The Study of Gamma Emission in the Fission Process

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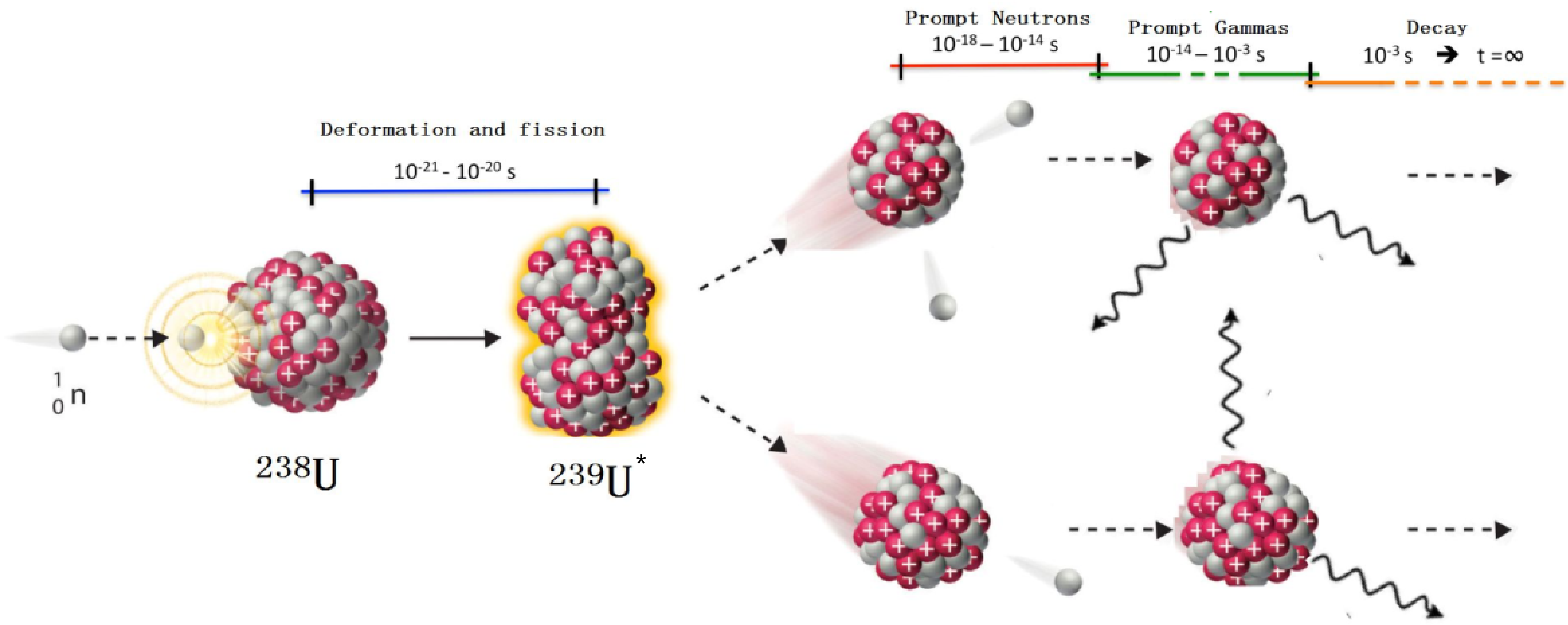
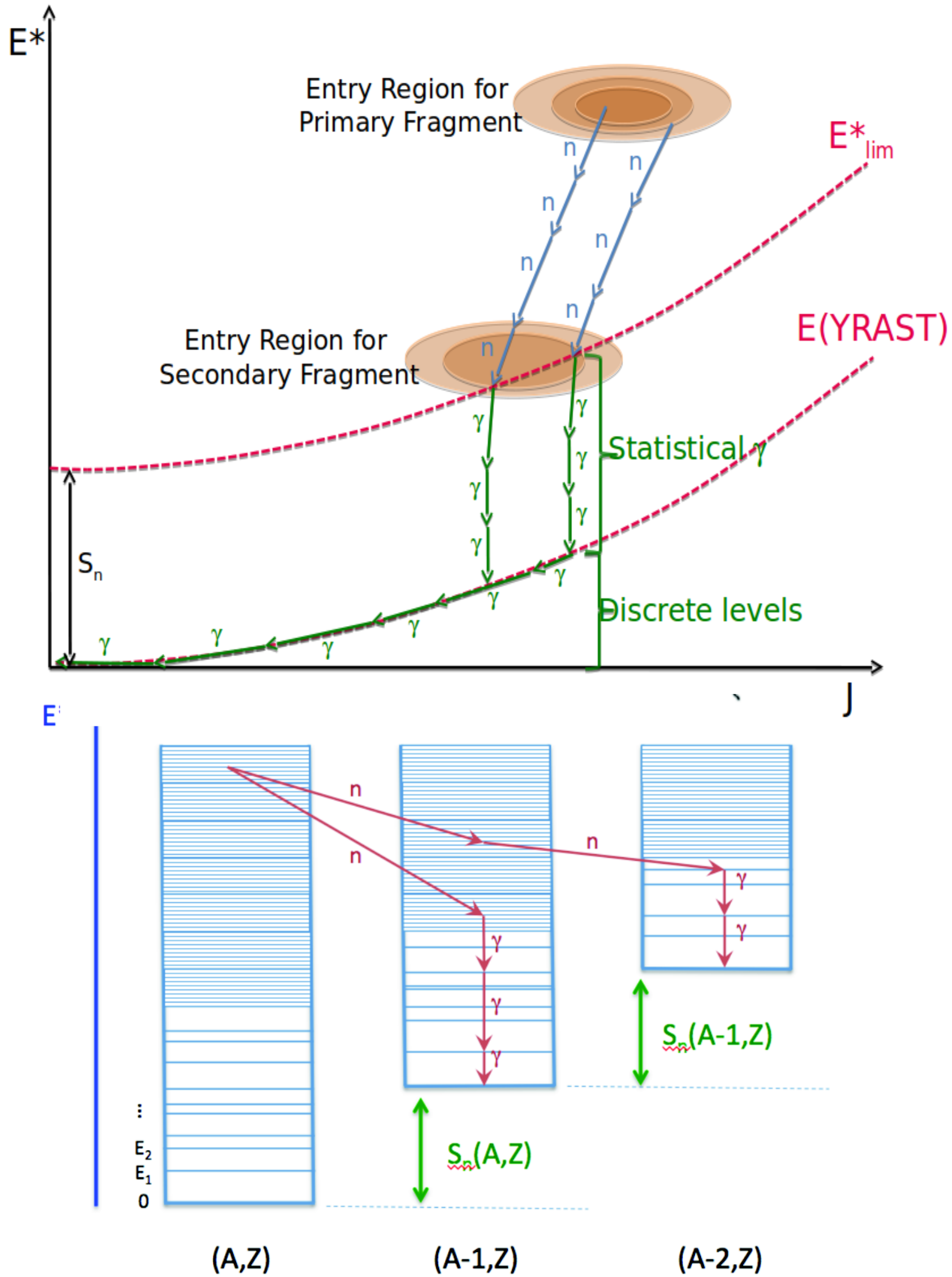
Fundamental Physics



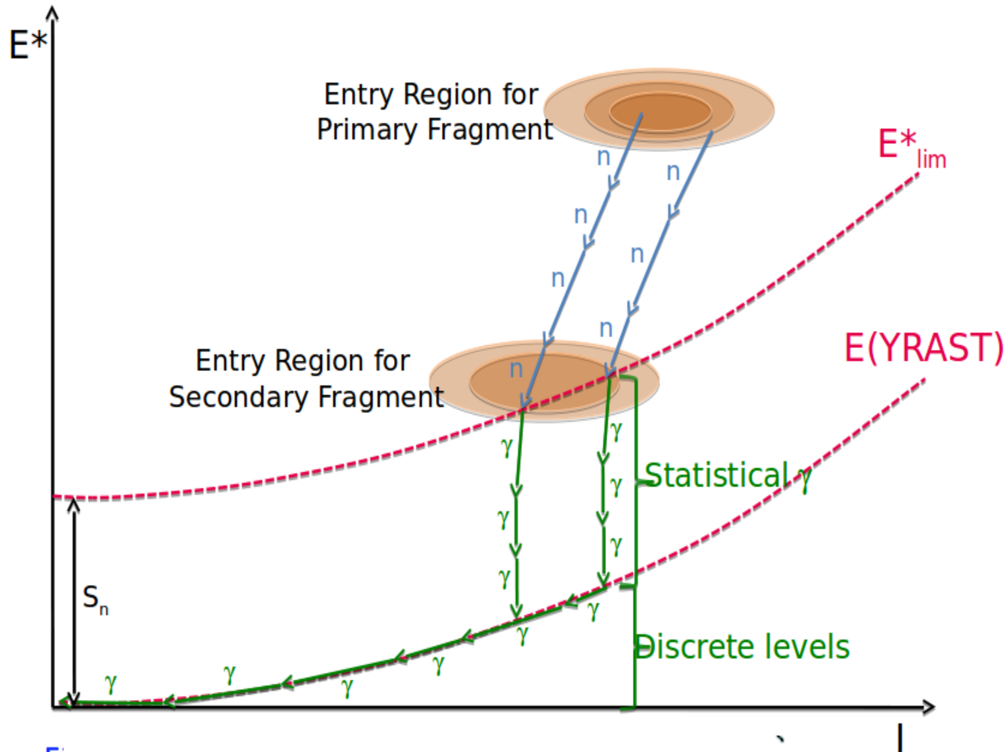
Q*	=	TKE* + TXE
<Q*>	~	196 MeV
<TKE*>	~	171 MeV
<TXE>	~	25 MeV

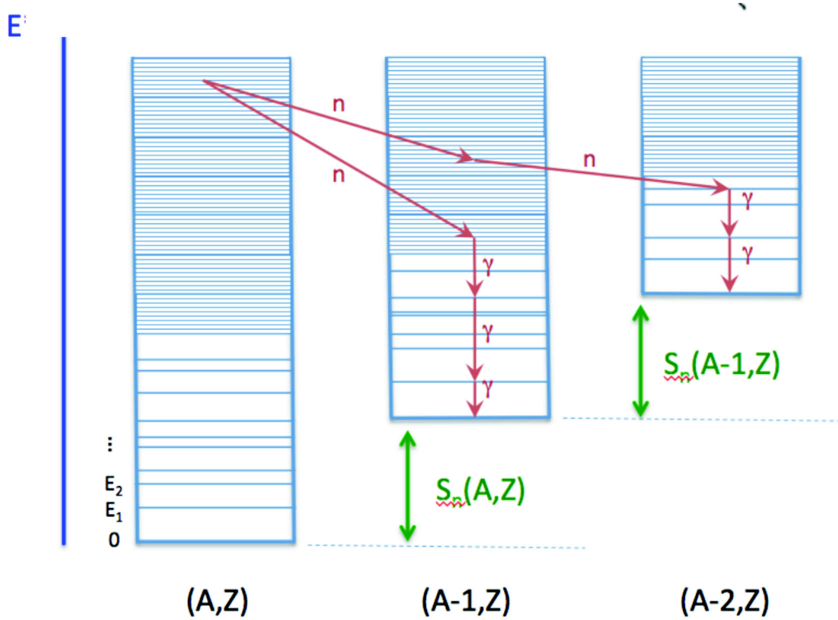
Fundamental Physics



- 1. Energy partition in fission
- 2. Angular momentum generation
- 3. Competition between neutron and gamma ray emission
- 4. Nuclear structure information

Fundamental Physics





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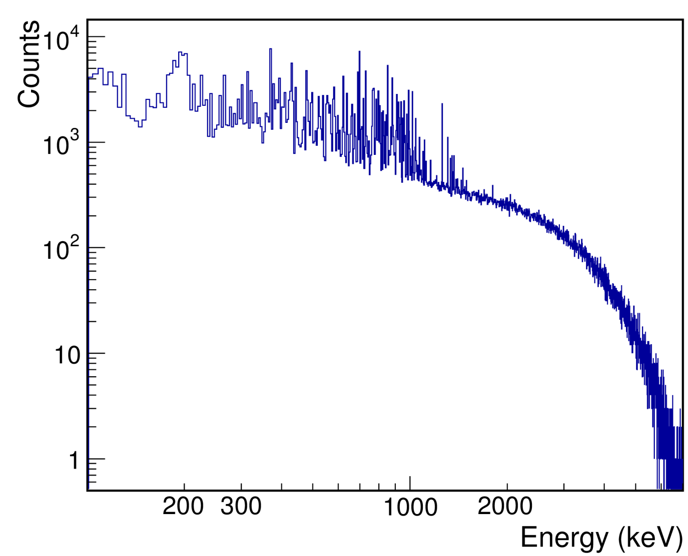
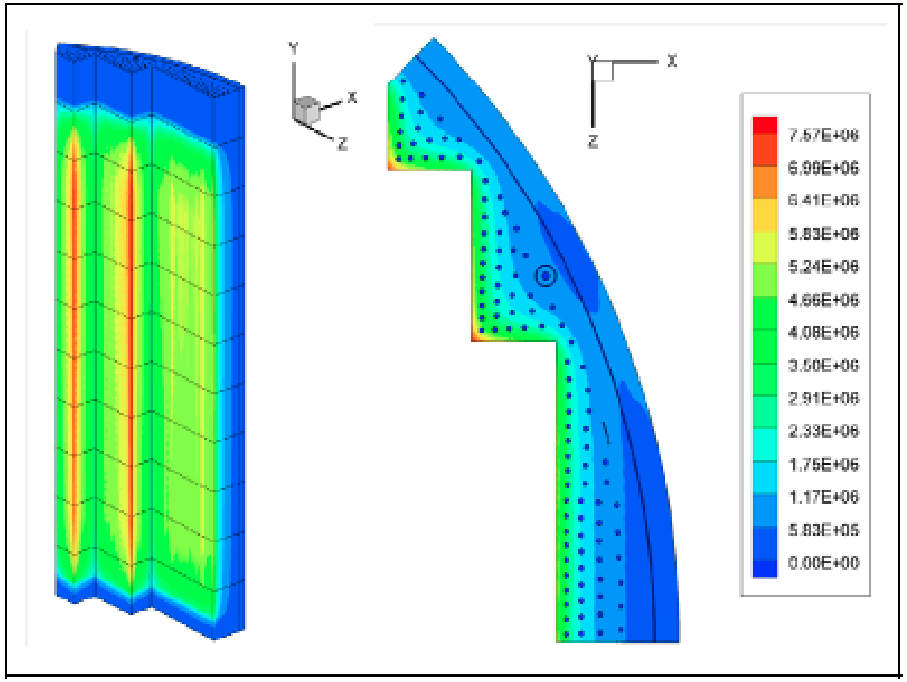


Reactor Physics



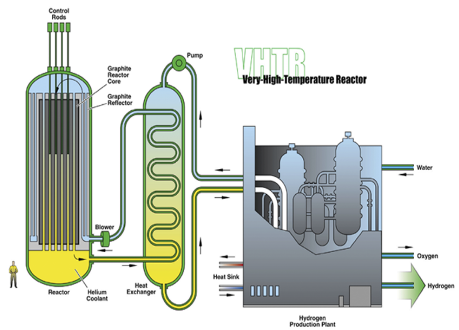
- Prompt Fission Gamma Spectrum (PFGS):

  → total energy, mean energy, multiplicity

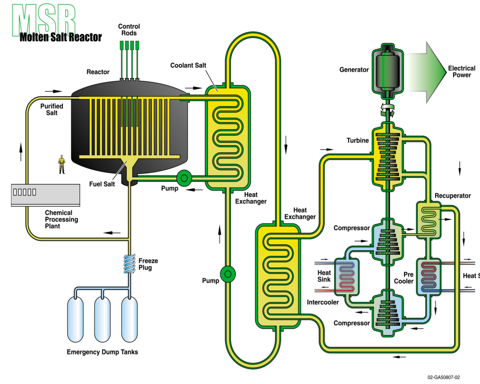
- Gamma heating is underestimated up to 28%

Reactor Physics

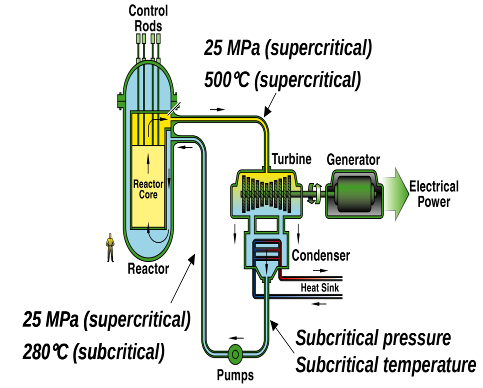
Thermal reactors



Very-high-temperature reactor (VHTR)

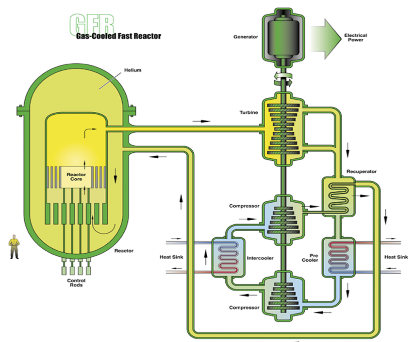


Molten-salt reactor (MSR)

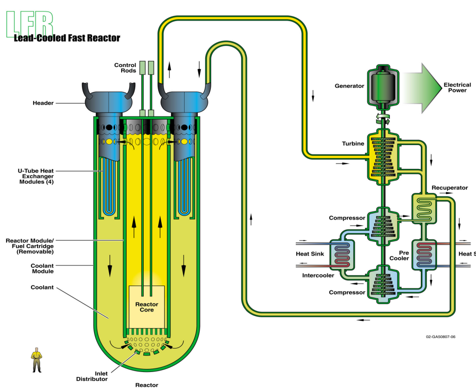


Supercritical-water-cooled reactor (SCWR)

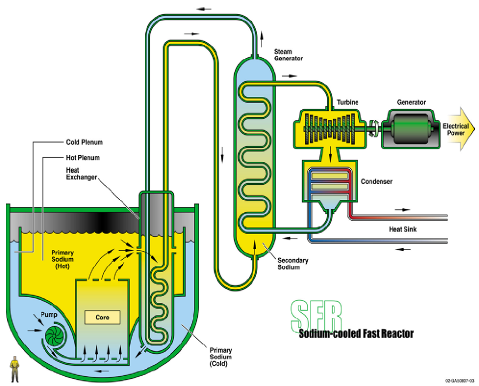
Fast reactors



Gas-cooled faster reactor (GFR)



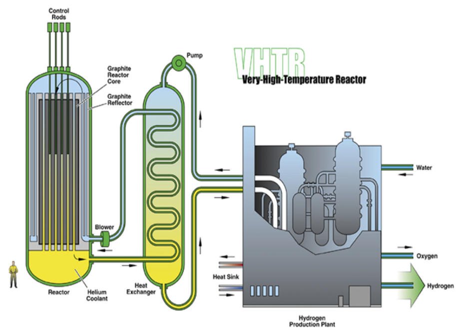
Lead-cooled faster reactor (LFR)



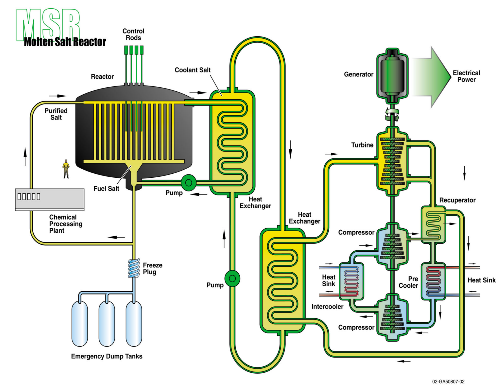
Sodium-cooled faster reactor (SFR)

Reactor Physics

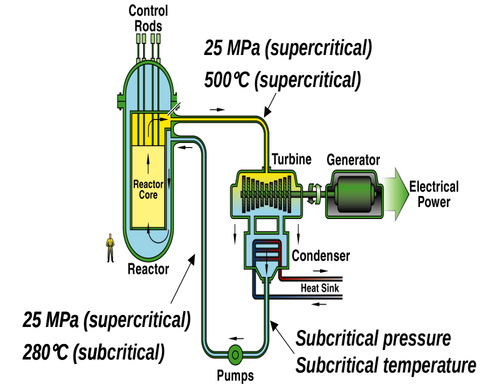
Thermal reactors



Very-high-temperature reactor (VHTR)

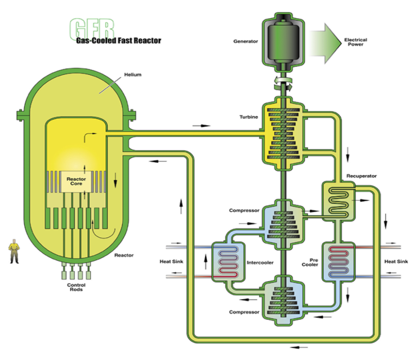


Molten-salt reactor (MSR)



Supercritical-water-cooled reactor (SCWR)

Fast reactors



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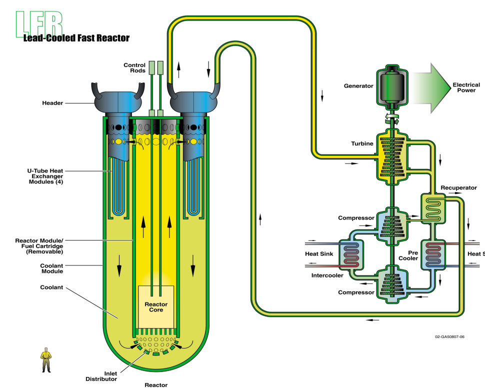

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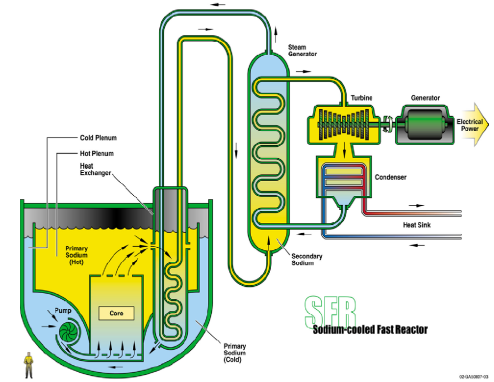
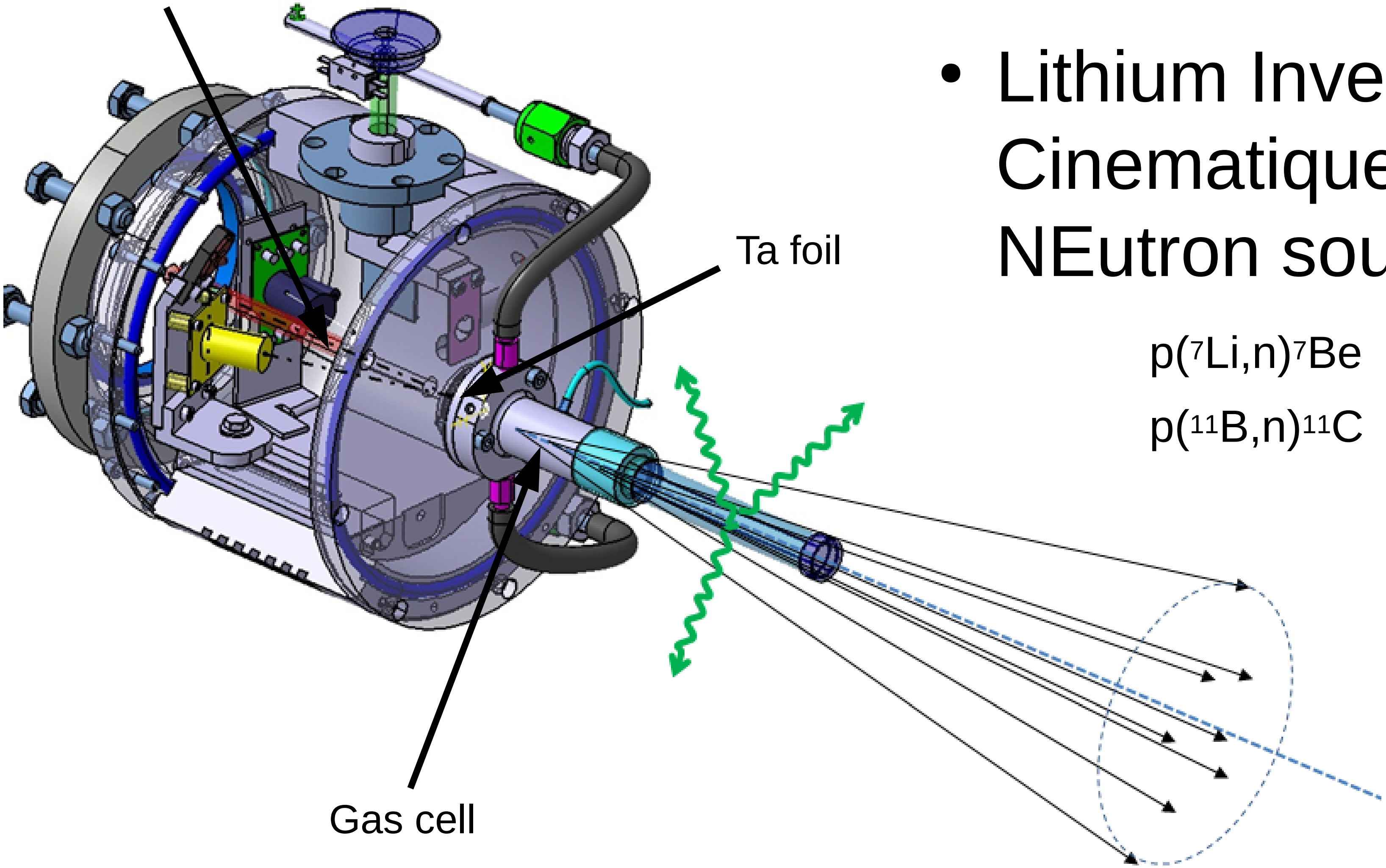


Sodium-cooled faster reactor (SFR)

^{238}U(n, f) in fast neutron energy of 2.0 MeV and 4.6 MeV

LICORNE Project

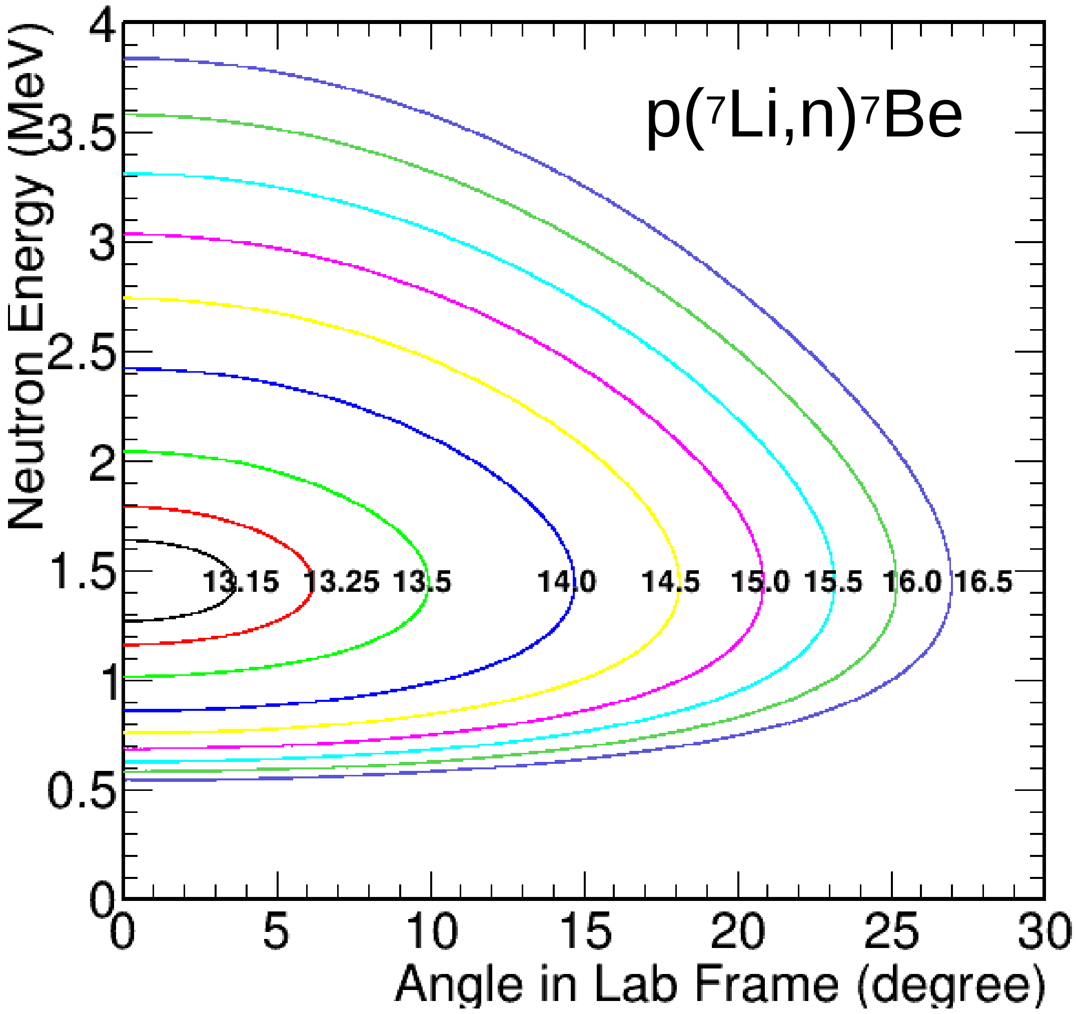


- Lithium Inverse Cinematiques ORsay NEutron source

$p(^{7}Li,n)^{7}Be$

$p(^{11}B,n)^{11}C$

Quais Mono-Energetic Neutron Source



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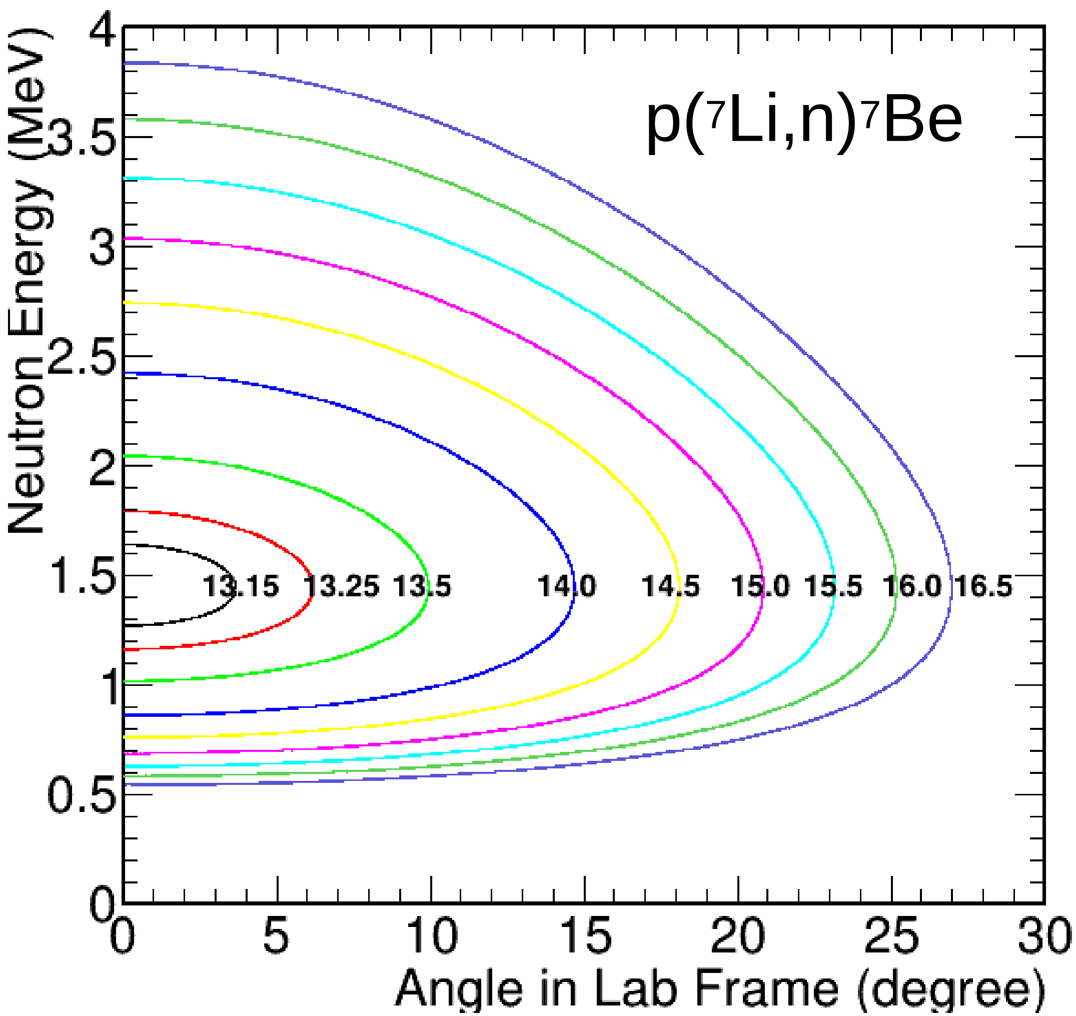

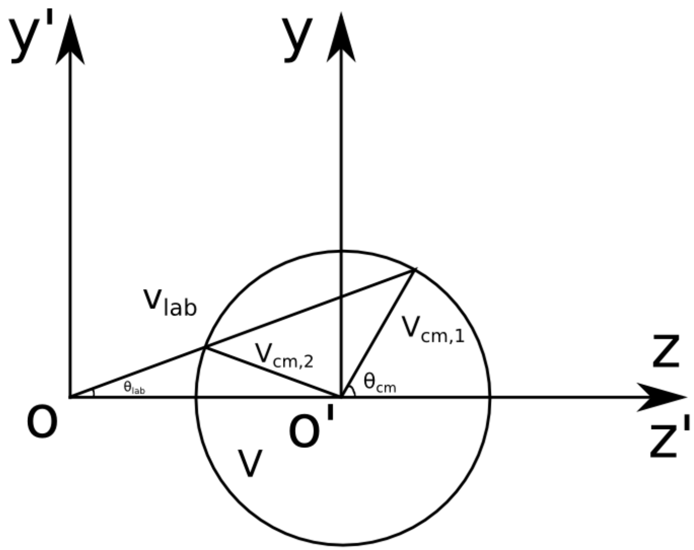

Inverse Kinematics

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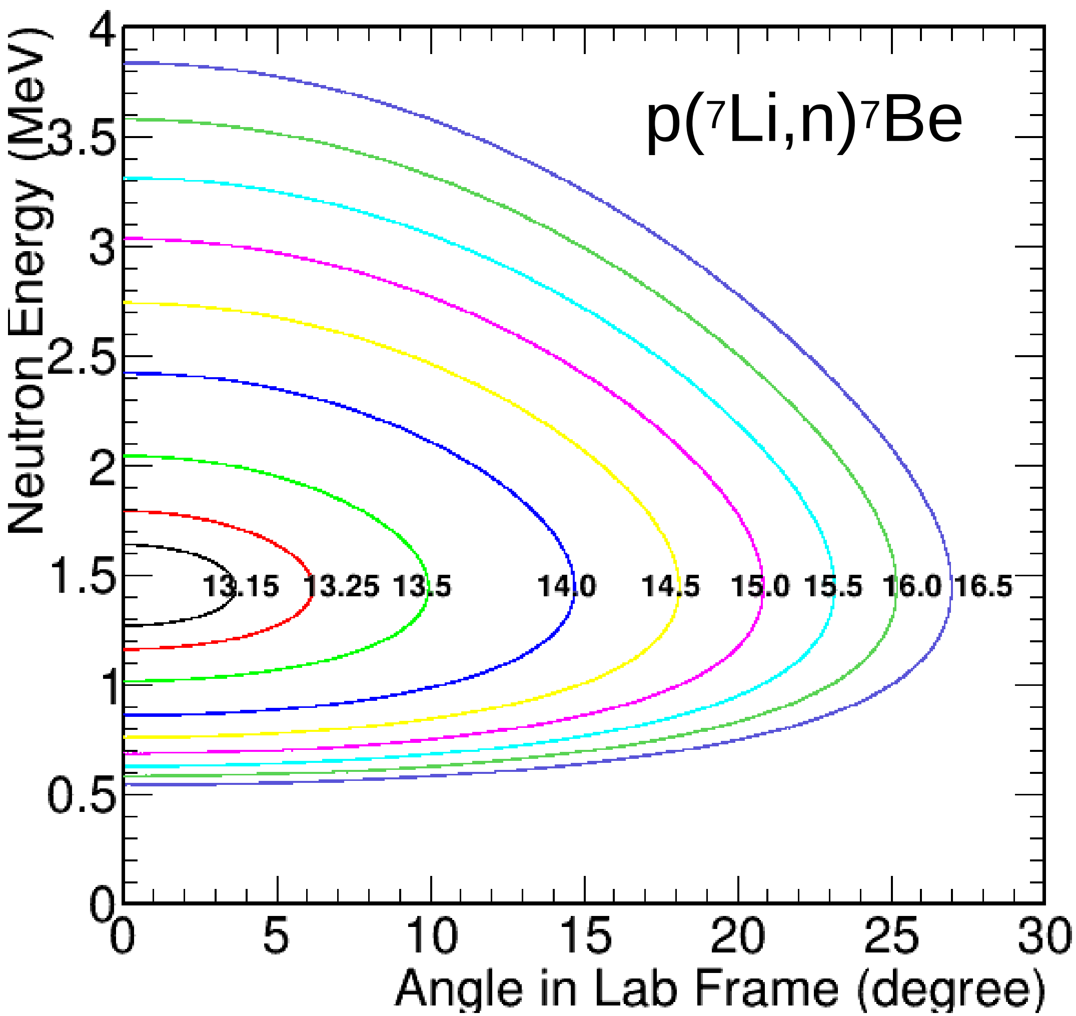

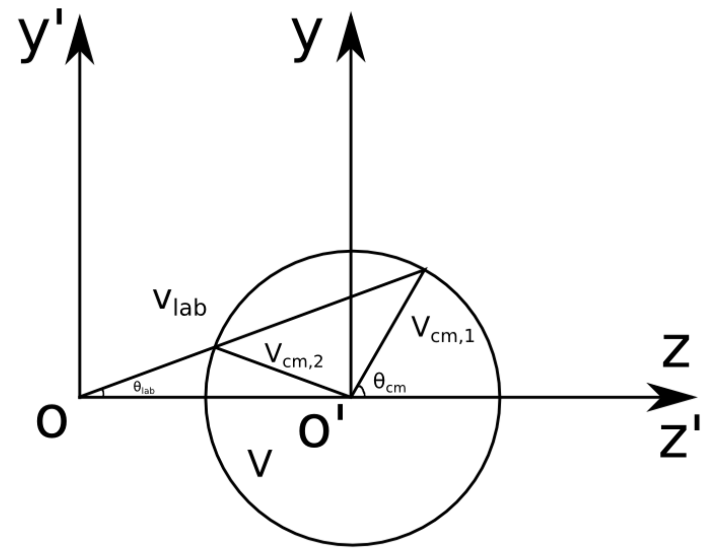

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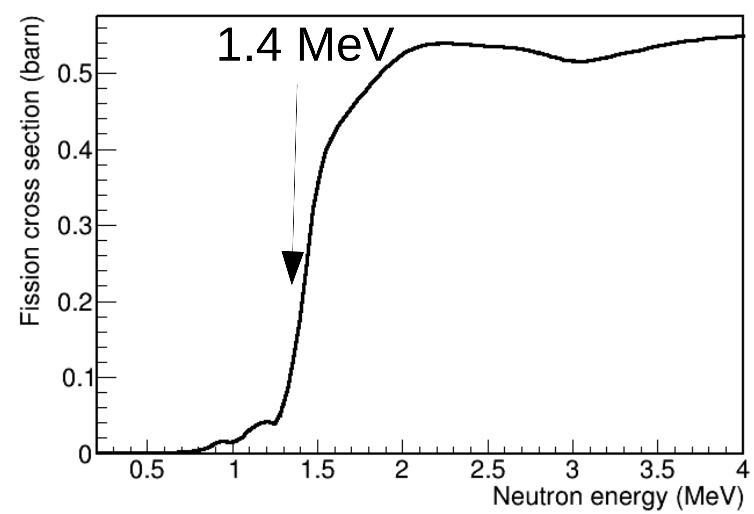
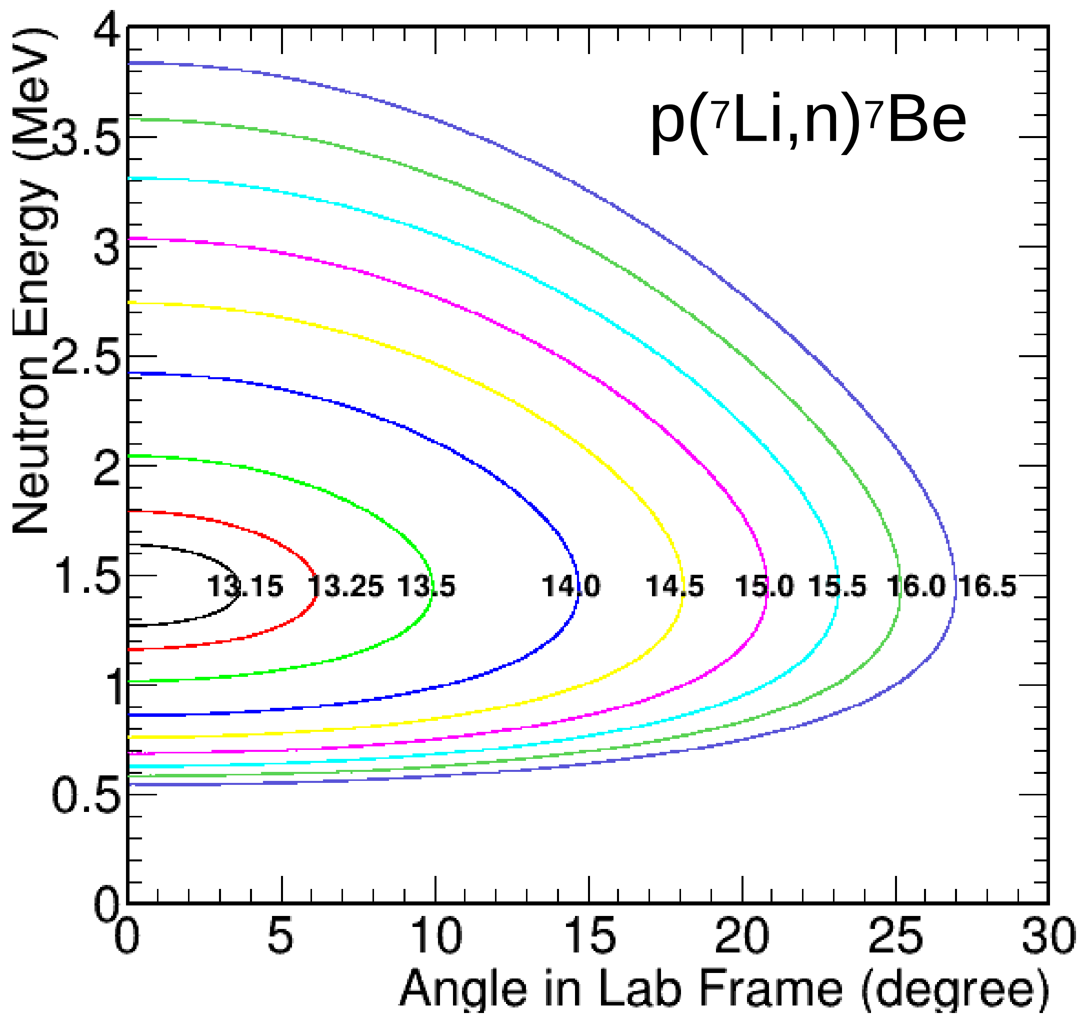
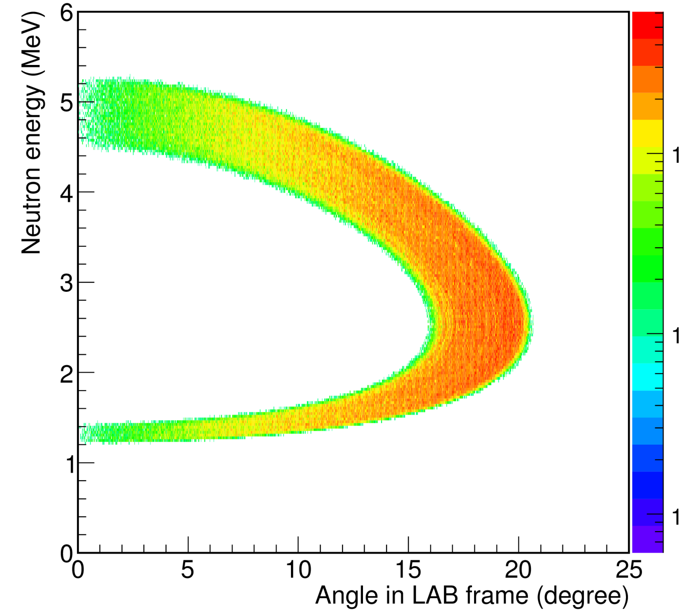
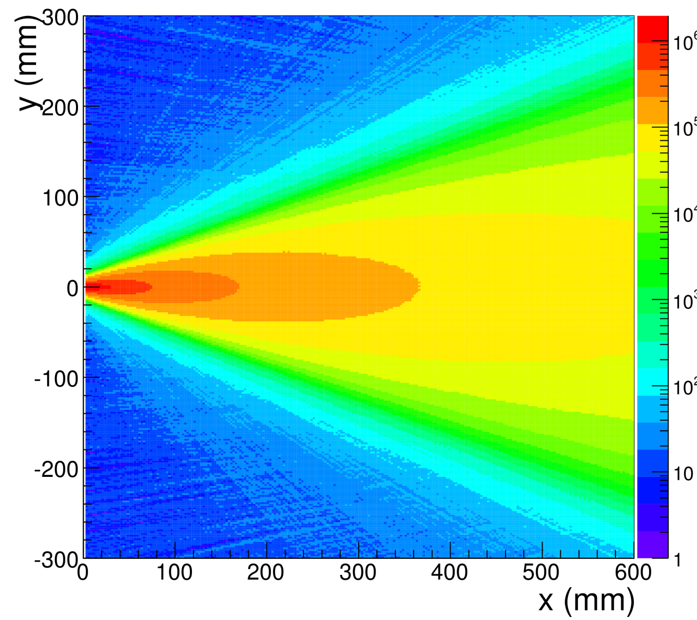


Fission cross section of ^{238}U
ENDF/B-VII.1

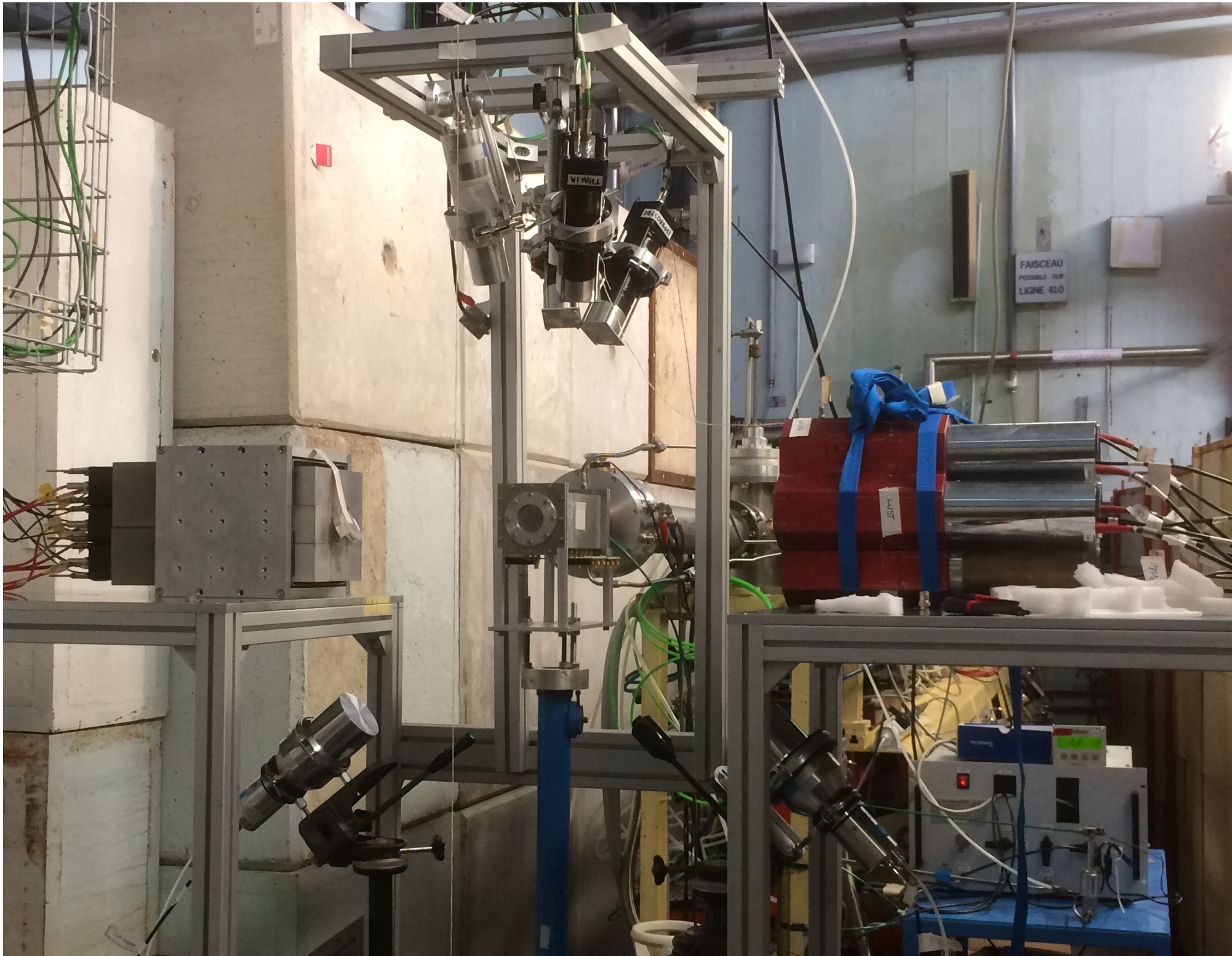
Quais Mono-Energetic Neutron Source







^{238}U(n,f) - March, 2016



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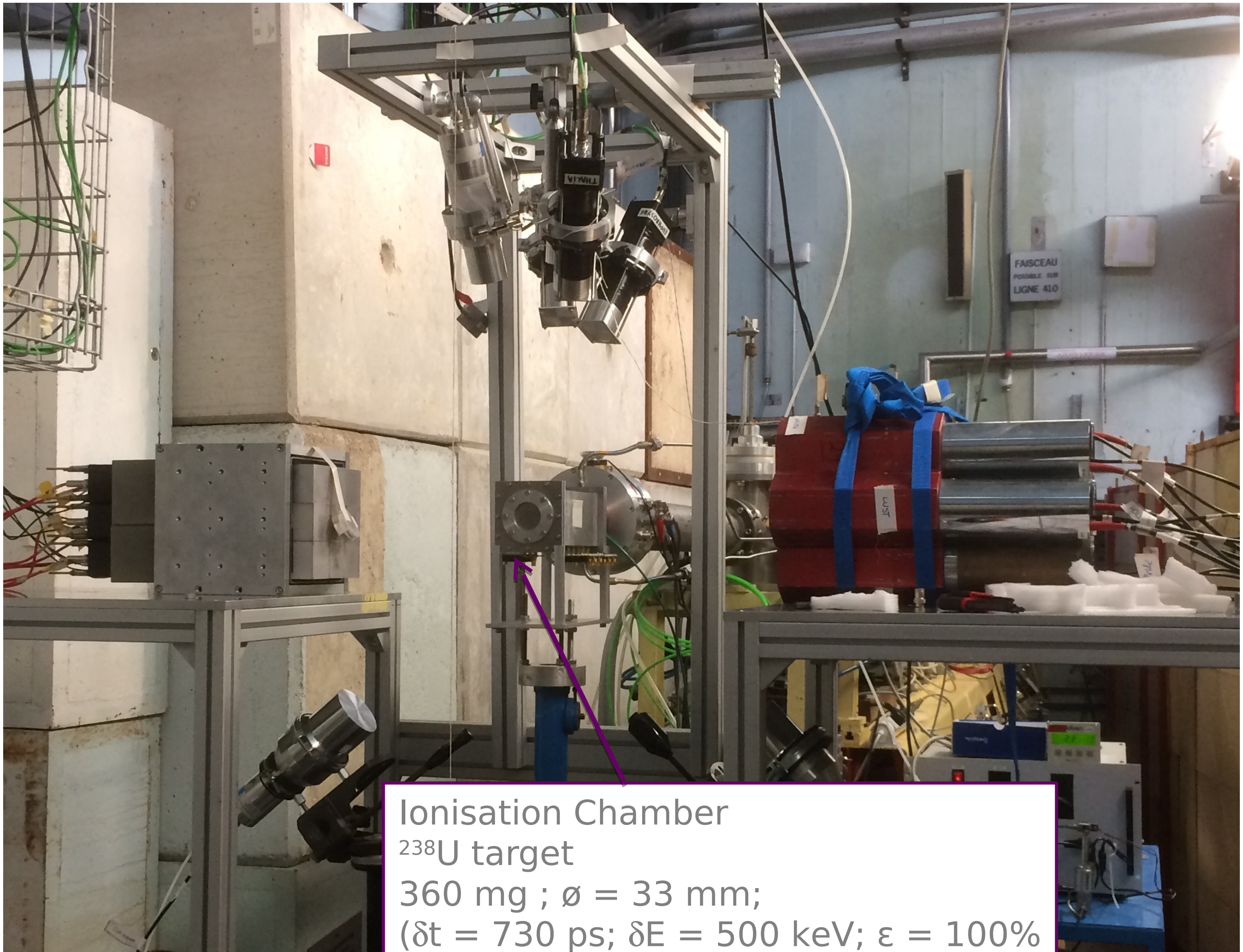
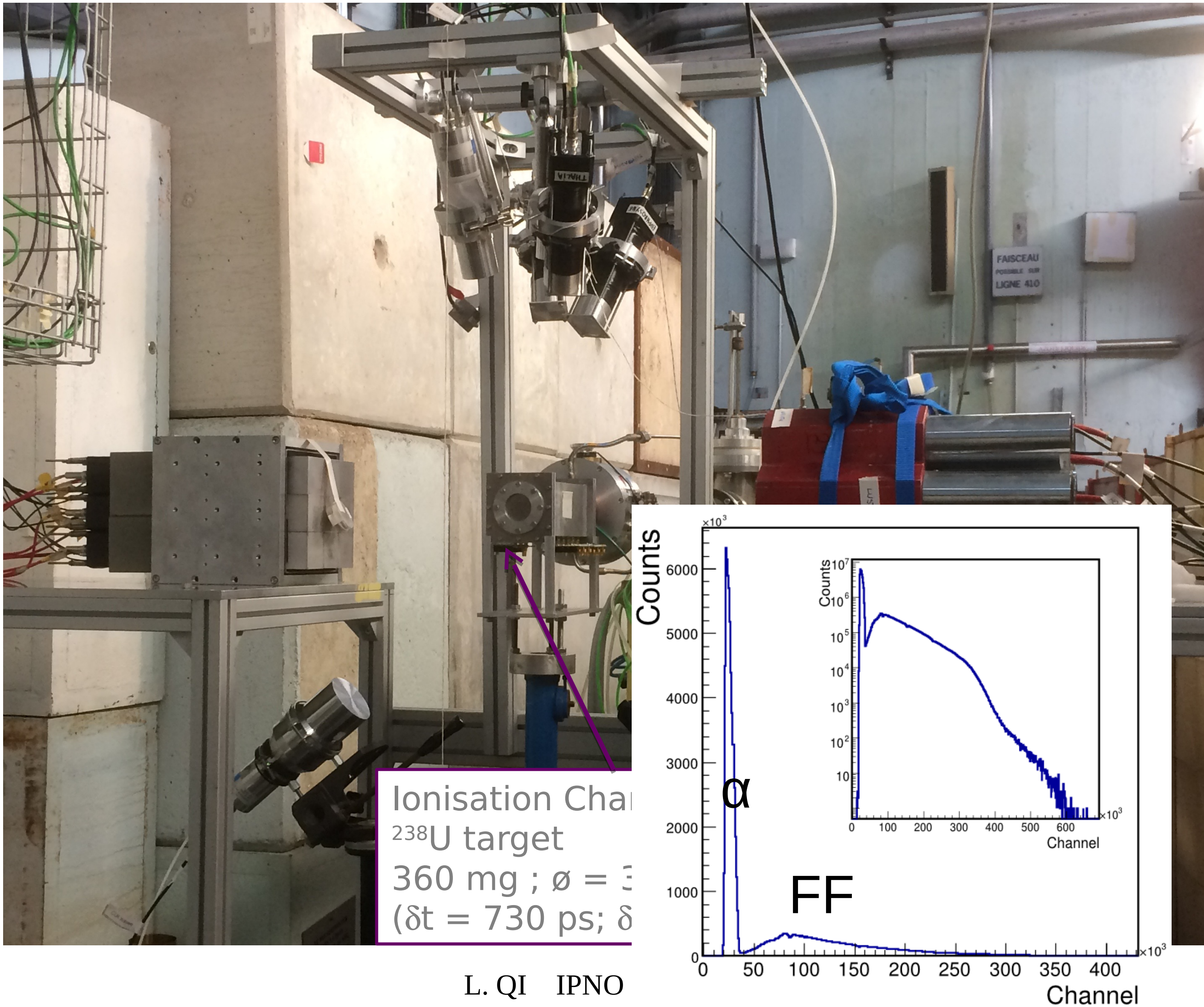


Ionisation Chamber
^{238}U target
360 mg ; ø = 33 mm;
(δt = 730 ps; δE = 500 keV; ε = 100%

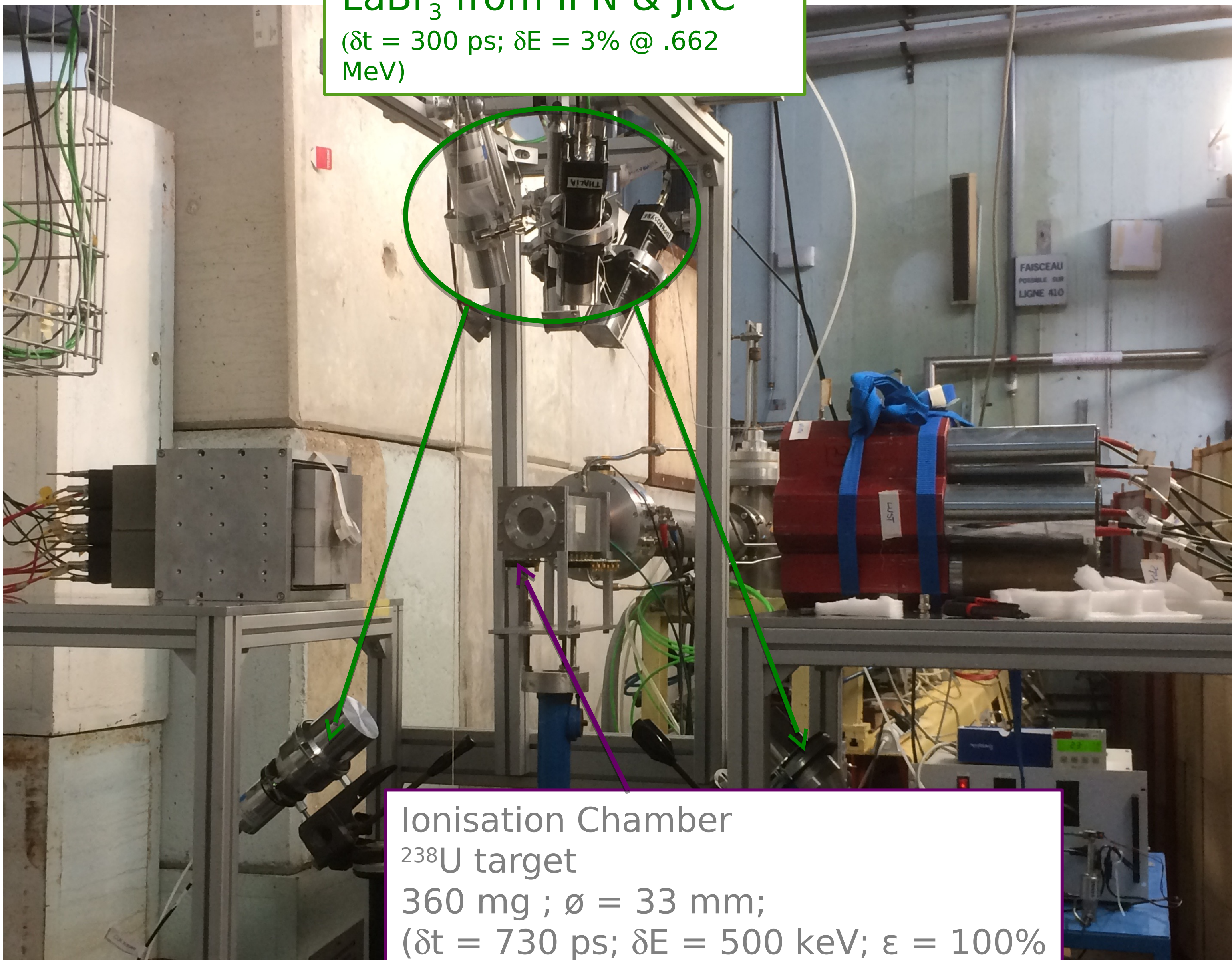
^{238}U(n,f) - March, 2016



Fission– alpha discrimination

^{238}U(n,f) - March, 2016

LaBr$_3$ from IPN & JRC
(δt = 300 ps; δE = 3% @ .662 MeV)



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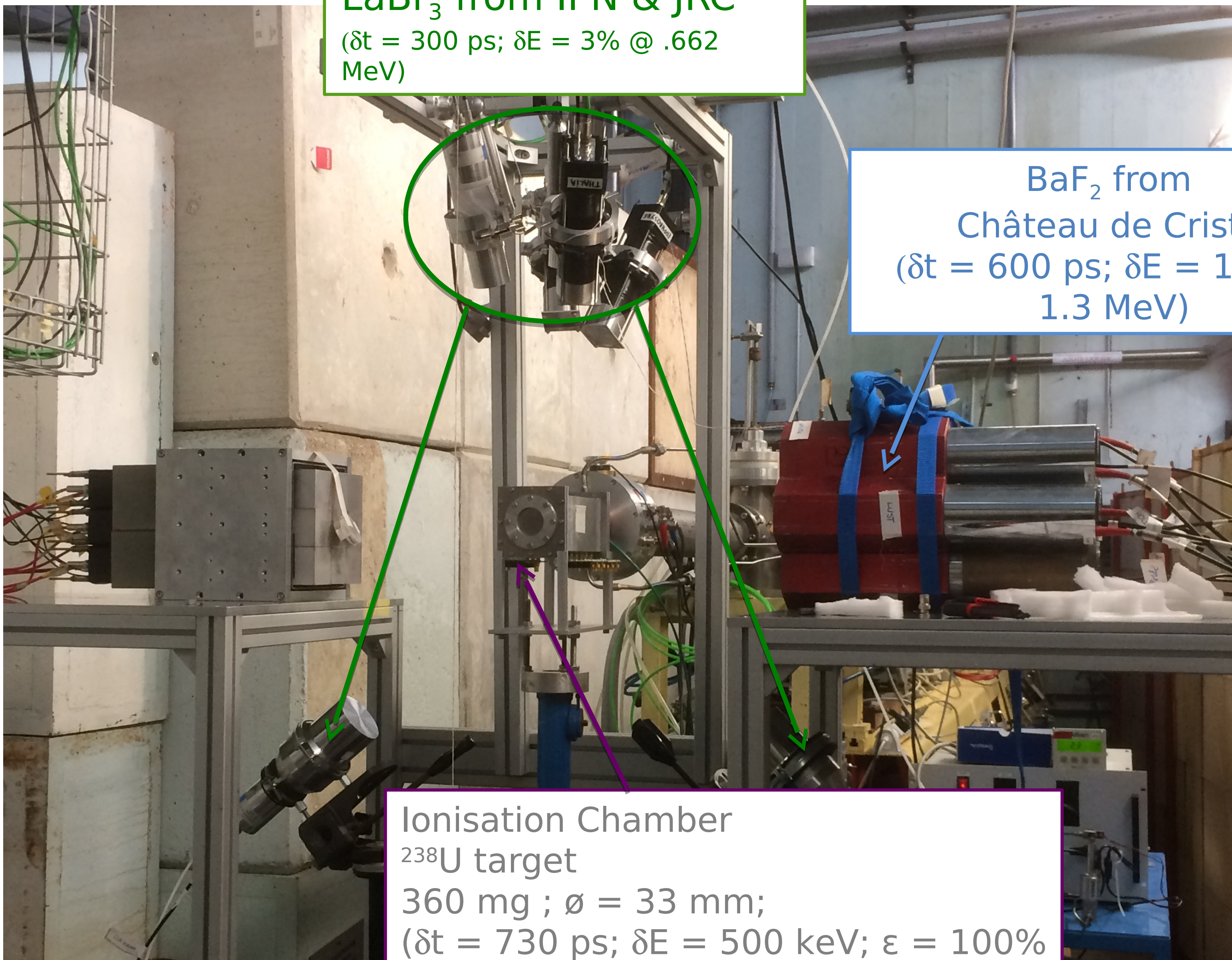

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(δt = 300 ps; δE = 3% @ .662 MeV)

BaF$_2$ from
Château de Cristal
(δt = 600 ps; δE = 10% @ 1.3 MeV)

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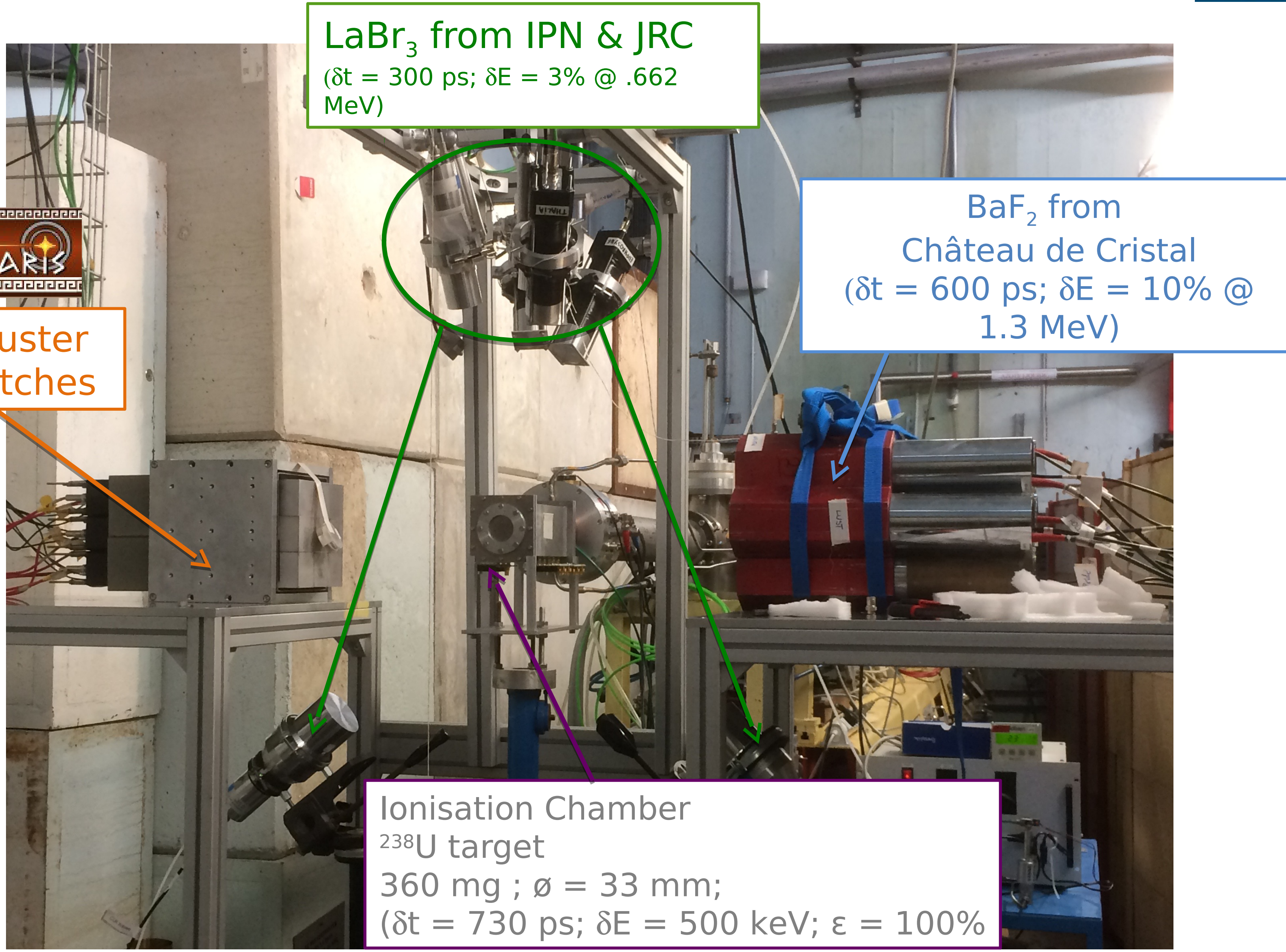
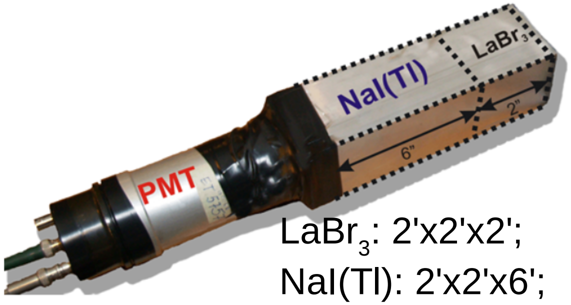
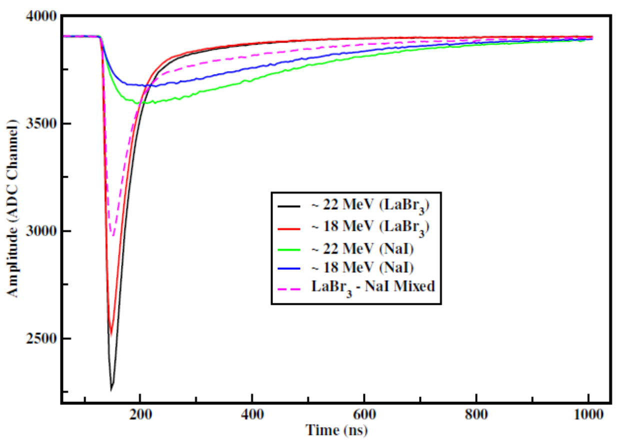
^{238}U(n,f) - March, 2016

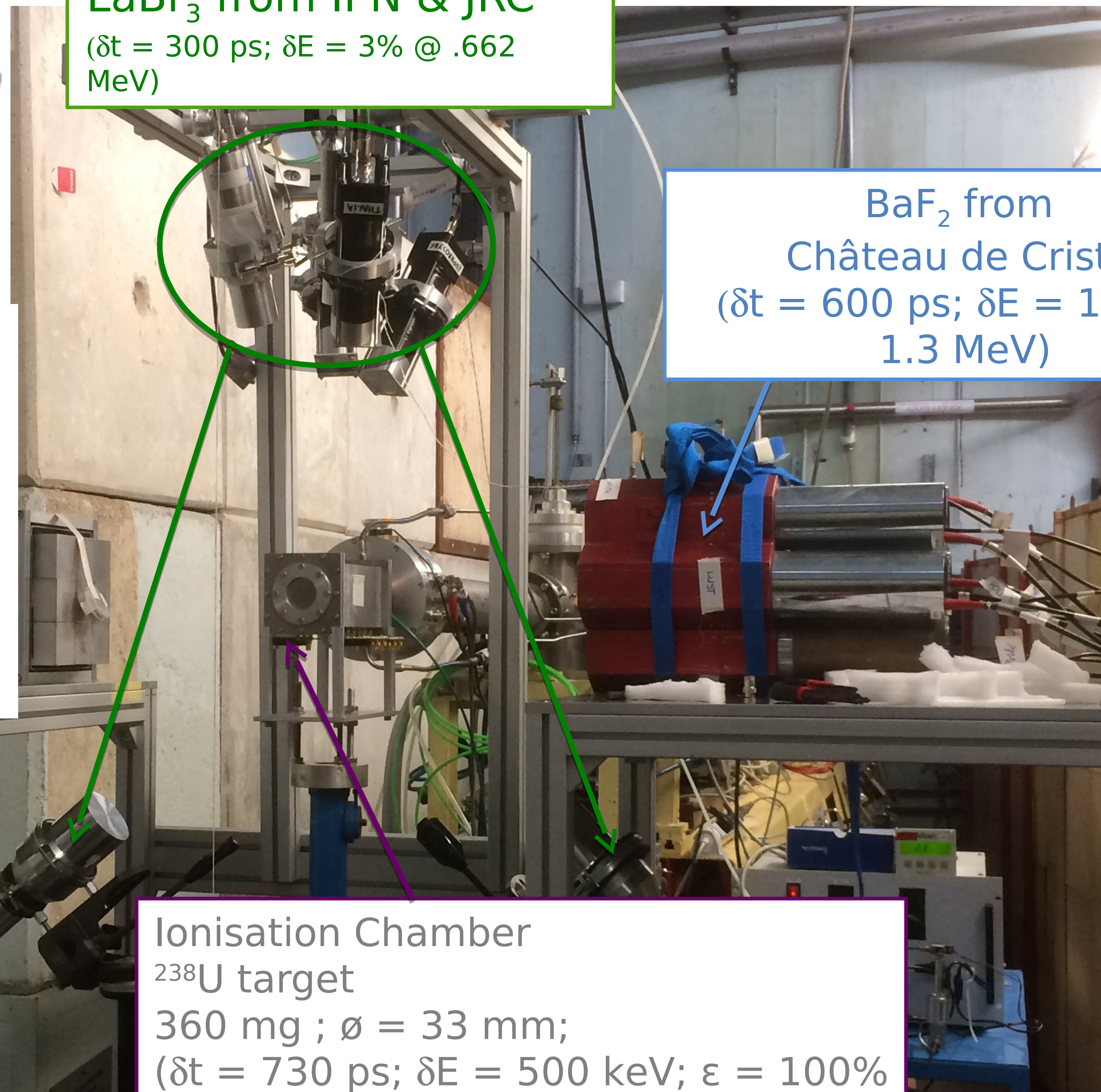


^{238}U(n,f) - March, 2016



$LaBr_3$: 2'x2'x2';
NaI(Tl): 2'x2'x6';





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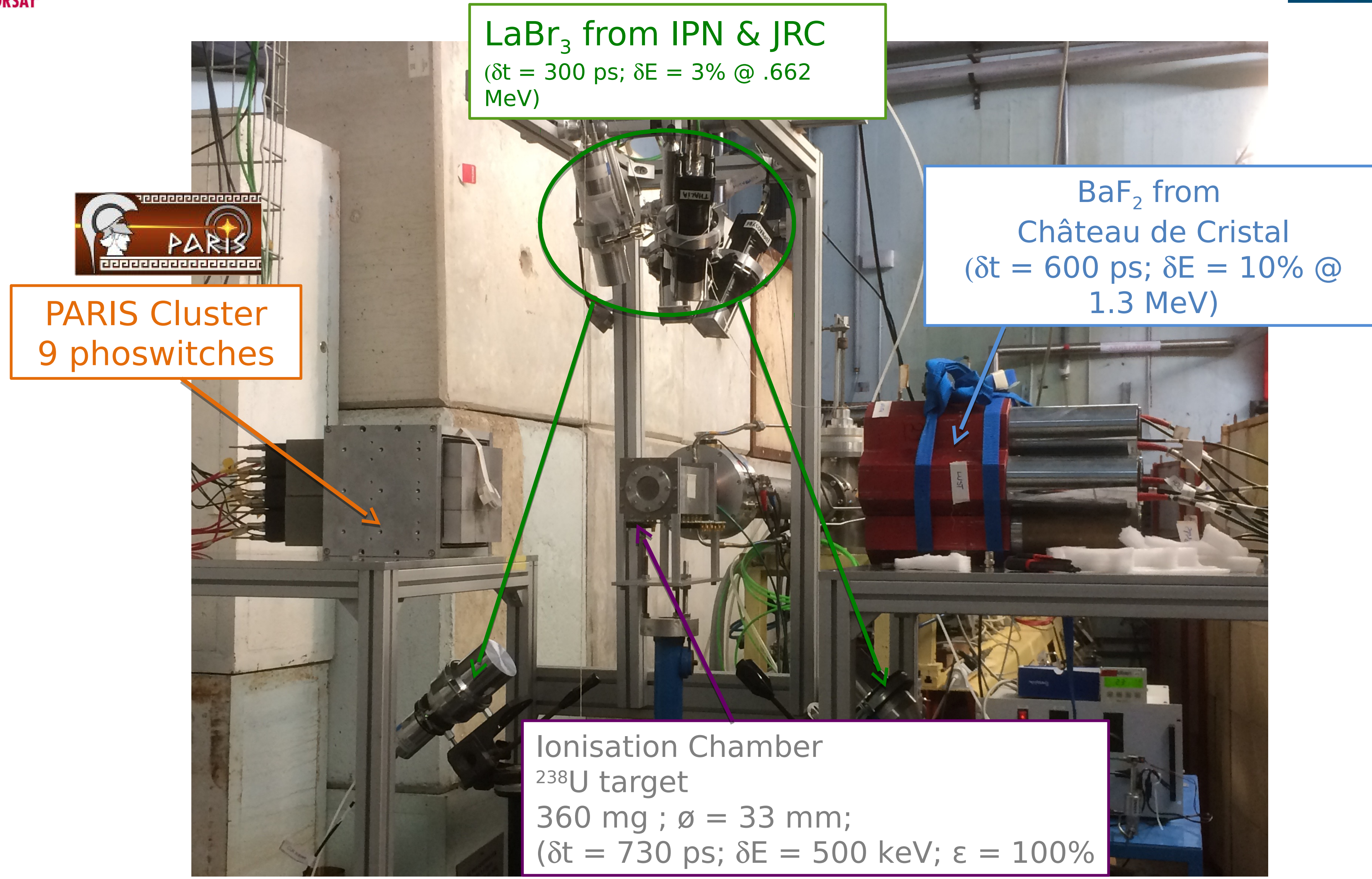
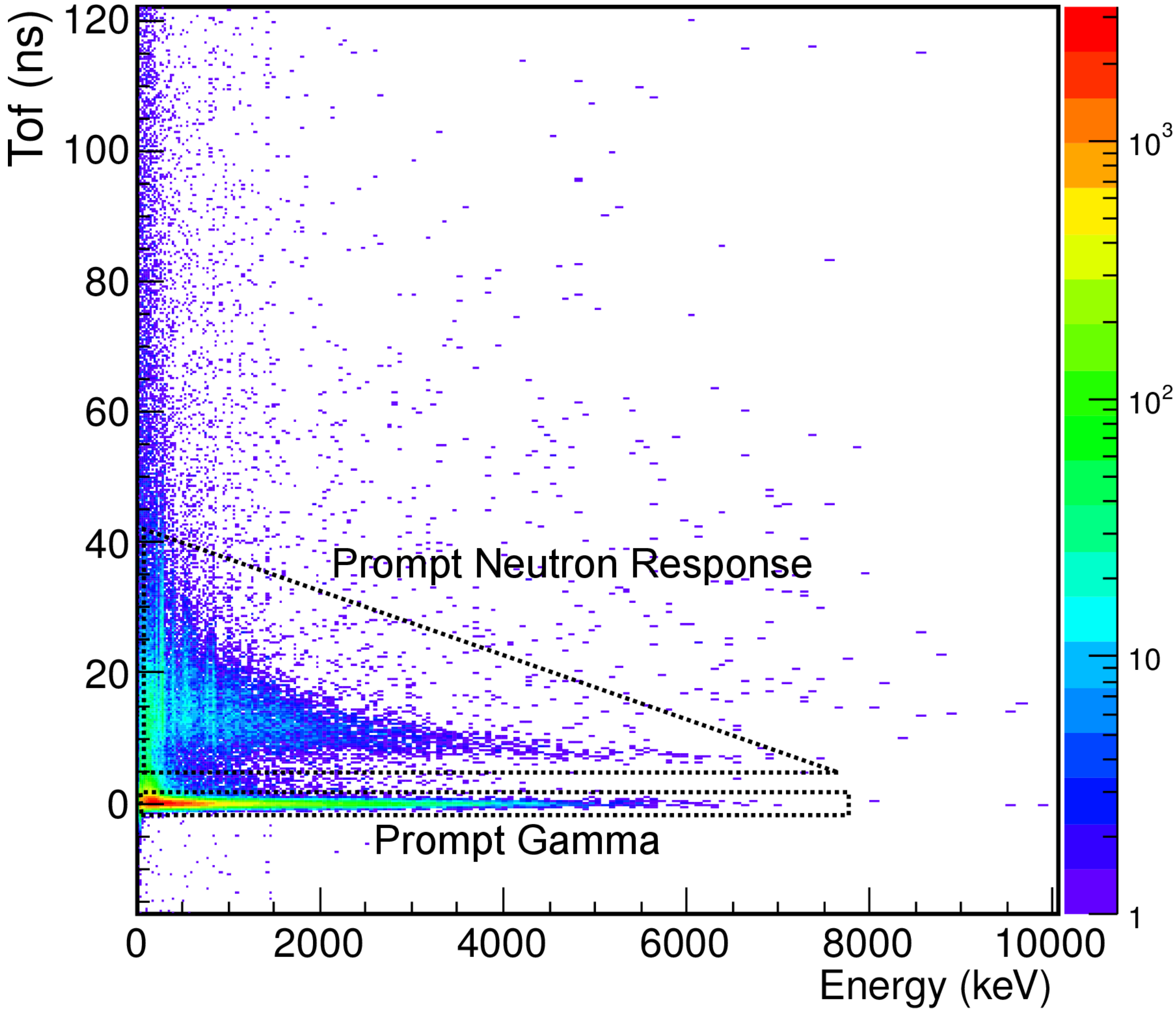


Measured Spectrum: g(x)



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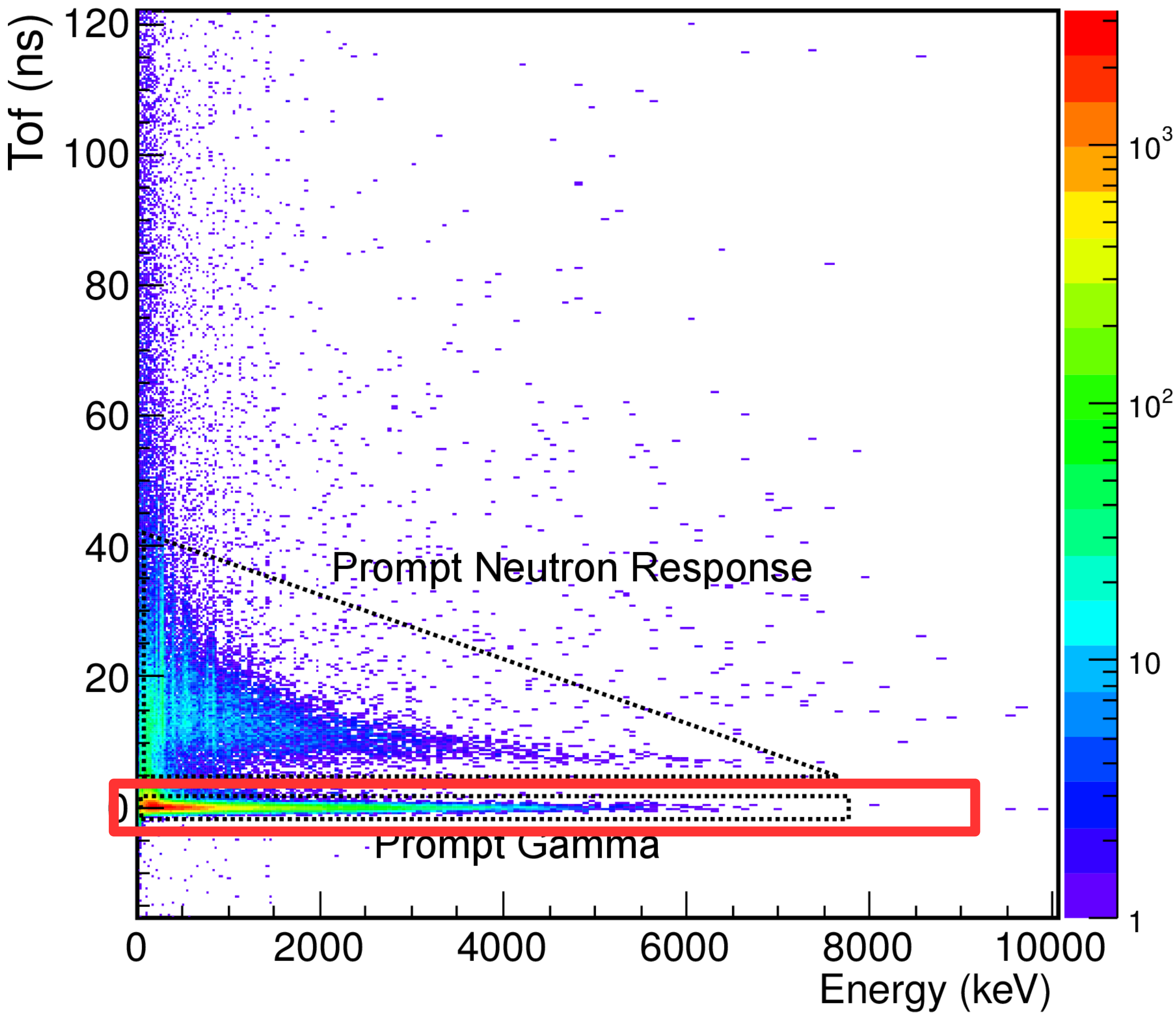
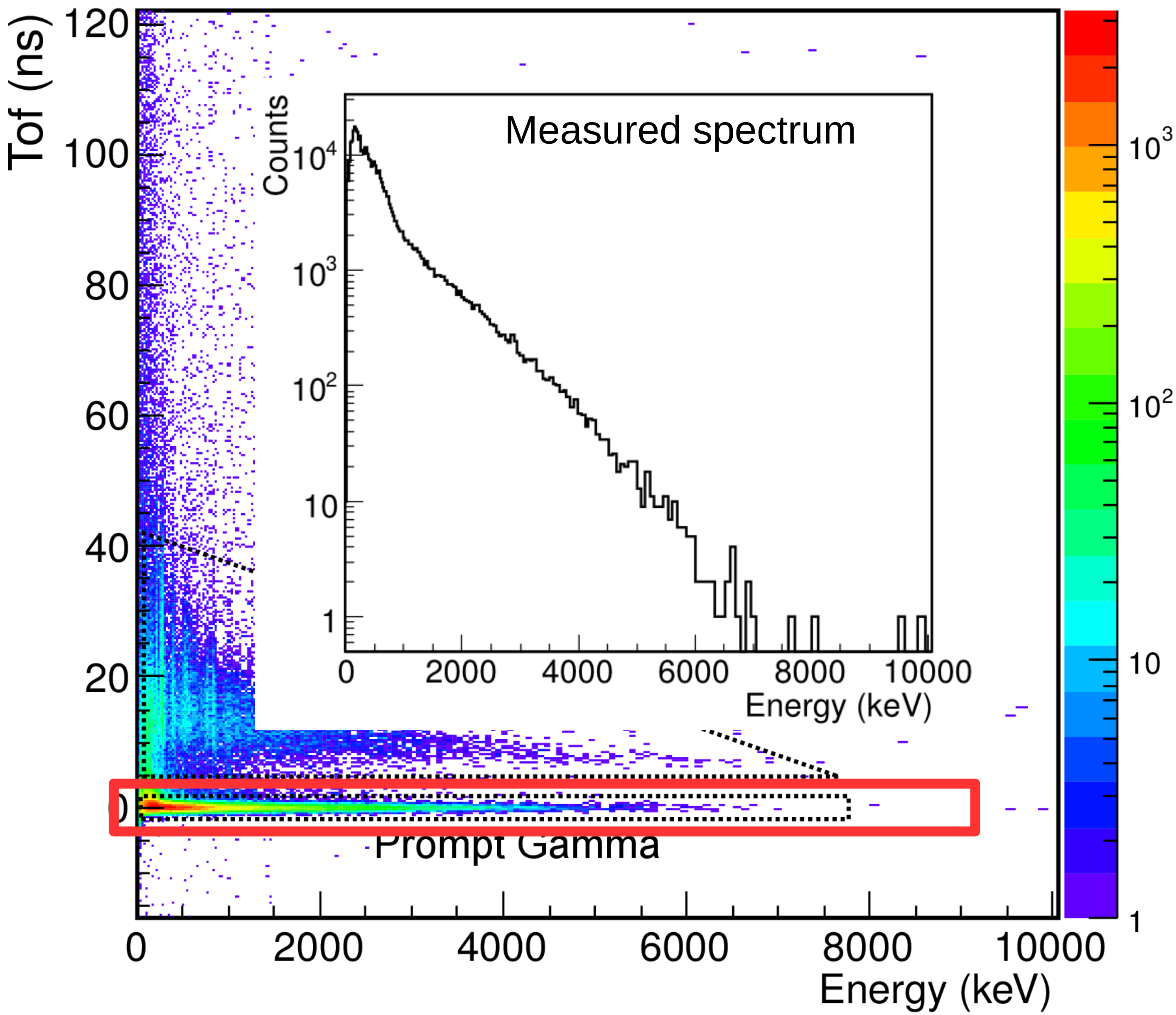
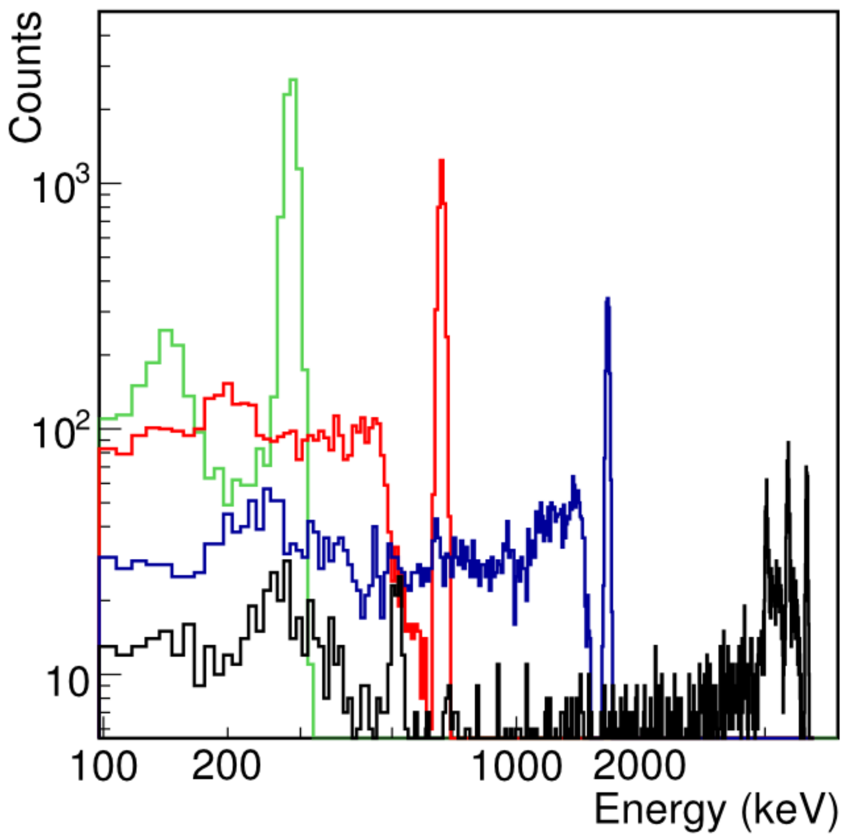


Measured Spectrum: g(x)



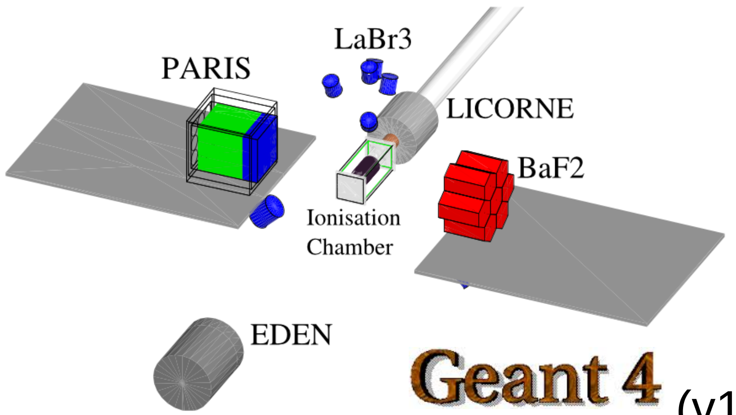
Deconvolution (Unfold)



Inverse problem:

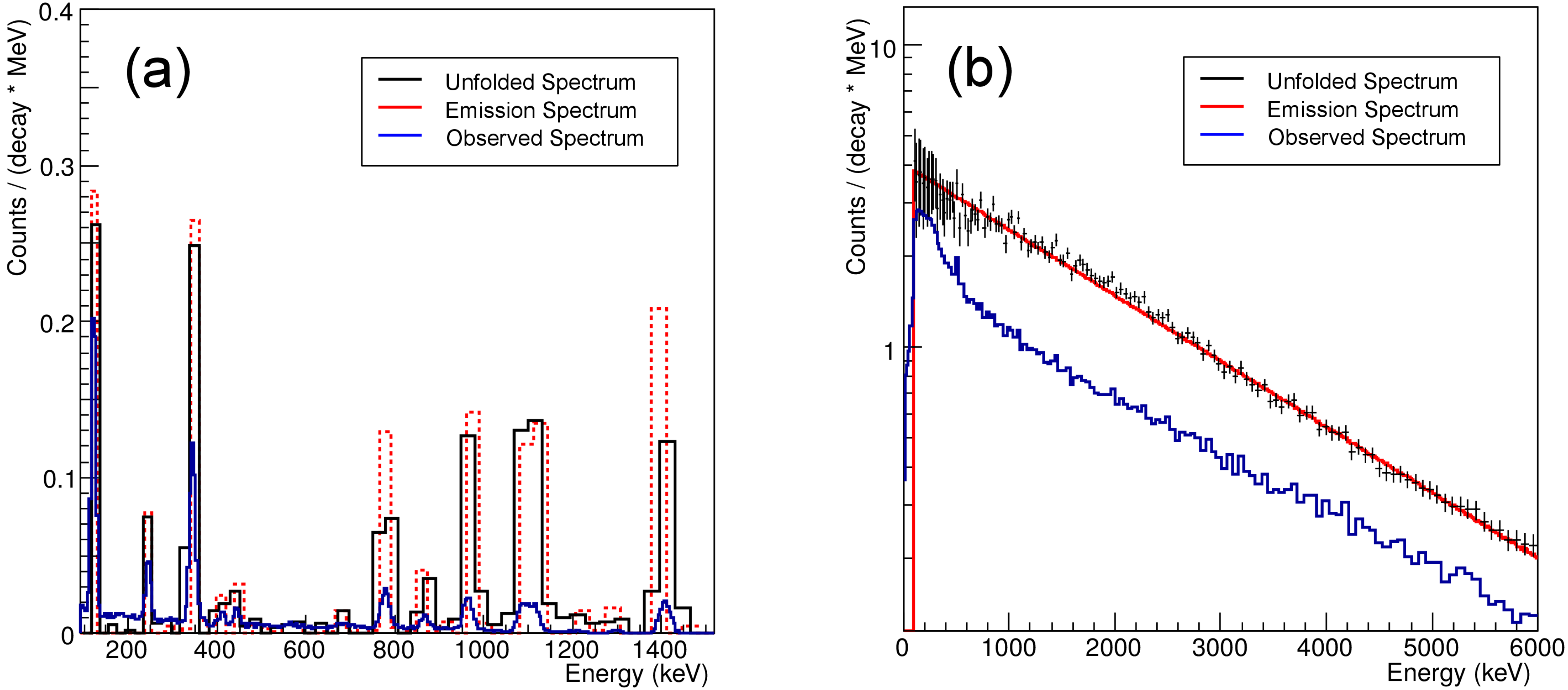
$$g(x) = \int_0^\infty R(x,y) f(y)$$

g(x):	measured spectrum (observation)
R(x,y):	response matrix (simulated)
f(y):	emission spectrum (unknown)



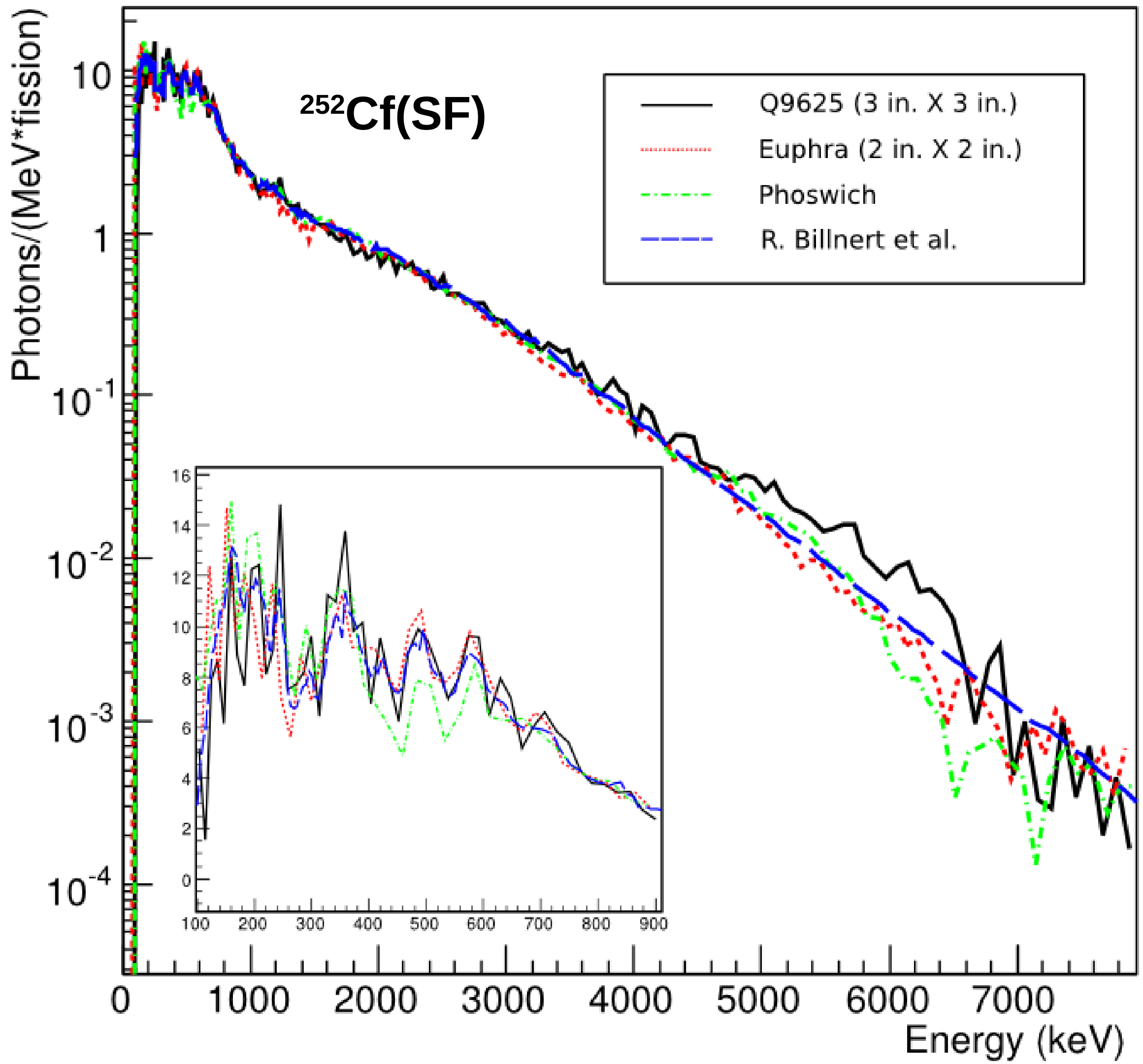
(v10.0)

Deconvolution algorithms



Methods	Test1 - discrete distribution			Test2 - continuum distribution		
	Multiplicity M_γ	Total Energy $E_{\gamma,tot}$(MeV)	Average Energy ϵ_γ(MeV)	Multiplicity M_γ	Total Energy $E_{\gamma,tot}$(MeV)	Average Energy ϵ_γ(MeV)
Bin-by-bin	1.54 ± 0.057	1.09 ± 0.049	0.71 ± 0.041	7.37 ± 0.12	13.09 ± 0.34	1.77 ± 0.054
Matrix Inversion	1.68 ± 0.027	1.19 ± 0.027	0.71 ± 0.020	7.25 ± 0.10	12.89 ± 0.35	1.78 ± 0.055
Linear Iteration	1.65 ± 0.058	1.16 ± 0.024	0.70 ± 0.029	7.28 ± 0.079	12.93 ± 0.073	1.77 ± 0.022
Non-linear Iteration	1.57 ± 0.013	1.11 ± 0.016	0.71 ± 0.012	7.24 ± 0.025	12.83 ± 0.061	1.77 ± 0.010
Regularization	1.59 ± 0.01	1.07 ± 0.015	0.67 ± 0.010	7.27 ± 0.014	13.27 ± 0.040	1.82 ± 0.006
Reference	1.58 ± 0.012	1.11 ± 0.001	0.71 ± 0.008	7.25 ± 0.015	12.86 ± 0.004	1.77 ± 0.001

Deconvolution algorithms



Results	M_γ	$E_{\gamma,tot}$ (MeV)	ϵ_γ
This work	8.35±0.17	6.65±0.07	0.80±0.02
R. Billnert et al. [1]	8.30±0.09	6.64±0.10	0.80±0.01
Chyzh et al. [2]	8.14±0.40	7.65±0.55	0.94±0.05
ENDF/B-VII.1	7.85	6.13	0.78

Results and Discussions

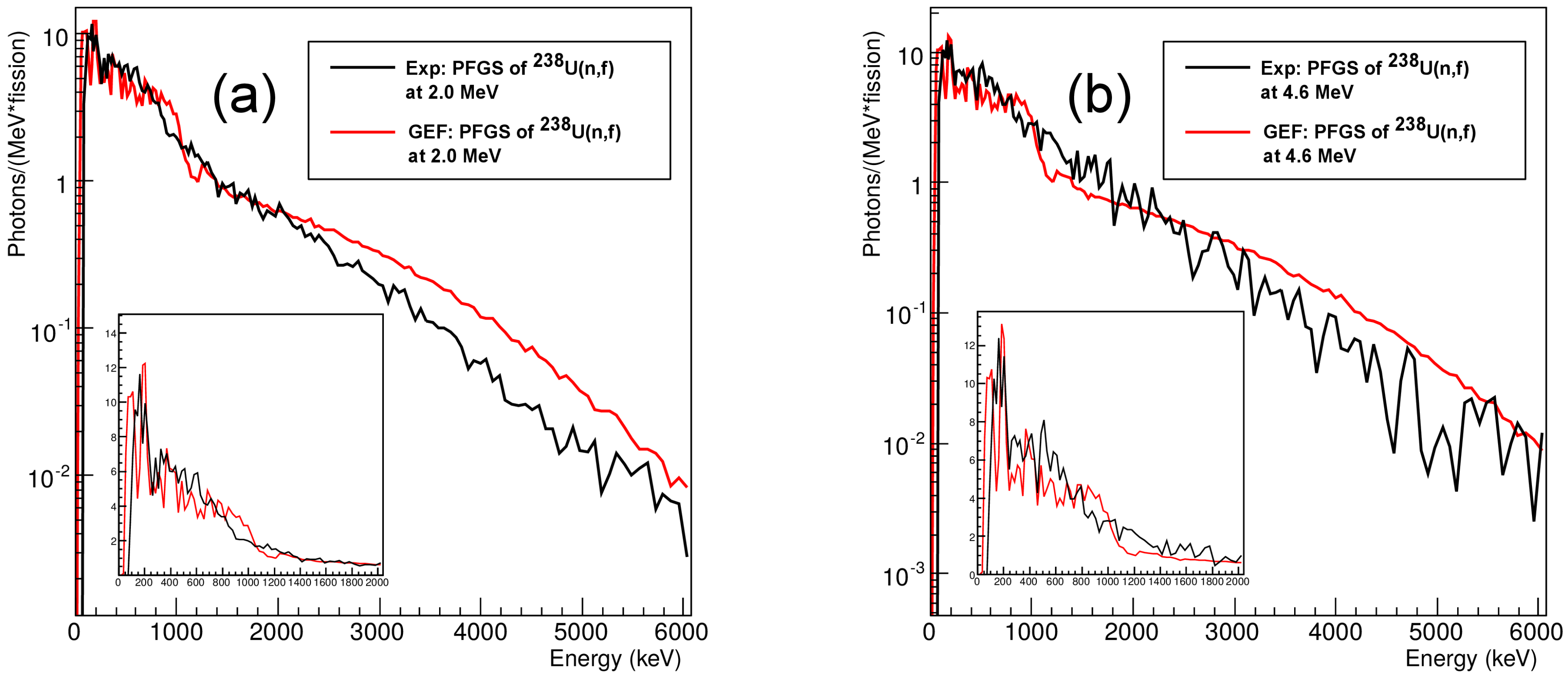


Figure: Comparison between experiments and theoretic calculation.

→ Neither the position of peaks in low energy region nor the slope of the high energy tail agrees with the experimental data. It suggests that the model requires better <u>level density function</u> and <u>gamma strength function</u>.

Results and Discussions

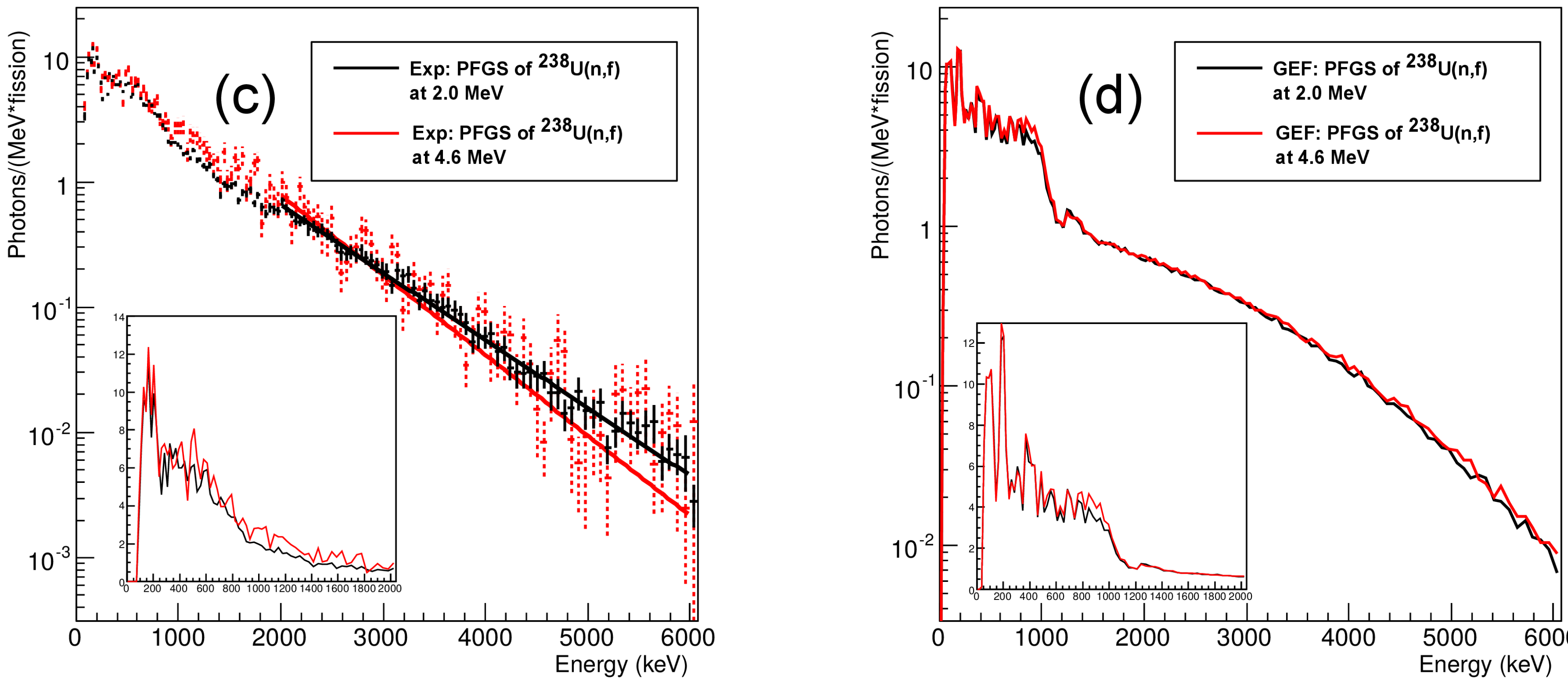
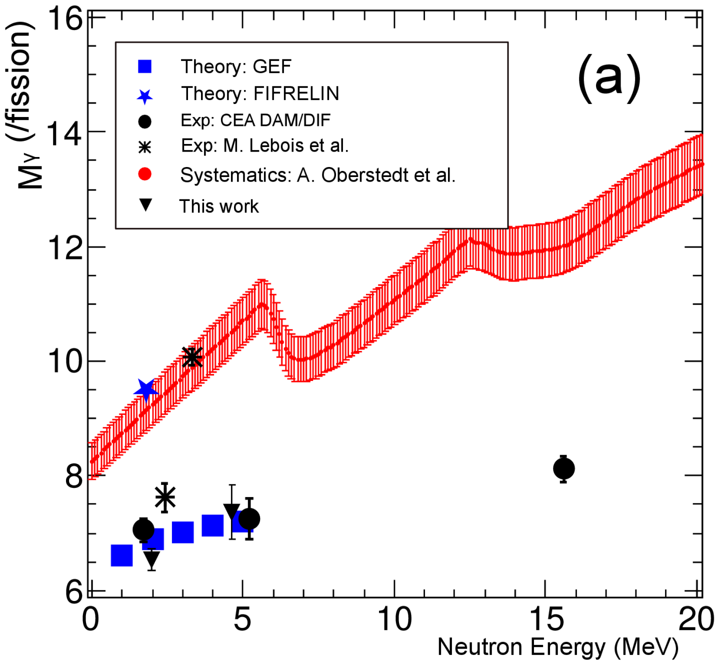


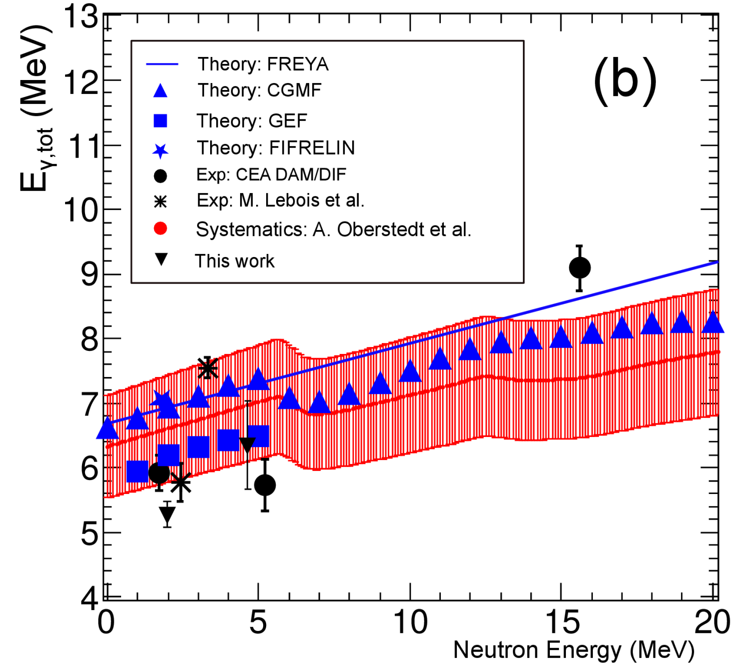
Figure: Internal comparison at different excitation energy.

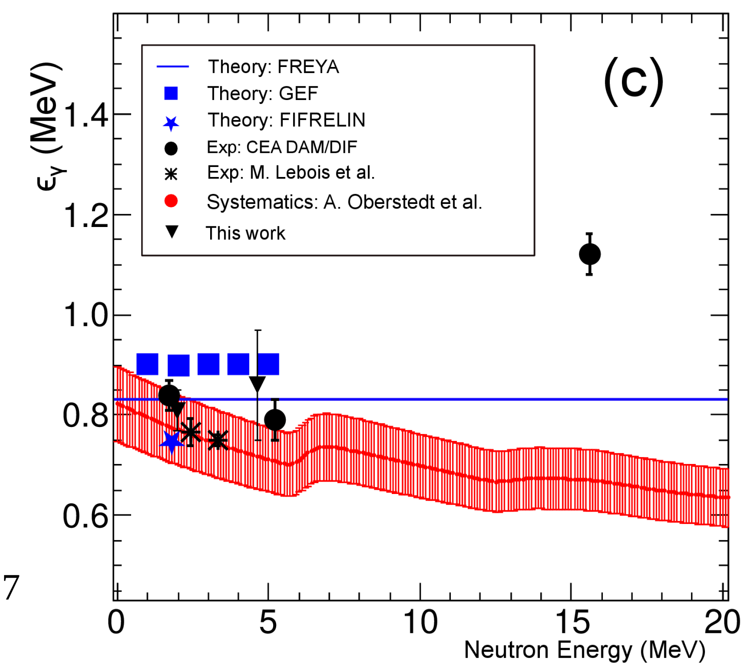
→ The slope change indicated the excitation energy partition, while not obvious in the GEF code calculation

→ Also confirms the idea that excess excitation energy is evacuated mainly by neutron evaporation instead of gamma emission.

Results and Discussions







→ Large discrepancy is observed, especially In terms of the gamma multiplicity;

Conclusions

1. ^{238}U(n, f) is not the origin of the underestimation of gamma heating in reactors;

2. Theory models need to be refined according to the discrepancy appearing in the ^{239}U* fissioning system;

3. Further physical interpretation is still undergoing.

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Thank you for your attention