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PROPOSAL FOR THE STUDY OF K-MESIC ATOMS

by

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As was already pointed out in an earlier proposal (PH III-67/32) the study of K-mesic X rays is expected to yield information about the K^--nucleus interaction as well as about properties of the nuclei[1]. In particular it is of interest to compare the data obtained from K-mesic X rays with those available from pionic atoms. It is the purpose of this note to add more information concerning the experimental programme proposed, to describe in more detail the experimental set-up and to give a more accurate estimate about rates and background conditions.

Experimental programme

Recently K-mesic X rays have been observed at the Berkeley Bevatron for a number of nuclei throughout the periodic system[2]. These data should provide sufficient information to select suitable K-mesic X-ray transitions for a more detailed study. It can be expected that from those measurements X-ray yields will be deduced. However, it is known from studies on pionic atoms that accurate data on the meson absorption by the nucleus are rather difficult to obtain in this way. It seems to be, therefore, most interesting to concentrate in the first place on precise measurements of the energies and line shapes for a few selected X-ray transitions from which energy shifts and absorption rates can be deduced. For example, the 3d-2p transition of 63 keV in carbon should occur with a yield of $\sim$ 10%; the energy shift due to the strong K-nucleus interaction $\Delta E \approx 1$ KeV [3] and the Lorentzian width $\Gamma \sim 2$ keV [4]. As will be discussed below one should be able to obtain sufficient statistics in order to measure these parameters. The statistical accuracy which can be attained depends on the number of stopped K-mesons and the ratio of the event rate to the background rate which is difficult to predict. However, it should be pointed out that the X-ray yield for a given transition decreases with Z whereas the energy shift ΔE and the line width increase with Z. It should, therefore, always be possible to choose suitable transitions which can be measured within a reasonable irradiation time. One first would like to establish the above-mentioned effects and then try to extend the measurements towards lower yield transitions which show greater effects.

At the same time X rays originating from Σ^- atoms can be looked for.

Experimental set-up

The general lay-out of the beam was described earlier[5]. A fractional separation of the K mesons from the π mesons is achieved by passing the beam through a degrader. As a conservative working hypothesis we assume a minimum expected stop rate for the K^- of 100/burst for 10^{11} protons and a π^-/K^- ratio of 50. The incoming particles are detected by a counter telescope. The usual technique of detecting stopped pions or muons with an anticoincidence counter behind the target does not work for stopped K^--mesons since in the majority of cases charged pions with energies > 90 MeV are produced by the K^- capture process which trigger the anticoincidence counter within the resolution time of the telescope. Therefore, the separation between K^- and π^- has to be done by a Cherenkov counter placed in the beam of incoming particles which vetoes the pions, and, if necessary, by a dE/dx counter in front of the target which discriminates against fast pions. In order to stop a maximum number of K mesons and to reduce as much as possible the self absorption of X rays the target will be adapted to the beam profile and will be viewed by Ge detectors from two or three sides.

Event rate

We assume to measure an X-ray line of 63 keV in Carbon with a yield of 10% and a Lorentzian width of 2 keV. With a stopped-K^- rate of 150 K^-/s we obtain an event rate of 0.06 s^{-1} assuming a detector surface of $\sim$ 10 cm^2. If we require the statistical fluctuations of the background to amount to less than 3% of the peak and if we assume a rather pessimistic peak-to-background ratio of 2 : 1 (see below) the observation of 6000 events in the line would be sufficient and should take 28 hours of running time.

These numbers should be regarded as representative order-of-magnitude estimates. The running time is reduced if the peak-to-background ratio is greater and increases for larger transition energies where, however, not only the detector efficiency but also the background is smaller. There are broader lines and lines with yields below 10% which will require longer running times. There is a great variety of X-ray transitions and it will always be possible to select lines which are measurable with the beam conditions we may achieve.

Background

The background is important in two respects. Firstly, accidental triggers are produced causing a background below the X-ray line to be measured. Secondly, even if the background appearing in the spectrum can be kept small the singles counting rates to which the Ge detectors are subjected may be large causing a decrease in the detector resolution. We have measured the general background occurring in the East Hall of the PS with the largest Ge detector we may use ($\sim$ 10 cm^3). There is a steep increase below 30 keV, a relatively flat section between 30 and 120 keV and a decrease towards larger energies (a factor 10 between 120 and 400 keV). Without any shielding we measure 650 everts/ burst or 270 s^{-1} above 8 keV. We may estimate the effect of the beam by comparison with the background produced by the stopped π^- beam at the SC. There are 4×10^5 incoming $\pi^- + \mu^-$ from which 6×10^4 π^- are stopped near the detector and these produce 4×10^3 counts/s in the Ge detector. We, therefore, estimate for the $\pi^- - K^-$ beam an upper limit of 10^3 counts/s yielding a total of 1.3×10^3 counts/s.

1) If we assume an efficiency of only 90% for the veto Cherenkov counter, a burst length of 100 ms and a coincidence resolution of 20 ns we obtain

an accidental trigger rate

$$n_a = 1.8\ s^{-1}.$$

Taking into account the shape of the background spectrum a rate of 0.015/s occurs in the 2-keV energy band below the 63-keV K^- X-ray line. This number must be compared with the 0.06 s^{-1} quoted above yielding a peak to background ratio of 8 : 1.

2) Taking into account the PS burst length of 100 ms and the duty cycle of the SC of $\sim$ 0.3 we arrive at a singles counting rate of the Ge detector of $0.3/0.1 \times 1.3 \times 10^3 = 4 \times 10^3$ which is of the same order as the present rates at the SC experiment where we achieve very good detector resolution.

Time request

If the beam will be installed in May the time until the September shut-down is needed for setting up the beam and for tests. Since it is necessary to carry out a rather complex investigation on a variety of X-ray transitions in a selected number of nuclei we ask for 8-10 weeks of running time. Since we have very similar beam requirements as those needed for the proposed experiment on hypernuclear γ rays we are collaborating with that group on the setting up of the beam and will share part of the electronic equipment. Therefore, an alternating running of the two experiments is conceivable.

The experiment will be carried out by physicists from CERN; Institut für Experimentelle Kernphysik der Universität Karlsruhe; Max-Planck-Institut für Kernphysik, Heidelberg.

The majority of the people have already participated on measurements on pionic atoms at the SC from which experiments the studies proposed now have evolved.

References

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4) J.R. Rook, Nucl. Phys. 9B, 441 (1969).

5) G. Petrucci, B. Povh and V. Soergel, Letter of Intention CERN 1968.