SIGMAPHI

RACCAM magnet design

- Damien Neuvéglise
- Thomas Planche
- Jean-Luc Lancelot

PAC 07 Albuquerque June 25 – 29, 2007

Summary

- Part 1 : project presentation
- Part 2 : magnet design
- Part 3 : tune shift correction
- Part 4 : cost reduction

See also posters TUPAN 07 and TUPAN 08

Project presentation

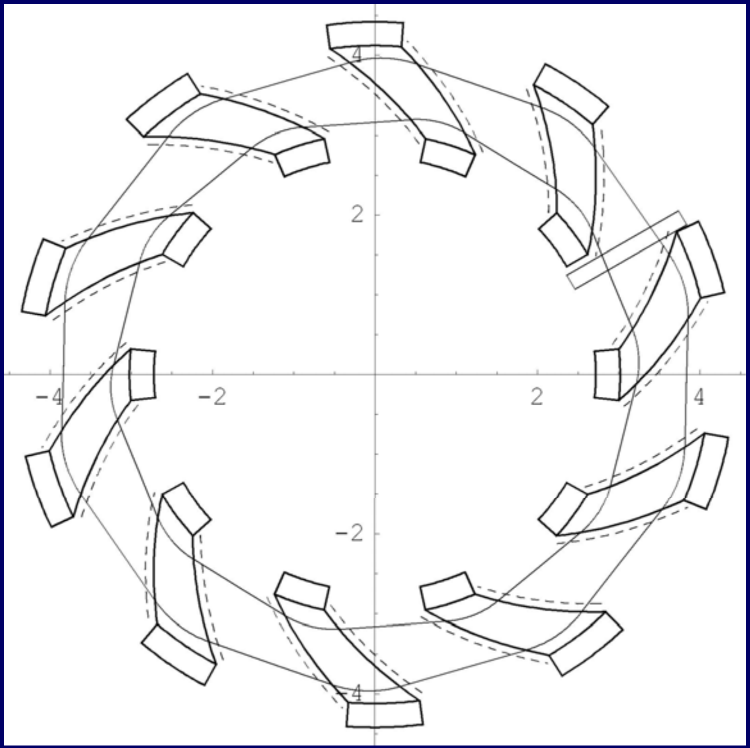
- RACCAM is a collaboration between
  - SIGMAPHI, Vannes (France)
  - IN2P3 / LPSC, Grenoble (France)
  - Grenoble Hospital, Grenoble (France)

- Build a spiral FFAG magnet prototype of a proton medical machine 17 – 180 MeV

Project presentation

Spiral Scaling Proton FFAG ring

E injection	17 [MeV]
E extraction	180 [MeV]
Injection radius	3.2 [m]
Extraction radius	3.9 [m]
B field at extraction	1.5 [T]
Field index K	≈ 4.8
Spiral Angle ζ	≈ 49.5 [°]



Project presentation

Radial field law in an FFAG is $B=B_0(r/r_0)^K$

Two solutions are being studied

Constant gap with distributed curents on the pole

Studied by LPSC

(+) variable k

(+) better vertical dynamics (not proved)

(-) cost (large amount of power needed)

Gap shaping

Studied by SIGMAPHI

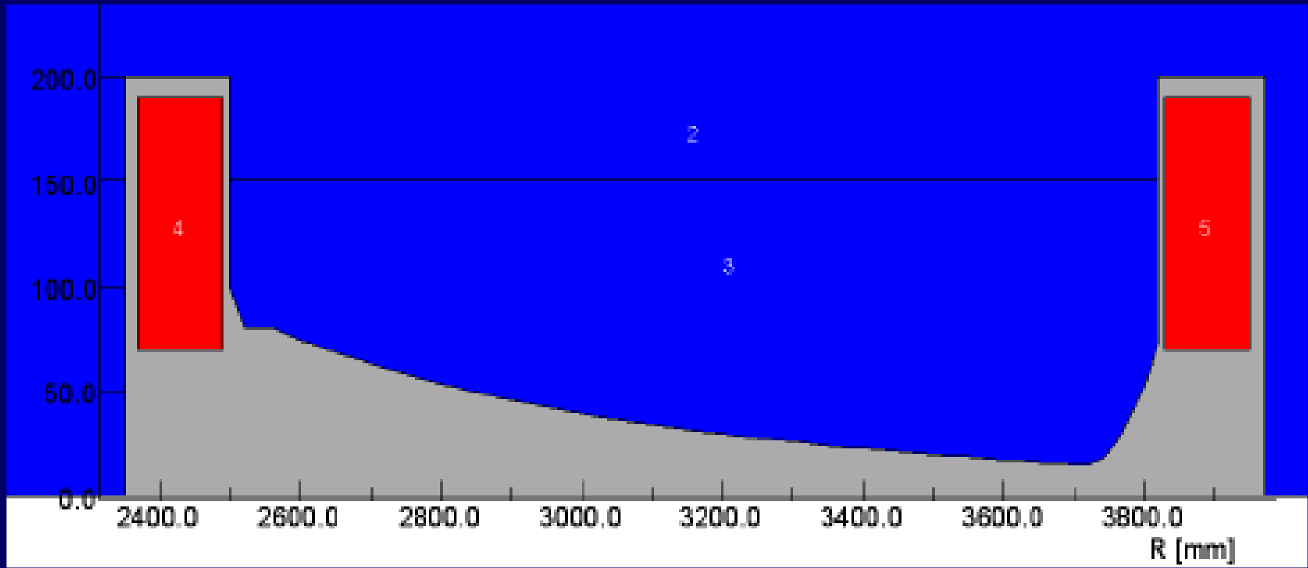
(+) the most economical solution

(-) k is not tuneable

(-) vertical dynamics becomes difficult

Magnet design

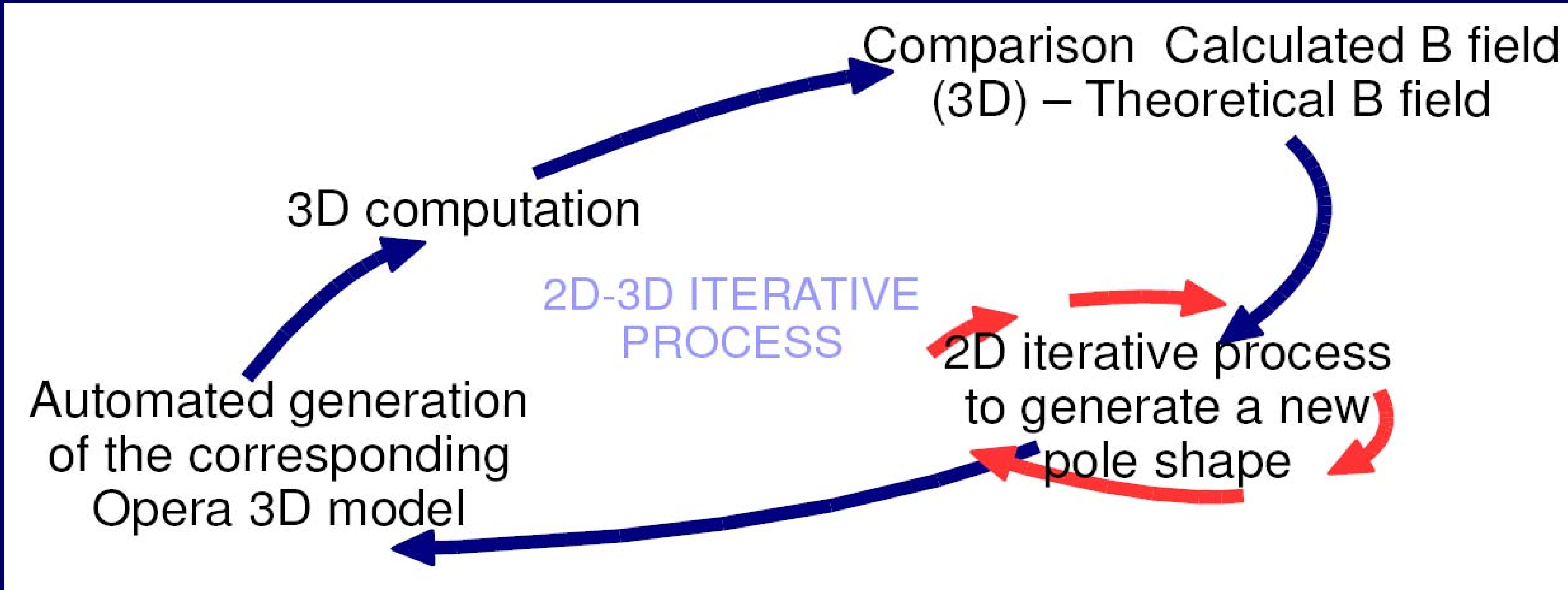
Fisrt step : automated 2D calculation of gap shape



→It converges rapidly (about ten iterations) and gives a relative field homogeneity better than 10^{-4} in the good field region

Magnet design

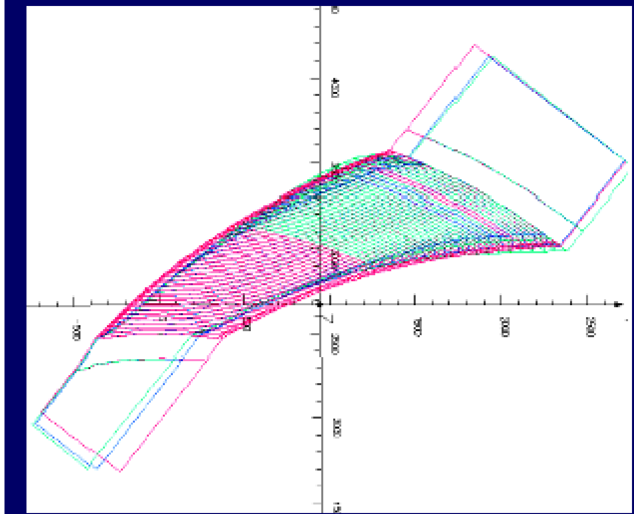
Second step : automated 3D calculation



→ After several of these iterations (3 to 8) a 3D model with a relative field homogeneity in its center of few 10^{-4} is obtained

Magnet design

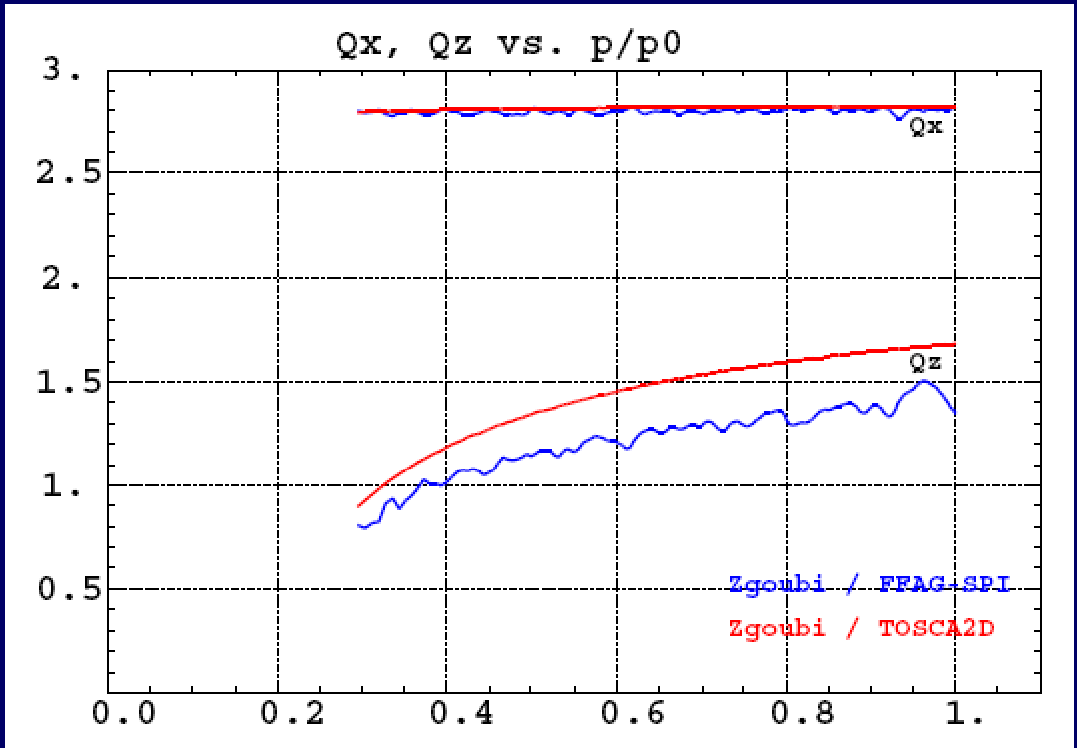
Reaching the correct magnetic spiral



- Effective length is measured at different radii on both sides of the magnet centre
- Spiral shape is tilted so that the effective length corresponds to the theoretical value at every radius
- A relative precision of 10^{-3} on effective length is reached after few iterations

Tune shift correction

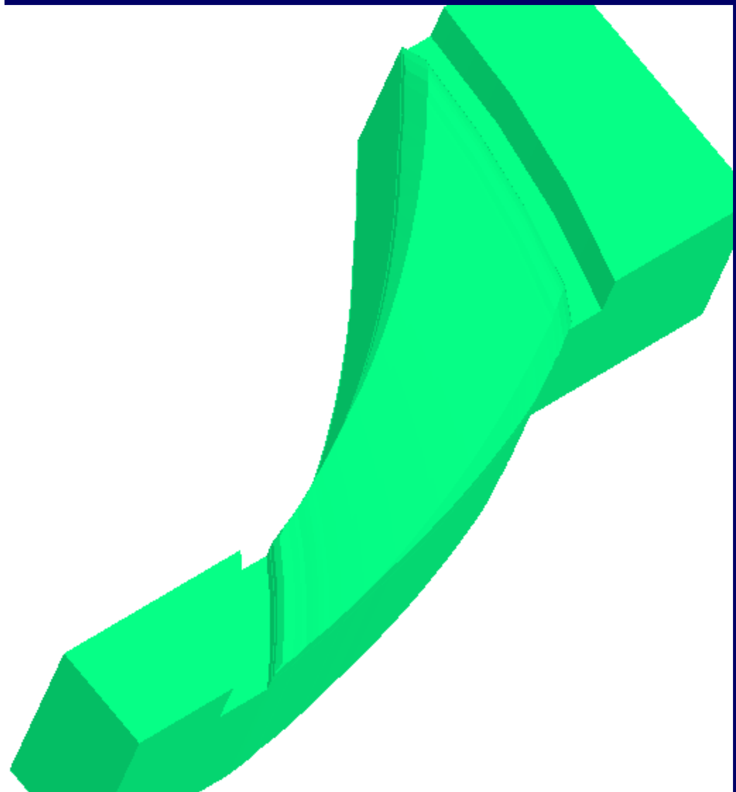
Major problem of gap shaped magnet : vertical tune variation with energy

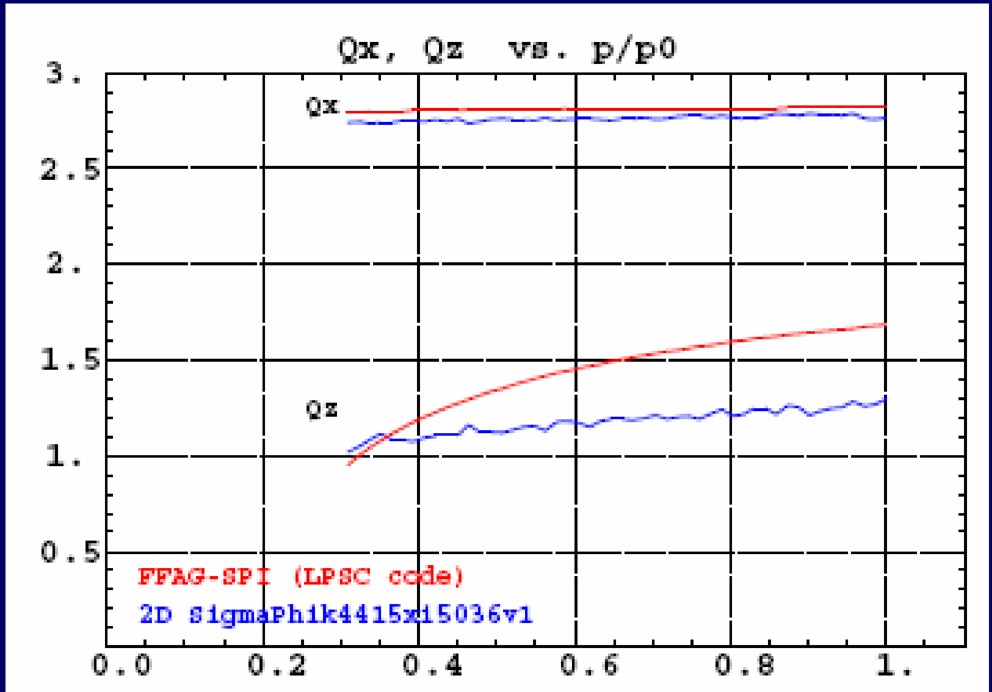


- Analytical model in red
- Calculated from 3D maps in blue
- Tracking done with Zgoubi code by J. Fourrier

Tune shift correction

Variable chamfer : increasing height with radius
→ flattens the tune behaviour



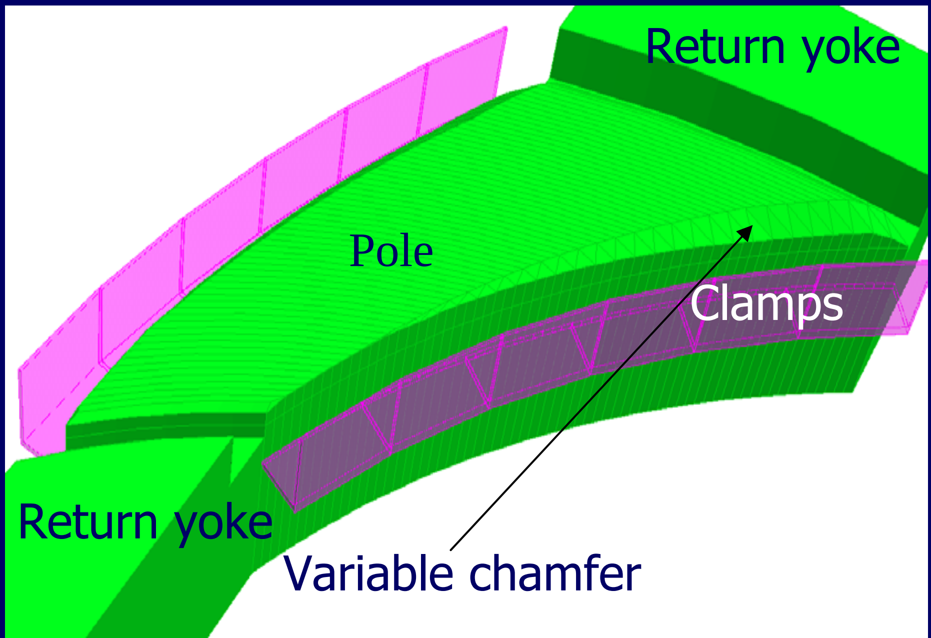


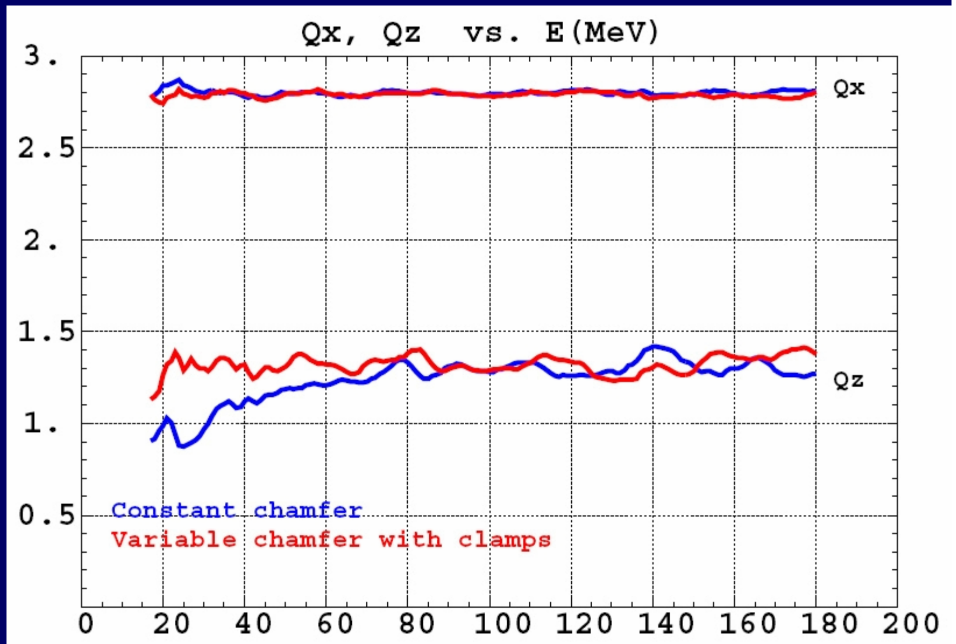
Still not sufficient !

Tune shift correction

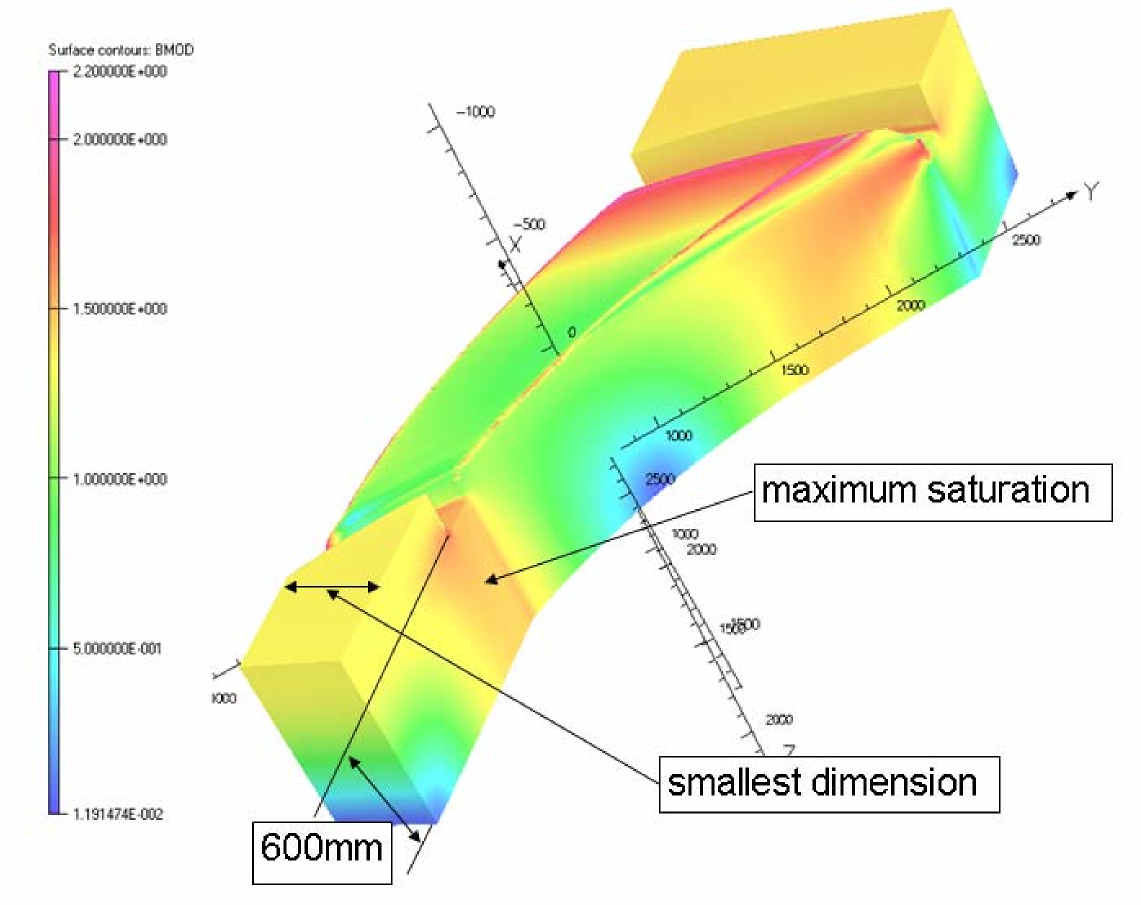
Adding field clamps on previous model

→ Reduce by a factor 2 vertical tune variation



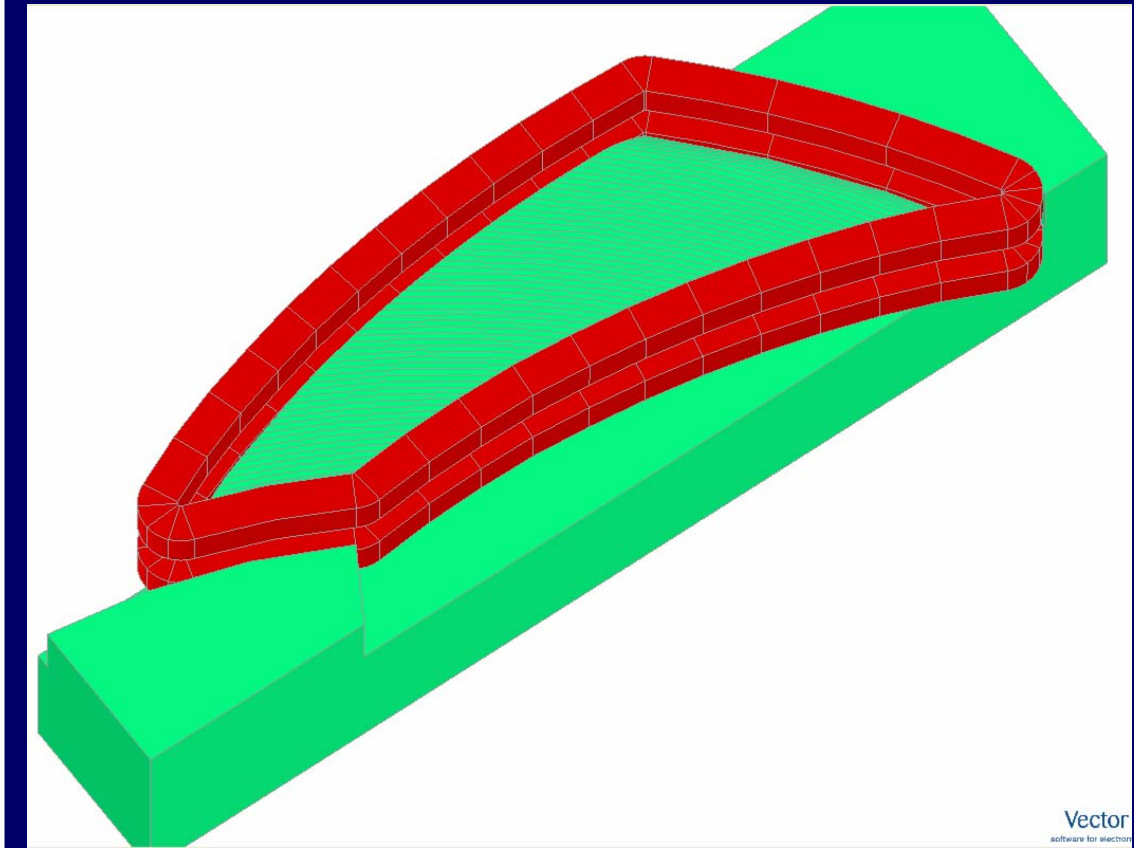


Cost reduction



- Maximum saturation imposes a very thick base plate (600mm)
- Magnet weigth about 20t
- Needed iron weigth bloc : 50t

Cost reduction



- Enlarged the base plate to reduce thickness (480mm)
- Magnet weight about the same
- Iron bloc 31t
- No major influence on beam dynamics

Cost reduction

- Other ways to reduce magnet cost
  - Increase k factor → decrease orbit excursion and so pole width
  - Increase maximum field in gap and yoke
- These solutions change machine working point → needs to validate beam optics

Cost reduction

Examples of previous considerations

Cases	Estimated weight (t)
K=4.8 Bmax and Bmax iron 1.5T	19.7
K=4.8 Bmax and Bmax iron 1.7T	15.7
K=7.6 Bmax and Bmax iron 1.5T	13.5
K=7.6 Bmax and Bmax iron 1.7T	12

Conclusion

- Developed efficient tools to model in 3D spiral magnets
- Found solutions to almost satisfy tunes constancy
- Integrated cost reduction problem and found efficient solutions
- Need to finalize the design and build a prototype magnet

Thank you for your attention