Fusion Neutron Diagnostics with CVD Diamond Detectors

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Content

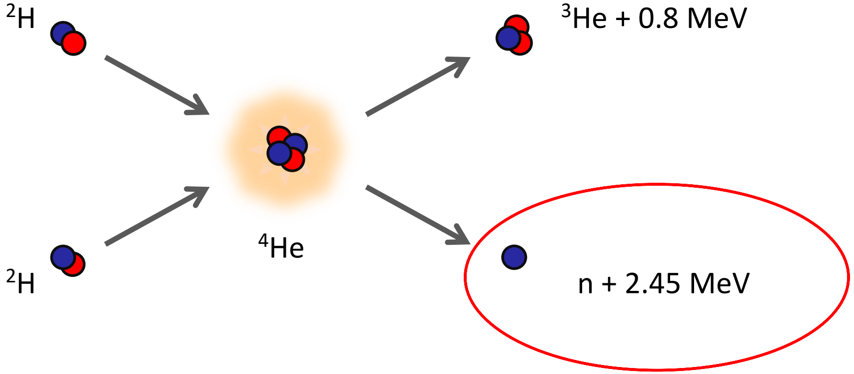
- Fusion neutrons
- CVD diamond technology
- Diagnostics with CVD diamond detectors
- CVD diamond performance
- Applications

FUSION NEUTRONS

Fusion neutrons

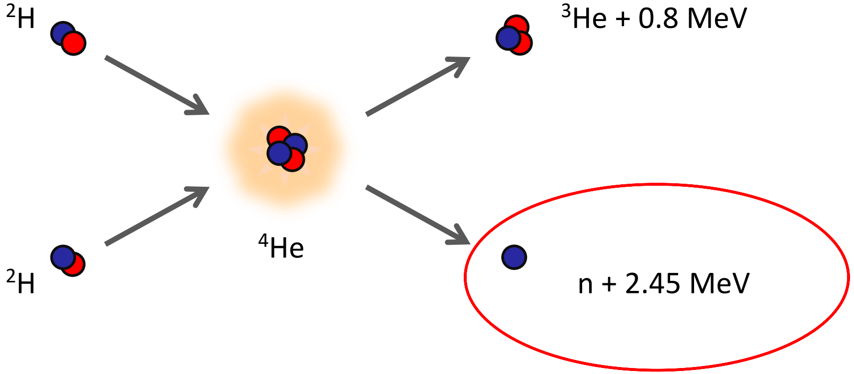
DD-Fusion

DT-Fusion

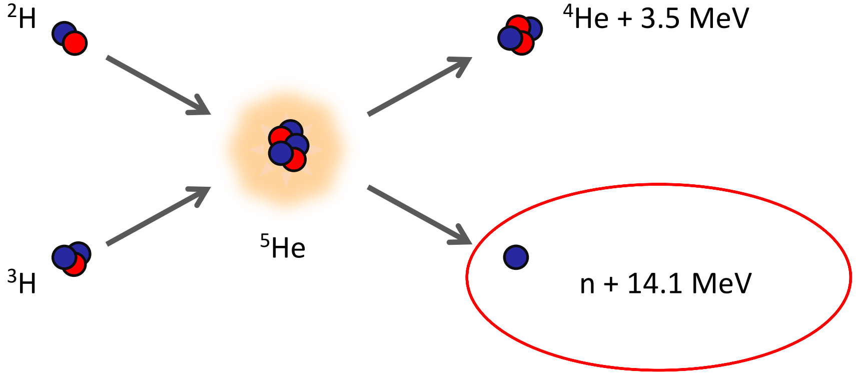


Fusion neutrons

DD-Fusion



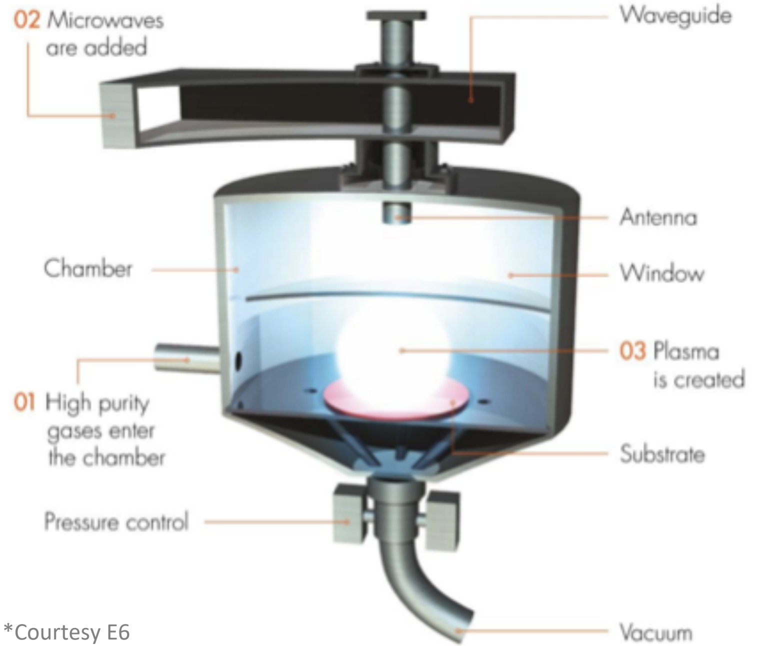
DT-Fusion



CVD DIAMOND TECHNOLOGY

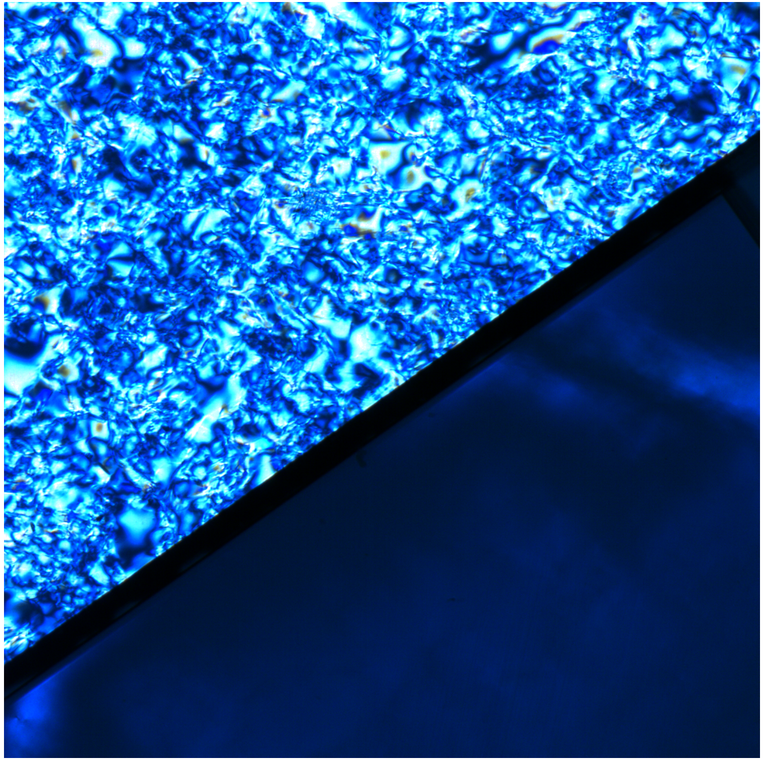
CVD diamond

Chemical vapor deposition

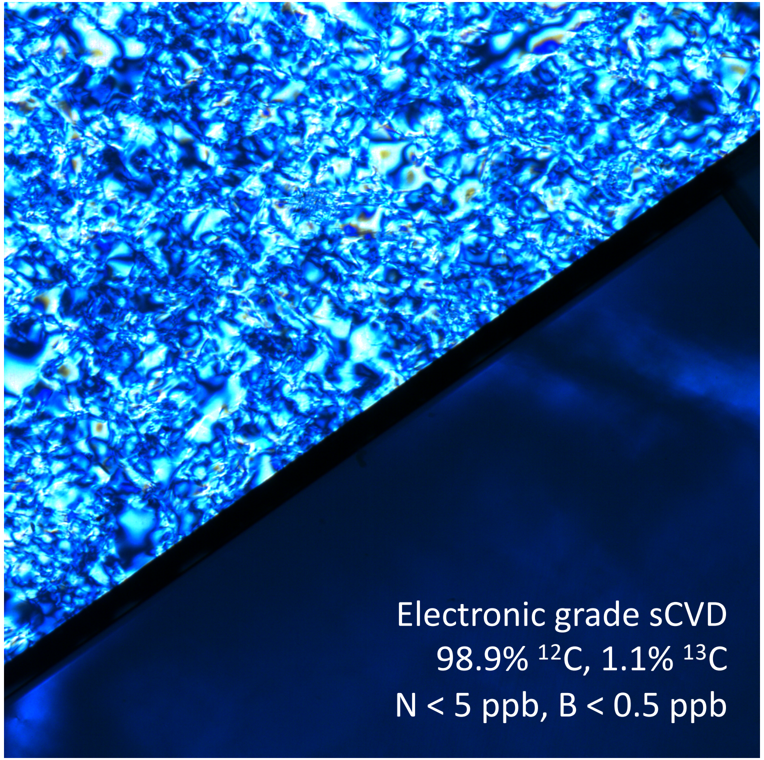


*Courtesy E6

CVD diamond



CVD diamond



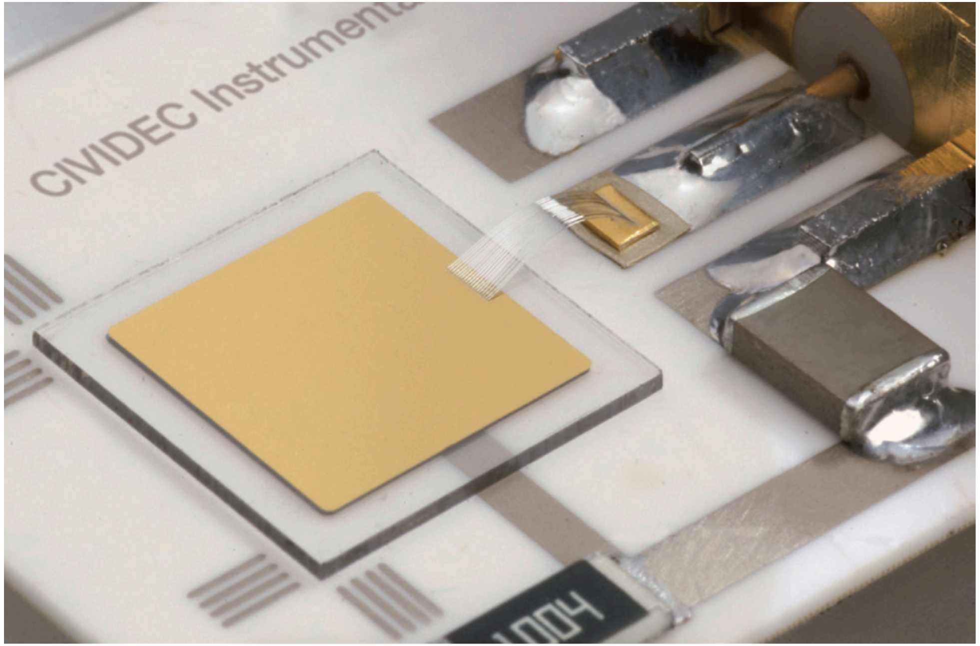
CVD diamond

Solid-state sensor

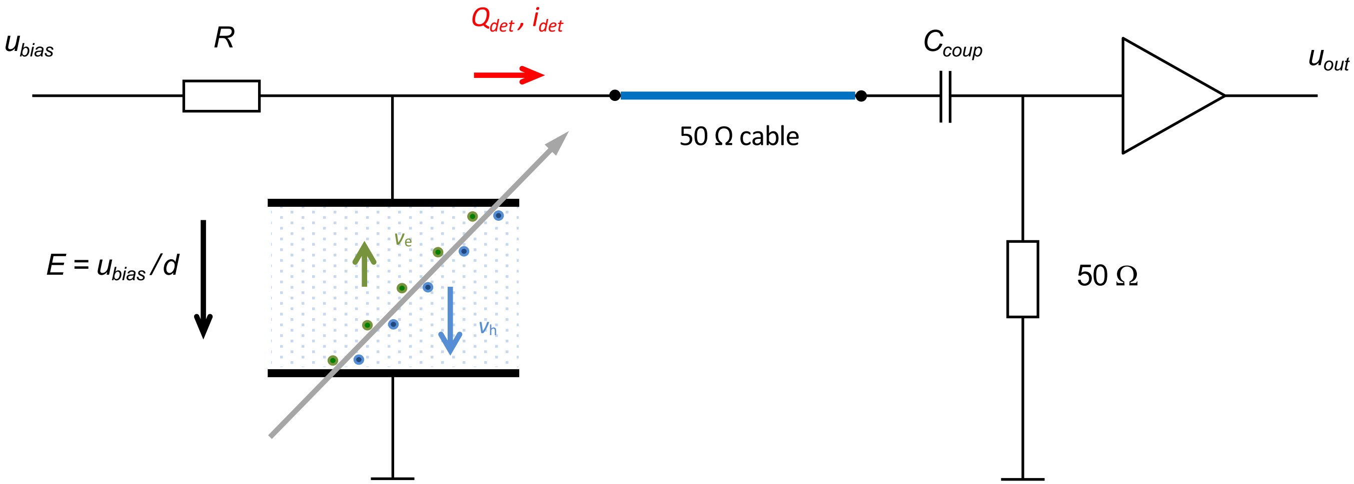
ε_{gap} = 5.47 eV

E_{ion} = 13 eV

CVD diamond sensor



Equivalent circuit diagram



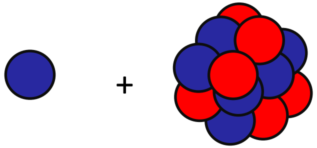
Neutron diagnostic system

FUSION NEUTRON DIAGNOSTICS WITH CVD DIAMOND DETECTORS

Neutron detection

Charged particles from nuclear interactions make neutrons detectable.

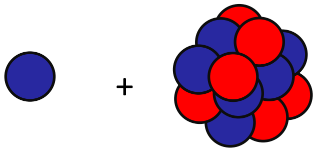
Neutron detection



n + ^{12}C

98.9%

Neutron detection



n

^{12}C

98.9%

Charged particle as reaction product.

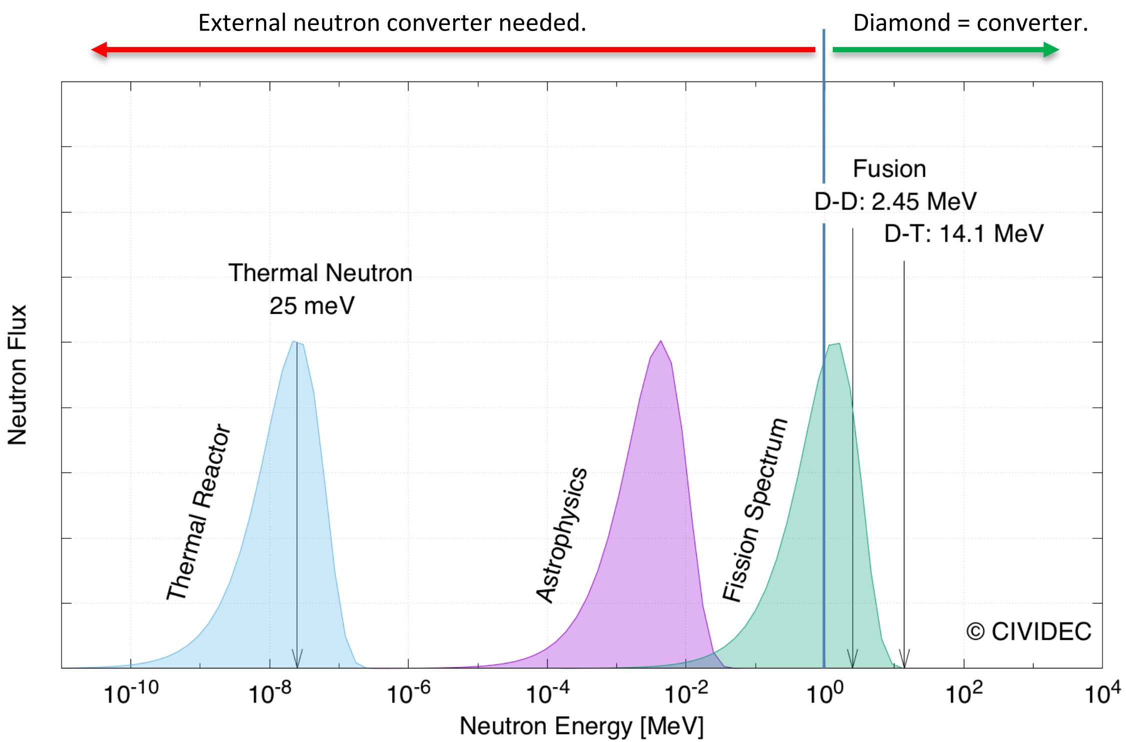
$$Q = [m_x + m_X - (m_y + m_Y)] \cdot c^2$$

Q-value Calculator (QCalc)

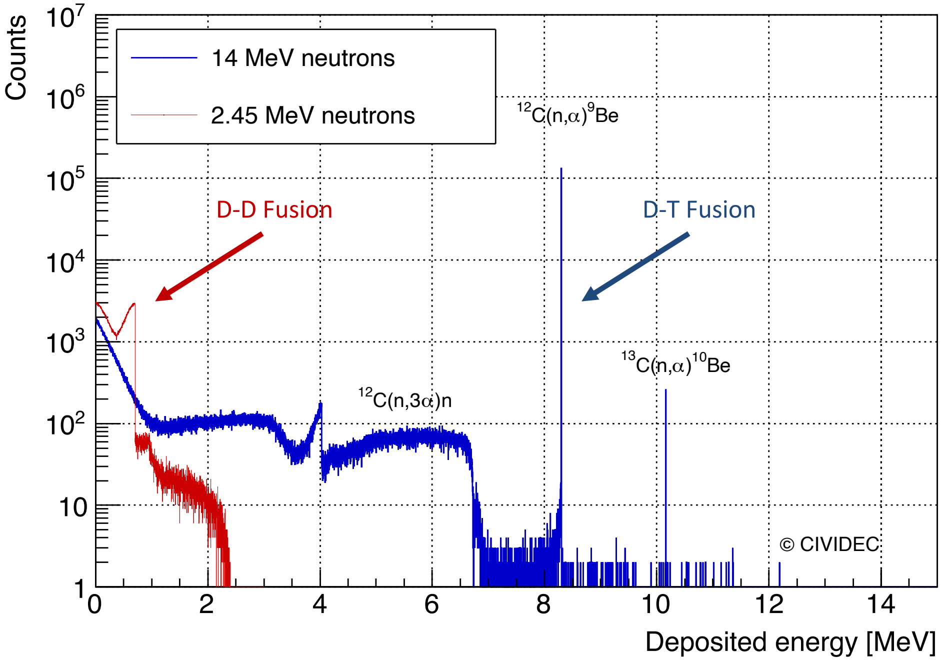
Reaction Q-values for $^{12}C + n(E_{lab}=20\ MeV)$

Reaction Products	Q-value (keV)	Threshold (keV)
$^{13}C+\gamma$	4946.31 *0.0*	0.0 *0.0*
$^{12}C+n$	0.0 *0.0*	0.0 *0.0*
$^{9}Be+\alpha$	-5702.05 *0.08*	6181.469 *0.0867*
$^{4}He+n+2\alpha$	-7274.7466 *6.59E-4*	7886.396 *7.14E-4*
$^{8}Be+n+\alpha$	-7366.5864 *0.035*	7985.9575 *0.0379*
$^{5}He+2\alpha$	-8009.7 *20.0*	8683.2 *21.7*
$^{12}B+p$	-12587.05 *1.32*	13645.35 *1.43*
$^{11}B+d$	-13732.113 *0.01*	14886.688 *0.0108*
$^{11}B+n+p$	-15956.678 *0.012*	17298.291 *0.013*

Neutron detection

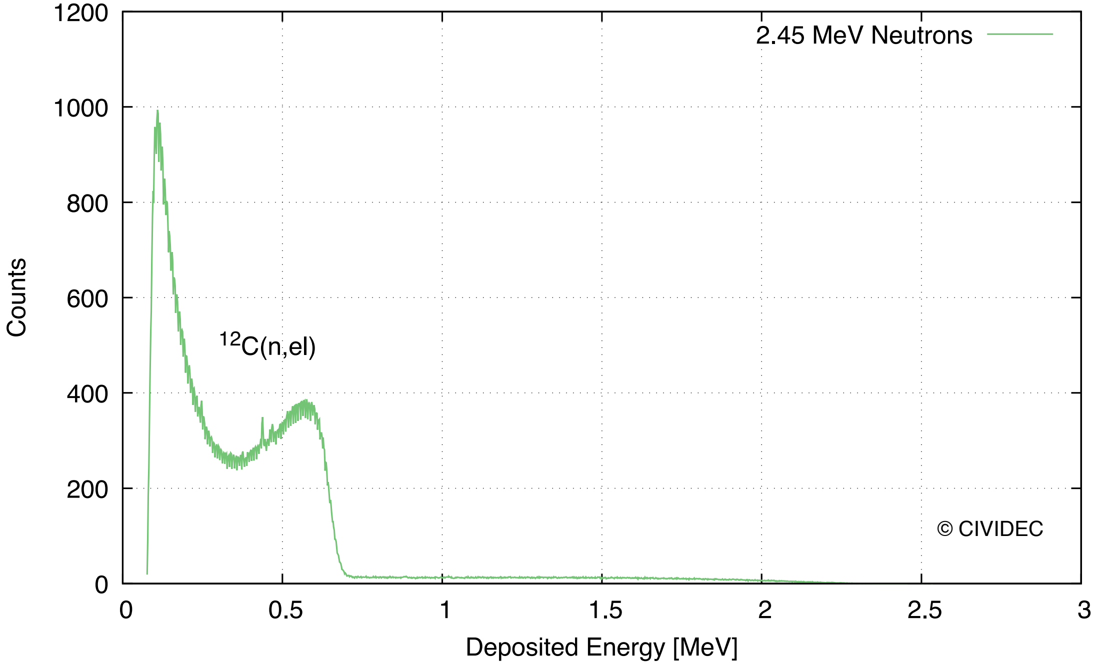


Simulation



Counts
10^7
10^6
10^5
10^4
10^3
10^2
10
1
14 MeV neutrons
2.45 MeV neutrons
$^{12}C(n,\alpha)^9Be$
D-D Fusion
D-T Fusion
$^{13}C(n,\alpha)^{10}Be$
$^{12}C(n,3\alpha)n$
© CIVIDEC
0
2
4
6
8
10
12
14
Deposited energy [MeV]

DD-Fusion Measurement



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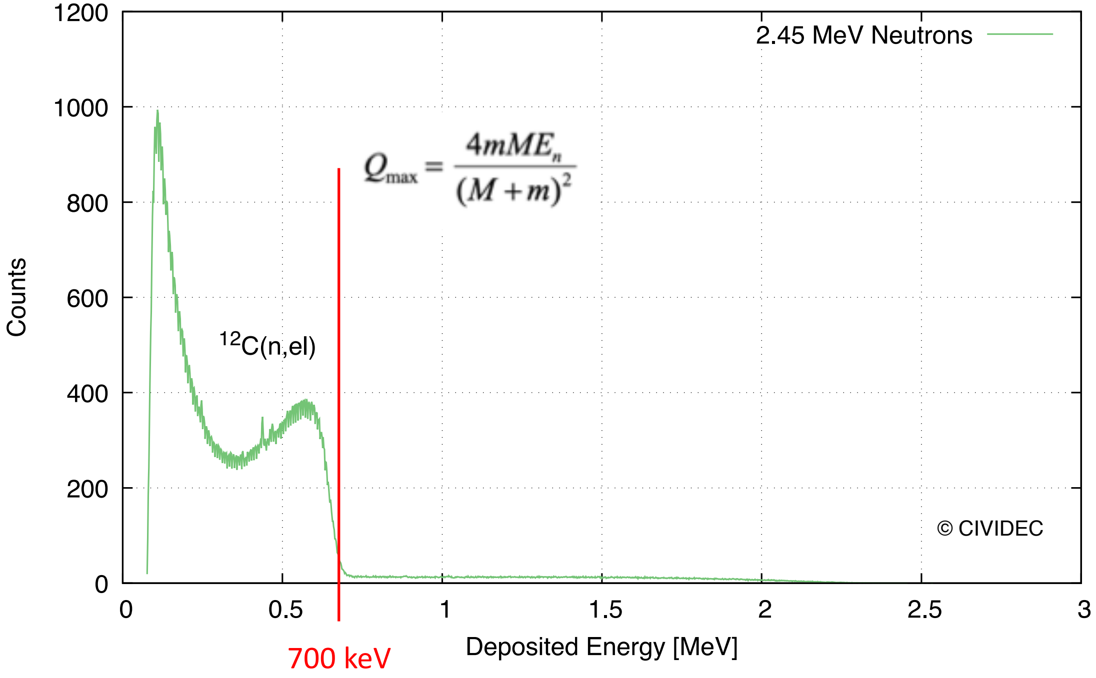
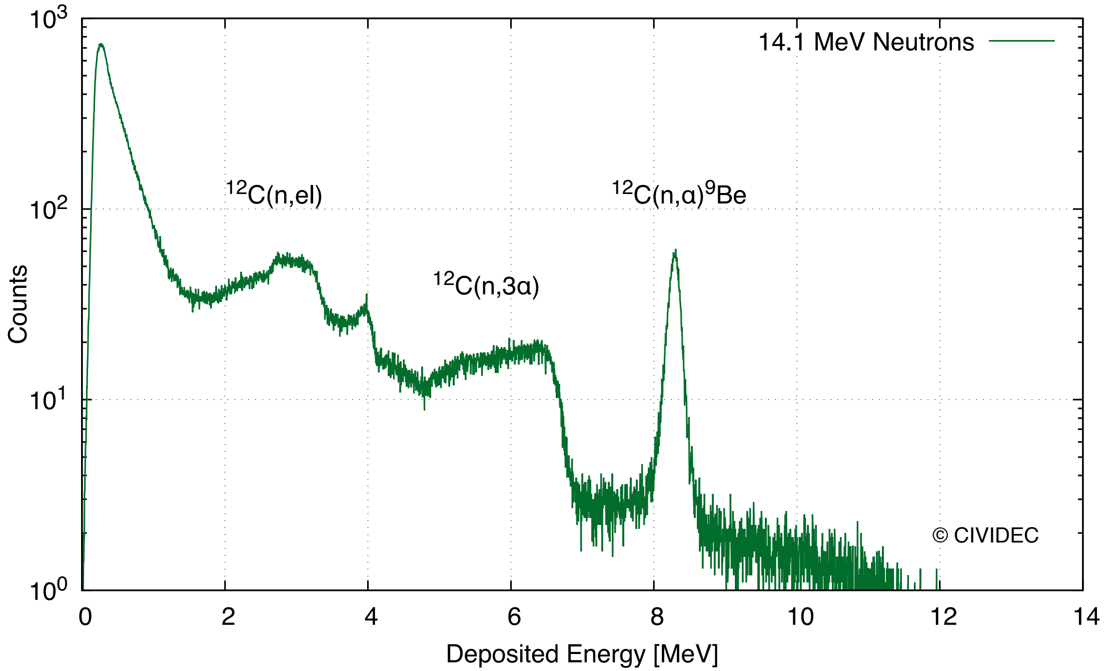
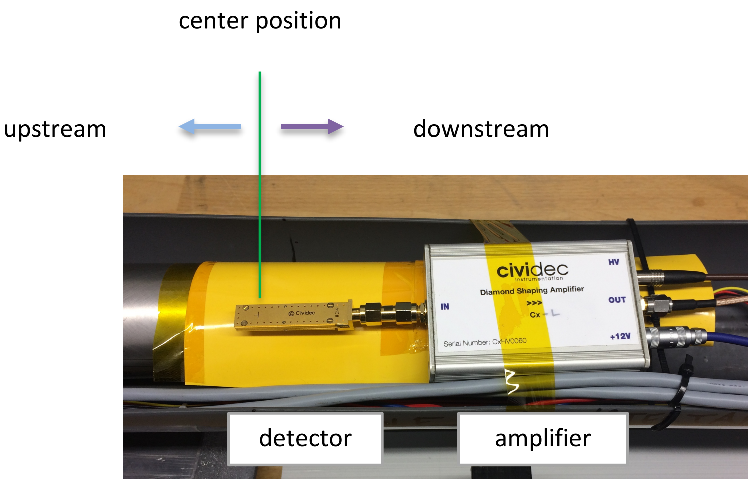
DD-Fusion Measurement

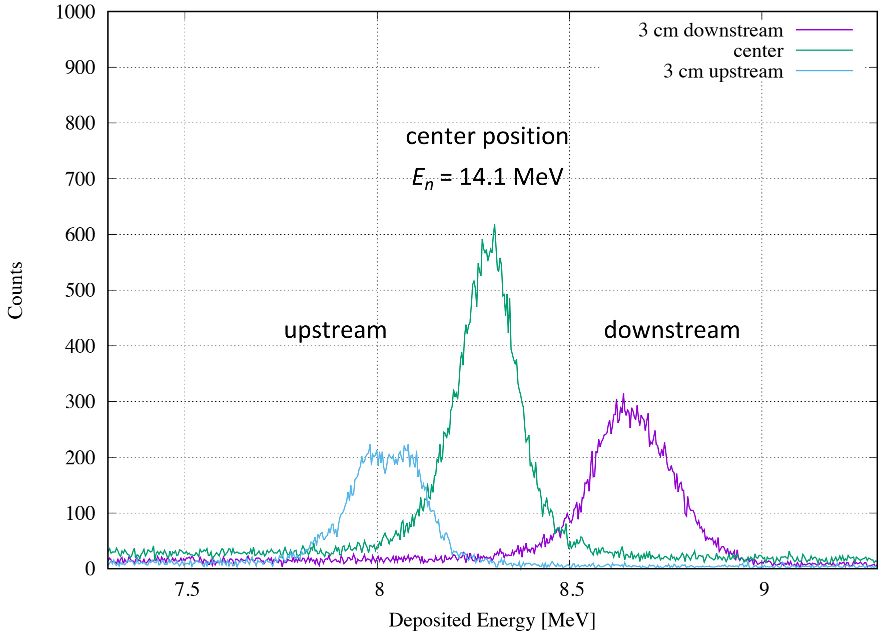


DT-Fusion Measurement



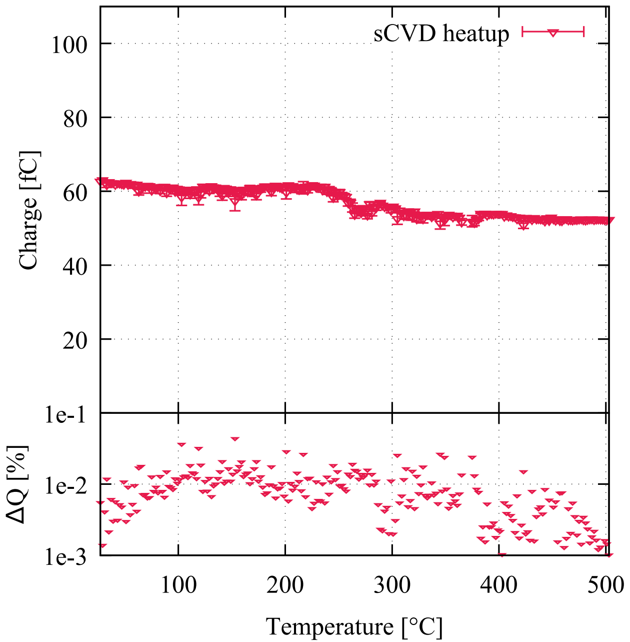
Neutron energy distribution





CVD DIAMOND PERFORMANCE

High-temperature compatible



C. Weiss *et al., NIMA 1040 (2022) 167182*: *High-temperature performance of solid-state sensors up to 500°C.*

Radiation hardness

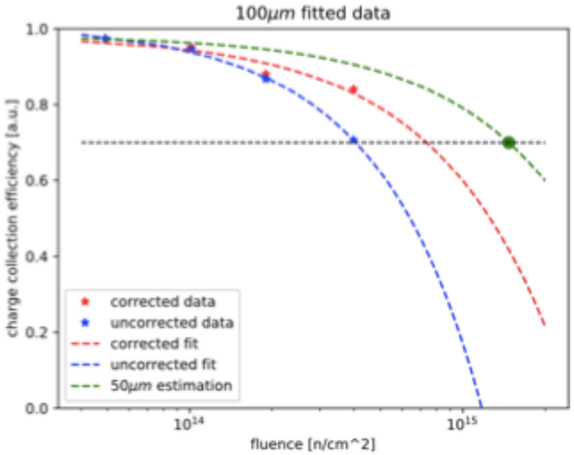
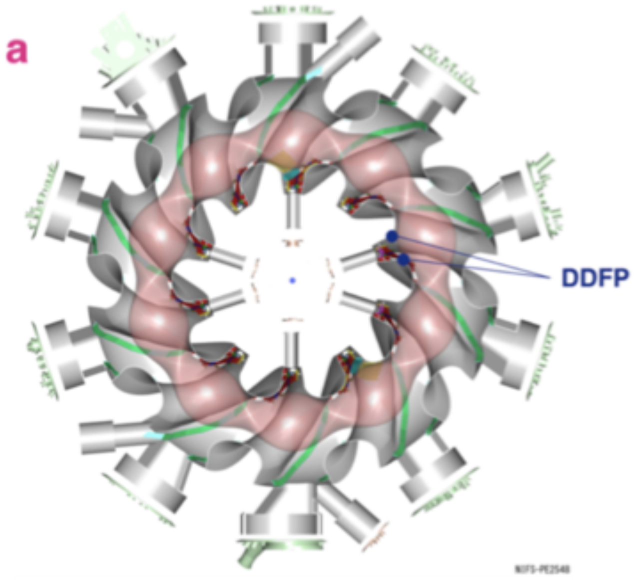


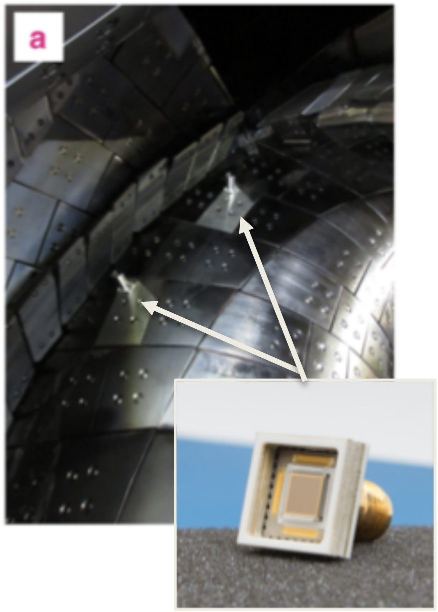
Figure 5.17: Performances of the 50 μm diamond estimated from 100 μm data.

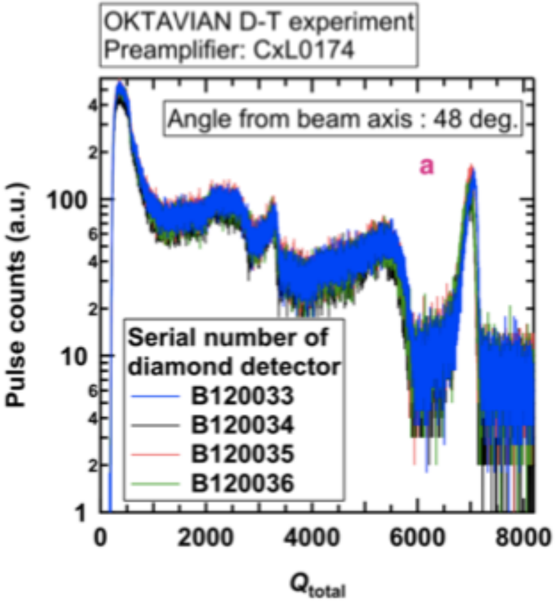
M. Passeri, PhD Università di Roma Tor Vergata (2020): *Experimental investigations of single Crystal Diamond detectors for the ITER Radial Neutron Camera.*

APPLICATIONS

Large Helical Device

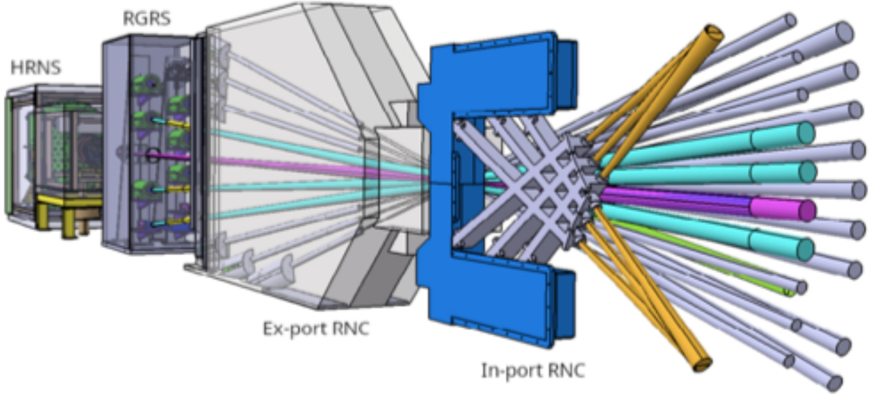


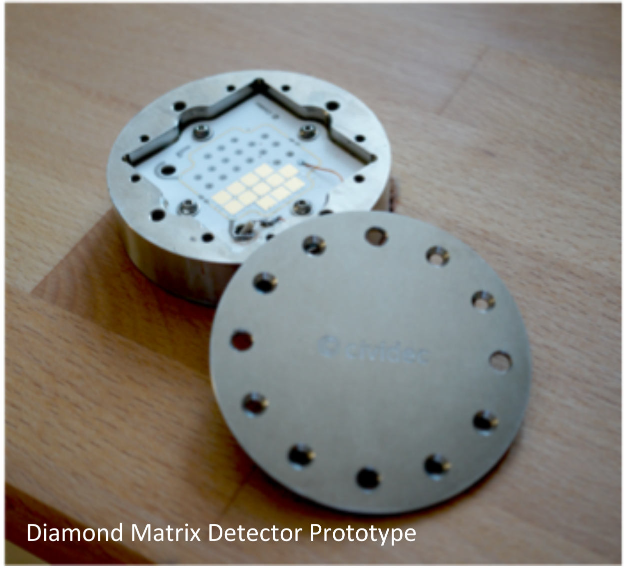




K. Ogawa *et al., 2023 JINST* **18** P01022: *Fusion product diagnostics based on commercially available chemical vapor deposition diamond detector in LHD.*

ITER Radial-Neutron Camera




Diamond Matrix Detector Prototype

B. Morgenbesser, Master Thesis TU Wien (2021): *A Novel Radial Neutron Camera CVD Diamond Detector Prototype for ITER.*
https://fusionforenergy.europa.eu/news/a-camera-to-see-iter-neutrons/

Conclusions

- Fusion neutron diagnostics with CVD diamond detectors:
  - Information on fusion plasma
- Radiation hardness: 10^{15} fusion neutrons on device.
- High-temperature compatibility: T ≤ 500°C.

Conclusions

- Fusion neutron diagnostics with CVD diamond detectors:
  - Information on fusion plasma
- Radiation hardness: 10^{15} fusion neutrons on device.
- High-temperature compatibility: T ≤ 500°C.

- Applications:
  - Large Helical Device
  - ITER: RNC & VNC
  - Fusion neutron generators
  - Industrial devices

Thank you for your attention!

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