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Memo

DATE: *April 7, 2006*

TO: RHIC E-Coolers

FROM: *Ady Hershcovitch*

SUBJECT: **Minutes of the April 7, 2006 Meeting**

Present: Ilan Ben-Zvi, Xiangyun Chang, Alexei Fedotov, Wolfram Fischer, Harald Hahn, Lee Hammons, Ady Hershcovitch, Dmitry Kayran, Jorg Kewisch, Vladimir Litvinenko, William Mackay, Thomas Roser, Triveni Srinivasan-Rao, Dejan Trbojevic, Gang Wang.

Topics discussed: Computations and Simulations, Cooling Protons

Computations and Simulations: the meeting started with a report by Jorg on his continuing work on optimization of electron bunch emittance. Jorg succeeded in further reducing bunch emittance at the end of the first accelerating cavity to 1.9 mm-mR. Optimization is being performed with PARMELA coupled with Jorg's optimization program. Bunches are followed and parameters were optimized from the gun cathode to the end of the first accelerating cavity. The latest simulation involves detailed studies of the dynamics within a bunch by examining 500 slices within each bunch. One peculiar feature, which may be an artifact of the simulation, is that the emittance of the leading edge of the bunch is larger than the emittance of the bunch tail. It is opposite of what is expected from the space-charge effects. With energy spread of 0.33 eV, 6 mm beam diameter at the cathode yields optimum results.

Jorg also simulated the case where the energy spread was reduced to 0.1 eV, which is expected from the diamond cathode. That case resulted with higher emittance (surprisingly), since the emittance compensation system was optimized for the larger energy spread. A discussion ensued regarding the sensitivity of the emittance to bunch shape, i.e., laser pulse shaping. It is still work in progress.

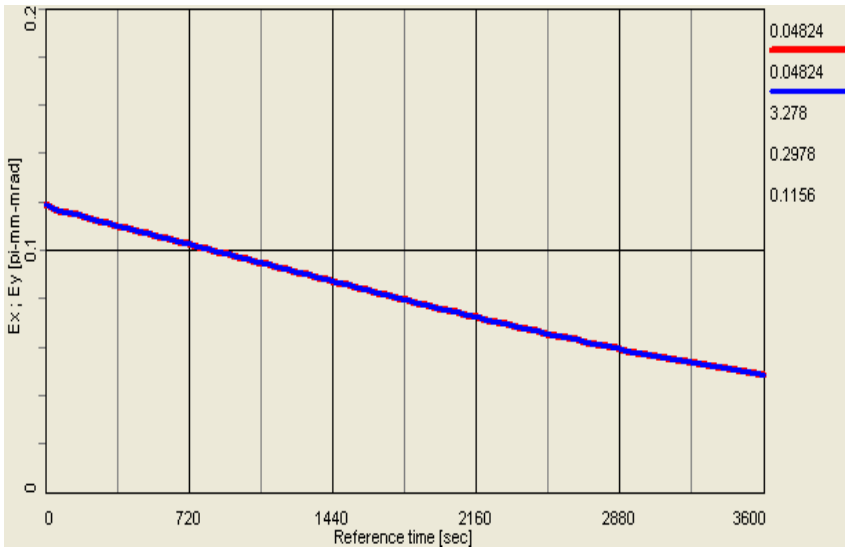
Cooling Protons: Alexei followed Jorg with a presentation on electron beam cooling of protons, using 5 nC electron bunches with 4 micron normalized rms emittance. Below is Alexei's presentation, in which he explored 4 cooling scenarios. The options examined are cooling the protons at 110 GeV with and without pre-cooling at 25 GeV and cooling of 250 GeV protons (requiring 137 MeV electrons) with and without pre-cooling at proton injection energy. Amazingly all options are feasible, even at 250 GeV without pre-cooling at proton injection energy. Pre-cooling is not as desirable, since it may require an additional electron cooler. Since cooling protons at full energy seems possible, a discussion ensued on whether to include the 137 MeV, 10 nC per bunch electron beam ERL in the CD0.

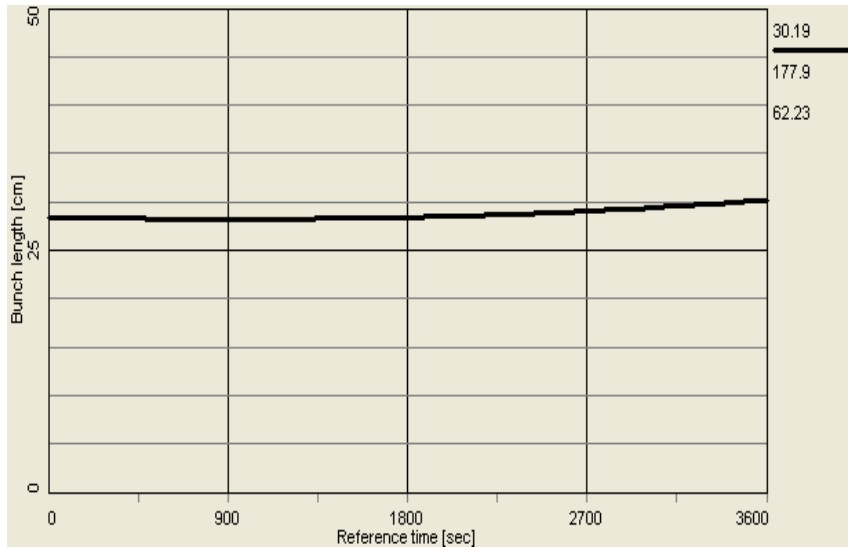
RHIC-II cooling of protons

(April 7, 2006)

Pre-cooling at injection energy

RHIC-II (N=2e11) at injection E_k=25 GeV (γ=28)
Electron beam: q=5nC, rms $\varepsilon_{e,n}$=4μm, $\sigma_{p,e}$=3e-4, L=80m
(plotted emittance is rms unnormalized)

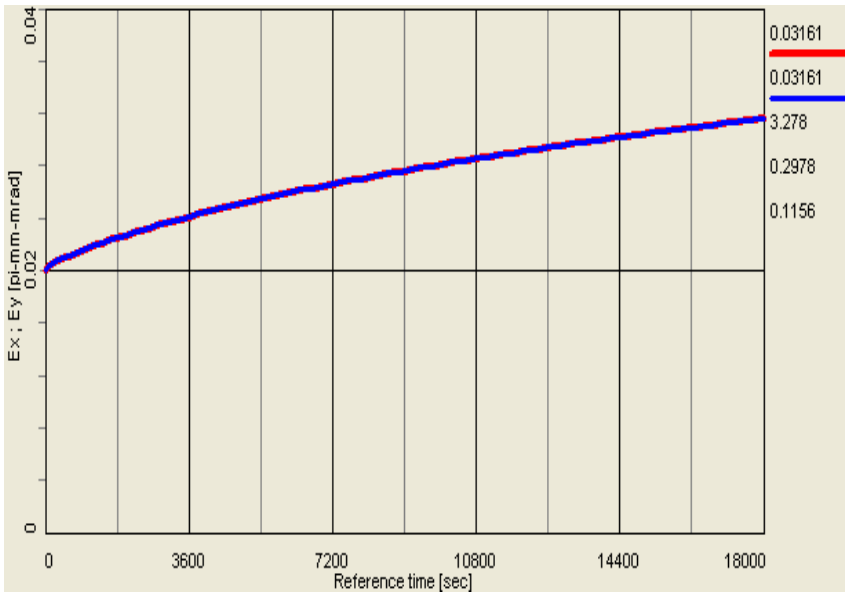


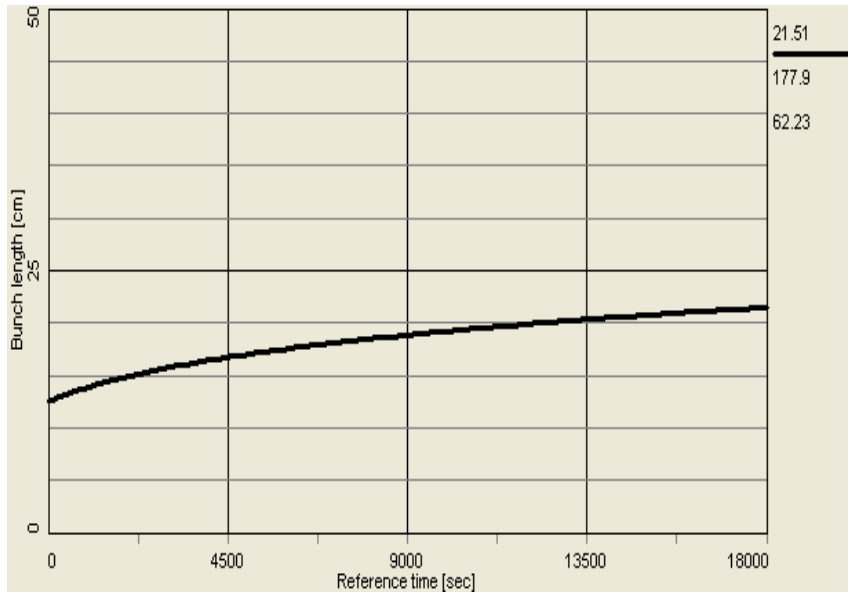


Protons emittance of 20 π (95%)
is cooled to 12 π in 2200 sec

RHIC-II protons at 110 GeV

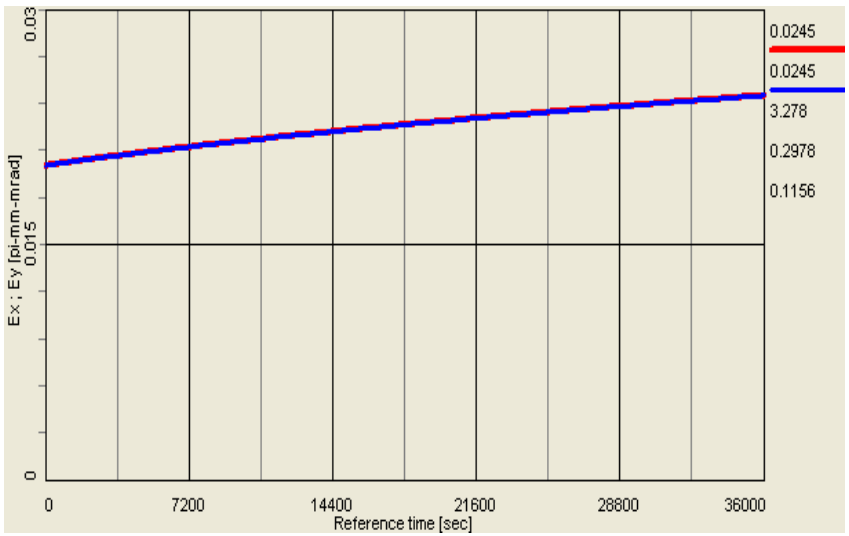
RHIC-II (N=2e11), IBS at 110 GeV (h=2520) for pre-cooled at injection protons to 12 π (95%) emittance

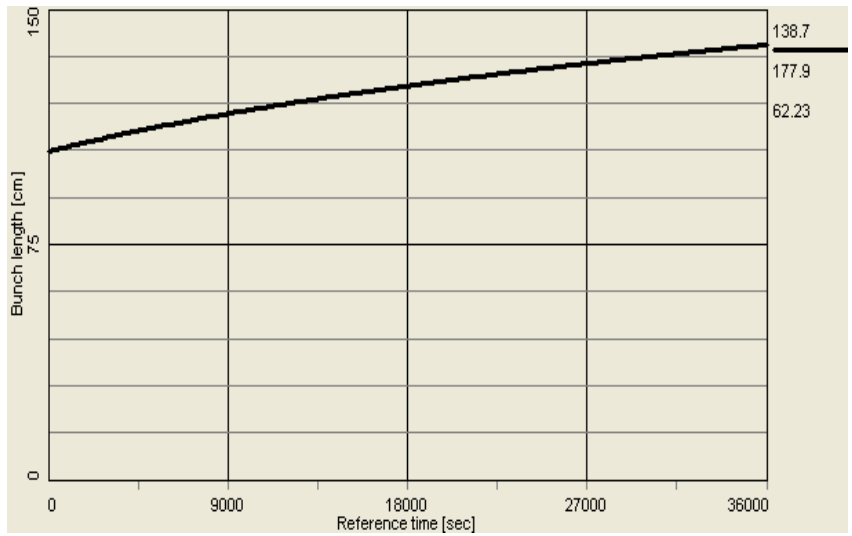




If switching to h=2520 is done then cooling at 110 GeV is not effective

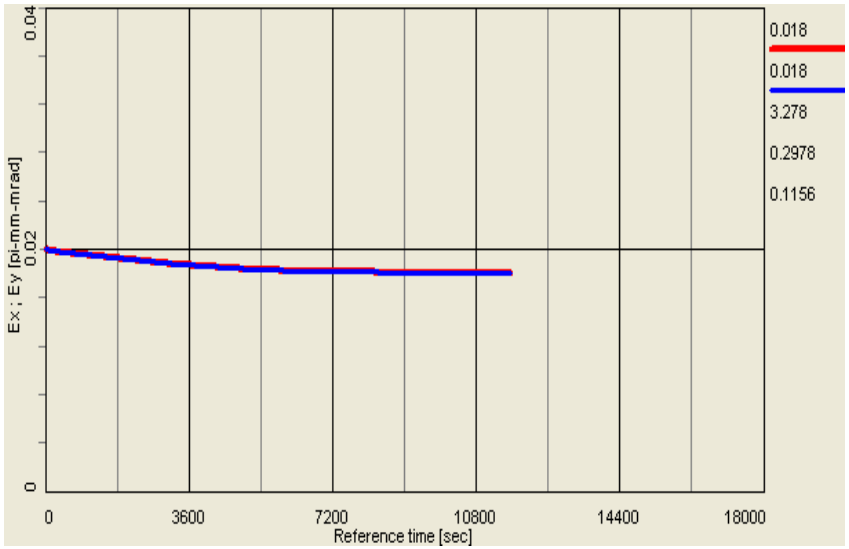
RHIC-II (N=2e11), IBS for pre-cooled at injection protons at 110 GeV (h=360)

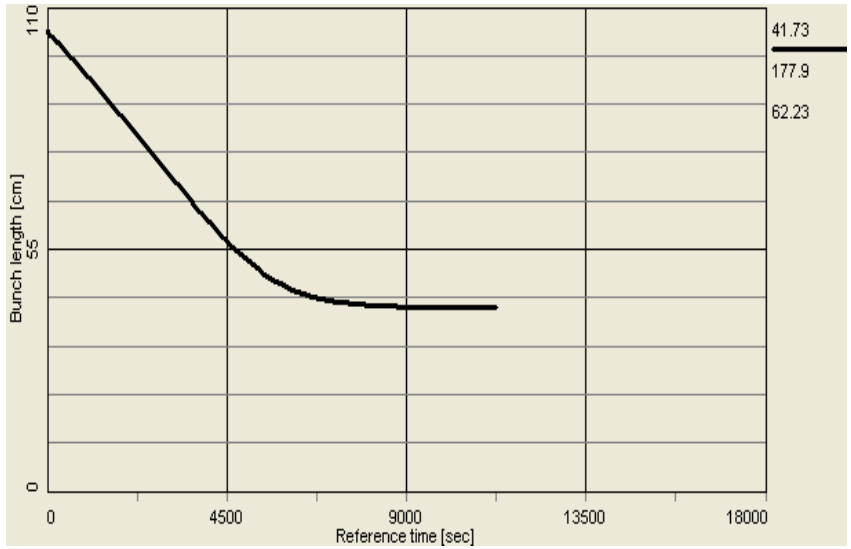




keeping h=360 at 110 GeV

RHIC-II (N=2e11), IBS+Cooling for pre-cooled at injection protons at 110 GeV (h=360)



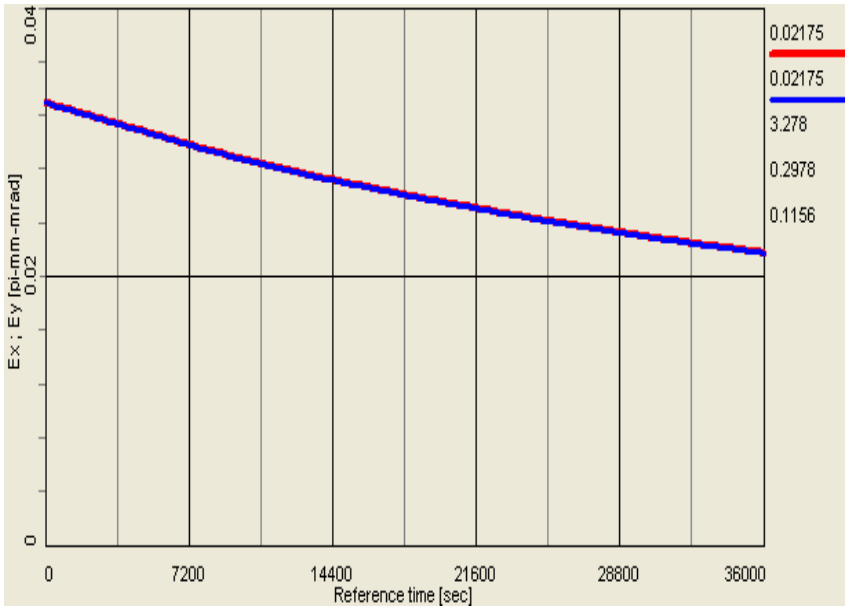


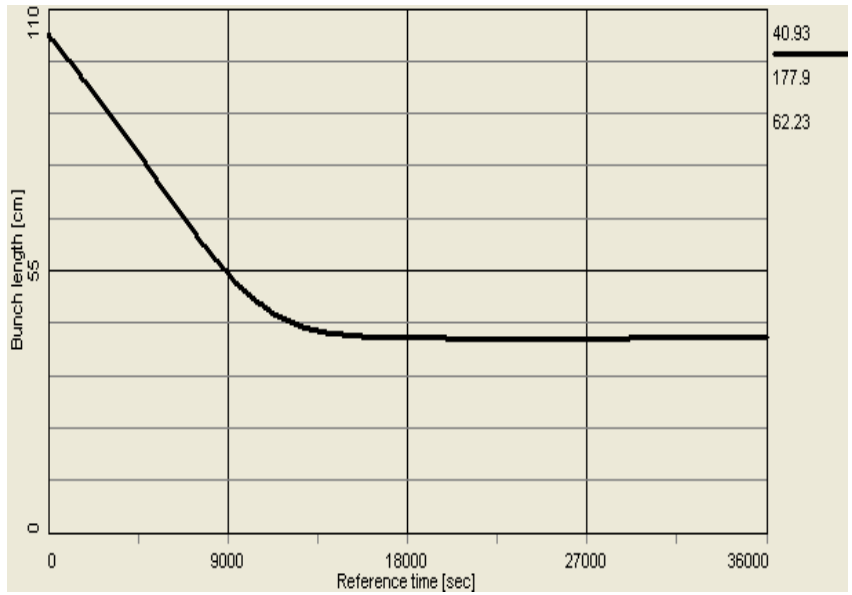
Cooling at 100 GeV is effective if h=360 is kept

However, doing first pre-cooling at injection 25 GeV and few minutes later cooling at 100 GeV maybe not possible with a single ERL.

Do we need two separate ERL's for such a scenario?

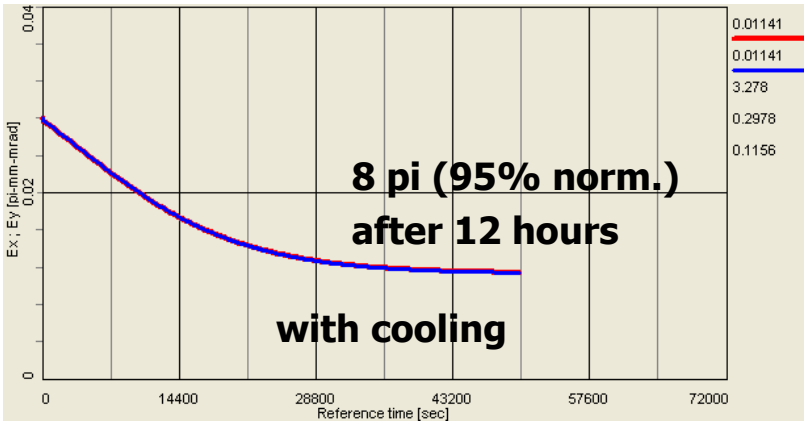
RHIC-II (N=2e11), NO pre-cooling at injection; Direct cooling of protons at 110 GeV (h=360)

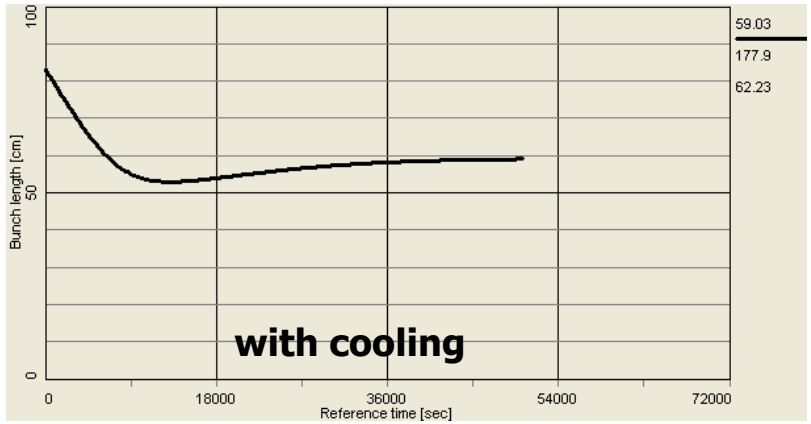


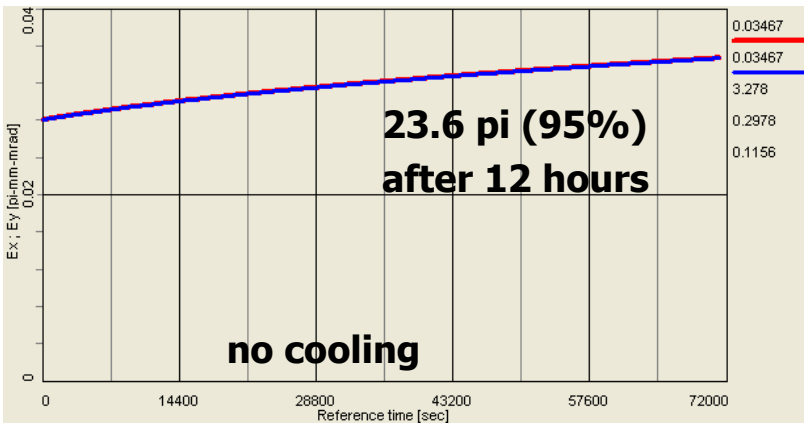


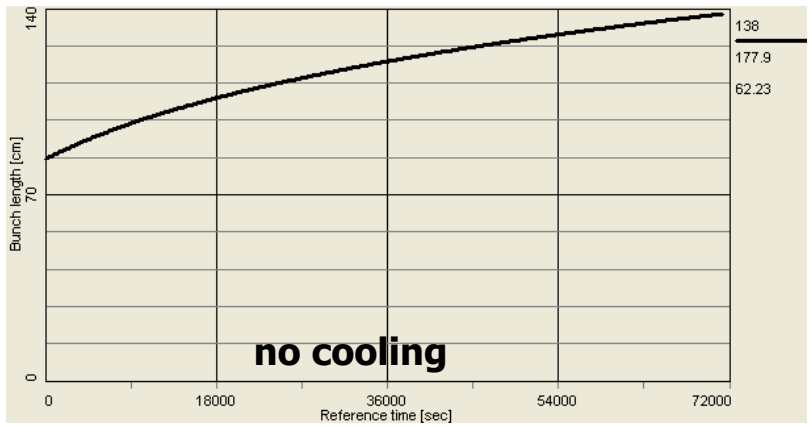
Direct cooling at 110 GeV, no pre-cooling

RHIC-II (N=2e11), NO pre-cooling at injection; Direct cooling of protons at 110 GeV (h=360) beta_ic=800m – optimized for better transverse cooling



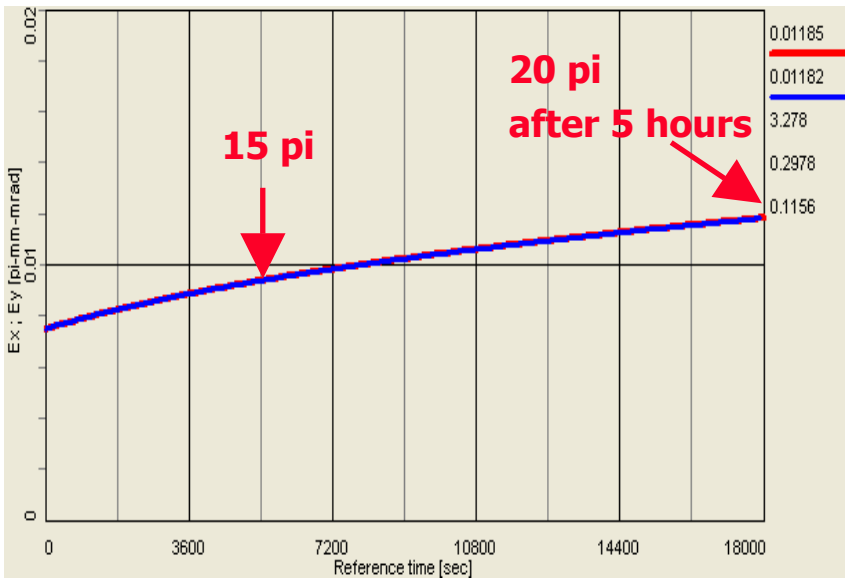


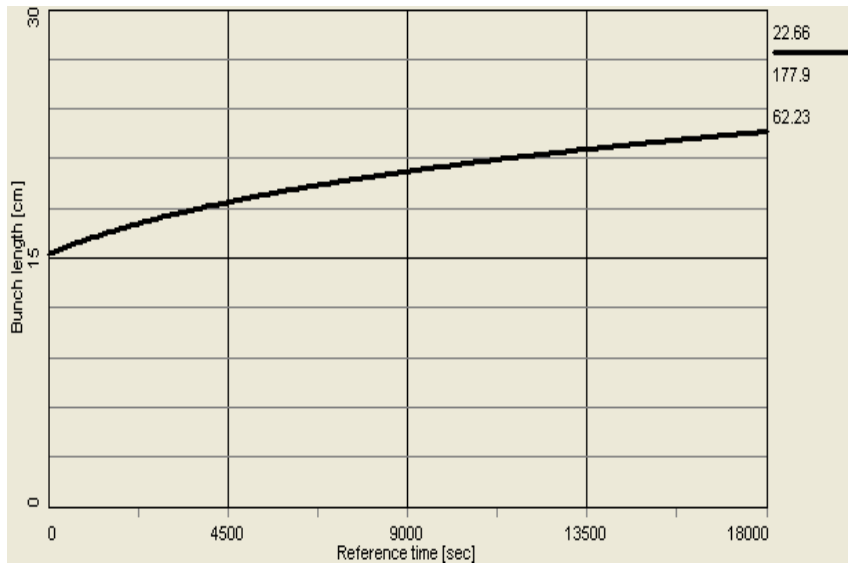




RHIC-II protons at 250 GeV

RHIC-II at 250 GeV with pre-cooling at injection
IBS growth for h=2520

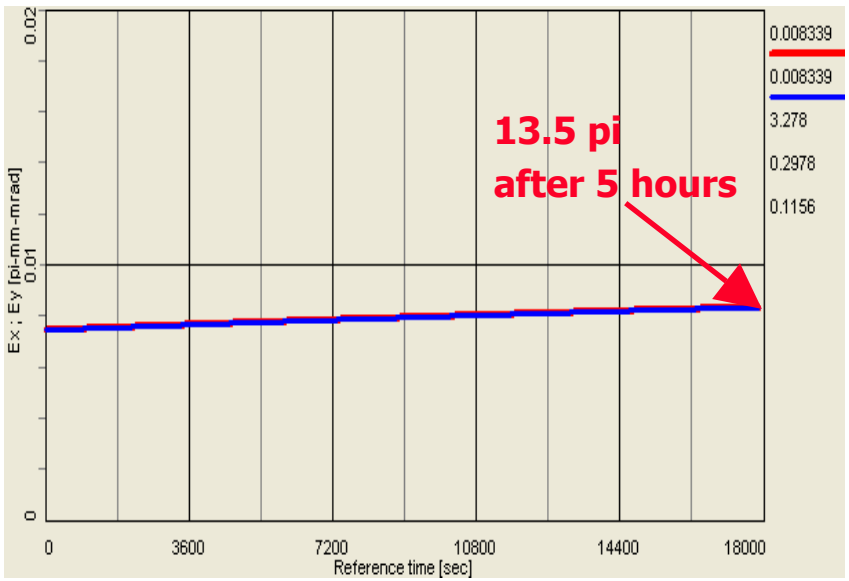


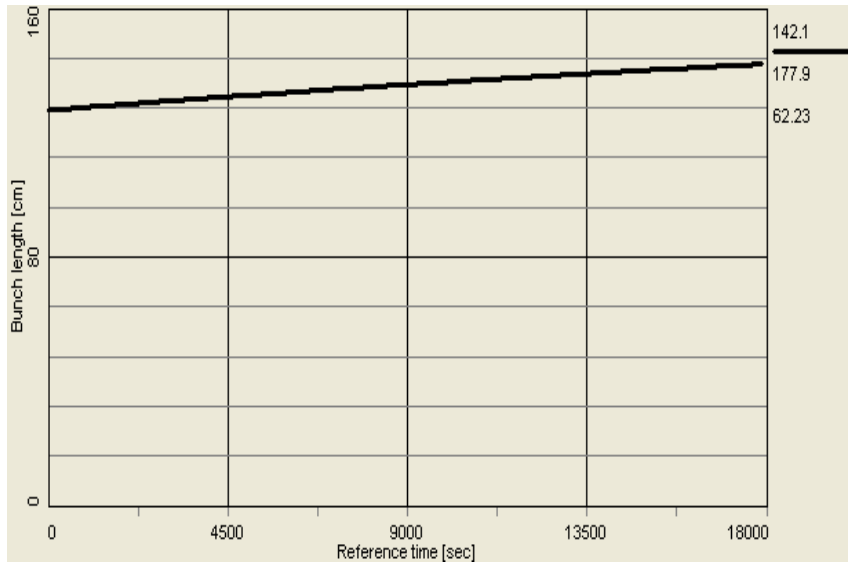


Initial growth rates are large but since both longitudinal and transverse emittance increase rate goes down: one gets factor 1.7 and 1.5 increase for transverse emittance and bunch length in 5 hours, respectively.

But one needs to get such low (12 pi instead of present 20 pi) initial emittances first – pre-cooling at RHIC or AGS injection ?

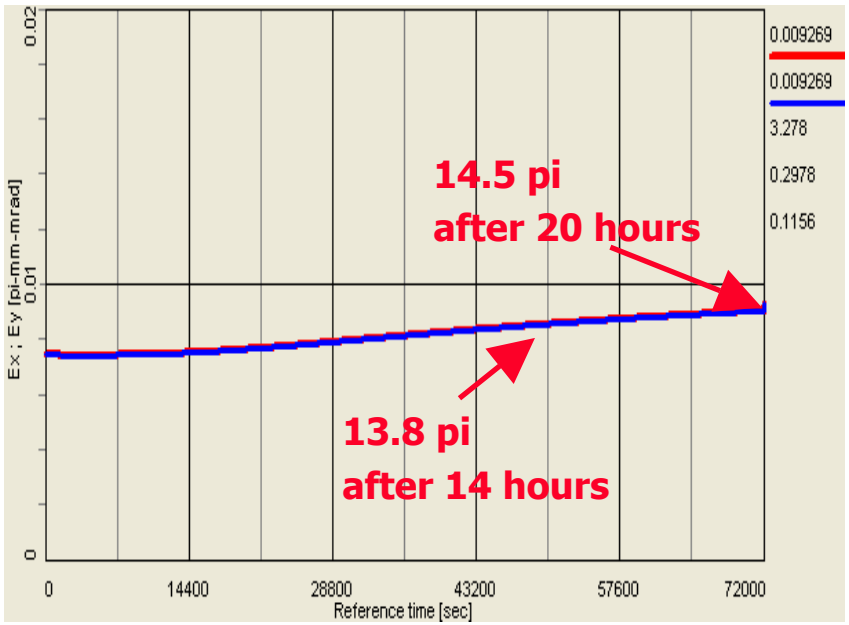
RHIC-II at 250 GeV with pre-cooling at injection
IBS growth without cooling at 250 GeV (h=360)

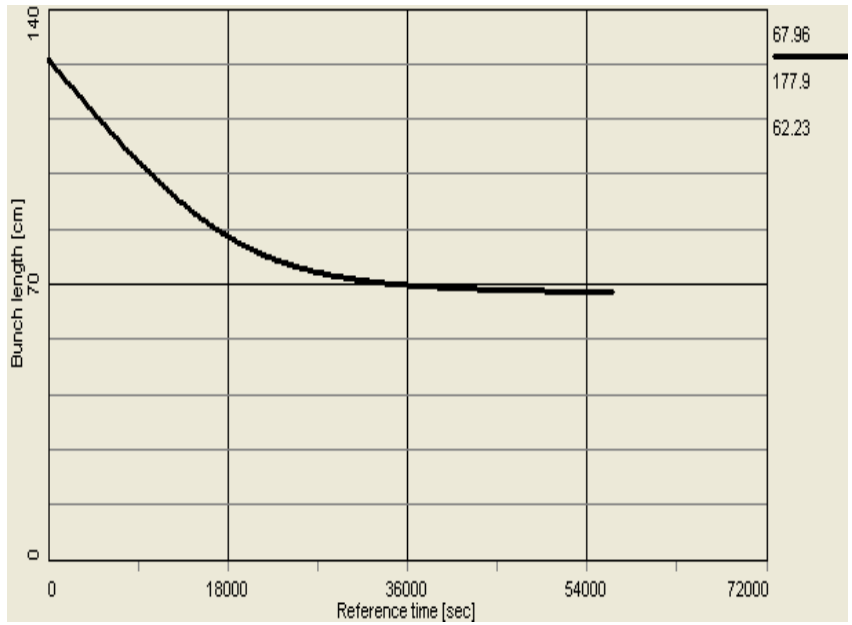




If only h=360 is used, no real problem from IBS but bunch length is too big

RHIC-II at 250 GeV with pre-cooling at injection
IBS plus Cooling for h=360





Looks nice, but this requires both pre-cooling
at low energy and cooling with 137 MeV electrons

RHIC-II (N=2e11), NO pre-cooling at injection; Direct cooling of protons at 250 GeV (h=360) needs e-cooler for 137 MeV