Review of Critical Radiation Areas for LHC Electronics and Mitigation Actions Radiation Monitoring and First Results

Radiation 2 Electronics

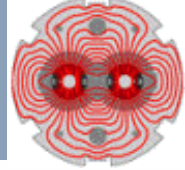
Session 6 - 27th January 2010

Chamonix 2010
January 27th

!! Many Thanks To Everybody !!!

R2E Study Group
www.cern.ch/r2e

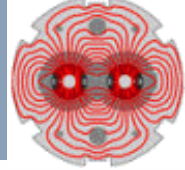
The Logical Approach



- **Radiation Levels (critical areas versus time)**
- Electronics (designed, COTS)
- Expected Sensitivity, Failure Cross-Section and Failure Rates → Talk T. Wijnands
- Failure Consequences
- **Early Monitoring (what can we learn to optimize)**
- **Mitigation options**
  - shielding (simple + complex)
  - relocation
  - rad-toldesign → Talk Y.Thurel, Talk J. Serrano
  - civil engineering options
  - SCL
- Operational Assumptions / Scenarios → After Chamonix?
- **How to compare the various options**
  - costs (high uncertainties) + time (not better)
  - remaining risk or not
  - sustainability and other long-term advantages
  - how to fit in operational planning

Summary in Talk R. Losito

Overview



Monitoring – "Benchmarking"– Early Operation :

- Experience from **Commissioning**
- **Calibration** of RadMons and Benchmarks
- The LHC **Radiation Environment**

What do we have to do more?

(Quick!) Review of Radiation Levels:

- Some examples of new **FLUKA Calculations**
- Summary as a function of '**LHC-Operation**'
- **Criticality List**

What is critical when?

Mitigation Options:

- How much can we do with **Shielding ('Simple' and 'Complex')**
- Where is **Relocation** required
  - **Early** Relocation
  - **Complete** Relocation
- What **Other Options** do we have (Civil Engineering, SCL)

What can we do about it?

Monitoring
&
Benchmark

Some Parts in Short

RadMon Improvements

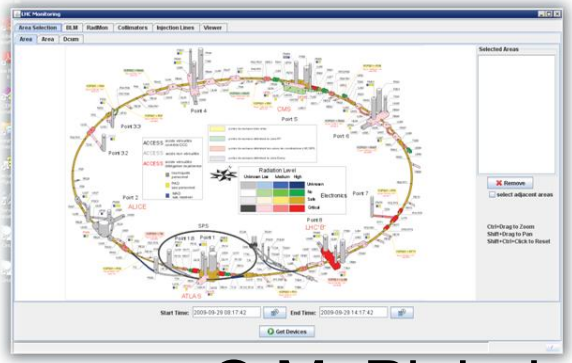
- Refined **Calibration** (benchmark experiments, dedicated tests,…)
- **Relocation** of detectors to allow for better early measurements
- The LHC **Radiation Environment**
- Change of **Voltage Settings**
- New **RadMon Developments (e.g., Battery Driven Version)**

Inventory & Additional Monitoring

- Through Point-Iterations **monitor locations** were checked & documented -> visualisation tool suggested (to be developed)
- more than **200 TLD detectors** placed around critical areas
- will allow for an **early analysis at even low-intensities**
- we will start collecting them in late-summer

Combined Monitoring Tool (see link):

- **Beta-Release** of Combined Monitoring Tool
- Allows for quick analysis of various detector types
- Extensively used during early operation
- **Not only useful for R2E purposes**



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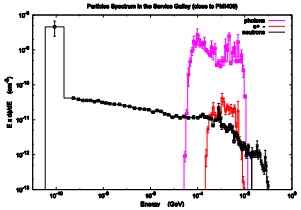
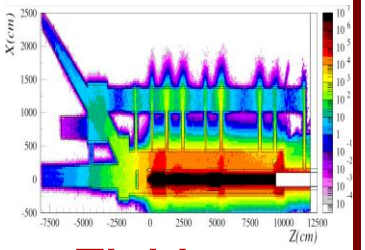
Radiation Physics/Effects/Monitoring

nuclear cascade

h > 20 MeV





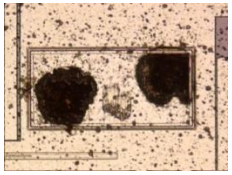
Radiation Field

h, e,.. > 100 KeV

EM cascade

radiation damage in semiconductors

Single Events



Effect in the Device

Displacement

Dose

Radiation Monitor

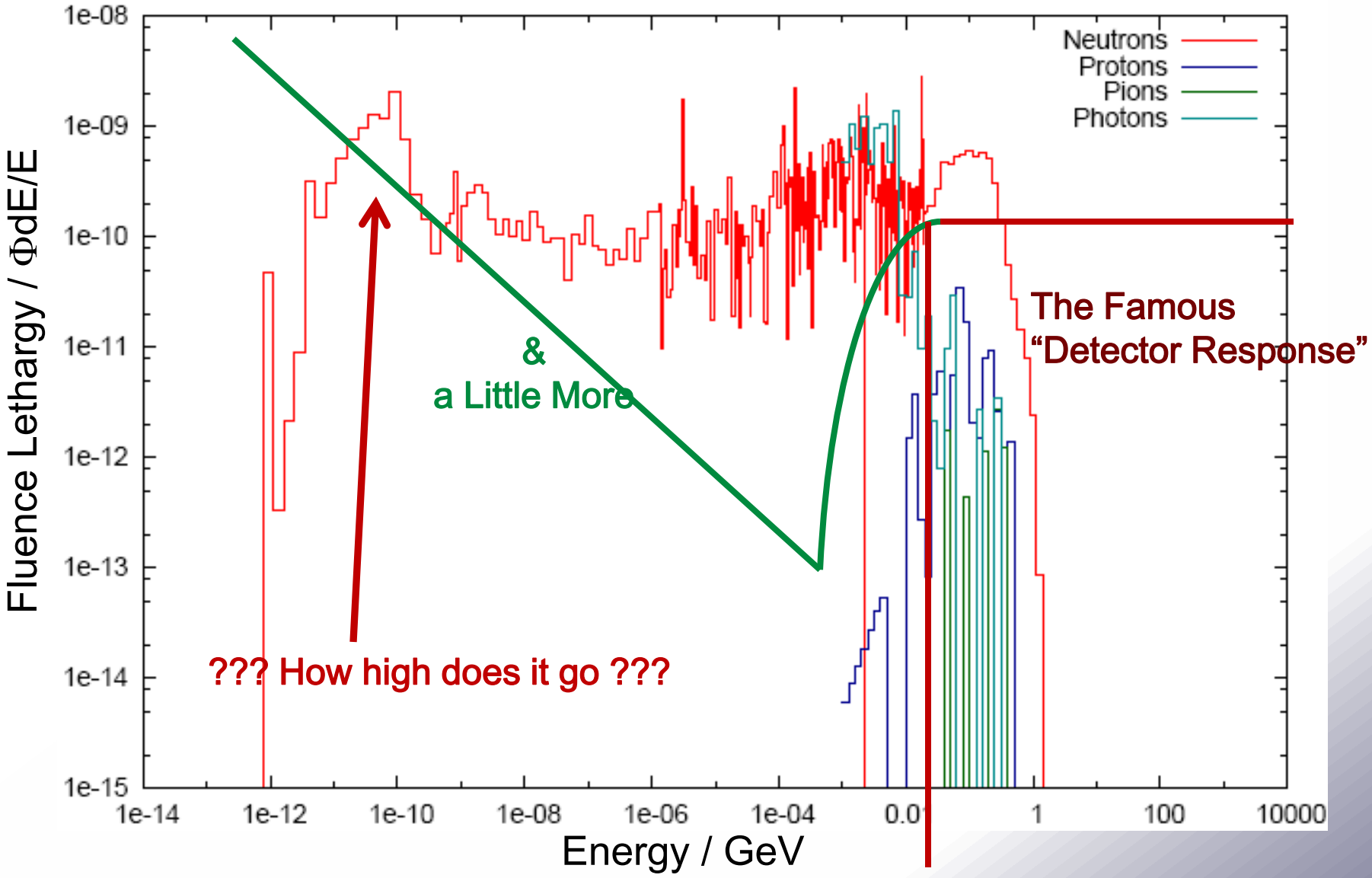
SEU counter

Measurement

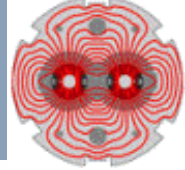
PIN Diodes

Radfet

Reality Is Complicated (e.g., UJ76)



The Risk of Low-Energy Neutrons



- Having a look in literature

DEVICE SEU CROSS SECTIONS, FROM THERMAL AND HIGH ENERGY NEUTRONS, CURRENT MEASUREMENTS

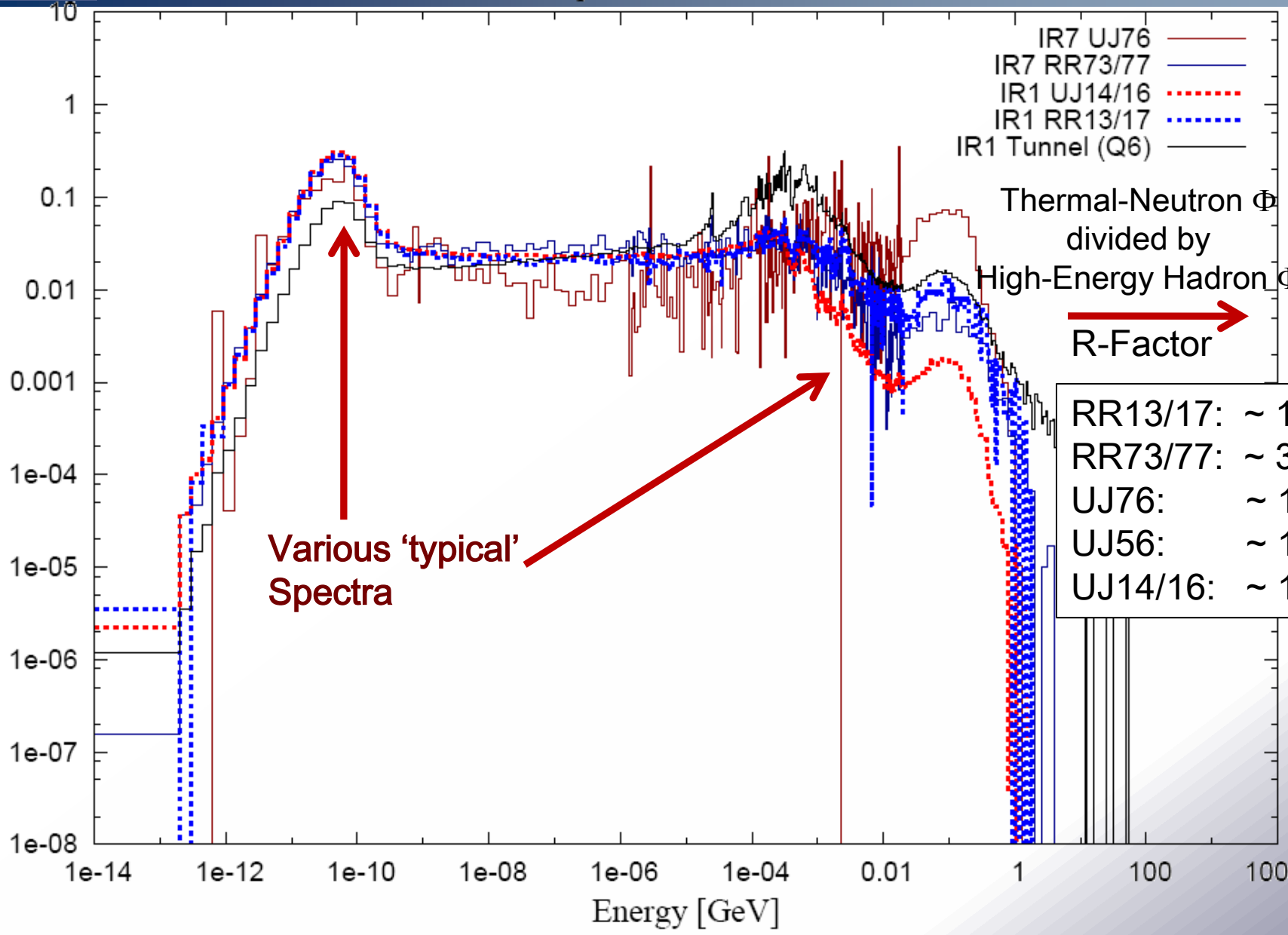
Part	Type	Vendor	DC/ Feat Size	Hi E SEU X-Sec, cm²/bit§	Therm SEU X-Sec, cm²/bit	Ratio-SEU, Therm/ Hi E
S-1	SRAM	VS-1	0446/0.15µ	2.1×10^{-14}	3.3×10^{-16}	1.6×10^{-2}
S-2	SRAM	VS-1	0446/0.15µ	7.9×10^{-15}	1.7×10^{-19}	2.2×10^{-5}
D-1	DRAM	VD-1	0446/0.15µ	6.4×10^{-17}*	1.3×10^{-15}	20
D-2	DRAM	VD-1	0422/0.13µ	2.95×10^{-16}*	1.18×10^{-16}	0.4
P-1	µprocess	VP-1	0240/0.18µ	1.5×10^{-14}	2.2×10^{-17}	1.5×10^{-3}
P-2	µcont.	VP-2	0439/0.13µ	1.02×10^{-3}†	1.68×10^{-5}†	1.7×10^{-2}
P-3	µcont.	VP-2	0532/0.15µ	6.99×10^{-4}†	6.03×10^{-6}†	8.6×10^{-3}
P-4	µcont.	VP-2	0341/0.18µ	1.54×10^{-4}†	1.34×10^{-5}†	8.7×10^{-2}
P-5	µprocess	VP-3	0311/0.18µ	1.3×10^{-15}	No upsets	0

† In units of Upset/dev-hr ;
* No actual upset detected; cross section based on 1 assumed upset
§ E> 10 MeV

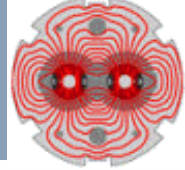
IEEE Trans. on Nucl. Sci., Vol 5, p. 3587-3595

- Sensitivity ranges over four order of magnitudes
  - Some: similar or larger xSection
  - Others: a factor of 10-100 or further below
- How does is compare to our particle energy spectra?

What's about the Critical Areas



The Risk of Low-Energy Neutrons

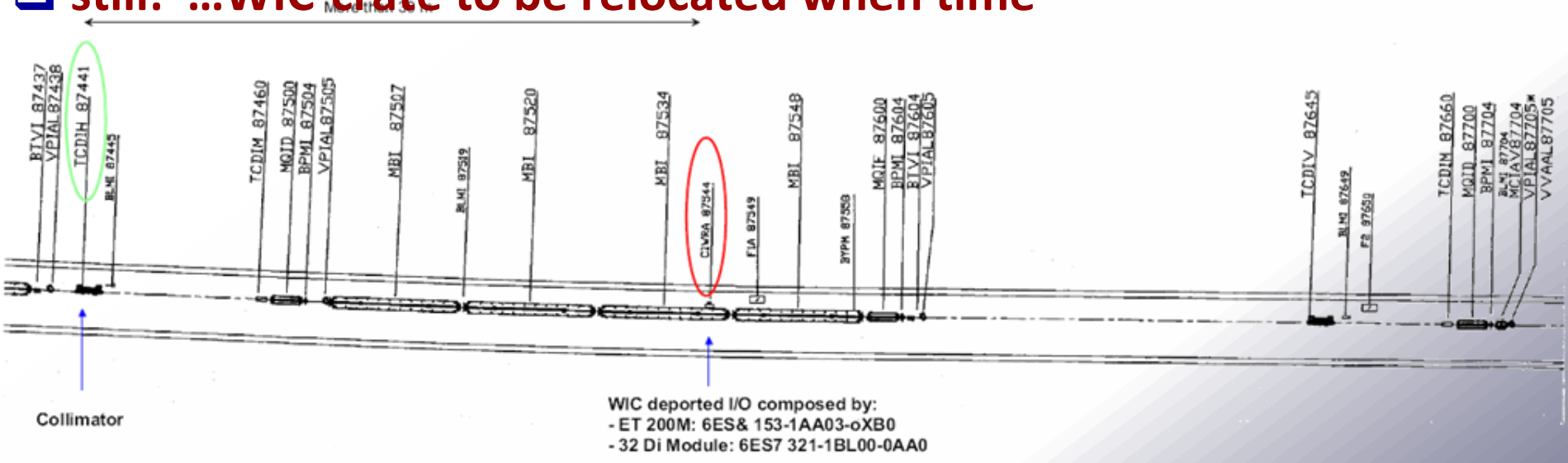


- The **Risk of low-energy neutrons can't be excluded**
  - after shielding and with similar cross-sections dominant
  - significant contribution even with a cross-section of a factor of 10-100 less
- Important **criteria for shielding and relocation** approaches
- **Only preliminarily studied so far** (main concern to reduce the high-energy hadron fluence – still helps for low energy neutrons)
- Different **shielding strategies** (Boron, …)
- **Risk:**
  - important for old components possibly containing borated glass
  - also not to be excluded for new COTS, etc…

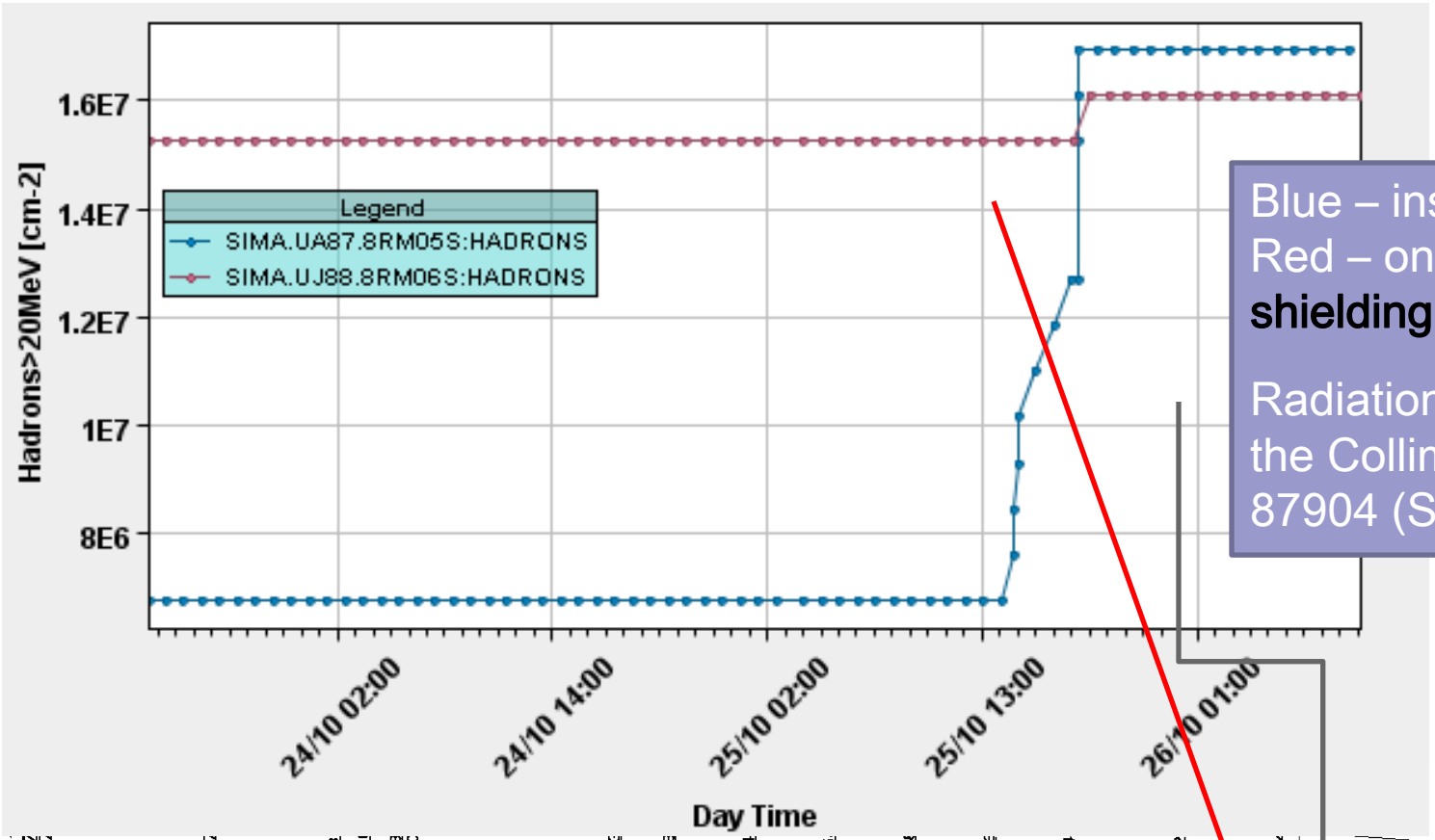
Do we have Early Measurements?

WIC Failure during TI8 Injection Test

- **WIC failure observed in June (stopped CNGS and LHC Injection)**
- **Immediate analysis** of available measurement data
- **FLUKA simulations:** respective radiation levels (10^{8}-10^{9}cm^{-2})
- Detailed review of WIC layout and available test measurements
- **Analysis confirmed that the failure was very unlikely**
- During the additional **TI2/8 test about 4x10^{13} protons** were 'dumped' on the upstream collimator **-> no WIC failure observed**
- **still: …WIC-crate to be relocated when time**

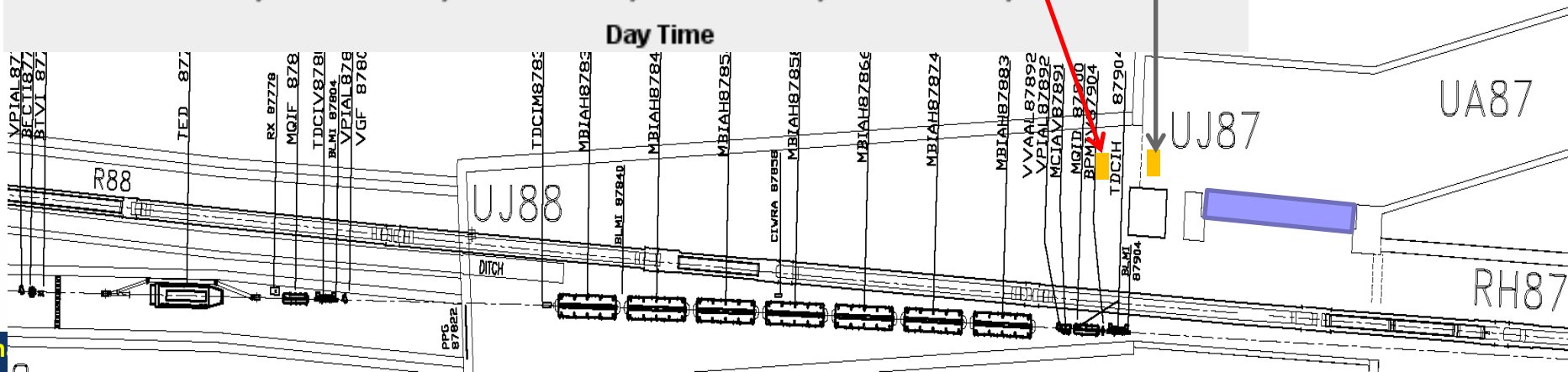


UJ87: setup of TCDIH.87904

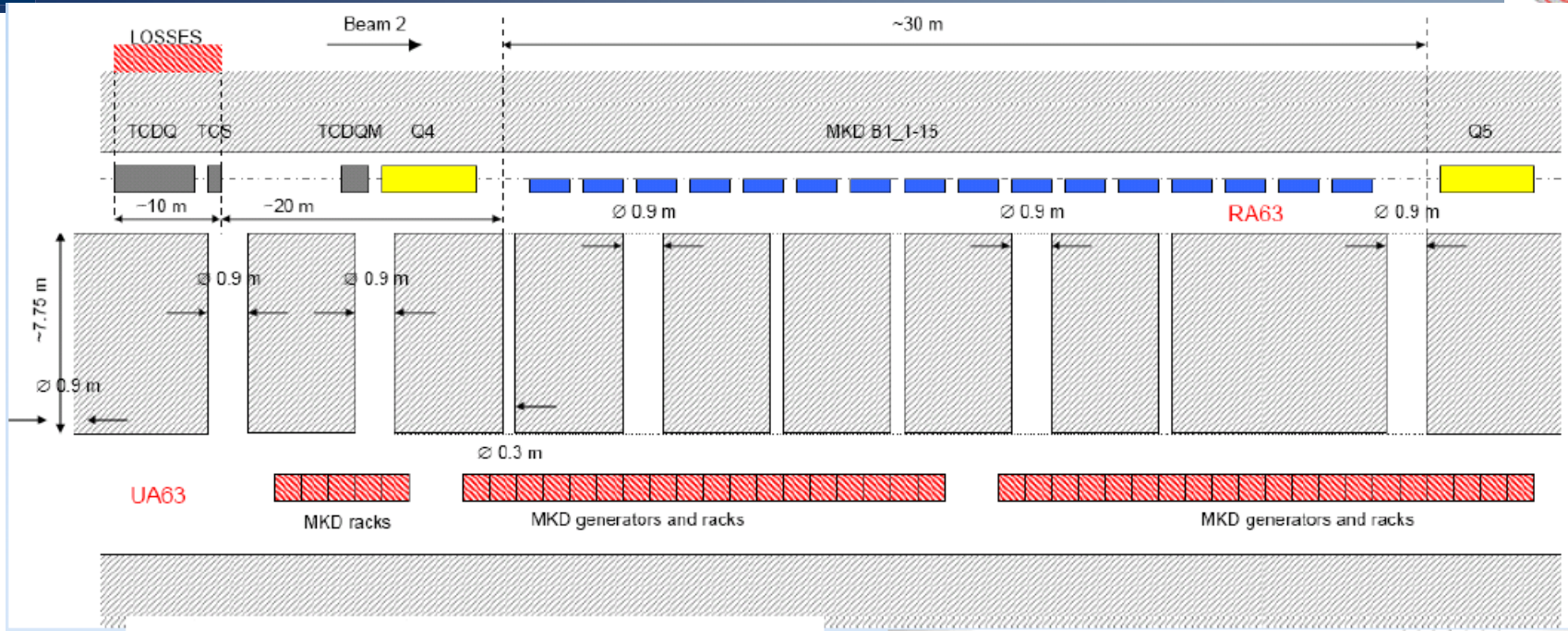


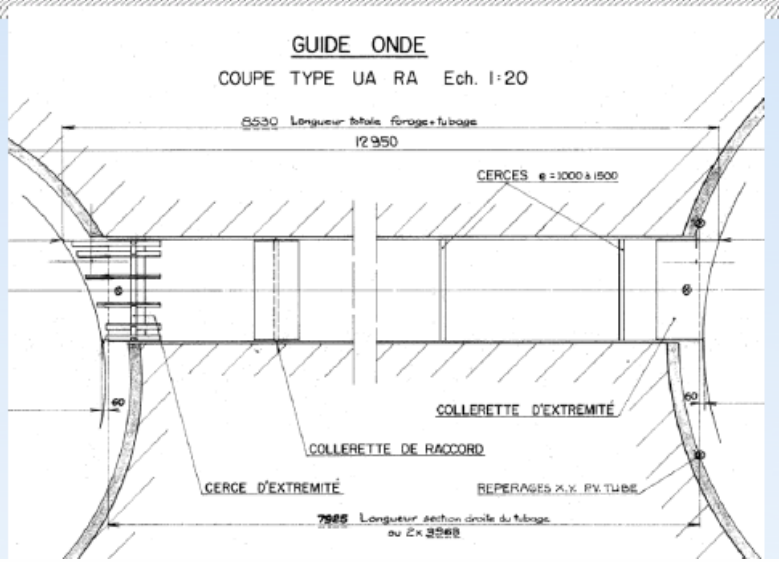
Blue – inside UJ87 (3V)
Red – on the **new shielding in UJ88** (5V)

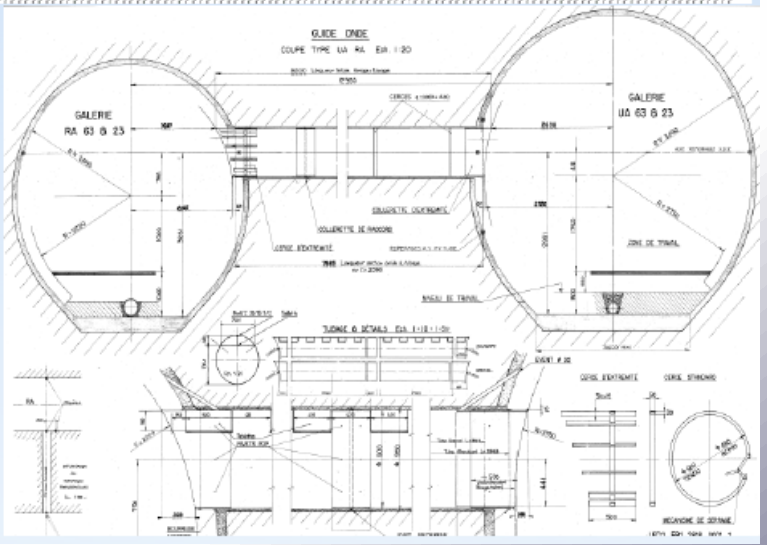
Radiation directly from the Collimator TCDIH 87904 (Setup)



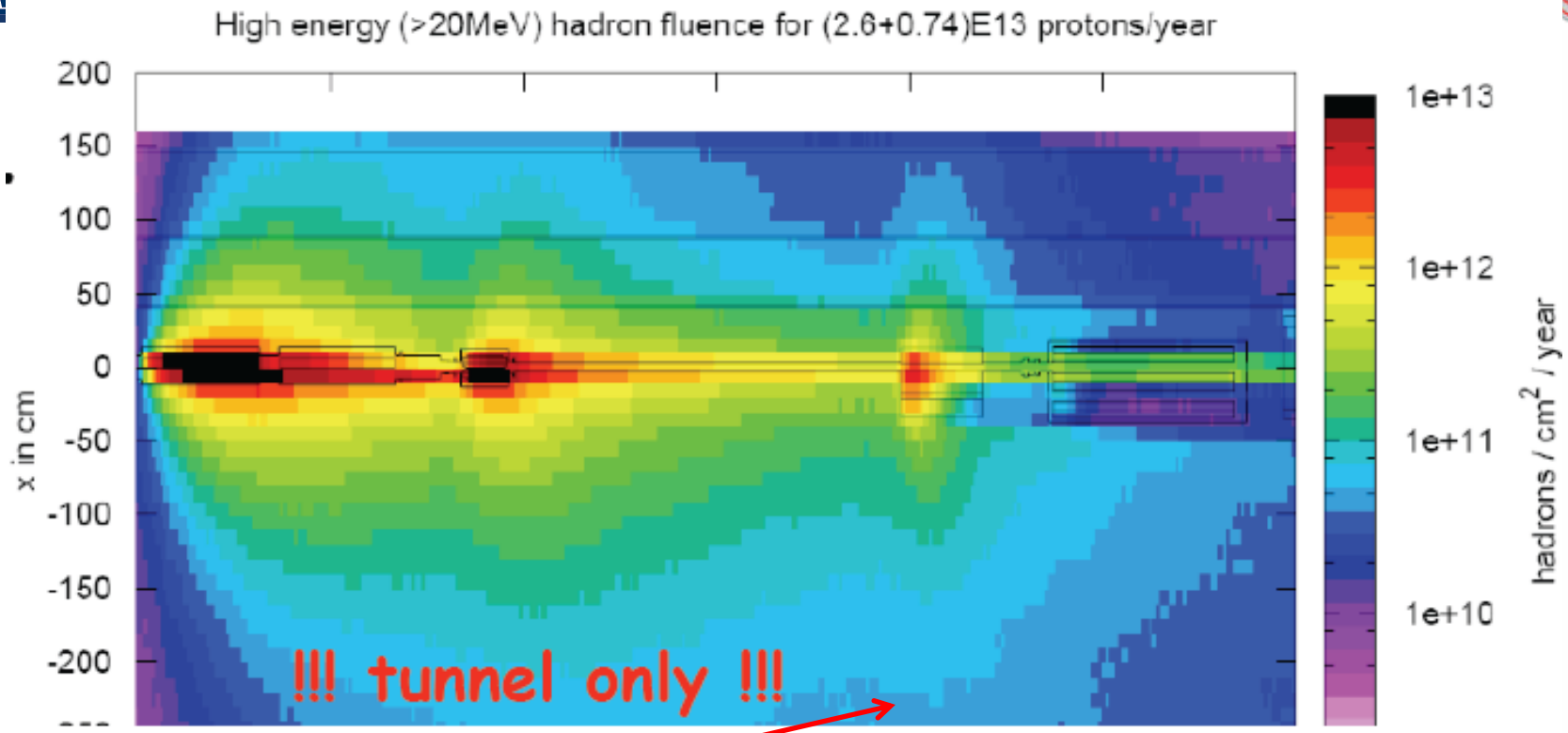
TCDQ Losses 07-09.11.2009







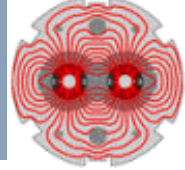
TCDQ Losses 07-09.11.2009



- ~3x10^{10} cm^{-2} high-E hadrons for 7TeV and 2.6x10^{13}
- rough scaling: ~2x10^{9} cm^{-2} at 450GeV
- this results in ~4x10^{5} per 5x10^{9} shot
- **We had about 50 (full) shots on the TCDQ -> ~2x10^{7} expected**
- **5.6x10^{7} measured at the tunnel location (~30counts!)**
- In the UA, the monitor is set to 3V (factor of 10 more sensitive) -> nothing measured -> confirms the expected attenuation factor of ~1000

Thanks Brennan!

Early Monitoring - Important Analysis

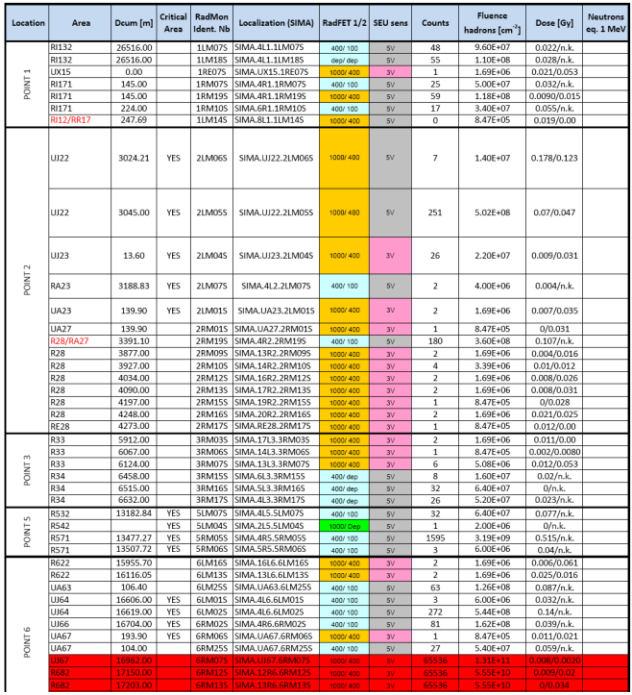


a long table -> don't try reading © E. Lebbos

- **Continuous analysis of monitor readings** helps verifying simulation predictions as well as identifying additional weak-points (in case)
- A draft table of possible loss-cases (**intended losses for R2E purposes**) was developed and is in iteration with operation (R. Assmann, B. Goddard)
- **Coming months will be particularly important** and time and effort is required for a dedicated R2E analysis

!!! HELP NEEDED !!!

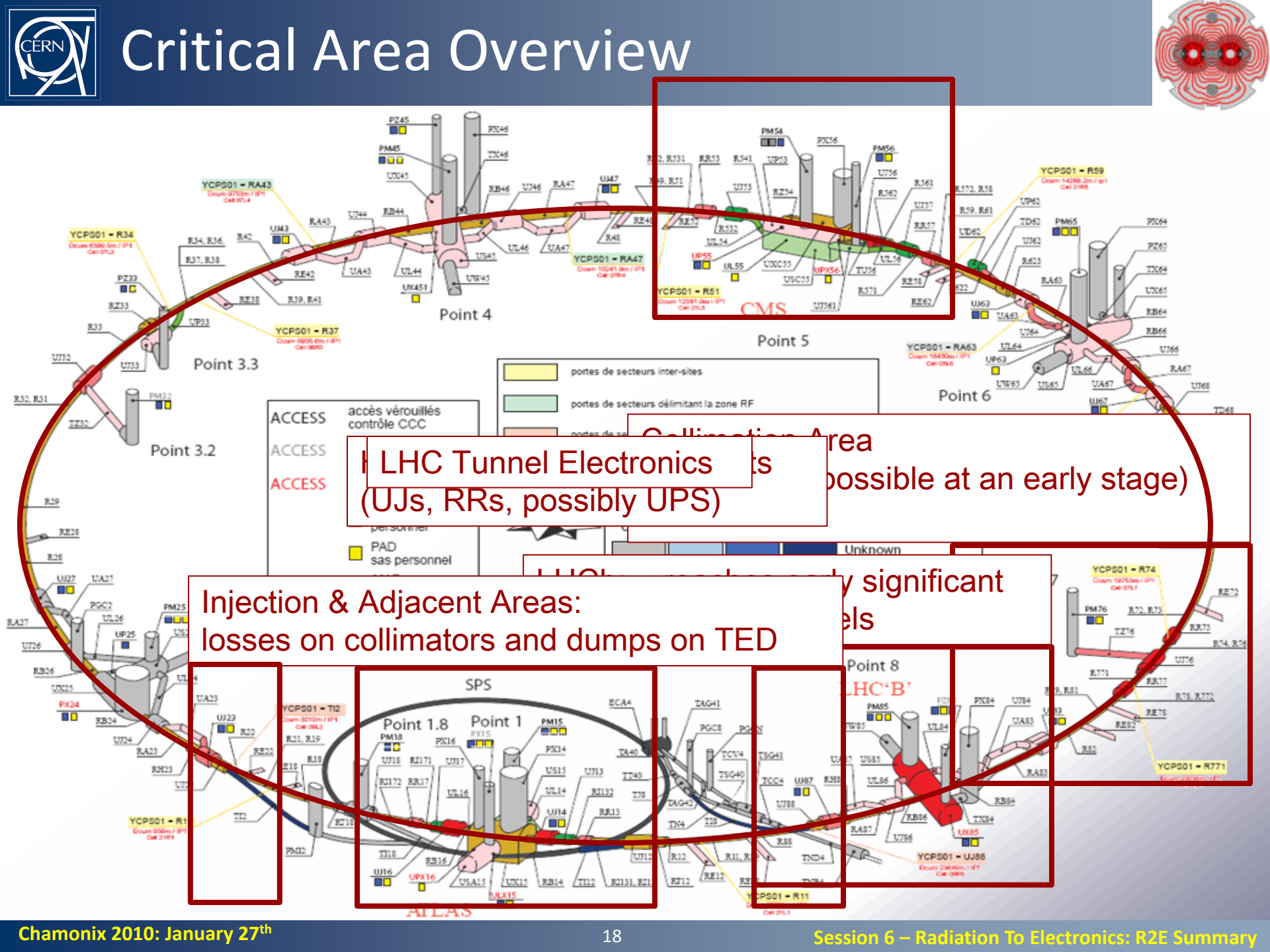
one example (first part)



Location	Area	Dcum [m]	Critical Area	RadMon Ident. Nb	Localization (SIMA)	RadFET 1/2	SEU sens	Counts	Fluence hadrons [cm^{-2}]
POINT 1	RI132	26516.00		1LM07S	SIMA.4L1.1LM07S	400/ 100	5V	48	9.60E+07
	RI132	26516.00		1LM18S	SIMA.4L1.1LM18S	dep/ dep	5V	55	1.10E+08
	UX15	0.00		1RE07S	SIMA.UX15.1RE07S	1000/ 400	3V	1	1.69E+06
	RI171	145.00		1RM07S	SIMA.4R1.1RM07S	400/ 100	5V	25	5.00E+07
	RI171	145.00		1RM19S	SIMA.4R1.1RM19S	1000/ 400	5V	59	1.18E+08
	RI171	224.00		1RM10S	SIMA.6R1.1RM10S	400/ 100	5V	17	3.40E+07
	RI12/RR17	247.69		1LM14S	SIMA.8L1.1LM14S	1000/ 400	5V	0	8.47E+05

Review Of Radiation Levels and Updates

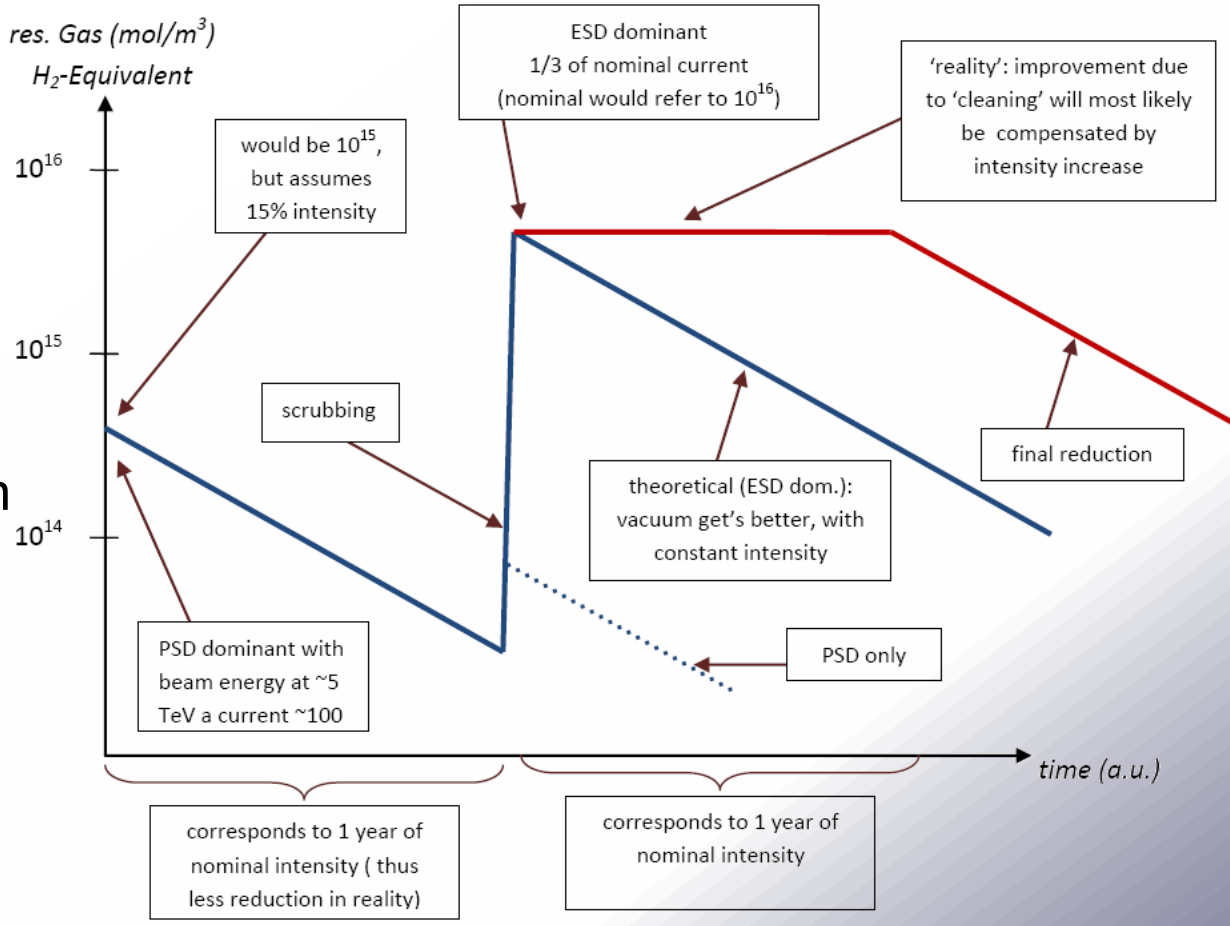
Critical Area Overview



Tunnel: DS/ARC

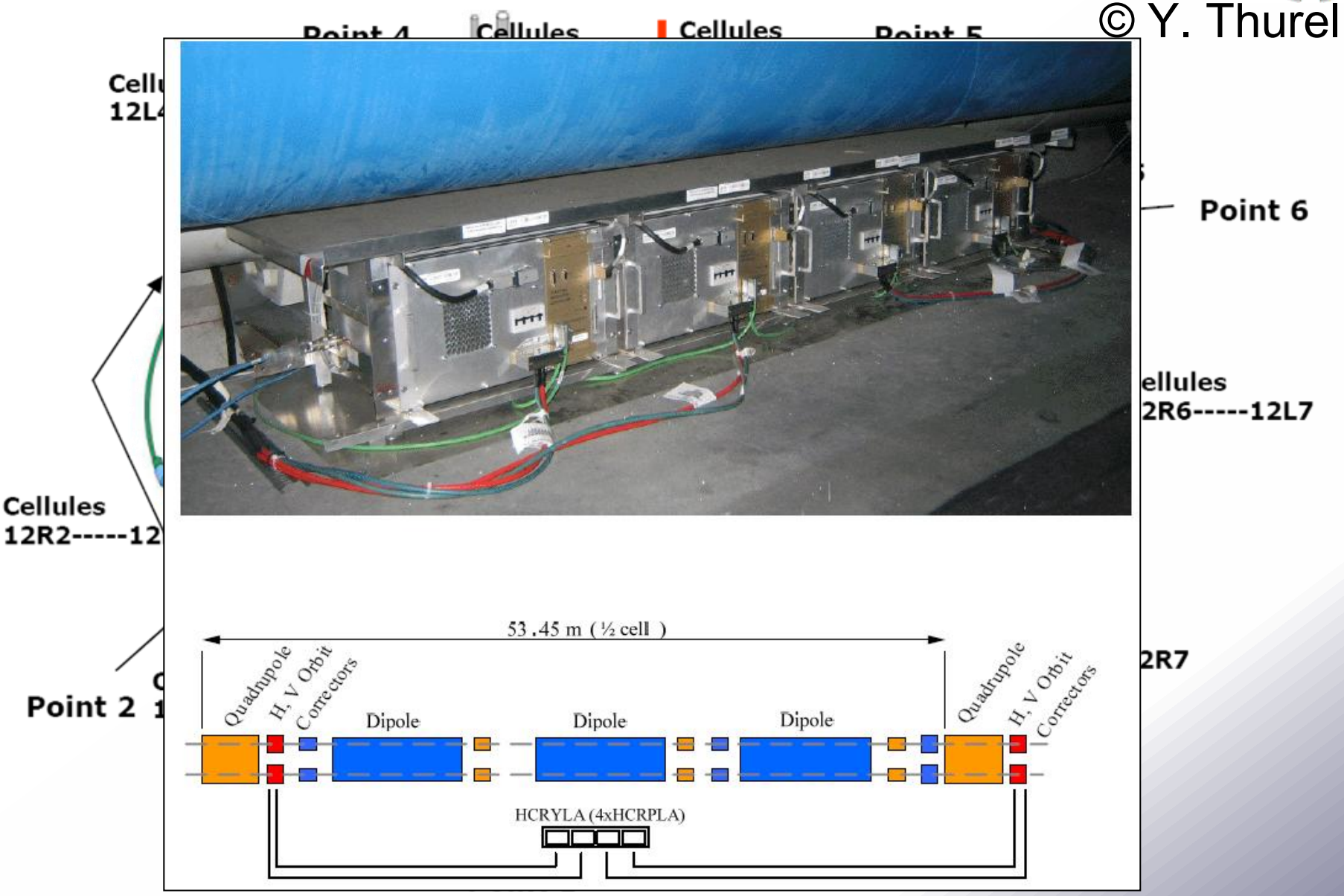
- **Beam-Gas calculation assumptions:**
  - residual gas density: **10^{15} mol/m^3 (H_2-equivalent)**
  - beam 1 only, results scaled by a factor of two
  - sampling as from D3 up to MBC13 (~250m)
  - scoring dose in air
- **Normalisation:**
  - **1 nominal LHC year**
  - 10^7s and 3.64x10^{18}p/s
  - 76mbarn cross-section [H_2]

© V. Baglin



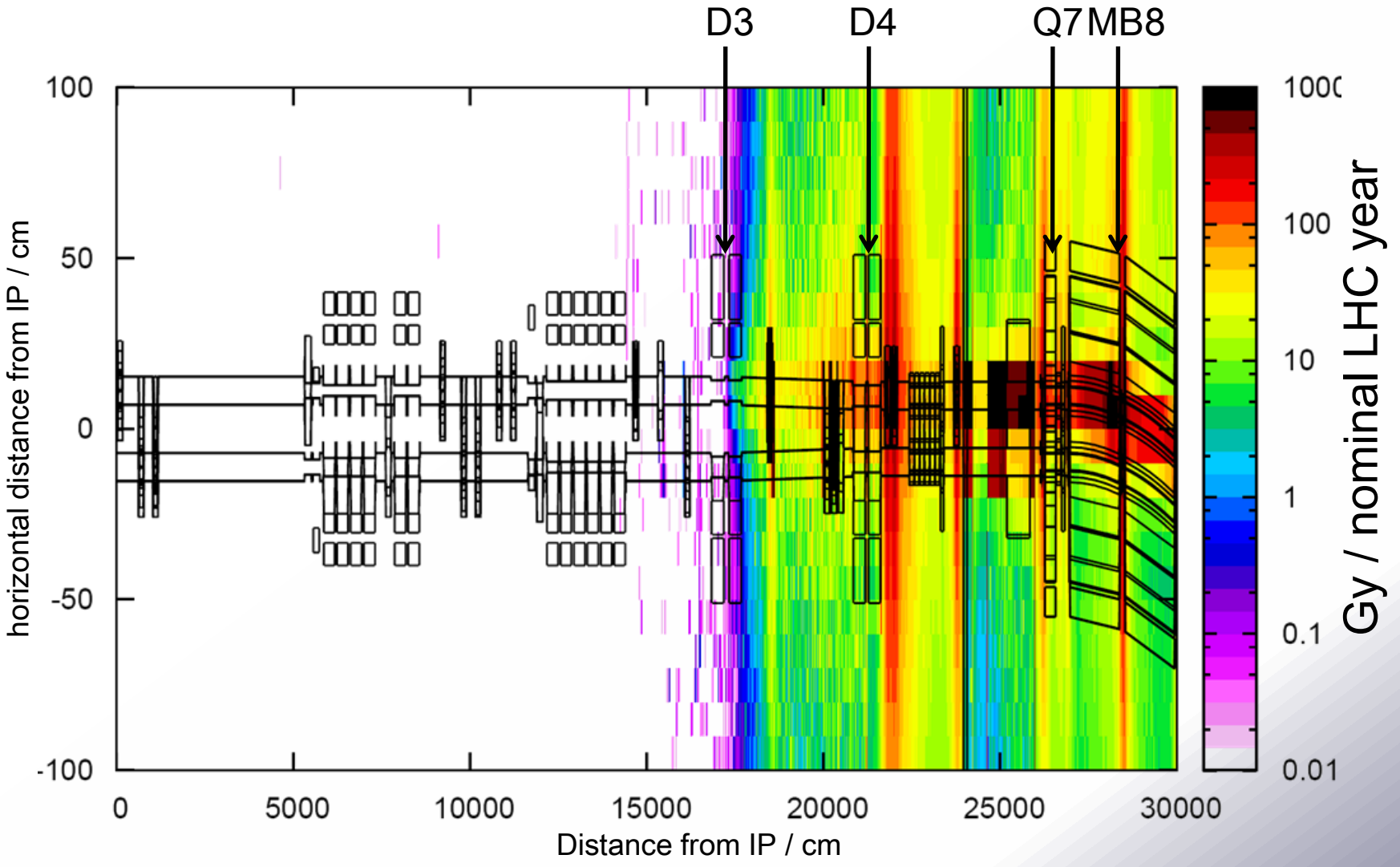
Tunnel: DS/ARC

© Y. Thurel

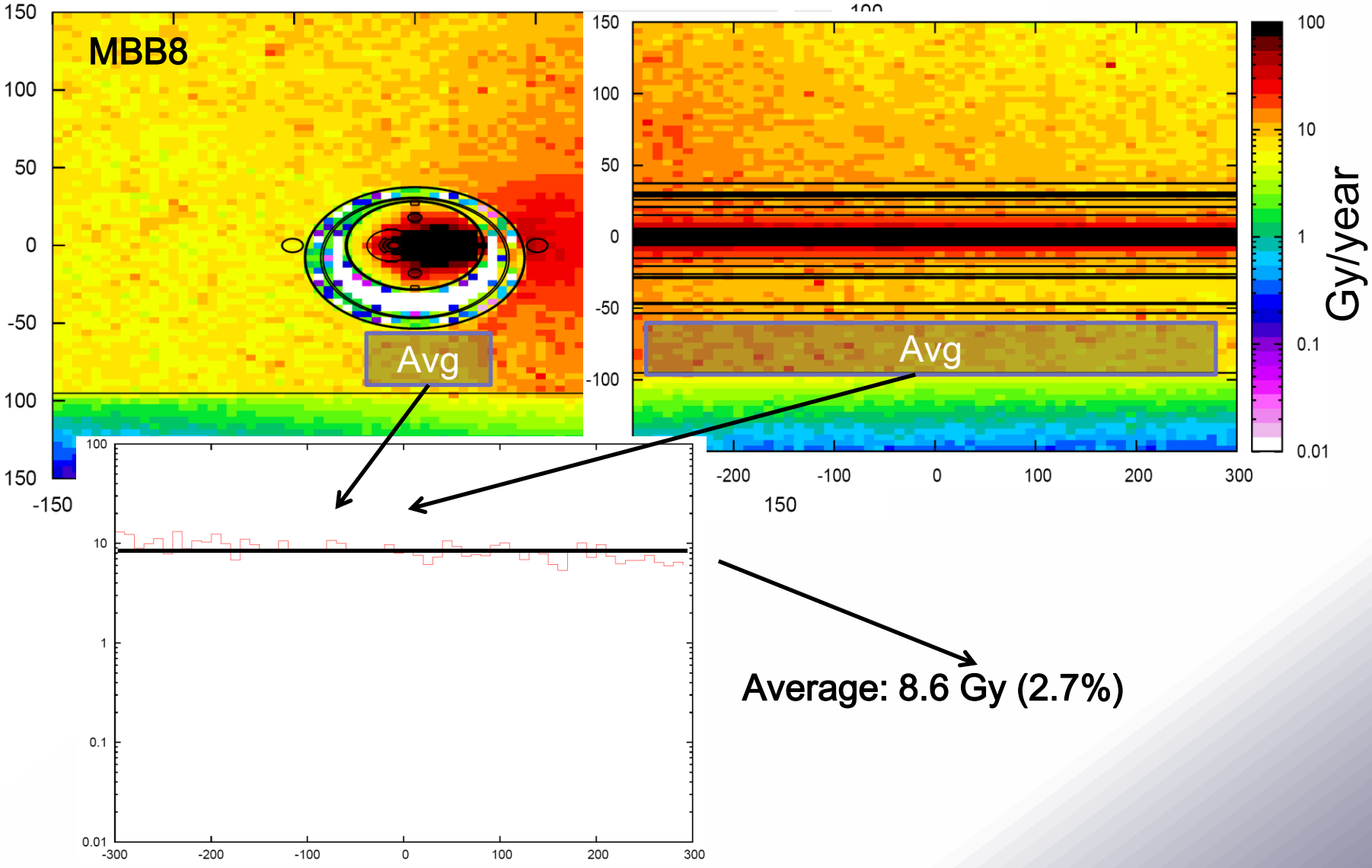


Tunnel: DS/ARC

IR7 FLUKA geometry extending from the LSS up to MBC13 (here not shown)

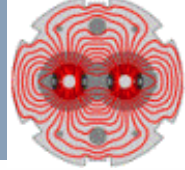


Tunnel: DS/ARC



Average: 8.6 Gy (2.7%)

Tunnel: DS/ARC

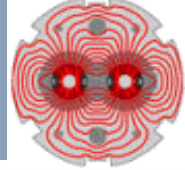


Magnet	Dose/Gy/y	Error / %
MQ 7:	26.3	6.3%
MQ 8:	37.0	8.7%
MBA 8:	13.9	2.0%
MBB 8:	8.6	2.7%
MQ 9:	32.9	6.3%
MBA 9:	7.1	2.5%
MBB 9:	6.7	2.3%
MQ 10:	34.2	5.5%
MBA 10:	6.9	2.1%
MBB 10:	6.2	2.4%
MQ 11:	14.4	4.8%
MBA 11:	6.8	3.4%
MBB 11:	6.3	3.5%
MQ 12:	2.8	12.0%
MBA 12:	6.1	2.8%
MBB 12:	1.4	6.7%
MBC 12:	0.4	10.1%
MQ 13:	3.5	10.3%
MBA 13:	0.4	7.9%
MBB 13:	0.3	12.2%
MBC 13:	0.2	10.2%

- Summary Table:
- Doses highest in change from LSS to bent region
- Peaks where matching is done (Q8, Q11)
- MBB12 worst case for Power-Converters
- >=MBB13: <=1Gy/y

-> what comes from the LSS?

Tunnel: DS/ARC



Beam-Gas Only as before

Magnet	Dose/Gy/y	Error / %
MQ 7:	26.3	6.3%
MQ 8:	37.0	8.7%
MBA 8:	13.9	2.0%
MBB 8:	8.6	2.7%
MQ 9:	32.9	6.3%
MBA 9:	7.1	2.5%
MBB 9:	6.7	2.3%
MQ 10:	34.2	5.5%
MBA 10:	6.9	2.1%
MBB 10:	6.2	2.4%
MQ 11:	14.4	4.8%
MBA 11:	6.8	3.4%
MBB 11:	6.3	3.5%
MQ 12:	2.8	12.0%
MBA 12:	6.1	2.8%
MBB 12:	1.4	6.7%
MBC 12:	0.4	10.1%
MQ 13:	3.5	10.3%
MBA 13:	0.4	7.9%
MBB 13:	0.3	12.2%
MBC 13:	0.2	10.2%

Scaled with…

- Collimation
  - horizontal Loss
  - limited statistics
- Quench
  - 1mW/cm3

!!!
only a quick and rough estimation
!!!

Thanks to R. Assmann et al.

Collimation Loss IR7 [Gy/y]	All Magnets at Quench [Gy/y]
bad statistics	926.2
417.2	497.7
bad statistics	277.2
5.3	69.4
501.9	418.2
348.2	181.0
258.3	84.7
349.6	447.6
20.2	264.9
7.5	78.4
2913.6	1100.3
321.5	173.9
110.1	74.1
scoring problem	632.2
43.2	252.1
1.7	45.8
bad statistics	64.7
30.2	527.7
bad statistics	60.0
bad statistics	43.0
bad statistics	54.1

IR1: UJs, RRs and ULs

- LHC Point 1, right side;

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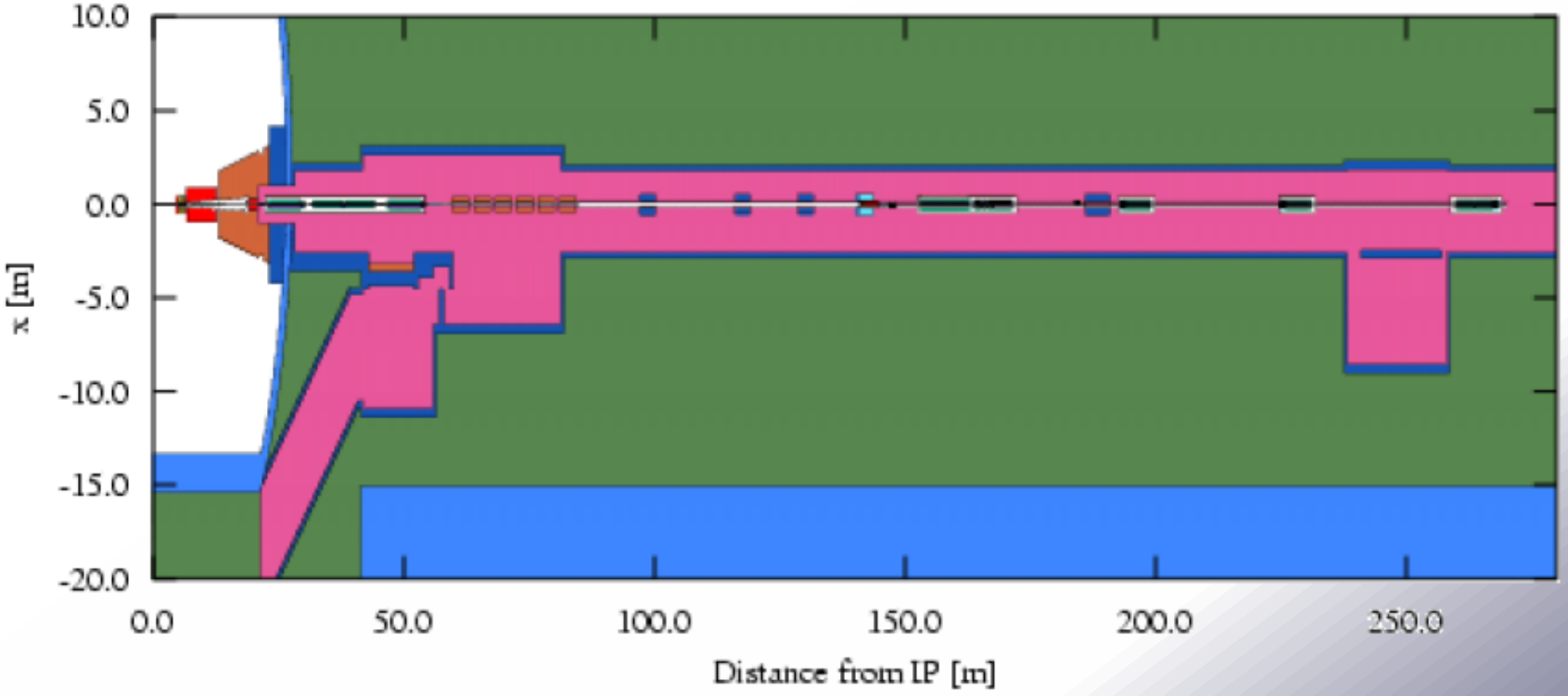
- FLUKA implementation of the ATLAS cavern, the LHC tunnel up to the RR17 with UJ16, UJ17 and UL16 service tunnels;



Beam-Beam collisions

High energy hadron fluence [units of 10^6 cm^{-2} per 100 fb^{-1}]

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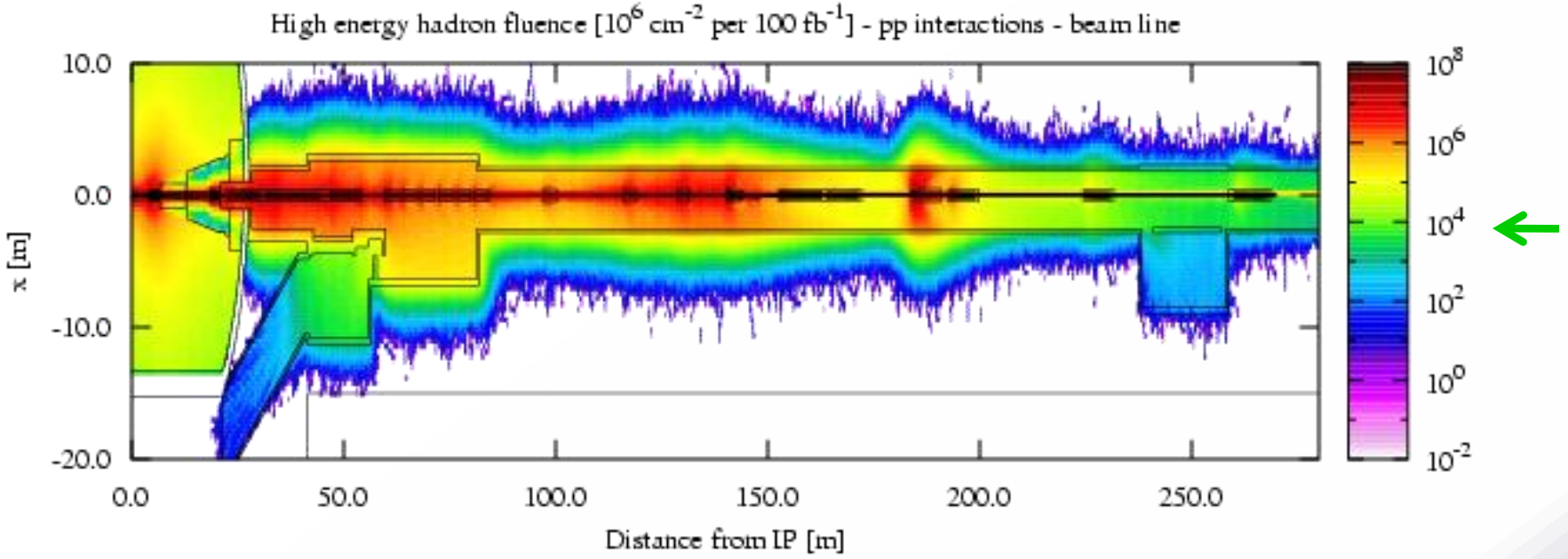

- Hot spots: Triplet, TCL5.R1.B1;
- RR: Consistent with earlier estimates Baishev et al.
- UL: long distance to UJ required (+shielding)

IR1: UJs, RRs and ULs

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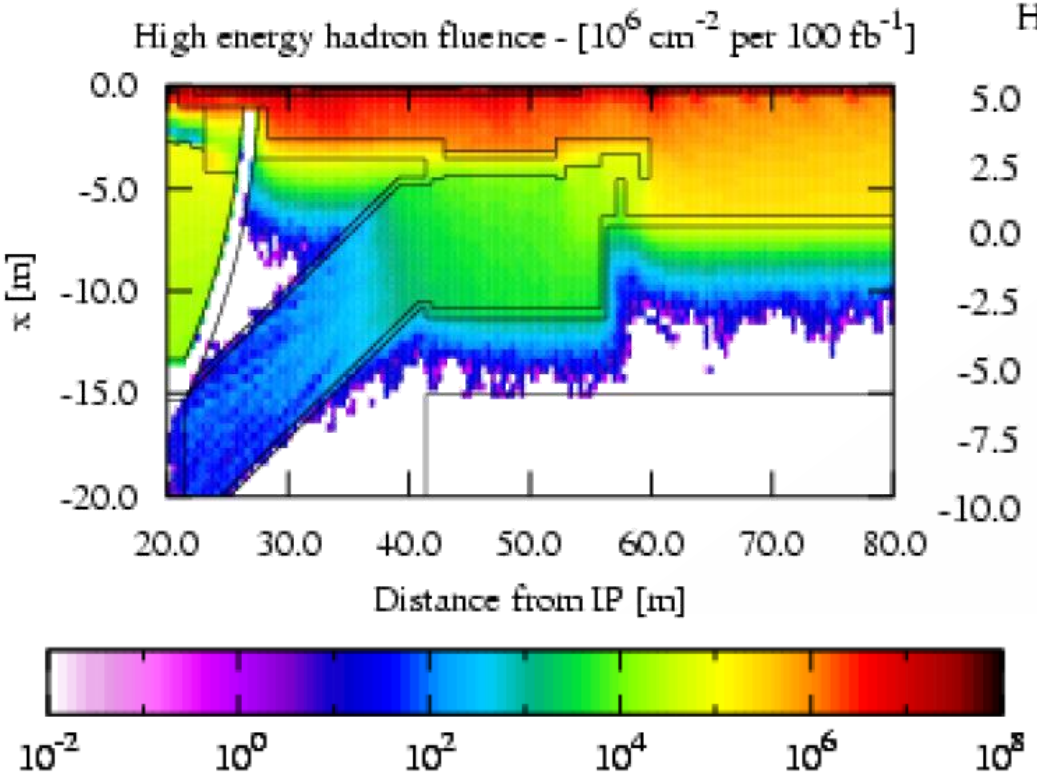
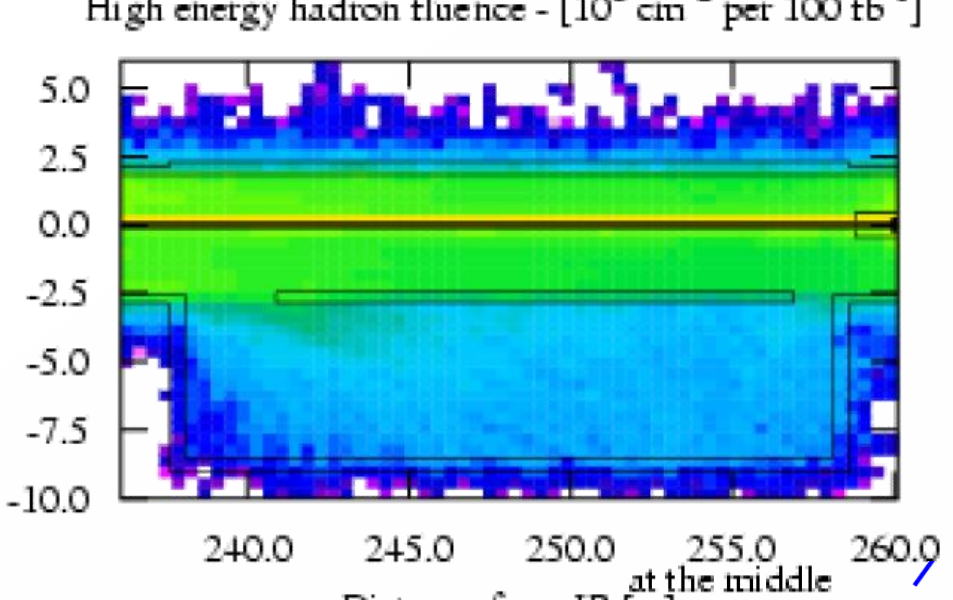
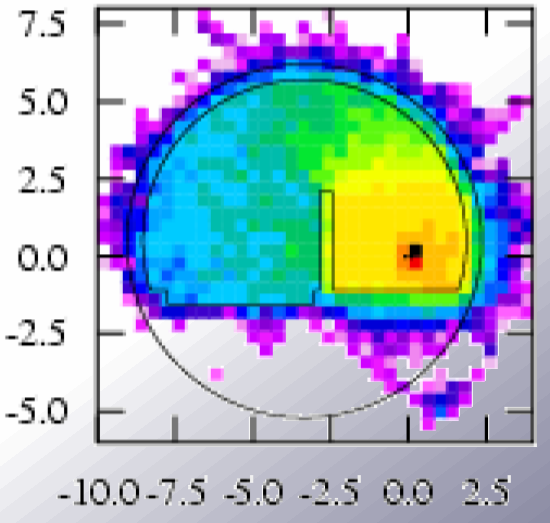






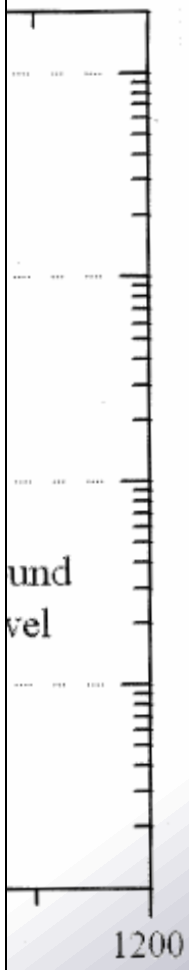
- UJ: $10^{9} – 10^{10}$ $cm^{-2}y^{-1}$
- RR: $10^{8} – 10^{9}$ $cm^{-2}y^{-1}$
- UL: $10^{7} – 10^{9}$ $cm^{-2}y^{-1}$

What is a ‘safe’ limit in terms of high-energy hadron fluence?

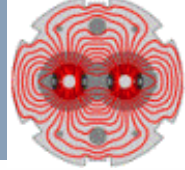
Can one Define a 'Limit'

10^7 $cm^{-2}y^{-1}$ as an annual 'limit':

- **ground level**: some 10^5, thus roughly a factor of 10 more where problems start?
- **CNGS experience**
  (PLC and Fire Detector failures)
- **PLCs at TCC2**
  (failure actually already below 10^7)
- **Risks always remains**
  (cross section, fluence, number of devices)
  - possible to predict/measure in case of full component/system control
  - estimate perhaps possible when analysing some components



Scaling With LHC - Operation



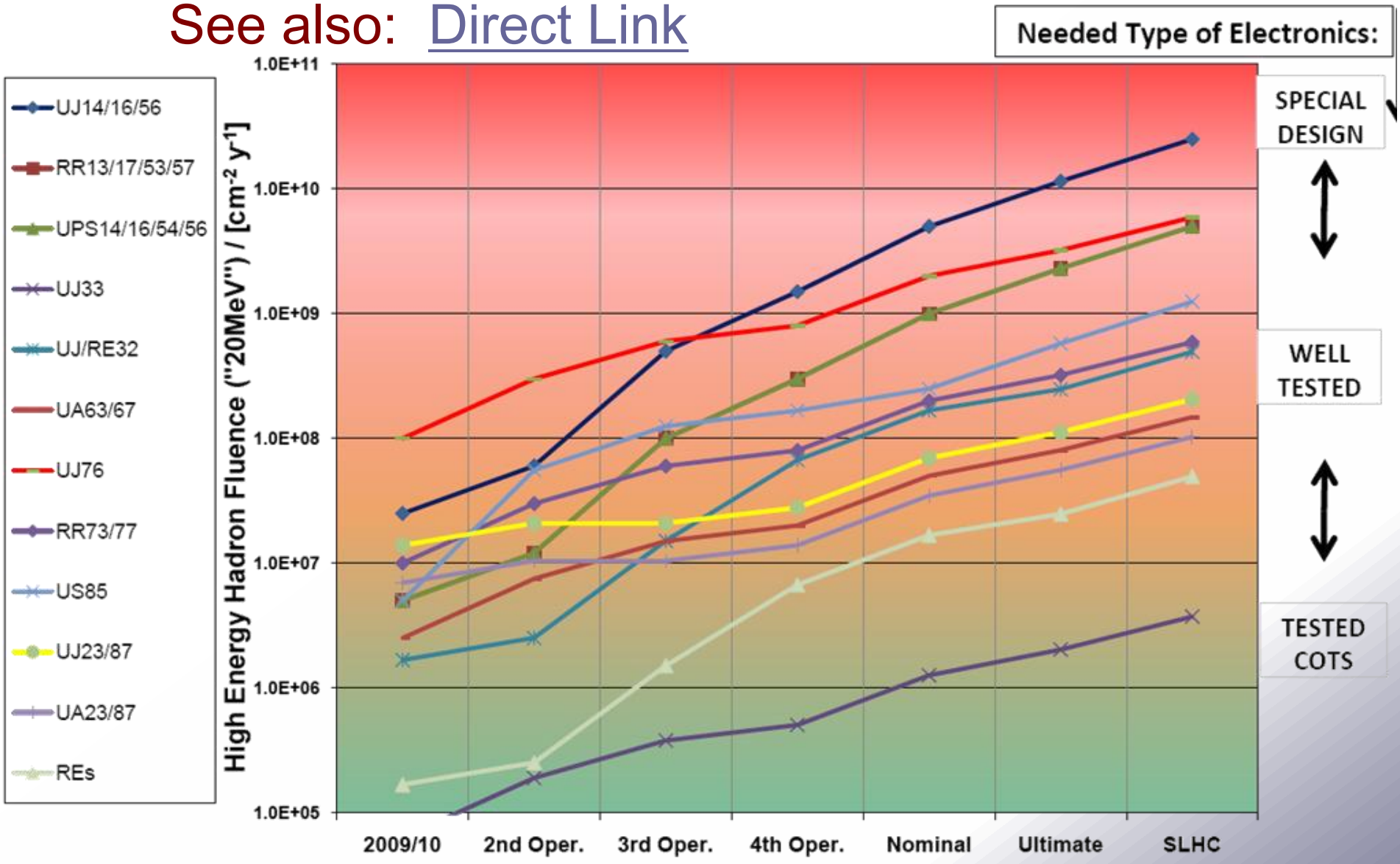
- Good idea for 2009/10
- Possible view for 2011
- General problem when putting ‘years’ (longer operational period, etc…)
- Below table as currently used (not final) and easy update possible

© M. Lamont

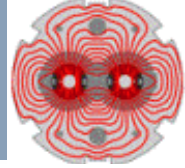
Loss Mode	2009/10	2nd Oper.	3rd Oper.	4th Oper.	Nominal	Ultimate	SLHC
Average Intensity (%of Nominal)	5	15	30	40	100	148	296
Peak Intensity (%of Nominal)	15	15	30	40	100	148	296
Peak Intensity (p/beam)	4.8E+13	4.8E+13	9.7E+13	1.3E+14	3.2E+14	4.8E+14	9.5E+14
Peak Intensity (p/beam/s)	5.4E+17	5.4E+17	1.1E+18	1.5E+18	3.6E+18	5.4E+18	1.1E+19
Peak Luminosity	1.0E+32	3.0E+32	1.0E+33	3.0E+33	1.0E+34	2.3E+34	1.0E+35
Average Luminosity	5.0E+31	1.0E+32	5.0E+32	1.0E+33	1.0E+34	2.3E+34	5.0E+34
BeamGas-Density (ARC)	2.00E+14	1.00E+14	3.00E+14	1.00E+15	1.00E+15	1.00E+15	1.00E+15
Integrated Luminosity (LHCb) [interactions/y]	3.2E+12	3.6E+13	8.0E+13	1.1E+14	1.6E+14	3.7E+14	8.0E+14
Integrated Luminosity (CMS, ATLAS) [fb-1]	0.5	1.2	10	30	100	230	500
Direct losses (IR7, single beam)	5.75E+14	1.73E+15	3.45E+15	4.60E+15	1.15E+16	1.85E+16	3.40E+16
Direct losses (IR3, single beam)	1.58E+14	4.73E+14	9.45E+14	1.26E+15	3.15E+15	5.07E+15	9.31E+15
Direct losses (DUMP)	5.75E+14	1.73E+15	3.45E+15	4.60E+15	1.15E+16	1.85E+16	3.40E+16
Direct losses (TCDQ)	1.70E+12	5.10E+12	1.02E+13	1.36E+13	3.40E+13	5.47E+13	1.01E+14
Direct losses (TED)	2.00E+15	3.00E+15	3.00E+15	4.00E+15	1.00E+16	1.61E+16	2.96E+16
Beam gas interactions (/m/y/beam)	2.76E+09	4.14E+09	2.48E+10	1.10E+11	2.76E+11	4.08E+11	8.16E+11
Beam gas P4 (/m/y/beam)	2.40E+08	3.60E+08	2.16E+09	9.60E+09	2.40E+10	3.55E+10	7.10E+10

Summary Of Areas

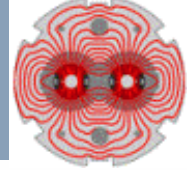
See also: Direct Link

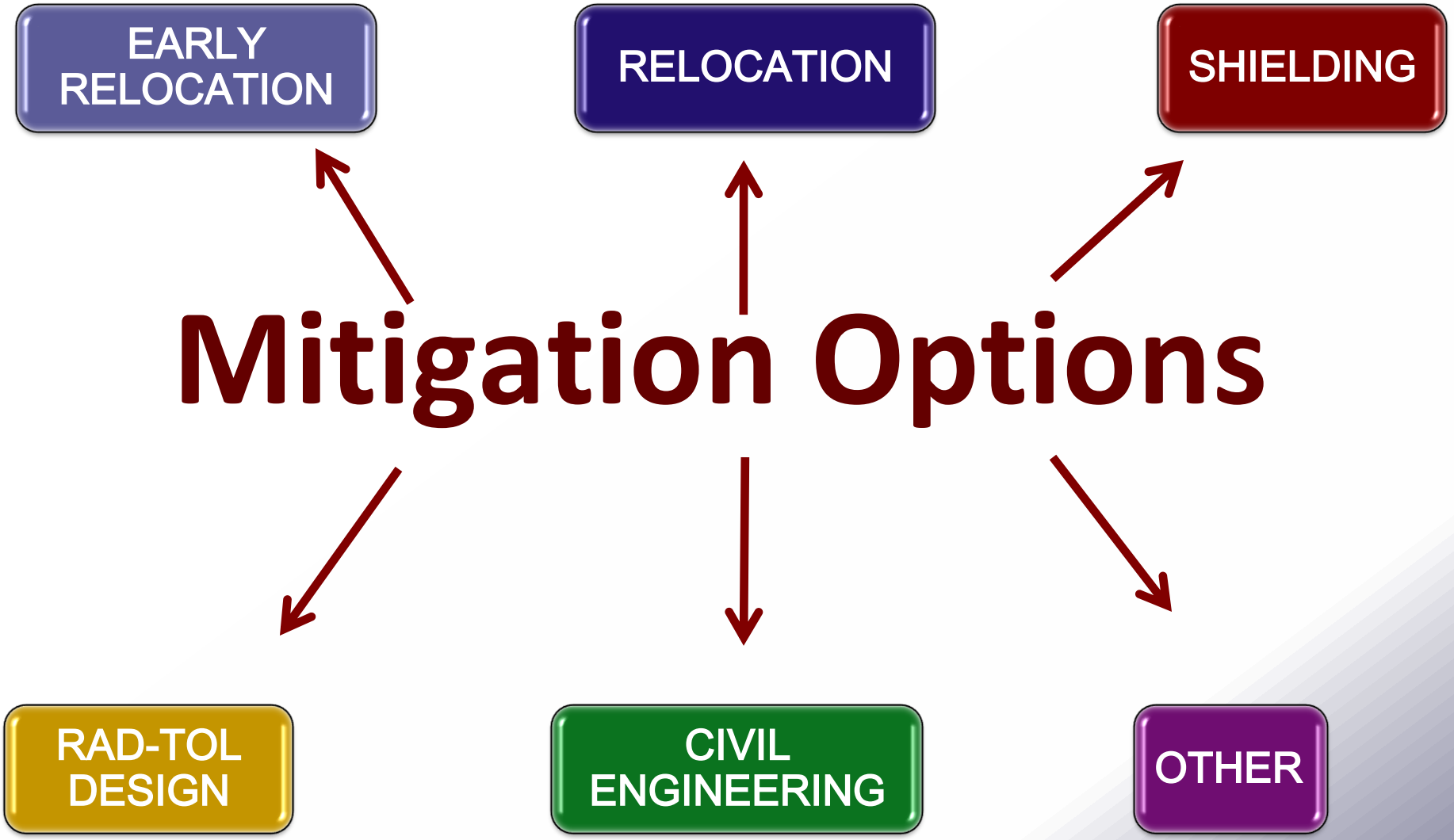


Summary Of Areas – See Direct Link



LHC Point	Area(s)	High-Energy Hadron Fluence [cm-2/y]							Thermal Ratio	Action Priority
		2009/10	2nd Oper.	3rd Oper.	4th Oper.	Nominal	Ultimate	SLHC		
Point 7	UJ76	1.0E+08	3.0E+08	6.0E+08	8.0E+08	2.0E+09	3.2E+09	5.9E+09	2.0	1
	RR73 RR77	1.0E+07	3.0E+07	6.0E+07	8.0E+07	2.0E+08	3.2E+08	5.9E+08	50.0	1
Point 1	TZ76 (start)	1.0E+06	3.0E+06	6.0E+06	8.0E+06	2.0E+07	3.2E+07	5.9E+07	10 (guess)	4
	UX85b	2.0E+07	2.2E+08	5.0E+08	6.7E+08	1.0E+09	2.3E+09	5.0E+09	0.2	1
Point 8	US85	5.0E+06	5.6E+07	1.3E+08	1.7E+08	2.5E+08	5.8E+08	1.3E+09	2 (guess)	2
	UW85	1.0E+06	1.1E+07	2.5E+07	3.3E+07	5.0E+07	1.2E+08	2.5E+08	10 (guess)	3
Point 3	UA83/87	5.0E+05	5.6E+06	1.3E+07	1.7E+07	2.5E+07	5.8E+07	1.3E+08	5 (guess)	4
Point 4	TI2 UJ23	1.4E+07	2.1E+07	2.1E+07	2.8E+07	6.9E+07	1.1E+08	2.1E+08	5 (guess)	3
	TI2 UA23	6.9E+06	1.0E+07	1.0E+07	1.4E+07	3.5E+07	5.6E+07	1.0E+08	10 (guess)	3
Point 5	TI8 UJ87	1.4E+07	2.1E+07	2.1E+07	2.8E+07	6.9E+07	1.1E+08	2.1E+08	5 (guess)	3
	TI8 UA87	6.9E+06	1.0E+07	1.0E+07	1.4E+07	3.5E+07	5.6E+07	1.0E+08	10 (guess)	3
Point 6	ALL ARC: MBs	6.4E+07	9.5E+07	5.7E+08	2.5E+09	6.4E+09	9.4E+09	1.9E+10	4.0	3
	ALL ARC: MQs	6.4E+08	9.5E+08	5.7E+09	2.5E+10	6.4E+10	9.4E+10	1.9E+11	2.0	3
	ALL DS: MBs	5.0E+09	1.5E+10	3.0E+10	4.0E+10	1.0E+11	1.6E+11	3.0E+11	4.0	3
	ALL DS: MQs	5.0E+10	1.5E+11	3.0E+11	4.0E+11	1.0E+12	1.6E+12	3.0E+12	2.0	3
	ALL REs	1.7E+05	2.5E+05	1.5E+06	6.7E+06	1.7E+07	2.5E+07	4.9E+07	20 (guess)	4

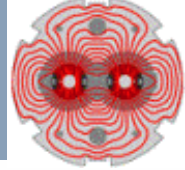



EARLY RELOCATION
RELOCATION
SHIELDING
Mitigation Options
RAD-TOL DESIGN
CIVIL ENGINEERING
OTHER

The Perfect Solution

“Easy Options”

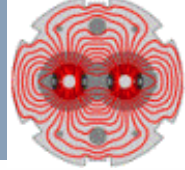
Some Easy Parts



- **Access-Gates in UJ14/16/23/87**
  - **Can be switched off during operation**
  - Procedure with OP in preparation
  - contact: L. Ponce, R. Nunes
- **Equipment which can remain (partly) in place**
  - **QPS** (further development possible)
  - **BPM** (mostly ok)
  - **BLM** (VME crate only temporarily)
  - **Some cryogenics control** (partly the same as in tunnel)
  - **Details in Equipment-Summary** (G. Spiezia, see link) and talks from D. Kramer and T. Wijnands

“Rad-Tol Design”

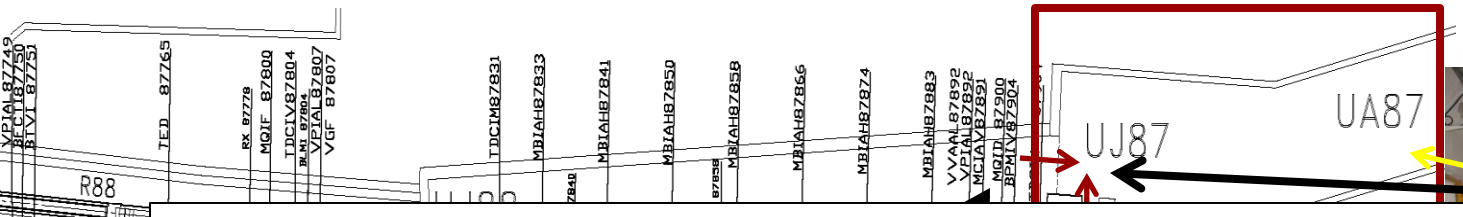
Radiation Tolerant Design

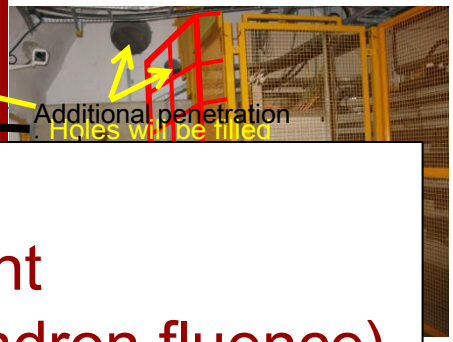


- **Remote-Valve-Controllers in US85**
  - Solution known from other areas
  - Order started – Installation in 2010/11
- **Power-Converters (120/600A)**
  - Details in talk from Y. Thurel
- **New FIP Development**
  - Details in talk from J. Serrano
- **Common Developments**
  - Possible working group with PH-ESE for common development of FPGA or micro-processors?
    - *e.g.*, generic field-bus, or acquisition module for temperature, pressure, low precision voltage measurement etc…

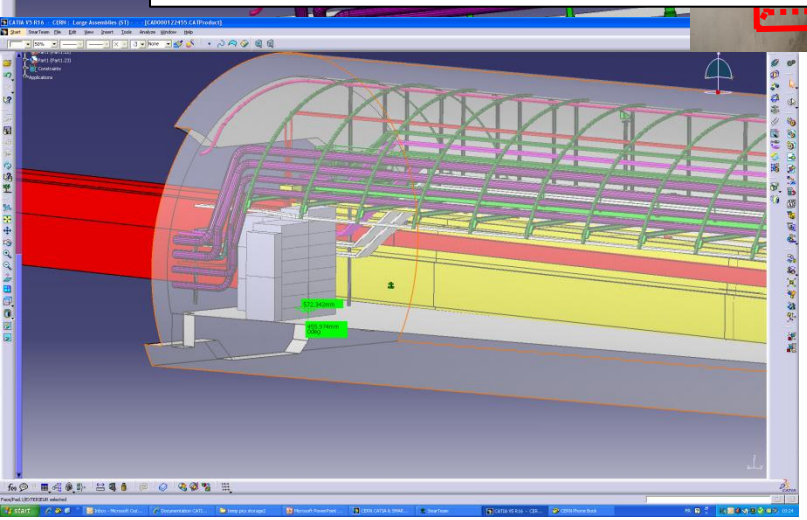
Shielding

UJ87/88 – UJ23/22 – Shielding





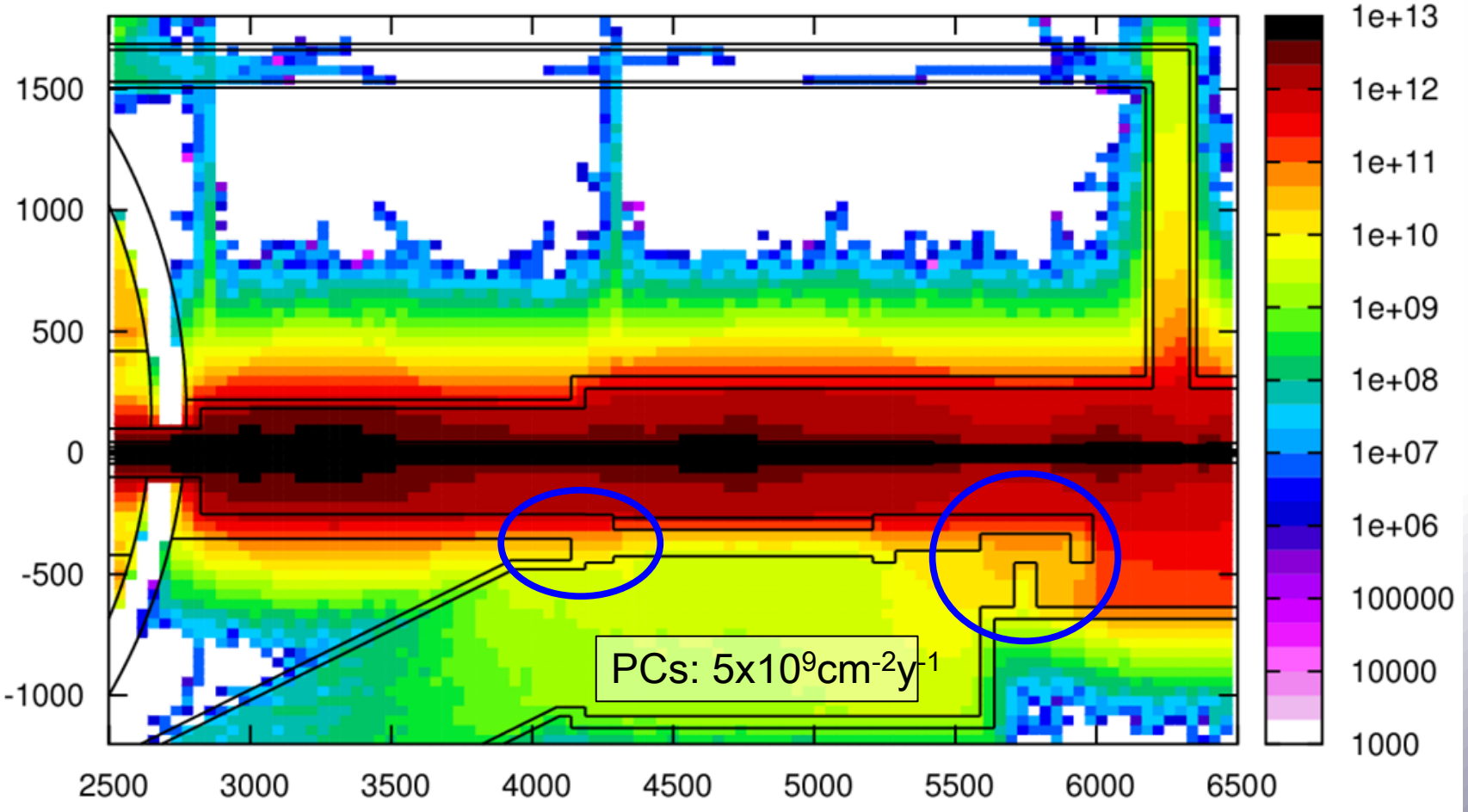
- Shielding installed before LHC-re-start
- Analysis confirms the expected improvement
- ~Factor of 10 less radiation (high-energy hadron fluence)
- Relaxed situation for this years operation
- Long-Term solution will require further measurements
- Possible issue with low-energy neutrons



UJ14/16 Shielding Options

Updated FLUKA Calculations for Various (Theoretical) Shielding Layouts

To Compare: Unshielded Case (as installed now) … at least theoretically



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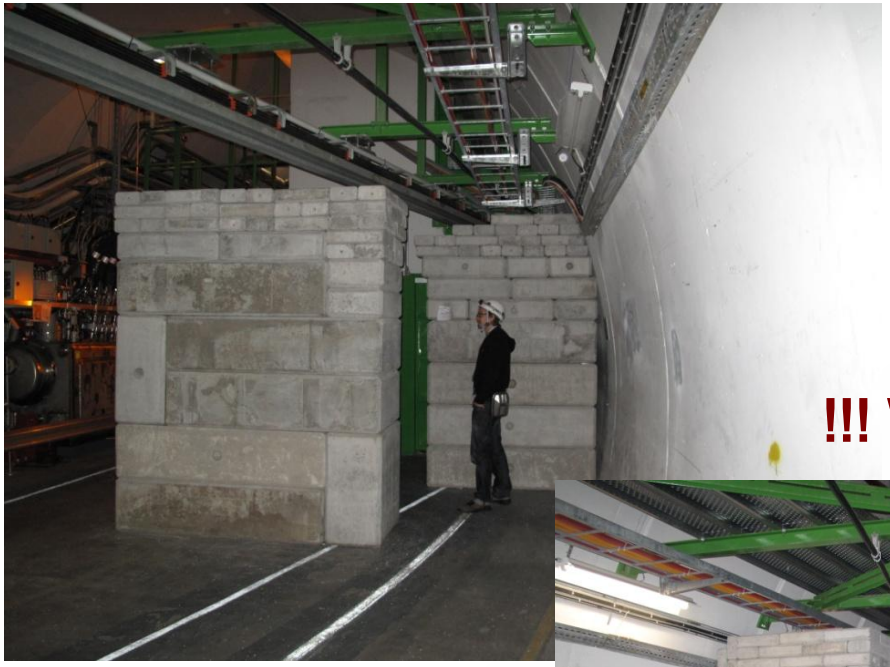
UJ14/16 Shielding Options

Correct …

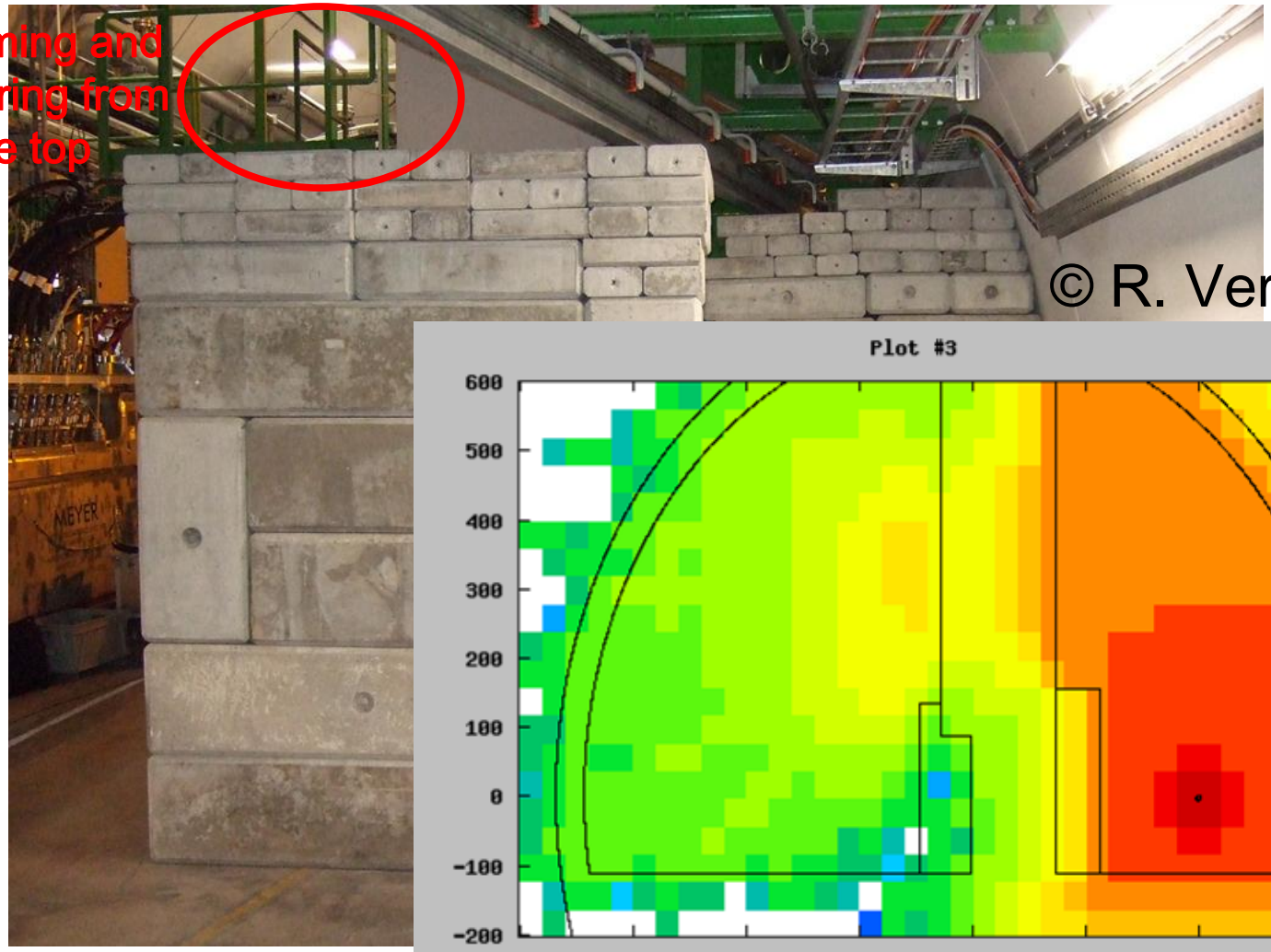


!!! Wrong Way !!!

UJ14/16 Shielding Options

Reason for Shielding Limitation:

streaming and scattering from the top



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UJ14/16 Shielding Options

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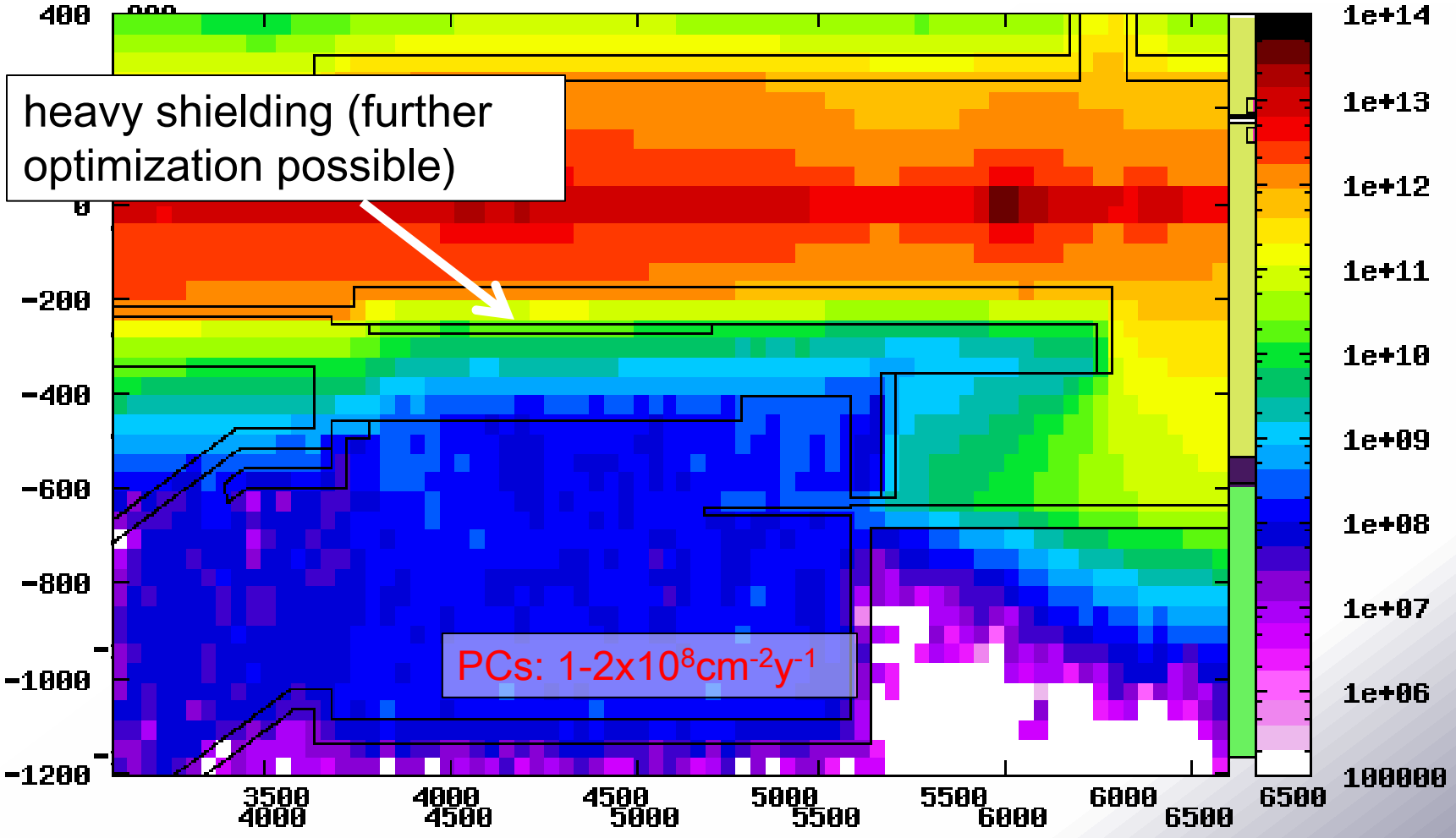
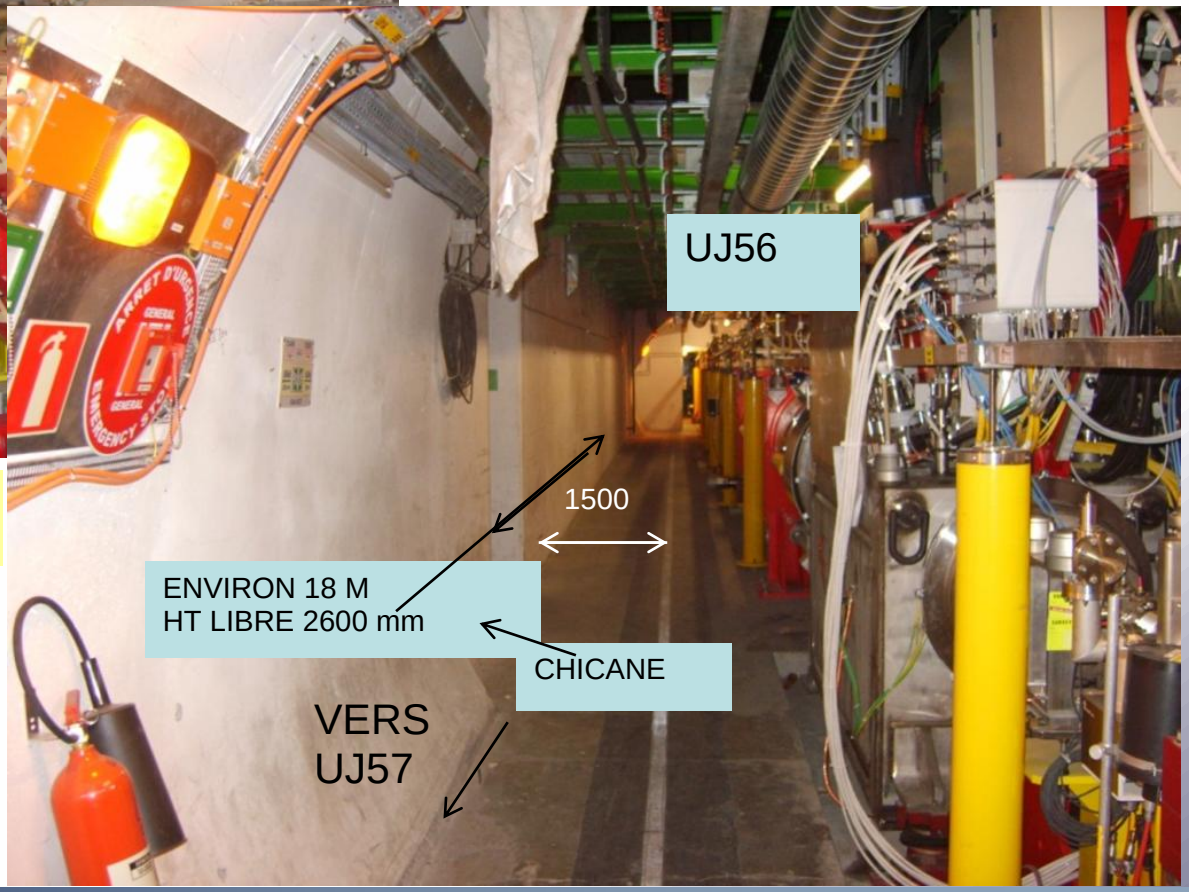
Improving the Weak-Points

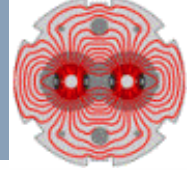


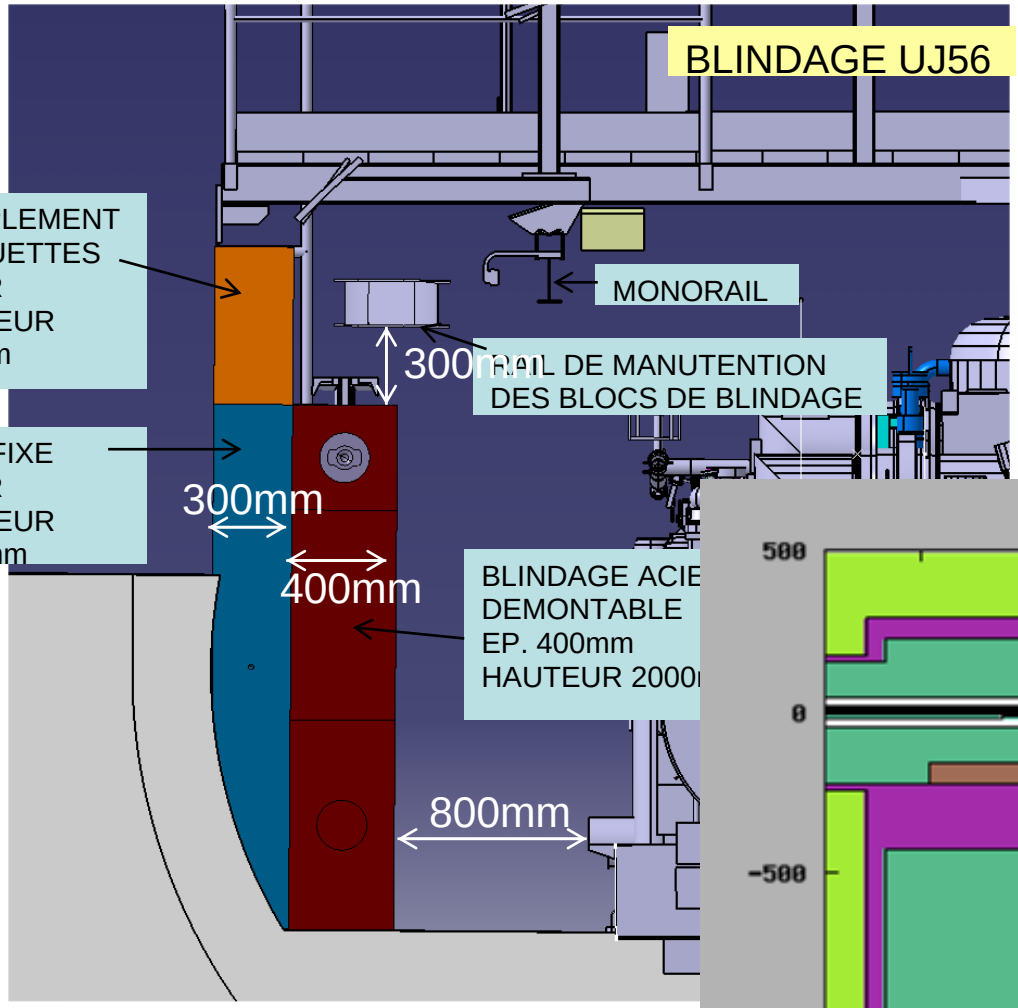
UJ56 Shielding Option

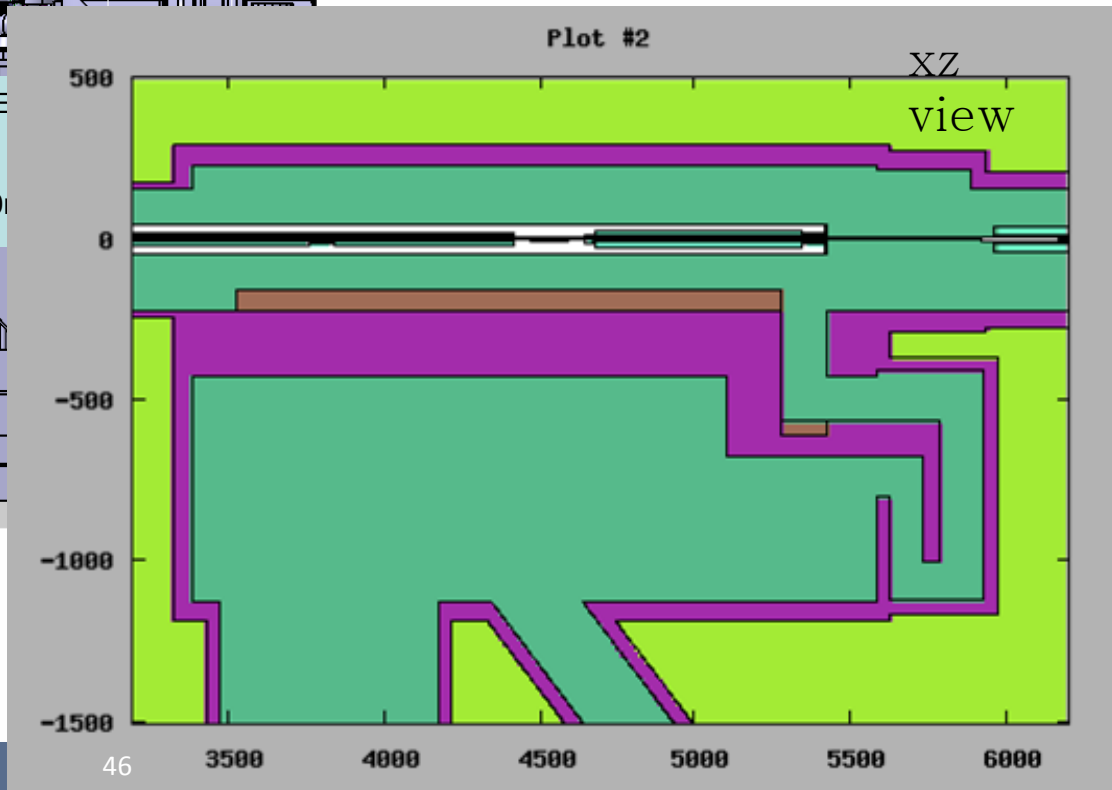
F. DELSAUX



UJ56 Shielding Option



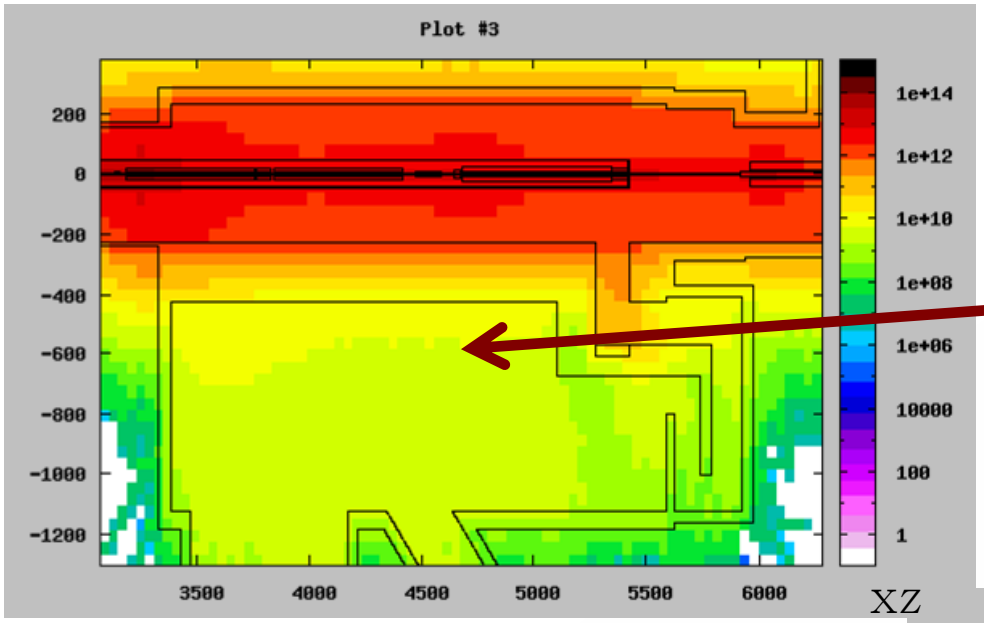




F. DELSAUX

UJ56 Shielding Option

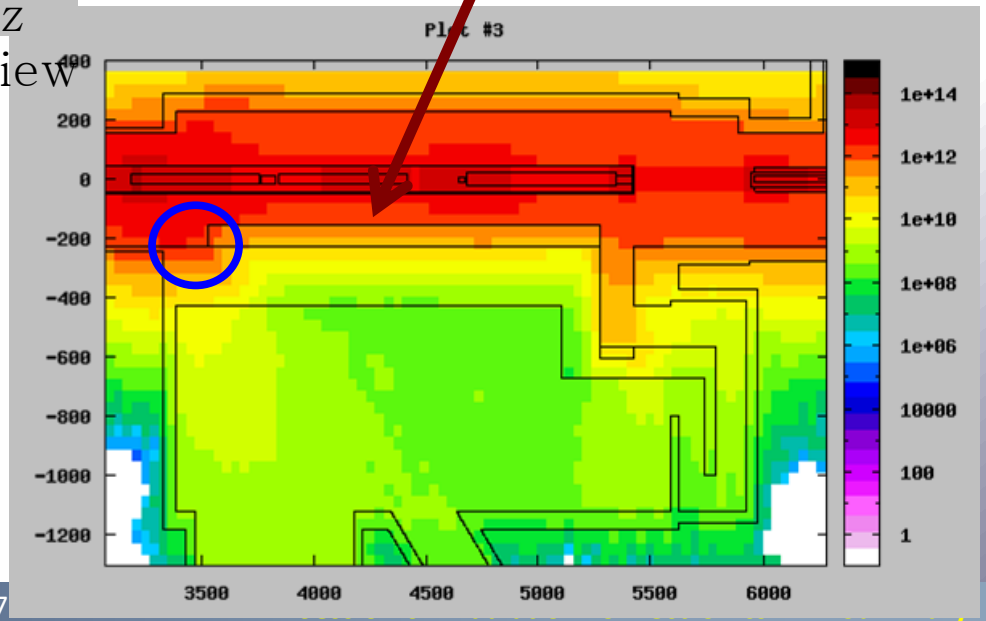
Assuming 1 year of operation at nominal luminosity (100 fb^{-1})



Shielding Effectiveness:

- Ground floor: ~10
- First floor: ~2

xz view



Upstream weak-point could be improved, so could be the maze … BUT

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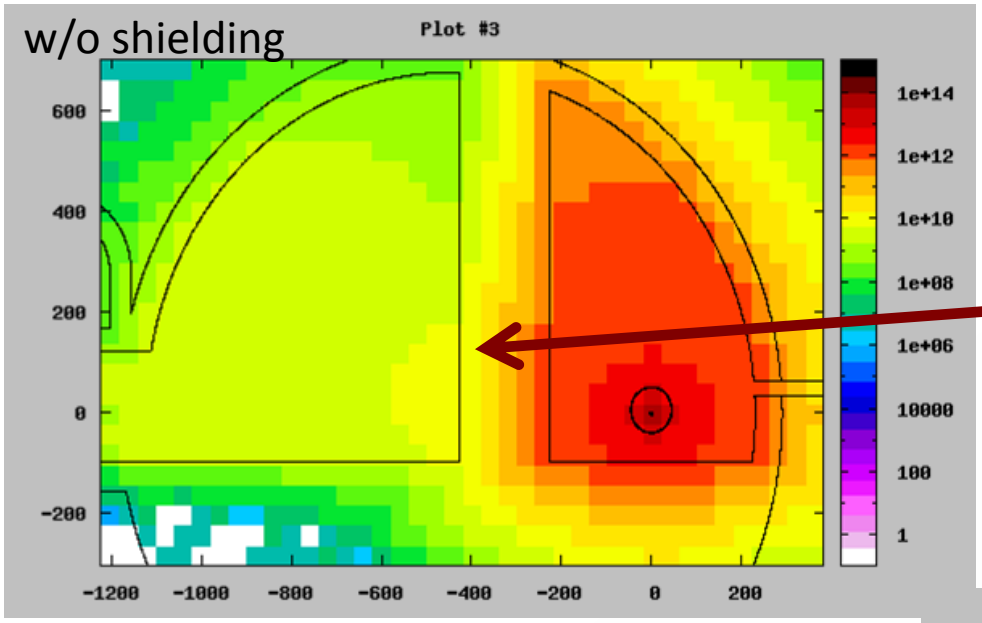
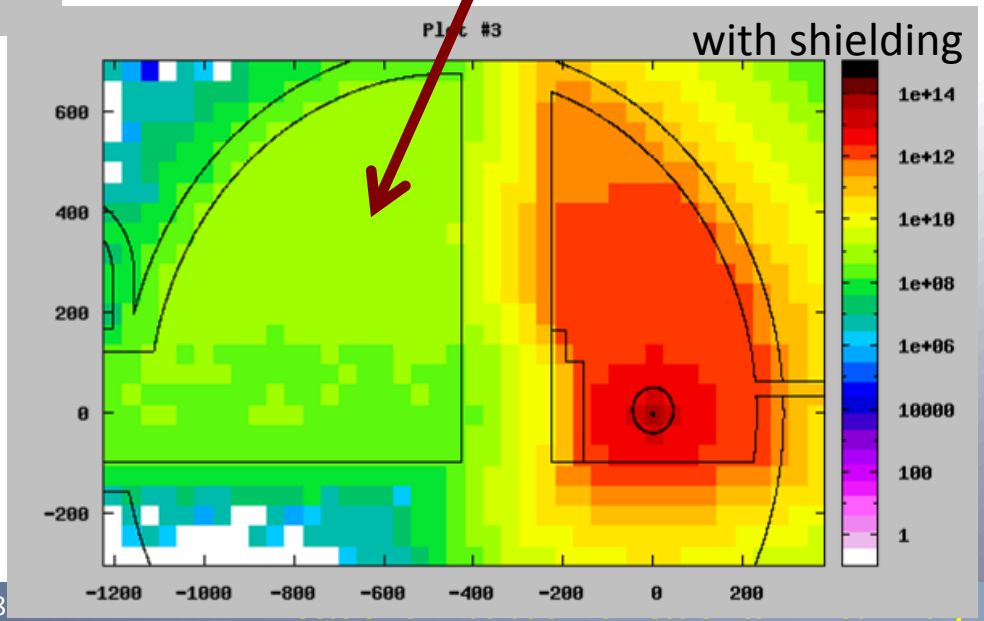
UJ56 Shielding Option

Assuming 1 year of operation at nominal luminosity (100 fb^{-1})



Shielding Effectiveness:

- Ground floor: ~10
- First floor: ~2



1st Floor-Shielding can hardly be improved

-> First Floor Critical

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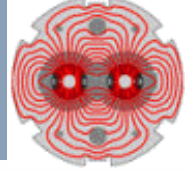
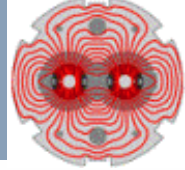
UJ14/16/56 - Conclusion



- **'Smart-Shielding'** in UJ14/16 can lead to significant improvement -> **not a final solution**, but also important in order to possibly use parts of the UL
  - staged implementation possible
  - detailed integration study to be launched as soon as possible
  - further optimization required (currently about 60m^3 iron and 40m^3 concrete)

- **UJ56-shielding is only effective at the lower-floor**
  - useful either for protection of safe-room equipment
  - or in case reshuffling with power converters has to be considered
  - cost estimate available: ~500kCHF
  - no other option in place…

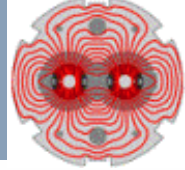
Other Areas – Where Shielding is an Option



- UJ76: Safe-Room shielding could be slightly improved
  - safe-room equipment remains at risk
- UJ/UA/23/87: already improved, further steps possible
  - combined simulation/integration study required
- RR/13/17/53/57
  - shielding similar to RR73/77 possible
  - more complex shielding could be envisaged (see existing conceptual ECR)
- UA63/67
  - ducts already shielded
  - additional rods could be added if required
- UJ32 (RE32)
  - in case monitoring shows that beam-gas is a long-term issue

Relocation

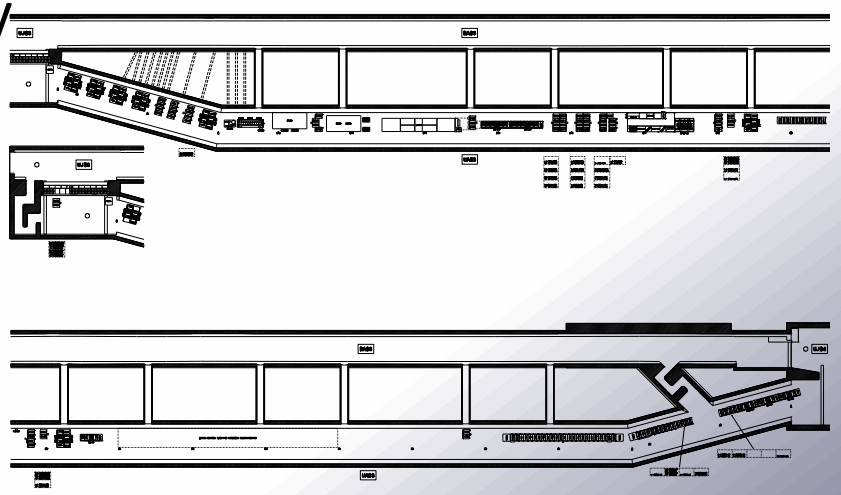
Early Relocations



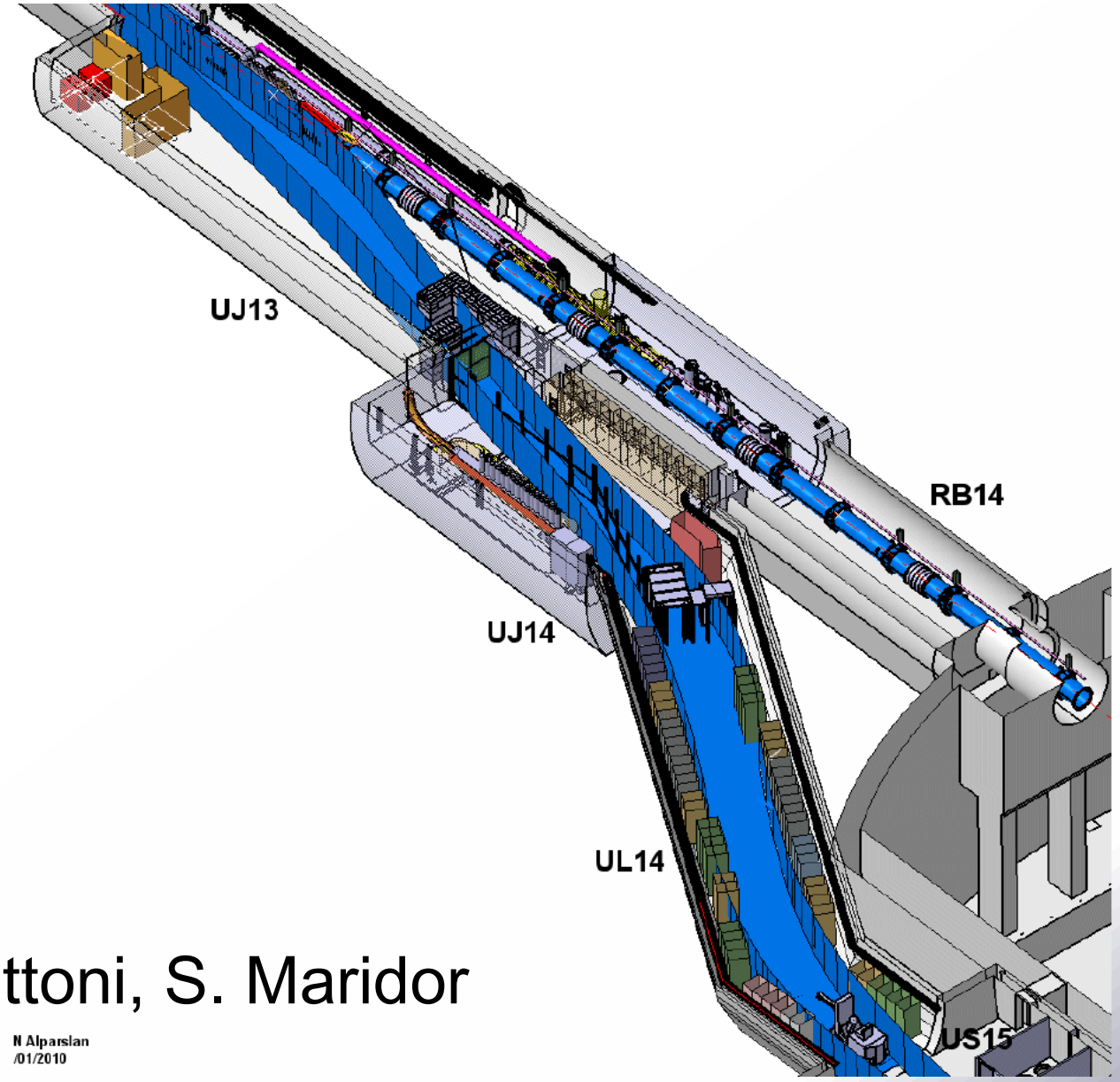
- **Fire/ODH Control Racks**
  - Relocation already performed in UX/S85
  - UJ76, UJ56 pending
  - **Possible impact on safety**
  - To be scheduled for next shutdown
- **Fire Detectors**
  - Possible impact on safety chain (not a safety issue)
  - **Most areas affected**
  - For long distances tests ongoing
  - To be scheduled for next shutdown
- **Other Equipment**
  - Scenarios studied (partly prepared for)
    - BIC, PIC, WIC
    - Timing/Remote-Reset

Complete Relocation: *e.g.*, US/UW85

- **Good News / Bad News**
  - **Solution exists / Expensive and Time Consuming**
- **Most of the Equipment has to be relocated**
  - Cryogenics, WIC, Timing, Remote-Reset, UPS, Access Control, Network, AUG control, Electrical Distribution (Control), GSM, Fire/ODH (already done)
- **Detailed Study (A.L. Perrot + Equipment Owners)**
  - **Cost and Time estimate available** (1MCHF, Long-Shutdown)
  - Cabling needs to be prepared early (4-6 month lead time)
  - 2-3 month of work to prepare for possible relocation (report in final draft version)
- **Planning/Coordination/Follow-Up required soon**



UJ14/16 – Upgrade Study



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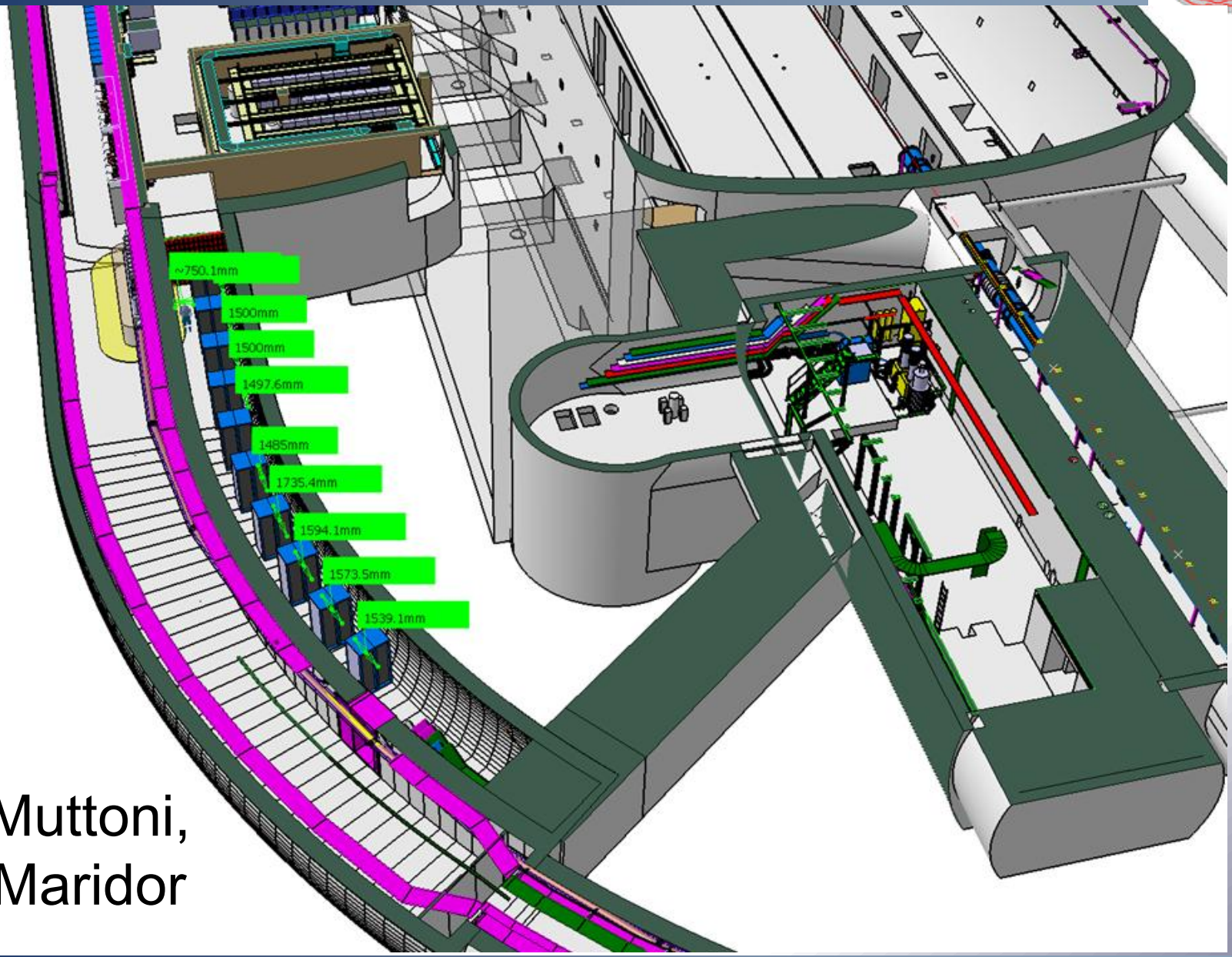
UJ56 – Upgrade Study



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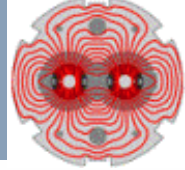
S. Maridor

Other Areas – Where Relocation is an Option



- **UJ76: preparations in place**
  - **change possible if required to house RR equipment**
  - decision required soon
- **UJ14/16: possibility in US15 and UL**
  - **first studies for upgrade – not trivial**
  - to be studied further
- **UJ56: option in UP/USC-bypass**
  - **first studies for upgrade – not trivial**
  - PM56 is most probably not an option
- **RRs**
  - RR73/77: possible to relocate equipment into TZ (see above), but requires significant TZ-layout changes
  - others: not possible

Civil Engineering

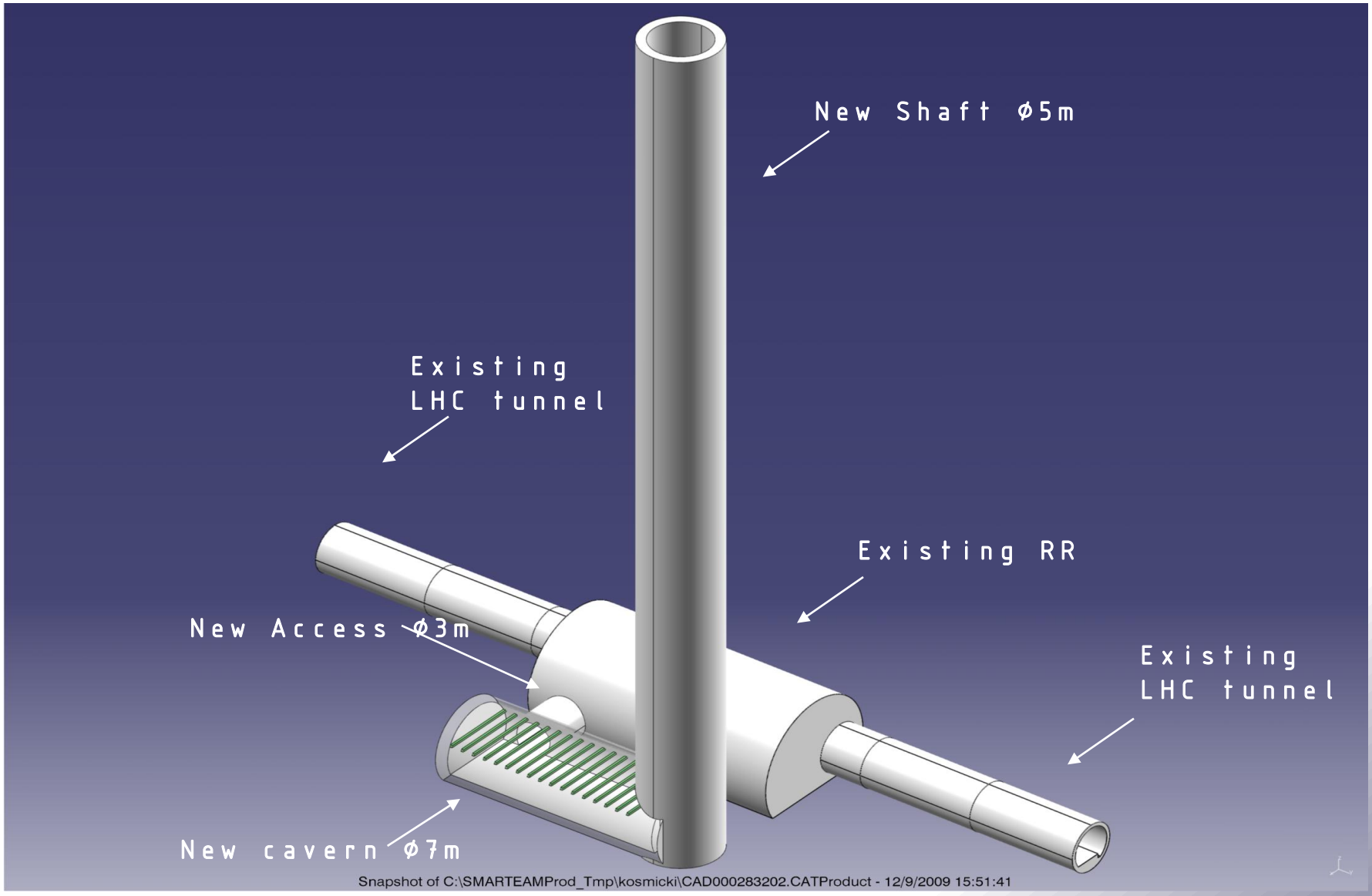
Locally Enlarging Areas

- Considered as hardly feasible with equipment in place…

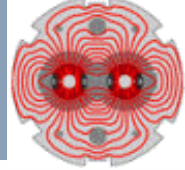
"Yvon wondering about the magnet transport zone"

RR Shafts & Caverns (P1 and P5)

© J. Osborne / S. Weisz



RR Shafts & Caverns (P1 and P5)



Constraints:

- **Large Costs** (~10MCHF each)
- **Important lead time** required (~4 years)

Known Solution:

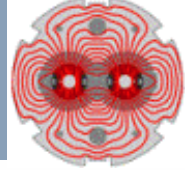
- Solves issue at RR13/17/53/57
- Allows for work during operation
- Relocation could be optimized during one shut-down
- No issue with cable lengths

In Addition – **See Talk(s) from S. Weisz**:

- Accidental Helium-Release
- Opens further doors for LHC Upgrade-Scenarios
  - could this also solve UJ56 ??? (UA extension)

Other Options

Superconducting Links



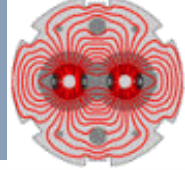
- **R&D Work** is being carried out at CERN for the development of HTS links on two fronts (A. Ballarino):

1) **Development of semi-flexible MgB_2 link** for the powering of the Triplets for the **upgrade phase-1** (up to 100 m length, ~ 120 kA in multiple circuits, EDMS N. 1046267) ;
2) **FP 7 European collaboration** for the development of gas- cooled HTS links operating at higher temperatures and suitable also for **vertical transfer of current**.

- 'Immediate' option for **power converters at Point-7** ? (similar to SCL at Point-3, DSLC-length of ~450m)

How To Compare

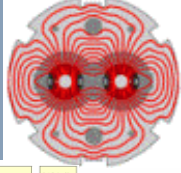
How To Compare the various 'Options'



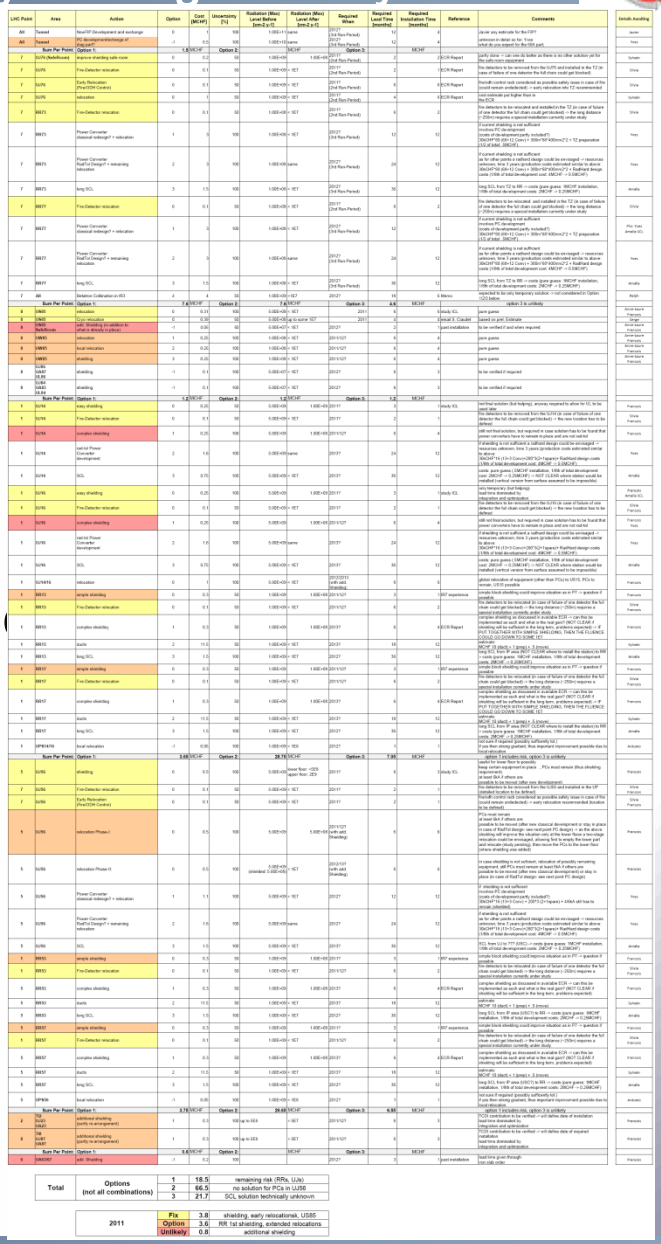
- Current planning summarized in 'working table', constantly updated (see link)
- Taking into account:
  - Area Priority
  - Possible Mitigation Option
- Comparing:
  - Radiation Levels (before and after)
  - Cost + Uncertainty
  - Required Lead- and Installation-Time
  - Long-term Sustainability
- **Next: grouping of options by operational period**
- A veeeery long table….

How To Compare

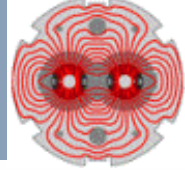
safety warning: don't try to read



- **Further Analysis necessary**
- Details required to fully compare various options
  - **YOUR SUPPORT IS NEEDED**
- **"Homework"** to be defined for all groups (draft list exists)
  - extended seminar will be organised t
    specify detailed needs
- **Workshop to be scheduled**
  - **~ Mid-April**
- Based on its result a (phased) proposal is to be prepared for the management

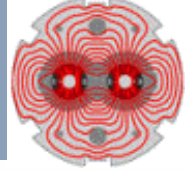


Conclusions



- **Radiation levels** currently based on simulations, early measurements will have to improve this
- **Local shielding** supposed to improve the situation, even if not a solution in the long term for most areas – **gaining time**
- **Relocation** options foresee all sensitive equipment
  - **safety issues**: Fire/ODH rack in P5/7, fire detectors general
  - when final locations are identified, **early relocations** possible
  - final relocation campaigns shall be done ideally for complete areas only
- **Alternative mitigation options**:
  - for areas where other solutions will be hard to find – their integration shall foresee also future requirements
- **First decisions required soon …**

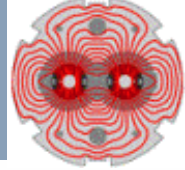
Conclusions



- **Review of radiation levels** important for the coming years
- **Early operation will be an important input – work needed now!**
- Detailed analysis of **mitigation options**
- Important **inter-departmental effort** to get as far as possible
- **Stringent time constraints**, it will not be enough to do things 'sequentially' (*i.e.*, first observe and then react)
  - Parallel work required (we already started in this direction)
- **Required resources** will significantly increase
- **Continued support required** from various key contributors (Planning and Integration, Equipment Owners, Point-Owners, FLUKA Team, RadMon Team, RP, RadWG,…)
- **Follow-Up Workshop Required** to prepare final proposal
  - **Homework for all to be defined soon**

Your Support Is Essential…

Documentation & Reports

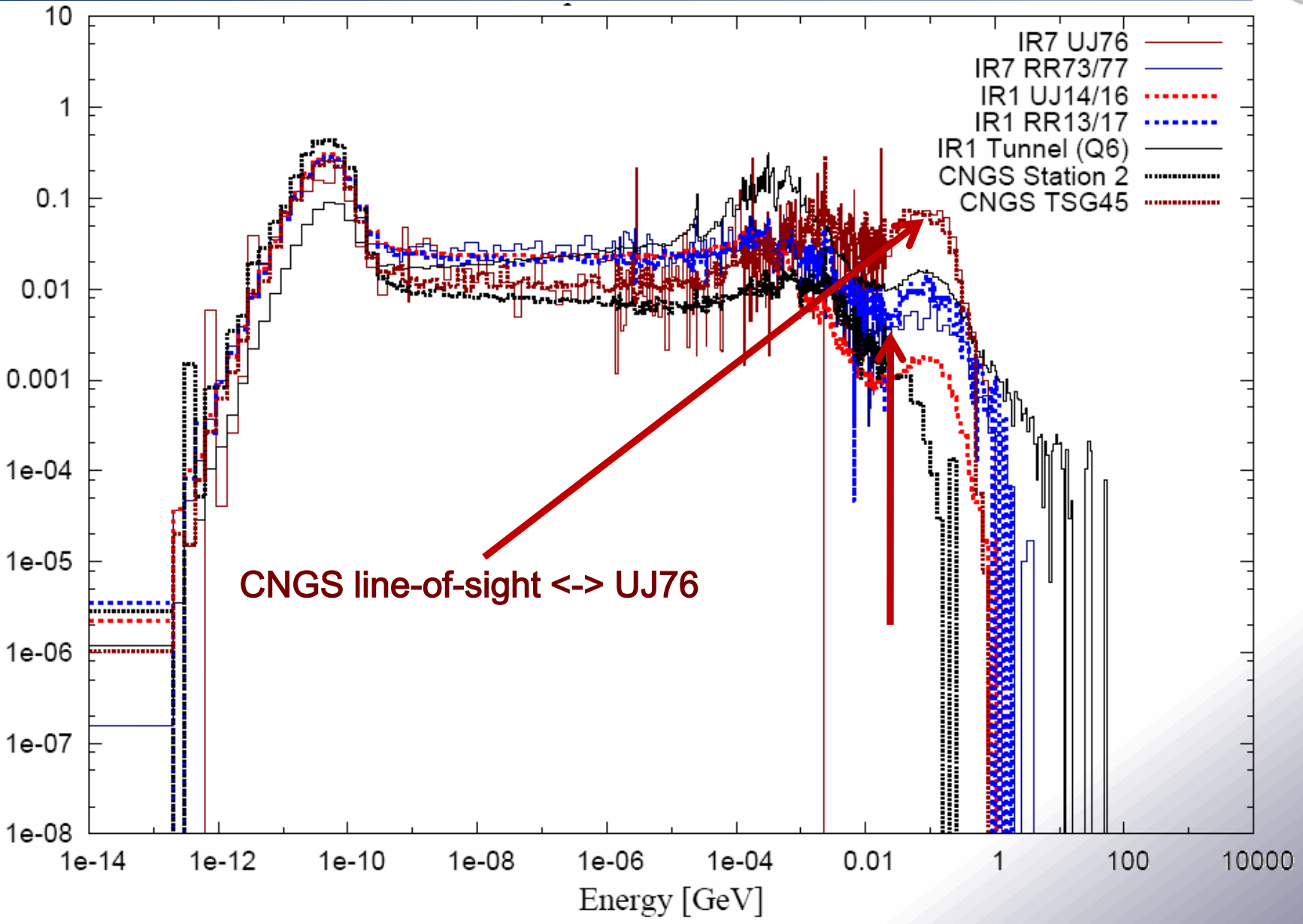


besides R2E meetings, minutes and presentations @ LMC, former Chamonix,…

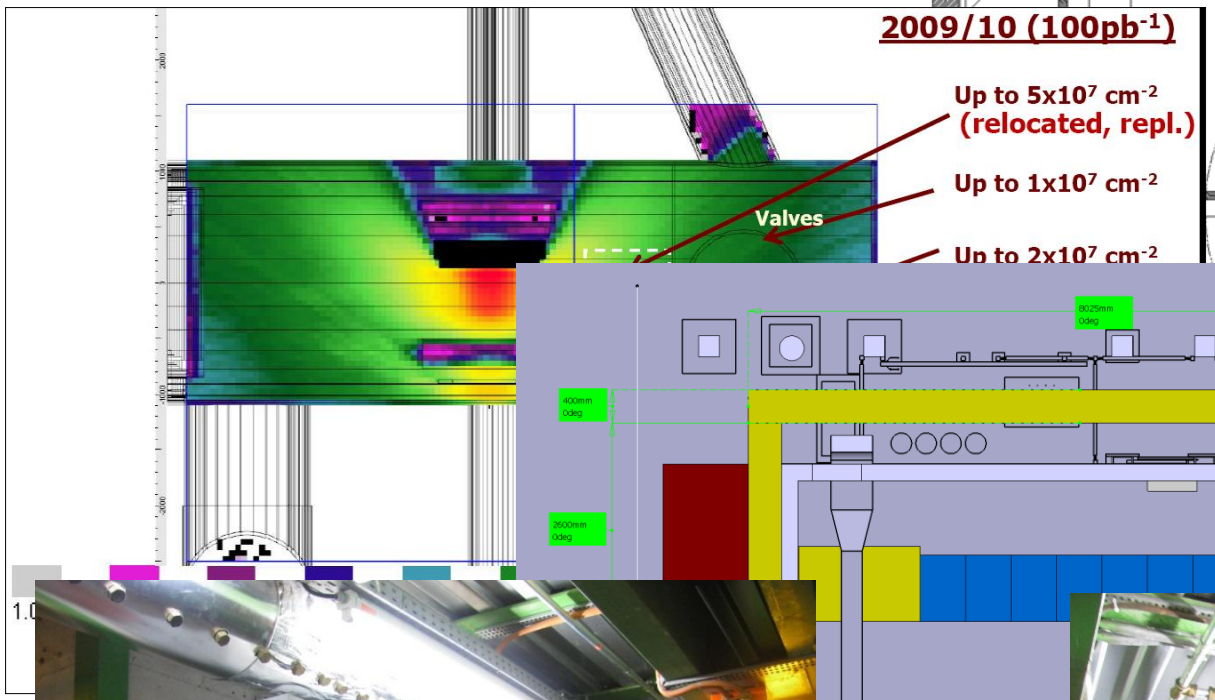
- **R2E Website: www.cern.ch/r2e**
- **Document Database & Questionnaires (linked through above): www.cern.ch/info-r2e-documents**
- **Area Overview of Radiation Levels (see link)**
- **Equipment Inventory (working document, see link)**
- **Mitigation Options (working document, see link)**
- **Memorandum for possible temporary move betatron cleaning to IR3**
- **UJ76 Relocation (see ECR)**
- **R2E Status Report @ Chamonix (see paper)**
- **RR73/77 Shielding Improvement (see ECR)**
- **Mid/Long-Term Action Plan (see report)**
- **R2E Memorandum for Short-Term Resources**
- **Power-Converter Summary (see internal report)**
- **Point-8 Iteration Summary (see final draft)**
- **Point-1/5 Iteration Summary (in preparation)**
- **Online Mitigation Project Tracking (see link)**
- **R2E Radiation School (see program and summary)**

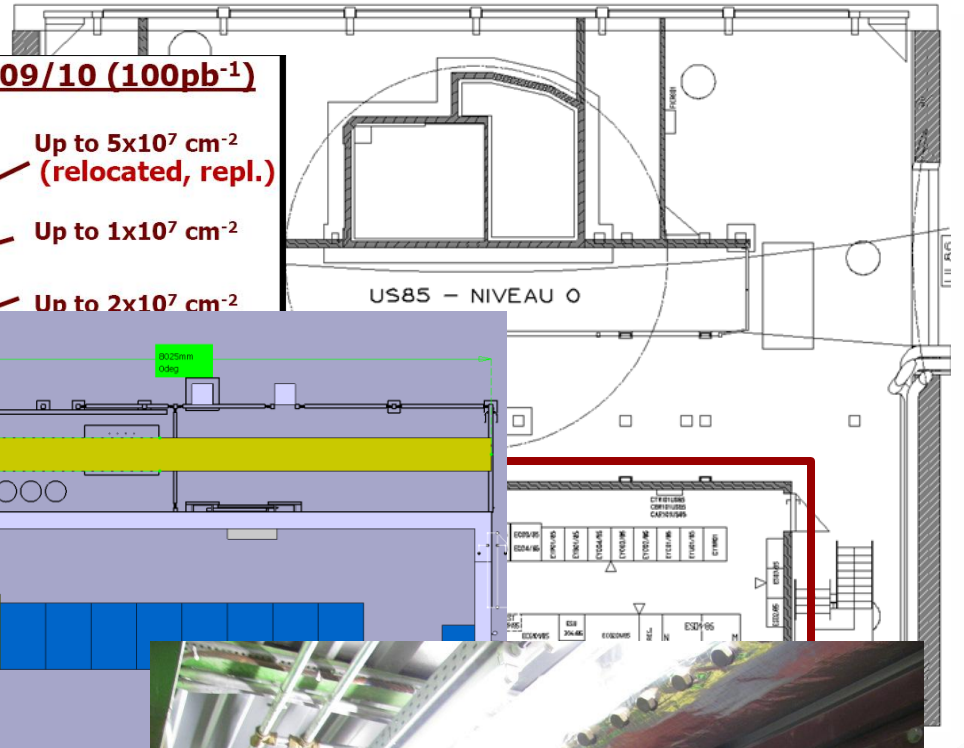
Backup

And Testing at CNGS?

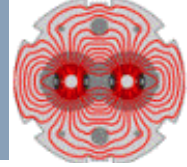


An Example: US85 Safe-Room Shielding

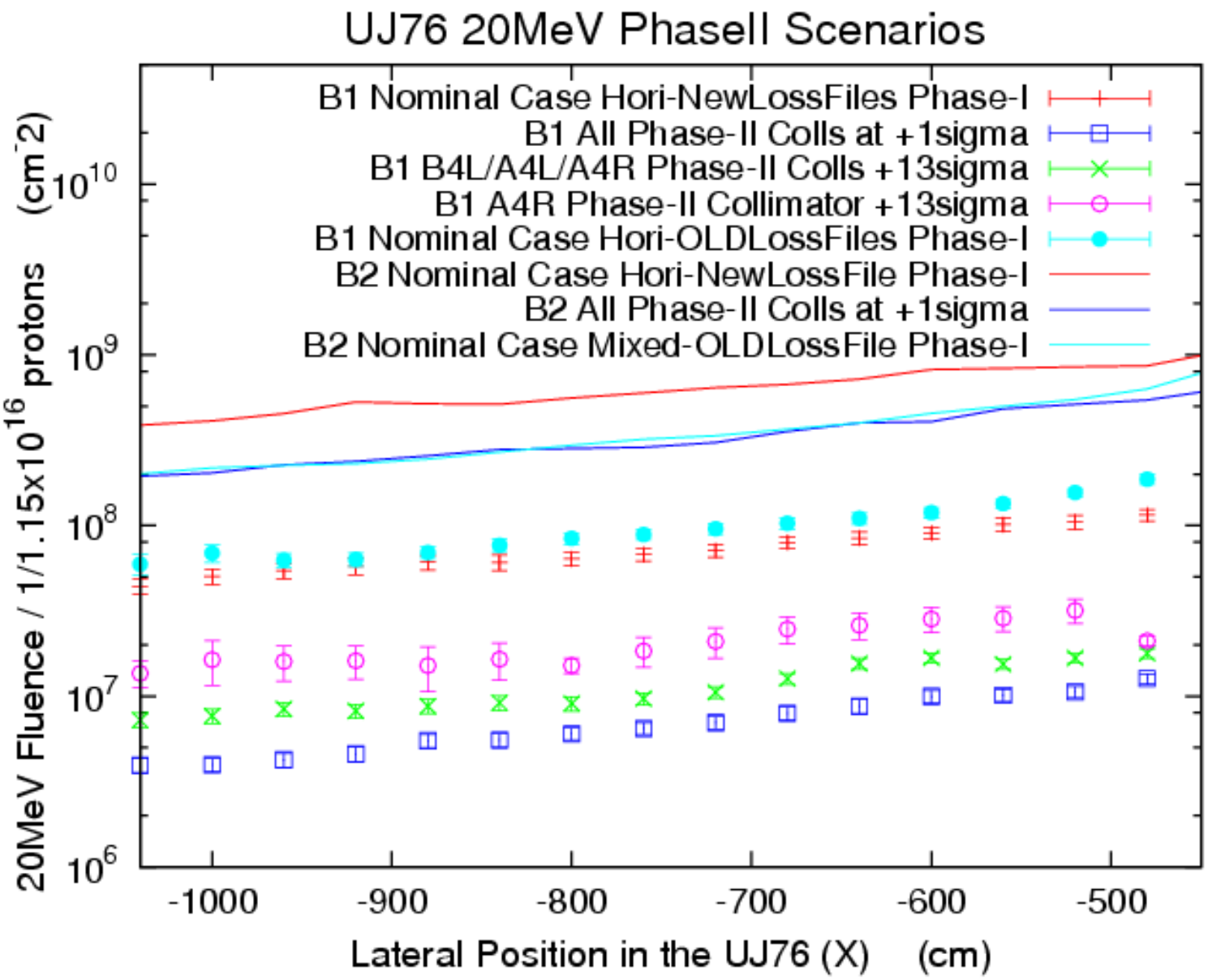




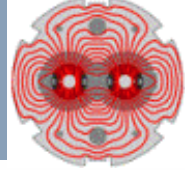
IR7: Phase-II Collimation as Absorbers



- Proposed
- Installing
- Openings
  - +1 sigm
  - +13 sigr
- Different
  - Beam-1
  - All-Phas
  - Only mc
- Effective
- Less effec of ~2)



IR7: Betatron-Cleaning in IR3



- Studied in the early R2E days
- Allows **relocating the losses from IR7 to IR3** (up to a certain beam intensity)
- Impact studied
  - tracking studies (R. Assmann et al.)
  - FLUKA studies radiation load in IR3 (UJ33, superconducting link, warm magnets,…)
- Results/Proposal summarized in **memorandum** (R. Assmann, see link)
- Proposal studied as **temporary solution**
- To be possibly reworked looking towards current collimation status and planned/possible upgrades

New equipment in US15

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