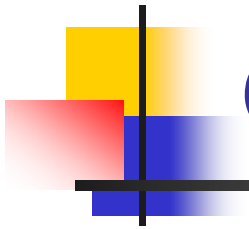
FiDeL- An Assessment and a View of the Future

Presented by L. Bottura

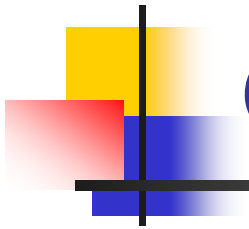
for the FiDeL Team

MARIC, June 11th, 2008



Outline

- Recap of the scope and plan of FiDeL
- Achievements (2006-2008)
  - Tracking test results
  - *REFHARM* and *REFPARM*
  - Error bounds of the present model
  - Balance of 2 years of work
- Loose ends and a trace for discussion



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Objective and targets of FiDeL

- The Field Description of the LHC (FiDeL) aims at **predicting the magnetic state of any magnet, magnet assembly or magnet circuit in the LHC**, following arbitrary operating cycles, to an agreed accuracy, as practical for accelerator control and beam dynamics studies
- FiDeL *clients*:
  - The **high-level LHC control software (LSA)**, requires **a parameterization of transfer function and harmonics** of the main magnet and corrector circuits to
    - Prepare machine settings for injection, define the ramp, and reach coast conditions
    - Provide trims for correction circuits during constant current plateaus, and especially to follow the field drift at injection
    - Provide trims for correction currents during the energy ramp, and especially during the snap-back at the beginning of the acceleration
  - The **LHC model (MAD)**, through WISE and LSA, requires **a snap-shot of the deviations from nominal optics (field errors)** in all magnets at an arbitrary time to perform studies on the LHC beams

Phys.Rev. ST, Accelerators and Beams, **9**, 012402 (2006)
Phys.Rev. ST Accelerators and Beams, **10**, 082802 (2007)

FiDeL Concept

- Field Model
  - Unified description of the field and field errors C_n applicable to all LHC magnets
  - Set of **parametric equations** for 7 physical components
    - Geometric (+ BS offset)
    - Persistent
    - Saturation
    - Residual magnetization
    - Decay
    - Snap-back
    - Ramp
- Field parameters
  - Adapt the parametric equations to fit the measured or expected behaviours of the magnets
  - Set of **≈ 20 parameters**, classified in 2 categories:
    - *Shape parameters*, equal for all magnets of the same type and family (e.g. all MB's with inner cable 01B)
    - *Amplitude parameters*, specific to each magnet (e.g. geometric C_n)

FiDeL and related work (MARIC, March 1st, 2006)

Phase I

- Short term (*2006 to sector test/commissioning*)
  - Define and validate the model
  - Create a common data structure
  - **Collect, prune, and complement data for all magnet types**
  - **Generate the configuration sets from the circuit and machine layout**

Phase II

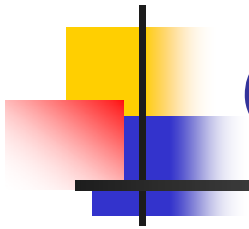
- Medium term (*2007-2008*)
  - Participate in the implementation and test of the LHC configuration and control system
  - Prepare for commissioning through studies of the effect of magnetic uncertainties (within the scope of FQWG)
  - **Adapt the parameters sets and create parameters trims tables during sector test/commissioning**
  - **Define, perform and analyse measurements on off-line benches in SM-18**

Phase III

- Long term (> *2008*)
  - Maintain data structures, tools and settings
  - **Participate/motivate MD and dedicated field measurements to optimise LHC operation**

time

NOTE: dates intentionally left unchanged from those announced at MARIC of March 1st, 2006



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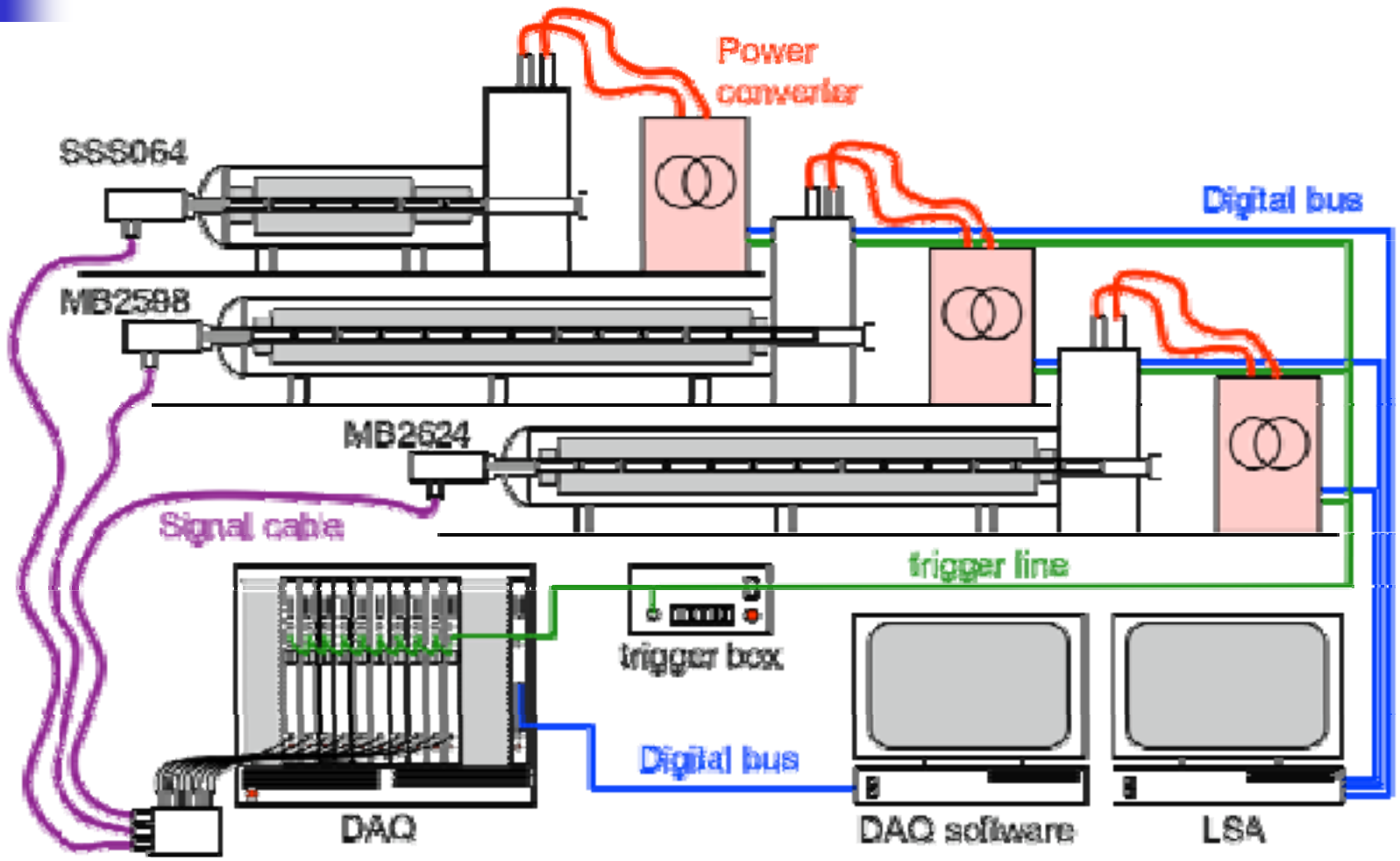
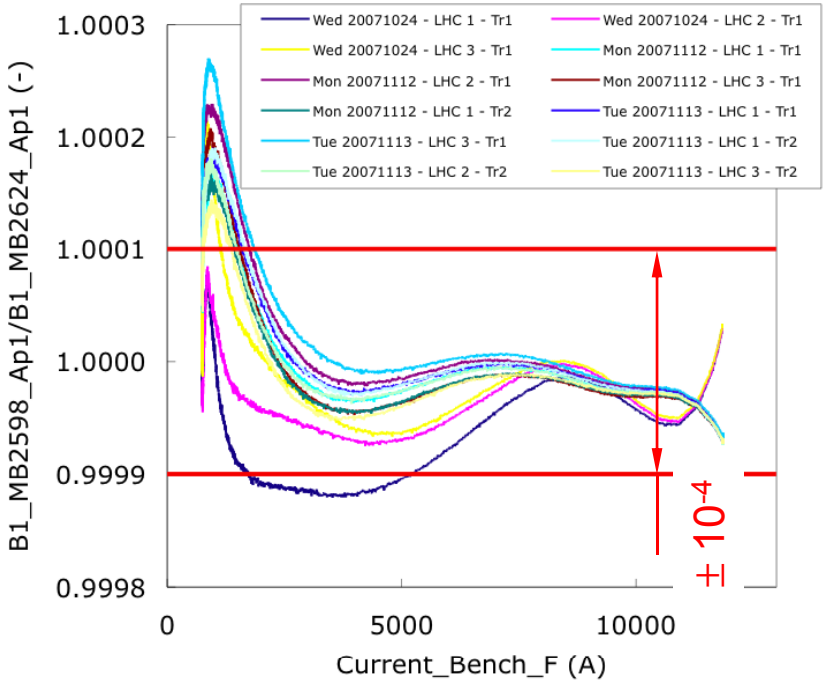
Tracking test



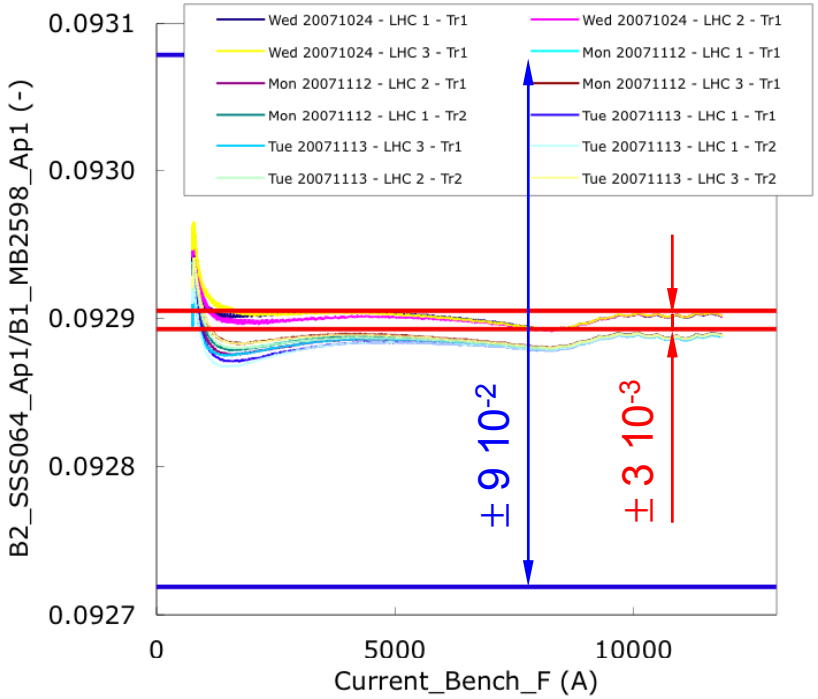
Credits to: J. Miles, W. Venturini, N. Sammut, P. Xydi, R. Alemany Fernandez, M. Lamont, M. Strzelczyk, G. D'Angelo, G. Deferne, R. Mompo, L. Deniau, S. Sanfilippo

Tracking test results - 1/2

Tracking of B1 (orbit)



Tracking of B2/B1 (tune)



Well within *commissioning specs*

Reproducibility of ramps close to nominal beam specs and in any case better than the (estimated) measurement accuracy

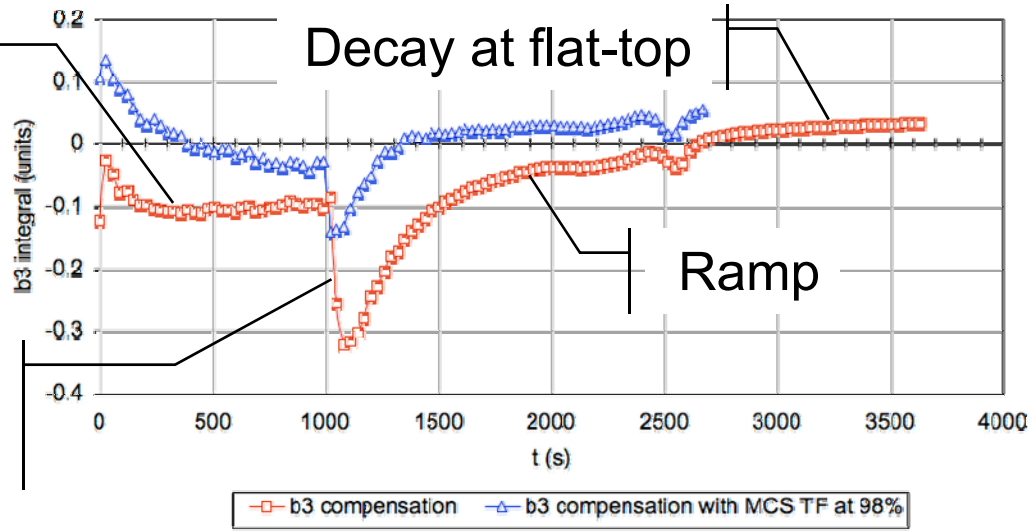
Tracking test results - 2/2

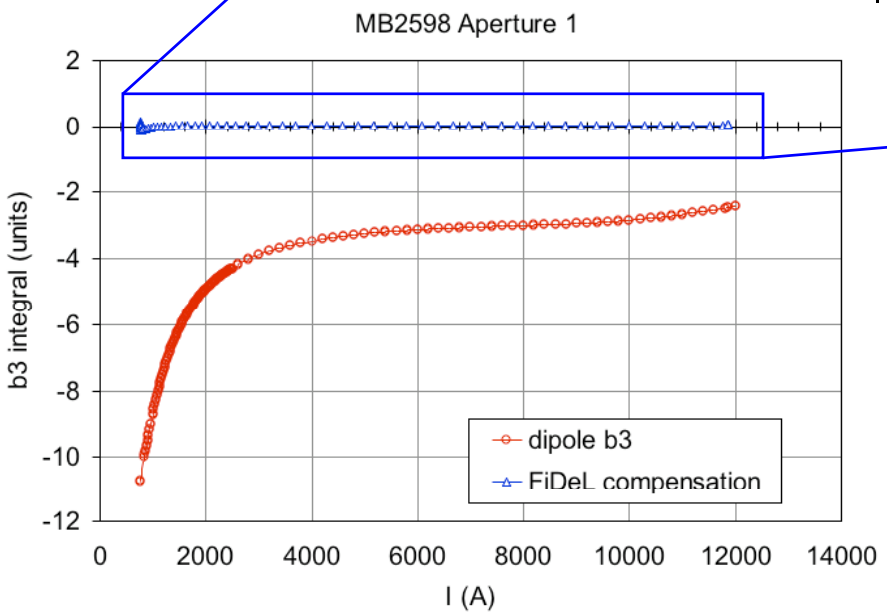
Decay at injection

Decay at flat-top

Ramp

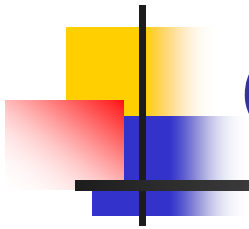
Snap-back and early ramp





Well within *commissioning specs*

Some residual *features* hint at the need for more work necessary to validate the whole chain (FiDeL in LSA)



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Data collection (REFHARM)

Status: Done | In progress | No data | None | Not applicable

Magnets	Contacts	Field Harmonics (REFHARM)	Model Parameters (REFPARM)	Layout (REFDESC)
MB @cold	L. Deniau, N. Sammut			-
MB @warm	P. Hagen, E. Todesco		-	-
MBX	J. Miles			-
MBR	J. Miles			-
MBW, MBXW, MCBW	M. Buzio			-
MQ @cold	L. Deniau			-
MQ @warm	P. Hagen		-	-
MQM @cold	W. Venturini, N. Catalan-Lasheras			-
MQM @warm	N. Catalan-Lasheras, P. Hagen		-	-
MQY @cold	W. Venturini			-
MQY @warm	N. Catalan-Lasheras		-	-
MQX	E. Todesco			-
MQW	M. Buzio, P. Xydi			-
MQTL @cold	W. Venturini			-
MQTL @warm	V. Remondino		-	-
Correctors @cold	W. Venturini			-
Correctors @warm	V. Remondino		-	-
Experimentals				-
Layout	P. Hagen	-	-	

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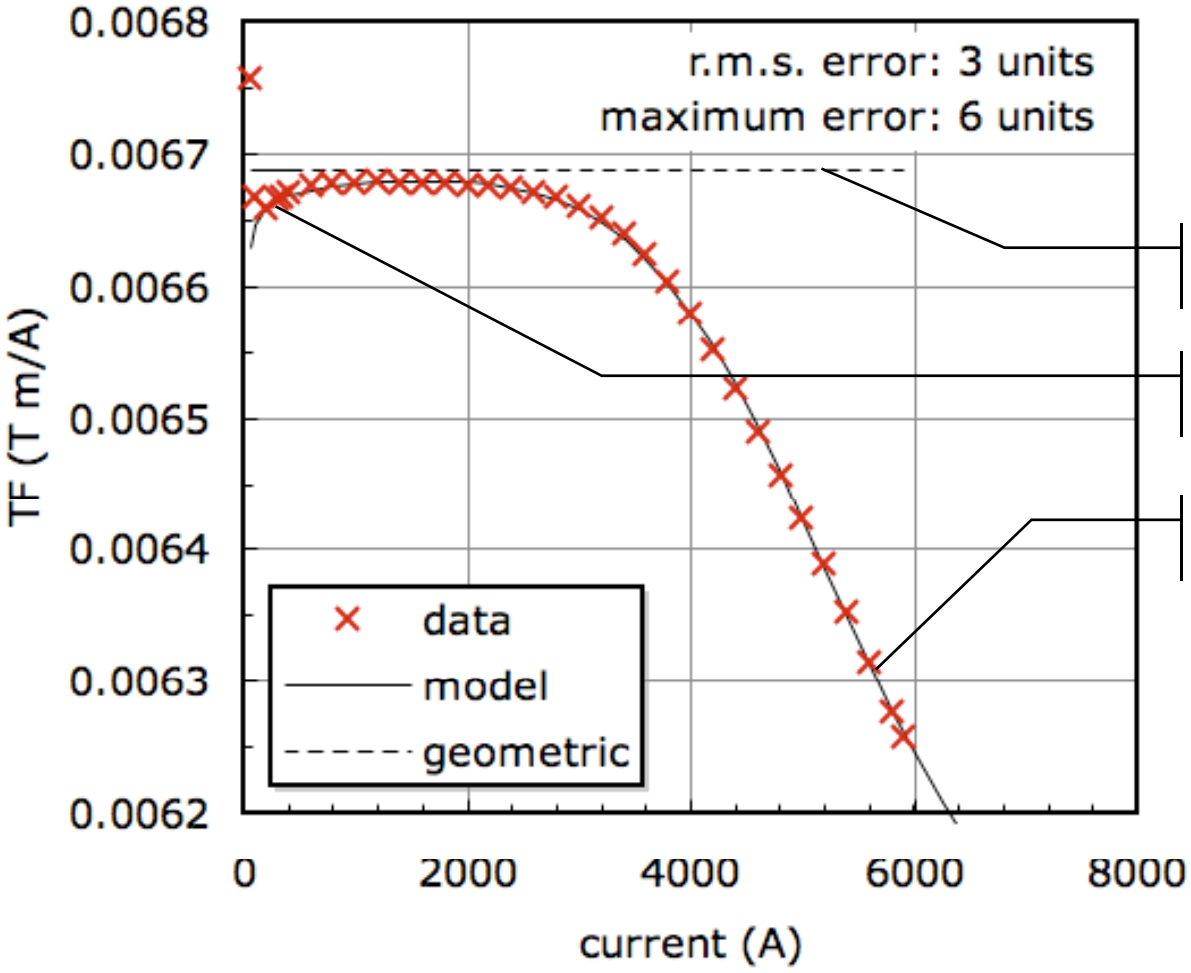
Model parameters (REFPARM)

Example: Integral transfer function for cold D1 (MBX)



Geometric (linear field)

Persistent

Saturation

LHC-ES-0012 ver.1.1
EDMS 908232

Model parameters (REFPARM)

Status: Done | In progress | No data | None | Not applicable

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Experimentals				-
Layout	P. Hagen	-	-	

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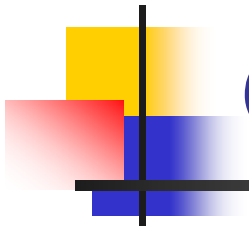
Comments on REFPARM

- MQY model completed by N. Catalan and W. Venturini, is being checked for formal consistency
- MQXA model completed by E. Todesco, detailed data on MQXB received last week-end
- Model of MQW completed, averaging per circuit is in the making (magnets are flipped in the same circuit !)
- Work on Q6 (6 x MQTLH) yet to be defined
- Work on experimental magnets (LHC-B, Alice) yet to be defined
- Modeling work on most warm magnets (all apart for MQW) was done by V. Remondino and R. Wolf



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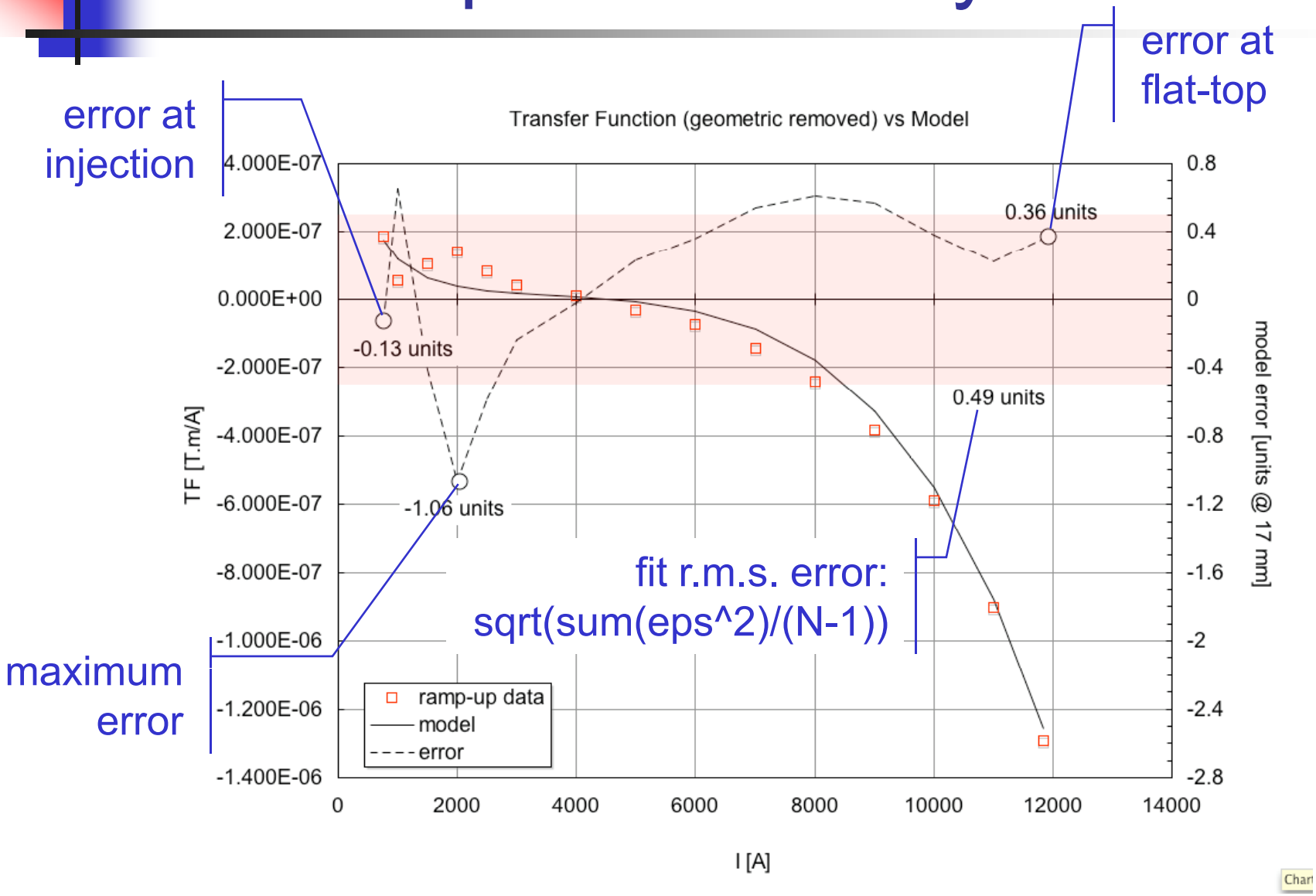
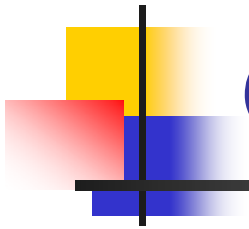
How to quote accuracy



Accuracy by magnet family (WIP)

Modeling error indicators on integral transfer function

Circuit type	ε_{rms}	ε_{max}	$\varepsilon_{injection}$	$\varepsilon_{flat\text{-}top}$	$\sigma_{magnets}$
MB	0.2	0.6	0.1	0.1	≈ 5
MBX (D1)	4.2	8.8	1.4	4.8	
MBRC (D2)	0.7	1.2	1.0	0.5	
MBRS (D3)	3.6	6.4	0.6	5.3	
MBRB (D4)	0.6	0.9	0.7	0.6	
MQ	0.5	1.1	0.1	0.4	≈ 10
MQM	1.1	5.7	0.5	1.0	
MQY	1.3	9.5	1.2	1.1	
MQXA	5…6	10	3	5	
MQXB (modeling in progress)					
MQWA	8.6	28	1.2	12	
MQWB	7.6	29	0.5	5.6	
Q6 (6 x MQTL) (TBD)					
Correctors	≈ 5				≈ 50



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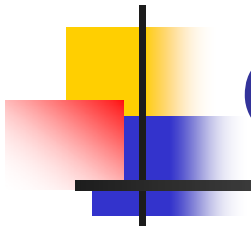
Summary of work done

Task	*completed*	*Estimated manpower (men-months)*	*Required manpower (men-months)*
Model Specification	Jan 2008	1	≈ 2
Create FiDeL data structures	Apr 2007	3	≈ 3
Implement FiDeL Engine	Apr 2008	4	2(1)
Normalization cycles	May 2008	2	≈ 2
Magnetic data consolidation	-	20	≈ 40(2)
Data modeling (circuits TF)	-	-	18(2)
MB/MQ/correctors powering and tracking test	Dec 2007	6	10
Sector powering test	-	-	-
Adapt WISE interface to FiDeL	Jun 2008	2	2
Total		**38**	**≈ 79**

NOTES:

(1) Evaluation of parameters from REFPARM files

(2) Work in progress, approaching completion



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Loose ends (Phase I + II)

- Tidy-up and check, check, check…
  - REFPARM
  - REFHARM
- Complete REFPARM to include harmonics
- Create and store data in a database (and use it)
- Complete cycling prescriptions
  - Verify settings vs. allowables vs. measured
- Tidy up and check, check, check…
  - On-line LSA/FiDeL
- Define, execute and analyse measurements in SM-18 and B4 on spares
  - Complete LSA/FiDeL off-line validation
    - B3 jump ?!?
    - Powering history ?!?
    - MS/MQ tracking
  - Magnet cycles
    - Insertion magnets
    - 5 TeV vs. 7 TeV
    - Cycle ramp-rate
  - Hysteresis !!! **(MQM/MQY)**

Where to go from here ? (Phase II + III)

- **Recap:** we have the accumulated knowledge of the magnetic field quality of the LHC and of the origins and physics of the phenomena:
  - Warm data for all SC magnets, field maps for all NC magnets
  - Alignment data for all magnets
  - Characterization data for components (strands and cables,
  - Cold data for 20 % of the production
  - Parametric model of all magnet circuits
- **Feed this wealth of knowledge into the operation (*useful for AB*)**
- **A reality check with beam provides feed-back on the hypotheses that were at the basis of the design and specifications of the LHC production (*useful for AT*)**

Why ? (an *AT perspective*)

- We are committed to the LHC in all aspects, including its optimal performance
- We want to learn what is important (and what not) in our largest accelerator, to make sure that we stay connected with our clients and reality. This will increase the quality of our work of magnet builders
- We want to bring home interesting and motivating work

What should we do

- Identify a core of people that insures:
  - A permanence during key times in CCC
    - Dry runs (now) and in general commissioning of the control system
    - Injection tests, threading, initial measurements of the optics (see LHCCWG procedures)
    - MD's dedicated to improvement of the beam quality
  - Dedicated MD proposals to understand magnet behaviors/uncertainties critical to performance
- NOTE: I think that sitting and waiting is not the right policy

How ?

either…

- Transform the MPP, changing the mandate and staffing to make it a support for the *magnetics*
  - Pro: a mechanism is already in place, mandate from DL, linked to operation
  - Contra: the structure is rather heavy, partially missing competences

…or

- Change the scope of FiDeL to cover support to operation of *magnetics* with beam, and define an overseeing body for the “AT Support to LHC” that takes care of CRG/VAC/MCS/MEI contributions (including MPP and its evolution)
  - Pro: competences on magnetics are practically all in the FiDeL Team, including links to AB-OP and AB-ABP
  - Contra: present work is rather informal, requires a departmental mandate to evolve

Summary - 1/2

- Phase I of the project is *nearly* over:
  - As far as we could tell (see results from the tracking test), the concept will work
  - A first version of the LHC magnetic configuration is *nearly* ready to be used (matter of weeks, feed-back from AB-OP is expected soon)
- Follow-up (Phases II and III):
  - Tidy-up, tie the loose ends and incrementally improve the model (this is the beauty of it !)
  - Measure to improve our knowledge/understanding:
    - **Low field hysteresis in insertion quads and selected correctors**
    - Effect of cycles different from those used for series measurement
  - **It is now urgent to define and realize the link to LHC operation**

Summary - 2/2


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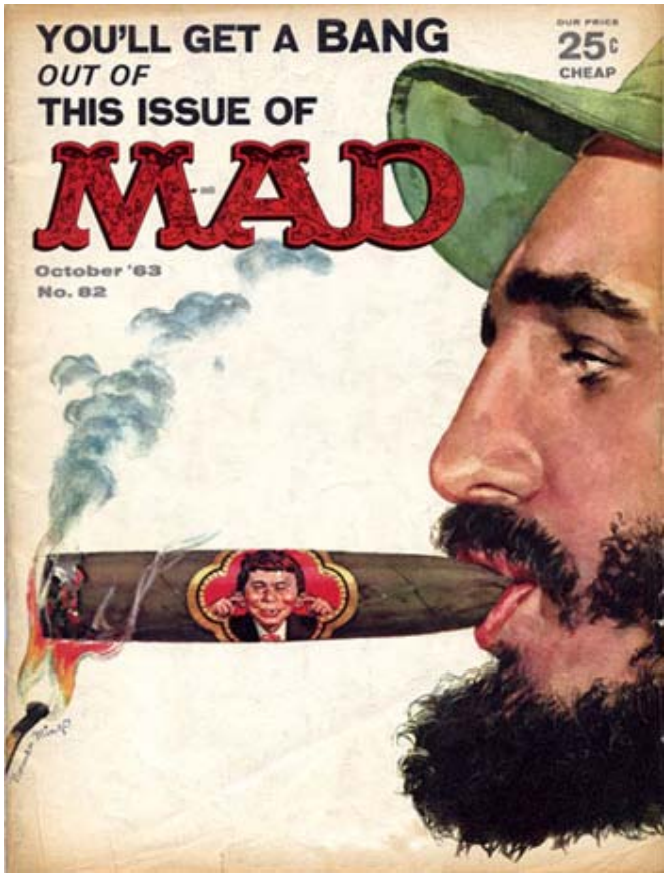
Acknowledgements

- It is a pleasure to acknowledge the work of a motivated and committed team:
  - Gilles Berard, Marco Buzio, Nuria Catalan Lasheras, Laurent Deniau (secretary for the team), Mario Di Castro, Per Hagen, John Miles, Vittorio Remondino, David Sernelius, Nicholas Sammut, Stephane Sanfilippo, Ezio Todesco, Walter Venturini-Delsolaro, Panagiota Xidi
- in collaboration with our colleagues in AB:
  - Reyes Alemany Fernandez, Ilya Agapov, Massimo Giovannozzi, Mike Lamont, Frank Schmidt, Marek Strzelczyk
- with the advice and help of some *wise men*:
  - Jean-Pierre Koutchouk, Louis Walckiers, Rob Wolf

And of course…



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