Operational scenario of the BLM System

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With the contribution of
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Questions addressed

1. Strategy for operation of the BLM System
2. Operation with less than 4000 channels available
3. Mobile BLMs
4. Requested tests without and with beam

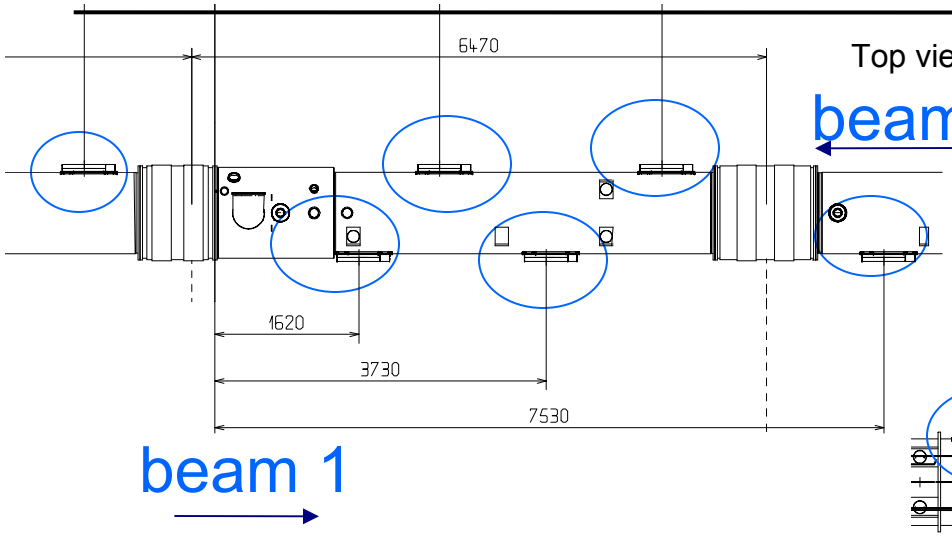
Outline

- Presentation of the system
- Initial settings of the thresholds
- Changing threshold
- Availability of the system
- Requested tests

1. Operation of the BLM system

- BLMs are part of the machine protection system:
  - to protect LHC from losses, the only system for fast losses between 0.3 and 10 ms.
- The system should prevent quenches and give a limited number of false dumps : operational efficiency
- All BLMs are interlocked and
- interlock is triggered if any one of signal is over threshold (based on HERA experience)
- There are 3 groups of monitors in terms of thresholds settings :
  - For cold elements (thresholds based on quench level)
  - For warm elements (thresholds based on the element damage level)
  - Mobile monitors (spare channels, not interlocked)

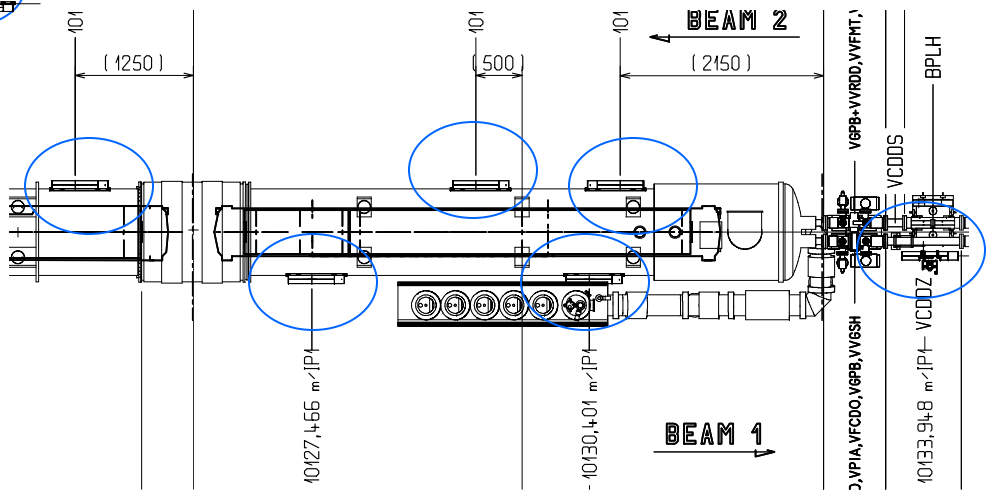
BLM for quench prevention



Top view of the arc cryostat

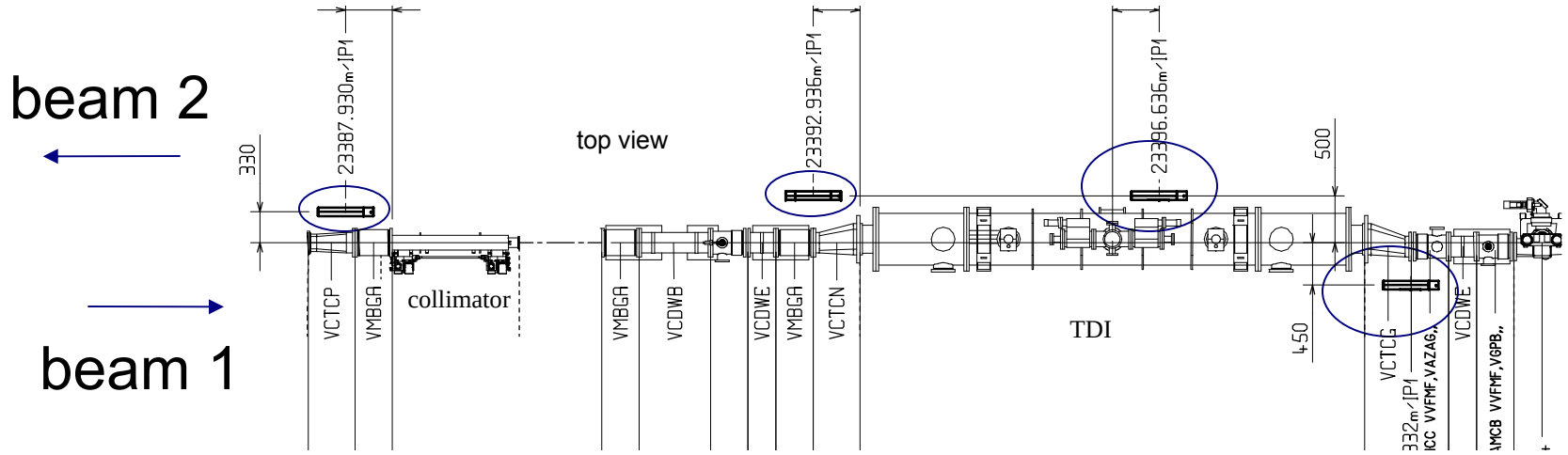
beam 2

Top view of the Q5.R4 cryostat



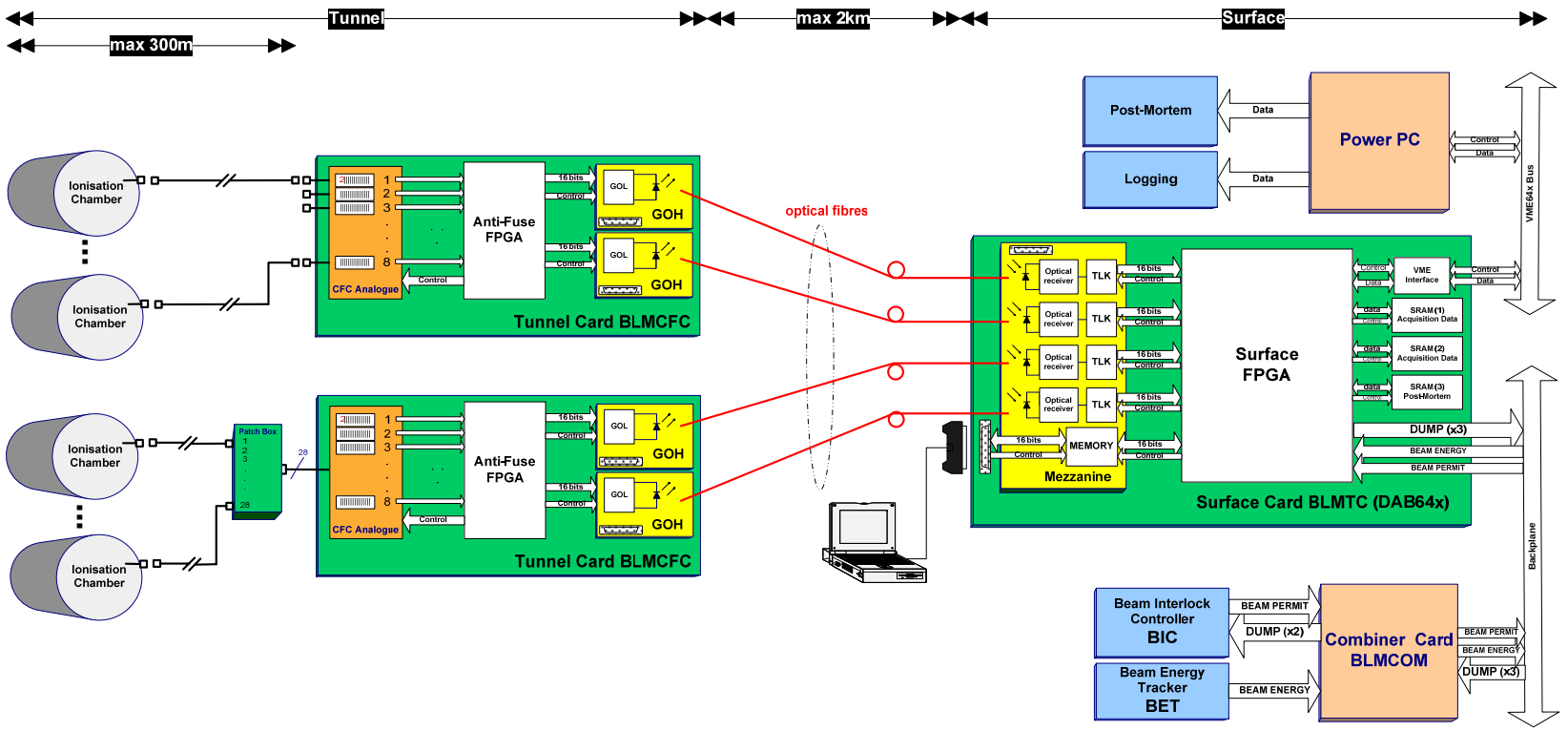
- 6 monitors per quadrupoles (arcs +LSS) + some on DS dipoles
- Beam dump threshold set relative to the quench level (margin depends on uncertainty on quench level knowledge)
- Consists of about 3200 Ionisation chambers

BLM for warm elements



- BLM in LSS : at collimators, warm magnets, MSI, MSD, MKD,MKB, all the masks…
- Beam dump threshold set relative to element damage level (need equipments experts to set the correct values)
- Consisting of about 200 IC + 300 IC-SEM pairs

BLM system : signal chain



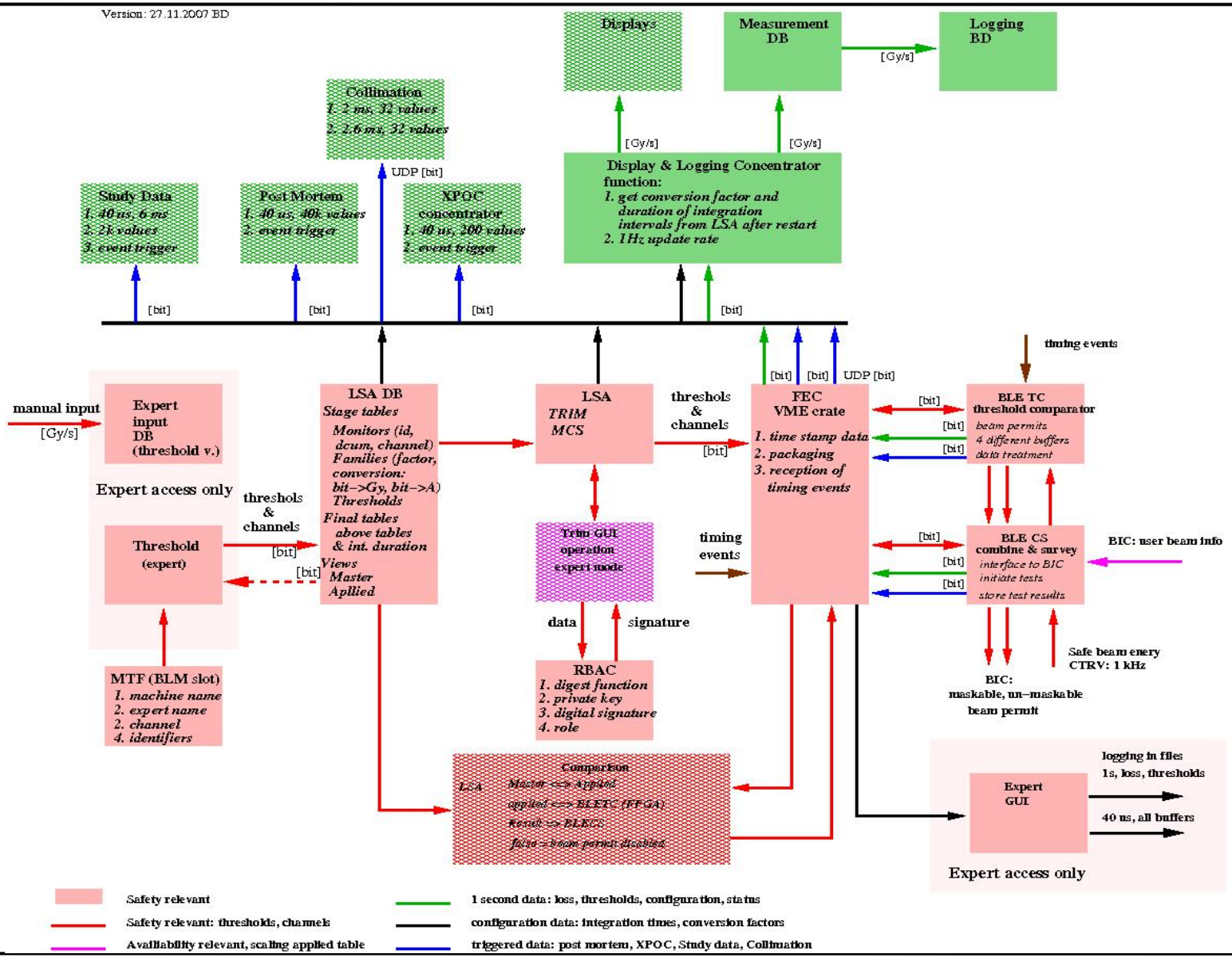
- 8 channels per tunnel card, 2 tunnel cards per surface card and 335 surface cards = 6400 channels (4500 connected to monitors)
- To follow the quench levels curves, depending on beam energy and loss duration, 12 integration periods for 32 beam energy levels per monitor
- For a given beam energy regime (32 sampling values), a signal from the 12 integration intervals is over threshold, beam dump request is generated via the BIC

Mobile BLMs

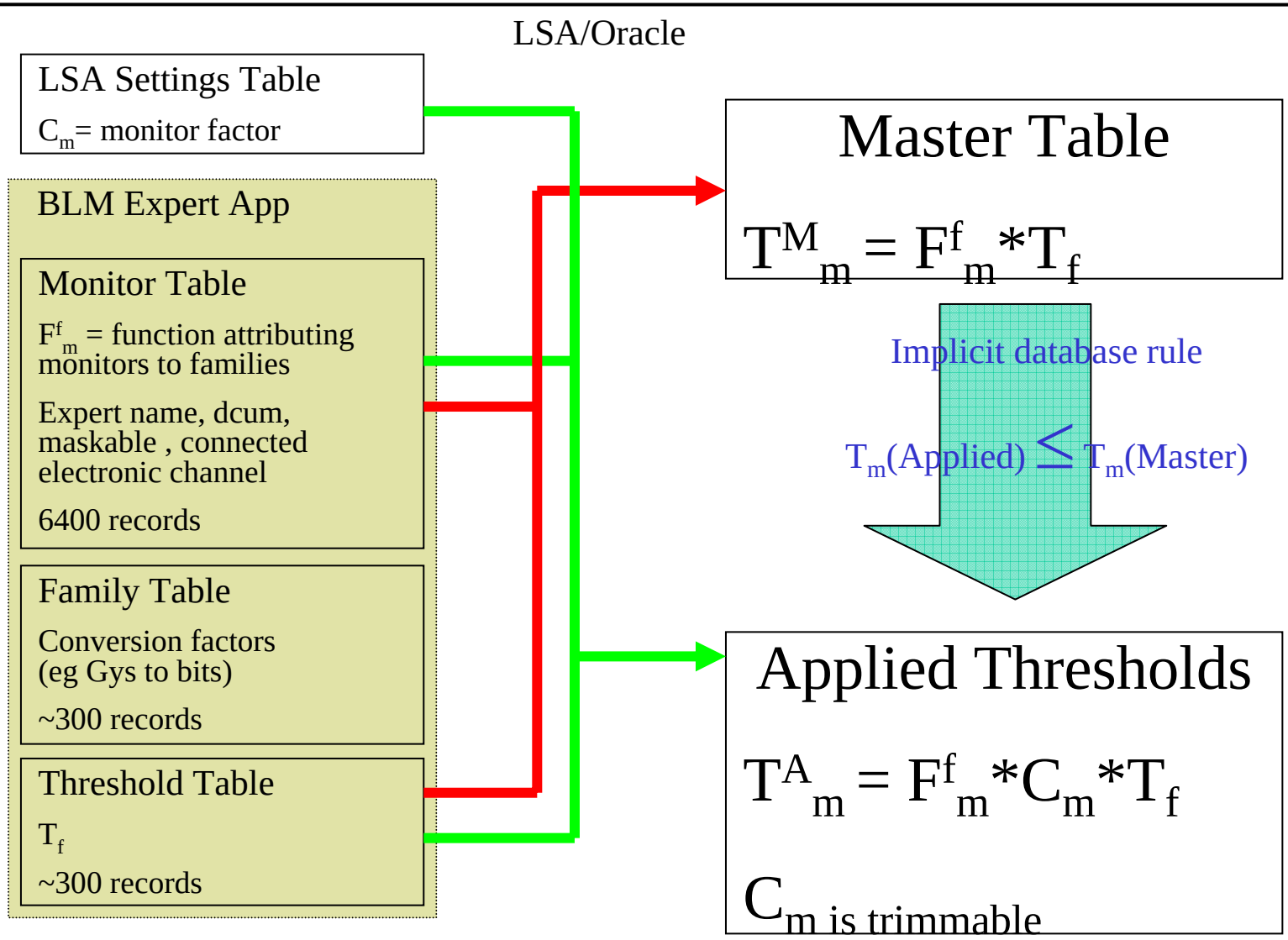
- Mobile BLMs
  - Monitors are the spare Ionisation Chambers
  - use the spare channels per tunnel card (total of 1900):
    - 2 at each quad in the arcs, a bit more complicated in the LSS because of more elements.
  - Electronics from the tunnel card is commissioned for all 6400 channels
  - All the spare channels/card are predefined in databases to allow configuration/use without touching the threshold tables
  - BUT need access to connect the extra chambers to the tunnel card
  - Can cover a half-cell every 3-m if 2 chambers per channel using also spare optical fibres
  - Mobile monitors do not generate interlocks

- He leak detection :
  - at nominal intensity, signal at the nominal vacuum pressure is a factor 6 above the minimum BLMS sensitivity

Software overview



Schematic representation of the database implementation



Courtesy of M. Sapinski

Initial settings: APPLIED table

- For each surface card, a table of 16*32*12 threshold values is loaded in the FPGA: APPLIED table
- The APPLIED threshold table is set to:
  - 30 % of the quench levels for cold elements
  - relative to the damage level for warm elements
- The APPLIED table is an LSA ORACLE database view derived from configuration tables stored within LSA database (details in the minutes of the 13th MPSCWG) by applying constraints.
- MPS requirement: redundant check
  - APPLIED table is sent to front-end using MCS
  - APPLIED table is read back for comparing with the one in the database:
  - Comparison is triggered after every change and before each fill
  - Beam permit given only by front-end when comparison result is OK
- BLM monitor thresholds are trim able individually or by families with a recorded trim history

Initial settings: MASTER table

- For machine protection, it is necessary to have a “garde-fou” for the trim. Therefore, in the LSA database, there is also a so-called “MASTER” table (same dimensions as the APPLIED one)
- The MASTER table is a ORACLE database view generated from the same configuration tables as for the APPLIED table, not including the C_m factor
- The MASTER table is protected and set to a so-called ”max safe allowed value” of the different equipment (energy and integration dependant).
- The MASTER table values are set above the quench level parameterisation and below the estimated damage levels values
- APPLIED thresholds value for a monitor is the MASTER thresholds value multiplied by a C_m factor : $0 < C_m < 1$
- Internal and external check within database: APPLIED table ≤ MASTER table

Initial settings: BLM families

- Due to the large number of BLM thresholds, BLMs are grouped in families
- Definition: a family is a set of monitors which see the same level of signal for the same level of energy deposited in the coil
- =>A family is defined by the type of element to which the monitor is attached (MQ, MQM, MSD,TCTH…) and the position on this element (entrance, middle, exit, beam 1/2, outside/inside…)
- About 250 different families:
  - BLMs in the arcs (~ 2200 IC) are only 6 families
  - the rest (~1500 IC + 300 SEM) are for the quad in the DS, LSS and warm elements
- One thresholds table (32*12 values T_f) is generated per family via an expert application
  - T_f is based on damage levels (warm) or quench/damage levels (cold)
  - T_f includes a safety factor (to be defined) to define the max allowed values

What is required by MPS

- Comparison between the APPLIED table and the MASTER table in the DB and external, on change of MASTER table or trim of APPLIED value
- Comparison between the APPLIED table in the front end and the APPLIED table in the DB (via MCS)
- Changes in the BLM MASTER table are recorded via LSA Database snapshots and the MASTER table change is confirmed by a before-after comparison
- Whenever the MASTER table is changed, the APPLIED table is regenerated and sent to the hardware.
- The MASTER table when generated is made read only so that inadvertent change cannot be made during normal operation.
- Time required for a change in the MASTER table need to be evaluated. Requested to be less than half a day by MPS, including the checks.

Baseline scenario

- The MASTER table should only be changed infrequently because this is the reference backed-up table for the BLM system
- APPLIED table is set to initial recommended value using pre-defined families
- if REALLY needed, thresholds can be trimmed up to the max allowed value (MASTER table value)
- All BLM are initially configured as unmaskable, configuring a BLM as maskable should only be done under exceptional circumstances (only one maskable CIBU per octant)
- Initially, only a group of few experts is allowed to do any change in the MASTER table and to TRIM the APPLIED table.
- Possibility to differentiate between 2 roles (RBAC permissions):
  - trimming applied thresholds
  - Changing MASTER table

Pending questions

1. Which value for the "max safe value" in the MASTER table?
    - Proposed values : 5 time the quench level (still 60 time bellow damage level for fast losses) and "Safe beam flag" for cold element?
    - Damage level x margin for warm element?
    - Small working group defined (D. Bocian, B. Dehning, T Kurtyka, A. Siemko)
2. With this strategy, MASTER table is far below the damage level for cold elements
    - too much conservative?
    - Do we want to fit better the damage level?
3. Who is the group of experts allow to perform the TRIM.
    - Proposal to be done by B. Dehning/OP
    - Group drawn from BLM/OP/MPS

Status of the software

- Expert application for thresholds generation exists (ROOT scripts) and is used to fill the DB (need to convert it from expert mode to user friendly mode)
- Database : Work in progress, structure defined, prototype exists and tested during the SPS test measurements in 2007
- TRIM for thresholds changes: to be done + program on top of existing TRIM functionalities
- Comparison DB applied table against master table: to be done, standard MCS package not usable, need further development (SIS possible candidate)
- comparison applied table DB vs. applied table HW: standard MCS
- Software to compare MASTER tables (before and after change): to be done
  - Critical path : safety relevant so significant test period is necessary.

Availability of the BLM system

- What can give a beam dump signal (safety issue):
  - losses level measured by ANY OF THE monitors above the attributed threshold value
  - failure of the internal reliability check (loss of communication with the chamber)
- What is needed to establish the User_Permit (availability issue)
  - connections OK : chamber connected to the correct channel + internal checks (optical line, HV, …)
  - FE thresholds table strictly equal to the LSA DB table
  - LSA DB APPLIED table strictly below the LSA DB MASTER table

Possible problems, origins and solutions

Possible problems	Signal affected	Origin	Possible Solutions	Who?	Safety/availability
Applied thresholds too low	Beam dump (improper signal)	Wrong evaluation of the thresholds	Redo the simulations! (need a lot of stats before identifying)	BLM team	Availability/ Safety? (critical)
		Wrong setting of the thresholds	Adjust the thresholds within predefined safe margin via TRIM	Limited experts group	Availability
Internal tests detect failure	Beam dump (proper signal)	Failure of a components	Analysis needed	BLM team	Safety (critical)
	Beam_Permit	Wrong connection, failure of a component…	1. Try to repair 2. Use a spare channel 3. disconnect	BLM team	Availability

Operation with < 4000 channels? (1/2)

- Problem 1: addressed by the possibility to trim the thresholds
- Problem 2 : Availability of the BLM system
  - G. Guaglio Ph-D thesis : 17 false dumps per year
  - Designed with the required redundancy, experience with the SPS…
  - acquire statistic with the existing system on SPS and LHC as soon as available (150 days of running for the moment): analysis to be done by KEK visitor (Hitomi Ikeda)
  - EMC effect study during the hardware commissioning phase (IP6 and IP8 with kickers magnet pulsing)

Operation with < 4000 channels? (2/2)

- Possibility to change status (disable or maskable) of channel via the same soft as for the Thresholds
  - but need a Master table regeneration
- Hardware for maskable/unmaskable is installed, but useful only below safe beam flag and a full octant is masked?

<u>Increase C_m:</u>
- single channel
- still damage protection

$\longleftrightarrow$

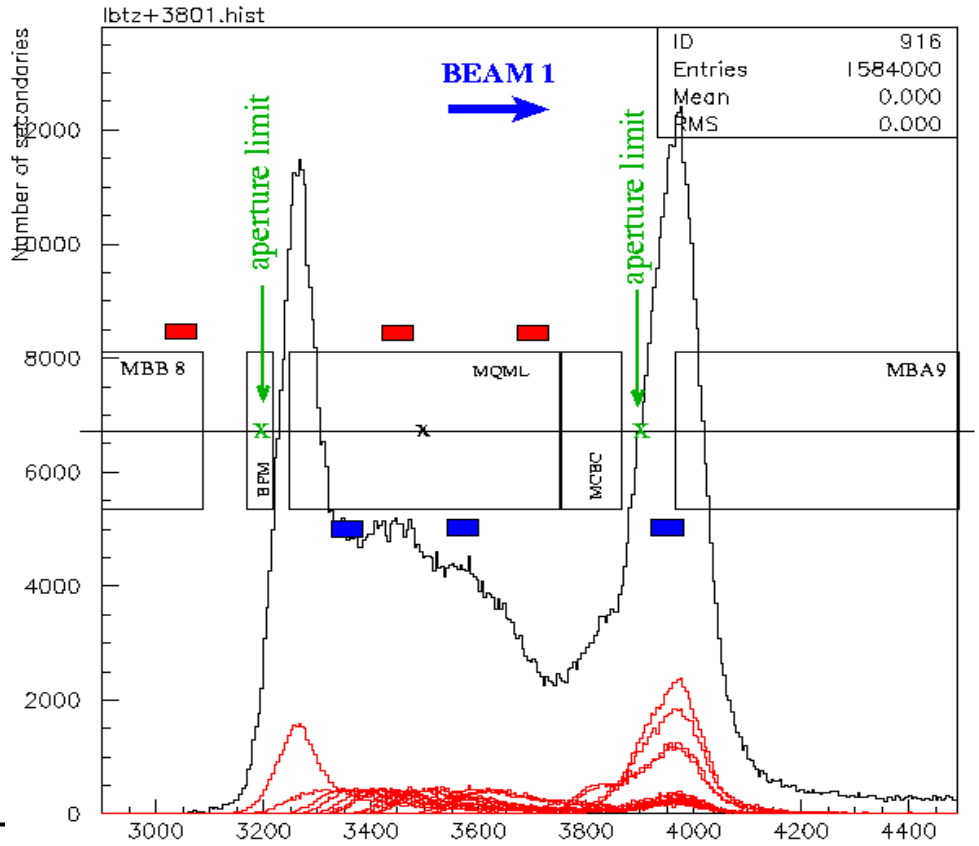
<u>Maskable:</u>
- whole octant
- works only for safe Beam
- Maintains monitoring

$\longleftrightarrow$

<u>Disable:</u>
- single channel
- no interlock
- maintains monitoring

How many channels we can lose?

- The loss can be seen by another monitor:
  - the machine protection function is still OK but not the quench prevention with only one out of 3 (private assumption)
- we have to go through the different loss patterns (especially accidental case) to evaluate the protection



BLM tests

- Functional test (connectivity) of full acquisition chain with Radioactive Source
  - The procedure for this test will be described in a dedicated document made in collaboration with TIS. The purpose is to create a signal on the chamber with the RA source and check its presence in the corresponding DAB card channels.
  - Time estimation : 0.5 to 1 hour per front-end station (8 BLMs)
- Provoked magnet quench: (A. Koschik's presentation in Chamonix XV)
  - check steady state losses quench limit with circulating beam (part of the MPS commissioning)
  - check fast losses quench behaviour with sector test

➢ required to give confidence in the model

➢ If we have no accidental beam induced quenches/dump, we will rely on simulations

Restricted tests?

- Testing only a given set of BLMs with the radioactive source?
  - No: this test verifies only the monitor position
- Motivation of the quench test:
  - **Verification of the correlation between energy deposition in the coil (= quench level) and BLM signal (= thresholds)**
  - **Verify or establish “real-life” quench levels**
  - Verify simulated BLM signal and loss patterns

=> Accurately known quench levels will increase operational efficiency and improve safety

Conclusion

- This implementation is done to allow flexibility to trim thresholds above the quench level (= operational efficiency problems) BUT always bellow the damage level (= safety problem)
- GO for implementation of BLM thresholds management, but some thresholds still need to be defined within the MPSCWG/LHCCWG
- Acquire statistics on the reliability of the BLM hardware (running continuously once installed) and
- Evaluate the applications during the coming dry runs
- Develop strategy to run with non-working channels?
  - Action for the MPSCWG? As much as possible before start-up
  - LHC Protection Panel during operation?