HL-LHC optics status.

R. De Maria for the Task 2.2 team and
input from WP3, WP4, WP5, WP10

CERN, Geneva

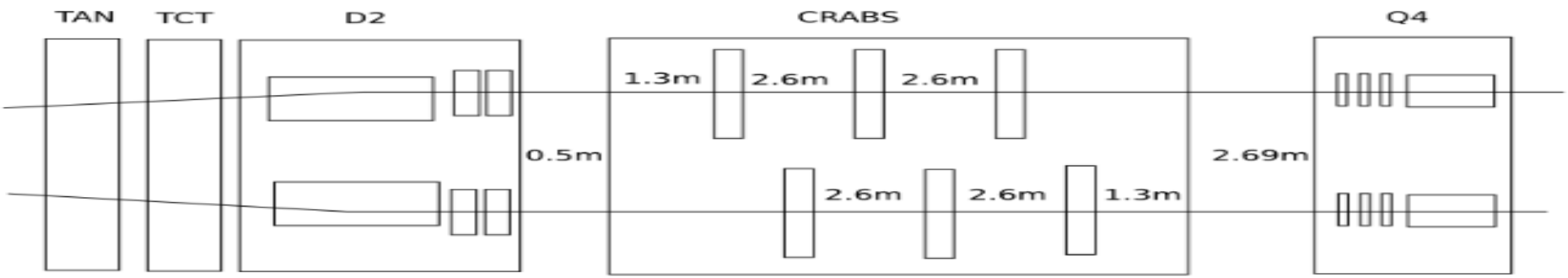
HL-LHC PLC, 2013/07/02

Status of the HLLHCV1.0 optics

- The optics repository `/afs/cern.ch/eng/lhc/optics/HLLHCV1.0` hosts the last optics and layout model for the HL-LHC. It followed the layout progress in the triplet/D1 area till this June.
- HLLHCV1.0 is now frozen and available for integration and simulation studies (please contact R. De Maria for setting up studies). Some areas are still under development (e.g. squeeze optimizations), but proofs of principle available for close configurations.
- The layout and optics are still pending validation in several areas by the relevant WPs (e.g TAN Q4 area, Q5 magnet types in IR1-5-6, orbit feedback with MCBX only). The impact of ground motion stability, field quality, beam beam effects on performance are being evaluated.
- Optics studies are ongoing for more radical changes in the Q4-Q7 region to improve optics flexibility and reduce crab voltage demands, but are not currently part of the baseline.
- Question: maximum β^* required for HL-LHC (e.g. for VDM scans).

Crab cavity voltage

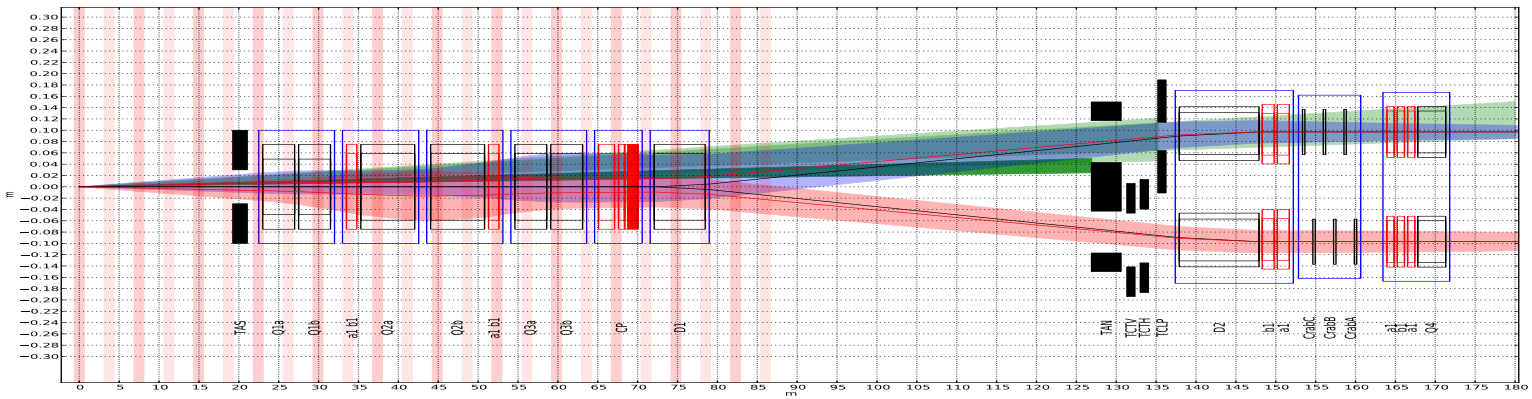
- Crab cavity required voltage is the results of: operation mode (full or partial crabbing), crossing angle (intensity, beta*, emittance), layout (location and aperture of surrounding elements) and optics.
- For full crabbing (no transverse offset for $1\sigma_z$ particles) with nominal parameters ($\beta^* = 15$ cm, $\theta_c = 590$ μrad): $V_{\mathrm{crab}} = 12.2$ MV.
- Voltage reduction options are under study: module layout (crossing plane independent or optimized), β-functions increase at the present position (relaxing pre-squeeze beta*, design of the matching section) or, if possible, change of the position closer to the IP.
- Fully integrated layout is challenging (TAN, TCT, TCL, LR wires, crab, D2, Q4, neutral debries, collimation, dump protection, background), final location might shift back to the arc resulting in a voltage increase.



D2 aperture for HL-LHCV1.0

The D2 aperture was set to 105 mm (SLHC-PR 55 in 2010) and recently 95 mm (S. Fartoukh) is being explored to:

- leave space for crab cavities in a high beta region,
- be still compatible with a TAN aperture that does not limit the β^* reach more than the triplets.



- D2 has to be protected by TAN (TAN aperture $\leq$ D2, but TAN beams are larger and $n_{1\mathrm{TAN}} > 7$ LHC Report 633);
- D2 is not protected by the TCT from the incoming beam ($n_{1\mathrm{D2}} > 14$?).
- Magnets, energy deposition and collimation performance have started to be studied by WP3, WP10 and WP5.

Backup

Selected LHC upgrade optics references

S. Fartoukh, Chamonix 2010 (detailed triplet layout for Phase I including corrector, min. beta* of 25-30 cm, and first optics concept to compensate for the off-momentum beta-betaig in the LHC)
S. Fartoukh, SLHCPR49 (2010), Chamonix 2011, and IPAC11 (removing the optics limitation with the ATS, description of scheme, corresponding optics with the Phase I triplet at 120 T/m, and first shopping list for new magnet aperture)
R. De Maria, S . Fartoukh, SLHCPR55 and IPAC11 (introduction of the crab-cavity in the layout and first specifications)
S. Fartoukh et al., Chamonix 2012, IPAC12 and ATS-Note 2013-04 MD (ATS optics developed for the nominal machine, and demonstration of the ATS in a series of MD down to 10 cm beta*)
S. Fartoukh, R. De Maria, IPAC12 (ATS optics developed for other triplet layout 100 T/m and 150 T/m, i.e. 140 mm for NbTi and Nb3Sn, respectively, and review of the HL-LHC magnet shopping list)
R. De Maria, S. Fartoukh, M. Giovannozzi, IPAC13 (IT corrector layout and specification)
R. De Maria, S. Fartoukh, A. Bogomyakov, M. Korestelev, IPAC13 (Optics and layout retuned for the baseline 150mm-140 T/m HL-LHC triplet)
B. Dalena et al., IPAC13 (Layout and optics variant by substancial modification of the matching section)

and reference therein.

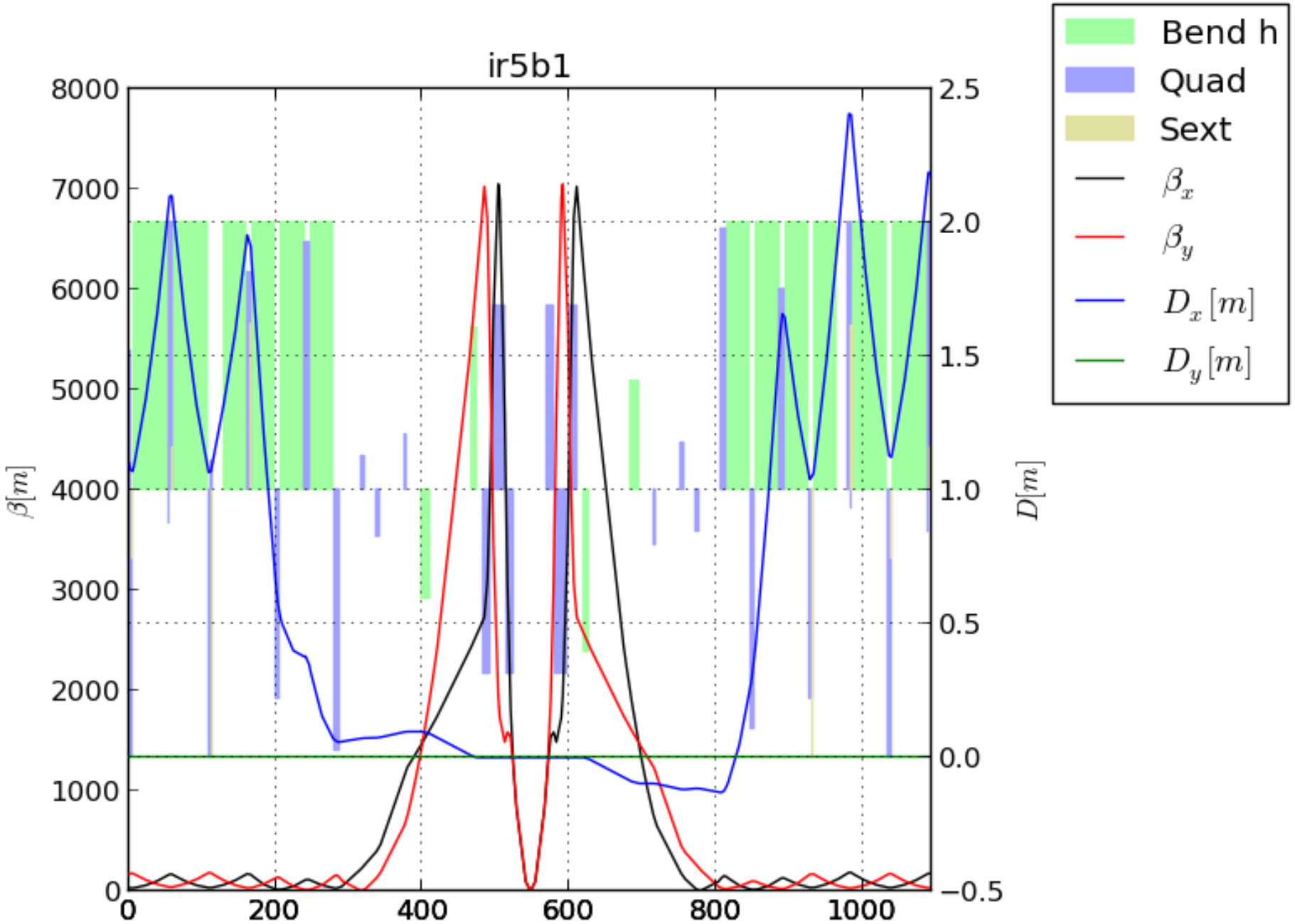
HL-LHC IR optics features

name	$\beta^*_\times$ [m]	$\beta^*_\parallel$ [m]	$\theta_\times$ [μrad]	$\Delta_\parallel$ [mm]	$\times_{\text{plane}}$ IP1/5
injection: $\beta^*_{2,8} = 10$ m, $\theta_{\times 2,8} = 340\mu$rad					
`inj`	6.0	6.0	490	4	any
ATS phase advances, $\beta^*_8 = 3$ m					
`presqueeze`	3.0	3.0	590	1.5	any
`presqueeze`	0.44	0.44	360	1.5	any
Telescopic squeeze					
`round`	0.15	0.15	590	1.5	any
`sround`	0.10	0.10	720	1.5	any
`flat`	0.075	0.30	550	1.5	V/H
`sflat`	0.050	0.20	670	1.5	V/H
`flathv`	0.075	0.30	550	1.5	H/V
`sflathv`	0.050	0.20	670	1.5	H/V
ion, $\beta^*_{2,8} = 50$ cm					
`ion`	0.44	0.44	360	1.5	any

HL-LHC IR optics features

- IR1-5: new layout and new optics,
- IR2-8: new phase, new injection, low beta, ATS optics,
- IR4: fairly similar to nominal, ATS squeeze with almost invariant straight section optics,
- IR6: injection similar to nominal, ATS squeeze optimized for dump,
- IR3, 7: only updates to the change of the arc no particular optimizations.

Pre-squeeze


ir5b1
Bend h
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β_y
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800
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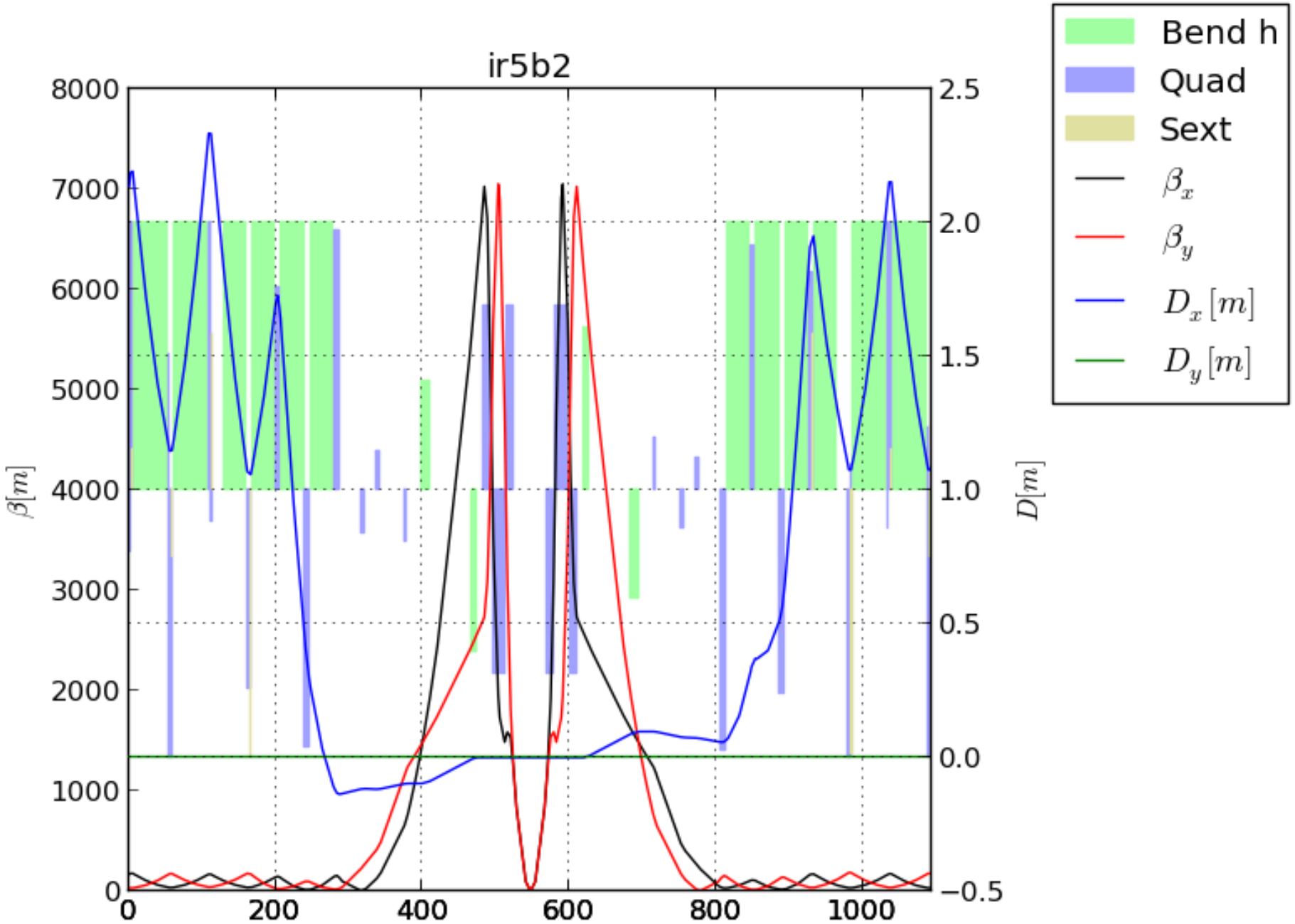
Pre-squeeze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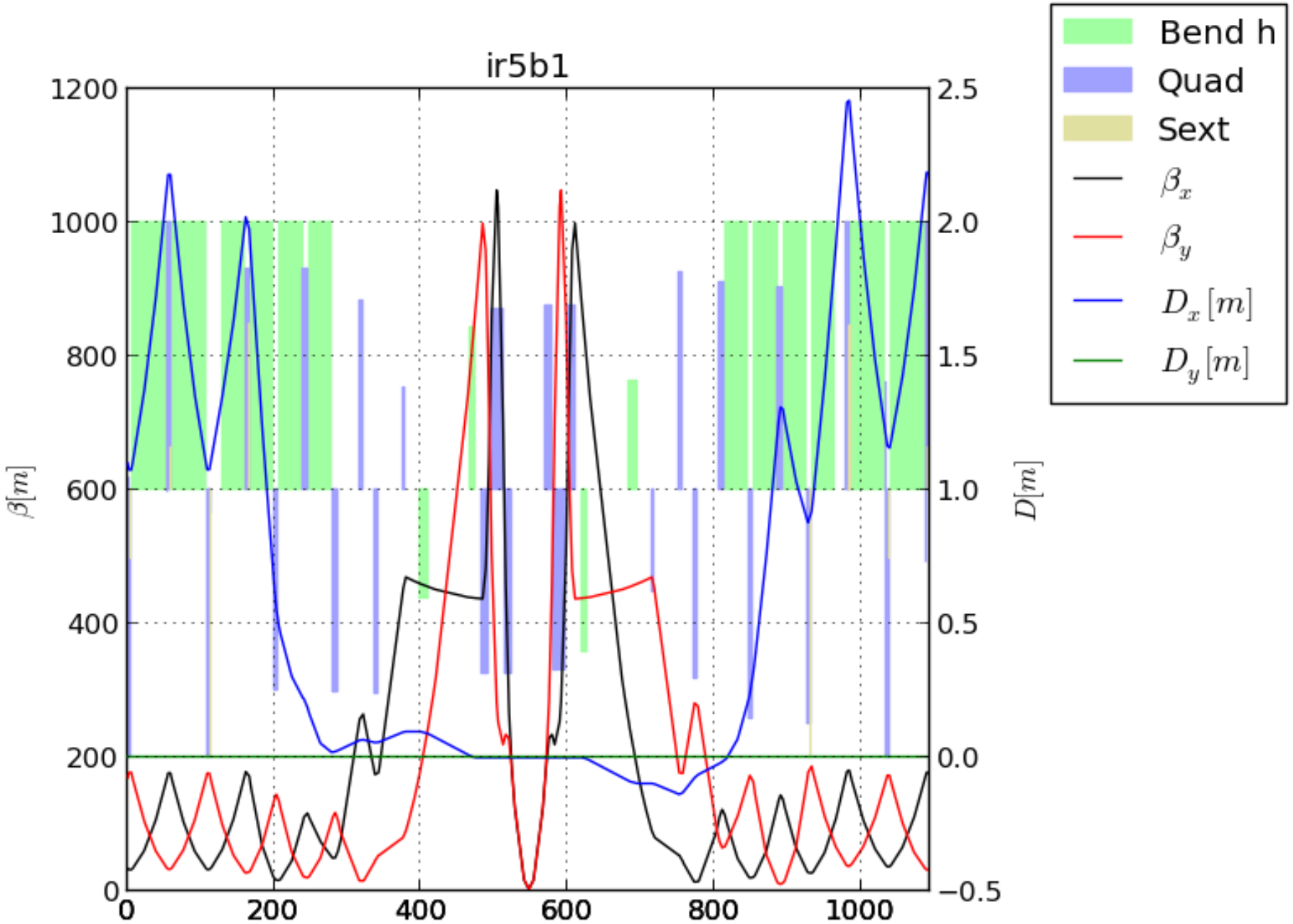
Injection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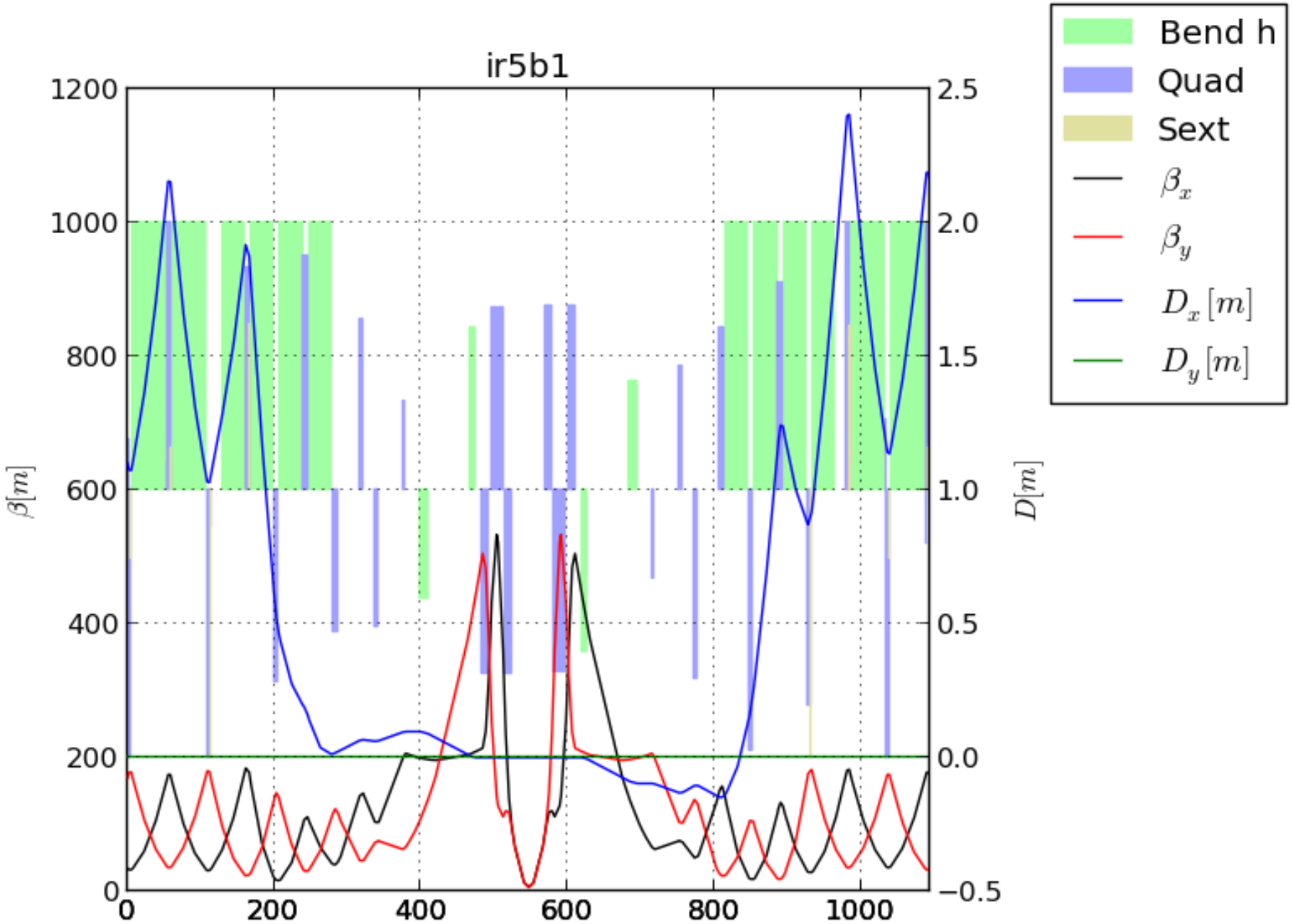
Injection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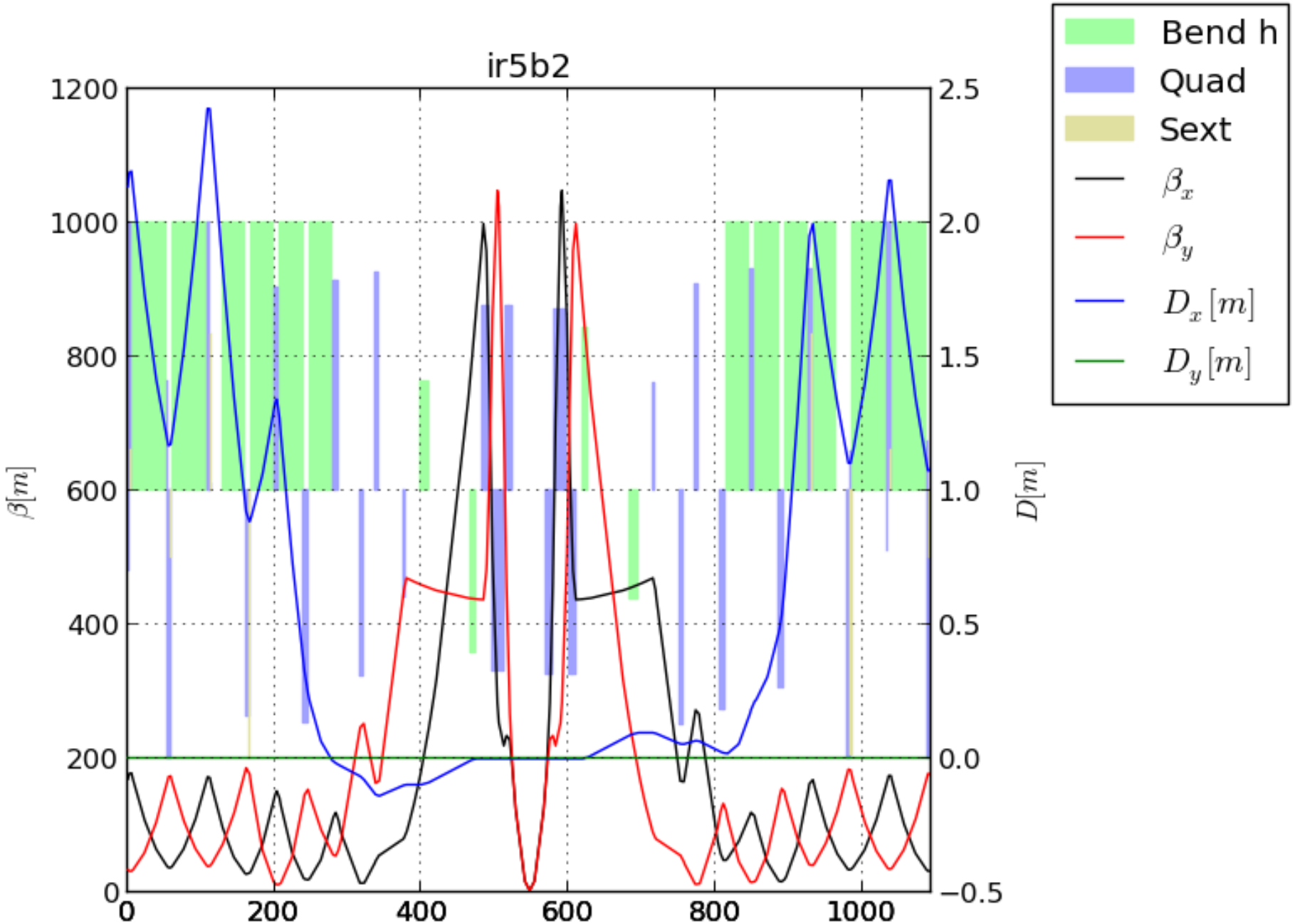
Injection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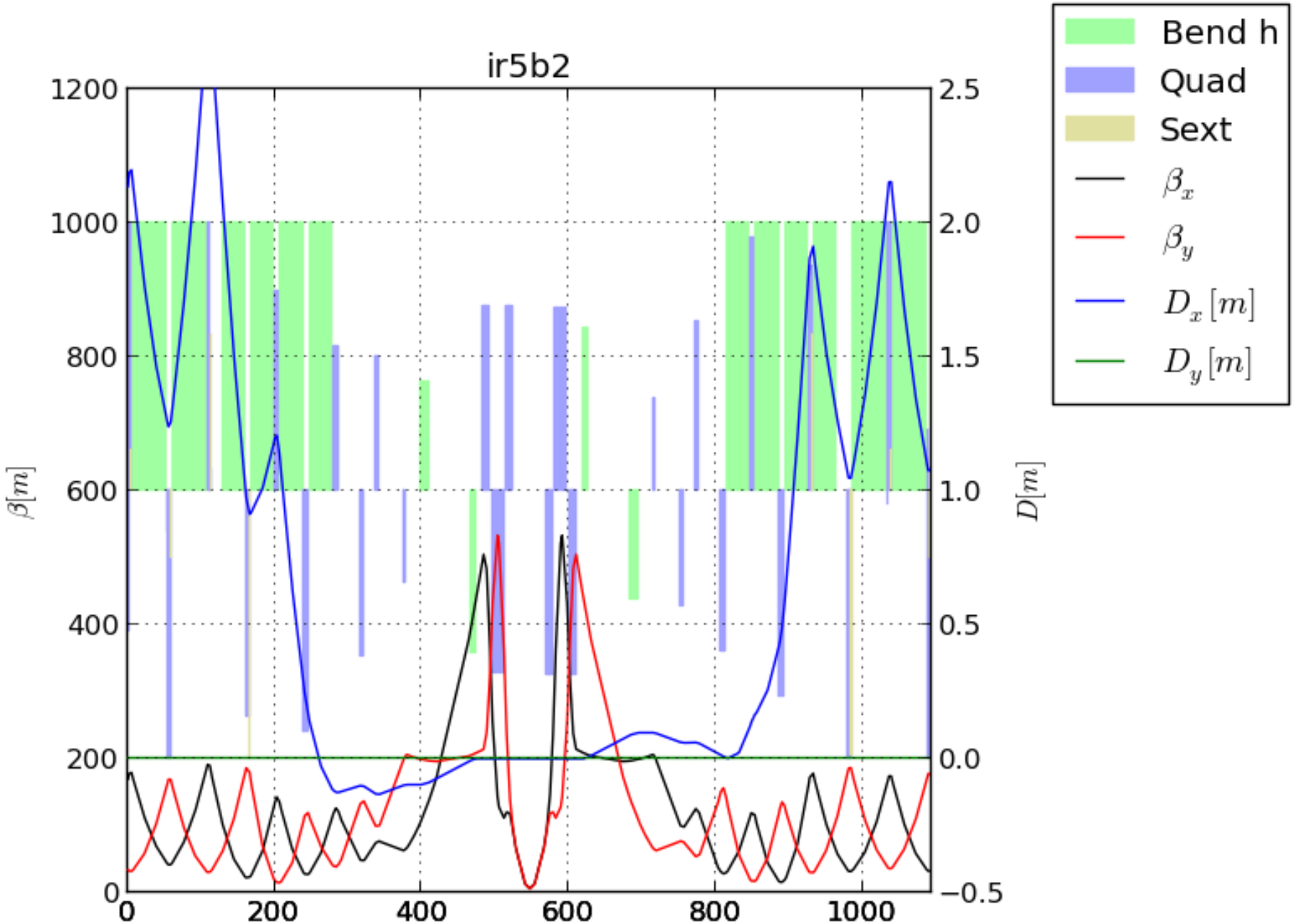
Injection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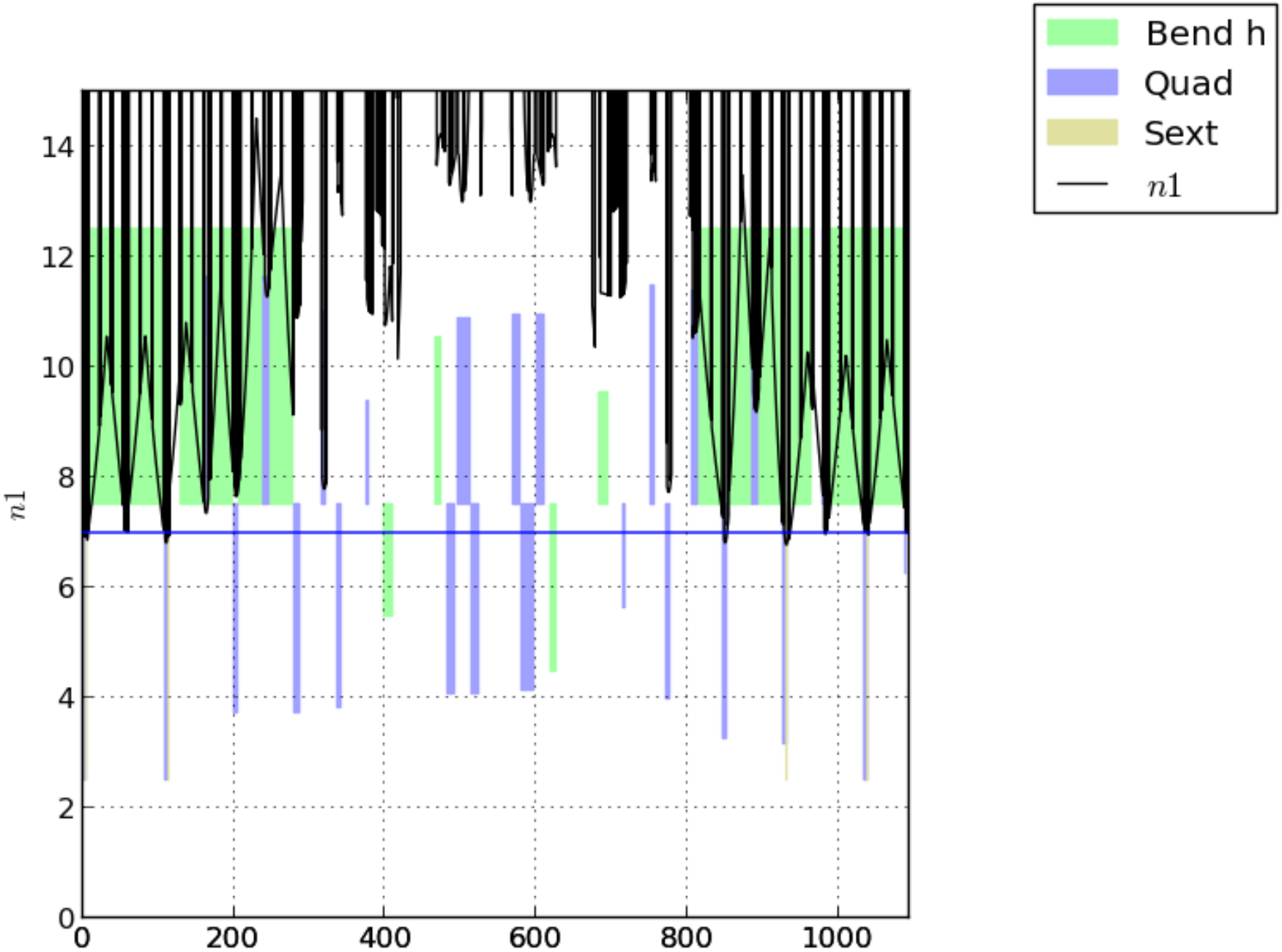

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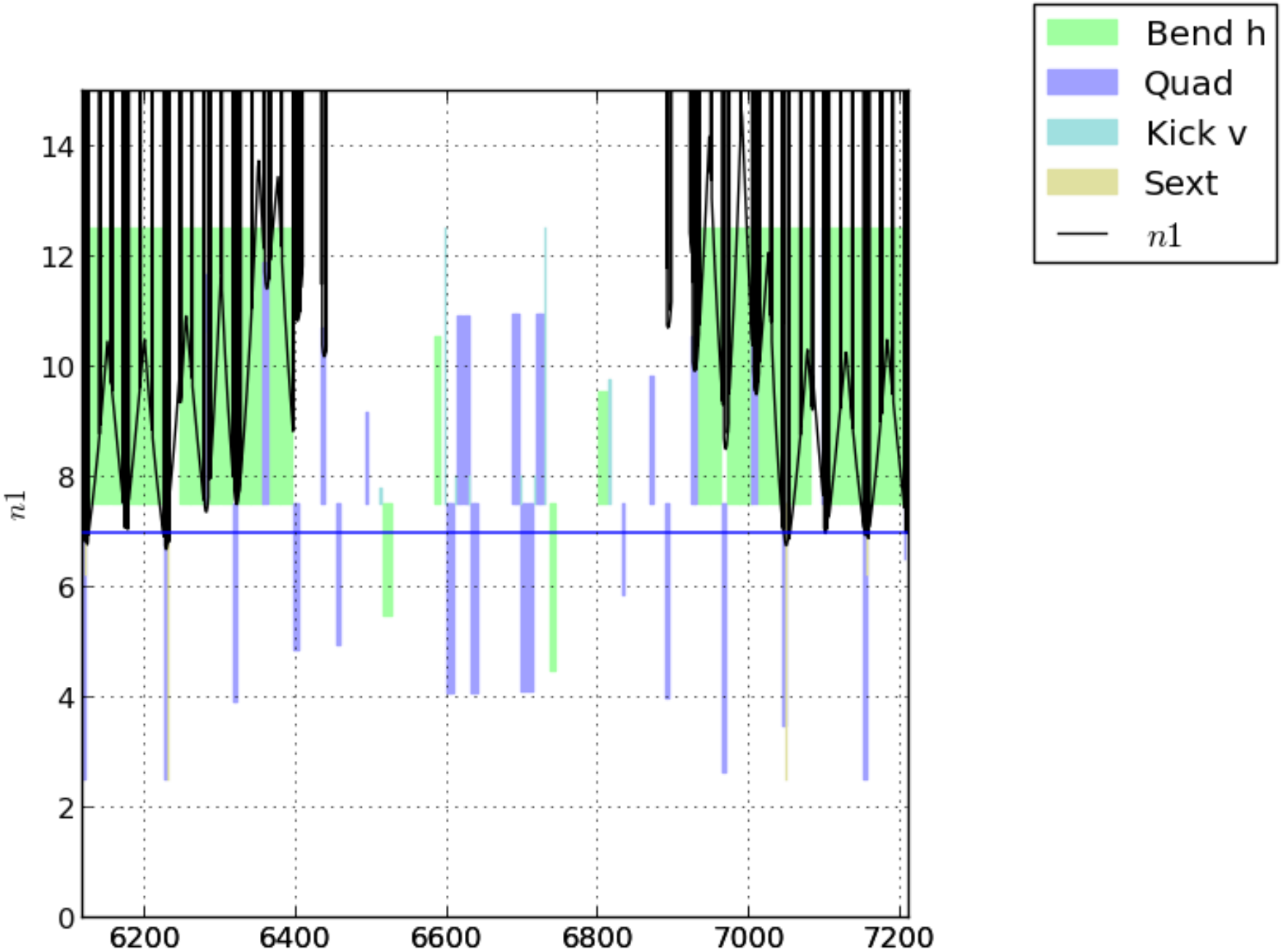
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$n1$
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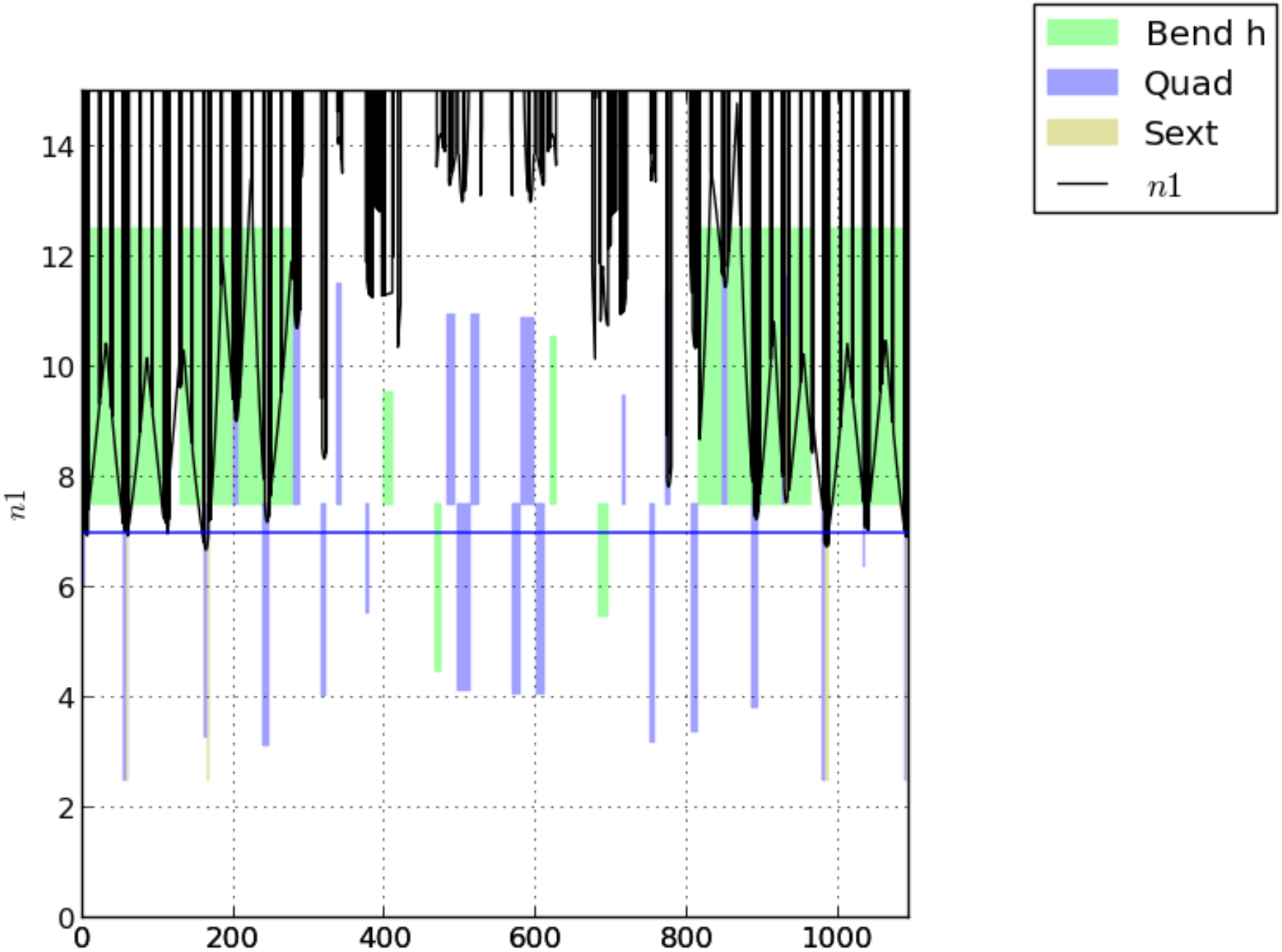
7000
7200

Injection



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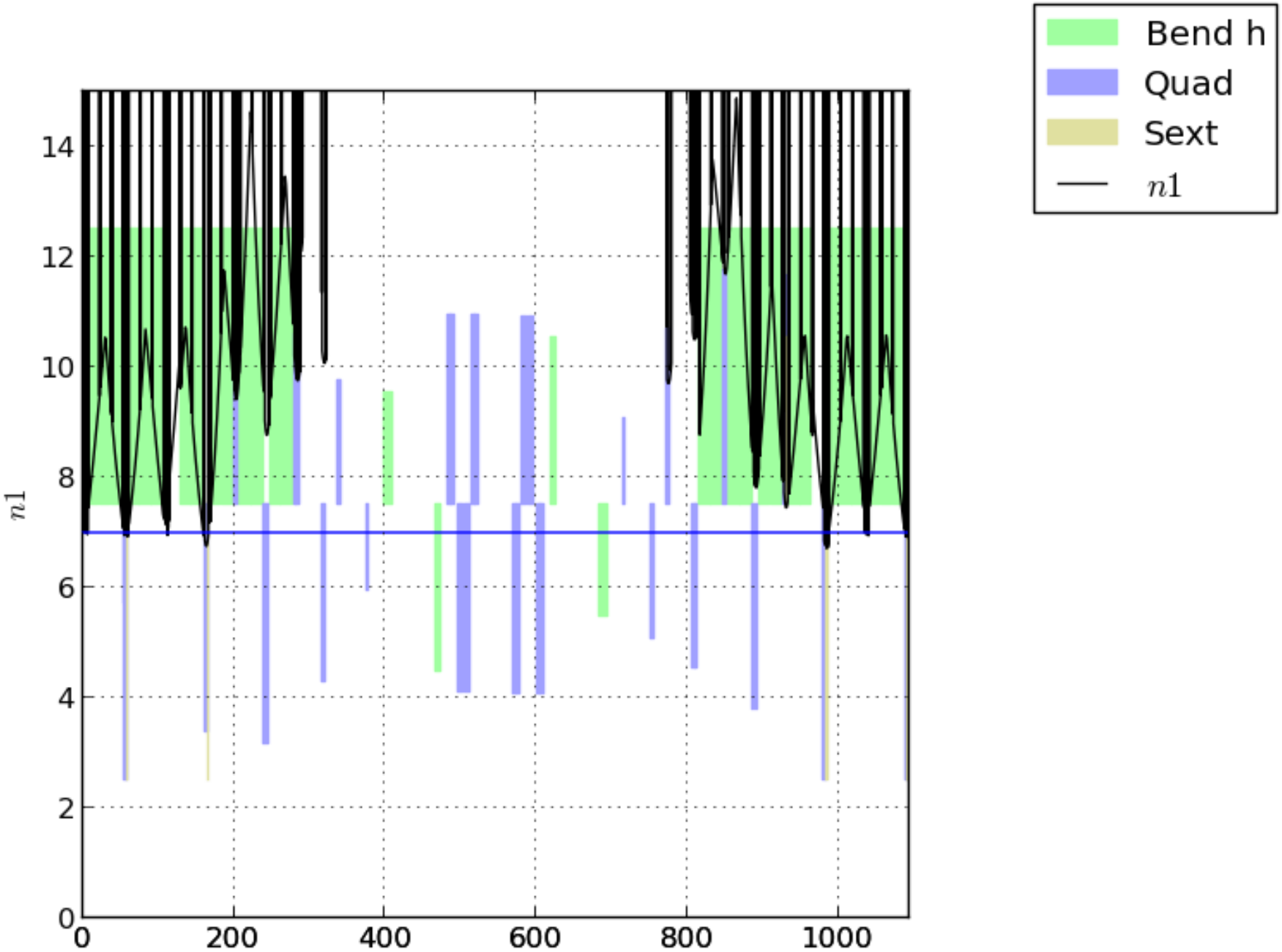
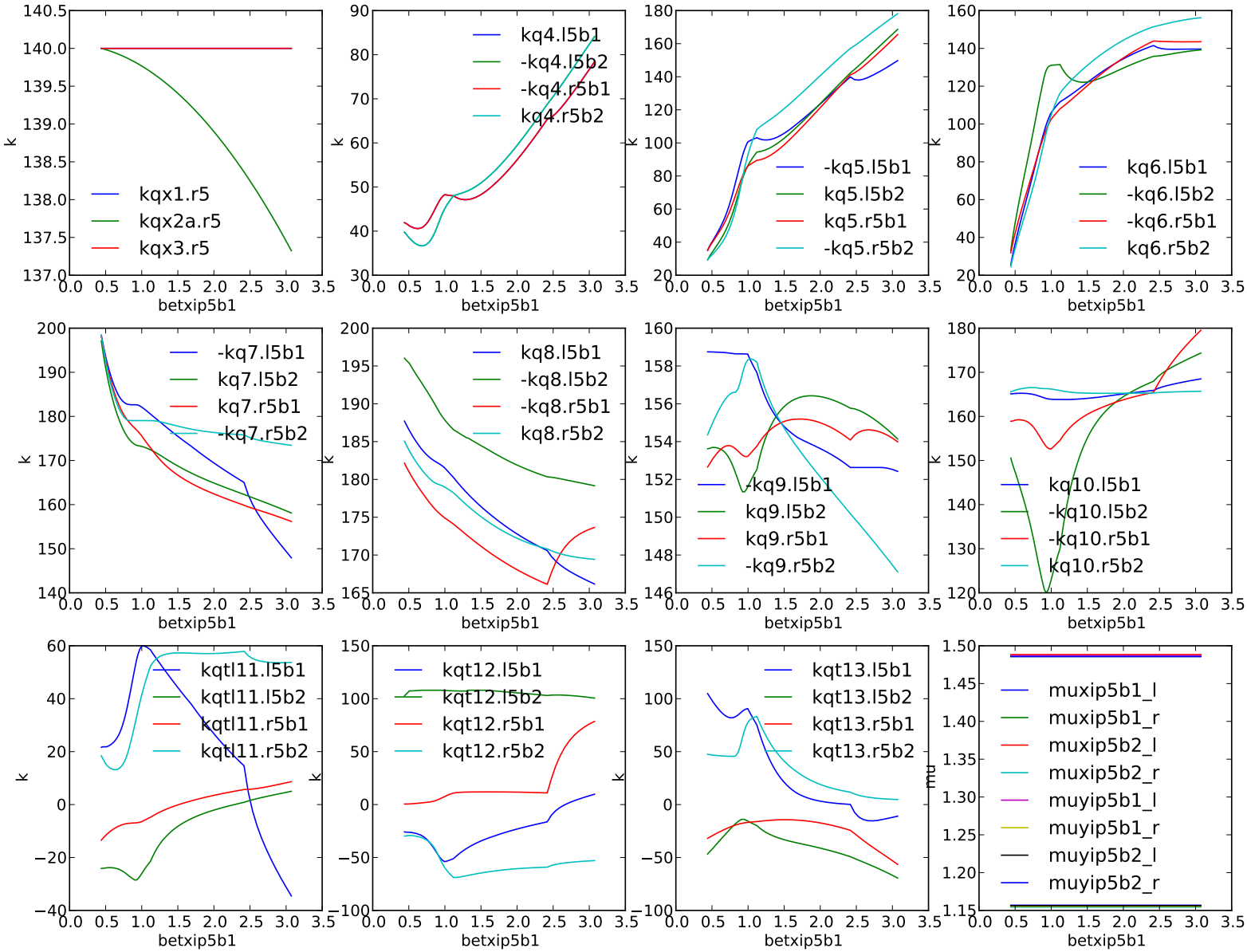


Squeeze


kqx1.r5
kqx2a.r5
kqx3.r5
kq4.l5b1
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-kq4.r5b1
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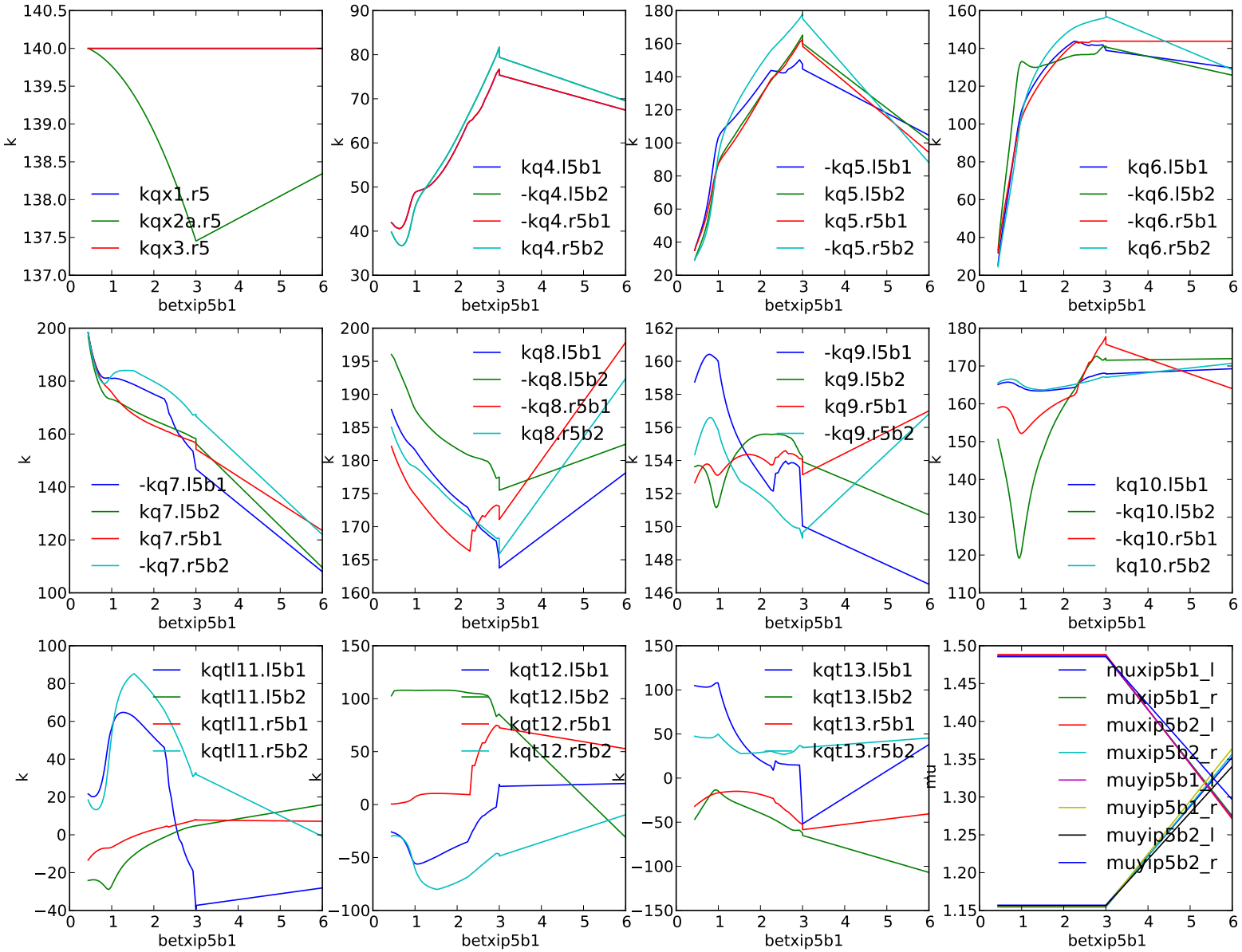
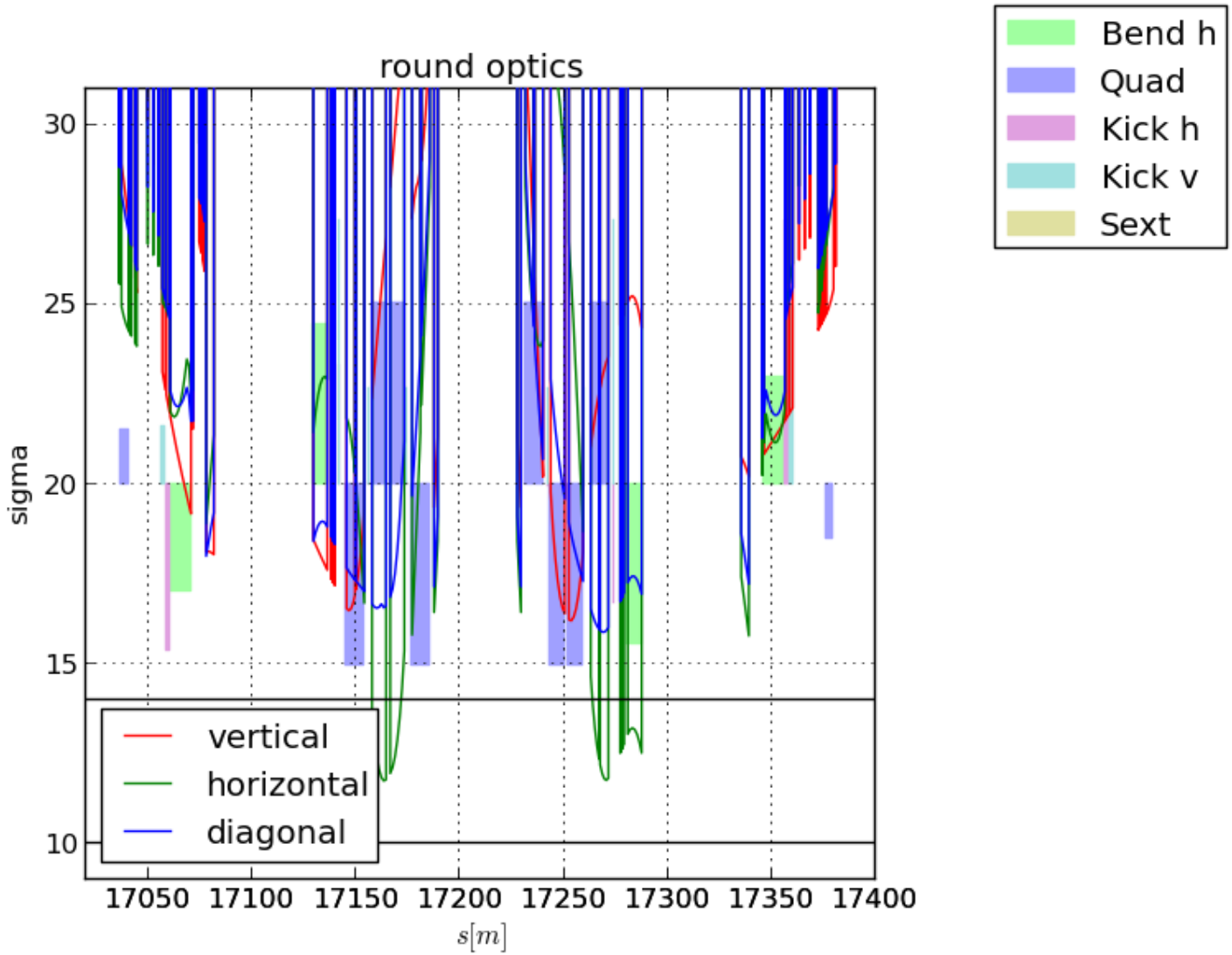
Squeeze extension not complete



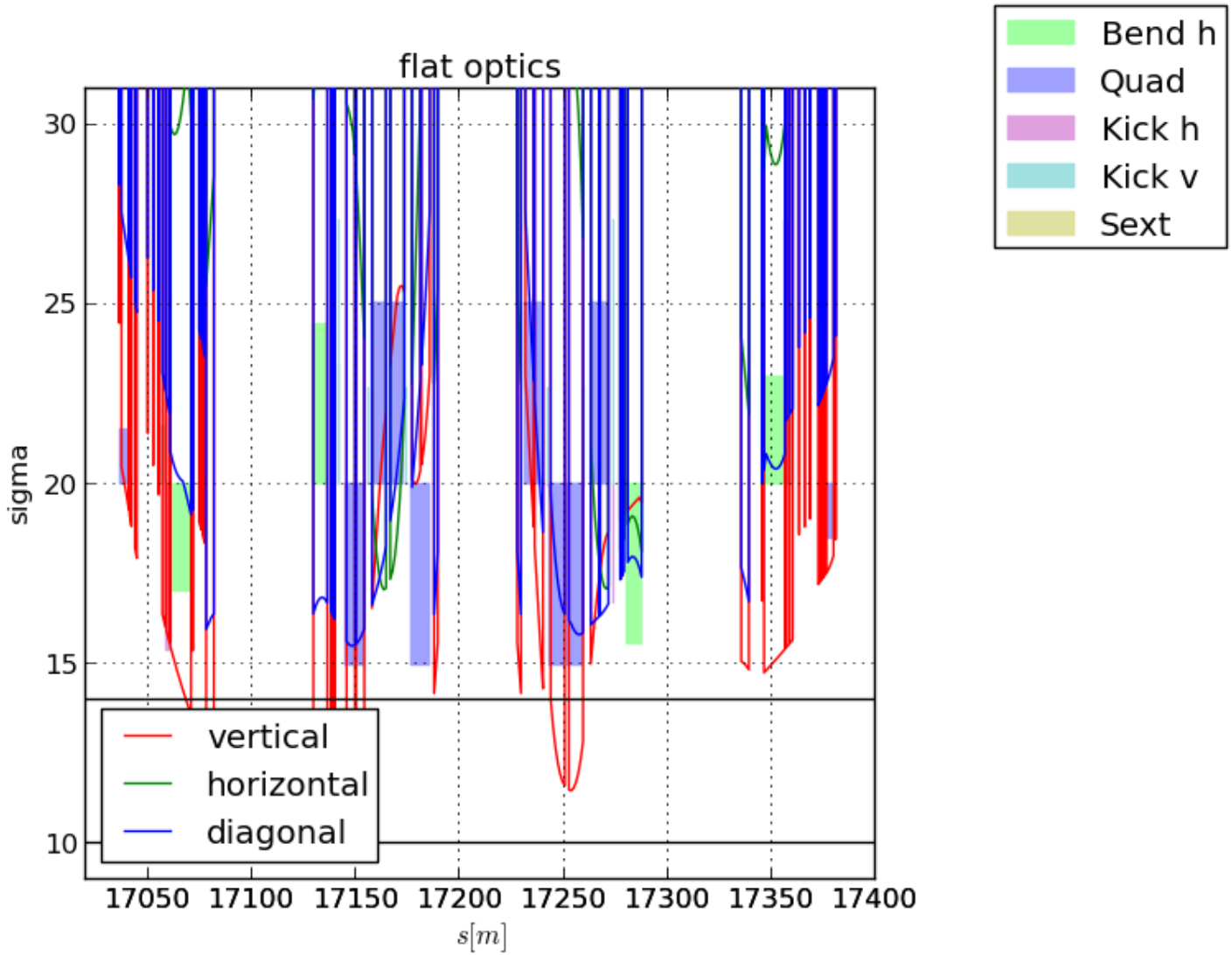
Triplet aperture baseline round beam

β^*=15 cm, $\theta_c = 590\mu$ rad, $\sigma = 3.5\mu$ m.



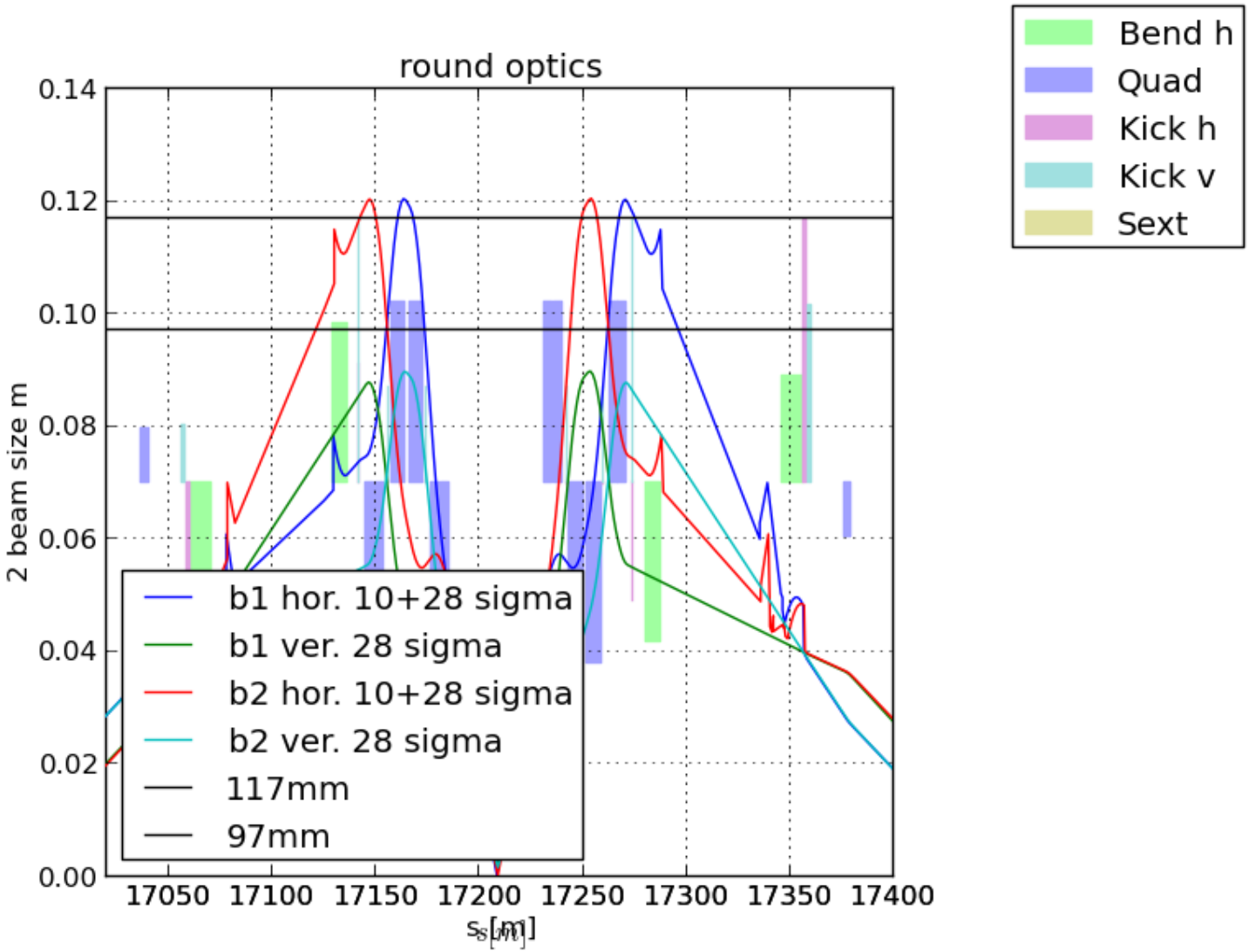
Triplet aperture baseline round beam

β^*=30,7.5 cm, $\theta_c = 550\mu$ rad, $\sigma = 3.5\mu$ m.



Triplet aperture baseline round beam

β^*=15 cm, $\theta_c = 590\mu$ rad, $\sigma = 3.5\mu$ m.



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β^*=30,7.5 cm, $\theta_c = 550\mu$ rad, $\sigma = 3.5\mu$ m.