2 stages, 325 MHz cooling channel

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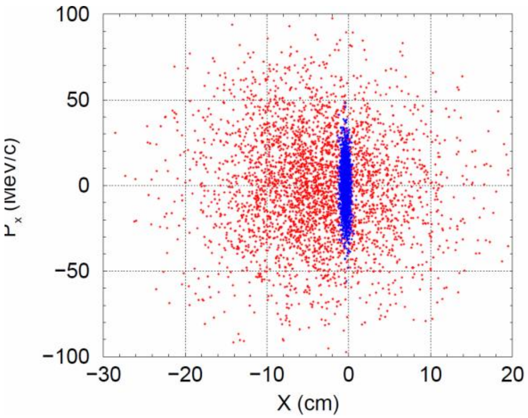
6D vacuum RF meeting 08/13/2013

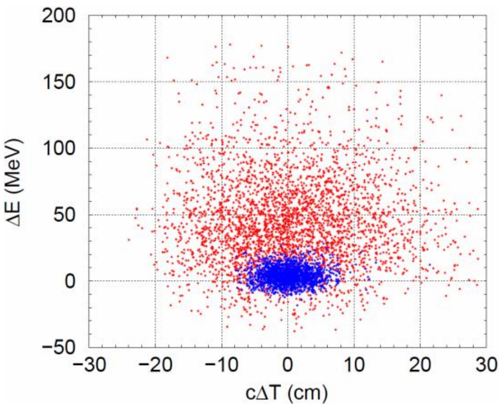
RF 325 MHz + 325 MHz

Beta 40 cm → ~4 cm

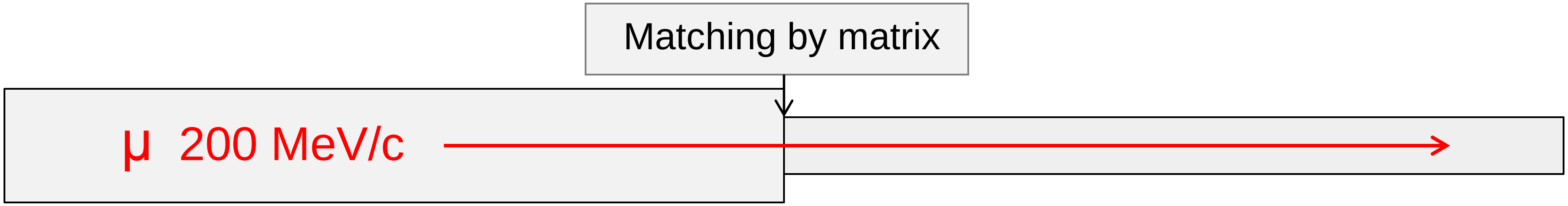
Trans. emit. 20 mm → 0.36 mm



Long. emit. 20 mm → 1.5 mm

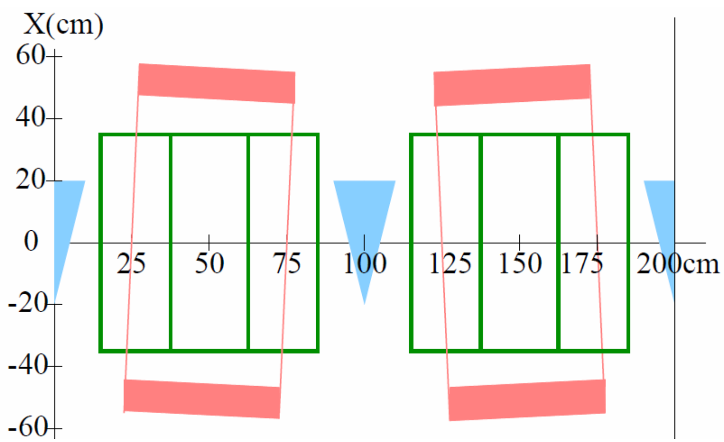


Schematic and overlook of the channel

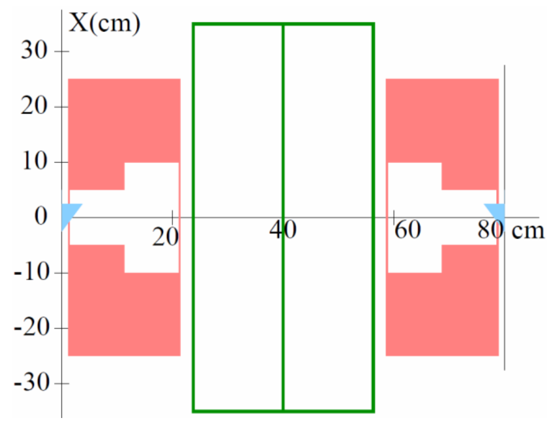


First stage: 100   2 m cells;
J = 77.6 A/mm^2, $B_{sol} \leq$ 6.0 T;
RF 325 MHz, 25 MeV/m;
LH_2 absorbers 22 cm / 57º;
Trans. cooling 2 cm → 2 mm

2nd stage: 150-200   0.8 m cells;
J = 134 A/mm^2, $B_{sol} \leq$ 13.4 T;
RF 325 MHz, 25 MeV/m;
LiH absorbers 3.8 cm / 86º
Trans. cooling 2 mm → 0.36 mm



Solenoid tilt ±45 mrad



Tilt ±20 mrad is not shown

The cells had been designed for 200+400 MHz channel. 1st stage is updated.

Why 325 MHz everywhere? (merits and demerits)

- Higher frequency RF (650 MHz) allows to reach higher acceleration and cooling rate.
- The cavities are more compact.

HOWEVER

- At the same synchronous phase, 650 MHz separatrix is 2 times shorter.

  Therefore, about twice more momentum spread is needed at given longitudinal emittance

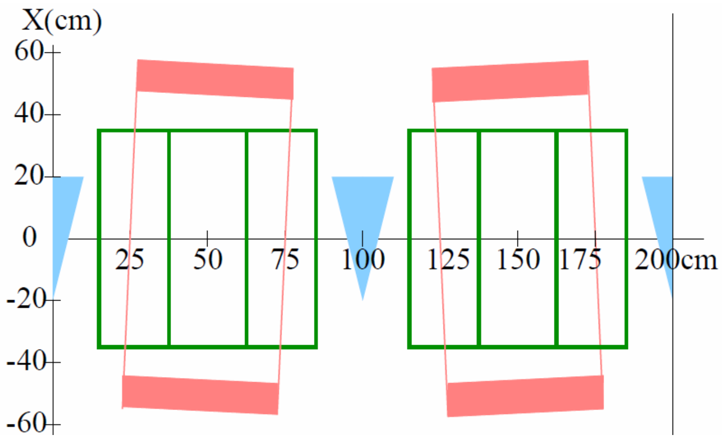
  conflicting with restricted momentum acceptance of RFOFO lattice.
- On other hand, larger synchronous phase is permissible with 325 MHz RF

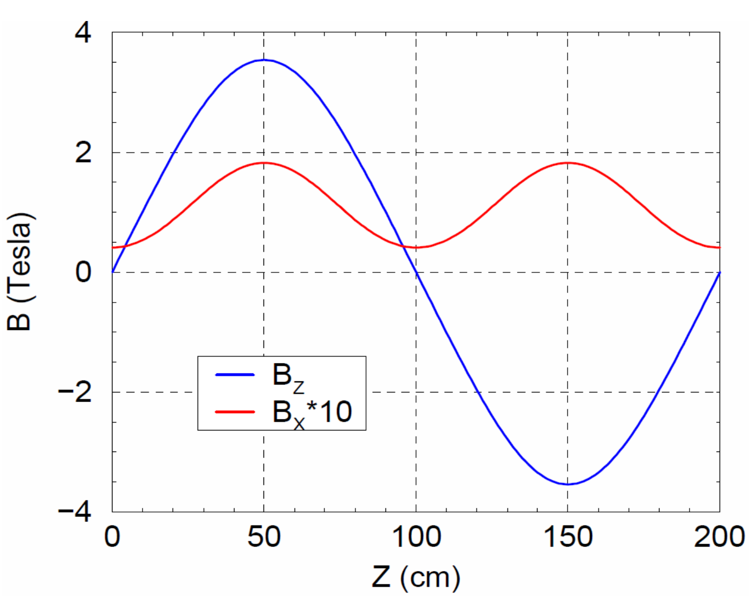
  allowing to increase the cooling rate.
- Higher acceleration rate requires longer and wider-angle wedge absorbers

  It is especially important with LH_2 absorbers.
- The cavity radius is immaterial factor if the cavities are placed between solenoids.

Stage 1: High acceptance -- low cooling

(schematic, field, list of parameters)

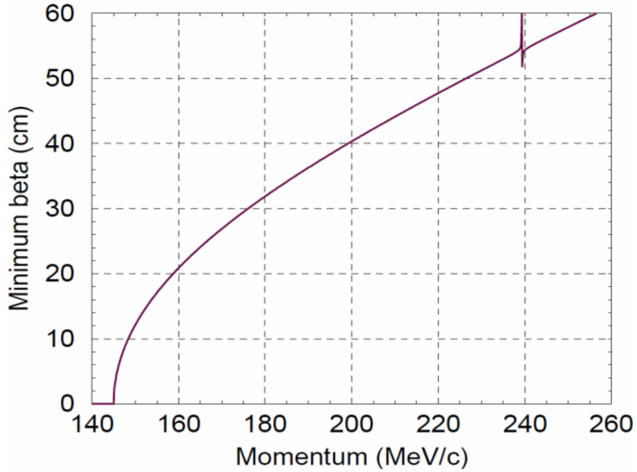




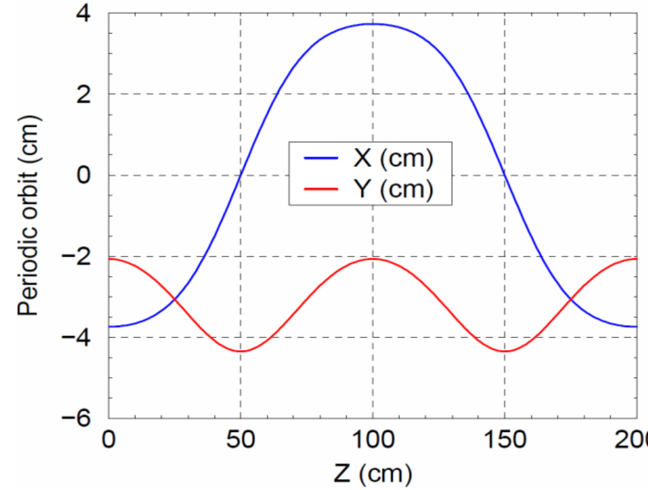
Period length	200 cm
Coil length	50 cm
Coil inner radius	45 cm
Coil thickness	10 cm
Coil tilt	40 mrad
Current density	77.6 A/mm^2
Maximal field strength in coil	6.0 T (NbTi?)
Reference momentum	200 MeV/c
Accelerating frequency	325 MHz
Accelerating gradient	25 MV/m
Synchronous phase	23°
LH_2 absorber center thickness	21.8 cm
Absorber opening angle	57.1º

Stage 1: High acceptance -- low cooling (cont'd)

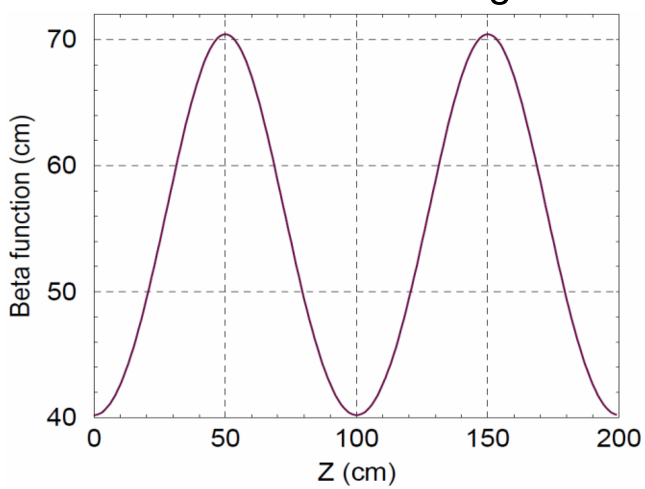
Beta. FOFO provides max momentum acceptance



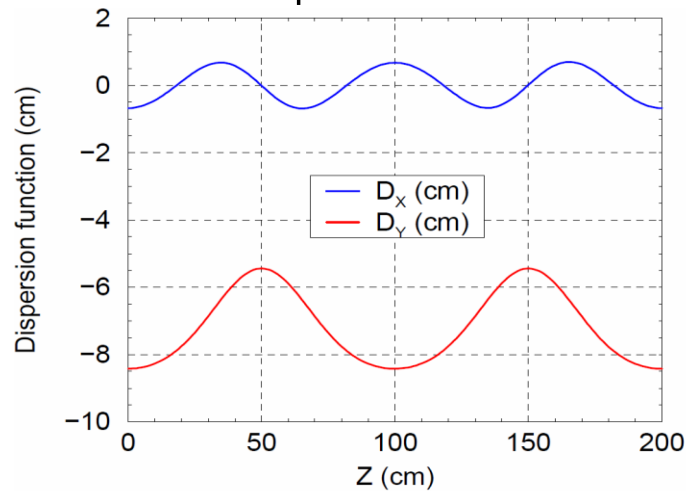
Closed orbit



200 MeV/c beta-function vs long.coordinate



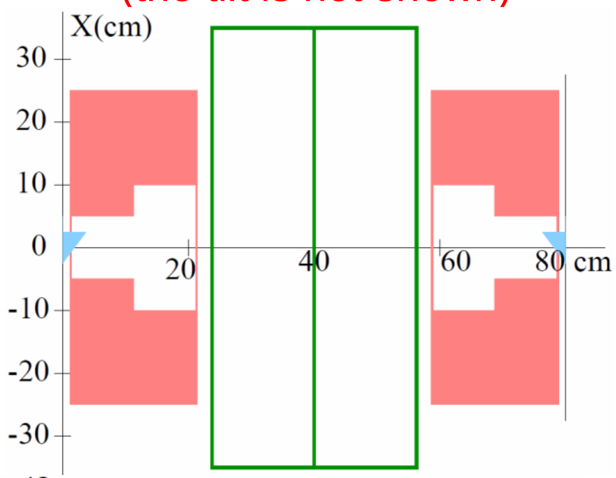
Dispersion function

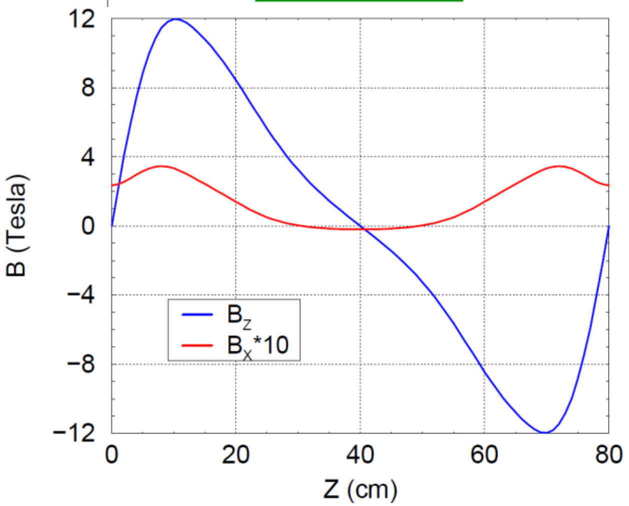


Stage 2: Lower acceptance -- higher cooling

(schematic, field, list of parameters)

(the tilt is not shown)

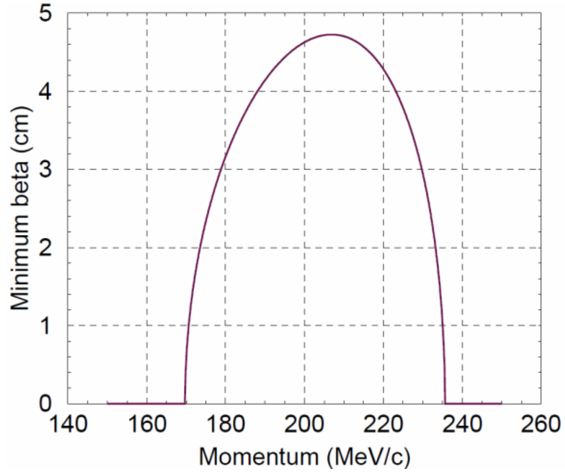




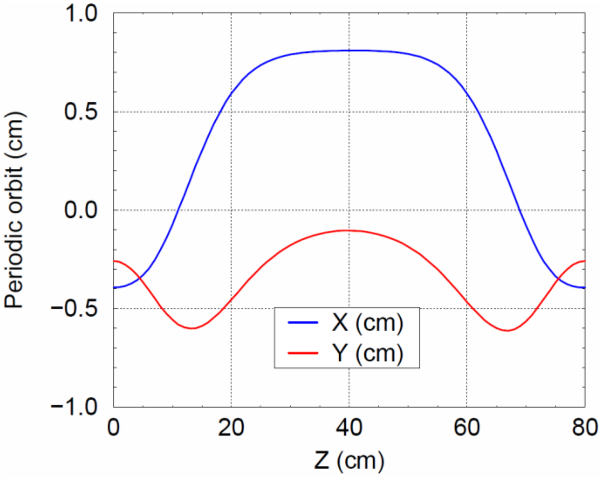
Period length		80 cm
Coil length		20 cm
Coil inner radius	5 cm and	10 cm
Coil thickness	20 cm and	15 cm
Coil tilt		20 mrad
Current density		134 A/mm^2
Maximal field strength in coil		13.4 T (NbSn?)
Reference momentum		200 MeV/c
Accelerating frequency		325 MHz
Accelerating gradient		25 MV/m
Synchronous phase		44.4°
LiH absorber center thickness		3.8 cm
Absorber opening angle		86.5°

Stage 2: Lower acceptance – higher cooling

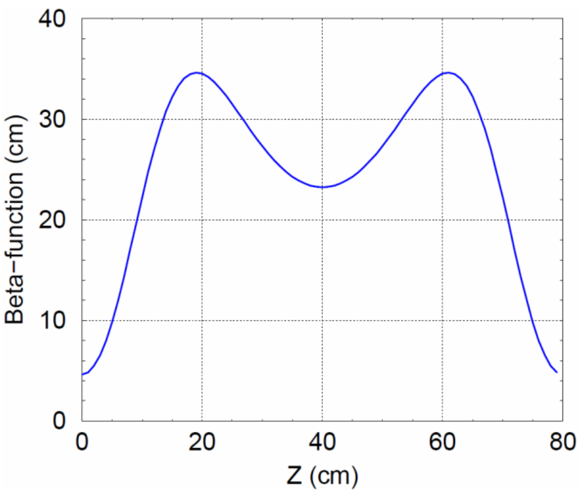
Beta-function vs momentum



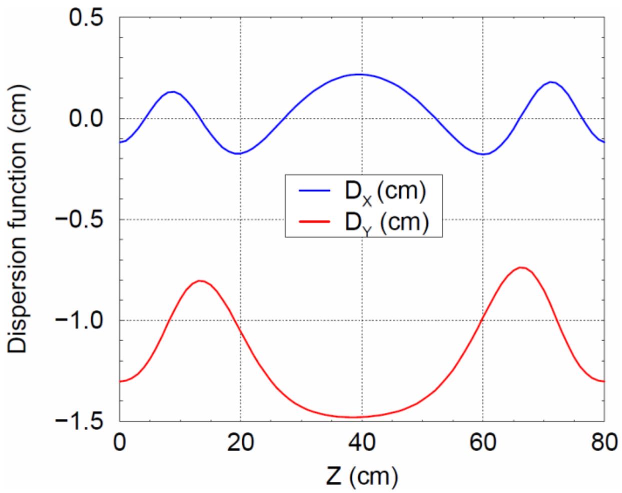
Closed orbit



Beta-function vs long. coordinate

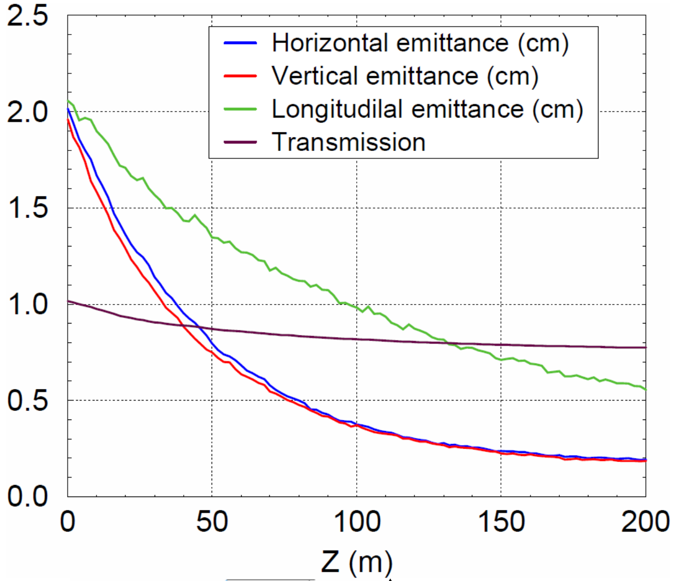


Dispersion function



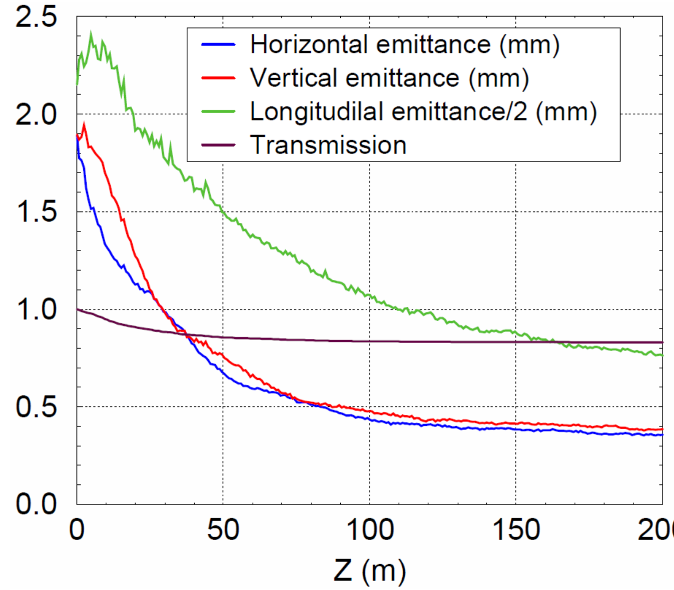
Cooling by 1st & 2nd stages (separately)

Self-consistent initial distribution
(10 skipped cells)

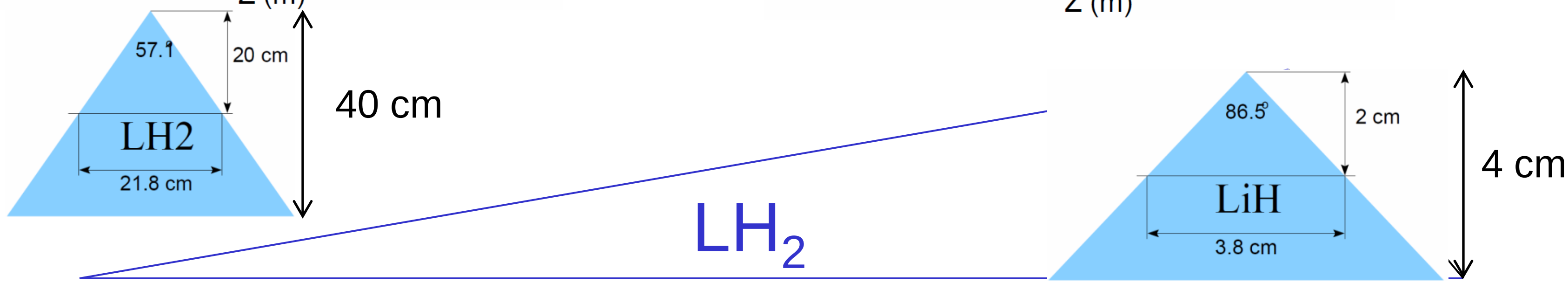


78%
5.3mm
1.8 mm

Gaussian initial distribution



83%
0.76 mm
0.37 mm



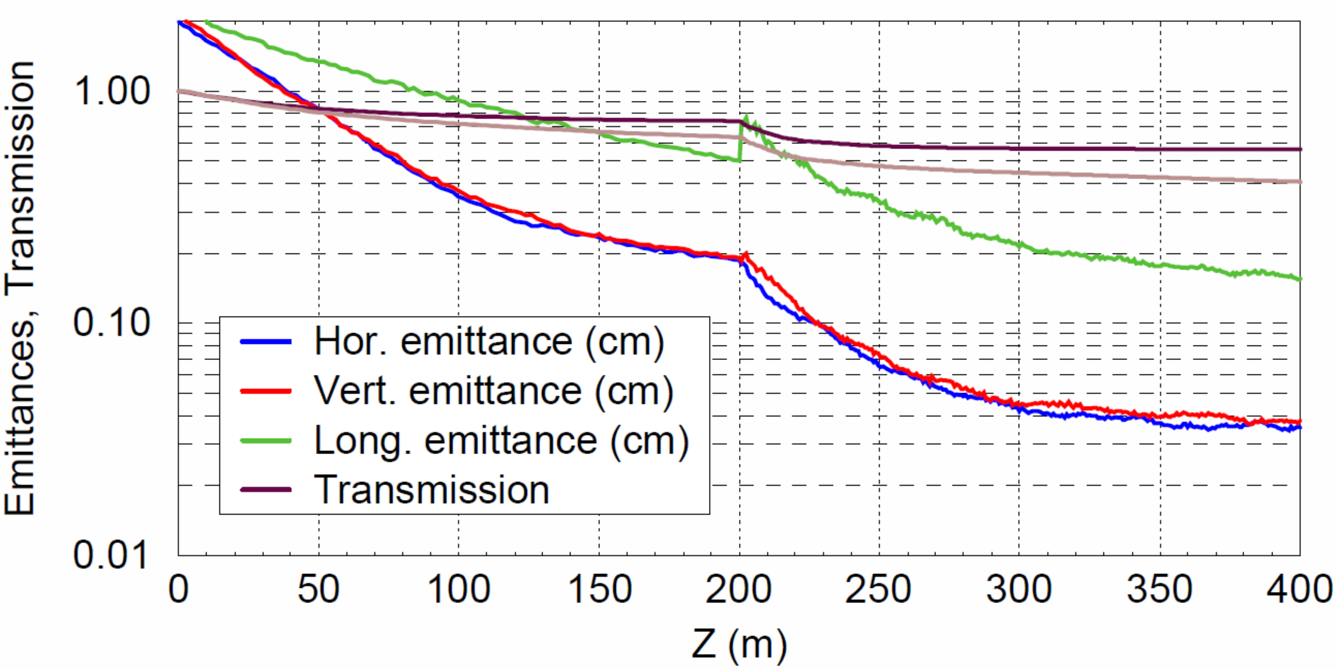
What does mean the ”selfconsistent distribution”?

- (Energy – Betatron Amplitude) correlation has to be used to mitigate dependence of flying time on betatron amplitude and to improve longitudinal stability.
- However, it is unclear which instruments could be actually used to create required correlation without considerable particle losses.
- On the other hand, any channel creates the correlations by itself through the scraping of the “excessive” particles. Preceding parts of entire cooling system (e/g/ front-end) can do the same more or less successfully.
- So, there is a choice: either to create and to optimize the correlations “by hand”; or to use several cells as a shaper of the beam.

  I have chosen second way with 10 shaping cells.

Cooling by 1st + 2nd stages

(self-consistent initial distribution, matching by matrix)

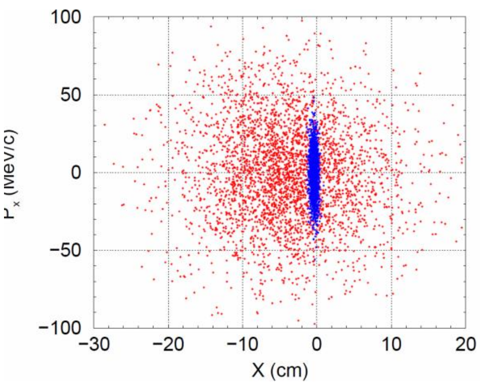


350 m	400 m
57%	57%
43%	42%
1.6 mm	1.5 mm
0.38 mm	0.36 mm

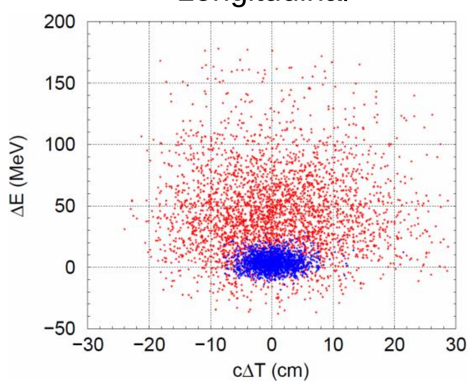
(0.21 mm with LH_2)

Phase space before and after the cooling

Transverse

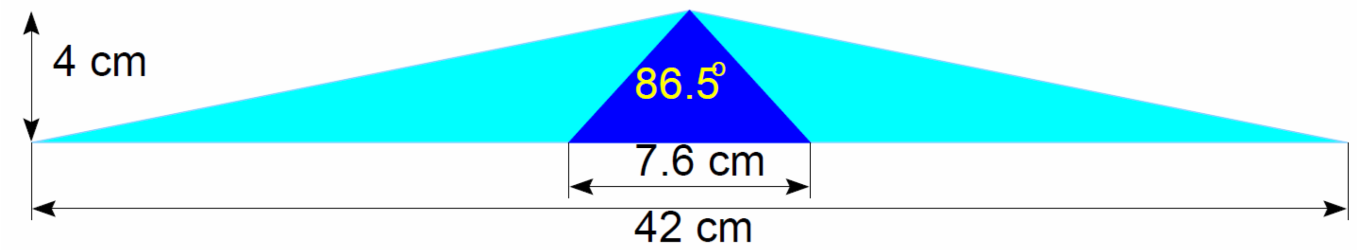


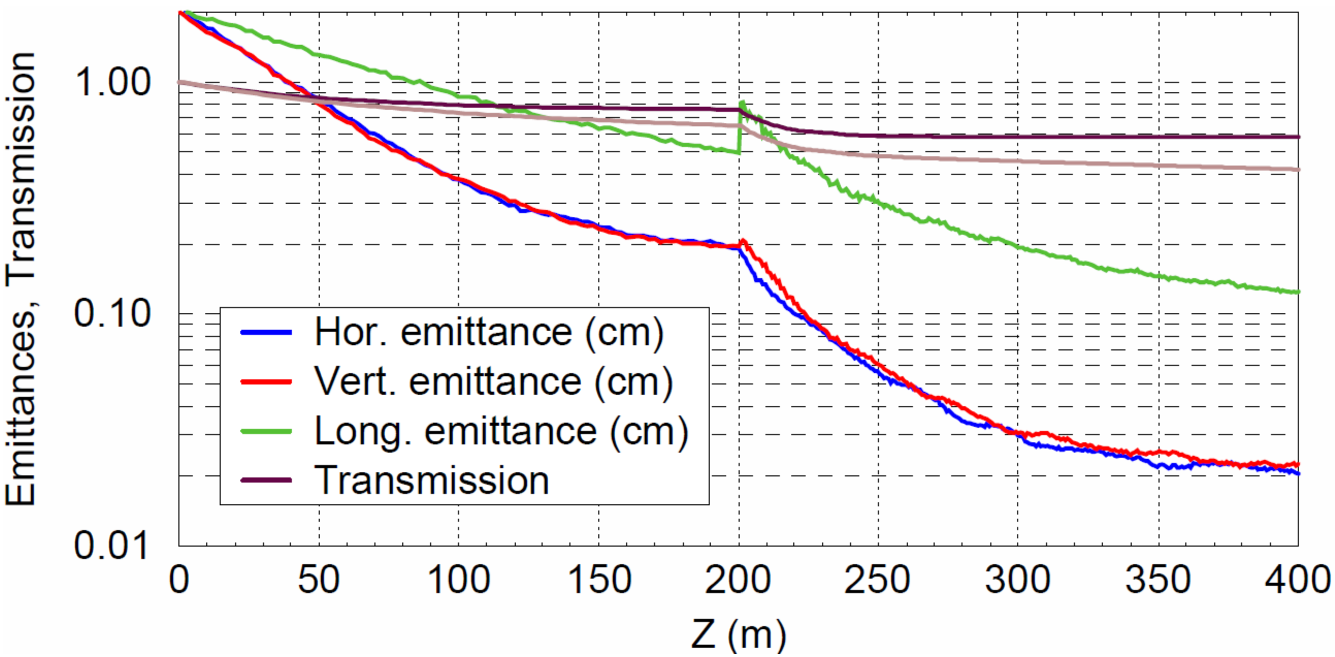
Longitudinal



Cooling by 1st + 2nd stages

2nd stage with "superdense" H_2 absorber: $\rho = 5.5\rho_0$

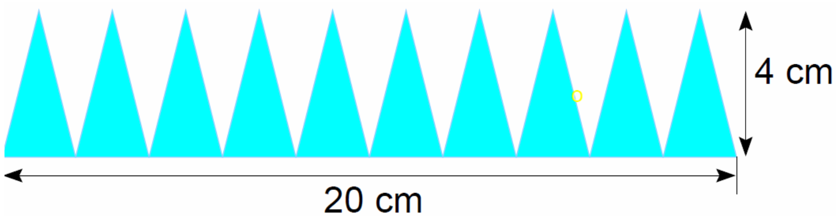




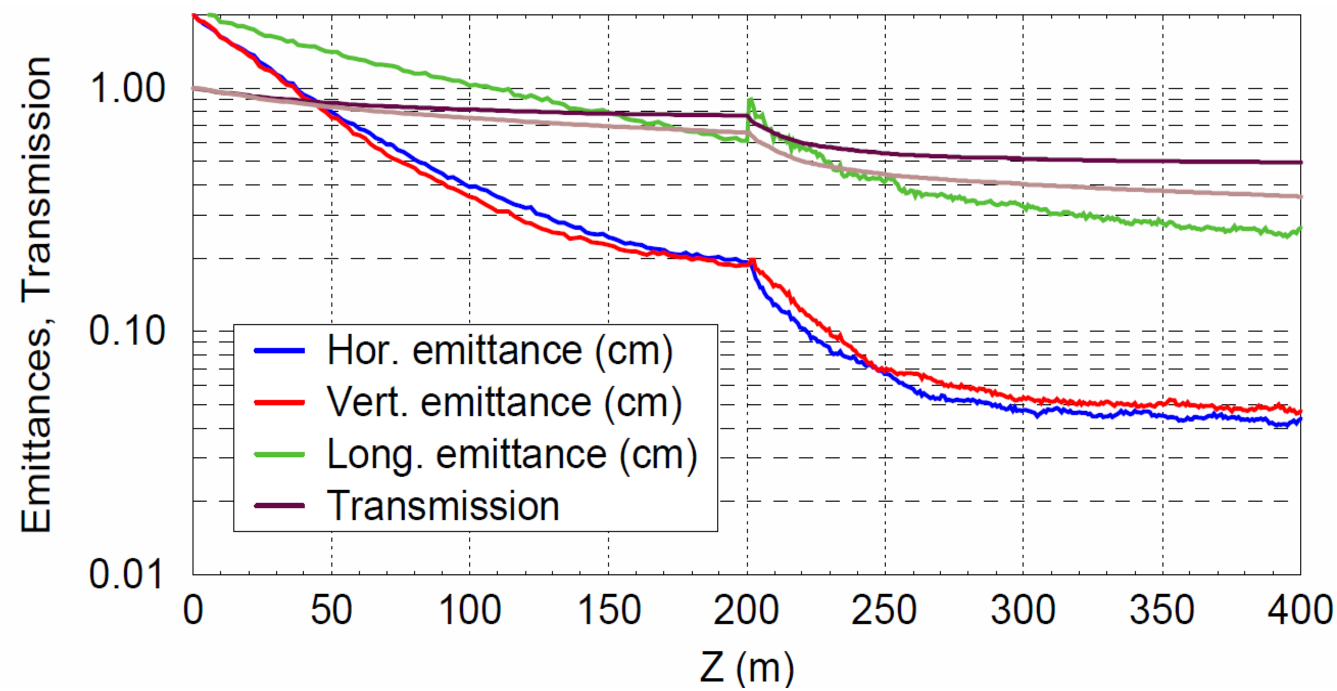
350 m	400 m
58%	58%
44%	42%
1.4 mm	1.2 mm
0.23 mm	0.21 mm

Cooling by 1st + 2nd stages

2nd stage with LH_2 notch absorber



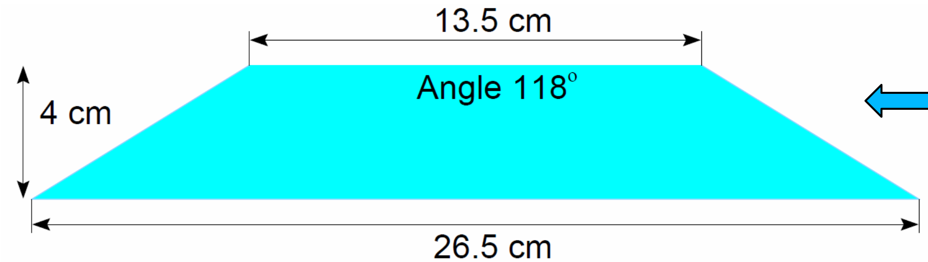
Average beta-function is about 12 cm in this area (factor 2.5)



350 m	400 m
50%	49%
38%	36%
2.8 mm	2.7 mm
0.48 mm	0.45 mm

Cooling by 1st + 2nd stages

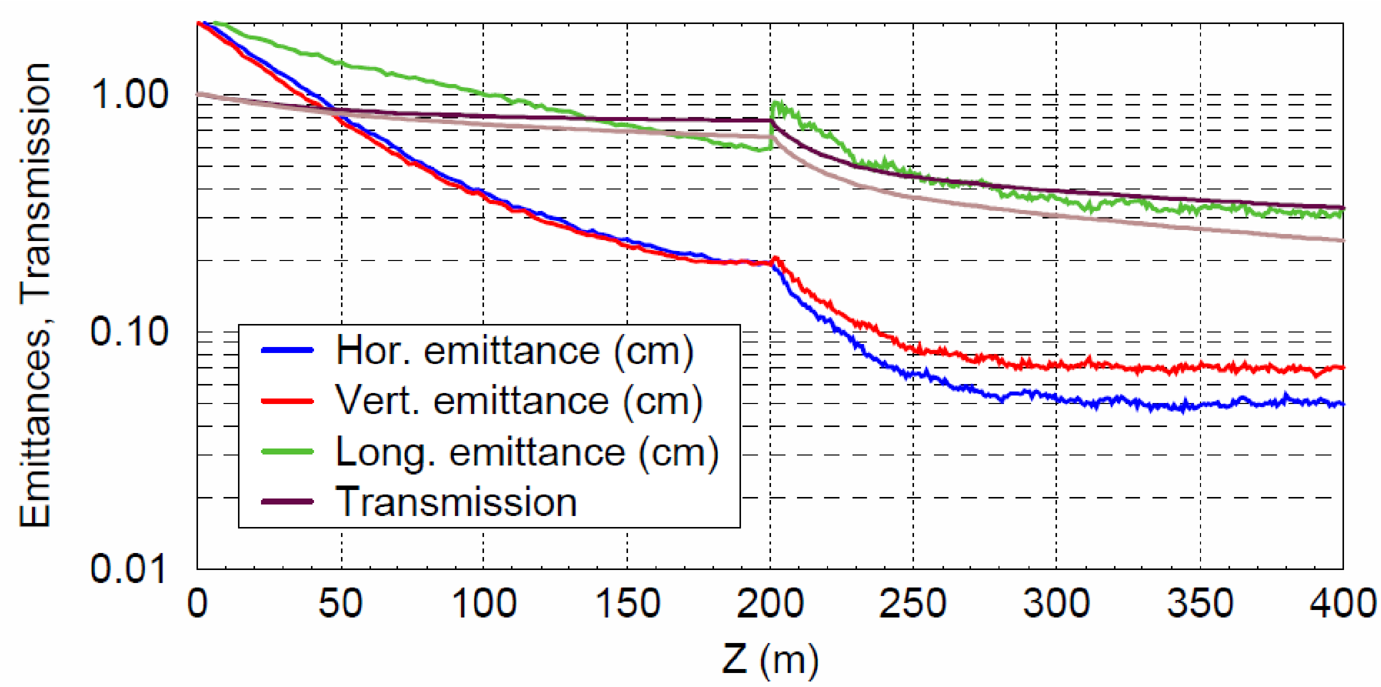
Solenoid tilt 20 mrad → 60 mrad resulting dispersion function -4.5 cm in 2nd stage



Second stage LH_2 absorber.

Very poor result:

350 m	400 m
36%	33%
3.4 mm	3.3 mm
27%	24%
0.59 mm	0.58 mm



Conclusion

- Two-stages cooling channel with 325 MHz RF system is considered.
- Tilted solenoids with tilt angle 45 mrad (1^{st} stage) and 20 mrad (2^{nd}) are used for dispersion.
- Current density and maximal magnetic field are:

  77.6 A/mm^2 and 6.0 T in 1^{st} stage, 134 A/mm^2 and 13.4 T in 2^{nd} stage.
- A self-consistent distribution is used for injection in the 1^{st} stage,

  and a matrix is used for matching of the stages.
- LH_2 wedge absorbers are used for emittance exchange in 1^{st} stage, LiH abs.– in 2^{nd} stage.
- Obtained transverse cooling is from 20 mm to 0.36 mm, longitudinal – from 20 mm to 1.5 mm
- The results are considerably worse with LH_2 absorbers in 2^{nd} stage

  because it should be excessively thick and wide-angle.
- Matching of the sections looks as the most hard problem causing a significant particle loss.