IP1-IP5 phasing in LHC optics V6.503

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LCU section meeting

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One of optics issues in V6.503

Phase advance between IP1-IP5 is preferable to be $\pi/2$.

Ref. W. Herr and D. Kaltchev, "Effect of phase advance between interaction points in the LHC on the beam-beam interaction", LHC Project Report 1082

Beam1	MUX	MUY		
IP1	0.000	0.000		0.65
IP5	31.977	29.649	0.33	
IP1L	64.310	59.320		0.67
Beam2				
IP1	0.000	0.000		0.76
IP5	32.062	29.762	0.25	
IP1L	64.310	59.320		0.56

Try $\pi/2$ starting from V6.503 optics

Possible solutions

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V6.503 collision
Beam1
       IR1      IR2      IR3      IR4      IR5      IR6      IR7      IR8
MUX   2.633    2.986    2.261    2.045    2.633    2.015    2.450    3.183
MUY   2.649    2.809    1.905    1.941    2.649    1.780    1.924    2.974
              (2.8086)

Beam2
       IR1      IR2      IR3      IR4      IR5      IR6      IR7      IR8
MUX   2.633    2.991    2.260    2.125    2.633    2.015    2.489    3.059
MUY   2.649    2.844    1.990    1.934    2.649    1.780    2.003    2.782
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- Freeze IR1, IR5 and IR6
  - IRs free from B1-B2 tune split (and fractional after 3rd digit)
- Solution 1 (Easy-to-implement)
  - Modify IR3, IR4 and IR7 (non-collision IRs)
- Solution 2 (Fully-satisfactory)
  - Modify IR2B2 and IR8B1 (non-injection IRs) in addition to non-collision IRs
    - Cost recalculation of squeezing/unsqeezing and crossing scheme...
  - Not only IP1-IP5 phasing but also eliminating B1-B2 tune split
  - Clean up the IR phase advances not to have fractional after 3rd digit, for example 2.80900... for IR2B1MUY. (Except for IR4 and IR7 for $\pi/2$ phasing)

Solution 1

V6.503 collision

Beam1

	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8			MUX	MUY		
										IP1	0.00	0.00		0.65
MUX	2.633	2.986	2.261	2.045	2.633	2.015	2.450	3.183		IP5	31.98	29.65	0.33	
MUY	2.649	2.809	1.905	1.941	2.649	1.780	1.924	2.974		IP1L	64.31	59.32		0.67

Beam2

	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8			IP1	0.00	0.00		0.76
MUX	2.633	2.991	2.260	2.125	2.633	2.015	2.489	3.059		IP5	32.06	29.76	0.25		
MUY	2.649	2.844	1.990	1.934	2.649	1.780	2.003	2.782		IP1L	64.31	59.32		0.56	

V6.503s1 collision

Beam1

	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8			MUX	MUY		
										IP1	0.00	0.00		0.75
MUX	2.633	2.986	2.260	2.129	2.633	2.015	2.367	3.183		IP5	32.06	29.75	0.25	
MUY	2.649	2.809	1.990	1.958	2.649	1.780	1.822	2.974		IP1L	64.31	59.32		0.57

Beam2

	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8			IP1	0.00	0.00		0.75
MUX	2.633	2.991	2.260	2.124	2.633	2.015	2.491	3.059		IP5	32.06	29.75	0.25		
MUY	2.649	2.844	1.990	1.922	2.649	1.780	2.015	2.782		IP1L	64.31	59.32		0.57	

IR3B2 cleaned up

Apertures in Solution 1 are similar to V6.503 (Problems remain).
LSS optics in IR3 and IR7 are unchanged except for IR7B1 (see next slide).
In IR4, Dx=Dx'=0 at the center, and the betas are OK for transverse feedback.

Problem in IR7B1 for solution 1

- No solution to keep the LSS optics has been found for the phase advances of (2.367, 1.882). Out of tunability range?
  - This would be OK if we assume no collimation in IR7,

    that is, assume momentum + betatron collimation in IR3.
- Tunability study for IR7 will be useful, not only for this study but for future uses

IR7B1, Solution1

Thin lines = V6.503
Thick lines = Solution 1
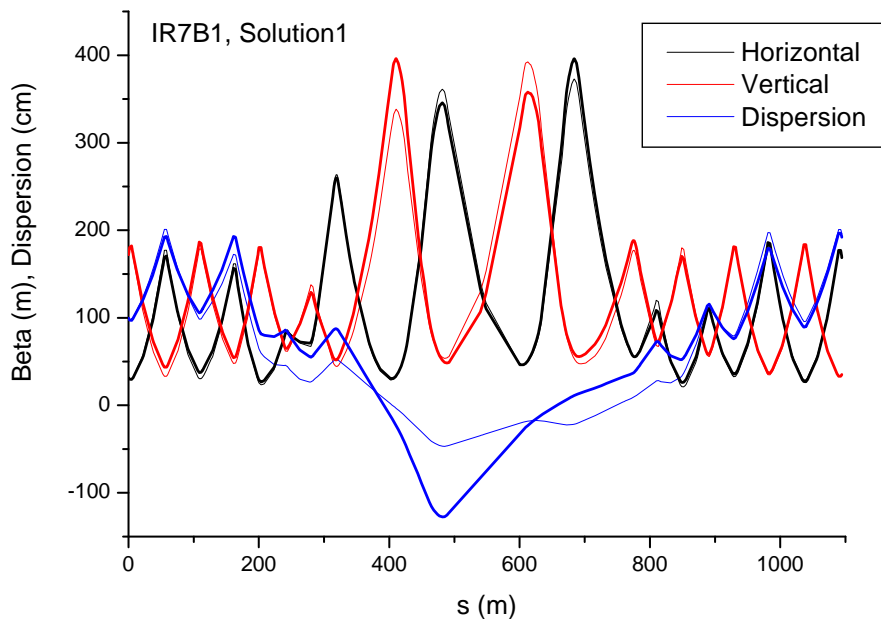
Solution 2

V6.503 collision

Beam1

	IR1	IR2	IR3	IR4		IR5	IR6	IR7		IR8			MUX	MUY		
											IP1		0.00	0.00		0.65
MUX	2.633	2.986	2.261		2.045	2.633	2.015		2.450	3.183	IP5		31.98	29.65	0.33	
MUY	2.649	2.809	1.905		1.941	2.649	1.780		1.924	2.974	IP1L		64.31	59.32		0.67

Beam2

	IR1	IR2	IR3	IR4		IR5	IR6	IR7		IR8						
											IP1		0.00	0.00		0.76
MUX	2.633	2.991	2.260		2.125	2.633	2.015		2.489	3.059	IP5		32.06	29.76	0.25	
MUY	2.649	2.844	1.990		1.934	2.649	1.780		2.003	2.782	IP1L		64.31	59.32		0.56

V6.503s2 collision

Beam1

	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8			MUX	MUY		
										IP1	0.00	0.00		0.75
MUX	2.633	2.986	2.260	2.12940	2.633	2.015	2.49060	3.059		IP5	32.06	29.75	0.25	
MUY	2.649	2.809	1.990	1.95787	2.649	1.780	2.01413	2.782		IP1L	64.31	59.32		0.57

IR2B1 cleaned up

Beam2

|	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8						
										IP1	0.00	0.00		0.75
MUX	2.633	2.986	2.260	2.12860	2.633	2.015	2.49140	3.059		IP5	32.06	29.75	0.25	
MUY	2.649	2.809	1.990	1.95713	2.649	1.780	2.01487	2.782		IP1L	64.31	59.32		0.57

Apertures in Solution 2 are similar to V6.503 (Problems remain).
LSS optics in IR3 and IR7 are unchanged except for IR7B1 (see next slide).
In IR4, $Dx=Dx'=0$ at the center, and the betas are OK for transverse feedback.

Improvement in IR7B1 for Solution 2

- Phase advances (2.491, 2.014) make it possible to have almost zero Dx in LSS. Good for betatron collimation

- For Beam2, this is already done in V6.503
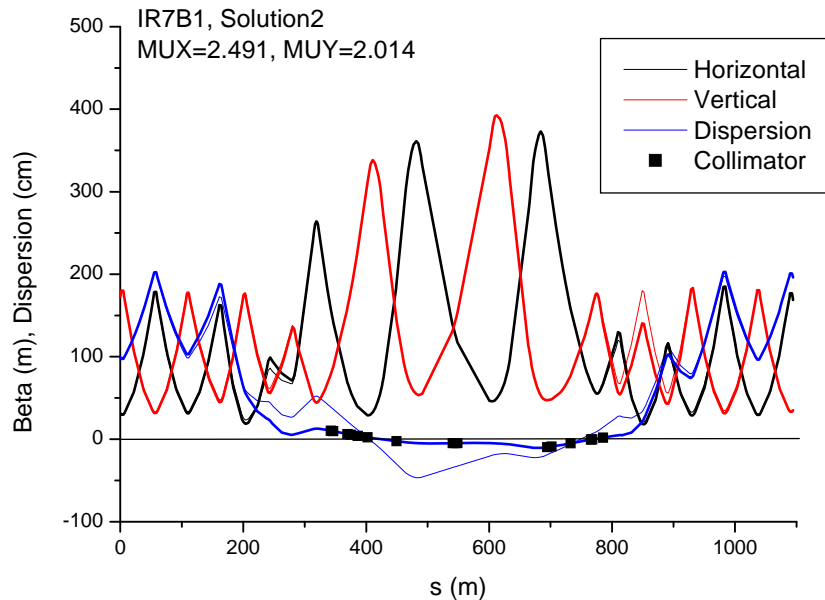
Thin lines = V6.503
Thick lines = Solution 2

Summary

- IP1-IP5 phasing is redone starting from V6.503
  - Solution 1 (Easy-to-implement)
    - Phasing is OK
    - The LSS optics in IR7B1 for betatron collimation is spoiled. Thus Solution 1 is interim solution as far as no good optics for IR7B1.
  - Solution 2 (Fully-satisfactory)
    - Phasing is OK
    - Improvement on Dx in IR7B1
    - B1-B2 tune splits are eliminated (except for IR4 and IR7)
    - Cost recalculation of squeeze/unsqueeze and crossing scheme for IR2 and IR8