



R2E – Experience and Outlook for 2012

R2E Project: www.cern.ch/r2e

LHC Chamonix Workshop 2012

M. Brugger for the R2E Project

!!! Many Thanks To Everybody !!!

Specials: M. Calviani (MCWG) & G. Spezia (RadWG)

- @ 2011 **radiation levels** -> 2012
- @ **Mitigation measures:**
 - @ applied **prior 2011**
 - @ **'on-the-fly'** during the year
 - @ **xMasBreak**
- @ Observed **failures during 2011**
- @ What's to be **expected for 2012**
- @ **What do we need to learn in 2012**

Integrated Luminosity:

- @ ATLAS/CMS: 5.6 fb^{-1} in 2011 – 10x to nominal (50 fb^{-1})
- @ LHCb: 1.2 fb^{-1} in 2011 – ~2x to nominal
→ LS2: upgrade to $\sim 10 \text{ fb}^{-1}$?

Energy scaling:

- @ (3.5-7TeV): P1/5/7/8 – 1.5x

Intensity and distribution of collimation losses:

- @ #ofProtons on Collimators – ~10x to nominal (?)
- @ IR7/3 sharing of proton losses: (?)
- @ Loss distribution within IR7 (?)

Beam-gas (radiation levels in the ARC):

- @ @25ns operation (10-100x to be understood)

2012 More Details

Point-1/5 UJs + RRs: 2012: ~3x (if no actions!)

- ⊙ Failures scale with **integrated luminosity**
- ⊙ **BUT: UJ14/16 shielding** with the aim of being at least compatible with present operation + **additional relocations and patches**

US85: 2012: max 1.5x

- ⊙ Failures scale with **integrated luminosity**
- ⊙ **BUT: additional relocations** with the objective of reducing downtimes

UJ76, RR73/77 2012: ~3x (loss distribution?)

- ⊙ Failures scale with **collimation losses**

DS/ARC: 2012: ~3-5x (scrubbing?)

- ⊙ Failures scale with leakage from **experiments (luminosity)** as well as **collimation losses and beam-gas**

Very good agreement!

**Operational Parameters
& Extrapolation**

(based on measurements)

Area	FLUKA 2011 (HEH/cm ²)	Measured 2011 (HEH/cm ²)
UJ14/16	~1.5*10 ⁸	~2*10 ⁸
RR13/17	~3*10 ⁷	7.0*10 ⁶
UJ56	5*10 ⁷ -10 ⁸	3.5*10 ⁷
RR53/57	~3*10 ⁷	1*10 ⁷
UJ76	~4*10 ⁶	5*10 ⁶
RR73/77	~2*10 ⁶	~8*10 ⁶
UX85B	~3*10 ⁸	2*10 ⁸
US85	~7*10 ⁷	3.5*10 ⁷

Critical LHC Areas	High-Energy	
	2011	2012
UJ14/16	2.1E+08	1.3E+08
RR13/17	7.0E+06	2.1E+07
UJ56	3.5E+07	1.1E+08
RR53/57	1.1E+07	3.3E+07
UJ76	5.4E+06	1.6E+07
RR73/77	8.1E+06	2.4E+07
UX85b	1.7E+08	2.1E+08
US85	3.5E+07	4.4E+07

© M. Calviani & MCWG

Beam-Gas & Collimation Losses

Beam-Gas: 25ns + average pressures in the DS/ARC

- ⊙ Defines radiation levels in the ARC
- ⊙ Important long-term impact for QPS, Cryo, PCs, BI
- ⊙ Possibly lower average pressure than assumed so far
- ⊙ **25ns scrubbing run can clarify situation**
- ⊙ **Dedicated time at 'stable' conditions**
- ⊙ Ramp in energy required

Collimation Losses

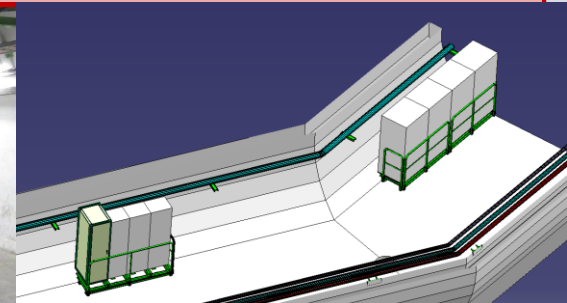
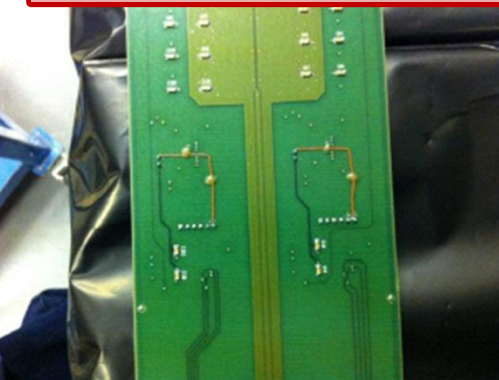
- ⊙ Tight collimator settings -> to be analyzed in detail
- ⊙ **IR3 and IR7 integrated loss sharing to be checked!**
(possible impact not only on R2E !)

Mitigation Measures < 2011

Area	Activity	Details	Time	Gain	
All	Tunnel + Shielded Areas	Upgrade	QPS Firmware Upgrade	2010/2011	Transparent
Point-2	UJ22/23	Shielding	Injection	2009/2010	~10
Point-5	UJ56	Relocation	Fire/ODH Control	2010	Safe
Point-5	UJ56	Relocation	EN/EL RTU	2010	Safe
Point-6	RA/UA 63/67	Shielding	RA/UA Connection Ducts	2009/2010	~5-10
Point-7	UJ76	Shielding	Wall (esp. SafeRoom)	2009/2010	~2-10
Point-7	UJ76	Relocation	EN/EL RTU	2010	Safe
Point-7	UJ76	Relocation	EN/EL UPS	2010	Safe
Point-8	UX85	Upgrade	Cryo Valves	2009/2010	Safe
Point-8	UX85	Relocation	Cryo-PLCs	2009/2010	Safe
Point-8	US85	Shielding	SafeRoom	2010	~10
Point-8	UJ88/87	Shielding	Injection	2009/2010	~10

- @ Following original **priority list**
- @ Improving the situation in most **critical areas**
- @ **Very effective** combined with 2011 patches and anticipated actions (see later)

Area	Activity	Details	Reference	Time	Gain	
Several	UJs, USs	Upgrade	Cryo ET200 Automatic Reset		2011	Transparent
Several	UJs, USs	Upgrade	Temperature Sensor	Mask partl. Manual	2011	More Robust
Several	UJs, USs	Upgrade	Temp.Sensor: Soft + Hardw.	ECR 1144903	xMas 2011/2012	Robust
Several	UJ14/16/56	Upgrade	Coll-Control	Watchdog for Controller	xMas 2011/2012	Robust
Point-1	UJ14/16	Relocation	P/W/BIC	PLC Part	2011	Safe
Point-1	UJ14/16	Relocation	Fire-Detectors	ECR 1053225	xMas 2011/2012	Safe
Point-1	UJ14/16	Shielding	UJ Junction	ECR 1182068	xMas 2011/2012	~5-10
Point-4	UX/US45	Relocation	Cryo-PLCs		xMas 2011/2012	Safe
Point-5	UJ56	Relocation	P/W/BIC	PLC Part	xMas 2011/2012	Safe
Point-5	UJ56	Relocation	EN/EL UPS	to UL557	xMas 2011/2012	Safe
Point-6	UX/US65	Relocation	Cryo-PLCs		xMas 2011/2012	Safe
Point-8	US85	Replacement	Cryo Power-Supply	Old-Model	2011	Robust
Point-8	US85	Relocation	WIC & Timing Rack	to UA83	xMas 2011/2012	Safe
Point-8	US85	Relocation	Cryo-PLCs		2011	Safe
Point-8	US85	Relocation	Ethernet (Starpoint)	to UL	xMas 2011/2012	Safe
Point-8	US85	Relocation	QURCb (EYQ)	Level-2 to Level-0	xMas 2011/2012	Better



See Talk from A.L. Perrot S05



Analysis of SEE induced Failures



Weekly R2E Shift

eLogBook + 8:30h

Equipment Groups

DBs

Rad WG web site-Detail

RadWG NEWS - QPS fault on RQTL11.R7B2

View

Version History | Alert Me

Edit Item | Manage Permissions | Delete Item

Manage | Actions

Title	QPS fault on RQTL11.R7B2
Body	two earlier cases due to SEE -> signature will be compared (recovered by power cycling) comment QPS team: RR77 DQGPU.E=RR77 RQTL11.R7B2 DQDQG #2A 20-09-2011 04:18:59.197 Soft error likely but no PM data, lack of PM data meanwhile understood
LHC point	Point 7
Area	DS
Caused by SEE	YES
Event Type	soft SEE
Beam Dump	Yes
Equipment Type	QPS
Equipment Failure Mode	Other
Mitigation Measures	Not Known
Effective Date	20/09/2011
LHC Fill #	2,127
Expires	

Link with the fill number

Post Mortem Database

Post Mortem Database - Data Browser

Global PM events

Event Timestamp	Event Category	Accelerator Mode	Beam Mode	Beam Energy [MeV]	Fill Number	Stable Beams [hours]	Fill Luminosity [nb ⁻¹]	Intensity B1 [1e10]	Intensity B2 [1e10]
21-SEP-11 07:14:00.978115 AM	PROTECTION_DUMP	PROTON PHYSICS	INJECTION PHYSICS BEAM	450120	2134	0	0	9597	9630
21-SEP-11 04:55:03.781585 AM	PROTECTION_DUMP	PROTON PHYSICS	RAMP	450120	2133	0	0	18742	18633
21-SEP-11 03:33:30.048091 AM	PROGRAMMED_DUMP	PROTON PHYSICS	INJECTION PHYSICS BEAM	450120	2132	0	0	18696	18851
21-SEP-11 12:27:57.219479 AM	PROTECTION_DUMP	PROTON PHYSICS	INJECTION PHYSICS BEAM	450120	2131	0	0	9151	9034
20-SEP-11 11:22:36.437883 PM	PROTECTION_DUMP	PROTON PHYSICS	INJECTION PHYSICS BEAM	450120	2130	0	0	17693	19723
20-SEP-11 08:25:16.053558 PM	PROTECTION_DUMP	PROTON PHYSICS	STABLE BEAMS	3500040	2129	10.3	76404.15	15217	15570
20-SEP-11 07:44:34.318800 AM	PROTECTION_DUMP	PROTON PHYSICS	SQUEEZE	3500040	2128	0	0	19260	19152
20-SEP-11 04:18:59.197561 AM	PROTECTION_DUMP	PROTON PHYSICS	STABLE BEAMS	3500040	2127	64	5393.773	18754	18856

Details on radiation failure

Mps Expert Comment

Mps Dump Cause

Mps First detection

Seu Dump

Seu Appeared Other Than Dump

Radwg Entry

Suspected SEU on QPS. Dump clean.

QPS

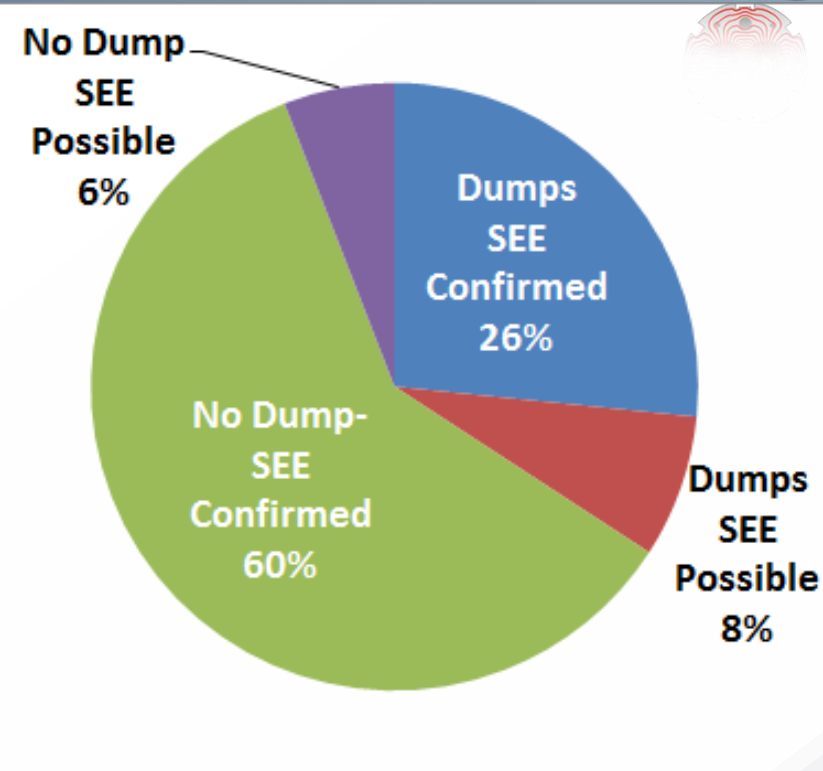
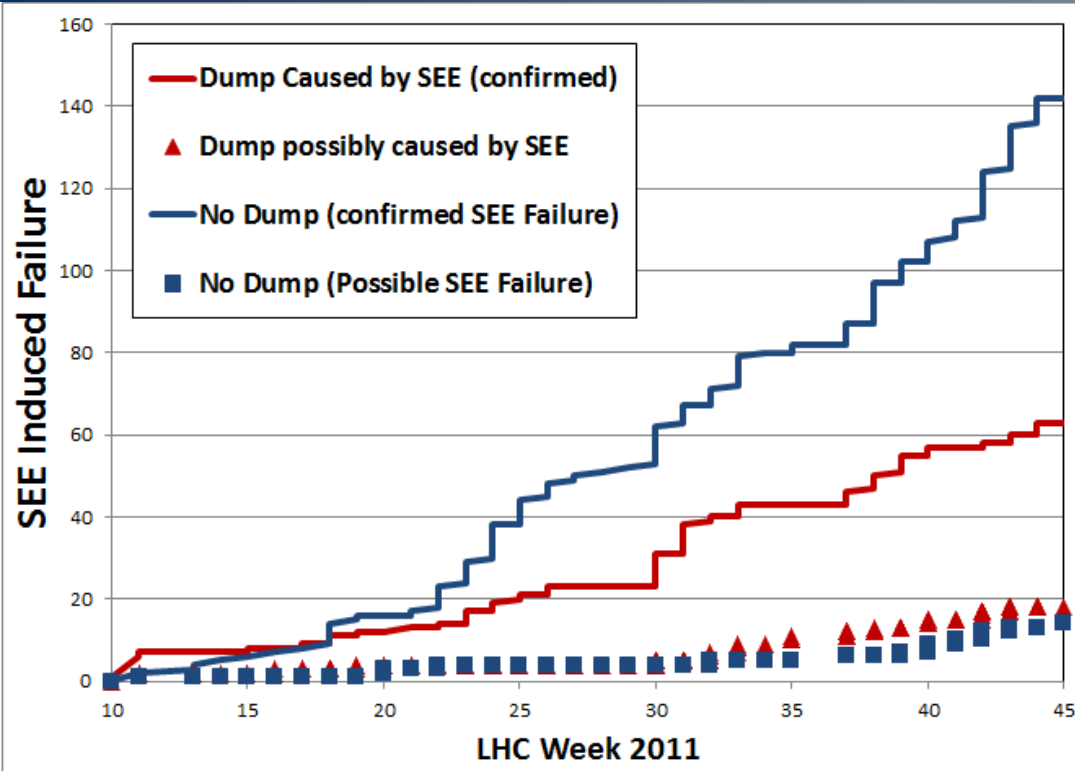
PIC

Possible

YES

RadWG link1
RadWG link2

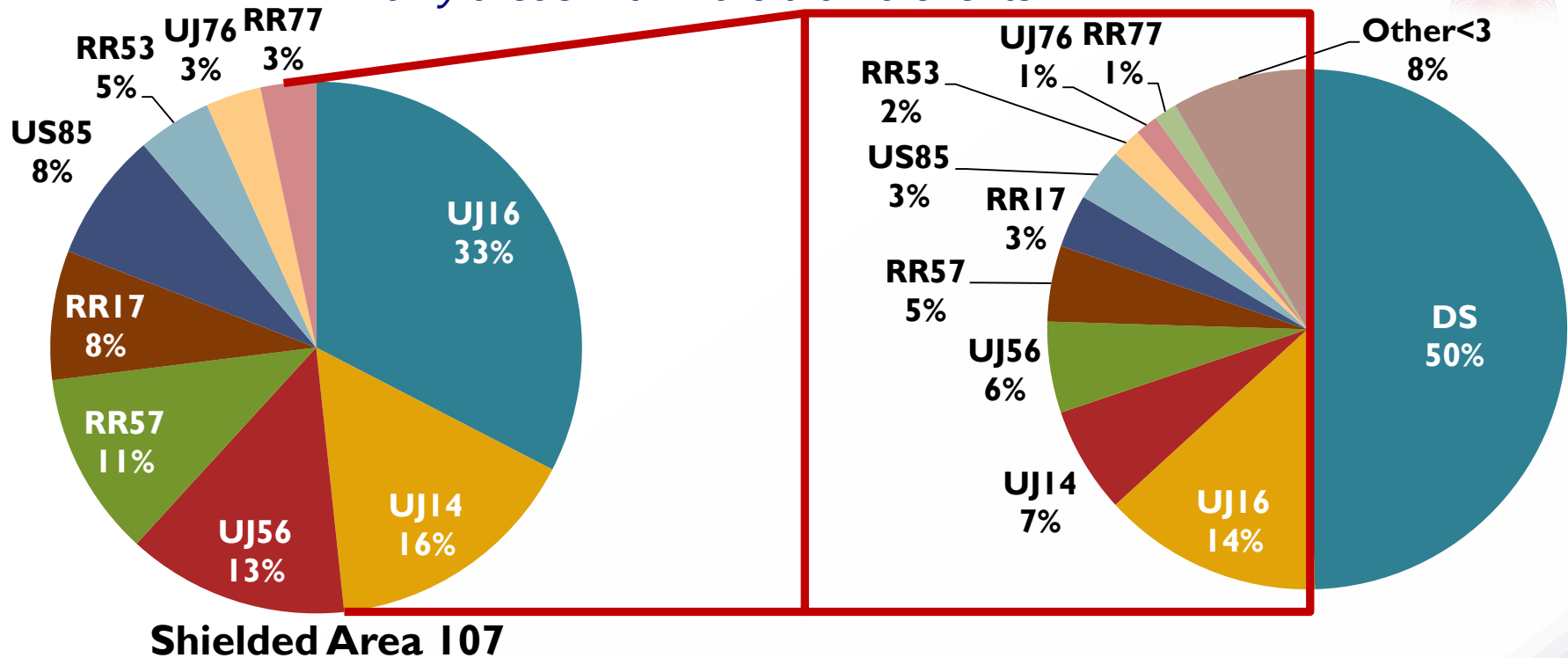
Failures during 2011 operation



- @ Events to be confirmed represent a relatively small fraction
- @ Increase of the “no dump events”
- @ consequence of patch solutions (QPS + Cryo)

Failures during 2011 operation

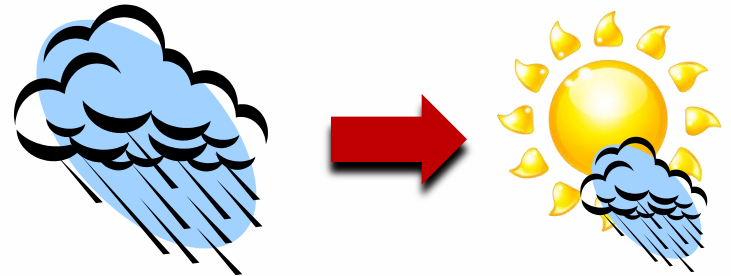
only areas with more than 3 events



- @ DS Events dominated by QPS
- @ Shielded area: UJ14/16 most critical
- @ ~50 events in total [in UJ14/16!]
- @ ~25 Beam Dump

In the following slides we've a more detailed look on the systems most affected during 2011

- @ QPS
- @ Cryogenics
- @ Power-Converters
- @ Collimation Control
- @ B/P/WIC Machine Interlock Systems
- @ EN/EL (UPS)
- @ Access Control (PAD/MAD)



Failures during 2011 operation

QPS

See Talk from R. Denz S06

- ⊙ **Location: Tunnel, UJs/RRs at Point 1, 5 and 7**
- ⊙ **Failure types (protection function never at risk!):**
ISO150, μ FIP, IPQ protection, 600A protection, DQQBS
- ⊙ **Mitigation:**
 - ⊙ all ISO150 mitigated (not dump, only access!)
(no impact, still final work during LS1)
many events (mostly transparent) in 2011
 - ⊙ auto-power-cycle (“BricofIP”)
few events (mostly transparent)
 - ⊙ new radiation tolerant IPQ sy
6 events (mostly transparent)
 - ⊙ new radiation tolerant for 60
11 events (mostly transparent)
 - ⊙ Firmware upgrade for DQQBS
8 events (mostly transparent), in 2011



Cryogenics

- @ **Location: UJs at Point 1, 5 and 7**
- @ **Failure types:**
 - @ PLC failures
 - @ Current lead temperature readings
 - @ Current lead valves
 - @ 24 VDC
- @ **Mitigation:**
 - @ PLC relocations (**6 events happened in 2011**)
 - @ ET200 Auto-Reset (**9 events happened in 2011**)
 - @ Switch to old power-supply (**2 events happened in 2011**)
 - @ Mask of wrong temperature reading
[xMasBreak soft- & hardware modification]
(**8 events happened in 2011**)

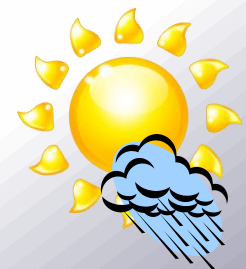


See Talk from L. Taviani S05

Failures during 2011 operation

Power Converters

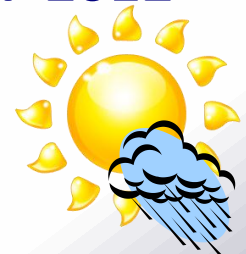
- ⊙ Location: Tunnel, UJ14/16,
RR (Point 1/5/7), UJs/UA (Point 2/8)
- ⊙ Failure types: 600A **Aux Power Supply**
(7 Destructive events), **Filter corruption FGC (3-4),**
120A Voltage Source (1-2),
4/6/8kA Voltage Source (1)
- ⊙ Mitigation:
 - ⊙ Digital filter improvement FGC
(**2011 + Christmas break**)
 - ⊙ Shielding UJ14/16 (**Christmas break**)
 - ⊙ Auxiliary Power-Supply Patch (**2012**)
 - ⊙ Re-Design/Relocation (**LS1 and beyond**)



Collimation Control



- @ **Location: UJs at Point 1 and 5**
- @ **Failure types: abnormal reboot of the controller, memory corruption, power supply failure**
- @ **Mitigation:**
 - @ **Survey of stuck bit-watchdog (Christmas break) – 4 events happened in 2011 – can lead to dumps in 2012**
 - @ **Shielding of the UJ14-16 (Christmas break) – 7/8 events happened in 2011**
 - @ **Power supply redundancy in UJ14/16/56 (on hold due to problem with delivered controller card) 3 events happened in 2011**
 - @ **Relocation (Long Shutdown 1)**



B/P/WIC – Machine Interlock Systems



- @ Location: UJ at Point 1 and 5
(and injection line in 2010)
- @ Type of failure: PLC communication lost, Deported I/O, (BIS [VME based] no problems)
- @ Mitigation:
 - @ Relocation of the WIC from TI2/8– **no more errors**
 - @ Relocation from UJ14/16 – **no more errors**
 - @ Relocation from UJ56 US85
(**Christmas break [BIS prep. UJ56]**)
 - @ **No more SEE induced events expected**



EN/EL equipment

- @ Location: UJ56, US85
- @ Type of failure: UPS system
(destructive failures)
- @ Mitigation:
 - @ Relocation from UJ56 (Christmas break)
 - @ Relocation from US85 (LS1)
 - @ New Type (esp. for REs) will be tested at H4IRRAD in 2012



Failures during 2011 operation

@ Access System (PAD/MAD)

- @ Location: Access to **UJ14 and UJ16**
- @ Type of failure: Block of the access system, iris scan
- @ General problem with end-of-life equipment in other points
- @ (part of) events in **UJ14/16 (and UJ23/87)** are likely to be radiation related



@ Mitigation :

- @ Shielding of the UJ14-16 (Christmas break)
- @ Relocation from Point1 (LS1)



What do we expect for 2012

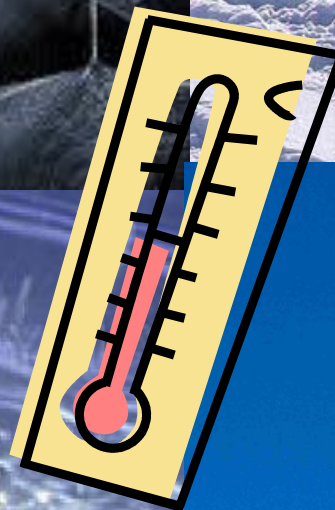
Affected Equipment Group	LHC Critical Areas	2011 #ofDumps	2011 #ofFailures	Estimated Downtime (partl. in shadow)	2011 Avoided SEE Dumps	2012 Expected Dumps	No Additional Mitigation	2012 Estimated Dumps	With Mitigation
QPS	Tunnel, UJs/RRs	23	140	~60 hours	150	69		~20	
Cryogenics	UJs	25	48	~250 hours	~25	75		1-2	
Power-Converters	Tunnel, UJs/RRs, UAs	13	15	~30 hours	few (FGC)	39		10-20	
Collimation Control	UJs (P1/5)	6	8	~20 hours	-	18		7	
B/P/WIC	UJs, US85	3	4	~15 hours	1-2	9		0	
Access	UJs	-	~4-8	~10 hours	-	-			
EN/EL	UJ56, US85	2	3	~15 hours	-	6		~1	
Totals		72	~220	~400h	~180	216		~30-50	

- @ xMas-Mitigation crucial
- @ Patches to continue during 2012
- @ Particular emphasis (analysis) of 'new' failures

Conclusions

- ⊙ **2011: ~70 dumps events**
- ⊙ Predicted ~100 in Chamonix 2011
- ⊙ Good agreement (considering 2011 patch solutions)
- ⊙ **2012: ~30-50 dump events expected**
- ⊙ Mitigation actions (patch solutions, shielding and relocation) were/are crucial to reduce dump events
- ⊙ Failure estimation has uncertainty factors
 - ⊙ Beam gas effect
 - ⊙ Collimation losses
 - ⊙ Equipment failure types not yet appeared
- ⊙ TS a lot to be done! (c.f. Anne-Laure's talk)
- ⊙ >LS1: benefit from relocation and shielding + new developments

Thank You



Conclusions

- ⊙ **2011: ~70 dumps events**
 - ⊙ Predicted ~100 in Chamonix 2011
 - ⊙ Good agreement (considering 2011 patch solutions)
- ⊙ **2012: ~30-50 dump events expected**
 - ⊙ Mitigation actions (patch solutions, shielding and relocation) were/are crucial to reduce dump events
 - ⊙ Failure estimation has uncertainty factors
 - ⊙ Beam gas effect
 - ⊙ Collimation losses
 - ⊙ Equipment failure types not yet appeared
- ⊙ **TS a lot to be done!** (*c.f.* Anne-Laure's talk)
- ⊙ **>LS1: benefit from relocation and shielding + new developments**

BACKUP

What's about Ion Operation

- ② **Analysis based on RadMons & BLMs (A. Nordt & MCWG)**
- ② **Losses during ion operation in the DS are equal and partly dominate respective radiation levels**
 - ② **P1/5: about factor of 2-5 (2011, nominal ~1:1?)**
 - ② **P3: factor of 10-15 higher (momentum losses)**
 - ② **P7: factor 2-3 (2011, nominal ~1:1?)**
- ② **Point-2: Ions only, values comparable to P1/5**
- ② **Dose/Fluence range (max P1/5): 5-200Gy, $5 \times 10^9 - 10^{11} \text{cm}^{-2}$**
- ② **Affected cells: 9-13 (very localized)**
- ② **TCL currently open (P1/5)!**
- ② **Additional RadMon coverage foreseen (>LS1)**

1st Safety
Critical



Immediate Relocation



2nd Shielding



"Fast" & Global Improvement



3rd Most
Sensitive



Highest Impact on Operation:
(1) Relocation
(2) Shielding



4th Remaining

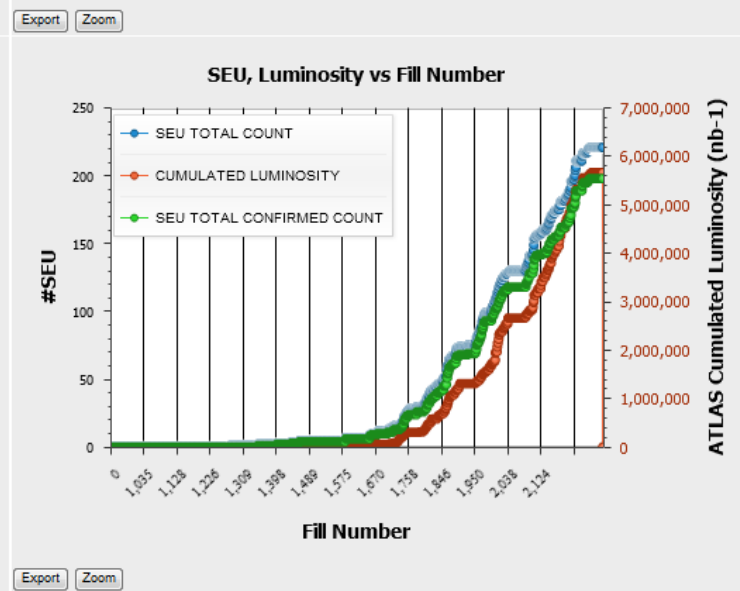
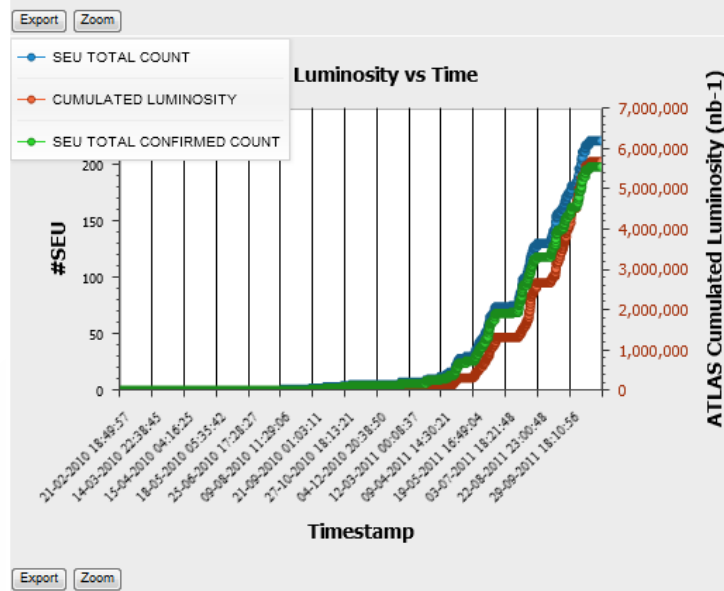
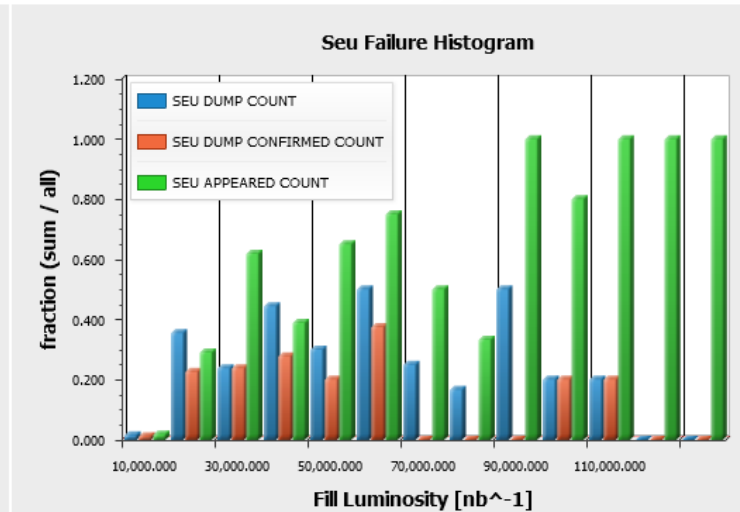
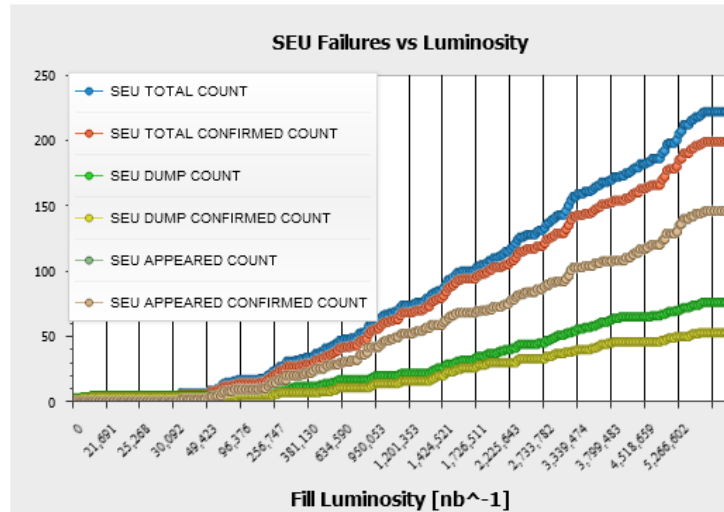


(1) Relocation
(2) Shielding
(3) New Design



Statistics through PM-DB

!!! Many thanks to R.M. Leszko & M. Zerlauth !!!



Mitigation Measures 2011

Mitigation Measures during 2011	
Type	Est. Gain
QPS firmware	-150 events
Cryo power supply	-3 events
Cryo automatic reset	-9 events
Cryo Temperature reading	-8 events
Cryo relocation	
B/P/WIC relocation	



What do we expect for 2012

Equipment	Equipment failure mode	Failures 2011		Possible dumps in 2012	
		Dump	UJ P1	Without 2011 + xMasBreak Actions	With Mitigation Actions
B/P/WIC	PLC communication lost			0	0
Collimation	controller	1	5	2	1
	Power supply	3	2	4	1
Cryo	Temperature reading	7	0	21	0
	ET200S	12	8	16	0
	Power supply + PLC	11	0	33	1
EN/EL	UPS	2	0	6	1
EPC	Power supply crash	7	2	15	15
	FGC error/reset	4	1	10	0
QPS	DAQ mitigated	no dump			20 (assumption: mitigation actions will allow a gain of 2.5)
	Other DAQ	no dump			
	DAQ microfip	no dump			
	DQQDG	10	5	17	
	DQQDI	6	3	10	
	nQPS DQQBS	6		18	
	nQPS comm problem				
	nQPS ok-lost				
Other	-				5
TOTAL		69	26	150	45

Failures during 2011 operation

	UJ14 UJ16	RR Point1	UJ-RR Point5	US85	UA23 UA87 UJ43	UX45 UX65	Total
Power Supply-PXI	2		1				3
Power Converter	2	2			3		8
EN/EL			2	1			3
CRYO	2			4		3	9

@ Destructive events

@ 23 over 60 confirmed beam dump

Destructive events 2012

	Total
Power Supply-PXI	0-1
Power Converter	10-12
EN/EL	1-2
CRYO	1-2

Considering

- UPS relocation from Uj56
- Cryo relocation from US85
- Double power supply for PXI
- Shielding UJ14/16

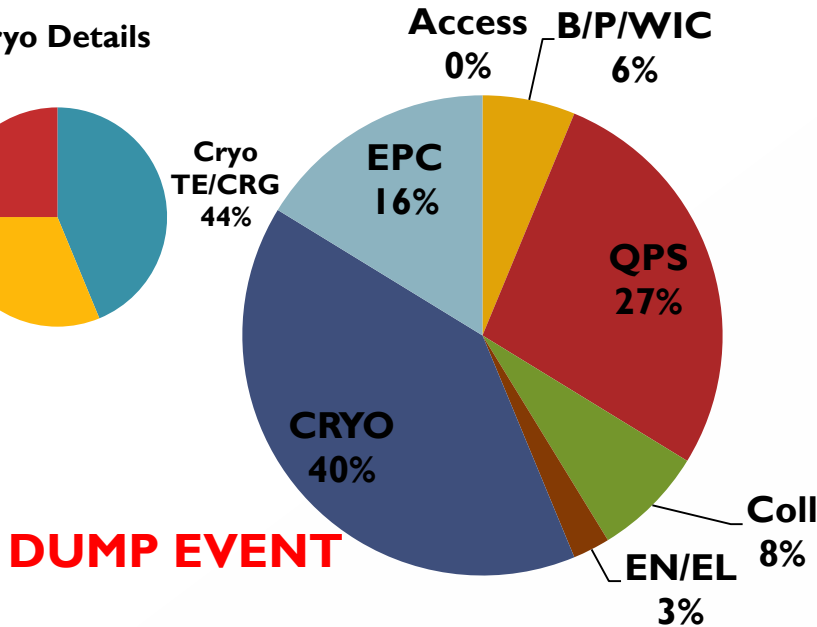
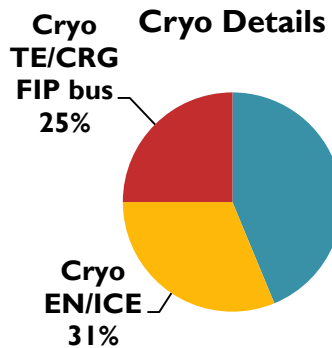
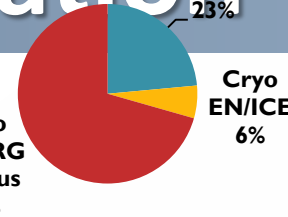
□ TOTAL 15-18

□ It is a rough estimation

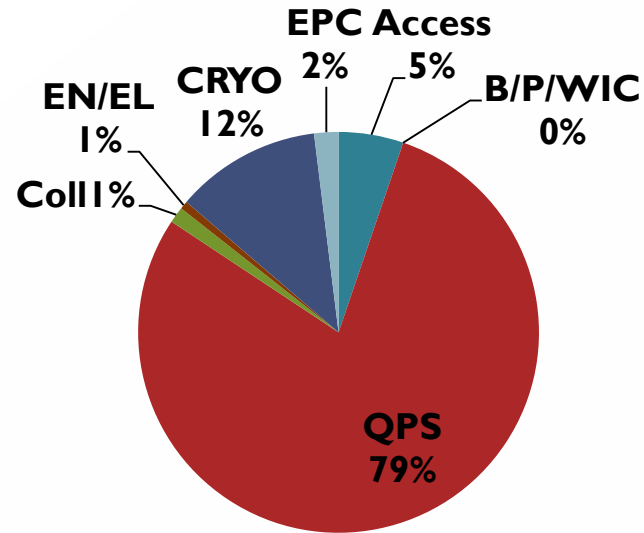


Failures during 2011 operation

Cryo details

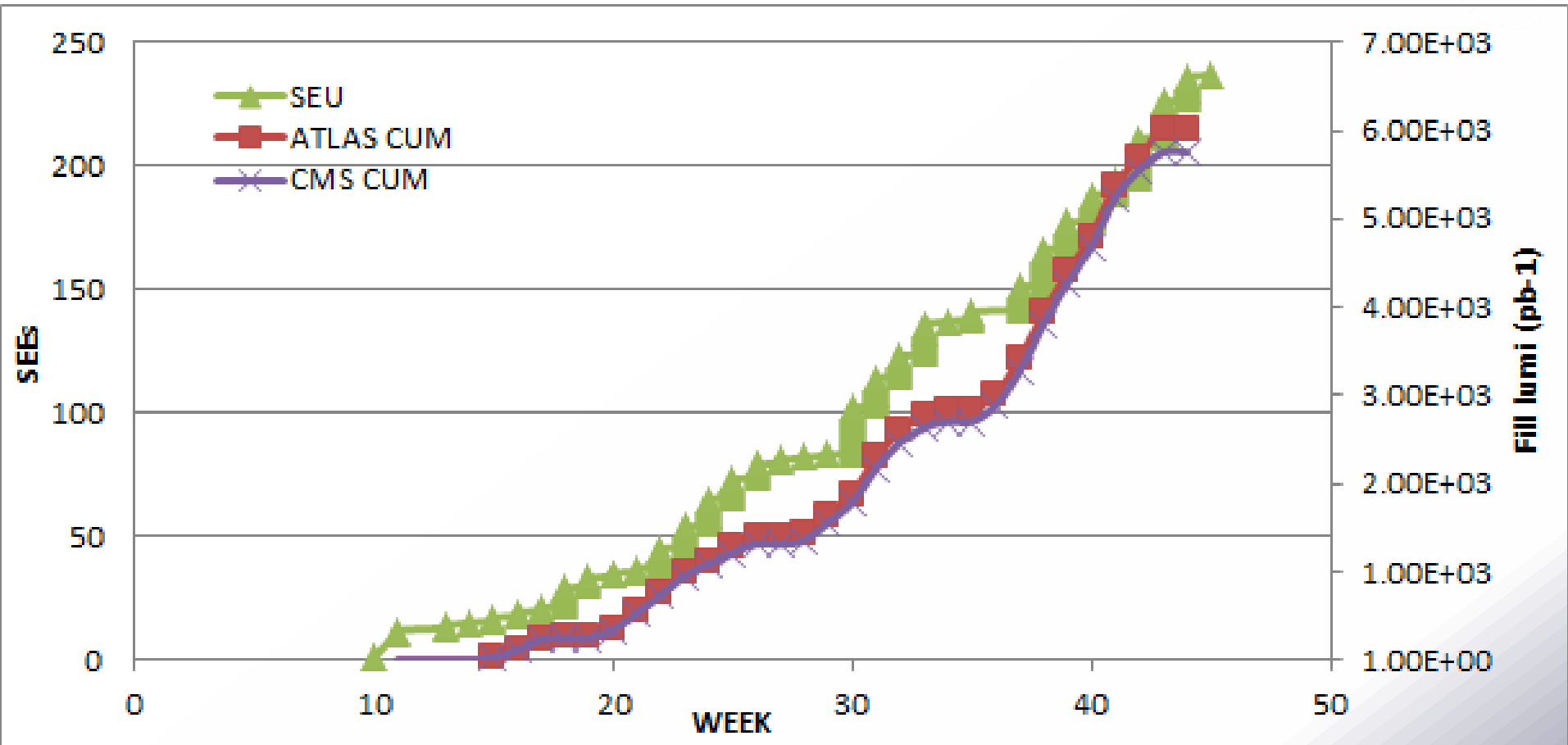


DUMP EVENT



No Dump Event

- QPS and Cryo - (high number of parts and more exposed)
- Failures on other equipment can rise up during next year operation



Mitigation Measures in 2011

- ④ QPS – firmware upgrade (ISO150) almost 100 events avoided since then
- ④ Cryo – PLC removed from US85
- ④ Cryo (via EN/EL) – Replacement of power supply with old models – 4 events happened in 2011
- ④ Cryo – Automatic Reset of PLC (TE/CRG) 9 (Dump) events avoided since then;
- ④ Cryo – Temporary mask (Software) of the false reading of the temperature sensors – 8 (Dump) events avoided since then
- ④ P/W/BIC – Relocation of the equipment from UJ14/16 – 3 events happened in 2011

Mitigation Measures at xMas

- ⊙ QPS – hardware updates (see details in the dedicated talk)
- ⊙ Cryo – Hardware modifications to fix the false temperature readings (5 events in 2011)
- ⊙ Cryo (EN/ICE) – PLC relocation at point 4, 6, 8 (8 events in 2011)
- ⊙ Collimation – Power supply redundancy; survey of stuck bits (3-5 events in 2011)
- ⊙ B/P/WIC – Relocation of the equipment from UJ56 and US85 (5 events happened in 2011)
- ⊙ Other relocation of Fire Detectors Equipment
- ⊙ Shielding of the area UJ14/16 → radiation reduced by a factor 2 in 2012. The factor 2 takes into account Shielding efficiency and radiation level increase
- ⊙ We can say: **~20 Dumps of 2011 will be avoided**

Downtime due to Failures

- ⊙ **A preliminary analysis was done** taking into account
 - ⊙ RadWG list PM database and e-logbook entries
 - ⊙ Time interval between beam fills
 - ⊙ Manual iteration of cases
- ⊙ **A detailed list is available** and will be iterated with equipment owners (for Chamonix)
- ⊙ **Dump (confirmed): ~350h**
- ⊙ **Required access** (not dump and not in the shadow of another access): **~50h**
- ⊙ **Unconfirmed cases: additional increase of ~100h**
- ⊙ **Most impacted:**
 - ⊙ Cryogenics: long downtimes due to PLCs
 - ⊙ QPS: number of events

converter	failure per year		
	2011	2012	>LS1
LHC60A-8V	4	10 .. 30	60 .. 200
LHC120A-10V	1	2 .. 3	10 .. 30
LHC600A-10V	7	7 .. 10	1 .. 15
LHC4-6-8kA-8V	1	1 .. 3	1 .. 45

- ❑ FGCs highest priority
- ❑ Destructive failures on auxiliary power-supply (600A)
 - > patch required during 2012
- ❑ Low radiation levels in the ARC (most units of 60A)
- ❑ H4IRRAD observations are coherent