CERN

System’s Performances in BI

Volker Schramm on behalf of the BI group

Special thanks to:

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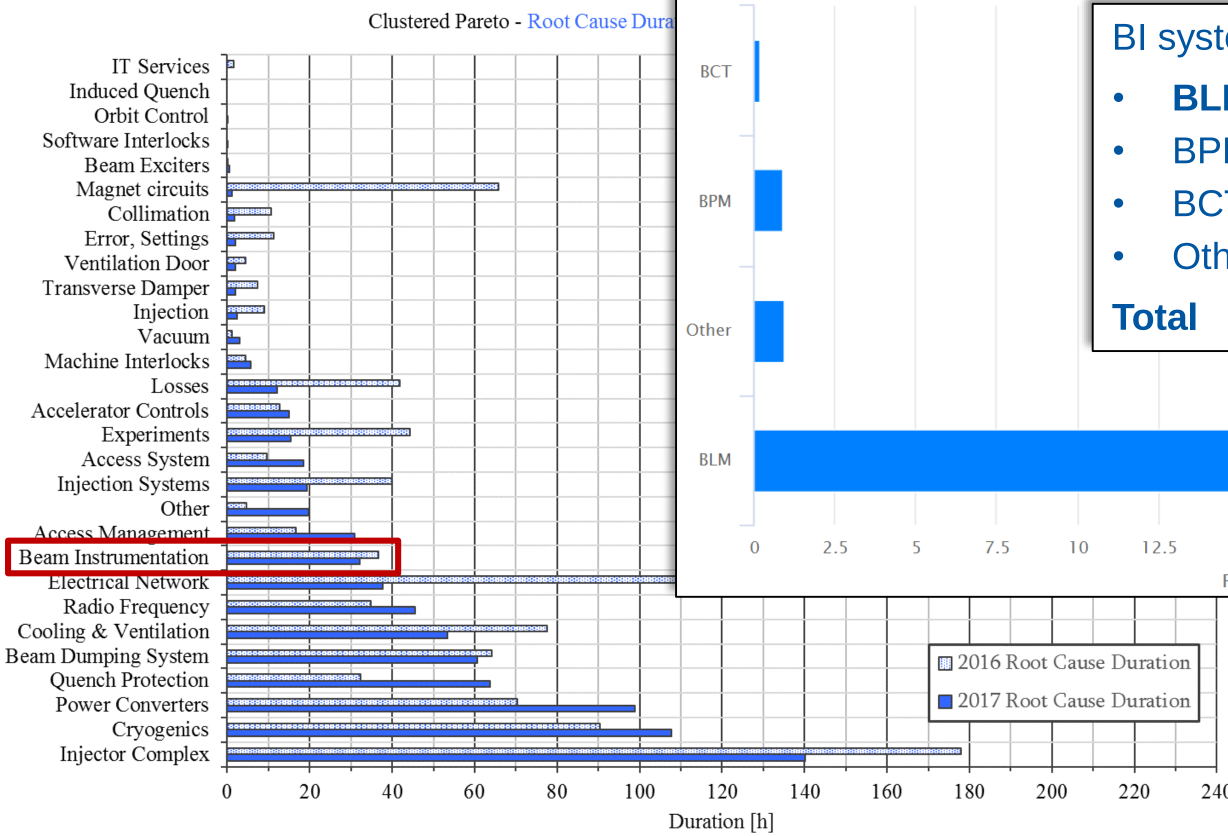
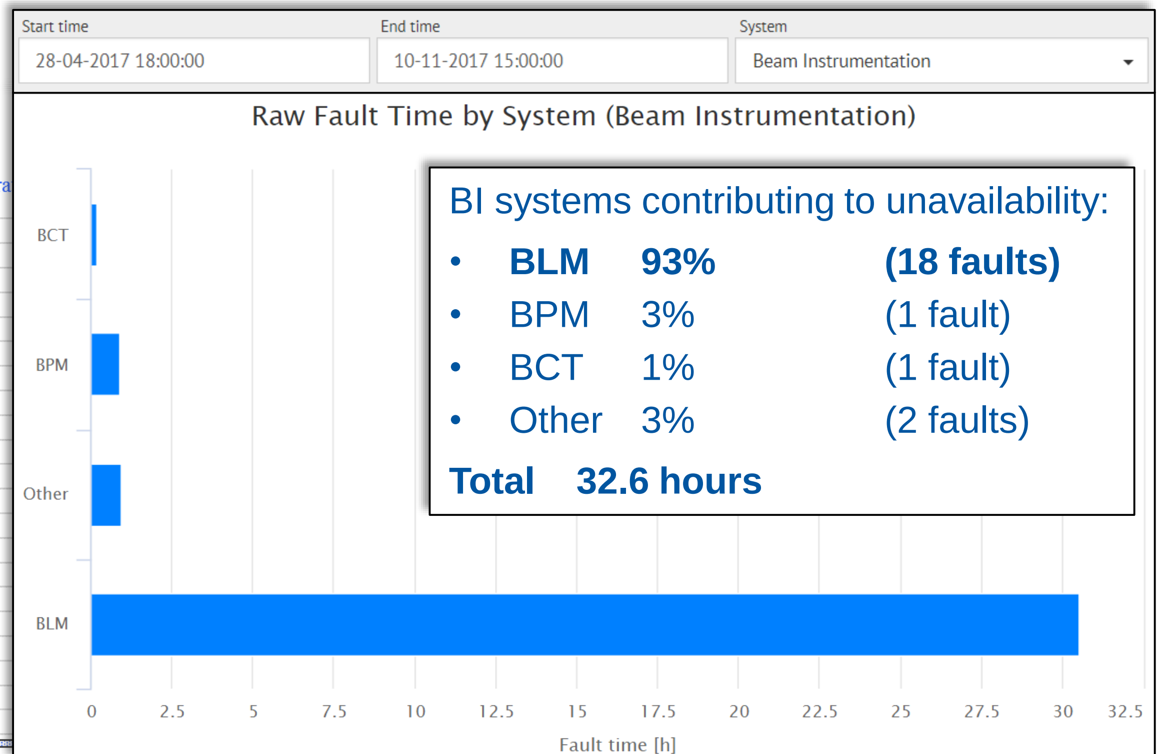
Agenda

- AFT statistics 2017 & previous years
- Upgrades 2017 - BCT, BPM, WS
- Faults analysis
- BI past and future efforts
- Conclusion

AFT statistics - 2017

Registered **22** BI faults in 2017 which account to **32h** LHC downtime





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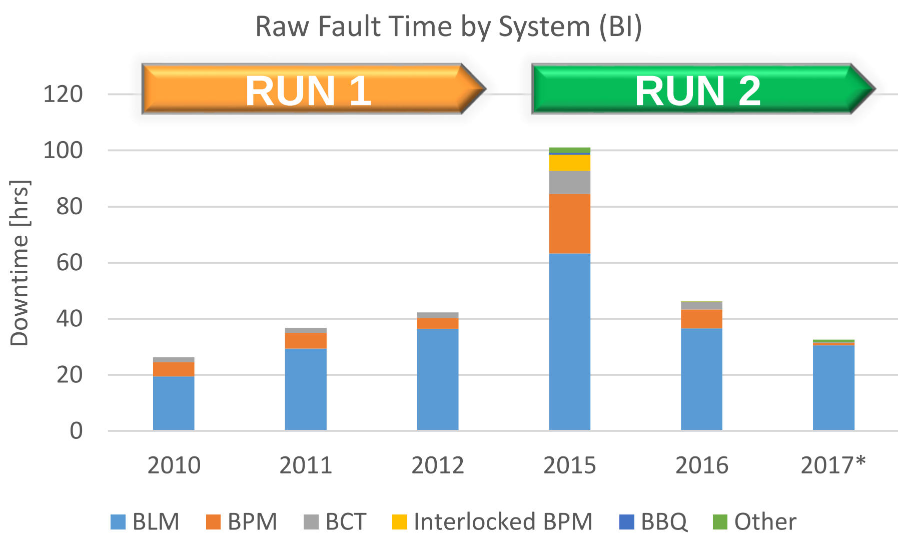
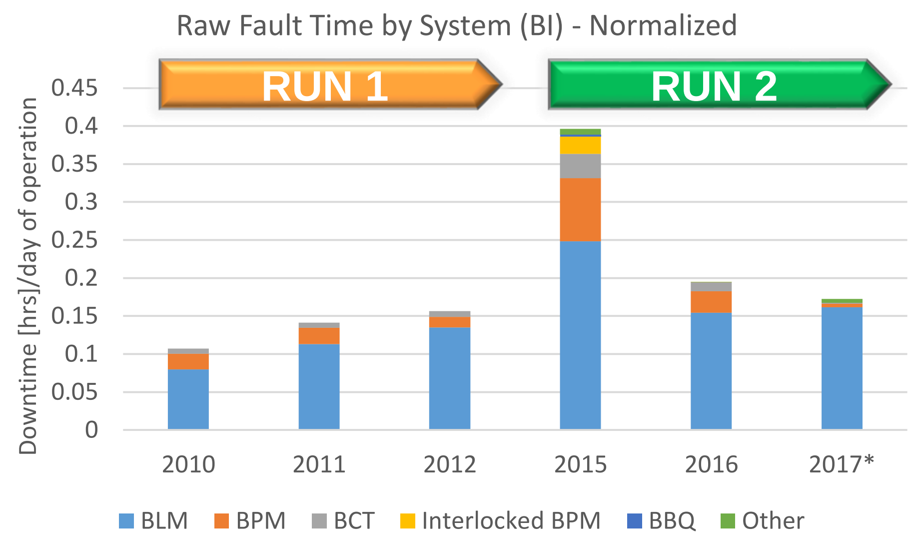
Courtesy B. Todd

AFT statistics – previous years





- BI availability increased for the 2nd year in a row (all systems!)
- 2017: Highest availability ever achieved for BPMs and BCTs
  - ➢ Strong positive trend since 2015 (consistent AFT recording since 2015)
- The BLM normalized downtime is almost constant during 2016 and 2017

Year	Days with fills
2010	245
2011	260
2012	270
2013	43
2014	0
2015	255
2016	237
2017	189*

Focus on the performance of the BLM

*2017: 28/04 – 10/11

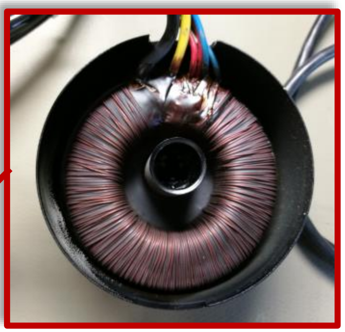
Upgrades 2017 – BCT, BPM, WS

- DCCT:
  → Software optimisation to eliminate issues with calibration & flickering of safe beam flag
  → System B front end electronic modification to reduce noise level by a factor of 3 (system A to be done YETS 17-18)
- FBCT:
  → New digital acquisition system with enhanced measurement precision which improves the instrument availability
- BPM:
  → Continuous analysis of "dancing BPMs" with interventions during TS to change front-end cards
  → New rack monitoring system put in place
- Wire Scanner:
  → Split of B1 & B2 electronics
  → Architecture change from LynxOS to Linux

Faults Analysis - BLM

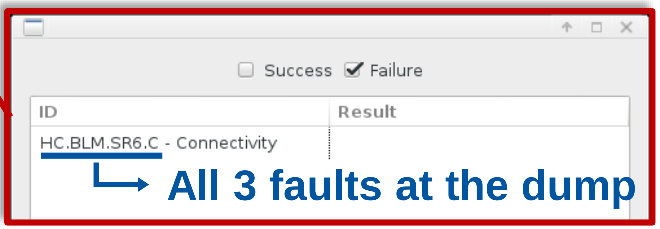
Detailed BLM faults in 2017:

Issue	2017			
	#	%	downtime	%
SEU (surface)	4	22%	04h 40m	15%
VME Power Supply Fail	1	6%	07h 47m	25%
Connection Lost: FESA/VME/CPU	1	6%	00h 04m	0%
HV Power Supply Drop				
HV Power Supply Noise				
Sanity Error: Communication/VME	4	22%	01h 23m	5%
Sanity Error: IC	1	6%	00h 29m	2%
Sanity Error: LIC				
Sanity Error: SEM	3	17%	13h 54m	46%
BLECF optical link issues	4	22%	02h 13m	7%
BLETC optical link issues				
Other optical link issues				
Other				
	18		1d 06h 32m	



Failed transformer

~50% Sanity Check related faults



Failed Connectivity Test

Faults Analysis - BLM

Detailed BLM faults of previous years: separate **AFT** & **BI-BL** accounting

- Throughout all years high number of Optical Link and Sanity Check related faults
- Own accounting helps to identify weak parts and to react earlier (e.g. Optical Link)

Issue	2012		2015		2016		2017	
	AFT*	Jira	AFT	Jira	AFT	Jira	AFT	Jira
SEU (surface)	3	3	2	3	1	1	4	3
VME Power Supply Fail	1	1					1	1
Connection Lost: FESA/VME/CPU	5	6	7	7	1	1	1	2
HV Power Supply Drop		4		1				1
HV Power Supply Noise			3	5	2	2		
Sanity Error: Communication/VME	3	9	6	20	2	3	4	6
Sanity Error: IC		3	1	5			1	3
Sanity Error: LIC		6		1				
Sanity Error: SEM	5	10	5	8	4	4	3	4
BLECF optical link issues	1	7				2	4	7
BLETC optical link issues	3	11	1	1	4	9		7
Other optical link issues	2	10		12				1
Other	2		2		2			
	25	70	27	63	16	22	18	35
	1d 12h 28m		2d 15h 16m		1d 12h 36m		1d 06h 32m	

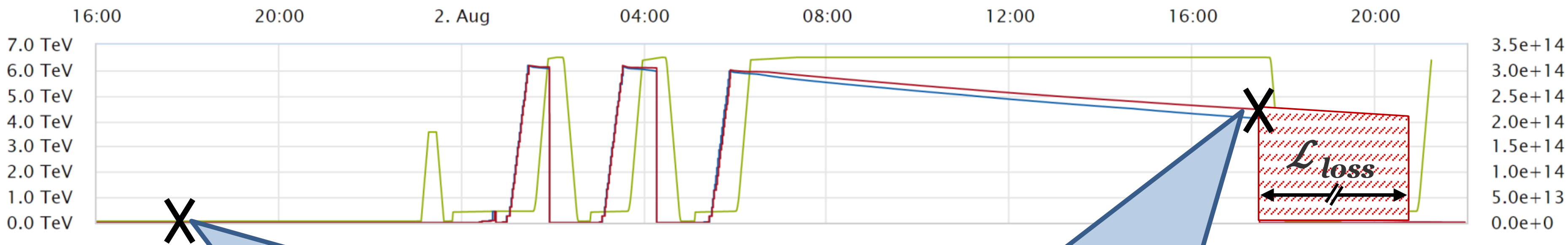
*No consistent AFT recording (Run1)

3 main fault cases:

- **Power supplies:**
  Constant low failure rate
- **SEMs (at the dump):**
  Constant high failure rate
- **Optical links:**
  Decreased, then in Run2 constant low failure rate

Faults Analysis – 1 example

2 BLM failures within 30 hours this August:



Failed Sanity Check
Accounted downtime: **5 h**

SIS interlock on HV status triggered
Accounted downtime: **4 min**

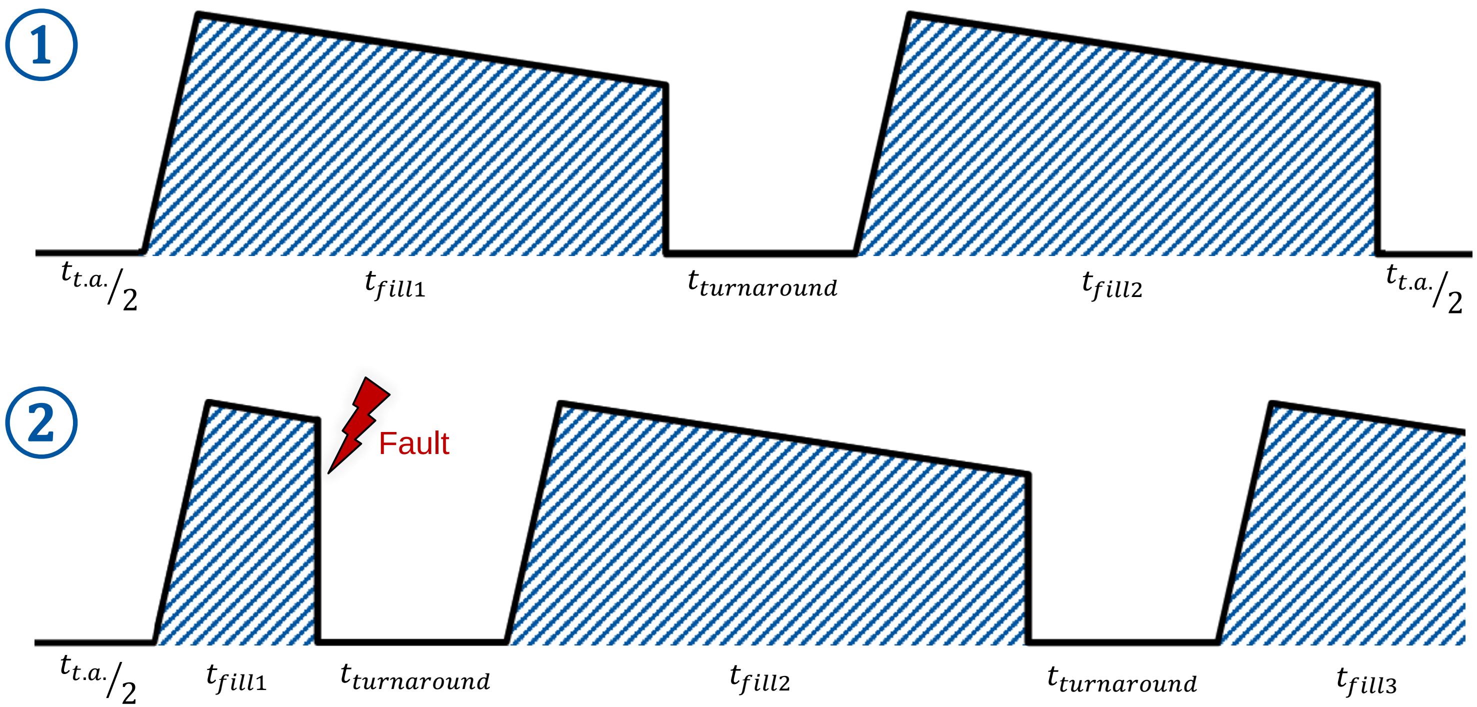
- System fault detected before it can lead to a dump (function fulfilled)
- $\mathcal{L}_{loss}$? → *'Equivalent to 5hours of scheduled operation'*

- Fault lead to unscheduled beam dump (false dump)
- $\mathcal{L}_{loss}$? → *'Equivalent to >>4min of scheduled operation'* ?

- **How to quantify the luminosity loss?**
- **How to scale availability and luminosity?**

Faults Analysis – 1 example

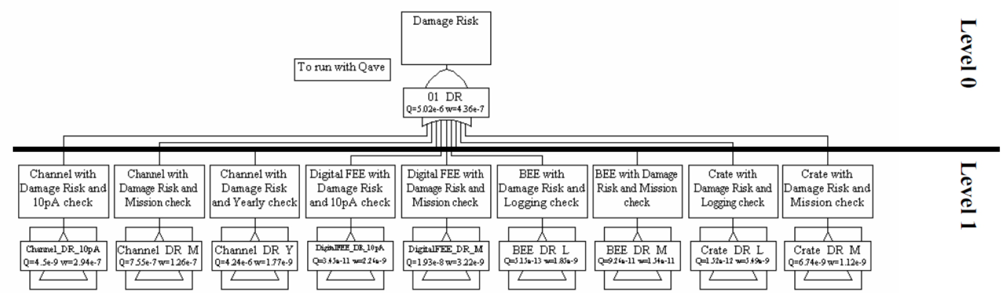
Example of two 12-hour fills as intended and the same scenario with a fault in the first fill:



By using intensities of a typical 12h13min fill at 6.5 TeV [03/09/2017,4:17am] as well as $t_{turnaround} = 6.2h$ the integrated area below the fills is **≥14%** bigger for the 1st scenario

Past Efforts – LHC BLM

2005
- ➢ Dependability analysis:
  - ○ Prediction
  - ○ FMECA
  - ○ FTA
  - ○ Sensitivity Analysis



Gianluca Guaglio, PhD thesis, 2005

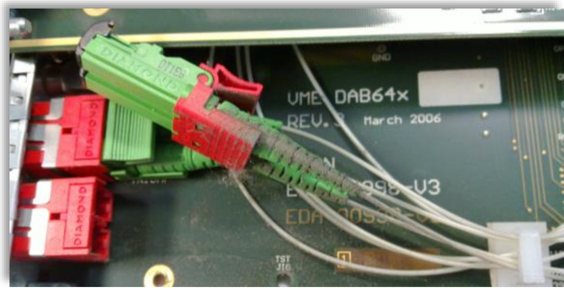
2008
- ➢ Redesign of the backend mezzanine

2012
- ➢ Preventive system fault analysis
  - ○ Daily automatic mails
- ➢ Jira failure logging

Optical link errors

Card	CF Ser		TC Ser	CS Ser	CRC_COMP		LK1 Err		LK2 Err		LK1 Lost		LK2 Lost		FID_COMP	
					A	B	A	B	A	B	A	B	A	B	A	B
2.L.1	0371	0328	16429131501618539521	17437937815547463425	0	0	0	0	0	0	42	0	0	0	0	0
3.R.14	0492	0488	10664523978582786561	16861477063165457409	0	0	0	0	0	0	0	0	0	1	0	0
4.L.6	0642	0591	10736581572621763841	14267403677825781249	1	0	1	0	0	0	0	0	0	0	0	0
7.C.5	0803	0682	9151314503787382017	7854277808467274753	0	0	0	0	0	0	0	0	1	0	0	0

2013 (LS1)
- ➢ 1st big maintenance intervention:
  - ○ Preventive exchanges: Cables, detectors, cards, fans
  - ○ Acquisition electronics modification & recalibration
  - ○ Clean-up: Optical adaptors, connectors
  - ○ Shuffle of optical links & firmware modification

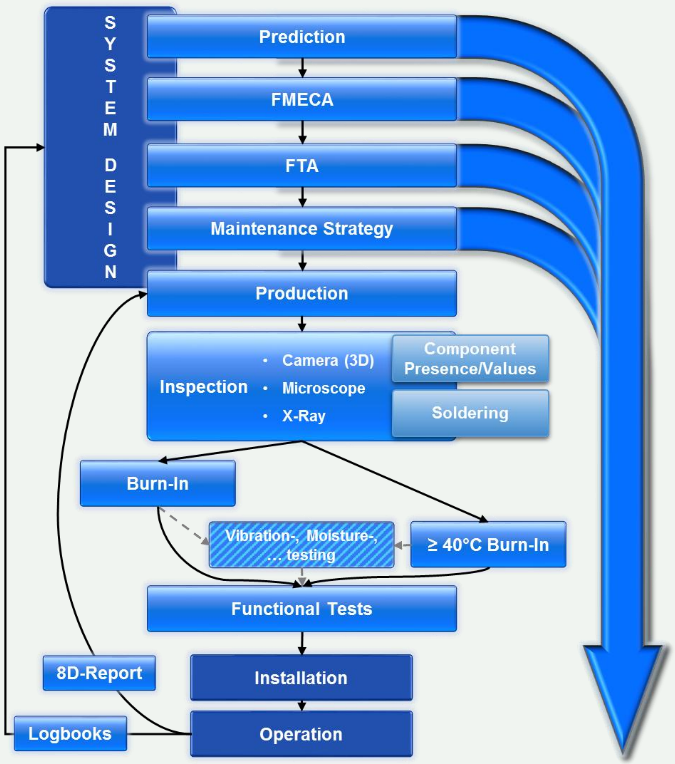


2017
- ➢ Dependability analysis update (PhD)

Future Efforts – LHC BLM

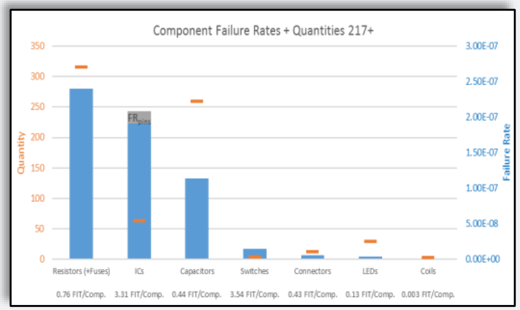
Ongoing PhD to study and improve the LHC BLM system. Results will also be projected to enhance the injector's upgrade and the new VFC processing card

Methodology for dependable PCB design, production, installation & operation



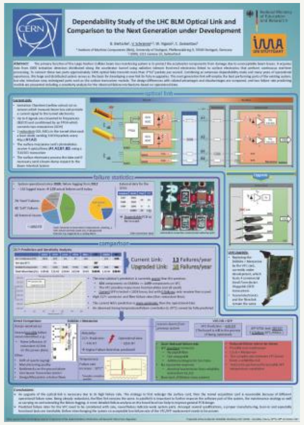
Dependability analysis update of the LHC BLM

- Reliability Prediction ✓
- FMECA + FTA (ongoing)
  - Assign system checks
- Failure analysis ✓



Failure analysis of the optical link
➔ Analysis of the new VFC card (ongoing)

- Optical link weaknesses identified ✓
- Improvements for the VFC suggested ✓
- Reliability prediction of the VFC ✓
- Definition of a testing strategy for the VFC (ongoing)



Presented at ARW, Versailles, Oct '17

Future Efforts – DAB64x upgrade

Post LS2 upgrade of the surface processing electronics. The DAB64x and mezzanine will be replaced by the new VFC:

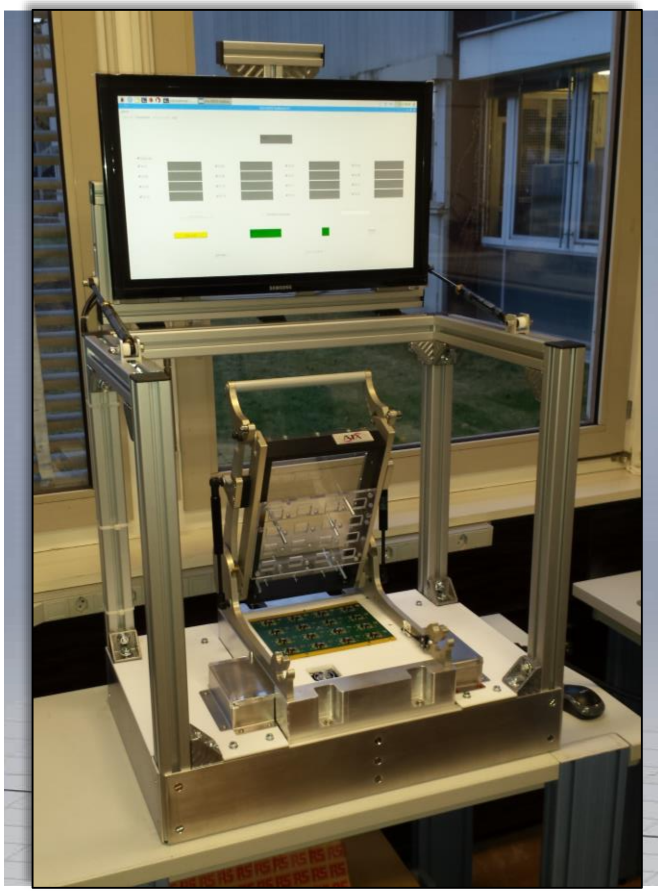
- Additional functionalities with an increased FPGA size
  - Possible to facilitate different processing
  - Improvement of the most critical part of the code using redundancies
- Mezzanine replacement by an SFP standard connector

Predicting the VFC performance:
- Higher number of components
- More functionalities
- Production quality

Demonstrate sufficient low failure rate!

Future Efforts – Testing

① Component tests



Reliability tester of VFC power supplies

② Functional tests

Functional tester VFC card

③ Burn-In/Reliability tests

Climatic chamber

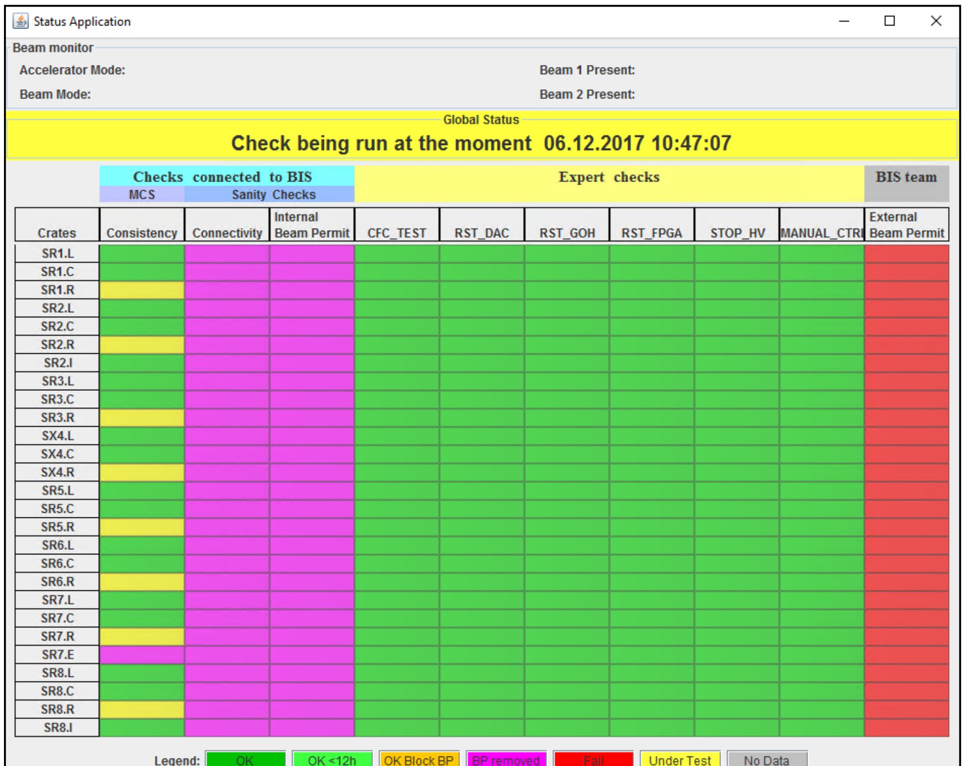
Model: BINDER MKF 240
Rapid temperature changes with humidity control

Temperature range: -40 °C to 180 °C
Humidity range: 10 % to 98 % RH

Future Efforts – Sanity Check

Optimising the Sanity Check sequence:

- Merge 5 sequence steps into 4 → **20%** time saving
- Enable to perform checks of only 1 group → Up to **75%** time saving
- Upgrades of the code in the long term



Checks sequence:

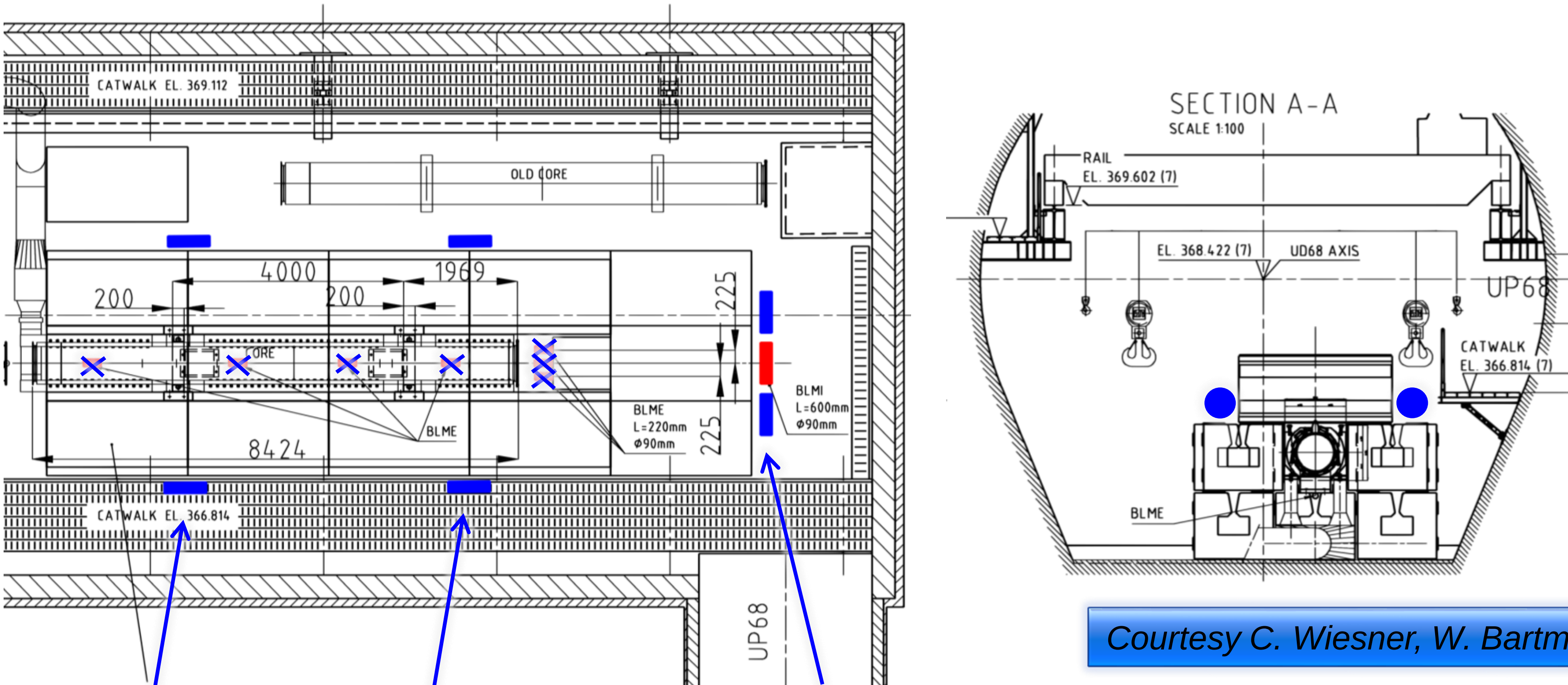
1. Each point center crate
2. Each point left crate
3. Each point right crate
4. Injection crate
5. Extra crate in point 7

→ **Merge steps 4 and 5**

Future Efforts – Dump Upgrade

6 new detectors to be installed outside of the dump for both dump regions:

- Exact positions have been defined with ABT
- Radiation tolerant cabling to be added locally



Courtesy C. Wiesner, W. Bartmann

2 BLM on each side (right/left)

2 additional BLM behind dump

Conclusion

- In 2017 a better availability was achieved than in previous years
  - Very strong performance of BCTs and BPMs
  - Future efforts need to focus on the BLM which contributed >90% of BI downtime
- Various measures are put in place:
  - Constant maintenance and exchange of less reliable systems
  - Preventive system fault analysis & failure logging
  - System upgrades which include:
    - Functional tests before installation
    - Component reliability testing
    - System burn-in/reliability testing
- To measure system performance both the availability and the luminosity impact of a fault needs to be considered

Thank you for your attention

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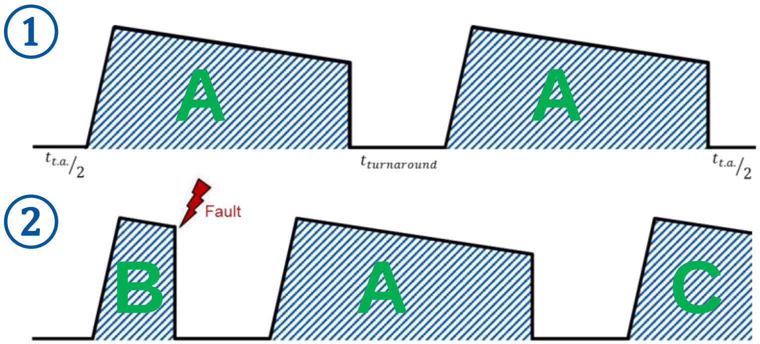
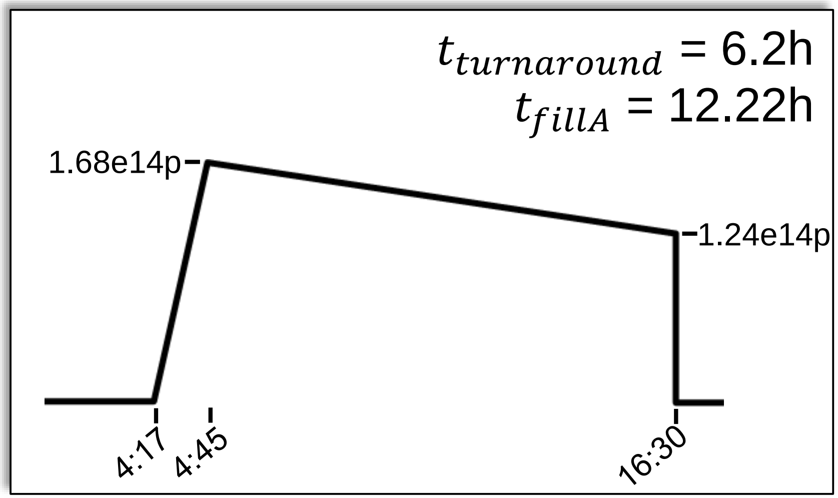
Backup



Calculation of the ~ 14% reduced luminosity:

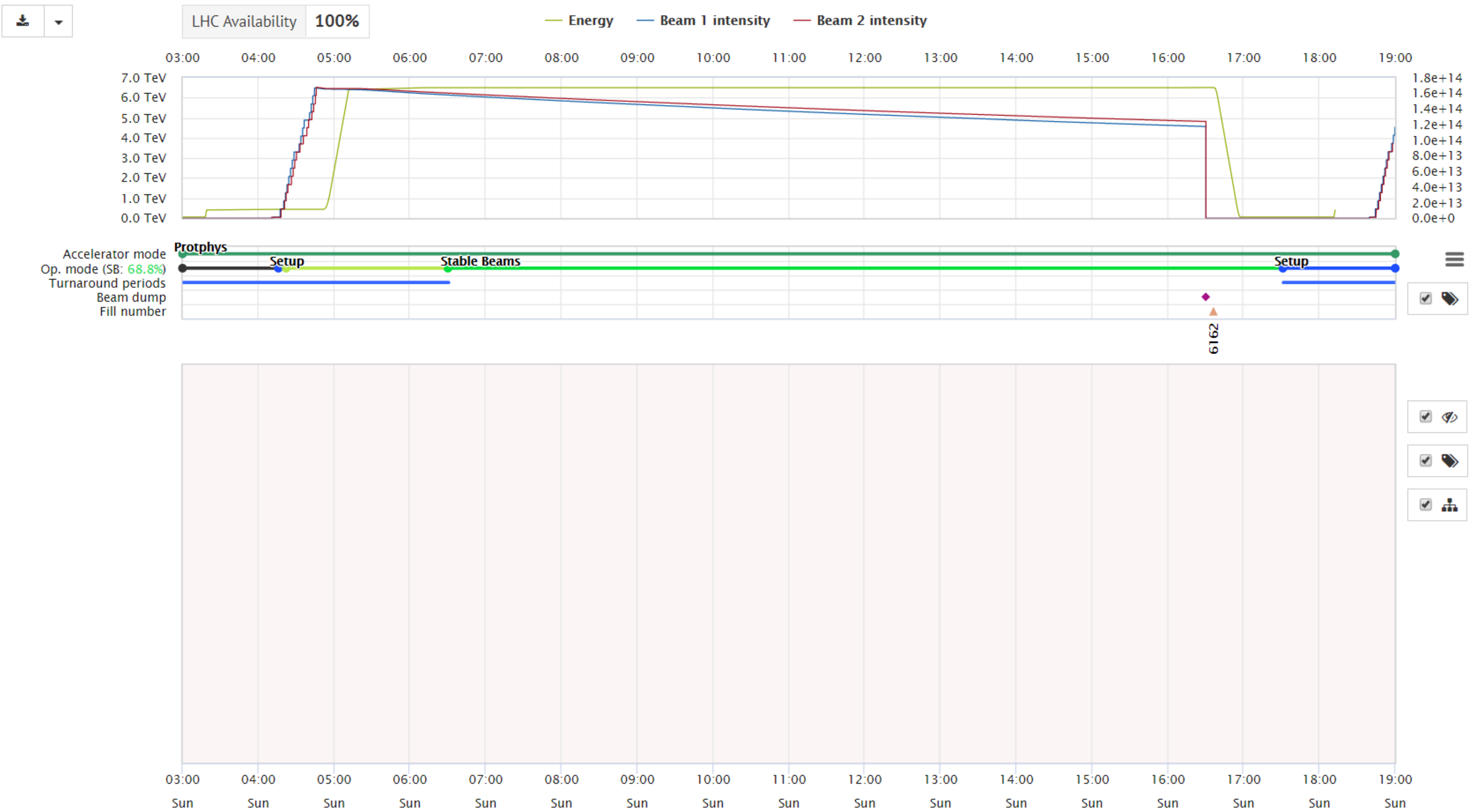
- $\mathcal{L}_{loss} = 2A - (A + B + C) = A - B - C$
- $t_{total} = 2 * 12h + 2 * 6.2h = 36.4h$
- $t_C = 36.6h - 12h - 2.5 * 6.2h - t_B$ → $t_B + t_C = 9.1h$ → Highest $\mathcal{L}$ for $t_B = t_C = 4.55h$
- $A = \frac{0.46h*1.68e14p}{2} + 11.75h * 1.24e14p + \frac{11.75h*0.44e14p}{2} = 17.55e14h * p$
- $B = C = \frac{0.46h*1.68e14p}{2} + 4.08h * 1.24e14p + \frac{4.08h*0.44e14p}{2} = 6.35e14h * p$
- ① $2A = 35.1e14$ ② $A + B + C = 30.24e14$

→ $"\mathcal{L}_{loss}" = \mathbf{4.85e14}$ $\approx$ **14%**



Backup

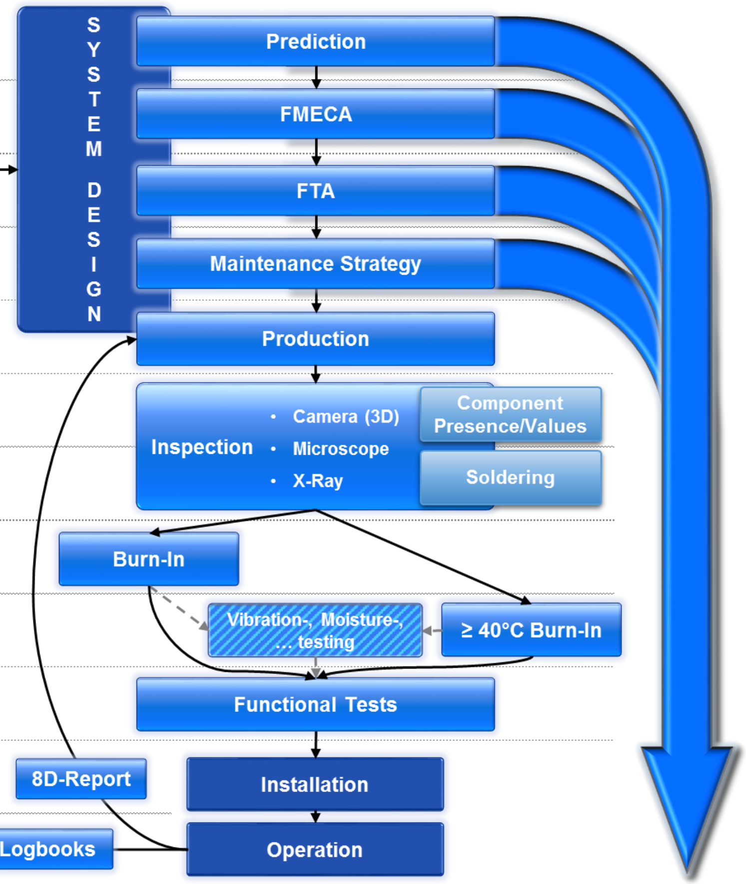
Example of a 12-hour fill at 6.5 eV:



Backup

Methodology PCB design:

#	Actions		Q_{ind}	Q_{tot}
1	FMECA performed/foreseen		0.4	0.5
		Additional FTA	0.1	
2	Maintenance strategy defined			0.2
3	Well-known manufacturer (CERN experience)			0.2
4	Inspection	Camera (3D)	0.2	0.4
		Microscope / X-Ray (BGA)	0.2	
5	Burn-In at operating temperature		0.5	1
		At ≥ 40°C	0.5	
6	Functional PCB Tests			0.2
7	Failure analysis of field returns by manufacturers			0.1
8	Failure/Repair logbook; Jira-Tracking			0.4
		Q_{SUM} (≤3)		3
		AdjustmentFactor A_Q ($0.25 \le A_Q \le 1$)		0.250



Backup

Dump Region with BLM:

Courtesy C. Wiesner, W. Bartmann