Characterization of fission ionization chambers using reference neutron beams

Activity part of the JRA2 of EFNUDAT

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Summary and motivation

- Necessity to improve the accuracy of n_flux measurements to reduce the uncertainty in the related cross sections. Is 2% achievable?

→

1. discussion of the uncertainties related to the analysis of fission chamber data
2. comparison with the primary standard
3. intercomparison between IRMM, IPHC, and PTB chambers

- H19, H21 PTB fission chambers are transfer instrument (n_TOF, n_ELBE, UCL, iThemba, TSL), but the last intercomparison was 20 years ago

Intercomparisons

Previous key comparison

1990

- o PTB chambers irradiated at different institutes
- o Fast neutron fluence rate with respect to different flux measuring devices
- o Quantity compared: detector sensitivity
- o Standard deviation of the results 1-2 %

Current comparison

- PTB, IRMM, IPHC chambers, RTP1, and 2″x2″ NE213 irradiated at the same conditions at 2 energies
- comparison of the measured target yield from standard (quasi-)monoenergetic fields

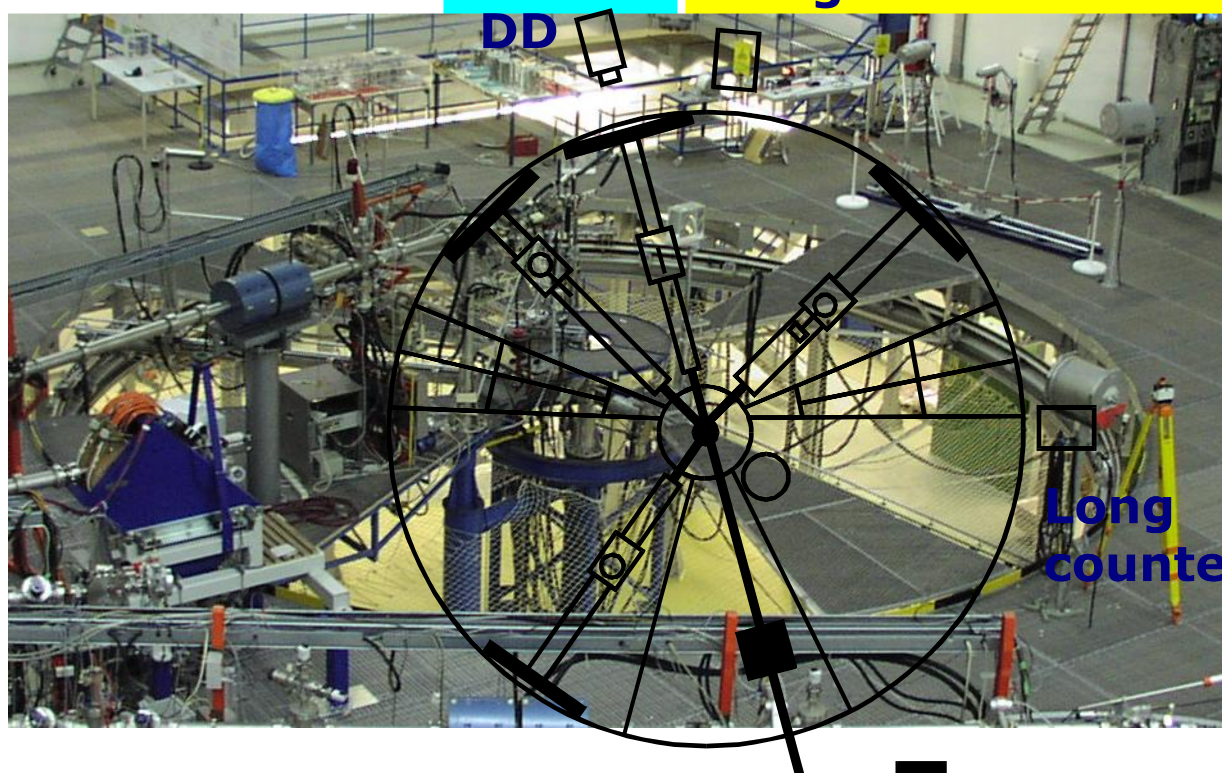
Irradiations with monoenergetic neutrons

D(d,n)^{3}He: 8.4 MeV

T(d,n)^{4}He: 15 MeV

Monitoring

- Charge
- Long counters
- NE213 scintillator



Neutron flux detectors: proton recoil telescope and TOF scintillator

General problem with d-beams: non-monoenergetic neutrons

Solutions: reliable gas out and TOF measurements

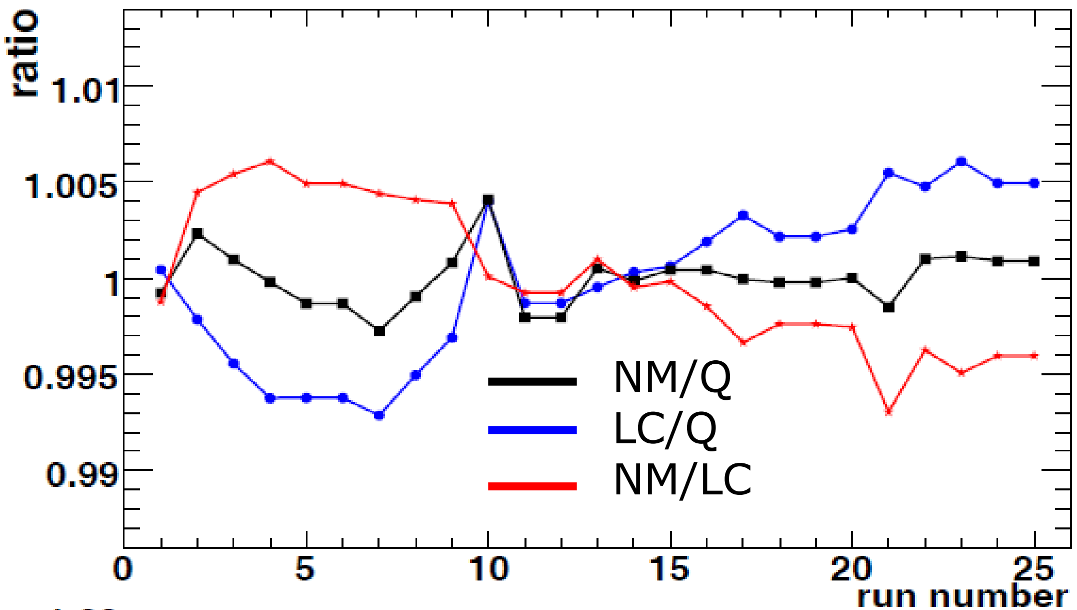
simulations

Monitoring

Solid target:

Monitor readings corrected for scattering by the detectors in the beam

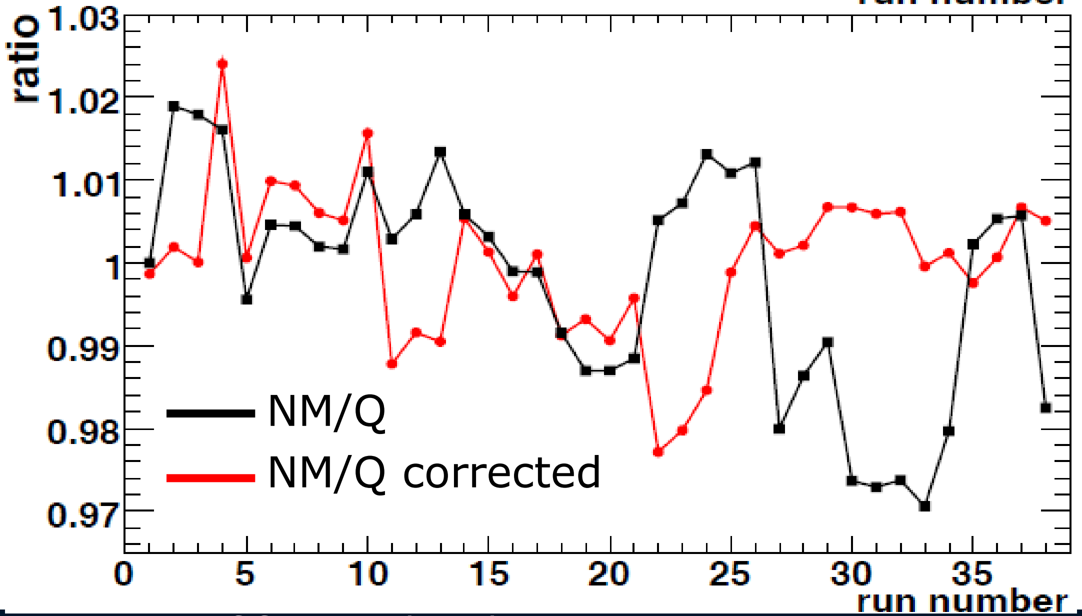
Stability of the monitor ratios within 1%



Gas target:

Monitor readings corrected for gas pressure, gas out contribution and scattering by the detectors in the beam

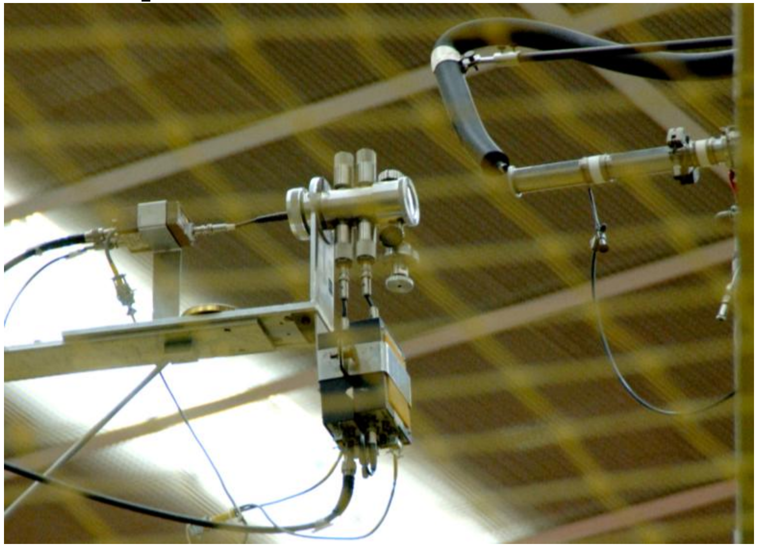
Stability of the monitor ratio within 2.5%

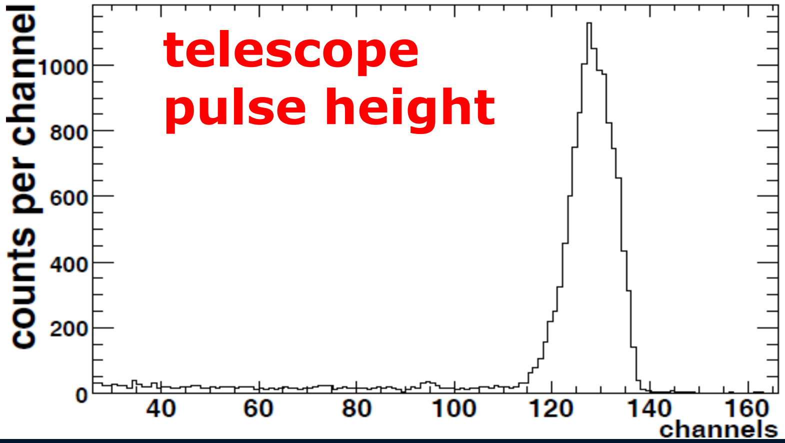


Fluence relative to (n,p) cross section

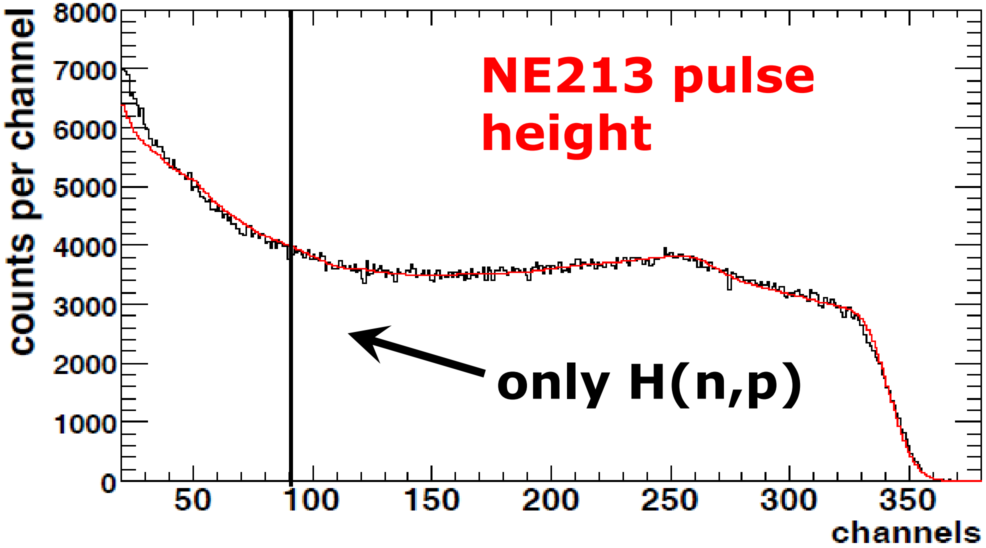
Telescope

$$E_p = E_n \cos^2 \theta$$





Scintillator

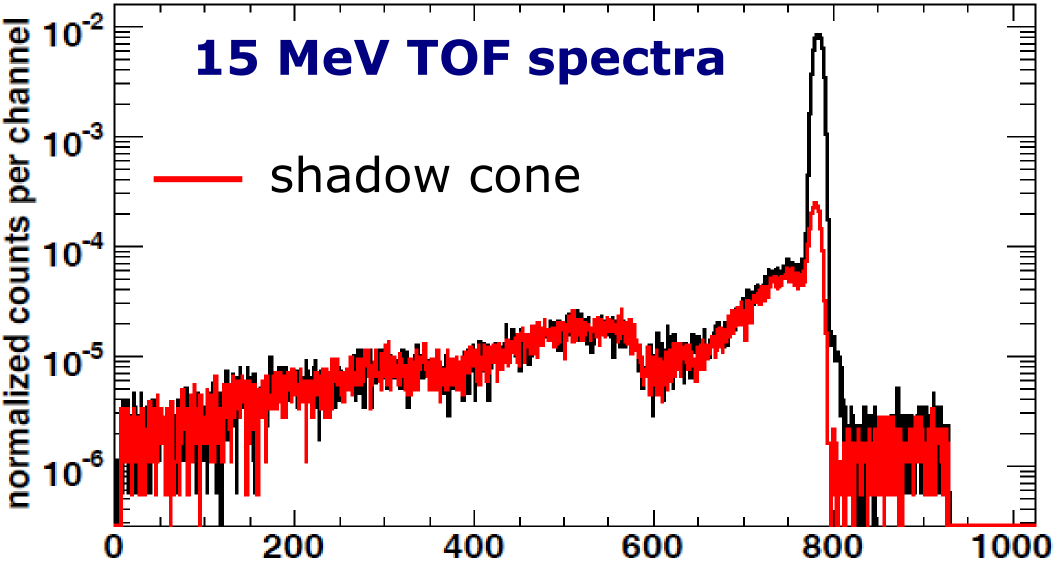


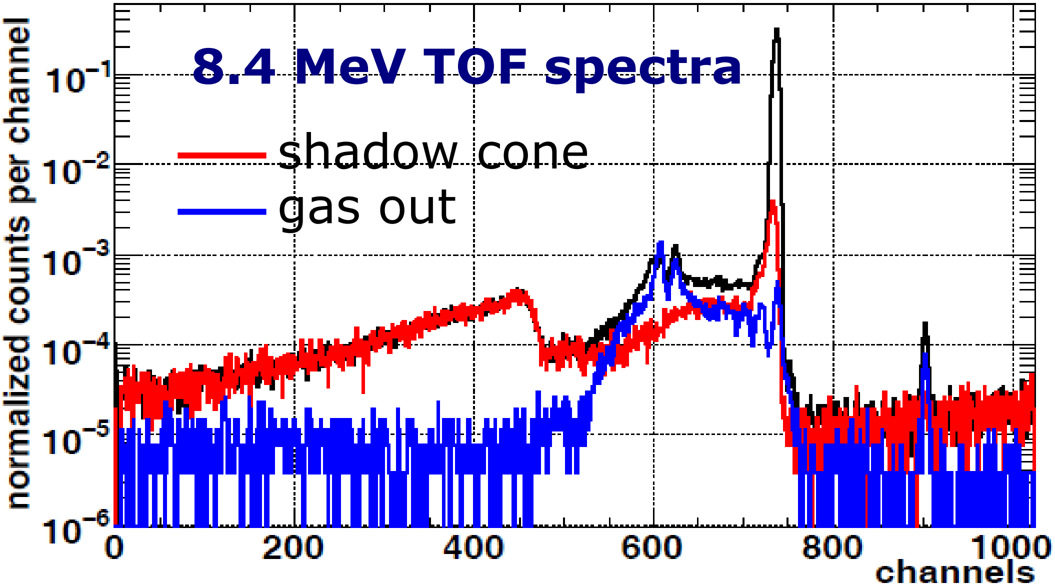
A well characterized scintillation detector can be a fluence detector

Very sensitive

Good time resolution

Fluence by scintillators: TOF and traceability

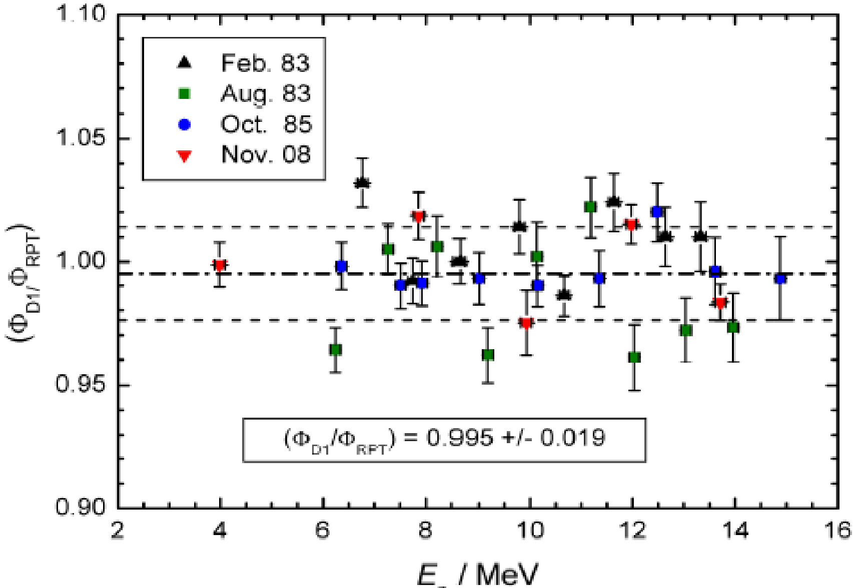




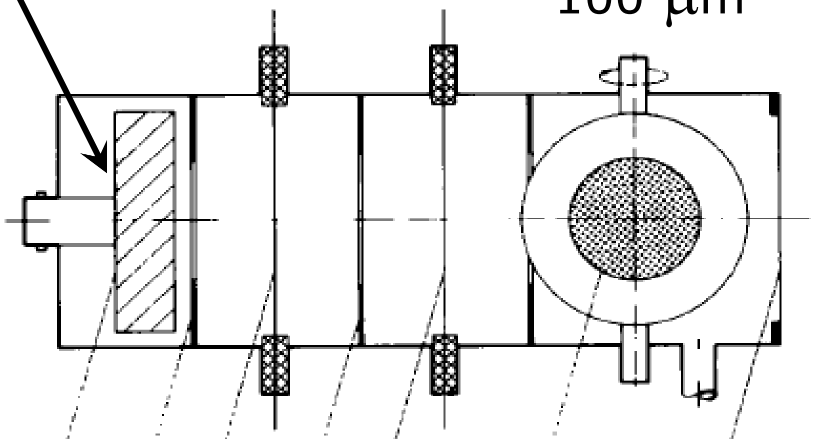
Scintillators are reliable Time-of-Flight detectors: TOF spectra allow background identification

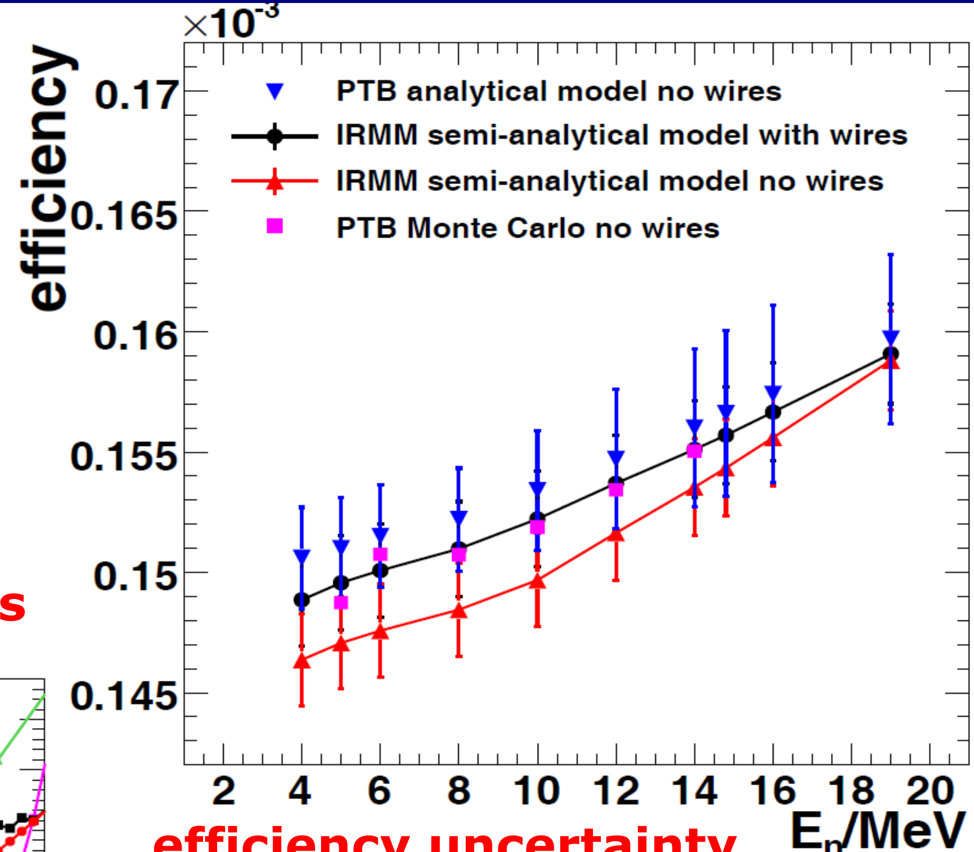
D1 compared with RPT1

1.9 % scattering over ~20 years

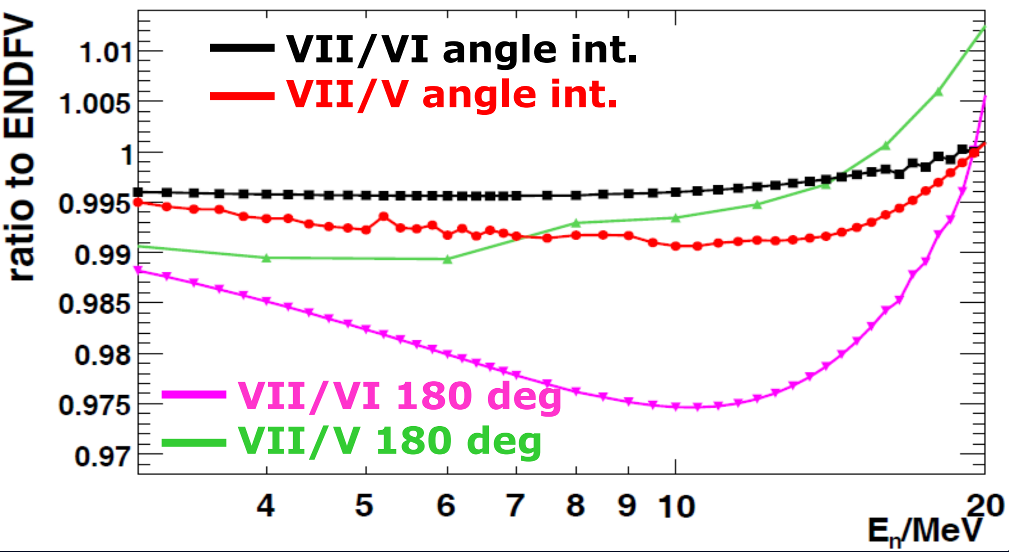


Uncertainty in flux determination with RPT1





H(n,n)H cross section evaluations



efficiency uncertainty

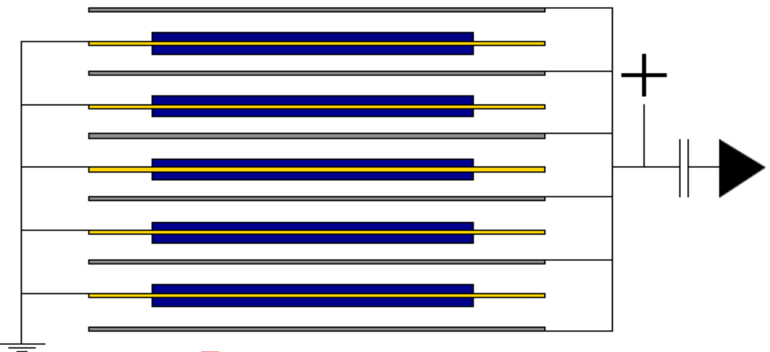
PTB 1.4%

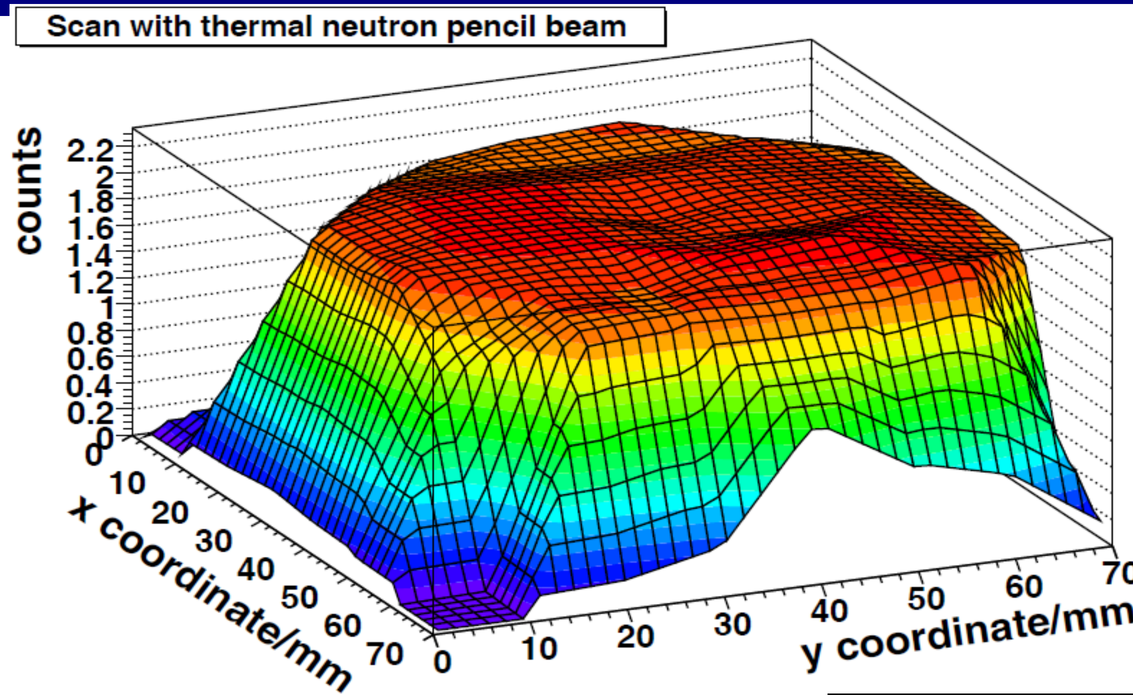
IRMM 1.3%

max 1% discrepancy

The effect of the wires must be further investigated

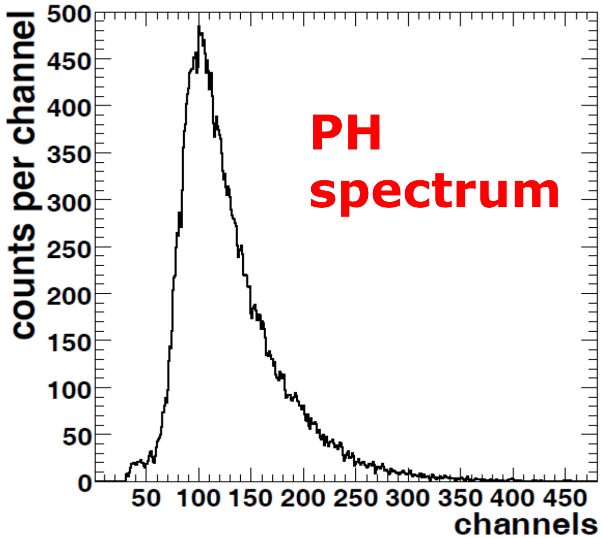
Compared instruments (PTB H19 H21)



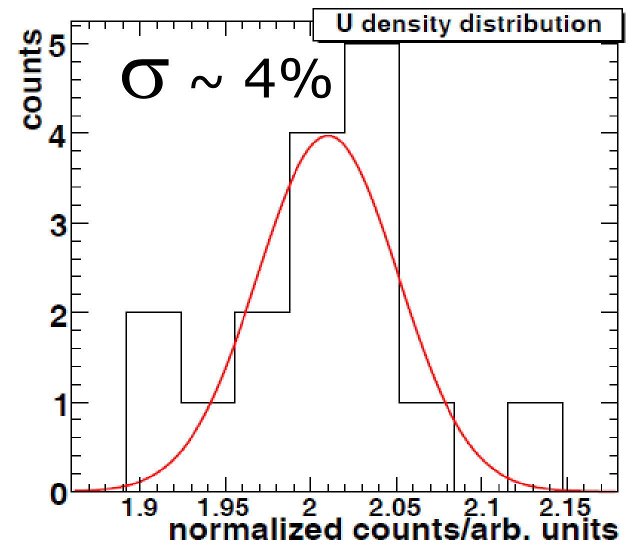


Parameters

	H19 ^{235}U	H21 ^{238}U
Ø/mm	76	76
m_U/mg	201.6 ± 0.5	197.8 ± 0.5

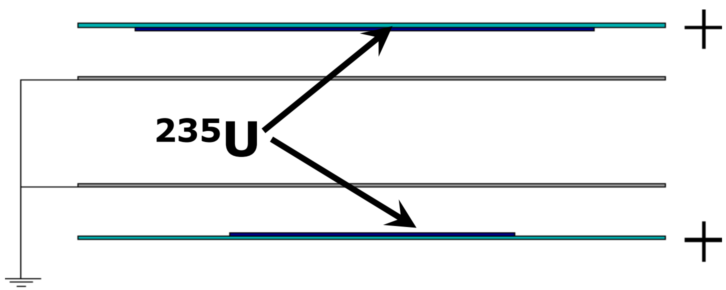


Homogeneity of H19 layers within 4%



Compared instruments (IRMM and IPHC chambers)

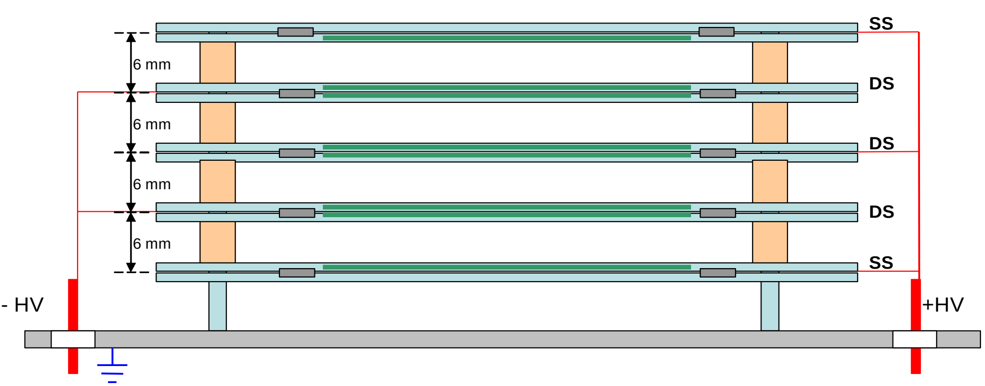
FC 16/30 IPHC

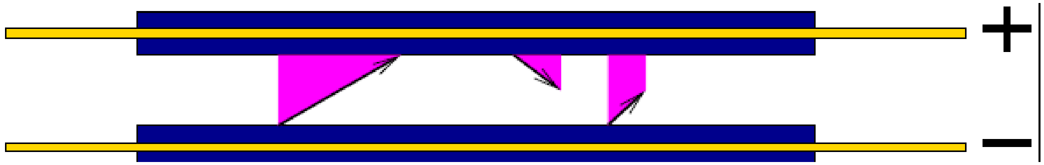


Parameters

	$^{235}U_3O_8$/layer 1	$^{235}UF_4$/layer 2
Ø/mm	1016	70
m_U/mg	49.02	12.46

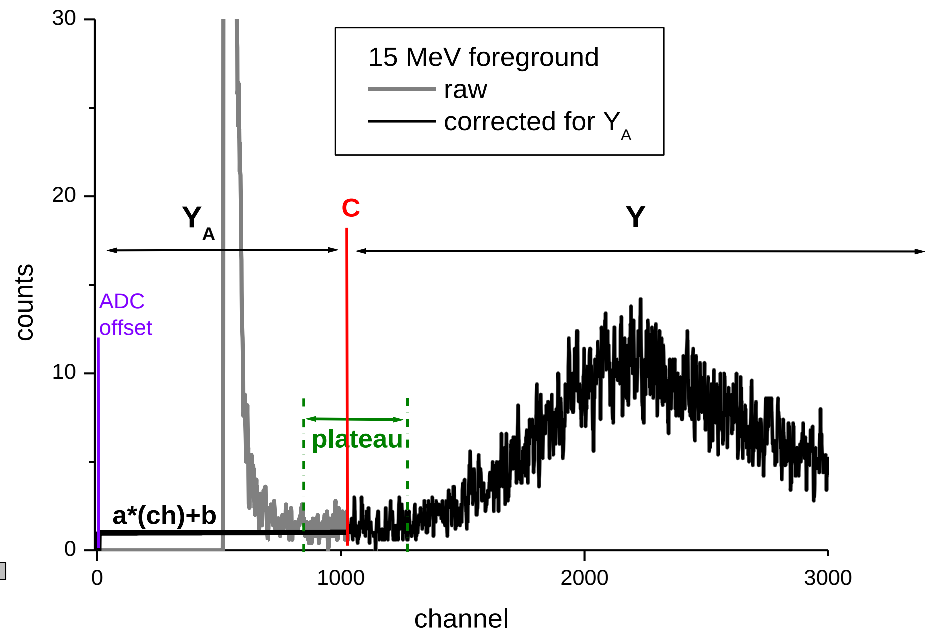
FC 3/200M IRMM





Parameters

	$^{235}UF_4$
Ø/mm	70
m_U/mg	117.80



Fission chamber analysis

$$\mathbf{N_f = \varepsilon f_1 f_2 \Phi N_U \sigma}$$

Sources of uncertainty:

1. U mass uncertainty
2. ^{235}U, ^{238}U cross sections
3. zero bias efficiency ε
4. f_1 events below threshold
5. f_2 in-scattering correction
6. identification of fission events

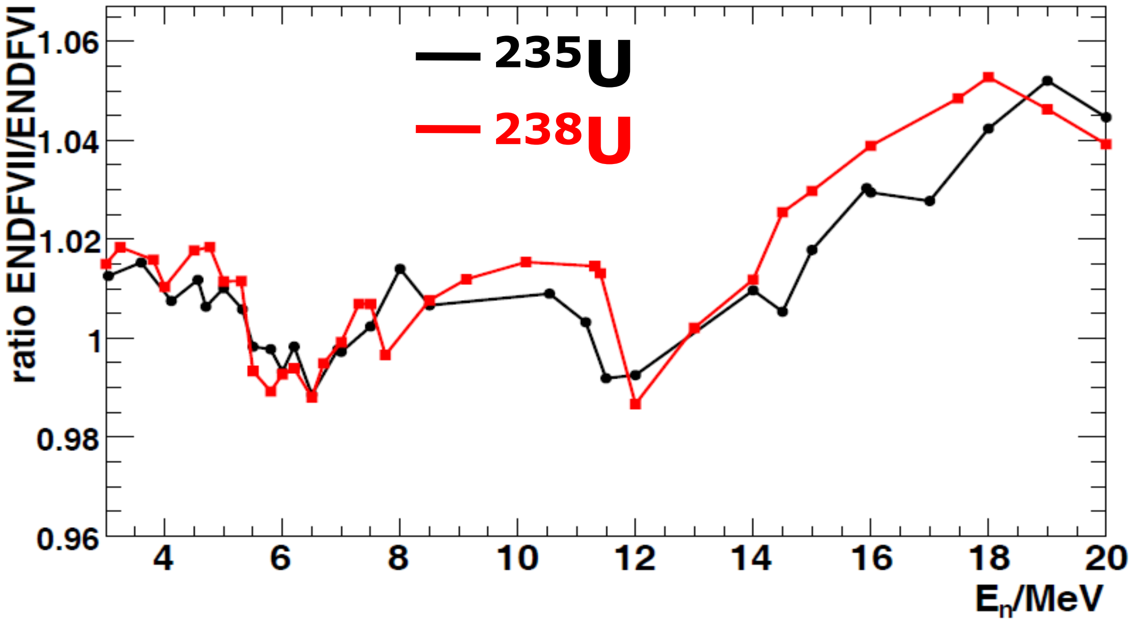
Fission chamber uncertainties

1. U mass determination

Weighting

α counting

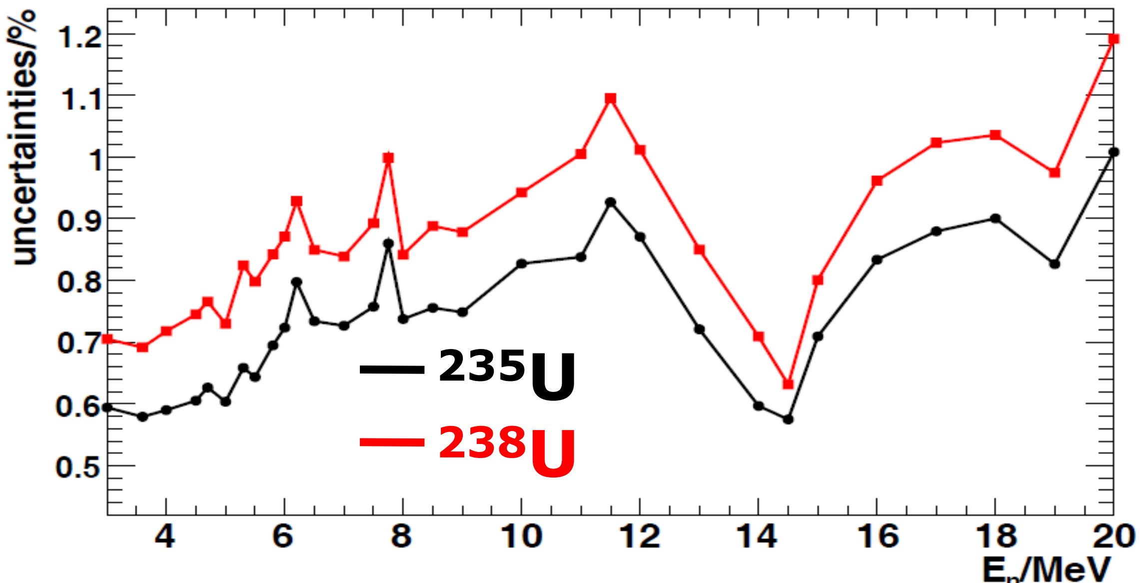
0.2% on the H19 result
0.3% on the H21 result



2. Fission cross sections

uncertainties below 1.1%

0.8% on the H19 result
0.9% on the H21 result

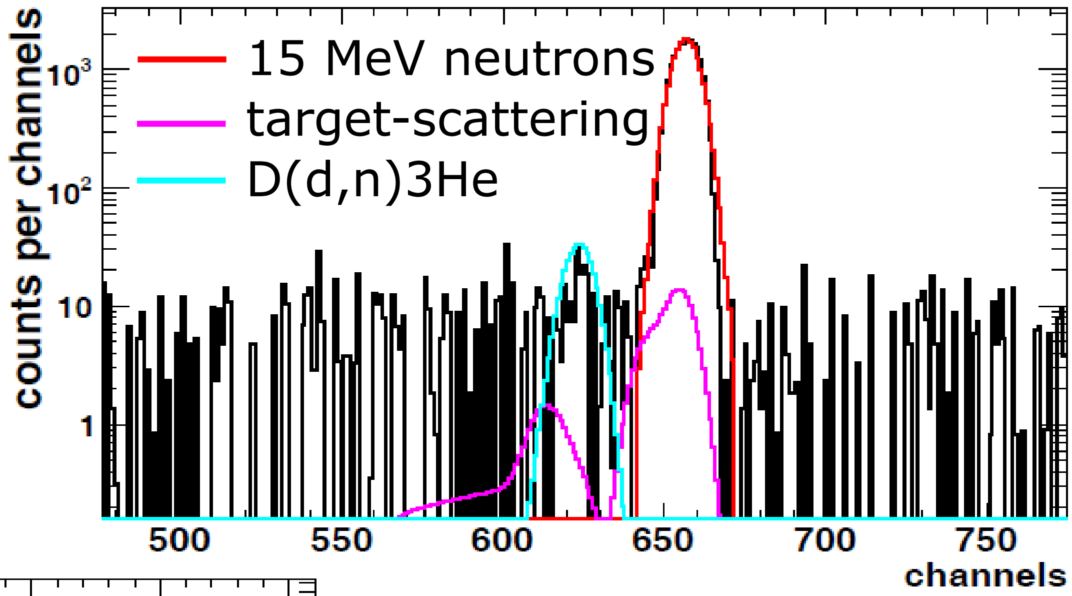


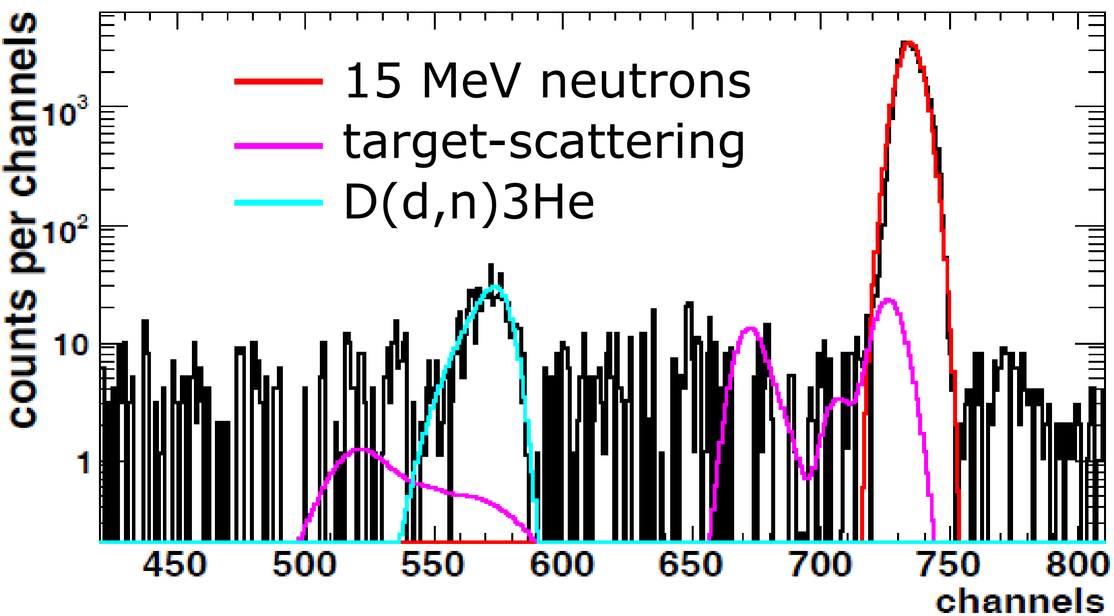
Number of fission events

Only for monochromatic neutrons

Background from TARGET Monte Carlo calculations[1]

1. D. Schlegel, **TARGET** User's Manual, Report **PTB**-6.41-98-1, 1998



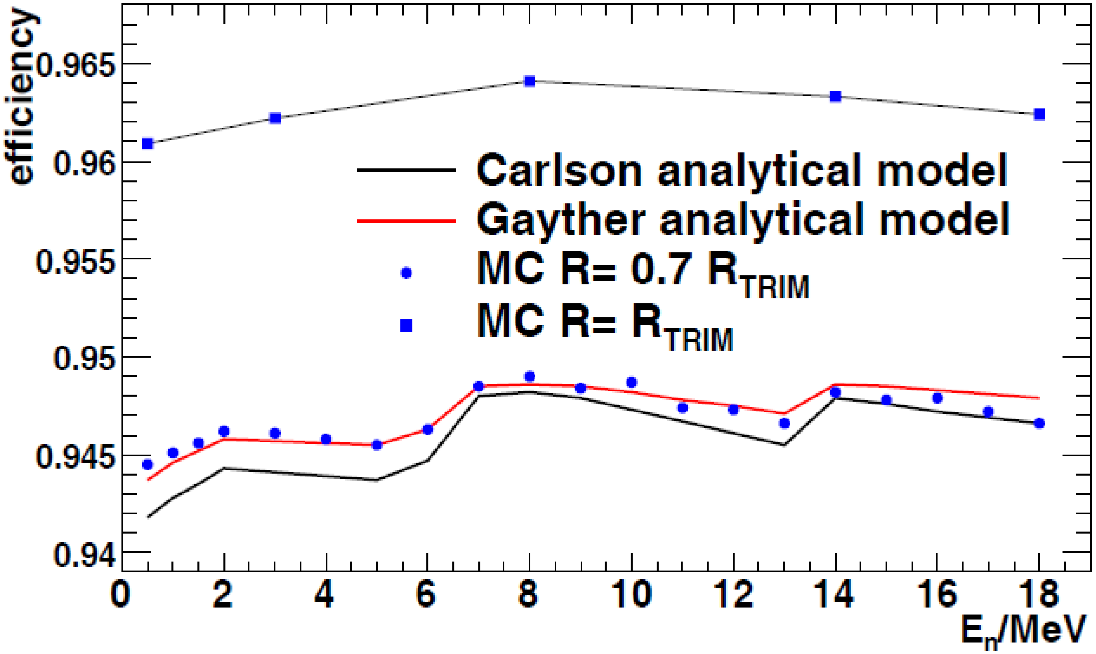


Scattering in the target 1%

Scintillator TOF spectra can separated the background components more clearly

Poor background statistics

ε efficiency, f_1 events below threshold



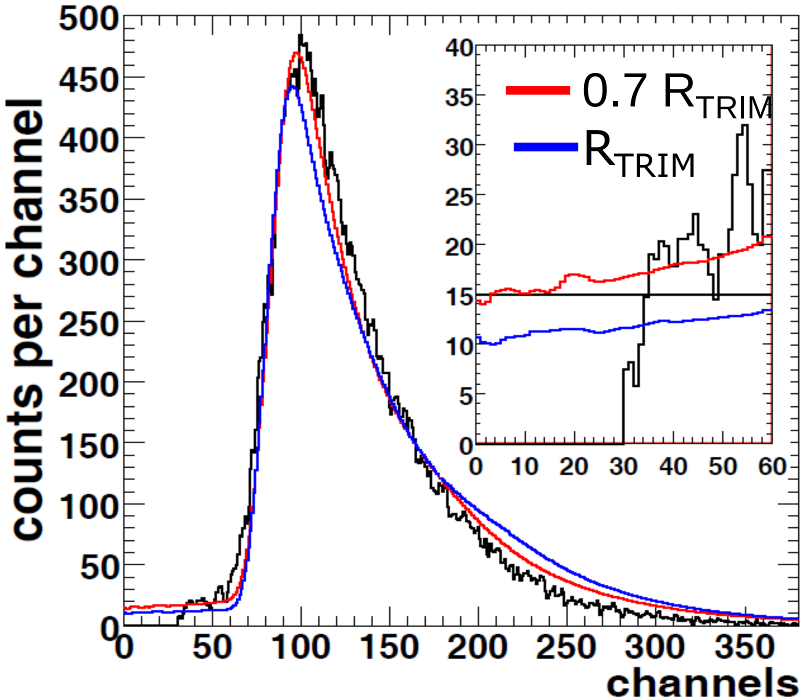
zero bias efficiency

Comparisons of analytical models and Monte Carlo calculations

uncertainty about 1%

f_1 events below threshold

Usual linear extrapolation versus Monte Carlo simulations : 5 % uncertainty on a correction of 2%



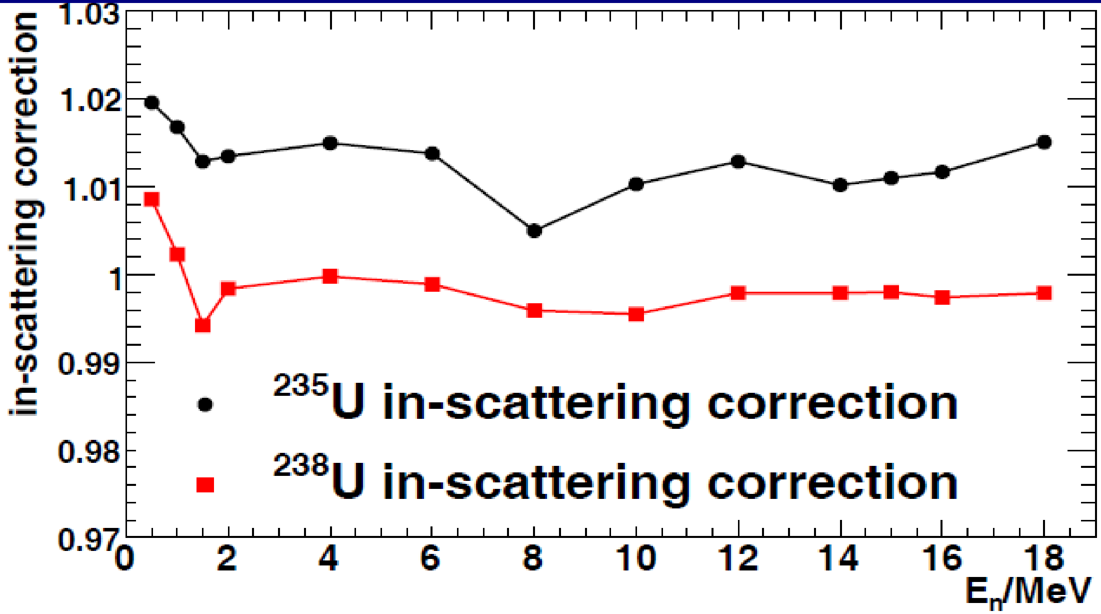
→ **Uncertainty of 1.2% for ε*f_1**

f_2 in-scattering correction

Gayther recommended corrections

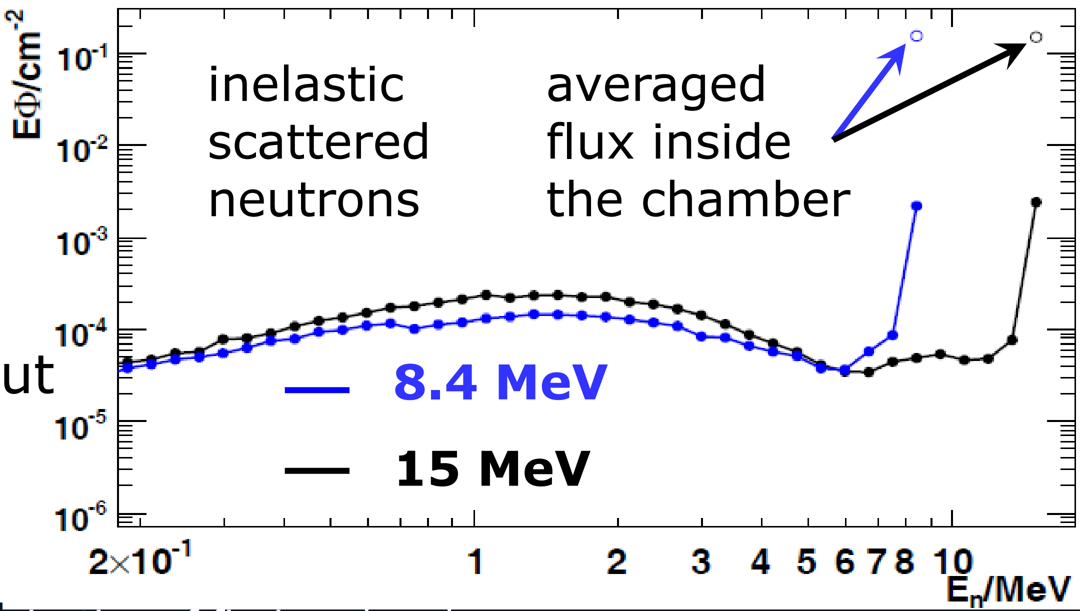
1.2 ± 0.9 % at 144 keV

1.6 ± 0.9 % at 14.8 MeV



MCNP simulations

deviations from recommended values



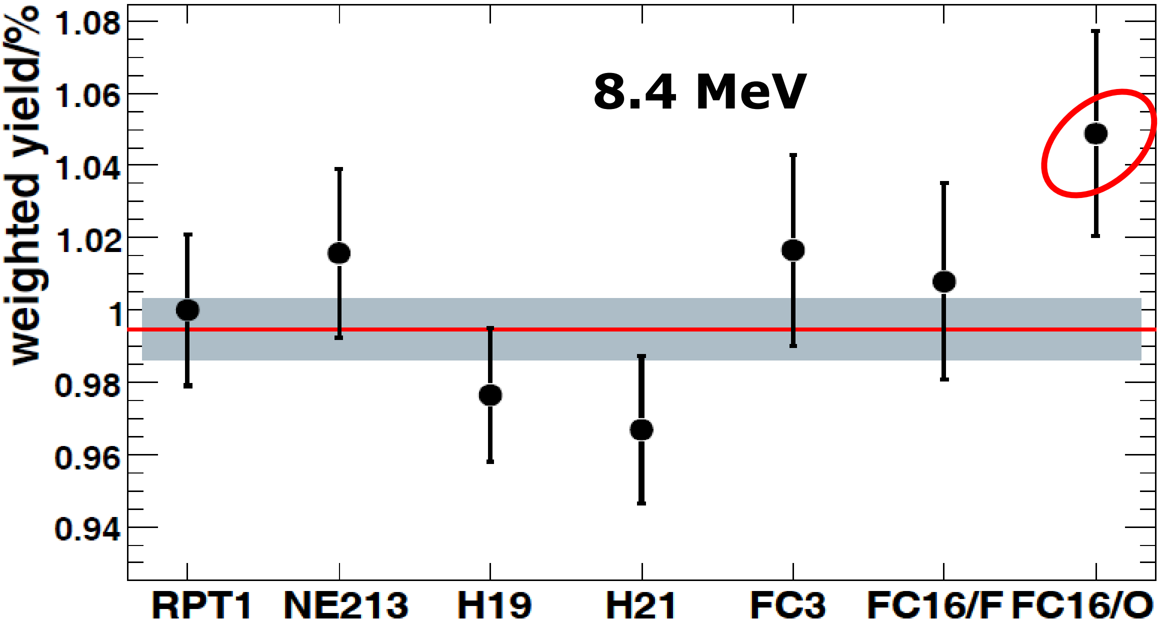
Updated uncertainty in the in-scattering correction: 0.2%, but Gayther corrections are still used for the current results

Measuring technique

- Irradiation at the same beam conditions
- Background measurements (gas out, shadow cone, and free field) for every detector
- Sequence of irradiations:

1. PTB telescope – flux determination
2. DD – beam inspection and additional flux measurements
3. Fission chambers in sequence

Results



Monitoring problem for 8.4 MeV

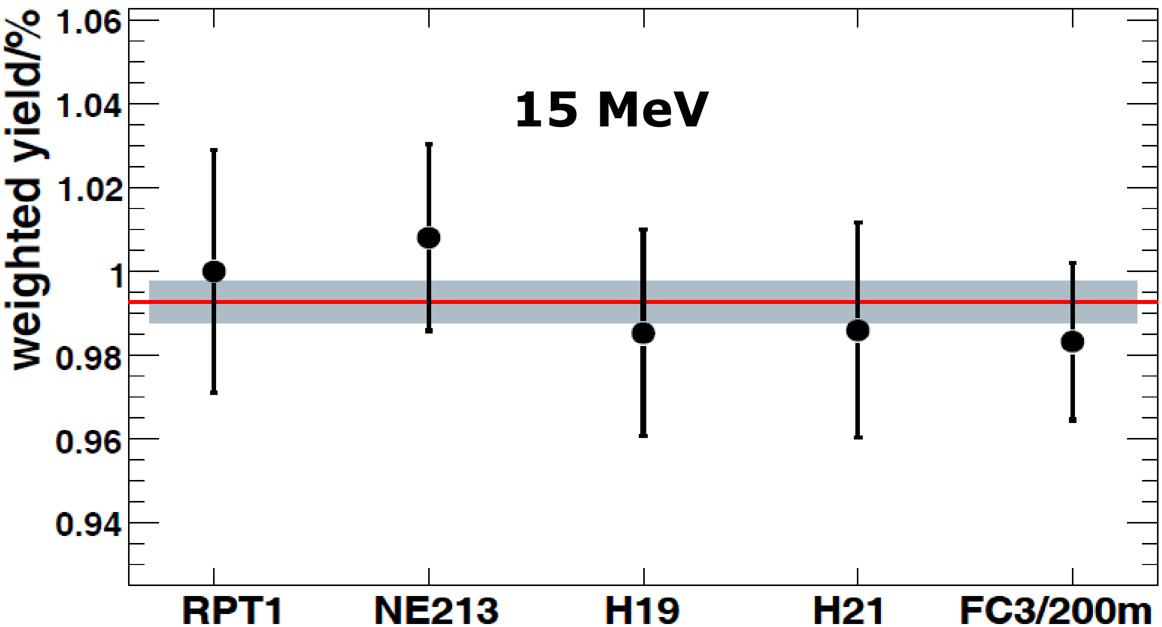
Standard deviation on the yield measurements:

1.0% at 8.4 MeV

0.5% at 15 MeV

Typical uncertainty of a fission chamber 2%

Improvements in the modeling of the detector can lead to larger reliabilities



Thank you for your attention