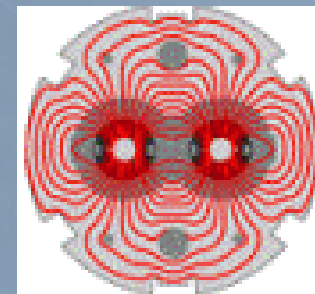




After LS1

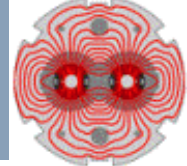
# Beam systems without failures – what can be done?



Session 07 - 09<sup>th</sup> February 2012

M.Solfaroli/J.Uythoven

Acknowledgements: T.Baer, C.Bracco, G.Bregliozi, G.Lanza, L.Ponce, S.Redaeli, A.Butterworth

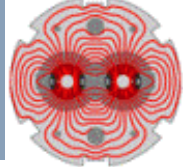


## Beam dumps analysis

### Per system:

- ✓ Failures
- ✓ Possible improvements
- ✓ Operation beyond 5 TeV

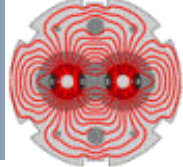
## Conclusions



# Analysis methodology

- All dumps of 2010/2011 runs analyzed:
  - Powering (PIC, cryo, QPS, EL,...) dumps excluded
  - MD periods excluded
  - Sorted by energy:
    - ❑ 450 GeV (only those with at least 300 bunches in 1 beam)
    - ❑ Ramp
    - ❑ 3.5 TeV
- Dumps screened and classified

Given the scope of the investigation, the outcome is not designed to determine the success or failure of systems, but rather to establish a way for yet a better performance

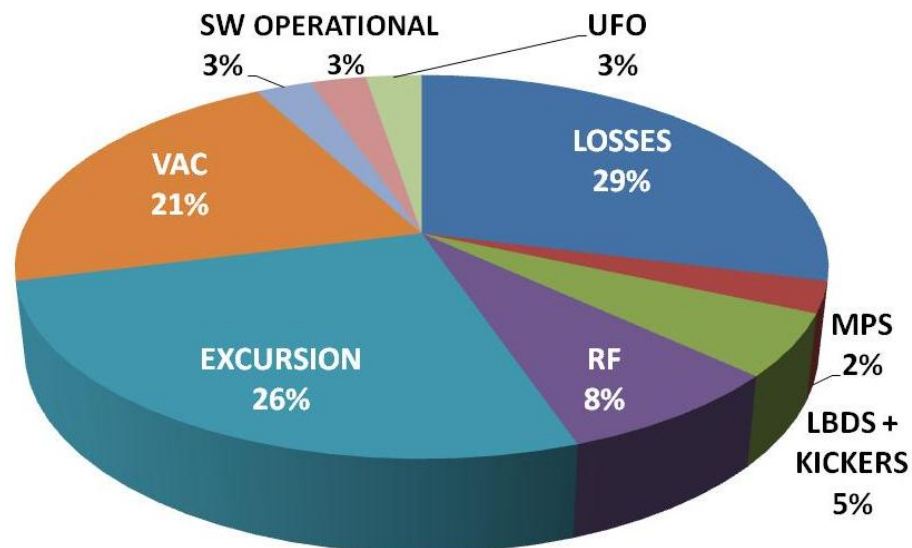


## 2010 (2 events)

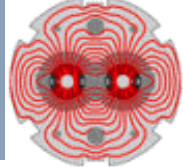


Beam dump cause	
LOSSES (injection region)	
BLM (failure of a processing card)	

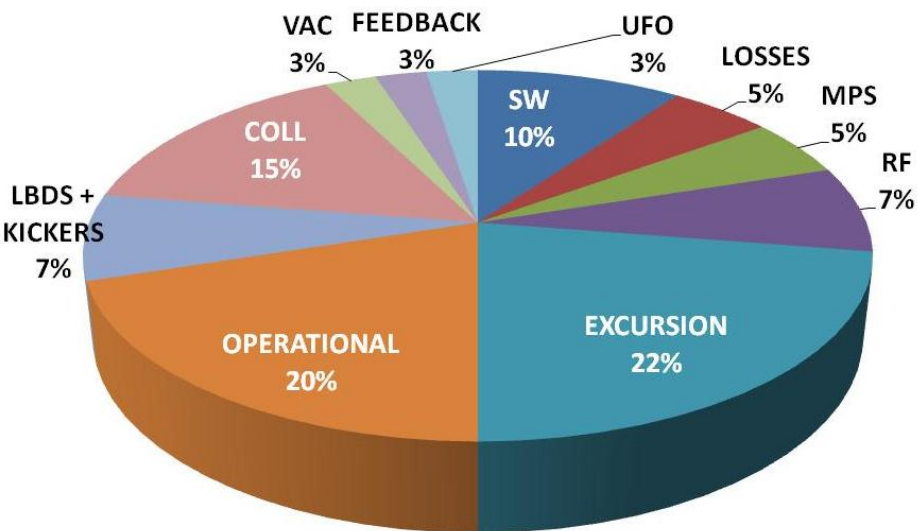
## 2011 (38 events)



Beam dump cause	
LOSSES	11
EXCURSION	10
VAC	8
RF	3
LBDS + KICKERS	2
MPS	1
SW	1
OPERATIONAL	1
UFO	1

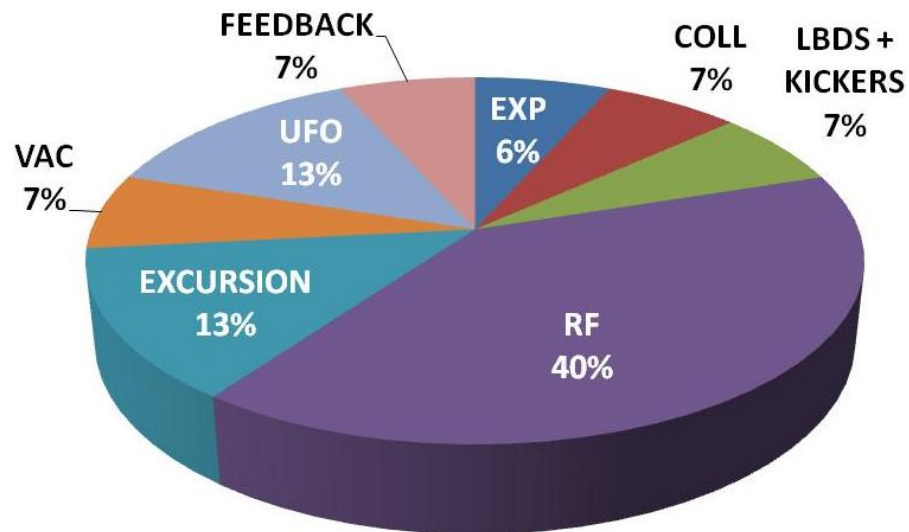


## 2010 (40 events)



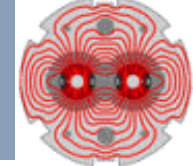
Beam dump cause	
EXCURSION	9
OPERATIONAL	8
COLL	6
SW	4
RF	3
LBDS + KICKERS	3
LOSSES	2
MPS	2
VAC	1
FEEDBACK	1
UFO	1

## 2011 (15 events)

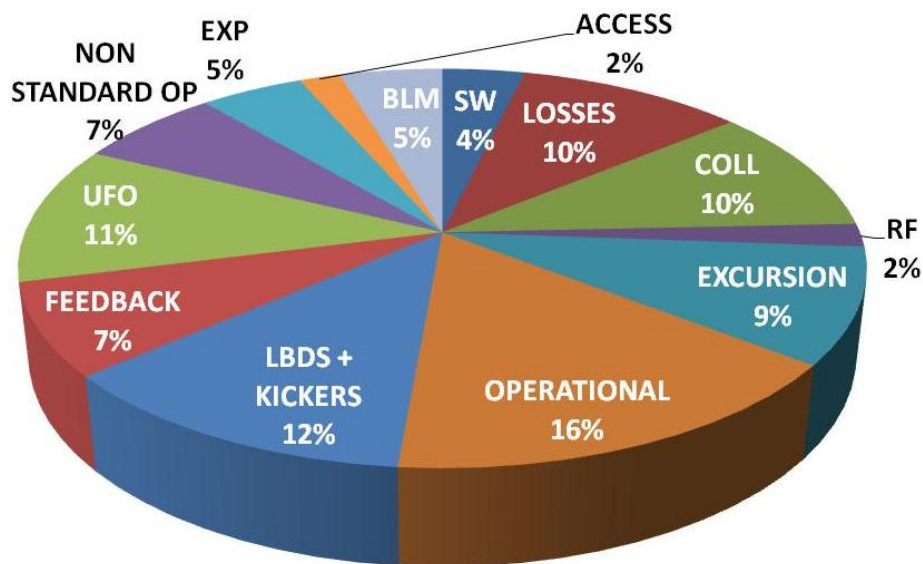


Beam dump cause	
RF	6
EXCURSION	2
UFO	2
EXP	1
COLL	1
LBDS + KICKERS	1
VAC	1
FEEDBACK	1



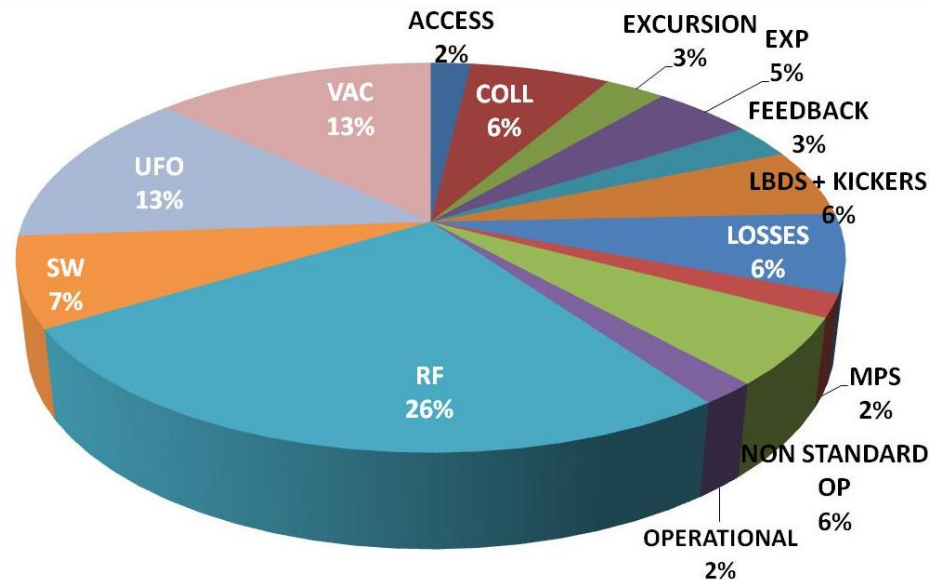


## 2010 (107 events)

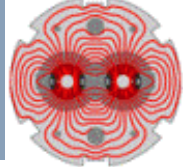


Beam dump cause	
OPERATIONAL	17
LBDS+KICKERS	13
UFO	12
LOSSES	11
COLL	11
EXCURSION	10
FEEDBACK	8
NON-STANDARD OP	7
EXP	5
BLM	5
SW	4
ACCESS	2
RF	2

## 2011 (107 events)



Beam dump cause	
RF	28
VAC	14
UFO	14
SW	8
LOSSES	7
COLL	7
LBDS + KICKERS	6
NON STANDARD OP	6
EXP	5
FEEDBACK	3
EXCURSION	3
ACCESS	2
MPS	2
OPERATIONAL	2



# General considerations

## At 450 GeV ( $I_{B1/B2} > 3E10^{13}$ p):

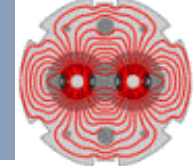
- Only 2 dumps in 2010
- Excursion the most important
- Losses are also significant but almost all at injection regions during injection; improvements are foreseen (see C.Bracco's talk):
  - ✓ Moving/adding TCDIs in the transfer lines to reduce showers in injection region (LS1)
  - ✓ BLM sunglasses
  - ✓ Possibly increasing BLM thresholds at injection
  - ✓ SPS MSE ripple reduction
  - ✓ SPS MKE4 beam position with respect to the waveform delayed (possible intervention on the magnet (out of specification) during LS1)

## During ramp:

- Situation strongly improved from 2010 (40 dumps) to 2011 (15 dumps)
- 40 % of dumps is due to RF

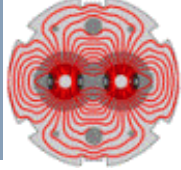
## At 3.5 TeV:

- Number of dumps in 2010 and 2011 is surprisingly equal (107 events)
- For 2011 RF is the major source of dumps with 26 %
- Vacuum is also important with 13 % of dumps
- 13 % of dumps due UFOs



Energy	Problem	Possible improvement
450 GeV	Cavity trip - <b>2 times</b>	Allow for smaller beam intensities
450 GeV	HOM on line too high temperature	Allow for smaller beam intensities
RAMP	2 cavities lost (arc detected)	'Solved' during 2011
RAMP	Interlock on total voltage	-
RAMP	Bad settings left in - <b>2 times</b>	'Solved'
RAMP	Reboot of LBDS-RF front-end	-
RAMP	Klystron current error	'Solved' during 2011
3.5 TeV	RF main coupler interlock (arc) – <b>6 times</b>	'Solved' during 2011
3.5 TeV	New total voltage interlock triggered	-
3.5 TeV	Trip of ACS module due to a faulty power supply – <b>3 times</b>	'Solved' during 2011
3.5 TeV	One of the temperature sensors for a HOM indicated too high temperature – <b>3 times</b>	Allow for smaller beam intensities
3.5 TeV	Cavity trip – <b>4 times</b>	Allow for smaller beam intensities
3.5 TeV	M1B2 cavity trip (sick cavity) – <b>5 times</b>	Problem will be solved in LS1
3.5 TeV	Vacuum power supply problem on a Klystron – <b>2 times</b>	
3.5 TeV	Klystron filament current low fault – <b>2 times</b>	-
3.5 TeV	Cavity quench	Allow for smaller beam intensities
3.5 TeV	PLC problem	-





On June 17<sup>th</sup> 2011 all RF interlocks connected to the BIS

- Protect RF equipment from power coming from the beam
- Required if beam current above half nominal ( $1400 \times 1.1e11p+$ )

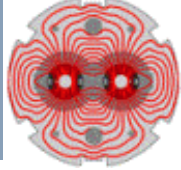
Since then, 25 beam dumps caused by RF, above injection

- 9/25 were connected to the RF interlock for high beam intensity
  - ✓ 7/9 where with high beam intensity (proton operation)
  - ✓ 2/9 where with low beam intensity (ion operation) and fill could have been saved

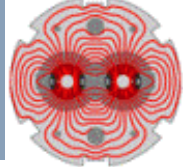
After LS1 could again separate RF Interlock from the BIS

- If beam current below half nominal ( $1400 \times 1.1e11 p+$ ) some RF interlocks don't dump the beam
- Needs reliable "Safe RF" beam intensity measurement
  - ✓ From BPM already used for set-up beam flag
  - ✓ From BCTs (need redundancy, unbunched beam to be treated)
- Will not save any high intensity proton fills

Reason for 50 % of 2011 RF trips should be solved, another 20 % will be solved during LS1 (see E.Jensen's talk)

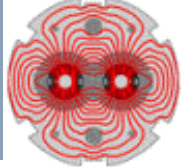


Energy	Problem	Possible improvement
450 GeV	Dump due to e-cloud (“Vacuum spike in P4 during scrubbing”)	No problems if operating at 50 ns, scrubbing if 25 ns
450 GeV	Vacuum spike dumps in IP2 and IP8 – <b>7 times</b>	“The origin of spikes are VAMTF vacuum modules (LMC 9-16/11/2011)” (see V.Baglin’s talk).  The problem could appear again during 2012 run.
RAMP	Vacuum spike dumps in IP2 and IP8	
3.5 TeV	Vacuum spike dumps in IP2 and IP8 – <b>9 times</b>	<b>The VAMTF will be re-designed for LS1!</b>
3.5 TeV	Vacuum interlock in IR4 – <b>3 times</b>	The 3 dumps appeared in a row and no problem was seen afterwards. X-rays performed, nothing abnormal was found
3.5 TeV	Instabilities on BGI HV led to a spark and beam dump due to vacuum	To be scheduled
3.5 TeV	It seems that the MCP in B1V detector aged and failed	-



# VAC beam dumps - 2011

- RF fingers problem:
  - For IP2/8 a completely new design will be installed during LS1
  - Pressure spike could become an issue at higher energy and beam current
  - Vacuum interlock threshold can be risen locally where the problem appears – if too much BLM will dump
- e-cloud:
  - A good scrubbing (20 h / 2 weeks, see G.Rumolo/G.Arduini talk) is needed to operate the machine at 25 ns (before or after the LS1)
- BGIs:
  - In a sense it was operational error, as it was known that this kind of operation can be dangerous – not to do it
  - It seems that the MCP in B1V detector aged and failed. Nothing can be done, except trying to minimize the ageing

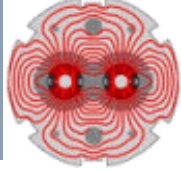


## Operation at nominal LHC performances

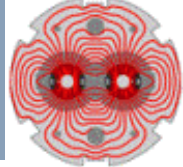
Chamonix 2012

25 ns, 2808 bunches, 7 TeV

- **Vacuum dynamic effects will be seen on all non-NEG coated components of arcs and LSS**
  - Pressure rise to be seen in LSS
  - Heat loads in arcs
    - Arc gauges “should not see” pressure rise
  - ☞ No pressure rise does not mean necessarily no electron cloud
- **Will “discover” the synchrotron radiation induced effects**
  - Heat loads
  - Photo-electrons
  - ☞ Effect on the electron cloud build-up will need some beam time to compare predictions with observations



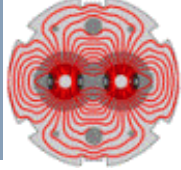
Energy	Problem	Possible improvement
450 GeV	MKI erratic	-
450 GeV	MKI erratic	-
RAMP	Power supply of MKD generator M faulty	Power supply instability fixed
3.5 TeV	Internal LBDS trigger: dump issued by the tracking system (BETS), following an unexplained increase in the generator voltage strength on the dilution kicker MKBH	Power supply instability fixed
3.5 TeV	Energy tracking verification error	Power supply instability fixed
3.5 TeV	Self trigger of LBDS B1.Vacuum pump in dump line of B1 off	Vacuum pump replaced
3.5 TeV	MKD: instability on the main power supply	Power supply instability fixed
3.5 TeV	Internal LBDS trigger. Dump issued by the tracking system (BETS), following an unexplained increase in the generator voltage strength on the dilution kicker MKBH	Power supply instability fixed
3.5 TeV	Internal trigger of LBDS: dilution kicker MKBH-B.B2 power supply problem	Power supply instability fixed



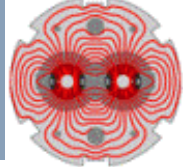
# LBDS + kickers beam dumps

- MKI erratics clearly need to dump the beam, as well as for LBDS MKD erratics (did not occur in 2011)
- Most LBDS failures were due to instabilities in the power converters of the MKD and MKB generators
  - Over Christmas all MKD and MKB power converters have been sent to the manufacturer and have been repaired for a known weakness. This should improve tracking performance.
  - If problem not solved, MKB generators tracking window could be enlarged (alarms to be installed, useful to know if a generators starts to lose stability)
- Vacuum interlocks on MKB: pumps were replaced during Christmas break – should be better now. Not possible to enlarge the limits due to danger of magnet flashover





Energy	Problem	Possible improvement
<b>RAMP</b>	Collimator temperature interlock triggered beam dump for TCTVB.4R2.	Adapted threshold
<b>3.5 TeV</b>	Collimator position interlock from both TCTs beam 1 at IP1. It looks like all of a sudden wrong measurement of position. It seems to be a SEU – tbc	<b>SEU</b> – mitigation ongoing
<b>3.5 TeV</b>	Collimators IP5 interlock. TCL.5R5.B1, TCTH.4R5.B2, TCTVA.4R5.B2 are off. Analysis showed that it was a power supply failure, unlikely to be an SEU	<b>SEU</b>
<b>3.5 TeV</b>	PRS problem in for TCTH.4L1.B1 and TCTVA.4L1.B1 of IR1, need to exchange RS power supply	<b>SEU</b> – mitigation ongoing
<b>3.5 TeV</b>	Collimator power supply problem in IP1 TCTVA and TCTH in 4R1.B2. Communication lost	<b>SEU</b> – mitigation ongoing
<b>3.5 TeV</b>	The measured gap exceeded the beta* limits for several collimators in IP1 and IP5. Beam dumped due to a problem with the new TCT beta* functions. The tighter function have a problem of interpolation in conjunction with the granularity of the beta* info (10 cm only)	Spurious setting problem (SOLVED)
<b>3.5 TeV</b>	Environment interlock on collimators in point 7 B1. Apparently collimator jaw becoming too hot	Adapted threshold
<b>3.5 TeV</b>	Collimator environment (temperature) dump, point 2 TCTVB_4R2TTRU	Adapted threshold



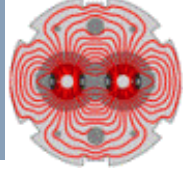
# COLLIMATORS beam dumps

## 2011 run

- No structural problem encountered
- Some dumps due to temperature reading: the thresholds have been increased and the whole monitoring system is being improved
- Few SEU observed, new shielding should reduce this effect by a factor 10 (for the same radiation level)

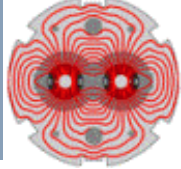
## After LS1

- A new PXI chassis with increased redundancy being developed to increase availability – it will be installed during LS1
- Although the system has been designed to be resistant, integrated radiation could become an issue, affecting equipment lifetime
- Collimator position limits will be tighter (as defined to be a fraction of sigma), but the reliability of the system is not expected to be affected



The number of operational mistakes has been reduced from 25 in 2010 to 3 in 2011, thanks to:

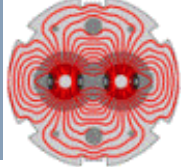
- An extensive work on establishment of solid operational procedures
- A big effort to improve SW tools
- Increased knowledge of systems and beam behavior



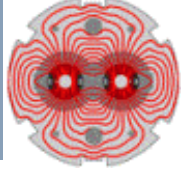
## 3 dumps in 2011 due to:

1. “New SIS interlock on RF voltage dumped the beam when the RF was switched off for asynch dump test for RPs. Forgot to mask it.”
2. “During end-of-fill the collimators were moved close to the beam in order to understand if close settings could increase the impedance and create instabilities. This was a preparation for the beta=1m operation. Things worked well, but when driving the TCSG in IR6 close to the beam, the SIS dumped since the distance between TCSG and TCDQ became too large. Beam dump clean.”
3. “A clear OP mistake with the tune FB switched on with too little signal. The beam 1 trajectory is growing over ~1000 turns to 0.4 mm rms.”

**Number 1, 2 are operational mistakes  
but due to non-standard operation**



- UFO's global number is dominated by MKI UFOs (limiting on Q4 and D2). Some improvements by increasing BLM thresholds in selected sectors (see T.Baer's talk) are ongoing but more studies will be done during 2012 run
- Dumps by arc UFOs are expected to dominate the statistics after LS1 as their number increases with E faster than the MKI UFOs' one. A new strategy is under discussion to increase BLM threshold (see A.Verweij's talk)

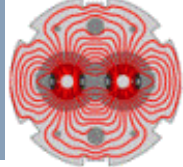


System	Energy	Reason for dump
<b>FEEDBACK</b>	3.5 TeV	Tune feedback did not get its function
	3.5 TeV	Tune FB dragged the tune of B2 H onto the resonance (1/3)
	3.5 TeV	OFB became unstable in IR2 squeeze
	RAMP	Problems with OFB during ramp
<b>ACCESS</b>	3.5 TeV	Door in Pt4 opened
	3.5 TeV	A door was left open and seen as such after many days of beam operation
<b>BLM</b>	3.5 TeV	BLM crate problem leading to loss of communication
<b>MPS</b>	450 GeV	Glitch on Beam Permit Loop A
	3.5 TeV	Identical to previous dump, again a glitch on BPL B2/A
<b>SW</b>	3.5 TeV	Communication problems
	3.5 TeV	Problem CMW library release
	3.5 TeV	Equipment SW bugs

Not easy to identify systematic sources of problem (if any), but problems should be addressed as:

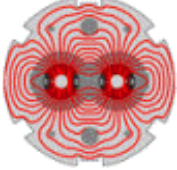
- Even 1 dump less can make a difference
- Secondary sources of dumps can become primary if not treated





# Conclusions

- The dumps caused in this talk are a minor part (see M.Zerlauth's talk) of the total, the gain is minimum, but still important!!
- Large improvement between 2010 and 2011 (it will not be easy to continue on this line after LS1, but we will try to do so!!)
- Largest improvement on discipline and operational procedures
- RF is dumping most. 50 % of 2011 dumps should have been solved and 20 % more during LS1. However, dumps with high beam currents will be very difficult to improve on.
- VACUUM has no fundamental problem
- UFOs might become an issue after LS1
- WHAT ABOUT **integrated radiation** (equipment lifetime)?
- WHAT ABOUT **ageing**?



THANK  
YOU!