Beam-beam effects for round optics: DA simulations summary

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Acknowledgement: R.DeMaria, M.Giovannozzi, lhc@home team

BB expected Effects for Possible Scenarios :

Baseline1 : Luminosity of 5e34

Head-on strong ΔQ = max 0.033 to → 0.01
Long Range:
IP1&5 From 26σ → 12.5σ (Int 2.2e11 → 1.1e11)
IP8 2 LR at 5s (others > 20σ)
IP2 all > 30σ

Baseline2 : Luminosity of 7.5e34

Head-on strong ΔQ = max 0.033 to → 0.01
Long Range:
IP1&5 From 18σ → 12.5σ (Int 2.2e11 → 1.5e11)
IP8 2 LR at 5s (others > 20σ)
IP2 all > 30σ

Extreme Case: no β* leveling

Head-on strong ΔQ = max 0.033 to → 0.01
Long Range: strongest
→ IP1&5 at 12.5 σ at Int 2.2e11

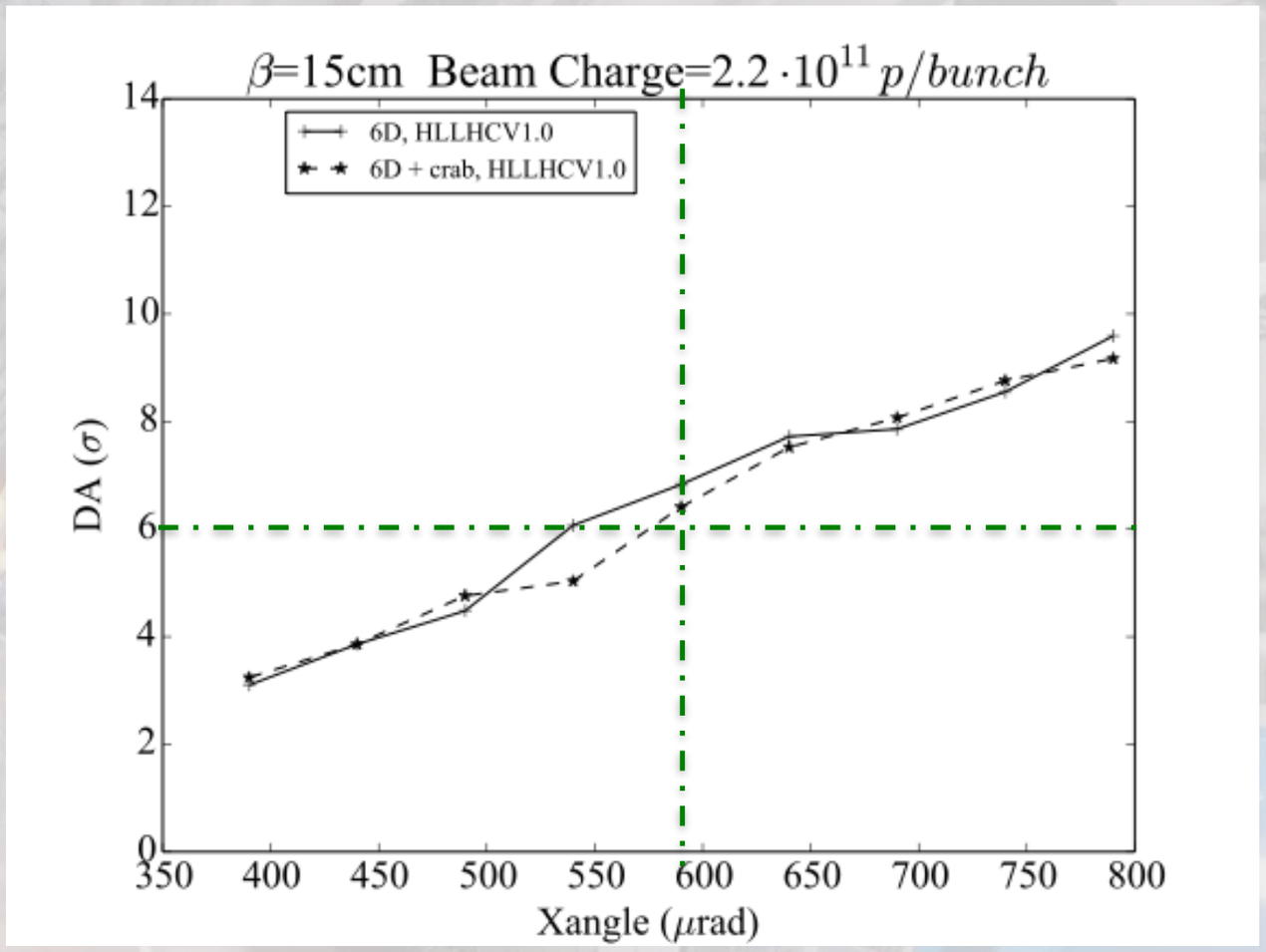
GOALS:

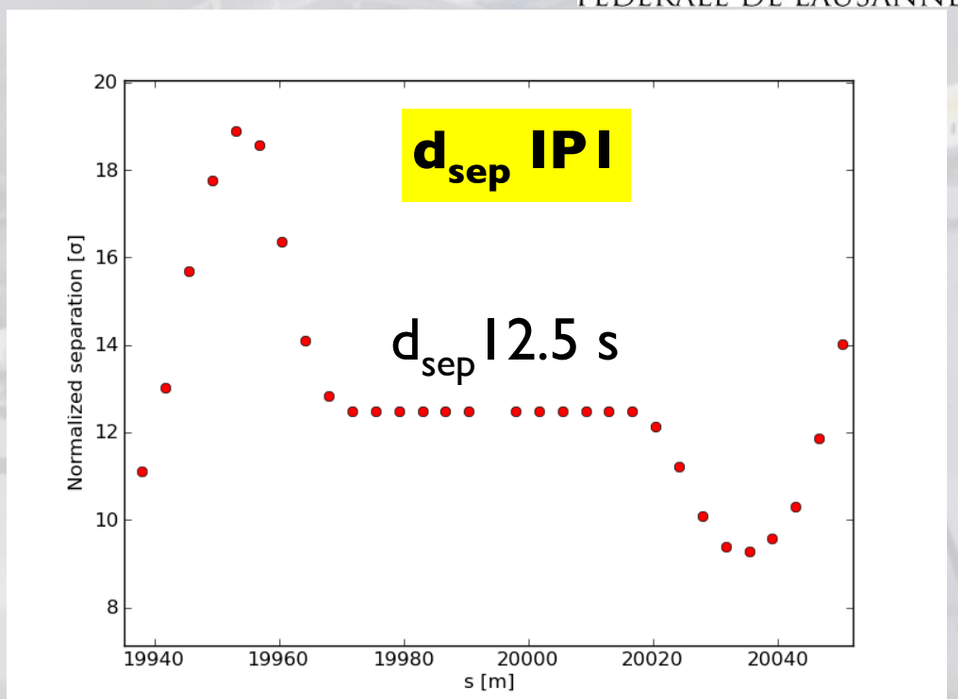
Ensure DA>6σ and define constrains:

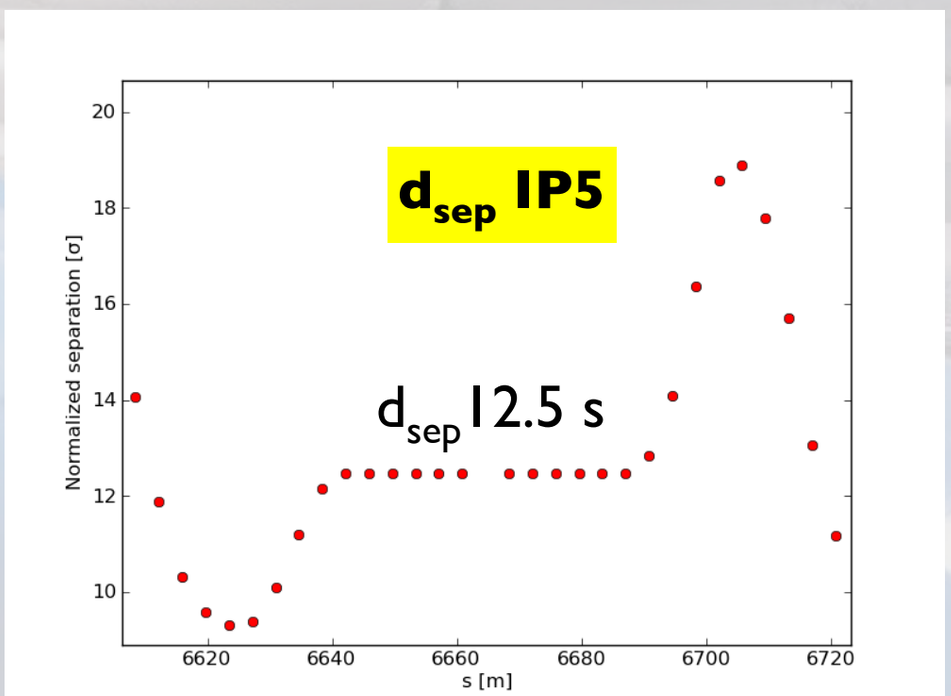
- Minimum crossing angle acceptable
- Intensity limits
- IPs contribution
- Multipolar errors effect
- Other parameters that could reduce performances

Round optics15 cm, 2.2E11: crossing angle scan

IP1 & IP5 only HLLHCV1.0 optic





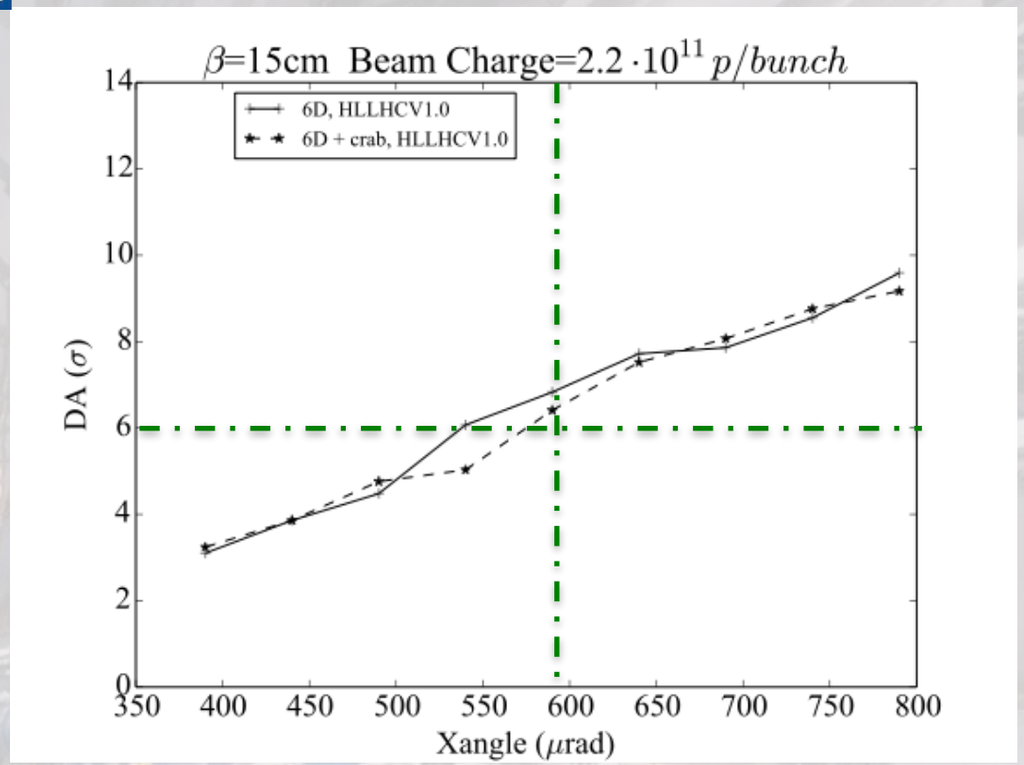


$$d_{sep} = \alpha \cdot \sqrt{\frac{\beta^*}{\epsilon/\gamma}}$$

$$DA \propto d_{sep} \propto \alpha$$

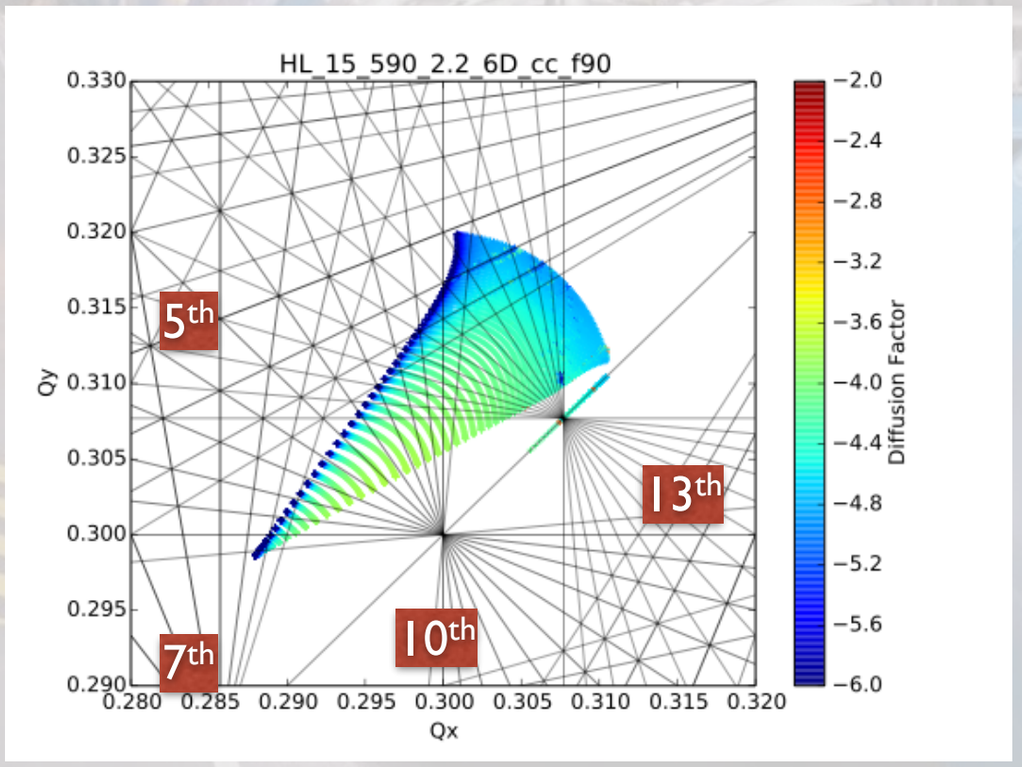
Beam beam LR separation is proportional to crossing angle. Reducing angle → reduce separation → increase beam beam LR effects and decreases DA linearly

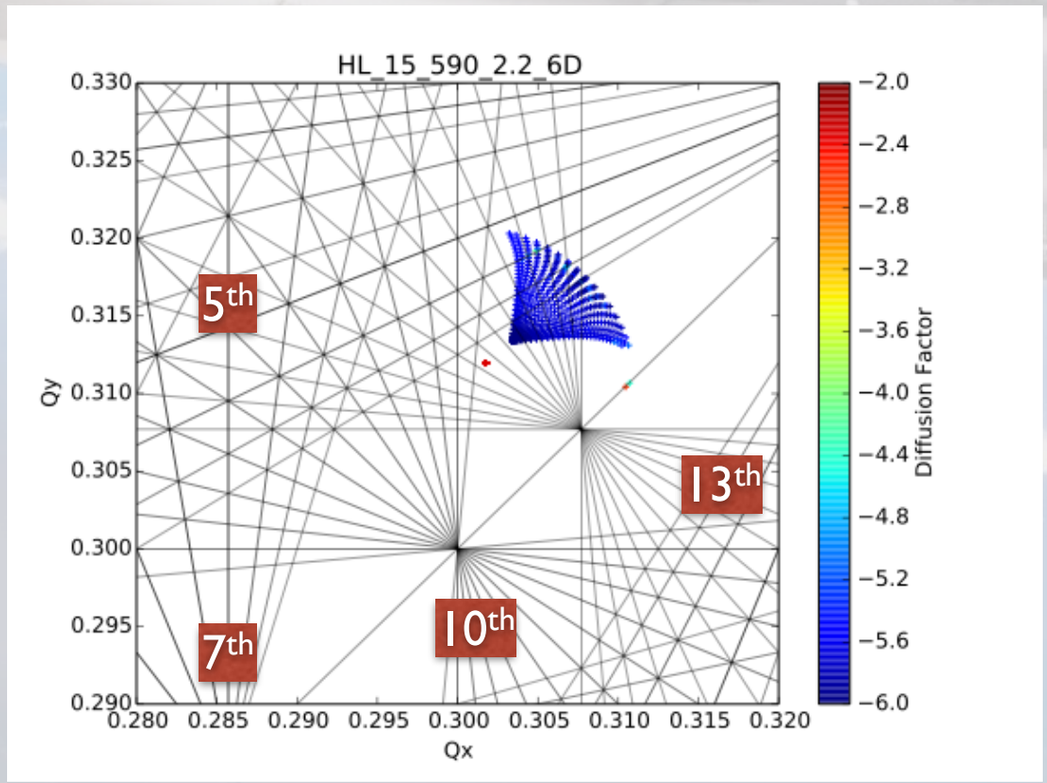
Nominal scenario: Full Crabing



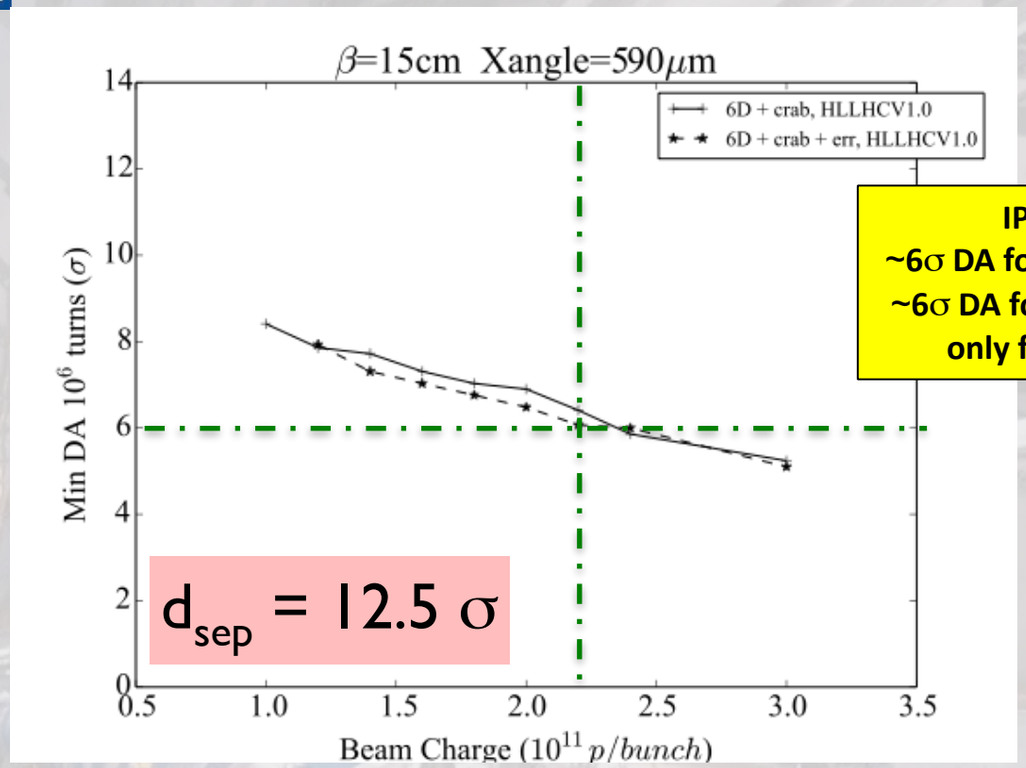
IP1 & IP5 only HLLHCV1.0 optic

Crab Crossing introduces large HO tune shift
Different resonances are crossed
We should choose working points very carefully to avoid reduction of performances.
Our limits seems coming from 13th-5th and diagonal resonances

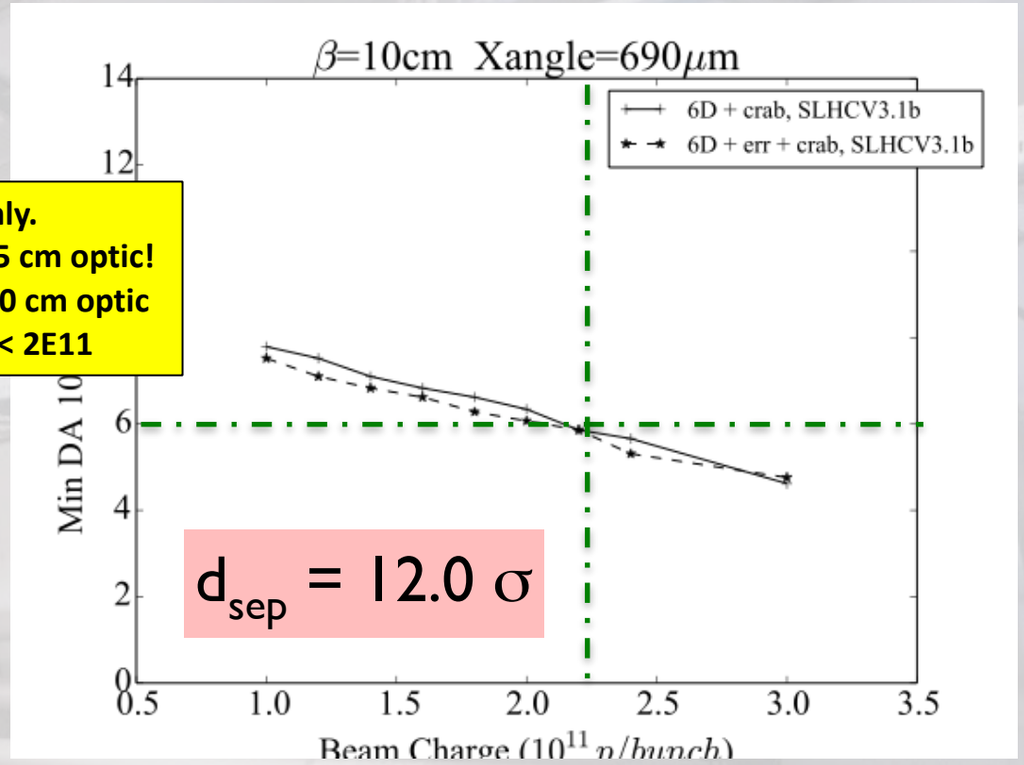


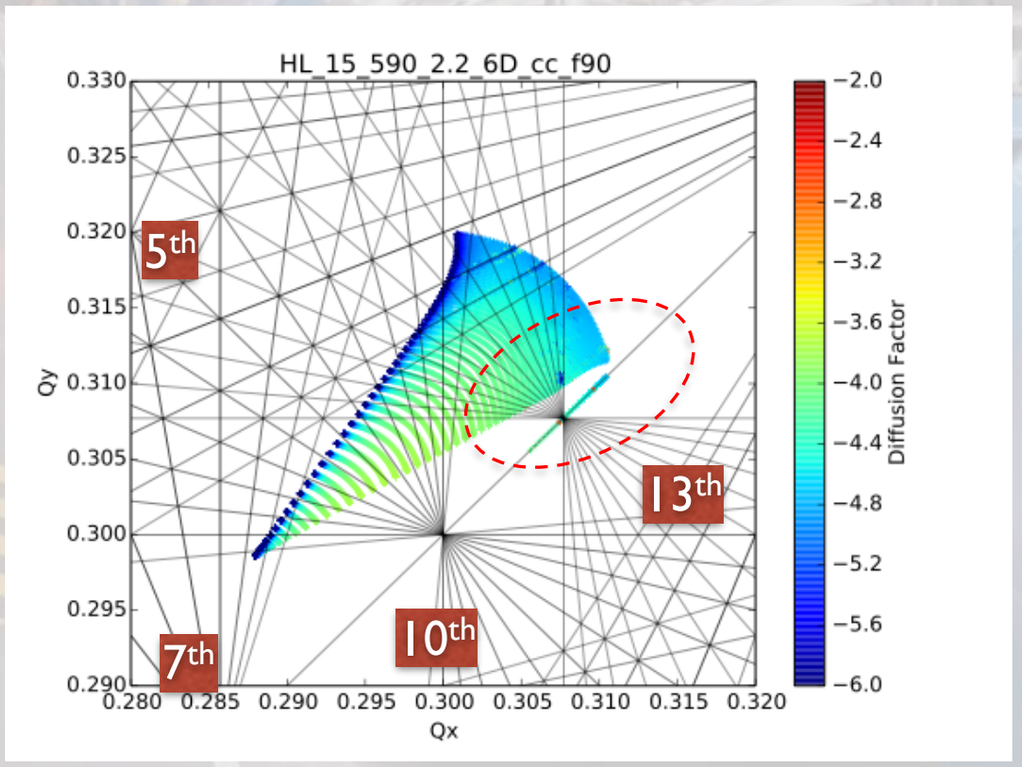


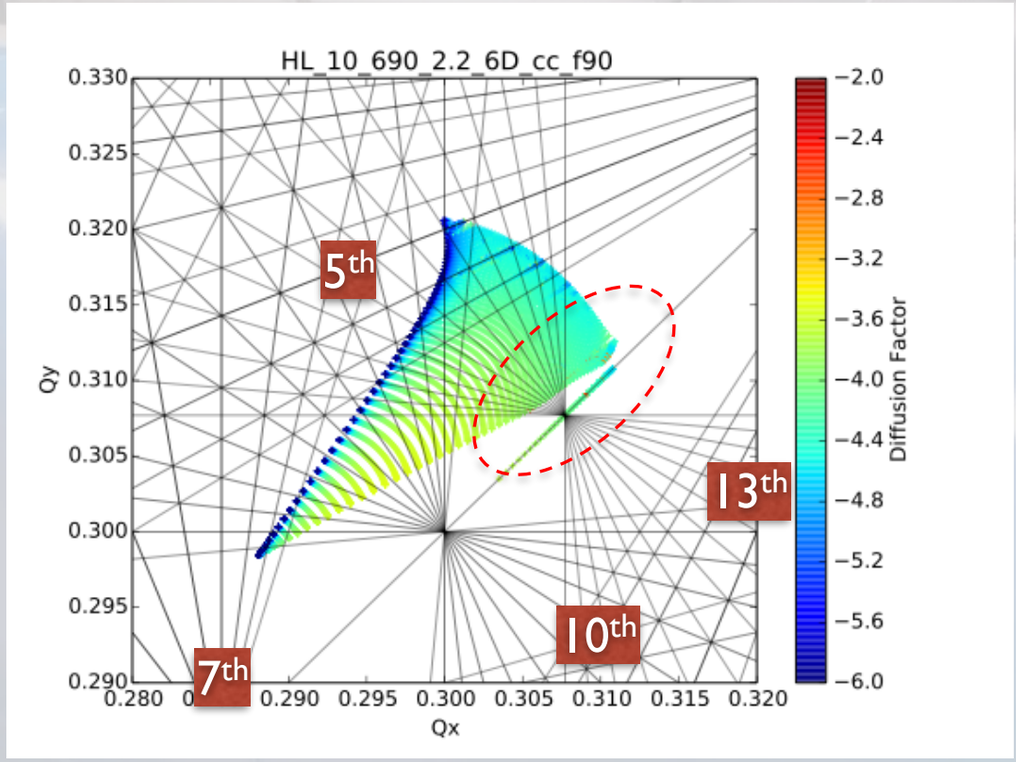
Round Optics: Multipolar Errors



IP1 and IP5 only.
~6σ DA for nominal 15 cm optic!
~6σ DA for nominal 10 cm optic only for intensity < 2E11

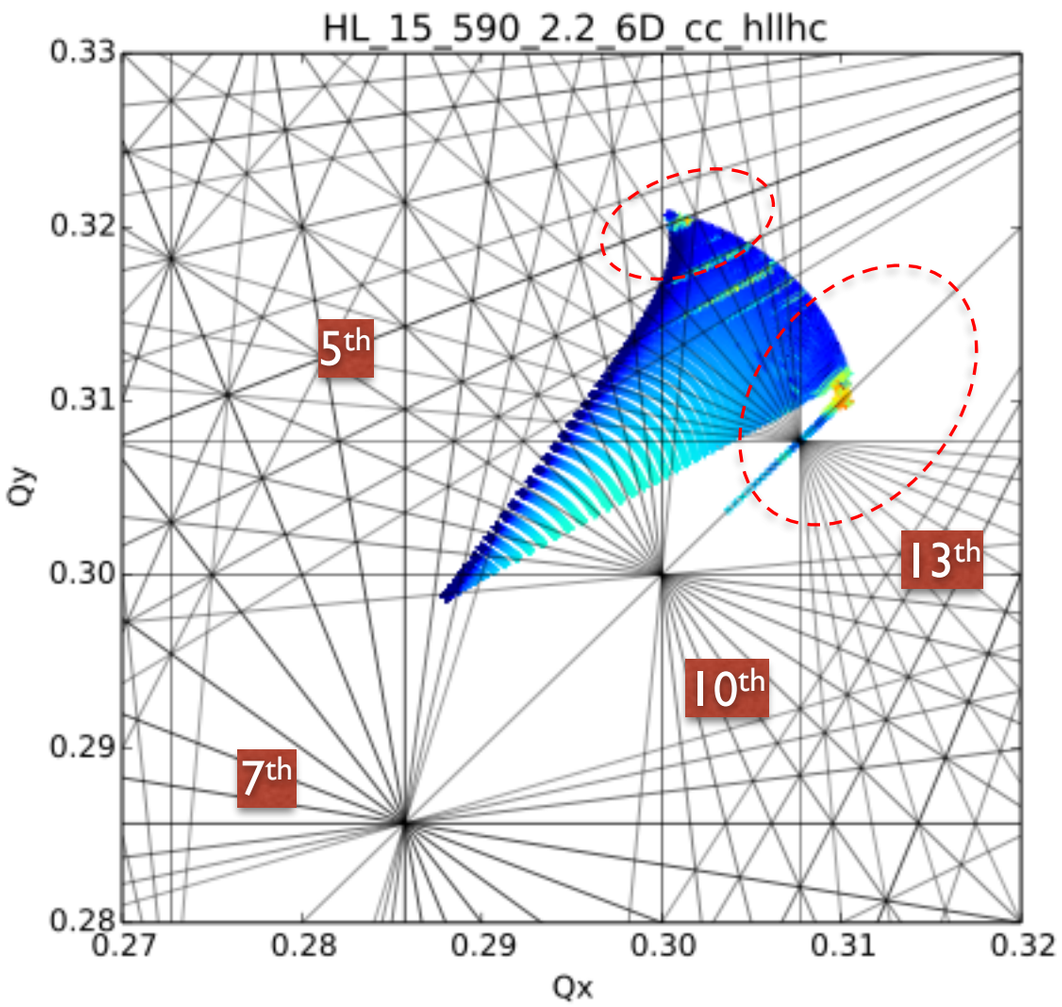


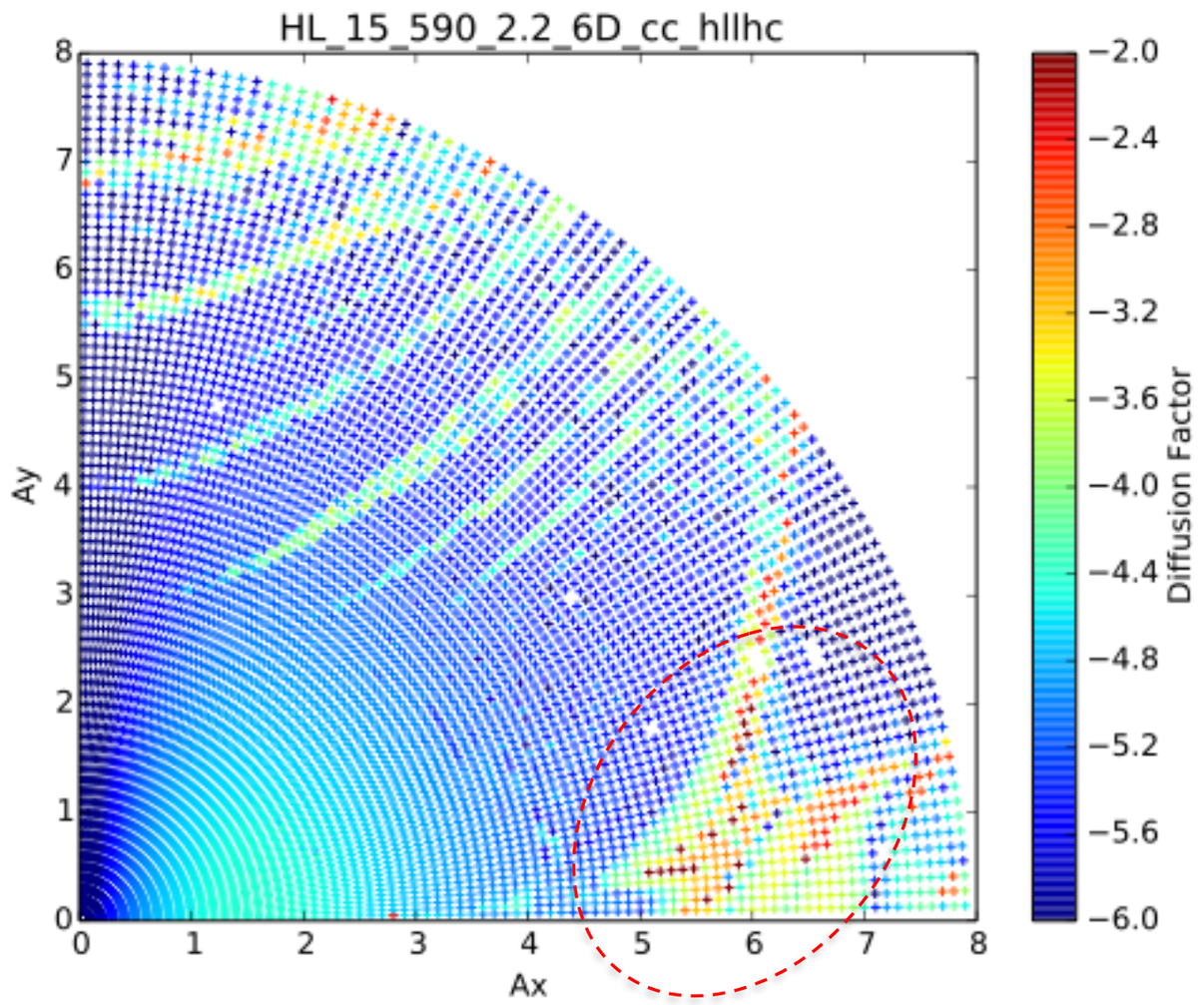




Round Optics: details for15cm

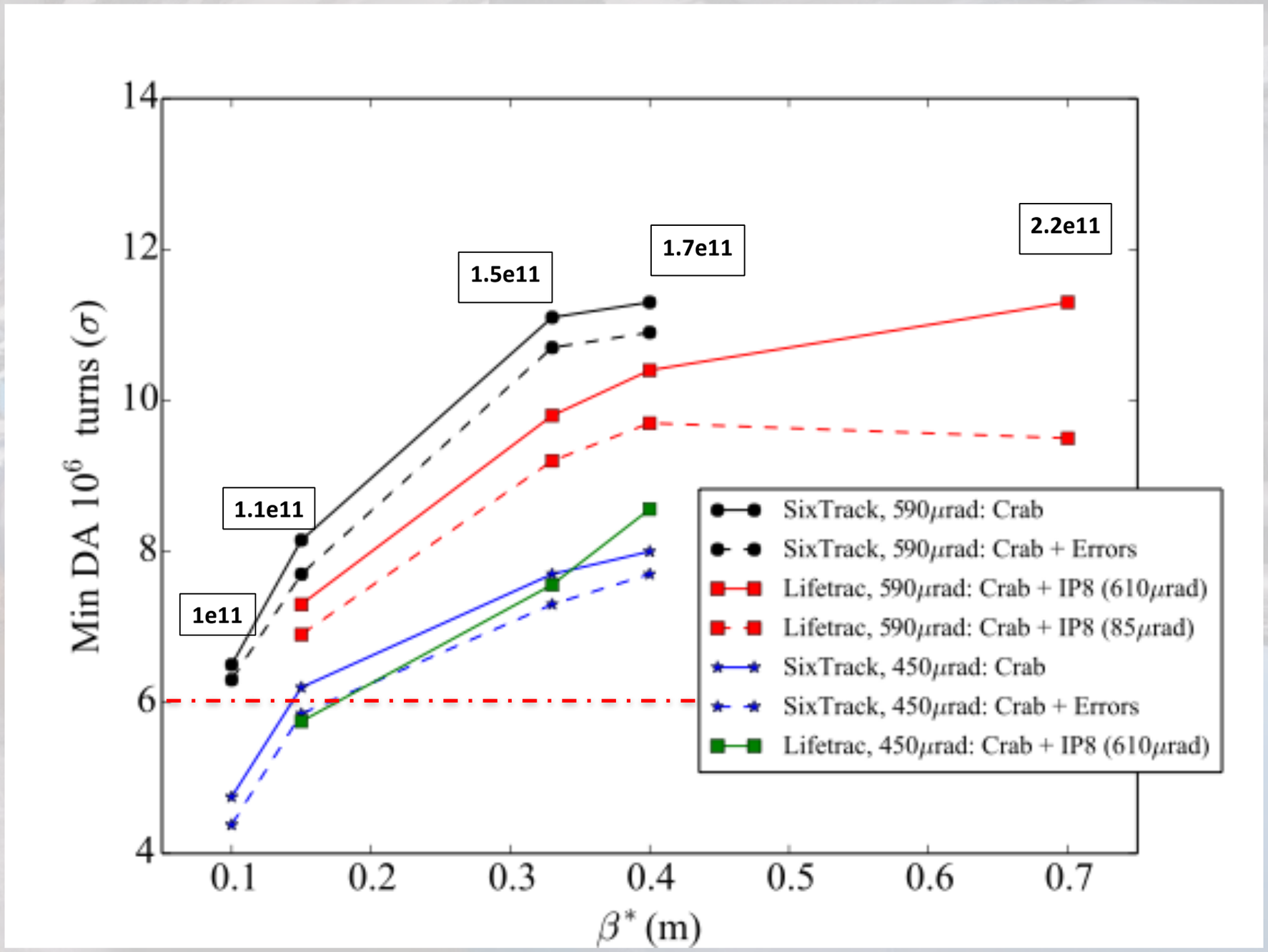
IP1 & IP5 only HLLHCV1.0 optic





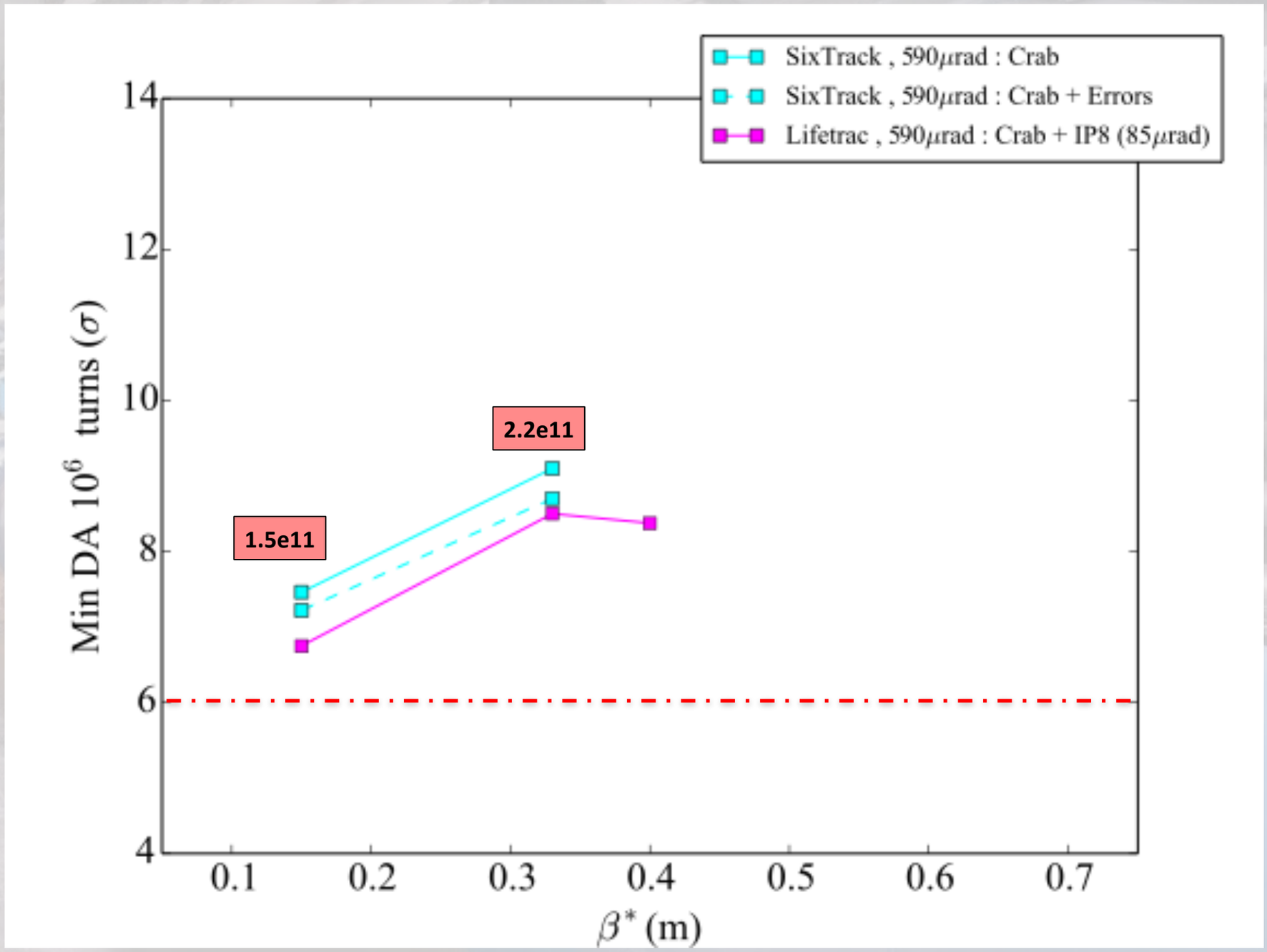
DA is 6σ but particles at 4-5 σ are affected by the BBLR show higher diffusion rates
Effect driven by 5th and 13th order resonance

β* leveling summary for 5e34 Lumi Leveled: Nominal and reduced x-angle



Baseline scenario with levelled lumi at 5e34 at 590μrad is robust thanks to b* leveling DA always above 7σ
Margin to reduce crossing angle 450μrad: reduce CC voltage or more intensity

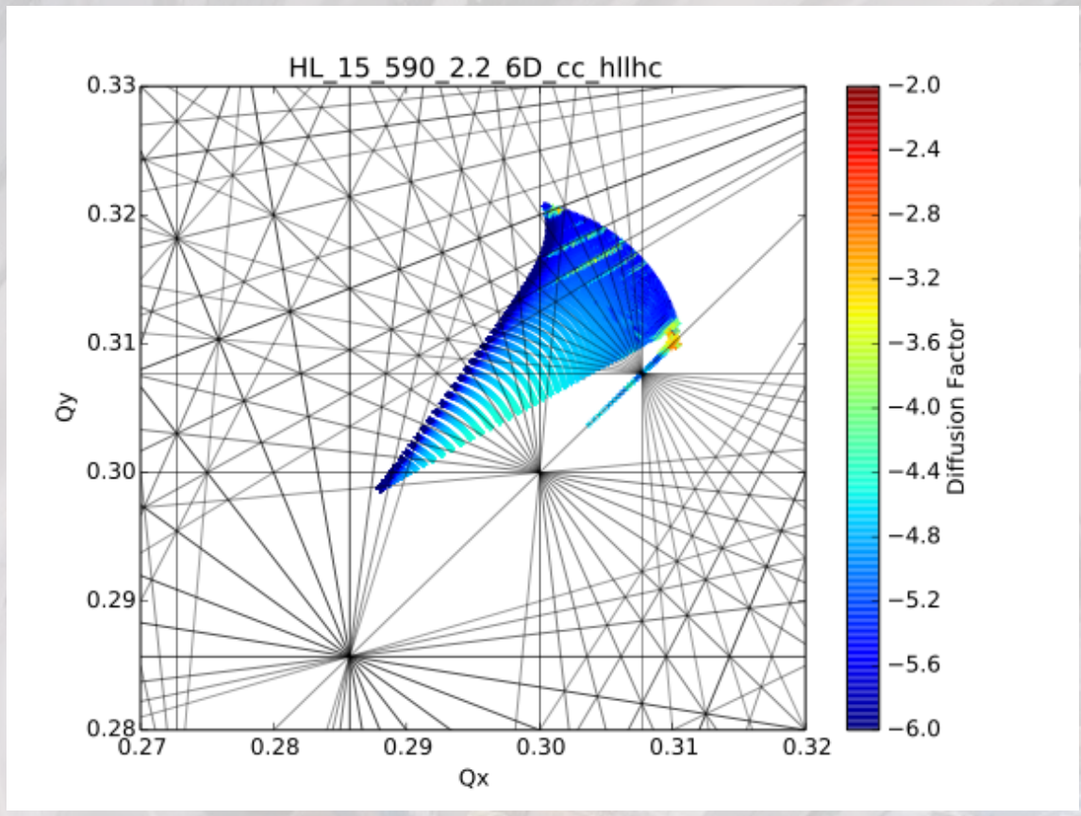
β* leveling summary 7.5e34 Lumi leveled



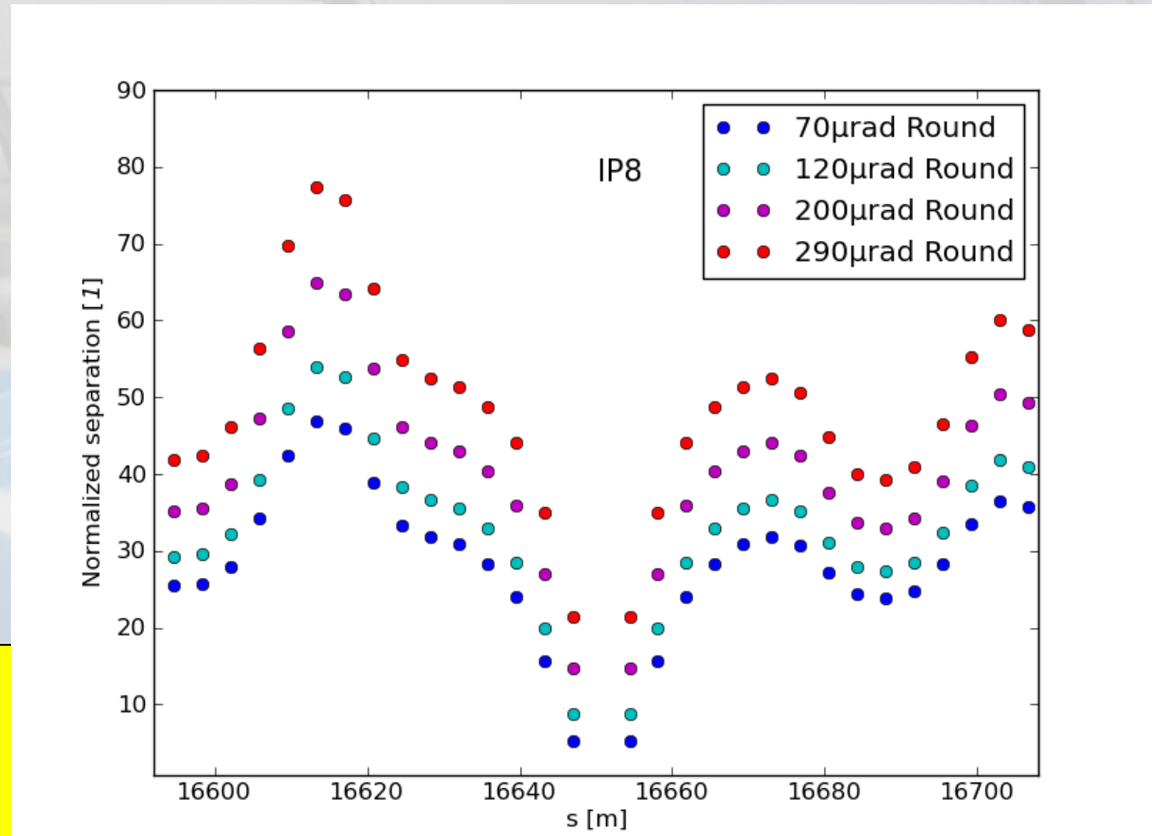
Ultimate scenario with leveled lumi at 7.5e34 at 590μrad is robust thanks to β* leveling DA always above 7σ
Margins also for reduced crossing angle if needed.

HLLHCV1.0: effect of IP8

IP1 & IP5 only HLLHCV1.0 optic



Int ppb I0	DA No Err No IP8
1.0	8.41
2.2	6.42



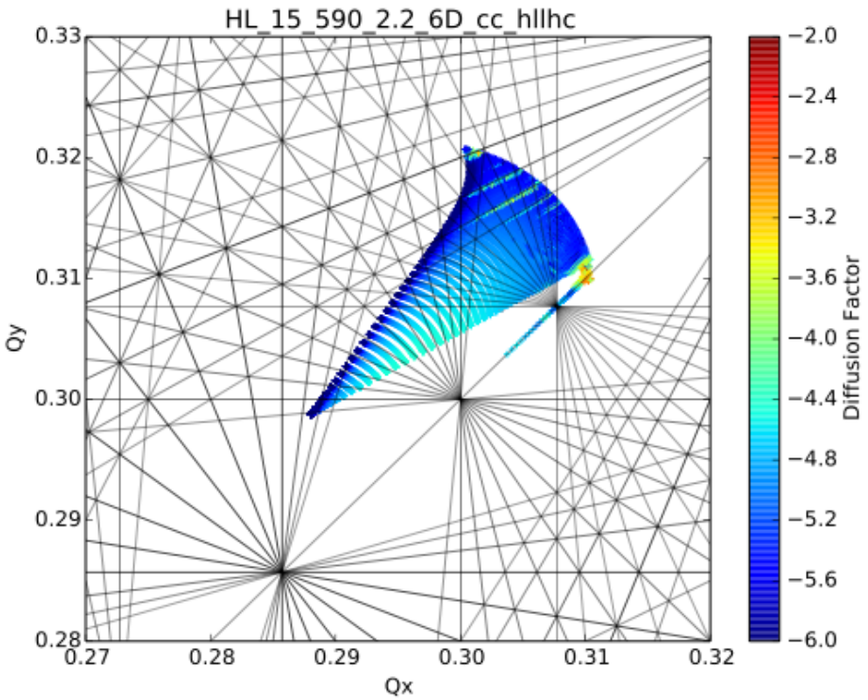
Full head-on from IP8 DQ = - 0.01

Three cases for IP8 LRs at 3m β*:

- α_{IP8} = 610 μrad → all LR $d_{sep} > 43\ \sigma$
- α_{IP8} = 290 μrad → 2 LR with d_{sep} 20σ all others LR $d_{sep} > 38\ \sigma$
- α_{IP8} = 70μrad → 2 LR with d_{sep} 5σ all others LR $d_{sep} > 15\ \sigma$

HLLHCV1.0: effect of IP8

IP1 & IP5 only HLLHCV1.0 optic



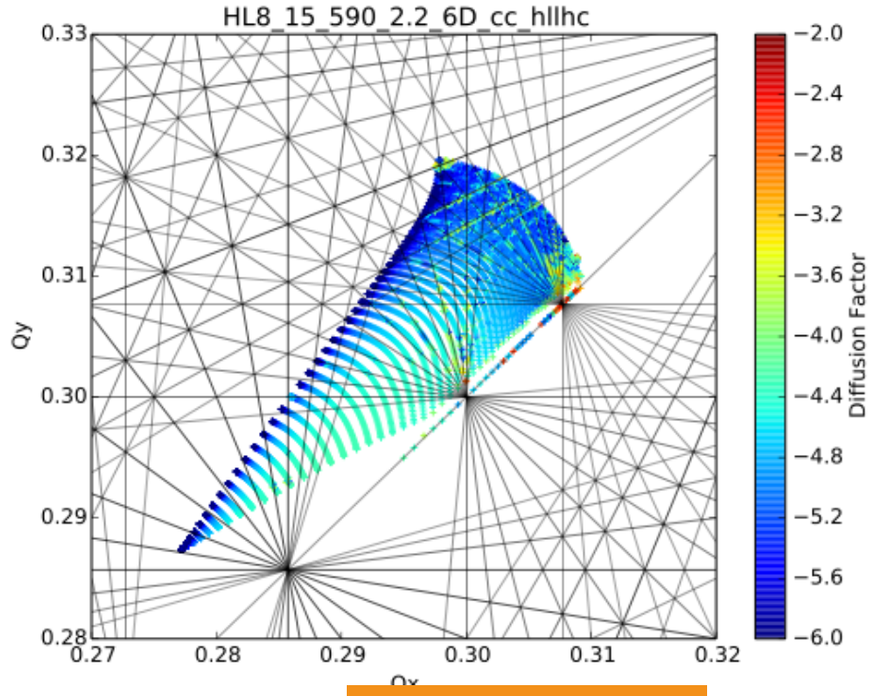
	No IP8	IP8 610µrad (neg spectr)	IP8 290µrad (pos spectr)	IP8 70µrad (pos spectr)
1.0	8.41	8.07	7.93	7.72
2.2	6.42	6.28	6.06	5.86

LHCb spectrometer add +/- 270 µrad, depending on polarity

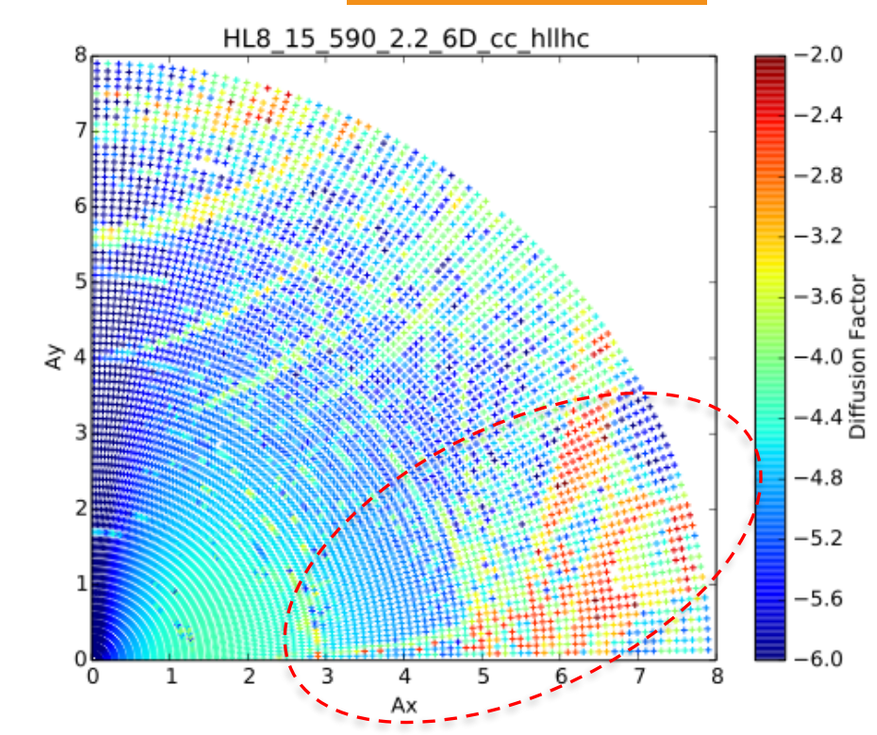
Full head-on from IP8 DQ = - 0.01

Three cases for IP8 LRs at 3m β*:

- **α_{IP8} = 610 µrad → ΔDA = -0.35@2.2e11 (0.14@1.0e11) σ**
- **α_{IP8} = 290 µrad → ΔDA = -0.5@2.2e11 (0.36@1.0e11) σ**
- **α_{IP8} = 70µrad → ΔDA = -0.7@2.2e11 (0.56@1.0e11) σ**

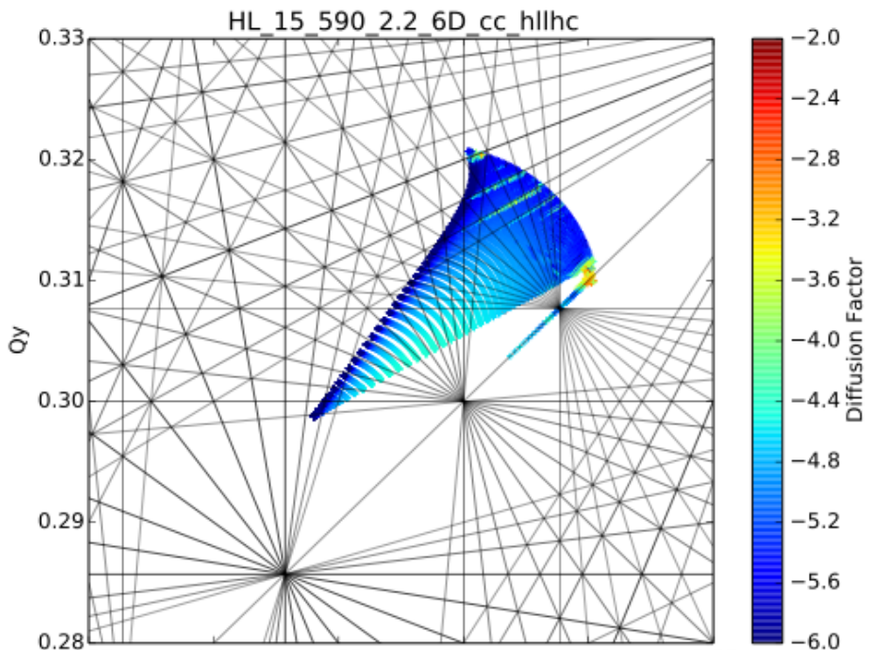


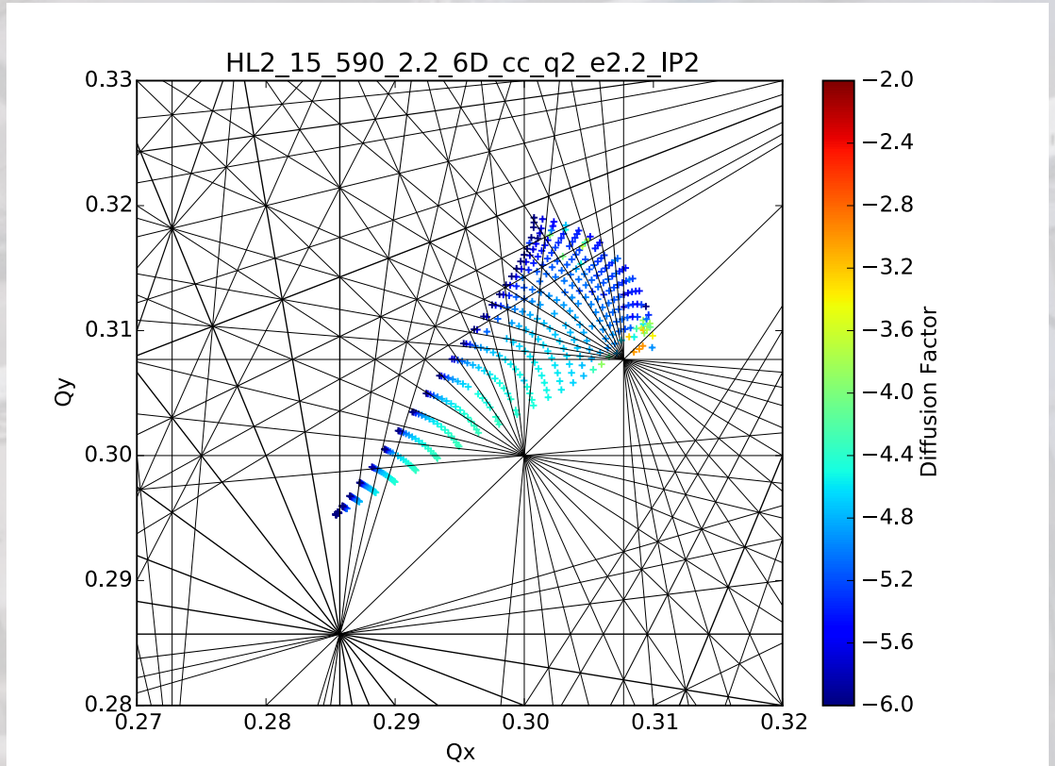
IP1&5 + IP8



HLLHCV1.0 : IP1 & IP5 + IP2

IP1 & IP5 only HLLHCV1.0 optic





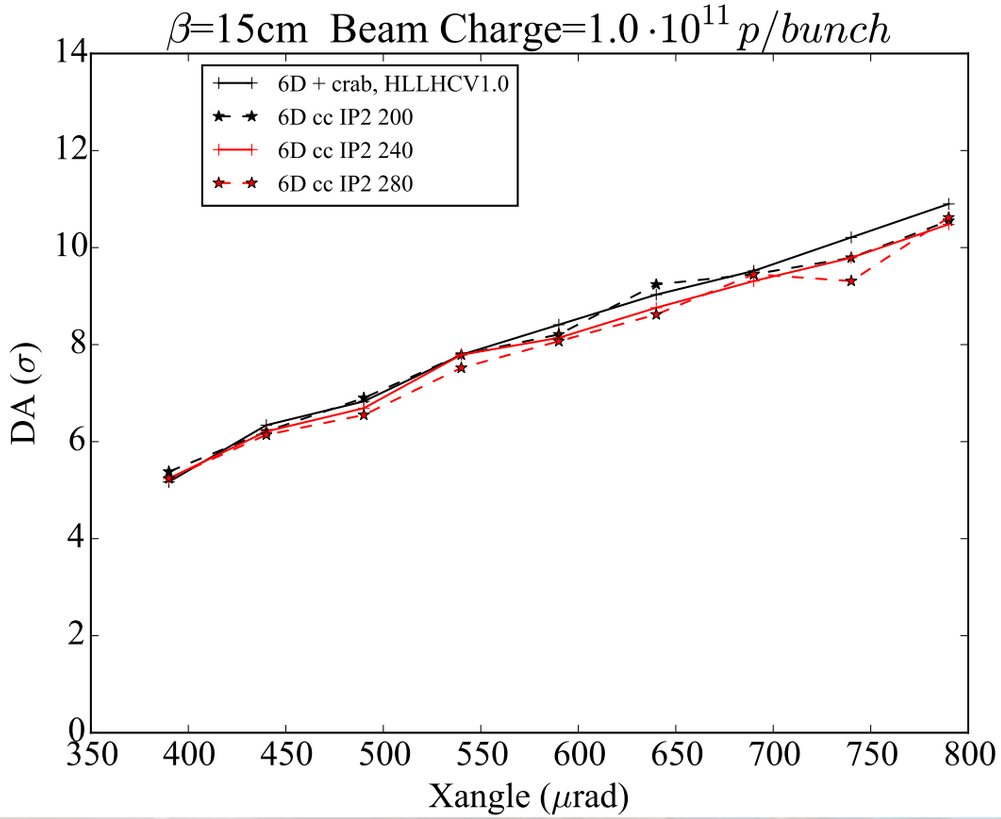
ALICE spectrometer add + 70 μrad

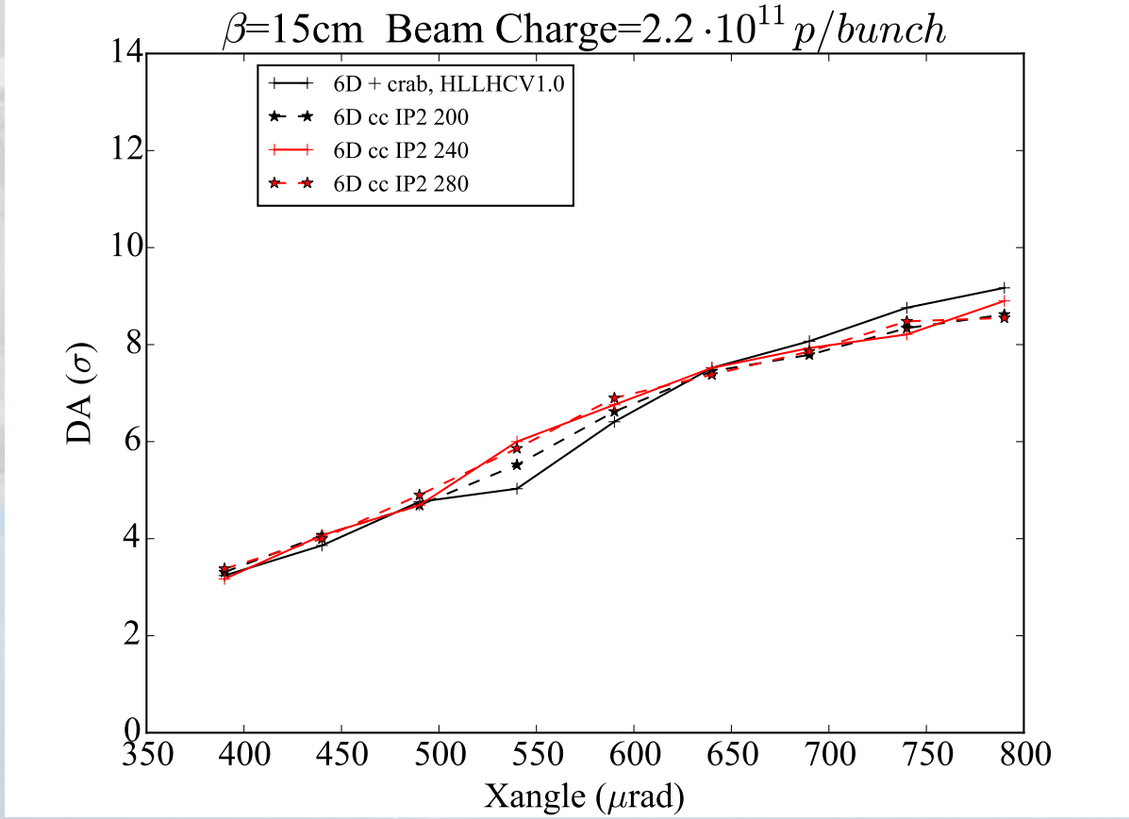
IP2 nominal half x-ing = 170 μrad, simulated also 130 μrad and 210 μrad

Full head-on from IP2 DQ = - 0.005

DA variation is very small, almost within 0.5 σ

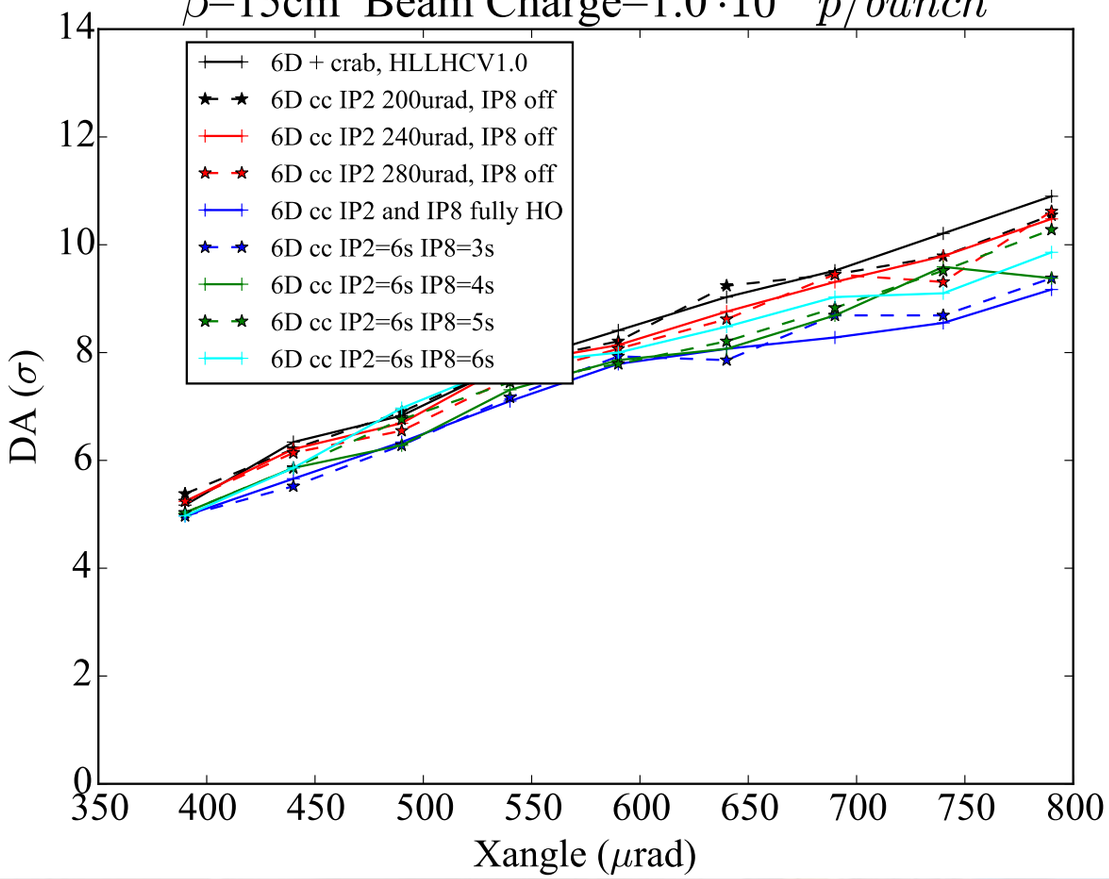
IP2

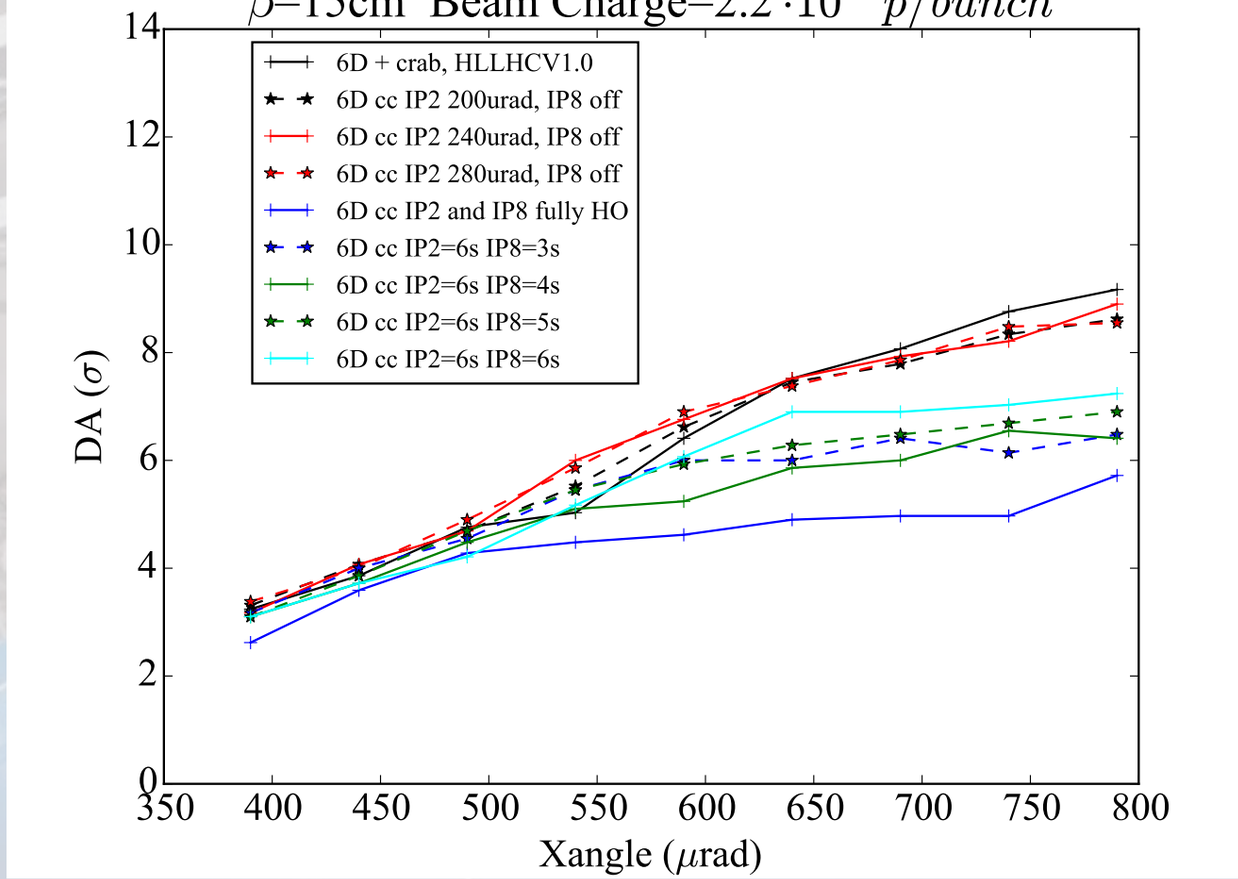




ALICE spectrometer add + 70 μrad
200 μrad (half)= 130 μrad external + 70 μrad Alice
240 μrad (half)= 170 μrad external + 70 μrad Alice
280 μrad (half)= 210 μrad external + 70 μrad Alice
Full head-on from IP2 DQ = - 0.005
DA variation is very small, almost within 0.5 σ

IP8 + IP2

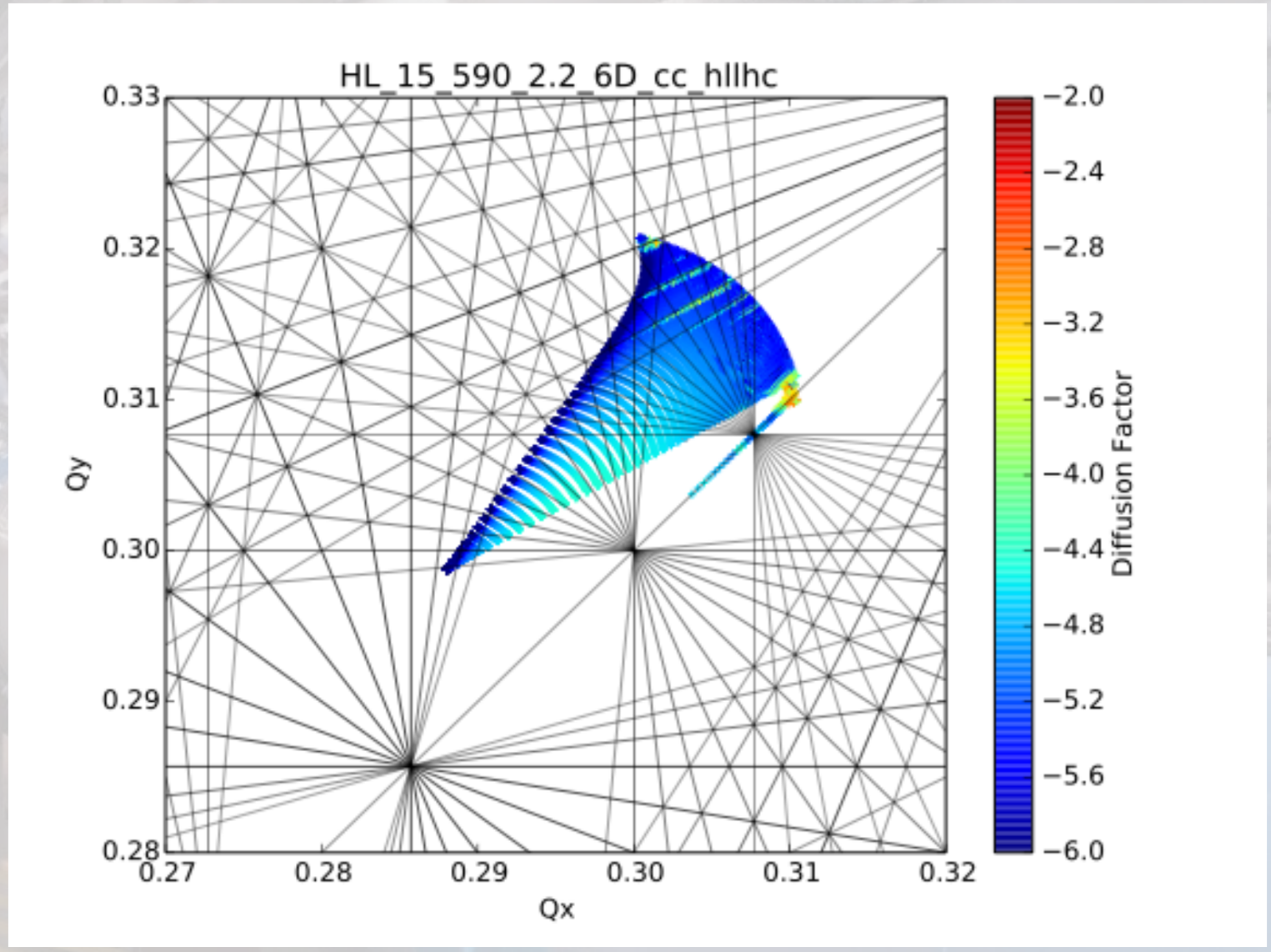




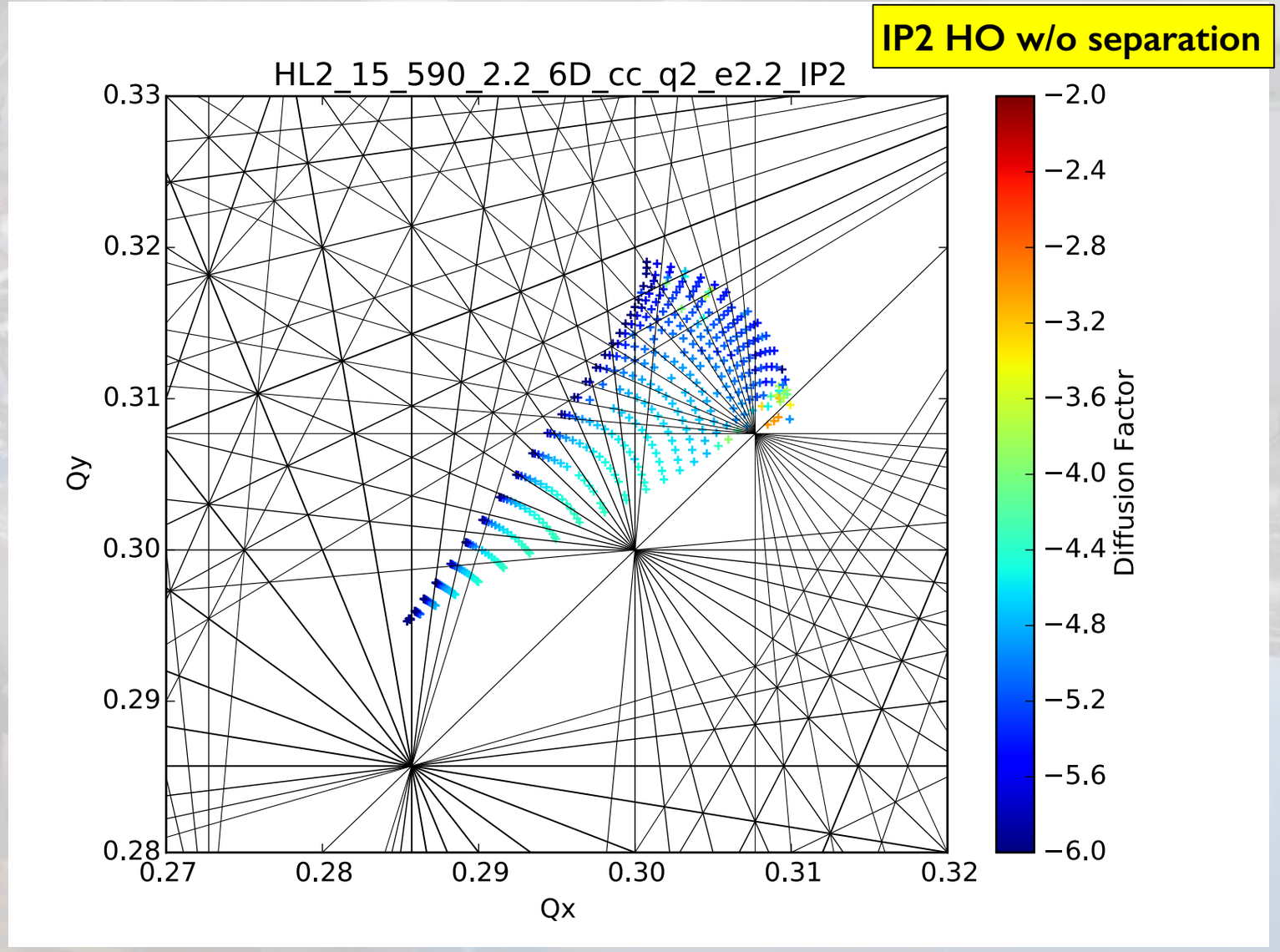
IP2 at 6 σ separation
IP8 from 6 σ to 3 σ

Nominal scenario with int=2.2E11is not realistic with IP2 and 8 at nominal separations

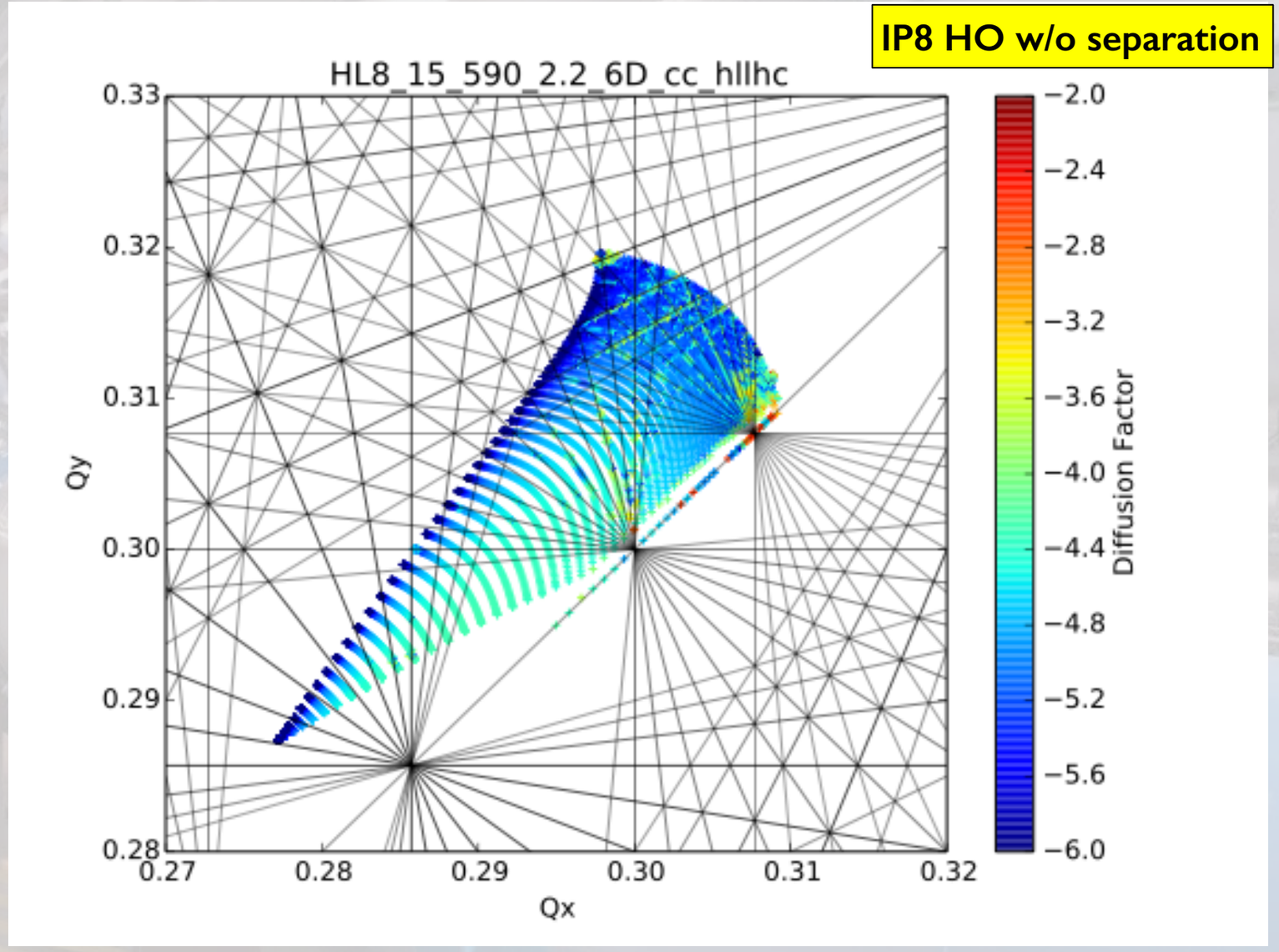
HLLHCV1.0 : IP1 & IP5



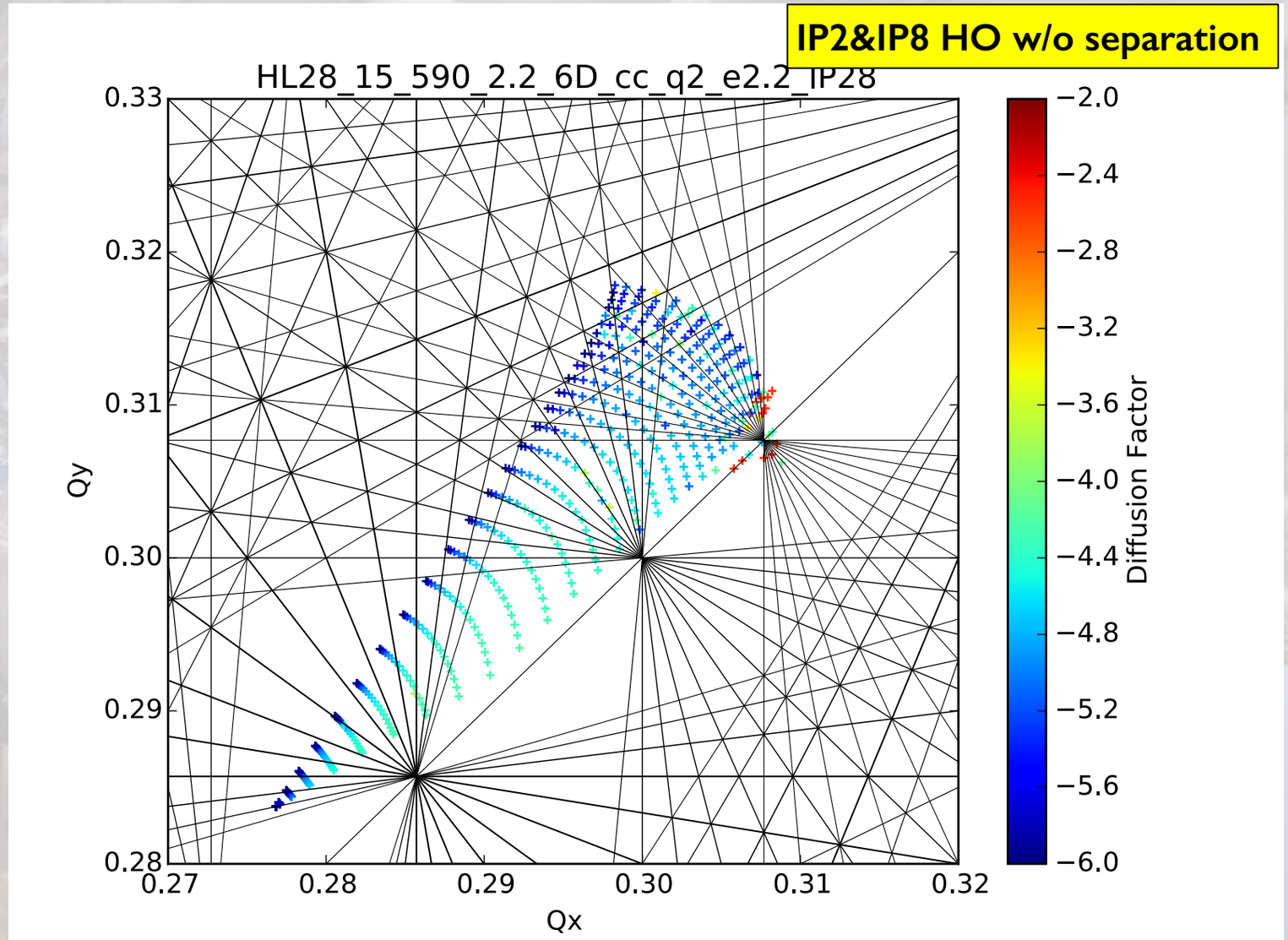
HLLHCV1.0 : IP1 & IP5 + IP2



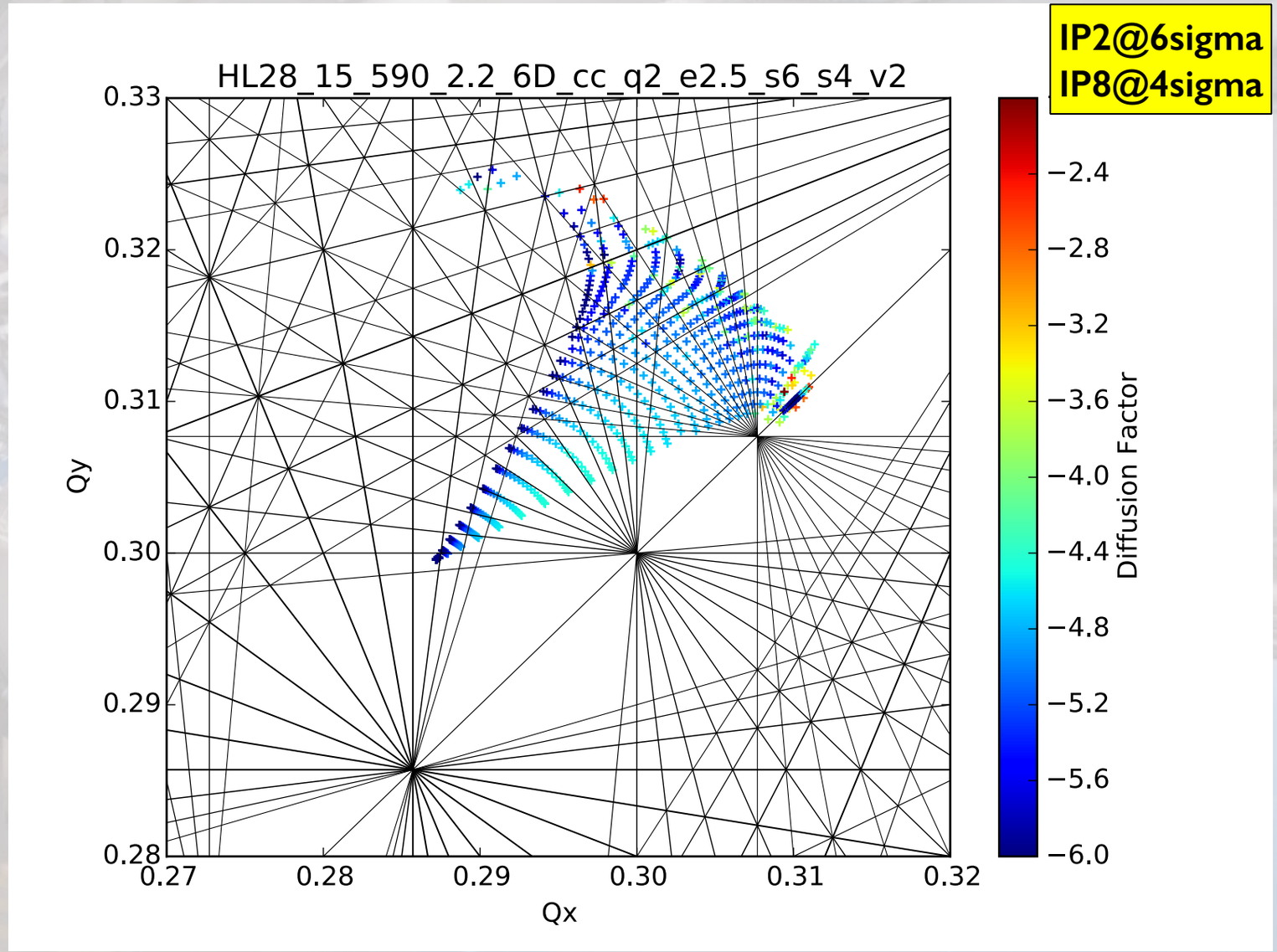
HLLHCV1.0 : IP1 & IP5 + IP8



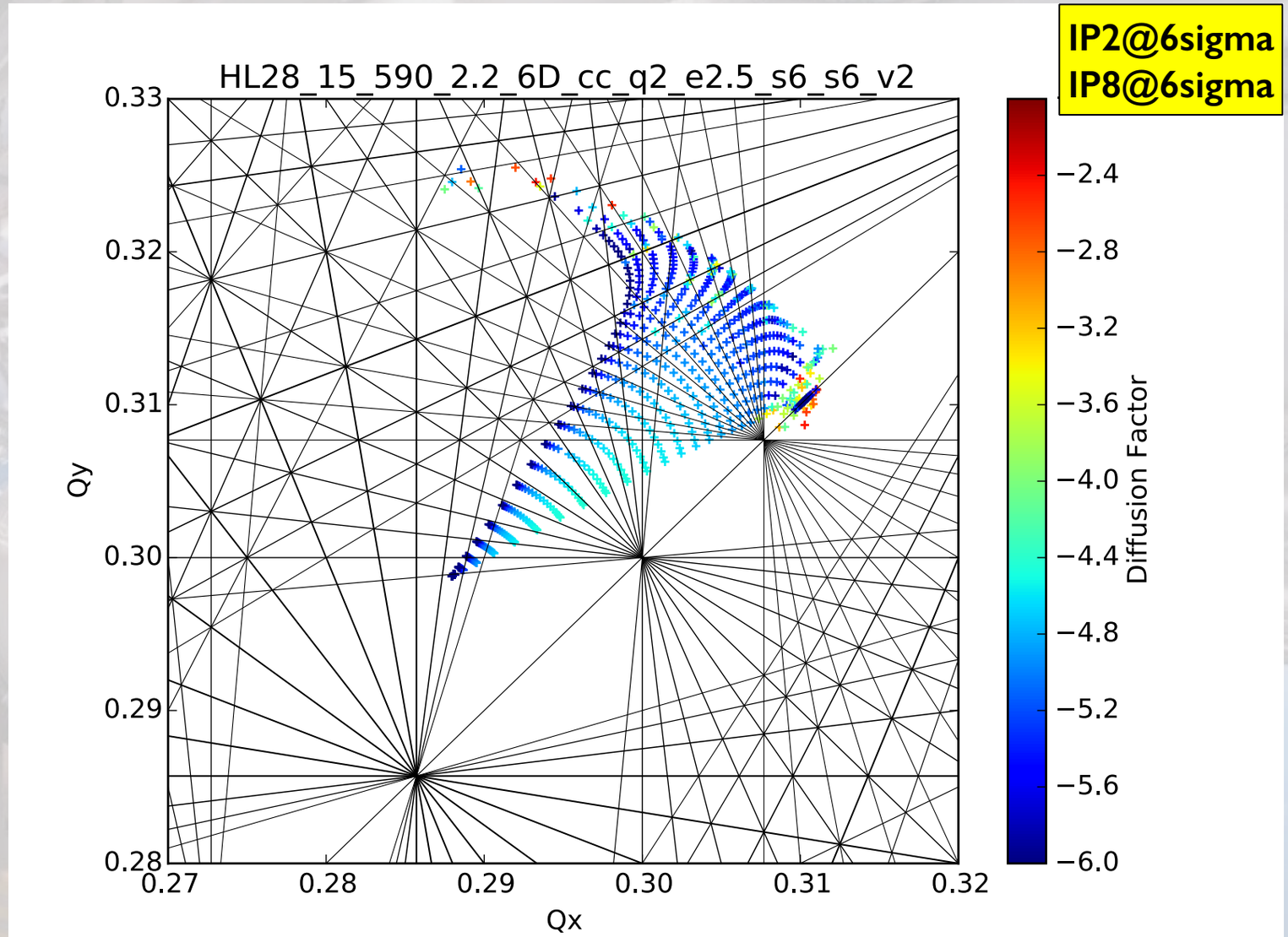
HLLHCV1.0 : IP1 & IP5 + IP2 + IP8



HLLHCV1.0 : IP1 & IP5 + IP2 + IP8



HLLHCV1.0 : IP1 & IP5 + IP2 + IP8



Summary

- **Without β* levelling:** at nominal crossing angle of 590µrad (IP1&5 only) the nominal intensity of 2.2E11 is below 6σ DA
- **Lifetrac and Sixtrack** are consistent and give equivalent results (within 10-20%)

Round Optics

- For both codes with **β* luminosity levelling at 5E34** the baseline scenario for round optic is robust: DA always above 7σ

  → room for an important reduction of crossing angle if needed (down to 450µrad) or allow for higher intensities
- For both codes with **β* luminosity levelling at 7.5E34** the scenario for round optic is also robust: DA always above 6σ
- **Multipolar errors reduce DA in the worst case of 0.5-1σ**.

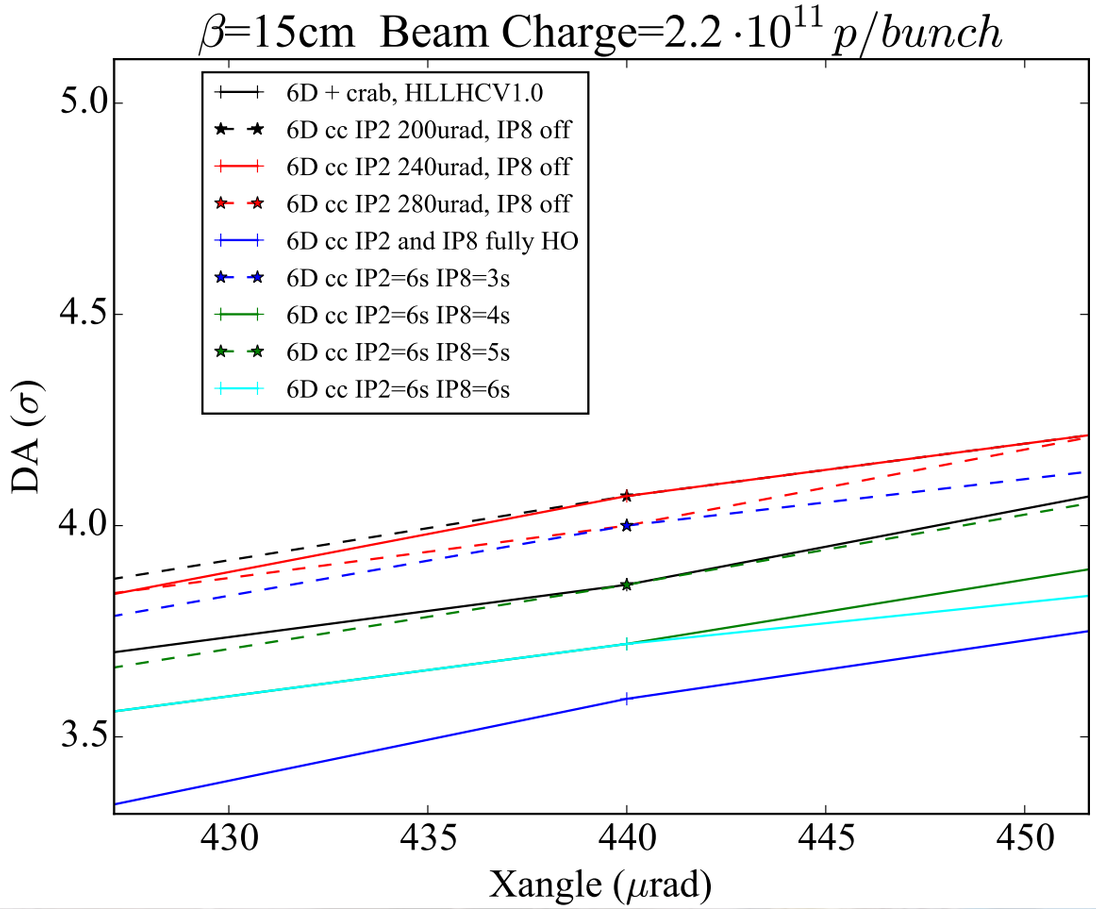
- **IP8 contribution to DA:** deterioration of maximum 0.5 σ expected in the worst case scenario (baseline & ultimate scenario are OK)
- **IP2 contribution to DA:** deterioration of maximum 0.5 σ expected in the worst case scenario (baseline & ultimate scenario are OK)
- extreme case **IP2&IP8 contribution to DA (0.035 BB parameter limit TO BE UNDERSTOOD) :**

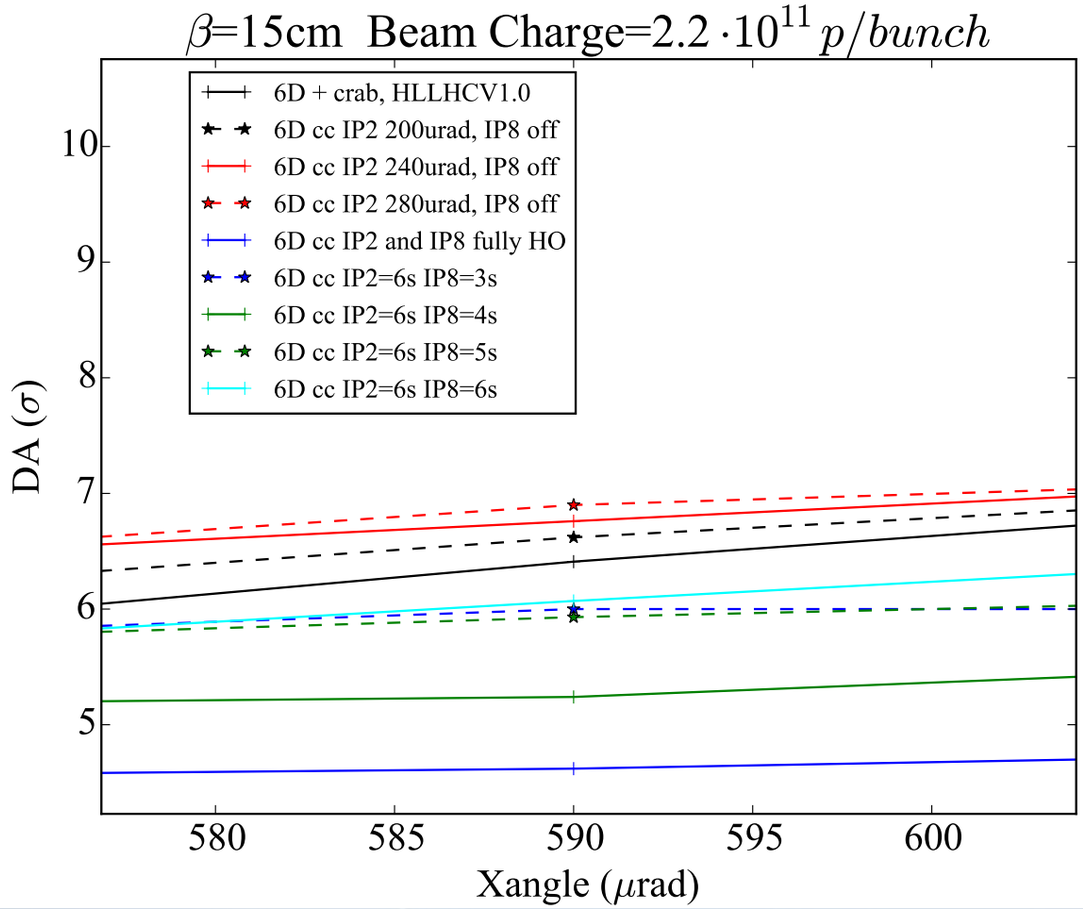
  - fully HO: 4 HO dominate DA(not realistic), DA below 6 sigma and independent on LR IP1&5

  - **separated**: at least 6 sigma separation needed in both IP2 & 8 to preserve ~6sigma DA

BackUp Slides

IP8 + IP2





IP2 at 6 σ separation
IP8 from 6 σ to 3 σ

Nominal scenario with int=2.2E11is not realistic with IP2 and 8 at nominal separations

Round optics - Simulation Details

optics files:

SLHC optics:

/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/opt_0400_0400thin.madx beta*=40cm in IR1/5, beta*=10 m in IR2/8
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/opt_0330_0330thin.madx beta*=33cm in IR1/5, beta*=10 m in IR2/8
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/opt_0150_0150thin.madx beta*=15cm in IR1/5, beta*=10 m in IR2/8
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/opt_0100_0100thin.madx beta*=10cm in IR1/5, beta*=10 m in IR2/8

HLLHC optics:

/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/opt_round_thin.madx

error tables:

for old simulations:

/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/errors/IT_errortable_v3 target error table for the new IT
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/errors/D1_errortable_v1 target error table for the new D1
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/errors/D2_errortable_v1 target error table for the new D2
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/errors/Q4_errortable_v1 target error table for the new Q4 in IR1 and IR5
/afs/cern.ch/eng/lhc/optics/SLHCV3.1b/errors/Q5_errortable_v0 target error table for the new Q5 in IR1 and IR5 and IR6

new error study:

/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/errors/IT_errortable_v3_spec";! target error table for the new IT
/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/errors/D1_errortable_v1_spec";! target error table for the new D1
/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/errors/D2_errortable_v5_spec ";! target error table for the new D2
/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/errors/Q4_errortable_v1_spec";! target error table for the new Q4 in IR1 and IR5
/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/errors/Q5_errortable_v0_spec";! target error table for the new Q5 in IR1 and IR5 and IR6

IP8 conf:

nominal crossing angle
sep = 0, solenoid on at nominal field
21 slices