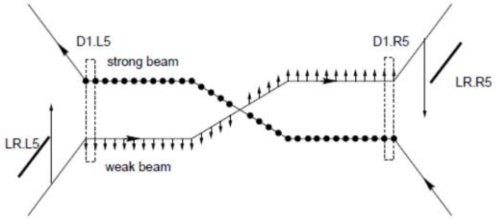


Plans of using Beam-Beam Long-Range (BBLR) compensators in B1 and B2 during high intensity operation - impact on interlocking and protection strategy

M. Solfaroli, Y. Papaphilippou, A. Poyet, **A. Rossi**, and G. Sterbini on behalf of the BBLR wire compensation team.

Special thanks to L. Ceccone, R. Mompo, J.Wenninger, D. Wollmann, M. Zerlauth.

173rd SPS and LHC Machine Protection Panel Meeting, 14/12/2018

Outline

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

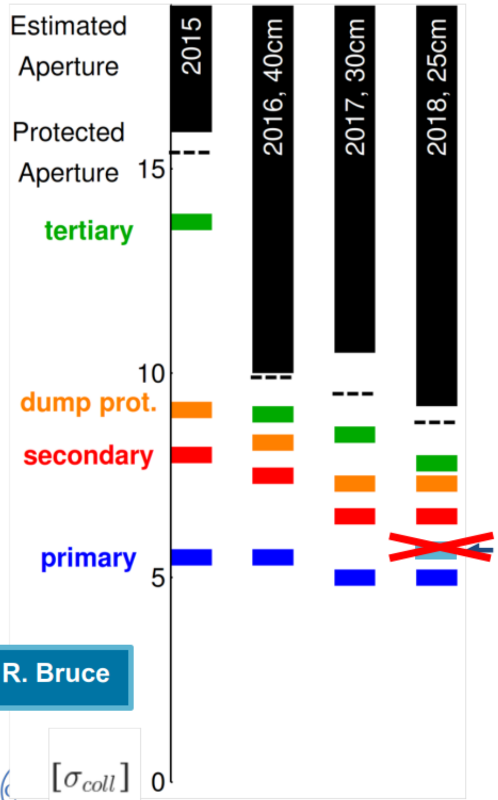
Motivations

BBLR compensation for operational configuration

LMC 359
TS2 Wire Re-cabling

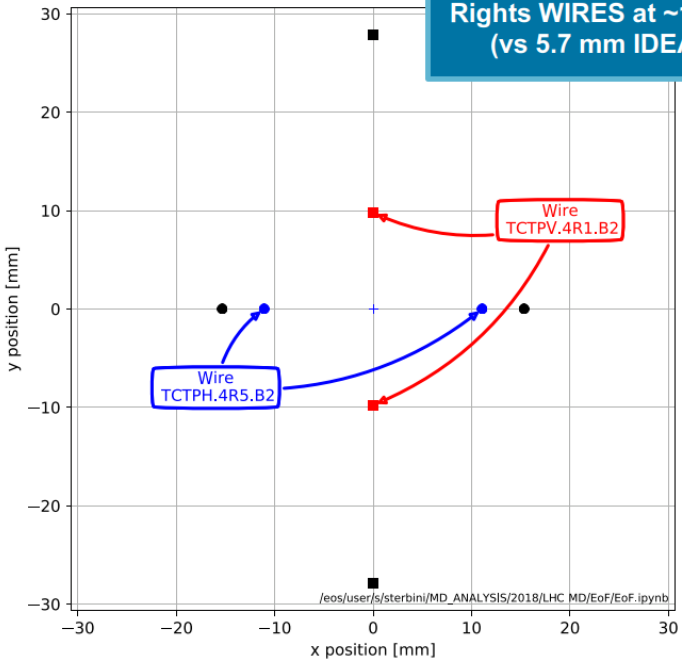
LMC 361
EoF Request

- Goal of MD4: **explore potential** of BBLR compensation in **operational conditions** (with trains) → wire-collimators to nominal TCT positions.



Courtesy of R. Bruce

Rights WIRES at ~10 mm (vs 5.7 mm IDEAL)



- During TS2, wires from both jaws **re-cabled in series** [EDMS 2027144].
- **Available I_w** could be **doubled** (only for "even" multipoles),
- Observe **BBLR global compensation** (two wires only effective)

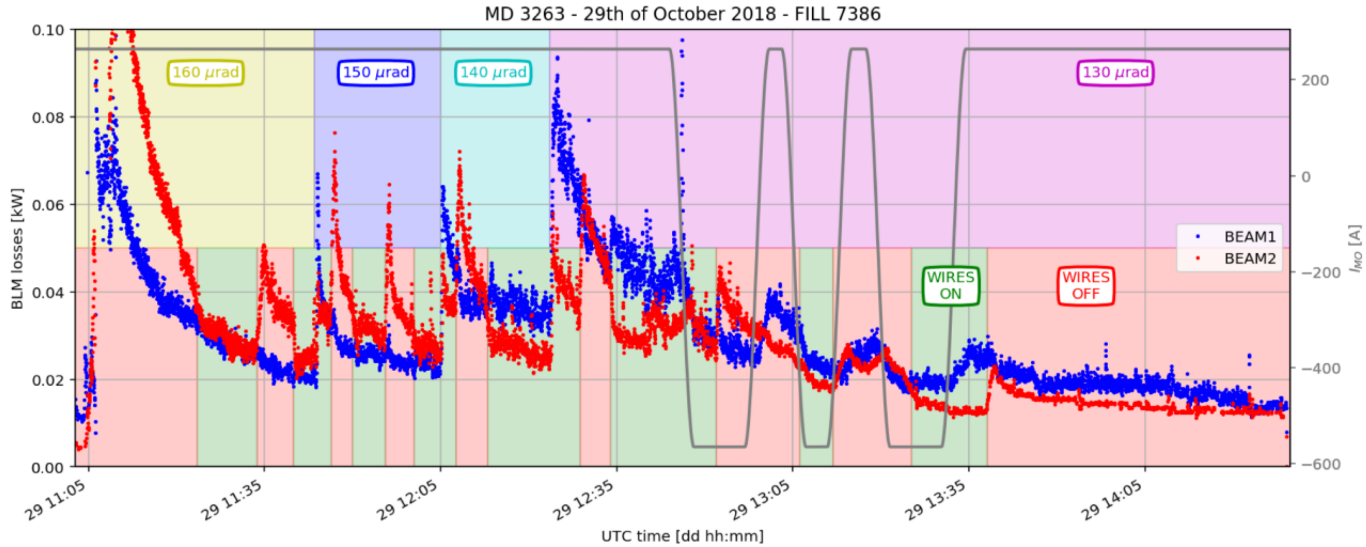
Motivations

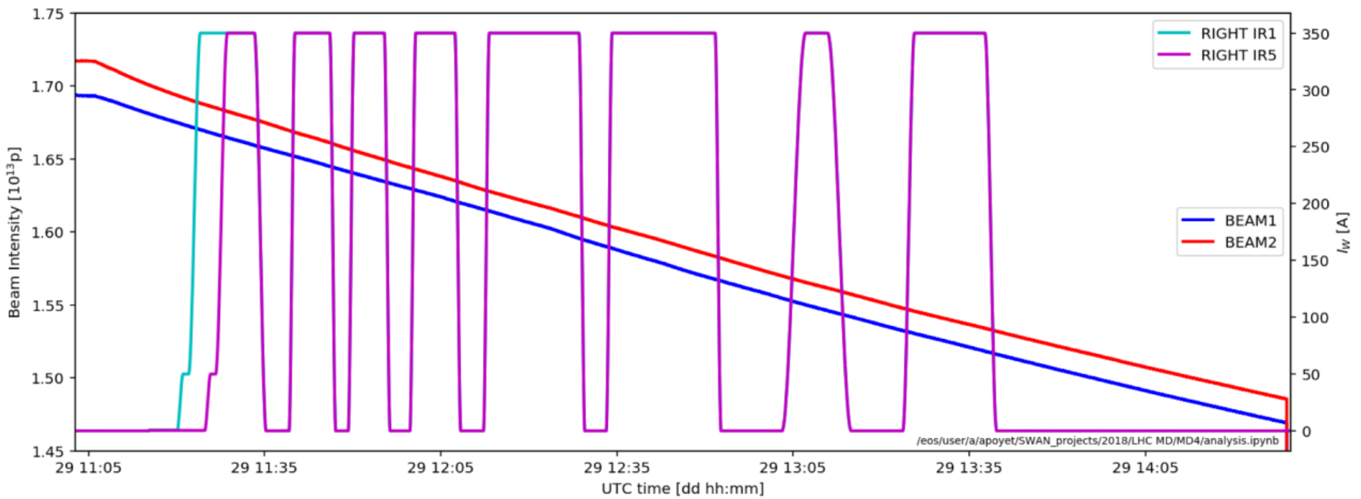
MD4: BBLR compensation with trains

MD4

29th October
FILL7386

TRAINS and NEW cabling

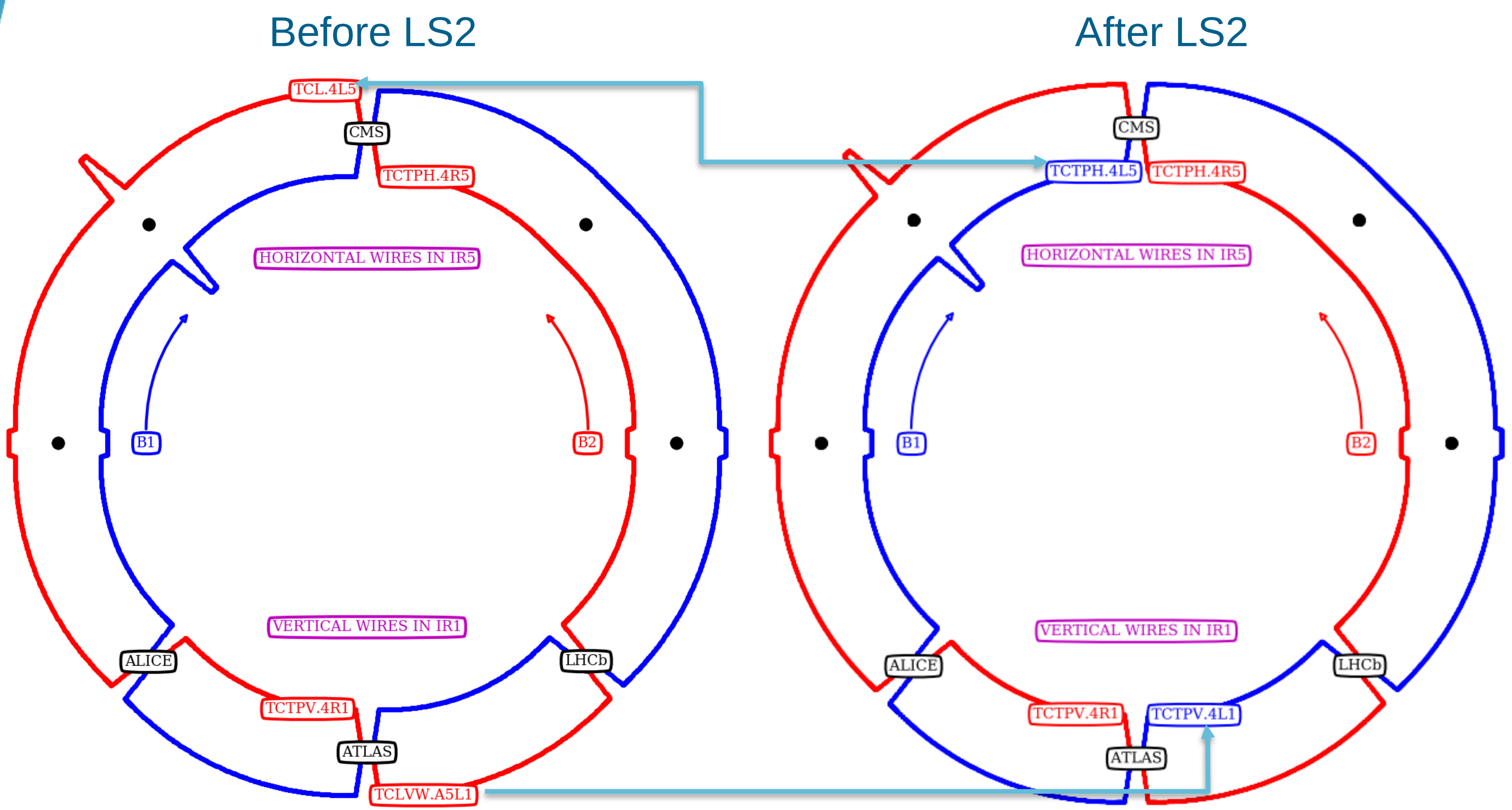




A. Poyet

- Very **clear compensation effect** even with trains and reduced crossing. Gain of ~10 µrad with wires on.

Changes during LS2



Courtesy of Guido Sterbini BE-ABP

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

Clear **potential to improve also B1** as shown for B2 during MD4.
Gain of operational experience with wires during operation in Run3 and prove potential for HL-LHC. **Wires used operationally**

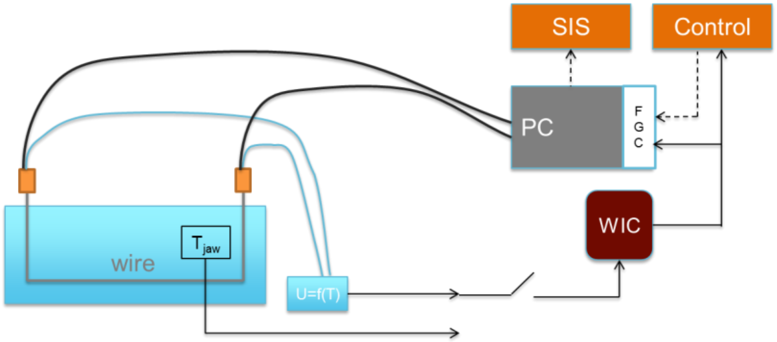
Present interlocks on wire

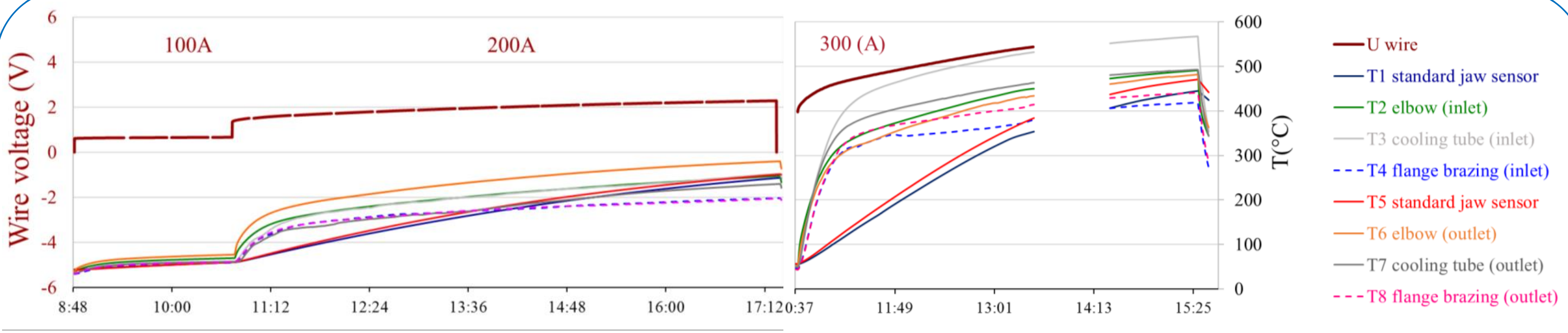
- Interlock to avoid wire overheating in case of loss of coolant: WIC cuts the power converter, no beam dump provided at present
- If power converter trips, for the moment no interlock foreseen

- Proposal: add beam dump for both cases
- Question: time constant?

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 side

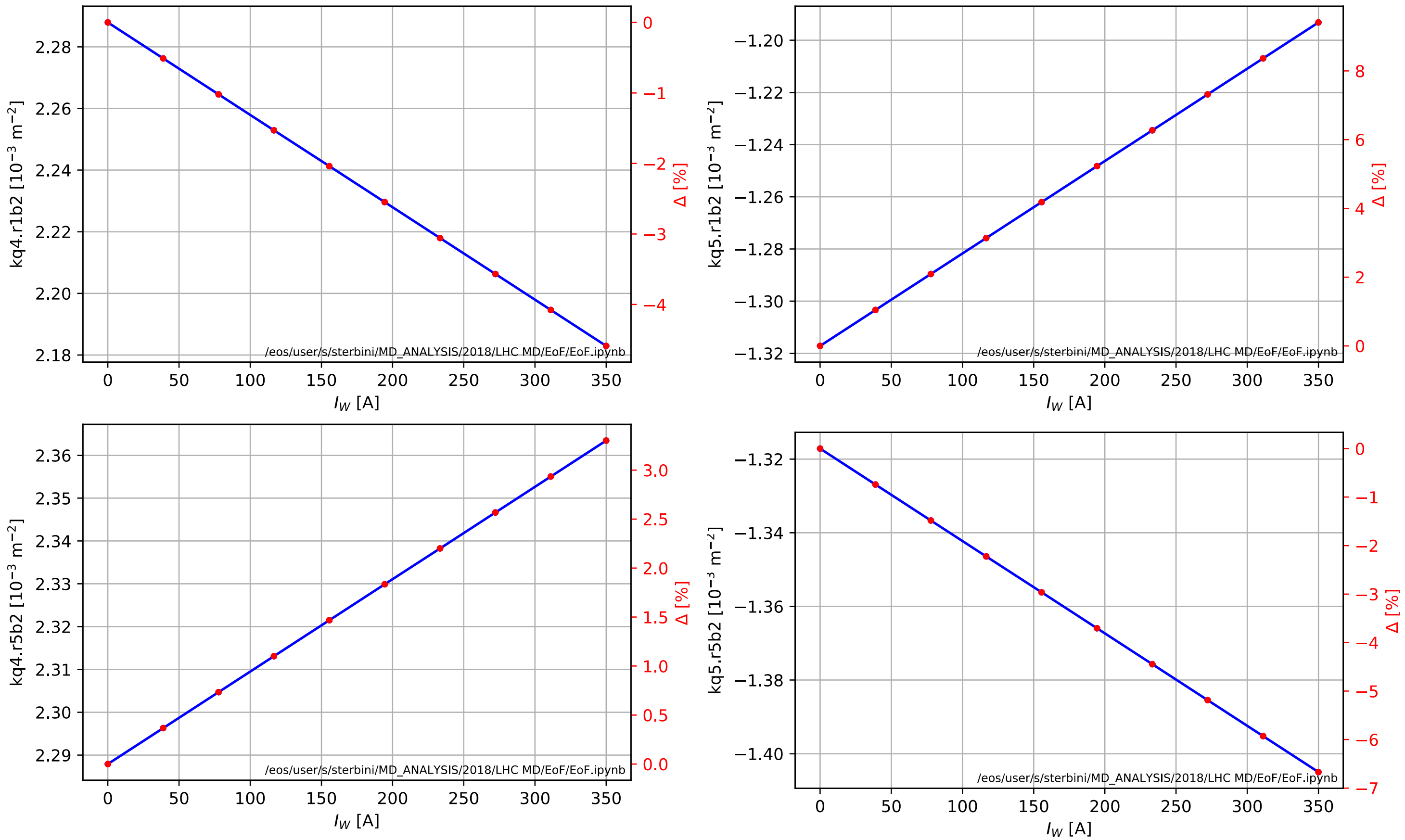




Tests performed on spare wire-in-jaw, under vacuum with no coolant

*Note this also correspond to Iw=375A

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.

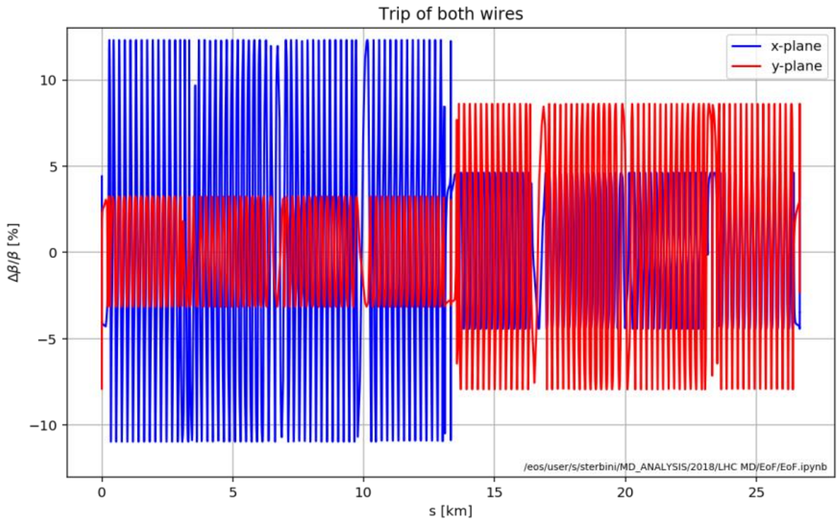
G. Sterbini, M. Solfaroli

What if a wire PCs trips?

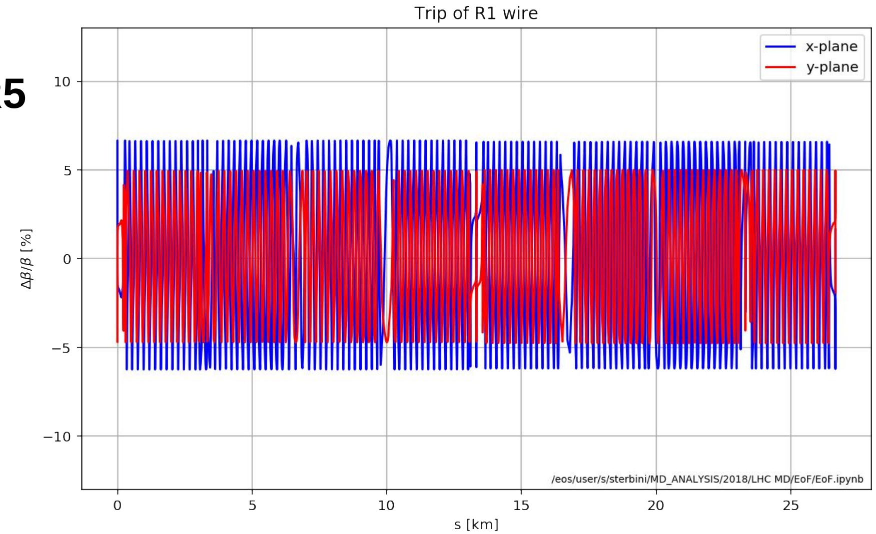
G. Sterbini

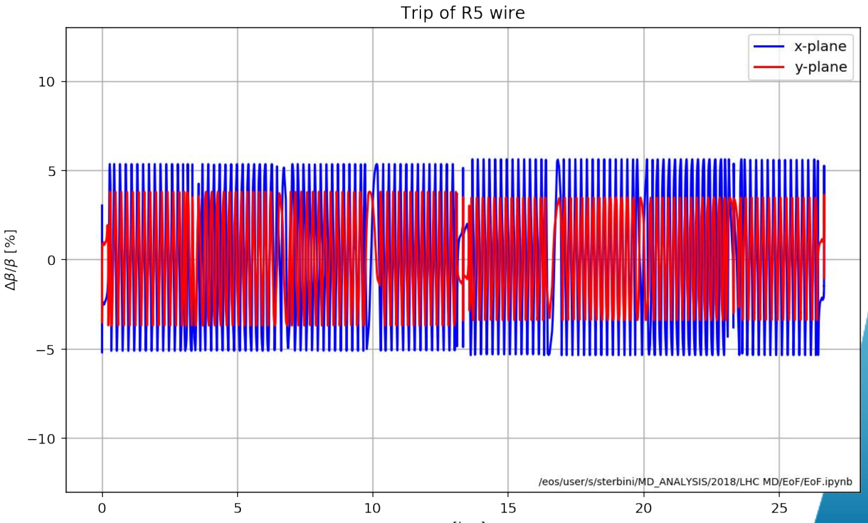
PRESENTLY IF the wire PC trips, the beam is **NOT** automatically dumped: the Q4/5 trim will cause tune shift and β-beating.

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

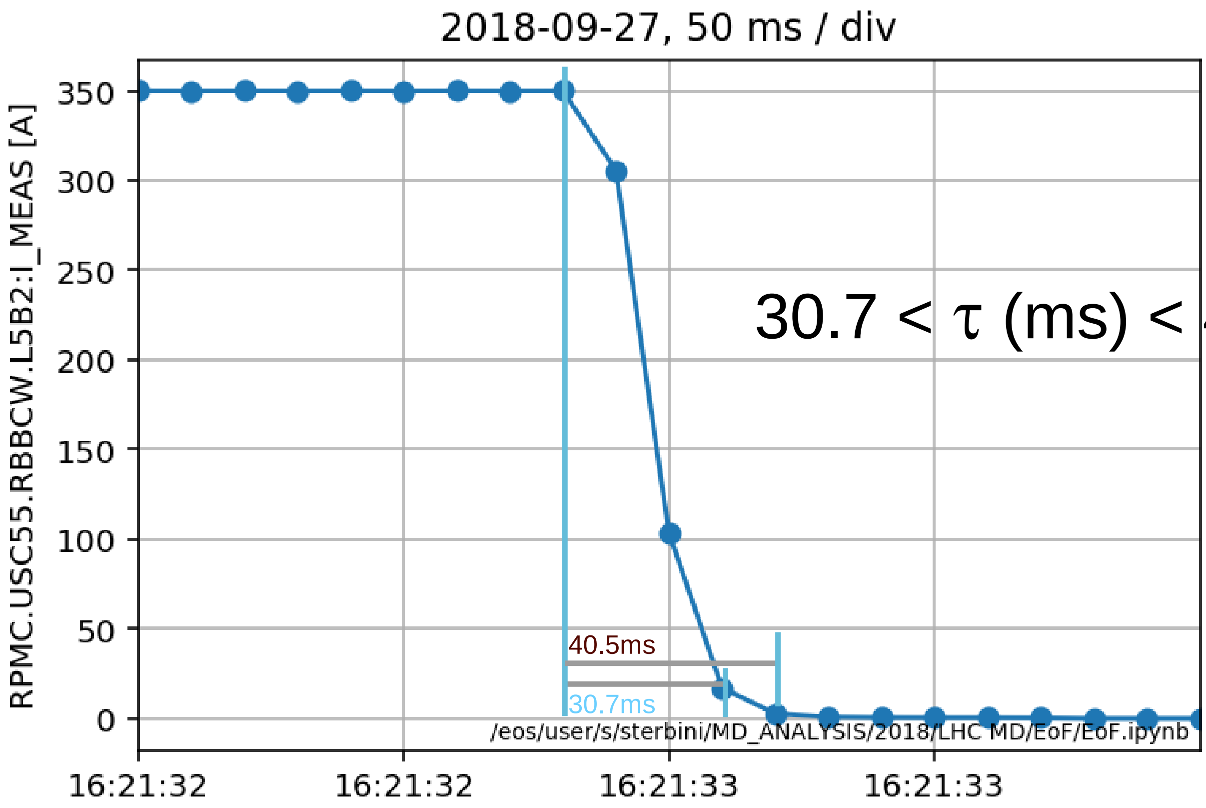
σ-setting	Nominal	Trip IR5
TCDQ.B4L6.B2	7.24	7.46
TCTPH.4R5.B2	8.5	8.43

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

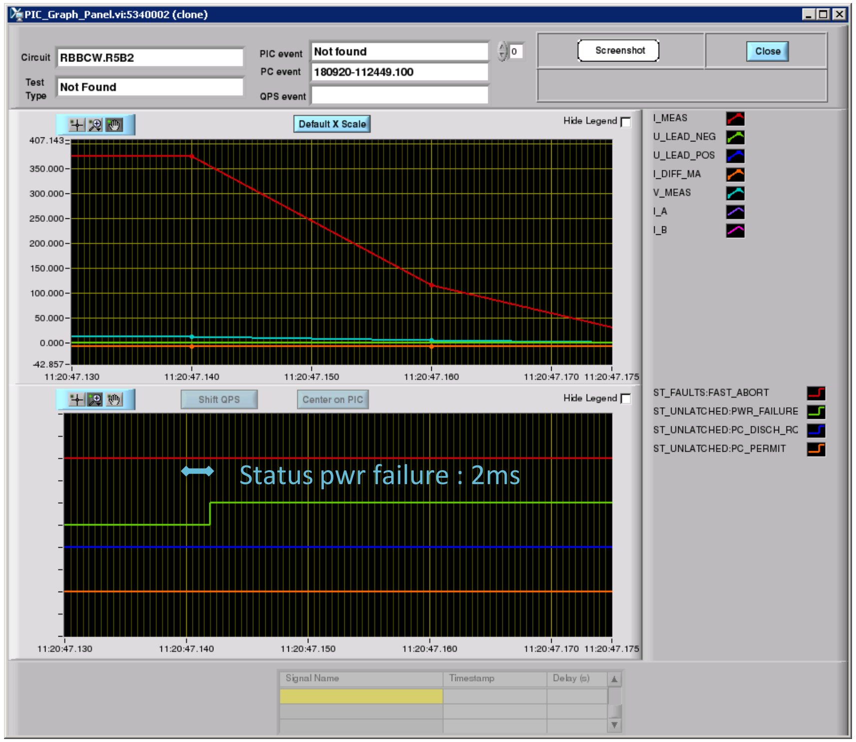
Time for the wire circuit to go to zero current

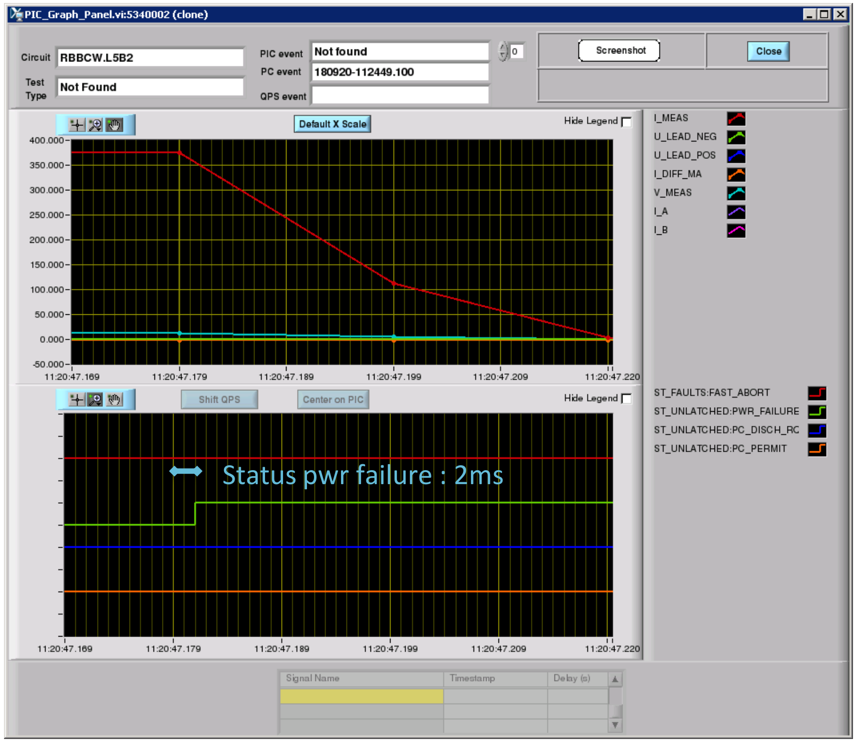


$30.7 < \tau$ (ms) < 40.5

Power converter characteristic times

RPMCx / LHC600A-40V





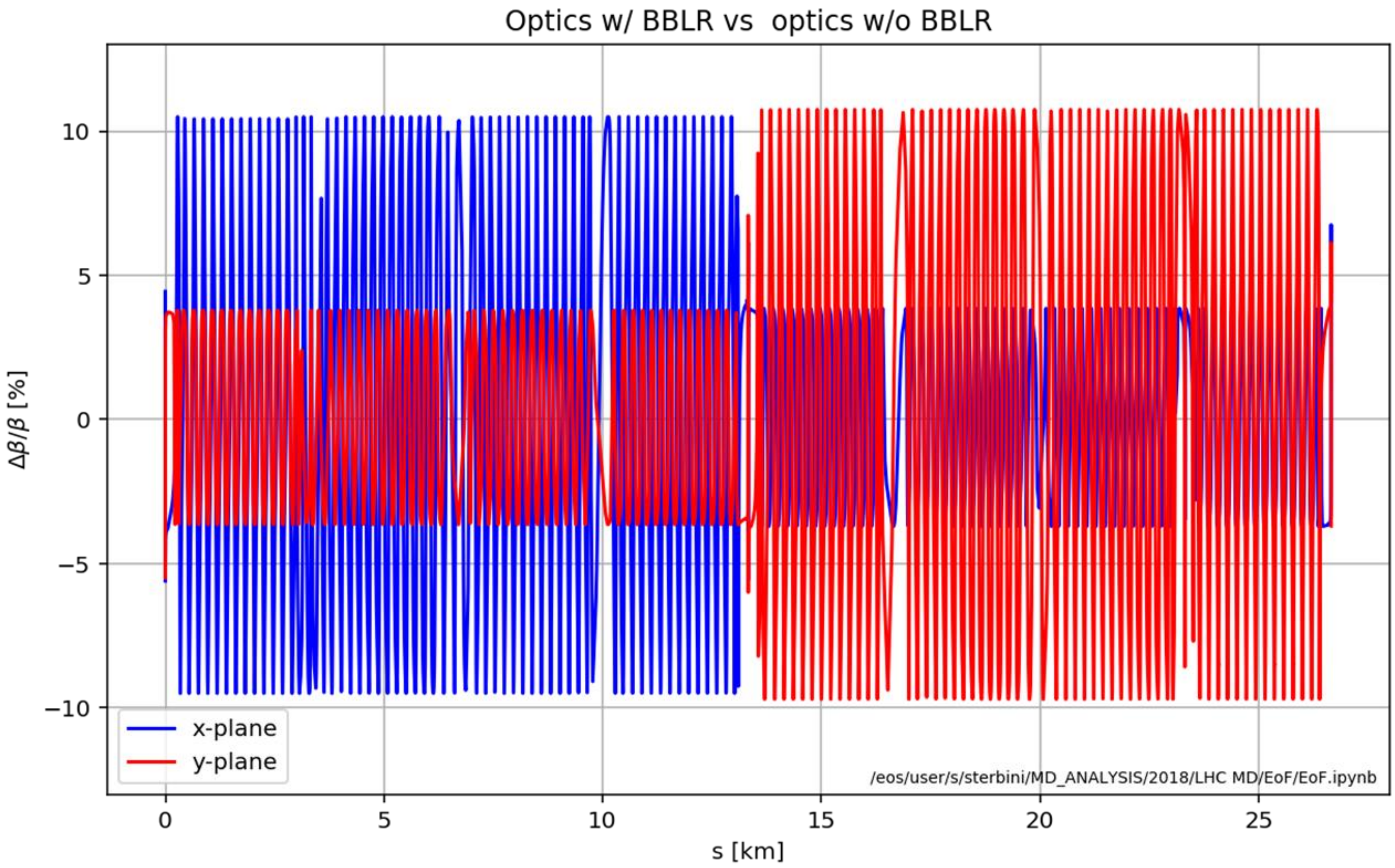
L. Ceccone TE-EPC

- ΔI_w (in 2ms) ~ 5A.
- WIC has the time to dump the beam before any effect of the Q4/5 trim can be noticed
- Note: Q4/5 trip $\propto$ to SET wire current. What to do if measured current $\neq$?

Summary and conclusions

- Wires will be used during RUN 3 on both beam, also operationally
- Wire interlocks have to be reviewed and a beam dump in case of water cooling or power converter failure should be introduced
- Time constants suggest that a ‘standard’ interlock from the WIC could be used

Thank you


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

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