Dynamic Aperture and β-Beating with Field Errors from 11T Dipoles

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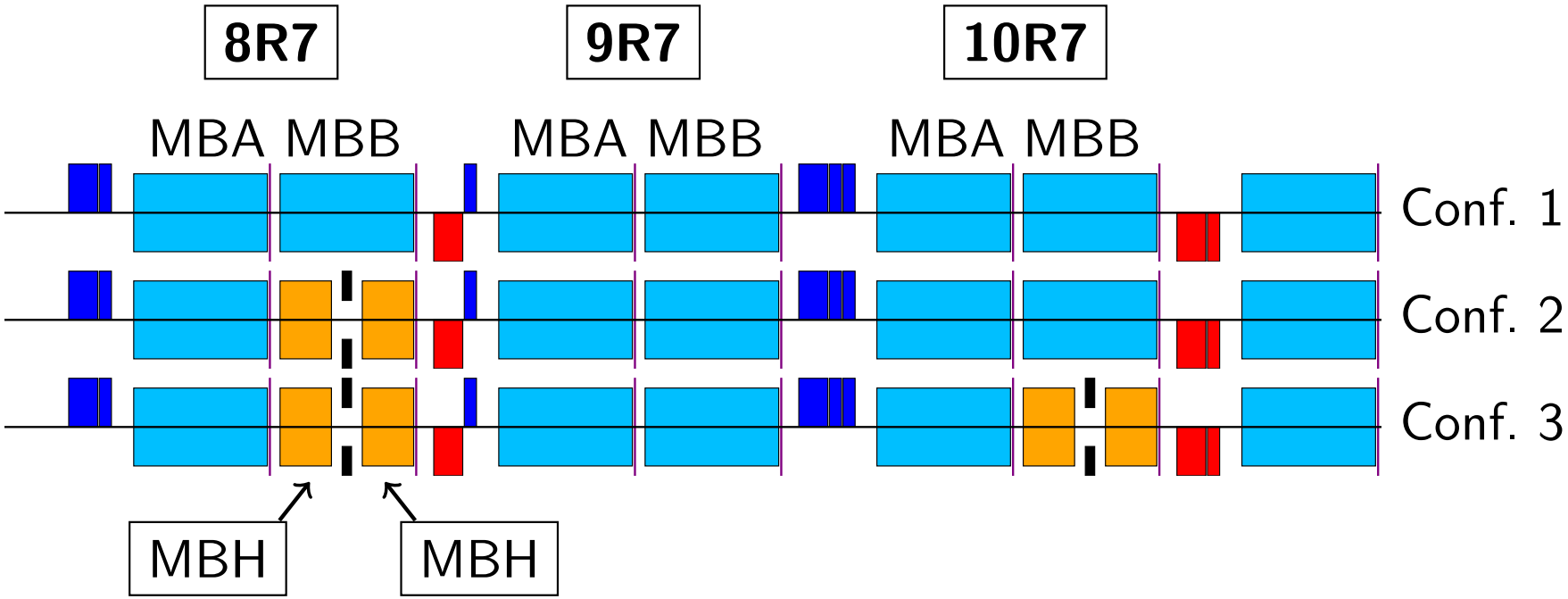
CERN

Acknowledgements :
S. Izquierdo Bermudez, R. De Maria, A. Mereghetti, F. Savary
And the LHC@home volunteers

WP2 Meeting

03.10.2017

Introduction



- HL-LHC baseline : new 11T dipoles (MBH) in 8L7/8R7 to provide space for additional collimators
- Possibly second set of MBH magnets + collimator in cell 10 (not baseline)

Introduction

- HL-LHC baseline : installation of new 11T dipoles (MBH) in cells 8L7/8R7 to provide space for additional collimators
- MBH field quality errors may
  - Impact dynamic aperture (DA)
  - Introduce β-beating
- This presentation : quantify the impact of MBH field quality errors on DA and β-beating
- Update on previous presentations on this topic :
  - 25.04.17 : LARP CM28/HiLumi Meeting, Napa, CA, USA
  - 21.03.17 : WP2 Meeting

Contents

Field quality

	DS-11T Dipole field quality version 5 February 2017 R_{ref}=17mm								
	Systematic					Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
1						20	20	20	20
2	0.000	-14.633	0.000	0.000	-14.633	1.705	1.705	1.7045	1.705
3	7.500	-0.611	-8.800	-1.300	6.889	1.079	1.079	1.0788	1.079
4	0.000	-0.859	0.000	0.000	-0.859	0.623	0.623	0.6229	0.623
5	-0.014	0.416	2.400	2.386	0.403	0.349	0.349	0.3490	0.349
6	0.000	-0.021	0.000	0.000	-0.021	0.175	0.175	0.1746	0.175

- Latest baseline from 05/02/2017 by S. Izquierdo Bermudez

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- What is the impact of all errors on dynamic aperture ?
- b_2 component at high field : impact on β-beating ?

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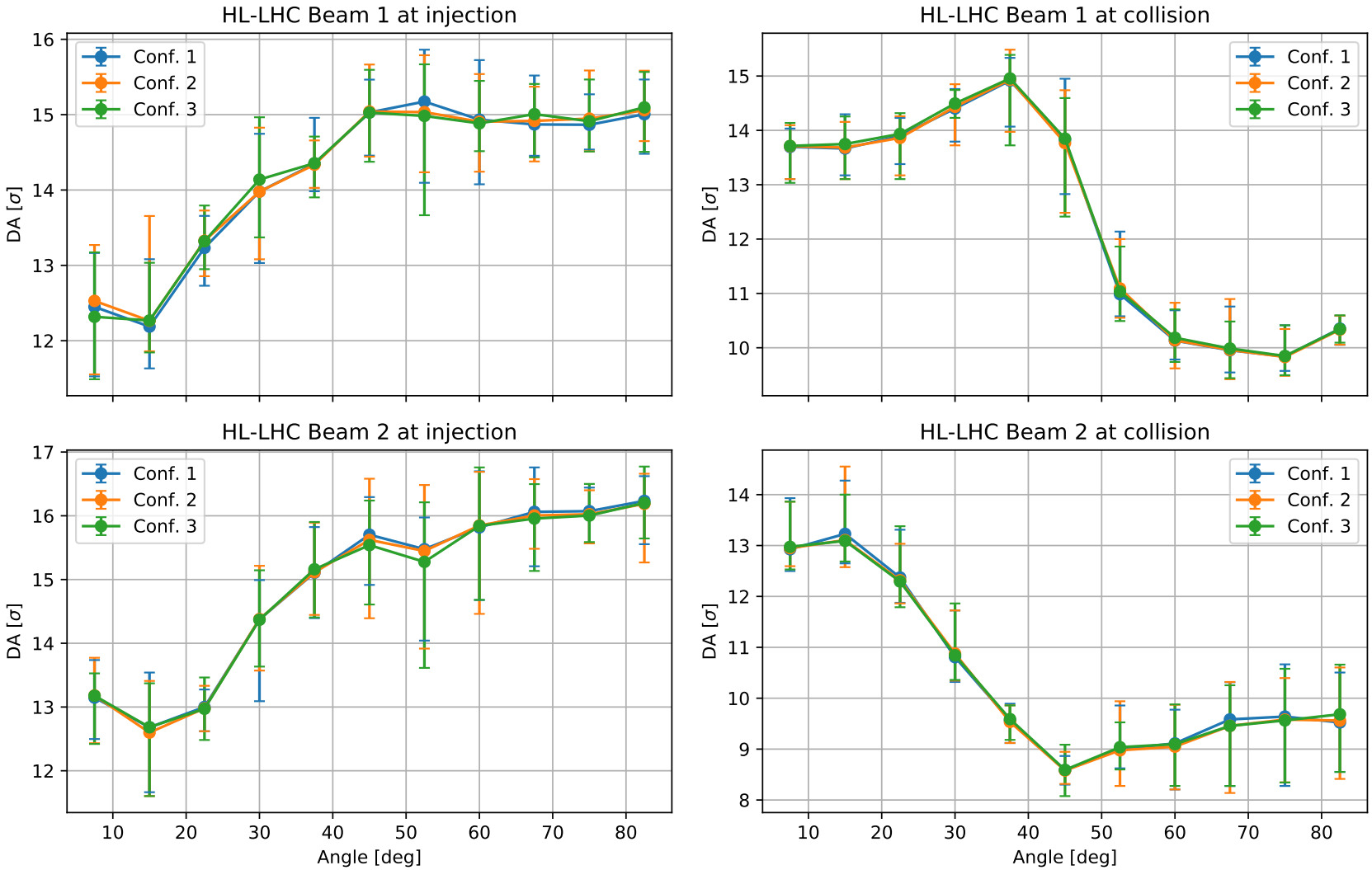
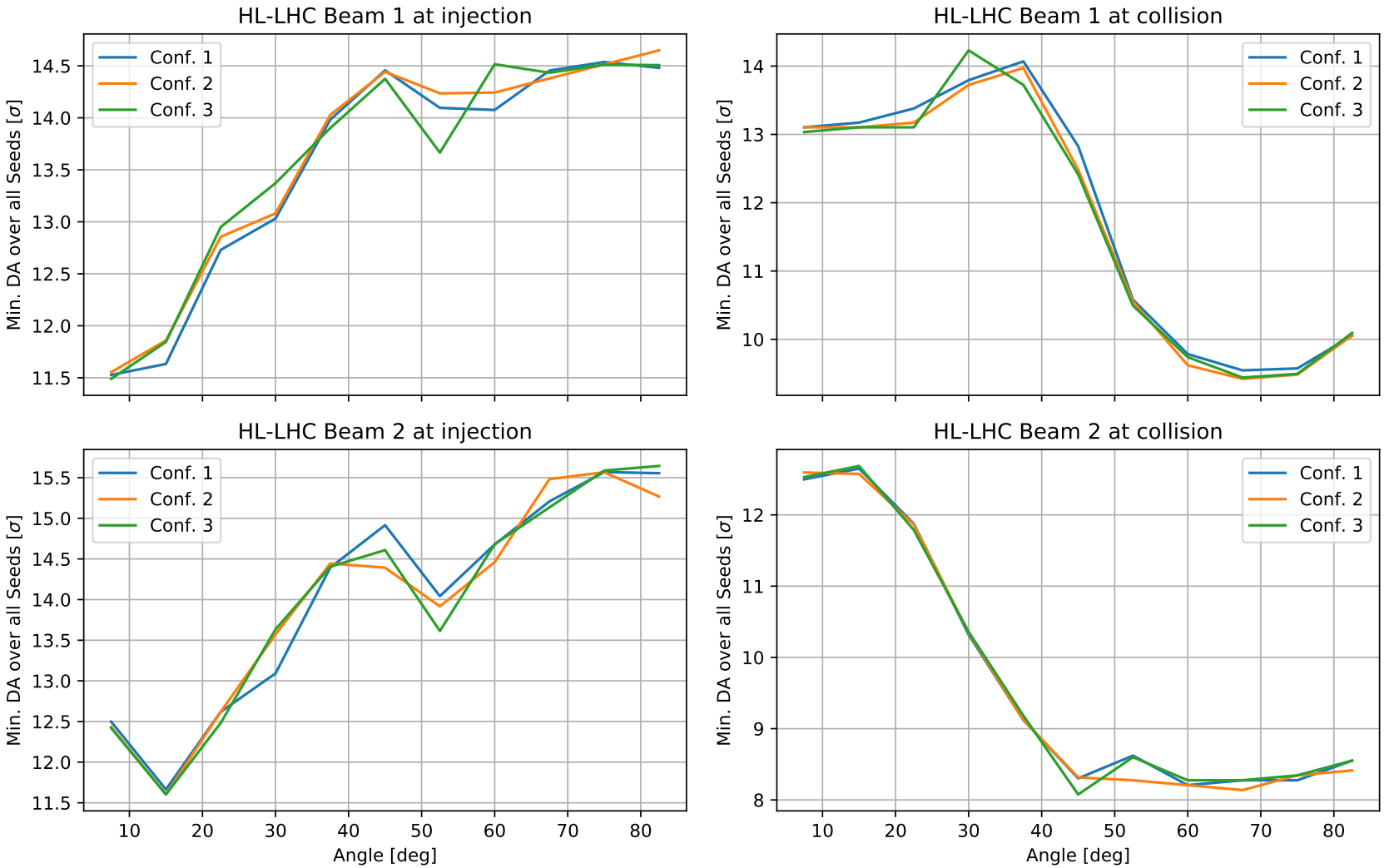
Dynamic Aperture with MBH field errors

- SixTrack : compare dynamic aperture
  - Conf. 1 : without MBH units
  - Conf. 2 : with one MBH unit in cell 8L7/8R7
  - Conf. 3 : with MBH units in cell 8L7/8R7 and 10L7/10R7
- LHC@home ≈18×5000 simulations over max. 100000 turns
- HL-LHC V1.0 optics at injection and collision with $\beta^* = 15$cm in IR1/5, $\beta^* = 10$m in IR2, 3m in IR8
- Include all field errors up to b_{15} and a_{15}
- Considered emittance : $\epsilon_N = 2.5\,\mu$m rad

Dynamic Aperture with and without MBH field errors



Dynamic Aperture with and without MBH field errors



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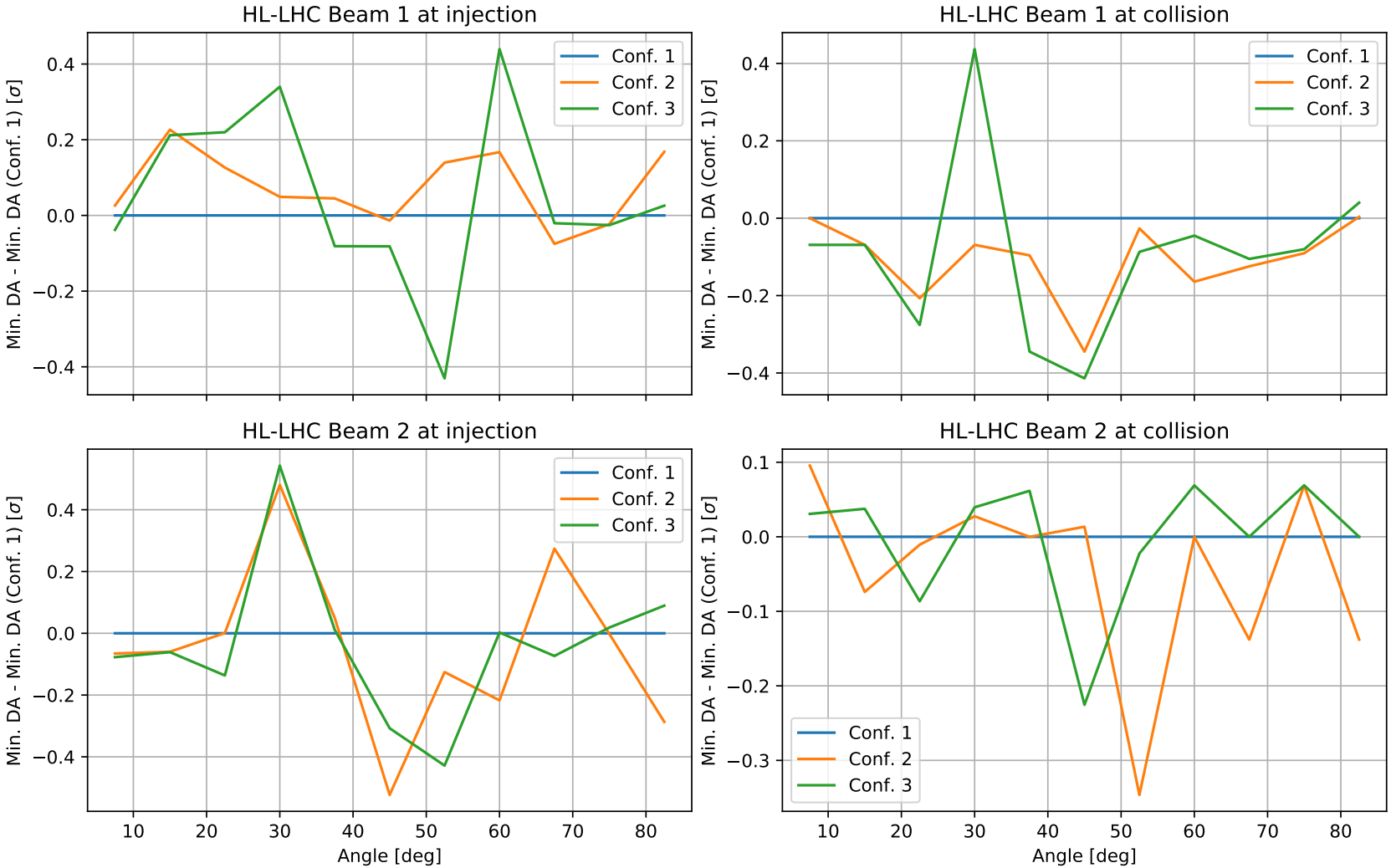


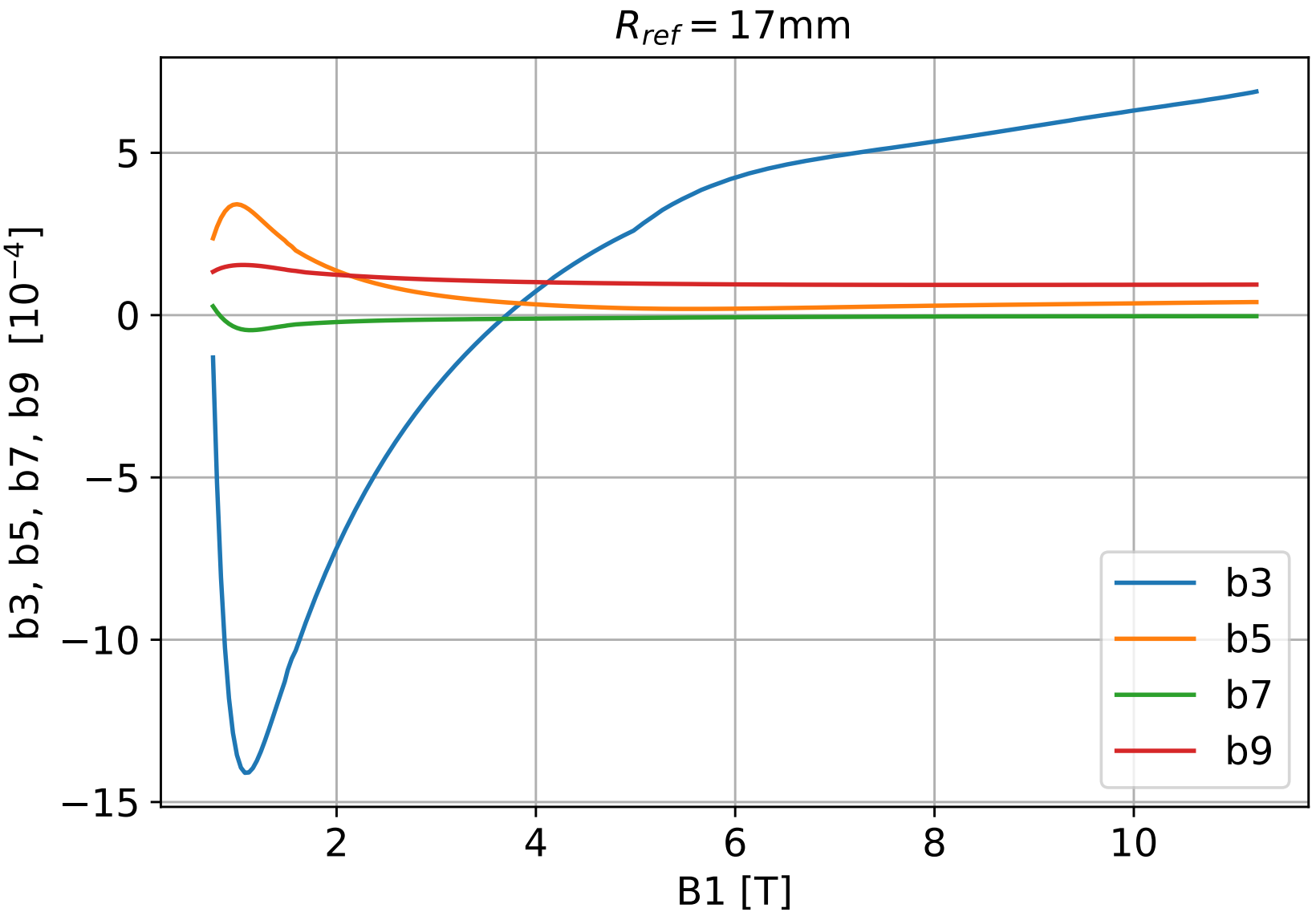
Dynamic aperture with MBH field errors

Summary

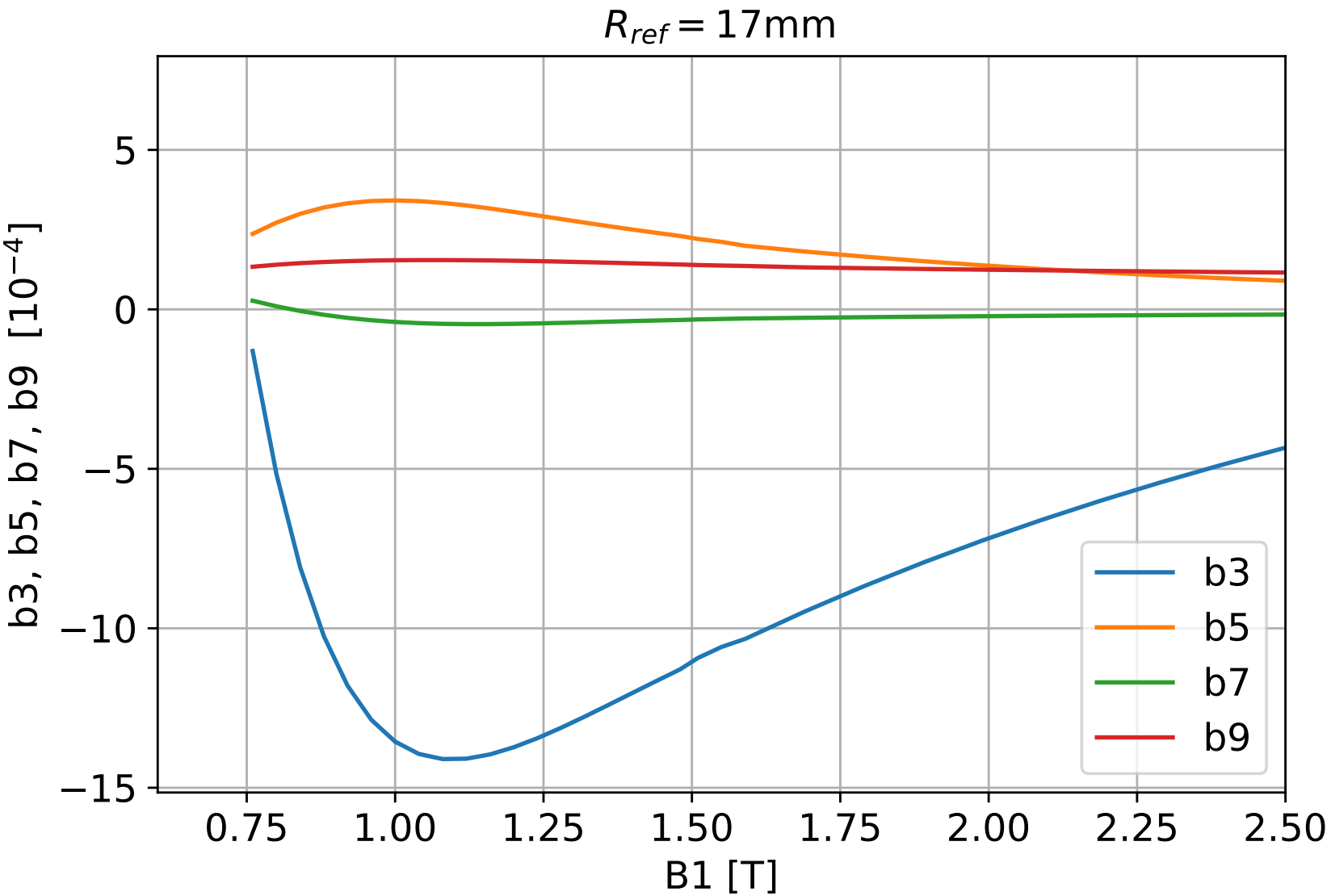
			Min. DA [σ]		
Beam	E [GeV]	Optics	Conf. 1	Conf. 2	Conf. 3
1	7000	Collision	9.4	9.4	9.4
1	450	Injection	11.5	11.5	11.5
2	7000	Collision	8.2	8.1	8.0
2	450	Injection	11.7	11.6	11.6

- All study cases show similar DA distributions as Conf. 1
- No significant change in DA with MBH field errors
- Maximum reduction for given angle : $< 0.5\,\sigma$
- Situation during ramp may be different

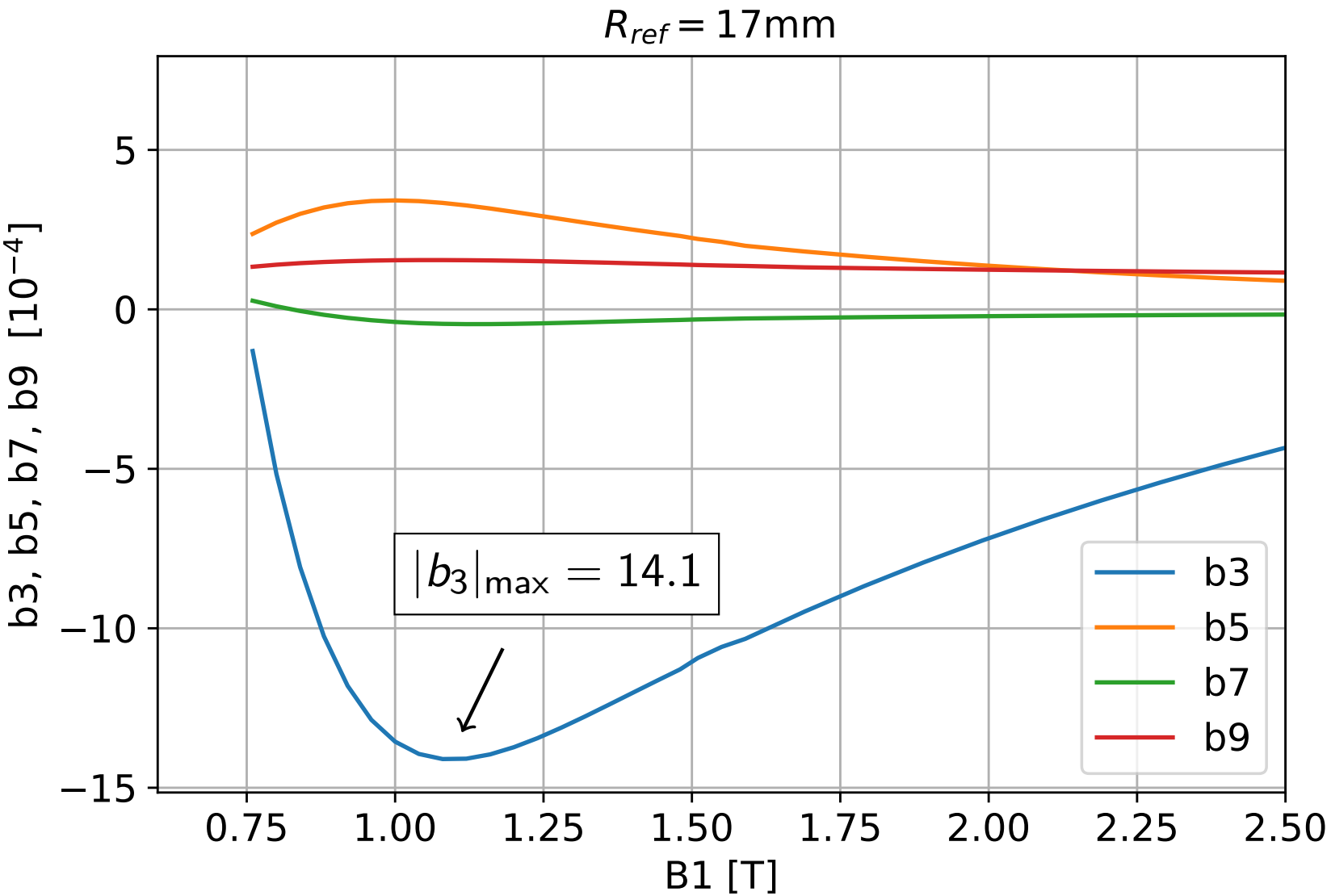
Evolution of field quality with current



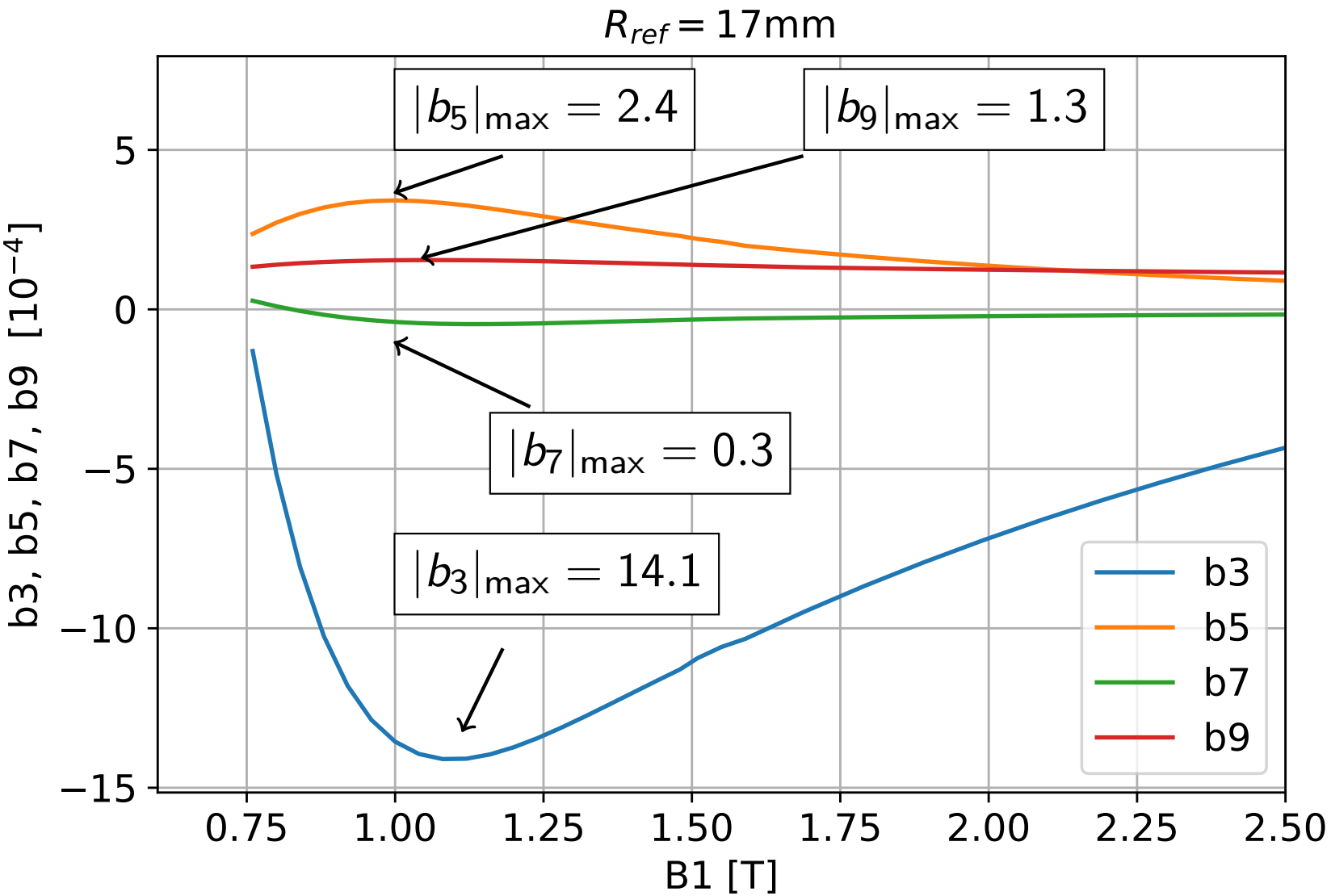
Evolution of field quality with current



Evolution of field quality with current



Evolution of field quality with current

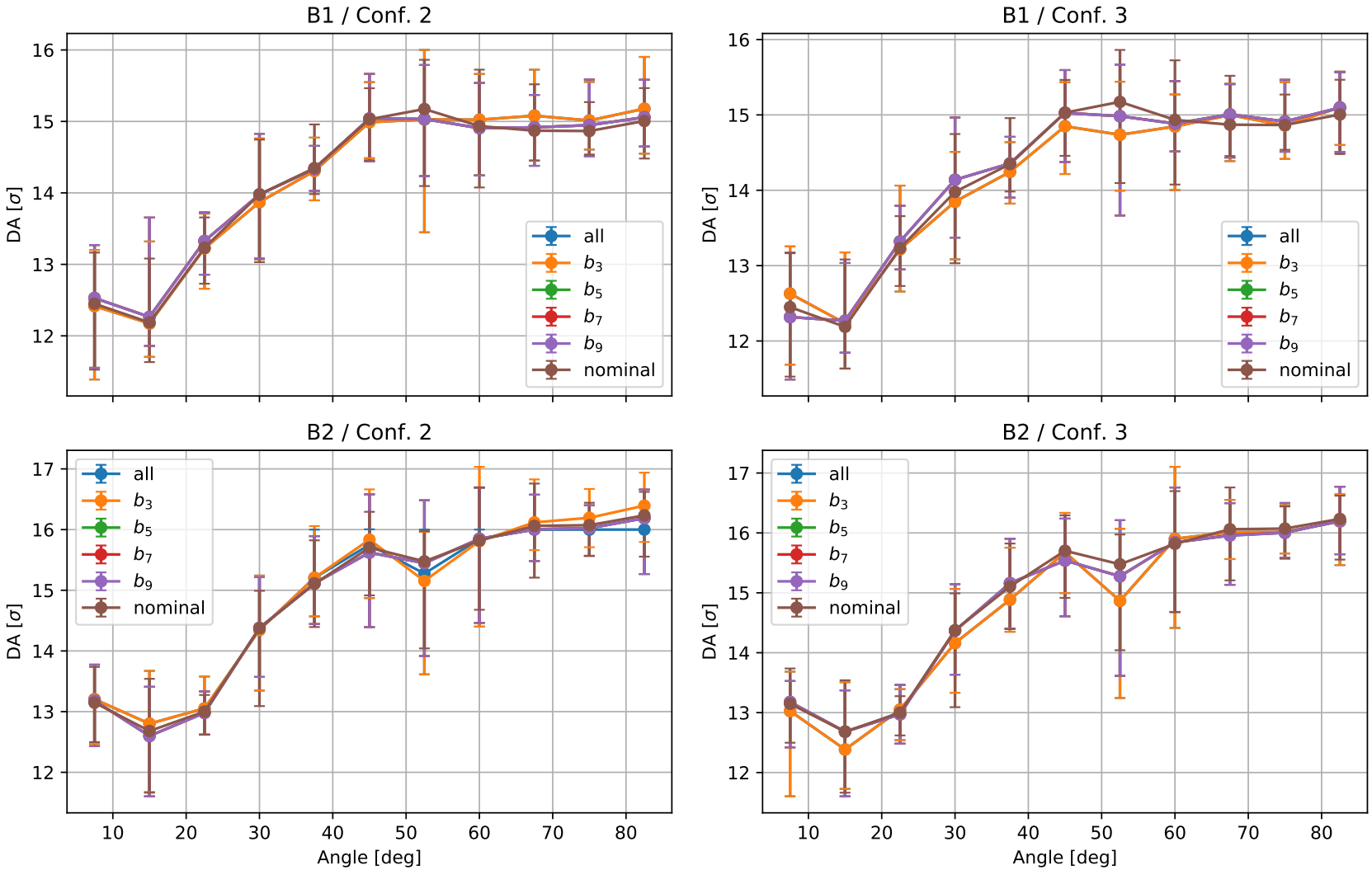


Study of DA during ramp

- Study with modified field quality table
- Set components individually to their maximum during ramp
- Remaining components from standard field quality table
- All studies at injection energy $\rightarrow$ comparability
- Conservative scenario : negligence of adiabatic damping

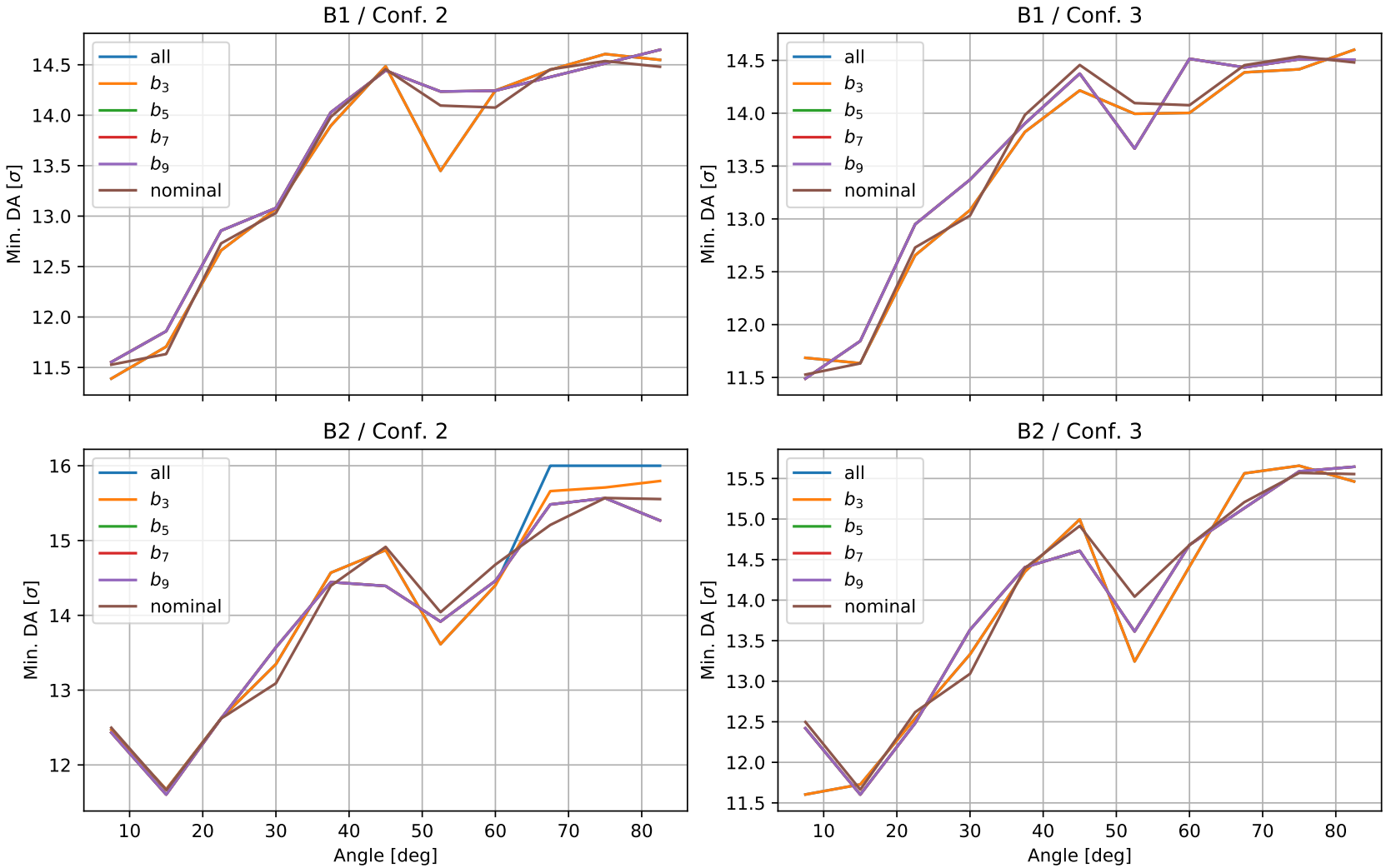
Dynamic aperture during ramp

Overview



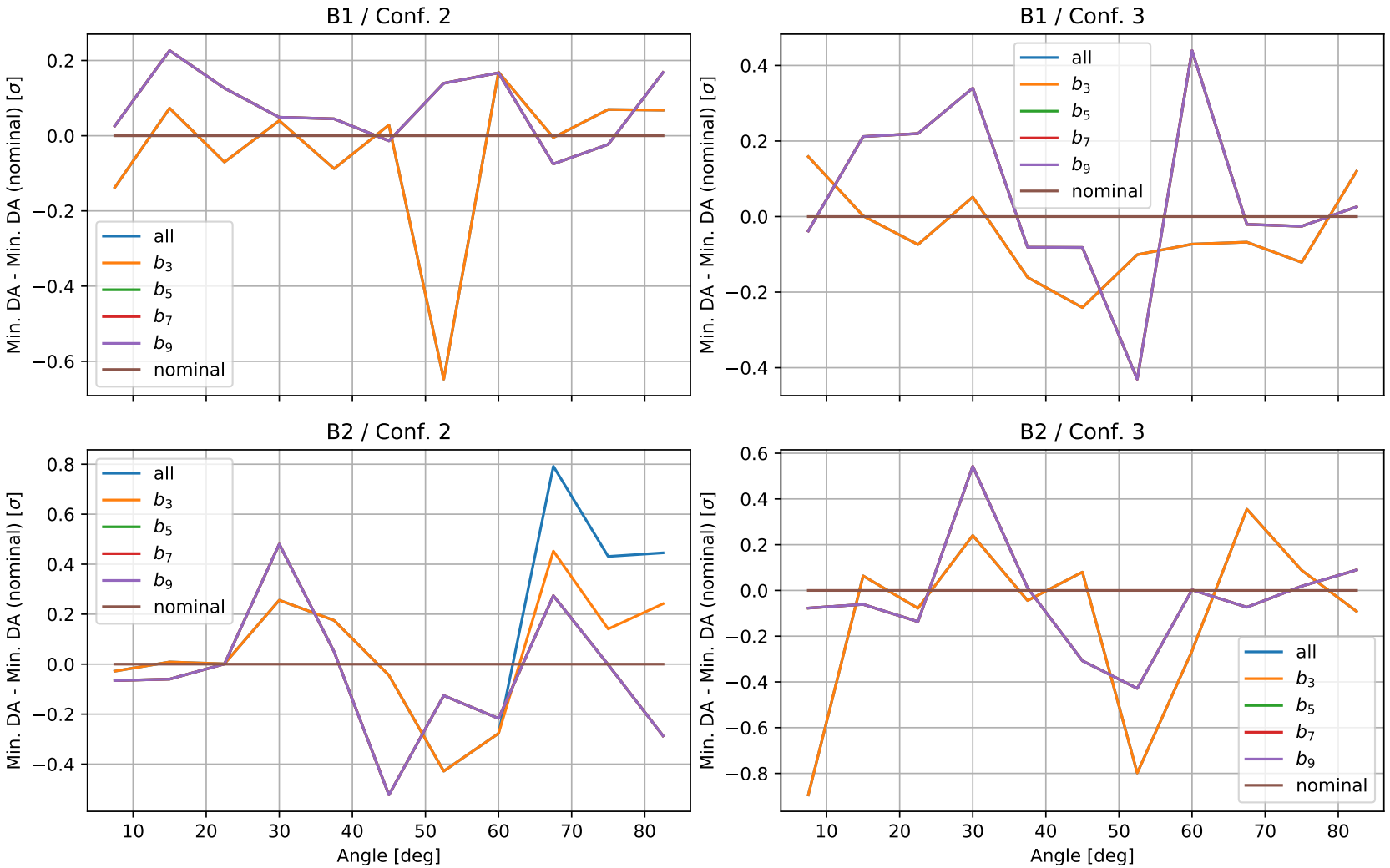
Dynamic aperture during ramp

Min. DA for all study cases



Dynamic aperture during ramp

Min. DA - Min. DA [nominal]



Dynamic aperture with MBH field errors

Summary

		Conf. 2		Conf. 3	
Beam	f.q. table	ΔDA $[\sigma]$	DA_{min} $[\sigma]$	ΔDA $[\sigma]$	DA_{min} $[\sigma]$
B1	nominal	$\pm$0.0	11.5	$\pm$0.0	11.5
B1	b_3 max.	-0.6	11.4	-0.2	11.6
B1	b_5 max.	-0.1	11.6	-0.4	11.5
B1	b_7 max.	-0.1	11.6	-0.4	11.5
B1	b_9 max.	-0.1	11.6	-0.4	11.5
B1	all max.	-0.6	11.7	-0.2	11.6

ΔDA : max. DA reduction for any angle

Dynamic aperture with MBH field errors

Summary

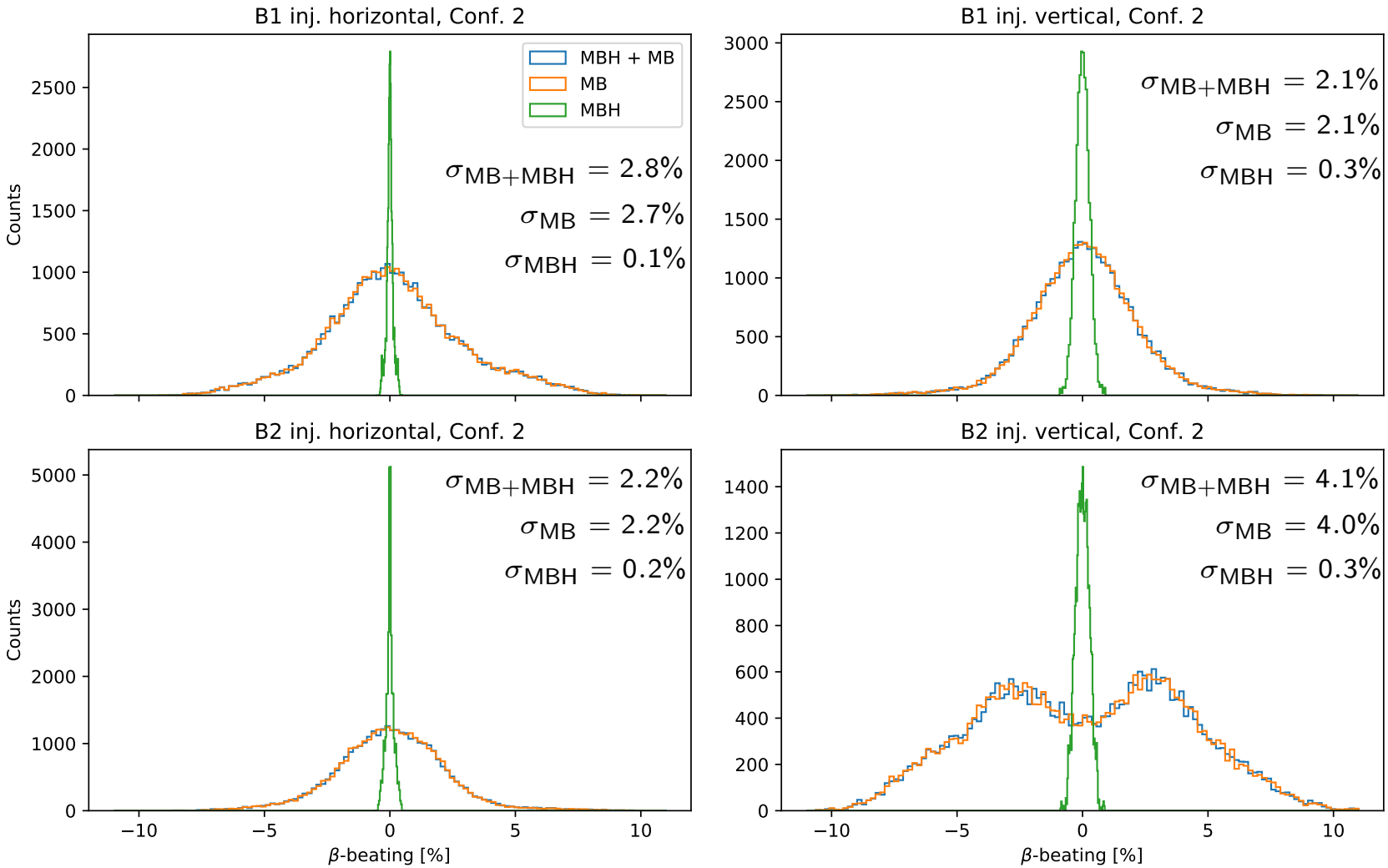
		Conf. 2		Conf. 3	
Beam	f.q. table	ΔDA $[\sigma]$	DA_{min} $[\sigma]$	ΔDA $[\sigma]$	DA_{min} $[\sigma]$
B2	nominal	$\pm$0.0	11.6	$\pm$0.0	11.6
B2	b_3 max.	-0.4	11.7	-0.9	11.6
B2	b_5 max.	-0.5	11.6	-0.4	11.6
B2	b_7 max.	-0.5	11.6	-0.4	11.6
B2	b_9 max.	-0.5	11.6	-0.4	11.6
B2	all max.	-0.4	11.7	-0.9	11.6

ΔDA : max. DA reduction for any angle

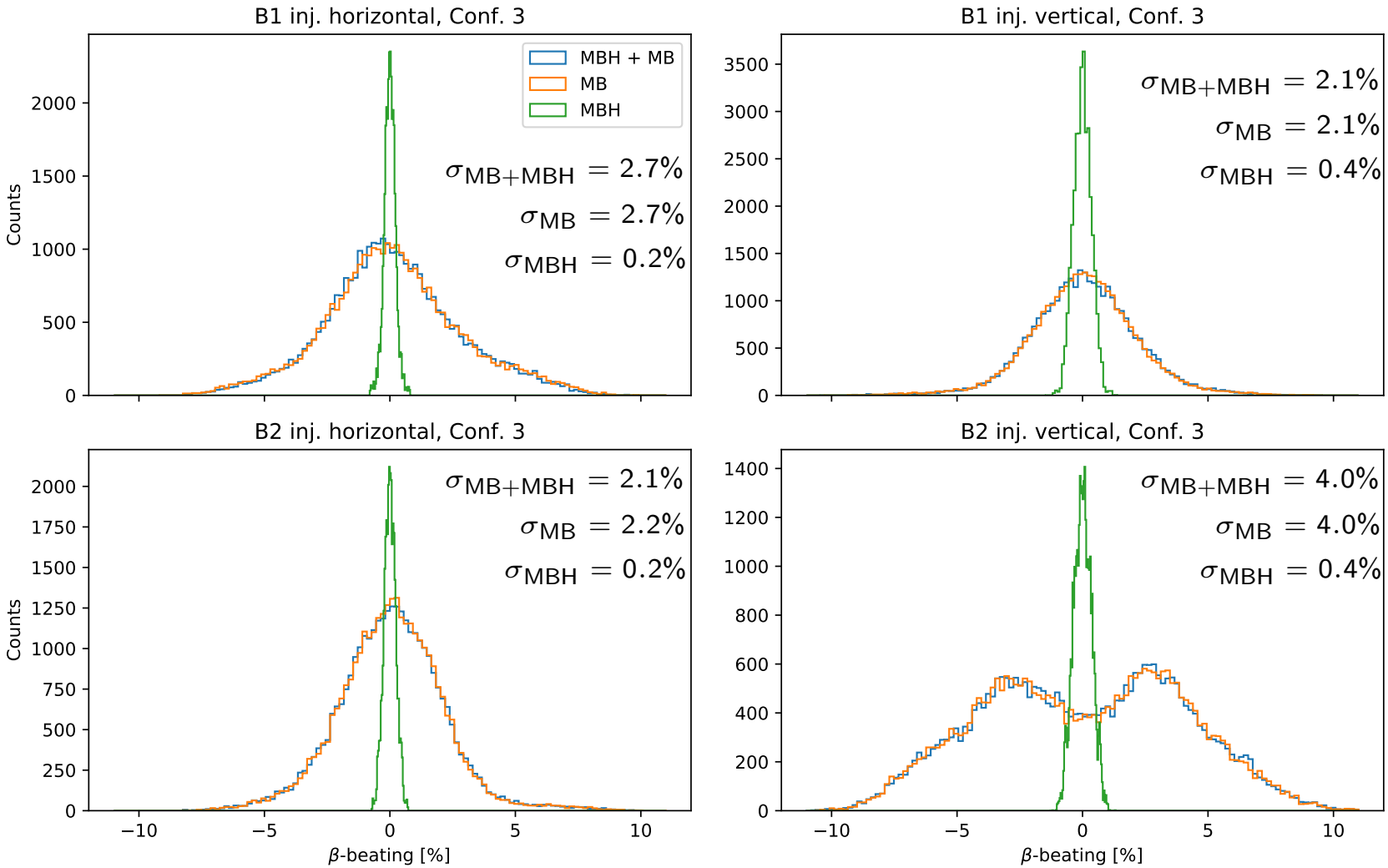
β-beating

- Switch off all field error components but b_2
- MBH magnets : high b_2 at collision
- Expected : higher β-beating from MBH in collision
- IR7 : beams are not changing aperture $\rightarrow$ no cancellation of b_2 from MBH
- Study cases : HL-LHC V1.0 as before
- Simulation with MAD-X for all seeds

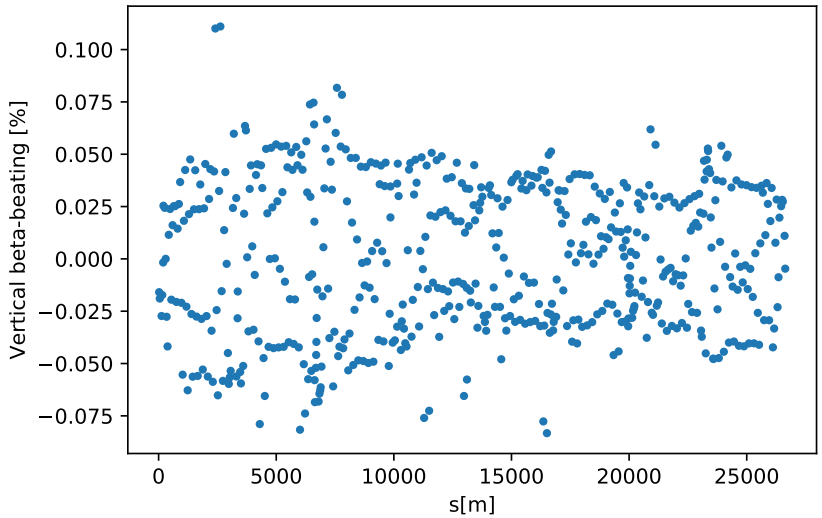
β-beating at injection

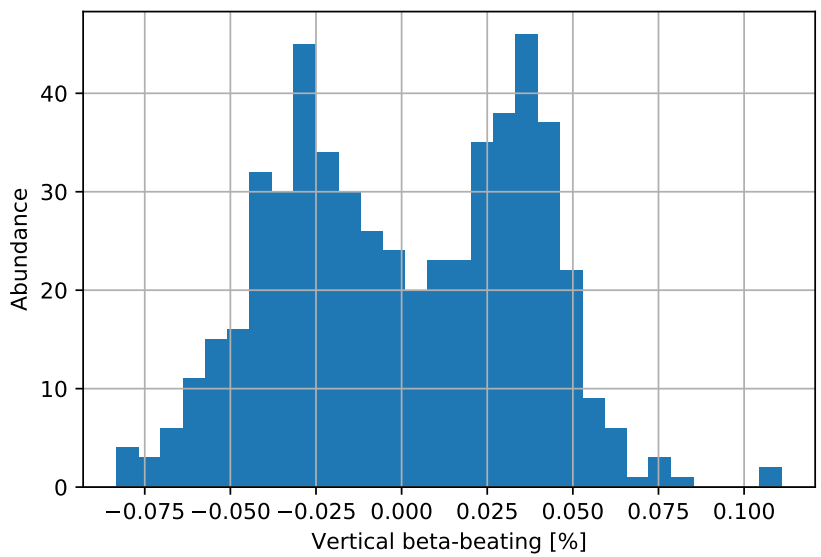


β-beating at injection

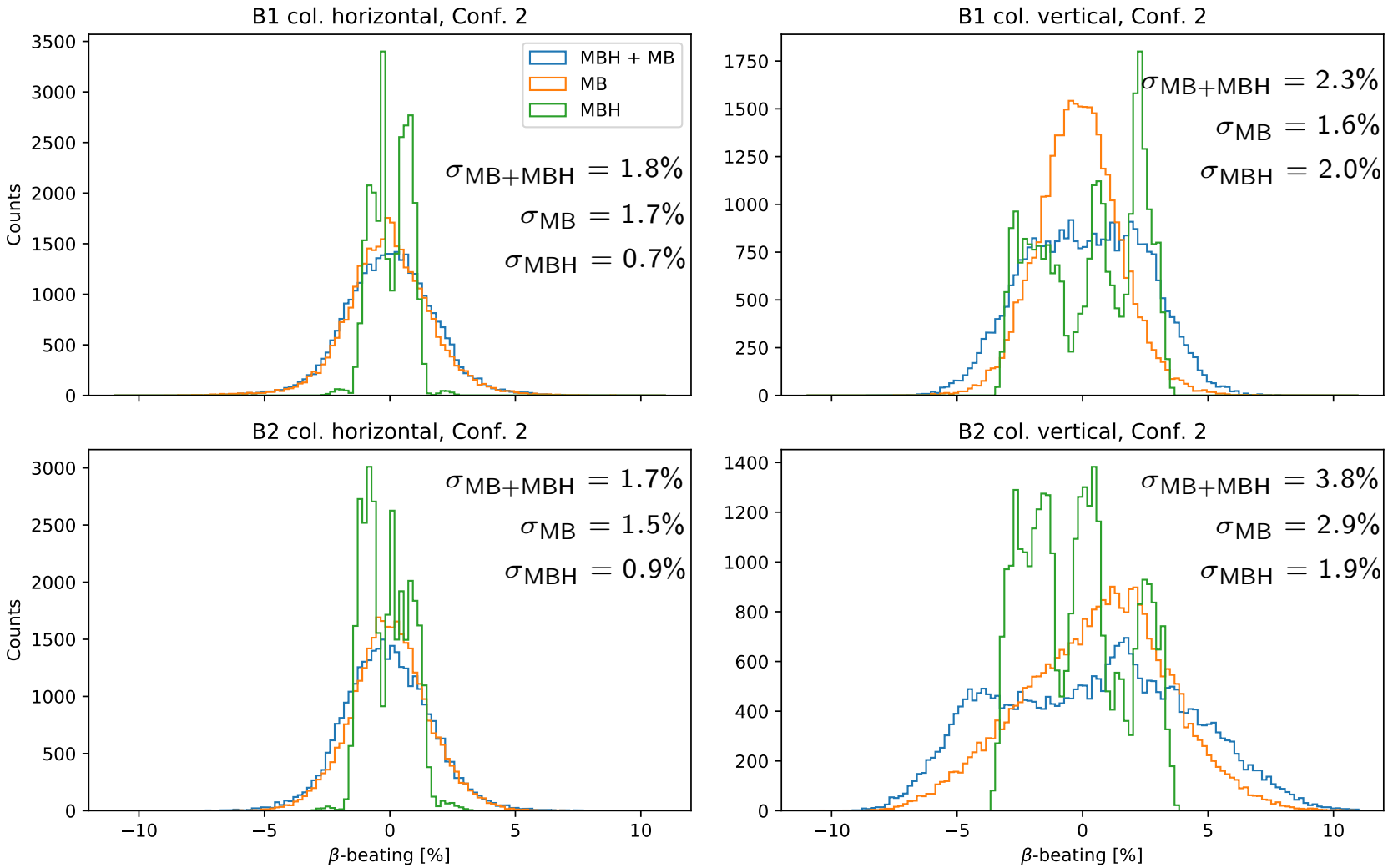


Distribution for B2V

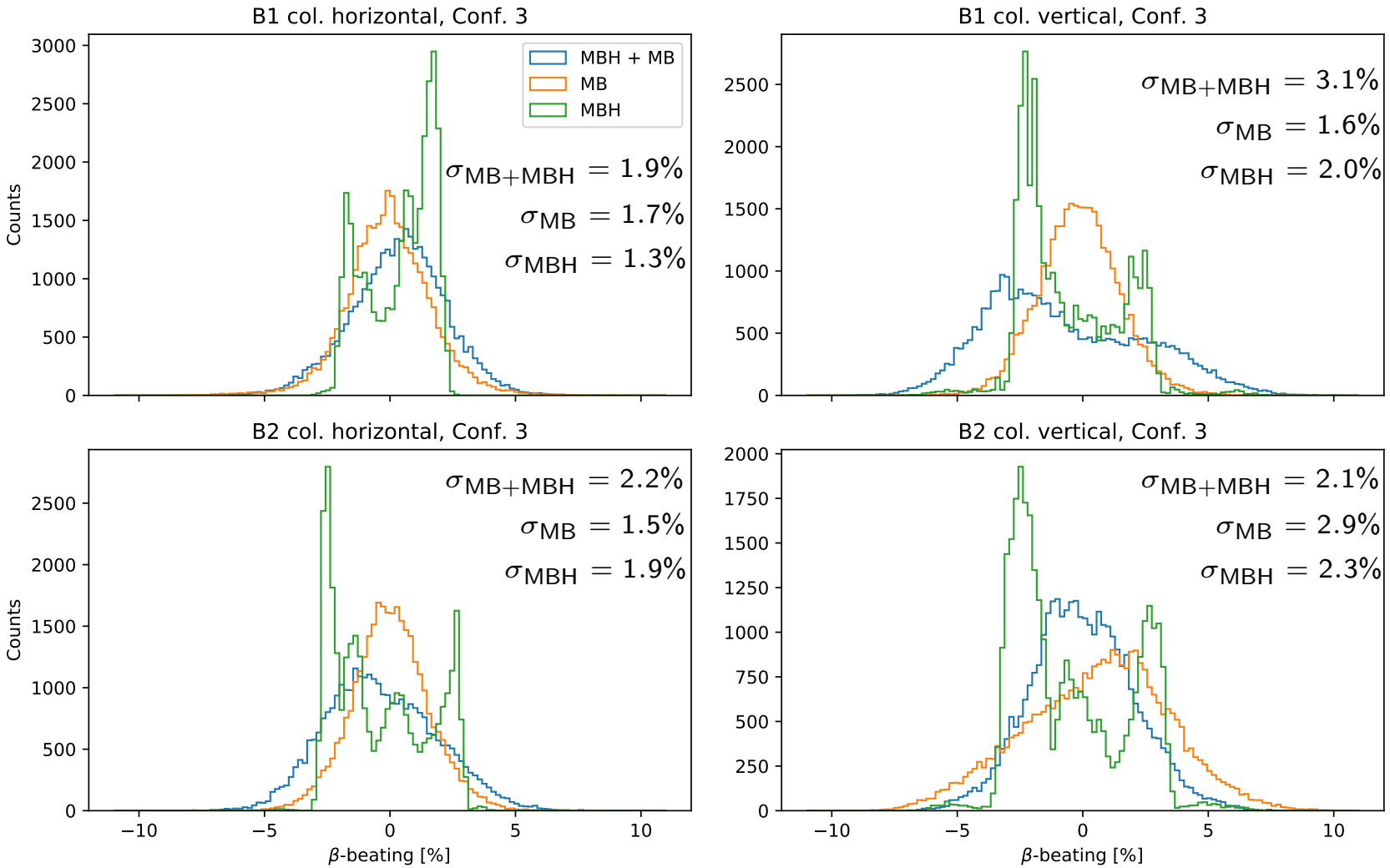




β-beating at collision



β-beating at collision



Outlook

- MBH is close to Q8
- Quadrupole could be rematched
- Compensate beta-beating from MBH b_2
- Work in progress

Summary and Conclusions

- DA and β-beating studied in three setups with MBH magnets
- Injection and Collision : minor effect on DA, no significant reduction
- Field errors during ramp with two MBH units per beam : reduction up to $0.8\,\sigma$
- β-beating from b_2 :
  - Injection : Very small effect
  - Collision : Additional β-beat compared to MB magnets, potential compensation with Q8R7/Q8L7

Appendix

Error Tables and Routines Used

db5=/afs/cern.ch/eng/lhc/optics/V6.503
slhc=/afs/cern.ch/eng/lhc/optics/HLLHCV1.0
wise=/afs/cern.ch/eng/lhc/optics/errors/0705

db5/measured_errors/rotations_Q2_integral.tab
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slhc/errors2/ITcs_errortable_v5 slhc/errors2/D1_errortable_v1
slhc/errors2/D2_errortable_v5 slhc/errors2/Q4_errortable_v2
slhc/errors2/Q5_errortable_v0 slhc/errors2/MCBXFAB_errortable_v1
/afs/cern.ch/eng/lhc/optics/HLLHCV1.0/errors2/MBH_errortable_v2
wise/injection_errors-emfqcs-1.tfs wise/collision_errors-emfqcs-1.tfs
db5/measured_errors/Efcomp_MBRB.madx
db5/measured_errors/Efcomp_MBRC.madx
db5/measured_errors/Efcomp_MBRS.madx
db5/measured_errors/Efcomp_MBX.madx
db5/measured_errors/Efcomp_MBW.madx

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