: Cryogenics assembly and surface tests

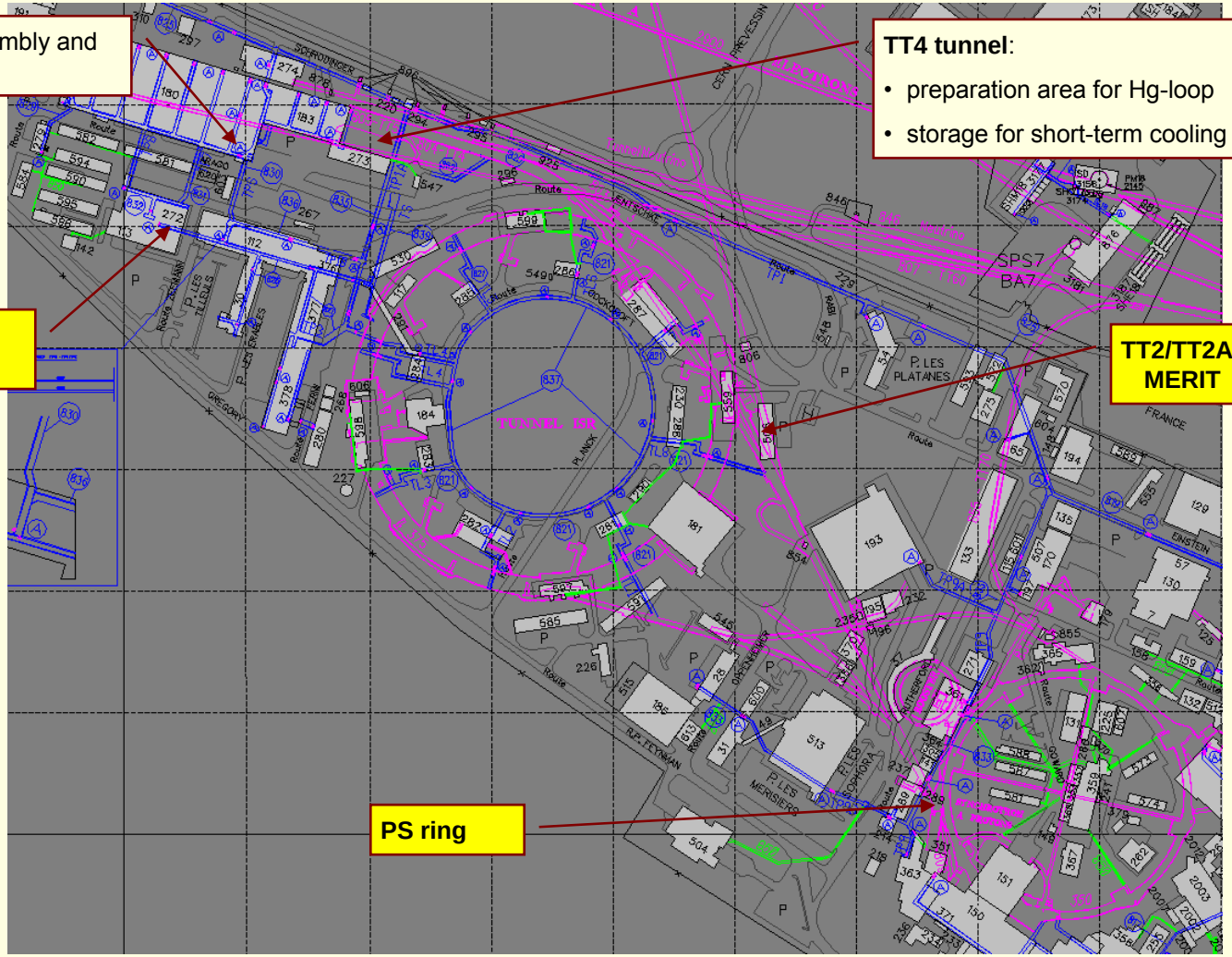
Build.272: Offices & Control Room

TT4 tunnel:

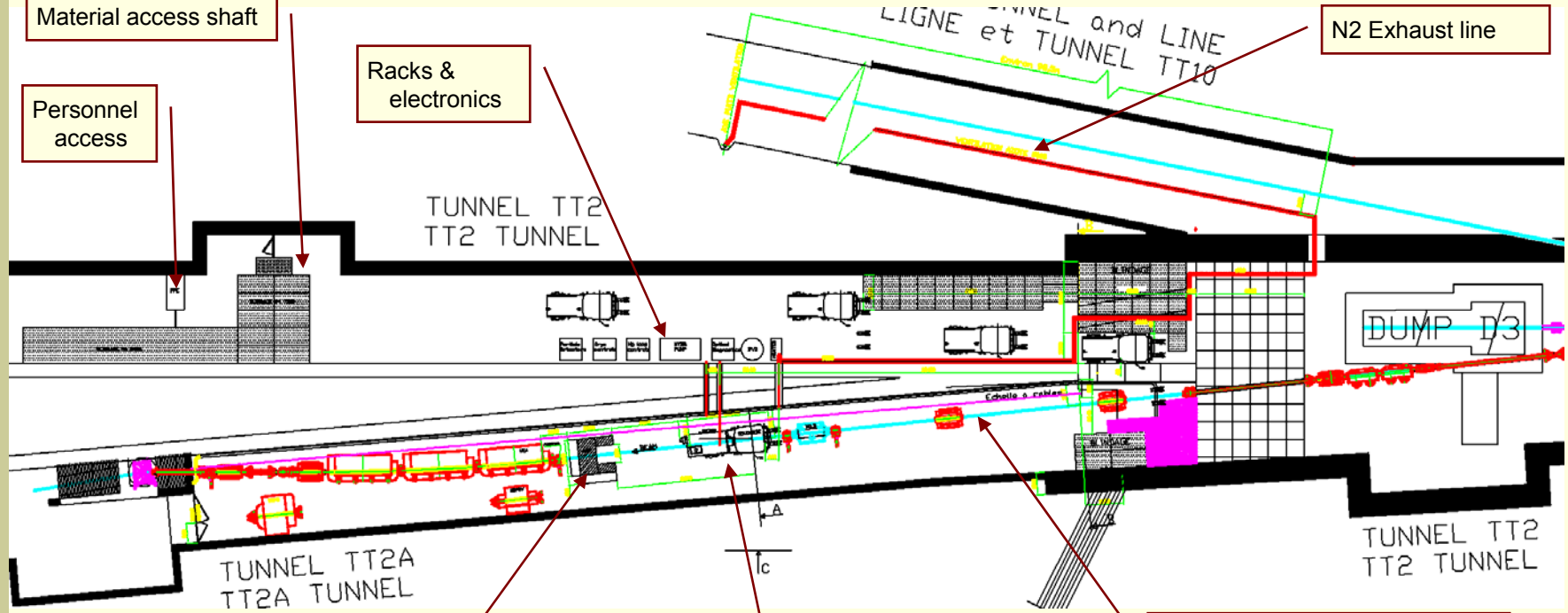
- preparation area for Hg-loop
- storage for short-term cooling

TT2/TT2A: MERIT

PS ring



MERIT Experiment – Layout



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- Activities at CERN
- Safety
- Beam & particle detectors

MERIT Experiment – Status

Since MUTAC'06 significant progress has been made in all aspects of the experiment

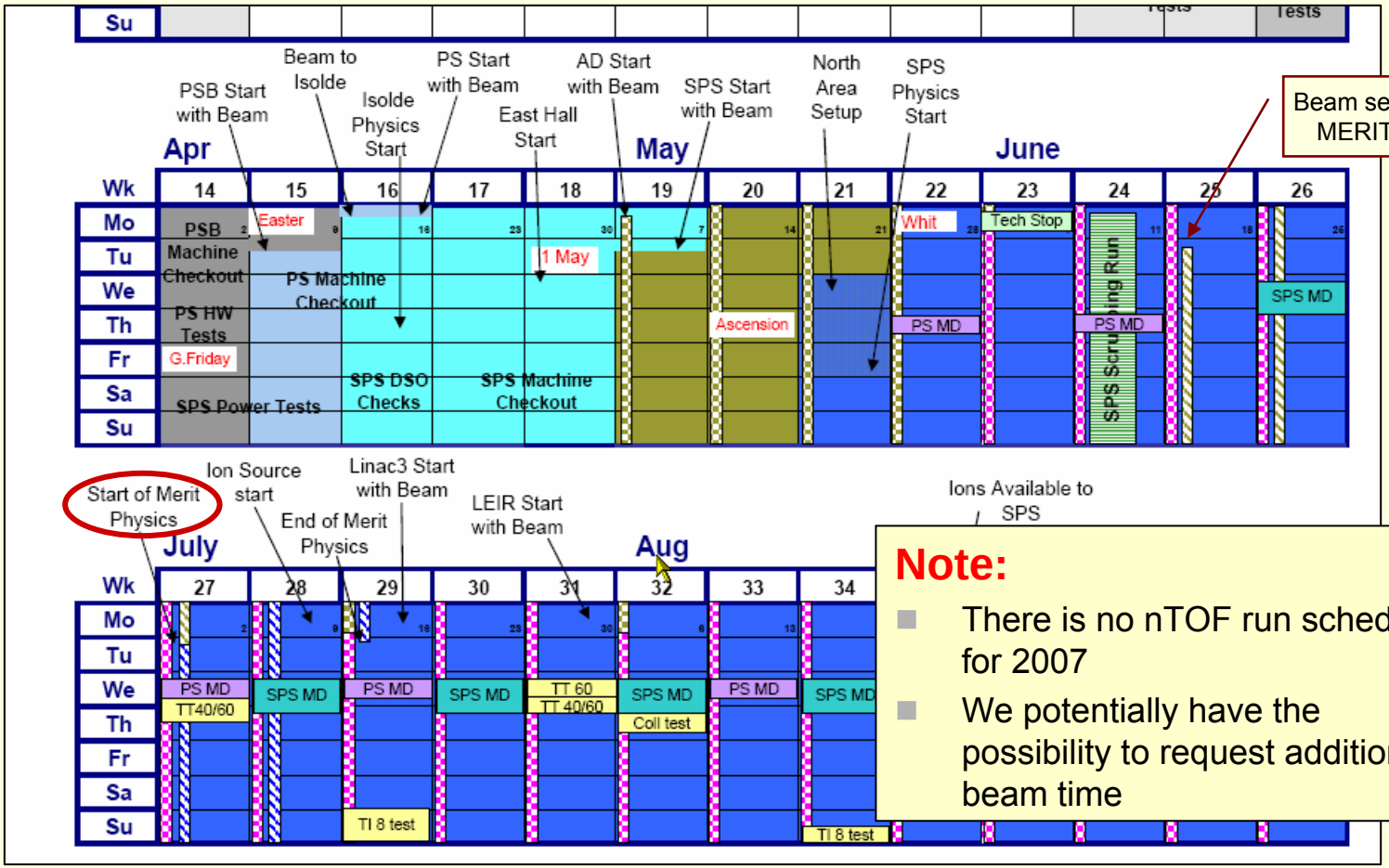
- Construction is basically completed for all experiment's components
- Delays have been accumulated due to technical problems:

Milestone	MUTAC'06	Update
DVB delivery	Sep.'06	Nov.'06
Hg-loop test @ ORNL	Oct.'06	Completed Feb.'07
Solenoid test @ MIT	Mar.'06	
Combined test @ MIT	Dec.'06	Mar.'07
Shipment to CERN	Dec.'06	14 Mar.'07

- But thanks to the fast shipment of components (air-cargo) some time was saved
- We are still on time for the installation, but we have lost a big part of our contingency

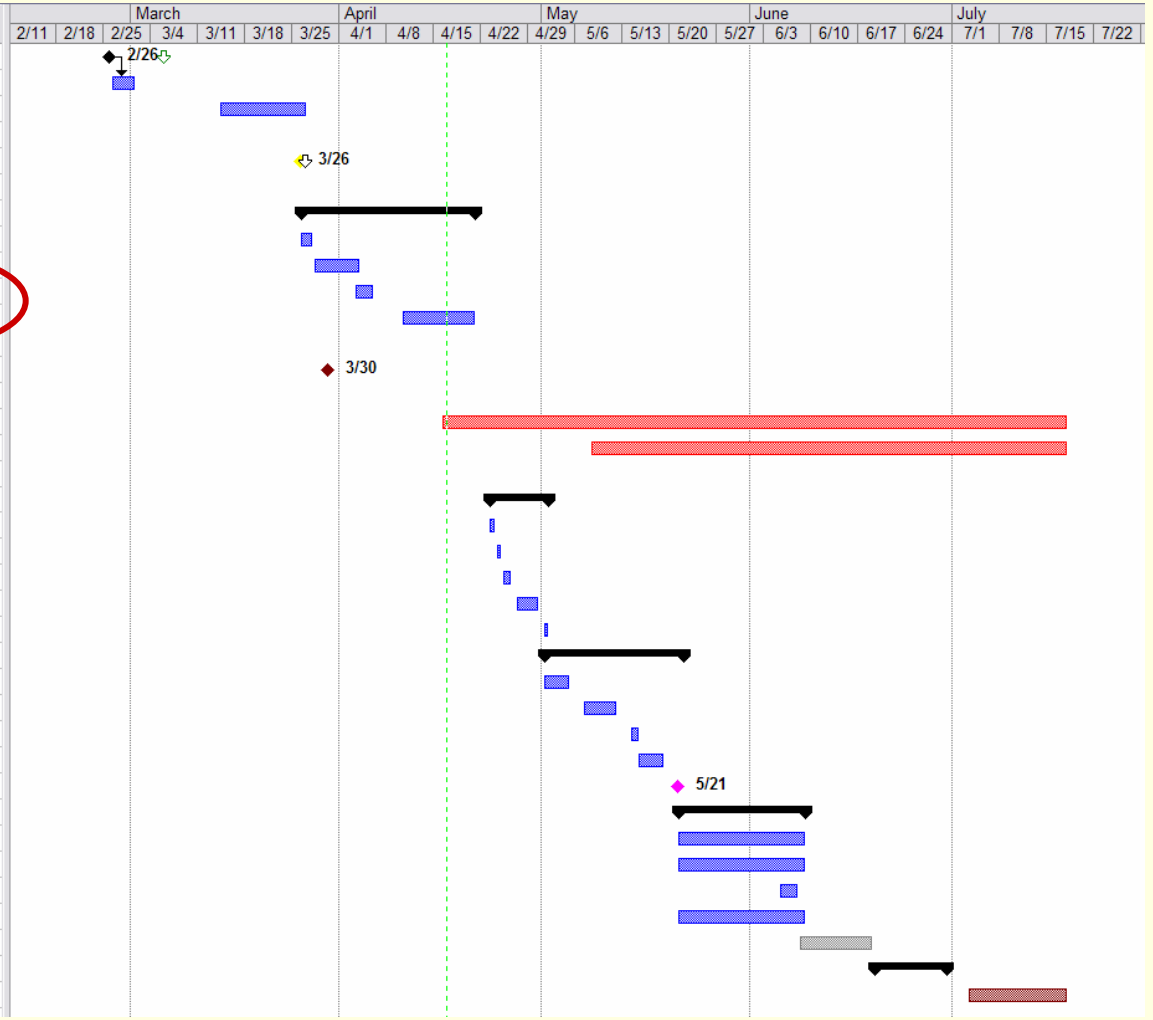
MERIT Experiment – Schedule

The 2007 CERN Accelerator Schedule



MERIT Experiment – Schedule

Task Name	Duration	Start	Finish
Hg-loop at MIT	**0 d**	**Mon Feb 26**	**Mon Feb 26**
Combined tests at MIT	3 d	Mon Feb 26	Thu Mar 1
Transport (Hg-loop + solenoid)	7.2 d	Wed Mar 14	Mon Mar 26
Hg-loop + solenoid at CERN	0.8 d	**Mon Mar 26**	**Mon Mar 26**
− **Magnet tests at bat.180**	**14.4 d**	**Mon Mar 26**	**Fri Apr 20**
Installation	1.6 d	Mon Mar 26	Tue Mar 27
Connection to the cryo system	4 d	Wed Mar 28	Tue Apr 3
Room temperature tests	2.4 d	Tue Apr 3	Thu Apr 5
Cold tests / recycling	7.2 d	Tue Apr 10	Fri Apr 20
Pre-installation safety review	4 d	Fri Mar 30	Thu Apr 5
PS start with beam	**53.6 d**	**Mon Apr 16**	**Tue Jul 17**
SPS start with beam	**40.8 d**	**Tue May 8**	**Tue Jul 17**
− **Installation in TT2/TT2A**	**5.6 d**	**Mon Apr 23**	**Tue May 1**
Lowering of material	0.8 d	Mon Apr 23	Mon Apr 23
Position solenoid + Hg loop to TT2A	0.8 d	Tue Apr 24	Tue Apr 24
Position beam elements	1 d	Wed Apr 25	Thu Apr 26
Installation cryo and racks in TT2	1 d	Fri Apr 27	Mon Apr 30
Close shaft - activate access system	0.8 d	Tue May 1	Tue May 1
− **Commissioning**	**12 d**	**Tue May 1**	**Mon May 21**
Cryogenics + solenoid + ps	3.2 d	Tue May 1	Fri May 4
Hg-loop + optic diagnostics	4 d	Mon May 7	Fri May 11
Insert Hg-loop into solenoid	1 d	Mon May 14	Tue May 15
Combined tests	3.2 d	Tue May 15	Fri May 18
all systems operational remotely	0.8 d	Mon May 21	Mon May 21
− **Finalize installation**	**12 d**	**Mon May 21**	**Fri Jun 8**
fine-tune beam diagnostics	12 d	Mon May 21	Fri Jun 8
fine-tune particle detectors	12 d	Mon May 21	Fri Jun 8
precise alignment	2.4 d	Tue Jun 5	Thu Jun 7
fine-tune all systems	12 d	Mon May 21	Fri Jun 8
Waiting for beam	5.6 d	Fri Jun 8	Mon Jun 18
+ **Commissioning with beam**	**7.2 d**	**Tue Jun 19**	**Fri Jun 29**
MERIT run	**8.8 d**	**Tue Jul 3**	**Tue Jul 17**



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Hg loop system

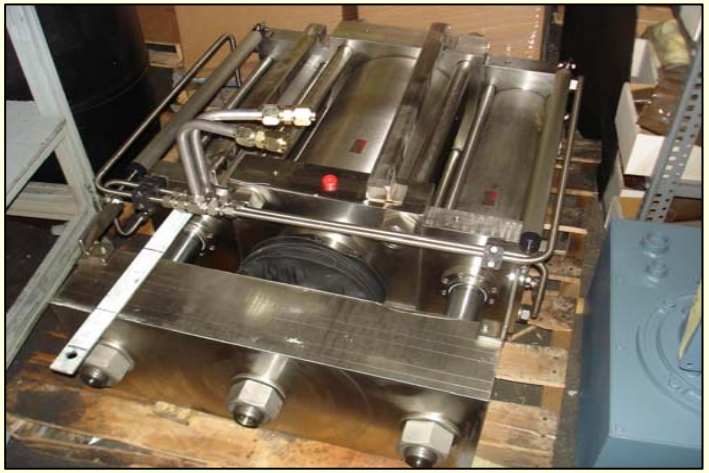
- Required flow: 1.57 lt/s
- Mercury inventory: **~23 lt**
- Piston velocity : 3.0 cm/s
- Hg jet duration of 12s
- Drive cylinders:
  - 15-cm diam
  - 45 lt/min
  - 20 MPa (200 bar)

Geneva's jet d'eau

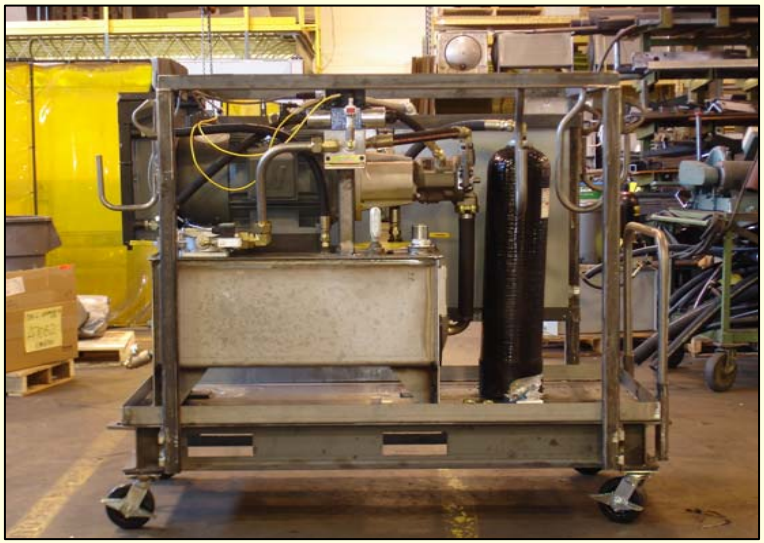
Hg-loop assembled - during water tests @ORNL

Hg loop system

Hg-nozzle

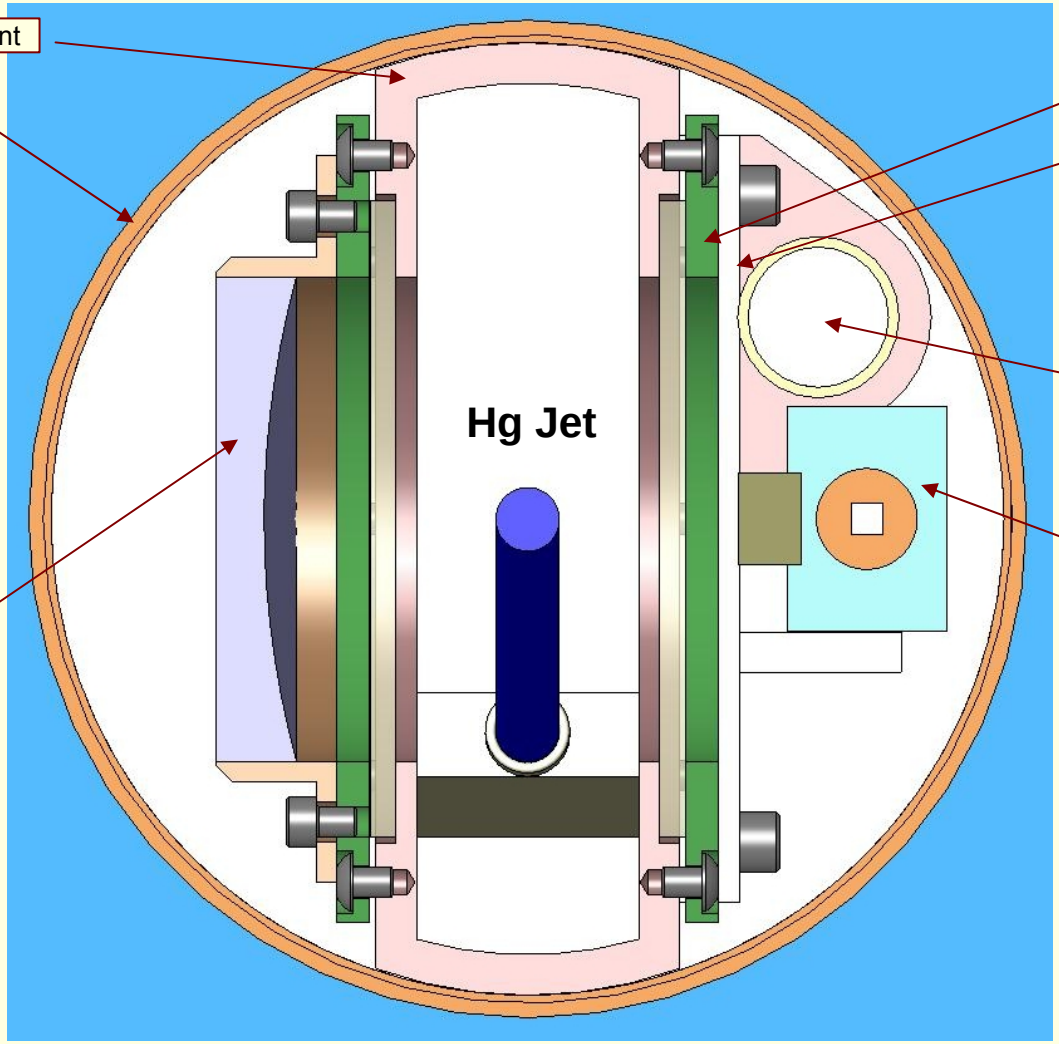


syringe system



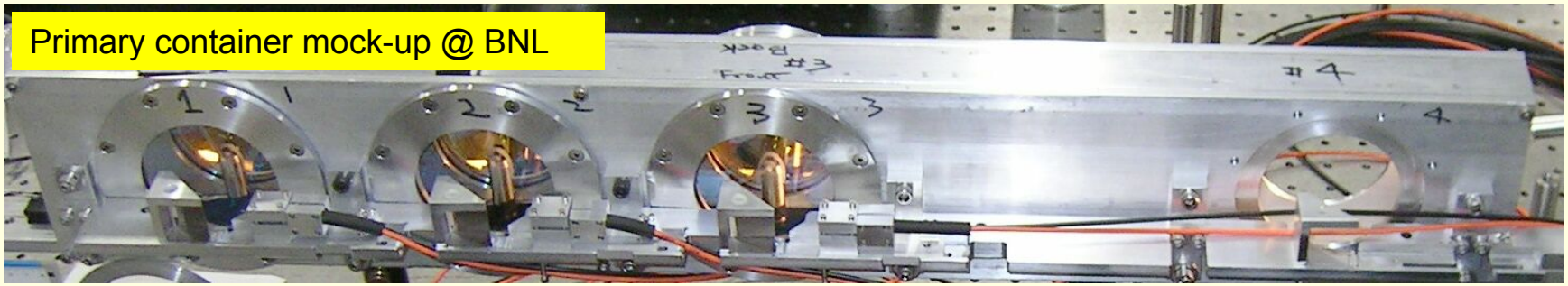
hydraulic pump unit

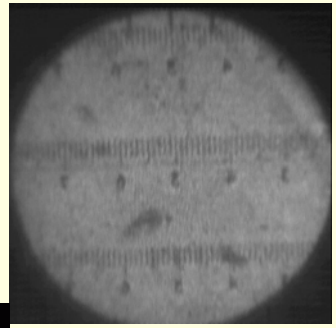
Optical diagnostics



Optical diagnostics

Primary container mock-up @ BNL

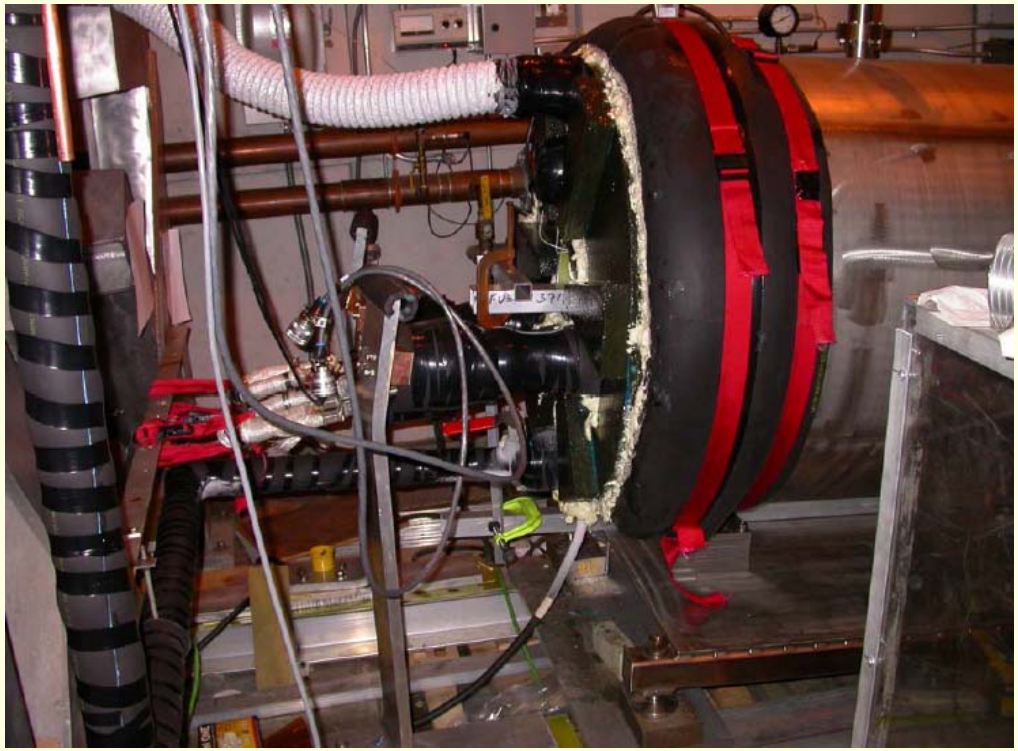


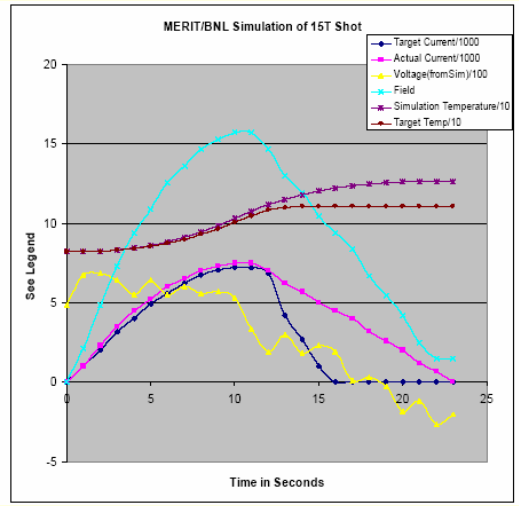


80 us/frame, 16 frames
pulsed NIR light
SMD camera

Solenoid

- first test at MIT in March 2006
  - 15T magnetic field reached !





Combined tests & MIT

- Details & results in Van's talk…

Transport to CERN

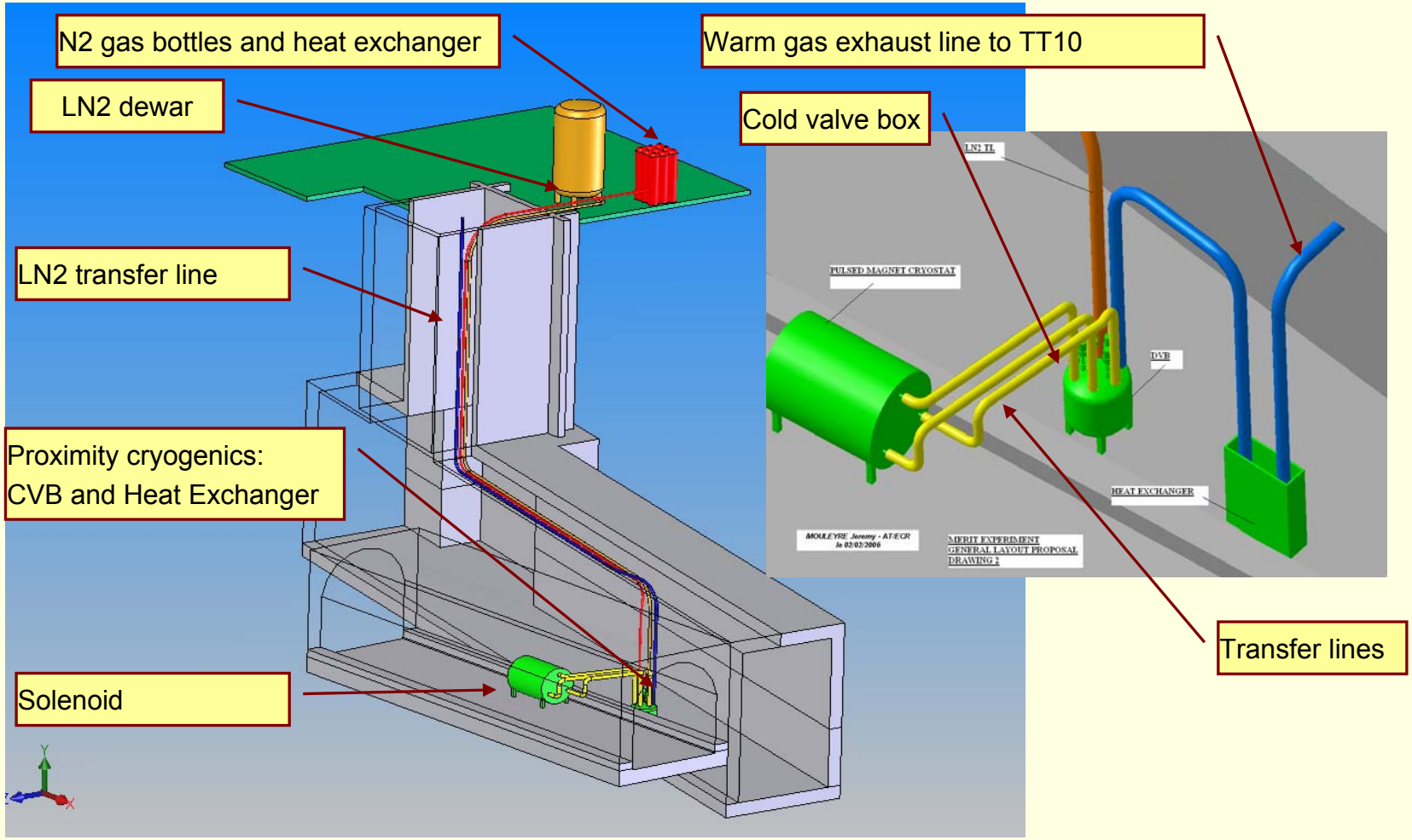
- Leaving MIT on **Wednesday March 14th**
- {solenoid, Hg-loop, optical diagnostics}

- Arrival at CERN on **Monday March 19th**

Transport to CERN

- Hg volume was send to CERN separately
  - 23-lt in 11 drums transported according to safety rules for chemically hazardous material

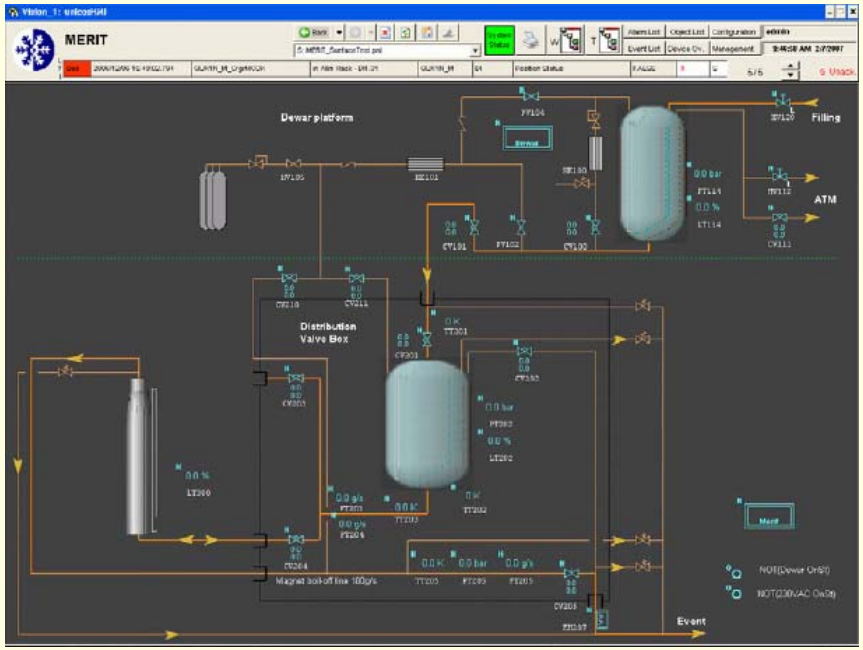
Cryogenics – Layout



Cryogenics – Surface tests

- Process control implemented
- Remote operation from control room tested
- Interlock with solenoid power supply defined

- Installation in build.180 for surface tests completed
  - System fully commissioned with dummy load



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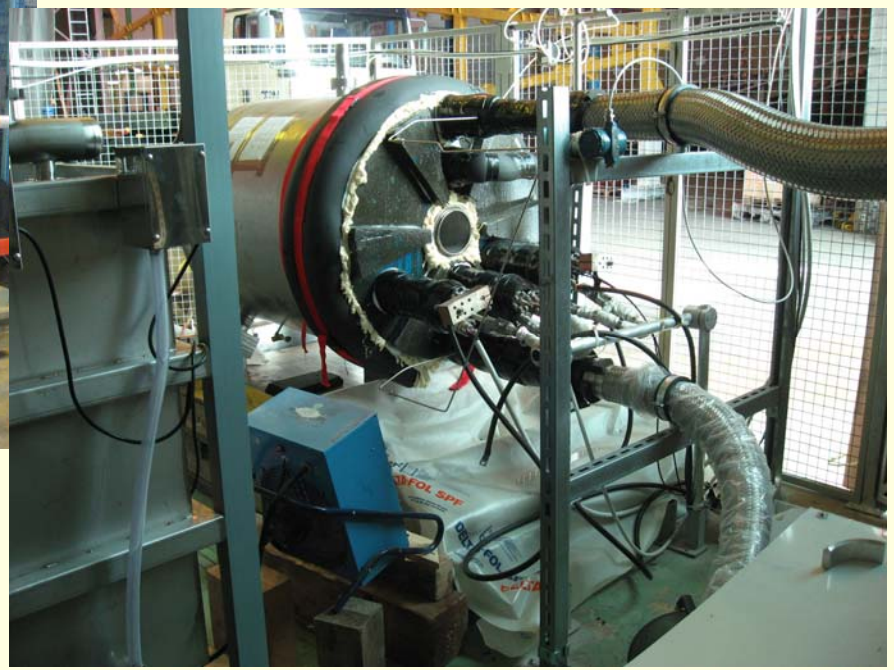
Cryogenics – Surface tests

- Due to the leaks in the solenoid observed during the MIT tests, it was decided to proceed with the **full commissioning** of the solenoid and the cryogenics **at surface** before installation in the tunnel



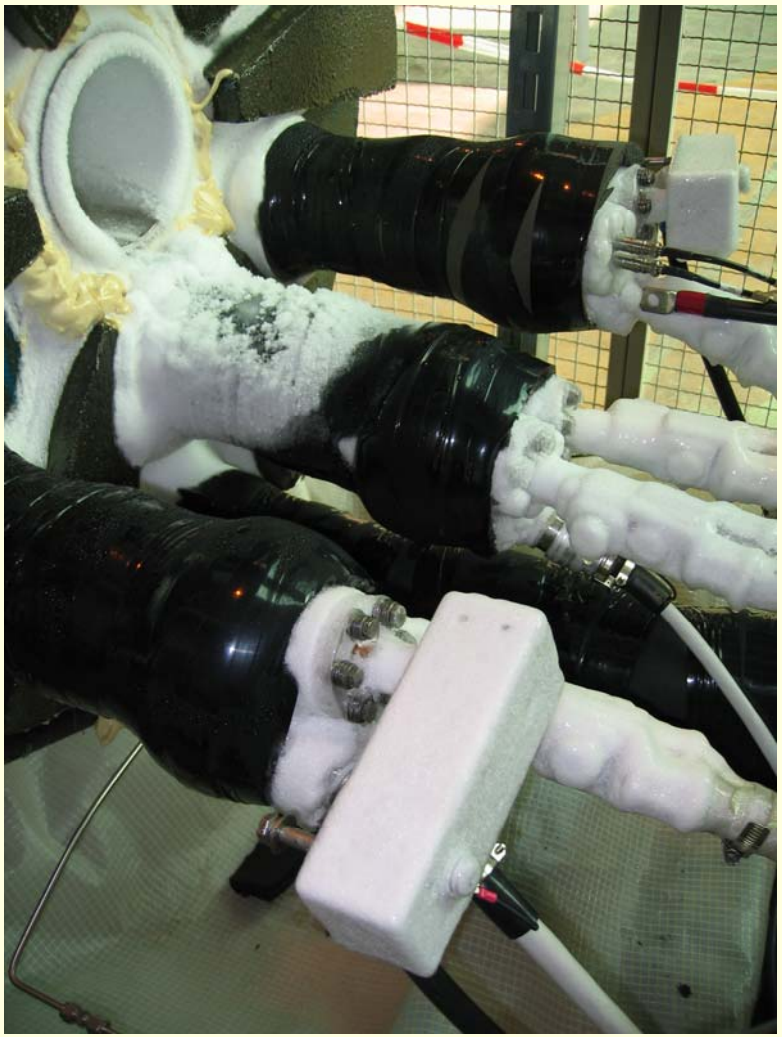
Cryogenics – Surface tests

Status

- CERN Safety inspection for the solenoid & cryogenics done
  - safety valves set
  - operation mode accepted

- First cool-down started on **Friday April 13**
  - No leaks at warm observed

  However
  - Leaks at cold were observed when filled with LN
  - Icing due to insufficient insulation was observed as well



Cryogenics – Surface tests

…Status

- Further tests ongoing to diagnose the exact location of the leaks
  - we do suspect failure of the insulating silicon-rubber material in the current leads and instrumentation connections
  - a possible solution is under consideration, to be reviewed by US and CERN cryo experts and safety officials

- Improvements in the insulation to minimize formation of ice need to be done as well

Detection and correction of the leaks and making the solenoid operational with the cryogenics system is on the critical path that may have implications for the installation schedule

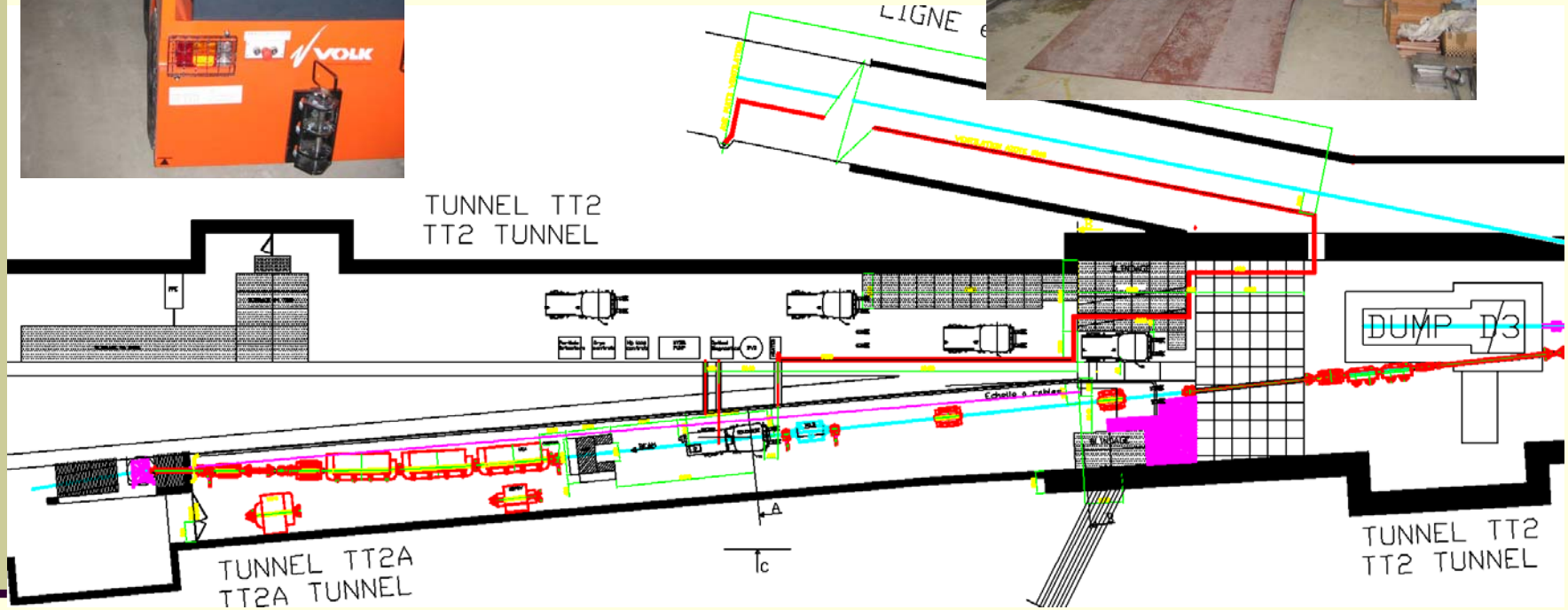
Transport & Installation

- The access shaft was opened on November 22, 2006
- It can remain open even when PS starts with beam
  - but not during the whole run

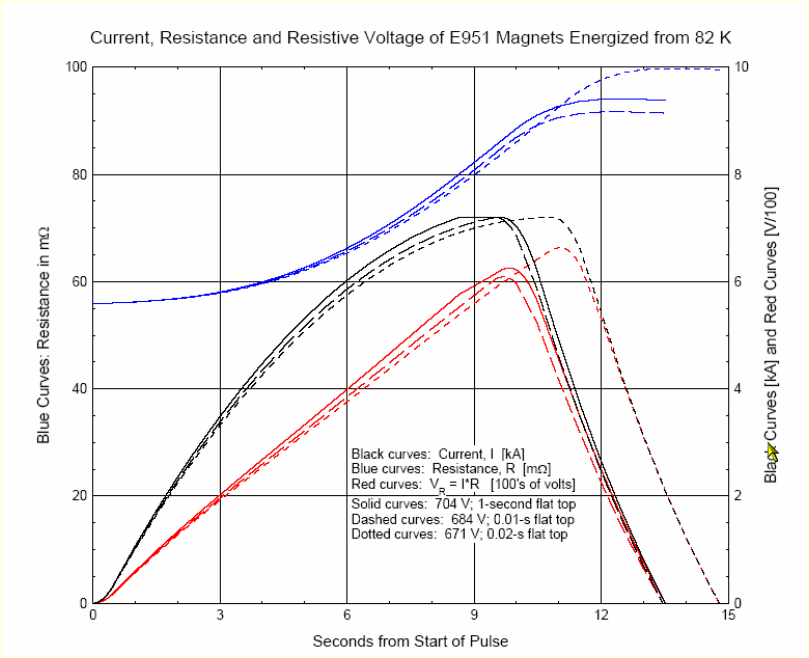
Transport & Installation

transport test with dummy load

access ramps TT2/TT2A



Power supply



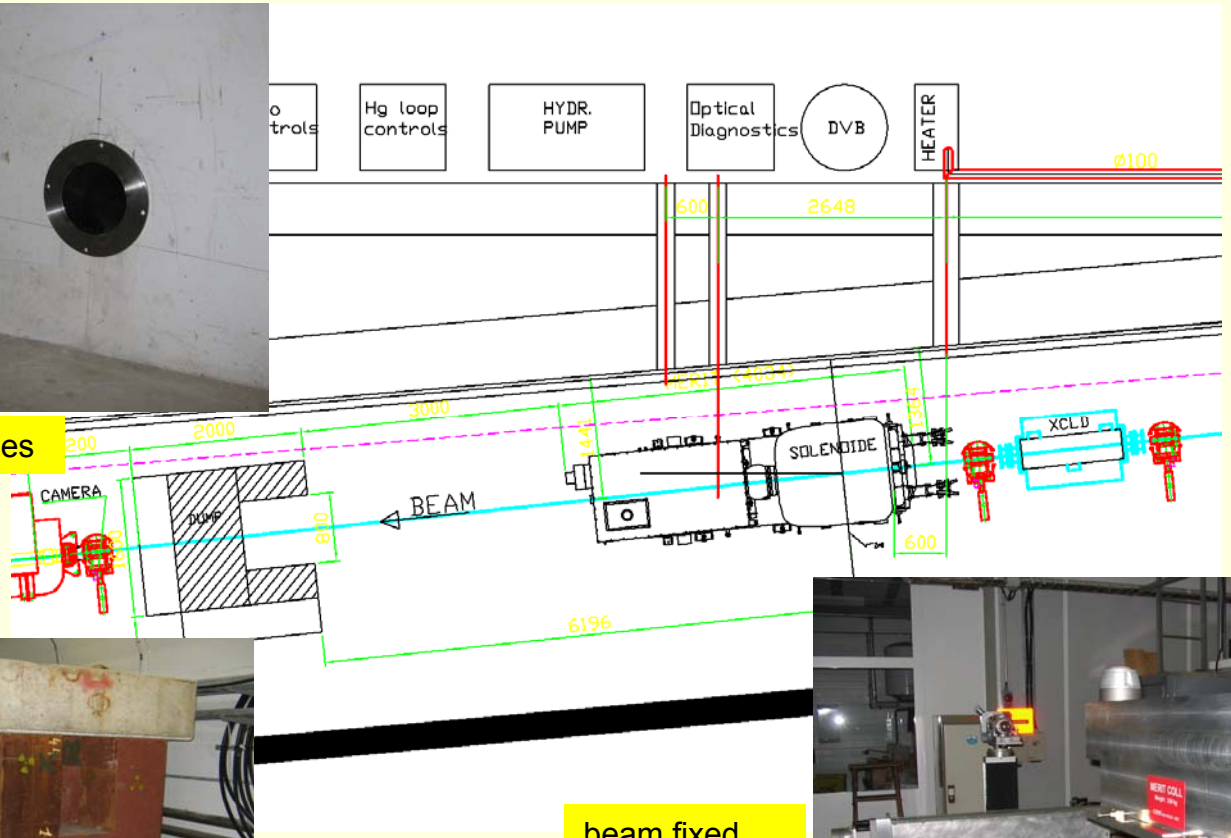
- Recuperated from the old SPS West Area extraction
- “pulsed” mode: 7kA / 30 min ; 5MW
- Installed (along with its transformer) in bat 193
- Refurbished to convert it to PS standards and controls

AC transfo outside build.193

PS in build.193

Experimental area

cable passage holes



beam dump

beam fixed jaw collimator

Experimental area

Auxiliary works:

- The **power supply** work is advancing well
  - Controls, interlocks and timing issues defined
  - Work on AC part is advancing as scheduled
- Installation of **services** (electricity, networking, etc.) is ongoing
- Installation of the **cryogenics line** completed as well as the preparation for the dewar platform on the surface
- **Platforms and pedestals** for the crates in the TT2 tunnel done
- **ODH monitoring** installation completed
- **Access** doors and interlocks defined and work ongoing

Significant progress over the last months, works proceed as scheduled

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Safety for MERIT experiment

1. Preliminary hearings with safety officials at CERN before the proposal submission and approval of the experiment

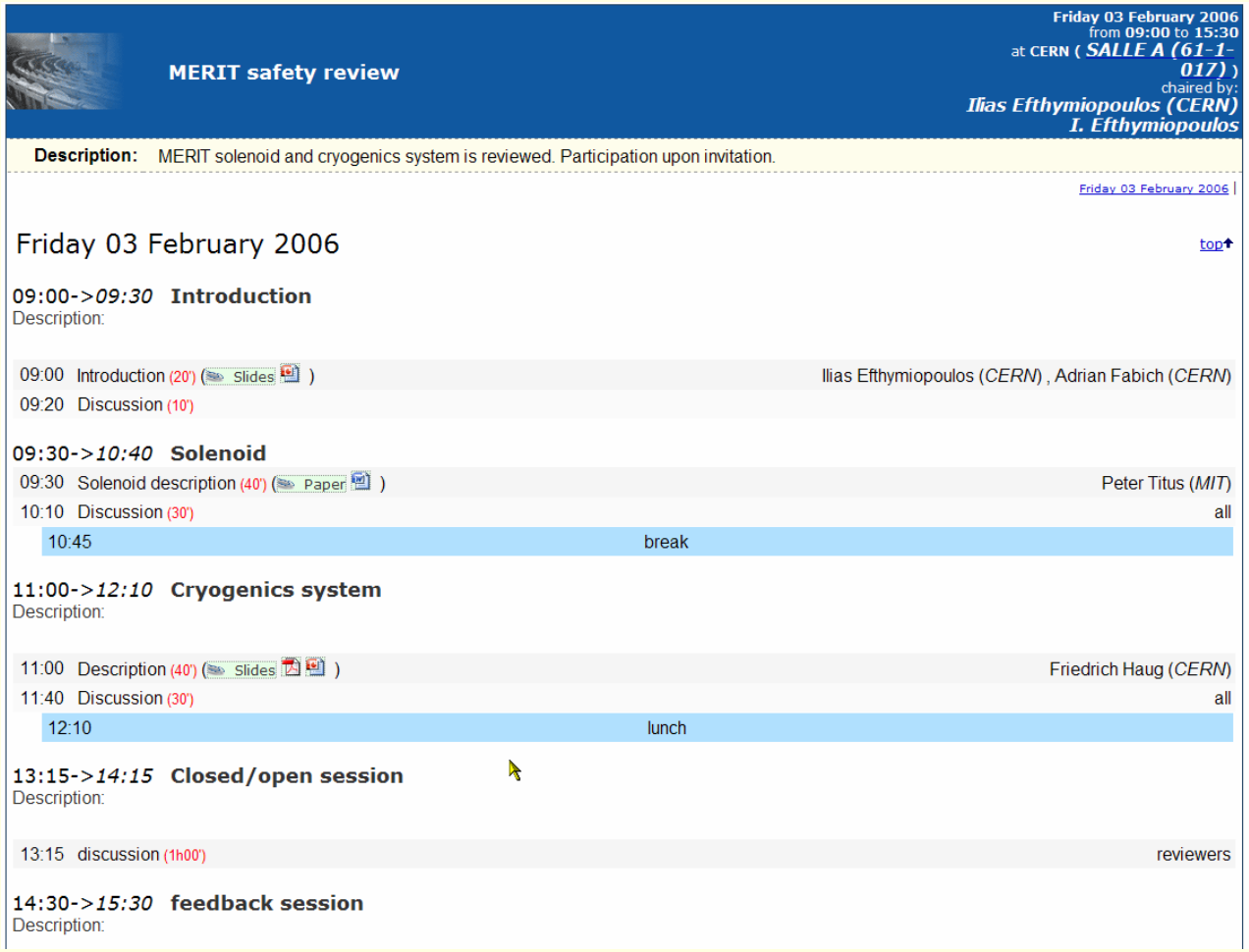
2. Safety reviews of the major sub-systems of the experiment, in time with their production
   - Cryostat and cryogenics – **February 3, 2006**
   - Hg-system – **June 20, 2006**

3. Safety pre-installation review **March 30, 2007**
   - Experience from the combined tests & MIT

4. Safety inspections in-situ
   - Transport, installation, Hg-handling, cryogenics, electrical safety, etc.
   - Access, interlocks, monitoring systems, etc.

Solenoid & Cryogenics Review

http://indico.cern.ch/conferenceDisplay.py?confId=673



MERIT safety review

Friday 03 February 2006
from 09:00 to 15:30
at CERN (*SALLE A (61-1-017)*)
chaired by:
Ilias Efthymiopoulos (CERN)
I. Efthymiopoulos

Description: MERIT solenoid and cryogenics system is reviewed. Participation upon invitation.

Friday 03 February 2006 |

Friday 03 February 2006 top

09:00->*09:30* Introduction
Description:

09:00	Introduction (20') (Slides)	Ilias Efthymiopoulos (*CERN*) , Adrian Fabich (*CERN*)
09:20	Discussion (10')	

09:30->*10:40* Solenoid

09:30	Solenoid description (40') (Paper)	Peter Titus (*MIT*)
10:10	Discussion (30')	all
10:45	break	

11:00->*12:10* Cryogenics system
Description:

11:00	Description (40') (Slides)	Friedrich Haug (*CERN*)
11:40	Discussion (30')	all
12:10	lunch	

13:15->*14:15* Closed/open session
Description:

13:15	discussion (1h00')	reviewers

14:30->*15:30* feedback session
Description:

Mercury System Review

http://indico.cern.ch/conferenceDisplay.py?confId=1785

"MERIT safety review of the mercury system"

Monday 19 June 2006 from **09:00** to **17:00**
at CERN (***SALLE B (61-1-009)***)

Description : The design, construction, operation, transport & decommissioning of the mercury loop system will be reviewed.

Monday 19 June 2006 |

Monday 19 June 2006

top

09:00	Introduction (15') presentation	Ilias Efthymiopoulos (*CERN*)
09:15	Discussion (15')	
09:30	Layout and construction of the Hg system (30') (Slides) presentation	Van Graves (*ORNL*)
10:00	Discussion (30')	
10:30	break	
11:00	Operation and handling (30') (Slides) presentation	Phil Spampinato (*ORNL*)
11:30	Discussion (30')	
12:15	lunch (..)	
13:30	Transport and decomissioning (30') (Slides) presentation	Van Graves (*ORNL*)
14:00	Discussion (30')	
14:30	Closed session (1h00')	review panel
15:30	coffee	
16:00	Discussion - feedback (1h00')	

Pre-installation Review

http://indico.cern.ch/conferenceDisplay.py?confId=13152

MERIT Pre-installation review

Friday 30 March 2007
from 10:30 to 16:05
at CERN (SALLE J.B.ADAMS (864-2-B14))
chaired by:
Ilias Efthymiopoulos (CERN) , Adrian Fabich (CERN)

Description: Review the installation steps of the MERIT experiment with emphasis on safety matters. Present the experience and results from the combined tests at MIT. Go through the plans for the operation of the experiment at CERN.

Participants: Astone, A; Bernard, Y; Clement, M; Delille, B; Efthymiopoulos, I; Fabich, A; Gulley, J; Kirk, H; Lazzaroni, M; Lindell, K; Mc donald, K; Otto, T; Prodon, S; Roy, G

Friday 30 March 2007 |

Friday 30 March 2007

top

10:30	Welcome (05') (Slides)	Ilias Efthymiopoulos (*CERN*)
10:35	Status of the Experiment (15') (Slides)	Adrian Fabich (*CERN*)
	Brief overview of the experiment focusing on the items that won't be discussed in detail during the meeting. Go through the installation and commissioning schedule.	
10:50	Mercury handling operations (30') (Slides)	Harold Kirk (*Brookhaven National Laboratory (BNL)*)
	Desrciption of the mercry system - "as built". Results from standalone and combined tests at MIT. Mercury loading and unloading operations. Plans at CERN.	
11:20	Solenoid - experience from the tests at MIT (20') (Slides)	Kirk Mc Donald (*Princeton University*)
	Present the operation and experience from the standalone and combined tests at MIT.	
11:40	Discussion (25')	
14:30	Installation plans (30') (Slides)	Michael Lazzaroni
	Go through the installation procedure foreseen. Address the issues of lowering of material from the shaft, manipulations inside the tunnels etc.	
15:00	Cryogenics installation and operation (20') (Slides ; more information)	(tbc)
	Update on the cryogenics installation and operation.	
15:20	Discussion (40')	

MERIT Safety Reviews

Chairman

- **Ghislain Roy (CERN-AB/DSO)**

Mercury experts & Chemical Safety

- Friedrich Groeschel (PSI)
- Bernie Riemer (ORNL)
- Jonathan Gulley (CERN/SC)

Radiation protection (CERN-SC/RP)

- Marco Silari
- Thomas Otto
- Pierre Carbonez

Mechanical safety (CERN-SC/GS)

- Benoit Delille
- Andrea Astone

General Safety (CERN-SC/GS)

- Bruno Pichler
- Karl Gunnar Lindell
- Ralf Trant

Fire protection (CERN-SC/GS)

- Fabio Corsanego

Safety issues

- MERIT Presentations in:
  - **AB Installation Committee (ABIC)**
    - interface with PS/SPS and CERN services teams
      - → permission to work in TT2/TT2A tunnel during PS/SPS operation
  - **AB Safety Committee (ABSC)**
    - Presented safety structure of the experiment and proposal for review program of various components
  - **AB Technical Committee (ATC)**
    - discussed status of the experiment, schedule, AB & CERN resources, safety…
  - **Radiation Protection Committee (RPC)**
    - Presentation to French and Swiss authorities; authorization to run obtained
- **ISIEC form** for the experiment submitted
  - Ardian Fabich (CERN) nominated as GLIMOS (**G**roup **L**iaison **I**n **M**atters **O**f **S**afety)

A very good and continuous contact with the CERN safety officials has been established

The "**safety file**" for MERIT sets the example on how safety should be handled for experiments at CERN

Dismantling

- At the end of the run the experiment will remain in place for a **cool-down time** until the machine shutdown (November '07)
  - The Hg will be emptied and stored in the flasks in TT2 tunnel
- During the **2008 shutdown** the experiment will be removed from the tunnel
  - All equipment will be stored at CERN for **one year cool down**
  - At the end of that period radioactivity will be minimal for all components which allows classifying them as **"exempted" packages** for shipment
- Transport back to US is defined & agreed with CERN officials
  - Hg volume : transported by air-cargo using the existing packaging
    - radioactivity will be minimal and chemical hazards precede
  - Hg loop: transported by air-cargo
    - Classified as "mercury wet" material (< 1lt of Hg)
  - Solenoid & other heavy material will be packaged and send separately

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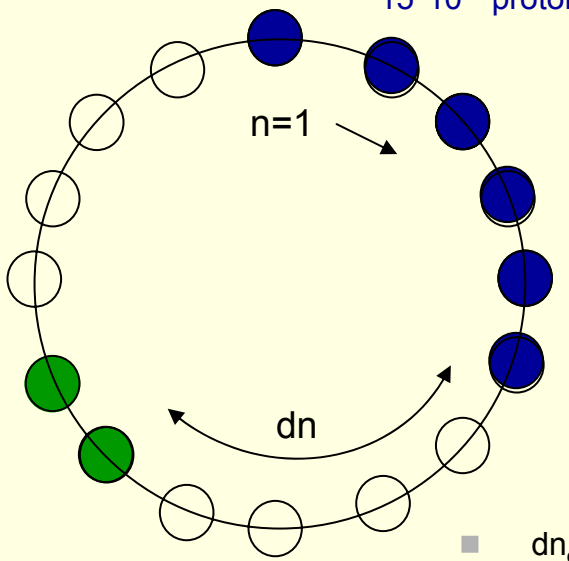
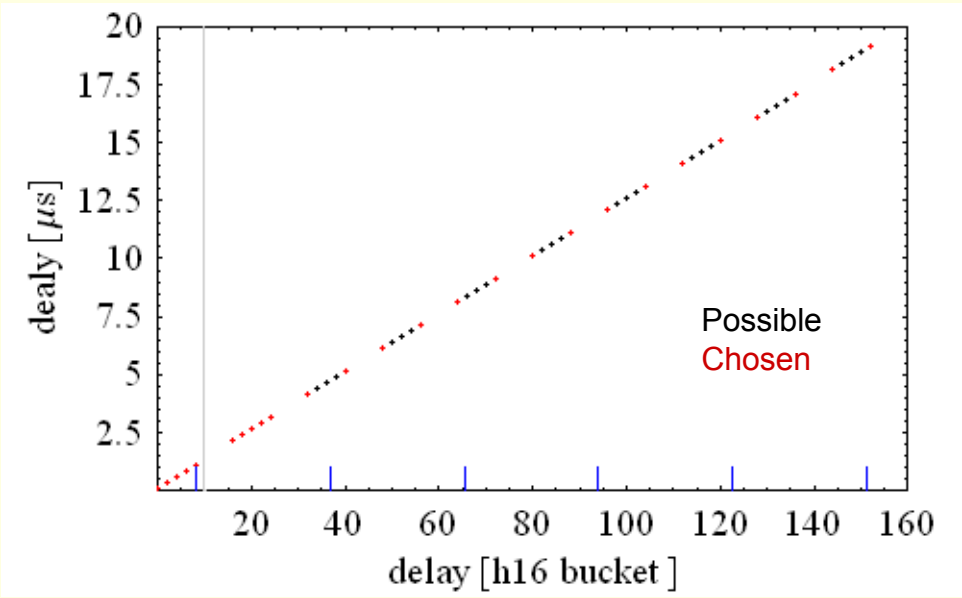
Beam setup for cavitation studies

- Operate the PS machine in harmonic-16
  - Fill the machine in bunch pairs



PUMP: 6 bunches, $15*10^{12}$ protons

PROBE: 2 bunches, $5*10^{12}$ protons



- $dn_{experiment}$ = 0,2,4,6,8, 16,18,20,22,24, 32,40, 48,56, ...
- Setup time is scheduled to provide all the requested configurations
  - Understand possible instabilities and intensity limits due to inhomogeneous intensity distribution
  - Similar requirements as for the HI CNGS beams

Beam pulse Priorities

General approach

- Repeat each parameter configuration twice
- Increase intensity gradually (up to $2.5*10^{13}$ protons/pulse)
- Do basic program, MHD first
- Each proton pulse configuration is performed at B=15 T (solenoid) and B=0 T (horn)
- Consider effort for PS operation to change settings

Schedule

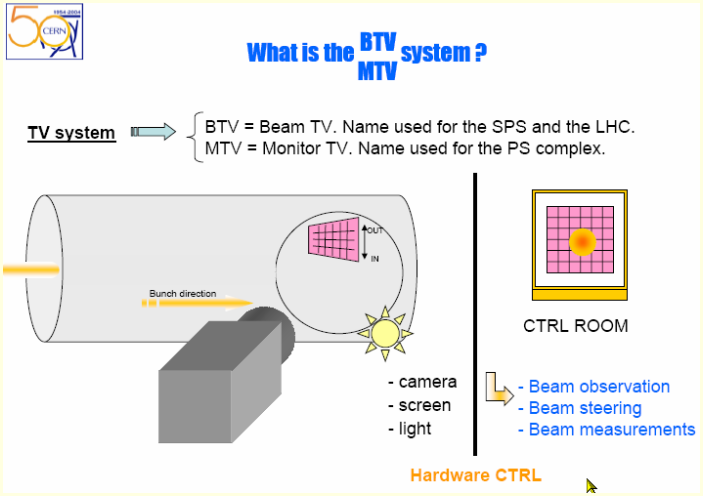
1. Beam setup – understand beam optics, parameters and tuning
2. MHD studies (i.e. magnetic field scans)
3. Beam position scan along the target
4. Pulse structure studies
    1. Cavitation
5. Spot size sensibility
6. Intensity ; aim to >3.2 TP !!!

- Operation scenarios with real time estimates are being worked out

Beam Instrumentation

Beam profile measurement

- MTV screens
  - “almost” readily available
  - Minor effort / minimum budget



Beam intensity

- Beam transformer at beginning of line and just upstream of experiment
- Measurement of intensity per bunch

Transverse beam parameters

- Position & spot size → MTV screens
- Direction → 2× MTV screens & collimator
- Divergence → not a direct measurement
  - Rely on beam simulations
  - Estimate from spot size monitors

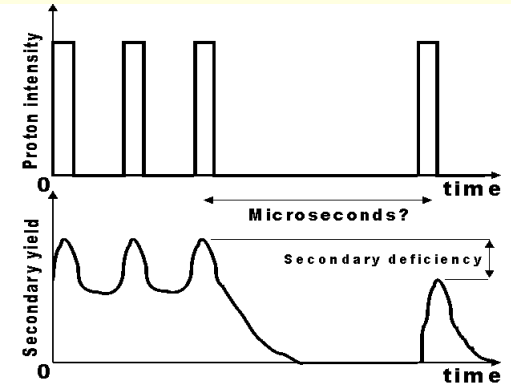
Longitudinal beam parameters

- Measured by pick-ups in the PS & TT2 line upstream of MERIT

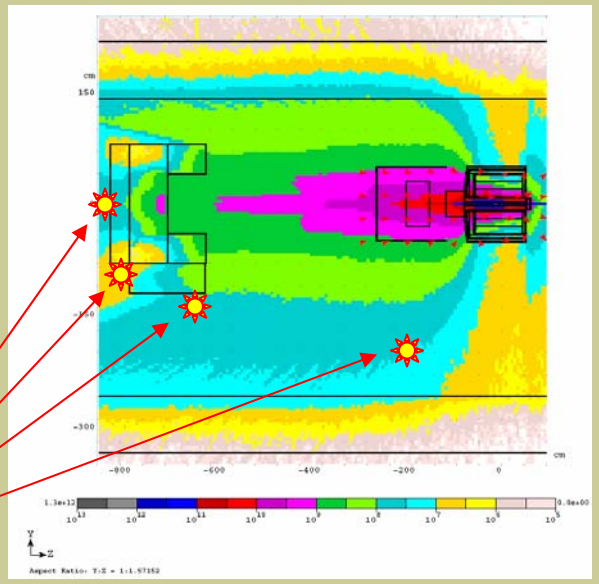
- Logging of all beam parameters and instrumentation possible

Particle Detectors

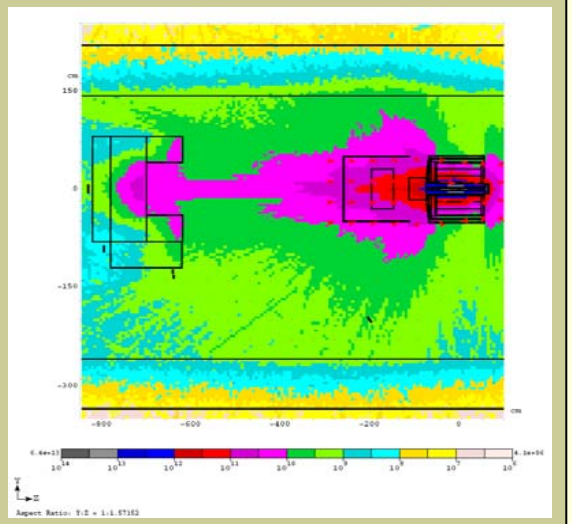
- Measure particle production in “pump-probe” method for cavitation studies: i.e. detect particle production per bunch
- Place detectors around the target at various locations
  - Detectors: pCVD diamonds, pin diodes, ACEM detectors
- Monitor the beam-target interaction



Particle fluxes - 3×10^{13} protons (MARS Simulation)



neutrons (E>100 KeV)



Particle Detectors

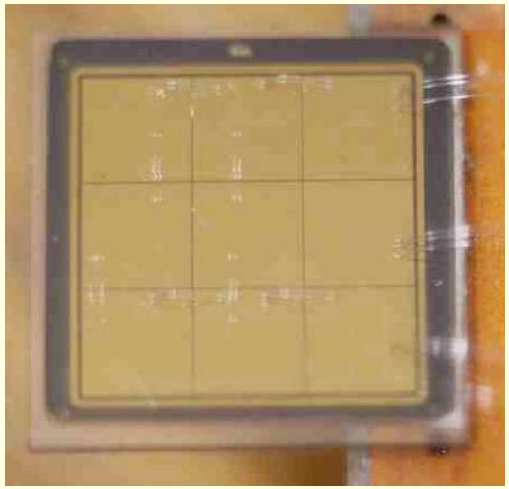
charged hadrons (E>200 KeV)

S.Striganov - FNAL

Particle Detectors

Diamond detectors

- Same principle as a PIN-diode, with reverse bias voltage and separation of electron-hole pairs, created by traversing MIPs.
- Previously tested in conditions similar to that of MERIT with good results.
- Will be used at LHC for the fast beam abort system around the experiments



ACEM

- Aluminum Cathode Electron Multiplier – Built like a photo multiplier, but with an aluminum foil functioning as a secondary electron emitter as cathode. See [1].
- Used in PS & PSB machines as beam loss monitors

Summary

- The experiment is in good track. Construction is completed and results from the tests so far are very encouraging.
  - The important milestone of combined tests at MIT was met in March'07
- The focus now moves to CERN with the installation and commissioning activities
  - Despite of the delays and technical problems, we remain on time for the July run with beam (3^{rd} - 17^{th}) but with very limited contingency
  - Correcting the leaks of the solenoid remains critical and will focus our attention in the coming week
- Safety has been handled very seriously; continuous contact and collaboration with CERN officials has been established
  - Several reviews organized – no show stopper identified
  - Our primary goal remains to perform a successful and safe experiment

We are looking forward for an exciting summer at CERN with good physics results to verify the liquid target concept