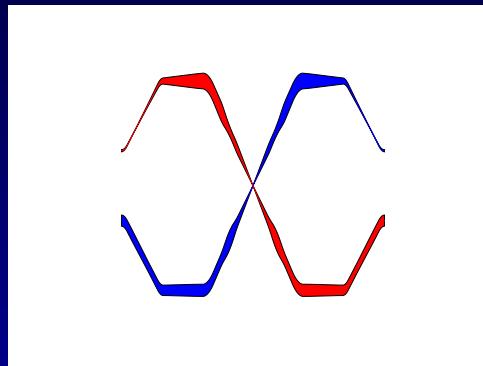


# Optics for Crab Cavities in the LHC



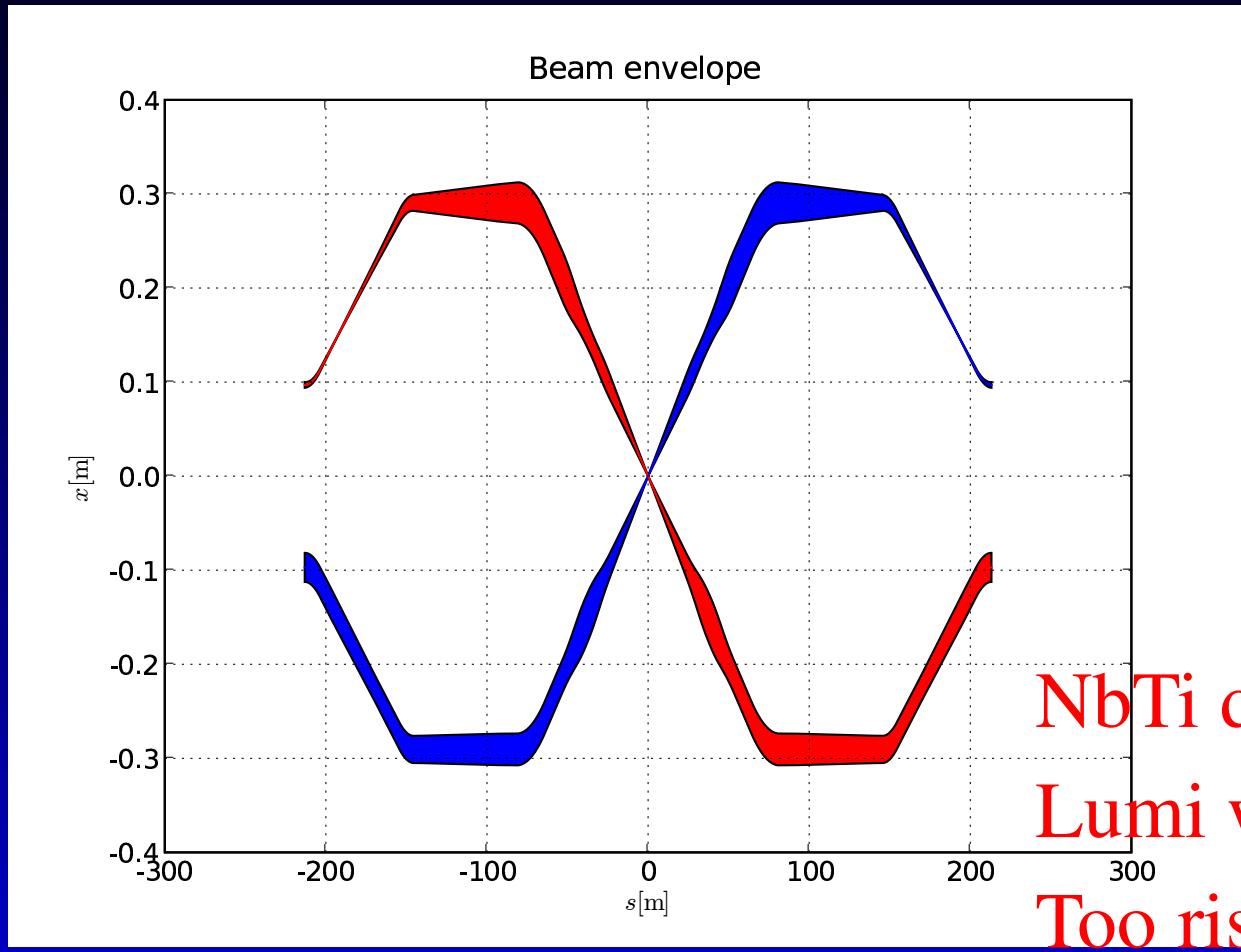
R. Tomás, Y. Sun, R. Calaga, S. Fartoukh, R. de Maria  
and F. Zimmermann

HHH-CC-08

# Contents

- Optics for local crab cavities
  - Old approach with  $\theta=8\text{mrad}$
  - New approach: separation between D1-D2
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  - Magnet requirements
- Particle stability for global and local CCs.
  - Synchrobetatron resonances
  - DA
- IP4 tunability (local CCs)
- Arc tunability (local CCs)

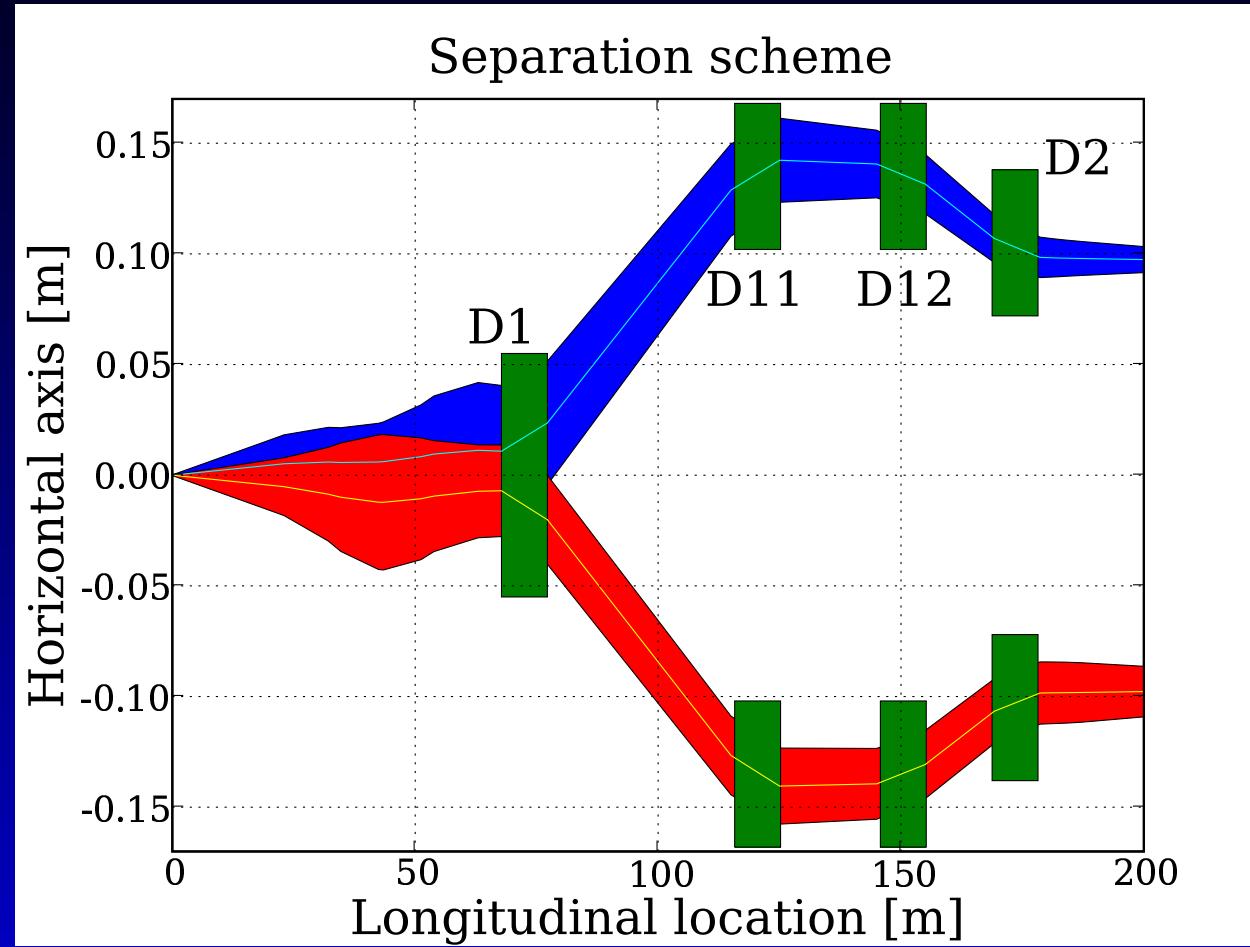
# Old approach with $\theta=8\text{mrad}$



[http://care-hhh.web.cern.ch/care-hhh/SuperLHC\\_IROptics/IROptics.html](http://care-hhh.web.cern.ch/care-hhh/SuperLHC_IROptics/IROptics.html)

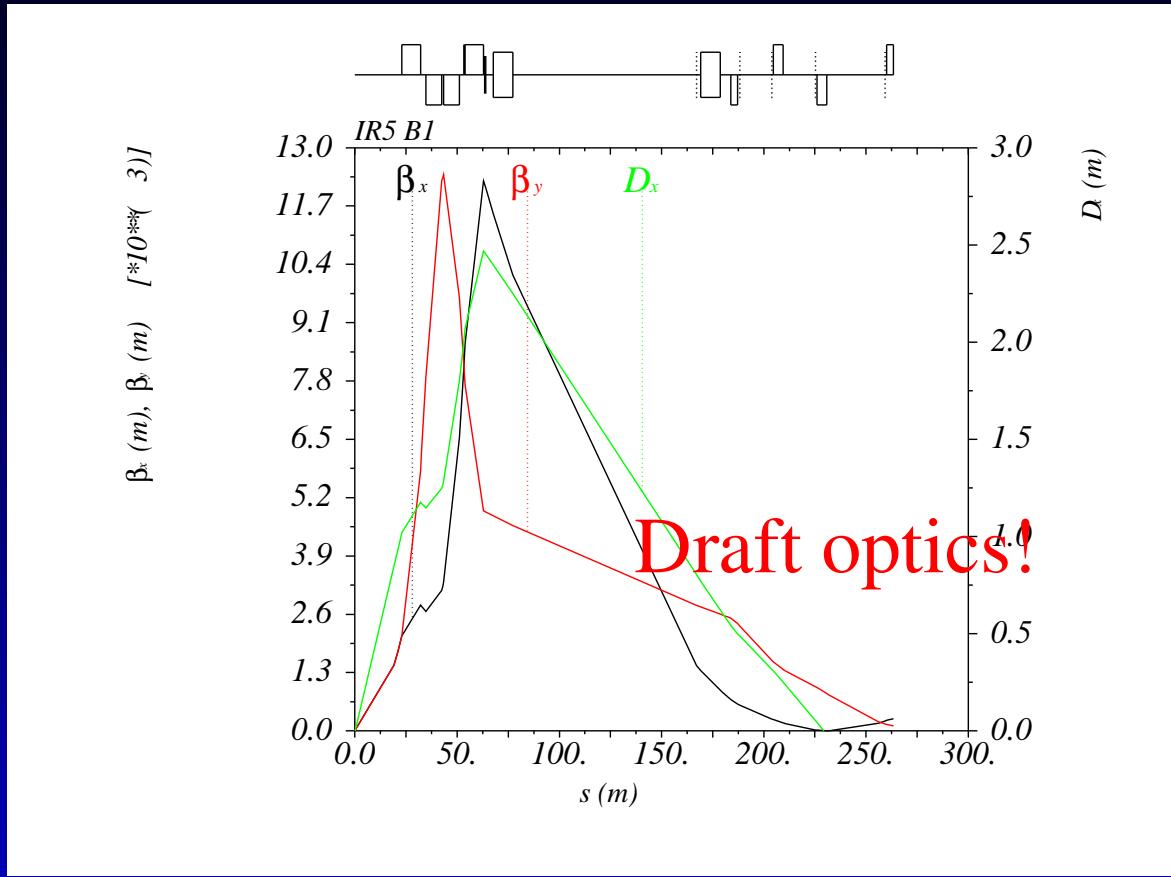
[http://care-hhh.web.cern.ch/CARE-HHH/LUMI-06/Proceedings/IR%20Upgrade%20II/proc\\_crab-rogioi.html](http://care-hhh.web.cern.ch/CARE-HHH/LUMI-06/Proceedings/IR%20Upgrade%20II/proc_crab-rogioi.html)

# New approach: separation between D1-D2



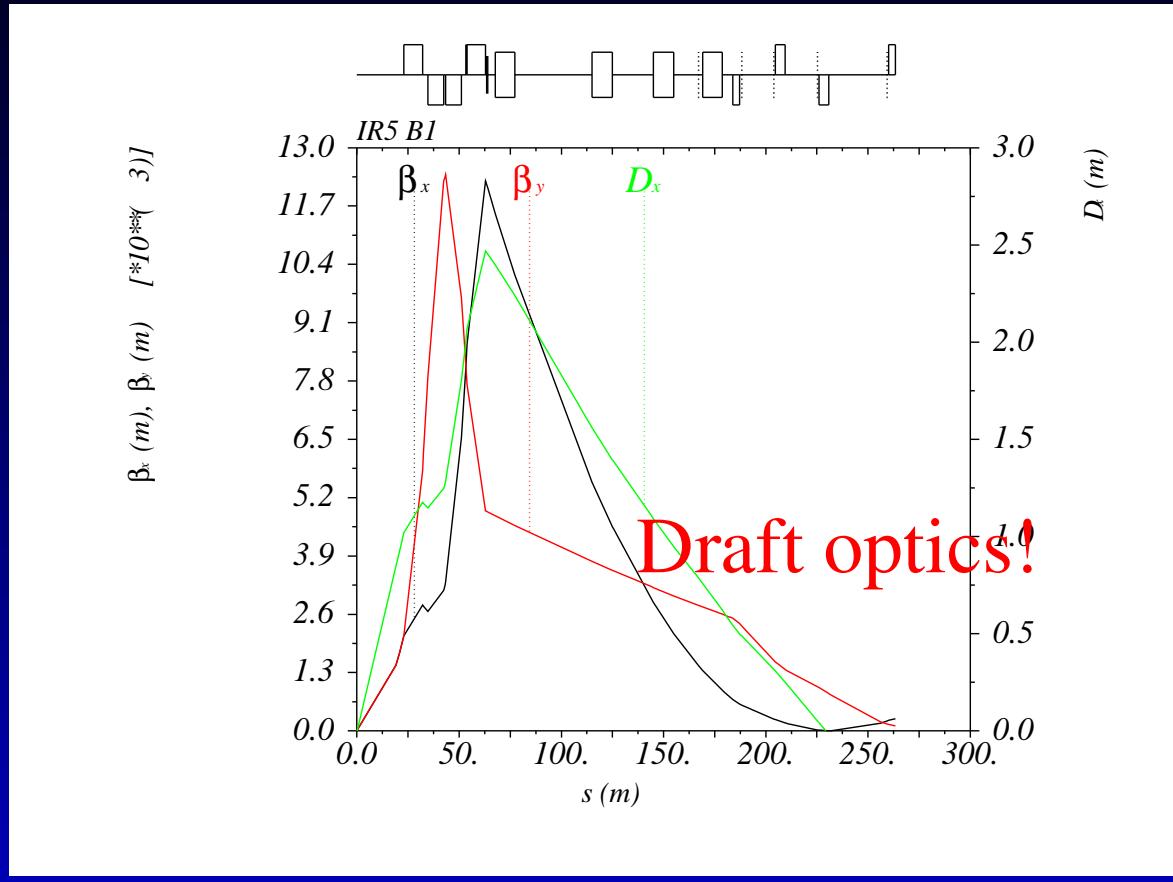
Approximate  $10\sigma$  envelope

# New idea from S. Fartoukh



Move D2, Q4 and Q5 towards the arcs to improve matchability and LSS aperture (space between D1 and D2 is increased) → Good for crab cavities!

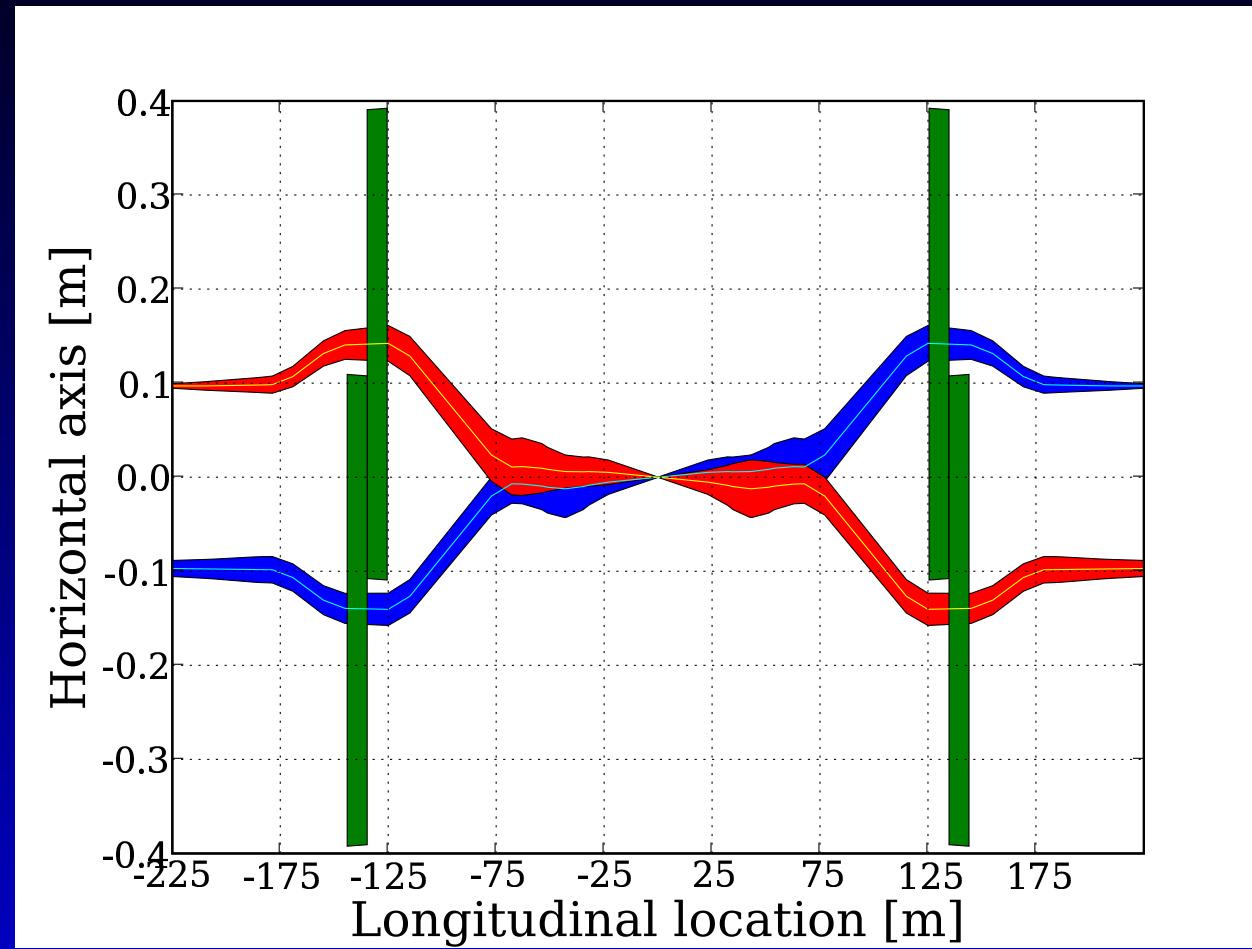
# Inserting D11 and D12



Small impact on lattice functions

D11 and D12: easy add-on for any optics.

# Local crab cavity scheme



Green boxes sketch the possible CCs vessels.

# Relevant parameters (local, preliminary)

Available space	20m
Beams separation	27cm
Max. hor. CC radius	23cm
CC betas range	3-4.5km
Max. $\Delta\phi_{IP \rightarrow CC}$	0.2515
Max. $D_x$ at CC	1.4m
IP betas	0.25m
$\theta_c$	$381\mu\text{rad}$

# Magnet requirements (preliminary)

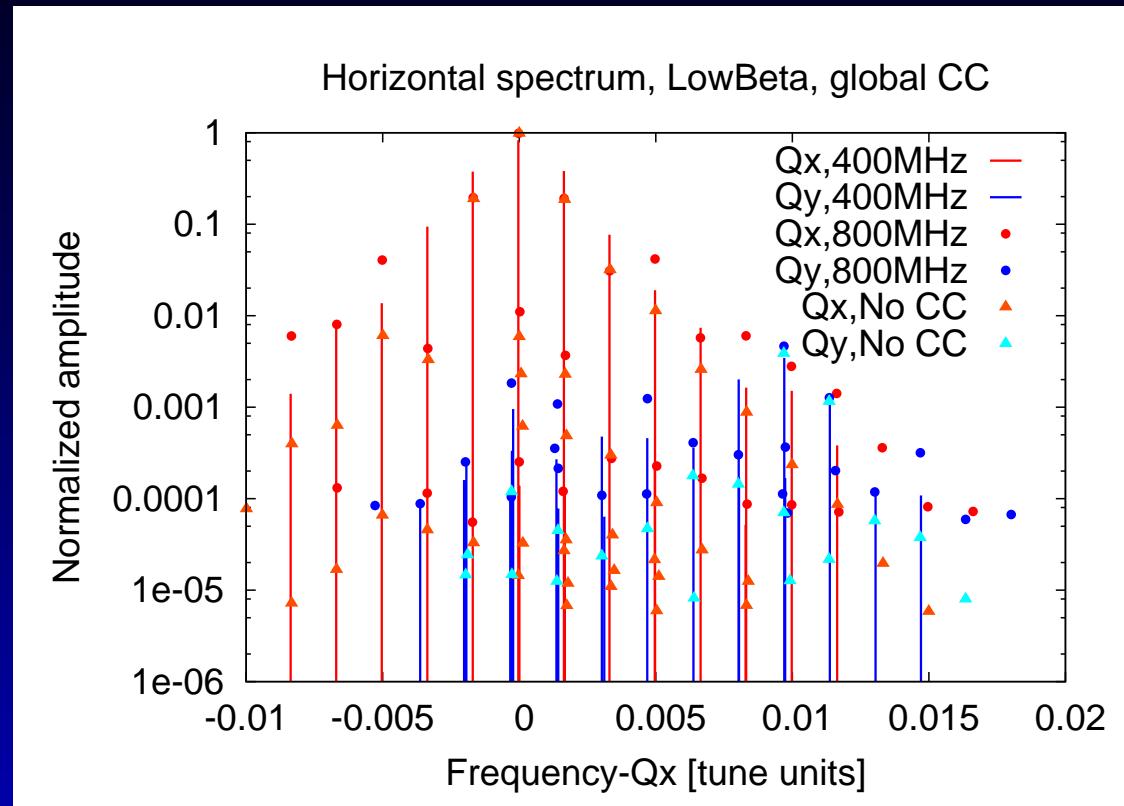
Magnet	Ap-H[mm]	Ap-V[mm]	Tesla	L [m]
D1	134	110	7	10
D11	106	70	7	10
D12	78	60	4	10
D2 (present)	69	53	3.85	10

- These are beam pipe apertures, not coil apertures!
- Large aperture D1 → Racetrack type?  $\cos(\theta)$ ?
- Reasonable for existing technology (NbTi)
- D12 similar to existing D2
- Optimization pending

# The D1 dilemma

- There are 2 options for the Phase I upgrade D1 magnet:
  - Warm and long magnet (resistive or superferric)
  - Cold and compact superconducting magnet
- Warm is not compatible with conventional CCs!!!
- We should support the cold D1 with two possible strategies:
  - D1 fully compatible with CCs from the beginning
  - Two D1s with enough aperture for a possible staged installation

# Synchrobet. resonances with global CCs



CCs enhance the 3<sup>rd</sup>, 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup> Qs sidebands  
Dangerous synchrobetatron resonances could be:

$$Q_x - Q_y + 6Q_s, \quad Q_x + 2Q_y + 30Q_s, \dots$$

# $10^5$ turns DA with CCs

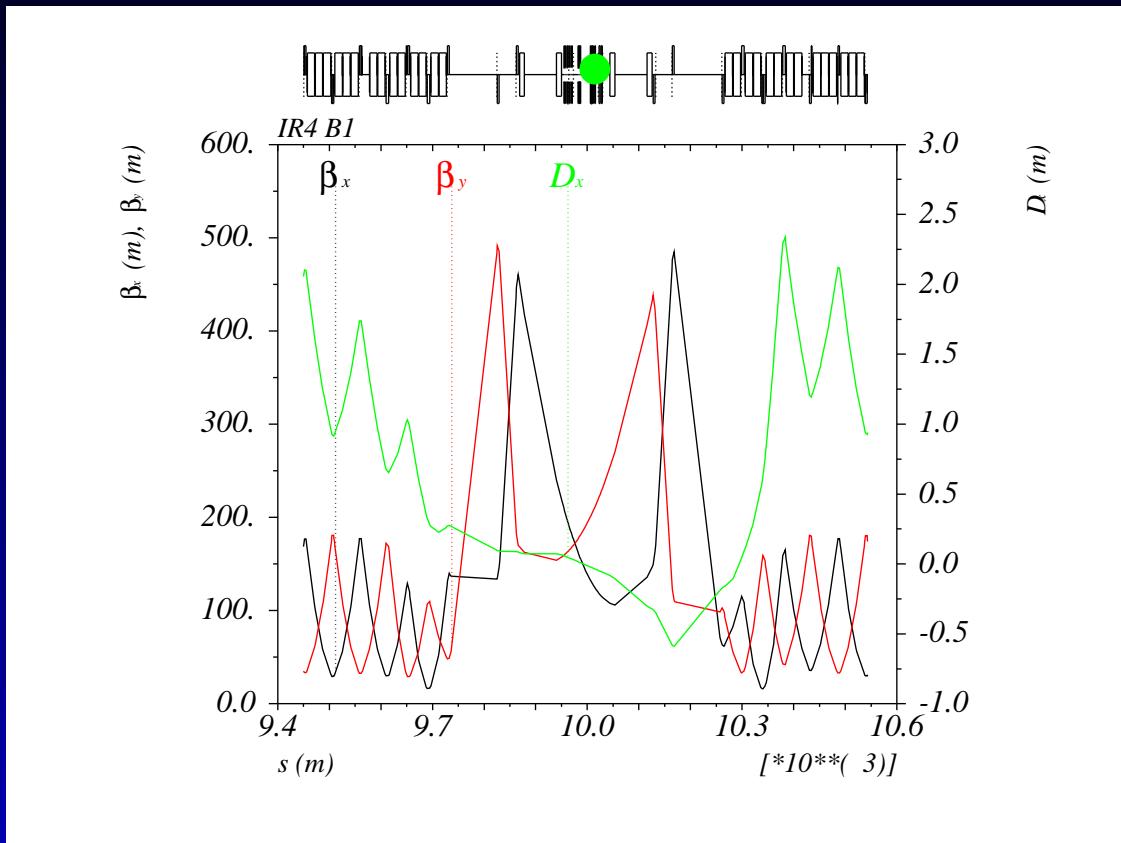
error= $\pm 0.5\sigma$	Nominal LHC	LowBeta
No CC	16.0	15.9
Local 400 MHz	14.1	15.5
Local 800 MHz	14.7	16.0
Global 400 MHz	12.1	14.3
Global 800 MHz	13.0	12.4
$\Delta\phi_{CC \rightarrow IP}$	0.278	0.239

Global CCs reduce the DA!

Bad  $\Delta\phi_{CC \rightarrow IP}$  in LHC nominal also affects DA

12 $\sigma$  DA for lattice only is typically a good number

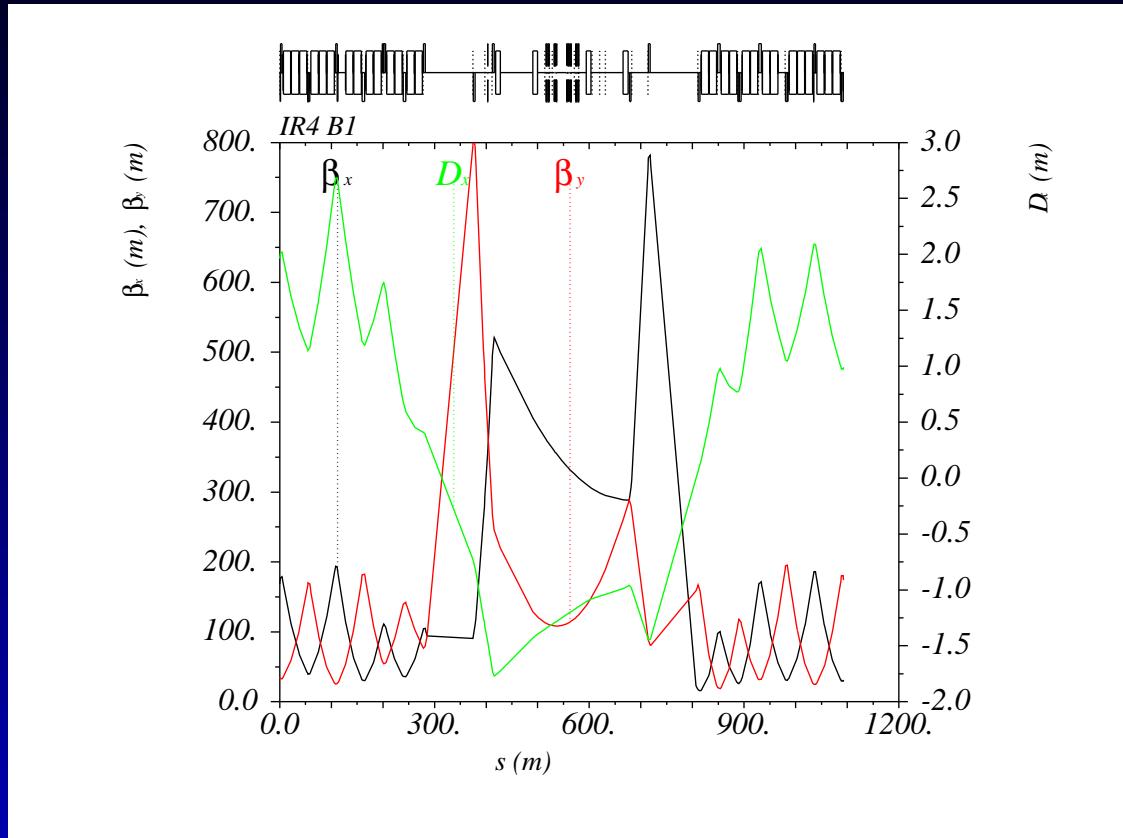
# IP4 tunnability (global CCs)



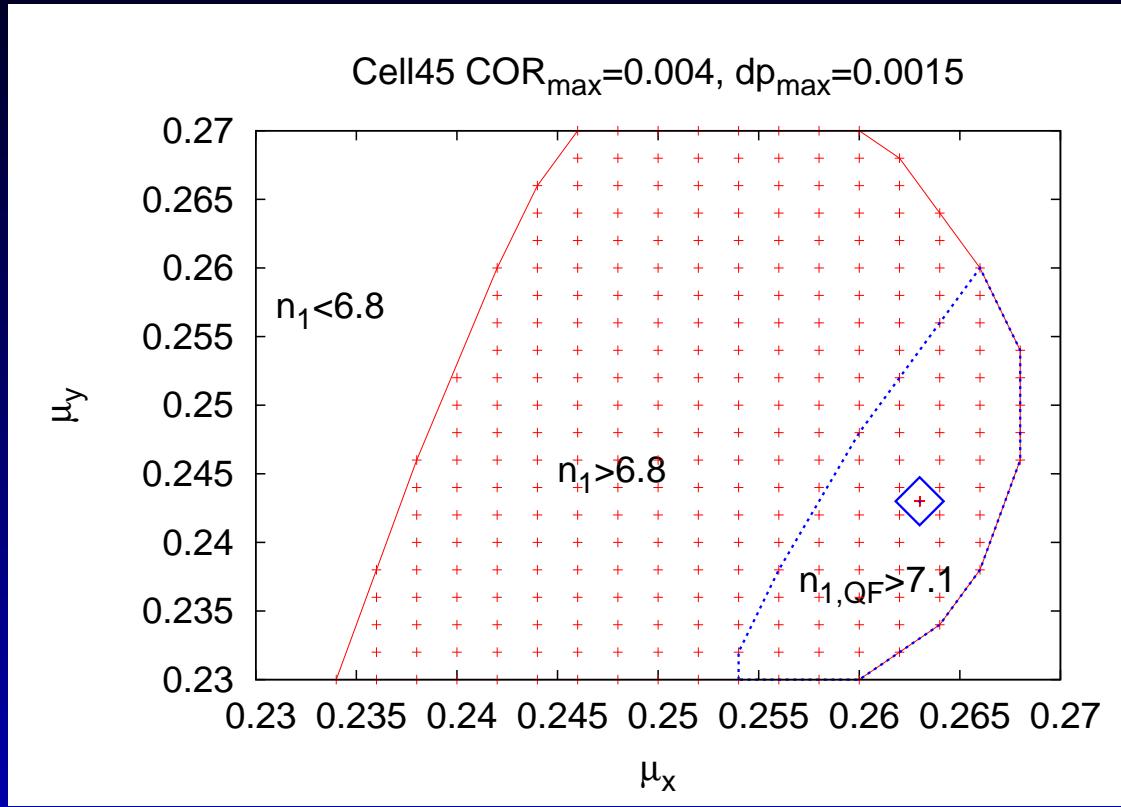
Aperture bottlenecks in MQYs for betas larger than 800m.

Maximum betas at CC with present hardware  $\approx 320$ m.

# IP4 tunnability: $\beta_x=320\text{m}$ at CC



# Arc tunnability (global CCs)



One arc has 23 cells  $\rightarrow \Delta\phi_x = [-0.60, 0.11]$  and  
 $\Delta\phi_y = [-0.16, 0.46]$

# Conclusions

- New idea from S. Fartoukh: move D2! Good for CCs.
- However phase I IR upgrade optics are not ready.
- Separation of beams to 27cm for 20m longitudinally achievable with present technology.
- CCs have an impact on particle stability
- Further studies with Beam-Beam required
- Betas at IP4 CC cannot be increased beyond 320m due to aperture constrains.
- Large phase tunability using arcs.