Impacts of SEEs

LHC Performance Workshop
Chamonix 2009

R2E Taskforce

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Overview

- R2E 2008 Activities and Conclusions
- Example of UJ76/RR73,77 to illustrate the chosen analysis & evaluation approach
- Underground Areas – Expected Radiation & Prioritization
- Suggested Priority Classification of Equipment
- 1st Iteration on Machine Protection related Systems
- Performed Radiation Tests
- Implications for 2009
- What is needed for the mid/long-term

R2E 2008 Activities and Conclusions

- **Review** of available simulation data and respective iteration
- Split of **priorities** in short/mid/long-term
- **Loss assumptions** and scaling for coming years
- **FLUKA simulations** for most critical areas
- **Shielding studies** for most critical areas, discussion of

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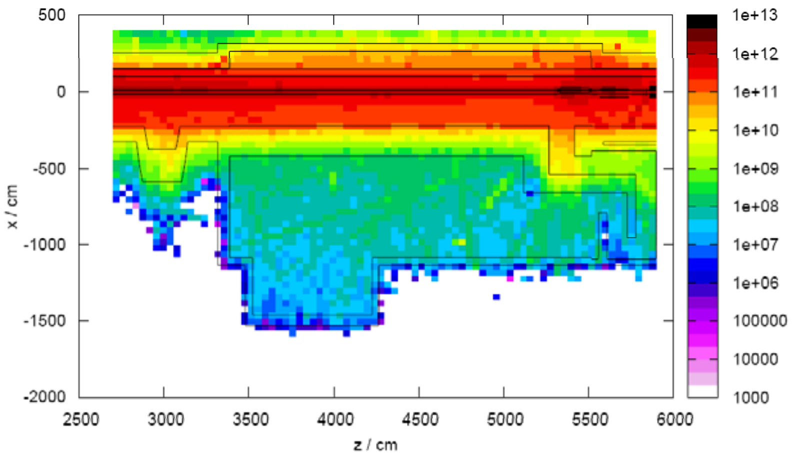
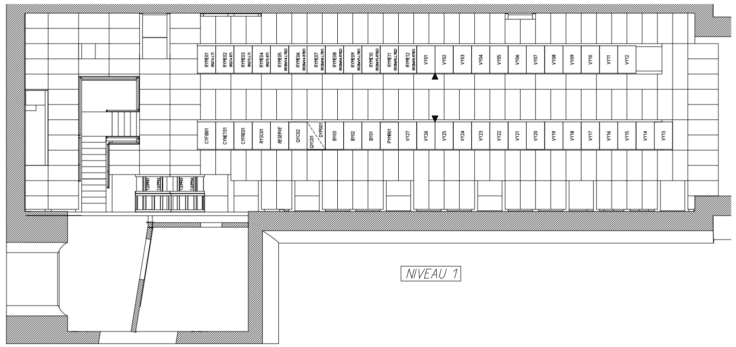
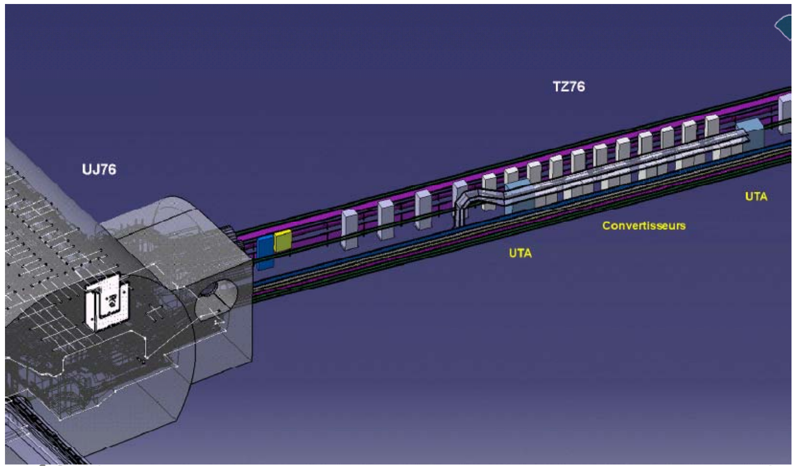
- Study of possible **temporary move of the betatron** cleaning to P3
- **Prioritization** of underground radiation areas containing electronics
- **Monitoring** during start-up, successful comparison with simulations
- **Radiation Tests** and implications
- SEE related **shutdown activities** (UJ76/TZ76, RR73/77, UA63/67, UX85)

UJ76/RR73/77 Approach

- **Early awareness** of radiation levels
- **Detailed analysis** based on **tracking studies** (SIXTRACK) and **cascade simulations** (FLUKA) to estimate the distribution and maximum radiation doses and fluences
- Analysis of **related uncertainties** (assumptions, models, statistics, limitations)
- **Inventory** and location of installed electronics
- Study of **consequences in case of failure**
- Study of **different solutions** (shielding, relocation, combinations)
- **Proposed solution** outlined and discussed in respective ECR (LHC-EC-UJ76)
- **Staged implementation approach** to allow for additional measurements during operation

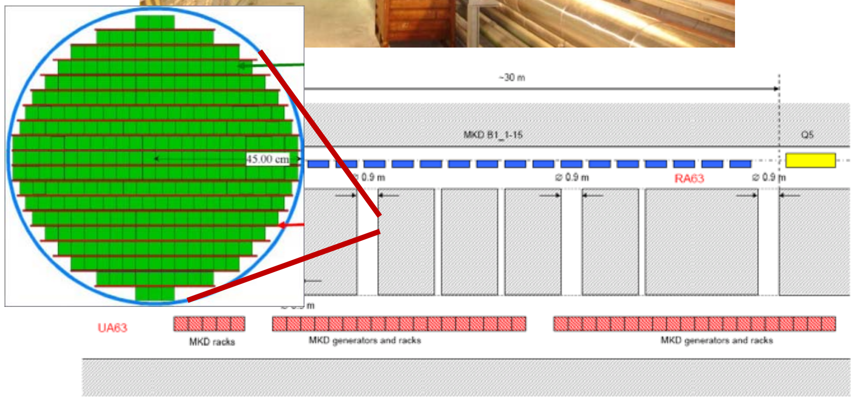


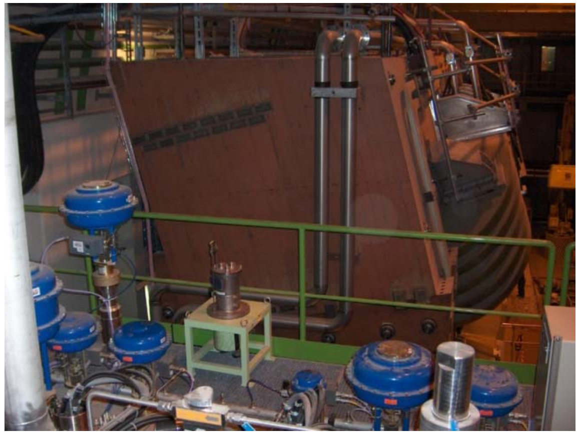




SEEs related 2008/9 Shutdown's Activities

- IR7
  - **RR73/77** installation of final shielding
  - **TZ76** preparation
  - **UJ76**
    - UPS removal (from UJ76 into TZ76)
    - additional shielding wall to increase protection of safe room
- IR6
  - Shielding of ducts between tunnel and **UA63/67**
- IR8
  - **UX85b** installation of remote controllers
- Additional identified holes in shielding were already mostly closed before first start-up (e.g., geometer holes)
- Critical Areas: check for **additional monitoring**, iterations





Radiation Levels- Summary - Prioritized

- Current knowledge based on **simulations only**, thus detailed analysis and iteration required during early operation
- **Important uncertainties** due to assumptions going into loss terms (real integrated luminosity, distribution of losses, …)
- **Priorities** assigned during 2008 according to
  - system sensitivity and criticality
  - uncertainty of loss assumptions (*e.g.*, UJ76)
  - possible short-term measures (*e.g.*, UA63/67)
- Continuous evaluation – Prioritization (colour coding)

  - [yellow] Ongoing work during this shutdown
  - [red] Highest priority for upcoming iterations/evaluations
  - [blue] Second priority, cross-check with measurements
  - [green] Lowest priority, layout check and evaluation

- Other color codes:

  - [peach] areas which require additional calculations
  - [light grey] analysis to be done

Radiation Levels - Summary - Prioritized

!!! Simulations Only !!! **!!! Loss Assumptions !!!**

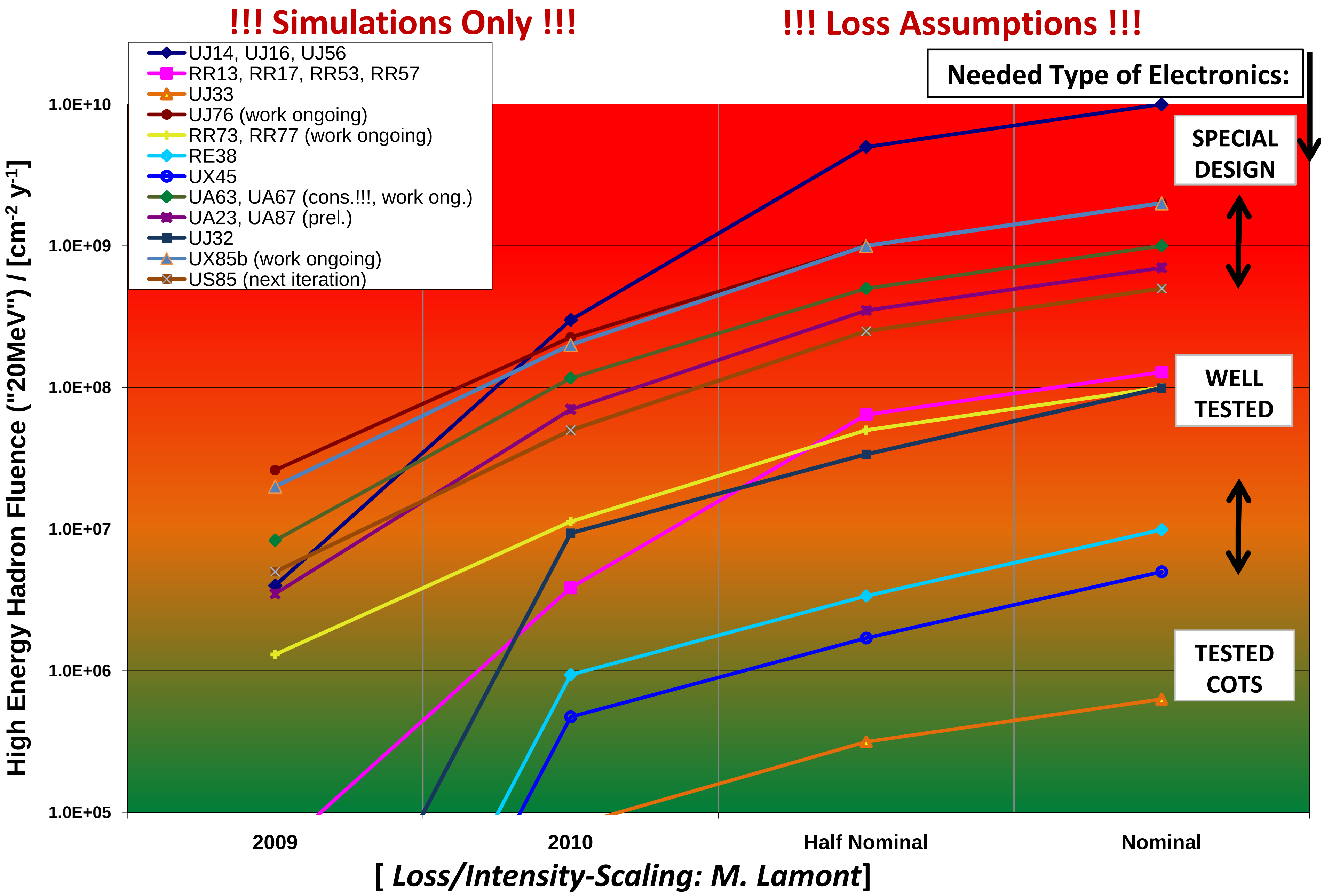
LHC Point	Area(s)	Radiation Levels						Priority
		20MeV [cm^{-2}/y]	1MeV [cm^{-2}/y]	Dose [Gy/y]	Normalisation	Scaling	Comments	
Point 1	UJ14 UJ16	1.E9-1.E10	1.E10-1.E11	1. - 10.	100 fb-1	Luminosity	1st Shielding Studues performed	2
	RR13 RR17	3E7-9E7	1.5E8-4.5E8	0.01-0.2	70 fb-1	Luminosity Beam-gas	full shielding assumed in calculations (last phase as in ECR)	2
	US15 USA15	1E6-1E7		0.001-0.02	100 fb-1	Luminosity	partly based on extrapolation	4
Point 2	UX25							4
	US25							4
Point 3	UJ33	1E4-2E6	5E4-7E6	1E-6-1E-3	1E16 p/y	Direct beam losses	Cryo Fquipment at Entry Point ("Worst Location")	4
	UJ32	1E7-1E8	1E8-1E9	< 0.01	1.65E11m-1y-1	Beam-gas	very conservative beam-gas assumptions	3
	RE38	2E5-1E7	1E6-5E7	5E-5-1E-3	1.65E11m-1y-1	Beam-gas	very conservative beam-gas assumptions	3
Point 4	UX45	5.0E+06	1.5E+07		2.4E10m-1y-1	Beam-gas	Different norm. for various beam-elements, dominating stated: can the density be higher?	3
Point 5	UJ56	1.E9-1.E10	1.E10-1.E11	1. - 10.	100 fb-1	Luminosity	1st Shielding Studues performed	2
	RR53, RR57	3E7-9E7	1.5E8-4.5E8	0.01-0.2	70 fb-1 2.E9-7E10m-1y-1	Luminosity Beam-gas	full shielding assumed in calculations (last phase as in ECR)	2

Radiation Levels- Summary - Prioritized

!!! Simulations Only !!! **!!! Loss Assumptions !!!**

LHC Point	Area(s)	Radiation Levels						Priority
		20MeV [cm^{-2}/y]	1MeV [cm^{-2}/y]	Dose [Gy/y]	Normalisation	Scaling	Comments	
Point 6	UA63 UA67	1E6-1E9	1E7-1E10		3.4E13 p/y	Direct beam losses	Simplified simulation	1
	UD62 UD68						crane and ventilation equipment	3
	US65							4
	UX65							4
Point 7	UJ76	1E7-1E9	5E7-5E9	1E-3-1E0	1.15E16 p/y	Direct beam losses	loss dominated by secondaries interacting in lateral beampipe	1
	RR73 RR77	1E7-1E8	5E7-5E8	0.01-2	1.15E16 p/y	Direct beam losses Beam-gas	real losses to be evaluated (monitoring @start-up), strong dependency on TCLAs	1
	TZ76	<1E8			1.15E16 p/y	Direct beam losses	TZ maximum levels to be evaluated after measurements at higher intensities	4
Point 8	UX85b	5E8-2E9	1E9-1E10		3.2E14 pp/y	Luminosity	values refer to valve location	1
	US85	5E7-5E8	2E8-2E9		3.2E14 pp/y	Luminosity		2
TI2	UJ23	>5E9			1.44E16 p/y	Direct beam losses	2 shots per day on the TED crane only!!!	3
	UA23	<7E8			1.44E16 p/y	Direct beam losses	2 shots per day on the TED	3
TI8	UJ87	>5E9			1.44E16 p/y	Direct beam losses	2 shots per day on the TED crane only!!!	3
	UA87	<7E8			1.44E16 p/y	Direct beam losses	2 shots per day on the TED	3
ALL	ARC	1E9-5E12		1-1000	1.65E11m-y-1	Beam-gas	Equipment spec. designed, Issue with 60A power converters?	2
	REs	2E5-1E7	1E6-5E7	5E-5-1E-3	1.65E11m-1y-1	Beam-gas	very conservative beam-gas assumptions	4
	DS	1E9-5E12		1-1000	1.65E11m-1y-1	Direct beam losses Beam-gas	Equipment spec. designed, Issue with 60A power converters?	2

Radiation Levels – Evolution

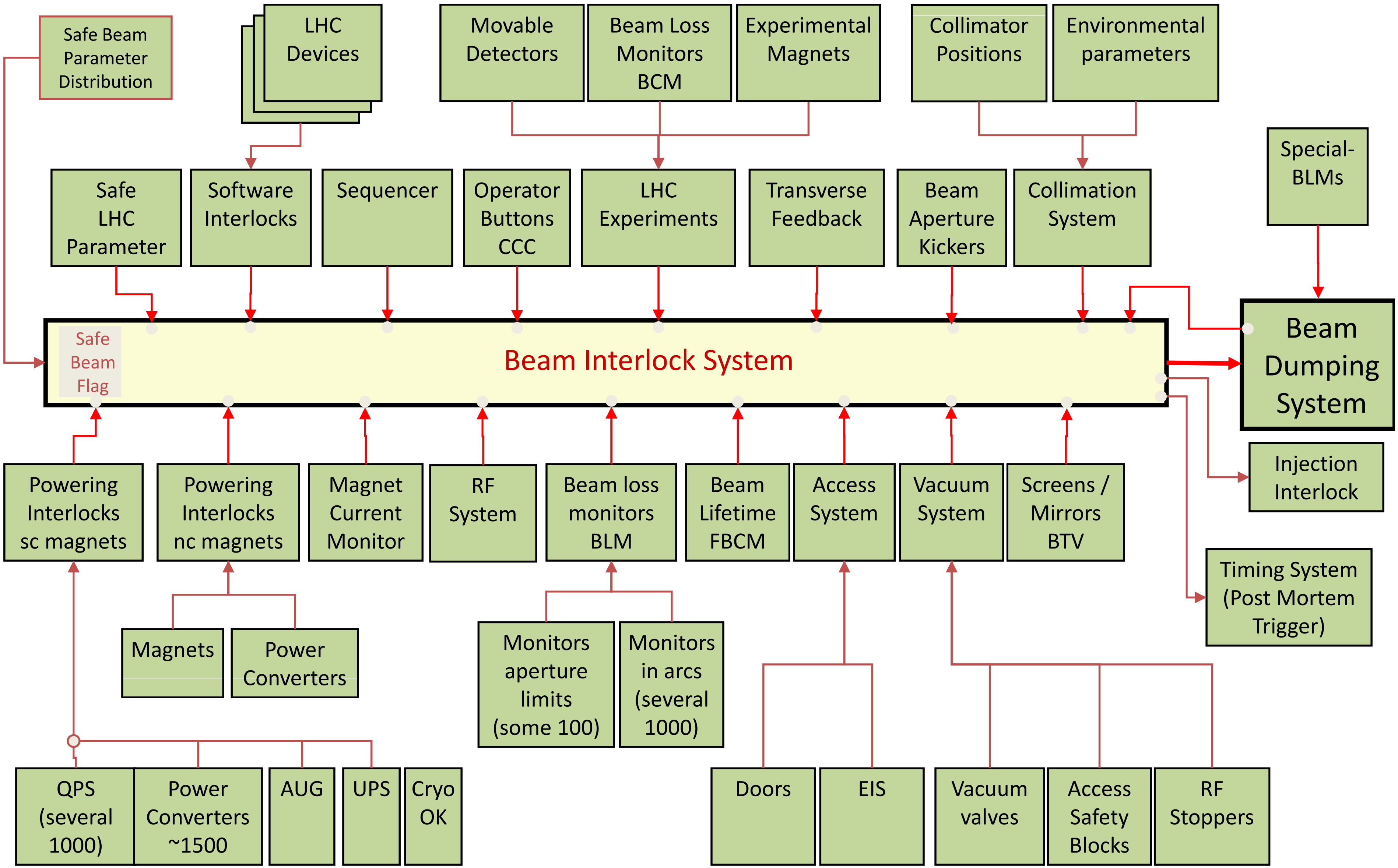


Equipment Criticality Levels

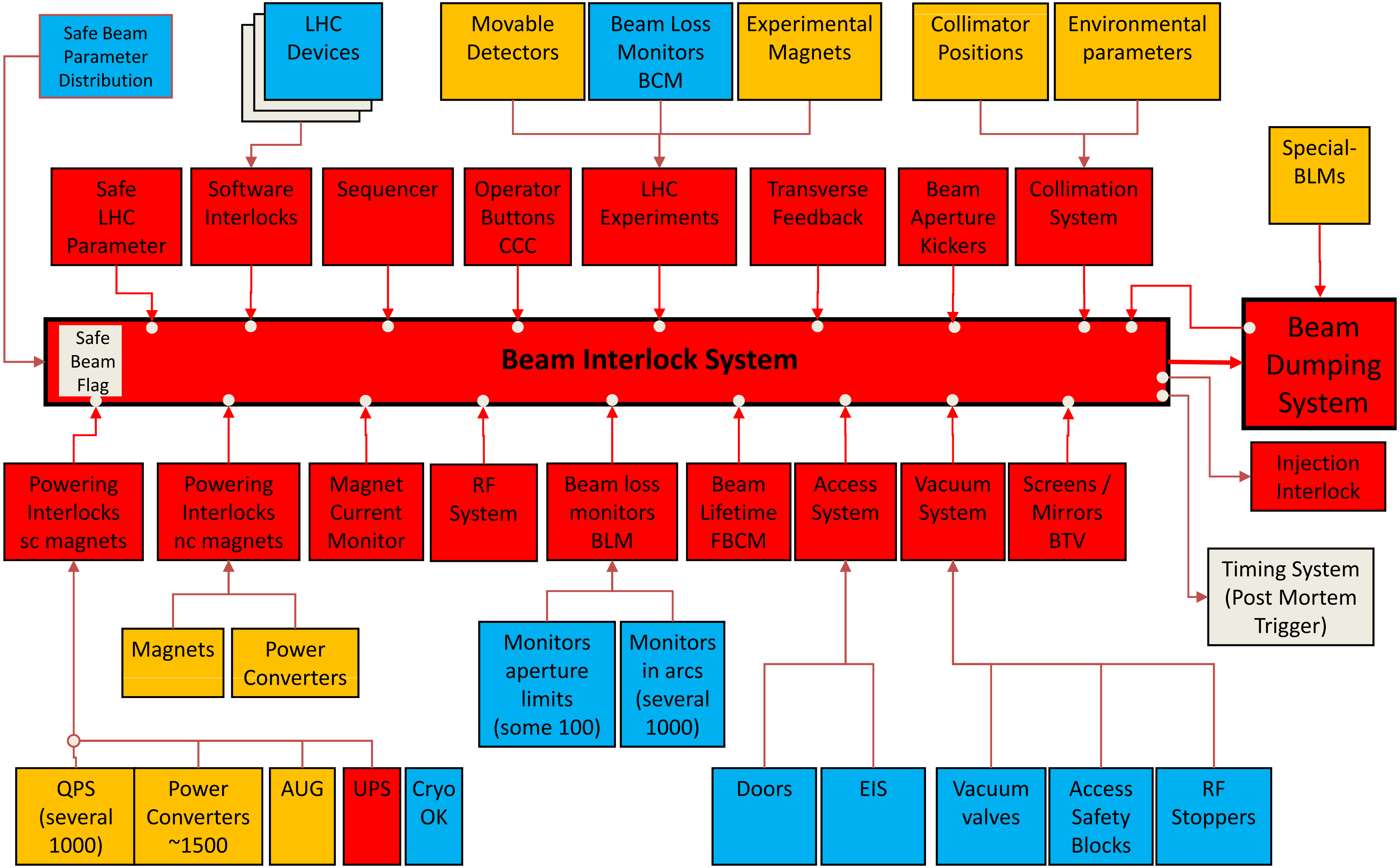
Suggested colour coding according to equipment classes and respective implications:

- 1. Machine Safety Control
  - Beam Interlock System (BIC)
  - Damage related sub-systems (PIC, WIC, FMCM, BDS,…)
- 1.b. Systems whose input is important to assure machine protection
  - *e.g.*, BLM
- 2. Systems whose dis-functionality leads to downtime or localized damage only
  - *e.g.*, Power Converters, BTV
- 3. Impact on Beam Quality
  - *e.g.*, Vacuum
- 4. Monitoring mainly
  - *e.g.*, RAMSES (tunnel monitors)

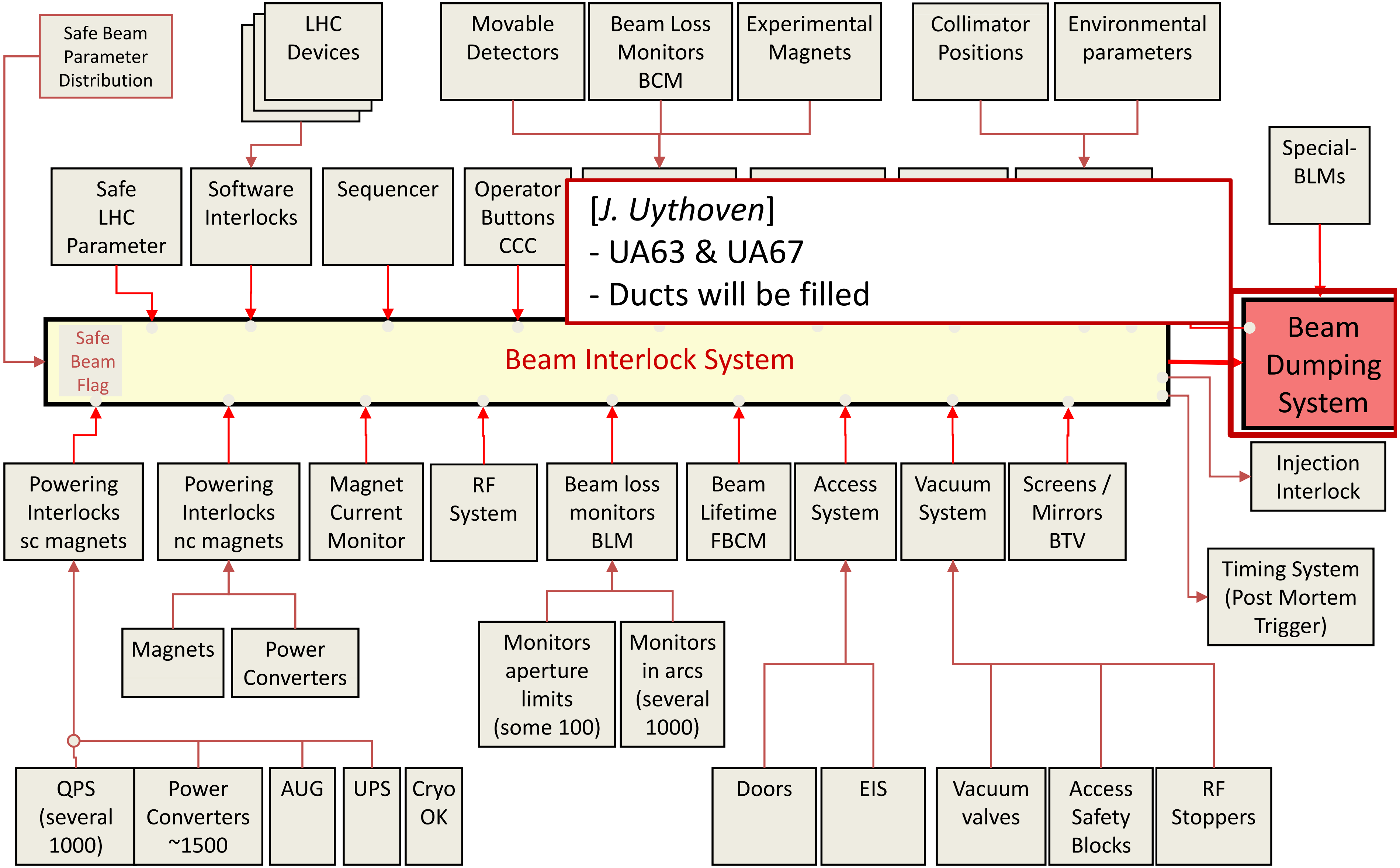
Application to Machine Protection



Machine Protection Overview

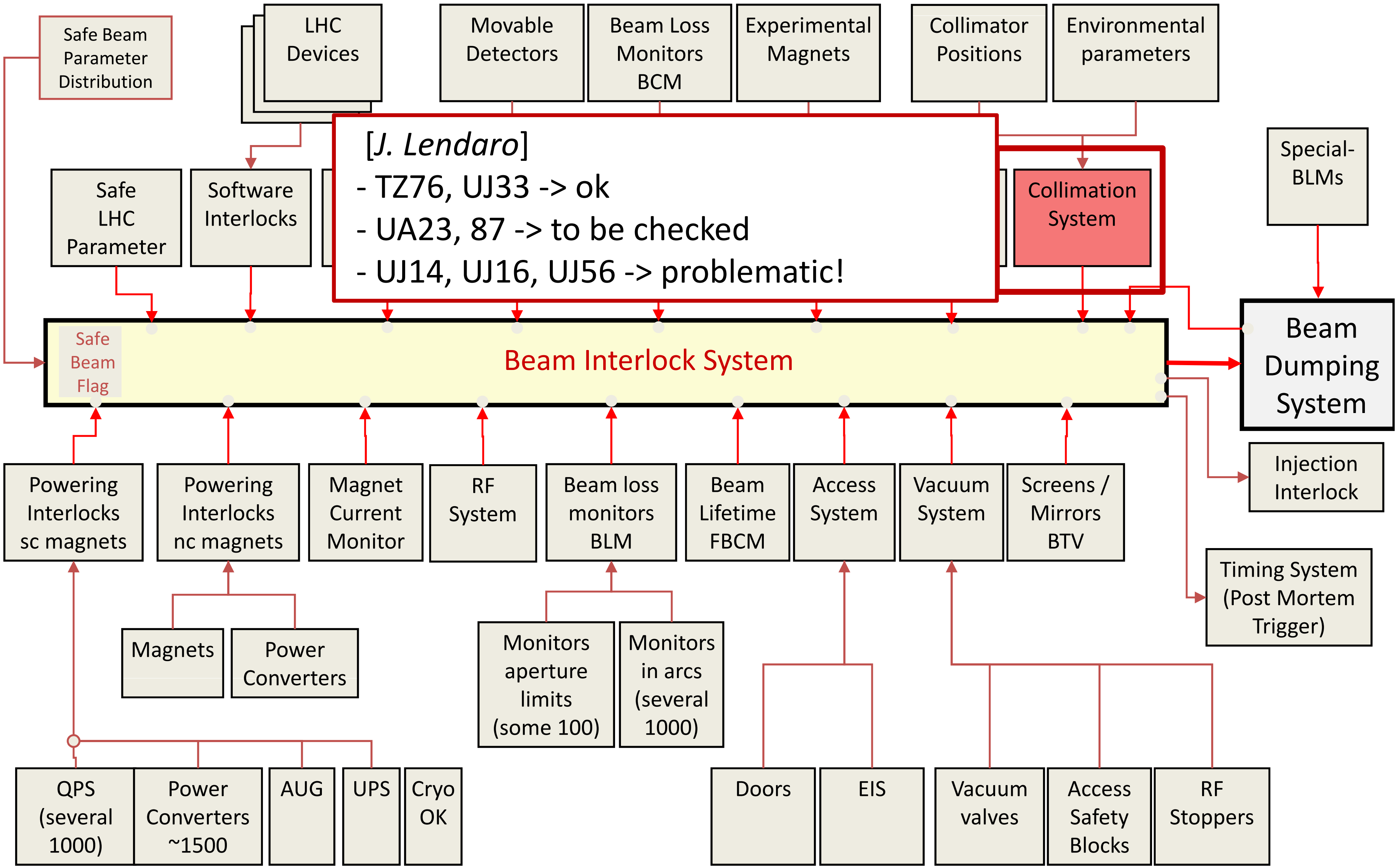


What Sits Where – Critical?



[*J. Uythoven*]
- UA63 & UA67
- Ducts will be filled

What Sits Where – Critical?



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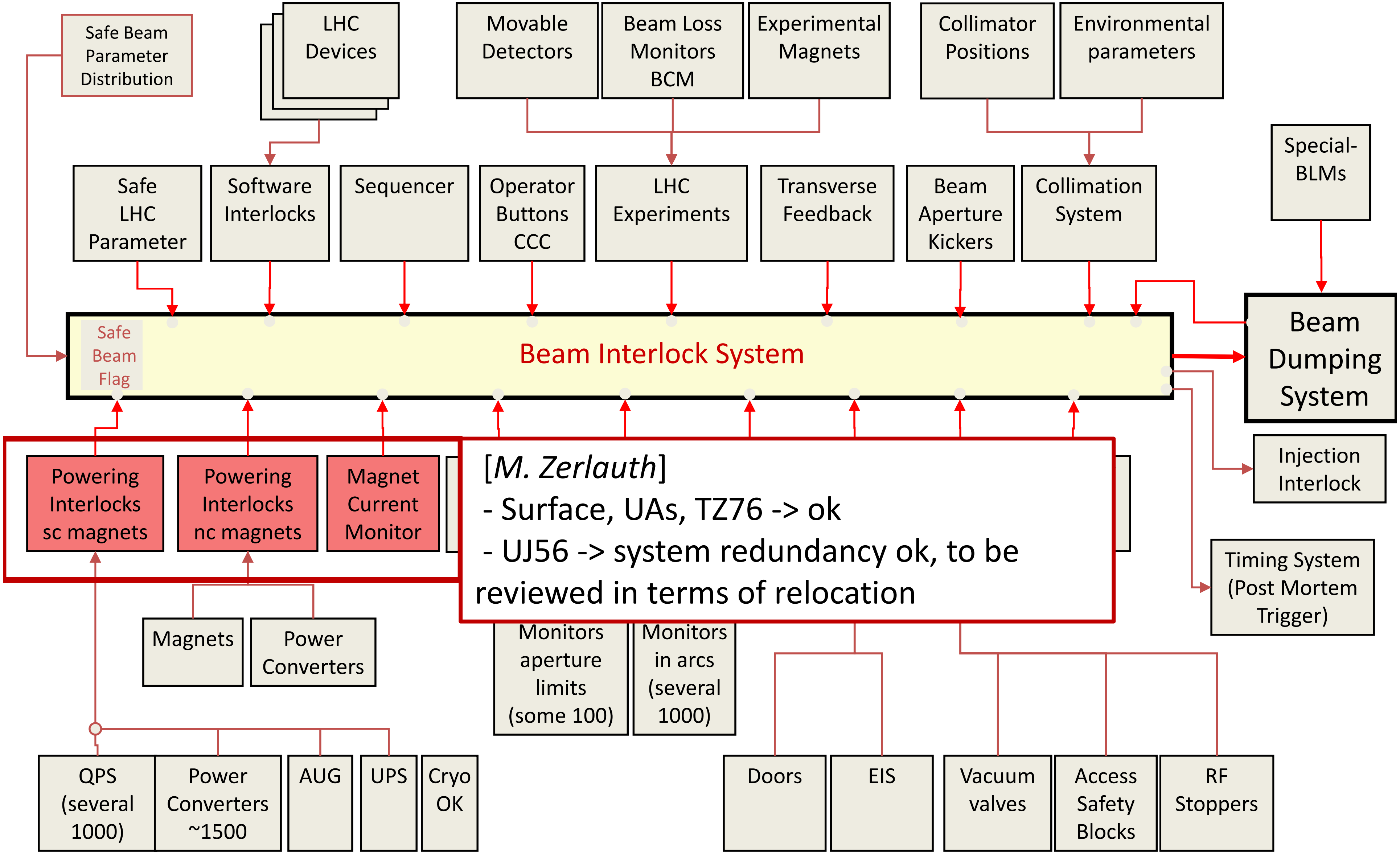

[*M. Zerlauth*]
- Surface, UAs, TZ76 -> ok
- UJ56 -> system redundancy ok, to be reviewed in terms of relocation

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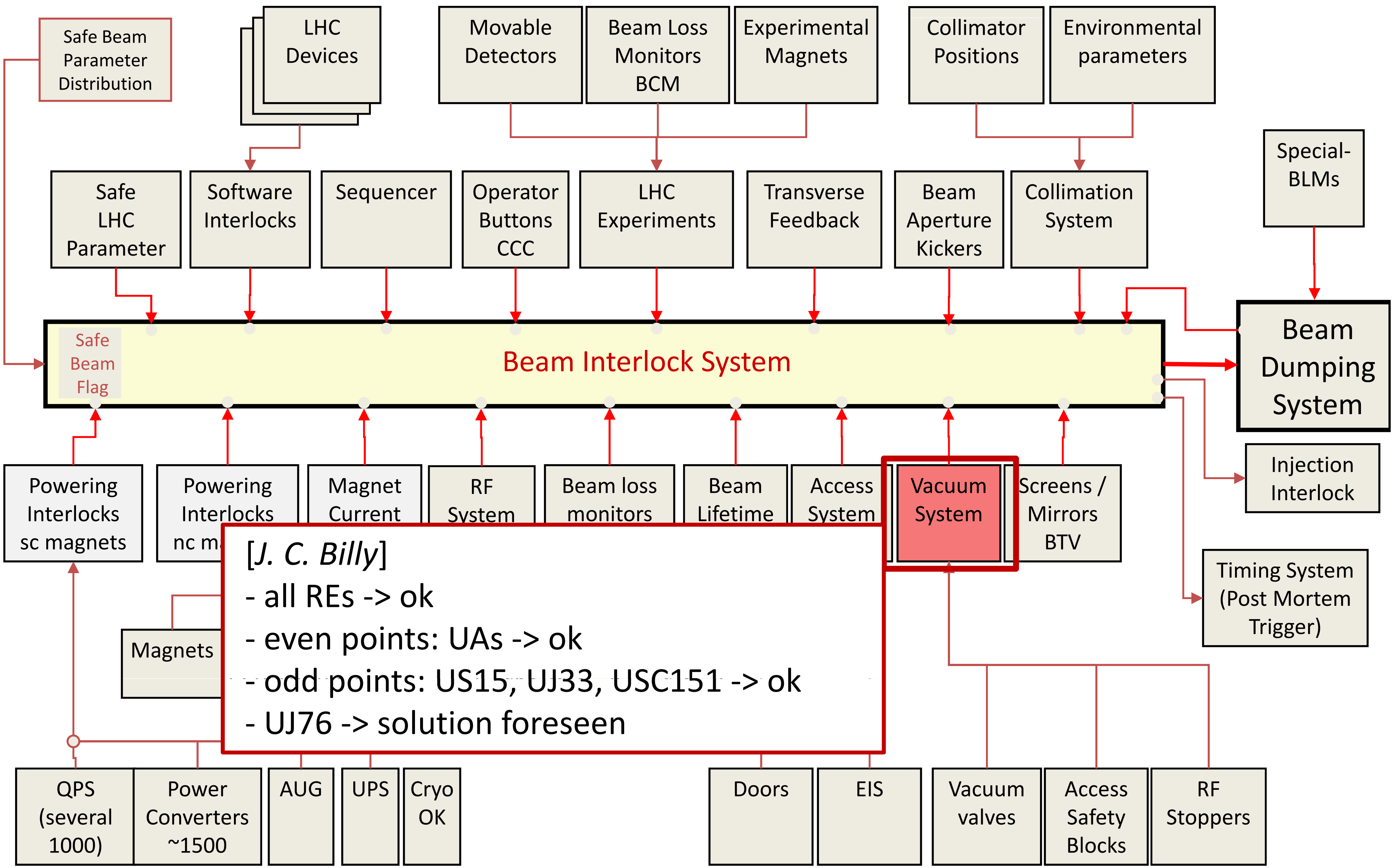
What Sits Where – Critical?



[*J. C. Billy*]
- all REs -> ok
- even points: UAs -> ok
- odd points: US15, UJ33, USC151 -> ok
- UJ76 -> solution foreseen

Machine Protection

[*R. Schmidt, M. Zerlauth*]

- **Machine protection control** equipment doesn't rely on standard communication – **hard links used where required**
- Electronics racks (controllers) are installed in **surface areas** and **certain underground areas** (UAs, USs, TZ76 and UJ56)
- One current concern is the BIC rack located in the **UJ56** (BIC, FMCM,…) where important radiation levels are expected (luminosity driven)
  - the design is redundant (fail safe except both units would fail at the same time), thus no direct impact on machine safety (dump would occur)
- The others are considered as radiation safe, with two 'reminders'
  - **UA63/67**: ducts to be filled (this shutdown) thus maximum radiation levels substantially reduced
  - **UJ-UA23/87**: equipment close to UJs (*e.g.*, access control rack), no early problem expected, possible impact due to injections on TED to be verified
- protection control equipment installed in the tunnel (*e.g.*, interfaces) were tested and showed high radiation resistance

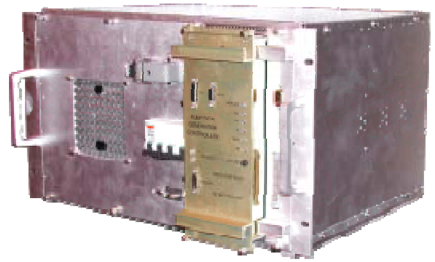
Machine Protection

- Further concern: **collimation racks** (for TCTs, TCLPs) **in UJ14/16 and UJ56**: options to be studied
- A closer look to what is in the UA: [*J. Uythoven*]
  - control of TCDQ position: **additional redundancy added**, will work similar as the BETS [see talk J. Uythoven]
  - BETS: problem with beam energy would lead to possible worst case accident, **sufficient redundancy**
  - Extraction kicker switches will be checked during operation, no problem expected for the UAs
- Energy extraction 13kA **switches** [*A. Vergara*]
  - Located at some points, RRs, UAs (1st floor)
  - radiation levels in the RRs of IP1 and IP5 to be reviewed
  - more detailed analysis required
- Transfer line dump on downstream **TED** [*J. Uythoven*]
  - UJ23/UA23, UJ87/UA87 radiation levels to be checked
  - general issue (not SEE): circulating LHC beam and affected BLM monitor
- Additional iterations ongoing through R2E/RadWG linked with MPWG

Recent Radiation Tests & Problems

Power Converters [Y. Thurel, Q. King]

- LHC60A-08V power part tests during 2008 were successful
- SEUs counted on FGC generic, auto-recovery worked
- FGC (special design) of the 60kA (network interface) failure is linked to the Xilinx CPLD, so far it can not be excluded that failure could also be non-radiation caused
- If radiation sensitivity is confirmed then 'extended MicroFIP' or similar solution possible for the LHC60A (within one year)
- For all designs, significant additional hardening possible already on software level
- Situation significantly more complicated (time required, costs) in case full redesign of convertors needed
- **Ok for 2009**
- **Additional radiation tests (1 month) required at CNGS**



Recent Radiation Tests & Problems

- New QPS devices to be installed in the tunnel (mid dipole only) [Reiner Denz]
  - tests with the presently installed QPS system were promising (no hardware failure, only software)
  - the new extended QPS device will be further modified
    - increased hardening concerning firmware (triple voting etc.)
    - power supplies (linear regulators etc.) including remote power cycle features
  - link to Field-bus: communication loss clears the 'Power Permit' condition for the corresponding circuit, *i.e.*, an alarm is created, the run can continue but re-start is not possible anymore.
  - detection systems do not depend on the Field-bus communication with respect to detection/ protection
  - **additional tests (March PSI, Summer CNGS)**
  - **Ok for 2009**

- Solid state relays used for the HTS current lead heating system [Amalia Ballarino]
  - two different types were tested at CNGS and both failed after some days of operation -> analysis ongoing, no details yet
  - located in UJs, RRs (1st floor)
  - additional radiation tests foreseen in 2009
  - **Ok for 2009**

Implications on 2009 Operation

- Based on current knowledge: **no showstopper** for 2009 restart
- BIC (and collimation crates) in **UJ56** (also in UJ14/16) to be kept in mind
- Equipment and radiation levels in **US85** to be checked
- **Monitoring** of radiation levels, **evaluation** of loss assumptions and comparison with respective simulations
- **Iterations of areas/systems** to continue
  - Machine Protection related systems
  - R2E iterations scheduled for all areas (following the assigned priorities) before startup
  - Additional analysis required in case it's decided to run through winter (possible short-term measures to be investigated)
- Additional **radiation tests** required (CNGS and elsewhere)

What we should do…

- **Review of areas**
  - scheduled Iterations: 1 every 4 weeks (R2E)
  - followed by a RadWG collecting detailed information of equipment/status/links/etc…
  - visits to be scheduled as from now
  - point owners collect/check global system information
  - integration drawings (racks, monitors,…)
  - review of monitor locations & settings
  - assignment of maximum fluence/dose values (based on simulations, scaling, applying uncertainties)

Challenging but Possible

- **Data collection**
  - general document database [existing]
  - radiation levels & classifications (critical areas) [ongoing]
  - inventory of concerned equipment systems [missing]

Realistic

  - inventory of concerned equipment systems [missing] (continued)
    - Class
    - Racks
  - equipment details and inter-dependencies to be collected
    - **general problem not only for SEE** [missing]
  - consequences of equipment failure/malfunctioning [missing]
  - repair (replacement) implications [missing]

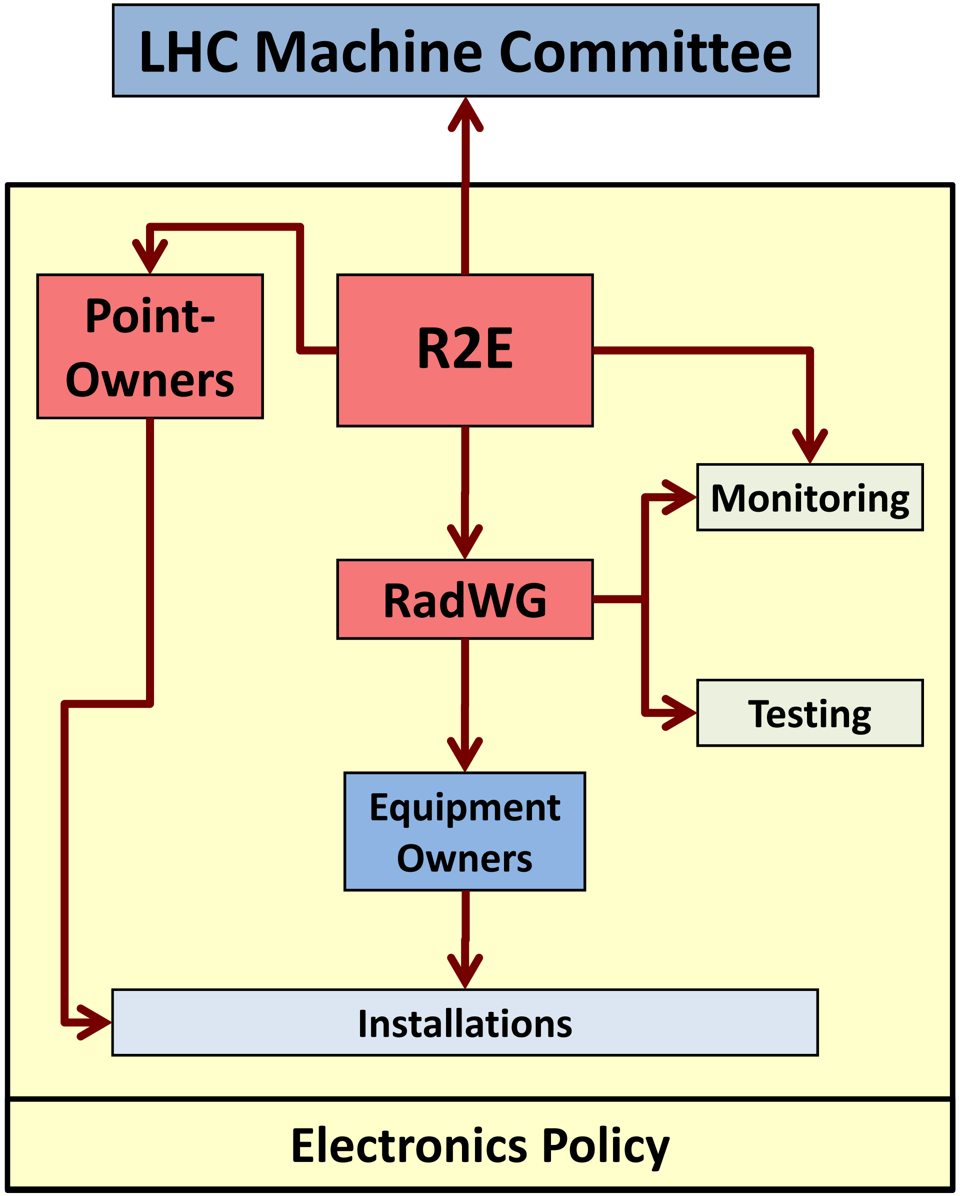
Currently not Possible

What else is needed…

- **Early 'Learning'**
  - efficient Monitoring tool allowing for quick analysis during early operation (monitor locations, settings to be reviewed now!)
  - during start-up: concentrating on most important areas (UJ76, RRs, US85, UJ56,…)
  - Continued/additional simulation studies
- **Knowledge & Development**
  - improve exchange between experiments & machine
  - 'SchoolDay' to be organised
- **Radiation Tests & Facilities**
  - Coordinated radiation test campaigns (RadWG)
  - External facilities
  - New CERN facility?
- **Structure**
  - Organisational
  - Procedures
  - Supported (requested) by all concerned department & group leaders

Structure: R2E Suggestion

1. **Policy** for Electronics installed in areas with elevated radiation levels (**R2E**)
2. **Evaluation** of Radiation Levels: simulations, monitoring, proposal of measures (**R2E**)
3. Structure to **implement** the Policy (**RadWG**)
4. **Radiation Tests** (**RadWG**)
5. **Control** (**Point Owners**)



Conclusions

- **No imminent SEE related machine protection problems** expected (identified so far!) during 2009 operation
- **Concerns discovered** for early operation - BIC and collimation racks installed in UJ56 (UJ14, 16)
- Further **important impacts on operation** to be expected (as soon as intensity/losses go up)
- Continuously **updated priority list** presented
- **Weak links & Redundancy**: information difficult to access
  - more **detailed inventory needed** on the mid/long-term
  - **equipment classes, evaluations** to be added first
- Related **short & medium term actions** discussed
- **R2E approach** presented:
  - **iterations** to tackle existing installations
  - **evaluation/selection** of implementations
  - **mid/long-term structure** proposed

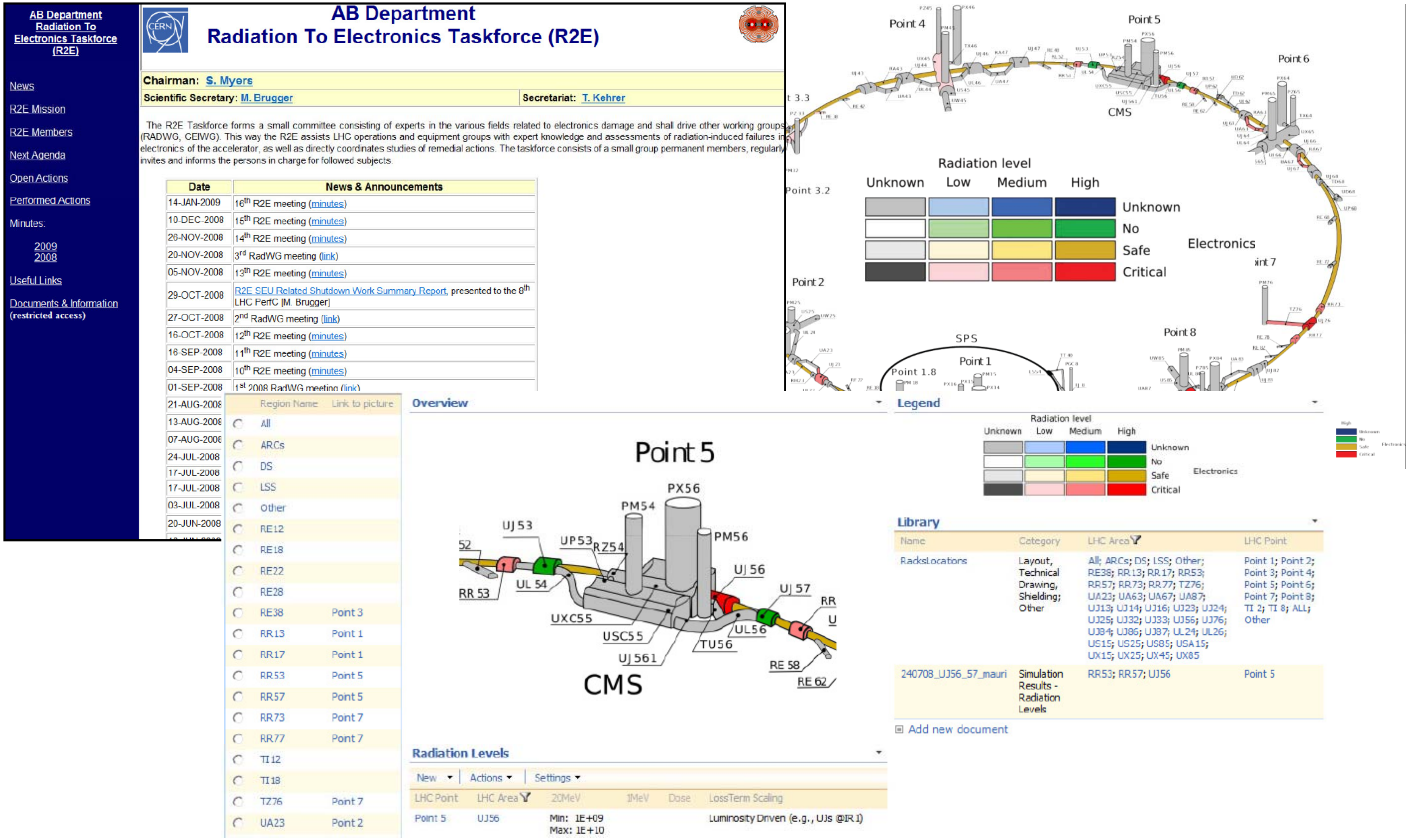
Conclusions

- R2E objectives for 2009
  - Detailed **review of areas**
    (one by one, bi-weekly/monthly schedule)
  - **Monitoring tool**
    (required for efficient analysis of early operation)
  - Review of **monitor locations** and setting
  - Definition of **Maximum Radiation Levels**
    (per area, and 'operational year')
  - Additional **simulation studies** of areas
  - Organization of '**SchoolDay**' for electronics installed in radiation areas
  - Definition of **electronics policy** for underground areas with radiation
  - **Evaluation/Monitoring** during start-up
  - Proposal of **2009/2010 shutdown** activities

Backup

R2E Website & Related Database

- https://ab-div.web.cern.ch/ab-div/Meetings/r2e/



Monitoring Tool

- Important to efficiently understand radiation levels during early operation
- Collection of available monitor data, units, storage & access details
  - prepared 'Definition Document'
- A staged implementation is followed starting from the simple and core objectives
  - post-mortem analysis
  - selection of available monitor data by area(s)
  - interface to existing logging tool (Timber, and other DBs not accessible through Timber) in order to obtain relevant data-files
  - unit conversion when available/needed
  - link to technical drawings for visualized monitor locations (where available)
- Important ingredients & first implementation
  - monitor inventory & locations updated/entered into LHC Reference Database
    - http://layout.web.cern.ch/layout/search.aspx
    - Radmon, BLM, RAMSES, BCM, …
  - detector locations further put into technical drawings

Policy & Procedures
What Experiments Where Doing

- Radiation Tolerance Documents kept in dedicated Data Base
- Policy for Electronics Design to be installed in Radiation Areas
- All electronic systems are required to provide detailed information
  - General Information
  - Technical Data Sheet
  - Radiation Test Report
  - For COTS components data sheet from the manufacturer, as well as chosen approach (e.g., redundancy)
  - For ASICs, FPGAs datasheets/details from the collaboration author are required
- To be installed components go through a coordinator and/or respective working group
- Installation in underground areas only with approved permit ('plaquette could be a nice idea')
- Has to be top-down, department/groups to agree on procedure

Knowledge & Development

- **R2E 'SchoolDay'**
  - jointly organised: PH/ESE – EN/STI – BE - …
  - Combined Experiments/Machine lectures based on radiation to electronics related experience, development and solutions
  - Organised on 1-Day Basis outside CERN (no WiFi!)
  - Focused on one central subject
  - Participants: electronic developers, equipment designers (owners),… [restricted group]
  - 1st Scheduled for
    - Theme: Design of electronics for radiation levels in the machine
    - Date: to be scheduled before summer
  - Possible repetition on various subjects

Radiation Test Requirements

- Need of irradiation facilities summarized in memo of '**Working Group on Future Irradiation Facilities at CERN**' [15.12.2008]
  - http://www.cern.ch/irradiation-facilities
- Test facility for electronics is important part of it
- Partly required for existing equipment as amount of tests ideally to be performed would be both:
  - very costly if through external institutions
  - limited in terms of radiation field (mixed-field requirements)
  - too time consuming
- Certainly required for replacements and new developments
- Indispensible for all LHC upgrade related activities