Searching for η-mesic ^{3}He with WASA-at-COSY facility

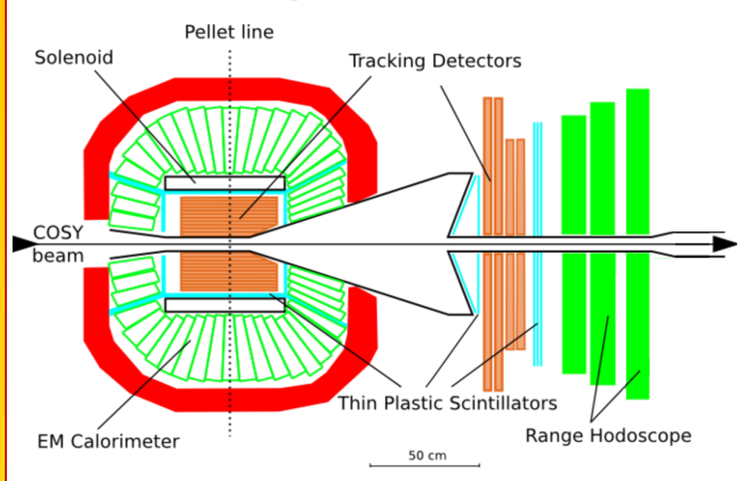
O. Rundel[1], O. Khreptak[1], M. Skurzok[1], P. Moskal[1,] W. Krzemień[1,2] for the WASA-at-COSY collaboration

1. M. Smoluchowski Institute of Physics, Jagiellonian University, 30-059 Cracow, Poland
2. National Centre for Nuclear Research, 05-400 Otwock, Świerk, Poland

Introduction

The scientific aim of this project is an experimental confirmation of the existence of mesic-nucleus: a new kind of nuclear matter consisting of nucleons and mesons bound via strong interaction. The existence of such mesonic matter was postulated in 1986 [1], however till now it was not confirmed experimentally. The discovery of η-mesic bound systems would give unique possibility for better investigation of the meson-nucleon interaction in nuclear medium, it would provide information about nucleon N^* (1535) resonance [2], about η meson properties in nuclear medium [3] as well as about the η meson structure [4,5].
We search for the **^{4}He-η** [6,7,8] and for **^{3}He-η** bound states using the WASA-at-COSY detector, installed at the cooler synchrotron COSY of the Research Center Jülich.
The poster presents the preliminary results of the data analysis.

Experiment



Beamtime: May 19 – June 2, 2014
Beam momentum ramped from **1.426 GeV/c** to **1.635 GeV/c**
Excess energy: $Q \in (-70, 30)$ MeV

Production and decay of ^{3}He-η

We search for the decay of the ^{3}He-η via two mechanisms:

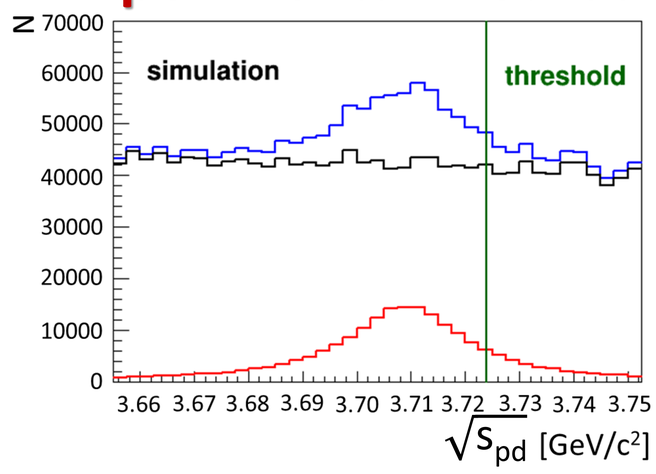
- absorption of the η meson and excitation of one of the nucleons to an N^* resonance, which subsequently decays into $N-\pi$ pair:

$$pd \rightarrow (^3\text{He-}\eta)_{bound} \rightarrow ppp\pi^-$$
$$pd \rightarrow (^3\text{He-}\eta)_{bound} \rightarrow pp n\pi^0$$

- decay of the η meson while "orbiting" around a nucleus:

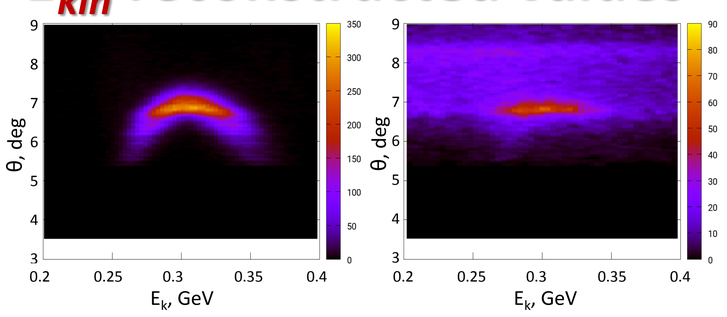
$$pd \rightarrow (^3\text{He-}\eta)_{bound} \rightarrow {}^3\text{He}2\gamma$$
$$pd \rightarrow (^3\text{He-}\eta)_{bound} \rightarrow {}^3\text{He}6\gamma$$

Experimental method



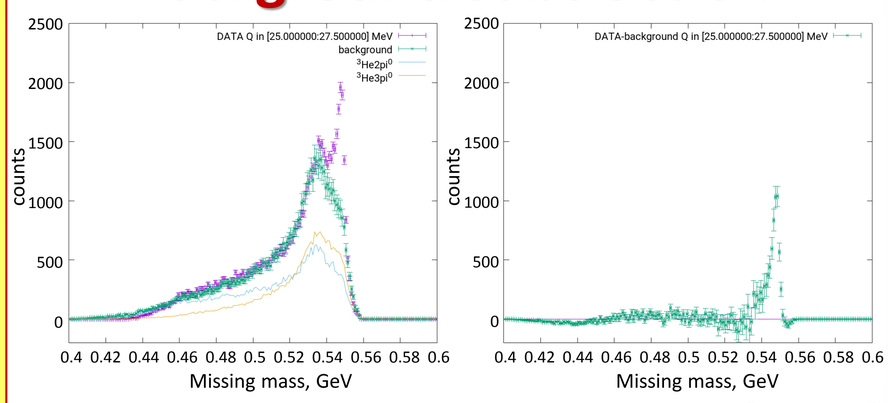
$pd \rightarrow pp n\pi^0$ and $pd \rightarrow (^3\text{He-}\eta)_{bound} \rightarrow pp n\pi^0$
$pd \rightarrow pp n\pi^0$
$pd \rightarrow (^3\text{He-}\eta)_{bound} \rightarrow pp n\pi^0$
$(^3\text{He-}\eta)_{bound}$ existence manifested by resonant-like structure below η production threshold

The distribution of θ and E_{kin} reconstructed values



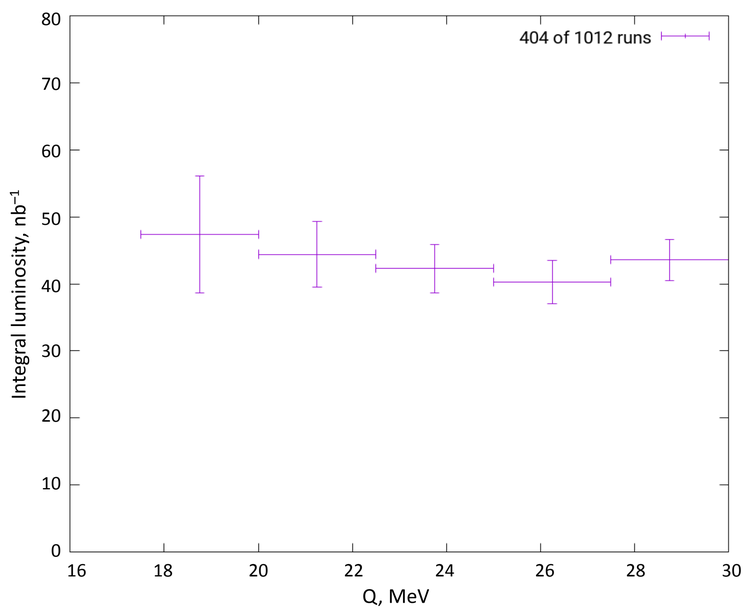
Left: Monte Carlo simulation: $pd \rightarrow {}^3\text{He}\eta$. Right: Data obtained in the experiment (after P_{beam} correction and E_{kin} correction). For the bin of $Q_{^3\text{He}\eta} \in [25.0; 27.5]$ *MeV*.

Background subtraction



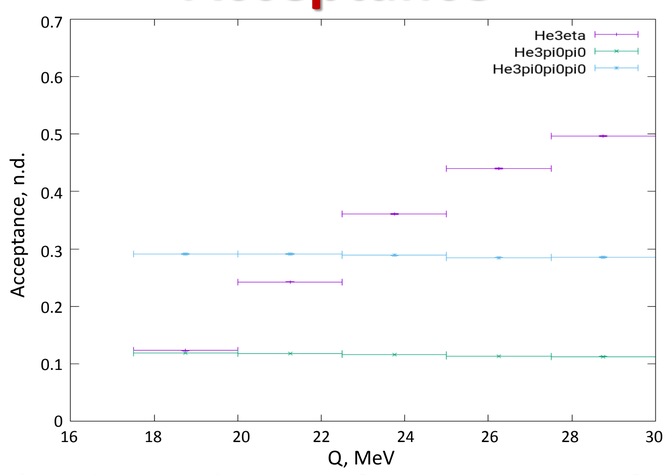
Left: background caused by $pd \rightarrow {}^3\text{He}2\pi^0$ and $pd \rightarrow {}^3\text{He}3\pi^0$ reactions.
Right: foreground $pd \rightarrow {}^3\text{He}\eta$ process missing mass spectrum obtained via background subtraction

Estimation of the luminosity



The estimation of the experiment's luminosity obtained from analysing $pd \rightarrow {}^3\text{He}\eta$

Acceptance



The dependence of acceptances for $pd \rightarrow {}^3\text{He}\eta$, $pd \rightarrow {}^3\text{He}2\pi^0$ and $pd \rightarrow {}^3\text{He}3\pi^0$

If we assume constant integral luminosity for all bins (40 bins) equal to 50 nb^{-1}:

$$\int L dt = 50 \cdot 40 \cdot \frac{N_{total\ runs}}{N_{analysed\ runs}},$$

where $N_{total\ runs} = 1012$ runs; $N_{analysed\ runs} = 404$ runs.
Then $\int L dt \approx 4500\ nb^{-1}$.
Experiment time: $t = 2$ weeks $\approx 10^6\ s$.
So, we got the value of the luminosity:

$$L \approx 4.5 \cdot 10^{30}\ cm^{-2}s^{-1}.$$

For the $(^3\text{He-}\eta)_{bound}$:
~ 270 nb – present experimental upper limit $ppp\pi^-$ [9]
~ 80 nb – theoretical estimation [10]
~ 15 nb – sensitivity expected from new WASA-at-COSY data

[1] Q. Haider, L. C. Liu, *Phys. Lett.* **B 172** 257 (1986). [2] D. Jido, H. Nagahiro, S. Hirenzaki, *Phys. Rev.* **C 66**, 045202 (2002). [3] T. Inoue, E. Oset, *Nucl. Phys.* **A 710**, 354–370 (2002). [4] S. D. Bass, A. W. Thomas, *Acta Phys. Polon.* **B 41**, 2239–2248 (2010). [5] S. D. Bass, A. W. Thomas, *Acta Phys. Polon.* **B 45**, 627–638 (2014). [6] W. Krzemień, *Ph.D. Thesis, Jagiellonian University, 2011, arXiv: 1202.5794*. [7] M. Skurzok, *Ph.D. Thesis, Jagiellonian University, 2015, arXiv:1509.01385*. [8] P. Adlarson *et al., Phys.Rev.* **C87** (2013) 035204. [9] P. Moskal, J. Smyrski, *Acta Phys. Polon.* **B41** (2010) 2281. [10] C. Wilkin, *Acta Phys. Pol.* **B45** (2014) 603.