2-stages, 325 MHz cooling channel

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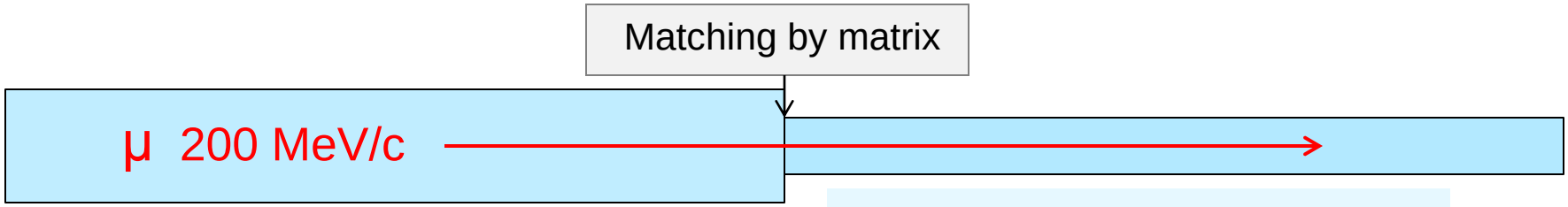
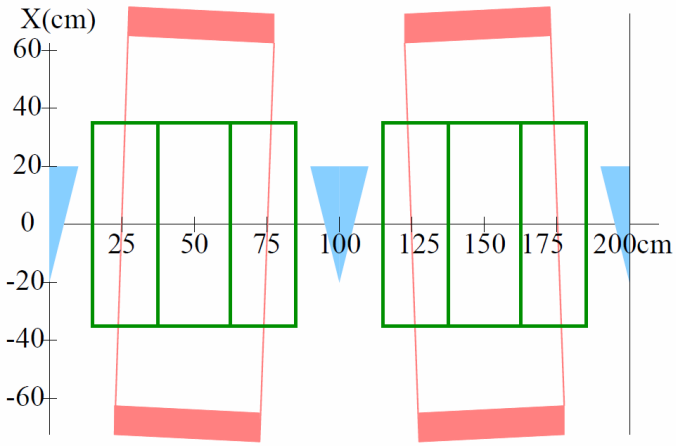
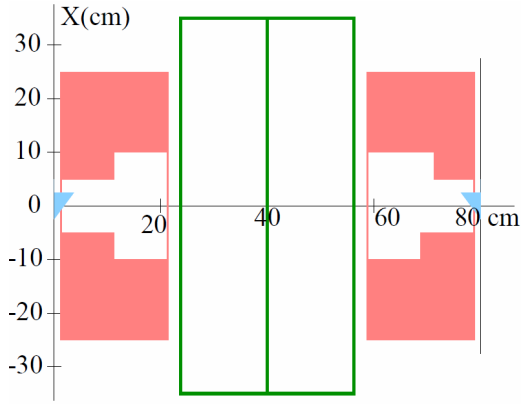
Schematic and overlook of the channel



First stage: 100 2 m cells;
J = 119 A/mm^2, $B_{sol} \leq 8.5$ 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 → 0.39 mm
(0.24 mm with LH_2 absorbers)





Tilt ±20 mrad is not shown

The cells have been designed for 200+400 MHz channel. Not updated.

Why 325 MHz everywhere? (merits and demerits)

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

HOWEVER

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

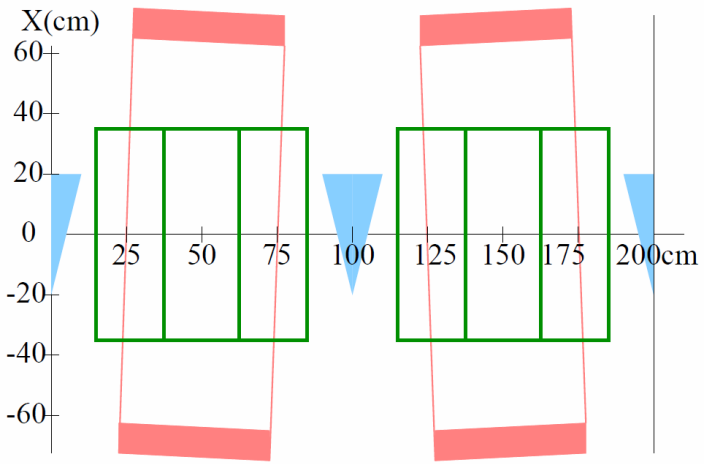
  Therefore, a larger phase may be used with 325 MHz RF increasing the cooling rate.
- At the same longitudinal emittance, a bunch has about twice more momentum spread

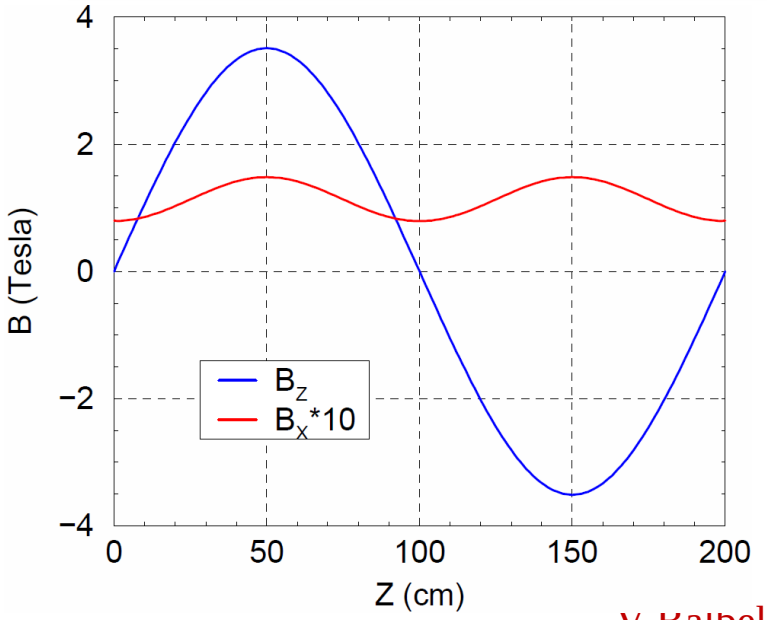
  with 650 MHz. This conflicts with restricted RFOFO momentum acceptance.
- Higher acceleration rate requires longer and wider-angle wedge absorbers

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

Stage 1: High acceptance / low cooling stage

(schematic, field, list of parameters)



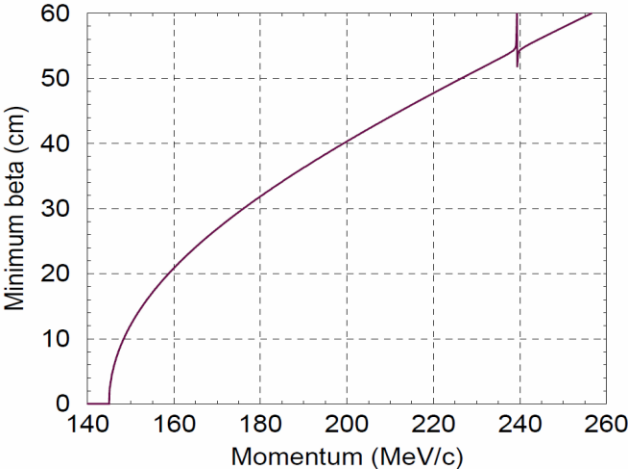


Period length	200 cm
Coil length	50 cm
Coil inner radius	62 cm
Coil thickness	10 cm
Coil tilt	40 mrad
Current density	119 A/mm^2
Maximal field strength in coil	8.5 T
Reference momentum	200 MeV/c
Accelerating frequency	325 MHz
Accelerating gradient	25 MV/m
Synchronous phase	23°
LH_2 absorber center thickness	21.8 cm
Absorber opening angle	57.1º

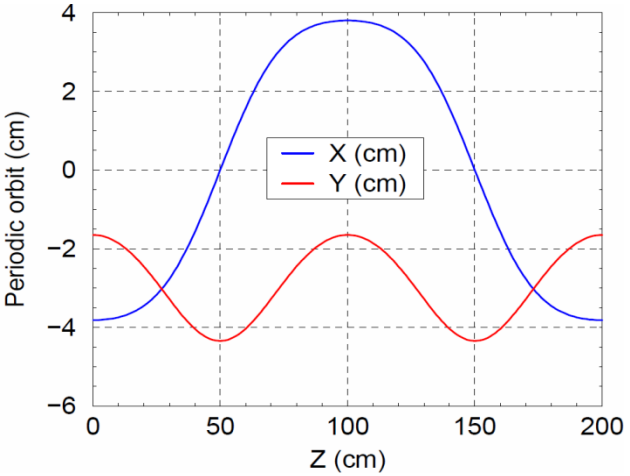
Stage 1: High acceptance / low cooling channel

(plots of beta-function, periodic orbit, dispersion functions)

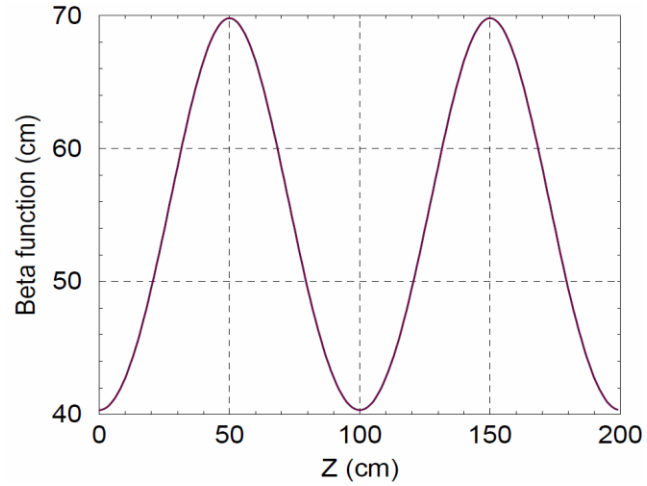
Beta. FOFO provides max momentum acceptance



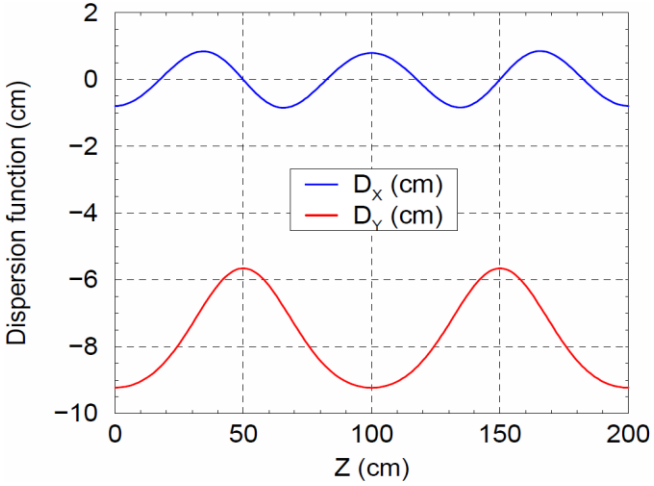
Closed orbit



200 MeV/c beta-function vs long.coordinate

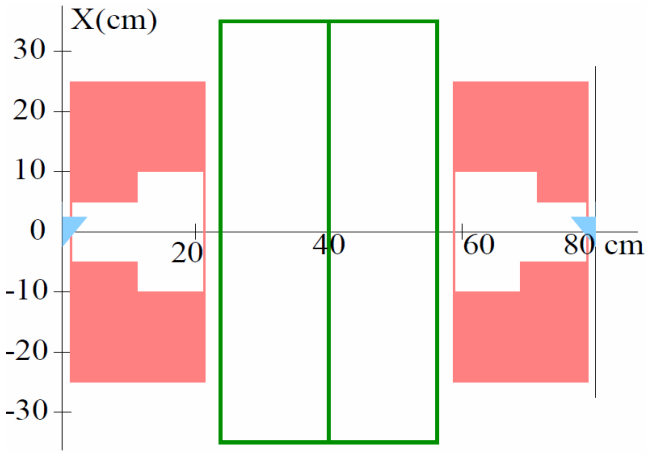


Dispersion function



Stage 2: Lower acceptance / higher cooling stage

(schematic, field, list of parameters)

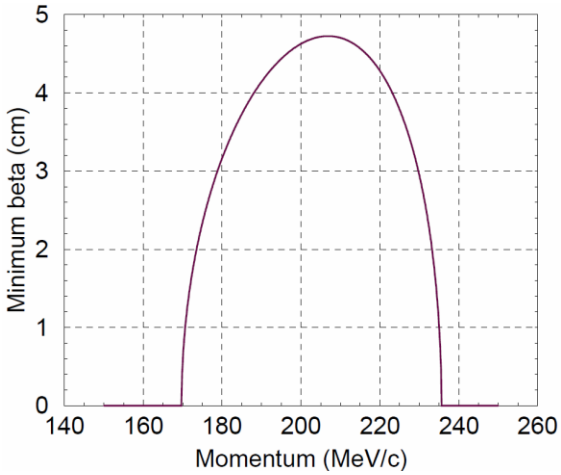


Period length	80 cm
Coil length	20 cm
Coil inner radius	5 cm and 10 cm
Coil thickness	20 cm and 15 cm
Coil tilt	20 mrad
Current density	134 A/mm^2
Maximal field strength in coil	13.4 T
Reference momentum	200 MeV/c
Accelerating frequency	325 MHz
Accelerating gradient	25 MV/m
Synchronous phase	44.4°
LiH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

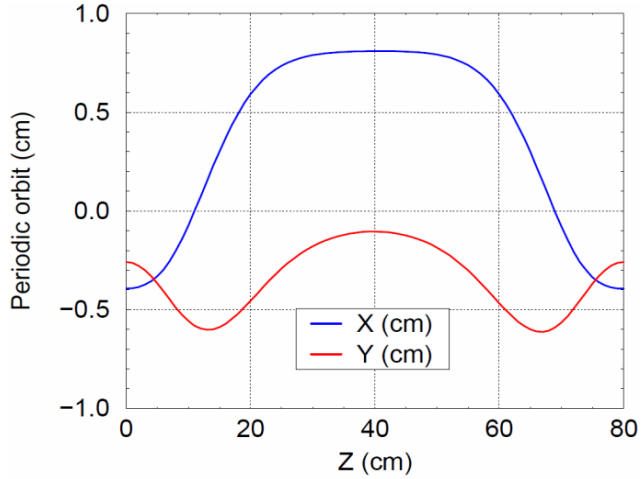
Stage 3: Lower acceptance – high cooling channel

(beta-function, periodic orbit, dispersion functions)

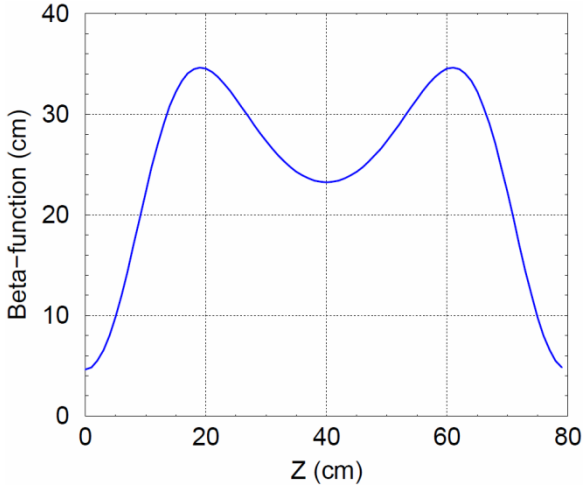
Beta-function vs momentum



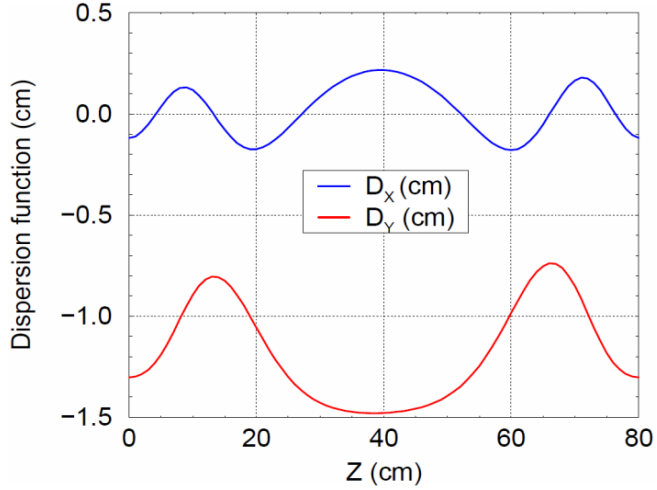
Closed orbit



Beta-function vs long.coordinate

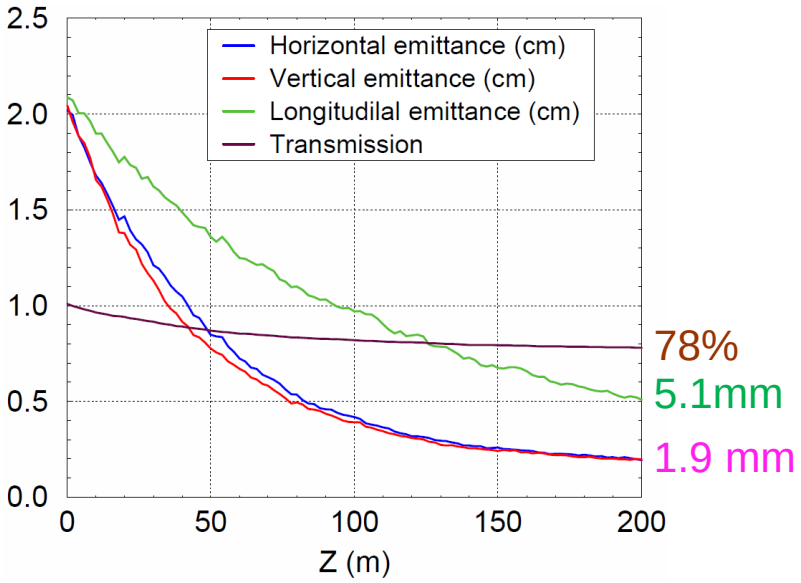


Dispersion function



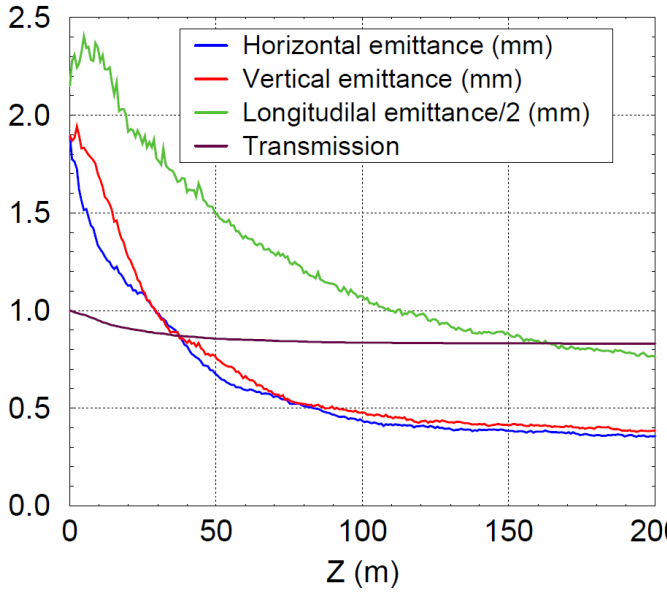
Cooling by 1st & 2nd stages

Self-consistent initial distribution
(10 skipped cells)

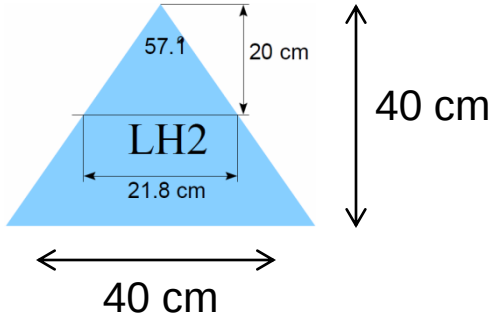


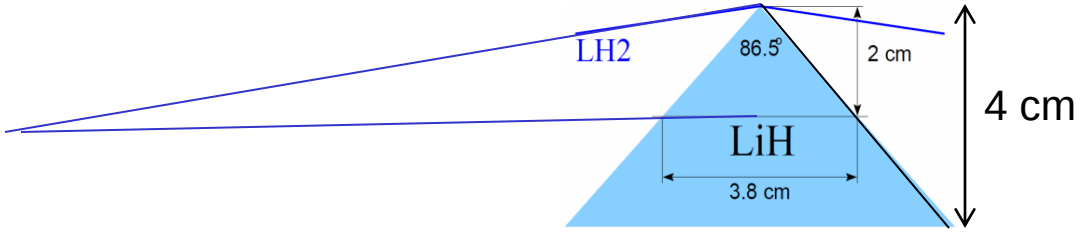
78%
5.1mm
1.9 mm

Gaussian initial distribution



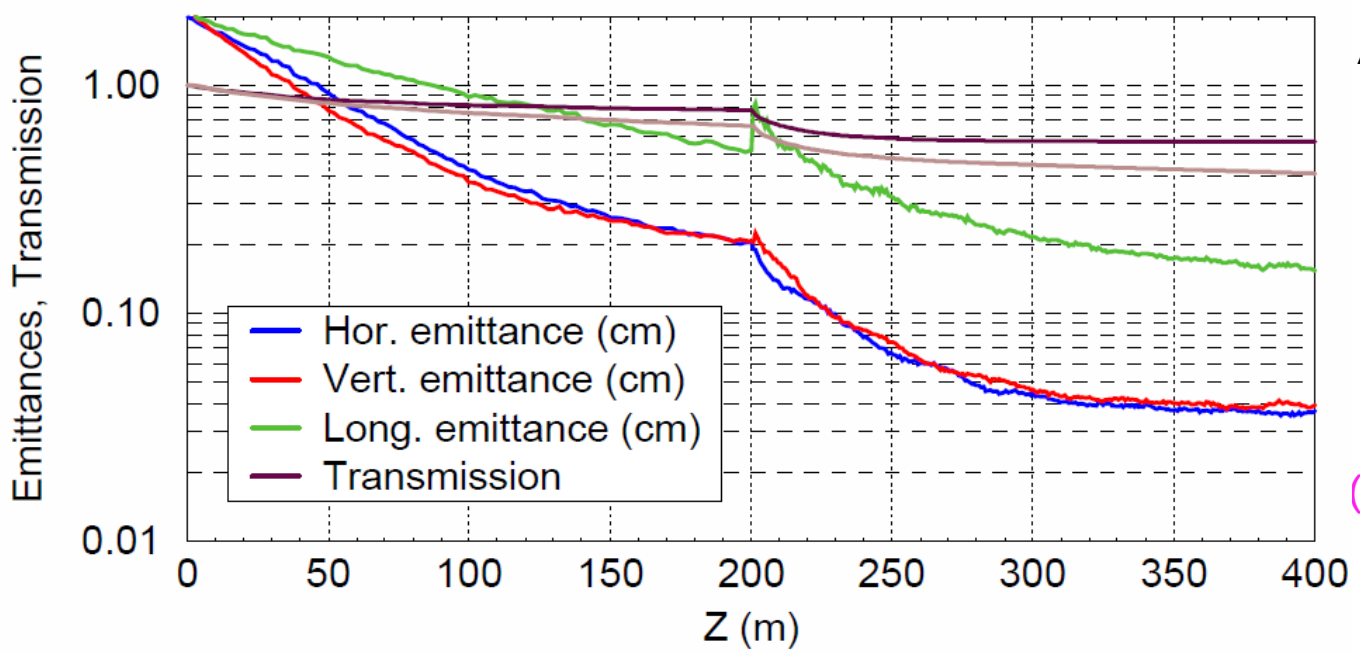
83%
0.76 mm
0.37 mm





Cooling by 1st+2nd stages

(self-consistent initial distribution, matching by matrix)



After 350 m

57%

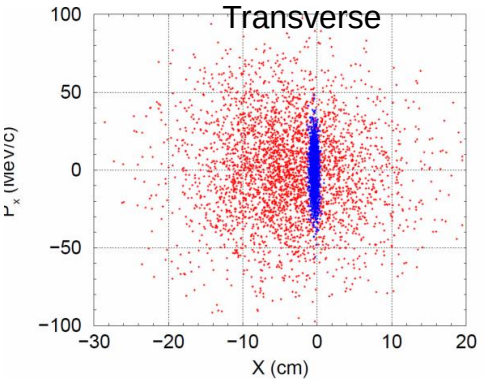
43%

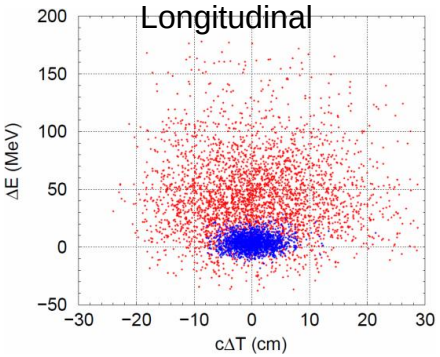
1.7 mm

0.39 mm

(0.24 mm with LH_2)

Phase space before and after the cooling





Conclusion

- Two-stages cooling channel with 325 MHz RF system has been considered.
- Tilted solenoids with tilt angle 40 mrad (1st stage) and 20 mrad (2nd) are used for dispersion.
- Magnetic field in the coils does not exceed 13.4 T at current density 134 A/mm^2.
- LH_2 wedge absorbers are used for emittance exchange in 1st stage, LiH abs.– in 2nd one.
- A self-consistent distribution is used for injection in the 1st stage,

  and a matrix for matching of the stages.
- Obtained transverse cooling is from 20 mm to 0.38 mm, longitudinal – from 20 mm to 1.5 mm.

  With LH_2 wedge absorbers in 2nd stage, estimated emittances are 0.22 mm and 1.3 mm. However, 4-5 times bigger dispersion and 80-100 mrad tilting angle are needed for this resulting a deterioration of the channel and no emittances decrease.
- The sections matching looks as the most difficult problem causing a significant particle losses.