CERN

System’s Performances in BI

Volker Schramm on behalf of the BI group

Special thanks to:

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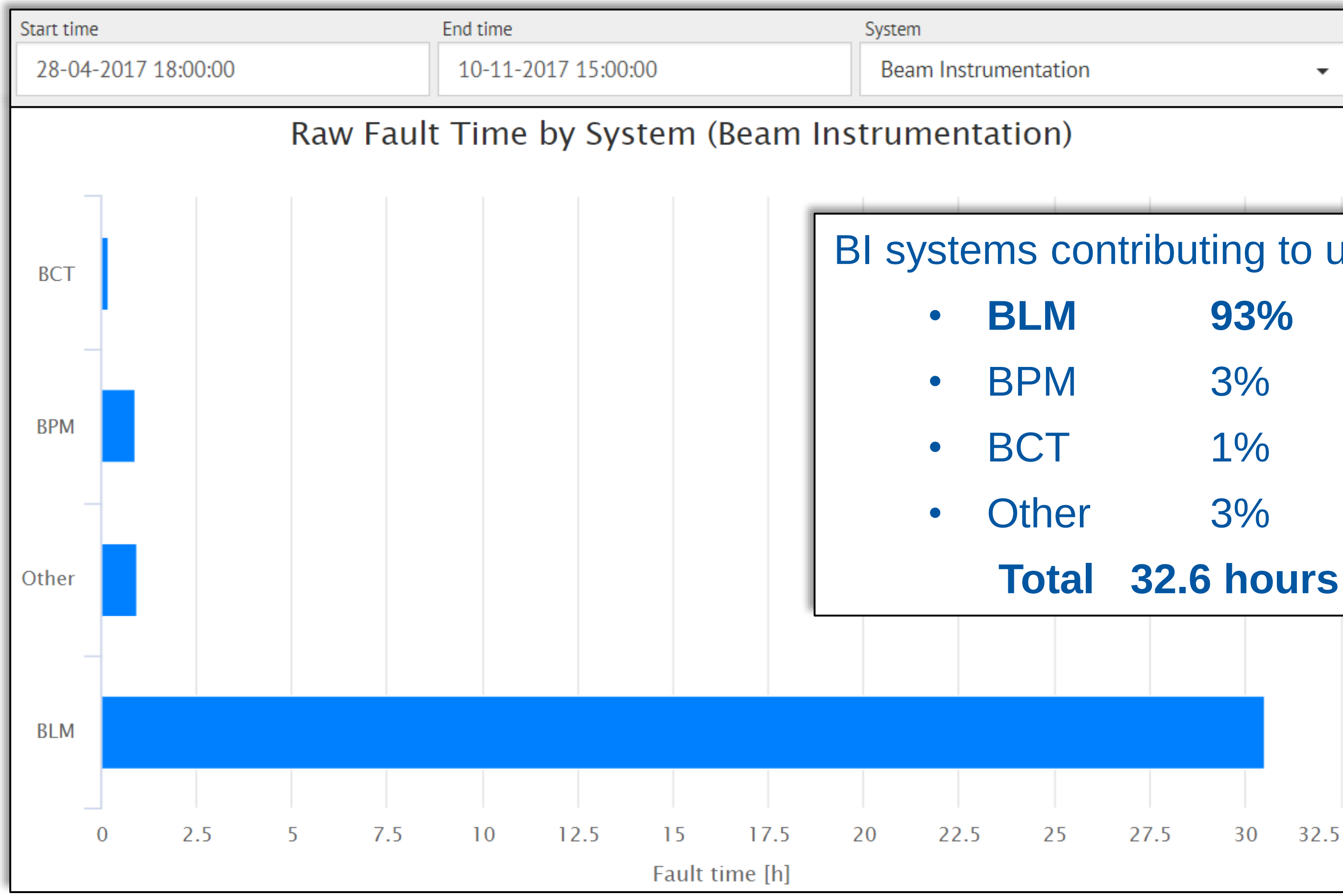
Agenda

- AFT statistics 2017 & previous years
- Faults analysis
- BI past and future efforts
- Conclusion

AFT statistics - 2017

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

The main unavailability contributor is the Beam Loss Monitoring system



BI systems contributing to unavailability:

- **BLM 93% (18 faults)**
- BPM 3% (1 fault)
- BCT 1% (1 fault)
- Other 3% (2 faults)

Total 32.6 hours

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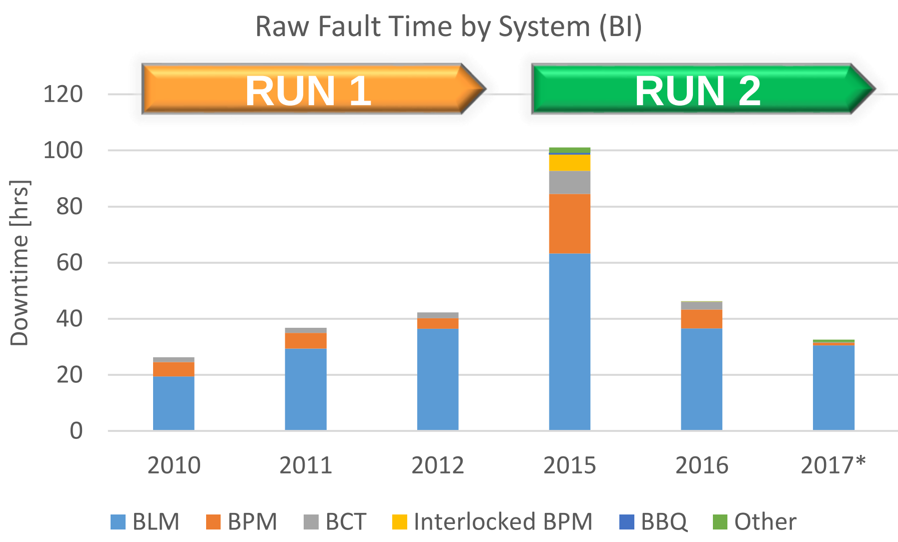
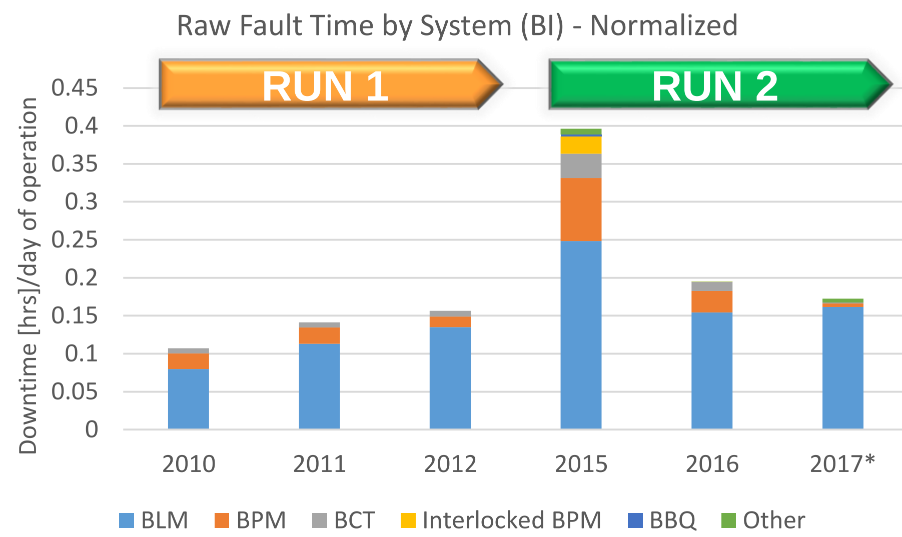
AFT statistics – previous years





- 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

➔ Focus on the performance of the BLM

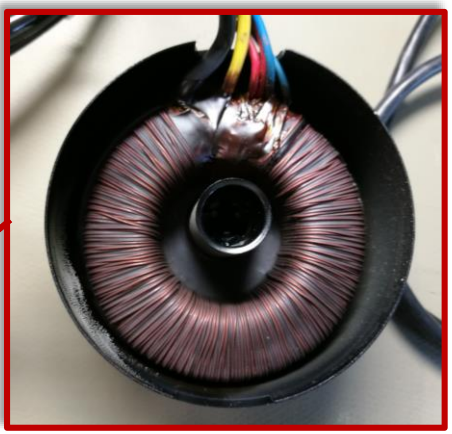
Year	Days with fills
2010	245
2011	260
2012	270
2013	43
2014	0
2015	255
2016	237
2017	189*

*2017: 28/04 – 10/11

Faults Analysis - BLM

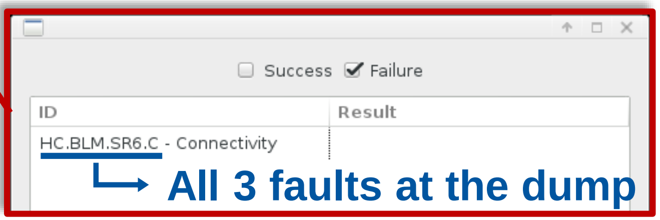
Detailed BLM faults in 2017:

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		1		4	
VME Power Supply Fail	1	1			1		1	
Connection Lost: FESA/VME/CPU	5	6	7		1		1	
HV Power Supply Drop		4						
HV Power Supply Noise			3		2			
Sanity Error: Communication/VME	3	9	6		2		4	
Sanity Error: IC		3	1				1	
Sanity Error: LIC		6						
Sanity Error: SEM	5	10	5		4		3	
BLECF optical link issues	1	7					4	
BLETC optical link issues	3	11	1		4			
Other optical link issues	2	10						
Other	2		2		1			
	25*	**70**	**27**		**16**		**18**	
	1d 12h 28m		2d 15h 16m		1d 12h 36m		1d 06h 32m	

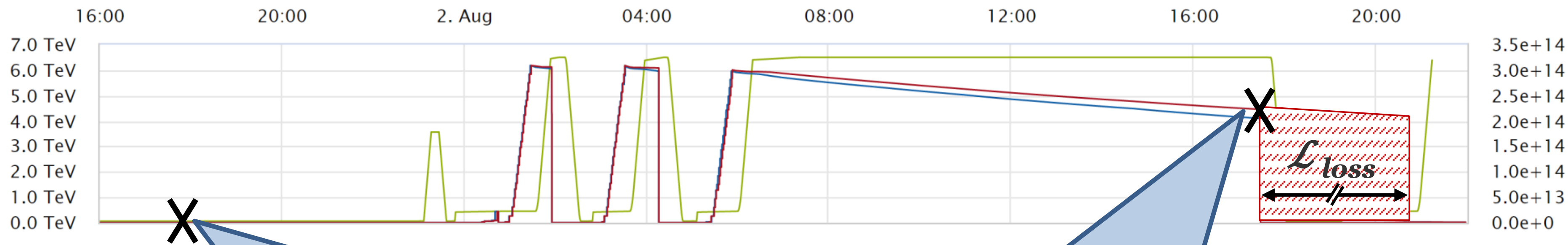
*No consistent AFT recording (Run1)

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**

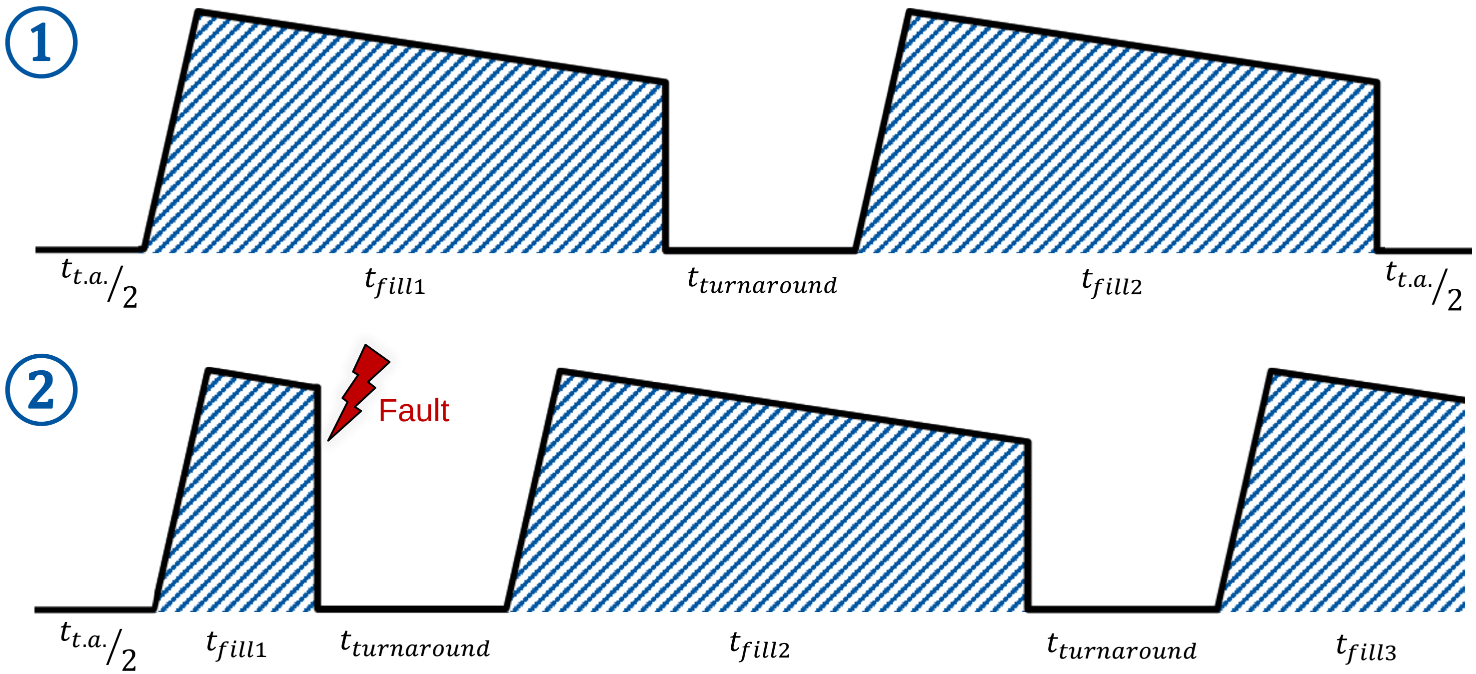
- System fault detected before it can lead to a dump (function fulfilled)
- $\mathcal{L}_{loss}$? → *'Equivalent to 5hours of scheduled operation'*

- 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:

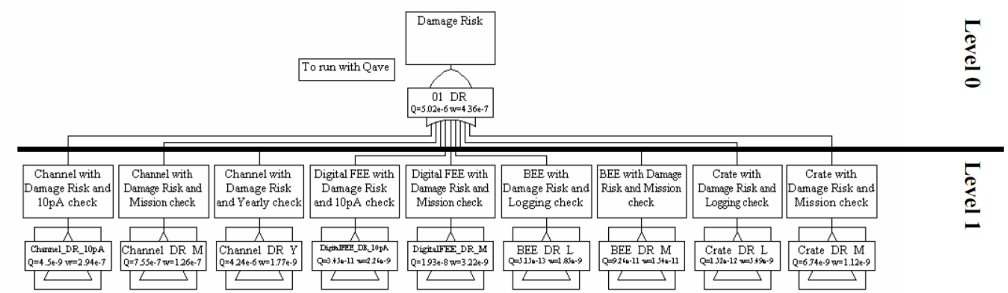


By using intensities of a typical 12h13min fill at 6.5 TeV [03/09/2017,4:17am] as well as $t_{turnaround} = 6.2h$ the integrated area below the fills is **≥14%** bigger for the 1st scenario

It is worth to invest in diagnostics and continuous system checks

Past Efforts – LHC BLM

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



Gianluca Guaglio, PhD thesis, 2005

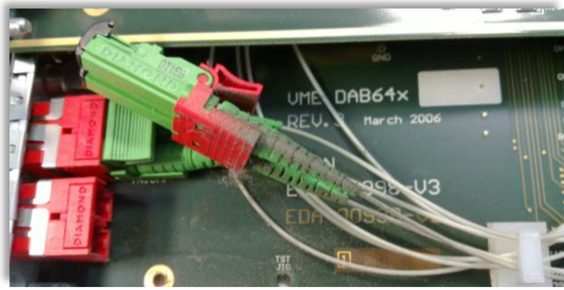
2008
- ➢ Redesign of the backend mezzanine

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

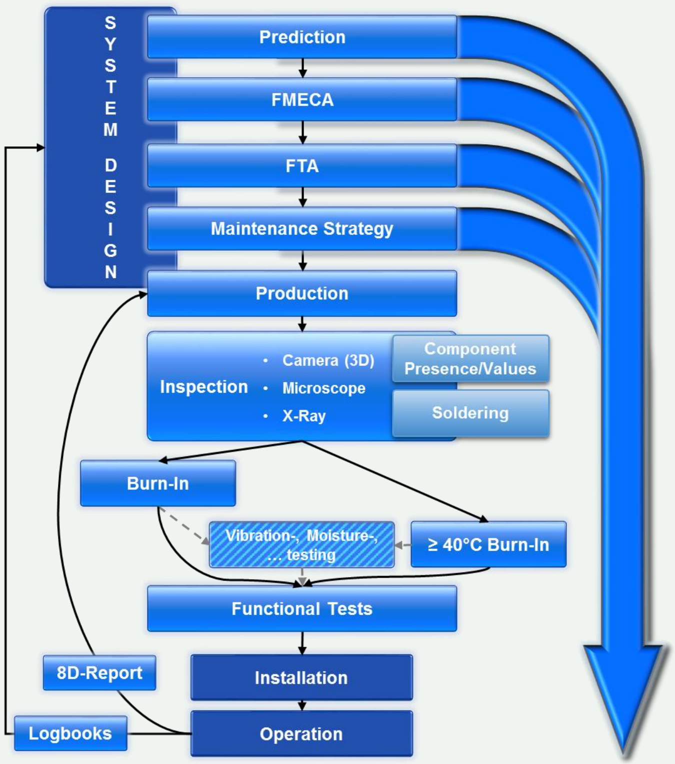


2017
- ➢ Dependability analysis update (PhD)

Past Efforts – LHC BLM

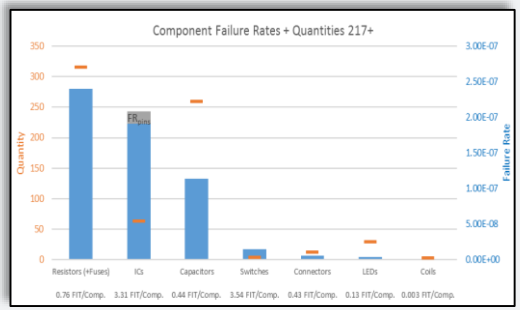
Ongoing PhD to study and improve the LHC BLM system. Results will be projected to enhance the injector's upgrade and the new VFC processing card:

Methodology for dependable PCB design, production, installation & operation



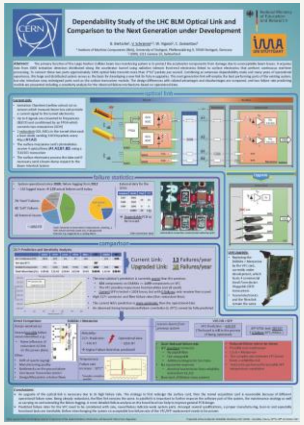
Dependability analysis update of the LHC BLM

- 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 – VFC upgrade

Installation of the VFC card to upgrade the surface processing card

- Eliminate system weaknesses
- Adding extra functionalities
- Testing and qualification prior to installation ! <u>Demonstrate low failure rate</u> !

VFC availability/reliability: - Higher number of components

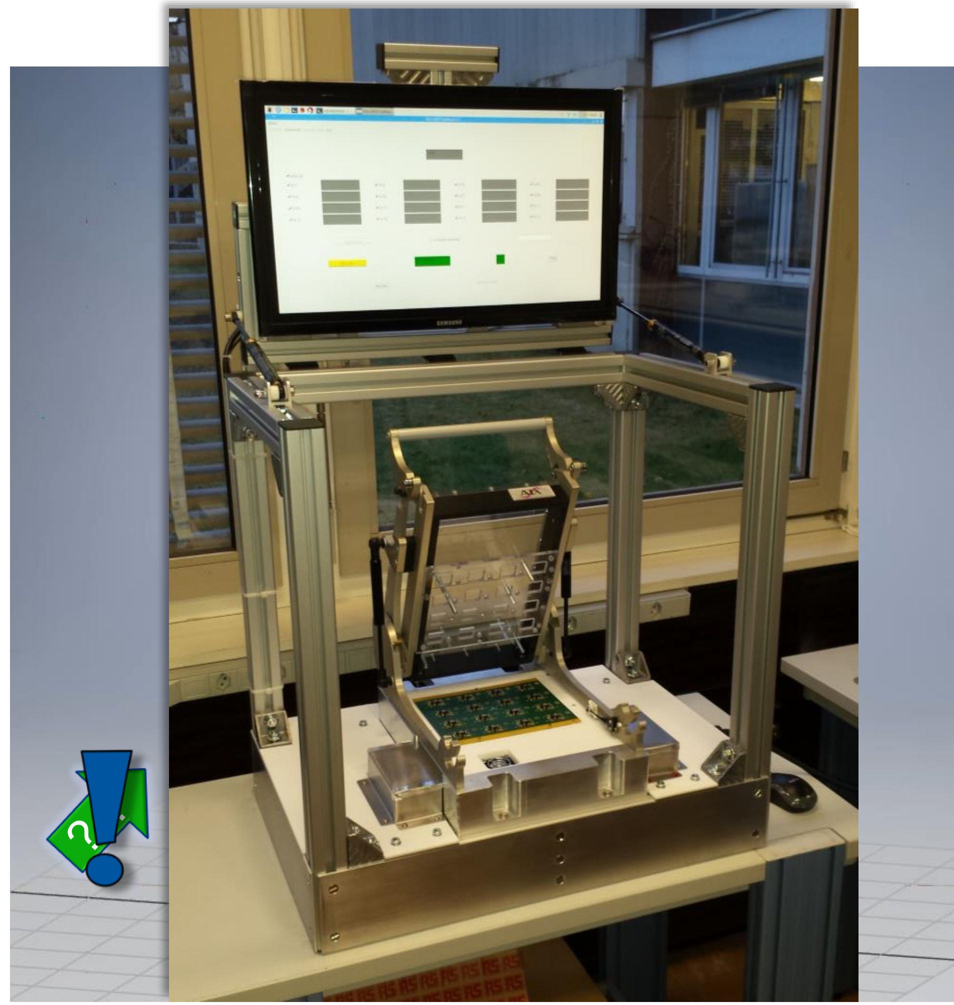
- More functionalities

- Better reliability

Future Efforts – Testing

Functional and reliability tests:

Functional tester for the VFC-HD card



Reliability tester of VFC power supplies

Future Efforts – Testing

W. Viganò

Climate chamber testing:

Dynamic climate chamber for rapid temperature changes with humidity control (BINDER MKF 240)

Temp.: -40 °C to 180 °C RH: 10 % to 98 %

Local PC equipped with APTCOM3 control software for remote control, temperature profiles definition and various settings.

Other available resources permanently installed at the climate chamber area:

- Working table
- Power sockets
- Optical fibers for all machine timings
- Ethernet hub
- USB hub

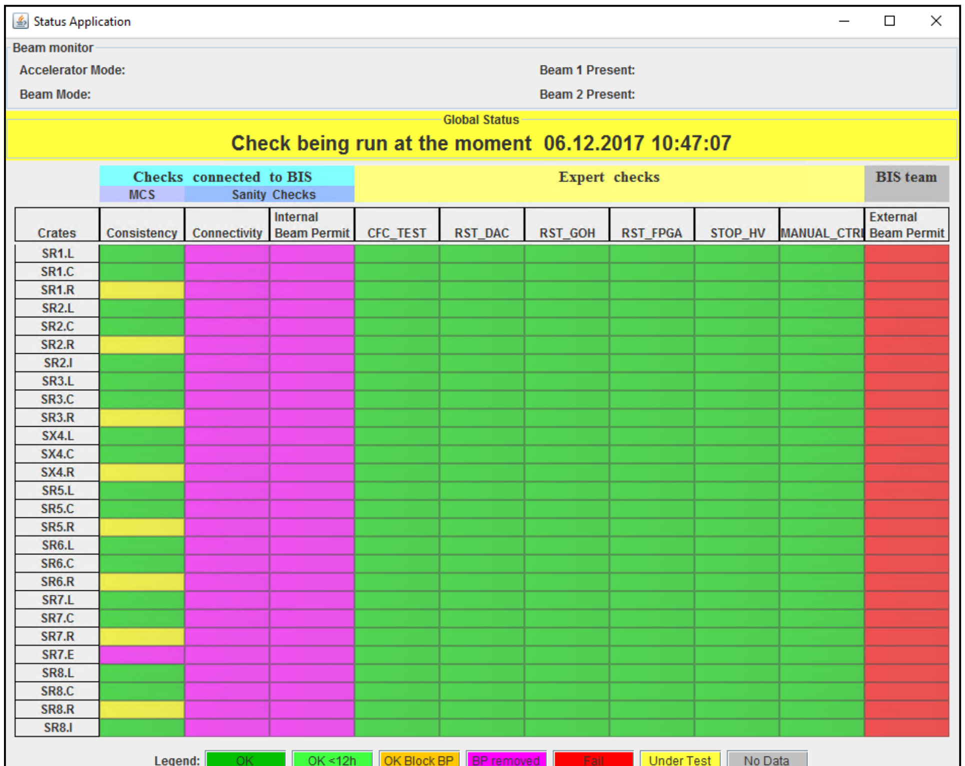
Optional resources

- PicoScope
- Function generator
- Others…

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:

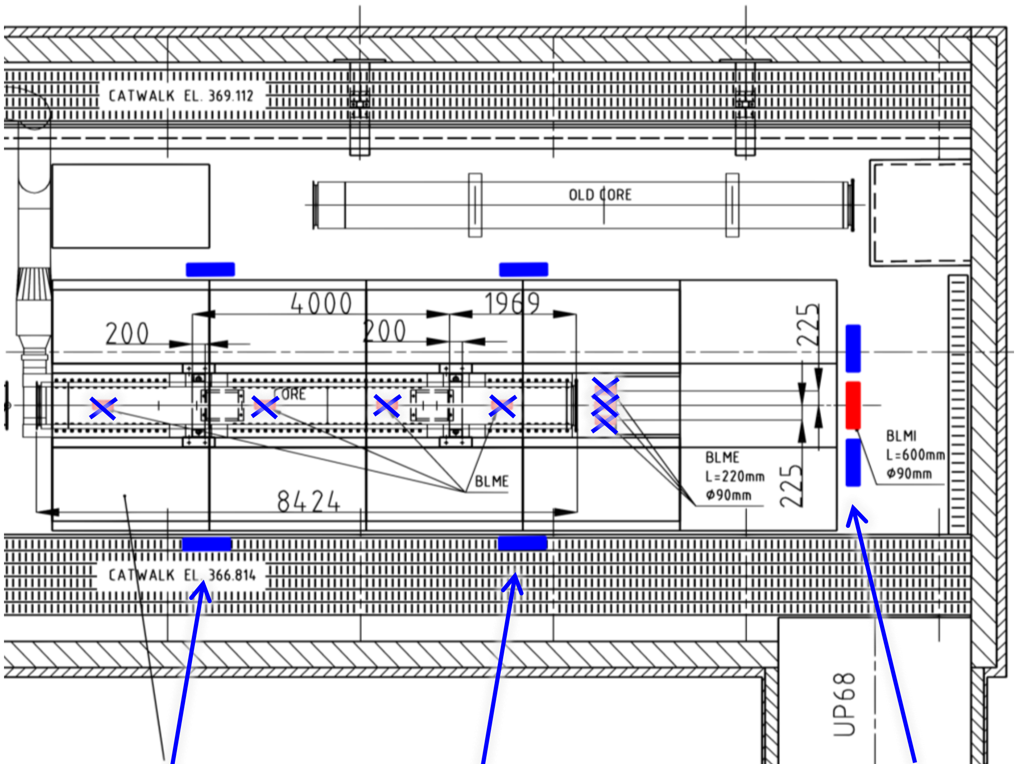
1. Each point center crate
2. Each point left crate
3. Each point right crate
4. Injection crate
5. Extra crate in point 7

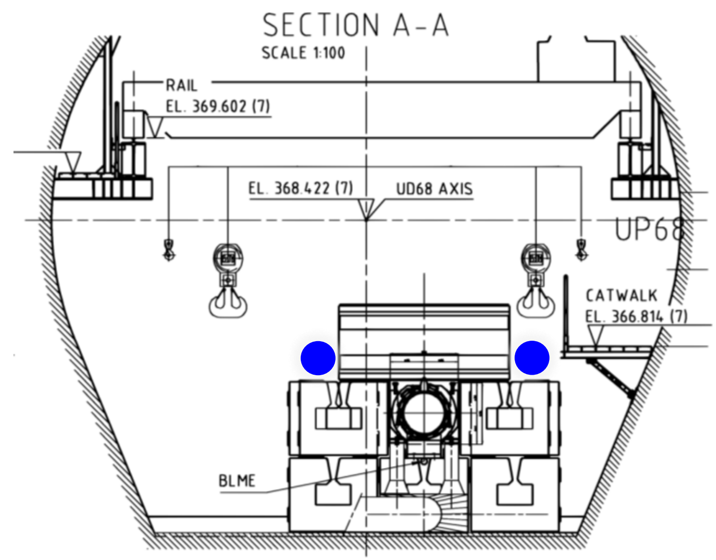
→ **Merge steps 4 and 5**

Future Efforts – Dump Upgrade

C. Wiesner
W. Bartmann

Proposal of 6 new BLM: LIC and/or IC with small filter (factor 20)





2 BLM on each side (right/left)

2 additional BLM behind dump

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

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
- Diagnostics and performing system checks can reduce availability **but** can in the same way increase luminosity

Thank you for your attention

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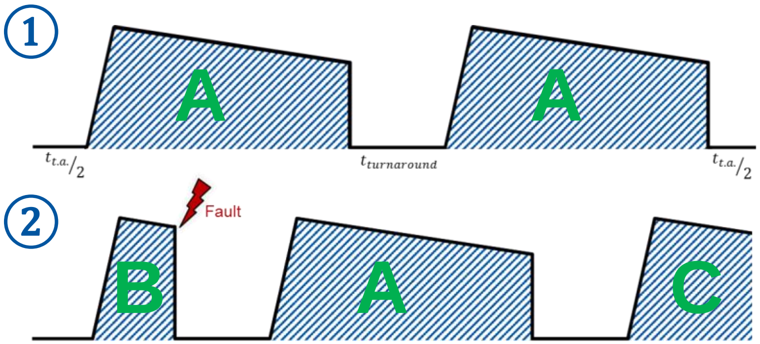
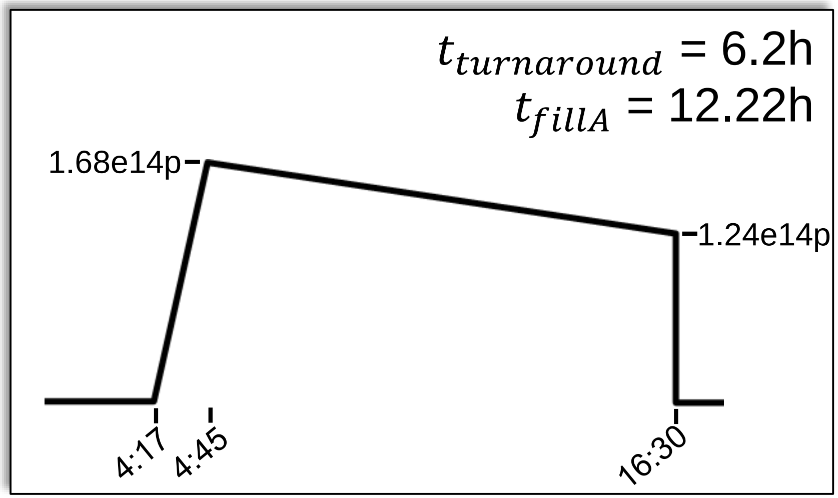
Backup



Calculation of the ~ 14% reduced luminosity:

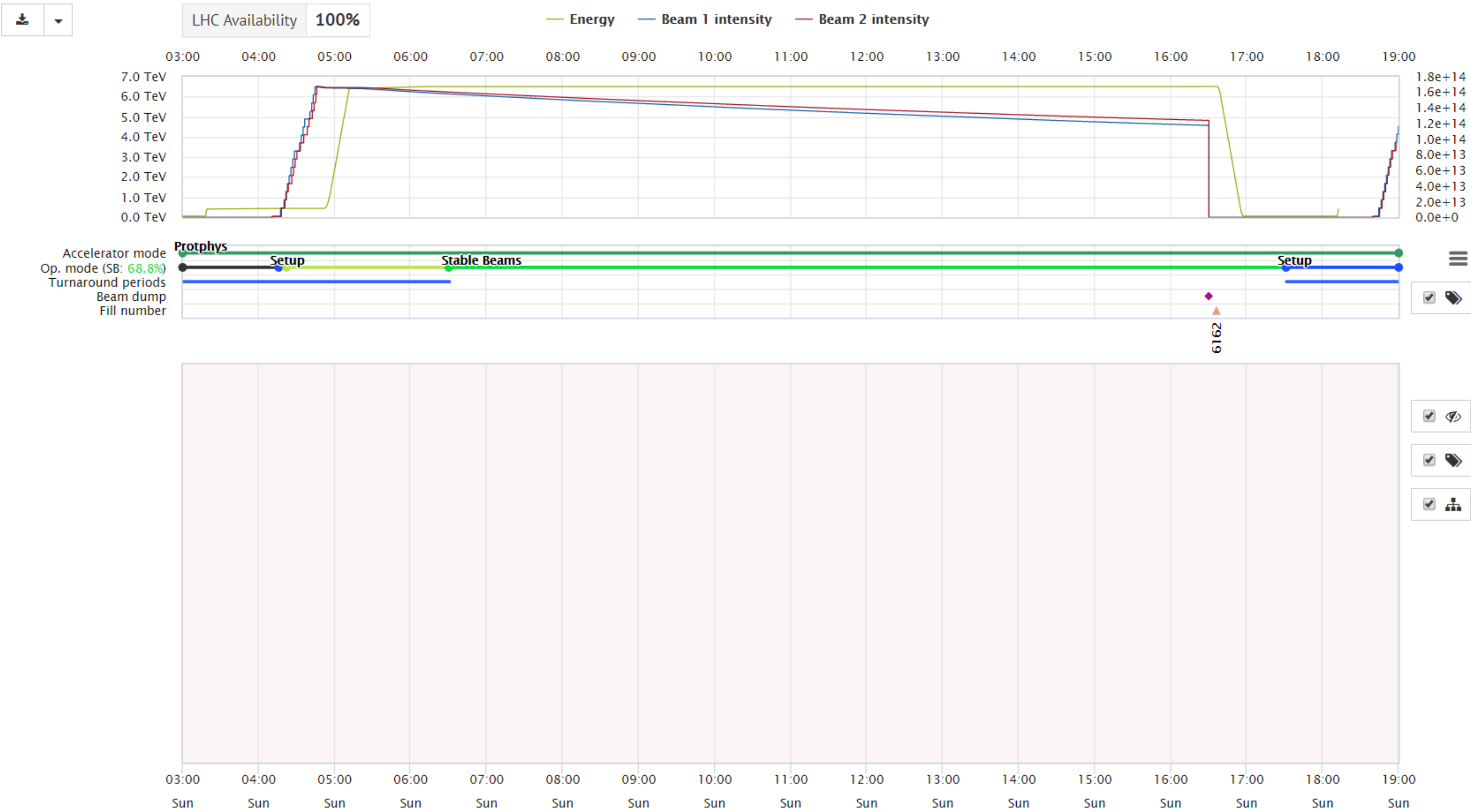
- $\mathcal{L}_{loss} = 2A - (A + B + C) = A - B - C$
- $t_{total} = 2 * 12h + 2 * 6.2h = 36.4h$
- $t_C = 36.6h - 12h - 2.5 * 6.2h - t_B$ → $t_B + t_C = 9.1h$ → Highest $\mathcal{L}$ for $t_B = t_C = 4.55h$
- $A = \frac{0.46h*1.68e14p}{2} + 11.75h * 1.24e14p + \frac{11.75h*0.44e14p}{2} = 17.55e14h *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

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



Backup

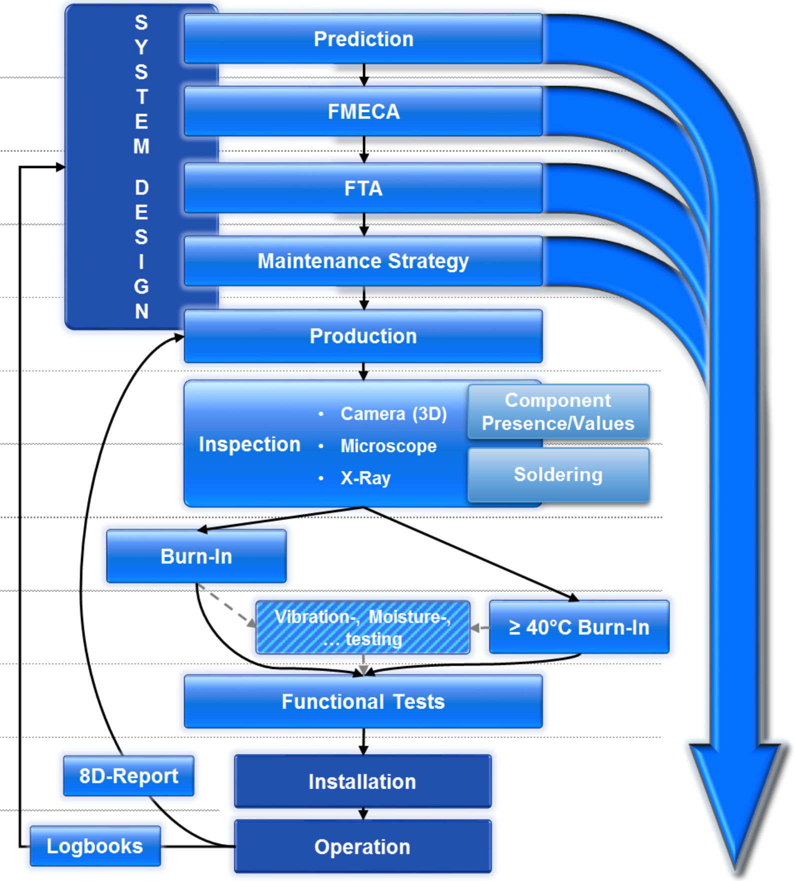
Example of a 12-hour fill at 6.5 eV:



Backup

Methodology PCB design:

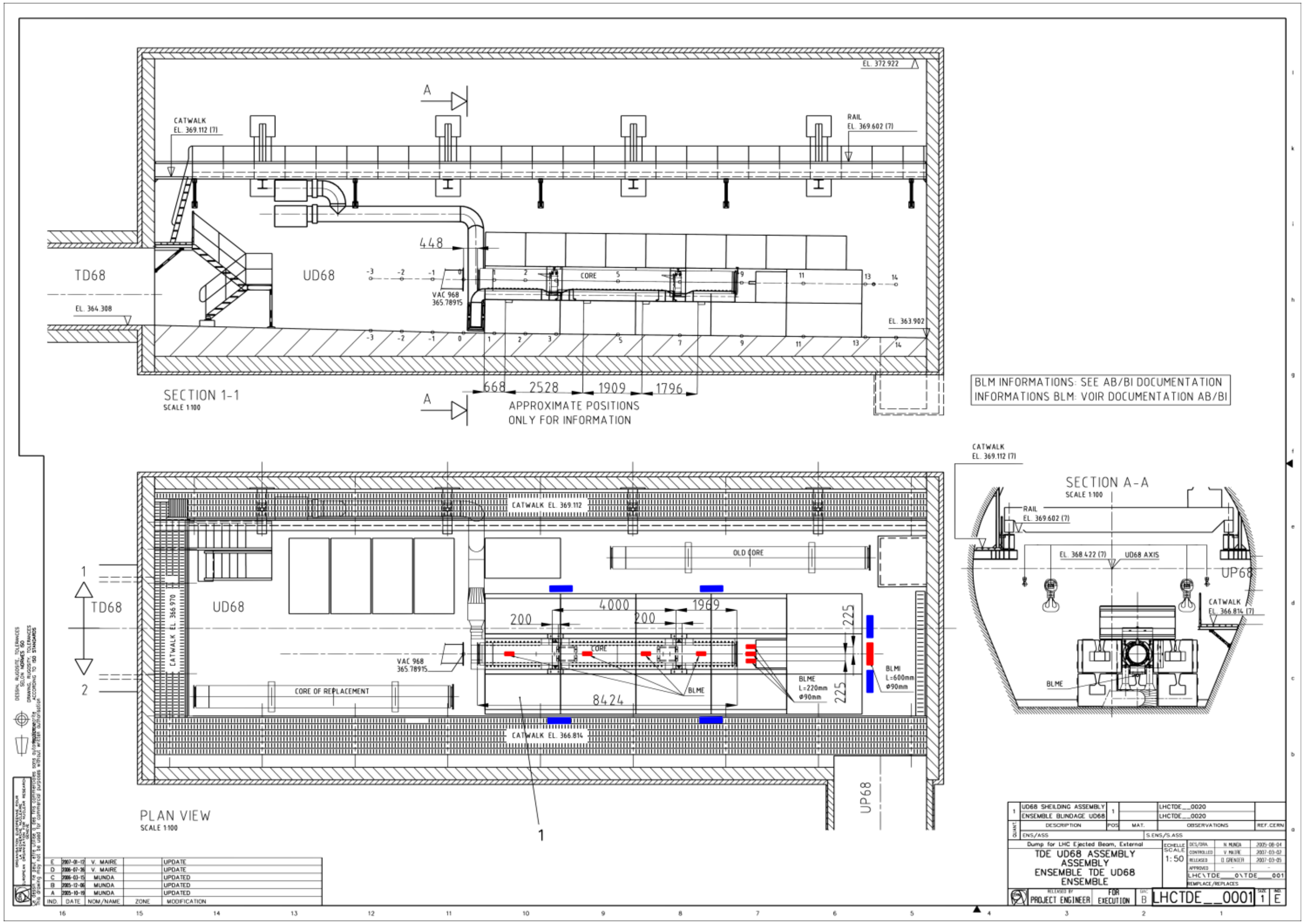
#	Actions		Q_{ind}	Q_{tot}
1	FMECA performed/foreseen		0.4	0.5
		Additional FTA	0.1	
2	Maintenance strategy defined			0.2
3	Well-known manufacturer (CERN experience)			0.2
4	Inspection	Camera (3D)	0.2	0.4
		Microscope / X-Ray (BGA)	0.2	
5	Burn-In at operating temperature		0.5	1
		At ≥ 40°C	0.5	
6	Functional 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:

C. Wiesner
W. Bartmann



Backup