MACHINE PROTECTION CONSIDERATIONS FOR 50 MeV LINAC4 BIS COMMISSIONING

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LINAC4 BIS: GENERAL CONSIDERATIONS

- Same implementation as LHC BIS (except differential links)
  - ✓ LHC BIS: SIL3
  - ✓ Very good experience from the past
  - ✓ Linac4 has more relaxed requirements (to be met also from the user side)
- Reaction time within the same Linac4 pulse (few tens of us)
- SIS: complementary role wrt to the BIS protection
- BIS Commissioning:
  - ✓ Try to reproduce realistic operation since the beginning
  - ✓ Try to avoid HW modifications in the following steps
  - ✓ Allow for flexible operation

LINAC4 BIS: COMMISSIONING STEPS

The BIS commissioning will match the 5 phases of the Linac4 commissioning [1]:

- Up to the DTL:
  - ✓ 3 MeV with 2 destinations (inline to 3 MeV dump and to diagnostic line + dump)
  - ✓ 12 MeV with 2 destinations (inline to Commissioning dump and to diagnostic line + dump)
- Downstream the DTL:
  - ✓ 50 MeV with 1 destination (inline to Commissioning dump)
  - ✓ 100 MeV with 1 destination (inline to Commissioning dump)
  - ✓ 160 MeV with 2 destinations (inline to L4Z and main Linac4 dump + second destination for HST)

BIS Commissioning: Approach

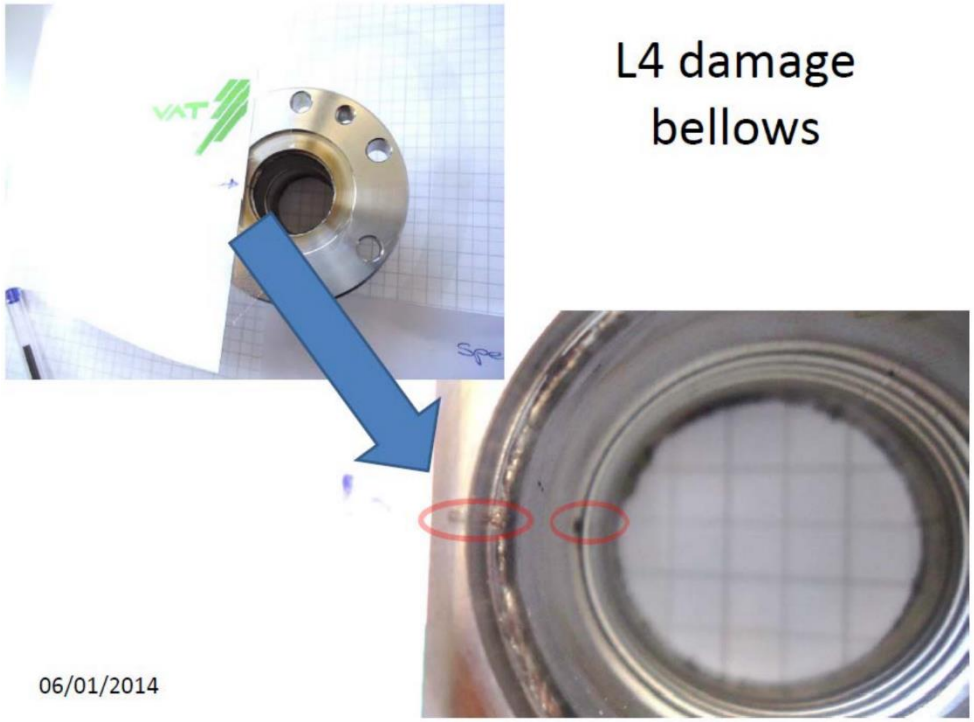
- For the start of the commissioning, not all the inputs of the BIS were/are available. The **criticality** of the different inputs was defined for the different commissioning steps.

- Machine Protection Considerations:
  - ✓ Damage to equipment possible at Low-Energy
  - ✓ No activation below 10 MeV [2]

DAMAGED BELLOW 3 MeV

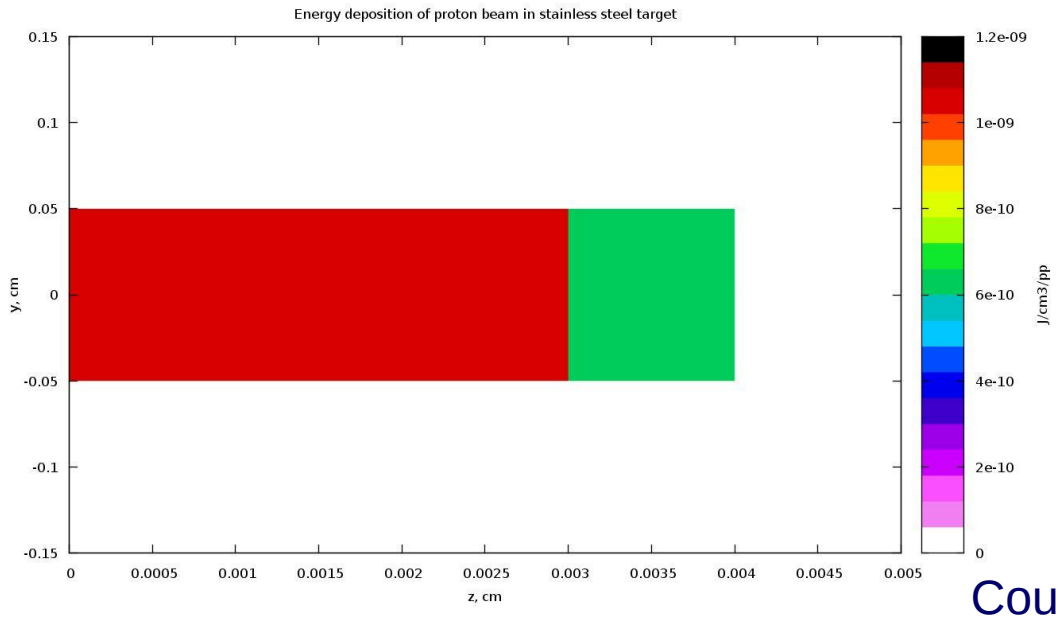
- A **severe misalignment** between the RFQ and the MEBT that was not present at the 3 MeV test stand and was later confirmed by survey
- An **optic that favoured** amplification of this misalignment whilst focusing the beam to sub mm size in the other direction
- A **phase advance** such that the loss occurred on the “wave” (or lip) of the bellow which is only 200 microns thick and it is an aperture limitation

“Report on the accident of 12.12.2013”, A. Lombardi et al.



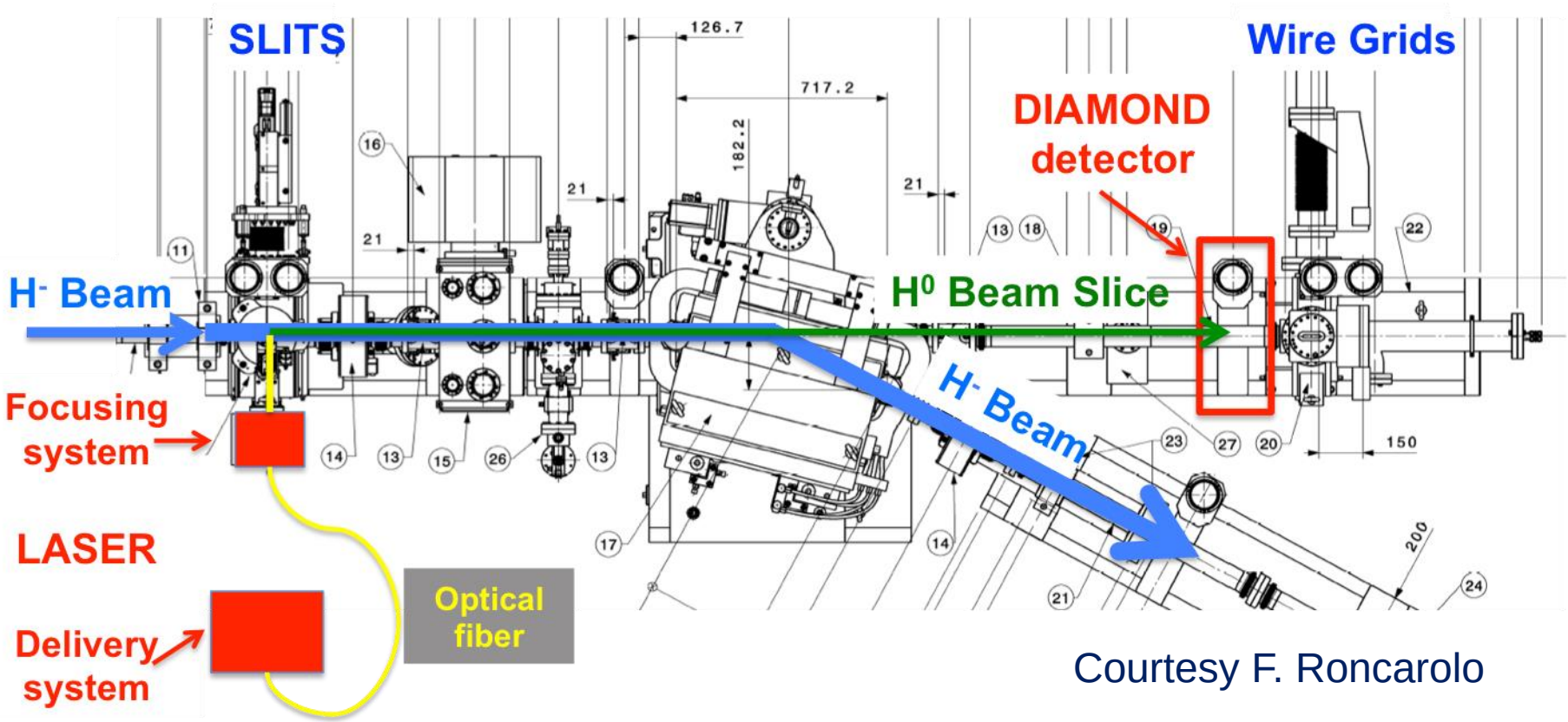
DAMAGE POTENTIAL AT 3 MeV

- Beam impact on a 200 um thick stainless steel bellow (aperture bottle neck)
- a 3 MeV proton beam is stopped at ~ 35 um in stainless steel
- Rectangular (uniform) beam distribution (13 mm x 1mm)
- Total energy deposition is ~12kJ/cm3/pulse
- Depositing 12 kJ in stainless steel will increase the temperature to ~2800K in case of head-on impact (melting point is ~1800 K)



Courtesy V. Chetvertkova

LINAC4: DAMAGED DIAMOND DETECTOR



Courtesy F. Roncarolo

- Stepping motor moving the diamond IN for H0 measurements
- Interlock logic:
  - If “CURRENT_BEND = LOW” AND “DIAMOND_POS = NOT_OUT” → USER_PERMIT = FALSE

LINAC4: DAMAGED DIAMOND DETECTOR

FACTS:

- Diamond detector IN
- CURRENT_BEND = LOW
- USER_PERMIT = FALSE (as it should be)
- BEAM_PERMIT = FALSE for both pre-chopper and chopper (as it should be)
- No beam stop possible due to **by-pass of the BIS** on BOTH pre-chopper and chopper

CONSEQUENCES:

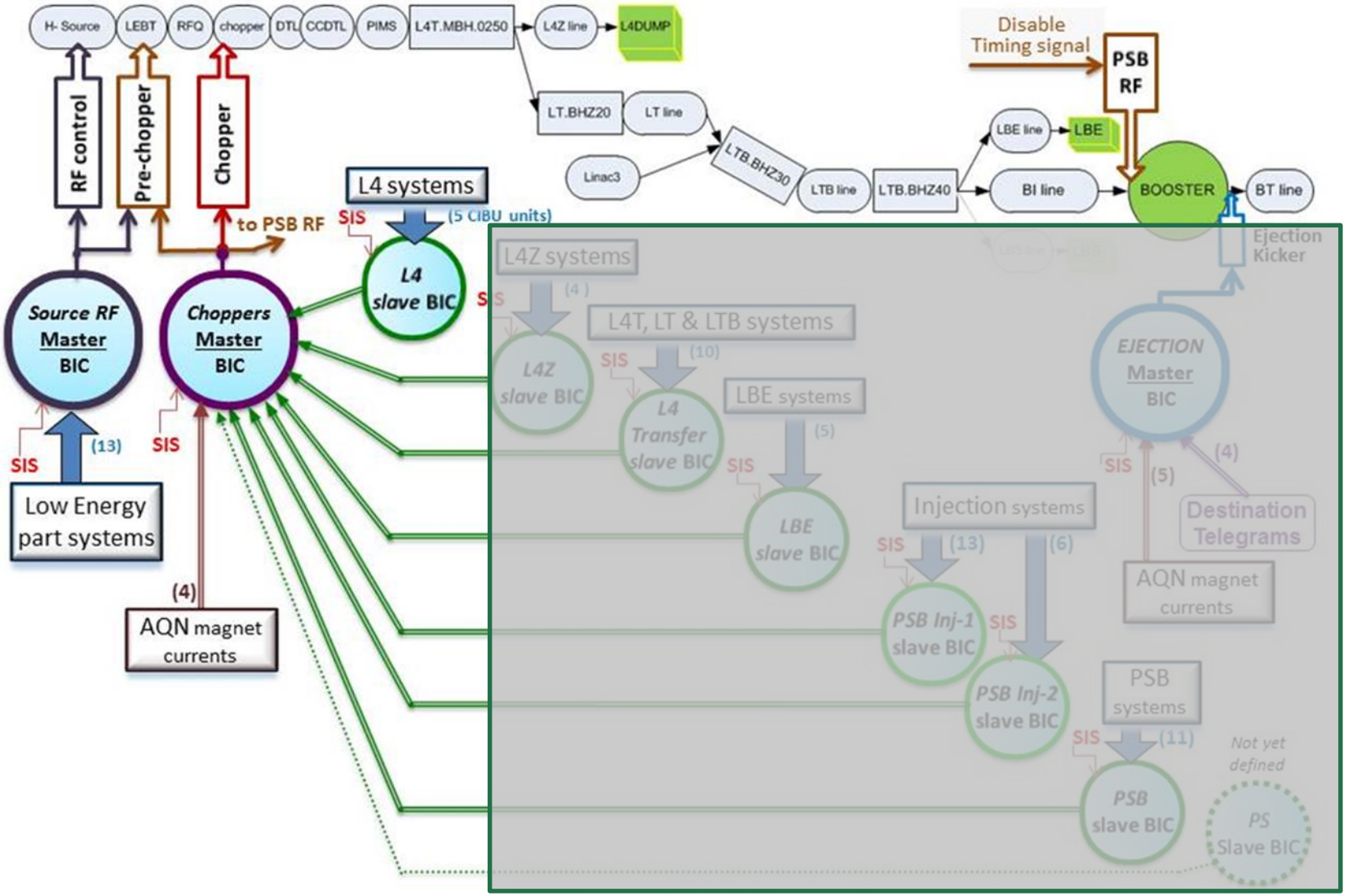
- Damaged diamond detector
- Successive H0 measurements were **ineffective** due to the degraded detector

BIS COMMISSIONING: 50 MeV

- The 50 MeV commissioning phase includes the Linac4 elements up to the third DTL tank + diagnostic line:
  - ✓ MASTER BIC SOURCE RF was already deployed since the 3 MeV phase
  - ✓ Slave BIC Linac4 used as ‘temporary master’ during the 12 MeV phase, used as slave for 50 MeV commissioning
  - ✓ MASTER BIC CHOPPERS: introduced for 50 MeV commissioning

- The criticality of the different inputs was updated for the Master Source RF and slave BIC Linac4 and defined for the Master Choppers

LINAC4 BIS: 50 MeV



BIS Linac4 & PSB layout

MASTER SOURCE RF: 50 MeV

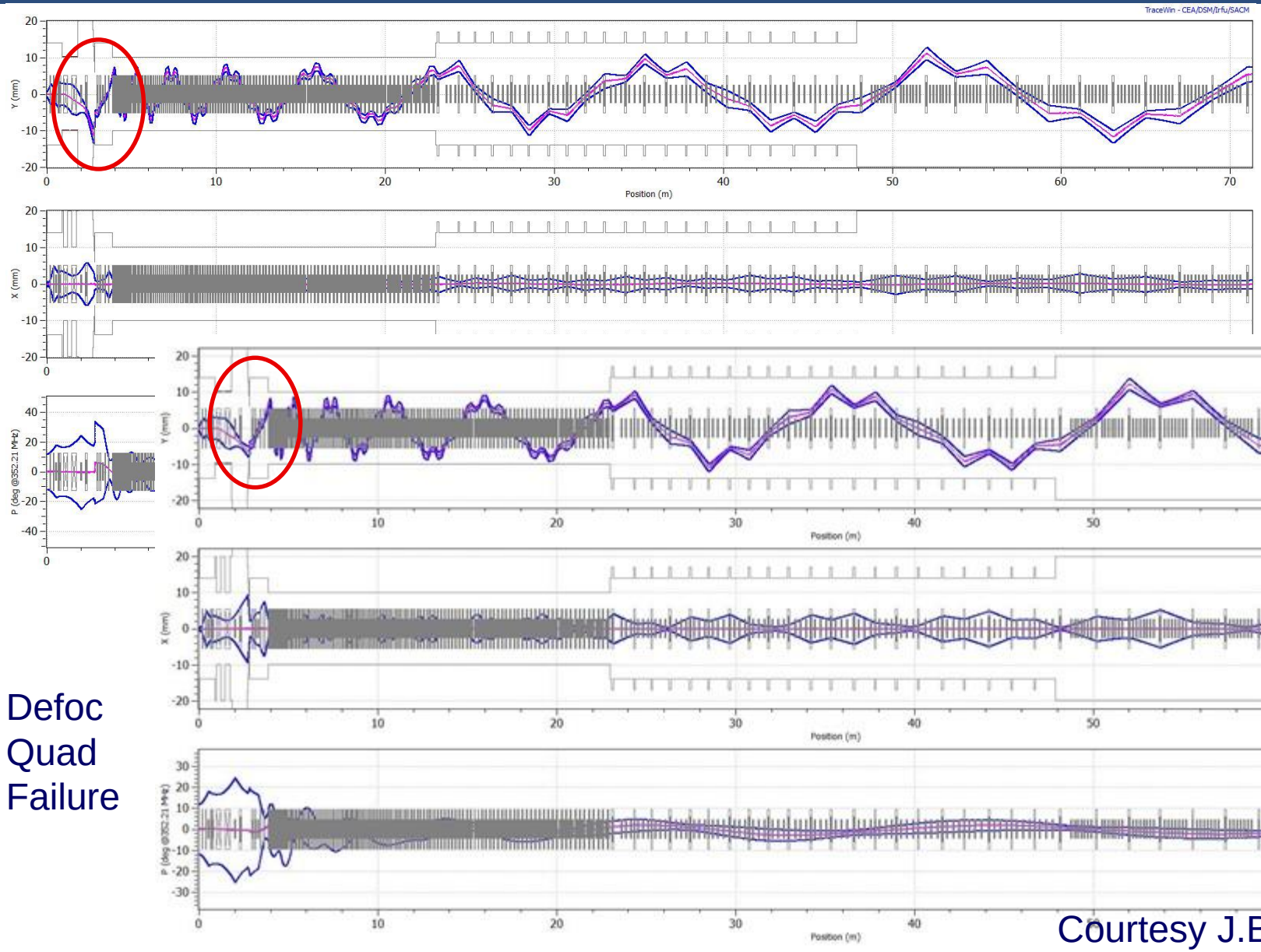
Ch.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OUT
Interlock Element	**SIS**	**Source Start**	**Source Internal**	**Source HV**	**Pre-chopper**	**Source Beam Stoppers Out/Moving**	**Source Beam Stoppers In**	**Chopper**	**L4 Low-Energy Watchdog**	**L4 Low-Energy Vacuum Valves**	**L4L.ChopperQuads**	**RFQ**	**Commissioning dump**	**L4 Operator Veto**	*Not used*	**Coppers Beam_Permit**
	1	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	x	**1**
	1	**0**	**1**	**1**	x	**0**	**1**	x	x	x	x	x	x	x	x	**1**
	1	**1**	x	x	x	**0**	**1**	x	x	x	x	x	x	x	x	**1**

- Source HV and Internal not ready for 50 MeV (Source HV in SIS as for 3 and 12 MeV)
- L4L.Chopper Quads, availability to be discussed

REQUIRED
RECOMMEND
NOT NEEDED

FINAL
NOT FINAL
NOT AVAILABLE

MASTER SOURCE RF: 50 MeV [3]



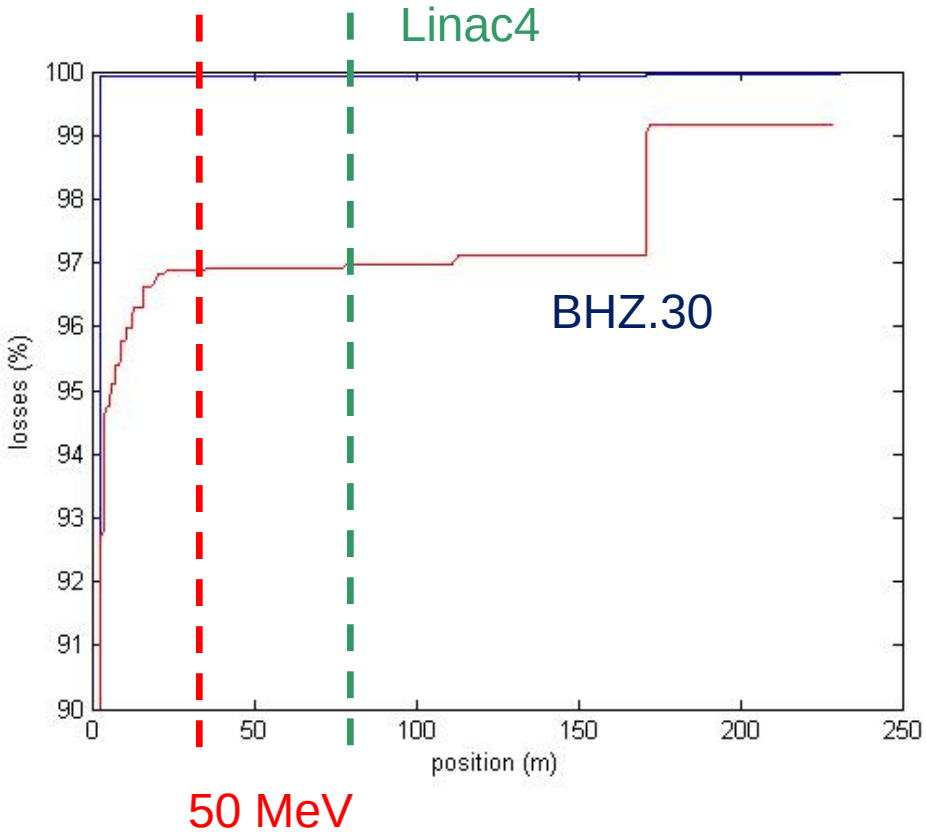
Nominal Case

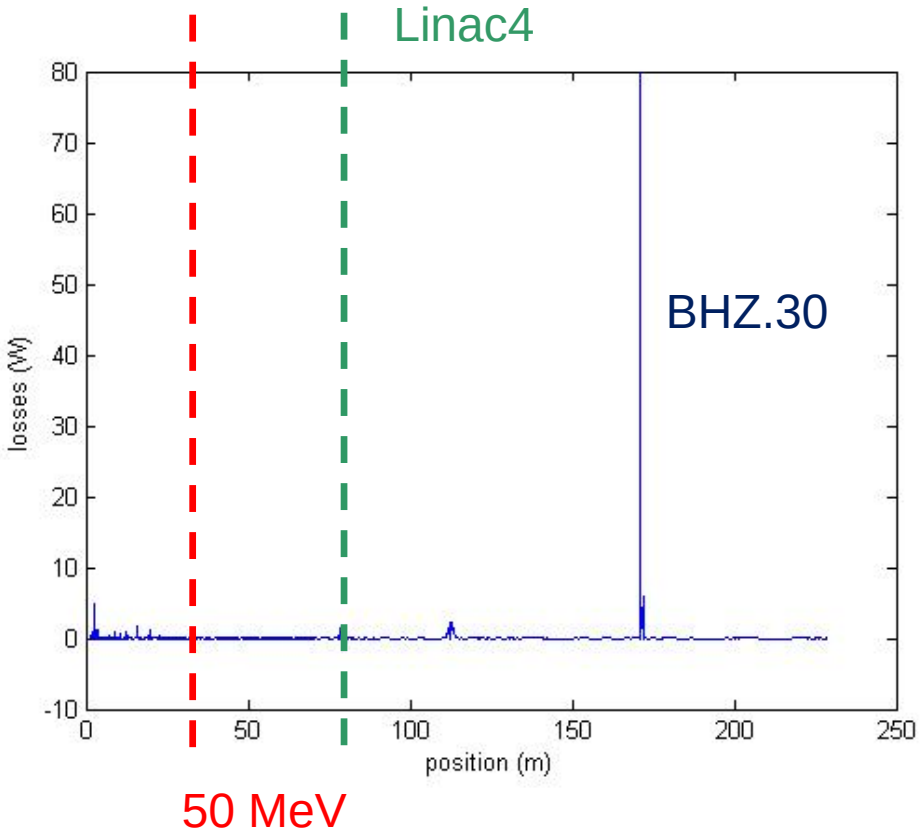
Defoc Quad Failure

Courtesy J.B. Lallement

MASTER SOURCE RF: 50 MeV

- Roughly 5% of the particles are not chopped in case of a failure of the quadrupole, and these would be lost downstream in BHZ.30 for normal Linac4 operation





MASTER ‘CHOPPERS’ : 50 MeV

Ch.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	OUT	
Interlock Element	**SIS**	**Source Beam Stoppers Out / Moving**	**Source Beam Stoppers In**	**Linac4 OK**	**AQN L4T.MBH_DUMP**	**L4Z OK**	**AQN L4T.MBH_LT**	**Linac4 Transfer OK**	**AQN LTB.BHZ40_LBE**	**LBE OK**	**AQN LTB.BHZ40_PSB**	**PSB Injection 1 OK**	**PSB Injection 2 OK**	**PSB & PS OK**	*Not used*	**Choppers Beam_Permit**	
	1	**0**	**1**	x	x	x										**1**	Beam to Stopper
	1	**1**	**0**	**1**	**1**	**1**	**0**	x	x	x	x	x	x	x	x	**1**	Beam to Dump
	1	**1**	**0**	**1**	**0**	x	**1**	**1**	**1**	**1**	**0**	x	x	x	x	**1**	Beam to LBE
	1	**1**	**0**	**1**	**0**	x	**1**	**1**	**0**	x	**1**	**1**	**1**	**1**	x	**1**	Beam to PSB & PS
					T	T	F	F	F	F	F	F	F	F			

Forced to use equation 2

REQUIRED
RECOMMEND
NOT NEEDED

FINAL
NOT FINAL
NOT AVAILABLE

- Beam Stopper signals necessary for correct measurements in the LEBT FC, in case of failures downstream the chopper

‘SLAVE’ BIC LINAC4: 50 MeV

Ch.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Interlock Element	**SIS**	**External Conditions (full pulse)**	**L4 Vacuum Valves + (L4T.VVGS.0101)**	**BLMs L4+L4Z**	*not used (L4 RF)*	**WIC L4**	**Diamond Detector**	*not used*	**L4 RF**	*not used*	*not used*	*not used*	*not used*	*not used*	*not used*
		D		D	D			D		D	D	D	D	D	D

Disabled (jumpers)

REQUIRED
RECOMMEND
NOT NEEDED

FINAL
NOT FINAL
NOT AVAILABLE

- RF: kept temporarily to maskable input #8
- WIC: only the surveillance of the magnets temperatures is available (survey the status of the power converters via the SIS?)

THE COMMISSIONING STEPS OF THE L4 BIS

https://edms.cern.ch/file/1310007/0.2/L4-CIB-ES-0005-00-20.pdf

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CH-1211 Geneva 23
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the Linac4 project

EDMS NO.	REV.	VALIDITY
1310007	0.2	DRAFT

REFERENCE
L4-CIB-ES-0005

Date: 2014-04-03

Engineering Specification

THE COMMISSIONING STEPS OF THE LINAC4 BEAM INTERLOCK SYSTEM

ABSTRACT:

The Beam Interlock System for Linac4 and its transfer lines to the PSB will be deployed in accordance with the global Linac4 schedule which includes five commission phases: 3MeV, 12MeV, 50MeV, 100MeV and 160MeV.

This document describes the steps to deploy the different Beam Interlock Controllers and to identify the connected systems which will be required for each phase of the commissioning.

BIS COMMISSIONING: CONCLUSIONS

- Damage to equipment is possible even at Low-Energy, leading to significant downtime and reduced functionality of sensitive instrumentation
- A good balance between the required flexibility for commissioning and protection needs to be found
- Changes of the BIS logic were proposed to meet operational requirements of Linac4
- An agreement should be defined for:
  - ✓ Responsibility for the Linac4 SIS implementation
  - ✓ Strategy for commissioning of the full interlock chain (user logic + BIS response)

THANK YOU FOR YOUR ATTENTION

[1] “THE COMMISSIONING STEPS OF THE LINAC4 BEAM INTERLOCK SYSTEM”, EDMS number 1310007
[2] F. P. Della Torre, M. Silari, “Predictions of induced radioactivity and residual dose rates in Linac4”, EDMS 1304119 (2013)
[3] https://espace.cern.ch/linac4-and-machine-protection/SitePages/Home.aspx