CAN WE IMPROVE THE MAGNETIC CYCLE/MODEL AND THEIR EFFECTS?

E. Todesco

For the FiDeL team:

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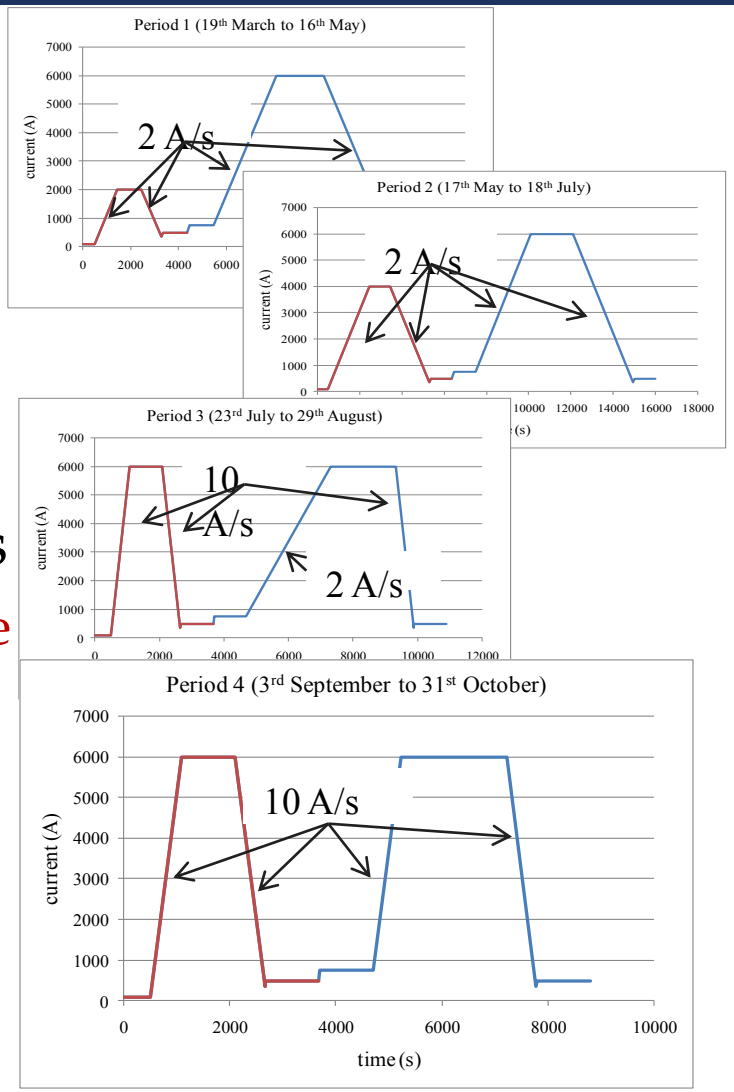
CONTENTS

- Precycle
  - How many types we had?
  - Has it been followed? Can we made it shorter ?
- Chromaticity
  - Decay at injection – how to include ?
  - During ramp – can be improved ?
- Tune
  - Decay at injection
- Hysteresis issue

How did we precycle the LHC ?

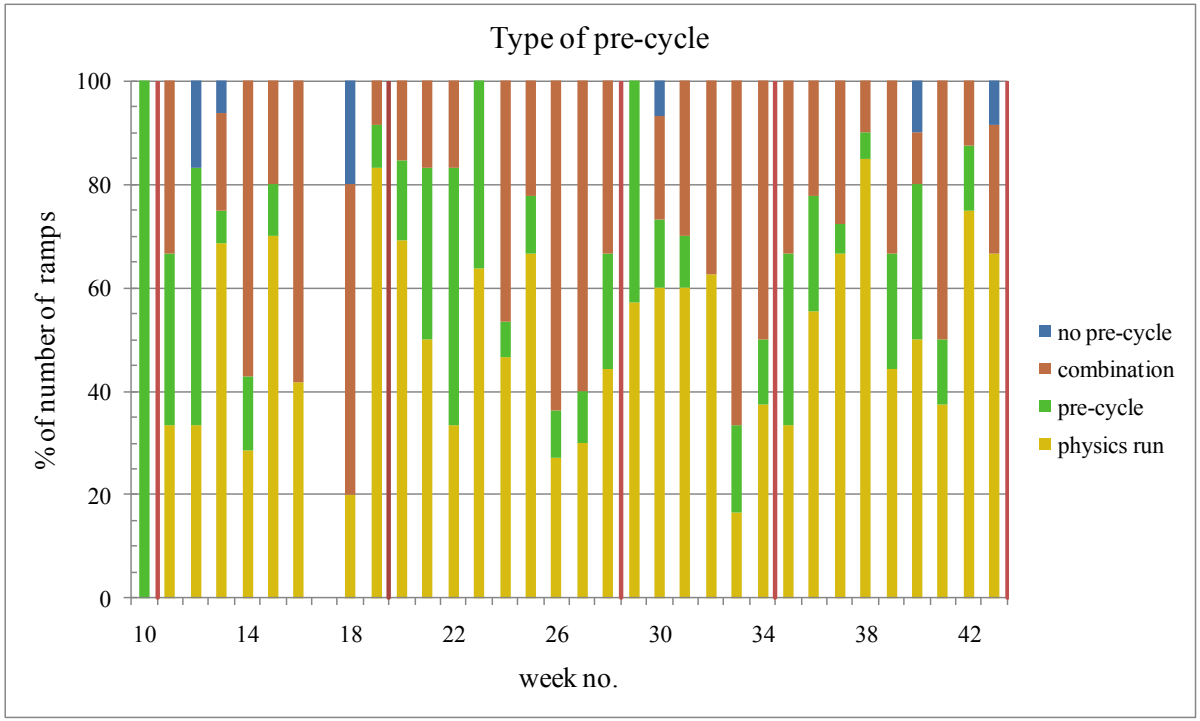
- Four combinations of precycle and cycle ramp rates and currents
  - We started rather far from nominal
  - No experience on decay and snapback in this regime
  - 2 A/s never explored in SM18
- Since September 3 we are at 10 A/s
  - With same parameters for physics cycle and precycle
- What still missing w.r.t. nominal
  - The energy … still at 6 kA
  - This should give smaller decay and snapback (about ½)



Combination of ramp and precycles in 2010 [N. Aquilina]

HOW DID WE PRECYCLE THE LHC ?

- The LHC from the first day of operations uses the previous physics run as a precycle!
  - If the physics run terminates abnormally one has to precycle
  - Procedure followed at 97% in 2010 ☺☺



Precycle type in 2010 for all ramps [N. Aquilina]

HOW DID WE PRECYCLE THE LHC ?

- The LHC from the first day of operations uses the previous physics run as a precycle!
  - 54% of the ramps used previous physics cycle ☺☺
  - Precycle takes 90 minutes
    - In average 45 minutes/ramp spent to precycle
  - At this stage of operation is not dominant in the turn around time
  - Anyway, it could be improved
    - Dominated by the MQM MQY – one could study possibilities to make it shorter
  - Other comments
    - Special ramp-down when an access will be given (to avoid ramping up dipoles
    - If a circuit trips, can we ignore it? General receipt is in CERN-ATS-2010-174 http://cdsweb.cern.ch/record/1283477/files/CERN-ATS-2010-174.pdf

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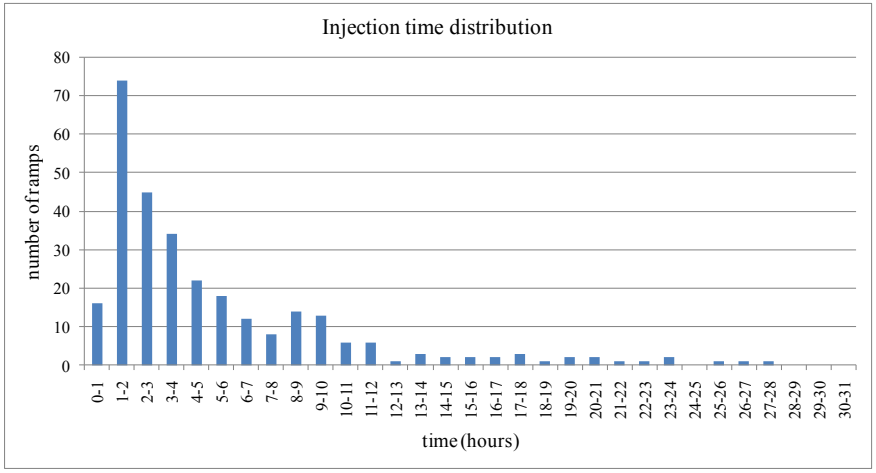
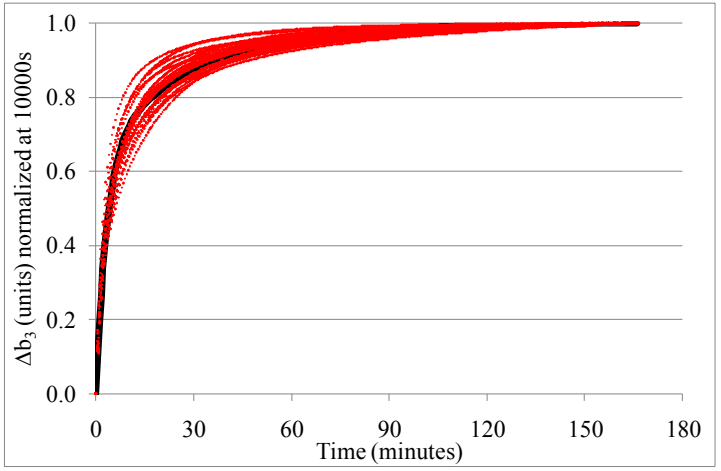
CHROMATICITY DECAY AT INJECTION

- How long we usually stay at injection?
  - At least 30 minutes, in general 1-2 h, in average 5 h



Time at injection for all ramps in 2010 [N. Aquilina]

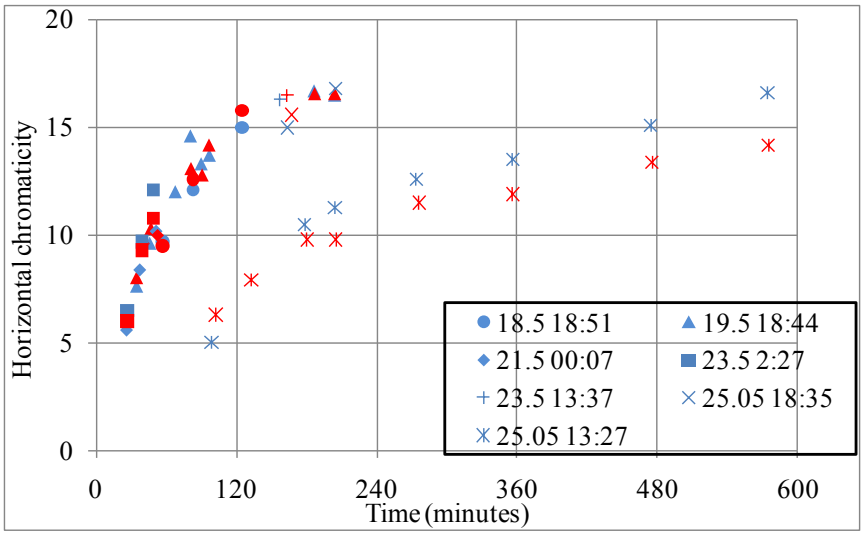


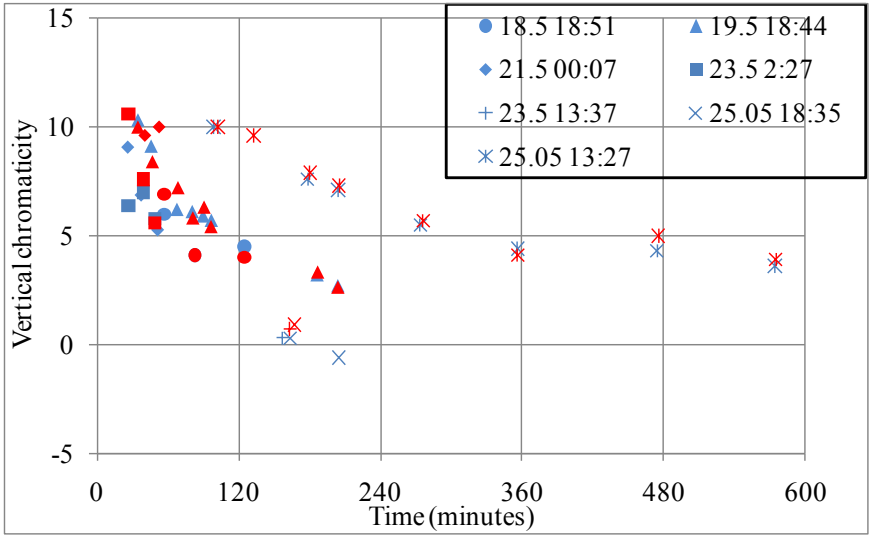
Decay of b3 over 10000 s in 20 cases [N. Aquilina, L. Deniau, N. Sammut]

- Measurements at SM18 showed that after 30 minutes most of the b_3 decay is ended (at 50 A/s ramp rate)
- Therefore we decided to correct the full decay via static trims thinking that in 2010 we always inject when decay is ended
- The option has been anyway coded and is available [M. Strzelczyk]

CHROMATICITY DECAY AT INJECTION

- Beam measurements show decay on longer times
  - The size of decay is in agreement with FiDeL (~0.5 units b_3, i.e., 20-25 units of chromaticity – but in the LHC is much slower!



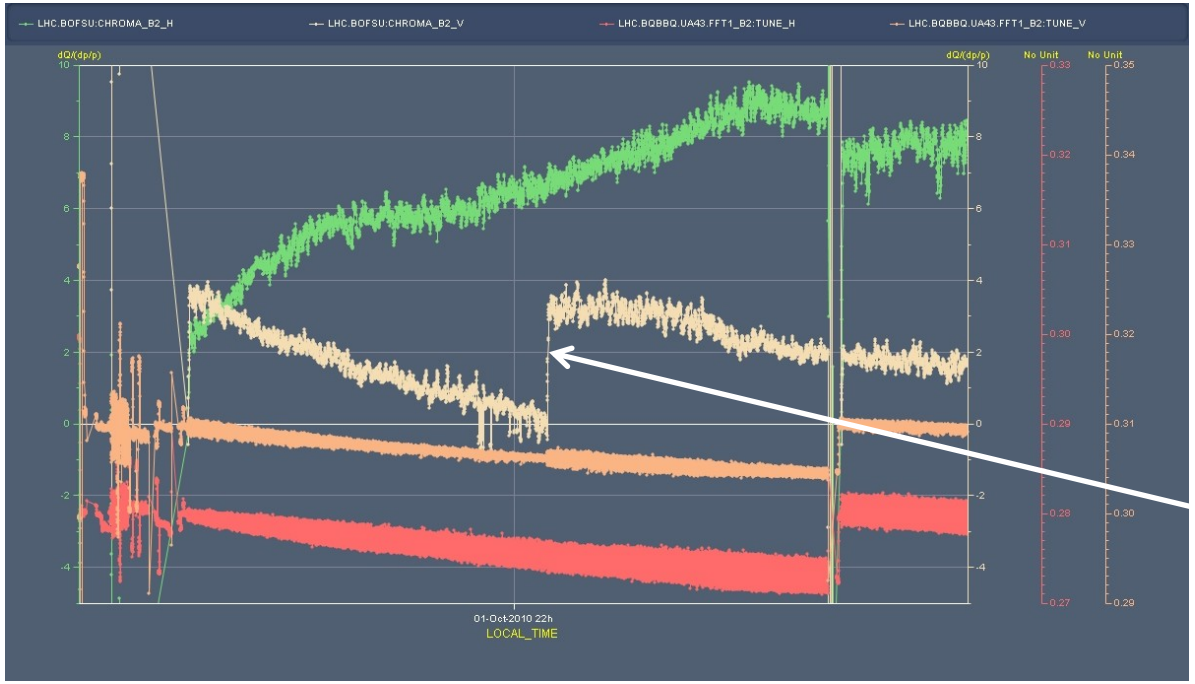


Chromaticity versus time at injection, beam1 (blue), beam2 (red) [W. Venturini Delsolaro]

- In 2010 variability in injection time changes chromaticity of 10-15
- Since trims of the previous injection are kept, one can inject on negative chromaticity and lose the beam

BEAM MEASUREMENTS

- Measurements from M. Pojer
  - Continuous measurements of chromaticity during injection (1 h)
  - About 4 units in 1 h – this after 1 h at injection
  - Compatible with previous measurements



Here chromaticity has been trimmed up by 4 units

Chromaticity versus time at injection, horizontal (green), vertical (beige) [M. Pojer]

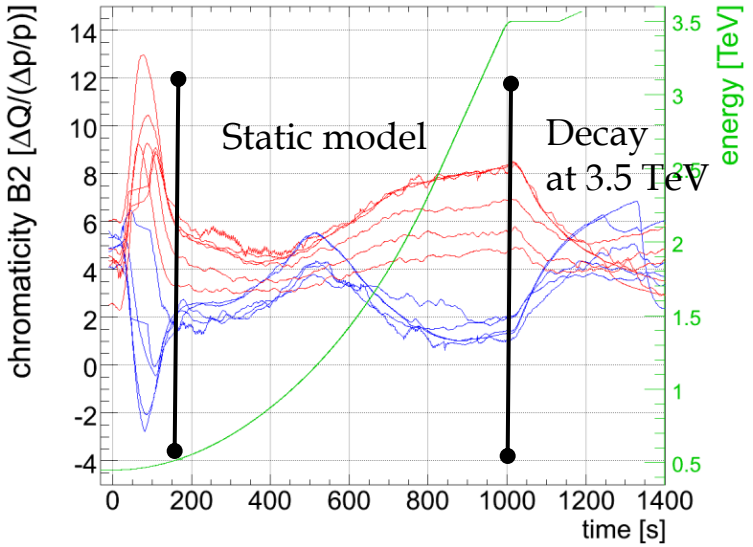
CHROMATICITY DECAY AT INJECTION

- How the EIC cope with this?
  - Manual trim based on experience – no general strategy
  - The trim is on the lattice sextupoles (MSF/D) whereas it should go on the MCS

- Solution for 2011
  - Use the process to correct decay at injection through MCS already prepared [M. Strzelczyk]
  - But change the FiDeL time constant according to beam measurements and
    - Measure periodically decay at injection in 2011
    - Measure decay in dipoles with 10 A/s and 6 kA for 10 h? But on one dipole probably this is not enough

CHROMATICITY DURING RAMP

- We have ~6 measurements of chromaticity during ramp [R. Steinhagen]



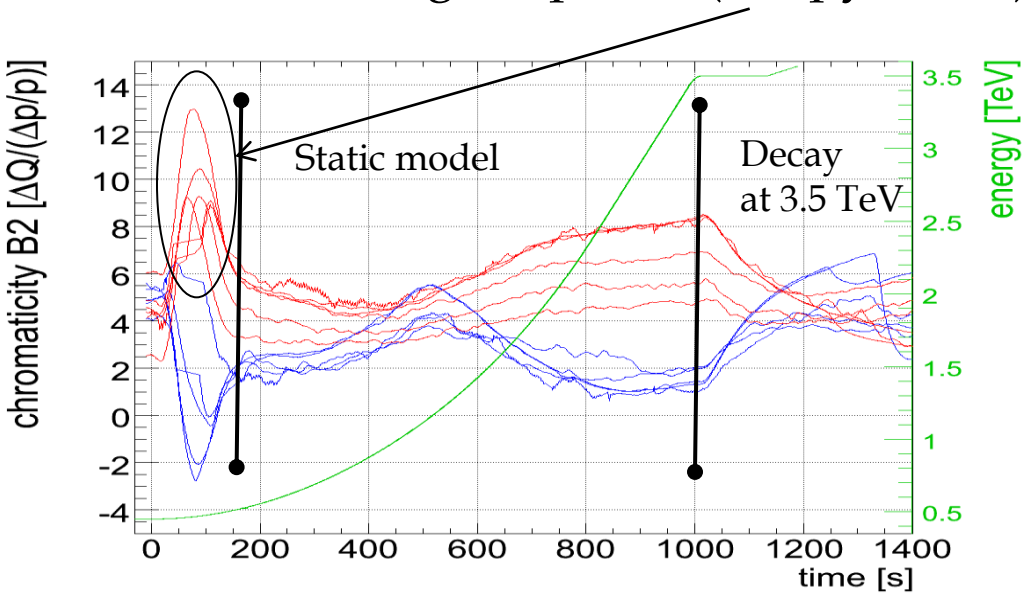
Chromaticity during the 10 A/s ramps , 6 cases blue: horizontal - red: vertical [R. Steinhagen]

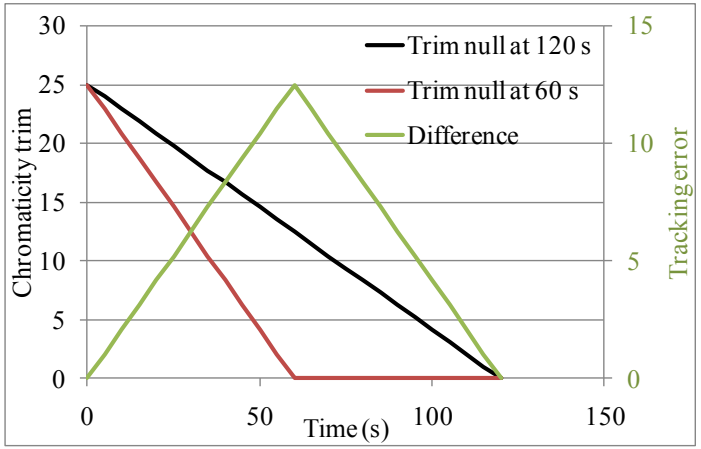
- FiDeL error during snapback: ±7 units – chromaticity is negative ☹
- FiDeL error after snapback during ramp: ±3 units – difficult to do better
- Decay at 3.5 TeV: 7 units

- Tracking precision is sufficient for operation – but it could be improved in the snapback part

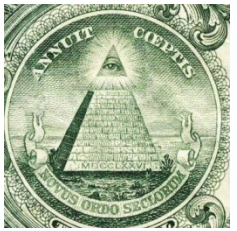
CHROMATICITY DURING RAMP

- Error during snapback (the pyramid): two possible causes





- Trim at injection decreases linearly with time up to 120 s
- If this trim vanishes too rapidly this can create the pyramid



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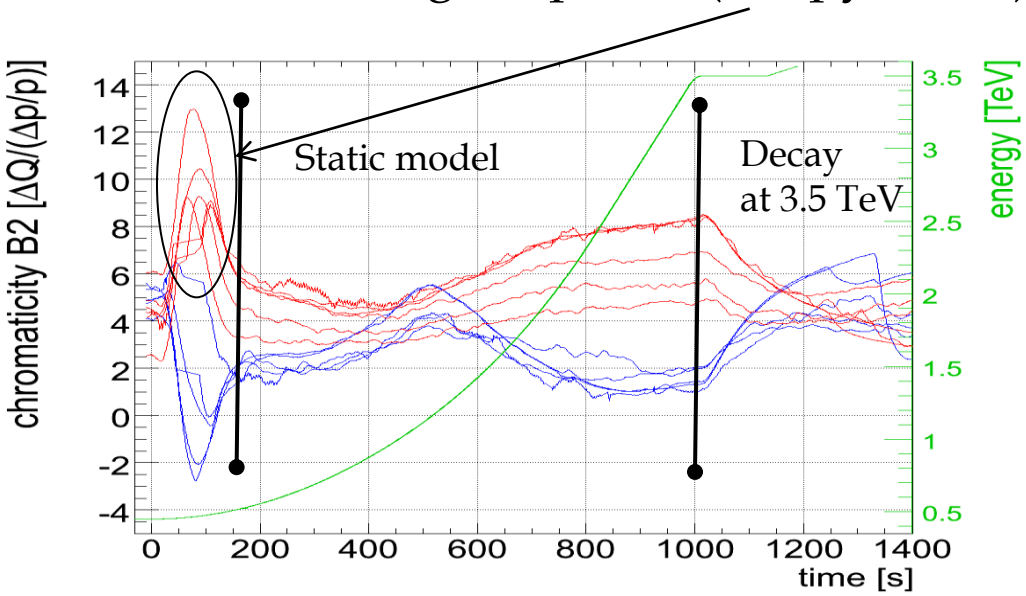
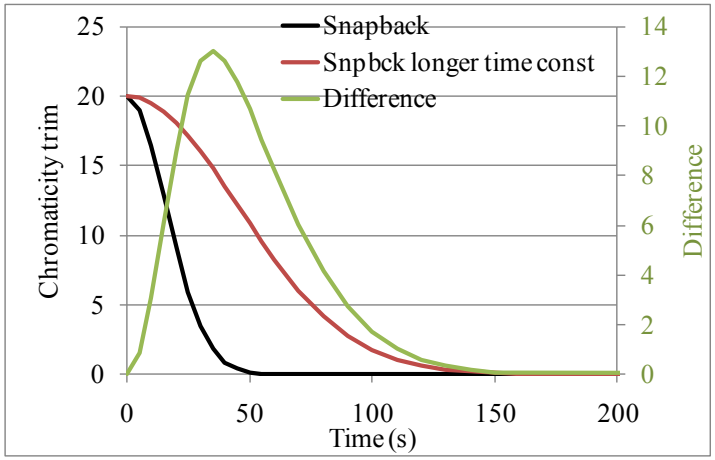
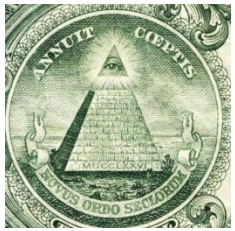




- If the snapback time constant is wrong one also gets a pyramid
- But it should be much, much longer … (factor 5-10)



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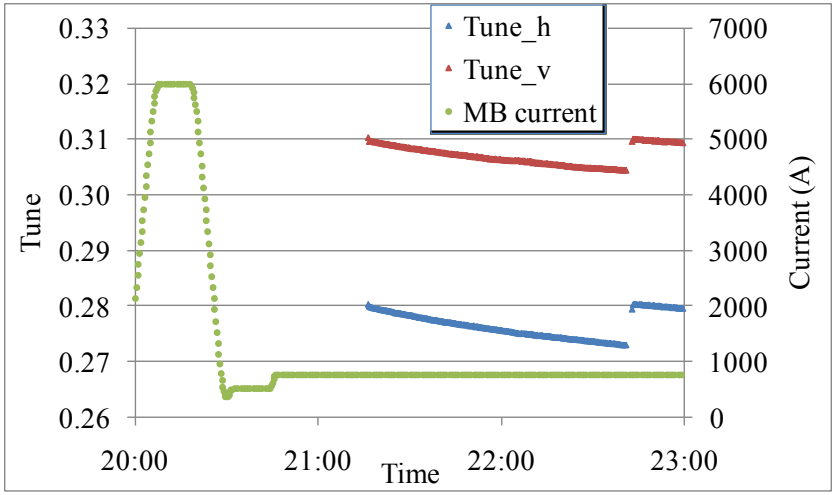
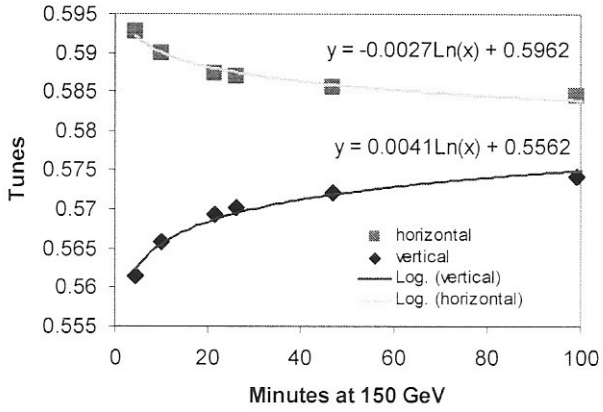
TUNE DECAY

- There is evidence of tune decay at injection

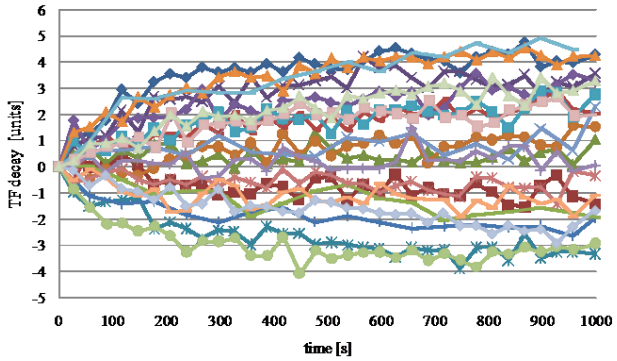


Decay of tune at injection on 1st Oct 2010 [M. Pojer]



Decay of tune at injection in Tevatron [G. Annala, et al.]

- About 0.005 over 1 h soon after precycle
  - As far as I understand not an issue
  - But it could be included
- Origin: could be decay in the quadrupoles
  - 0.005/60= 1.2 unit – compatible with meas.



Decay of MQ transfer function[L. Deniau]

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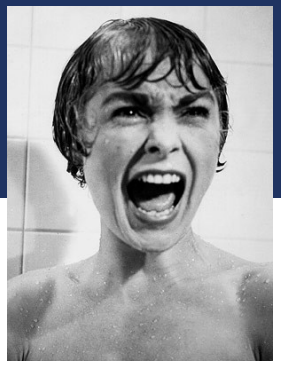
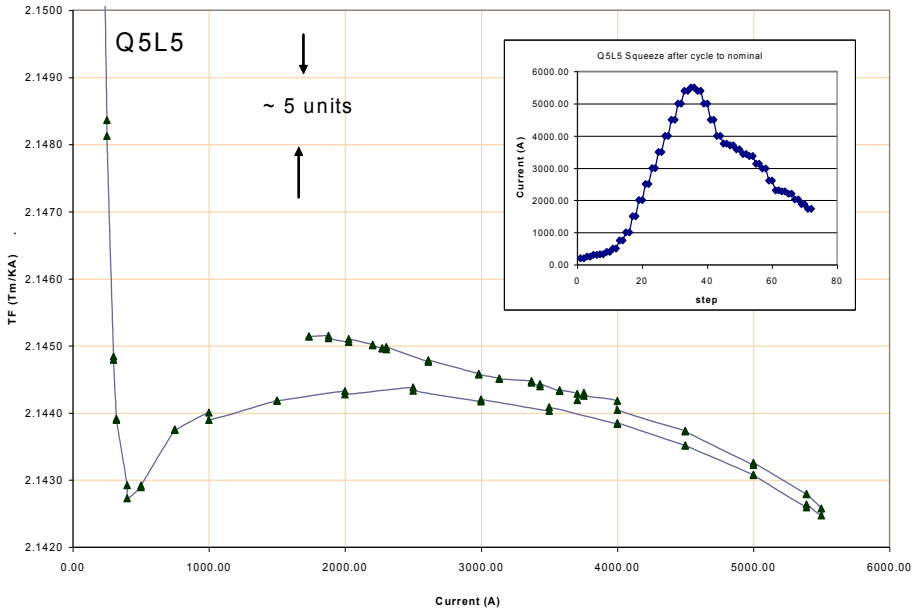
HYSTERESIS



Psycho, 50 years celebration
[A. Hitchcock]

- Hysteresis is a ghost which is periodically hunting our nights … since years
  - Two issues:
    - IR quads during squeeze, having current ramping down
    - Correctors, which are trimmed down and up by EiC and feedback

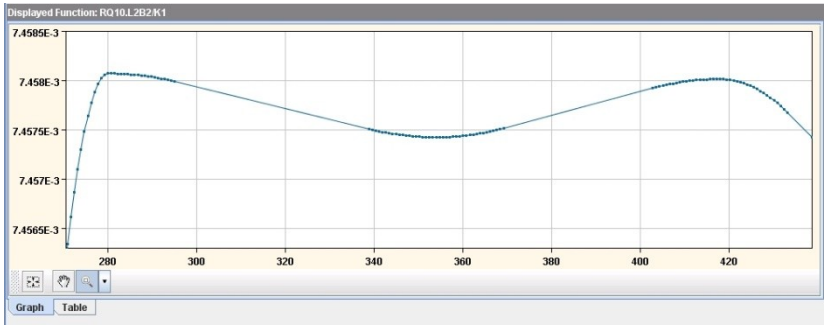


Measured transfer function during squeeze [W. Venturini Delsolaro]

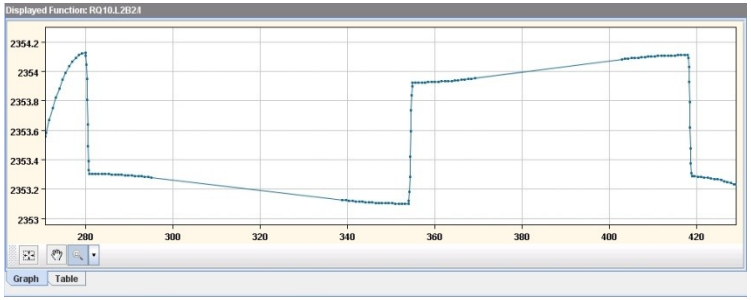
- Implemented strategy
  - When the dI/dt < 0 the model automatically changes hysteresis branch [M. Strzelczyk]
    - With smoothing needed for not tripping the power converters and QPS

HYSTERESIS

- Problems - 1

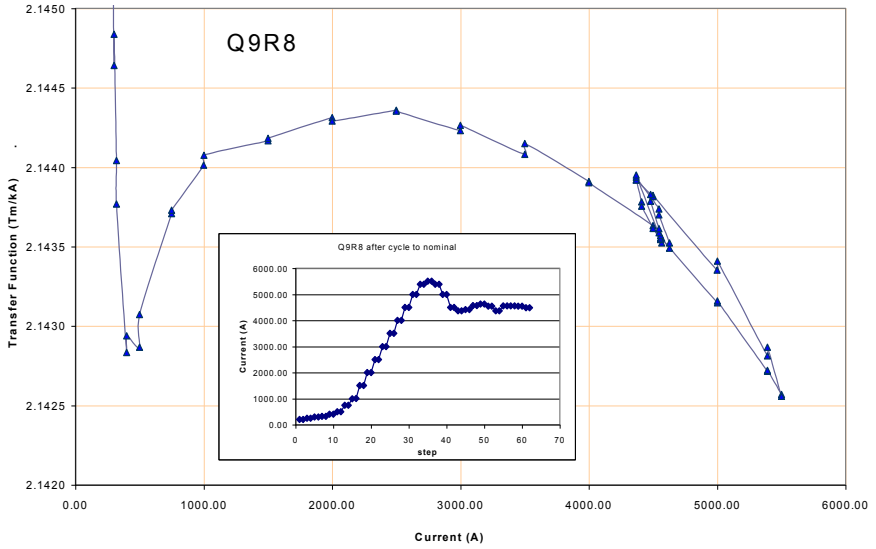


Required gradient during squeeze [M. Strzelczyk]



Corresponding current in PC [M. Strzelczyk]

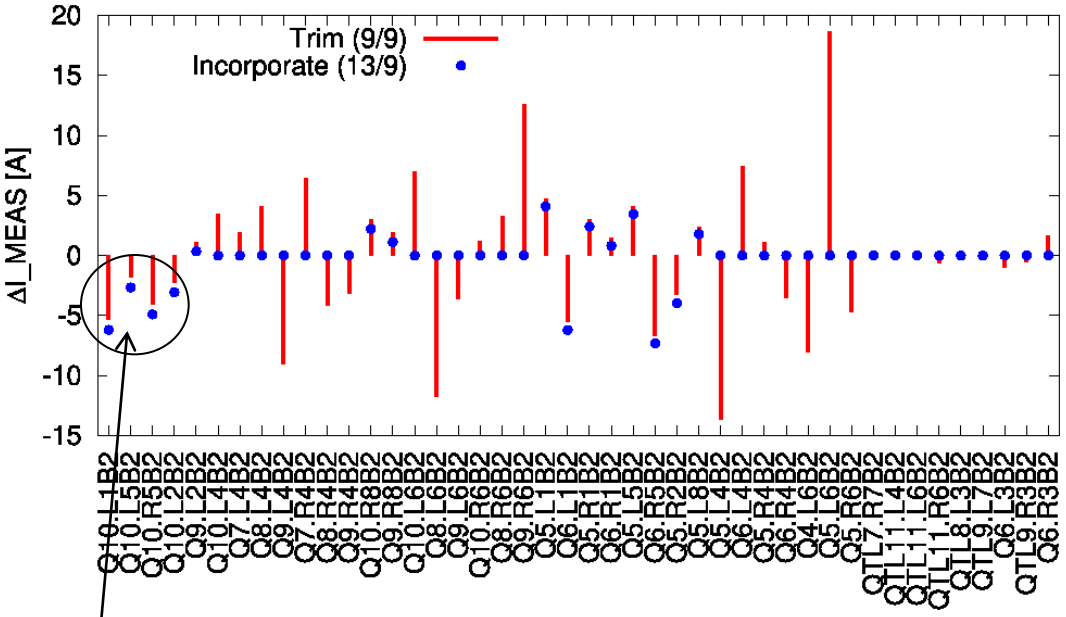
- For small changes of currents, one has jumps whereas the magnet in reality stays on the same branch
- Not nice, not necessary, and can induce beam losses [X. Buffat]



Measured transfer function during squeeze [W. Venturini Delsolaro]

HYSTERESIS

- Problems - 2

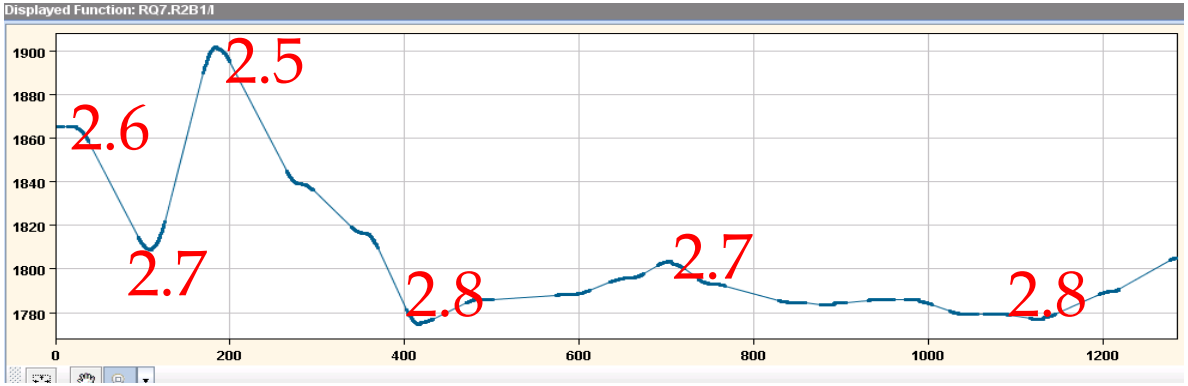


Difference between trims at 3.5 TeV and incorporated trims [R. Tomas]

- When trims are first tried on actual settings and then incorporated, the branching causes a small difference – seen for beta beating correction
- This gives negligible effects on beta beating, but it is not nice

HYSTERESIS

- Estimates show that in squeeze the impact of hysteresis is small



Error in units due to neglecting hysteresis during squeeze [P. Hagen]

  - Going to 1.1 m becomes important (10-50 units) in a few cases which are well known a priori (mainly MQM) – if neglected this gives 10% beta beating
- No evidence of problems related to hysteresis, neither in correctors nor during squeeze
  - We propose to remove it – we will include as trim for the few magnets that need it, and for β* that needs it

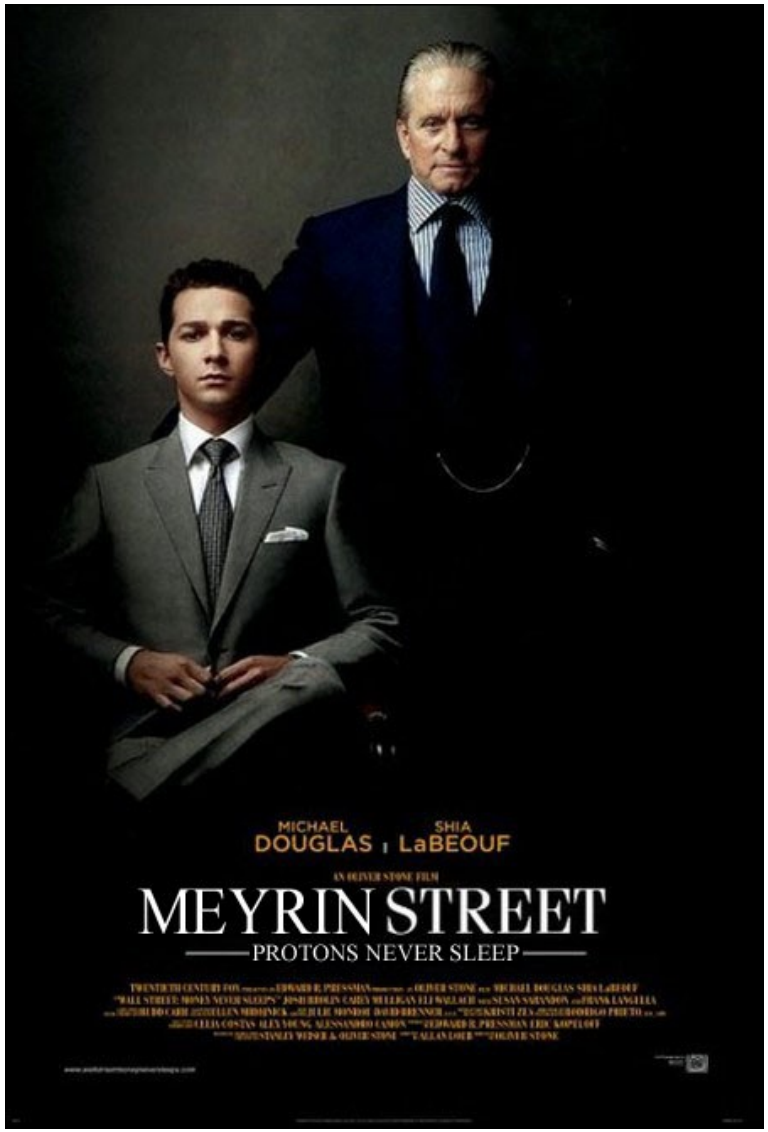
CONCLUSIONS

- Precycling
  - Is correctly followed – 50% of times previous physics cycle is used
- Decay of chromaticity
  - ~20 units of decay, as expected by FiDeL, but on much longer times
  - It is an issue for operation – should now be included
  - It will be in 2011, parameters based on beam measurements
- Chromaticity during ramp
  - Tracked within ±7 units – we can improve the initial part

CONCLUSIONS

- Tune decay
  - About 0.005 units, possibly due to MQ – could be automatically tracked
- Hysteresis
  - No evidence of problems related to hysteresis, neither in correctors nor during squeeze
  - Some side effects due to its implementation
  - We propose to remove it – we will include it only if really needed

ACKNOWLEDGEMENTS

- Thanks for discussions and comments
  - EIC: R. Alemany Fernandez, A. Macpherson, V. Kain, G. Papotti, M. Pojer, L. Ponce, S. Redaelli, W. Venturini Delsolaro
  - R. Steinhagen: feedback chromaticity and tune
  - M. Lamont, M. Strzelczyk: controls and strategies

WE'RE GETTING FAMOUS!