Charge symmetry breaking in the reaction $dd \to {}^4He\,\pi^0$

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Up and down quarks are the basic constituents of protons and neutrons which build, together with the electron, all stable elements in the universe. The interactions of protons and neutrons are nearly identical — only nearly, because the quark flavors differ in mass as well as in charge. Quark masses — or rather quark mass differences — have quite some impact on our existence. In a world with equal masses of the up and down quarks the mass difference of the proton and the neutron would be solely based on electromagnetic effects resulting in the proton being heavier than the neutron. In such a world the proton — instead of the neutron — would have a finite lifetime and stable hydrogen atoms could not exist. Individual quark masses, however, are not directly accessible by experiments. Instead, net effects of quark mass differences or quark mass ratios in hadronic reactions serve as experimental observables.

The approximate symmetry between up and down quarks is called isospin symmetry, any differences showing up when one replaces an up quark by a down quark, or vice versa, are signatures of broken isospin symmetry — like the proton-neutron mass difference. Experiments studying those effects typically have to deal with two major challenges: the isospin symmetry breaking signature of the signal is i) small compared to isospin symmetry conserving contributions and ii) often dominated by the electromagnetic effects mediated via the $\pi^0 - \pi^\pm$ mass difference. This can be avoided by selecting a certain class of possible reactions.

A special case of isospin symmetry is charge symmetry describing the interchange of up and down quarks and, thus, a rotation by 180° around the I_2 axis in isospin space. As the $\pi^0 - \pi^\pm$ mass difference is symmetric under this transformation it does not contribute to charge symmetry breaking signals and one gets sensitive to quark mass effects. In addition, one can choose such observables which would vanish in a charge symmetric world. Examples are the forward-backward asymmetry in the reaction $np \to d\pi^0$ and the pion production amplitude in $dd \to {}^4\text{He}\pi^0$. Both signals are quite small and a careful design of the experiments is essential for a successfull measurement.

In this working group we will focus on the reaction $dd \to {}^4\text{He}\pi^0$. We will start with the necessary theoretical basics for this particular experiment, work out the demands on the detector based on the reaction kinematics and finally come up with a proposal on how to perform the measurement.