Idea for a new experiment:

High-statistics study of the α-decay of the Hoyle state in complete kinematics

The CMAM data allowed us to place upper limits of $\sim 10^{-3}$ on non-sequential decay modes. R-matrix calculations suggest that the ghost of the ^{8}Be ground state contributes at the level of $\sim 0.6 \times 10^{-4}$. Therefore, if we perform a new experiment, similar to the CMAM experiment, but with higher statistics (two orders of magnitude), we should be able to observe sequential decay via the ghost. To achieve the required statistics we could run for longer time (a week instead of just 13 hours) and at higher beam intensity (e.g. 10 nA instead of just 1 nA). Getting so much beam time may prove difficult at CMAM, but in Aarhus it should not be a problem. Correct?

The primary objective is, simply, to determine the peak-to-ghost ratio. A secondary objective, which requires more statistics, could be to study the shape of the ghost.

Why bother? My hope is (though this is something we need to discuss) that we could learn something about the structure of the Hoyle state. Fig. 1 illustrates my reasoning. In (a) the three α particles are arranged in a triangle. One α particle (the top one) moves away from the others. At a separation of $r + \delta r$ it no longer feels the attractive nuclear force of the other two α particles and can escape by tunneling through the Coulomb barrier as indicated by the arrow. Similar comments apply to (b) except here the three α particles are arranged in a linear chain. The Coulomb barrier that the α particle has to tunnel through, is given by

$$V_{(a)} \sim \frac{2}{r+\delta r}$$

$$V_{(b)} \sim \frac{1}{r+\delta r} + \frac{1}{2r+\delta r} \approx \frac{3/4}{r+\delta r}$$

In other words, the Coulomb barrier is slightly smaller (by a factor 2/3) if the three α particles are arranged in a linear chain instead of an equilateral triangle. This is obviously an extremely simplified model, but nevertheless it suggests some structural sensitivity.

In Fig. 2 I have computed the decay distribution assuming $r = 5.7$ fm, $\delta r/r = 0.2$, and an experimental resolution of $\sigma = 10$ keV (the one achieved at CMAM). The size of the ghost is 0.65×10^{-4} for the triangular configuration (a) and 1.2×10^{-4} for the linear-chain configuration (b).

Note that experimental response tails could become a problem!

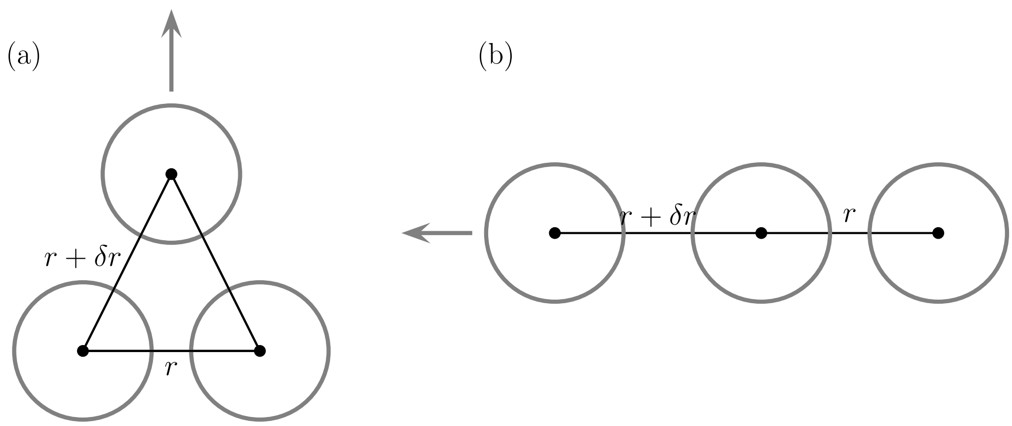

Figure 1: Configurations of three α particles.

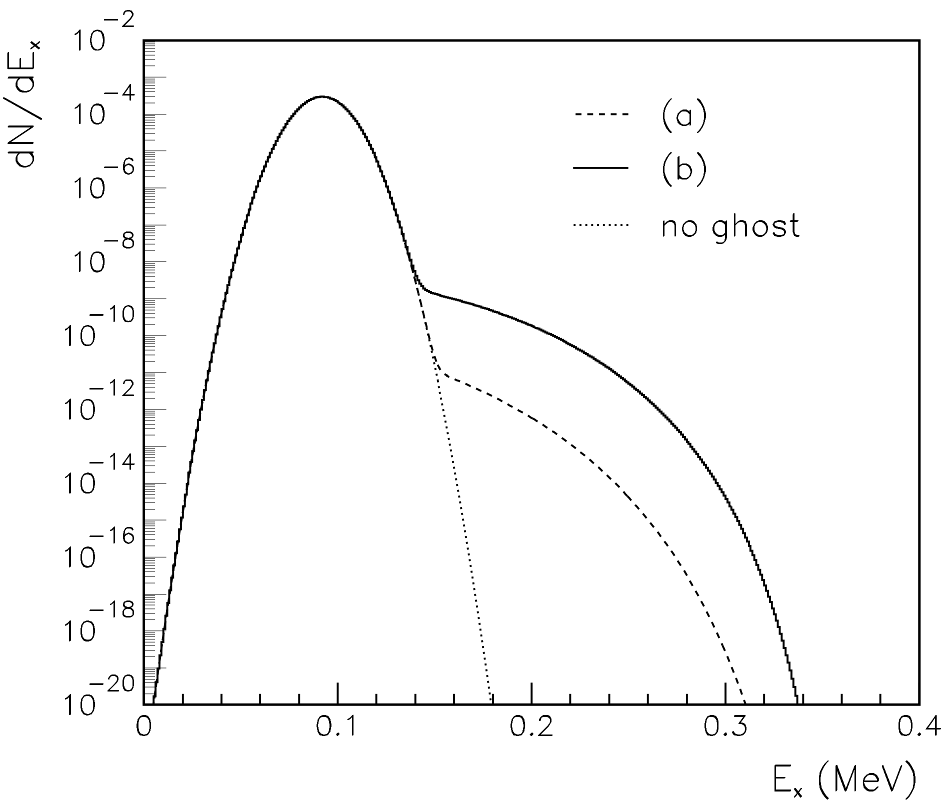

Figure 2: Decay distribution of the Hoyle state.