R2E – Experience and Outlook for 2012

(R2E) Mitigation Project: www.cern.ch/r2e

Evian Workshop 2011

G. Spiezia for the R2E Project

!!! Many Thanks To Everybody !!!

Overview

- Radiation levels and source terms
- Mitigation Measures:
  - applied prior 2011
  - ‘on-the-fly’ during the year
  - Upcoming at xMas
- Failures observed during 2011
- What’s to be expected for 2012

R2E Mitigation Strategy

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

Mitigation Measures < 2011

Shielding: thanks to EN/MEF

- P6 ducts (RA/UA 63/67) – kicker equip. (gain factor ~5-10) – during 2009/2010
- UJ76 wall (Fe - gain factor of ~2-10) – during 2009/2010
- RR73/77 maze (Fe - gain factor ~10) – during 2009 (ECR: 985313)
- US85 safe room (gain factor ~10) – during 2010 (ECR: 1053225)
- UJ22/23/88/87 – injection protection (gain factor ~10) – 2009/2010

Mitigation Measures < 2011

Relocations: thanks to EN/MEF

- **Fire detector control racks UJ56/76, US85 (safe) (ECR: 1053225)**
- **Relocation of fire-detectors US85 (safe) (ECR: 1053225)**
- **EN/EL RTU relocated from safe room in UJ56/76 (safe)**
- **UPS removed from UJ76 (safe)**
- **CRYO relocation/valve replacement in UX85 (safe)**
- **CRYO removed PLCs from UX85 (2009-10) and US85 (2011) (safe)**

Radiation levels and scaling

2011 LHC Operation – Scaling?

Luminosity:

- ATLAS/CMS: 5 fb^{-1} in 2011 – 10x to nominal (50fb^{-1})
- LHCb: 1.2 fb^{-1} in 2011 – ~2x to nominal
  –> upgrade to 5-10 fb^{-1}?

Energy scaling:

- (3.5-7TeV): P1/5/7/8 – 1.5x

Intensity and distribution of collimation losses:

- Total losses – 10x to nominal (?)
- IR7/3 sharing: (?)
- Loss distribution within IR7 (?)

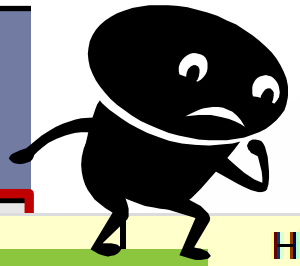
Beam-gas:

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

Confidence in our Predictions

Very good agreement!

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



Operation & Extrapolation

Areas		High-Energy Hadron Fluence			
		011	2012	Nominal	Ultimate
Critical	UJ14/16	2.1E+08	1.3E+08	6.3E+08	2.5E+09
	RR13/17	7.0E+06	2.1E+07	2.1E+08	8.4E+08
	UJ56	3.5E+07	1.1E+08	5.3E+08	2.1E+09
	RR53/57	1.1E+07	3.3E+07	3.3E+08	1.3E+09
	UJ76	5.4E+06	1.6E+07	8.1E+07	3.2E+08
	RR73/77	8.1E+06	2.4E+07	2.4E+08	9.7E+08
	UX85b	1.7E+08	2.1E+08	4.3E+08	4.3E+09
	US85	3.5E+07	4.4E+07	8.8E+07	8.8E+08

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2012 More Details

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

- Failures scale with cumulated luminosity
- BUT: UJ14/16 shielding and relocation with the aim of being at least compatible with present operation

US85: 2012: max 1.5x

- Failures scale with cumulated luminosity
- BUT: additional relocations with the objective of reducing downtimes

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

- Failures scale with collimation losses

DS/ARC:

- Failures scale with leakage from experiments (luminosity) and collimation losses and beam-gas

Beam-Gas & Collimation Losses

25ns and average pressures in the DS/ARC

- Good news: possibly lower average pressure
- 25ns scrubbing run can clarify situation
- Dedicated time at ‘stable’ conditions
- Ramp in energy required

Collimation Losses

- Tight collimator settings -> additional measurement periods required!
- IR3 and IR7 loss distribution to be investigated (possible impact not only on R2E !)

What's about Ion Operation

- Preliminary analysis based on RadMons, BLM analysis ongoing (A. Nordt & MCWG)
- Losses during ion operation in the DS are equal and partly dominate respective radiation levels
  - P1/5: about factor of 2-5 (2011, nominal ~1:1?)
  - P3: factor of 10-15 higher (momentum losses)
  - P7: factor 2-3 (2011, nominal ~1:1?)
- Point-2: Ions only, values comparable to P1/5
- Affected cells: 9-13 (very localized)
- TCL currently open (P1/5)!
- Total Dose/Fluence 2011 (max P1/5): 5-100Gy, $2x10^{9} – 5x10^{10}cm^{-2}$
- Additional RadMon coverage suggested

Failures analysis

Information collection

- **R2E weekly shift** to collect information
- First information source: **e-logbook, 8h30 LHC meeting**
- **TE/MPE, TE/CRG, TE/EPC, EN/STI** have assured a continuous follow-up
- **Other:** suspicious events analysed by means of continuous mail exchange
- **What we store:**
  - Location
  - Date-Time failure
  - Equipment/Component
  - Consequence of the failure
  - Beam fill

Information collection

Rad WG web site-Detail

RadWG NEWS - QPS fault on RQTL11.R7B2

View

Edit Item | Version History | Manage Permissions | Delete Item | Alert Me

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 DQQDG #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	

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	9934
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	16754	18856

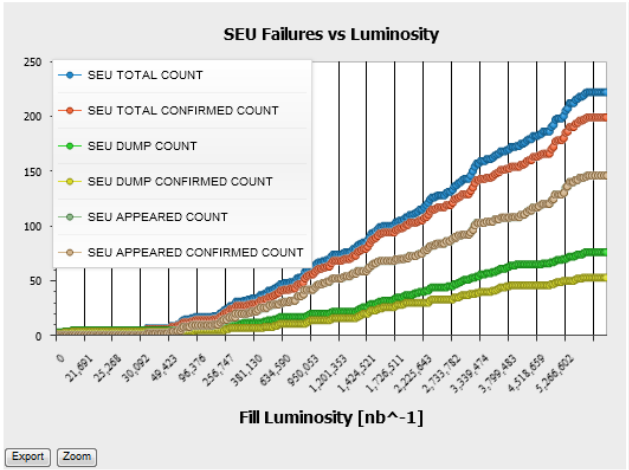
Link with the fill number

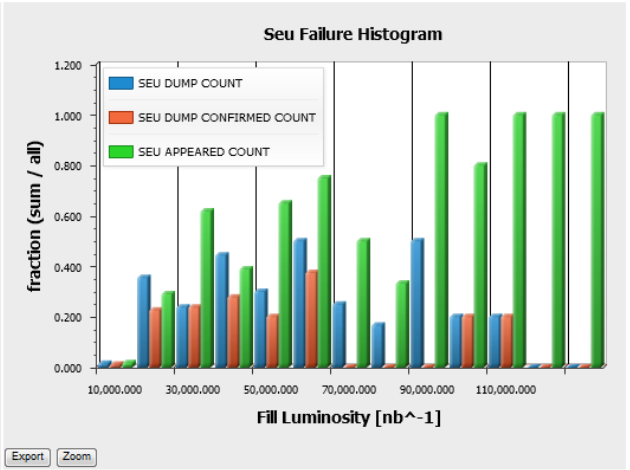
Details on radiation failure

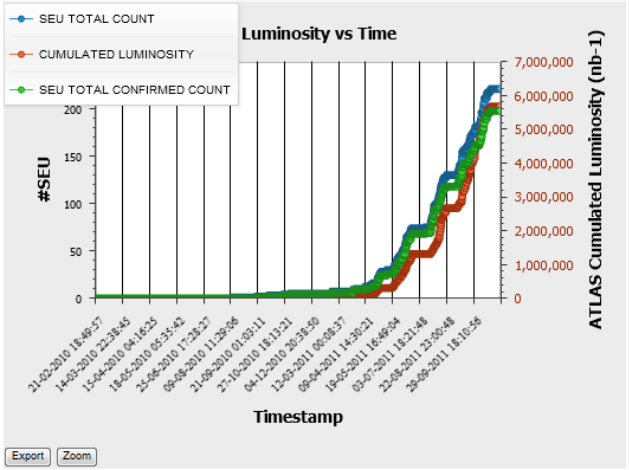
Mps Expert Comment	Mps Dump Cause	Mps First Detection	Seu Dump	Seu Appeared Other Than Dump	Radwg Entry
Suspected SEU on QPS. Dump clean.	QPS	PIC	Possible	YES	RadWG link1 RadWG link2

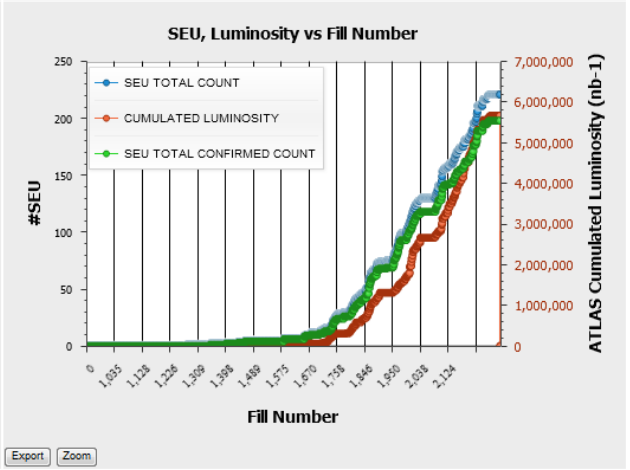
Information collection

- Friendly tool to retrieve statistics

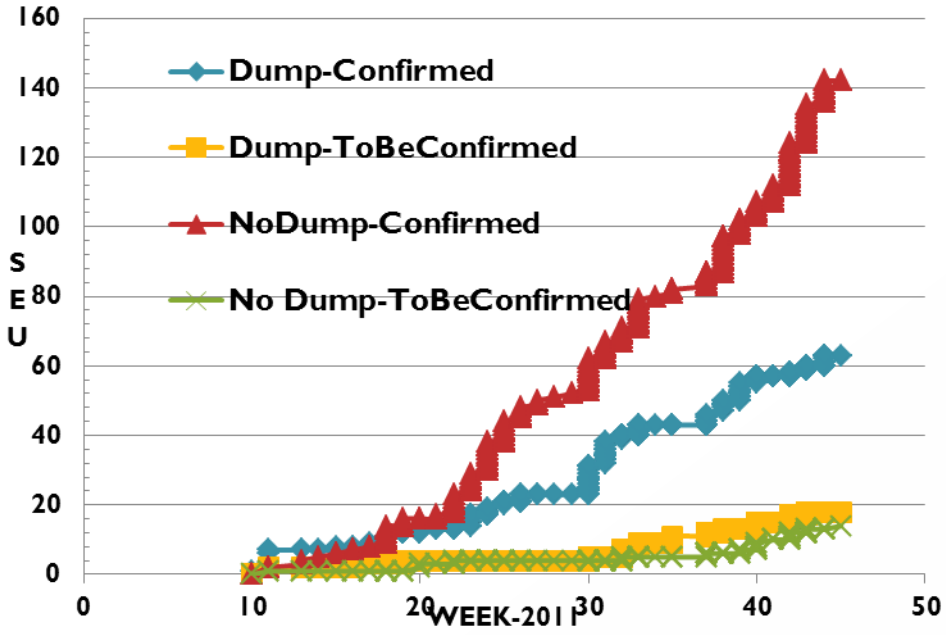


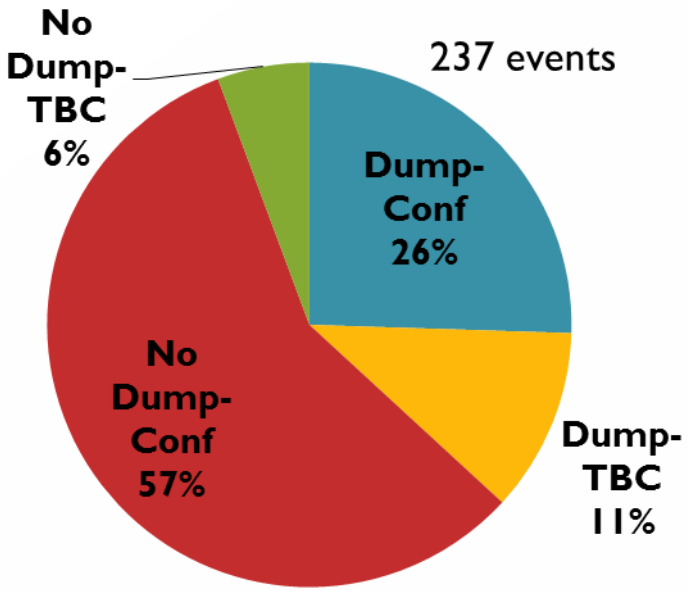






Failures during 2011 operation

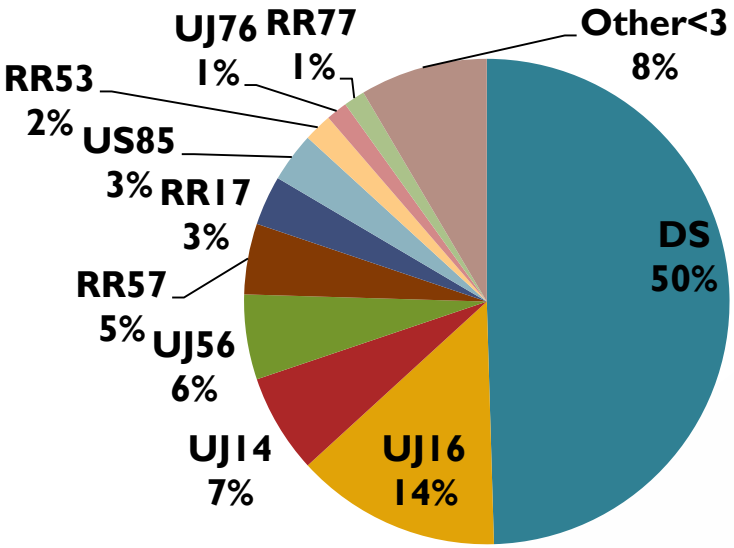


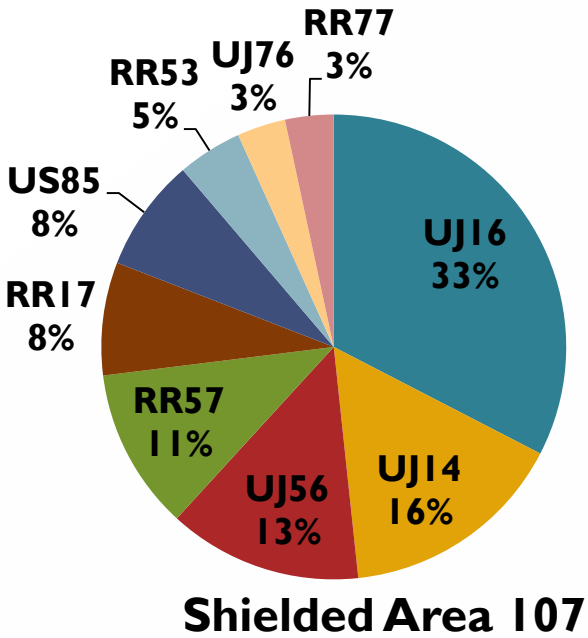


- Events to be confirmed represent a smaller fraction
- Increase of the "no dump events"
  - Consequence of patch solutions

Failures during 2011 operation

Area with more than 3 events





Shielded Area 107

- DS Events dominated by QPS (but only 8 Dumps)
- Shielded area: UJ14/16 most critical
  - ~50 events in total
  - ~25 Beam Dump

Failures during 2011 operation

Collimation Control

- Location: UJs at Point 1 and 5
- Failure types: abnormal reboot of the controller, memory corruption, power supply failure
- Mitigation:
  - Power supply redundancy in UJ14/16/56 (Christmas break) –
    3 events happened in 2011
  - Survey of stuck bit-watchdog (Christmas break) –
    4 events happened in 2011
  - Shielding of the UJ14-16 (Christmas break) –
    7/8 events happened in 2011
  - Relocation (Long Shutdown 1-2013)

Failures during 2011 operation

- **Access System**
  - Location: Access door 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 radiation related
  - **Mitigation :**
    - Shielding of the UJ14-16 (Christmas break)
    - Relocation from Point1 (LS1)

Failures during 2011 operation

B/P/WIC – Interlock Control

- Location: UJ at point 1 and 5 (and injection line in 2010)
- Type of failure: PLC communication lost, Deported I/O
- Mitigation:
  - Relocation of the WIC from TI2/8 (2010)– no more errors
  - Relocation from UJ14/16 – no more errors
  - Relocation from UJ56 US85 (Christmas break)
  - No more SEE expected

Failures during 2011 operation

Power Converters

- Location: UJ14/16, RR (Point 1/5/7), UJs/UA (Point 2/8)
- Failure types:
  - Aux Power Supply (8 Destructive events)
  - Filter corruption on FGC
- **Mitigation:**
  - Digital filter improvement FGC (Christmas break)
  - Shielding UJ14/16 (Christmas break)
  - Re Design/Relocation (LS1 and beyond)

Failures during 2011 operation

EN/EL equipment

- Location: UJ56, US85
- Type of failure: UPS system (Destructive failures)
- Mitigation:
  - Shielding / Relocation
  - Relocation from UJ56 (Christmas break)
  - Relocation from US85 (LS1)

Summary and outlook for 2012

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 → avoid downtime due to other failures
- 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

Mitigation Measures Summary

Mitigation Measures during 2011	
Type	**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	

- **Most important 'on fly' actions**
- **Significant reduction of the SEU failures**

Mitigation Measures Summary

Mitigation Measures @ Christmas	
Type	Gain
QPS	see details
Cryo hardware patch on temperature reading	no event expected
Cryo relocation	no event expected
Collimation-power supply	no event expected
B/P/WIC relocation	no event expected
Shielding of Uj14/16	Radiation levels reduced by a factor 2 wrt 2011

What do we expect for 2012

Equipment	Equipment failure mode	Failures 2011		2012 Expectation	
		Dump	UJ P1	Without mitigation	With mitigation actions
B/P/WIC	PLC communication lost			0	0
Collimation	controller	1	5	0.5	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	9.5	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

What do we expect for 2012

Equipment	Failures 2011	2012 Expectation	
	Dump	Without mitigation	With mitigation actions
B/P/WIC		0	0
Collimation	1	0.5	1
	3	4	1
Cryo	7	21	0
	12	16	0
	11	33	1
EN/EL	2	6	1
EPC	7	15	15
	4	9.5	0
QPS	10	17	20 mitigation actions will allow a gain of 2.5
	6	10	
	6	18	
Other			5
TOTAL	69	150	45

Conclusions

- **2011: ~70 dumps events**
  - Predicted 100 in Chamonix 2011
  - Good agreement (considering on fly mitigations)
- **2012: ~30-50 dump events expected**
  - Mitigation actions (patch solutions, shielding and relocation) are crucial to reduce dump events
  - Failure estimation has uncertainty factors
    - Beam gas effect
    - Collimation losses
    - Equipment failure types not yet appeared
- **>LS1: relocation and shielding**
  + new developments

THANK YOU FOR YOUR ATTENTION

Back-up

What do we expect for 2012

Equipment	Equipment failure mode	Failures 2011		Expected dump in 2012	
		Dump	UJ P1	Without mitigation actions	With mitigation actions
B/P/WIC	PLC communication lost			0	0
Collimation	controller	1	5	0.5	1
	Power supply	3	2	4	1
Cryo	Temperature reading	13	0	39	0
	ET200S	9	8	7	0
	Power supply + PLC	8	0	24	1
EN/EL	UPS	2	0	6	1
EPC	Power supply crash	7	2	15	15
	FGC error/reset	4	1	9.5	0
QPS	DAQ mitigated	no dump			20 (assumption: mitigation actions will allow a gain of 2.5)
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	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 fromUS85
- Double power supply for PXI
- Shielding UJ14/16

❑ TOTAL 15-18

❑ It is a rough estimation

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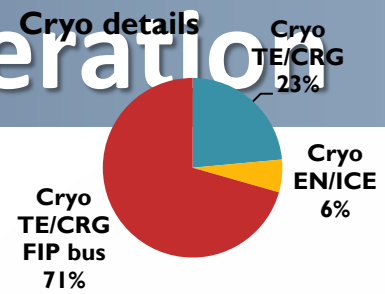
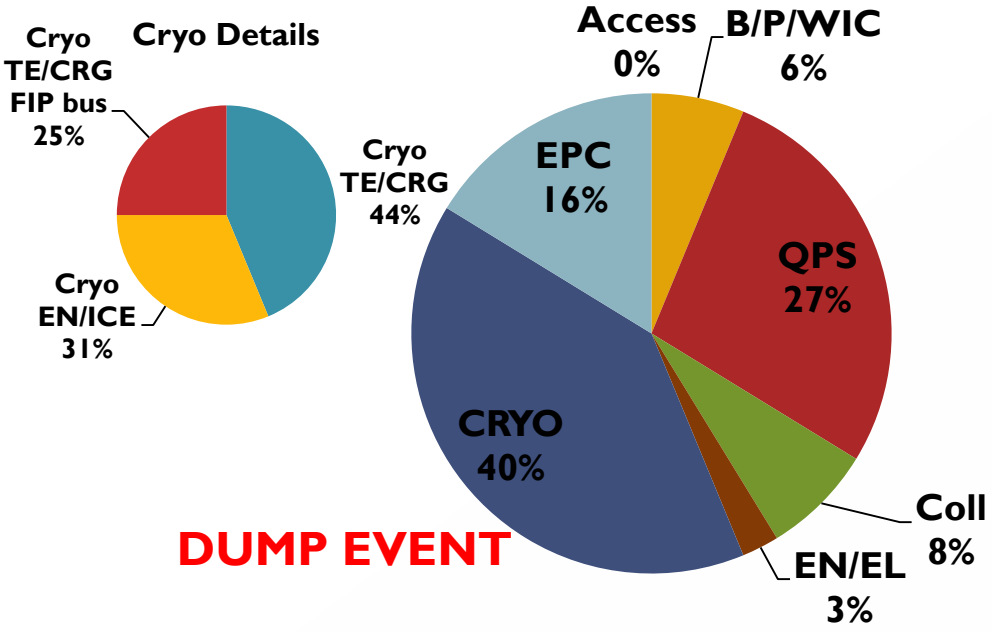
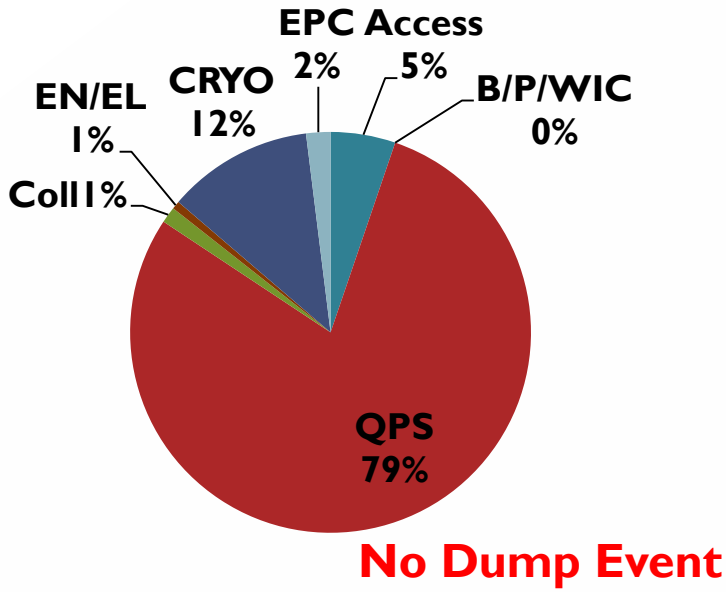
Failures during 2011 operation







- 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

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