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DX magnet requirements for p-AU operation

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This document addresses the question of moving the DX magnets for p-Au operations. First the beam geometry is addressed. Next, the beam sizes are covered. Finally, a conclusion is presented.

Geometry

The beam trajectory for p-Au operation through the crossing dipoles with 0*mrad* collision angles is shown in Fig. 1.

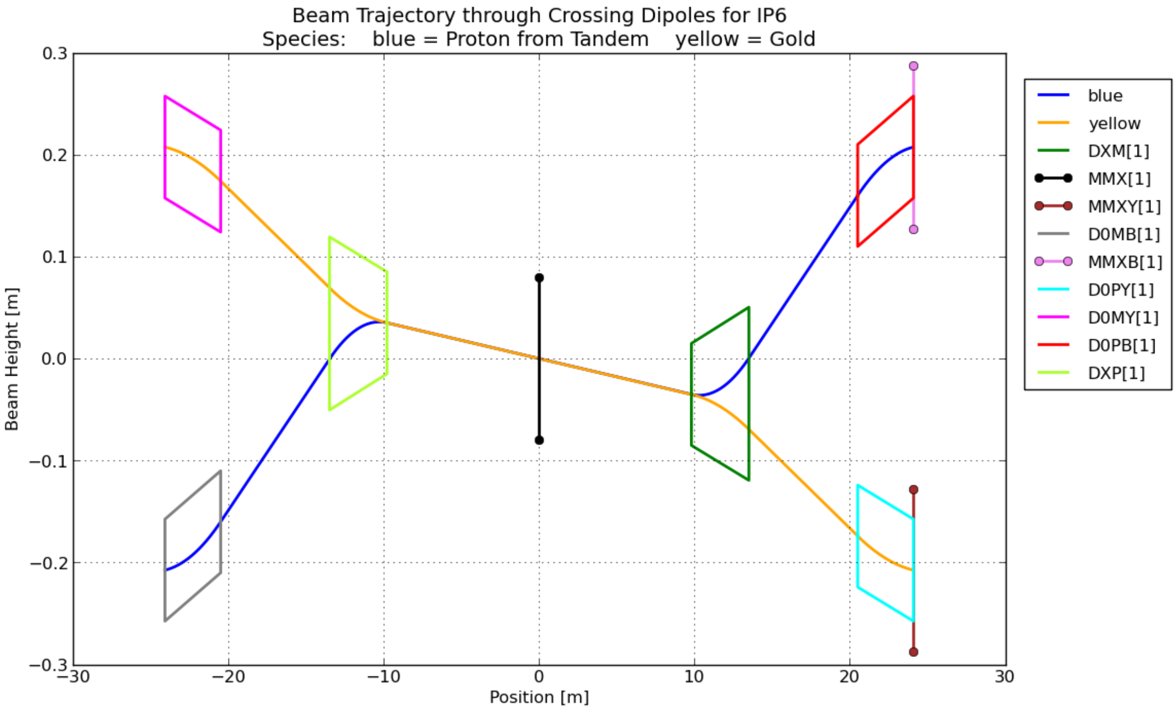

Figure 1. The beam trajectory through the crossing dipoles D0 and DX. The Au beam is 69.4mm from the central line in the DX magnet in the worst case. Additional room for beam size must also be taken into account.

For colliding beam operations, at IP6 and IP8, the DX magnets must be moved due to the aperture limitations. The aperture for the beam tube in the DX magnet is a radius of 68.3*mm*. Only, the Au beam is the limit for colliding operations when the crossing angle is zero.

In the non-colliding beam IRs, at IP10, IP12, IP2 and IP4, a colliding angle of -0.3305*mrad* is used. In this case as shown in Fig. 2., both beams reach a maximum distance from the central axis of the DX beam pipe. Further decreasing the crossing angle causes the blue beam trajectory to increase. This configuration reduces the aperture requirements by almost 10*mm* overall from the colliding beam configuration. In the next section, the beam sizes are studied to see how much the DX magnets may need to be moved.

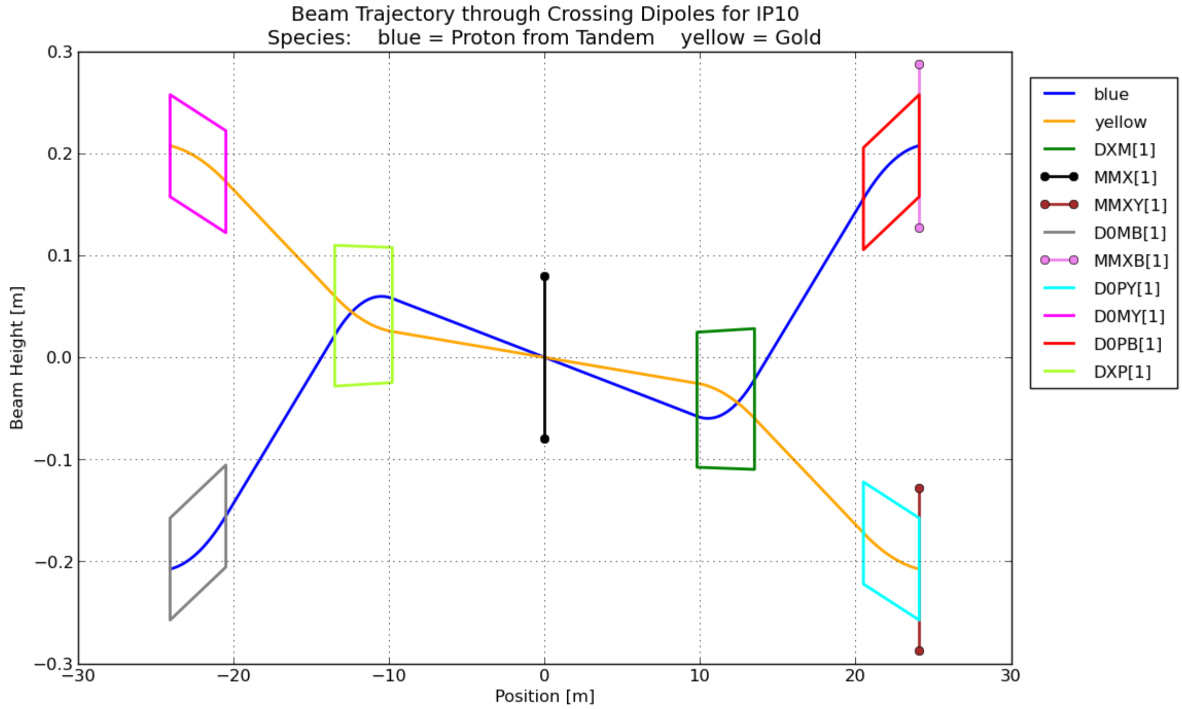

Figure 2. A non-colliding insertion. The crossing angle is -0.3305mrad. The beam trajectory is 59.8mm from the central axises for both beams in the DX magnet. The Blue beam reaches its peak at 10.5m from the IP, while the Yellow beam reaches its peak at 13.5m from the IP.

Beam Sizes

Next, the beam sizes are calculated. Ideally, the beam should have at least ±3σ with an additional 2*mm* free space around its center before aperture limit is reached. The expected beam size can be calculated using:

$$\sigma = \sqrt{\frac{\left(\frac{\epsilon_N}{\pi}\right)\left(\beta^* + \frac{s^2}{\beta^*}\right)}{6(\beta\gamma)}}$$

where ϵ_N is the 95% normalized emittance of the beam, β^* is the beta function at the IP, s is the distance from the IP and (βγ) is from the Lorentz factor.

Table 1. gives the beam sizes and the space from the 3σ beam boundary to the wall. For this table the injection Bρ for the gold beam is 86*T-m*, the same as the dAu82 ramp. Furthermore, the Bρ for the proton beam is chosen to have the same RF frequency as the gold beam.

Conclusion

Table 1. suggests we can pass the beam without needing to move the DX magnets at IP10, IP12, IP2 and IP4. This is doable if the injection emittance of both the proton and gold beam are about 10π *μm*. In Row 2 from the table, the proton beam with a 20π *μm* emittance will just barely squeeze by with 1*mm* space to the aperture wall. As seen in Row 6 from the table, the gold beam at 20π *μm* emittance already exceeds the wall boundary.

The last three rows of Table 1. is for the gold beam at store for IP6 and IP8. If the gold beam grows as large as 40π *μm* emittance (perhaps due to IBS growth, etc), then the DX magnets, at IP6 and IP8, should be moved by at least 15*mm*. Otherwise, a smaller displacement could be applied.

Table 1. The beam sizes for protons and gold are calculated using expected operating conditions in a p-Au scenario at RHIC. Column 2 is the species, column 3 is the operation state, column 4 is the beam emittance, column 5 is the β at the IP, column 6 is the distance from the IP where the beam is farthest from the center in the DX magnet (see Figs 1. and 2.), column 7 is the beam Bρ, column 8 is from the Lorentz factor, column 9 is the calculated beam size, column 10 is the beams trajectory center and column 11 is the free space from the 3σ beam boundary to the aperture wall. A positive Space means the beam remains within the aperture. Ideally, the Space column should be at least +2mm.*

Row	Species	Operation	ε_N/π	β^*	s	Bρ	(βγ)	σ	Center	Space
			[μm]	[m]		[T-m]		[mm]		
Non-Colliding IRs										
1	p	Injection	10	10	10.5	34.776	11.111	1.78	59.777	3.22
2	p	Injection	20	10	10.5	34.776	11.111	2.51	59.777	1.01
3	p	Store	10	4	10.5	358.647	114.593	0.68	59.777	6.52
4	p	Store	20	4	10.5	358.647	114.593	0.96	59.777	5.67
5	Au	Injection	10	10	13.5	86	11.104	2.06	59.777	2.37
6	Au	Injection	20	10	13.5	86	11.104	2.91	59.777	-0.18
9	Au	Store	10	4	13.5	831.763	107.391	0.88	59.777	5.92
10	Au	Store	20	4	13.5	831.763	107.391	1.24	59.777	4.83
11	Au	Store	40	4	13.5	831.763	107.391	1.75	59.777	3.29
Colliding IRs										
7	Au	Injection	10	10	13.5	86	11.104	2.06	69.362	-7.21
8	Au	Injection	20	10	13.5	86	11.104	2.91	69.362	-9.77
12	Au	Store	10	0.7	13.5	831.763	107.391	2.01	69.362	-7.07
13	Au	Store	20	0.7	13.5	831.763	107.391	2.85	69.362	-9.58
14	Au	Store	40	0.7	13.5	831.763	107.391	4.03	69.362	-13.11