COSY Proposal

For Lab. use	
Exp. No.:	Session No.
189	35

Title of Experiment

Machine Acceptance Studies with electron-cooled beam

Collaborators: PAX and ANKE Collaboration

Spokespersons for collaboration: Name: Frank Rathmann (IKP-FZJ)
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No support from the LSF program of the EC was requested

Date: 14.4.2008

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Total number of particles and type of beam (p, unpolarized or polarized)	Momentum range (GeV/c)	Intensity or internal reaction rate (particles per second)	
		minimum needed	maximum useful
protons or deuterons	0.294 (at injection)	$1 \cdot 10^{10}$	$5 \cdot 10^{10}$
Type of target	Safety aspects (if any)	Earliest date of installation	Total beam time (1week)
ANKE H_2 or D_2 Cluster Target	-	August 1, 2008	1 week

Summary of experiment:

With this proposal we are focusing again on the issue of beam lifetimes at injection energy in COSY, which has been addressed already in proposal **#169** and in the beam request **#169.1**. With and without target, the presently observed beam lifetimes at COSY are roughly by a factor 15 too small compared to the theoretical expectations. This presents a major drawback and a limitation for the envisaged spin–filtering studies. We present a detailed evaluation of the COSY beam lifetimes, based on the machine optics, the known horizontal and vertical aperture restrictions, and the residual gas composition.

In order to make progress towards longer beam lifetimes, we would like to continue our investigations by a series of beam lifetime measurements with electron–cooled beam. The idea is to carry out a careful measurement of the machine acceptance with electron–cooled beam for different conditions (varying beam intensity, target on/off, etc.) using the COSY beam scraper system and the movable large aperture system, which was previously used at ANKE for the determination of the dimensions of the storage cell for the polarized internal target.

Request:
We request one week of beam time in the second half of 2008 to carry out a measurement of the machine acceptance of COSY with electron–cooled beam at injection energy of T_p = 45 MeV using the scraper system and the movable large aperture system at ANKE.

Attach scientific justification and a description of the experiment providing the following information:
For proposals:
Total beam time (or number of particles) needed; specification of all necessary resources
For beam requests:
Remaining beam time (allocations minus time already taken)

Scientific justification:
What are you trying to learn?
What is the relation to theory?
Why is this experiment unique?

Details of experiment:
Description of apparatus.
What is the status of the apparatus?
What targets will be used and who will supply them?
What parameters are to be measured and how are they measured?
Estimates of solid angle, counting rate, background, etc., and assumptions used to make these estimates.
Details which determine the time requested.
How will the analysis be performed and where?

General information:
Status of data taken in previous studies.
What makes COSY suitable for the experiment?
Other considerations relevant to the review of the proposal by the PAC.

EC-Support:
The European Commission supports access of new users from member and associated states to COSY. Travel and subsistence costs can be granted in the frame of the program Access to Large Scale Facilities (LSF).

Proposal to COSY
on

Machine Acceptance Studies with electron–cooled Beam

(ANKE and $\mathcal{PAX}$ Collaborations)

Jülich, April 2008

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Abstract

With this proposal we are focusing again on the issue of beam lifetimes at injection energy in COSY, which has been addressed already in proposal **#169** and in the beam request **#169.1**. With and without target, the presently observed beam lifetimes at COSY are roughly by a factor 15 too small compared to the theoretical expectations. This presents a major drawback and a limitation for the envisaged spin–filtering studies. We present a detailed evaluation of the COSY beam lifetimes, based on the machine optics, the known horizontal and vertical aperture restrictions, and the residual gas composition.

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Contents

1 Evaluation of beam lifetimes in COSY

The presently observed beam lifetimes of electron–cooled beams at COSY at the injection energy of $T_p = 45$ MeV are roughly by a factor 10 too small compared to the theoretical expectations with and without target. We present a detailed evaluation of the COSY beam lifetimes, based on the machine optics, the known horizontal and vertical aperture restrictions, and the residual gas composition.

1.1 Residual gas composition

We start the discussion from the measured absolute pressure distribution in COSY, shown in Fig. 1. Here, the absolute pressures between the different gauges in COSY were linearly interpolated. There are eight quadrupole mass analyzers (QMA's) installed in COSY, one

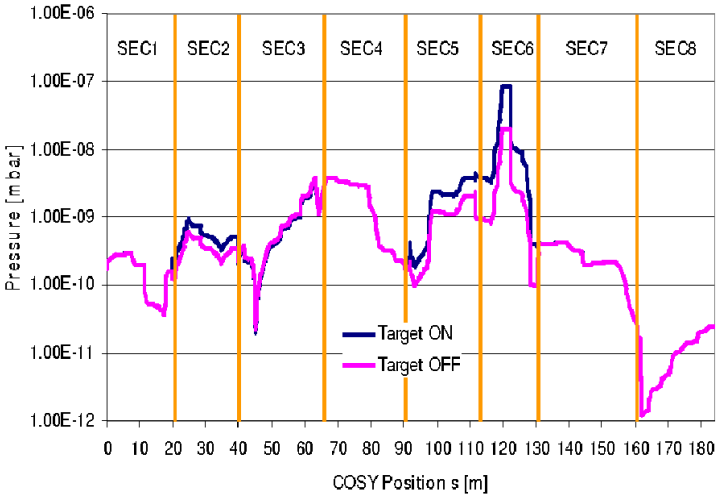

Figure 1: Pressure distribution in COSY on November 11, 2007 without and with deuterium cluster target of $d_t = (2.0 \pm 0.2) \times 10^{14}$ atoms/cm^2 at ANKE.

in each of the eight sections. Their partial pressure readings for target on and target off are listed in Table 1. The partial pressures of the most prominent gases were scaled to match the reading of an absolute pressure gauge nearby the location of each QMA. Then, using the absolute pressures in COSY from Fig. 1, the partial pressures for the most prominent gases as function of position in COSY were determined. These are shown in Fig. 2.

1.2 COSY beam optics

The β–functions of COSY for two–fold and six–fold symmetry are shown in Fig. 3. Using the horizontal and vertical aperture restrictions in COSY, r_x and r_y, one can calculate the local machine acceptance r_x^2/β_x and r_y^2/β_y, which is also shown in Fig. 3. This evaluation

Gas type	Sec. 1	Sec. 2	Sec. 3	Sec. 4	Sec. 5	Sec. 6	Sec. 7	Sec. 8
H_2	2.11E-10	1.19E-10	9.21E-10	2.10E-09	1.25E-09	4.82E-11	1.58E-10	1.23E-11
He	7.42E-13	2.27E-12	2.56E-11	6.08E-10	2.19E-09	3.39E-10	2.33E-11	1.14E-12
CH_4	3.45E-11	6.53E-11	1.34E-11	1.88E-10	1.08E-11	8.82E-12	1.14E-11	7.32E-13
H_2O	4.11E-11	8.49E-11	1.15E-11	4.67E-11	2.11E-12	2.65E-12	3.16E-12	1.93E-13
Ne	6.66E-13	3.16E-12	2.07E-12	5.33E-12	8.66E-12	8.19E-14	4.84E-13	1.91E-13
N_2	6.84E-12	3.11E-11	2.10E-11	4.58E-11	3.22E-10	5.29E-13	2.99E-12	1.22E-13
O_2	1.83E-12	8.49E-12	6.29E-13	5.44E-17	5.60E-12	7.42E-14	2.67E-14	2.63E-15
Ar	2.80E-13	3.60E-12	2.91E-12	3.32E-12	1.08E-11	1.30E-13	8.79E-13	2.34E-13
CO_2	2.87E-12	2.60E-12	2.29E-12	7.69E-12	1.97E-13	8.43E-14	2.08E-13	5.00E-14

Gas type	Sec. 1	Sec. 2	Sec. 3	Sec. 4	Sec. 5	Sec. 6	Sec. 7	Sec. 8
H_2	2.11E-10	7.83E-11	1.02E-09	2.08E-09	1.35E-09	6.40E-11	1.68E-10	1.29E-11
He	1.25E-12	1.35E-12	2.75E-11	6.27E-10	2.36E-10	1.61E-11	1.07E-11	5.44E-13
CH_4	3.53E-11	4.12E-11	1.39E-11	1.95E-10	1.26E-11	1.49E-11	1.22E-11	7.93E-13
H_2O	3.92E-11	5.50E-11	1.08E-11	3.43E-11	3.00E-12	3.52E-12	3.23E-12	2.27E-13
Ne	4.57E-13	2.22E-12	2.05E-12	4.59E-12	1.19E-11	2.03E-13	3.28E-13	2.13E-13
N_2	8.05E-12	2.29E-11	2.23E-11	5.13E-11	3.64E-10	8.79E-13	3.63E-12	1.28E-13
O_2	1.39E-12	5.20E-12	5.19E-13	2.02E-13	7.93E-12	9.37E-14	4.45E-14	2.84E-15
Ar	2.91E-13	2.28E-12	2.69E-12	3.18E-12	1.31E-11	2.17E-13	1.11E-12	1.18E-13
CO_2	2.61E-12	1.61E-12	2.48E-12	6.31E-12	5.26E-13	1.78E-13	2.99E-13	4.93E-14

Table 1: Partial pressures registered on November 6, 2007 for target on (top panel) and target off (bottom) in the eight sections of COSY for the nine most prominent residual gases.

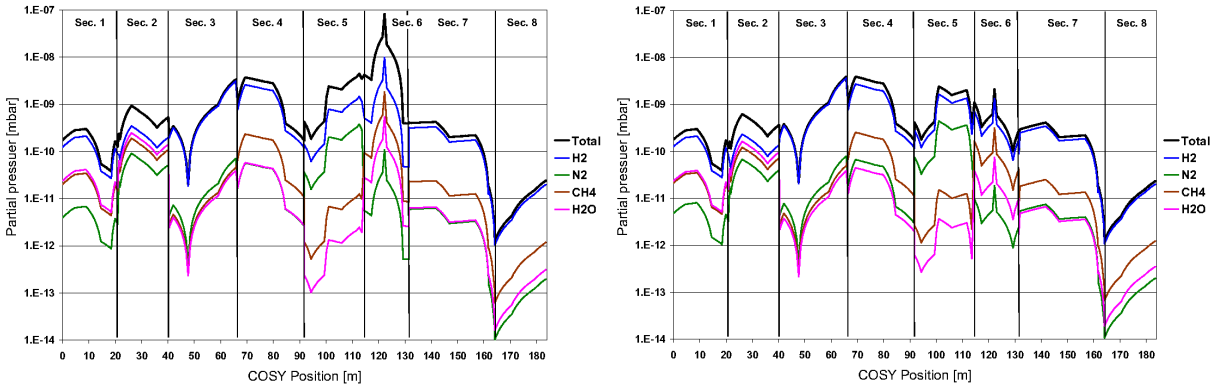

Figure 2: Partial pressures registered for target on (left panel) and target off (right) in COSY for the most prominent residual gases.

yields the machine acceptances (minima in Fig. 3) for the different symmetries, listed in Table 2.

1.3 COSY beam lifetime

With electron cooling, those particles are removed from the beam that are scattered in a single–scattering event outside of the machine acceptance. In order to estimate this effect

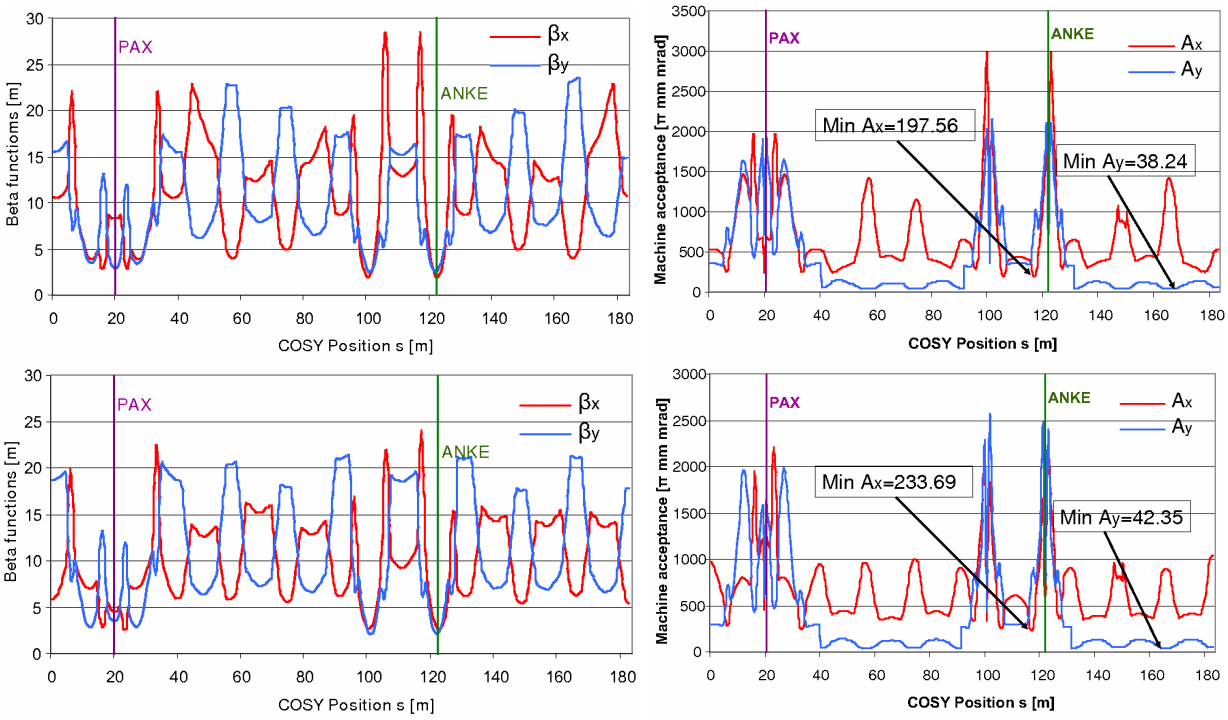

Figure 3: β–functions of COSY for two–fold (top left panel) and six–fold symmetry (bottom). The corresponding machine acceptances are shown in the two panels on the right.

	Symmetry	
Machine Acceptance	two–fold	six–fold
A_x (π mm mrad)	197.56	233.69
A_y (π mm mrad)	38.24	42.35

Table 2: COSY machine acceptance for two– and six–fold symmetry.

as accurately as presently possible, it is necessary to take into account the residual gas composition and the machine acceptance at the same time. The calculation uses as an input the machine acceptances for the different symmetries (Table 2), the residual gas composition as function of position s in COSY, and the local acceptance angle in COSY, calculated from $\theta_{acc}^{x(y)}(s) = \sqrt{A_{x(y)} \cdot \gamma_{x(y)}(s)}$. The three lattice functions $\alpha(s)$, $\beta(s)$, and $\gamma(s)$, are related via $\gamma(s) \cdot \beta(s) = 1 + \alpha(s)^2$. This procedure yields the distribution of the single–scattering losses in COSY, and also the fractional contribution of these losses to the total beam lifetime. In Fig. 4, we show for both symmetries the distribution of the Coulomb-losses in COSY. Finally, we give in Table 3 for the two symmetries the calculated COSY beam lifetimes. The discrepancy between the measured and the theoretically expected beam lifetimes, based on the COSY lattice, the aperture restrictions, and the residual gas composition is illustrated by the two graphs in Fig. 5. The highest measured beam lifetimes with and without target

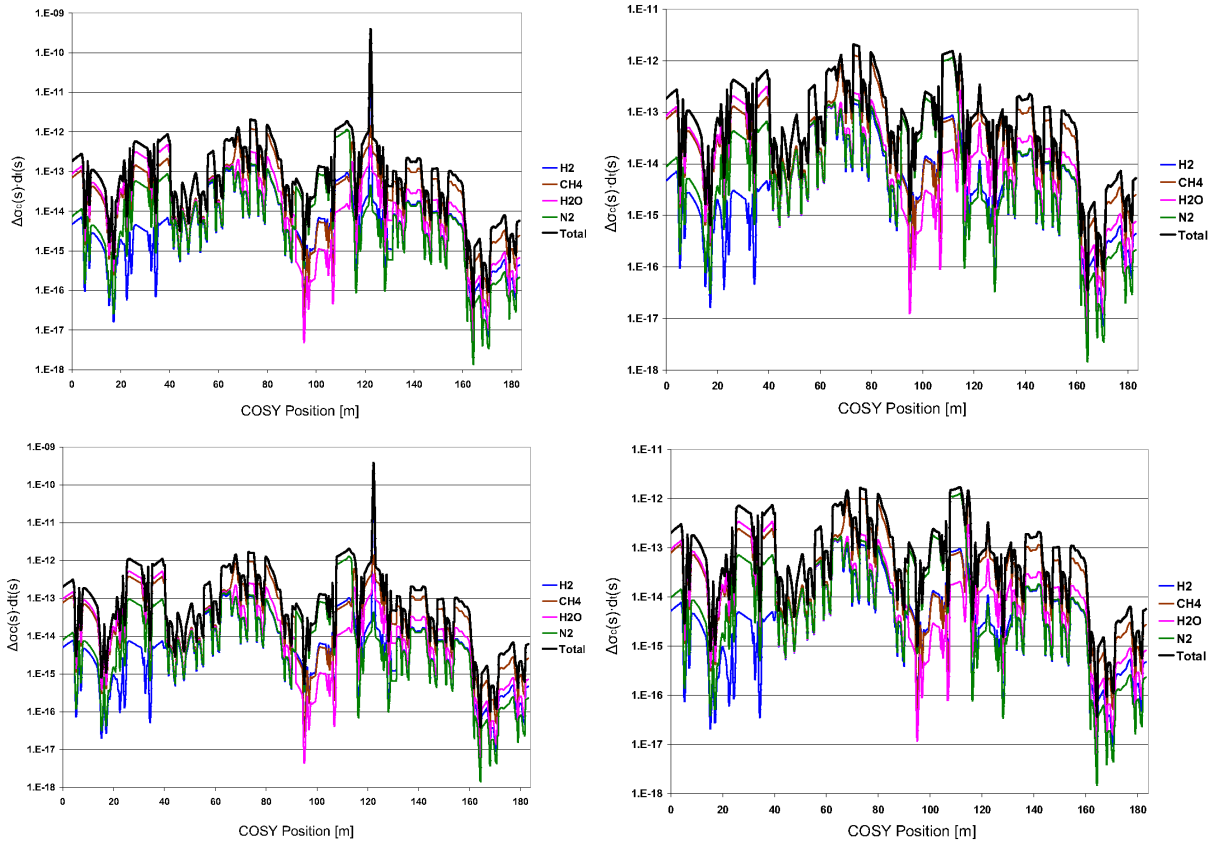

Figure 4: Coulomb–losses $\Delta\sigma_c(s) \times d_t(s)$ as function of position in COSY for two–fold (top panels) and six–fold symmetry (bottom). The panels on the left are for target on, those on the right for target off.

	two-fold symmetry		six-fold symmetry	
	τ [sec]	τ^{-1} [%]	τ [sec]	τ^{-1} [%]
H_2	5 175	91.2	5420	90.5
He	249 111	1.9	247 825	2.0
Ne	2 686 458	0.2	2 596 961	0.2
N_2	165 508	2.9	155 566	3.2
O_2	2 568 982	0.2	2 219 128	0.2
Ar	740 032	0.6	706 706	0.7
CH_4	318 280	1.5	318 007	1.5
H_2O	366 015	1.3	337 685	1.5
CO_2	1 889 444	0.2	1 914 748	0.3
τ total	**4 721**	**100.0**	**4 906**	**100.0**

	two-fold symmetry		six-fold symmetry	
	τ [sec]	τ^{-1} [%]	τ [sec]	τ^{-1} [%]
H_2	513 671	12.0	525 873	11.4
He	1 508 075	4.1	1 607 528	3.7
Ne	2 749 497	2.2	2 654 088	2.3
N_2	153 844	40.0	146 110	41.0
O_2	3 124 861	2.0	2 750 395	2.2
Ar	765 886	8.0	737 999	8.1
CH_4	368 691	16.7	375 331	16.0
H_2O	511 899	12.0	471 897	12.7
CO_2	2 056 474	3.0	2 193 266	2.7
τ total	**61 533**	**100.0**	**59 871**	**100.0**

Table 3: Contributions to the COSY beam lifetime for two–fold and six–fold symmetries for target on (left) and target off (right).

during the November run were $\tau_{\rm off} = 4639 \pm 70$ s and $\tau_{\rm on} = 321.3 \pm 0.4$ s, where a deuterium cluster target density of $d_t = (2.0 \pm 0.2) \times 10^{14}$ atoms/cm^2 was used. One can conclude, that there is a discrepancy of about a factor of 15 when one compares the theoretically expected beam lifetimes with the experimentally observed ones. It should be noted that the experimentally observed beam lifetimes can be reproduced, if one uses in the calculation instead of the machine acceptances listed in Table 2 a value of 3 π mm mrad.

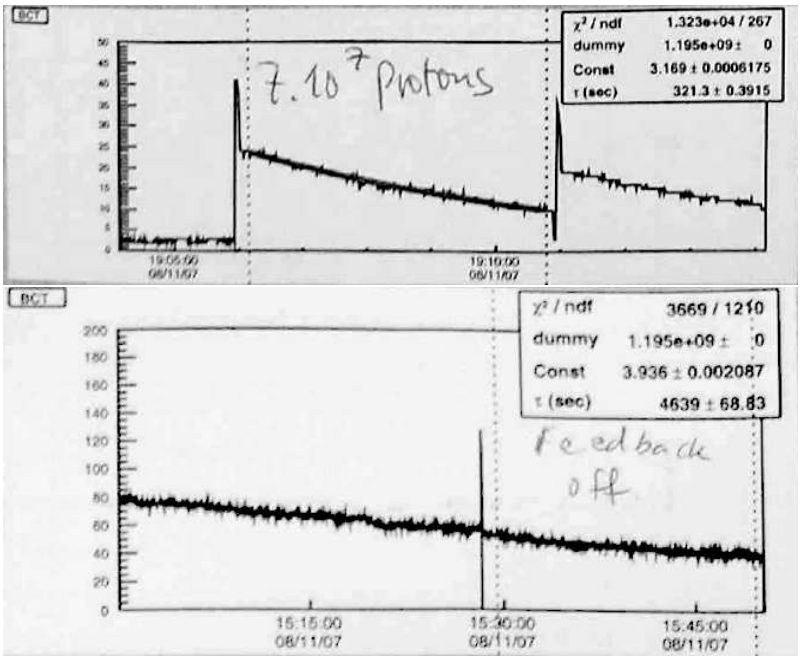

Figure 5: Measured beam lifetimes with (top panel) and without target (bottom) on November 8, 2007.

2 Beam Request

- **We request one week of beam time in the second half of 2008** to carry out a measurement of the machine acceptance of COSY with electron–cooled beam at injection energy of $T_p = 45$ MeV using the scraper system and the movable large aperture system at ANKE.