Review of the crossing scheme for SLHCV3 crab-cavity optics

R. De Maria

Thanks to M. Giovannozzi, S. Fartoukh, O. Brüning, R. Calaga, R. Tomas

February 8, 2011

Content and motivation

- review of the crossing scheme proposed for LHC-CC10.
- proposal for an alternative crossing scheme closed before D2 [1]

closing at D2:

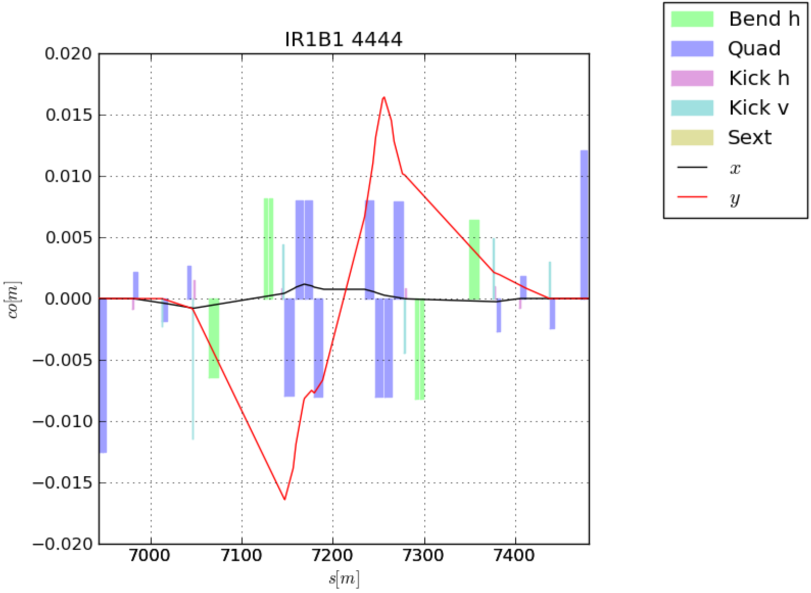
- implies that the closed orbit at the crab cavities is not affected by any crossing scheme gymnastic (change of specifications between runs, change of crossing angle from injection to collision, removal of separation)
- allows to reduce the aperture required in D2 and Q4 that can be used either for simplifying the magnet requirements or, possibly, reduce the voltage in the cavity at constant kick.

[1] For an earlier discussion see LHC project report 315, where this option (probably in the lost LHC project note 136) was dismissed due to strength and complexity reasons.

Specifications

- collision:
  - $\beta^* = 15$cm, crossing angle $580\,\mu\mathrm{rad}$, separation 1.5mm
- The max close orbit excursion at the cavity is:
  - $3.354\,\mathrm{mm}$ for 10σ crossing angle
  - $0.67\,\mathrm{mm}$ for $1.5\,\mathrm{mm}$ separation
- injection:
  - $\beta^* = 13$m, crossing angle $340\,\mu\mathrm{rad}$, separation 5.0mm

CC10: Crossing scheme orbits



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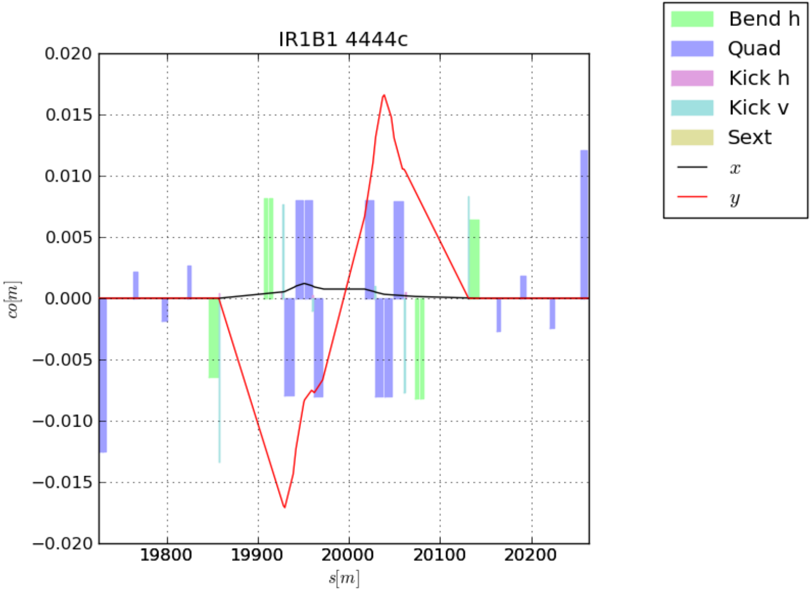

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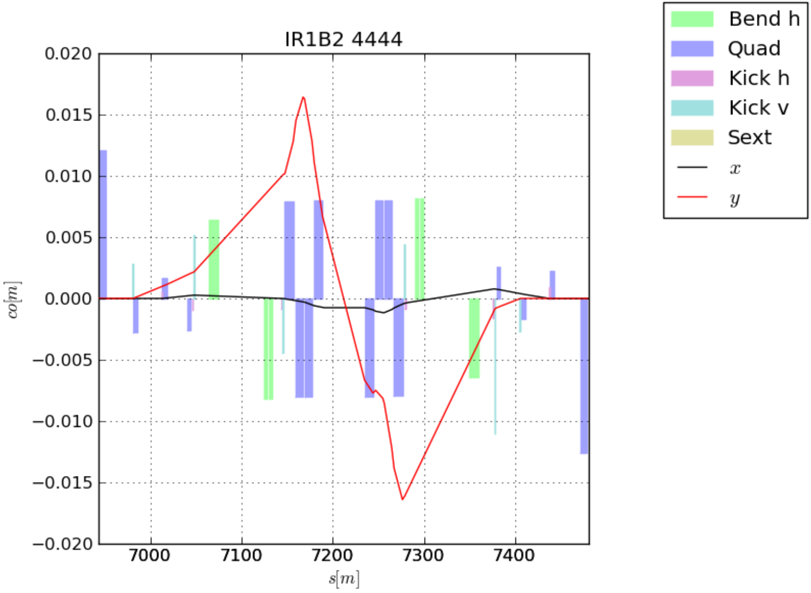

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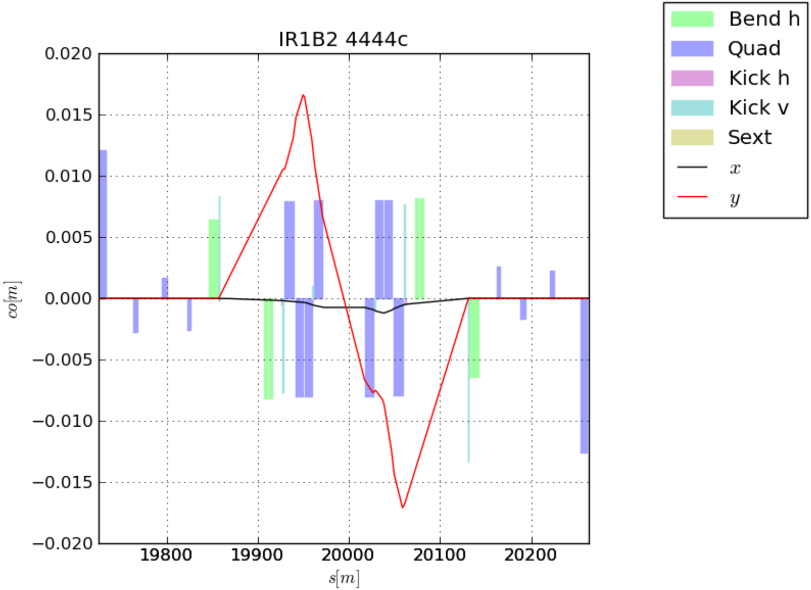

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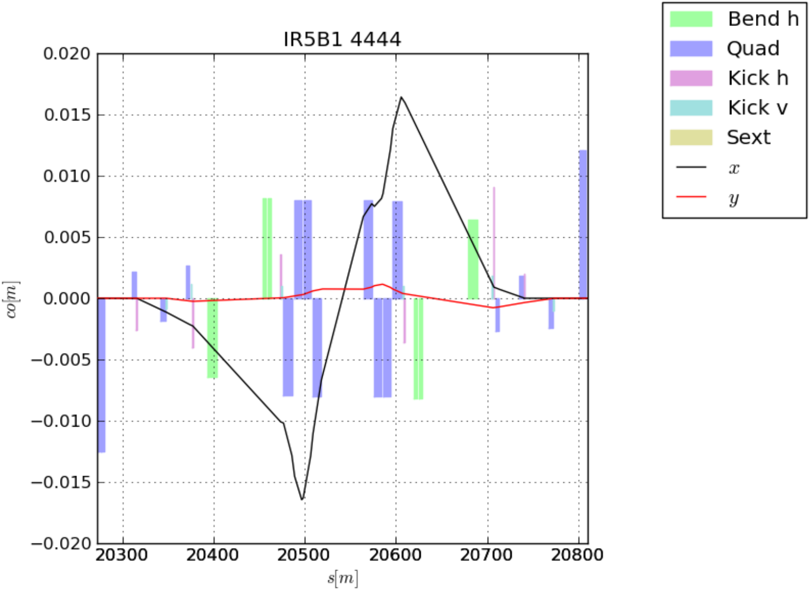

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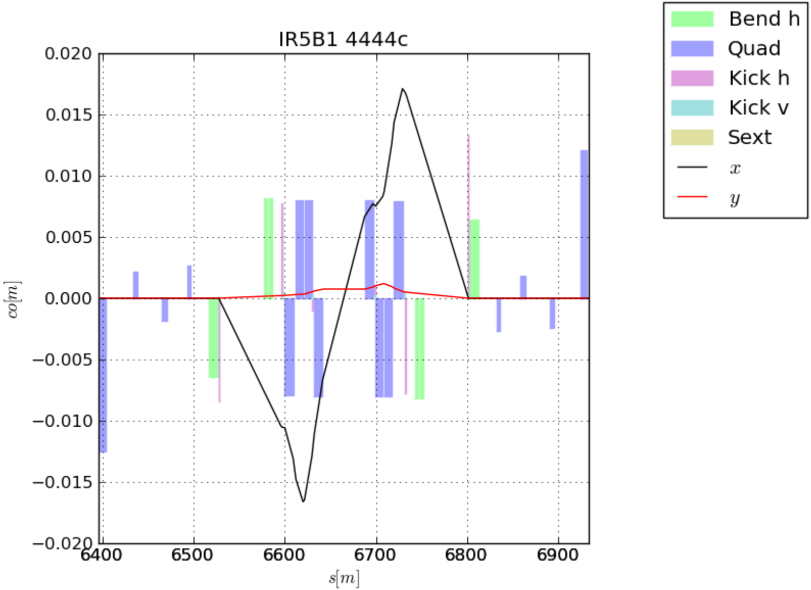

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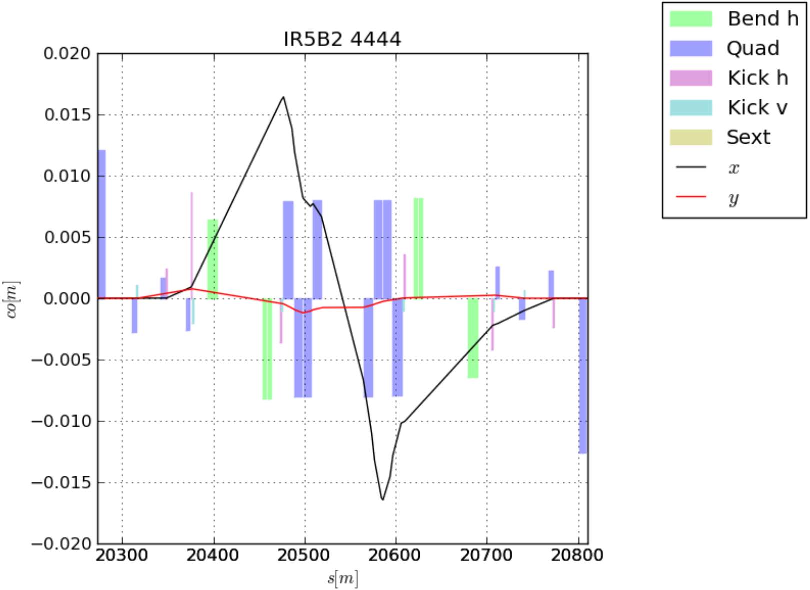

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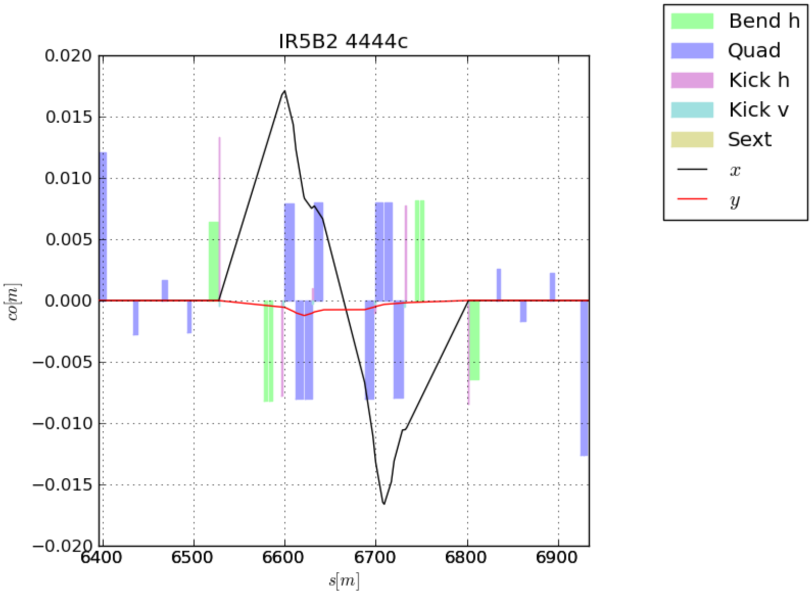


CC10: Crossing scheme strengths

```
acbxh3.l1    :=   10.80E-6 * on_sep1;  acbxh3.l5    :=   49.00E-6 * on_x5  ;
acbxv3.l1    :=   49.00E-6 * on_x1  ;  acbxv3.l5    :=   10.80E-6 * on_sep5;

acbyvs4.l1b1 := -126.26E-6 * on_x1  ;  acbyvs4.l5b1 :=   13.18E-6 * on_sep5;
acbyvs4.r1b1 :=   54.68E-6 * on_x1  ;  acbyvs4.r5b1 :=   20.58E-6 * on_sep5;
acbcv5.l1b1  :=  -24.71E-6 * on_x1  ;  acbcv5.l5b1  :=   -9.25E-6 * on_sep5;
acbcv6.r1b1  :=   33.33E-6 * on_x1  ;  acbcv6.r5b1  :=  -11.07E-6 * on_sep5;
acbyhs4.l1b1 :=   20.77E-6 * on_sep1;  acbyhs4.l5b1 :=  -53.69E-6 * on_x5  ;
acbyhs4.r1b1 :=   13.88E-6 * on_sep1;  acbyhs4.r5b1 :=  123.55E-6 * on_x5  ;
acbch6.l1b1  :=  -11.30E-6 * on_sep1;  acbch6.l5b1  :=  -34.55E-6 * on_x5  ;
acbch5.r1b1  :=   -9.86E-6 * on_sep1;  acbch5.r5b1  :=   27.04E-6 * on_x5  ;

acbyvs4.l1b2 :=   57.33E-6 * on_x1  ;  acbyvs4.l5b2 :=  -21.71E-6 * on_sep5;
acbyvs4.r1b2 := -121.14E-6 * on_x1  ;  acbyvs4.r5b2 :=  -11.48E-6 * on_sep5;
acbcv6.l1b2  :=   31.06E-6 * on_x1  ;  acbcv6.l5b2  :=   12.09E-6 * on_sep5;
acbcv5.r1b2  :=  -29.71E-6 * on_x1  ;  acbcv5.r5b2  :=    7.69E-6 * on_sep5;
acbyhs4.l1b2 :=  -12.07E-6 * on_sep1;  acbyhs4.l5b2 :=  117.95E-6 * on_x5  ;
acbyhs4.r1b2 :=  -21.93E-6 * on_sep1;  acbyhs4.r5b2 :=  -56.43E-6 * on_x5  ;
acbch5.l1b2  :=    8.21E-6 * on_sep1;  acbch5.l5b2  :=   32.51E-6 * on_x5  ;
acbch6.r1b2  :=   12.36E-6 * on_sep1;  acbch6.r5b2  :=  -32.05E-6 * on_x5  ;
```

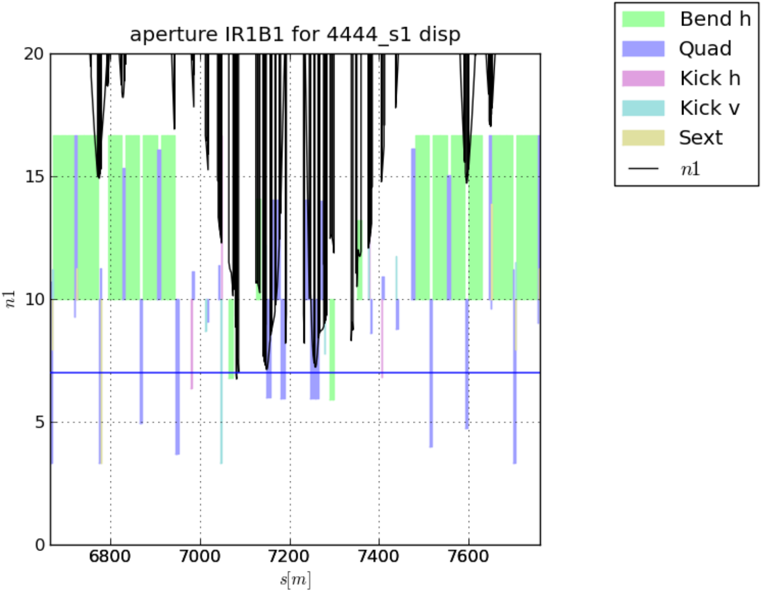
closed: Crossing scheme strengths

```
acbxh2a.l1   :=    5.02E-6 * on_sep1; acbxh2a.l5   :=  -17.66E-6 * on_x5  ;
acbxh2a.r1   :=    5.02E-6 * on_sep1; acbxh2a.r5   :=   17.66E-6 * on_x5  ;
acbxv2a.l1   :=  -17.66E-6 * on_x1  ; acbxv2a.l5   :=    5.02E-6 * on_sep5;
acbxv2a.r1   :=   17.66E-6 * on_x1  ; acbxv2a.r5   :=    5.02E-6 * on_sep5;

acbxh3.l1    :=    9.83E-6 * on_sep1; acbxh3.l5    :=  140.89E-6 * on_x5  ;
acbxh3.r1    :=    9.83E-6 * on_sep1; acbxh3.r5    := -140.89E-6 * on_x5  ;
acbxv3.l1    :=  137.67E-6 * on_x1  ; acbxv3.l5    :=    9.60E-6 * on_sep5;
acbxv3.r1    := -137.67E-6 * on_x1  ; acbxv3.r5    :=    9.60E-6 * on_sep5;

acb2h_l1b1   :=    7.10E-6 * on_sep1; acb2h_l5b1   := -152.92E-6 * on_x5  ;
acb2h_l1b2   :=    2.49E-6 * on_sep1; acb2h_l5b2   := -243.11E-6 * on_x5  ;
acb2h_r1b1   :=    2.49E-6 * on_sep1; acb2h_r5b1   :=  243.11E-6 * on_x5  ;
acb2h_r1b2   :=    7.10E-6 * on_sep1; acb2h_r5b2   :=  152.92E-6 * on_x5  ;
acb2v_l1b1   := -239.89E-6 * on_x1  ; acb2v_l5b1   :=    2.71E-6 * on_sep5;
acb2v_l1b2   := -149.70E-6 * on_x1  ; acb2v_l5b2   :=    7.33E-6 * on_sep5;
acb2v_r1b1   :=  149.70E-6 * on_x1  ; acb2v_r5b1   :=    7.33E-6 * on_sep5;
acb2v_r1b2   :=  239.89E-6 * on_x1  ; acb2v_r5b2   :=    2.71E-6 * on_sep5;
```

closed inj.: Crossing scheme strengths

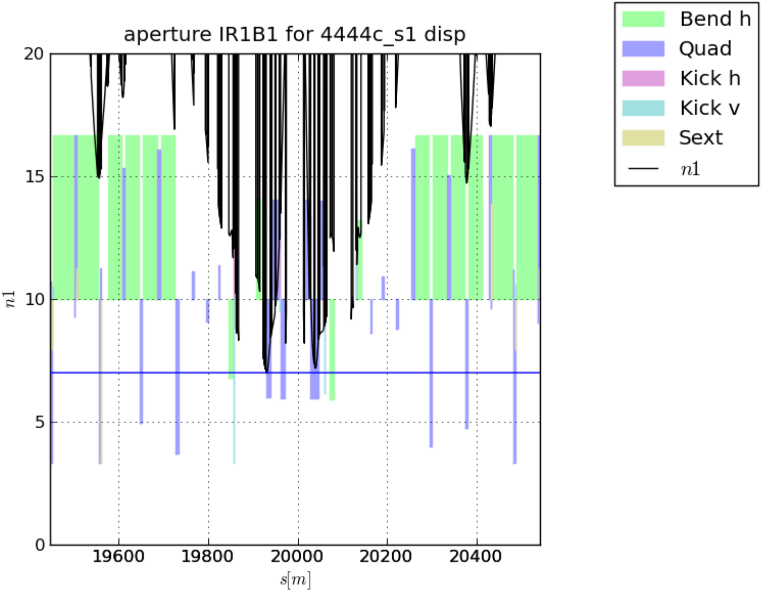
```
acbxh2a.l1   :=    6.01E-6 * on_sep1;  acbxh2a.l5   :=   12.26E-6 * on_x5  ;
acbxh2a.r1   :=    6.01E-6 * on_sep1;  acbxh2a.r5   :=  -12.26E-6 * on_x5  ;
acbxv2a.l1   :=   12.26E-6 * on_x1  ;  acbxv2a.l5   :=    6.01E-6 * on_sep5;
acbxv2a.r1   :=  -12.26E-6 * on_x1  ;  acbxv2a.r5   :=    6.01E-6 * on_sep5;

acbxh3.l1    :=   39.32E-6 * on_sep1;  acbxh3.l5    :=   72.65E-6 * on_x5  ;
acbxh3.r1    :=   39.32E-6 * on_sep1;  acbxh3.r5    :=  -72.65E-6 * on_x5  ;
acbxv3.l1    :=   70.98E-6 * on_x1  ;  acbxv3.l5    :=   38.42E-6 * on_sep5;
acbxv3.r1    :=  -70.98E-6 * on_x1  ;  acbxv3.r5    :=   38.42E-6 * on_sep5;

acb2h_l1b1   :=   21.49E-6 * on_sep1;  acb2h_l5b1   :=  -86.17E-6 * on_x5  ;
acb2h_l1b2   :=    3.98E-6 * on_sep1;  acb2h_l5b2   := -131.73E-6 * on_x5  ;
acb2h_r1b1   :=    3.98E-6 * on_sep1;  acb2h_r5b1   :=  131.73E-6 * on_x5  ;
acb2h_r1b2   :=   21.49E-6 * on_sep1;  acb2h_r5b2   :=   86.17E-6 * on_x5  ;
acb2v_l1b1   := -130.07E-6 * on_x1  ;  acb2v_l5b1   :=    4.88E-6 * on_sep5;
acb2v_l1b2   :=  -84.51E-6 * on_x1  ;  acb2v_l5b2   :=   22.39E-6 * on_sep5;
acb2v_r1b1   :=   84.51E-6 * on_x1  ;  acb2v_r5b1   :=   22.39E-6 * on_sep5;
acb2v_r1b2   :=  130.07E-6 * on_x1  ;  acb2v_r5b2   :=    4.88E-6 * on_sep5;
```

CC10: Crossing scheme apertures [2]



[2] TAN not optimized

CC10: Crossing scheme apertures [2]



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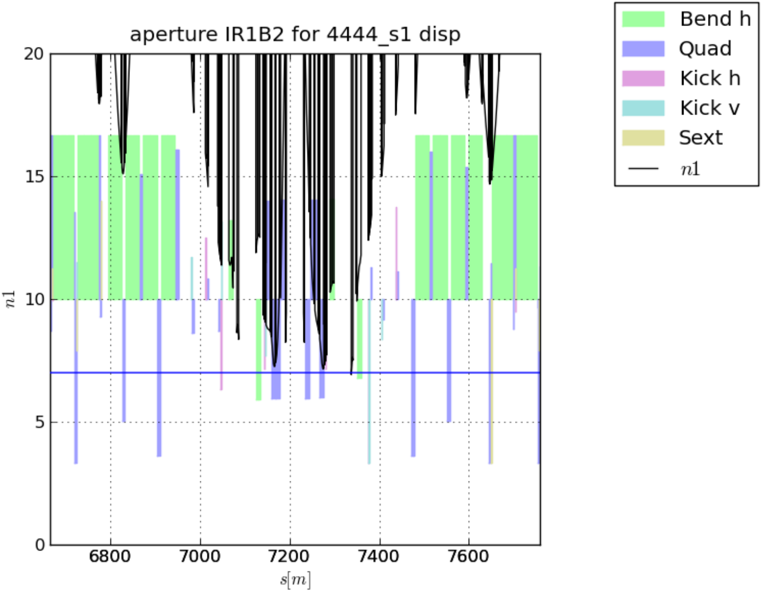

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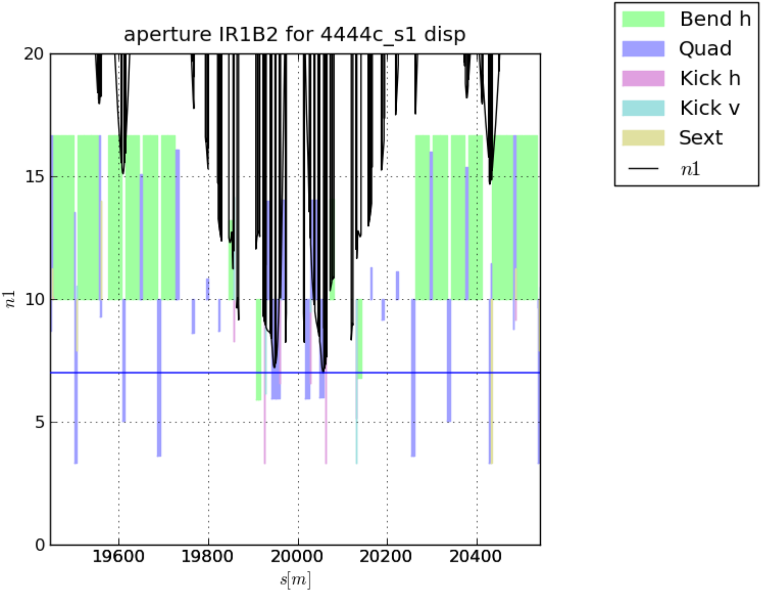
CC10: Crossing scheme apertures [2]



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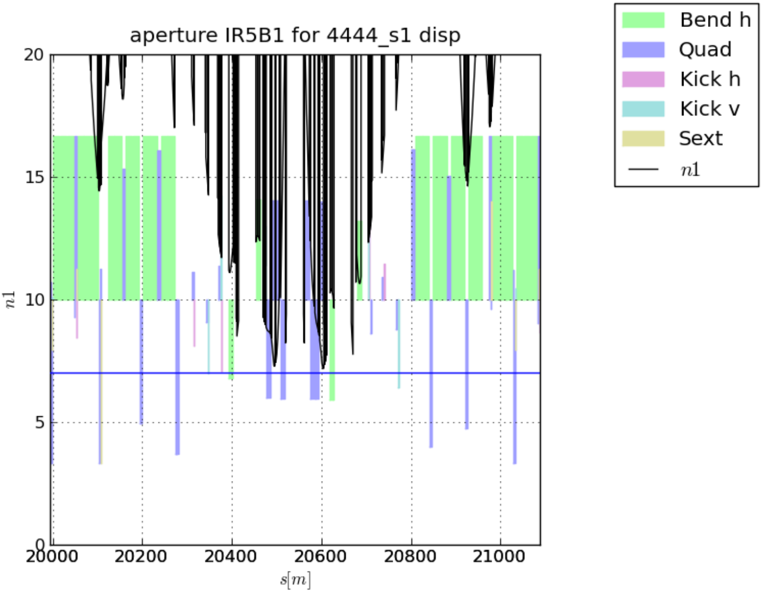
CC10: Crossing scheme apertures [2]



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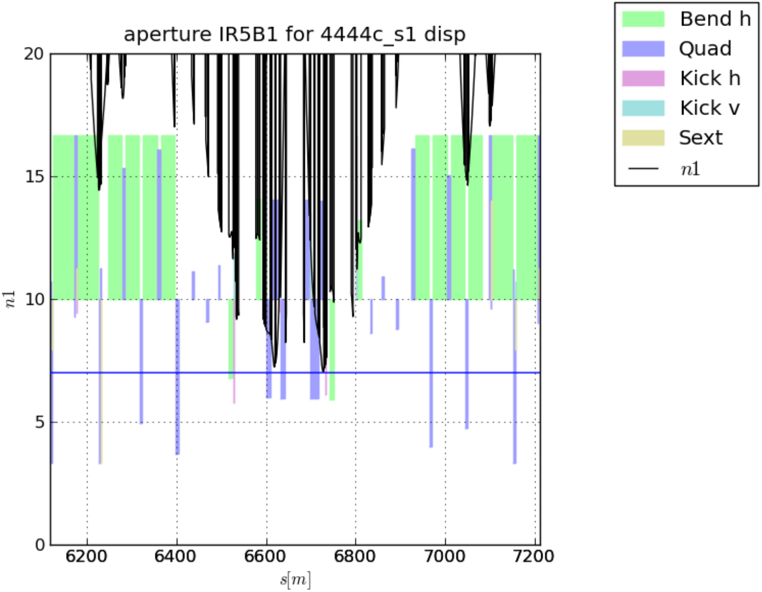
CC10: Crossing scheme apertures [2]



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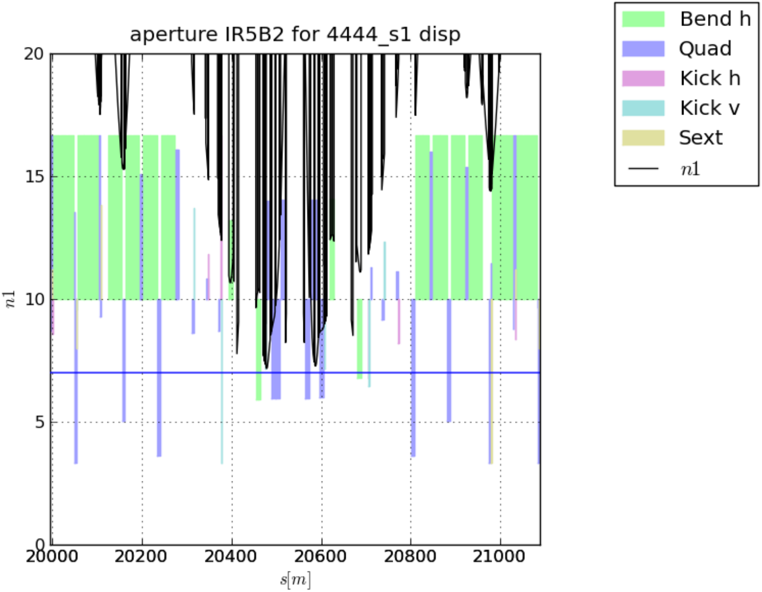
CC10: Crossing scheme apertures [2]



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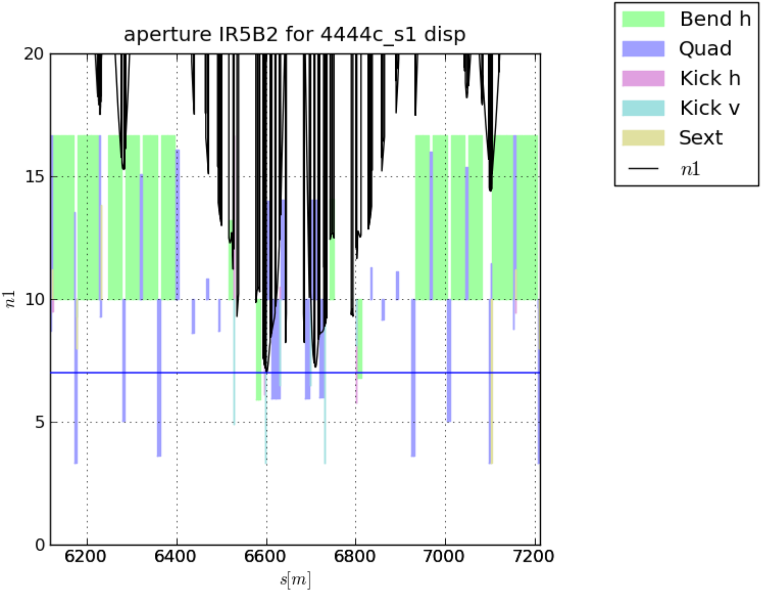
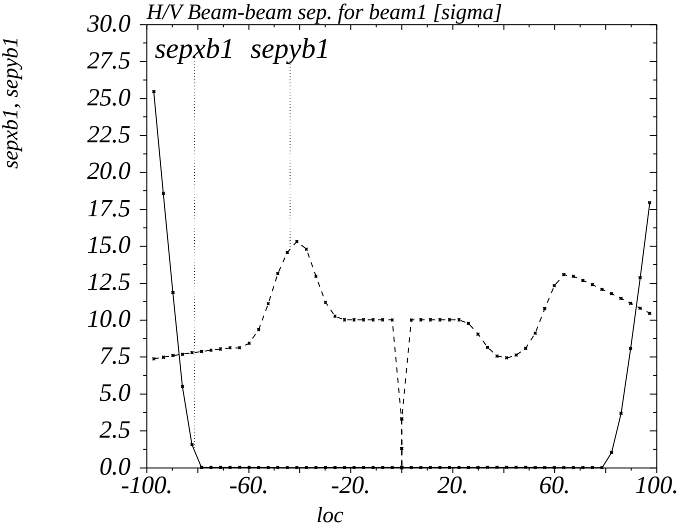
CC10: Crossing scheme apertures [2]

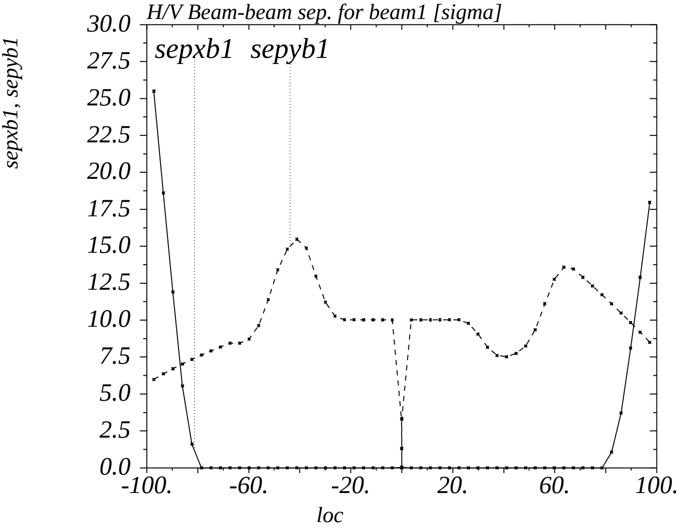


[2] TAN not optimized

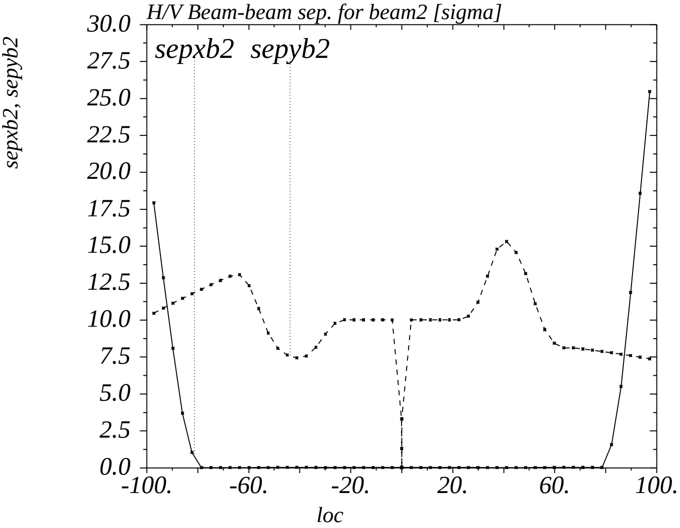
Observations CC10: IR1 beam1 sep



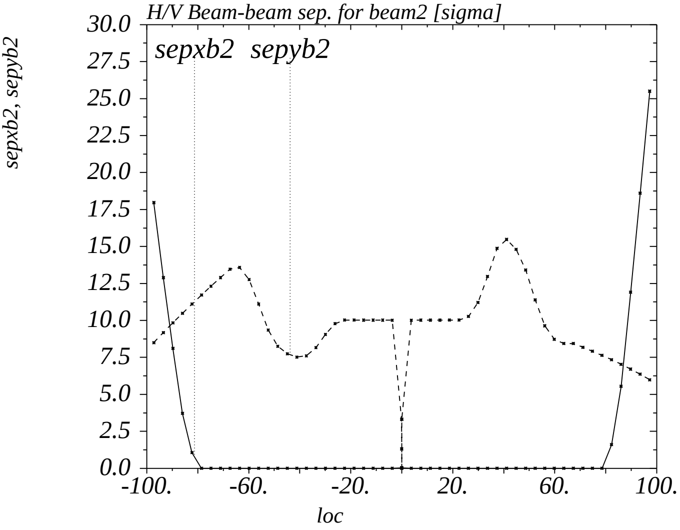
Observations closed: IR1 beam1 sep



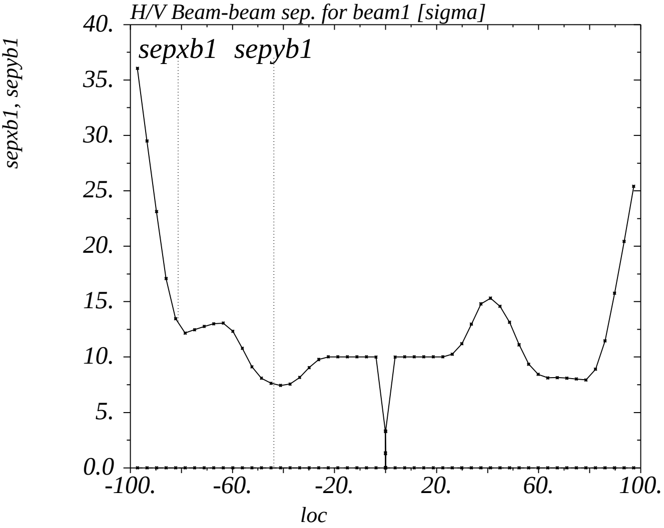
Observations CC10: IR1 beam2 sep



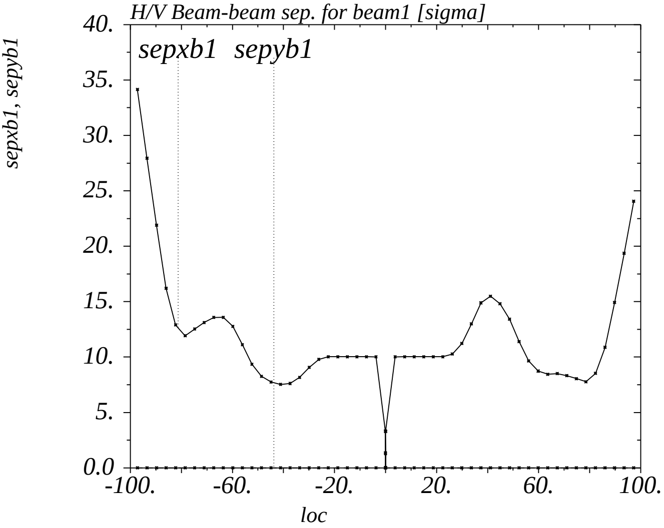
Observations closed: IR1 beam2 sep



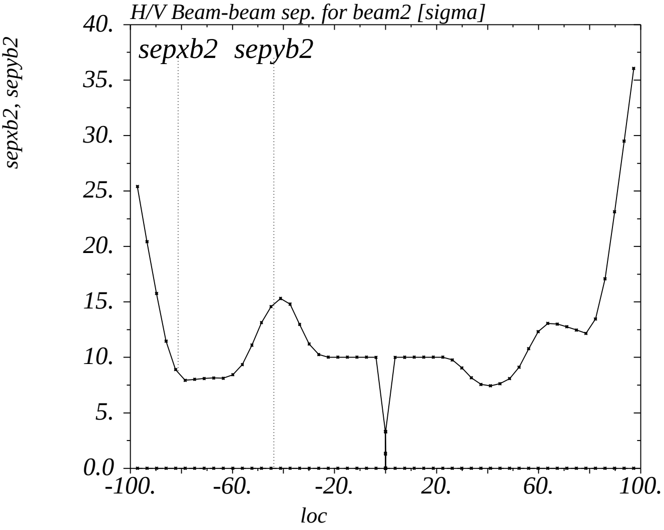
Observations CC10: IR5 beam1 sep



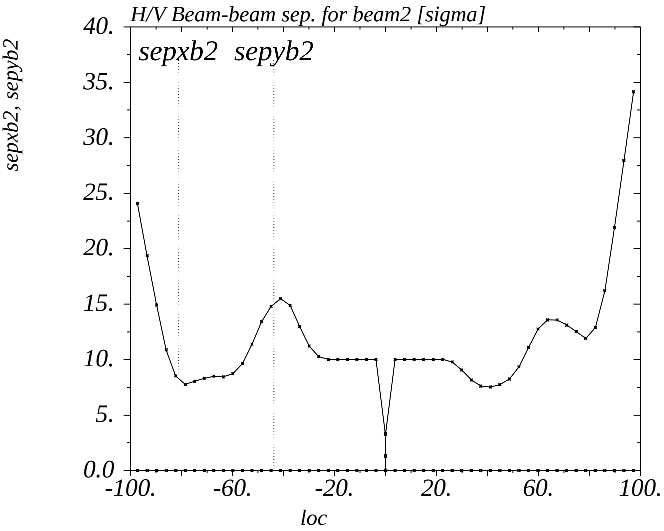
Observations closed: IR5 beam1 sep



Observations CC10: IR5 beam2 sep



Observations closed: IR5 beam2 sep



Conclusion

- Orbit correctors in D2 correspond to a strengths of 1/6 of D2 [3].

- The separation in the vertical plane is more problematic with the new scheme

- Actions:
  - verify failure scenarios with machine protection team
  - optimize the TAN, TCT, MCB, D2 region with collimation team

- In alternative:
  - combine the regular and the closed scheme, such that the former sets a base line and the latter absorb the variations at the cavity.

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[3] D2 provides ($1600\,\mu\mathrm{rad}$ for the upgrade where D2 is pushed towards the IP, $1160\,\mu\mathrm{rad}$ for nominal)