What may be measured at COSY-11 on deuteron target

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The deuteron target was successfully tested at the COSY-11 facility. Utilizing the COSY proton beam with the momentum up to 3.5 GeV/c, the CMS energy up to $\sqrt{S}$=4.2 GeV is now available. The presence of 3 baryons in the exit channel absorb roughly 2.8 GeV [1]), but additional 1.4 GeV may be used for the creation of new mesons and/or transformation of nucleons to a heavier (e.g. strange) baryons.

Since the COSY-11 acceptance is large only close to the reaction threshold, a production of particles with a narrow mass, shown in table 1, is considered in this paper. Assuming up to 6 particles in the exit channel and including conservation of the energy, momentum, charge, strangeness and the baryon number, roughly 300 different reactions may take place.

Baryons :	p, n, d, He^3, T, Λ, Σ^+, Σ°, Σ^-, Ξ^0, Ξ^-, $\Xi^\circ(1530)$, $\Xi^-(1530)$, Ω^-
Mesons :	π°, π^+, π^-, η, ω, η', $\Phi(1020)$, K^+, K^-

Table 1: Particles with a sharp mass up to 1.7 GeV/c^2

The kinematically complete reconstruction of event is possible only for some of them. The number of measured independent variables (N_{var}) have to be not less than the number of kinematical degrees of freedom (N_{free}) for the system of N outgoing particles: $N_{free} = 4 \cdot N - 4$.

It is reasonable to assume at COSY-11, that for positively charged particles (i.e.: p, d, T, He^3, π^+, K$^+$) a four-momentum vector is measured (N_{var}=4) by means of drift chambers, magnetic field and scintillators (S1, S3), as shown in fig. 1. Neutrons will be identified in the new developed neutron detector (N-det), delivering the time information as well (N_{var}=2). For negative particles (i.e.: π^-, K$^-$) the pad number of the silicon detector inside the dipole gap is registered (N_{var}=1). These assumptions reduce a set of measurable at COSY-11 reactions to 35, as shown later in tables 3 and 4.

[1]There is to few energy for the creation of a baryon - antybaryon pair.

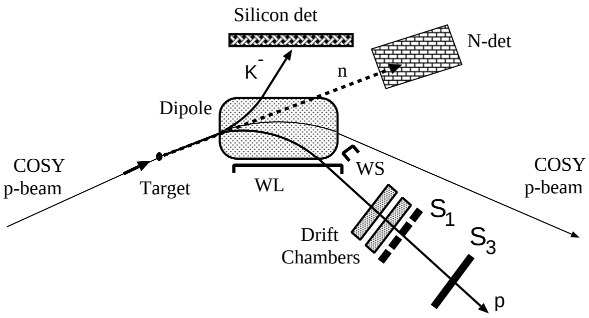

Figure 1: Detection of particles produced at threshold at the COSY-11 facility. The large (WL) and small (WS) exit windows of the scattering chamber, limiting the geometrical acceptance, are schematically sketched.

The exit windows of the scattering chamber (see fig. 1) and the finite size of the applied detectors limit a geometrical acceptance. In the momentum space, the acceptance for outgoing particle with a positive charge depends only on the ratio between its momentum vector $\vec{P_i}$ and the beam momentum P_b (see e.g. fig.5 in ref [1]).

Since at the reaction threshold all energy is used for the creation of new particles, their LAB momenta are collinear with $\vec{P_b}$ and an acceptance for any particle is described by two constances limiting the ratio $P_i/P_b \in [C_1, C_2]$.

The energy in CMS ($\sqrt{S}$) is given by $P_b = \sqrt{S} \cdot \beta^* \cdot \gamma^*$, where β^* is the CMS velocity and $\gamma^* = 1/\sqrt{1-\beta^{*2}}$. Similar holds for any outgoing particle: $P_i = m_i \cdot \beta_i \cdot \gamma_i$. At threshold $\beta^* = \beta_i$ and $\sqrt{S} = \Sigma m_j$, so finally $P_i/P_b = m_i/\Sigma m_i$.

Taking into account also a charge q_i larger than the elementary one , the acceptance limits finally depends on $m_i/(q_i\sqrt{S})$, as shown in table 2.

Since m_i and q_i are fixed it results with limits for $\sqrt{S}$, as presented in fig. 2. It is also shown there, that the COSY-11 apparatus is suitable for measurement of reactions listed in table 3. Reactions in table 4 may be

	Limits for $m_i/(q_i \cdot \sqrt{S})$
Large Window	0.05 $\longleftrightarrow$ 0.48
DC1, DC2, S1	0.12 $\longleftrightarrow$ 0.46
S3	0.25 $\longleftrightarrow$ 0.46
Small Window	0.55 $\longleftrightarrow$ 0.70

Table 2: COSY-11 acceptance for particles with a mass $\mathbf{m_i}$ and a positive elementary charge $\mathbf{q_i}$.

measured only somewhat above the threshold, where $\vec{\beta}_i \neq \vec{\beta}^*$.

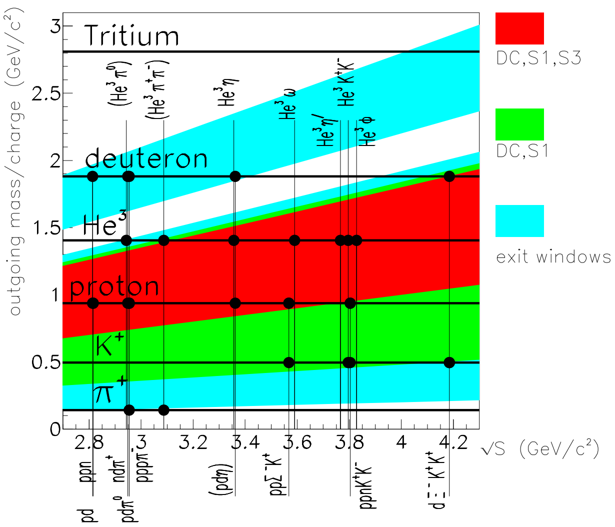

Figure 2: The grey area depict an acceptance of the COSY-11 for positively charged particles. Solid lines correspond to m_i/q_i values for particles with a positive charge. Threshold for possible to measure at COSY-11 reactions are marked by vertical lines. Reactions in brackets are at the acceptance limit.

P_{BEAM} (GeV/c)	$\sqrt{S}$ (GeV/c^2)	reaction products	variables N_{var}/N_{free}
.0792	2.8161	$p\ p\ n$	10/ 8
.6422	2.9434	$He^3\ \pi^\circ$	4/ 4
.6573	2.9489	$p\ d\ \pi^\circ$	8/ 8
.6724	2.9544	$p\ p\ p\ \pi^-$	13/12
.6734	2.9547	$n\ d\ \pi^+$	10/ 8
.9966	3.0875	$He^3\ \pi^+\ \pi^-$	9/ 8
1.5708	3.3559	$He^3\ \eta$	4/ 4
1.5822	3.3613	$p\ d\ \eta$	8/ 8
2.0125	3.5676	$p\ p\ \Sigma^- K^+$	12/12
2.0603	3.5903	$He^3\ \omega$	4/ 4
2.4341	3.7662	$He^3\ \eta'$	4/ 4
2.4978	3.7957	$He^3\ K^+\ K^-$	9/ 8
2.5145	3.8034	$p\ p\ n\ K^+ K^-$	15/16
2.5674	3.8278	$He^3\ \Phi$	4/ 4
3.3664	4.1842	$d\ \Xi^- K^+ K^+$	12/12

Table 3: Reactions detectable at threshold with 100% geometrical efficiency at COSY-11.

P_{BEAM} (GeV/c)	$\sqrt{S}$ (GeV/c^2)	reaction products	variables N_{var}/N_{free}
.6564	2.9485	$\cancel{T}\ \cancel{\pi}^+$	0/ 4
.6794	2.9570	$p\ n\ n\ \cancel{\pi}^+$	8/12
.9874	3.0835	$\cancel{T}\ \pi^\circ\ \cancel{\pi}^+$	0/ 8
1.0090	3.0930	$p\ d\ \cancel{\pi}^+\ \pi^-$	9/12
1.0140	3.0953	$p\ p\ n\ \cancel{\pi}^+ \pi^-$	11/16
1.3018	3.2277	$\cancel{T}\ \cancel{\pi}^+\ \cancel{\pi}^+ \pi^-$	1/12
1.3150	3.2339	$n\ d\ \cancel{\pi}^+ \cancel{\pi}^+ \pi^-$	7/16
1.8395	3.4849	$\cancel{d}\ \Lambda\ K^+$	4/ 8
1.8626	3.4960	$\cancel{T}\ \cancel{\pi}^+\ \eta$	0/ 8
2.0003	3.5618	$\cancel{d}\ \Sigma^\circ\ K^+$	4/ 8
2.0718	3.5958	$p\ \cancel{d}\ \omega$	4/ 8
2.3057	3.7063	$\cancel{d}\ \Sigma^-\ \pi^+\ K^+$	8/12
2.3574	3.7305	$\cancel{T}\ \cancel{\pi}^+\ \omega$	0/ 8
2.4459	3.7717	$p\ \cancel{d}\ \eta'$	4/ 8
2.5096	3.8012	$p\ \cancel{d}\ K^+\ K^-$	9/12
2.5793	3.8333	$p\ \cancel{d}\ \Phi$	4/8
2.7390	3.9063	$\cancel{T}\ \cancel{\pi}^+\ \eta'$	0/8
2.8042	3.9358	$\cancel{T}\ \cancel{\pi}^+ K^+ K^-$	5/12
2.8180	3.9421	$n\cancel{d}\ \pi^+ K^+ K^-$	11/16
2.8754	3.9679	$\cancel{T}\ \cancel{\pi}^+\ \Phi$	0/ 8

Table 4: Reactions detectable at COSY-11 only somewhat above the threshold. Particles canceled by a vertical lines do not leave the scattering chamber of COSY-11.

References

[1] J. Balewski et al., Phys. Lett. B 388 (1996) 859