EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Addendum to the Proposal INTC-P-507 for the ISOLDE and Neutron Time-of-Flight Committee

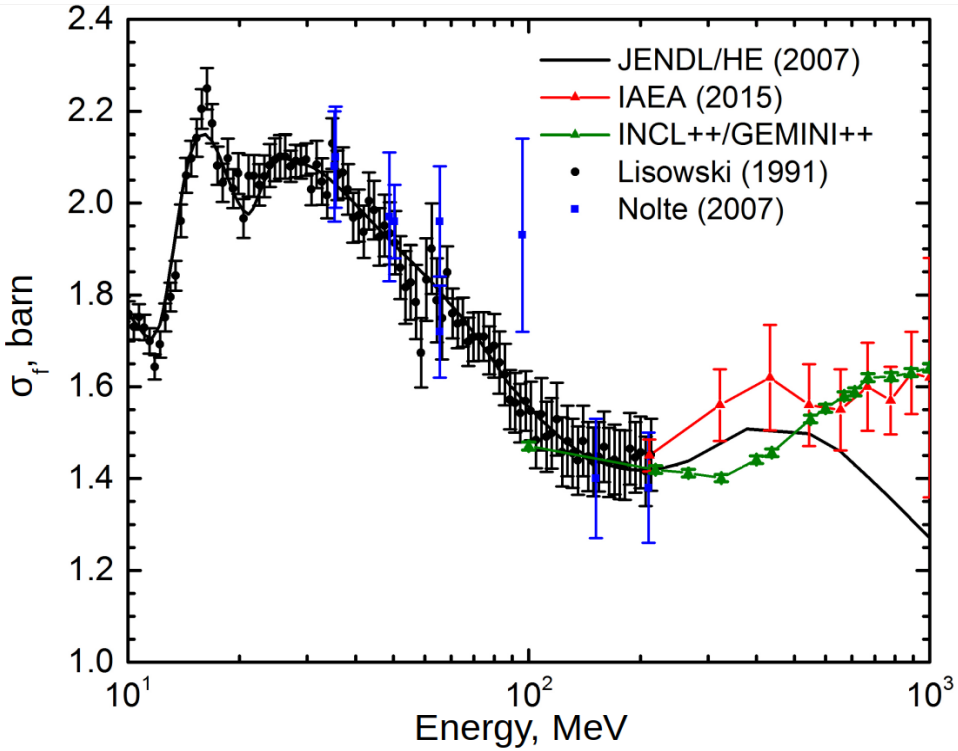
Measurement of the ^{235}U(n,f) cross section relative to n-p scattering up to 1 GeV

January 7, 2024

L. Audouin[1], N. Colonna[2], L. Cosentino[2], M. Diakaki[3], I. Duran[4], P. Finocchiaro[2], J. Heyse[5], C. Le Naour[1], A. Manna[2,6], C. Massimi[2,6], P.F. Mastinu[2], A. Mengoni[2,7,8], P.M. Milazzo[2], A. Musumarra[2,9], C. Paradela[5], E. Pirovano[10], P. Schillebeeckx[5], L. Tassan-Got[1], G. Vannini[2,6], A. Ventura[2], and the n_TOF Collaboration

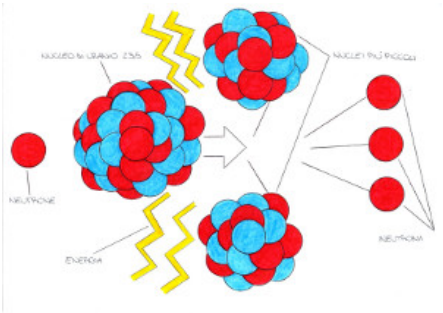
^{235}U(n,f) cross section

Dynamic effects of the nuclear fission process

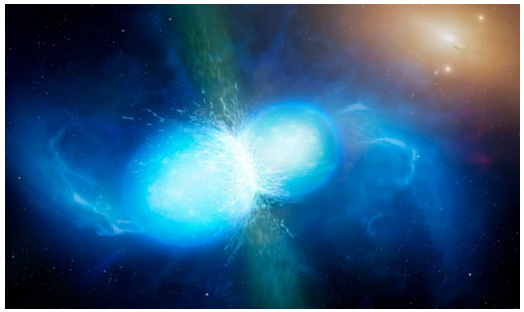


Collective Single particle degrees of freedom in nuclei

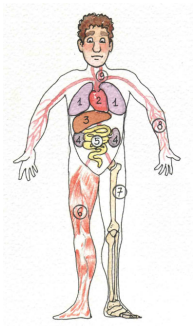
Nuclear Physics

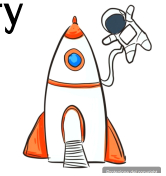


Nuclear Astrophysics

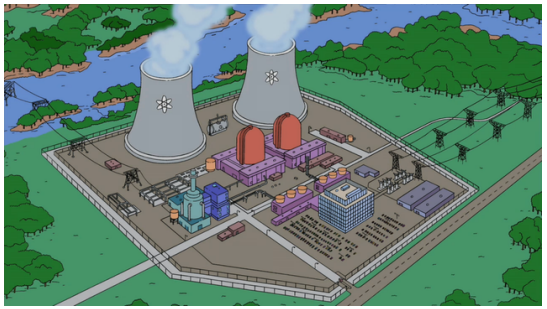


Dosimetry



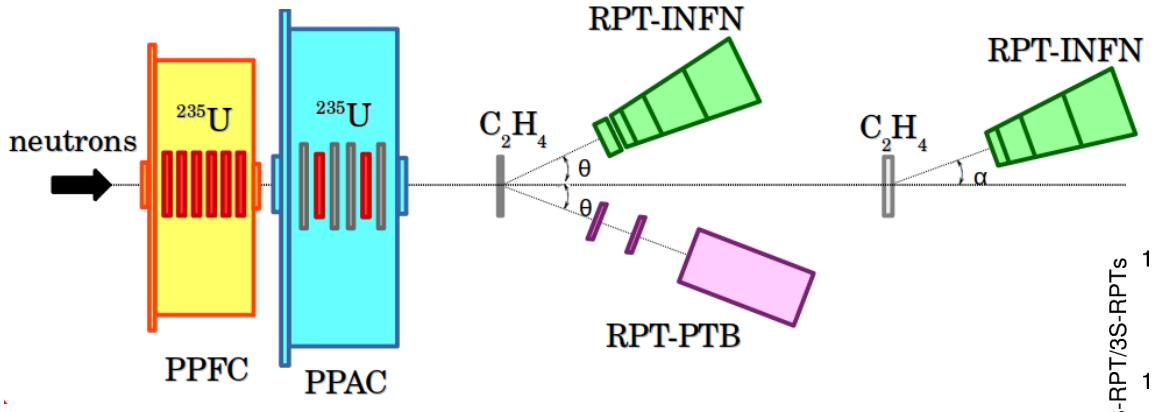


Reactor technology



Proposal 2017

Requested protons: 4×10^{18} protons on target
Experimental Area: EAR1



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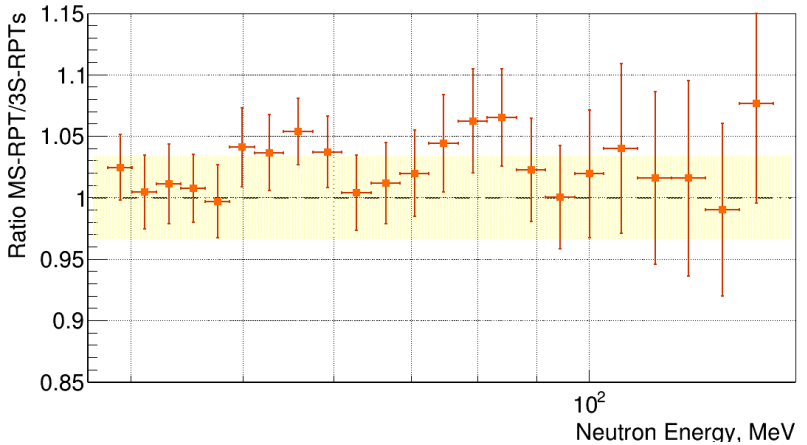
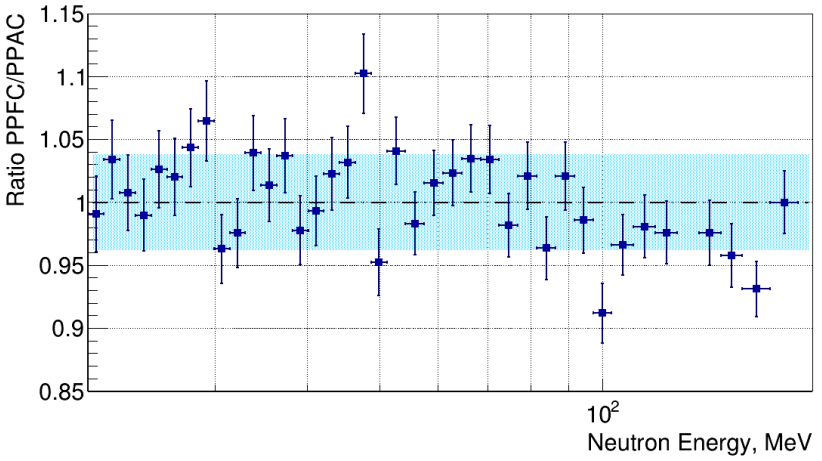
May 06, 2017

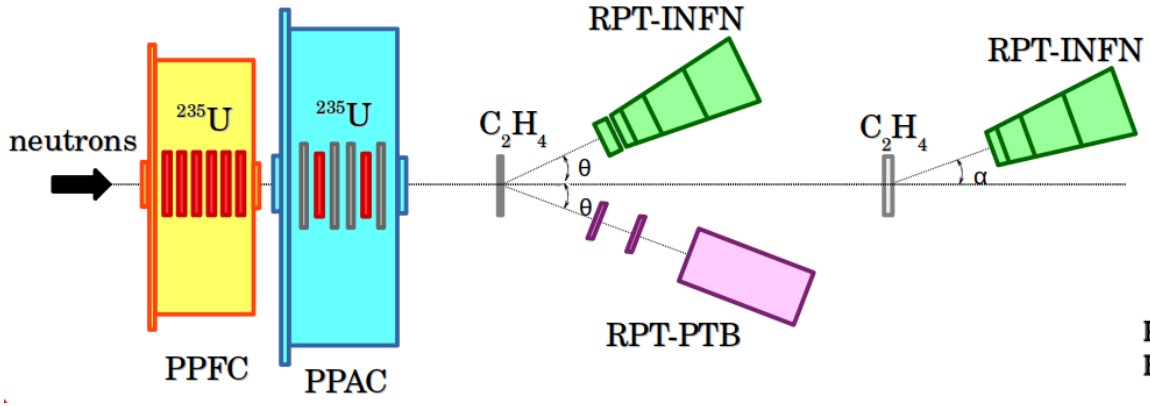
Sample	PPFC		PPAC	
	# Protons (pot)	Running time	# Protons (pot)	Running time
^{235}U	3.387×10^{18}	35 days	3.83×10^{18}	40 days

Sample	RPTs at 25°		RPT at 20°	
	# Protons (pot)	Running time	# Protons (pot)	Running time
C_2H_4 - 1 mm	7.08×10^{17}	7 days	-	-
C - 0.5 mm	3.27×10^{17}	3.5 days	-	-
C_2H_4 - 2 mm	1.11×10^{18}	11 days	-	-
C - 1 mm	3.88×10^{17}	4 days	-	-
C_2H_4 - 5 mm	7.44×10^{17}	8 days	2.07×10^{18}	20 days
C - 2.5 mm	3.14×10^{17}	3.5 days	1.55×10^{18}	16 days
Sample Out	1.48×10^{17}	1.5 days	2.23×10^{17}	2.5 days
Beam Off	-	0.25 days	-	0.25 days





The obtained result



Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of the ^{235}U(n,f) cross section relative to n-p scattering up to 1 GeV

May 06, 2017

Requested protons: 4×10^{18} protons on target
Experimental Area: EAR1

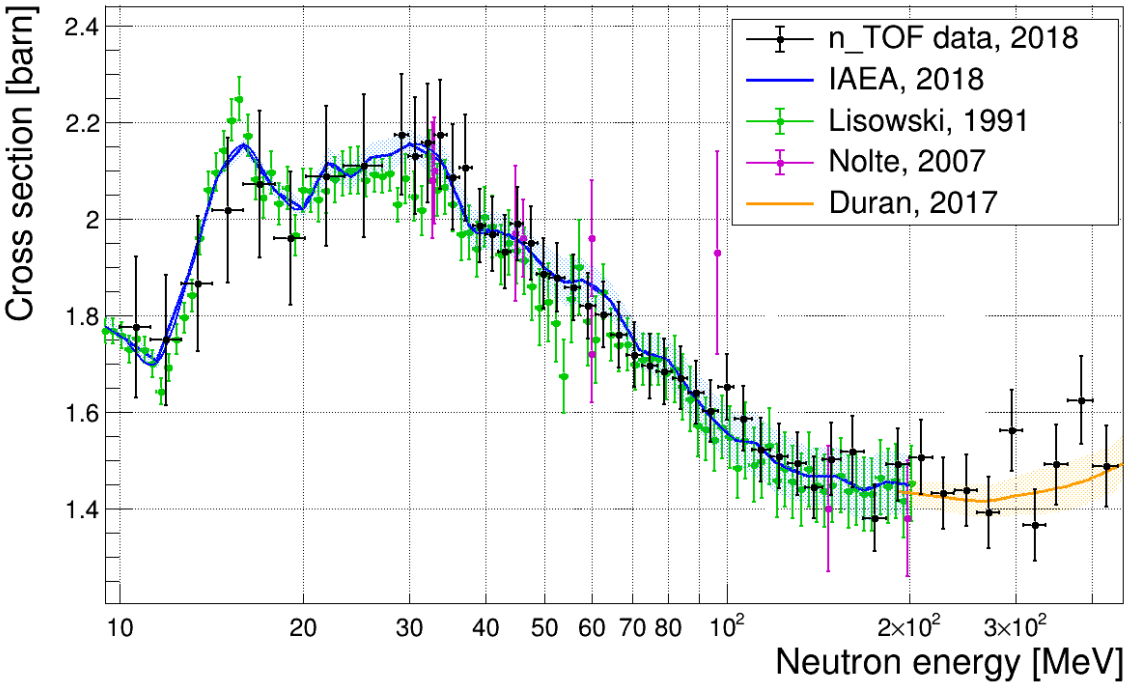
The **limitation** of the 2018 measurement:

maximal energy: 425 MeV

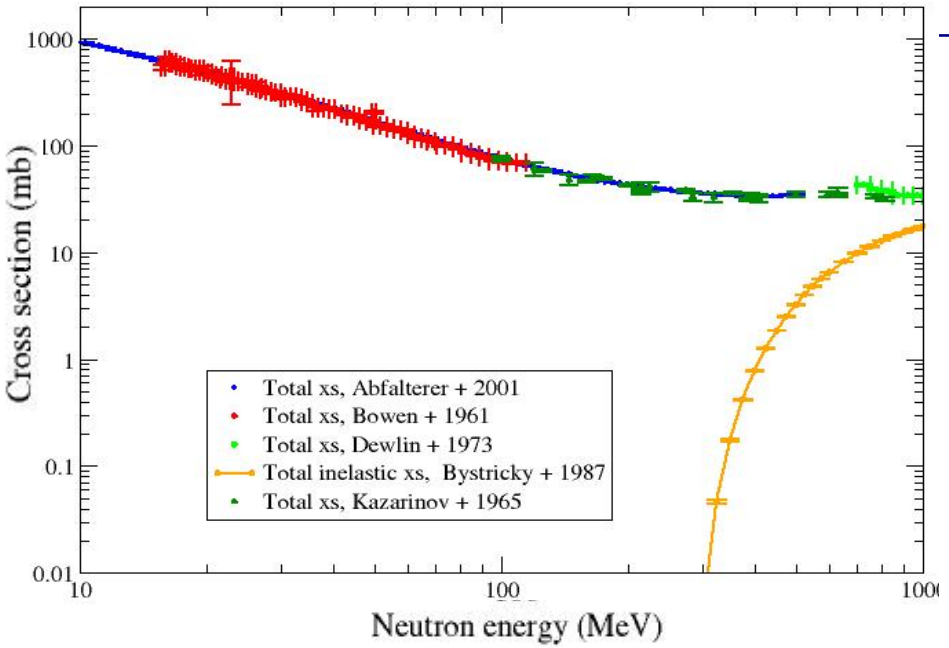
opening of the inelastic channel in the n-p scattering

above 150 MeV statistical fluctuation

when only PPAC and RPT-INFN work



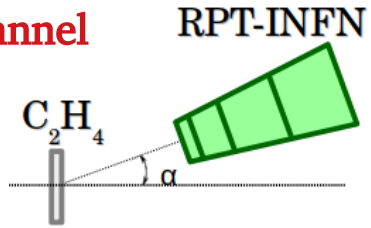
The inelastic scattering



From ~ 300 MeV:

opening of the inelastic channel

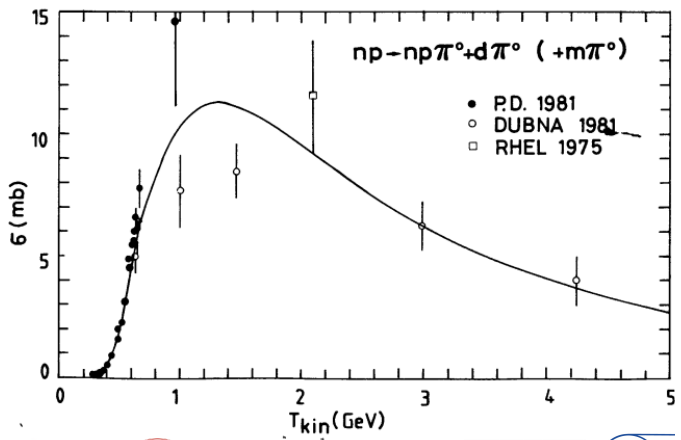
$$n + p \rightarrow N + N + \pi$$

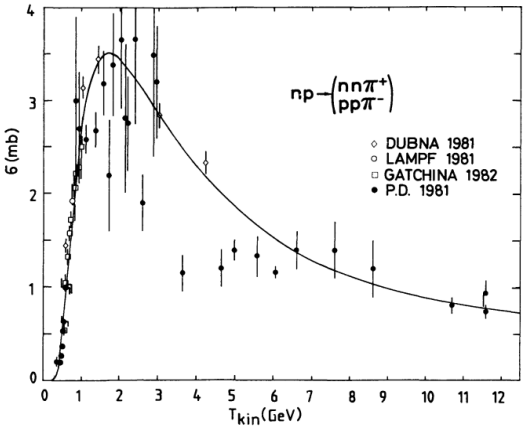


How we correct for it:

- calculate the angular distribution considering the boost effect

- simulate the proton energy distribution - 3-body

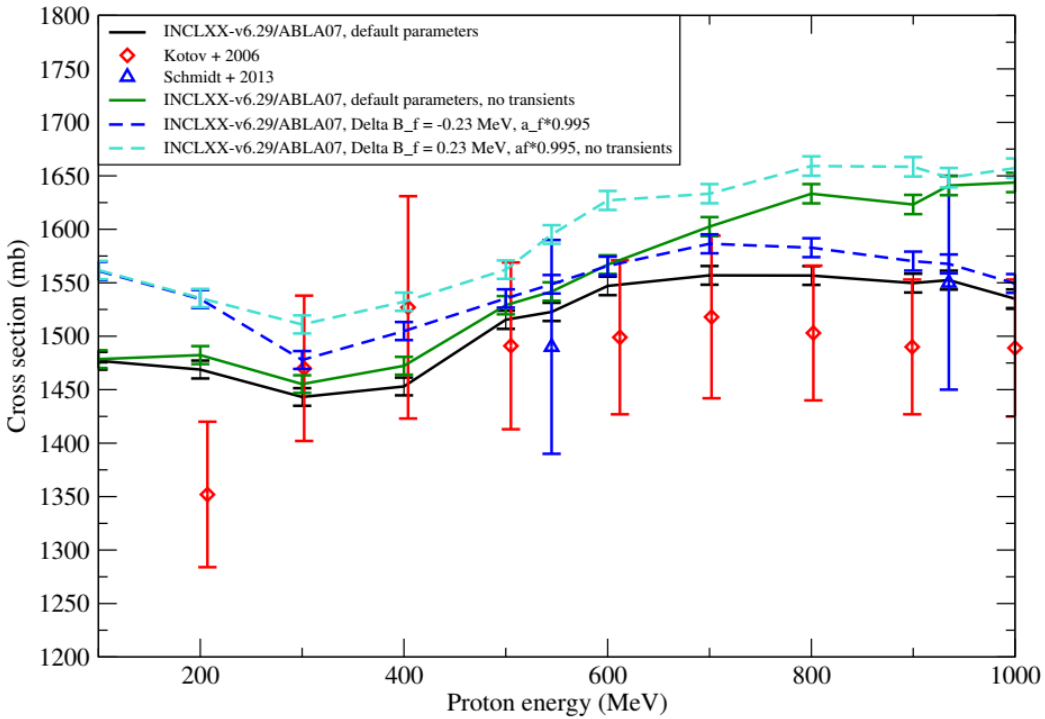




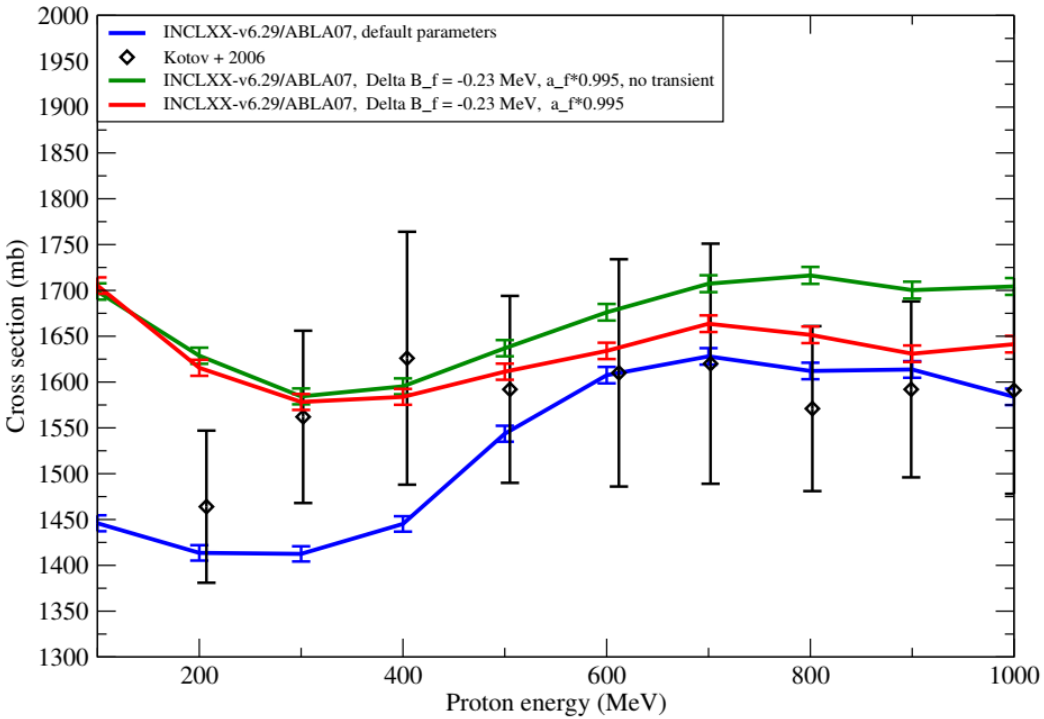
En, MeV	corr, % - 20°	corr, % - 25°
300	0.0	0.0
350	0.0	0.0
400	0.9	0.0
425	3.1	0.8
450	6.4	2.7
475	11.4	5.9
500	18.5	10.7

Why fission at high energy

$^{238}U(p,f)$



$^{235}U(p,f)$



the dynamics of the process + intrinsic and collective excitations

→ influences the fission probability and the evolution

→ a fission hindrance

transient time

A new neutron detector

A detector able to descriminate:

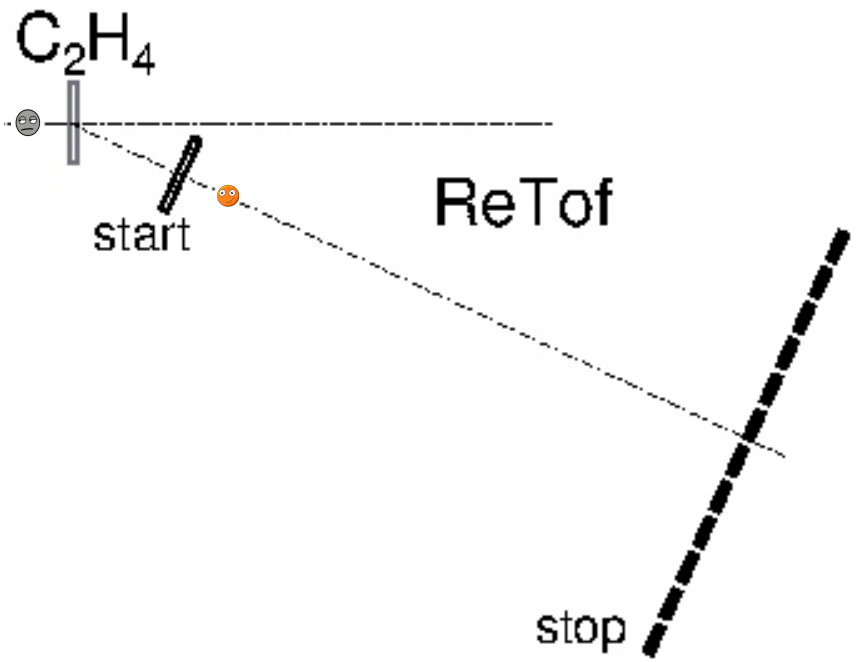
- protons from: $n + p \rightarrow n + p$
- protons from: $n + p \rightarrow n + p + \pi^0$ m(π) = 139.6 MeV/c

$n + p \rightarrow p + p + \pi^-$

Collaboration with CEA
(Julien Taieb and collaborators)

The Re-TOF telescope

neutron TOF **Re**lated to proton **TOF**



Least-favourable scenario:

1 GeV neutron

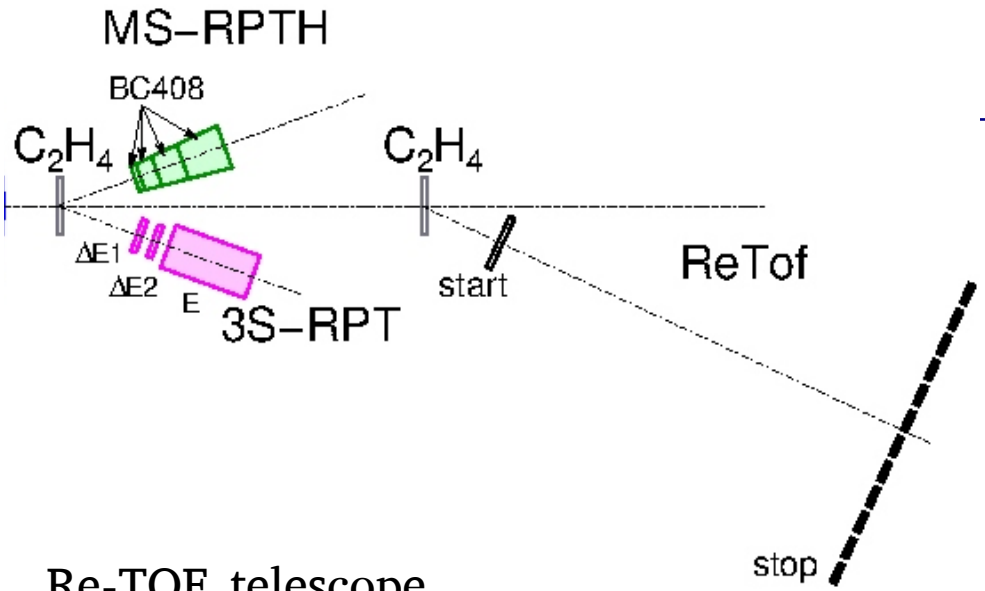
the nucleons take the full kinetic energy after creation of the pion

Δt (elastic - inelastic protons) = 440 ps

Time resolution of 300 ps

- a start detector : plastic scintillator
- a stop detector: a plastic scintillator "wall"
  2 m far from the start- 60 x 60 cm²
  divided in 20 bars – 3 cm each
  coupled with 2 PMT – 1 PMT at each side of the bars

Re-TOF detector test



Re-TOF telescope

@25° wrt the neutron beam direction,

facing a PE sample at ~20 cm.

+ a RPT used in the 2018 experimental campaign

$7 \cdot 10^{17}$ proton on target

- Response to the γ-flash

- Time resolution in EAR-1

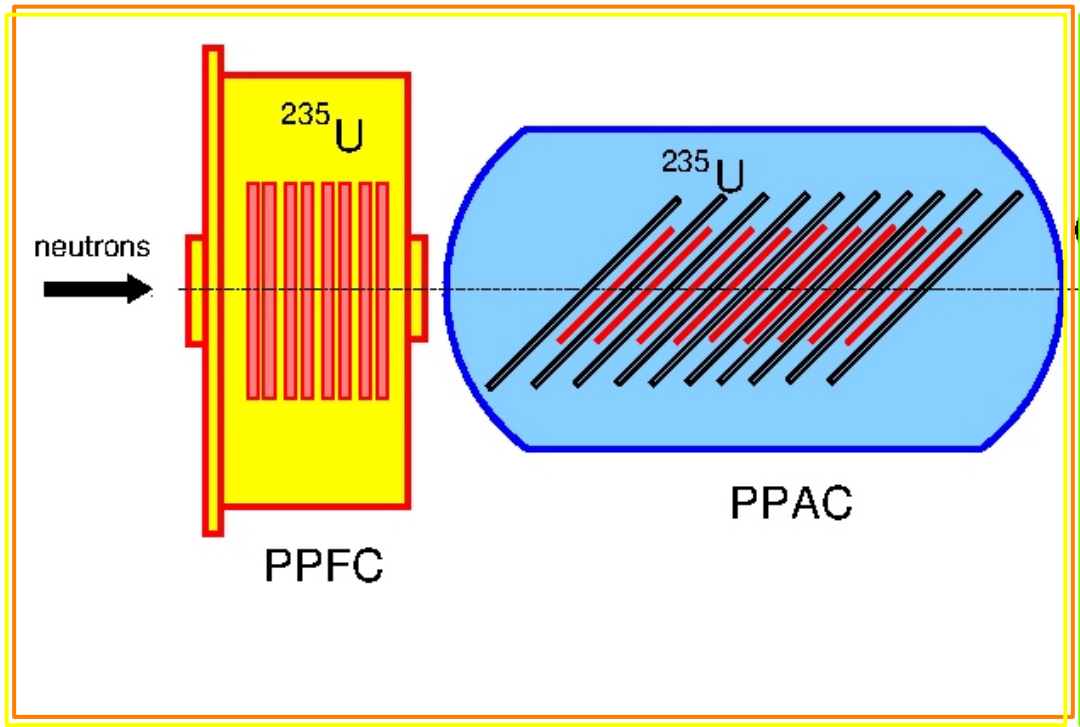
combining
neutron Time Of Flight and
the proton Time Of Flight information

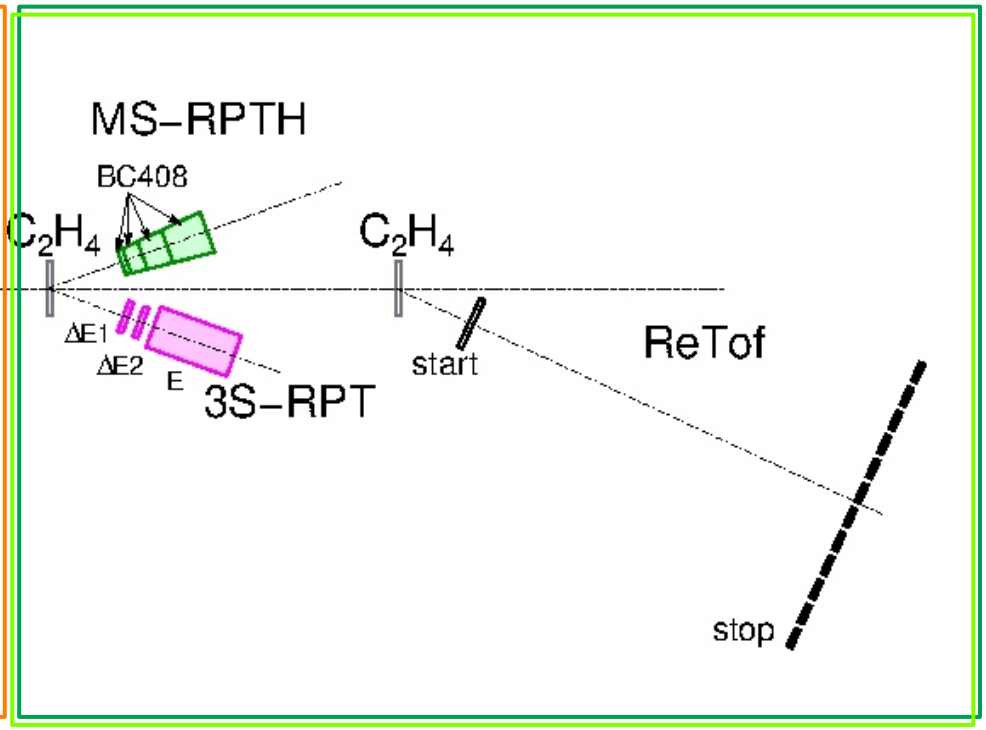
Verify:

the elastic and inelastic proton discrimination

the possibility to discriminate $^{12}C(n,lcp)$ products

The complete setup





Fission events

PPAC: 10 PPAC and 9 ^{235}U samples

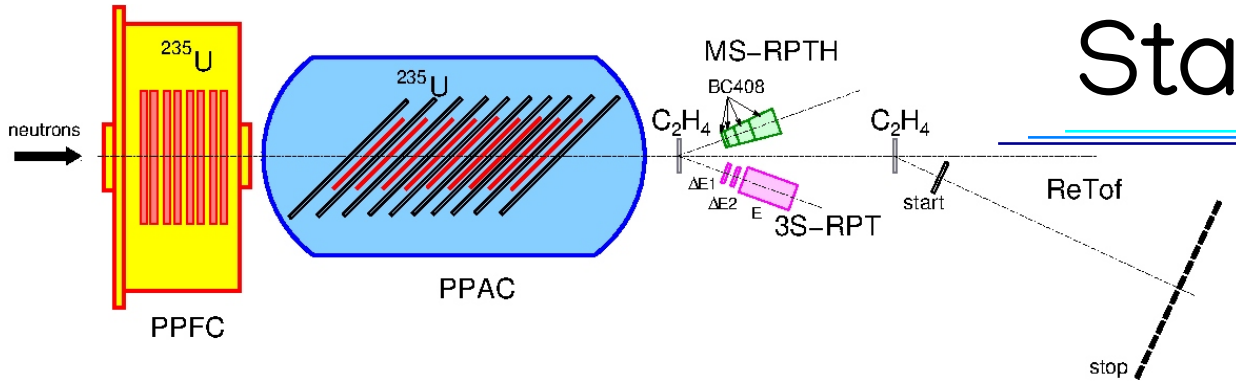
PPFC: 8 ^{235}U samples

Neutron flux

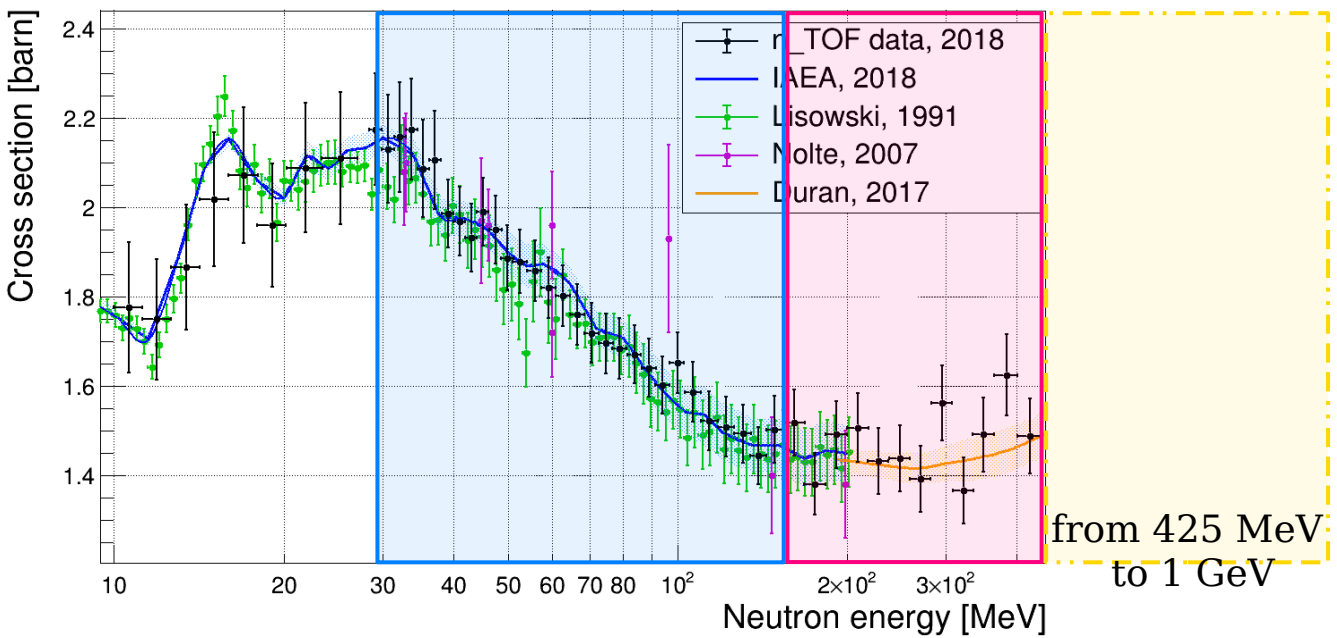
Re-TOF: pointing PE sample – 25° wrt neutron beam

1 or 2 RPT used in 2018 for the lower energy region + benchmark

Statistical uncertainty



4·10¹⁸ proton on target for the measurement



from 425 MeV to 1 GeV

The **limitation** of the 2018 measurement:

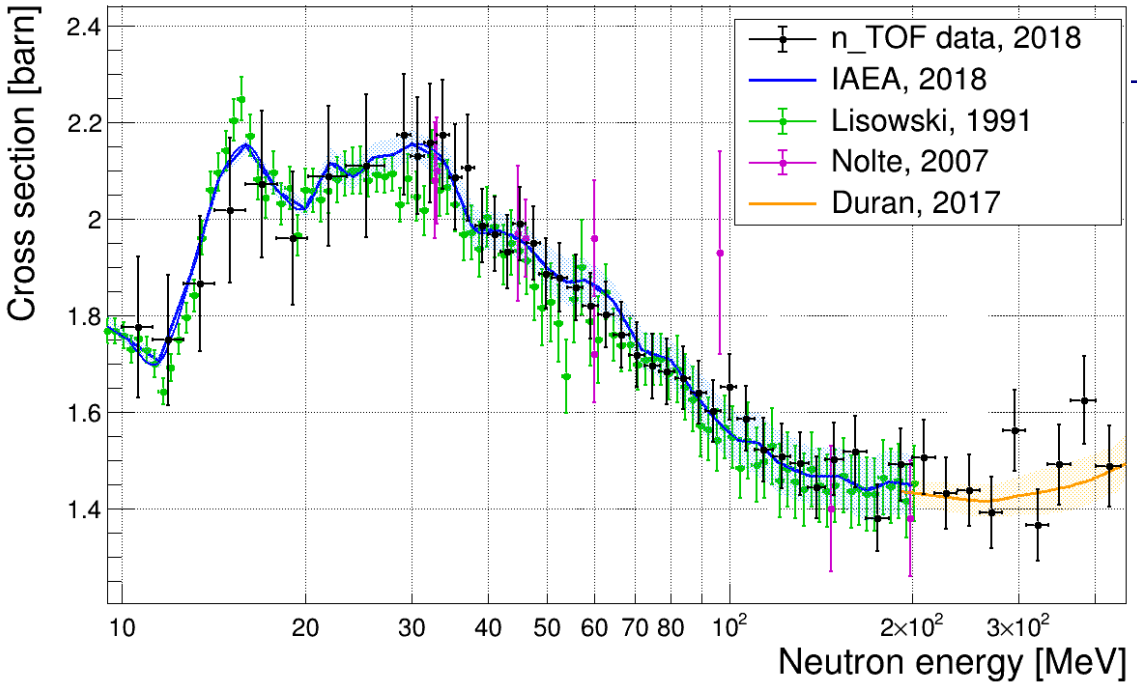
Statistics above 150 MeV

up to 3.8 % statistical uncertainty

up to 5.7 % total uncertainty

2018 measurement	2.0% to 2.7%	2.9% to 3.8%	2.7% to ~ 5%
This addendum	1.7% to 2.2%	2% to 2.7%	

Beam request



EAR-1 capture collimator

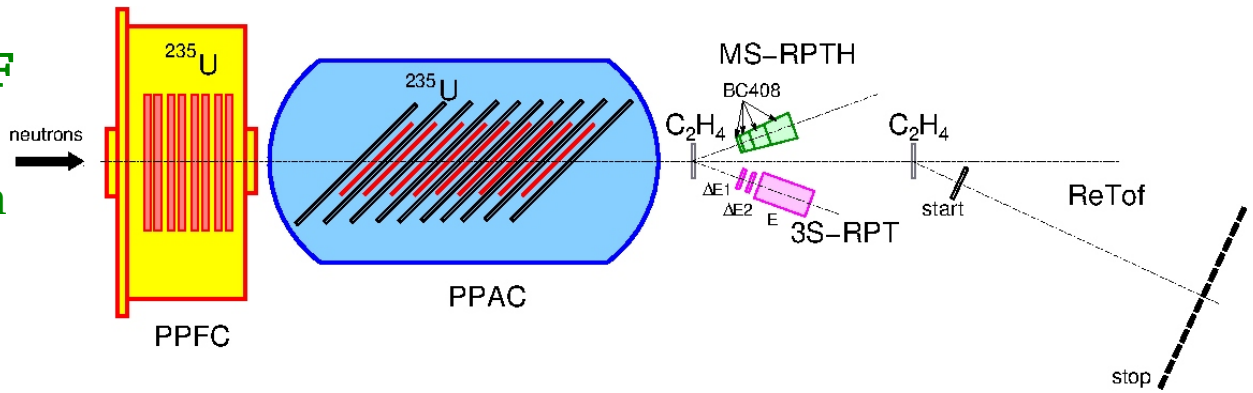
$7\cdot10^{17}$ proton on target for the detector test

$4\cdot10^{18}$ proton on target for the measurement

The **limitation** of the 2018 measurement:

maximal energy: 425 MeV → **Re-TOF**

above 150 MeV statistical fluctuation
→ increase the ^{235}U samples
+
Re-TOF



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Thank you for your attention

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