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LHC Collimator Impedance Studies 06/30/2017

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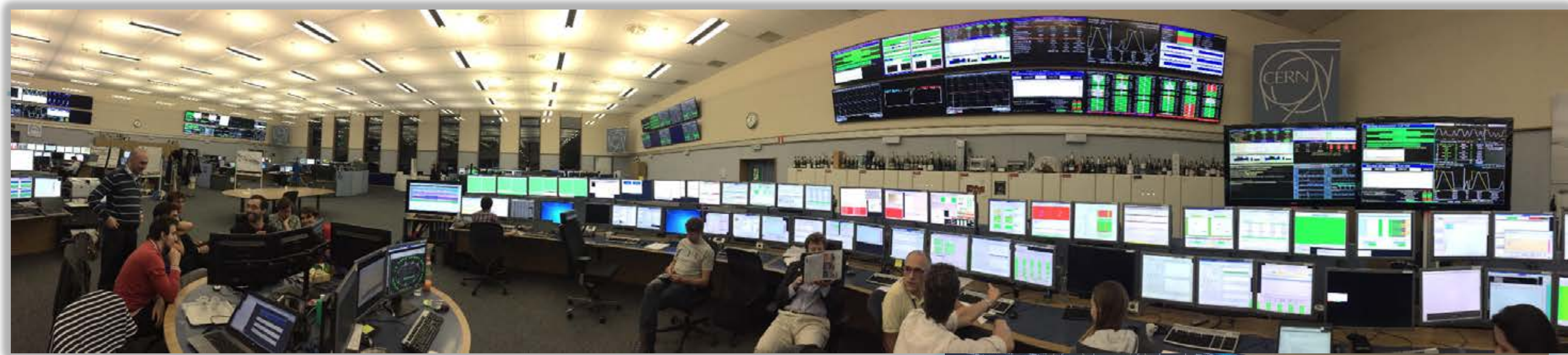
APC Seminar

03 August 2017



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* Many thanks to Sergey for the data

Planning

Motivation:
For the HL-LHC project, the LHC collimation system will undergo a major upgrade - it is foreseen to replace all secondary collimators in IR7 (TCSG) with low-impedance ones (TCSPM), to reduce their contribution to machine impedance.

Goal: to demonstrate with beam the reduction in impedance seen by the circulating beam, characterising also the effect of each material (layer).

CERN
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the Large Hadron Collider project

LHC Project Document No.
LHC-xxx rev 0.1

CERN Div./Group or Supplier/Contractor Document No.
BE-ABP

EDMS Document No.
xxx

Date: 2015-06-13

LHC MD Test Program – MD Class A

IMPEDANCE MEASUREMENTS OF TCSPM COLLIMATOR

Abstract

This note summarises the program proposed for characterizing the impedance of the TCSPM.D4R7.B2 collimator, i.e. a prototype low-impedance collimator the design of which is going to be deployed in the context of the HL-LHC project. The collimator was installed during EYETS 2016 for carrying out tests with beam. The detailed program along with the necessary modifications of the machine protection systems is presented and responsibilities for the latter are defined.

Prepared by:	*Checked by:*	*Approved by:*
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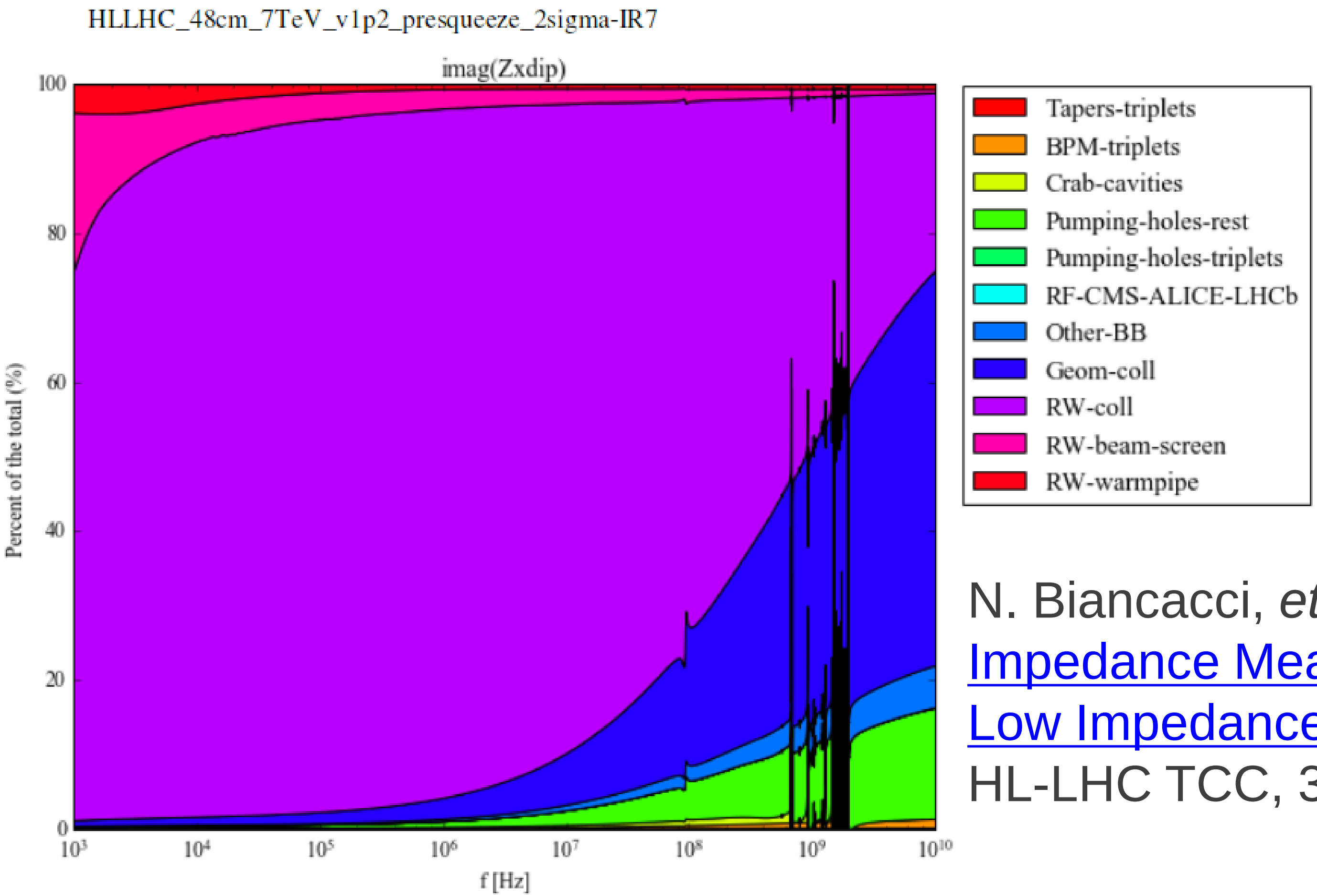
Distribution list:

...ngineers in charge, LHC operators

Number of MD's	1
Time required per MD [h]	8
Beams required [1, 2, 1&2]	2
Beam energy [GeV]	6.5 TeV
Optics (injection, squeezed, special)	Injection optics
Bunch intensity [#p, #ions]	Nominal bunch (1.2E11)
Number of bunches	2 bunches of different intensities
Transv. emittance [m rad]	Not relevant, but not too large
Bunch length [ns @ 4s]	Not relevant
Optics change [yes/no]	No
Orbit change [yes/no]	No
Collimation change [yes/no]	Yes: the TCSPM.D4R7.B2 will be move repeatedly in and out to perform the measurements; the same will be done with the TCSG.D4R7.B2 (installed immediately upstream). For cleaner signals, all other TCSGs and TCLAs will be moved out. TCP collimators could be further closed, to measure smaller gaps of the TCSPM.
RF system change [yes/no]	No

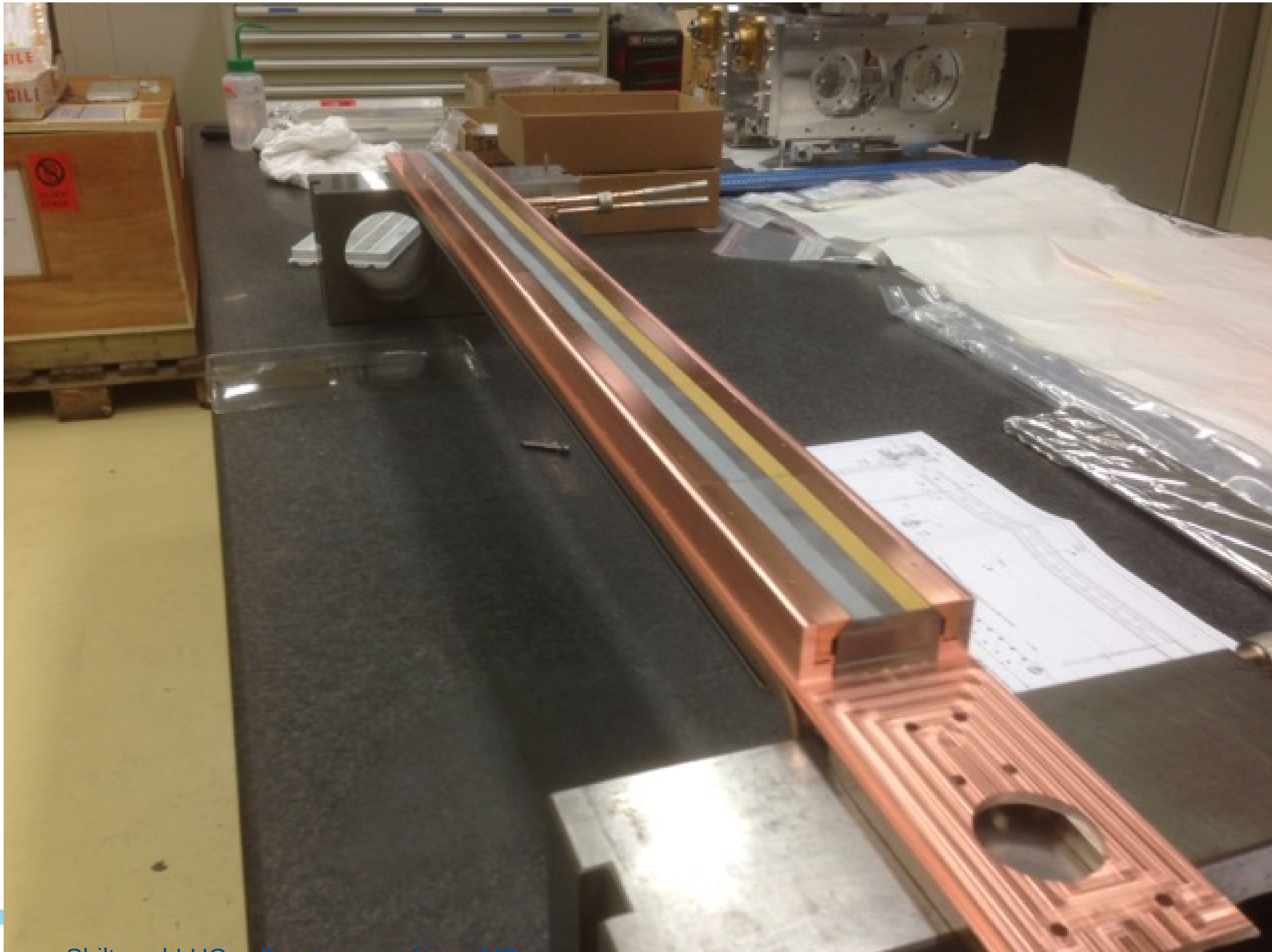
Motivation

- The HL-LHC transverse impedance is largely dominated by the collimators contribution.



N. Biancacci, *et al.*, [Impedance Measurements of Low Impedance Collimator](), HL-LHC TCC, 30.03.2017

TCSPM: “Three Stripes” Collimator Jaw



Expectations

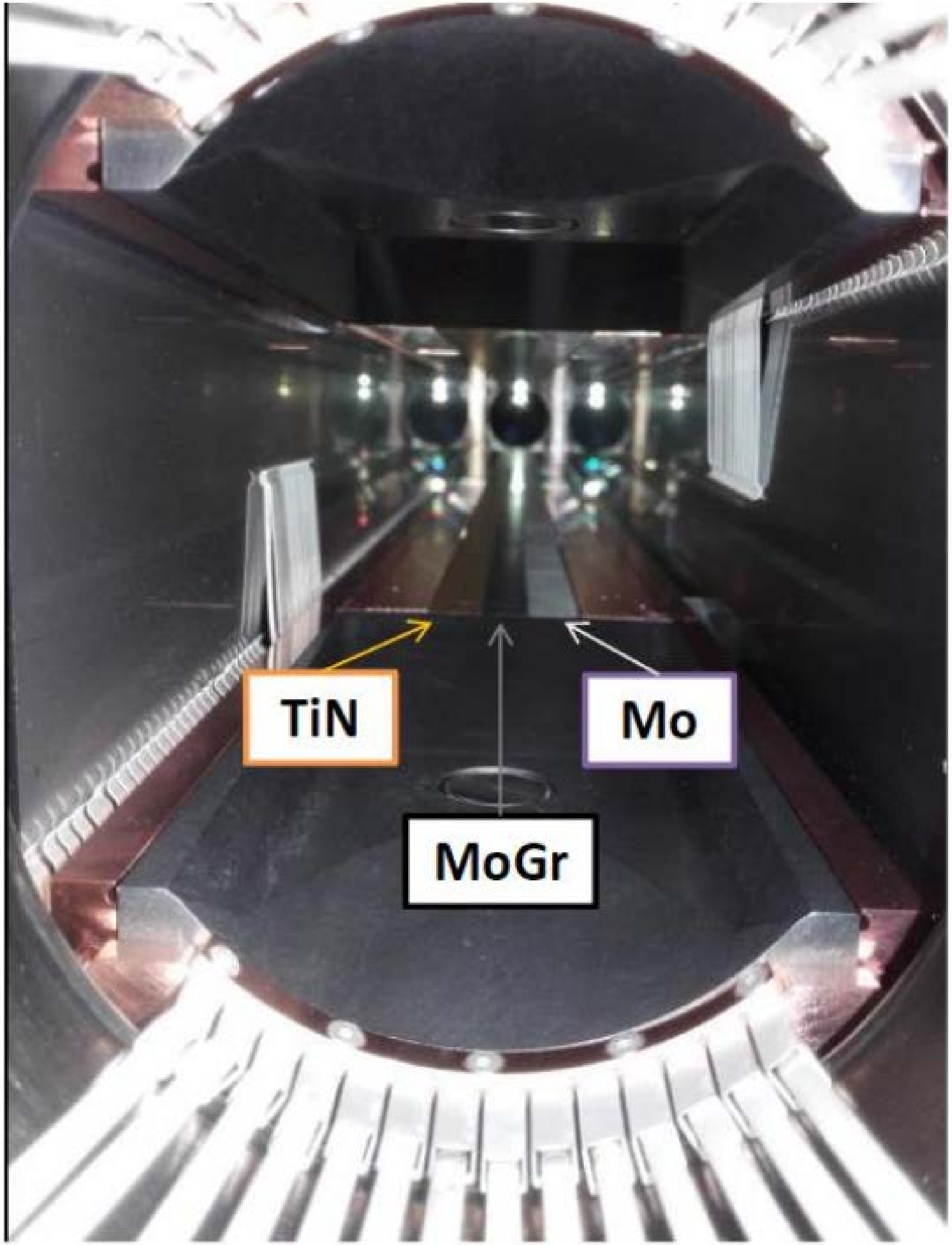
$$k_{\perp} = \frac{cL}{\pi^2 b^3}\sqrt{\frac{2Z_0\rho}{\sigma_z}}\Gamma\left(\frac{5}{4}\right)$$

carbon fiber-reinforced composite (CFC) :
rhoDC=7e-6 Ohm.m

MoGr bulk
rhoDC = 1e-6 Ohm.m

TiN coating
rhoDC = 4e-7 Ohm.m

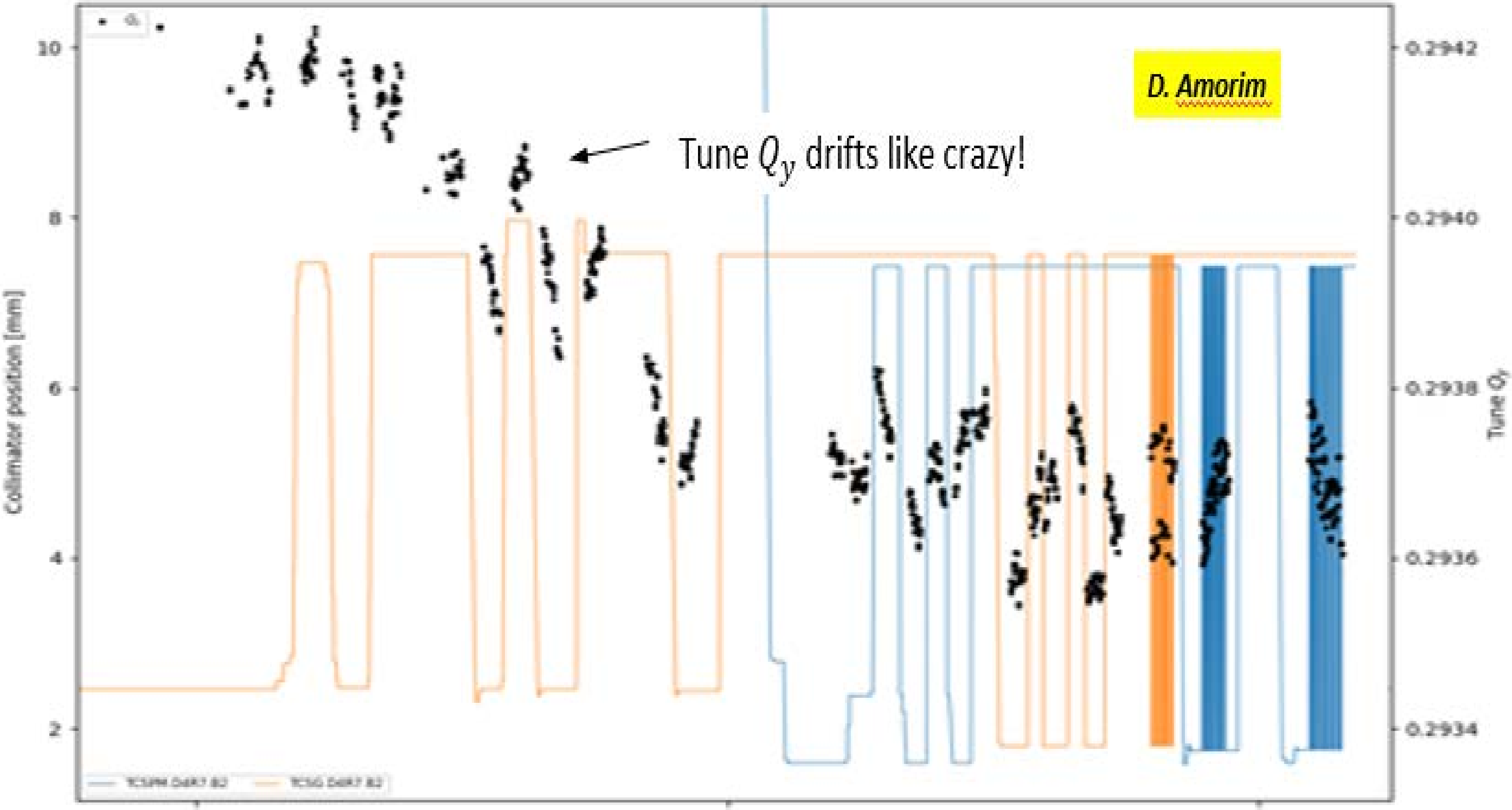
Mo coating
rhoDC = 5.35e-8 Ohm.m



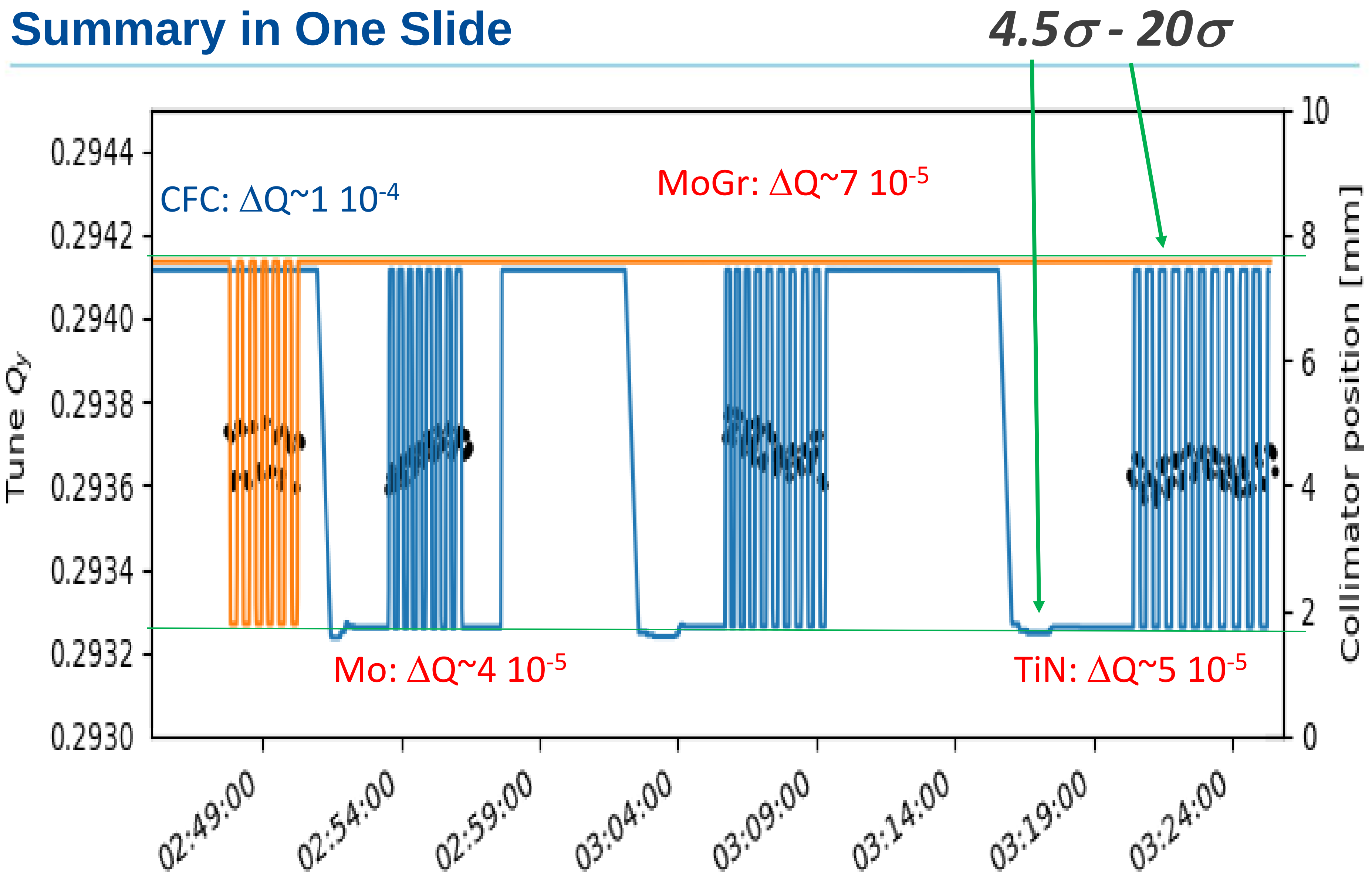
MD Studies - Notes

- Very smooth MD, carried out in ideal machine conditions and constructive team spirit
- Spent ~2h to properly set up beam to be injected (0.8 & 1.2 10^{11} p/b, norm emittances ~2μm) , ADT kicks (B2V, 10-30μm amplitude, no losses on TCPs) and gain, chroma Q'~8units and octupole current (282A);
- Careful set-up paid off – Managed to:
  - reach tune measurements sensitivity of ~ 10^{-5}
  - measure all the TCSPM stripes, and compare against TCSG.D4R7;
- Lots of interesting data

Complications: Tune drifts ~6e-4



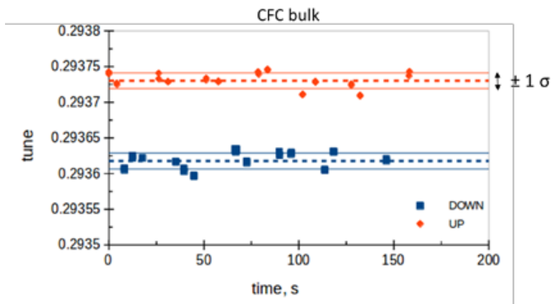
Summary in One Slide

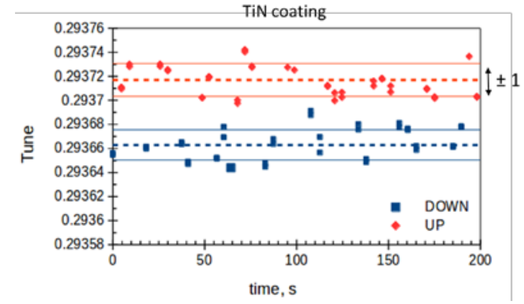


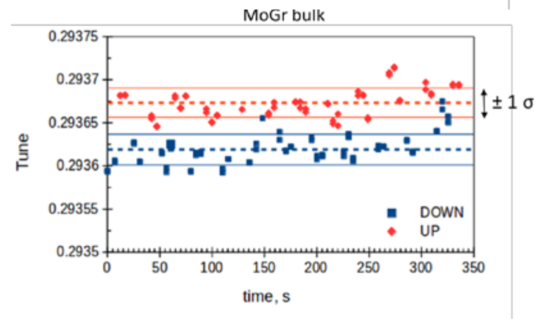
Tune Changes : 4.5 sigma to 20 sigma → rms ~(1-2)e-5

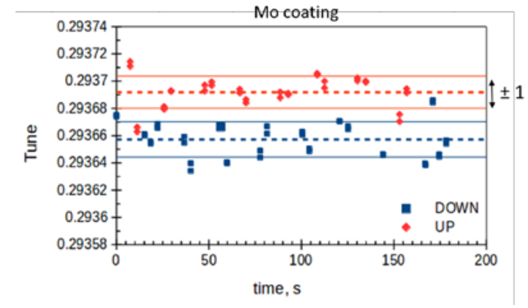
Counter measures:

1) Open-close collimators faster
2) Make few tunes measurements – fast
3) Extract drifts during data processing (off-line)





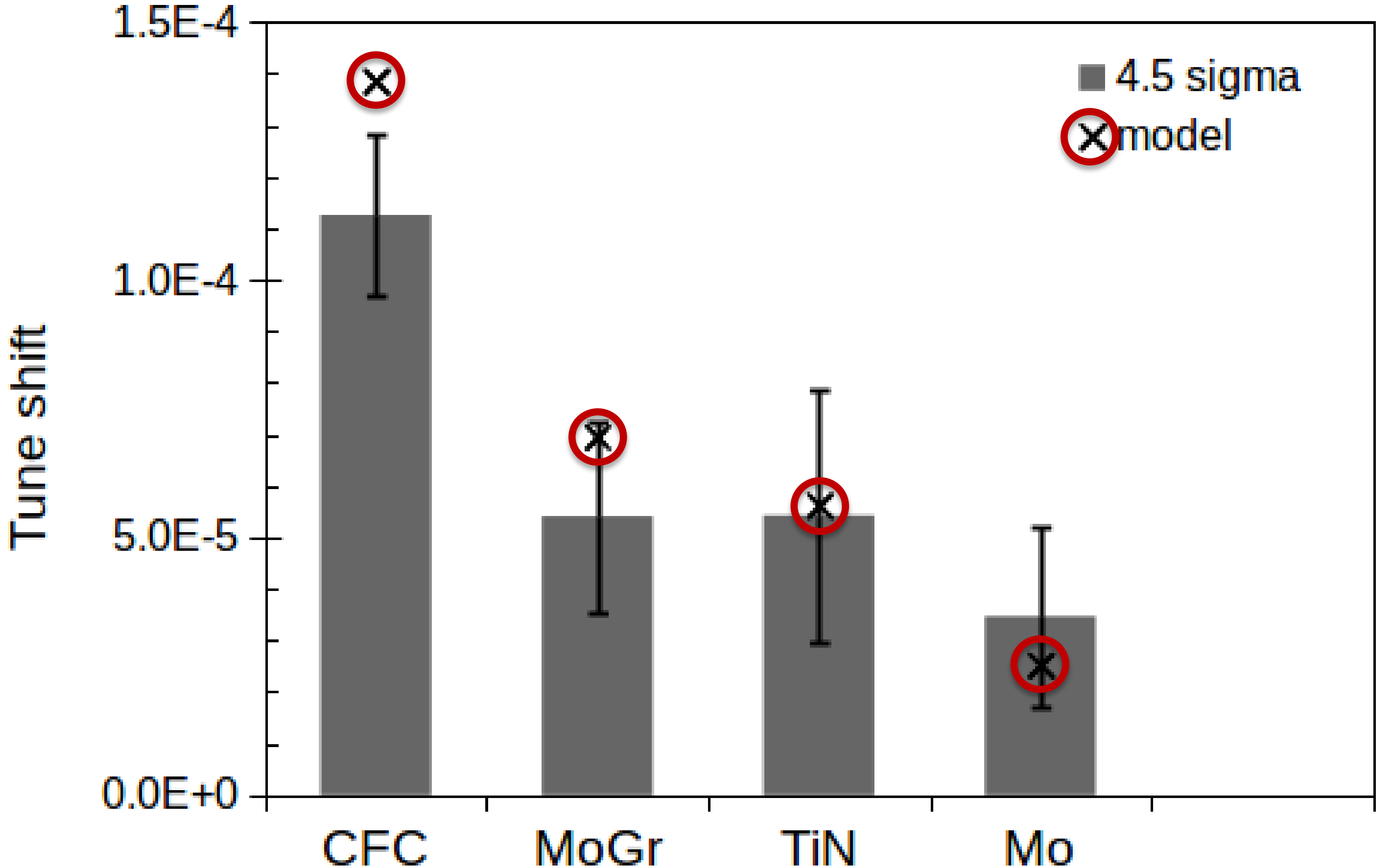




Collimator	Tune at 4.5 σ	Tune at 20 σ	dQ
TCSG	0.293618 ± 1.1x10^{-5}	0.293730 ± 1.1x10^{-5}	-11.2 x10^{-5}
TCSPM: MoGr	0.293619 ± 1.8x10^{-5}	0.293673 ± 1.7x10^{-5}	-5.4 x10^{-5}
TCSPM: TiN	0.293663 ± 1.2x10^{-5}	0.293717 ± 1.4x10^{-5}	-5.4 x10^{-5}
TCSPM: Mo	0.293657 ± 1.3x10^{-5}	0.293692 ± 1.2x10^{-5}	-3.5 x10^{-5}

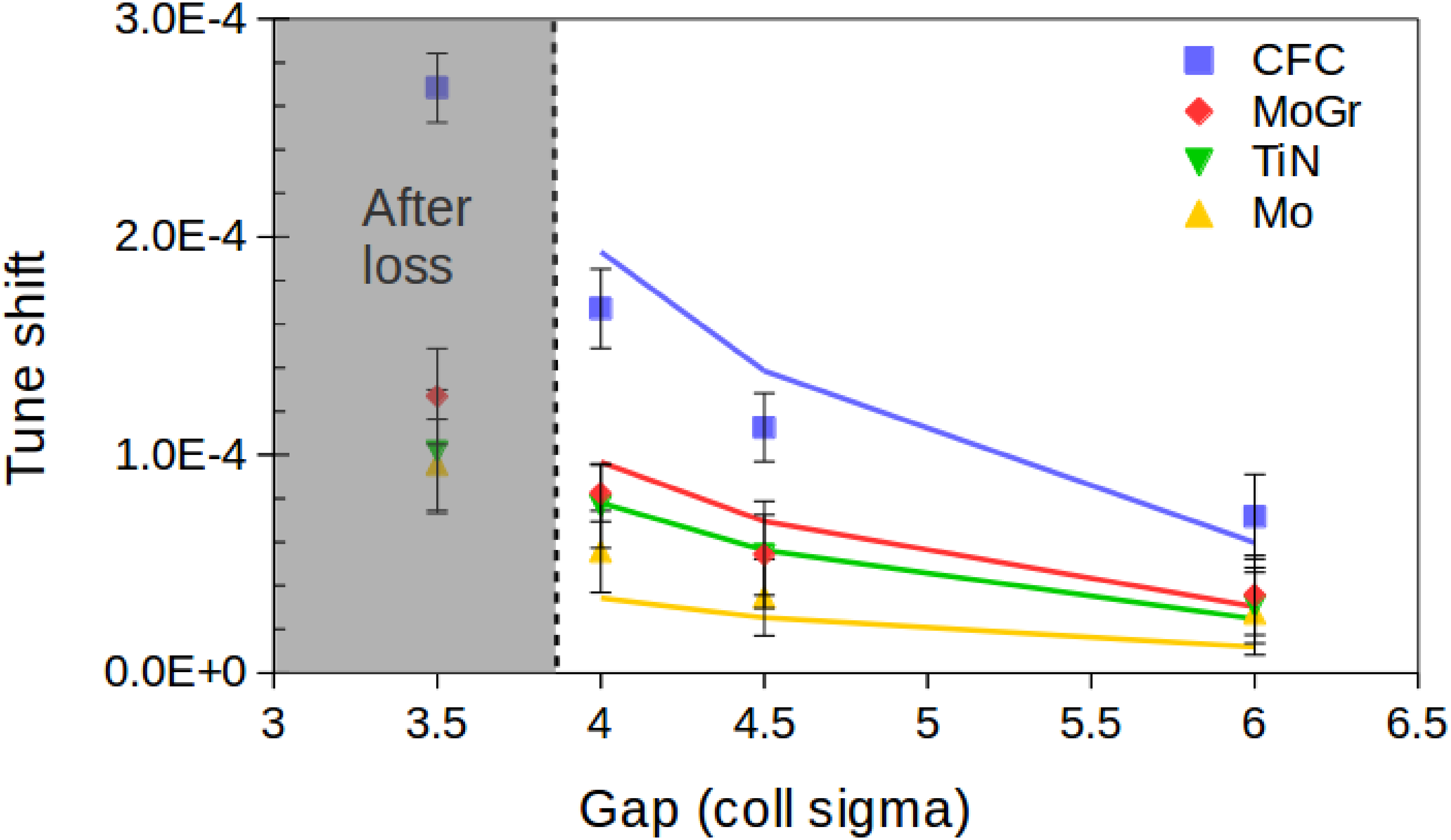
4.5 Sigma Data vs Model

- Significant decrease of tune shift for Mo coating with respect to CFC
- No major difference between MoGr and TiN



More on Data vs Model (3.5, 4, 6 sigma)

- The model includes both RW and geometric contribution
- Model tune shifts (line) computed using the actual collimator setting, used during the MD



Conclusions

- Individual tunes measured at the level of ~10^{-5}
  - Allowing to measure impedance of individual collimators with good accuracy.
- The tune shifts are measured for three materials and ref the reference (CFC) and “more-or-less” agree with the predictions of the impedance model
- A clear reduction of the tune shifts can be seen with Mo, MoGr, and TiN
  - TiN and MoGr are similar within the experimental uncertainties
- The smallest tune shifts were observed with Mo, indicating factor of ~3 reduction of the “effective” transverse impedance compared to “standard” CFC secondary collimator
  - That offers an effective impedance reduction opportunity for HL-LHC

Thanks for your attention !