MD 3583
LR beam-beam 2018

S. Fartoukh, N. Karastathis, Y. Papaphilippou, M. Pojer, A. Poyet, K. Skoufaris, G. Sterbini

https://asm.cern.ch/md/requests/LHC/3583

rMPP Meeting
10.07.2018

MD 3263

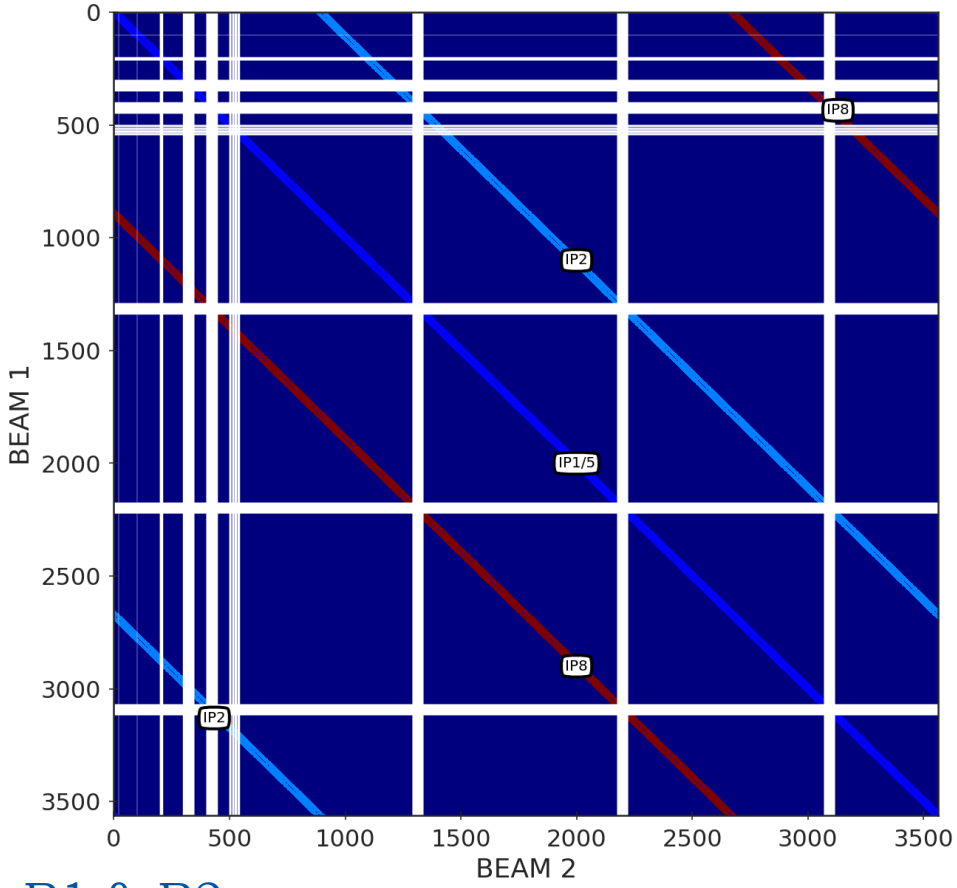
MD MERIT:

*"The main aim of the MD is to **investigate the asymmetry of the lifetime of Beam 1 and Beam 2** and **quantify the impact of the long-range beam-beam interactions** on them. The main knobs that will be used are the crossing-angle bias in IP1 and IP5 and the IP1-IP5 phase advance of Beam 1."*

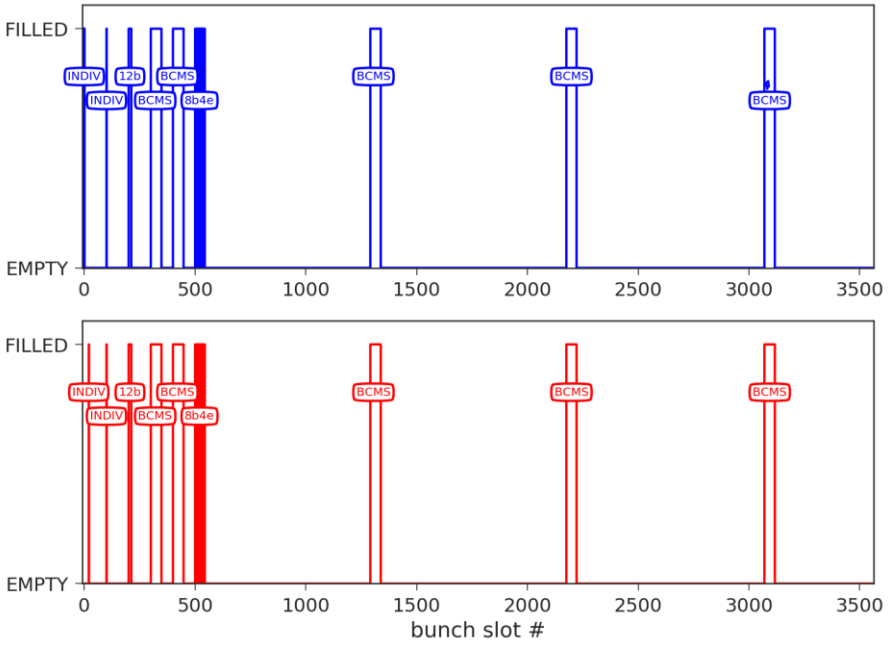
Collisions with trains at 160μrad-130μrad and 30cm and 25cm β*

- Assigned Slot:
  THU 26.07.2018 18H00 - FRI 27.07.2018 01H00 (7h)

Filling Scheme



BEAM 1		BEAM 2	
# bunches	collisions	bunches	collisions
LHCINDIV	LR 1/5	LHCINDIV	LR 1/5
LHCINDIV	HO 1/5	LHCINDIV	HO 1/5
12b	HO 1/5	12b	HO 1/5
1st BCMS	HO 1/5	1st BCMS	HO 1/5
2nd BCMS	HO 1/2/5/8	2nd BCMS	HO 1/2/5/8
8b4e (32b)	HO 1/5	8b4e (32b)	HO 1/5
3rd BCMS	HO 1/2/5/8	3rd BCMS	HO 1/2/5/8
4th BCMS	HO 1/2/5/8	4th BCMS	HO 1/2/5/8
5th BCMS	HO 1/2/5/8	5th BCMS	HO 1/2/5/8



B1 & B2:

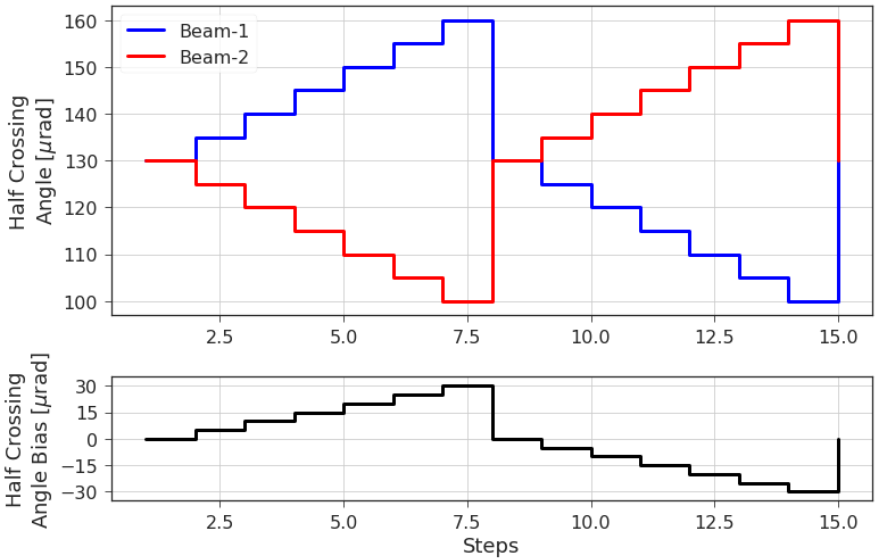
Total of 572b in the LHC

2 LHCINDIV
12b
5x48 BCMS
1x32 8b4e

"1x32b 8b4e ready from injectors" H. Damerau

Crossing Angle Knobs

- After reducing the half-crossing angle to **130µrad** using the **nominal orchestration**, scan the **crossing angle bias knob**
  - **Partial experience from 2017 MD2202**



!Beam1 / IR1
Δ(ACBYVS4.L1B1) := 0.198121207041E-06 * on_x1s;
Δ(ACBYVS4.R1B1) := -0.137259444590E-06 * on_x1s;
Δ(ACBCV5.L1B1) := -0.403691649328E-06 * on_x1s;
Δ(ACBCV6.R1B1) := 0.339503516763E-06 * on_x1s;

!Beam2 / IR1
Δ(ACBYVS4.L1B2) := 0.109827234585E-06 * on_x1s;
Δ(ACBYVS4.R1B2) := -0.279491986473E-06 * on_x1s;
Δ(ACBCV6.L1B2) := -0.312706050017E-06 * on_x1s;
Δ(ACBCV5.R1B2) := 0.483843781180E-06 * on_x1s;

!Beam1 / IR5
Δ(ACBYHS4.L5B1) := 0.142847973076E-06 * on_x5s;
Δ(ACBYHS4.R5B1) := -0.198301363819E-06 * on_x5s;
Δ(ACBCH6.L5B1) := -0.333554477113E-06 * on_x5s;
Δ(ACBCH5.R5B1) := 0.402299481385E-06 * on_x5s;

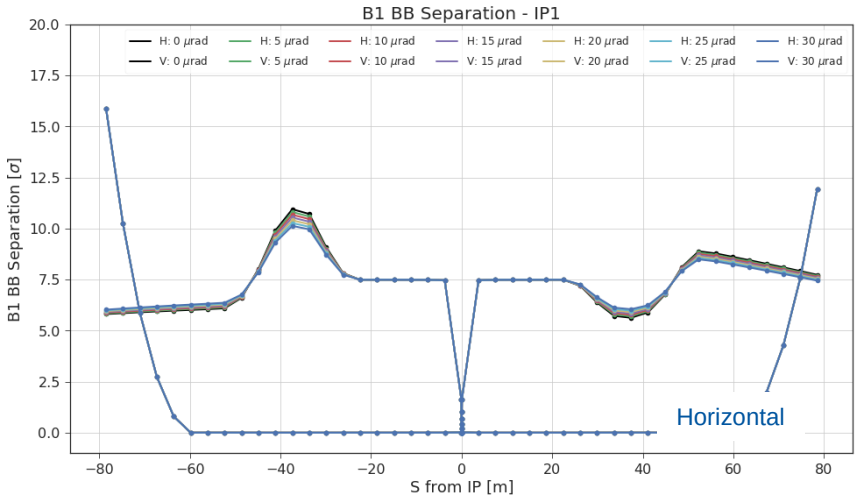
!Beam2 / IR5
Δ(ACBYHS4.L5B2) := 0.279507750043E-06 * on_x5s;
Δ(ACBYHS4.R5B2) := -0.118592681770E-06 * on_x5s;
Δ(ACBCH5.L5B2) := -0.483853060948E-06 * on_x5s;
Δ(ACBCH6.R5B2) := 0.304937956476E-06 * on_x5s;

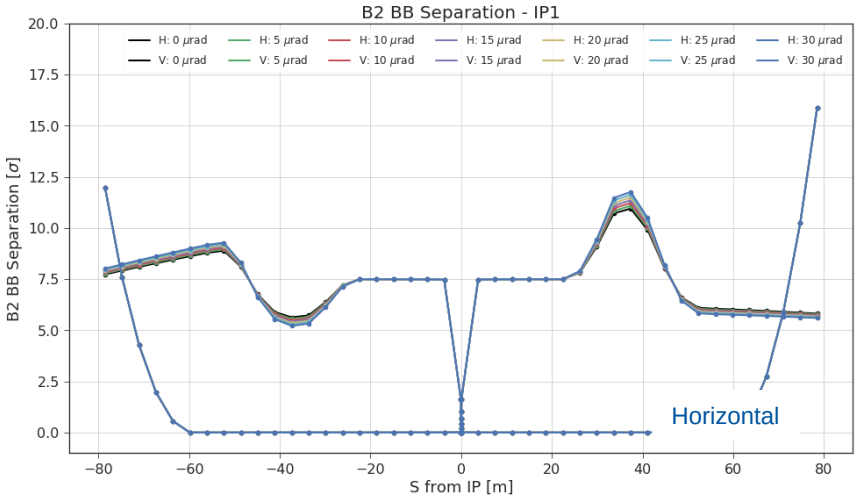
To be applied using the MD Toolkit (registered as "orbit knob")

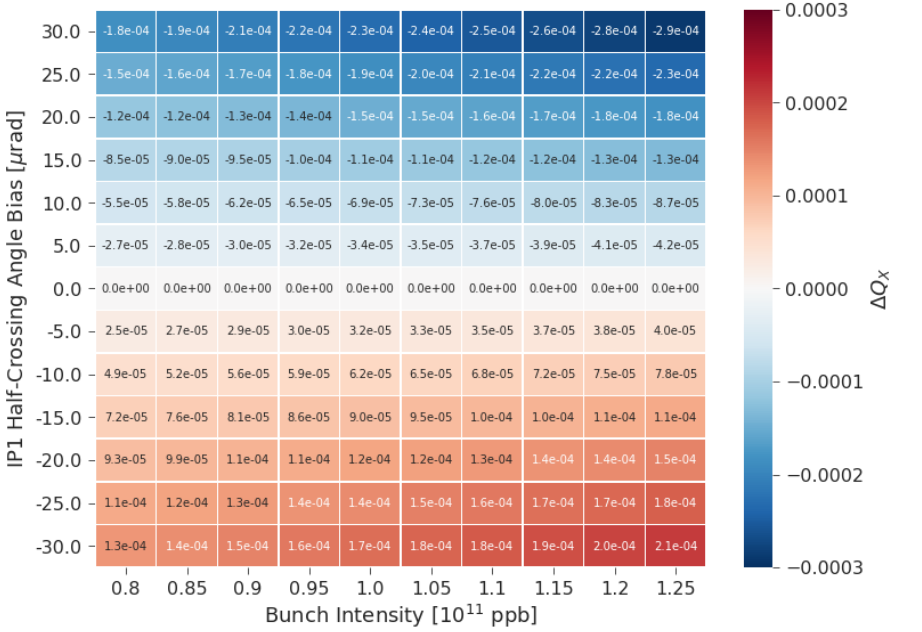
Maximum absolute trim applied for 30µrad bias : 14.515 µrad

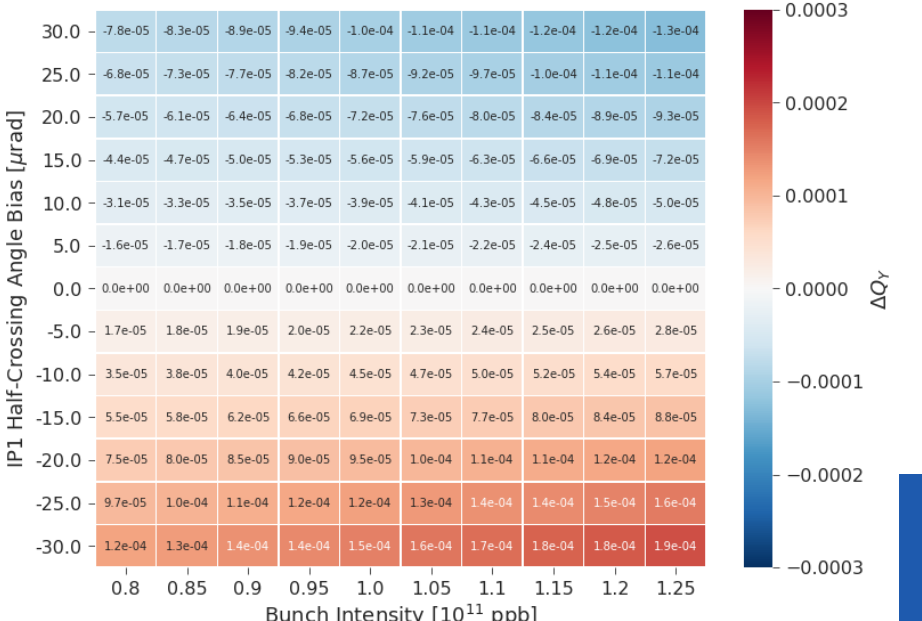
Crossing Angle Knobs - Impact

IP1 scan



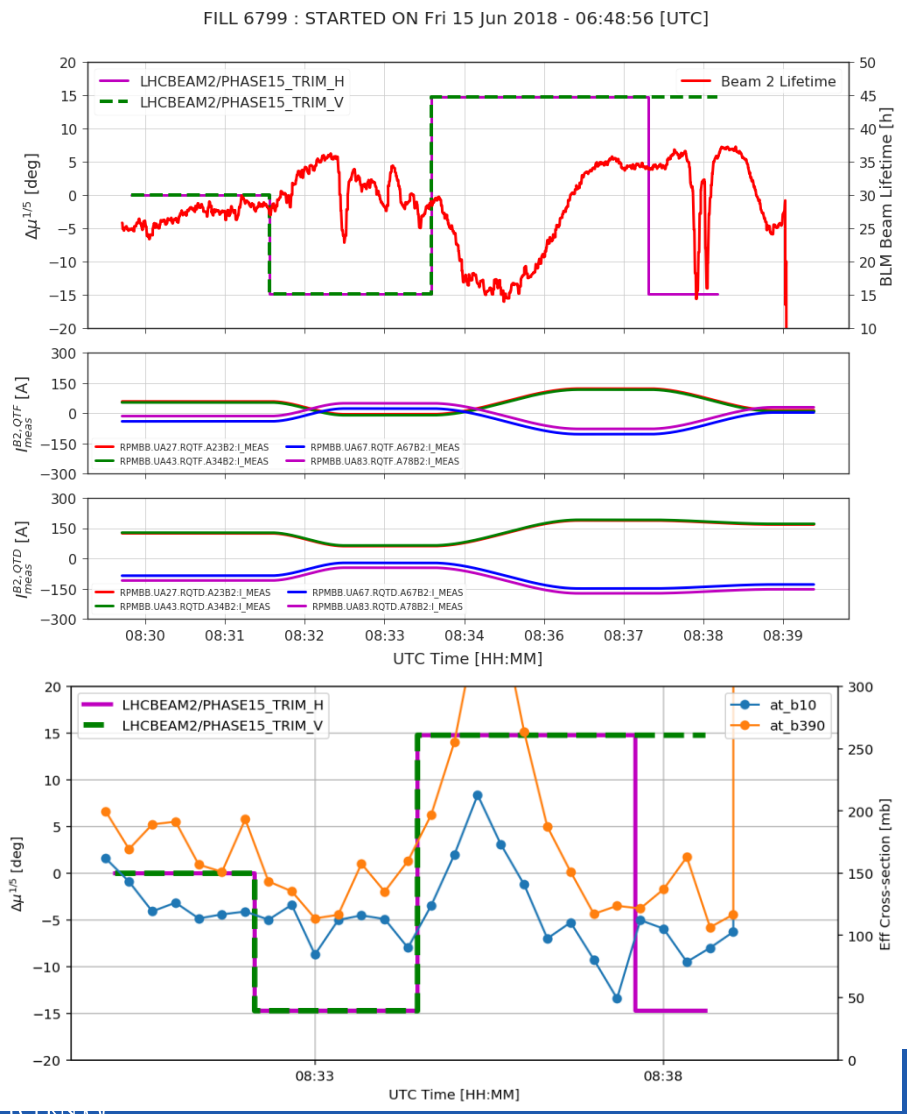






Phase Advance Knobs

- Experience with the knob during **2016 ATS MD** & **2018 Wire MD**



To make B1 look like B2 (in terms of phase) we would need:
→ $\Delta\mu_x$ = 0.105459 = +37.96524°
→ $\Delta\mu_y$ = 0.113462 = +40.84632°

Use only Beam-1

Trim Quads

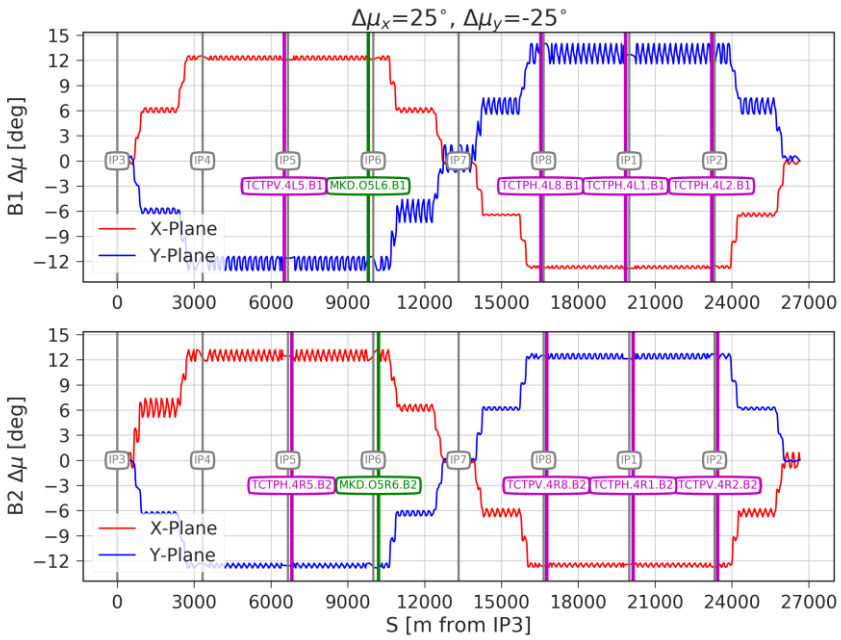
Knob Definition

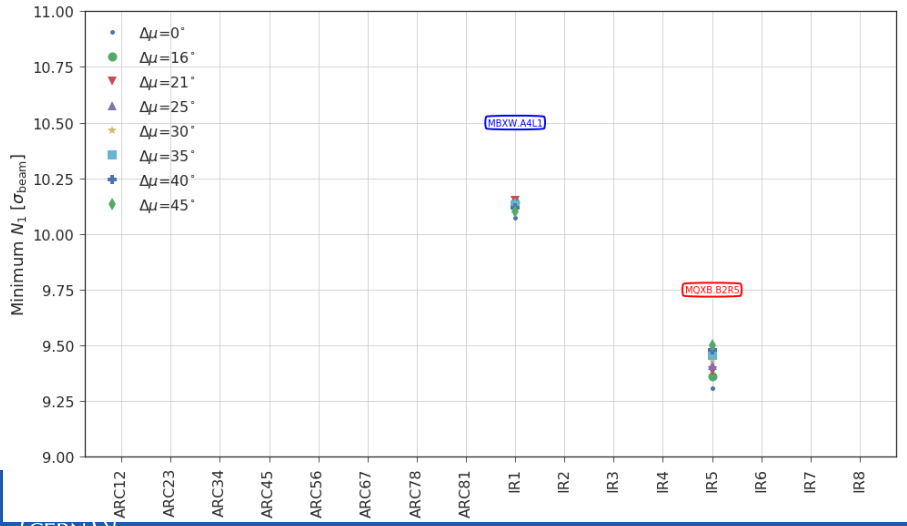
KQTF.A78B1 := -0.01449289331 * dmux15.b1 - 0.00264968902 * dmuy15.b1;
KQTF.A23B1 := 0.01449289331 * dmux15.b1 + 0.00264968902 * dmuy15.b1;
KQTF.A34B1 := 0.01449289331 * dmux15.b1 + 0.00264968902 * dmuy15.b1;
KQTF.A67B1 := -0.01449289331 * dmux15.b1 - 0.00264968902 * dmuy15.b1;

KQTD.A78B1 := 0.00269237170 * dmux15.b1 + 0.01440520498 * dmuy15.b1;
KQTD.A23B1 := -0.00269237170 * dmux15.b1 - 0.01440520498 * dmuy15.b1;
KQTD.A34B1 := -0.00269237170 * dmux15.b1 - 0.01440520498 * dmuy15.b1;
KQTD.A67B1 := 0.00269237170 * dmux15.b1 + 0.01440520498 * dmuy15.b1;

Maximum variation for 45 deg:
0.00213 ($\Delta\mu_x$=$\Delta\mu_y$=+0.125)
0.00148 ($\Delta\mu_x$=+0.125, $\Delta\mu_y$=-0.125)

Phase Advance Knobs – MKD/TCT





- **At least 150deg** phase advance between **MKD & TCT**
- From the model:

MKD.O and TCTPH.4L1
μx = **180.1036476**
μy = **58.851144**

MKD.O and TCTPV.4L1
μx = **180.1668708**
μy = **58.94344080000108**

MKD.A and TCTPH.4L1
μx = **175.5292752**
μy = **54.6860664**

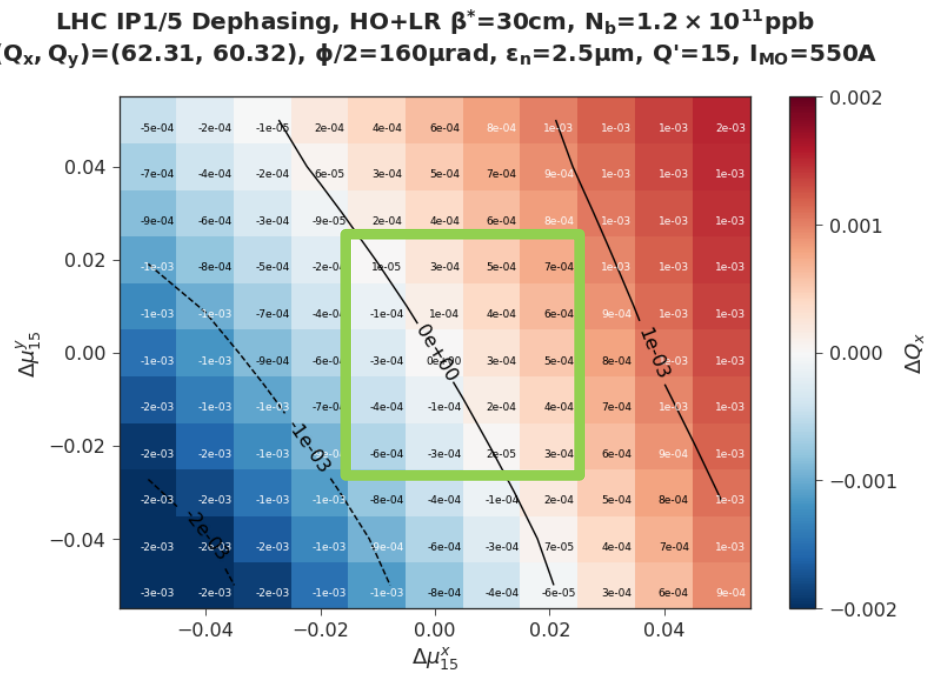
MKD.A and TCTPV.4L1
μx = **175.5924984**
μy = **54.77836320000108**

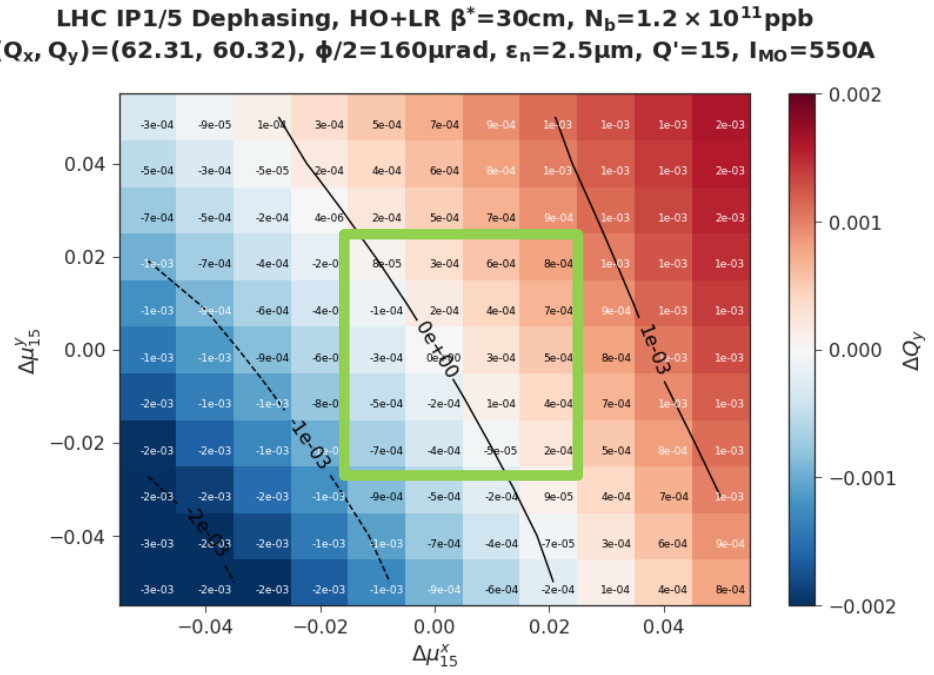
Minimum X: 25.5292752
No limit in Y
→ **Restrict ourselves to 25 deg?**
→ Maximum variation in k_{QT}: 1.2e-3

- **Maximum relevant induced β-beating less than 2.5%**
- **No aperture restriction from induced phase advance (increase @ MQXB.B2R5 with Δμ=+)**

Phase Advance Knobs – Tune Shift

Assuming the tune is not corrected





A window up to ~9° can be scanned by playing a sequence to save time, without a measurable effect on the tune → split in smaller regions & test

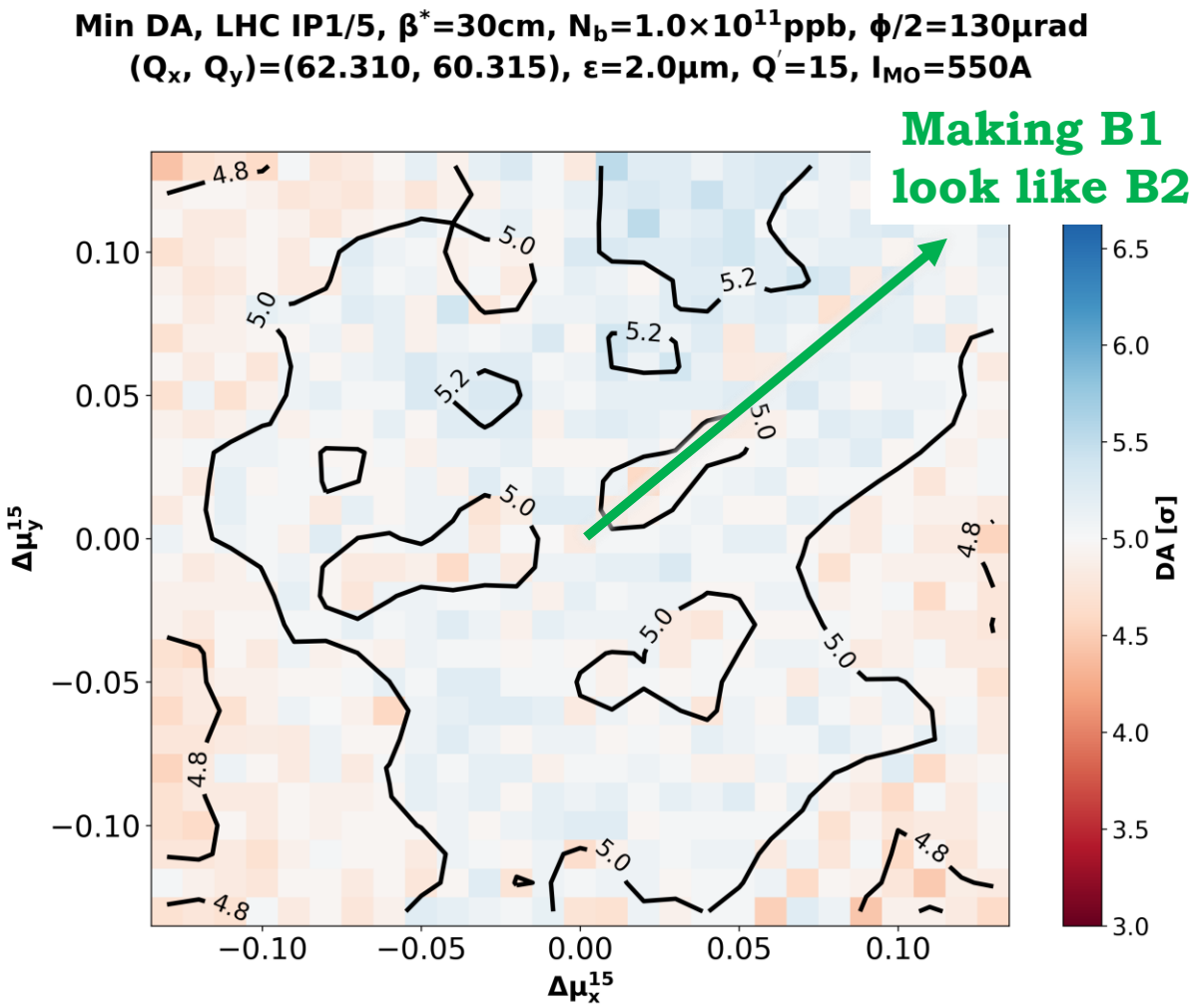
Phase Advance Knobs – DA

Simulation Expectation:

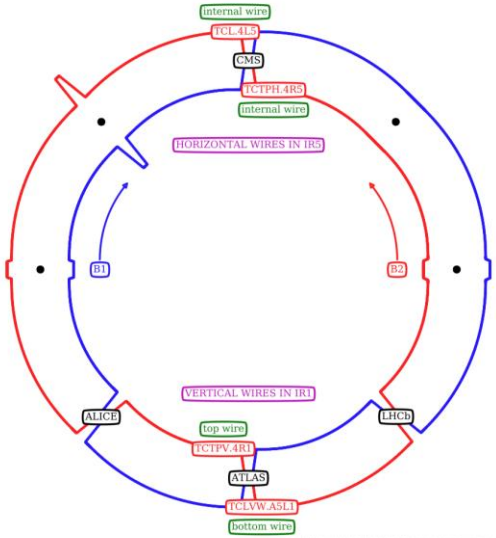
Not a significant effect is expected (with what is included in our simulation framework)

Qualitative results agree so far with expectation (observations?)

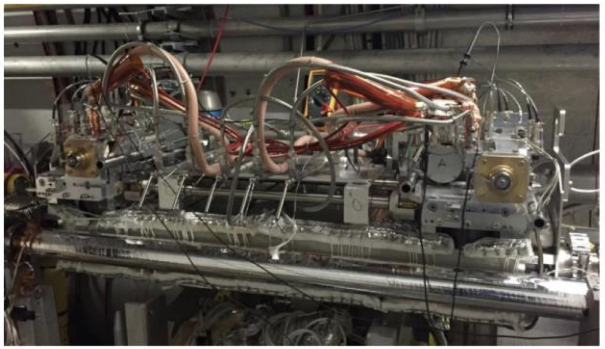
Tracking Beam-1:



BBLR Compensation with DC Wires



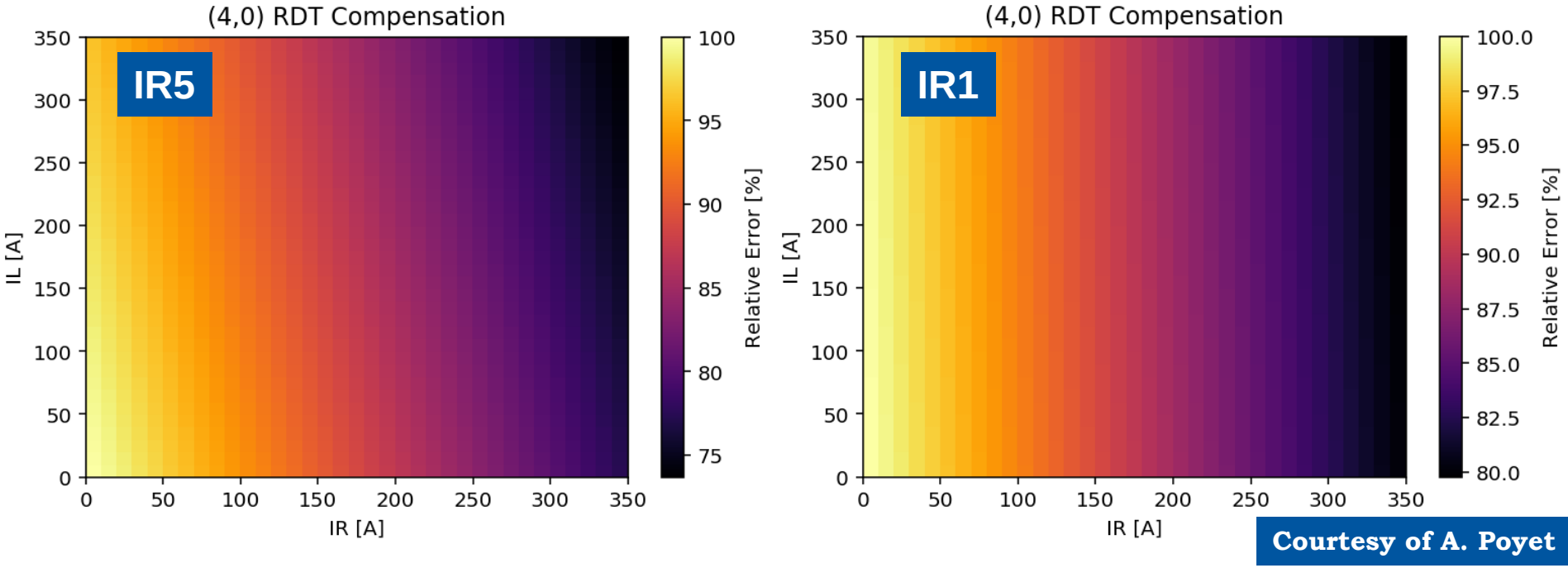
Courtesy of G. Sterbini



- At **130µrad** and **β*=30cm:** power on the DC wire, **WITHOUT moving the wire collimators from their operational position → sub-optimal configuration**
  → Collimators are **moving with the crossing angle (operational orchestration)**

- Position of wire in IR5:
  - d_L = 15.32mm (jaws at 16.3 σ_{coll})
  - d_R = -11.06mm (jaws at 8.45 σ_{coll})

BBLR Compensation with DC Wires



Courtesy of A. Poyet

- In this sub-optimal configuration the wire needs to be **fully powered on** to have even an effect
  → 25% compensation of RDT (4,0)
- **Feedforward tested and proved robust → Vary Q4/Q5 limits**
- Possibility of moving the **5th axis**
- Possibility of **varying the crossing-angle** (going up to 160μrad) after having reached 130μrad

IF time allows…

- **Using the operational configuration while being at 130μrad, squeeze to 25cm (from 30cm) β***
  - Observe BBLR pattern for different trains & collision schemes
  - Assuming no interlock at intensity exists!

- **Reduce octupoles & switch polarity**
  - Observe BBLR compensation with octupoles

- **Perform chromaticity & octupoles scan**

Putting everything together

- **Crossing Bias Knobs:**
- Very close to operational envelope
  → **Corrector limits should be opened to allow for ±30μrad bias**

- **Phase Advance Knobs:**
- Restrict ourselves to **25 deg horizontal**, **45 deg vertical**
  → **relax limit of MQT to accommodate the trim**

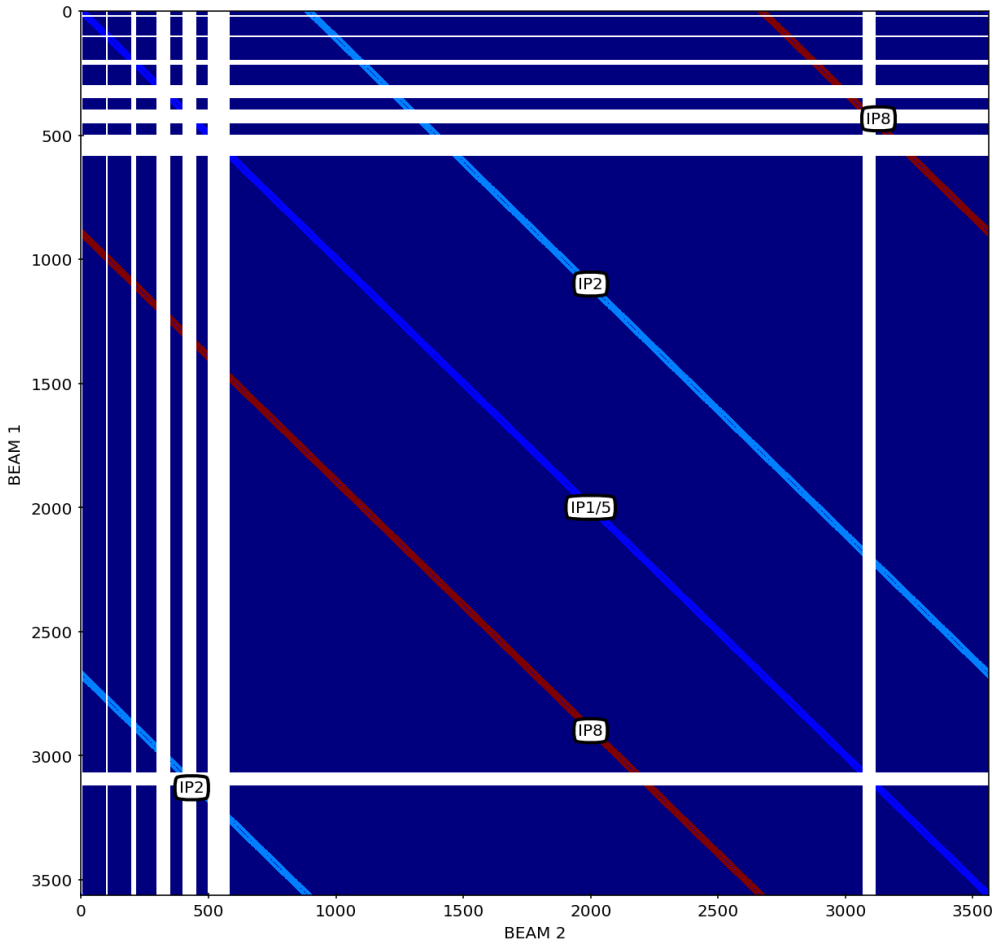
- **Wire:**
  → **Vary Q4/Q5 (R) limits to avoid dumping**
  → **Move the 5th axis**

- **Overall:**
- **Bi-directionally** moving the crossing angle
- **Revert octupole** polarity.


CERN

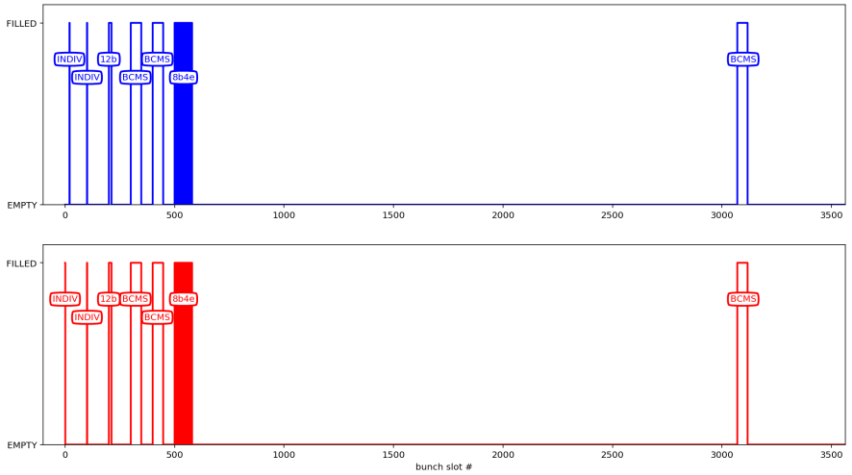
SPARE SLIDES

Alternative Filling Scheme



BEAM 1		BEAM 2	
# bunches	collisions	bunches	collisions
LHCINDIV	LR 1/5	LHCINDIV	LR 1/5
LHCINDIV	HO 1/5	LHCINDIV	HO 1/5
12b	HO 1/5	12b	HO 1/5
1st BCMS	HO 1/5	1st BCMS	HO 1/5
2nd BCMS	HO 1/5/8	2nd BCMS	HO 1/2/5
8b4e (32b)	HO 1/5	8b4e (32b)	HO 1/5
3rd BCMS	HO 1/2/5	3rd BCMS	HO 1/5/8

Total Bunches in LHC : 380



Beam Parameters & Instrumentation

Number of MD's	**1**
Time required per MD [h]	8 +2 of recovery
Beams required [1, 2, 1&2]	1&2
Beam energy [GeV]	6500
Optics (injection, squeezed, special)	Nominal collision optics (ATS 30→25 cm and 160-130 urad)
Bunch intensity [#p]	1.1e11
Transv. emittance [m rad]	2.3e-6 at collision
Bunch length [ns @ 4s]	1
Optics change [yes/no]	No
Orbit change [yes/no]	Yes, reduced crossing angles in IP1 and 5
Collimation change [yes/no]	5th axis on the wire collimator
RF system change [yes/no]	No
Feedback changes [yes/no]	No
Tune changes	Small tune scans, max deviation from nomimal tunes 0.01.
What else will be changed?	Crossing angle bias Phase knobs on B1 (modify the QTrim tolerance windows) Wire current
Are parallel studies possible?	No

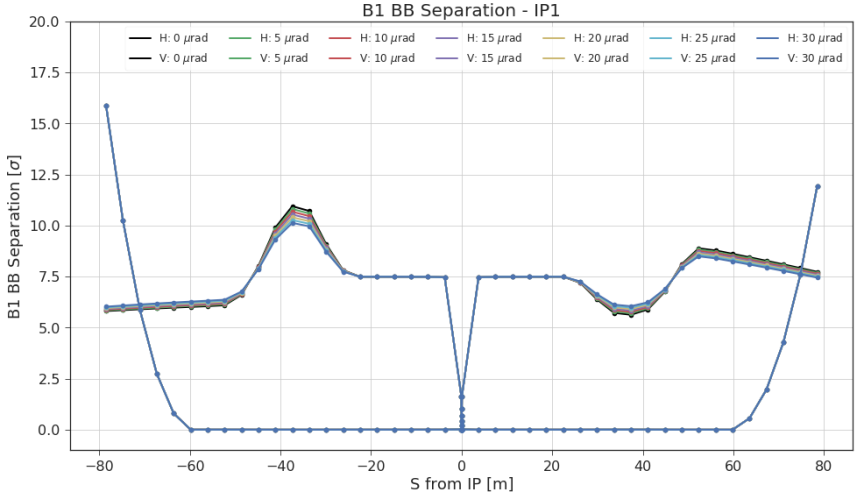
Instrumentation	
Lifetime	BLM, dBLM
Intensity	fBCT
Profiles	BSRT
Luminosity	IP1/IP5
Activity	ADT
Orbit (Position)	ObsBox
Tune	BBQ

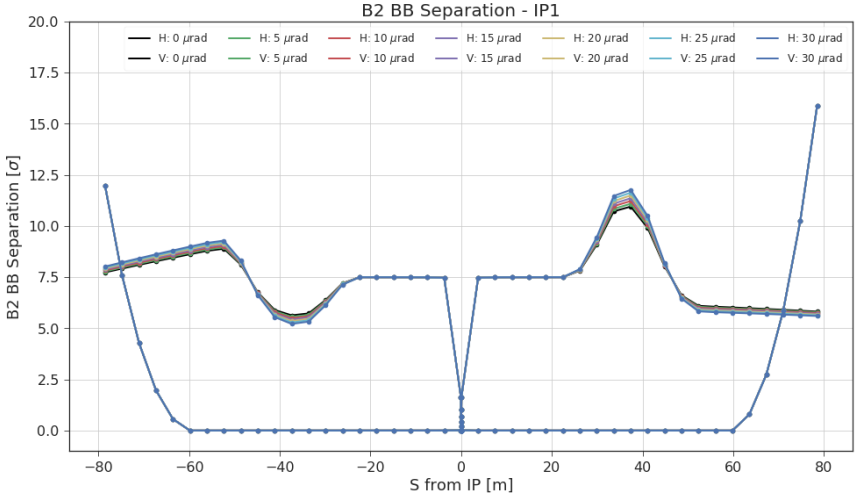
Crossing Bias Knob – Full definition

```
ACBXV1.L1     := (   0.375594145850E-07 )*on_x1;
ACBXV1.R1     := (  -0.375594145850E-07 )*on_x1;
ACBXV2.L1     := (   0.375594145850E-07 )*on_x1;
ACBXV2.R1     := (  -0.375594145850E-07 )*on_x1;
ACBXV3.L1     := (   0.375594145850E-07 )*on_x1;
ACBXV3.R1     := (  -0.375594145850E-07 )*on_x1;

!Beam1
ACBYVS4.L1B1  := (  -0.200423164188E-06  )*on_x1+(   0.198121207041E-06  )*on_x1s;
ACBYVS4.R1B1  := (   0.164534648296E-06  )*on_x1+(  -0.137259444590E-06  )*on_x1s;
ACBCV5.L1B1   := (  -0.132174848509E-06  )*on_x1+(  -0.403691649328E-06  )*on_x1s;
ACBCV6.R1B1   := (   0.901819902090E-07  )*on_x1+(   0.339503516763E-06  )*on_x1s;

!Beam2
ACBYVS4.L1B2  := (   0.171821441414E-06  )*on_x1+(   0.109827234585E-06  )*on_x1s;
ACBYVS4.R1B2  := (  -0.173781115060E-06  )*on_x1+(  -0.279491986473E-06  )*on_x1s;
ACBCV6.L1B2   := (   0.830638023750E-07  )*on_x1+(  -0.312706050017E-06  )*on_x1s;
ACBCV5.R1B2   := (  -0.158417892796E-06  )*on_x1+(   0.483843781180E-06  )*on_x1s;

!! IR5
ACBXH1.L5     := (   0.375594145850E-07 )*on_x5;
ACBXH1.R5     := (  -0.375594145850E-07 )*on_x5;
ACBXH2.L5     := (   0.375594145850E-07 )*on_x5;
ACBXH2.R5     := (  -0.375594145850E-07 )*on_x5;
ACBXH3.L5     := (   0.375594145850E-07 )*on_x5;
ACBXH3.R5     := (  -0.375594145850E-07 )*on_x5;

!Beam1
ACBYHS4.L5B1  := (  -0.163047625743E-06  )*on_x5+(   0.142847973076E-06  )*on_x5s;
ACBYHS4.R5B1  := (   0.200356876660E-06  )*on_x5+(  -0.198301363819E-06  )*on_x5s;
ACBCH6.L5B1   := (  -0.886034635238E-07  )*on_x5+(  -0.333554477113E-06  )*on_x5s;
ACBCH5.R5B1   := (   0.131723492791E-06  )*on_x5+(   0.402299481385E-06  )*on_x5s;

!Beam2
ACBYHS4.L5B2  := (   0.173767757545E-06  )*on_x5+(   0.279507750043E-06  )*on_x5s;
ACBYHS4.R5B2  := (  -0.169490659688E-06  )*on_x5+(  -0.118592681770E-06  )*on_x5s;
ACBCH5.L5B2   := (   0.158426292190E-06  )*on_x5+(  -0.483853060948E-06  )*on_x5s;
ACBCH6.R5B2   := (  -0.810019380868E-07  )*on_x5+(   0.304937956476E-06  )*on_x5s;
```

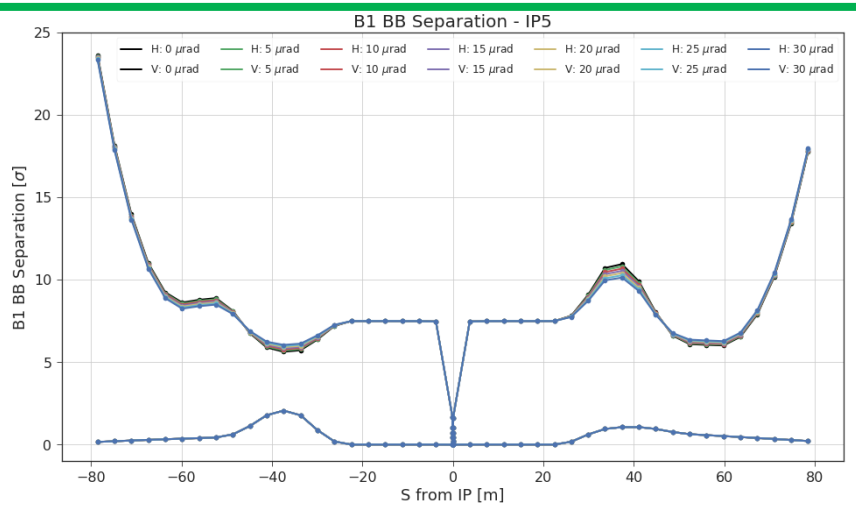
Crossing Angle Knobs – BB Separation

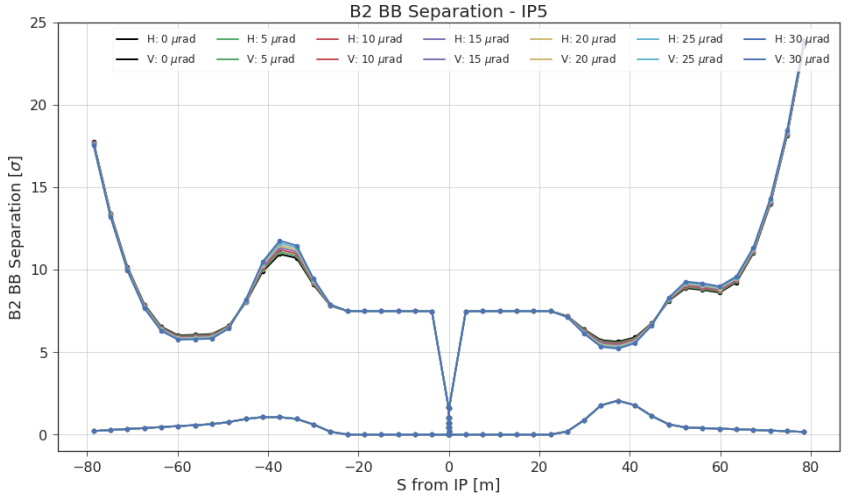
IP1 scan





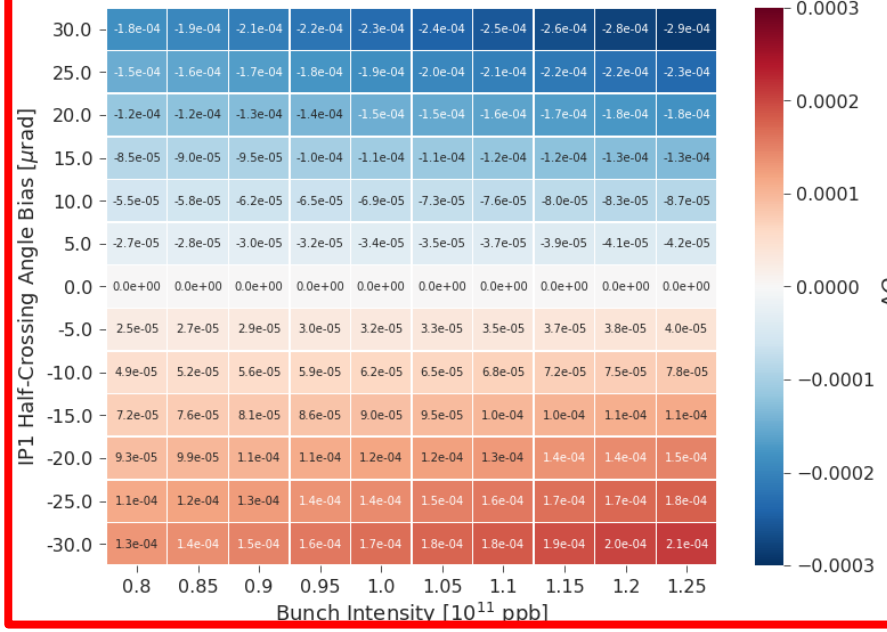
IP5 scan

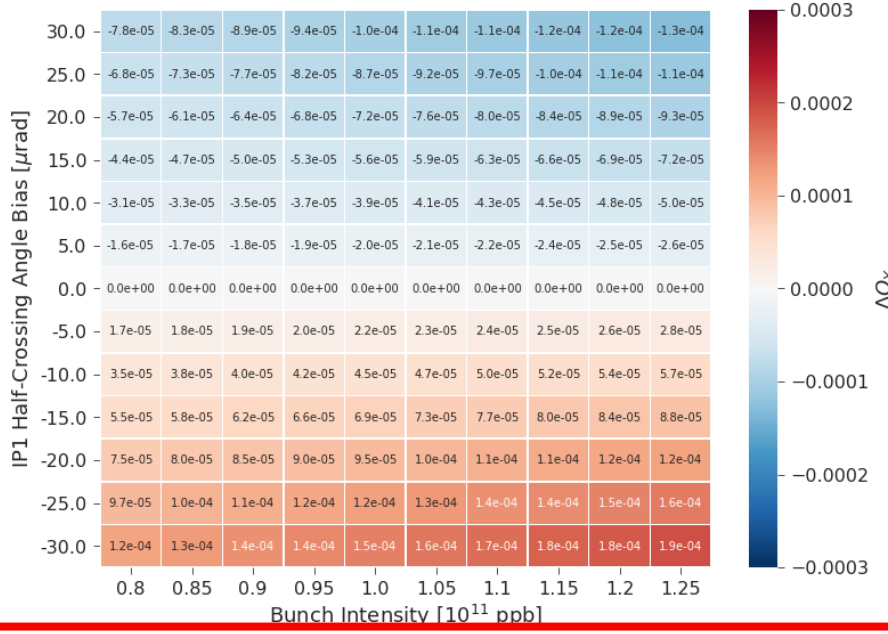




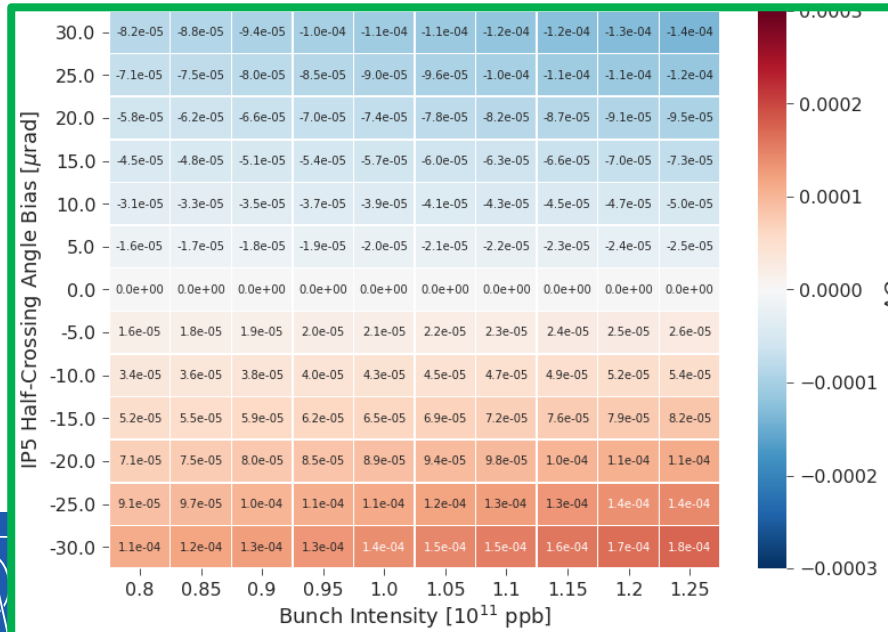
Crossing Angle Knobs – Tune Variation

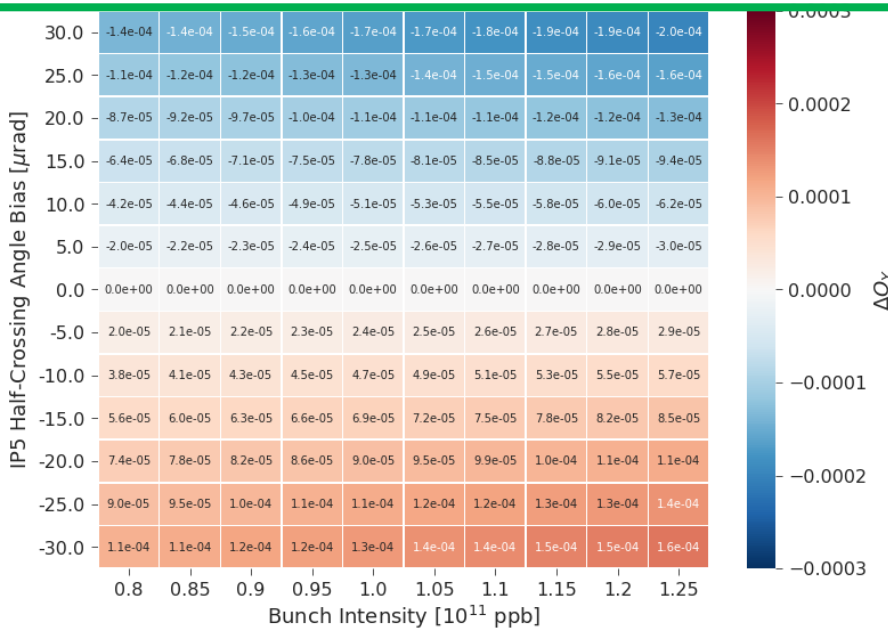
IP1 scan



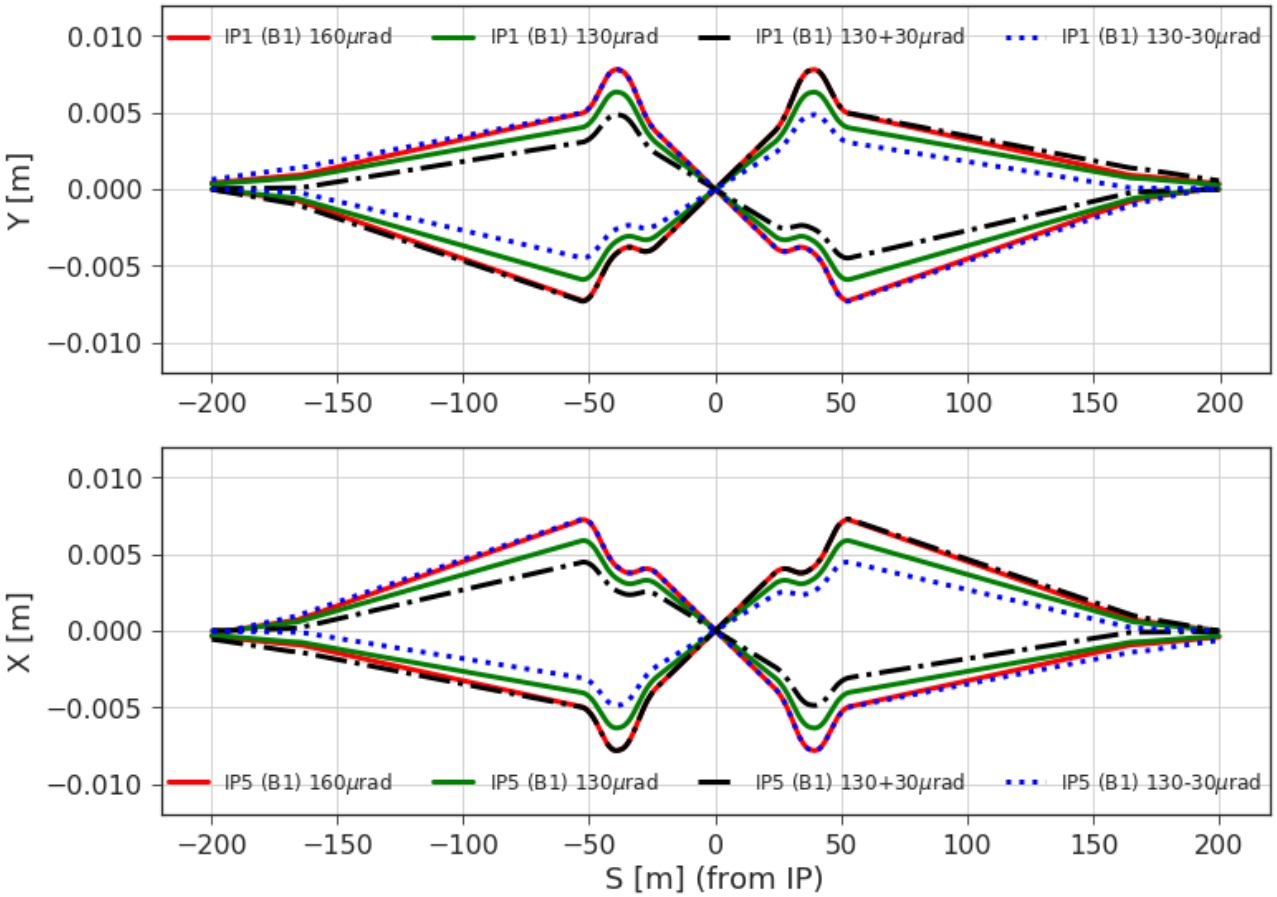


IP5 scan



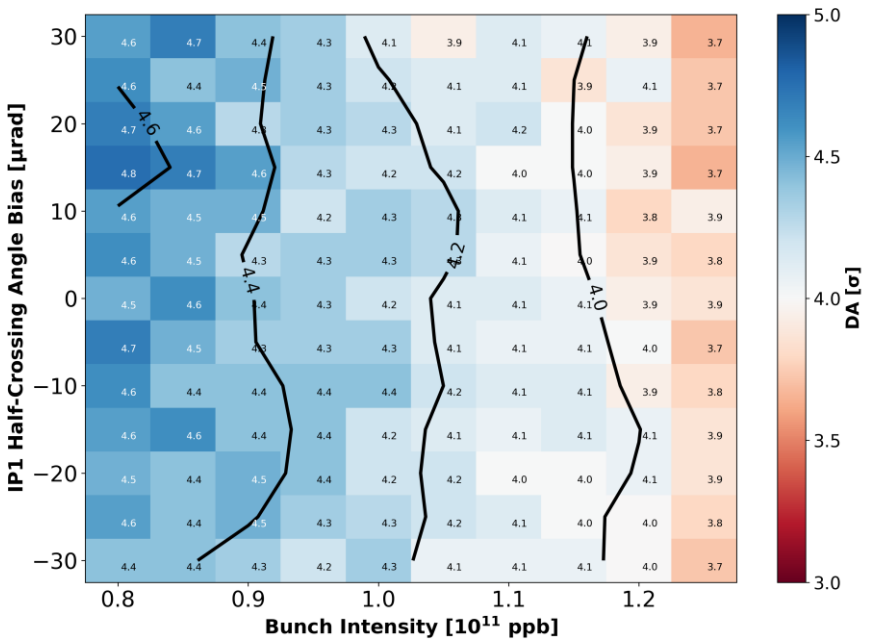


CO Bump Crossing Knob

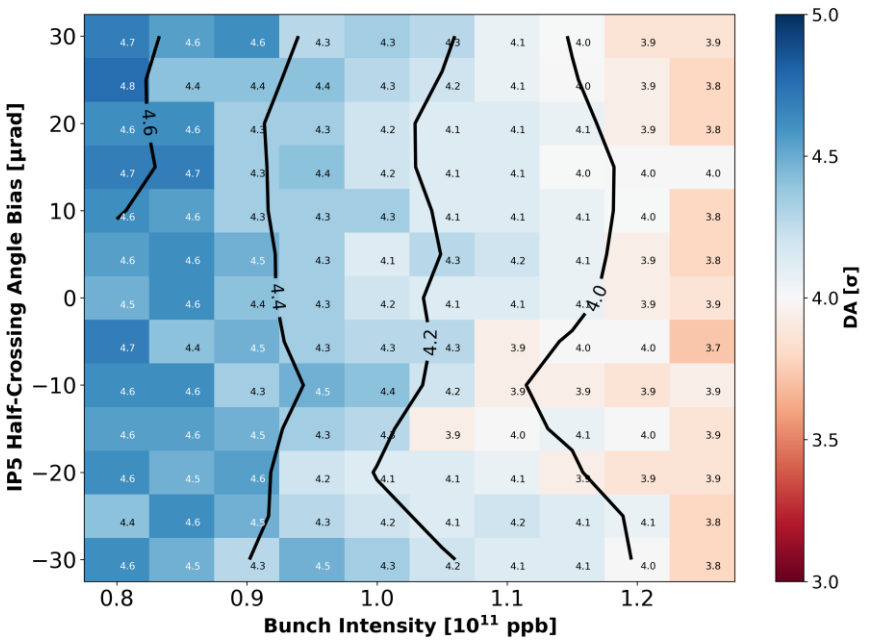


DA Crossing Knob

IP1 scan

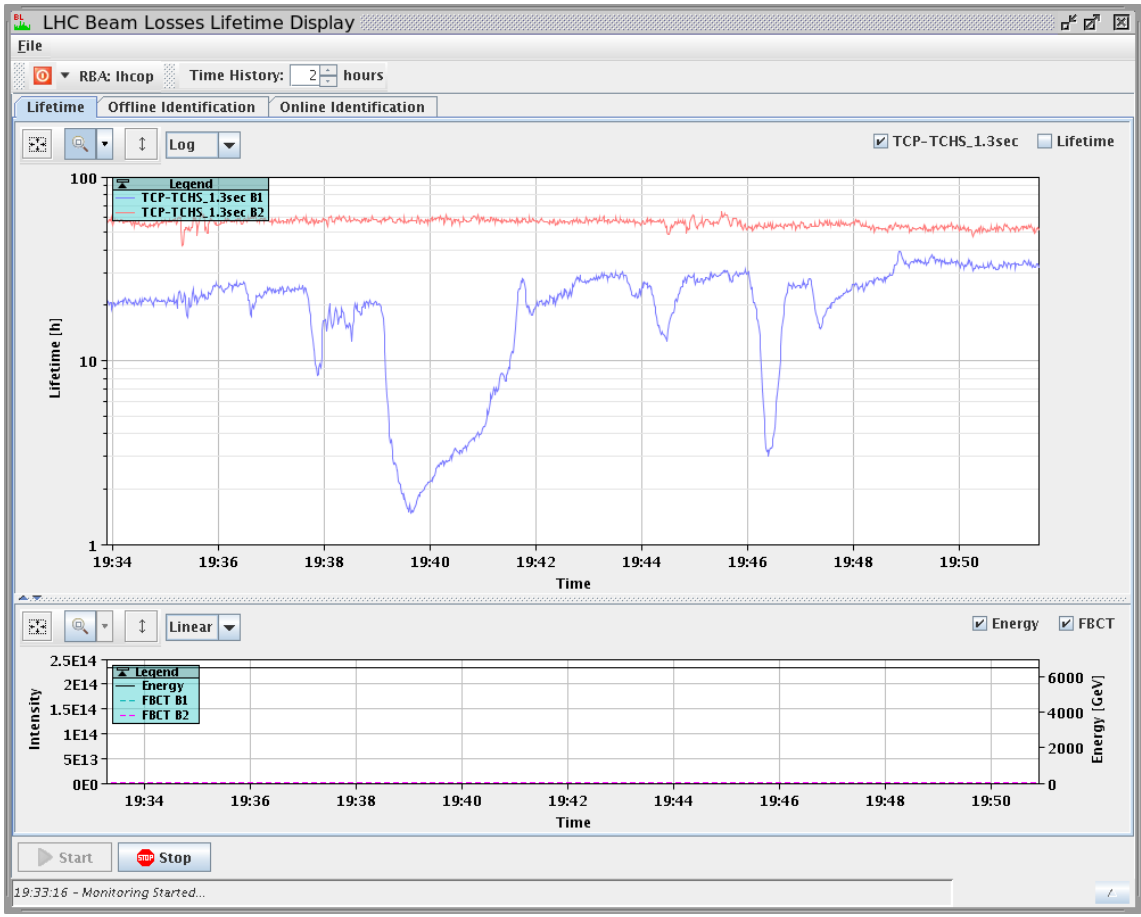


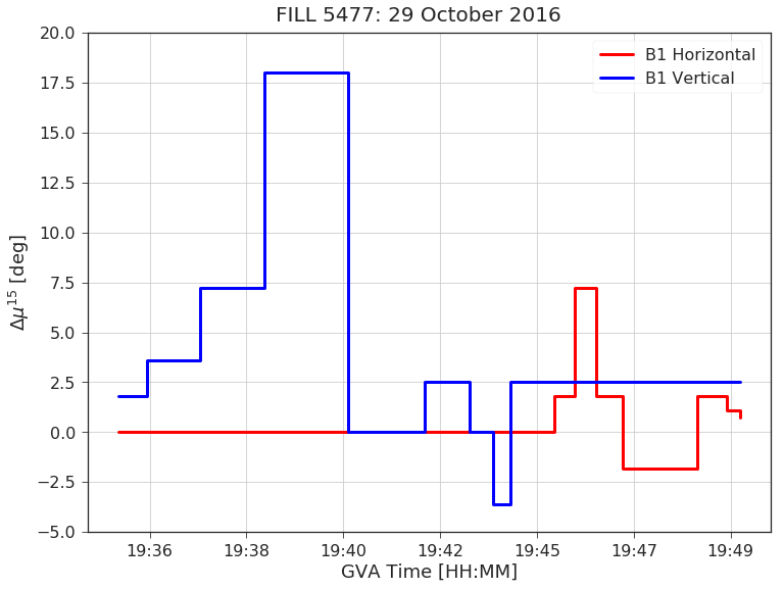
IP5 scan



ATS MD Crossing Knob

- HO only bunches
- We can really make it bad!
- Gain of ~10h for 2.5σ vertical (0.007)→ need of a refined scan

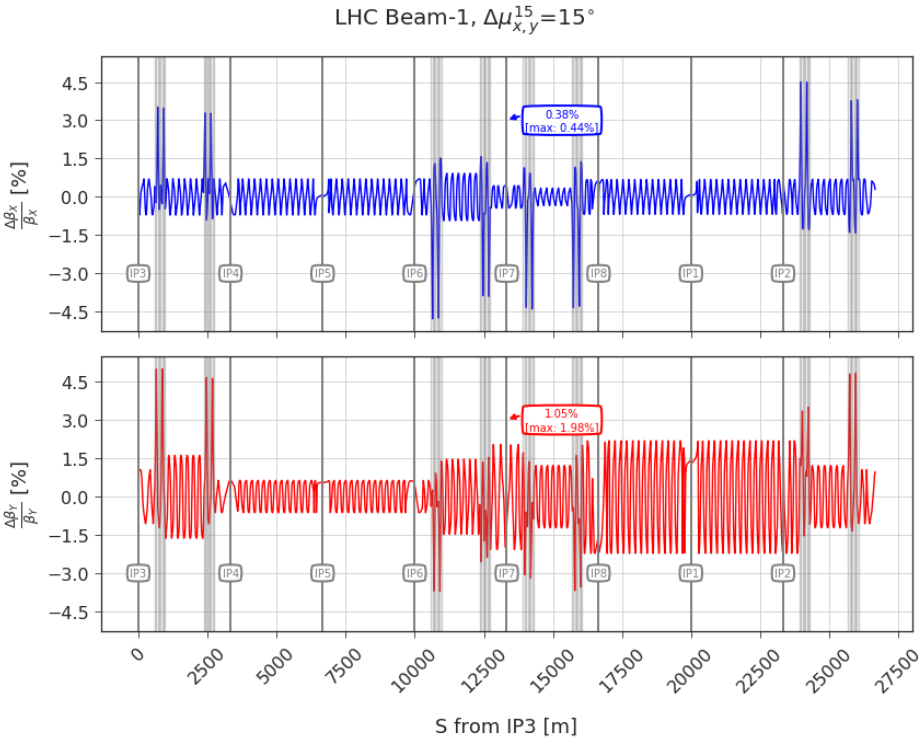


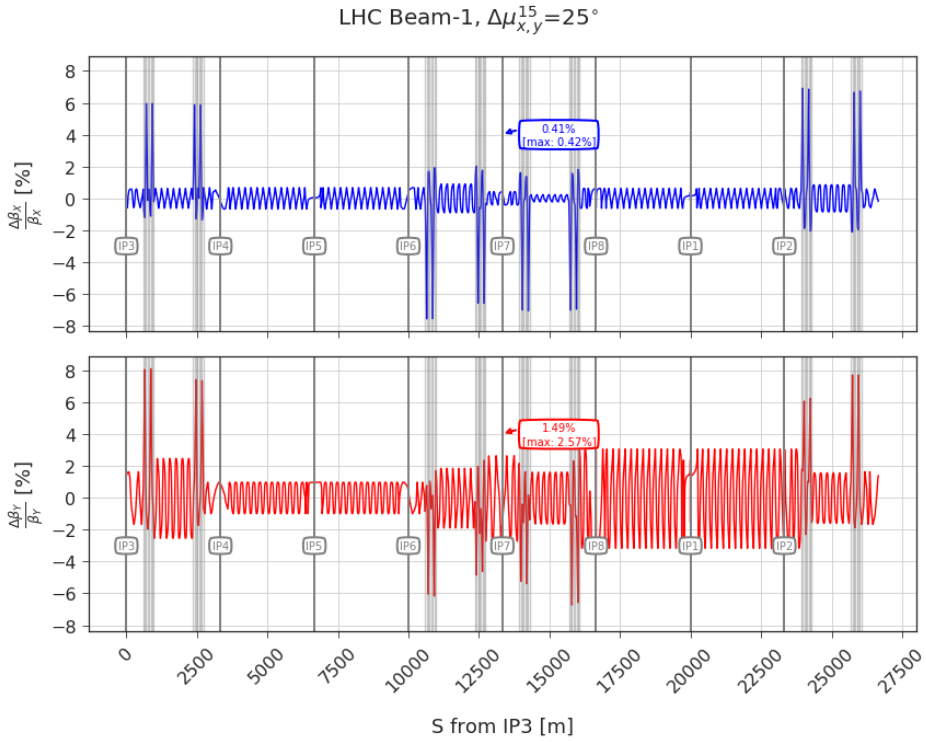


Phase knob – Full Definition

```
KQTF.A78B1  := -0.01449289331 * dmux15.b1 - 0.00264968902 * dmuy15.b1;
KQTF.A23B1  :=  0.01449289331 * dmux15.b1 + 0.00264968902 * dmuy15.b1;
KQTF.A34B1  :=  0.01449289331 * dmux15.b1 + 0.00264968902 * dmuy15.b1;
KQTF.A67B1  := -0.01449289331 * dmux15.b1 - 0.00264968902 * dmuy15.b1;
KQTD.A78B1  :=  0.00269237170 * dmux15.b1 + 0.01440520498 * dmuy15.b1;
KQTD.A23B1  := -0.00269237170 * dmux15.b1 - 0.01440520498 * dmuy15.b1;
KQTD.A34B1  := -0.00269237170 * dmux15.b1 - 0.01440520498 * dmuy15.b1;
KQTD.A67B1  :=  0.00269237170 * dmux15.b1 + 0.01440520498 * dmuy15.b1;

KQTF.A78B2  := -0.01449247771 * dmux15.b2 - 0.00265943757 * dmuy15.b2;
KQTF.A23B2  :=  0.01449247771 * dmux15.b2 + 0.00265943757 * dmuy15.b2;
KQTF.A34B2  :=  0.01449247771 * dmux15.b2 + 0.00265943757 * dmuy15.b2;
KQTF.A67B2  := -0.01449247771 * dmux15.b2 - 0.00265943757 * dmuy15.b2;
KQTD.A78B2  :=  0.00269988488 * dmux15.b2 + 0.01446286429 * dmuy15.b2;
KQTD.A23B2  := -0.00269988488 * dmux15.b2 - 0.01446286429 * dmuy15.b2;
KQTD.A34B2  := -0.00269988488 * dmux15.b2 - 0.01446286429 * dmuy15.b2;
KQTD.A67B2  :=  0.00269988488 * dmux15.b2 + 0.01446286429 * dmuy15.b2;
```

Phase Knob βB





Wire – RDT Compensation Vs Angle

IR5

150 urad
=== MIN ERROR ===
(4,0): 86.265093545 [%]
(0,4): 68.7541434699 [%]
=== NEEDED CURRENT ===
(4,0): IR = 350 [A] and IL = 350 [A]
(0,4): IR = 350 [A] and IL = 350 [A]
140 urad
=== MIN ERROR ===
(4,0): 89.4128950381 [%]
(0,4): 75.915191577 [%]
=== NEEDED CURRENT ===
(4,0): IR = 350 [A] and IL = 350 [A]
(0,4): IR = 350 [A] and IL = 350 [A]
130 urad
=== MIN ERROR ===
(4,0): 91.9829846567 [%]
(0,4): 81.7619471434 [%]
=== NEEDED CURRENT ===
(4,0): IR = 350 [A] and IL = 350 [A]
(0,4): IR = 350 [A] and IL = 350 [A]

IR1

150 urad
=== MIN ERROR ===
(4,0): 79.1913103232 [%]
(0,4): 55.0209137216 [%]
=== NEEDED CURRENT ===
(4,0): IR = 350 [A] and IL = 350 [A]
(0,4): IR = 350 [A] and IL = 350 [A]
140 urad
=== MIN ERROR ===
(4,0): 83.9544860843 [%]
(0,4): 65.3175455957 [%]
=== NEEDED CURRENT ===
(4,0): IR = 350 [A] and IL = 350 [A]
(0,4): IR = 350 [A] and IL = 350 [A]
130 urad
=== MIN ERROR ===
(4,0): 87.8496420601 [%]
(0,4): 73.7369533923 [%]
=== NEEDED CURRENT ===
(4,0): IR = 350 [A] and IL = 350 [A]
(0,4): IR = 350 [A] and IL = 350 [A]