

Is there an isobaric analog state of the tetra-neutron in hydrogen-4 ?



Quentin Délicnac – Post-Doc – IJCLab

22/09/2026

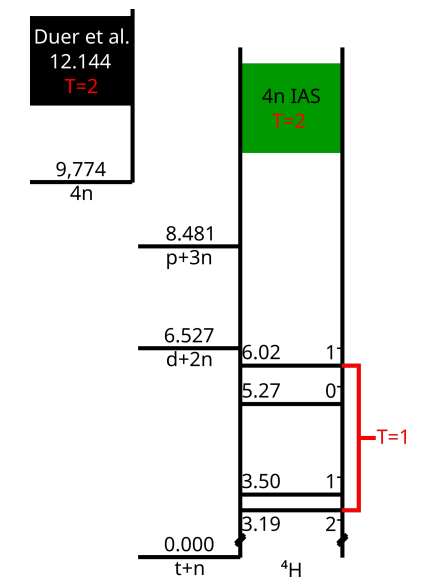
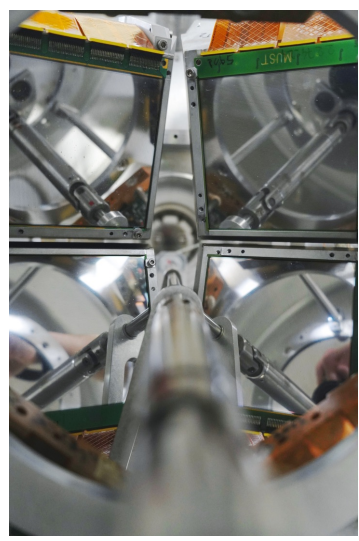
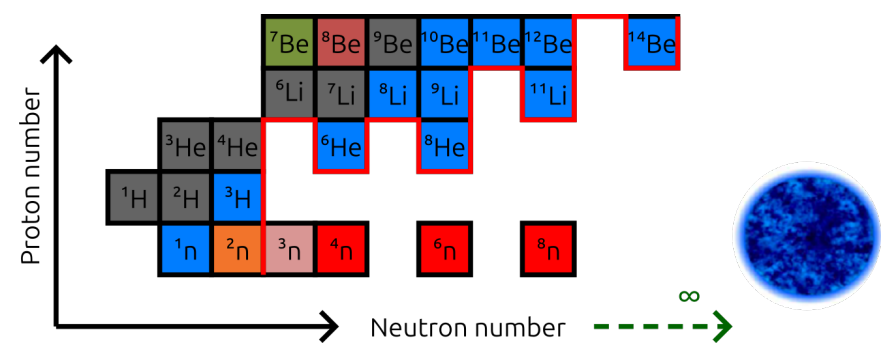
Outline

I. Context

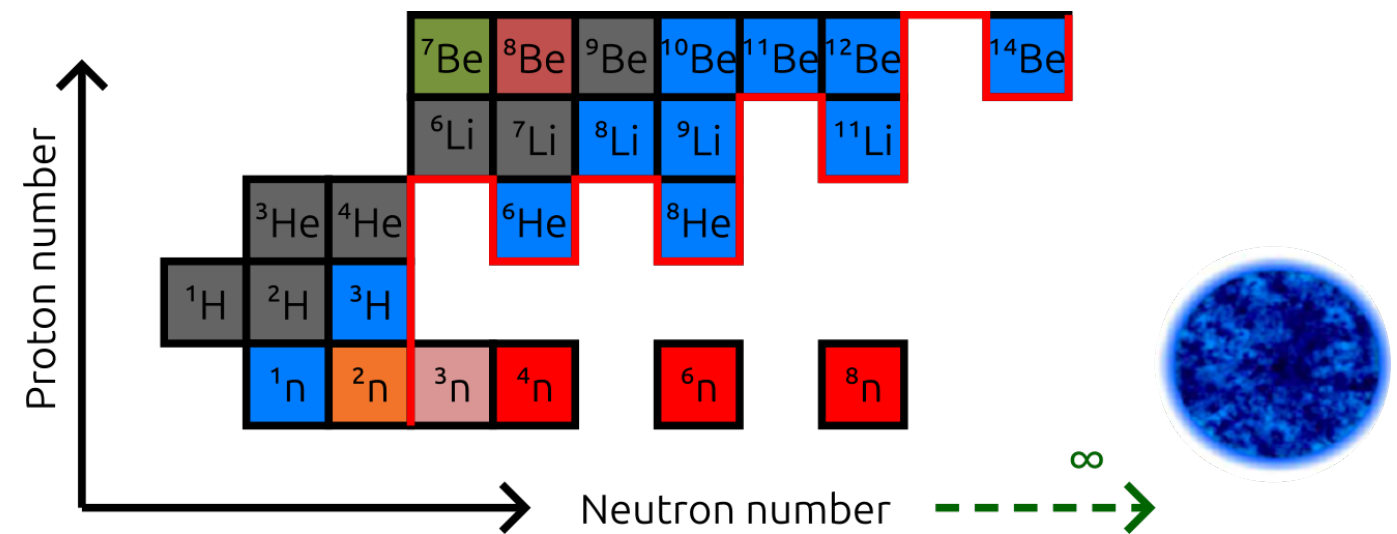
II. E873 - A Mugast exp

II. Benchmark on ${}^6\text{He}(p,t){}^4\text{He}$

II. Preliminary results

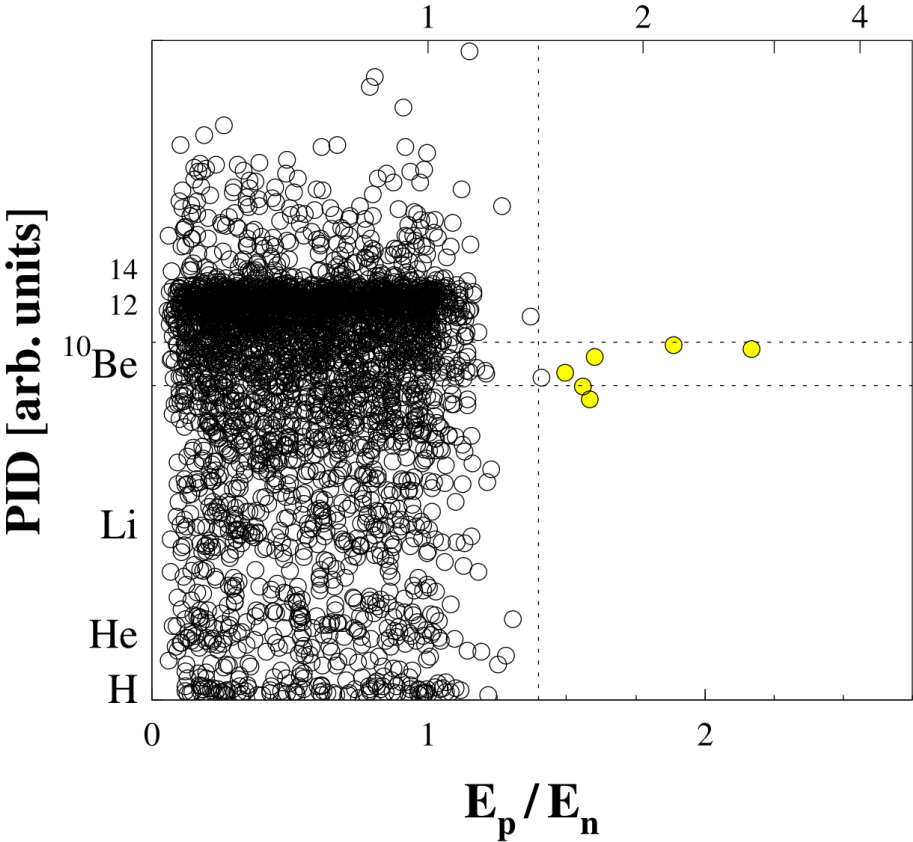


Proton-less / Neutral systems



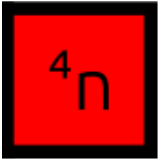
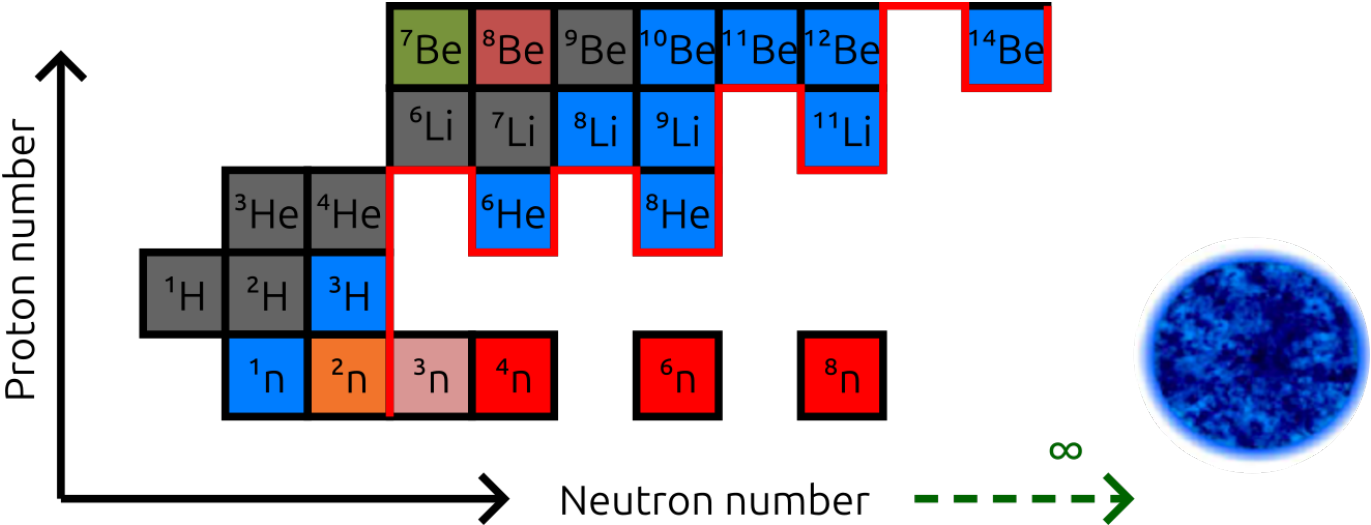
First hint of its observation
Marqués et al., PRC 65, (2002)

(^{14}Be , X+n) reaction

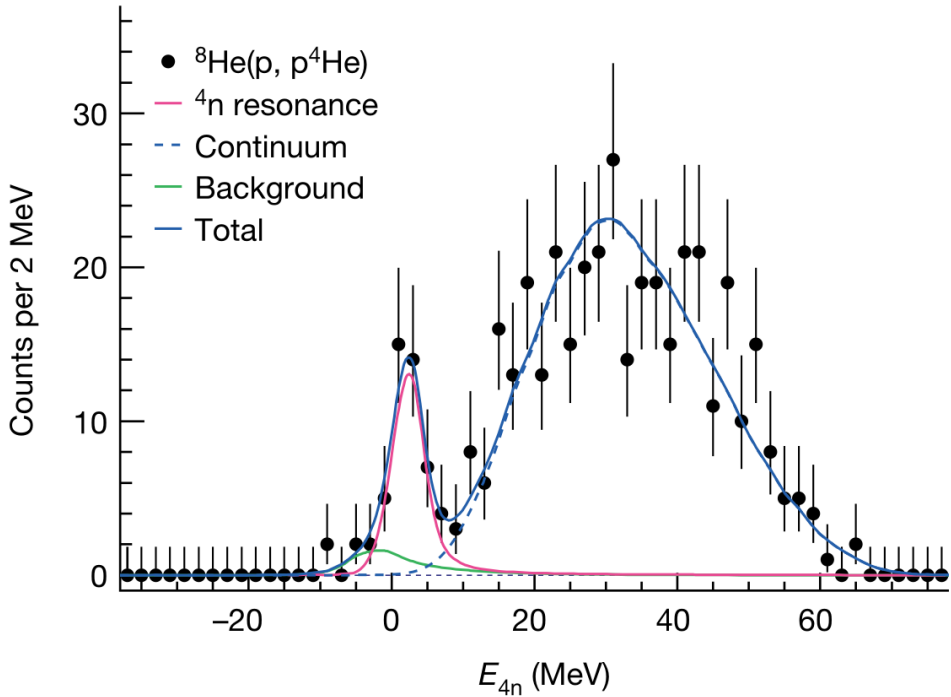
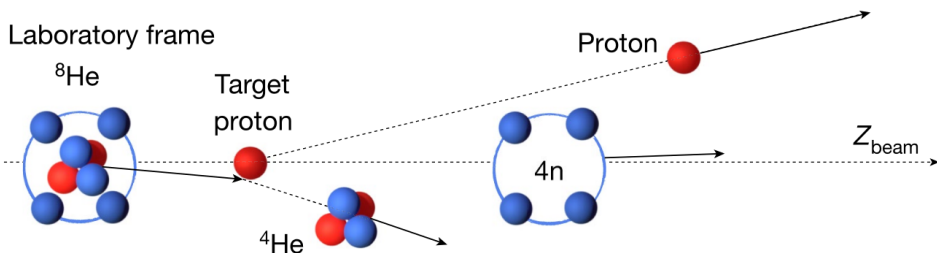


Some events (6#) match with a system of 4n

Proton-less / Neutral systems

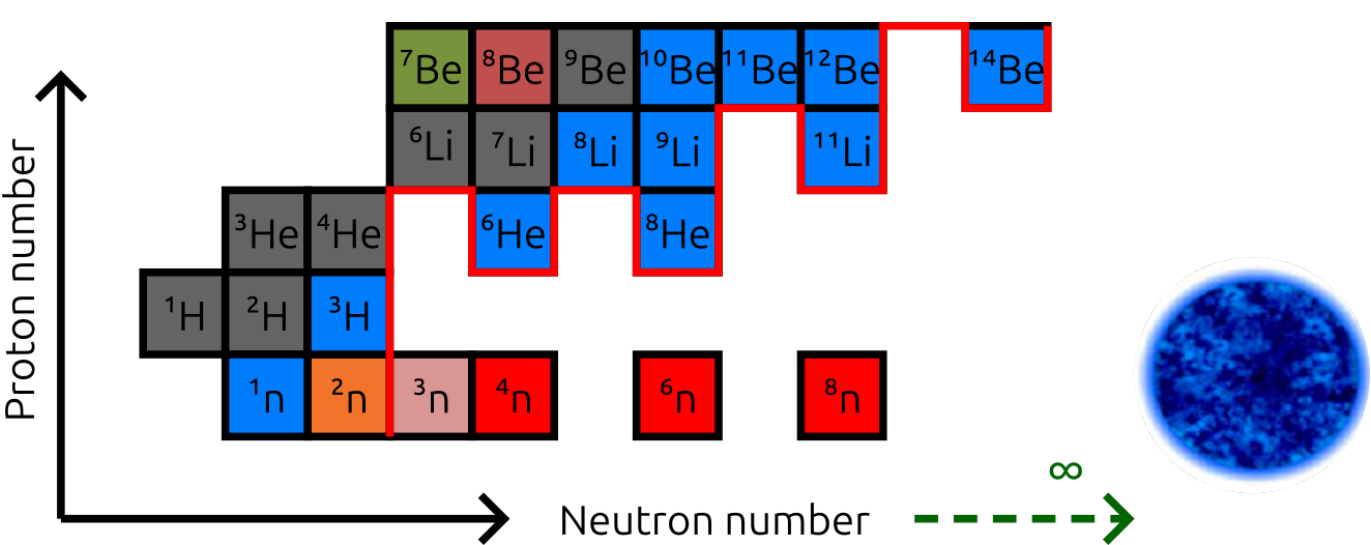


An other hint of its observation
Duer et al., Nature, 2022 :
 $E_r = 2.37 \text{ MeV}$ and $\Gamma = 1.75 \text{ MeV}$

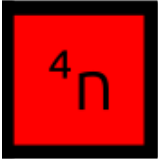


4n systems

Isospin : $T = \left| \frac{Z - N}{2} \right|$



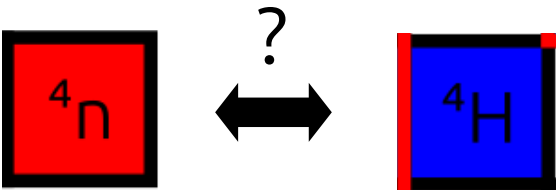
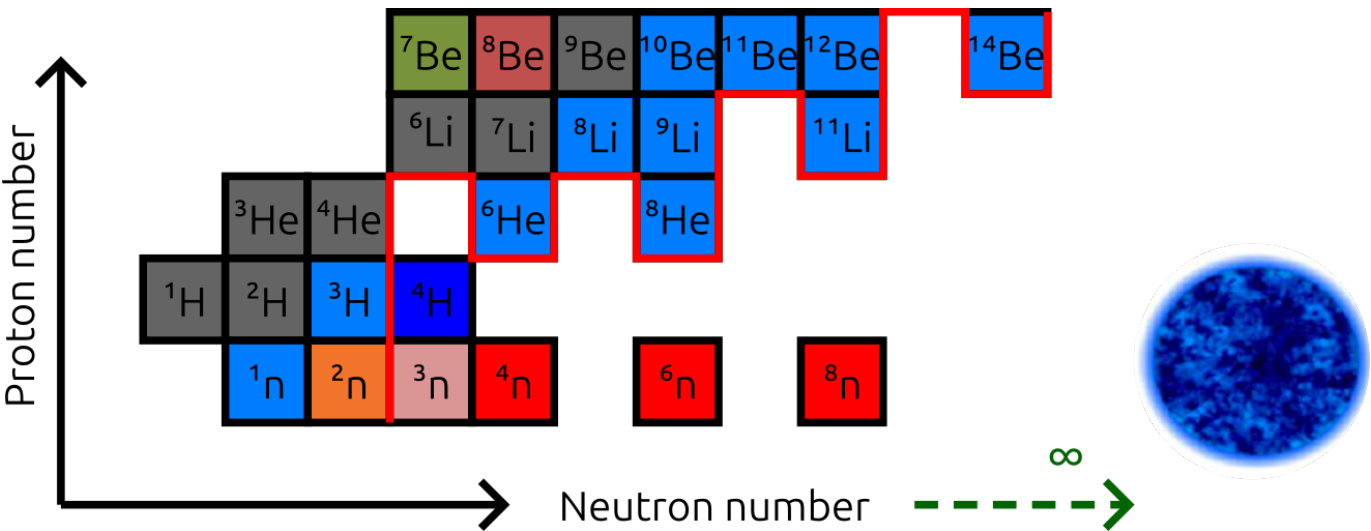
Duer et al.
12.144
$T=2$
9,774
4n



Any equivalent system to observe this state ?

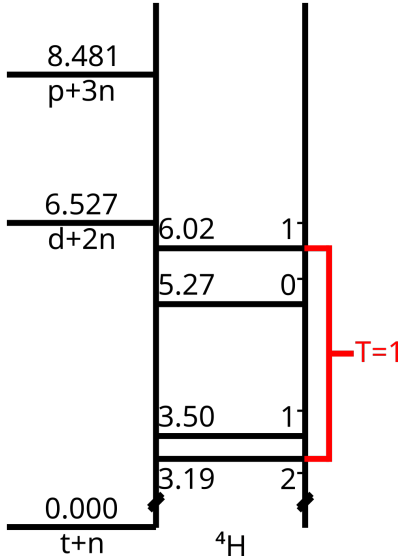
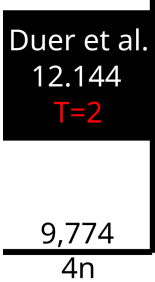
4n systems $\longleftrightarrow$ 4 nucleons systems ?

Isospin : $T = \left| \frac{Z - N}{2} \right|$



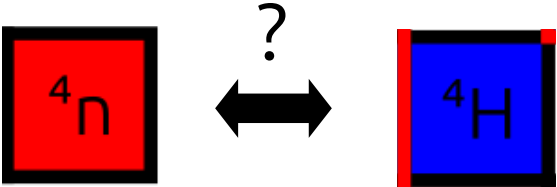
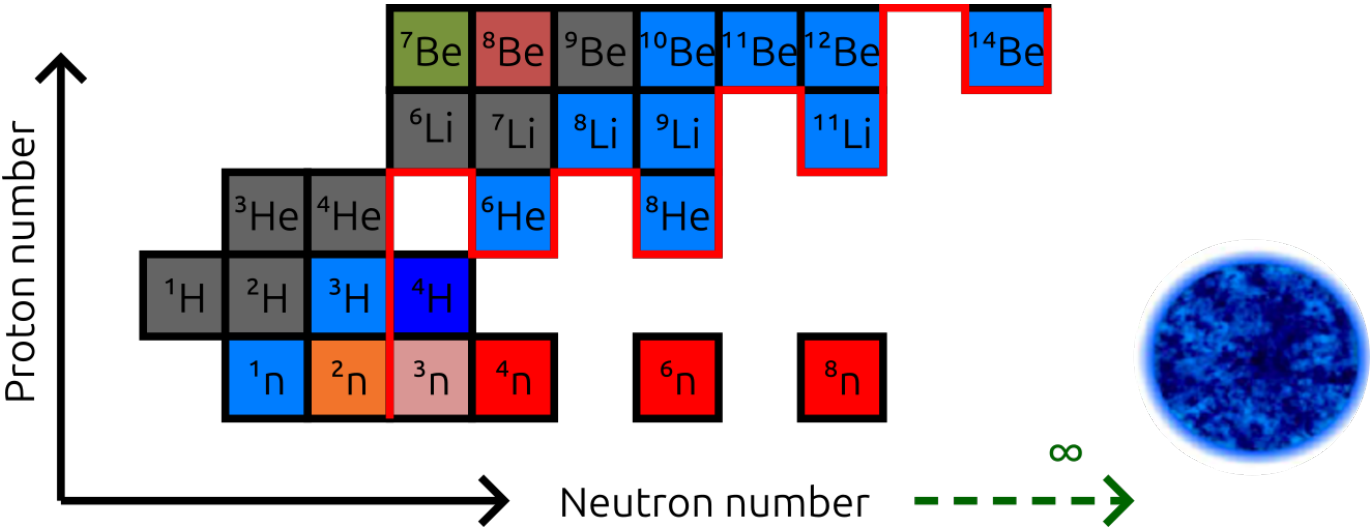
Any equivalent system to observe this state ?

1 Proton & 3 Neutrons



4n systems $\longleftrightarrow$ 4 nucleons systems ?

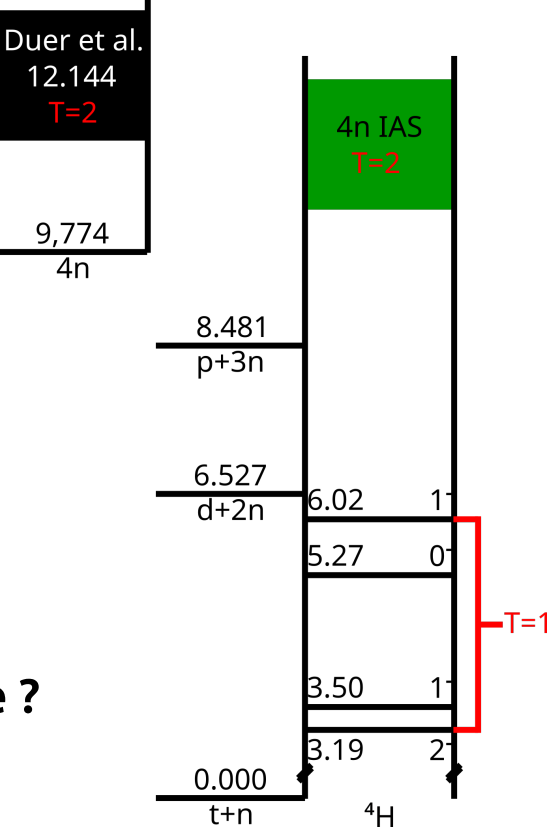
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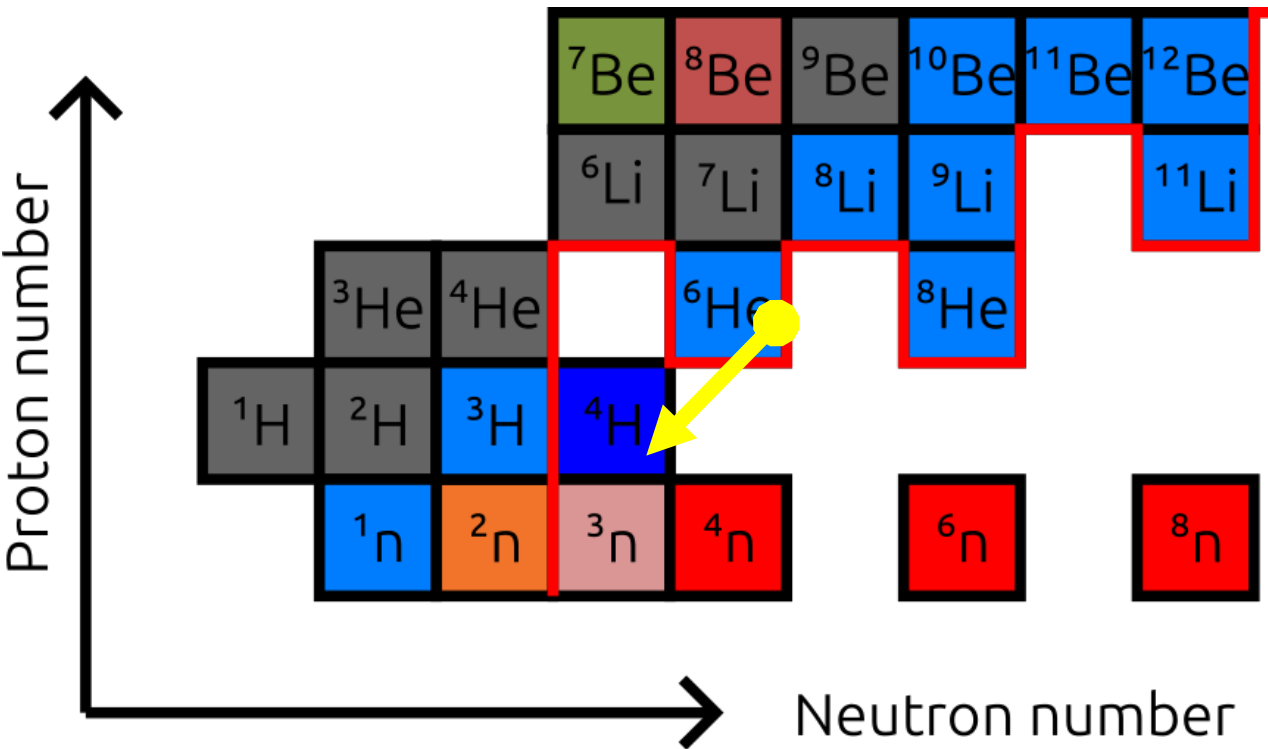
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1 Proton & 3 Neutrons

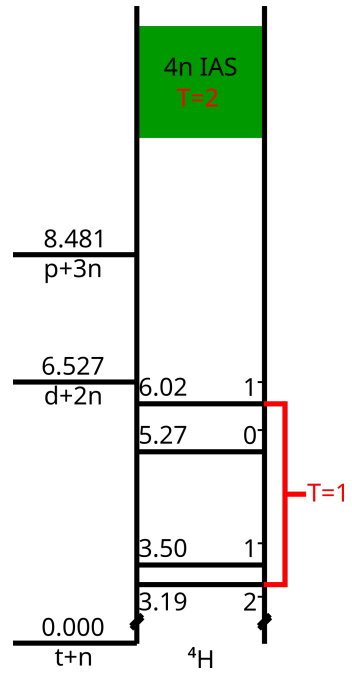
Is there an Isobaric Analog State (IAS) of the tetra-neutron in hydrogen-4 ?



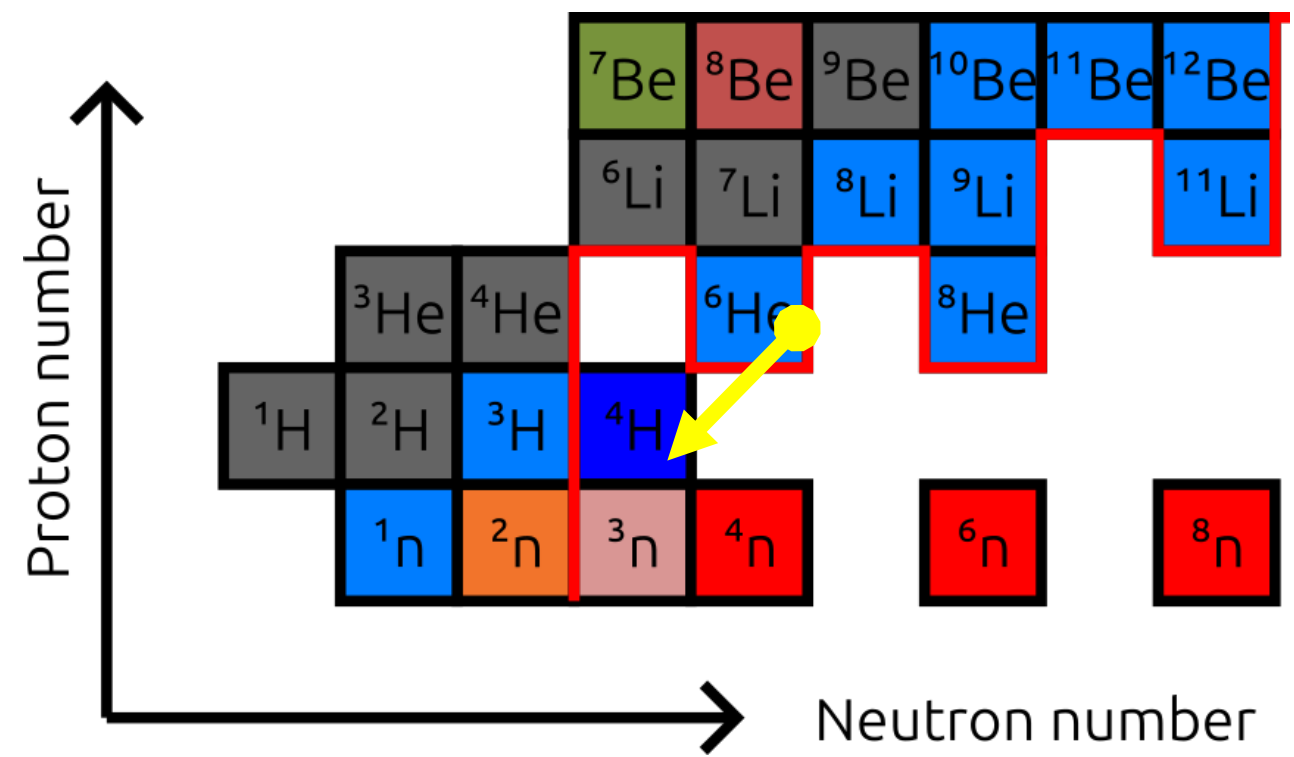
How populate states in hydrogen-4 ?



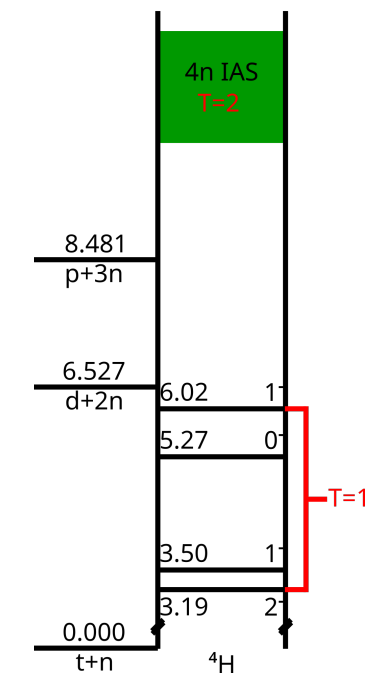
$^6\text{He}(p, ^3\text{He})^4\text{H}$ transfert reaction



How populate states in hydrogen-4 ?



$^6\text{He}(p, ^3\text{He})^4\text{H}$ transfert reaction



- Allow to populate $T=1$ and $T=2$
- ^4H decay via triton/deuteron/proton
- By isospin symmetry, IAS $T=2$ decay via **$p+3n$** , so **high selectivity**

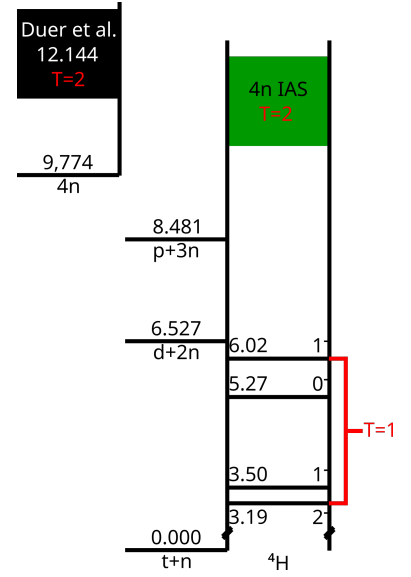
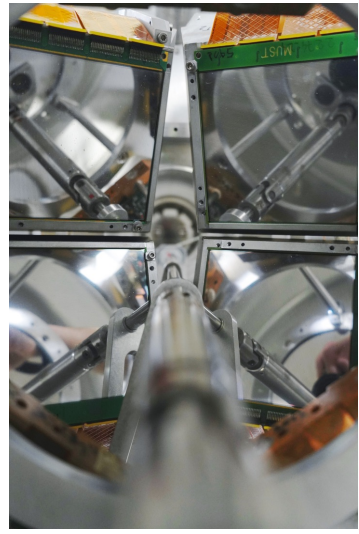
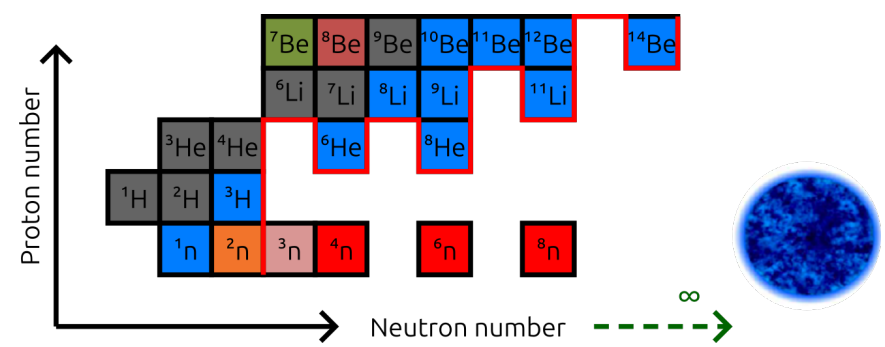
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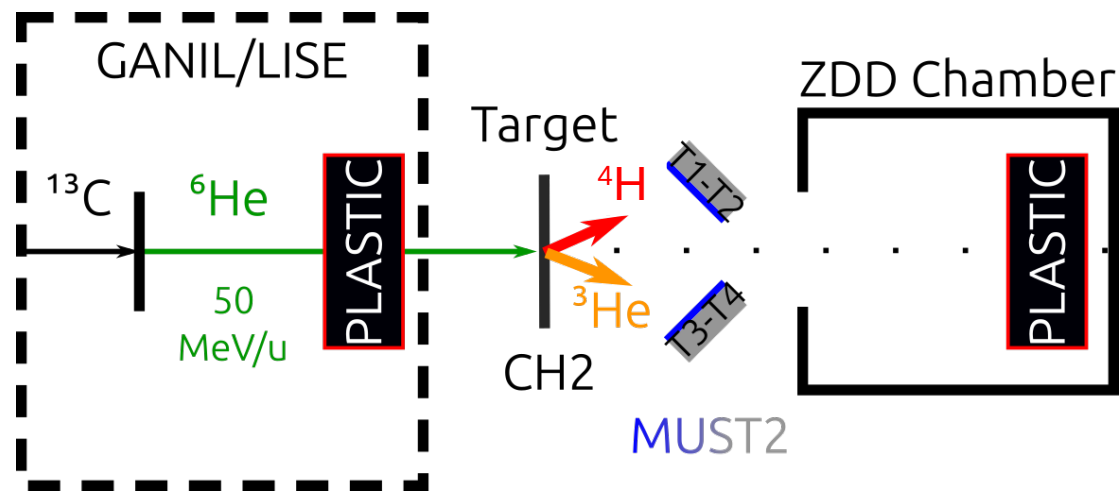
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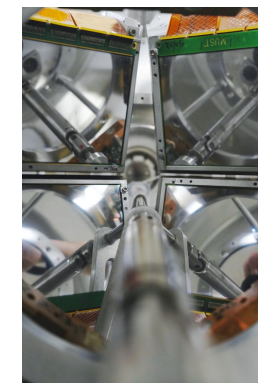
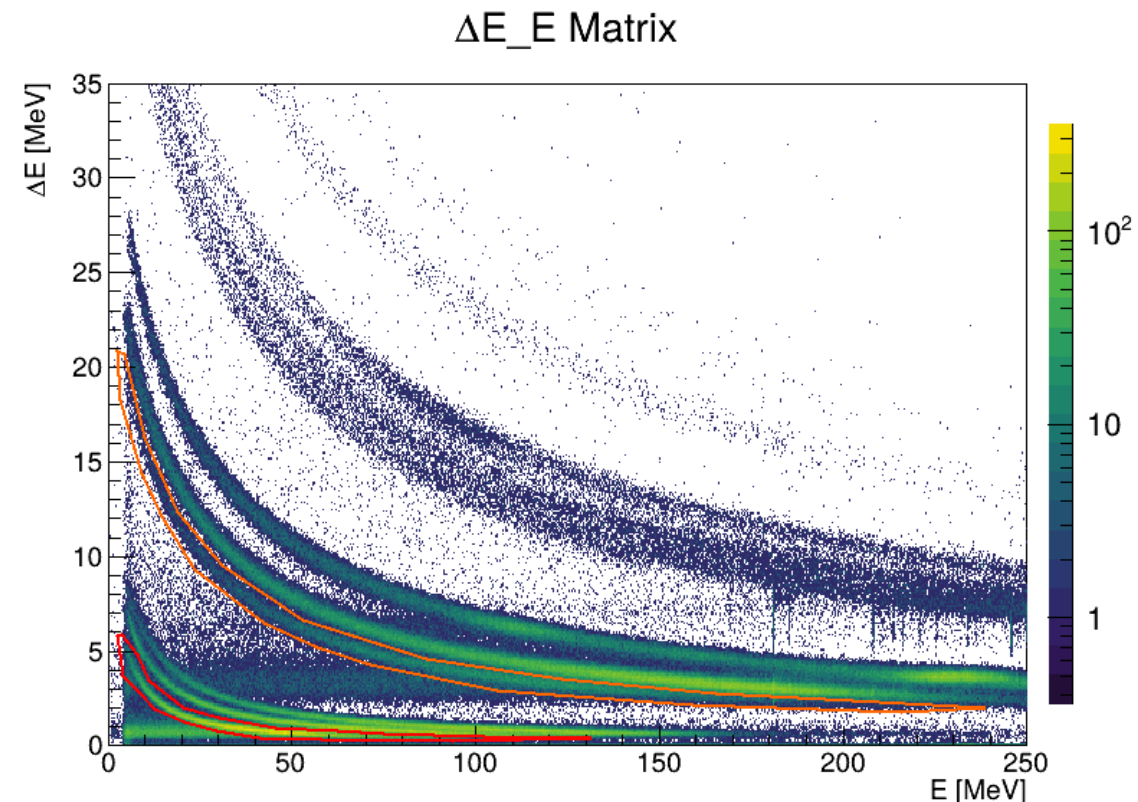


Experimental setup : MUGAST@LISE



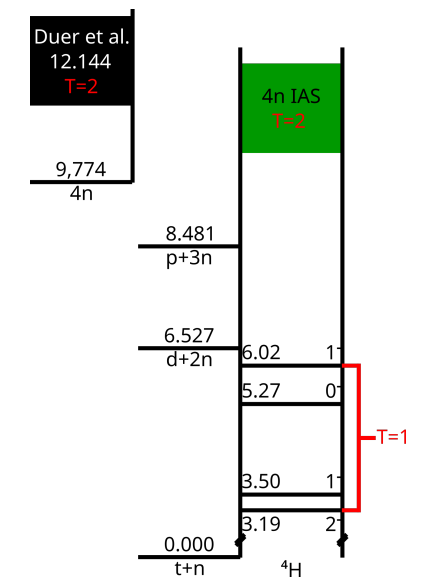
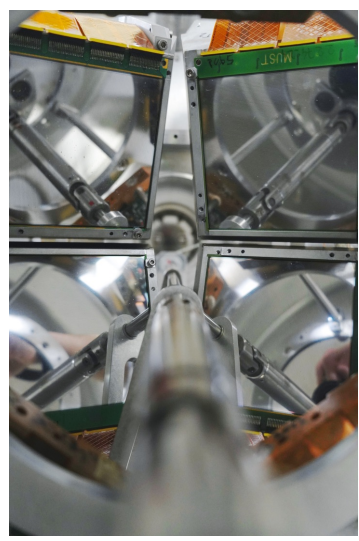
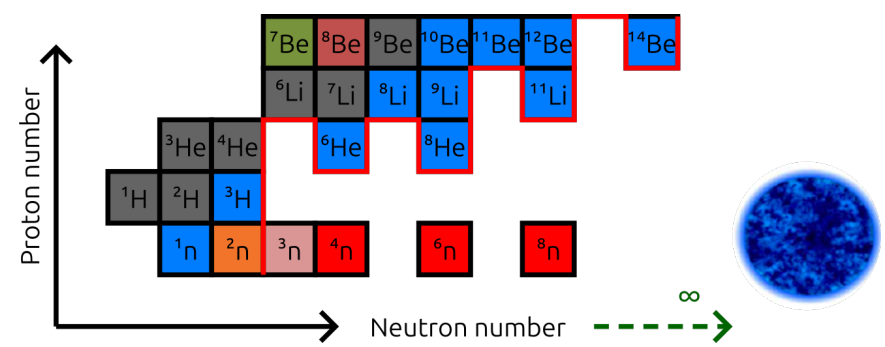
MUST2 telescope :
 Particle identification & kinematic reconstruction ($E_{\text{Lab}}/\theta_{\text{Lab}}$)
 Missing mass method because neutrons not detected

Plastic :
 Normalisation of the beam



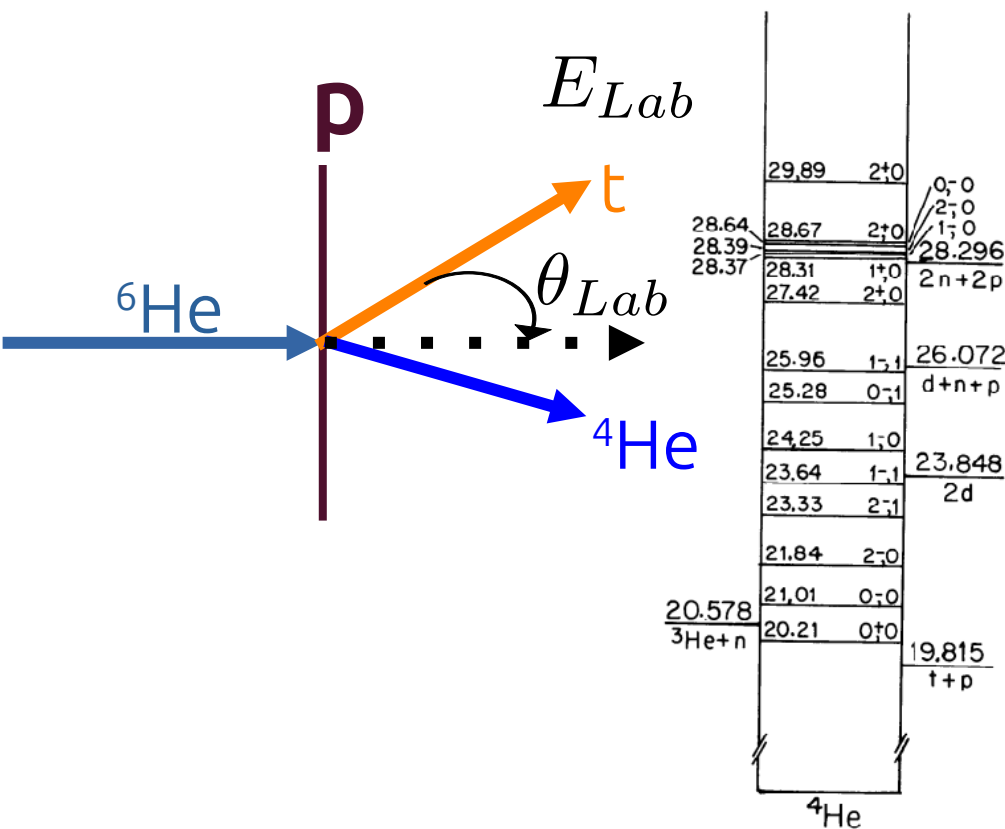
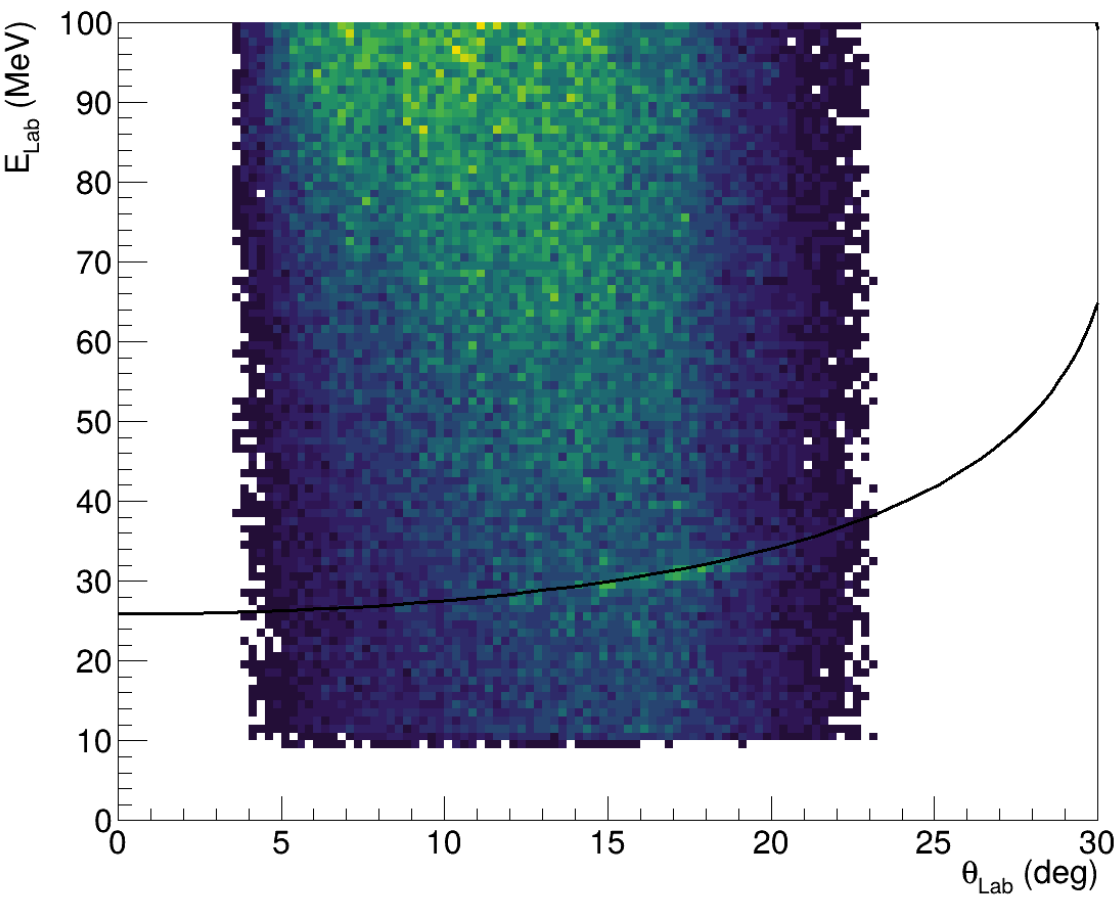
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- II. Benchmark on ${}^6\text{He}(p,t){}^4\text{He}$
- II. Preliminary results



Benchmark on ${}^6\text{He}(p,t){}^4\text{He}$ reaction

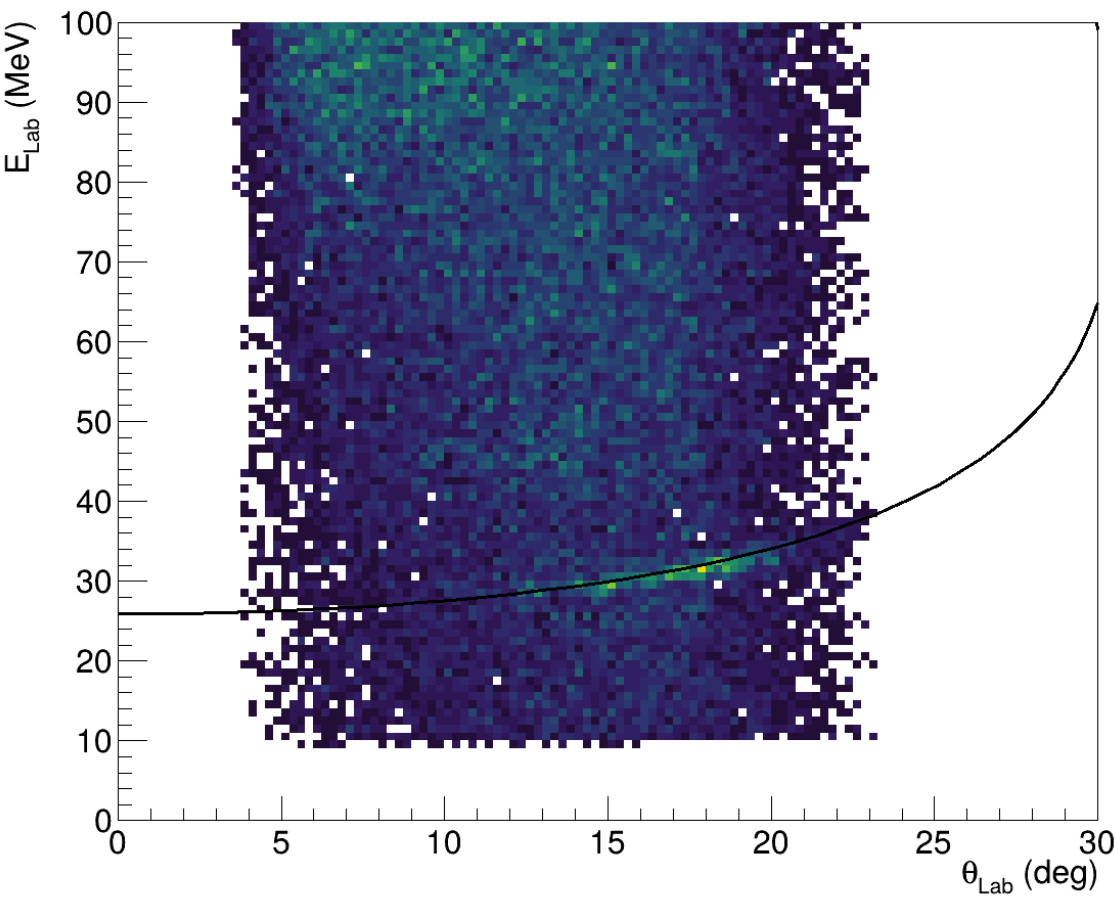
E_{Lab} vs θ_{Lab} for 3H - Coinc 4He



Imposing ${}^4\text{He}$ coinc - Only g.s can be observed

Benchmark on $^6\text{He}(p,t)^4\text{He}$ reaction

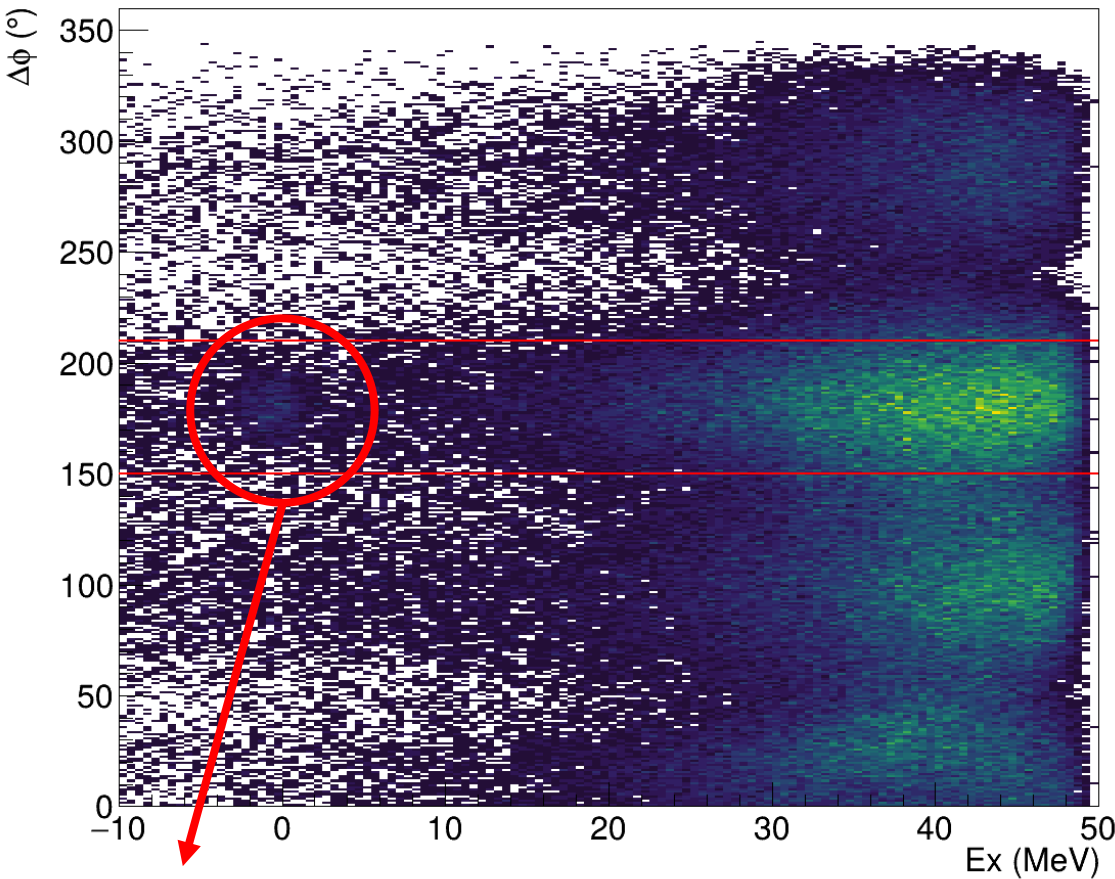
E_{Lab} vs θ_{Lab} for 3H - Coinc 4He - $150^\circ < \Delta\phi < 210^\circ$



$$\Delta\phi = |\phi_t - \phi_{^4\text{He}}|$$

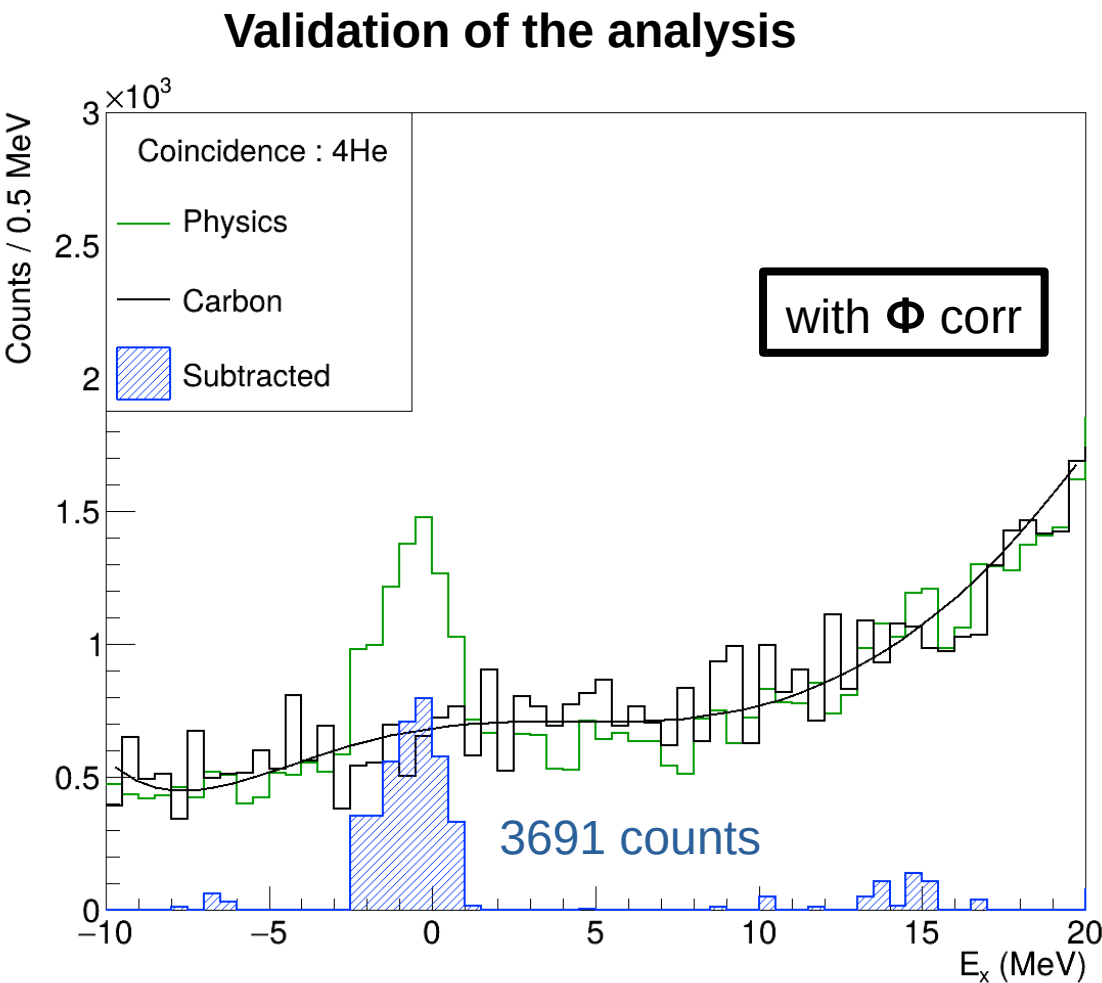
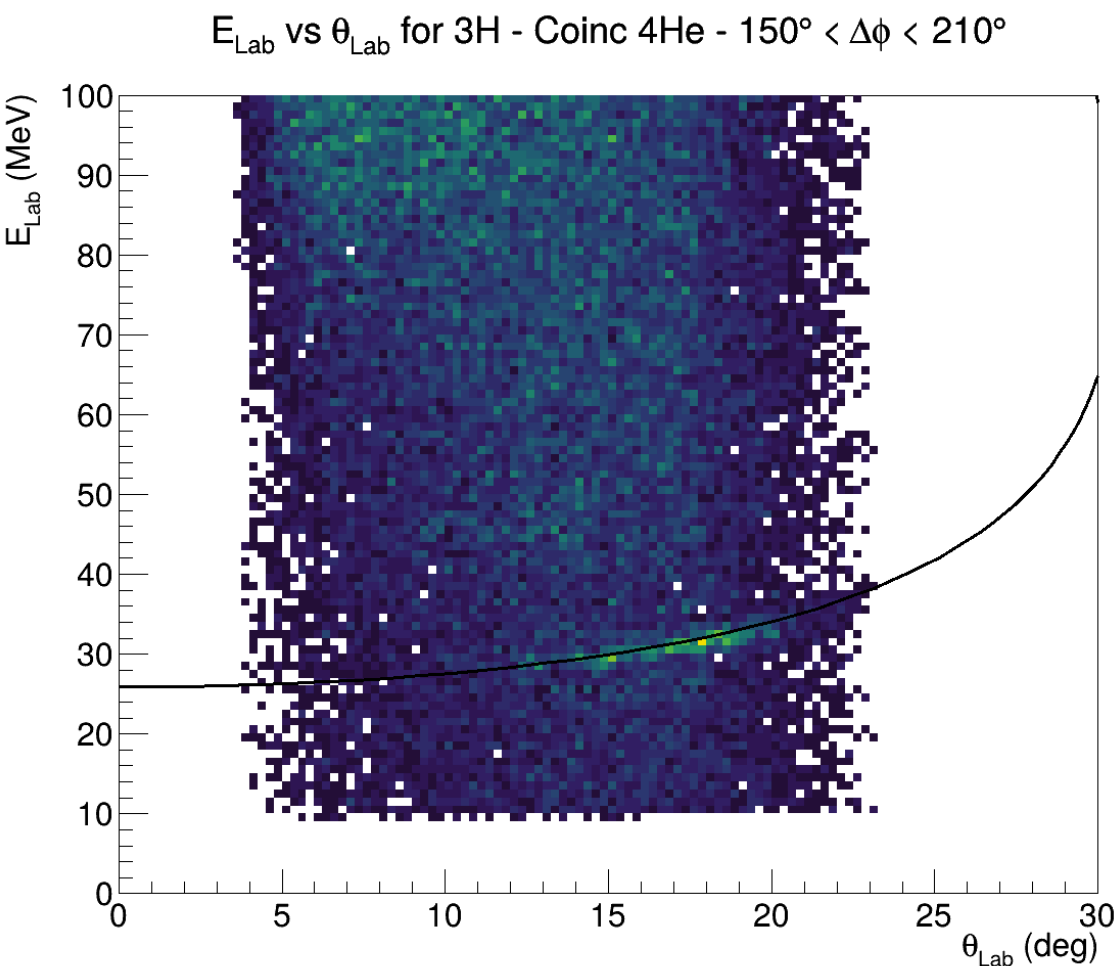
$\Delta\phi = 180^\circ \rightarrow$ Back-to-back reaction

$\Delta\phi$ vs E_x for 3H - Coinc 4He - $150^\circ < \Delta\phi < 210^\circ$



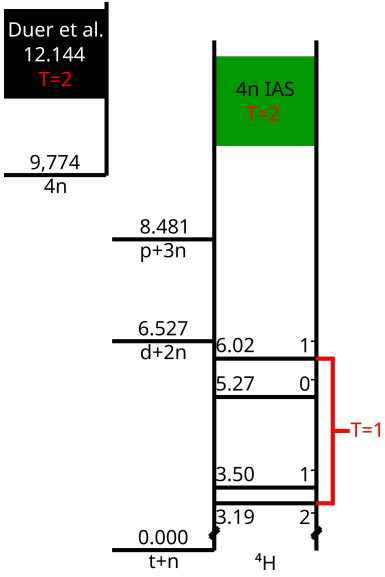
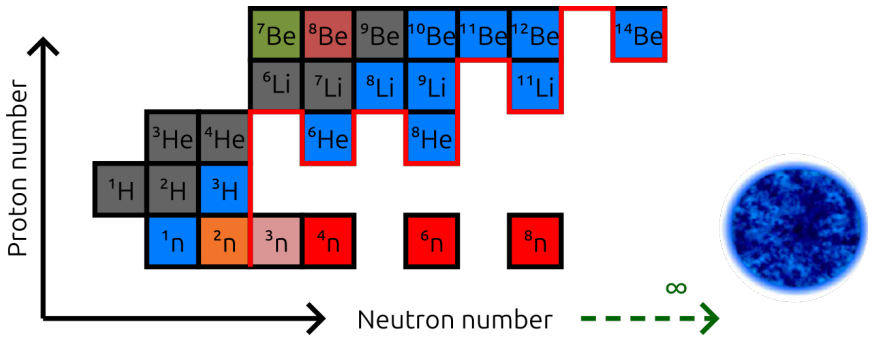
^4He g.s is well located at 180°

Benchmark on ${}^6\text{He}(p,t){}^4\text{He}$ reaction

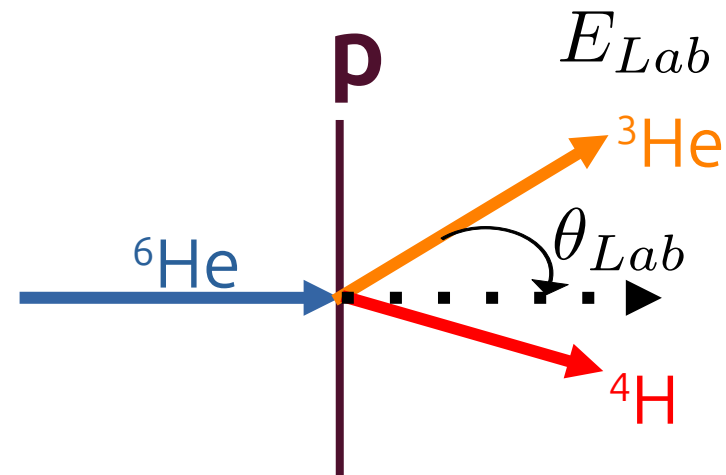
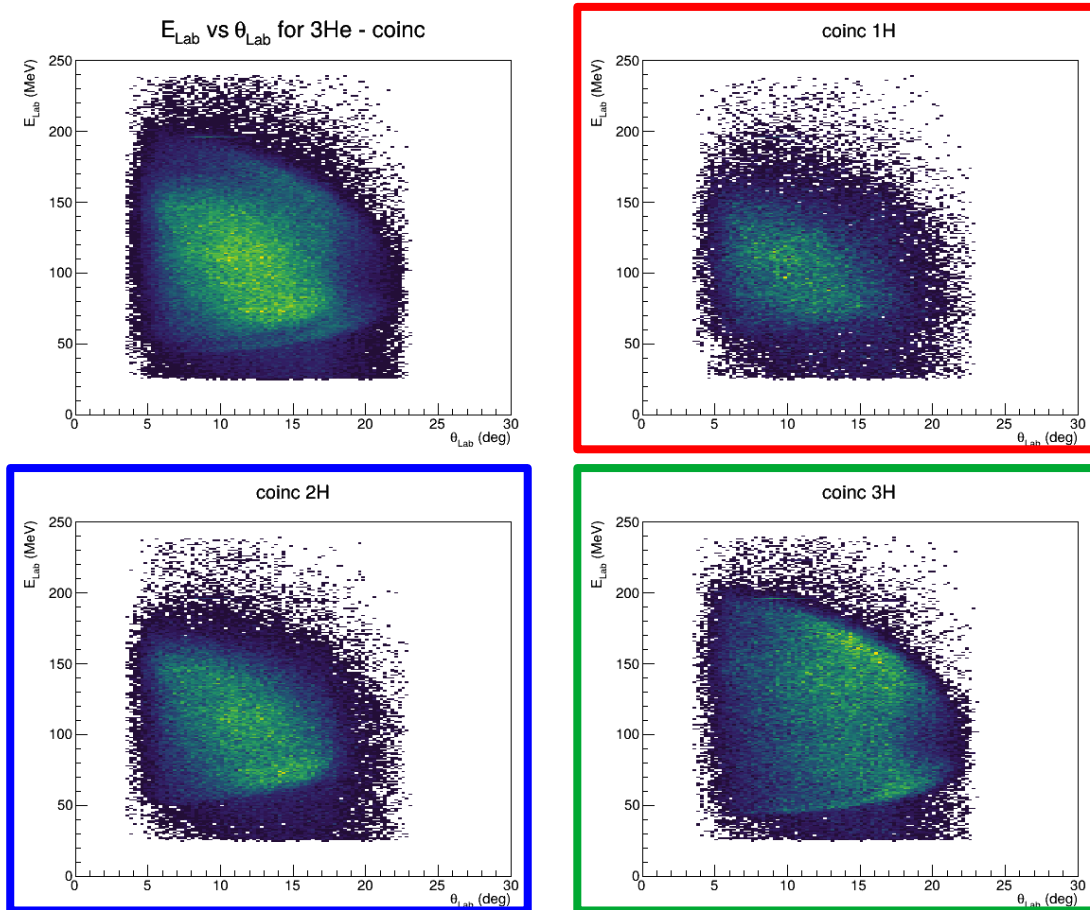


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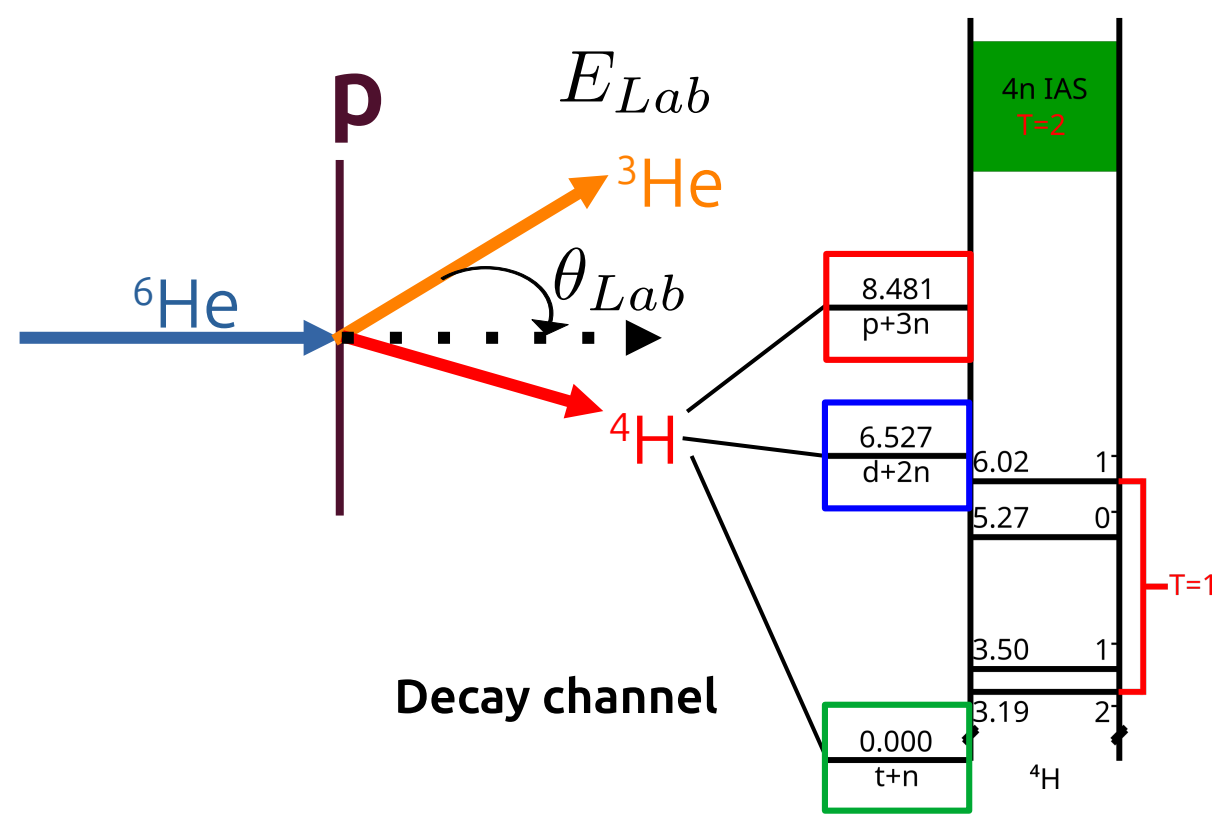
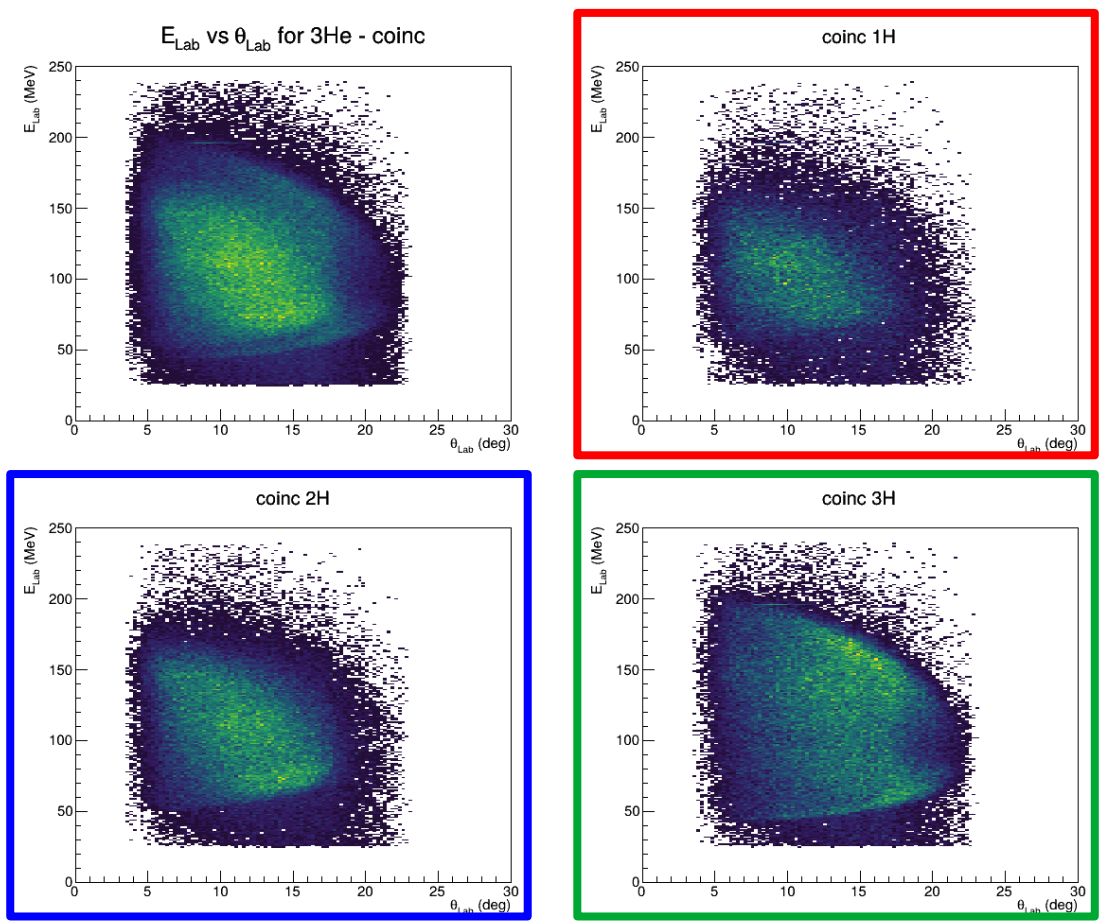
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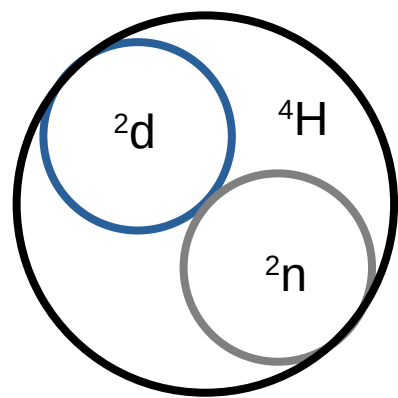
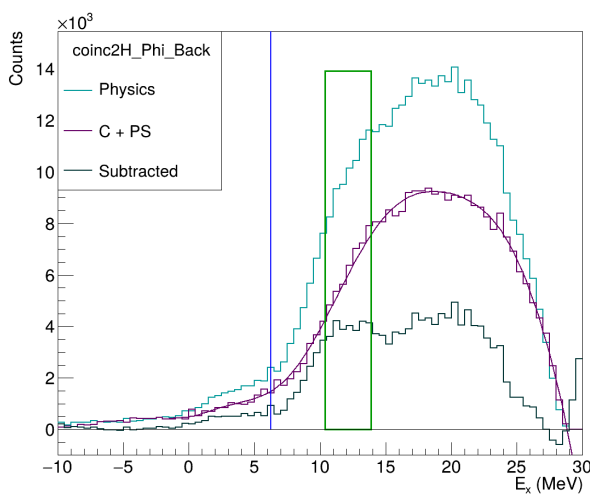
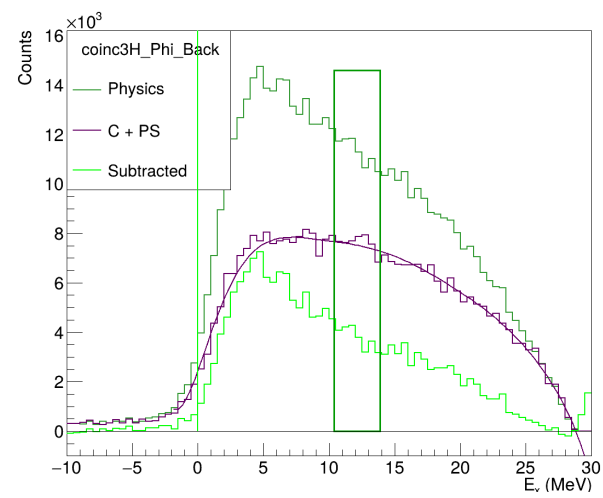
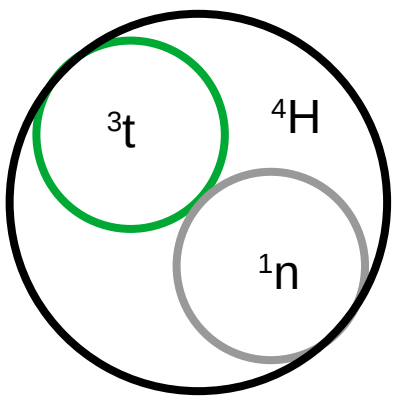
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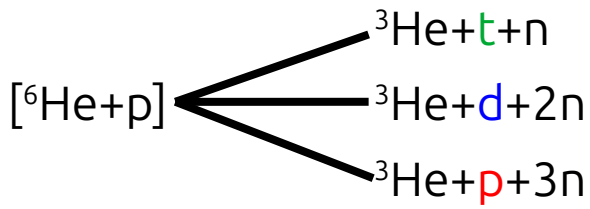


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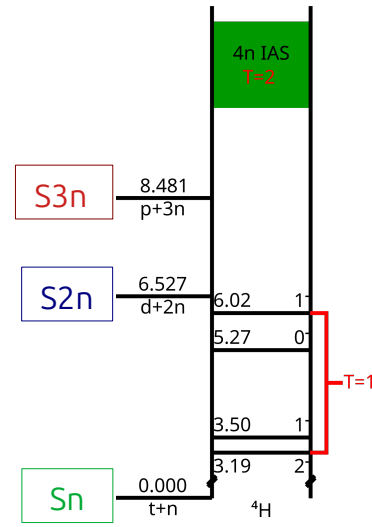
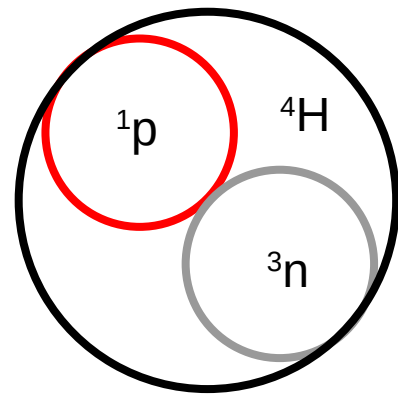
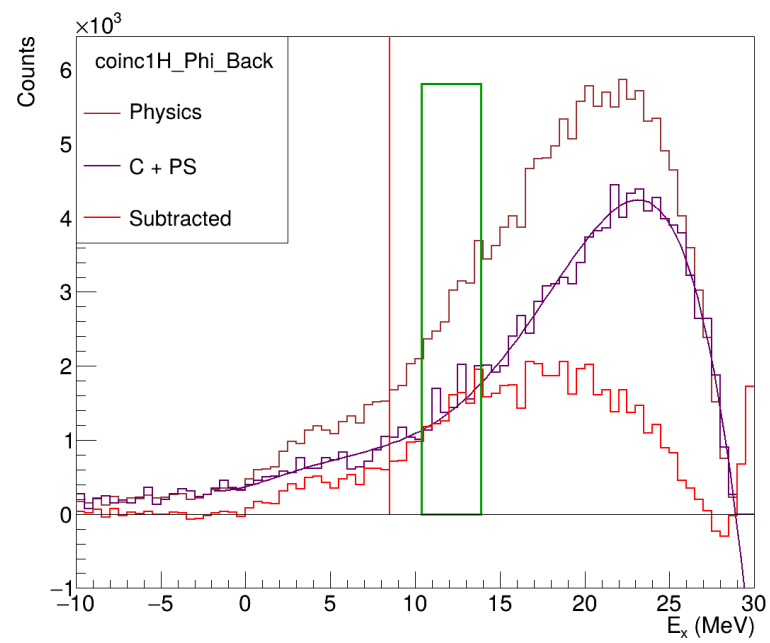


With Φ correlation
Same cut as (p,t) reaction

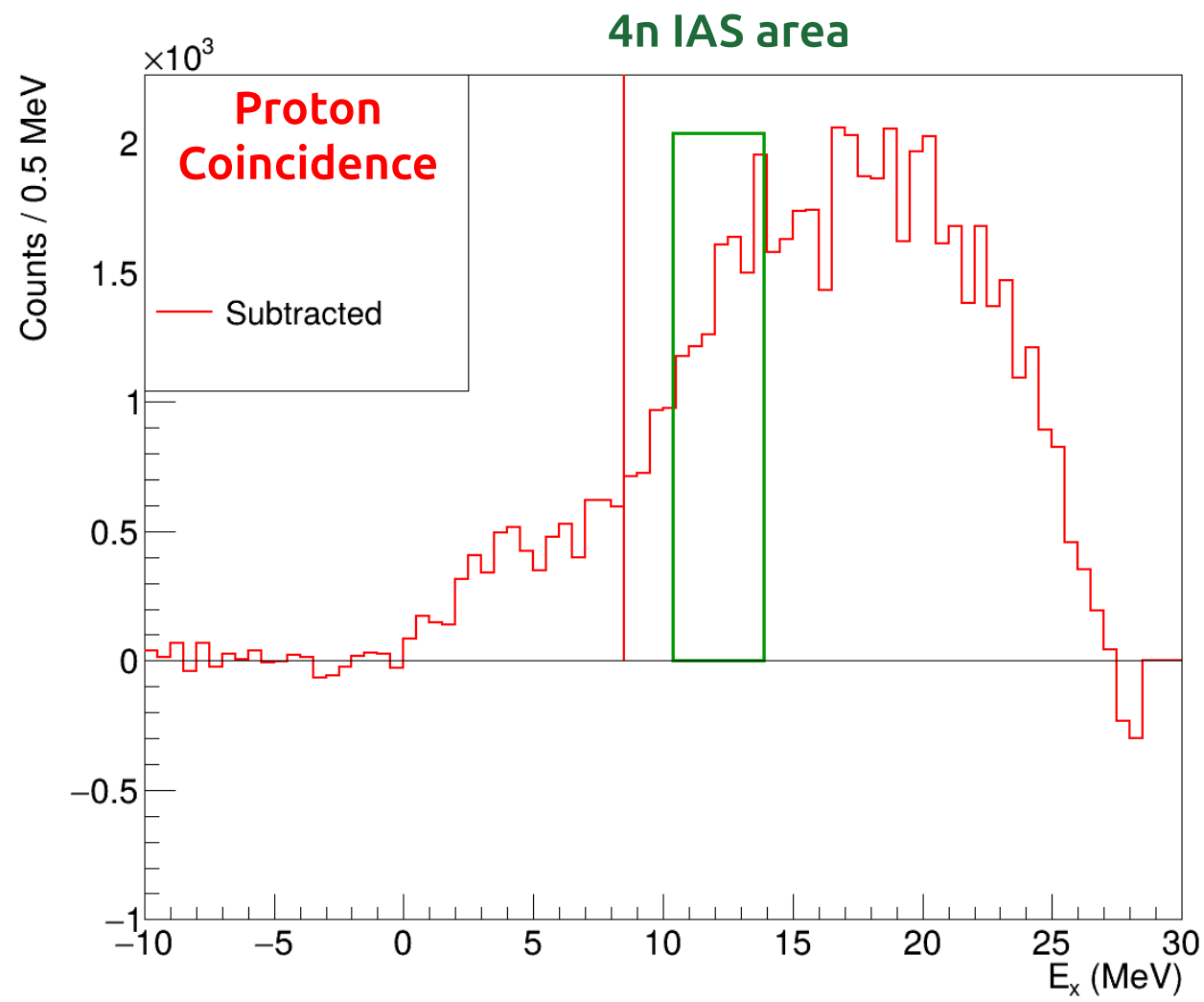
Carbon & PhaseSpace subtraction



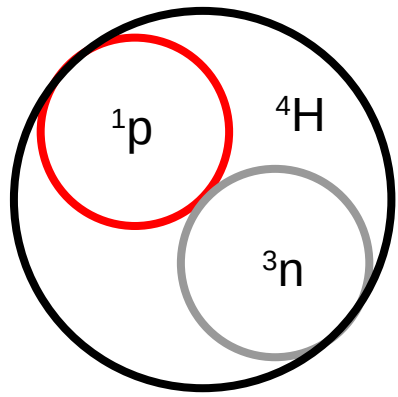
Non-Correlated decay



$^6\text{He}(p, ^3\text{He})^4\text{H}$ reaction

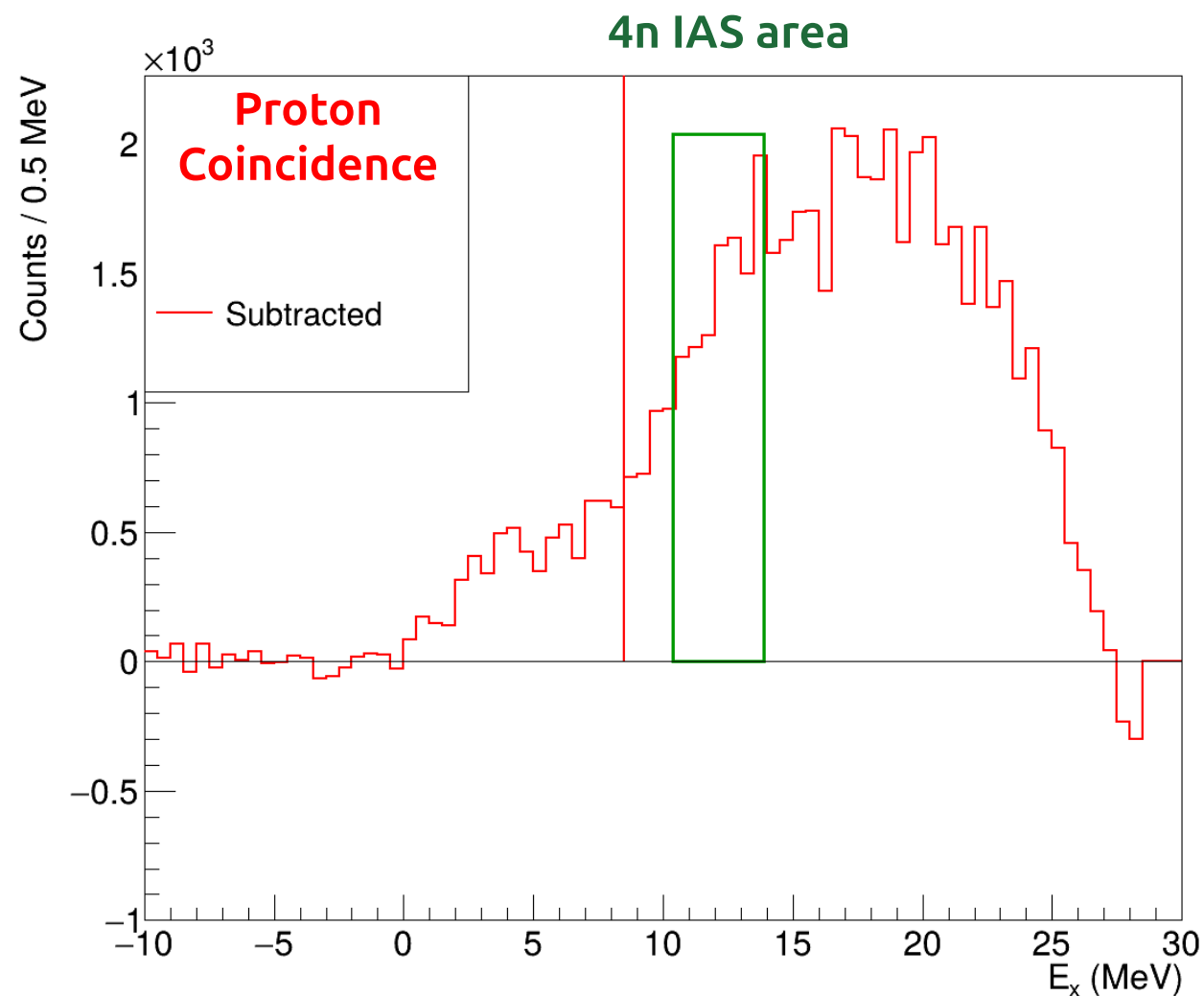


Main results :

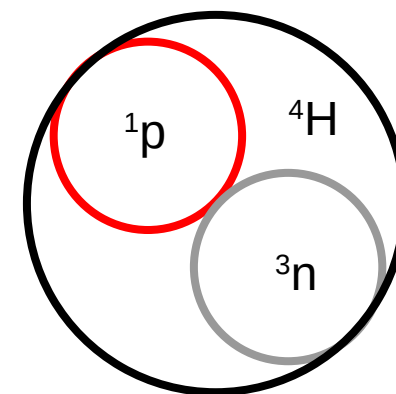


Broad structure beyond S3n (or proton threshold)

${}^6\text{He}(p, {}^3\text{He}){}^4\text{H}$ reaction



Main results :



Broad structure beyond S_{3n} (or proton threshold)

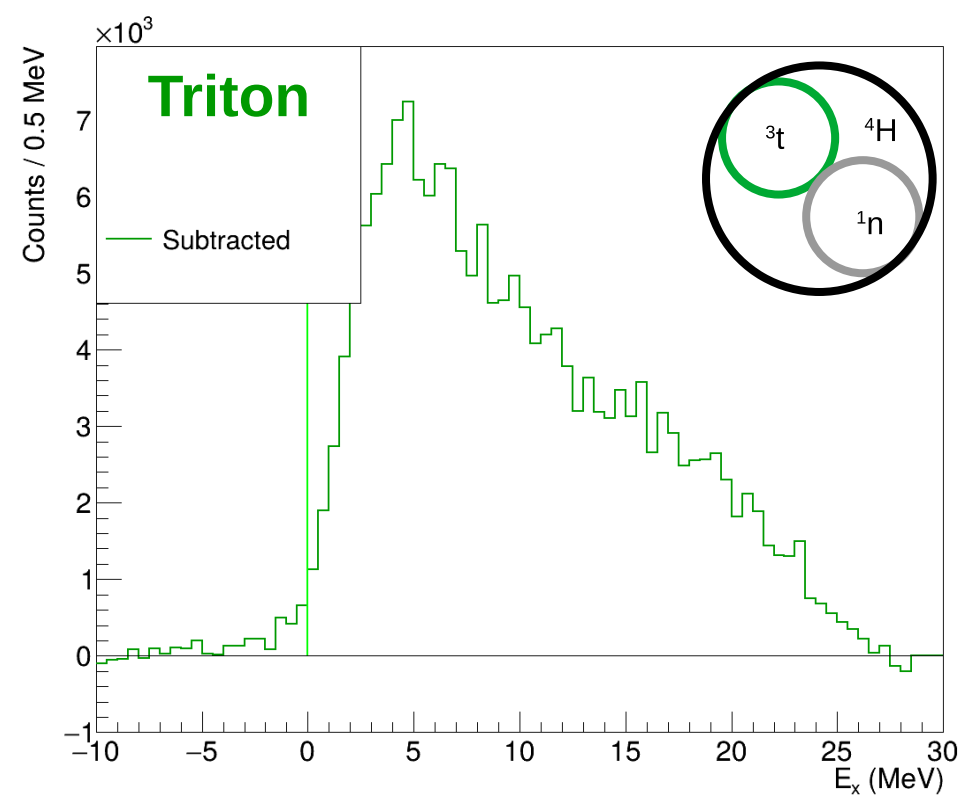
No « sharp » structure :

$\Rightarrow$ **No clear signature of the ${}^4\text{n}$ IAS !**

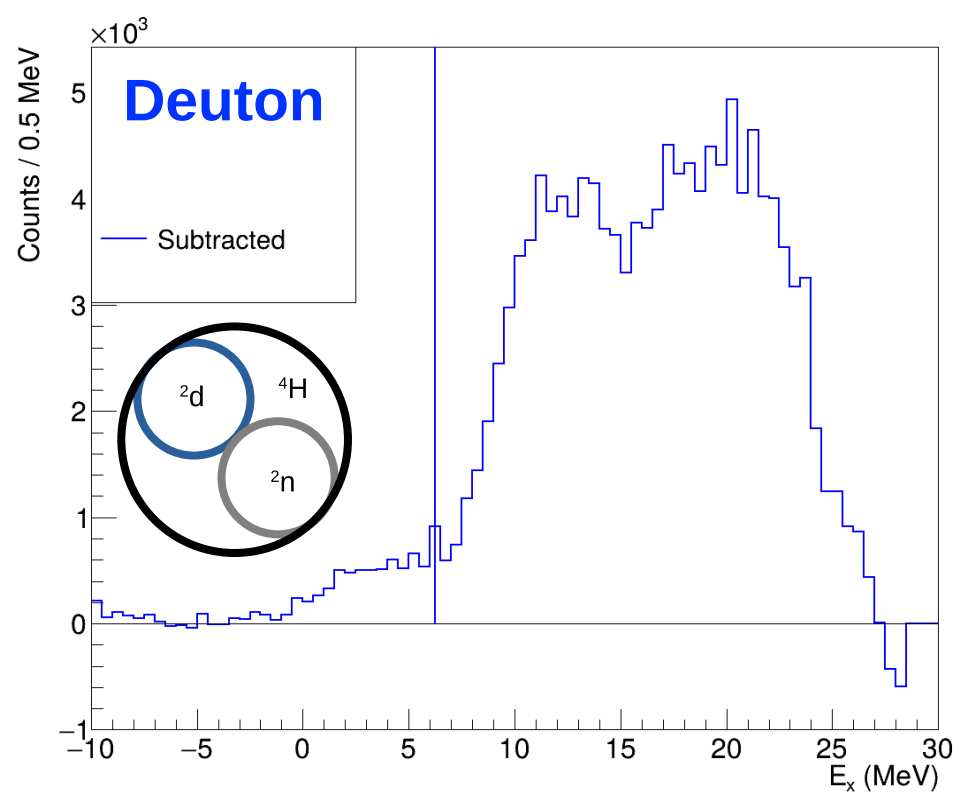
$\Rightarrow$ Upper limit on cross-section to determine

$^6\text{He}(p, ^3\text{He})^4\text{H}$ reaction

Other decay channel :

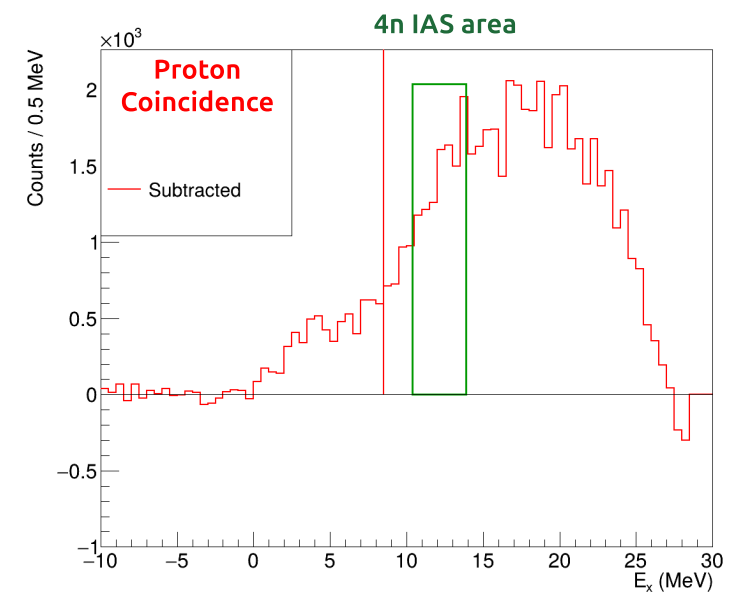
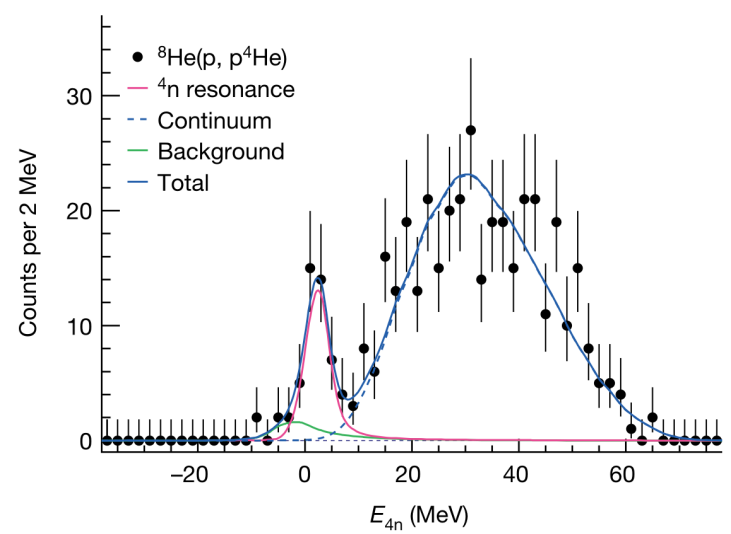


Unbound ground state of ^4H

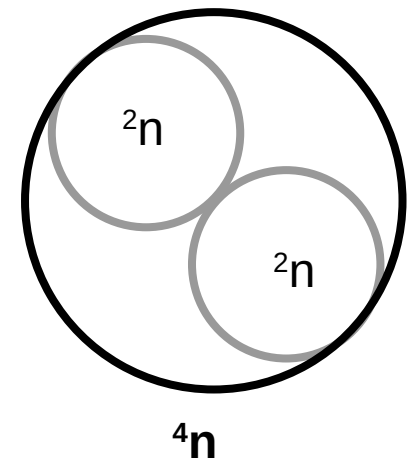


Resonance structure appears in the deuteron channel

Conclusion



IAS not observed !



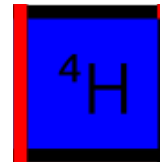
Current interpretation
of « tetra-neutron »
observation

Di-neutron/Di-neutron
final state interaction

Thank you for your attention !

Quentin Délignac

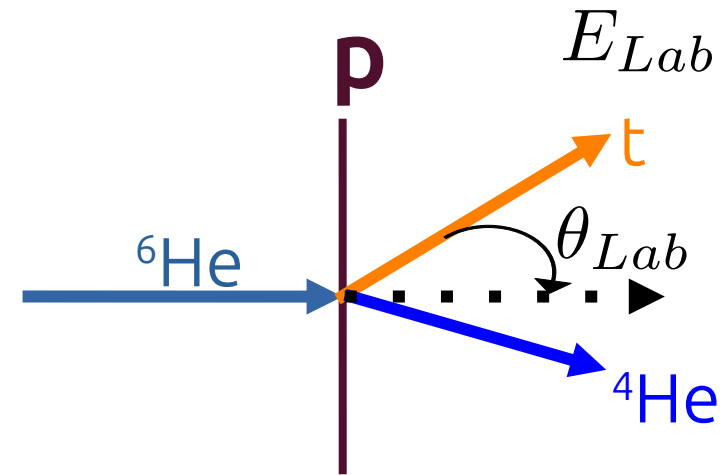
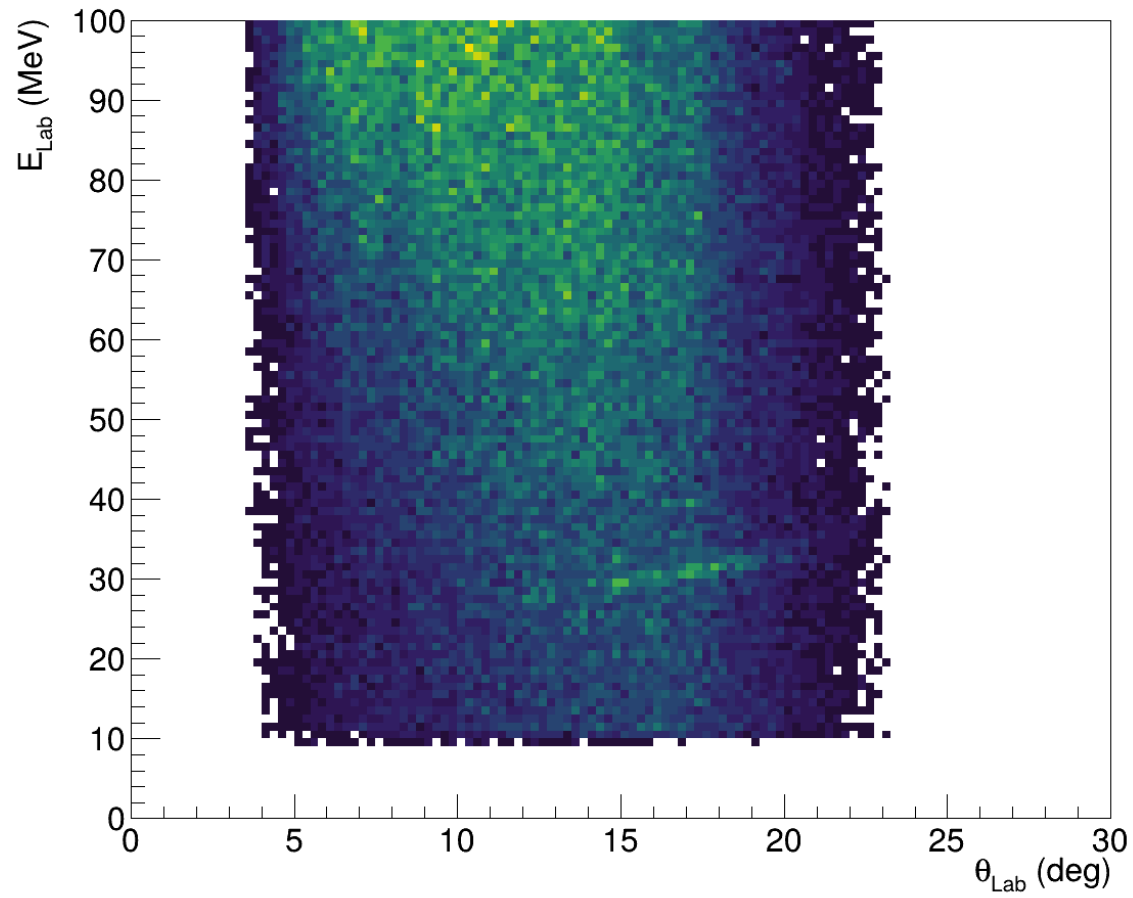
E873 Collaborator :



M. Assié, A. Macchiavelli, V. Alcindor-Girard, A. Bahini, D. Beaumel, Y. Blumenfeld, S. Bottoni, E. Clément, N. De Séréville, L. Dienis, F. Galtarossa, N. Giha, A. Gottardo, H. Guerin, F. Hammache, H. Jacob, D. Mengoni, O. Nasr, R. Nicolas des Alamo, C. Paxman, S. Pigliapocco, F. Rotaru, P. Sharma, O. Sorlin, I. Stefan, M. Stanoiu, J.C. Thomas, T. Zanatta Martinez

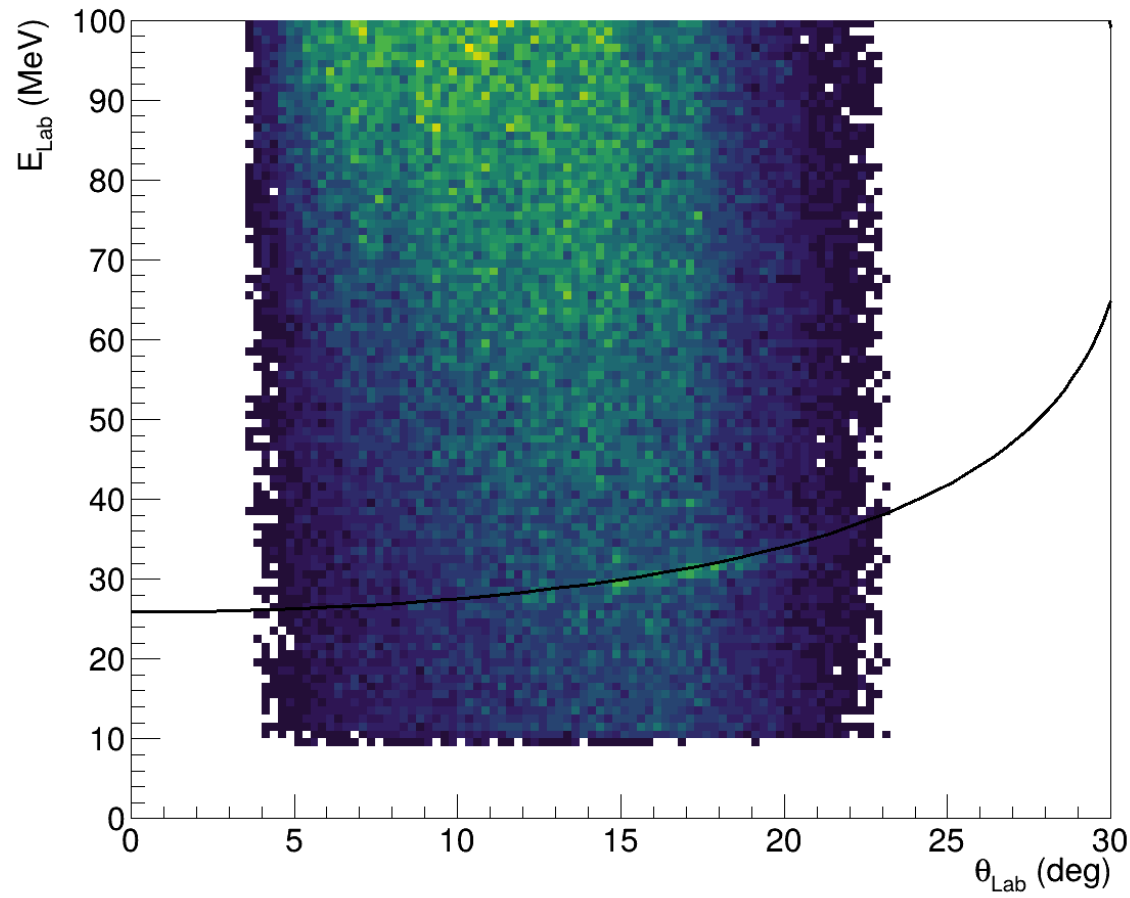
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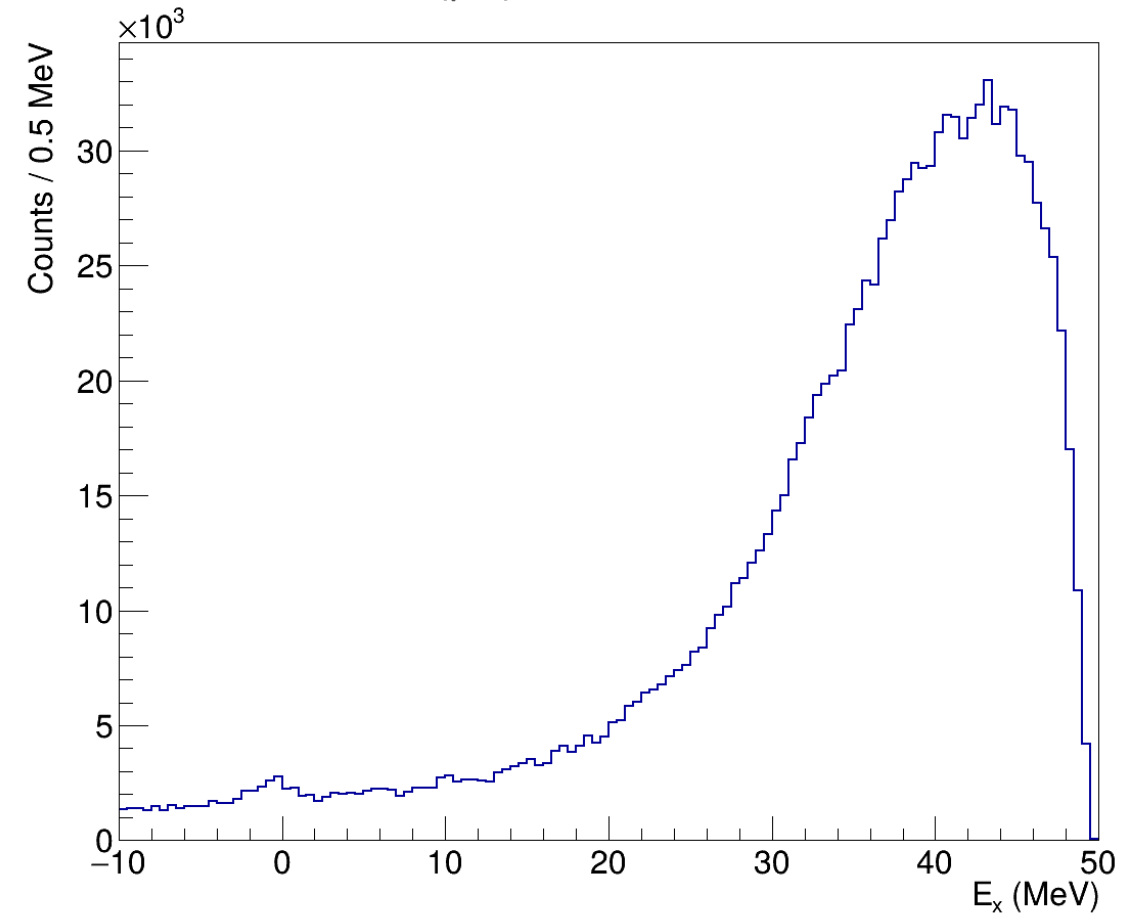


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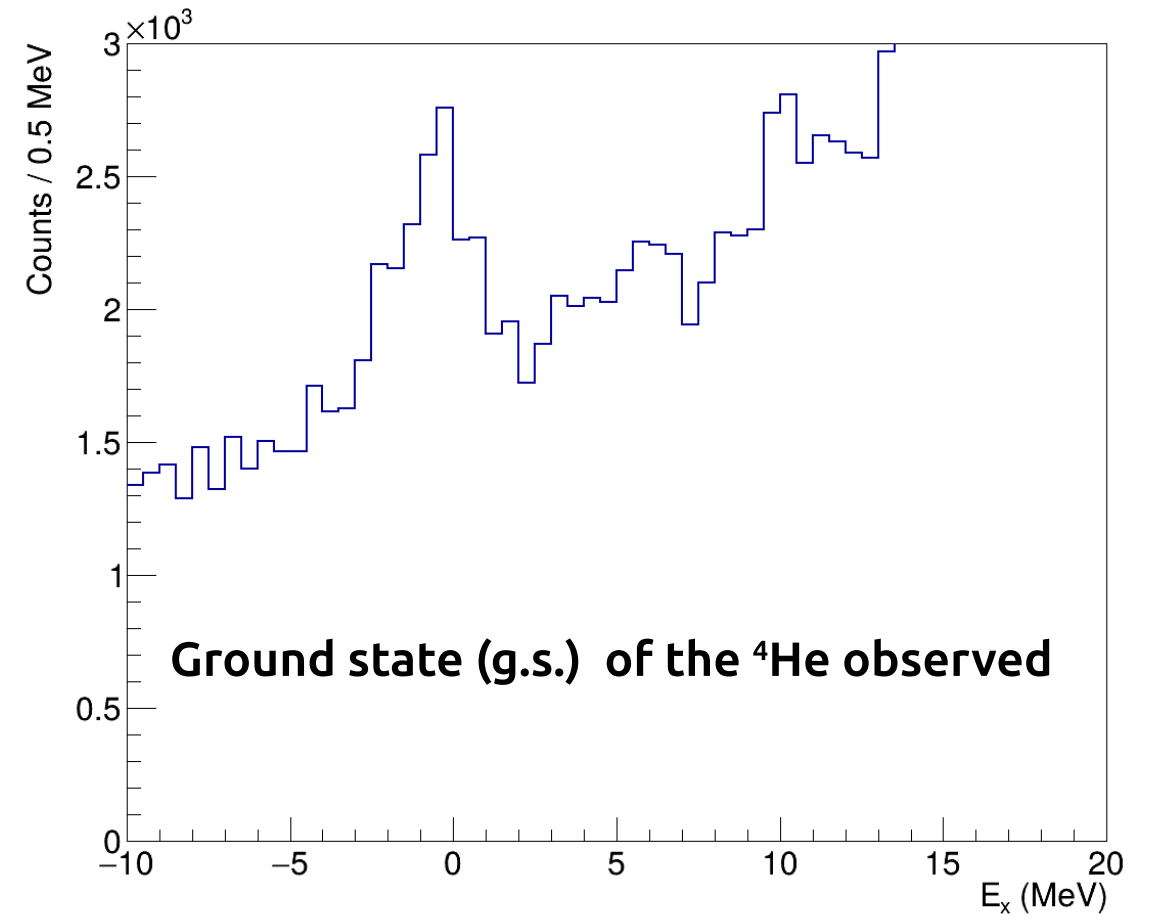
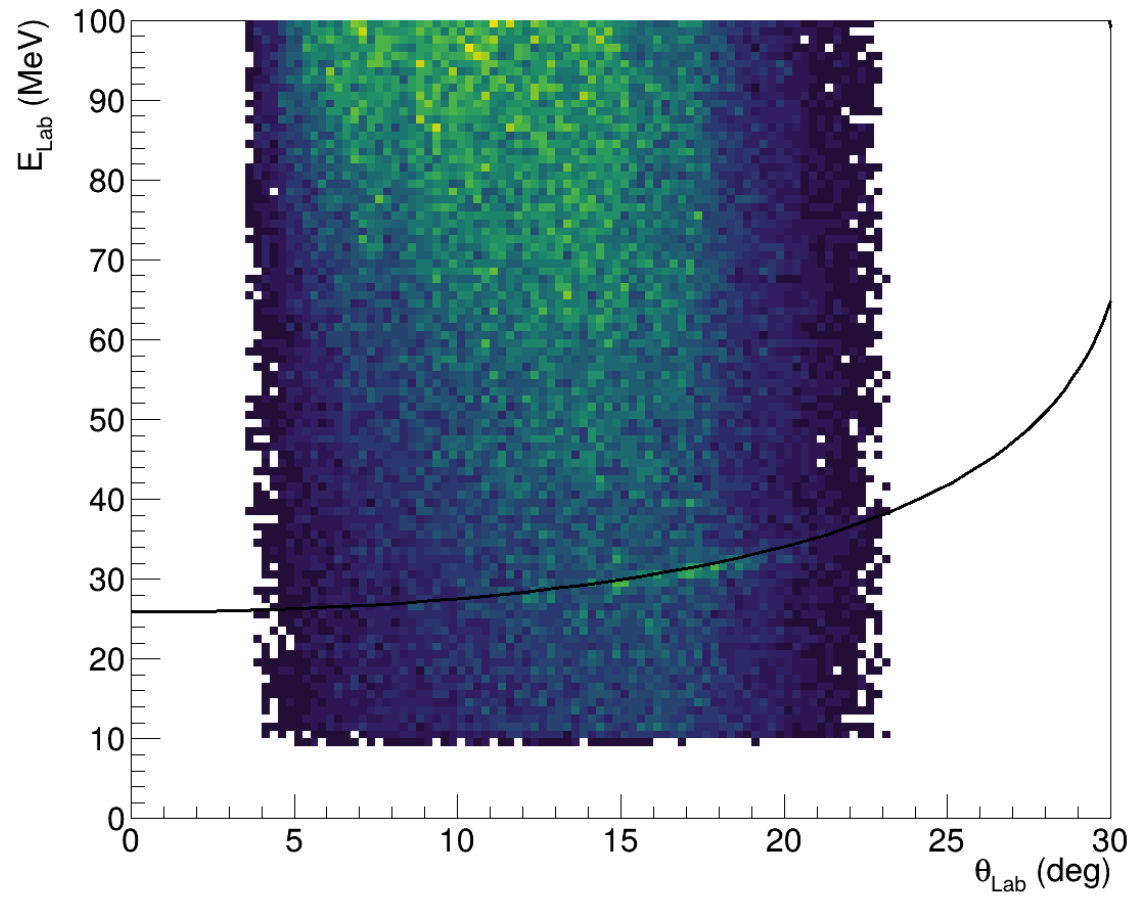


${}^6\text{He}(p,t){}^4\text{He}$ - Coinc 4He



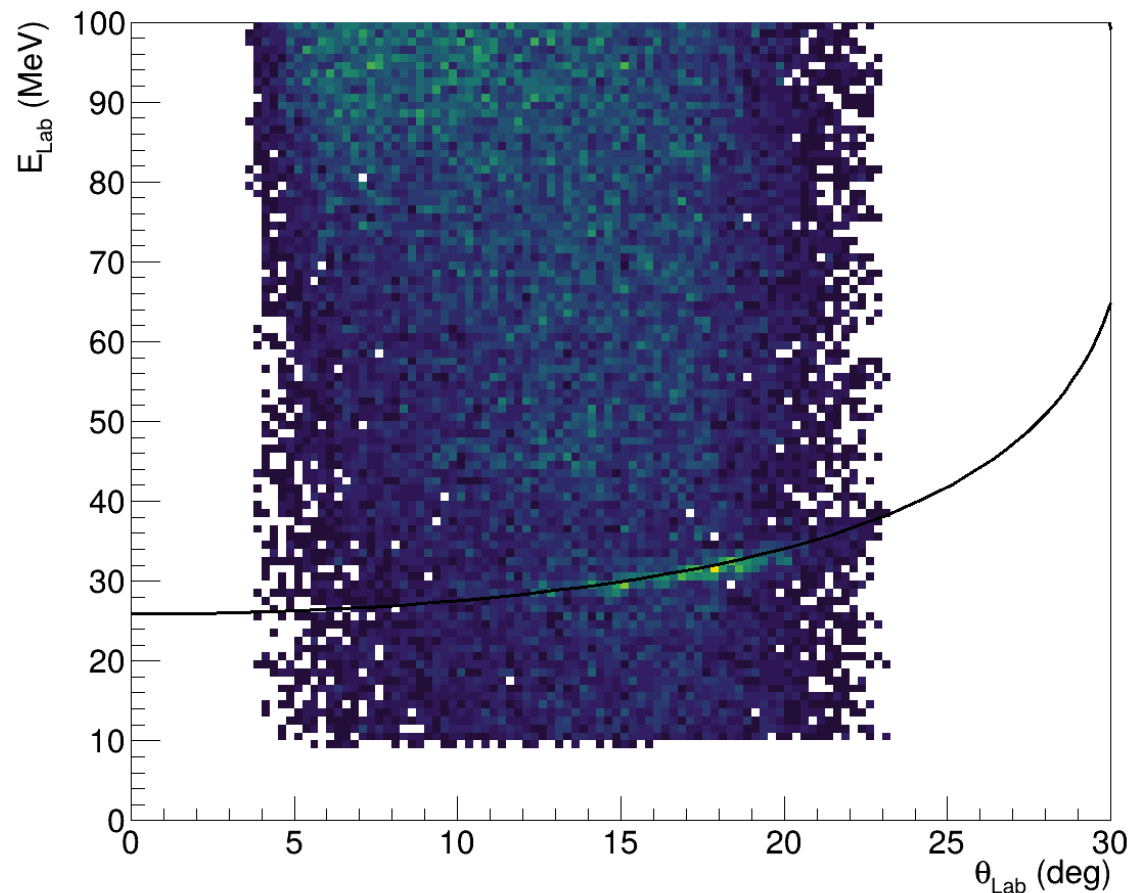
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E_{Lab} vs θ_{Lab} for 3H - Coinc 4He - $150^\circ < \Delta\phi < 210^\circ$



All the physic is included in the Phi cut !

