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Steering of the Electron Beam in the AD Electron Cooler at 300MeV/c

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This note summarises the effect of the steering/correction coils of the AD electron cooler on the trajectory of the electron beam in the interaction region at the 300 MeV/c flat top. The measurements were performed between April and October 2002. A linear response matrix was found which will facilitate the steering of the electron beam.

1. Set-up

The position of the electron beam was measured with the four pickups (2 horizontal and 2 vertical), inside the drift solenoid. The pickups at the gun side are named DH (horizontal) and DV (vertical), the ones at the collector side TH and TV. The distance between them is 1.3 meters. The correctors used are GBH (horizontal) and GBV (vertical) in the gun solenoid, TBH and TBV inside the toroid on the gun side, DBH and DBV in the drift solenoid and DCHV, a combined horizontal and vertical correction in the drift tube. DBG, a gradient coil, which corrects longitudinal magnetic filed errors in the drift tube, was investigated as well. The correctors at the collector side were not used, as they do not influence the beam position in the interaction region.

The polarities of the steering coils are the ones of the 2002 run. They are given in the table below, where 1 and 2 do represent opposite polarities:

GBH	2
GBV	1
TBH	1
TBV	2
DBH	1
DBV	2
DCHV	1

And for completeness:

DBG	1
UBH	2
UBV	2
CBH	1
CBV	1
CDH	2
CEC	not installed

Table 1: Polarities of steering coils during the run 2002.

2. Measurement of the electron beam position

The program "*ecoolbump*" was used to record the position of the electron beam. The program calculates the beam offset and angle from the position measurement of the pickups. The measurement procedure is the following:

1) Enable the timing: DAX3.SORB-B to measure on FT 300B
(DAX4.SORB-B is the corresponding timing for FT 100B)
2) Program "*ecoolbump*": enable "E-Beam Modulation" and choose the corresponding flat top.

The value of DAX3.SORB-B is 5000, corresponding to 5 second, which corresponds approximately to the middle of the flat top 300B. When triggered automatically with above timing, the measurement is stable (to about 0.1mm offset and 0.1mrad angle) from cycle to cycle and is not influenced by the presence of antiprotons in the machine, which are debunched at FT 300B (and 100B). When the cycle is paused on a flat top and the measurement is triggered manually with the "Trig Timing" button of the program, the measurement is not stable.
The AD dipole magnets used to bump the antiprotons in the electron cooler region of the AD do influence the position of the electron beam. It changes by order of magnitude of a few 100 μm and a few 100 μrad, when the current in the dipoles close to the gun side of the cooler is changed by some 5 to 15 A.

3. Results

The correction coil DBG does not influence the measured position of the electron beam, and is hence not included in the results. It does however influence the emittance of the antiproton beam after cooling (as measured with the scrapers). The vertical emittance could be reduced by 13% by adjusting DBG.

Table 2 summarizes a series of measurements of electron beam position as function of the current control value (CCV) of one corrector coil. The other coil currents were kept constant during the scanning, generally at the nominal operational values at the time of the measurement. The electron beam during operation in 2002 had an angle close to zero and an offset of about 5 mm in horizontal and vertical. Offset and angle measures the beam displacement with respect to the central axis of the drift solenoid. The range of the coil current is from 0 to 5 A.

	CCV [A]	offset H [mm]	angle H [mrad]	offset V [mm]	angle V [mrad]
GBH	2	1.9	-1.8	5.3	0.4
	3	2.9	-1.7	5.1	0.3
	4	3.8	-1.6	5	0.1
	5	4.8	-1.5	4.8	0
GBV	0	5.6	-0.4	10.4	0.2
	1	5.5	-0.4	9.4	0.1
	3	5.2	-0.3	7.4	-0.1
	4	5.1	-0.3	6.4	-0.1
	5	5	-0.3	5.4	-0.2
TBH	0	1.8	-2.1	4.9	0.6
	1	3.8	-1.6	5	0.1
	2	6	-1.2	4.9	-0.3
	3	8.3	-0.8	4.9	-0.7
	4	10.7	-0.6	4.8	-0.9
	5	13.1	-0.4	4.6	-1.2
TBV	0	5.1	-0.4	8.5	0.1
	2	5	-0.4	7.3	0
	4	5	-0.3	6.0	-0.2
	5	5	-0.3	5.4	-0.2
DBH	0	5.1	-0.4	8.5	0.1
	1.5	3.8	-1.6	5	0.1
	2.5	4.6	-0.4	4.9	-0.1
	5	6.8	2.2	4.7	-0.5
DBV	0.2	5	-0.3	5.4	-0.2
	1.2	5	-0.4	5.9	0.5
	3	5.1	-0.6	7.5	3.1
	5	5.8	0.1	9	5.5
DCHV	0	3.7	-1.9	4.2	-1
	1.5	3.7	-1.8	4.4	-0.8
	2.5	3.7	-1.8	4.6	-0.5
	3.5	3.8	-1.7	4.8	-0.2
	4.5	3.8	-1.6	5	0.1

Table 2: Measured electron beam offset and position.

The measured data can be represented by a linear dependence of the electron beam position (horizontal and vertical offset and angle) on the current in the correction coil (CCV value), see Figure 1 and 2. Table 3 summarizes the gradient of the beam offset and angel with a change in the corrector coil current, $\partial(offset)/\partial(coil\ current)$, $\partial(angle)/\partial(coil\ current)$.

	GBH	GBV	TBH	TBV	DBH	DBV	DCHV	Unit
Horizontal offset	0.96	-0.124	2.271	-0.018	0.723	0.163	0.026	mm/A
Horizontal angle	0.1	0.062	0.34	0.023	0.947	0.073	0.063	mrad/A
Vertical offset	-0.16	-1.0	-0.06	-0.623	-0.064	0.771	0.18	mm/A
Vertical angle	-0.14	-0.078	-0.354	-0.066	-0.162	1.23	0.251	mrad/A

Table 3: Gradient of beam offset and angle on the steering coil current: $\frac{\partial(offset)}{\partial(coil\ current)}\left[\frac{mm}{A}\right]$ **and** $\frac{\partial(angle)}{\partial(coil\ current)}\left[\frac{mrad}{A}\right]$.

The linear response of the beam offset and angle to one corrector depends to some extent on the electron trajectory within the cooler ensemble. The results in table 3 are valid for parallel electron beams with an angle between +/- 2mrad and an offset of a few mm (around 5 mm) in horizontal and vertical plane. With these constraints, the calculated gradient is, within the precision of the measurement, independent of the setting of the other correction coils. Table 4 and Figure 3 gives an example of a scanning of GBH with a different setting of the other corrector coils. The absolute beam position is of course different from the previous measurement, but the fitted gradients are the same as in table 3. In this measurement both polarities of the power supply where used.

	CCV [A]	offset H [mm]	angle H [mrad]
GBH	-3	-1.1	-2
	-2	-0.3	-1.7
	-2	-0.3	-1.8
	-1	0.6	-1.7
	-1	0.4	-1.7
	0	1.9	-1.8
	0	1.3	-1.5
	1	2.7	-1.4
	2	3.6	-1.4
	3	4.5	-1.2
	4	5.4	-1.2
	5	6.5	-1.1

Table 4: Measurement with a different setting of the other corrector coils and both polarities.

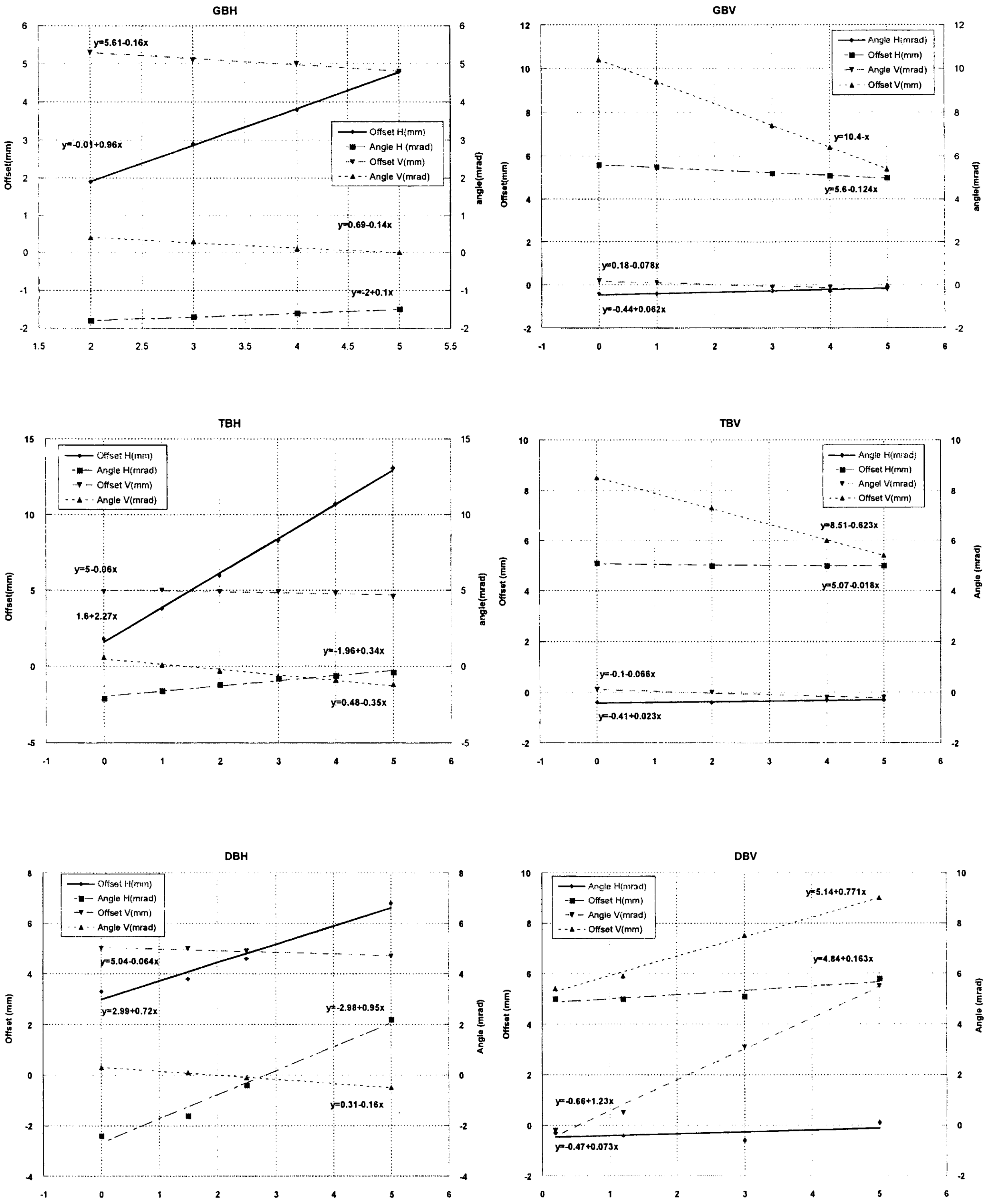

Figure 2.1: Variation of electron beam offset and angle with GBH, GBV, TBH, TBV, DBH and DBV.

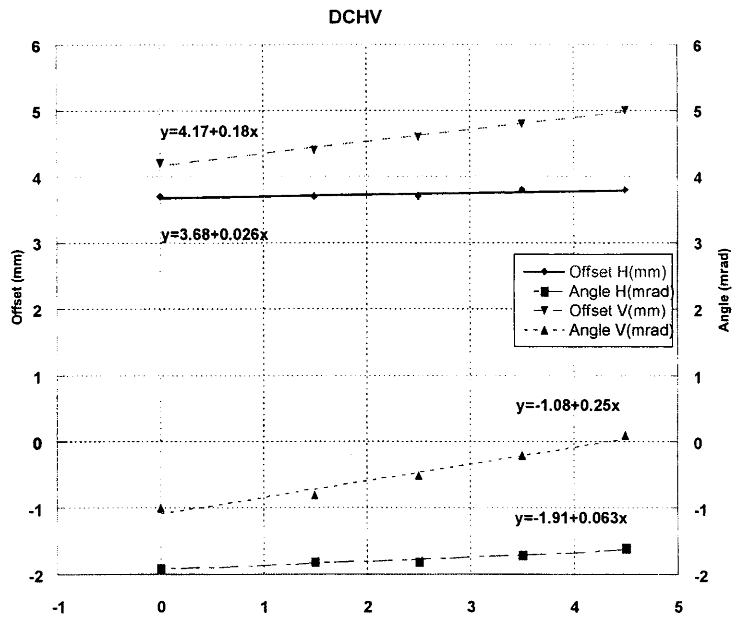

Figure 2: Variation of electron beam offset and angle with DCHV.

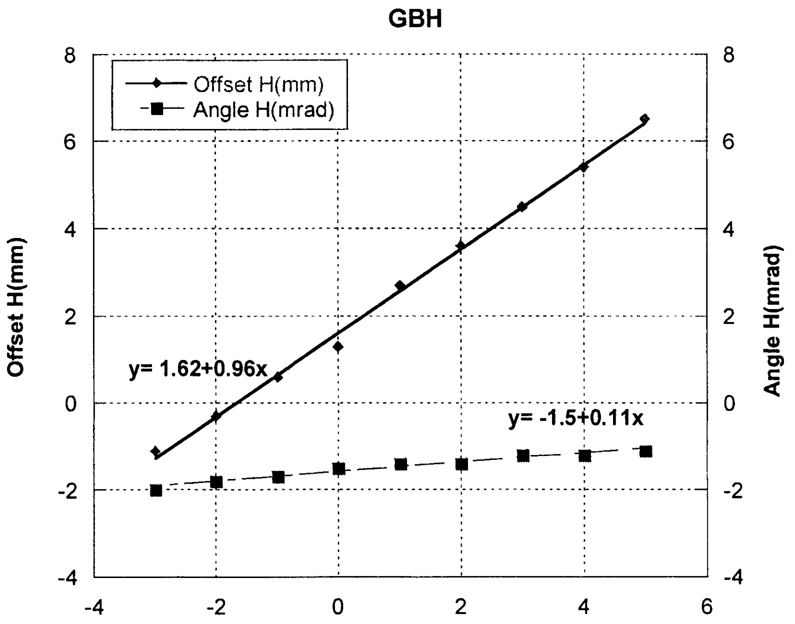

Figure 3: Variation of electron beam offset and angle with GBH and different (as compared to figure 1) currents in the other corrector coils. Both polarities of the power supply are scanned.

3. Conclusions

The response of the electron beam trajectory in the interaction section of the cooler on the steering/corrector coils GBH, GBV, TBH, TBV, DBH, DBV and DCHV was found to be linear. DBG influences the final emittance, but not the measured beam position.

The response matrix of the electron beam position to the current in the coils was measured. These measurements will allow for faster steering of the electron beam. If automatisation was desired, a simple computer program could be developed, to propose coil settings depending on desired electron beam trajectories.