Polarization Measurement of laser-accelerated ^{3}He Ions

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working group 3: Laser-Plasma

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Polarized ^{3}He is of particular importance for fundamental research since the spins of the two protons are oriented anti-parallel so that the nuclear spin is basically carried by the unpaired neutron. That is why polarized ^{3}He[1] can be used, for example, as an effective polarized neutron target for studying the neutron structure by scattering with polarized electrons [Tan98]. For many experiments in nuclear and particle physics, like experiments with stored particle beams, the use of polarized ^{3}He ion beams would be advantageous.
^{3}He gas can be polarized for long time durations at standard conditions. However, building a spin-polarized ^{3}He ion source for nuclear and particle physics experiments with high degrees polarization is extremely challenging. Until now, only a few approaches could be accomplished - but not with the desired particle currents or an adequate beam polarization[2]. At Brookhaven National Lab's Relativistic Heavy Ion Collider (RHIC) a polarized ^{3}He ion beam source is currently being developed. But again, until now all approaches stood fruitless.
Conventional accelerators reach fundamental, technological, and, as one of the most important aspects, financial limits of the achievable particle energies. Some limitations essentially concerning cost-benefit relations do not apply to laser-induced particle acceleration. During the past 50 years the achievable laser intensities have been increased continously. Since the invention of chirped pulse amplification (CPA) in 1985[3], the higher-and-higher intensities have opened new applications for laser physics experiments. With a high-intense laser pulse impinge on a suitable target, a plasma is formed out of which charged particles can be accelerated to energies of several MeV.
An unsolved question in this context is the influence of the strong laser fields on the spin polarization of the particle beams. Two scenarios are possible here: either the magnetic fields of the incoming laser beam change the spin direction of the accelerated particles, or the spins are too inert so that the short laser pulse has no effect on the spin alignment of, *e.g.*, a pre-polarized target. While the first scenario has been successfully investigated by spin dependent hadronic proton scattering off nuclei in silicon[4], for the second one pre-polarized ^{3}He gas can be used as production target.
The spin-relaxation rate of polarized ^{3}He depends on several conditions, like *e.g.* gas pressure or magnetic field gradients. Also the absence of one electron in the shell decreases the polarization degree rapidly: the interaction time τ_{HF} for the coupling of the nuclear spins with the spin of the remaining electron is only around $0.2\,\text{ns}$[5]. Thus, a fully ionization of the pre-polarized ^{3}He has to be accomplished within a few picoseconds. This can be easily achieved with currently available laser intensities.
If measurements of the laser-accelerated ^{3}He ions reveal a high degree of polarization, this could also help to increase the efficieny of fusion reactors, since the relevant fusion cross sections in the plasmas are polarization dependent.
Goal of the working group is to **outline an experiment on laser-induced particle acceleration** with a subsequent **measurement of the beam polarization** as well as a **measurement of the particle yields from fusion reactions**.

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