Electromagnetic processes in strong crystalline fields
- exploring the Schwinger field

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We propose to extend the investigations by the NA43 collaboration on a number of aspects of radiation from single crystals in high energy electron and positron beams (10-300 GeV).

The knowledge gained on radiation processes by the NA43 collaboration has stimulated substantial activity in theoretical as well as supportive experimental areas that now render it very desirable to extend the measurements and pursue new phenomena. The intent is to clarify the role of a number of important aspects of radiation in strong fields - comparable to the Schwinger field, $\mathcal{E}_0 = m^2c^3/e\hbar = 1.32 \cdot 10^{16}$ V/cm, as e.g. observed in crystals.

Essentially all the equipment is existing and the desired beam is as used in NA43, i.e. 10-300 GeV electrons. The possibility of going to high energies (above 200 GeV) with an essentially parallel beam is crucial to the proposed measurements. Therefore, CERNs H2 or H4 beam is the only place where these experiments can be performed.

The comparatively high cross sections for QED processes - even for higher order contributions - mean that datataking time for each target is rather limited. The total beam time to complete the measurements is of the order 10 weeks, possibly distributed over 2-3 years, with the following main subjects:

- Klein-like trident production

  Lately, the interest in the Klein paradox has been revived through theoretical studies with wave-packets and space-time resolved simulations that reach very different conclusions concerning the probability of positron production by electrons, $e^- \rightarrow e^-e^+e^-$ so-called trident production, in a strong field. Crystals may provide the possibility of an experimental test.

- Photon splitting in a strong field

  Recently, the observation of photon-splitting has been reported in an amorphous target. The cross section for this process is calculated to be nearly doubled for reachable photon energies in the coherent fields of crystals. Thus, crystals provide the opportunity of a measurement where a number of systematic effects may be eliminated by a comparison of the aligned and non-aligned crystal rates of the process.

- Delbrück scattering in a strong field

  In the same setup as that used to measure the photon splitting, it is possible at least to set limits on the Delbrück scattering angles of photons in strong fields. Calculations for energies just below the strong field regime show that the scattering angles are too small to be measured with the intended setup, but a significant increase is to be expected in the strong field regime.

- Crystalline Undulator

  During the last 5 years the subject of a crystalline undulator - a crystal specially designed to generate an undulator-like motion of a penetrating positron - has been treated theoretically in some detail. The advantage of crystals is the much stronger fields available and therefore much higher photon energies than in a conventional undulator. The possibility of stimulated emission of photons in the MeV region has been discussed. We propose to study the undulator-like radiation emitted by a $\lesssim$10-20 GeV positron in a crystalline undulator.

- Investigations of spin-flip radiation

  During interaction with a magnetic dipole field, an electron beam slowly becomes polarized. The radiation emitted during these spin-flip transitions is of very low energy in storage rings. In crystals, however, again due to the strength of the fields, the polarization time becomes picoseconds and the emitted radiation dominates the high end of the radiation spectrum for high enough electron energies. The study of this effect was initiated by NA43 for axial orientations and we wish to continue the study using positrons and planar effects.

- Sandwich (structured) targets

  Following the succesful measurements of formation length effects (LPM test) at CERN, an investigation of the detailed behaviour of the formation length of radiation in a 'sandwich target' is planned. The 'sandwich target' provides the opportunity of 'squeezing' the formation length such as to reduce the yield of low energy photons from a stack of foils. This may be particularly useful for future photon beams generated from TeV electrons and also gives insight into the formation of gluon-jets from finite-sized interaction regions. Furthermore, interference effects reminiscent of coherent bremsstrahlung are expected to appear.