Study of the reaction $^{6}Li + p \rightarrow {}^{3}He + {}^{4}He$ with DINEX telescope

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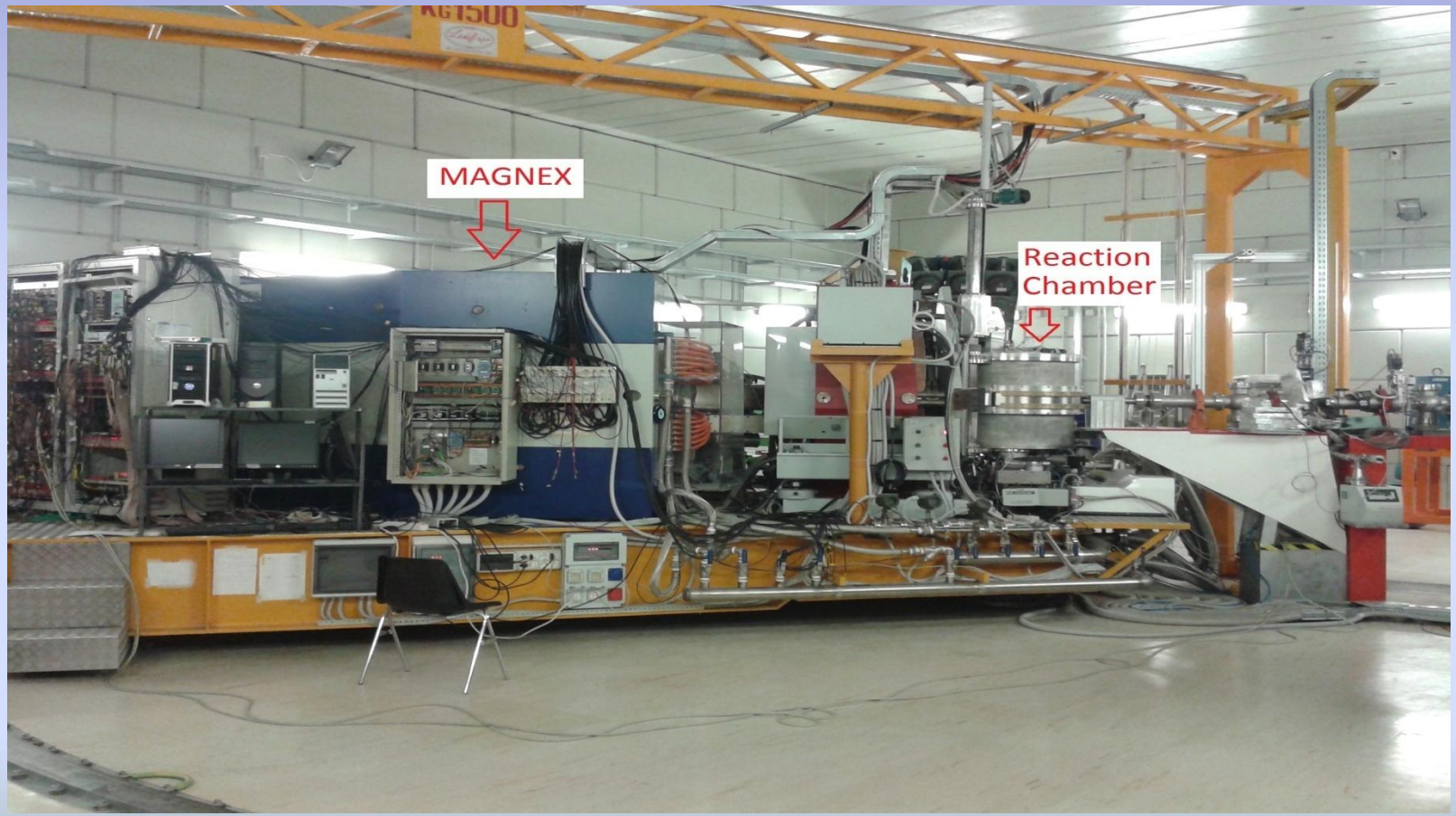
Motives for studying the $^{6}Li + p \longrightarrow {}^{3}He + {}^{4}He$

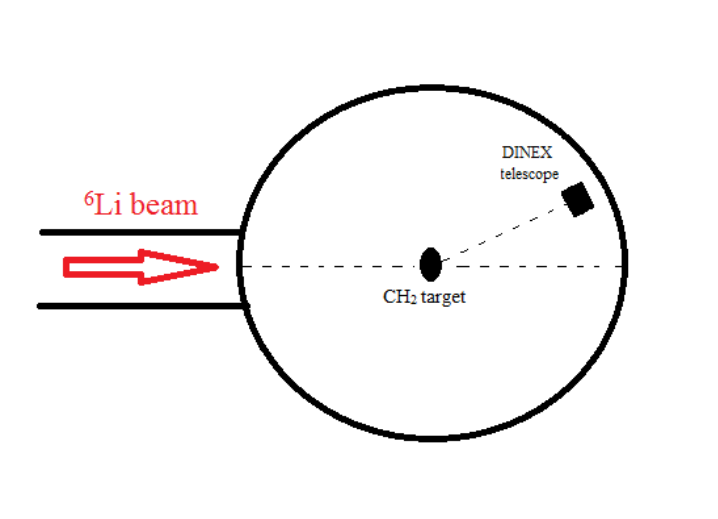
- The study of $p(^{6}Li,^{3}He)^{4}He$ is a complementary part of the LIPMAGNEX experiment (measurements of elastic scattering and breakup modes) and will contribute for understanding the reaction mechanism of $^{6}Li + p$
- This reaction is significant for astrophysical problems and for energy production both in stars and in thermonuclear reactors

Experimental set-up

The experiment was conducted in Instituto Nazionali di Fisica Nucleare - Laboratori Nazionali del Sud in Catania (INFN-LNS), Italy



Inside the reaction chamber..



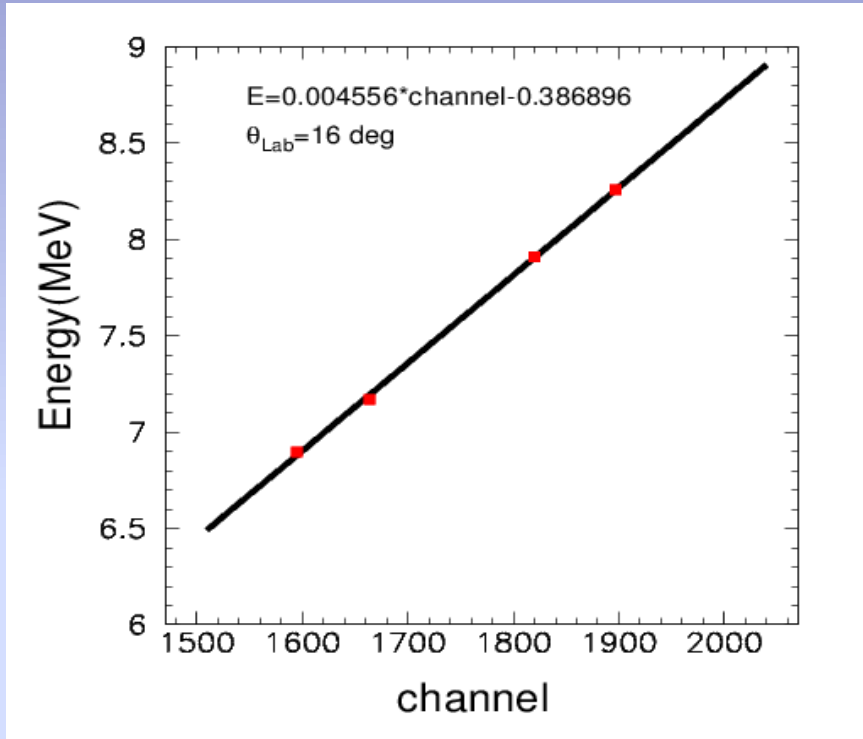
^{6}Li beam impinged on a ~300 μg/cm^2 CH_2 target
^{3}He and ^{4}He were recorded by one DINEX telescope

The **DINEX** telescope:
•set at a distance 15.5 cm from the target
• allocating from θ_{lab} =16˚-34˚ $\theta_{c.m.}$ =40˚-140˚
Consists of:
❑ 1 **ΔE** *DSSSD* Silicon detector:
-48 μm thick
-Active area of 5 x 5 cm
-16 vertical & 16 horizontal strips
❑ 2 **E** Silicon detectors
-530 μm thick

Energy calibration of ΔE and E

- Necessary for the identification of ^{3}He και ^{4}He in spectrum
- Based on measurements performed with gold and carbon

$$E = a * channel + b$$



Differential cross section:

$$\frac{d\sigma(\theta)}{d\Omega} = \frac{\mathrm{N}(\theta)}{\Phi * \Omega * D}$$

where:

N: number of counts/time

Φ: beam's flux (particles/time)

Ω: solid angle(steradian)

D: hydrogen's scattering centers (atoms/cm^2)

units: mbarn/sr (1 mbarn=$10^{-27}cm^2$)

Solid angle Ω:

$$\Omega = \frac{\mathrm{N}}{\Phi * D * \sigma_{Ruth.}}$$

Units: steradian

based on measurements performed with gold at Elab= 25MeV (*Rutherford scattering*)

where:

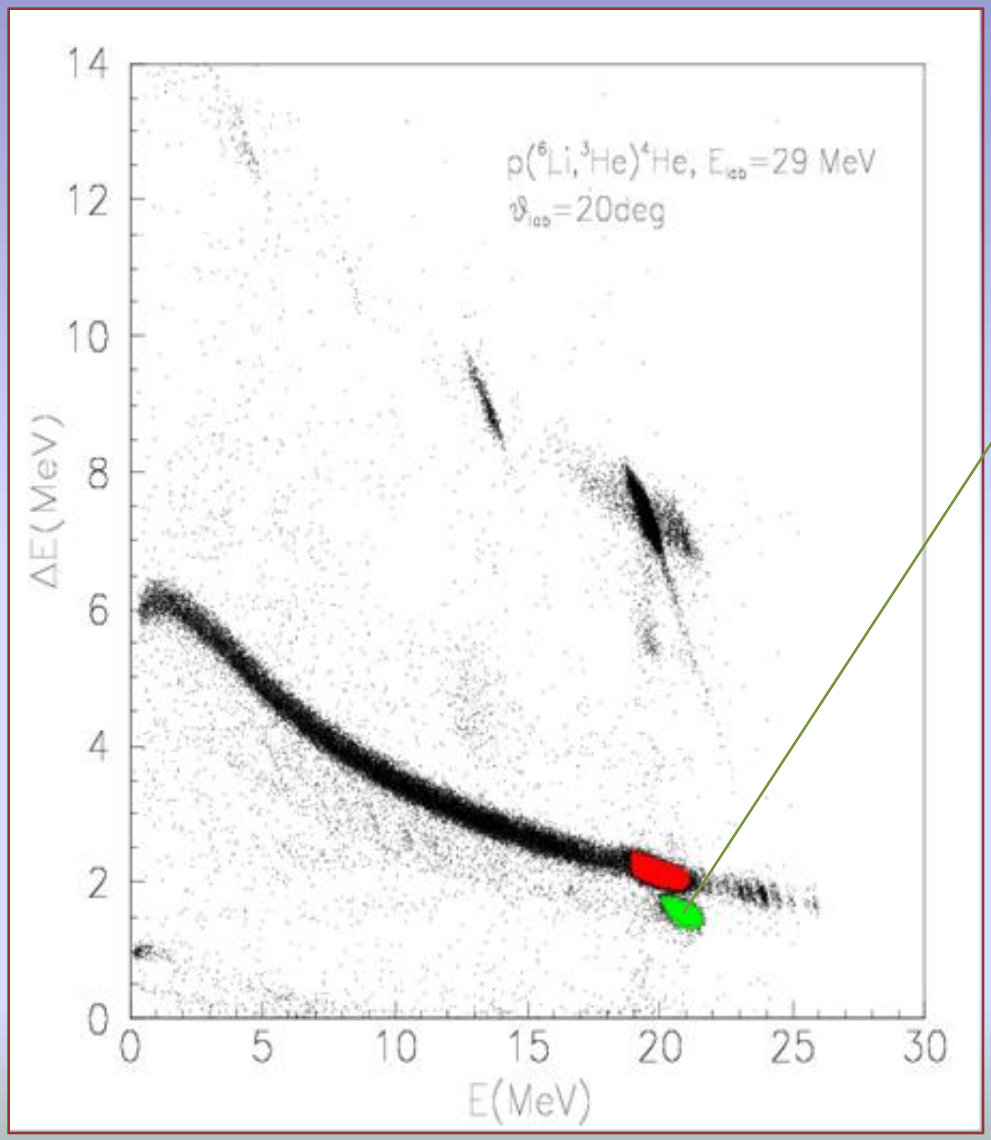
N: number of counts/time

Φ: beam's flux (particles/time)

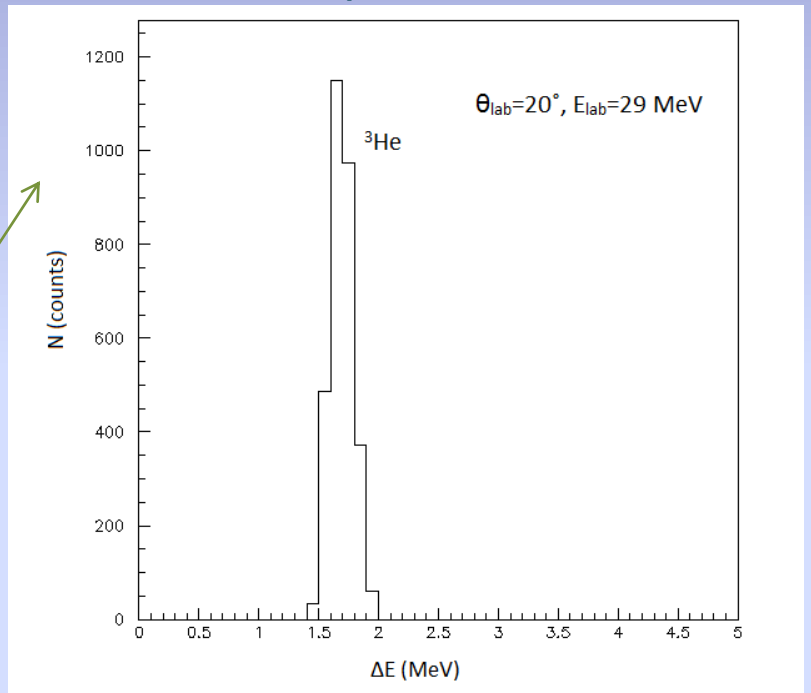
$\sigma_{Ruth.}$: Rutherford cross section (mbarn/sr)

D: scattering centers of ^{197}Au (atoms/cm^2)

In a two-dimension spectrum...

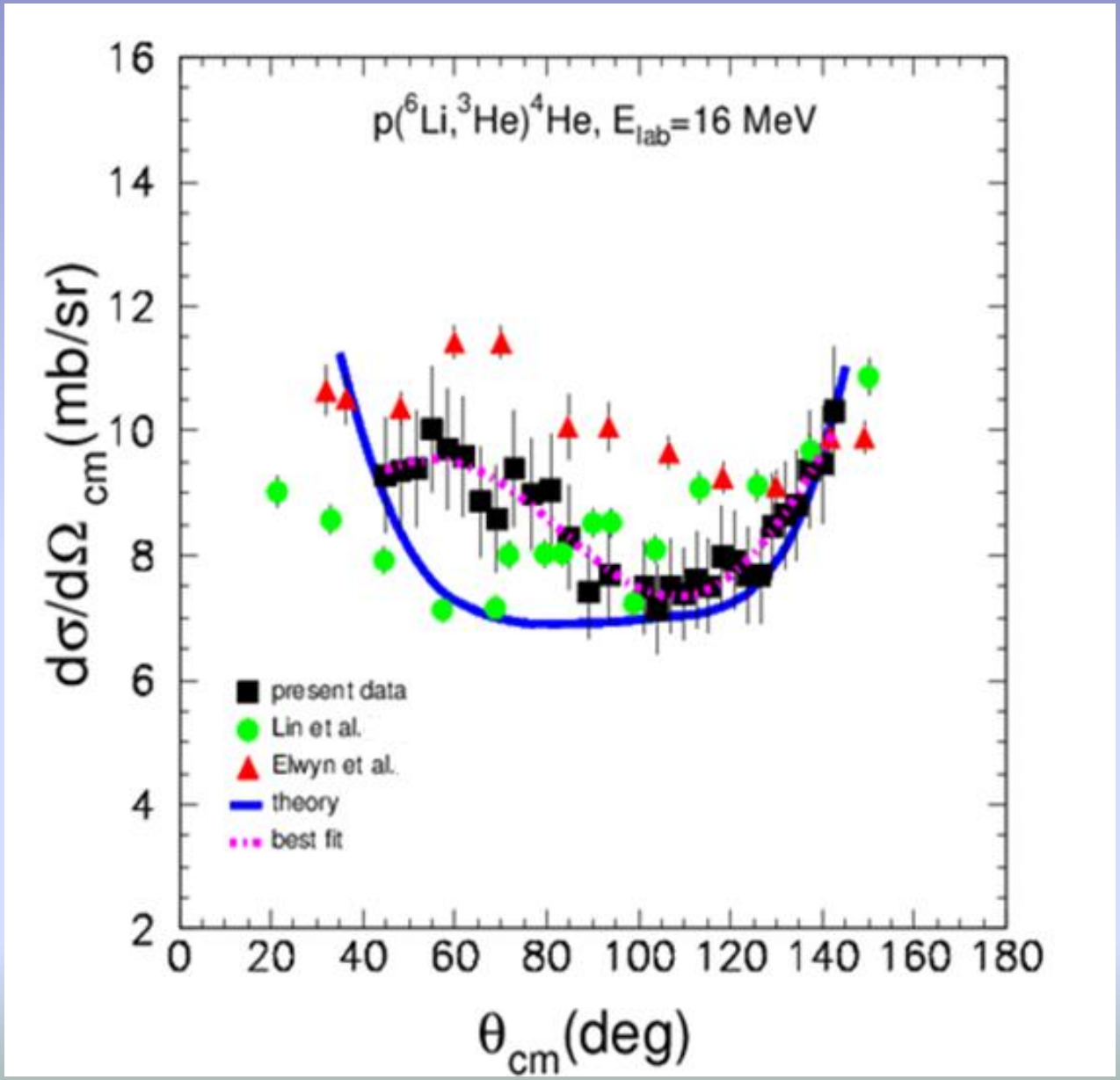


Identification of ^{3}He και ^{4}He via ΔE-E technique



$$\frac{d\sigma(\theta)}{d\Omega} = \frac{\mathrm{N}(\theta)}{\Phi * \Omega * D}$$

Angular distribution at 16 MeV



^4He is observed from $\theta_{c.m}$ =45˚ to 94˚ and *^3He* from $\theta_{c.m}$=101˚ to143 ˚

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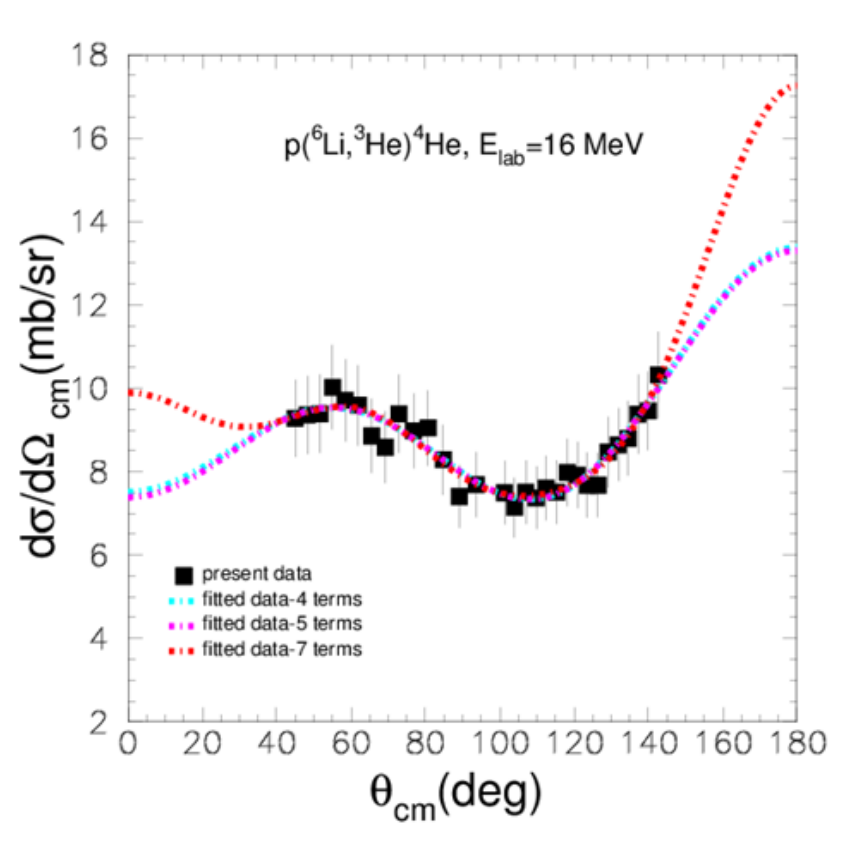
Determination of reaction cross section at 16 MeV



Fit of the $\frac{d\sigma}{d\Omega}$ to a sum of Legendre polynomials $\sum_{l=0} B_l P_l(\cos(\theta))$ with 4, 5 and 7 terms

→ reaction cross section

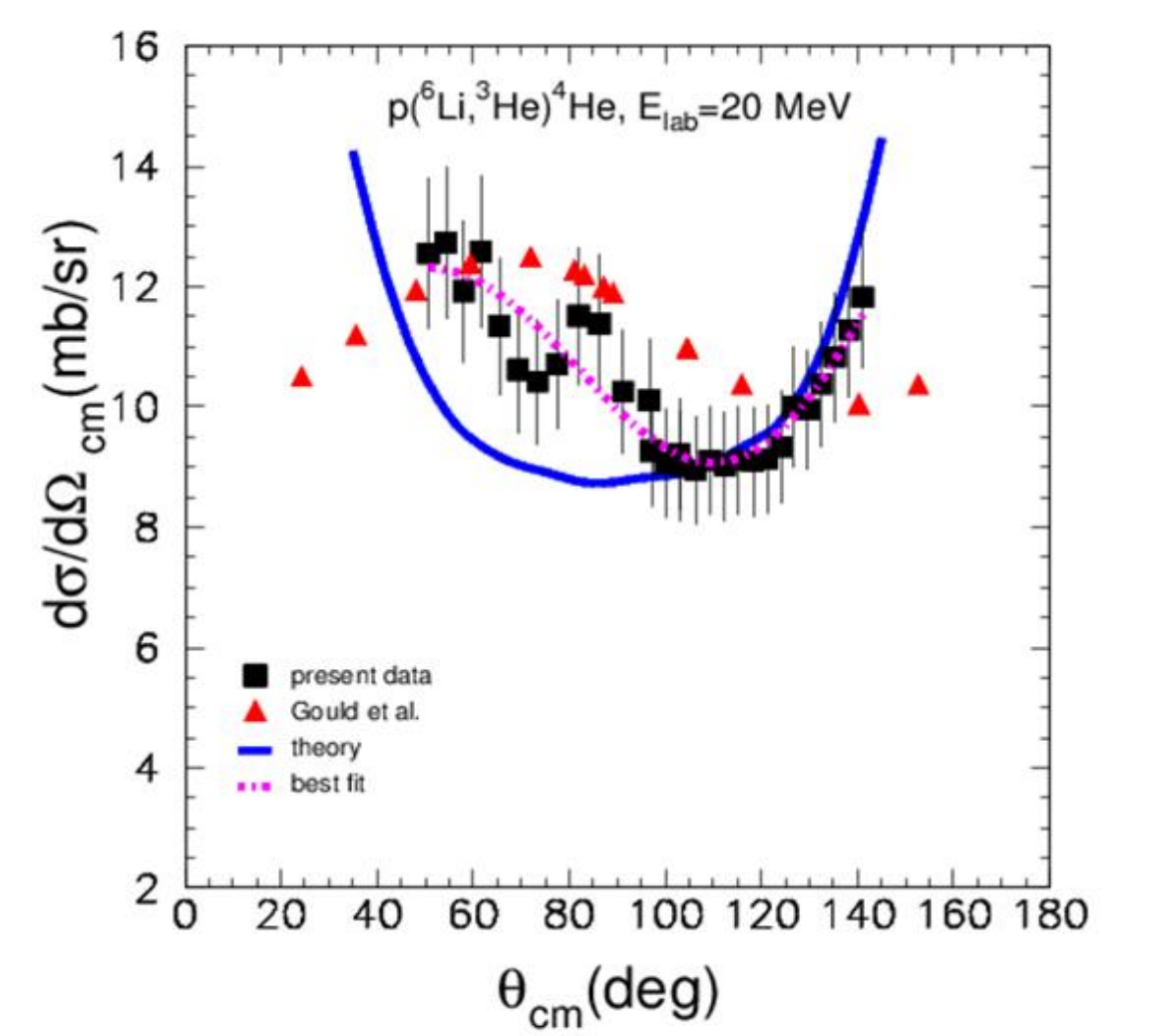
$\sigma_r = 4\pi B_o$

Taking the mean value of cross sections from various fits:

↓

$\sigma_r = (111 \pm 2)$ mb

Angular distribution at 20 MeV



4He is observed from $\theta_{c.m}$=47˚ to 103˚ and *3He* from $\theta_{c.m}$=97˚ to141 ˚

The overlapping of ^{3}He and ^{4}He at the angular range from 97˚ to 103˚ confirms the background subtraction

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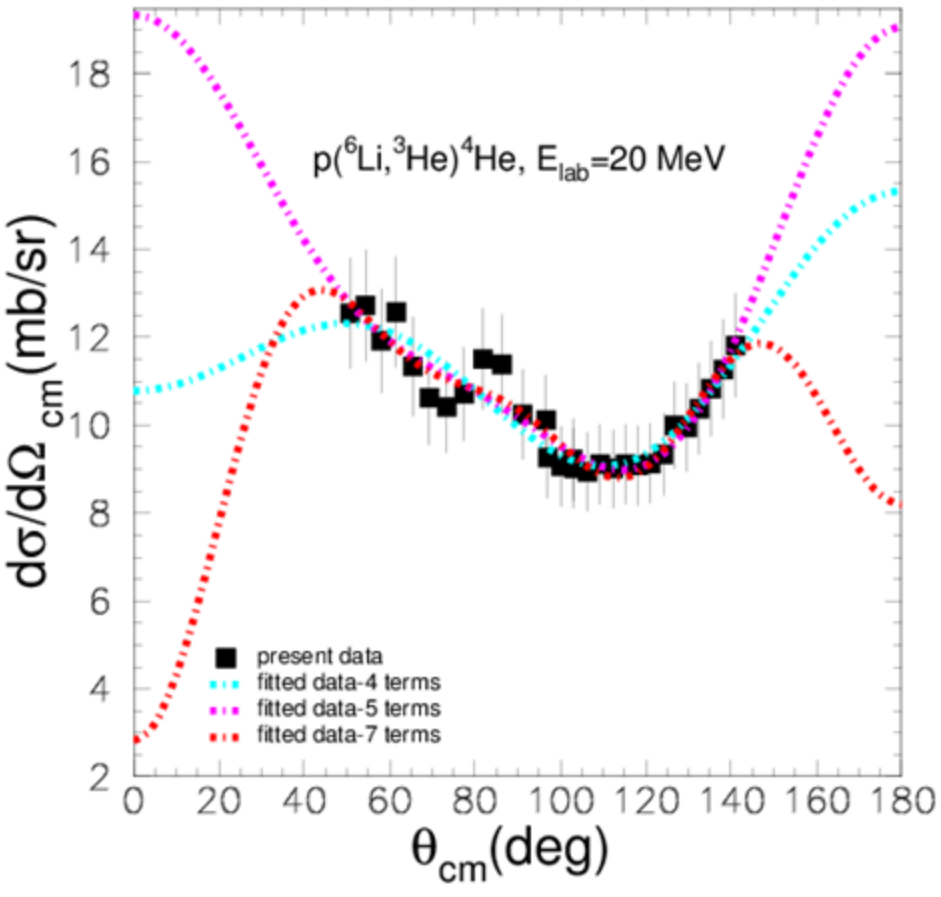
Determination of reaction cross section at 20 MeV



Fit of the $\frac{d\sigma}{d\Omega}$ to a sum of Legendre polynomials $\sum_{l=0}^{l} B_l P_l(\cos(\theta))$ with 4, 5 and 7 terms

→ reaction cross section

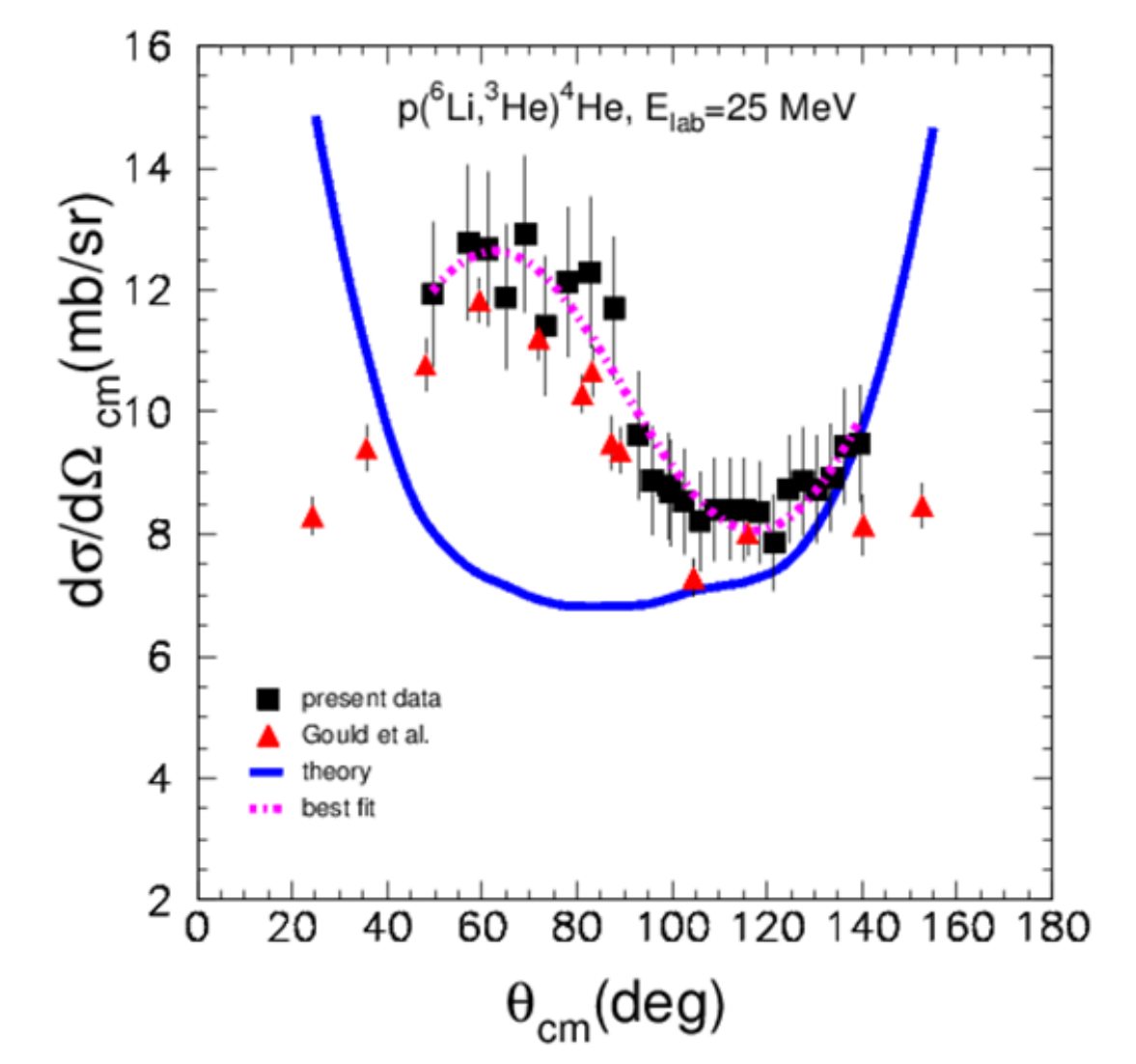
$\sigma_r = 4\pi B_o$

Taking the mean value of cross sections from various fits:

↓

$\sigma_r = (140 \pm 8)$ mb

Angular distribution at 25 MeV



4He is observed from $\theta_{c.m}$=50˚ to 100˚ and *3He* from $\theta_{c.m}$=96˚ to140 ˚

The overlapping of ^{3}He and ^{4}He at the angular range from 96˚ to 100˚ confirms the background subtraction

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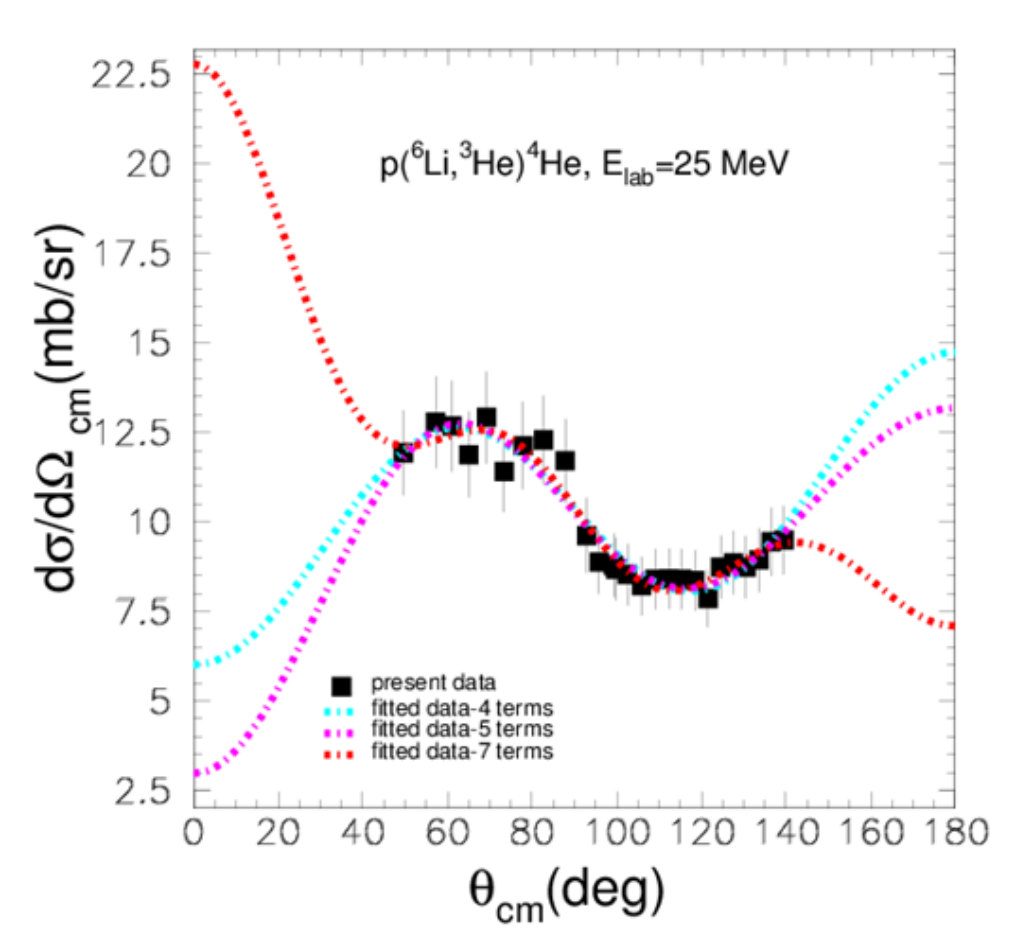
Determination of reaction cross section at 25 MeV



Fit of the $\frac{d\sigma}{d\Omega}_{l}$ to a sum of Legendre polynomials $\sum_{l=0} B_l P_l(\cos(\theta))$ with 4, 5 and 7 terms

→ reaction cross section

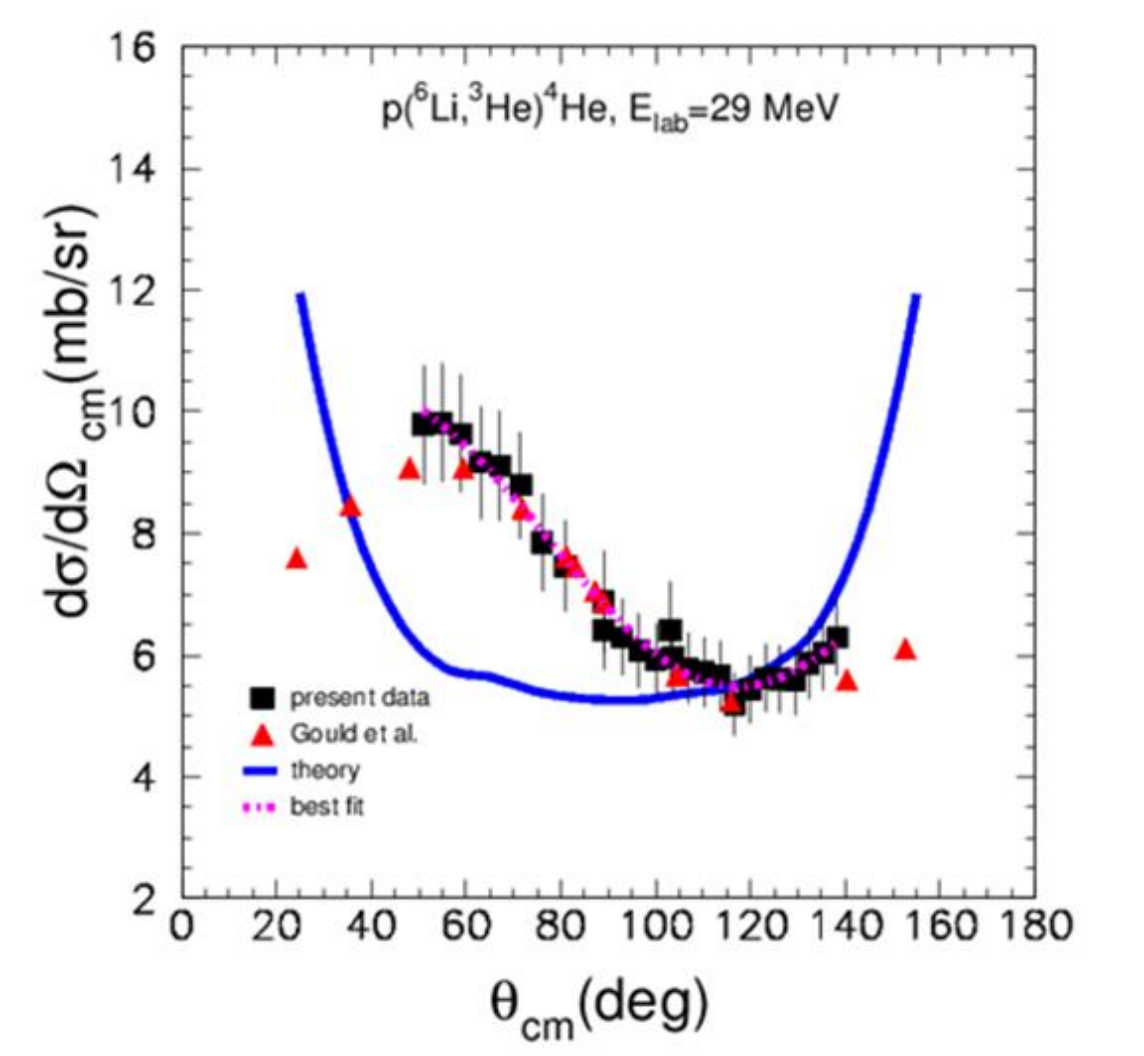
$\sigma_r = 4\pi B_o$

Taking the mean value of cross sections from various fits:

↓

σ_r= (131±6) mb

Angular distribution at 29 MeV



^{4}He is observed from $\theta_{c.m}$=51˚ to 103˚ and *^{3}He* from $\theta_{c.m}$=89˚ to138˚

The overlapping of ^{3}He and ^{4}He at the angular range from 89˚ to 103˚ confirms the background subtraction

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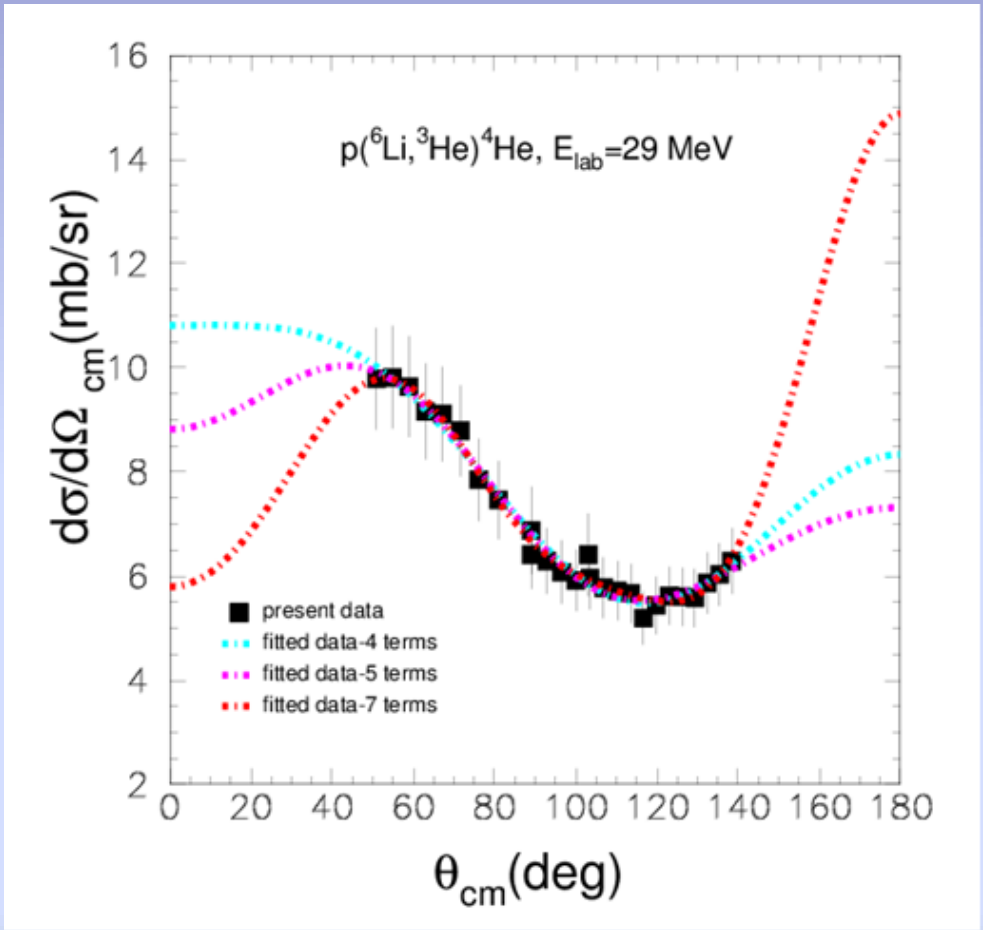
Determination of reaction cross section at 29 MeV



Fit of the $\frac{d\sigma}{d\Omega}$ to a sum of Legendre polynomials $\sum_{l=0}^{l} B_l P_l(\cos(\theta))$ with 4, 5 and 7 terms

→ reaction cross section

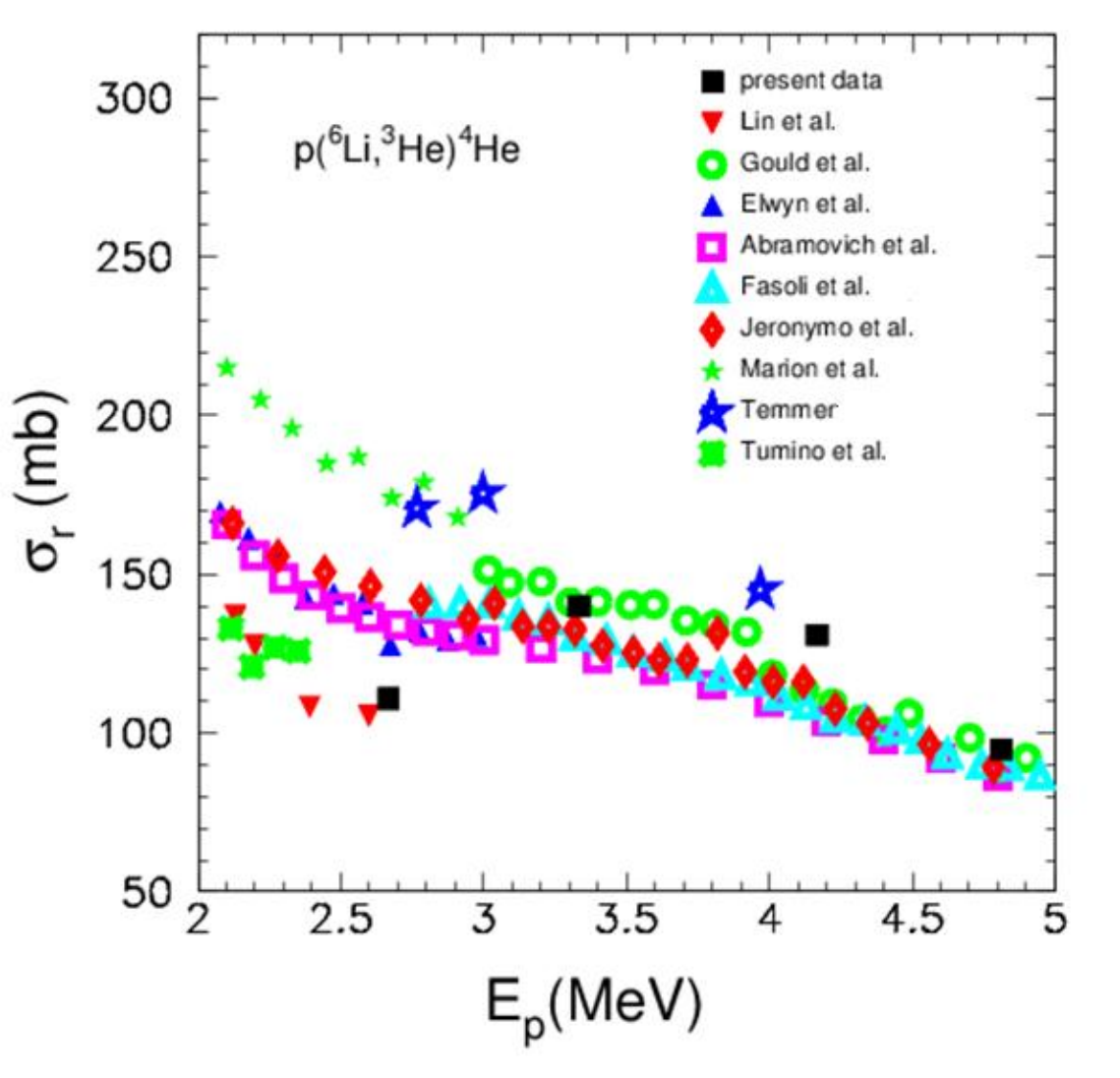
$\sigma_r = 4\pi B_o$

Taking the mean value of cross sections from various fits:

↓

σ_r= (95±2) mb

Reaction cross section



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Total cross section of the reaction

E_{lab} (MeV)	σ_r (mb)	σ_{MECO} (mb)	σ_{CDCC} (mb)
16	111±2	114	131
20	140±8	145	162
25	131±6	114	133
29	95±2	90	110

- Compound calculations with the code MECO for the production of ^{4}He and ^{3}He by Dr. N. Nicolis → indicates the strong presence of compound mechanism

- Coupled Reaction Channels (CRC) calculations for the ^{6}Li(p,^{3}He)^{4}He with the code FRESCO carried out by Dr. N. Keeley → small contribution from direct mechanism

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Total cross section of the reaction

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29	95±2	90	110

•The experimental data from the elastic scattering $^{6}Li + p \rightarrow {}^{6}Li + p$ were reproduced in a Continuum Discretized Coupled Channel calculation framework (CDCC) performed by Prof K. Rusek→ determination of total cross sections and breakup cross sections → absorption cross section→ the $^{6}Li + p \rightarrow {}^{3}He + {}^{4}He$ is the most prominent reaction

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Conclusions

- Inter consistency of all data recorded in LIPMAGNEX experiment (elastic scattering, breakup and p(^{6}Li,^{3}He)^{4}He) → validity of present data which:
  - favor Lin et al. results
  - indicate a possible new resonance centered at E_p=3.7MeV
- Strong presence of the compound mechanism and a small contribution from direct mechanisms

Acknowledgements

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Thank you for your attention