Crab cavity aperture and alignment
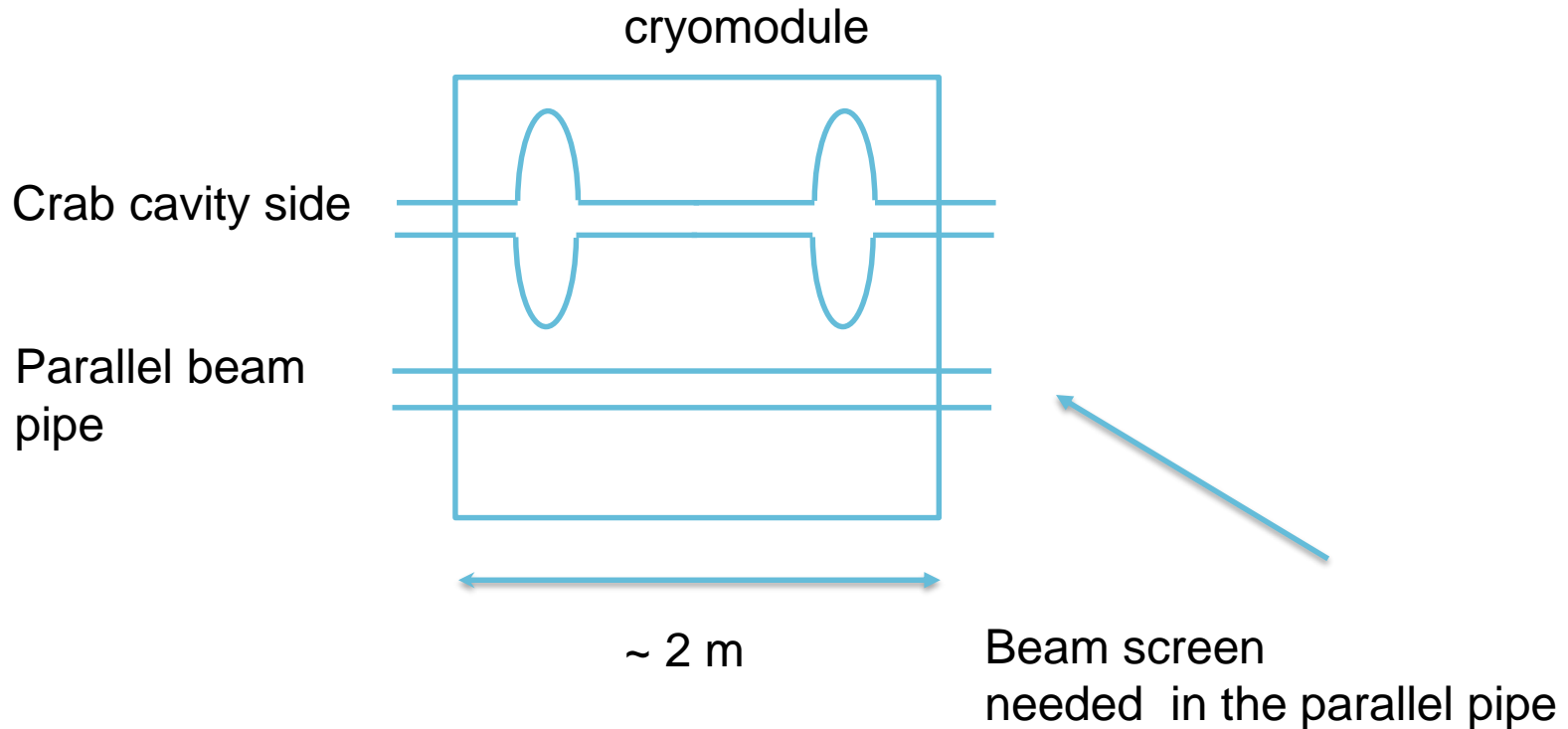
R. De Maria

Crab cavity

Cavity aperture: circle 84 mm
Parallel pipe: circle 84 mm
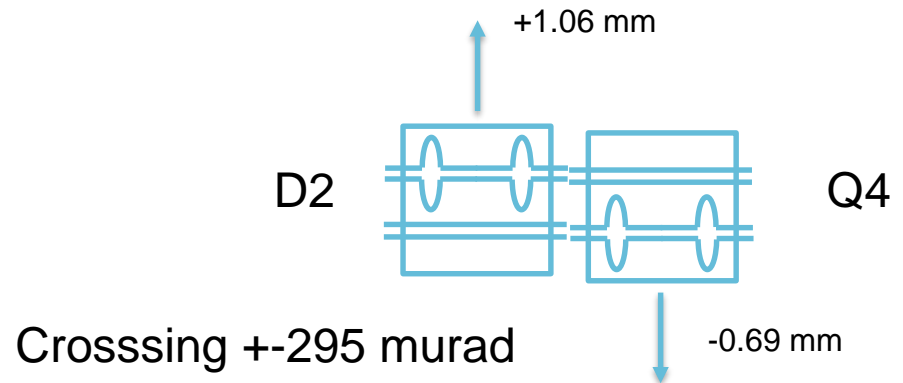Separation: 194 mm

cryomodule

Crab cavity side

Parallel beam
pipe

~ 2 m

Beam screen
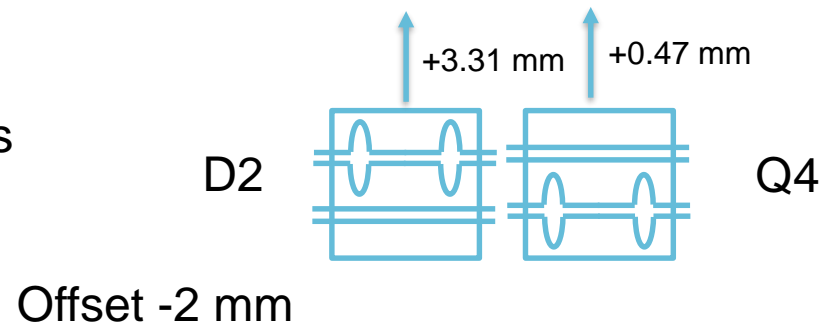needed in the parallel pipe

Crab Cavity Alignment

Cavities needs to be aligned on the closed orbit (potentially no margin left after alignment).

Crossing angle orbit is not zero in the in the center of the cavities.

+1.06 mm

D2   Q4

Crosssing +-295 murad

-0.69 mm

IP offset implemented with orbit corrector generate orbit at the cavities in the opposite direction

+3.31 mm   +0.47 mm
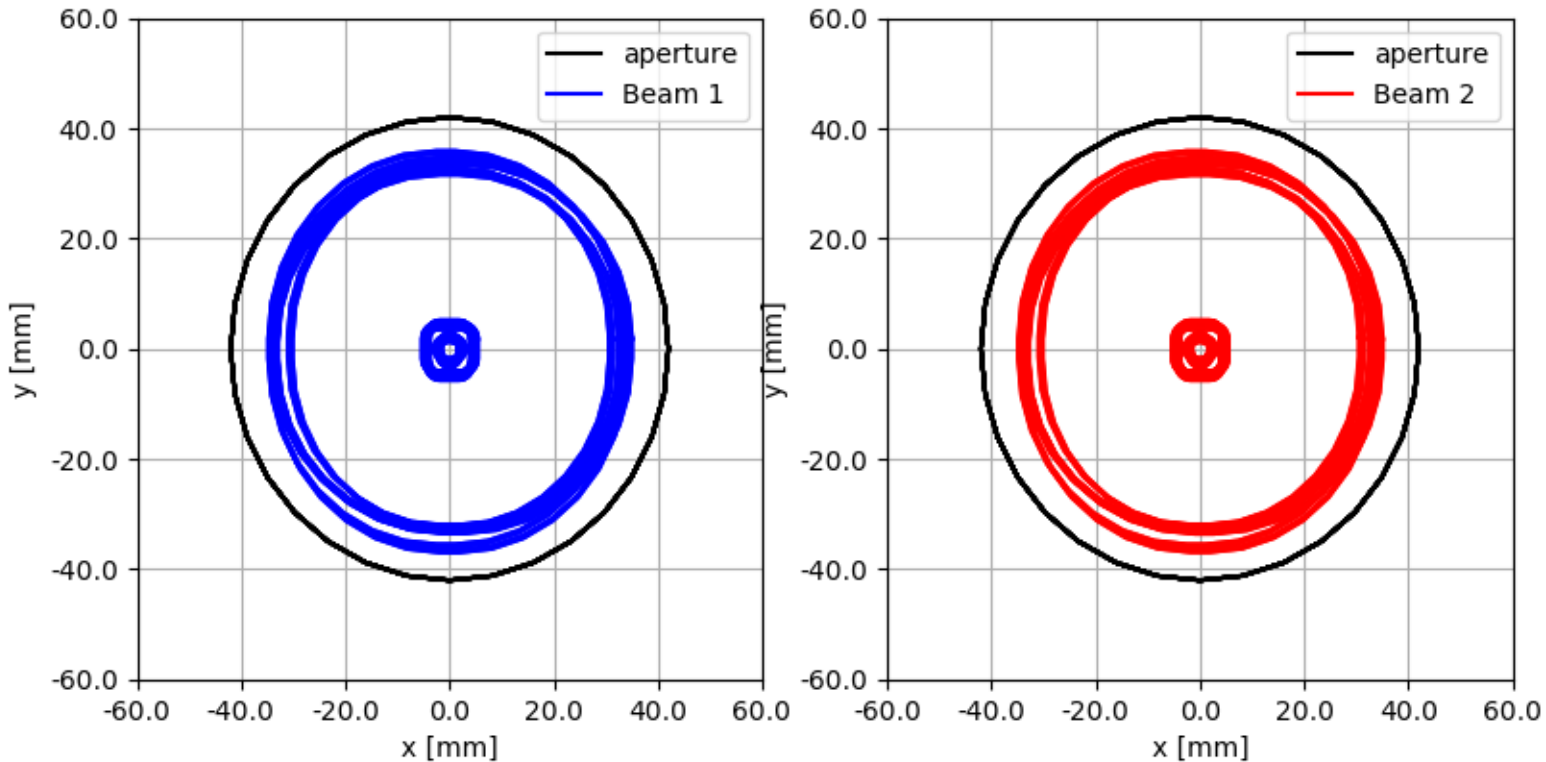
D2   Q4

Offset -2 mm

Parallel pipe will be will be misaligned with respect to the beam closed orbit.
Still margin (>5 mm in radius) to add a beam screen.

Crab Cavity Aperture

Parallel pipe without beam screen

beta*=7.5 cm, 14.2 sigma with usual tolerance

Protected Apertures

Δμ$_x$ MKD-TCT [°]	Aperture [σ@2.5µm]
0-20	11.2
30	11.9
40	12.9
50	13.8
60	14.5
70-90	14.6
No TCT	19.4
Injection	12.6

Parameter	7 TeV	0.45 TeV
Radial CO [mm]	2	
Mom offset	$2 \cdot 10^{-4}$	
Dispersion	0.1	
Beam size	1.1	1.025

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Aperture Margins: Round 15 cm, 12.5 σ

	Bare	Mech	Beam	Crab	Offset
TAXS	24.0	21.4	17.3	17.3	15.1
MQXFA.[AB]1	21.2	19.4	16.4	16.4	15.1
MQXF[AB]..[23]	15.5	14.4	12.2	12.0	11.0
MBXF	16.9	16.0	13.6	13.5	12.7
TAXN	22.3	20.9	17.7	17.2	15.5
MBRD	26.7	23.7	19.9	19.0	16.4
MCBRD	29.2	26.3	22.1	21.2	18.3
TCLMB.4	24.9	23.3	19.0	18.0	14.7
MCBY[HV].[AB]?4	26.2	24.1	19.6	18.6	15.1
MQY.4	29.2	26.6	21.7	20.7	17.1
TCLMB.5	36.3	34.3	28.7	28.5	25.2
MCBY[HV].[AB]?5	37.5	35.3	29.4	29.4	26.2
MQY.5	39.4	37.1	31.0	31.0	27.9
TCLMC.6	37.0	34.4	28.1	28.1	25.6
MCBC[HV].6	38.2	35.9	29.4	29.4	27.2
MQML.6	38.6	35.8	29.3	29.3	27.1

$\theta_c = \pm 295$ µrad;
$d_{sep} = \pm 0.75$ mm;

needs phase <=30° and slightly reduced margins
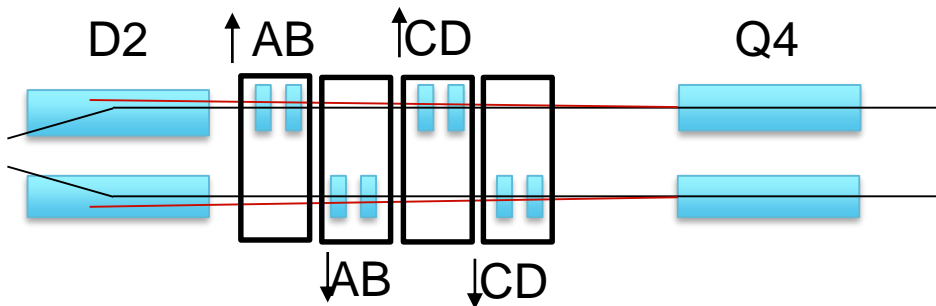
Aperture in σ at 2.5 µm/γ at 7 TeV

Nominal crossing bump

Baseline closed in MCBY.4 (acby.4=0.2 acbrd)

Impact on crab cavity alignment

Crossing angle:
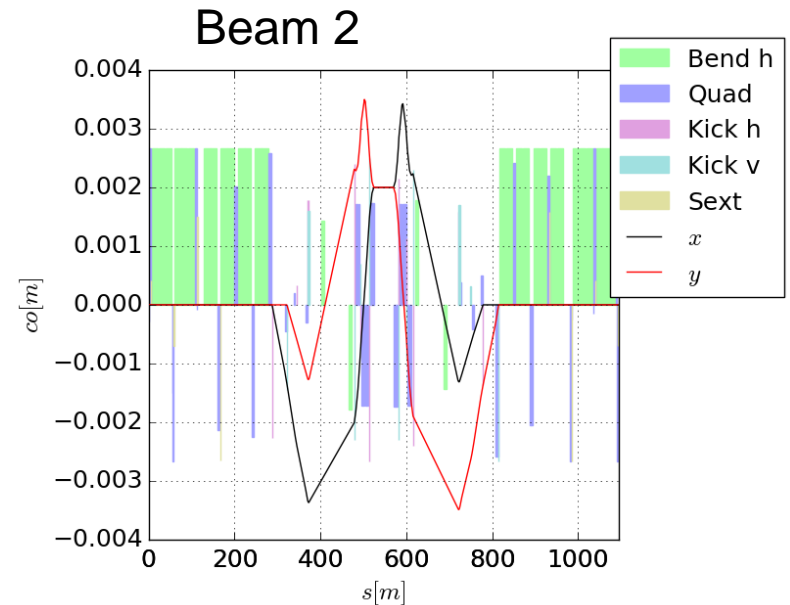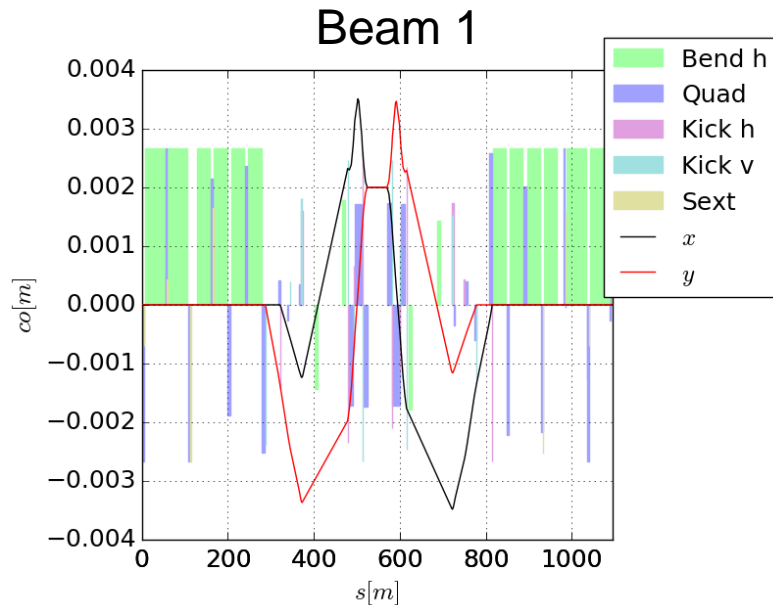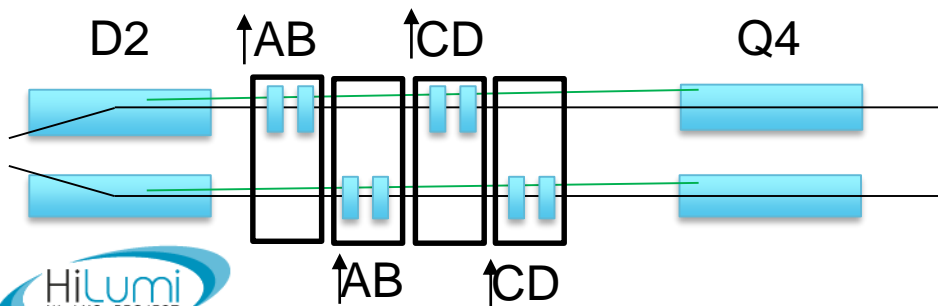x,y: ±1.15 mm (Beam 1, AB)
x,y: ±(-0.5) mm (Beam 2, AB)
For cryomodules:
- average offset 0.3 mm
- shear 1.65 mm

Orbit knobs - offset

Beam 1

Beam 2

IP Offset knob: x,y= ±2 mm same for the two beams to accommodate alignment needs of the experiments with machine realignment, besides crab cavities.
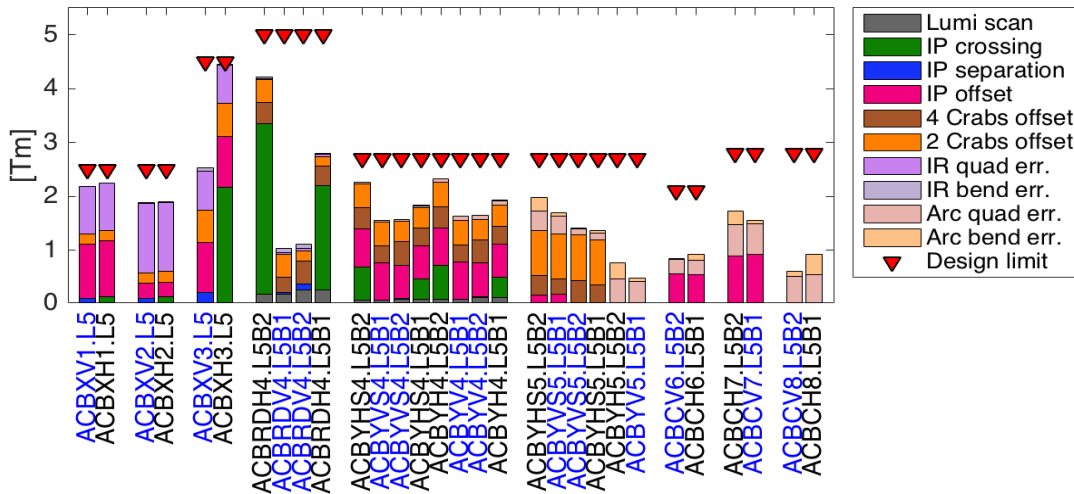

D2   ↑AB   ↑CD   Q4
↑AB   ↑CD

IP offset:

x,y: ±3.4 mm (Beam 1, CD),
x,y: ±1mm (Beam 2, CD),
For cryomodules:
- avg. offset 2.2 mm
- shear 2.4 mm

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Corrections Budget requirements

For the Right and Point 1 symmetries apply:
- Left B1 -> Right B2,
- Left B2 -> Right B1
- H Point 5 -> V Point 1

- <u>Correct quadrupole misalignments and dipole tilt and transfer function errors</u>:
  - uniformly distributed, uncorrelated error distribution (**2 σ** cut in the strengths):
    - quadrupoles triplets and arc: **0.5 mm** max transverse displacement, **1 mrad** max roll
    - dipoles D1, D2 and arcs: **10 mm** max longitudinal displacement, **0.5 mrad** max roll, **0.2%** max field error
  - <u>Reduced estimates compared with LHC design (worst case) based on LHC experience</u>
- <u>Adjust the IP position limiting the realignment of HW components (crab cavities only)</u>:
  - offset in H/V planes: **±2.0 mm**
- <u>Align beam in the crab cavities in both planes</u>:
  - Adjust for average offset and separation (**±0.5 mm**) between cavities in Beam 1 and Beam 2.
  - Adjust for average offset between cavities of the same beam but in different cryomodules (**±0.25 mm**, relevant for 4 cavities per beam per plane per side).