MONITORING OF TENSOR POLARIZATION OF HIGH ENERGY DEUTERON BEAMS

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A method measuring tensor component of high energy polarized deuteron beams is discussed.The method is based on measurement of the tensor analyzing power in the deuteron stripping reaction. It is convenient for monitoring during long runs with the tensor polarized deuteron beams. The method was tested in the 5-day run at the JINR Synchrophasotron with 3 and 9 GeV/c tensor polarized deuterons. The results let estimate a short and long duration beam polarization unstability.

Study of tensor analyzing power T_{20} of deuteron breakup $\vec{d}A \to pX$ performed in Saclay [1] and in Dubna [2] at different ratio of proton to deuteron momenta , corresponding internal momenta up to $k = 1$ GeV/c, showed the following:

– $|T_{20}|$ reaches its maximum at $k \simeq 0.3$ GeV/c;
– Dependence of T_{20} on A of a light nucleus target is absent within the error limits up to k=0.28 GeV/c and is not exceed 10% at k <0.33 GeV/c;
– T_{20} is independent of a deuteron momentum from p_d =2.5 to 9.0 GeV/c and there is no theoretical reason to reveal p_d-dependence at higher energies;
– T_{20} is constant from k=0.23 to 0.32 in the deuteron breakup on carbon target, in accordance with Saclay and Dubna data it is equal to $T_{20}^S(k = .3) = -0.825 \pm 0.025 \pm 0.025$ and $T_{20}^D(k = .3) = -0.820 \pm 0.040 \pm 0.033$ correspondingly.

These features of deuteron stripping reaction make it possible to use it for prompt measurement of tensor polarization of deuteron beams. The procedure is reduced to measuring of proton yields in forward direction at proton momentum $p_p = 0.65 p_d$ for polarized and unpolarized beam states $(n^\pm, n^0)$:

$$p_{zz} = \frac{2\sqrt{2}}{T_{20}(0.3)}(1 - \frac{n^\pm}{n^0}).$$

There was used $T_{20}(0.3) = -0.82 \pm 0.04$ obtained by averaging the carbon target data at p_d=3.5 GeV/c (Saclay) and 9.0 GeV/c (Dubna) over k=0.23 to 0.32 GeV/c. The indicated error is a quadratic average of statistic and systematic errors of these measurements. One of the advantages of this polarimetry method is minimum requirements to equipment. At the beam line momentum resolution of dp/p=2-3% stripping protons of 6 GeV/c can be easily separated out by time-of-flight technique. Moreover, because the deuteron admixture is about 6-7% (Fig.1), p_{zz} can be measured simply by counting rate in a final focus of beam line with the corresponding correction ($\simeq 2\%$).

The method was used during 100 hour run for monitoring of tensor polarization of deuterons accelerated up to 9 GeV at Synchrophasotron from the ion source POLARIS [3]. In all, the 23 measurements have been done.

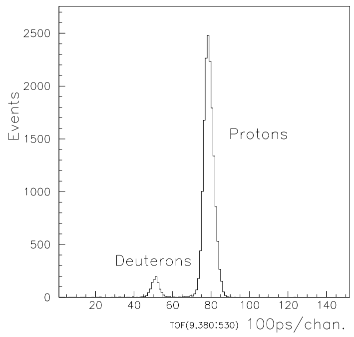

Figure 1: TOF-spectrum for 6 GeV/c positive particles emitted at 0° in 9 GeV deuteron fragmentation ($L_{TOF} = 27m$).

Results for positive and negative polarization, p^+_{zz} and p^-_{zz}, are presented in Fig.2 (denotes $p_{zz}(+)$ and $p_{zz}(-)$ are used for absolute values of $p^{\pm}_{zz}$). The averaged values of $p^{\pm}_{zz}$ over the run were equal to $p^+_{zz} = 0.676 \pm 0.012 \pm 0.033$ and $p^-_{zz} = -0.753 \pm 0.008 \pm 0.037$, which is in full agreement with ALPHA-polarimeter measurements [4]: $p^+_{zz} = 0.643 \pm 0.033 \pm 0.026$, $p^-_{zz} = -0.729 \pm 0.024 \pm 0.029$.

This agreement confirms long duration stability of polarization levels of both polarization states, p^+_{zz} and p^-_{zz}. However, χ^2 criterion shows that the dispersion of $p^{\pm}_{zz}$ points exceeds that one according to statistical errors (dp^{stat}_{zz}):
$\chi^2(+)$/n.d.f.=2.4, $\chi^2(-)$/n.d.f.=2.6. One needs to conclude, that short duration fluctuations of beam polarization dp^b_{zz} take place. The value of dp^b_{zz} can be estimated by reducing of $\chi^2(-)$/n.d.f. to 1 using the effective error
$dp^{ef}_{zz} = \sqrt{(dp^{stat}_{zz})^2 + (dp^b_{zz})^2}$.
We suppose that these fluctuations have a time structure comparable with duration of separate measurements (10-15 min) and that the signs of dp^{stat}_{zz} and dp^b_{zz} are not correlated.

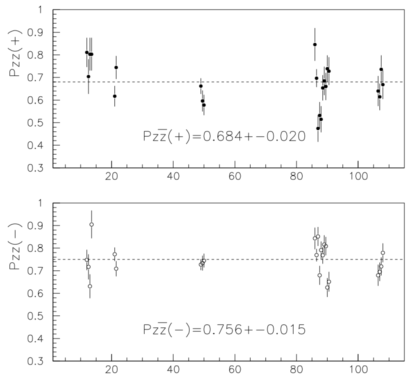

Figure 2: Results of measurement of tensor components, $p^{\pm}_{zz}$, of polarized deuteron beam in the 5-day run. Errors are the effective, dp^{ef}_{zz}.

The estimated beam polarization unstability is about 10%, it is slightly higher at (+)-state: $dp^b_{zz}(+)/p_{zz}(+) = 0.106$, $dp^b_{zz}(-)/p_{zz}(-) = 0.080$. The monitoring of beam polarization confirmed the empirical fact that the fluctuation of sum $p_{zz}(+-) = p_{zz}(+)+p_{zz}(-)$ is smaller: $dp^b_{zz}(+-)/p_{zz}(+-) = 0.060$.

To clarify the long term unstability of beam polarization there was estimated the dispersion of $p_{zz}(+-)$-values averaged within the limits of separate sets of measurements (T_{meas}=1-1.5 hours for each of sets). In this case $\chi^2(+-)$/NDF was equal to 1.4 for 5-day operation and 0.8 excluding the first day of the operation. Thus we can conclude that the beam polarization, averaged over 1-hour observation time, was stable within of $\pm 2\%$. One can assume that the factor of beam polarization unstability at long duration measurements ($T_{meas} \geq 1h$) is negligible.

In conclusion:

– The method of polarimetry based on measuring of yield of stripping protons at zero angle can be used for monitoring the tensor polarization p_{zz} of high energy deuteron beams in a wide energy range. The energy independence of T_{20} for $C(d,p)X$ is confirmed from 3 to 9 GeV experimentally. There is no reason for limitation at higher energies.

– The large stripping cross section, increasing as p_d^2, provides high statistical precision of the method.

– The optimum ratio of the proton to deuteron momenta $p_p/p_d \simeq 0.65$, corresponding the internal momentum $k = 0.3$ GeV/c, is not changed, practically, with increasing p_d.

– Systematic error of p_{zz}-measurement is estimated to be of 5%, it is determined by uncertainty of available T_{20}-data of deuteron breakup.

– The monitoring of polarized deuteron beam showed, that the short duration fluctuations of beam polarization take place; these fluctuations can cause the additional uncertainty of 10% in an analyzing power of the studied reaction at short measurements ($\simeq 10min$). In case of long duration measurements ($\geq$ 1h) influence of these fluctuations upon uncertainty of measurements is insignificant, it is estimated to be of $\leq 2\%$.

References

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