




PSB radiation alarm during L4 LBE run: post-mortem analysis and actions

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Context

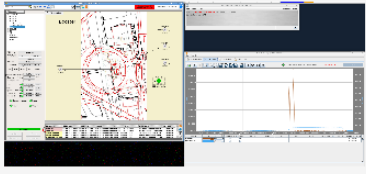
- On Friday 8th November, a radiation alarm in the PSB ring was triggered while sending beam to the LBE


08/11/2019 15:15 DAY LINAC 4  In4op@CWO-CCC-B0LC

Radiation Alarm from PAXB102 -> treshold overteken to 4500uSv/h.

Beam cut, the reson not yet found.

Beam To LBE destination removed from Supercycle until further notice.



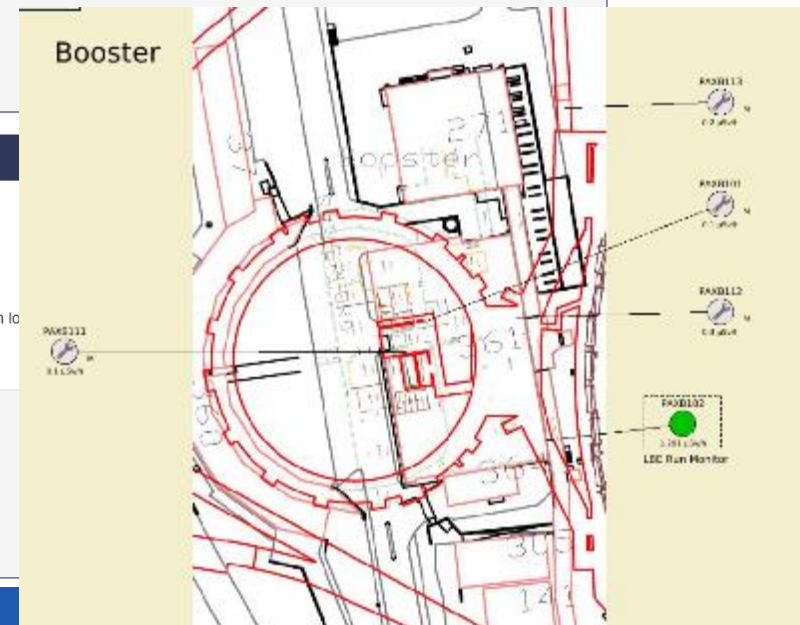
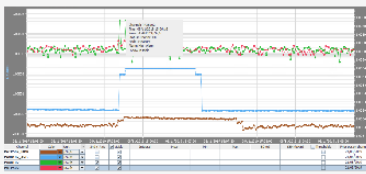
08/11/2019 15:20 DAY LINAC 4 

Message from Markus:

Losses on 2 cycles (8/11/2019 15:06:11 and 15:06:16)

- Increased level on PAXB102 (Booster side): about 1.46 and 1.48 uSv per pulse
- Increased level on PATP502 (PS gallery towards PS ring centre, SS25): lower levels, but consistent with lo

PSk

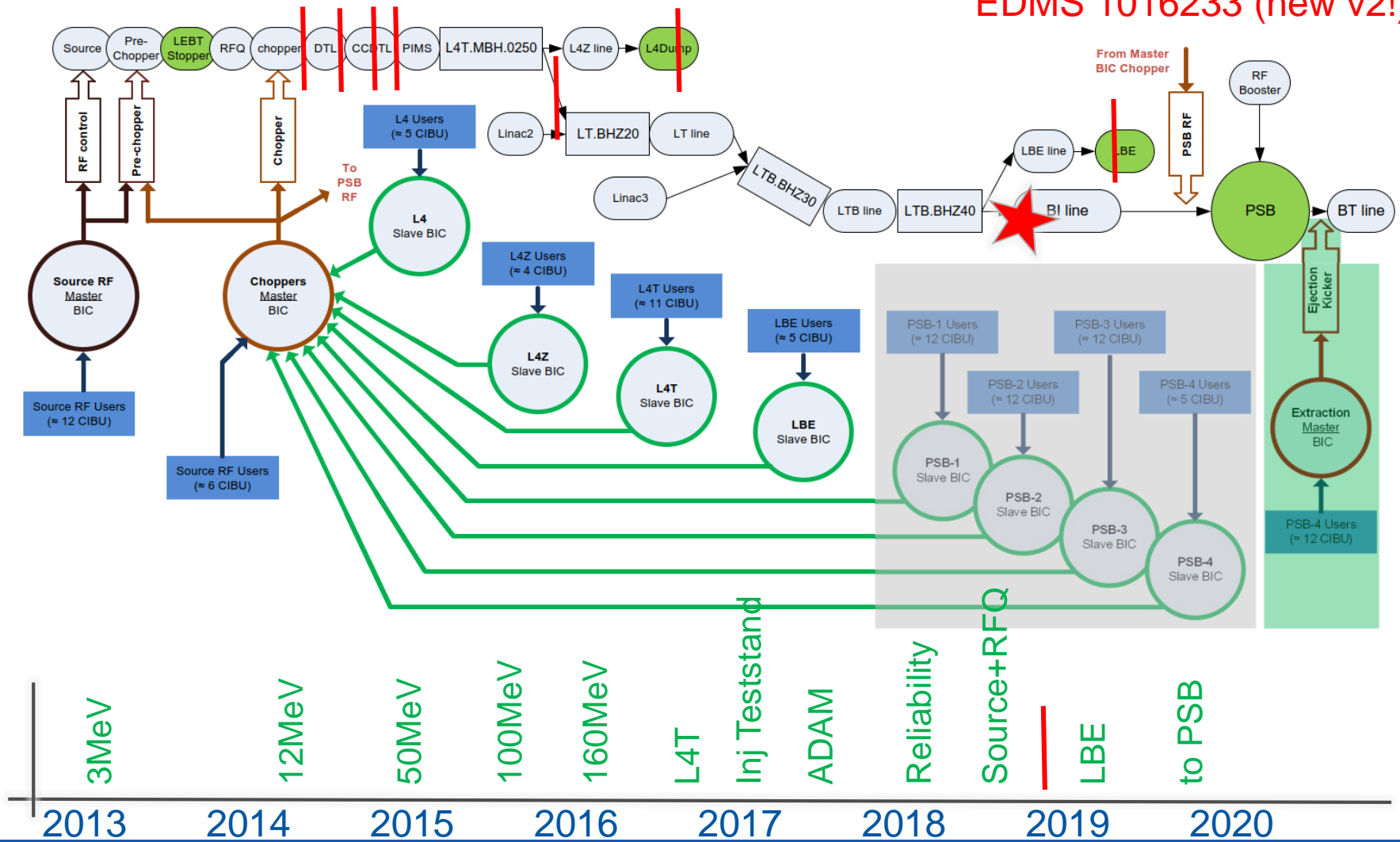


Questions triggered by event

1. What caused the initial beam loss?
 - Unplanned and unannounced intervention on LTB.RBHZ40 power converter...
2. Why was there a radiation alarm?
 - Calculations rechecked and an increase in concrete shielding implemented a few days later
3. Why was beam produced when the power converter was turned OFF?
 - Several factors examined in following slides

LINAC4 Machine Protection architecture

EDMS 1016233 (new v2!)



Event sequence

Key events from Friday 8th November:

15:06:07.222

LTB.BHZ40 to OFF

15:06:11.141

LBE settings, but BIS Beam Equation gives PERMIT for PSB -> **alarm 1**

15:06:15.941

LBE settings, but BIS Beam Equation gives PERMIT for PSB -> **alarm 2**

15:06:18.109

EPC interlock test = **WIC interlock** stops all PSB and LBE beams

15:06:39.336

LTB.BHZ40 to OFFLINE (FGC restarted) = **AQN always FALSE**

15:07:40.301

LTB.BHZ40 to OFF (FGC online) = AQN FALSE (need to resend settings)

Beam to PSB

15:06:11.141

LBE settings, but BIS Beam Equation gives PERMIT for PSB -> *alarm 1*

AQN LTB BHZ40_PSB	The corresponding USER_PERMIT is TRUE if the measured current is within the defined tolerance window corresponding to the destination PSB for H ⁻ . This magnet is also used to bend ions into LBE and LBS.	CHOPPERS (Master)
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LTB.BHZ40 settings correctly configured for LBE operation (I=-175A) and PSB operation (I=0A)

Examination of BIS matrix equations shows that it is possible to request LBE beam but send to PSB if both

{LTB.BHZ40 = 0A} AND {PSB rings 1-4 = OK}
(see next slide)

L4 Choppers Matrix

CIBX.400.LN4.CH - BIS Device Overview					
Cycle View BIC Overview History Buffer Matrix Equations Expert View CIBU Monitoring					
Inputs		1	2	3	4
0	SOFTWARE INPUT	TRUE	TRUE	TRUE	TRUE
1	Source BS Out/Mov CH	FALSE	TRUE	TRUE	TRUE
2	Source BS In CH	TRUE	FALSE	FALSE	FALSE
3	Linac4 OK		TRUE	TRUE	TRUE
4	AQN L4T.MBH_DUMP	Stopper IN		FALSE	FALSE
5	L4Z OK		TRUE		
6	AQN L4T.MBH_LT		FALSE	TRUE	TRUE
7	L4T OK		L4Z		TRUE
8	AQN LTB.BHZ40_LBE			TRUE	FALSE
9	LBE OK			TRUE	
10	AQN LTB.BHZ40_PSB			FALSE	TRUE
11	PSB1 OK				TRUE
12	PSB2 OK				TRUE
13	PSB3 OK				TRUE
14	PSB4 OK				TRUE
15	SAFE BEAM FLAG				

Following experience from alarm, action taken to ensure no PSB conditions can be true

- AQN BHZ40 and PSB Ring BICs forced FALSE

If LBE settings, but
 $\{LTB.BHZ40 = 0A\}$
 AND
 $\{PSB\ rings\ 1-4 = OK\}$
 then PSB = PERMIT

LBE

PSB

Actions taken

- Status on 8th Nov
 - BHZ40 PSB active when I=0A
 - All new PSB BICs connected to LINAC4, but inputs disabled
 - Hence PSB LOCAL PERMIT state is TRUE
- Status on 20th Nov
 - BHZ40 PSB forced to FALSE
 - SIS input forced to FALSE in FESA class
 - Hence PSB LOCAL PERMIT state is FALSE
- Definitive action (still to complete)
 - Remove disable jumper on 1 or more channels

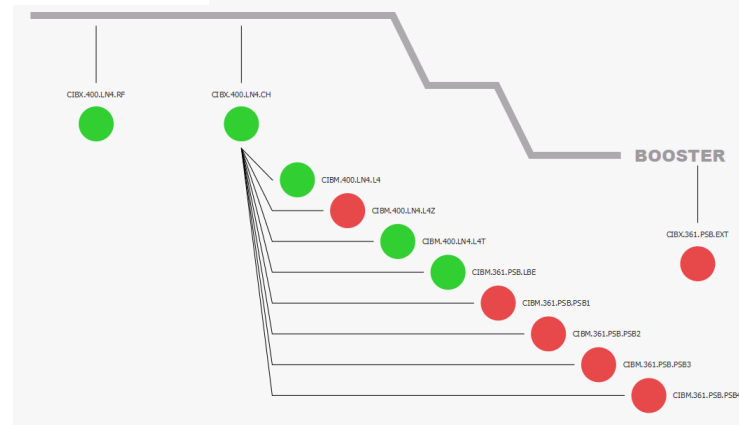
2019112151422.png

COMMENT : Detailed interlock result of Fgc LTB:BHZ40 PSB

FGC BIS interlock	FGC BIS Setting	LSA BIS Setting	Interlock result
Channel result	OFF	OFF	NOT OK
PC state	ENABLED	ENABLED	NOT OK
Current reference	0.0 +/- 1.0	0.0 +/- 1.0	NOT OK

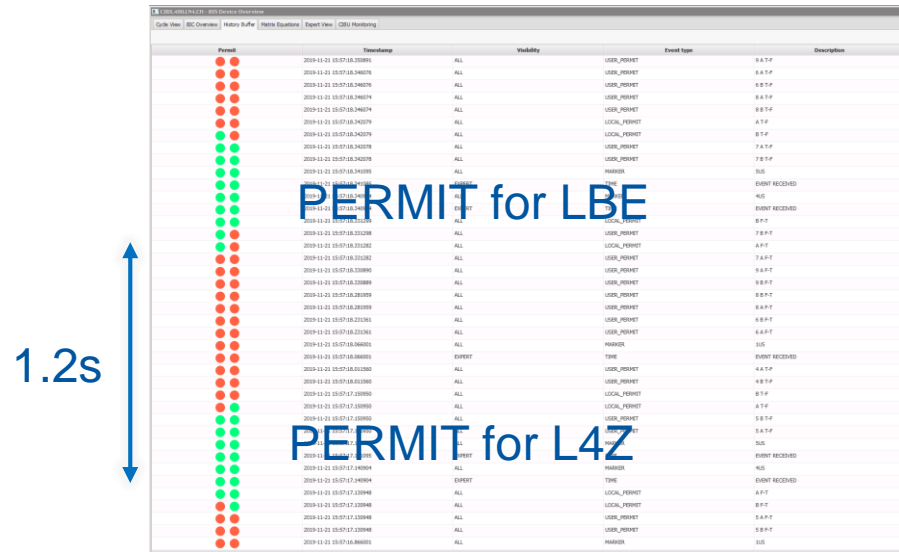
CIBM.361.PSB.PS01 - BIS Device Overview

Channel	INPUT	SAFE BEAM FLAG		MATRIX	Interlock	Interlock
		DISABLED	MARKED			
Software Permit	FALSE			FALSE	FALSE	FALSE
1/A BE WD	FALSE	YES		TRUE	FALSE	FALSE
2/A PSB In Watchdog	FALSE	YES		TRUE	FALSE	FALSE
2/B	FALSE	YES		TRUE	FALSE	FALSE
3/A HPH- Current Monitor	FALSE	YES		TRUE	FALSE	FALSE
3/B	FALSE	YES		TRUE	FALSE	FALSE
4/A Distributor	FALSE	YES		TRUE	FALSE	FALSE
4/B	FALSE	YES		TRUE	FALSE	FALSE
5/A BLNB BE line+PSB int	FALSE	YES		TRUE	FALSE	FALSE
5/B	FALSE	YES		TRUE	FALSE	FALSE
6/A BE.SW	FALSE	YES		TRUE	FALSE	FALSE
6/B	FALSE	YES		TRUE	FALSE	FALSE
7/A not used	FALSE	YES		TRUE	FALSE	FALSE
7/B	FALSE	YES		TRUE	FALSE	FALSE
8/A BEI.KSW	FALSE	YES	NO	TRUE	FALSE	FALSE
8/B	FALSE	YES	NO	TRUE	FALSE	FALSE
9/A BEI.BSW	FALSE	YES	NO	TRUE	FALSE	FALSE
9/B	FALSE	YES	NO	TRUE	FALSE	FALSE
10/A Injection Fail 1	FALSE	YES	NO	TRUE	FALSE	FALSE
10/B	FALSE	YES	NO	TRUE	FALSE	FALSE
11/A SF Vacuum Valve 1	FALSE	YES	NO	TRUE	FALSE	FALSE
11/B	FALSE	YES	NO	TRUE	FALSE	FALSE
12/A not used	FALSE	YES	NO	TRUE	FALSE	FALSE
12/B	FALSE	YES	NO	TRUE	FALSE	FALSE
13/A not used	FALSE	YES	NO	TRUE	FALSE	FALSE
13/B	FALSE	YES	NO	TRUE	FALSE	FALSE
14/A not used	FALSE	YES	NO	TRUE	FALSE	FALSE
14/B	FALSE	YES	NO	TRUE	FALSE	FALSE



Other observations

- Offset in time-stamps of BIC history buffers
 - A jump of 1s can occur at any time
 - Can affect each BIC, but independently and randomly
 - Makes event reconstruction of cycling machines very difficult



Other observations

- FEI PSB application for FGC systems now in operation
- After the radiation alarms, some confusion in the CCC led to both machine settings and interlock settings being updated to wrong values
 - Would have generated a permit for a wrong setpoint
 - Indicates that enabling some settings protection is advised
- Recommendation
 - Machine Critical Settings (MCS) RBAC roles should be implemented, limiting access to protection settings
 - Allows OP_MCS roles to set values in hardware, but only EXPERT_MCS roles can modify the protection settings

ISOHRS_LBE (Beam to LBE)
PSB.USER.MD2

CURRENT ROLE: NONE

DRIVE LINAC4

LINAC4

L4L.NFH L4L.QUADS L4T.RBH.021 L4T.RBV.121 LT.BHZ LTB.BHZ40

Crate name: CFC-400-RL4SRC
BIC input: Source RF Master BIC - CIBX.400.LN4.RF.PUB - 9

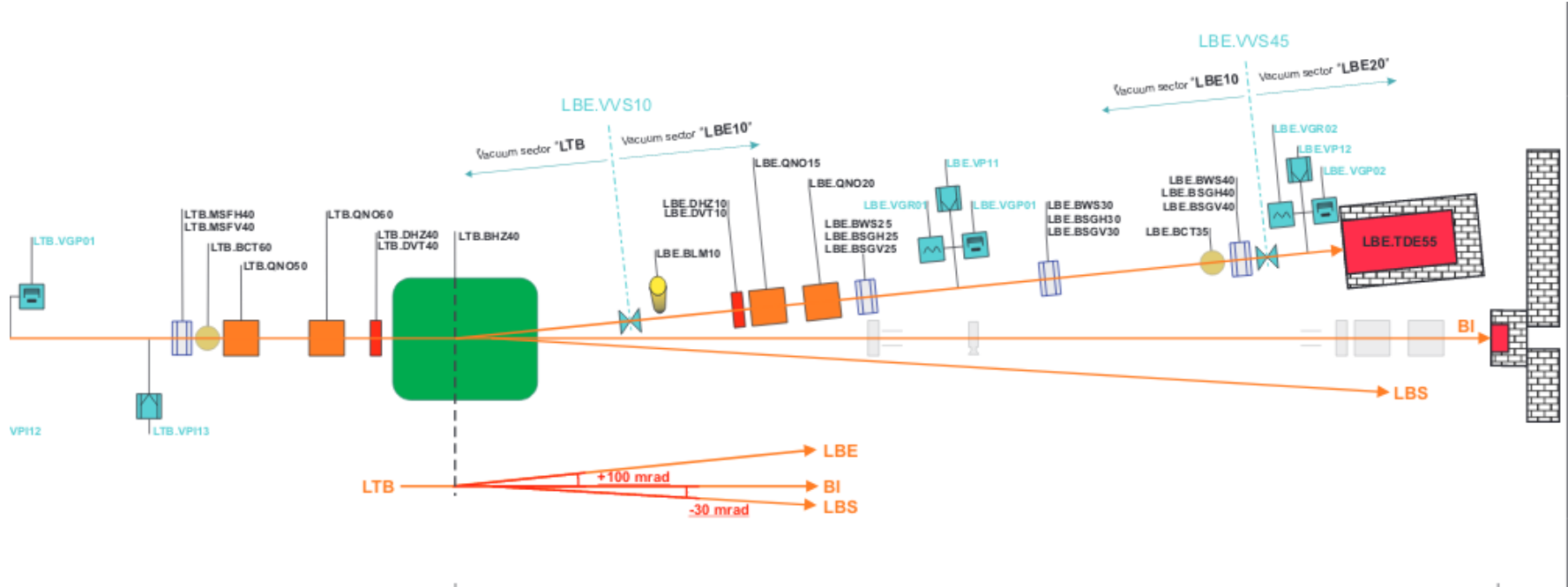
PC Name	Channel	All Interlocks Enabled		PC State	PC State Interlock E...		Interlock Reference				Interlock Tolerance		Ref./Tot. Interlock E...		PC Value		PC Max.Valu...	Required role	BIC entry	OP mode
		HW	LSA		HW	LSA	HW [A]	LSA [A]	HW [A]	LSA [A]	HW	LSA	Meas [A]	LSA [A]						
L4L.RQD.361	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CYCLING	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	133	133	10	10	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	139.644	139.56	...	NONE	9	NORMAL		
L4L.RQF.351	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CYCLING	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	78	78	10	10	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	71.974	72.03	...	NONE	9	NORMAL		
L4L.RQF.371	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CYCLING	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	123	123	10	10	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	129.863	129.88	...	NONE	9	NORMAL		

Conclusion

- Investigating PSB radiation alarm lead to some actions to assure protection integrity for the LBE run
 - Inhibit AQN for PSB of LTB.RBHZ40 power converter
 - Inhibit local permit from PSB ring BICs
- Some resulting actions still need to be followed up
 - How to ensure BIC history buffer has correct timestamps?
 - Implementing MCS RBAC roles for the power converter settings should be implemented as soon as reasonable
- Event reconstruction with matrix equations and ppm operation is challenging – may need improved tools for analysis?

Spare Slides

Geometry



LTB.RBHZ40 switching magnet

LBE_H- (-175A)

PSB_H- (0A)

LBS_IONS (-60A±5A)

LBE_IONS (+95A±10A)

=> BIS surveillance

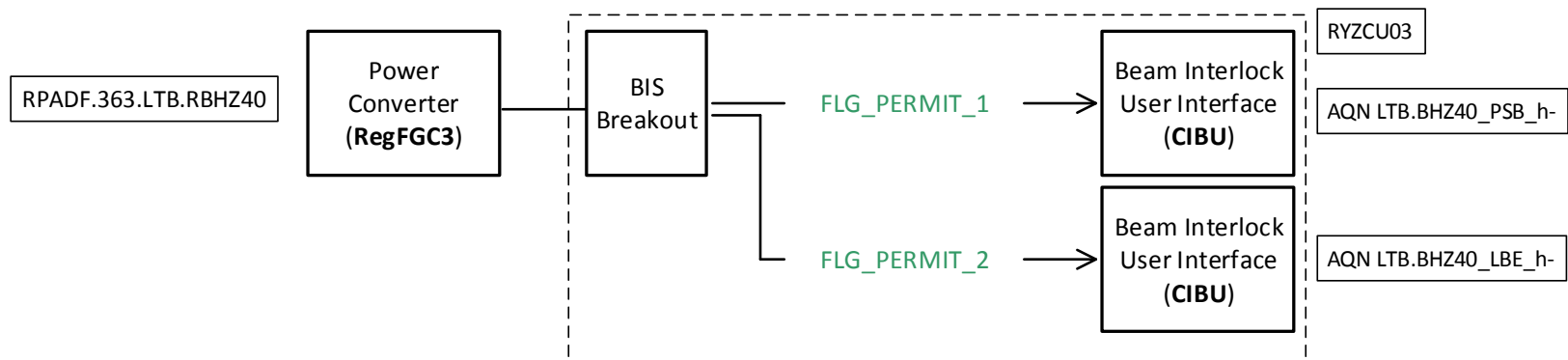
=> BIS surveillance

=> not monitored by BIS

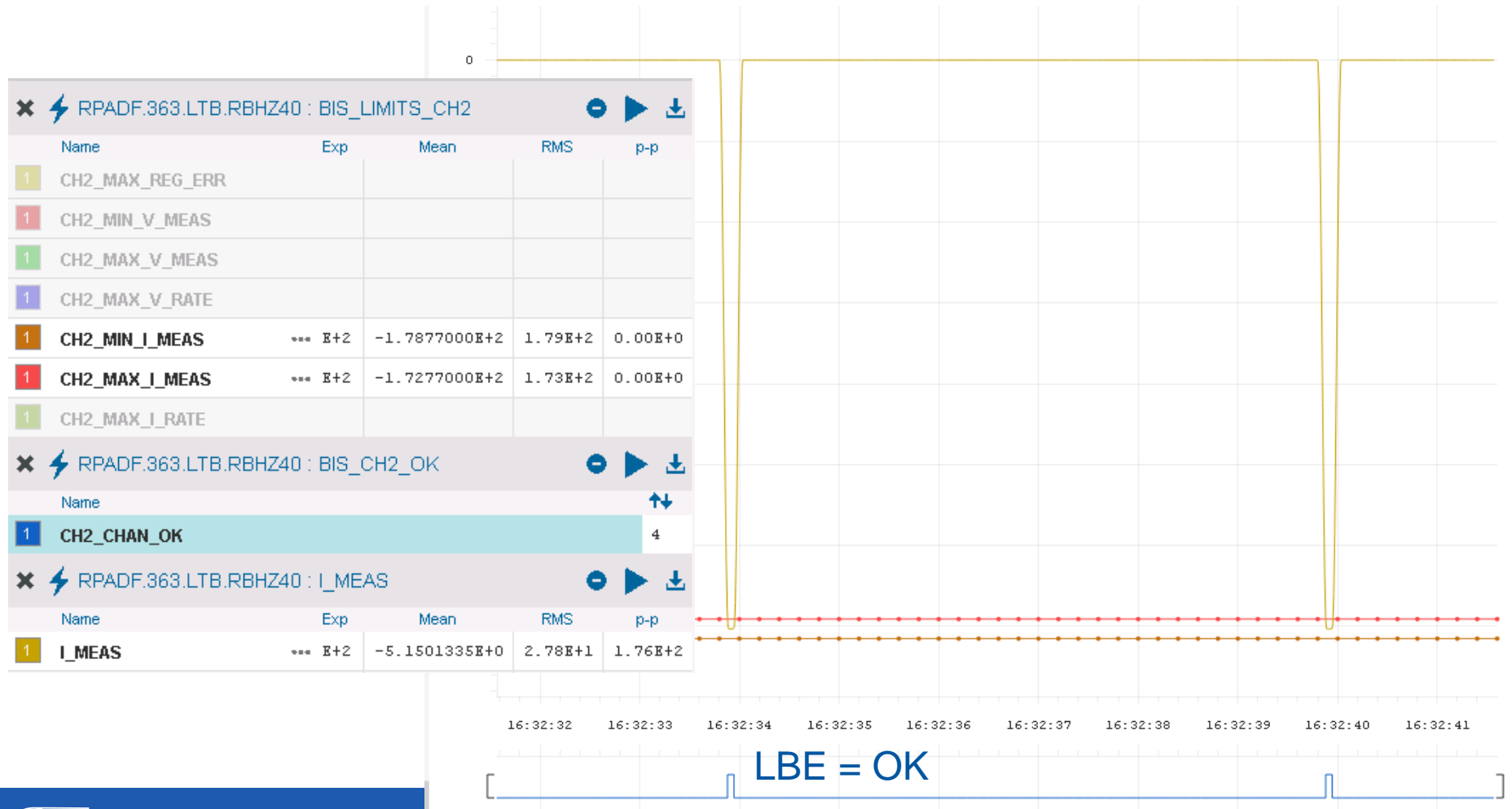
=> not monitored by BIS

LTB.RBHZ40 Hardware

- On 8th November, both channels configured and active
 - For AQN PSB -> [0A ±1A]
 - For AQN LBE -> [-175A ±3A] AND [REGULATING]



LTB.RBHZ40 waveforms



View from L4 Chopper BIC

