Search for η-mesic ^{3}He in the $pd \to dp\pi^0$ Reaction Using the WASA-at-COSY Detector

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September 30, 2020

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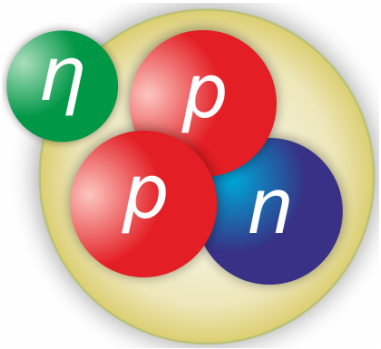
An η-mesic nuclei

The scientific aim of our research is experimental confirmation of the existence of *mesic nucleus*: a new kind of nuclear matter consisting of nucleons and mesons.



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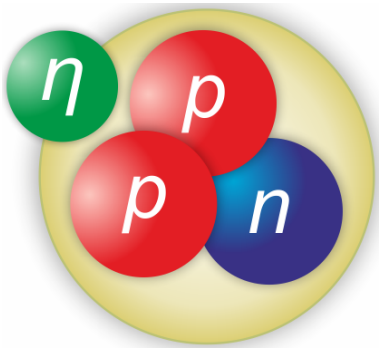

In 1986 Haider and Liu [1] postulated the existence of η mesic nuclei in which the η meson is bound within a nucleus via the strong interaction, however, until now it has not been confirmed experimentally.

[1] Q. Haider, L. C. Liu, *Phys. Lett. B* **172** (1986), 257.

Status of the search for η-mesic helium with WASA

$(^4\text{He-}\eta)_{bound}$

- **2008**: $dd \to {}^3\text{He}p\pi^-$ reaction [2]
- **2010**: $dd \to {}^3\text{He}p\pi^-$ and $dd \to {}^3\text{He}n\pi^0$ reactions [3]

[2] P. Adlarson *et al.*, *Phys. Rev. C* **87** (2013) 035204.

[3] P. Adlarson *et al.*, *Nucl. Phys. A* **959** (2017) 102.

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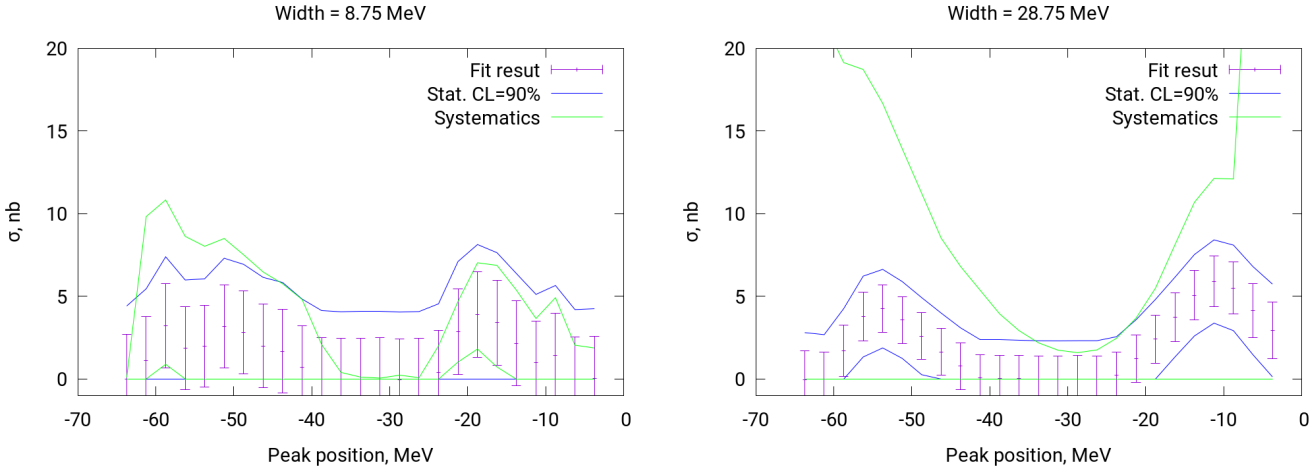
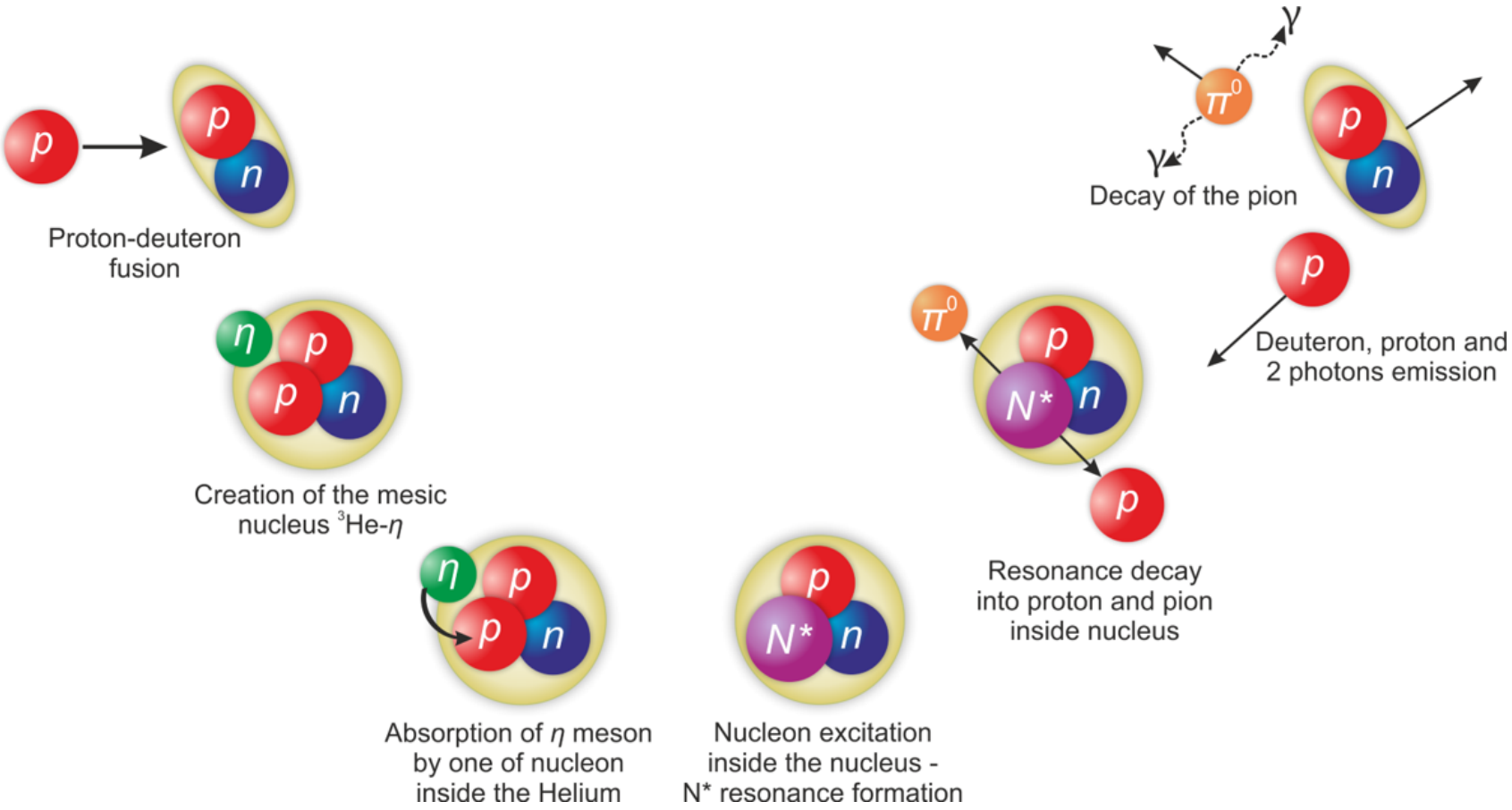
- **2014**: $pd \to {}^3\text{He}2\gamma$ and $pd \to {}^3\text{He}6\gamma$ reactions [4]



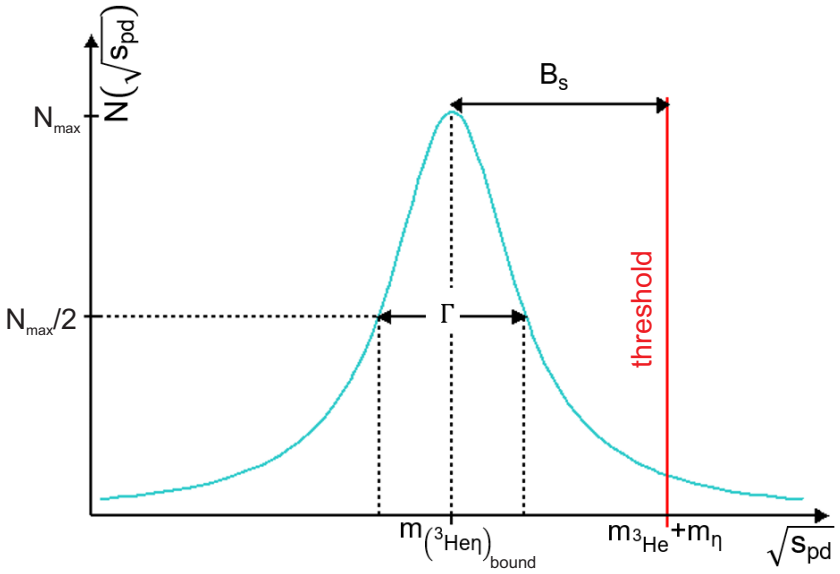
[4] P. Adlarson *et al.*, *Phys. Lett. B* **802** (2020) 135205.

Kinematical mechanism of the $pd \to (^3\text{He-}\eta)_{bound} \to dp\pi^0$ reaction

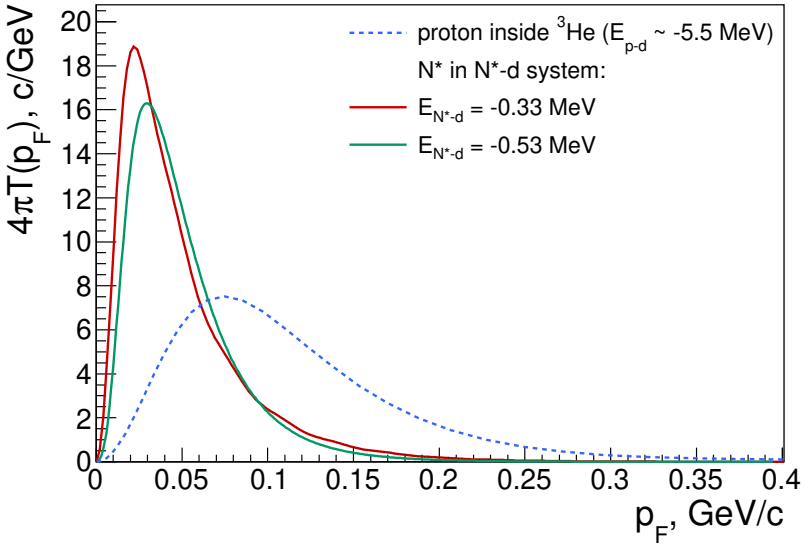


Simulation assumptions

Breit-Wigner distribution



N* momentum distribution [5]



Breit-Wigner formula

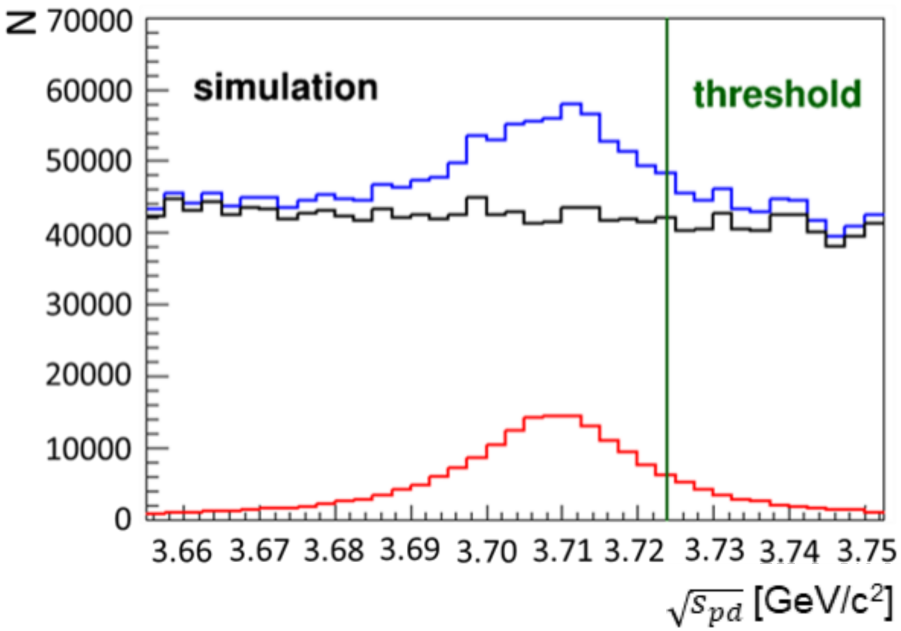
$$N(\sqrt{s_{pd}}) = \frac{\Gamma^2/4}{\left(\sqrt{s_{pd}} - (m_\eta + m_{^3He} - B_s)\right)^2 + \Gamma^2/4}$$

$$B_s \in (0, 40)\ MeV; \Gamma \in (5, 50)\ MeV$$

[5] N. Kelkar *et al.*, *Int. J. Mod. Phys. E* **28** (2019) 1950066; *Nucl. Phys. A* **996** (2020) 121698.

Experimental method

The signatures of the η-mesic nuclei are searched for by studying the excitation function for the decay channel of the ^{3}He-η system in the vicinity of the η production threshold



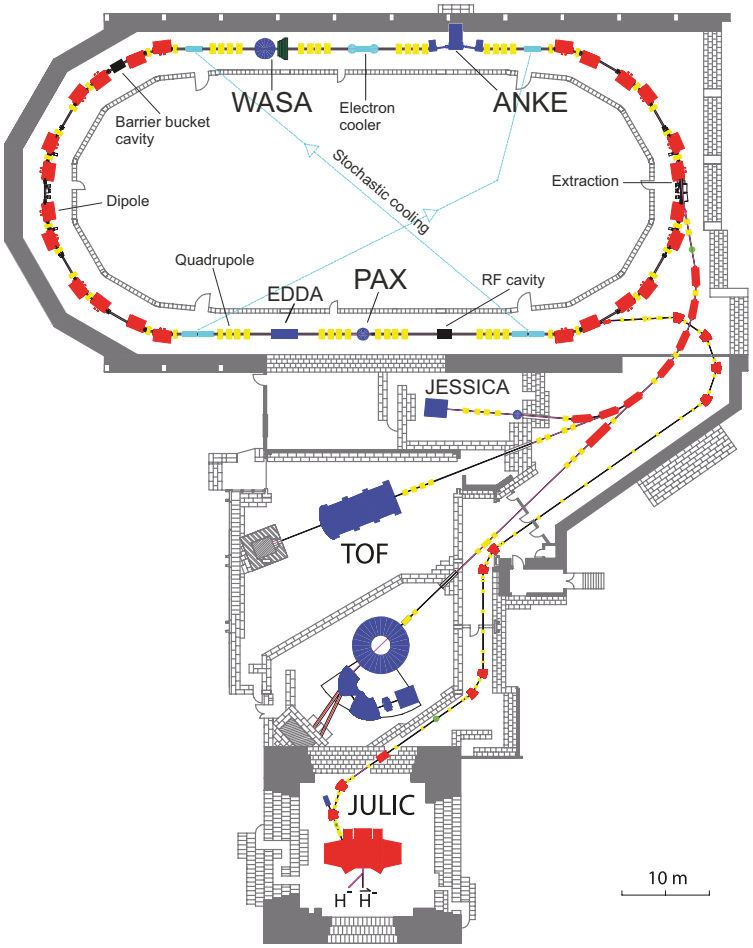
$pd \to dp\pi^0$ and $pd \to (^3\text{He-}\eta)_{bound} \to dp\pi^0$

$pd \to dp\pi^0$

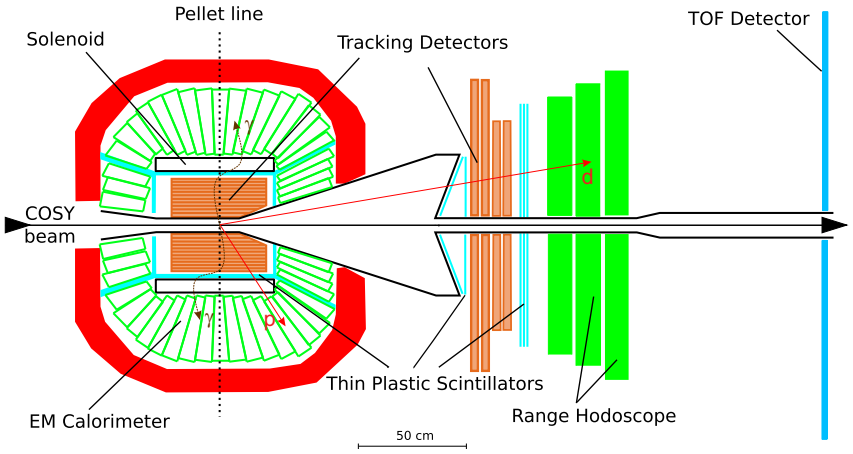
$pd \to (^3\text{He-}\eta)_{bound} \to dp\pi^0$

Experiment: May 2014 [6]

COSY (**Co**oler **Sy**nchrotron)



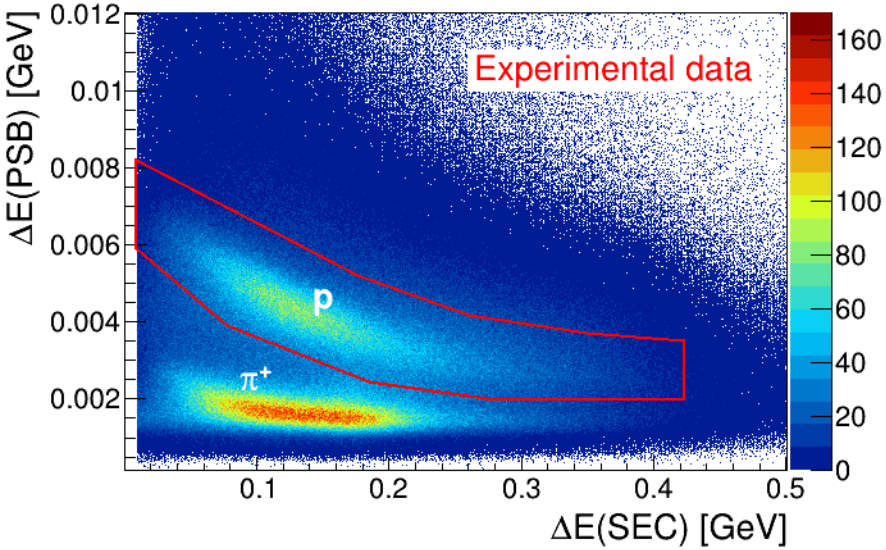
WASA (**W**ide **A**ngle **S**hower **A**pparatus) [7]

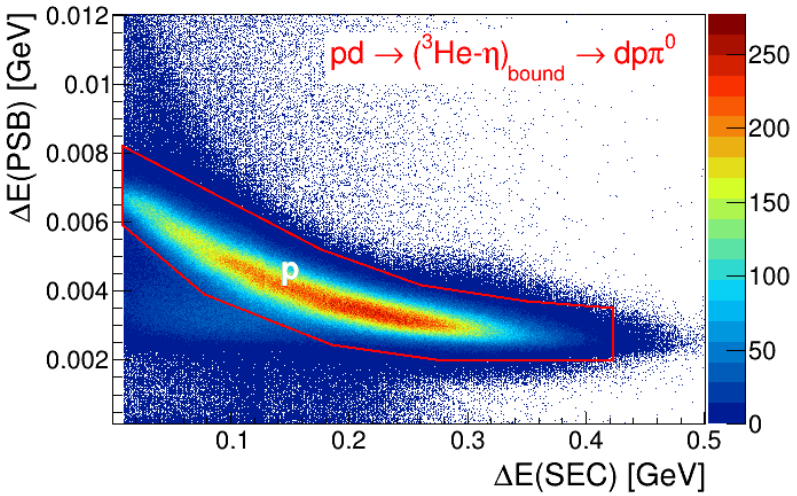


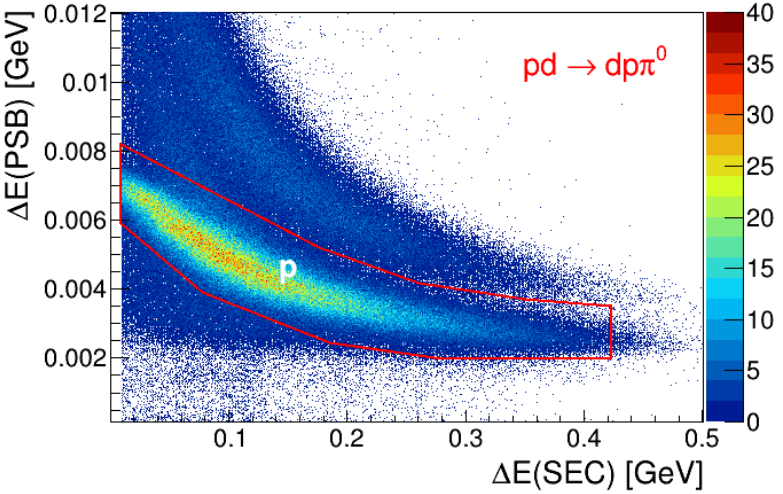
Beamtime: 21.05 – 02.06.2014
Effective time: 245 h
Measurements were performed with the beam momentum ramped from 1.426 GeV/c to 1.635 GeV/c, corresponding to the range of excess energy $Q \in (-70, 30)$ MeV

[6] P. Moskal, W. Krzemien, M. Skurzok, *COSY proposal No. 186.3*, 2014.
[7] H.-H. Adam *et al.*, WASA-at-COSY Collaboration, arXiv:nucl-ex/0411038.

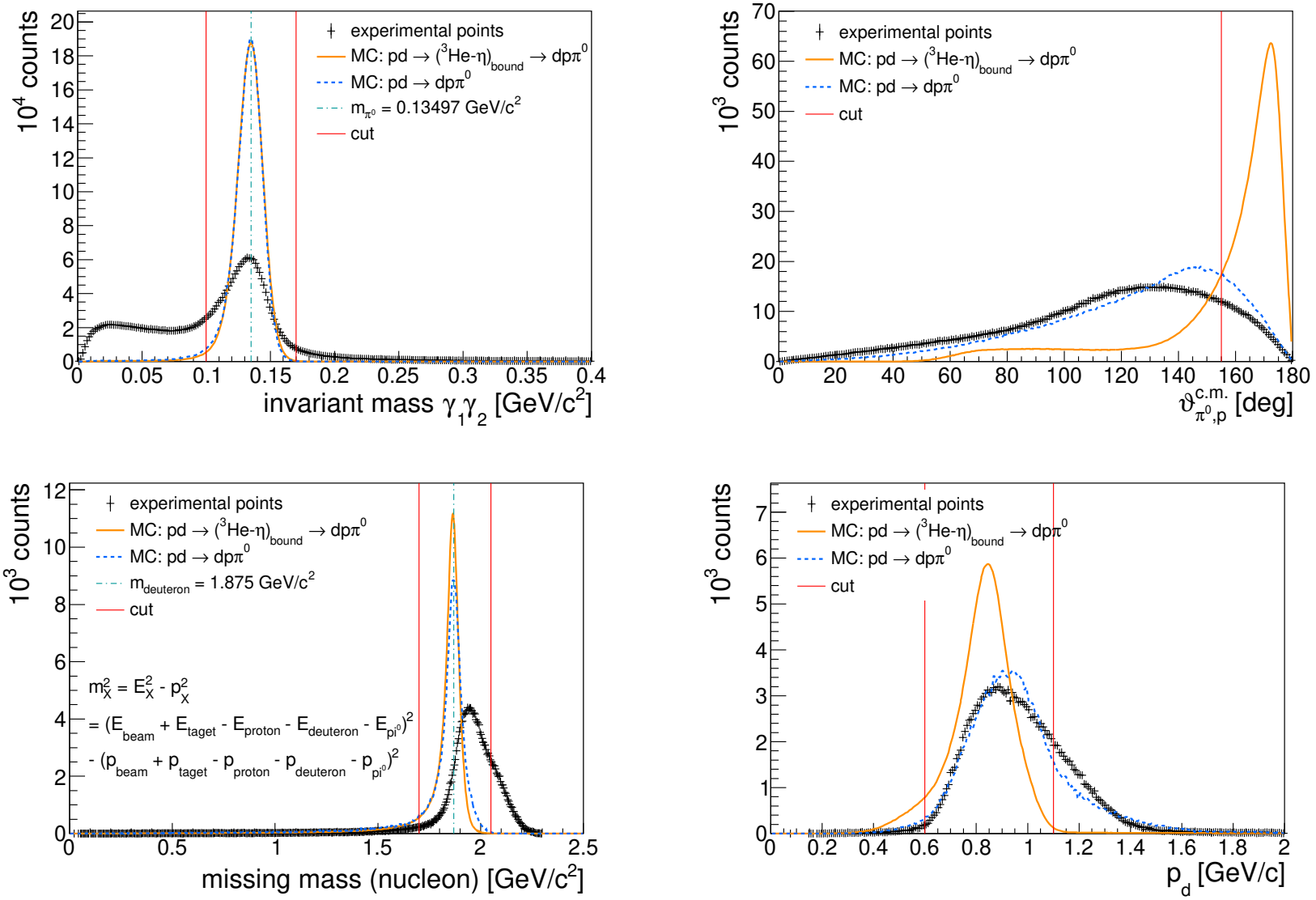
Proton identification in the Central Detector







Selection criteria



Determination of the excitation function

Excitation function

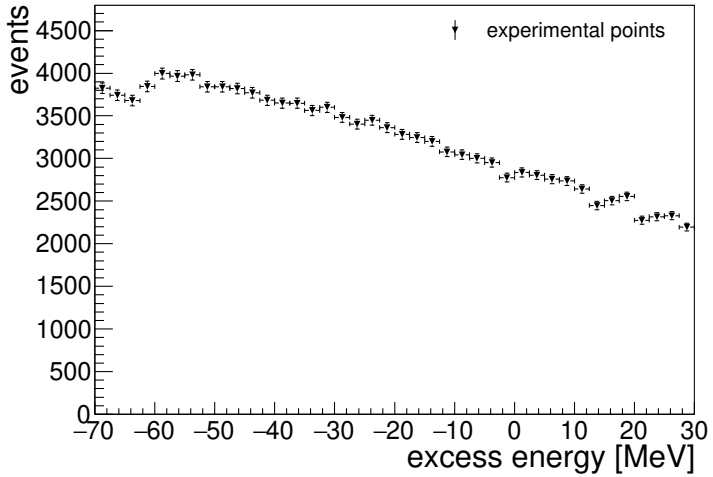
$$\sigma(Q) = \frac{N(Q)}{\varepsilon(Q) \cdot L(Q)}$$

N – number of experimental events

ε – reconstruction efficiency

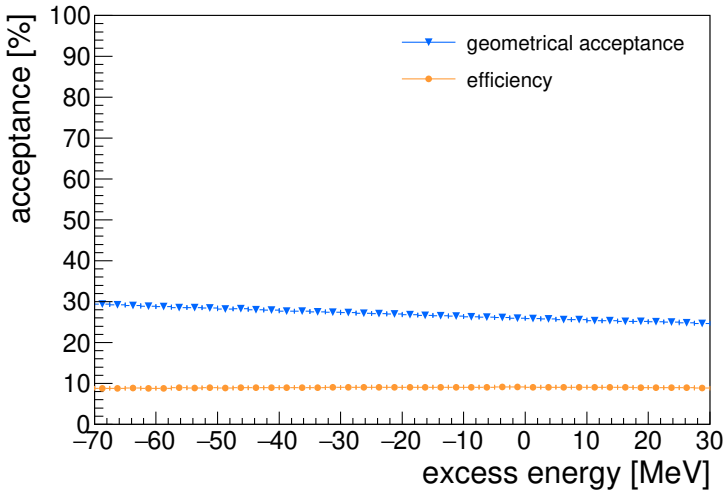
L – integrated luminosity

Number of events



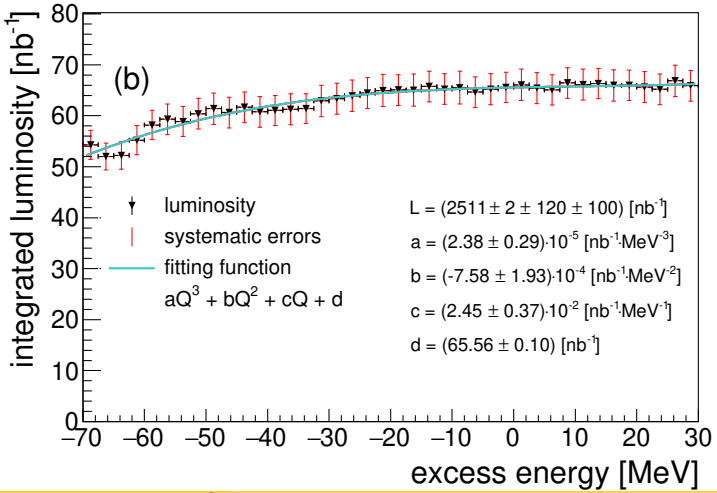
Efficiency

$$pd \to (^3\text{He-}\eta)_{bound} \to dp\pi^0$$

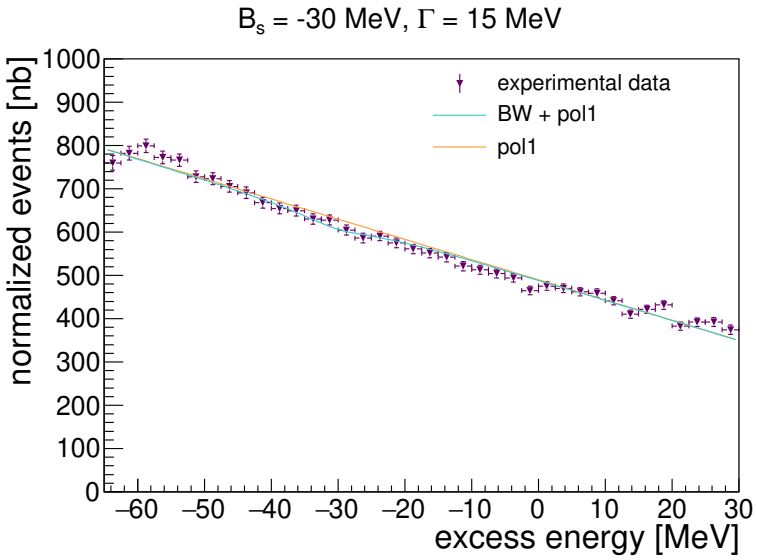


Integrated luminosity

$$pd \to ppn_{spectator}$$



Calculation of the upper limit of the total cross section



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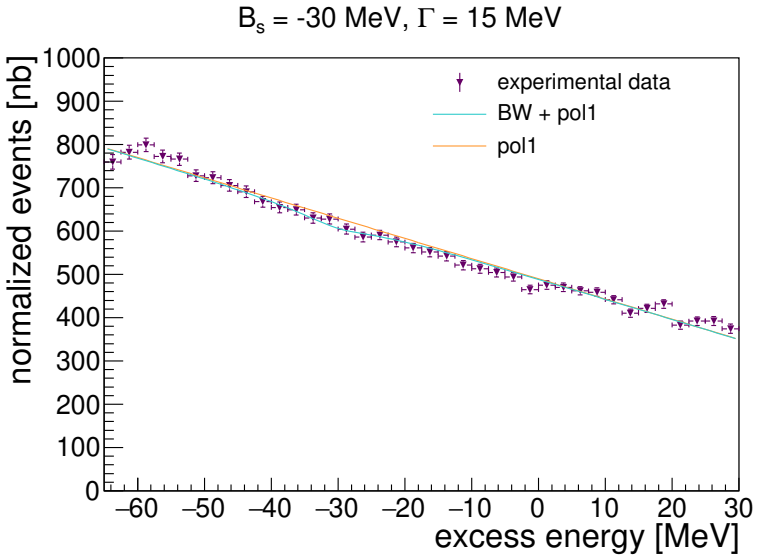


Fit with a Breit–Wigner function combined with a first order polynomial:

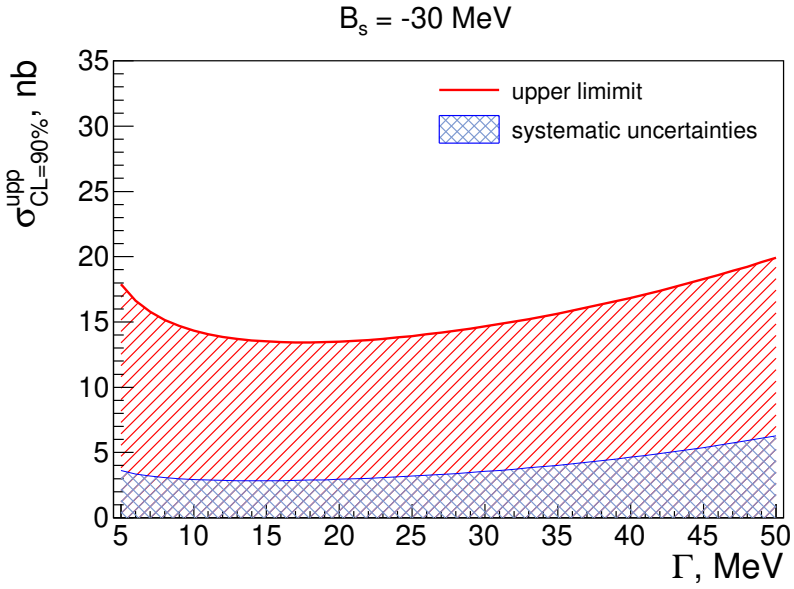
$$\frac{A \cdot \frac{\Gamma^2}{4}}{(Q - B_s)^2 + \frac{\Gamma^2}{4}} + BQ + C$$

Breit-Wigner (signal) + pol1 (background)

B_s and Γ are fixed parameters; A, B, C are free parameters.

$$\sigma^{upp}_{CL=90\%} = k \cdot \sigma_A, \; k = 1.64 \; (CL = 90\%)$$

Upper limit of the total cross section



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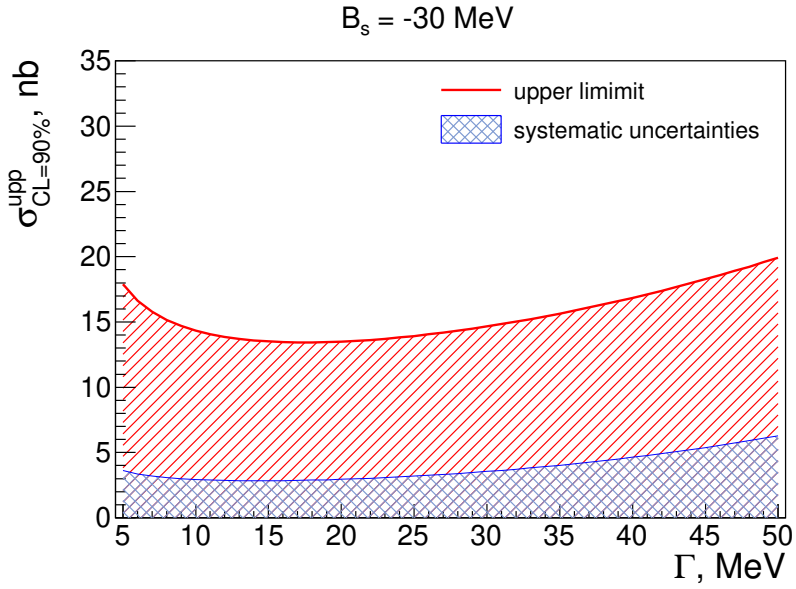

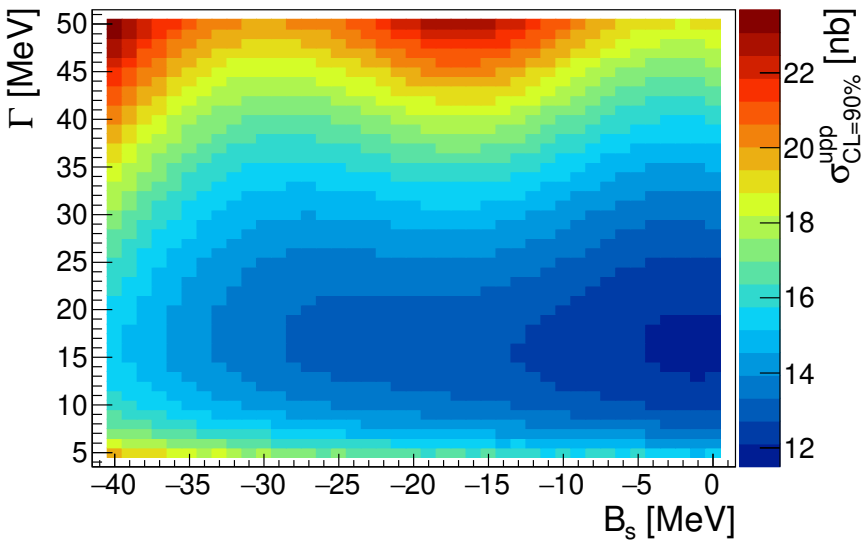

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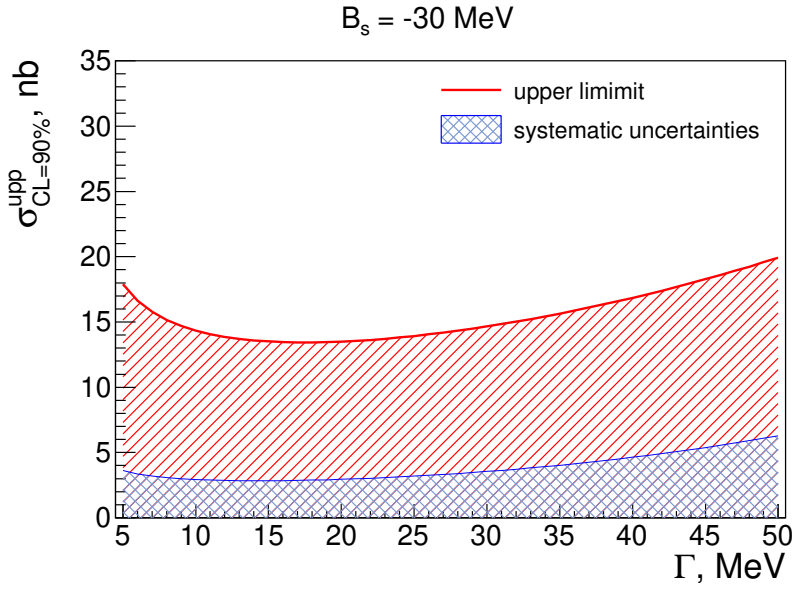

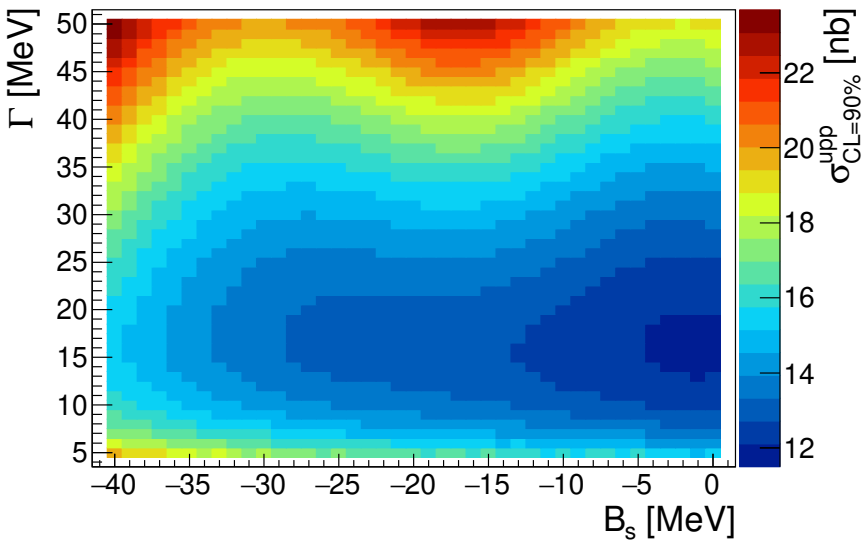

Result

$$13\ nb \leq \sigma^{upp}_{pd\to(^3\text{He-}\eta)_{bound}\to dp\pi^0} \leq 24\ nb$$

[8] P. Adlarson *et al.*, *Phys. Rev. C* (2020) – accepted, *arXiv:2007.15494*.

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- The results of the analysis of the $pd \to {}^3\text{He}2\gamma$, $pd \to {}^3\text{He}6\gamma$ and $pd \to dp\pi^0$ don't show a narrow signal of η-mesic nuclei.
- The upper limit of the total cross section was for the first time determined for those reactions.

Thank You for attention!