MAGNETIC MEASUREMENTS OF THE RACCAM PROTOTYPE FFAG DIPOLE

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Abstract

The paper presents the magnetic measurements of the FFAG RACCAM magnet prototype, manufactured by SIGMAPHI for the RACCAM ANR medical FFAG project.

This magnet prototype work, started early 2006, is being performed in collaboration between the IN2P3/LPSC laboratory team and the magnet engineering firm SIGMAPHI.

This paper describes the magnetic measurement results and comparison with Tosca simulation.

INTRODUCTION

The RACCAM [1] project has produced a design of a spiral lattice, scaling FFAG, for protontherapy application (Fig 1) [2].

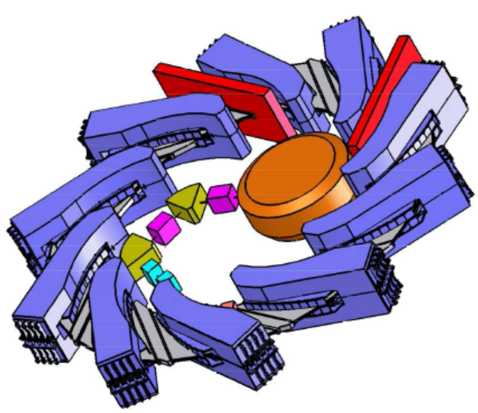


Figure 1: Principle layout of the RACCAM installation.

The RACCAM magnet prototype has been designed [3], constructed and measured in view of validating computation methods, fabrication methods and of thoroughly comparing results from both.

We perform several Hall probe mapping in 3D with an XYZ table. Then the field mappings along each trajectory were compared with Tosca and with tracking results [4].

MAGNET SPECIFICATIONS

This prototype is representative of the main dipole of a 10-cell spiral FFAG (Fig 2). The general *theoretical* specifications of the magnet are given in Tab.1.

Table 1: Parameters of the RACCAM magnet prototype

Type	Gap shaping
Packing factor (pf)	0.34
Field index (k)	5
Spiral Angle (ζ) (deg)	53.7
Min./Max. radius of good field region (m)	2.9/3.3
Max. field at min./max. radius (T)	0.58/1.7
Bend angle (β) (deg)	36
Sector angle (A) (deg)	12.24

MAGNET CONSTRUCTION

Mechanical and electrical specifications for the magnet prototype are given in Tab. 2, relating picture of the half yoke is given in Figure 2.

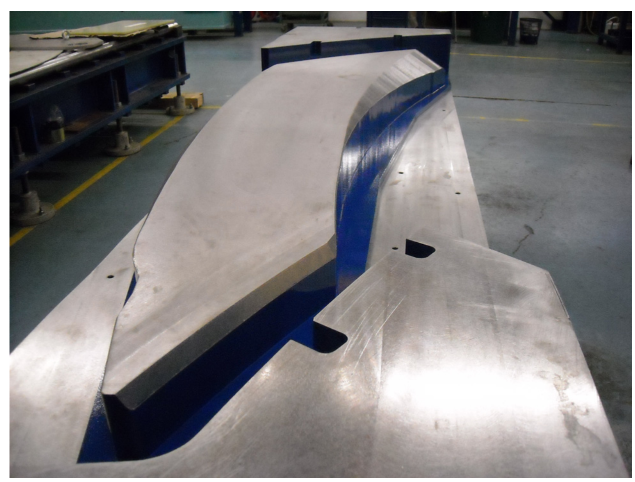


Figure 2: Half-yoke, gap shaping pole.

Table 2: Mechanical and electrical specifications

Yoke shape	Parallelepipedic
Lamination thickness (mm)	1.5
Gap shape	shaping
Gap at r_{xtr} (cm)	4
Gap at r_{inj} (cm)	11.6
Overall dim LxWxH (mm)	2913 x 579 x 1230
Total weight of magnet (t)	18
Magnet Voltage (V)	159
Current (A)	225
Total water flow (l/min)	12.13
Water temperature, in/out (°C)	24/44

MAGNETIC MEASUREMENT PROCESS

Instrumentation Used

For the RACCAM project, we have improved our equipement : the field was acquire in the 3 directions with a 20 channels multimeter, using a BH703 Hall probe sensor. In order to garantuee a good linearity, the Hall probe is temperature regulated (30°C +/- 0.2°C). Magnetic measures were performed on our air-conditionned (20°C+/-1°C) laboratory.

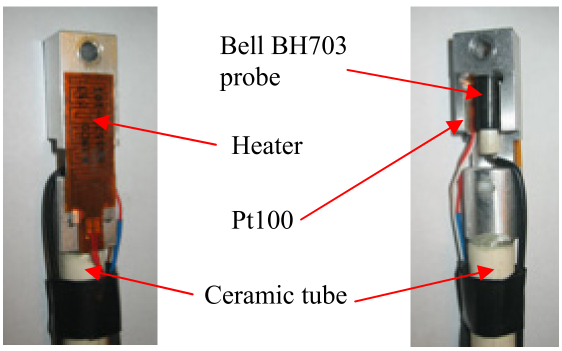


Figure 3: Hall probe Bell (3 axis) + heater and Pt100.

Alignment Process

First, magnet and mapping table are levelled and aligned together, using reference surfaces and pins (Fig4). Then adjustement of the Hall probe angle (H and V) and magnetic alignment with checking in the plateau of radial and axial componants.

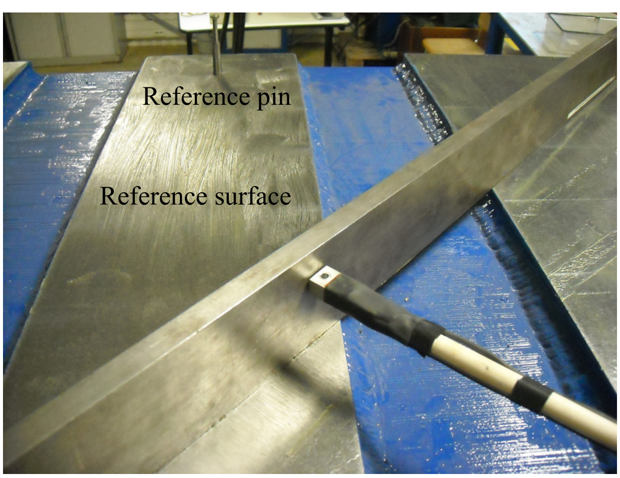


Figure 4: Mapping table and magnet alignment.

Magnetic Measurement Accuracy

- Hall probe calibration until 1.8T, accuracy 3.10^{-5}
- Current stability < 5.10^{-5}
- Hall tension stability < 0.2 Gauss
- Mechanical alignment accuracy < 1mm

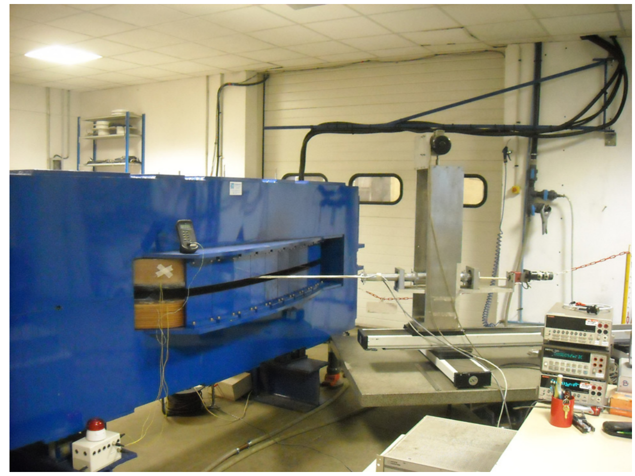


Figure 5: Magnet, mapping table and Hall probe system.

Measurement Strategy

Measures have been performed along arcs of circles GJE at constant radius, according to the scaling law (Fig6).

The meshing size step 0.2°, Rmean+/-55mm step 11 mm (11 trajectories), yields reasonable measurement duration, whereas insuring satisfactory precision on the measurements of the various magnet parameters.

Rmean = 2750, 2900, 3125, 3300 and 3450mm so insuring coverage of the good field region of the prototype (2.9 to 3.3m, table1).

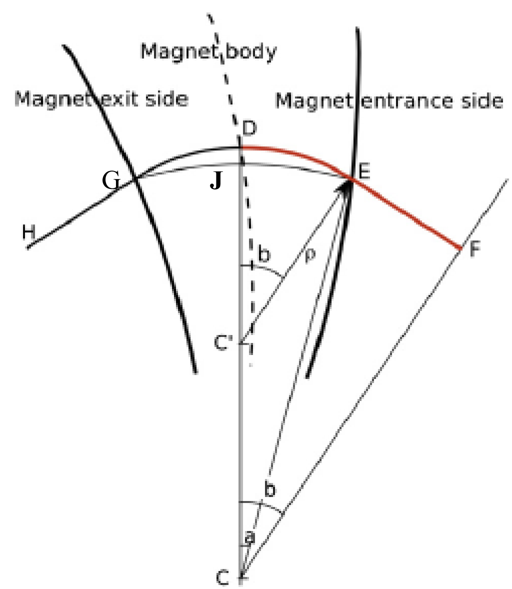
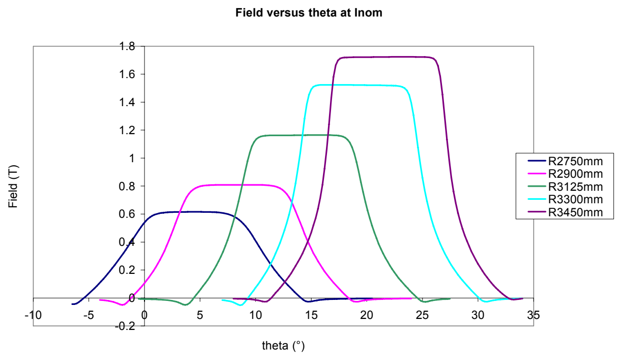


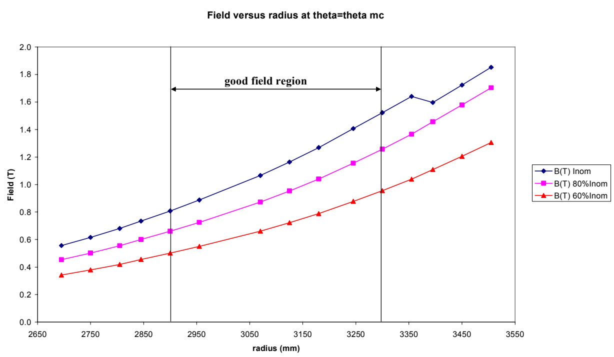
Figure 6: Integration path (GJE).

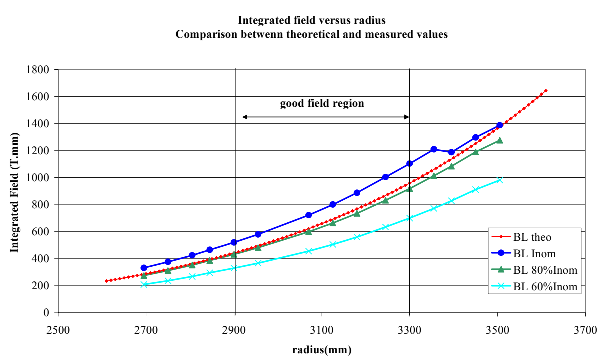
First set of measurements: (plane 0 +/-4mm) One of the goals in measuring 3D map was to asses the vertical dynamic aperture from ray-tracing (see ref 4).

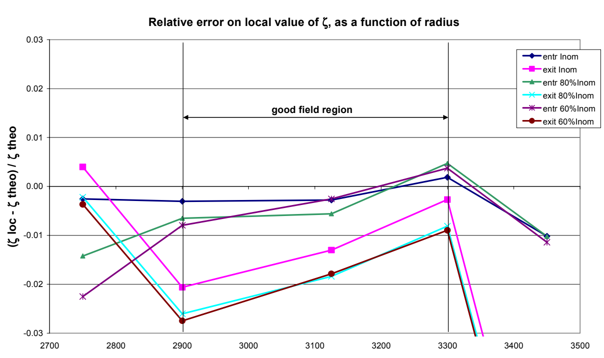
Second set of measurements: 2D maps, the goal is to have systematic assessment of magnet parameters in various regions inside the gap and at various magnetic field regimes.

MAGNETIC MEASUREMENT RESULTS

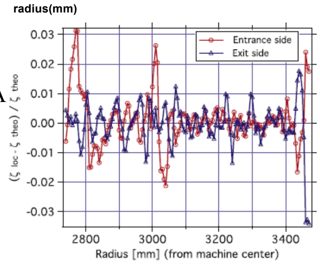






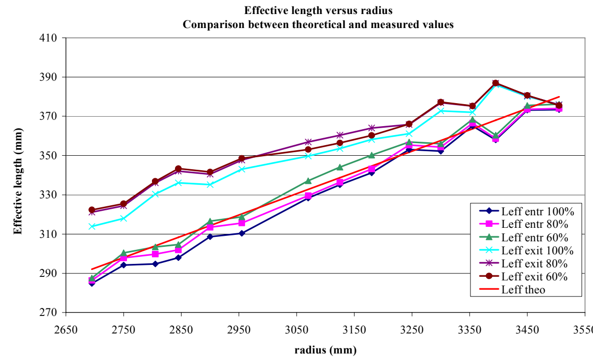


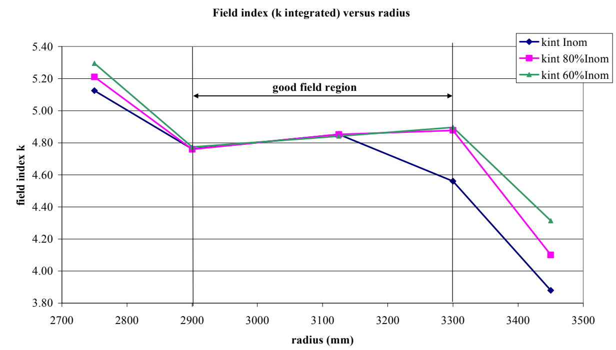
Comparison with TOSCA results

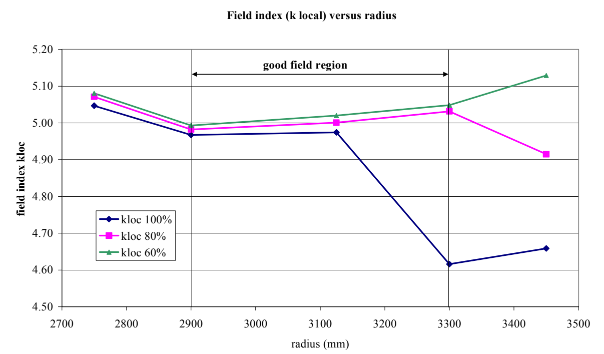


Relative error on local value of ζ, as a function of radius.

Measured Spiral Angle ζ (on the GFR) = 53.22°







CONCLUSION

· Main magnetic measurement results and Tracking in measured field maps are being compared with prototype specification.

· A total of 600 hours for this full magnetic measurement campaign and improvement of our instrumentation

· Measurement analysis is still in progress, and more time would have been necessary to check dB/dt, or the influence of a magnetic mass.

· Really good collaboration between LPSC and Sigmaphi team.

REFERENCES

[1] RACCAM : http://wwwlpsc.in2p3.fr/RACCAM/

[2] Design of a prototype gap shaping spiral dipole for a variable energy protontherapy FFAG, T. Planche et al., NIM A 602 (2009) 293305

[3] Design of the RACCAM magnet prototype, T. Planche, note LPSC 08-73 (RACCAM).

[4] Tracking periodic parameters in the measured magnetic field maps of a spiral FFAG, F. Méot, these proceedings