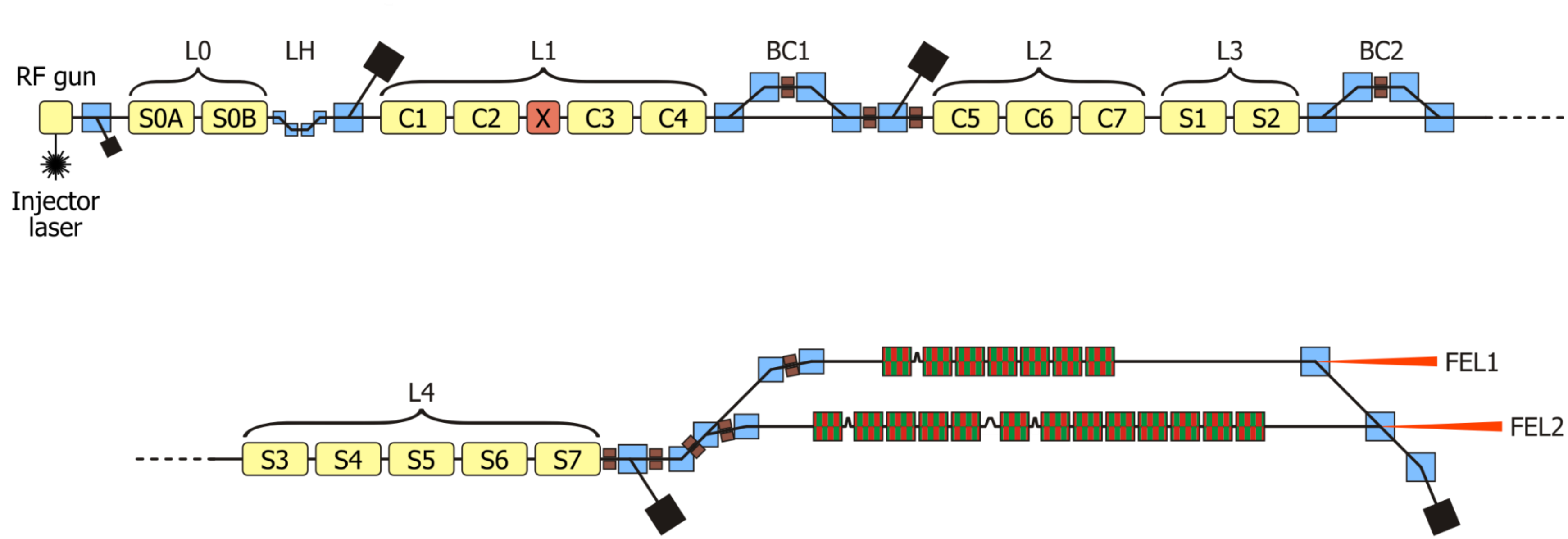
Failure Detection - Summary

The FIVE presentations:

1) B.Dehning: LHC Beam Loss Detection System
2) S. Mallows: Studies for the CLIC TBM BLM System
3) L. Froehlich: Diagnostics for MP at FERMI@Elettra
4) B. Puccio: Equipment fault Detection Sequence
5) V.Kain: Beam Quality Assessment for the LHC beams (real time and post-pulse)

FERMI@Elettra



	Energy	Bunch Charge	Repetition Rate	Beam Power
Typical	1.2 GeV	350 pC	10 Hz	4.2 W
Design	1.5 GeV	1 nC	50 Hz	75 W

Main Purpose: General Diagnostics and Protection on PM Undulators

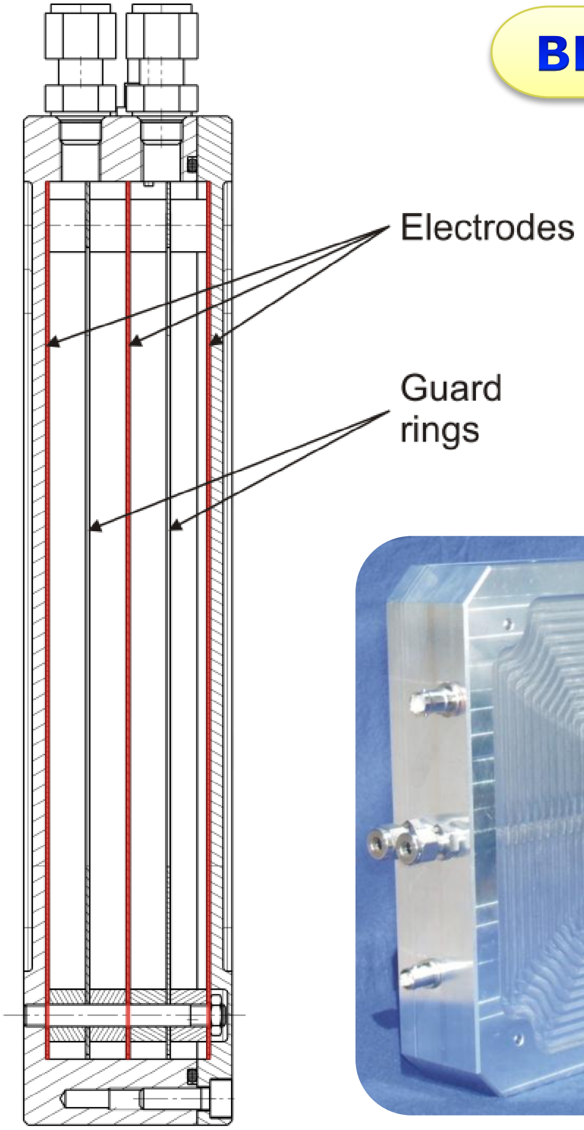
Nice “collection” of technologies

- Ionization chambers
- Cherenkov Light in fibres
- Multi Pixel Photon Counter Readout
- RADFET Dosimeters

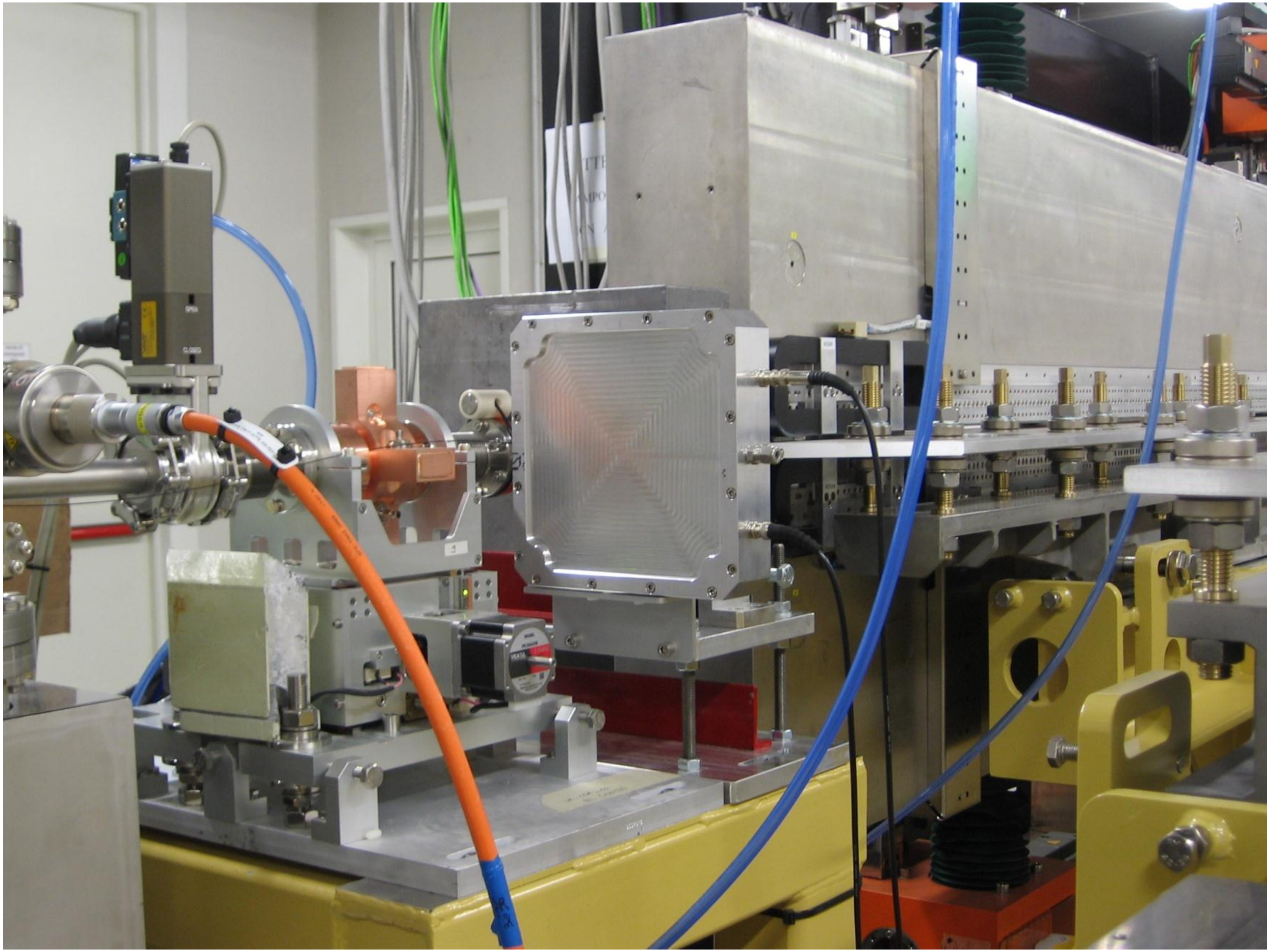
Ionization Chambers

- Milled aluminum enclosure
- Electrodes: printed circuit boards
- Use in air or with gas flux
- Volume:
  1.3 l
- Voltage:
  up to 1000 V
- Sensitivity (air):
  ~46 μC/Gy
- Leakage current:
  ≪ 200 fA (at 1000 V)
- Fermi:
  1 ionization chamber in air
  per undulator segment (19 total)

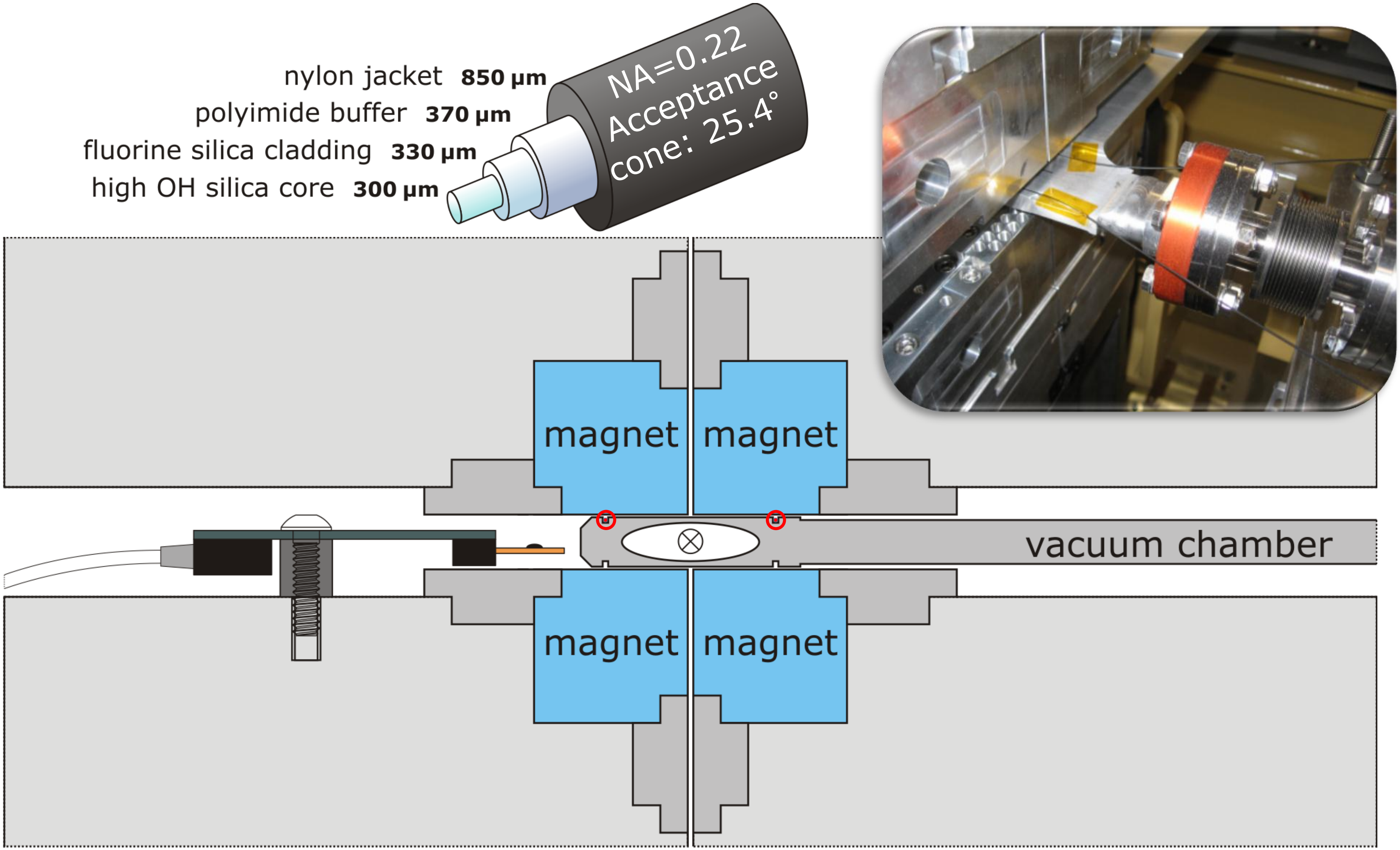
BLM–IC02



Ionization Chambers

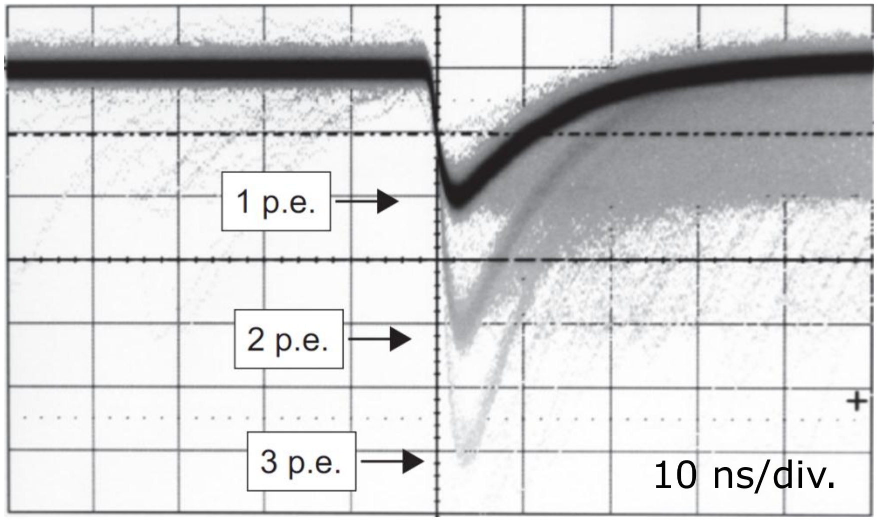


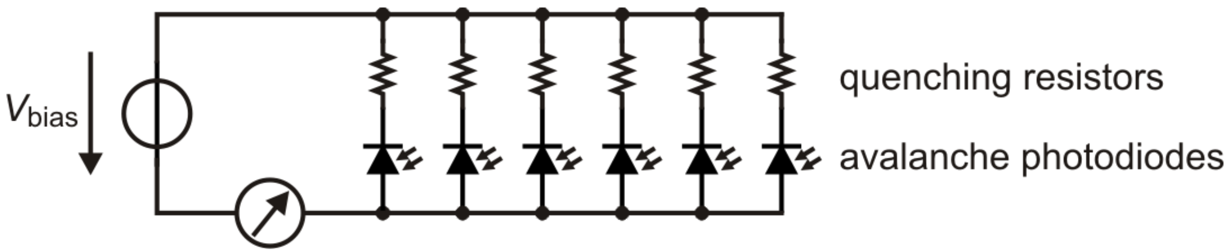
Undulator Cross Section



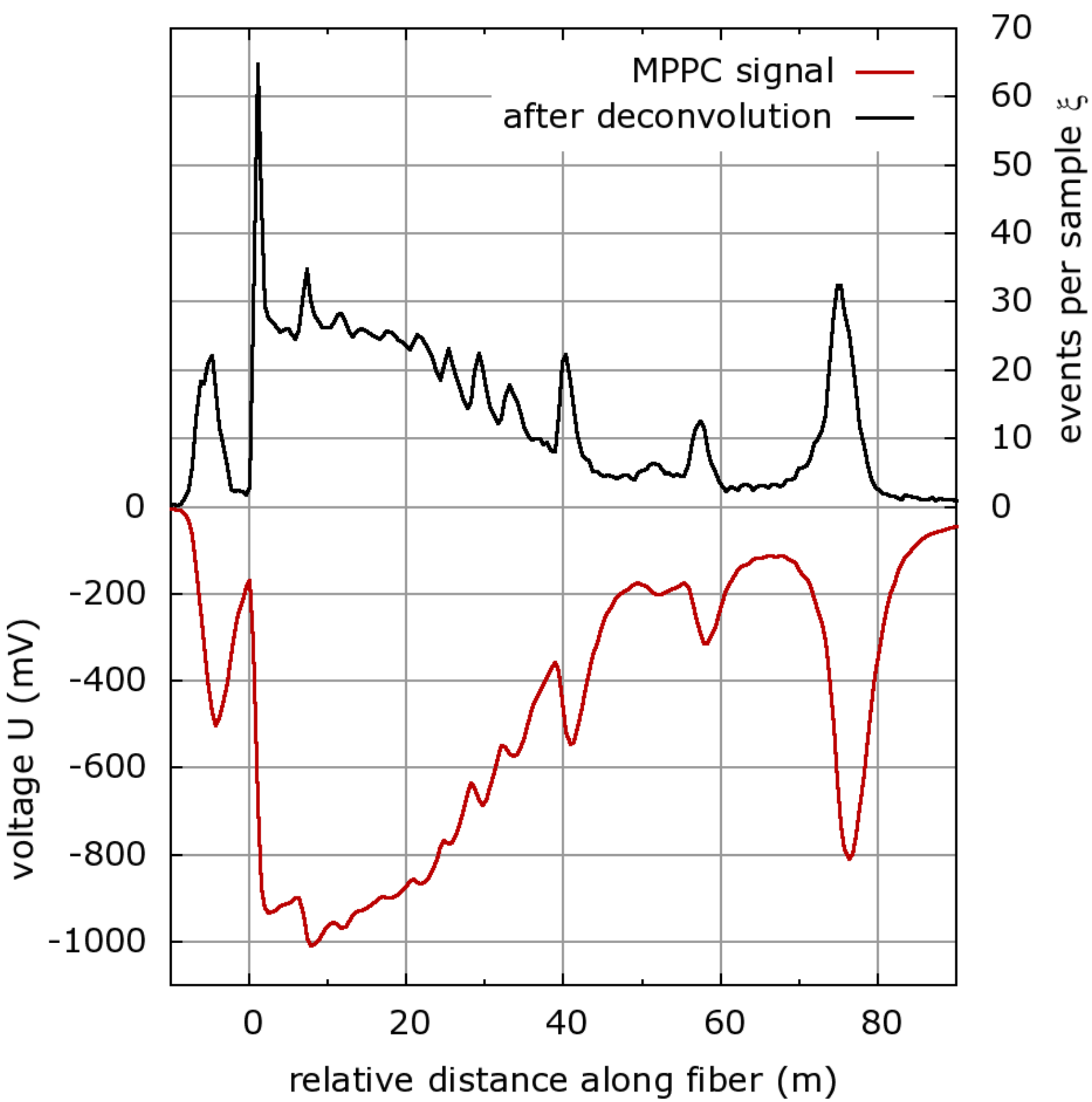
Multi-pixel Photon Counters (MPPCs)

- Array of avalanche photodiodes (APDs) connected in parallel
- Reverse bias → photon causes APD breakdown
- Photomultiplier-like gain
- Dynamic range limited by number of APDs
- Rise time: some 100 ps
- Hamamatsu S10362-11-050U: 400 APDs at ~70 V reverse bias





Signal Processing

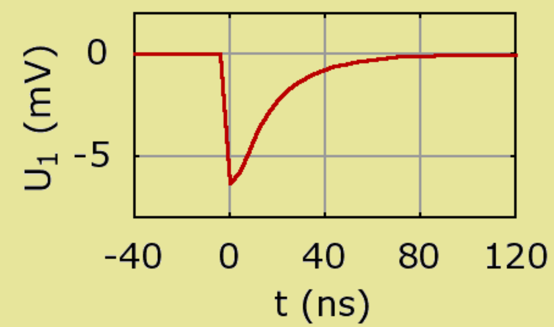


number of photodiode breakdowns

↑

deconvolution

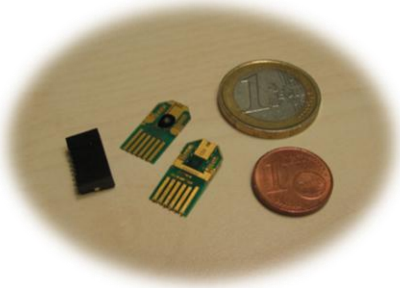
$$\xi(t) = \mathcal{F}_\nu^{-1}\left[\frac{\mathcal{F}_t[U(t)]}{\mathcal{F}_t[U_1(t)]}\right]$$



↑

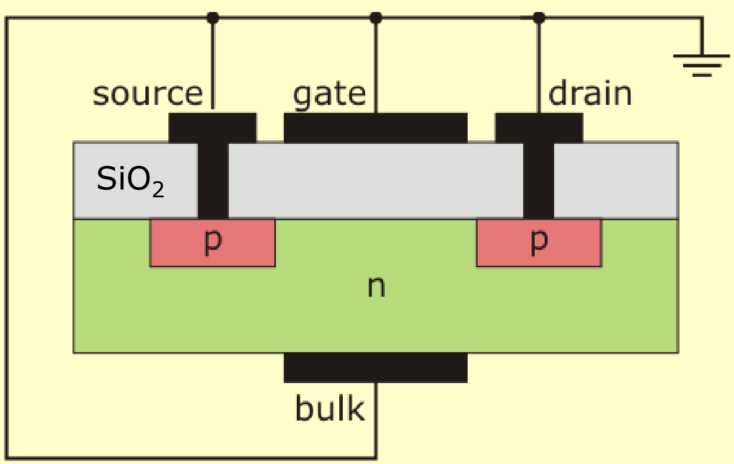
MPPC output signal

RADFET Dosimeters

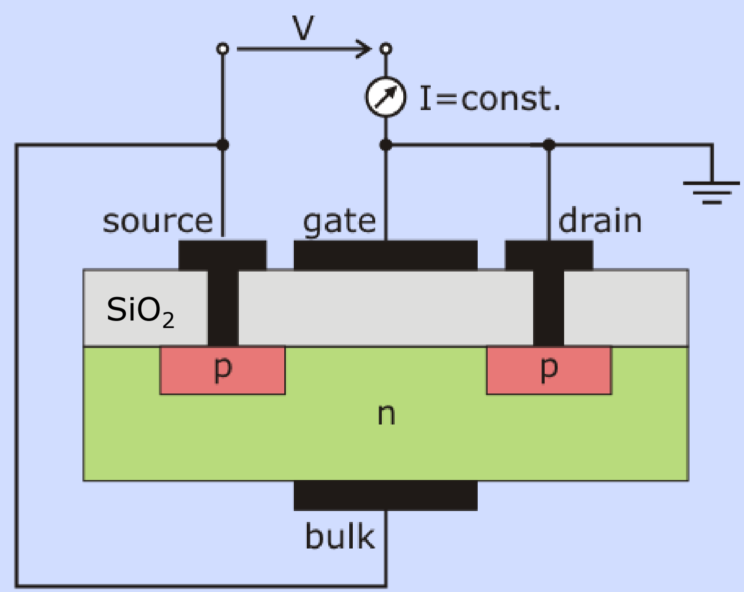


- REM Oxford Ltd. RADFET RFT-300-CC10G1
- Chip contains 2 p-channel MOSFETs with 300 nm insulator layer

exposure
"zero bias"



read-out

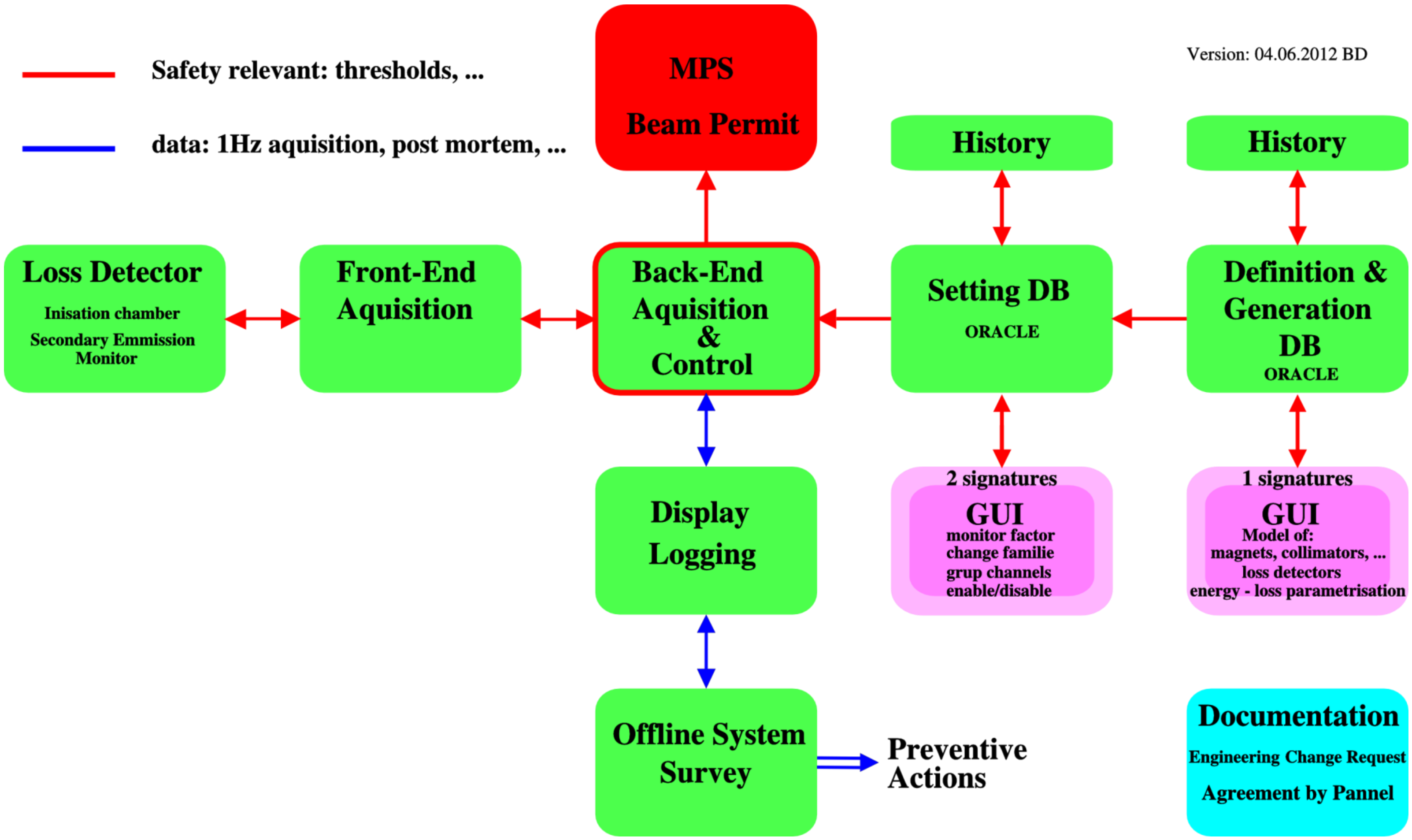


Track voltage for constant current (490 μA) between source and drain

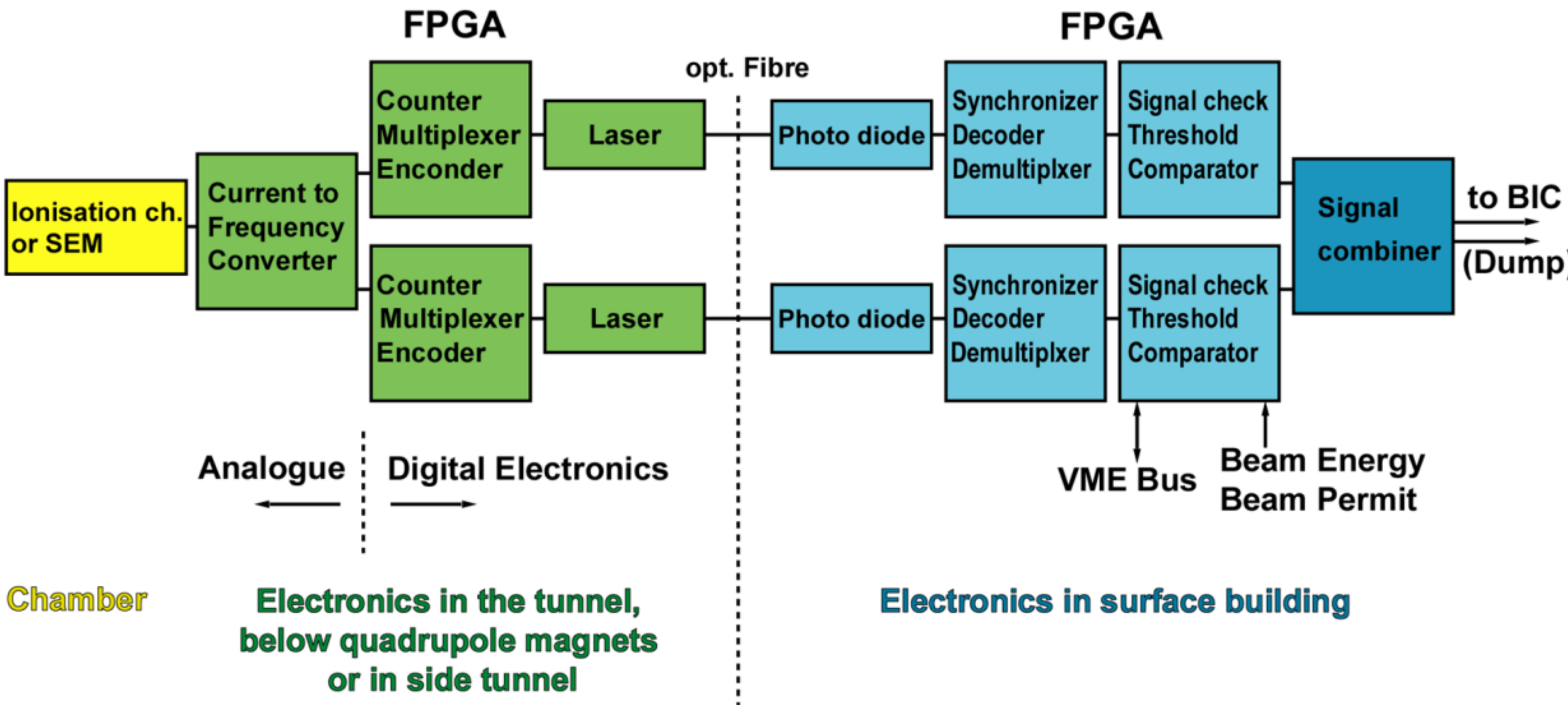
From a small dedicated system to very large system

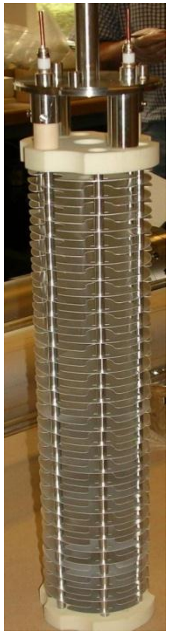
- LHC BLM system:
  - Choice of detectors:
    About 4000 Ionization Chambers and SEM detectors
  - Designed to be highly reliable and available
  - Combines Diagnostics needs and is major component of LHC MP
  - Anticipates human errors and changing of teams over years: Fully data base driven and well documented
  - Would be interesting to get the information on investment:
    My guess: 20 MCHF and 200 FTEyears

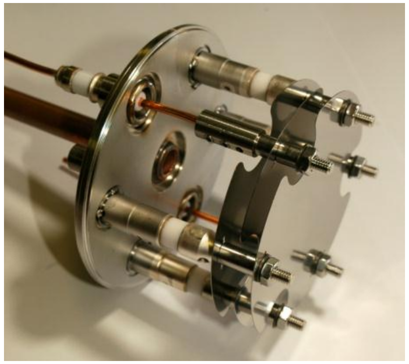
BLM System Knowledge Flow



Beam Loss Measurement System Layouts



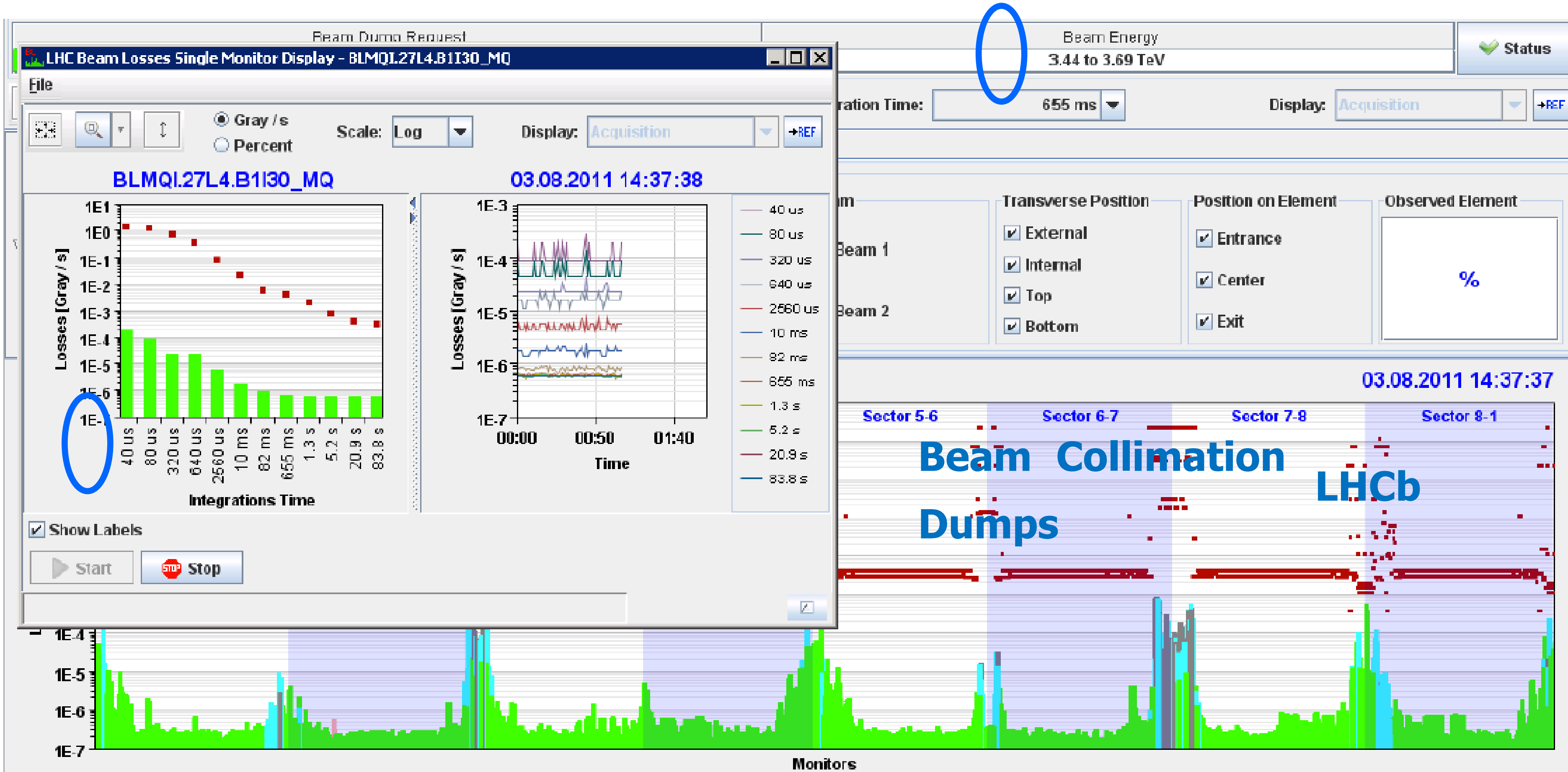




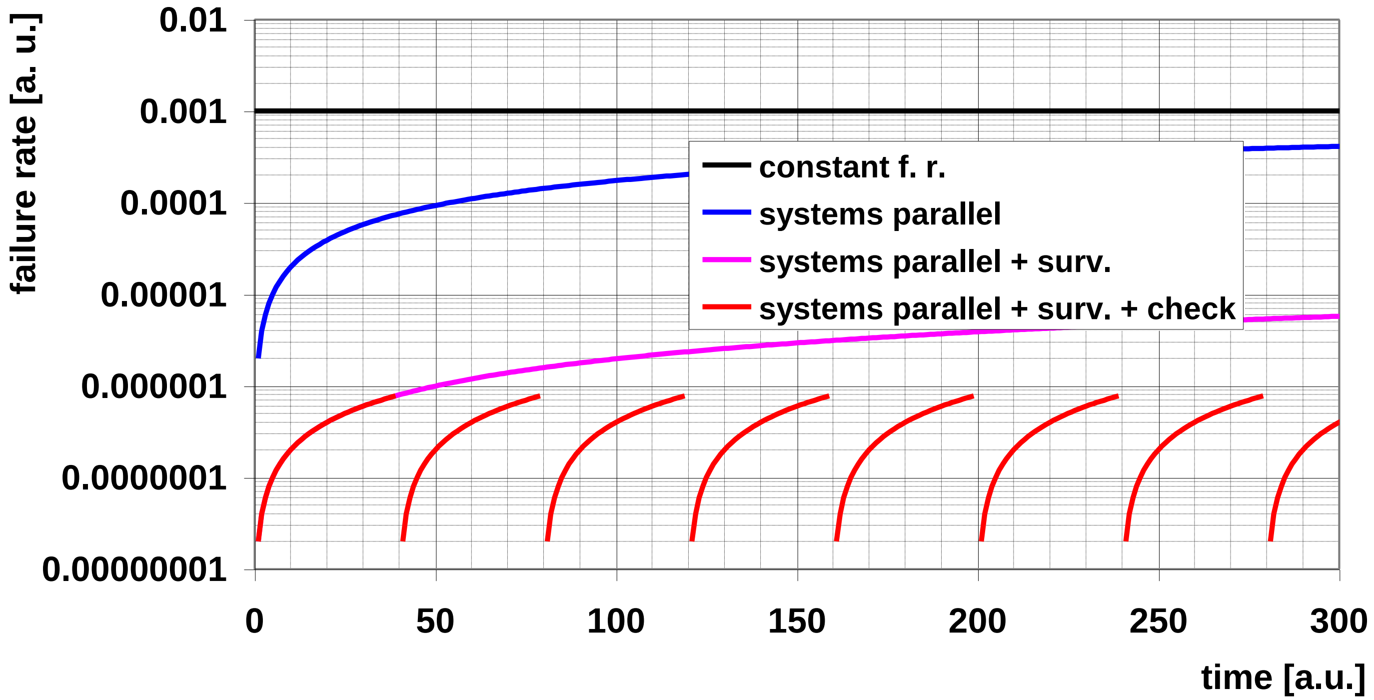
- Ionisation chamber
  - Function: observation and interlock
  - 3700 installed
  - Over 90 % connected to interlock/dump system
- Secondary emission detector
  - Function: observation
  - 300 installed

BLM System – Online Display

- Extensively used for operation verification and machine tuning
- 1 Hz Logging (12 integration times, 40 us to 83 s)
  - Integration times < 1s: maximum during the last second is logged
    - short losses are recorded and loss duration can be reconstructed (20% accuracy)
  - Also used for Online Display



Reliability: Failure Rate and Checks



Systems parallel + survey + functional check:

1. in case of system failure dump beam (failsafe)
2. verification of functionality: simulate measurement and comparison with expected result => as good as new

Key implementation to obtain low failure rate

Steps taken for a Failsafe System: Avoiding Human Errors

To avoid misplacement of
- electronic cards or
- threshold and masking tables

- Tunnel Card ID
  - Unique number embedded in the FPGA (16bit)
  - Included in every transmitted frame
  - Compared with the one stored in the LSA DB

- Surface Card Serial number
  - Unique number embedded in a IC (64bit)
  - Compared with the one stored in the LSA DB

Steps taken for a Failsafe System: System Failures

To avoid loss of data

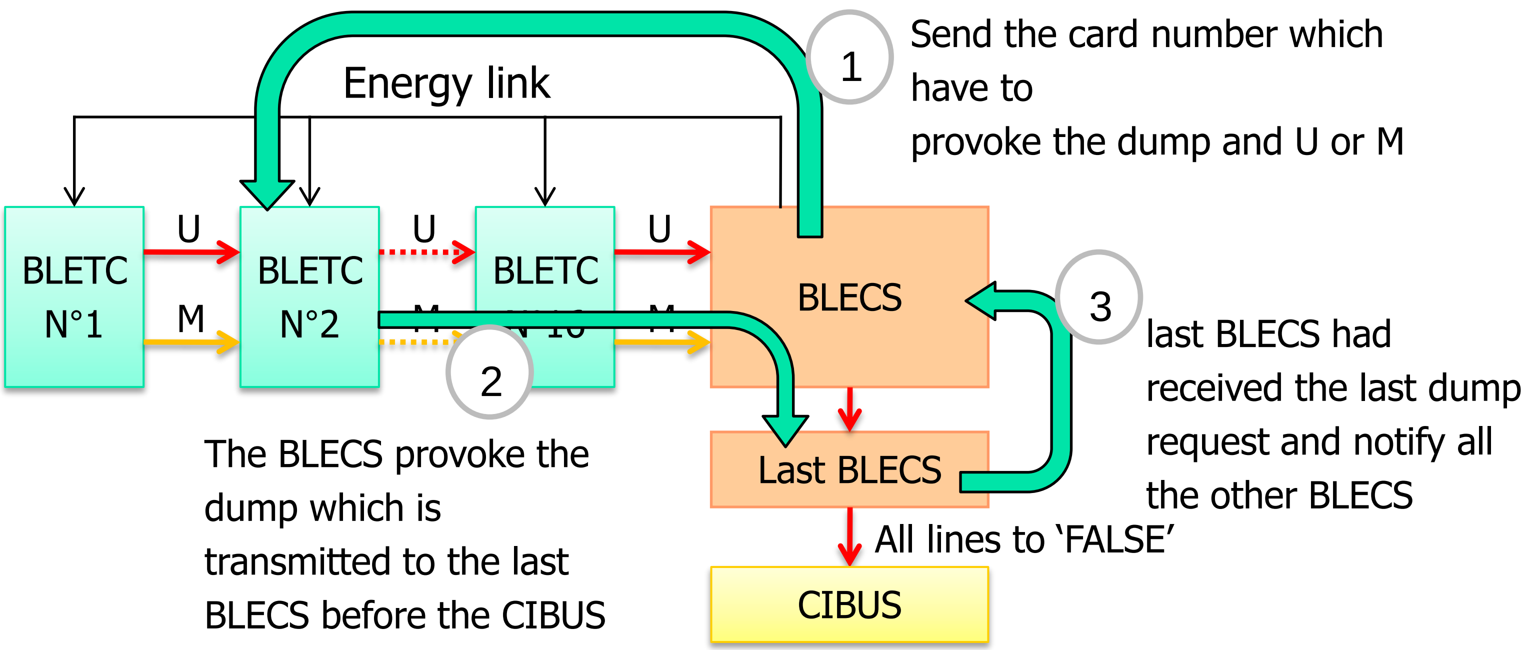
- Frame ID
  - Surface FPGA checks for missing frames
  - Incrementing number included at every transmission
- Optical link is always active
  - 8b/10b encoding sends "commas" when no data
  - Disconnection is detected in max 25ns

To ensure recognition of system failures and beam dump requests

- FPGA Outputs (Beam Dump signals) as frequency
  - At a dump request, reset, or failure the transmitted frequency will be altered
- Beam Permit lines are daisy-chained between cards
  - Custom VME backplane
  - Dummy cards on empty slots to close circuit

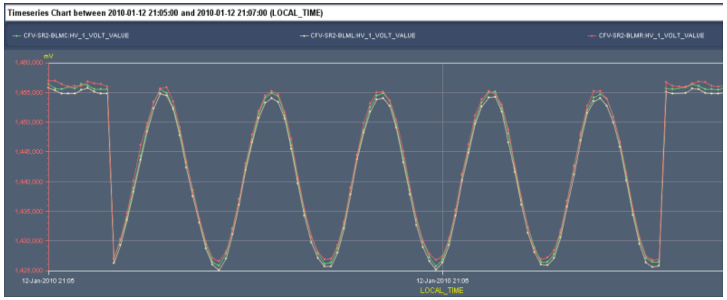
Internal (VME crate) beam permit check

- Check the beam permit lines (BPL) inside the crate
- Check the BPL between the crates (on the same IP)
- Check results are saved in the database

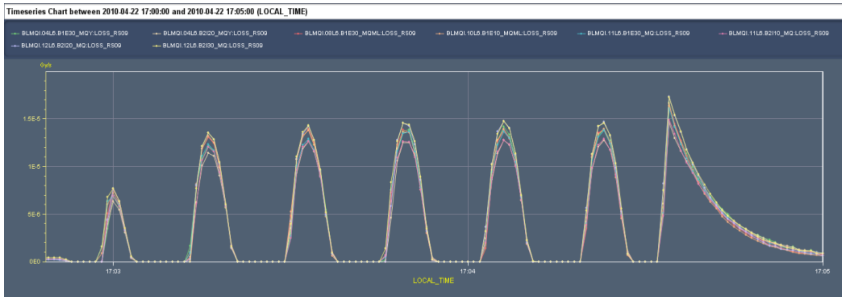


Connectivity check

The high voltage is modulated with a 30V/60mHz signal

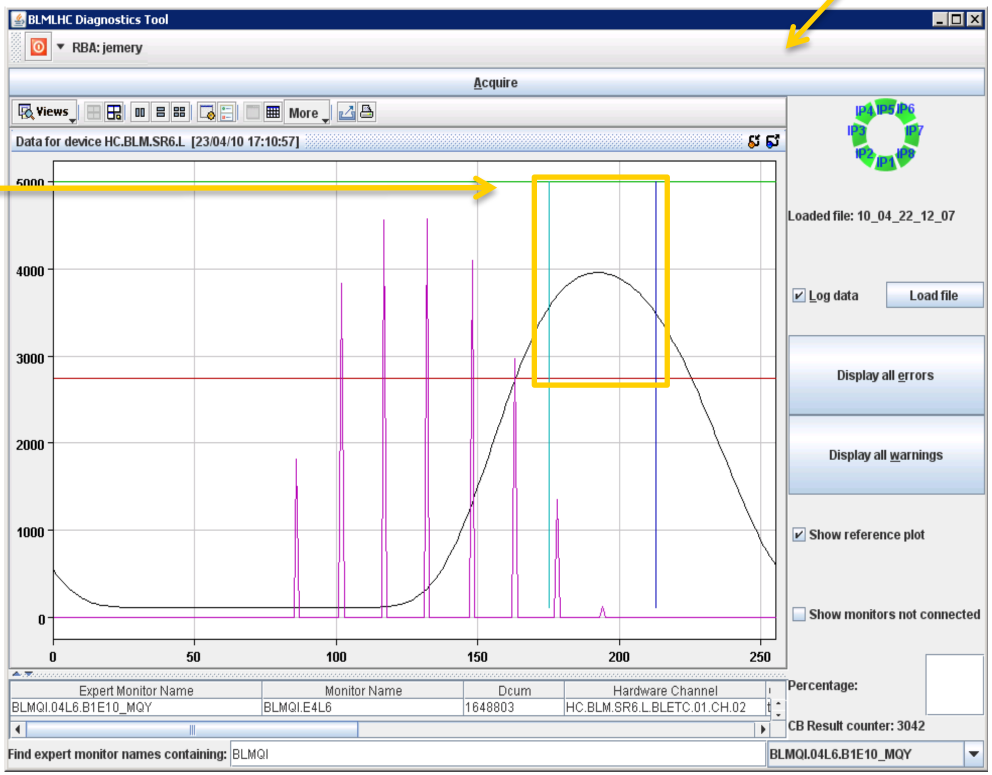


A current is induced in the monitors and measured by the system



Internal thresholds settings overview in the diagnostic tool. (unique for each monitor)

1. Check of cabling
2. Check of components, R- C filter
3. Check of chamber capacity
4. Check of stability of signal, pA to nA
5. Not checked: gas gain of chamber



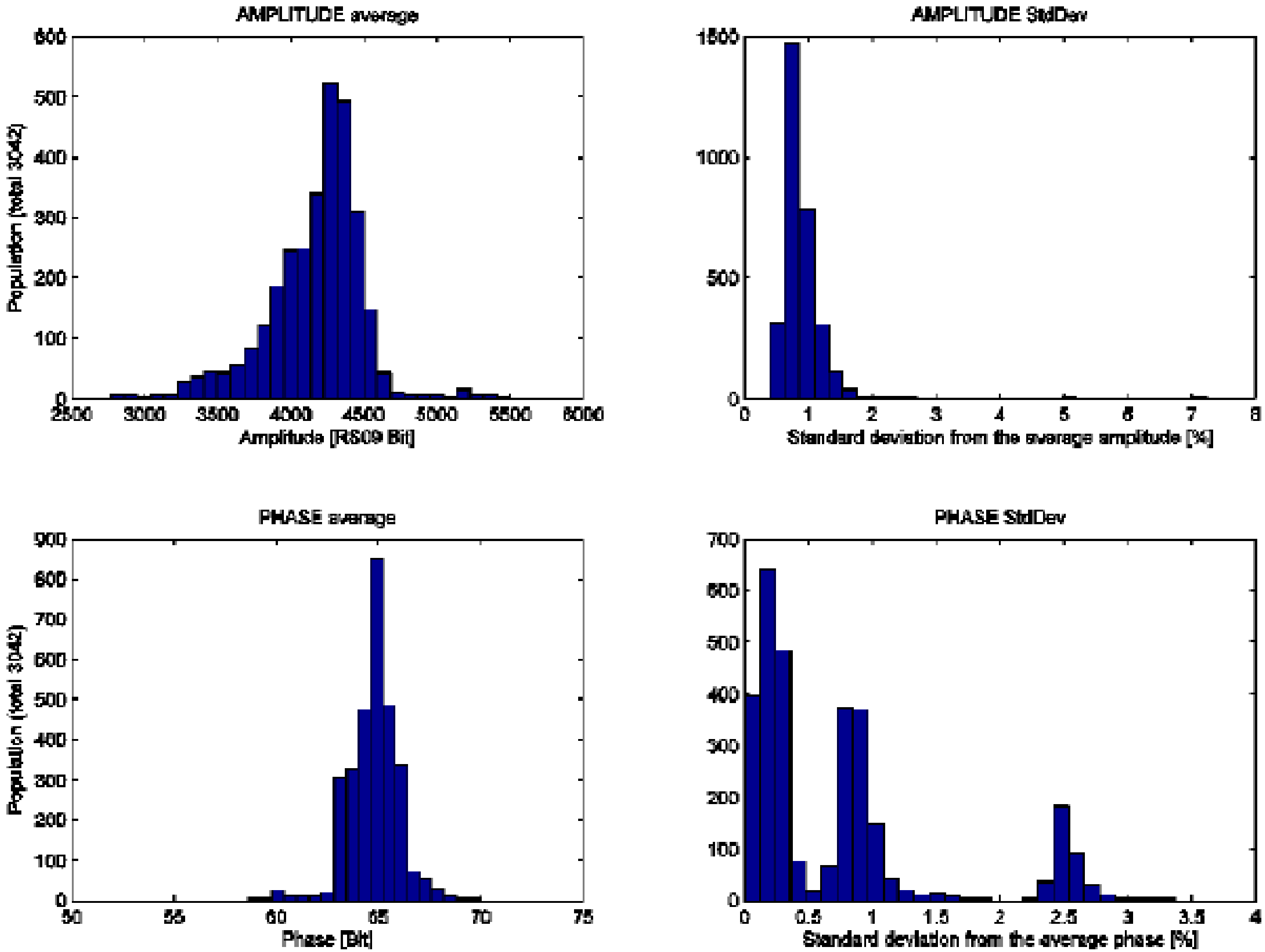
Last full period in saved in the SRAM and processed

The phase and amplitude are calculated and compared to predefined thresholds in the BLECS card.

The raw and filtered data is kept into the SRAM and can be retrieved with the Diagnostic application

High Voltage Modulation Results

Connectivity check measurements (100x) on BLMQI monitors (Ionization chambers in the arcs)



Continuous effort for high performance...

....through online (and offline) checks of critical beam parameters

...essential to get highest integrated luminosity
... Provides first indication of deteriorations

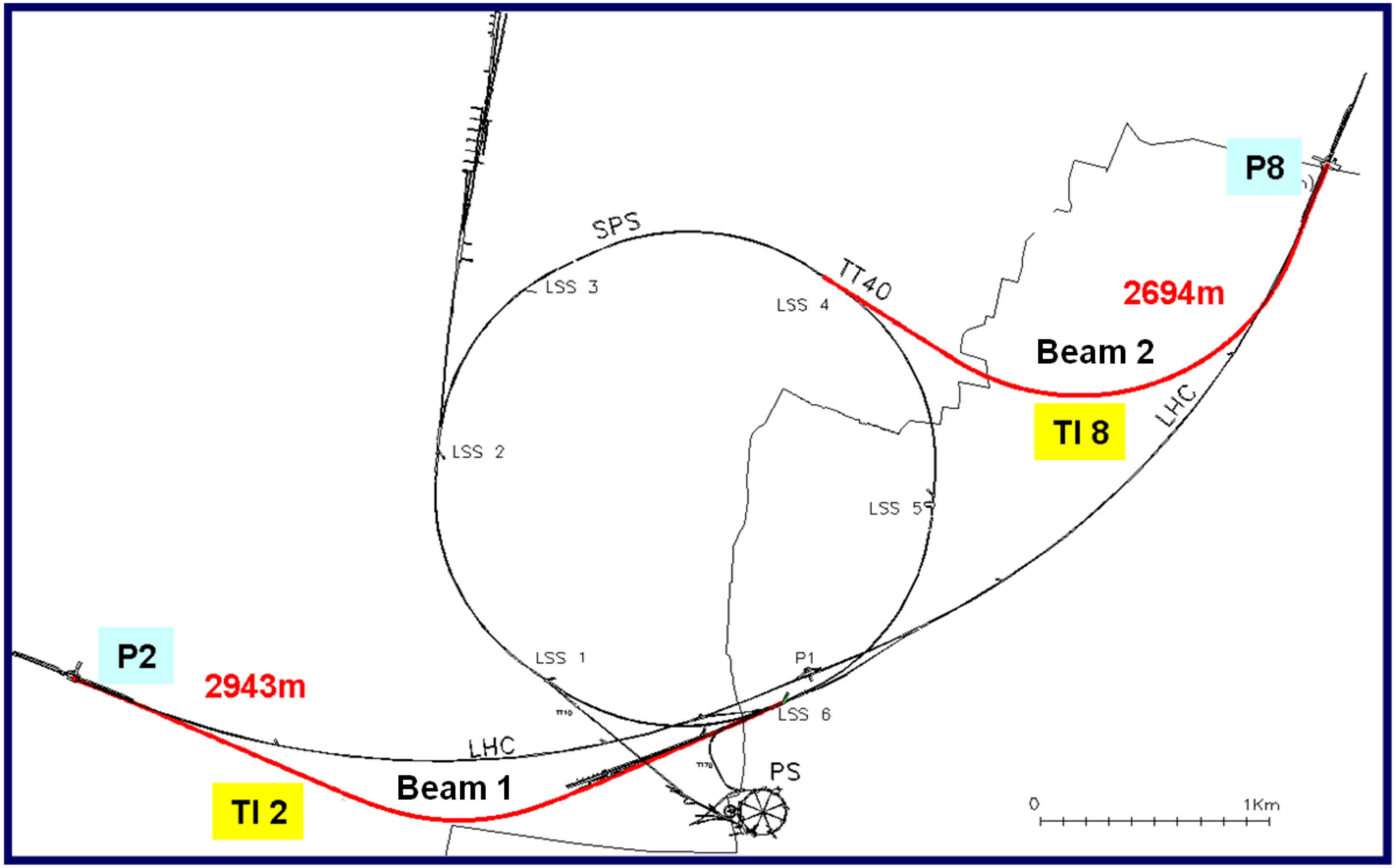
which, if followed –up, contribute essentially to the understanding and protection of the accelerator

and create ideas for improvements

Needs a complete set of Instruments for Diagnostics

Layout SPS to LHC

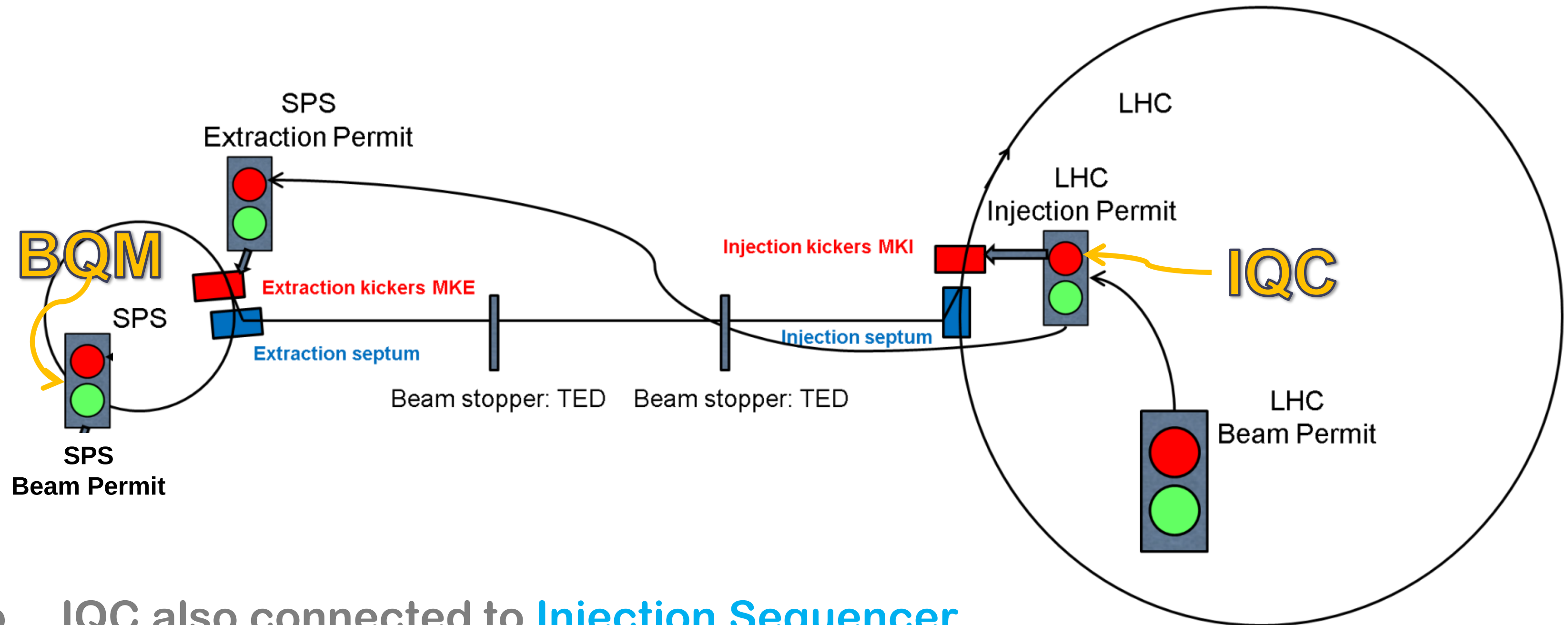
- 2 3 km long transfer lines to fill the LHC from the SPS



- Need ~ 12 injections per ring to fill LHC; LHC cycle in the SPS ~ 20 s.
- Fast extraction from the SPS
- As soon as extraction launched cannot stop it anymore

BQM and IQC signals used online

- BQM connected to SPS Beam Permit
- IQC connected to injection Software Interlock System (SIS), the injection SIS is connected to the injection permit

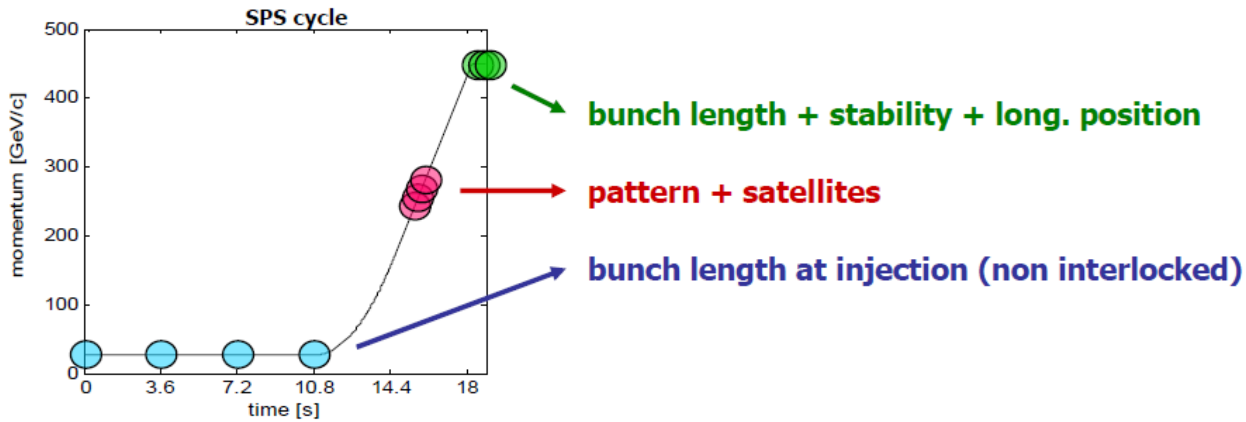


- IQC also connected to Injection Sequencer
  - Programs the next injection in the injector timing system
  - Programs all the equipment with required settings for next injection:
    - ❑ Pattern of BQM
    - ❑ Next injected bunches for bunch-by-bunch measurement systems
    - ❑ …

Beam Quality Monitor in the SPS

- Beam Quality Monitor (BQM) – checks longitudinal quality of beam in the SPS

BQM measurements

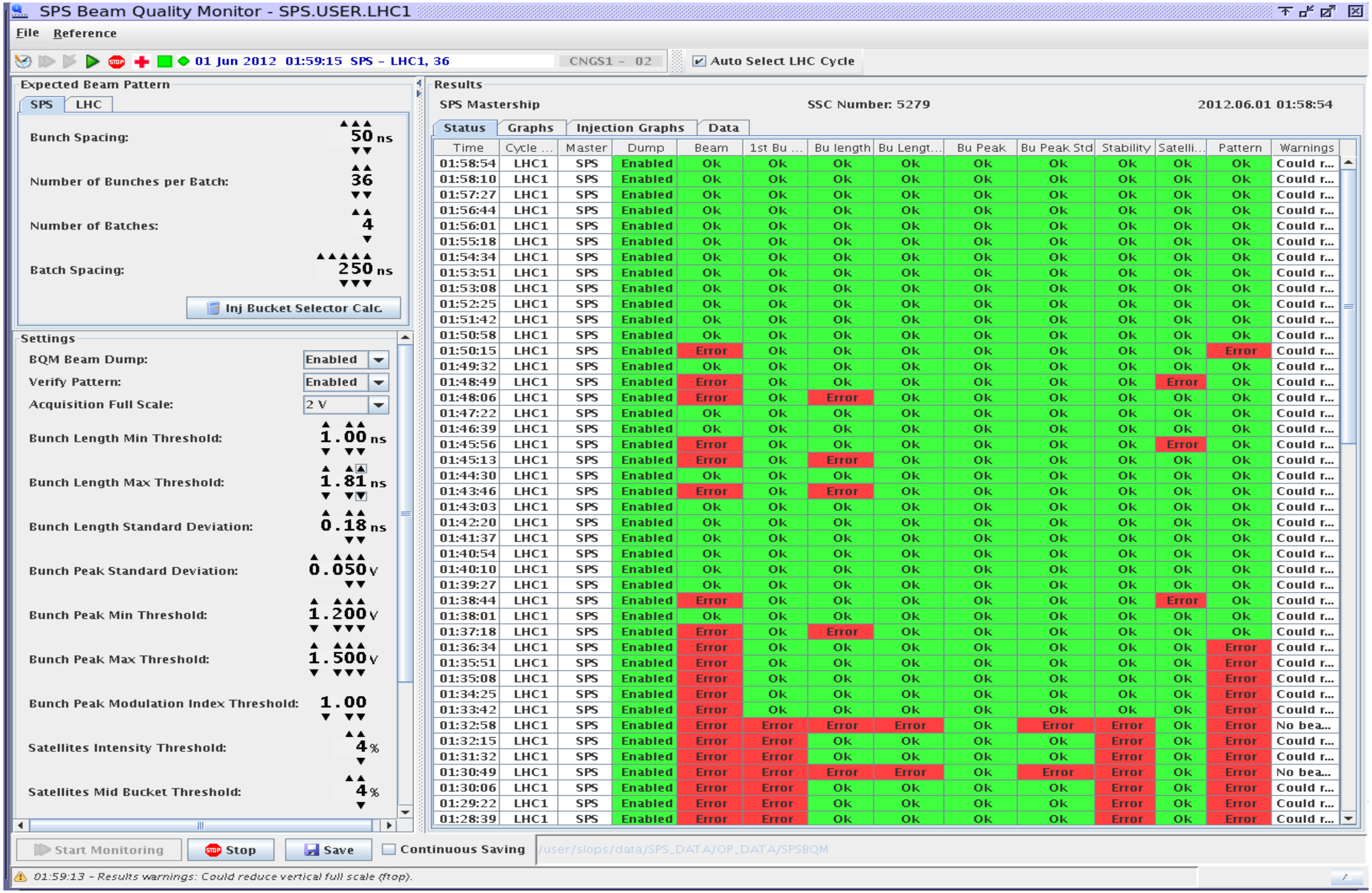


- Based on Wall Current Monitor Beam Profile. Analysis running on FESA class.
- Dumps beam in the SPS in case of bad quality. Last check ~ 20 ms before extraction.
- Analysis speed: 10 ms data acquisition + 10 ms analysis
- Typical errors caught:
  - Rephasing not working correctly
  - Fully debunched (PS cavity missing)
  - Bad injection phase or bad PS bunch splitting
  - Injections in wrong bucket or missing injections in the SPS
  - Bunch intensity spread too large

G. Papotti

Beam Quality Monitor in the SPS

- The BQM analyses each SPS cycle, no matter whether beam requested by LHC or not.

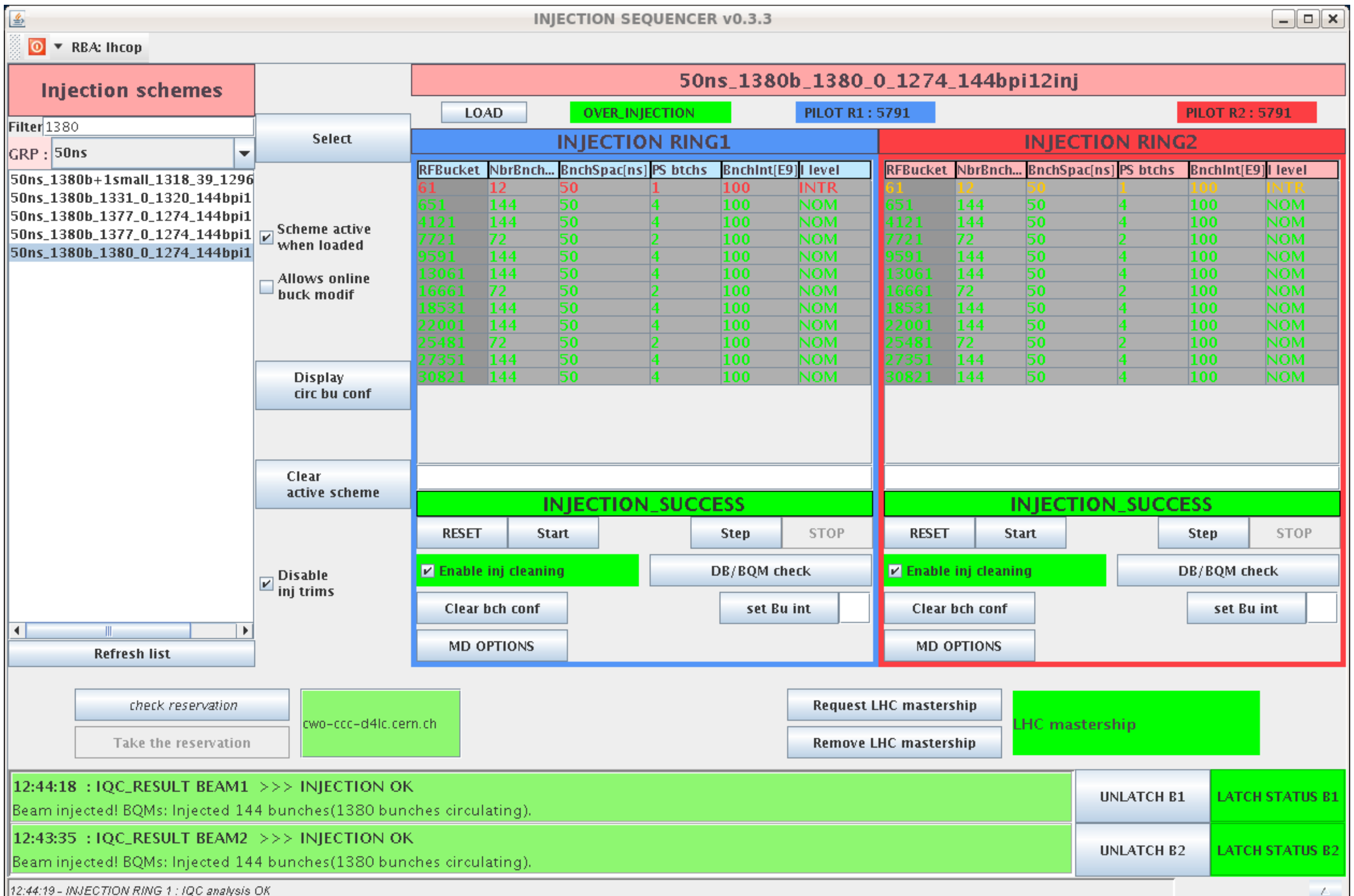


Time	Cycle ...	Master	Dump	Beam	1st Bu ...	Bu length	Bu Lengt...	Bu Peak	Bu Peak Std	Stability	Satelli...	Pattern	Warnings
01:58:54	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:58:10	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:57:27	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:56:44	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:56:01	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:55:18	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:54:34	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:53:51	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:53:08	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:52:25	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:51:42	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:50:58	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:50:15	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Error	Could r...
01:49:32	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:48:49	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Error	Ok	Could r...
01:48:06	LHC1	SPS	Enabled	Error	Ok	Error	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:47:22	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:46:39	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:45:56	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Error	Ok	Could r...
01:45:13	LHC1	SPS	Enabled	Error	Ok	Error	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:44:30	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:43:46	LHC1	SPS	Enabled	Error	Ok	Error	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:43:03	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:42:20	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:41:37	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:40:54	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:40:10	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:39:27	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:38:44	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Error	Ok	Could r...
01:38:01	LHC1	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:37:18	LHC1	SPS	Enabled	Error	Ok	Error	Ok	Ok	Ok	Ok	Ok	Ok	Could r...
01:36:34	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Error	Could r...
01:35:51	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Error	Could r...
01:35:08	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Error	Could r...
01:34:25	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Error	Could r...
01:33:42	LHC1	SPS	Enabled	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Error	Could r...
01:32:58	LHC1	SPS	Enabled	Error	Error	Error	Error	Ok	Error	Error	Ok	Error	No bea...
01:32:15	LHC1	SPS	Enabled	Error	Error	Ok	Ok	Ok	Ok	Error	Ok	Error	Could r...
01:31:32	LHC1	SPS	Enabled	Error	Error	Ok	Ok	Ok	Ok	Error	Ok	Error	Could r...
01:30:49	LHC1	SPS	Enabled	Error	Error	Error	Error	Ok	Error	Error	Ok	Error	No bea...
01:30:06	LHC1	SPS	Enabled	Error	Error	Ok	Ok	Ok	Ok	Error	Ok	Error	Could r...
01:29:22	LHC1	SPS	Enabled	Error	Error	Ok	Ok	Ok	Ok	Error	Ok	Error	Could r...
01:28:39	LHC1	SPS	Enabled	Error	Error	Ok	Ok	Ok	Ok	Error	Ok	Error	Could r...

- Logical "AND" of all analysis results, if FALSE beam dumped before extraction

Injection Sequencer and IQC

- Injection sequencer: pre-programmed series of different shots
  - Different number of bunches, different RF bucket, …
- Injection sequencer only plays next request if IQC result was good.



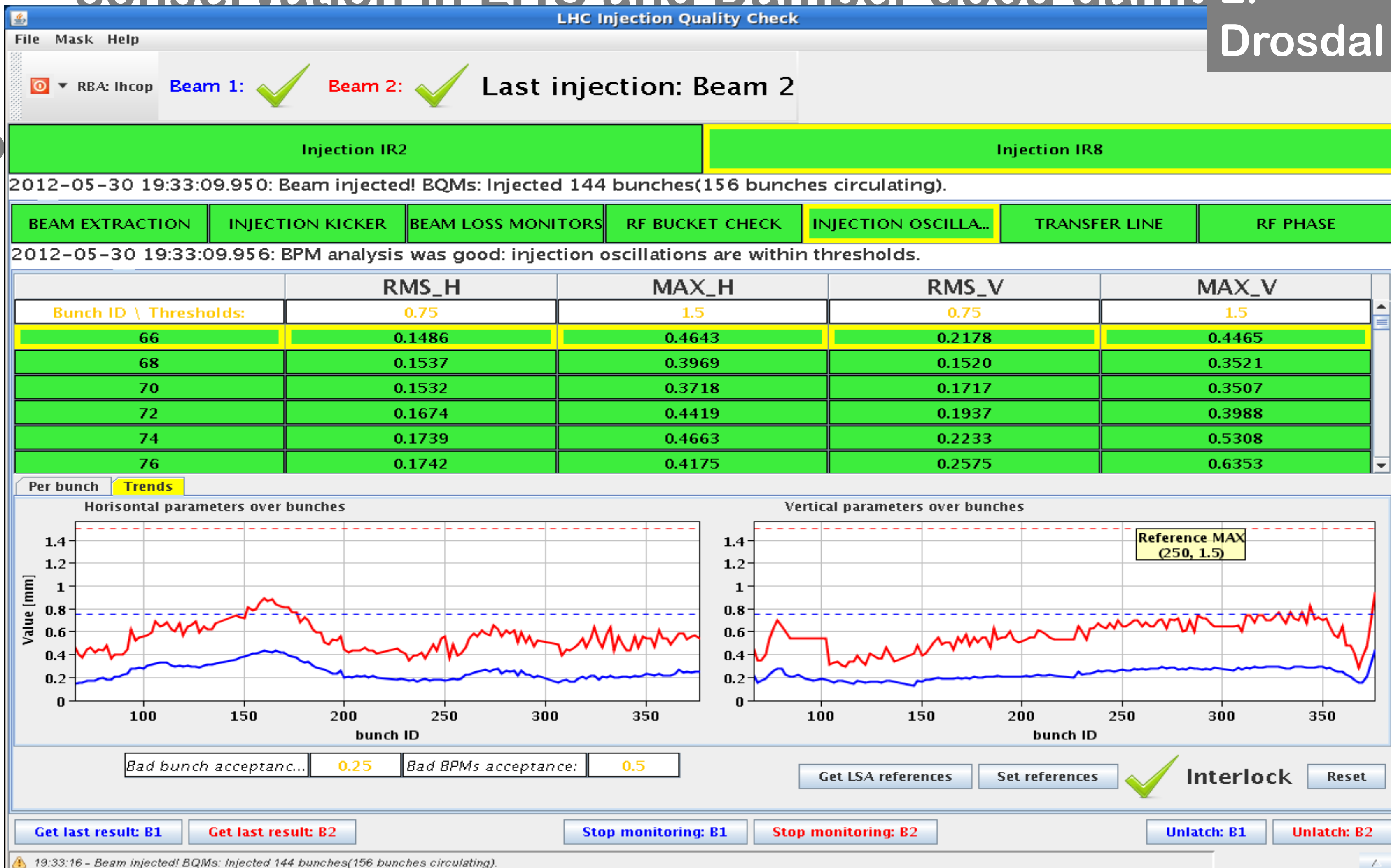
D. Jacquet

Injection Quality Check in the LHC

- If injection oscillations are above limit – can only re-inject with maximum 12 bunches. Aperture conservation in LHC and Damper good damp

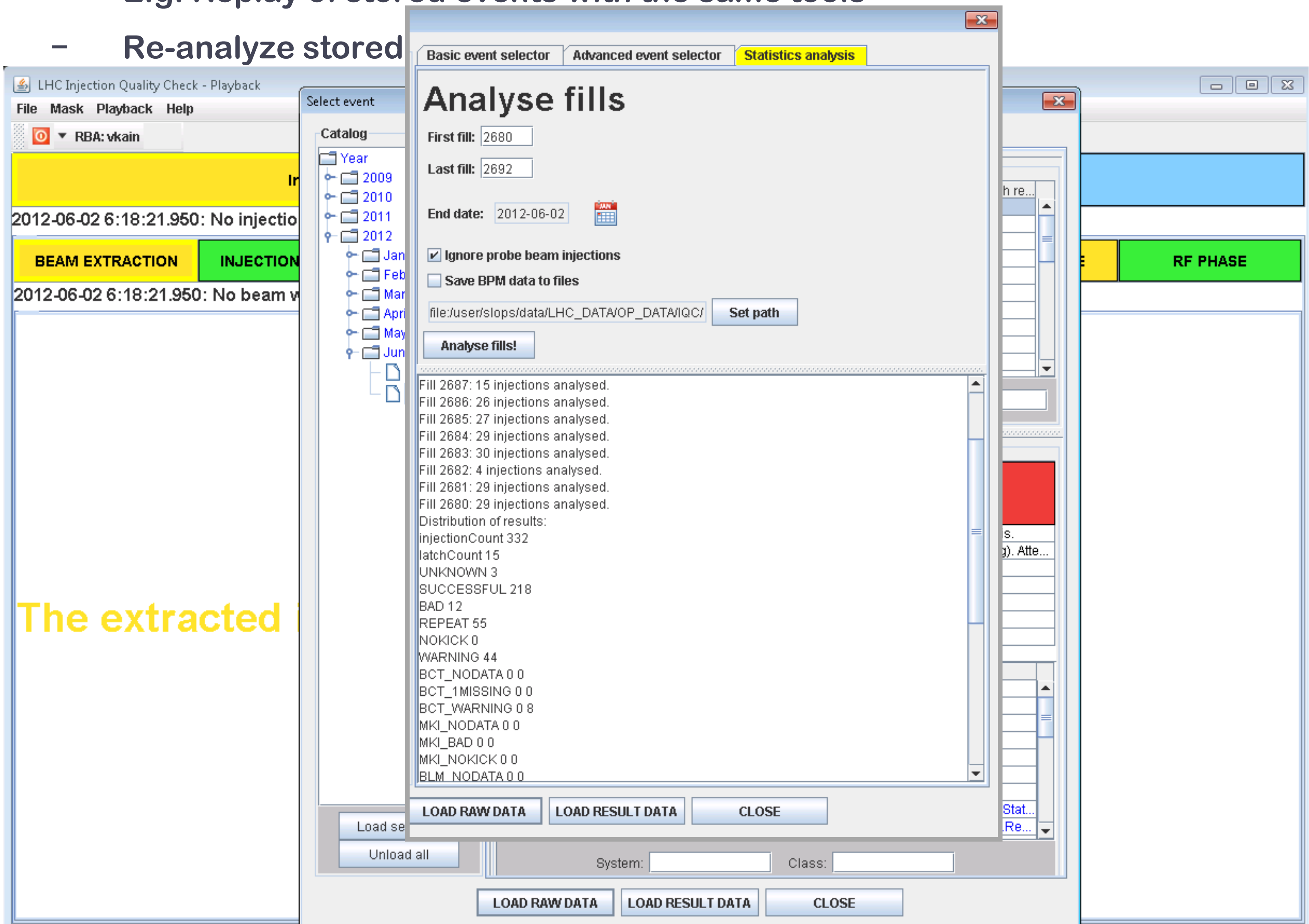
L. Drosdal

-



IQC in the LHC – playback, statistics

- The LHC injection process is now well understood due offline analysis
- IQC comes with all the LHC postmortem infrastructure
  - E.g. Replay of stored events with the same tools
  - Re-analyze stored



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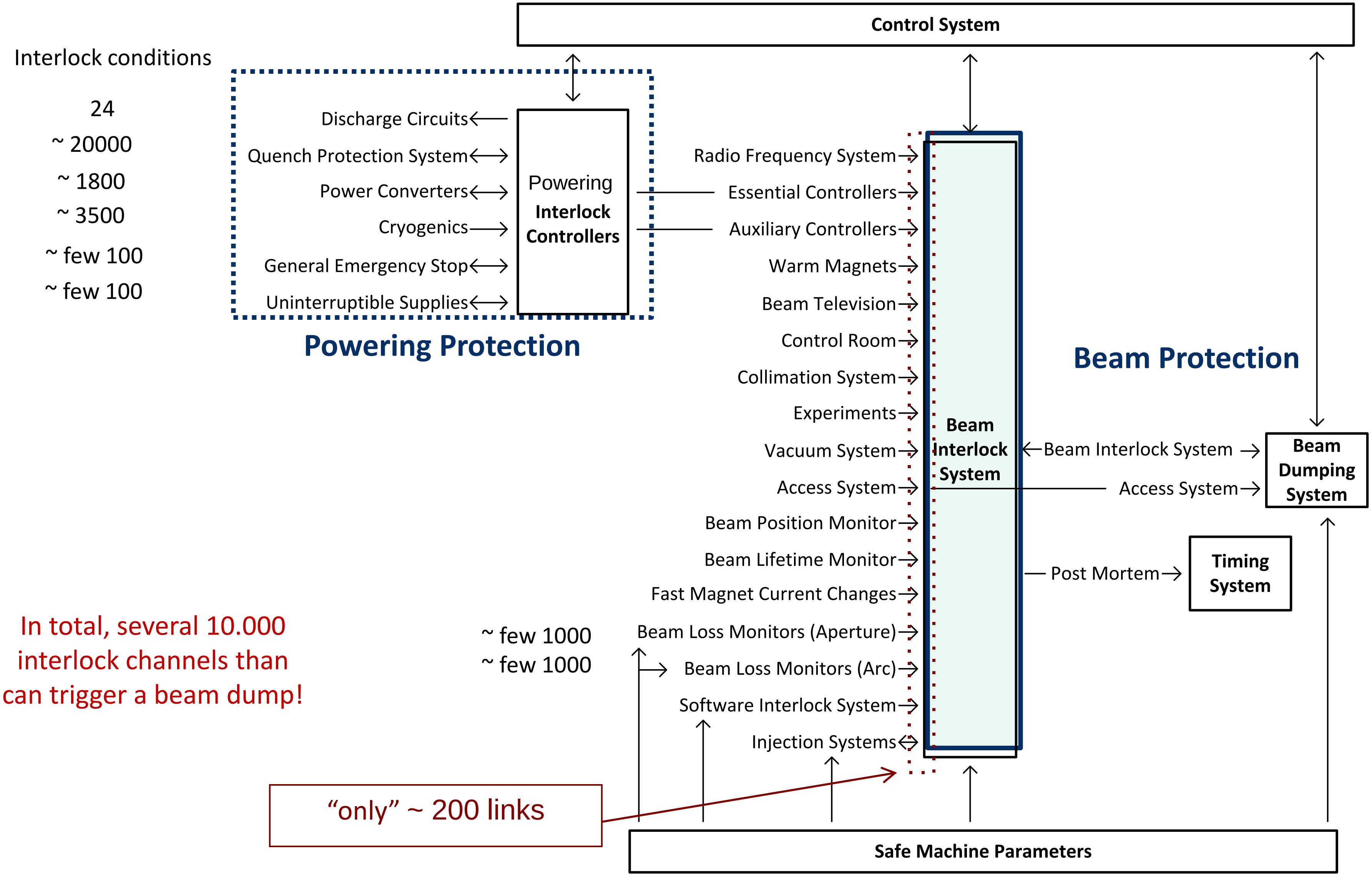
The MPS: Just the final executioner or more?

LHC

- Basic functionality:

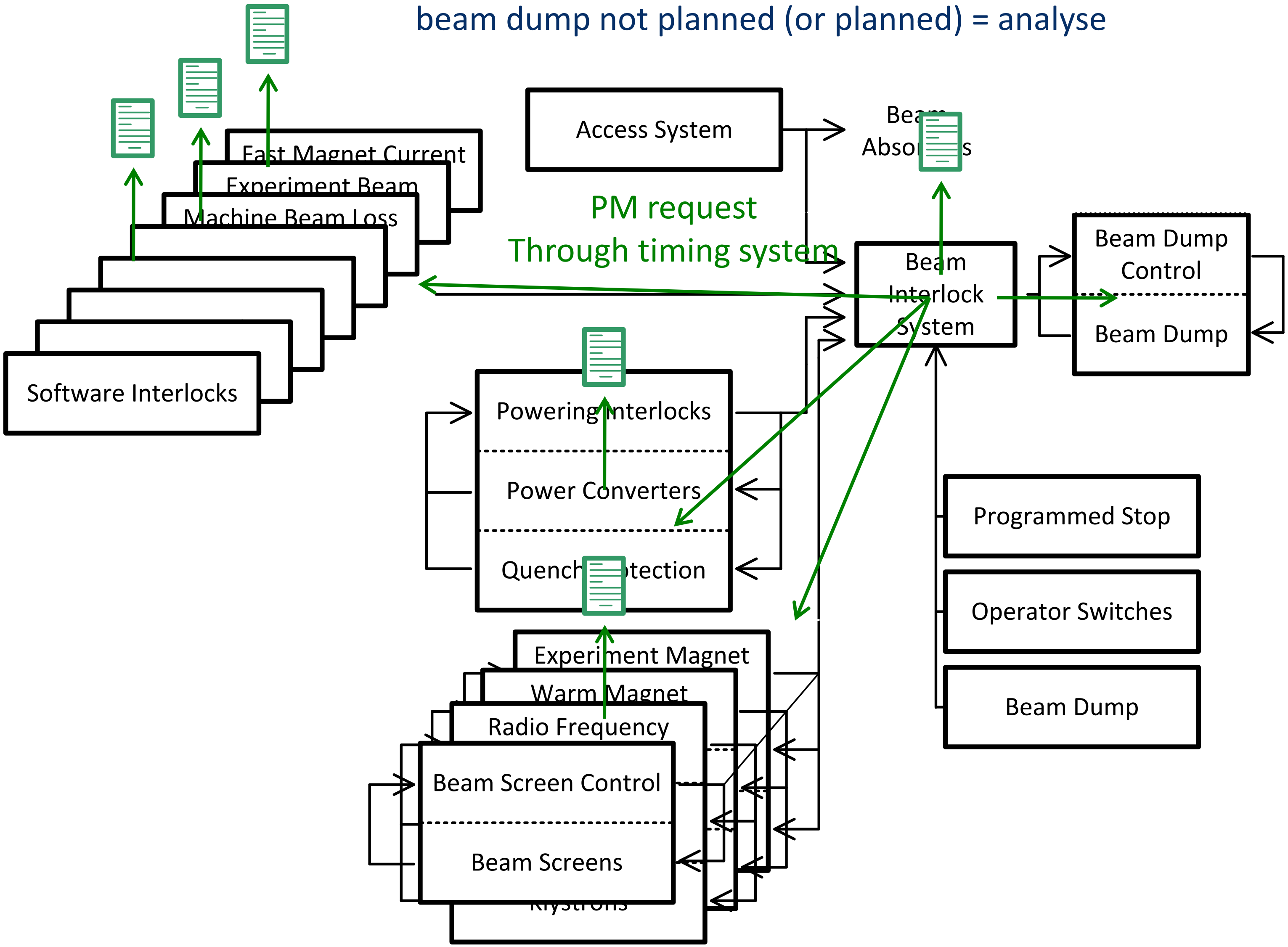
- Distributed system to collect all necessary machine interlocks
- Able to activate the LHC beam dumps within one machine turn
- Fail-save, highly reliable, highly available
- Strongly connected to the machine general timing system
- "Orchestrates" a powerful offline utility called:
  ' Post Mortem analysis'
- One (of many) diagnostics tools of this post mortem analysis is establishing in detail the causality of a beam dump by time correlation of individual interlocks → need front end equipment to have synchronized clocks on the **microsecond** level!

BIS = Core of LHC Machine Protection



Post-Mortem layout

beam dump not planned (or planned) = analyse



An example of event sequence

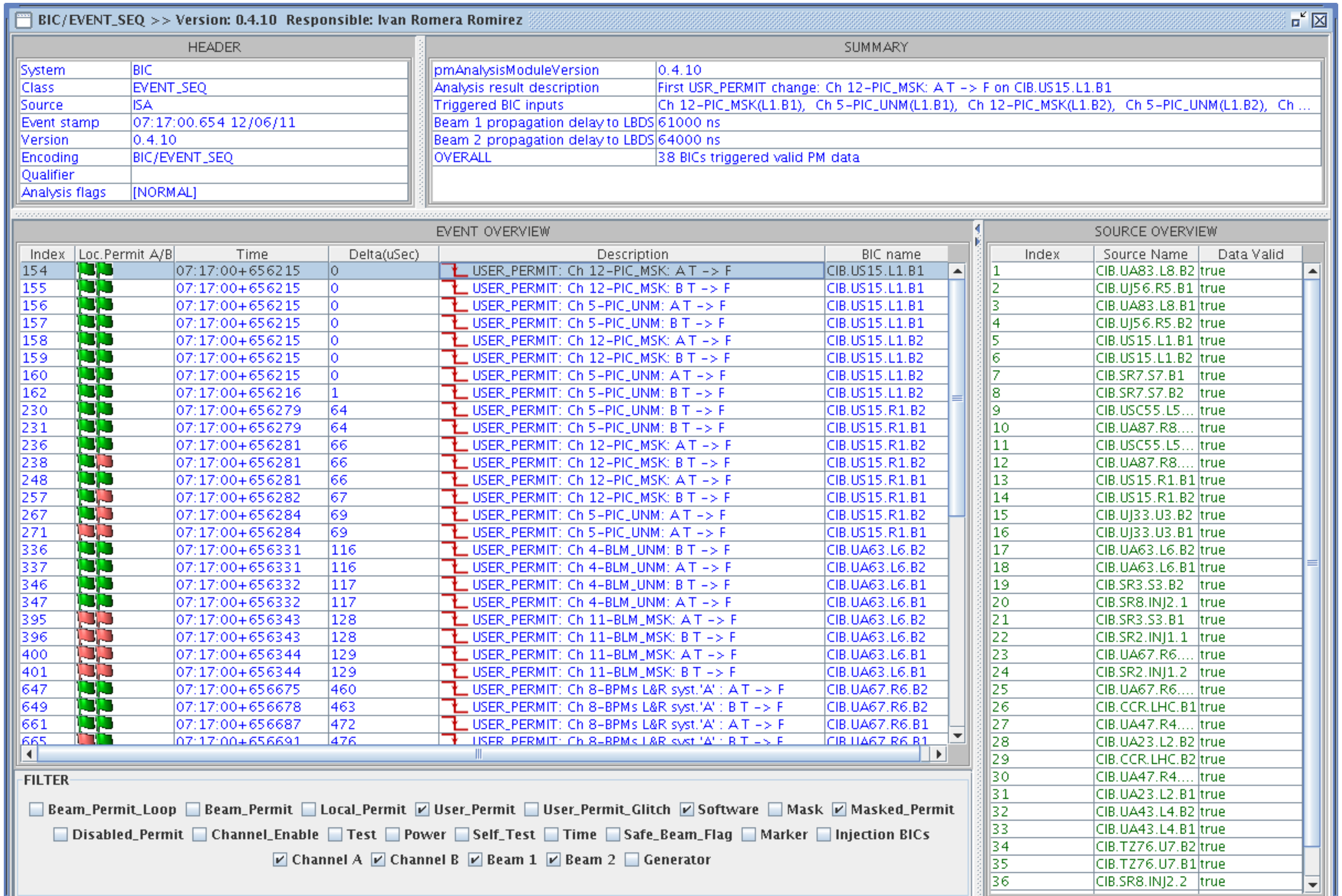
Event Timestamp: **12-JUN-11 07.17.00.656290 AM**

Beam Energy: **3500040**

Mps Expert Comment : **Quench of RD2.L1 magnet**

(+ due to suspected imbalance as well RQ4 some 17 sec. after the dump…

Dump clean.



BIC/EVENT_SEQ >> Version: 0.4.10 Responsible: Ivan Romera Romirez

HEADER

System	BIC
Class	EVENT_SEQ
Source	ISA
Event stamp	07:17:00.654 12/06/11
Version	0.4.10
Encoding	BIC/EVENT_SEQ
Qualifier	
Analysis flags	[NORMAL]

SUMMARY

pmAnalysisModuleVersion	0.4.10
Analysis result description	First USR_PERMIT change: Ch 12-PIC_MSK: A T -> F on CIB.US15.L1.B1
Triggered BIC inputs	Ch 12-PIC_MSK(L1.B1), Ch 5-PIC_UNM(L1.B1), Ch 12-PIC_MSK(L1.B2), Ch 5-PIC_UNM(L1.B2), Ch …
Beam 1 propagation delay to LBDS	61000 ns
Beam 2 propagation delay to LBDS	64000 ns
OVERALL	38 BICs triggered valid PM data

EVENT OVERVIEW

Index	Loc.Permit A/B	Time	Delta(uSec)	Description	BIC name
154		07:17:00+656215	0	USER_PERMIT: Ch 12-PIC_MSK: A T -> F	CIB.US15.L1.B1
155		07:17:00+656215	0	USER_PERMIT: Ch 12-PIC_MSK: B T -> F	CIB.US15.L1.B1
156		07:17:00+656215	0	USER_PERMIT: Ch 5-PIC_UNM: A T -> F	CIB.US15.L1.B1
157		07:17:00+656215	0	USER_PERMIT: Ch 5-PIC_UNM: B T -> F	CIB.US15.L1.B1
158		07:17:00+656215	0	USER_PERMIT: Ch 12-PIC_MSK: A T -> F	CIB.US15.L1.B2
159		07:17:00+656215	0	USER_PERMIT: Ch 12-PIC_MSK: B T -> F	CIB.US15.L1.B2
160		07:17:00+656215	0	USER_PERMIT: Ch 5-PIC_UNM: A T -> F	CIB.US15.L1.B2
162		07:17:00+656216	1	USER_PERMIT: Ch 5-PIC_UNM: B T -> F	CIB.US15.L1.B2
230		07:17:00+656279	64	USER_PERMIT: Ch 5-PIC_UNM: B T -> F	CIB.US15.R1.B2
231		07:17:00+656279	64	USER_PERMIT: Ch 5-PIC_UNM: B T -> F	CIB.US15.R1.B1
236		07:17:00+656281	66	USER_PERMIT: Ch 12-PIC_MSK: A T -> F	CIB.US15.R1.B2
238		07:17:00+656281	66	USER_PERMIT: Ch 12-PIC_MSK: B T -> F	CIB.US15.R1.B2
248		07:17:00+656281	66	USER_PERMIT: Ch 12-PIC_MSK: A T -> F	CIB.US15.R1.B1
257		07:17:00+656282	67	USER_PERMIT: Ch 12-PIC_MSK: B T -> F	CIB.US15.R1.B1
267		07:17:00+656284	69	USER_PERMIT: Ch 5-PIC_UNM: A T -> F	CIB.US15.R1.B2
271		07:17:00+656284	69	USER_PERMIT: Ch 5-PIC_UNM: A T -> F	CIB.US15.R1.B1
336		07:17:00+656331	116	USER_PERMIT: Ch 4-BLM_UNM: B T -> F	CIB.UA63.L6.B2
337		07:17:00+656331	116	USER_PERMIT: Ch 4-BLM_UNM: A T -> F	CIB.UA63.L6.B2
346		07:17:00+656332	117	USER_PERMIT: Ch 4-BLM_UNM: B T -> F	CIB.UA63.L6.B1
347		07:17:00+656332	117	USER_PERMIT: Ch 4-BLM_UNM: A T -> F	CIB.UA63.L6.B1
395		07:17:00+656343	128	USER_PERMIT: Ch 11-BLM_MSK: A T -> F	CIB.UA63.L6.B2
396		07:17:00+656343	128	USER_PERMIT: Ch 11-BLM_MSK: B T -> F	CIB.UA63.L6.B2
400		07:17:00+656344	129	USER_PERMIT: Ch 11-BLM_MSK: A T -> F	CIB.UA63.L6.B1
401		07:17:00+656344	129	USER_PERMIT: Ch 11-BLM_MSK: B T -> F	CIB.UA63.L6.B1
647		07:17:00+656675	460	USER_PERMIT: Ch 8-BPMs L&R syst.'A' : A T -> F	CIB.UA67.R6.B2
649		07:17:00+656678	463	USER_PERMIT: Ch 8-BPMs L&R syst.'A' : B T -> F	CIB.UA67.R6.B2
661		07:17:00+656687	472	USER_PERMIT: Ch 8-BPMs L&R syst.'A' : A T -> F	CIB.UA67.R6.B1
665		07:17:00+656691	476	USER_PERMIT: Ch 8-BPMs L&R syst.'A' : B T -> F	CIB.UA67.R6.B1

FILTER

☐ Beam_Permit_Loop ☐ Beam_Permit ☐ Local_Permit ☑ User_Permit ☐ User_Permit_Glitch ☑ Software ☐ Mask ☑ Masked_Permit

☐ Disabled_Permit ☐ Channel_Enable ☐ Test ☐ Power ☐ Self_Test ☐ Time ☐ Safe_Beam_Flag ☐ Marker ☐ Injection BICs

☑ Channel A ☑ Channel B ☑ Beam 1 ☑ Beam 2 ☐ Generator

SOURCE OVERVIEW

Index	Source Name	Data Valid
1	CIB.UA83.L8.B2	true
2	CIB.UJ56.R5.B1	true
3	CIB.UA83.L8.B1	true
4	CIB.UJ56.R5.B2	true
5	CIB.US15.L1.B1	true
6	CIB.US15.L1.B2	true
7	CIB.SR7.S7.B1	true
8	CIB.SR7.S7.B2	true
9	CIB.USC55.L5…	true
10	CIB.UA87.R8.…	true
11	CIB.USC55.L5…	true
12	CIB.UA87.R8.…	true
13	CIB.US15.R1.B1	true
14	CIB.US15.R1.B2	true
15	CIB.UJ33.U3.B2	true
16	CIB.UJ33.U3.B1	true
17	CIB.UA63.L6.B2	true
18	CIB.UA63.L6.B1	true
19	CIB.SR3.S3.B2	true
20	CIB.SR8.INJ2.1	true
21	CIB.SR3.S3.B1	true
22	CIB.SR2.INJ1.1	true
23	CIB.UA67.R6.…	true
24	CIB.SR2.INJ1.2	true
25	CIB.UA67.R6.…	true
26	CIB.CCR.LHC.B1	true
27	CIB.UA47.R4.…	true
28	CIB.UA23.L2.B2	true
29	CIB.CCR.LHC.B2	true
30	CIB.UA47.R4.…	true
31	CIB.UA23.L2.B1	true
32	CIB.UA43.L4.B2	true
33	CIB.UA43.L4.B1	true
34	CIB.TZ76.U7.B2	true
35	CIB.TZ76.U7.B1	true
36	CIB.SR8.INJ2.2	true

Triggered BIS Inputs:

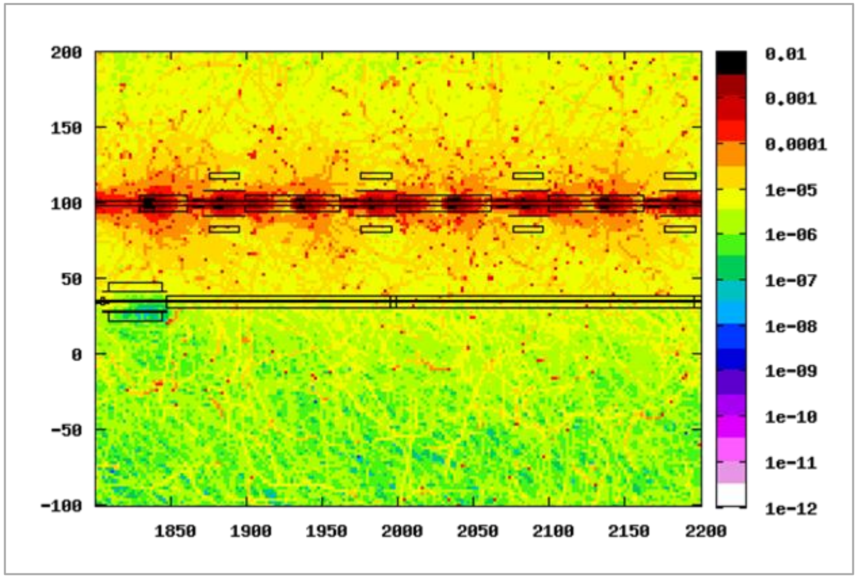
Ch 12-PIC_MSK(L1.B1),
Ch 5-PIC_UNM(L1.B1),
Ch 12-PIC_MSK(L1.B2),
Ch 5-PIC_UNM(L1.B2),
Ch 5-PIC_UNM(R1.B2),
Ch 5-PIC_UNM(R1.B1),
Ch 12-PIC_MSK(R1.B2),
Ch 12-PIC_MSK(R1.B1),
Ch 4-BLM_UNM(L6.B2),
Ch 4-BLM_UNM(L6.B1),
Ch 11-BLM_MSK(L6.B2),
Ch 11-BLM_MSK(L6.B1),
Ch 8-BPMs L&R syst.'A' (R6.B2),
Ch 8-BPMs L&R syst.'A' (R6.B1),
Ch 10-BPMs L&R syst.'B' (L6.B1)
Ch 10-BPMs L&R syst.'B' (L6.B2)
Ch 3-LBDS-b2(R6.B2),
Ch 3-LBDS-b1(L6.B1),
Ch 4-Vacuum b1b2(R1.B2),
Ch 4-Vacuum b1b2(R1.B1),
Ch 1-Vacuum b2(L1.B2),
Ch 1-Vacuum b1(L1.B1)

Finally some CLIC information

- "Severeness " of CLIC beams understood (see Michel's introductory talk)
- Present study concentrated on main linac tunnel…in particular the two beam acceleration module (TBM)
  (choice motivated by the availability of technical integration and developments of the TBM, …also the highest capital investment in the CLIC project
- Baseline choice: One Ionization chamber per MB and DB quadrupole
  (i.e. About 50000 BLMs…aarrrgh, LHC has "only" 4000)
- Pilot study to use Cherenkov radiation in fibres
- Pilot beam simulations in order to establish the signal levels in the two different detectors
- First glance at MB and DB crosstalk

Sensitivity Requirements

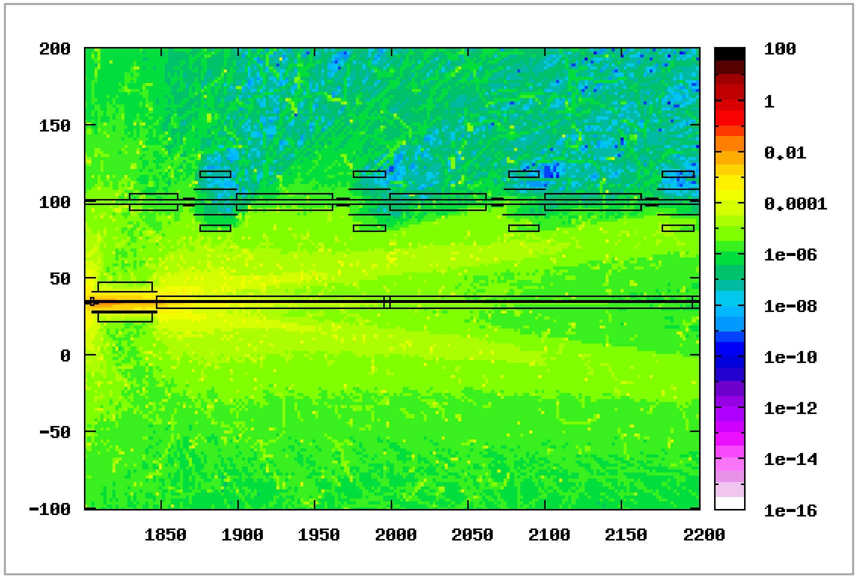
- *Standard Operational Losses (mainly due to beam gas scattering)*
- *FLUKA – losses are distributed longitudinally*
- ***Lower Limit of Dynamic Range**: 1% loss limit for beam dynamics requirements (to detect onset of such losses)*
  - *10^{-5} train distributed over MB linac, DB decelerator*



Example: Spatial distribution of absorbed dose for maximum operational losses distributed along aperture (DB 2.4 GeV) Scaling: 10^{-3} bunch train/875m

Destructive Losses

- *Detect onset of Dangerous losses*
- *FLUKA Loss at single aperture*
- ***Upper Limit of Dynamic Range,** 10% destructive loss (desirable)*
  - *0.1% DB bunch train, 0.001% bunch train MB*



Example: Spatial distribution of absorbed dose resulting from loss of 0.01% of 9 GeV Main Beam bunch train at a single aperture

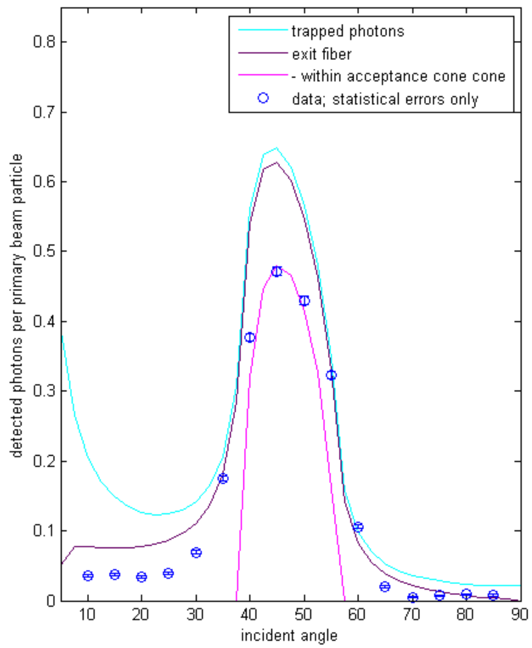
CDR Summary Table for BLMS

Machine Sub-Systems	Dynamic Range	Sensitivity (Gy/pulse)	Response time (ms)	Quantity	Recommended
Main Beam					
e^- and e^+ injector complex	10^4	10^{-7}	<8	85	
Pre-Damping and Damping Rings	10^4	10^{-9} (Gy per millisecond)	1	1396	Insensitive to Synch. Rad.
RTML	10^4	10^{-7}	<8	1500	
Main Linac	10^6	10^{-9}	<8	4196	Distinguish losses from DB
Beam Delivery System (energy spoiler + collimator)	10^6	10^{-3}	<8	4	
Beam Delivery System (betatron spoilers + absorbers)	10^5	10^{-3}	<8	32	
Beam Delivery System (except collimators)	$>10^5$	$<10^{-5}$	<8	588	
Spent Beam Line	10^6	10^{-7}	<8	56	
Drive Beam					
Injector complex	5.10^4	5.10^{-6}	<8	4000	
Decelerator	5.10^6	5.10^{-8}	<8	41484	Distinguish losses from MB
Dump lines	tbd	tbd	<8	48	

Cherenkov Fibers – Verification of Model

- *Verification of Analytical Model at test beam lines*
  - Test beams North Area, East Area
  - Fibers mounted on a rotable support, impacted by *120 GeV protons (North Area)*
  - *Angular Dependency*
  - *Diameter Dependency*

J. van Hoorne

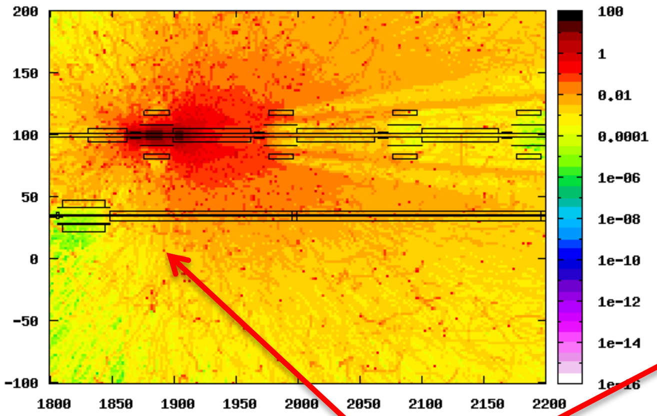


Results for the angular dependency of the photon yield in a fiber with:

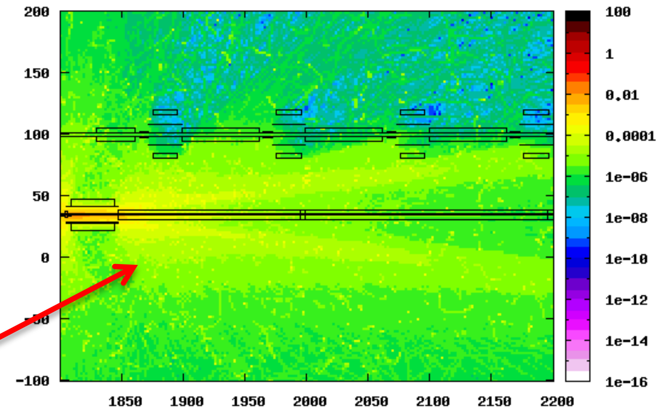
- d_{fiber}=0.365mm
- NA=0.22
- L_{fiber}~4m

- Desirable to distinguish between a failure loss from each of the beams
- Spatial Distribution of prompt Absorbed Dose (Gy) from FLUKA Simulations:

Destructive DB 1.0% of bunch train hits single aperture restriction



Destructive MB 0.01% of bunch train hits single aperture restriction



- Loss of 1.0% in DB provokes similar signal as a loss of 0.01% of MB in region close to MB quadrupole.
- NOT a Machine Protection Issue – **Dangerous loss would never go unnoticed**
- **Compare signals from both fibers each side to distinguish Main and Drive Beam losses.**

My comments:

- The main linac tunnel is “protectable”, any onset of dangerous losses in the DB or MB can be detected
- The required dynamic range looks very high; it should be better understood if this is required on a single pulse basis, or by integration, or if a limited dynamic range is possible for different machine operations:
  single bunch, DB only
- Like for the LHC I consider the diagnostics potential of the BLM system equally important to the basic MP function:
  i.e. Resolution in “s” down to each quadrupole (DB = 1m)
  Almost full diagnostics potential must be available on operational beams

Crosstalk MB<->DB for me is the major concern

Summary:

1) Fail-Save, Highly Reliability, High Availability Engineering is a specific engineering discipline, which needs

- highly skilled and specifically trained people
- Lots of them
- has to be conveyed from the presently running high energy machines to the new ones
- the teams need to be involved very early in the beam dynamics considerations and into the diagnostic needs of the machine

-2) The MP systems are complex and distributed...also very expensive.
2..5% of the total accelerator cost have to be accepted by managers

-3) The link to beam diagnostics and machine operation is essential:
High quality beam instrumentation
(Quote Lyn Evans: "Never economize on beam instrumentation",
best use of instruments by operations teams and an effort to analyze the acquired data and do the follow up is the basis for good machine protection.