New insights on the D(T, ^{5}He)γ reaction and prospects for D-T fusion power measurements at ITER

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[2]Department of Physics, UNIMIB Milan, Italy
[3]Diagnostic Program, ITER Organization, Saint Paul-lez-Durance, France
[4]Plasma Science and Fusion Center, MIT, Cambridge, Massachusetts, USA

Outline

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- New insights on the D(T,^{5}He)γ reaction (at JET)

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- Benefits for fusion power measurements

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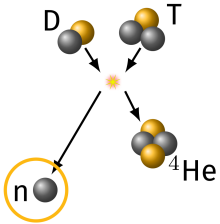
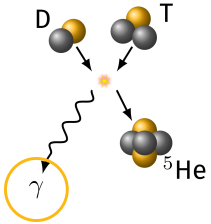
- Fusion power measurements with gammas at ITER
- Conclusions

The two branches of the D-T fusion reaction

The DT reaction has 2 possible channels:





$$D + T \rightarrow n + {}^4He$$

$$D + T \rightarrow \begin{cases} \gamma_0 + {}^5He \\ \gamma_1 + {}^5He^* \end{cases}$$

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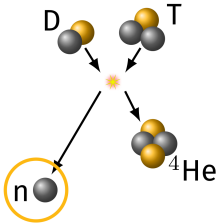

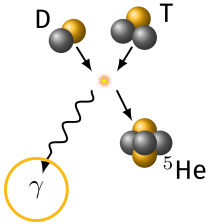

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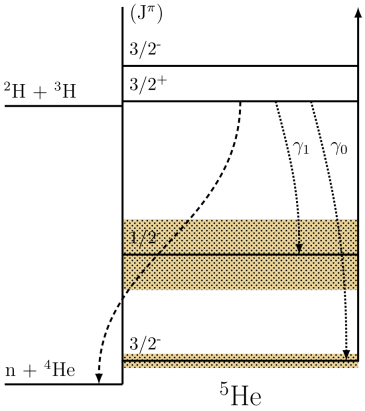

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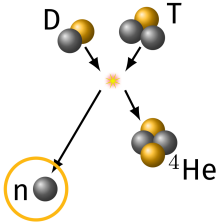

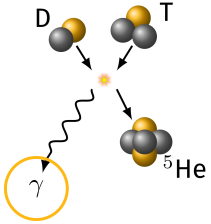

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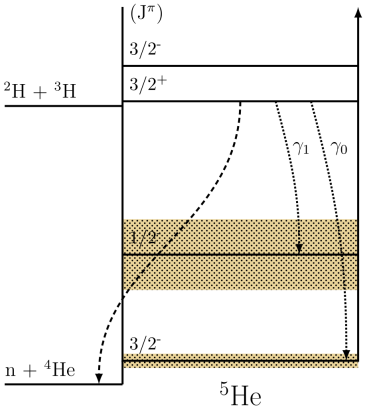
fusion power measurement



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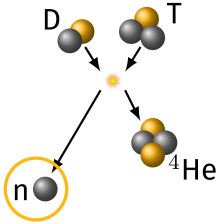

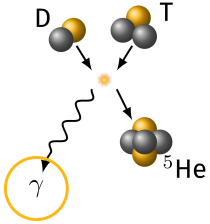

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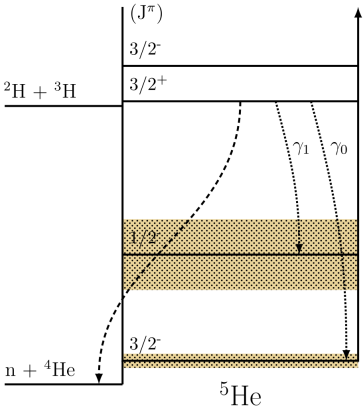
...also?



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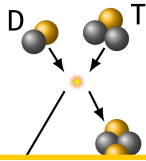

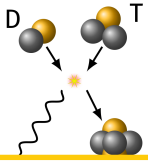

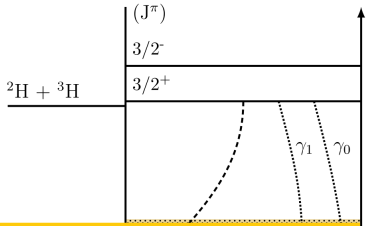

poorly known probabilities
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no direct
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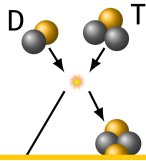

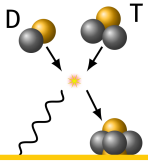

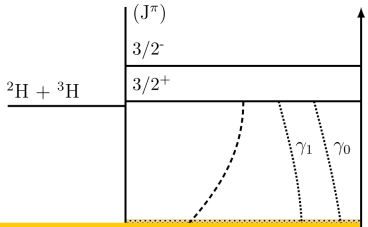

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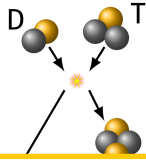

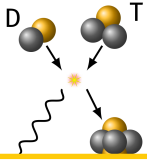

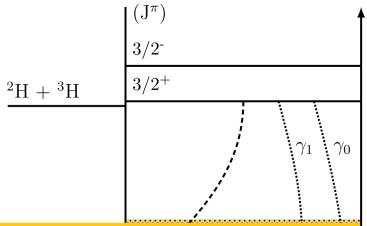

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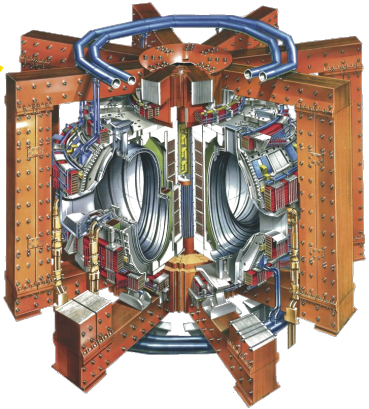
New insights on the D(T,^{5}He)γ reaction at JET

- DTE2 (2021)
- DTE3 (2023)

neutron monitors



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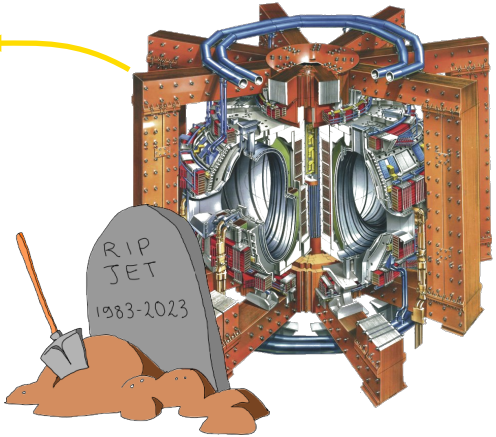

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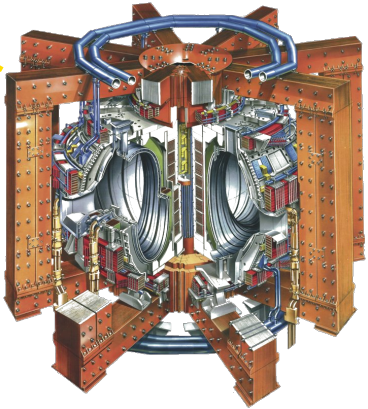
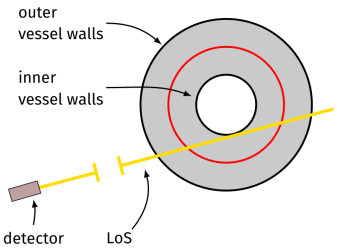


- $LaBr_3$-based gamma-ray spectrometer



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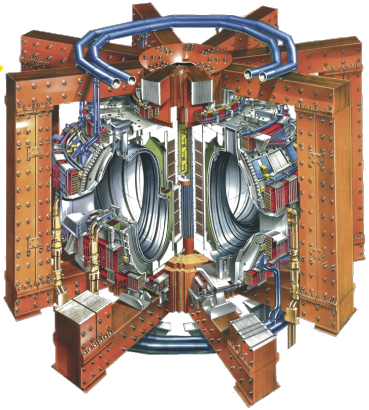

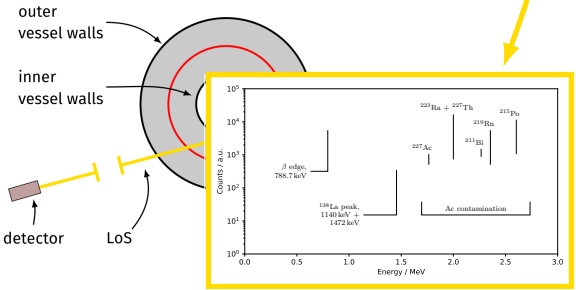

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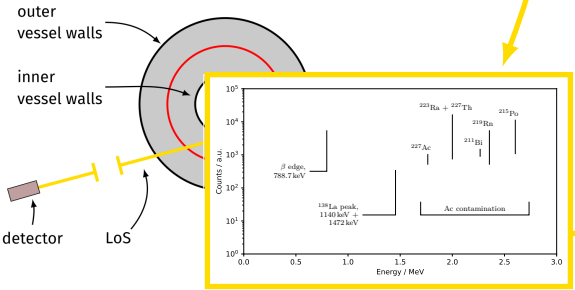
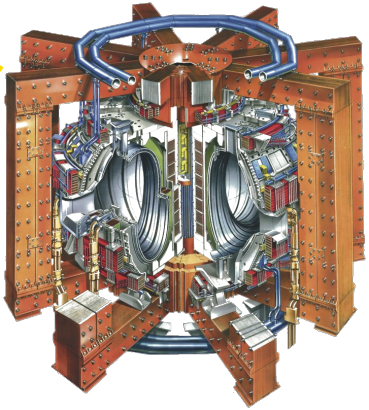
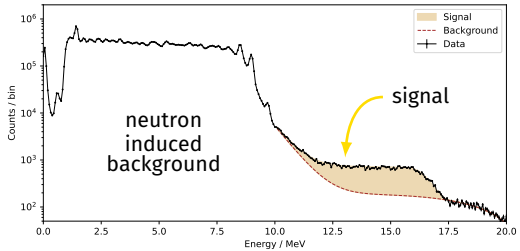




- absolute measurement
- spectral measurement

D(T,^{5}He)γ reaction: spectral measurement



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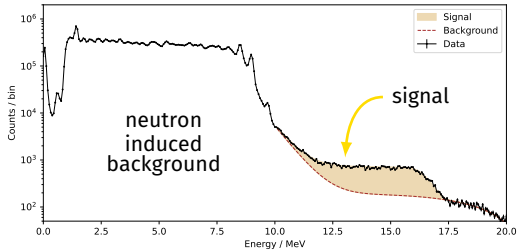
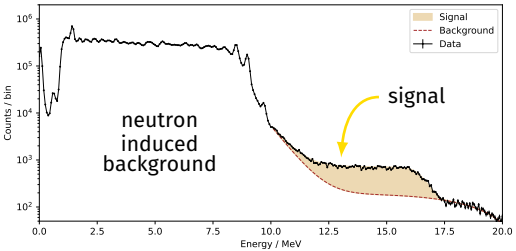
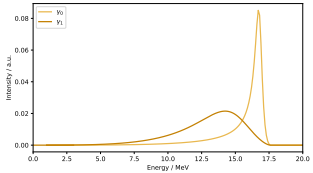


- Issues: dead time, pile-up, etc.

D(T,^{5}He)γ reaction: spectral measurement

- R-matrix theory: predicts spectral shapes





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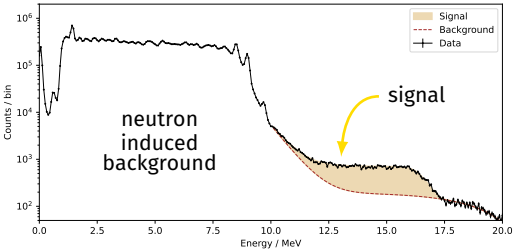
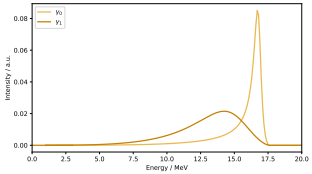
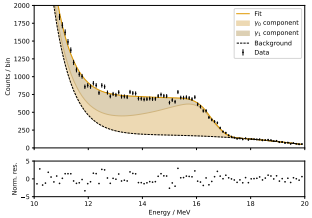
D(T,^{5}He)γ reaction: spectral measurement

- R-matrix theory: predicts spectral shapes
- Fit: gives relative intensities







- Issues: dead time, pile-up, etc.

$\Gamma_1/\Gamma_0 = 1.09 \pm 0.25$

D(T,^{5}He)γ reaction: probability

$$BR_{\gamma/n} = \frac{Y_\gamma}{Y_n}$$

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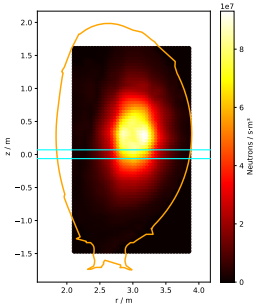

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MCNP, Linalytic...

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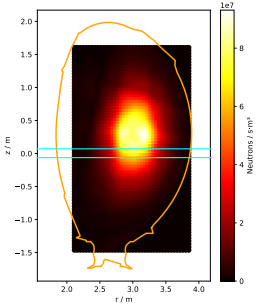

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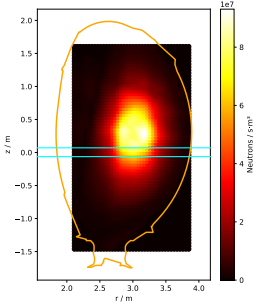

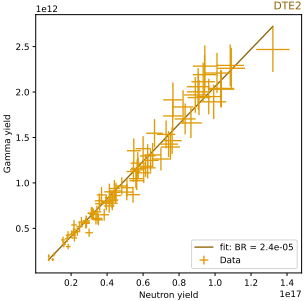

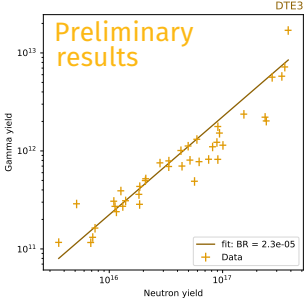

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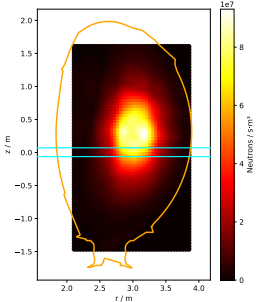
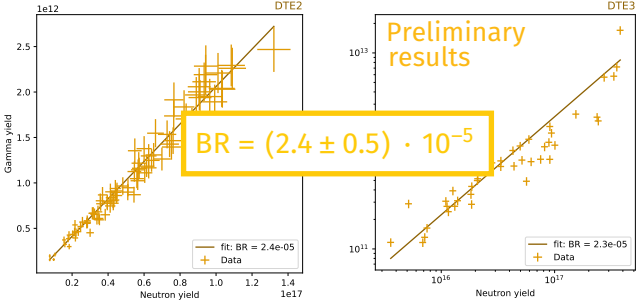
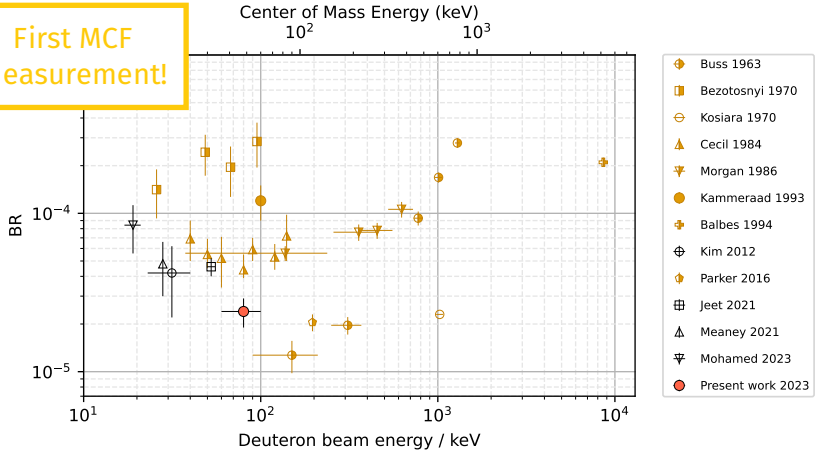




$BR = (2.4 \pm 0.5) \cdot 10^{-5}$

D(T,^{5}He)γ reaction: probability

First MCF measurement!



Benefits for fusion power measurements

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Fusion power validation

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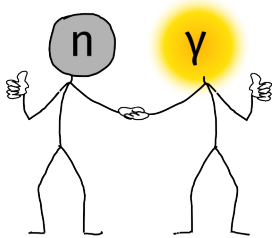
- neutron independent
  → benchmark of standard method



Benefits for fusion power measurements

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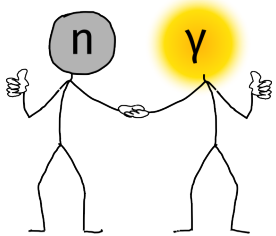
- easier gamma transport
  → no time-consuming in-vessel calibrations



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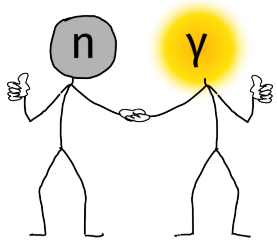
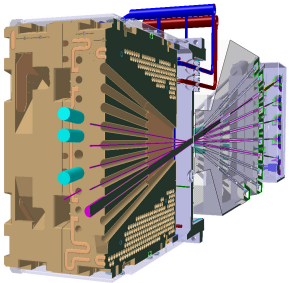


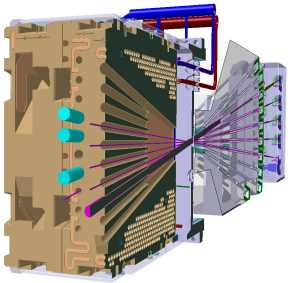
second method for ITER?

Fusion power measurements with gammas at ITER



- 3 detectors
- coplanar, radial LoS
- $LaBr_3$

Fusion power measurements with gammas at ITER



- 3 detectors
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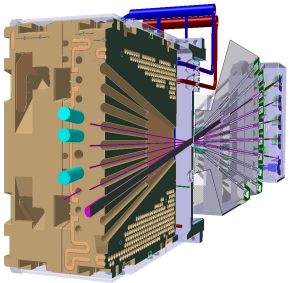

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- $Y_n \in (10^{18}\,\mathrm{n/s} - 10^{20}\,\mathrm{n/s})$
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- uncertainty: 10%

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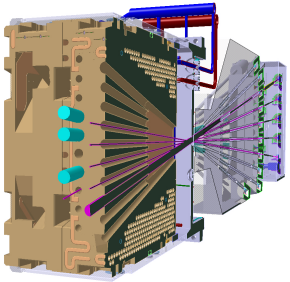

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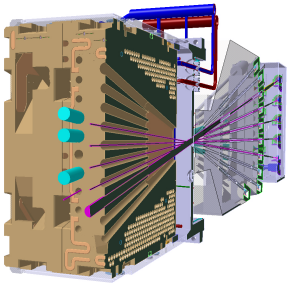

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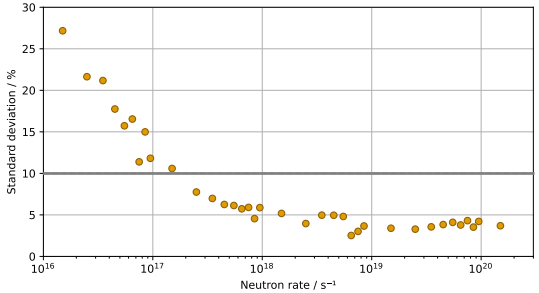

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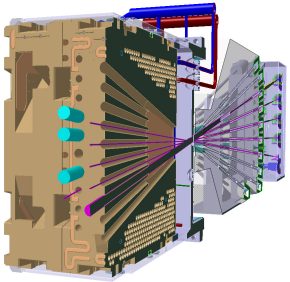

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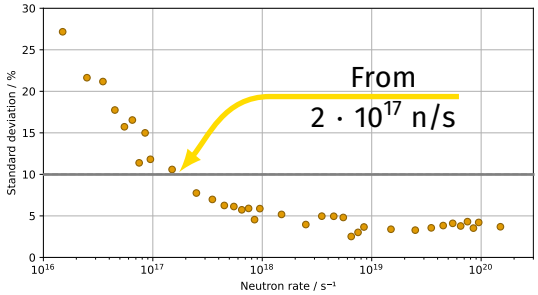

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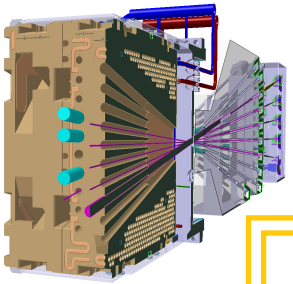

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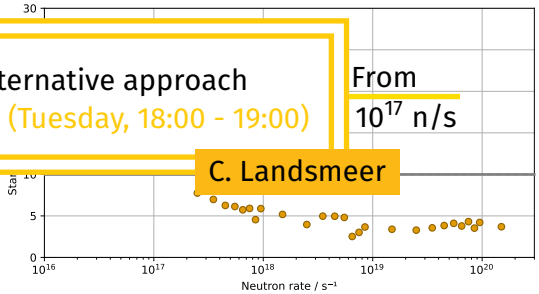

AI -based alternative approach

Poster Session B (Tuesday, 18:00 - 19:00)

C. Landsmeer

From 10^{17} n/s

ITER requirement

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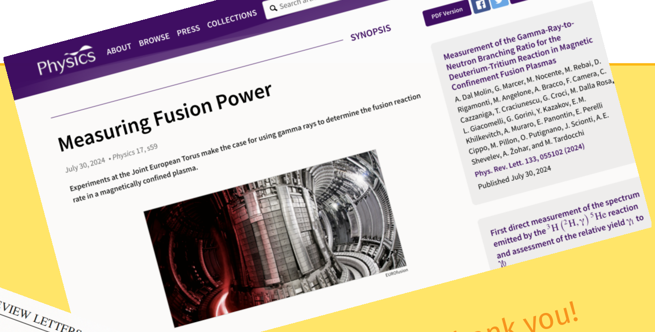
- At ITER, this method will allow to measure the fusion power
- within the required operational range.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SYNOPSIS

Measuring Fusion Power

July 30, 2024 • Physics 17, s59

Experiments at the Joint European Torus make the case for using gamma rays to determine the fusion reaction rate in a magnetically confined plasma.

EUROfusion

PDF Version

Measurement of the Gamma-Ray-to-Neutron Branching Ratio for the Deuterium-Tritium Reaction in Magnetic Confinement Fusion Plasmas

A. Dal Molin, G. Marcer, M. Nocente, M. Rebai, D. Rigamonti, M. Angelone, A. Bracco, F. Camera, C. Cazzaniga, T. Craciunescu, G. Croci, M. Dalla Rosa, L. Giacomelli, G. Gorini, Y. Kazakov, E. M. Khilkevitch, A. Muraro, E. Panontin, E. Perelli Cippo, M. Pillon, O. Putignano, J. Scionti, A. E. Shevelev, A. Žohar, and M. Tardocchi

Phys. Rev. Lett. 133, 055102 (2024)

Published July 30, 2024

First direct measurement of the spectrum emitted by the $^3H(^2H,\gamma)^5He$ reaction and assessment of the relative yield γ_1 to γ_0


Featured in Physics

PHYSICAL REVIEW LETTERS 133, 055102 (2024)

Measurement of the Gamma-Ray-to-Neutron Branching Ratio for the Deuterium-Tritium Reaction in Magnetic Confinement Fusion Plasmas

A. Dal Molin,[1] G. Marcer,[2] M. Nocente,[1,2] M. Rebai,[1] D. Rigamonti,[1,*] M. Angelone,[3] A. Bracco,[4] F. Camera,[4] C. Cazzaniga,[5] T. Craciunescu,[6] G. Croci,[2,1] M. Dalla Rosa,[2] L. Giacomelli,[1] G. Gorini,[1,2] Y. Kazakov,[8] E. M. Khilkevitch,[11,†] A. Muraro,[1] E. Panontin,[9] E. Perelli Cippo,[1] M. Pillon,[10] O. Putignano,[1] J. Scionti,[1] A. E. Shevelev,[11] A. Žohar,[12] and M. Tardocchi[1]

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[2]Department of Physics, University of Milano-Bicocca, Milan, Italy
[3]Department of Industrial Engineering, University of Rome Tor Vergata, Rome, Italy
[4]Department of Physics, University of Milan, Milan, Italy
[5]ISIS Facility, UKRI-STFC, Rutherford Appleton Laboratory, Didcot, United Kingdom
[6]National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania
[7]European Commission—Joint Research Centre, Ispra, Italy
[8]Laboratory for Plasma Physics, LPP-ERM/KMS, TEC Partner, Brussels, Belgium
[9]Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA
[10]Nuclear Department, ENEA, Frascati, Italy
[11]Scientist from St. Petersburg, Russian Federation
[12]Reactor Physics Department, Jozef Stefan Institute, Ljubljana, Slovenia

(Received 2 January 2024; accepted 14 May 2024; published 30 July 2024)

At present, magnetic confinement fusion devices rely solely on absolute neutron counting for measuring fusion power. Absolute counting of deuterium-tritium gamma rays could provide a neutron-independent technique required for the validation of scientific results ... power plants. However, this approach necessitates an accurate ... branching ratio. The gamma-ray-to-neutron branching ... $^3H(^2H,n)^4He$ was determined in magnetic ... predominantly deuterium beam heat... 10^{-5} over the deuterium ... branching ratio ... confin...


PHYSICAL REVIEW C **110**, 014625 (2024)

Featured in Physics

First direct measurement of the spectrum emitted by the $^3H(^2H,\gamma)^5He$ reaction and assessment of the relative yield γ_1 to γ_0

Marica Rebai,[1] Davide Rigamonti,[1] Andrea Dal Molin,[1,*] Giulia Marcer,[2] Angela Bracco,[3] Franco Camera,[3] Daniela Farina,[1] Giuseppe Gorini,[1,2] Evgeniy Khilkevitch,[4] Massimo Nocente,[1,2] Enrico Perelli Cippo,[1] Oscar Putignano,[1] Jimmy Scionti,[1] Alexander Shevelev,[4] Andrej Zohar,[5] and Marco Tardocchi[1]

[1]Institute for Plasma Science and Technology, Consiglio Nazionale delle Ricerche, Via Cozzi 53, 20125 Milan, Italy
[2]University of Milano Bicocca, Piazza della Scienza 3, 20126 Milan, Italy
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[4]Scientist from St. Petersburg 190000, Russian Federation
[5]Reactor Physics Department, Jozef Stefan Institute, 1000 Ljubljana, Slovenia

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... the reaction $^3H(^2H,\gamma)^5He$ has been measured for the first time in a magnetic ... iment at the Joint European Torus. A custom developed gamma ... mbined to a LiH neutron attenuator and a zero dead ... emission under the $\approx 10^5$ more intense ... predict the expected gamma ... intensity of the γ ... from

Thank you!