EMITTANCE EXCHANGE AT THE RING COOLER – BUNCH COMPRESSOR

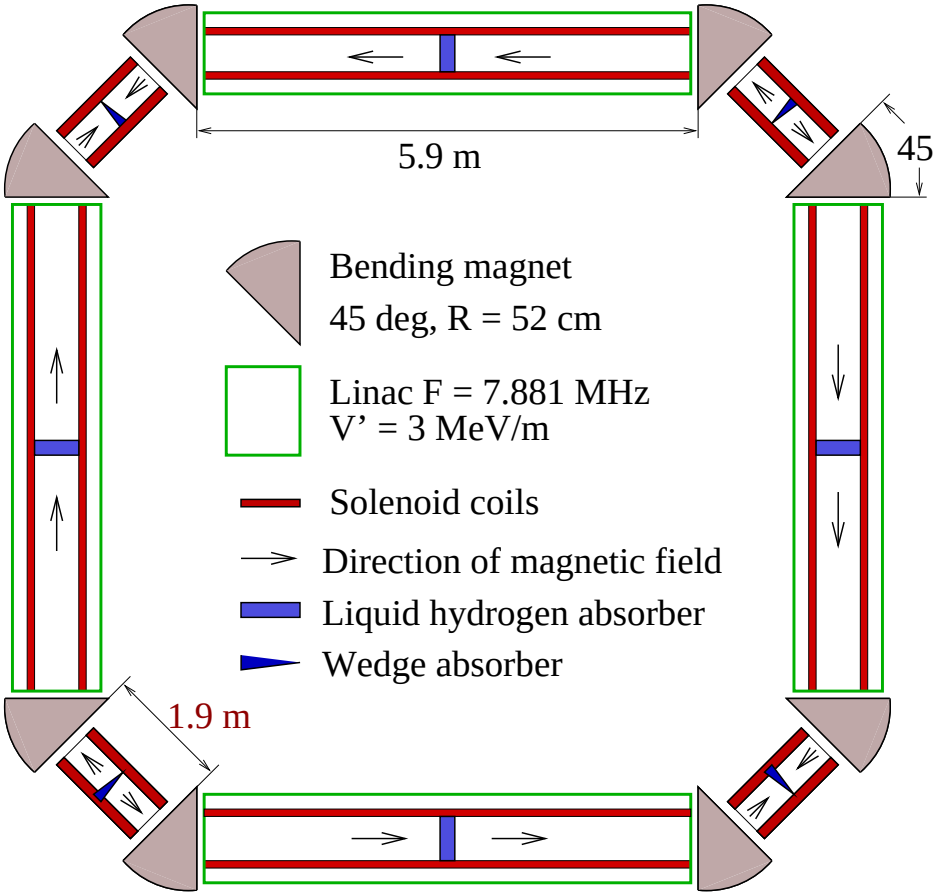
V.Balbekov, Fermilab, October 2001

One of the problems at the Higgs factory design is a creation of a short high intensity muon bunch. The precooling part can provide the bunch of 6-10 m length in the best case, whereas a 200 MHz cooling channel requires 10-15 times shorter one. A strong emittance exchange combined with the beam cooling appears to be the most reasonable method to this end.

Outline

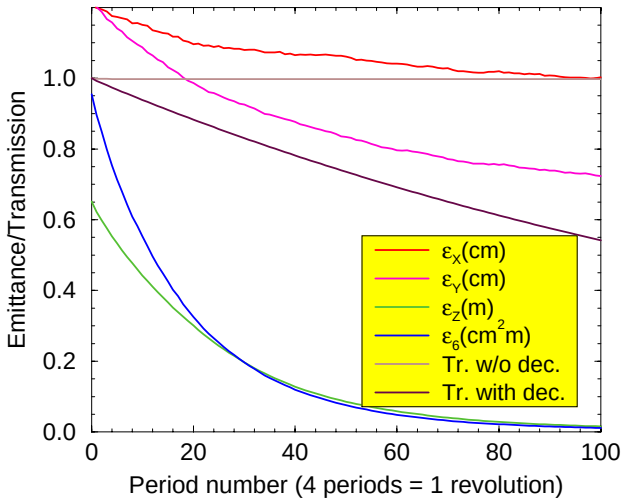
- Layout.
- Parameters.
- Solenoid coils and field.
- Beta-function and dispersion.
- Cooling simulation.
- Conclusion.

Layout

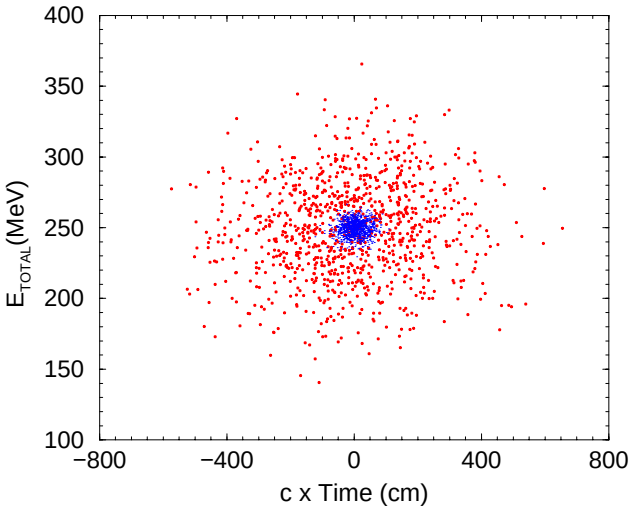


Layout of the ring cooler – bunch compressor.

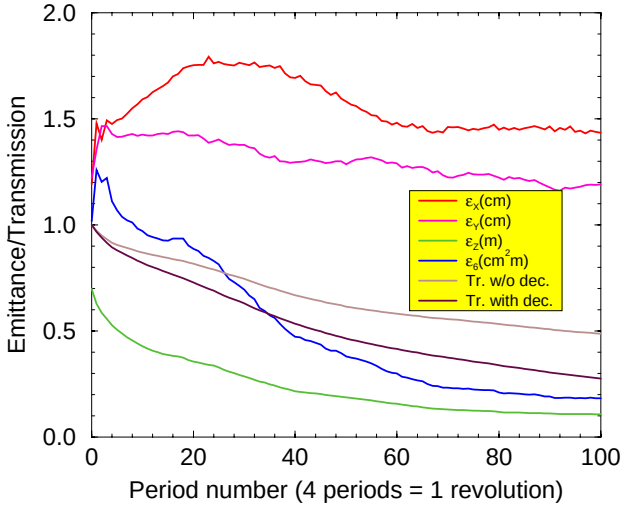
Simulation: linear approximation



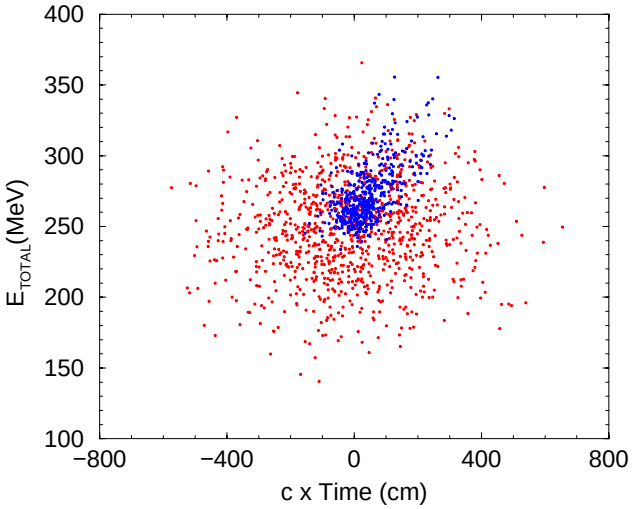
Longitudinal emittance decreases from 66.3 cm to 1.6 cm (cooling factor 41), and 6D emittance – from 97.1 cm^3 to 1.2 cm^3 (cooling factor 81). Transmission is 54%; the only cause of the particle loss is muon decay.



Longitudinal phase space before and after the cooling.



Longitudinal emittance decreases to 10.8 cm at almost constant transverse emittance (cooling factor about 6). Transmission after 25 turns is 28% with decay and 49% without decay.



Longitudinal phase space before and after the cooling.

Reasons of the degradation

• Dependence of revolution frequency on transverse momentum.
• Nonlinear dispersion.
• Chromaticity and betatron resonances.

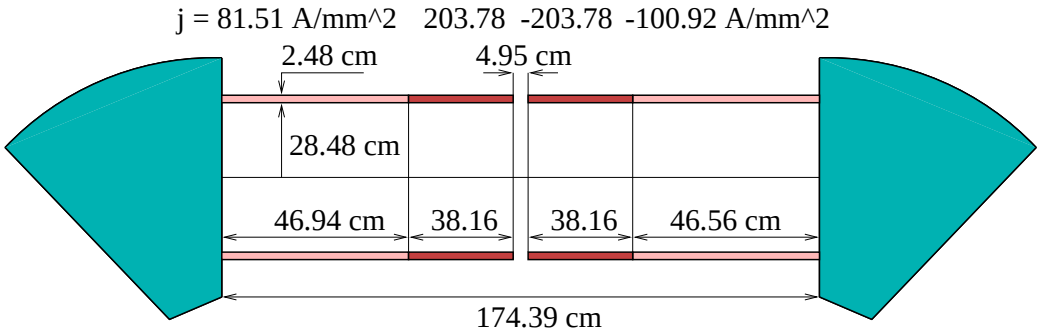
Increase of magnetic field to get less transverse emittance does not improve the situation because the equilibrium transverse momentum does not depend on beta-function.

Table of Parameters

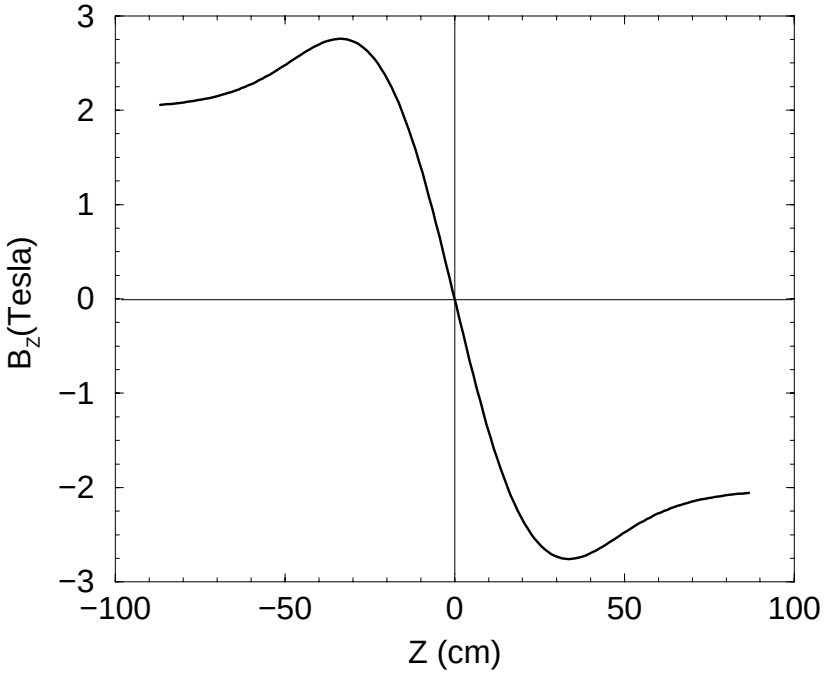
Parameter	1st compr.	2nd
Circumference	34.921 m	same
Nominal energy (total)	220 MeV	same
Number of bending magnets	8	same
Bending angle	45°	same
Bending radius	52 cm	same
Bending field	1.238 T	same
Normalized field gradient	0.5	same
Length of short SS	2.014 m	same
Length of long SS	5.900 m	same
Axial field of the long solenoid	1.751 T	same
Beta function at nominal energy	0.735 m	same
Synchronous phase	30°	same
Revolution frequency	7.53 MHz	same
Accelerating frequency	15.06 MHz	60.24
RF harmonic number	2	8
Accelerating gradient	4 MeV/m	8
LH_2 main absorber, length	37.8 cm	75.5
LiH wedge absorber, dE/dy	0.16 MeV/cm	0.34

Short Straight Section

Function: to create dispersion only in the short SS

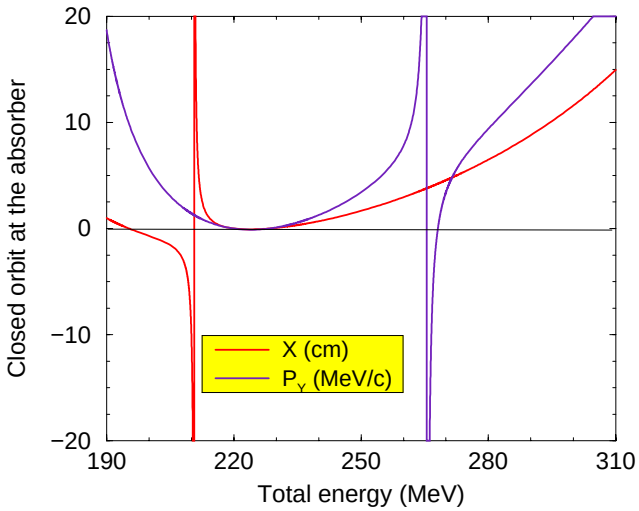


Layout of the Short Straight Section.

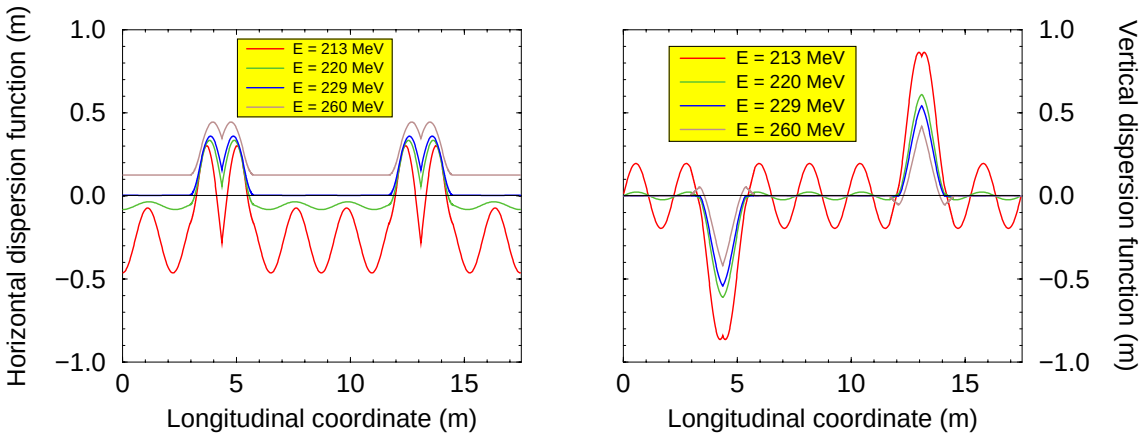


Axial field of the Short Straight Section.

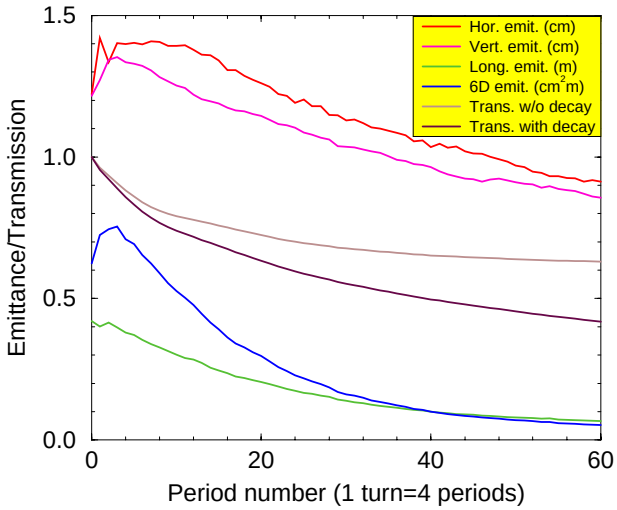
Dispersion Function



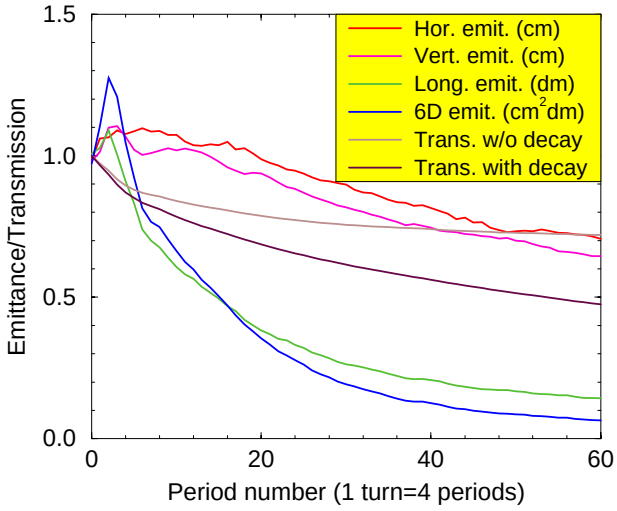
Dependence of dispersion on energy at the center of long SS. Equilibrium energy is 220 MeV, $Y = P_x = 0$ here.



Dispersion function vs Z at various energy. Equilibrium energy is 220 MeV.



After 10 turns in the 1st compressor, the longitudinal emittance decreases from 42 cm to 10 cm, and 6D emittance – from 62 cm^3 to 10 cm^3. Transmission is 65% without decay and 50% with decay.



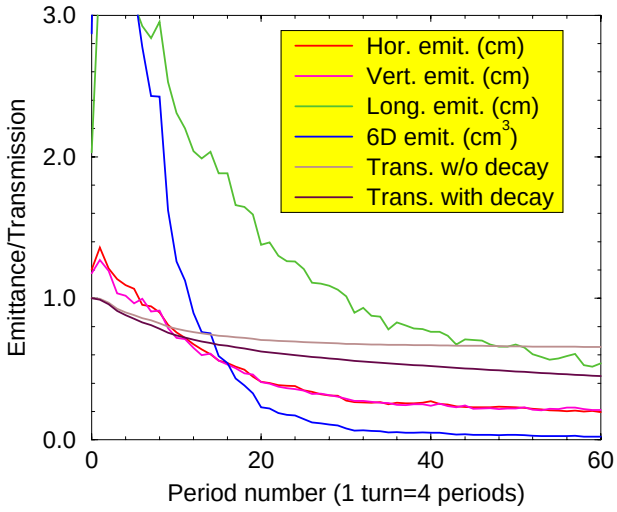
After 10 turns in the 2nd compressor, longitudinal emittance decreases from 10 cm to 2.1 cm, and 6D emittance – from 9.7 cm^3 to 1.2 cm^3. Transmission is 74% without decay and 56% with decay.

Conclusion

Low RF ring coolers with strong emittance exchange can provide longitudinal bunch compression required for the Higgs factory. Evolution of the beam parameters in 2 ring coolers, 40 turns in each, is presented in the Table:

Parameter	Begin	1st com.	2nd com.
Trans. emittance (cm)	1.2	1.0	0.8
Long. emittance (cm)	42	10	2.1
6D emittance (cm^3)	62	10	1.3
Transmission (%)	100	50	28

Cooling of this beam by 200 MHz ring cooler is plotted below:



After 15 turns, trans./long. emit. are: **2/5 mm**.
Higgs factory requirements are: **0.06/20 mm**.