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Memo

DATE: *August 18, 2002*

TO: RHIC E-Coolers

FROM: *Ady Hershcovitch*

SUBJECT: **Minutes of the August 16, 2002 Meeting**

Present: Ilan Ben-Zvi, Xiang Yun Chang, Gregory Citver, Ady Hershcovitch, Michael Iarocci, Derek Lowenstein, William Mackay, Satoshi Ozaki, Thomas Roser, Triveni Srinivasan-Rao, Dejan Trbojevic, Dong Wang.

Topics discussed: Simple Physical Model.

Simple Physical Model: Ilan initiated a discussion on layman view of intra-beam scattering (IBS) aimed at developing a simple pictorial model for IBS. For electron beam cooling an obvious simple pictorial model exists. One can show a population of hot ions and a population of cold electrons (each represented by "balls") colliding, exchanging energy and reaching thermal equilibrium. For IBS, the problem is non-trivial. The physical model is more complex than in cooling. For ion heating to occur due to intra-beam scattering external (to an ion bunch) energy is needed. External energy sources are the ion beam drift motion, which is coupled to the ion bunch through guiding and confining fields, and when the ions are accelerated, the energy source is externally applied rf fields. To represent this type of energy coupling to an ion bunch, Ilan suggested showing ions confined by oscillating walls or an oscillating potential well. Intra-beam collisions then thermalize the coherent energy impressed upon ions in the bunch leading to heating, hence, the dependence of heating on ion density. Derek suggested looking into an analogy from solid-state physics. Dejan and Thomas suggested analogies from crystalline beam formation. Ady suggested a plasma physics model, in which the fields can be represented by macroparticles that generate such fields. Macroparticles moving through an ion bunch impart energy via dynamic friction, which is directly proportional to the ion density. An additional advantage is that, a relatively simple and heuristic procedure [outlined in A. Hershcovitch Physics of Fluids **23**, 942 (1980)] can be used to perform analytical calculation, once the fields are represented by equivalent macroparticles.

The meeting concluded with a discussion about the scale-lengths needed for beam magnetization. It is clear that gyroradius must be much smaller than the bunch size, and that gyrofrequency must exceed the collision frequency. The JINR people also require the gyroradius to be smaller than interparticle distance. Below are Ilan's calculations of the relevant scale lengths, the condition mentioned in the JINR draft intermediate report is not met. A clarification is needed.

Some characteristic length scales for the RHIC electron cooler. Ilan Ben-Zvi, 8/16/2002.

All units are SI except when noted, PRF=Particle Rest Frame

Electron's mass in eV, charge, speed of light, Boltzmann's constant, permittivity of free space:

$mc2 := 0.511 \cdot 10^{6}$ $\quad q := 1.6022 \cdot 10^{-19}$ $\quad c := 2.998 \cdot 10^{8}$ $\quad k := 1.381 \cdot 10^{-23}$ $\quad \varepsilon_0 := 8.842 \times 10^{-12}$

Magnetic field of cooling solenoid, beam energy: $B := 1\ \text{Tesla}$ $\quad \gamma := 106.61$

electron's bunch length, number of electrons and normalized rms emittance:

$\sigma_c := 0.05$ $\quad N_c := 6.25 \cdot 10^{10}$ $\quad \varepsilon_{cn} := 40 \cdot 10^{-6}$

The ion beta function and normalized rms emittance: $\beta ic := 60$ $\quad \varepsilon_{in} := 2.5 \cdot 10^{-6}$

Number of ions, ion bunch length: $N_i := 10^{9}$ $\quad l_i := 0.75$

Beam rms radius: $r_c := \sqrt{\dfrac{\varepsilon_{in} \cdot \beta ic}{\gamma}}$ $\quad r_c = 1.186 \times 10^{-3}$

Electron temperature (in eV, degrees): $Te := \dfrac{mc2 \cdot \varepsilon_{cn}^{2}}{r_c^{2}}$ $\quad Te = 581.096$ $\quad Tct := Te \cdot \dfrac{q}{k}$

Electron plasma density and average distance between electrons (PRF)

$n_c := \dfrac{N_c}{\pi \cdot r_c^{2} \cdot \sigma_c \cdot \gamma}$ $\quad n_c = 2.653 \times 10^{15}$ $\quad r_{ave} := \dfrac{1}{n_c^{.333}}$ $\quad r_{ave} = 7.31 \times 10^{-6}$

Ion plasma density and average distance between ions (PRF)

$n_i := \dfrac{N_i}{\pi \cdot r_c^{2} \cdot l_i \cdot \gamma}$ $\quad n_i = 2.829 \times 10^{12}$ $\quad r_{avi} := \dfrac{1}{n_i^{.333}}$ $\quad r_{avi} = 7.138 \times 10^{-5}$

Debye shielding length (PRF): $L_D := \sqrt{\dfrac{\varepsilon_0}{q^{2}} \cdot \dfrac{k \cdot Tct}{n_c}}$ $\quad L_D = 3.477 \times 10^{-3}$

Larmor radius: $Vet := c \cdot \sqrt{\dfrac{Te}{mc2}}$ $\quad \rho_L := \dfrac{mc2}{c \cdot B} \cdot \dfrac{Vet}{c}$ $\quad \rho_L = 5.748 \times 10^{-5}$