Operatività a Lungo Termine del Magnete e Mappatura del Campo Magnetico

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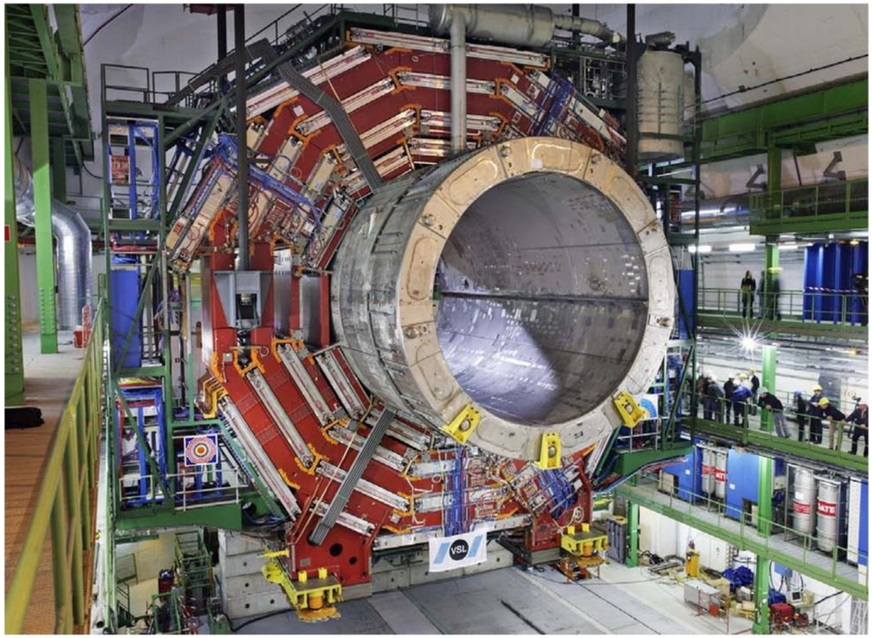
CMS ITALIA – Spoleto - 14 Dic 2016

Il solenoide di CMS: Oggi

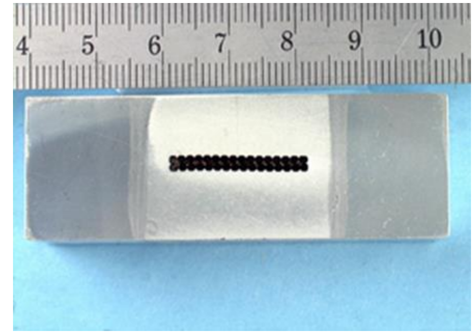
CMS Solenoid	
Inner diameter	6.320 m
Outer diameter	6.946 m
Number of layers	4
Number of turns	2189
Nominal current	18164 A
B max	3.8 T
B max over conductor	4.2 T
Stored energy	**2.67 GJ**
Strain over conductor	1.5e-3



Il cavo lavora vicino al regime plastico.
Quanti cicli può ancora svolgere prima di usurarsi?

Effetto dei cicli on/off sul conduttore

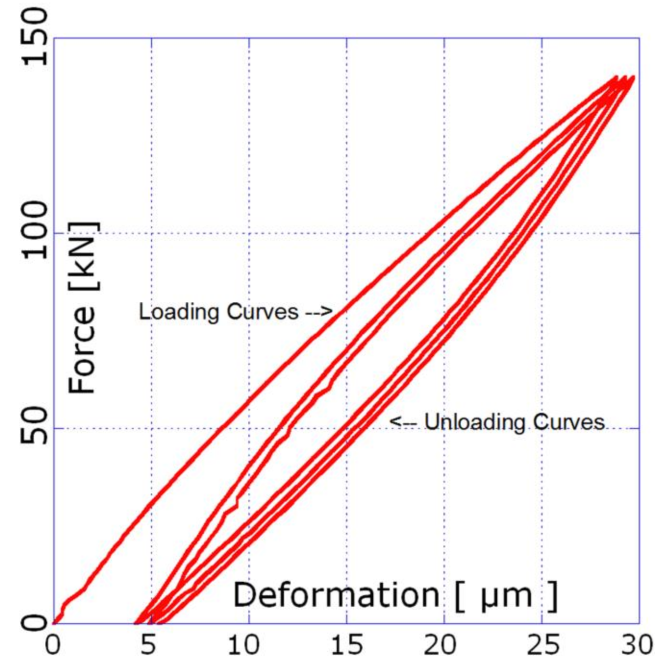
@INFN-Genova, con CERN e CEA
Serie di misure per stabilire
l’effetto dei cicli sul conduttore



Conditions to be reproduced

- Fast discharge of the magnet
- Normal charge of the magnet

Every sample of conductor **has been cycled** 100 times at **different speed** applying a linear ramp up to 140kN to **deform it up to 0.15%.**



Current Transfer Length

Voltage Drop Between Al matrix and SC cable

$$V(x) = r_{contact}\frac{dI(x)}{dx}$$

Ohm law

$$\frac{dV(x)}{dx} = r_{Al}I(x)$$

Combining

$$\frac{d^2I(x)}{dx^2} = \frac{1}{\lambda^2}I(x)$$

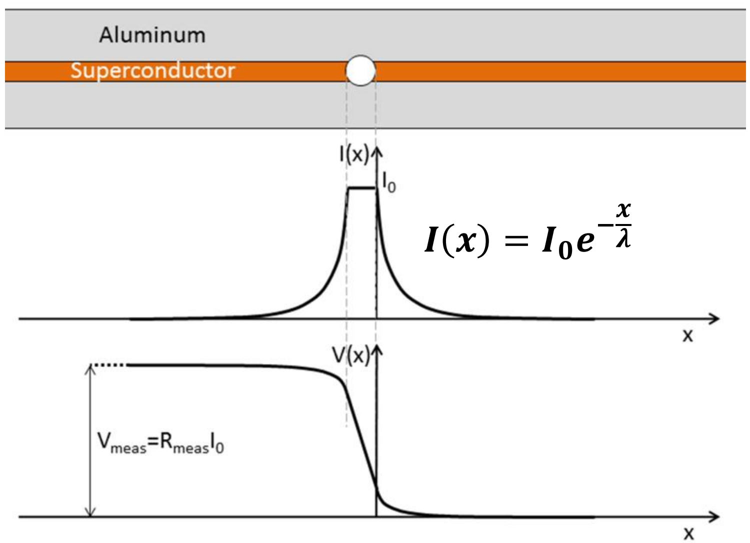
$$\boldsymbol{\lambda} = \sqrt{\frac{\boldsymbol{r_c}}{\boldsymbol{r_{Al}}}}$$

where

$$[r_{contact}] = [\Omega \cdot m]$$
$$[r_{Al}] = [\Omega/m]$$

Current Transfer Length

Indicator of the quality of the contact between the Rutherford strands and the aluminum matrix.



$$\boldsymbol{I(x) = I_0 e^{-\frac{x}{\lambda}}}$$

How to measure?

$$V_0 = 2\int_0^{+\infty} r_{Al}I(x)dx = r_{Al}\lambda I_0$$

Measured Resistance

$$R_{meas} = 2r_{Al}\lambda + R_{hole}$$

Current Transfer Length

$$\lambda = \frac{R_{meas} - R_h}{2r_{Al}}$$

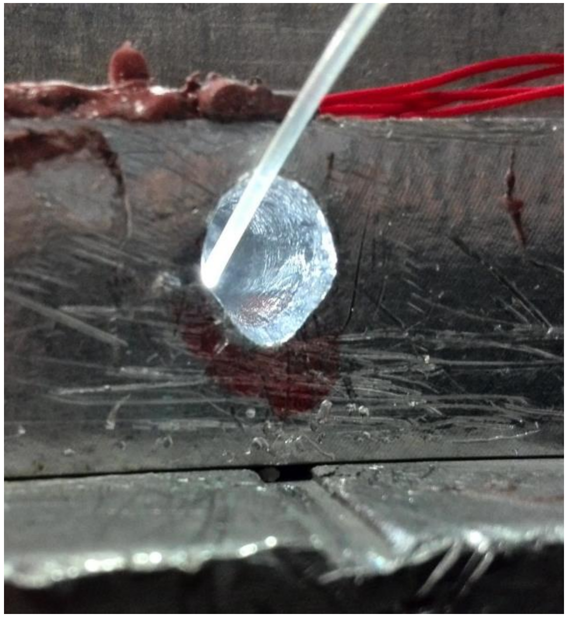
Contact Resistance

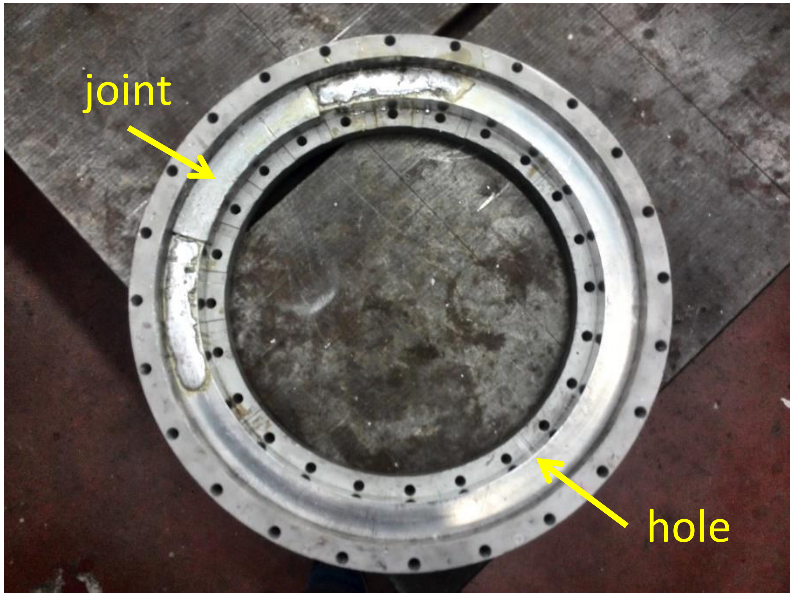
$$r_{contact} = \frac{(R_{meas} - R_h)^2}{4r_{Al}}$$

Measurements

Current up to 20kA
B Field up to 4.5 T

$$\frac{d\Phi}{dt} = L\frac{dI}{dt} + R_{Tot}$$



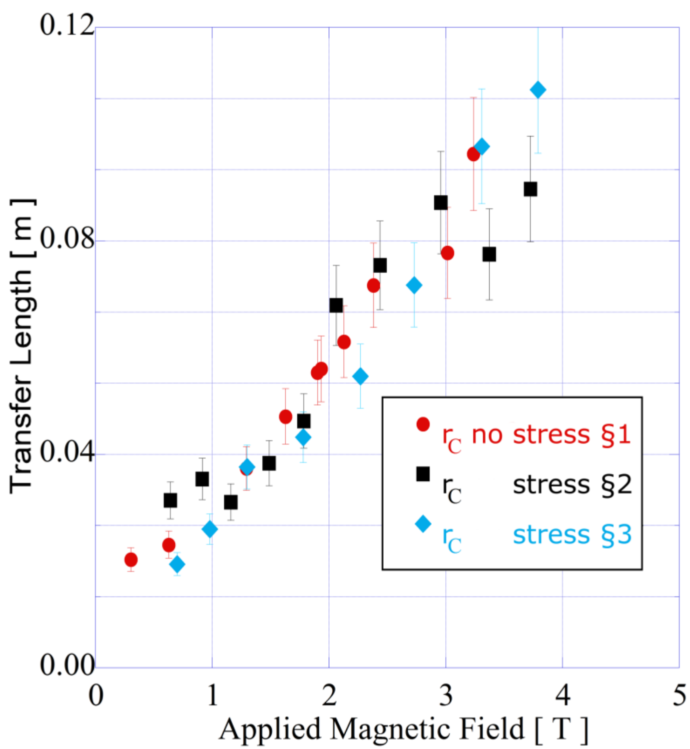


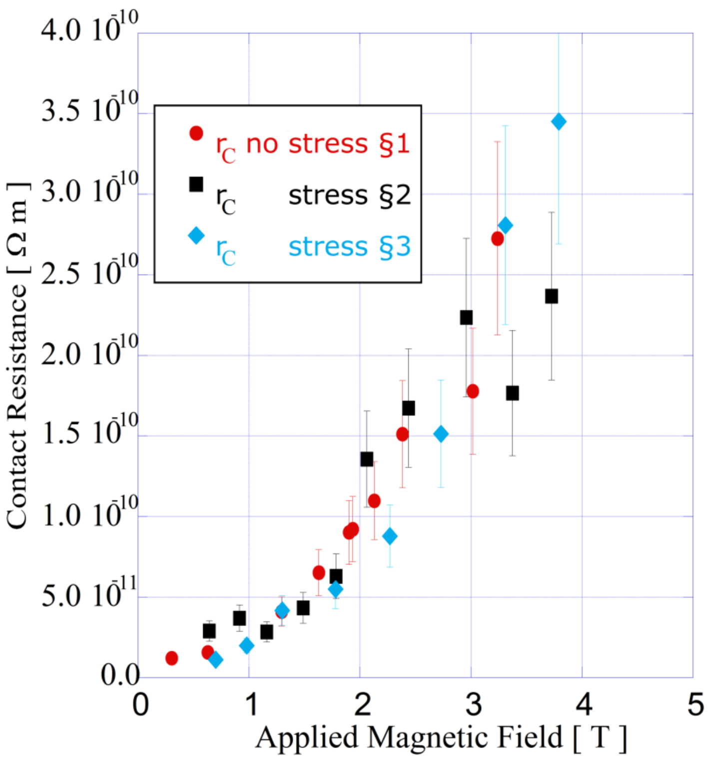
Decay Method

$$I(t) = I_0 \exp(t/\tau)$$

$$\tau = \frac{L}{R_{Joint} + R_{meas}}$$

Results





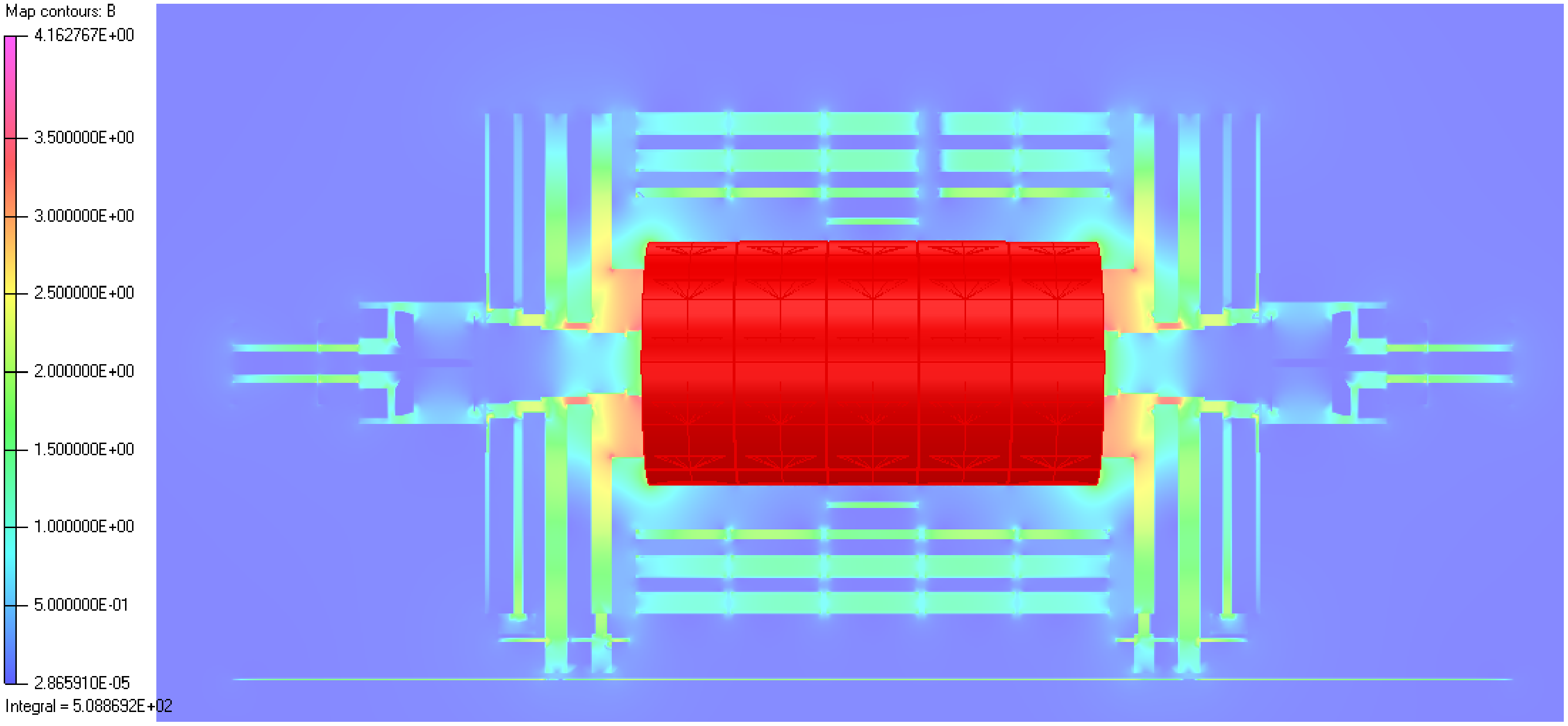
Strong dependance from B field

but

No dependance from the induced stress!

Operating @ 3.8 T is fine

A new FEM Magnetic Model for CMS



Phylosophies of the CMS Models

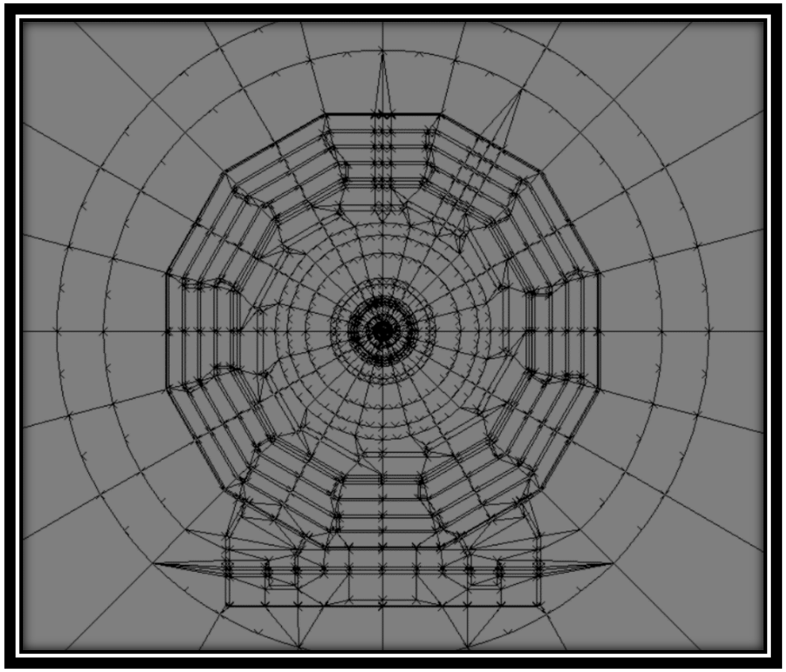
Present Model (Slava Klyukhin) Best Optimization	New Model (Valerio Calvelli) Widest Versatility
Close Code for the Geometry	Open Code for the Geometry
Mesh is defined by the User point by point	Mesh is automatically defined by the Geometry
Fixed Model	Parametric Model
Building is not user-friendly	Building is user-friendly
Best Ratio Mesh Complexity/Computation Time Mesh Complexity/Memory Stored	Minimize Human Time

Geometry Implementation

Present Model

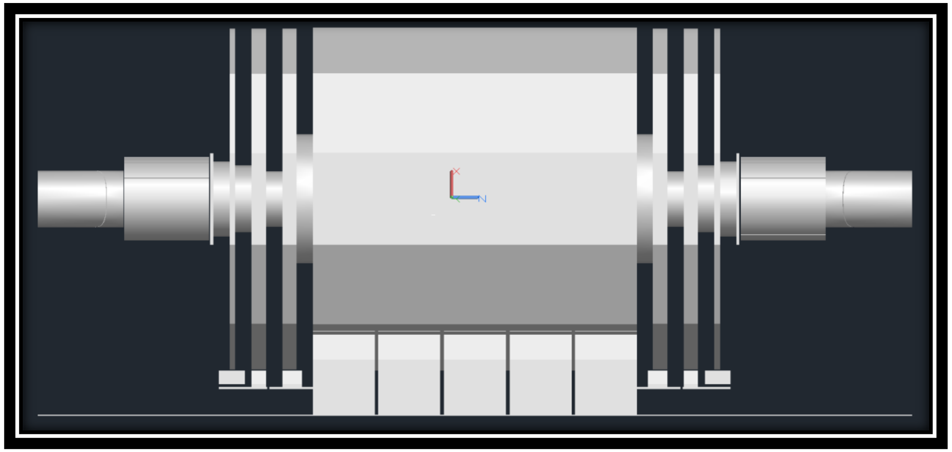
Geometry is defined

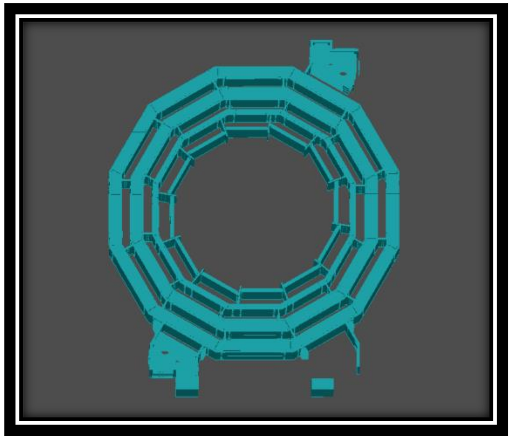
- layer by layer
- point by point



New Model

Geometry is imported by drawings (.stp, .sat, .iges,...)

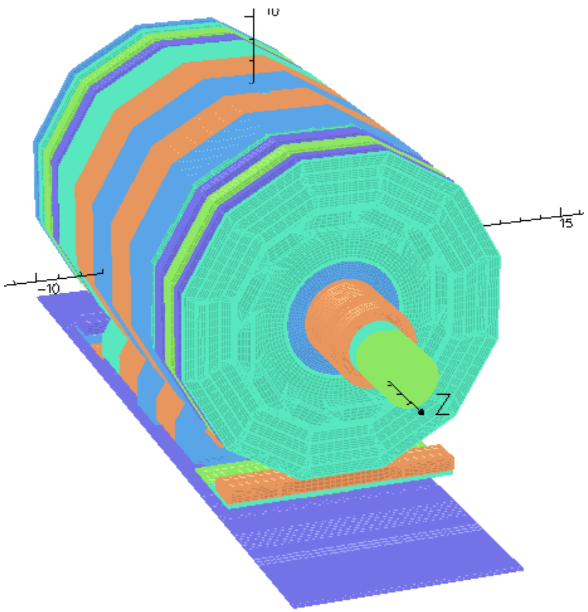




Mesh Implementation

Present Model

Every point of the Geometry is a vertex for the mesh.



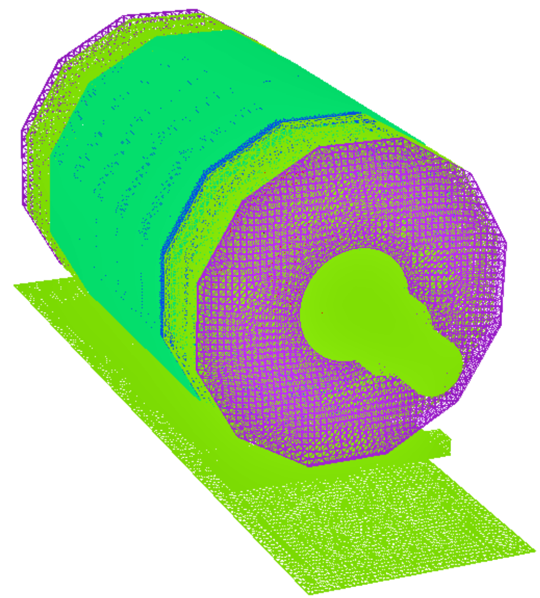
Full Control of the Mesh.

Best optimization possible between precision of the solution and time computing

Hard human work

New Model

Mesh is automatically generated where the geometry is defined.



Parametric Model

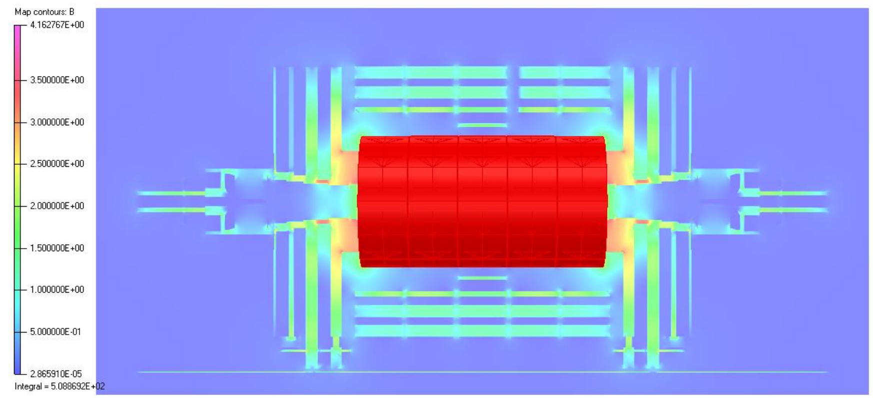
Every User can **vary the mesh** size of every object to find the required mesh **precision**

The model can be optimized iteratively

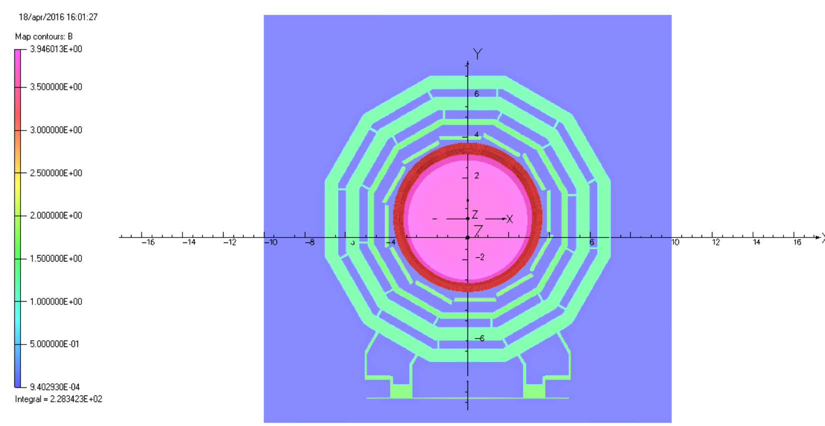
Comparison Between the Models

An accurate analysis was performed to find if the two models were compatible.

1. **Global Evaluation** of the two models
(numerical and systematic deviations)
2. **Compatibility with the new flux loop measurements**



opera
simulation software

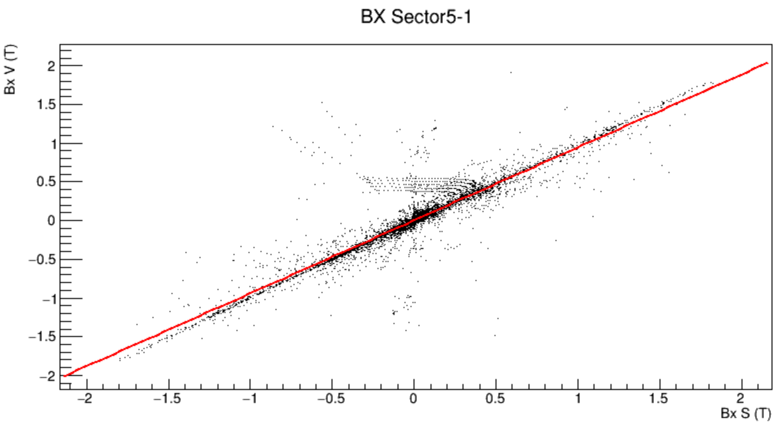


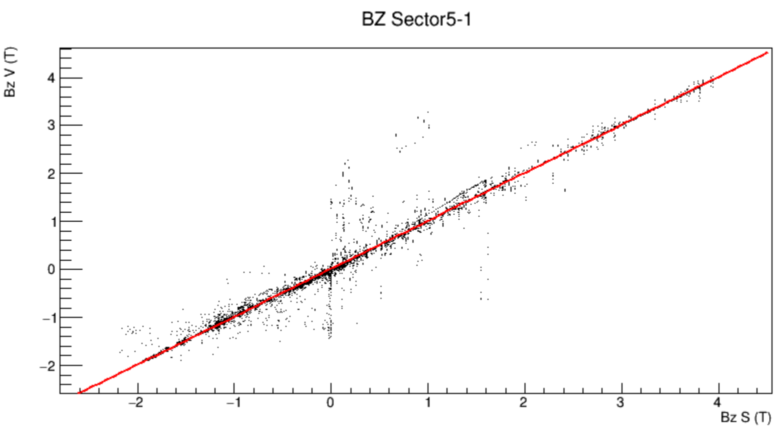
opera
simulation software

Global Evaluation

Procedure:

- Random extraction of coordinates (x_i, y_i, z_i) in every CMS Sector
- Evaluation at (x_i, y_i, z_i) of the magnetic field and the magnetic permeability in both models
- Plot the magnetic field/magnetic permeability of one model as function of the other
- Linear fit and analysis of non-random pattern



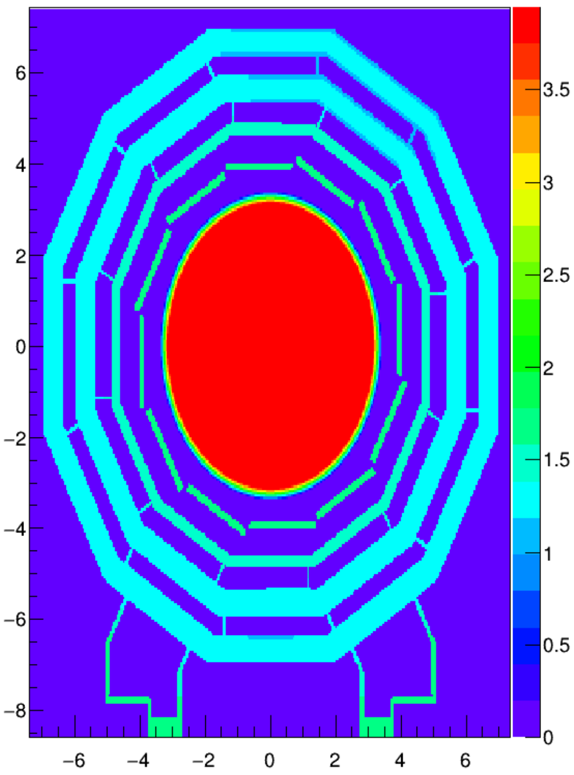


Example of the results with systematic deviations

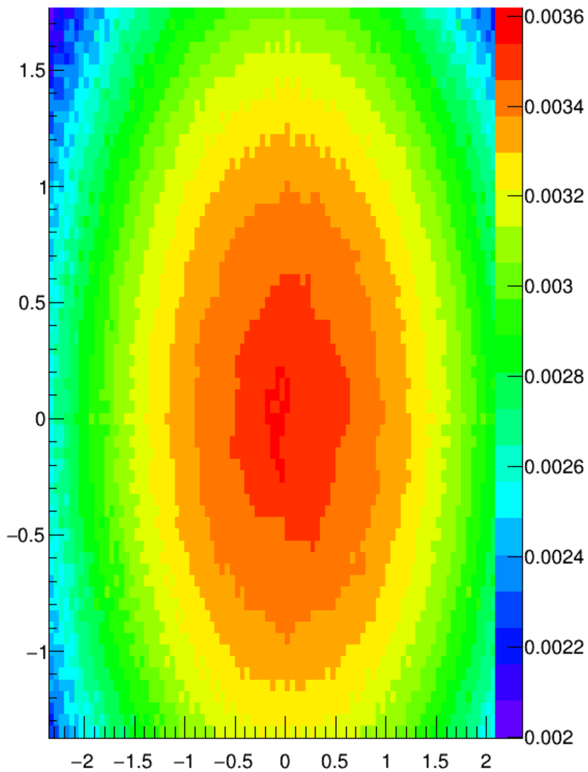
Systematic Deviation Detection

B Field @ Z = 0.0 m

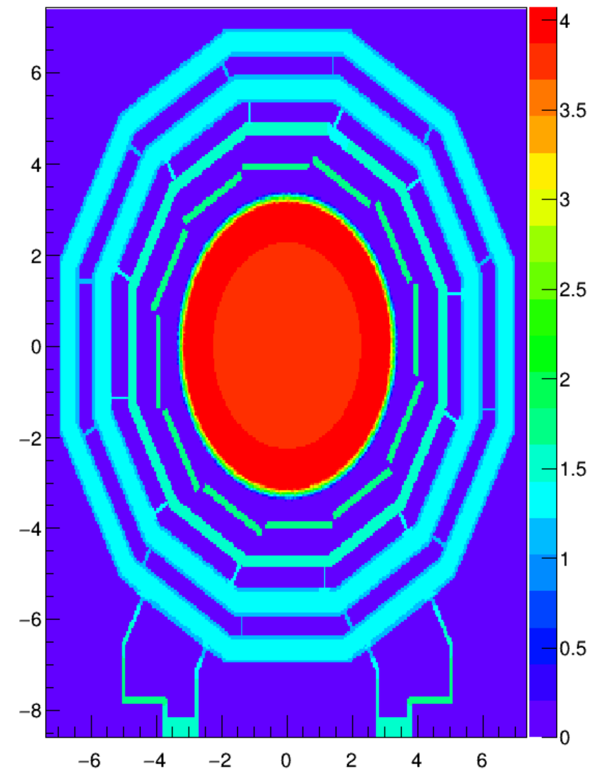
B present



ΔB in the center



B new



Fit Results

Results from every sector are almost the same.

Given $y = ax + b$ as fit function

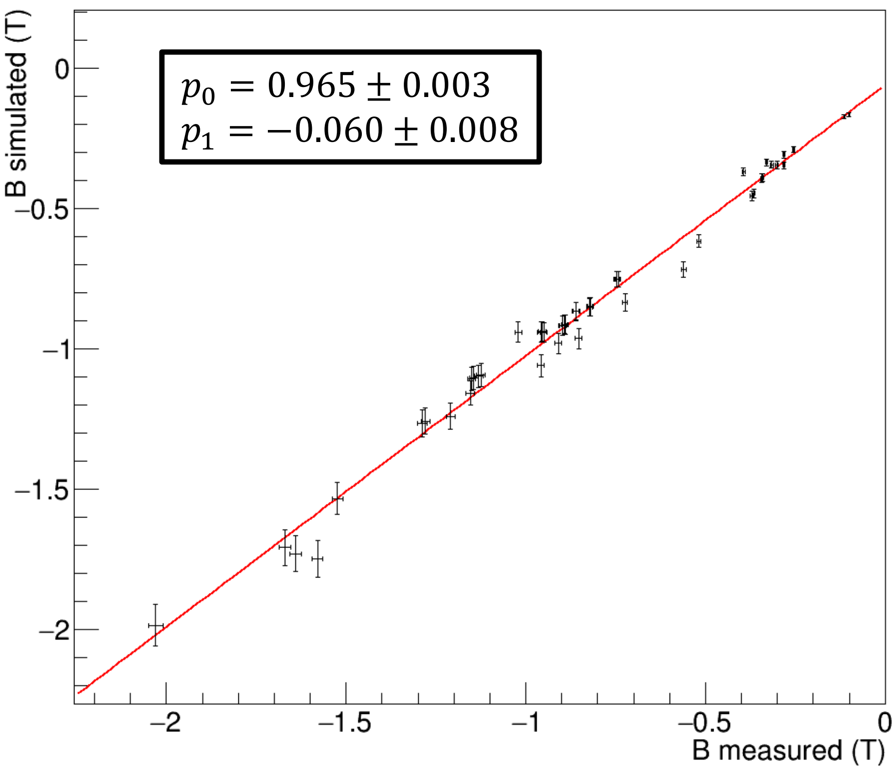
Results on all sectors are

$$Bx_n = (1.006 \pm 0.004)Bx_p + (0.0010 \pm 0.0001)$$
$$By_n = (0.966 \pm 0.005)By_p + (-0.005 \pm 0.001)$$
$$Bz_n = (0.9898 \pm 0.0008)Bz_p + (0.002 \pm 0.001)$$
$$\mu_n = (0.982 \pm 0.002)\mu_p + (-2.2 \pm 0.8)$$

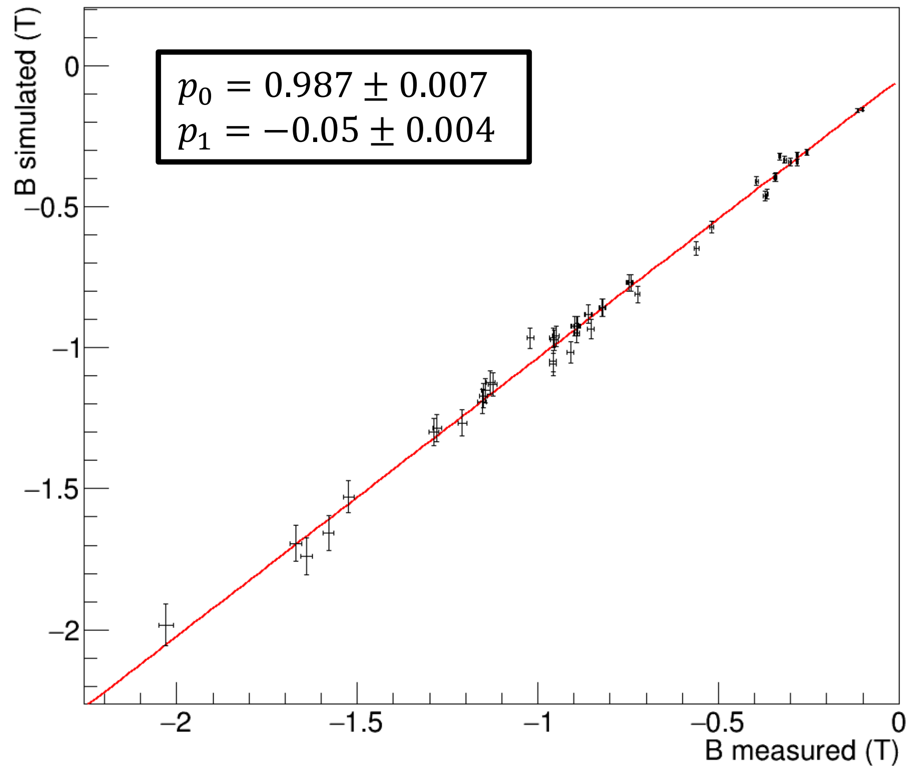
Comparison with Measurements

BZ Hall Probes (2015) in the return Yoke

Present Model



New Model



Conclusions

Analysis performed shows that

- Between the models there are modest systematic deviations

- **Globally, the two models can be considered compatible:**
  - the highest deviations are in the irons, not in the air
  - globally, both models agrees at 99% over Bz and 96% over By/Bx
  I expect the same or even the better over the bending power

- The new model behaves slightly better than the present in the Yoke.
  In particular, **maximum deviations** from the measured field **@muons chambers are about 3%, instead of 7%**

Conclusions

The new model is a powerful tool:

- It is (quite) easy to implement new geometries

- Building of the model is automatic, as well as the meshing

- Depending on few parameters, can be optimized
(it's a matter of time computing, not human time)

- Different versions (less/more accurate) can be provided.
Especially:

  - *One for notebook* (less than 4GB RAM) to be used to know approximatively the values of the field.

  - *One for cluster* to be used for Montecarlo simulations (20 GB RAM or more)