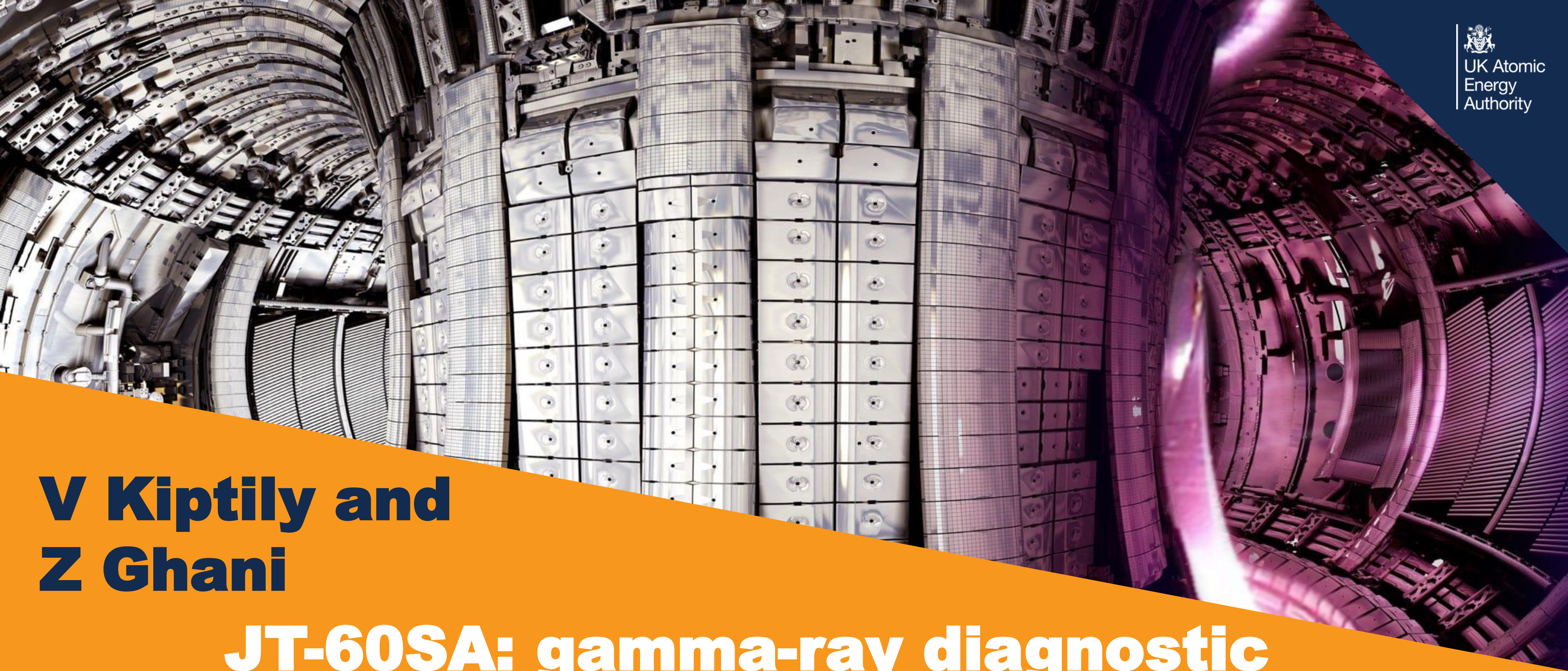

UK Atomic Energy Authority

V Kiptily and Z Ghani

JT-60SA: gamma-ray diagnostic enhancement proposal

WPSA Project Planning Meeting

Remote, 15 – 17 March 2021

European Commission

Energy

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Contract for the Operation of the JET Facilities Co-Funded by Euratom
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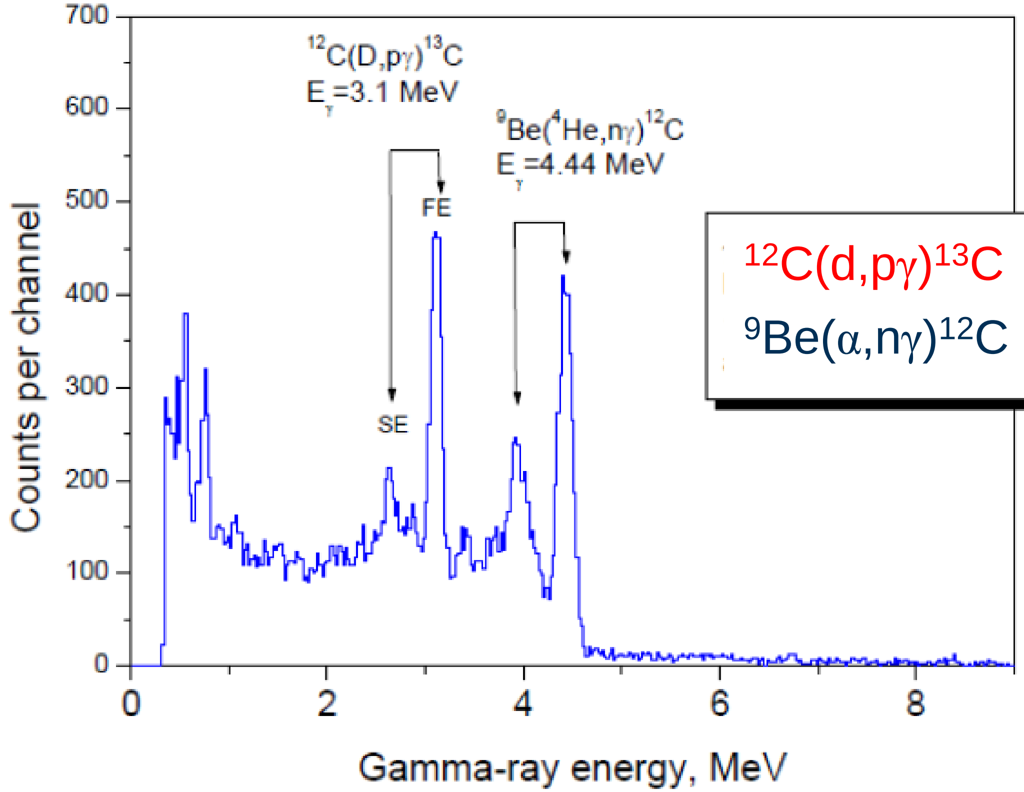
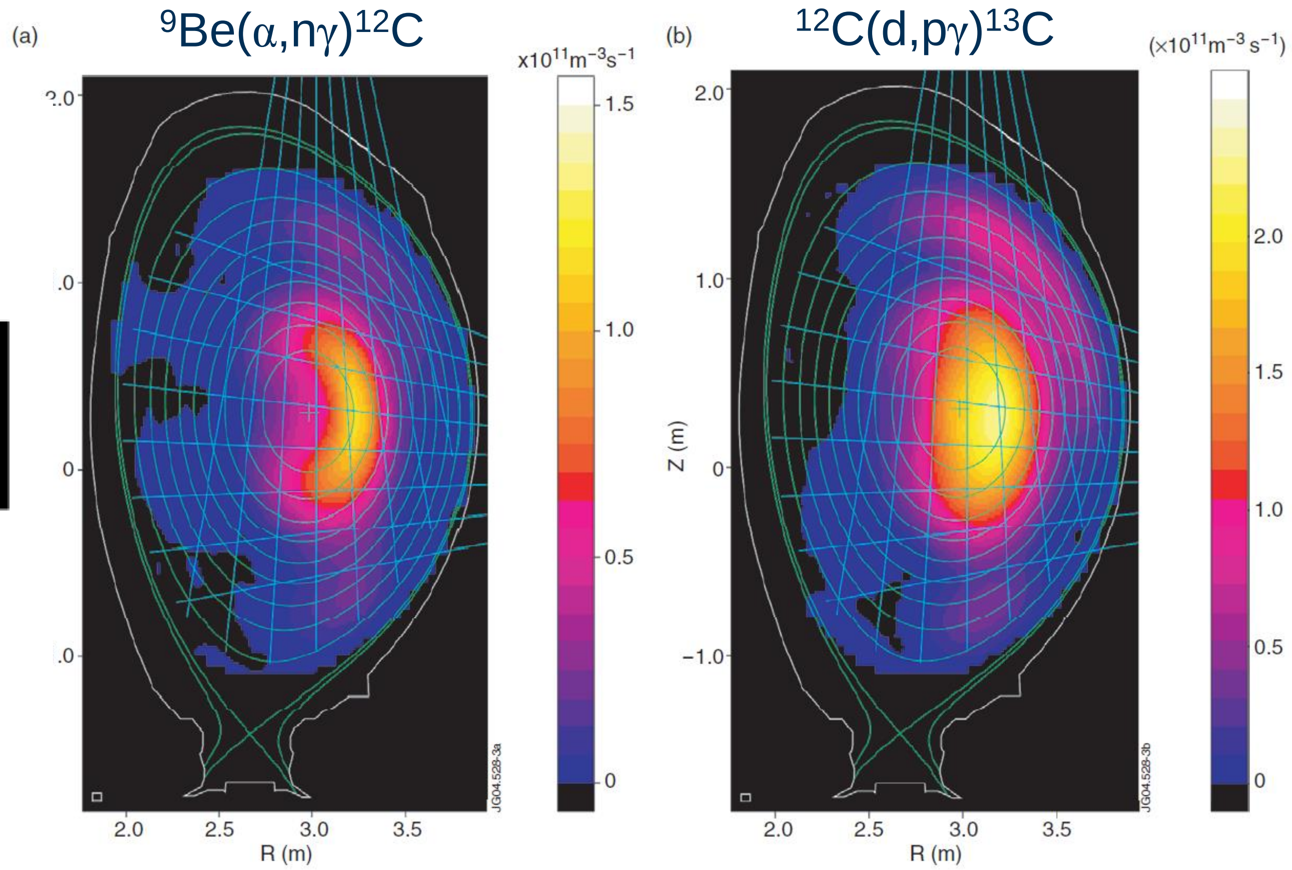
Gamma-rays in JET

This diagnostics became a routine instrument for fast-ion studies on JET in XXI century: energy distribution function, imaging of fast-ions and effects of spatial redistribution



$^{12}C(d,p\gamma)^{13}C$

$^{9}Be(\alpha,n\gamma)^{12}C$



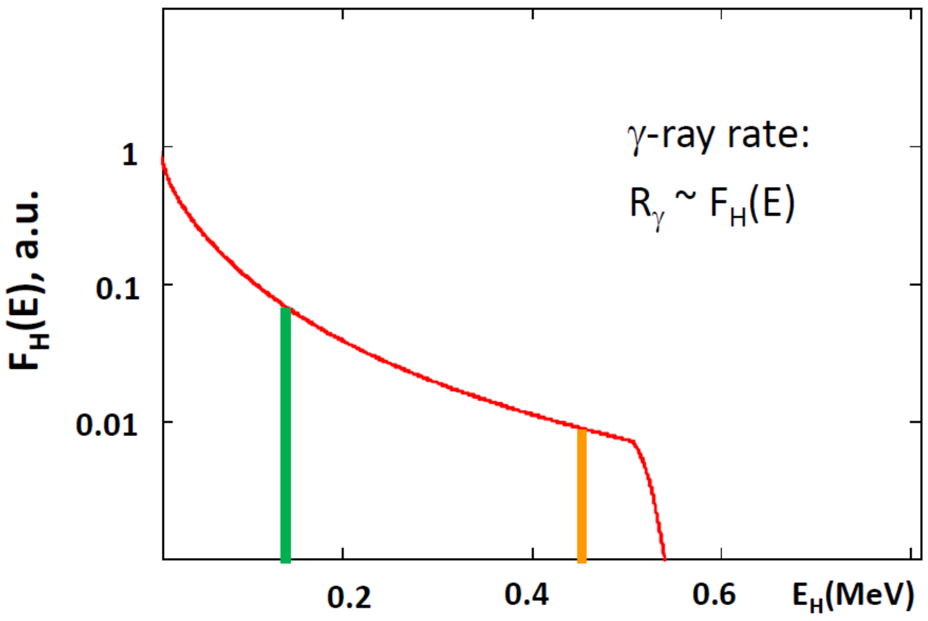
V.G. Kiptily *et al* 2005 *Nucl. Fusion* **45** L21

H/He plasmas in JT-60SA: H-beams

Nuclear reactions, which could be suitable for fast-ion studies with hydrogen N-NBI

Reaction	Resonance, keV	E_γ, MeV	$\sigma(E_R)$, mb
$^{7}Li(p,\gamma)^{8}Be$	441	17.64	3.5
$^{11}B(p,\gamma)^{12}C$	162	11.67 & 4.44	0.152
$^{12}C(p,\gamma)^{13}N$	457	2.365	0.124

Li or **LiH**/**LiD** pellet injection; ^{6}**Li (7.42%)** and ^{7}**Li (92.58%)** isotopes are available



- ❑ H-ion slowing down
- ❑ Transport studies

H/He plasmas in JT-60SA: D-beams

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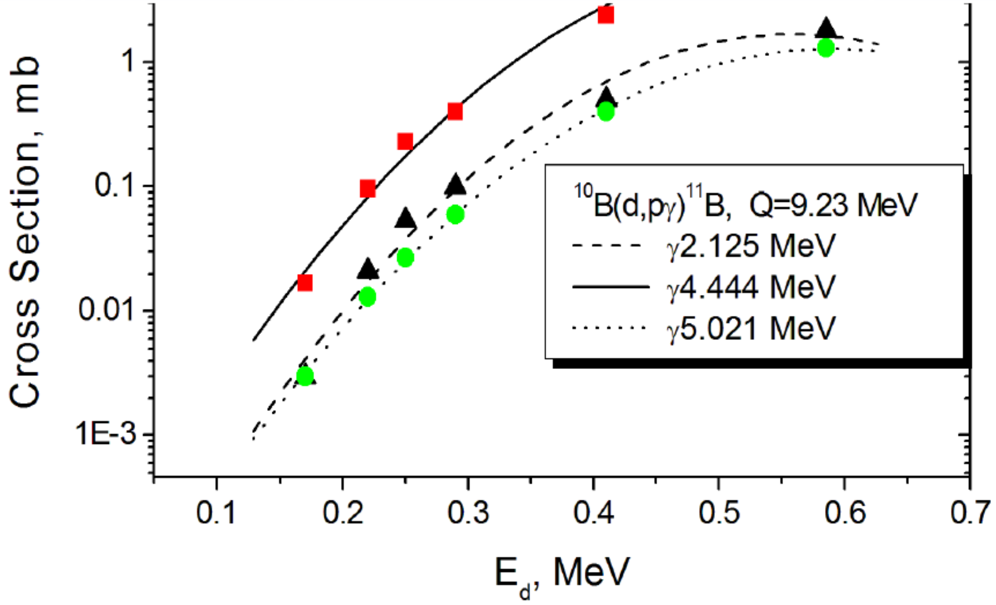
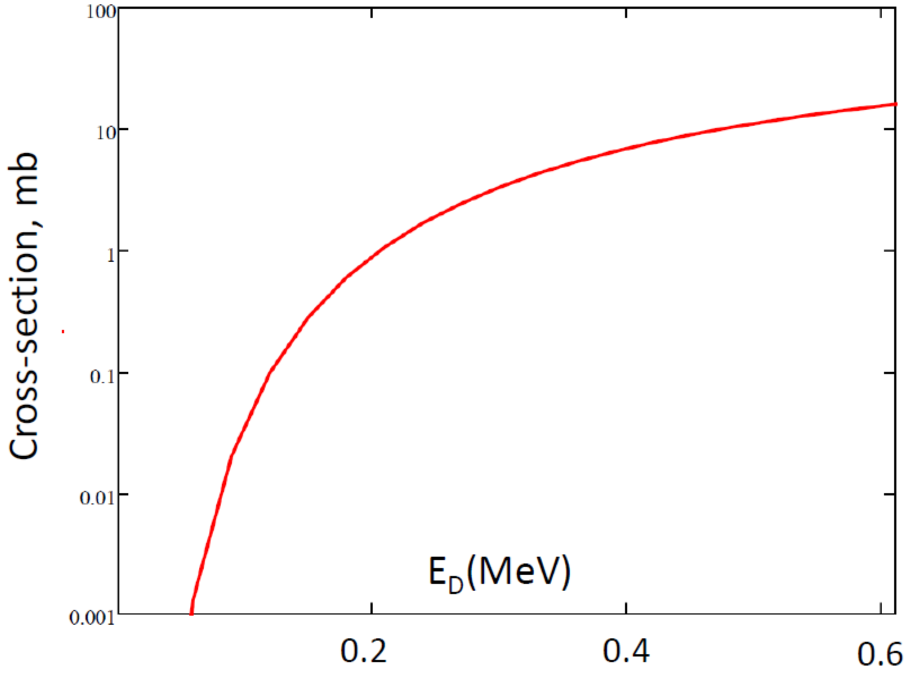
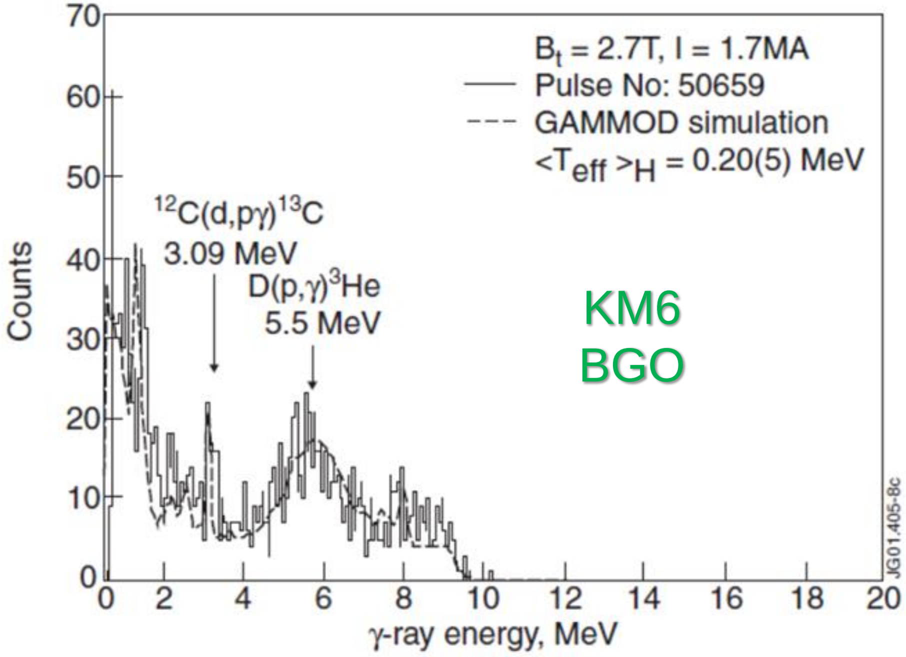
Reaction	Q, MeV	E_γ, MeV	σ(500 keV), mb
$^{6}Li(d,n\gamma)^{7}Be$	3.381	0.429	~75
$^{6}Li(d,p\gamma)^{7}Li$	5.026	0.478	~40
$^{10}B(d,n\gamma)^{11}C$	6.465	2.00, 4.319 & 4.804	~20
$^{10}B(d,p\gamma)^{11}B$	9.230	2.125, 4.444 & 5.021 2.125	~1.5, 7 & 1
$^{11}B(d,p\gamma)^{12}B$	1.145	0.953	~10



H plasmas in JT-60SA: D-beams

H(D,γ)^{3}He reaction will be useful with deuterium N-NB





Kiptily et al 2002 Nucl. Fusion **42** 999

Gamma-ray line analysis could provide information on D-beam ion distribution

Peak energy: $E_\gamma = Q + E_G$ and broadening : $$\Delta E_{\mathrm{fwhm}} \approx 2\sqrt{4E_G\frac{\langle T_{Dp}\rangle}{3} + 2\ln 2\frac{Q^2}{M_{^3He}c^2}\langle T_{Dp}\rangle}\ \mathrm{(MeV)}$$

where $E_G = 0.74 <T_{Dp}>^{2/3}$; $Q = 5.5$ MeV

D plasmas in JT-60SA: D-beams

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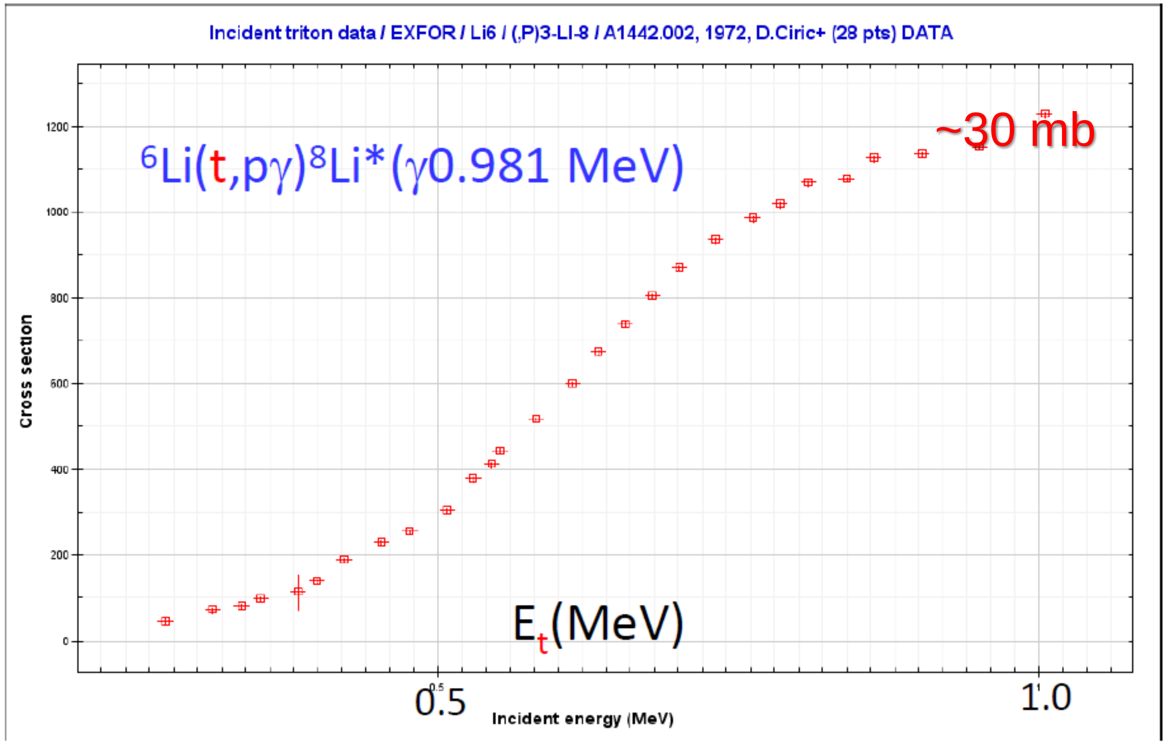
Reaction	E_γ , MeV
$^{10}B(d,n\gamma)^{11}C$	2.0, 4.32
$^{10}B(d,p\gamma)^{11}B$	2.13, 4.44, 5.0
$^{11}B(d,n\gamma)^{12}C$	4.44, 3.21
$^{12}C(d,p\gamma)^{13}C$	3.09

$$D + D \rightarrow p\ (3.02\ \text{MeV}) + t\ (1.01\ \text{MeV})$$

$$D + D \rightarrow {}^{3}He\ (0.82\ \text{MeV}) + n\ (2.45\ \text{MeV})$$

Fusion products studies: p& t

Reaction	E_γ, MeV
$^{6}Li(p,p'\gamma)^{6}Li$	3.56
$^{10}B(p,p'\gamma)^{10}B$	0.718, 1.022, 2.868
$^{11}B(p,p'\gamma)^{11}B$	2.125
$^{11}B(p,\gamma)^{12}C$	11.67



A unique possibility to study p & t transport with ^{6}Li-pellet injection

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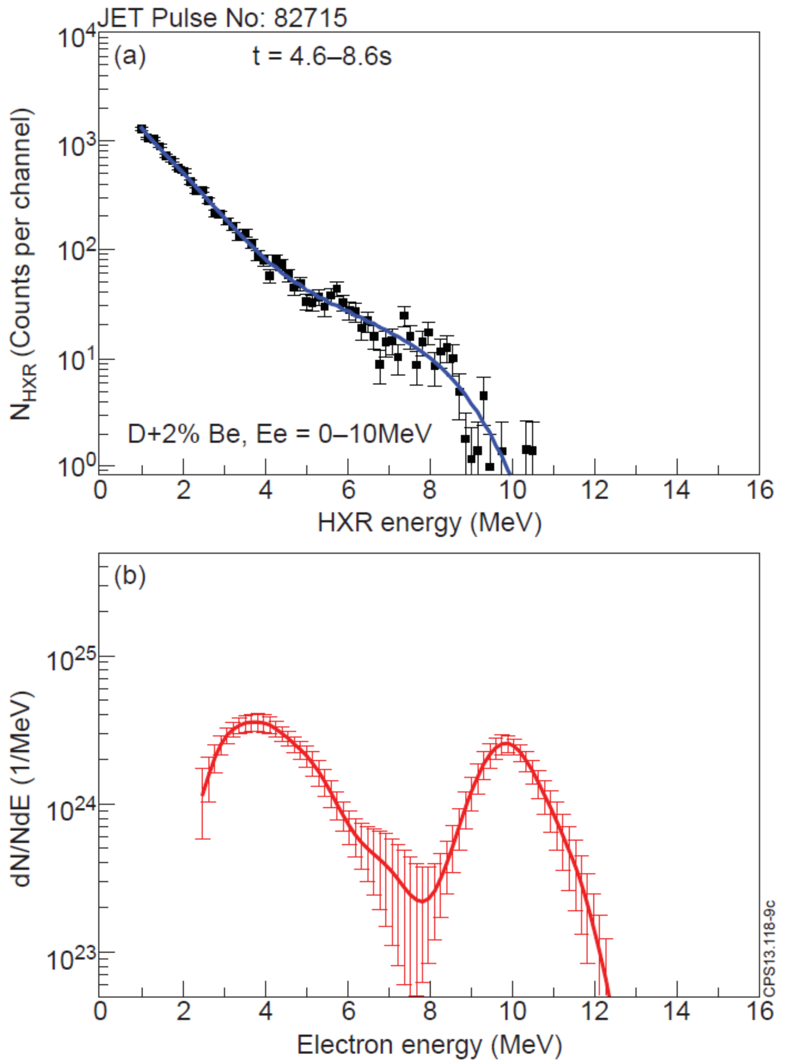
Runaways in JT-60SA: HXR spectra



a) HXR spectrum, recorded with NaI(Tl) during 4.6-8.6 s in shot #82715 (black dots) and spectrum obtained after convolution of reconstructed electron spectrum with detector response function (blue line);

b) Reconstructed energy distribution of fast electrons generated during start-up in a hybrid scenario discharge

Conclusion:

- Runaways are more energetic (up to ~12 MeV) than measured E_{γ}^{MAX} <10 MeV
- There are at least 2 components of electrons

Proposal for γ-diagnostics allocations

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Sector P4

- Upper:
  - neutron and γ-ray profile monitors
  - NPA + γ-ray spectrometer (it could be installed behind of NPA, as in ITER)
- Lower Oblique:
  - D_α emission monitor + oblique γ-ray spectrometer (it could be installed behind of D_α-monitor)

Sector P8

- Horizontal:
  - NPA + γ-ray spectrometer (it could be installed behind of NPA)

Sector P10

- Horizontal:
  - neutron and γ-ray profile monitors

✓ γ-ray profile monitor could be setup
  a) with independent collimators in neutron profile monitors
  b) on slider in front of neutron detectors as on JET (a restricted use of the diagnostics)

✓ $LaBr_3$ and $CeBr_3$ fast scintillators are used on JET (high energy/time resolution at several MHz count-rate)

Existed diagnostics: Table D-6 Vacuum Vessel Port and Allocation, page 177 (version 4.0, 2018) – in blue

Proposed diagnostics – in red

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A preliminary work plan

- Introduction to the developed diagnostics
  - *neutron profile monitors*
  - *NPAs*
  - D_α *emission monitor*
- Preparation of proposals for
  - γ*-ray profile monitors*
  - *vertical, horizontal and oblique* γ*-ray spectrometers*
- Conceptual design for γ-ray diagnostics
- Also, as per our extensive experience of running the JET N&G suite of diagnostics, we can provide support with a wide range of neutron diagnostics:
  - their optimisation, modelling, calibration, cross-calibration and absolute neutron yield monitoring

Thank you
for your attention