On the Tevatron Luminosity

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3/18/2010

Tevatron Luminosity

$$L_0 = f_0 n_b \frac{H\left(\sigma_z/\beta^*\right)}{\beta^*} \frac{N_p N_a}{\varepsilon_p + \varepsilon_a} \qquad \int L dt = L_0 \tau_L \ln\left(1 + \frac{T}{\tau_L}\right)$$

- β^* (28 cm) is limited by aperture in triplets, orbit stability, and H (0.59)
- τ_L (5 h) in the absence of beam-beam effect is determined by luminosity and IBS. Beam-beam accounts for 5-7% loss of integral
- N_a (80-90 $\times 10^9$) and ε_a (7-8 mm mrad) are determined by
  - Stacking rate
  - Beam-beam tune spread in proton beam (ξ=0.02, ~N_a/ε_a)
  - Proton losses in squeeze (long-range beam-beam)
- N_p (2.7-2.8 $\times 10^{11}$) and ε_p (18 mm mrad) are determined by
  - Upstream machines
  - Beam-beam effect in pbar beam (ξ=0.025, parasitic separations)

Luminosity Integral

- Nominal configuration:

Taking the average stacking rate of 24.5×10^{10}/h, unstashing fraction 0.95, pbar transfer efficiency Recycler to LowBeta 0.82, shot setup time 1h, store length 17h, yields

- Stash size 400×10^{10}
- $L_0=3.5\times10^{32}$ cm^{-2} s^{-1}
- Luminosity per store 8.5 pb^{-1} (with 5% beam-beam)
- Luminosity per week 79 pb^{-1}

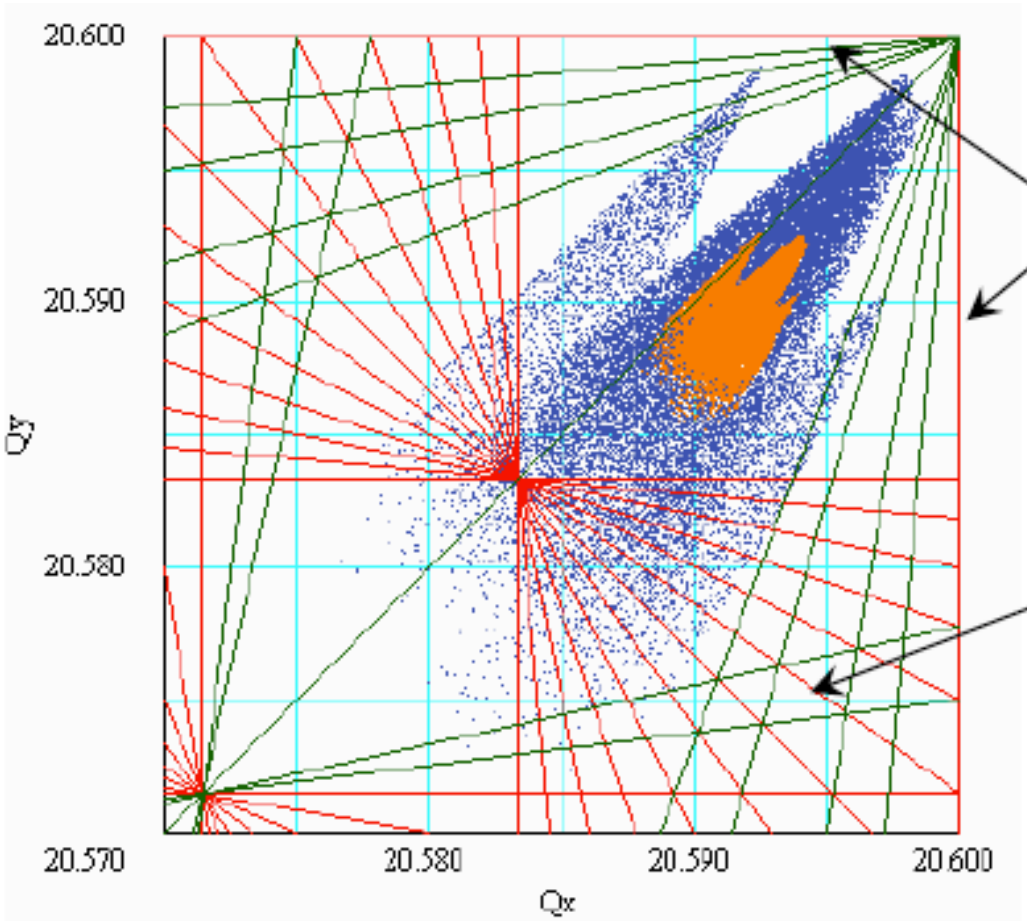
Change	Performance	Weekly Integral (pb-1)
T=19h	Stash 450×10^{10}, $L_0=3.8\times32$	82 (+4%)
ε_a=6 mm mrad (no PBJ)	$L_0=3.67\times10^{32}$	80.5 (+2%)
Stacking rate 22×10^{10}/h (-10%), T=19	Stash 400×10^{10}, $L_0=3.5\times10^{32}$	75 (-5%)
$N_p=3.3\times10^{11}$ (+20%)	$L_0=4.2\times10^{32}$	90 (+14%)
Stacking rate 22×10^{10}/h (-10%), $N_p=3.6\times10^{11}$ (+30%)	Stash 365×10^{10}, $L_0=4.0\times10^{32}$	85 (+8%)

Questions

- Is it possible to integrate luminosity at current rate with fewer pbars by raising N_p?
  - Can MI deliver higher bunch intensity?
    - No, if you request the same emittances (would require improvements in Booster)
    - Yes, if you sacrifice e.g. longitudinal emittance
  - What is the current single bunch intensity limit due to collective instabilities?
  - I'm assuming that smaller pbar intensity will benefit proton losses up the ramp and through the squeeze.
  - Are pbar losses on ramp and in squeeze going to increase? So far we don't see a sign of a limit.
  - Is it possible to operate with large Np at present working point?
    - Can we increase separation at first parasitics, e.g. by optimizing optics (this would reduce stopband width)?
    - Can we decouple better on pbar helix (open tune space)?
    - Proposed study: on a low stash store inject a few bunches with large N_p

Tevatron Tune Working Point

- In Run II the w.p. was established at ~0.585, and considerations of a different w.p. were initiated in 2005 as a way of increasing luminosity



5th order resonances ⇒ emittance blow-up

12th order resonances ⇒ losses/lifetime

At the present w.p. the available tune space is 3/5-7/12=0.017
Beam-beam tune shifts are
$\xi a=0.025$ $\xi p=0.02$