Summary of Session II
Optics & Beam Physics Aspects

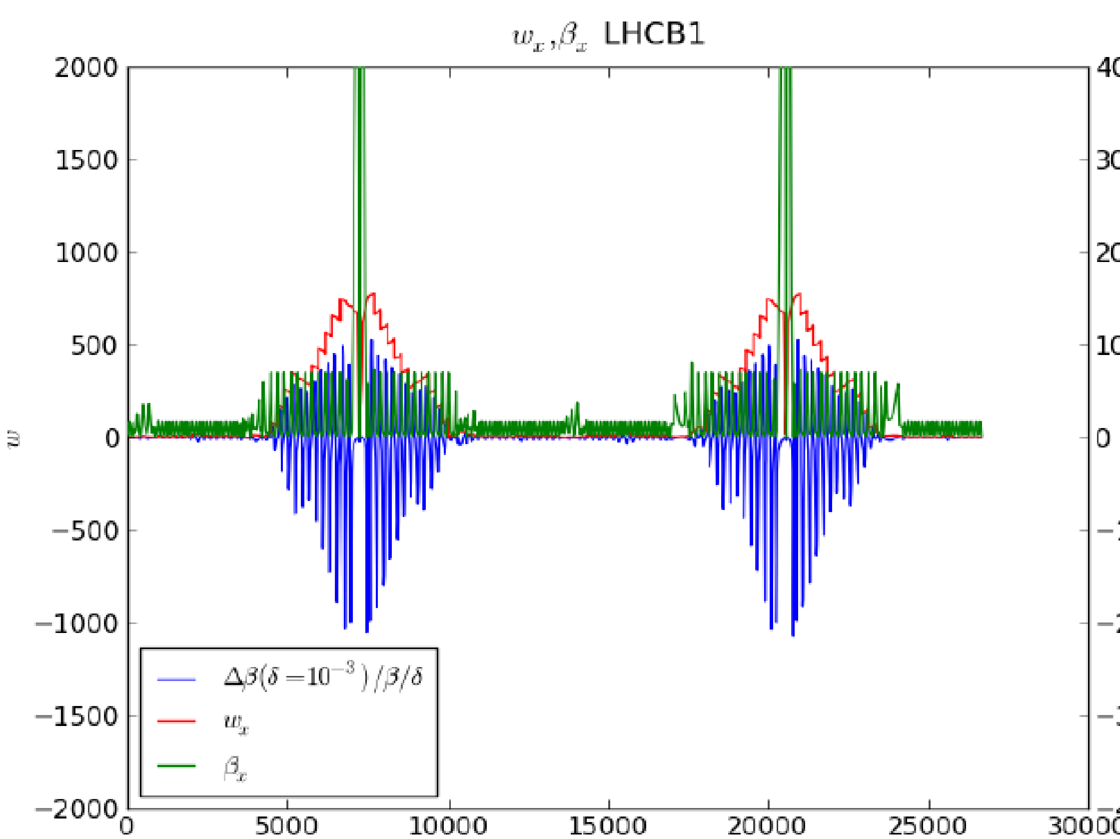
M. Giovannozzi

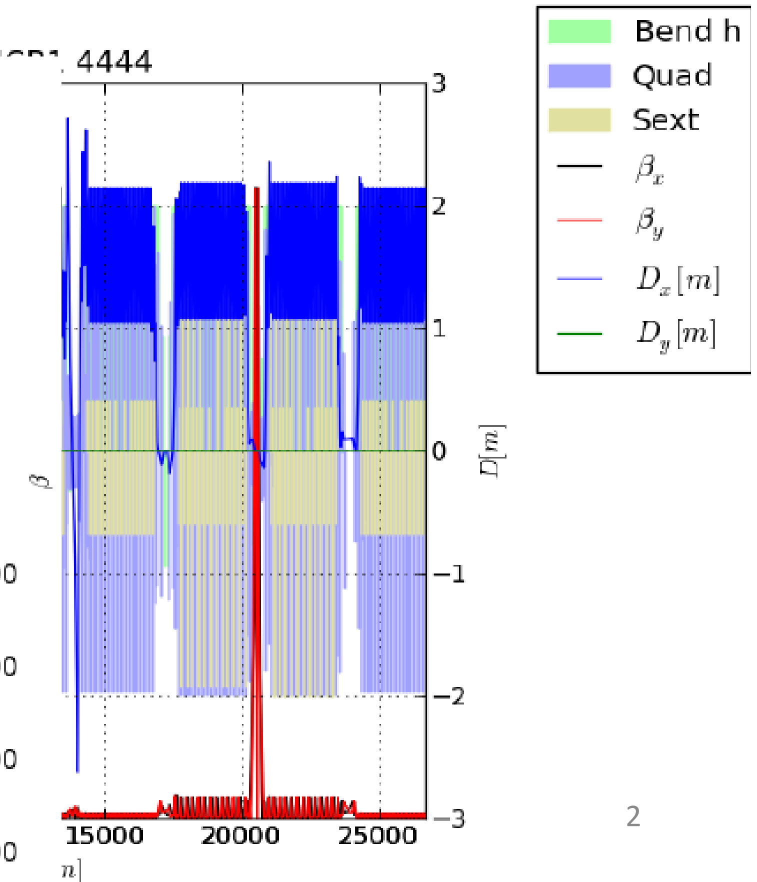
- Upgrade optics with crab cavities - *Riccardo De Maria*
- Effect of non-zero dispersion – withdrawn
- Impedance effects during injection, energy ramp & store - *Elena Shaposhnikova*
- Luminosity leveling with crabs - *Guido Sterbini*
- Very large crossing angle & magnet technology - *Ezio Todesco*

Upgrade optics with crab cavities

- Based on sLHCv3 layout - S. Fartoukh sLHC-Project-Report -049
- Beta*=15 cm
- Crossing angle = 0.58 mrad (10 σ separation)
- Off-momentum beta-beating corrected

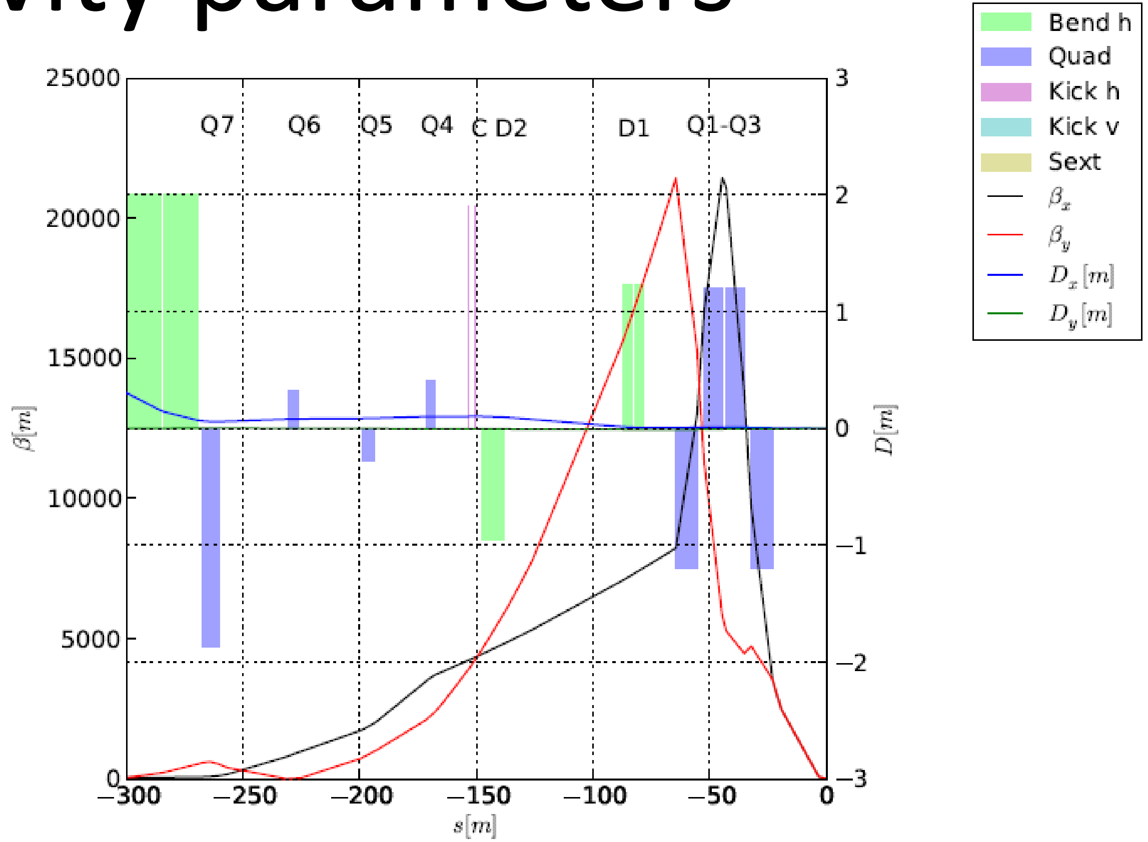
LHC features alternating crossing planes in IR1/5

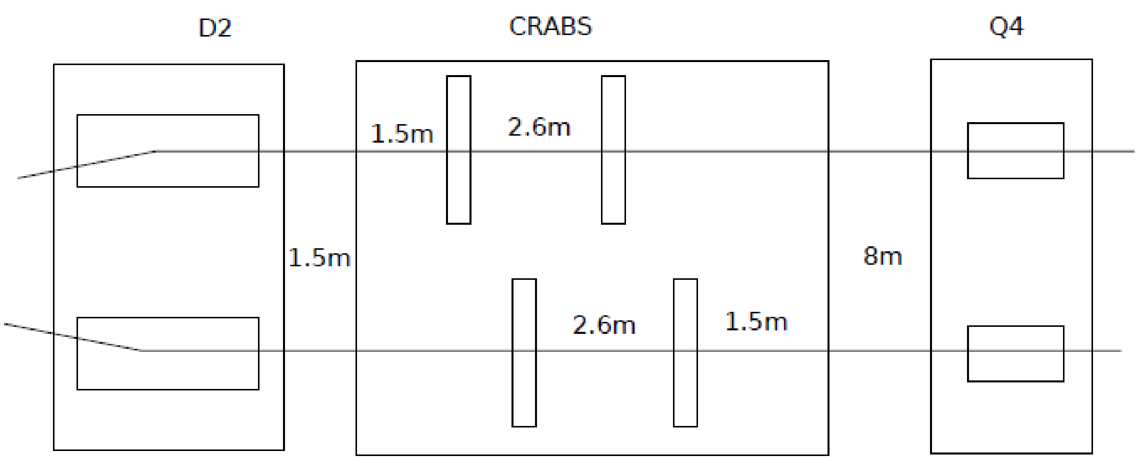




Crab cavity parameters

- Two CC per beam and per side of IR
- Pushed towards the D2 (to profit from large betas)
- 10 MV of total active voltage





On-going studies

- Analysis of dynamic aperture:
  - MS field has an impact on dynamic aperture.
  - MB, MQ, field quality of main dipoles at top energy do matter!
  - Reduction of betas in arcs should improve the situation
  - Beam-beam effects to be simulated
  - Field quality of crab cavity to be studied (ac multipoles)
- Synchro-betatron effects to be studied.

Identified issues/improvements - I

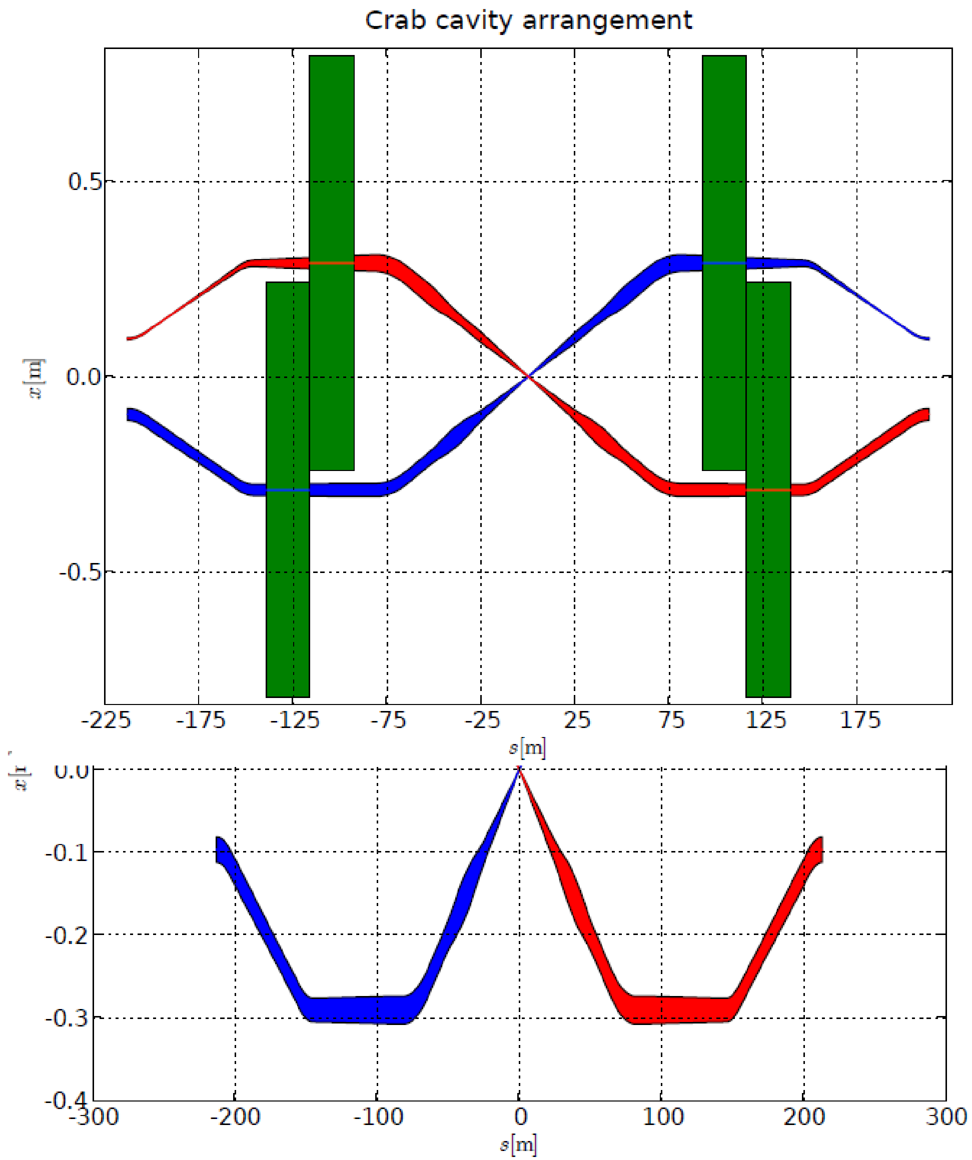
- The crossing and separation bumps are not closed at the location of the crab cavities.
  - Need to change crossing angle: Van der Meer scans, change of sign (remove systematic effects – requested by experiments)
  - Possible solutions:
    - Crab cavity mechanically re-aligned at each change of parameter? Clearly not optimal from an operational point of view.
    - Try to close the bumps upstream of the cavities -> to be looked at.
    - Alternatively try to set x=0 in the crab cavity (with x' not zero)

Identified issues/improvements - II

- Optimisation of the crab cavity location in order to reduce the voltage needed.
  - Move the cavity towards the IP side of the D2. In between D1 and D2:
    - Beta increases quadratically with s
    - Aperture required increases linearly with s
    - Beam pipe separation reduces linearly with s
  - An optimum might be found -> detailed study of the whole region to be done.

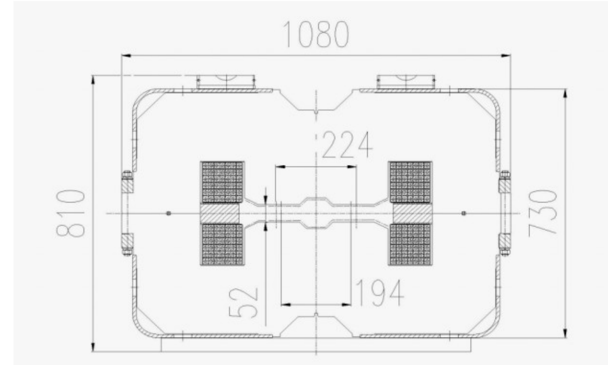
Very large crossing angle & magnet technology

- This study was triggered by a layout presented at Lumi 06 by R. Tomas *et al.*
- Crossing angle is 8 mrad (to allow installing CC)
- Extreme layout (the required crab cavity voltage is hardly achievable)!

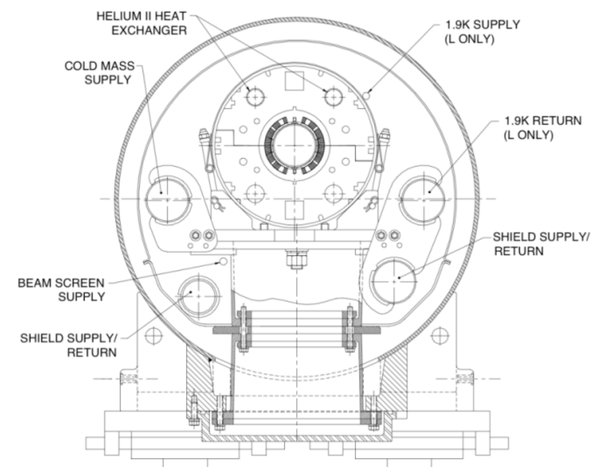


Separation dipoles – Nb-Ti

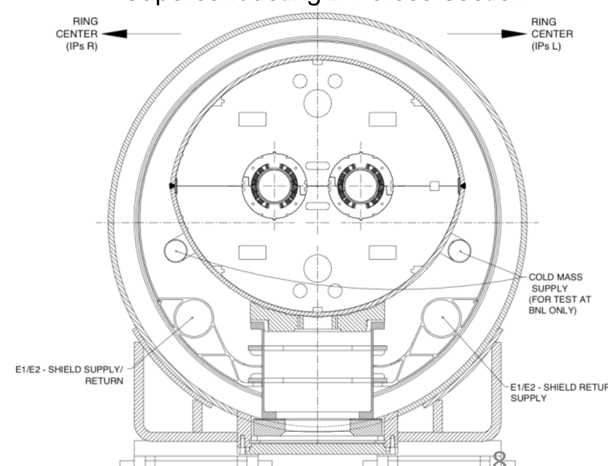
- D1 IP1 and IP5: resistive magnets
  - Single aperture
  - Field ~1.3 T, Kick: ~26 T m
  - Length: 6*3.4 m ~20 m
- D1 IP2 and IP8: RHIC-like sc magnets
  - Single aperture 80 mm
  - Field ~3.8 T, Kick: ~36 T m
  - Length: ~9.5 m
- D2: RHIC-like sc magnets
  - Double aperture 80 mm
  - Field ~3.8 T, Kick: ~36 T m
  - Length: ~9.5 m



Resistive D1 cross-section



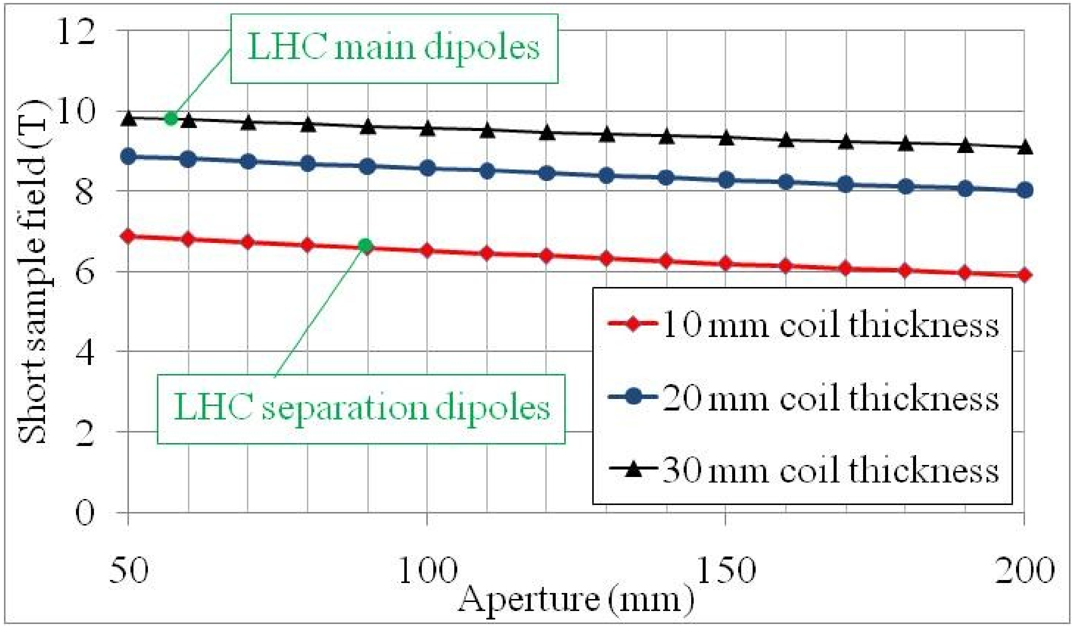
Superconducting D1 cross-section



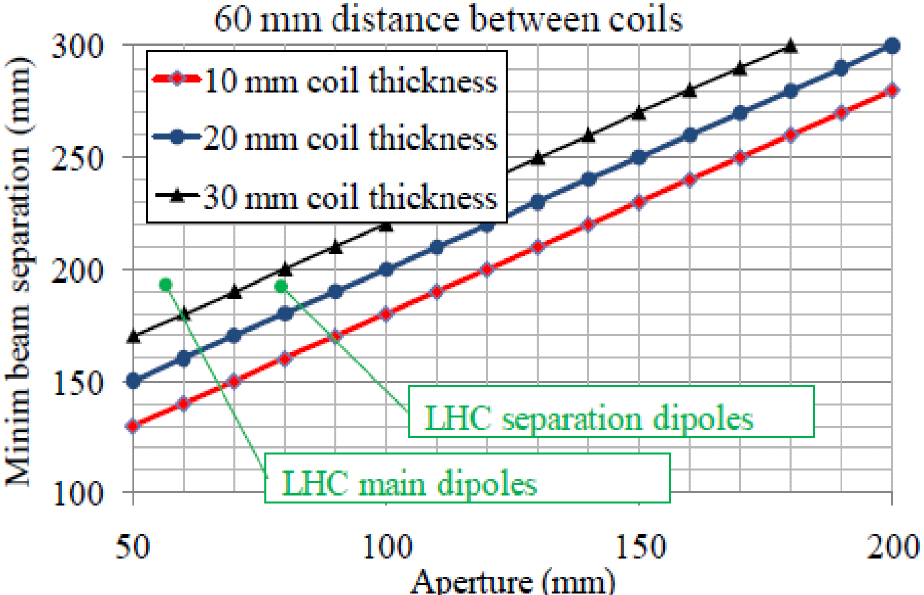
Superconducting D2 cross-section

Dipoles: potential improvements

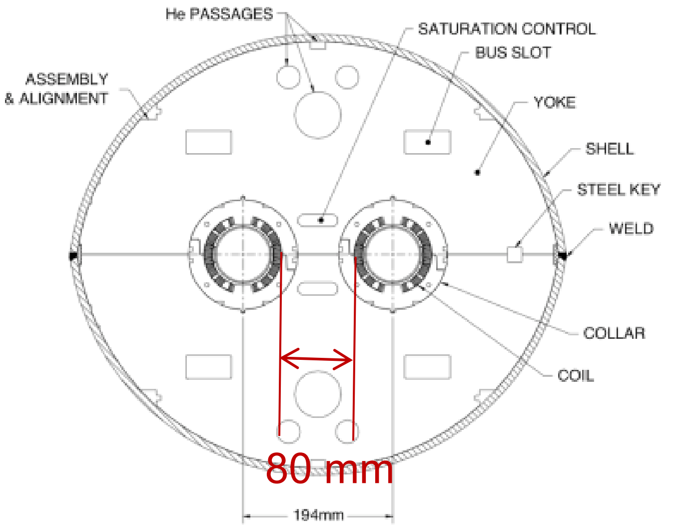
- Aperture – Field
  - Possibility to shorten considerably D1.



- Aperture – Field – beam separation

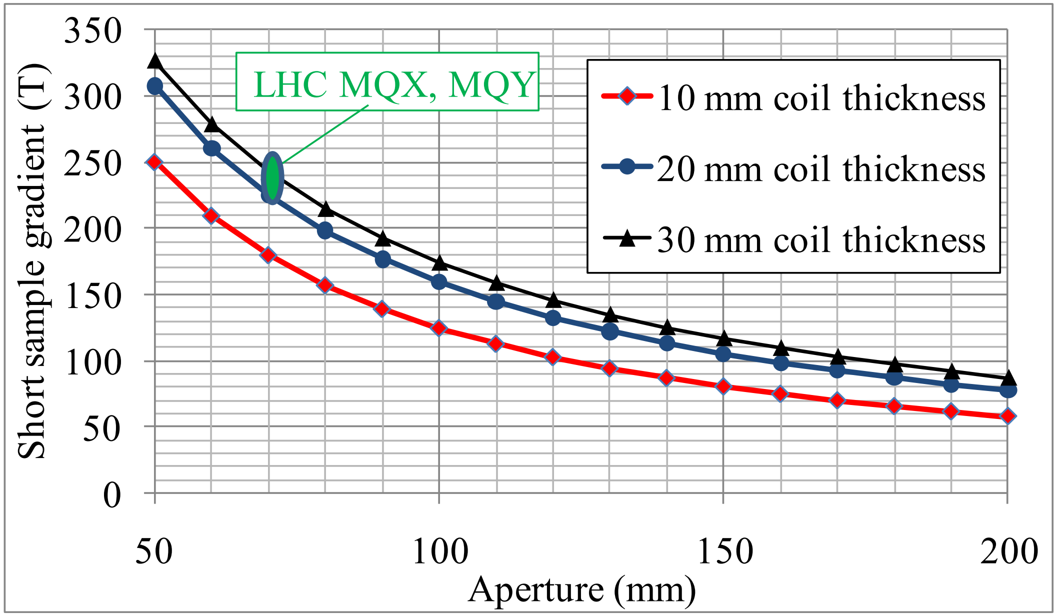


LHC-CC10

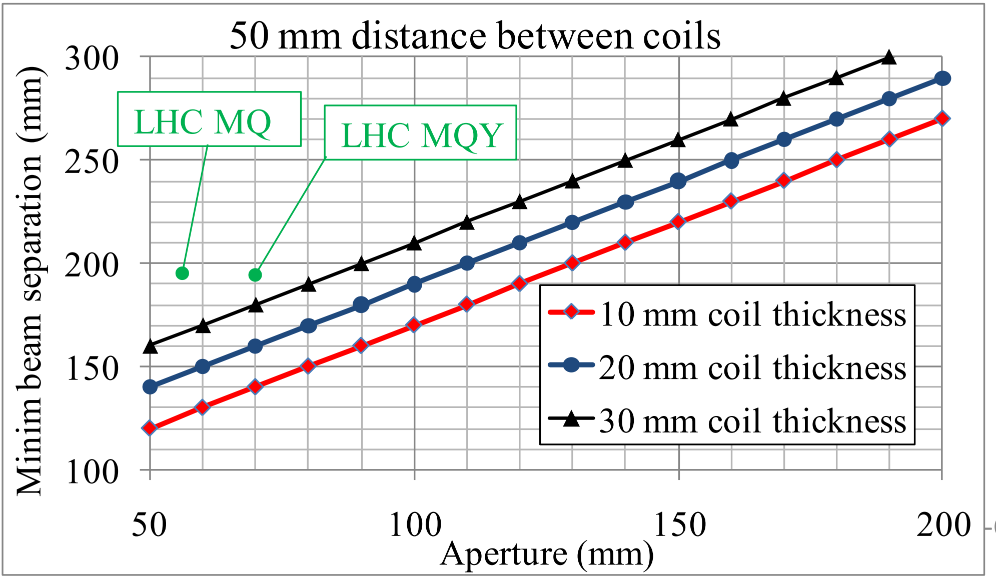


Quadrupoles: potential improvements

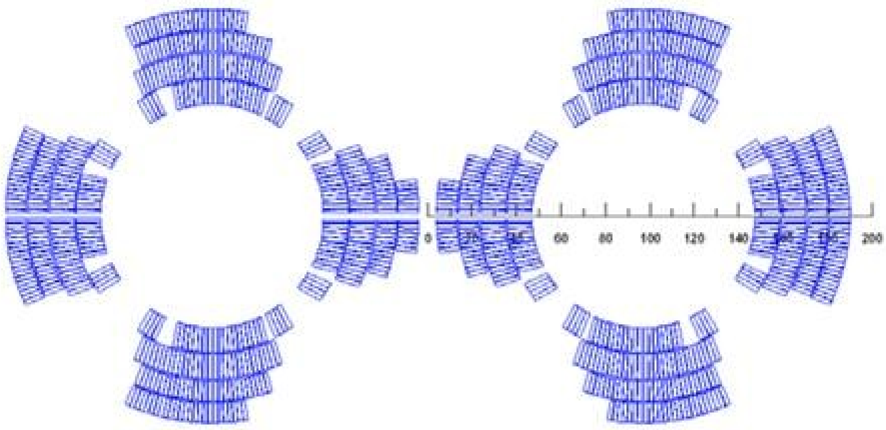
- Aperture – Field



- Aperture – Field – beam separation

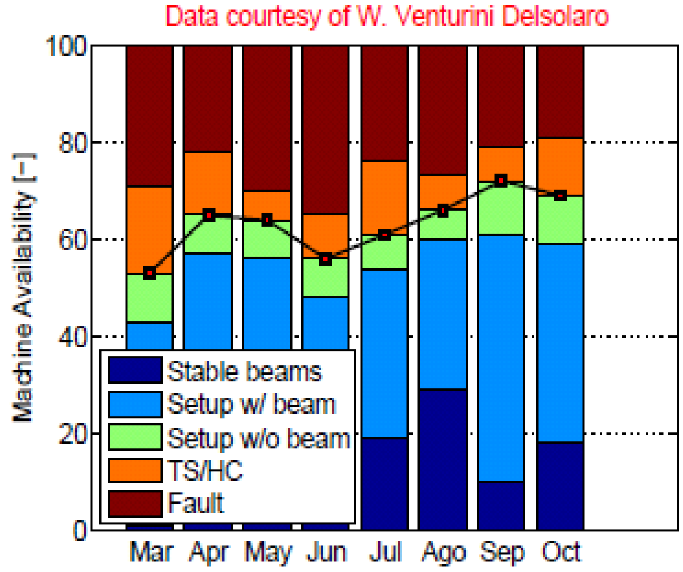


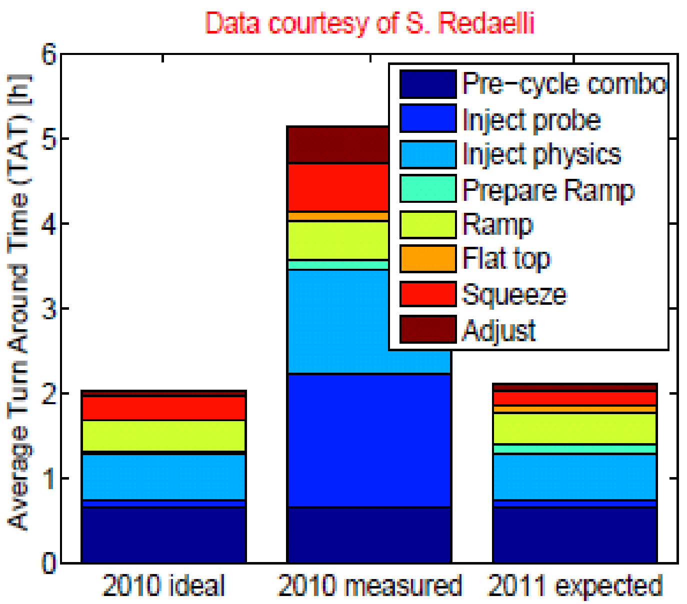
Asymmetric coil design



Luminosity leveling with crabs

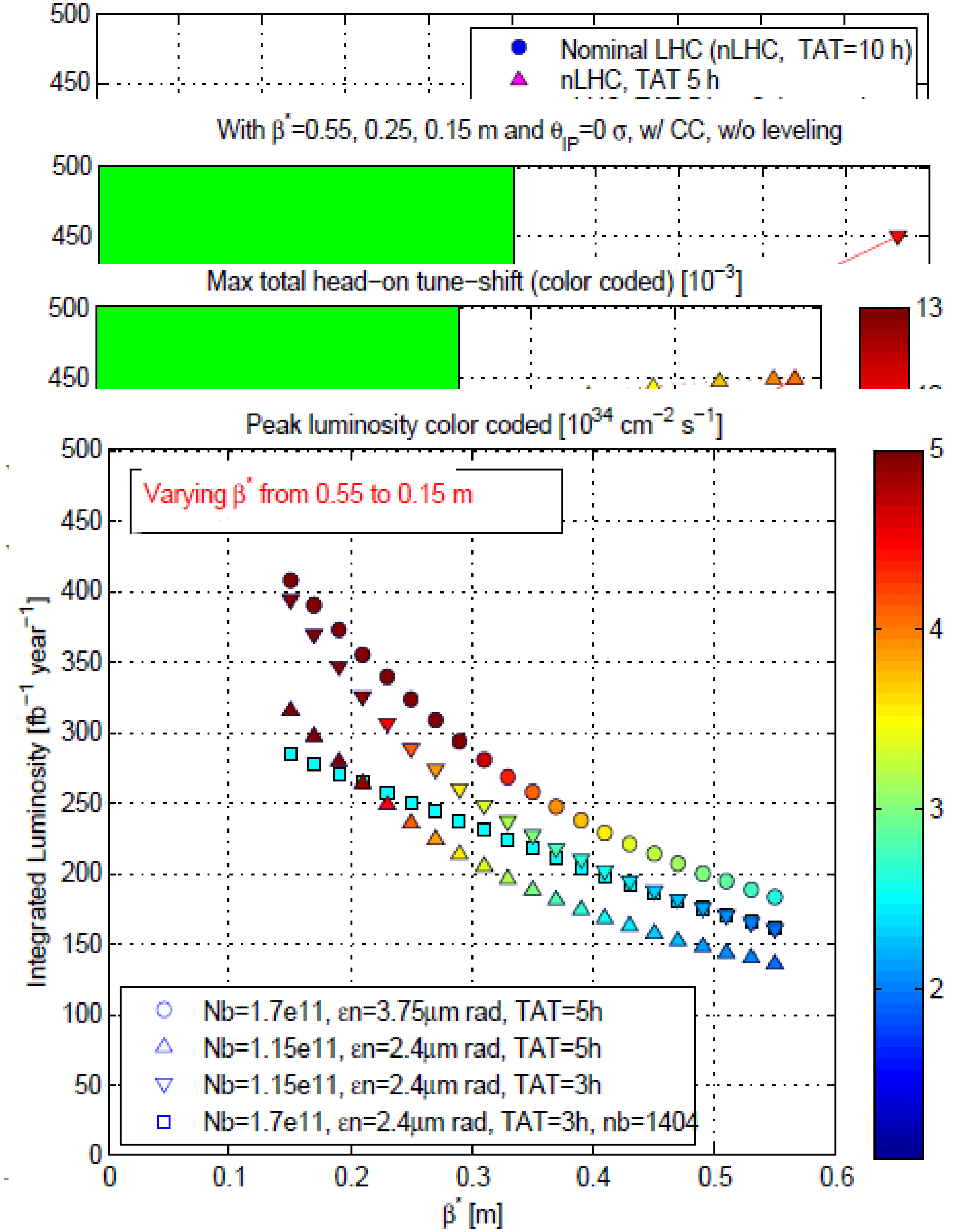
- Ingredients of simulations:
  - IBS, rest-gas scattering
  - Proton burn-off
- Machine availability and turn-around-time from 2010 LHC run (but likely too optimistic in simulations)
- Target: 300 fb^{-1}/year, pile-up < 100
- Cross-check of model with fill 1450 (to be extended to a larger number of fills).





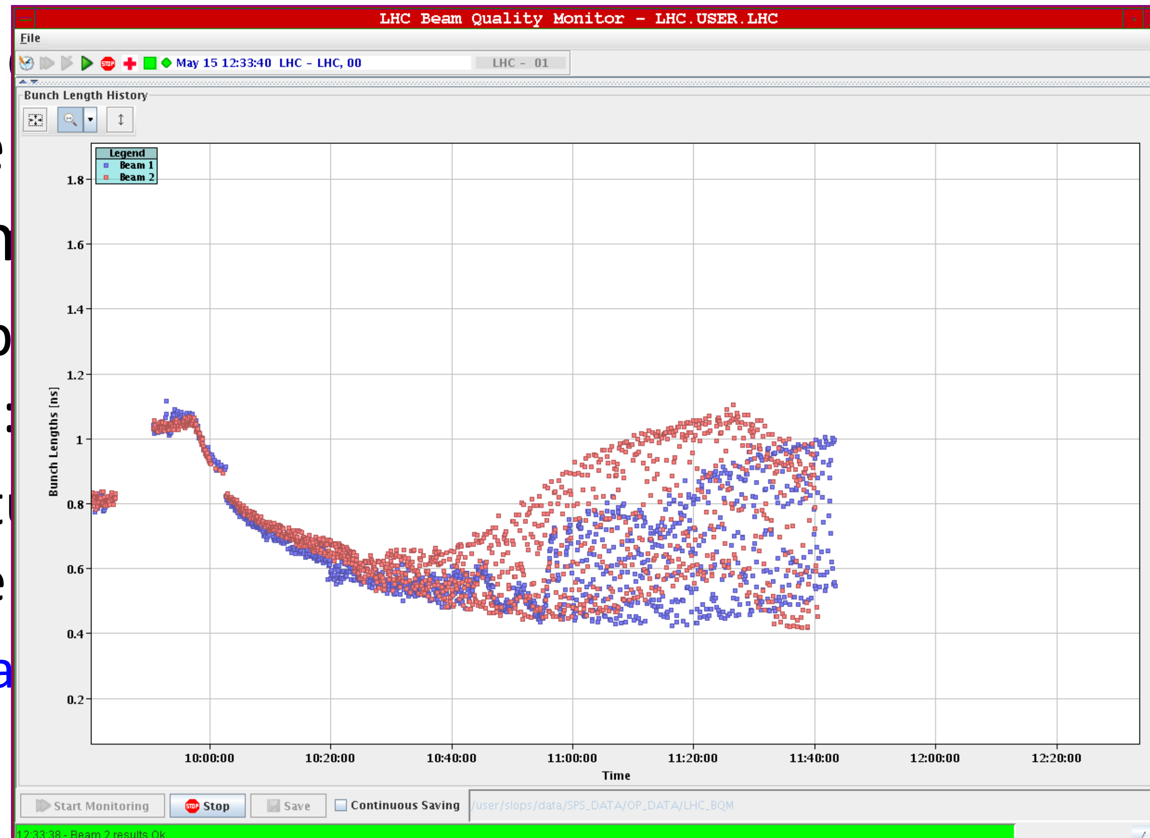
Luminosity leveling with crabs

- CC boosts performance
- Leveling allows achieving goals (integrated luminosity, pile-up).
- Rather wide optimization possibilities.
- 50 ns bunch spacing is not far from required performance.



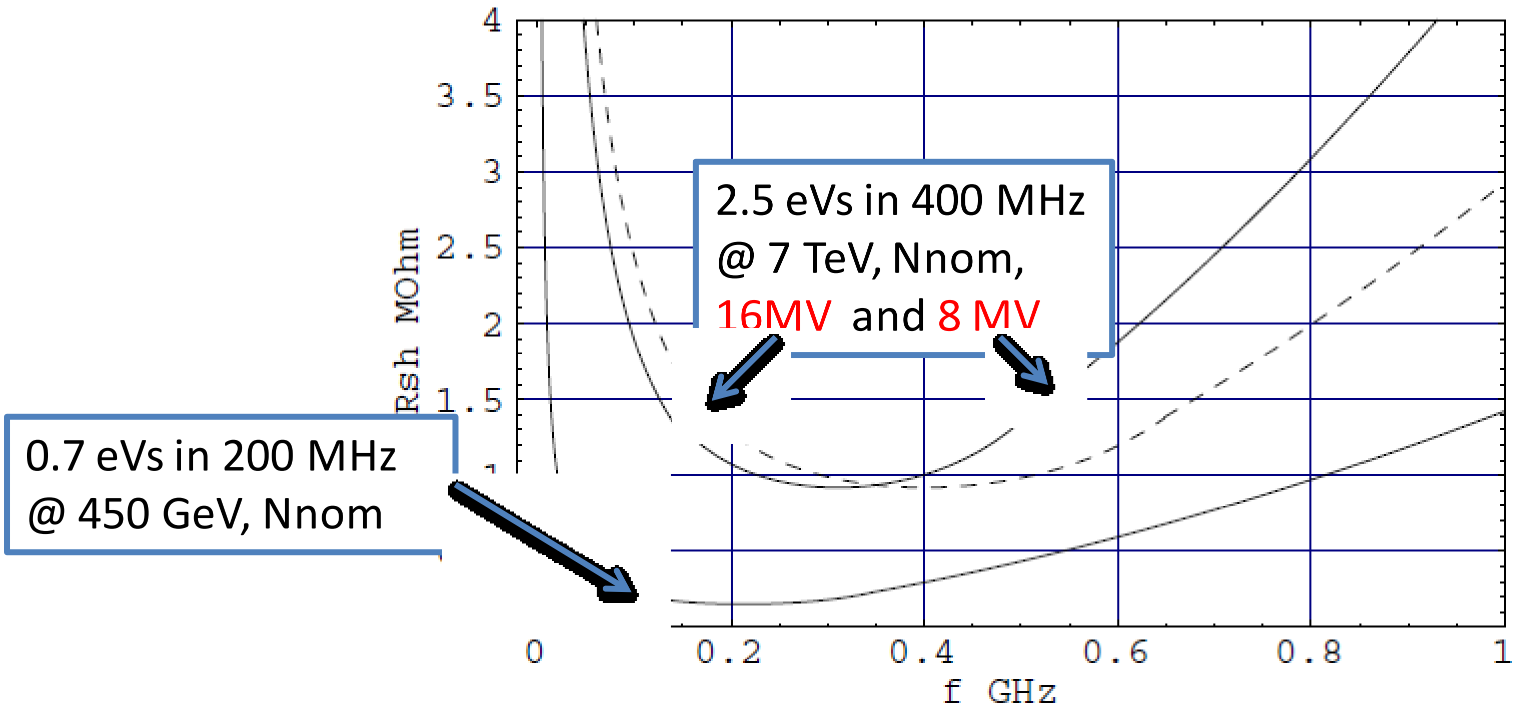
Impedance effects during injection, energy ramp & store

- Longitudinal stability in LHC:
  - Feedback and feedforward systems and longitudinal damper at 400 MHz (~ 1 MHz bandwidth)
  - Landau damping (
    spread inside the
    stabilise the bean
    - ImZ/n of broad-b
      Landau damping:
    - Controlled longit
      operation on the
      - From 0.6 eVs a



Impedance effects during injection, energy ramp & store

- LHC Design Report: HOM damping below 60 kOhm (defined by stability in a single 200 MHz RF at 0.45 TeV)



Limit: 40 kOhm/Ncc for ultimate intensity

Impedance effects during injection, energy ramp & store

- Transverse plane:
  - In LHC there is a bunch-by-bunch transverse feedback system (20 MHz bandwidth) to damp injection oscillations and unstable rigid bunch motion.
  - Impedance limit defined by damping time of feedback system (to avoid any emittance blow-up).

    0.8 MOhm/m/Ncc at 800 MHz for ultimate intensity

  - Additional factor proportional to local beta-function $\beta/\langle \beta \rangle$

Summary

- 2010 beam experience already included in some studies.
- A promising solution for a low-beta lattice with local crab cavities is available. Studies and further optimizations are on-going.
- There is some margin in the parameters of separation dipoles to fit the requirements of the new layout. Less margin is available for quadrupoles. “Fancy” cross-sections are available.
- Impact of crab cavities and leveling on overall performance was shown. There is room for optimising the parameters (bunch intensity, emittance, turn-around-time, spacing).
- Bounds on impedance (transverse and longitudinal) for crab cavities were worked out. They seem realistic. It would be useful to review in more details the estimate taking into account frequency, optics...etc.