Gamma ray spectroscopy measurements for diagnosis of ITER plasmas

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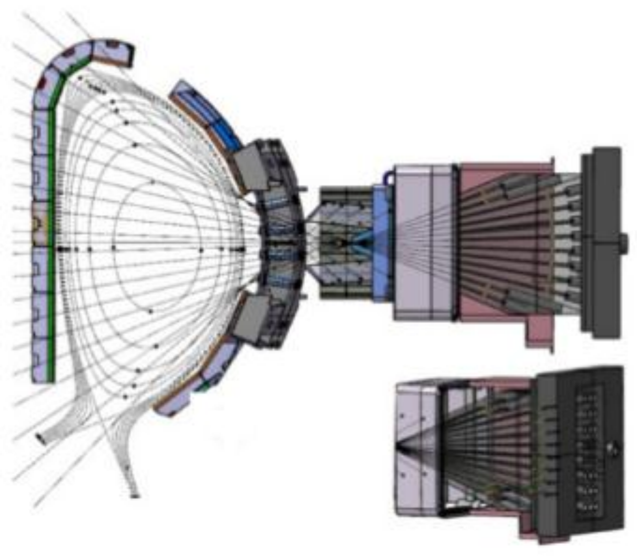
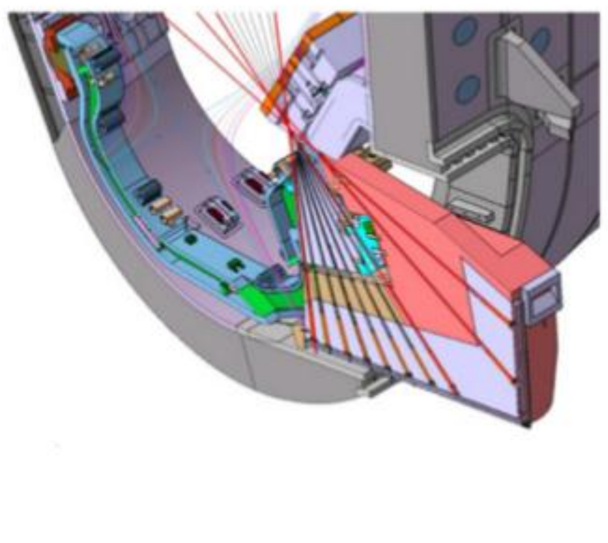
Motivation

- Gamma-ray spectroscopy is being proposed as a diagnostic of confined α-particles on ITER.
- Fusion products diagnostics will play an essential role on self-heating burning plasma studies.
- High rate measurements can be used for burn control and MHD studies.

$$\alpha + {}^{9}Be \rightarrow n + {}^{12}C^{*} \; (\rightarrow {}^{12}C + \gamma)$$

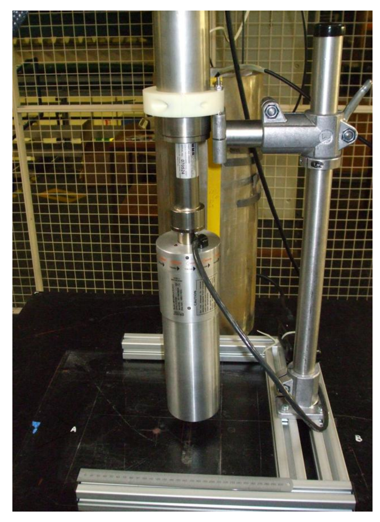
Gamma rays are produced by interaction among fast ions (E > 0.5 MeV typically) and impurities present in the plasma.

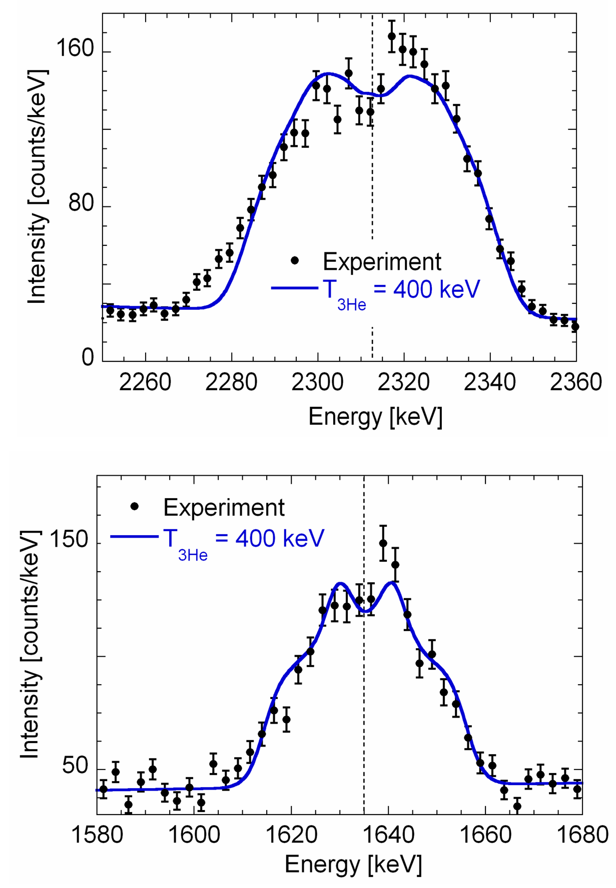
Gamma ray diagnostic tomography system studied for ITER

First measurement of gamma ray Doppler broadening on fusion plasmas with the HpGe spectrometer

High efficiency germanium detector:
Relative photopeak efficiencies: 100%
High resistance to neutron damage: N-Type detector
Energy range for spectroscopy measurements from 50 keV to 10 MeV
Energy resolution: less than 2.8 keV at 1.33 MeV
Peak to Compton Ratio: above 60:1



Photograph of KM6-G installed at JET in the roof laboratory.



Gamma peaks from the $^{3}He+^{12}C \rightarrow p+^{14}N^{*}$ reaction: simulation and experiment

The spectral broadening of characteristic γ-ray emission peaks from the reaction $^{3}He(^{12}C, p)\,^{14}N^{*}$ was measured in $D(^{3}He)$ plasmas of the JET tokamak with ion cyclotron resonance heating (ICRH) tuned to the fundamental harmonic of ^{3}He.

Successful simulations using a physics model combining the kinetics of the reacting ions with a detailed description of the nuclear reaction differential cross sections

Gamma ray spectroscopy with the new $LaBr_3$ scintillator

Good energy resolution:

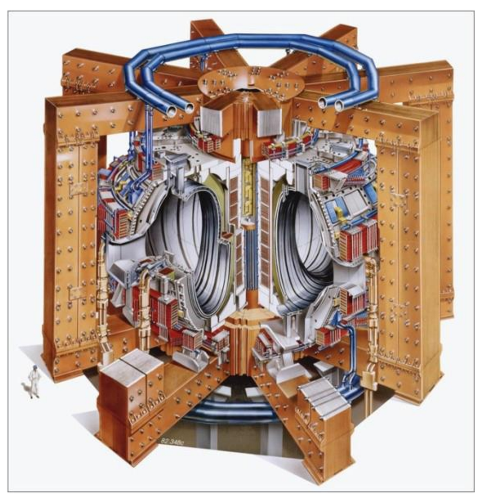
- High light yield (63000 photons per MeV)

High efficiency (25% for 4.44 MeV gammas)

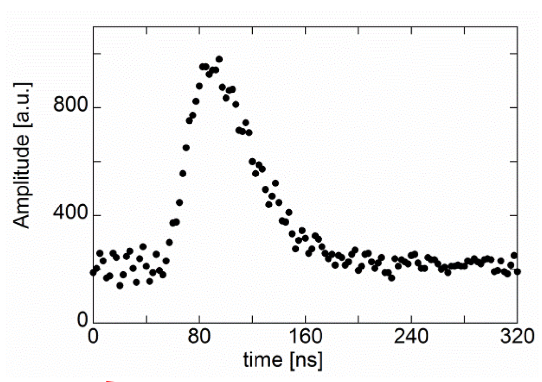
- Big volume (3''x6'' cylinder)
- High Z and high density (5.08 g/cm^3)

High rate capability (up to few MHz):

- Fast scintillation time (16 nsec)
- PMT with active voltage divider
- ADC acquisition (400 MHz, 14 bit)

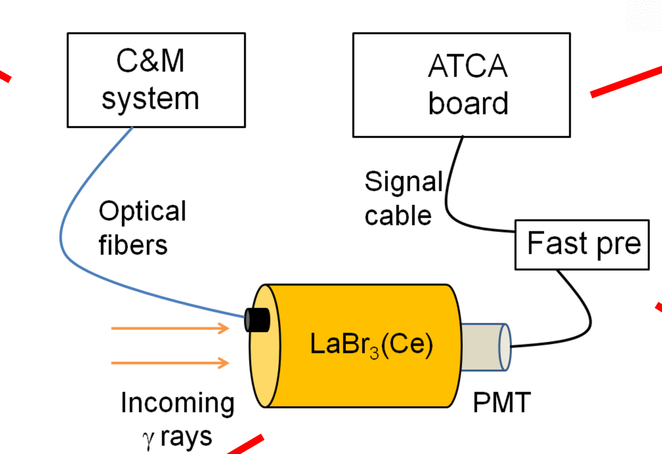


The detector is now operating at the JET tokamak.



Digitize each pulse from pre

LED to monitor detector behaviour

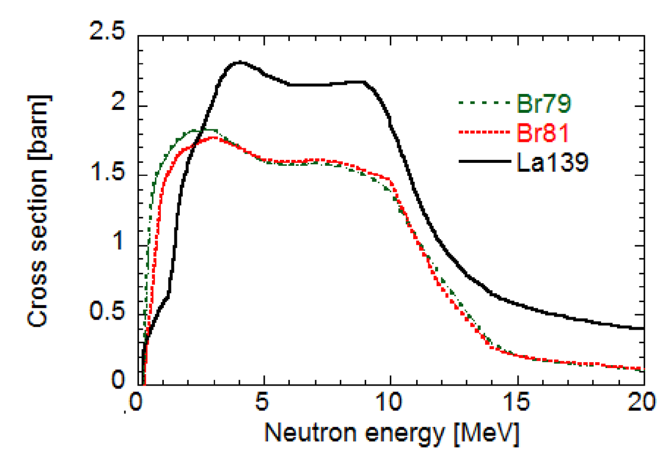


Increase pulse height but keep fast pulse decay time

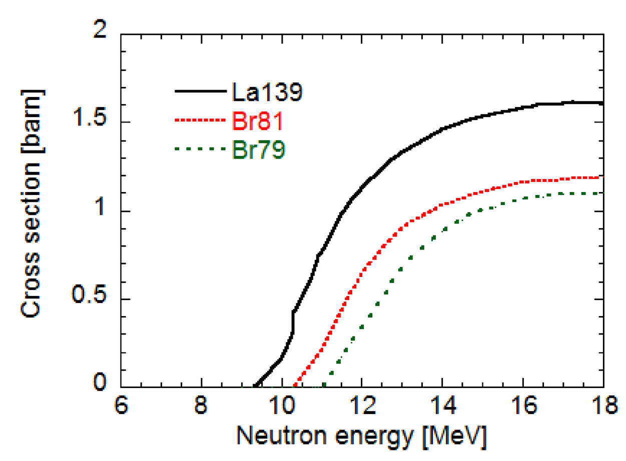
Aim of the project:
i) Measure Doppler Broadening of gamma ray emission from JET plasmas
ii) Demonstrate high counting rate γ-ray spectrometry
iii) Explore the diagnostic information on fast ions which can be inferred from the measured gamma ray spectra

$LaBr_3$ response to fusion neutrons

Inelastic scattering

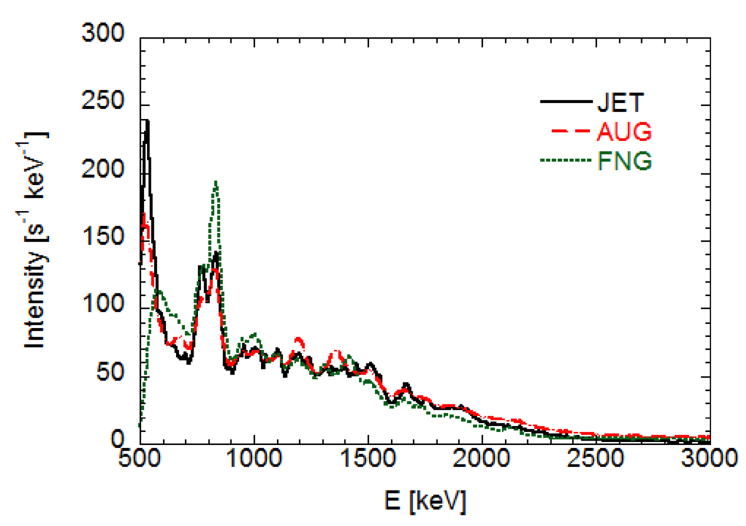


(n,2n) reaction

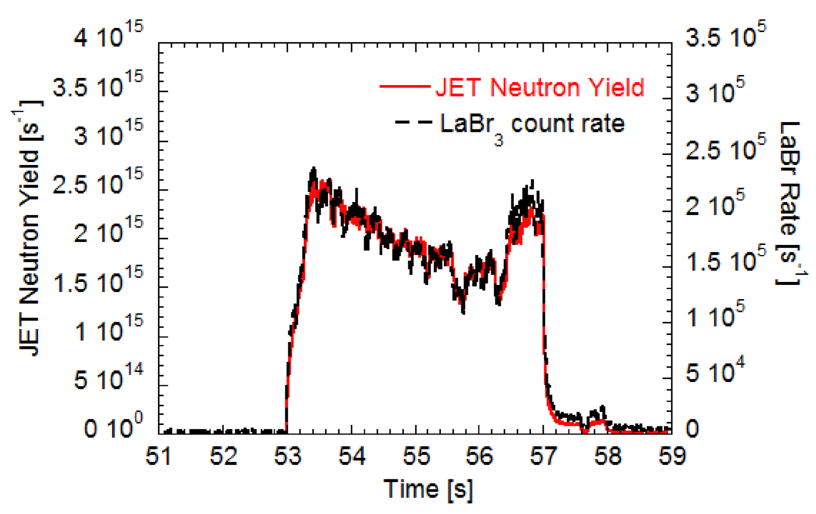


Neutrons are major concern for γ-ray measurement in a tokamak environment.

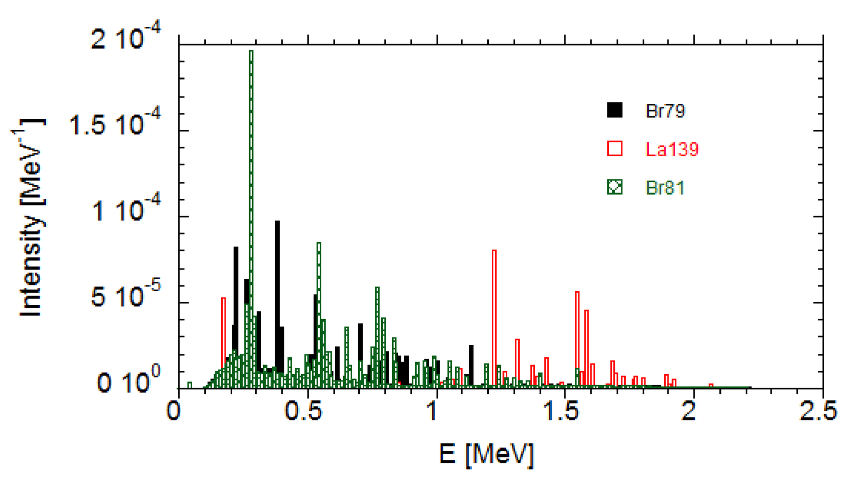
- Measurement has been carried out at the Frascati Neutron Generator (FNG) with 2.5 MeV neutrons (DD) and 14 MeV neutrons (DT).
- FNG measurement has been compared with data collected at the AUG and JET tokamaks.
- A preliminary MCNP model gives a good interpretation of the results.



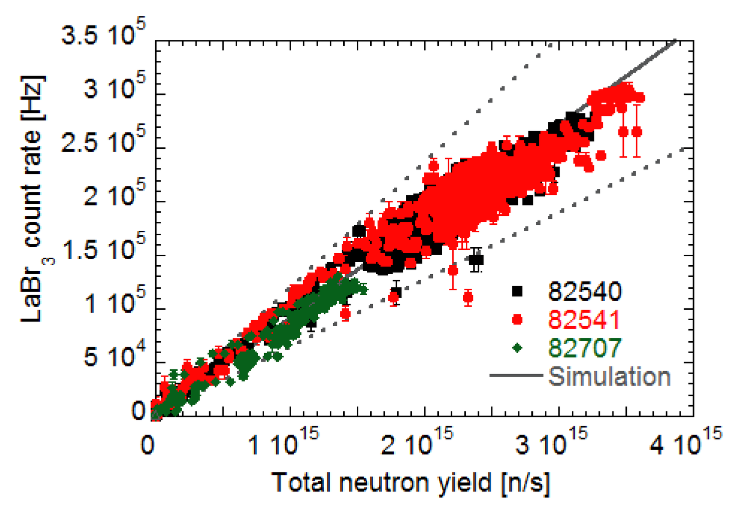
Energy spectra induced by 2.5 MeV fusion neutrons on a 3''x6'' LaBr3 scintillator, measured at AUG, JET and FNG.



Temporal evolution of the counting rate of the LaBr3 spectrometer and JET total neutron yield



Energy distribution of g-rays induced by 2.5 MeV mono-energetic neutrons simulated with MCNP



LaBr3 detector count rate as a function of the total neutron yield of JET.

These results are important for ITER in order to optimize the **detector size, shielding and line of sight**

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