n_TOF high accuracy & resolution $^{235}U(n,f)$ cross section from thermal to 170 keV: preliminary results

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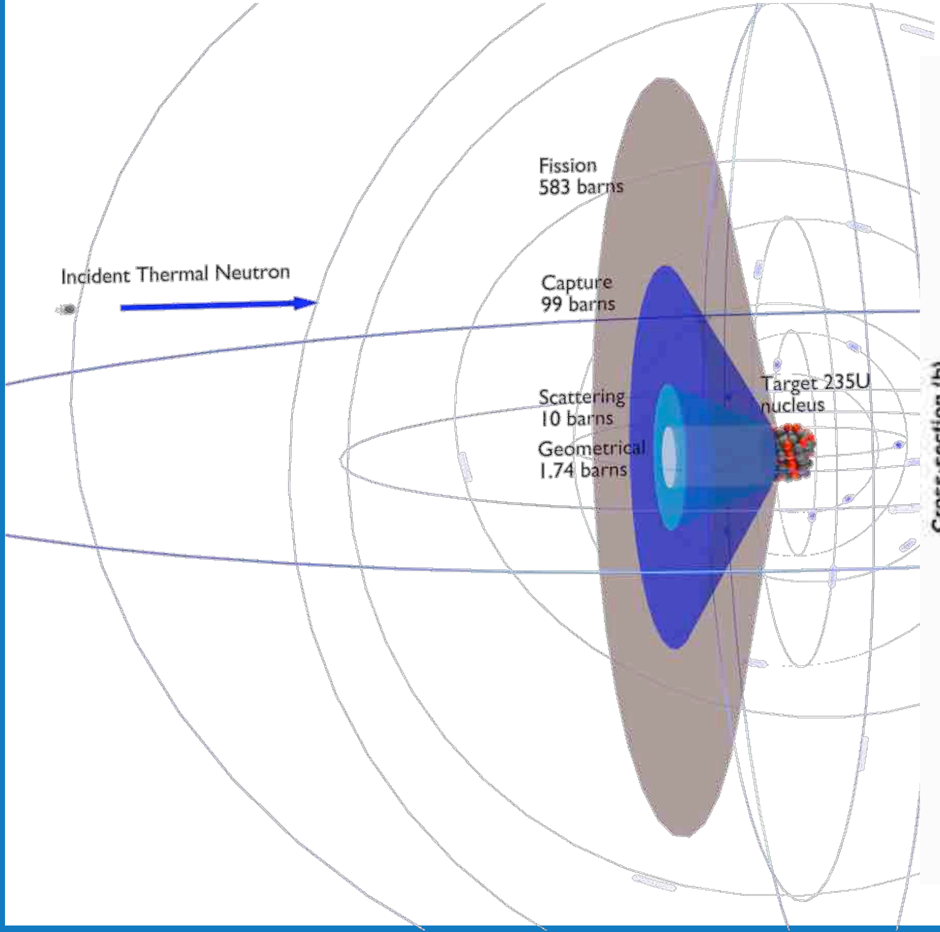
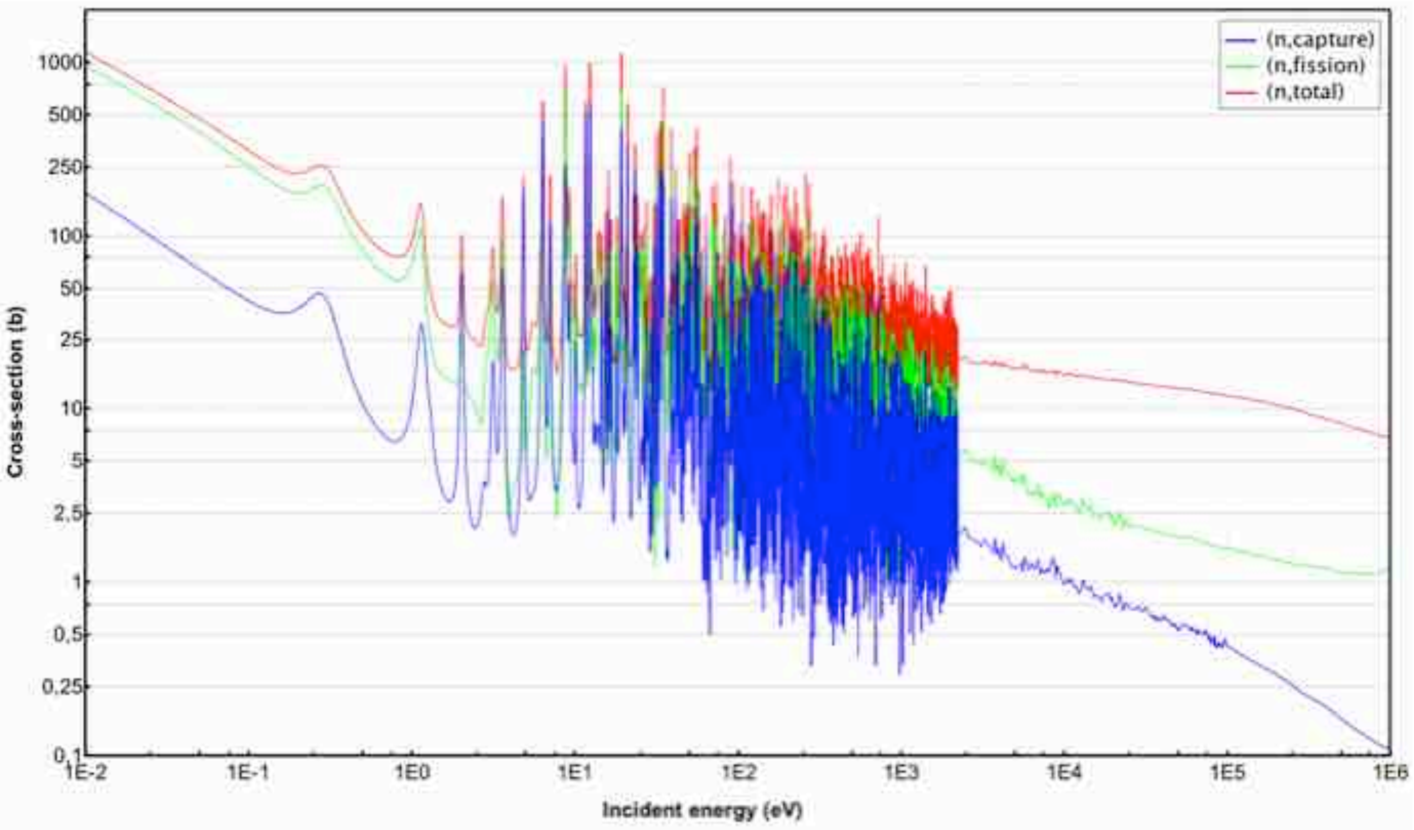
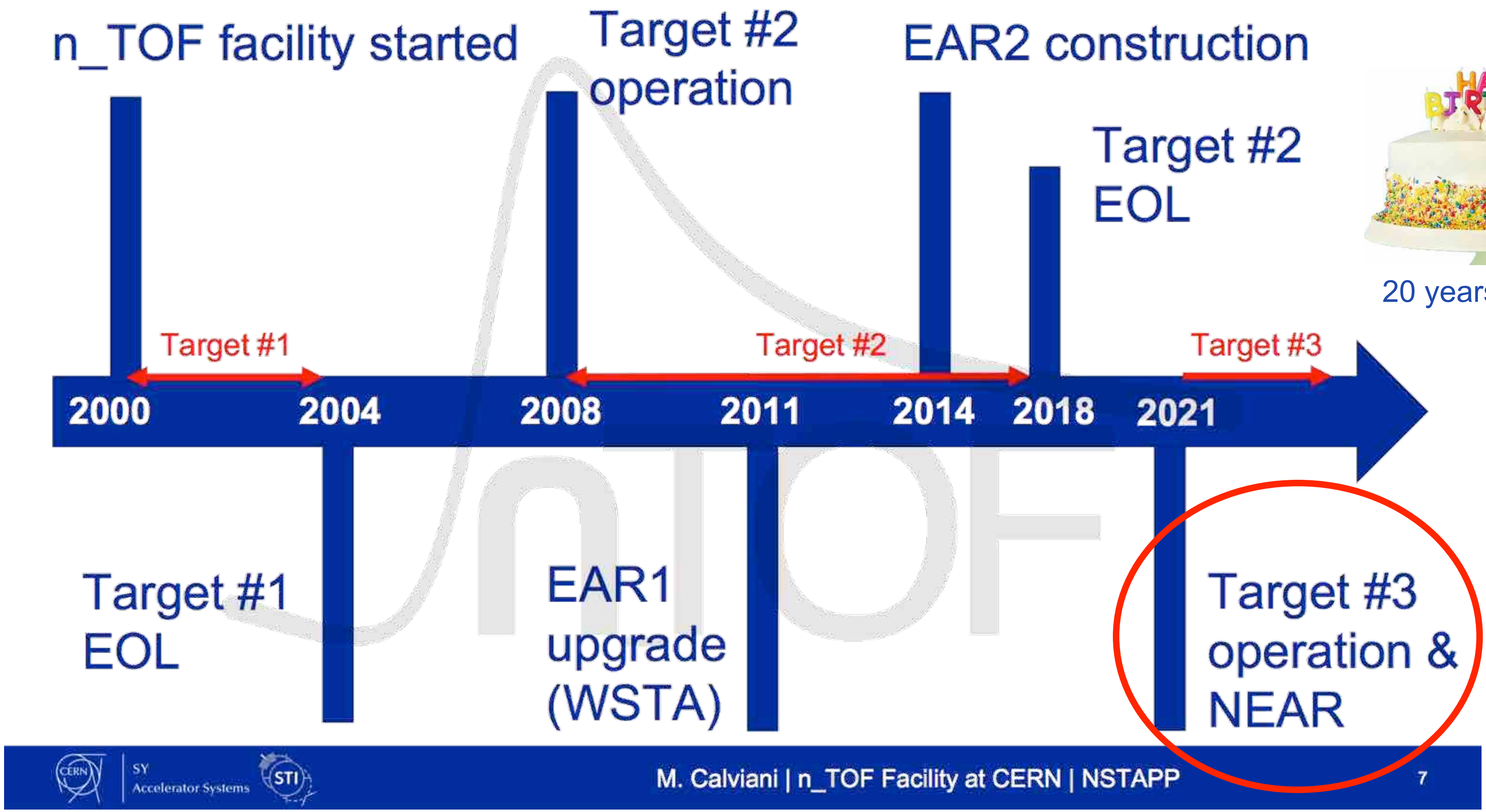
Luigi Cosentino, Nicola Colonna, Alberto Mengoni,
and the n_TOF collaboration





Summary

- Status of the n_TOF facility & its upgrade
- The $^{235}U(n,f)$ measurement
- Experimental apparatus
- Previous results (medium resolution)
- Preliminary results (high resolution)
- Perspectives



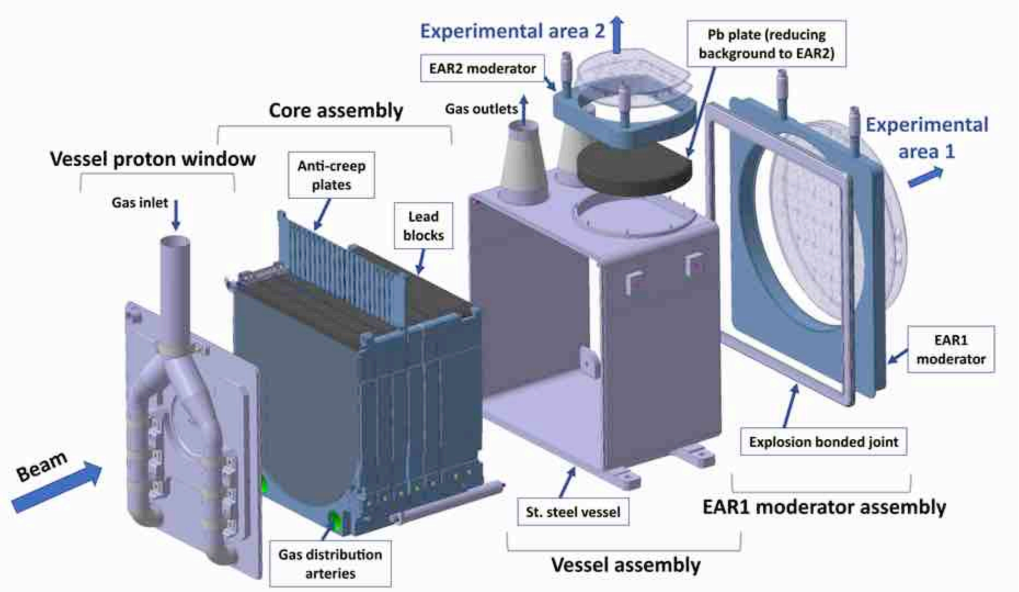
20 years operation

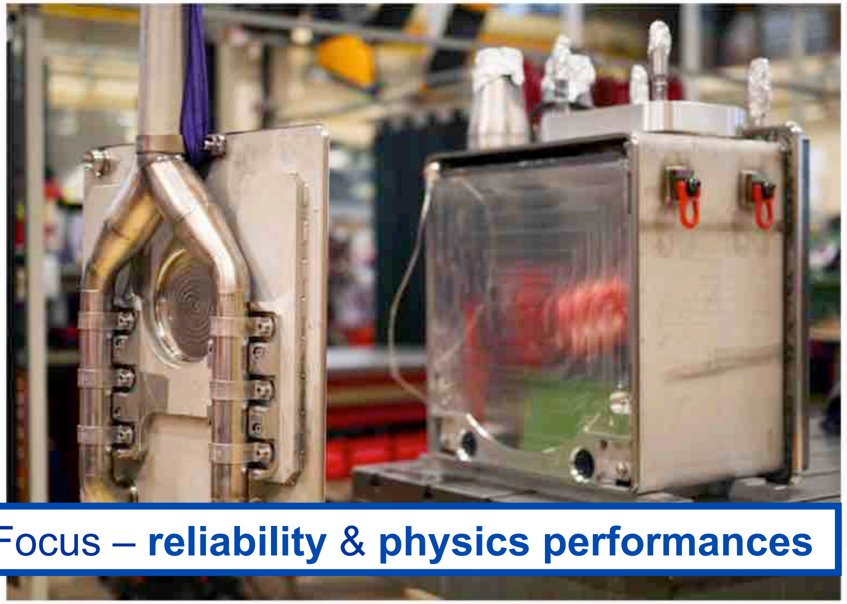
Third generation n_TOF spallation target

2021-

Phys. Rev. Accel. Beams 24, 093001 (2021)

- 3[rd] generation spallation target, pure Pb based, N_2-gas cooled, water moderated, operational since July 2021
- Several innovations have been introduced





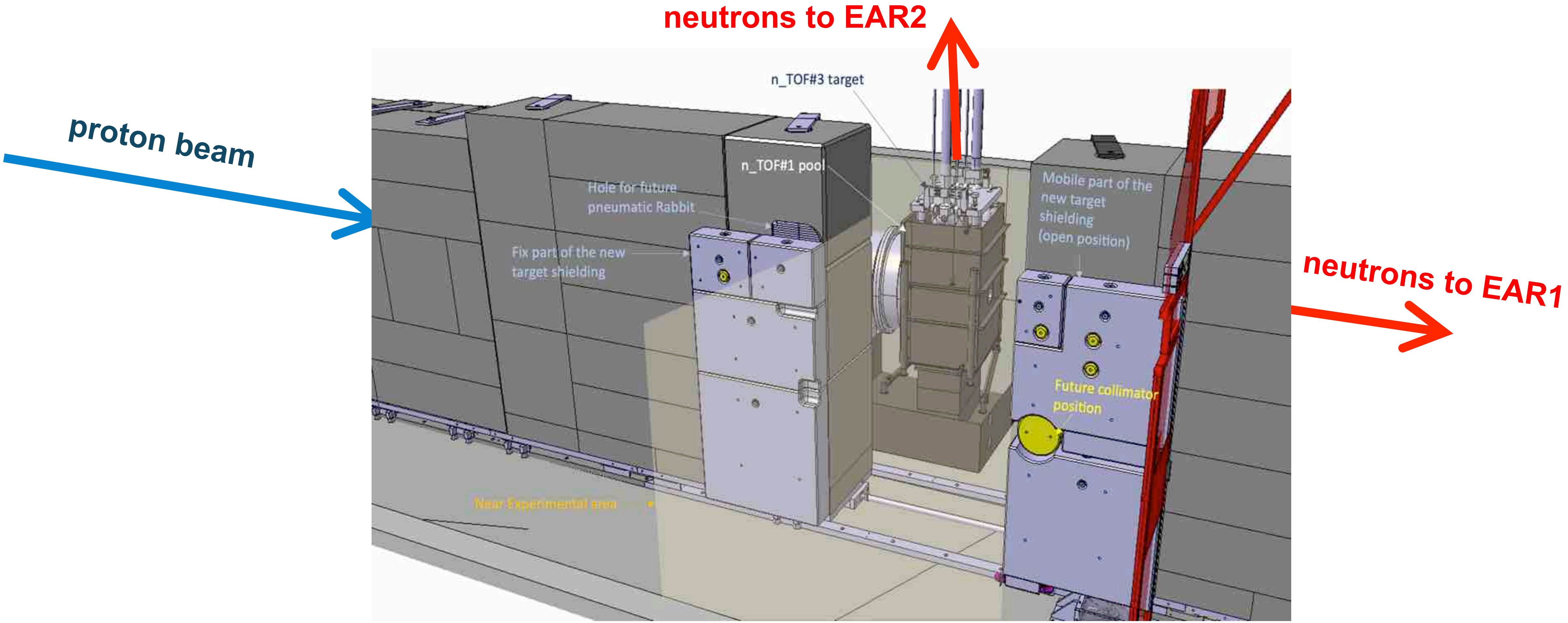
Focus – **reliability & physics performances**

New n_TOF Experimental station

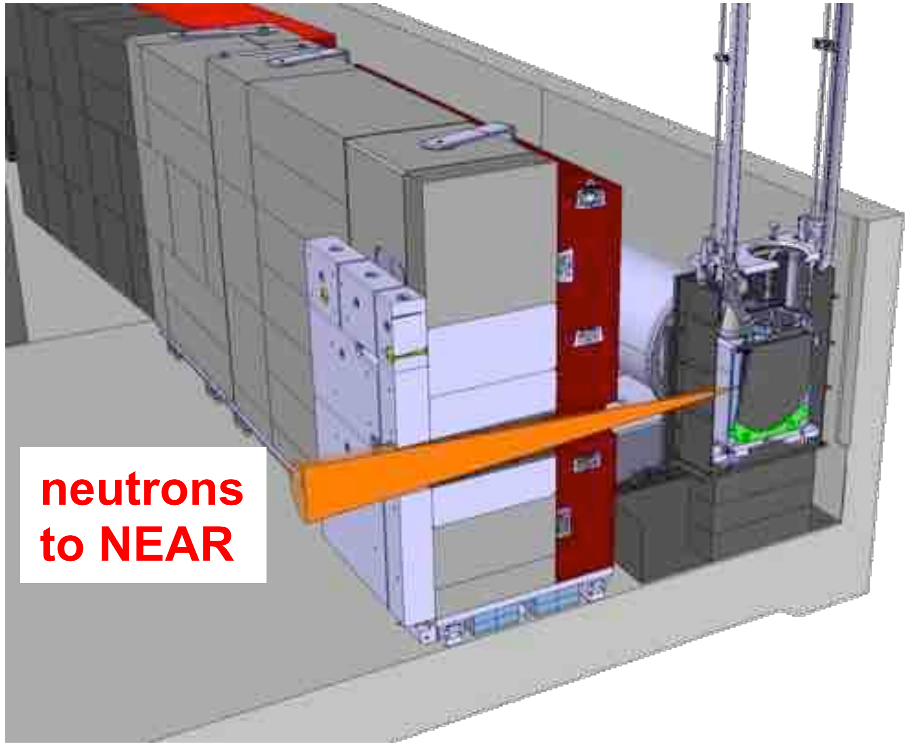
NEAR

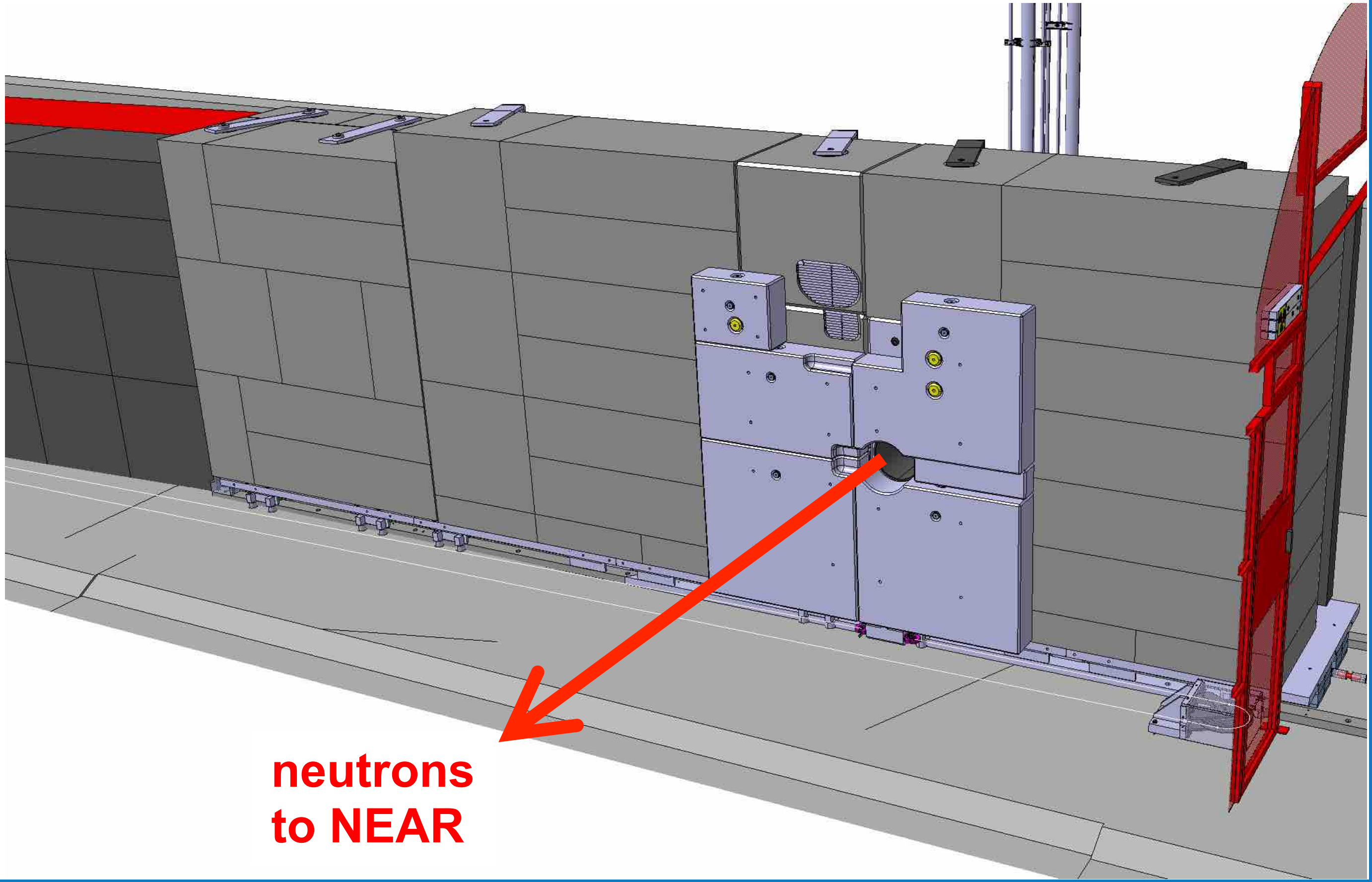
- CERN's Long Shutdown 2:
  - new spallation target
  - target shielding pit upgrade
  - creation of a near-target experimental station (NEAR)
    - **In-target** irradiation station (up to 1 MGy/y mixed field, radiation damage studies)
    - **Out-target** irradiation station (irradiation station for physics measurements, radiation-to-electronics)

The NEAR station: a new irradiation area at n_TOF

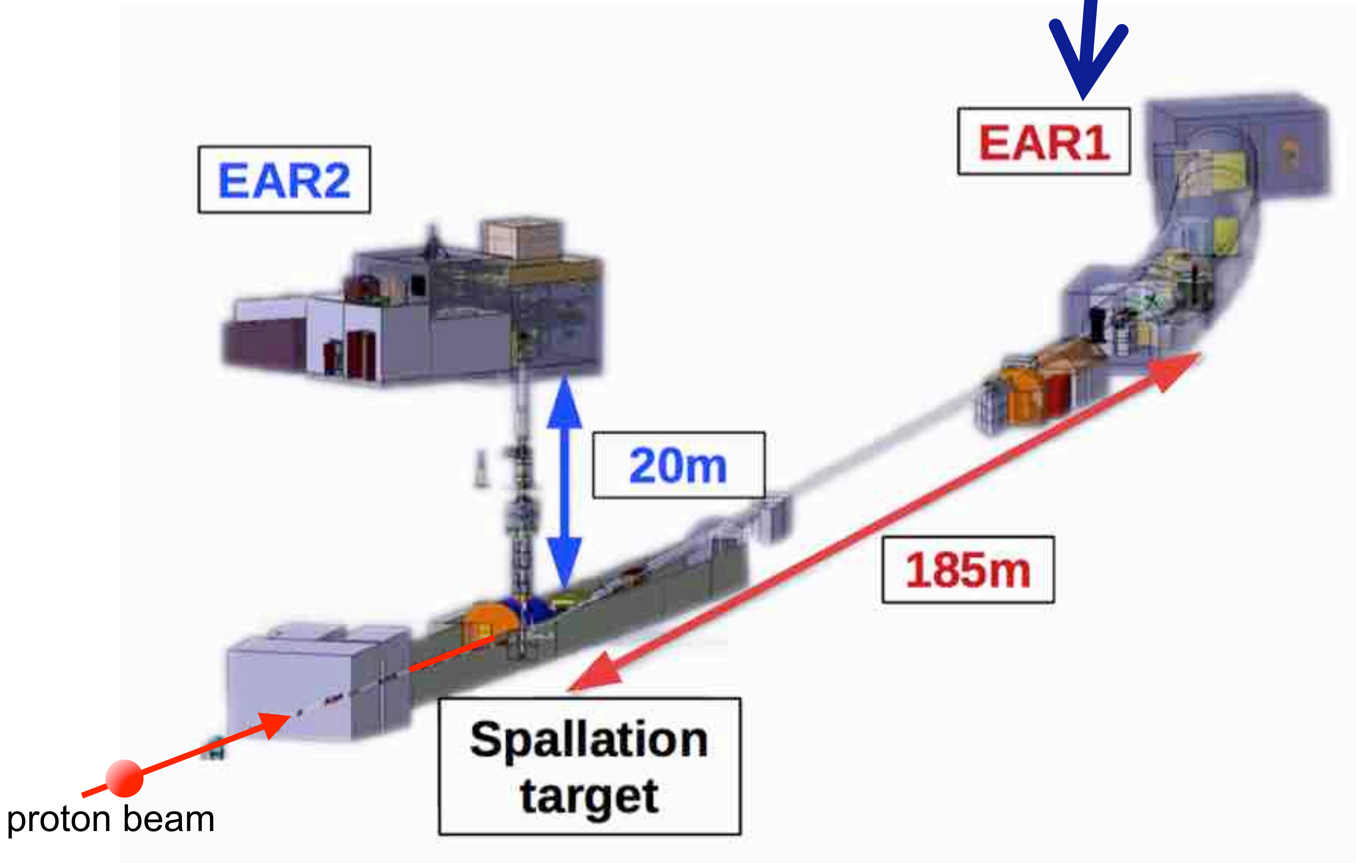


The NEAR station: a new irradiation area at n_TOF





The ^{235}U(n,f) measurement

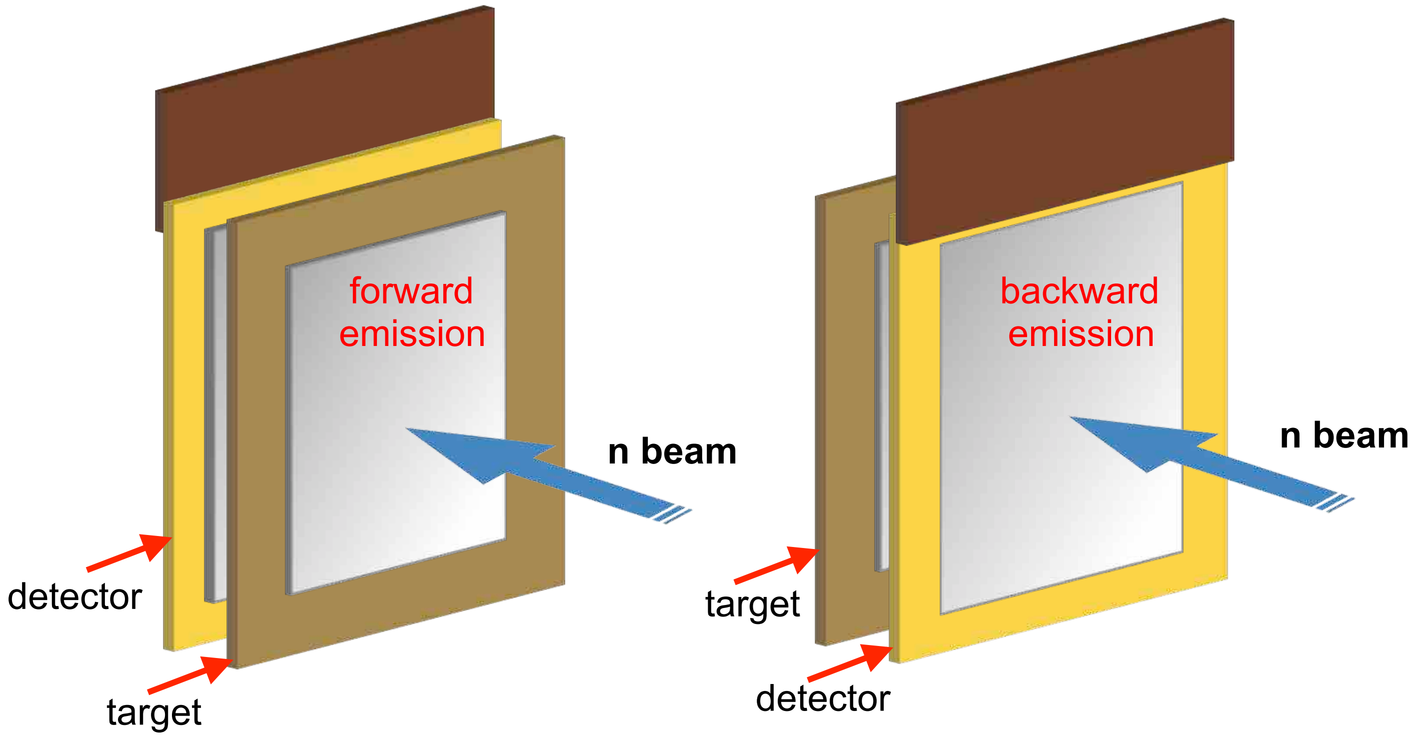


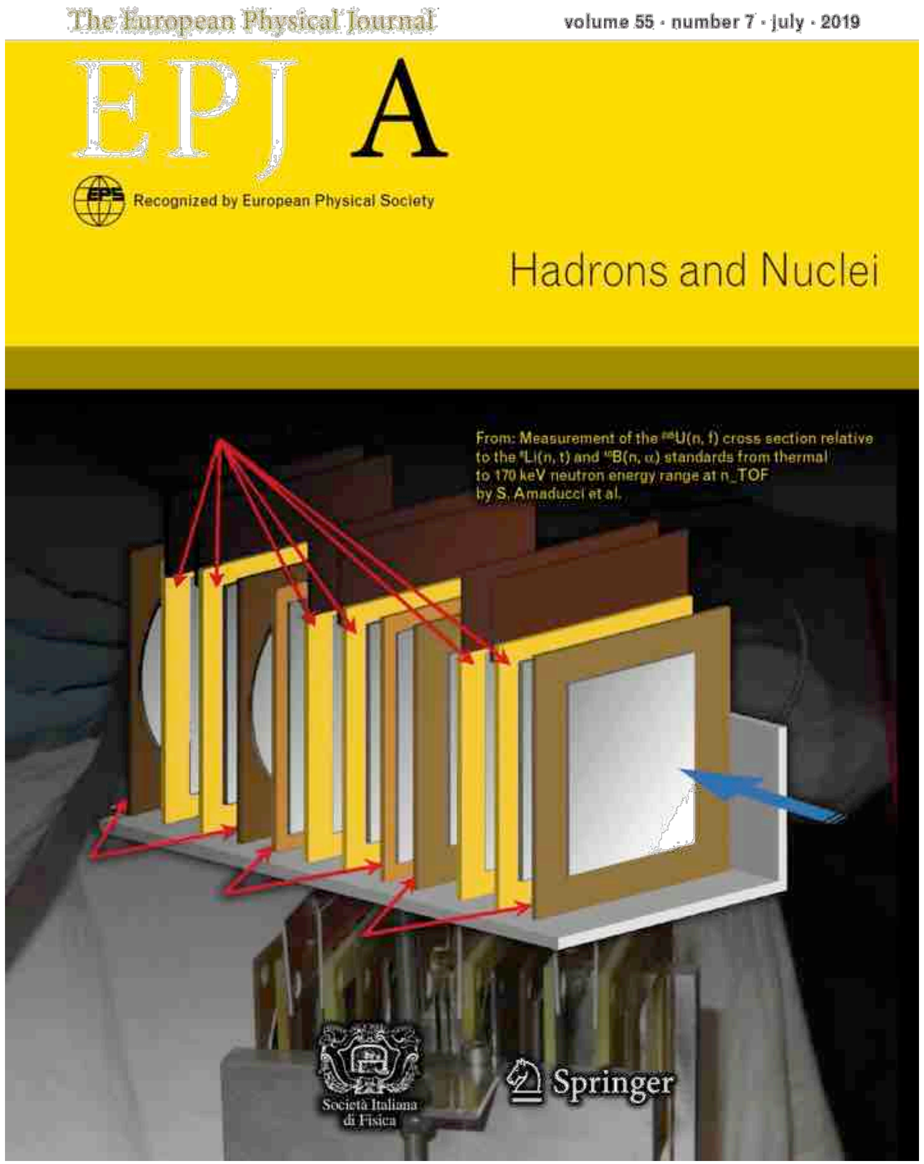
Original goal of the experiment proposal:

High accuracy measurement of the ^{235}U(n,f) reaction cross-section in the 10-30 keV neutron energy range

we soon realized that the experimental setup we had devised allowed us to collect high quality fission data in a broader range

2 (target & detector) arrangements to account for forward and backward emission



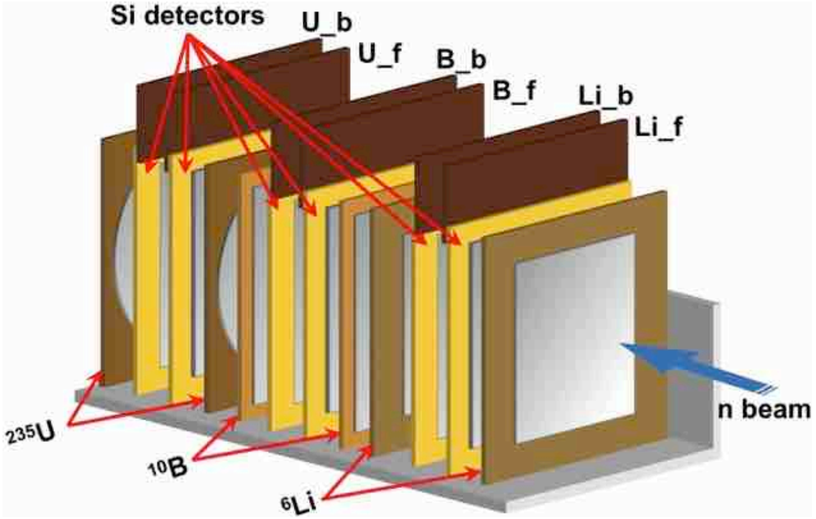


the reaction products could only reach their own detector (backing thickness)

the experimental setup

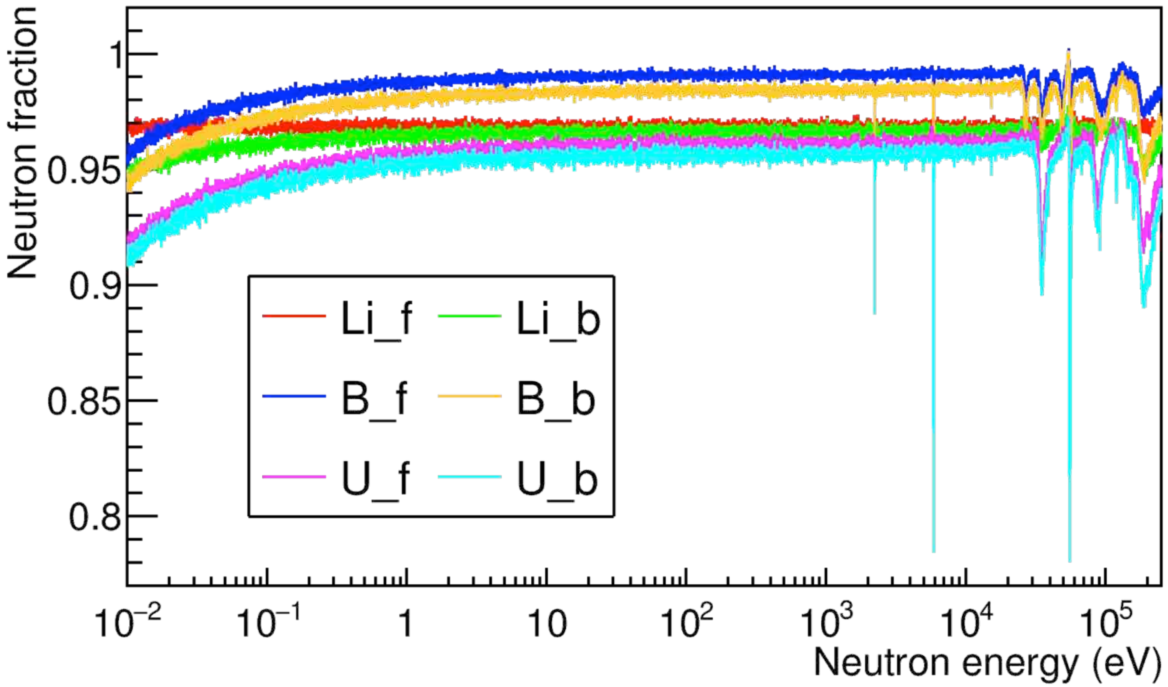
6x (target +silicon detector)

- ^{6}Li forward emission
- ^{6}Li backward emission
- ^{10}B forward emission
- ^{10}B backward emission
- ^{235}U forward emission
- ^{235}U backward emission



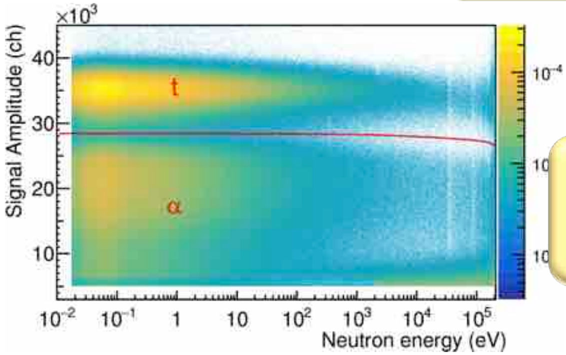
counting rate stable throughout the whole experiment
no detector wear out

Geant4 simulation: reconstruction of the neutron fraction

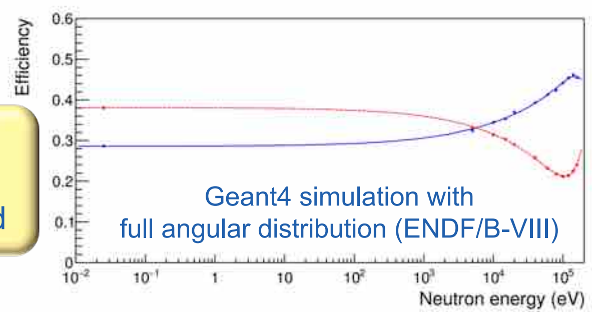


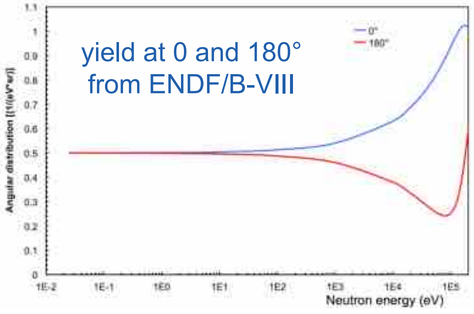
correction for the effective neutron fraction

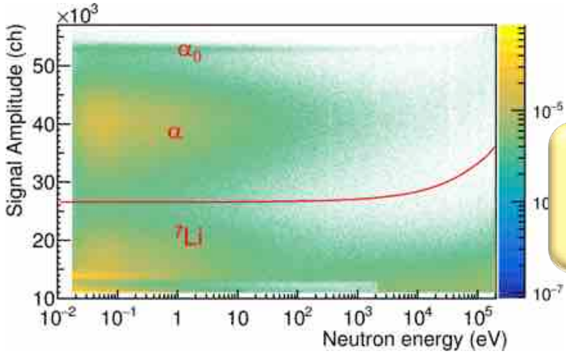
identification & threshold setting



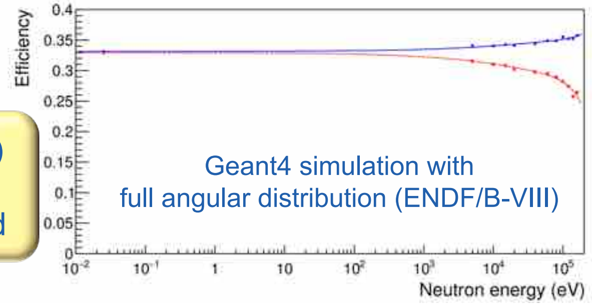
^{6}Li(n,t)
tritons
selected

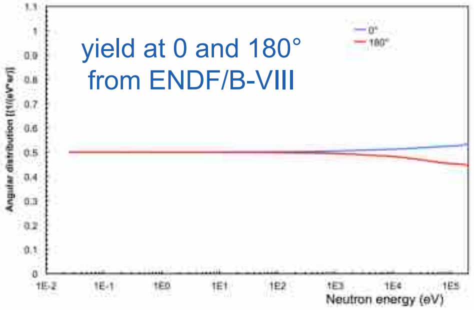


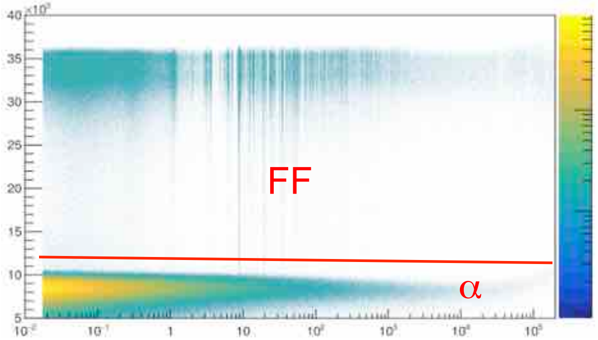




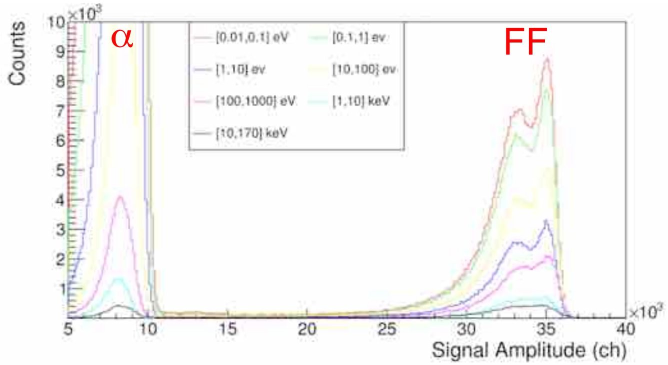
^{10}B(n,α)
alphas
selected





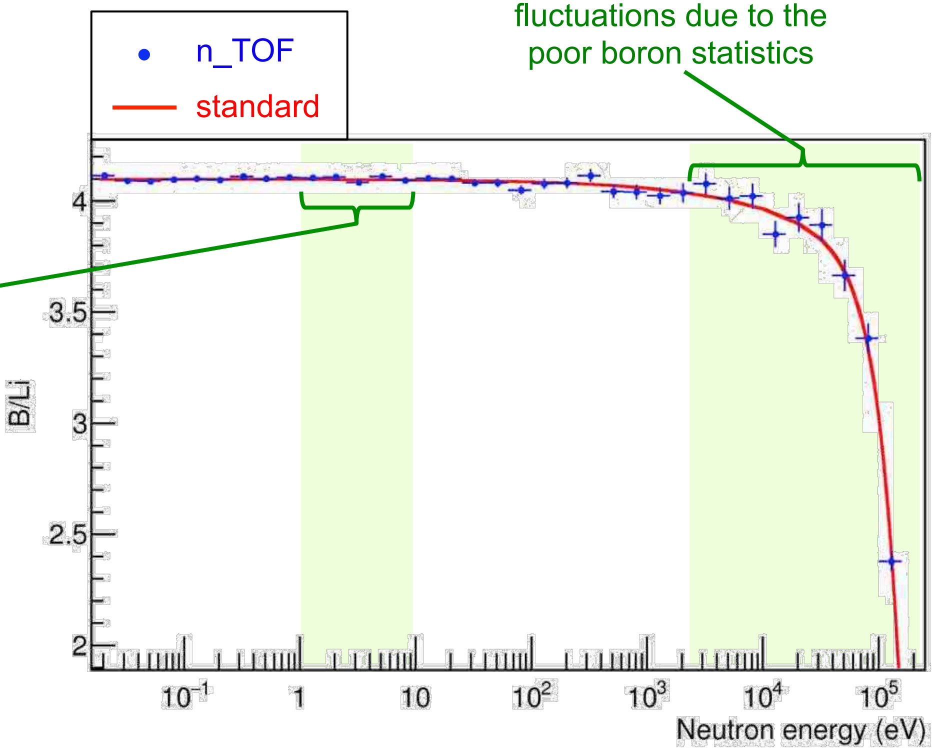


^{235}U(n,f)
FF
selected



reference cross check: calculation of the $^{10}B/^{6}Li$ ratio comparison with the standard ratio

fluctuations due to the poor boron statistics

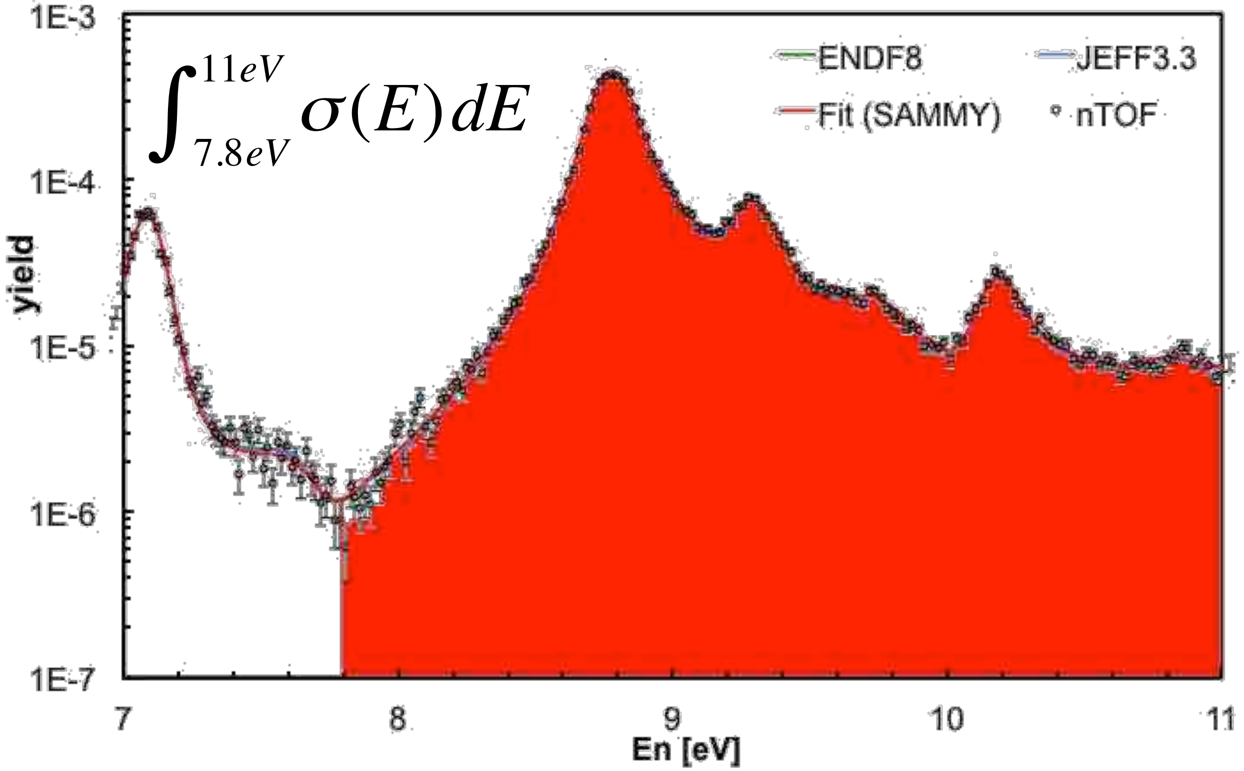


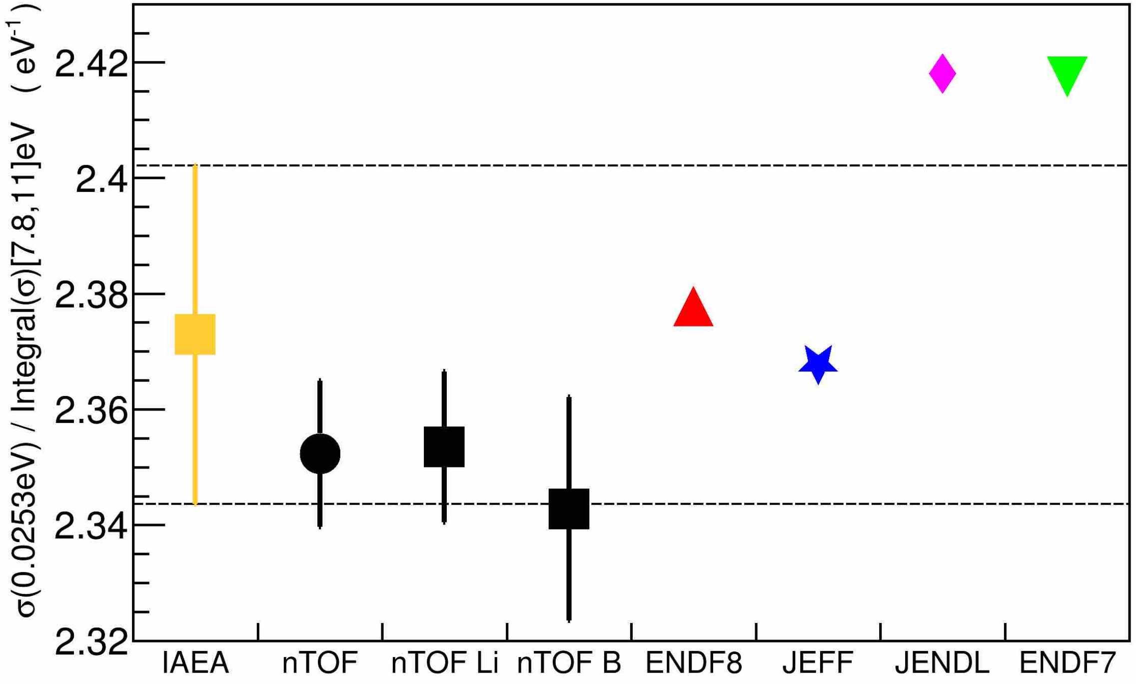
data normalized to the standard ratio removed the systematics due to the target areal density

^{235}U normalization: 25.3 meV or 7.8÷11 eV integral?

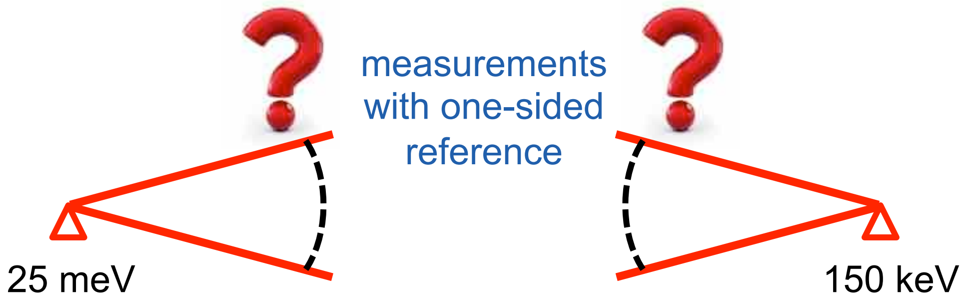
Test: ratio between σ(25.3 meV) and integral σ[7.8,11 eV]

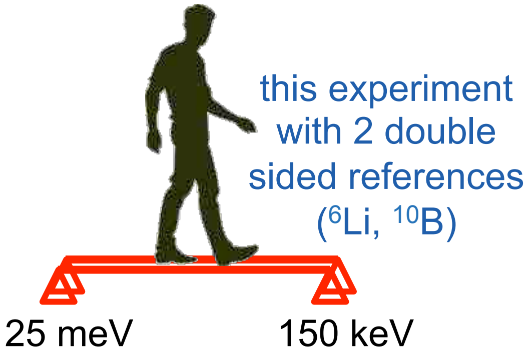
$$\frac{\sigma(25.3meV)}{\int_{7.8eV}^{11eV}\sigma(E)dE}$$



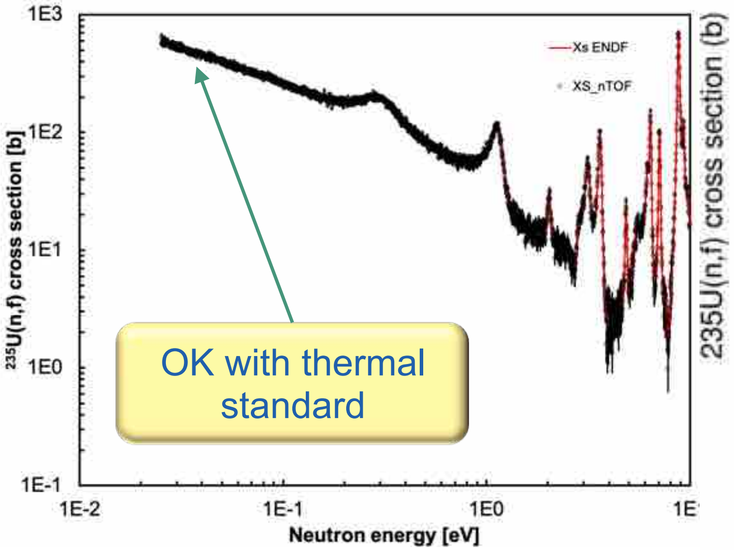


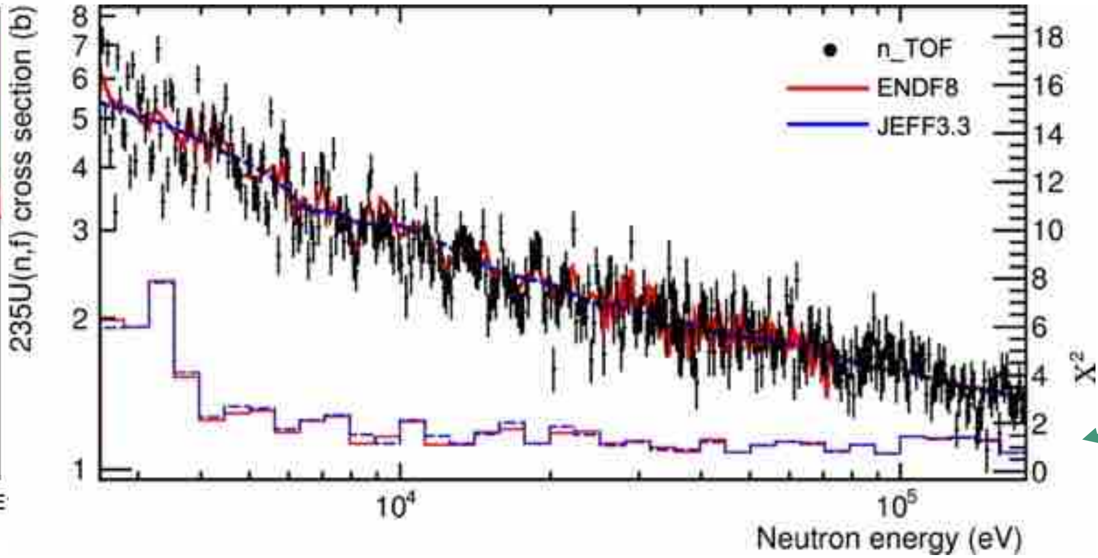
equivalent within uncertainty, integral preferred (IAEA)





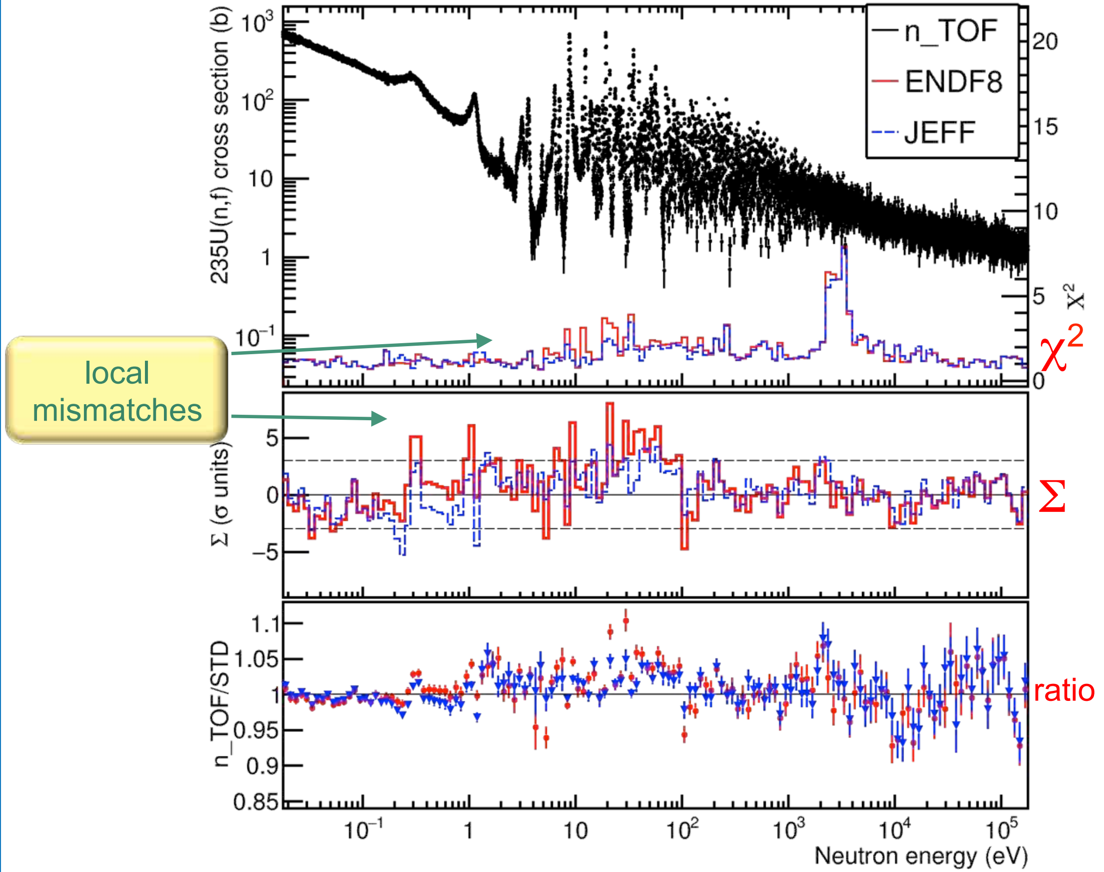
measured cross section matches the standard at both ends

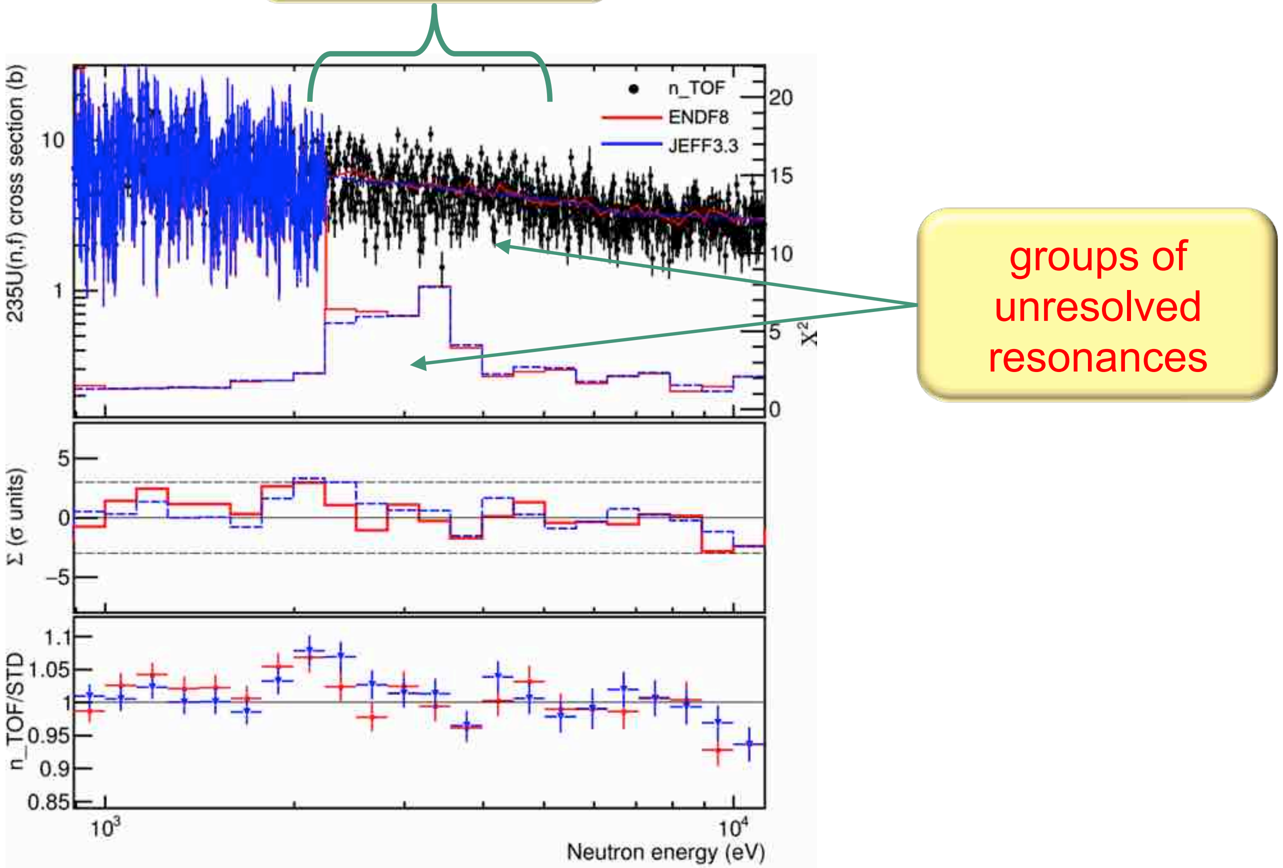




OK with 150÷170 keV standard

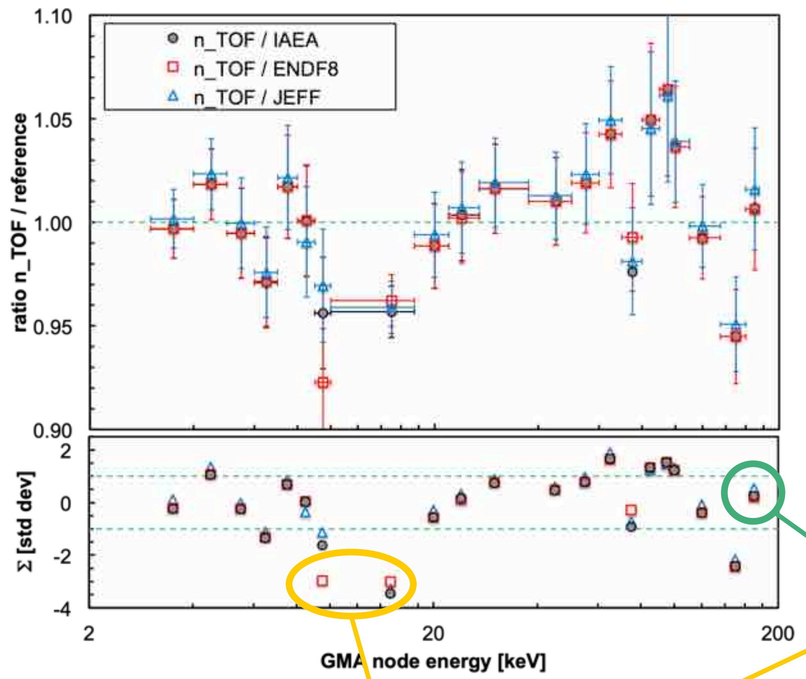
χ^2 and Σ provide statistical hints

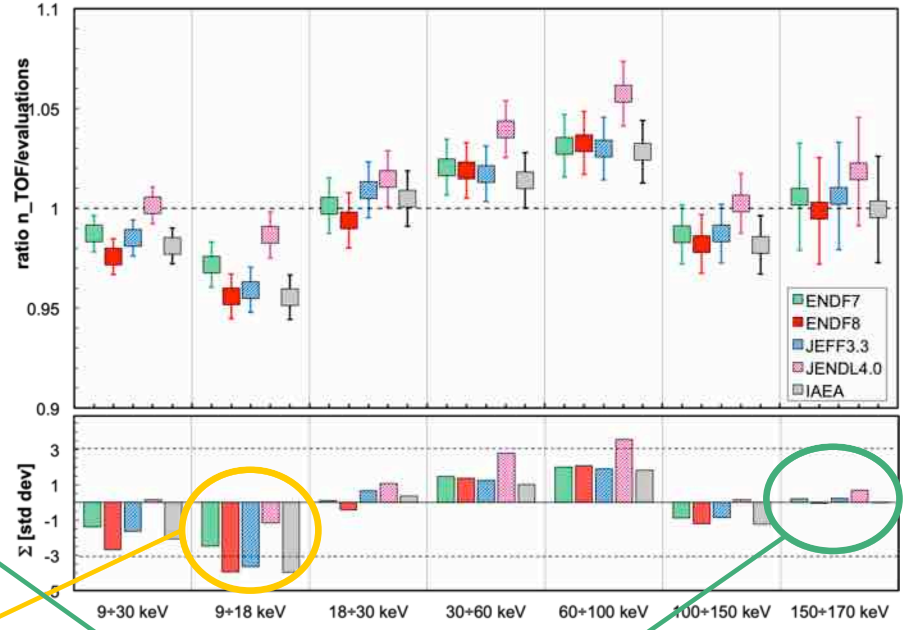




URR

comparison with the main libraries



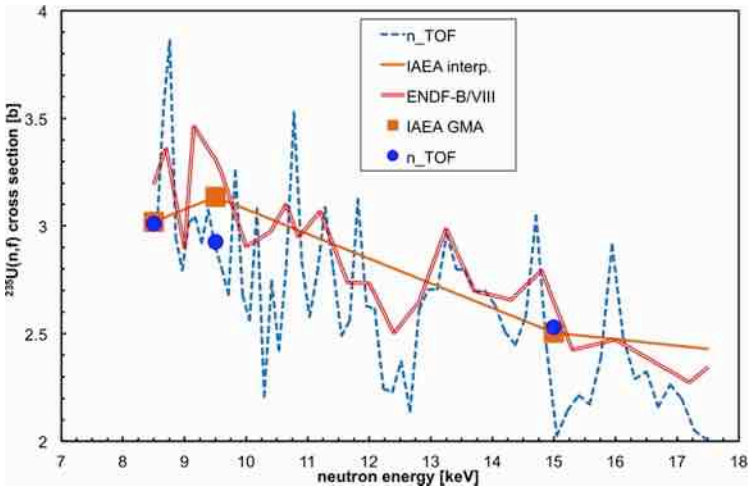


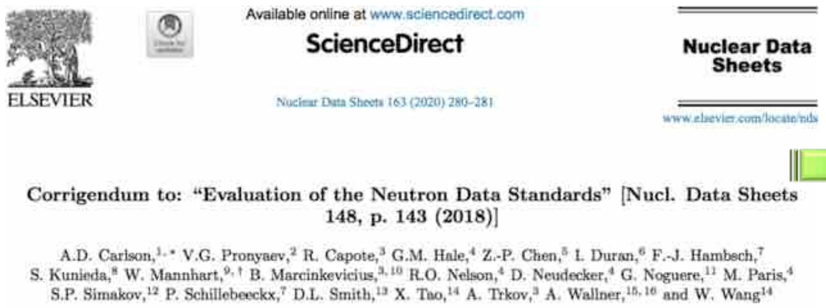
disagreement at 9÷18 keV

perfect agreement at 150÷170 keV

disagreement at 9÷18 keV
IAEA GMA interpolation

following the guidelines of
Nucl. Data Sheets 148, p.143 (2018)
a 7% difference at the 9.5 keV node
produced a systematic difference...





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Nuclear Data Sheets 163 (2020) 280–281

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Corrigendum to: "Evaluation of the Neutron Data Standards" [Nucl. Data Sheets 148, p. 143 (2018)]

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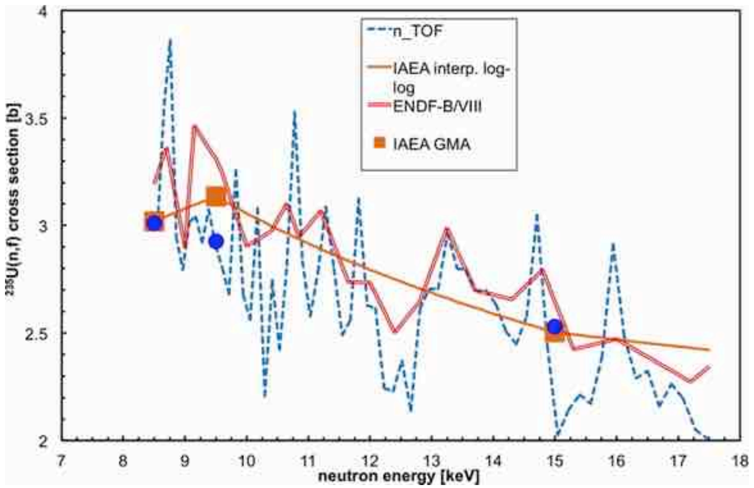
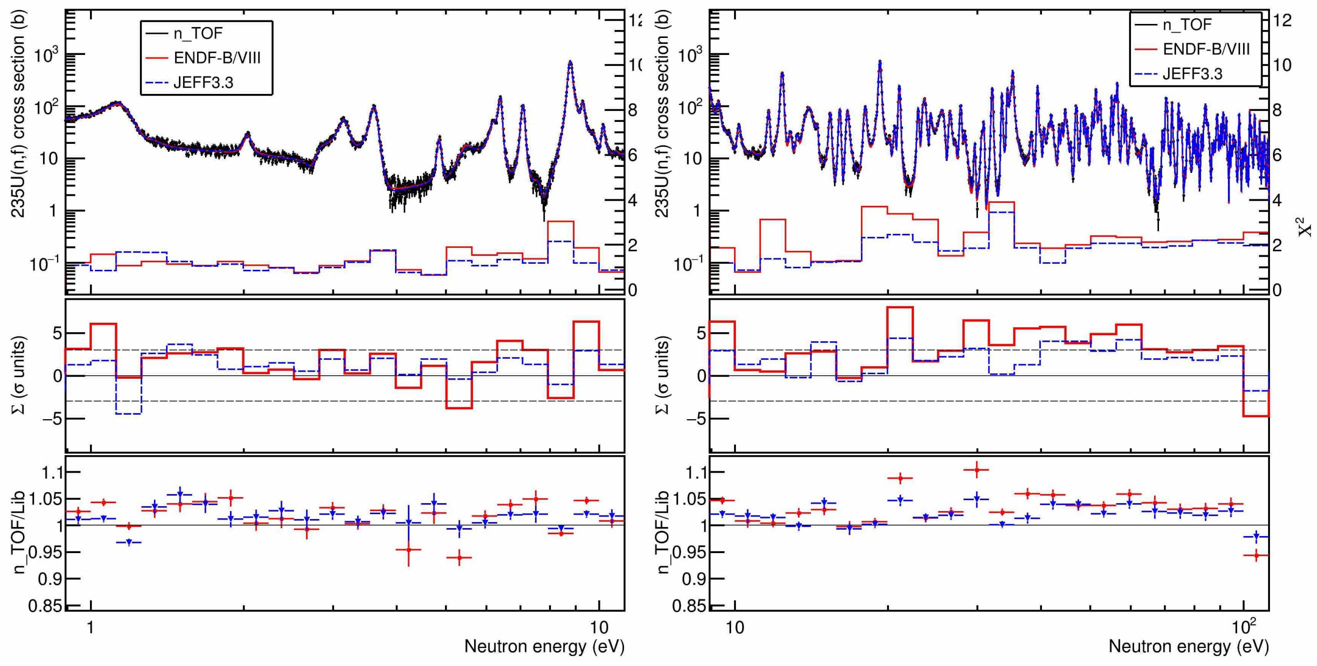
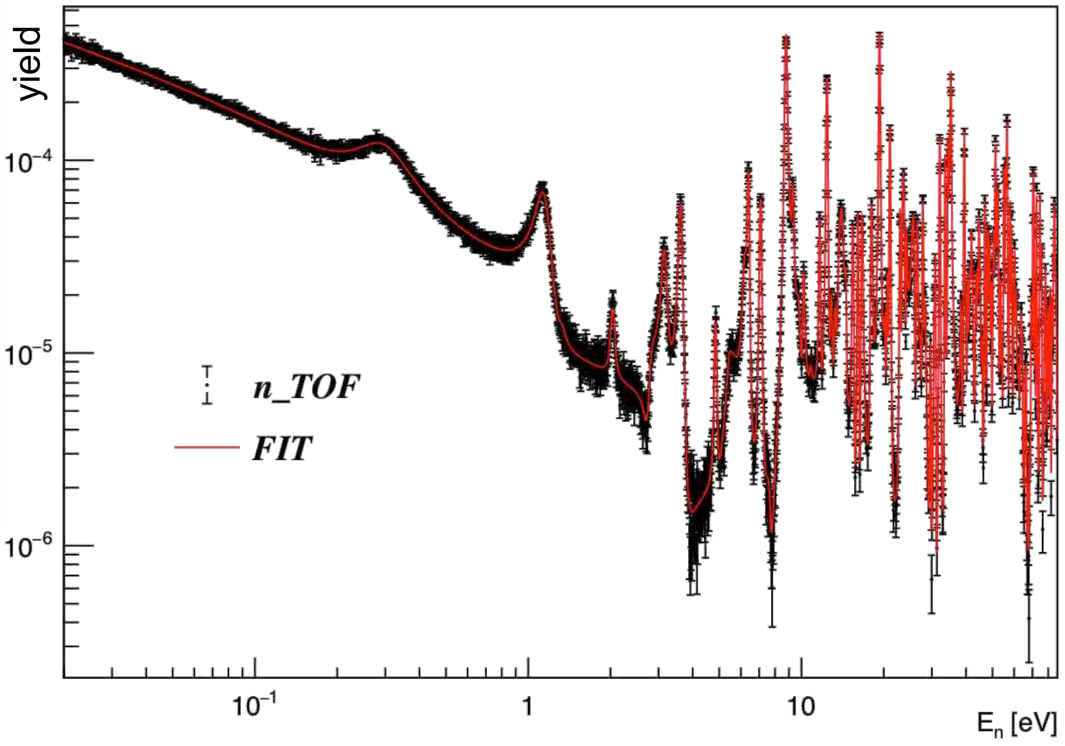


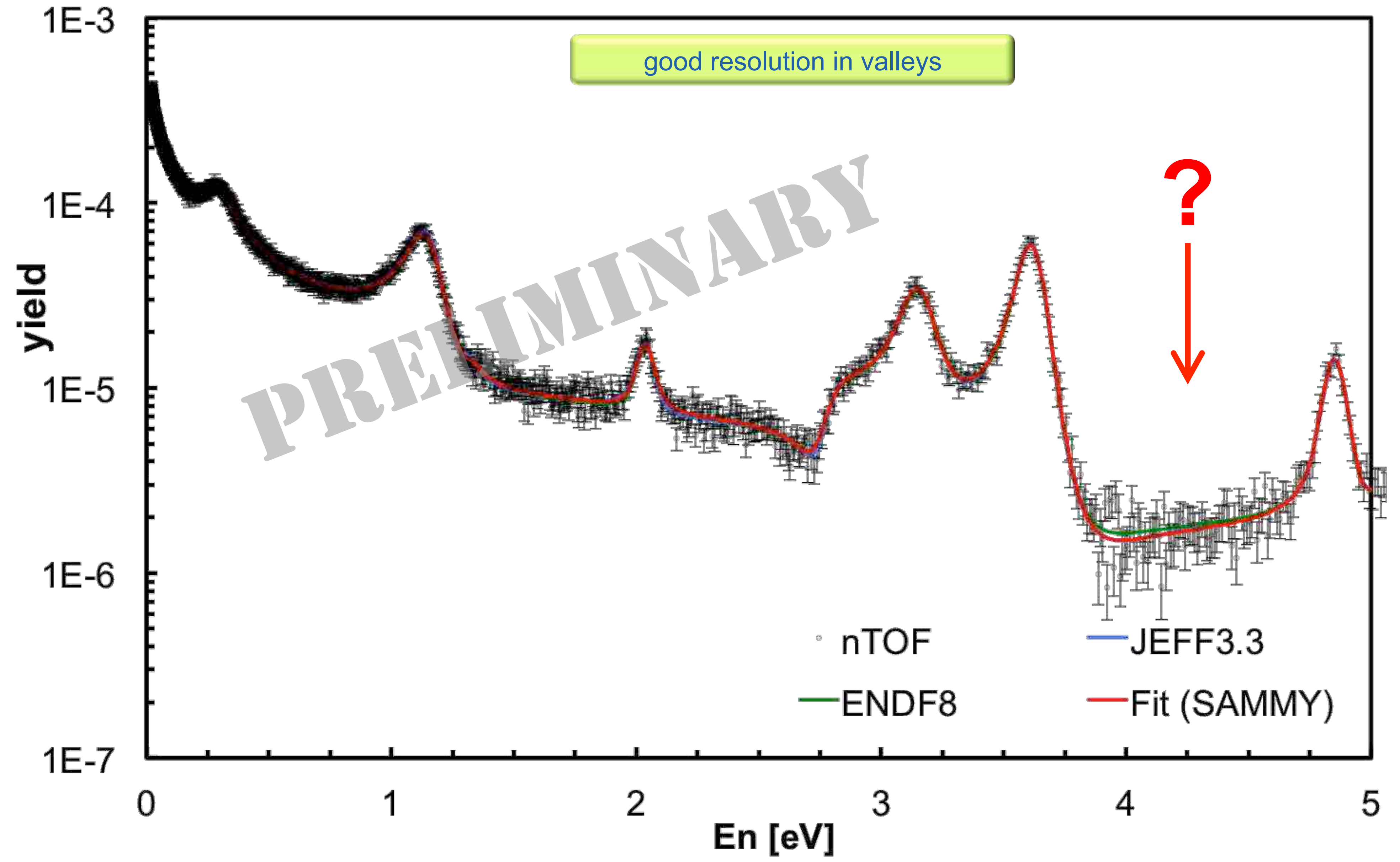
with the new guidelines the systematic
difference improved slightly
but not enough...

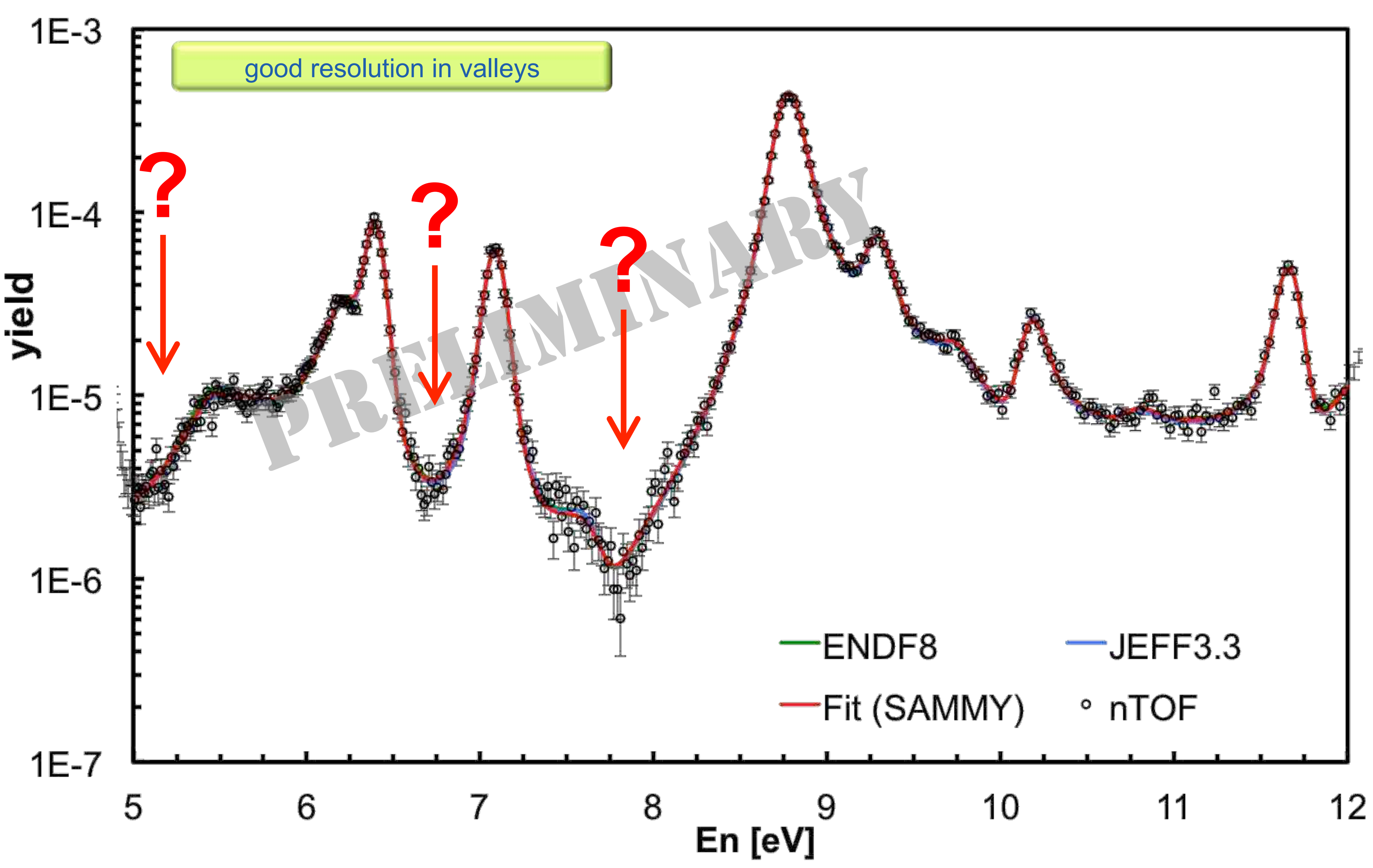
RRR
χ^2 hints of statistically significant shape mismatches?

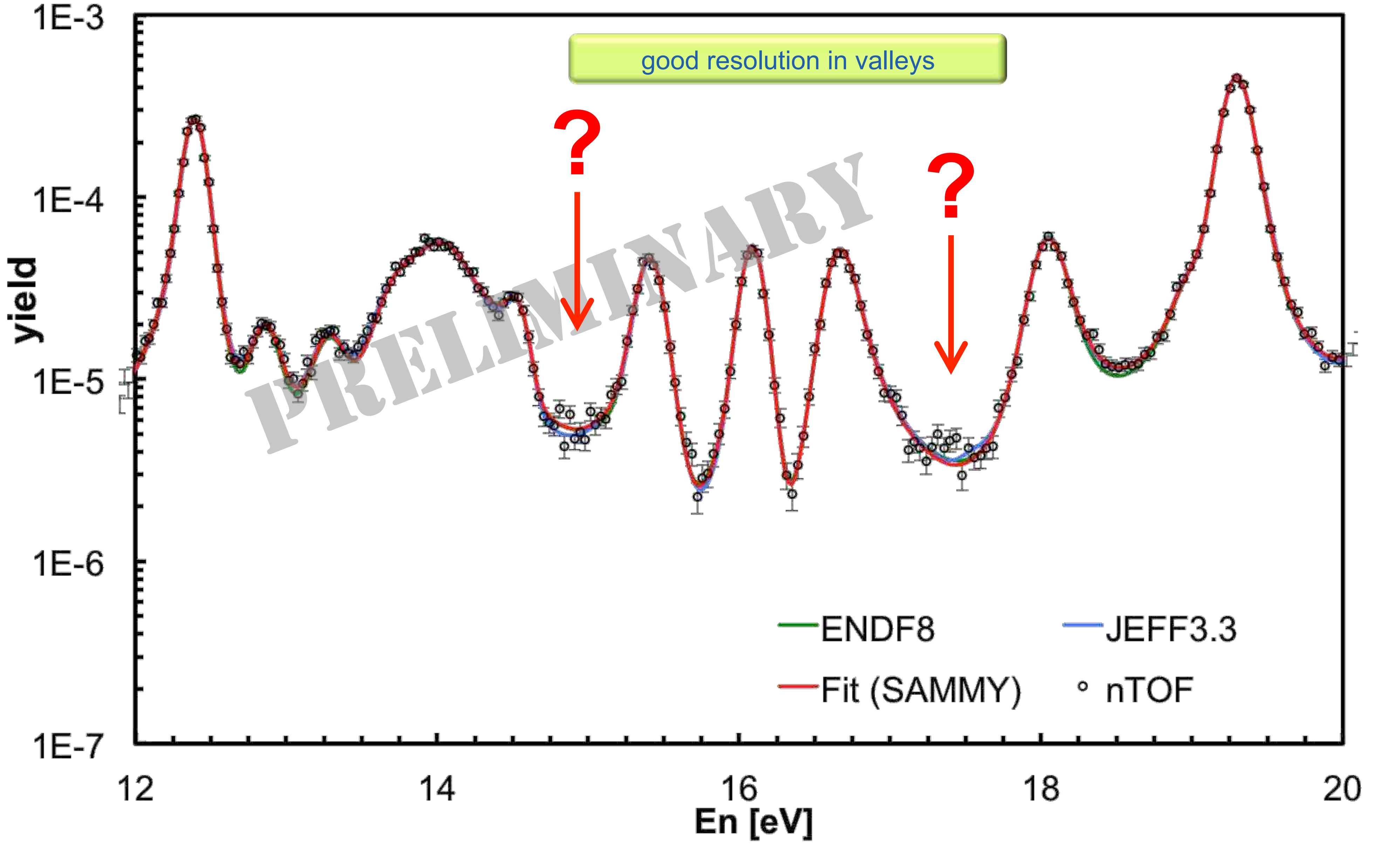


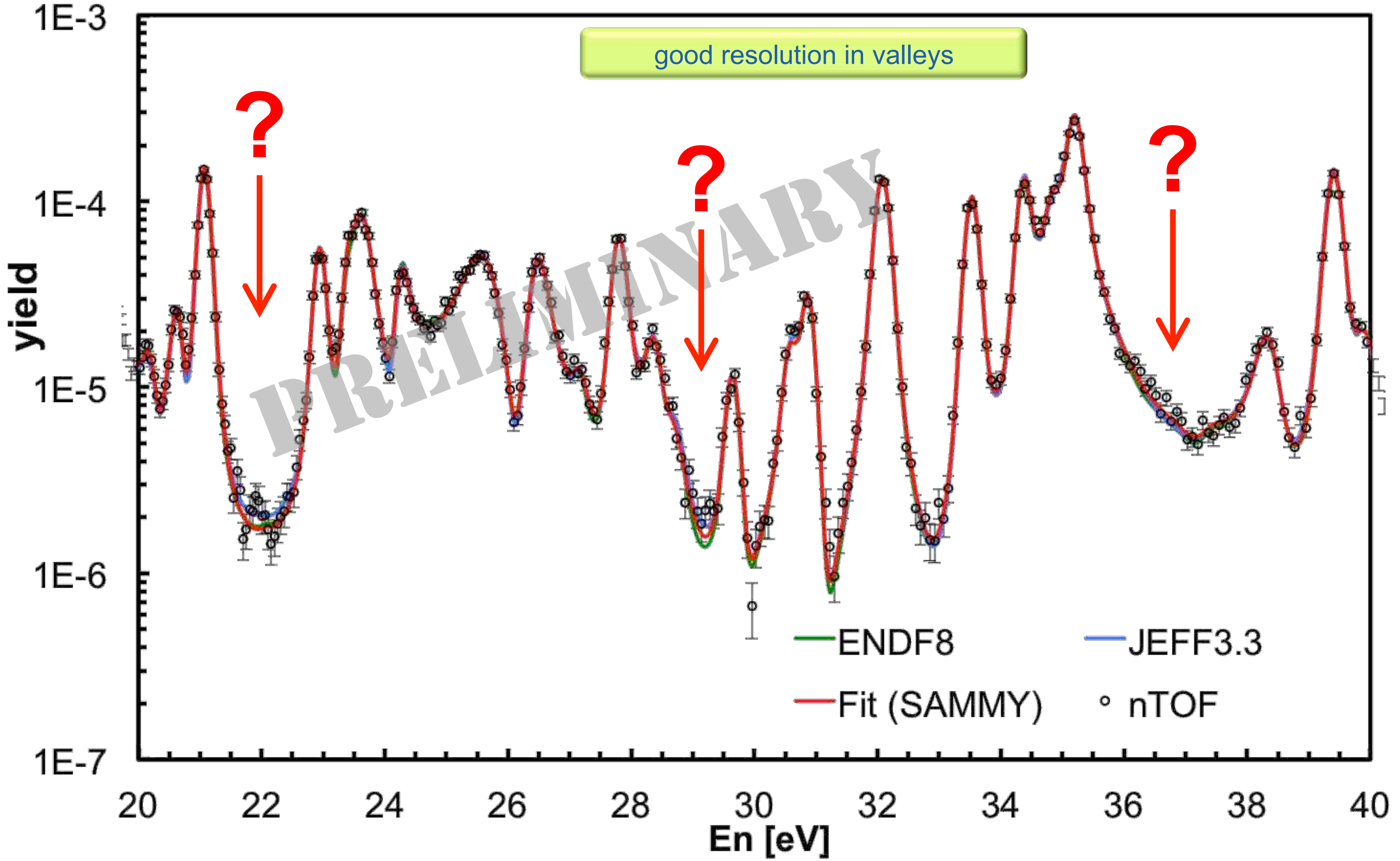
resonance fit up to 90 eV

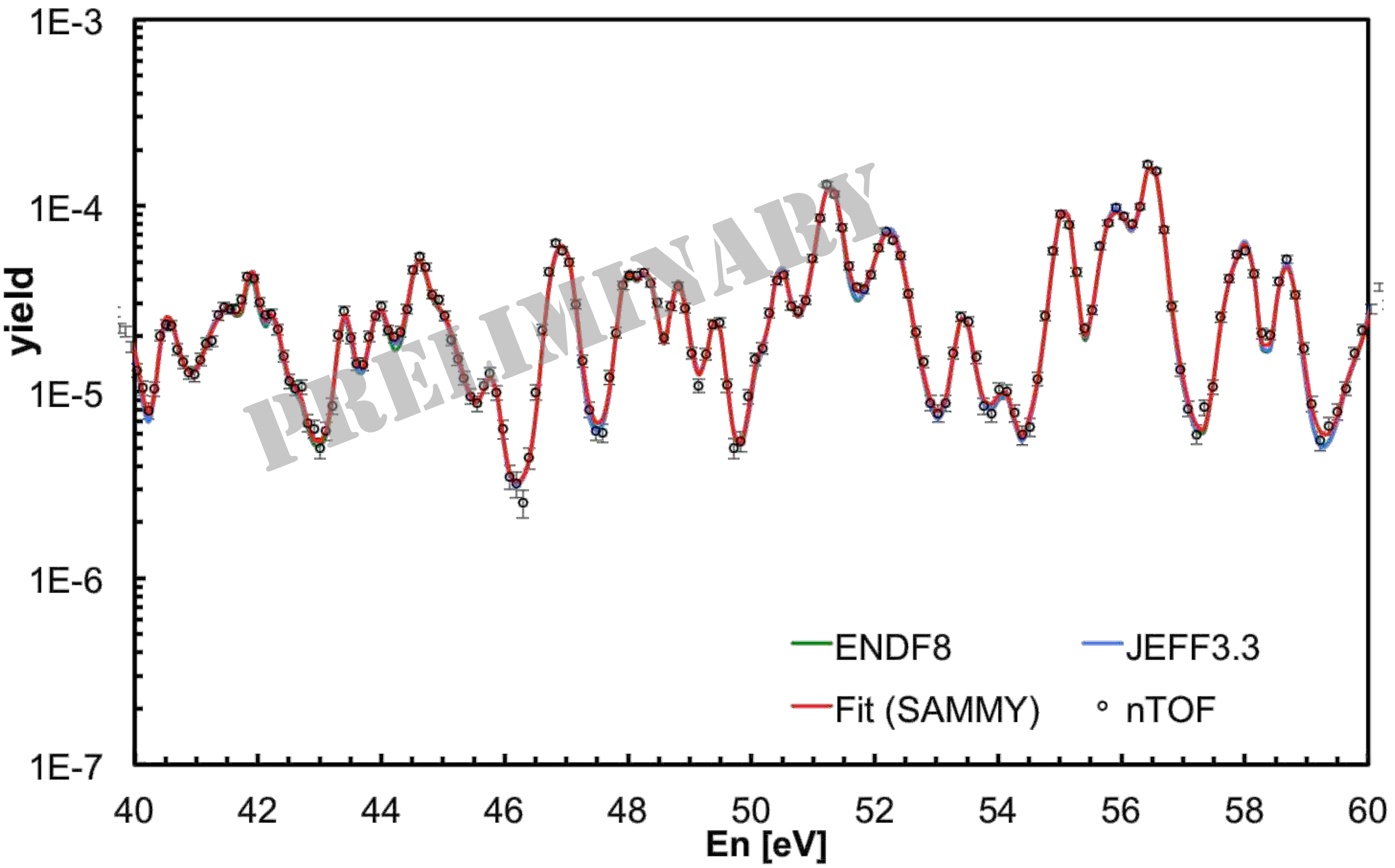


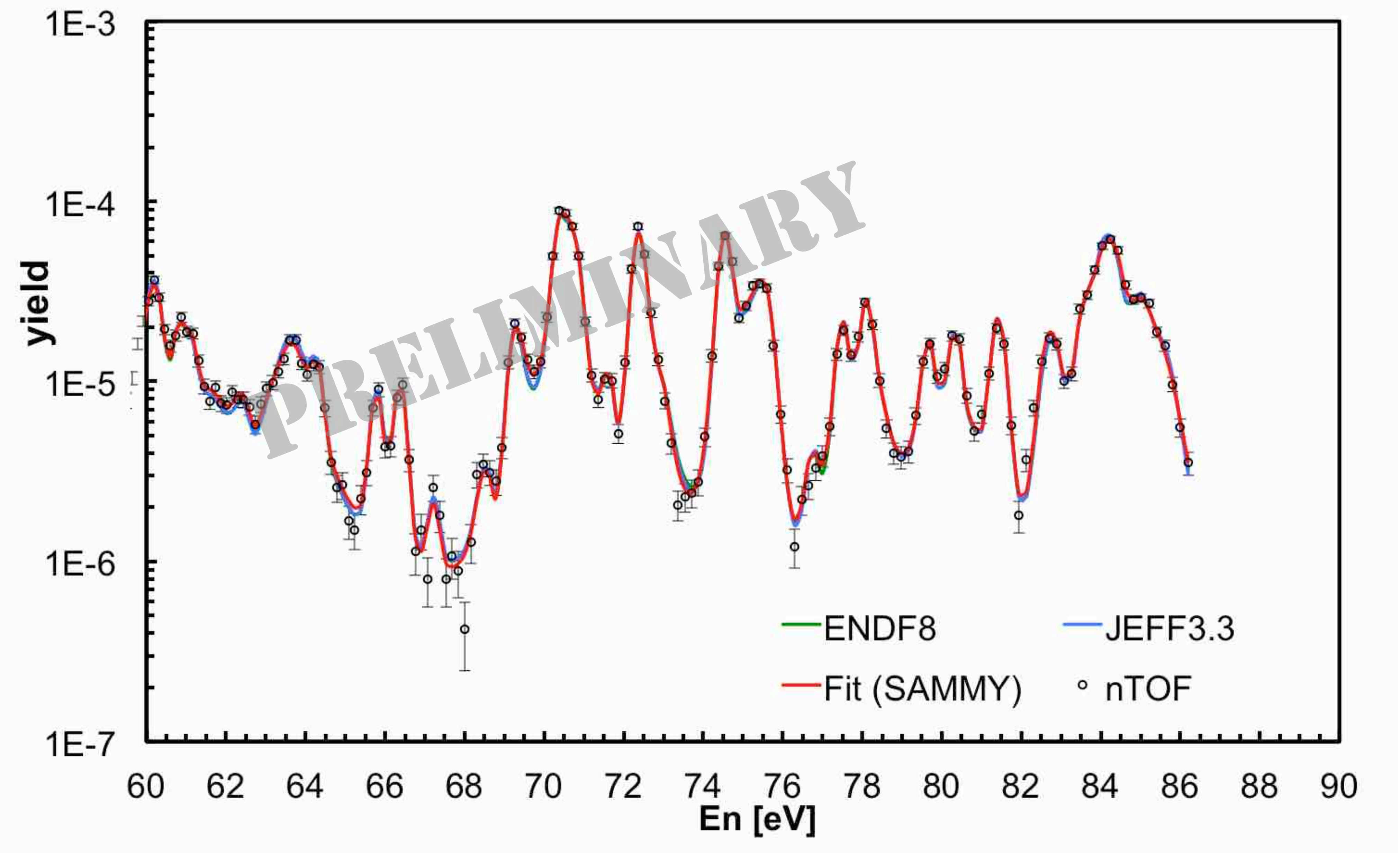

good resolution in valleys
PRELIMINARY
?
yield
1E-3
1E-4
1E-5
1E-6
1E-7
0
1
2
3
4
5
En [eV]
nTOF
JEFF3.3
ENDF8
Fit (SAMMY)


good resolution in valleys
?
?
?
PRELIMINARY
1E-3
1E-4
1E-5
1E-6
1E-7
yield
5
6
7
8
9
10
11
12
En [eV]
ENDF8
JEFF3.3
Fit (SAMMY)
nTOF

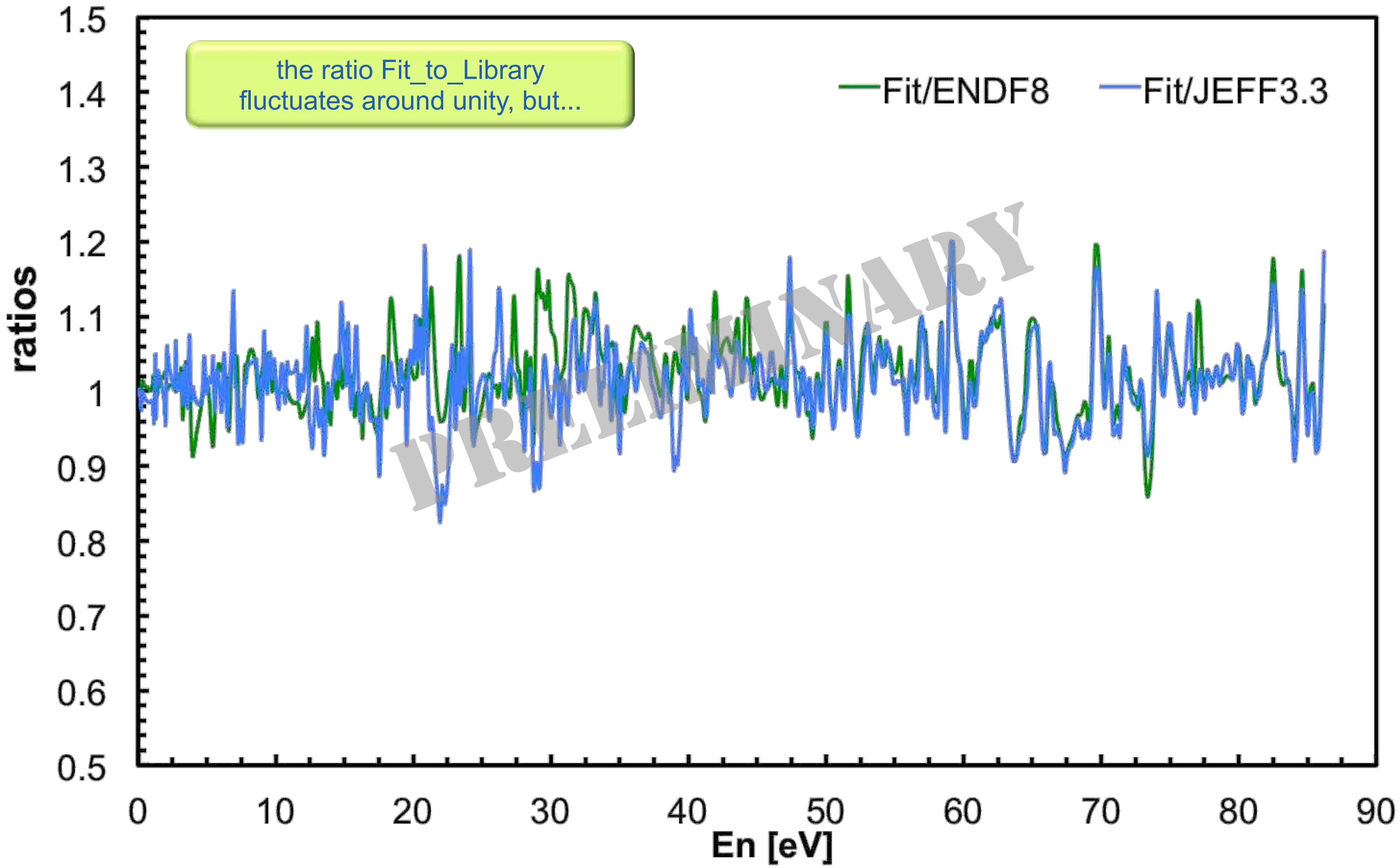

good resolution in valleys
?
?
PRELIMINARY
1E-3
1E-4
1E-5
1E-6
1E-7
yield
12
14
16
18
20
En [eV]
ENDF8
JEFF3.3
Fit (SAMMY)
nTOF

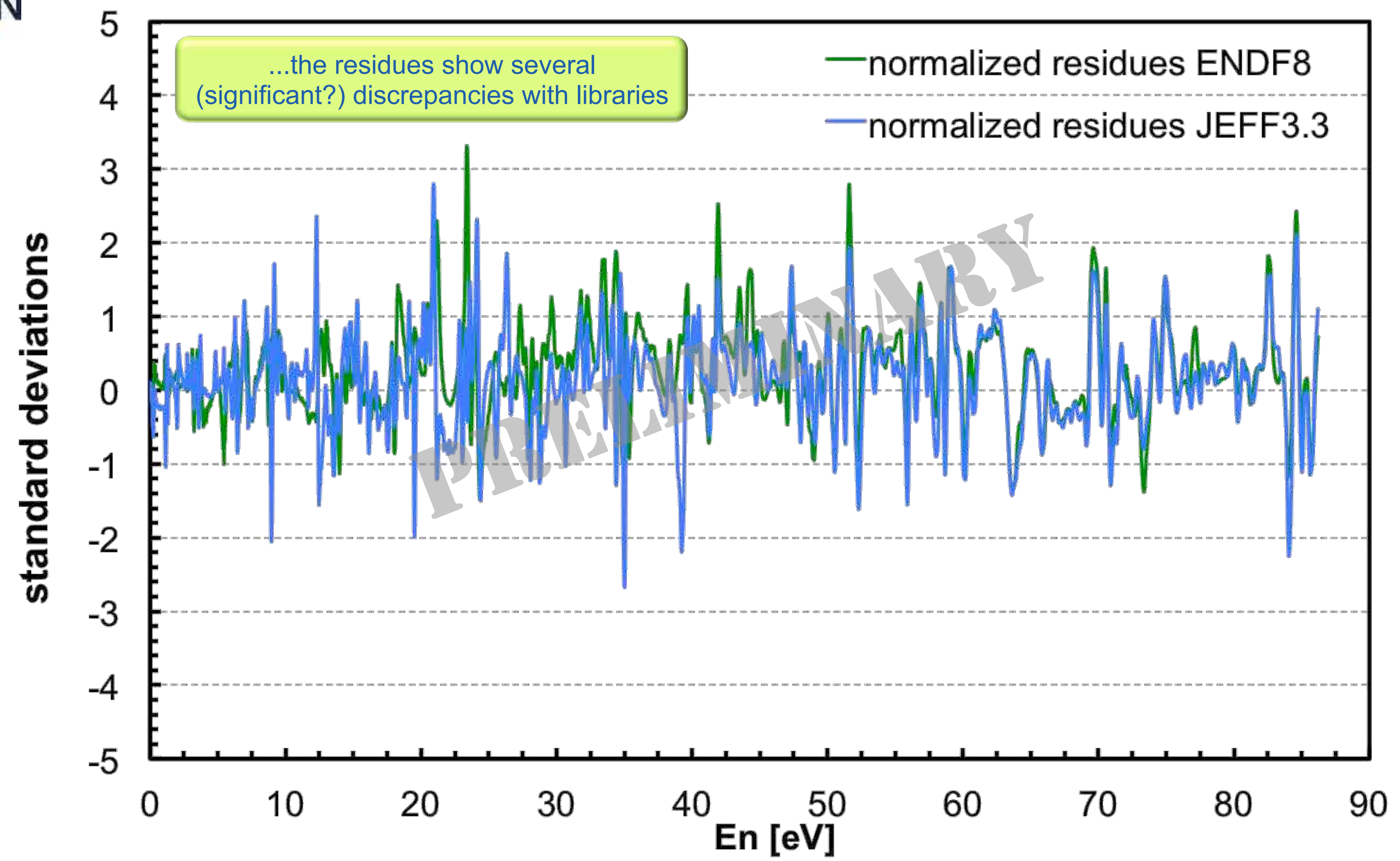

good resolution in valleys
?
?
?
PRELIMINARY
1E-3
1E-4
1E-5
1E-6
1E-7
yield
20
22
24
26
28
30
32
34
36
38
40
En [eV]
ENDF8
JEFF3.3
Fit (SAMMY)
nTOF


1E-3
1E-4
1E-5
1E-6
1E-7
yield
40
42
44
46
48
50
52
54
56
58
60
En [eV]
PRELIMINARY
ENDF8
JEFF3.3
Fit (SAMMY)
nTOF



1E-3
1E-4
1E-5
1E-6
1E-7
yield
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
En [eV]
ENDF8
JEFF3.3
Fit (SAMMY)
nTOF
PRELIMINARY

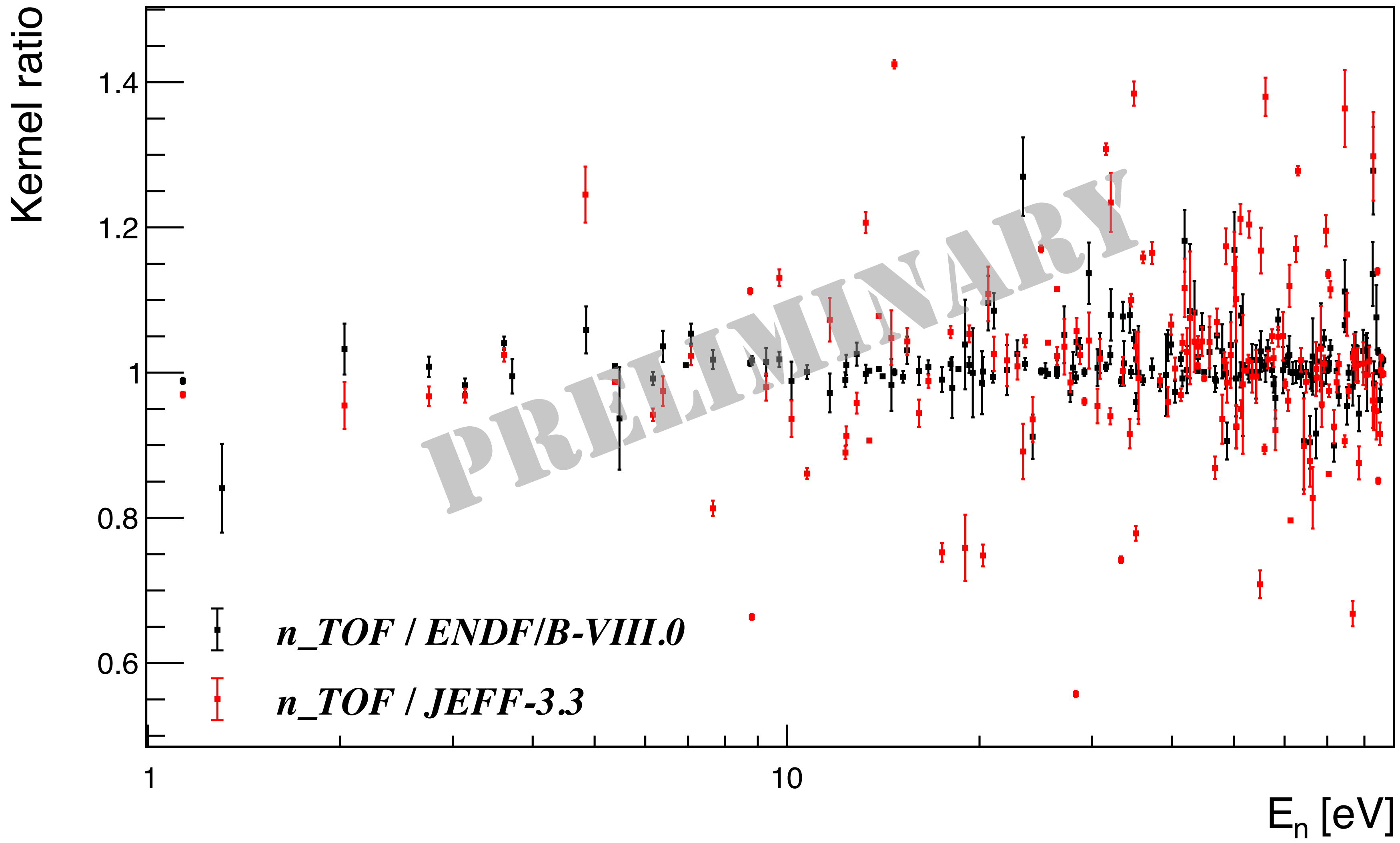

the ratio Fit_to_Library
fluctuates around unity, but...
Fit/ENDF8
Fit/JEFF3.3
ratios
En [eV]
PRELIMINARY
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0
10
20
30
40
50
60
70
80
90



...the residues show several (significant?) discrepancies with libraries
normalized residues ENDF8
normalized residues JEFF3.3
standard deviations
En [eV]
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
10
20
30
40
50
60
70
80
90
PRELIMINARY

kernel ratios → quite encouraging for ENDF/B-VIII.0

not so much for JEFF-3.3



INFN LNS

n_TOF

perspectives

- in-beam silicon sandwich detection system proved very effective
- electronics being improved to reach the MeV range
- possible use for other fission measurements
- high quality data obtained for $^{235}U(n,f)$, $^{6}Li(n,t)$, $^{10}B(n,\alpha)$
- agreement with $^{235}U(n,f)$ standards at thermal and at 150÷170 keV
- URR: resonance clusters found above 2.25 keV
- URR: major discrepancy with libraries found between 9 and 18 keV

  GMA node at 9.5 keV?
- RRR: χ^2 and Σ hint at several discrepancies with libraries
- RRR: discrepancies likely due to n_TOF good resolution in valleys
- paper on the RRR in preparation
- high resolution data to be released to EXFOR within January 2022

Thank you