PSB H- chicane magnets: Inconel vacuum chamber option & consequences on beam dynamics

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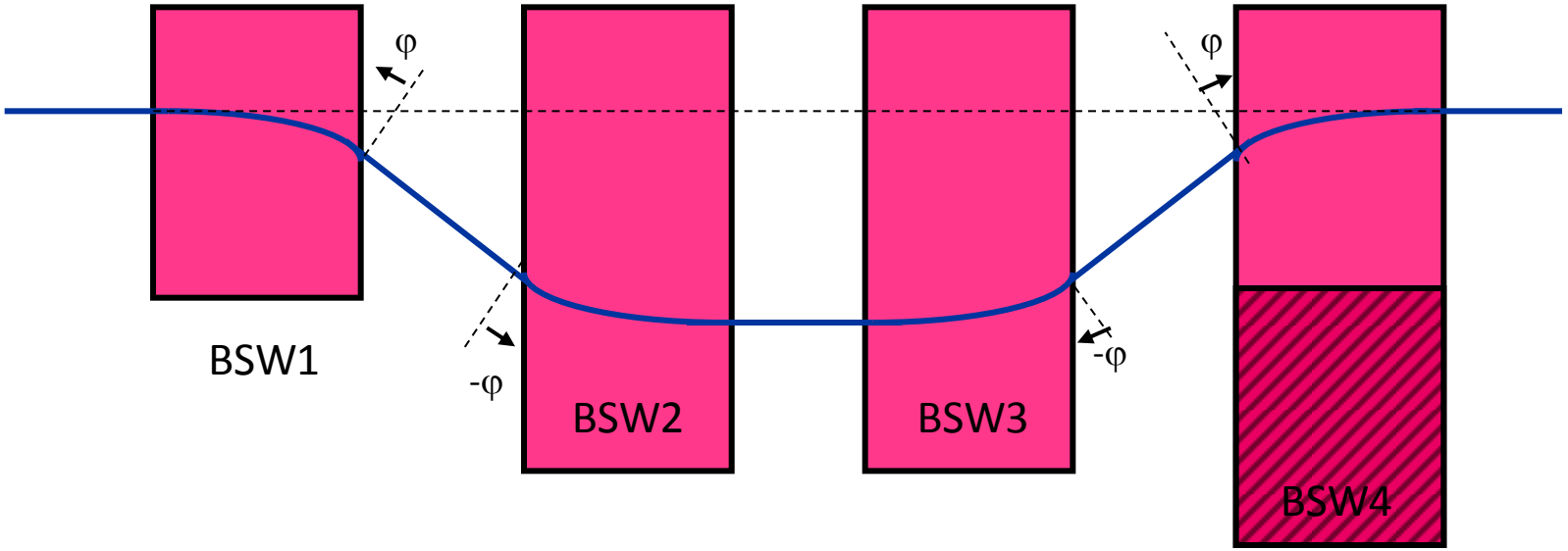
Thanks: C. Carli, B. Balhan, J. Borburgh, G. Arduini, R. De Maria, L. Deniau, A. Molodozhentsev

Outline

- Introduction & ~order of magnitudes
- Simulations
- New correction settings
- Caveats
- Conclusions

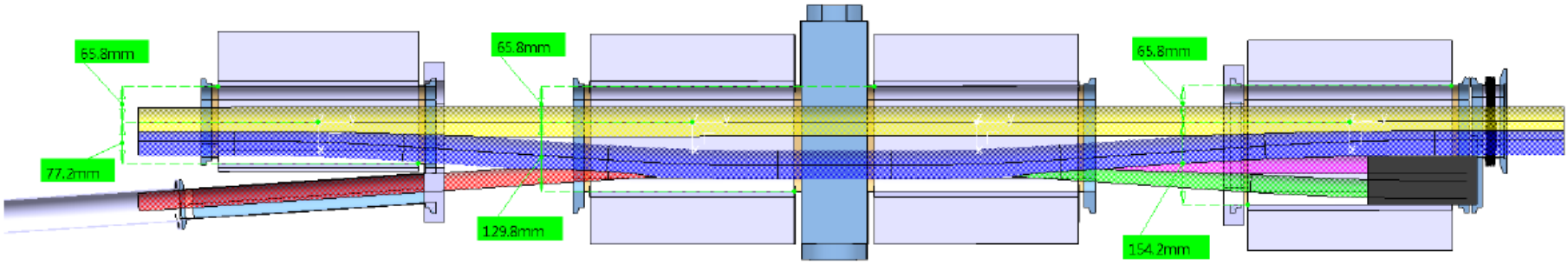
Introduction



- Chicane magnets for H- injection
  - 46mm (φ=66mrad), falls linearly to 0mm in 5ms
- Proposed corrugated Inconel vac. chamber new baseline
- Influence on beam dynamics of induced Eddy currents:
  - Delay of ~50us (hp: it is compensated by power supplies)
  - Higher order field components (sextupolar)
    - Quadrupolar feed-down
    - Excitation 3rd order resonance

Drawings

from W.Weterings, 09/01/13



BSW Aperture & Offset

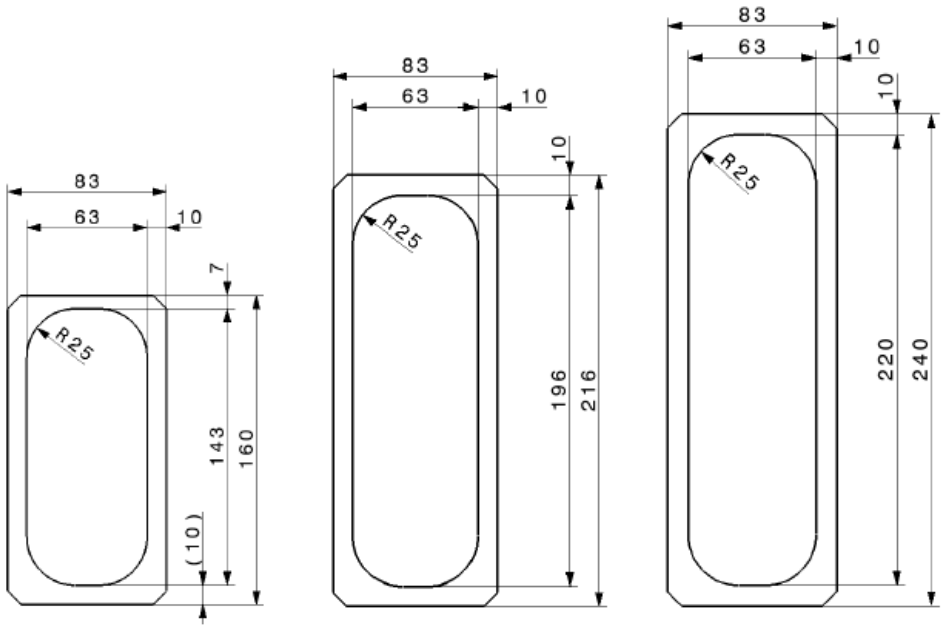
Yellow; Reference orbit

Blue; Bumped (35mm) and chicane deflected beam

Red; Injected beam

Purple; Dumped H0 beam

Green; Dumped H- Beam



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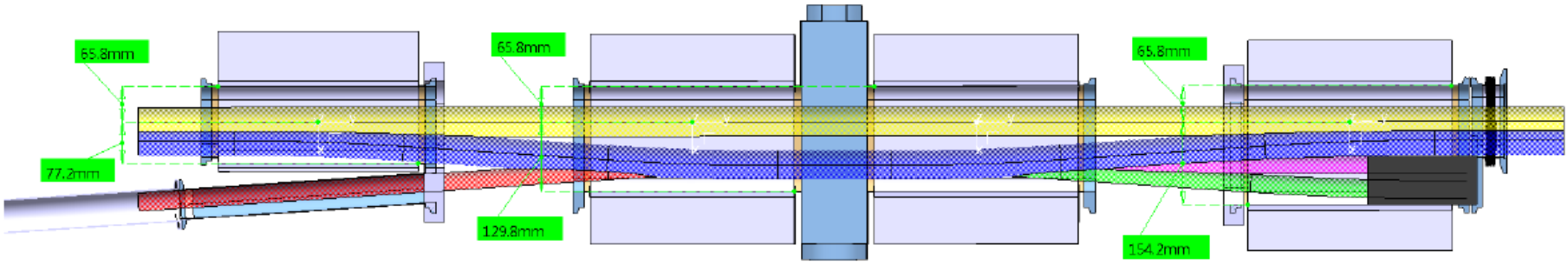

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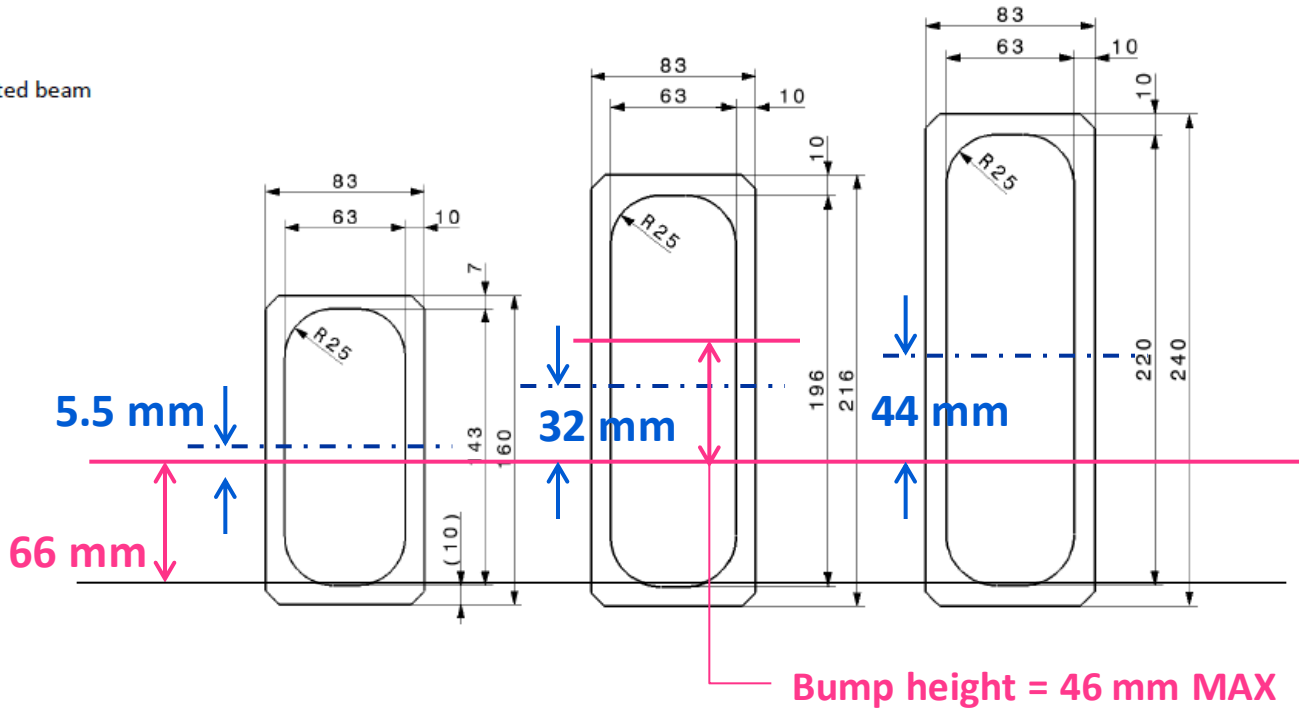


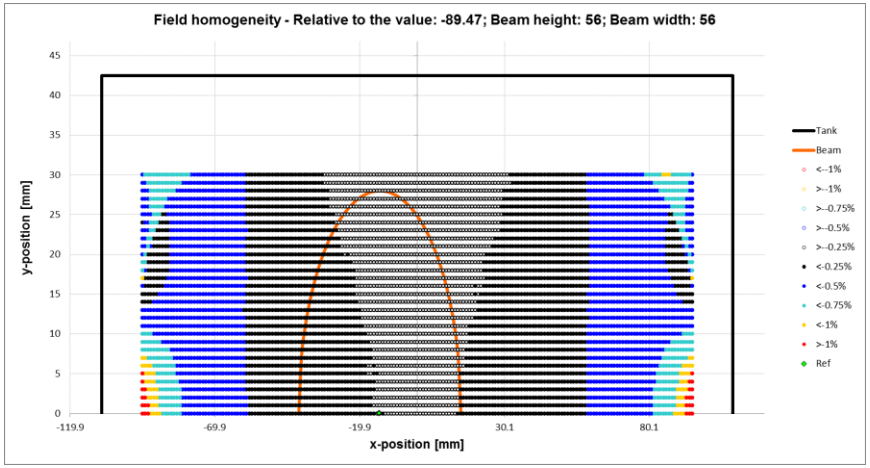
Order of magnitude of perturbation

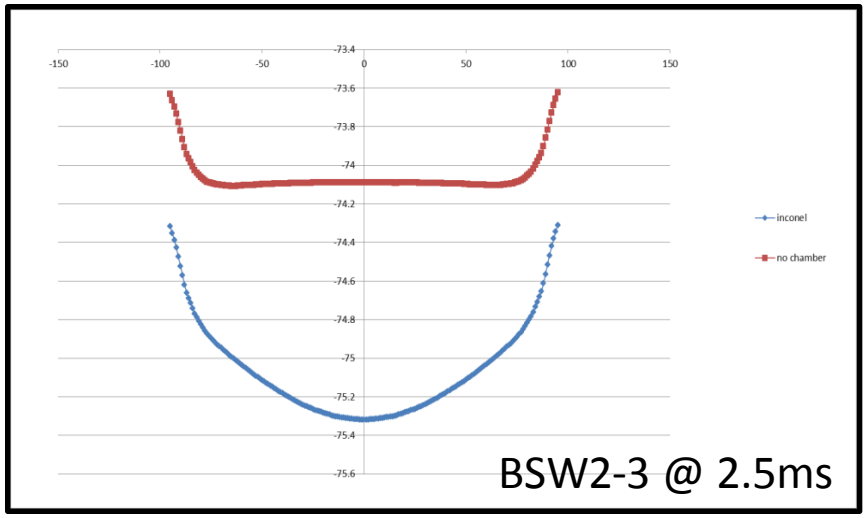
- Edge effect (rectangular magnet):
  - $k1L \sim \varphi^2/2L \sim 6e\text{-}3$
- Feed-down from sextupole:
  - $\mathrm{Int}(Bdl) \sim c0 + c1\ x + c2\ x^2 + \ldots$
  - $x0 = -50\,mm$
  - → $k1L \sim 3.4e\text{-}3$

Cfr. presentatin by C. Carli 19/11/09
at PSB beam dynamics w. L4 WG

Extraction BSW multipoles

from B. Balhan

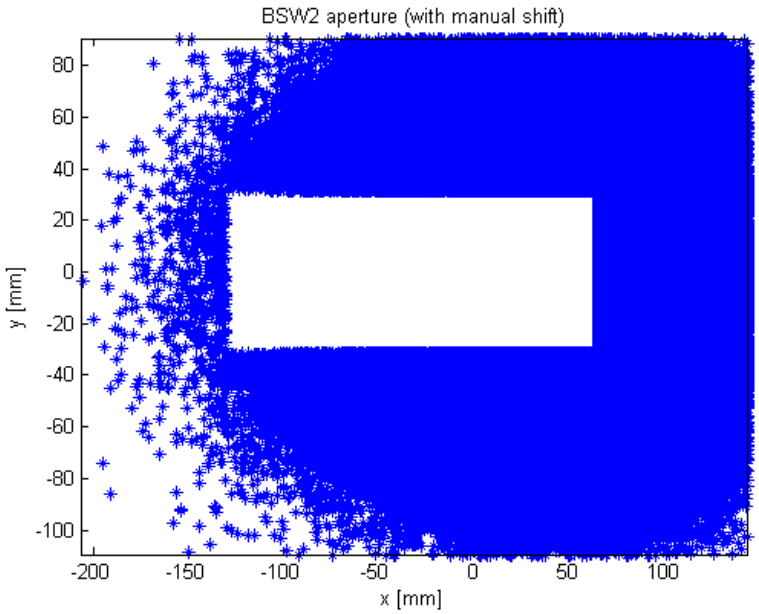




- Sextupolar component from eddy currents
- Took k2L=0.084
  - assumed constant for 5ms
  - the same for the 4 BSW
- Quadrupolar component at BSW1 (similar for both chambers) not considered

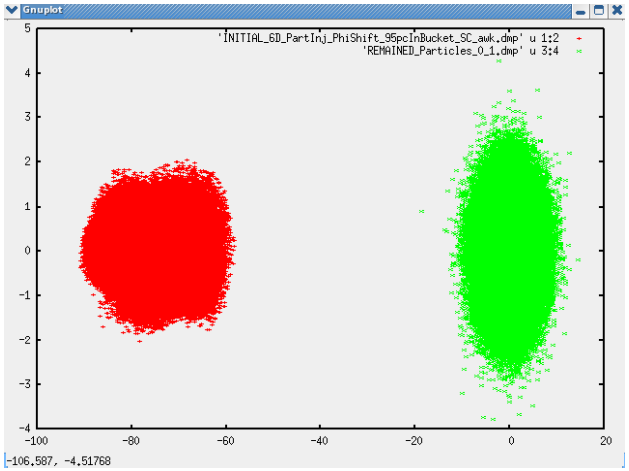
Implementation MADX-PTC/PTC-Orbit:

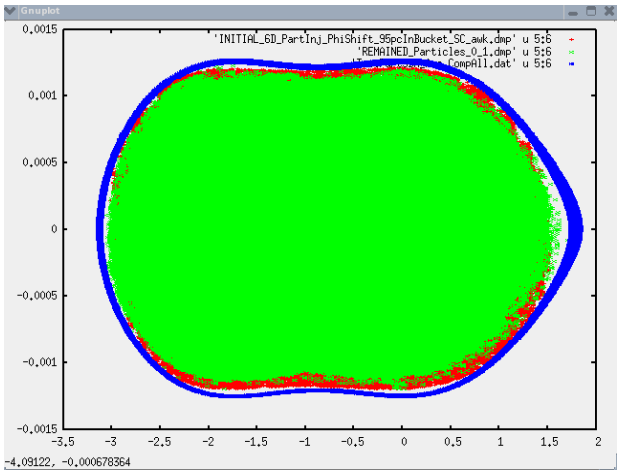
- Understand edge effects in PTC
- Time-varying fields w. Multipolar components (thanks A. Molodozhentsev)
- Misalignments
- BSW apertures (they are shifted!)



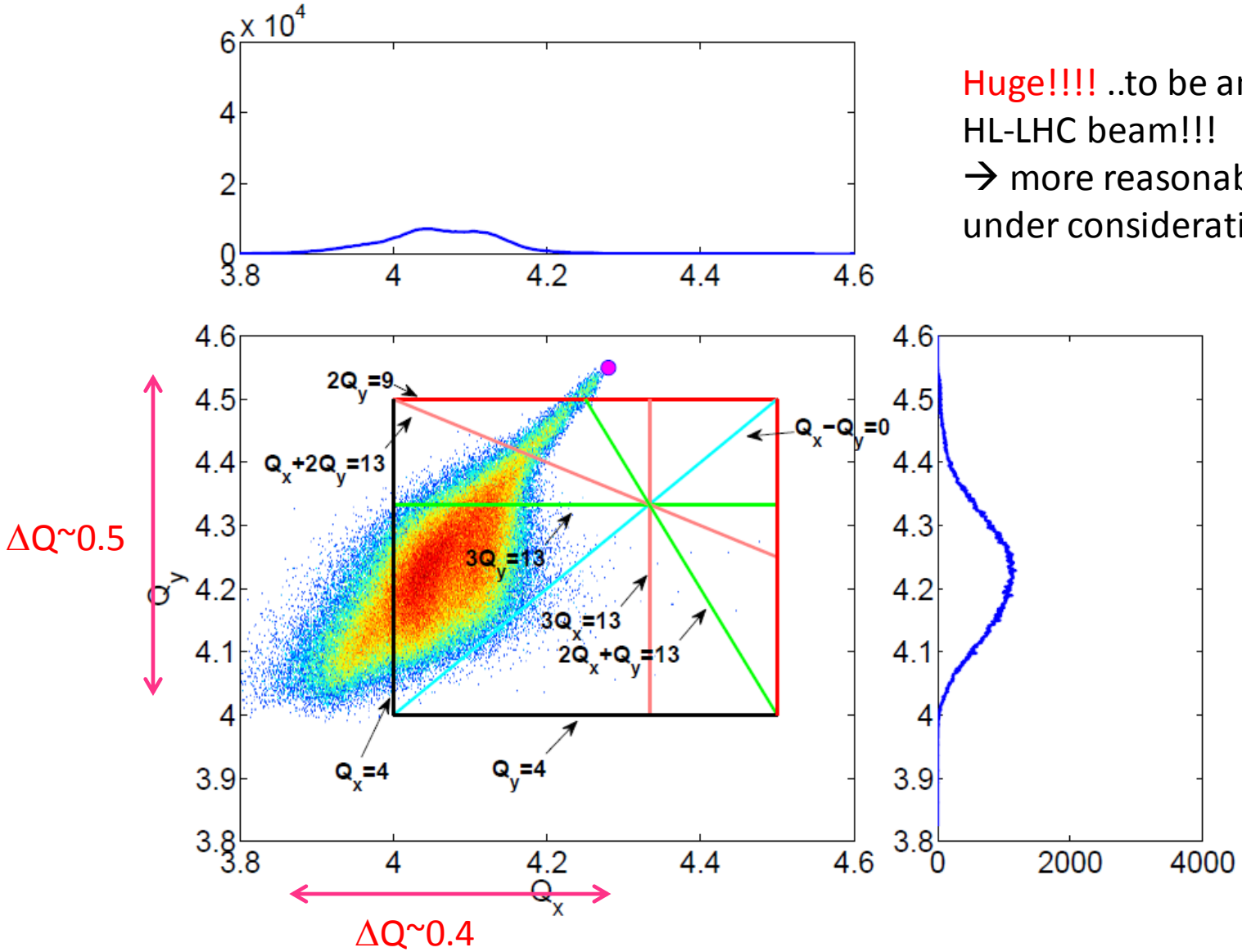
The beam

- Nb=35e11 (~twice)
- Ex,Ey=2, 2.3 um (...normalized are E*=1.20, 1.38um!!!)
- Bf=0.56, V1=8kV, V2=6kV, Brhodot=10 Tm/s
- Painting horiz and longitud (20 turns)
- Cut @ 95% bucket acceptance after 20t-injection to remove uncapured particles (~0.4%) & avoid artifacts





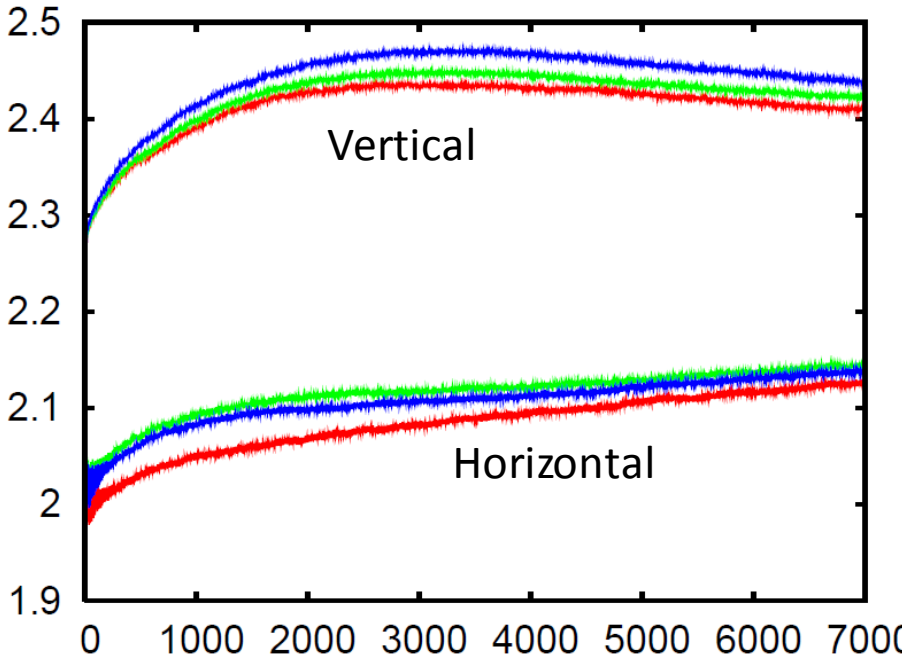
The beam: tune footprint



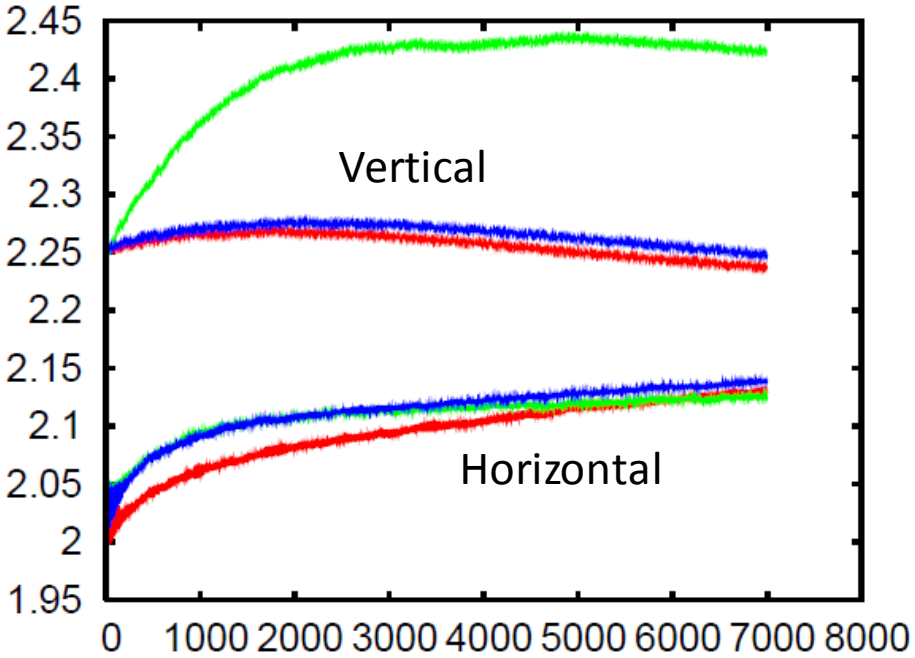
Huge!!!! ..to be an LIU or HL-LHC beam!!!
→ more reasonable param under consideration

RMS emittance evolution vs.Turn

Qv=4.45 (Qh=4.28)



Qv=4.55 (Qh=4.28)



RED: ceramic chamber

GREEN: inconel, only dipole edge compensation

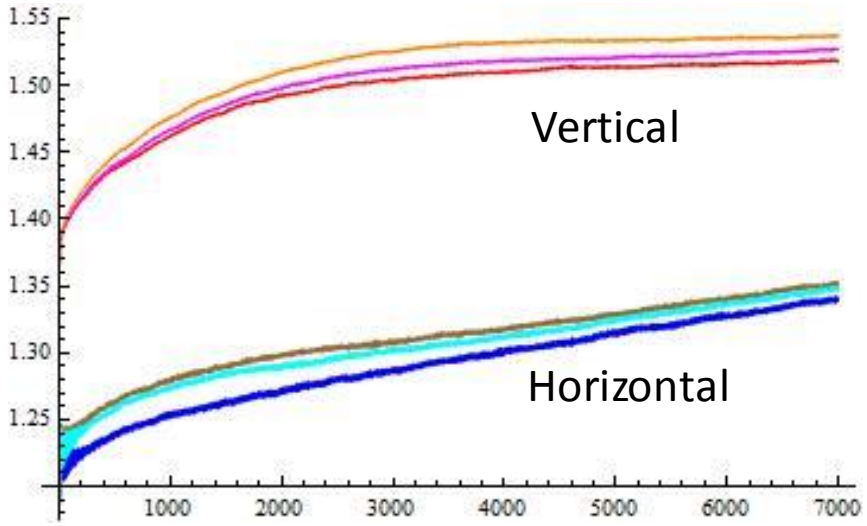
BLUE: inconel, new compensation settings

Large growth in horizontal…due to (too) large ΔQ & integer x-ing

- Does it "hide" effect of multipoles?
  → Check ongoing
- For ISOLDE, Qh needs optimization

RMS normalized emittances

Qv=4.45 (Qh=4.28)



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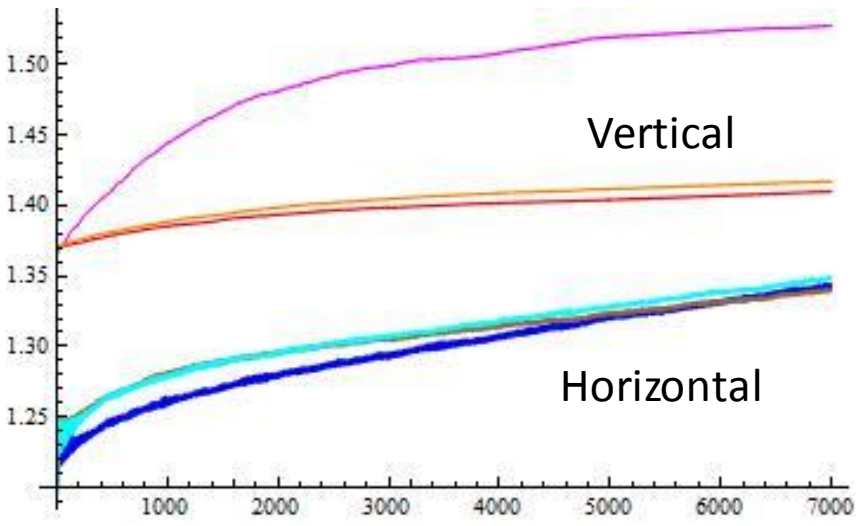
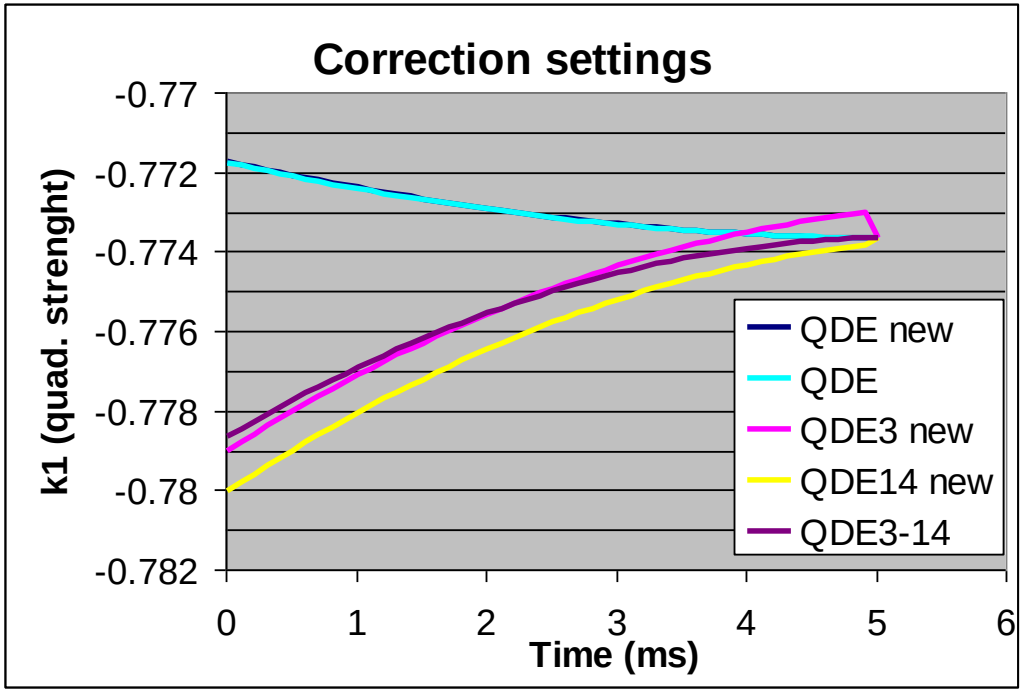
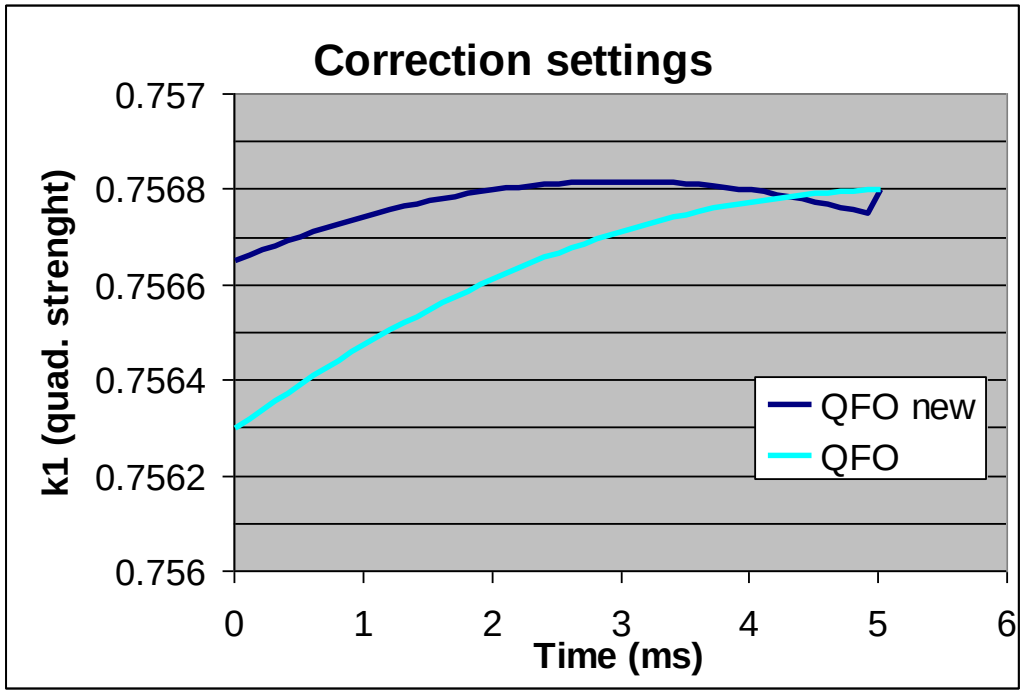


Compensation settings

- Extra trims on QDE3, QDE14
- Selected for active compensation of Vertical BetaBeating from edge effects (quad. error)
  - Cfr many presentation by C.Carli et al. 2009-2011
- Used also for perturbation (feed-down from sextupolar errors) in Inconel vac. Chamber
- What is left uncorrected:
  - Almost no correction for the horizontal plane (what if Qx moves close to 0.5?)
  - Feed-down from sextupoles induces also small dipole error → COD of <1mm (not corrected, but could it be adjusted with delays?)

New settings QDE3,14 and QFO, QDE (w. Q-strips)





Not taken into account

- Transient for the multipoles rise/fall (discontinuities in Bdot) → foresee smooth transition?
- Delay (i.e. individual powering would compensate for it), i.e. bump is closed
- Quad. component at BS1 (septum), similar for both chambers → could it be reduced with poles shaping?
- Case if not perfect compensation ~10% off (→ what could be achieved?)
- Operation/future beams:
  - High intensity (ISOLDE) beams → losses!!!
  - A more realistic LIU beam (w. no painting?) with $\Delta Q=-(0.2,0.3)$

Passive compensation

idea by C. Carli

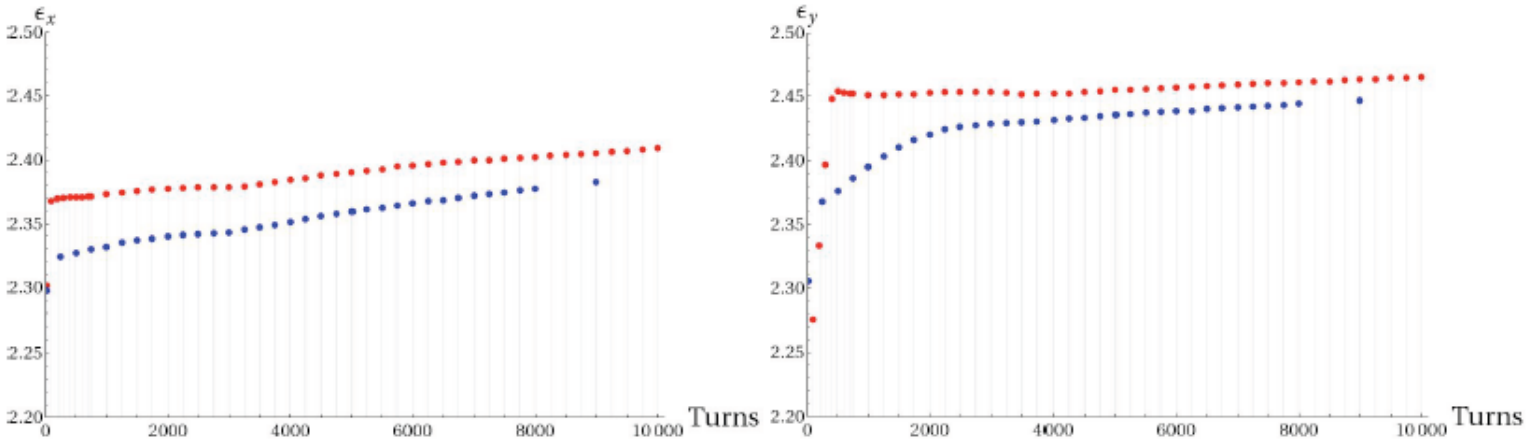
- Eddy currents (and induced multipoles) proportional to Bdot.
- *"One could minimize multipolar effects by implementing a compensation with the help of the shape of the magnet poles:*
  - *Assume that he chicane decrease is not linear, but following an exponential with a time constant 5ms [..]*
  - *Take the field perturbation due to eddy currents say at the beginning (full bump) and shape the pole-face to compensate.*
- *During the (exponential) decrease of the chicane, both the field perturbation due to induced currents and the compensation decrease exponentially. Thus, compensation remains!"* (C.Carli email, 26/3/13)
- All implication should be evaluated (e.g. pole shape depends on time constant, change angle incoming/circulating beam) but avoids transients and it is passive.

Summary

- Eddy current induced multipoles have an effect and need proper compensation, but do not seems to be a show-stopper
- TODO or ongoing:
  - Effects of a not perfect compensation should be evaluated (Question: what are the limits of power supplies? What about transients?)
  - Simulations for an ISOLDE beam (losses!!!) and for an LHC beam generated with no painting and lower intensity.

Back-up slides

Emittances with aperture limit



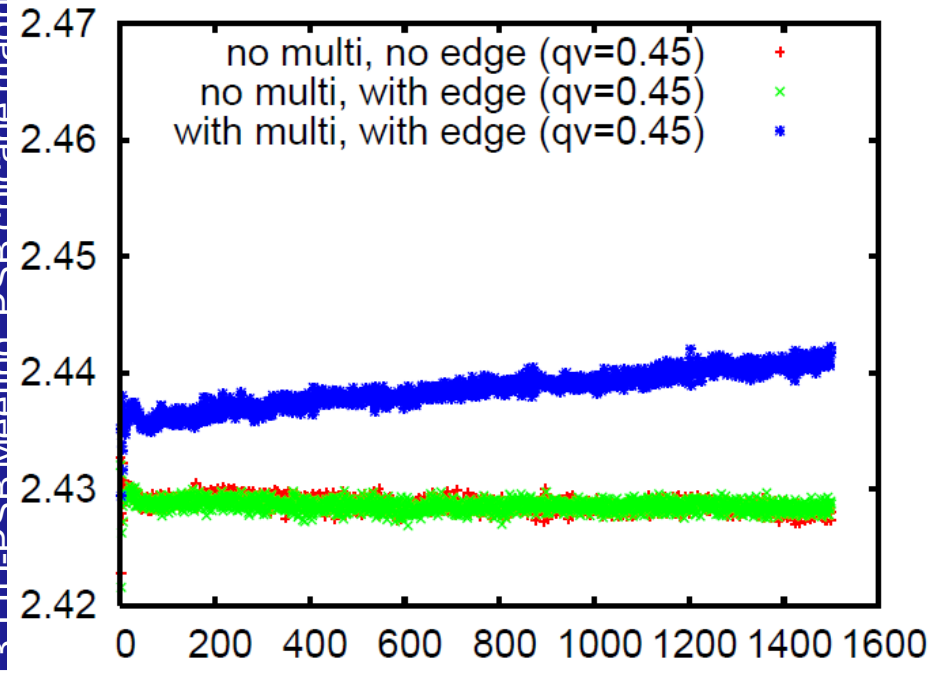
(5×10^5 macro-particles)

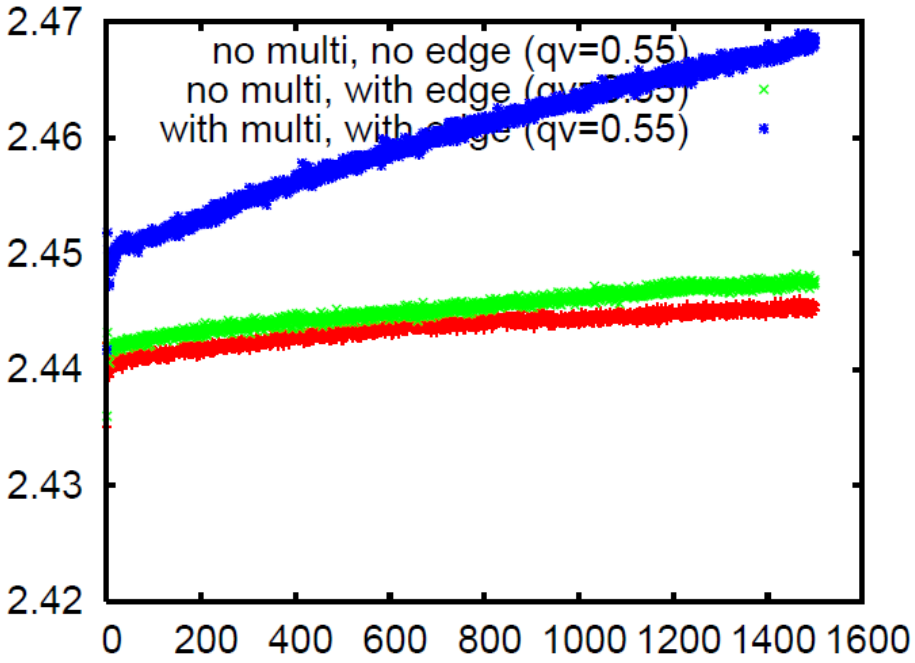
1. **Left: normalized horizontal emittance evolution over 10000 turns (passive/active compensation schemes)**
2. **Right: normalized vertical emittance evolution over 10000**

“Static” simulations

- Ramp @ 2ms (out of 5ms)
- Assumed:
  - trajectory bump
  - edge effects
  - multipoles
- Correction for the vertical BetaBeating with QDE3, QDE14

Horiz emittance vs. time





Vertical emittance vs time