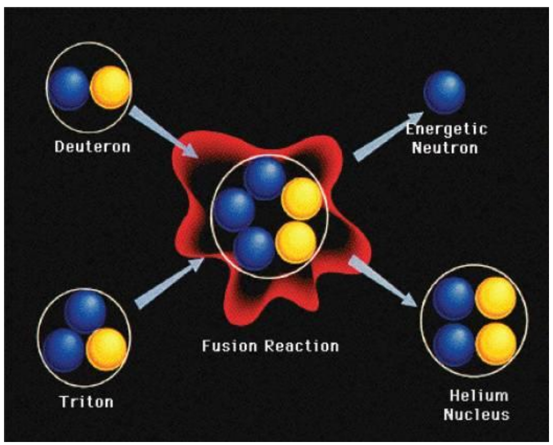
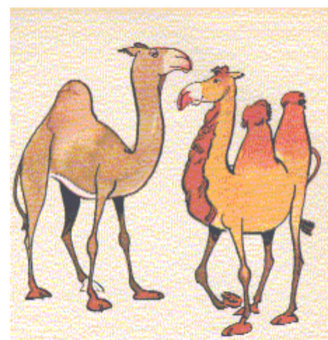
Transforming a camel into a dromedary: Fast neutron spectroscopy with very high energy and time resolution for diagnosing fusion DT burning plasmas





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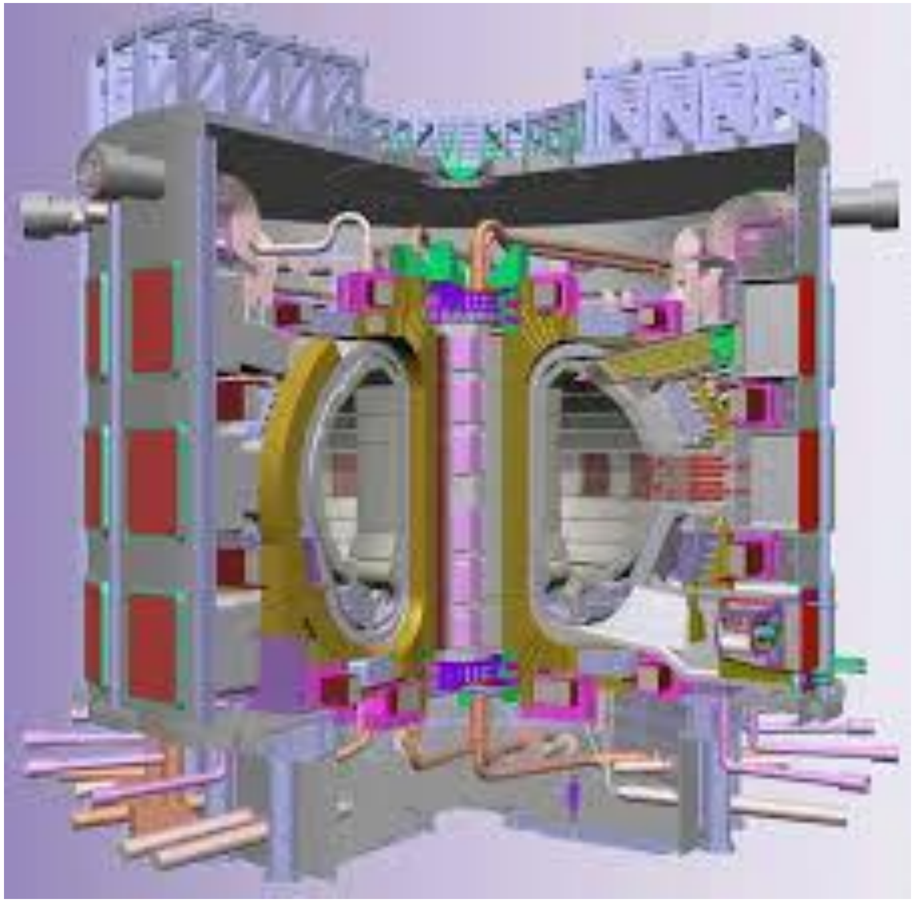
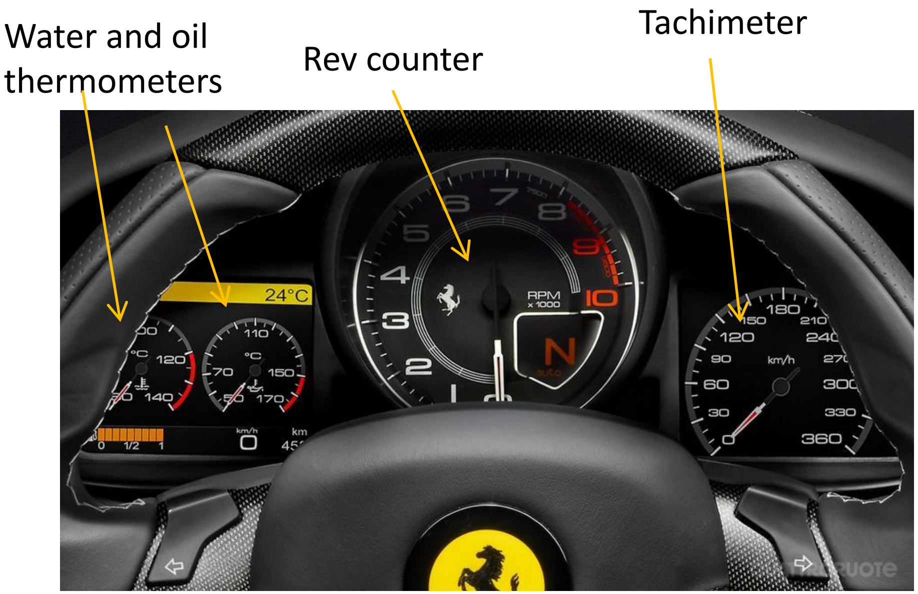
Nuclear Fusion



The ITER tokamak

The road to power production through nuclear fusion needs reliable diagnostics of the magnetically confined DT plasma.

Fusion plasma diagnostics

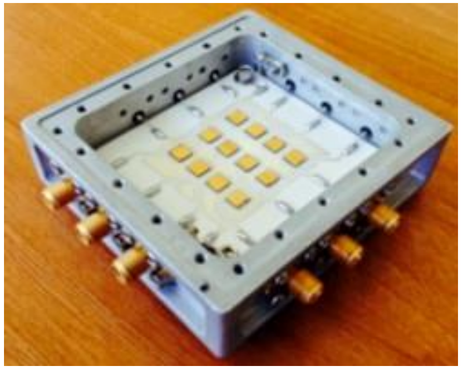


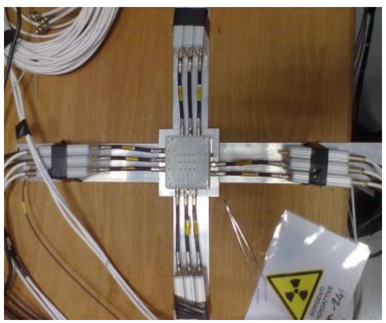
Just as engine dials, a fusion plasma diagnostics must be

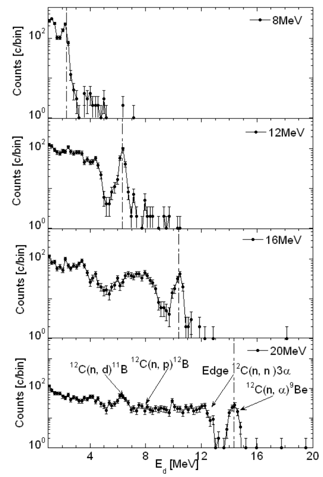
- Fast
- Reliable (must resist to harsh environment: high T and B)
- Clear
- NO FRILLS !!!!

Neutron spectroscopy is a fundamental diagnostic that can determine the fusion power, reagent temperature and the *fuel ion ratio* n_D/n_T of the concentration of D and T isotopes in the plasma, a parameter difficult to obtain with other diagnostics.

Diamonds as neutron detectors







Diamond-based detectors have the highest potential as neutron spectrometers.

Today's diamond neutron spectrometers combine very high energy resolution (FWHM ~ 1% @ 14 MeV) and MHz counting rate capability (which allows for 10 – 100 ms time resolution).

Moreover, they are rad-hard, and can operate at ambient or high temperature and are insensitive to magnetic fields.

CVD diamond detectors installed as neutron spectrometers at JET VNS (but also at ASDEX, ChipIr, etc.......)

Diamonds are a neutron's best friend!!!

However...........

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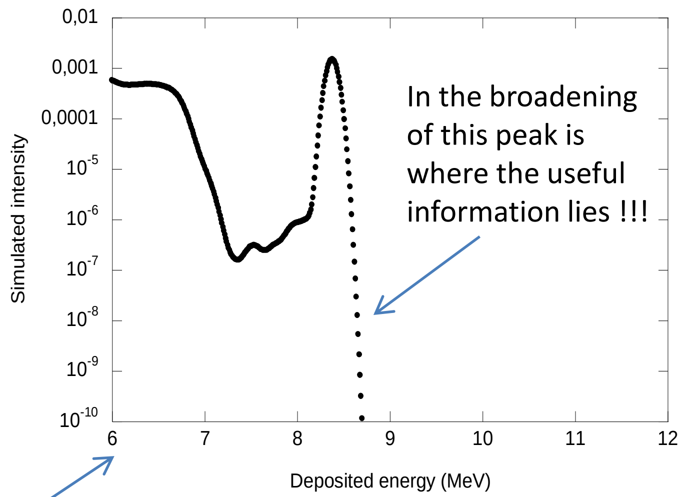
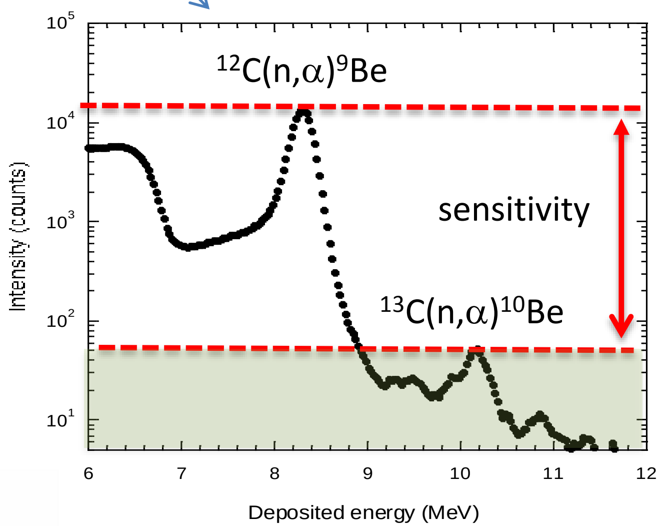
Diamonds as neutron detectors



Simulated (MCNP + FENDL3) CVD response to 14 MeV neutrons and measured one



Two **competitive neutron capture reactions** of in the MeV energy range, namely $^{12}C(n,\alpha)^9Be$ which is used for spectroscopy, and $^{13}C(n,\alpha)^{10}Be$, the latter featuring a Q value of about 2 MeV lower.

The sensitivity of present diamond neutron spectrometers to weak components in the neutron spectrum is today limited to ≥ 1%.

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Our proposal: ^{13}C-free CVDs as improved neutron detectors

1) ^{13}C-free diamond spectrometer grown with the CVD techniques
2) custom low noise/fast spectroscopy electronics

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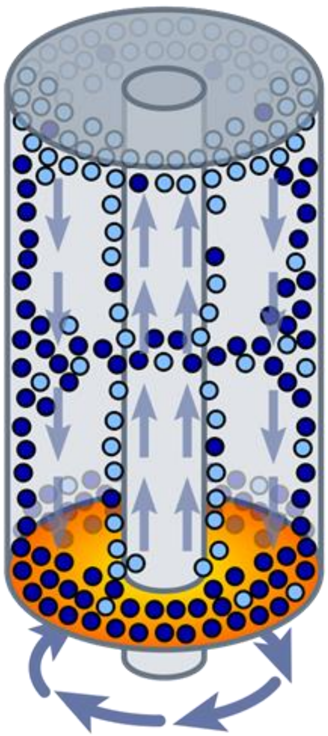

Gas centrifugues are not only used to enrich uranium!!! They are used to separate and refine rare hearts or metals like zinc and lithium.

Applications in material treatements, drugs preparations etc.

The *separation capability* required to provide ^{13}C-free methane is *just* 1/17 (it is 3/268 to separate uranium isotopes....)

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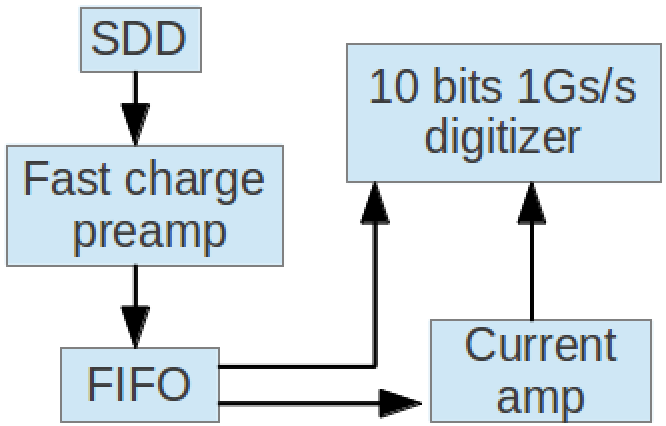
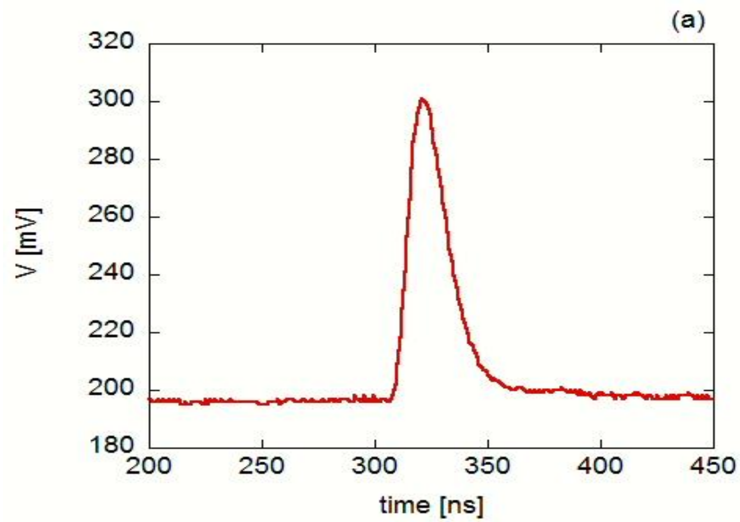


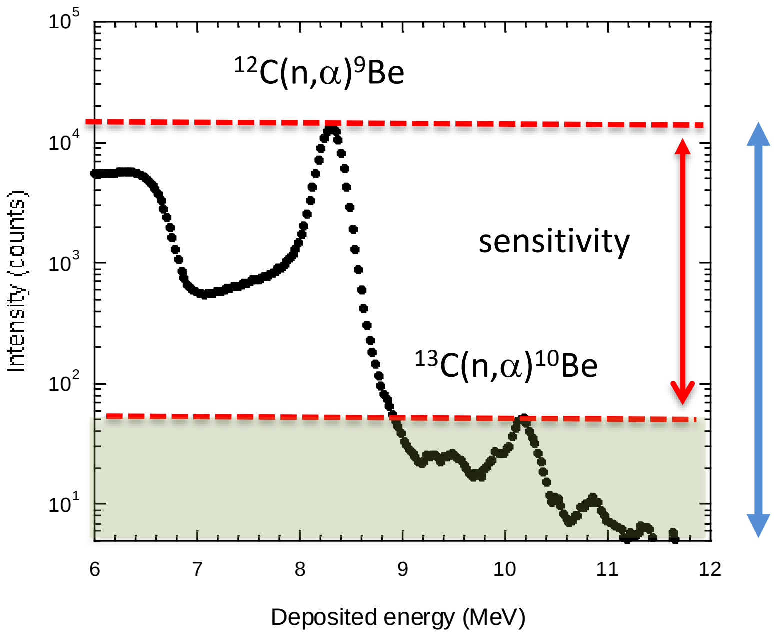
Fast electronic chains developed by our Unit for JET and ASDEX



Signal of α (14 MeV chain)

Envisaged improvements

* **signal to background > 10^4** in the neutron energy range 12-20 MeV.
***energy resolution < 0.5% @ 14 MeV,**
***counting rate capability up to 5 MHz**



Sensitivity improved of one order of magnitude

Resolution doubled

MUCH simpler and faster deconvolution in signal analysis

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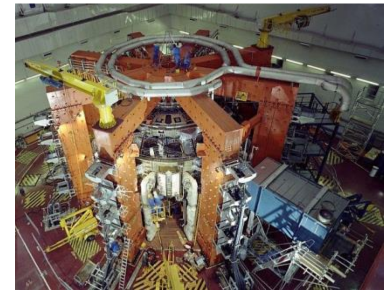
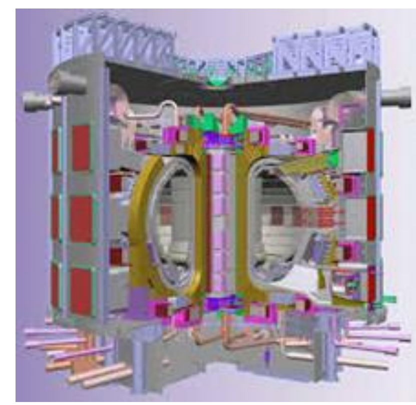
Potential impact

A new generation of **high rate/high energy resolution/high sensitivity** neutron spectrometers



Next future applications:

- Improved VNS at JET tokamaks (D/T campaign 2018)
- ITER (2025)
- DEMO (2050)
- Fast neutron irradiation beamlines (2018 - .....)



Remote future applications:

- Improved semiconductor detectors with the advantages (respect to Si and Ge) of AMBIENT TEMPERATURE and AMBIENT LIGHT applications