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Measurements of nucleon form factors at large momentum transfer in space-like (JLab) $e^- + p \to e^- + p$ and time-like region (GSI) $\overline{p} + p \to \ell^+ + \ell^-$, $\ell = e$ or μ.

The knowledge of nucleon electromagnetic form factors (FFs) is fundamental for the understanding of the nucleon structure. They can be experimentally measured as well as theoretically calculated. Their first determination valued the Nobel Prize to R. Hofstadter in 1961. Recent data brought new and exciting developments, due to the availability of high intensity, highly polarized electron beams, polarized targets and hadron polarimeters, in the space-like (SL) region of momentum transfer square Q^2 and high energy antiproton beams in the time-like (TL) region.

Form factors are analytical functions of Q^2, being real functions in the SL region (due to the hermiticity of the electromagnetic Hamiltonian) and complex functions in the TL region. The existing data on the magnetic proton form factor G_M show a dipole behavior $G_M(Q^2)/\mu_p = G_d = [1 - Q^2/(m_d^2)]^{-2}$, $m_d^2 = 0.71$ GeV^2 up to the highest measured value, $Q^2 \simeq 31$ GeV^2. The independent determination of both G_M and G_E FFs, from the unpolarized $e - +p$-cross section, has been done up to $Q^2 = 8.7$ GeV^2, and the further extraction of G_M assumes $G_E = G_M/\mu_p$, $\mu_p = 2.79$.

The electric FF, G_E, deduced from polarization experiment $p(\vec{e}, e'\vec{p})$ differs from G_M/μ_p, with a deviation from G_d up to 70% at Q^2=5.6 GeV^2. A measurement at Q^2 up to 9 GeV^2 is planned at JLab in 2006.

With the upgrade of JLab at 12 GeV and with the new set-up in construction in Hall C it is possible to extend the measurement of G_E up to Q^2=12 GeV^2. The new data can eventually show a zero of the electric proton form factor.

The Rosenbluth separation of the $|G_E|^2$ and $|G_M|^2$ contributions, in TL region, for the processes $\overline{p} + p \leftrightarrow e^+ + e^-$ has not been possible, due to the poor statistics. One typically assumes that the G_E-contribution plays a minor role in the cross section at large Q^2 and the experimental results are usually given in terms of $|G_M|$, under the hypothesis that $G_E = 0$ or $|G_E| = |G_M|$[1]. Data exist up to s=18 GeV^2.

The results for which a large debate is going on concern the following results.

- It has been found from polarization measurements in SL region, that the electric and the magnetic distribution in the proton, at small distances, are not equal, and that the electric charge distribution does not follow a dipole behavior, as a function of the momentum transfer, as previously assumed. However the unpolarized cross section data show a behavior compatible with dipole.

- The values of $|G_M|$ in the TL region, obtained under the assumption that $|G_E| = |G_M|$, are larger than the corresponding SL values. This has been considered as a violation of the

[1]In TL region, one uses the notation $s = q^2 = -Q^2$, $s = 2m^2 + 2Em$, E is the energy of the antiproton beam (in the LAB system of $\overline{p} + p$-collisions).

Phràgmen-Lindelöf theorem, and therefore an evidence that the asymptotic regime is not reached.

Polarization phenomena will be especially interesting in $\overline{p}+p \to \ell^+ + \ell^-$ to achieve a global interpretation of the nucleon FFs (electric and magnetic) in TL and SL momentum transfer region.

Future measurements with a polarized antiproton beam (or with unpolarized antiproton beam on a polarized proton target) address the following problems:

- The separation of the electric and magnetic FFs, through the angular distribution of the produced leptons: the measurement of the asymmetry $\mathcal{A}$ (from the angular dependence of the differential cross section for $\overline{p}+p \leftrightarrow \ell^+ + \ell^-$) is sensitive to the relative value of G_M and G_E.
- The presence of a large relative phase of magnetic and electric proton FFs in the TL region, if experimentally proved at relatively large momentum transfer, can be considered a strong indication that these FFs have a different behavior.
- The study of the processes $\overline{p}+p \to \pi^0 + \ell^+ + \ell^-$ and $\overline{p}+p \to \pi^+ + \pi^- + \ell^+ + \ell^-$, will allow to measure proton FFs in the TL region, for $s \leq 4m^2$, where the vector meson contribution plays an important role, m is the nucleon mass).

It will be possible, at the future GSI facility, to separe the electric and magnetic FFs in a wide region of s and to extend the measurement of FFs up to the largest available energy, corresponding to $s \simeq 30$ GeV^2.

This program is especially interesting with respect to the transition to the asymptotic behaviour of nucleon electromagnetic FFs, predicted by QCD, which actually gives rise to many discussions and speculations.

For these programs, collaborations exist and are open for new members. At JLab, presently, it is the G_{Ep} collaboration, at GSI the PANDA, ASSIA and PAX collaborations. AT JLab one can contributes mainly with electronics, software, participation in the future runs, data analysis and interpretation. At GSI one could contribute in all directions, as it is in the stage of conception of detectors and submission of Letter of Intent. Several European groups (especially from Italy) are already involved, France is represented only by individuals.