LHC "Post Mortem" Workshop: Introduction

Initiative by Robin Lauckner, Adriaan Rijllart and myself, helped by many other colleagues

This is the first workshop on the **recording and analysis of data after an event** in the LHC, such as a **magnet quench or a beam dump - Post Mortem**. Data will come from transient recorders, from the logging systems, from alarms and probably other sources

The main aims of the workshop are:

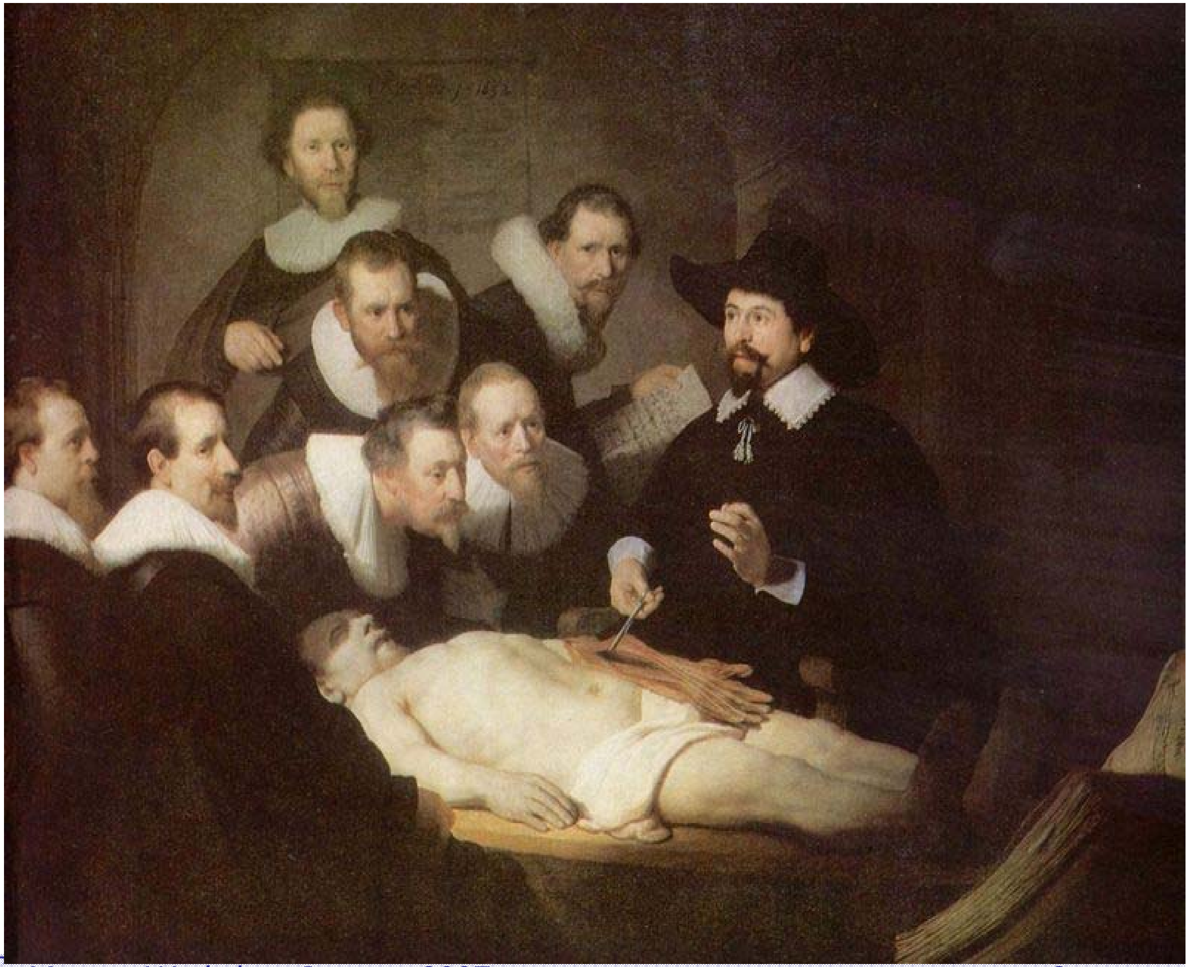
- to verify readiness of hardware and software systems for imminent powering of the cold circuits
- to develop the roadmap for beam operation in 2007 and beyond

Many groups have started to prepare their systems for the different phases of commissioning and operation. The workshop will review their activities, identify open issues and help to define the future roles and responsibilities

Post Mortem – not exactly a new concept

Autopsy or **Post-mortem examination**: medical **procedure that consists of a thorough examination** of a human corpse **to determine the cause and manner of** a person's **death** and to **evaluate any disease or injury that may be present**. It is usually **performed by a specialized** medical **doctor** called a pathologist.

1) Diseases or injuries present?
2) Why did he die?



The Anatomy Lesson of Dr. Nicolaes Tulp, by Rembrandt, depicts an autopsy, 17th century

other accelerators: HERA at DESY

THE USAGE OF TRANSIENT RECORDERS IN THE DAILY HERA MACHINE OPERATION

R. Bacher, M. Clausen, P. Duval and L. Steffen, DESY, Hamburg, Germany

PAC 1997, HERA operating in the 7th year

Many parameters of HERA machine components such as RF systems or quench protection as well as important beam parameters are continuously measured using transient recorders. **In general, these recorders are not synchronized among one another and sample the data with very different rates ranging from 200 Hz to 50 MHz**. At present, **work is going on to integrate the different existing transient recorders into a global system**. The article reviews the transient recorder hardware in operation at HERA. In addition, the proposed trigger distribution based on the HERA Integrated Timing system as well as the software concept to archive, retrieve and display the data will be described.

not exactly a new concept…also not for LHC

Conclusion

- Equipment safety (equipment interlock and controls) not yet defined
  - Beam and power permit link to be considered
  - Beam abort link to be considered - must be very reliable
  - Power abort links to be considered - must be very reliable
  - BNL (RHIC) has beam abort and power abort link - some 100 modules
- Transient recorders should be available
  - for signals required to understand beam dumps and power aborts (beam monitors, radiation monitors, magnet protection, power converter, ...)
  - data coherence for different systems
  - synchronisation of measurements from transient recorders at the level of milliseconds - acquisition frequency depend on system
- For safety relevant systems - watch out for consequences of mains failure

simple and robust

SCADA day - RS 22/1/99

- What data is needed to understand failures during LHC operation? R.Lauckner (Chamonix 10, 2001)
- The LHC Post-Mortem System, E.Ciapala, F.Rodriguez Mateos, R. Schmidt, J. Wenninger (LHC Project Note 303, October 2002)
- What do we see in the control room? R.Lauckner (Chamonix 12, 2003)
- Machine Interlock Systems (LHC Design Report, 2004)

Post Mortem – why such fuzz about it

…did not have it at LEP…
…HERA only after many years …

- Energy stored in magnets and beams orders of magnitude higher
  - Highly complex Machine Protection Systems required
- LHC has superconducting magnets, at 1.9 K, little margin at 7 TeV
- Complexity of LHC versus LEP
- Criticality of operation: collimators close to beam, no damping, tiny beam losses (10^{-8}) could quench a magnet

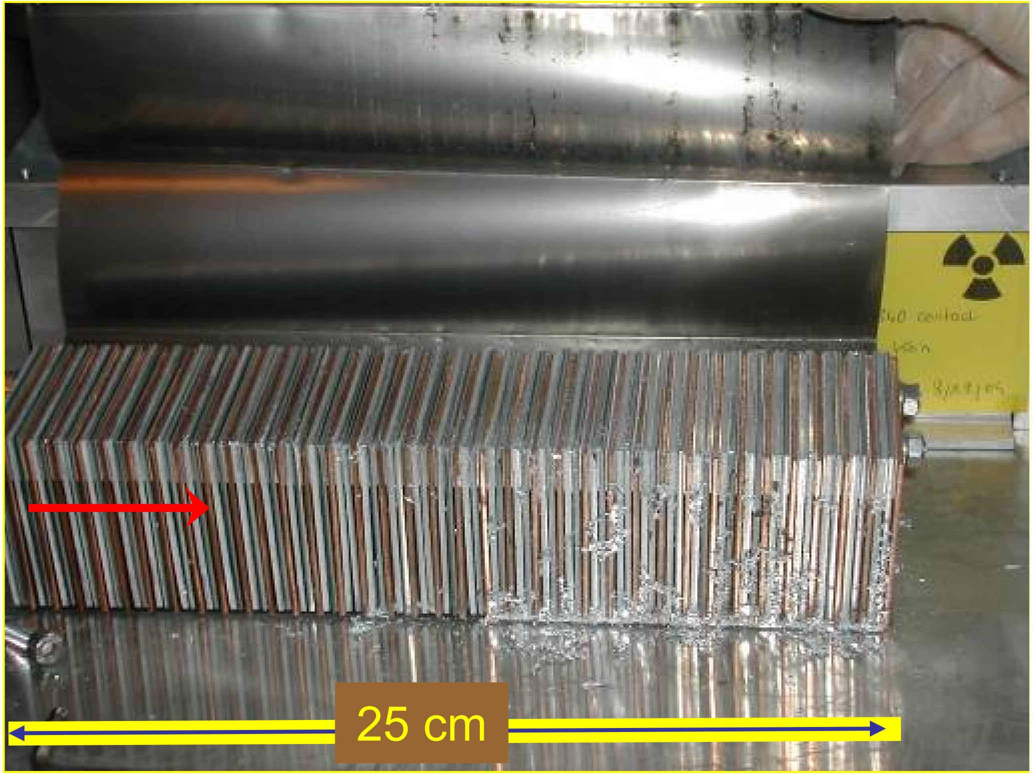
Protection

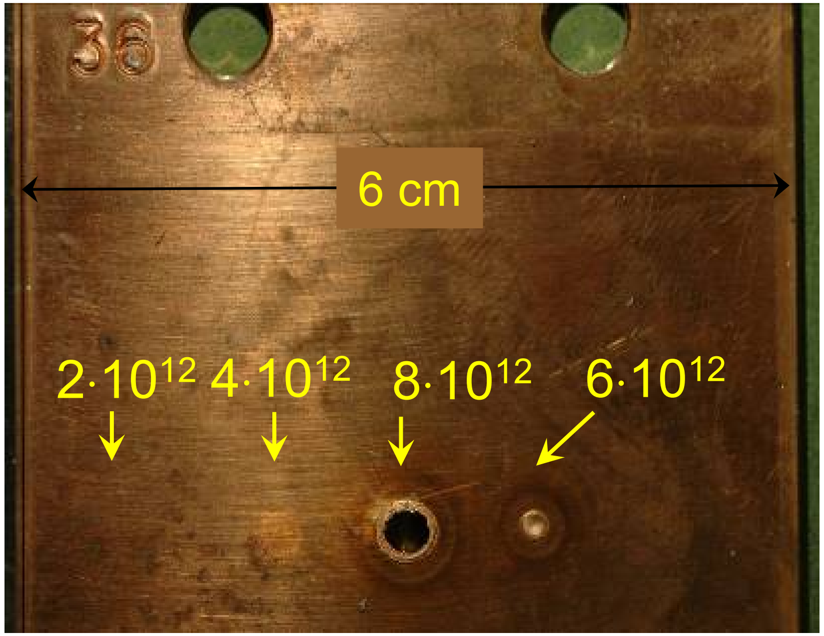
Beam damage experiment at 450 GeV at SPS

Controlled SPS experiment

- $8 \cdot 10^{12}$ protons
- beam size σx/y = 1.1mm/0.6mm
- **above damage limit**

- $2 \cdot 10^{12}$ protons
- **below damage limit**





0.1 % of the full LHC beam

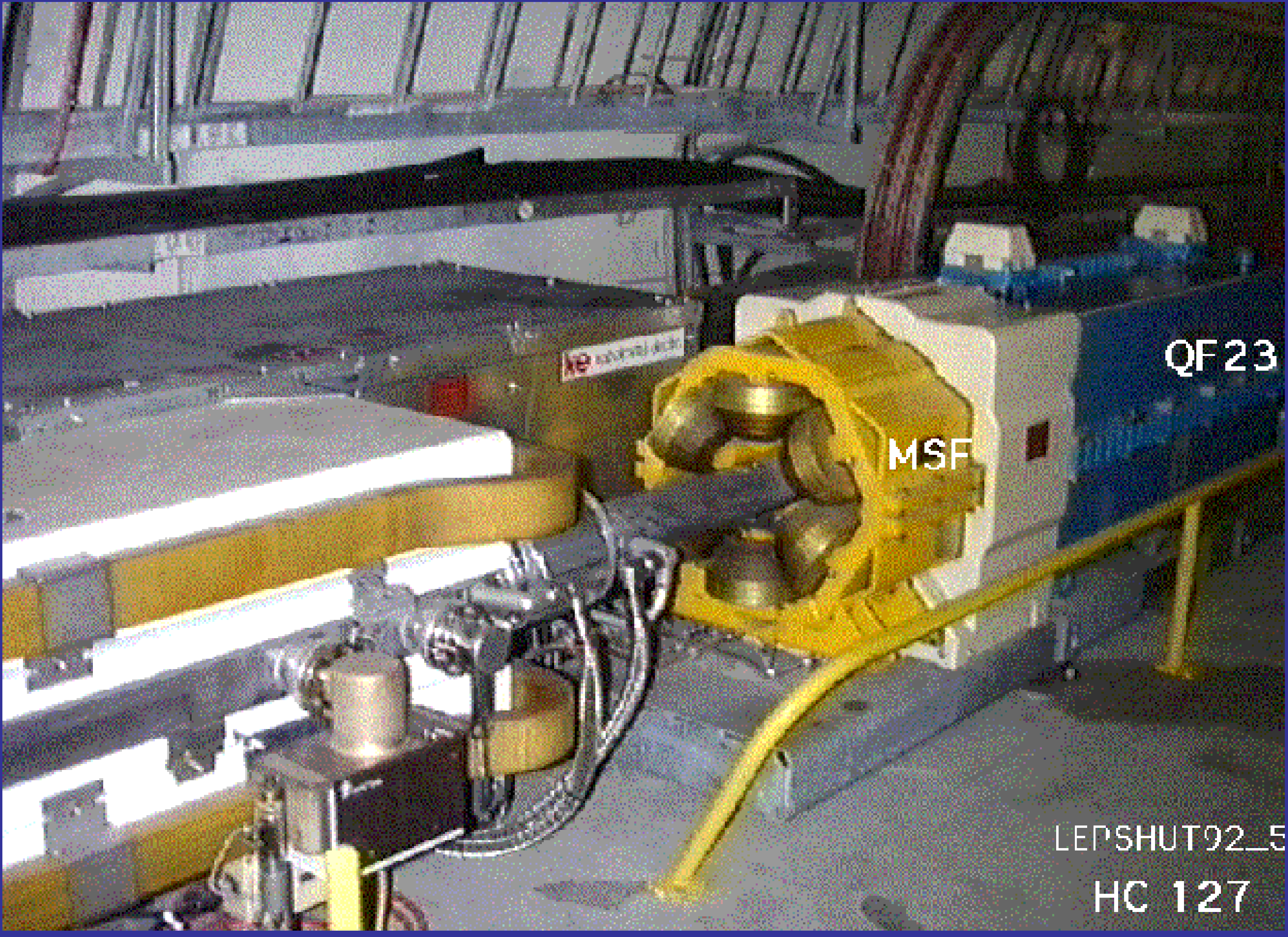
V.Kain

Damaged LHC dipole magnet coil

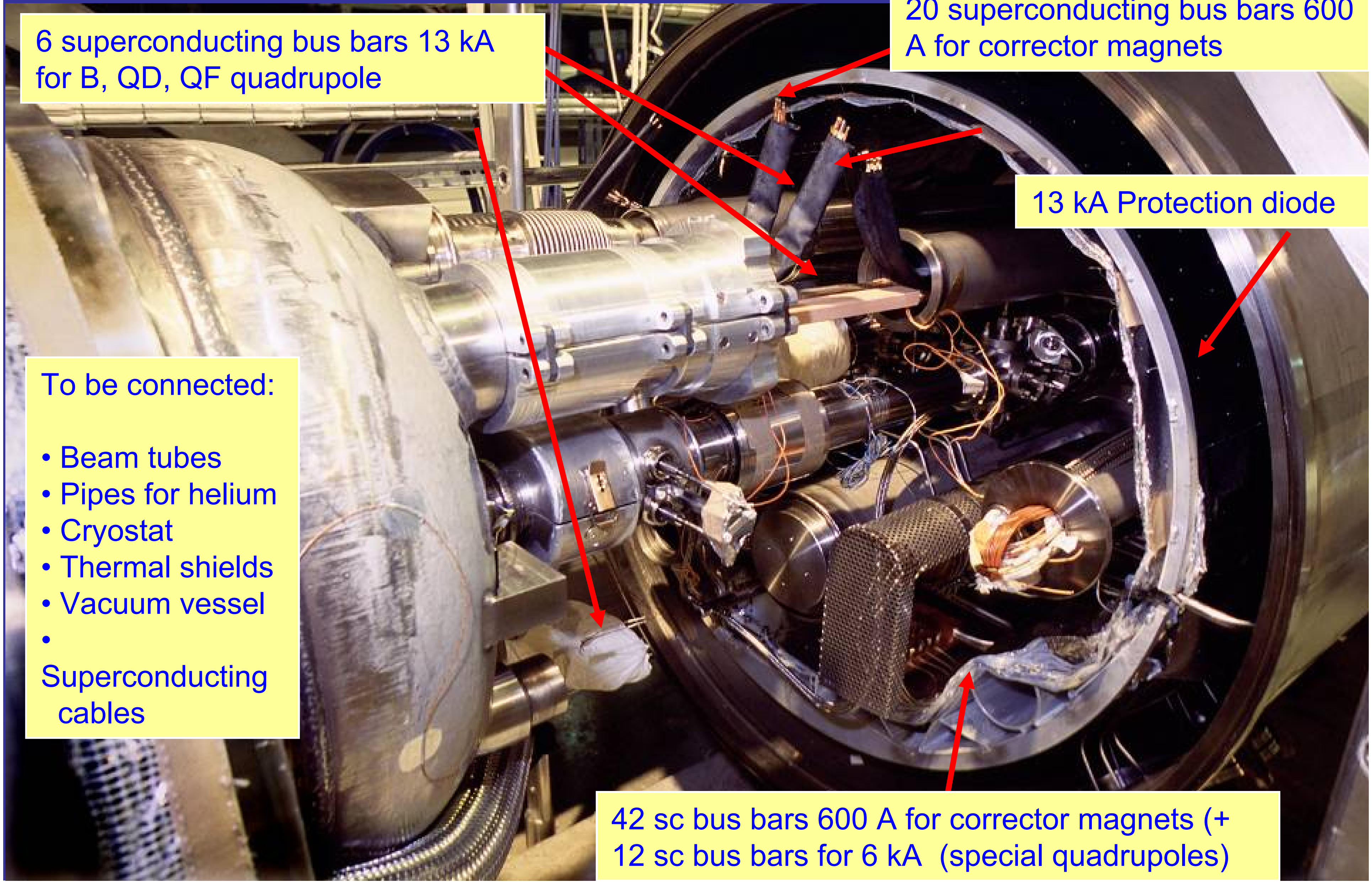
P.Pugnat

Complexity

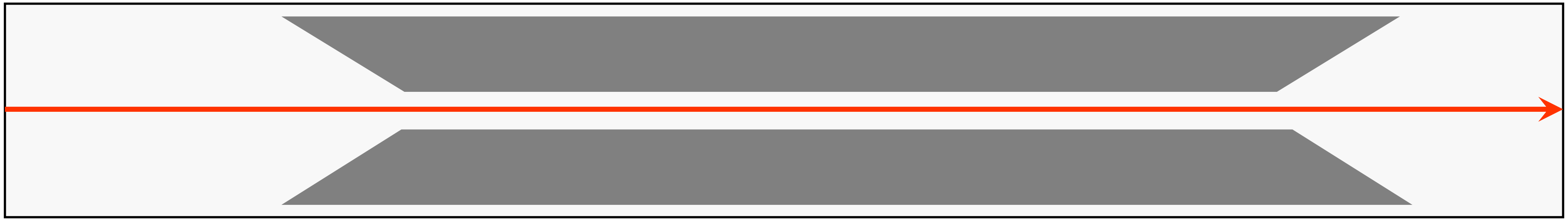
Interconnection between magnets: LEP

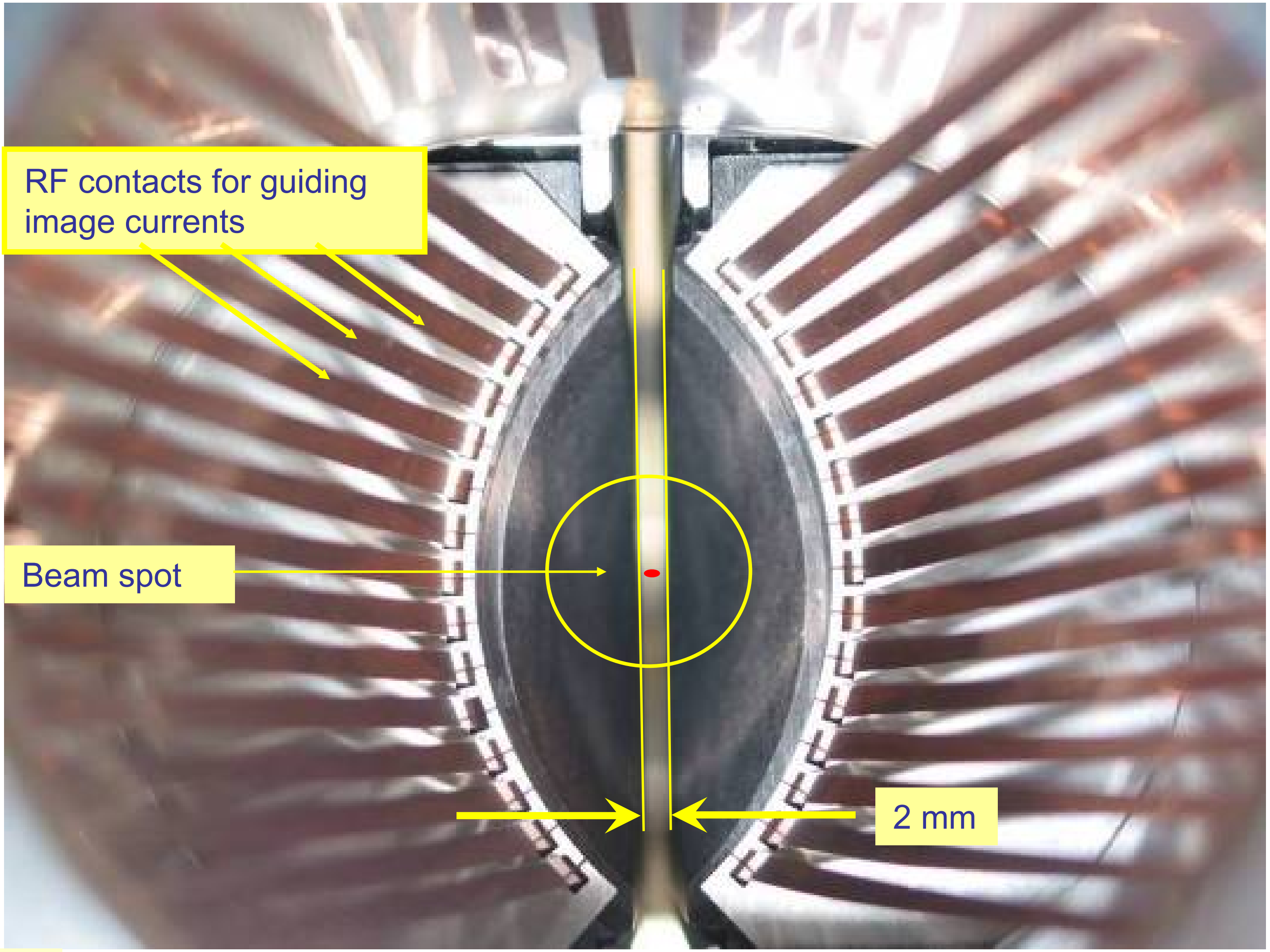


One of 1800 interconnection between two superconducting magnets: LHC



Criticality of operation





R.Assmann et al

LHC collimator setting at 7 TeV

Machine protection and Post Mortem

- Powering operation: safe discharge of magnet energy in case of a failure
- Beam operation: safe discharge of beam energy in case of a failure

If machine protection fails, major damage to LHC equipment expected

- We will not power the magnets after a quench without understanding if Quench Protection System and Interlock Systems worked correctly
- We will not inject after a beam dump without understanding if the last beam dump worked correctly

Understanding of the correct functioning of the protection systems is a MUST and not a luxury

Machine Protection Systems …. and their redundancy

Typical question

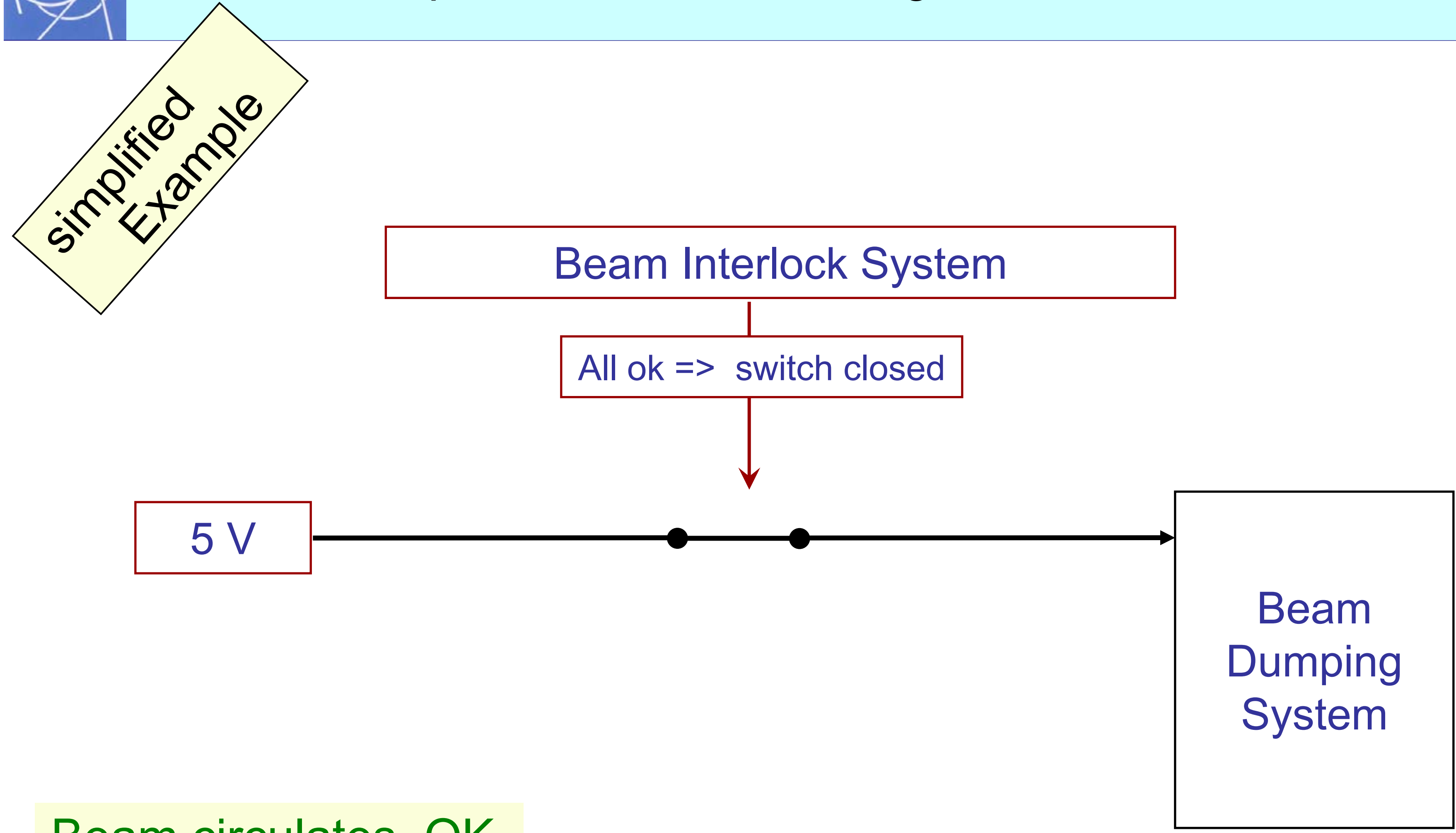
Questions that will arise daily

- Did the protection systems work correctly?
  - after a powering failure (e.g. quench) leading to emergency energy extraction
  - for scheduled beam dumps
  - for emergency beam dumps
  - redundancy still operational? …see following slides…
- Why did a magnet quench?
- Why did we lose the beam?

Question that hopefully we will not have to ask…

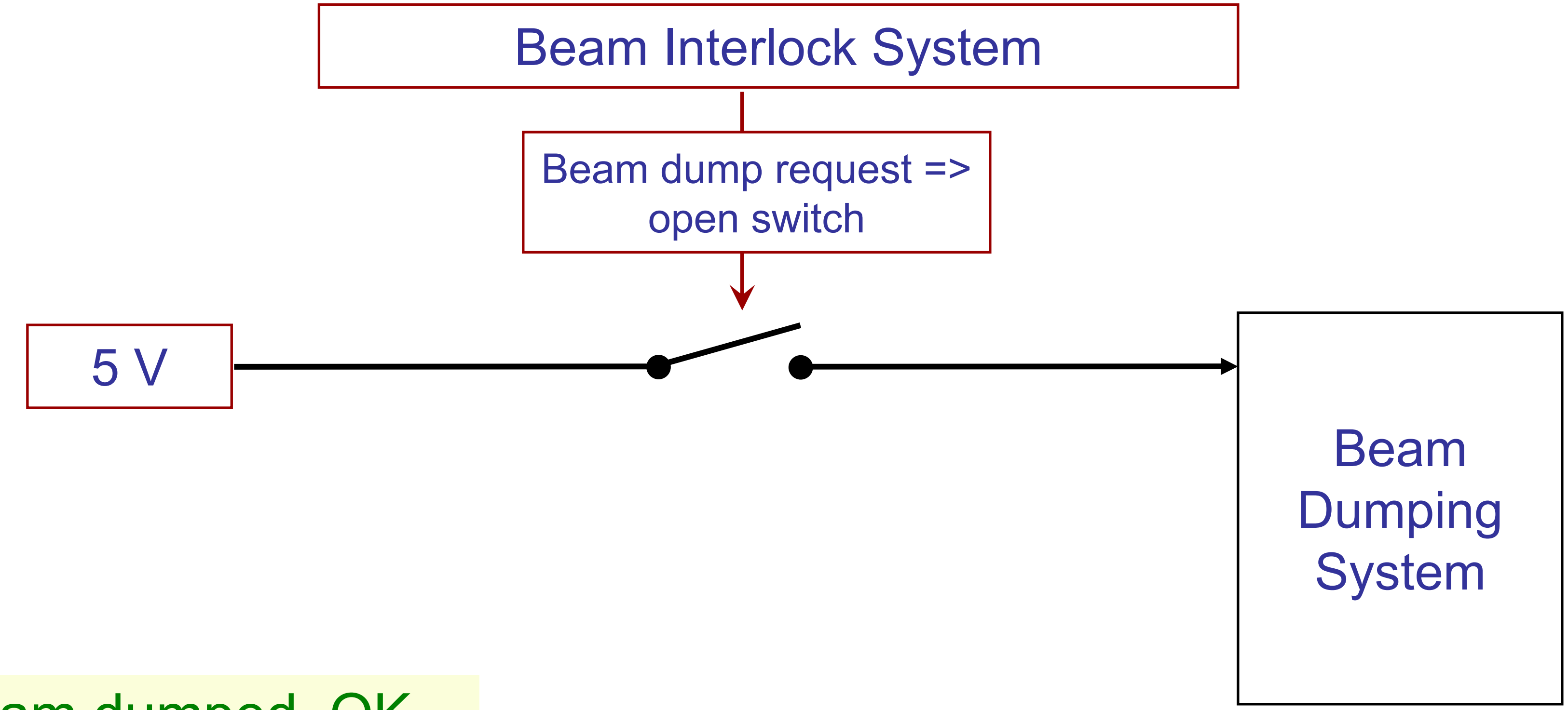
- Why did we damage equipment?

Step 1: Beam is circulating, LBDS receives 5 V



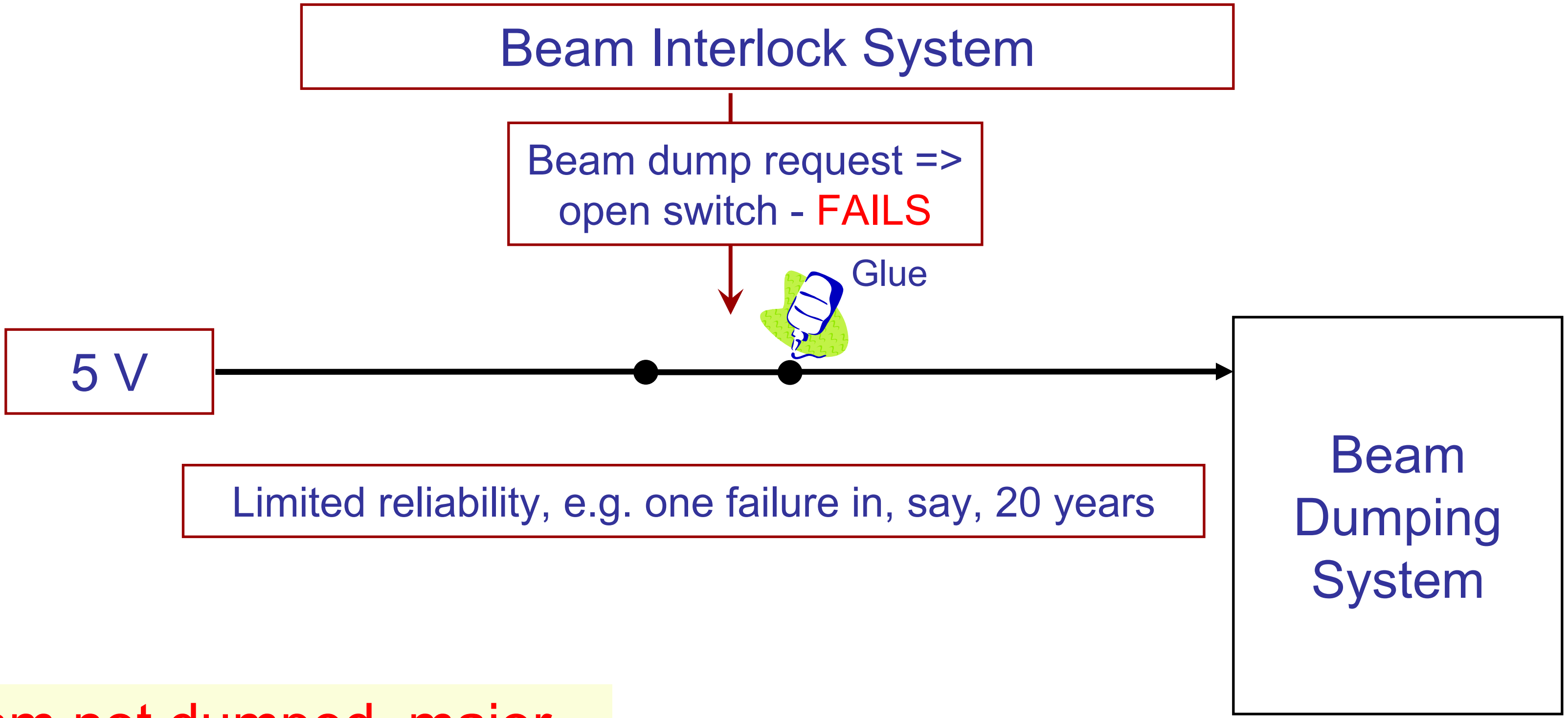
Beam circulates, OK

Step 2: Beam Dump Request, 5 V stops



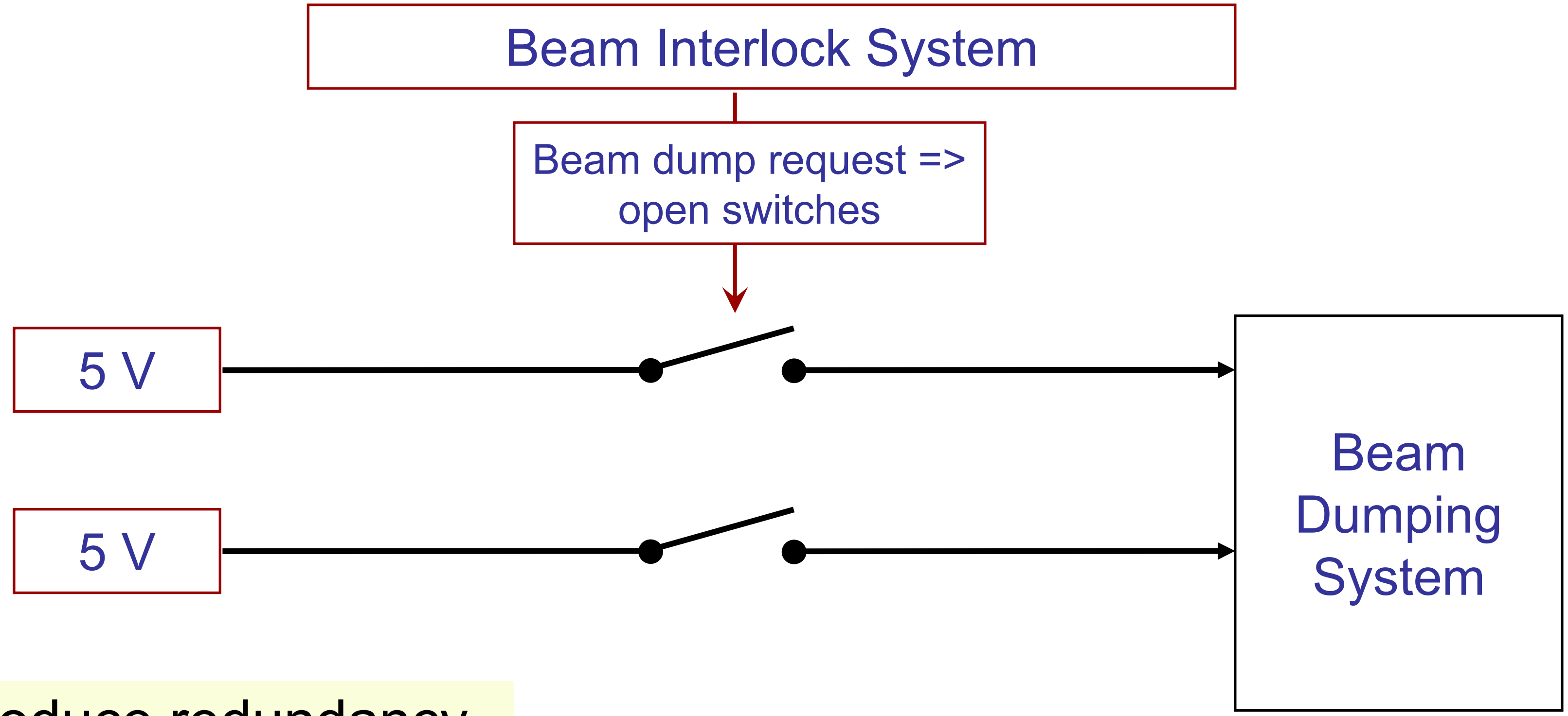
Beam dumped, OK

Step 3: Beam Dump Request, failure of switch



Beam not dumped, major damage of LHC, not acceptable

Step 4: Beam Dump Request, introduce redundancy



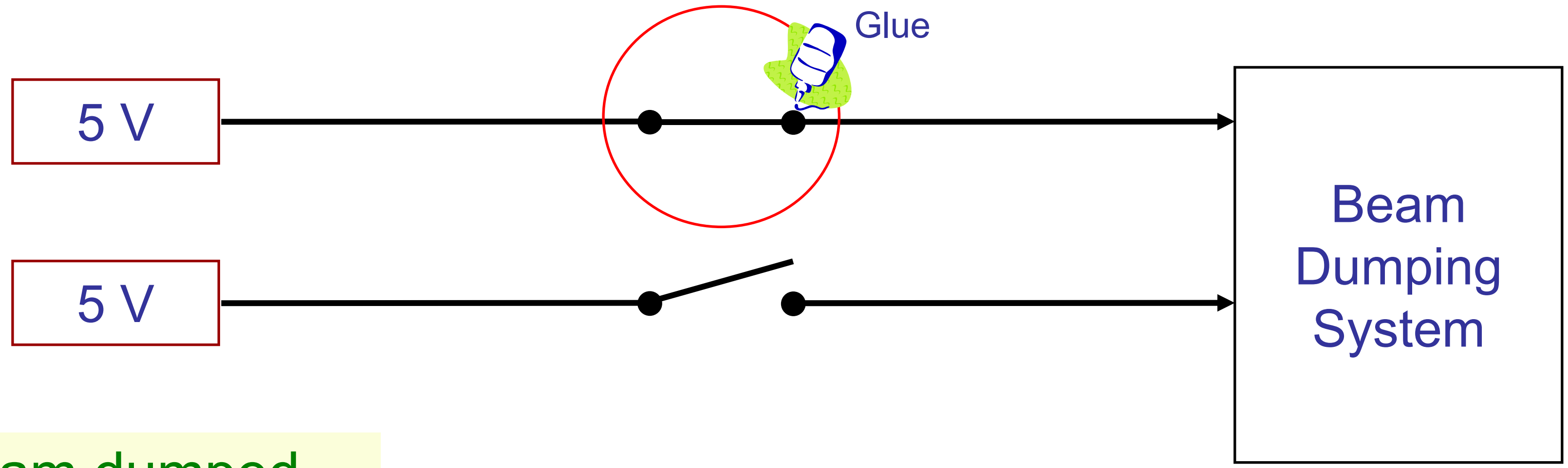
Introduce redundancy

Beam dumped, OK

Step 5: Beam Dump Request, failure of one switch

Beam Interlock System

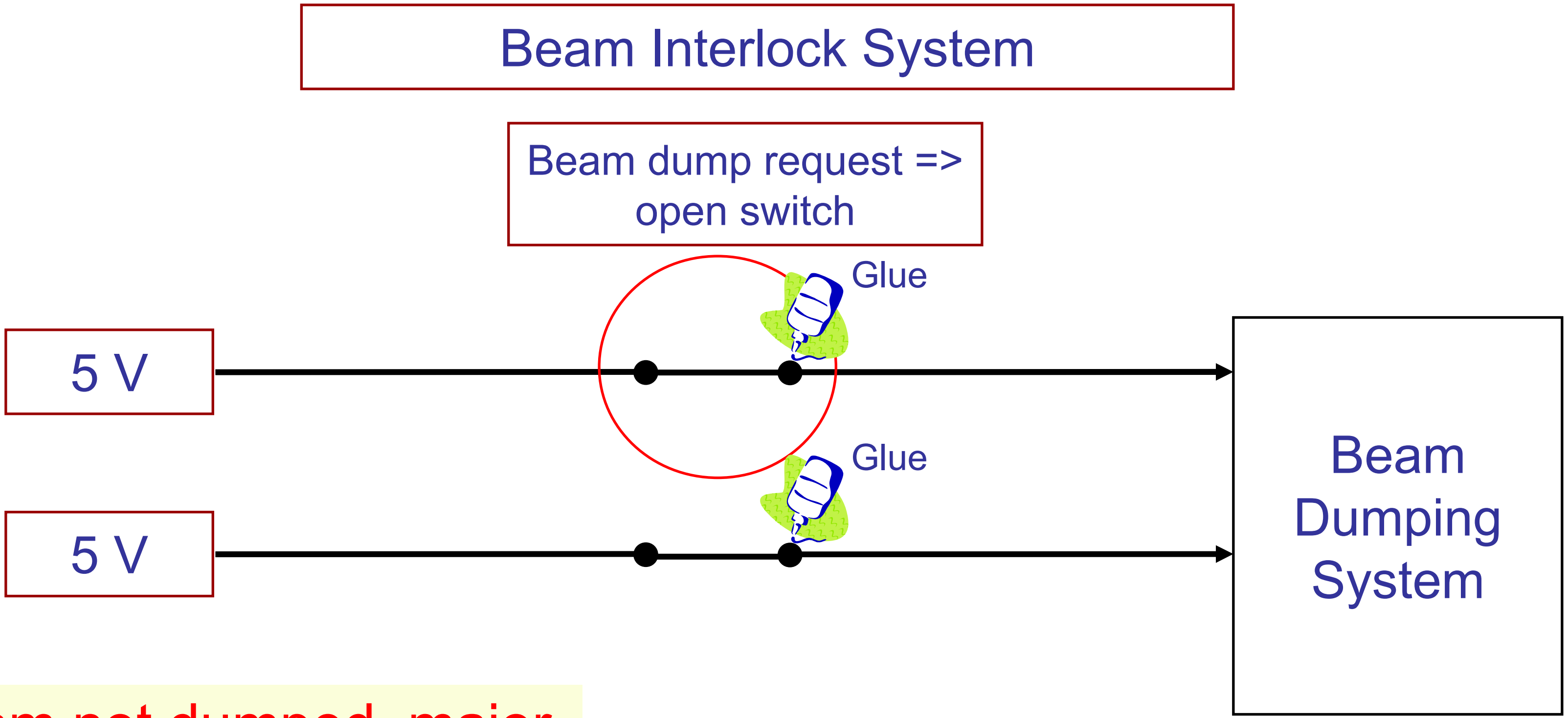
Beam dump request => open switch fails on one switch



Beam dumped, still OK

This is likely to happen in a period of, say, 20 years

Step 6: Beam Dump Request, failure of second switch



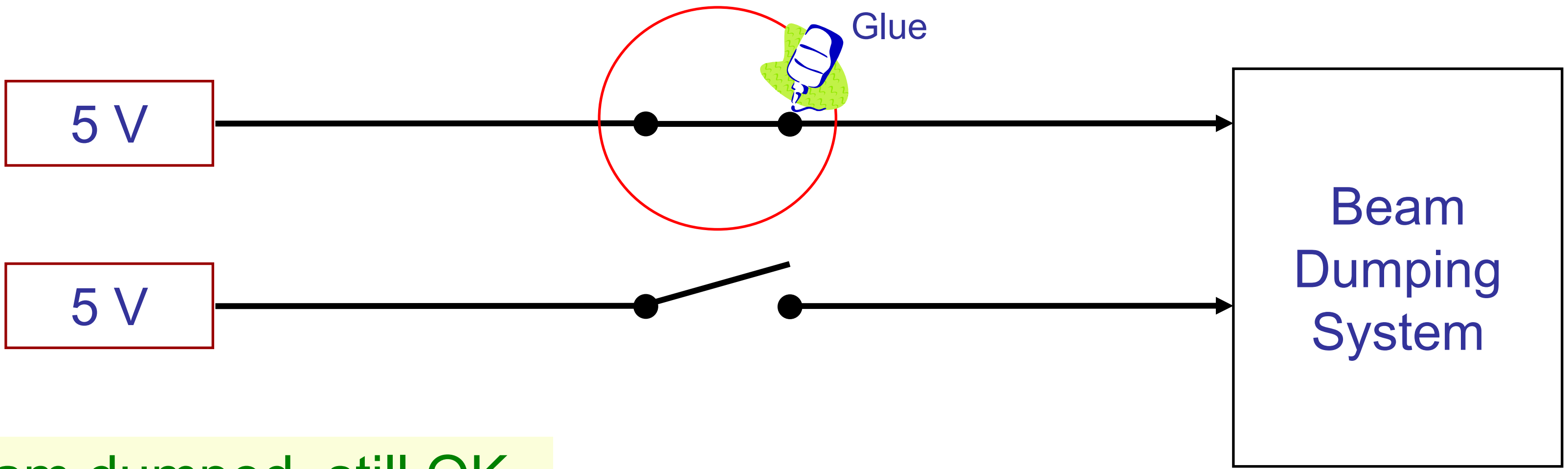
Beam not dumped, major damage of LHC

This is still possible to happen in a period 20 years

Step 5+: Beam Dump Request, failure of one switch with redundancy monitoring

Beam Interlock System

Beam dump request => open switch fails on one switch



Beam dumped, still OK

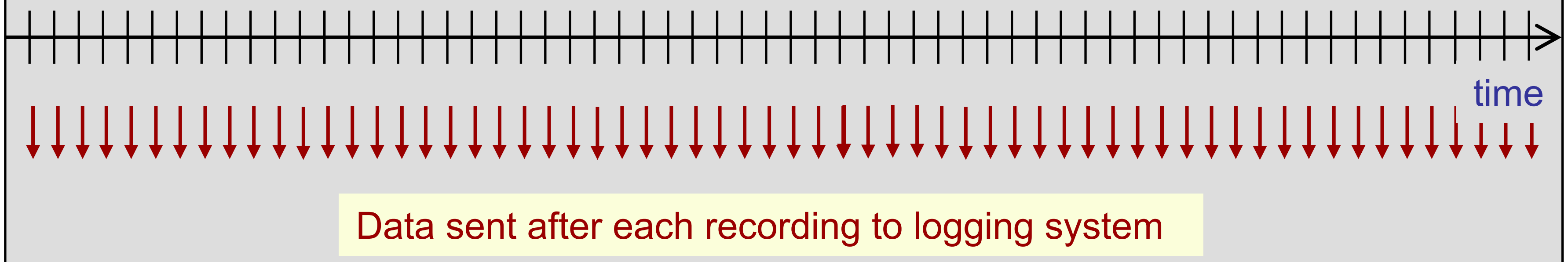
System in UNSAFE state, needs repair

Detect that switch did not open

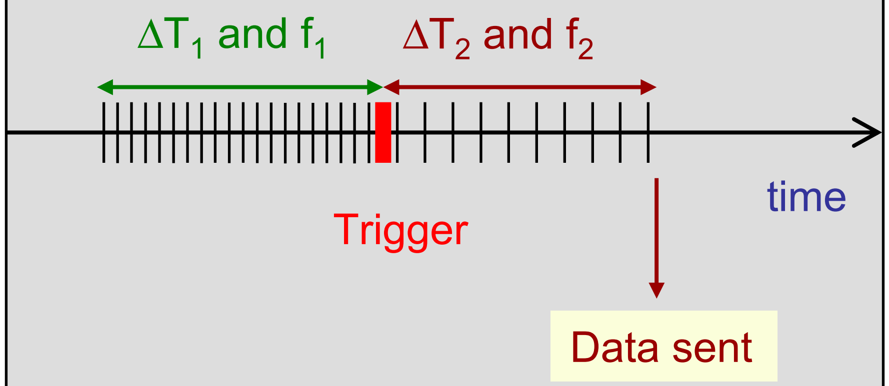
What data ?

Logging, transient recording, alarms

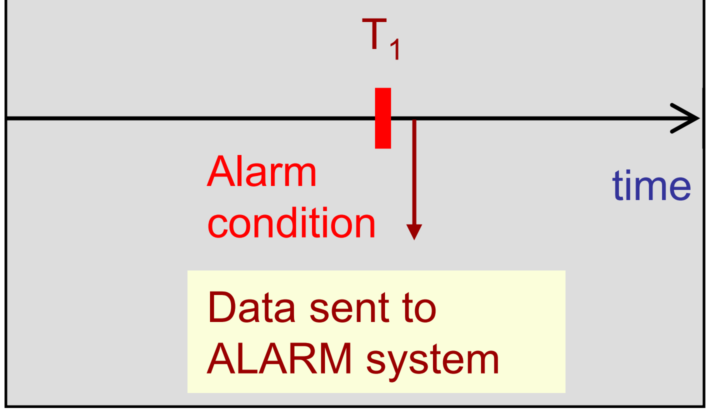
Logging: data recorded continuously at regular intervals, e.g. 0.1 Hz



Transient data: data recorded around a trigger (internal or external)

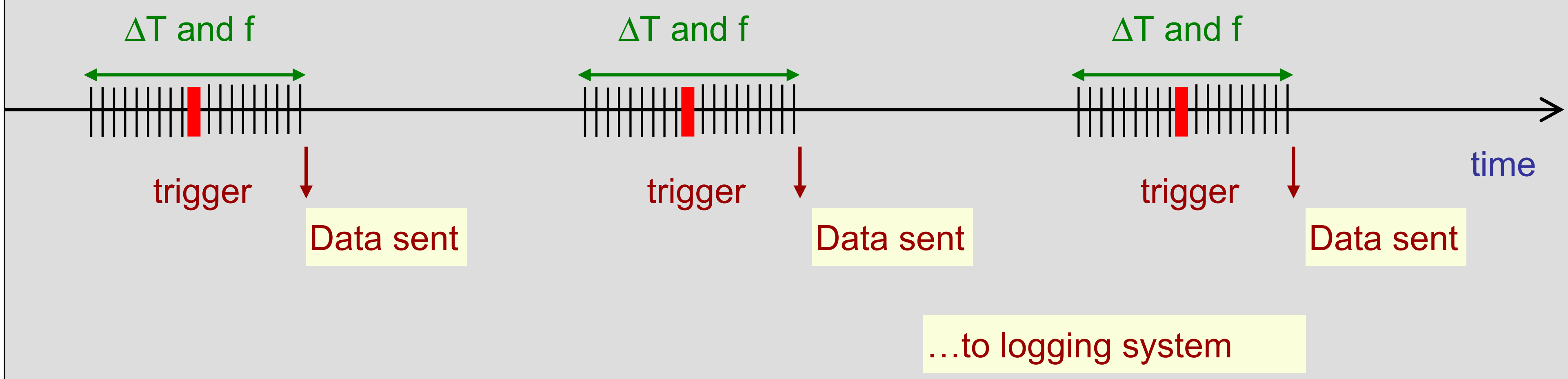


Alarm: data recorded after an exceptional condition is detected by the system



Shot-by-Shot Logging

Shot-by-Shot Logging: transient data recorded at regular intervals, for each extraction from the SPS



"Post Mortem" ?

Use of data from a large variety of systems to understand LHC operation

- Recording and analysis of the data
- Clocks across systems must be synchronised with appropriate resolution (1ns…..1s)

The system should not be limited to analysis data after a powering failure, a magnet quench or a beam dump

- during transfer and injection: did the beam get in correctly?
- for specific moments during operation (e.g. start of the energy ramp)
- on request, for beam measurements

Not only after the "death" of beam / equipment

Ingredients

Define data recording

- what systems to be considered ?
- what data ?
- transient recording Yes or No ?
- if transient recording, what trigger ?
- what frequency of recording ?
- what length of the (transient) recording ?

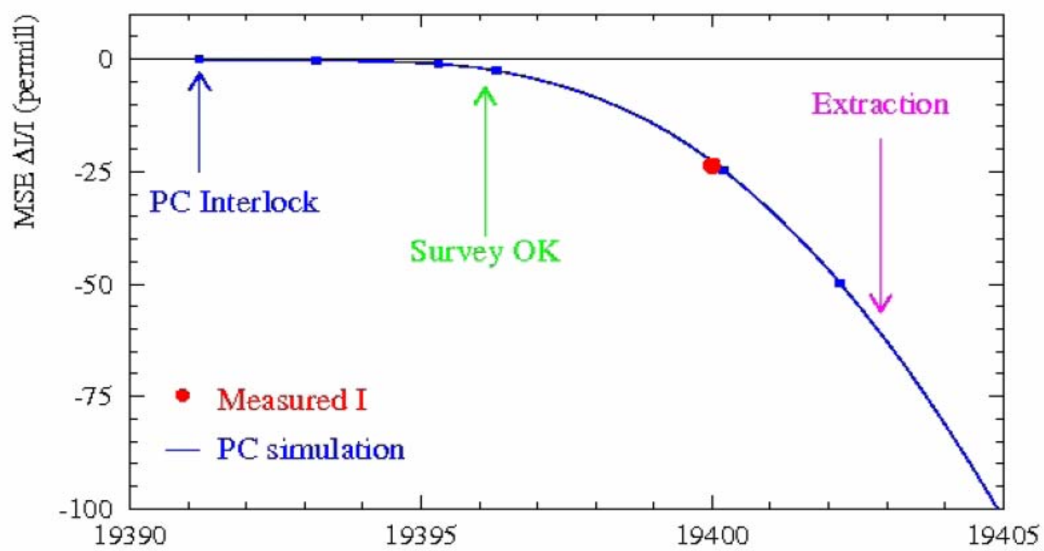
- Collecting data from various systems
  - how to get data ?
  - how do we put them together ?
  - how to store data ?
- Using the data
  - what do we want to know? (e.g. redundancy of protections systems)
  - what is required?
  - what are the tools?

Lesson from TT40 damage 2004

1 full nominal batch $3 \cdot 10^{13}$ above damage limit (gazing incidence)

25th of October: MSE trip during high intensity extraction. Damage of QTRF pipe and magnet.

- Shot-by-shot logging was operational
- Logging was operational
- Data was used to understand event



Transfer line damage during high intensity proton beam extraction from the SPS in 2004, B. Goddard et al.

Workshop programme

1. General Introduction with the main aims of the Post Mortem System (Convener: A.Rijllart)
2. Cold circuits – data, analysis (Convener: Felix Rodriguez-Mateos)
   - Last check before powering cold circuits that starts end February / begin March (where are we?)
3. Operation with beam - PM requirements (Convener: J.Wenninger)
4. Data providers, volume, type of analysis (Convener: R.Lauckner)
5. Discussion Session (Convener: Mike Lamont)
   - Open issues: structure, technology, roadmap, priorities

Conclusions

Recording and using data for LHC operation

- For powering, for injection, when dumping the beams, …

Status: What is presently available? What is in development? Who works on what?

Data volumes and data flow should become clear for the different systems

- Do our solutions scale to full LHC with the current solutions?
- How and where is the data stored? How long should the data be kept? Might be different for different systems, and different data.

The objective is to get a roadmap – where do we want to go, how to get there, who is involved

- What is needed for hardware commissioning? This is required soon and should have priority.
- What are the minimum requirements for the first year(s).
- Who provides basic functionality, analysis tool etc. ?