LHC Injectors Upgrade

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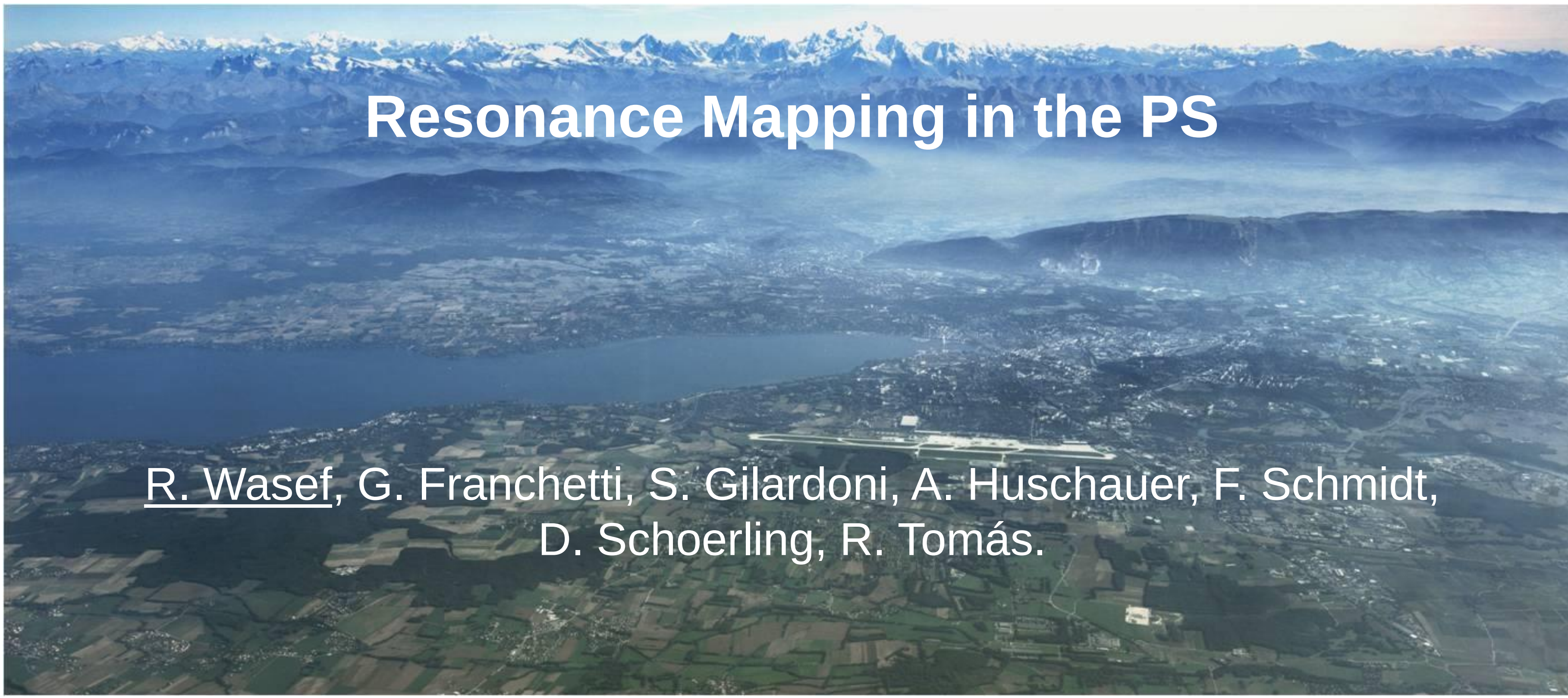

Resonance Mapping in the PS

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D. Schoerling, R. Tomás.

Outline

I. Status and Introduction of the PS

I. Measurement of Octupolar Errors

I. Resonance Driving Terms Measurement

I. Resonance Compensation

I. Summary and Conclusion

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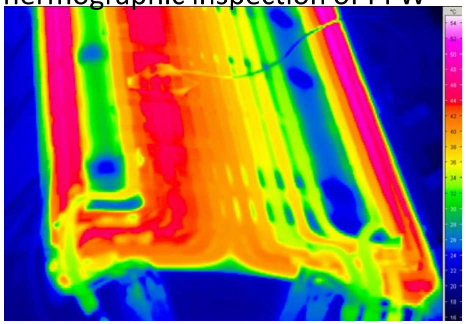
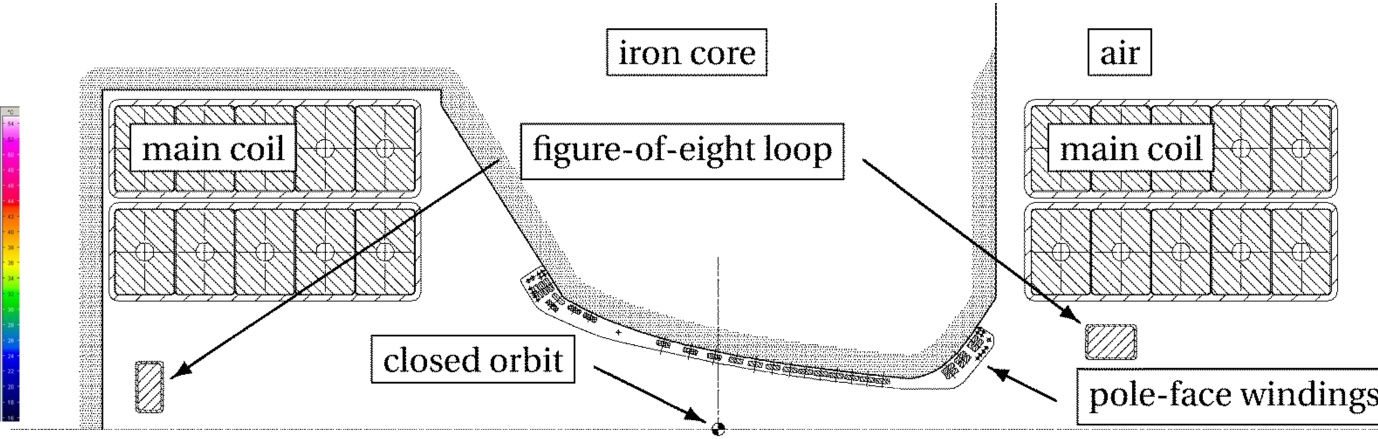
Status and Introduction of the PS

- Started operation in 1959
- 100m radius
- 100 combined function magnets
- Each magnet consists of 10 blocks: 5 F and 5 D (cell: FDODF)
- Tunes are controlled with:
  - LEQ at low energy
  - PFW at high energy
- Injection kinetic energy 1.4GeV.

Coil system: main circuit and auxiliary coils

Thermographic inspection of PFW





pole-face windings

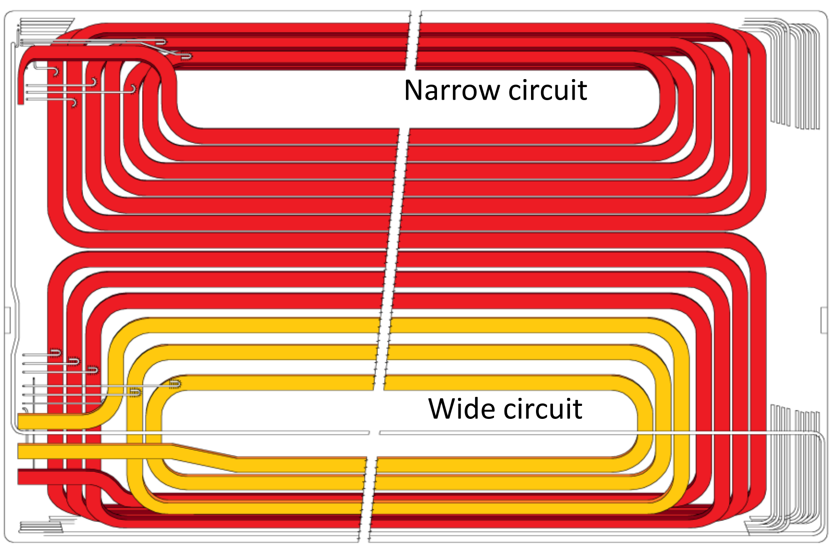
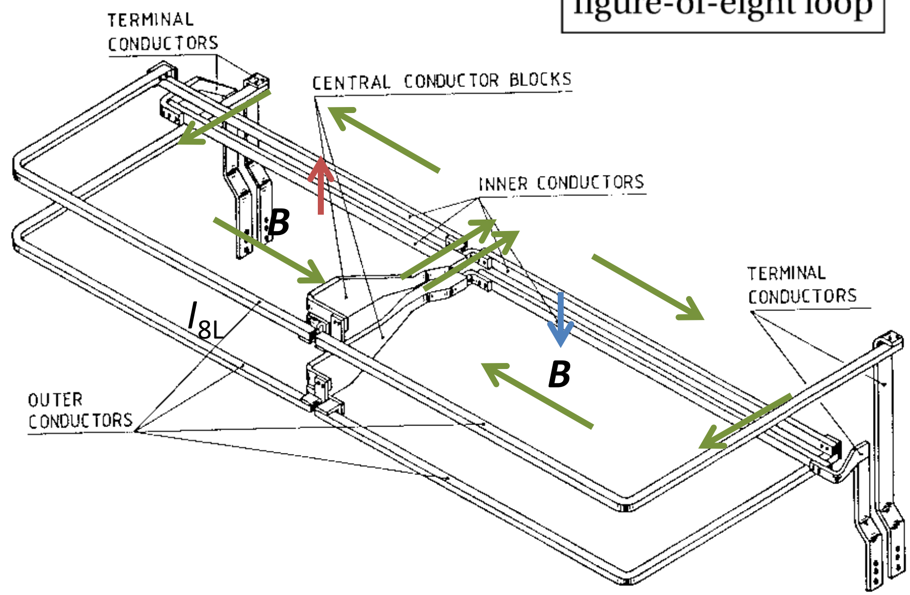


figure-of-eight loop



Coil system contributions

Main coil

– Hyperbolic pole shape
– Only **dipolar** and **quadrupolar** field at **low field** level

– Iron saturation
– Sextupolar and higher order components at high field level

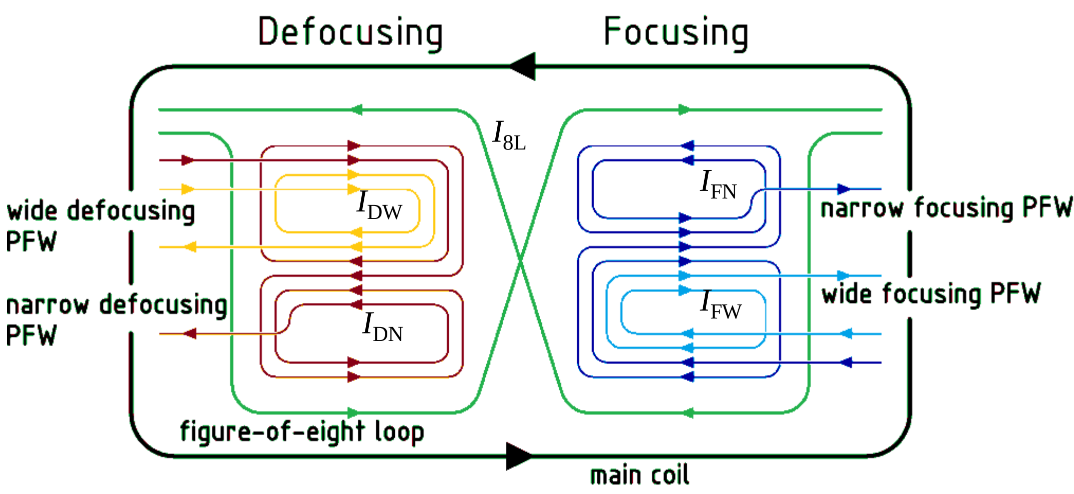
Pole-face windings + and figure-of eight loop

– 5-Current Mode

– *Un-balanced N and W circuit current generate octupolar and higher components*

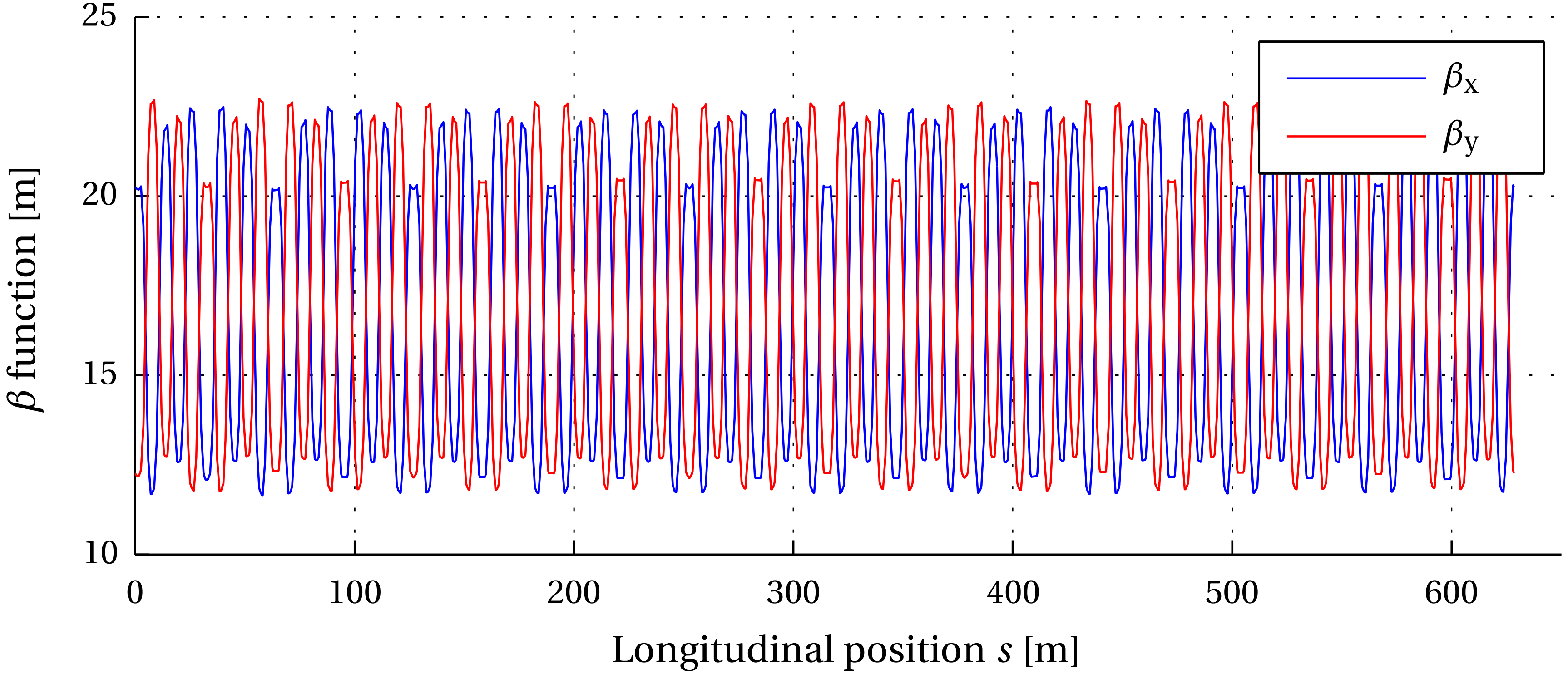
– Non-linearities at high field (iron saturation)

– Field probably up to decapole



Regular lattice optics (FDODF)

- Regular β functions between 12m and 22m.
- Dx between 2.2m and 3.8m.

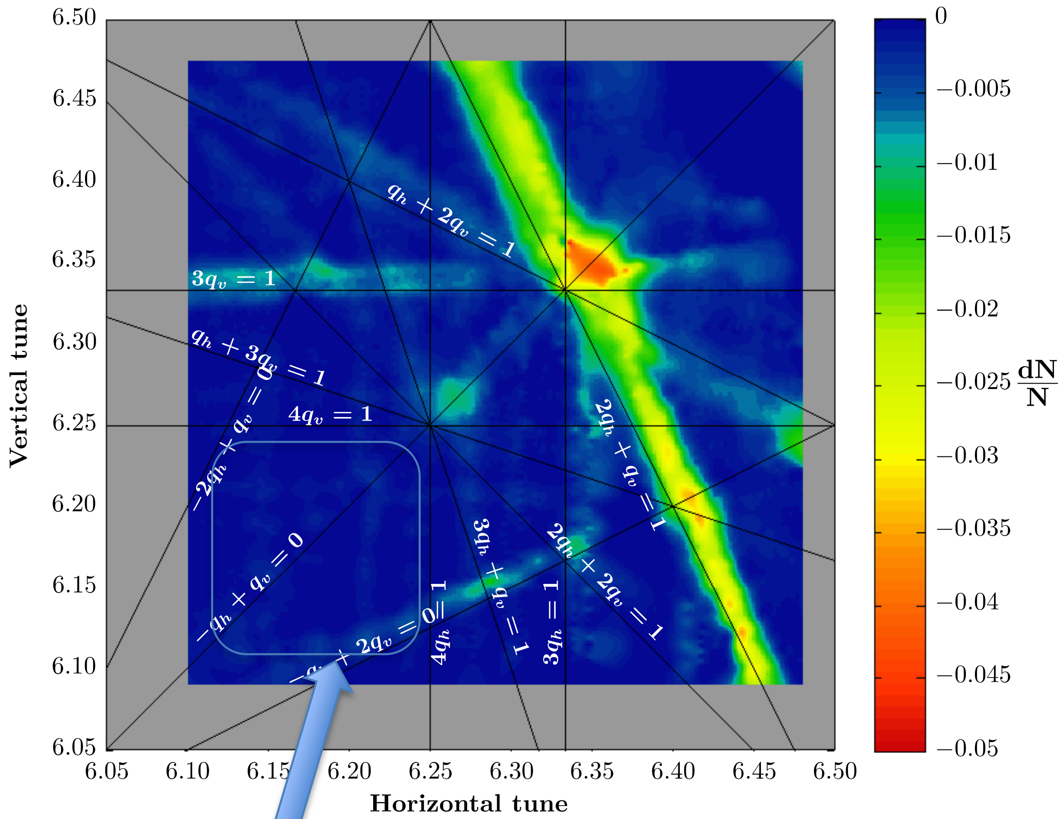


Current Situation in the PS

- Loss maps showed a relatively strong **skew sextupolar** resonances

- **Similar situation** at high energy (using PFW) and after re-alignment of the machine.

Measured at 2GeV

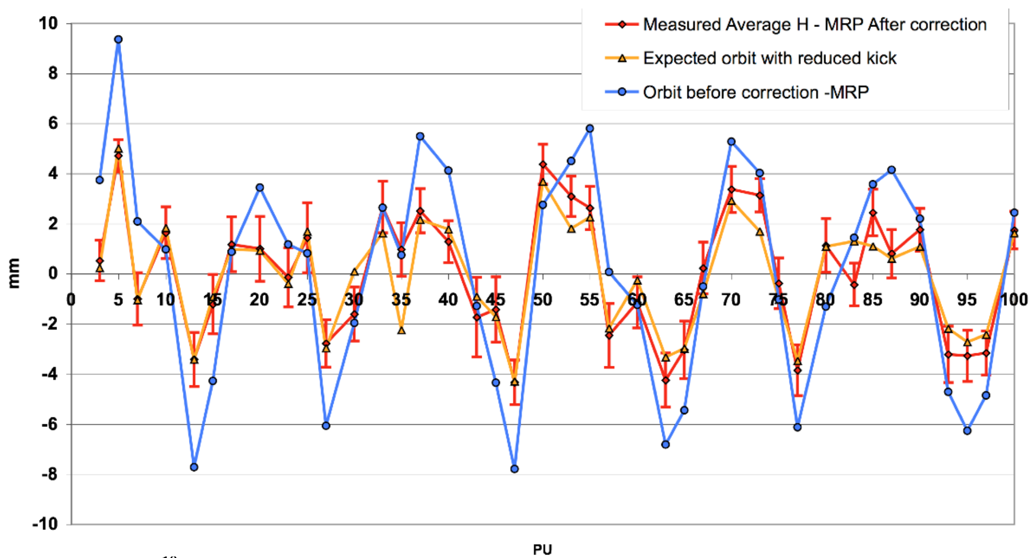


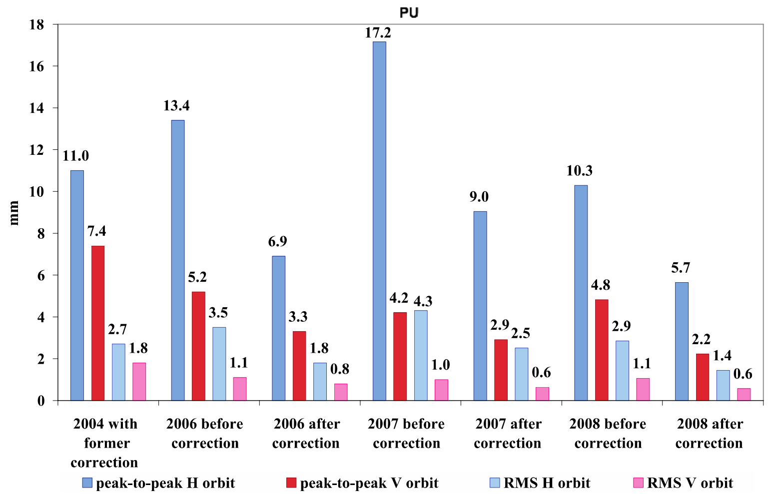
Current working area

Orbit correction by magnet tilting

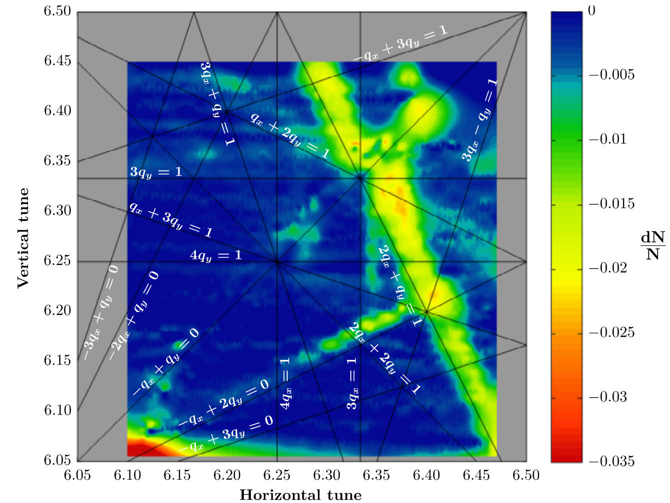
-Some magnets are rotated (3 per plane) to correct orbit and maximize aperture

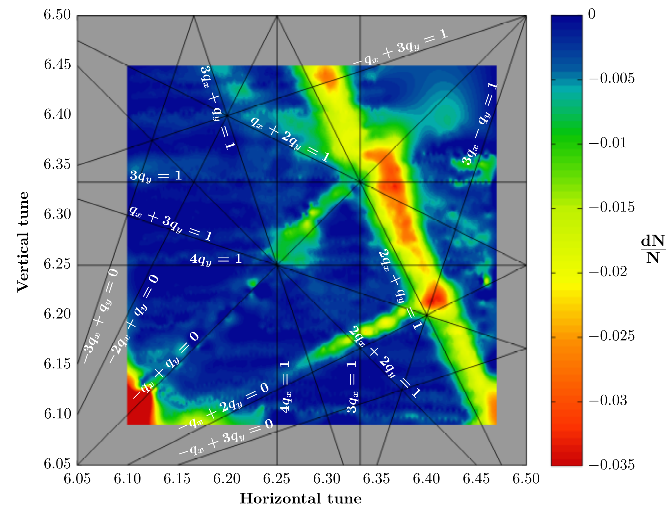
-Unfortunately some of the resonances are enhanced
and prediction is still not sufficiently precise





Before align.





After align.

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Measurement of octupolar errors

- To measure and localize an octupolar error:
  - Vary the amplitude of a localized bump
  - Measure the tune shift w.r.t. the bump amplitude

- To test this method: a horizontal bump was introduced in the sections 53-57, as well as a fake octupolar errors.

  The measurement was carried out:
  - without octupoles
  - with a single octupole located in the middle of the closed bump
  - with a single octupole located outside the closed bump

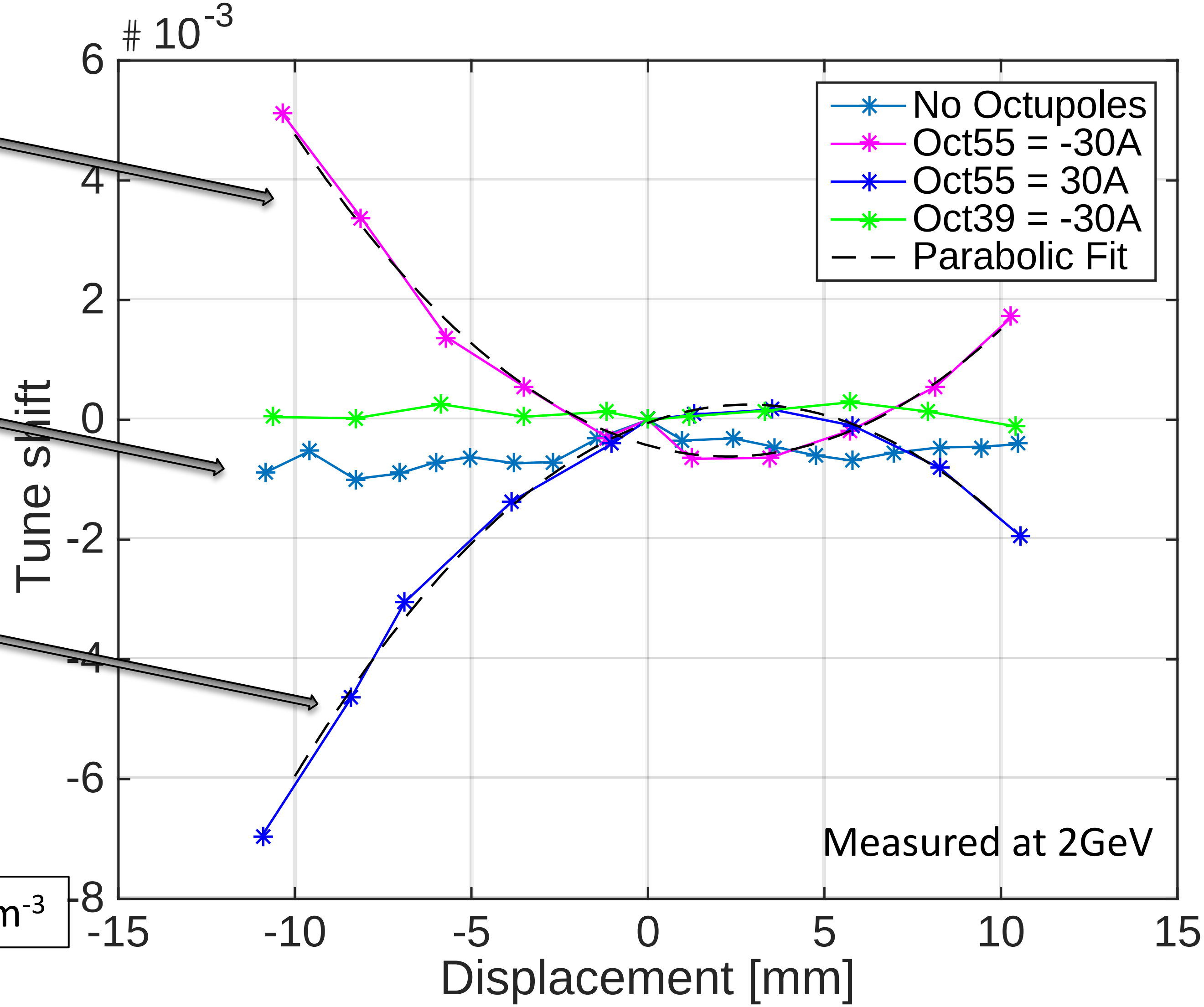
Measurement of octupolar errors

From the fit: K_3=35.6 m^{-3}

No octupolar component for the bare machine

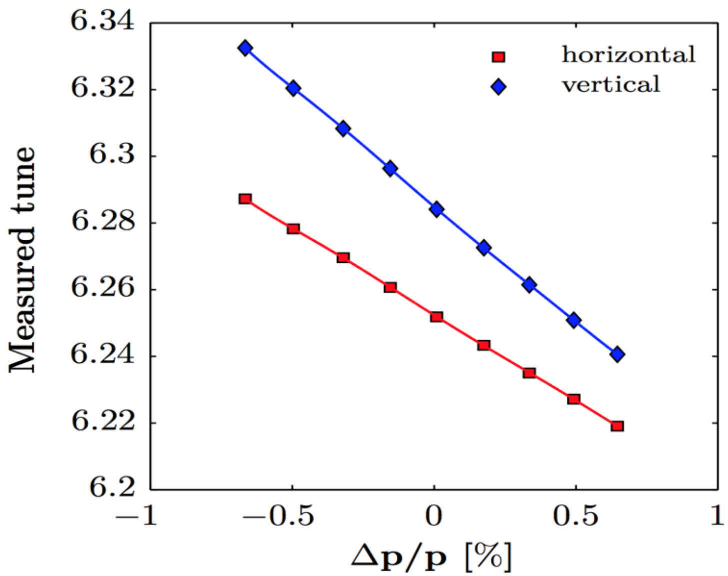
From the fit: K_3=37.5 m^{-3}

Expected value of K_3=37.9 m^{-3}



Measurement of octupolar errors

- Successful identification and localization of the excited octupolar error.
- No octupolar error was measured in the main magnets at low energy (over 4 straight sections).
  - ➔ agreement with high order chromaticity & no excitation of the 4Q resonance



Chromaticity measurement, bare machine at 2GeV

- This method could be applied to a running bump in the whole machine to localize octupolar errors.

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Resonance Driving Terms

- **43 shoe box pickups** located at the end of every magnet numbered x0,x3,x5,x7, with a respective phase advance of **67.5°, 45°** and **45°** and **100µm resolution**.

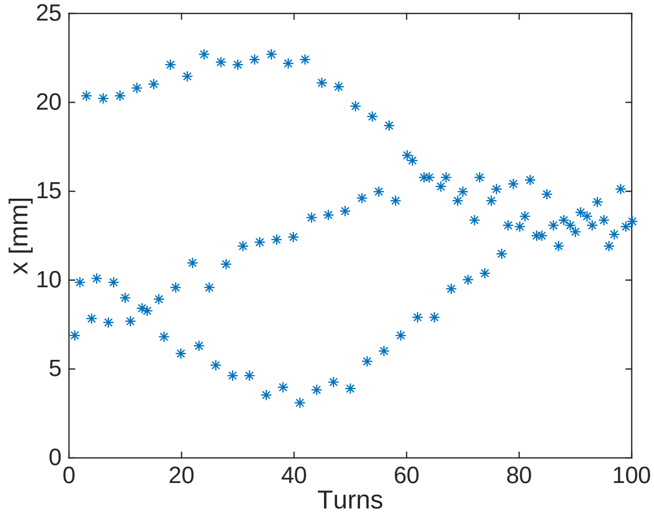
- **Turn by turn** data available (**5000 turns** with the current acquisition system).

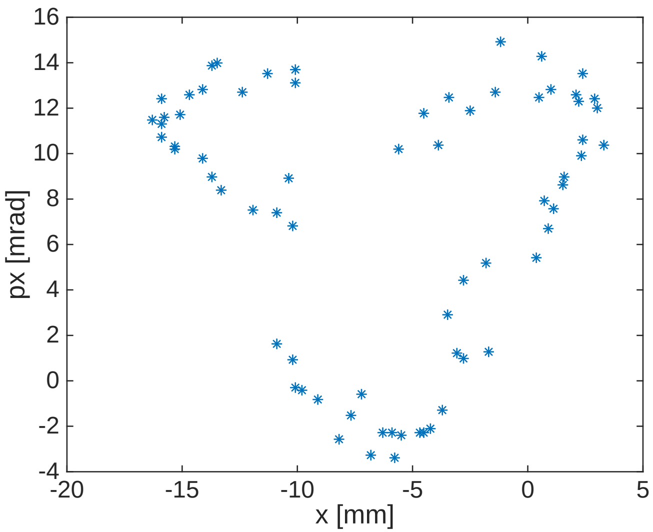
- Challenges:
  - No vertical kicker
  - Horizontal kickers available are too strong at low energy
  - Large natural chromaticity (Q'~-6) ➔ very fast decoherence

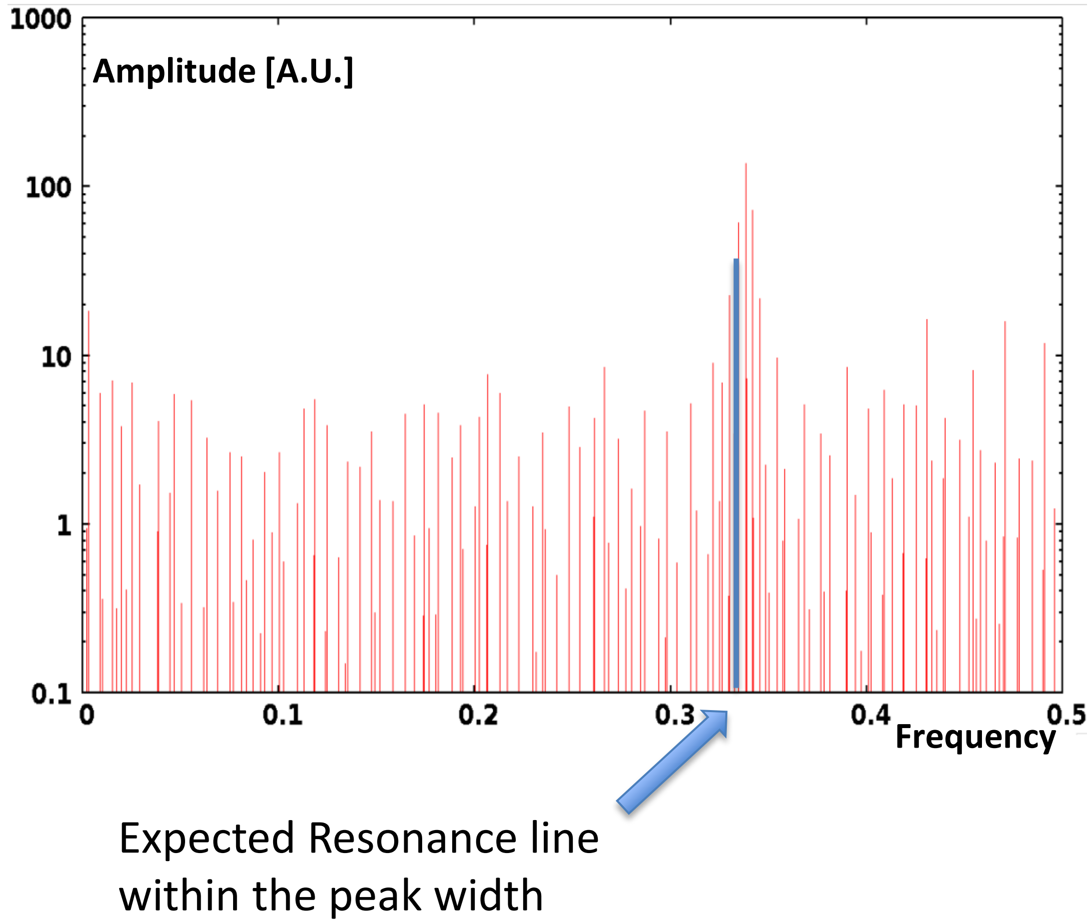
- Transverse feedback has been prepared to be used as **AC-dipole** after the winter shutdown.

Resonance Driving Terms

- Injection missteering: **Injection bump** (tune variation) ➔ only **80 turns** available at injection (~6% noise and peaks merged)







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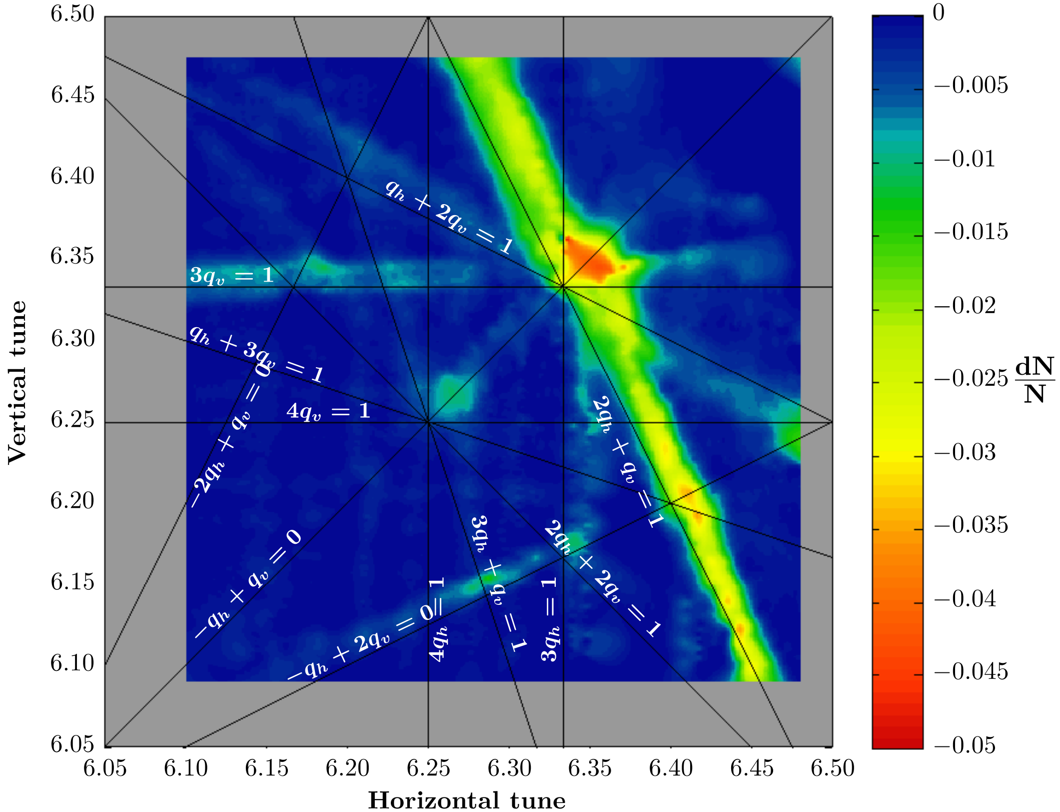
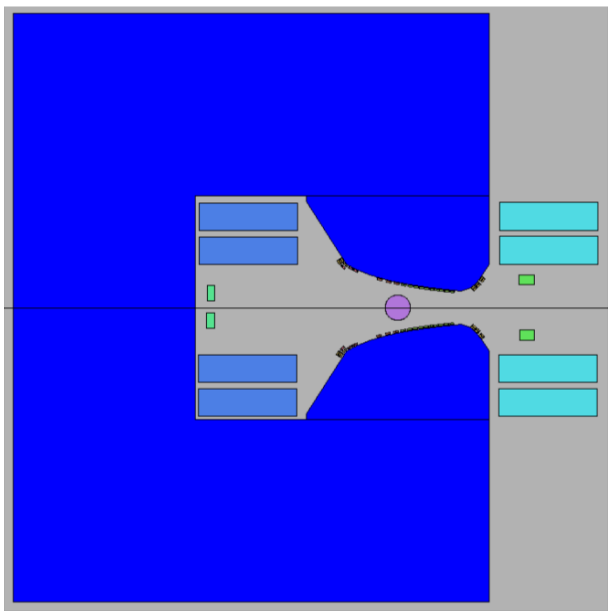
Resonance compensation

- The bare machine (only main magnets powered) measurements show relatively strong skew sextupolar resonances ($2Q_x+Q_y=19$ and $3Q_y=19$).
- As a proof of principle, we tried to compensate each of these resonances during the 2013 run.



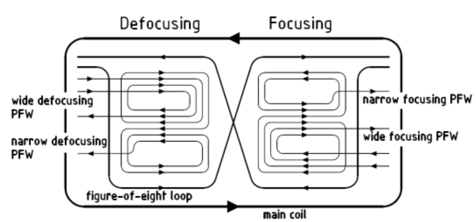
Resonance compensation

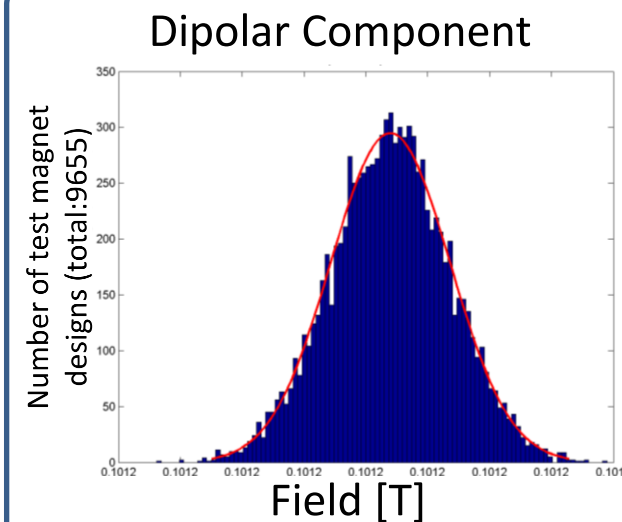
- 2D calculation including Gaussian distribution of the position of the coils and the shape of the iron with up to 22 DOFs per magnet (OPERA) were performed.
- 1000 models per magnet type (4 types) and current level have to be calculated. Performed for momentum of 2.14 GeV/c, 2.78 GeV/c, 14 GeV/c, 26 GeV/c.



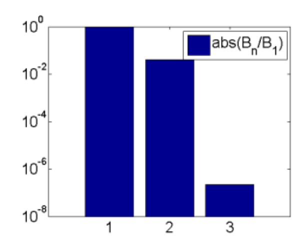
Coils can be displaced, no rotation:
Main coils (2 x 4 DOFs), σ = 3 mm
F8 (2 x 4 DOFs), σ = 1 mm
PFW (2 x 2 DOFs), σ = 0.7 mm

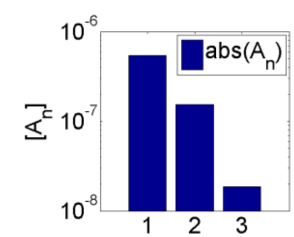
Iron is displaced in y-direction,
σ = 0.02/3 mm





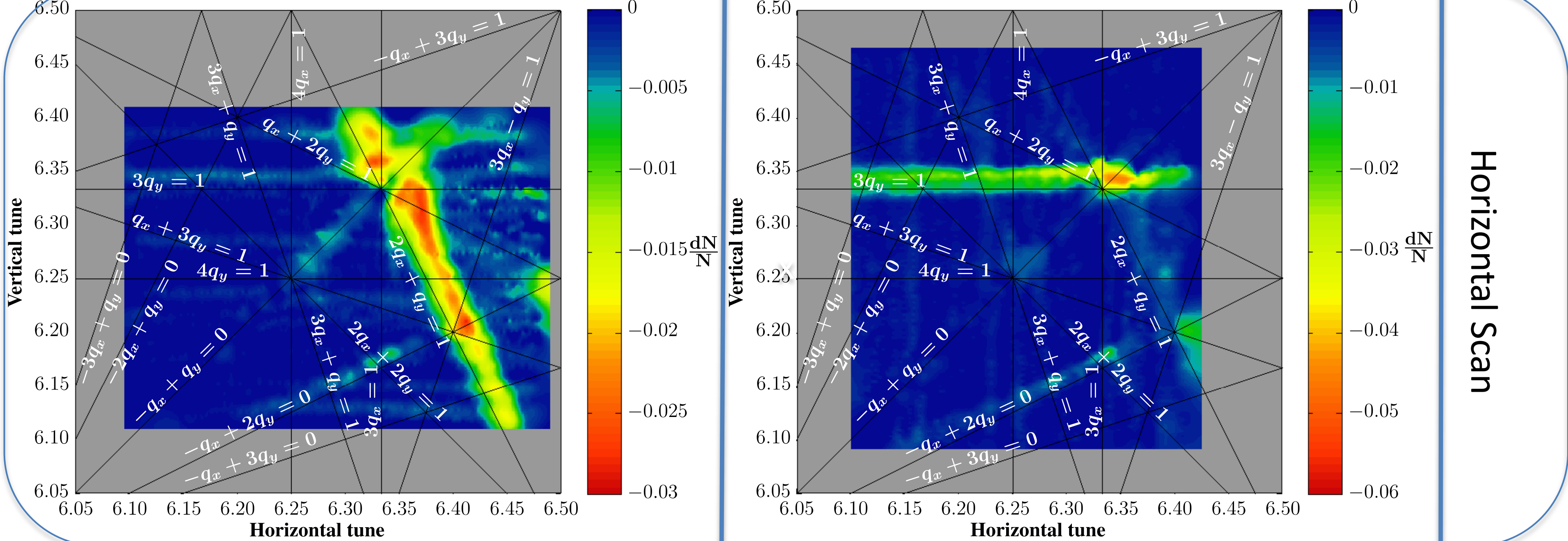
Kinetic energy: 1.4GeV
Reference radius
r = 10 mm
Vacuum chamber: 140x70mm

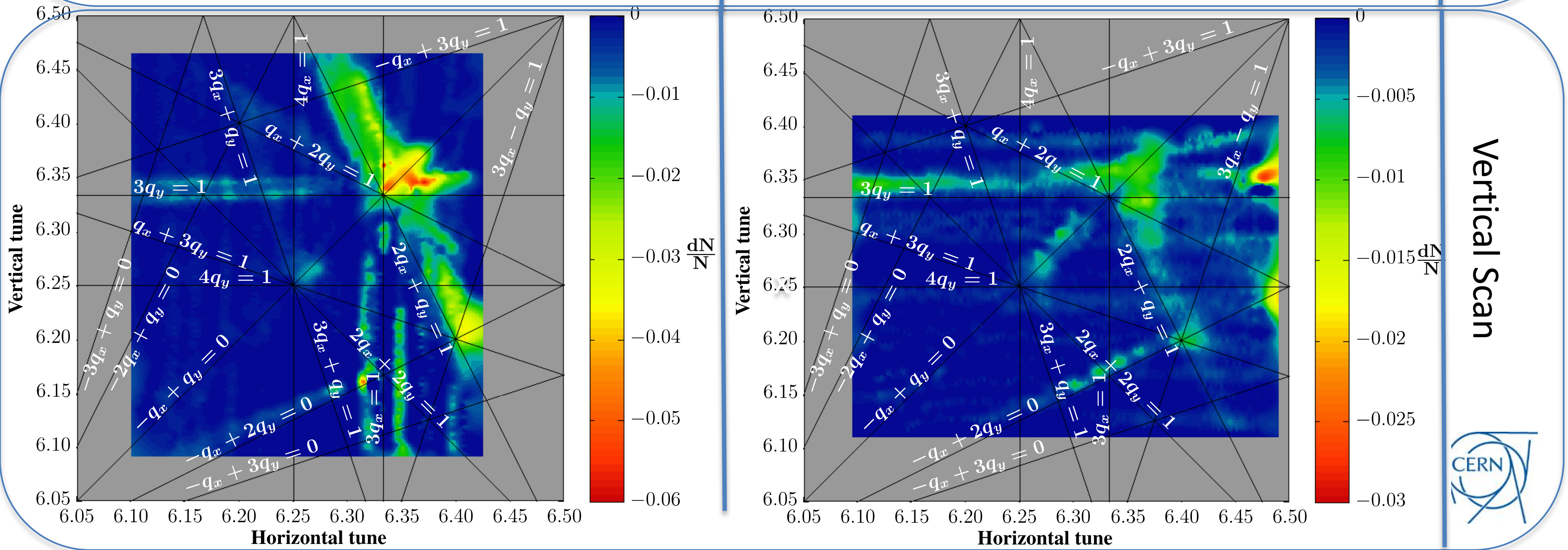




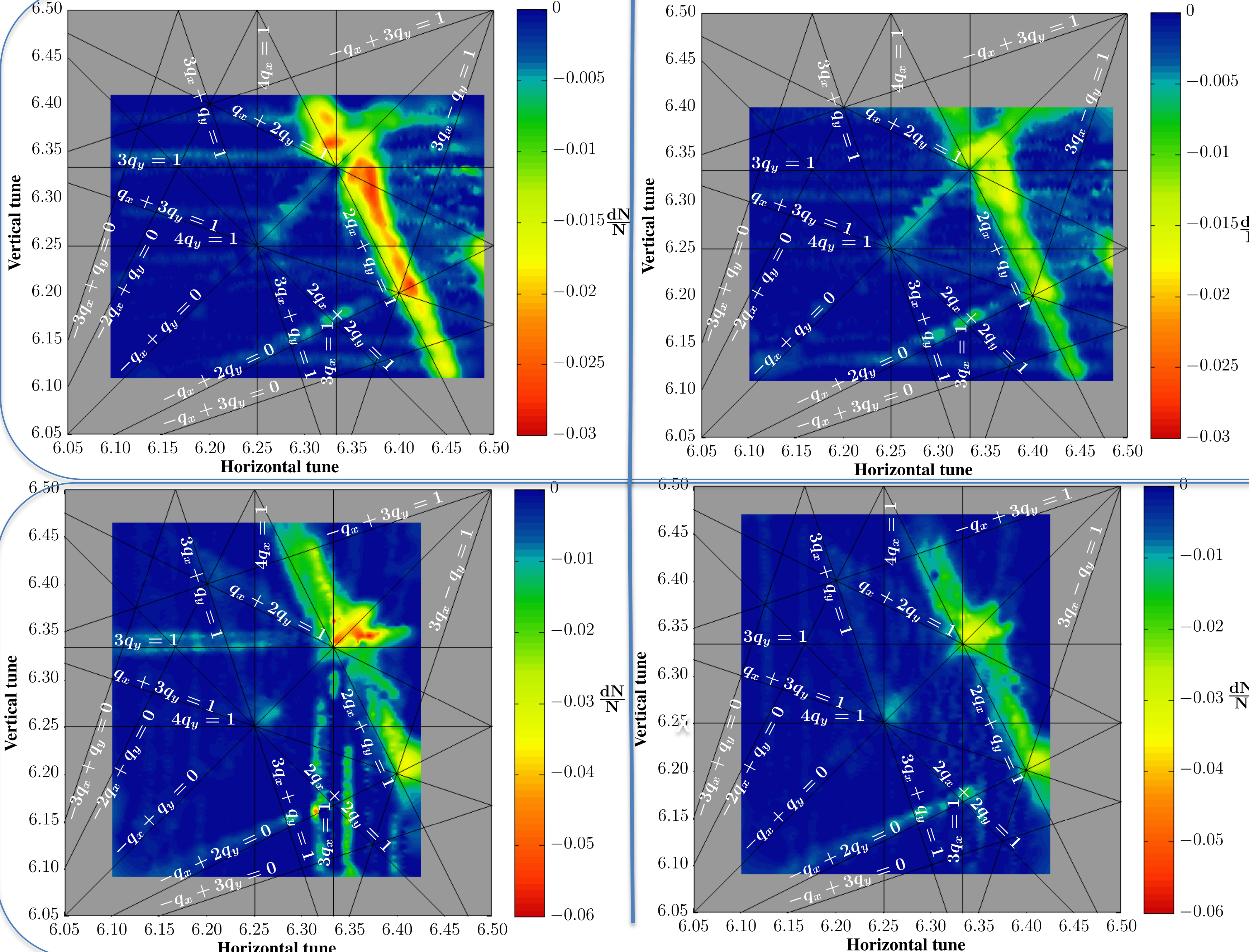
→ These errors were randomly distributed on the magnets in the PTC model to compute the driving terms of each of the resonances.

2Qx+Qy Resonance





3Qy Resonance



Horizontal Scan

Vertical Scan

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Summary & Conclusion

- Measurement of octupolar errors showed that the bare machine has very small octupolar errors.

- Resonance Driving Terms measurements planned in 2015 with an AC Dipole.

- A successful implementation of resonance compensation was achieved but further investigations are needed to a better understand the source of of these errors.

LHC Injectors Upgrade

THANK YOU FOR YOUR ATTENTION!

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