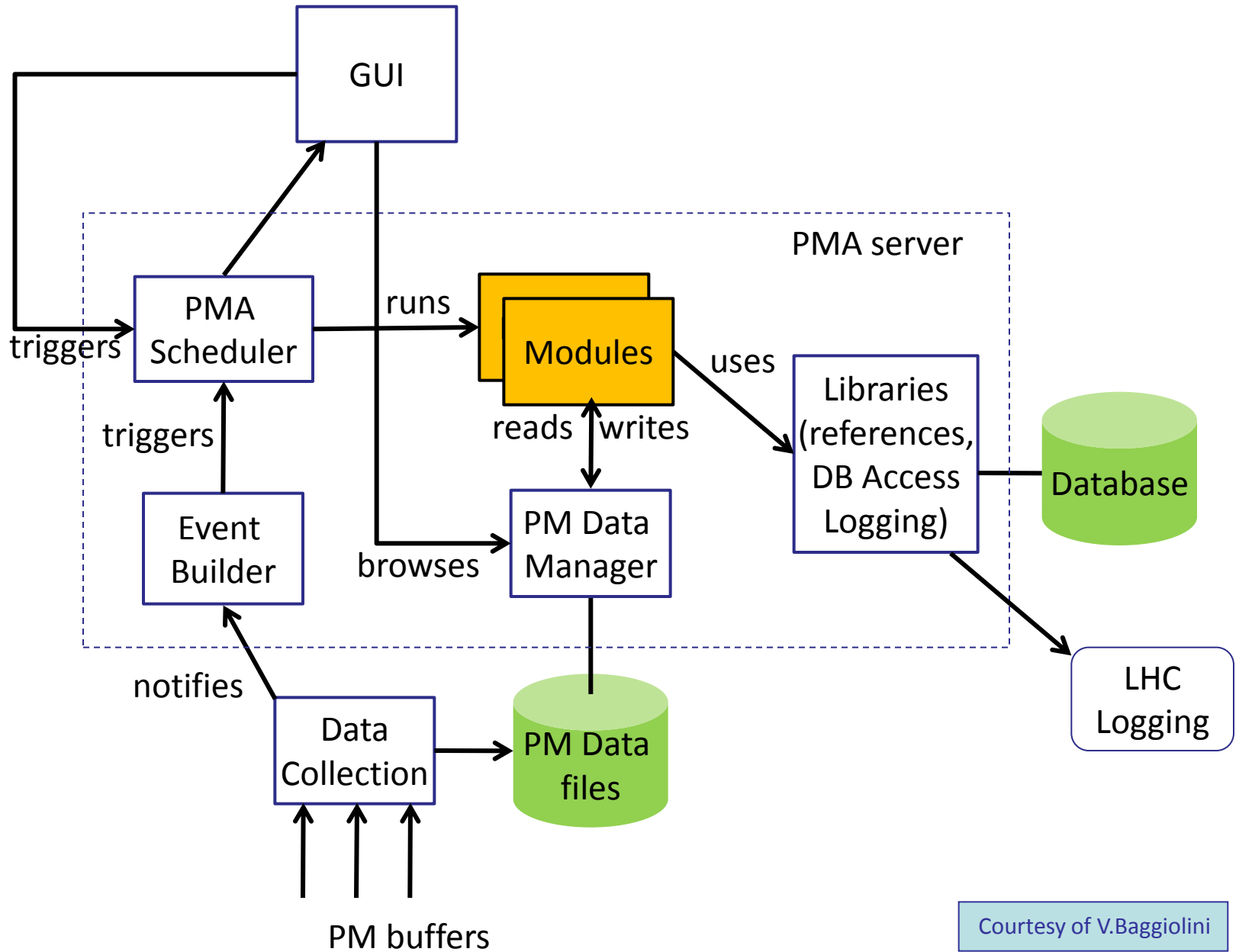


LHC PM Analysis for Machine Protection



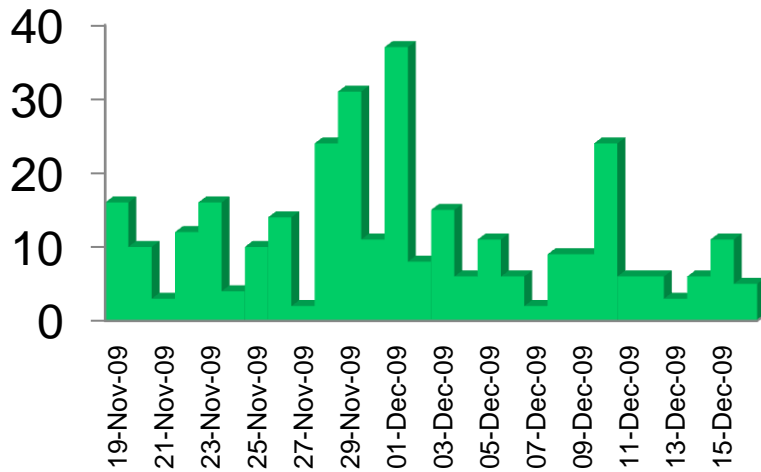
M.Zerlauth for the LHC Post Mortem Team

- ➔ LHC Post Mortem is **not an active machine protection system**
- ➔ Nevertheless it is **meant to support machine protection** by helping the operations crews and experts **in understanding the machine performance and beam dump events** and answer fundamental questions:
 - What happened?** (ie the initiating event / event sequence leading to dump/incident)
 - Did the protection systems perform as expected?**
 - + assist in trend analysis, statistics of machine performance, ...**
- ➔ During past 2 years **considerable joint effort** of BE-CO, TE-MPE, BE-OP and EN-ICE to
 - **consolidate and prepare PM hardware infrastructure** for LHC operation
 - Develop a **generic and open PM analysis framework** (including event building layer and GUI framework)
 - Implement a first series of analysis modules and data viewers for **analysis of global PM events**
- ➔ First version operational for 2009 run, full ONLINE/OFFLINE server architecture since start of 2010 run

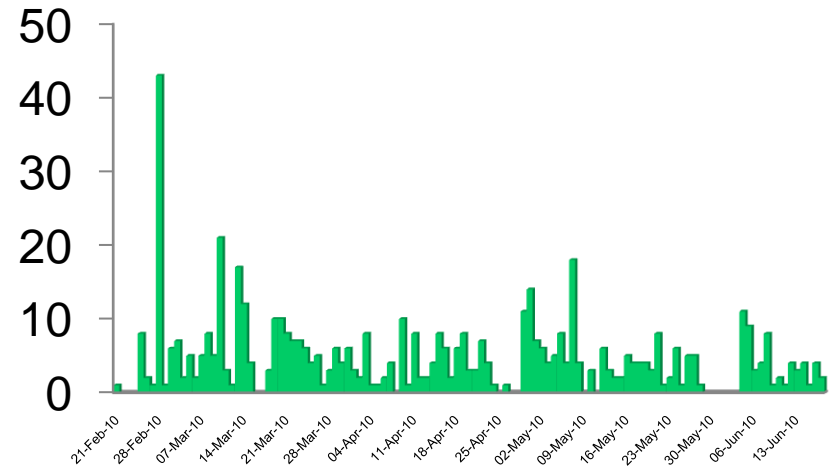


- ➔ Very good dependability of redundant data collection and storage infrastructure
 - No record of a ‘lost’ PM file (if actually sent by FE), able to swallow ‘busy’ days with >50 PM1 events (each PM1 event = 1 GB of data to be stored and analyzed)
 - Data volume growing 10 faster than initially estimated (launched upgrade campaign of disk space)
- ➔ Flexible layer of event building, allowing identification of different events which will trigger subsequent analysis configuration (Global, Powering, XPOC, IQC, QPS Snapshots, ...)
- ➔ Performing analysis framework (moved to dedicated proliant cs-ccr-pm3), allowing analysis of PM1 data set in ~ 20 seconds
- ➔ Due to good record of performance and synergies of requirements, PM infrastructure and analysis/GUI framework is also used for LBDS XPOC, IQC and POWERING analysis (latter still in DEV)
- ➔ No major problems with ONLINE servers (mainly used in CCC), although monitoring and (expert-)recovery tools exist at any level in case of e.g. ‘missed’ or incorrectly built events, etc...

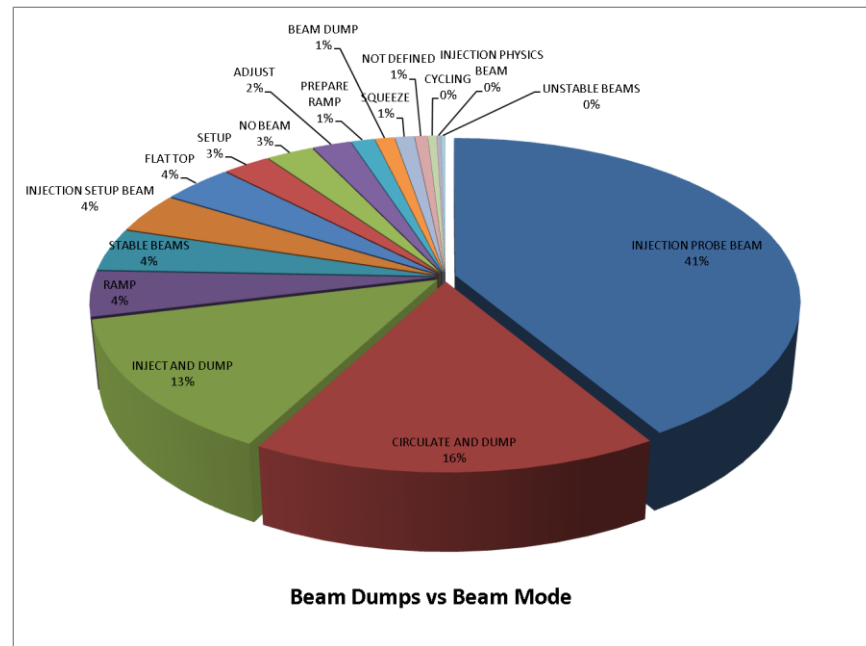
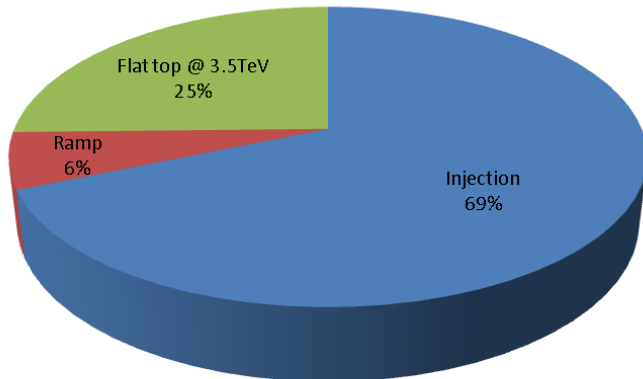
Global PM Events in 2009



Global PM Events in 2010



Beam dumps vs Energy



GLOBAL : GPM1 : 18.06.2010 06:33:18 (1276835598311142900) Final analysis is finished

Session confirmation
Modules graph
Results

Dump context

Event timestamp:	2010.06.18 06:33:18 CEST
Acc mode:	BEAM SETUP
Beam mode:	INJECTION PROBE BEAM
Energy:	450120 [MeV]
Intensity B1:	0 [e ¹⁰ charges]
Intensity B2:	0 [e ¹⁰ charges]
SMP B1 / SMP B2:	PRESENT, SAFE / SAFE

Event sequence

Event Category:	PROGRAMMED_DUMP
Event Classification:	SINGLE_SYSTEM_DUMP
Event Sequence:	First input change detected: USER_PERMIT: Ch 1(Programable Dump b1): A T -> F on CIB.CCR.LHC.B1
Triggered BIC inputs:	Ch 1(Programable Dump b1), Ch 3(LBDS-b1), Ch 3(LBDS-b2)
SCEvents:	No power converter events found

Machine protection features

Event Description:	Machine Protection features OK, safe for next injection
Highest Beam Losses:	
Magnet Quenches:	No magnet quenches found
nQPS Triggers:	No nQPS events found

BIC IPOC: ✔	FMCM ISA: ✔	PIC IPOC: ✔
XPOC B1: ✔	XPOC B2: ✘	
Safe for injection ?: ✔	PM Overall: ✔	

Comments

User:

Input your comment for session confirmation:

Confirm
Discard
Release SIS

Console

```

06:42:19 - FGC_EXT_ISA FINISHED
06:42:19 - New results have been received from the module FGC_EXT_ISA
06:42:19 - Final analysis is finished
06:42:19 - FGC_EXT_ISA data ready
06:42:19 - New analysis session progress: Final analysis is finished
        
```

Console
Running tasks

```

06:56:14 - Ignoring IQC PM event: [IQC] 1276836971480238525
06:57:47 - Ignoring IQC PM event: [IQC] 1276837065080238525
07:53:10 - Ignoring IQC PM event: [IQC] 1276840387880238525
11:54:51 - FFT windowing OFF
        
```

blm | bllb | BPM/ORBIT

BIC/IPOC

pic_ipoc

HEADER		SUMMARY	
System	PIC	Is Global Event?	S SINGLE EVENT - ST_ABORT_PIC
Class	IPOC	Beam Dump Origin	CIP.UA67.AR6 /
Source	ISA	CMD Maskable Output	✔ OK
Event stamp	03:33:39.693 17/06/10	CMD Unmaskable Output	✔ OK
Version	0.3.24	Aux Loop opened	✔ OK
Encoding	PIC/IPOC	Ess Loop opened	✔ OK
Qualifier		StMatrix	✔ OK
Analysis flags	0	Aux Loop reacted in Time	✔ OK
		Ess Loop reacted in Time	✔ OK
		OVERALL RESULT	✔ OK

AUX LOOP OPENED IN:	
Index	Value
1	CIP.UA67.AR6
2	CIP.UA63.AL6

ESS LOOP OPENED IN:	
Index	Value
1	CIP.UA67.AR6
2	CIP.UA63.AL6

CIRCUITS INVOLVED IN THE BEAM DUMP	
Index	Value
1	RQ10.R6
2	RQTL11.L6B1
3	RQTL11.L6B2
4	RSD1.A56B1
5	RSD1.A56B2
6	RSD2.A56B1

AUX LOOP TIME REPORT

CMD_PWR_PERM FALSE at: 1276738419697000000 ns (17/06/10 03:33:39.697+000000)
 CMD_UPERM_B1B2_MSK.CIP.UA67.AR6 - CMD_PWR_PERM = 0ms
 StLoopAux.CIP.UA63.AL6 - CMD_PWR_PERM = 1ms
 StLoopAux.CIP.UA67.AR6 - CMD_PWR_PERM = 1ms

ESS LOOP TIME REPORT

CMD_PWR_PERM FALSE at: 1276738419697000000 ns (17/06/10 03:33:39.697+000000)
 CMD_UPERM_B1B2_UNM.CIP.UA67.AR6 - CMD_PWR_PERM = 0ms
 StLoopEss.CIP.UA63.AL6 - CMD_PWR_PERM = 1ms
 StLoopEss.CIP.UA67.AR6 - CMD_PWR_PERM = 1ms

RESULTS DESCRIPTION

Single Event: ST_ABORT_PIC in RQ10.R6 declared as: Ess & Aux
 ST_MATRIX: OK
 ST_LOOP_ESS_CIRC: OK
 ST_LOOP_AUX_CIRC: OK

Losses [Grav / s]

PM Event @ 13/03/10 21:09:15.001

ms

- ➔ First set of most relevant analysis modules (and related panels) exist and start to be more widely used
- ➔ Analysis modules mostly provided by system experts/operators,... which assures efficient development (code re-usage) and long-term maintenance
- ➔ Much more can (and will have to) be done still, currently in work
 - PM raw data from RF
 - BBQ and collimator analysis modules (Anthony and Eric)
 - Improved FGC_ext + dedicated GUI panel to allow easier identification of current changes in circuits (e.g. feedback,...)
 - Powering analysis as part of global events
- ➔ Current tools allow for reasonably efficient analysis and understanding of beam dump events
 - Identification of initiating event / event sequence works reliably
 - nevertheless the **input and comment of EIC/operations is vital for the (later) understanding of events** (ie what was done @ time of dump?)

- ➔ PM should determine whether it is safe or not to re-inject and proceed
- ➔ Overall PM Result used for SIS interlock, which currently verifies
 - BIC IPOC (Sequence and timing of BPLs, user and beam permit redundancy, timing alignment of controllers, missing data from BIS)
 - PIC IPOC (Triggering of MSK/UNM BIS channels and redundant CPLD path, propagation delays of beam dump requests, identification of global events)
 - FMCM ISA (Threshold consistency, trigger delay for self-triggered events)
 - Possible Circuit Quenches in any of the sc circuits which will require detailed analysis
 - Overall result of LBDS XPOC (to be included in next release)
- ➔ Even for this (small) amount of checks a reliable automated decision has proven difficult (endless amount of possible use- and failure cases)
 - still **rely on help of EICs/operations to take ultimate decision** to go on
- ➔ **Can to better and probably need to be more rigorous on this (input from MPP/operations appreciated)**
 - Experts need to be informed if existing IPOC modules and/or OVERALL result fails
 - What additional checks should be added in OVERALL result for > intensities ?
 - Should PM SIS channel become unmaskable?

- ➔ Generation of a PM1 event and subsequent data-collection + analysis currently impose a 'dead-time' of ~ 10 minutes (SIS interlock will be FALSE)
 - Note: Analysis only takes ~ 20 seconds, but long data collection of up to 8 minutes in QPS/FGC requires this timeout before finalizing event
- ➔ To nevertheless provide asap a first result, concept of preliminary and final analysis has been introduced
 - Preliminary event and analysis results are produced ~ 1 minute after dump
 - Final analysis is launched after data collection timeout of 8 minutes
 - Final confirmation and unlatch of SIS only possible with final results
- ➔ Not an issue for normal operational cycle, but slowing down (re-)injection when beams are lost/dumped with a subsequent PM1 event
 - SIS interlock is often masked (and several unconfirmed sessions accumulated) during injection process
- ➔ Risk to forget to unmask and to overlook early warnings of possible issues
- ➔ **Proposal:** Could allow unlatching of SIS already with preliminary results (which will include all data but for QPS/FGC_self which anyway would not go unnoticed)?

- Implement 1st version of automated POWERING event analysis
 - Dedicated analysis server (as global, XPOC, IQC)
 - Fully automated process to support MP3/operations and assure deterministic analysis of all powering events (also outside of beam operation)
 - Recovery of HWC modules through LV interface
 - Super-locking of circuits in case of major problems
 - First DEV version up and running, first operational version for July-Aug

- Additional granularity for classification of dumps and improved operator comments (based on suggestion of Jorg/Matteo)
 - Extend/add in confirmation panel a number of pre-defined drop down selections for event types, dump origins, standard checks, etc..)
 - Will allow for more refined and powerful follow-up and statistics (will try to provide some web-based tools for standard statistics)

- More versatile data viewer - PM shopping basket

- Shopping basket will allow to assemble and visualize any collection of any data item across the PM framework



- Collection of data from all data levels, ie raw data, event data and analysis result data
- Will allow correlation of e.g. circuit related data with beam lifetimes, orbit movements, in a single plot
- Will allow trend analysis/correlation of different events (e.g. compare orbits evolution of two different events)
- 1st version for PM data only, but generic design to include e.g. DB data, online acquisitions,...
- Data collection is done via
 - dedicated ‘data picker component’ (to allow free selection across events)
 - Drag & Drop (also across GUI components)
 - centrally stored user-defined templates (‘Logging-like’)
- Needs some **additional work/help from BI colleagues** to introduce possibility of calculation/reconstruction of absolute time relations also in beam related data

GLOBAL : GPM1 : 18.06.2010 06:33:18 (1276835598311142900)

Final analysis is finished

Session confirmation | Modules graph | Results

Dump context

Event timestamp: 2010.06.18 06:42:10

Acc mode: BEAM SETUP

Beam mode: INJECTION

Energy: 450120 [MeV]

Intensity B1: 0 [e¹⁰ ch]

Intensity B2: 0 [e¹⁰ ch]

SMP B1 / SMP B2: PRESENT, NONE

Event sequence

USER_PERMIT: Ch T -> F on

, Ch 3(LBDS-b1),

bound

Shopping basket

CONTENTS

- [-] BCT BCTFRLHC LHC.BCTFR.B6R4.B1 08/06/10 04:53:52.852+488525
 - pmBunchIntensityHistory
- [-] FGC 51_ext_pmd RFM.SR7.SPARE.1 08/06/10 04:53:52.852+488525
 - STATUS.CLASS_ID
 - STATUS.I_EARTH_PCNT
 - STATUS.I_ERR_MA

Legend:

- RPMBS.RR77.RQ6.R7B1
- RR77.RQ6.R7B1
- RQ6.R7B1
- RQ6.R7B1
- RPMBS.RR77.RQ6.R7B1
- RPMBS.RR77.RQ6.R7B1

Legend:

- RPLA.16R8.RCBH15.R6B2
- RPLA.16L5.RCBH16.L5B1
- RPLA.32L1.RCBH31.L1B2
- RPLA.32L6.RCBH32.L6B2
- RPLA.26R1.RCBH26.R1B2
- RPLA.26R7.RCBH26.R7B1
- RPLA.30R3.RCBH23.R3B4
- RPLA.32L2.RCBH32.L2B2
- RPLA.12R8.RCBH11.R6B2
- RPLA.30R8.RCBH23.R6B2
- RPLA.30L3.RCBH23.L3B2
- RPLA.14R5.RCBH14.R5B2
- RPLA.20L2.RCBH20.L2B2
- RPLA.18R2.RCBH18.R2B1
- RPLA.26R2.RCBH26.R2B1
- RPLA.22R2.RCBH22.R2B1
- RPLA.22L5.RCBH22.L5B1
- RPLA.24L3.RCBH23.L3B2
- RPLA.14L5.RCBH13.L5B2
- RPLA.28L4.RCBH28.L4B2
- RPLA.34L4.RCBH33.L4B1
- RPLA.30R8.RCBH30.R6B1
- RPLA.18L3.RCBH17.L3B2
- RPLA.16R2.RCBH16.R2B1
- RPLA.28R2.RCBH28.R2B1

Console | Running tasks

```
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07:53:10 - Ignoring IQC PM event: [IQC] 1276840387880238525
```

11:54:51 - FFT windowing OFF

- ➔ Infrastructure and framework well established, no major issues left
 - Development environments for additional JAVA and LV modules provided
- ➔ Basic analysis configuration available, still a lot can/has to be done, ie
 - few analysis modules still missing
 - better correlation, visualization and manipulation of data cross systems and events
 - Improved classification / documentation of dumps
- ➔ What **needs to be added/sorted out for higher intensities**
 - Quality/Dependability of PM data (few issues left with BCT, BBQ,...)
 - No masking of PM result, but follow-up module warnings/failures with experts (LBDS-XPOC like)
 - Should we allow unlatching with preliminary result?
 - Additional (automated checks) to support OP, or short check-list for main systems
 - Systematic (offline) follow-up of possible issues

THANKS FOR YOUR ATTENTION