Modifications of AD optics in view of new electron cooler

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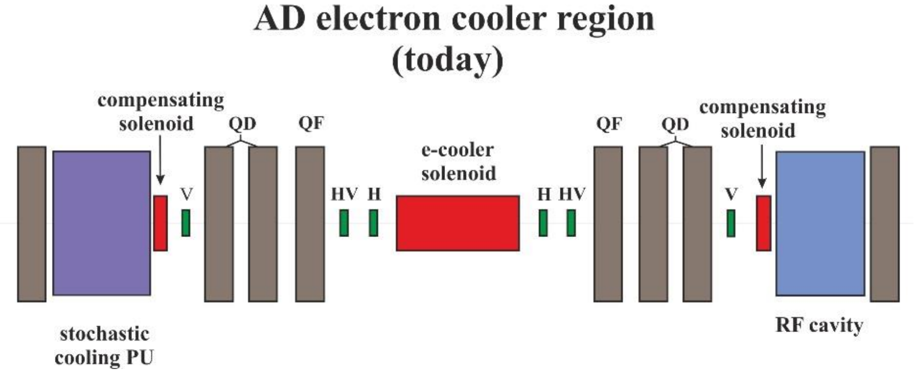
AD optics and electron cooling

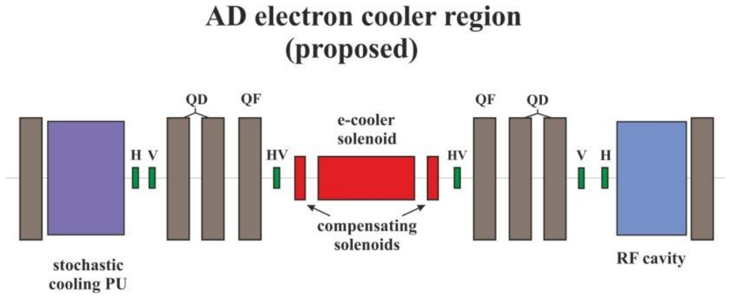
- The Antiproton Decelerator was built on the bases of the former Antiproton Collector with many modifications to make it operational not only at fixed energy, but to be suitable at the low energies as well
- As result of that AD was equipped with many systems like:
  - ➢ RF system for deceleration
  - ➢ upgraded diagnostics
  - ➢ upgraded vacuum system to make operation possible at vey low energies
  - ➢ electron cooler from LEAR to keep emittances small at all range of operation
- With new cooler in AD one can look what can be done on the side of optics to improve machine performance

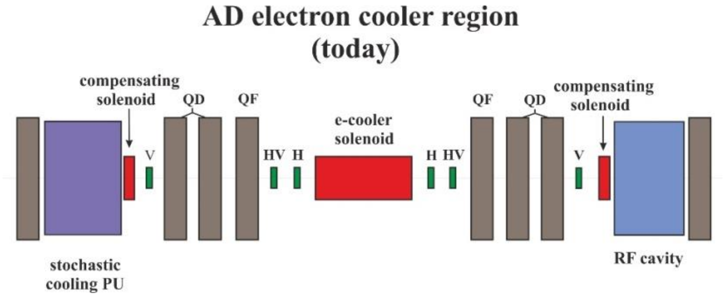
Transverse coupling in AD

- The current layout of electron cooling section emerged as result of minimal modifications in AC ring, no optimization has been done that time
- Solenoid of electron cooler and two compensating solenoids are separated by quadrupole triplets, resulting in non zero coupling. This makes AD operation more complicated



Let's eliminate coupling in AD by use of this major intervention!





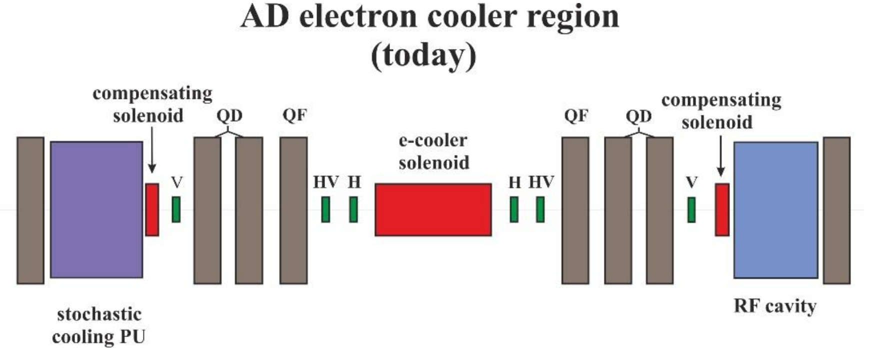
The main difference between two schemes is that with new cooler in AD compensating solenoids are placed right on sides of the main solenoid. The coupling compensation will be local which makes machine operation much more comfortable and provide conditions for better performance

Orbit bump around electron cooler: why do we need it in AD?

- Due to machine imperfections orbit in electron cooler is not coincide with electron beam trajectory, which result in slow beam cooling or no cooling at all
- To establish fast electron cooling antiproton beam has to be well aligned w.r.t. electron beam of cooler, no beam offset or angle is allowed
- It is very practical to keep the orbit in the ring constant for various reasons like provide stable beam position and angle at extraction kicker position, keep maximal acceptance etc. Due to that antiproton beam alignment w.r.t. electron beam of cooler should be local, keeping orbit in the most part of the ring the same

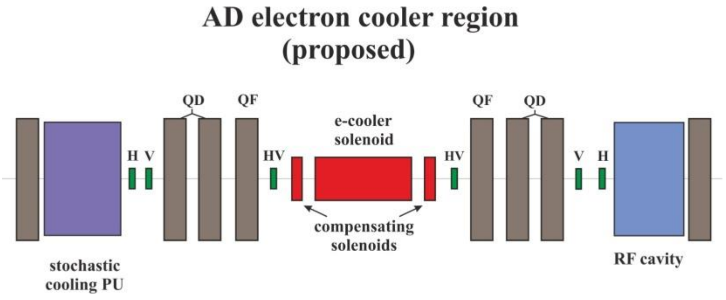
Orbit bump around electron cooler: how it works in AD now?

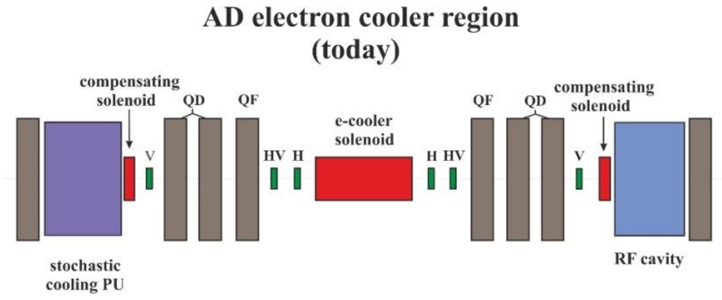
- Now in AD two vertical correctors on the left (right) side of the cooler are well distanced from each other. Due to that corrector strengths used effectively to produce required orbit offset and/or angle to align two beams w.r.t. each other
- Two horizontal correctors on the left side of the cooler are very closed to each other. Due to that one has to make them strong to produce given orbit offset or angle inside of electron cooler. Sometimes one needs to make big local offset/angle to align two beams, and this could be out of available strengths of corrector



Let’s make the horizontal orbit bump around electron cooler more effective

- Let’s swap the horizontal orbit corrector and compensating solenoid on each side of the cooler
- Now in both planes correctors strengths are used in optimal way for making orbit bumps

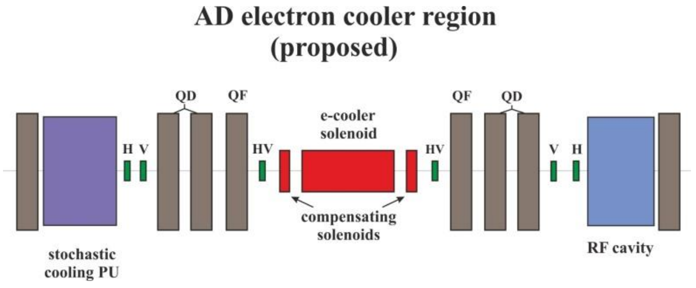


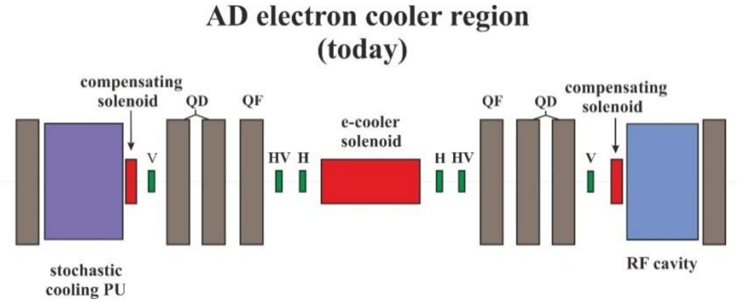


Effectiveness of the horizontal orbit bump around electron in new and in old optics

	DHZ2904, kick (mrad)	DHZ2908, kick (mrad)	DHZ2913, kick (mrad)	DHZ2917, kick (mrad)
x=1 mm, x'=0	1.47	-1.47	-1.47	1.47
x=0, x'=1 mrad	-2.87	3.87	-3.87	2.87

	DHZ26xx, kick (mrad)	DHZ2908, kick (mrad)	DHZ2913, kick (mrad)	DHZ31xx, kick (mrad)
x=1 mm, x'=0	-0.11	0.186	0.186	-0.11
x=0, x'=1 mrad	1.03	-0.490	0.490	-1.03



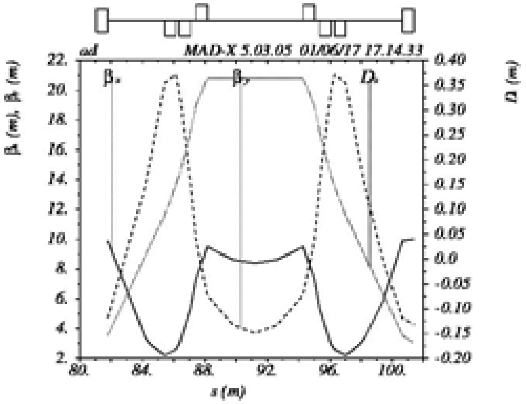


Possible modifications in AD cycle with new cooler in operation

- At 2 GeV/c stochastic cooling is applied to make beam emittances and momentum spread small for the last time. Then at 300 MeV/c and at 100 MeV/c electron cooling is used to keep beam sizes small. The momentum range between two coolings is big and beam losses may occur. The tails in beam distribution are not well cooled, and might be lost during the next ramp down.
- The major thing would be to start electron cooling earlier in cycle, say around 400 MeV/c. In this case the momentum range between stochastic and electron cooling will be smaller and AD performance on the more safe side. The precise value of momentum for the first electron cooling will depend both on the new cooler design, and on performance of stochastic cooling system

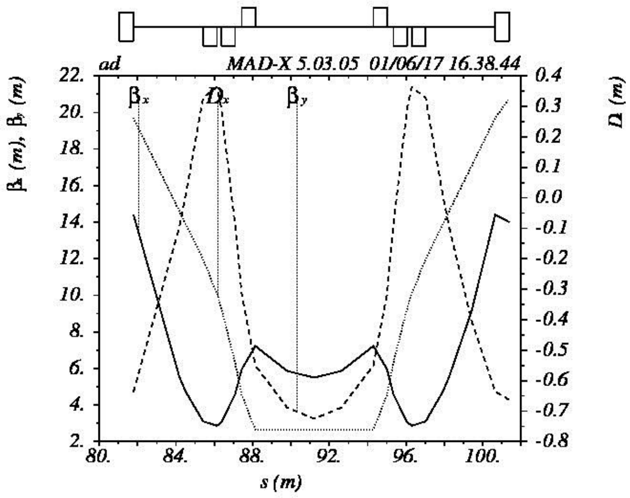
How good is AD optics for electron cooling?

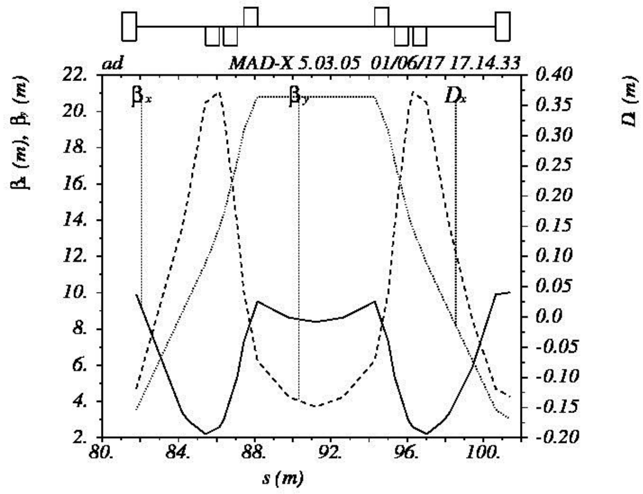
- Now at the cooler β_x=8.7 m, β_y=4.1 m (and dispersion around zero), with horizontal beta on high side (keep in mind that beam tail cooled much slower and that electron beam alignment w.r.t. antiproton beam is not perfect)
- By reducing the β_x to smaller value one can achieve faster cooling speed on plateaus. Potentially this can provide reduction of beam losses which occurs at the beginning of cooling (particles with big amplitudes are not cooled and lost during next ramp) and makes cooling faster.



New optics in AD cooler

- Optics with smaller beta functions ($\beta_{x,y}$=5.5m / 3.2m on the left figure compared with $\beta_{x,y}$=8.7m / 4.1m on the right figure), and non zero dispersion D_x=-0.8m (compared with dispersion around zero now). Non zero dispersion in cooler region provides faster cooling.
- No extra equipment need, but some time for commissioning





Thank you for attention!