What else can go wrong

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The session

- Maximum Credible Incidents – J. Strait
- Risks due to UPS malfunctioning – H. Thiesen
- Impact of SEUs – M. Brugger
- Beam induced damage - what is a safe beam? – V. Kain
- Worst case beam incident causes and protection – B. Goddard
- Weaknesses of the MPS – B. Holzer

Not the most re-assuring session…

MCI – Maximum Credible Incident

- Bus failures, '19th September style', seem to be the most serious SC magnet failures that one can think of.
- Worst consequences to be expected if it affects:
  - A DBF.
  - Triplets.
  - Matching/dispersion suppr. sections.

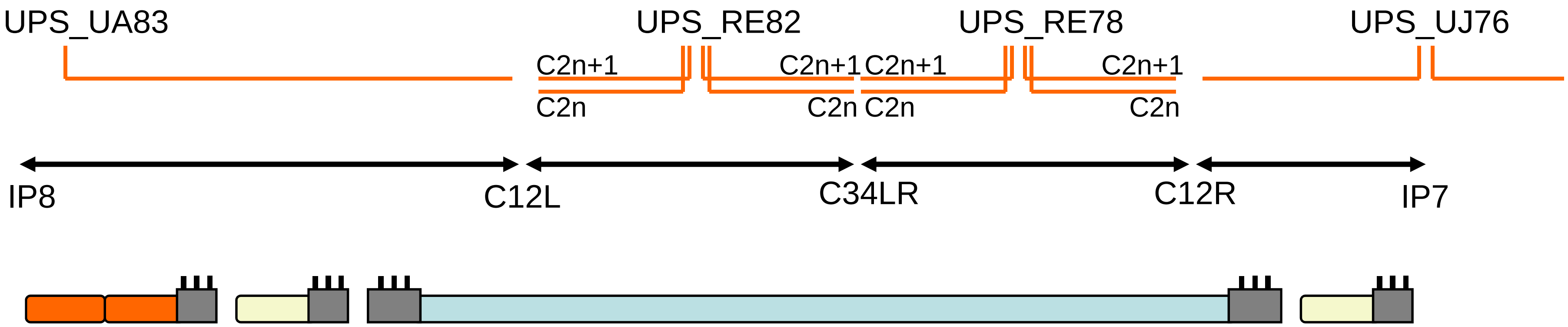
Improve cryostat pressure relief

- Collateral damage can be severe for:
  - DBFs.
  - SC cavities.
  - Injection kickers.
  - Experiment beam tubes/inner detectors.
  - In general for the (beam) vacuum..

Beam vacuum relief, fast(er) valves?

- Issue of the 'praying hands' joints in MQM - insufficient protection?

UPS for Circuit Protection Systems



4 redundant UPS systems to protect 1 sector

- 1 UPS in UA => IT, IPQ and IPD
- 1 UPS in RE => C12L to C34L (77 MB and 24 MQ)
- 1 UPS in RE => C34R to C12R (77 MB and 24 MQ)
- 1 UPS in UJ => IT, IPQ and IPD

Must be tested very carefully (AUG tests)
and time must be allocated for these tests !

UPS Issues

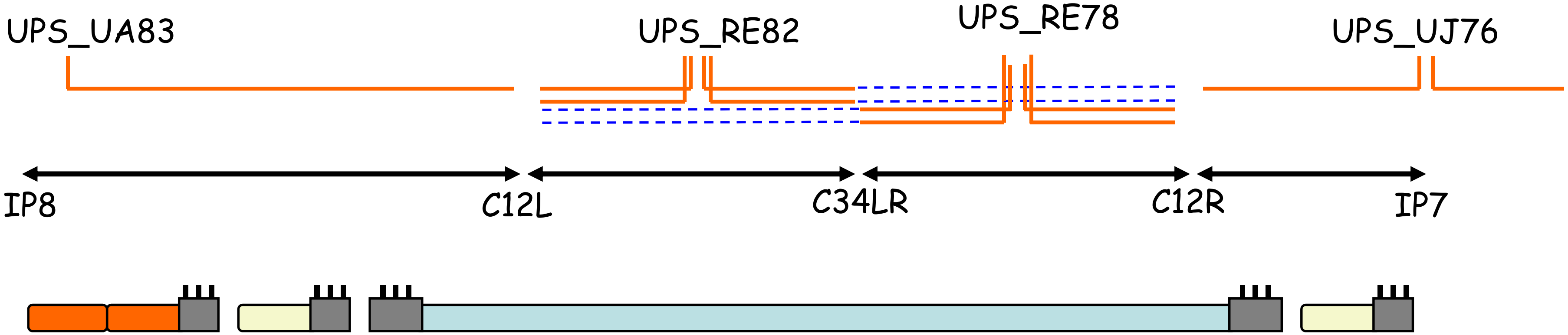
In the event of a failure of the UPS: power abort is initiated.

Consequences:

- Post-mortem data is lost.
- No control over the 60A orbit correctors.
- RB & RQ (13 kA) circuits are not protected during the power abort.

<u>Decision</u> (after Chamonix): upgrade of the UPS facility for the QPS.

QPS connected to the UPS systems from 2 different points.



Radiation - SEUs

- Following the failure of CV equipment near the CNGS target area after only hours of high intensity running

  >> raising awareness about SEUs issues → R2E group.

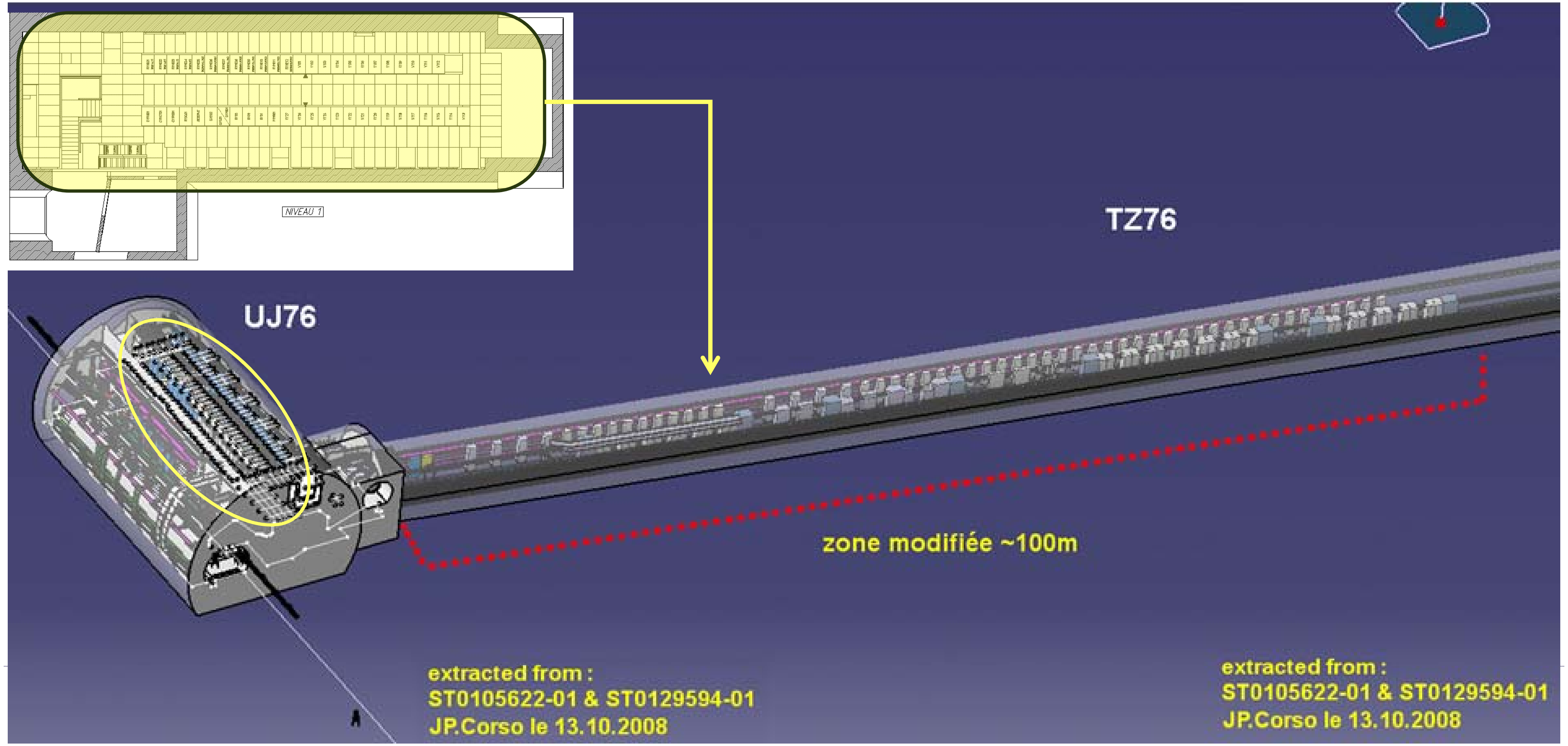
- A lot of work ongoing within R2E to:
  - Assess fluence/dose values.
  - Complete inventory of electronics.
  - Identify problem areas and find solutions (re-location).
- Outlook for 2009/2010:
  - 156 bunch operation : no showstopper was identified.
  - No problems with MPS equipment, but BIC and collimation crates in UJ56, UJ14/16 must be monitored carefully. Equipment must be moved if necessary.
  - Monitoring of radiation levels to evaluate simulation assumptions.

Shutdown 08-09

- Modification of the underground integration of Point 7 (TZ76 and UJ76) – Priority 1

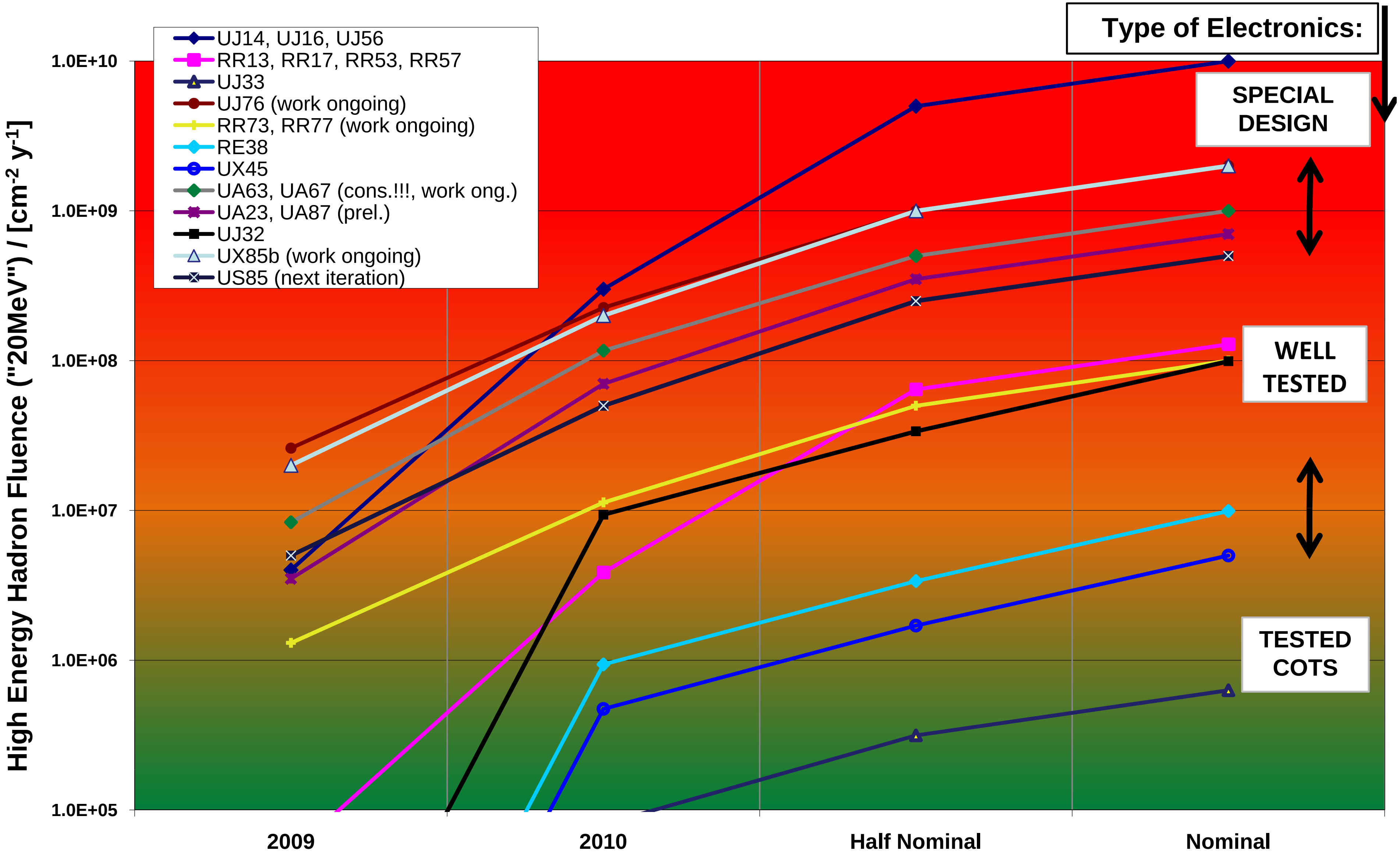
  Objective: relocation of UPS and electronics from UJ76 to the TZ76 ~ until end of June 09

  Reason for these modifications: radiation levels – triggered by R2E



Radiation Levels – Evolution

‼ Simulations Only ‼ ‼ Loss Assumptions ‼ ‼ Failure modes ‼



Damage from beams

- Damage limits for typical 'metallic objects' seem to be consistent (better than order of magnitude) – see next slide.

  >> plastic deformation & shock waves may lead to lower limits!

- Damage limit for <u>complex equipment</u> (SC magnet, RF cavity) is rather poorly known, or not at all.

  >> experimental verification on SC cables would be more than useful.

- Recent simulation results show that:
  - tertiary collimator can be damaged by pilot bunch at 7 TeV.
  - a SC magnet can be sliced open over a length of ~ meter with a beam of a **<u>few MJ</u>** >> possible trigger of a sector 34-like incident !

<u>Even our 'safe' beams are not safe under all condition.</u>

Energy Scales

'Safe' Beam Lim
72 kJ

Pilot b
360 J

Nominal b
8.3 kJ

0 GeV

Stored Energy (J)

100 | 1k | 10k | 10

'Safe' Beam Limit - 1.7x
13.6 kJ

Pilot b
4 kJ

Nomin
92

5 TeV

Stored Energy (J)

100 | 1k | 10k | 10

What can go wrong with beam

… many things !!!!

- The MPS is designed to cope with the ‘worst’ scenarios:
  - ✓ High reliability design for critical components.
  - ✓ Equipment and beam monitoring (reaction times).
  - ✓ Redundancy of the protection where possible.

    Beam loss monitors are the last line of defense!

- We are now analyzing more severe cases:
  - Multiple failures.
  - ‘Bird strikes’ : a single cause
    takes out more than one component.

Birdstrikes – single causes can lead to multiple failures

3.) What can go wrong ?

a rough statistics of 20 years HERA

Injection: **too early (during magnet cycle)**
too late (during accleration)
into a filled bucket (timing problem)
with kicke
with magn
after wron
with close
with close
with wron

Acceleration: **failure of p**
errors in r
tune jump
collimator
head tail p
magnet fa

Luminosity: **aperture li**
beam qua
orbit corr
dedicated beam orbit steering
coasting beam (rf problems)
failure at dump kicker
failure of dump timing system
collimator control defect (radiation problem)
error in BLM / BPM signal processing (server)
vacuum valve closes during luminosity run

Some of those failures cannot happen at the LHC, prevented by the MPS !

All of them have been considered for the LHC.

The LHC MPS strategy is based on a highly reliable and well tested interlock hardware network designed to catch 'all' failure scenarios.

Some 'flaws' of Tevatron, HERA and SPS MPS systems have been avoided at the LHC.

Nota bene: each of these errors lead to a beam loss alarm or quench

LHC Natural Predators

Sc n…

LHC Natural Predators

- Operators and experts are able to trigger a large palette of actions/failures that stress the MPS or that open cracks in our armor.
- Some ‘errors’ are inevitable when tuning the machine !

  The LHC is not a turn-key system, commissioning the LHC is R&D !!
- Expert actions and errors may disable part of the MPS functions: leads to the worst possible failures, in particular a priori rare ‘combinations’.
  - Follow procedures, log what you do.
  - Think twice, consult a colleague / MPS expert.
  - Track changes.
  - Test, test, test.

The Ultimate (and popular) MPS Question

"What do we do if the dump doesn't react to a programmed request"

Possible answers are

- Call Bruno and Etienne in to fix the problem.
- Cut RF Revolution Frequency to LBDS, to provoke synchronous dump.
- Force access system door to produce asynch. dump trigger.
- Start blowing beam up slowly with tune kicker, or transverse damper.
- Scrape beam slowly away with collimators, while staying below quench limit.
- Provoke a software interlock.

We must agree and maintain a procedure for the CCC…

The last word for the 'scary' session

The LHC is a difficult and 'extreme' collider,
the risks have become very concrete on Sept. 19th.

To cope with the risks of beam operation
we have designed a large and reliable MPS,
and the one thing that we absolutely need is
TIME to test it very very carefully !

It will not be easy, but there is no reason to panic !