Measurements of permanent magnet blocks for undulators and modelization of their inhomogeneities

Valentí Massana, J. Campmany, J. Marcos,
C. Colldelram, Ll. Ribó

CELLS – ALBA

Outline

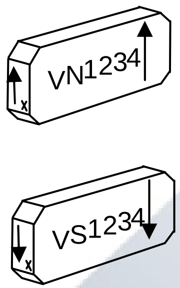
- ❑ What we want to do and why?
- ❑ Helmholtz coil system
  - ➢ Modules (singlets & triplets)
- ❑ Fixed Stretched Wire bench
  - ➢ First field integral
- ❑ Models of simulation
  - ➢ Geometrical errors
  - ➢ Magnetic inhomogeneities
- ❑ Application: short array of magnets

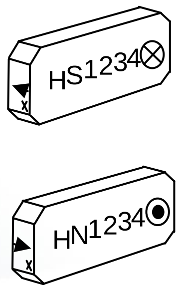
Magnetic elements

4 kinds of NdFeB magnets depending on the main component of the magnetization vector.

Transversal die-pressing

vertical
magnet blocks



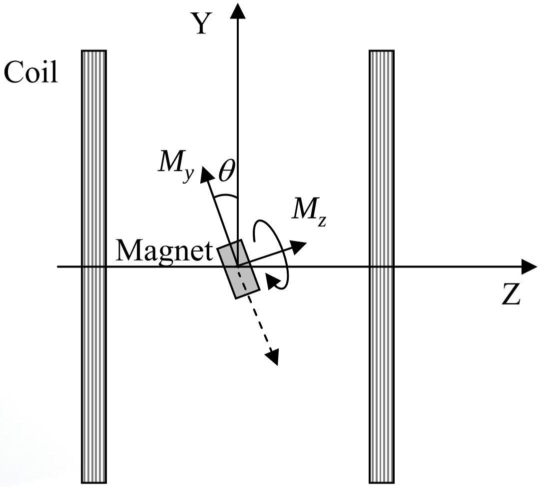


horizontal
magnet blocks

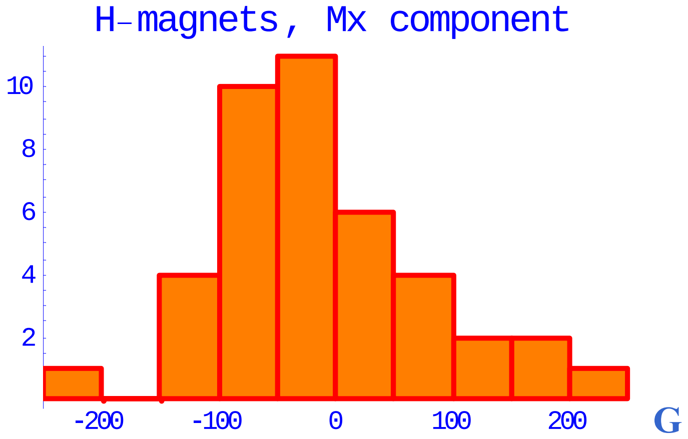
Block dimensions (LxHxW):
50 x 16 x 5.3 mm

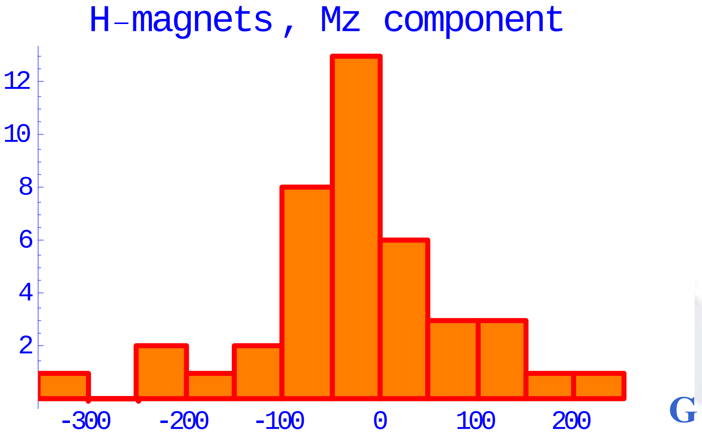
Helmholtz coil measurements

Average magnetization vector of the individual magnetic blocks have been measured using a system of Helmholtz coils.

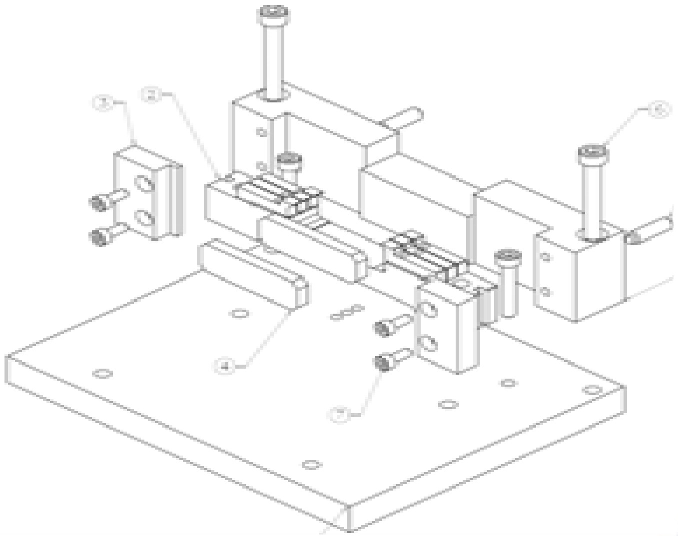


Cross checking with the data from the manufacturer

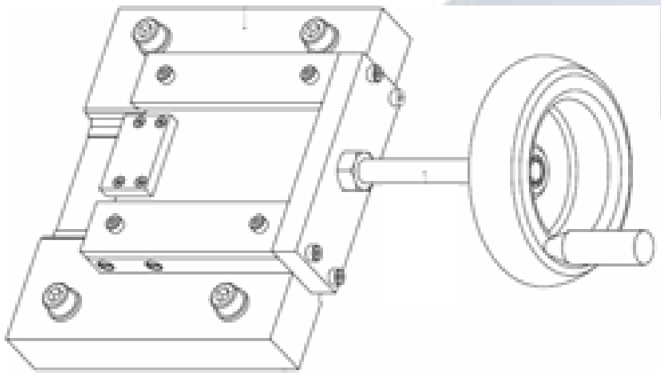




Assembly of the blocks



Special tool of assembly



We arranged the blocks in two sorts of modules:

• single horizontal magnets mounted into single holders (***singlets***).

• groups of three blocks (VN-HS-VS) mounted into a common holder (***triplets***)

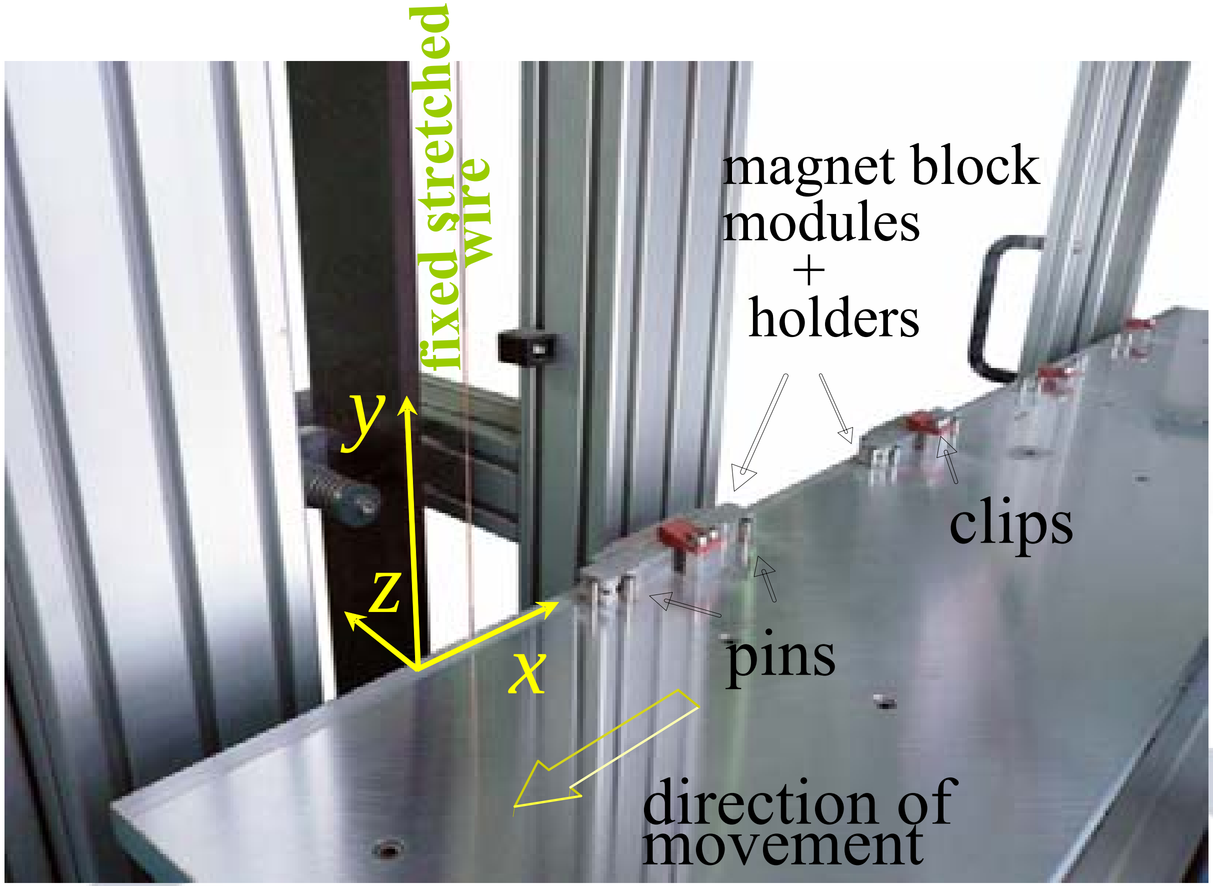
copper film between blocks
(real block dimensions measured)

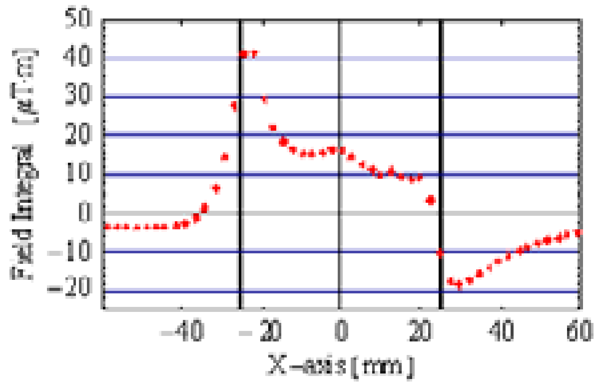
but...

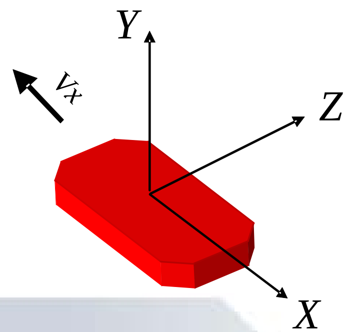
we make errors in the assembly process.

FSW measurements

Fixed stretched wire bench (FSW) to measure field integral of groups of magnet blocks assembled into a common holder.







Reference system definition

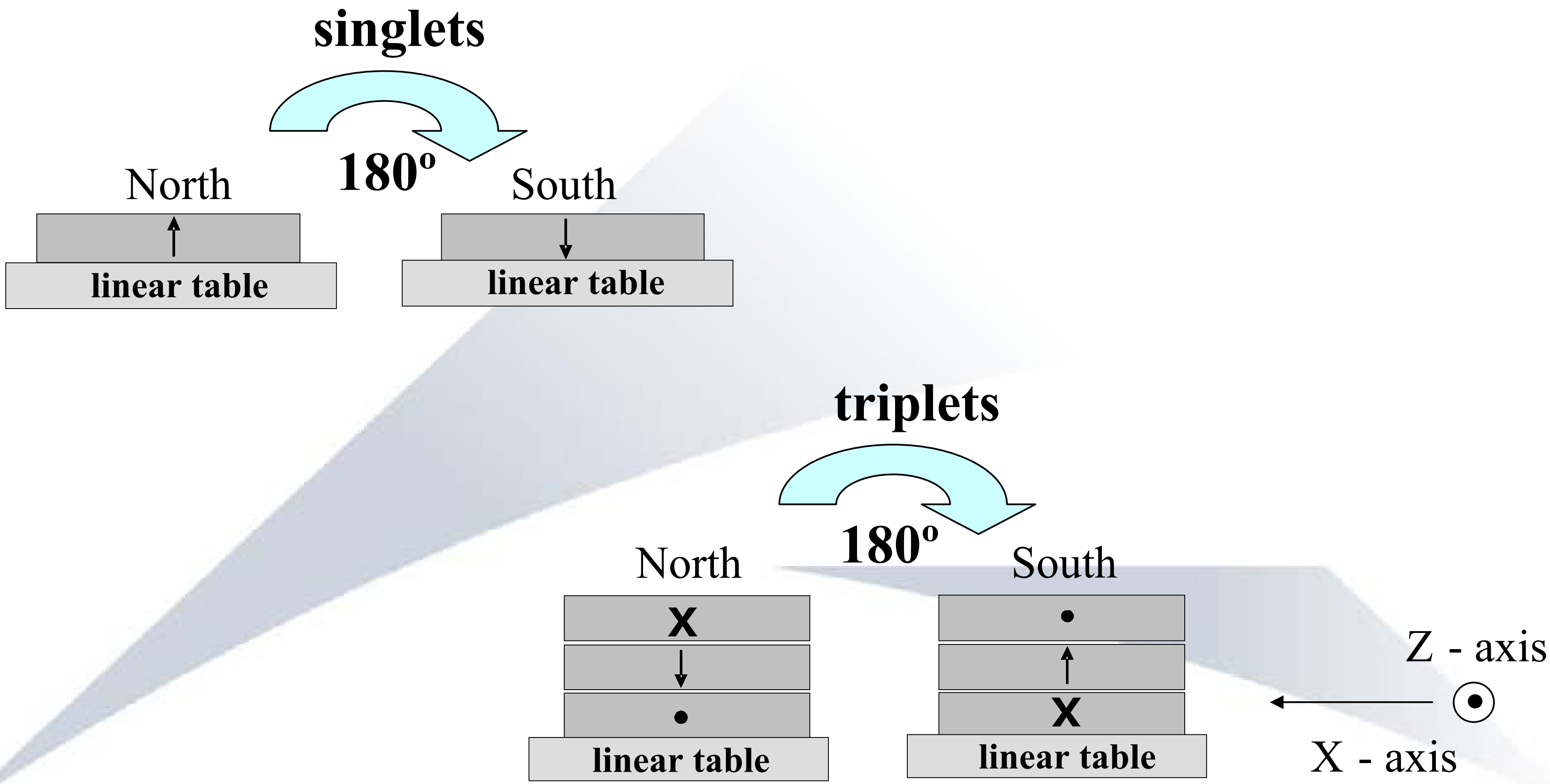
FSW bench

FSW specs

Specifications for a fixed stretched wire system	
Characteristics of the blocks to be measured	
Width, w	50 mm
Voltage measurement equipment	
Keithley low-noise multimeter model 2010	
Parameters of the system	
Number of turns, N	10
Length of the stretched wire, L	1.2 m
Height of the pick-up coil, H	1 m
Range of interest, d	$2w = 100$ mm
Scanned range, Δx	$4w = 200$ mm
Distance between blocks, D	$6w = 300$ mm
Integration window, τ	10 ms
Displacement velocity, $\overline{v_x}$	70 mm/s
Sensitivity, S	0.7 μV/(G·cm)
Intrinsic error, σ_I (sampling+electric noise)	0.4 G·cm

FSW measurements, II

Experimental data are the average of the field integrals obtained flipping the magnets around z-axis and measuring them in two opposite sides of the blocks. This minimizes the angular errors produced in the measurement process.



FSW vs Helmholtz coils

First field integral deduced from Helmholtz coils measurements

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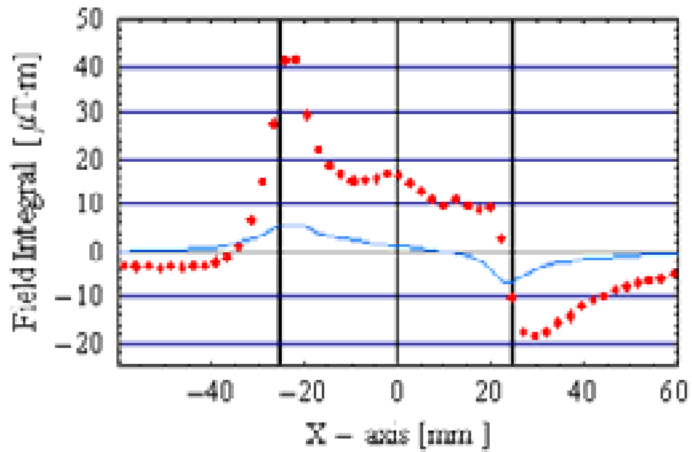
First field integral obtained from FSW bench

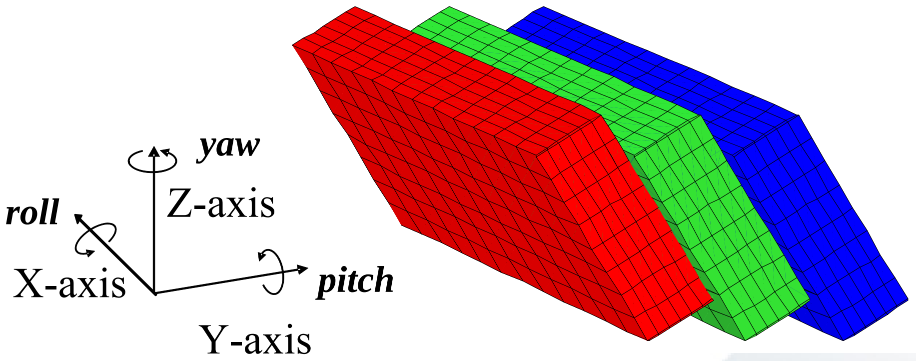
Geometrical errors

How to evaluate them ?



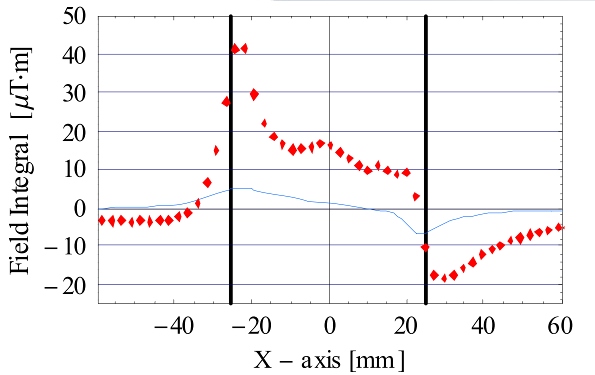
Geometrical errors

Rotating homogeneous magnet blocks with the magnetization vector measured using the Helmholtz coil bench.

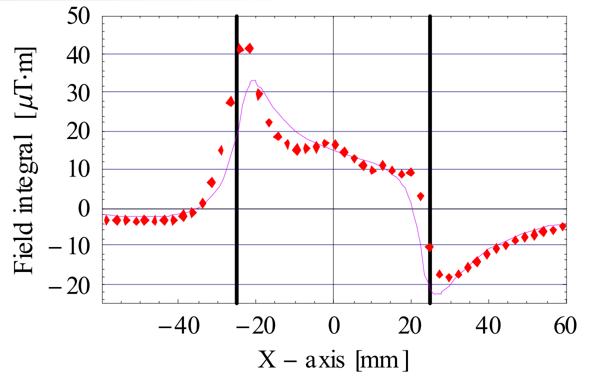


Geometrical errors made in the assembly of magnets into their holders have been evaluated modelizing homogeneous magnet blocks rotating according pitch and roll angles.

These angles were obtained using a mathematical code based in the Simplex algorithm.

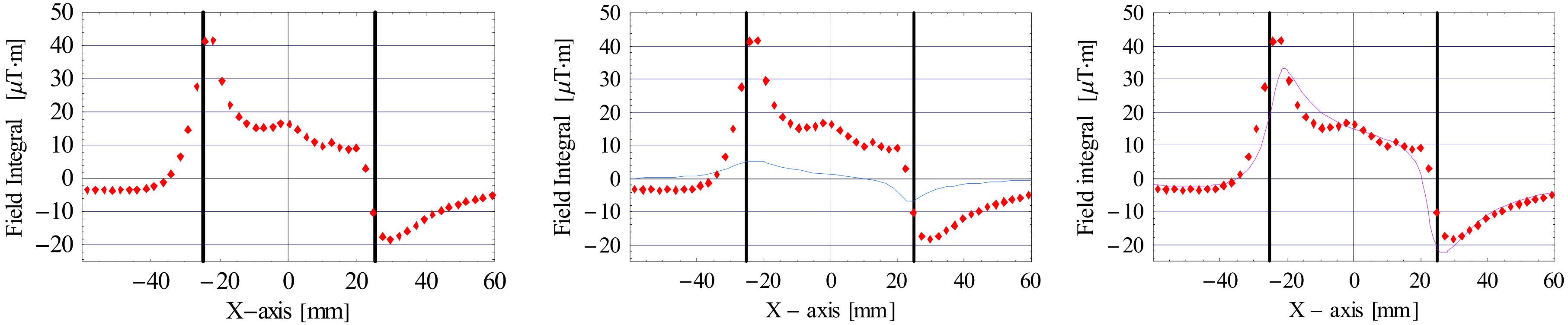


Simulation (blue line) from magnetization data.



Applying geometrical errors to the model.

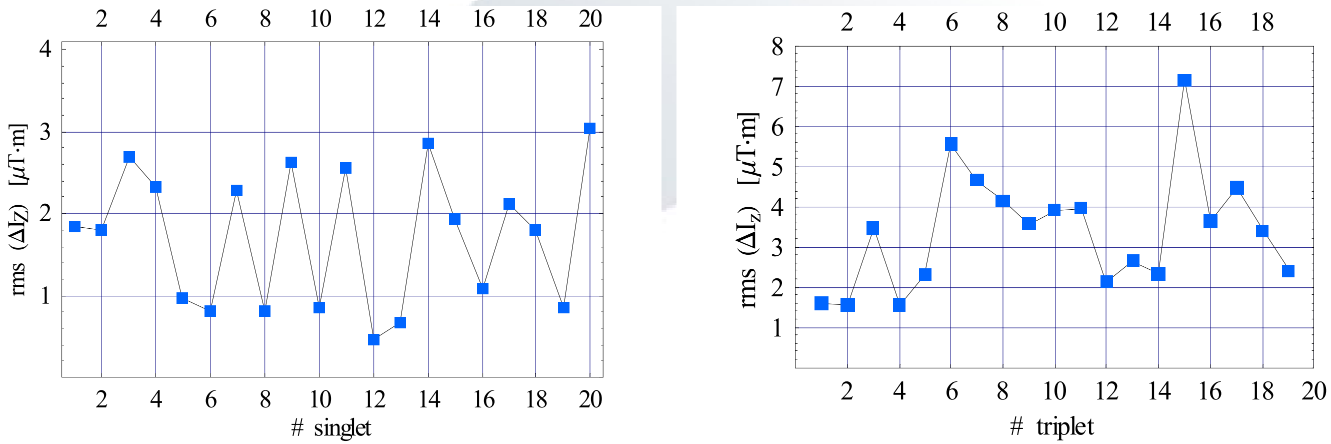
Testing the model, I



average signature of a particular triplet measured with the FSW and the simulated one (blue line) from the magnetization data

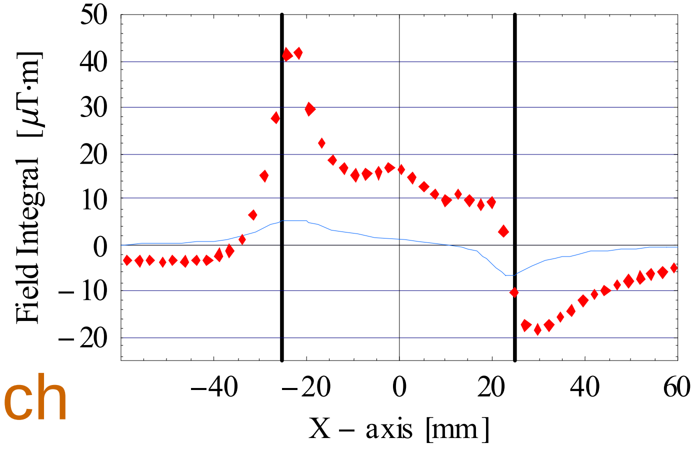
Applying geometrical errors to the model.

ΔIz = Iz (measured) – Iz (simulated) at each measured point
error = RMS value of ΔIz



Taking into account only geometrical errors we can not explain the experimental results obtained with the FSW, even in the case of singlets.

FSW vs Helmholtz coils



First field integral deduced from Helmholtz coils measurements

$\neq$

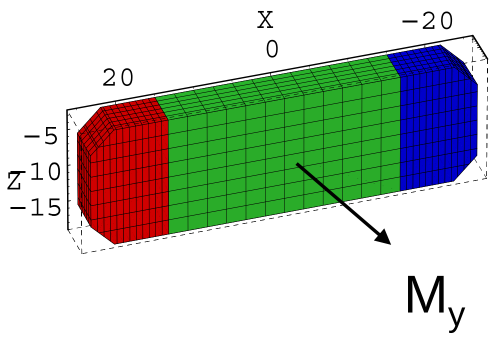
First field integral obtained from FSW bench

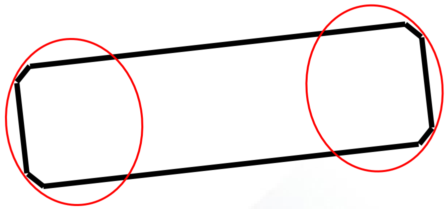
Geometrical errors + Magnetic Inhomogeneities

How to simulate them ?

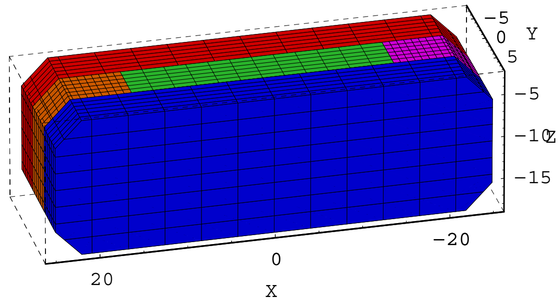
Model of magnetic inhomogeneities

Model of magnetic inhomogeneities: Magnets split in three parts applying the angles previously determined.



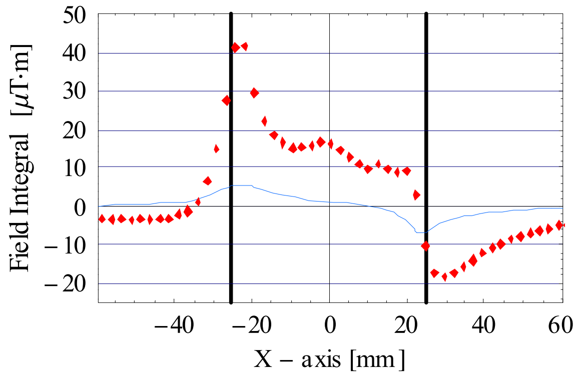


inhomogeneities are located in the edges.

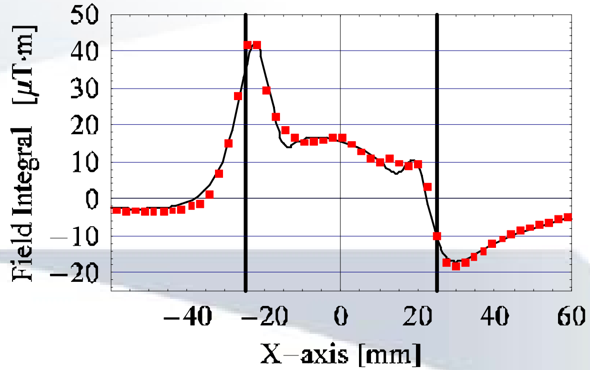


Model of an individual magnet block (*singlet*) divided in three homogeneous parts.

Model of a group of three magnets (*triplet*).

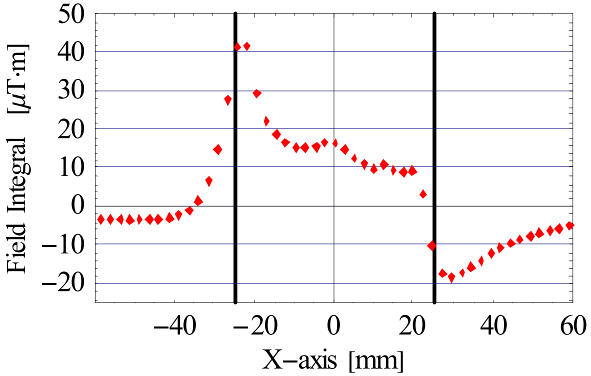


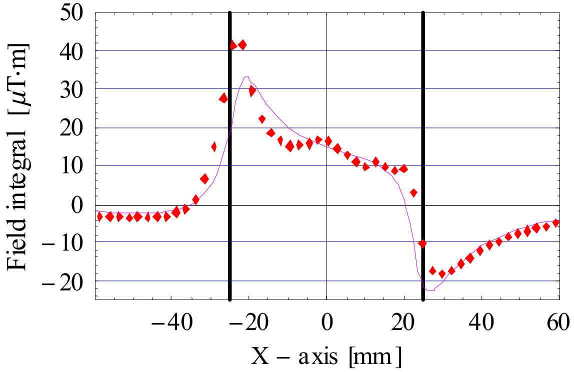
Simulation (blue line) from magnetization data.

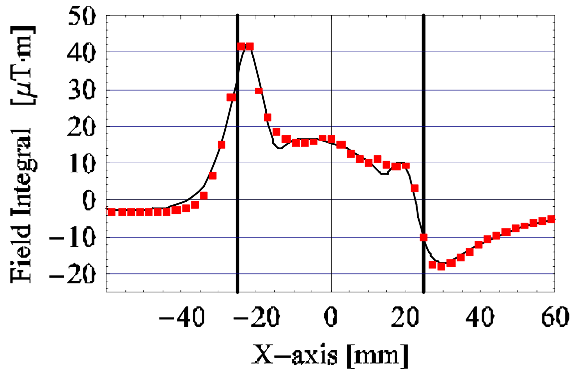


Simulation (solid line) from model of inhomogeneities.

Testing the final model

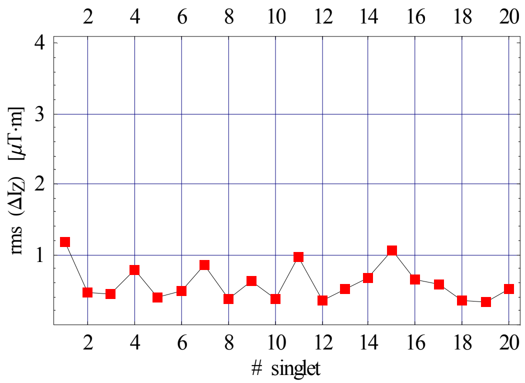


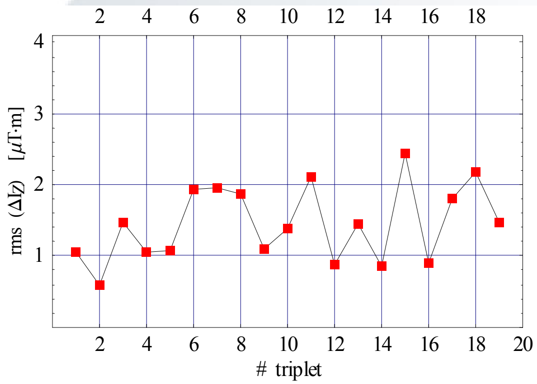




average signature of a particular triplet measured with the FSW and the simulated one (violet line) from the model of rotations

ΔIz = Iz (measured) – Iz (simulated) at each measured point
error = RMS value of ΔIz





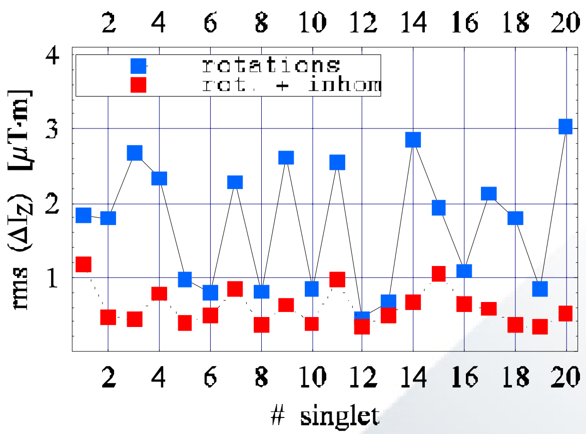
Experimental data from the FSW (red points) and the fitting curve generated with the model of inhomogeneities for triplets (solid line).

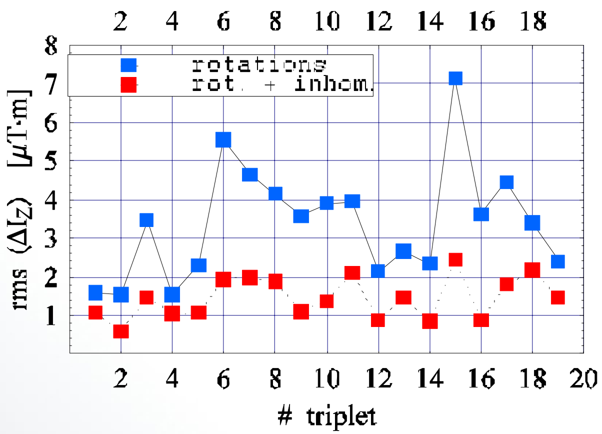
Two black vertical lines correspond to the transversal dimensions of the blocks.

Model of blocks split in three parts fit reasonably good with the experimental data, even in the case of groups of magnets.

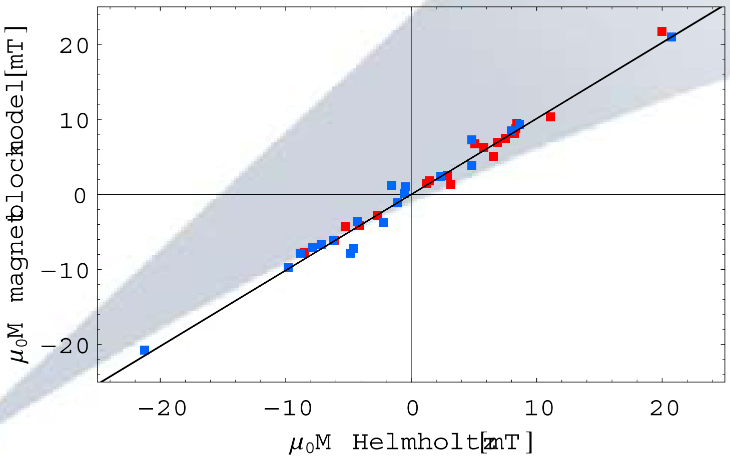
Results over the whole of modules

ΔIz = Iz (measured) – Iz (simulated) at each measured point
error = RMS value of ΔIz





The results of the model fit with experimental data within an rms error of 0.6 μT·m for individual blocks and 1.7 μT·m in the case of magnet groups.



Average magnetization of the model fit with the average magnetization measured with the Helmholtz coil system.

$$M_K = \frac{M_{1k} \cdot V_1 + M_{2k} \cdot V_2 + M_{3k} \cdot V_3}{V_T}$$

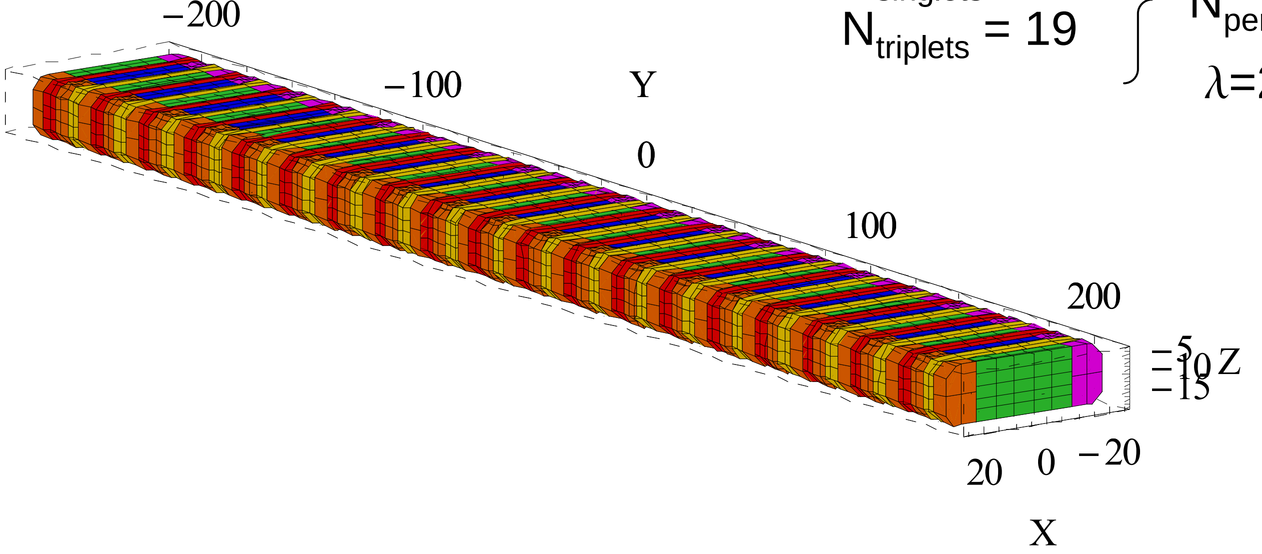
Number of magnetic moments must be the same

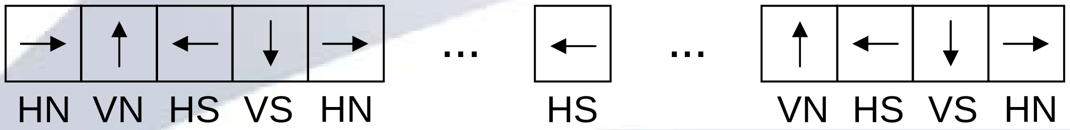
Practical application: short PPM

Building a short undulator

$$\left.\begin{array}{l} N_{singlets} = 20 \\ N_{triplets} = 19 \end{array}\right\} \quad N_{periods} = 19$$

λ=21.3 mm



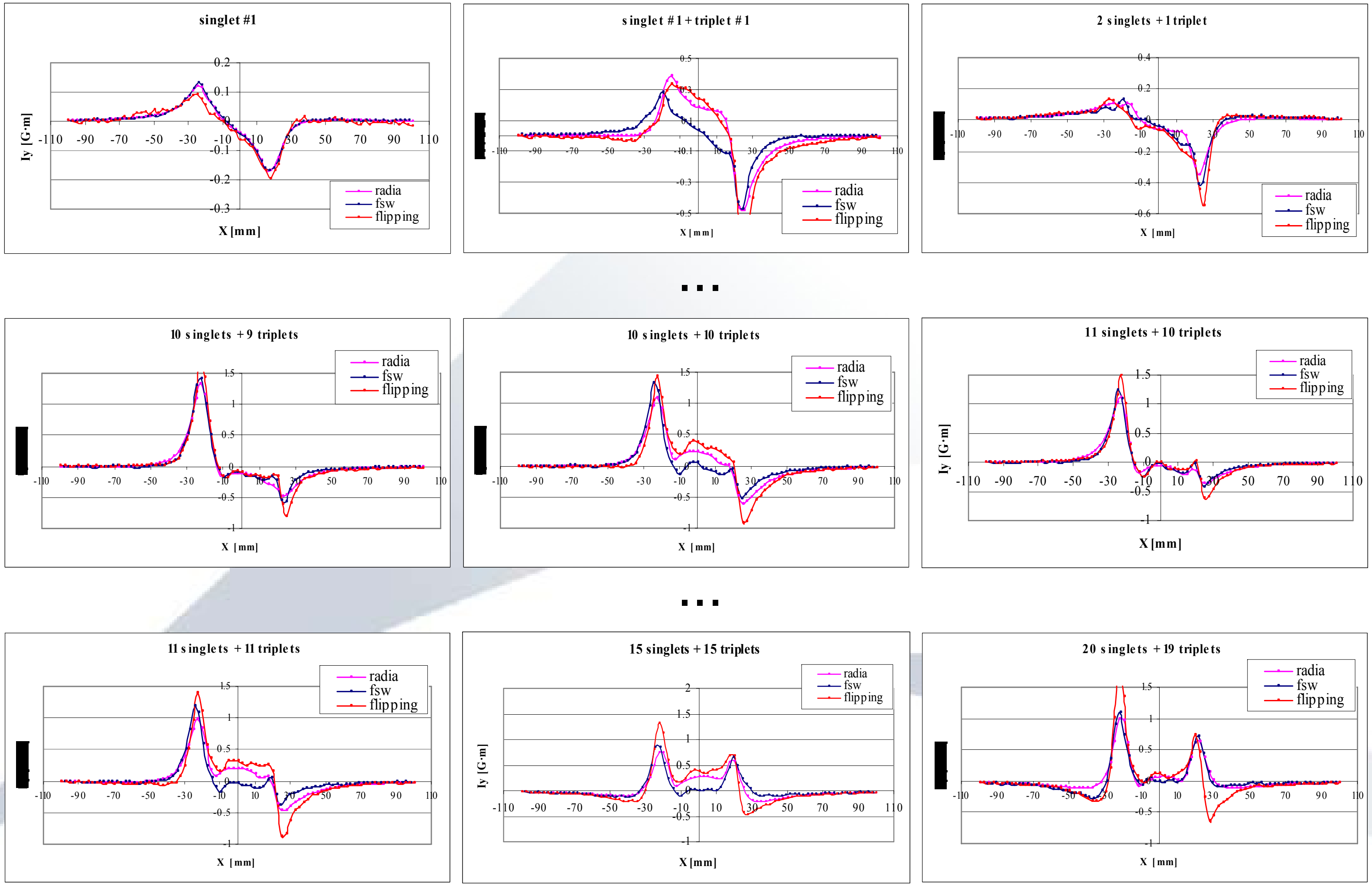


Control of the process

First field integral @ gap = 5.3 mm

χ=(0.06,0.10)

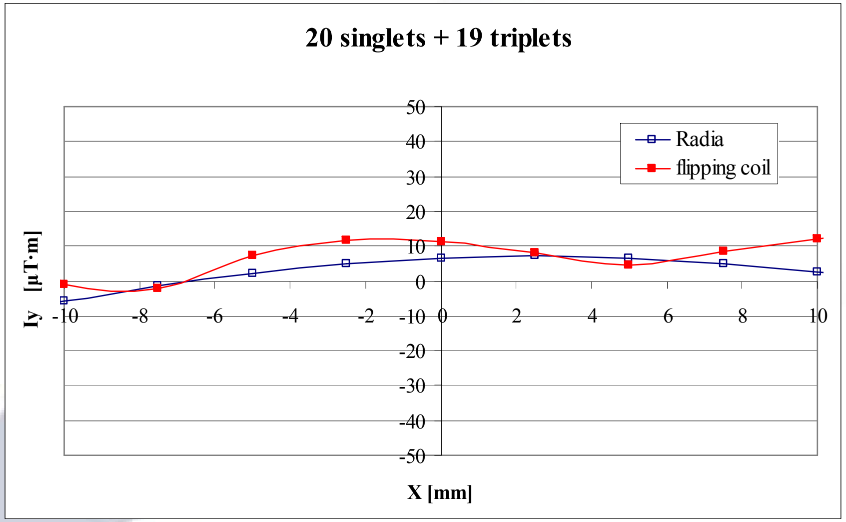
- FSW (principle of superposition)
- flipping coil bench
- Radia (model of inhomogeneities)



Final result

Good field region: ± 10 mm

We get a reasonable agreement between experimental results obtained with the flipping coil bench and the predicted data from the model.



Conclusions

- First integrals simulated from magnetization data don't match with the experimental measurements.

- These discrepancies cannot be understood taking into account only geometrical errors.

- Geometrical errors can be evaluated determining the angles of rotation which minimize Iz (measured) – Iz (simulated).

- Split block model, with the geometrical errors previously evaluated, permit the understanding of the magnetic behaviour of the blocks, even for groups of magnets, predicting accurately the first field integral of a set of modules.

- This model has been tested with success in a short single array.

THANKS FOR YOUR ATTENTION