



Emergency Dump Post-Mortem or Post-Mortem in the Context of Beam Operation

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Focus on the PM data analysis,
with a few words on other transient data recording.



Aims of the PM system

Some questions that should be answered with the PM data :

1. What happened?
 - A. Initiating event
 - B. Event sequence leading to the dump
2. The beam is dead, but is the machine still okay?
 - A. Powering & magnets ('abnormal' signals in QPS...)
 - B. Beam Dumping System XPOC
3. Did the protection systems perform as expected?

The answers will arrive on a time scale ranging from minutes to months !

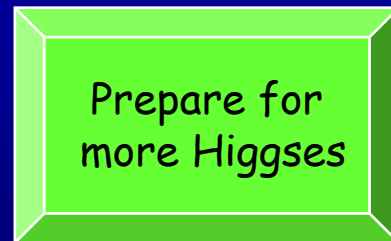


Analysis top priority

A beam just died, but life goes on...

Can we (OP) proceed and re-inject or do we stop ?

~10 Gbytes transformed into...



on the time scale of ~ 1-15 minutes



Analysis 'specs'

There are specifications/ideas on data analysis of for some critical systems, mostly aimed at system integrity checks, for example :

- Magnet Protection
- Beam Dumping System
- Beam Interlock System

'Machine OK' questions

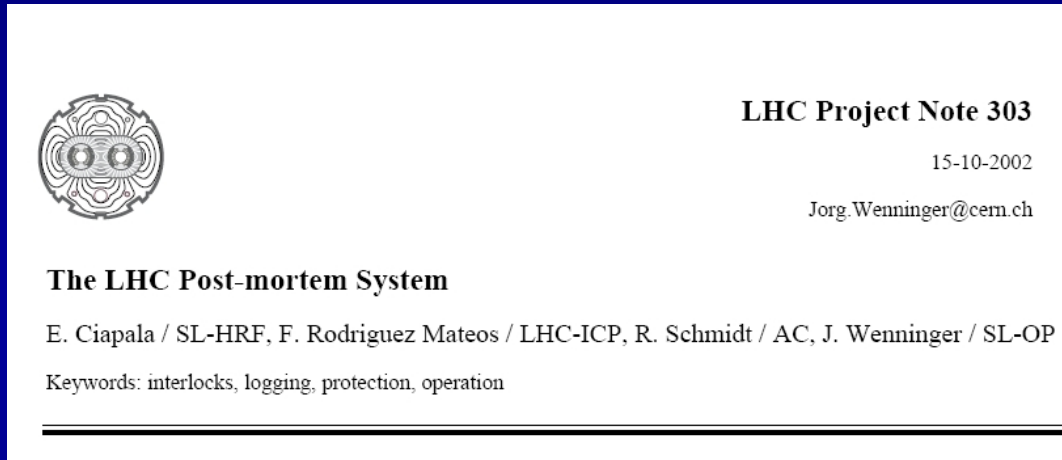
But we do not have a precise 'spec' concerning the global analysis of the beam related data. It is not defined how far the analysis must be pushed in order to restart the machine !

The failure phase space is gigantic and complex !



References...

The only CERN document (besides ppt) on the global LHC post-mortem system :



Described / discussed :

- Time stamping
- Triggering
- Buffer sizes
- Analysis
- Storage
- ...

Even after 4 years this document is still quite up to date (at least for the concepts), although at that time many aspects were still rather open !
Clearly there are no detailed answers to today's questions in that document !



Triggering

- The **trigger to freeze the PM buffers** for systems that are not self-triggering is provided by the **machine timing system**. This principle was proposed in Note 303. Small exception for RF which triggers on the Beam Permit state changes.
- It was already recognized that in some cases the PM data is not needed (or not desired...). From Note 303:

"A selective dump of the beam in one ring will certainly be required at injection (...). For a clean beam dump no post-mortem information is a priori needed, with the exception of the beam dumping system (of the corresponding ring) where the post-mortem data is always required for internal dump diagnostics. **It is therefore proposed not to trigger a general post-mortem recording when a single beam is dumped by an operator**, to avoid freezing buffers while one beam is still present in the machine.."

At that time implementation details were not discussed because too many points were still open (for example around the beam interlock system).

- J. Lewis will discuss the PM trigger issues in a moment.



Use case 1

A 'simple' and common failure case...

- Initiating event : a power converter fails!*
- Possible BIS (Beam Interlock System) event sequence:
 - PC → PIC → BIC → dump! (for critical circuits)
 - Current decay → FMCM → BIC → dump! (for some fast circuits)
 - PC → orbit change → beam moves towards collimators :
 - Beam loss at collimator → > BLM threshold → BIC → dump!
 - Loss in cleaning efficiency → Beam loss at SC mag. → Quench → QPS → PIC → BIC → dump!
 - Loss in cleaning efficiency → Beam loss at SC mag. → > BLM threshold → BIC → dump!
 - Fast orbit change → BPM interlock → BIC → dump!

A nice illustration of the REDUNDANCY in the machine protection system,
but also of the complexity of the event sequence !

(*) The failure itself may be due to services...



Use case 2

A tricky one....

- Initiating event :
 - A systematic (and unphysical) drift of a BPM position reading in the collimation section.
 - The orbit FB steers on the bad BPM signal and drives the beam towards a collimator jaw.
- Possible BIS event sequence:
 - Beam loss at collimator → > BLM threshold → BIC → dump!
 - Loss in cleaning efficiency → Beam loss at SC mag. → Quench → QPS → PIC → BIC → dump!
 - Loss in cleaning efficiency → Beam loss at SC mag. → > BLM threshold → BIC → dump!



Use case 3

Another common one...

- Initiating event :
 - In an attempt to improve the 'performance' of the machine, a parameter is changed too much or in the wrong direction... by OP.
 - Let's take the example of a secondary collimator jaw that is closed too much and becomes a primary: after a certain time delay (from ms to many seconds) the beam is dumped.
- Possible BIS event sequence:
 - Loss in cleaning efficiency → Beam loss at SC mag. → Quench → QPS → PIC → BIC → dump!
 - Loss in cleaning efficiency → Beam loss at SC mag. → > BLM threshold → BIC → dump!



Comments on the use cases

The three use cases have quite different characteristics :

- Use case 1:
 - Simple initiating event, easy to identify.
 - Full analysis of the event data requires knowledge of circuit time constants, of the beam characteristics (emittance, tails, intensity), BLM thresholds and collimator settings !
- Use case 2:
 - Difficult to identify the initiating event.
 - Needs a sophisticated analysis.
- Use case 3:
 - Cause is 'evident'.
 - Understanding of why the beam was dumped may require a detailed analysis.

In all 3 cases: if the machine quenches, we have an indication the BLM thresholds may have to be revised !



CCC context

- In the CCC OP is not totally helpless and dependent on PM data & analysis to get an idea of what is going on.
- There are/will be supervision & diagnostics applications for BIC, PIC, QPS, PCs etc etc
- And alarms !

→ We will know what's still on and what is faulty
(e.g. the PC in use case 1)

The added value of PM is coming from the fast transient recordings & and their analysis. It is the PM analysis that allows you to make the definite link between the PC and the dump (use case 1).



Essential analysis

- In order to decide on how to go on with beam operation, it is evident that the essential 'system integrity' analysis of:
 - The circuit data (QPS, EE, PC...)
 - Beam dump XPOC
 - ...

must be performed as specified by the system experts.

- I will not mention it explicitly, but assume that is done in any case.



Beam analysis break-down

- Data analysis should clearly proceed in a similar fashion to what was discussed for HW commissioning:
 - Starting with individual systems.
 - Grouping of systems into logical entities.
 - Etc...
- At each stage summary data must be produced and saved for more complex analysis or simply for browsing (analyzed volume \ll raw volume).
- For beam events an alternative is to **sequence the analysis into a logical order based on the BIS info.**
- I will refer to that sequence as first, second ... level analysis.



First Level Analysis: BIS

The primary information on the emergency dump is all contained in the beam interlock system (BIC) history (PM) buffers :

- Which input(s)/system(s) triggered the dump request.
- When the triggers arrived.

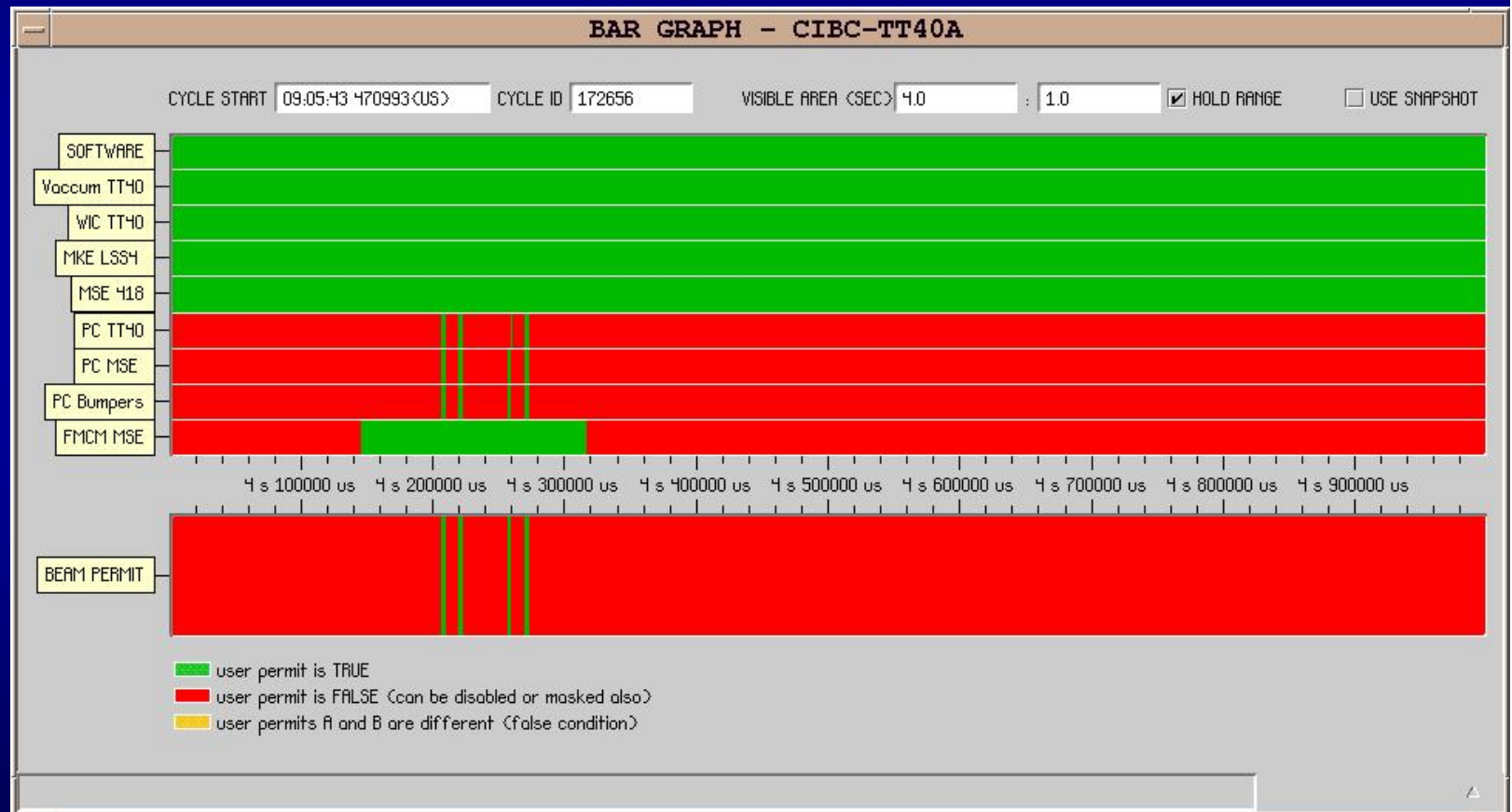
>>>>>>> This is the FIRST data to look at !!! <<<<<<<<<<<

- Gives indication which systems to analyze first.
- Indication on the event sequence.
- It is a very modest data volume.
- Note :
 1. Some triggers may arrive AFTER the beam dump (for example : use case 1, QPS).
 2. Sometimes the initiating system is not visible:
 - A. Use case 1 : if the PC is an orbit corrector (no HW interlock)
 - B. Use cases 2&3 : neither the FB nor OP appear in the BIS !!!



BIC Bufffer from CNGS

A graphical representation of a BIS history (PM) buffer from the CNGS transfer line: all the key info is there !! For CNGS there is one PM every 6 seconds.





First Level Analysis

Other first level sources of information on the dump are:

- **The PIC history buffer:** indicates the circuit that is concerned (if the circuit is interlocked and faulty, the BIS only receives a summary !).
- **The PM of the PC status:** which PC (if any) is in fault. Partly redundant with PIC.
- **The QPS PM:** which (if any) magnet quenched.
- **Vacuum:** all valves open ?
- **The status of the RF:** need to be aware that with high intensity the RF may trip every time !

From BIC + PIC + PC + QPS PM we know :

- Systems that are DIRECTLY involved in the dump request.
- Status of powering and magnets - confirm supervision application info.
- First information on the event sequence.



First Level Analysis : event sequences

A reasonable objective at this stage would be to present a time ordered event sequence (wrt time of beam permit state change):

-2221 μs	PC MCBH.30L2.B1 fault
0 μs	CIBC.L6 BLM.B1 input FALSE
+42 μs	CIBC.R7 BLM.B1 input FALSE
+120 μs	CIBC.L6 PIC input FALSE \rightarrow QPS circuit YYYY
...	...



Second Level Analysis

Time to tackle the large volumes of BI data. The BI data tells you (hopefully) what the beam did during its last instants. Possible things to look at:

- **Trajectory change at every BPMs (in space)** over the last '1000 turns', respectively over the depth of PM buffer. Interpolate position change at critical elements (collimators, absorbers...).
- **Loss pattern change at every BLMs** over the last '1000 turns',...
Integrity check of BLMs : do the loss rates correspond to the expected trigger thresholds (beware of dump request delay !)
If quench : what was the local BLM rate, how far from the threshold...
- **Beam current loss ...**
- ...

Such data can be summarized and in the early days looked at by the OP crews. Significant effort will go into optimizing BLM thresholds in the early days !



More...

From LHC note 303, Chapter 8 :

"Since the analysis of complex equipment like RF, dampers, feedbacks... is delicate, the corresponding software must be developed by or in close collaboration with the equipment experts. Assistance of equipment experts may be required to understand certain failures. The analysis of post-mortem data will clearly evolve substantially as more experience is gained over the years. As a general rule all the software components should be modular and be easy to integrate and activate. "

- Use case 2: in the early LHC days there is little chance to understand that event 'online' since that requires a detailed analysis and 'play back' of the FB inputs and outputs.
- Similarly the analysis of RF signals will require guidance from RF experts.
- Etc...
- Subtle analysis will only come with time and will be performed offline in the beginning (or always?).



Comments on analysis / I

- The online analysis should produce events tags (keys) to classify each event for further analysis:
 - General info: beam energy, intensity.
 - List of systems that triggered BIS.
 - PC & QPS status: list of failed PCs, quenched magnets.
 - List of BLMs above threshold.
 - RF status: tripped or not.
 - ...
- Easy selection of events for further offline analysis !

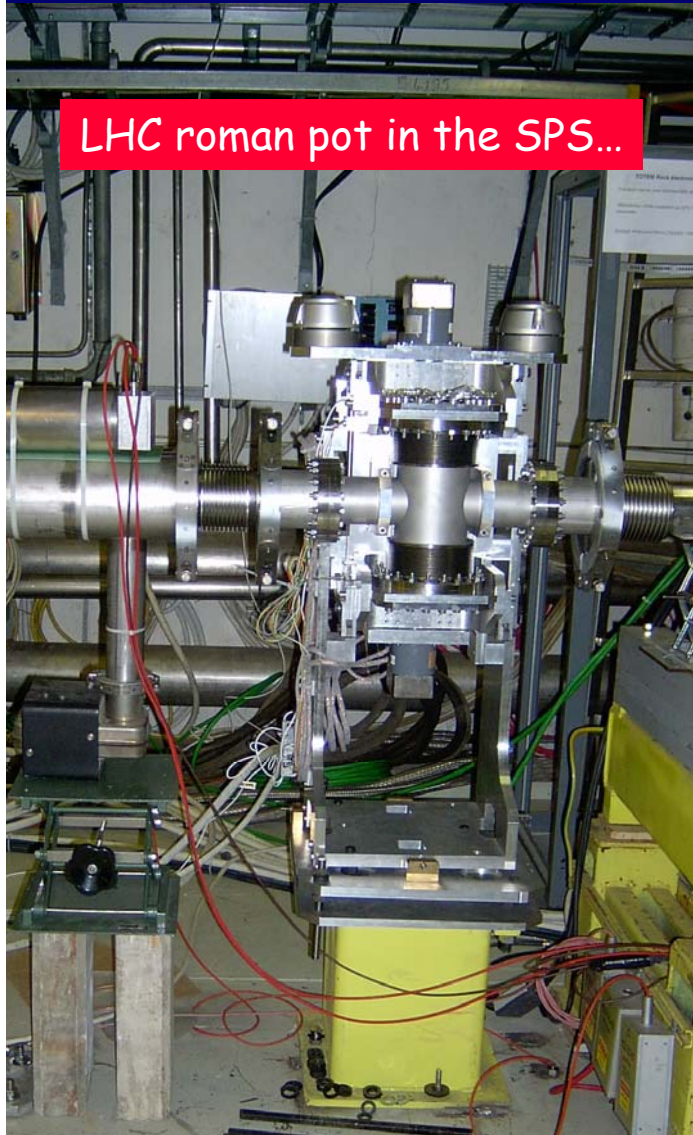


Comments on analysis / II

- The PM software should
 - be able to integrate code written by non-PM core members (system experts) for analysis. Mostly likely the code will be tuned through offline analysis of PM events.
 - accept user-provided C/C++ /JAVA code.
- The PM software should impose/provide some standards:
 - I/O formats (also for external modules), provide libraries to easily read in (parts of) the data for offline analysis. Issue of complex path names.
 - Naming convention for signals, also for data that comes out of the analysis.
- The PM data must remain available for months and years.
- It must be possible to re-run the analysis offline.



Experiments



Out there in the wilderness we have 4 clients (or data providers) that must not be forgotten:

- All 4 large (and also the smaller) experiments have the possibility to dump the beam in case of emergency (unacceptable rates, movable devices).
- We must not forget to integrate the data they can provide to diagnose their own beam dump requests.
- Get the data via DIP ????



Non-PM transient recordings

- In the context of beam operation there are frequently demands for a 'grouped' acquisition of data, most frequently BI data.
 - High frequency turn-by-turn, bunch-by-bunch
 - 'Continuous' data (tune, BCT)
 - Accurate synchronization/trigger will be provided by timing events

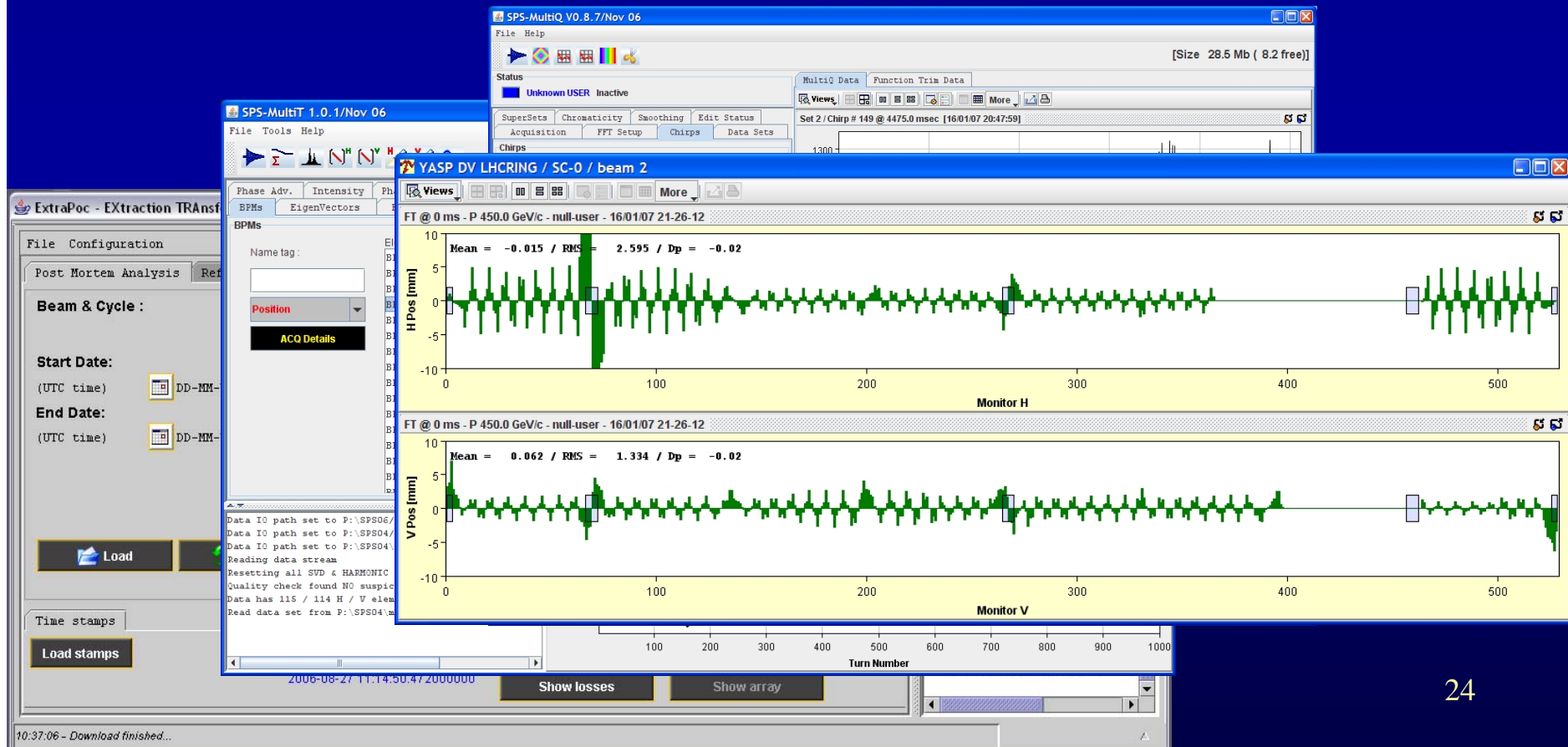
This is typical for Machine Development (MD), machine 'debugging' by OP (ramp, squeeze, snapback...) or certain types of measurements.

- There is clearly interest to extend such acquisitions to other systems and possibly other triggers:
 - The 'configurable acquisition trigger' presented yesterday is definitely interesting in this respect ! Efforts into that direction should be pursued.



LSA CCC SW

- Applications to view and analyze such BI data are developed in the context of LSA in a standard CO-AP JAVA environment (including tools for acquisition) with data embedded in FESA classes.
- A lot of stuff is already there and there is much more to come !





But...

I do not see that the LSA and PM worlds fit together well !

...except maybe through the SDDS data format !

Something to improve there ?



A proposal...

For the machine startup we should concentrate PM on:

- Ensuring that we capture all the data.
- Analysis SW for 'integrity checks' that are essential to be able to decide if beam operation can resume or not.
 - Define within the MPWG (?) what analysis we consider essential (and feasible) for machine protection issues in the context of beam operation for LHC startup.
- Clear and simple to understand reconstruction of the time sequence of major events around the beam dump based on BIC, PIC (powering)...
- Simple but well targeted BI data analysis, in particular of BLMs since the optimization of thresholds (to prevent quenches) will clearly be essential in the early days. A graphical representation of beam position and loss changes along the ring on various time scales can already tell us many things !
- RF ? Proton RF systems are tricky