Experience - Protection of the Linac4 LEBT settings

R. Scrivens, 03/09/2021

Thanks to T. Bukovics and P. Skowronski

Machine Protection Panel 03/09/2021

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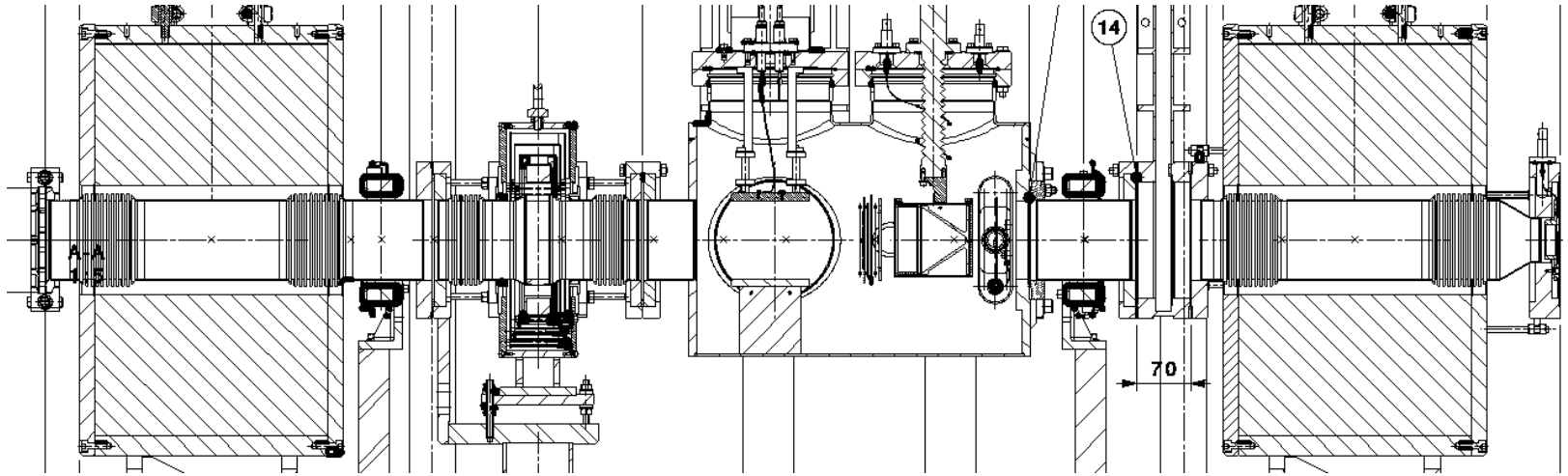
Layout of the LEBT

Source



RFQ

Solenoid Steerer BCT Pre-chopper Steerer Beam-Stopper Solenoid

Introduction

- Transmission of the Linac4 RFQ (measured from LEBT BCT to first MEBT BCT) is in the range of 70% with the present source/LEBT/RFQ combination.
- It is very strongly dependent on LEBT settings.
- By keeping the equipment parameters in a narrow window, we avoid new losses, and keep those that occur is a consistent pattern.
- The SIS_LEBT system surveys that device acquisitions are within defined windows.

Operation Scenarios

- More than one operational scenario:
  - **Standard operation** MODE1.
    - Requires best transmission to deliver 25mA out of the RFQ.
    - Pulse length of beam is varied by the pre-chopper (and chopper).
    - Beam settings to RFQ are for maximum transmission (25mA), and static.
    - Autopilot varies the source intensity (via source RF) to stabilize RFQ output.
  - **Low transmission** mode (7-8mA out of RFQ) MODE2.
    - Used for setting up the RF phases (RFQ, DTL, etc).
    - Source intensity lowered to minimum (limitation to ignite and maintain a plasma).
    - Beam settings to RFQ lose beam in the LEBT. The settings are static.
    - Autopilot should be disabled.
  - **Machine Development** for source/LEBT/RFQ MODE3.
    - E.g. attempting higher currents and different settings.
    - This mode would only be used if justified.

- MODE2 and MODE3 have a maximum allowed time they can be used.

Rights to change parameters

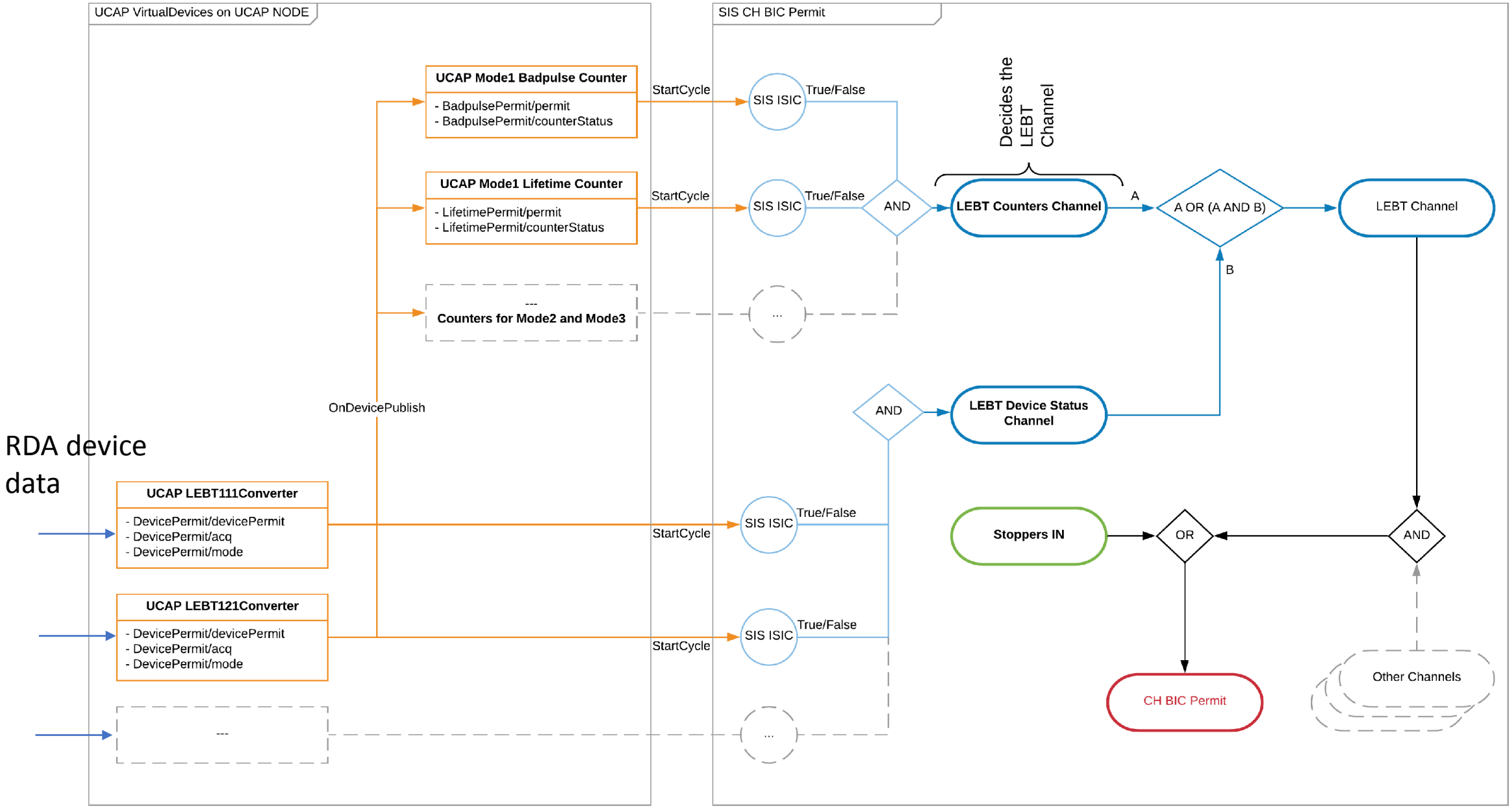
	RBAC /MCS
Min / Max Limits	MCS for Linac Supervisors
Operation Mode	MCS for Linac Supervisors
Reset Counters	No RBAC - Operator
UCAP Node Configuration	RBAC role for Linac4 UCAP developers (2 people)

Implementation Choice

- Needed a flexible approach for multiple system types.
- Implementing directly into BIS would require many implementation steps to different systems controls.
- Decision to use the software UCAP->SIS->BIS chain kept the implementation to a set of UCAP/SIS software functions.
- UCAP has more flexibility and unit testing possibilities compared to SIS.
- UCAP allows access to intermediate data for logging in NXCALS -> Very useful.
- This is now a normal concept in the PSB.

Example of Settings - Mode2 Low Intensity

Mode 2 __ LOW INTENSITY	Window	Central Value	Comment
solenoidLEBT111_Mode2_Min/Max	+/-0.5	65.25	
solenoidLEBT121_Mode2_Min/Max	+/-0.5	115.0	
steererLEBTH111_Mode2_Min/Max	+/-0.5	-3.4	
steererLEBTV111_Mode2_Min/Max	+/-0.5	-4.1	
steererLEBTH121_Mode2_Min/Max	+/-0.5	2.1	
steererLEBTV121_Mode2_Min/Max	+/-0.5	0.0	
einzelLens_Mode2_Min/Max	+/-1050.0	29000.0	
	Value		
tailclipperTime_Mode2_Max	275.11e6		i.e. 0.1 ms pulse
rfPower_Mode2_Max	30000		W
watchDogLowLossMinTrans_Mode2_Min	9		%
lifetime_Mode2_Max	3000		(1 hour)
beamCurrentLEBT	-25.0		


UCAP VirtualDevices on UCAP NODE
SIS CH BIC Permit
RDA device data
UCAP Mode1 Badpulse Counter
- BadpulsePermit/permit
- BadpulsePermit/counterStatus
UCAP Mode1 Lifetime Counter
- LifetimePermit/permit
- LifetimePermit/counterStatus

Counters for Mode2 and Mode3
UCAP LEBT111Converter
- DevicePermit/devicePermit
- DevicePermit/acq
- DevicePermit/mode
UCAP LEBT121Converter
- DevicePermit/devicePermit
- DevicePermit/acq
- DevicePermit/mode

OnDevicePublish
StartCycle
StartCycle
StartCycle
StartCycle
SIS ISIC
True/False
SIS ISIC
True/False
...
SIS ISIC
True/False
SIS ISIC
True/False
...
AND
Decides the LEBT Channel
LEBT Counters Channel
A
A OR (A AND B)
B
LEBT Channel
AND
LEBT Device Status Channel
Stoppers IN
OR
AND
CH BIC Permit
Other Channels

Deployment and Testing

- OP (with support from CO) developed the system.
- It was deployed, and went through its main testing in July 2020.
- A detailed testing programme was run, and helped to find several issues.

- Documentation :
  - Specification : L4-CIB-ES-0007
  - Wiki: https://wikis.cern.ch/display/LISRC/LEBT+Setting+SIS-BIS+Interlock

Operational Experience I

- Mode Usage
  - Operation is the default.
  - Low current mode (for RF tuning) ~3x in 2021.
  - MD mode used 1-2 times per month.

Operational Experience II

- Limit Changes for Operation Mode
  - 2020 - Limits were changed a few times (<10), after optimizations for transmission (possibly as the source conditioned).
  - ~2 changes in 2021.
- Limit Changes for Low Transmission Mode
  - 2020 - the mode was commissioned.
  - 2021 – no changes to the parameters.
- Limit Changes for MD Mode
  - 2021 - Few changes, the windows are set rather wide.

Operational Experience III

- True fault incidents
  - There have been several cases of beam being correctly stopped by some equipment faults.
  - Mode2 was left for a weekend – the lifetime counter stopped the source (correctly).
  - …

- False positives
  - These have been too frequent.
  - The main issue has been difficulty in identifying the reasons, usually coming from poor quality equipment data.
  - Regular issues with power converters. E.g. publishing “out-of-date” data, noisy/unphysical values, very late data.
  - Spring 2021 – issues with network connections from FGCs (possibly due to poor quality cables).
  - Technical Network issues, causing packet delays etc….
  - It has become necessary to make the system more tolerant against these, and improve the monitoring of the SIS_LEBT to identify more quickly the device causing the issue.

Table of SIS_LEBT stops in July/August 2021

Date - Time	Source	Comment
31/08/2021 – 15:42	Einzel	Possible FGC false data published
31/08/2021 – 10:16	Einzel	Possible FGC false data published
30/08/2021 – 17:07	Multiple converters tripped	
20/08/2021 – 10:39	Einzel	
15/08/2021 – 17:23	RFQ Break Down	Coincidental
15/08/2021 – 01:40	Einzel	
07/08/2021 – 13:05	Solenoid	Power glitch
27/07/2021 - 07:37	?	
25/07/2021 - Multiple	Solenoid	Power Converter Fault
17/07/2021 – 12:30	Einzel	

This is a rather calm period

Ongoing Development

- Increase in window to receive data in SIS
  - Some data received too late, the window has been increased to 2000ms.
- Missing data
  - System was blind to some missing data cases. Next update will cause a bad pulse count.
- *First updates* and older data
  - Some equipment send unexpectedly data from another time. *Logic implemented to reject "first updates"* and older data.
- *Latch on SIS on the condition causing the interlock, to allow operators to see the cause.*
- Improved Monitoring
  - Implement a monitoring UCAP node, that stores bad pulse, missing data and exception events for 1 hour.
  - Data to be published to Laser, for ANY of these events.
  - Has no safety impact, so can be regularly updated.
- These are described in a document (by email) and being readied (partial deployment possible deployment in Sept TS). Propose to add as appendix in specification.

Closing Remarks

- Thanks to OP / CO for implementing the system.
- It works, and has kept settings under control.
- We have not experienced any false negatives.
- No crashes of the UCAP or SIS “servers”.
- False positives, and their tracing is a major issue.
- SIS development and debugging is not user friendly and missing tools. In this respect UCAP is much better.
- Specification written up in EDMS L4-CIB-ES-0007 (In Work). It has been updated with comments some time ago, but is not recirculated/released. Add appendix and circulate again.

Thanks for your attention