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ON large-angle scattering in Tevatron

* Dean discovered beam (some protons) at ~10 mm from the beam core after ~Δt~5 min at flat-top
* Hypothesis – that's due to large-angle scattering (hard to imagine such halo coming from 150 GeV)
* Estimates: IBS and vacuum scattering have crossections $\frac{d\sigma}{d\Omega} \sim \frac{1}{\theta^4}$ if $\theta << 1$

for small angles $d\Omega = 2\pi\theta\, d\theta = \pi\, d\theta^2$

so $d\sigma \sim \frac{d\theta^2}{\theta^4}$; # of particles scattered is then $\Delta N \sim d\sigma \sim \frac{1}{A_{max}^2} \cdot const$ $\left(A_{max} \sim 10\text{ mm}\right)$

* The constant can be estimated from avg. emittance growth

indeed, for $a^2 = \left(\frac{d\varepsilon}{dt}\right)_{IBS+V} \cdot \Delta t$ $\Delta N \sim 100\%$

Thus, fraction of beam scattered to A after time Δt: $\frac{\Delta N}{N_0} \approx \frac{a^2}{A_{max}^2} = \left(d\varepsilon/dt\right)_{IBS+V} \frac{\Delta t}{\varepsilon^{95\%}} \cdot \frac{1}{R}$, where $R = \frac{A_{max}^2}{\sigma_{rms}^2}$

* for Tev: $\left(\frac{d\varepsilon}{dt}\right)_{IBS+V} \sim (1.5-2)\cdot\frac{\pi}{hr}$ (early in stores (see beams-doc-1512))

$\varepsilon^{95\%} \sim 15\,\pi$

$\Delta t = 5\text{ min} = 1/12\text{ hr}$

$R = \left(\frac{10\text{ mm}}{0.6\text{ mm}}\right)^2 \approx 300$

so $\frac{\Delta N}{N_0} \approx \frac{2\cdot 1/12}{15}\cdot\frac{1}{300} = 4\cdot 10^{-5}$ or $\Delta N = 0.5e9$ out of total intensity $1.3\cdot 10^{13}$

* Note, that such ("transverse") losse are about 20% of total losses, dominated by longitudinal IBS and inelastic beam-gas — according to doc-1512, $\tau \sim 300$ hrs so after 5 min $\Delta N/N_0 \sim \frac{1}{300}\cdot\frac{1}{12} = 2.7\cdot 10^{-4}$