



R2E – Experience and Outlook for LS1

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

Evian Workshop 2012

G. Spiezia for the R2E Project

!!! Many Thanks To Everybody !!!

- @ Radiation levels and source terms**
- @ Failures observed during 2012**
- @ What's to be expected for 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



Radiation levels and scaling

Radiation Levels

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

Predictions ↔ versus Observations
(scaled to exp. lumi)

1.1x10⁸



1.8x10⁷



1.2x10⁸



1.8x10⁷

Decrease: TCL closed

5.5x10⁷

Increase: Tight Collimators

3.0x10⁷



2.6x10⁸



6.5x10⁷



...and Today

1.4E+08
2.3E+07
1.5E+08
2.5E+07
6.0E+07
3.9E+07
3.5E+08
8.8E+07

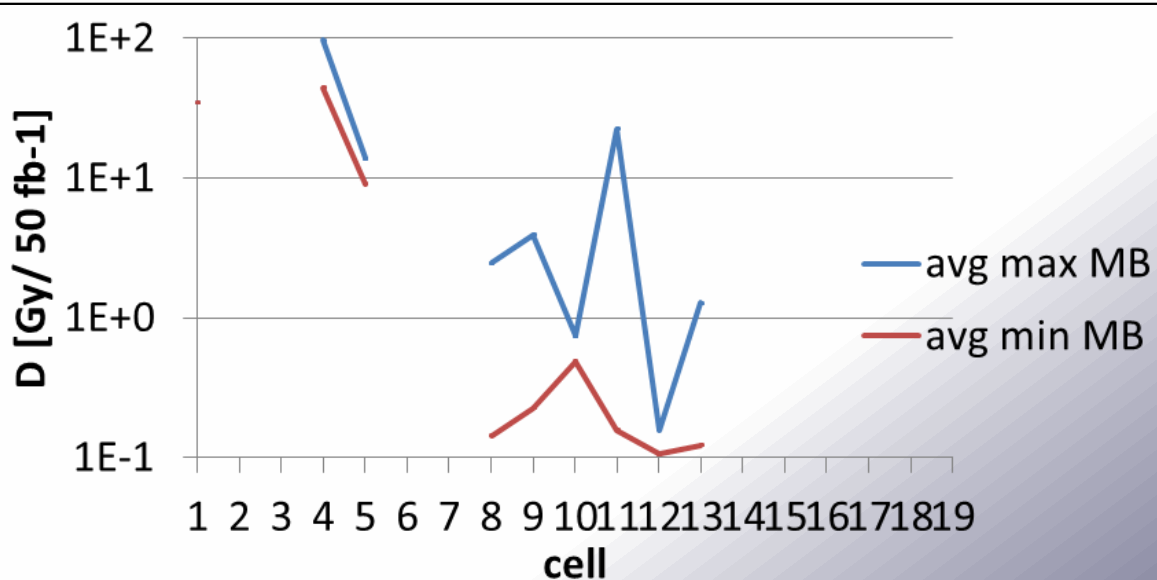
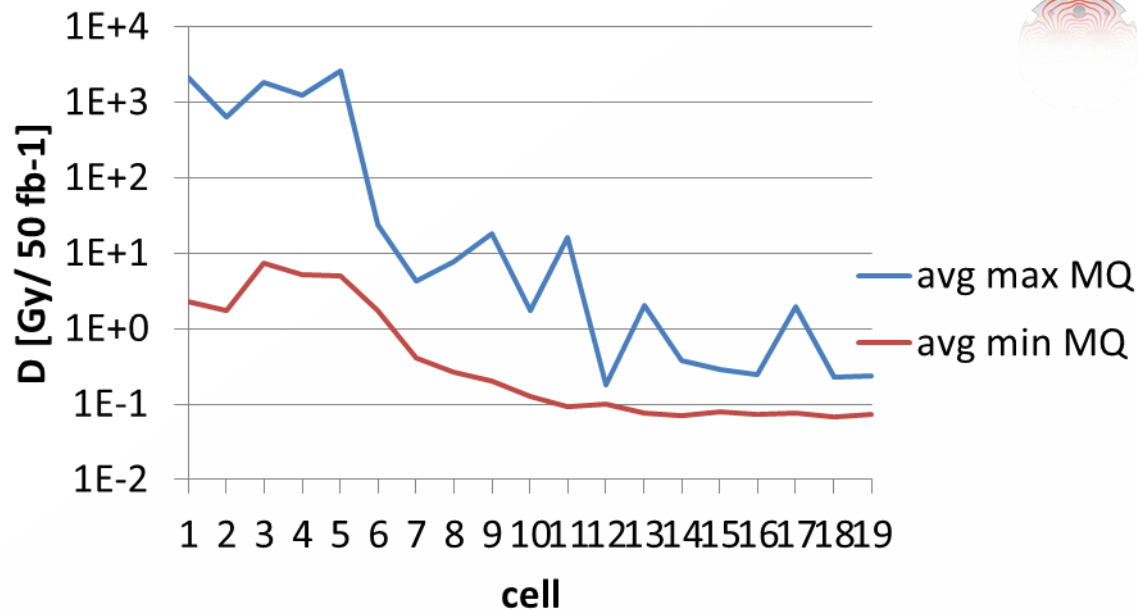
- Ⓢ Critical areas **well within predictions** for radiation levels
- Ⓢ Operational parameters can have important impact
- Ⓢ Other areas not to be forgotten:
 - Ⓢ e.g, **UX45**
 - Ⓢ 2011: 2.6x10⁶
 - Ⓢ 2012: almost 2x10⁷cm⁻²

Effect of Operation

- @ Leakage into DS
- @ Cells 7-10: ~10Gy
- @ <Cell17: ~1Gy
- @ >Cell17: ~0.1Gy

- @ Currently relatively low vacuum activity

- @ ?How will this possibly change with 25ns?



Failures analysis

Information collection

@ **R2E weekly shift** to collect information

@ **Analysis**

@ Radiation levels at the failure location

@ Failure mode and comparison with the rad-test

@ Rate of the failures

@ Iteration with the equipment owners

@ **What we store:**

@ Location

@ Date-Time failure

@ Equipment/Component

@ Consequence of the failure

@ Beam fill

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 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:

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 07:14:00.976115 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 11:22:36.457883 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	18866

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

Shielding

thanks to EN/MEF

- Ⓢ P1 (UJ 14/16) – various equipments

Gain factor ~2. Take into account shielding efficiency and radiation level increases.

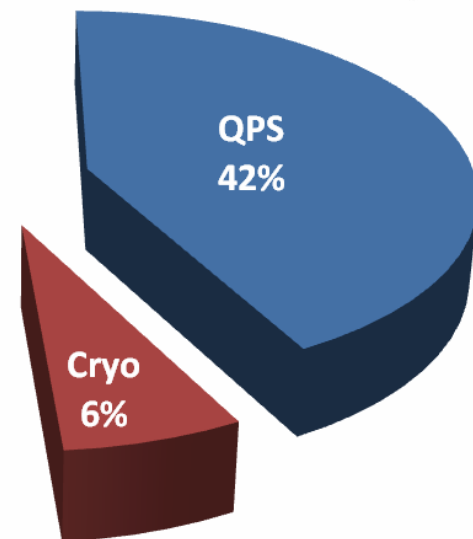
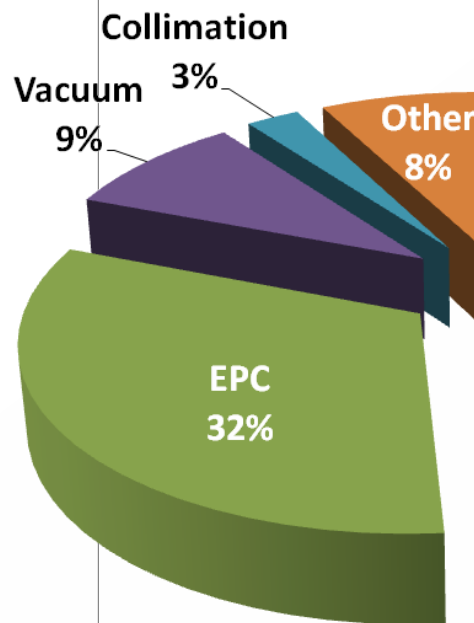
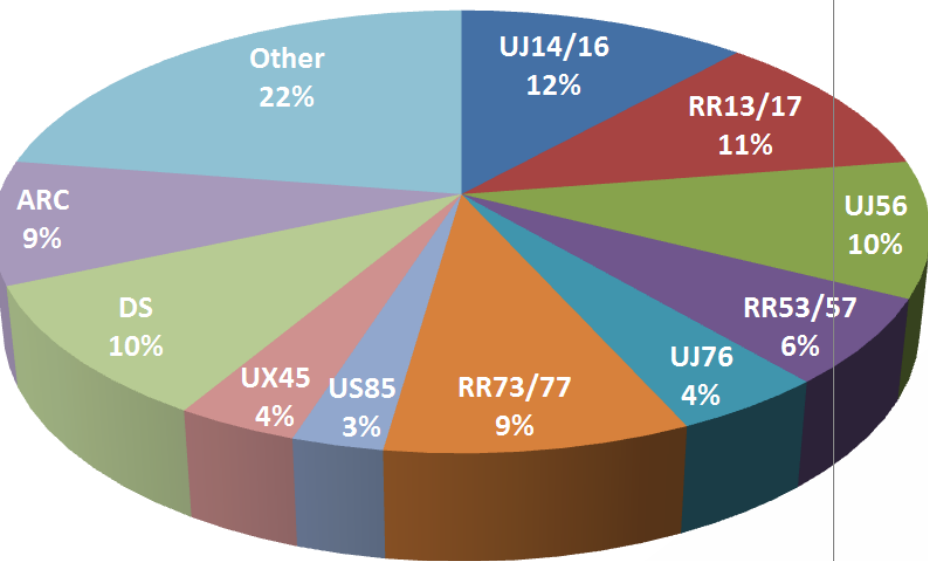
Relocation

- Ⓢ Cryogenic equipment from Point 4/6/8
- Ⓢ B/P/WIC equipment from UJ56 US85
- Ⓢ EN/EL UPS from UJ56
- Ⓢ **No events anymore**

Equipment actions

- Ⓢ QPS: Fw, Hw updates
- Ⓢ EPC: Fw updates
- Ⓢ CRYO: Hw updates (Temperature sens)

Failure Overview



Status November 2012

Dump Confirmed	Dump TBC	No Dump	No Dump TBC
58	10	36	7
Destructive failures			
Dump Confirmed	Dump TBC	No Dump	No Dump TBC
17	1	4	0

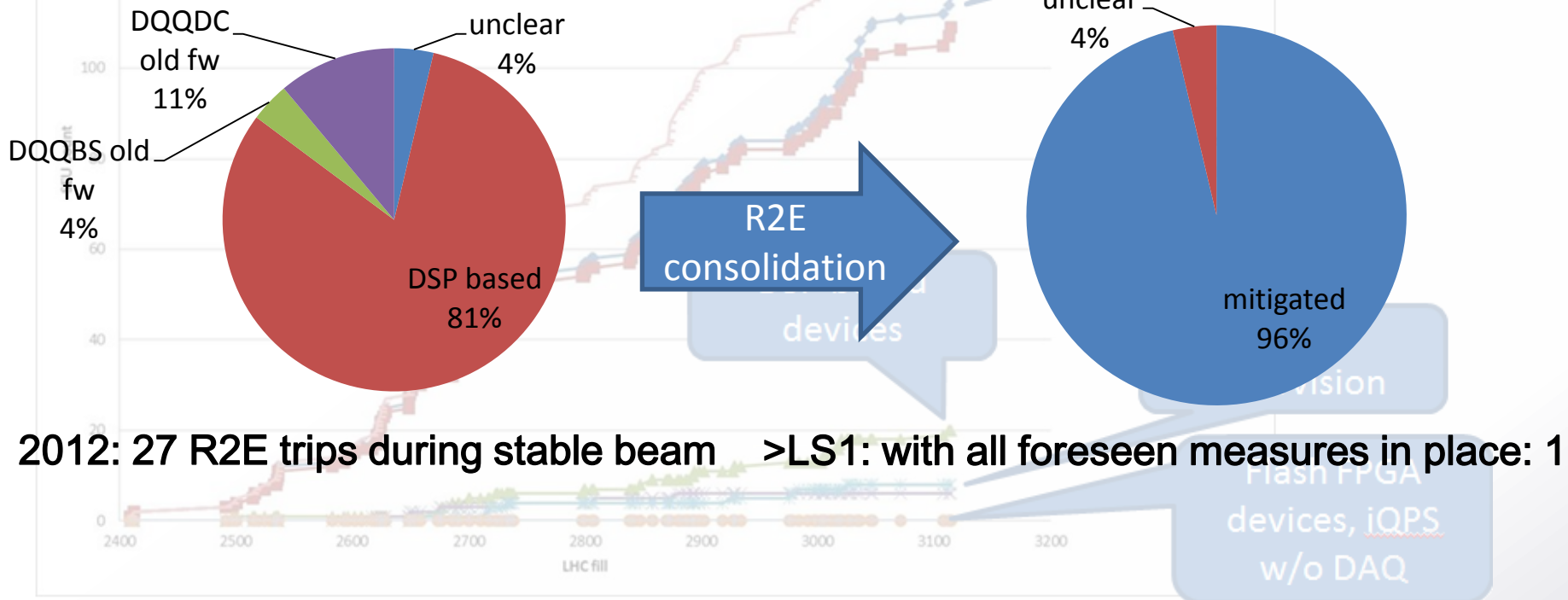
Dump	Dump/TBC	No Dump	No Dump/ TBC
32	2	22	1

- ⊙ **Locations:** UJ14/16, UJ56, RRs P1/P7, DS
- ⊙ **Failure types:**
 - ⊙ Digital detection system for nQPS (very few)
 - ⊙ 600A protection (DSP based system)
 - ⊙ uFIP communication
 - ⊙ DAQ&uFip: no dump but required access
- ⊙ **Mitigations:**
 - ⊙ New DAQ system under design (FPGA)
 - ⊙ Firmware upgrades
 - ⊙ BricoFip (mid-term)/NanoFip (long-term)
- ⊙ **Main Impact:** caused most of the R2E dumps

QPS – Detail

- 2011: 3.5 dumps per fb⁻¹
- 2012: 1.4 dumps per fb⁻¹
- 1/3 of errors in UJ14/16/56

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2012: 27 R2E trips during stable beam >LS1: with all foreseen measures in place: 1

- ➔ Most SEUs are caused by DAC systems which are mitigated
- ➔ SEUs in DSP based systems (DQQDI/DQQDG) are critical (lead to beam dump)
- ➔ nQPS(magnet) was designed to be rad tolerant: no SEU induced errors so far

Dump	Dump/TBC	No Dump	No Dump/ TBC
14	0	11	0

- ⊙ **Locations:** UJs, RRs, ARC
- ⊙ **Failure types (only confirmed ones kept in follow-up):**
 - ⊙ 600A: Aux Power Supply [14 events]
 - ⊙ FGC [10 events]
 - ⊙ 120A failure [1 event]
- ⊙ **Mitigations:**
 - ⊙ AC/DC power supply problem understood, corrected during LS1
 - ⊙ New FGClite design (on-going)
 - ⊙ Radiation tolerant power converters (started)
- ⊙ **Main Impact:**
 - ⊙ Many destructive failures

Dump	Dump/TBC	No Dump	No Dump/ TBC
4	2	1	0

- ⊙ **Locations:** UJ56, UJ76, UX45, US85
- ⊙ **Failure types**
 - ⊙ Mecos AMB
 - ⊙ Profibus communications
- ⊙ **Mitigations**
 - ⊙ AMB case (UX45, UX65, US85): Relocation under study [Mecos, S2M]
 - ⊙ Profibus: Relocation from UJs during LS1
 - ⊙ 31 events mitigated due to autoreset
- ⊙ **Main Impact**
 - ⊙ Important contribution to R2E downtime

Dump	Dump/TBC	No Dump	No Dump/ TBC
4	3	0	0

- @ **Locations:** UJ76, UX45
- @ **Failure types**
 - @ Loss of the PLC control (soft)
 - @ Power supply (destructive failures)
- @ **Mitigations**
 - @ Relocation from UJ76

Dump	Dump/TBC	No Dump	No Dump/ TBC
1	0	0	0

@ **Locations:** US85

@ **Failure types**

@ IGBT failure

@ **Mitigations**

@ Relocation from US85 to UA83

@ Remain REs

@ Recently tested at H4

Dump	Dump/TBC	No Dump	No Dump/ TBC
1	0	2	0

@ **Locations:** UJ16, UJ56

@ **Failure types**

@ Loss of communication

@ **Mitigations:**

@ Relocation

Dump	Dump/TBC	No Dump	No Dump/ TBC
1	2	0	0

@ **Locations:** UX45

@ **Failure types**

@ Power supply

@ Vacuum gauge

@ **Mitigations**

@ Cases are still under investigations

@ Radiation effects to confirm

Dump	Dump/TBC	No Dump	No Dump/ TBC
0	0	5	0

@ **Locations:** P1, P5

@ **Failure types**

@ Functionality loss of the MAD/PAD system

@ Difficult to relate to Radiation

@ Higher failure rate in exposed areas

@ **Mitigations**

@ Relocation

@ **Main Impact**

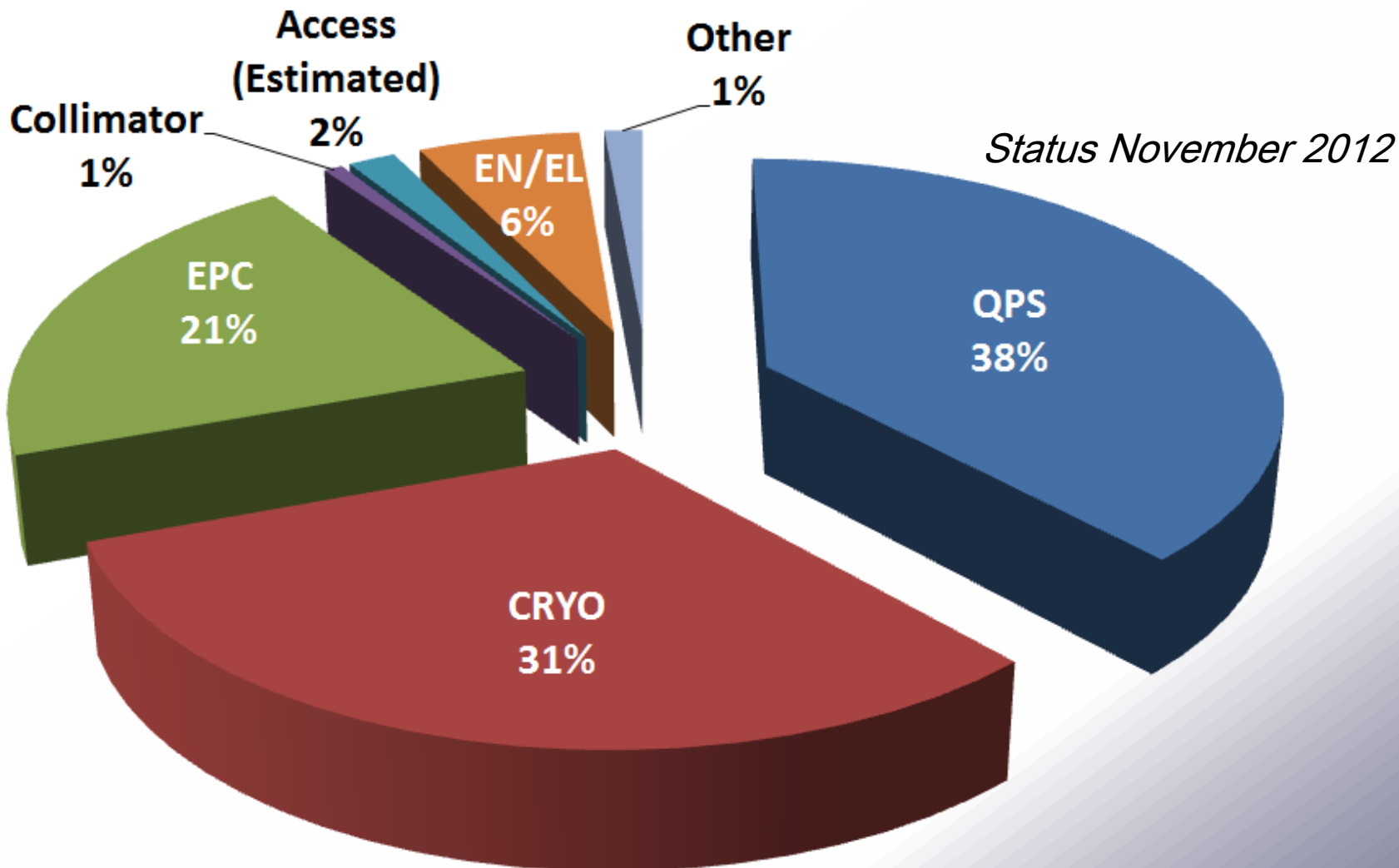
@ Downtime during access

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**

Downtime Analysis

- Ⓢ Total R2E related downtime ~250h-300h
- Ⓢ Mainly based on dump cases (others difficult to track)



Summary and outlook for >LS1

What Changes After LS1

Ⓢ Main impacted systems – observed failure

signatures:

- Ⓢ Equipment Upgrades
 - Ⓢ New developments
 - Ⓢ Relocation (UJs, US85, UX45 partly)
 - Ⓢ Shielding (RRs)
- } Enormous Effort during LS1
- ## Ⓢ Remaining (future) commercial systems:
- Ⓢ Full relocation (except REs)
 - Ⓢ No new installation in critical areas without radiation tests & developments
 - Ⓢ Equipment inventory for P4 (UX45)

@ Tunnel Equipment:

- @ **DS/ARC** will be more and more loaded
- @ **Long-term damage** to be considered in cells 8-13
- @ Impact of **25ns operation** to be evaluated
- @ Future **upgrades/changes/new installations**

@ RRs & Power Converters

- @ **FGClite** prototype available, available in time and to be deployed
- @ **Power-part R&D started** & component tests on-going

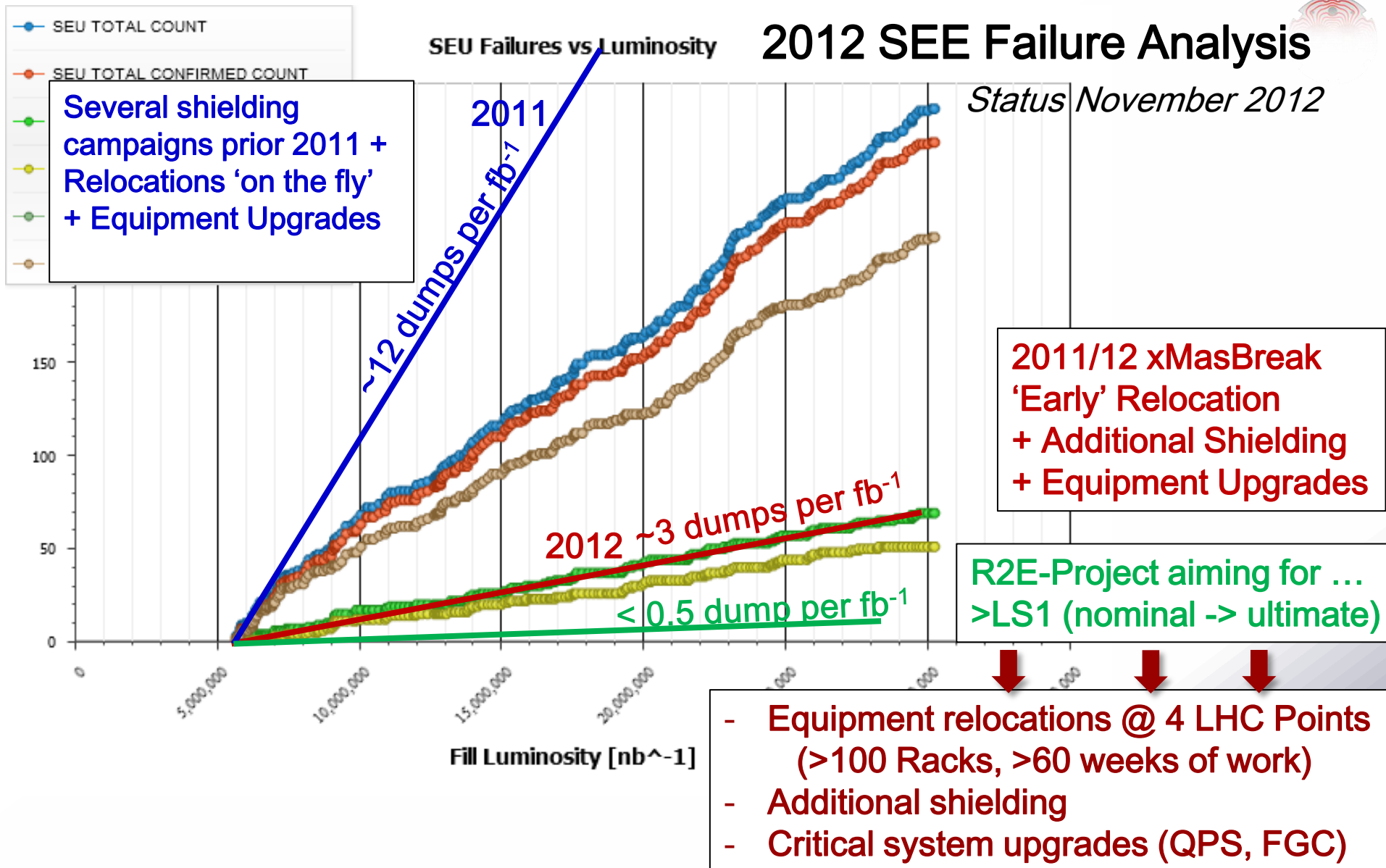
@ Areas to be watched

- @ **UX45, UX65, UX25, UJ/UA23, UJ/UA87 (+REs)**

What do we expect for LS1

Equipment	Dump	
	2012	>LS1 Expectations
QPS	31	5
Power Converter	14	3
Cryo	4	1
EN/EL	1	0
Vacuum	4	2
Collimation	1	0
Other		5

10-20 Expected Dumps



- ⊙ **2011, xMasBreak and previous actions very efficient**
- ⊙ **2012 Failures**
 - ⊙ Within Chamonix predictions
 - ⊙ *... and the winner is: QPS + EPC (+Cryo)*
- ⊙ **LS1: ~10-20 dump events**
 - ⊙ Mitigations
 - ⊙ Enormous relocation campaign (4+ Points)
 - ⊙ Remaining shielding
 - ⊙ Numerous system upgrades (QPS, EPC)
 - ⊙ **To be taken into account**
 - ⊙ **Long-Term Damage & 25ns Operation**



THANK YOU



Back-up



Radiation Levels

@ Predictions based on the integrated luminosity for many critical areas

Cum lumi (fb ⁻¹)	2011	2012
ATLAS	5.3	23.1
CMS	5.4	23.1
ALICE	4.8 (pb ⁻¹)	9.7 (pb ⁻¹)
LHCb	1.2	2.2

▶ Cumulated lumi
~1.5x larger than
initially foreseen for
2012

High Energy Hadron Fluence [Φ/cm^2]					
Area	2011	2012	2011/fb ⁻¹	2012/fb ⁻¹	Comments
UJ14	2.8*10 ⁸	1.4*10⁸	5.1x10 ⁷	7.9x10 ⁶	Physics deb.
UJ16	2.2*10 ⁸	1.1*10⁸	4.2x10 ⁷	6.2x10 ⁶	Physics deb.
UJ23	1.5*10 ⁶	2.6*10⁶	2.8x10 ⁵ (*)	1.5x10 ⁵ (*)	Injection
UJ56	3.9*10 ⁷	1.3*10⁸	7.2x10 ⁶	7.3x10 ⁶	Physics deb.
UJ76	6.4*10 ⁶	6.0*10⁷	1.2x10 ⁶ (*)	3.4x10 ⁶ (*)	Collimation
UJ87	3.0*10 ⁶	2.6*10⁶	5.7x10 ⁵ (*)	1.5x10 ⁵ (*)	Injection

(*) = ATLAS/CMS luminosity

- Ⓢ **P1: decrease** by factor of 6x, thanks to additional shielding
- Ⓢ **P7: increase** due to tight collimator settings
- Ⓢ **P2/8: reduction** because of cleaner injections in the LHC

High Energy Hadron Fluence [Φ/cm^2]					
Area	2011	2012	2011/fb ⁻¹	2012/fb ⁻¹	Comments
RR13	7.2*10 ⁶	1.4x10⁷	1.4x10 ⁶	7.9x10 ⁵	Physics deb.
RR17	8.4*10 ⁶	2.0x10⁷	1.6x10 ⁶	1.1x10 ⁶	Physics deb.
RR53	1.2*10 ⁷	2.0x10⁷	2.3x10 ⁶	1.1x10 ⁶	Physics deb.
RR57	1.0*10 ⁷	2.0x10⁷	1.9x10 ⁶	1.1x10 ⁶	Physics deb.
RR73	7.7*10 ⁶	4.2x10⁷	1.5x10 ⁶ (*)	2.4x10 ⁶ (*)	Collimation
RR77	1.1*10 ⁷	2.1x10⁷	2.1x10 ⁶ (*)	1.2x10 ⁶ (*)	Collimation

(*) = ATLAS/CMS luminosity

- Ⓢ P1/5: **decrease** up to a factor of 2x (1.5-2x) due to TCL.4 closure
- Ⓢ P7: **asymmetry** L/R (also observed in operation)

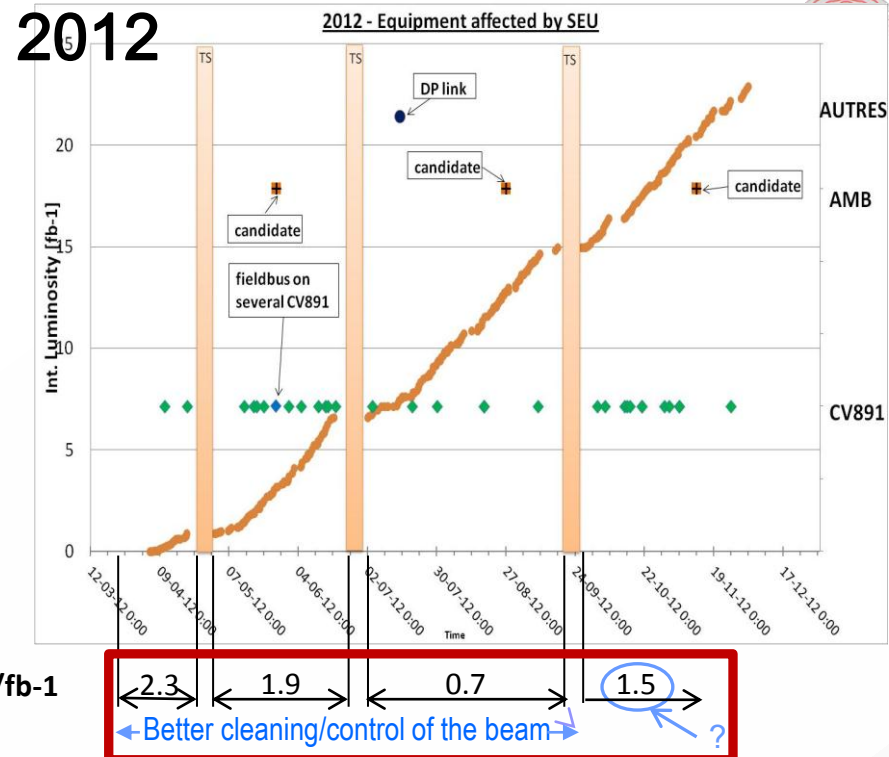
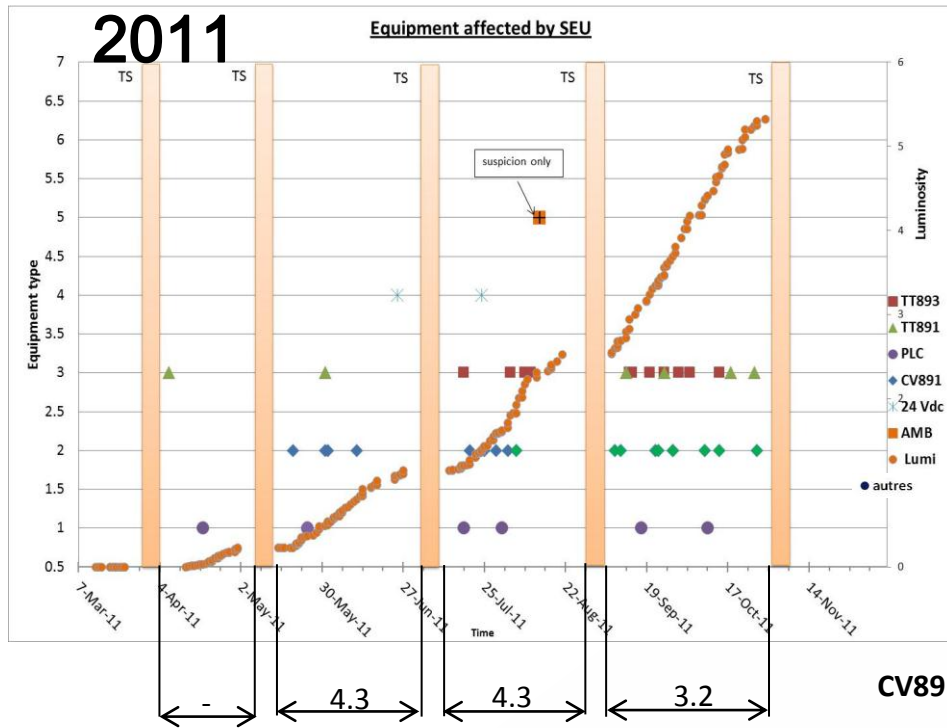
High Energy Hadron Fluence [Φ/cm^2]					
Area	2011	2012	2011/fb ⁻¹	2012/fb ⁻¹	Comments
UX45	2.6*10 ⁶	1.4x10⁷	4.3x10 ⁵ (*)	8.2x10 ⁵ (*)	Beam-gas
UX65	N/A	~1.x10⁶	N/A	N/A	Beam-gas
UX85	2.1*10 ⁸	2.8x10⁸	1.7x10 ⁸ (**)	1.6x10 ⁸ (**)	Physics deb.
US85	4.4*10 ⁷	7.0x10⁷	3.7x10 ⁷ (**)	4.1x10 ⁷ (**)	Physics deb.

(*) = ATLAS/CMS luminosity
 (**) = LHCb luminosity

- ⊙ **P4: increase**, beam-gas coupled with higher cumulative current in the machine
- ⊙ How much can/will it go up in view of 25ns operation?

Areas	HEH Fluence		
	2012	Nominal	
		Lumi =50fb-1	Lumi=100fb-1
UJ14/16	1.60E+08	3.95E+08	7.90E+08
RR13/17	2.50E+07	5.00E+07	1.00E+08
UJ56	1.50E+08	3.65E+08	7.30E+08
RR53/57	2.50E+07	5.00E+07	1.00E+08
UJ76	6.00E+07	1.70E+08	3.40E+08
RR73/77	5.00E+07	1.20E+08	2.40E+08
UX85b	3.50E+08	3.52E+08	3.52E+08
US85	8.80E+08	9.02E+07	9.02E+07
	TID		
DS	25	50	100
ARC	1	1	2

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CV891/fb-1

2.3 1.9 0.7 1.5
 ← Better cleaning/control of the beam → ?

	CV891	TT893	TT891	PLC	24 Vdc	AMB	AUTRES	Total
Beam Dumped	9	2	6	6	2	1	0	25
Beam Saved	10	10	0	0	0	0	0	20
Total SEU	19	12	6	6	2	1	0	45
23 weeks with stable beam > 640 bunches								
Rate (of beam dumped)	0.39	0.09	0.26	0.26	0.09	0.04	0.00	1.09
Rate (of beam saved)	0.43	0.43	0.00	0.00	0.00	0.00	0.00	0.87
								1.96

	CV891	TT893	TT891	PLC	24 Vdc	AMB	AUTRE	Total
Beam Dumped	0	0	0	0	0	3	1	4
Beam Saved	30	0	0	0	0	0	0	30
Total SEU	30	0	0	0	0	3	1	34
19.5 weeks with stable beam > 640 bunches								
Rate (of beam dumped)	0.00	0.00	0.00	0.00	0.00	0.15	0.05	0.21
Rate (of beam saved)	1.54	0.00	0.00	0.00	0.00	0.00	0.00	1.54
								1.74

⊙ xMasBreak Actions very efficient

⊙ Mecos AMB Events (P4/8) ⊙ TS2/3 Period interesting

Downtime analysis

@ Example

Beam Stop		(Next Beam Ramp)		Delay [h:m]	Accounted [h:m]	shadow	Manual Change	Access (yes/no)	Dump (yes/no)	Group	Point	Area	Failure Type	Comment
Date (2012)	TimeStamp	Next Date (2012)	Next TimeStamp											
10-Apr	06:48:55	10-Apr	15:54:00	09:05:05	04:50:00			yes	yes	QPS	5	UJ56	Protection 600A	
16-Apr	14:21:54	16-Apr	17:57:00	03:35:06	00:40:00			no	no	EPC	7	ARCs	FGC COD	
19-Apr	10:10:00	19-Apr	17:39:00	07:29:00	02:00:00			yes	no	QPS	5	DS	DAQ system	during access to RF

Equipment actions

- Ⓢ **Cryo.**
 - Ⓢ Relocation of the AMB from UX45
 - Ⓢ Better distribution of the charge for 24V DC

- Ⓢ **QPS.**
 - Ⓢ Relocation from UJs
 - Ⓢ Firmware update (RR)
 - Ⓢ DSP replaced by FPGA
 - Ⓢ Auto reset of MicroFip → Then, NanoFip