Transverse Damping Requirements

Elias Métral for the instability team (and BE-ABP-HSC section)

6th HL-LHC Collaboration Meeting, Paris, 15/11/2016

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    - What is the role of e-cloud in the instabilities observed since 2015?

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  - E-cloud is the main worry
    - What is the role of e-cloud in the instabilities observed since 2015?
    - Can simulations explain the observations?
    - What will happen for HL-LHC?

Predicted beam stability without e-cloud

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- Nominal collimator settings for HL-LHC parameters and machine components for the present baseline: 2 CC/beam/IP side and low-impedance collimators in LSS7. Assumed here DQW cavities and machine at the end of the pre-squeeze => Further work has been done to reduce the impedance of a remaining HOM at 920 MHz by a factor ~ 20 (new table from 21-10-2016 used)

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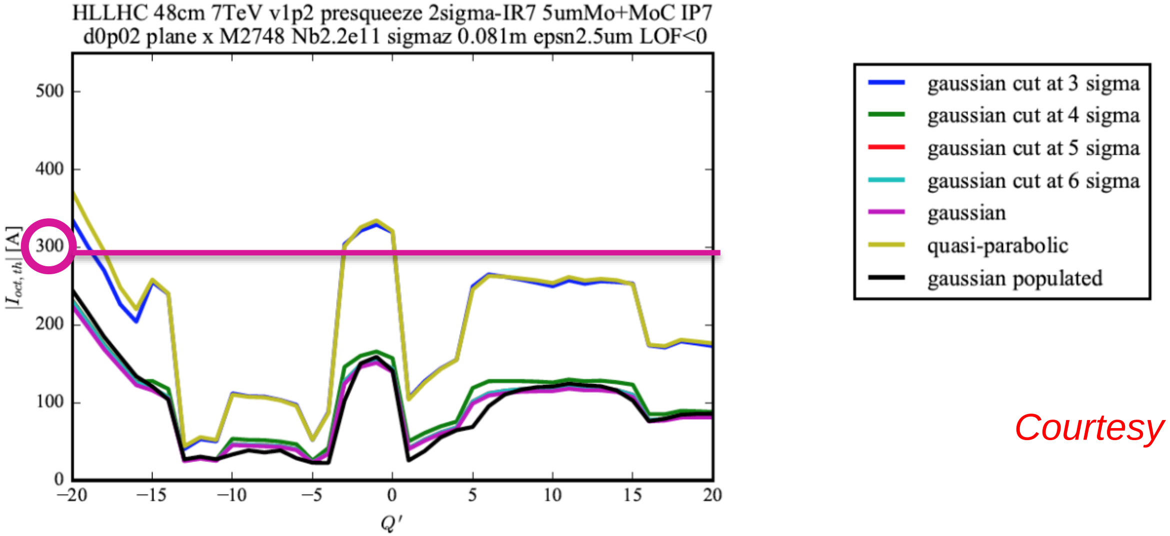
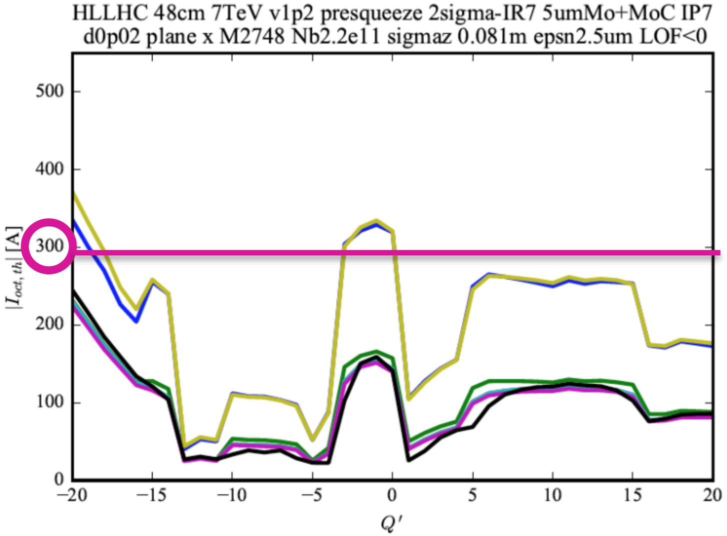
- Beam is stable for a current in the Landau octupoles (LOF) < ~ 300 A, what ever the sign and even if the transverse tails would be cut down to ~ 3 σ

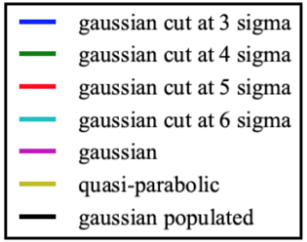
LOF < 0



Courtesy of N. Biancacci

LOF < 0





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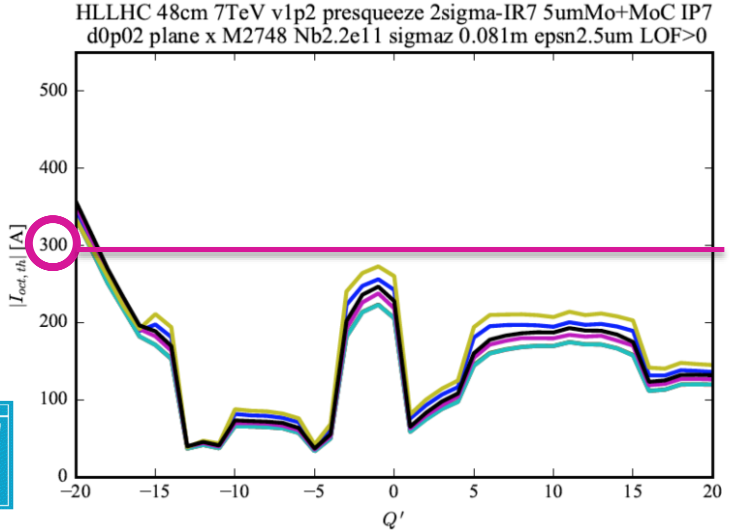
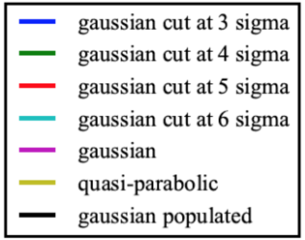
LOF > 0





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Parameter	***LHC***
Energy [TeV]	*7*
Bunch population [10^{11}]	*1.15*
Transv. emittance [μm]	*3.75*
Brightness [10^{11} / μm]	*0.31*

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Parameter	*LHC*	HL-LHC
Energy [TeV]	*7*	7
Bunch population [10^{11}]	*1.15*	2.2
Transv. emittance [μm]	*3.75*	2.5
Brightness [10^{11} / μm]	*0.31*	0.88

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Energy [TeV]	*7*	7	6.5
Bunch population [10^{11}]	*1.15*	2.2	**1.9**
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Brightness [10^{11} / µm]	*0.31*	0.88	1.27

Factor 4.1!

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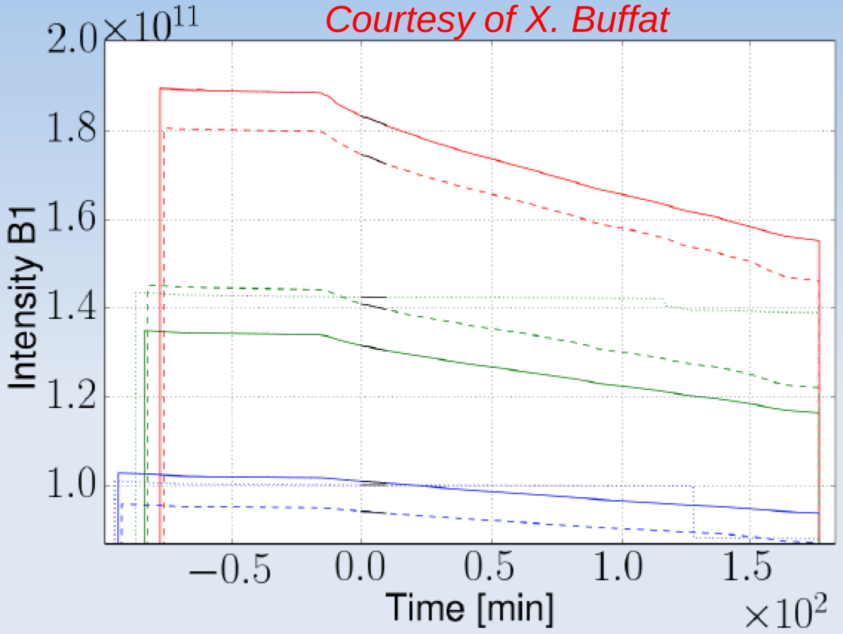
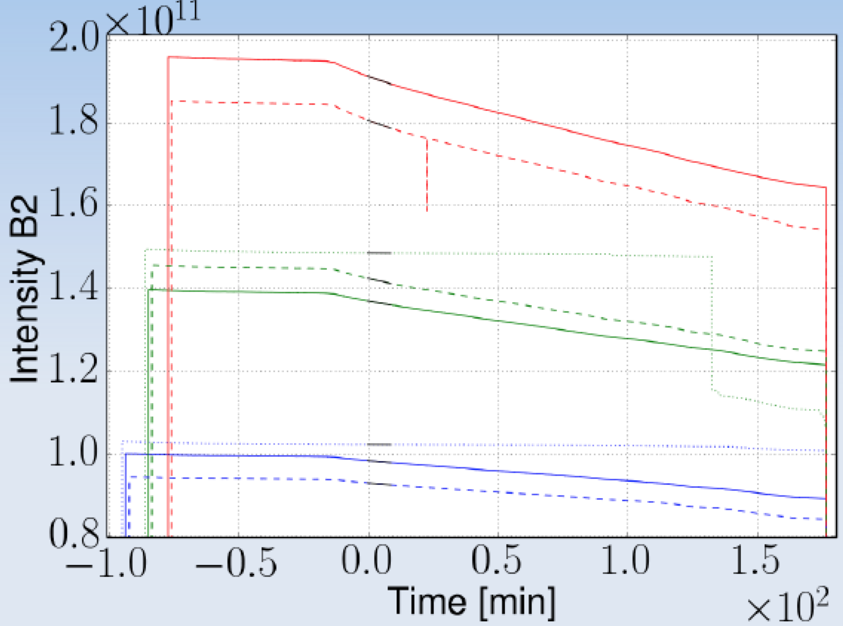
Parameter	*LHC*	HL-LHC	LHC 2016	Delta [%]
Energy [TeV]	*7*	7	6.5	- 7
Bunch population [10^{11}]	*1.15*	2.2	**1.9**	- 14
Transv. emittance [μm]	*3.75*	2.5	**1.5**	- 40
Brightness [10^{11} / μm]	*0.31*	0.88	1.27	**+ 44**

Factor 4.1!





Solid : 50 turns / colliding	High
Dashed : 200 turns / colliding	Intermediate
Fine dashed : 50 turns / non-colliding	Low

Tune shift	Measured loss rate [%/h]	Burn-off [%/h]
0.018±0.001	7.4±0.5	6.7±0.3
0.012±0.001	5.5±0.5	4.9±0.3
0.017±0.001	3.4±0.2	3.5±0.2

- Lifetime at the beginning of the study (highest beam-beam tune shift, without extra noise) is burn-off dominated

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  - Instability in physics with 600 bunches disappeared after coupling correction => A coupling (closest tune approach) of ~ 0.005 is bad!
  - A measurement from 2012 revealed an important coupling in October (~ 0.01)

Sunday 25/09/16, Fill #5332: Instability with 600 bunches

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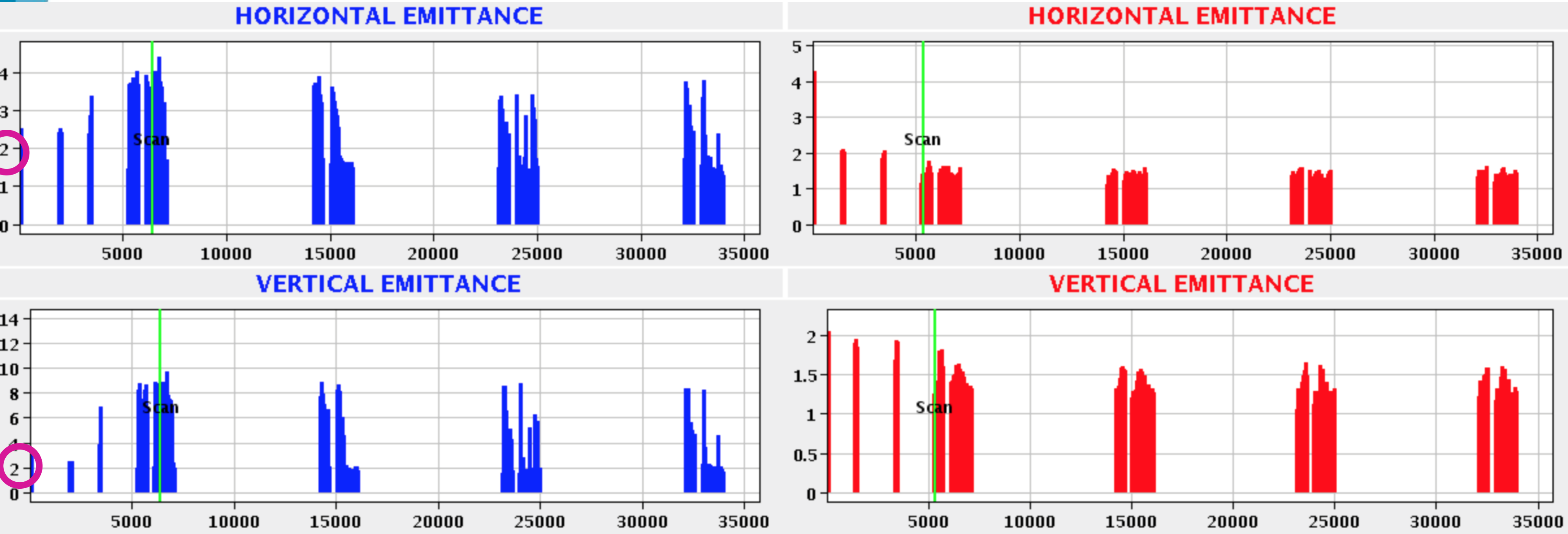


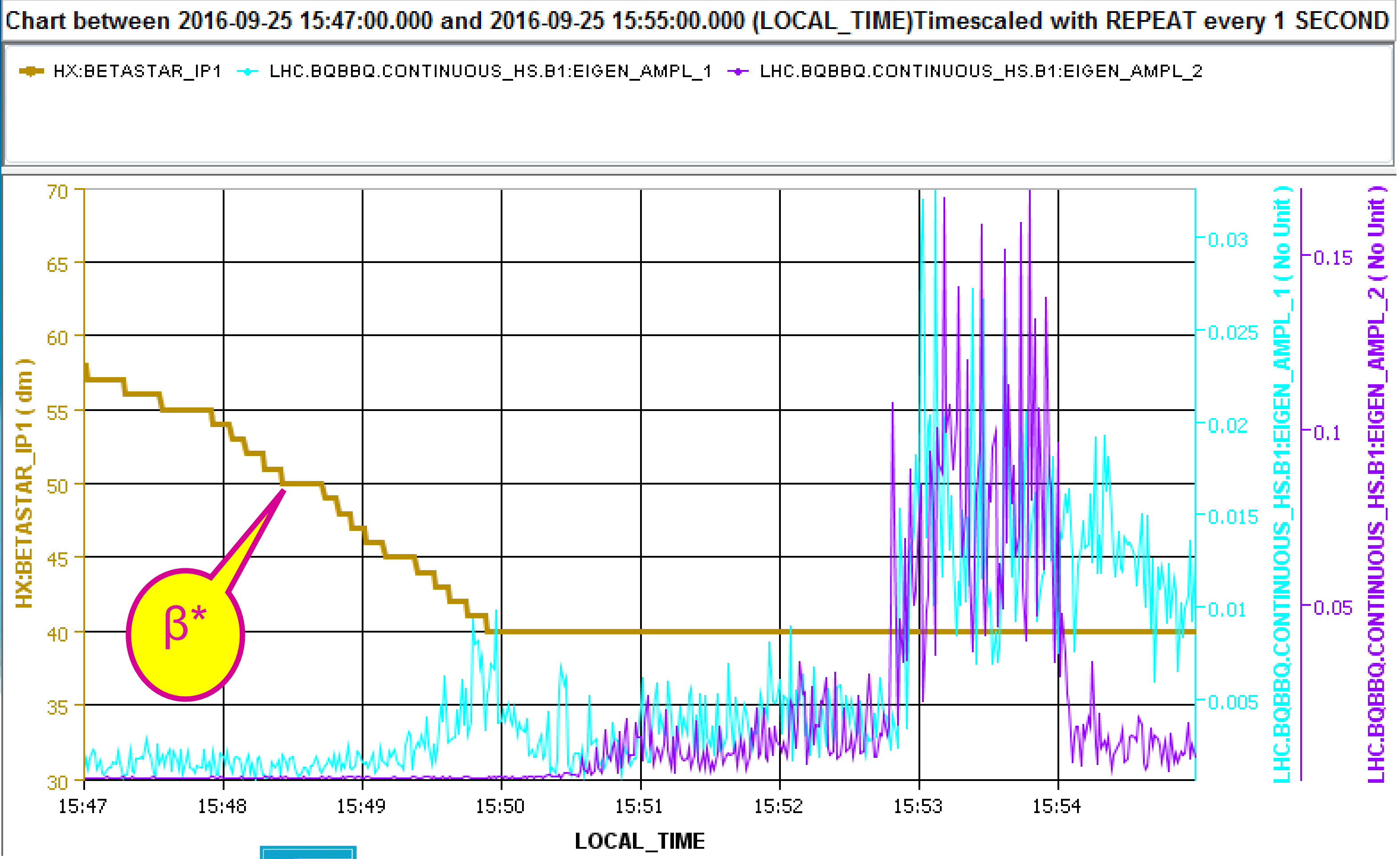
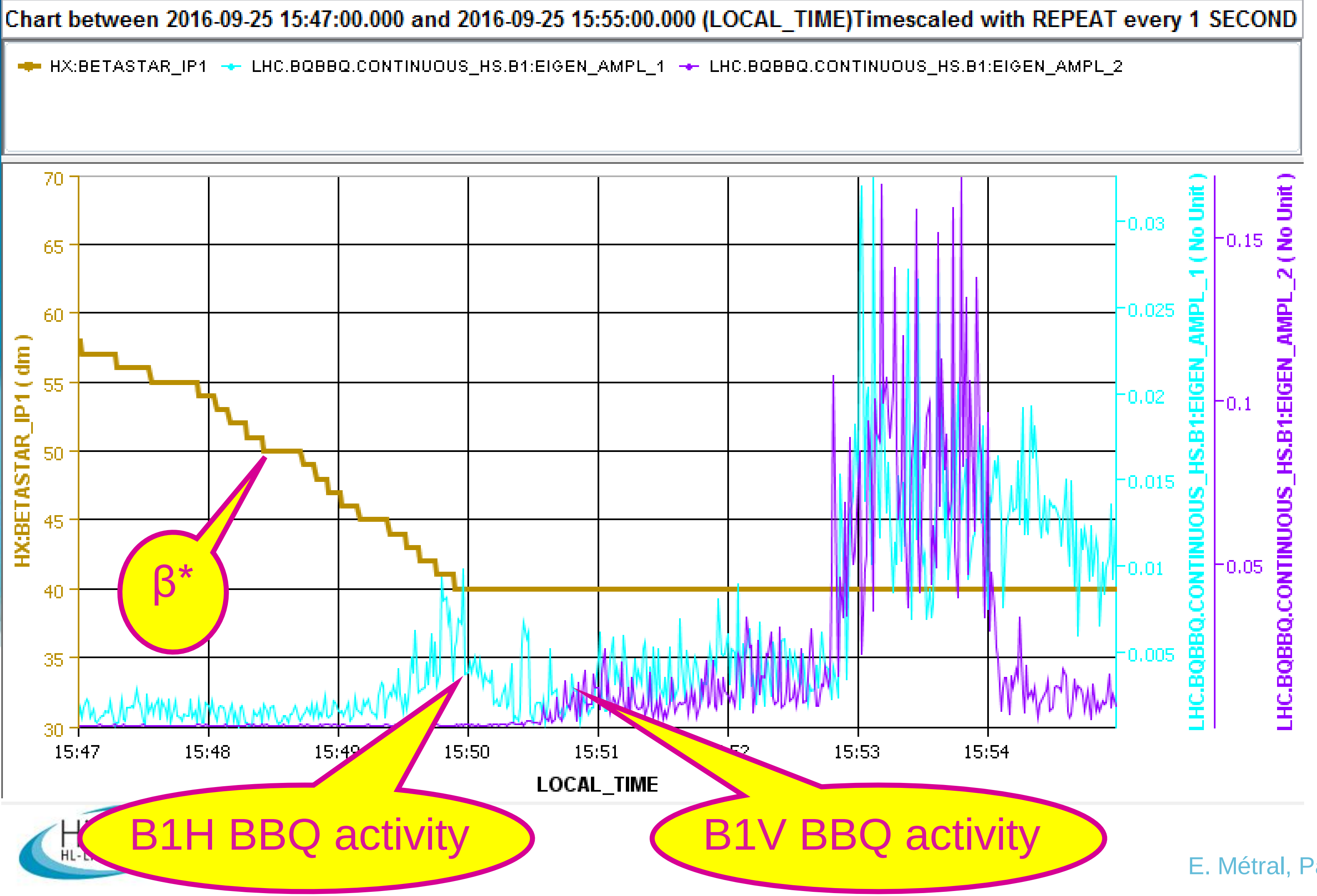


Chart between 2016-09-25 15:47:00.000 and 2016-09-25 15:55:00.000 (LOCAL_TIME)Timescaled with REPEAT every 1 SECOND
HX:BETASTAR_IP1
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2
HX:BETASTAR_IP1 (dm)
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1 (No Unit)
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2 (No Unit)
70
65
60
55
50
45
40
35
30
0.03
0.025
0.02
0.015
0.01
0.005
0.15
0.1
0.05
15:47
15:48
15:49
15:50
15:51
15:52
15:53
15:54
LOCAL_TIME
β*



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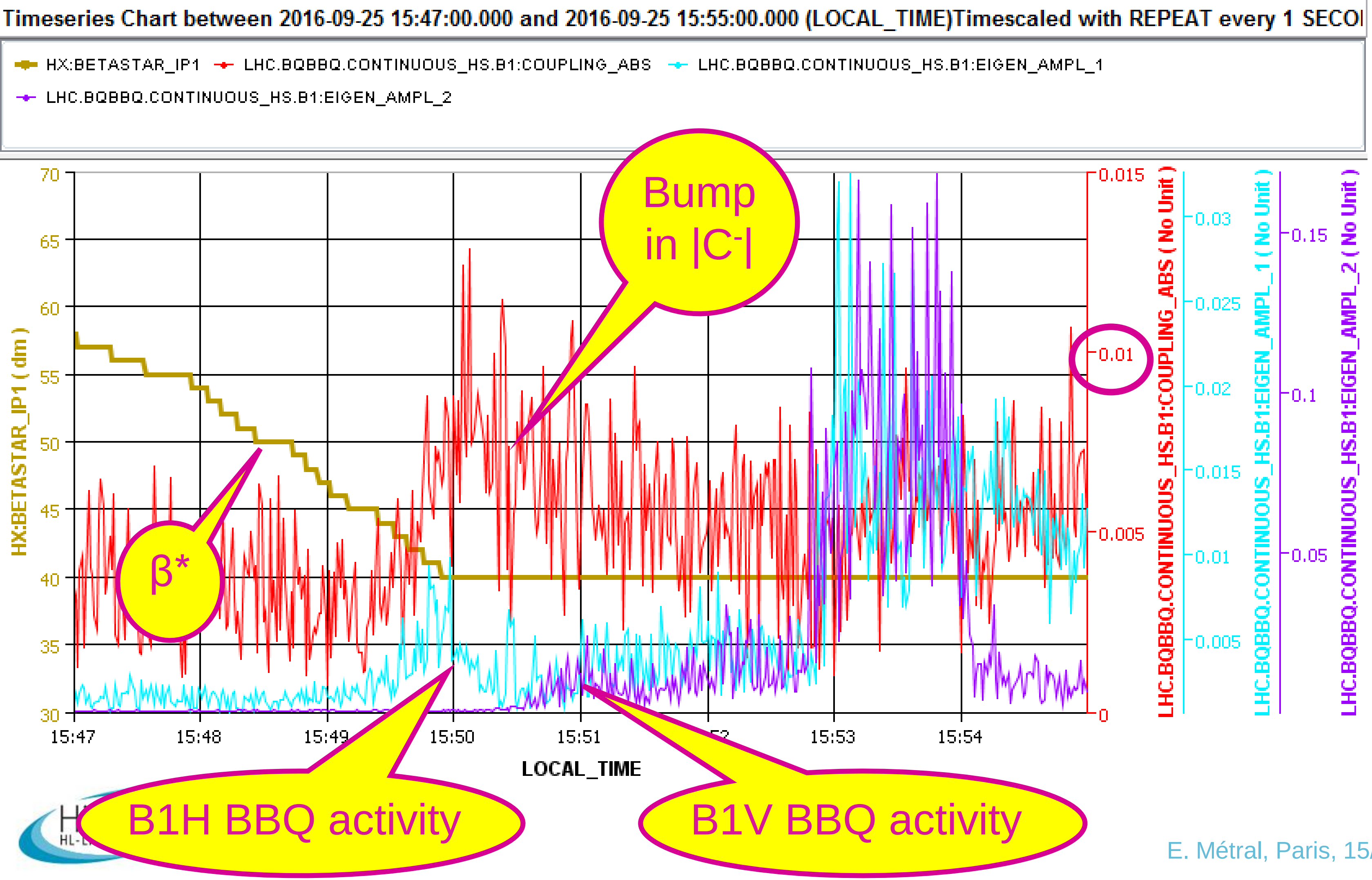
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1 (No Unit)
0.15
0.1
0.05
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2 (No Unit)
15:47
15:48
15:50
15:51
15:53
15:54
LOCAL_TIME
β*
B1H BBQ activity
B1V BBQ activity


Timeseries Chart between 2016-09-25 15:47:00.000 and 2016-09-25 15:55:00.000 (LOCAL_TIME)Timescaled with REPEAT every 1 SECOI
HX:BETASTAR_IP1
LHC.BQBBQ.CONTINUOUS_HS.B1:COUPLING_ABS
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2
HX:BETASTAR_IP1 (dm)
70
65
60
55
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35
30
15:47
15:48
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15:50
15:51
15:53
15:54
LOCAL_TIME
0.015
0.01
0.005
0
LHC.BQBBQ.CONTINUOUS_HS.B1:COUPLING_ABS (No Unit)
0.03
0.025
0.02
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0.01
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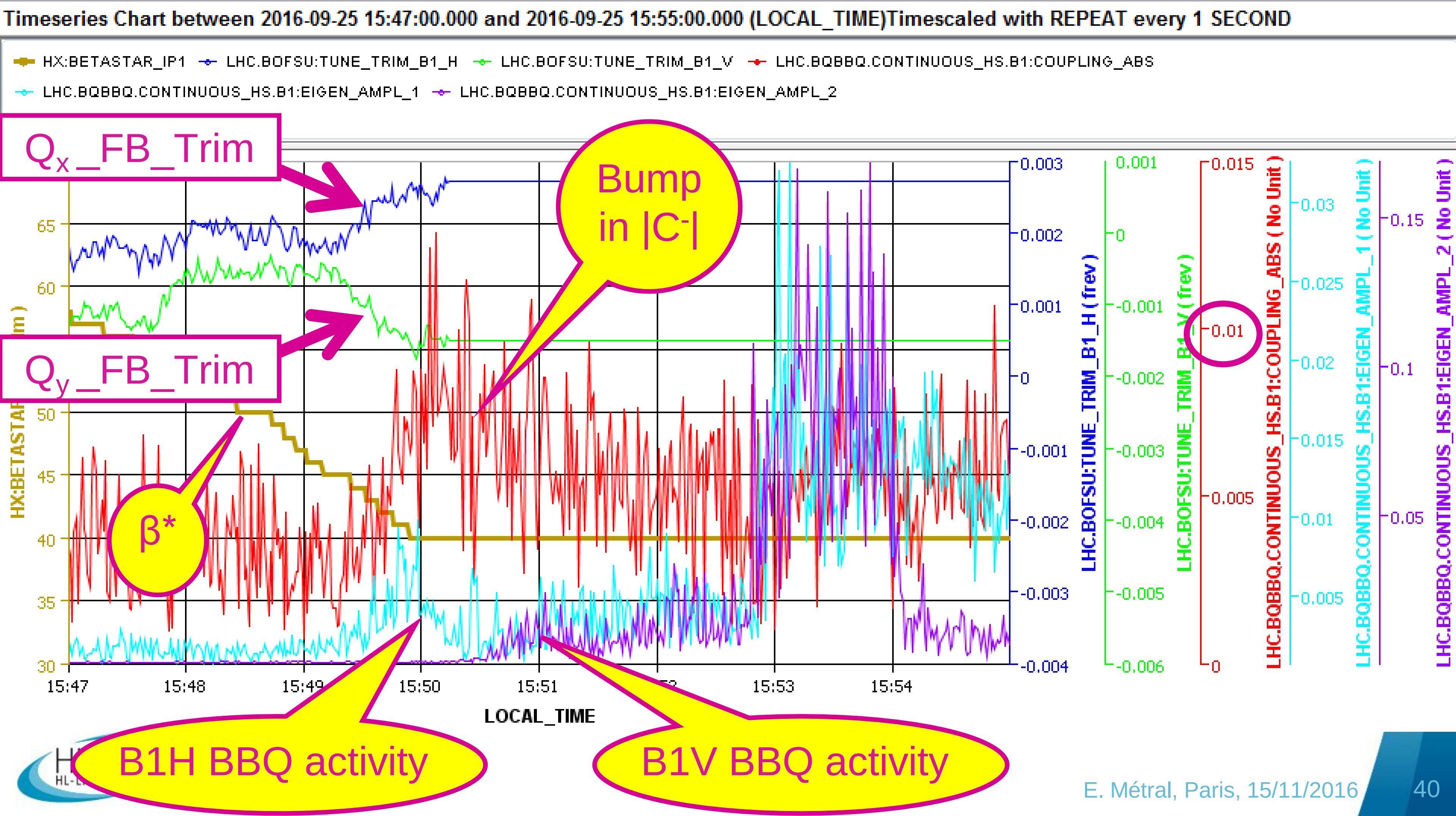
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1 (No Unit)
0.15
0.1
0.05
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2 (No Unit)
Bump in |C-|
β*
B1H BBQ activity
B1V BBQ activity



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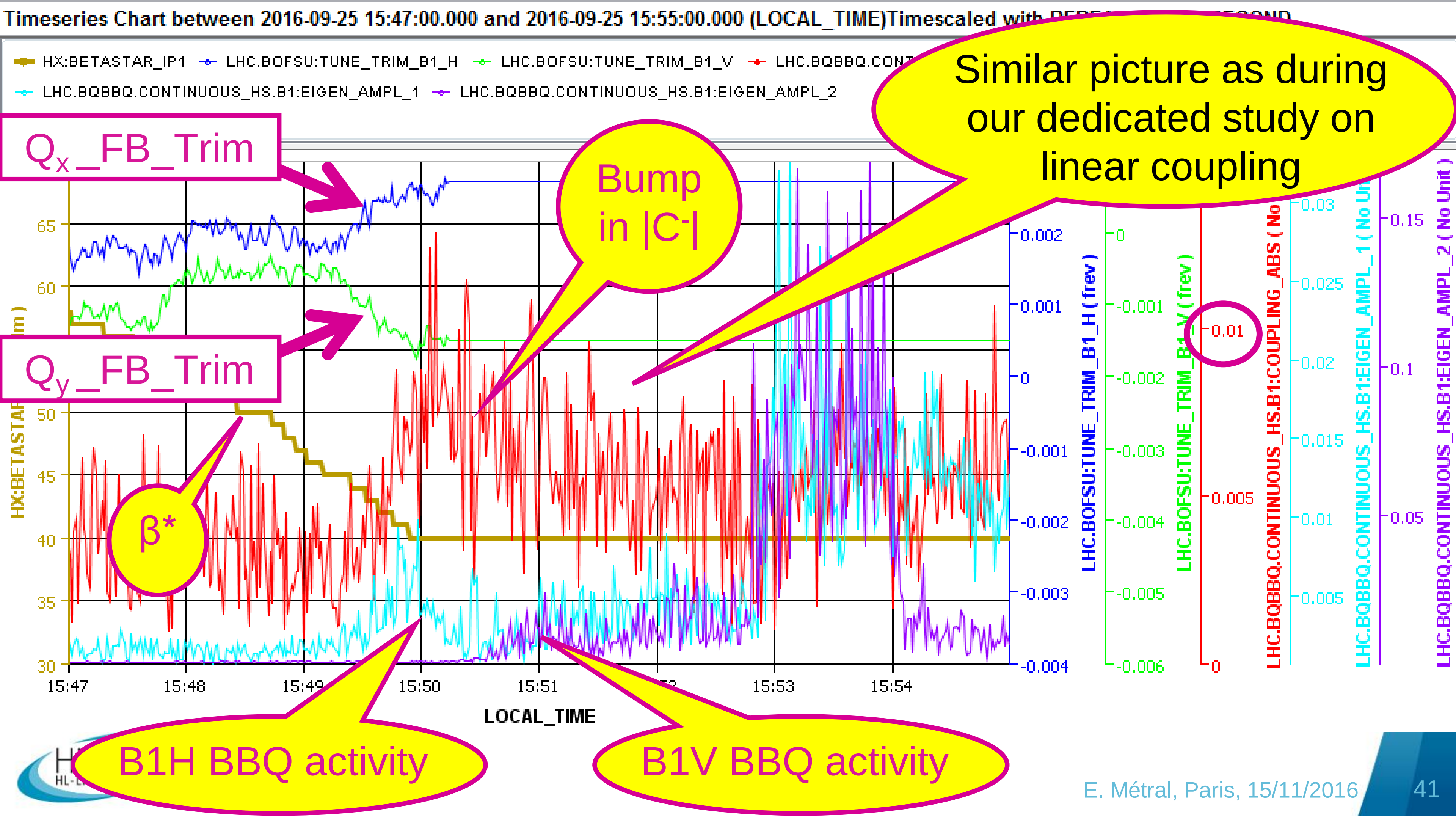
LHC.BOFSU:TUNE_TRIM_B1_H
LHC.BOFSU:TUNE_TRIM_B1_V
LHC.BQBBQ.CONTINUOUS_HS.B1:COUPLING_ABS
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2
Qx _FB_Trim
Qy _FB_Trim
Bump in |C-|
β*
B1H BBQ activity
B1V BBQ activity
LOCAL_TIME
15:47
15:48
15:49
15:50
15:51
15:53
15:54
HX:BETASTAR
LHC.BOFSU:TUNE_TRIM_B1_H (frev)
LHC.BOFSU:TUNE_TRIM_B1_V (frev)
LHC.BQBBQ.CONTINUOUS_HS.B1:COUPLING_ABS (No Unit)
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1 (No Unit)
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2 (No Unit)



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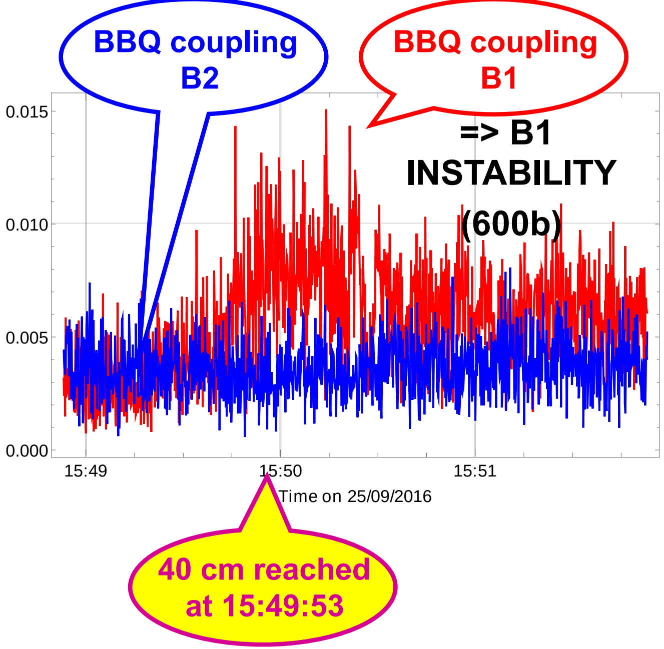
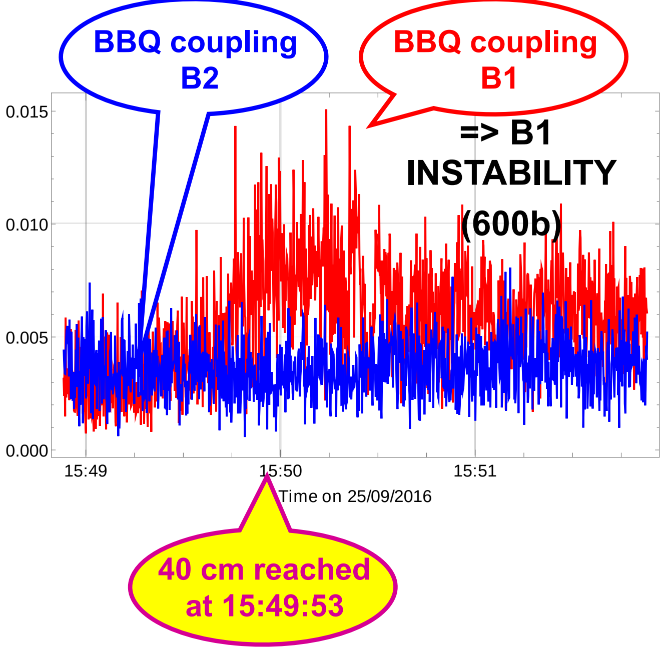
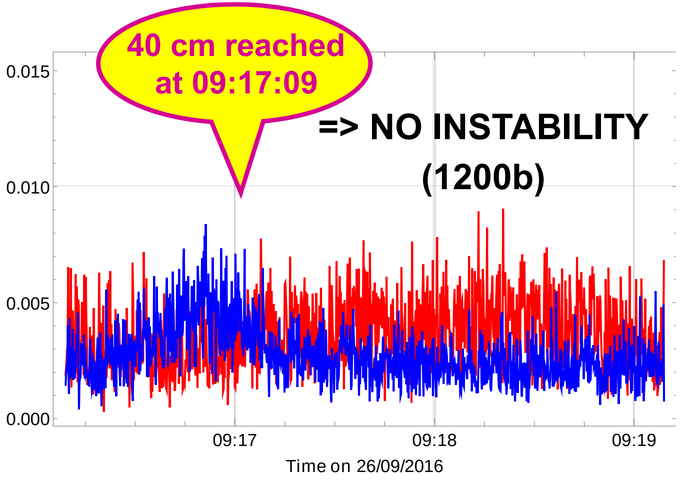
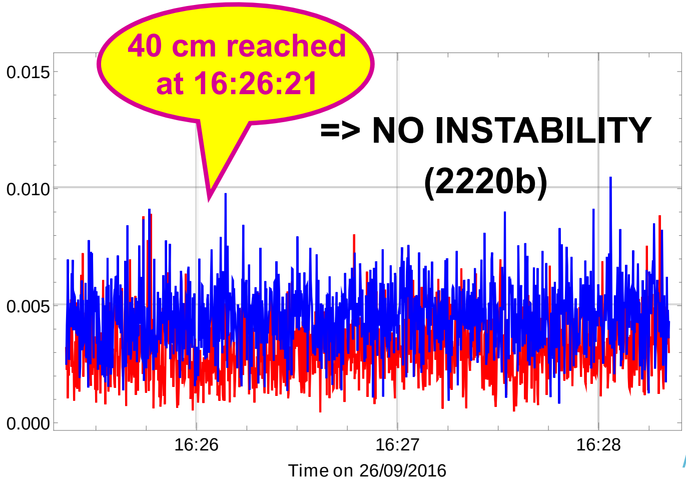
HX:BETASTAR_IP1
LHC.BOFSU:TUNE_TRIM_B1_H
LHC.BOFSU:TUNE_TRIM_B1_V
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2
Similar picture as during our dedicated study on linear coupling
Q_x_FB_Trim
Q_y_FB_Trim
Bump in |C⁻|
β*
B1H BBQ activity
B1V BBQ activity
LOCAL_TIME
15:47
15:48
15:49
15:50
15:51
15:53
15:54
30
35
40
45
50
60
65
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
LHC.BOFSU:TUNE_TRIM_B1_H (frev)
-0.003
-0.004
-0.005
-0.006
0.01
0.005
LHC.BQBBQ.CONTINUOUS_HS.B1:COUPLING_ABS (No
0.03
0.025
0.02
0.015
0.01
0.005
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_1 (No Un
0.15
0.1
0.05
LHC.BQBBQ.CONTINUOUS_HS.B1:EIGEN_AMPL_2 (No Unit)


BBQ coupling B2
BBQ coupling B1
=> B1 INSTABILITY (600b)
0.015
0.010
0.005
0.000
15:49
15:50
15:51
Time on 25/09/2016
40 cm reached at 15:49:53

Linear coupling was then corrected







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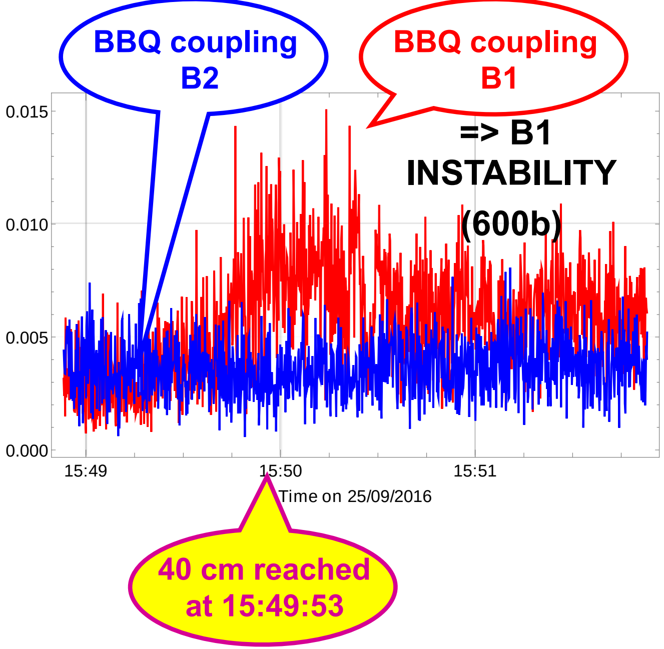

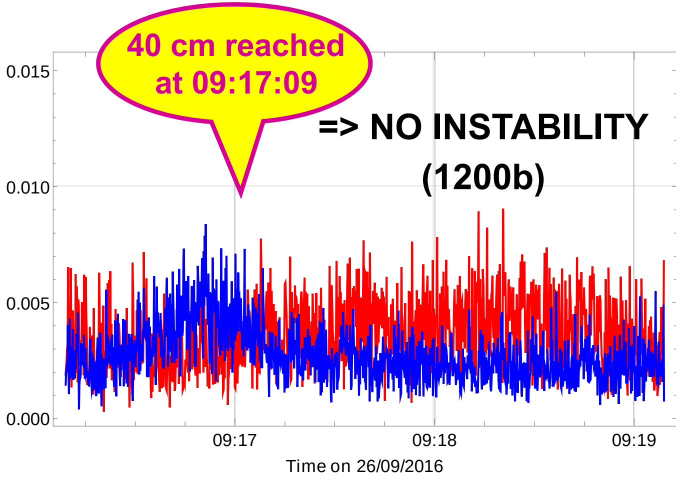

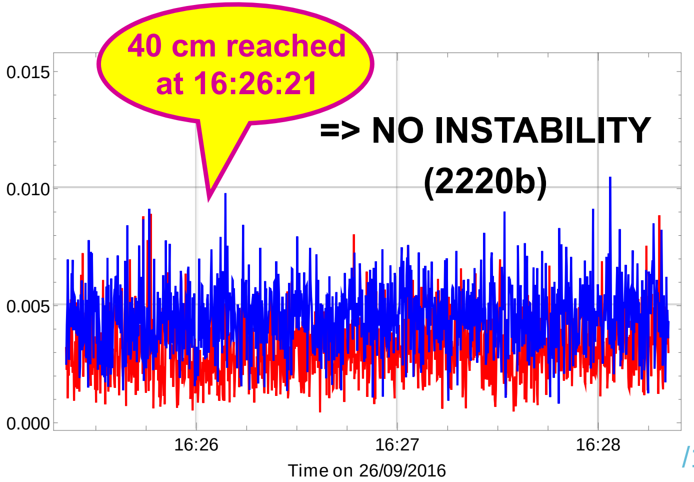

- Warning for BBQ coupling => Measurement from OMC team with AC dipole + pilot:
  - ~ 0.005 before correction
  - < 0.001 after correction

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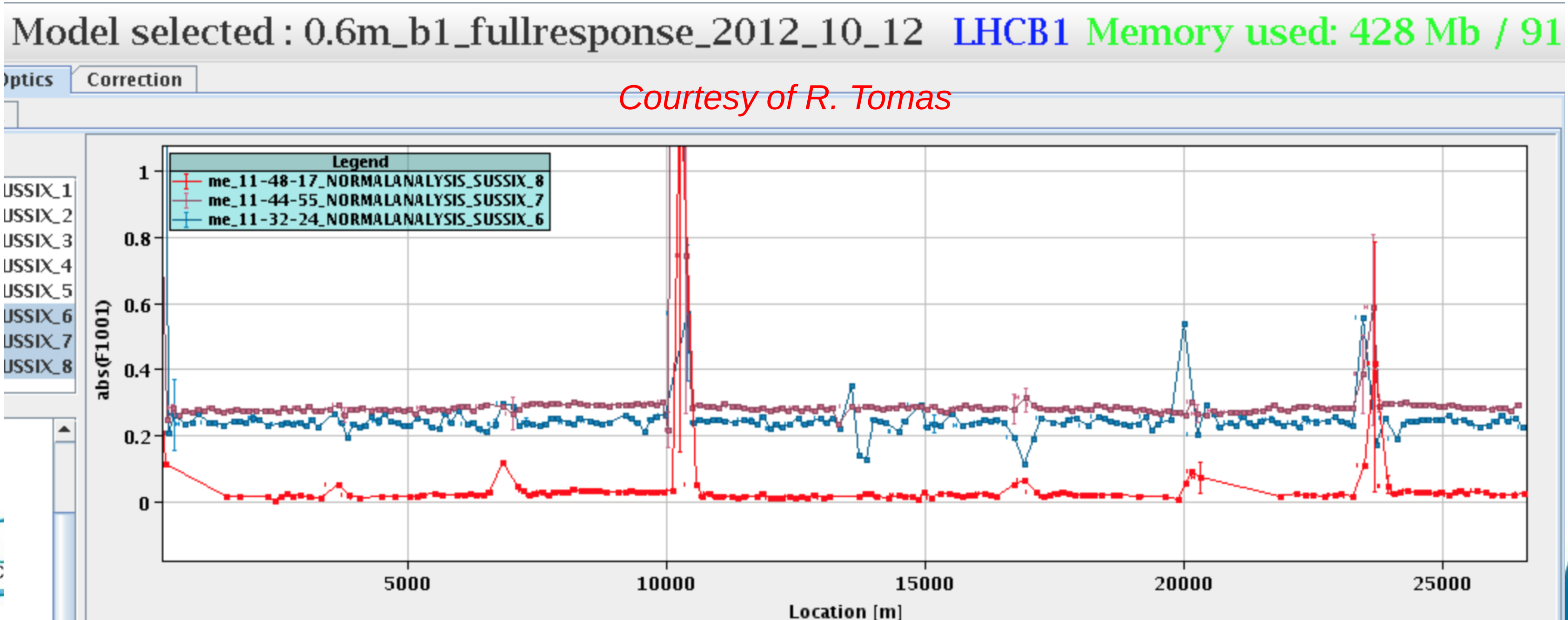

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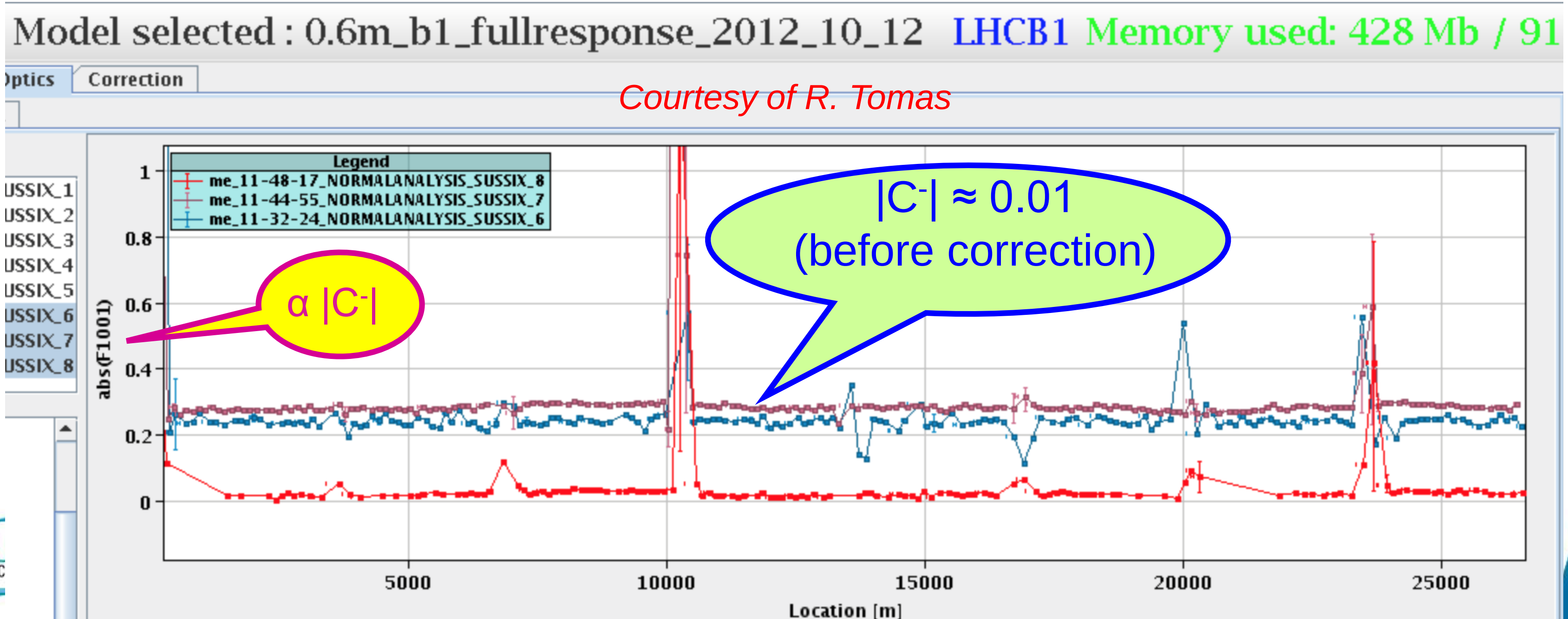

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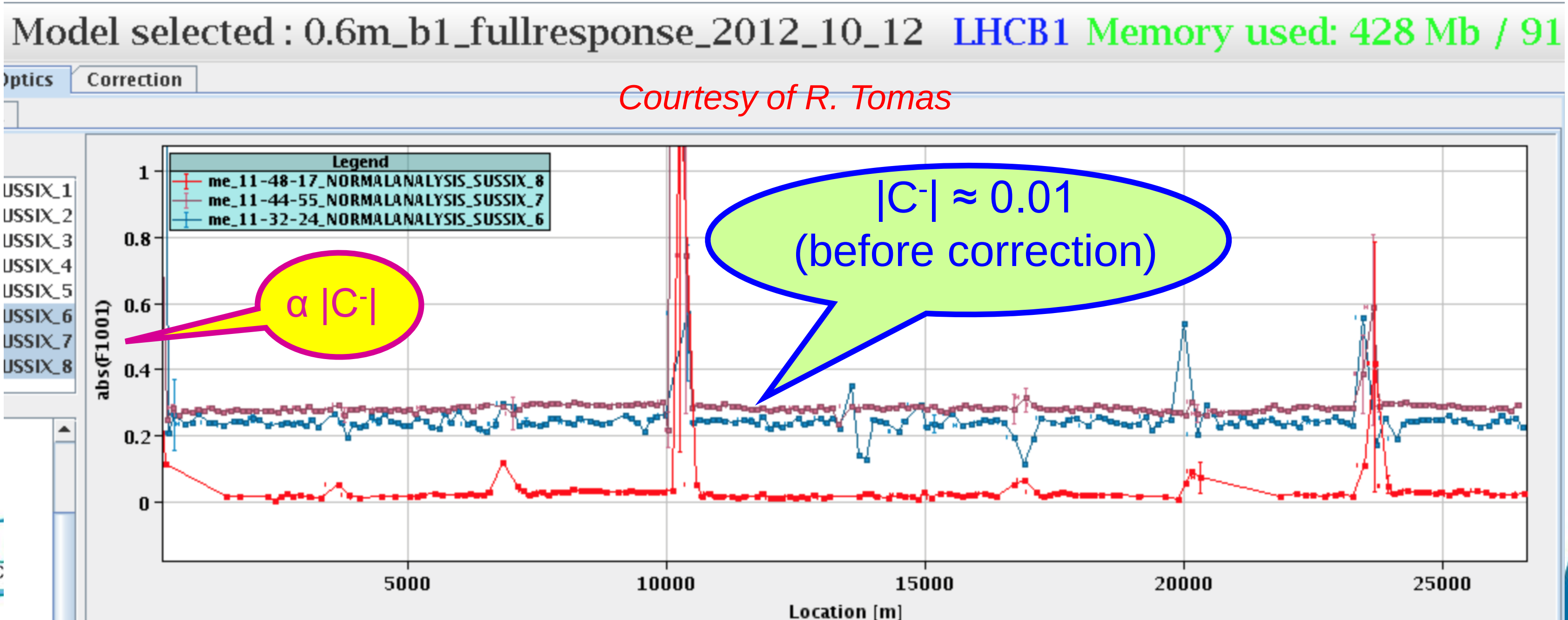

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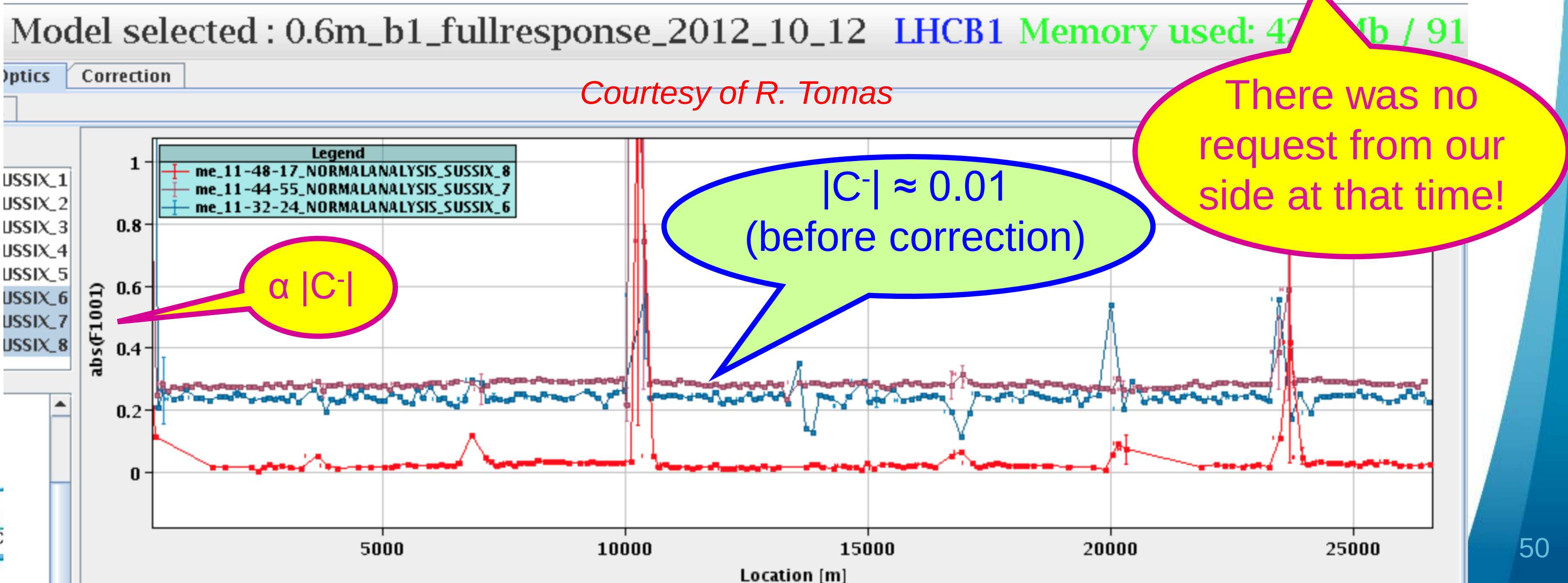

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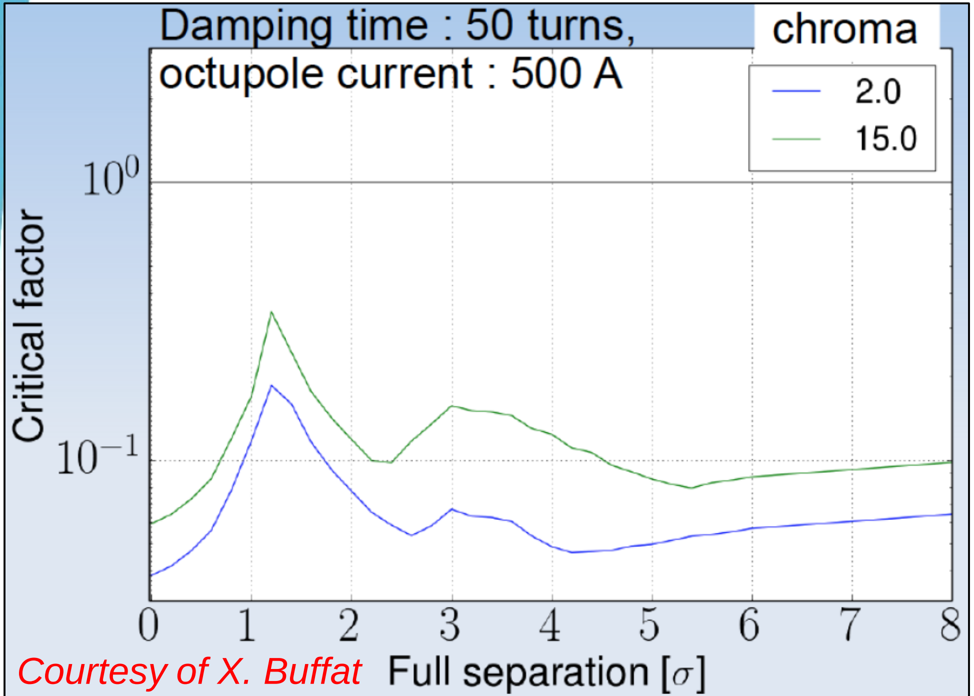

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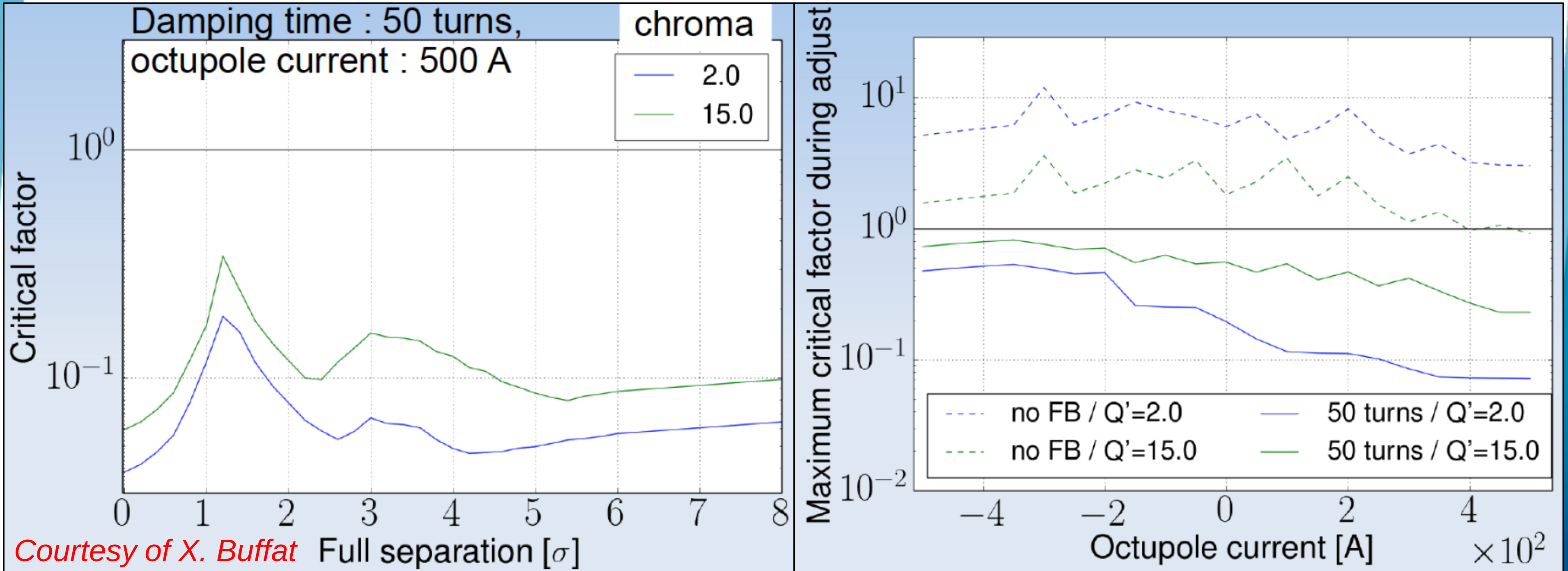

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- No instabilities were observed in dedicated tests with reduced octupole current and chromaticity
- A strong instability was observed when the damper was off (as predicted)
- Some instabilities observed in ADJUST in the vertical plane of B1 during physics fill and some studies remain to be understood…

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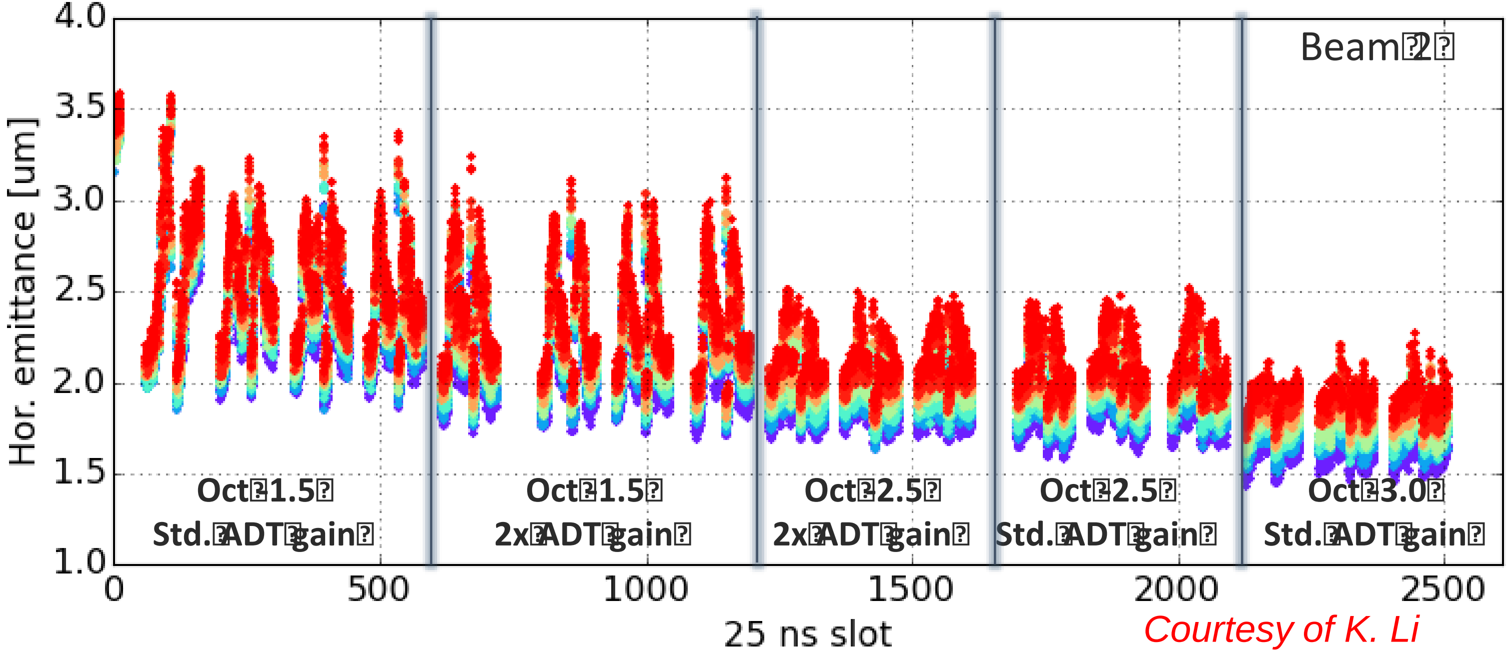
Fill #5217, 18/08/16 => Similar results for H and V



Courtesy of K. Li

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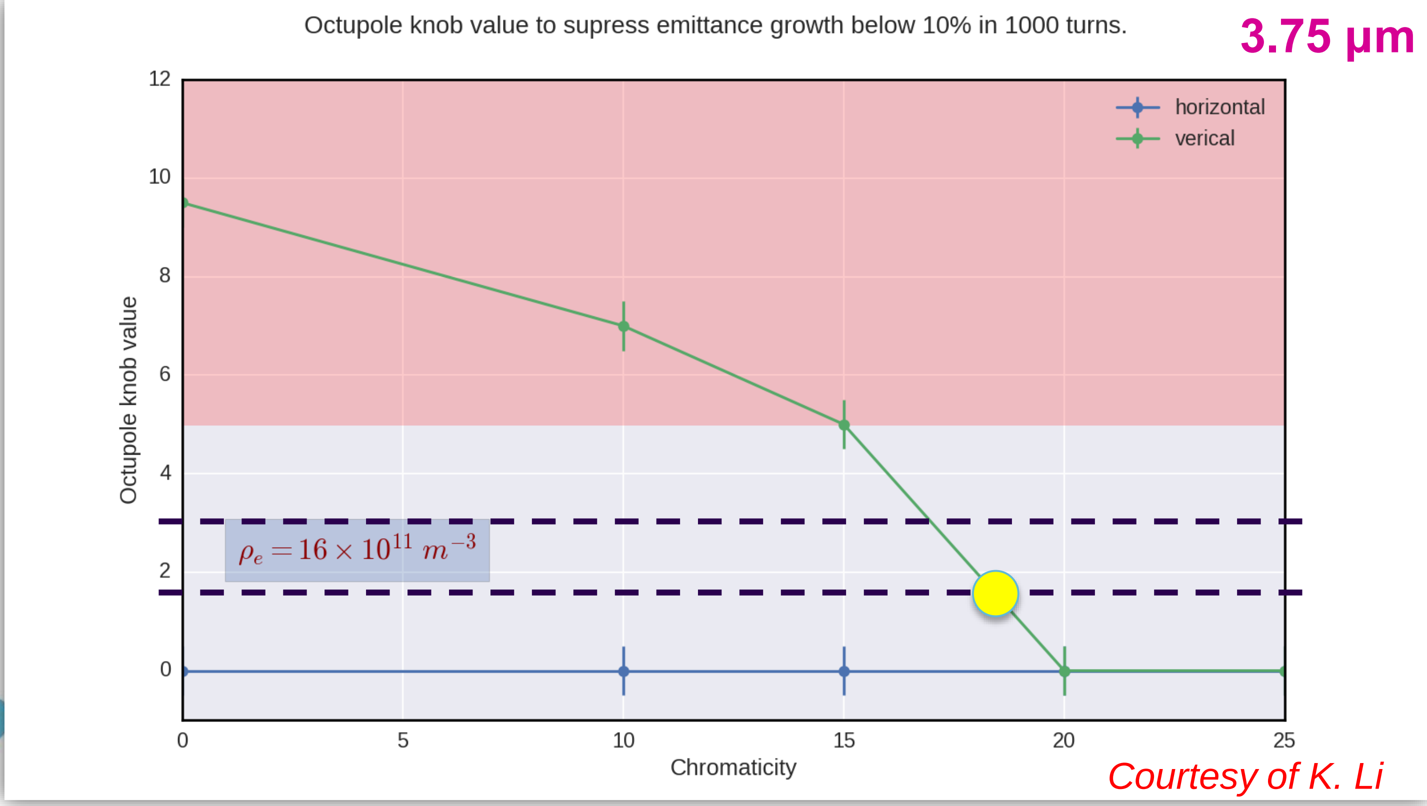

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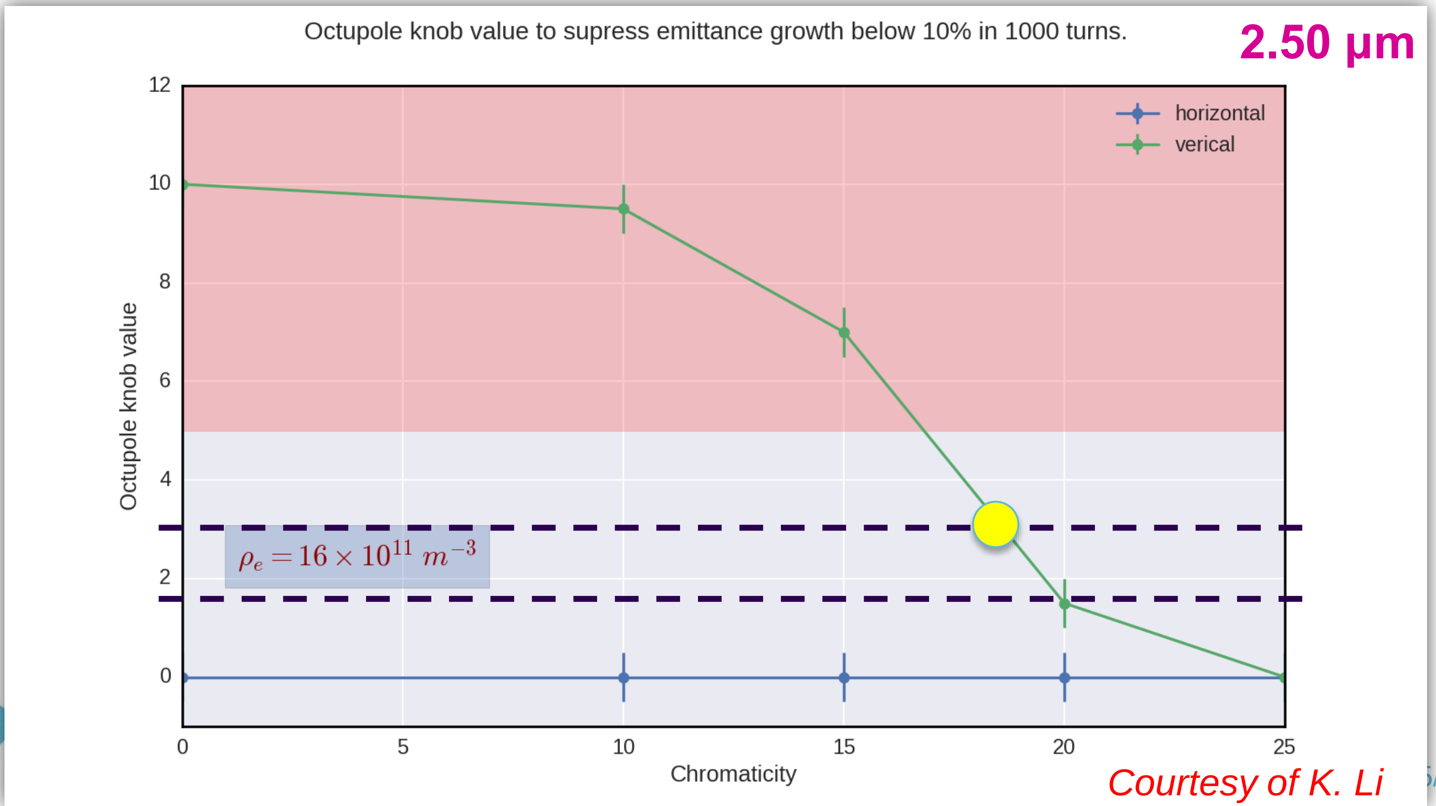

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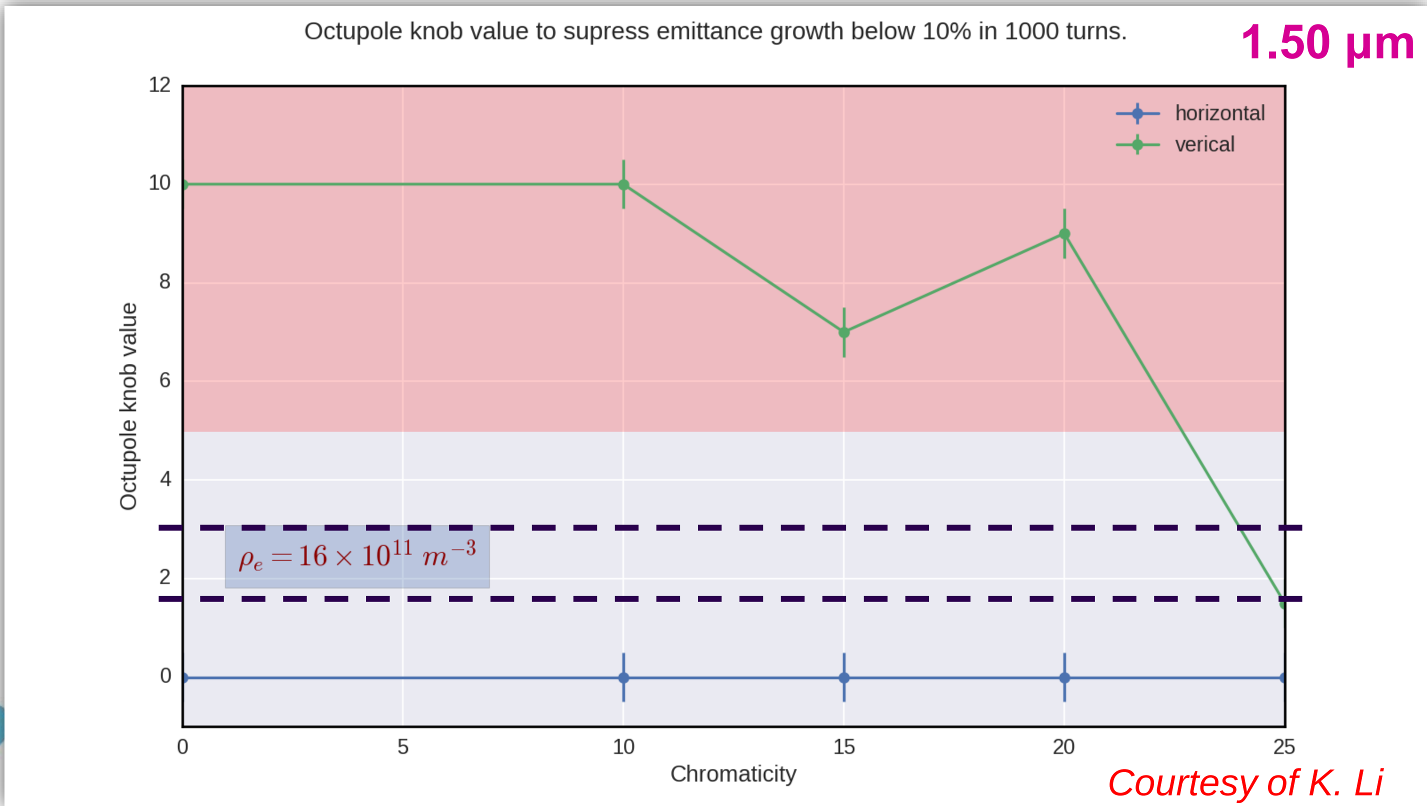

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  - E-cloud (from dipoles only) could explain the observations in V-plane

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  - E-cloud (from dipoles only) could explain the observations in V-plane
  - However, the H-plane should be stable => Simulations ongoing adding e-cloud in quadrupoles, etc.

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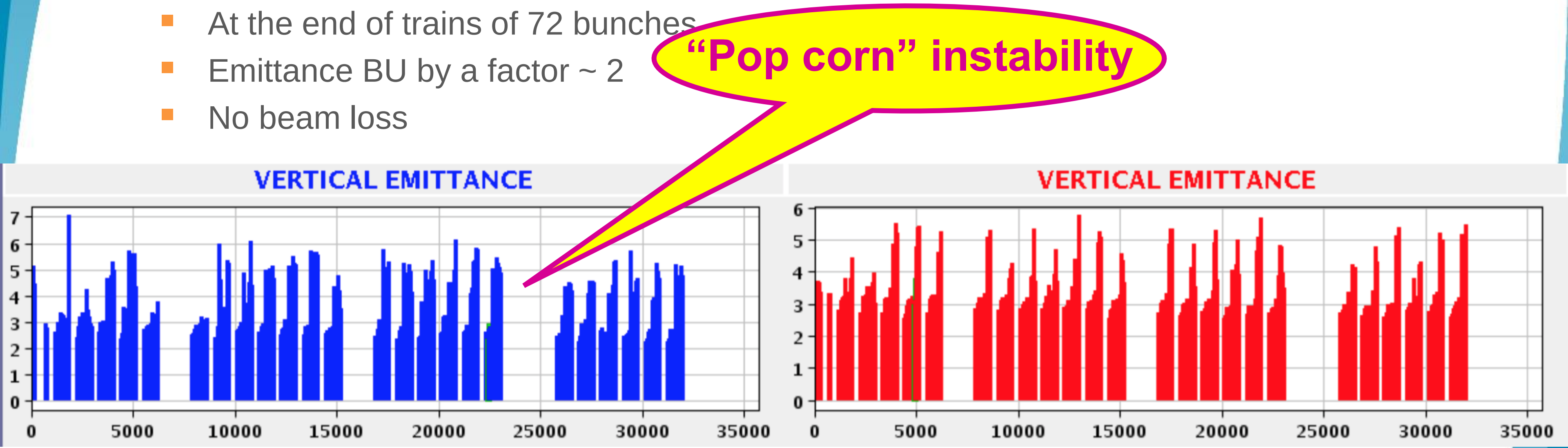

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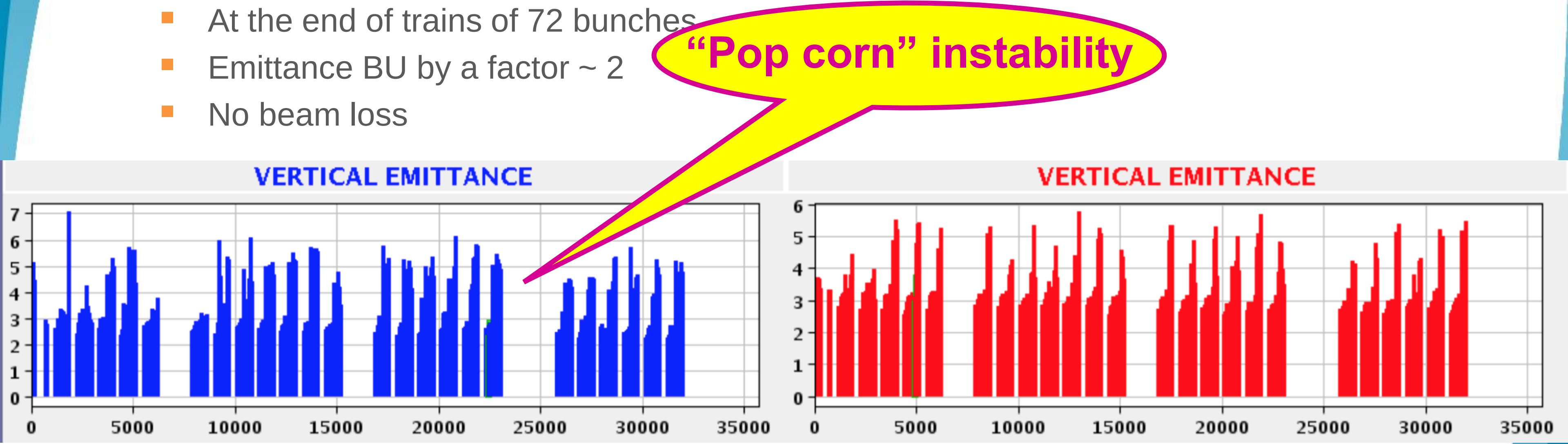

=> Was cured by increasing the vertical chromaticity (+7) in stable beam (to ~ 22)

E-cloud induced instabilities

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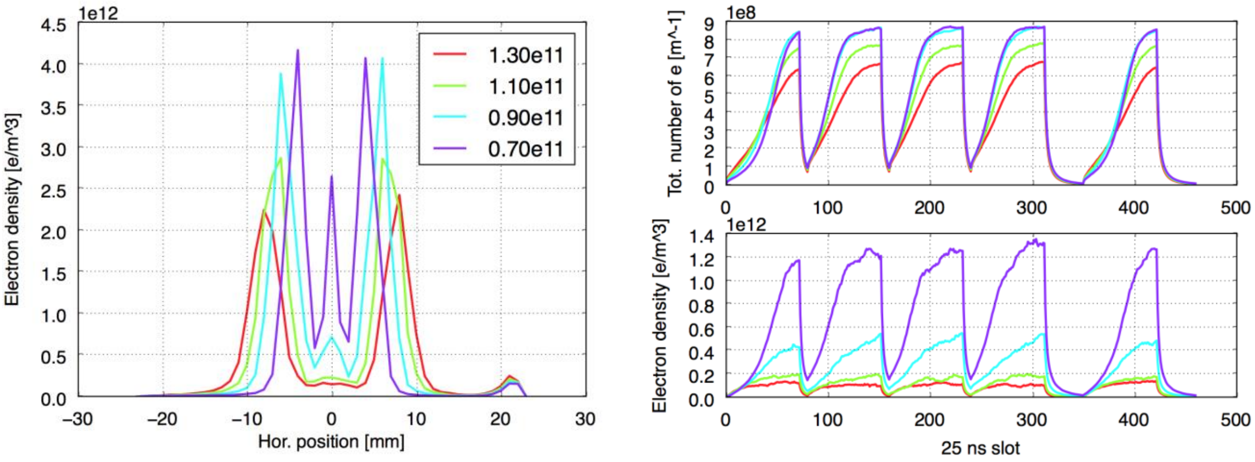

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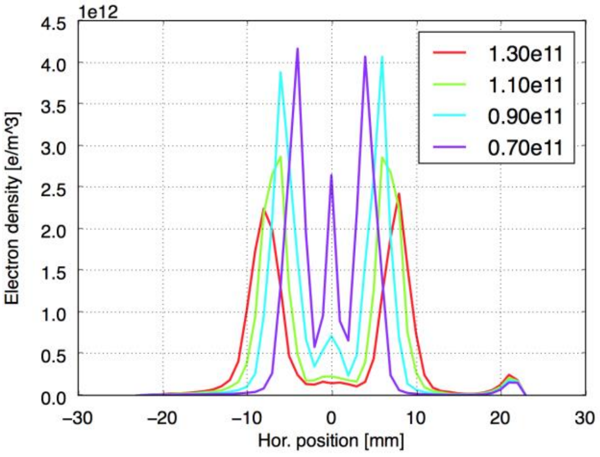

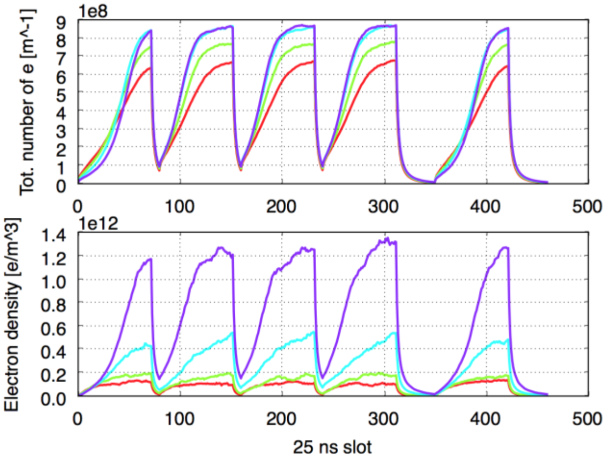

  - Huge simulation work which seems to confirm the predicted effect

Courtesy of G. Iadarola and A. Romano

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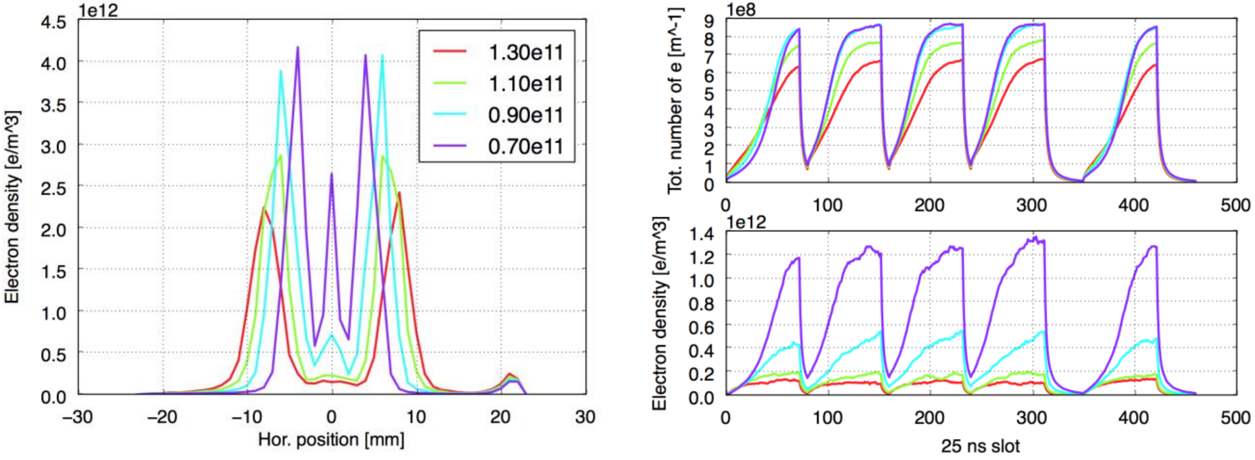

  - Huge simulation work which seems to confirm the predicted effect
  - If confirmed, should not be a problem for HL-LHC

Courtesy of G. Iadarola and A. Romano

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- 2 mechanisms are critical for beam stability (from both simulations and measurements)
  - Linear coupling between the transverse planes => OK when corrected (at the ~ 0.001 level)
  - E-cloud => From injection till stable beam!

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  - Q”
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  - Wide-band feedback system

Thank you for your attention!