Helium-4 Collaboration

^{4}He Photoneutron Cross Sections between 20 and 40 MeV

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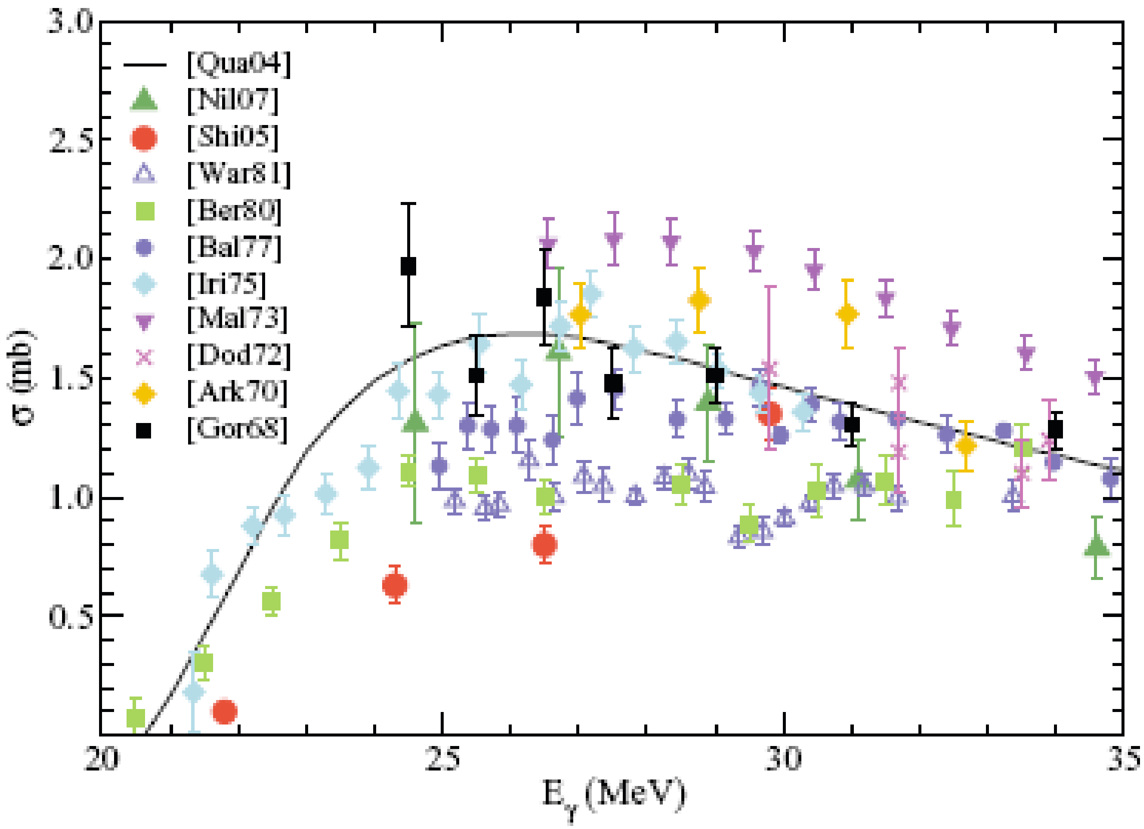


Total cross-section $^4He(\gamma,n)^3He$ reaction
by W.Tornow *et al.* Phys. Rev. C85, 061001 (R) (2012)

Discrepancy of data of different laboratories amounts up to 2 times

Experiment Summary

We will measure the $^{4}He(\gamma, n)$ cross section in the energy range 20 MeV to 40 MeV. This is to address the long standing uncertainty in the absolute value and shape of the photoneutron cross section in this energy range. We propose a careful measurement that realistically controls systematic uncertainties. We aim for final uncertainties of the order 3%. Such a measurement will be in a position to discriminate between nucleon-nucleon interactions in a comparison with theoretical calculations using, for example, the Lorentz Integral Transform technique.

The research of the structure of ^{4}He nucleus

Table 1. Probabilities of the states with spin S = 0, 1 and 2 for ground state of ^{4}He nucleus .

Interaction	*S(%)*	S^1*(%)*	*P(%)*	*D(%)*
AV18	85.45	0.44	0.36	13.74
CD-Bonn	88.54	0.50	0.23	10.73
AV18+UIX	82.93	0.28	0.75	16.04
CD-Bonn+TM	89.23	0.43	0.45	9.89

by Nogga *et al*. Phys. Rev. **C65**, 054003 (2002).

It is obvious from the Table 1 that the consideration of the 3N forces contribution increases the probability of $^3P_0$ states by a factor of ~2.

We propose for the research of structure of ^{4}He nucleus to use reaction $^4He(\vec{\gamma},n)^3He$

In the E1, E2 and M1 approximations, the laws of conservation of the total momentum and parity for two-body *(γ,n)* reaction of ^{4}He nuclear disintegration permit two multipole transitions with the spin *S*=0 and four transitions with *S*=1 of final-state particles

Table 2. Angular distributions for E1, E2 and M1 multipoles

Spin of final-states	Multipole transition	Angular distribution
S=0	E1 $\|{}^1P_1\|^2$ E2 $\|{}^1D_2\|^2$	$\sin^2\theta$ $\sin^2\theta\cos^2\theta$
S=1	E1 $\|{}^3P_1\|^2$ M1 $\|{}^3S_1\|^2$ M1 $\|{}^3D_1\|^2$ E2 $\|{}^3D_2\|^2$	$1+\cos^2\theta$ isotropic $5 - 3\cos^2\theta$ $1-3\cos^2\theta + 4\cos^2\theta$

The sum of total cross sections of transitions with the spin *S*=1 is ~10^{-2} of the total cross section of the reaction.

The origin transitions with spin S=1 can be conditioned by the contribution of meson exchange currents (MEC). In addition, these transitions can take place from $^3P_0$ states ^{4}He nucleus.

We will consider the value: $\alpha = \dfrac{\sigma(\gamma, n; S=1)}{\sigma_1(\gamma, n; S=0)}$, where

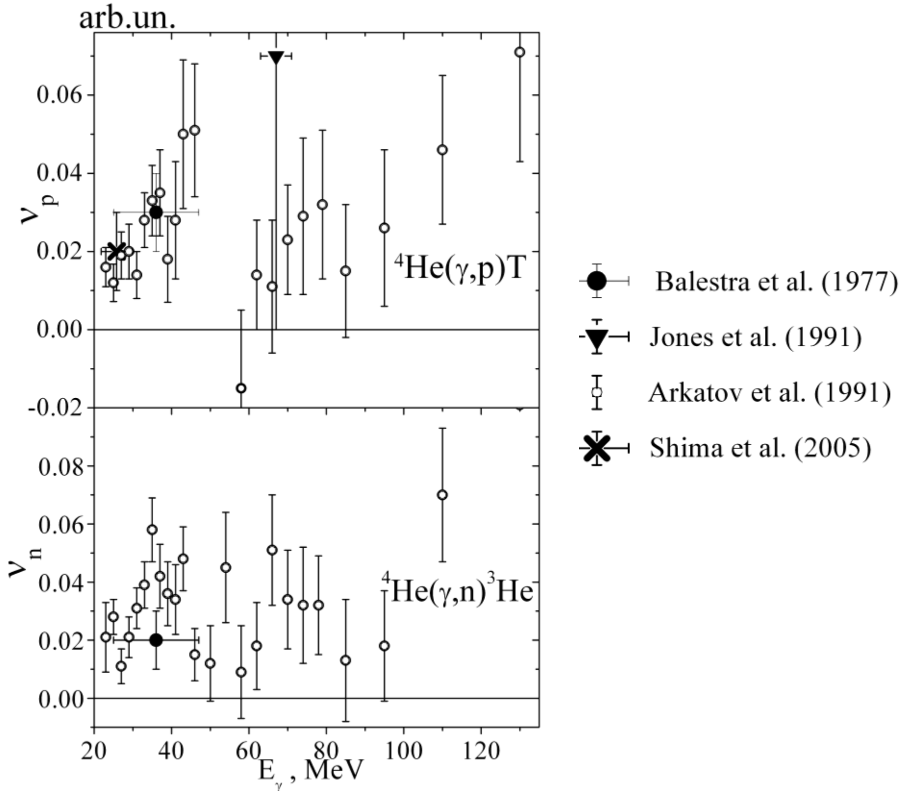
$\sigma(\gamma, n; S=1)$ -total cross-section of the transitions with the spin S=1

$\sigma_1(\gamma, n; S=0)$ -total cross-section of the main electrical dipole transition with the spin S=0

It should be noticed, that the MEC contribution depends on the photon energy and accordingly, the value α will depend on the photon energy

If transitions with spin S=1 come from $^3P_0$ states, than the value α may not depend on the photon energies

We analyzed available experimental data about transitions with the spin of *S*=1

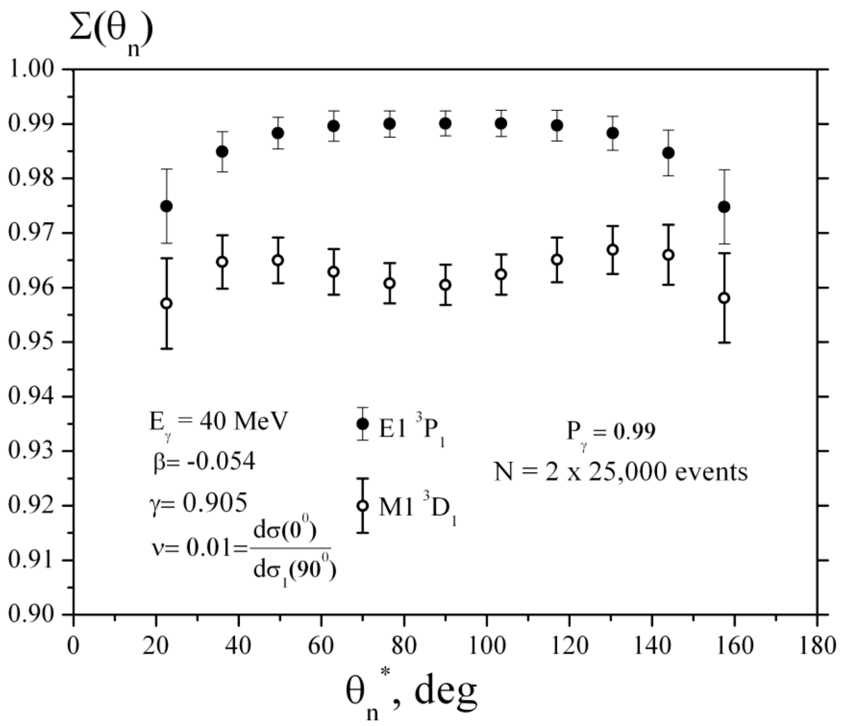


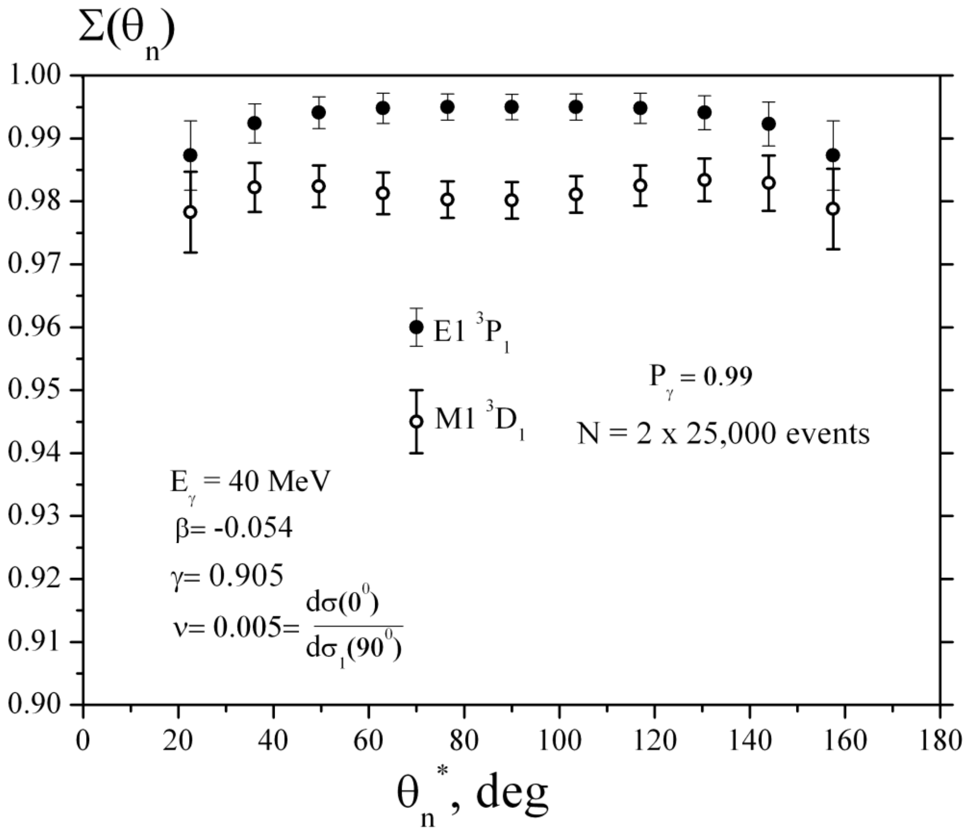
It can be seen from the figures that within the statistical errors the ratio of the cross-section in collinear geometry of the *S*=1 transitions to the cross-section of the electrical dipole transition with the spin *S* = 0 at the angle of nucleons emission $\theta_N = 90^0$ ν_p and ν_n in the range $22 \leq E_\gamma \leq 100$ MeV is independent of the photon energy. $\bar{\nu}_p = 0.01 \pm 0.002$ *and* $\bar{\nu}_n = 0.015 \pm 0.003$

What transition with the spin S=1 is the main one?

- Available in literature experimental data about transitions with spin S=1 are contradictory
- The transition M1$^3S_1$ is conditioned by S-wave final-state particle system, and can be supposed, that this transition is the main only at the reaction threshold
- It can also be supposed, that the E2 $^3D_2$ amplitude is the smallest
- New information about transitions with spin S=1 can be received by measuring the angular dependence of the $\Sigma(\theta_n)$ asymmetry of the cross-section reaction with linear polarized photons

We propose to conduct measuring $\Sigma(\theta_n)$ in to as possible more wide area of energies of photons, for example, at E_γ = 27 MeV and E_γ = 40 MeV.





Angular dependent asymmetry of the cross section of Σ(θ) reaction $^{4}He(\vec{\gamma},n)^{3}He$ for $E1^{3}P_{1}$ and $M1^{3}D_{1}$ transitions is varied

Thus:

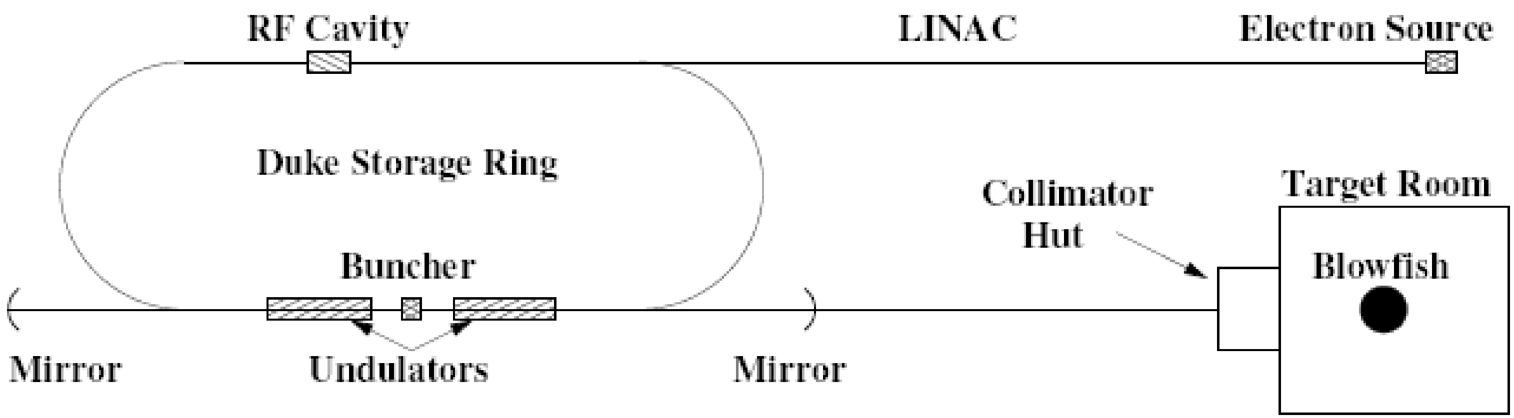
- If the dominant transition, which gives a contribution to ratio ν, is $E1\,^3P_1$ than the executing integration of proper angular distribution over the solid angle, we obtain:

$$\alpha = \nu$$

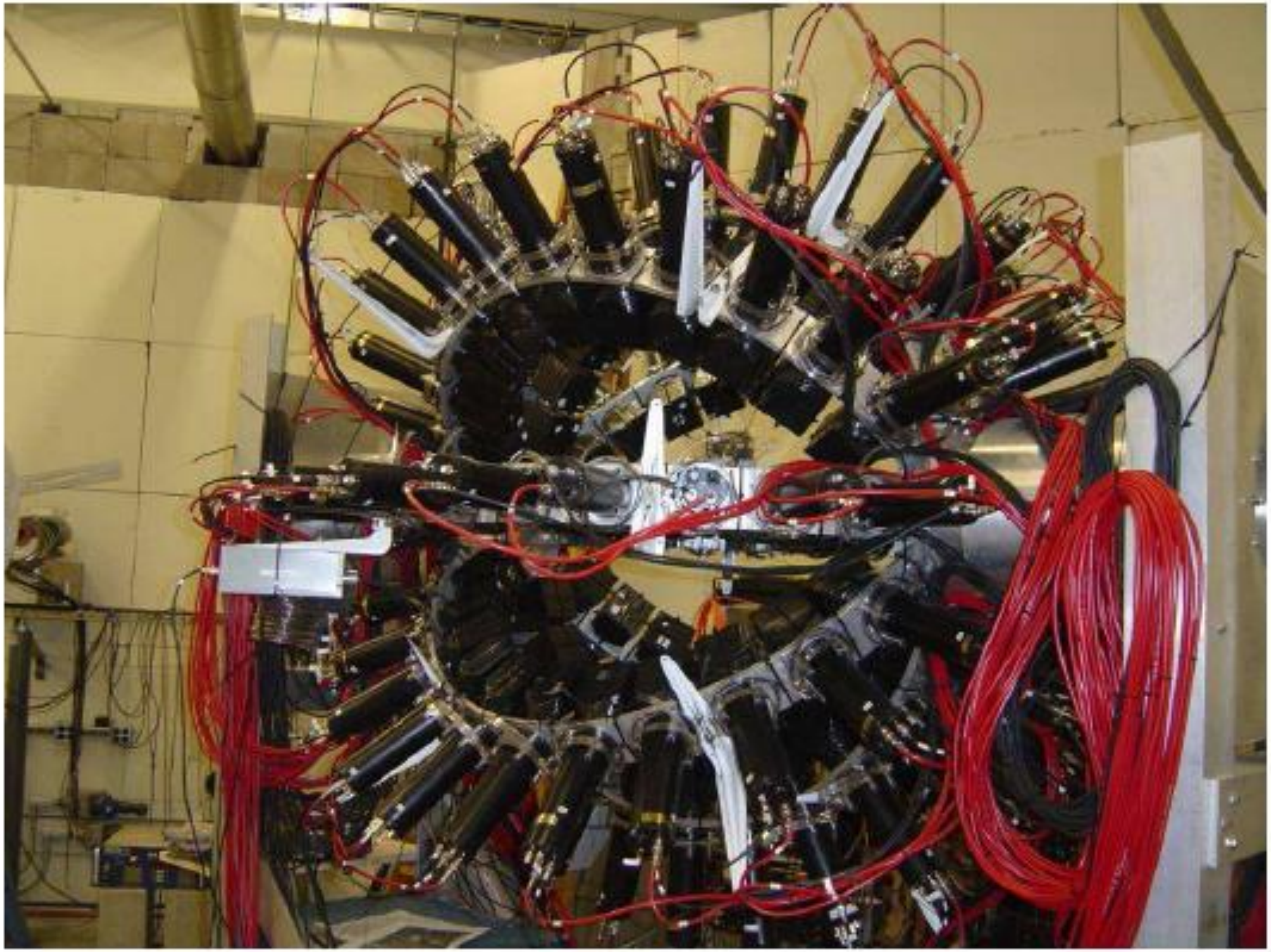
- If the dominant transition with the spin S=1 is the $M1\,^3D_1$ transition, then:

$$\alpha = 3\nu$$

High Intensity Gamma-Ray Source (HIGS)



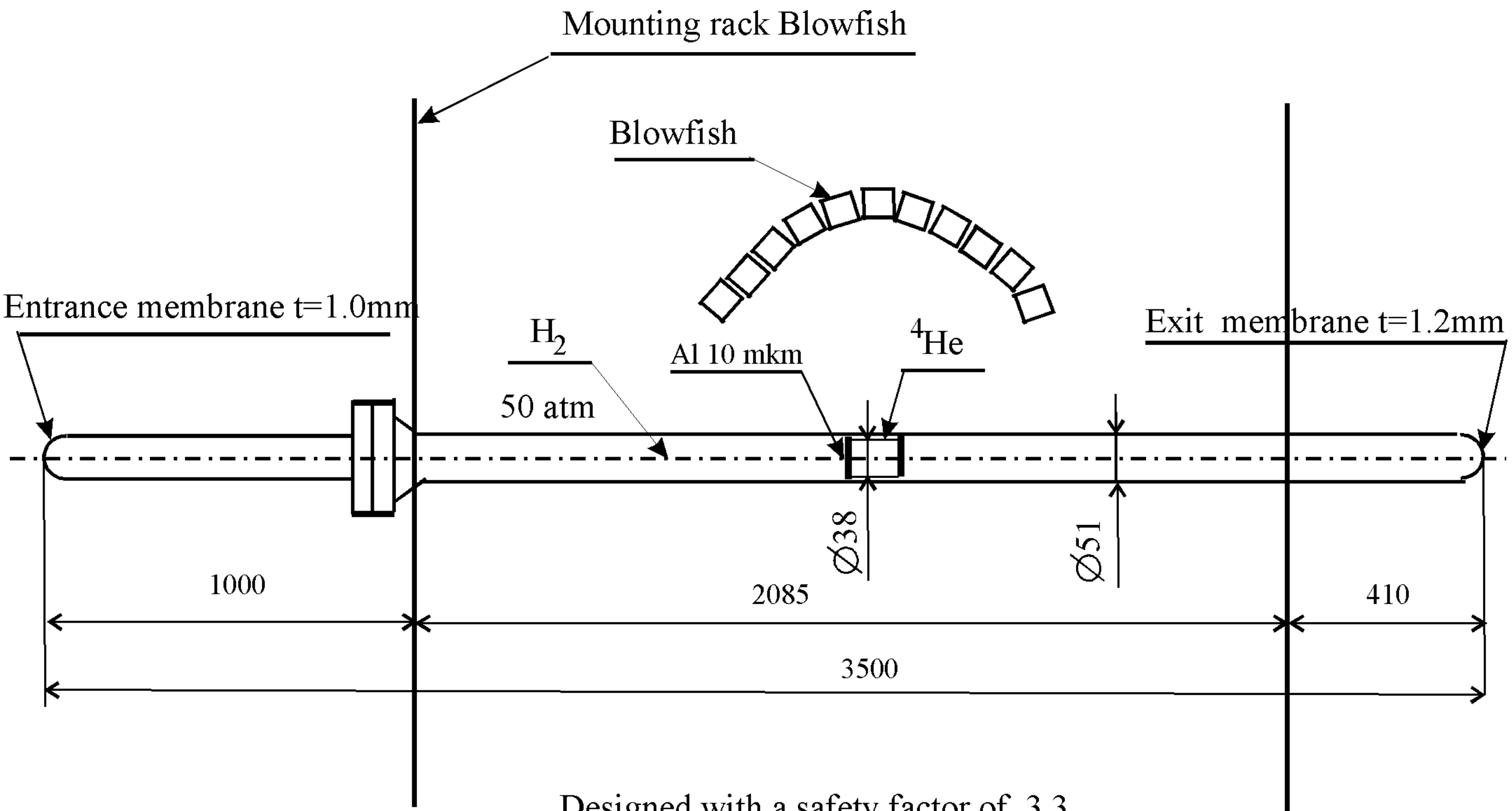
The wide-acceptance neutrons detector: Blowfish Detector Array.



Helium-4 Collaboration possess two different types of nucleus targets:

1. Helium cryogenic target
2. Gas target of helium

The scheme of the gas target of helium

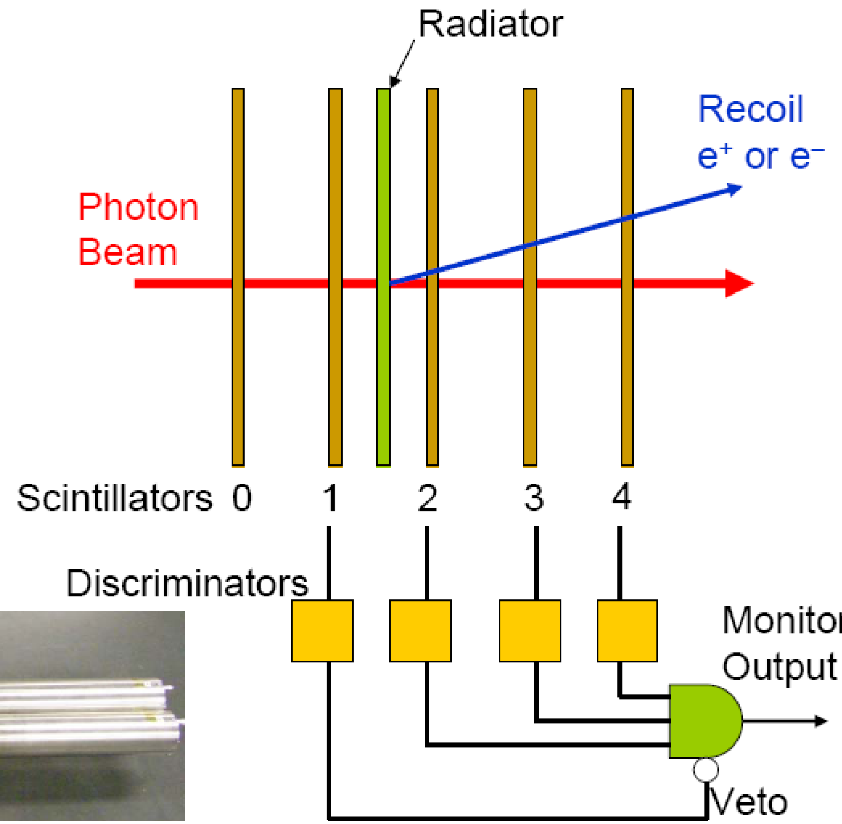


Designed with a safety factor of 3.3

A gas target provides possibility of turn of Blowfish on a angle $\varphi = 90^0$

Photon Flux Monitor

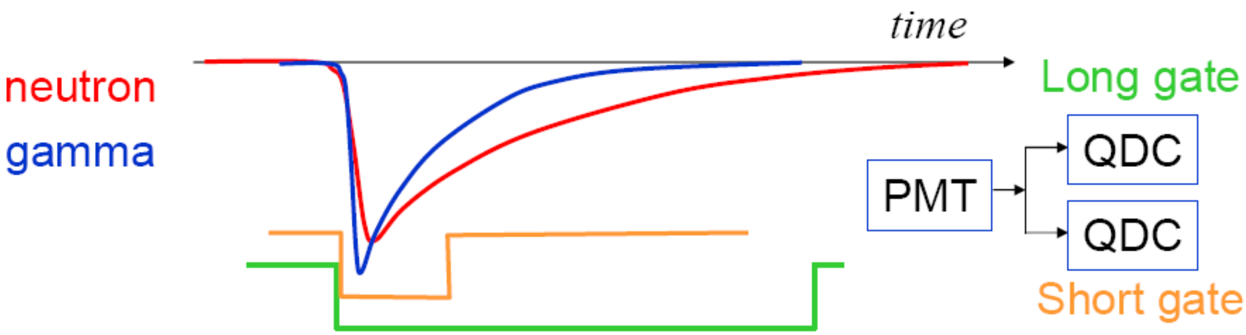
- Detects recoil electrons and positrons from a radiator.
- Described well with a GEANT4 simulation.
- Gains can be monitored by sampling paddle spectra.



Pulse Shape Discrimination

- Fortunately the is a way to tell the difference between recoil protons (neutrons) and recoil electrons (photons).
- Because of the different way electrons and protons deposit energy in the BC-505, the resulting scintillation light has a different time structure.

Signal from the photomultiplier:



Conclusions

1. In the result of the experiment will be measured the total cross-section of the $^{4}He(\gamma,n)^{3}He$ reaction with the final uncertainty of ~ 3-5%

2. The measurement of angular dependence of asymmetry $\Sigma(\theta)$ of the reaction cross-section allows to receive new information about multipole transitions with the spin S=1.

3. The experimental equipment meets the requirements of this experiment.