

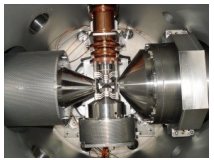
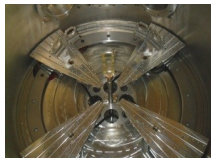

WONDER-2023

Study of (n,α) reactions of interest for nuclear reactors: The SCALP Project

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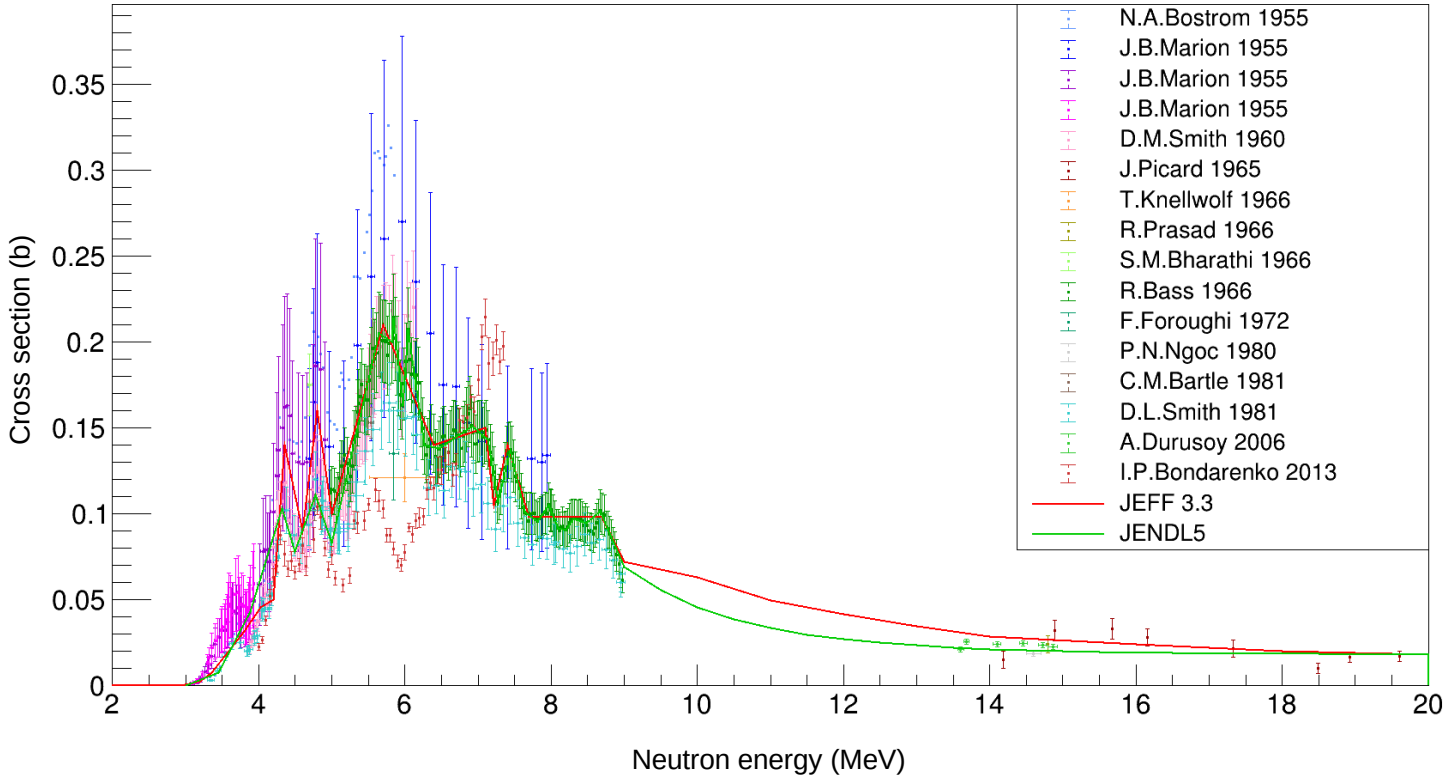
Motivations and scientific context

$^{19}F(n,\alpha)^{16}N$

- Large discrepancies between data sets (up to a factor 3) (EXFOR library)
- Potential use of ^{19}F in molten salt reactors:
  → Uncertainty on k_{eff} (up to ~200 pcm) (JEFF4 meeting - 2023)
- Interests for theory/evaluation :
  → Resonnance parameters (CONRAD/SAMMY)

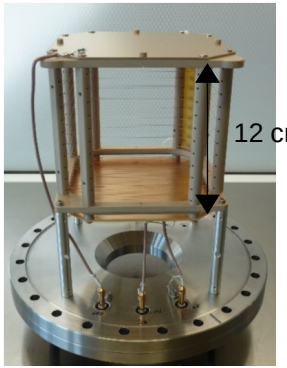


Experimental setup: SCALP

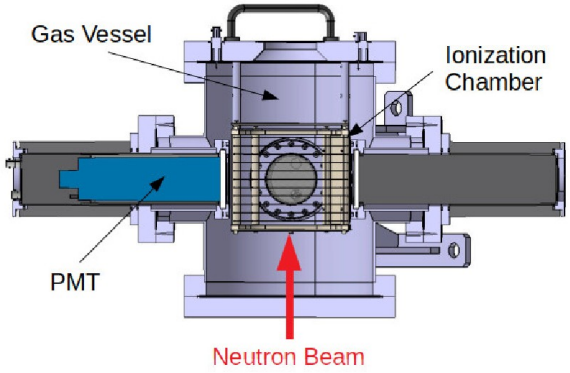
SCALP = Scintillating ionization **C**hamber for **ALP**ha particle detection in neutron induced reactions

4 photomultipliers (PMTs) → Measurement of neutron time of flight with good resolution

1 ionization chamber (IC) → Measurement of deposited energy



drift chamber



Detector resolutions measured with alpha sources:

gas	CF_4
IC energy resolution	150 keV (1σ)
PMTs time resolution	250 ps (1σ)

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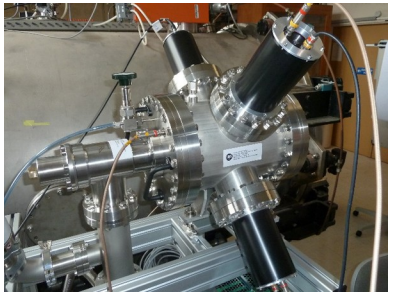
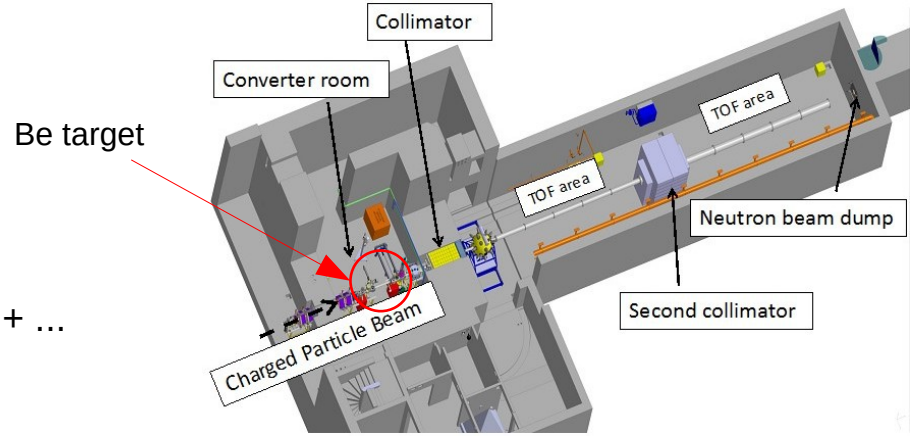
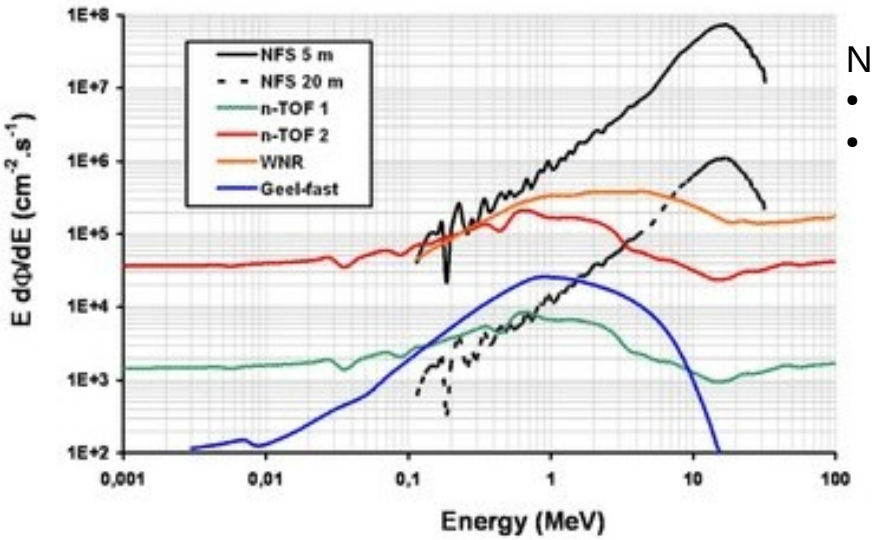

SCALP Detector

Neutron production at Spiral2 NFS (GANIL)

Spiral2 → LINAG accelerator
LINAG frequency: 88 MHz
Beam intensity: up to 5 mA
Beam energy: up to 40 MeV

Neutron production at NFS (Neutron For Science) : d + Be → n + ...
NFS → Neutron line with a TOF area





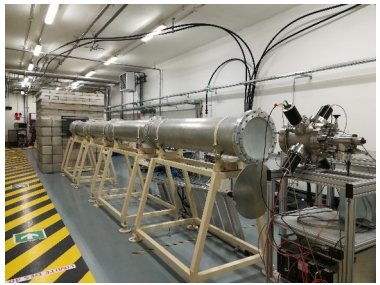
NFS specific properties:
- Limited γ flash
- Well adapted between 1 and 40 MeV

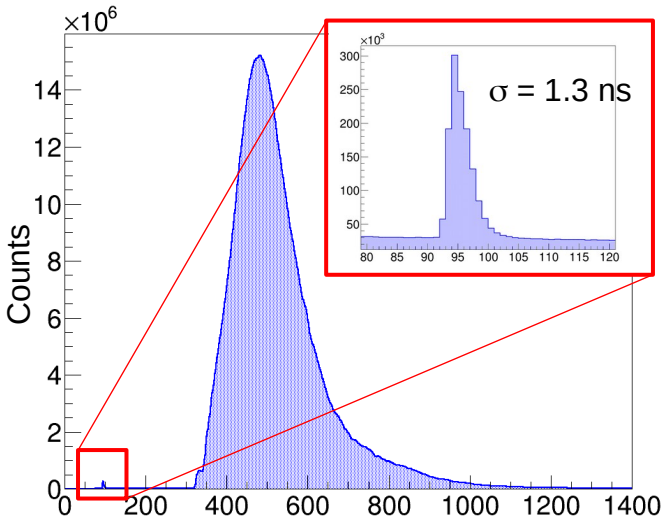
NFS Parameters	Maximum	Used
Chopper	1/100	1/120
Beam intensity	50 µA	7.5 µA
Flight distance	30 m	28 m

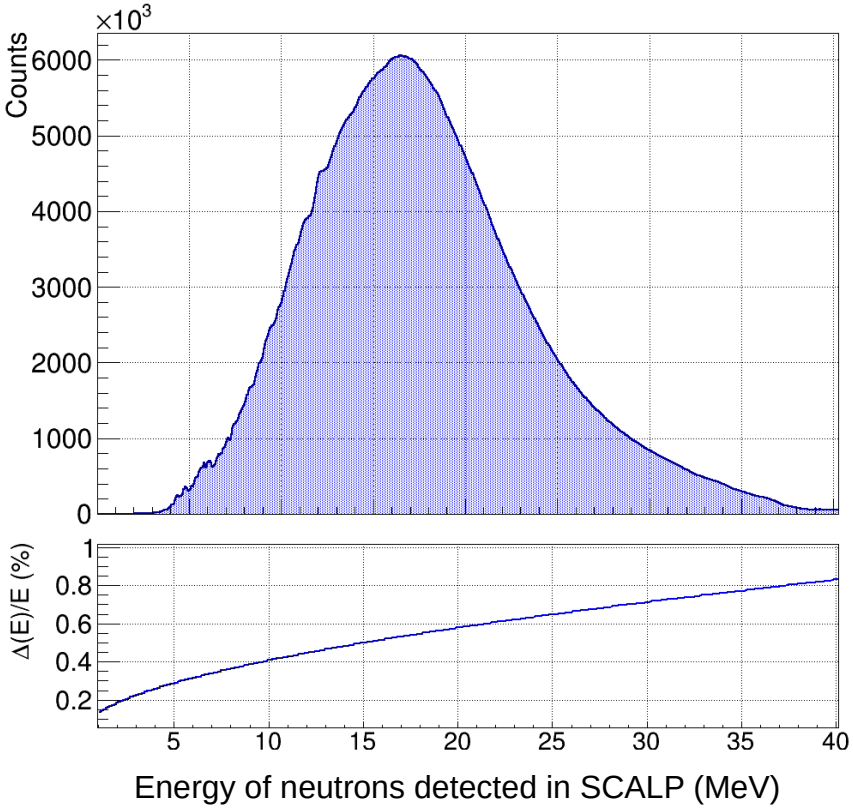
First SCALP experiment at NFS

$$tof = t_{PMt} - t_{HF}$$

Time of flight PMt time HF time





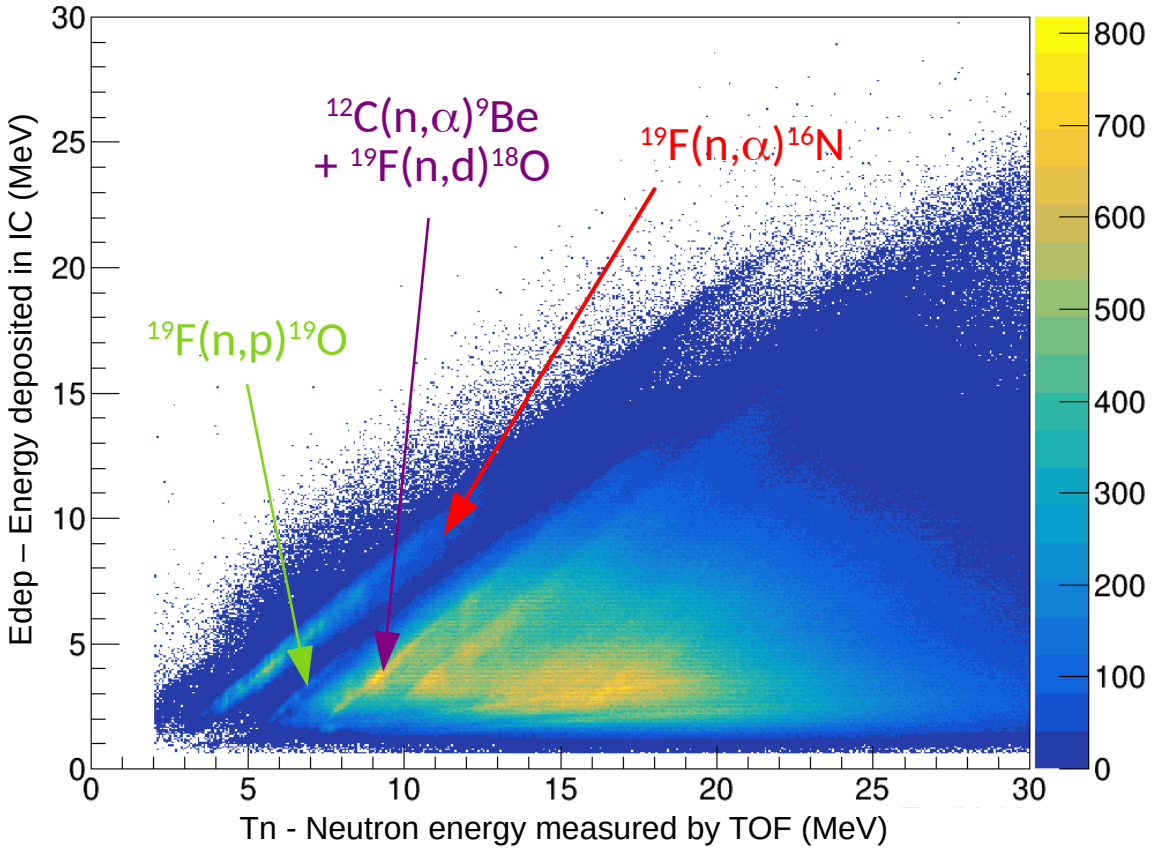


Identification matrix

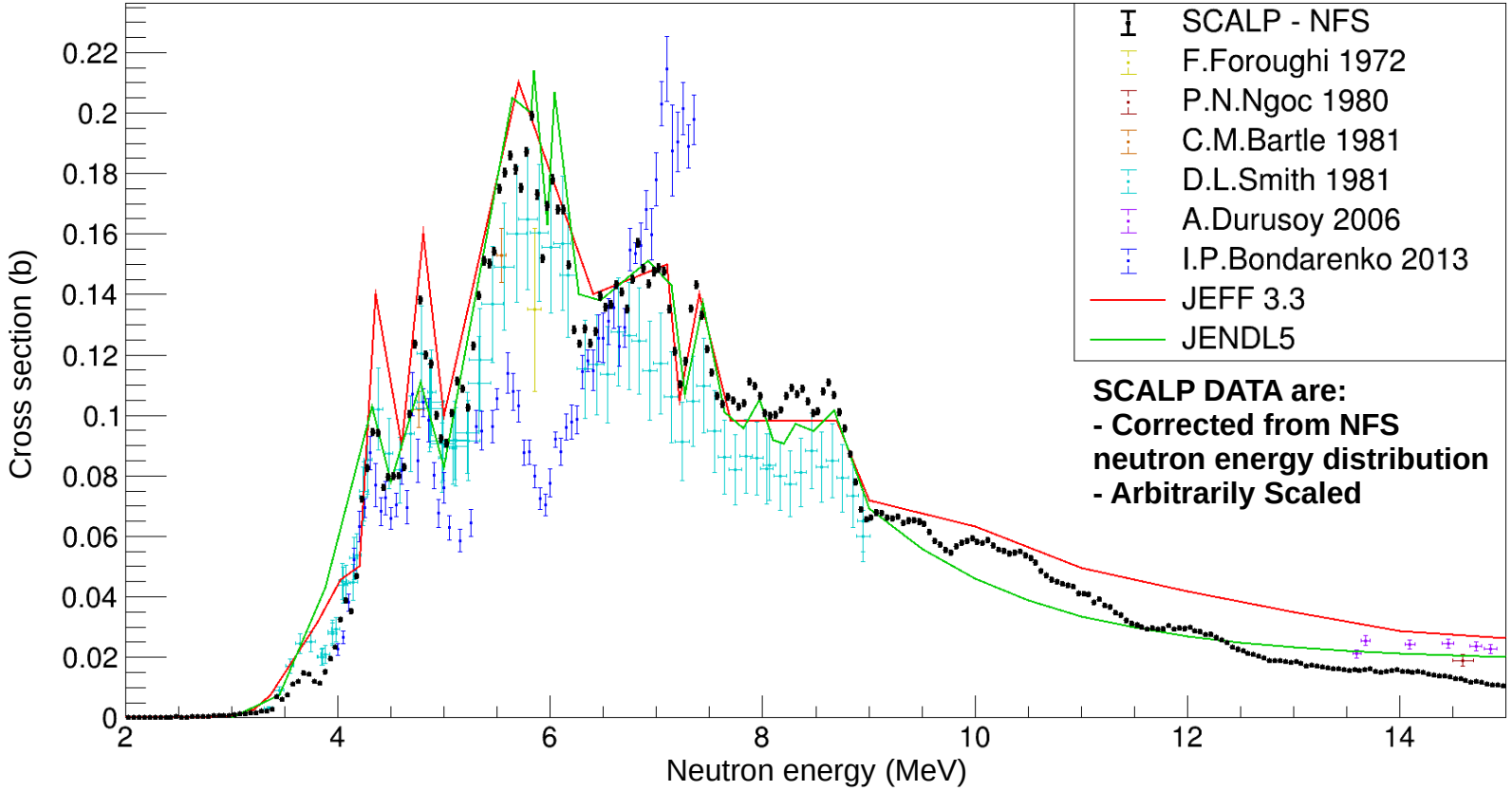
For 2-body kinetics:

$$E_{dep} = T_n + Q$$

	Q (MeV)	$E_{threshold}$ (MeV)
^{19}F(n,α)^{16}N	**-1,52**	**1,61**
^{19}F(n,p)^{19}O	-4,04	4,25
^{19}F(n,d)^{18}O	-5,76	6,08
^{12}C(n,α)^{9}Be	-5,70	6,18
^{19}F(n,t)^{17}O	-7,56	7,96

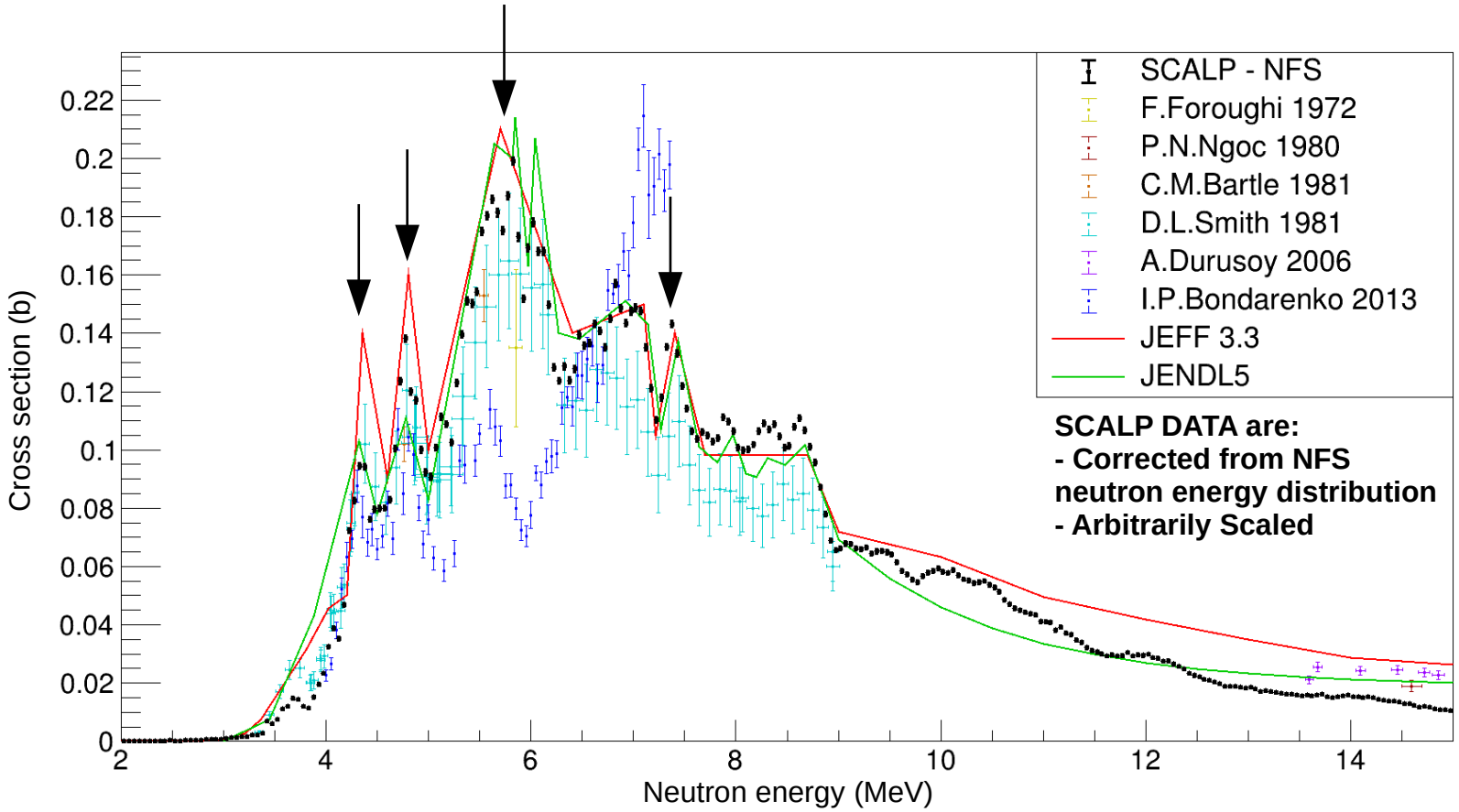


$^{19}F(n,\alpha)^{16}N$: comparison with some previous works



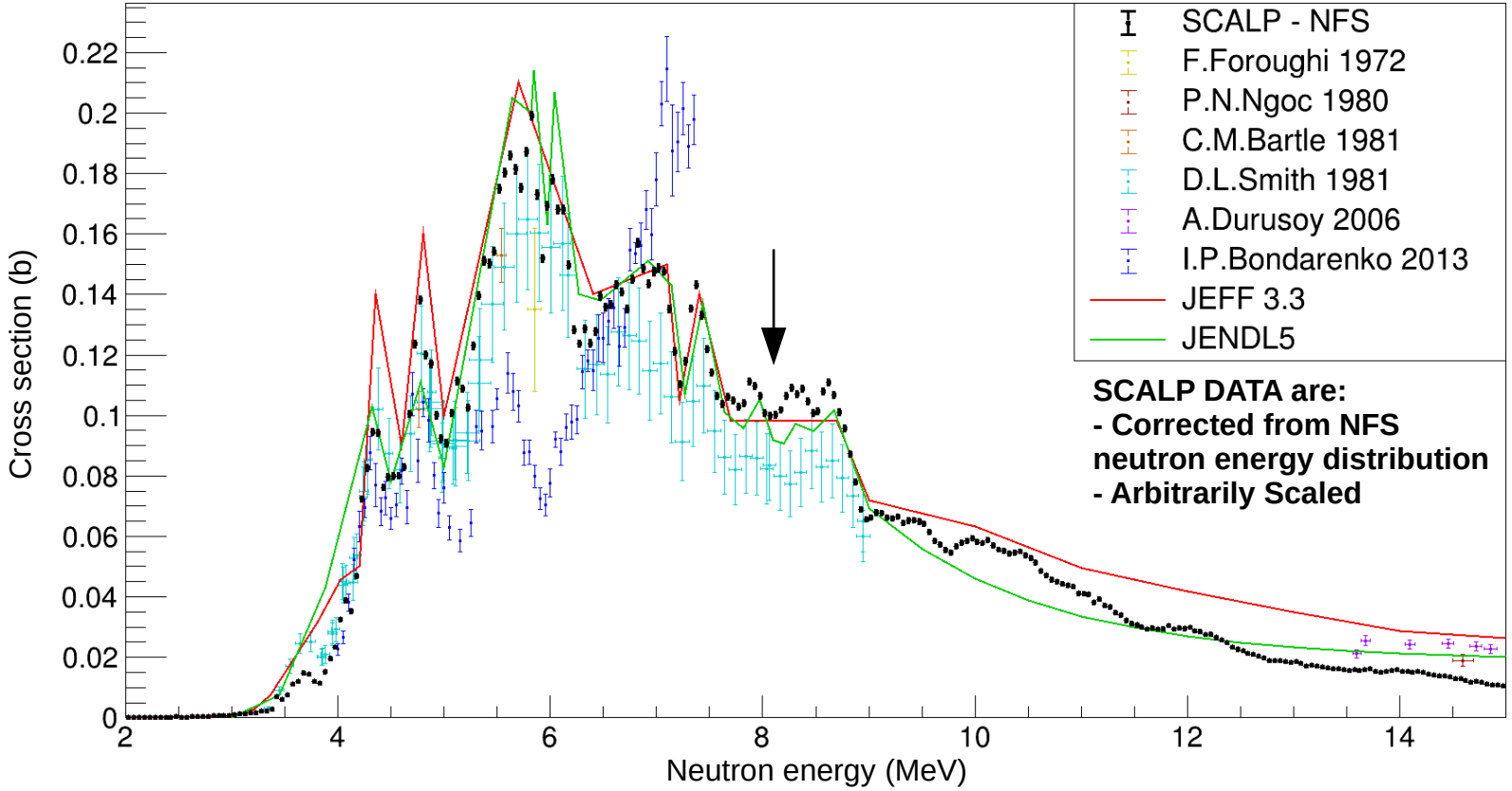
PRELIMINARY

$^{19}F(n,\alpha)^{16}N$: comparison with some previous works



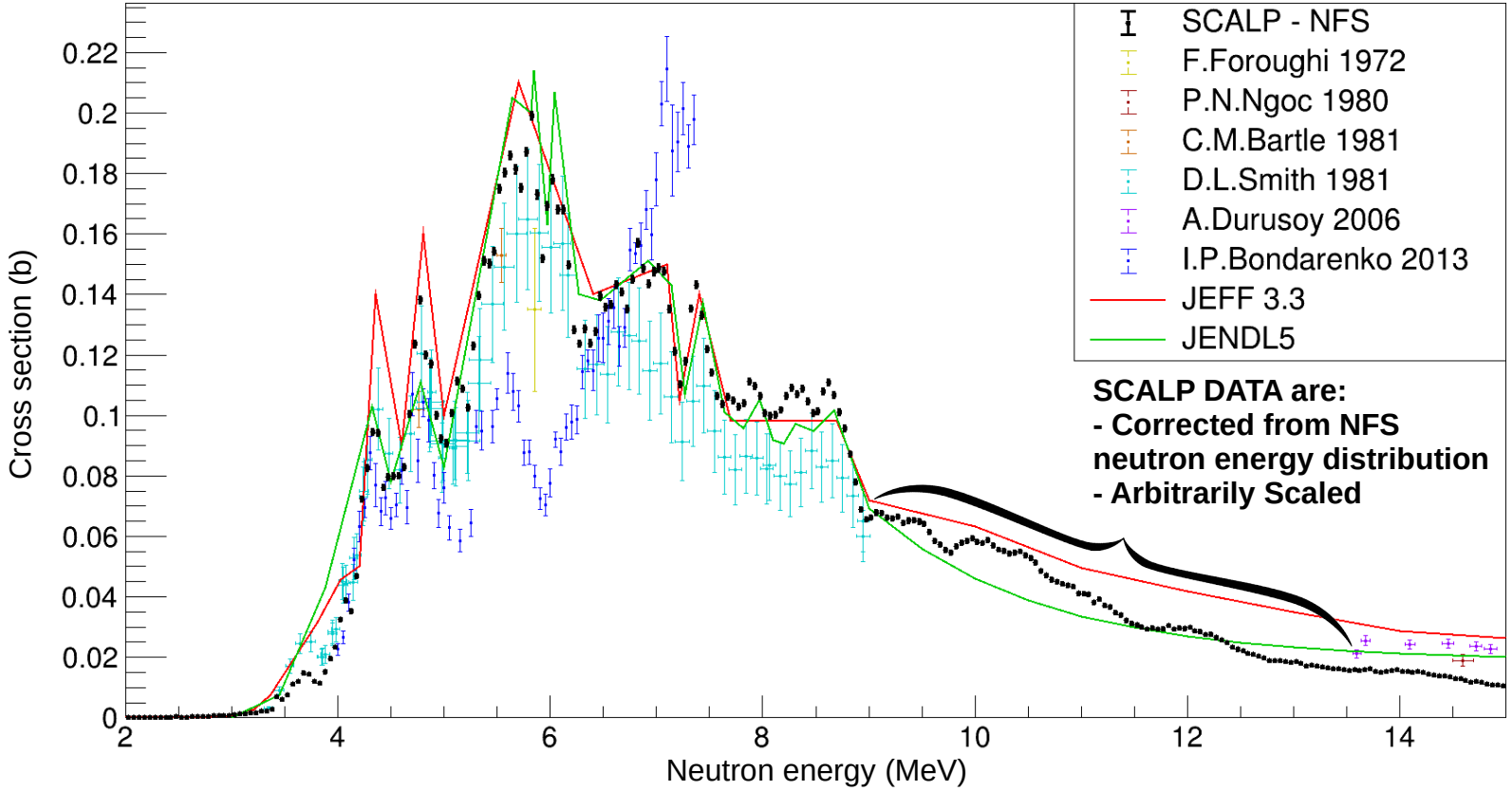
PRELIMINARY

$^{19}F(n,\alpha)^{16}N$: comparison with some previous works



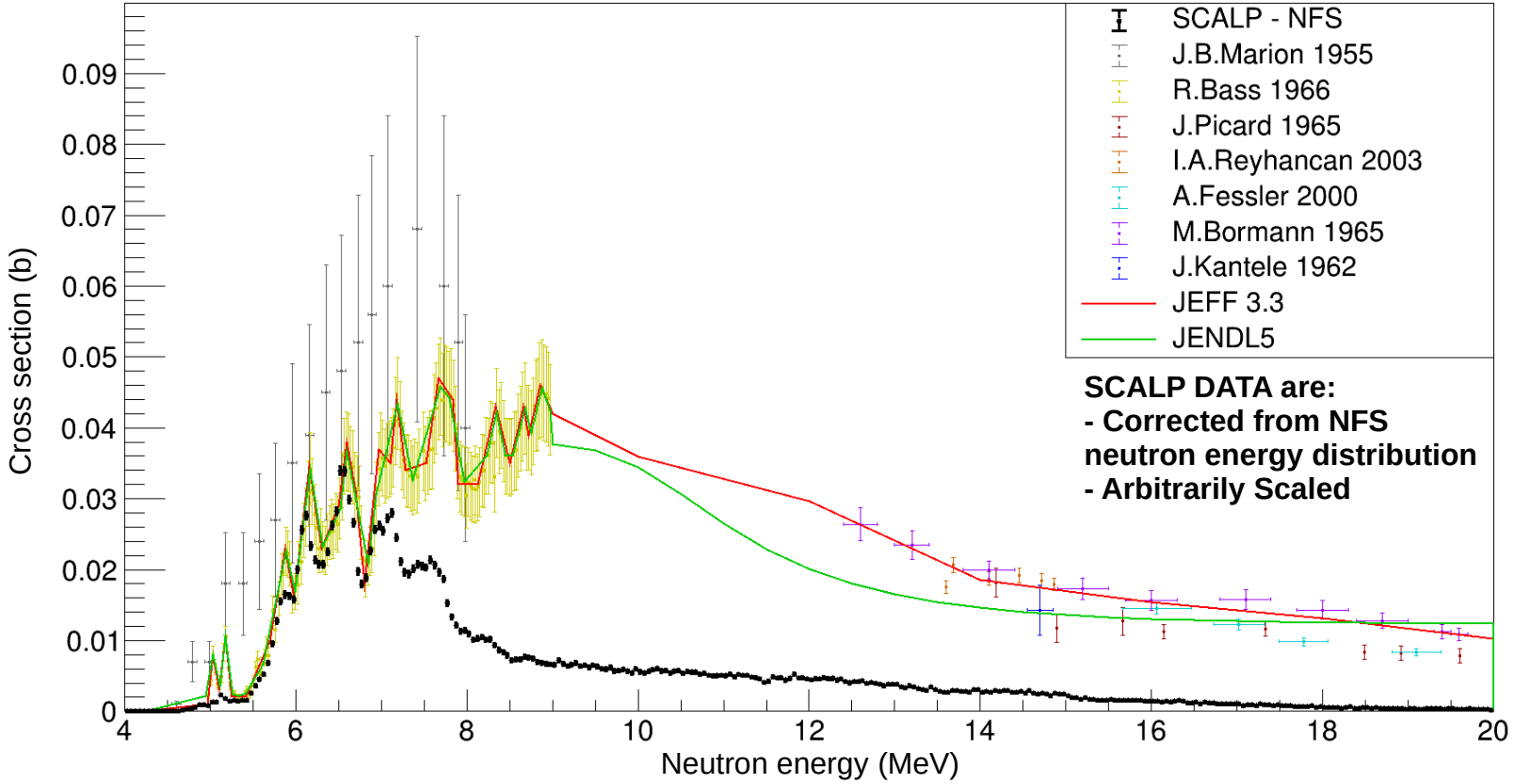
PRELIMINARY

$^{19}F(n,\alpha)^{16}N$: comparison with some previous works



PRELIMINARY

By-product: the case of $^{19}F(n,p)^{19}O$



PRELIMINARY

Conclusions

Some (n,α) cross sections of interest for nuclear reactors exhibit large uncertainties
→ new measurements of $^{19}F(n,\alpha)^{16}N$ cross-sections needed
→ SCALP: a new scintillating ionization chamber filled with CF_4
→ new experiments performed at SPIRAL2-NFS

Data analysis of $^{19}F(n,\alpha)^{16}N$ and $^{19}F(n,p)^{19}O$ cross section measurements is on-going:

- Reaction channels well separated from other reactions
- For $^{19}F(n,\alpha)^{16}N$ energy dependent cross-sections:
  - Some structures observed in SCALP data as those present in previous works
  - Structures in agreement with the latest evaluations
  - First cross section measurements in some energy ranges

Future Work

Coming next:

- Complete simulations of the experiment to take into account detector response and perform a sensitivity analysis of SCALP data
- Absolute normalization of data taken at NFS (count → barn) using neutron monitors

- Analysis of the same experiment performed at nELBE (HZDR, Dresden)

SCALP can also be filled with a mixture of CF_4 and an another gas of interest for cross section measurement:

- Import reaction $^{16}O(n,\alpha)^{13}C$ (HPRL, NEA)
  → Experiments already performed with a gas mixture of CF_4 (97%) and CO_2 (3%) at NFS and nELBE

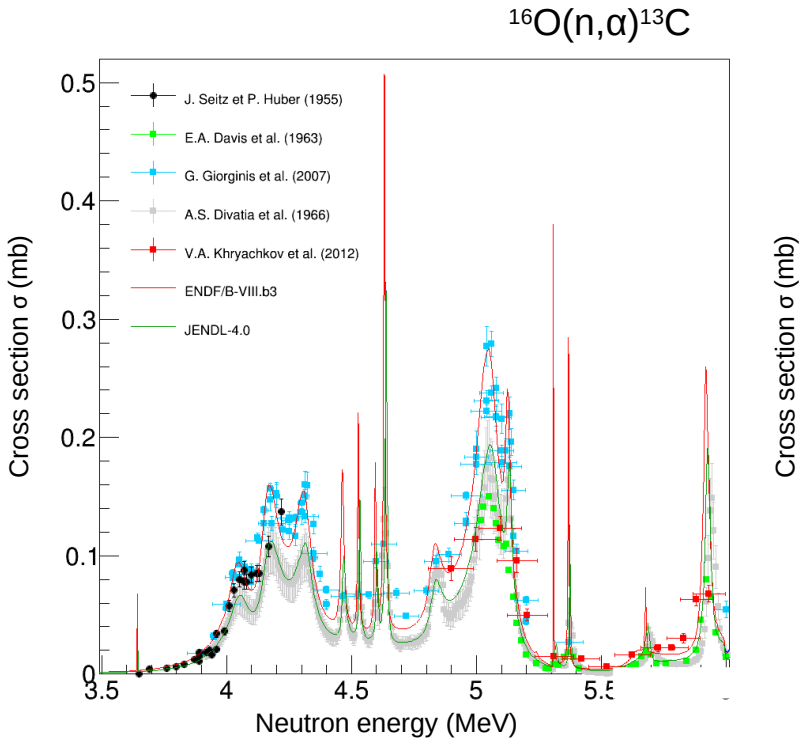
THANK YOU FOR YOUR ATTENTION

(n,α) cross sections on ^{16}O

$\sigma(^{16}O(n,\alpha)^{13}C)$

- (Re)measurement is important:
  - ➔ Large discrepancies (up to 30%)
  - ➔ NEA: HPRL & WPEC 26 (2005) & WPEC 40 (2015)

- Uncertainties on $\sigma(^{16}O(n,\alpha)^{13}C)$:
  - Sensitivity analysis (WPR, FR)
    - ➔ Uncertainty on helium formation in fuel (± 7%)
    - ➔ Uncertainty on k_{eff} (± 100 pcm)
    - ➔ …



Experimental setup: SCALP with CO_2

Resolutions measured with alpha source for 2 gas setup:

gas	CF_4	CF_4 (97 %) - CO_2 (3 %)
IC energy resolution	± 150 KeV	± 220 KeV
PMTs timing resolution	± 250 ps	± 700 ps

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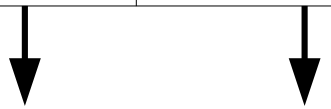
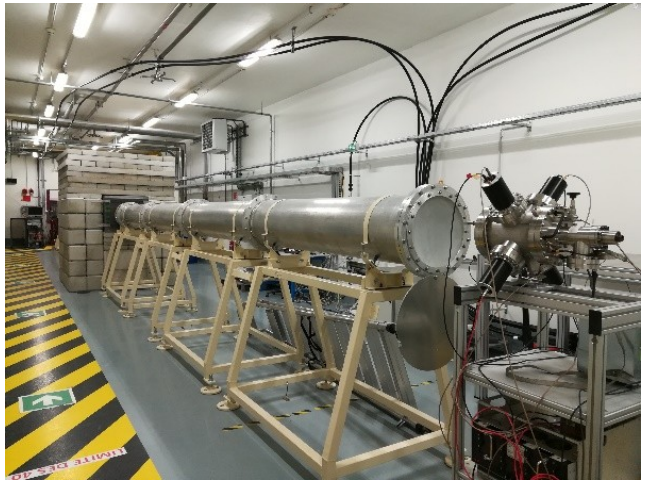


$\sigma(^{19}F(n,\alpha)^{16}N)$

$\sigma(^{19}F(n,\alpha)^{16}N)$
$\sigma(^{16}O(n,\alpha)^{13}C)$

First SCALP experiments at NFS

Accepted proposal : 12 UT, 30 µA



	Experiment E800 (parasit on A. Prokofiev's experiment)			Experiment E811		
gas	CF_4	CF_4	CF_4	CF_4-CO_2	CF_4-CO_2	CF_4-CO_2
<I> (µA)	33	33	7.5	7.5	0.15 → 5.0	7.5
d (m)	~7	28.413	28.413	28.77	28.77	28.77
T (UT)	0.18	1.31	13.5	10.5	1.5	2

$\sigma(^{19}F(n,\alpha)^{16}N)$

$\sigma(^{19}F(n,\alpha)^{16}N)$
$\sigma(^{16}O(n,\alpha)^{13}C)$

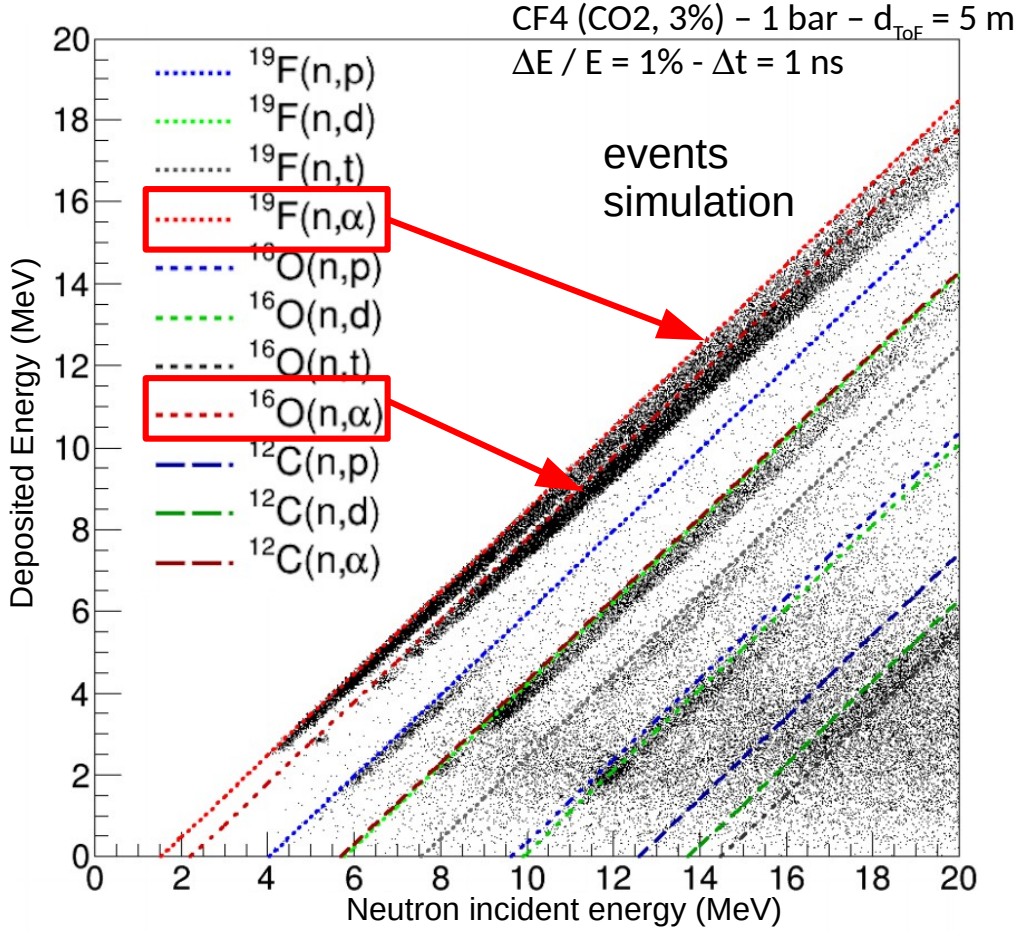
How to identify two-body reactions of interest

$$E_{dep} = T_n + Q$$

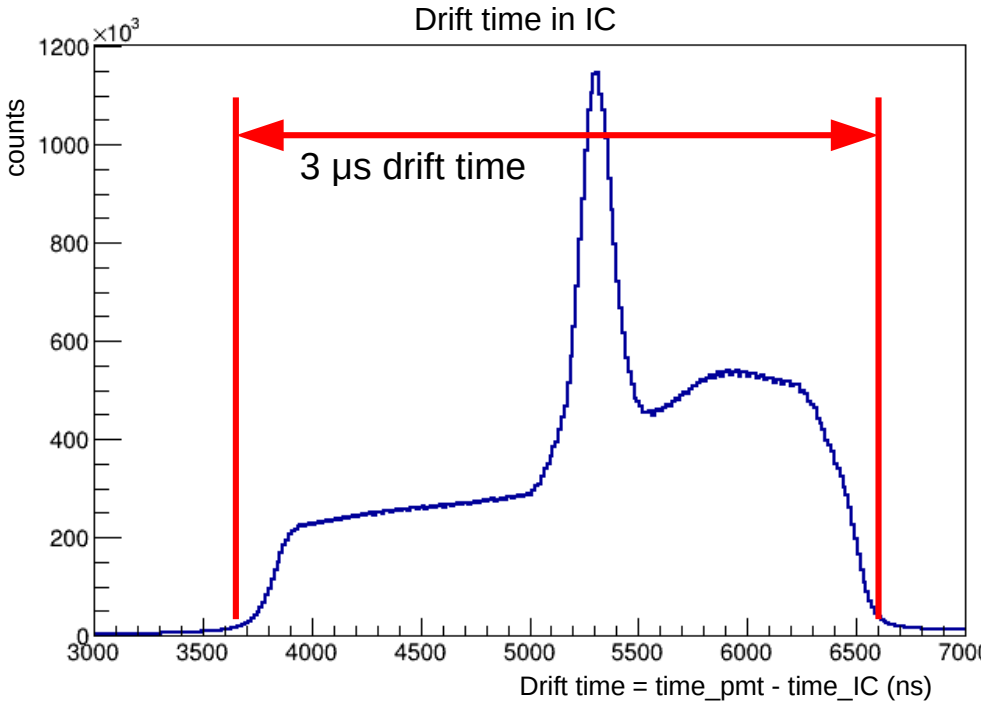
$$T_n = (\gamma - 1)mc^2$$

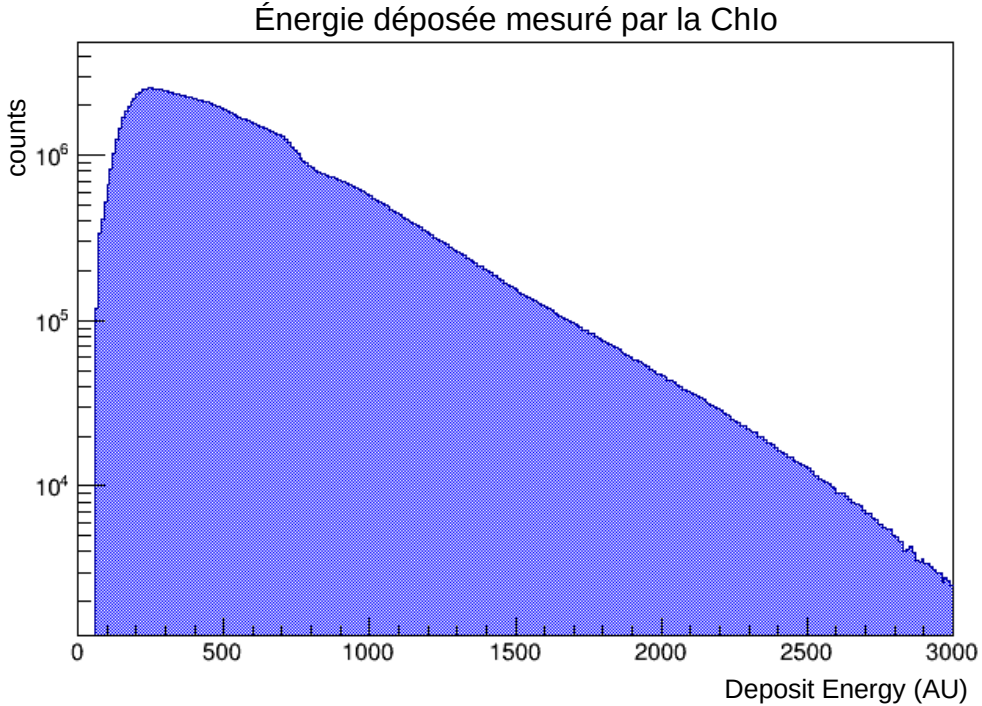
	Q (MeV)	$E_{threshold}$ (MeV)
$^{19}F(n,\alpha)^{16}N$	-1.52	1.61
$^{16}O(n,\alpha)^{13}C$	-2.22	2.36
$^{19}F(n,p)^{19}O$	-4.04	4.25
$^{19}F(n,d)^{18}O$	-5.76	6.08
$^{12}C(n,\alpha)^{9}Be$	-5.70	6.18
$^{19}F(n,t)^{17}O$	-7.56	7.96

Separated by 750 KeV



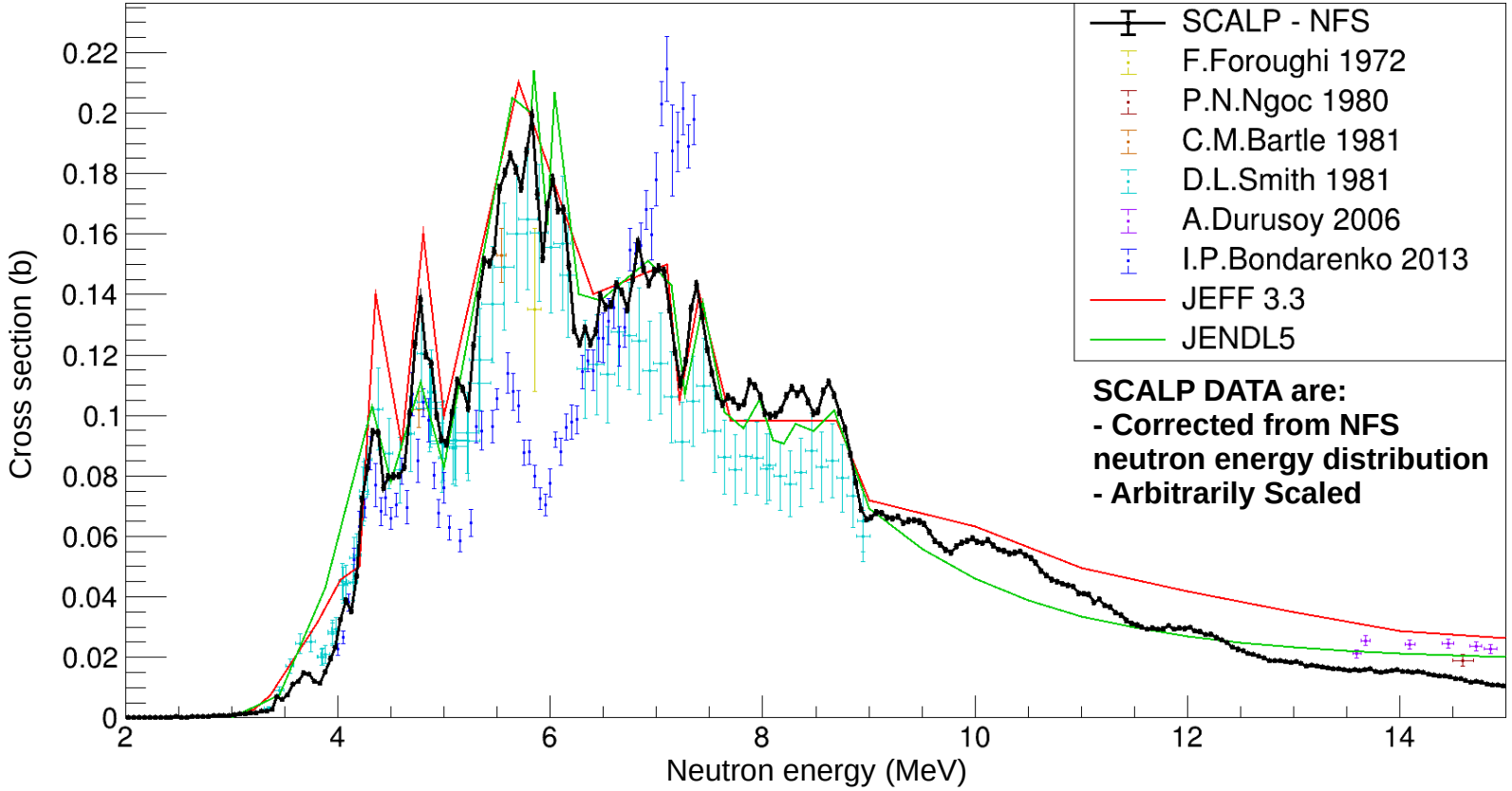
IC data





Drift time → localisation of Z

$^{19}F(n,\alpha)^{16}N$: comparison with some previous works



PRELEMINARY

nELBE Experiment

Neutron production : bremsstrahlung effect on ^{208}Pb

Flight distance : 8.205 m

RF = 10 μs

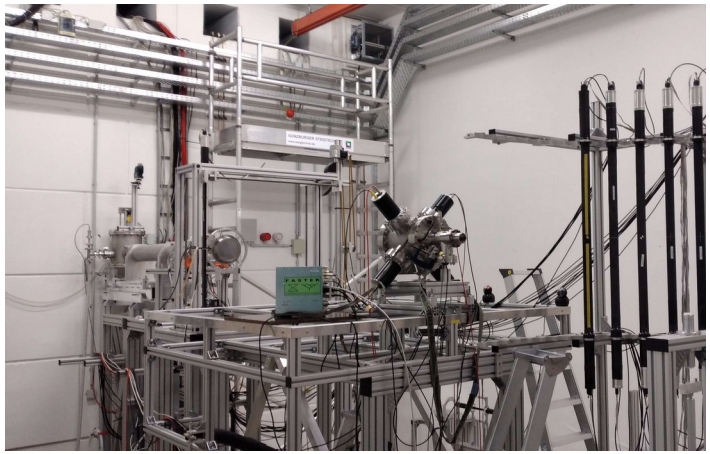
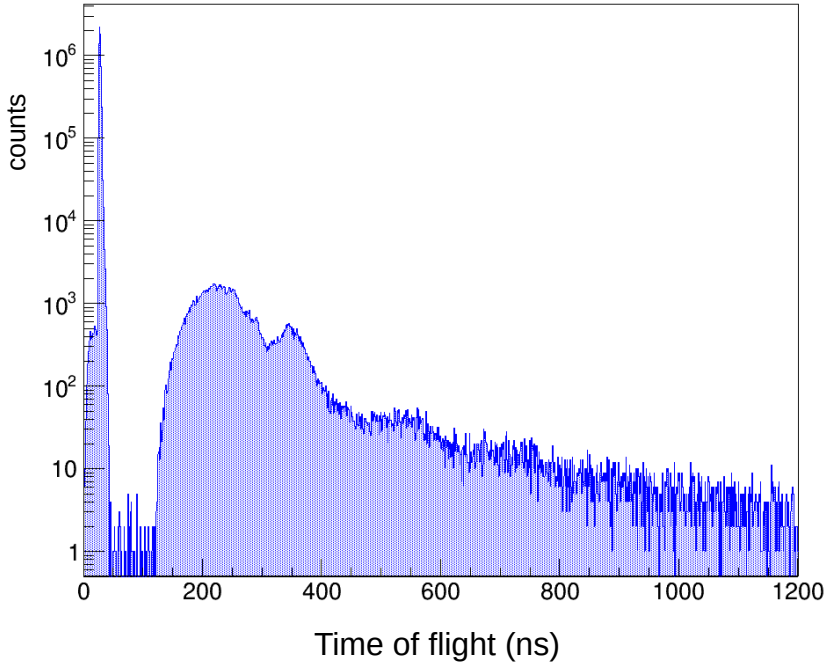


Photo of nELBE line with SCALP detector

Date	09/2022	12/2022	02/2023
T (UT)	12	24	7
gas	CF_4	CF_4-CO_2	CF_4-CO_2

nELBE data

Incident neutron time-of-flight in nELBE data in pure CF_4 configuration



Reaction identification matrix of nELBE data in pure CF_4 configuration