

Preparation for LHC optics 2015

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M. Giovannozzi, J. Jowett, D. Mirarchi,
T. Risselada,

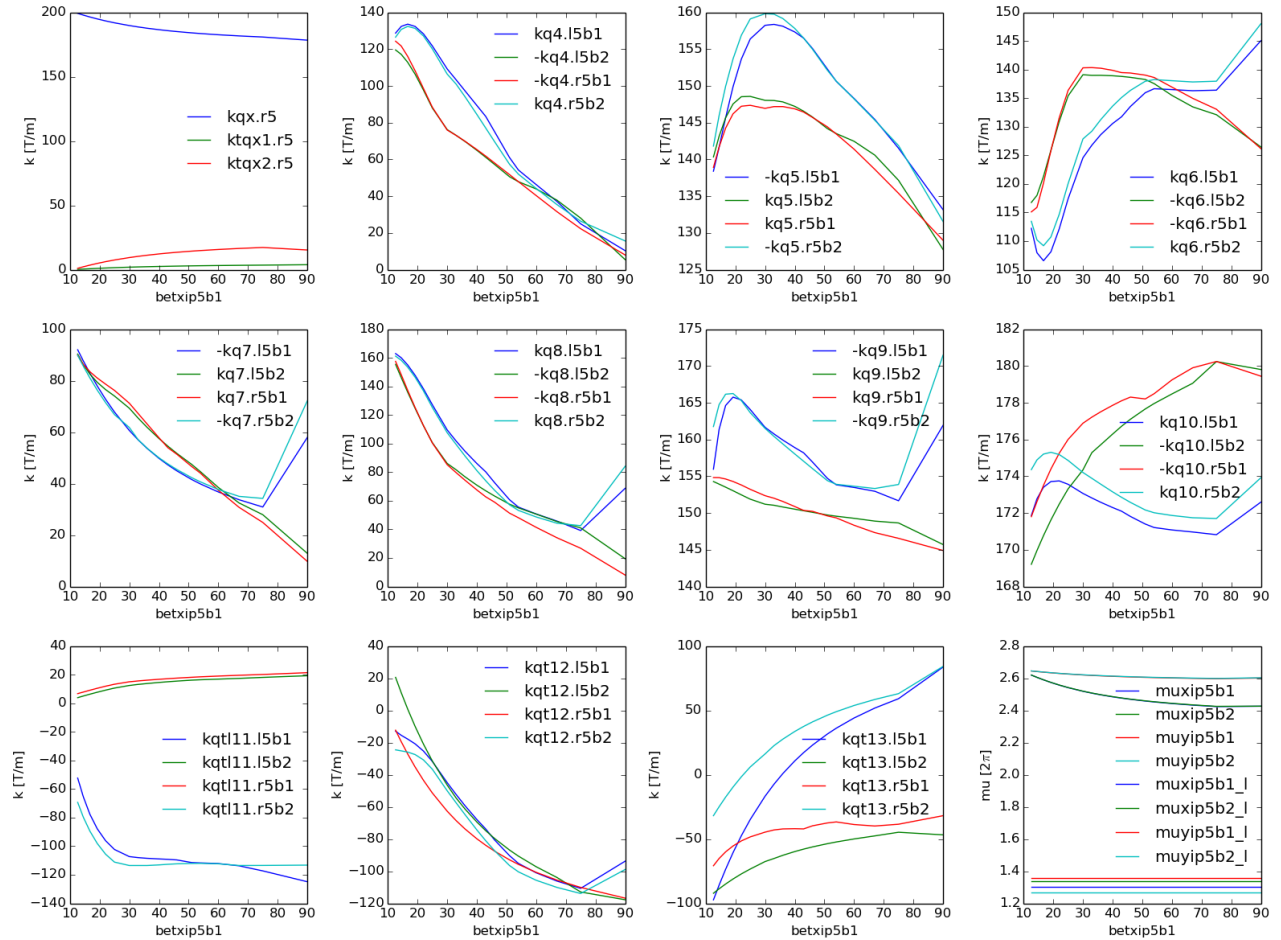
Updates from last meeting

- LMC opted for option MED
- First part (up to 19m) of unsqueeze to 90m as VDM
- Iteration with OP (optics files format)
- Iteration with official sequence
- Iteration on squeeze options

VDM – 90m unsqueeze

VDM stop at 19m.

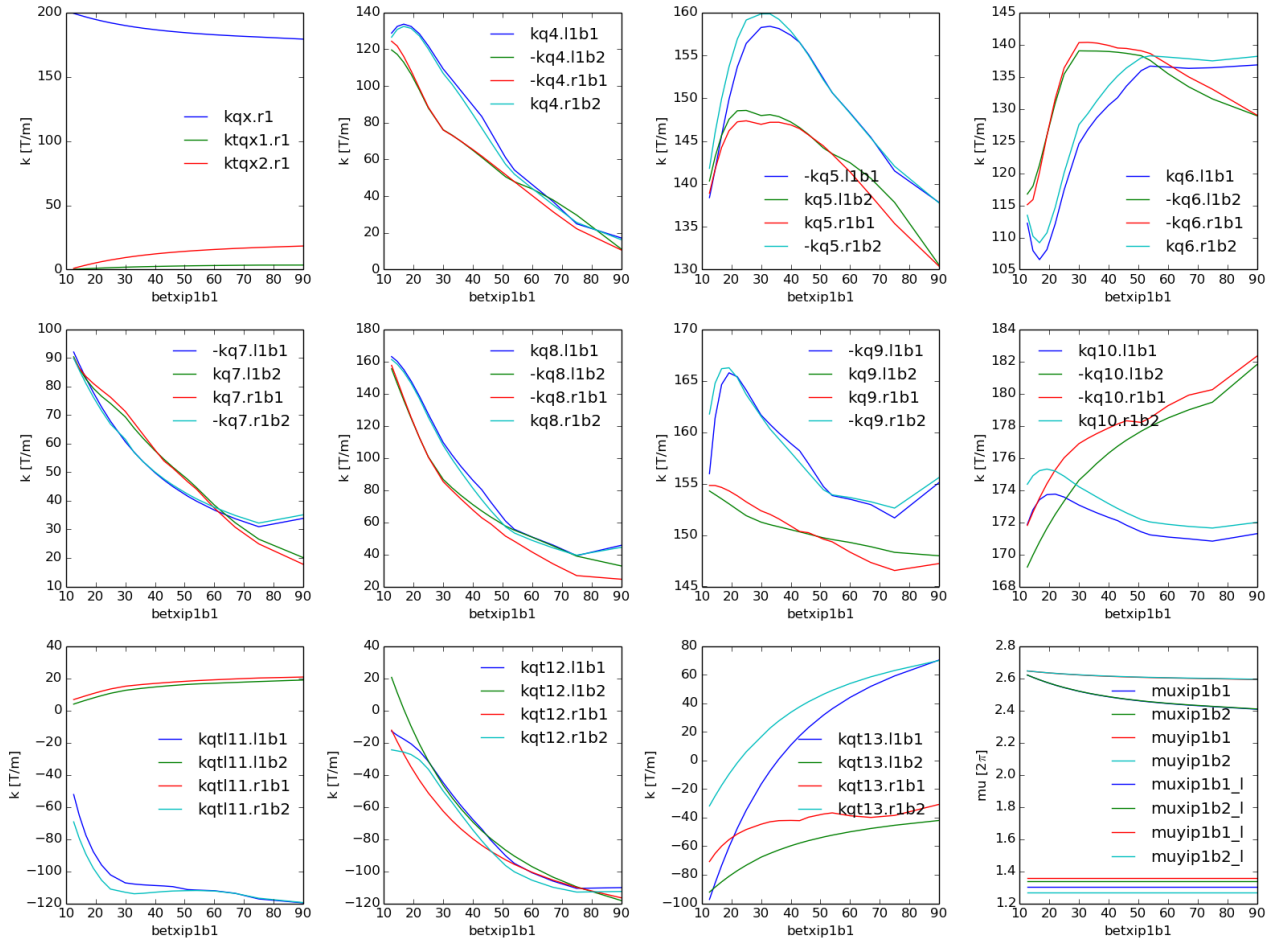
Strength reported at 7TeV.



VDM – 90m unsqueeze

VDM stop at 19m.

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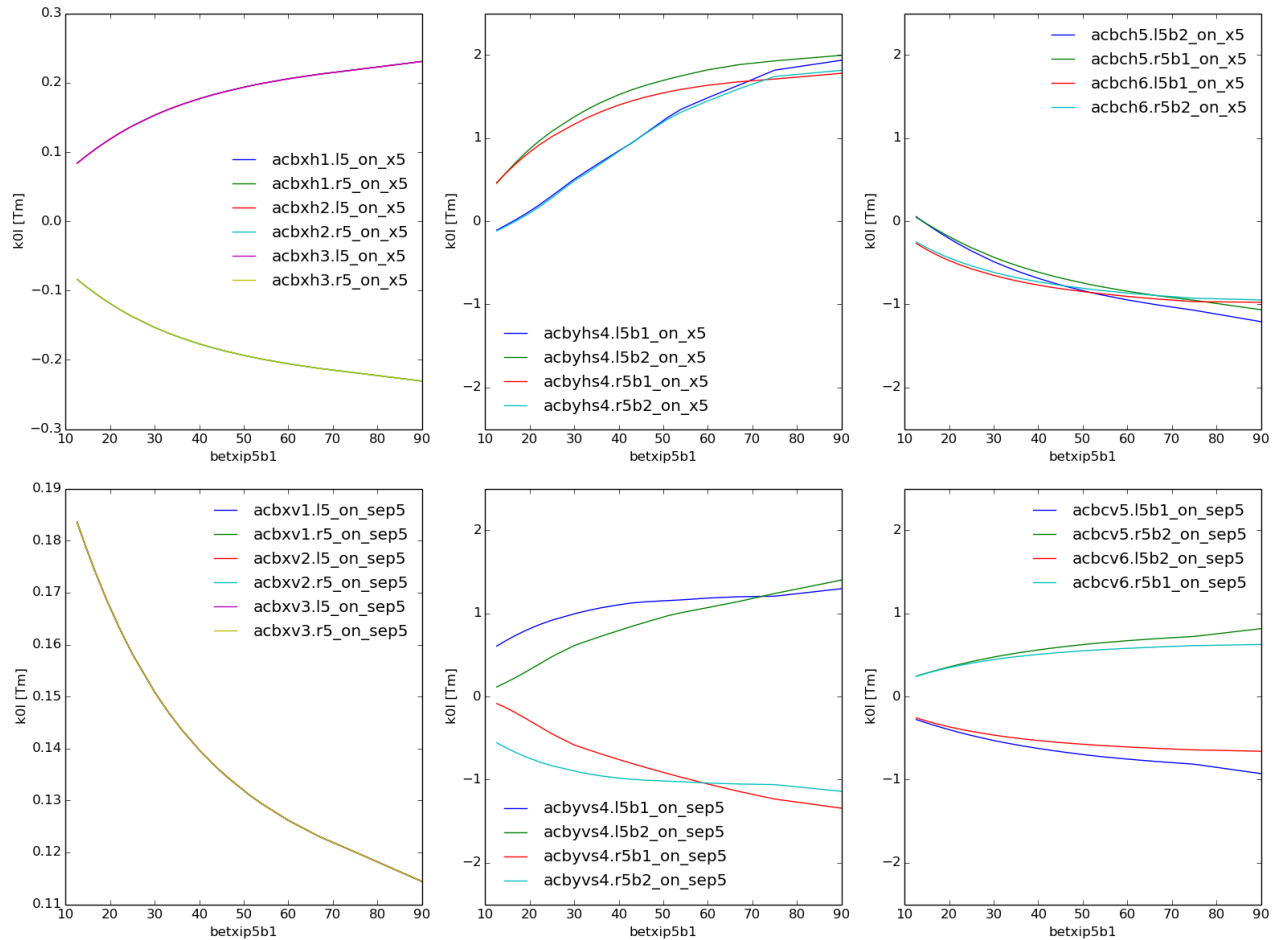
VDM – 90m unsqueeze

VDM stop at 19m.

Strength reported at 7TeV.

Separation and crossing (not normally needed) knobs defined for 1mm and 60 murad (about maxim possible values).

H. Burkhard is reviewing the orbit bumps (maybe different symmetry for MCBX for crossing).



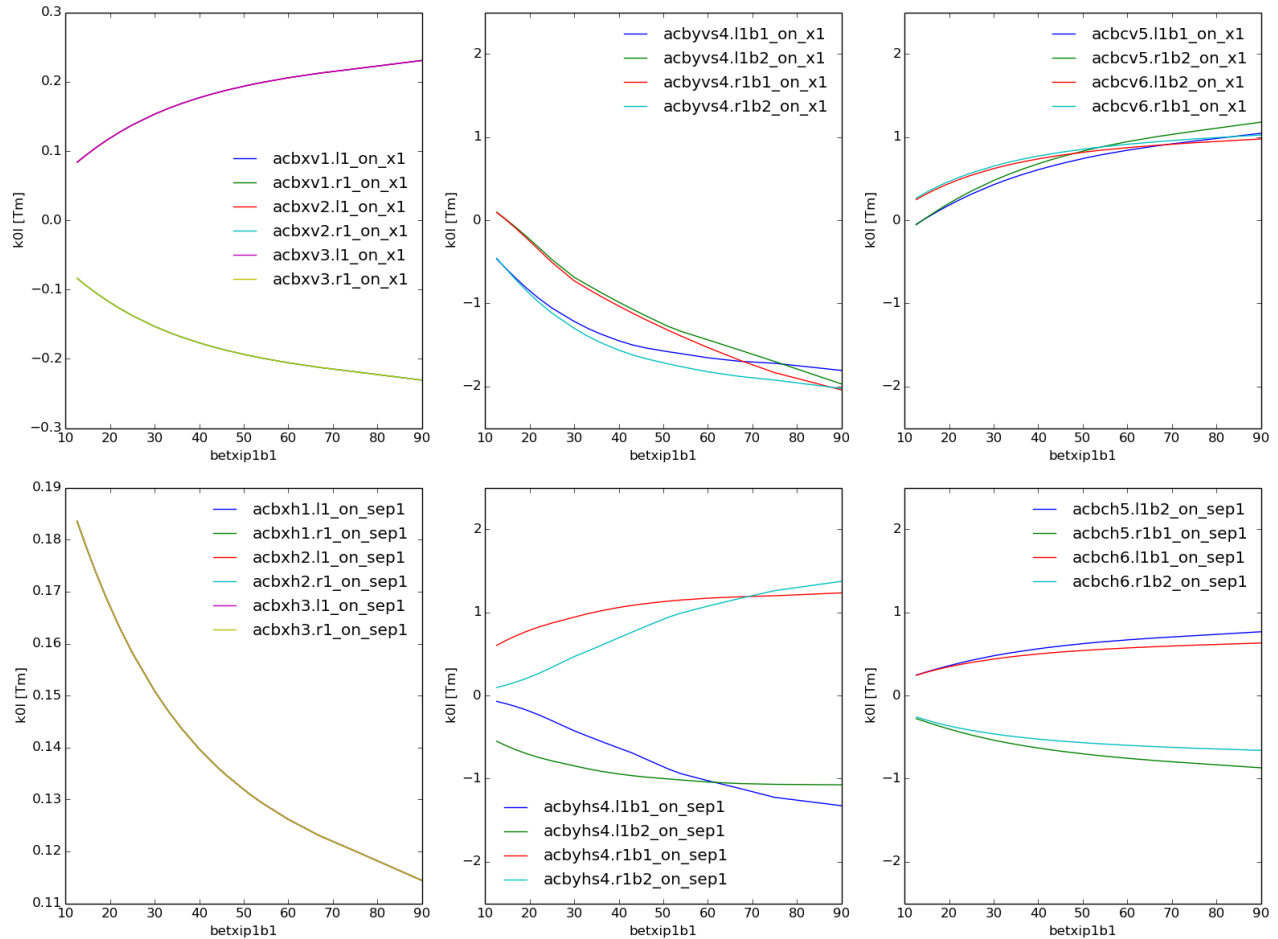
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Separation and crossing (not normally needed) knobs defined for 1mm and 60 murad (about maxim possible values).

H. Burkhard is reviewing the orbit bumps.



Iteration with OP

- LSA software stack had problem with:
 - Multiple statements in one line:
 - e.g. `on_x5=1; on_sep5=0...`
 - Now separated lines
 - Variable associated with a knob ending with b1 or b2 and not being a magnet:
 - e.g. `xip1b1=0.002*on_sep1`
 - “information-only variables” commented for the time being
 - Unused/undefined: knobs normalized for no effect (zero coefficients) or knobs defined for an optics stage and not defined for other (e.g. `on_a8`)
 - kept all knobs defined even if not used, anyway full optics will have default settings for `on_...` Variables
- Incorporation test succeeded on early dump of repository, updated files to be incorporated this week. Still room for optics changes before restart.

Official Sequence

- As built sequence are evolving (not always in the good direction):
 - Hardware commissioning has introduced/will likely introduce new non-conformities
 - Layout database STUDY version is being modified: new features (e.g. BPMSW.IR1.B1_DOROS), new bugs are being introduced (, old non conformities are not removed, new nonconformities have not been update
- Update layout database generated sequence and manually edit problems.
 - Source for electrical conformities:
<https://twiki.cern.ch/twiki/bin/view/MP3/SummaryIssues>

Iteration on squeeze option

With respect to validated opt med version

- Smoother squeeze for IR1/5 from 55cm to 40cm
- Smoother squeeze for IR8 from 4m to 1.6m with small beta and dispersion changes.

New cleaning studies (D. Mirarchi) shows small (5% in the worst case) difference between the options.

Open issues

Further reduction β^* in IP8 for ions.

Additional matched points in IR2 lowbeta squeeze for ions.

Update as-built sequence and as-built aperture files.

Backup

Optics option for 2015

- Option Min: what is (strictly) needed to change w.r.t. Run I
 - IR8 crossing scheme (introduce large vertical separation and angular offset at injection for `bad` LHCb polarity)
 - IR8 squeeze (kqt13.l8b1 out of strength from $\beta^*=6\text{m}$ to $\beta^*=3\text{m}$ at 7TeV up to 166.5 T/m)
 - IR2 squeeze (for $\beta^*<3\text{m}$, reduced triplet strength)
 - For IR1-5, Kqt13.r5b1 127.9 T/m at 7TeV for $\beta^*=40\text{cm}$ (no problem below 6.73 TeV)
 - Ramp and squeeze for IR2, 8 and Triplet (215T/m at 6.78 TeV). Collision at larger than 205 T/m no problem for IR2. IR8 205T/m reached at $\beta^*=3\text{m}$ at 7TeV
 - Use all MCBX to reduce corrector strength and speed-up separation collapse.
 - Inject with tune-jumped IR1-5 optics and MQT trim.
 - New VDM optics and squeeze for IR2 and IR8 and corresponding squeeze.
 - Common un-squeeze for IR1-5 β^* VDM optics and 90 m optics (updating crossing scheme).
- Option Med: few local improvements
 - New IR4 optics (different phase for B2 -0.077 2pi (28°) , BSRT, ADT kicker) to enhance beta at instruments and IR8 Beam 2 to compensate for phase (+0.077 2pi).
 - *IR6 optics optimized MKD-Septum phase advance (not necessary)*
- Option Max: ATS compatible optics for very small β^* reach, enhanced octupole strengths, reduction of chromatic effects (dispersion and non linear chromaticity):
 - All optics: change of phase advances, minimal changes in beta functions.

R. De Maria, M. Giovannozzi, [Validation of the MIN and MED optics from the optics point of view](#), 197th LMC, 10/12/2014.

M. Giovannozzi, [Optics options for the 2015 LHC run](#), Chamonix, 23/9/2014 and reference there in.

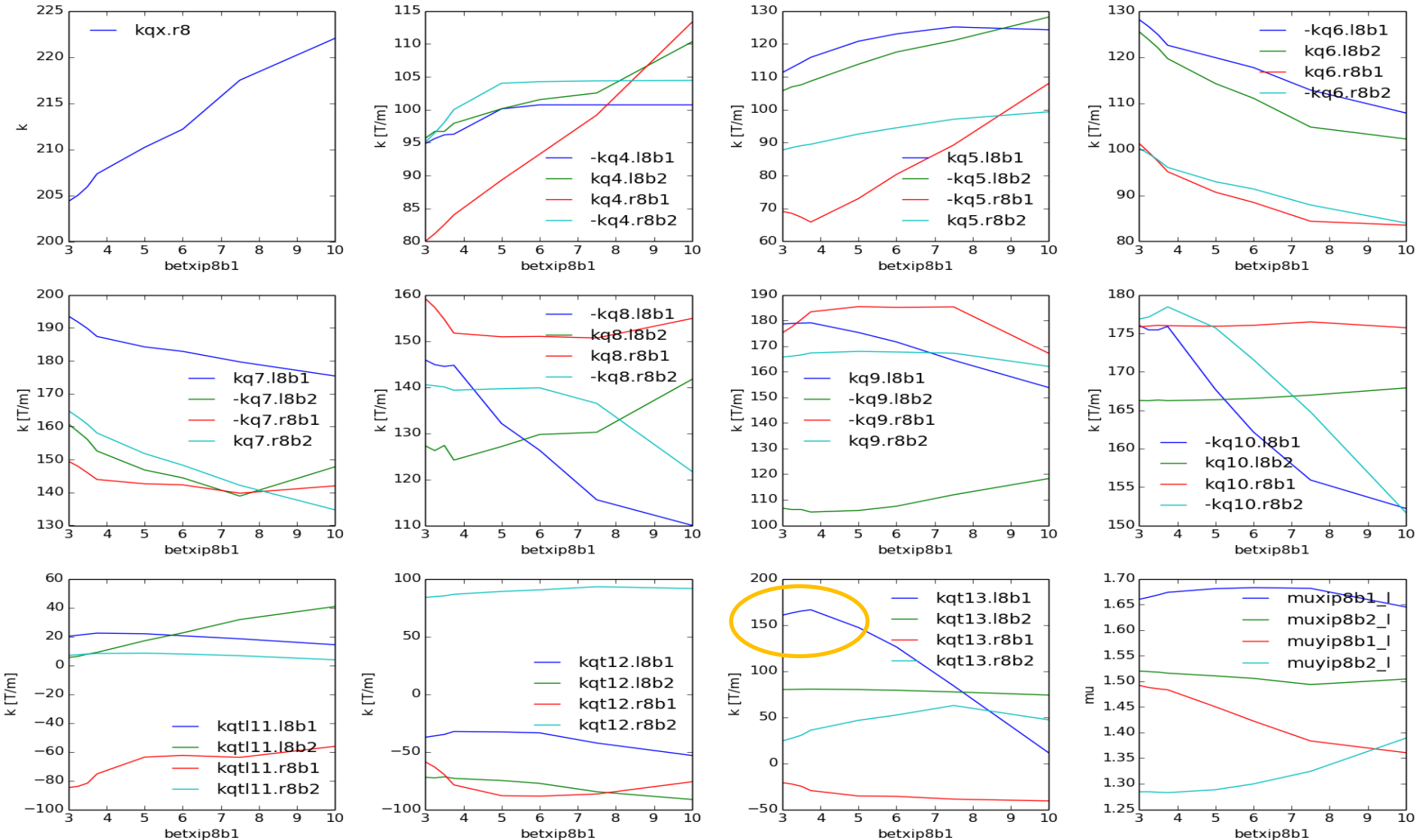
S. Fartoukh, [LHCb crossing scheme for Run II and Run III](#), 167th LMC 19/6/2013; [Optics change requests for Run II and possible options for 2015](#), 18th LBOC, 29/4/2014; [Optics for 2015](#), 179th LMC, 30/3/2014.

Jowett, M. Schaumann, [Optics for the 2015 Pb-Pb run](#), 17th LBOC, 15/4/2014.

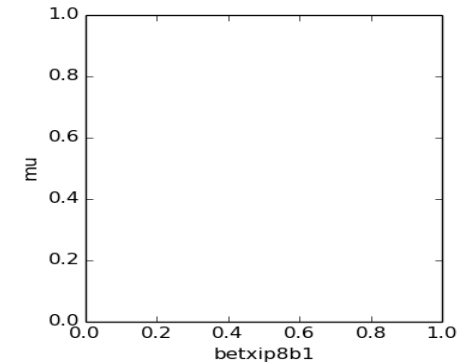
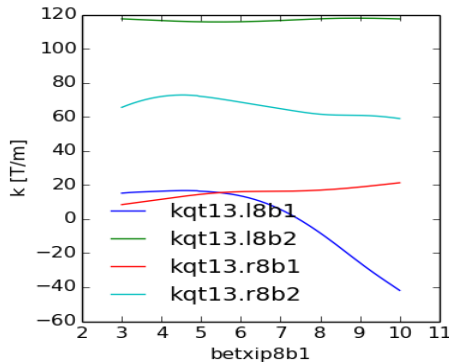
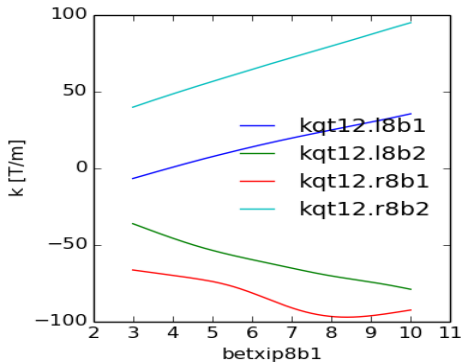
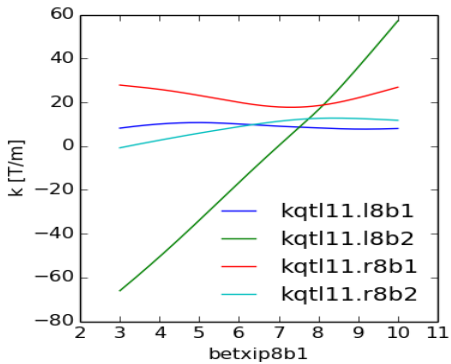
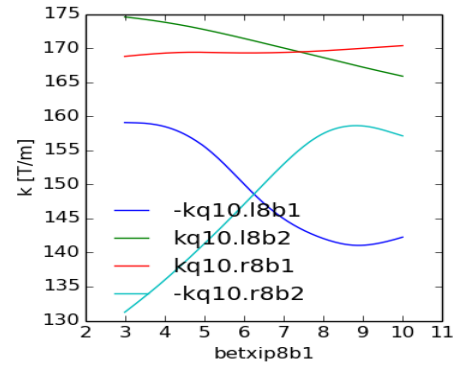
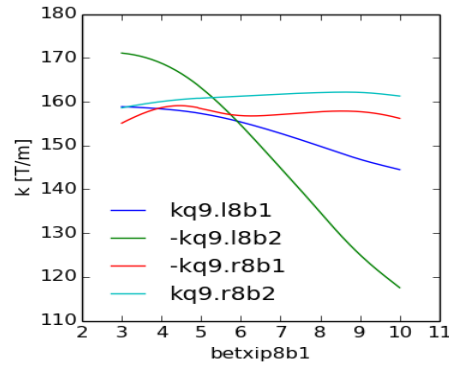
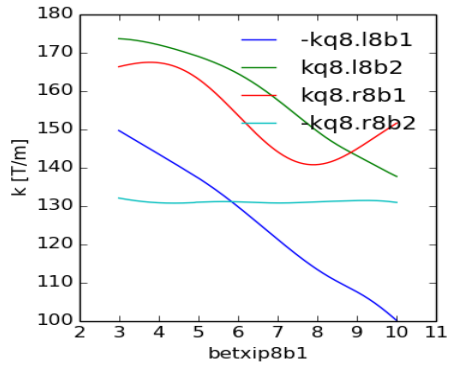
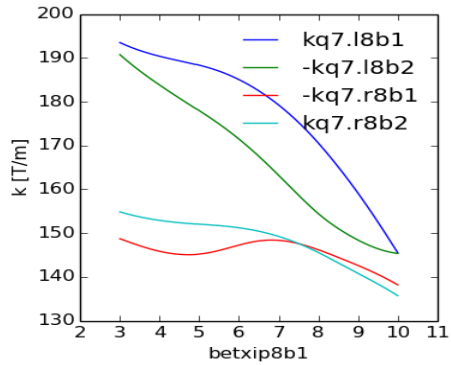
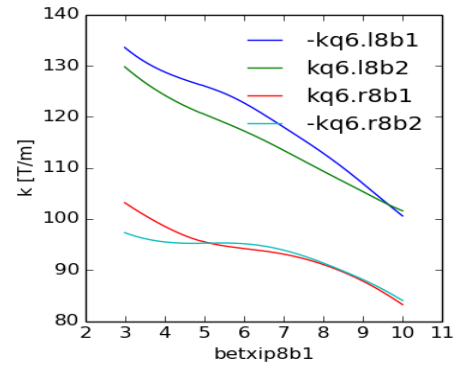
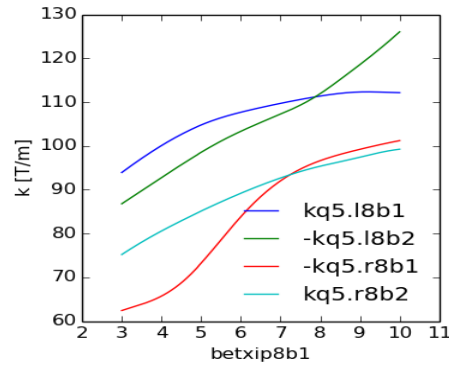
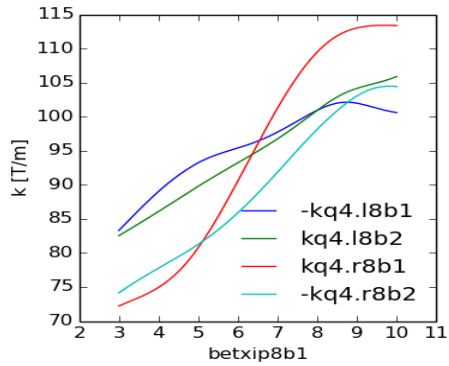
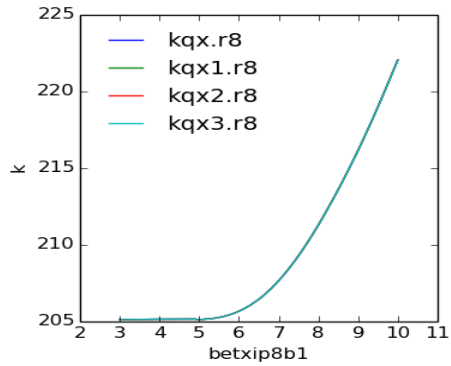
Outline

- New repository
- Working point strategy through the cycle
- Injections optics, orbit and apertures:
IR4,IR8,IR1,IR5,IR2,IR5
- Low- β Squeeze: IR8,IR1-5,IR2
- High- β Squeeze: IR1-5,IR2, IR8

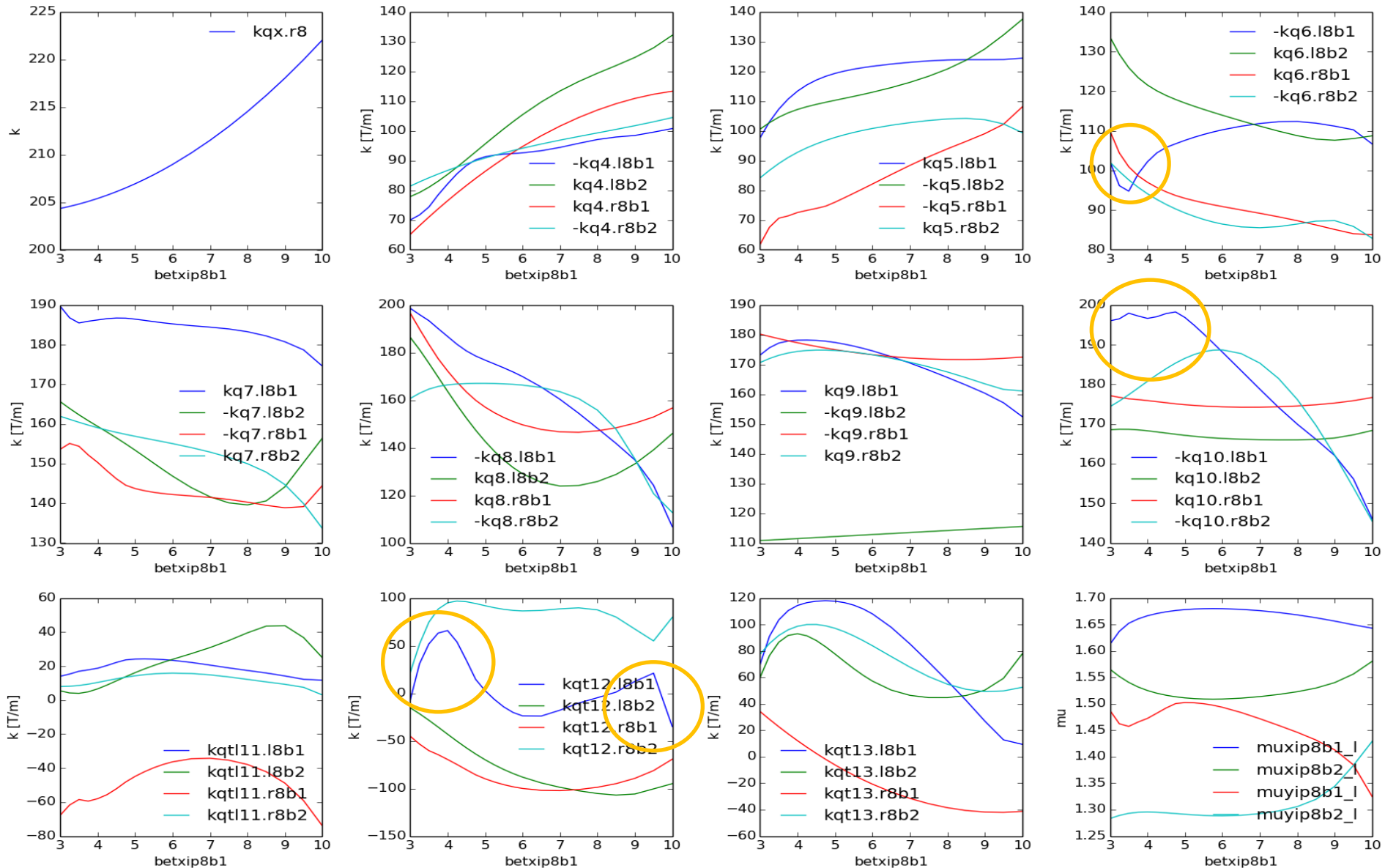
IR8 Squeeze 2012



IR8 Squeeze ATS

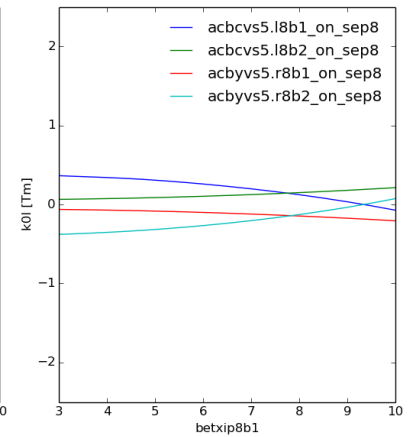
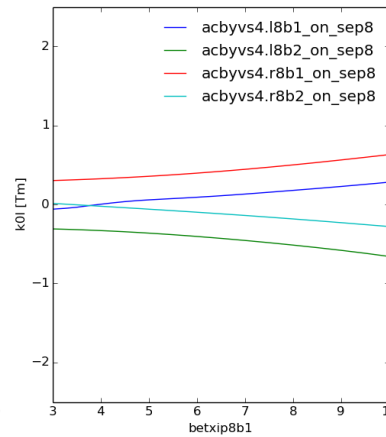
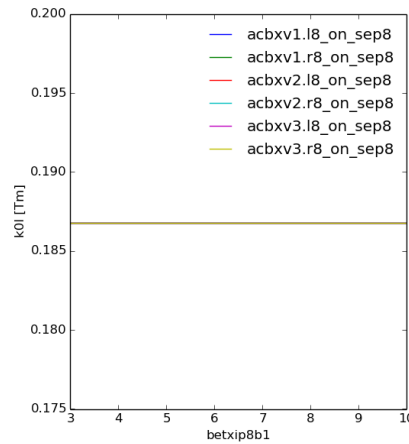
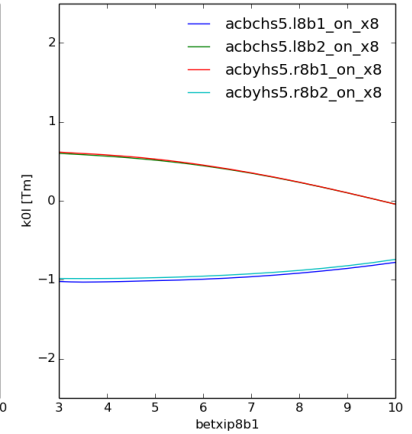
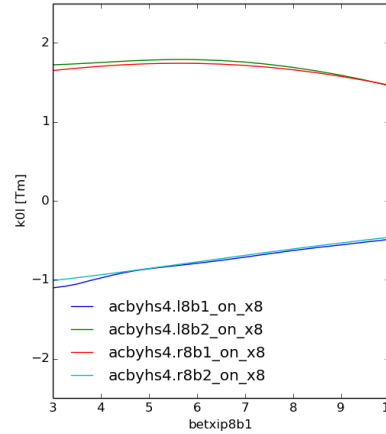
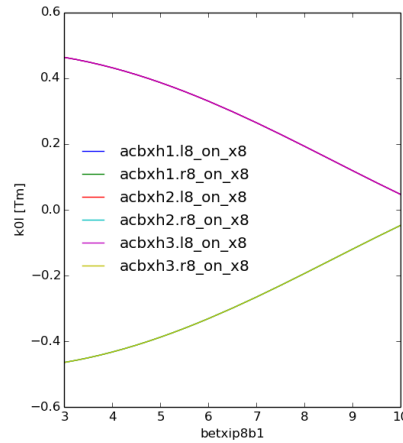


IR8 Squeeze Opt Med

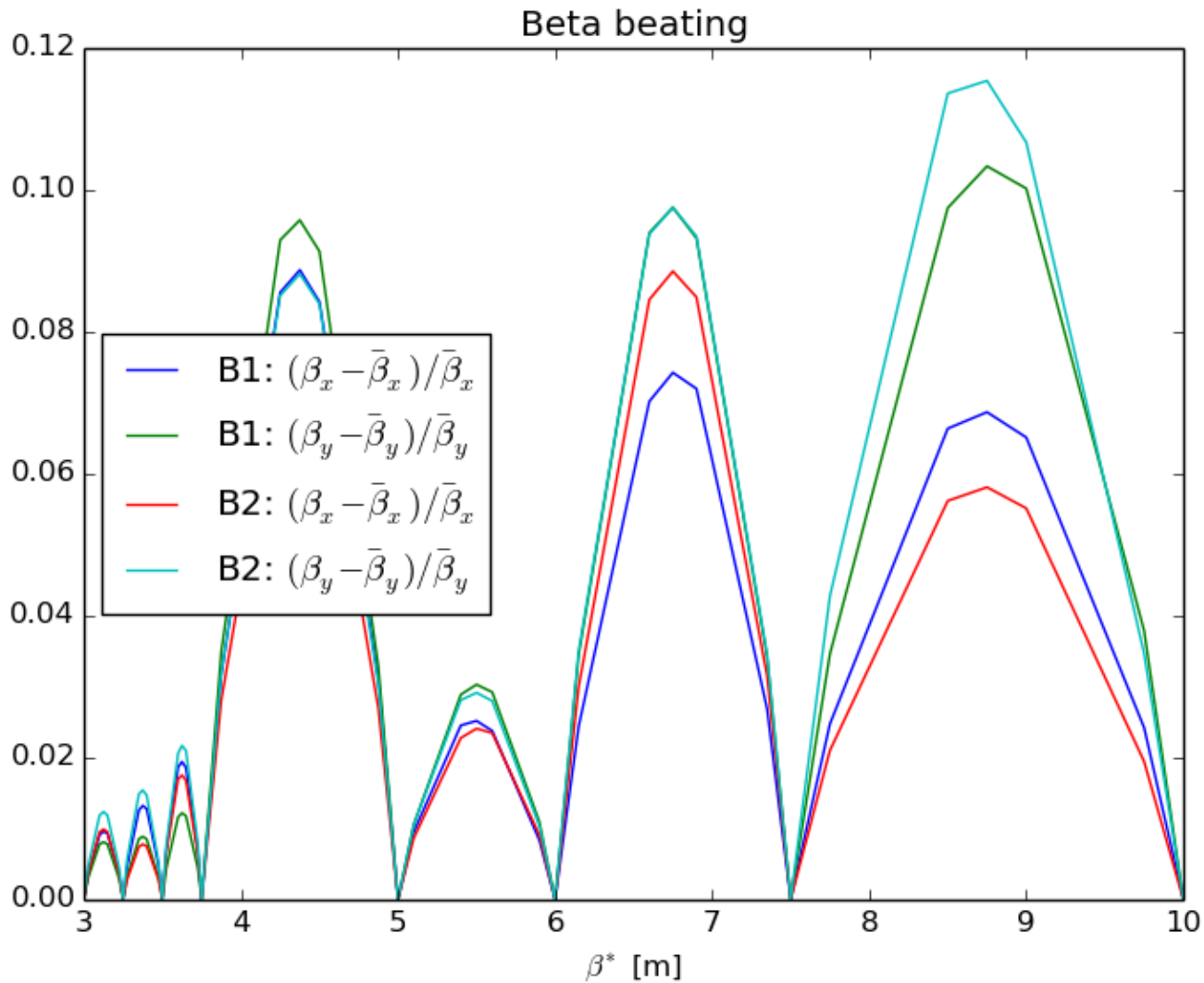


IR8 Squeeze Opt Med

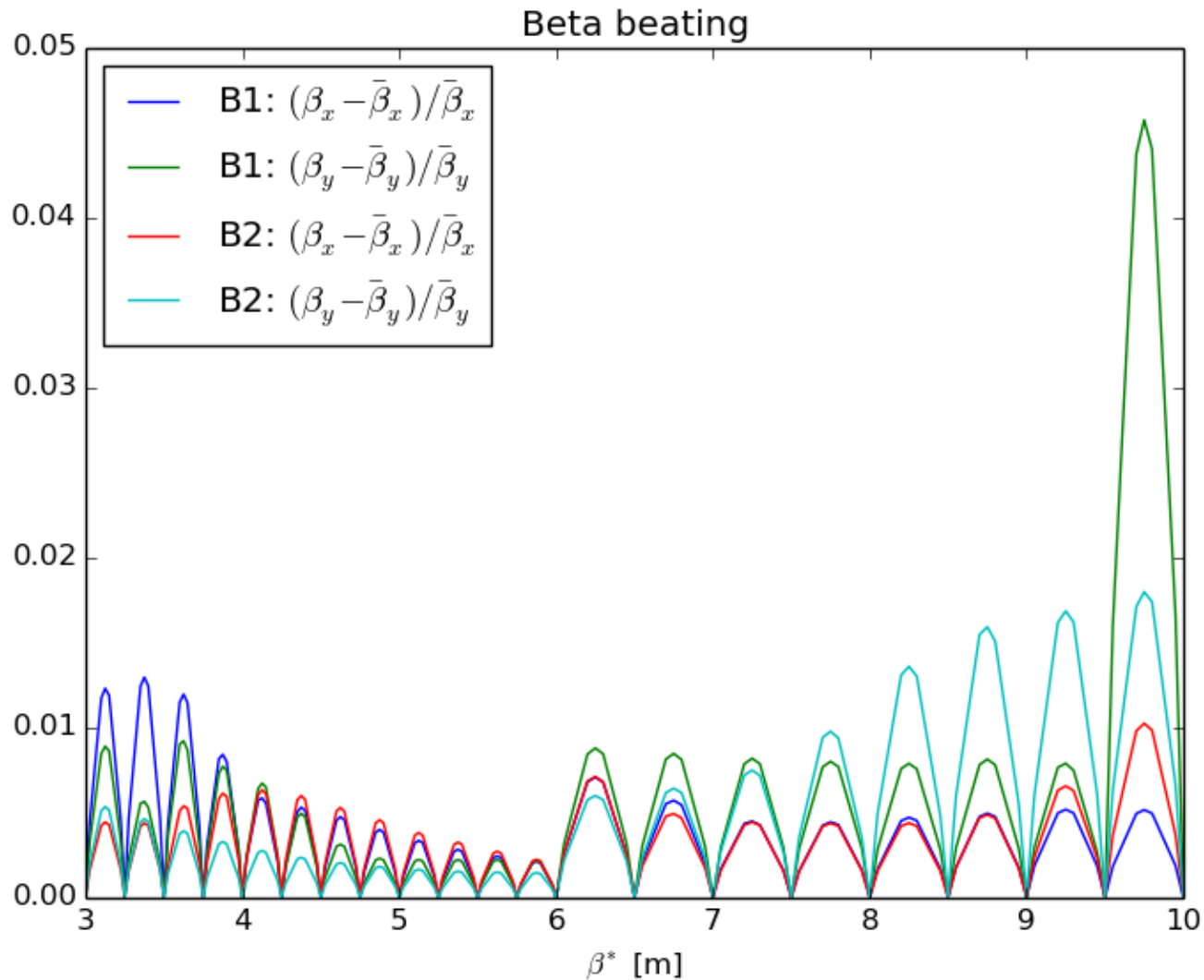
250 μrad \leftarrow 170 μrad



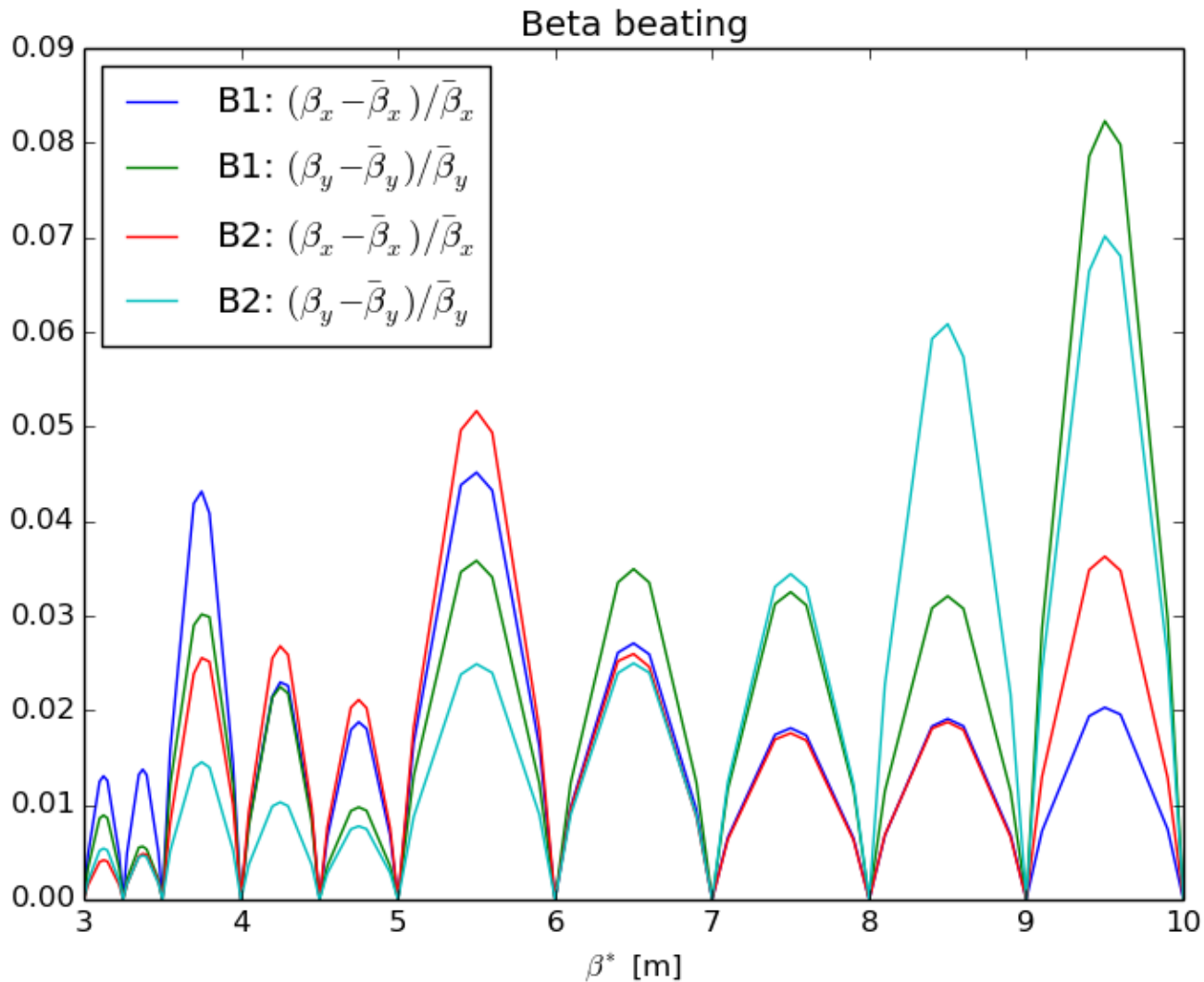
IR8 Squeeze 2012



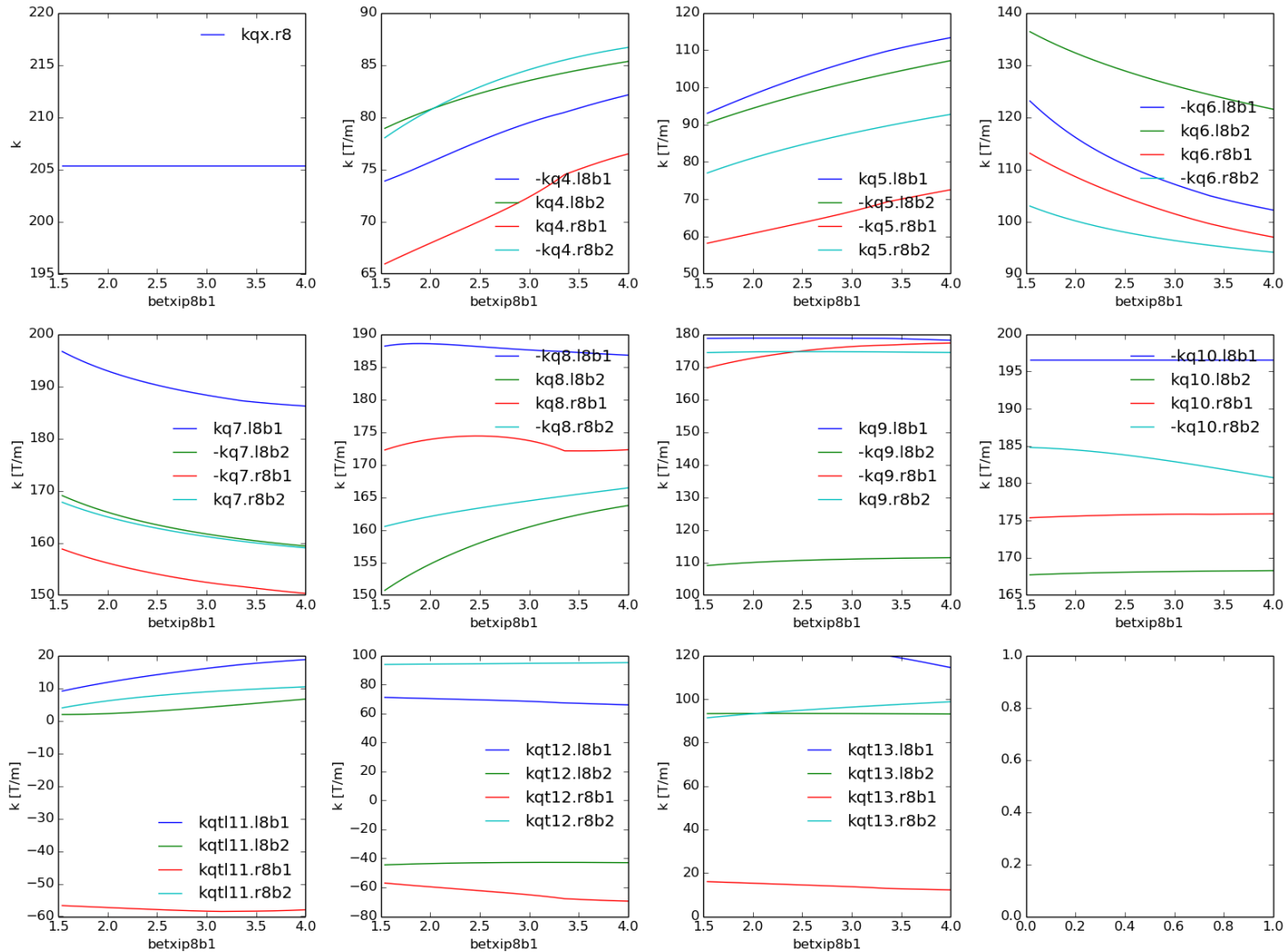
IR8 Squeeze Opt Med (all steps)



IR8 Squeeze Opt Med (selection)

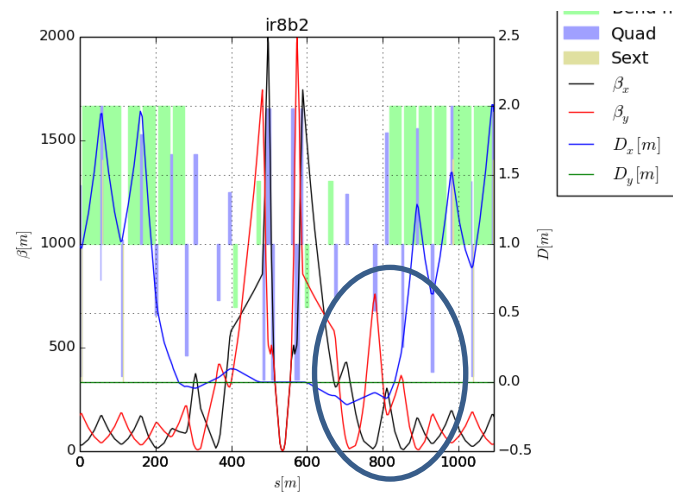
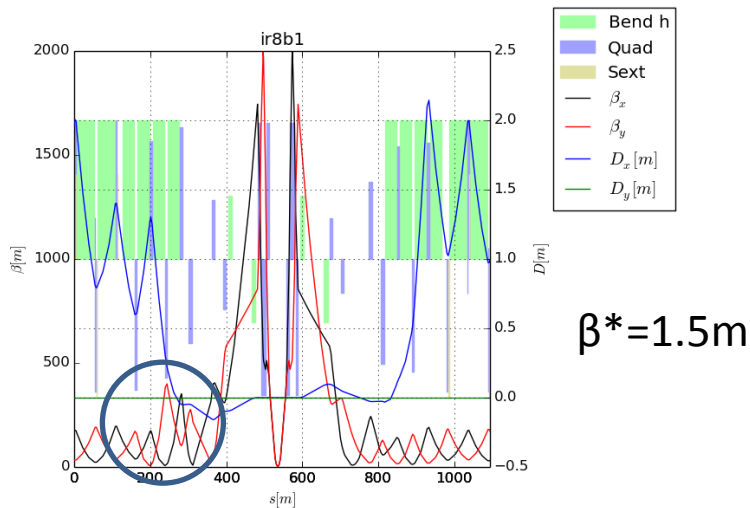
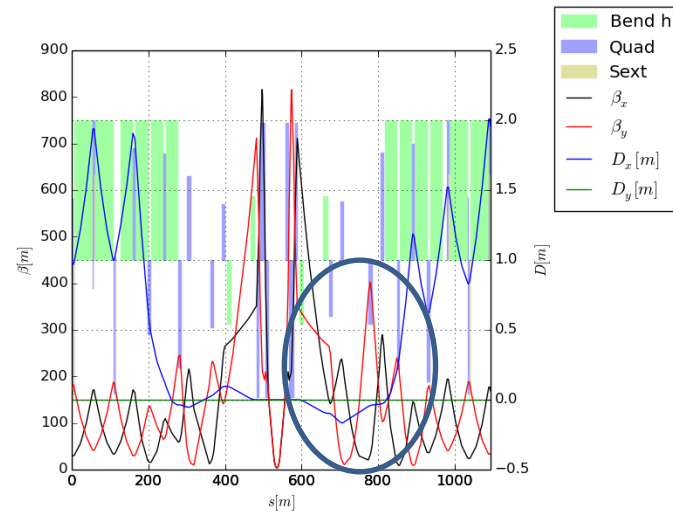
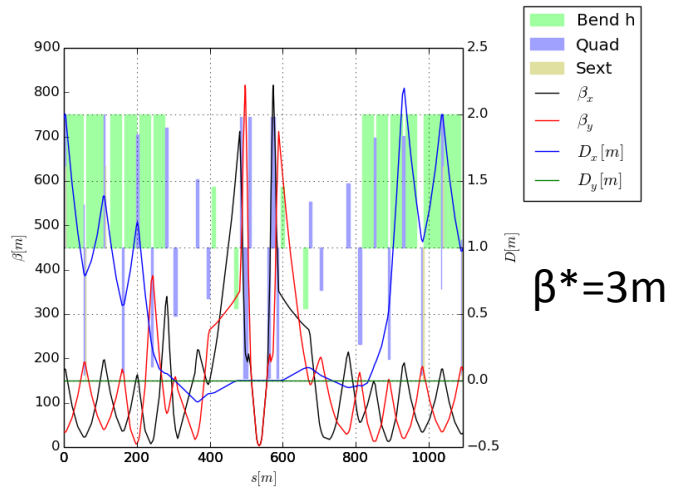


IR8 Squeeze Opt Med V2

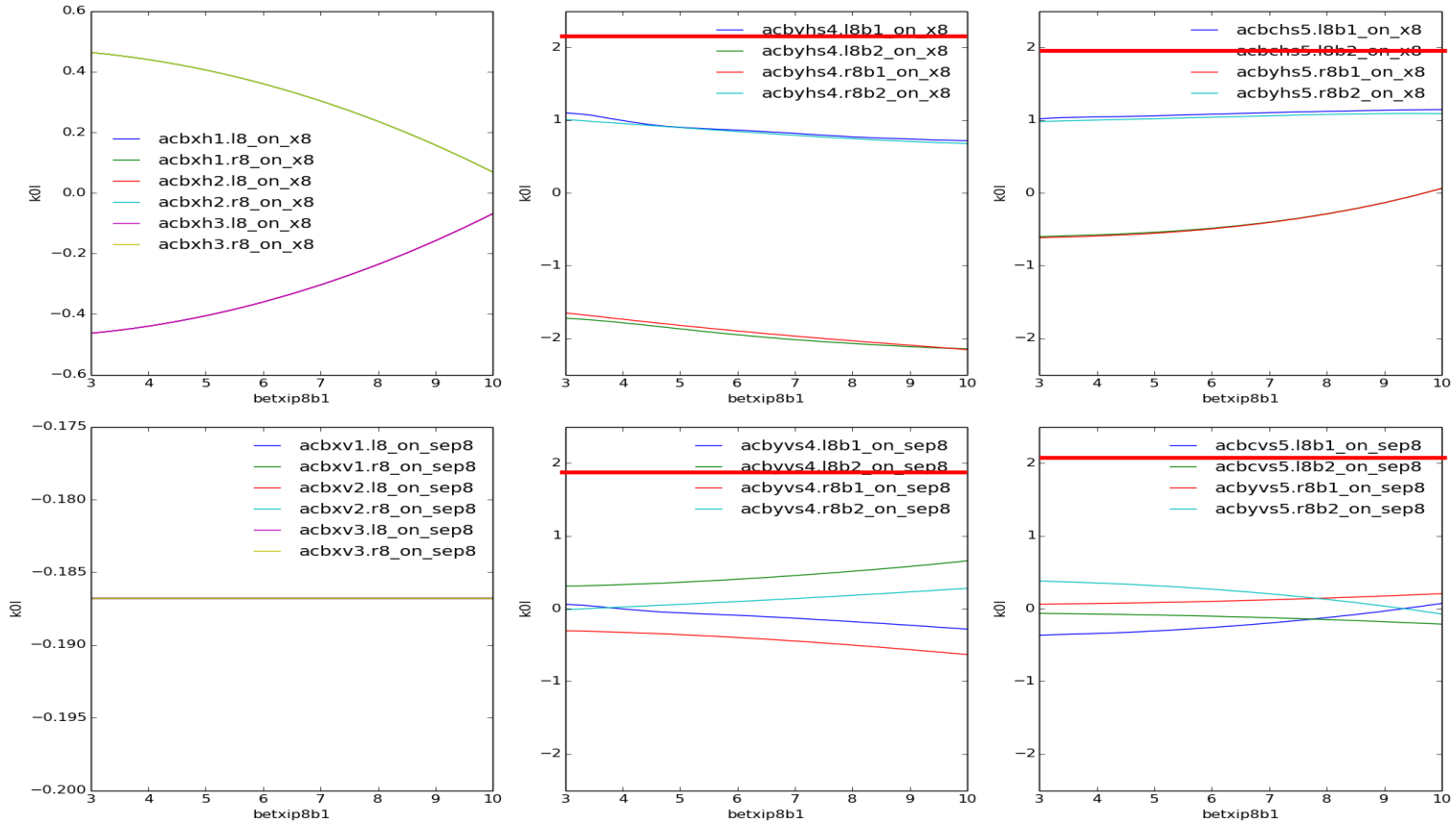


IR8 Squeeze Opt Med V2

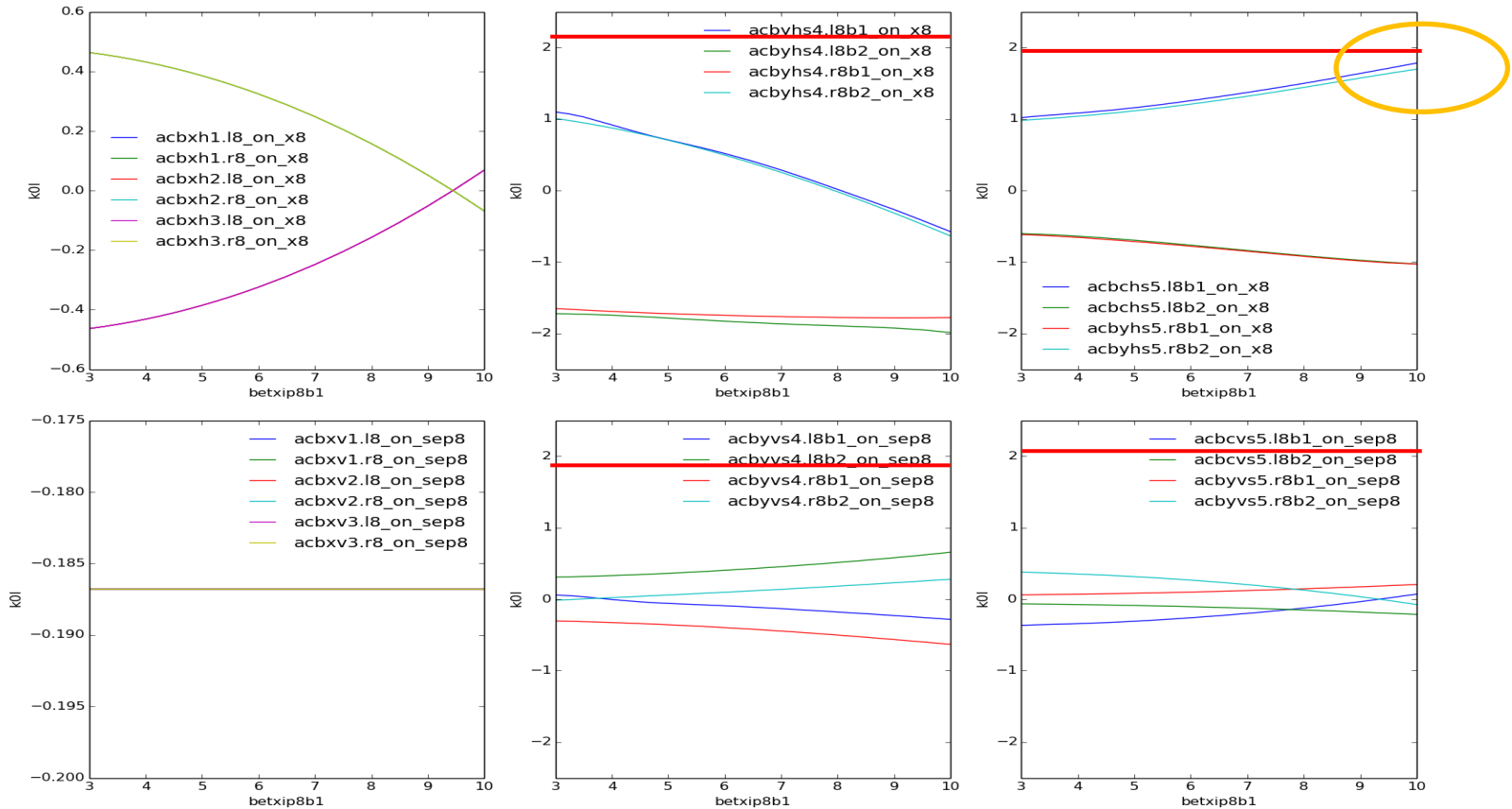
Second iteration is smoother but Beta peaks in Q6-Q8 need to be assessed.
Reducing beta* further for ion can be still attempted.



IR8 Squeeze Opt Med (orbit)



IR8 Squeeze Opt Med (orbit)



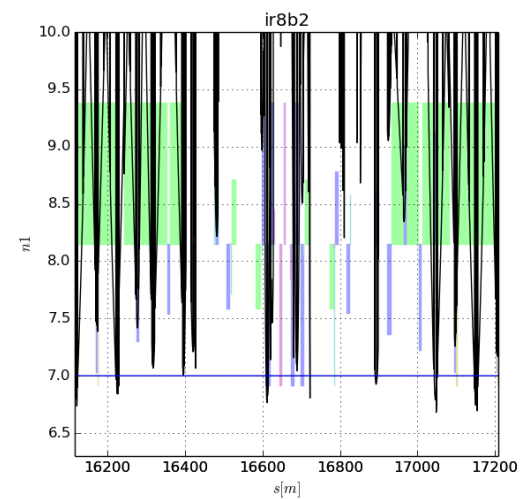
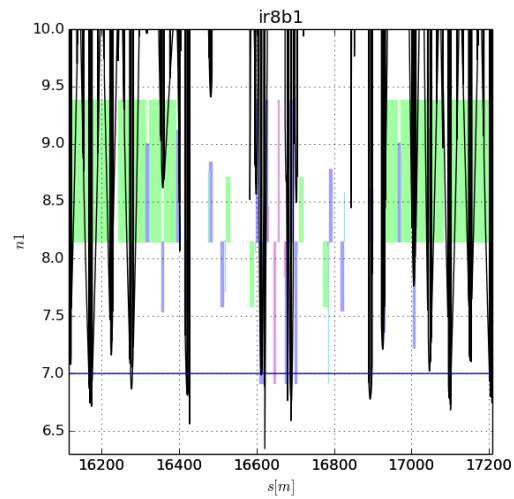
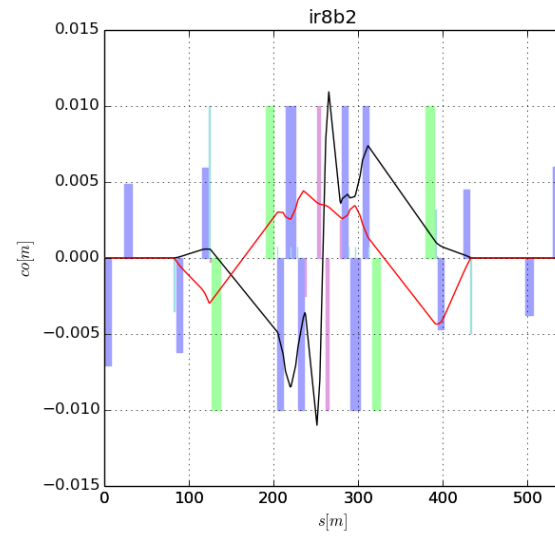
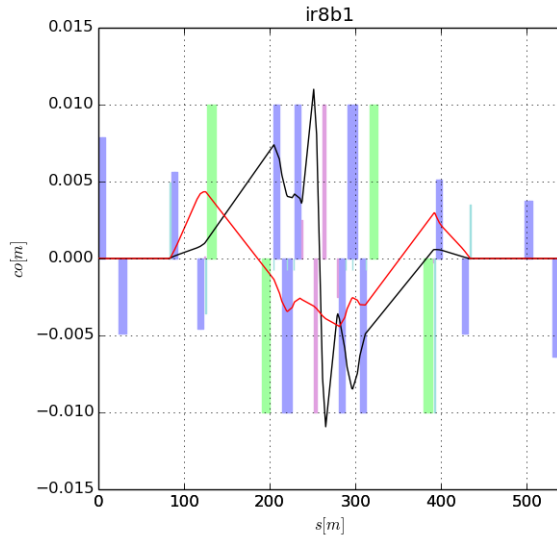
In alternative: Imbalancing acbx1/2 with acbx3 should help acbc5 correctors (see HL-LHC)

Crossing schemes IP8

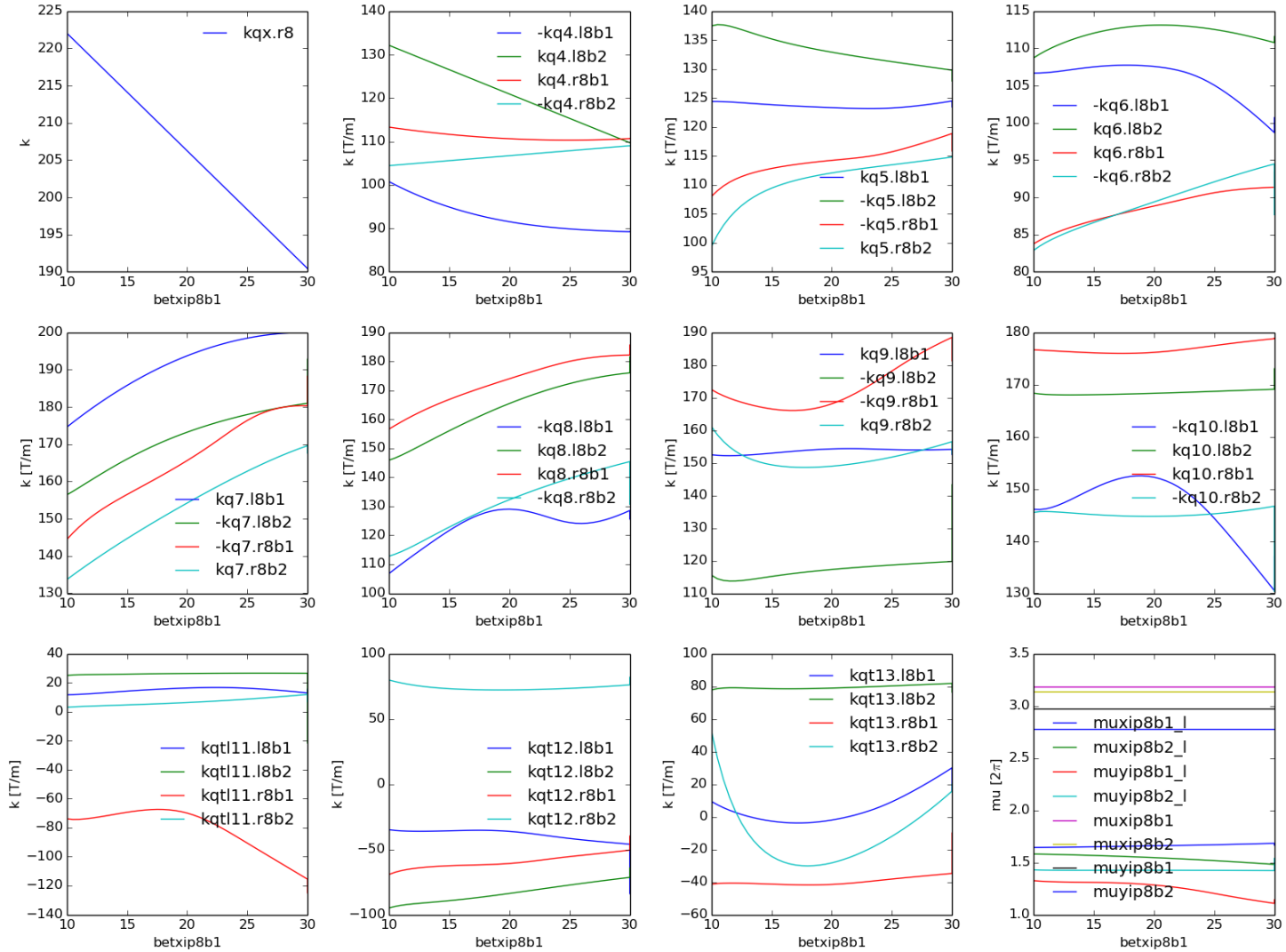
		Xing H [μ rad]	MCBX [μ rad]	#	Sep V [mm]	MCBX [μ rad]	#	p_y off. [μ rad]	x off. [mm]
ATS 2015	Inj	-170	-3.617	123	-3.5	-31.5	123	-40	0
ATS 2015	Col	-170	-13.5	123	-2.0	-16	123	0	0
ATS 2015	VDM	-170	-28.0	123	-2.0	-11.5	123	0	0
v6.503	Inj	-170	-2.5	12	-2.0	-30	1	-20	0.5
v6.503	Col	-130	-1.91	12	-0.7	-1.05	1	0	0
Run I	Inj	-170	-2.5	12	-2.0	-30	1	0	0
Run I	Col	-220	-3.23	12	-0.65	-0.975	1	0	0
2015	Inj	-170	-3.617	123	-3.5	-31.5	123	-40	0
2015	EoR	-170	-3.617	123	-1.0	-8	123	0	0
2015	Col	-250	-19.8	123	-1.0	-8	123	0	0
2015	VDM	0	0	0	-1.0	-8	123	0	0

In V6.503 $x_{8v} \rightarrow 90 \mu$ rad and $sep_{8h} \rightarrow 0.7$ mm were also defined, acbch5.l8b1 used instead of acbchs5.l8b1. For 2015 using LMC 167 data and Chamonix 2014.

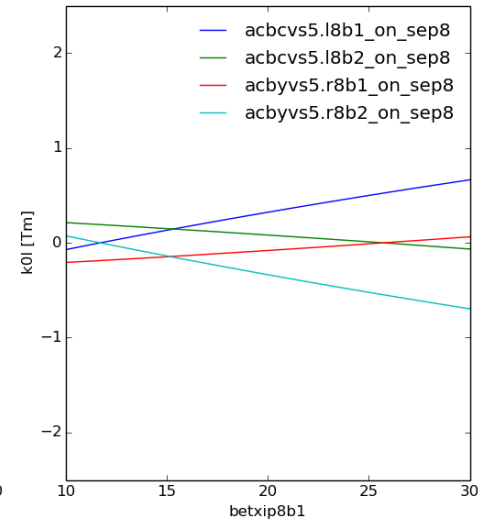
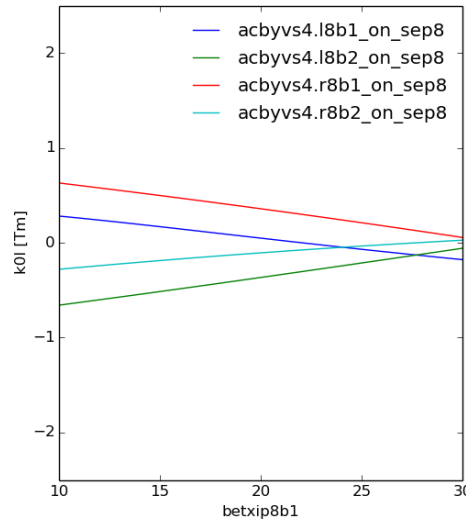
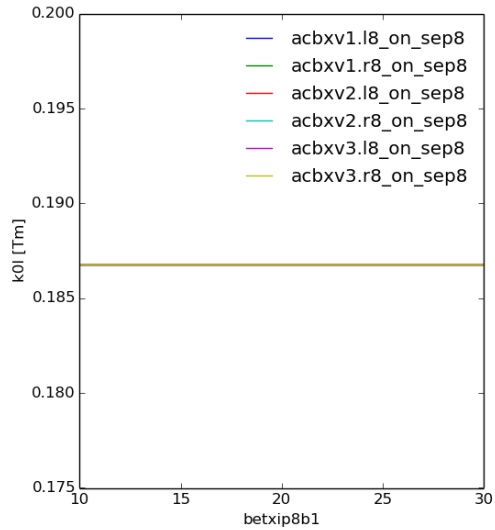
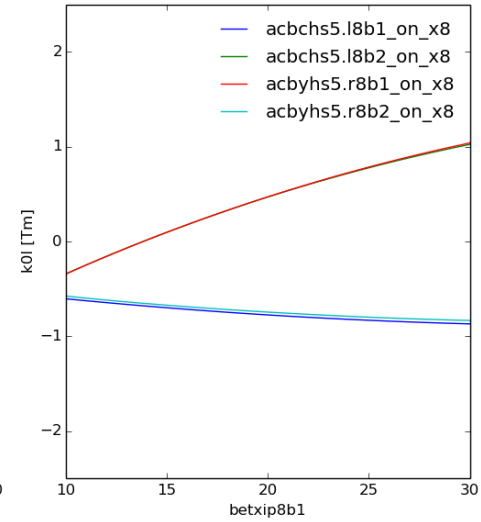
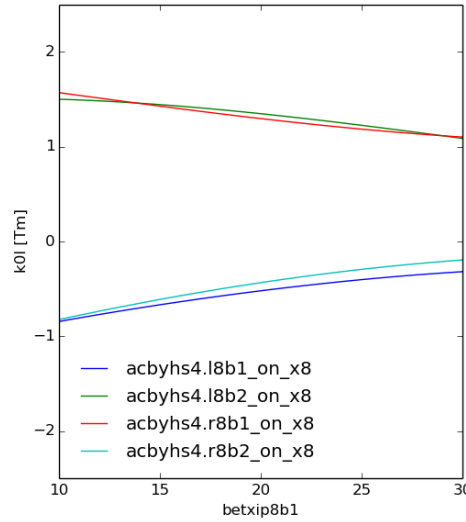
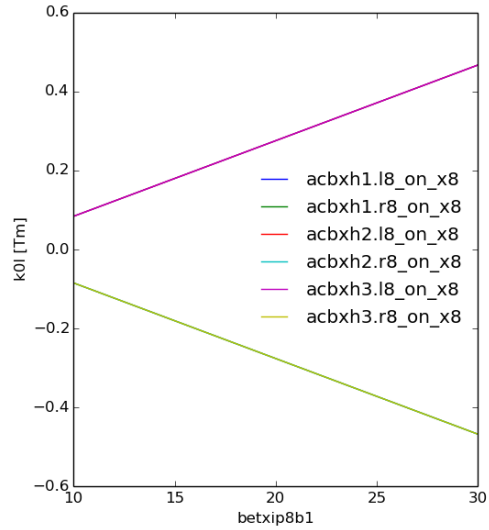
Crossing IP8



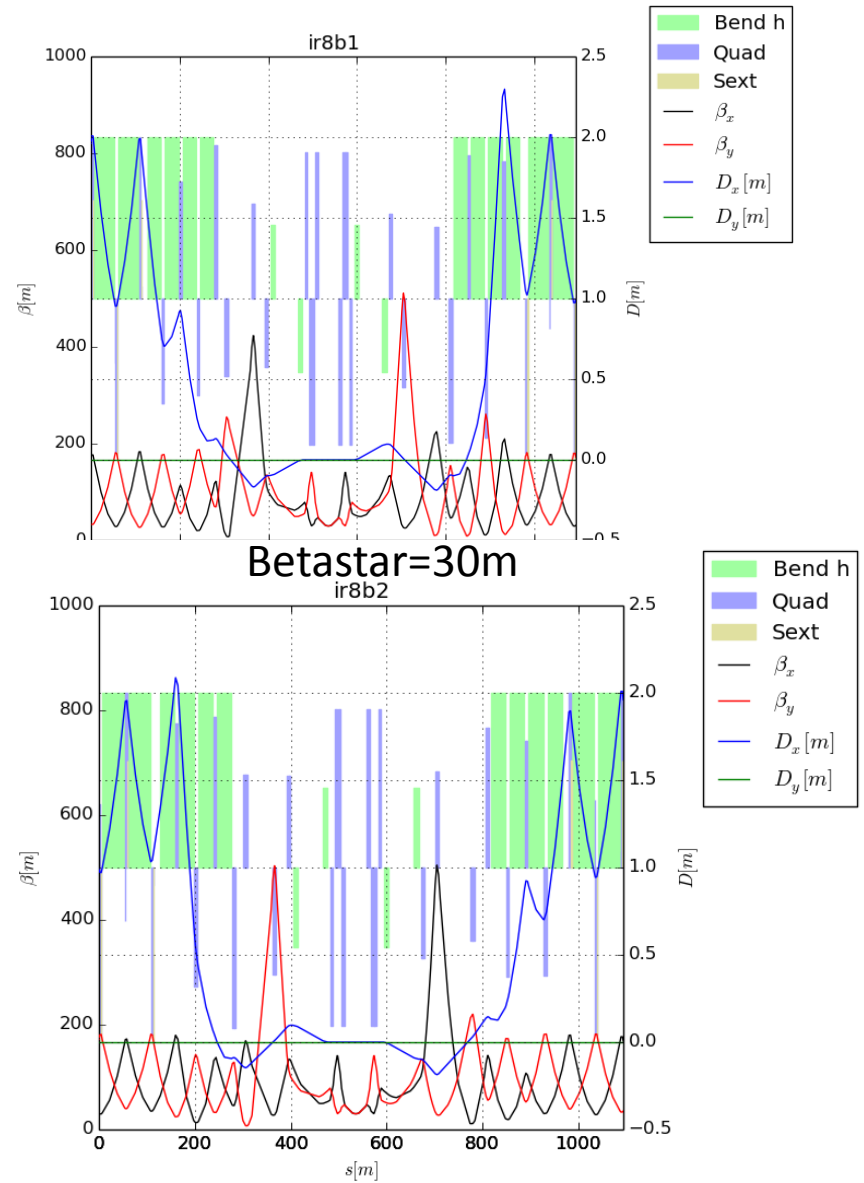
IR8 VDM



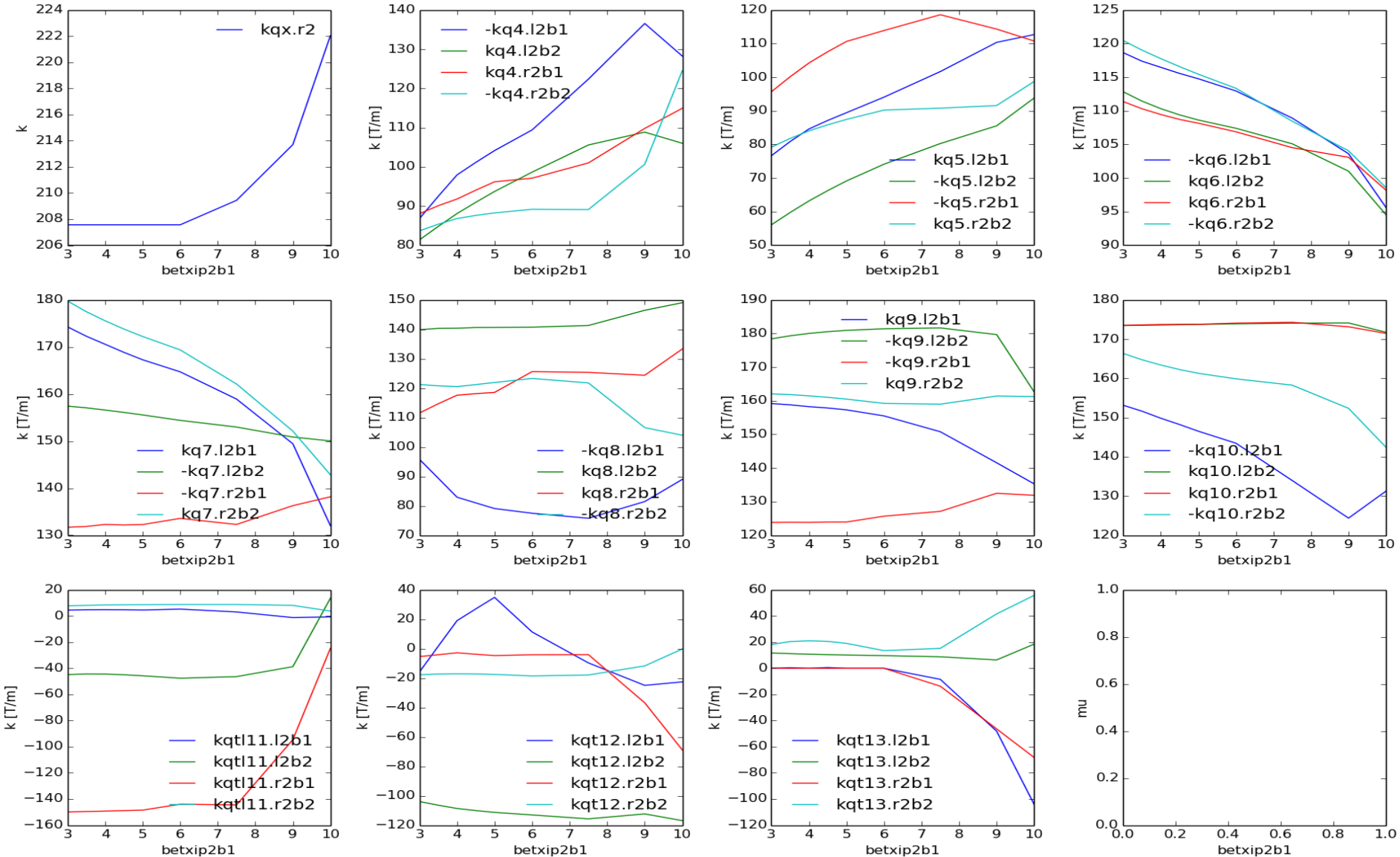
IR8 VDM



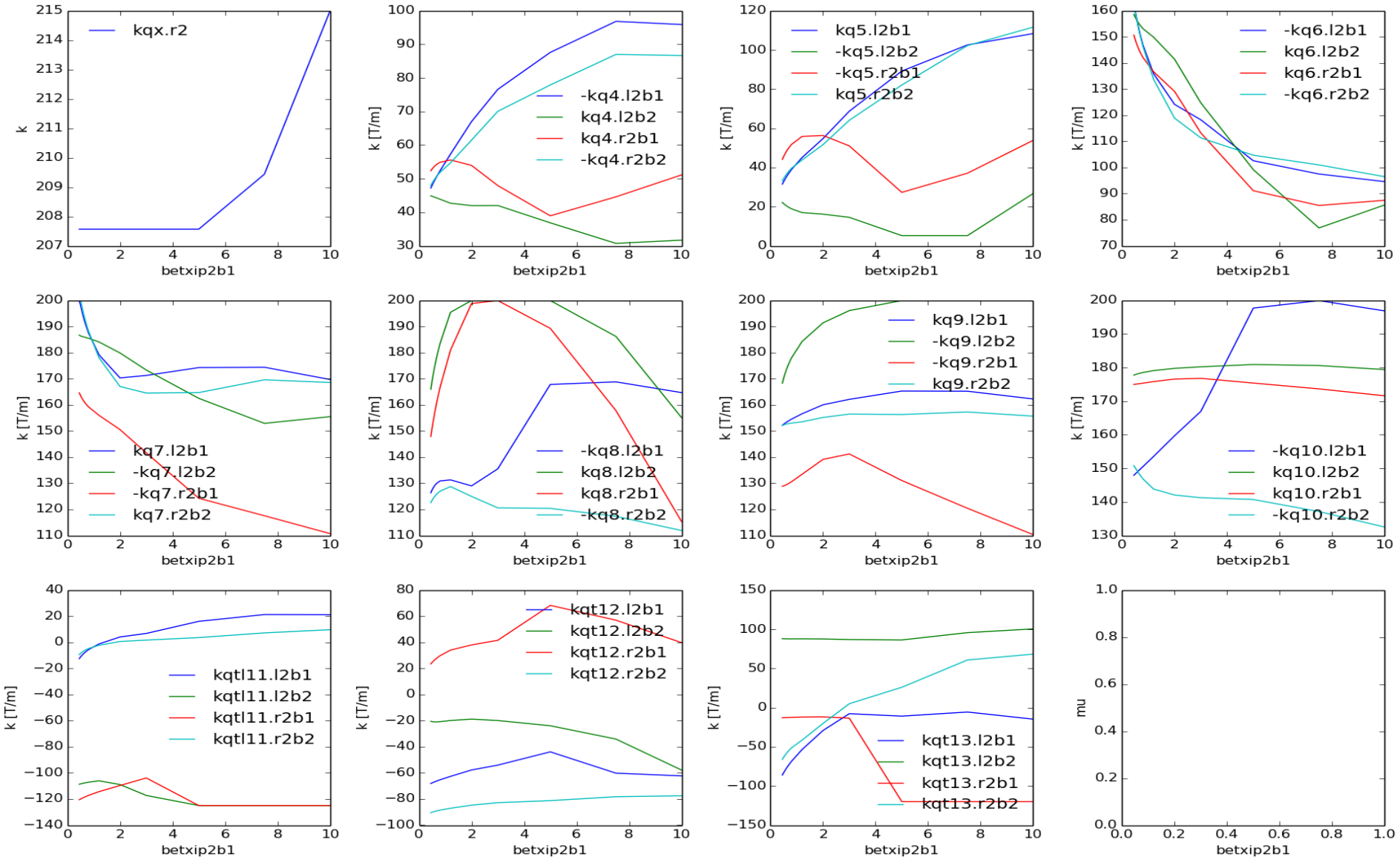
IR8 VDM



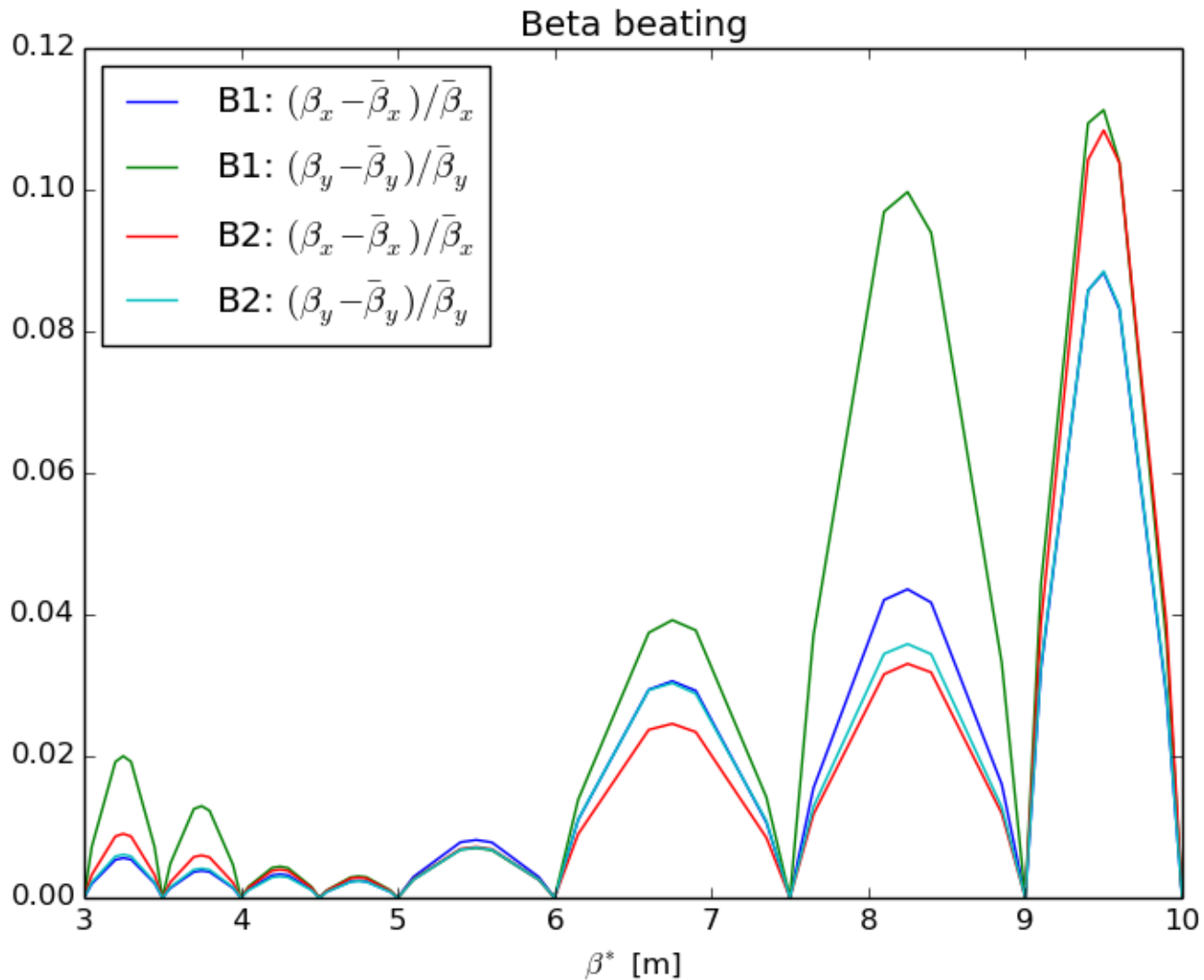
IR2 Squeeze 2012 (7TeV strength)



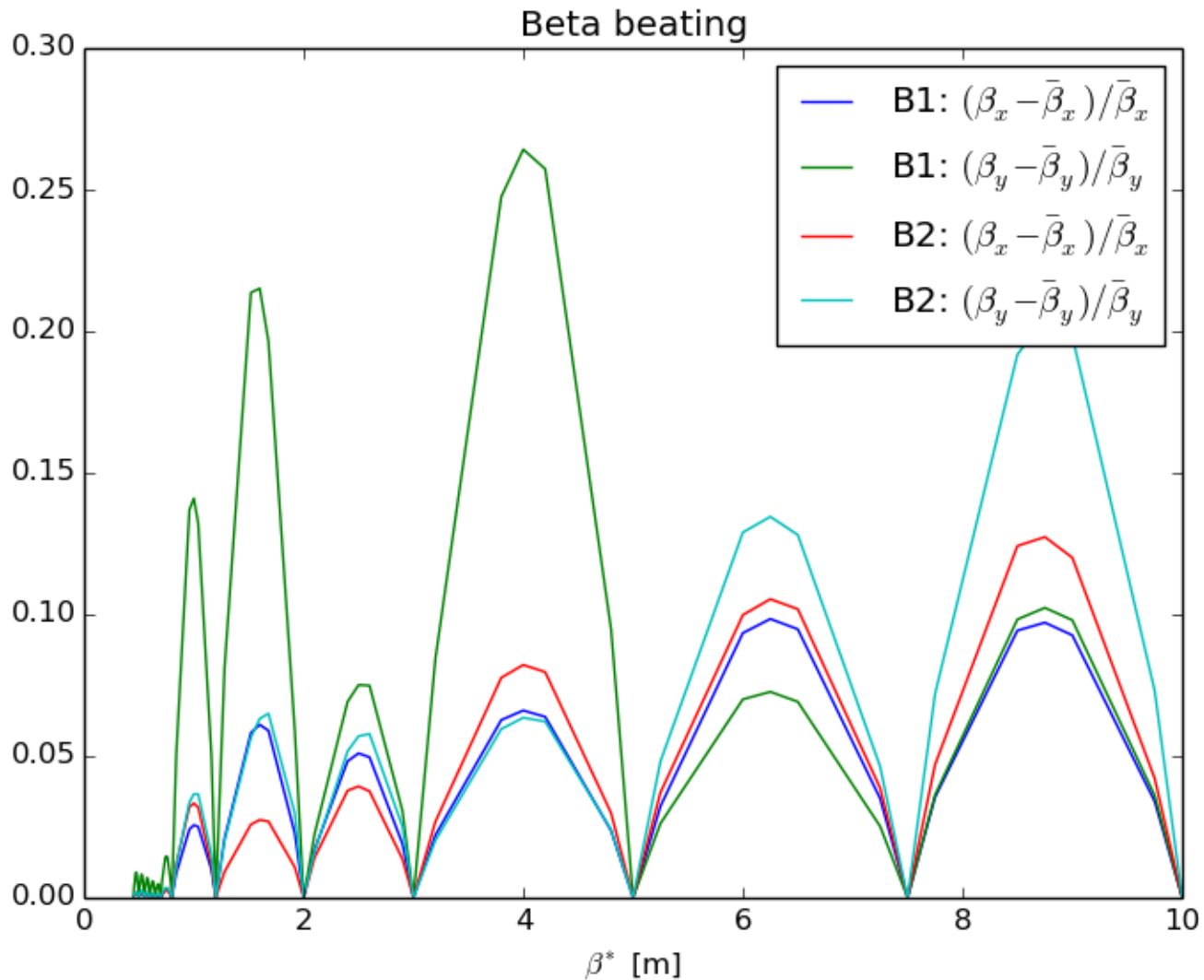
IR2 Squeeze Opt Med (7TeV strength)



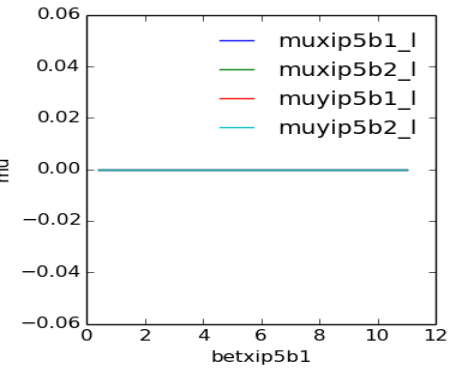
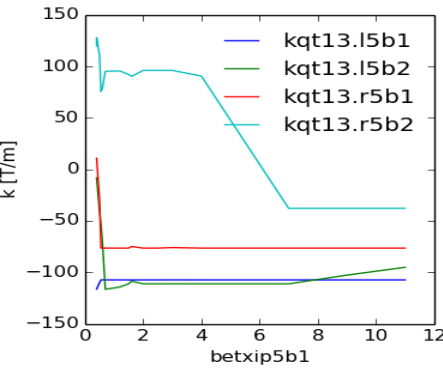
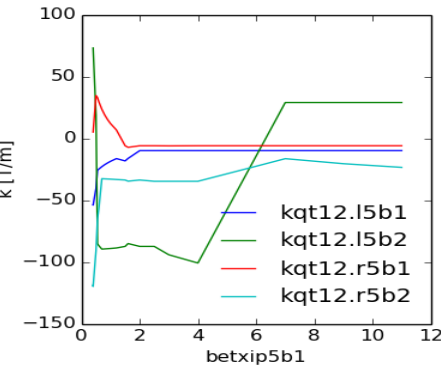
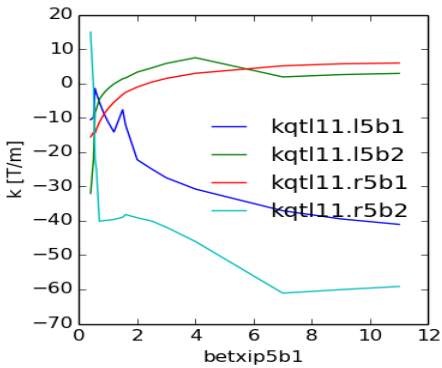
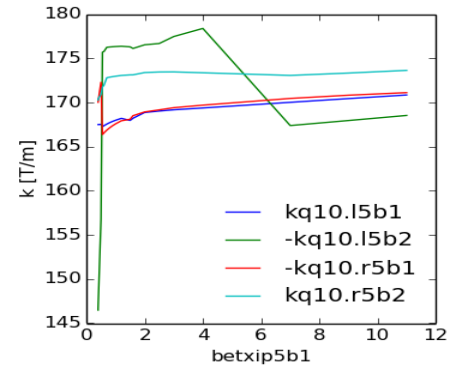
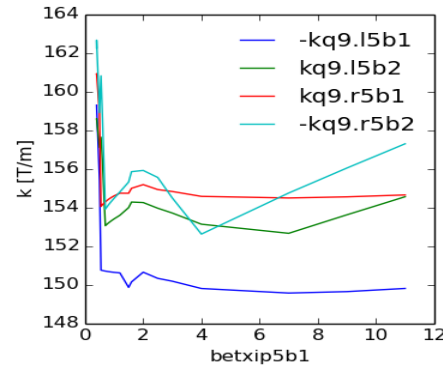
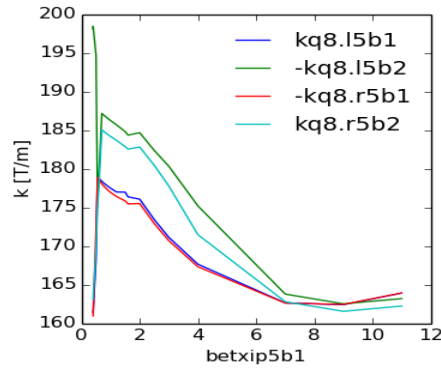
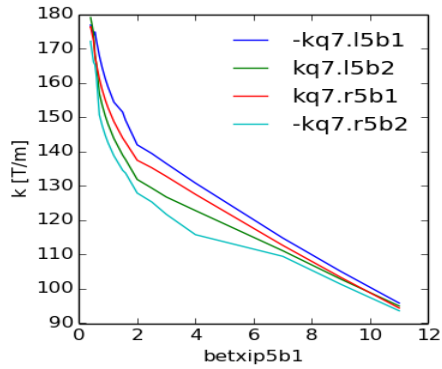
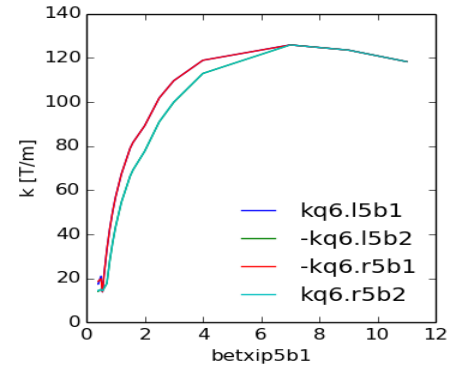
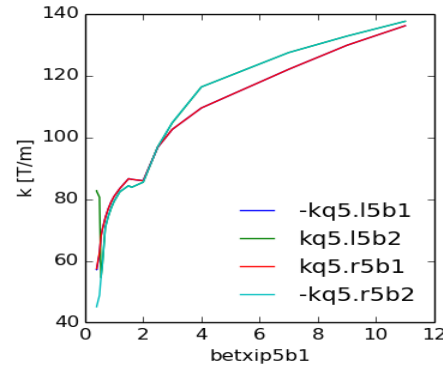
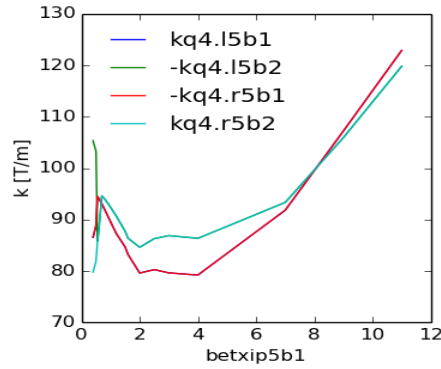
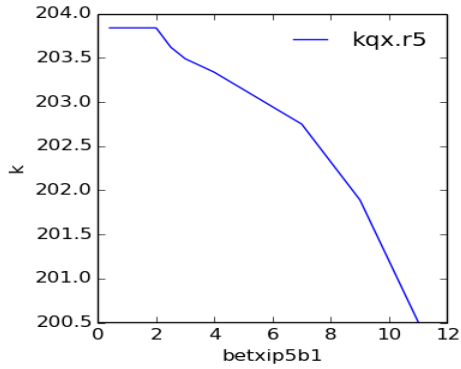
IR2 Squeeze 2012



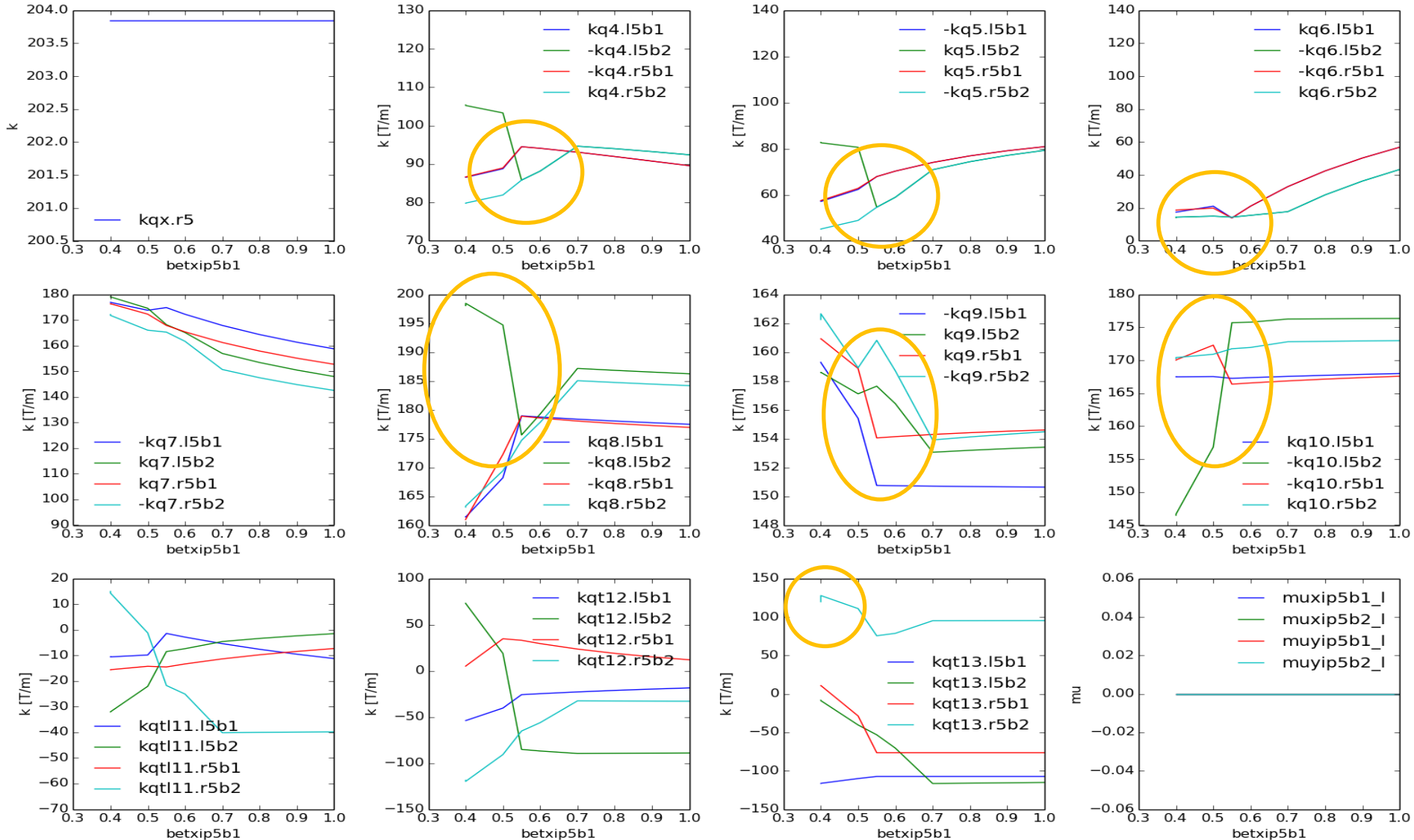
IR2 Squeeze Opt Med



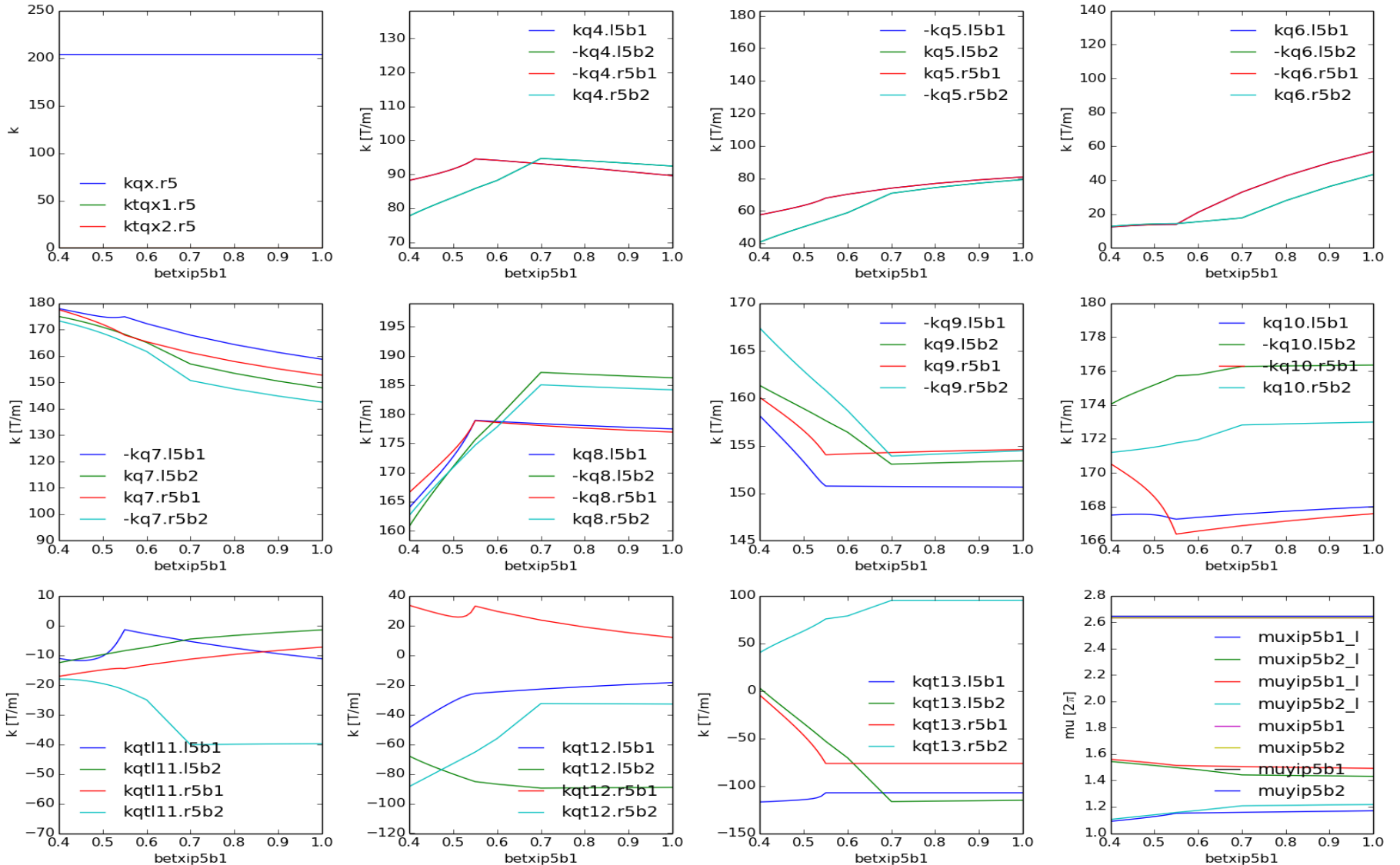
Squeeze IR1 and IR5



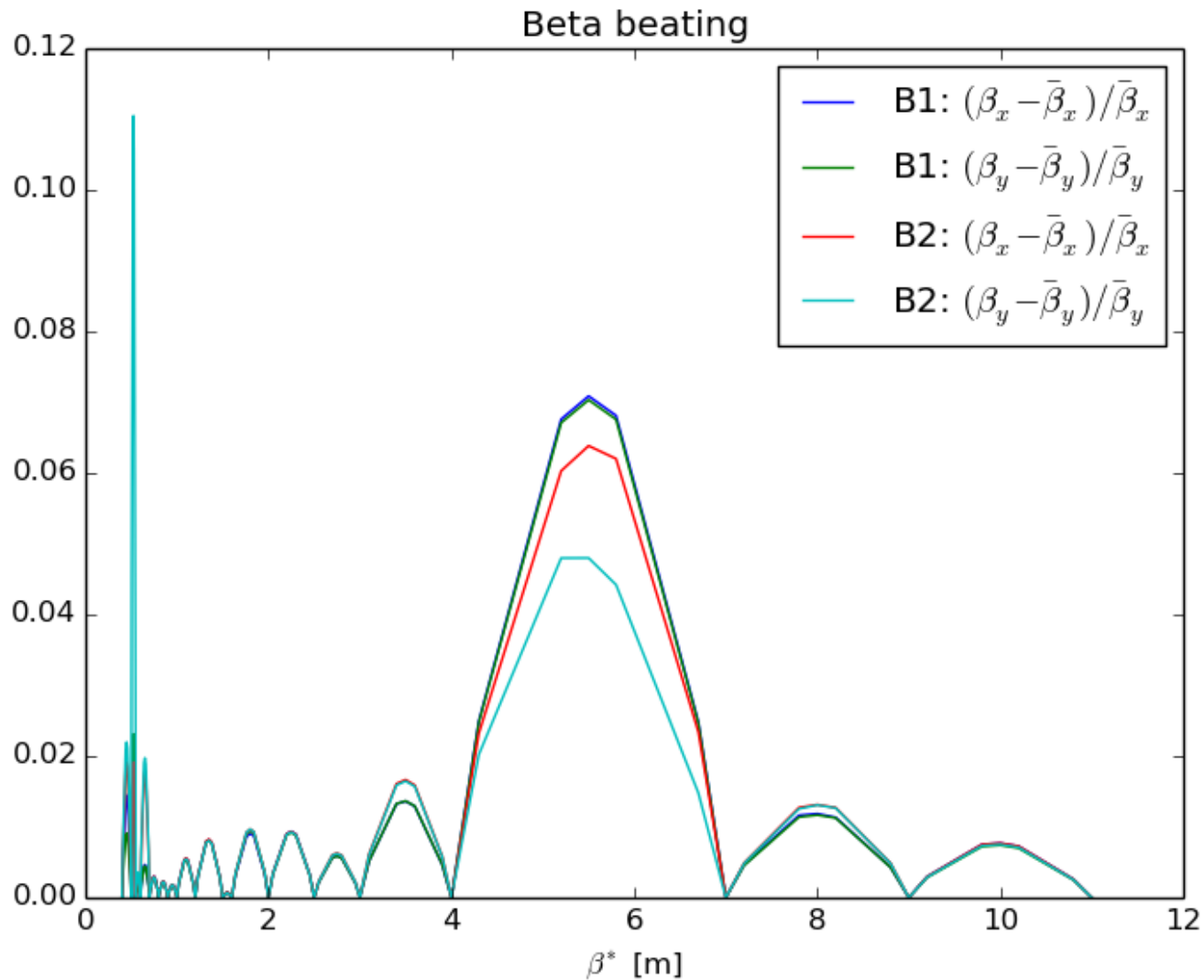
Squeeze IR1 and IR5



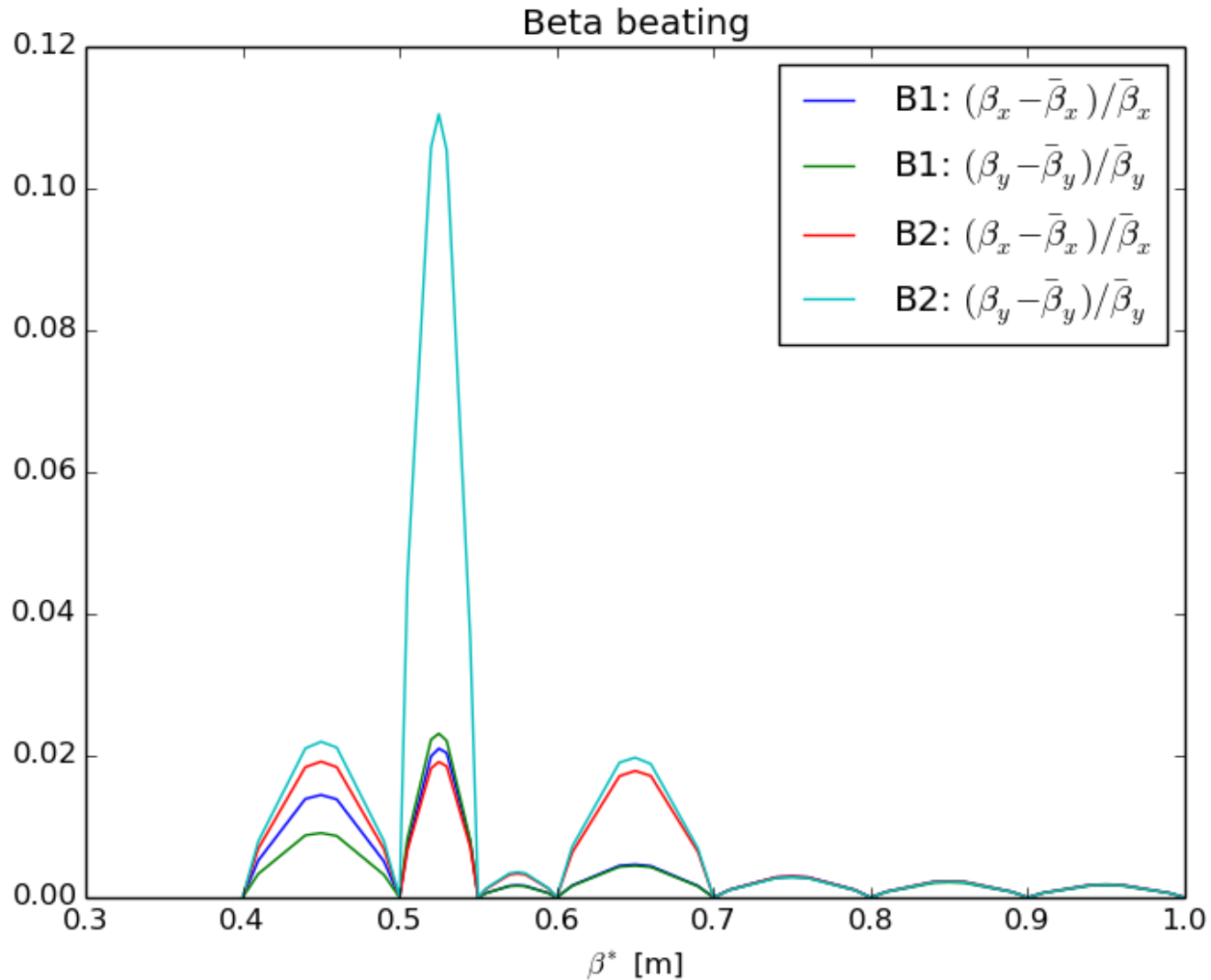
Squeeze IR1 and IR5 V2



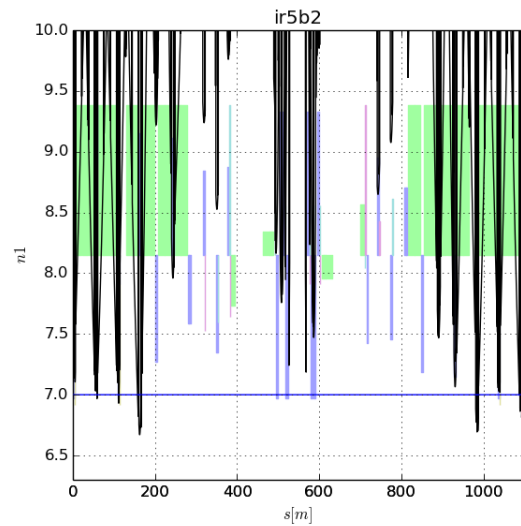
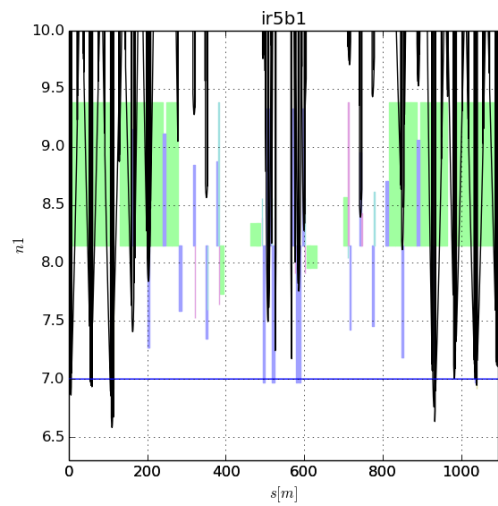
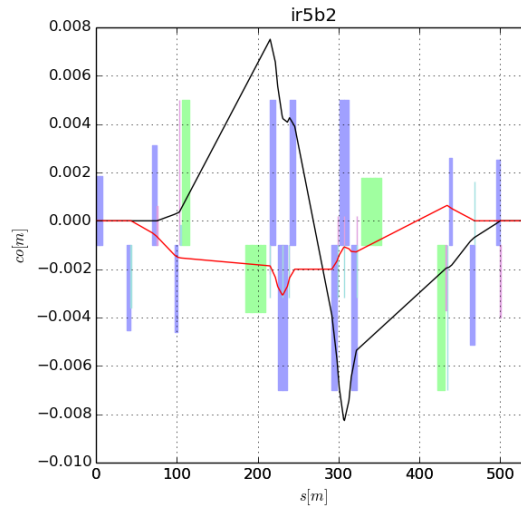
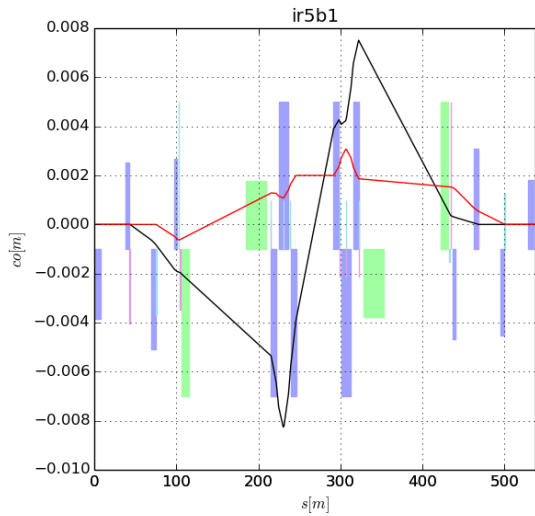
Squeeze IR1 and IR5



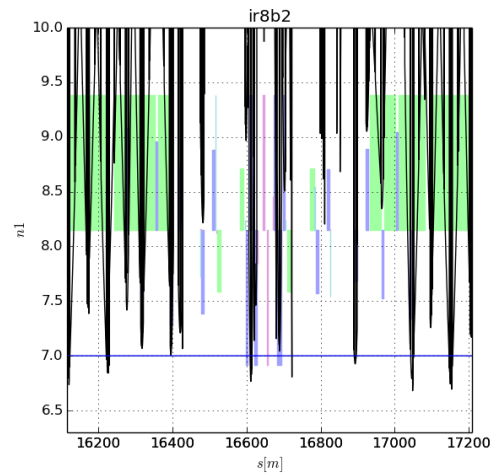
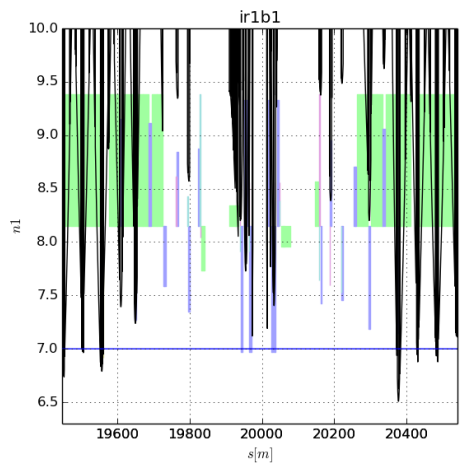
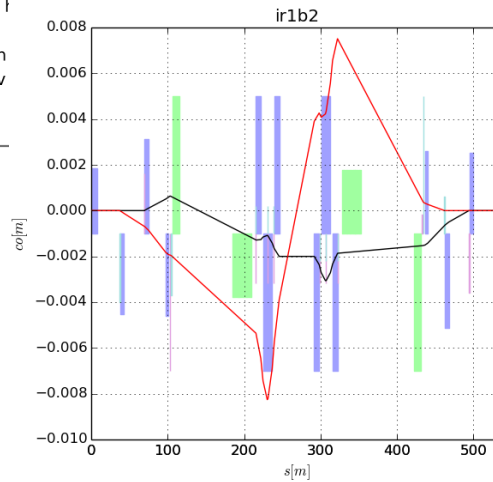
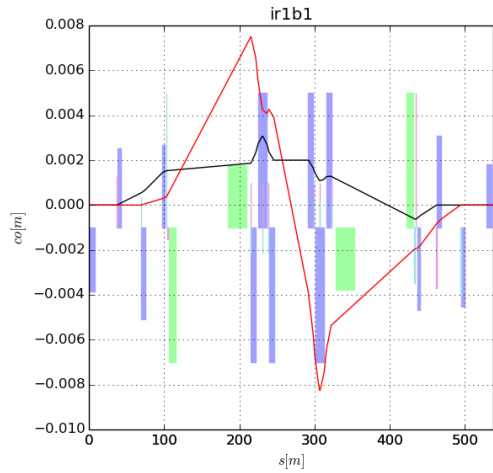
Squeeze IR1 and IR5



Crossing IP5



Crossing IP1



Crossing knobs IP1

		Xing V [μ rad]	MCBX [μ rad]	#	Sep H [mm]	MCBX [μ rad]	#	p_y off. [μ rad]	x off. [mm]
ATS_2015	Inj	170	9.333	123	-2	-16	123	0	0
ATS_2015	Col	170	9.333	123	-2	-16	123	0	0
ATS_2015	VDM	170	28.0	123	-2	-48	123	0	0
v6.503	Inj	170	35	1	-2	-40	1	0	0
v6.503	Col	142.5	10	1	-0.5	-10	1	0	-0.5
Run I	Inj	-170	-35	1	-2	-40	1	0	0
Run I	Col	-145	10.17	1	-0.5	-10	1	0	0
2015	Inj	-170	-9.333	123	-2	-16	123	0	0
2015	EoR	-145	-7.96	123	-0.5	-4	123	0	0
2015	Col	-145	-7.96	123	-0.5	-4	123	0	-0.5
2015	VDM	0	0	0	-2	-16	123	0	0

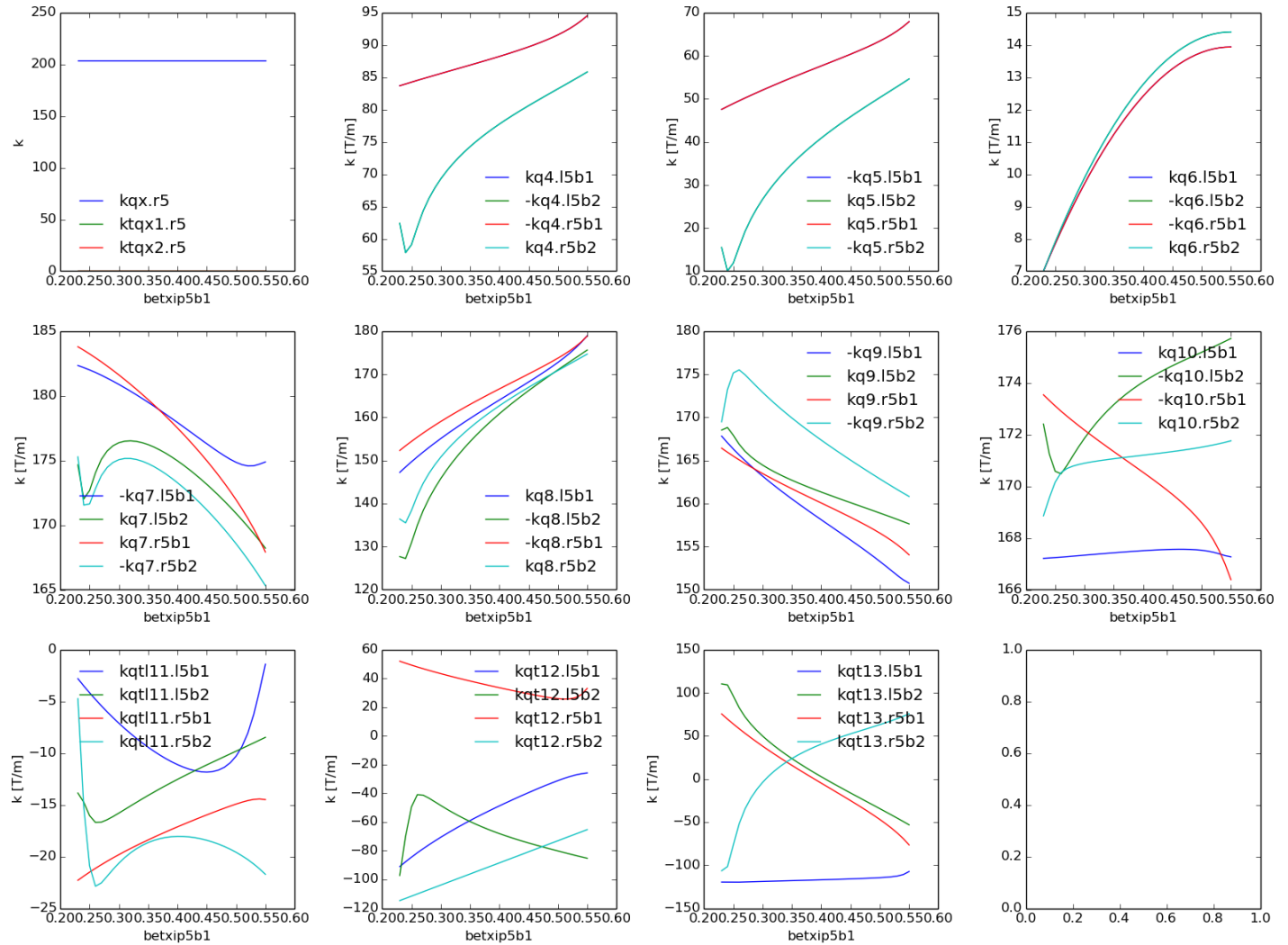
Crossing knobs IP5

		Xing H [μ rad]	MCBX [μ rad]	#	Sep V [mm]	MCBX [μ rad]	#	V off. [μ rad]	H off. [mm]
ATS 2015	Inj	170	9.333	123	2	16	123	0	0
ATS 2015	Col	170	9.333	123	2	16	123	0	0
ATS 2015	VDM	170	28.0	123	2	48	123	0	0
v6.503	Inj	170	35	1	2	40	1	0	0
v6.503	Col	142.5	10	1	0.5	10	1	0	0.5
Run I	Inj	170	35	1	2	40	1	0	0
Run I	Col	145	10.17	1	0.5	10	1	0	0
2015	Inj	170	9.333	123	-2	-16	1	0	0
2015	EoR	145	7.96	123	-0.5	-4	1	0	0
2015	Col	145	7.96	123	-0.5	-4	1	0	-0.5
2015	VDM	145	7.96	123	-2	-16	1	0	0

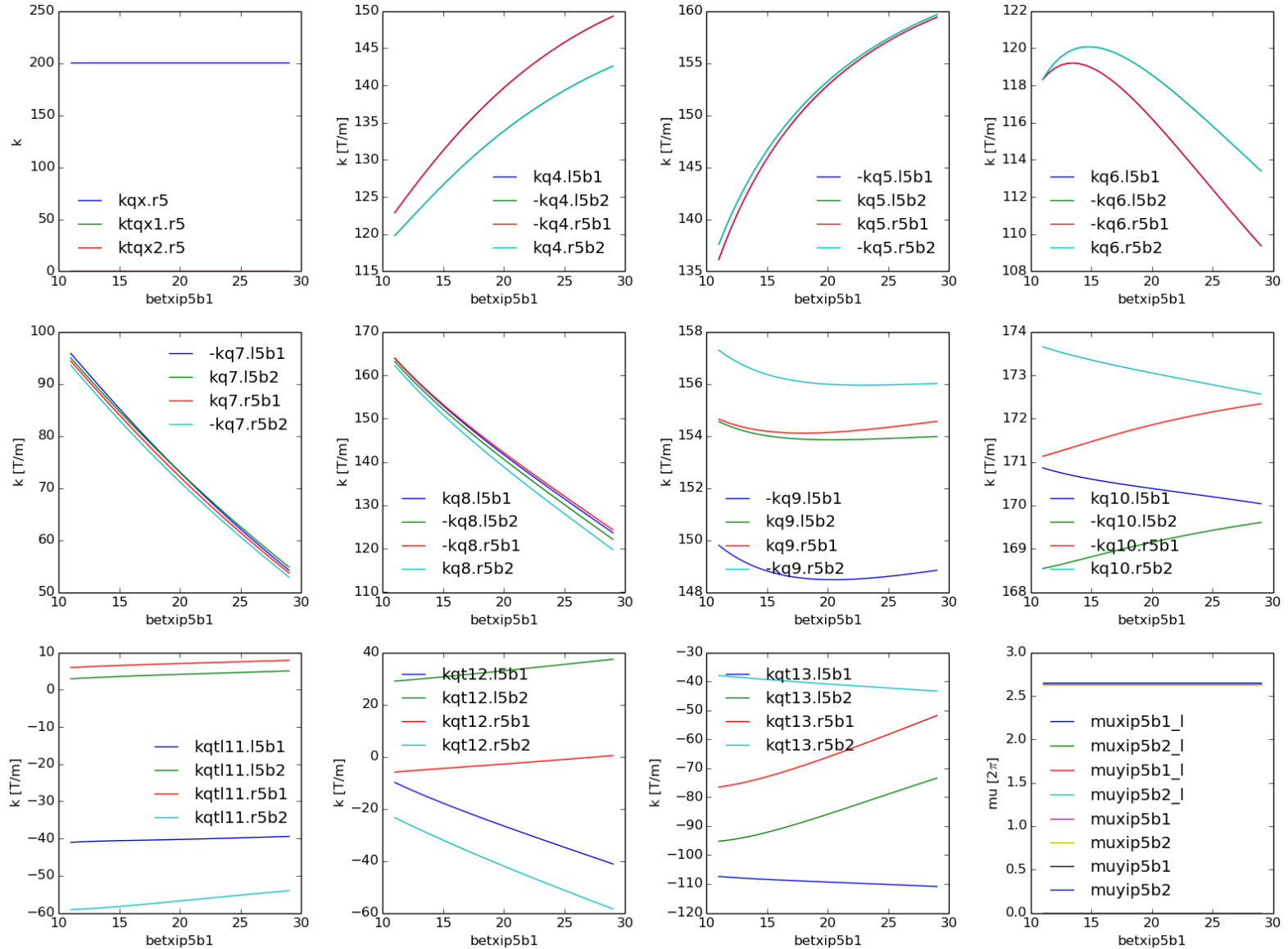
Crossing knobs IP2

		Xing V [μ rad]	MCBX [μ rad]	#	Sep H [mm]	MCBX [μ rad]	#	H off. [μ rad]	V off. [mm]
ATS 2015	Inj	170	1.0	123	2.0	16	123	0	0
ATS 2015	Col	170	14.0	123	2.0	16	123	0	0
ATS 2015	VDM	170	14.5	123	2.0	16	123	0	0
v6.503	Inj	170	0	-	2.0	35	1	-20	0.5
v6.503	Col	80	0	-	0.7	12.25	1	0	0
Run I	Inj	170	0	-	2.0	35	1	0	0
Run I	Col	145	0	-	0.7	12.25	1	0	0
2015	Inj	170	14.0	123	2.0	16	123	-20	0.5
2015	EoR	170	14.0	123	2.0	16	123	-20	0.5
2015	Col	120	9.88	123	0.7	5.6	123	0	0.5

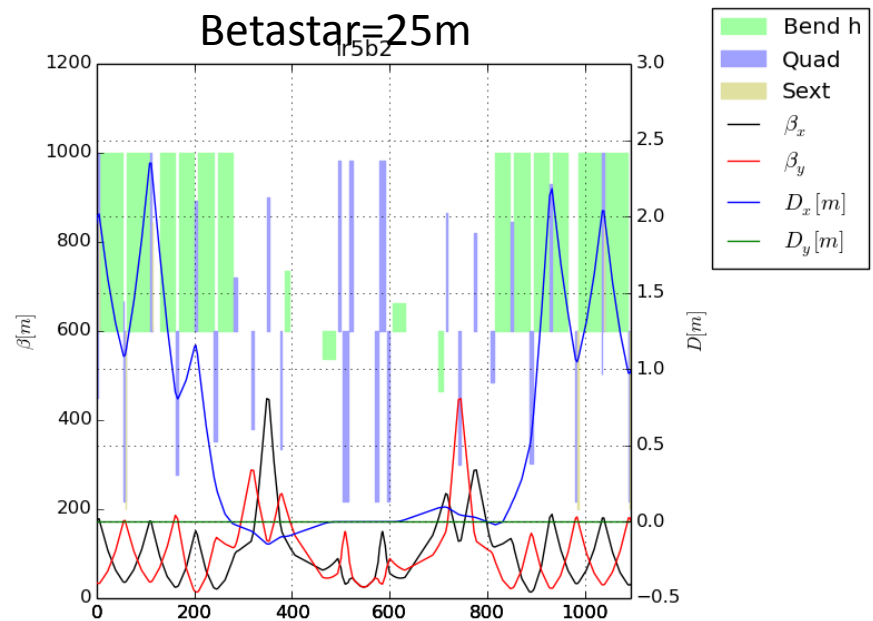
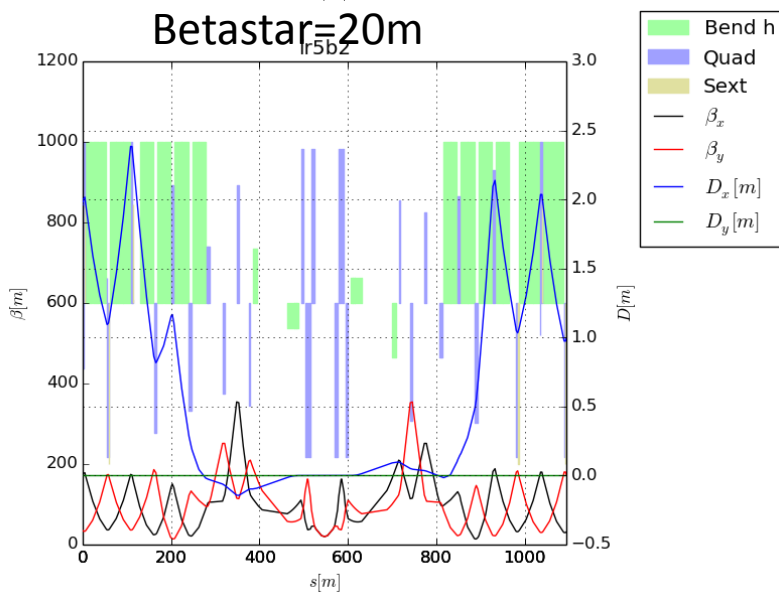
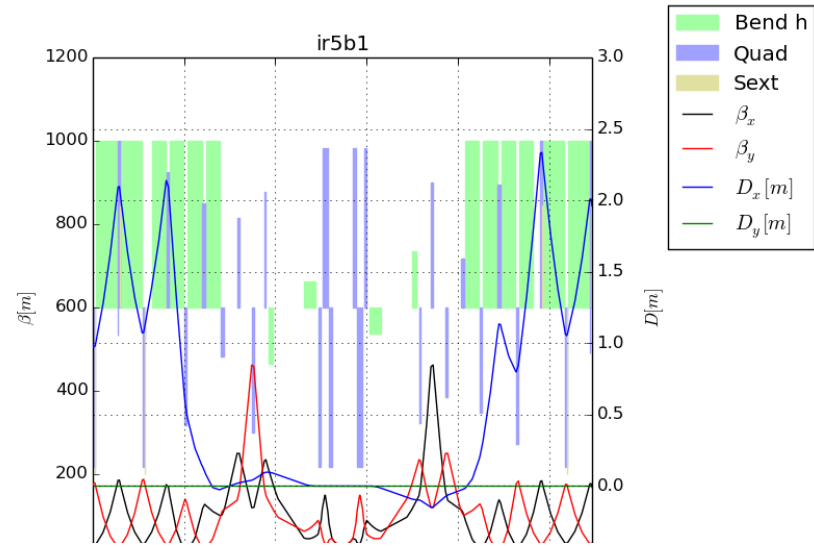
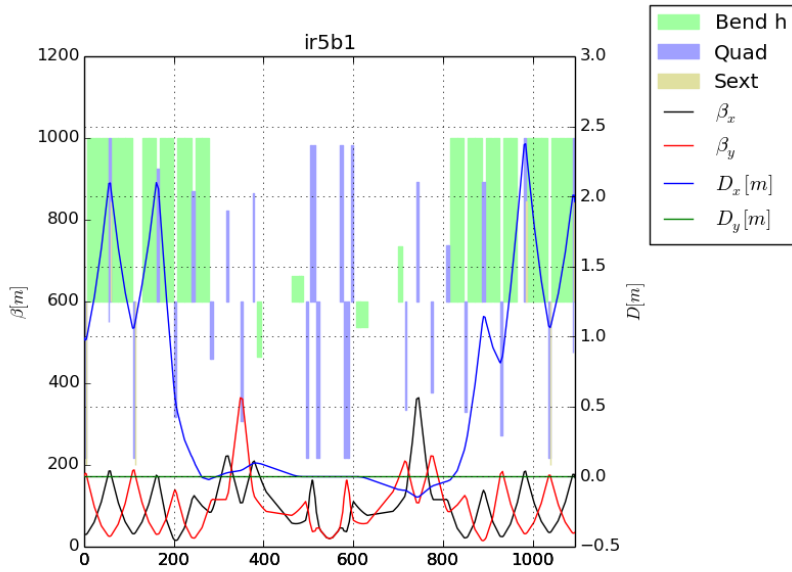
IR15 to low beta* V2



IR15 VDM (to be merged with 90 m)



IR15 VDM (to be merged with 90 m)



Summary: done recently

Optics developments:

- New IR8 3 m optics with/without new B2 phase
- New IR8 squeeze with new phase (with old phase not needed, but a rough version exists); Newer smoother squeeze up to 2 m.
- Checked IR7/IR3 MQTL current limitations using Fidel models
- Checked consistency of MCBX settings for IP1/2/5/8 with MCBC/MCBY strength (check in particular weak MCBCH)
- Update slicing method and re-matching strategy.
- Smooth IR5 final beta* points
- Use 90m optics as VDM optics
- Iterate with OP on IR8 crossing and tune jump transitions
- Made VDM optics for IR2, IR8

Repository management:

- New crossing angle matching, optics regeneration, optics writer scripts.

Summary: still to be done

Optics developments:

- Add point to IR2 squeeze to high beta*
- Check beta-beating combined squeeze
- Injection aperture checks with old/new tolerances
- Follow non-conformities if any
- Generate crossing scheme for IR5 VDM/90m optics

Repository management:

- Fill missing squeeze optics files
- Generate consistent as-built optics (waiting for next version from Markus/Sami)
- Generate run1 optics structure
- Fix bugs and inconsistencies...

Present non-conformities

To be re-commissioned during HW2014:

- MCBX from 350A to circle 540A (14) 400A-508A (10) and elliptical 540 A, except RCBXH1.L5 to 490 A.
- RCSX3 to 100A RCTX3 to 80A, but limited in op. to 10A
- RCS.A34B2: 4 out of 154 may be bypassed
- RCBCH7.R3B1, RCBCH10.R3B2 reduction to 80-90 A, 60A might be needed

Reduced:

- RCSSX3.L1 limited to 60A from 100A
- RD3.L4 limited to 5600A from 5850A
- RQ6 in IR3-7 limited to 400A
- RQTL: 8.L7B[12], 11.L7B[12], 11.R6 to 300A; 11.L6B1 to 350A; 11L6B2, 11L3B[12], 9L7B[12] to 400A; 9.R3B2 to 425A; 8L3B[12], 9R3B1, 10.R3B[12] to 450A; 9R7B[12], 10L7B[12], 11.R3B[12], 11.R5B[12] to 500A;
- RU.[LR]4 to 400A
- RCBYH4.R8B1, RCBYHS4.L5B1, RCBYV5.L4B2 to 50A
- RCBYHS5.R8B1 reduced to 0.3 A/s and probably to 40A

Disabled: RCOSX3.L1, RCOSX3.L2, RCOX3.L2, RCSSX3.L2, RCBCH6.L2B2,

4 of 8 RQTF.A81B1, RCO.A78B2 (B20L8, C19L8), RCO.A81B2(B11L1, B12L1), ROD.A34B[12] (Q28 and Q32, i.e. 11/13 MO available), RSS.A34B1,

Improvements from nominal LHC (improvements from LS1 not mentioned):

- RQ4.L5 and RQ4.R5 no current limits on imbalance between apertures
- All ROD/F 590A
- RSD in S12, S45, S56, S81 to 590A

Concerns on non-conformities

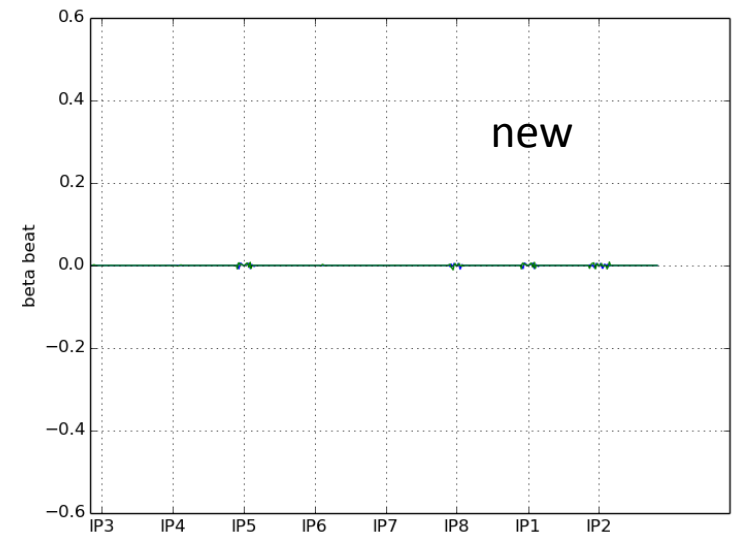
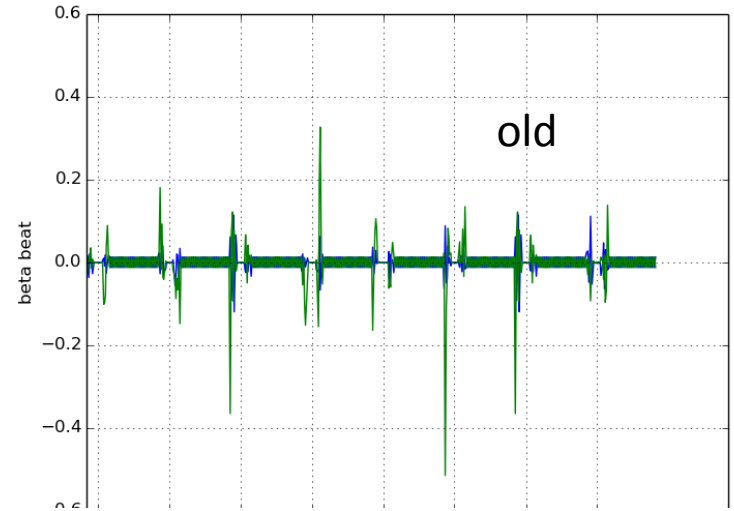
- MQTL in IR3 and IR7 are very close to limit at 7 TeV (still within by using Fidel curves [1]): RQTL9.I7B2, RQT13.L3B1, RQT13.L3B1, RQT12.L3B1, RQTL10.R3B2.
- Orbit correctors RCBYHS4.L5B1, RCBYHS5.R8B1 weak magnets but still compatible with the strengths (perhaps better for crossing than for orbit feedback).
- During HWC 2014 new non conformities may appears (e.g. RQTL9.I7B1).

[1] P. Hagen, Fidel Database and models

Thin optics

- Adopting slicing methods be better close to thick optics: new makethin method, more slices, IP phase advance kept.

Slices per element	V6.503	HL-LHC and 2015
MB, MQ	1	2
Mqw[ab], MQY, MQM[CL]	2	4
Mbx, mbr[bcs]	4	4
Mqx[ab]	4	16
Mqtl[hi],mqt	1	2
Total [Beam 1 and Beam 2]	14567	23389



Crossing schemes and knobs

Optics provides:

- `on_x`, `on_sep`, `on_o`, `on_a` knobs for IP1,2,5,8.
- In the past also `on_sep8h` and `on_x8v` where provided. Thanks to 167h LMC, `on_sep8h` and `on_x8v` no longer needed.
- Knobs are normalized to reference values, ideally the ones to be used in operation but often not the case.

What follow shows:

- the optics knobs defined in V6503 and ATS_2015 repositories
- the values (supposedly) used in Run I
- the proposal for 2015 optics using strength from ATS_2015 and normalized to 2015 operational values.
- in italics are indicated knobs defined but not used
- knobs are always normalized to positive values for Beam 1