Radiation To Electronics Collimation Areas (IR7/3)

IR7/IR3 Analysis - (R2E) Mitigation Project

Collimation Review, June 14th 2011

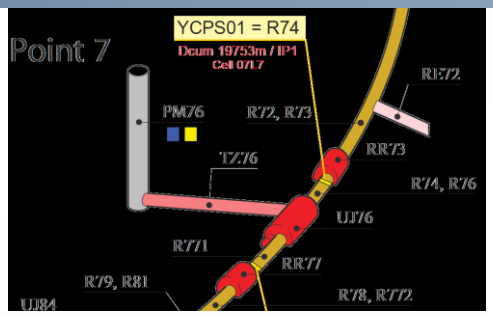
M. Brugger on behalf of the R2E Project

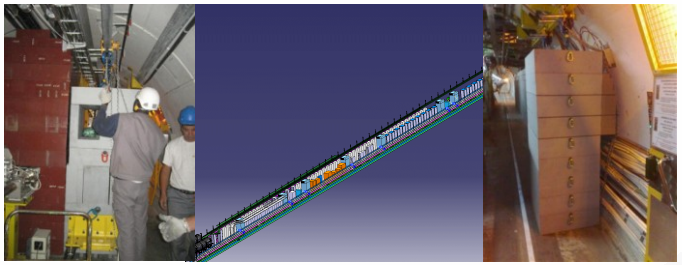
!!! Many Thanks To Everybody !!!

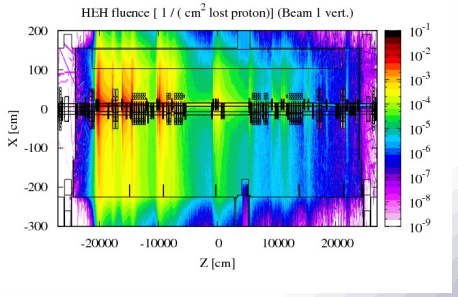
www.cern.ch/r2e

Overview

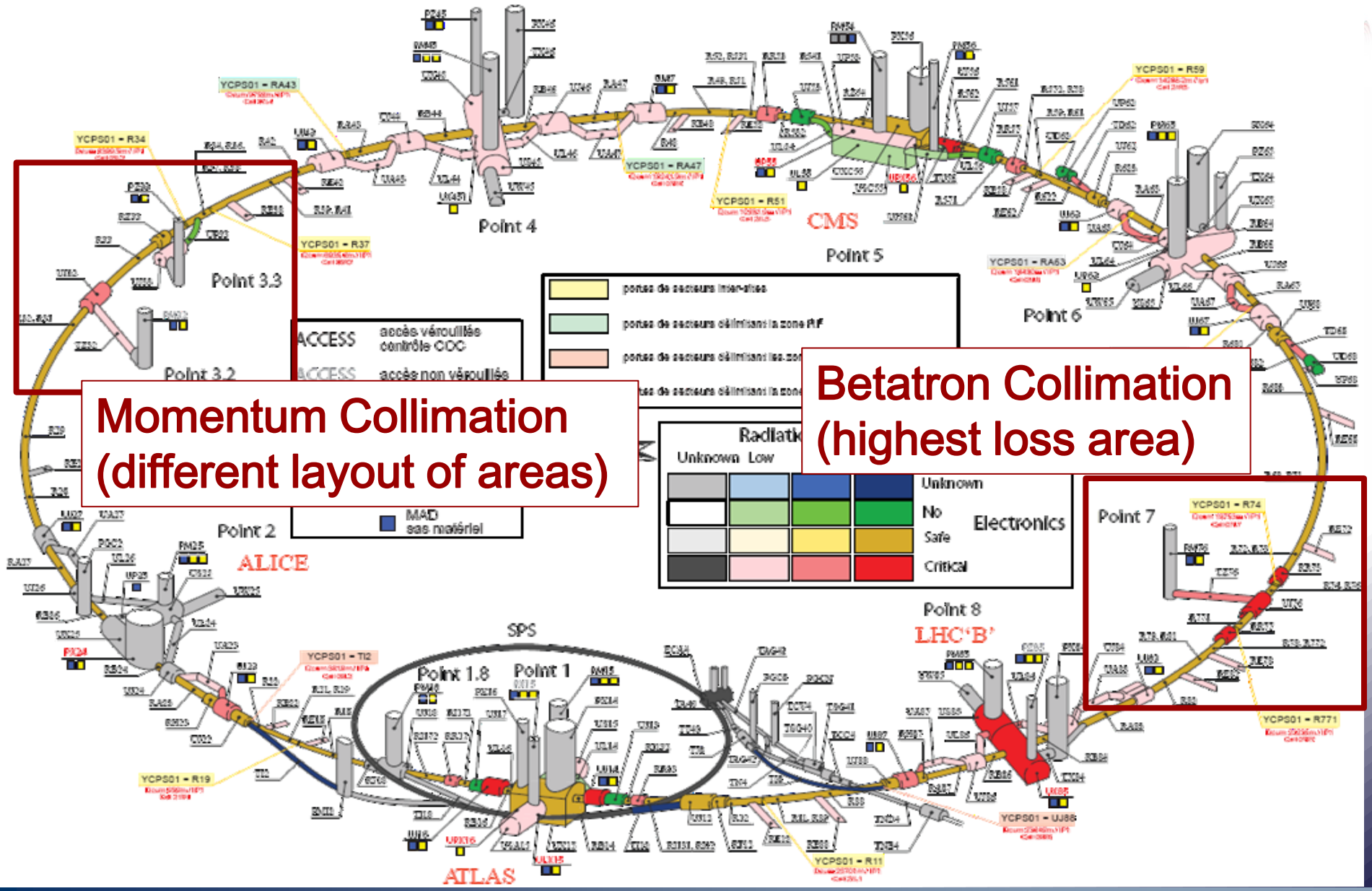
- Layout of Critical Areas @ Point-7
- Concerned Equipment
- Mitigation Actions
- Radiation Levels: Now & Outlook
- Proposed Strategy



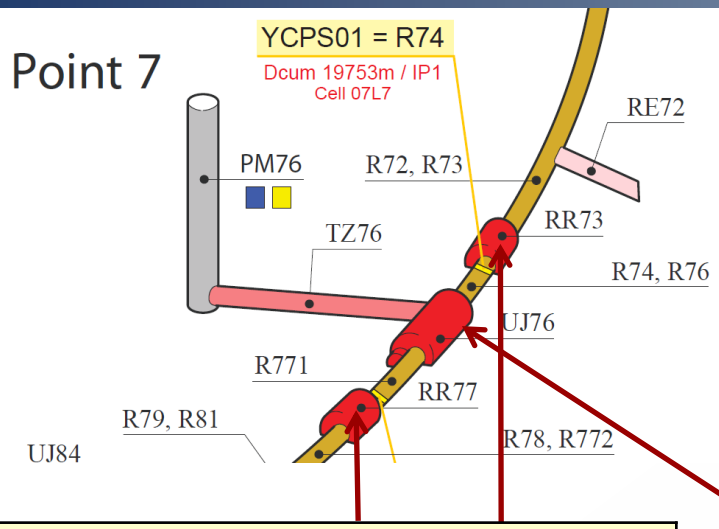




Collimation: Concerned Areas



IR7 Critical Areas & Equipment



Equipment Inventory (EDMS #1092167)

Equipment RR73/77	
Fire/ODH detectors	Beam Position Monitors
Power Converter	Cryogenics Instrumentation (FIP)
QPS	WorldFip
Cooling and Ventilation	Current Lead Heaters
Power Interlock	Electrical Distribution

Equipment UJ76	
Fire/ODH control & detectors	Cryogenics Instrumentation (Profibus)
AUG control	Vacuum
UPS	Beam Television Monitor
Electrical Distribution & Control	Ramses
Remote-Reset & Timing	GSM Diagnostics
Access System Control	Beam Loss Monitors
Power Converter	Beam Position Monitors (temporary)
Ethernet	Optical Fiber
Cooling and Ventilation	WorldFip

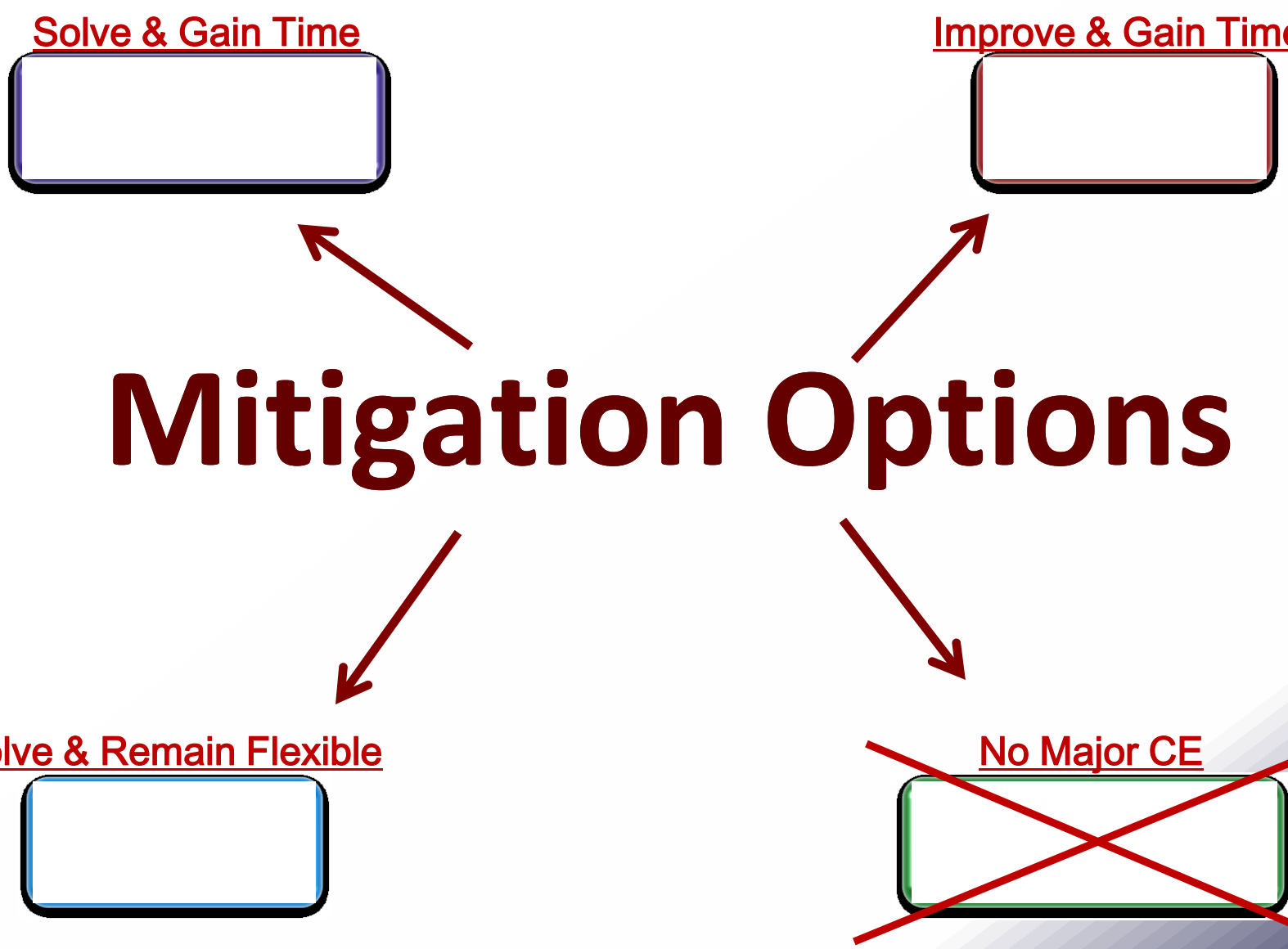
- Less radiation critical equipment
- Fire/ODH detectos to be relocated
- Current Lead Heaters ok for the levels
- QPS known patch solution

Power Converters – Big Unknown

- Various critical equipments
- Several tested at CNGS and shown high radiation sensitivity
- Few cases allow for ‘patch’ solutions

Global Solution Required

What Can Be Done (in general)



IR7 Mitigation Strategy

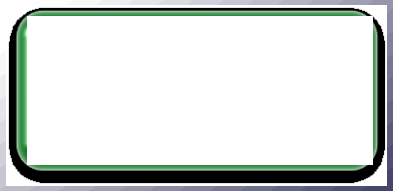
Immediate Relocation

"Fast" & Global Improvement

Highest Impact on Operation

(1)Relocation for UJ76
[safe-room to be clarified]

(2)Options for RR73/77

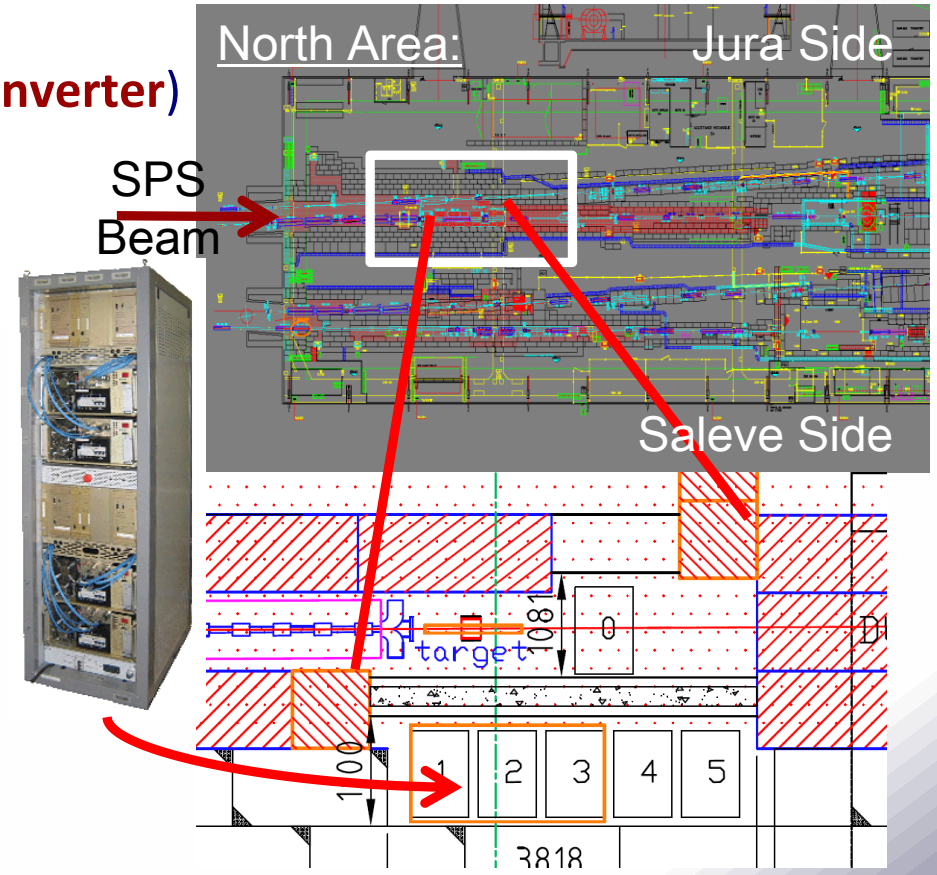


IR7 Performed Mitigation Actions

- **Shielding installed:** [ECRs: 985313 and 977085]
  - RR73/77 (**we gained ~factor 10 in radiation levels**)
  - UJ76 (**we gained ~factor 10 for safe-room, 3-4 for the 1st floor**)
- **Relocation of UPS from UJ76 (safe) [ECR: 977085] (safety critical at that time!)**
- **Relocation of fire control racks (safe) (possible impact on safety not excluded):**
  - UJ76 -> TZ76 (see ECR 1126688)
- **Relocation of fire detectors (possible impact on safety redundancy):**
  - Prepared for UJ76 and RR73/77 (see ECR 1126688)
- **Relocation of EN/EL control equipment (safe)**
  - RTU relocated from safe room in UJ76 -> TZ76
- **Rack installation & cabling preparations: UJ76 -> TZ76**

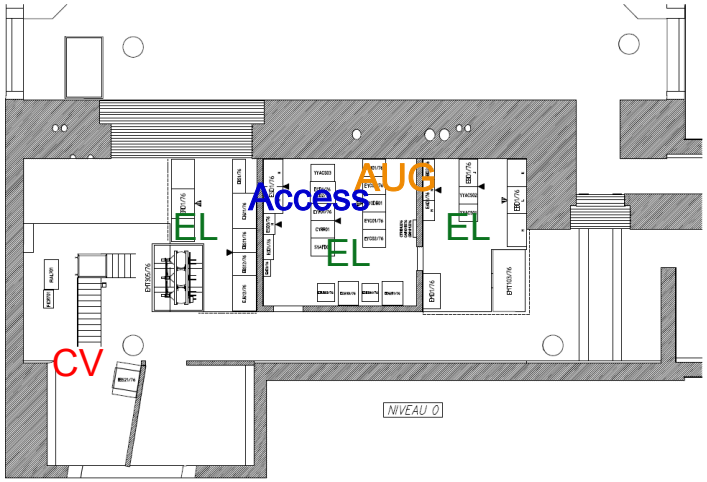
Power-Converters & Tolerance

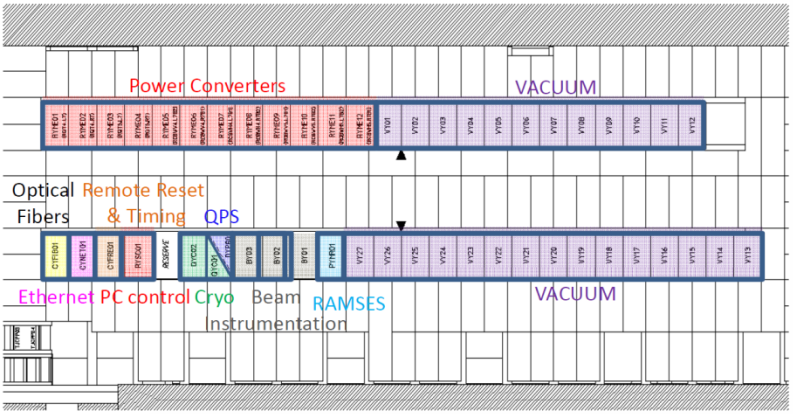
- **Parts have been tested at CNRAD**
  - Expected sensitivity ~1x10^{-8}
    (= **one failure every ~1x10^{8}cm^{2} per converter**)
- **LHC Observations**
  - **so far four failures confirmed as SEE**
    (sensitive module: AC/DC part)
- **New Test-Area H4IRRAD:**
  - Commissioning ongoing these days
  - LHC-like conditions (spectra)
  - About 1 year of nominal LHC within one week of test
  - **Results after the summer!**
    (if we get sufficient beam!)
- **What will we learn:**
  - confirm LHC observations
  - verify weak links and investigate patch-solutions
    (important for 2012
    and 2014/15/16 operation)
  - **optimize global mitigation strategy**

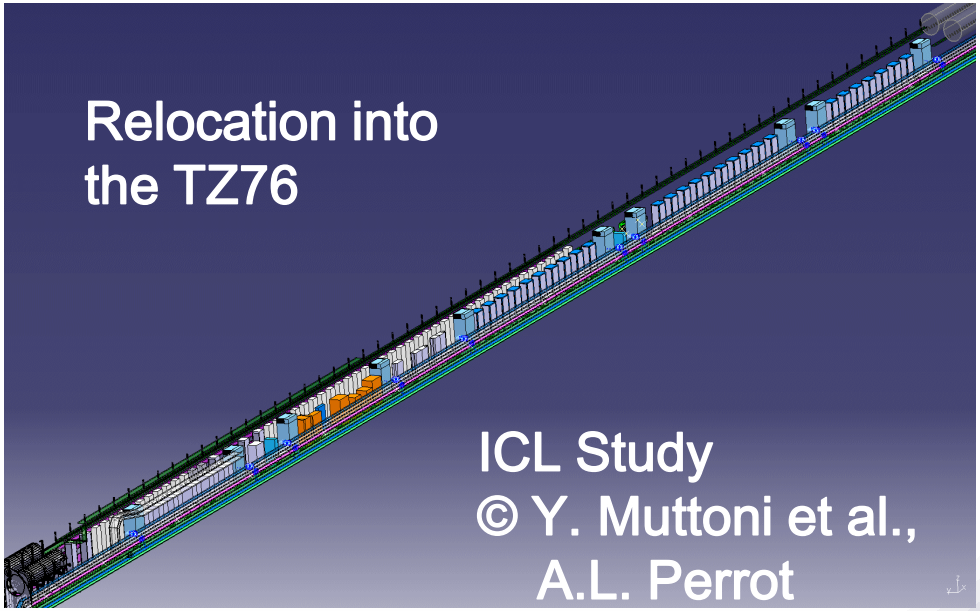


Power-Converter's are the Key Point for the final R2E Mitigation Strategy

UJ76 Relocation







- Cabling Bottleneck in UJ76/TZ76 Junction
- Safe-Room equipment & 'Safety Review'

RRs: Power-Converter R&D

- TE-EPC Planning for Rad Tolerant Converter Project

© Y. Thurel

Project	2011	0	2012	1	2013	2	2014	2015	2016
R2E-FGClite	Design, component Choice		Prototype, demo test		Pre-series Rad Tests		Production/ installation	Installation	
R2E-Rad-DIM	Design, component Choice		Pre-series Rad Tests		Production/ installation		Prod Installation	Installation	
					Prod				

HC120A-10V Rad-Tol	Risk Analysis on existing converters Rad test	Modification of existing part or total redesign.	Pre-series Rad Tests	Production	Production, Recep. Tests &	Tunnel Install Commissioning
H600A-10V Rad-Tol	Pre-Design Technical Study, Solution & Principles	Mechanical, prototype, demo board	Pre-series Rad Tests	Production	Production, Recep. Tests &	Tunnel Install Commissioning

-LHC4-6-8kA-08V Rad-Tol	Pre-Design Technical Study, Solution & Principles	Mechanical, prototype, demo board	Pre-series Rad Tests	Production	Production, Recep. Tests &	Tunnel Install Commissioning
						Prod
Rad-Tol Analogue Studies	Component Selection, Component testing, bibliography, theoritical analyze...		Testing of demo board, critical fctions			

Link: R2E Power Converter R&D

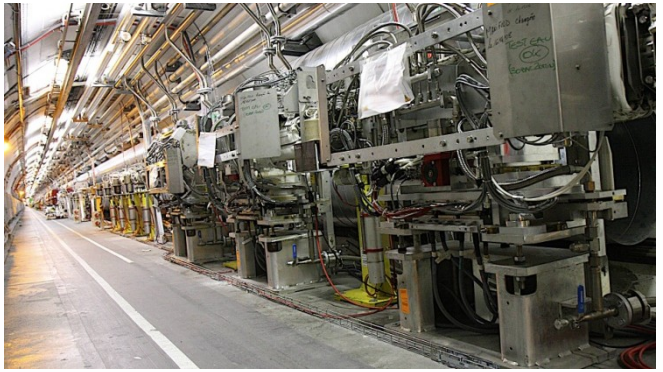
Int/Ext Review **Stop** / **Go**

RRs Additional/Alternative Options

Betatron Collimation in IR3

© R. Assmann *et al.*

- No significant SEE impact for IR3
- Low radiation levels in IR7
- Additional flexibility
- Standard collimators to be added



R&D for Superconducting Links

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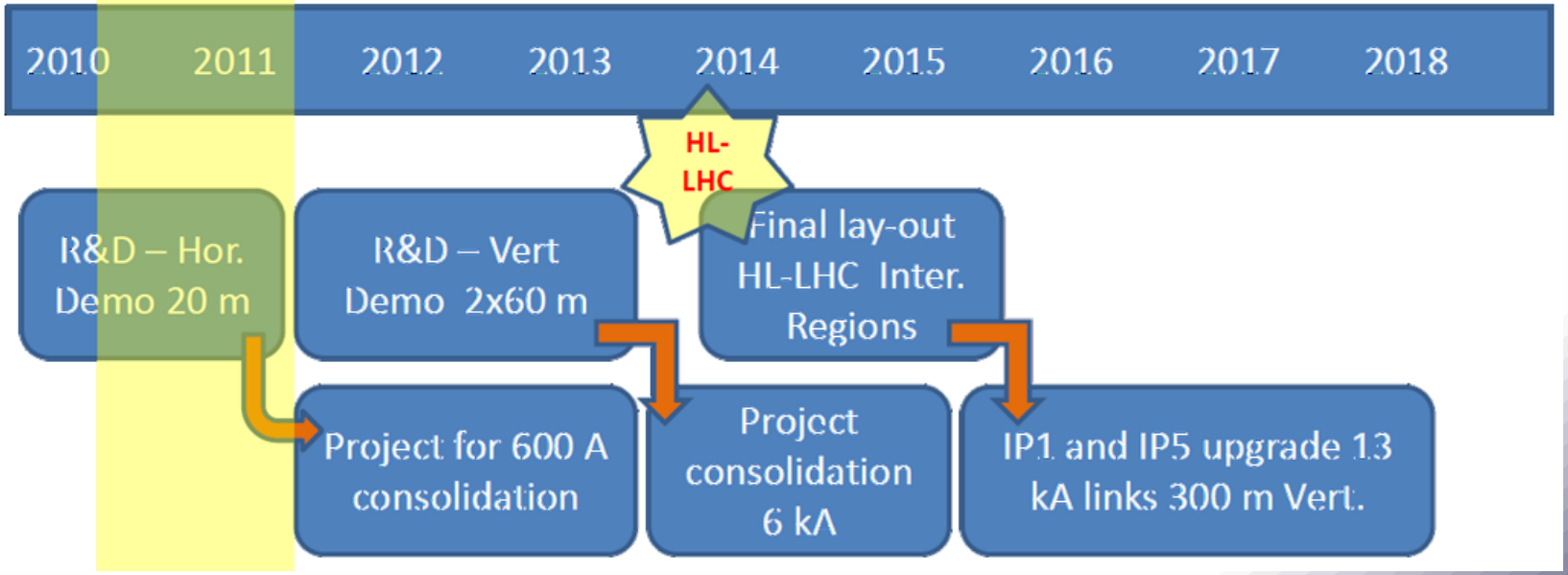
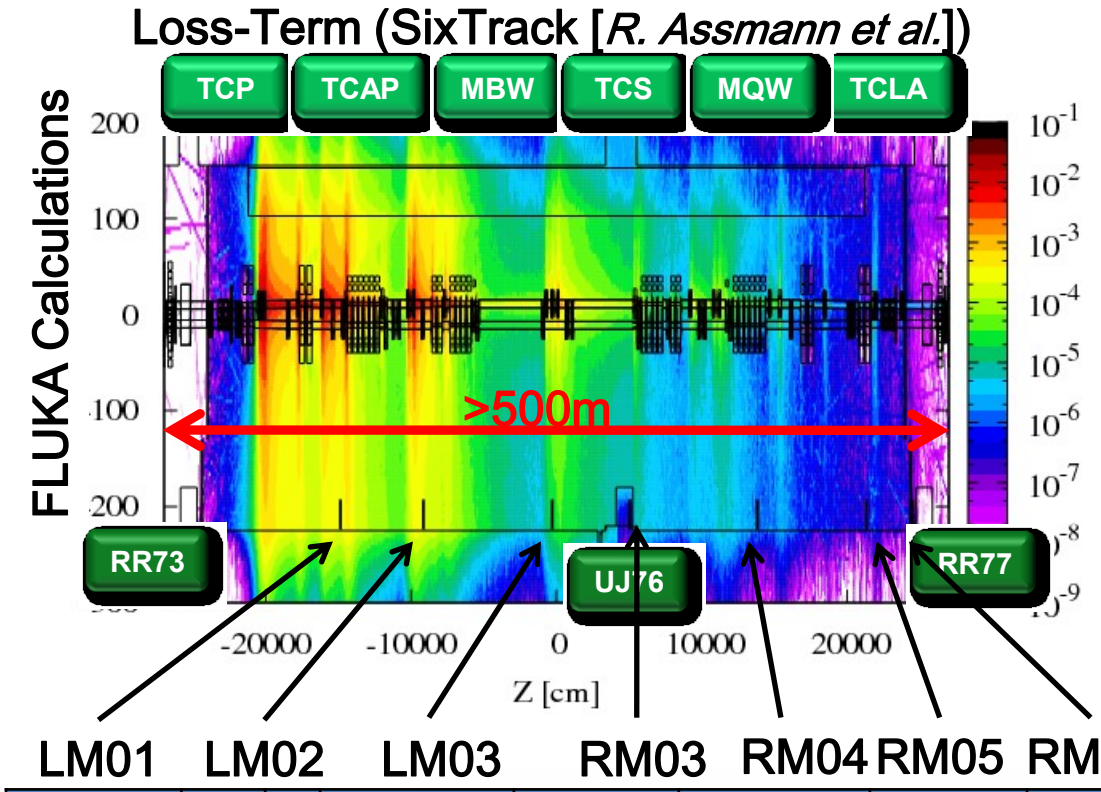


IR7 FLUKA Application Benchmark

© K. Roeed



→ Assumptions

↓

Normalisation

RadMon	Dcum	Rth	SEU (3V) Measured	Beam contribution	SEU (FLUKA) Expected	Error [%] Stat. only	Exp./Mes.
6L7.7**LM03**S	19846	5	14401	**B1**	15015	3	**1.04**
5L7.7**LM02**S	19904	3	5253	**B1**	9765	3	**1.86**
4L7.7**LM01**S	19991	5	2689	**B1+B2**	3116	6	**1.16**
4R7.7**RM03**S	20045	3	950	**B1+B2**	401	6	**0.42**
5R7.7**RM04**S	20133	5	18727	**B2**	13032	4	**0.70**
6R7.7**RM05**S	20208	31	303	**B2**	962	8	**3.17**
RR77.7**RM06**S	20241	1	13	**B1+B2**	17	22	**1.33**

2010 Operation

Summary (Protons)		
In	6.02E+15	
Dumped	5.82E+15	96.70%
Lost in Machine	1.99E+14	3.30%
Of Lost protons		
Collisions	2.33E+13	11.73%
Elsewhere	1.76E+14	88.27%

BLM ratio IR7 / IR3		
	Ratio	**% Loss in IR7**
TCSG.A6L7.B1 / TCSG.5L3.B1	3.1	**76**
TCSG.A6R7.B2 / TCSG.5R3.B2	5.6	**85**

Radiation: Where are we Today?

- **Combined Loss Analysis** © A. Nordt, A. Thornton (BLMs & Injected/Dumped Intensities):
  - IR3 lost in 2011: ~6E13 protons (per beam)
  - IR7 lost in 2011: ~2E14 protons (per beam)
- We're a **factor of ~50x below nominal** (~1x10^{16}p/b/y)

Latest Weekly Report (www.cern.ch/r2e)

RRs	*shielded areas*		*tunnel*	
	HEH (cm-2/w23)	HEH (cm-2/2011)	HEH (cm-2/w23)	HEH (cm-2/2011)
13	<1.0E+6	1.6E+06	1.0E+07	6.2E+07
17	<1.0E+6	1.8E+06	8.6E+06	5.4E+07
53	<1.0E+6	2.0E+06	2.6E+07	7.6E+07
57	<1.0E+6	1.8E+06	1.2E+07	6.4E+07
73	<1.0E+6	2.3E+06	<1.0E+6	<1.0E+6
77	<1.0E+6	3.4E+06	2.4E+07	8.1E+07

UJs	*shielded areas*		*tunnel*	
	HEH (cm-2/w23)	HEH (cm-2/2011)	HEH (cm-2/w23)	HEH (cm-2/2011)
14 (13, tun)	9.1E+06	4.0E+07	2.8E+10	2.7E+10
16 (17, tun)	6.3E+06	3.0E+07	2.1E+09	3.7E+10
22	N/A	N/A	5.2E+07	7.8E+08
23	<1.0E+6	<1.0E+6	1.4E+07	9.5E+07
32	N/A	N/A	<1.0E+6	<1.0E+6
33	<1.0E+6	<1.0E+6	<1.0E+6	<1.0E+6
56	<1.0E+6	7.5E+06	2.7E+09	1.2E+10
76	<1.0E+6	<1.0E+6	1.2E+09	5.7E+09
87	<1.0E+6	<1.0E+6	3.7E+08	1.9E+09
88	N/A	N/A	3.6E+07	6.1E+08

RR73/77: ~2-3x10^{6}cm^{-2}
UJ76: ~1x10^{6}cm^{-2}

Scaling: x75 (Energy!)

Nominal Year:
RR73/77: ~2x10^{8}cm^{-2}
UJ76: ~8x10^{7}cm^{-2}

- **Can nominal operation lead to 'relatively' higher losses?**

Conclusion

Performed mitigation options	☑ very efficient
2011/12 Operation	☑ not limited by IR7
UJ76 relocation	☑ next step (safety)
Power-converter tests & R&D for RadTol Dev.	➡ high-importance to judge for RRs
Betatron collimation in IR3	↷ Would provide additional flexibility

Backup

Possible SEE Failures Observed in 2010

CONFIRMED or very LIKELY

WIC crate failure in TI8
Observed in 2009
Known problem with moderate x-section

QPS Tunnel Card Failures
(2x in 9L7 [ions], 2x in 8R8 [inj.], + others)
ISO150 -> permanent PM trigger
SEE confirmed (EMC has same effect)

QPS tunnel Card Failures in 9R7 & 9L7
uFip communication lost (2x)
SEE confirmed (seen in CNRAD)

CRYO tunnel card SEE in 8L2
1 Fault in uFip
(as observed in CNRAD 2010)
SEE confirmed

TE/EPC power supply burnout in UA87
Same effect observed in CNRAD
SEE is very likely the cause
(Streaming through Maze)

NOT CONFIRMED (unlikely)

VAC power supply burn out
In UA23 between maze and duct
(TDI losses + TCDI losses)
SEE rather unlikely

~~**PXI power supply burnout in UJ16**~~
~~To be confirmed by producer~~
~~(comparison with CNRAD burnouts)~~
~~SEE unlikely (early 2010 operation)~~

Failures 2011 [Mitigation]

- Collimation Control UJs@P1 (**3x, confirmed**) [Soft + Relocation]
- Cryogenics UJ14/16/56/76 (**several confirmed**) [Relocation]
- Biometry UJ14/16 (**2x, likely**) [Operation + Rel.?]
- US85 PLCs (Cryo, **3x, confirmed**) [Relocation]
- Power Converters (**4x, TE/EPC**) [New Develop.]
- UPS UJ56/US85?(**unlikely, but possible**) [Relocation]
- QPS Control UJ14/16 (**few, corrector circuits**) [Relocation]
- QPS ISO-150 (**many, tunnel & shielded areas**) [Soft + New Develop.]
- uFIP as used in QPS/Cryo (**few times, tunnel + shielded areas**) [Soft + New Develop.]

- Limitation-1: SEEs which are not SEEs?
- Limitation-2: hidden failures (not related to SEEs, caused by 3rd party equipment with indirect impact, *e.g.* Ethernet Switches)?

Power Converter Failures

ID-Power Module (Logbook Link)	LOCATION	LOOGBBOOK ID	DATE	TRIP TIME	LOGBOOK RECORD	LAB A7 REPAIR ANALYZE	SEE Confidence
RPMBB.UJ14.RQSX3.L1	**UJ14**	51648	**06/10/11**	00:51	**REMOTE:** > TRG: OUTPUT_STAGE_POWER_SUPPLY > TRG:AUX_POWER_SUPPLY_/_FANS + FABORT_UNSAFE + RESET IMPOSSIBLE **INTERVENTION:** - Converter seems dead (no LED)- AC Breaker not tripped - Aux PSU Crash suspected	AC-DC Crash	100
RPMBB.UJ14.RCBXV3.L1	**UJ14**	51611	**06/04/11**	16:19	**REMOTE:** > TRG: OUTPUT_STAGE_POWER_SUPPLY > TRG:AUX_POWER_SUPPLY_/_FANS + FABORT_UNSAFE + RESET IMPOSSIBLE **INTERVENTION:** - Converter seems dead (no LED)- AC Breaker not tripped - Aux PSU Crash suspected	AC-DC Crash	100
RPMBB.RR17.ROD.A12B1	**RR17**	51354	**04/30/11**	08:20	**REMOTE:** > TRG: FAST_ABORT > TRG:AUX_POWER_SUPPLY_/_FANS + FABORT_UNSAFE + RESET IMPOSSIBLE **INTERVENTION:** - Converter seems dead (no LED)- AC Breaker not tripped - Aux PSU Crash suspected	AC-DC Crash	100
RPMBB.UA87.RCBXV2.R8	**UA87**	49390	**11/03/10**	13:49	**REMOTE:** > TRG:AUX_POWER_SUPPLY_/_FANS + FABORT_UNSAFE + RESET IMPOSSIBLE **INTERVENTION:** - Converter seems dead (no LED)- AC Breaker not tripped - Aux PSU Crash suspected	AC-DC Crash	100

LHC POWER CONVERTERs

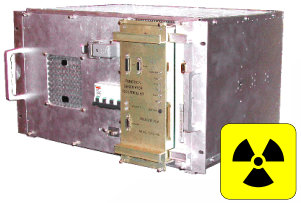
- Minimize the number of converter types:
  - Only the LHC60A-08V was specified for a radioactive environment !
  - 3 other converter types are part now of the radioactive sensitive areas!

LHC120A-10V
4-Quadrant
300 Units

LHC600A-10V
4-Quadrant
400 Units

LHC4..6kA-08V
1-Quadrant
200 Units

LHC60A-08V
4-Quadrant
752 Units



Units : Quantity in all machine (UA, RR, UJ, tunnel)

Radiation Levels 2010

- Source terms, operational conditions as well as monitor readings have to be carefully evaluated

Threshold of monitors is ~10^6!
(lower values only by 'trick' [big uncertainties!])

VERY GOOD AGREEMENT (given the underlying uncertainties)

	FLUKA & Operation		MEASUREMENTs	
	2010 using 2009 estimations	2010 with actual operation	2010 with RadMON (FLUKA r)	2010 with RadMON (TLD r)
UJ14 UJ16	2.5E+06	1.3E+06	1.6E+05	1.1E+06
RR13 RR17	5.0E+05	2.5E+05	1.0E+05	6.2E+05
UJ56	2.5E+06	1.3E+06	2.1E+05	
RR53 RR57	5.0E+05	2.5E+05	1.0E+05	6.2E+05
UJ76	6.9E+06	1.1E+06	5.9E+05	2.1E+06
RR73 RR77	3.4E+06	5.7E+05	2.1E+05	3.1E+06
UX85b	1.0E+07	1.3E+07	4.8E+07	1.0E+07
US85	5.0E+06	6.3E+06	3.6E+06	2.9E+06

2010/2011/2012 Radiation Levels

	FLUKA & Operation		MEASUREMENTs		FORECAST			
	2010 using 2009 estimations	2010 with actual operation	2010 with RadMON (FLUKA r)	2010 with RadMON (TLD r)	2011	2012	NOMIN	ULTIM
UJ14 UJ16	2.5E+06	1.3E+06	1.6E+05	1.1E+06	7.2E+07	1.2E+08	2.1E+09	4.2E+09
RR13 RR17	5.0E+05	2.5E+05	1.0E+05	6.2E+05	4.3E+07	7.1E+07	1.2E+09	2.5E+09
UJ56	2.5E+06	1.3E+06	2.1E+05		1.7E+07	2.9E+07	5.0E+08	1.0E+09
RR53 RR57	5.0E+05	2.5E+05	1.0E+05	6.2E+05	4.3E+07	7.1E+07	1.2E+09	2.5E+09
UJ76	6.9E+06	1.1E+06	5.9E+05	2.1E+06	4.7E+07	8.0E+07	7.4E+08	8.3E+08
RR73 RR77	3.4E+06	5.7E+05	2.1E+05	3.1E+06	6.9E+07	1.2E+08	1.1E+09	1.2E+09
UX85b	1.0E+07	1.3E+07	4.8E+07	1.0E+07	9.4E+07	1.9E+08	3.3E+08	3.3E+09
US85	5.0E+06	6.3E+06	3.6E+06	2.9E+06	2.7E+07	5.4E+07	9.4E+07	9.4E+08

!!! Amazing !!! Close to 'Threshold' Critical Dramatic?

IP8/TI8 Radiation Detectors

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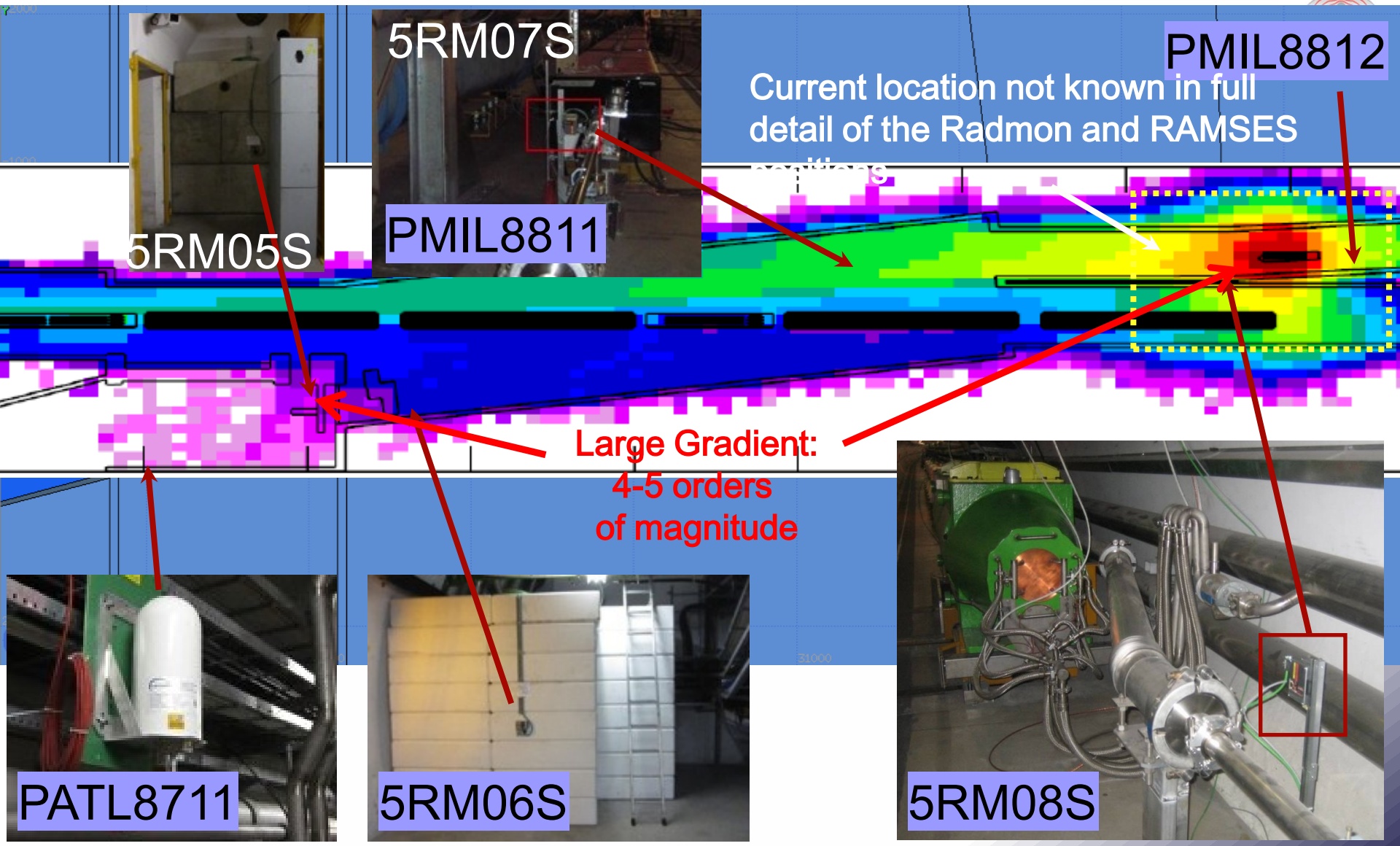
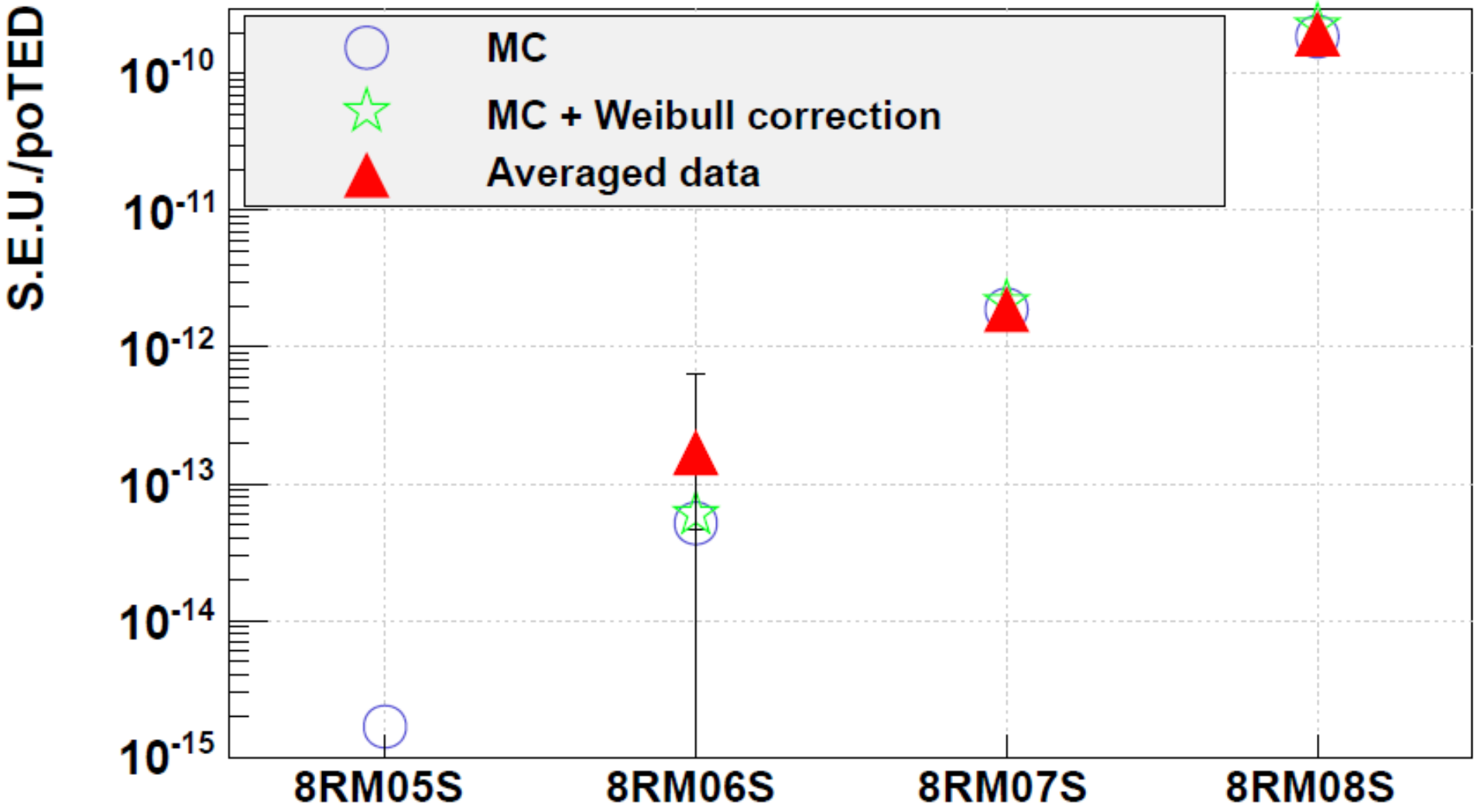


TED Loss: RadMon Downstream



UJ87: Loss on TCDIH.87904

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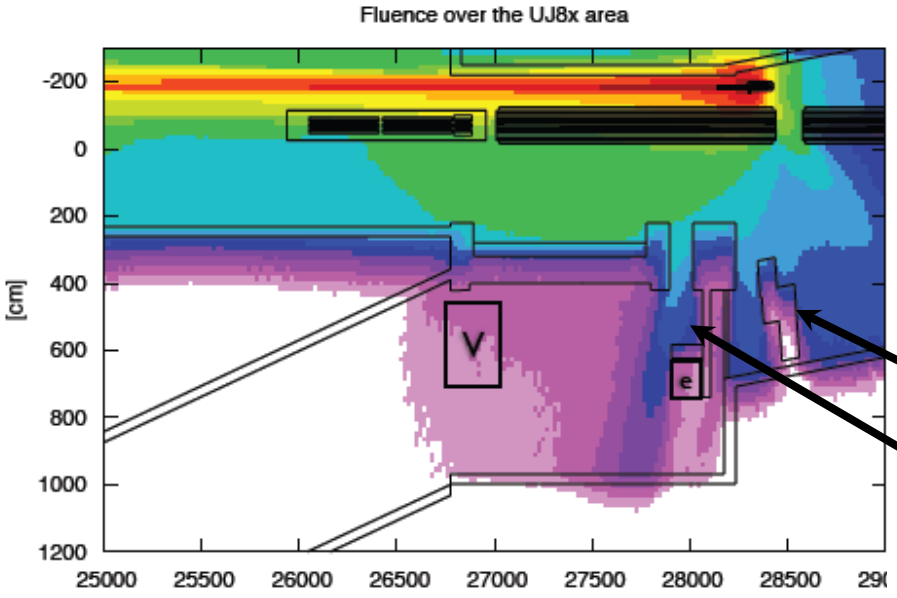

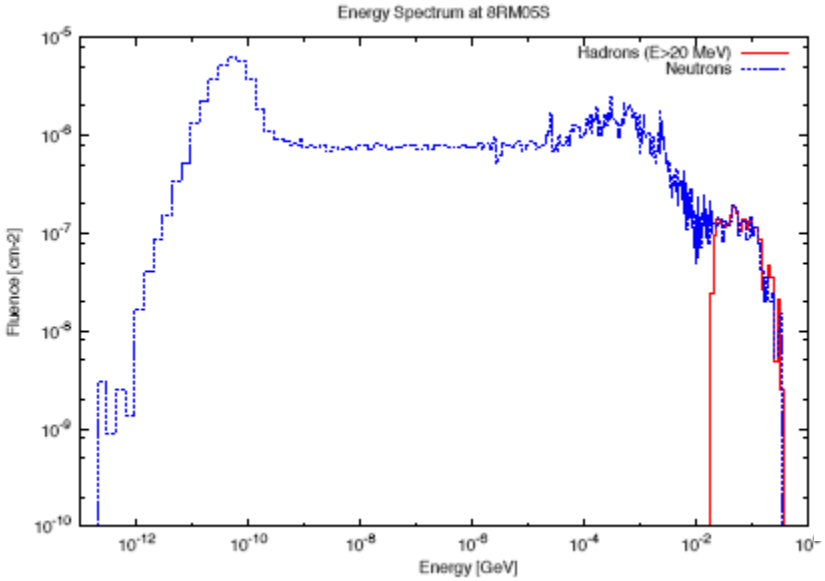

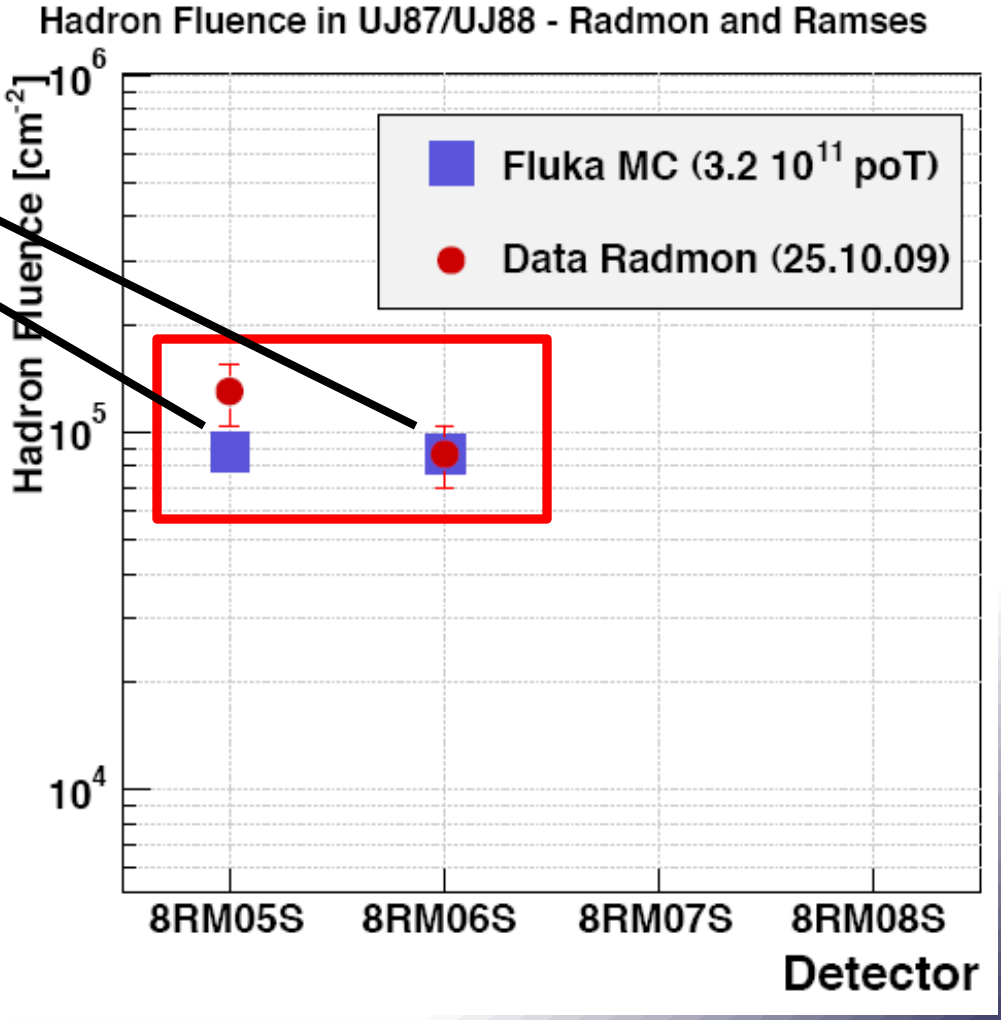

Point-8 Application Benchmark

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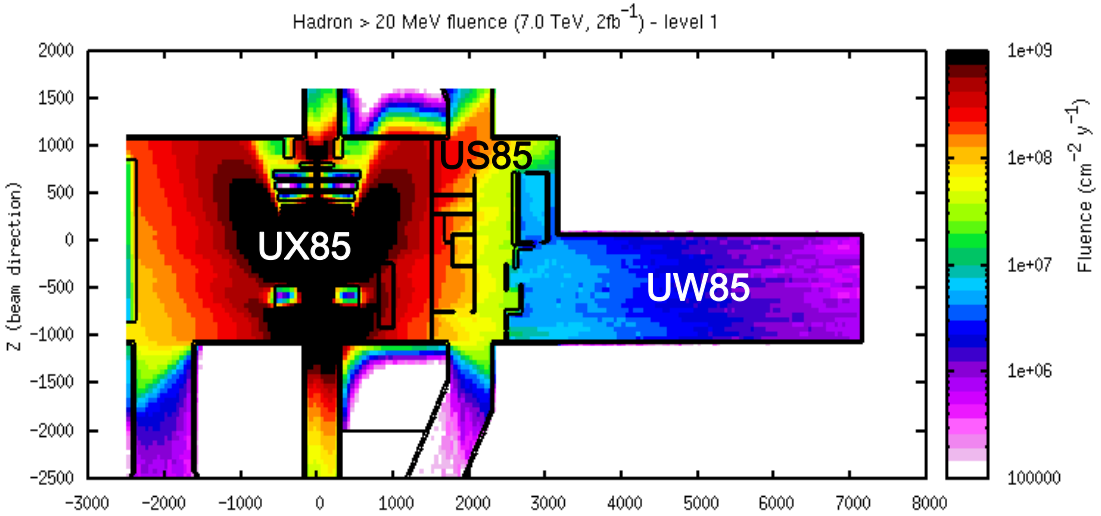

FLUKA/RAMSES benchmark

Detector	Measured dose (μSv/h) @10.6MHz	Ratio (meas/simu)
PMI8501 (UX85)	24.0	1.1
PMI8511 (UX85)	120.0	0.8
PAT8511 (US85)	36.7	0.6

FLUKA/RadMon benchmark

Detector	Ratio (FLUKA exp/measure)
8LE10S	1.6
8LE07S	2.0
8LE04S	1.6
8LE08S	2.2

FLUKA Simulations provide high energy hadron fluence, dose and 1 MeV Si equivalent in the LHCb cavern according to the Phase-2 shielding implementation proposed in the R2E Project

- Very good agreement with PMIs and PATs RAMSES detectors
- RadMons set at 3V more difficult (at low count rates)
- Significant uncertainties to be considered (thermal neutron contribution, detector geometry, etc…)
- Uncertainty at least a factor of 2