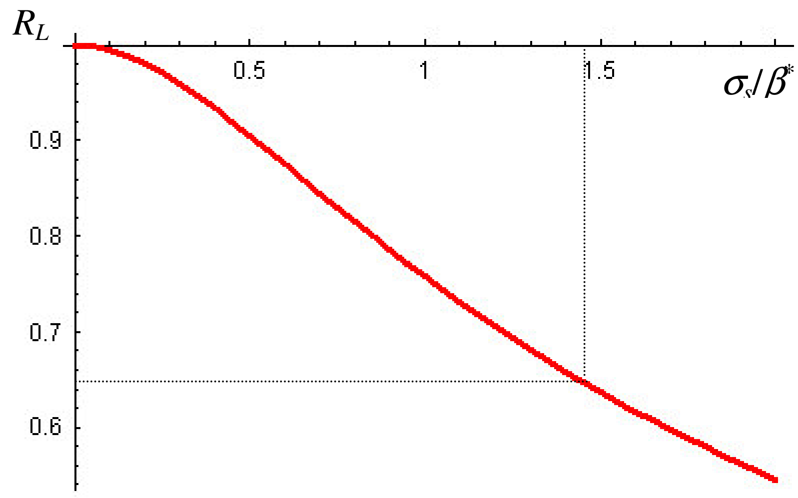
Tevatron Lattice and GTeV-BTeV Compatibility

For head-on colliding round beams

$$\mathcal{L} = f_c \frac{3\gamma N_1 N_2}{\varepsilon_{95\%}\beta^*} R_L(\sigma_s / \beta^*)$$



Luminosity reduction factor due to "hour-glass effect"

To obtain by a factor of 5 lower GTeV luminosity compared to BTeV one would need in the case of head-on collisions

$$\beta^*_{GTeV} = \frac{\mathcal{L}_{BTeV}\beta^*_{BTeV}}{\mathcal{L}_{GTeV} R_L(\sigma_s / \beta^*_{BTeV})} \approx \frac{5 \cdot 0.35 \text{ m}}{0.65} = 2.7 \text{ m}$$

- There is no big problems with the optics in B0 interaction region for β^* = 0.35÷2.7m and the triplets pulled away by 2m from the IP.
- However there are complications associated with:

  - beam-beam interaction in head-on collisions at large values of β^*,

  - closure of the helix in the case of a large difference in β-functions at the separator locations and inappropriate phase advances between them.

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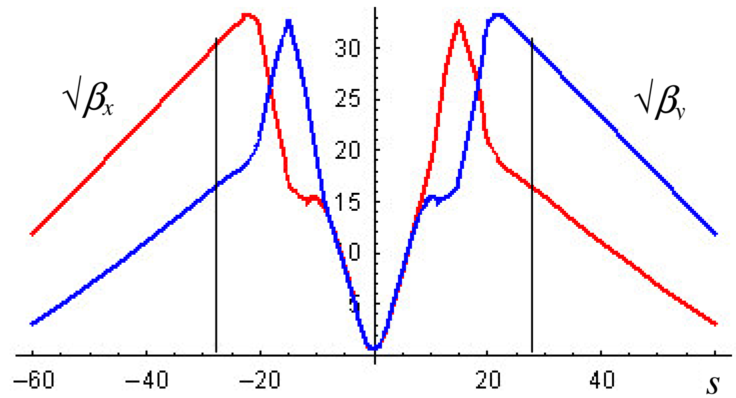
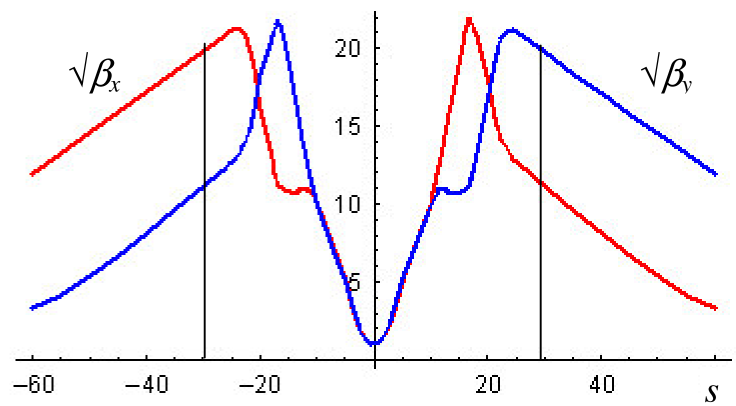
quad	CDF $\beta^* = 0.35$m	GTeV $\beta^* = 1.0$m
AQB	-8.88889	-33.21066
AQ0	-5.98766	59.05007
AQ9	-33.02219	-23.28106
AQ8	0.	9.33134
AQ7	36.10513	11.60123
B0Q6UP	-108.41541	-55.48279
B0QT6UP	-4.60158	22.8605
B0Q5UP	-58.63214	1.14176
B0Q2UP	139.83867	127.5200
B0Q3UP	-137.92767	-129.3342
BQ7	-40.42313	-51.04947
BQ8	-8.88889	15.21007
BQ9	28.51412	-32.79576
BQ0	2.96130	0.83271

B0 IR quadrupole gradients (Tesla/m)

- replace AQ0 and BQ7 trim quads with stronger quads;
- use separate power supplies for B0Q6UP and B0Q6DOWN quads



Optical functions with the present B0 IR configuration ($\beta^* = 0.35$ m)



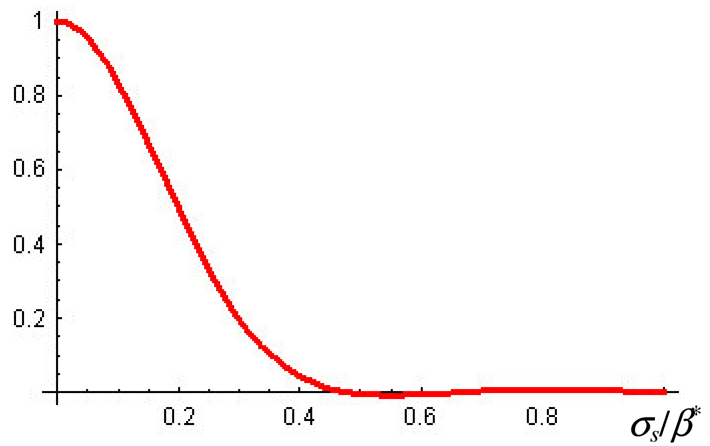
Optical functions with the proposed GTeV configuration ($\beta^* = 1.0$ m)

Tevatron Lattice and GTeV-BTeV Compatibility

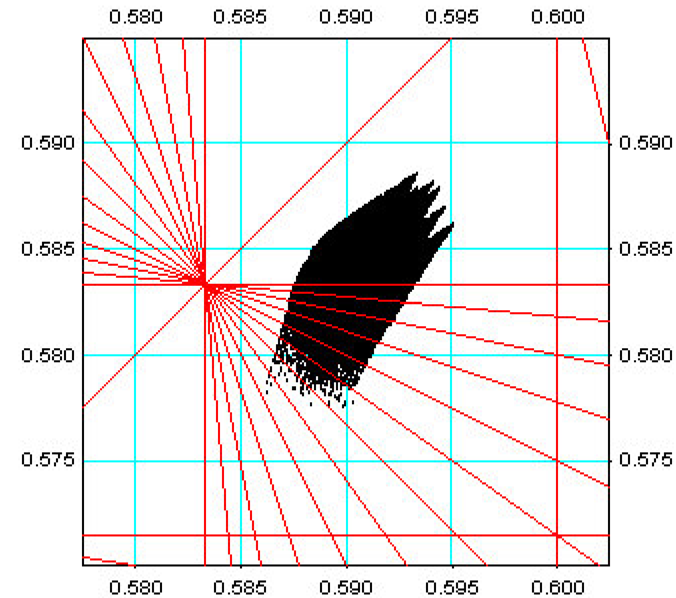
Beam-beam tuneshift in head-on colliding round beams

$$\xi = \frac{3 r_p N_p}{2 \varepsilon_{95\%}}, \quad r_p = 1.535 \cdot 10^{-18}\,\mathrm{m}$$

does not depend on β^*, collisions at GTeV will blow up the pbar tunespread pushing some particles onto 5th and 7th order resonances.



Reduction factor for 12th order resonances owing to phase averaging of head-on interaction with long bunch



Pbar tunes with BTeV running alone (02/18/04 version)

Low luminosity collisions at GTeV with high β^* (~3m) will:

- introduce large tunespread
- strongly excite 12th order resonances

Tevatron Lattice and GTeV-BTeV Compatibility

Separation (one plane): $$d_x(s) = A_x \sqrt{\beta_x(s)}\, \sin[\varphi_x(s) - \varphi_x(s_1)]$$

Invariant amplitude: $$A_x = \sqrt{\beta_x(s_1)}\, \frac{4eUL}{E\Delta} n_{\mathrm{mod}}$$

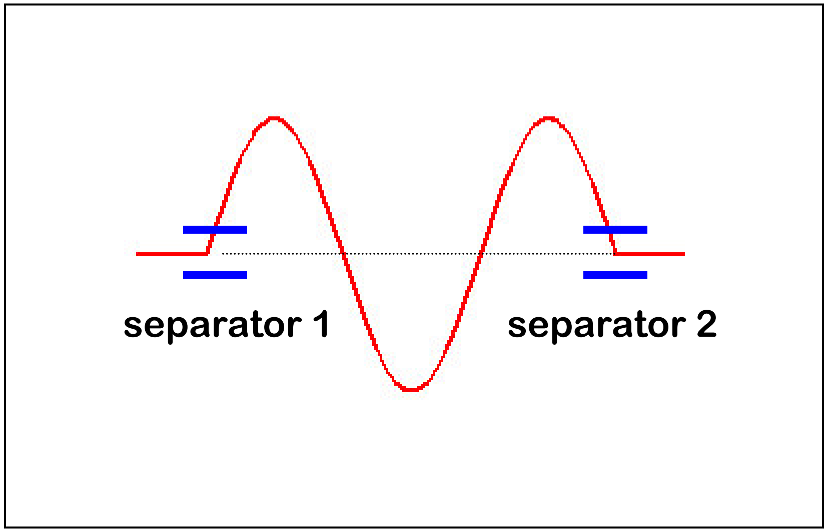
At the nearest parasitic IPs: $$d_x = \frac{4eUL}{E\Delta} n_{\mathrm{mod}} (s_{pip} - s_1)$$

- separation does not depend on the optics, requires maximum possible voltage

Conditions of the helix closure do depend on the optics:

$$\sqrt{\beta_x(s_1)}\, U_1\ n_{\mathrm{mod}\,1} = \sqrt{\beta_x(s_2)}\, U_2\ n_{\mathrm{mod}\,2}$$
$$\varphi_x(s_1) - \varphi_x(s_2) = \pi \times \mathrm{integer}$$

- even if the phase advances were correct, large difference in β-function values would impede the helix closure



Tevatron Lattice and GTeV-BTeV Compatibility

Optics functions at separator locations between B0 and C0:

	B0	B11H (1)	B11H (2)	B11V	B49V	B49H (1)	B49H (2)	C0
β_x (m)	2.7	56.6	50.3	44.7	245.4	325.2	416.3	0.35
$\varphi_x/2\pi$	0	0.242	0.250	0.259	3.864	3.866	3.867	4.116
β_y (m)	2.7	155.1	145.2	135.7	1088.9	1274.9	1475.6	0.35
$\varphi_y/2\pi$	0	0.249	0.252	0.255	3.580	3.581	3.581	3.830

- there is no chance to close the helix with high β^* at B0 (hence low β at the B11 separators) !

We have to lower β^* at BTeV and in order to reduce the luminosity to resort to either of:

- beam-beam offset(s);
- high dispersion function D_x at the IP: $\sigma_x = \sqrt{\varepsilon_{rms}\beta_x^* + (D_x\sigma_E)^2}$
- crossing angle(s)

The first two options involve adjustment of the phase advances between IPs (certainly would require some modifications to C0 IR) and installation of an additional vertical separator (the space again can be obtained by replacing 3 normal bending magnets with 2 high-field dipoles)

The third option comes for free: neither modifications to C0 IR nor additional separators will be necessary.

Tevatron Lattice and GTeV-BTeV Compatibility

	BTeV	+GTeV		BTeV	+GTeV
A49H	0	-41.0	A17V	0	8.6
B11H	0	-33.0	A49V	64.4	4.9
B17H	45.3	45.2	B11V	-64.4	104.9

Changes in the separator voltages (kV) necessary to eliminate offsets at B0 (but allowing for crossing angles)

Default values of the crossing angles:

$\chi_x = 2 \times 0.226$ mrad, $\chi_y = 2 \times 0.254$ mrad

Corresponding luminosity ratio:

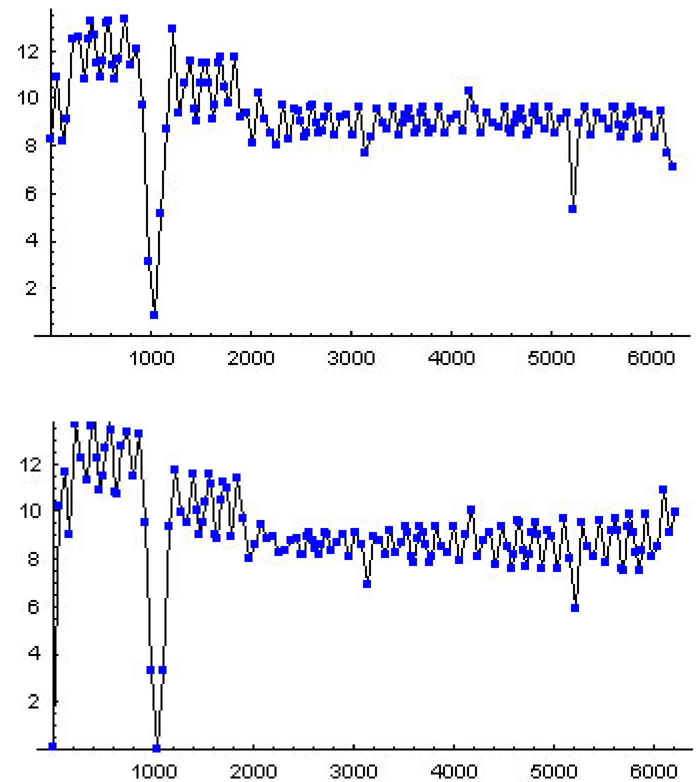
$$\mathcal{L}_{\mathrm{BTeV}} / \mathcal{L}_{\mathrm{GTeV}} = 5.5$$

with $\varepsilon_{95\%}$=20π mm·mrad and σ_s=0.48m.
Beam-beam tuneshifts:

$$\xi_x = 0.0033,\ \xi_y = 0.0030$$

Coupling (closest tune approach): $C = 0.0033$.

There is also a noticeable contribution to odd-odd resonaces (like $Q_x + 11 Q_y$ = integer) but anyway it is much smaller than that from the parasitic IPs around C0.



Radial separation $S = \sqrt{d_x^2 / \sigma_{x\beta}^2 + d_y^2 / \sigma_y^2}$ **vs. distance from B0: top – BTeV alone (02/18/04 version), bottom – BTeV + GTeV with** β^* **= 1.0 m and default crossing angles**