$^{13}C(n,\alpha_0)^{10}Be$ cross section measurement

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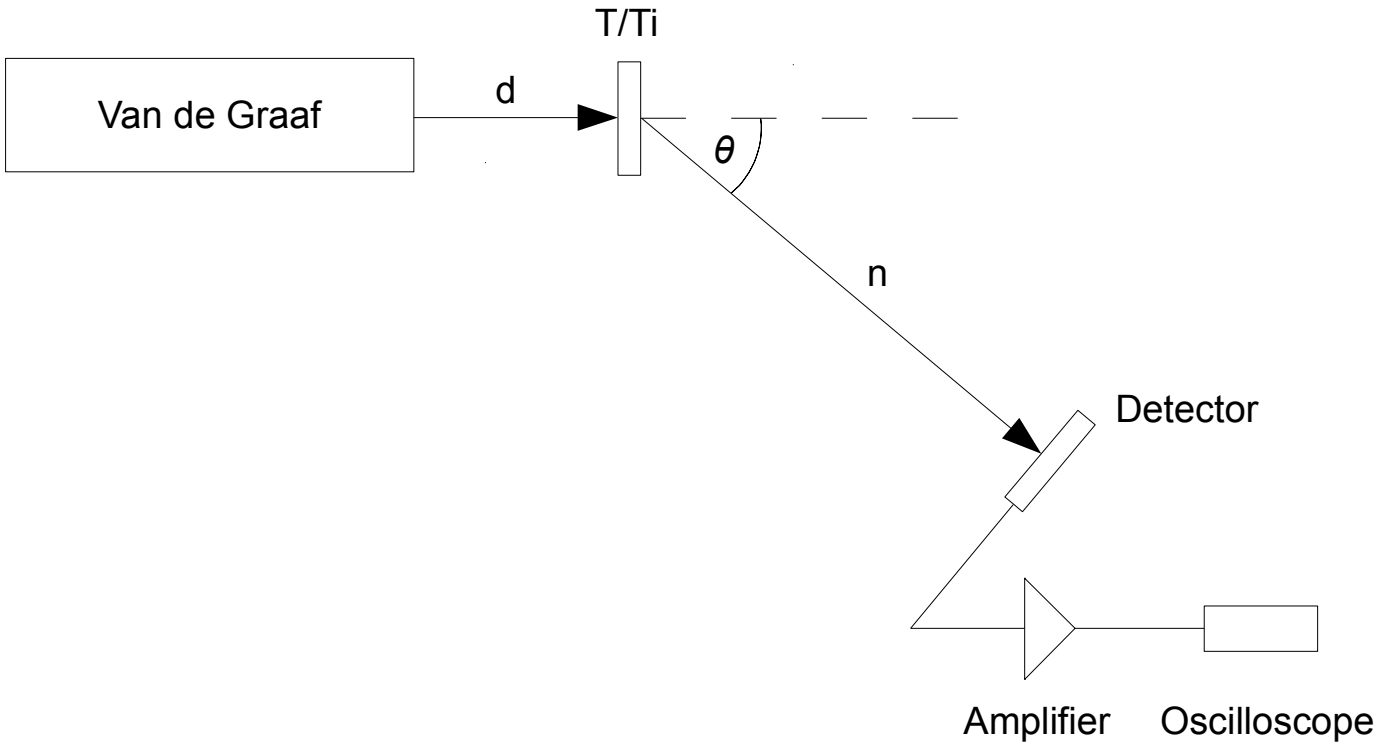
- Experimental setup
- Simulation of the response function
- Data analysis conditions
- Results
- Conclusions

Neutron source

- 7 MV Van de Graaff accelerator, EC-JRC Geel, Belgium
- Quasi-monoenergetic neutron beam via T(d,n)^{4}He reaction
- Deuteron (2 MeV) on Ti/T target
- Neutron energy has angular distribution

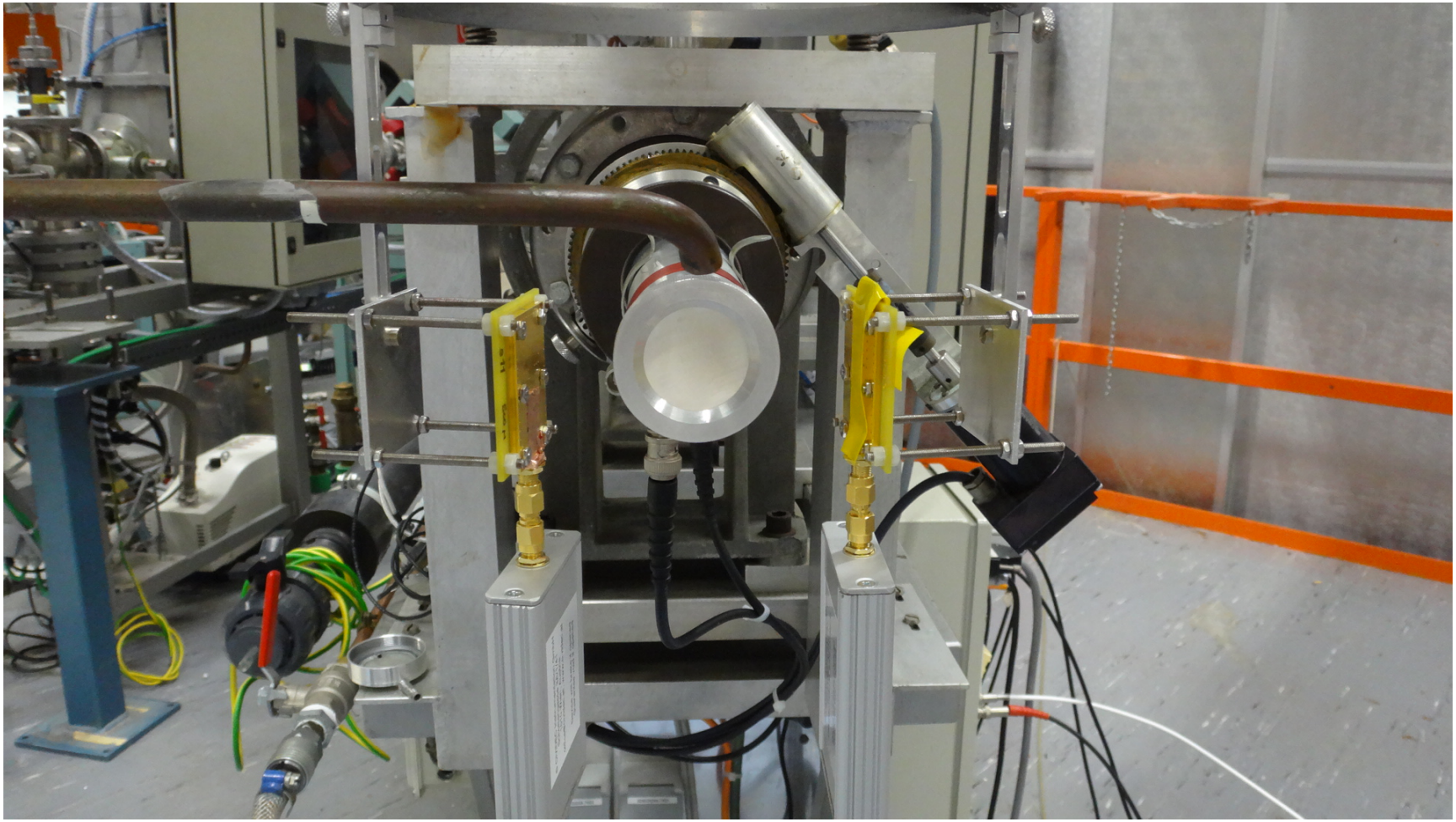
Scheme of the experimental setup



Experimental setup (I)

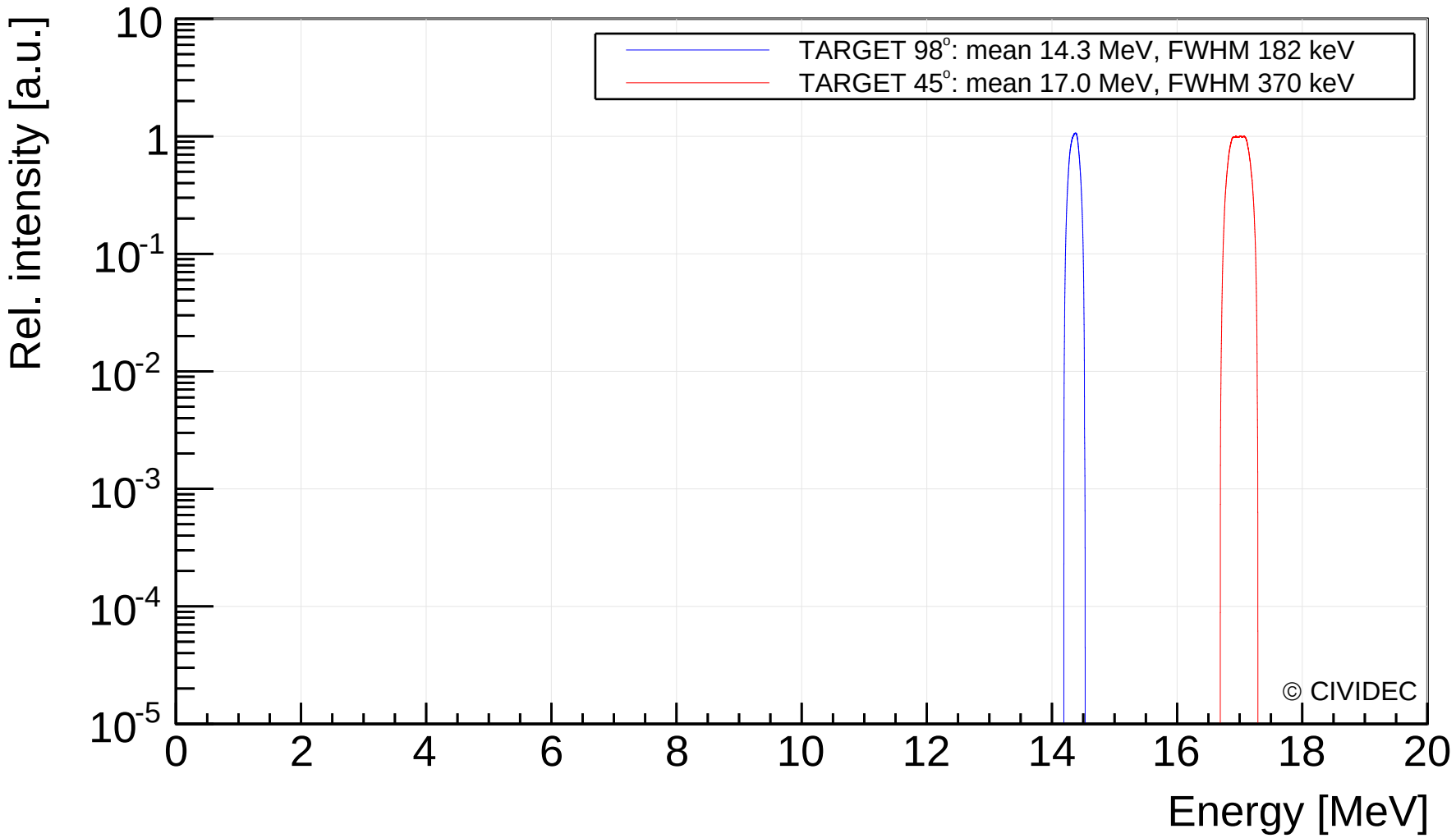
- Van de Graaff facility of the EC-JRC, Geel, Belgium
- Neutron energies: 14.3 MeV and 17.0 MeV
- CIVIDEC B1 Single-Crystal Diamond Detector
  - Thickness 500 μm
  - Active area 4 mm by 4 mm
  - Bias electric field 1 V/μm
  - Diamond detector was used as a sample and as a sensor
- CIVIDEC C2 Broadband Amplifier
  - Analogue bandwidth 2 GHz
  - Equivalent input current noise 0.4 μA
- LeCroy Waverunner oscilloscope
- Dedicated pulse-shape analysis for background rejection
- Cross section of ^{13}C(n,α)^{10}Be was measured relatively to ^{12}C(n,α)^{9}Be

Experimental setup (II)



Simulation of the response function

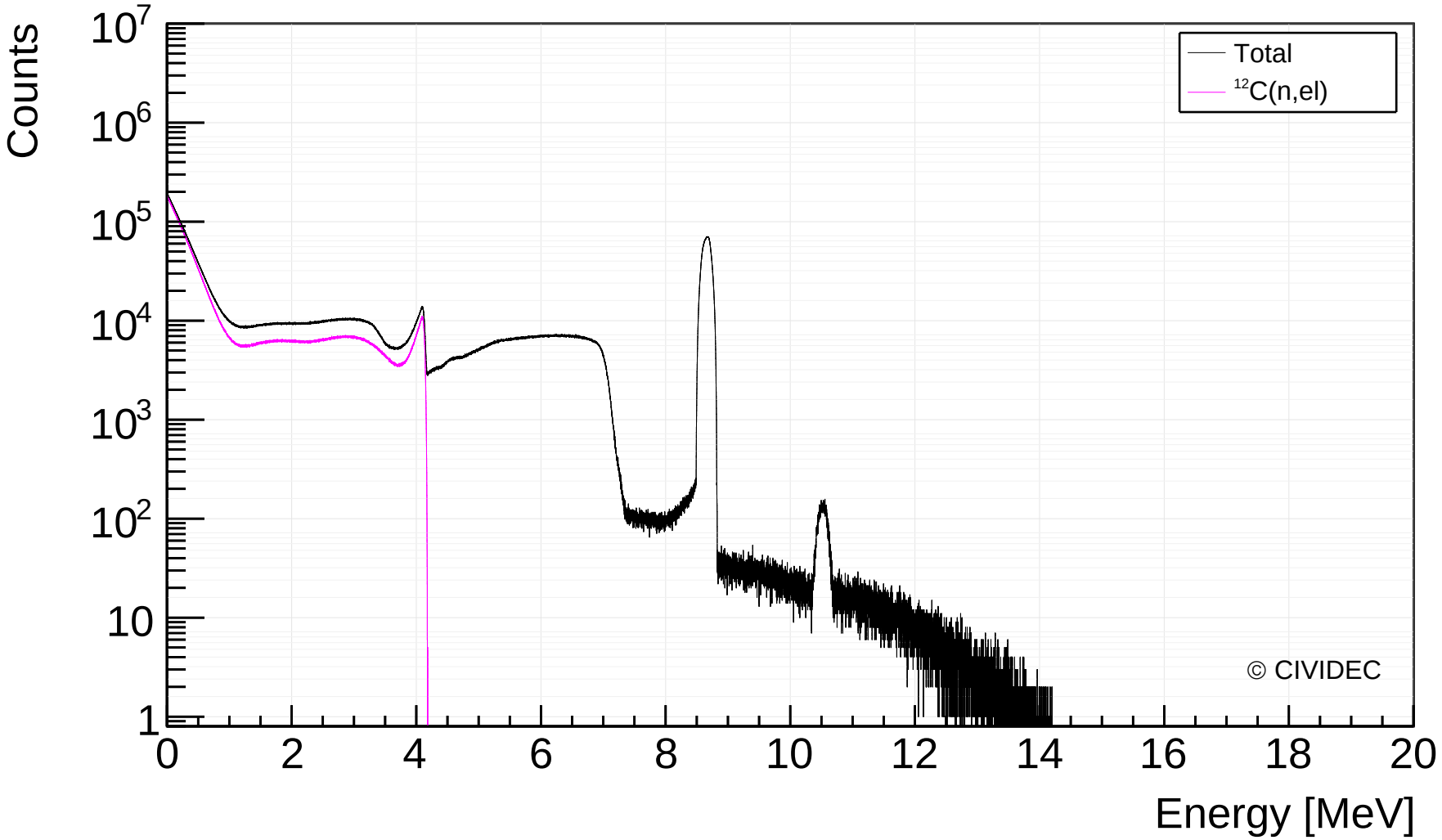
Neutron beam parameters



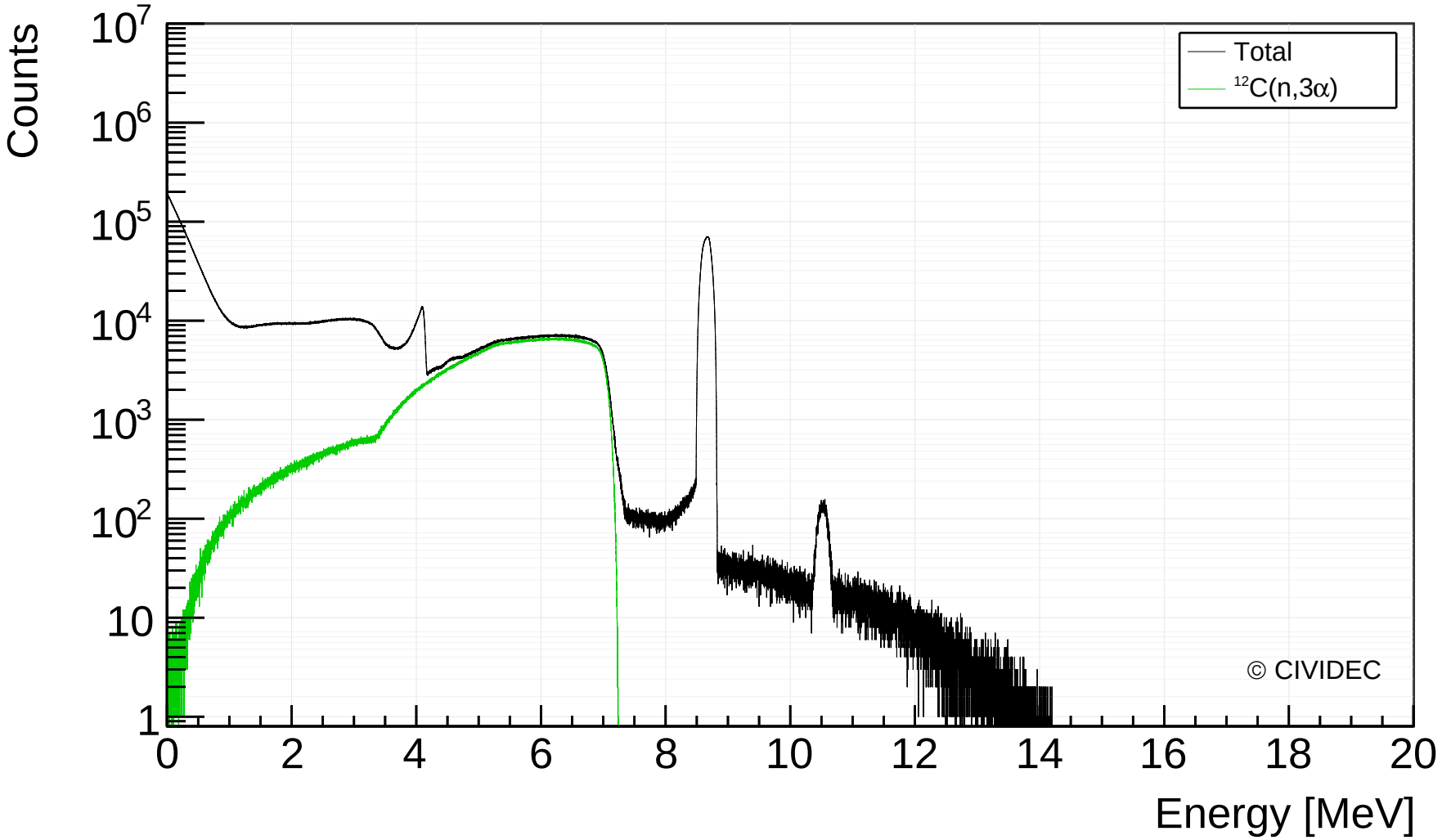
Neutron interactions in diamond

Reaction	Q [MeV]	E_{th} [MeV]
^{12}C(n,el)^{12}C	0	0
^{13}C(n,α)^{10}Be	- 3.836	4.134
^{12}C(n,α)^{9}Be	- 5.702	6.182
^{12}C(n,n+2α)^{4}He	- 7.275	7.886
^{12}C(n,p)^{12}B	- 12.587	13.645
^{12}C(n,d)^{11}B	- 13.732	14.887

Geant4 simulation: (n,el)

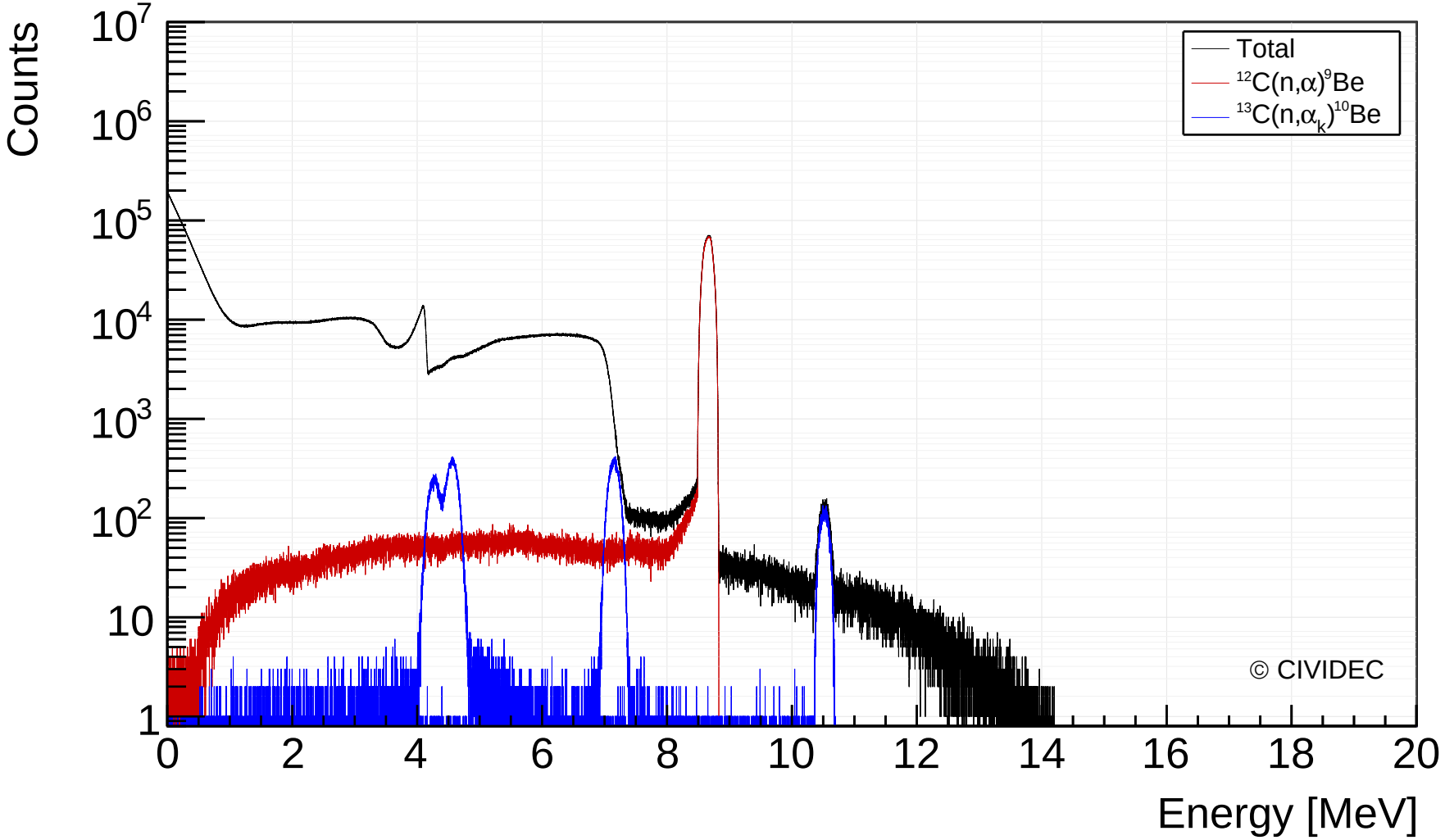


Geant4 simulation: (n,3α)

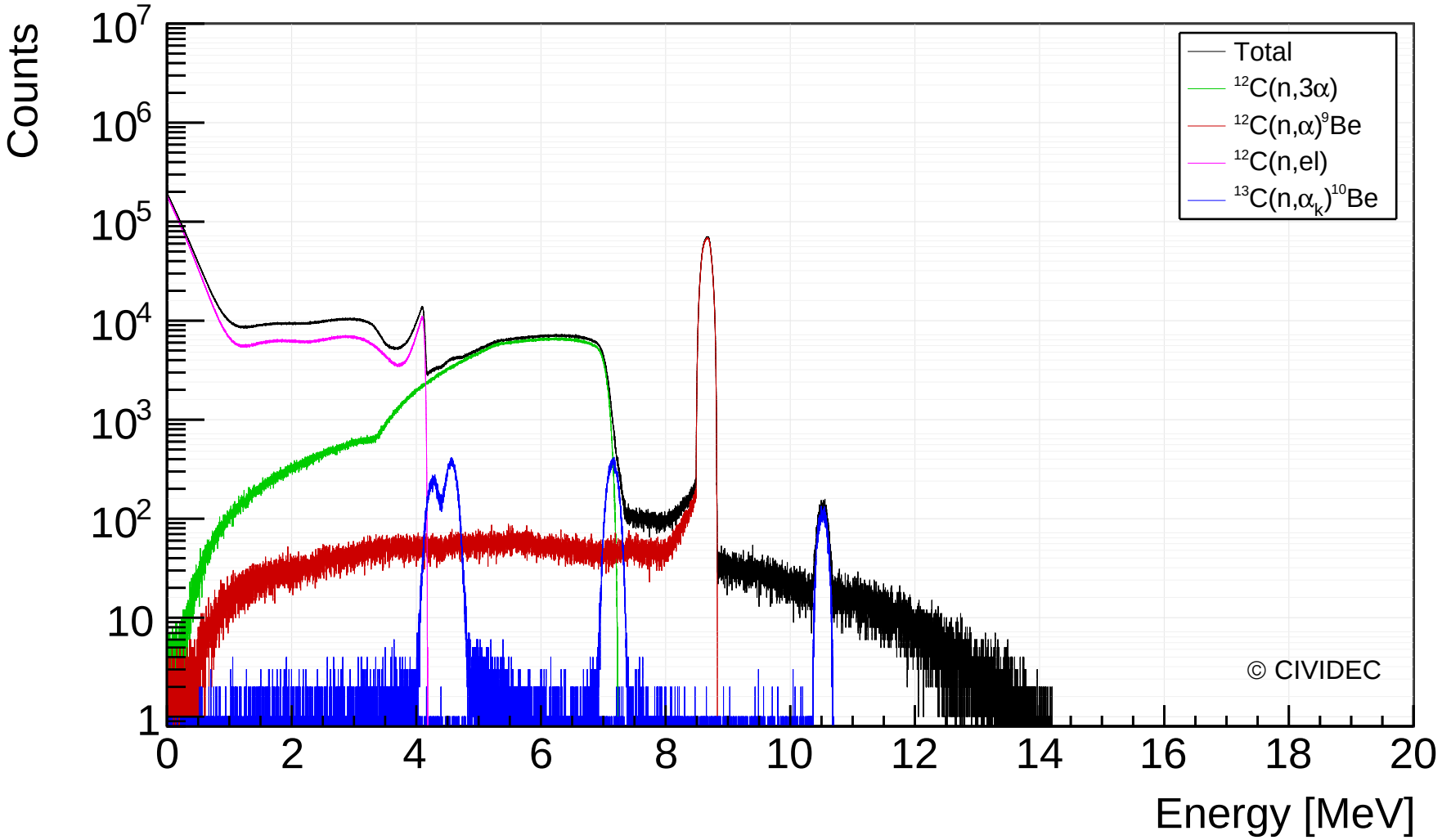


Geant4 simulation: (n,α)

^{12}C(n,α_0)^{9}Be: mean 8.6 MeV, FWHM 177 keV
^{13}C(n,α_0)^{10}Be: mean 10.5 MeV, FWHM 180 keV



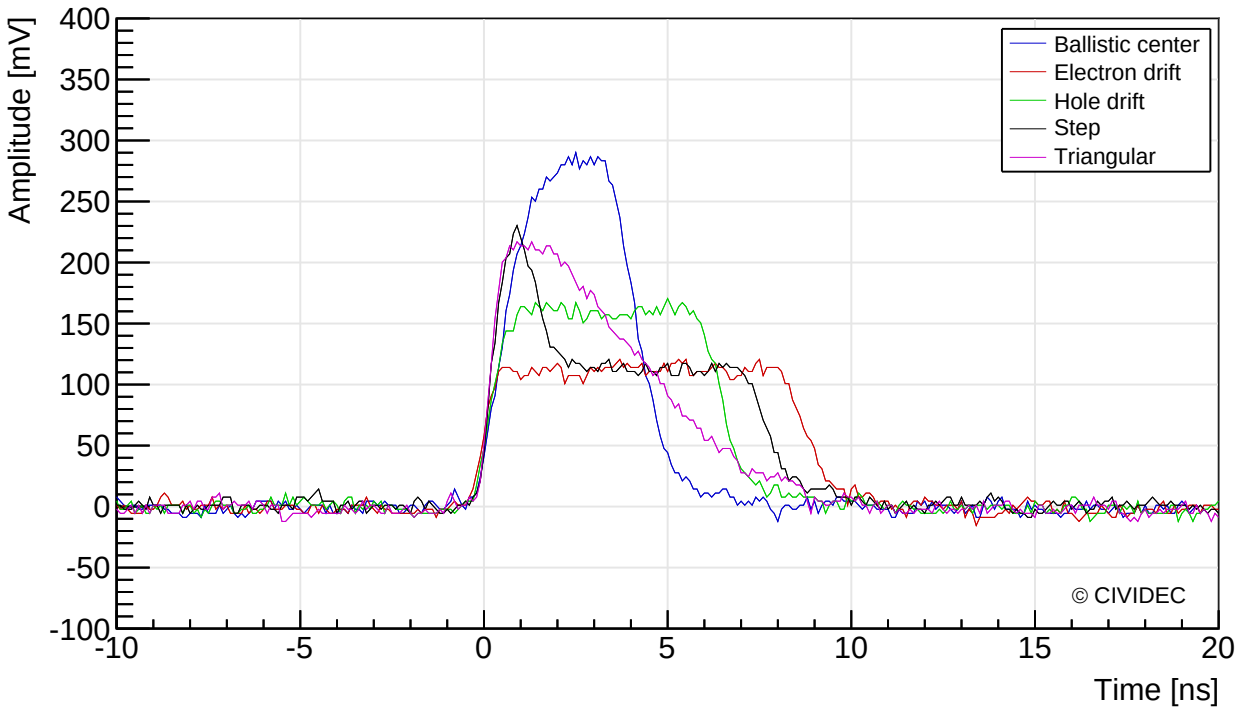
Geant4 simulation: total



Data analysis conditions

Pulse-shape analysis

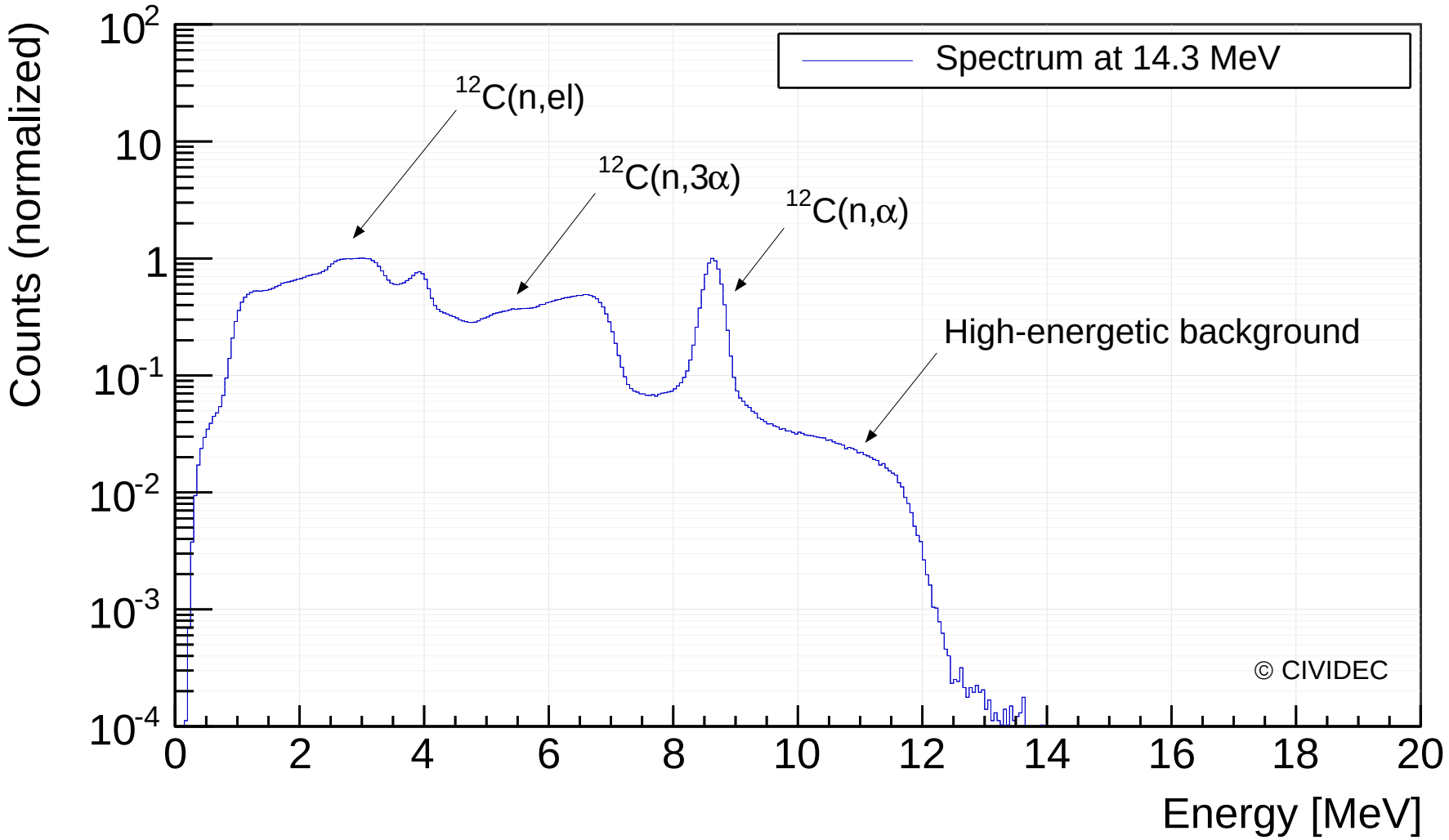
C. Weiss, "Neutron Diagnostics", ADAMAS 2016



- Fast neutrons interacting in the *ballistic center* produce **rectangular** pulses with a minimum **drift time**
- Pulse **amplitude** threshold allows to remove the spectra below the ^{12}C(n, n+2α)^{4}He edge

Results

Measurement vs. simulation, 14.3 MeV



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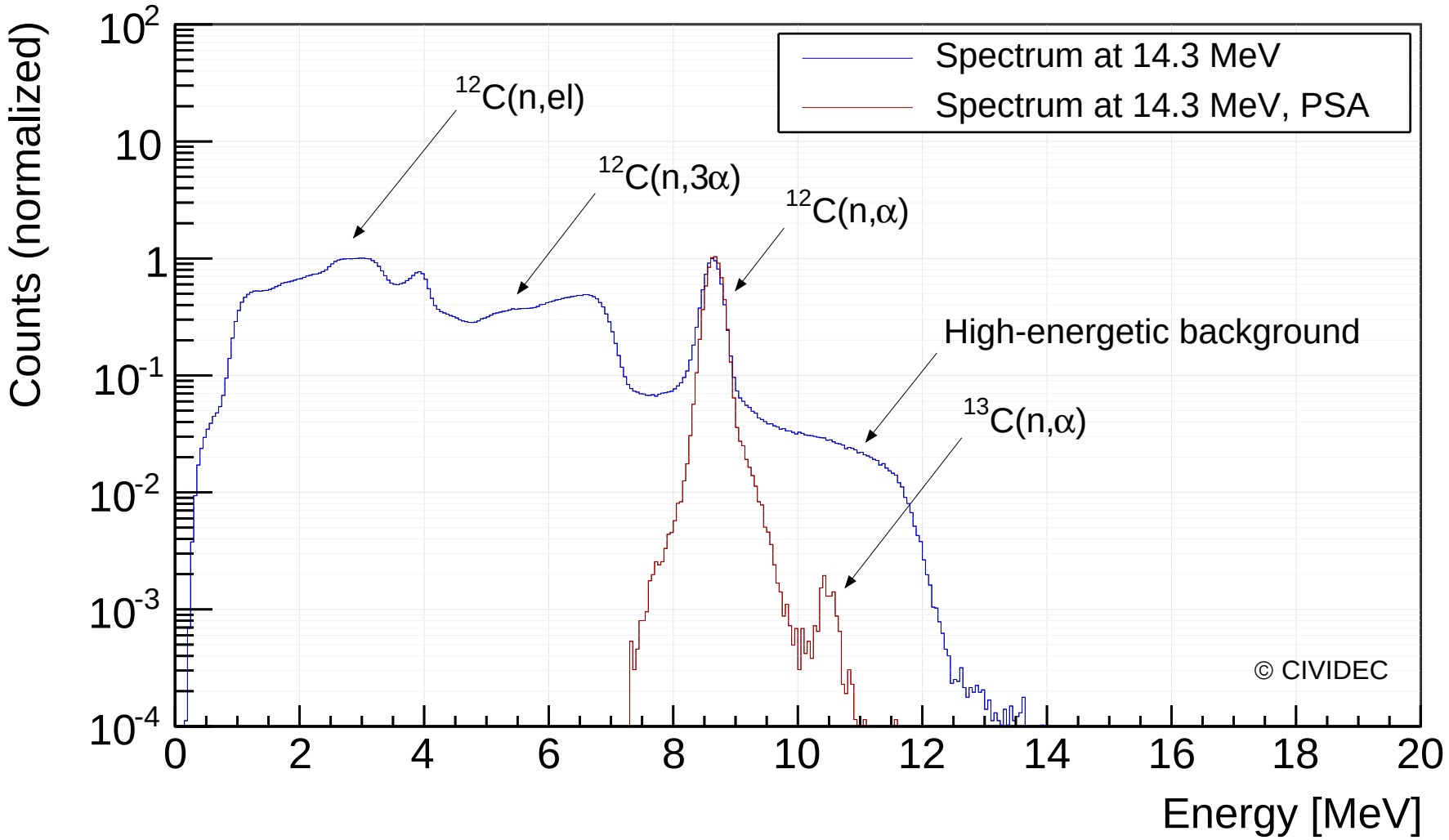
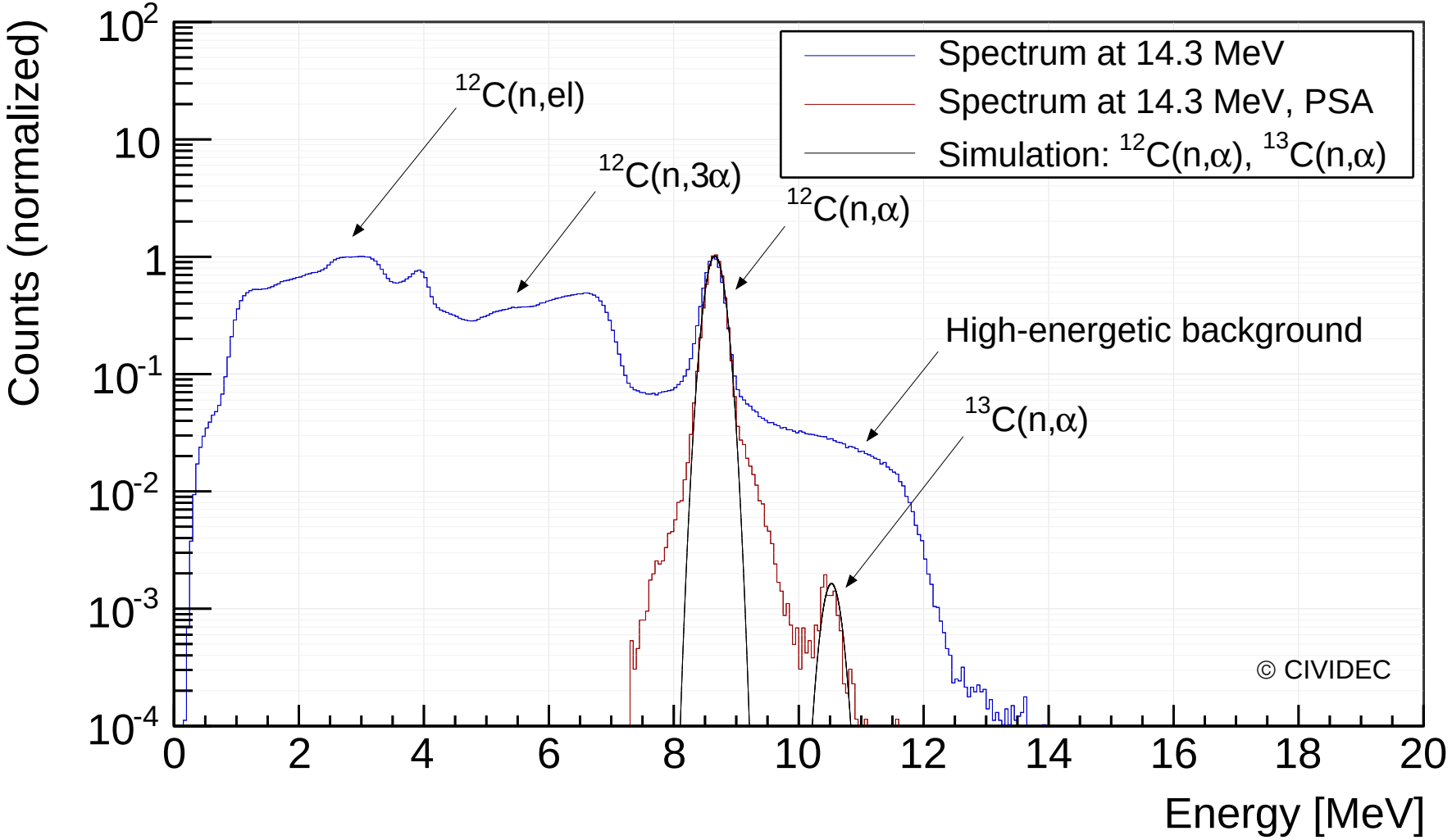


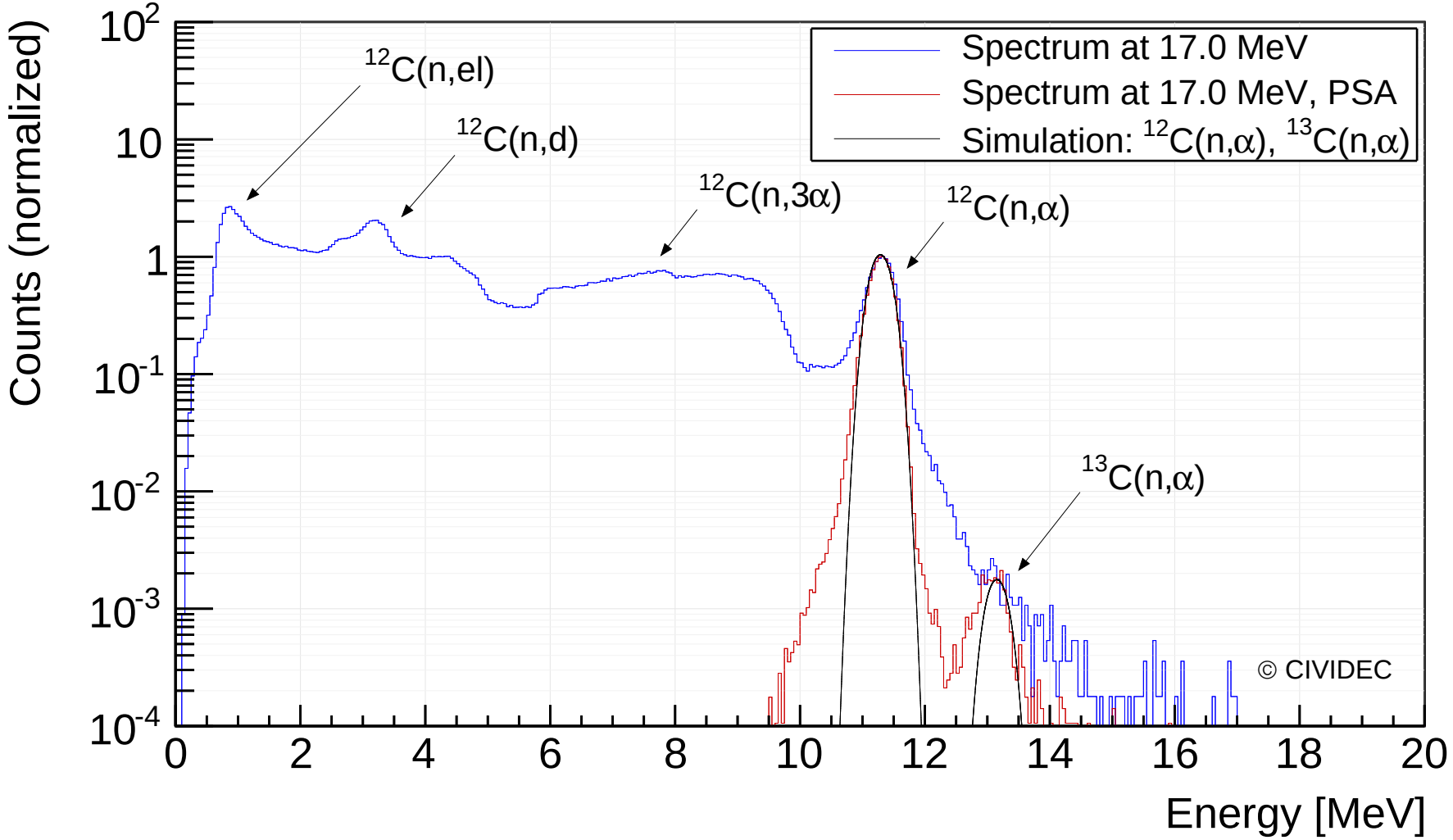
Measurement vs. simulation, 14.3 MeV

$^{12}C(n,\alpha_0)^{9}Be$: mean 8.6 MeV, FWHM 310 keV
$^{13}C(n,\alpha_0)^{10}Be$: mean 10.5 MeV, FWHM 324 keV



Measurement vs. simulation, 17.0 MeV

$^{12}C(n,\alpha_0)^{9}Be$: mean 11.3 MeV, FWHM 418 keV
$^{13}C(n,\alpha_0)^{10}Be$: mean 13.2 MeV, FWHM 428 keV



Cross section ratio calculation

The ratio of the $^{13}C(n,\alpha_0)^{10}Be$ and $^{12}C(n,\alpha_0)^{9}Be$ reaction was derived as:

$$\frac{\sigma_{13}}{\sigma_{12}} = \frac{I_{13}}{I_{12}} \cdot \frac{N_{12}}{N_{13}} \tag{1}$$

where I_{12} and I_{13} are the net peak areas corresponding to the two reactions of interest, N_{12} and N_{13} are the fractions of ^{12}C and ^{13}C isotopes in diamond.

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Uncertainty estimation:

- Uncertainty of the abundance of ^{13}C in diamond (N_{13}/N_{12}) which is 0.3% (M. Berglund, M.E. Wieser, Pure Appl. Chem. **83**, 397 (2011)).

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- Statistical uncertainty dominated by the ^{13}C(n,α_0)^{10}Be statistics, with 5.9% at 14.3 MeV, and 4.0% at 17.0 MeV.

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- Uncertainty of the analysis method dominated by the pulse width selection, which was estimated as 8.3%.

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- Statistical uncertainty dominated by the $^{13}C(n,\alpha_0)^{10}Be$ statistics, with 5.9% at 14.3 MeV, and 4.0% at 17.0 MeV.
- Uncertainty of the analysis method dominated by the pulse width selection, which was estimated as 8.3%.
- Energy resolution of the detector system, which was 168 keV FWHM.
- The total uncertainty is below 11% for both measurements.

Results

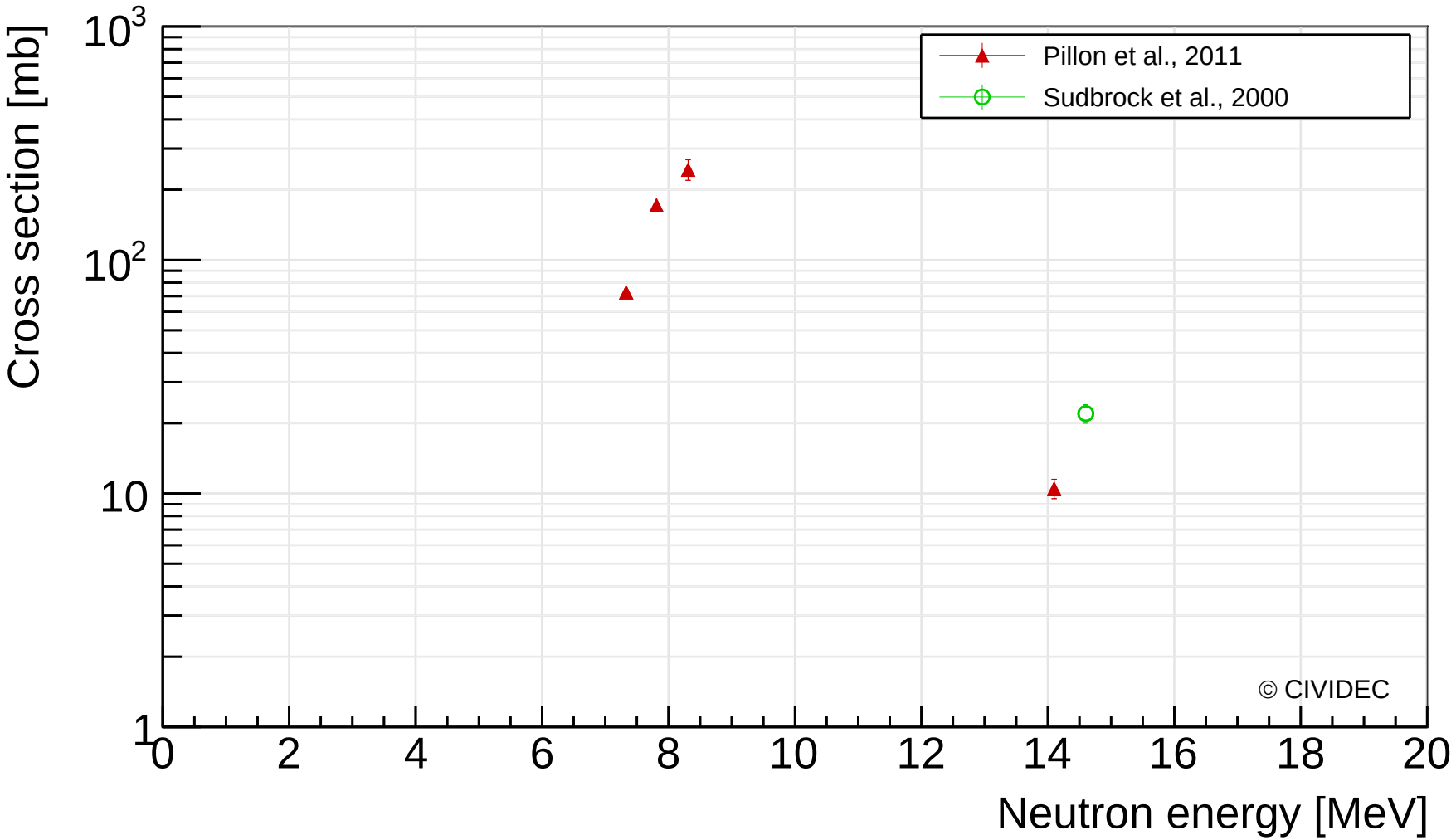
- Cross section ratio:

$$\sigma_{13}/\sigma_{12}=(0.15\pm0.01) \text{ at } 14.3 \text{ MeV.}$$
$$\sigma_{13}/\sigma_{12}=(0.17\pm0.01) \text{ at } 17.0 \text{ MeV.}$$

- Using the evaluated cross section σ_{12} at 14.3 MeV and 17.0 MeV (CENDL-3.1), the derived ^{13}C(n,α_0)^{10}Be cross section is:

$$\sigma_{13}=(10.4\pm1.1) \text{ mb at } 14.3 \text{ MeV.}$$
$$\sigma_{13}=(7.1\pm0.7) \text{ mb at } 17.0 \text{ MeV.}$$

$^{13}C(n,\alpha_0)^{10}Be$ cross section



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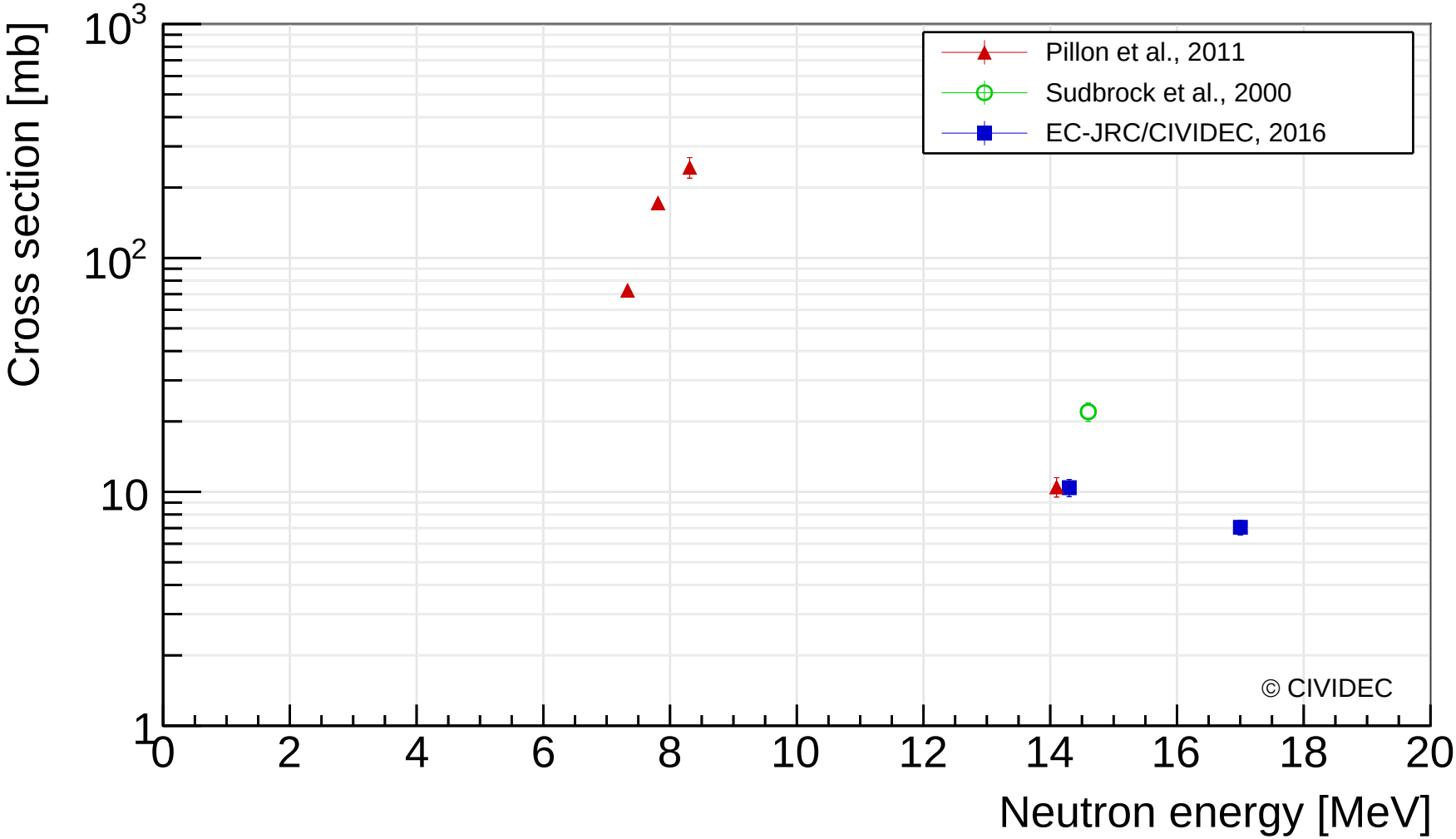
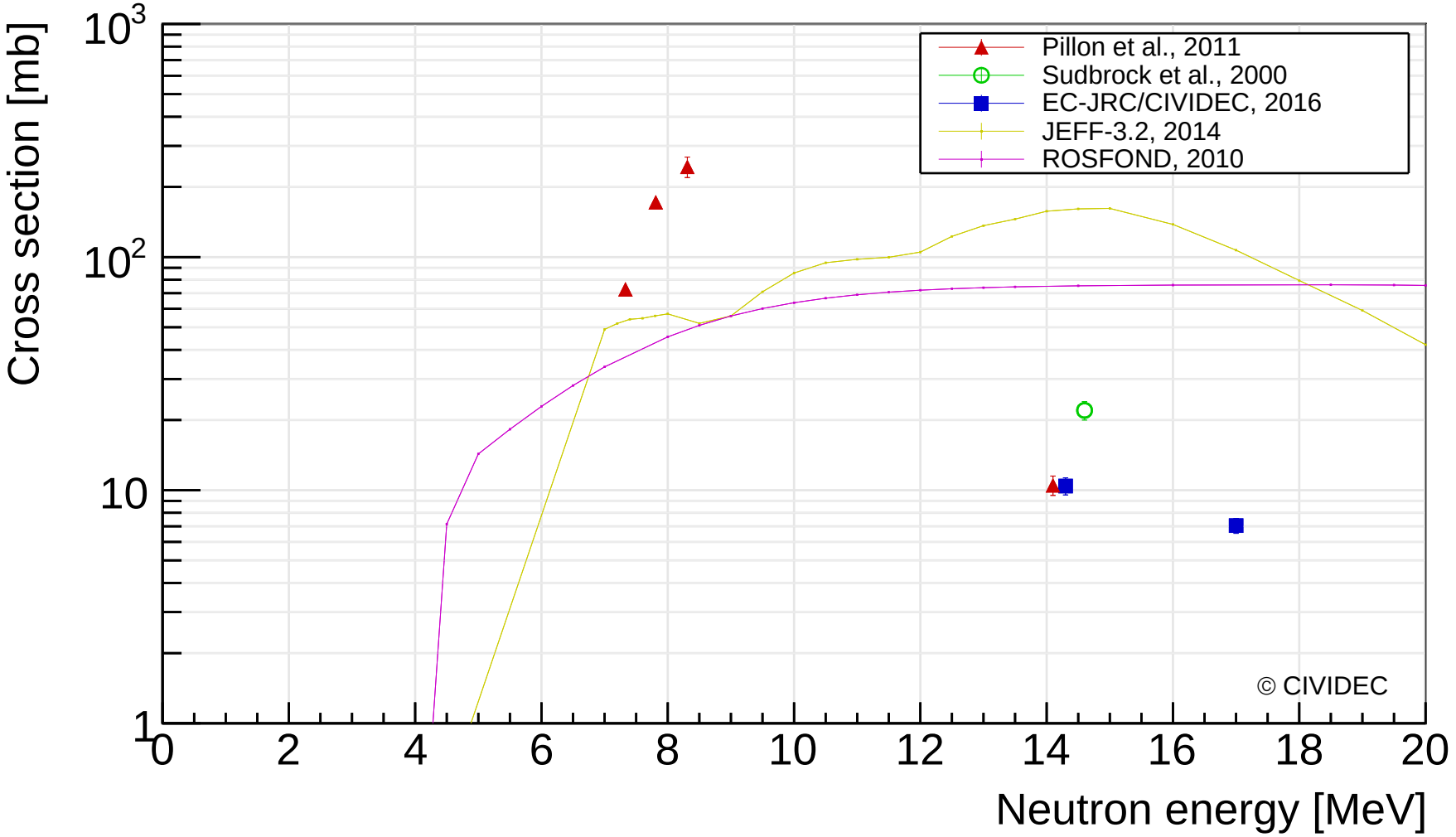


$^{13}C(n,\alpha_0)^{10}Be$ cross section



Conclusions

- ^{13}C(n,α_0)^{10}Be cross section was measured relatively to ^{12}C(n,α_0)^{9}Be.
- Measurement was performed with an sCVD diamond detector using the selective pulse-shape analysis technique.
- The analysis method allowed to reject the high-energetic background, and extract the ^{13}C(n,α_0)^{10}Be spectrum.
- Using the evaluated cross section of ^{12}C(n,α_0)^{9}Be at 14.3 MeV and 17.0 MeV (CENDL-3.1), the derived ^{13}C(n,α_0)^{10}Be cross section is:

$$\sigma_{13}=(10.4\pm1.1) \text{ mb at } 14.3 \text{ MeV}.$$

$$\sigma_{13}=(7.1\pm0.7) \text{ mb at } 17.0 \text{ MeV}.$$

References

- P. Kavrigin, E. Griesmayer, F. Belloni, A.J.M. Plompen, P. Schillebeeckx, C. Weiss, $^{13}C(n,\alpha_0)^{10}Be$ *cross section measurement with sCVD diamond detector*, Eur. Phys. J. A **52**, 179 (2016)

- C. Weiss, H. Frais-Kölbl, E. Griesmayer, P. Kavrigin, *Ionization signals of diamond detectors in fast neutron fields*, Eur. Phys. J. A **52**, 269 (2016).

Thank you for your attention!

Addendum I - Neutron interactions in diamond

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