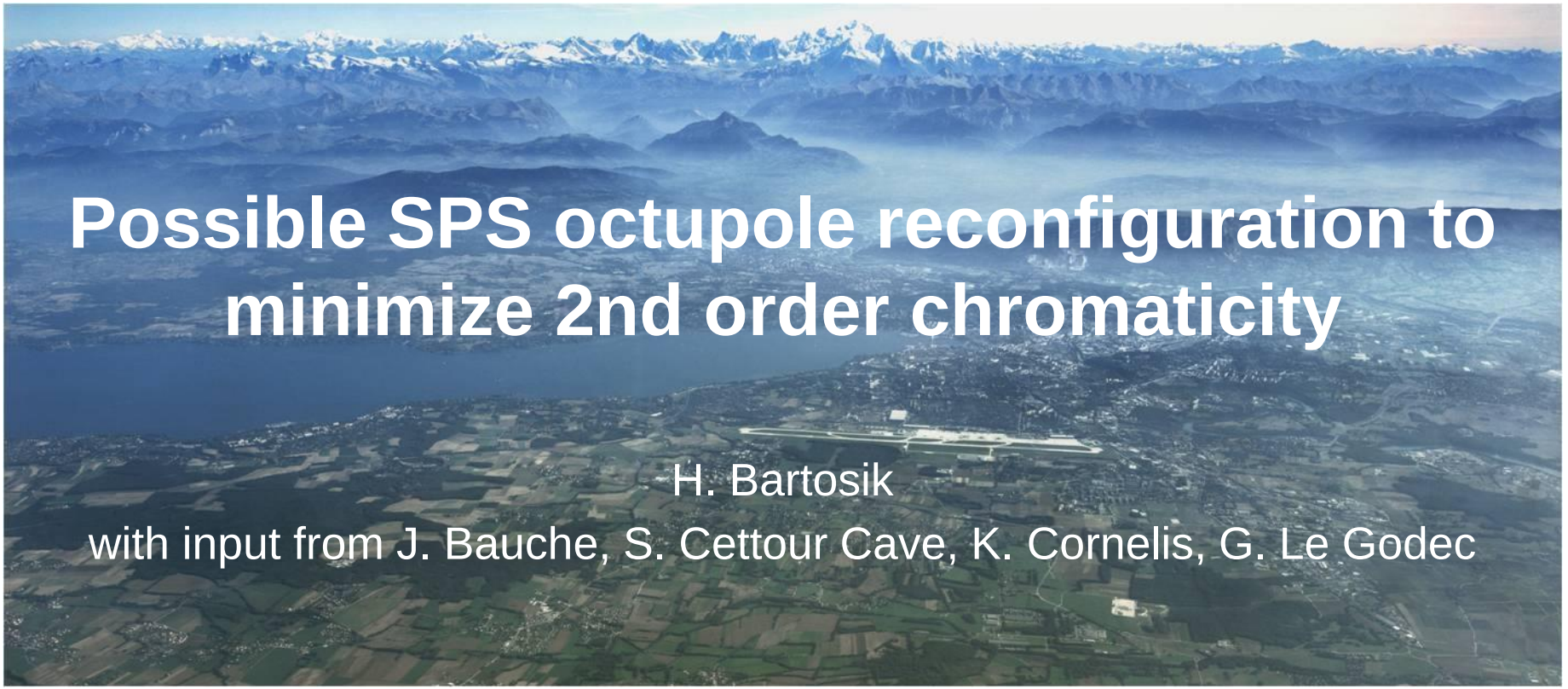

LHC Injectors Upgrade

Possible SPS octupole reconfiguration to minimize 2nd order chromaticity

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with input from J. Bauche, S. Cettour Cave, K. Cornelis, G. Le Godec

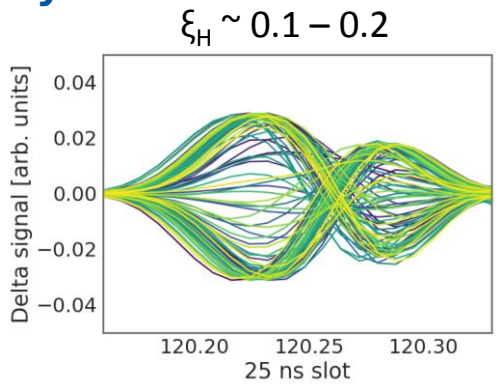
MSWG, 1 June 2018

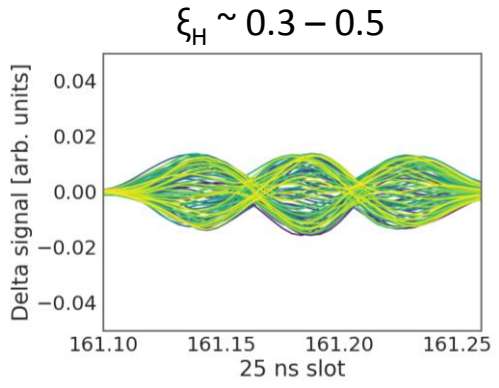
CERN

Introduction

- **Transverse instabilities encountered in high intensity multi-bunch regime (Q20)**
  - The 20 MHz coupled bunch instability from 2015 was not observed in 2017 (now higher gain at 20 MHz in the transverse damper, but also only 4 x 48 bunches …)
  - With transverse damper, 4 x 48 bunches exhibit single bunch instabilities in the later batches

- **Single bunch instabilities can be cured with chromaticity**
  - ξ_H ~ 0.1 – 0.2 → mode 1
  - ξ_H ~ 0.3 – 0.5 → mode 2
  - ξ_H > 0.5 → instability mostly suppressed but enhanced losses (maybe due to large chromatic detuning of uncaptured beam?)

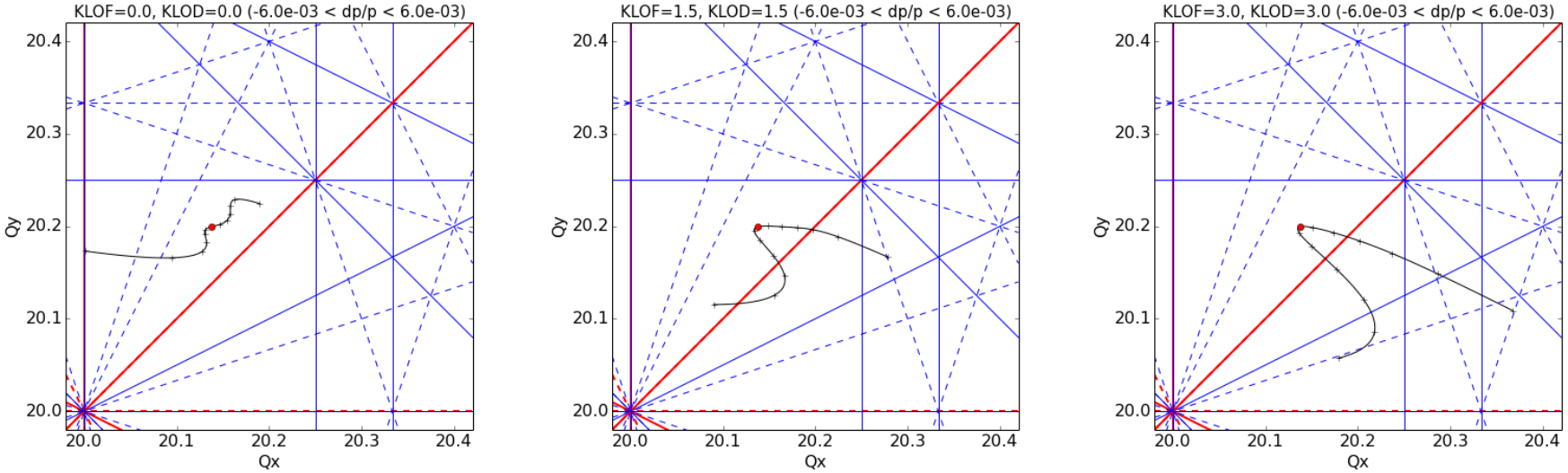




Motivation

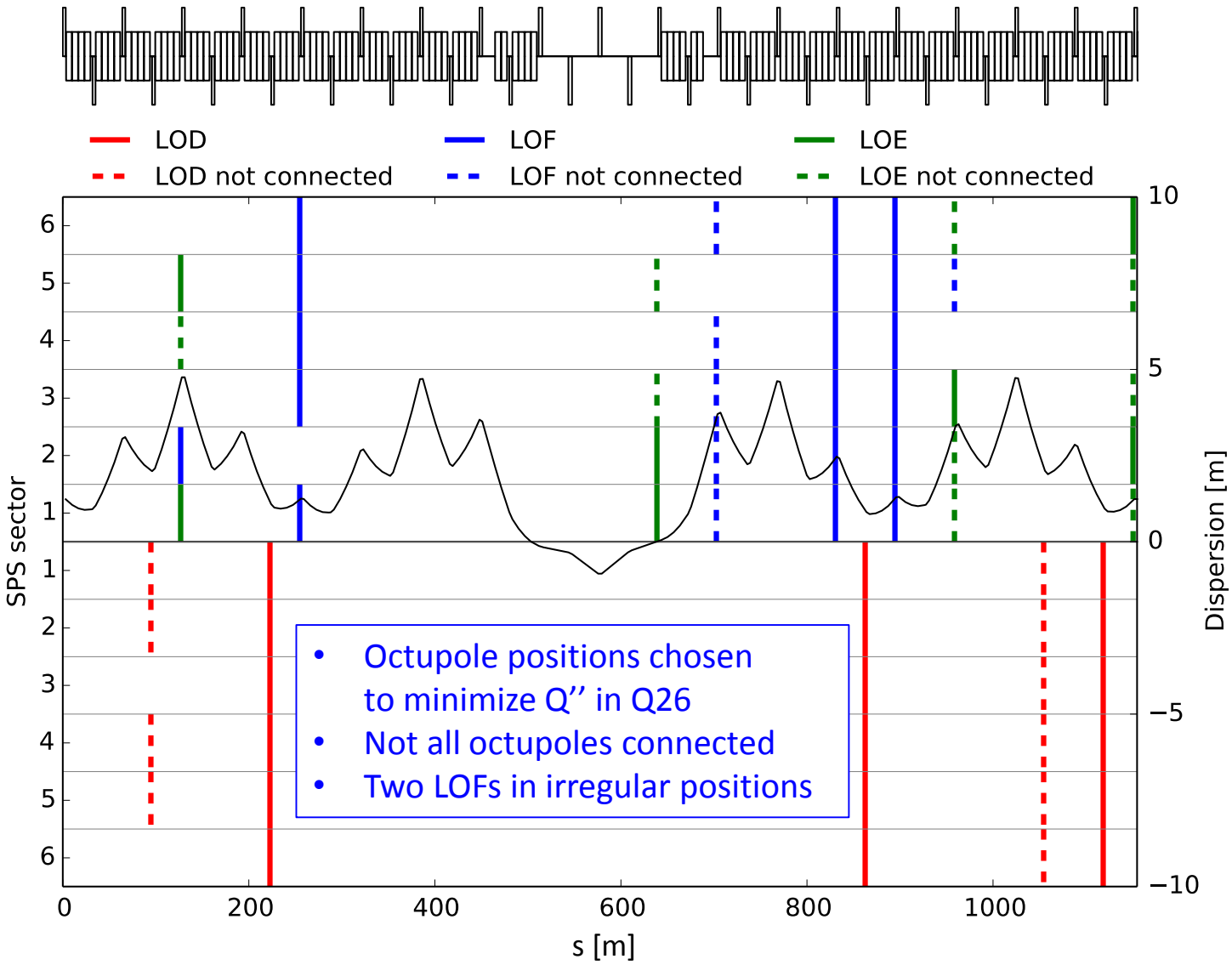
- **Stabilization of single bunch horizontal instability with octupoles?**
  - KLOF > 1.5 mostly suppressed these instabilities but incoherent losses similar as with high ξ_H
  - Incoherent losses most likely due to 2nd order chromaticity Q'' induced by large dispersion in Q20:

Q'' depends on $D^2\beta$ (i.e. dispersion squared times octupole strength)

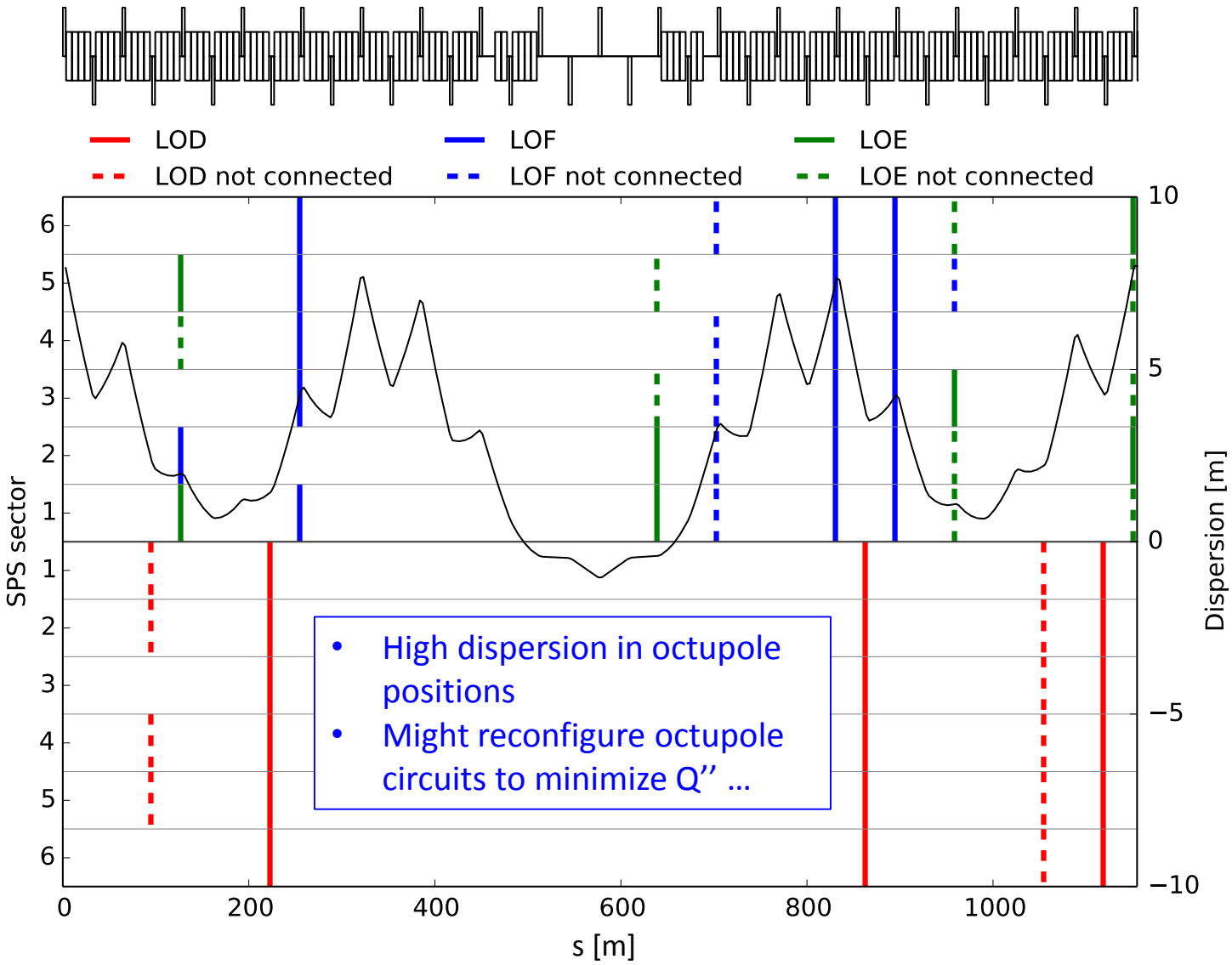


- **Tune spread from octupoles can be an efficient way of suppressing (unexpected) instabilities at LIU intensities (if Q'' can be avoided)**
  - Successfully used in SPS for stabilization of fixed target beam, critical for LHC operation, …
  - Could hope for better transmission compared to stabilization by linear chromaticity

SPS octupoles and dispersion (Q26 optics)



SPS octupoles and dispersion (Q20 optics)



Proposed octupole circuit reconfiguration

- **Aim is to minimize Q'' induced by octupoles in Q20 without compromising Q26**
  - Exploit the already installed octupoles and change powering scheme
  - Optimize powering to minimize Q'' on all optics

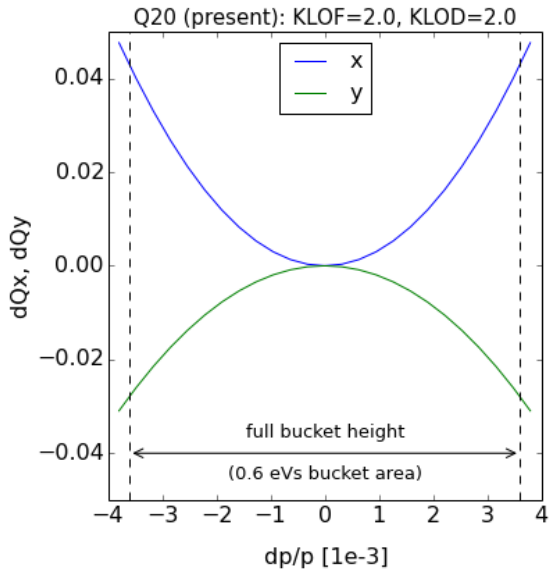
- **Proposal**

LOF position	x08 (04)	x22 (30)	x26	x28
present polarity	+1	0	+1	+1
proposed polarity	+1	+1	-1	+1

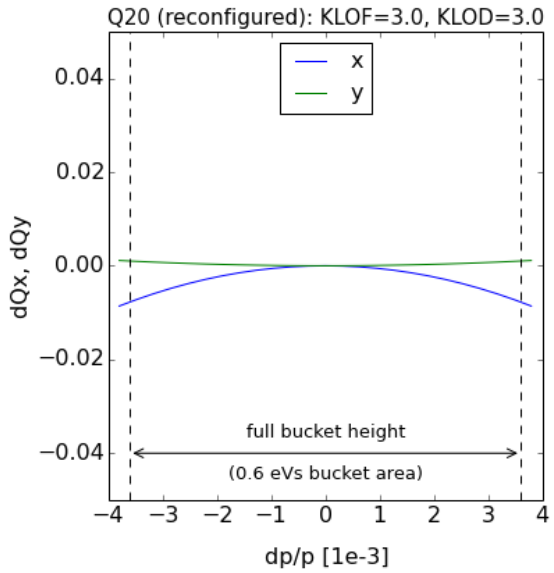
LOD position	x03	x07	x27	x33	x35
present polarity	0	+1	+1	0	+1
proposed polarity	0	+1	+1	+1	-1

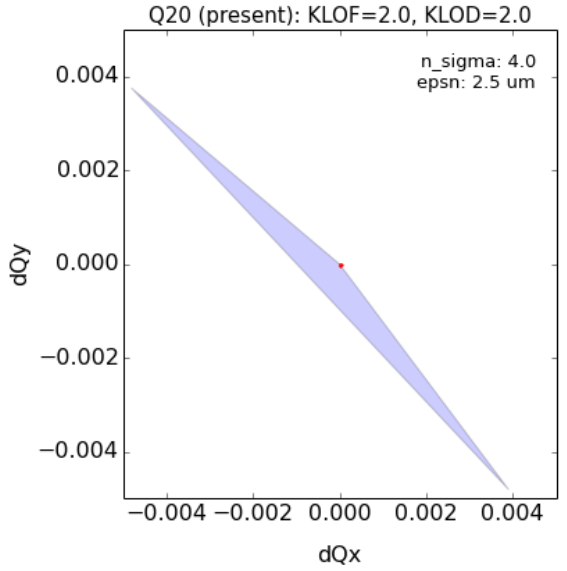
  - Octupoles at positions with largest dispersion inverted to ~ cancel Q''
  - **No major hardware change! (just some interventions on patch panels ...)**
  - **Need 1.5 times higher K for same amplitude detuning** (effectively 2 octupoles / arc generate amplitude detuning in new scheme compared to 3 / arc in original scheme)
  - Enough margin for operational use on FT beam
  - In addition envisage re-establishing symmetry of octupole layout / lattice periodicity (i.e. moving LOF204 to position 208 and LOF530 to 522, see later)

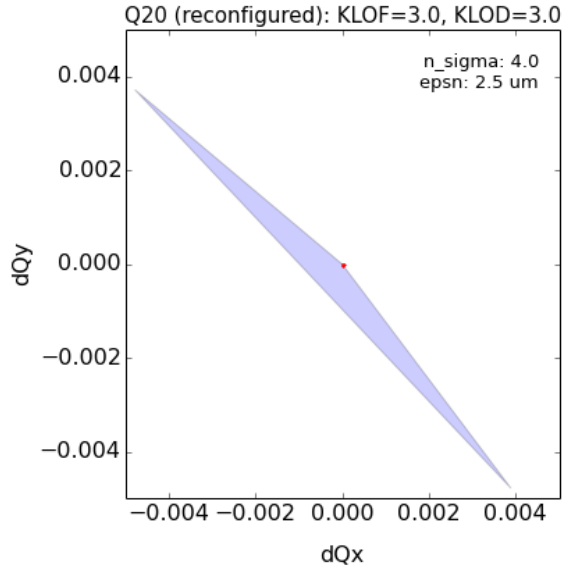
Present vs. proposed octupole scheme (Q20)



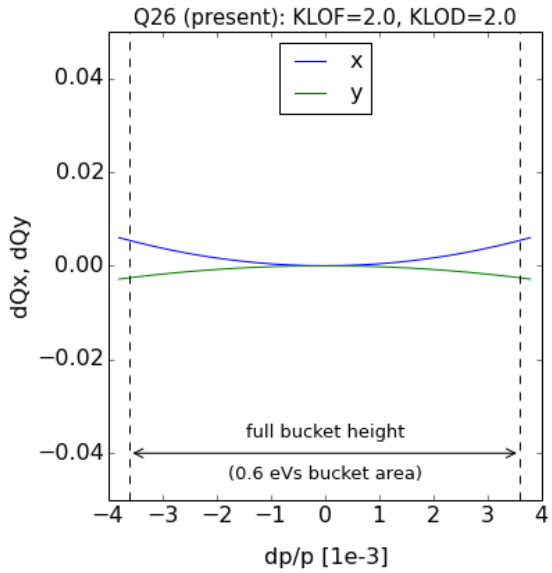
reconfiguration



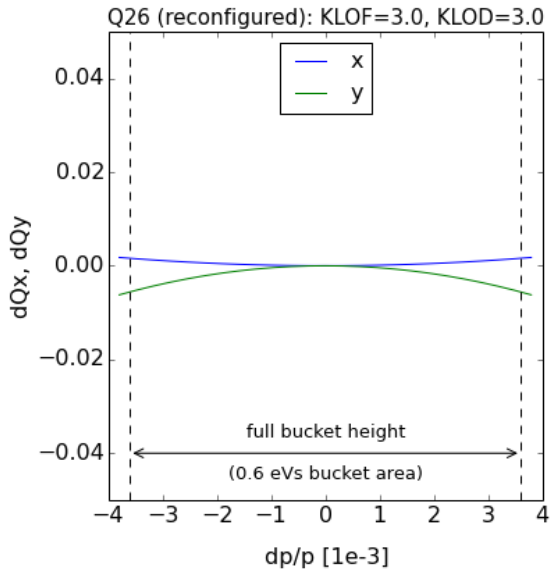


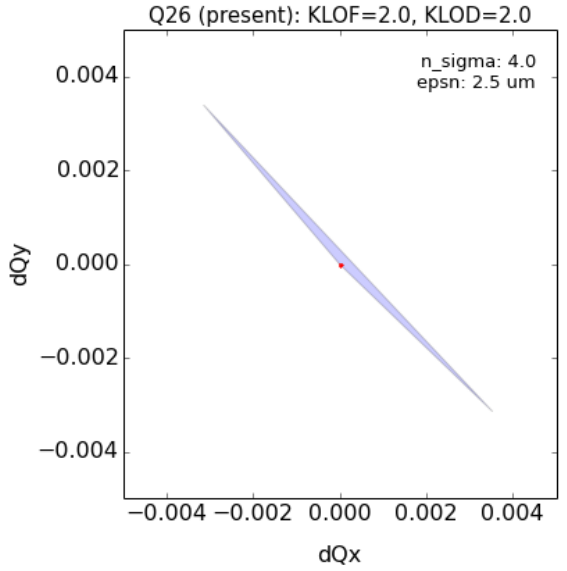


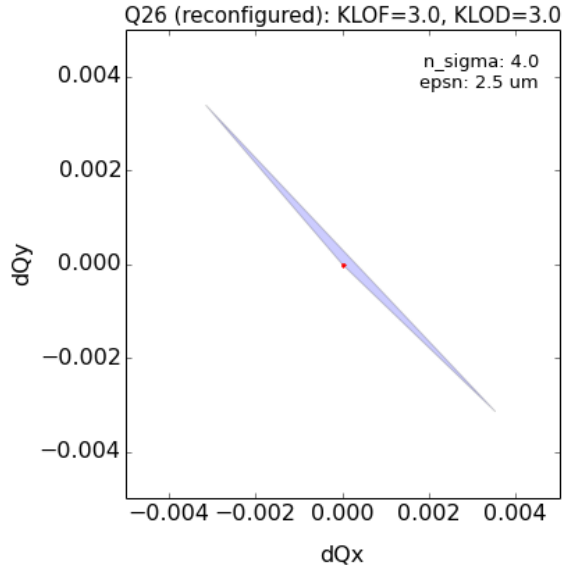
Present vs. proposed octupole scheme (Q26)



reconfiguration

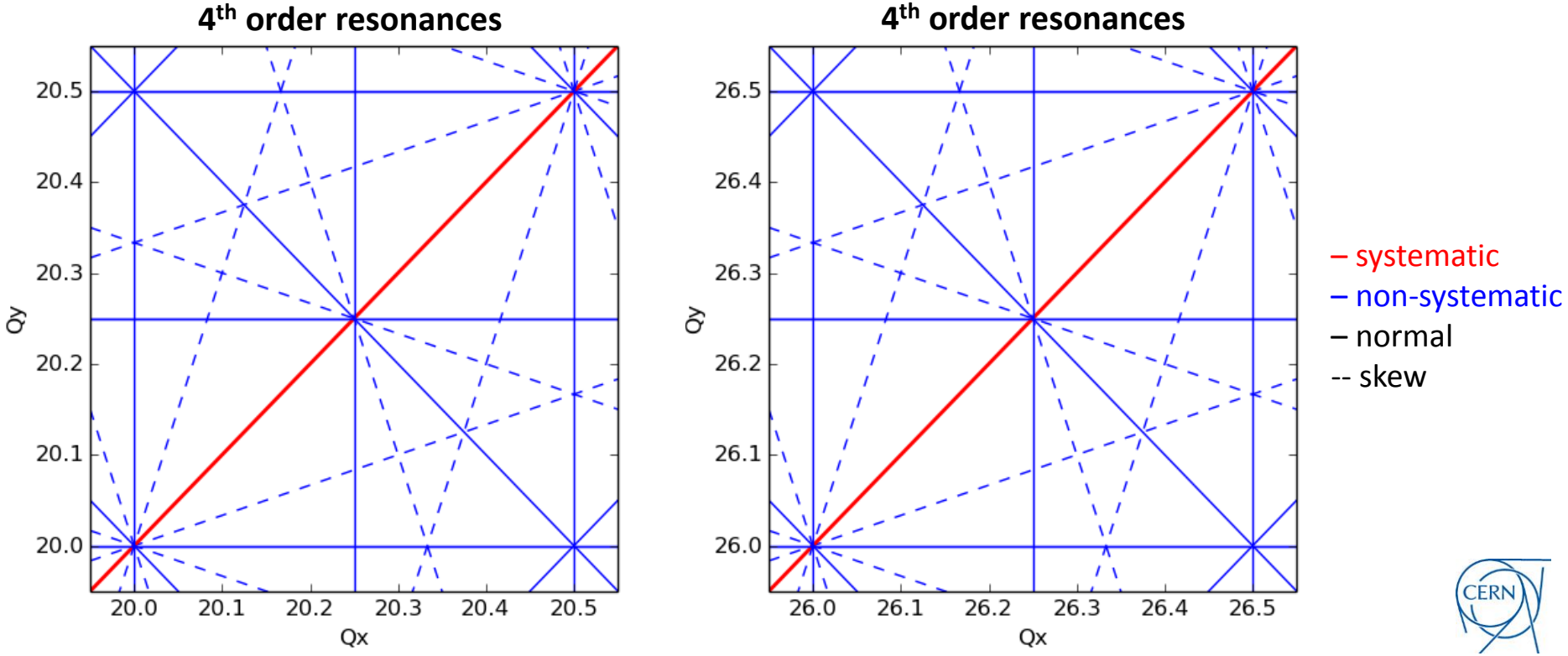






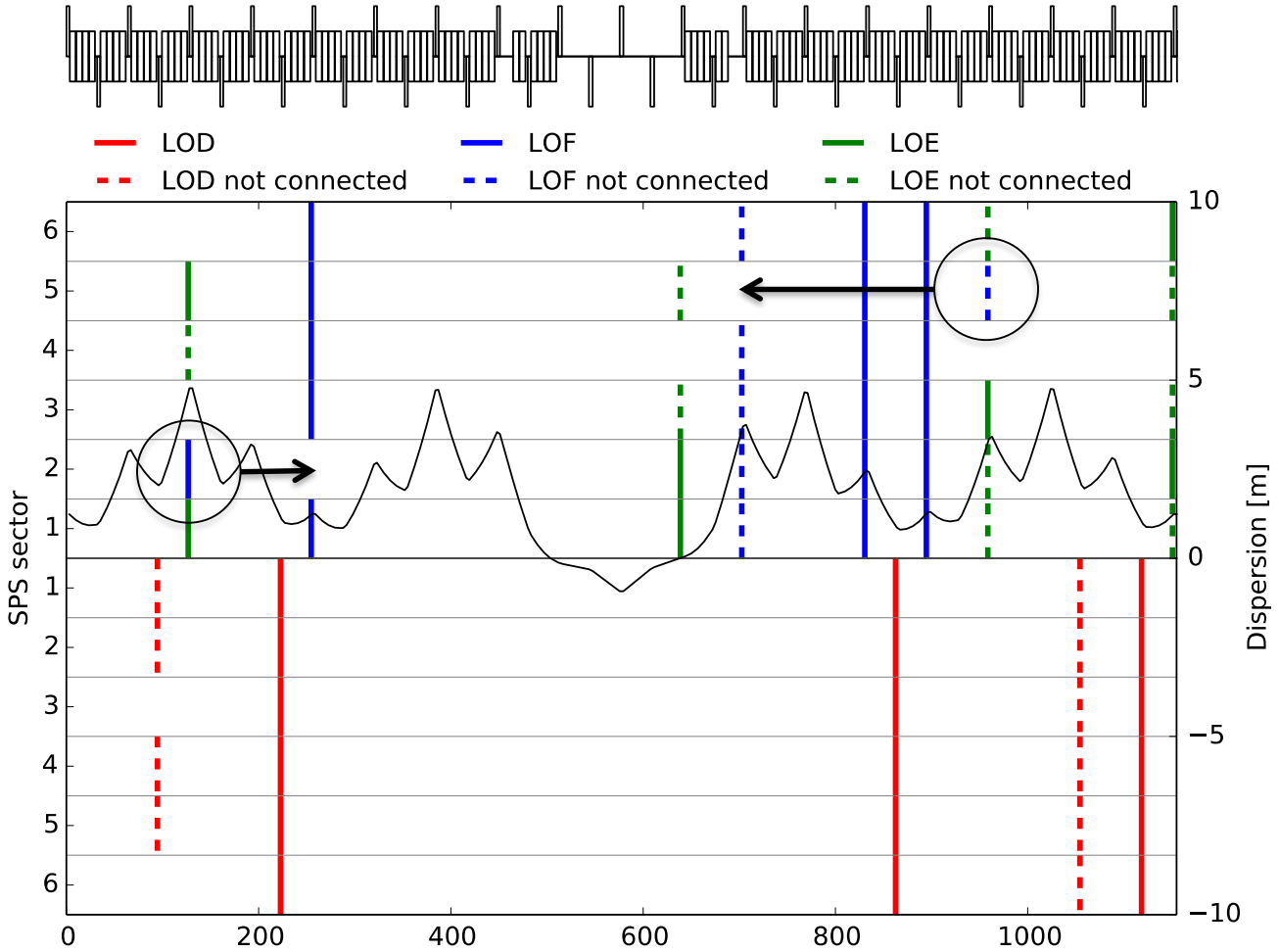
Impact on resonances?

- **Most of the 4th order resonances suppressed by super periodicity**
  - Assuming 6 fold symmetry of octupole arrangement which is presently not the case due to LOF204 and LOF530, but might be fixed (e.g. during LS2, see next slide)
  - Only the diagonal (2Qx-Qy=0) is systematic
  - Expect no big impact on resonances as beta-beating in SPS relatively small (to be checked in more detail, in particular in dedicated MD where octupole reconfiguration could be tested)



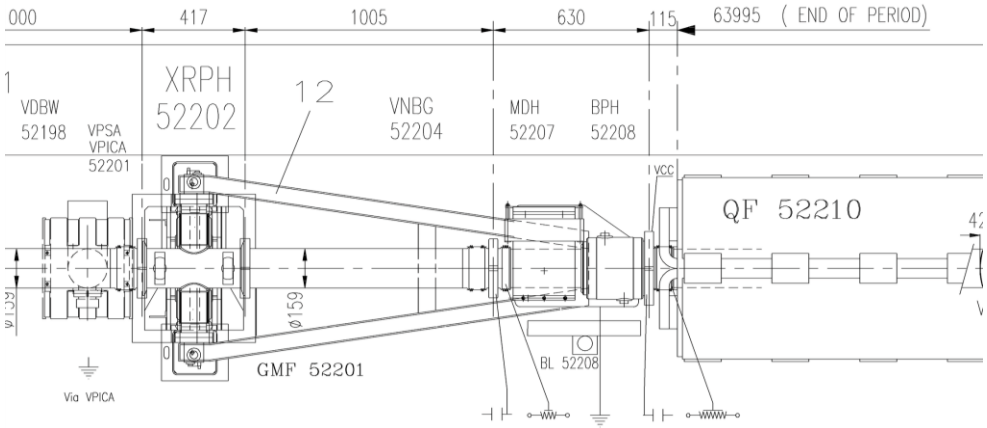
Proposal for octupole relocation in LS2

- To restore (6-fold) lattice symmetry would need to move 2 octupoles

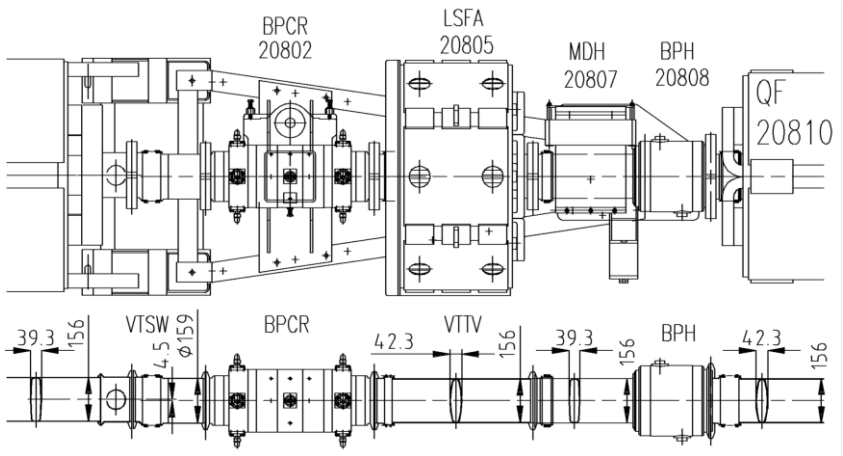


Proposal for octupole relocation in LS2

- **To restore (6-fold) lattice symmetry would need to move 2 octupoles**
  - LOF53001 to position 52201



  - LOF20401 to position 20801 (BPCR20802 would need to placed elsewhere, presently under BI)



Summary & Conclusions

- **Amplitude detuning from octupoles is a powerful knob for controlling instabilities**
  - Should be prepared in case of unexpected instabilities with LIU intensities
- **SPS Landau octupoles induce large Q'' in Q20 optics due to high dispersion**
  - The chromatic tune shift is at least one order of magnitude higher than amplitude detuning (for present 25 ns standard beam parameters)
  - Incoherent losses limit the accessible parameter range to KLOF/D ~ ±2
- **Proposal for octupole curcuit reconfiguration**
  - Using only already installed octupoles (some of them presently not connected)
  - The proposed scheme implies inverting polarity on strategic octupoles, which allows cancelling most of induced Q'' for all SPS optics, i.e. Q20, Q26 and even Q22 (not shown here)
  - For same amplitude detuning 1.5 times higher K in new scheme compared to present scheme
  - Expect no big impact on resonances
  - Can be tested in a dedicated MD by intervention on the respective octupole patch panels in the tunnel → proposed for ITS2
  - Load should be OK for power converter (being verified by Gilles Le Godec)
- **Additional proposal to relocate 2 octupoles to restore lattice symmetry**
  - Feasibility for LS2 under investigation