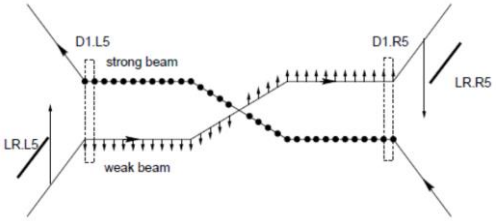


Progress with the wire interlocks for Run3

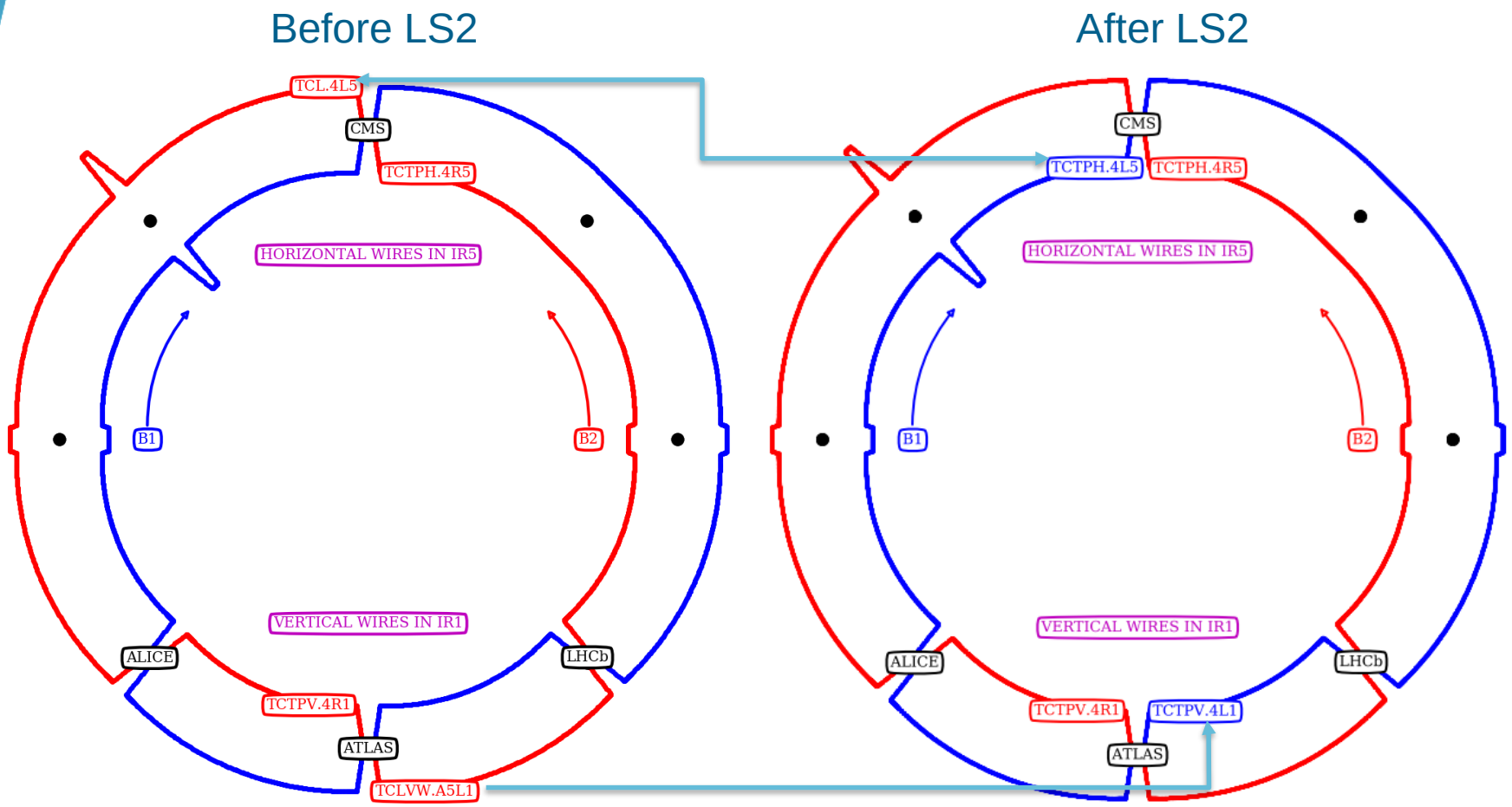
R. Bruce, L. Ceccone, R. Mompo, M. Solfaroli, Y. Papaphilippou, A. Poyet, **A. Rossi**, G. Sterbini, J. Uythoven, J.Wenninger, D. Wollmann, M. Zerlauth.

Beam-Beam and Luminosity Meeting on February 7th 2020

Outline

- New installation during LS2
- 2018 studies on effect of wire off (and Q4/5 trim on) on β-beating, tune shift and collimation hierarchy
- Power converter + circuit time constant
- Wire overheating
- Proposal for interlocks

Changes during LS2

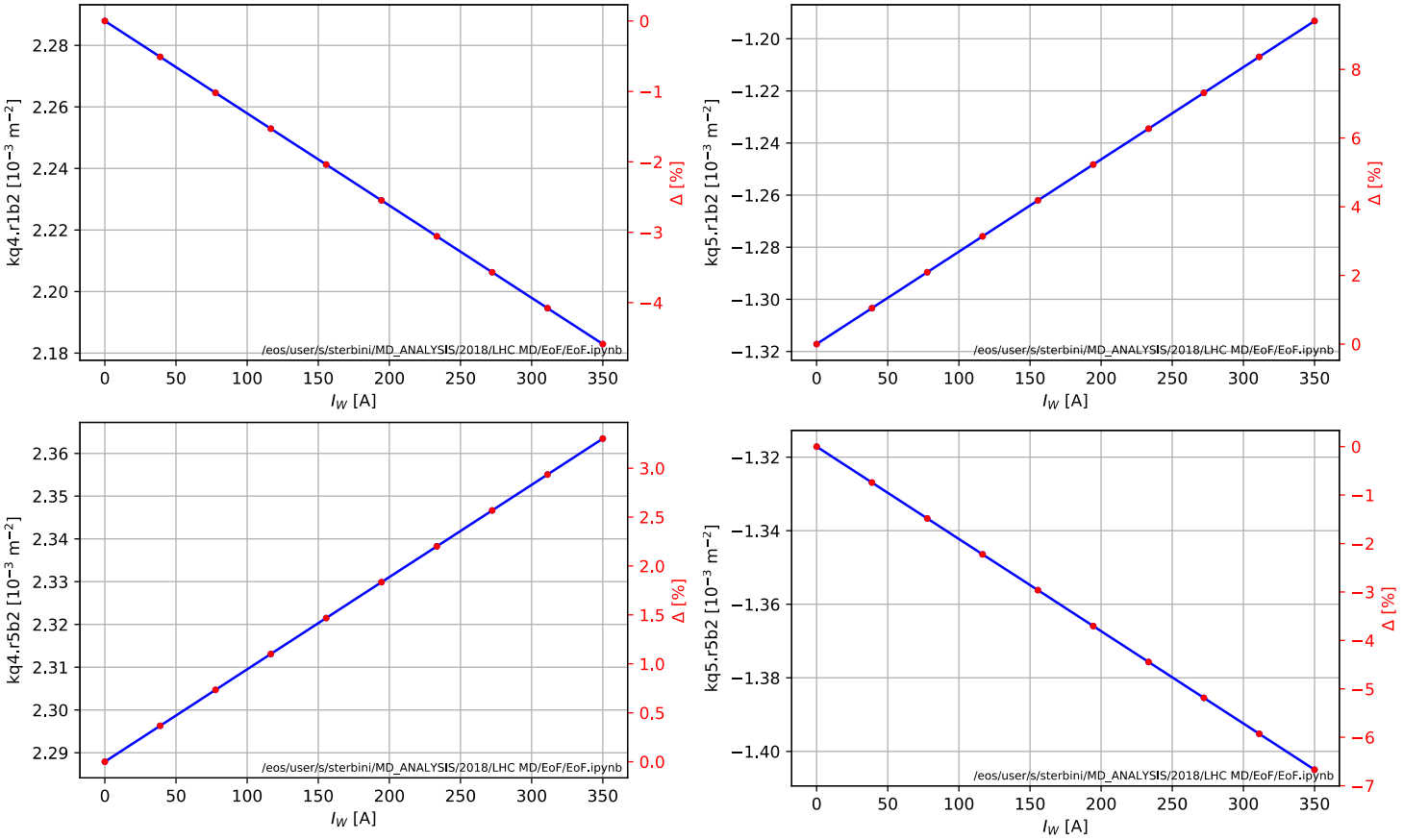


Courtesy of Guido Sterbini BE-ABP

/eos/user/s/sterbini/MD_ANALYSIS/2018/LHC MD Optics/OpticsInjection.ipynb

Wire-in-jaw collimators have been moved to new position.
Commissioning planned for Q4 of 2020

Q4/5-feedforward on when wires on



When we trim a wire the Q4/5 close to the wire are trimmed to compensate as close as possible the quadrupolar perturbation of the wire.

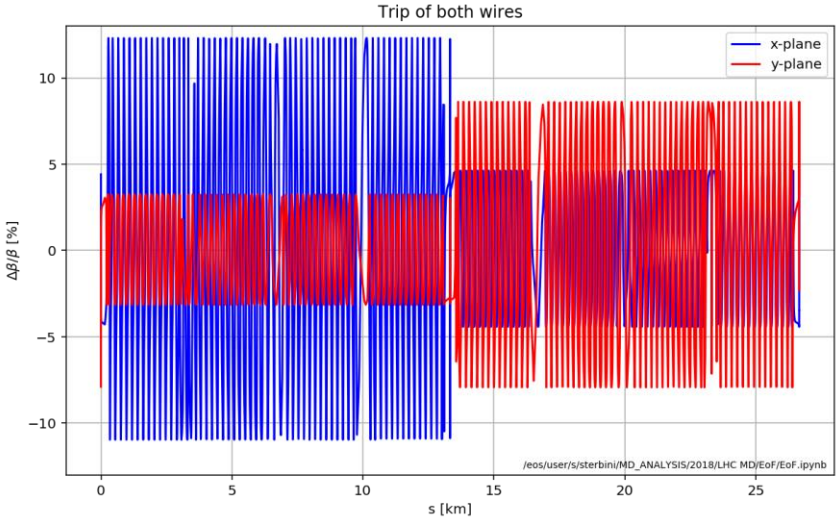
G. Sterbini, M. Solfaroli

What if a wire PCs trips?

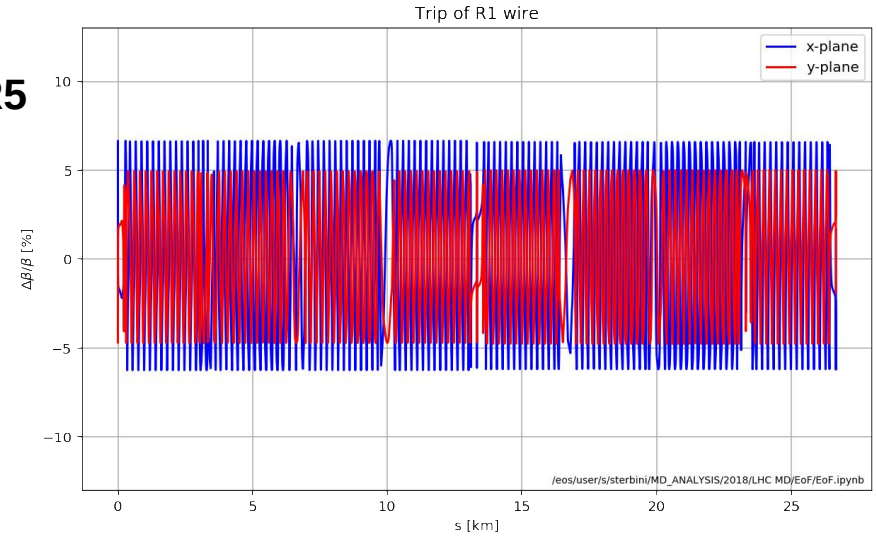
G. Sterbini

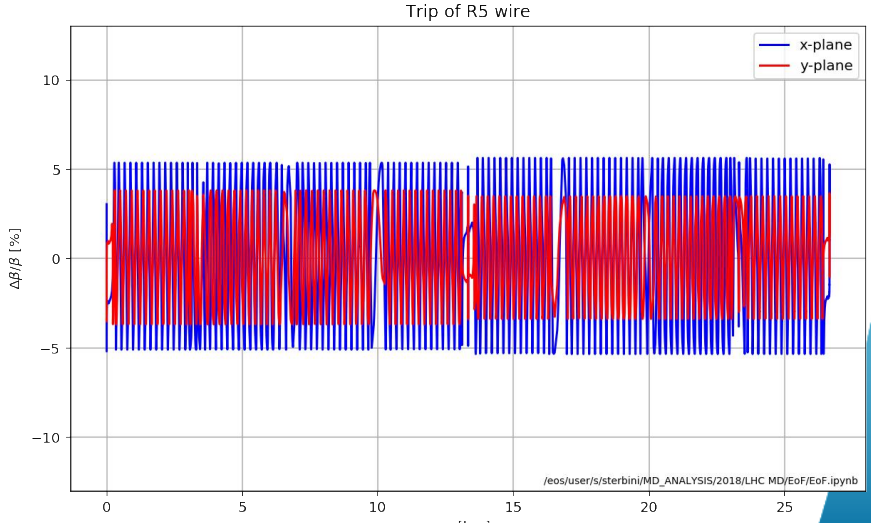
IF the wire PC trips, **AND** the beam is **NOT** automatically dumped: the Q4/5 trim will cause tune shift and β-beating.

Assuming we are using TCT4.R1 and TCT4.R5 at β*=30 cm and θc/2=130 mrad



	ΔQH	ΔQV
Trip on both wires	-0.001788	0.002006
Trip on R1 wire	-0.009535	0.006858
Trip on R5 wire	0.008327	-0.005695





Effect on collimation hierarchy (R. Bruce)

Studying effect on collimation hierarchy from β-beat due Q4/Q5 correction still running after wire trips on 2018 baseline optics

- Typically observing up to 0.2 σ difference in effective collimator settings
  - Not expected to be critical for most collimators
  - No hierarchy breakage expected in IR7, unless β-beating from other effects comes on top
  - Up to 0.7 σ difference in the worst case
- Most critical case: Effective σ-setting of dump protection and IR5 TCT

30 cm

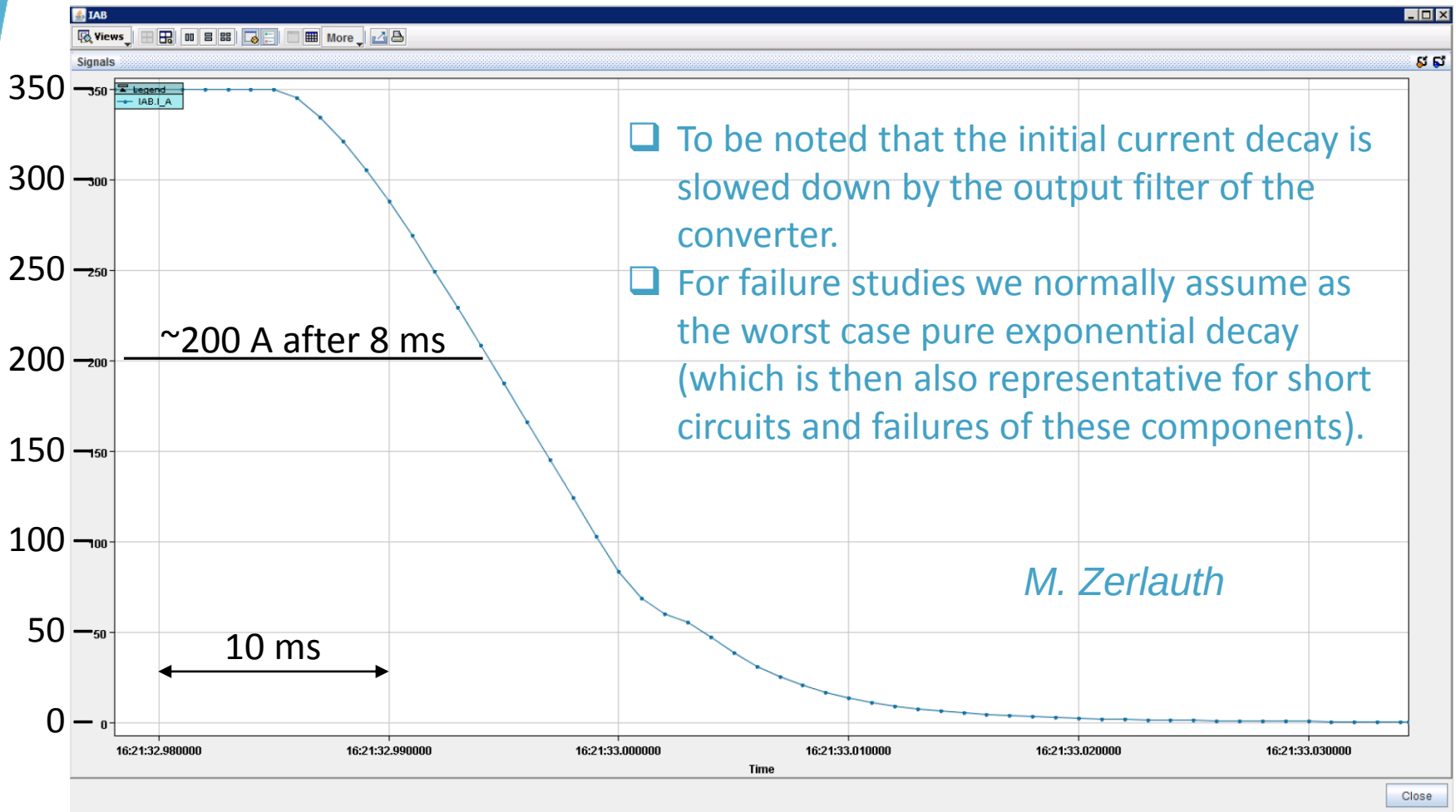
σ-setting	Nominal	Trip IR5
TCDQ.B4L6.B2	7.24	7.46
TCTPH.4R5.B2	8.5	8.43

25 cm

σ-setting	Nominal	Trip IR5
TCDQ.B4L6.B2	7.3	7.56
TCTPH.4R5.B2	7.8	7.68

- At 25 cm, margin between TCDQ and TCT is reduced to about 0.1 σ
  - On top of other sources of β-beat, risk to be out of tolerance at 25 cm – discouraged running scenario
  - For regular operational use, preferable to do loss maps with wire off and compensation running
- Phase advance MKD-TCT shifts by 1-2 degrees and stays within tolerance – no issue expected
- For any operational use in Run 3, all studies should be repeated with final optics

Wire current decay after converter fault



- To be noted that the initial current decay is slowed down by the output filter of the converter.
- For failure studies we normally assume as the worst case pure exponential decay (which is then also representative for short circuits and failures of these components).

M. Zerlauth

Power converter failure, FPG and WIC

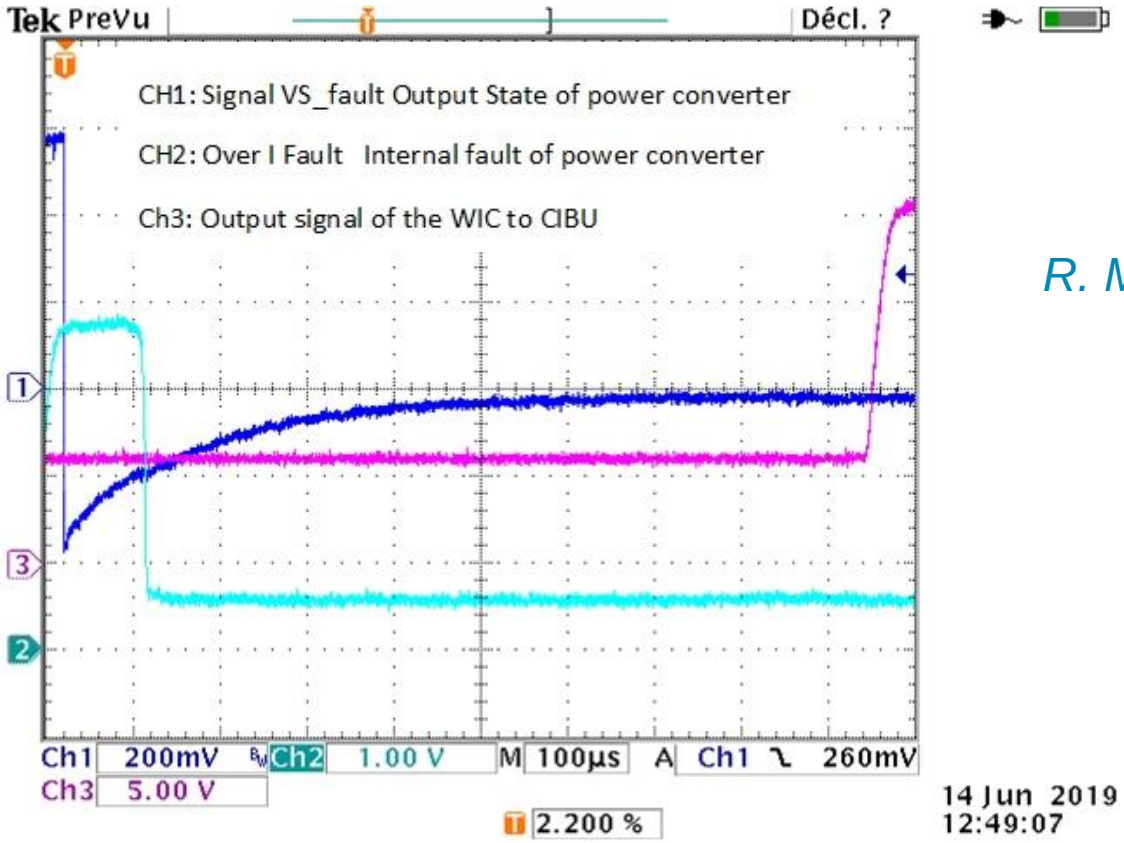
- There are 4 main reasons to generate POWERING_FAILURE on the FGC2 (which is the one used for the BBCW) and the FGC3 (which is relevant for the RD1s, RD34s and in the future for newer converter installations):
  1. VSFAULT: Voltage source Internal Fault (fast power abort unsafe, over voltage, over current, aux PSU)
  2. VSEXTINTLK: Voltage source External Interlock (water, earth current, equipment stop button)
  3. DCCT faults
  4. FGCFAULT: which is used for remote testing as asserted from the software as well as the PIC2 tests.

- In the first 3 cases, the signal gets from the voltage source buffers to the FGC FPGA, via a relay to the WIC. Max reaction time = max. 350us (voltage source signal delay) + max. 10us (FPGA processing delay) + max. 3ms (relay reaction time) = **3.36ms**

- In the latter case, it depends on the software and might take from **~8ms** (FGC2, FGC3) to **20/40ms** (FGClite).

M. Zerlauth

- Very small overall delay between the occurrence of an internal converter failure until the beam dump to the BIS: 1.2ms for the latest FGC3 version, and 1ms for the FGC2



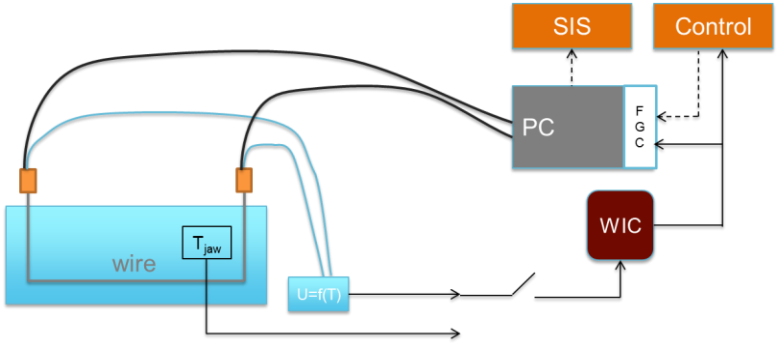
R. Mompo, L. Ceccone

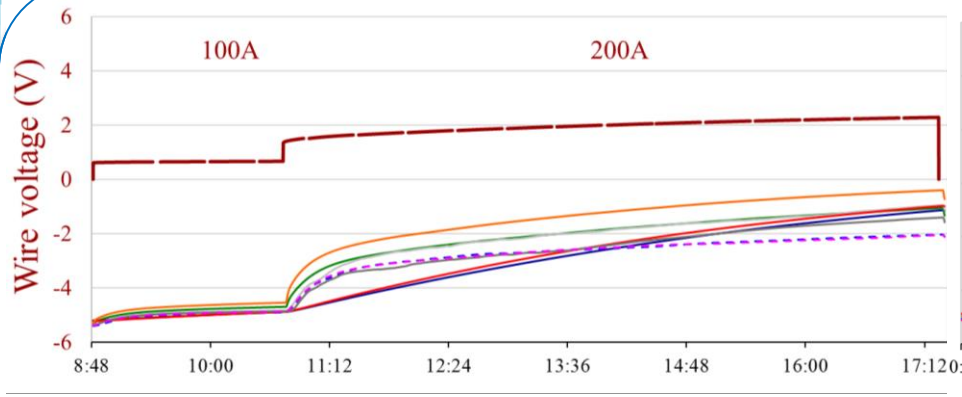
FGC2

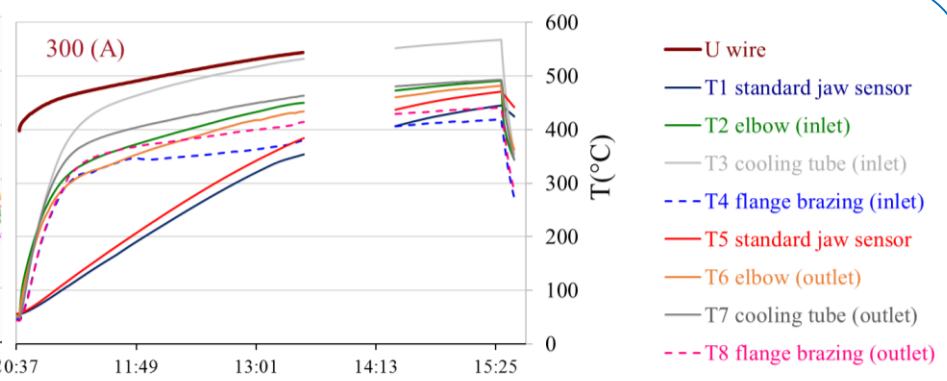
- Confirm (*M. Zerlauth*) WIC path sufficient interlock chain even for the most (time) critical failures of the wire compensator

Wire overheating

- Wire resistivity f(T)
- If wire voltage > 2.6V*
  = if hottest point @ 350A
  < 200°C, WIC cuts the PC
- WIC could dump at the same time
- **Long time constant of system**, no constraints on collimator HW







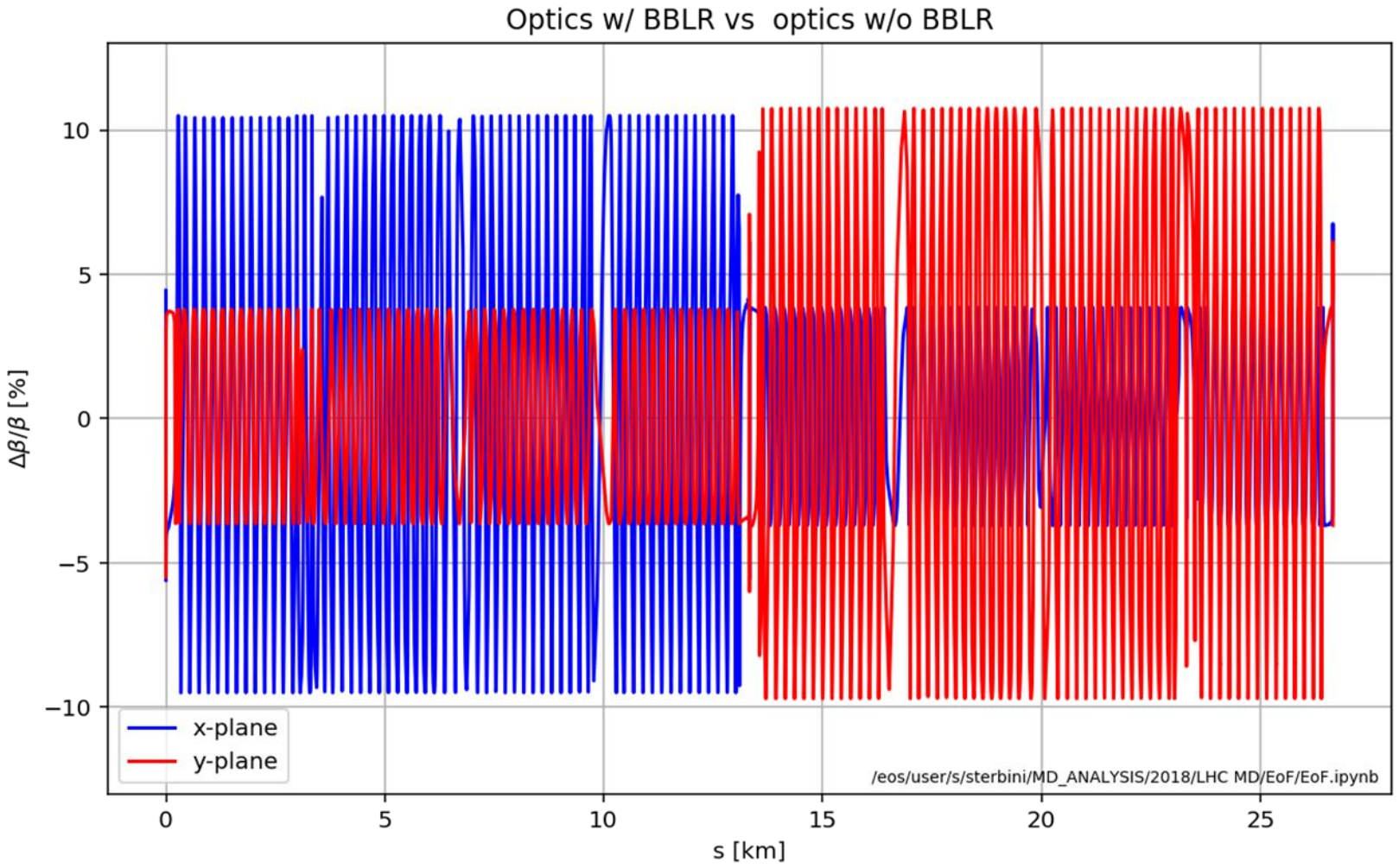
Tests performed on spare wire-in-jaw, under vacuum with no coolant

*Note this also correspond to Iw=375A

Future work

- Insert wire power converter into the matrix of converters for beam dump
  (R. Mompo) – to be tested during commissioning
- Finalize tests on interlock delays with FGC2 : During standard commissioning, trigger a fast powering failure → observe the effect on the circulating beam and measure the reaction time of interlocks
- Define required controls changes : Jorg foresees introducing the control of the wire in the LHC sequence LBOC (3 Dec. '19) BUT not possible for all cycle. Needs discussion on operational use cases
  - (Guido at LBOC - 3 Dec. '19), wire switched on at end of levelling (still to be finalised).
- Commissioning procedure to be done, including list of tests after installation, revalidation after failure and replacement of voltage measuring card or power converter, after shut-downs.

Thank you


Optics w/ BBLR vs optics w/o BBLR
Δβ/β [%]
s [km]
x-plane
y-plane
/eos/user/s/sterbini/MD_ANALYSIS/2018/LHC MD/EoF/EoF.ipynb
10
5
0
−5
−10
0
5
10
15
20
25

Backup – effective collimator settings

collimator	nominal 25cm	lhcb2_nominal_25cm	lhcb2_nominal_30cm	lhcb2_trip_25cm	lhcb2_trip_30cm	lhcb2_tripr1_25cm	lhcb2_tripr1_30cm	lhcb2_tripr5_25cm	lhcb2_tripr5_30cm
TCTPH.4R8.B2	15.00	14.91	14.92	14.52	14.59	14.51	14.58	14.90	14.93
TCTPV.4R8.B2	15.00	14.82	14.84	14.28	14.36	14.53	14.58	14.61	14.65
TCP.D6R7.B2	5.00	4.97	4.97	4.98	4.98	4.96	4.96	4.97	4.97
TCP.C6R7.B2	5.00	5.03	5.04	5.06	5.06	4.91	4.93	5.20	5.17
TCP.B6R7.B2	5.00	5.01	5.01	5.04	5.03	4.95	4.96	5.09	5.08
TCSG.A6R7.B2	6.50	6.54	6.53	6.68	6.65	6.58	6.56	6.64	6.61
TCSG.B5R7.B2	6.50	6.51	6.50	6.66	6.62	6.73	6.68	6.43	6.43
TCSG.A5R7.B2	6.50	6.52	6.51	6.67	6.63	6.74	6.69	6.44	6.44
TCSG.D4R7.B2	6.50	6.68	6.65	7.01	6.93	6.88	6.82	6.81	6.77
TCSG.B4R7.B2	6.50	6.53	6.52	6.69	6.66	6.75	6.71	6.45	6.46
TCSG.A4R7.B2	6.50	6.48	6.48	6.46	6.47	6.54	6.53	6.41	6.43
TCSG.A4L7.B2	6.50	6.45	6.46	6.34	6.37	6.42	6.44	6.38	6.40
TCSG.B5L7.B2	6.50	6.43	6.45	6.19	6.25	6.23	6.28	6.39	6.42
TCSG.D5L7.B2	6.50	6.44	6.46	6.20	6.25	6.25	6.29	6.39	6.41
TCSG.E5L7.B2	6.50	6.45	6.46	6.21	6.27	6.25	6.30	6.41	6.43
TCSG.6L7.B2	6.50	6.52	6.53	6.35	6.38	6.35	6.38	6.52	6.53
TCLA.A6L7.B2	10.00	9.89	9.90	9.73	9.77	9.77	9.81	9.82	9.85
TCLA.B6L7.B2	10.00	10.05	10.05	9.78	9.83	9.87	9.91	9.93	9.96
TCLA.C6L7.B2	10.00	10.14	10.10	10.65	10.52	10.43	10.34	10.35	10.27
TCLA.D6L7.B2	10.00	10.04	10.04	9.87	9.90	10.13	10.12	9.77	9.81
TCLA.A7L7.B2	10.00	9.91	9.90	9.88	9.89	10.20	10.15	9.59	9.64
TCDQA.A4L6.B2	7.30	7.32	7.26	7.36	7.31	7.14	7.12	7.56	7.46
TCDQA.C4L6.B2	7.30	7.32	7.26	7.36	7.31	7.14	7.12	7.56	7.46
TCDQA.B4L6.B2	7.30	7.32	7.26	7.36	7.30	7.13	7.12	7.56	7.46
TCSP.A4L6.B2	7.30	7.31	7.25	7.34	7.29	7.12	7.10	7.55	7.45
TCTPH.4R5.B2	7.80	7.78	8.52	7.57	8.33	7.65	8.41	7.68	8.43
TCTPV.4R5.B2	7.80	7.78	8.50	7.91	8.62	7.83	8.55	7.83	8.55
TCP.6R3.B2	15.00	15.11	15.10	16.02	15.85	15.63	15.53	15.52	15.43
TCSG.5R3.B2	18.00	18.14	18.13	18.29	18.27	18.29	18.26	18.22	18.20
TCSG.4L3.B2	18.00	17.93	17.92	19.04	18.84	18.52	18.41	18.43	18.34
TCSG.A5L3.B2	18.00	17.93	17.91	18.95	18.76	18.59	18.46	18.30	18.22
TCSG.B5L3.B2	18.00	17.94	17.93	18.81	18.66	18.54	18.42	18.24	18.17
TCLA.A5L3.B2	20.00	20.19	20.20	20.36	20.33	20.75	20.66	19.78	19.84
TCLA.B5L3.B2	20.00	19.94	19.94	20.13	20.11	20.12	20.09	20.05	20.02
TCLA.6L3.B2	20.00	20.28	20.29	19.54	19.68	19.93	19.99	19.96	20.01
TCLA.7L3.B2	20.00	19.78	19.78	20.05	20.02	19.90	19.89	19.93	19.91
TCTPH.4R2.B2	37.00	36.86	36.85	39.27	38.95	38.13	37.98	37.94	37.79
TCTPV.4R2.B2	37.00	36.97	36.98	36.86	36.98	36.12	36.36	37.80	37.67