AD Note 040
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Minutes of the meeting on compensation of the linear coupling due to the E-cool solenoid in the AD machine

Present:

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Switching on the electron cooling solenoid at 400 A a strong perturbation of the AD optics is introduced:
- The working point at 100 MeV/c is shifted from the forseen (5.39,5.37) to (5.44,5.35);
- The second order resonances $Q_x+Q_y = 11$ and $Q_x-Q_z = 0$ are excited. The uncompensated values of their the driving terms (at 100 MeV/c) is

$$C^+ = 0.0314, \qquad C^- = 0.0894. \tag{1}$$

The sum resonance can lead to instability while the difference resonance causes an energy exchange between the two degrees of freedom of the transverse motion that tends to make the beam round.
The distance of the working point from these resonance lines which has to be mantained during machine operation in order to prevent serious beam blow up is given by the relations

$$Q_x + Q_y - 11 \geq 5C^+ \longrightarrow C^+ < 0.048 \tag{2}$$

$$Q_x - Q_y \geq 5C^- \longrightarrow C^+ < 0.004. \tag{3}$$

The available correctors are two skew quadrupoles (placed in section 13 and 44) and two solenoids placed upstreams and downstreams of the electron cooling device and separated from it by three normal quadrupoles.

The best linear coupling compensation [1] can be achieved (see tab.1):
- By having at disposal one independent power supply for the corrector solenoids;
- By placing the skew quadrupoles (fed by the same power supply with opposite polarity) as close as possible to QFN14(44).

Both these conditions are not going to be satisfied for the AD start up: the two corrector solenoids will be connected in series with the electron cooling solenoid and only the skew quadrupole in section 13 will be placed in the favourable position. In tab.2 the two solutions relative to the start up configuration (found using MAD) are quoted.

[1] Perfect compensation of the 2x2 off axis blocks of the one turn matrix calculated in one arbitrary point and minimization of C^+ and C^-.

KSOLG (rad/m)	KSKEW (m^{-2})	$\|C^-\|$	$\|C^+\|$	$\Delta K_1(m^{-2})$	$\Delta K_2(m^{-2})$
$-3.283 \cdot 10^{-1}$	$\pm 8.69 \cdot 10^{-2}$	10^{-4}	$2.45 \cdot 10^{-2}$	$\Delta K_{KF6} = 4.6 \cdot 10^{-3}$	$\Delta K_{KDEC} = 7.6 \cdot 10^{-3}$
$-3.377 \cdot 10^{-1}$	$\pm 1.135 \cdot 10^{-1}$	$1.3 \cdot 10^{-3}$	$2.97 \cdot 10^{-2}$	$\Delta K_{KFEC} = 3.7 \cdot 10^{-2}$	$\Delta K_{KDEC} = 1.4 \cdot 10^{-2}$

Table 1: Parameters of the coupling compensation using two solenoids fed by an independent power supply and two skew quadrupoles placed as close as possible to QFN14(44).

KSOLG (rad/m)	KSKEW (m^{-2})	$\|C^-\|$	$\|C^+\|$	$\Delta K_1(m^{-2})$	$\Delta K_2(m^{-2})$
$-3.834 \cdot 10^{-1}$	-	$1.53 \cdot 10^{-2}$	$4.13 \cdot 10^{-2}$	$\Delta K_{KF6} = 5 \cdot 10^{-3}$	$\Delta K_{KDEC} = 8 \cdot 10^{-3}$
$-3.834 \cdot 10^{-1}$	$\pm 8 \cdot 10^{-2}$	$7.3 \cdot 10^{-3}$	$4.72 \cdot 10^{-2}$	$\Delta K_{KF6} = 5 \cdot 10^{-3}$	$\Delta K_{KDEC} = 10^{-2}$

Table 2: Parameters of the coupling compensation using two solenoids in series with the main one and two skew quadrupoles placed (not simmetrically in section 13 and 44).

For the first one we took care only about the retuning of the machine. This is possible only if the compensator solenoids are used together with the two normal quadrupole families QF6 and QDEC. The residual values of C^+ and C^- are such that only the difference resonance is going to be "seen" by the beam.
The second solution forsees the additional use of the two skew quadrupoles (fed by the same power supply). In this the residual effect of the difference resonance is strongly reduced.

When connected in series with the main solenoid the strengths of the corrector ones is given by the condition (compensation of the integrated field)

$$k_M l_M + k_C l_C = 0 \tag{4}$$

where k_M and l_M are the strength and the length of the electron cooling solenoid and k_C and l_C are the strength and the total length of the corrector solenoids. An uncertainty of about 10% on $k_C l_C$ has to be taken into account due to the fact that the two correctors are quite short and sensitive to the surrounding enviroment.
Comparing the value of $k_C l_C$ fixed by the condition (4) with the ones which allow the best coupling correction (see tab.1), one can conclude that, once the skew quadrupoles position is optimized, it would be possible to approach it by means of shunting the current supplied to the corrector solenoids. However the impedance of the three solenoids connected in series and, consequently, the time constant would be increased ; moreover the shunting would not allow a flexible use of the corrector apparatus.
For these last reasons it is recommendable to have for next years of machine operation an inde-

pendent power supply for the two corrector solenoids.

Following the discussion it was decided:
- To connect the compensation solenoids in series (with opposite polarity) with the main one for this year start up;
- To forsee a separate power supply for the compensators for the future (next years);
- To move (next year) the skew quadrupole in section 44 close to QFN44.

The operation of the electron cooler was discussed. Probably the best solution for this year is to switch on the solenoid at 300 MeV/c and leave it on at constant current for the rest of the cycle. About 4s time needed for switching on are acceptable in the initial operation.

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