Transients scenarios for the cryogenic operation of superconducting magnets of LHC experiments

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Content of the presentation

- Details for CMS and ATLAS of:
  - cooling down process
  - static heat load
  - dynamic heat load
  - fast discharge of the magnets
  - recovery after a fast dump

Structure of the s/c magnets

- CMS is composed of
  - a s/c solenoid, divided in 5 sectors
- ATLAS is composed of
  - a s/c Central Solenoid (CS)
  - a Barrel Toroid (BT), formed by 8 s/c race-track coils
  - 2 End Cap Toroids (ECT), each formed by 8 s/c squared coils

Cooling methods for CMS & ATLAS

- CMS
  - The solenoid is indirectly cooled by LHe, driven by thermosyphon movement (i.e. gravity driven)
- ATLAS
  - The CS is indirectly cooled either by the JT circuit of the Main Refrigerator (MR) or by thermosyphon movement
  - Both BT and ECT's coils are indirectly cooled by forced LHe flow produced by a 1.2 kg/s centrifugal pump

Cold Mass Inventory

- CMS total cold mass is 220 Tons (cylinder 6.6 m x 12.5 m)

- ATLAS total cold mass is ca. 700 Tons
  - CS ca. 6 Tons (cylinder 2.5m x 5.3m)
  - BT (340 +20) Tons (8: 25 m x 5 m)
  - ECT's (2 x 160) Tons (8: 5m x 5m)

Where we are with the commissioning

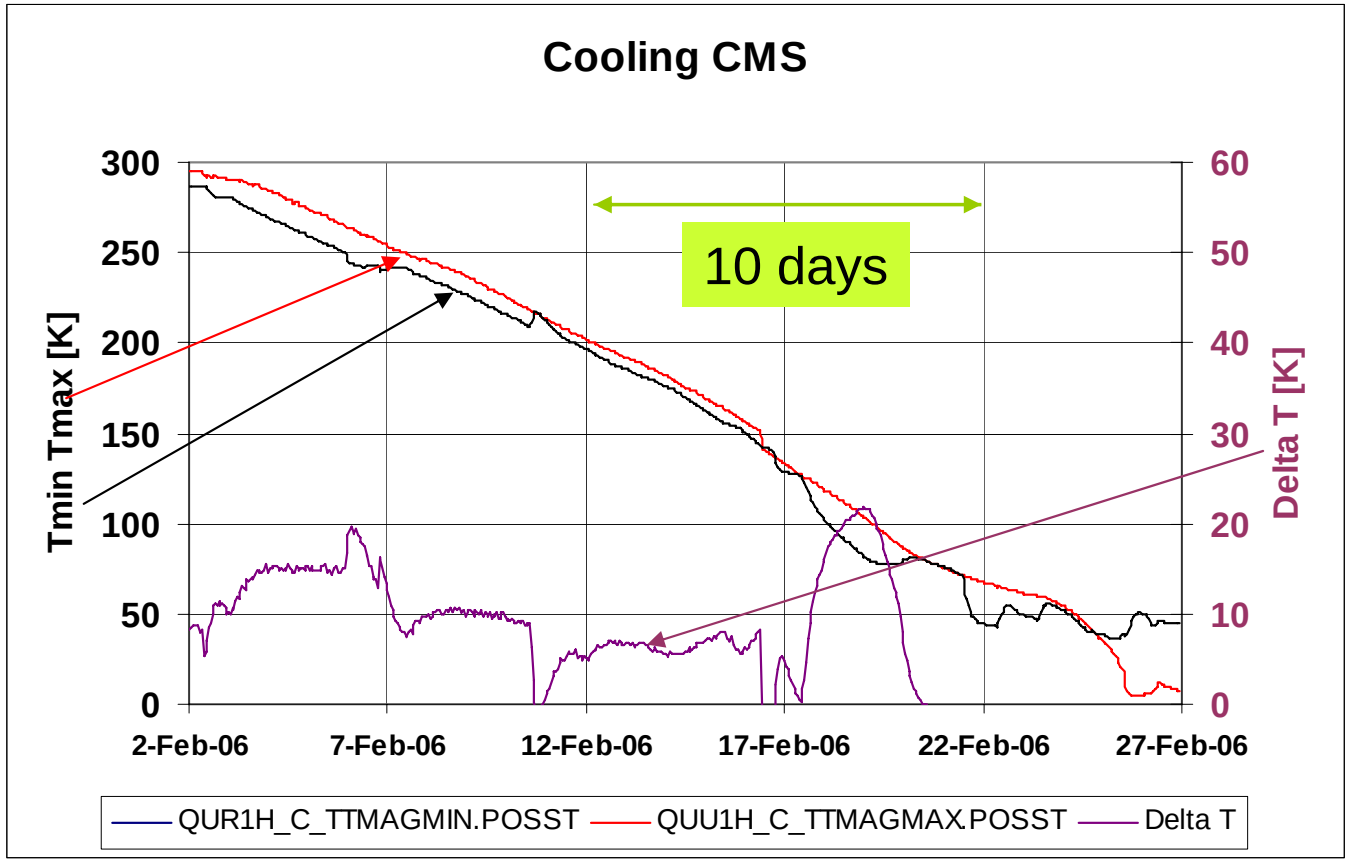
- Actual status:
  - CMS fully tested on the surface
  - ATLAS
    - CS fully tested (surface and cavern)
    - BT fully tested (surface and cavern)
    - ECT-A tested at LN2 temperature on surface
    - ECT-C under test on the surface

Cooling down of the Magnets

Cooling down of the Magnets

➢ CMS

1.2 kW @ 4.5 K Refrigerator used



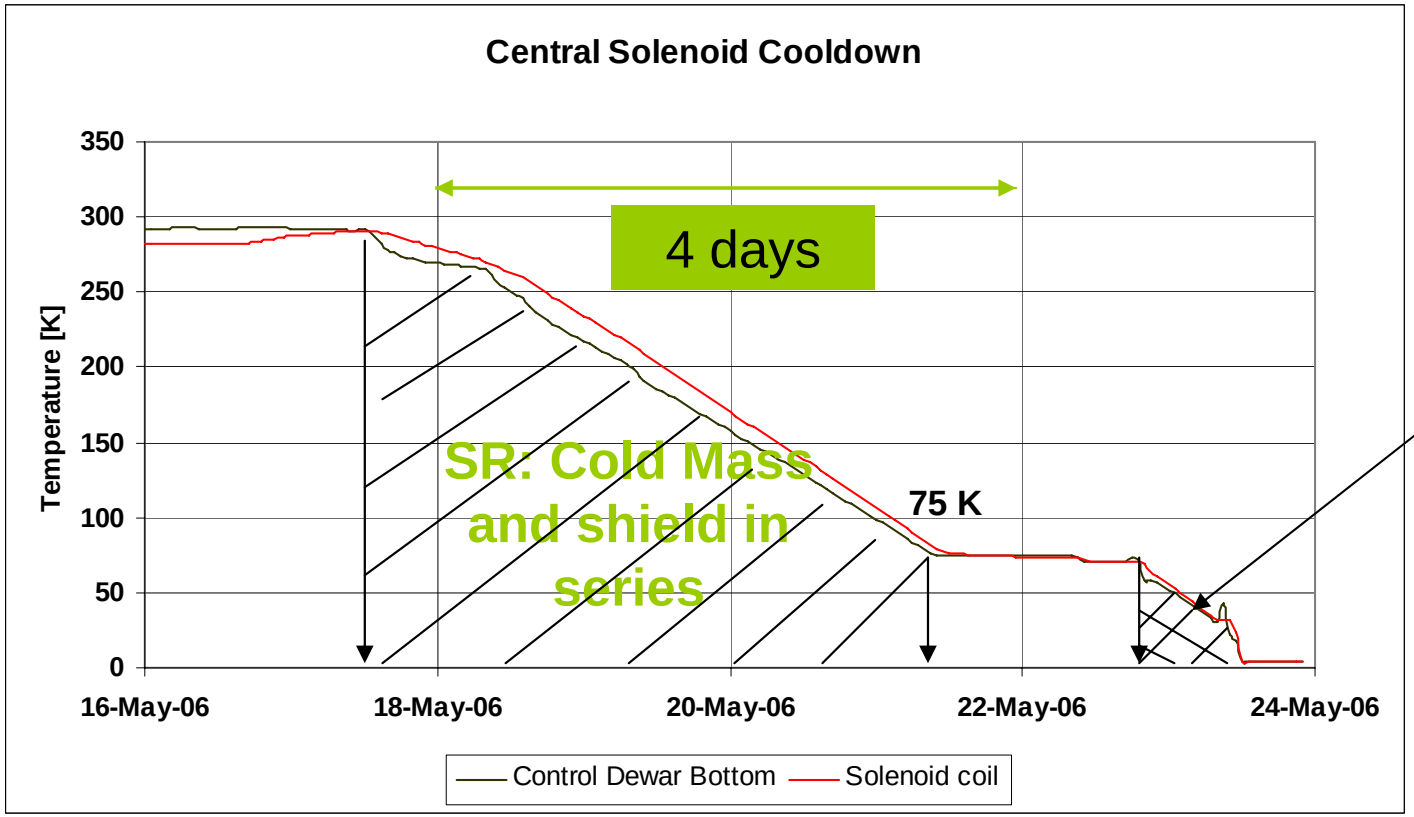
DT< 22K

Cooling Time ca. 22 days

Cooling down of the Magnets

ATLAS :CS

- **Shield Refrigerator (SR) & Main Refrigerator (MR) used**



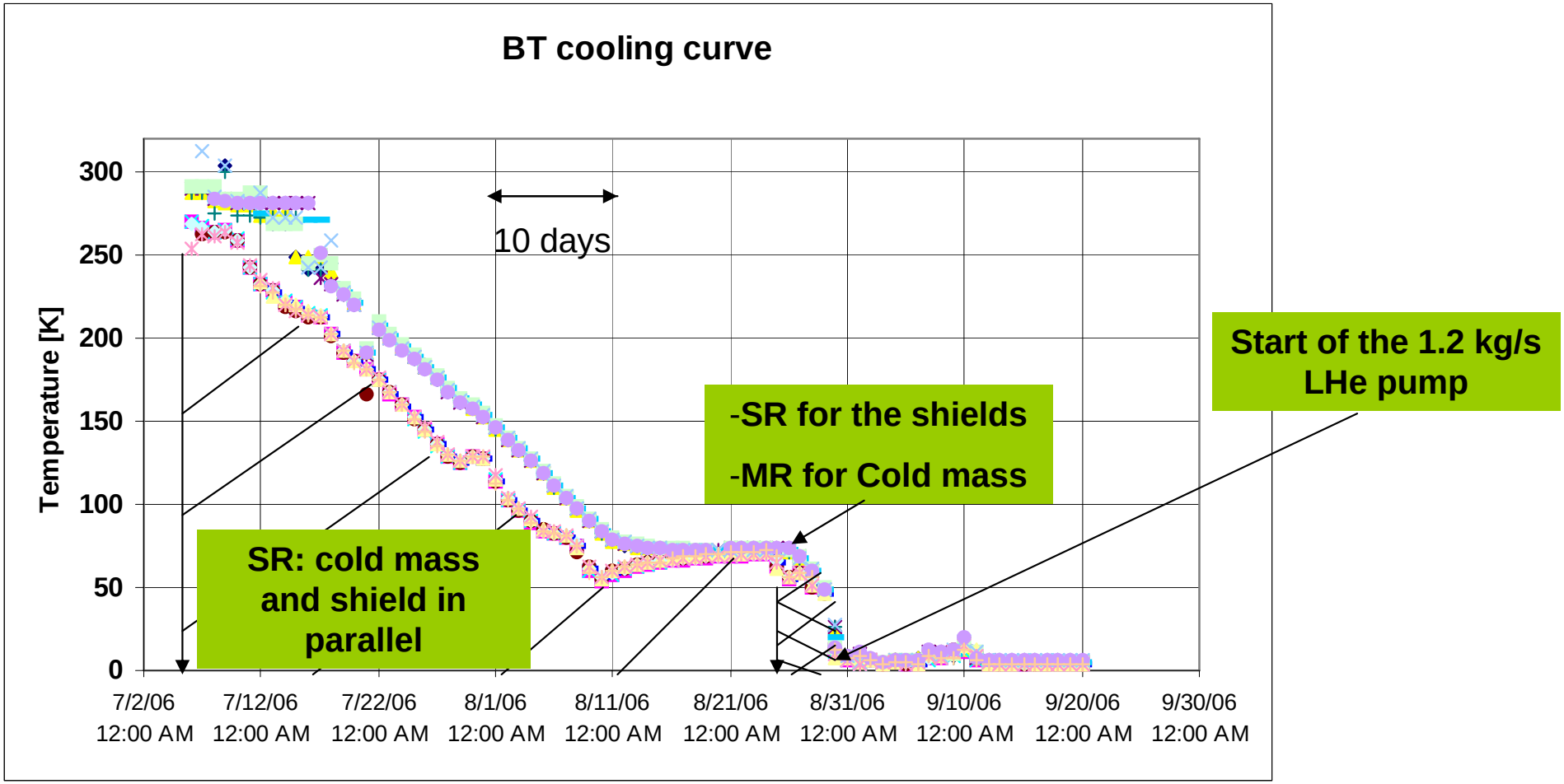
-SR for shield

- MR for CM

Cooling down of the Magnets

ATLAS :BT

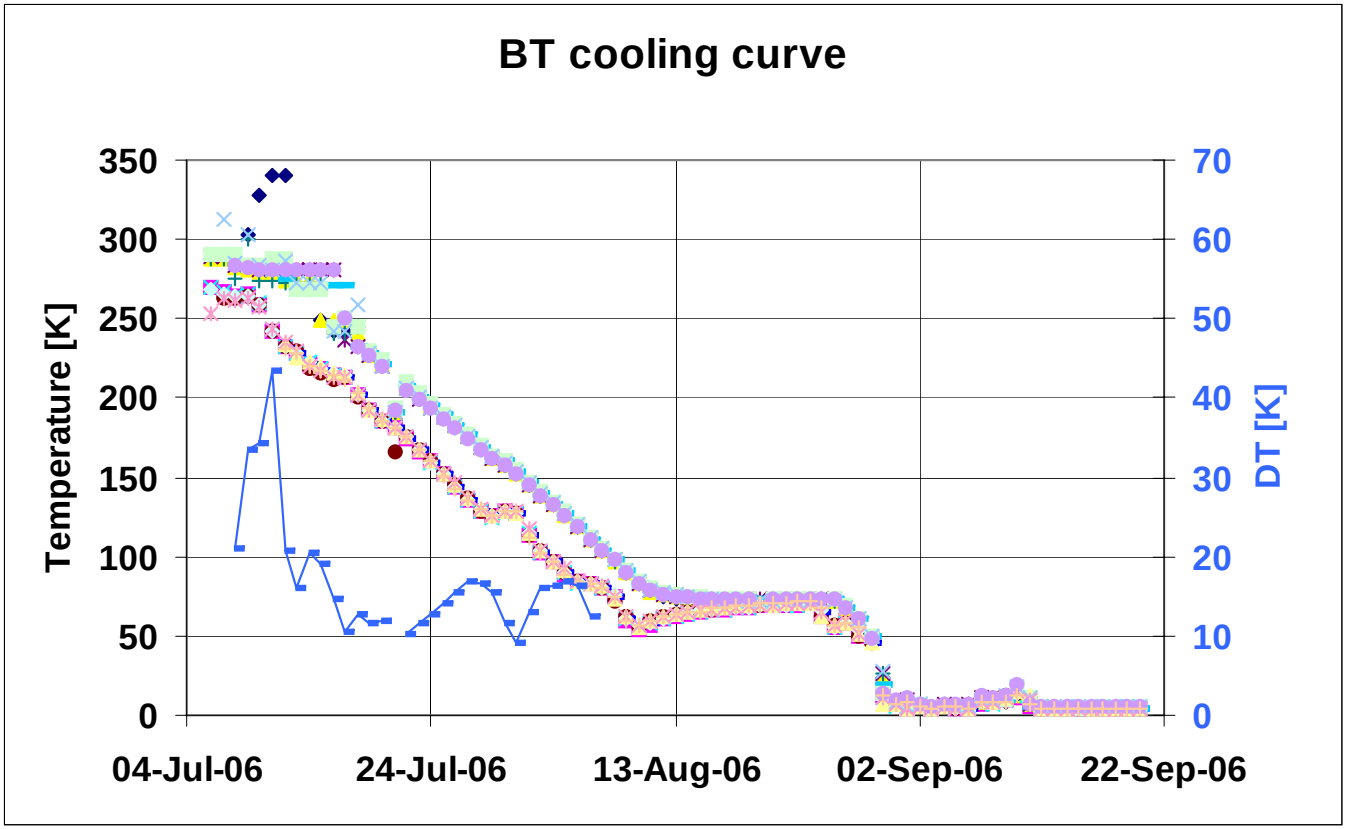
- **Shield Refrigerator (SR) & Main Refrigerator (MR) used**



Cooling down of the Magnets

➢ ATLAS :BT

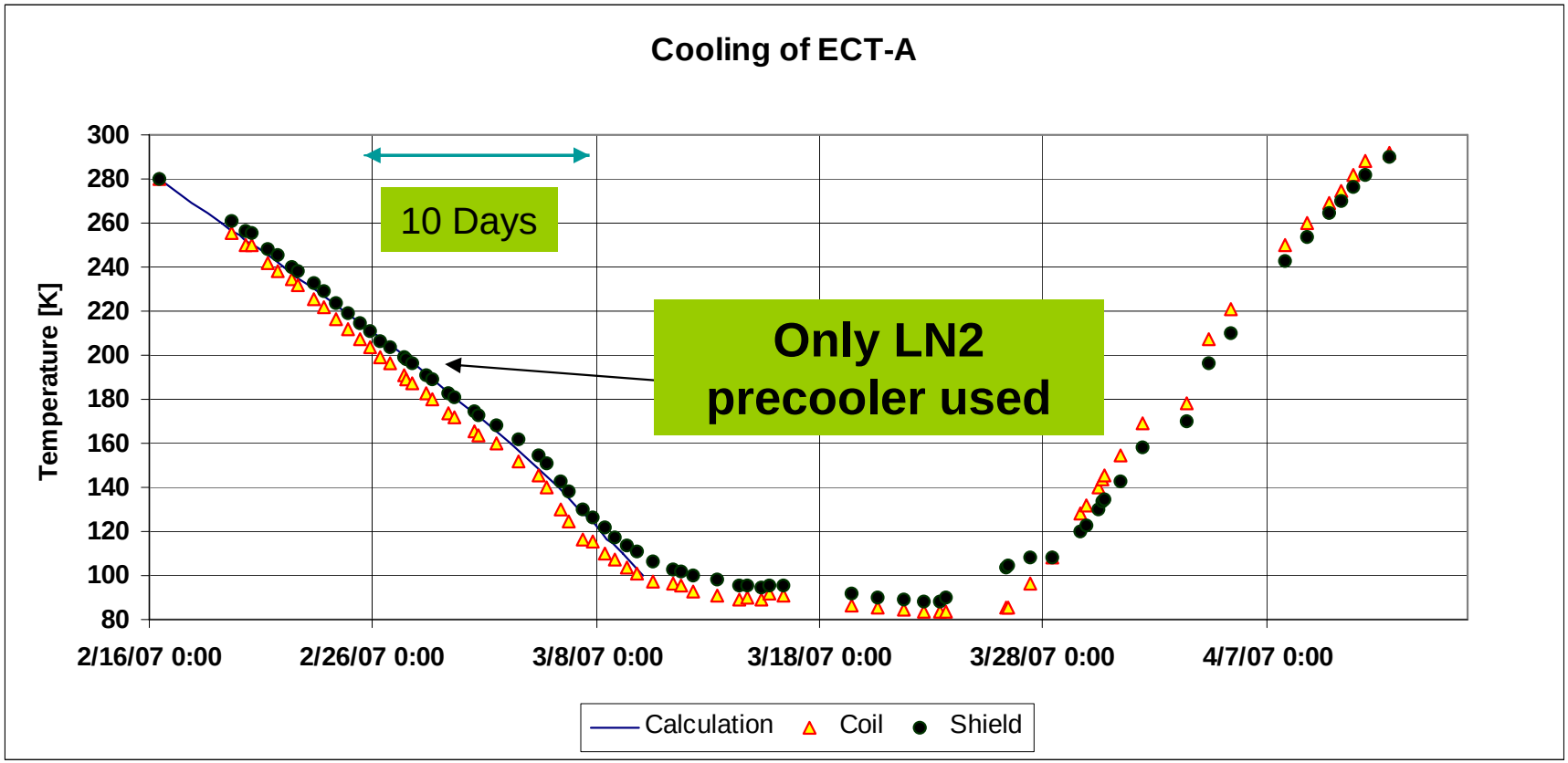
- **Shield Refrigerator (SR) & Main Refrigerator (MR) used**



DT< 40 K

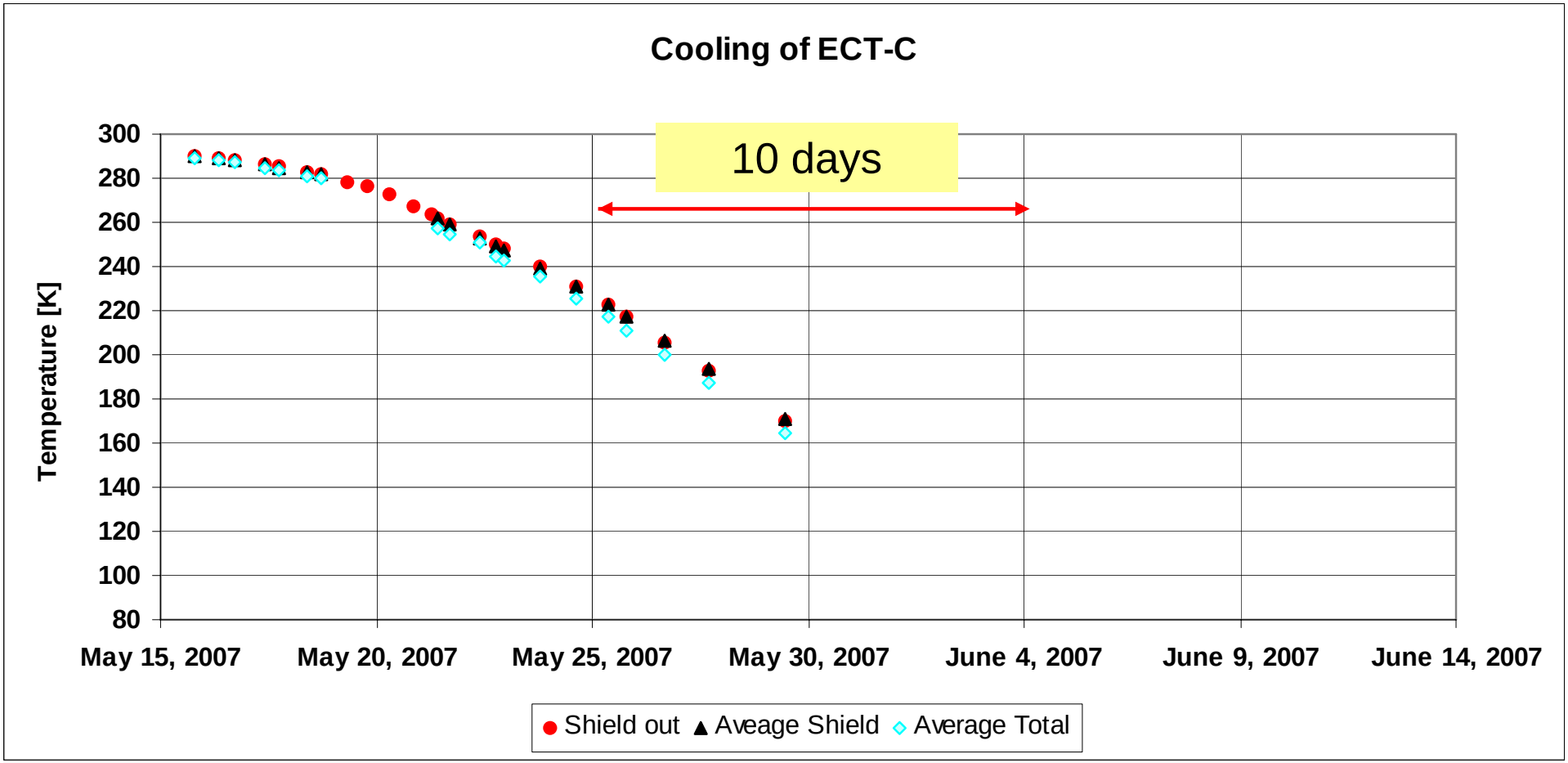
Cooling down of the Magnets

- ATLAS : ECT-A



Cooling down of the Magnets

➢ ATLAS : ECT-C (in progress)



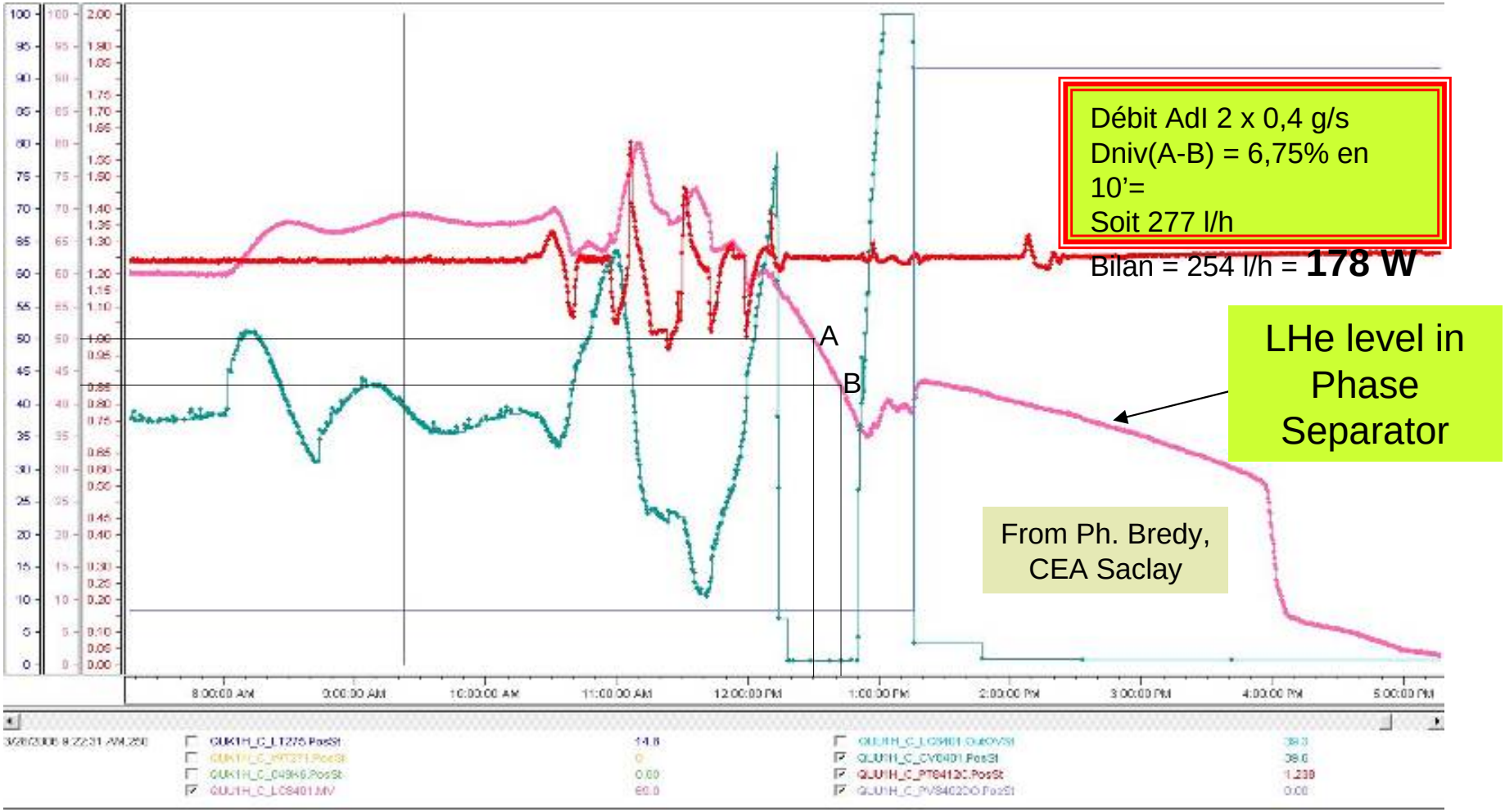
STATIC HEAT LOAD

STATIC HEAT LOAD

- CMS
  - Measured by LHe level decreasing in Phase Separator
  - Natural Temperature increasing on the cold mass

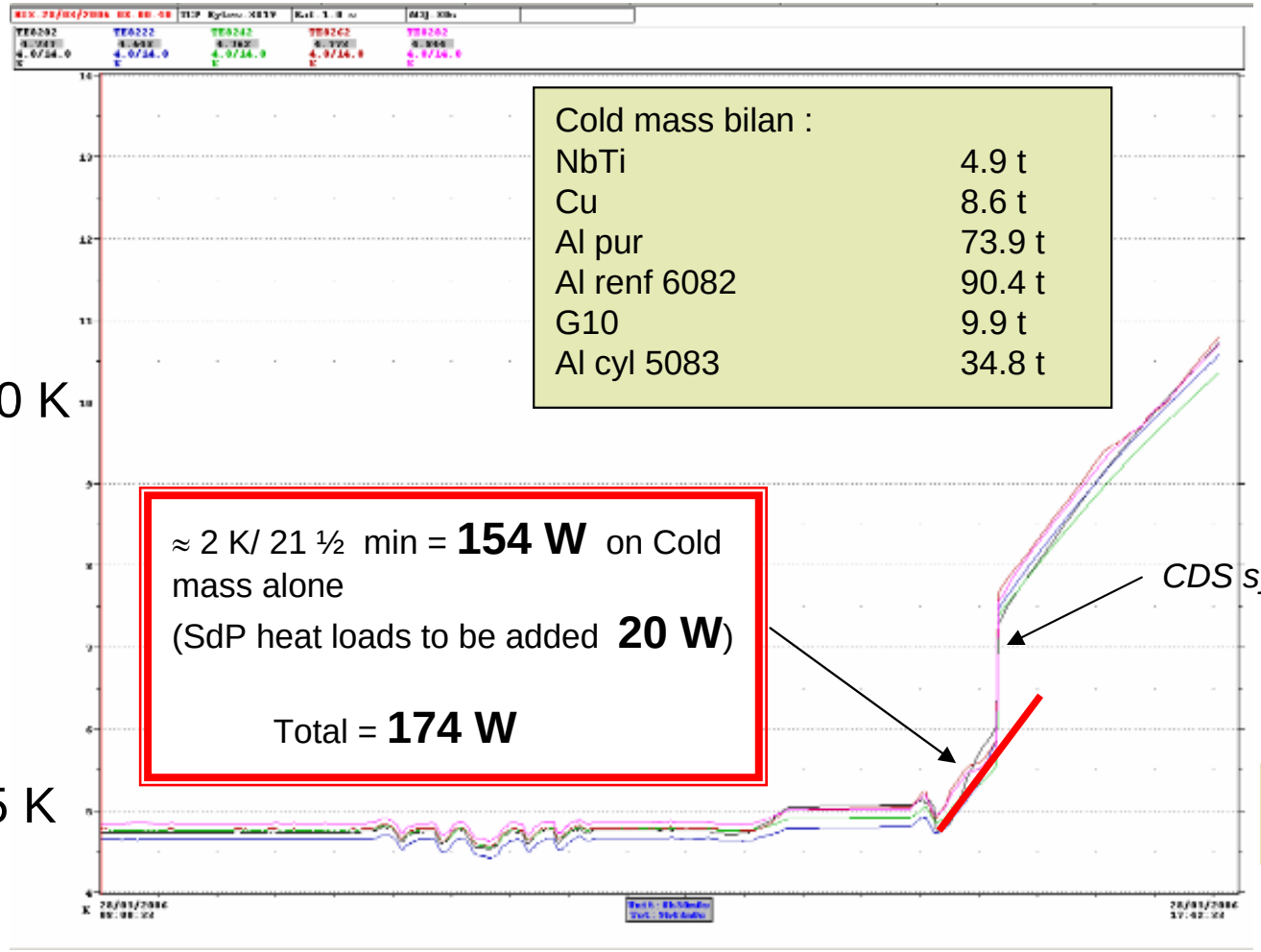
STATIC HEAT LOAD

- CMS: Measured by LHe level decreasing in Phase Separator (178 W)



STATIC HEAT LOAD

- CMS: Natural Temperature increasing of the cold mass (174 W)



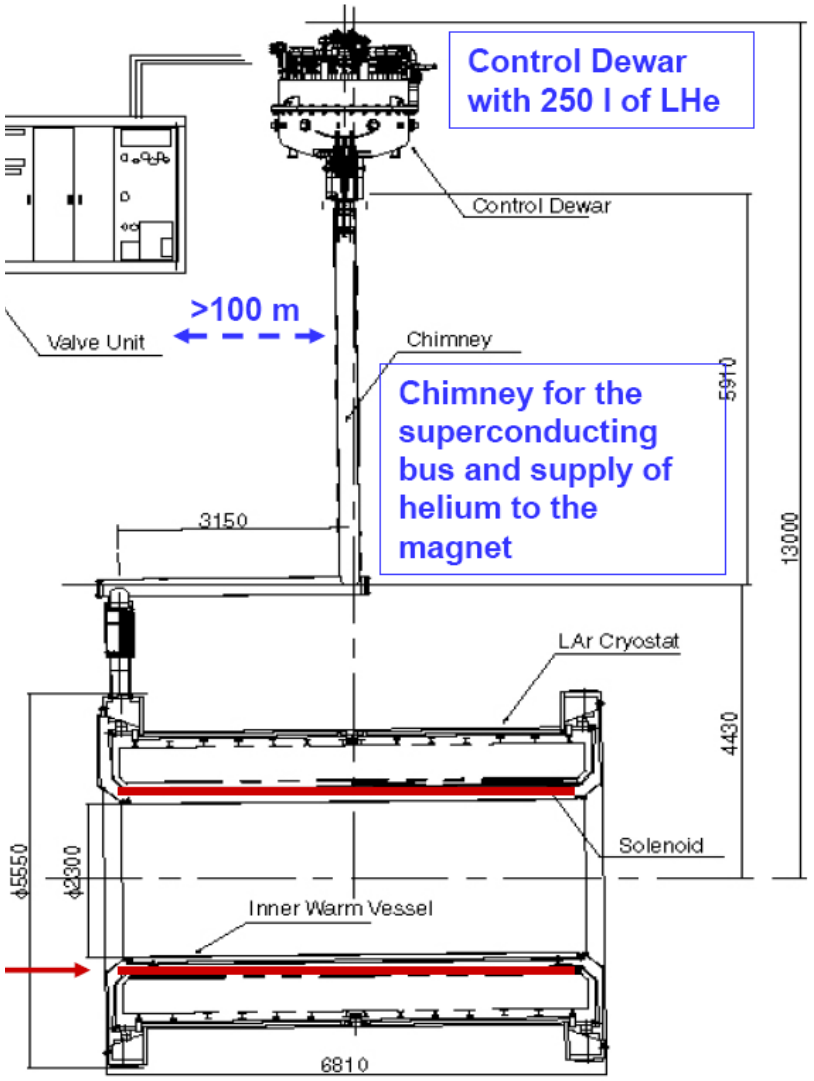
From Ph. Bredy, CEA Saclay

STATIC HEAT LOAD

- ATLAS: CS
- Measurement of total loss was done *during thermosyphon operation* mode with *disconnected refrigerator* and looking at the *level/time change in the control dewar*

Results:

- 17 Watts for the solenoid and the chimney;
- below 10 Watts for the dewar.

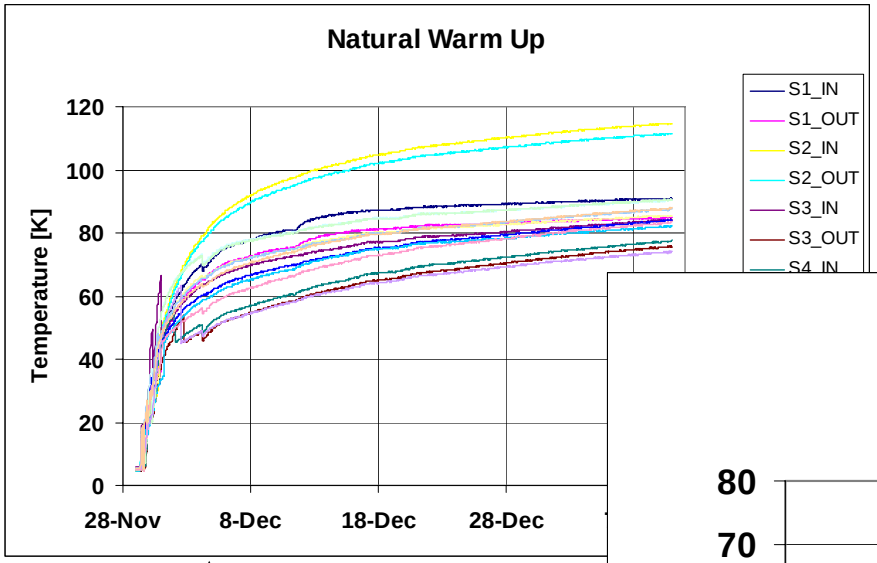


STATIC HEAT LOAD

- ATLAS: Barrel Toroid CM
  - For each of the 8 race-track coils the heat load has been measured
    - in the surface test hall (Mass-flow meter)
    - in the UX15 cavern after assembling into BT (natural temperature increase)
  - The total heat load of the BT has been also measured in the cavern

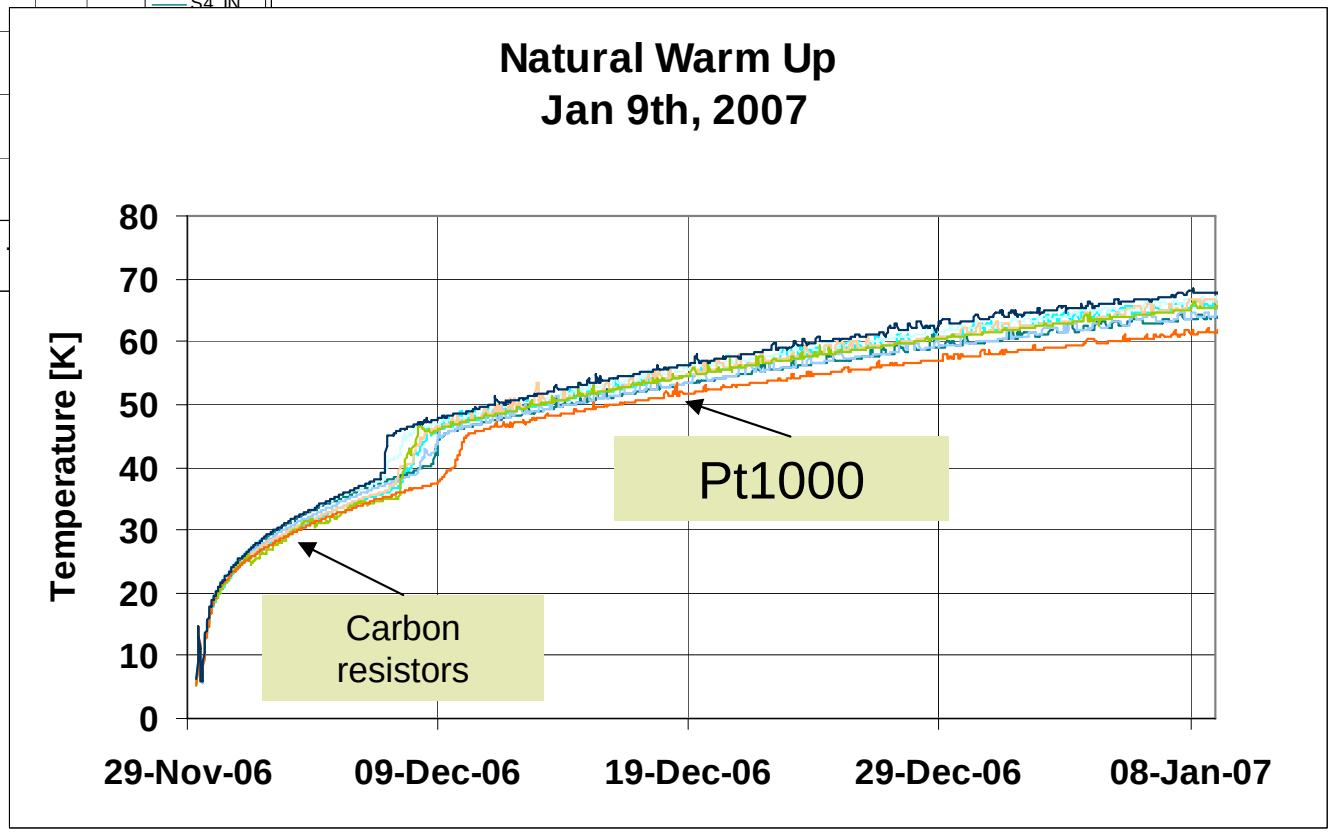
STATIC HEAT LOAD

ATLAS: Barrel Toroid

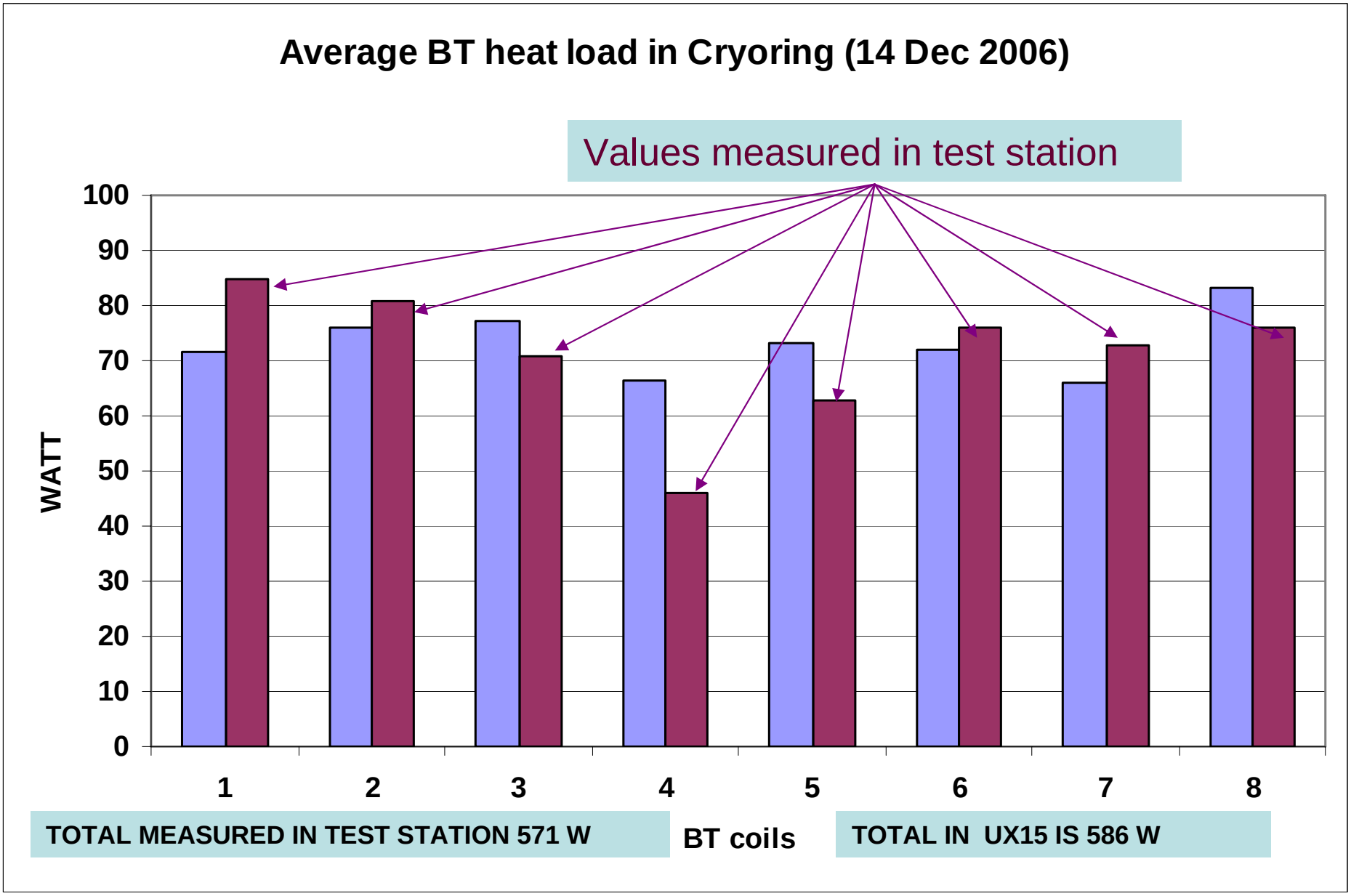


Tin-Tout on the pipes

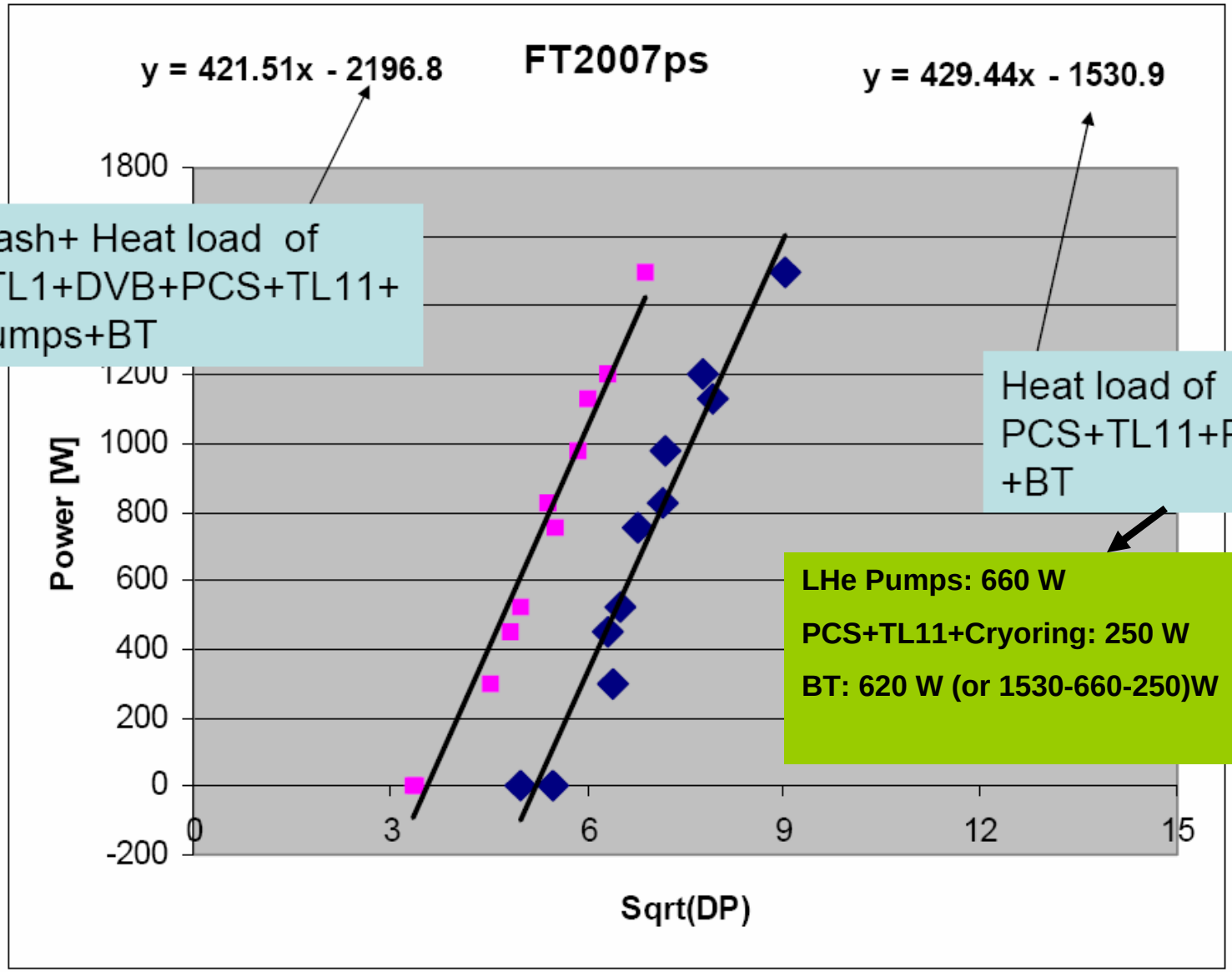
Tmax, Tmin on coils



STATIC HEAT LOAD



STATIC HEAT LOAD



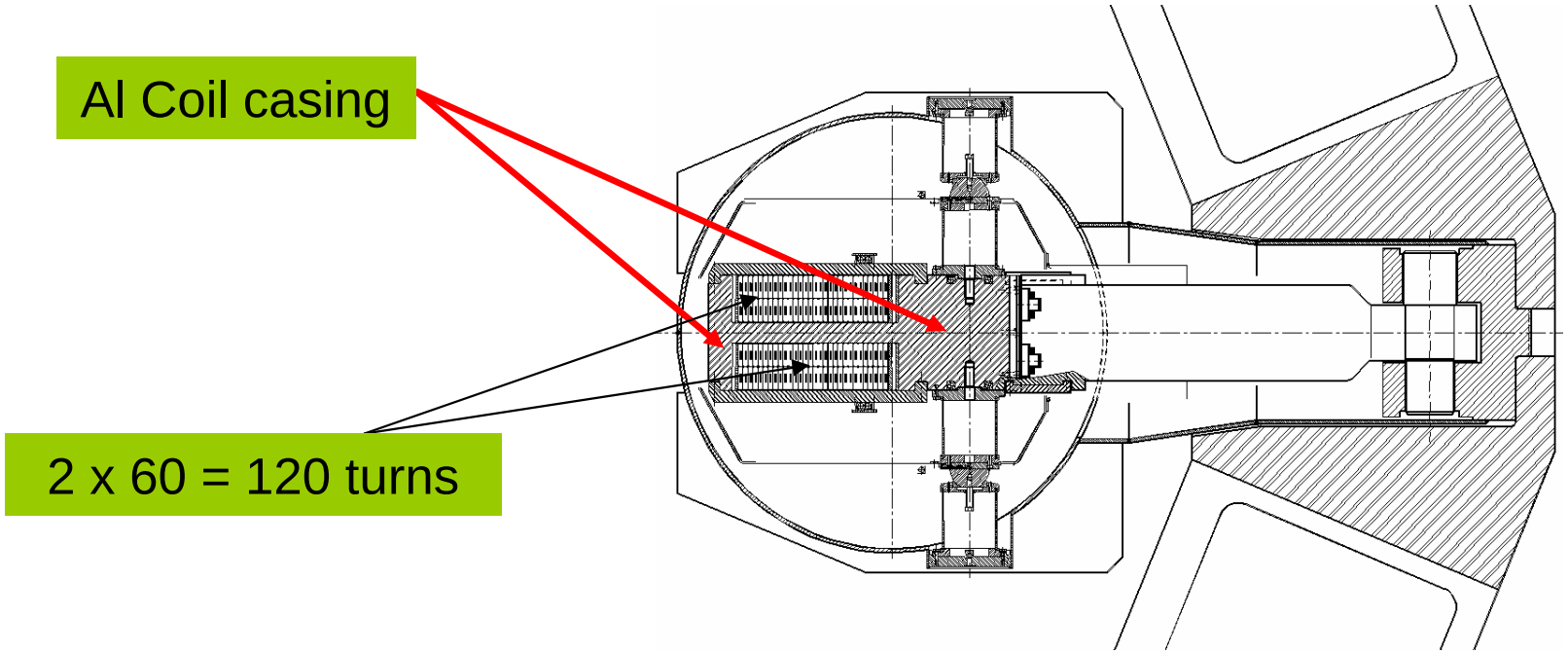
STATIC HEAT LOAD

- ATLAS: Barrel Toroid Shields
  - For each of the 8 cryostats
    - in the surface test hall (Mass-flow meter)
      - Average 800 W
    - the total heat load of the BT shield has been also measured in the cavern (Mass-flow meter)
      - Total 6000 W

DYNAMIC HEAT LOAD

DYNAMIC HEAT LOAD

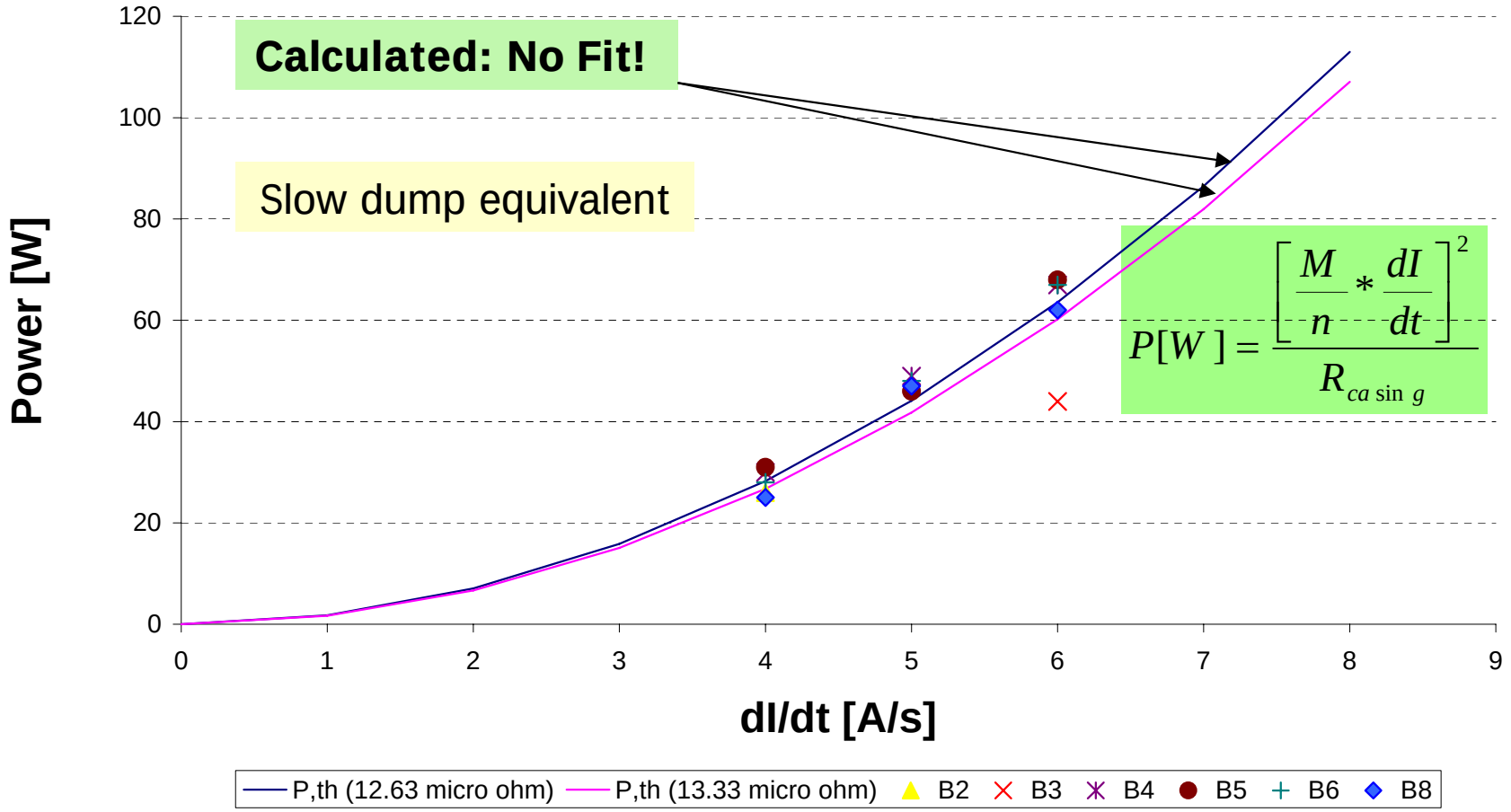
- Flux is proportional to Current:
  - $\Phi = L \times I$, $V = -d\Phi/dt = -L \times dI/dt$
    - Voltage is induced when changing current
      - And energy is dissipated by the induced current on the casing (~ autotransformer)



DYNAMIC HEAT LOAD

➢ ATLAS:

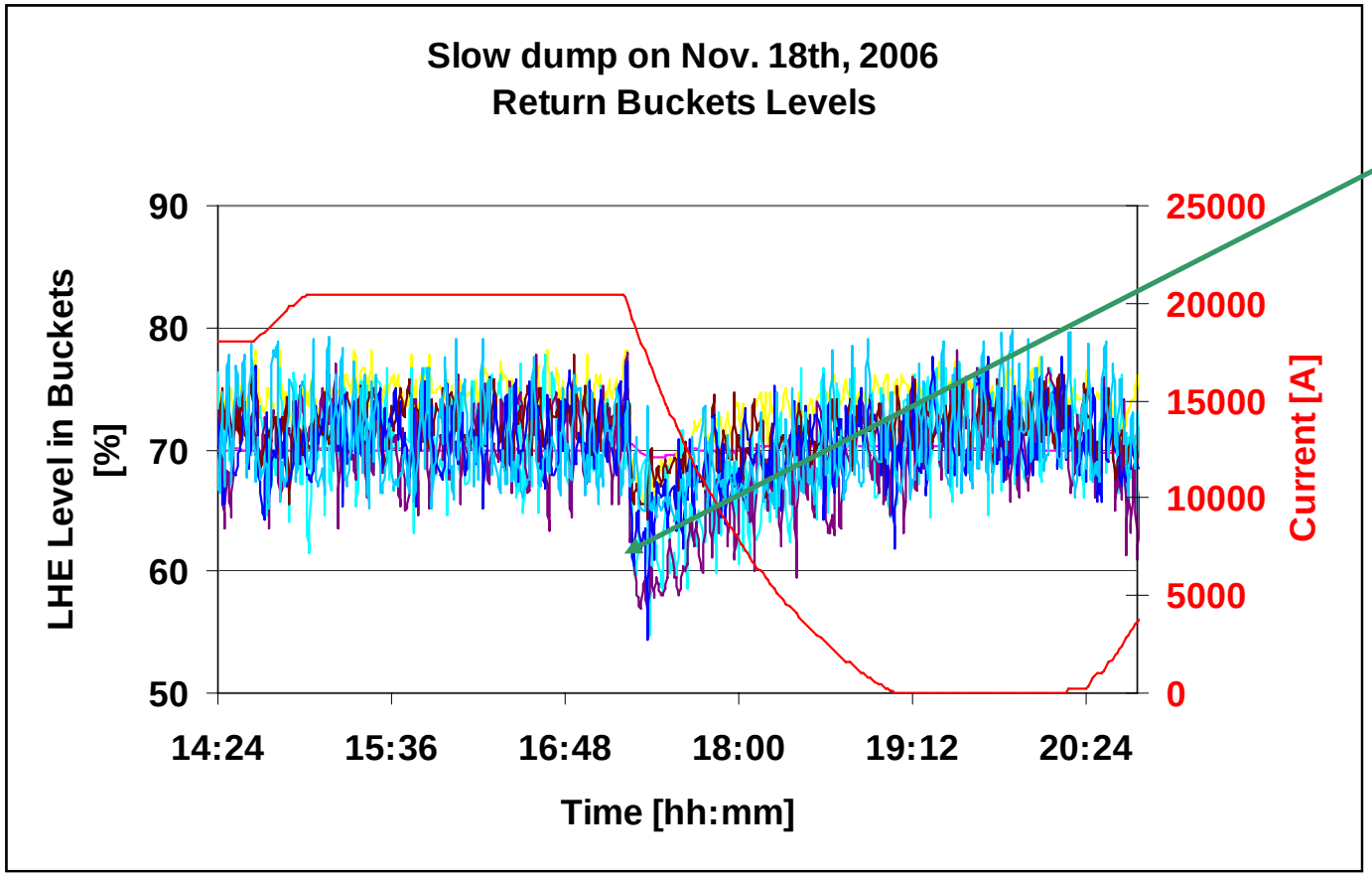
Dynamic heat load



One coil: L = 0.5667 H, Total BT: L= 5.5 H => expected value 350 W

DYNAMIC HEAT LOAD

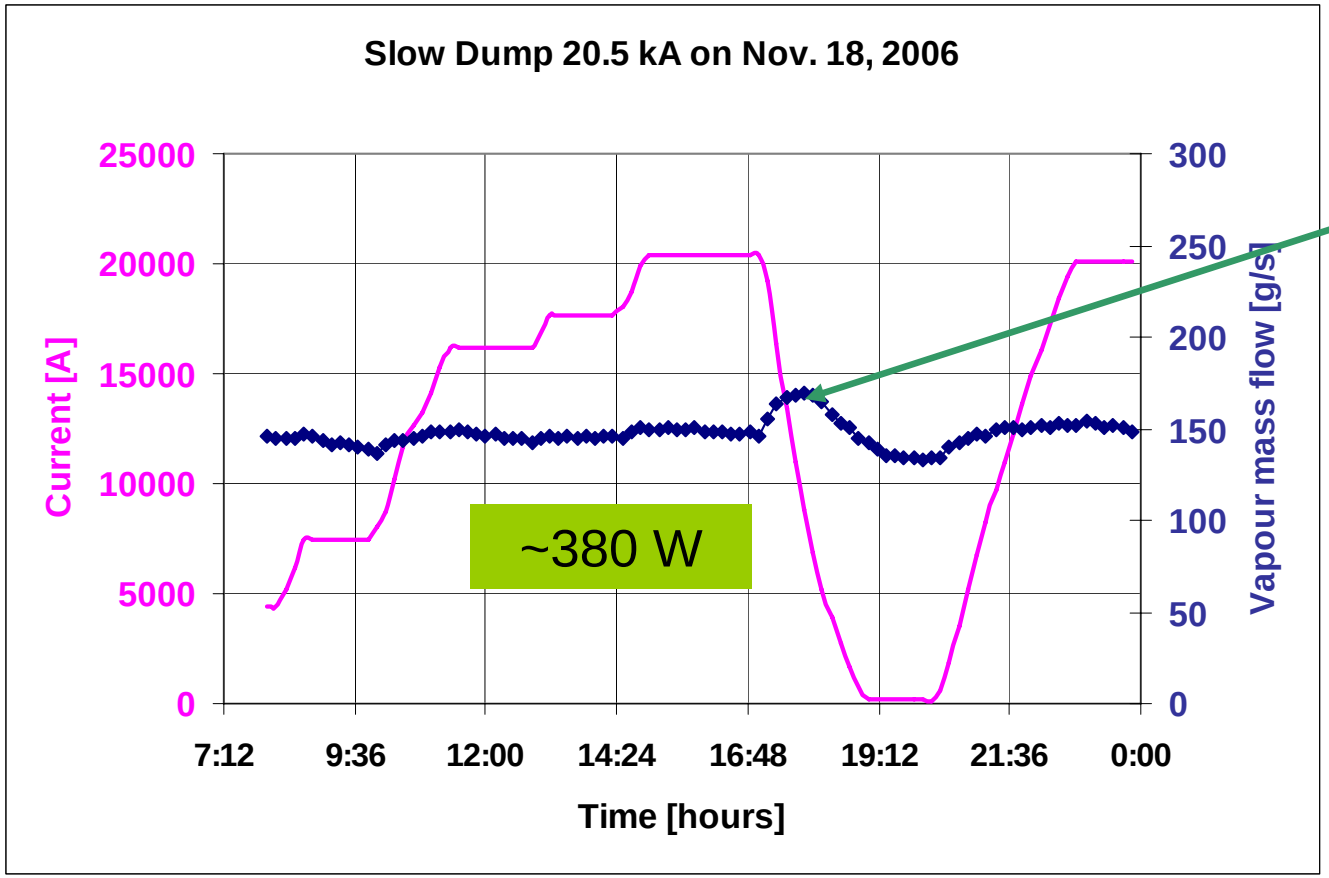
➢ ATLAS: BT



Level of LHe is reduced due to the higher vaporization during slow discharge

DYNAMIC HEAT LOAD

➢ ATLAS: BT



LHe vapor mass flow on the phase separator is increased due to the higher heat load

DYNAMIC HEAT LOAD

➢ ATLAS: CS

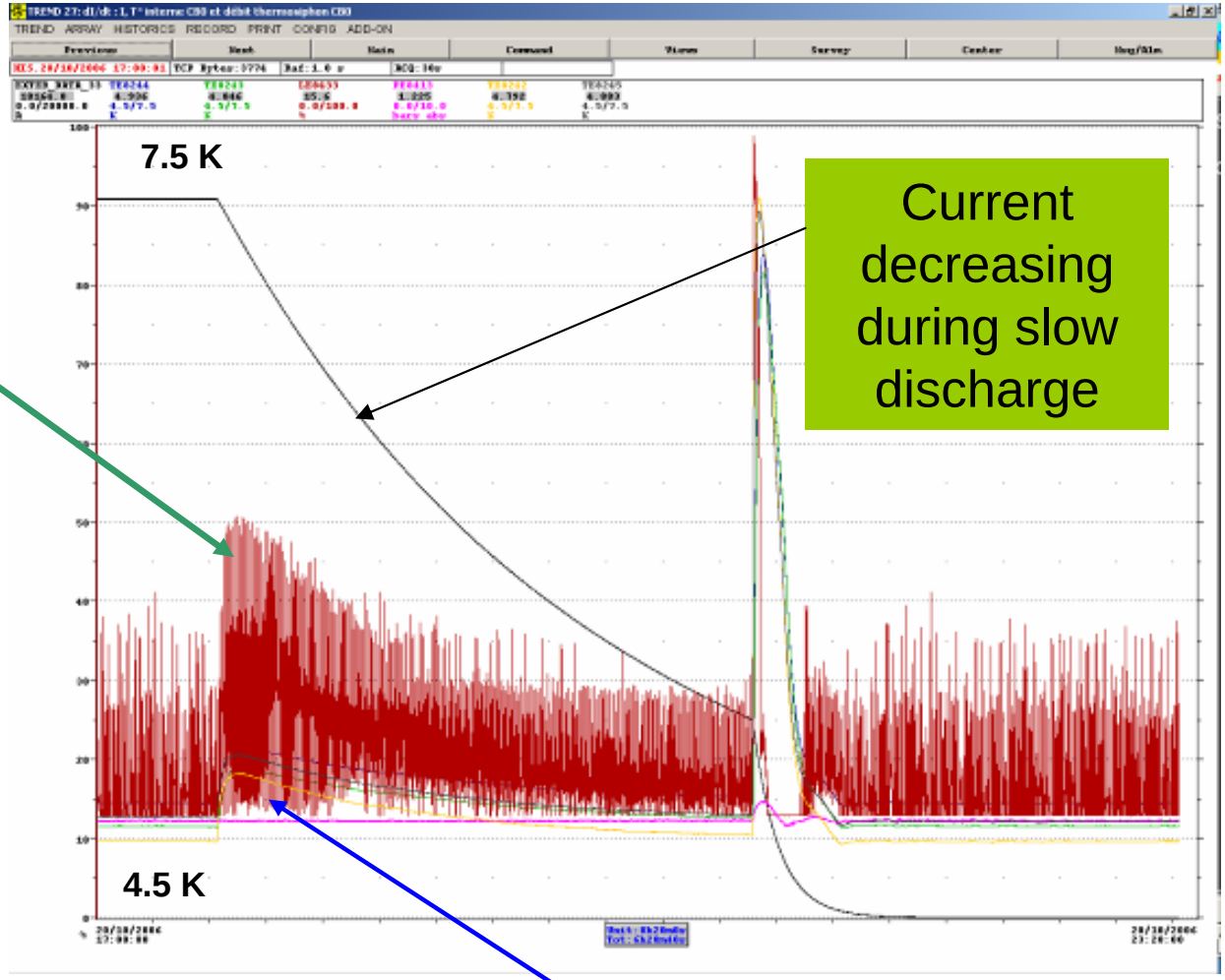
- Eddy current loss are around 25 Watts.

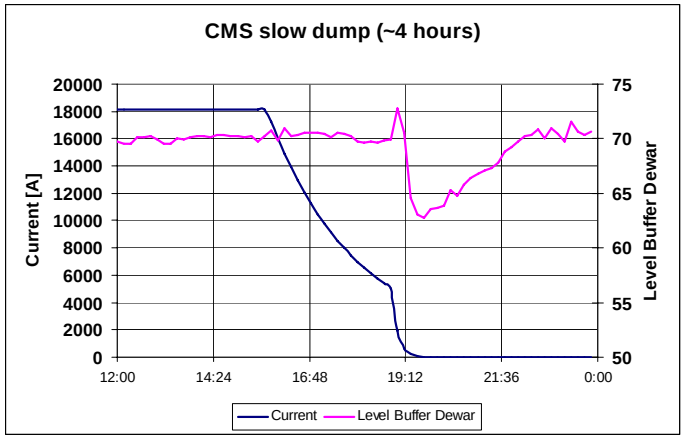
- ➢ Measurement principle:
- ➢ compare *consumption during ramp up* at 6 A/s with previously measured static losses by looking at the heater power in the control dewar which is reduced by 25 watts.
- ➢ Furthermore "gas counting".

DYNAMIC HEAT LOAD

➢ CMS:

Thermosyphon Mass flow is naturally increased due to the higher heat load

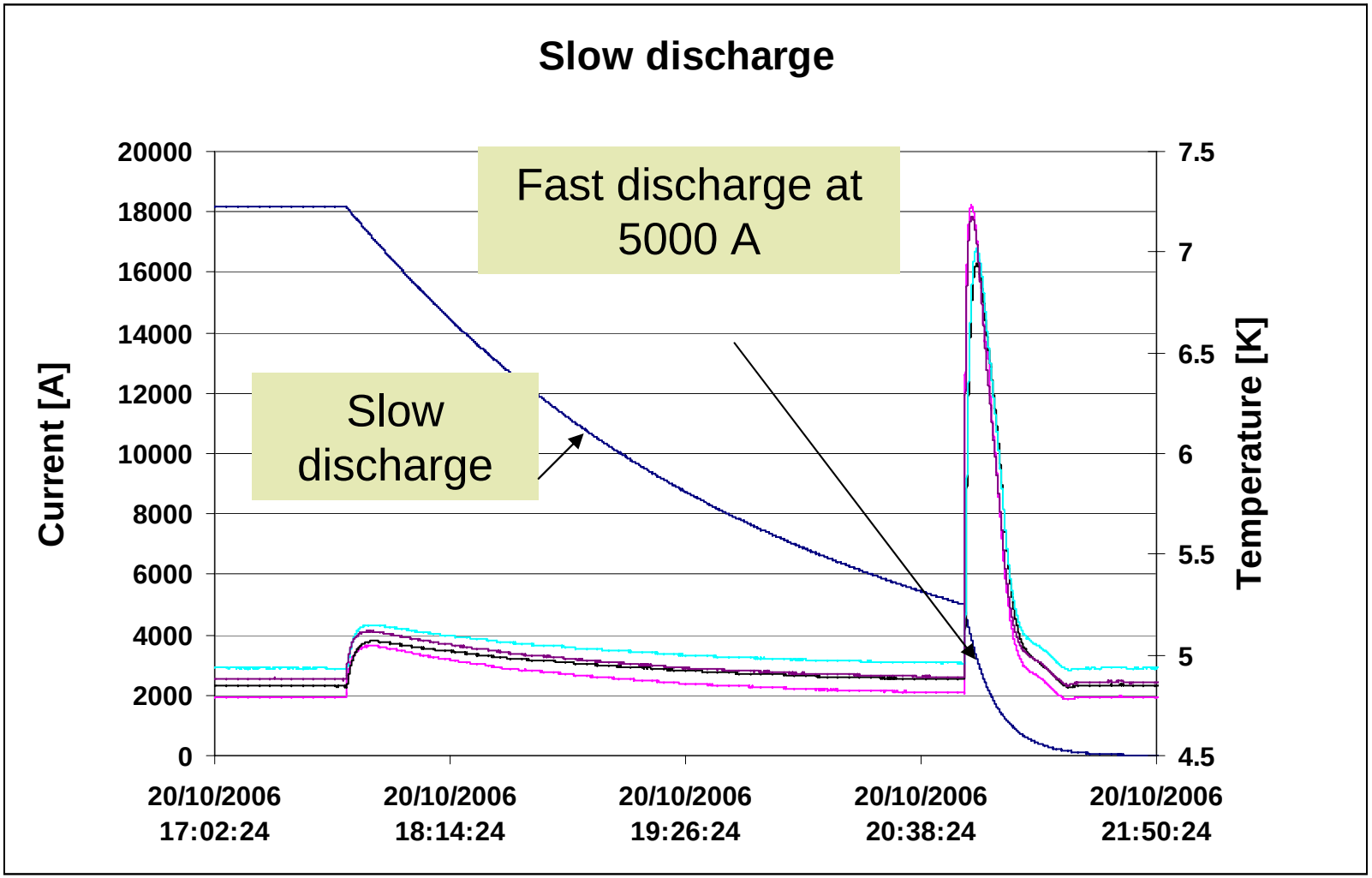




DYNAMIC HEAT LOAD

➢ CMS

Temperature increase ~ 0.28 K



FAST CURRENT DISCHARGE

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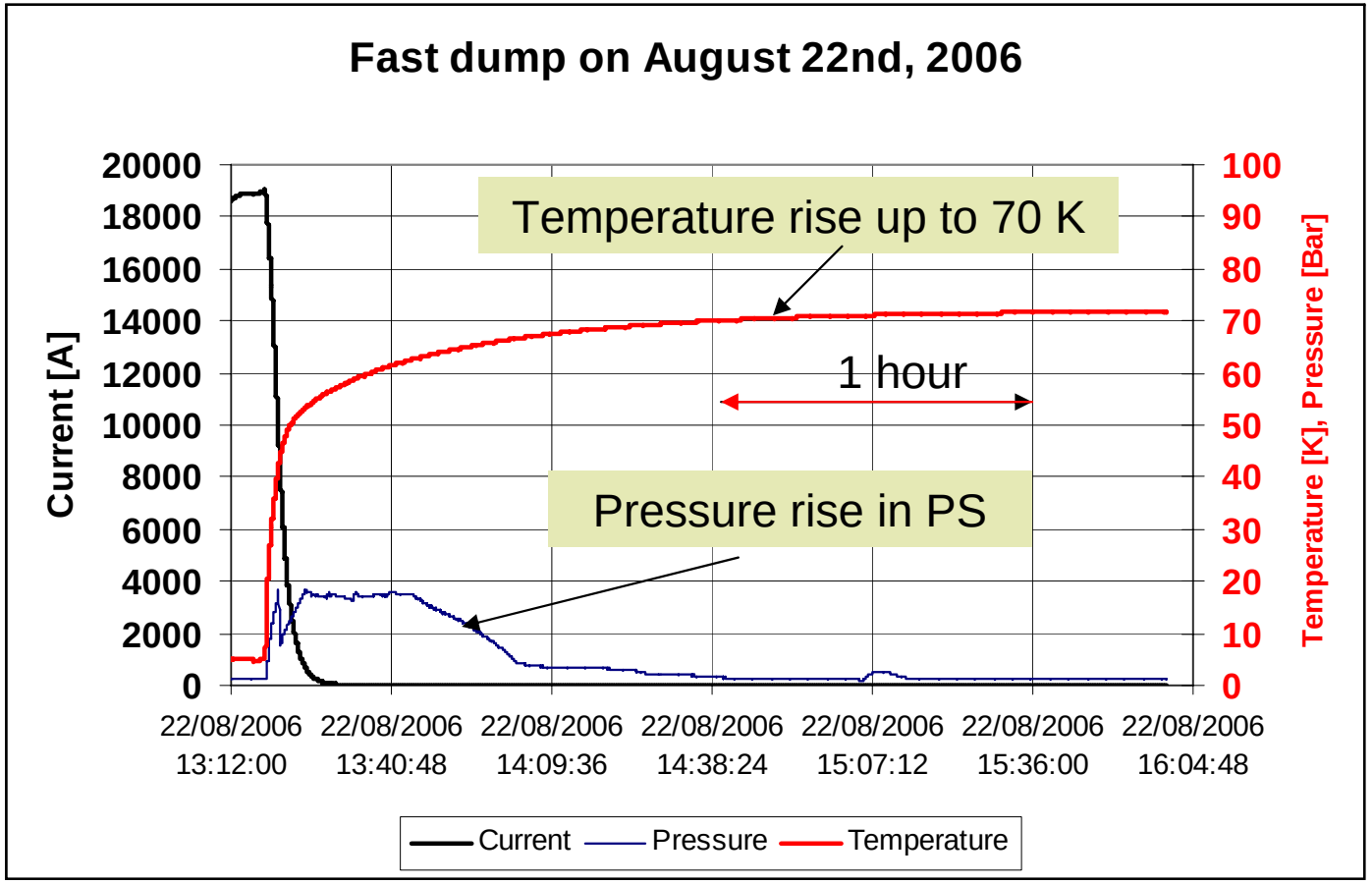
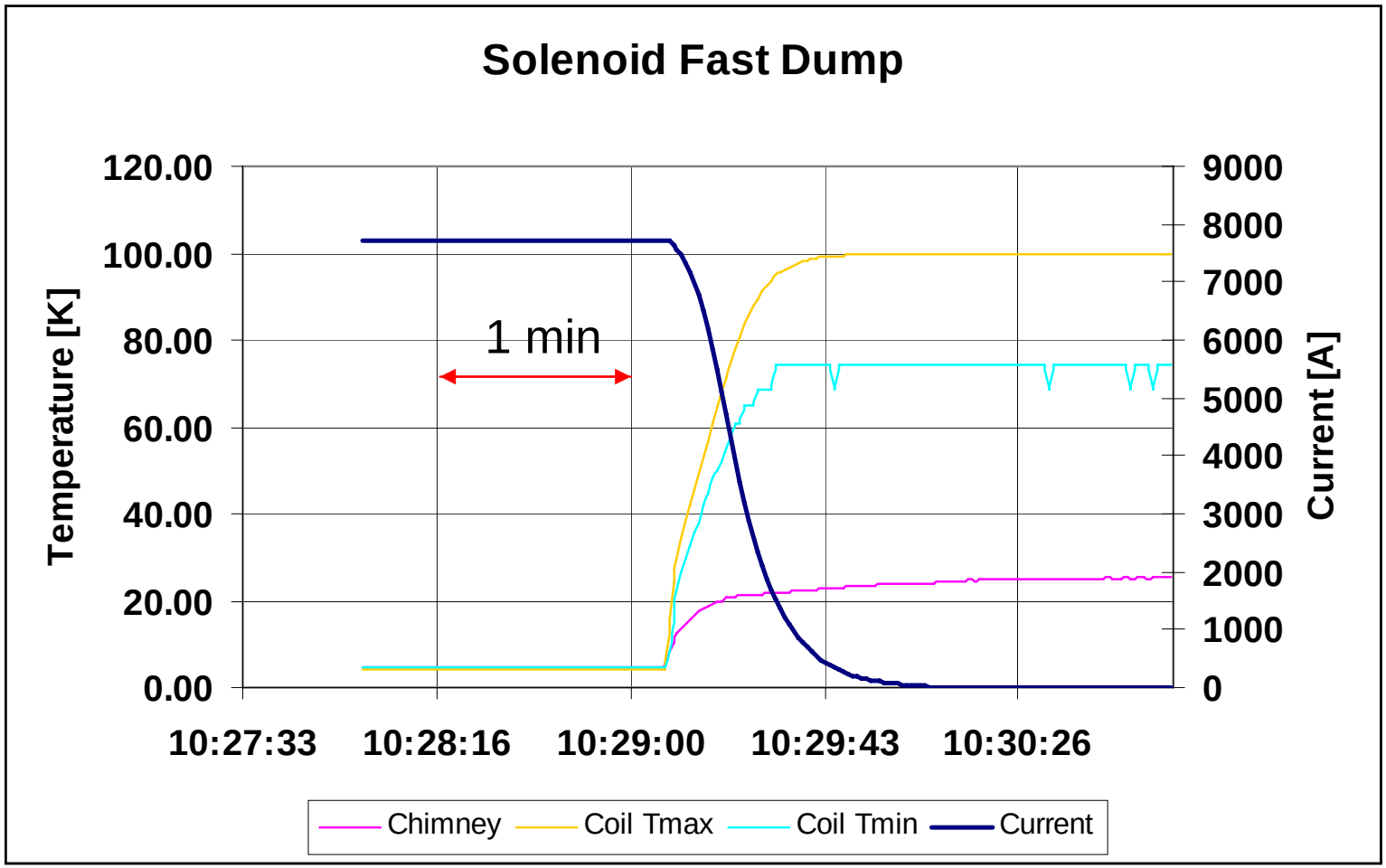
- CMS: stored EM energy is 2.5 GJ (about 220 Tons)



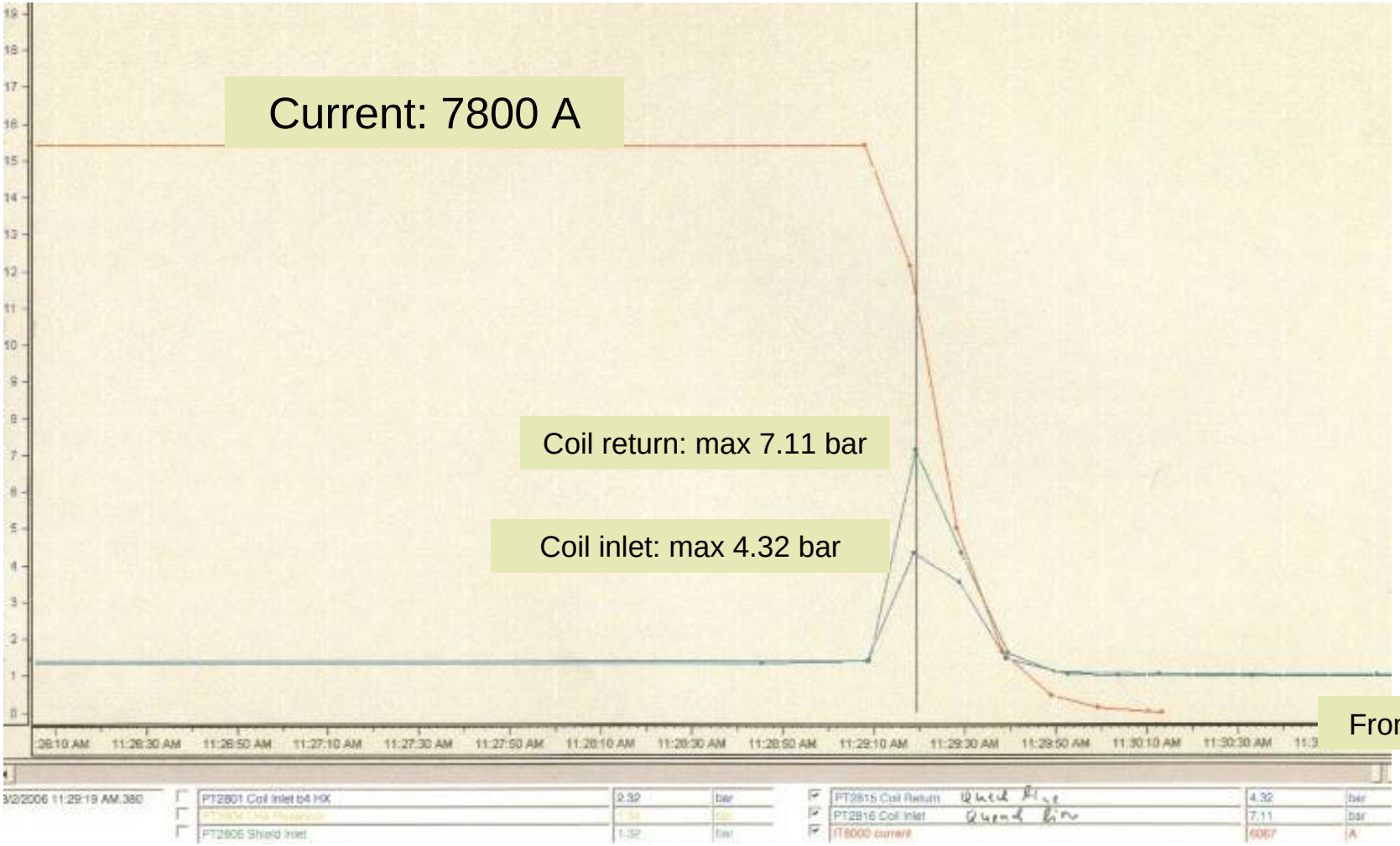
FAST CURRENT DISCHARGE

- ATLAS-CS: Stored EM energy is 40 MJ

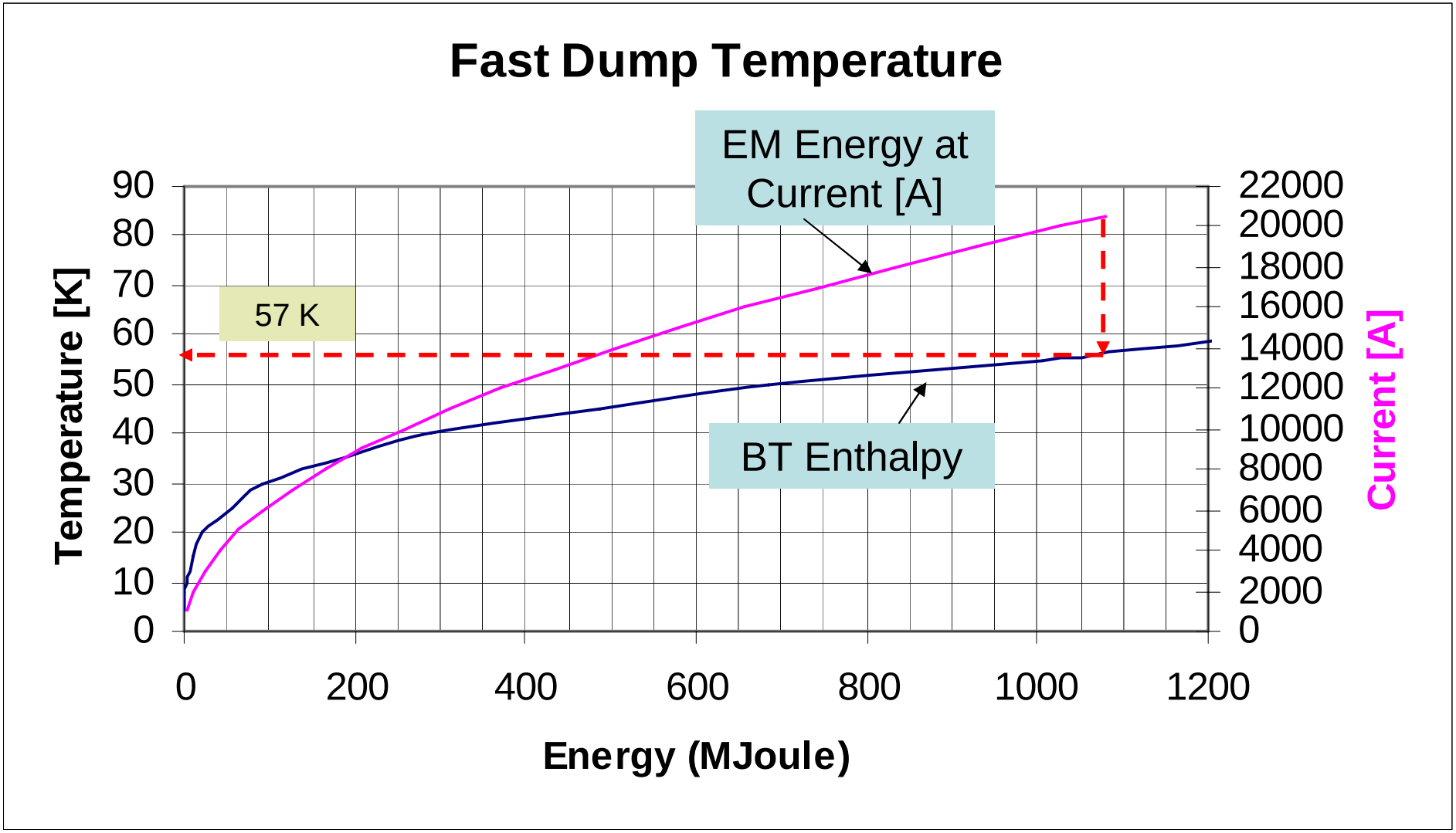


FAST CURRENT DISCHARGE

➢ ATLAS-CS: pressure rise

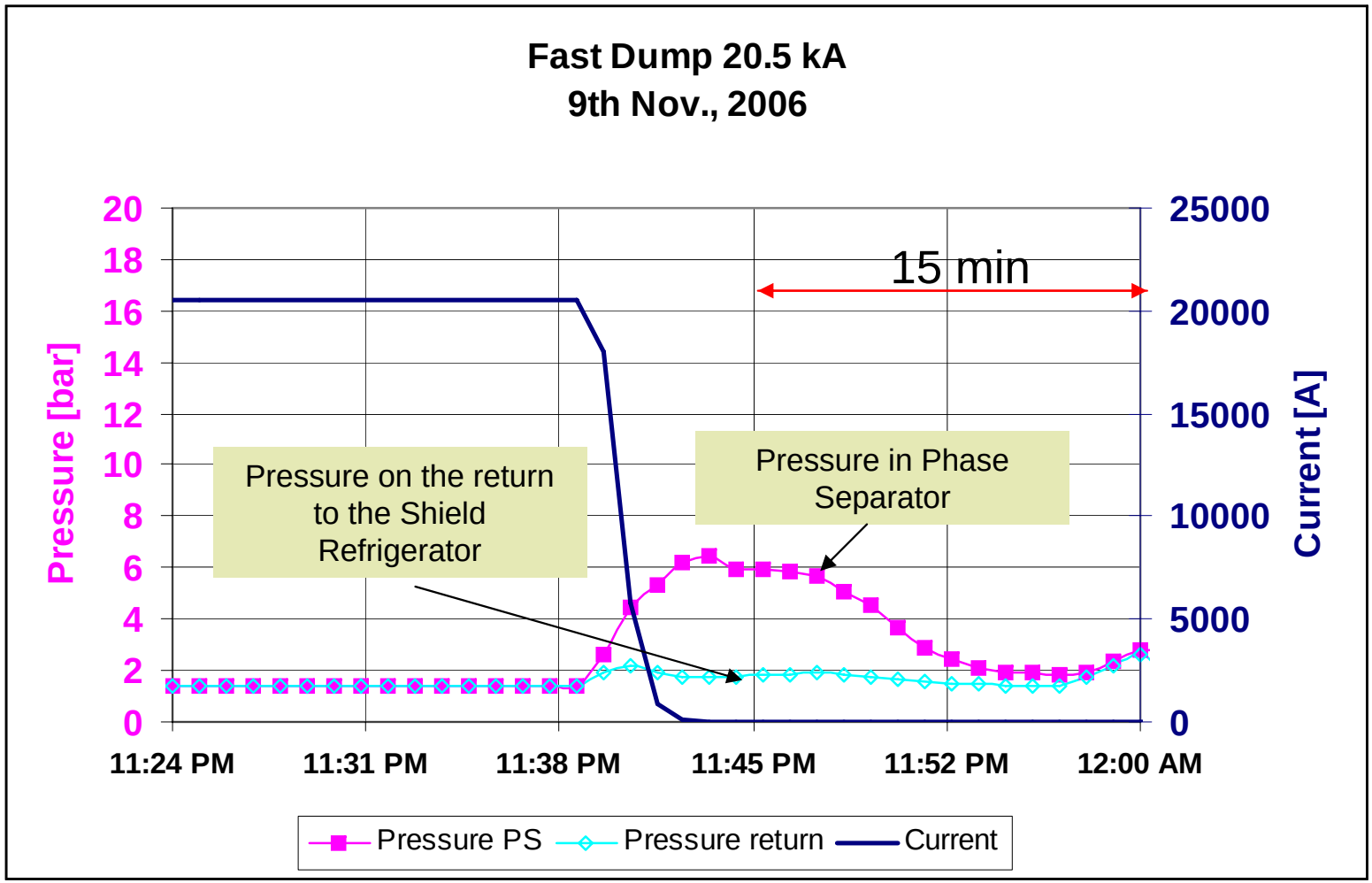


➢ ATLAS-BT: Stored EM vs. Enthalpy



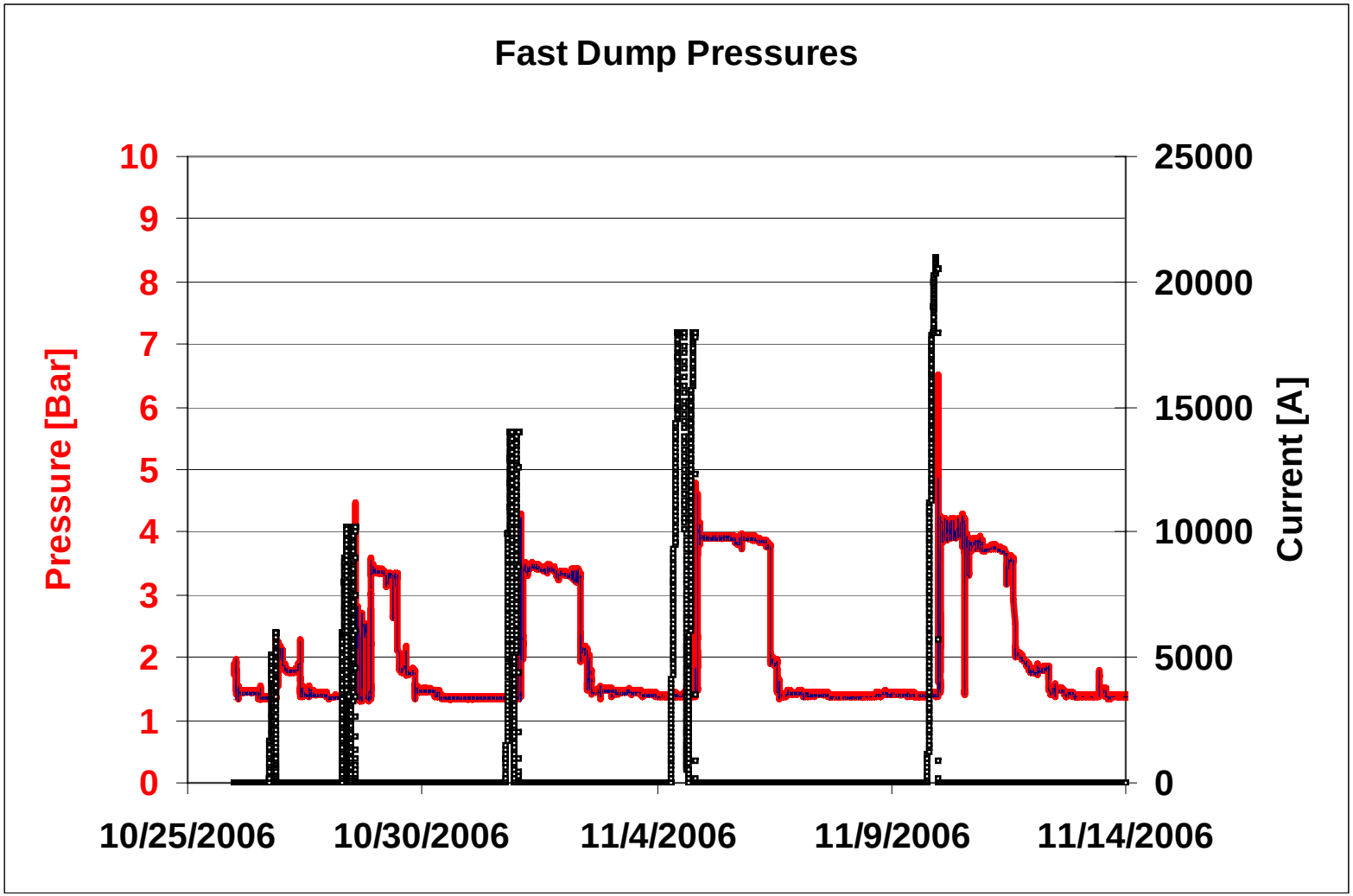
FAST CURRENT DISCHARGE

- ATLAS-BT:



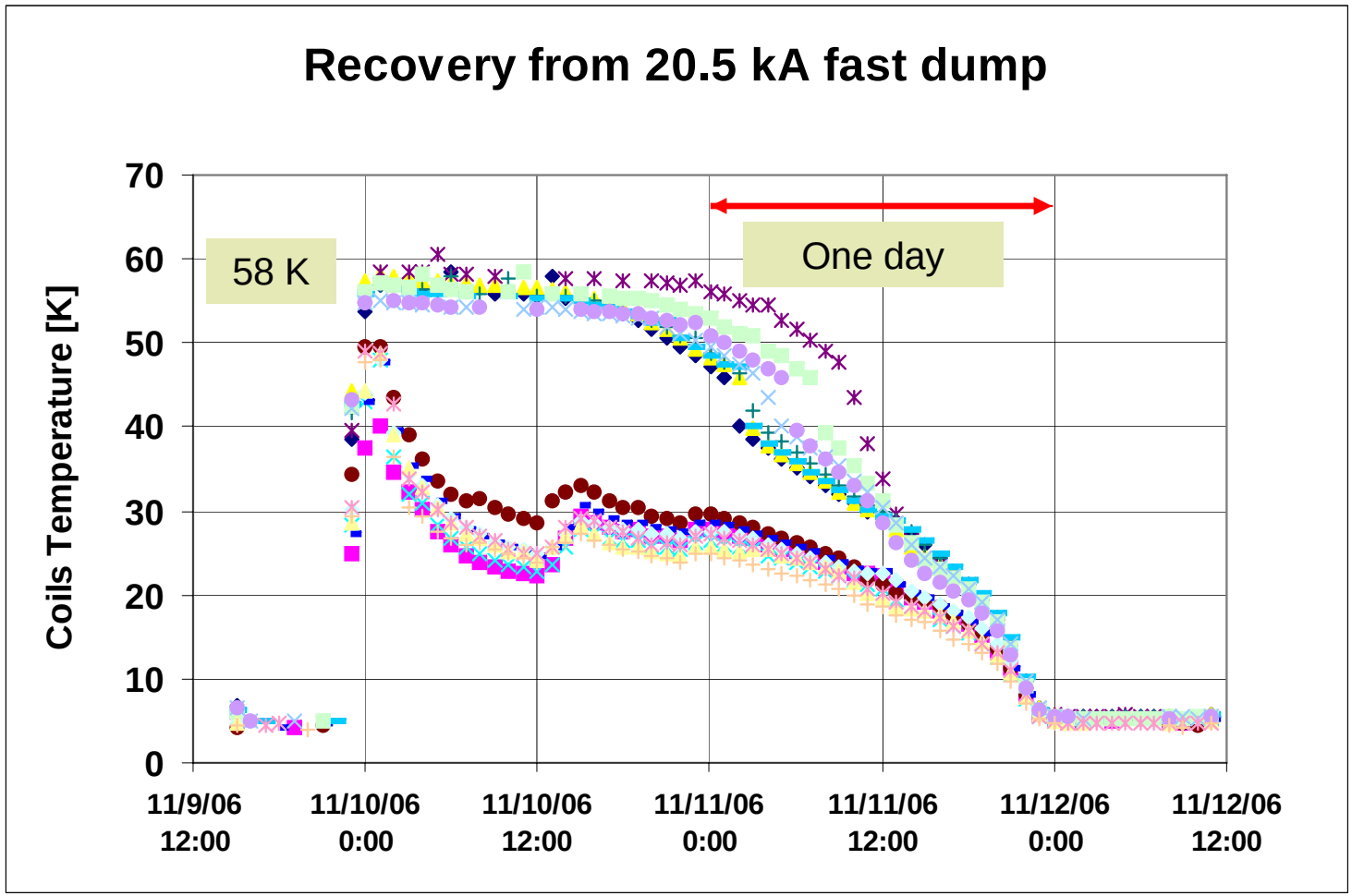
FAST CURRENT DISCHARGE

- ATLAS-BT:



FAST CURRENT DISCHARGE

- BT: Recovery after a full current fast dump



Summary

Data on transient modes of operation have been displayed and discussed, namely:

- *cooling down process*
- *static heat load*
- *dynamic heat load*
- *fast discharge of the magnets*
- *recovery after a fast dump.*

The results are in good agreement with the design

I would like to thank for their collaboration all colleagues from CERN and from the external

Institutes involved (CEA-SACLAY,INFN,KEK,RAL)