Measurement of ^{7}Be(n,α) and ^{7}Be(n,p) cross sections for the Cosmological Li problem in EAR2@n_TOF

Addendum to CERN-INTC-2014-049/INTC-P-417

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CERN INTC 50th meeting, July 1st 2015

Outline

- Physics Case

- ^{7}**Be(n,α)** measurement
  - Test measurement for experimental setup
  - Sample preparation
  - Protons request

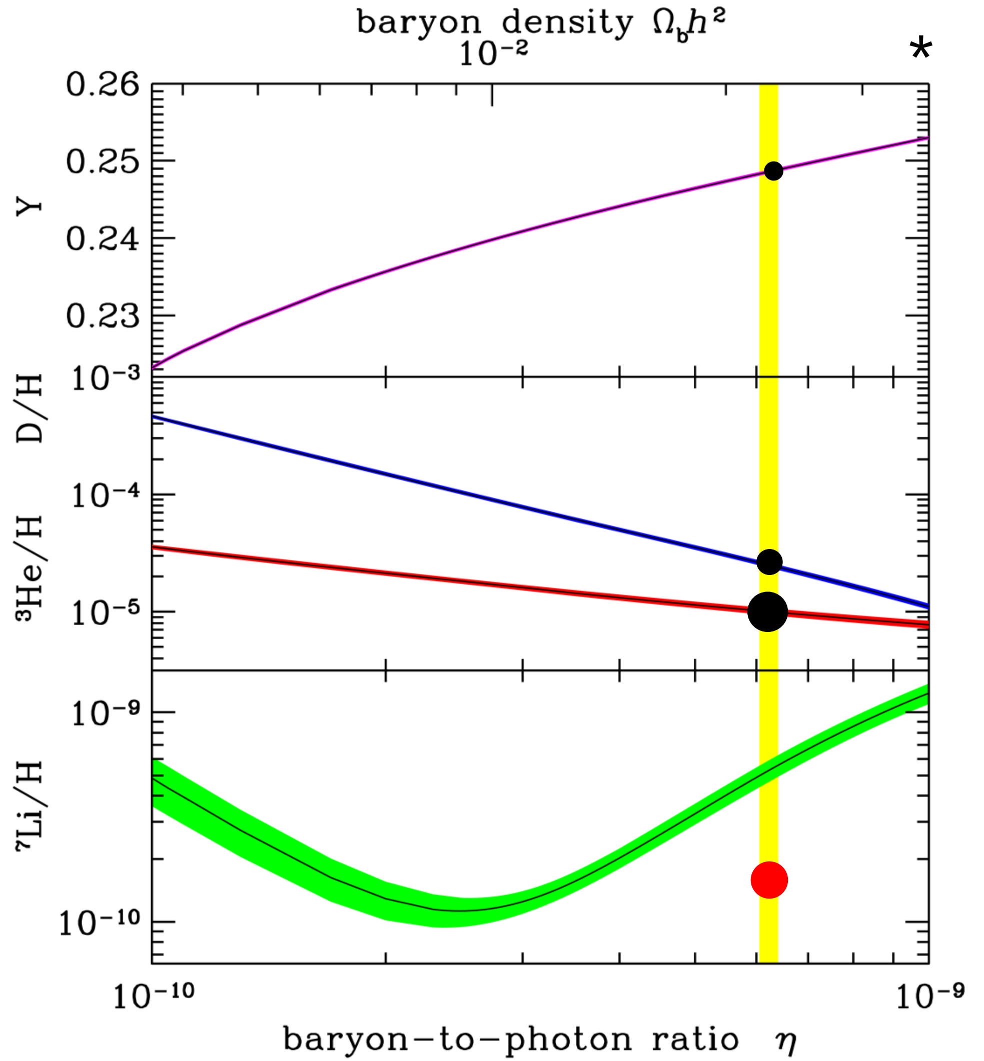
- ^{7}**Be(n,p)** measurement
  - Experimental setup
  - Protons request

The Cosmological Lithium Problem

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 **^{7}Li** and the value inferred by measurements (Spite et al, many others.)

Cosmological Lithium Problem (CLiP)



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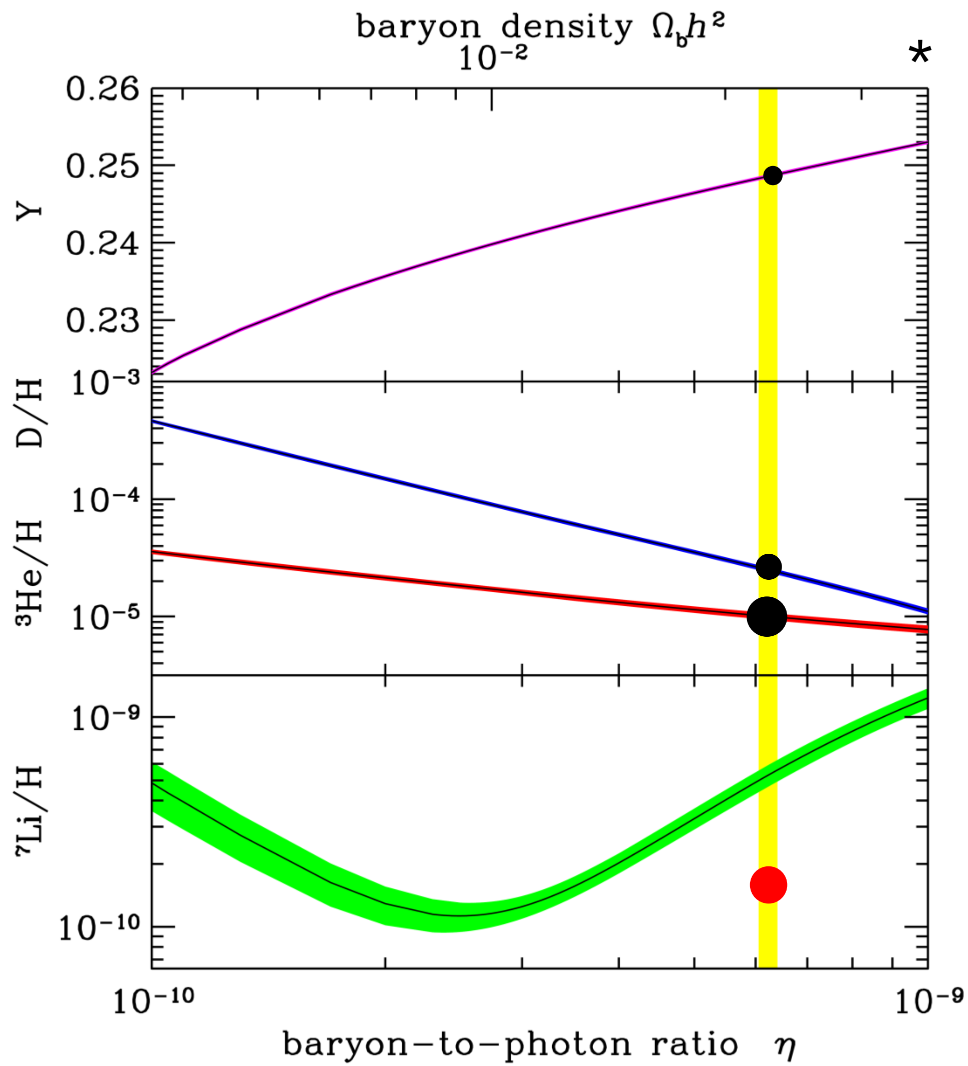


A serious discrepancy **(factor 2-4)** between the predicted abundance of ^{7}**Li** and the value inferred by measurements (Spite et al, many others.)

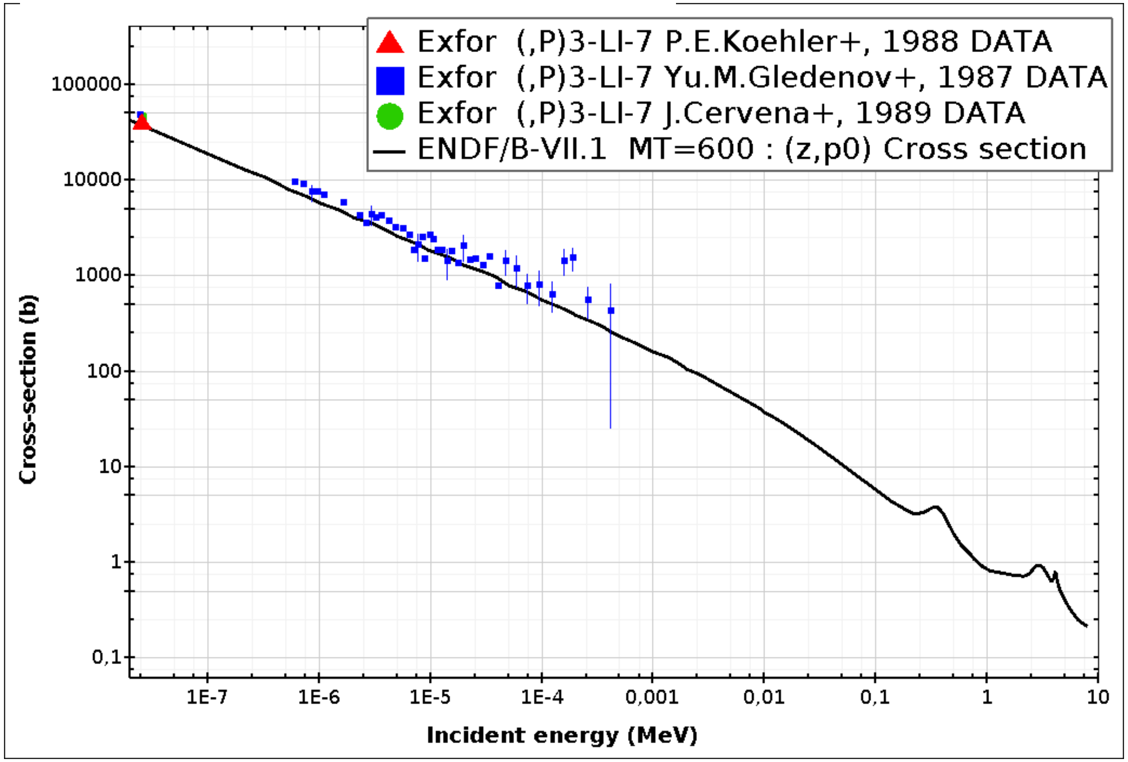
Cosmological Lithium Problem (CLiP)

Nuclear Physics solution to the problem?

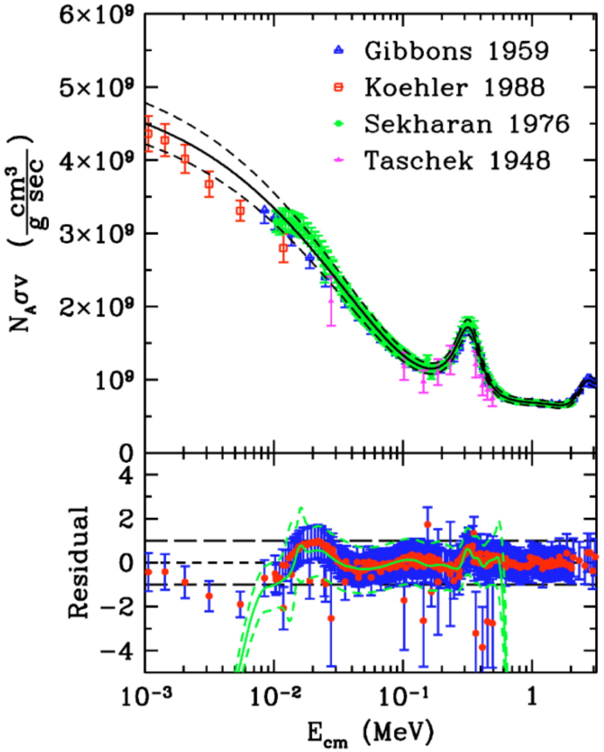
Status of evaluations and experimental data: $^7Be(n,p)$

Only one direct measurement (Koehler et al., 1988, 0.025 eV - 13.5 keV), covering partially the range of BBN interest **(few keV–few hundreds of keV).**

Direct measurements



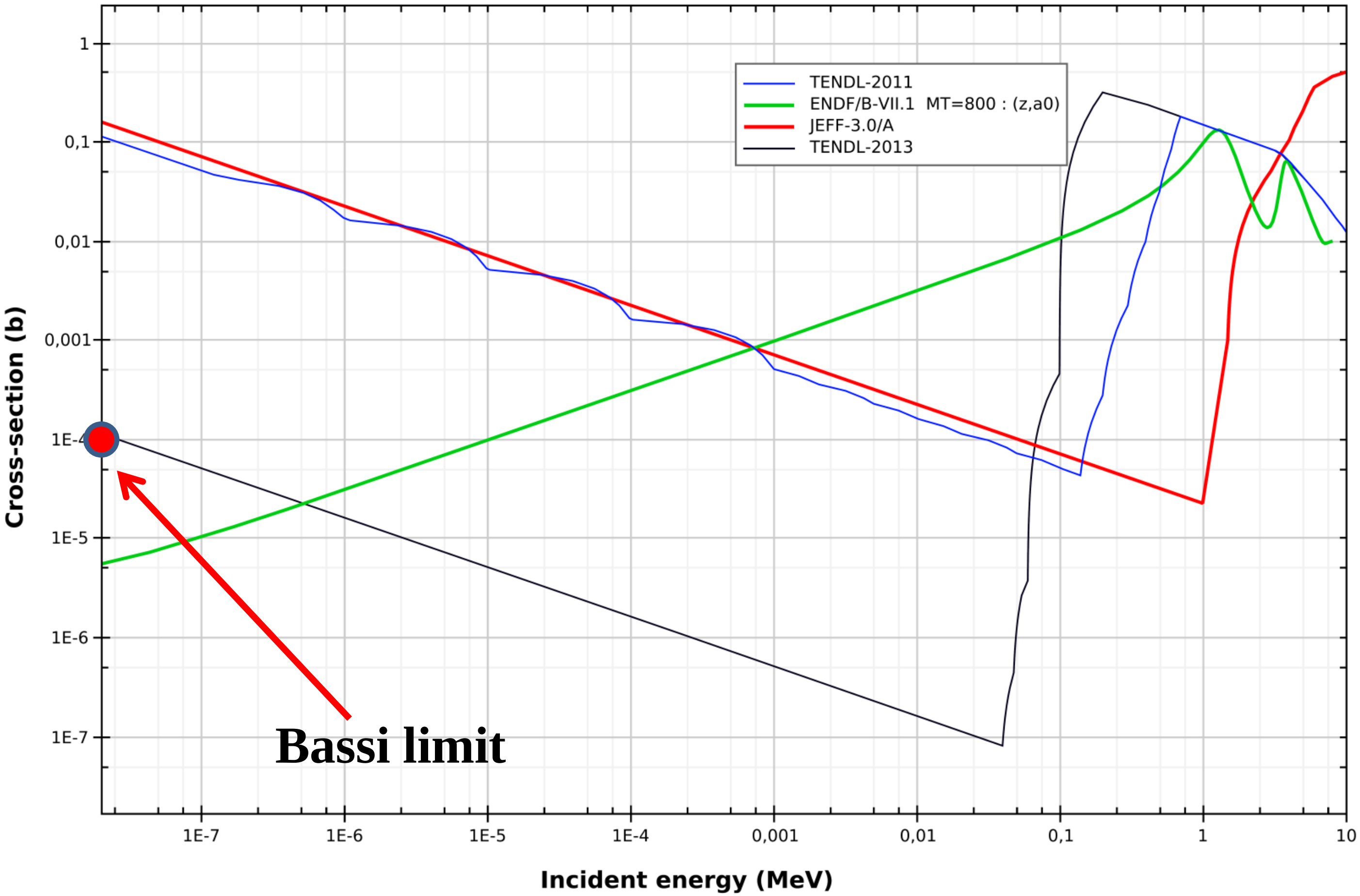
Indirect measurements



BBN calculations rely on **extrapolation to higher energies** of Koehler data or on **indirect measurement**

Status of evaluations and experimental data: $^{7}Be(n,\alpha)$

Only one direct measurement (P. Bassi et al., 1963, **@ <u>0.025 eV</u>**) giving an **upper limit** for the cross section at thermal **(<0.1 mb)**

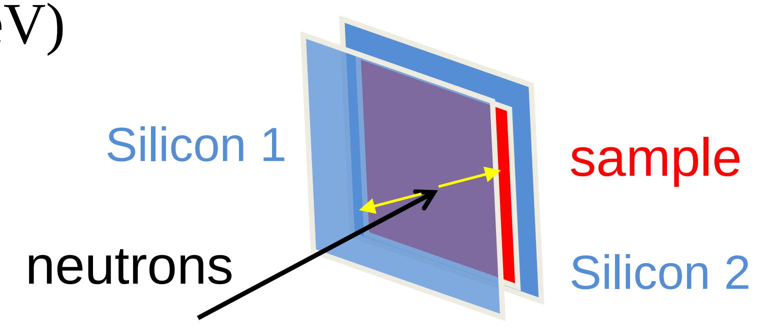


The (n,α) measurement in EAR2@n_TOF

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

Sandwich of silicon detectors **directly inserted in the beam**.

Detection of both alpha particles (E~ 9 MeV)



Coincidence technique: **Strong rejection of background**

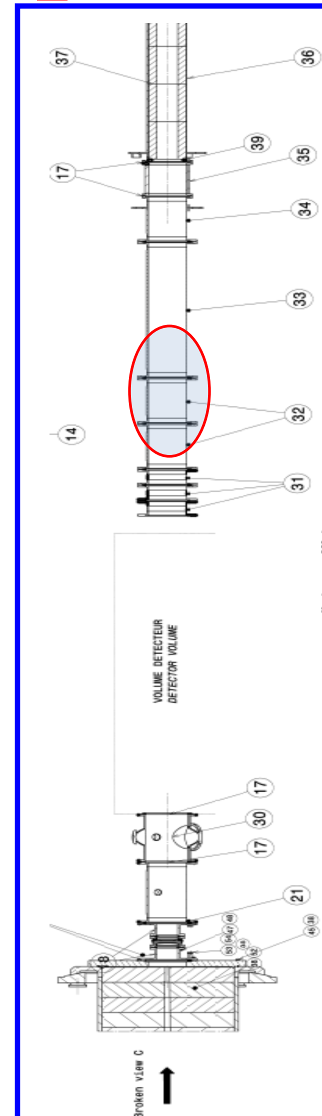
Setup of the test measurement

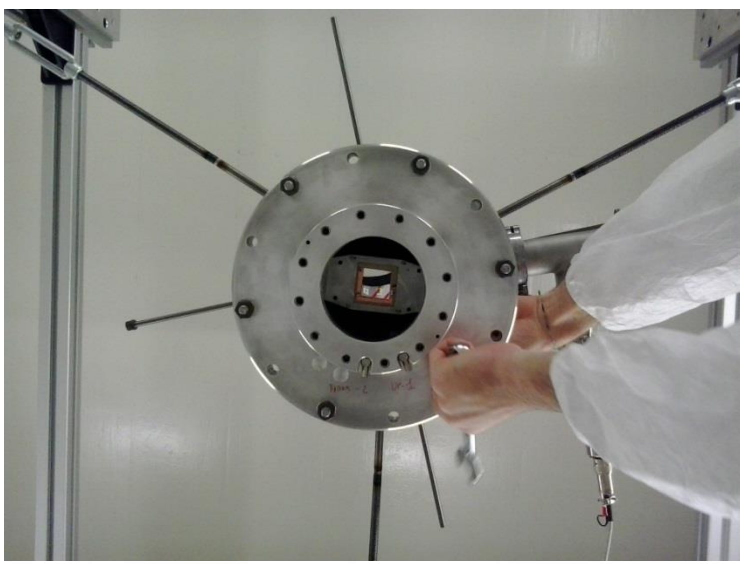
Sandwich of Silicons (140 μm, 3x3 cm^2)

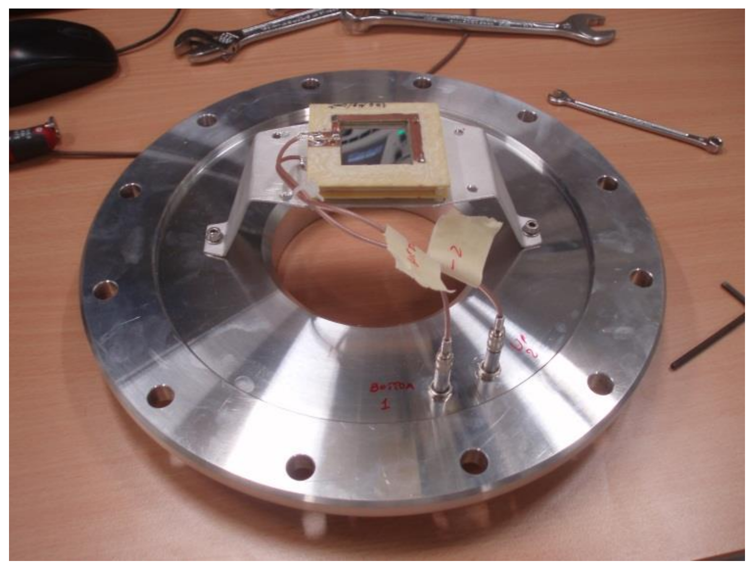
LiF converter (105 μg/cm^2) on mylar

Lower part of the beam dump

n_TOF-EAR2

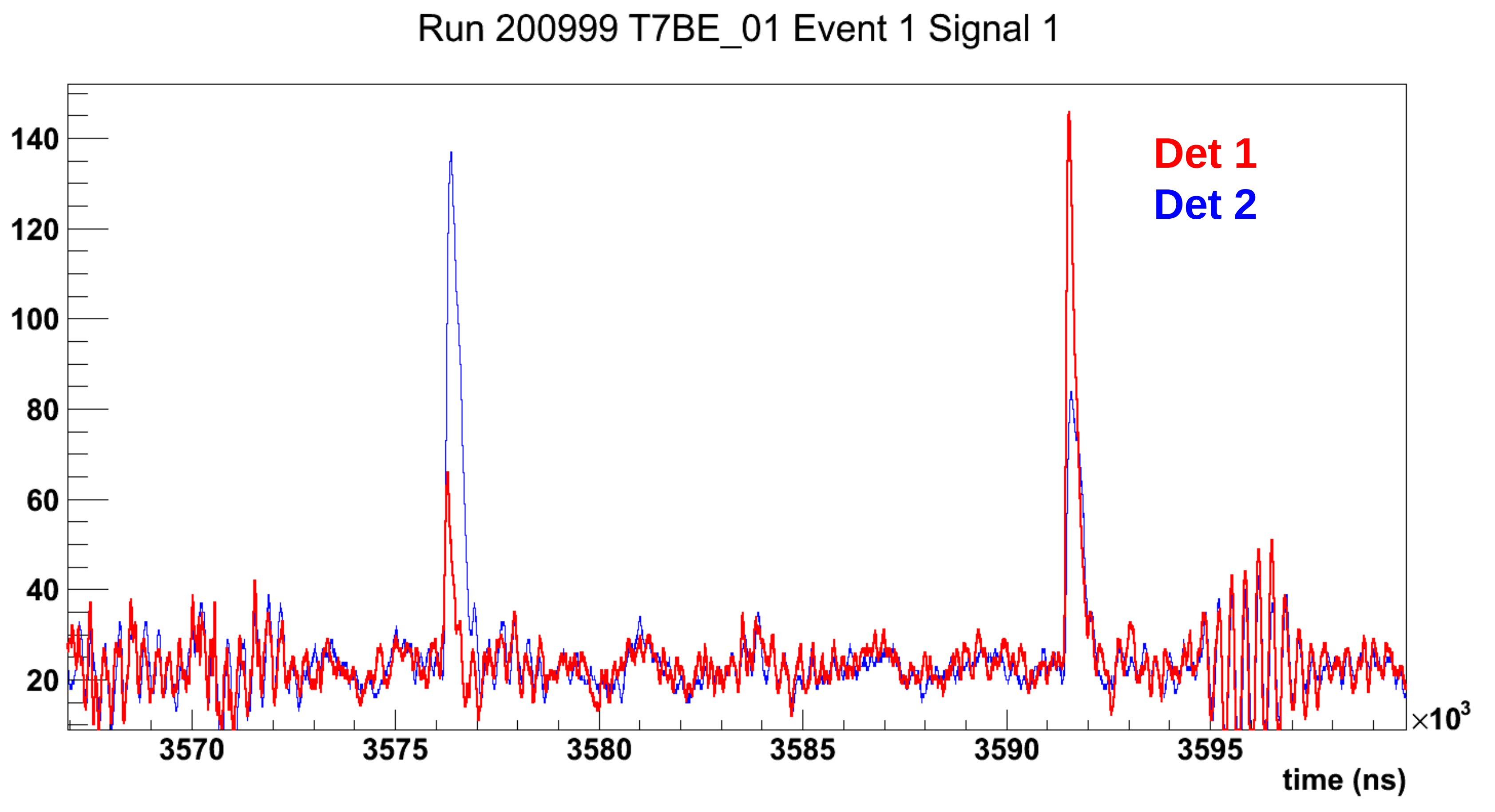






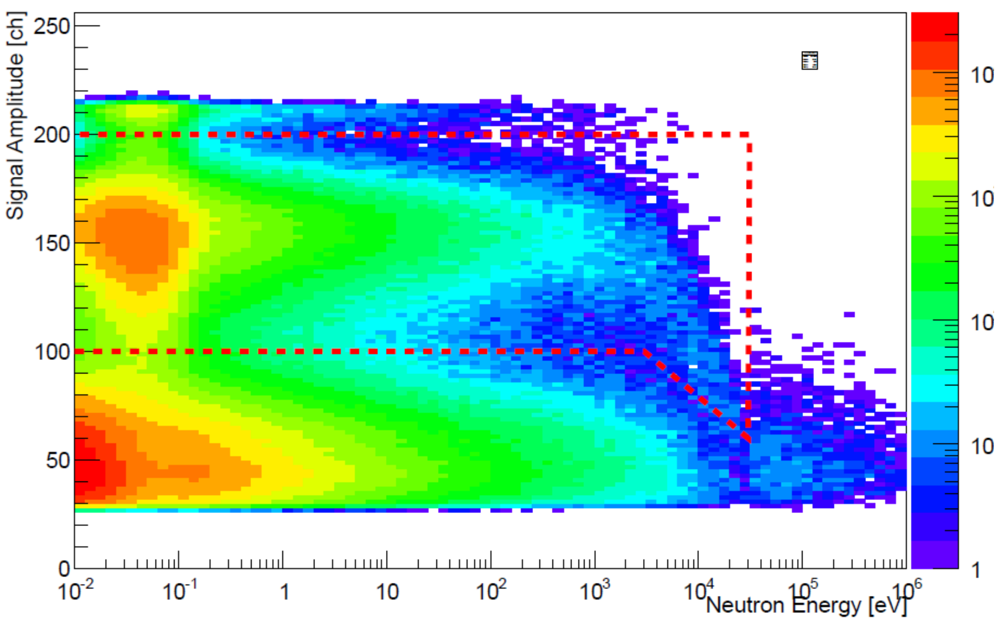
Feedback of the test

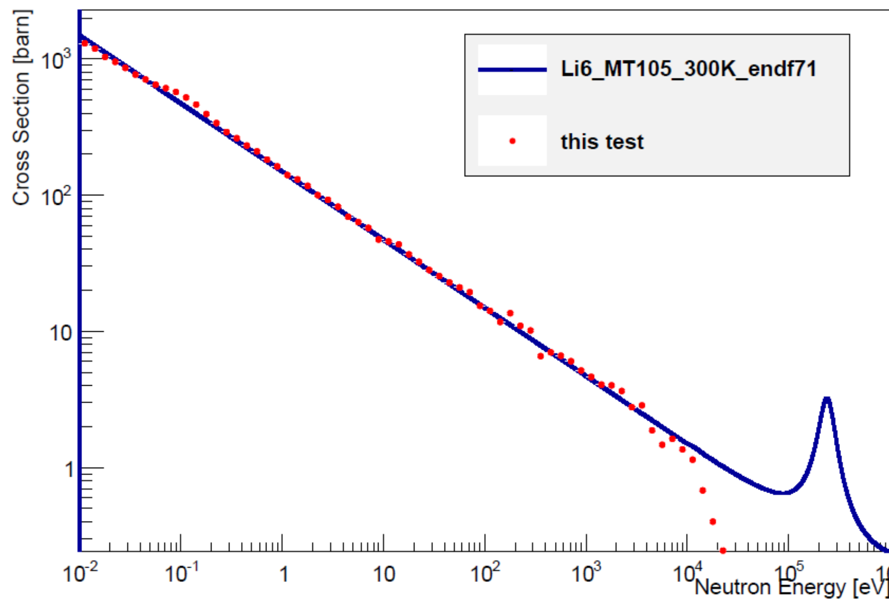
1-Possible to detect coincidences



Feedback of the test

2-With the preamplifiers tested so far (and the particles detected in the test) the upper energy limit is 10 keV.

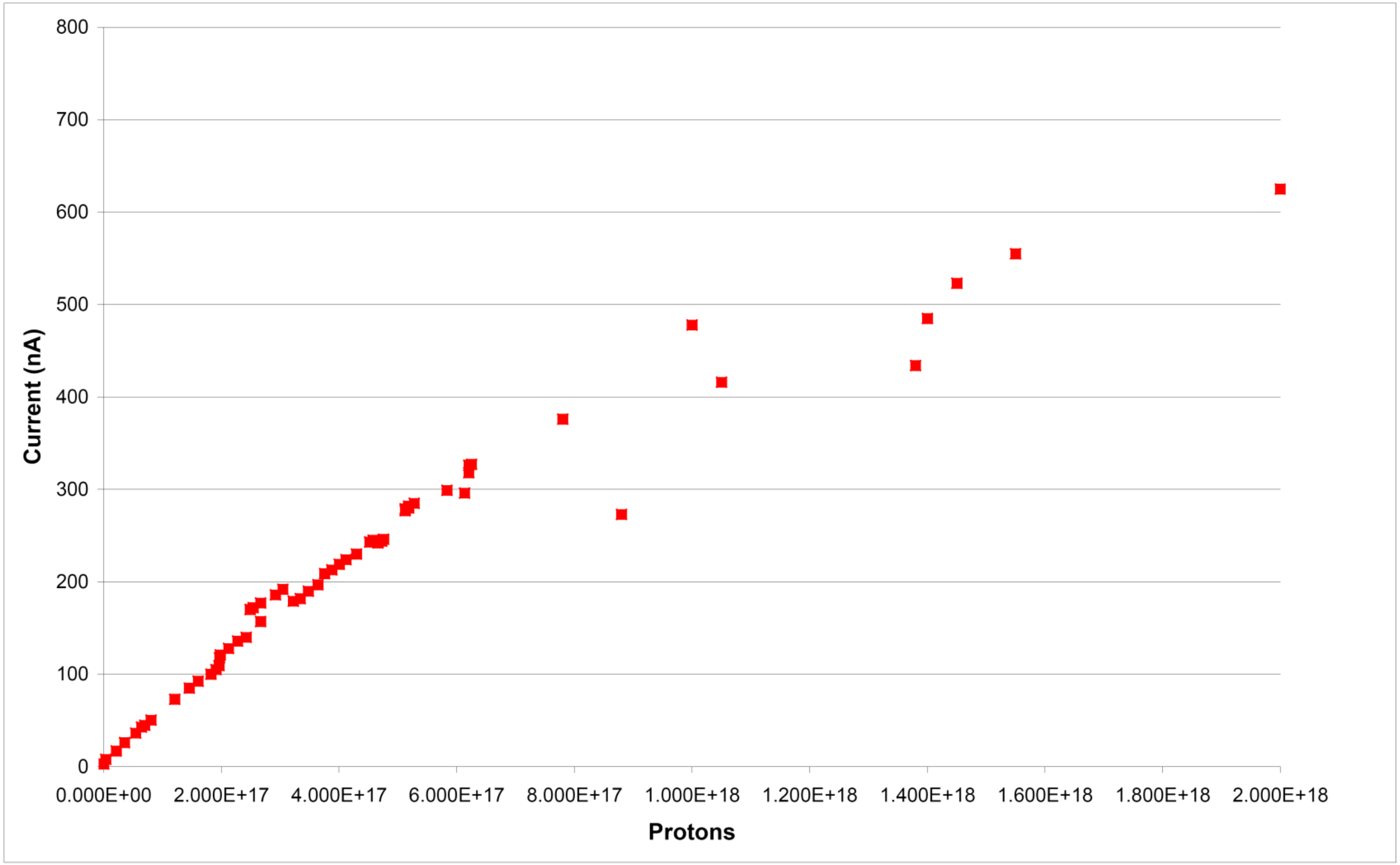




New, fast preamplifiers will be tested before the measurement.

Feedback of the test

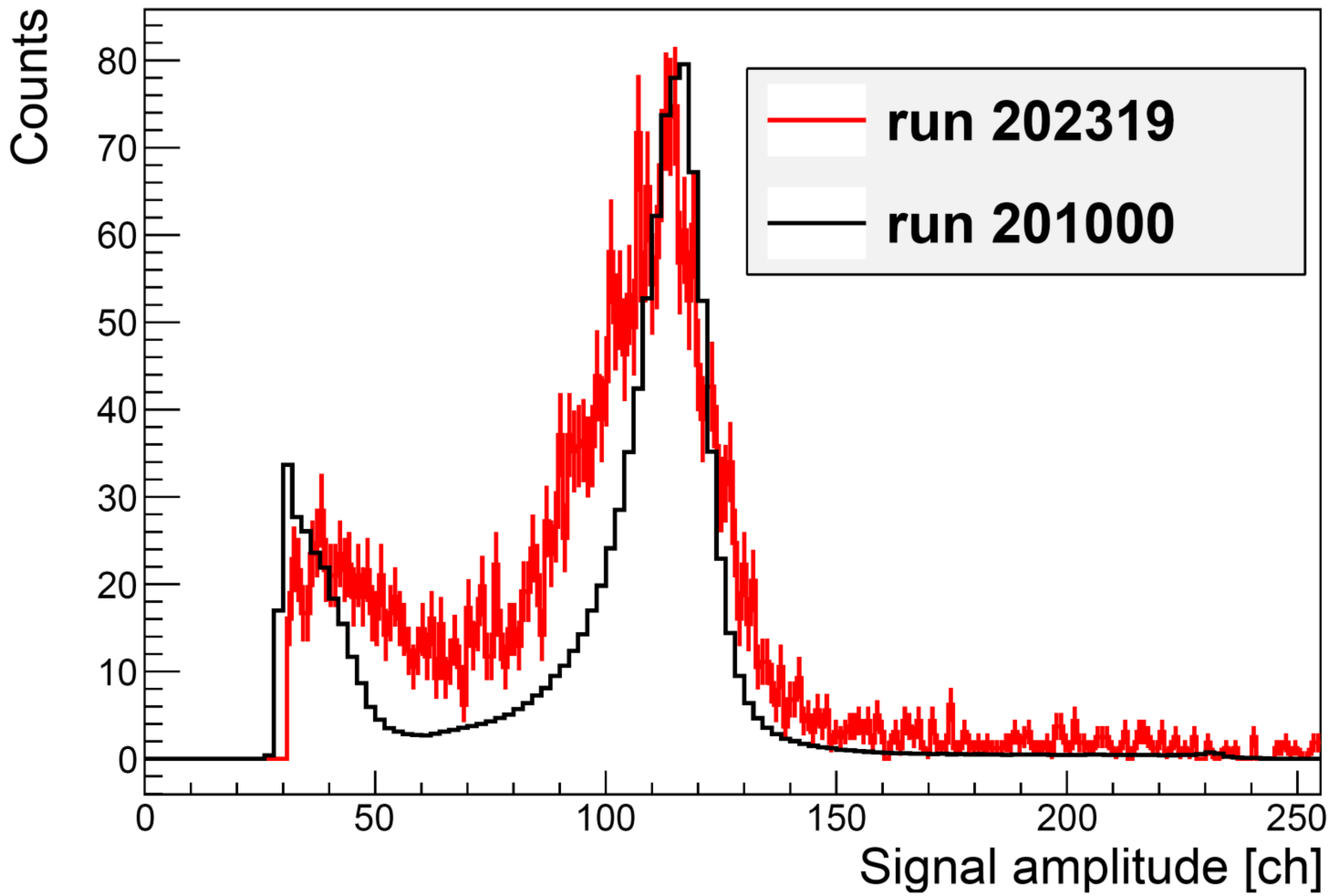
3- Leakage current is increasing with protons, as expected.



Expected value at the end of the ^{7}Be(n,α) measurement: 2 μA

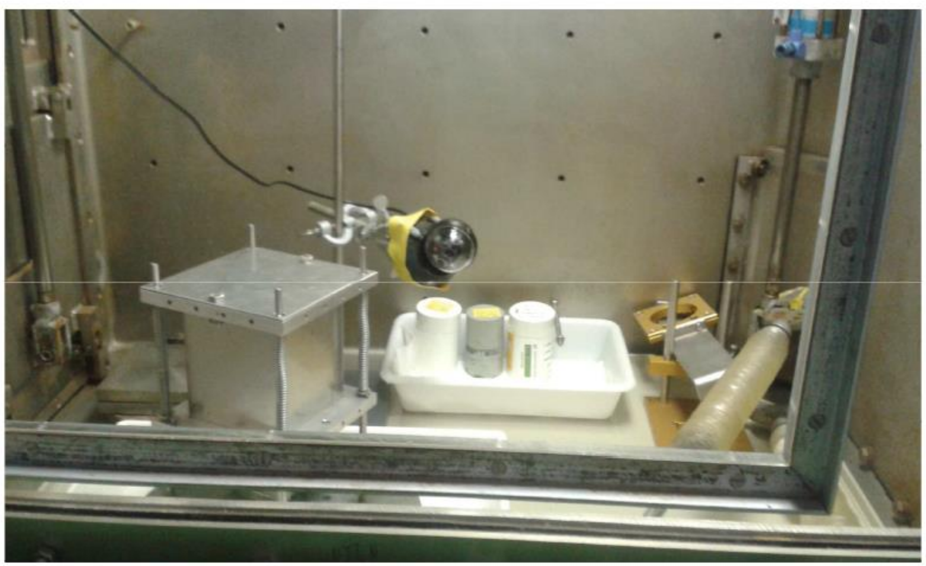
Feedback of the test

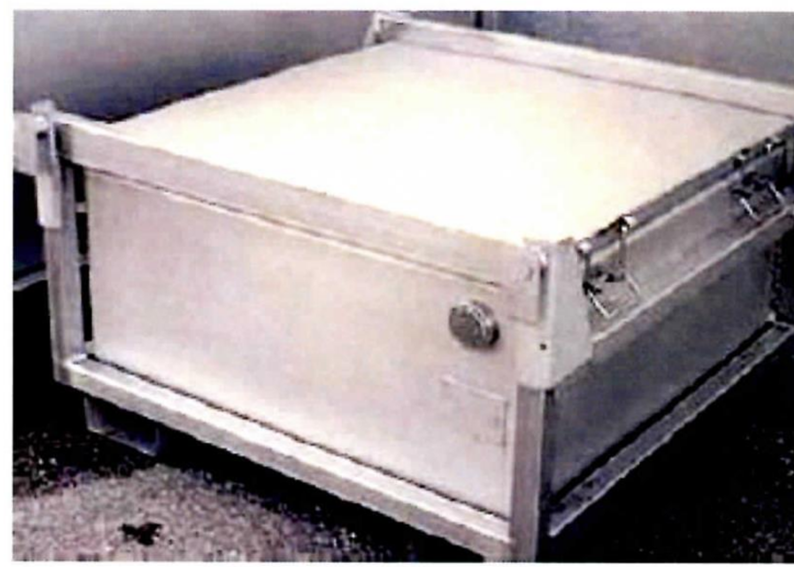
3- Leakage current is increasing with protons, as expected, but no significant worsening of the detector response was observed.



Sample

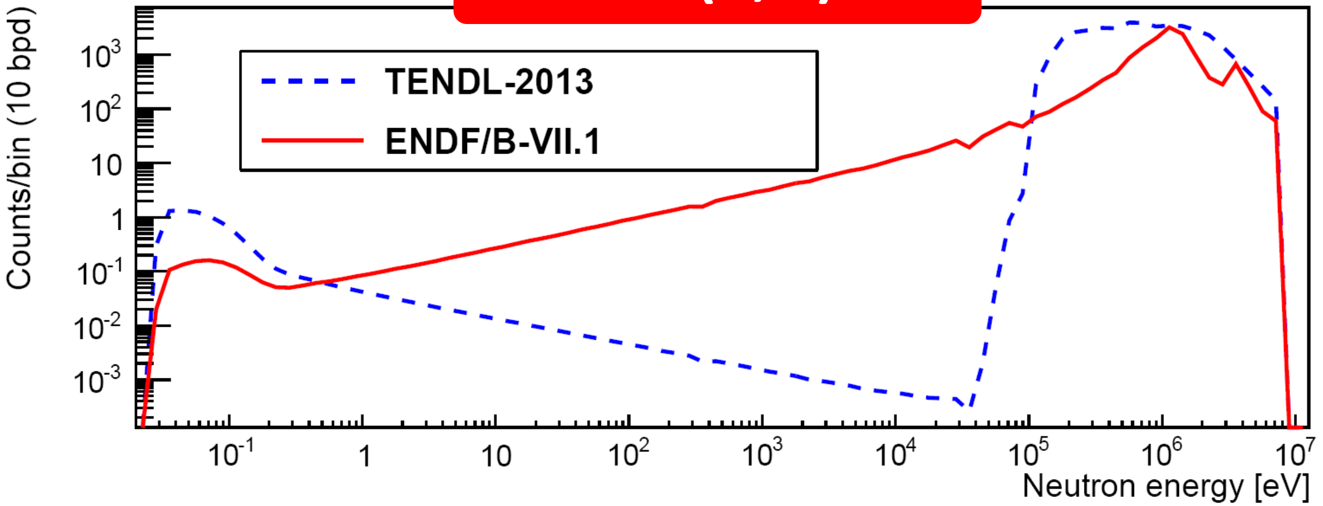
- 50 GBq (~4 μg) of ^{7}Be from water cooling of SINQ spallation target (batch already extracted)
- Isotopic composition: 1:1 ^{7}Be-^{10}Be 1:5 ^{7}Be-^{9}Be
- Chemical compound: nitrate, chloride or oxide
- Backing: Al, C, PI or PE foil (Electrodeposition or Evaporation)

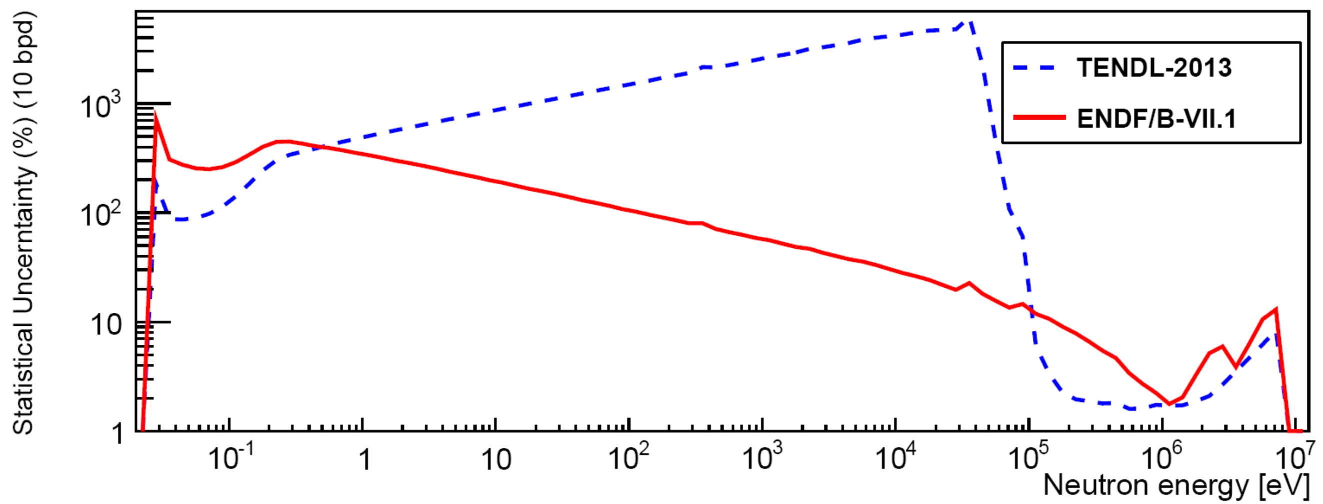




Protons request

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





Protons requested:

$5x10^{18}$

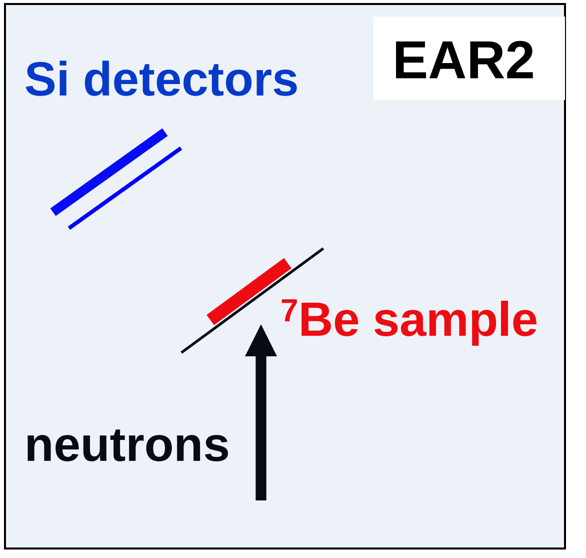
- 50 GBq of ^{7}Be on 2.5 cm diameter circular area
- Efficiency 95%
- EAR2
- $5.0x10^{18}$ protons

^{7}Be(n,p)

Silicon telescope outside of the beam

Two silicon strips detectors (16 strips, 5x5 cm^2, **20** and **300 μm** thick) tilted of 45°

Detection of protons (E ~ 1 MeV or 1.4 MeV)

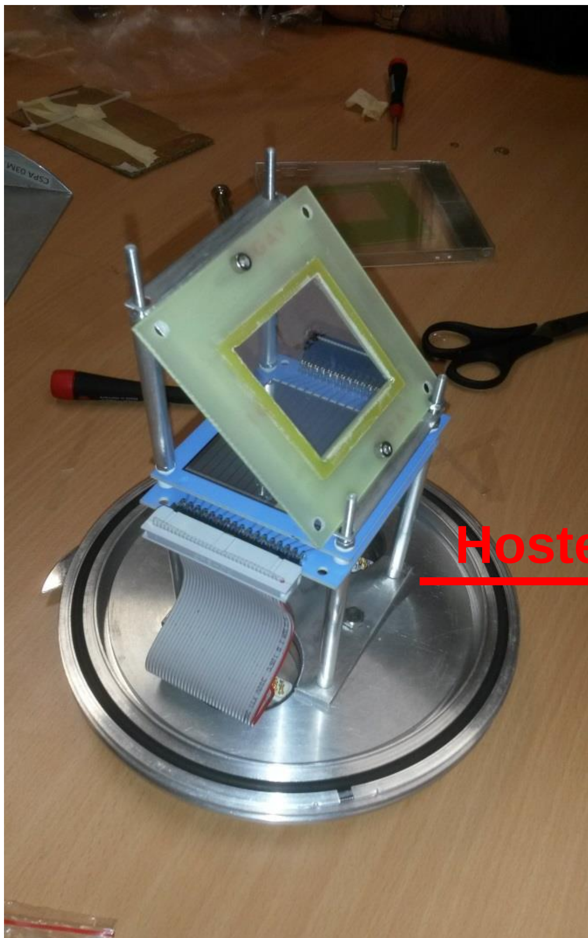


The (n,p) measurement in EAR2 @n_TOF

105 μg/cm^2 thick LiF converter

2.05 MeV **α-particles** are stopped in ΔE detector

2.73 MeV tritons lose ~1 MeV



Hosted in SiMon2 chamber

SiMon2 detector removed with its flange and replaced with the Silicon Telescope Setup.

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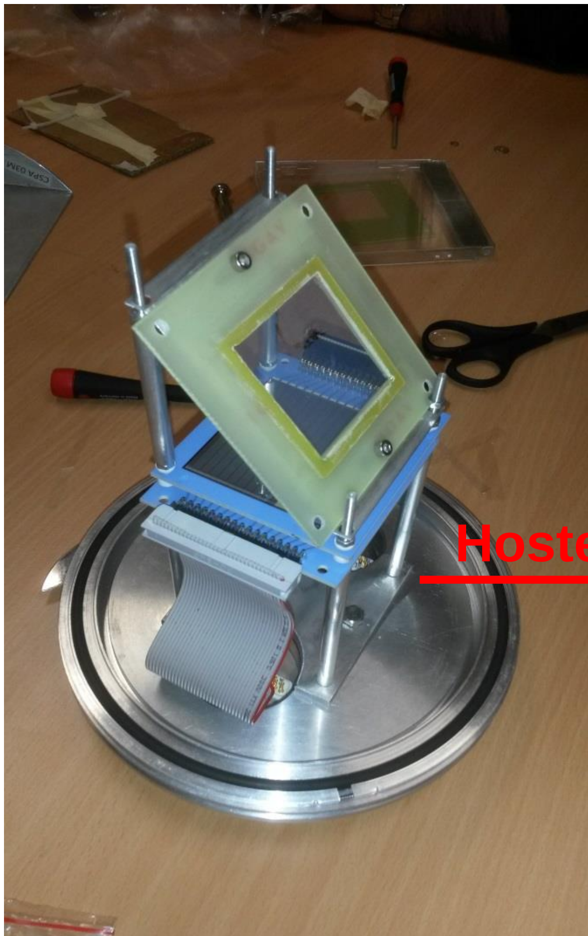

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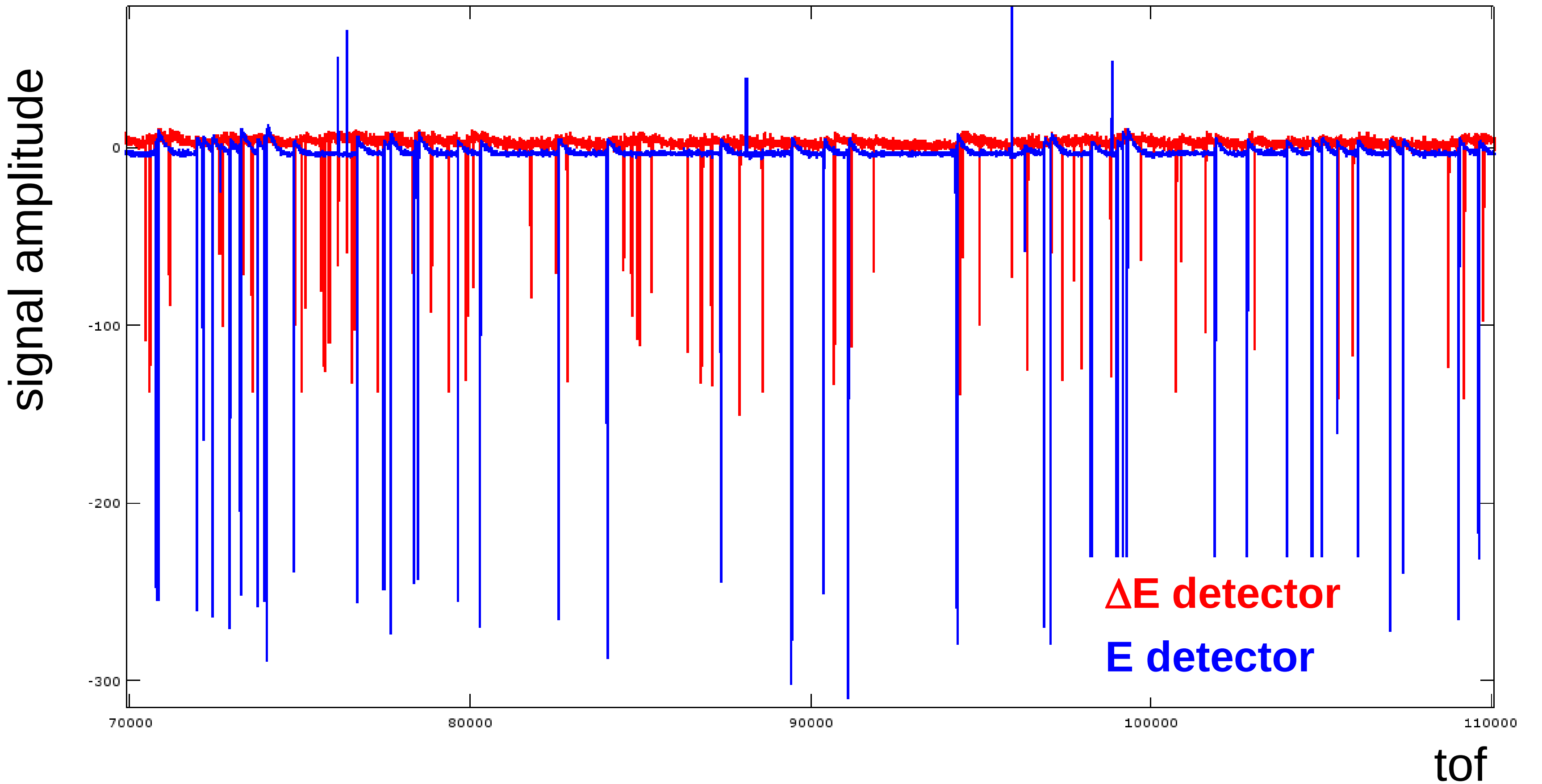
The (n,p) measurement in EAR2 @n_TOF

- **Low noise detector, good noise to signal ratio**
- **Coincidences in few selected strips**



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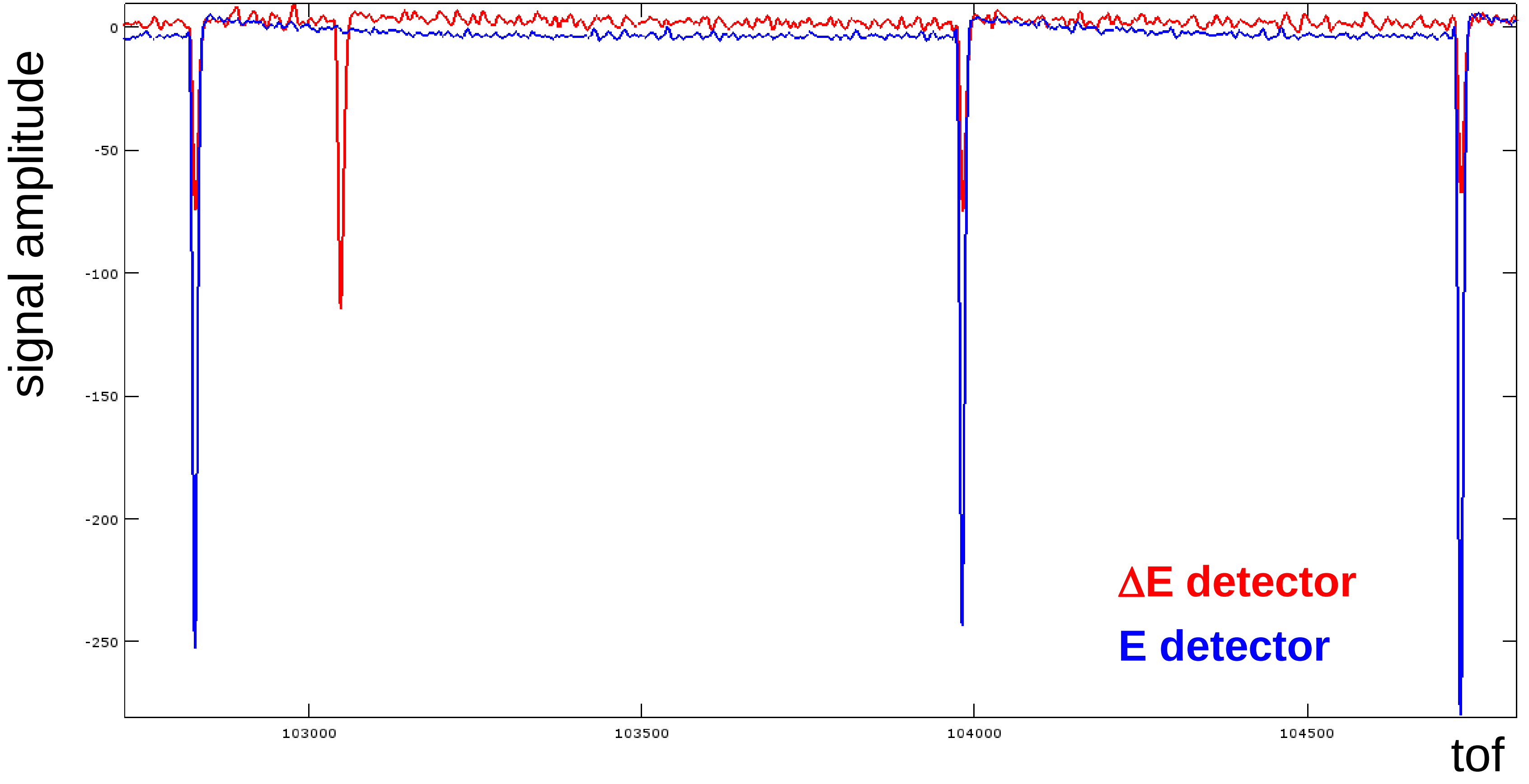
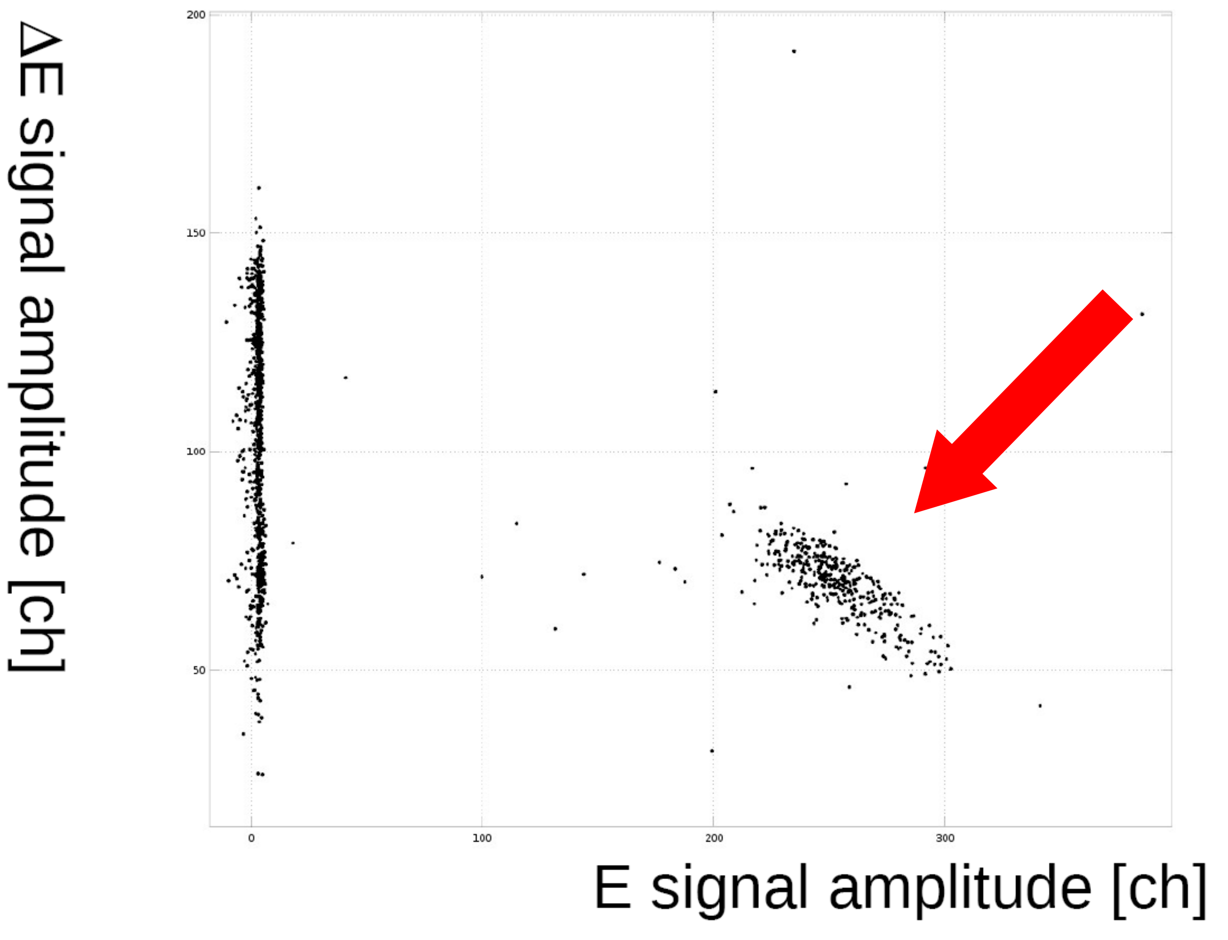


E-ΔE matrix shows clearly the region of tritons



Sample

Coincidence technique NOT POSSIBLE

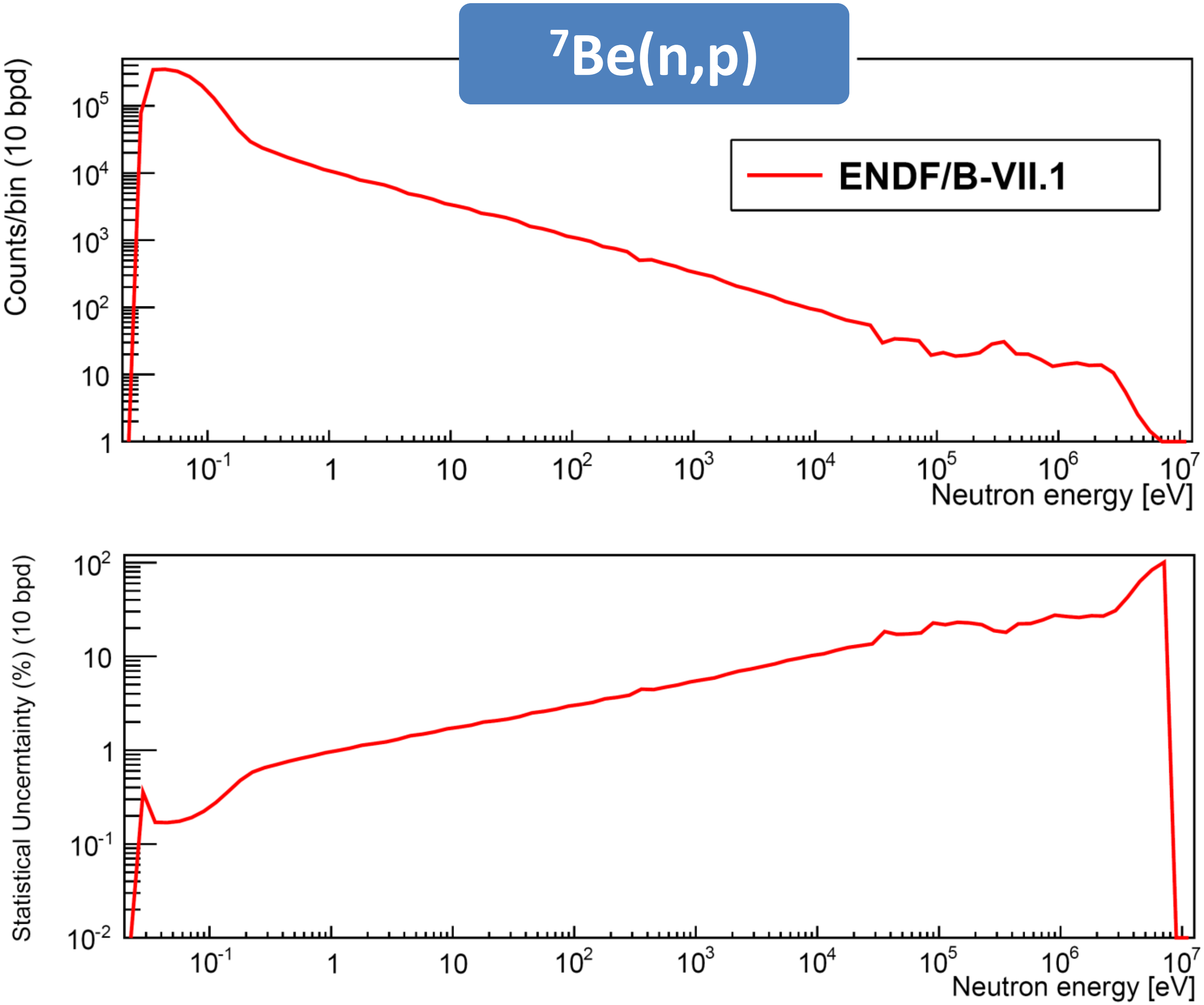
^{7}Be(n,p)

↓

Purification of sample needed: **ISOLDE**

- 100 ng of ^{7}Be (material from water cooling of SINQ spallation source at **PSI**)
- Mass separation required at ISOLDE **~3 shifts** (already allocated in CERN-INTC-2014-049/INTC-P-417), foreseen for 2016.
- Implantation on C backing

Protons request



Protons requested:
1.5x10^18

- 100 ng of ^7Be on 2.5 cm diameter circular area
- Efficiency 10%
- EAR2
- $1.5X10^{18}$ protons

Conclusions

• Uncertainties in nuclear data strongly affect the Big Bang Nucleosynthesis calculations for the abundance of ^{7}Li and could probably explain (at least partially) the **C**osmological **Li**thium **P**roblem.

• We plan to measure at **n_TOF EAR2** **for the first time** the ^{7}**Be(n,α)** cross section and the ^{7}**Be(n,p)** cross section in the range of interest for BBN, with the aim of reducing uncertainties in nuclear data used in calculations, thus setting stronger constraints to BBN theory and on CLiP.

• The needed ^{7}Be is **available at PSI**:
- For the (n,p) measurement, isotopic purity will be done at ISOL (100 ng)
- For the (n,α) measurement, no need for isotope separation (~4 μg)

• Protons request:

1.5×10^{18} protons for the ^{7}Be(n,p) measurement

5.0×10^{18} protons for the ^{7}Be(n,α) measurement