Fission cross sections measurements via the surrogate reaction method

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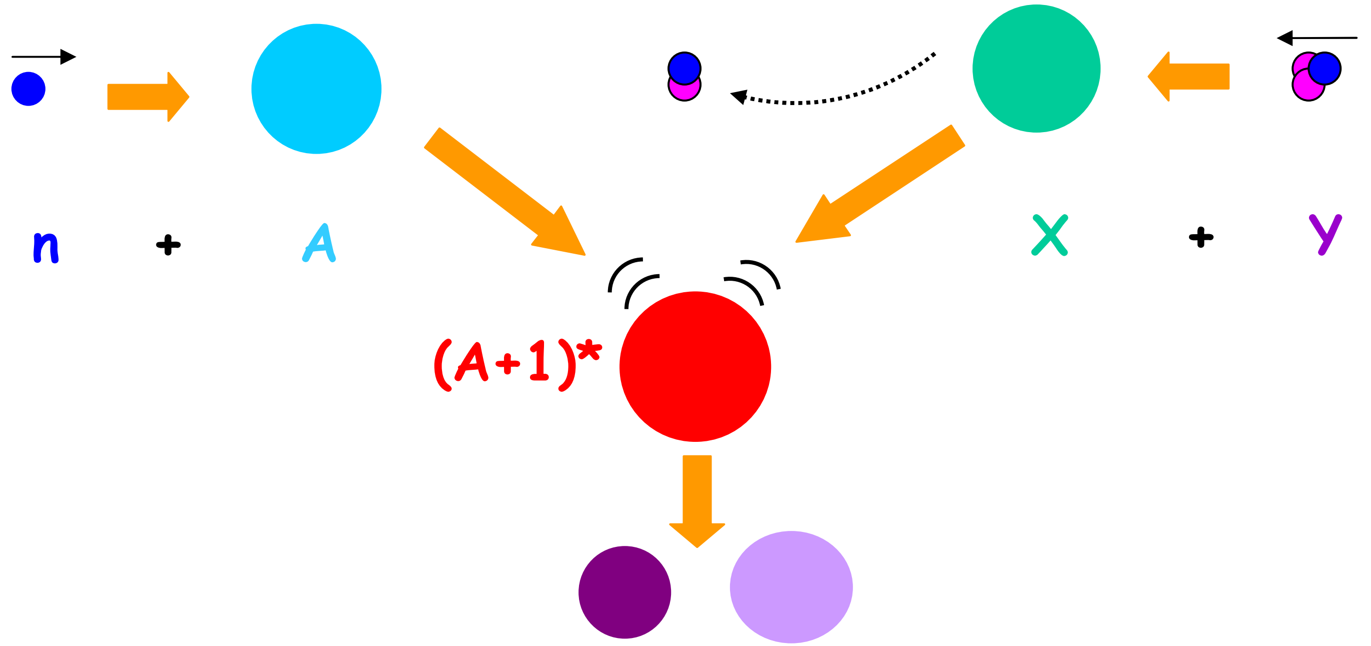
Neutron-induced fission cross sections and the surrogate method

Neutron-induced reaction

Surrogate reaction

Cramer and Britt (Los Alamos 1970...!!)



$$\sigma_{n,f}\left(E_n\right) = \sigma_{CN}\left(E_n\right) \cdot P_f\left(E_n\right)$$

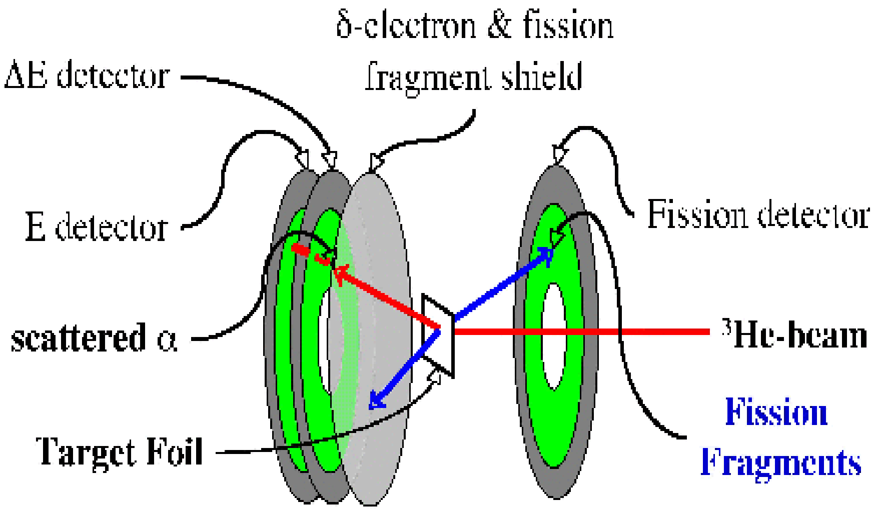
Optical model calculation ($\sigma_{CN}(E_n)$)

Measured ($P_f(E_n)$)

Experimental set-ups

STARS

(LBNL & LLNL, USA)



Surrogate ratio method
Forward detection of light particles
High light-particle detection efficiency

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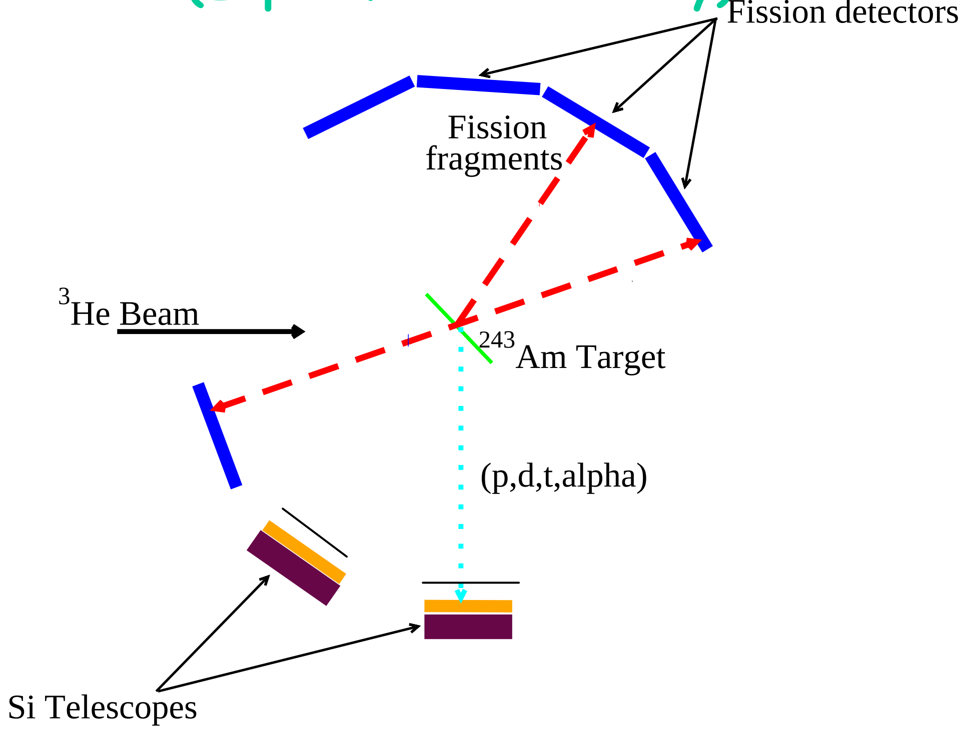
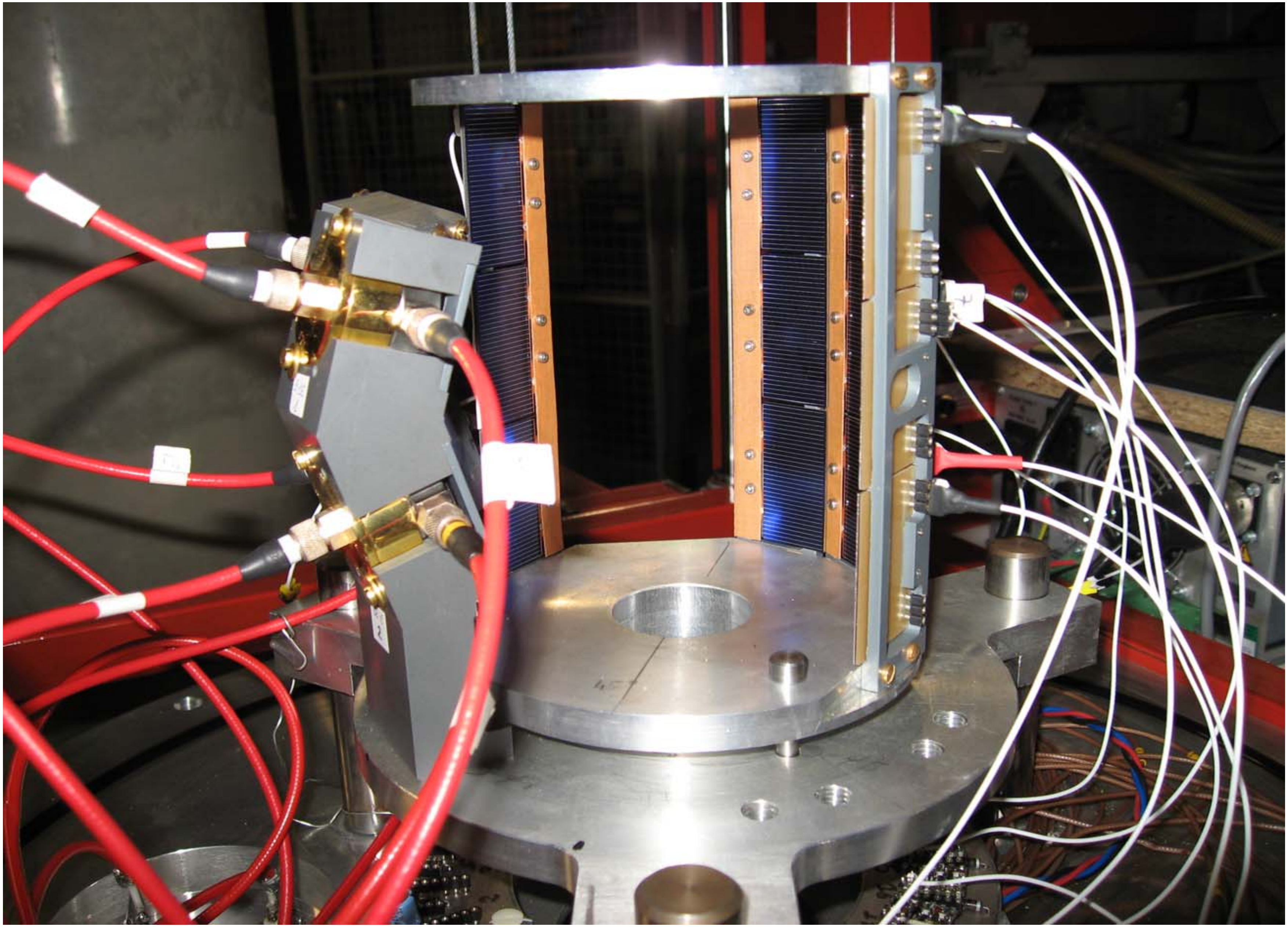
(Experiments at Orsay)



Absolute surrogate method
Backward detection of light particles
High fission detection efficiency
Fission fragment angular & mass distrib.

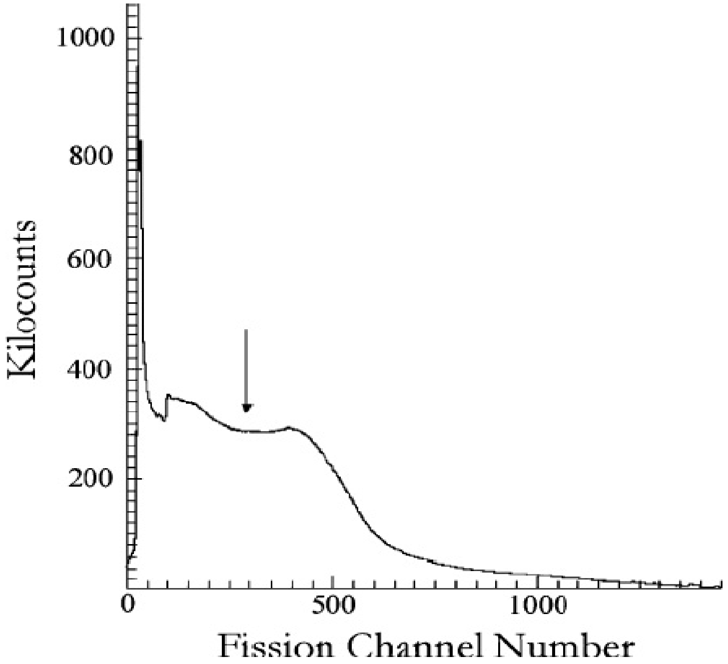
CENBG SET-UP



STARS

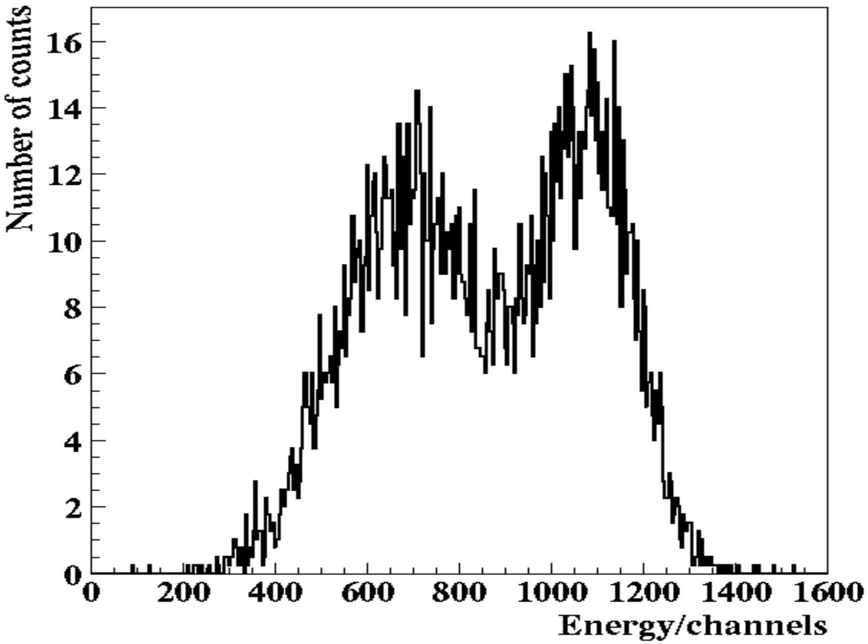
CENBG

Fission spectrum
$^{238}U(^{3}He,\alpha)^{237}U$



B. Lyles et al., PRC 76 (2007) 014606

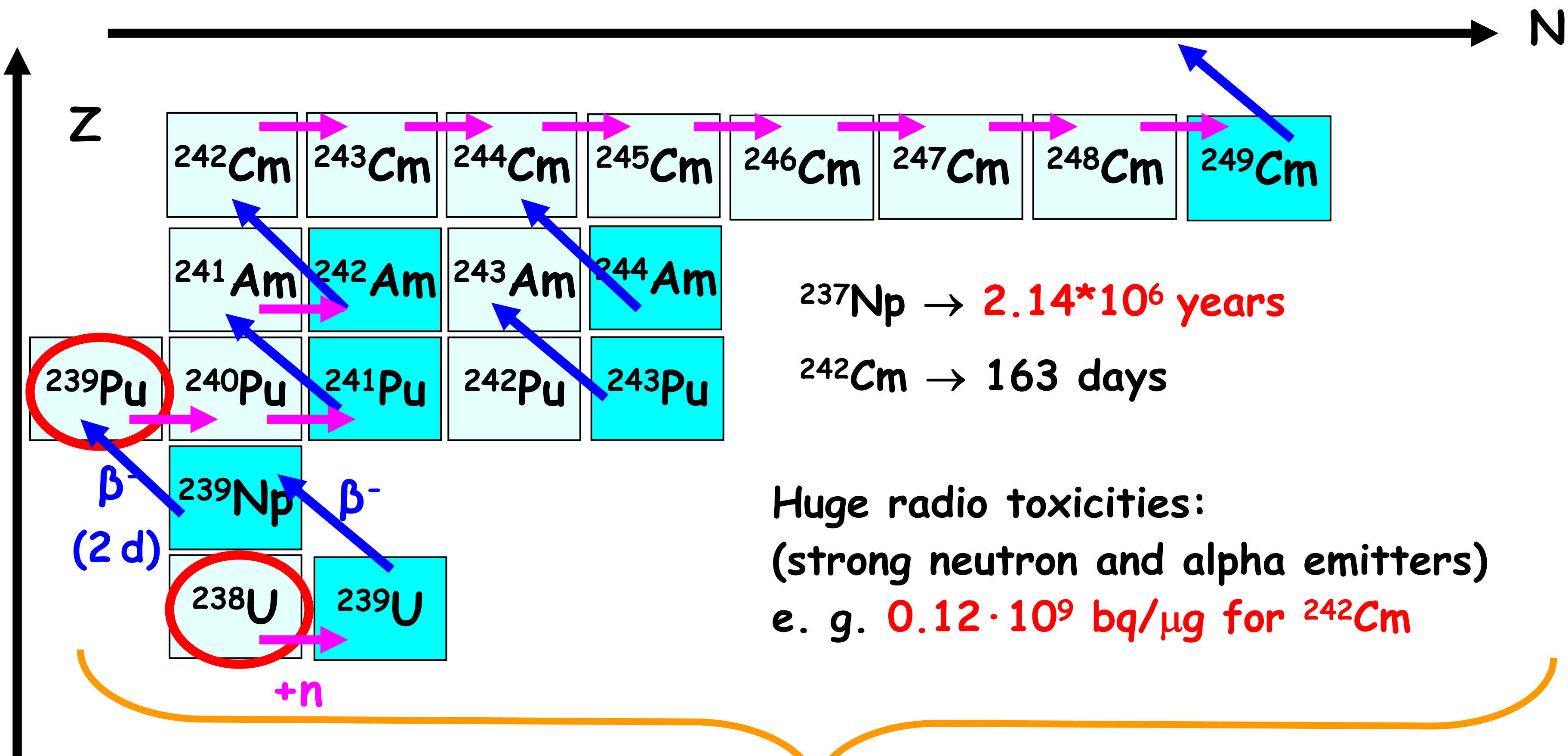
Fission spectrum
$^{243}Am(^{3}He,d)^{244}Cm$



Neutron-induced Minor Actinides Fission Cross Sections

Centre d'Études Nucléaires Bordeaux-Gradignan

Paths for minor-actinides formation in the U-Pu cycle

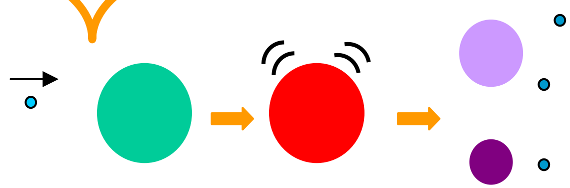


^{237}Np → 2.14*10^{6} years

^{242}Cm → 163 days

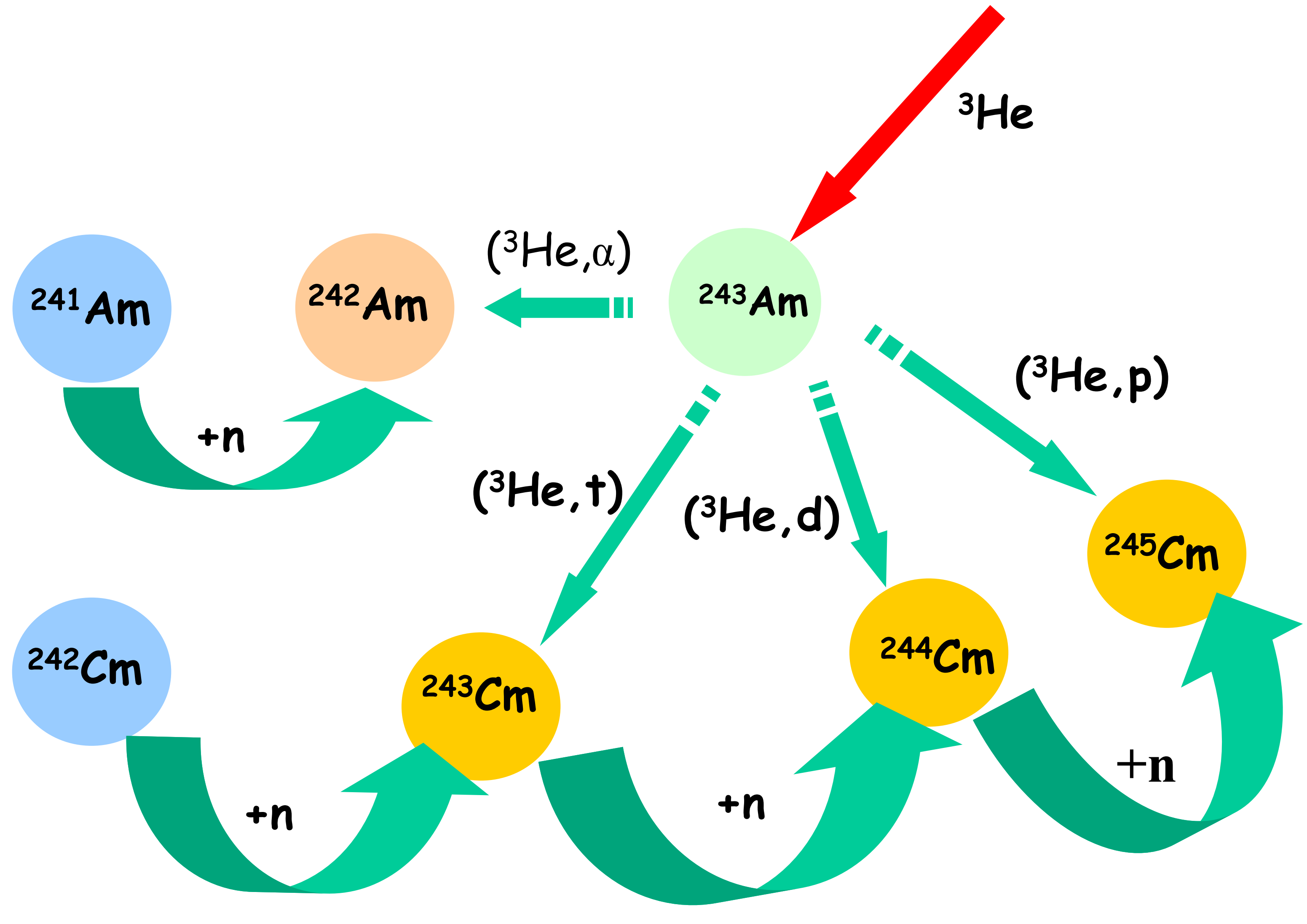
Huge radio toxicities:
(strong neutron and alpha emitters)
e. g. 0.12·10^{9} bq/μg for ^{242}Cm

Incineration!

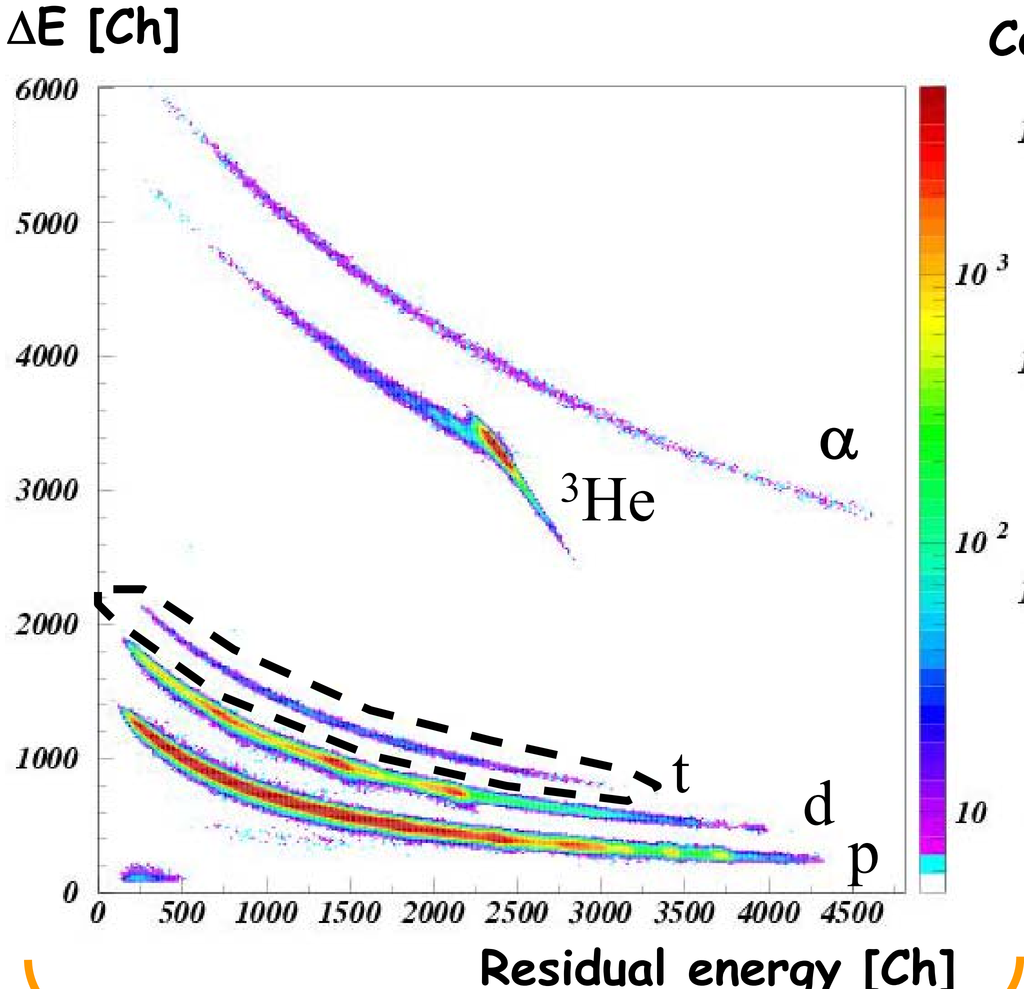


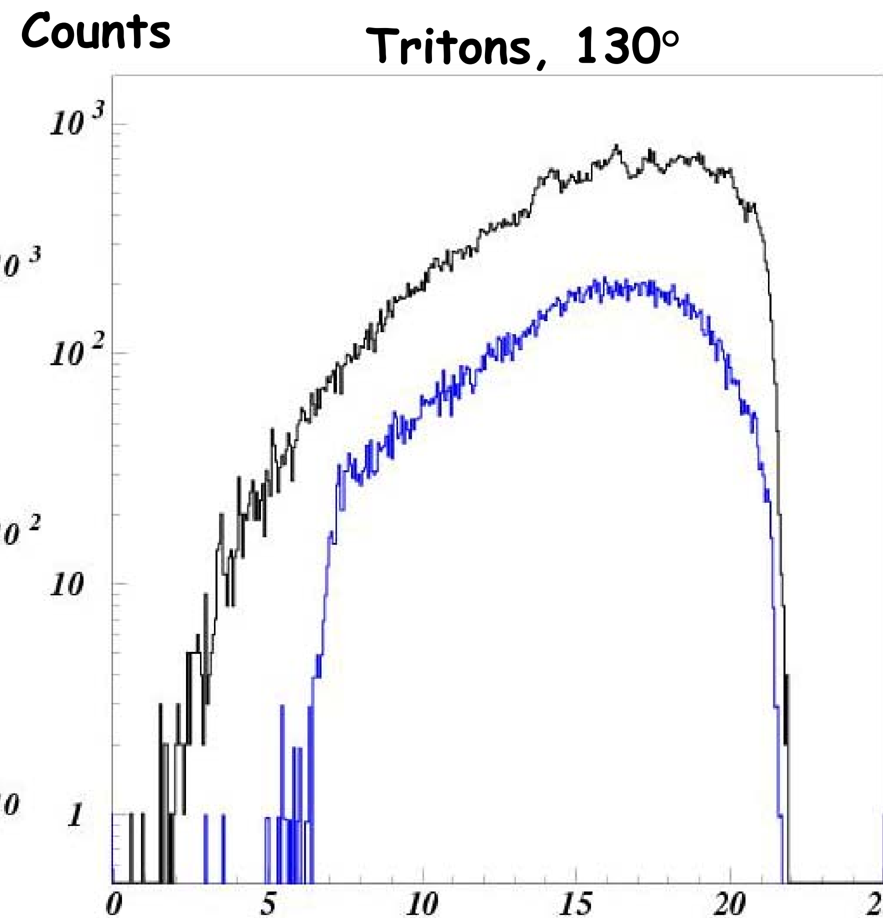
σ(n,f) of Am and Cm isotopes needed!!

Cm and Am fission cross sections via ^{3}He-induced reactions



Fission probability





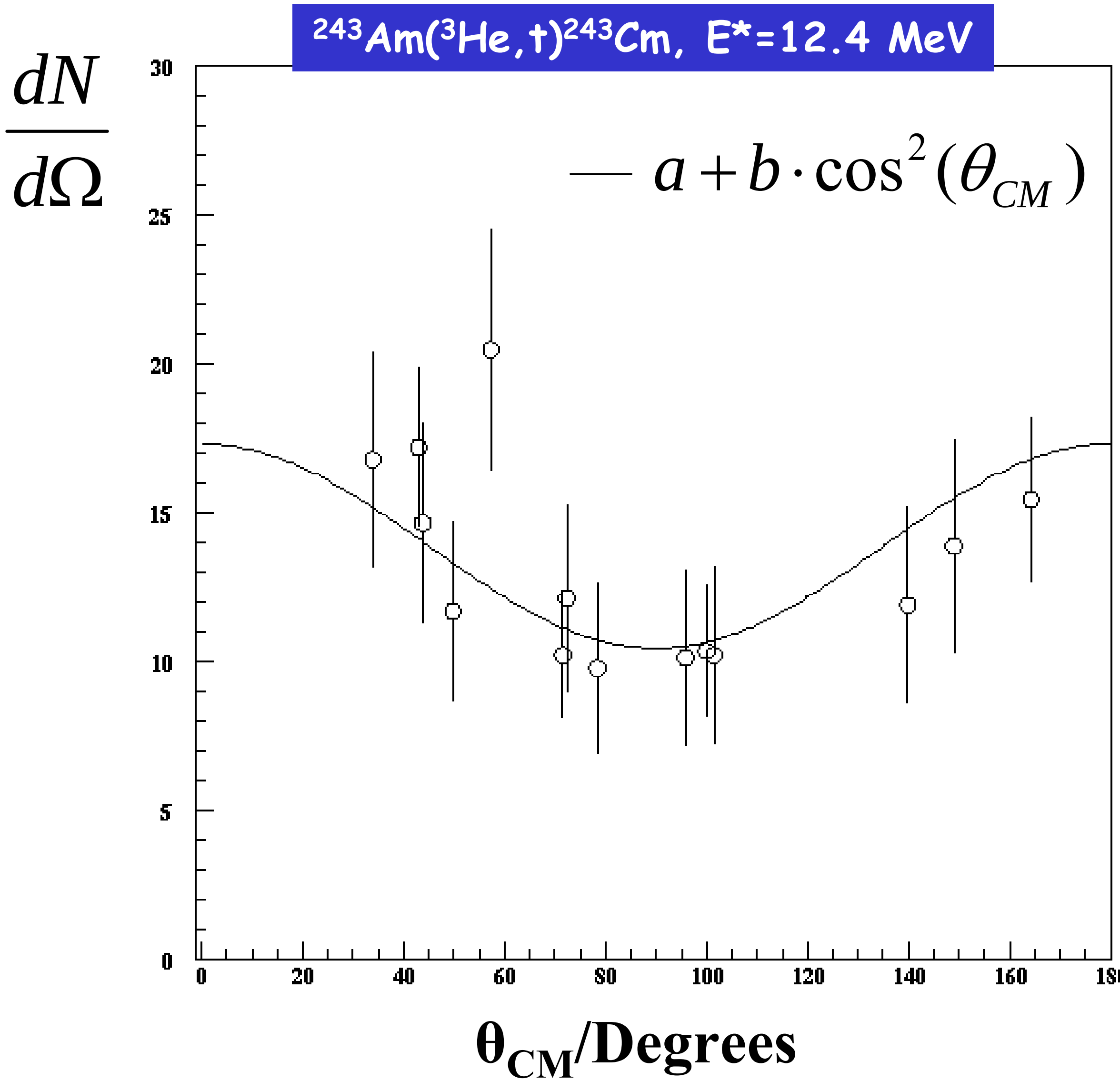
Light-particle kinematics + Q-values

E* of the CN

$$P_f\left(E^*\right)=\frac{N_{coin}\left(E^*\right)}{N_{CN}\left(E^*\right)\cdot Eff\left(E^*,\frac{W(0^\circ)}{W(90^\circ)}\right)}$$

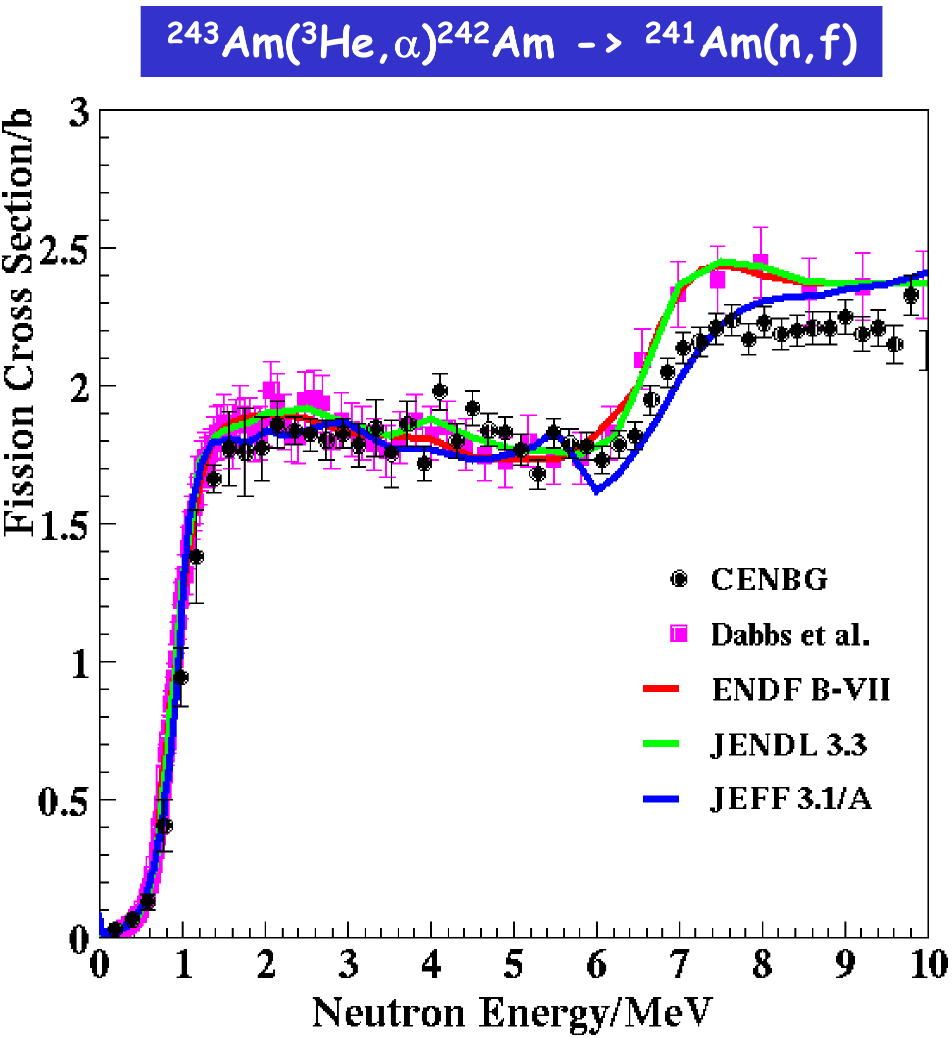
$$E^*=\frac{A}{A+1}E_n+B_n$$

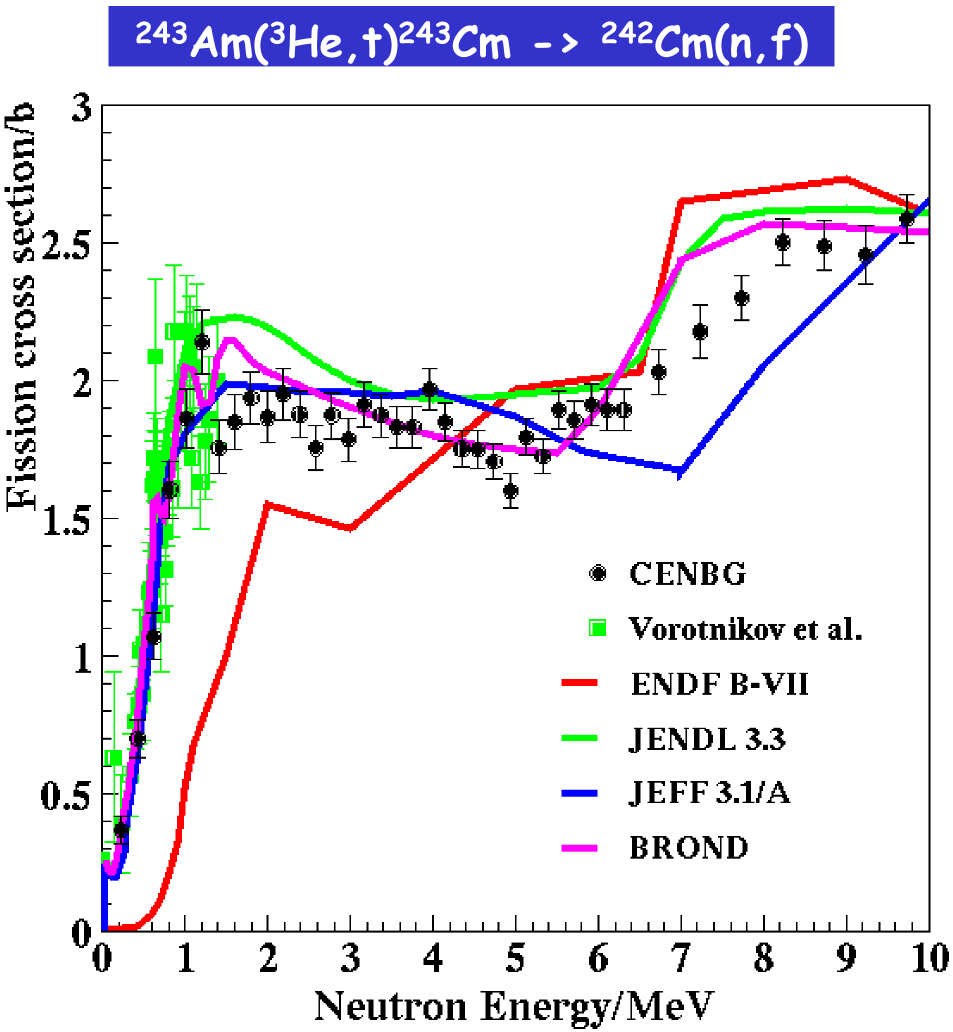
Fission fragment angular distribution



Preliminary Results!

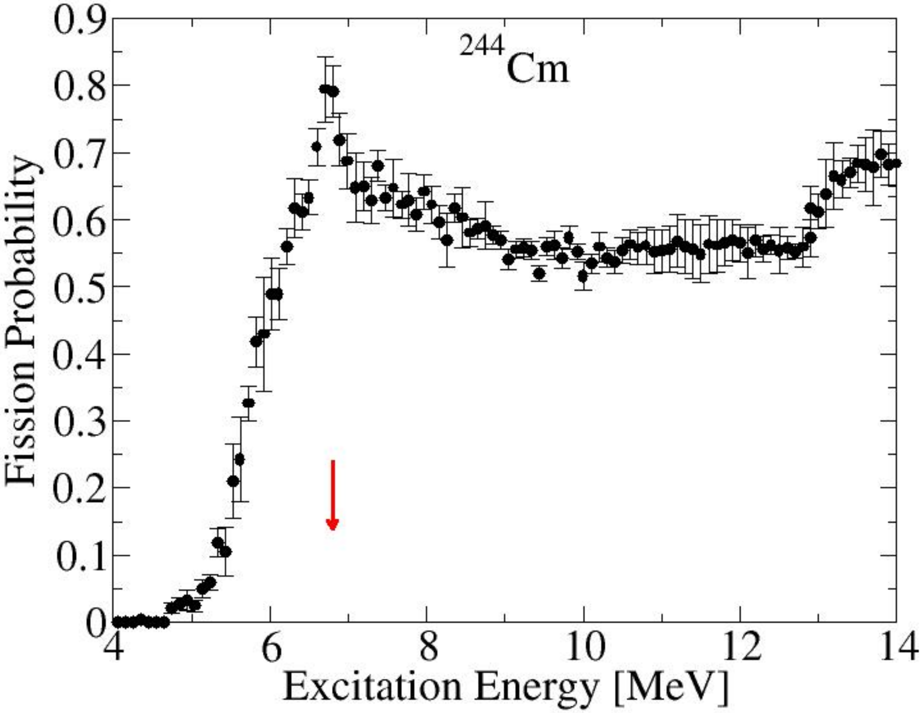
$\sigma_{CN}(E_n)$ from microscopic optical model calculation, CEA Bruyères le Châtel



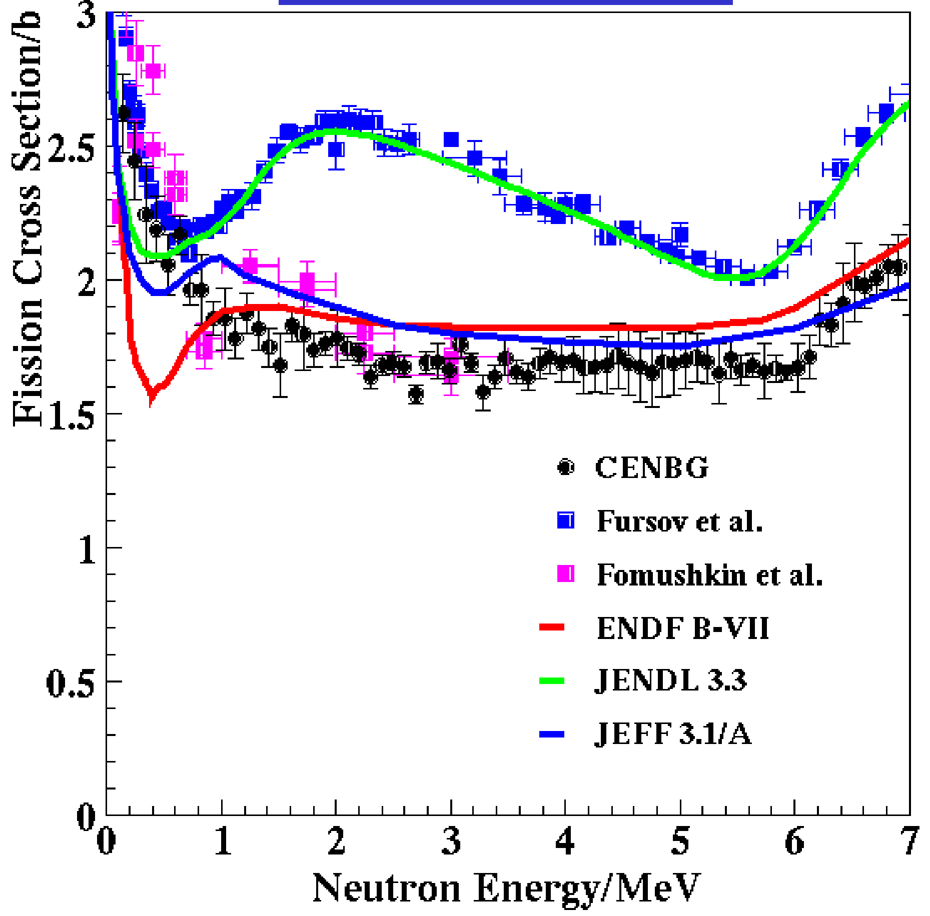


Preliminary Results!

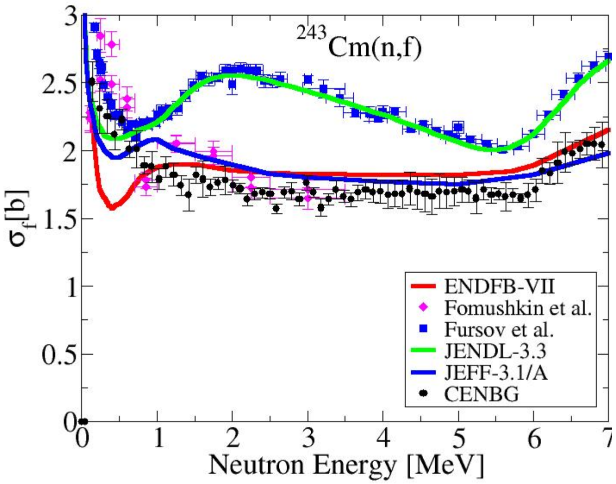
$^{243}Am(^{3}He,d)^{244}Cm$

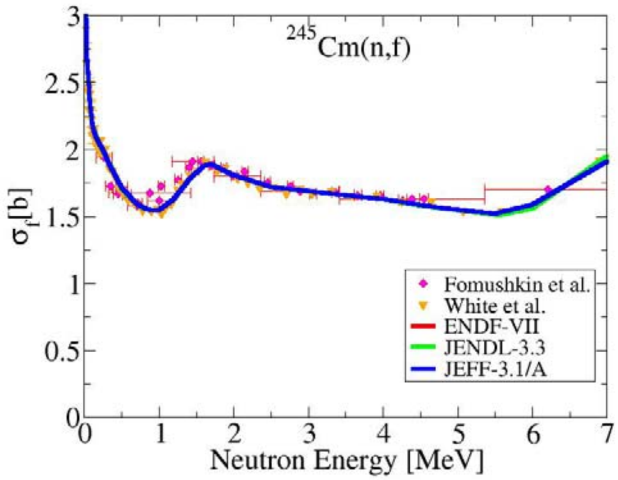


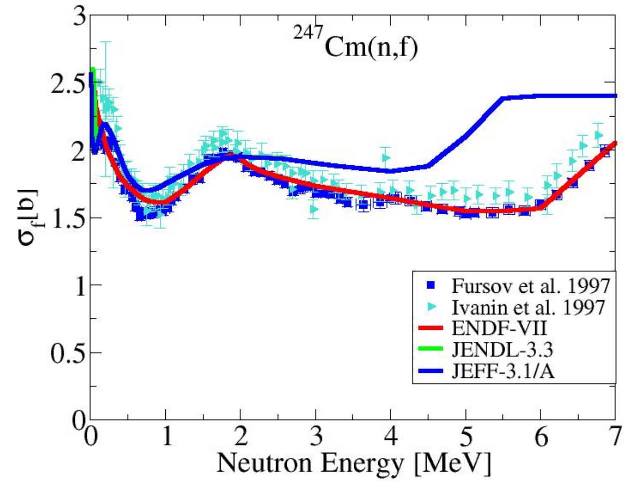
$^{243}Cm(n,f)$



Case of $^{243}Cm(n,f)$







At E_n=2 MeV, $\sigma_{CN} \approx \sigma_{CN}(n,n') + \sigma(n,f)$

At E_n=2 MeV $\sigma_{CN}(n,n') \approx$ 1-1.5 b -> σ_{CN}= 3.6-4.1 b

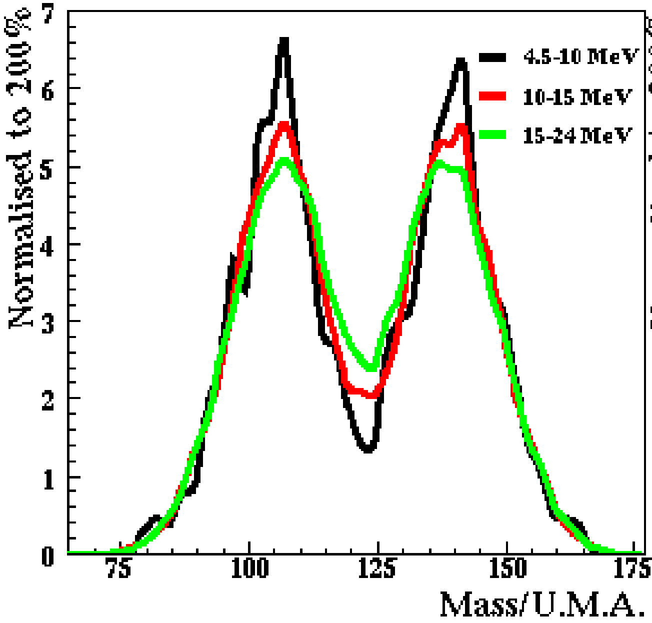
But…

σ_{CN}= 3 b from calculations of Bruyères le Châtel!!

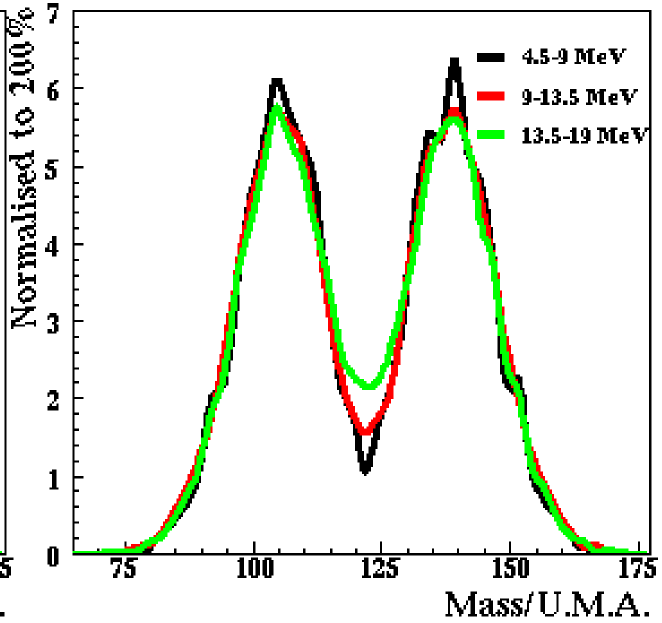
Fission fragment "pseudo-mass" distributions

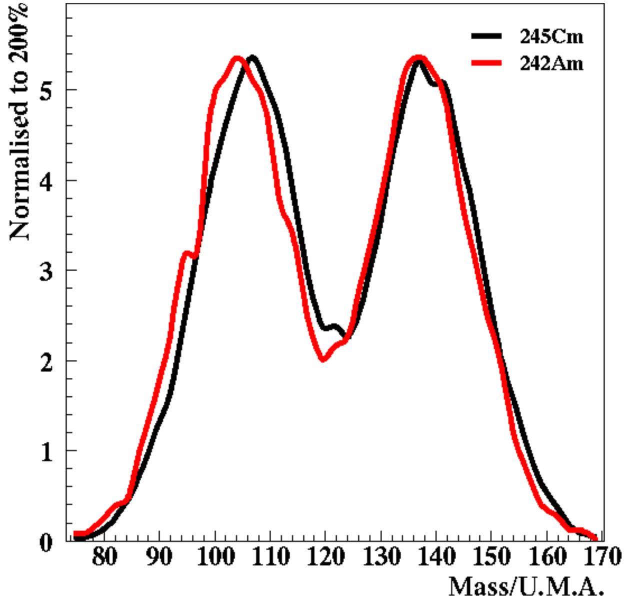
(Preliminary: Masses not corrected for prompt neutron emission!)

^{245}Cm



^{244}Cm





Conclusions and perspectives

- $^{241}Am(n,f)$
- $^{242}Cm(n,f)$ first measurement for E_n>1.7 MeV
- $^{243}Cm(n,f)$ clearly below Fursovs' results

} Excellent agreement with neutron-induced data at the fission threshold!!

- First measurement of fission fragment "pseudo-mass" distributions of $^{243,244,245}Cm$ and ^{242}Am as a function of E*
- Increase particle detection efficiency
- Comparison with model calculations:

  fission barriers

  transition states

  level densities

  shell effects as a function of E*

  infer $\sigma(n, \gamma)$, $\sigma(n, n')$ and $\sigma(n, 2n)$