BEAM CROSSING IN TECHNICAL INSERTIONS

Crossings in Technical Insertions

FCC-ee has four IP’s with both beams arriving from the inside and exiting on outside: Points A, D, G, and J.

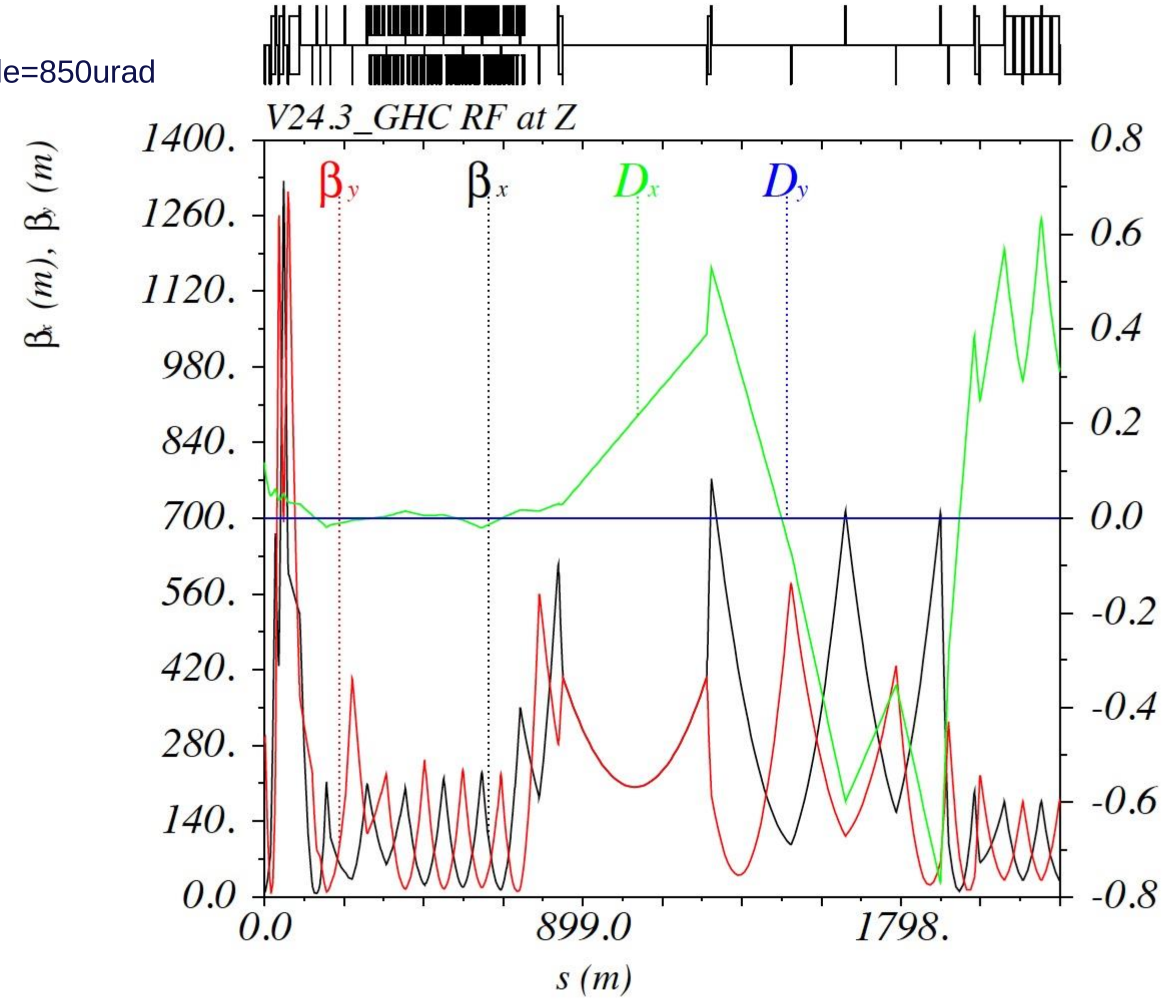
Hence the need to cross the beams, “outside to inside” between IP’s, in all technical insertions, at Point B (injection and dumps), Point F (Collimation), Point H (Collider RF) and Point L (Booster RF, no identified function for collider)

Small horizontal crossing angles (1.6 mrad full angle) to limit radiated power in insertions
Limited tunnel real estate and cannot increase angle over a long distance as in IP’s

Common crossing scheme is required at all energies in PB, PF and PL
Different crossing at ZH and t-tbar (electro-magnetic combined elements) in Point H (Collider RF)

High number of bunches at Z and W implies the possibility of long-range beam-beam encounters in the crossing region in technical insertions

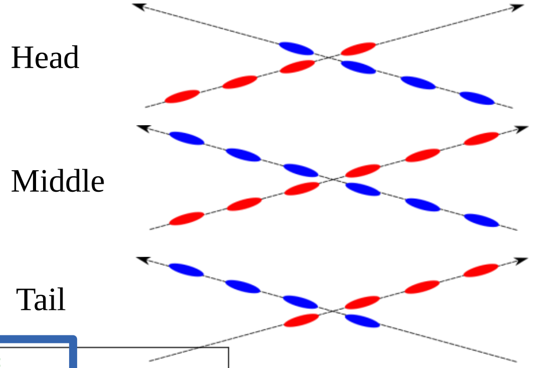
BRX1: l=10m, angle=850urad

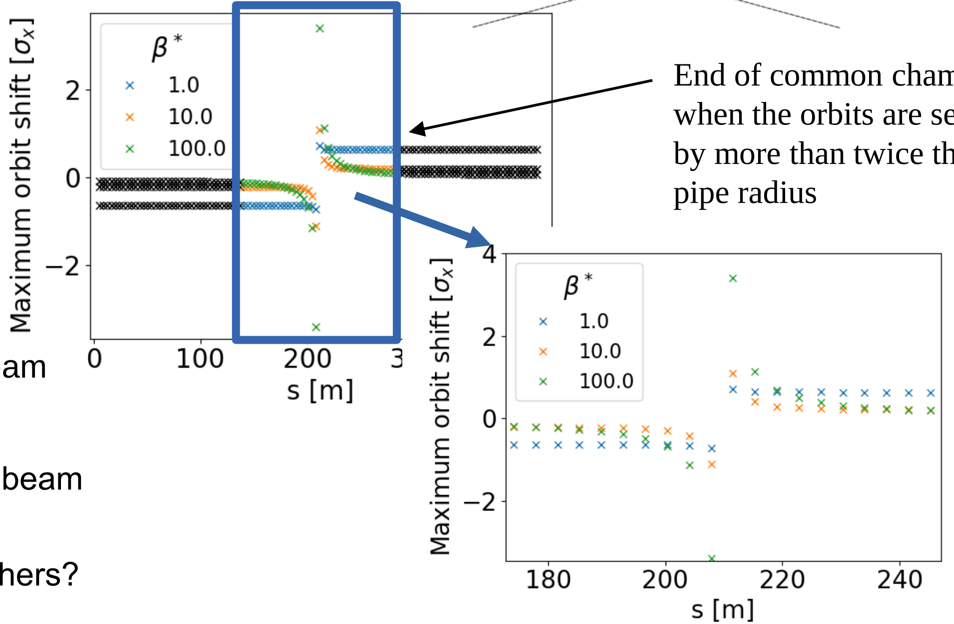


Orbit effect due to long-range beam-beam interaction

X.Buffat

- A common chamber longer than the bunch spacing leads to multiple bunch crossings
  → Parasitic long-range beam-beam interactions.
  To first order, these interactions lead to a change of the beam orbits
- Due to the bunch train structure featuring gaps, some bunches are missing parasitic encounters
  → bunch-by-bunch orbit spread (PACMAN effect)
- Assumption:
  - Full crossing angle: 1.6mrad
  - Drift space with minimum β at the center of the common chamber (smallest beta function at closest encounters minimizes the effect)





- The horizontal orbit spread is in the order of the beam size, which is significant, **mitigation is required**.

→ Vertical separation bump allowing for separate beam pipes and no long-range encounters

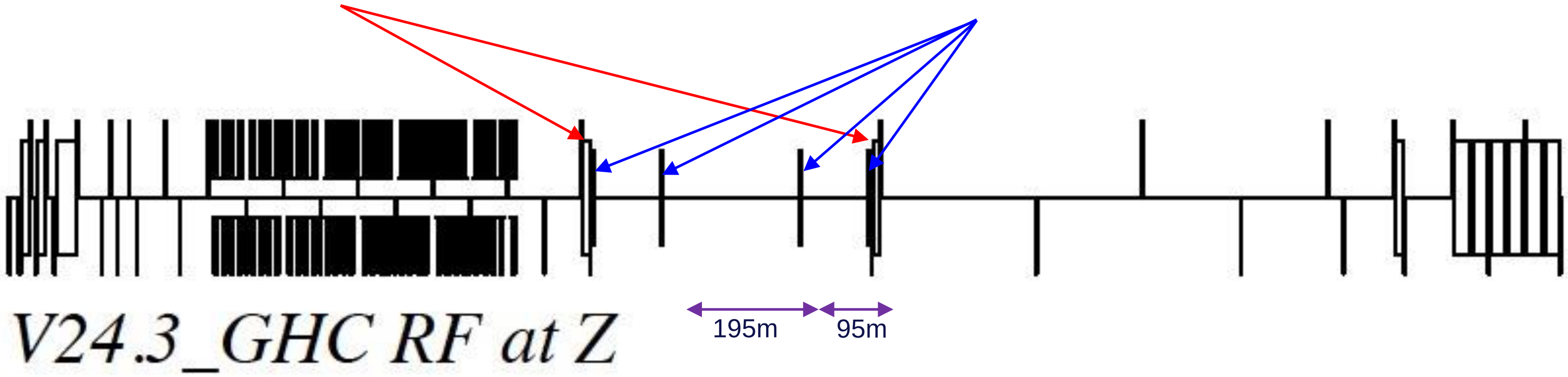
→ Larger crossing angle, active compensation, others?

Vertical crossing in separate beam pipes

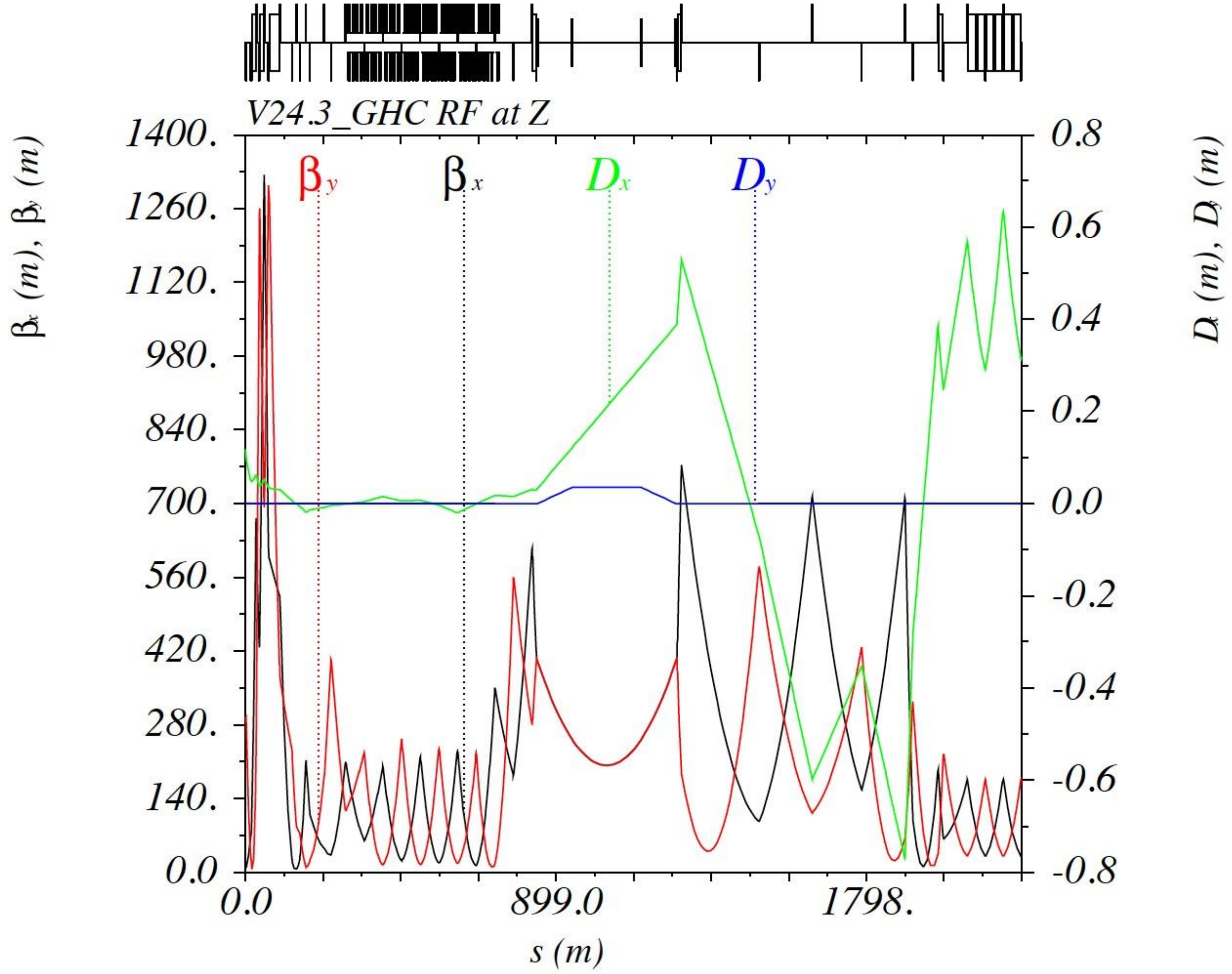
Vertical dipoles

closed vertical bump; no interleaved elements; single power supply;
field equivalent to that of horizontal switch dipoles

BRX1: L=10m, angle=835 urad   MBD: L=5m, angle=350 urad



Provides 70 mm vertical beam separation, over two times the beam pipe radius


V24.3_GHC RF at Z
βy
βx
Dx
Dy
βx (m), βy (m)
Dx (m), Dy (m)
1400.
1260.
1120.
980.
840.
700.
560.
420.
280.
140.
0.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
0.0
899.0
1798.
s (m)

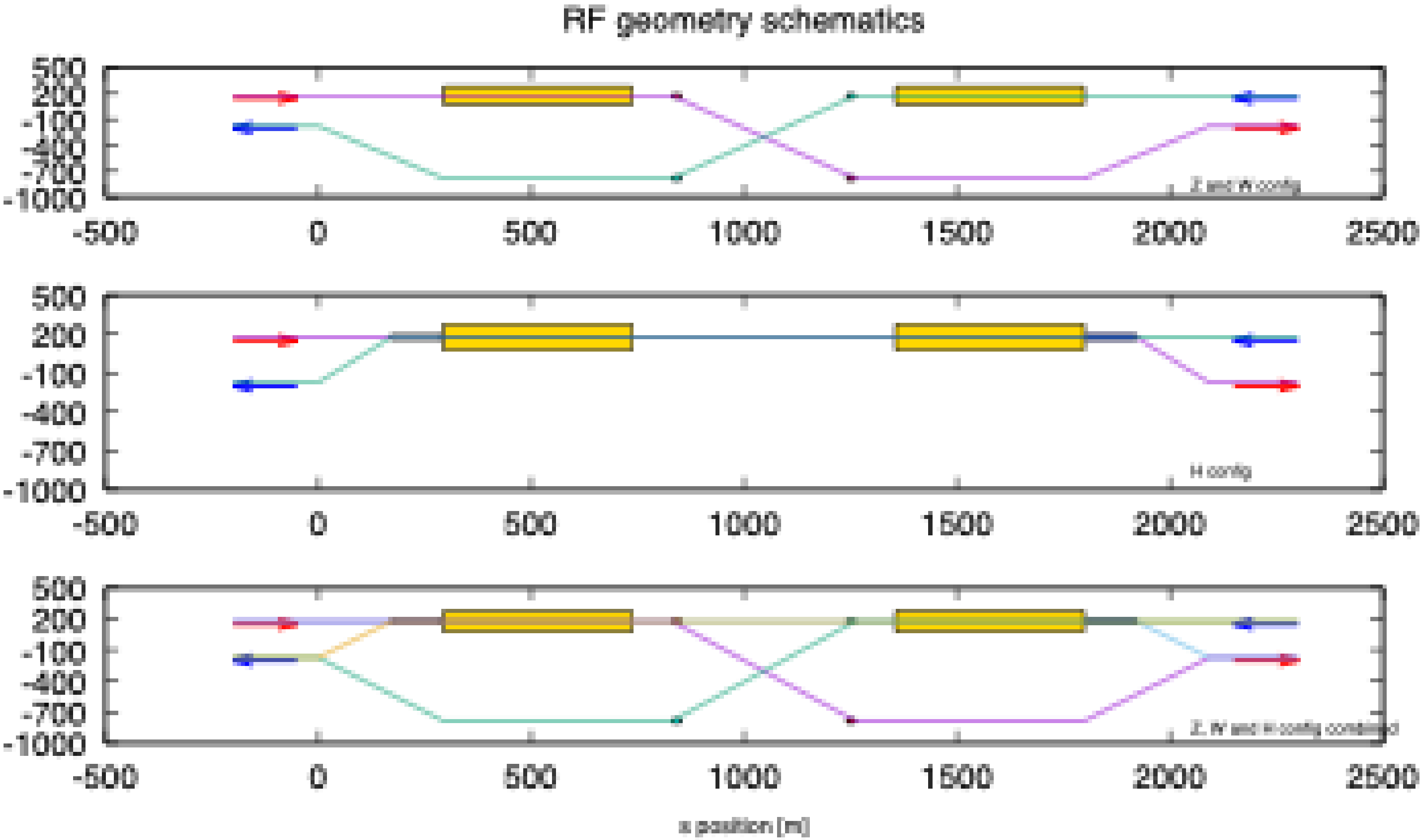
Conclusions

A closed vertical bump is possible in the different technical insertions at all energies.

This allows beam crossings in different vacuum chambers,
and suppresses entirely the long-range beam-beam interactions.

Layout to be optimised for mechanical integration, powering scheme and limitation of Synchrotron Radiation generation in technical insertions, close to sensitive equipment.

Effect of vertical bumps on polarisation?


RF geometry schematics
500
200
-100
-400
-700
-1000
-500
0
500
1000
1500
2000
2500

Added after the meeting:

Effect of 4 vertical chicanes on emittance

Evaluated with MAD-X Emit command on V24.3_GHC at Z mode :

Energy loss per turn goes from 38.959280 MeV to 38.983146 MeV; increase of 23.87 keV

Vertical emittance goes from 0.11326377E-28 pi.um to 0.42761890E-08 pi.um or 4.3 e-15 **π**.m

Note that the ZH and t-tbar lattices have the same RF optics, with electro-magnetic separators, in all technical insertions. Emittance increase evaluation requires first a rematching of the PB, PF and PL insertions.

Thank you for your attention.