# FIELD MODEL AT 7 TEV

N. Aquilina, E. Todesco
CERN, Geneva, Switzerland

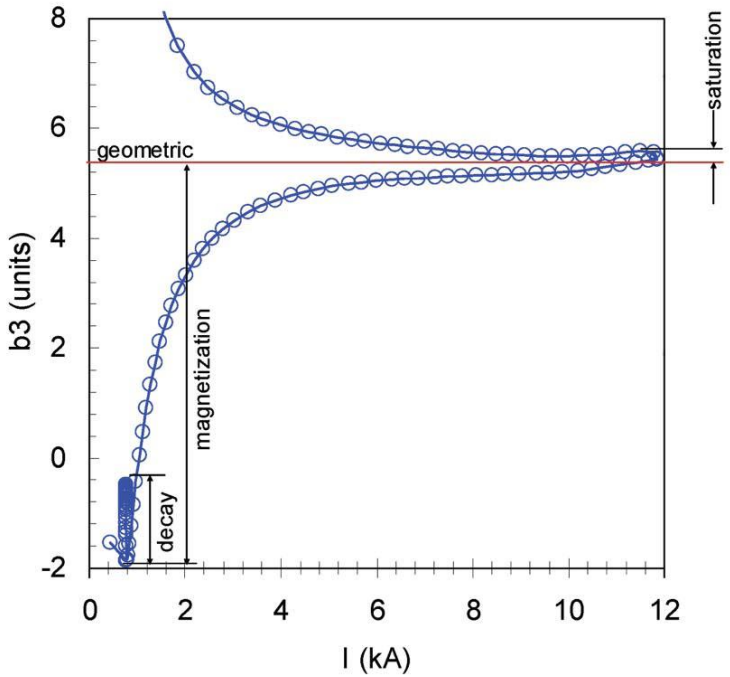
On behalf of the FiDeL team
http://www.cern.ch/fidel

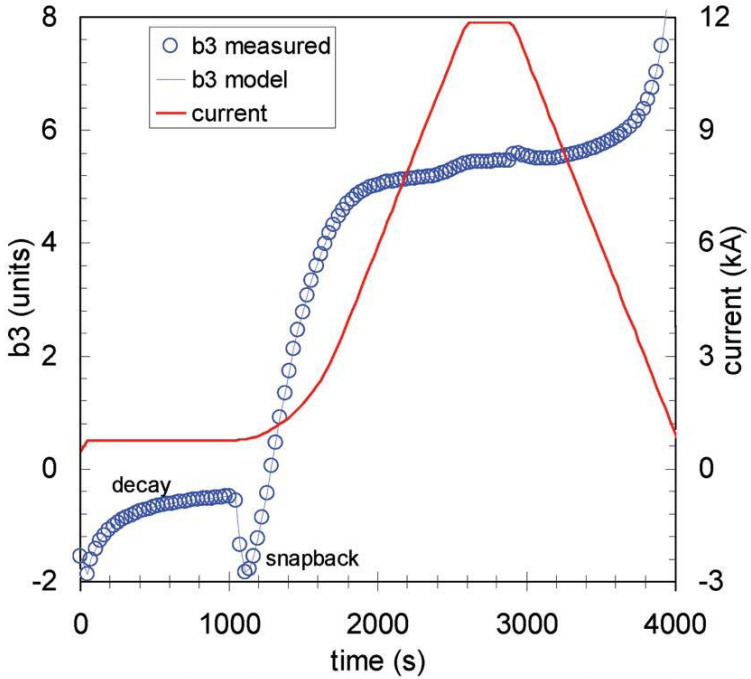
# CONTENTS

- Transfer functions at 7 TeV
  - Dipole (energy, orbit)
  - Quadrupoles (tune, optics, beta beating)
- Decay and snapback
- Hysteresis
- Precycling
- Cross-checks and errors

# DEFINITIONS

- FiDeL (Field Model of the LHC) is the recipe to convert current in field/gradients, plus the precycling strategy
  - Based on equations with free parameters to fit the measurements
  - All the knowledge of the magnetic measurements during correction lumped in these equations plus their coefficients

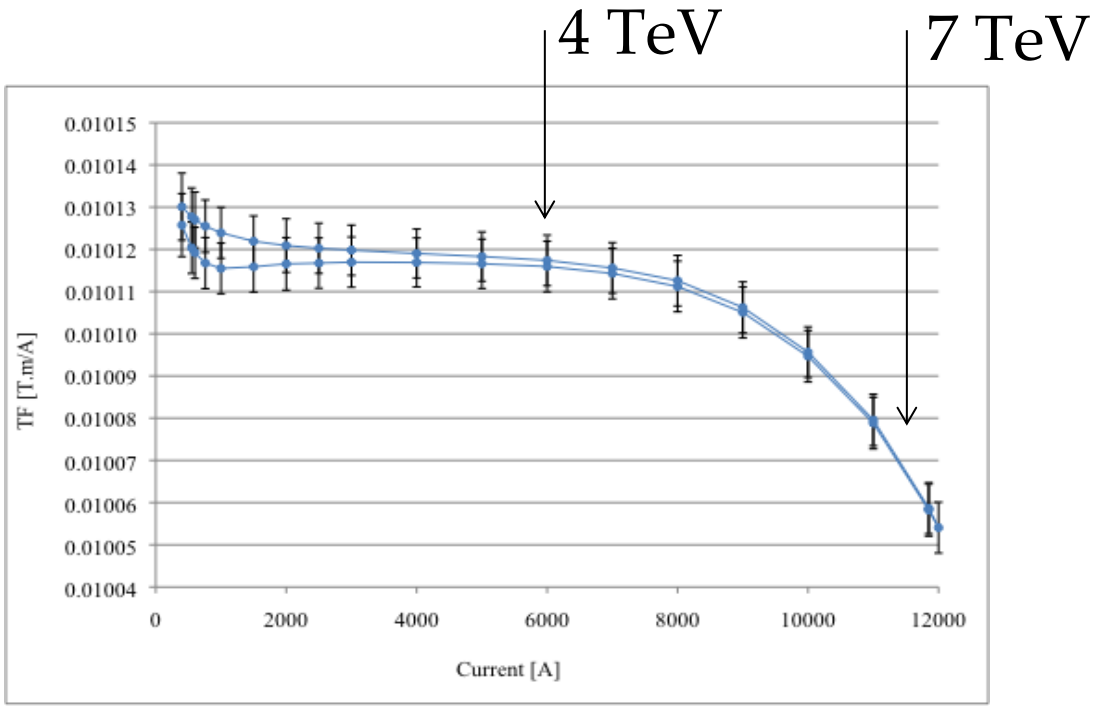



Field Description of the LHC [N. Sammut, L. Bottura, et al, Phys. Rev. STAB 9 (2006) 012406]

# TRANSFER FUNCTIONS

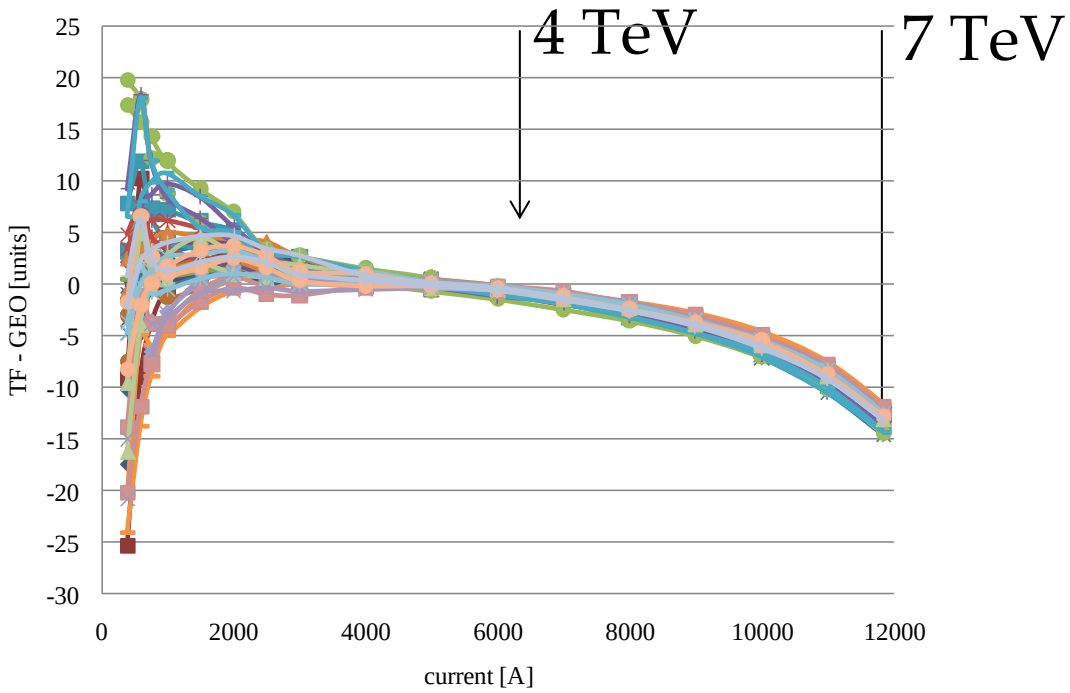
- At 7 TeV many LHC magnet will enter a regime of saturated iron (nonlinear transfer function)
  - MB: 70 units
  - Implemented, relative precision ~5%, we can expect 3 units error




LHC main dipole transfer function [L. Deniau]

# TRANSFER FUNCTIONS

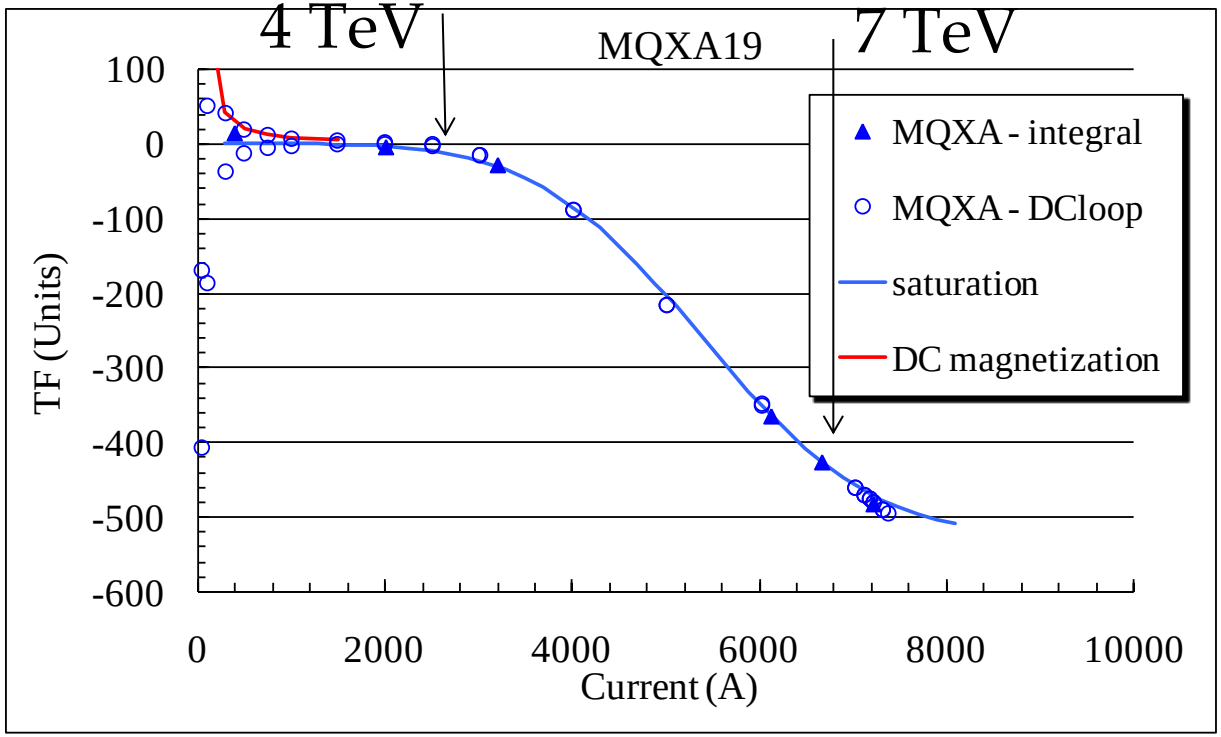
- At 7 TeV many LHC magnet will enter a regime of saturated iron (nonlinear transfer function)
  - MQ: 15 units
  - Implemented, we can expect 1 units error – not an issue




LHC main quadrupole transfer function [L. Deniau]

# TRANSFER FUNCTIONS

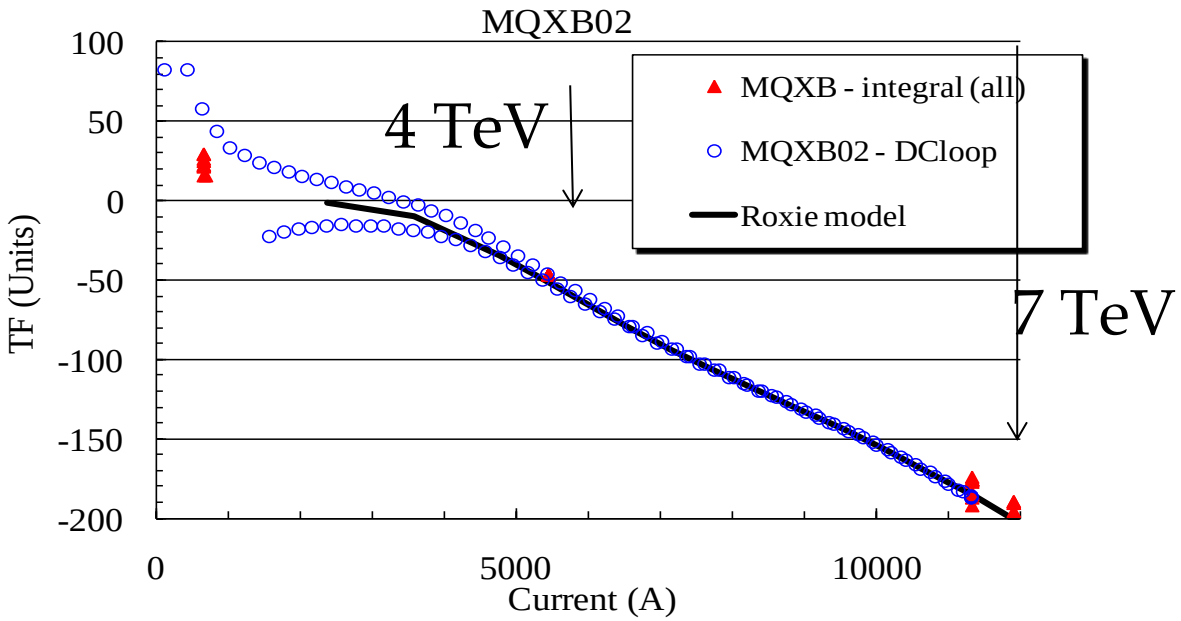
- At 7 TeV many LHC magnet will enter a regime of saturated iron (nonlinear transfer function)
  - MQXA: 500 units  this is the largest saturation in the LHC
  - Implemented, but we can easily expect 25 units error




LHC MQXA transfer function [E. Todesco]

# TRANSFER FUNCTIONS

- At 7 TeV many LHC magnet will enter a regime of saturated iron (nonlinear transfer function)
  - MQXB: 180 units
  - Implemented, we can easily expect 10 units error




LHC MQXB transfer function [E. Todesco]

# TRANSFER FUNCTIONS

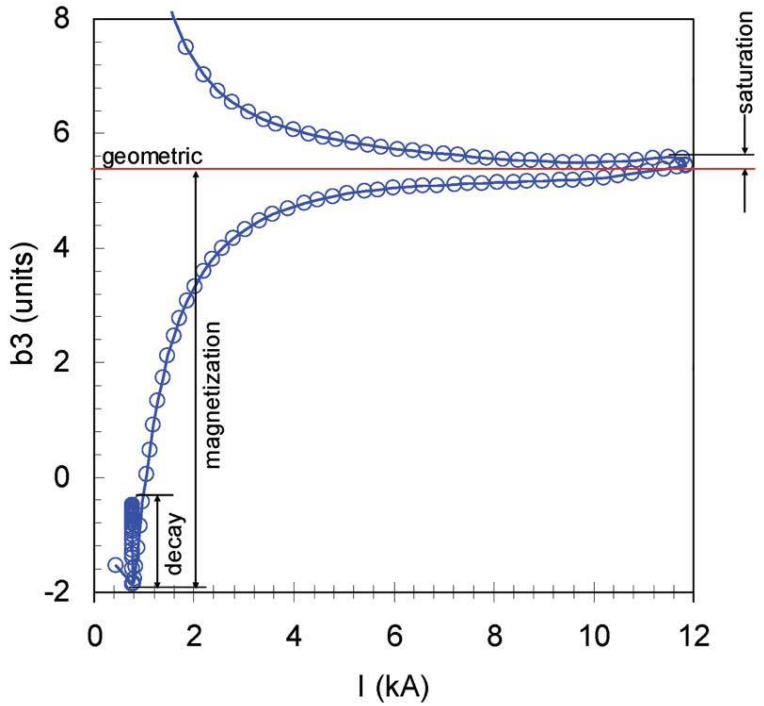
- Saturation summary
  - All saturations are implemented in the model since 2008
  - Some components are large, so with a relative precision of 5% one can have some uncertainty
  - Worse case: inner triplet quads, 500 units saturation in MQXA and 150 in MQXB
    - This can induce large beta beating after squeeze
  - For the dipole should not be an issue
    - 70 units saturation, error of a few units

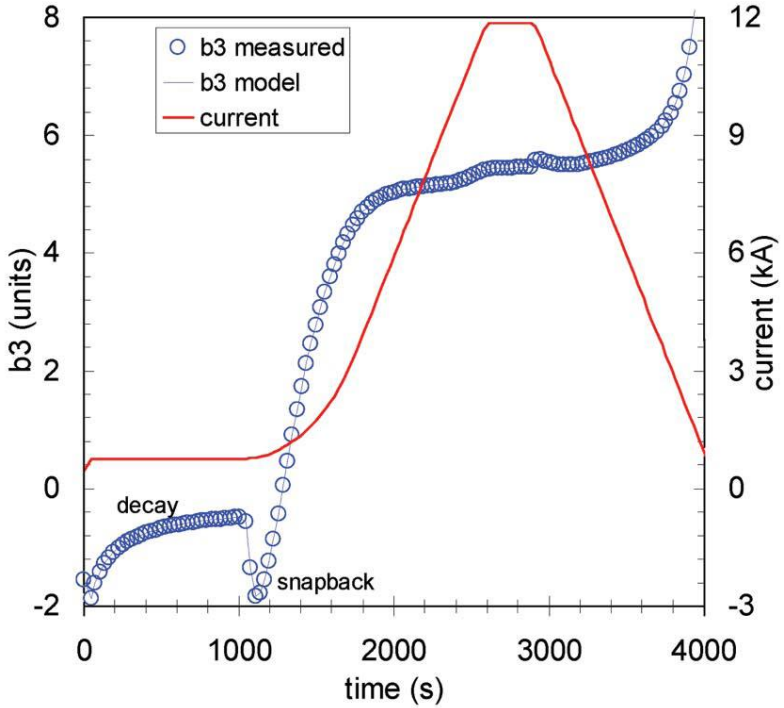
# CONTENTS

- Transfer functions at 7 TeV
  - Dipole (energy, orbit)
  - Quadrupoles
- Decay and snapback
- Hysteresis
- Precycling
- Cross-checks and errors

# DECAY AND SNAPBACK

- Decay of tune and chroma are modelled
  - Corrected on the inejction plateau - 0.02 of tune, 25 units of chroma
  - Chroma snapback implemented
- Amplitude of decay depends on top energy

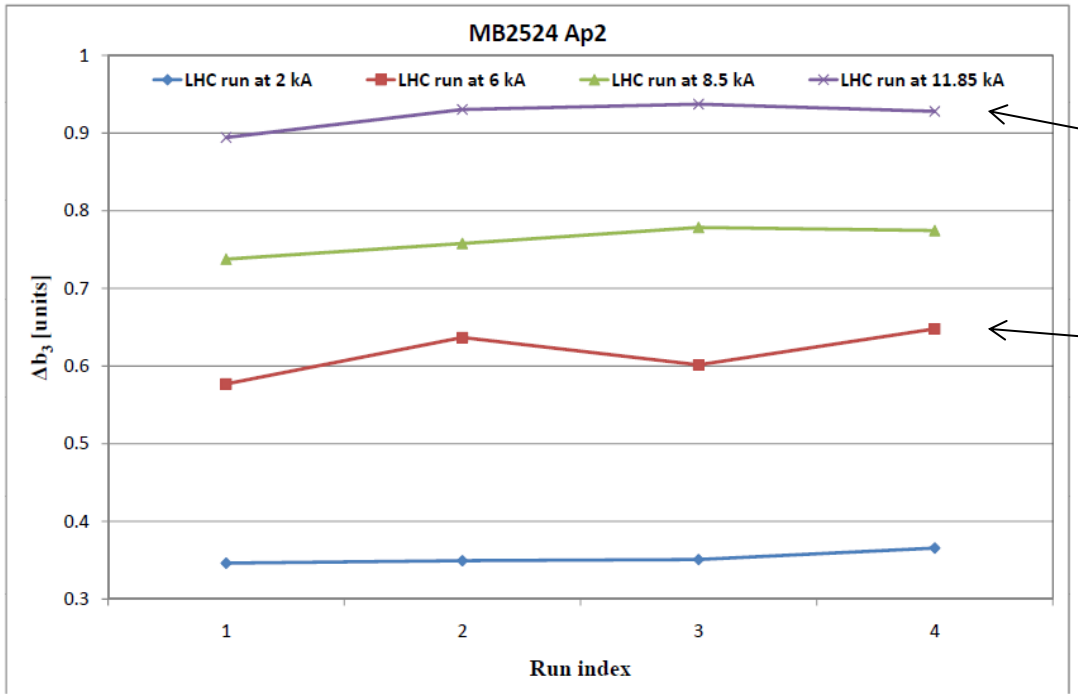



FiDeL model of injection and ramp [L. Bottura, N. Sammut]

# DECAY AND SNAPBACK

- Decay and snapback will increase of 50% from 4 to 7 TeV
  - This was measured in LHC dipoles
  - A chroma decay of 25 units will become of ~40
  - Powering history will have to be restimated



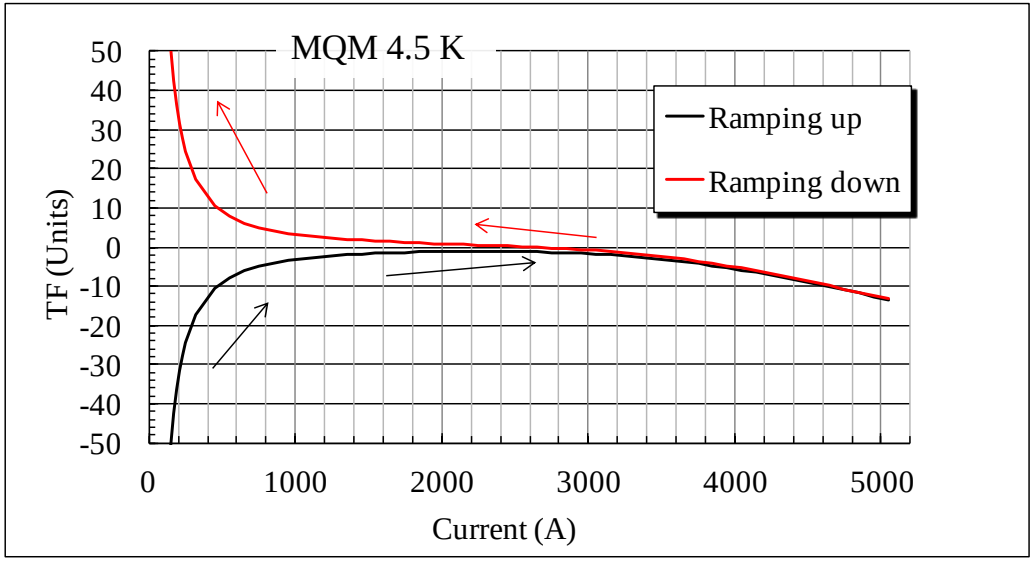

7 TeV

3.5 TeV

Amplitude of b3 decay at different energies [G. Montenero, N .Aquilina]

# HYSTERESIS

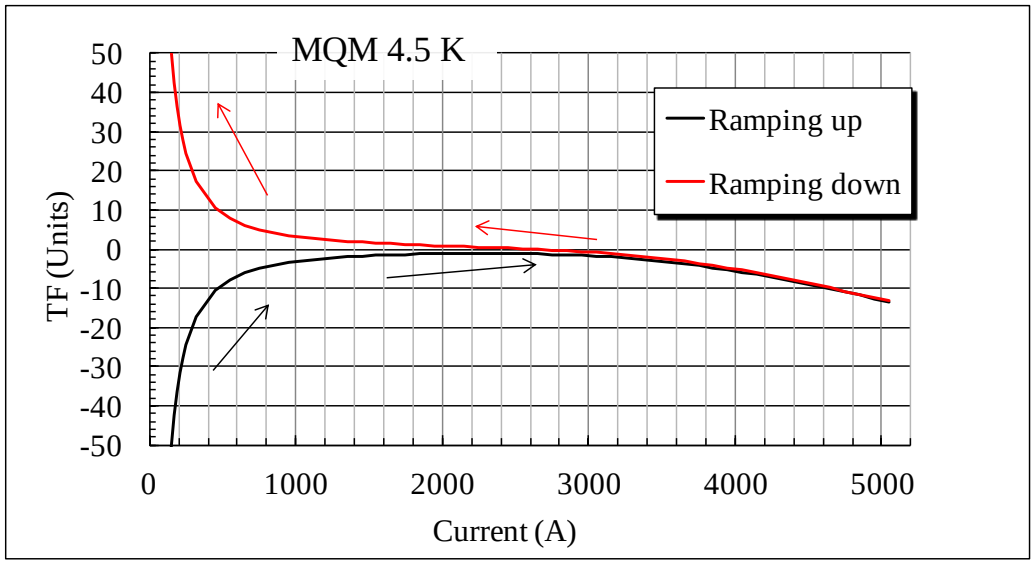
- Issue discussed since long time
  - Old nightmare of field modelers
- Some magnets ramp up and down
  - In a reproducible way: IR quads
  - In a way determined by feedback systems and other: correctors
- Both branches are implemented in the model, but not used




Transfer function in MQM, and branching when ramping up and down[E. Todesco]

# HYSTERESIS

- Both branches are implemented in the model, but not used
  - Switching from one branch to the other is not obvious, and creates discontinuities
  - Hysteresis removed
    - Not an issue for correctors
    - For MQM, MQY quads: we will implement the hysteresis as a trim

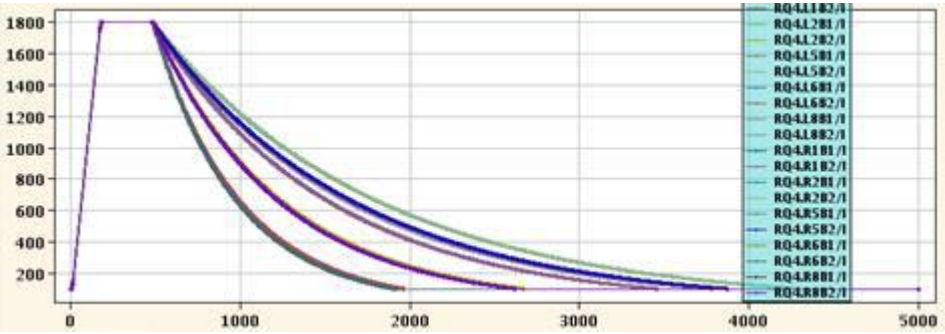



| β* (m) | RQ6.L1B2/I (A) | RQ6.L5B2/I (A) | RQ6.R1B2/I (A) | RQ6.R5B2/I (A) | Error (units) |
|---|---|---|---|---|---|
| 11 | 1846 | 1850 | 1843 | 1847 | 2 |
| 1 | 668 | 670 | 667 | 669 | 11 |
| 0.9 | 560 | 561 | 559 | 560 | 16 |
| 0.8 | 431 | 432 | 430 | 431 | 25 |
| 0.7 | 274 | 274 | 273 | 274 | 40 |
| 0.6 | 239 | 239 | 239 | 239 | 52 |

# CYCLING

- Proper precycling is the key of reproducibility
- Previous physics run can be used as a precycle
- At 7 TeV, no surprise, the linear part will be prolonged
  - Little space for reducing ramping time, dominated by the linear part (not possible to go faster than 10 A/s)

- For the precycling time we are dominated by IR quads



# CROSS-CHECKS

- The field model has several hundred parameters
- Cross-check is a must, error is probable

- Two examples:
  - A wrong precycle found by P. Hagen in 2009
    - The minimum current of the precycle was larger than injection current, so we were on the wrong branch
  - Several transfer functions of MQY wrong by 50-100 units, found by S. Fartoukh in 2012
    - Data were reviewed by P. Hagen, good matching with trims done with beam based measurements by R. Tomas Garcia

# CONCLUSIONS

- At 7 TeV (or 6.5 TeV) we will have strong saturation of many magnet families
  - Main issue: IR quads, precision of 10-20 units, induced beta beating,
  - Cure: corrections based on beam measurements as done in Run I
  - Should not pose problems for orbit and tune (MB and MQ)
- Decay and snapback will be 50% larger
- Hysteresis will be implemented as a trim
- Cross-check, cross-check, cross-checks …

# QUESTIONS ?