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Gold ion diffusion due to pair production

Pair production is NOT a potent transverse or longitudinal diffusion mechanism. This can be seen as follows.

The cross section for pair production from gold ions at full energy (T = 100 GeV/u) is [1]

$$\sigma_{pair} = 33{,}000 \text{ barns} = 3.3 \times 10^{-20} \text{ cm}^2 \qquad 1$$

so that the rate of such collisions for 2 IRs at the design luminosity of 2×10^{26} cm^{-2}sec^{-1} is

$$\frac{dN}{dt} = 2\, L\, \sigma_{pair} = 1.32 \times 10^7 \text{ pairs per second} \qquad 2$$

Since there are nominally $N_B = 57$ bunches each containing $N_I = 10^9$ gold ions, the mean number of pair producing events that a single test ion undergoes during a $T_{store} = 36{,}000$ second store (assuming all parameters are constant) is

$$\langle n \rangle = \frac{\frac{dN}{dt} T_{store}}{N_B\, N_I} = 8.3 \qquad 3$$

that is, a small number of order 1. It only remains to show that the typical longitudinal and transverse kicks on a gold ion during pair production are small compared to the natural bunch distributions.

The rms transverse momentum kick and rms instantaneous energy loss during pair production are expected to be of order 1 MeV/c and 1 MeV, respectively[1,2]. In contrast, the rms transverse beam momentum is typically

$$\langle x'^2 \rangle^{1/2} = \sqrt{\frac{\varepsilon_N}{6\pi\, \beta_{typ}\, \beta\gamma}}\, m_u\, W\, \beta\gamma c = 0.45 \text{ GeV/c} \qquad 4$$

where the normalized emittance is at least 10π microns, a typical beta value $\beta_{typ} = 30$ meters, the relativistic factor $\beta\gamma = 108.4$, the atomic weight for gold is $W = 197.0$, and an atomic mass is $m_u = 0.931$ GeV. The rms energy spread in the beam is typically approximately

$$\sigma_E \approx \frac{\sigma_p}{p_0} W (T + m_u) = 17.7 \text{ GeV} \qquad 5$$

where the relative momentum spread $\sigma_p/p = 8.9 \times 10^{-4}$ at collision differs from the relative energy spread by the relativistic factor of $\beta \approx 1$.

Since $\langle x'^2 \rangle^{1/2}$ and σ_E are both very much greater than their pair production kick counterparts, and since there are so few such events per gold ion per store, there is no problem with beam diffusion from this source.

Acknowledgements

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References

1 J-S Wu, M.J. Rhoades-Brown, C. Bottcher and M.R. Strayer, "Detailed analysis of the background e^+, e^- spectra generated by relativistic heavy-ion beam crossing", Nuclear Instruments and Methods in Physics Research A311 (1992) 249-257

2 Private communications with Sebastian White.