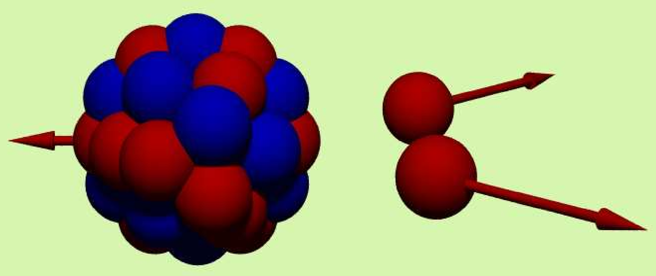
The Optical Time Projection Chamber for imaging of nuclear decays

K. Miernik[1], H. Czyrkowski[1], M. Ćwiok[1], R. Dąbrowski[1], W. Dominik[1], A. Fomichev[2], M. Golovkov[2], Z. Janas[1], W. Kuśmierz[1], M. Pfützner[1], A. Rodin[2], S. Stepantsov[2], R. Slepnev[2], G. M. Ter-Akopian[2], R. Wolski[2]

[1] Institute of Experimental Physics, University of Warsaw, Poland; [2] Joint Institute for Nuclear Research, Dubna, Russia

1. Two-proton radioactivity



$^{45}Fe \rightarrow {}^{43}Cr + 2p$

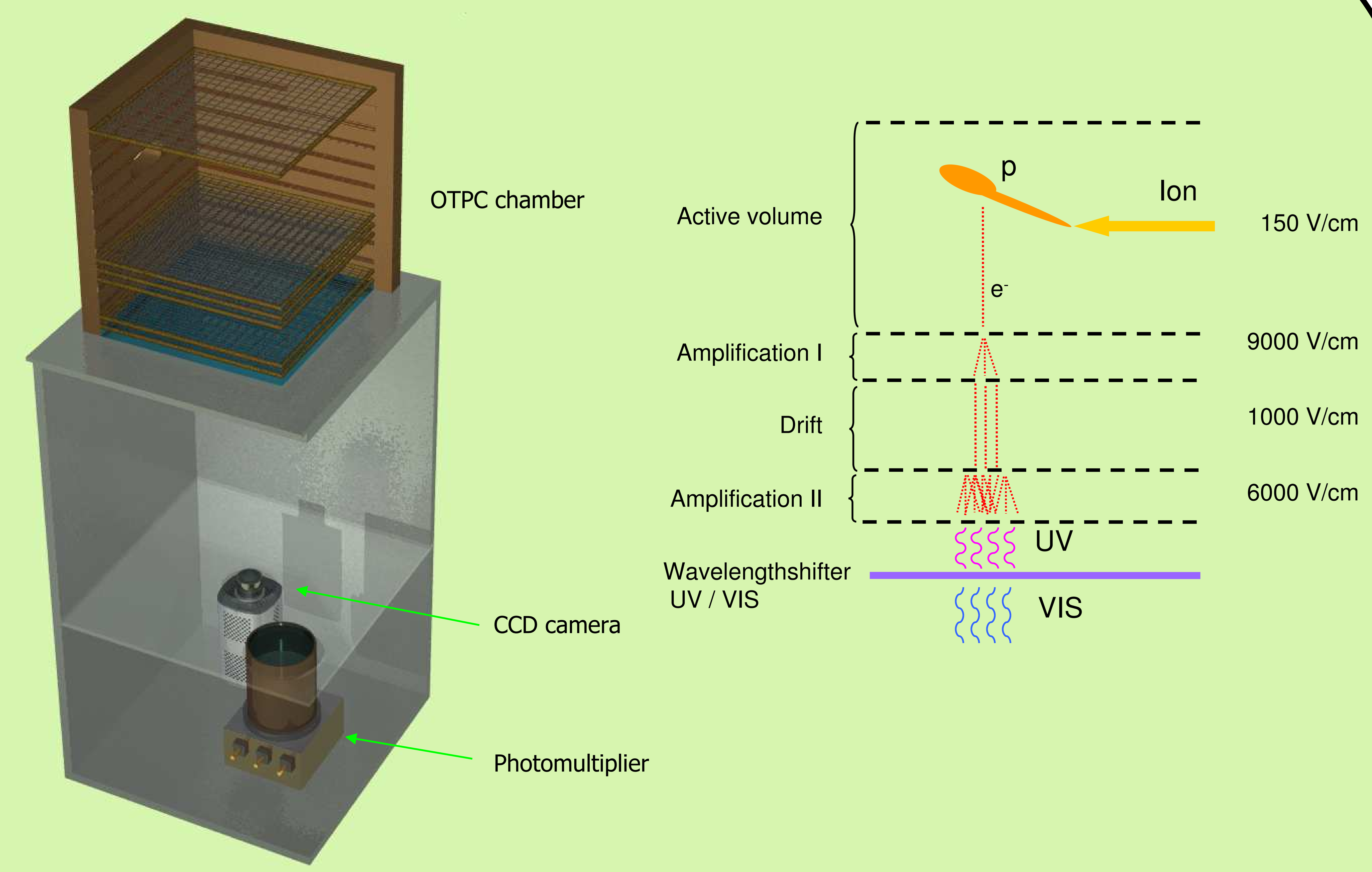
$E_{2p} \approx 1$ MeV

$T_{1/2} \approx 3$ ms

Recently, a new type of radioactive decay was observed in which an extremely neutron-deficient atomic nucleus in the ground state emits two protons simultaneously. The first evidence for the two-proton radioactivity has been obtained for ^{45}Fe nucleus in the experiment performed at the GSI Darmstadt [1]. The technique of ion implantation into a silicon detector was employed. The decay energy and the ion life-time were the only observables that could be established until now. Determination of the mechanism of the 2p-emission was the main motivation behind the development of a new experimental device. The angular correlations between protons have to be measured in order to distinguish between different theoretical models. This creates a challenge of recording tracks of low-energy protons emitted in the decay of ^{45}Fe.

[1] M. Pfützner, Eur. Phys. J. A 14, 279 (2002)

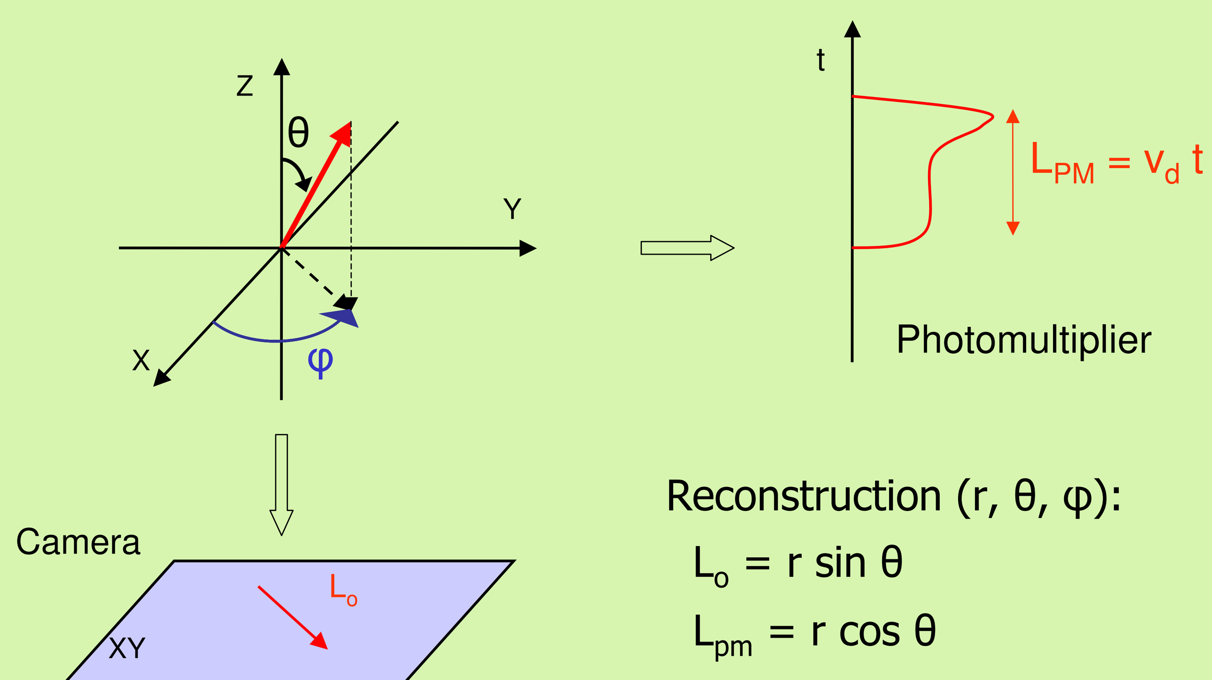
2. OTPC detector



The detector module, designed for geometrical reconstruction of the 2-proton decay topology, consists of a gaseous volume of uniform electric field in which reactions investigated occur. Primary ionization charges appearing in the reaction volume drift towards an amplification structure composed of flat and parallel wire-mesh electrodes. Light emitted during charge avalanche process in the vicinity of the last electrode, after UV/Visible conversion in a WLS foil, is recorded simultaneously by means of a CCD camera and a photomultiplier. Optical Time Projection Chamber (**OTPC**) allows the 3-D detection by combining the image of reaction projected on the electrode plane with the drift-time profile recorded by the PM.

The detector was designed and constructed in the Institute of Experimental Physics of Warsaw University.

3. Decay event reconstruction



The image recorded by the CCD camera corresponds to the projection of the ionizing particle track onto XY plane. The time structure recorded simultaneously by the photomultiplier allows one to measure the track projection on Z axis.

Both, the energy deposited and the particle charge can be measured by analysing the optical trace structure.

Reconstruction (r, θ, φ):

$L_o = r \sin\theta$

$L_{pm} = r \cos\theta$

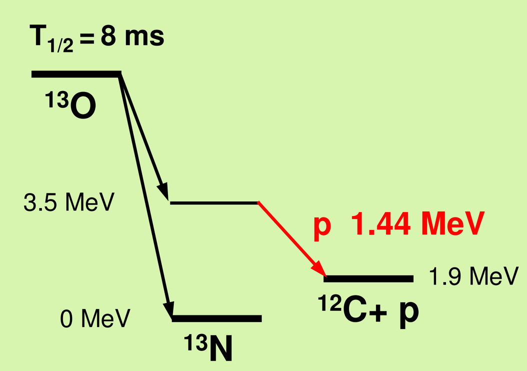
$r^2 = L_o^2 + L_{pm}^2$

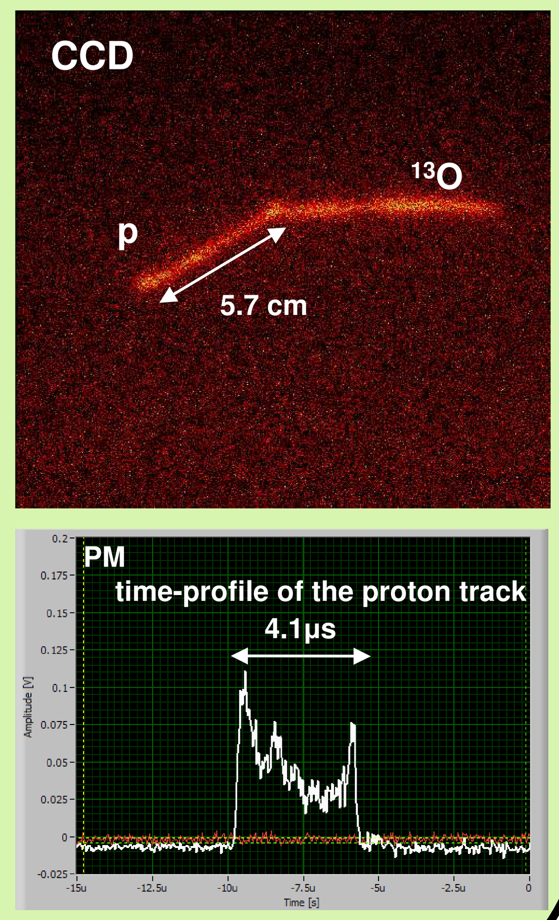
$\Theta = \arctan(L_o/L_{pm})$

4. Detector tests

The prototype unit of 20×20×15cm^3 active volume, filled at atmospheric pressure with the gas mixture of 49%Ar + 49%He + 1%N_2 + 1%CH_4, has been tested with the radioactive ions produced in Acculinna facility of JINR in Dubna. The decays of ^{13}O, ^{12}N i ^{8}Li nuclei with charged particle emission were observed.

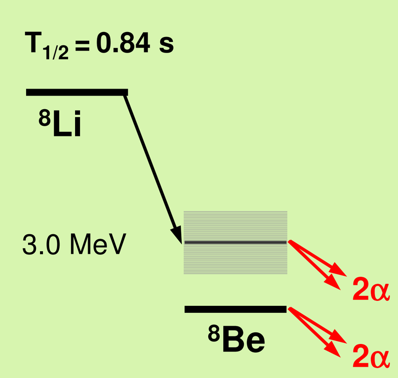
5. Protons from the decay of ^{13}O

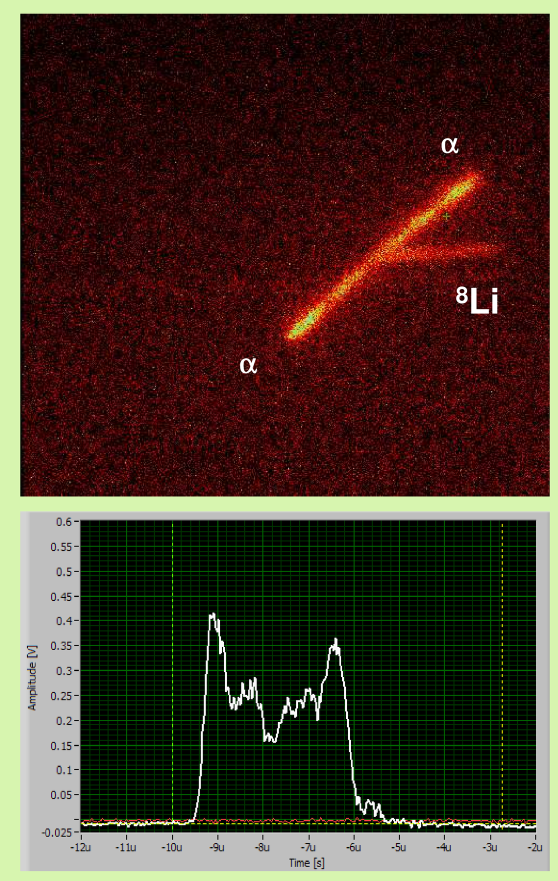




^{13}O ion stops in the active volume of the OTPC and after 6 ms it decays to an excited state of ^{13}N. The successive emission of proton of energy 1.44 MeV at $\theta = 145°$ is observed.

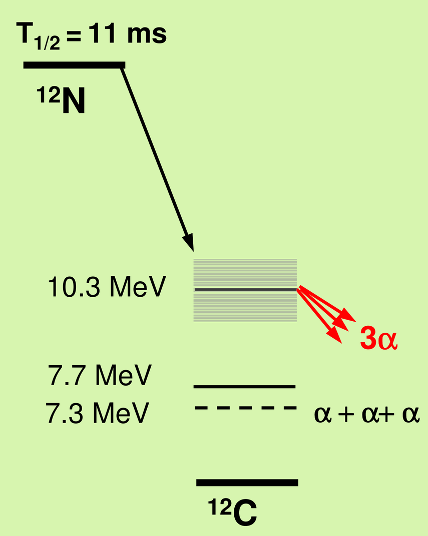
6. 2α decay of $^{8}Be^{*}$

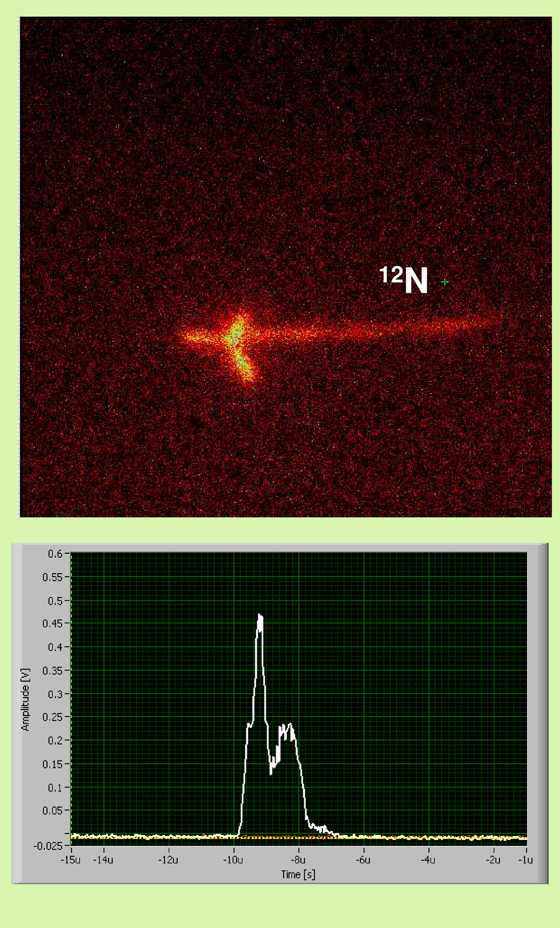




^{8}Be nucleus in an excited state breaks up into two α particles emitted back-to-back.

7. 3α decay of $^{12}C^{*}$





^{12}C nucleus in an excited state decays into three α particles.