$^{7}Be(n,\alpha)$ and $^{7}Be(n,p)$ cross section measurement for the Cosmological Lithium Problem at n_TOF-EAR2

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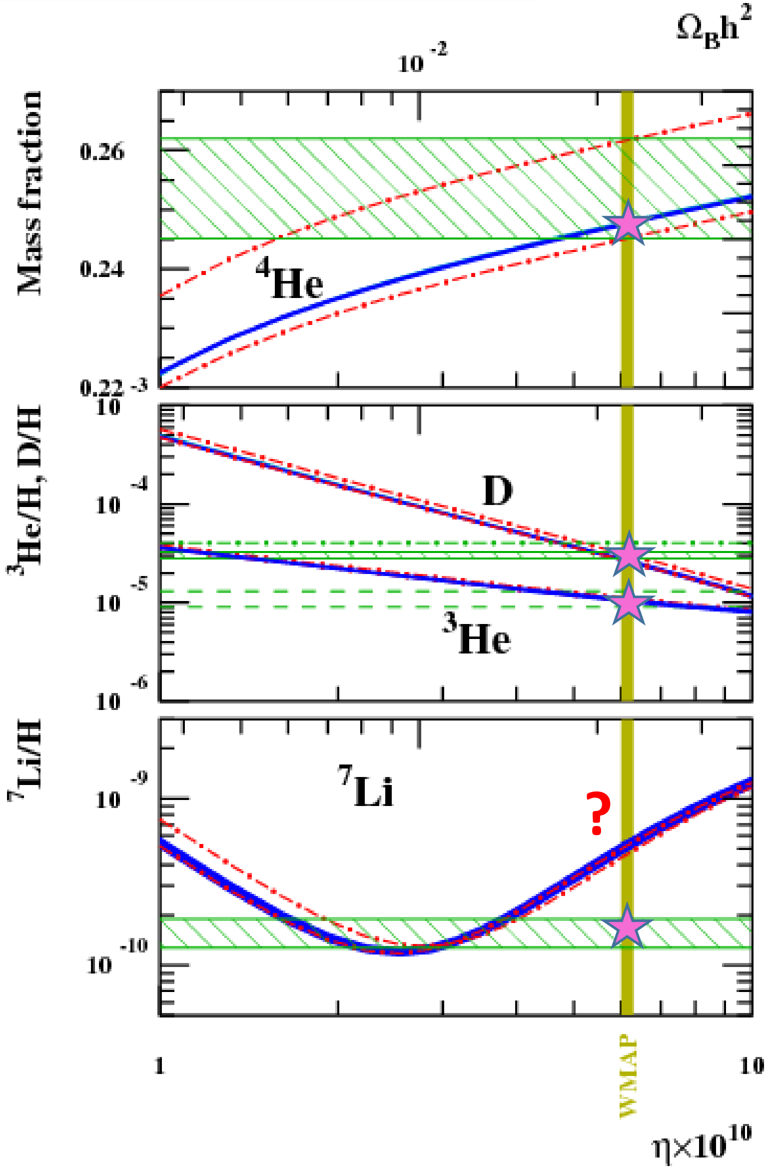
Outline

- Physics case: The Cosmological Lithium problem
- experimental set-up and results on the $^{7}\mathrm{Be}(n,\alpha)$ measurement
- experimental set-up and preliminary results on the $^{7}\mathrm{Be}(n,p)$ measurement
- Conclusions

The Cosmological Lithium Problem

The **Big Bang Nucleosinthesys (BBN)** successfully predicts the abundances of primordial elements such as ^{4}**He**, **D** and ^{3}**He**

A **serious discrepancy** (factor **2**-**4**) between the predicted abundance of ^{6}Li and the value inferred by measurements

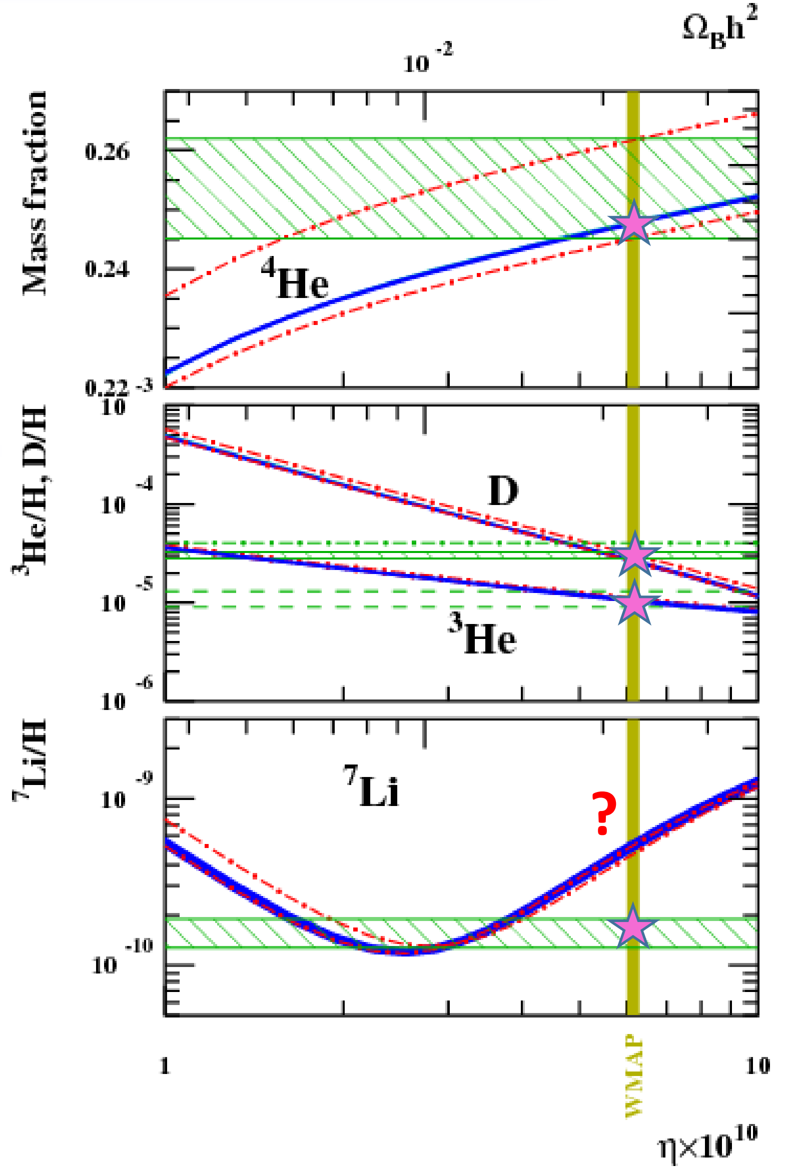


The Cosmological Lithium Problem

The **Big Bang Nucleosinthesys** succ
predicts the abundances
elements such as ^{4}H

COSMOLOGICAL LITHIUM PROBLEM (CLiP)

actor **2**-**4**) between
abundance of ^{6}Li and the
erred by measurements



The Cosmological Lithium Problem

In the BBN 95% of the primordial ^{7}Li is produced by the electron capture decay of ^{7}Be → The abundance of ^{7}Li is essentially determined by the production and destruction of ^{7}Be

A higher destruction rate of ^{7}Be can solve or at least partially explain the CLiP

^{7}Be can be destroyed via:

$$n + {}^7\mathrm{Be} \rightarrow p + {}^7\mathrm{Li} \quad \mathbf{Q} = 1.644\ \mathrm{MeV}\ (\sim \mathbf{95\%})$$

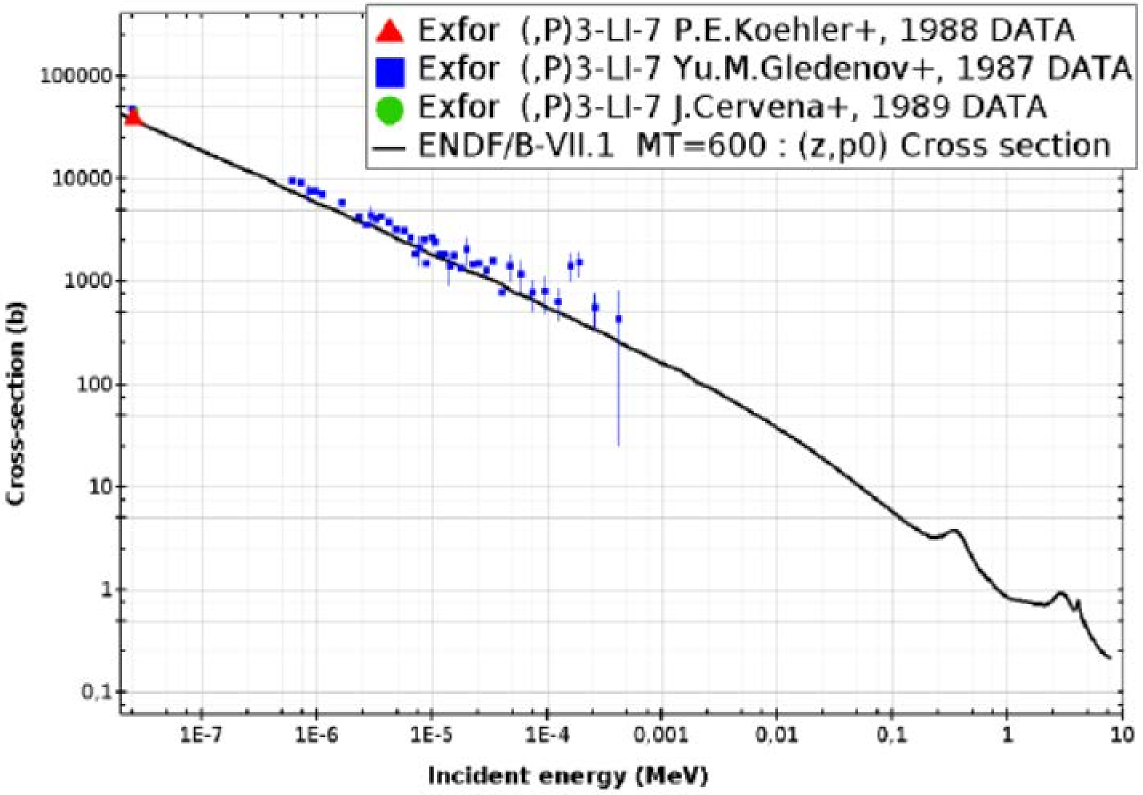
$$n + {}^7\mathrm{Be} \rightarrow \alpha + \alpha \quad \mathbf{Q} = 16.6\ \mathrm{MeV}\ (\sim \mathbf{2.5\%})$$

Status of evaluations and experimental data

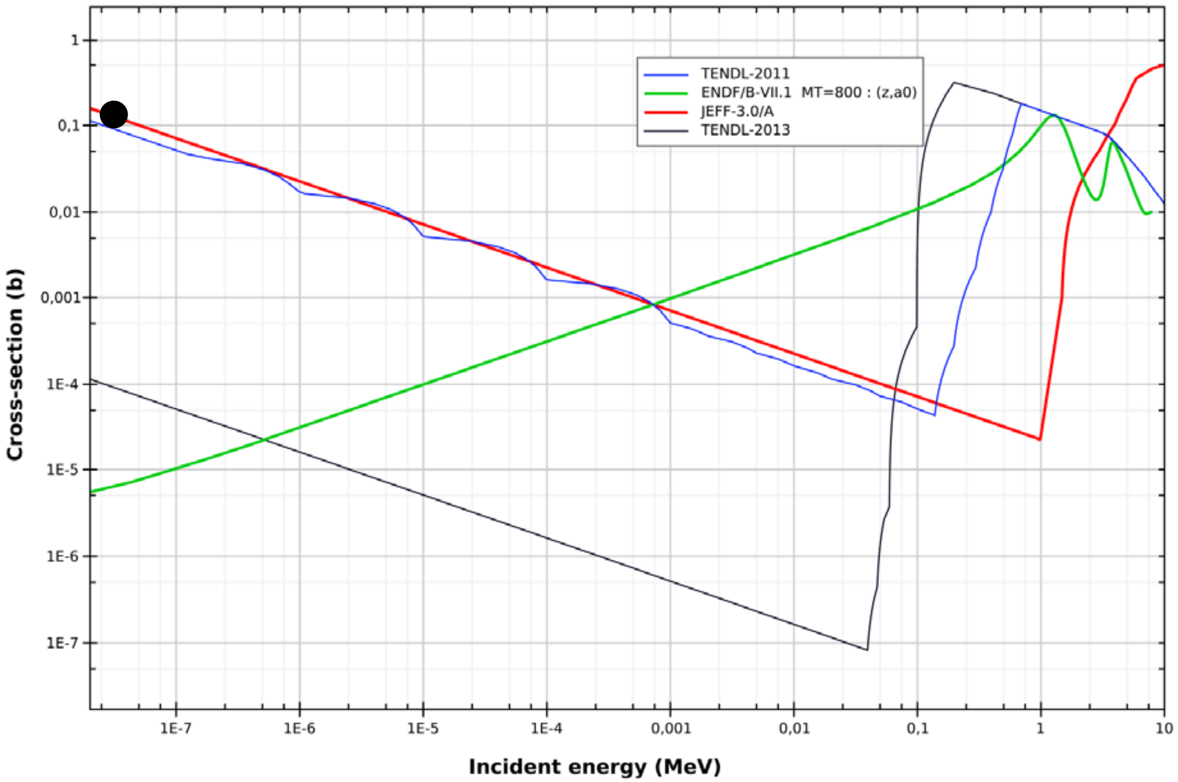
Only one direct measurement (**Koehler at al.**, 1988, **0.025 eV-13.5 keV**)

Only one direct measurement (**P. Bassi et al.**, 1963), at **thermal energy**.

$^{7}\mathbf{Be(n,p)}$



$^{7}\mathbf{Be\ (n,\alpha)}$



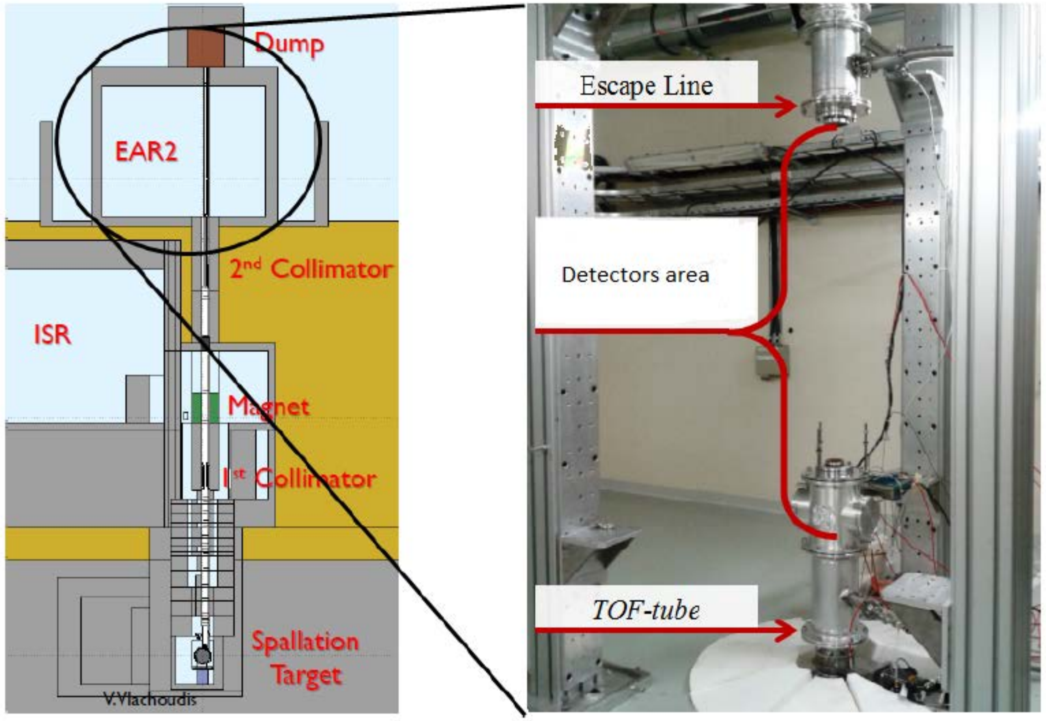
The second experimental area (EAR2) at n_TOF

Intrinsic difficulty of the measurement

- low cross section
- extremely high specific activity of ^{7}Be (**13 GBq/μg**)
- available in very small amounts
- short half-life: **53.3 d**

EAR2 *allows to perform a measurement of this two reactions* ***in the range of BBN interest*** ***(20-200 keV****)*

- very high instantaneus neutron flux: $\mathbf{10^7}$- $\mathbf{10^8\ n/cm^2/s}$
- wide energy range: from **thermal energy** up to **100 MeV**
- good energy resolution
- low repetition rate: **0.8 Hz**



Two different measurements at n_TOF

$n + {}^{7}Be \rightarrow \alpha + \alpha$ → **Coincidences tecnique (2015)**

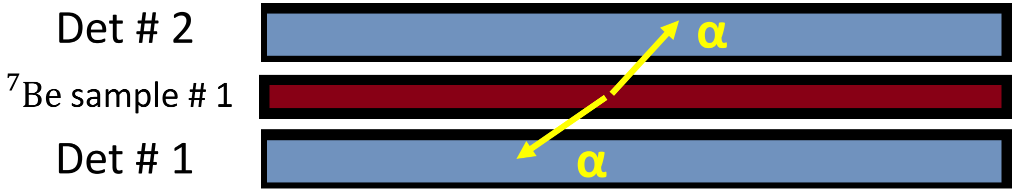
$n + {}^{7}Be \rightarrow p + {}^{7}Li$ → **Telescope tecnique (2016)**

^{7}Be(n, α) cross section measurement

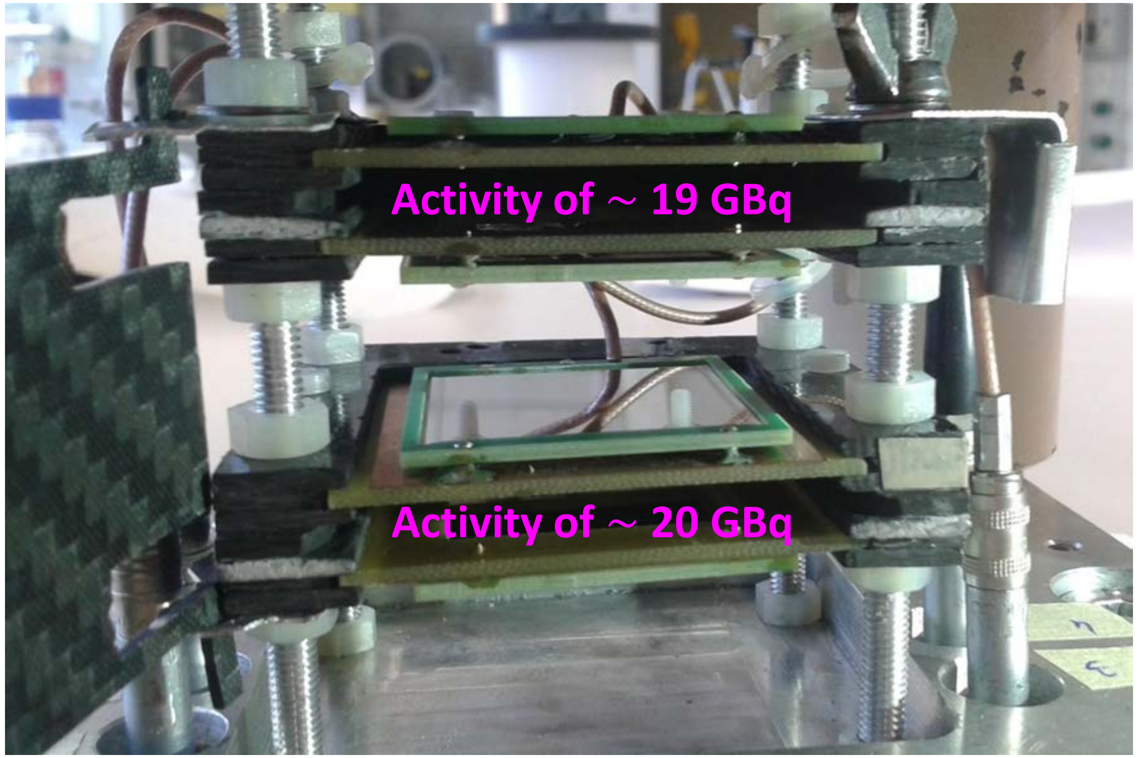
Silicon detectors directly inserted in the beam (**3 x 3 cm^2** active area, **140 μm** thickness)

Electrodeposited sample on 5μm thick Al foil

Droplet sample on 0.6 μm thick polyethylene foil



Time window of ± **100 ns** for α-α coincidences



^{7}Be(n, α) cross section measurement

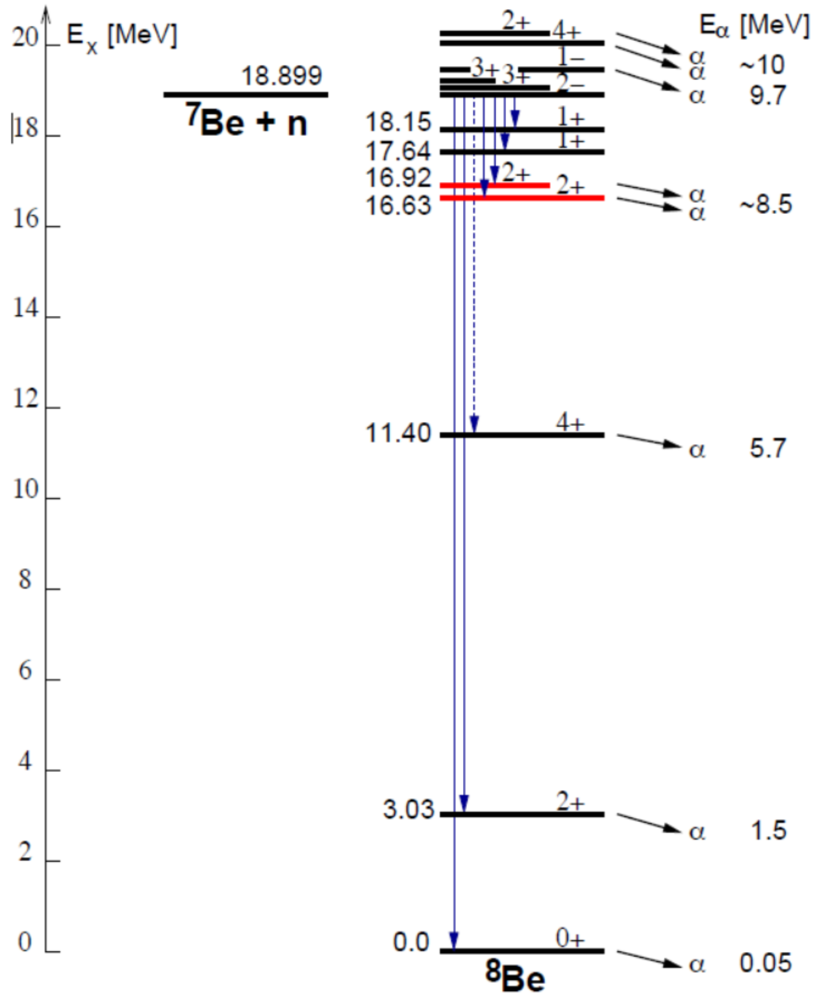
Background

❖ **γ-rays** from the ^{7}Be decay → 2 MeV threshold

❖ $^7Be\ decay$

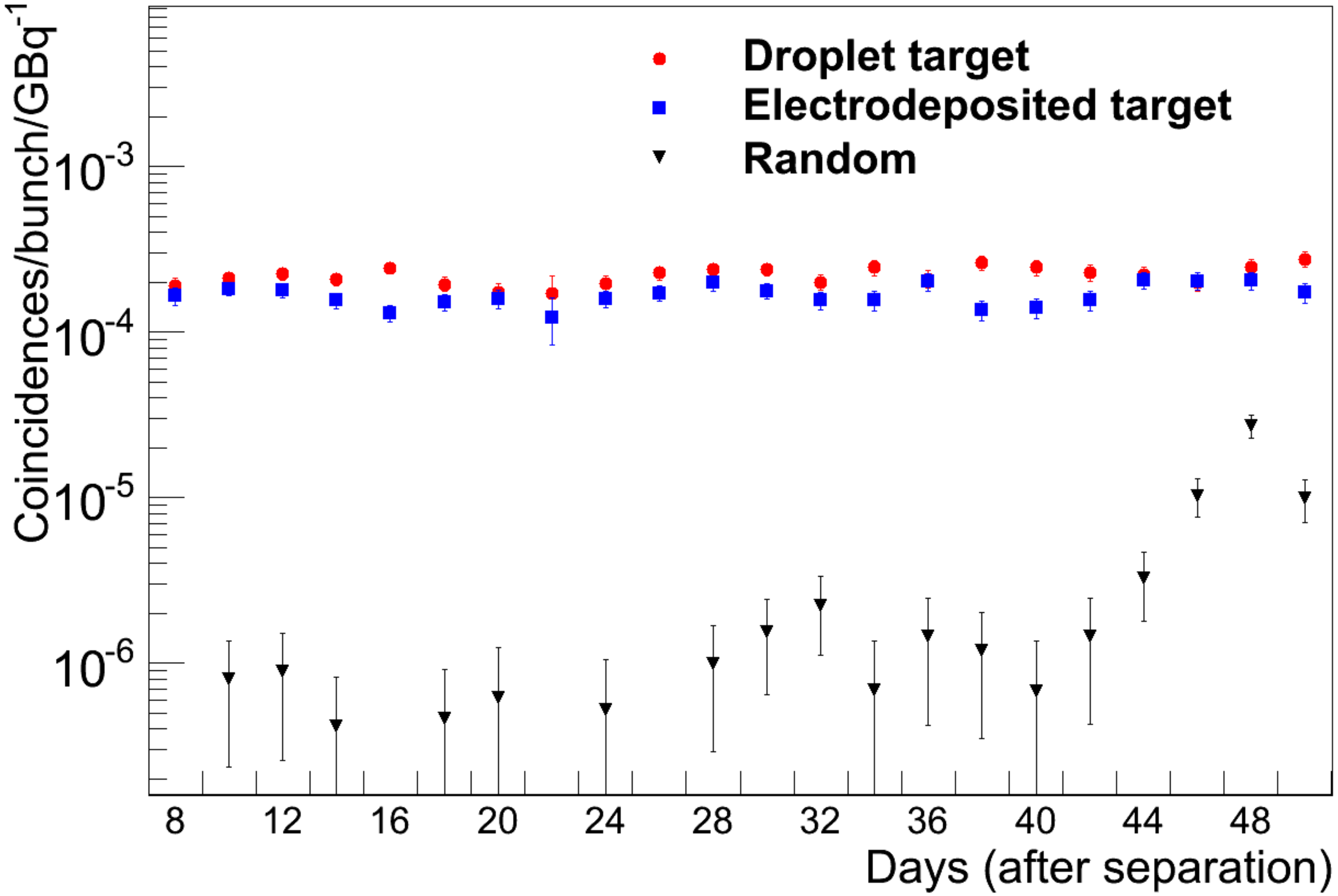
$n + {}^7\mathrm{Li} \rightarrow {}^8\mathrm{Li}$ —β decay→ ^{8}Be (~800 ms)

$2\alpha \sim 1.5\ MeV$



$^{7}Be(n,\alpha)$ cross section measurement

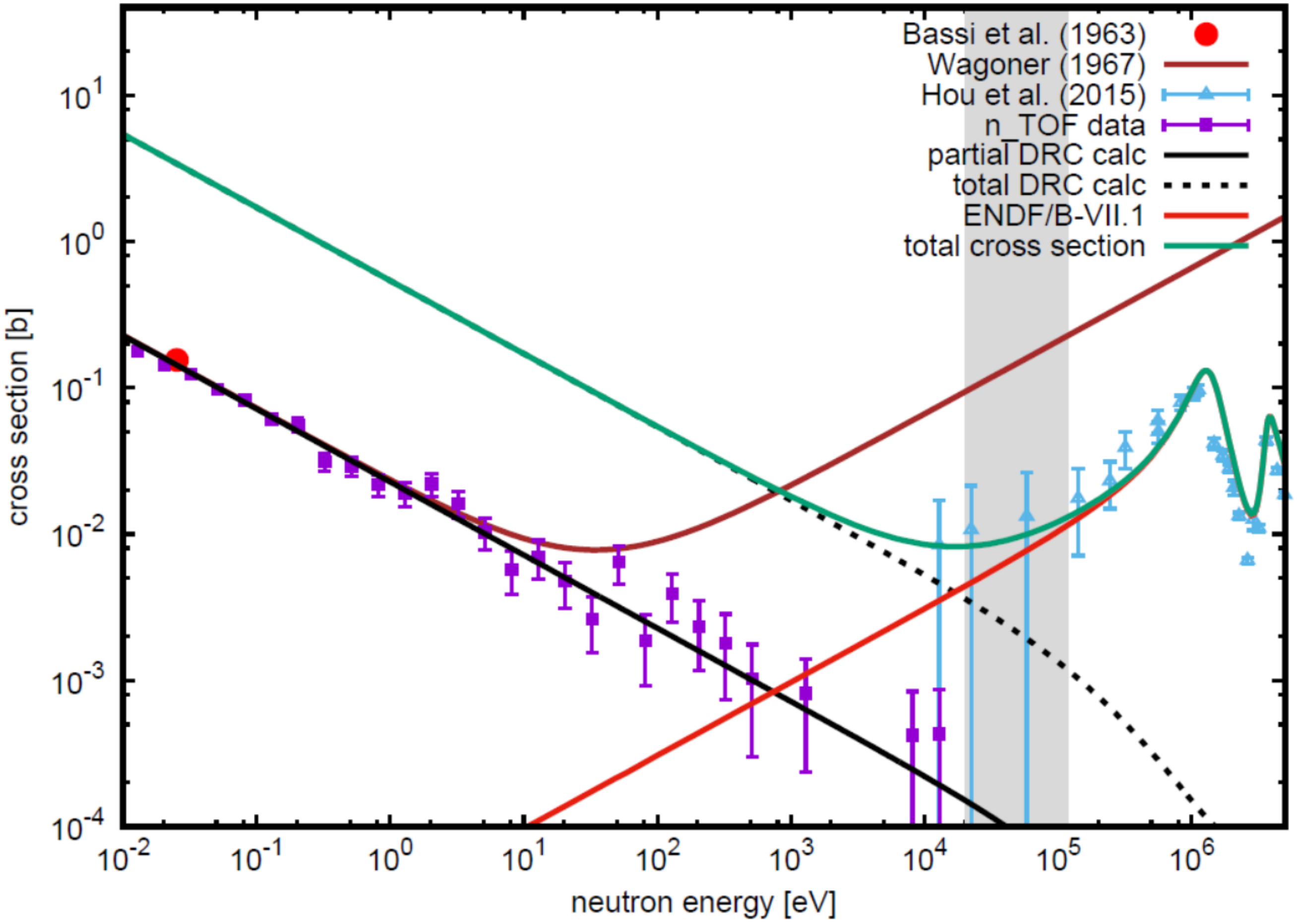
the **sample backing** and the **deposition technique** had no visible effect on the detection efficiency and the background



$^{7}Be(n,\alpha)$ cross section measurement

First Signal

$^{7}Be(n,\alpha)$ cross section measurement

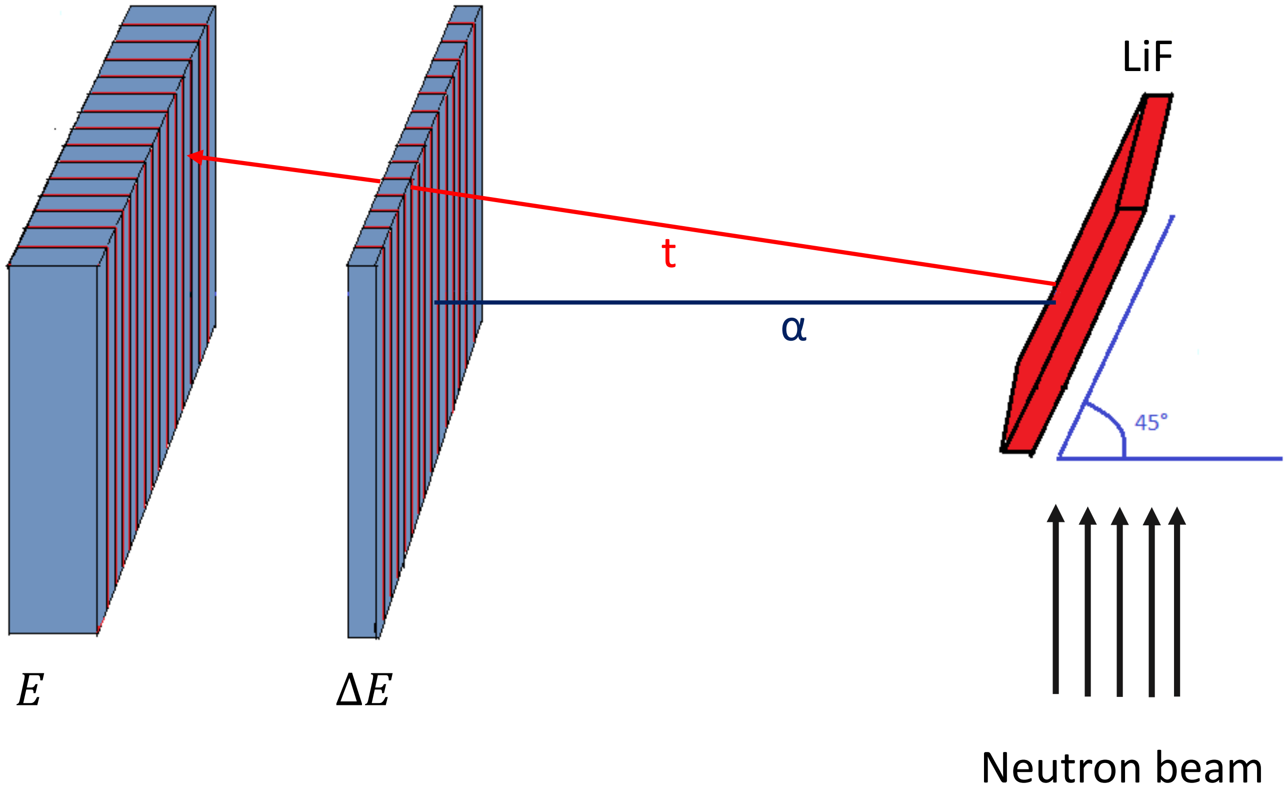


1/v behaviour of the $^{7}Be(n,\alpha)\ ^{4}He$ reaction cross – section

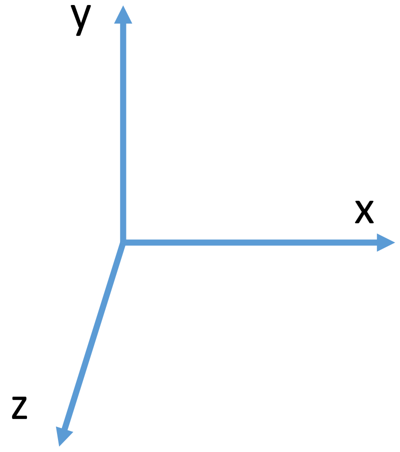
Good agreement with the only previous measurement (@0.025 eV)

$^{7}Be(n,p)$ cross section measurement

$$n + {}^{6}Li \rightarrow \alpha + t$$

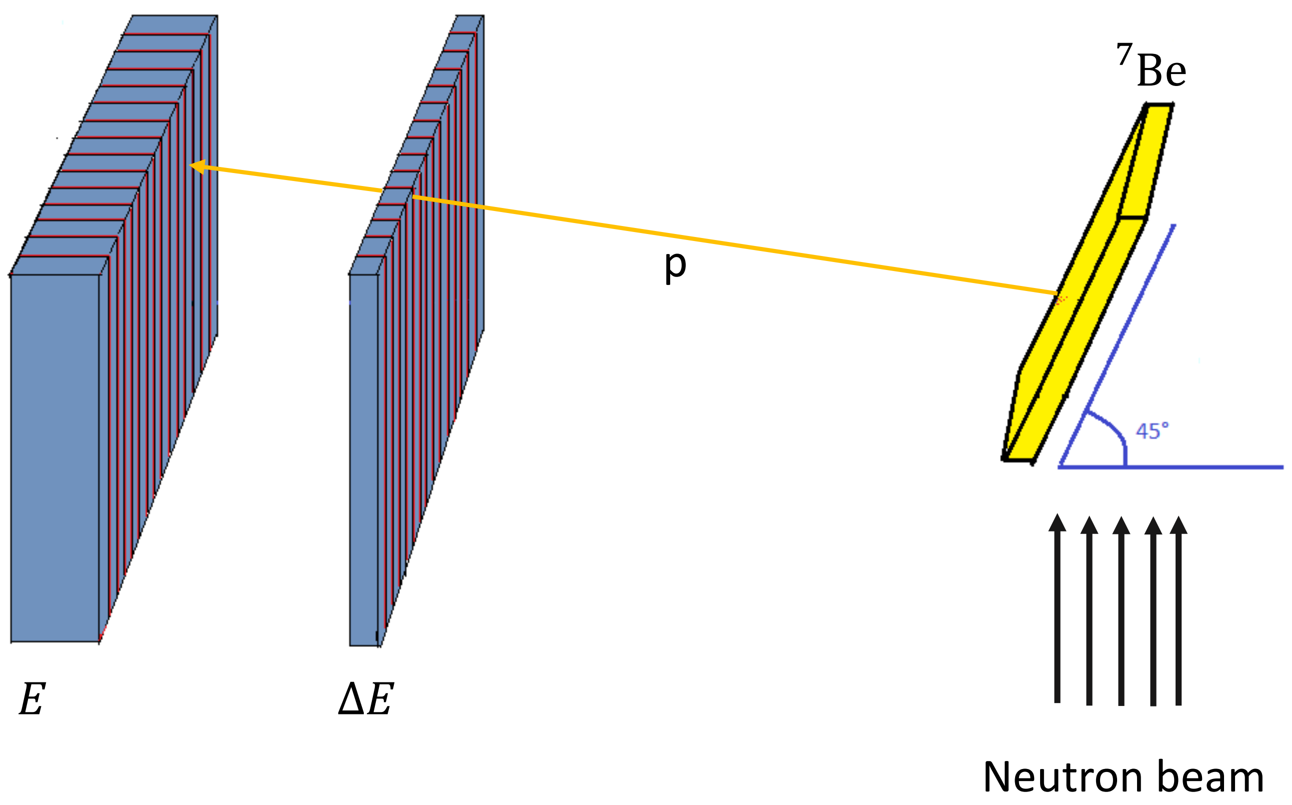


	ΔE	E	LiF
$y \times z$	$5 \times 5\ cm^2$	$5 \times 5\ cm^2$	$1.5 \times 1.5\ cm^2$
x	$20\ \mu m$	$300\ \mu m$	$1.8\ \mu m$



$^{7}Be(n,p)$ cross section measurement

$$n + {}^{7}Be \rightarrow p + {}^{7}Li$$



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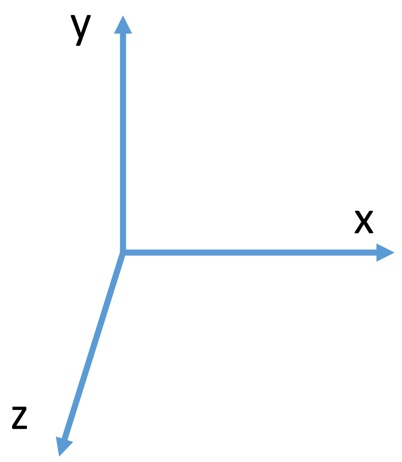
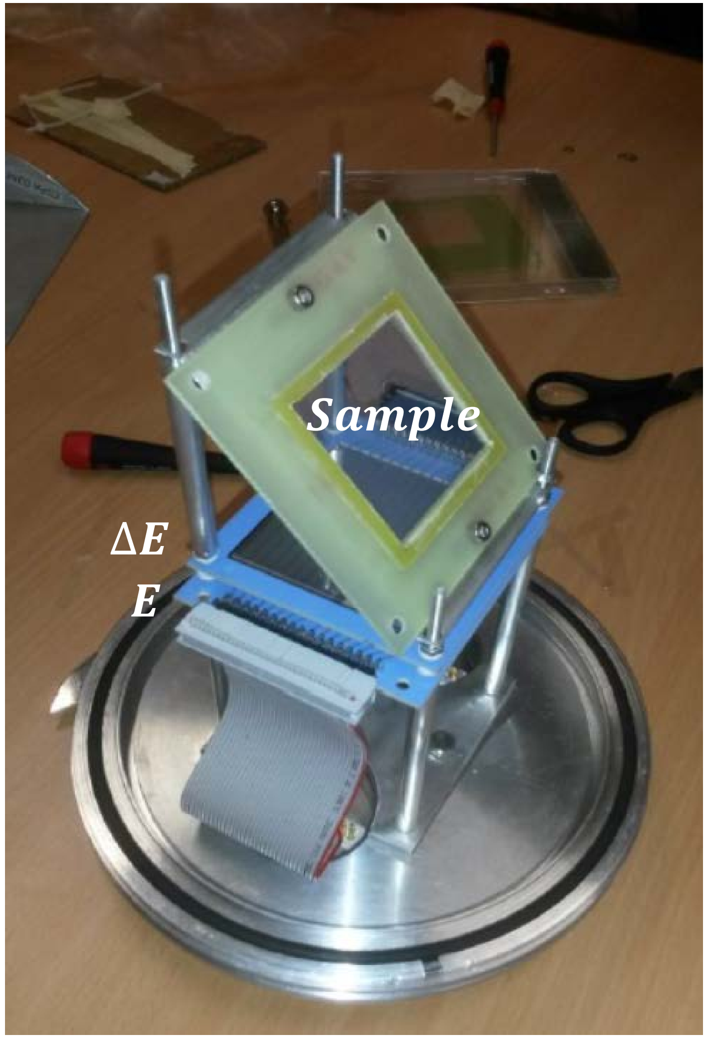


$^{7}\mathrm{Be(n,p)}$ cross section measurement



High purity sample needed:
PSI+ ISOLDE

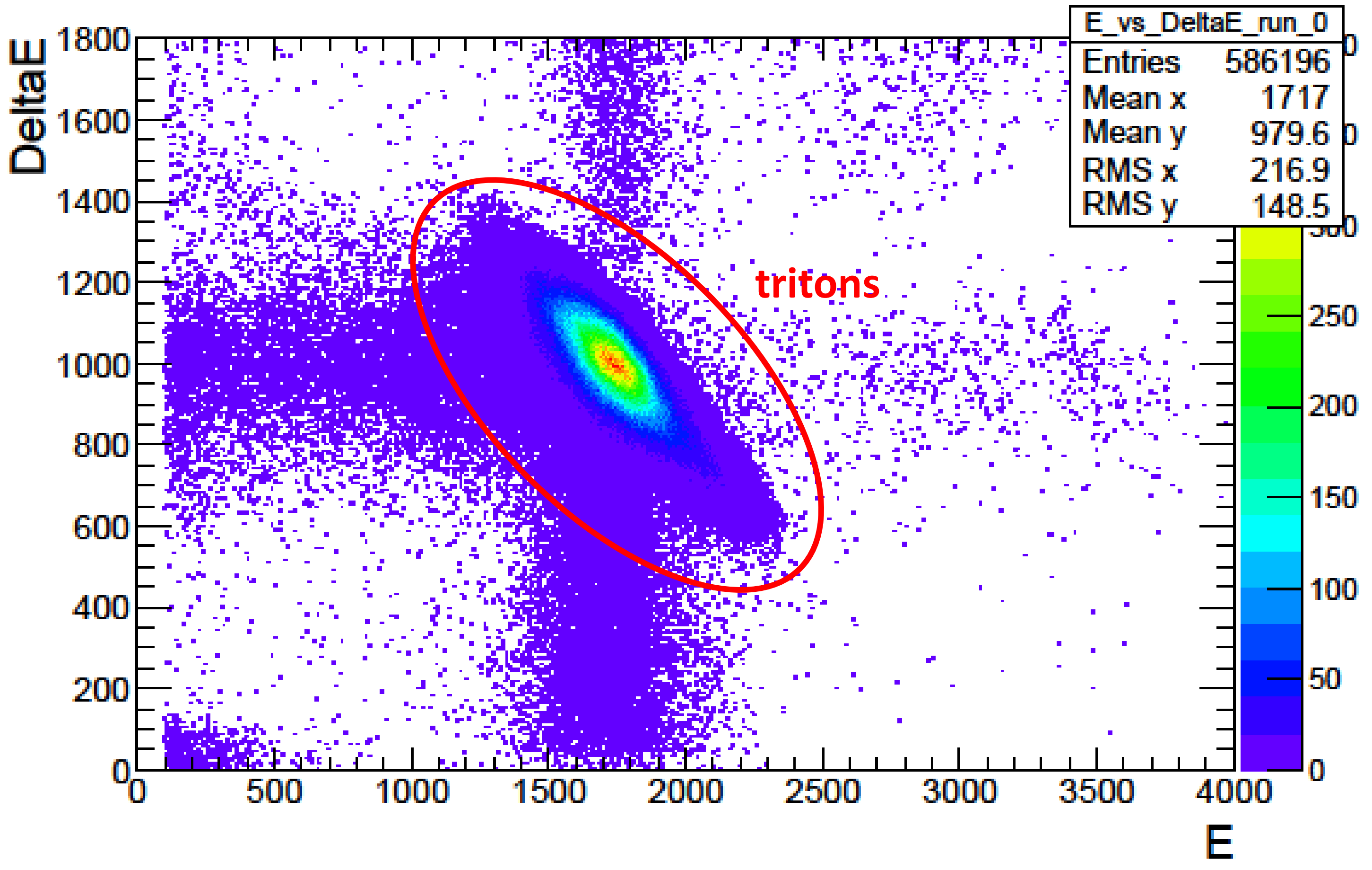
<u>1 GBq activity sample required</u>

- *20 MBq (16/04) due to issues of the ISOLDE beamline*
- *1.1 GBq (14/05)*

CNMO M11 type container used for the shipment from PSI to CERN

$^{7}Be(n,p)$ cross section measurement

LiF

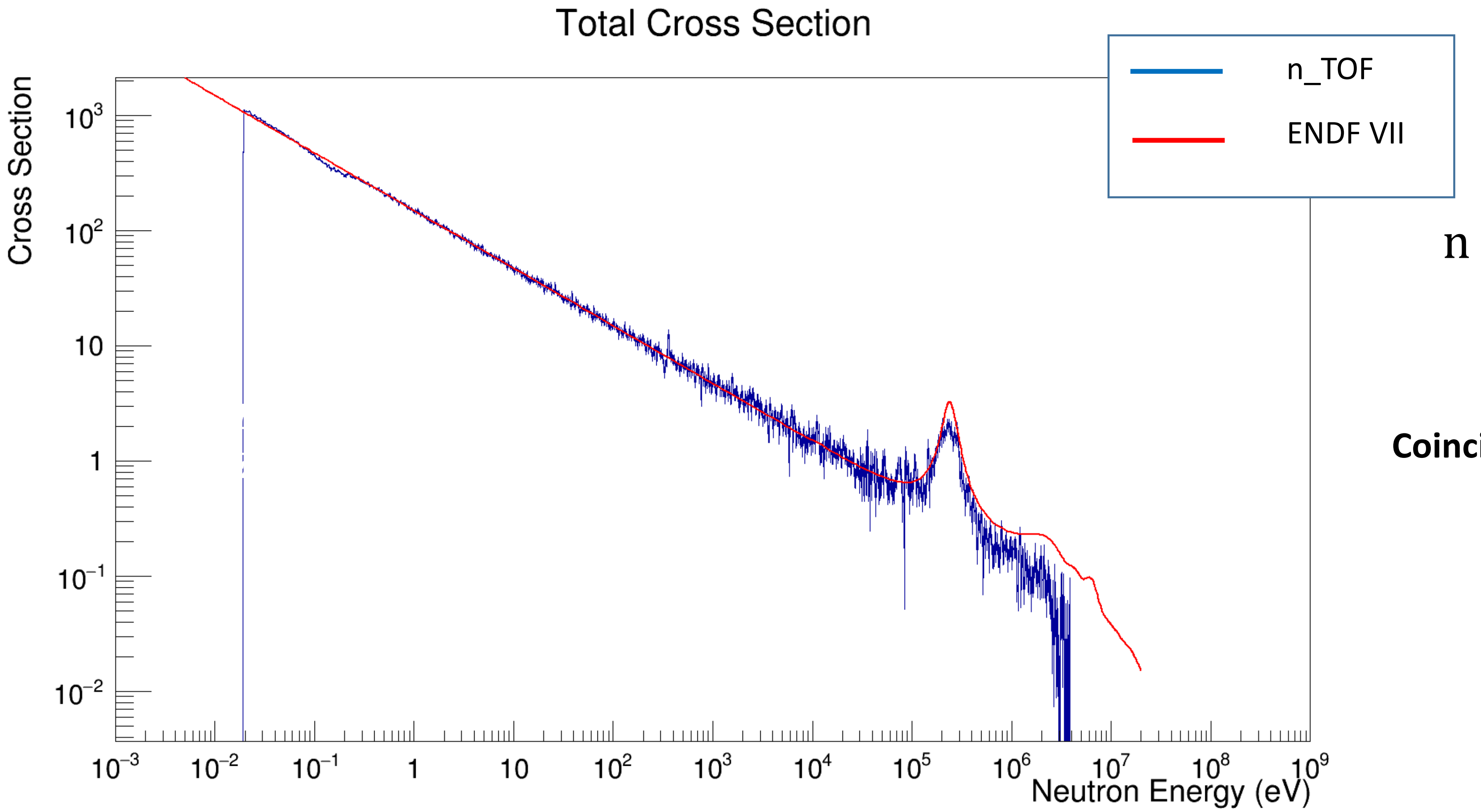


$$n + {}^{6}Li \rightarrow \alpha + t$$

$Q = 4.78\ MeV$

Coincidence window = 100 ns

$^{7}Be(n,p)$ cross section measurement



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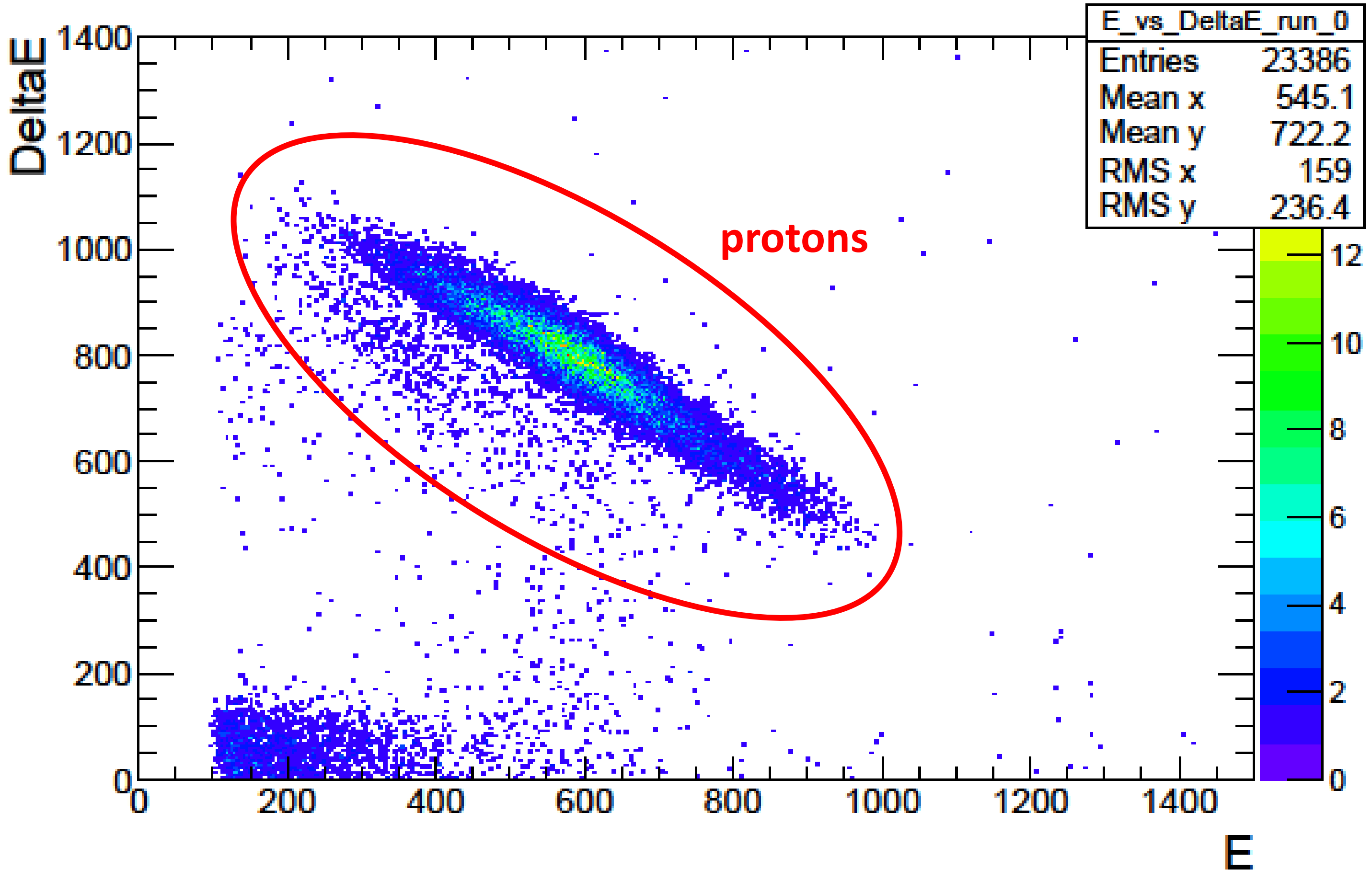
$^7Be(n,p)$ cross section measurement

^7Be



$$n + {}^7Be \rightarrow p + {}^7Li$$

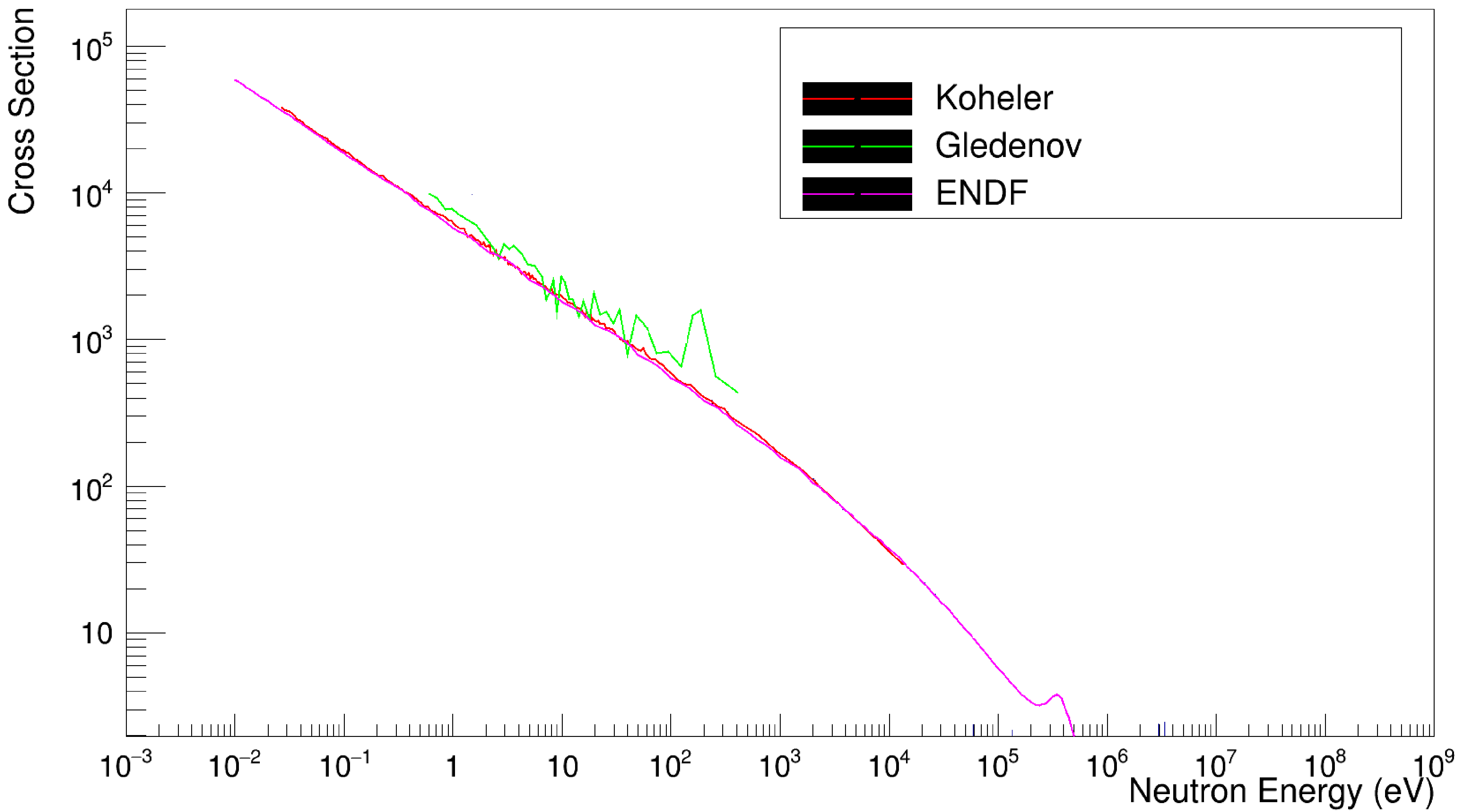
Q = 1.644 MeV (~ **95%**)

Conclusions

- The energy-dependent $^{7}\mathrm{Be}(\mathrm{n},\alpha)\ ^{4}\mathrm{He}$ and $^{7}\mathrm{Be}(\mathrm{n},\mathrm{p})\ ^{7}\mathrm{Li}$ cross section has been measured for the first time over a wide neutron energy range in the high flux experimental area (EAR2) at n_TOF

- Coincidences of two α particles coming from $^{7}\mathrm{Be}(\mathrm{n},\alpha)\ ^{4}\mathrm{He}$ reaction have been observed for the first time above 0.025 eV

- Preliminary results from the $^{7}\mathrm{Be}(\mathrm{n},\mathrm{p})\ ^{7}\mathrm{Li}$ cross section measurement performed with a low activity sample are extremely encouraging, already proving that a final answer on the role of this reaction in BBN can be providing in the ongoing experiment



Cross Section
Koheler
Gledenov
ENDF
10^5
10^4
10^3
10^2
10
10^{-3}
10^{-2}
10^{-1}
1
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
Neutron Energy (eV)