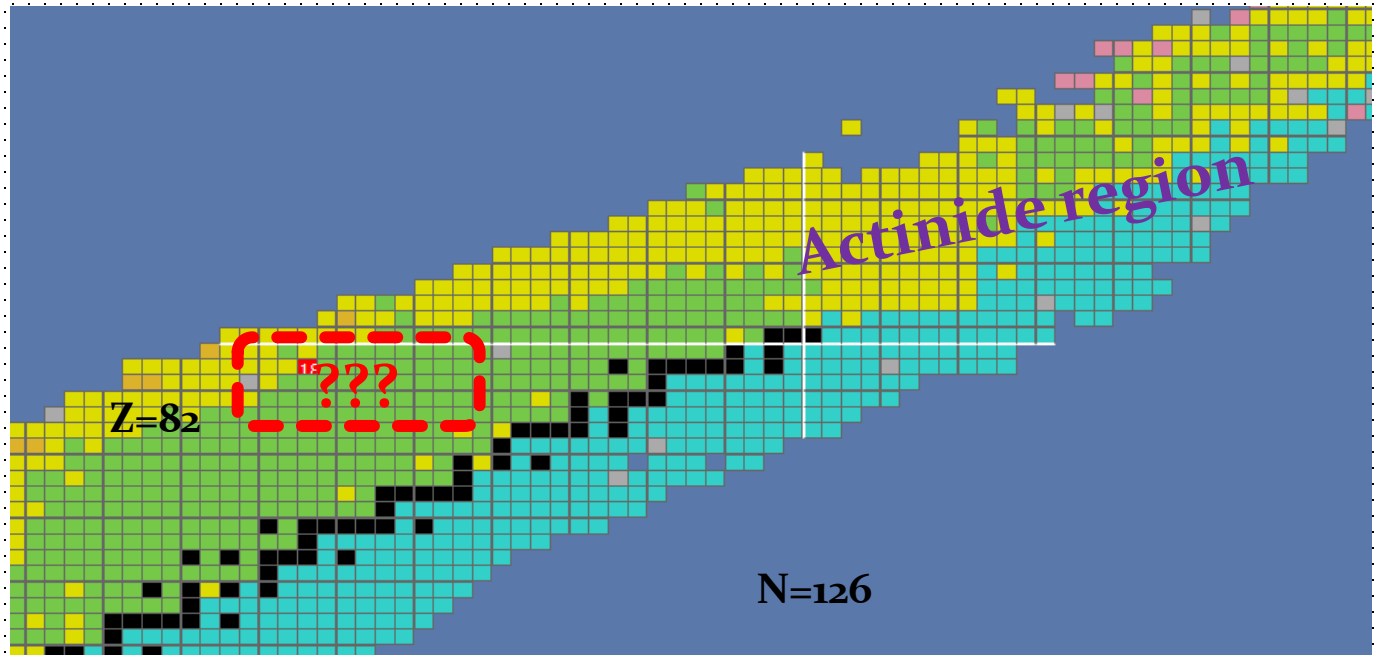
Igor Tsekhanovich

FISSION PROPERTIES OF NUCLEI IN THE ^{180}HG REGION



15th International Conference on Nuclear Reaction Mechanisms
Varenna, June 11-15, 2018

OUTLOOK

- Introduction:
  1) Interest to the ^{180}Hg region and
  2) Theory expectations and some experimental results

- JAEA experiment : fusion-fission of ^{178}Pt
  1) Experiment
  2) Results (velocities, MED, fission modes)

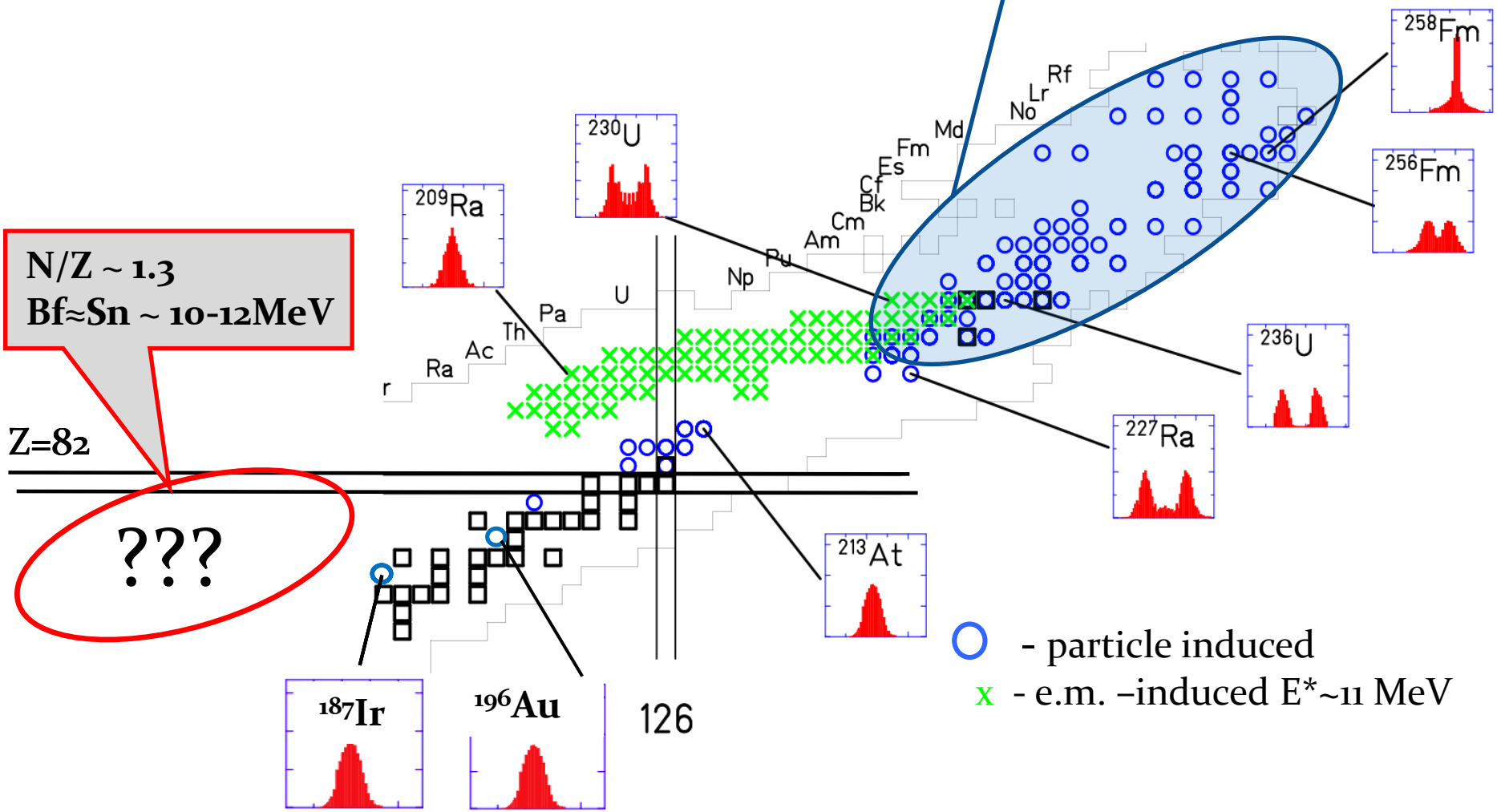
- Summary & Future work

Region of interest : nuclei with low isospin

Fission properties as a function of isospin ??

Actinides N/Z ~1.57 : MD : asymmetric

N/Z ~ 1.3
Bf≈Sn ~ 10-12MeV

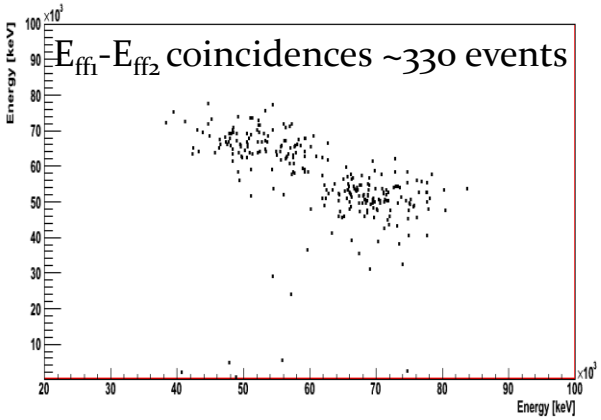


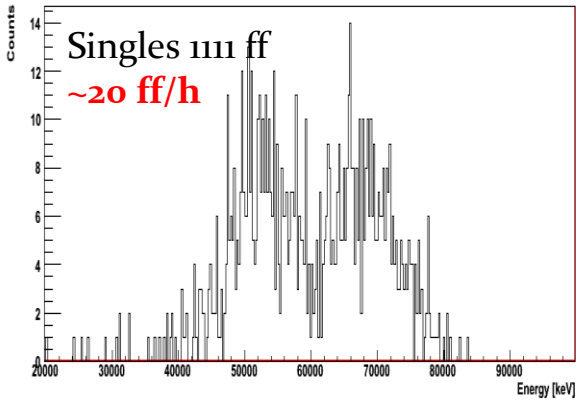
K.-H. Schmidt et al.

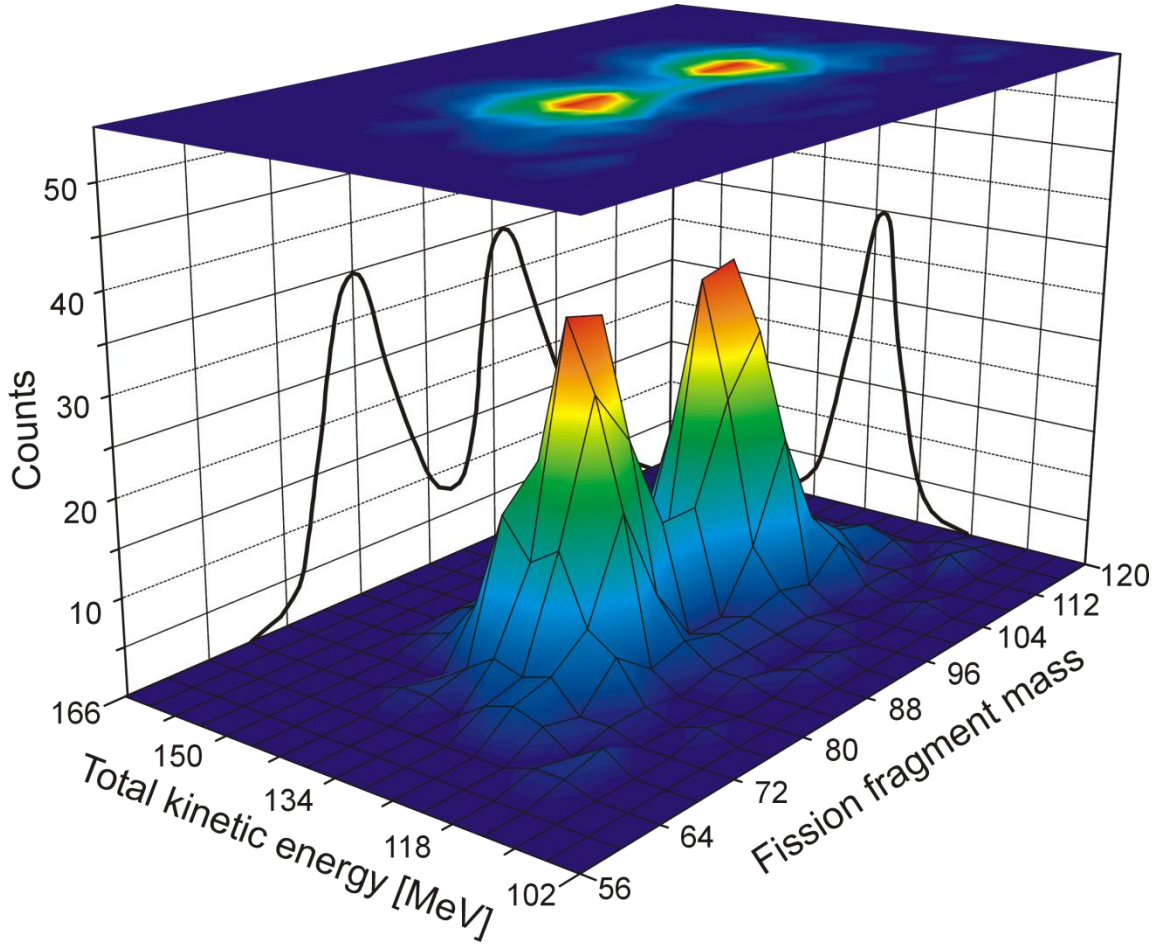
Trigger : Mass Distribution from fission of ^{180}Hg

Andreyev *et al.* (PRL 105 (2010) 252502):

ASYMMETRIC mass split : M_H=100(4) & M_L= 80(4)







Z identification : UCD rule ➔ ^{100}Ru (N=56,Z=44) and ^{80}Kr (N=44,Z=36)

New Region of Asymmetric Fission : p-rich sub-lead region

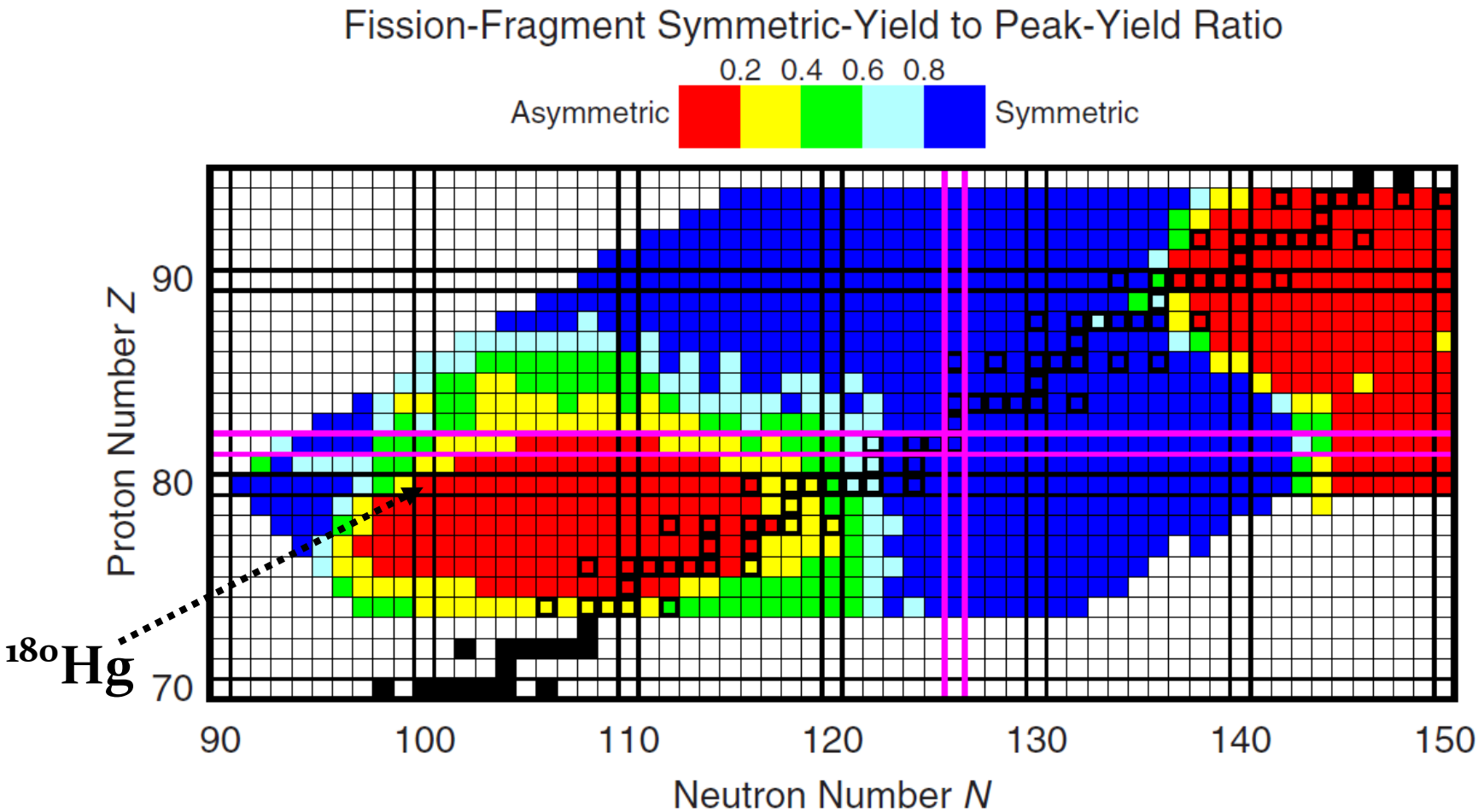


FIG. 3. (Color online) Calculated symmetric-yield to peak-yield ratios for 987 fissioning systems. Black squares (open in colored regions, filled outside) indicate β-stable nuclei. We find a new, contiguous region of asymmetric fission separated from the classical location of asymmetric fission in the actinides by an extended area of symmetric fission.

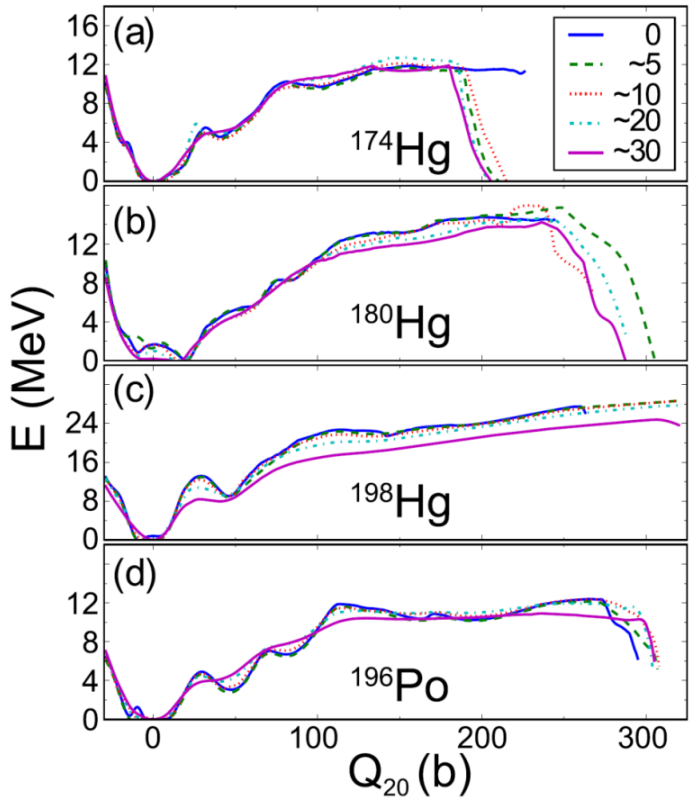
P. Moller & J. Randrup: PRC 91, 044316 (2015)

Microscopic Effects and Excitation Energy in the Pb region

PHYSICAL REVIEW C **90**, 021302(R) (2014)

Excitation-energy dependence of fission in the mercury region

J. D. McDonnell,[1,2] W. Nazarewicz,[2,3,4] J. A. Sheikh,[2,3,5] A. Staszczak,[2,6] and M. Warda[6]



Conclusions: Our self-consistent theory suggests that excitation energy weakly affects the fission pattern of the nuclei considered. The transition from the asymmetric fission in the proton-rich nuclei to a more symmetric fission in the heavier isotopes is governed by the shell structure of pre-scission configurations.

JAEA : Mass Distributions from fission of ^{180,190}Hg

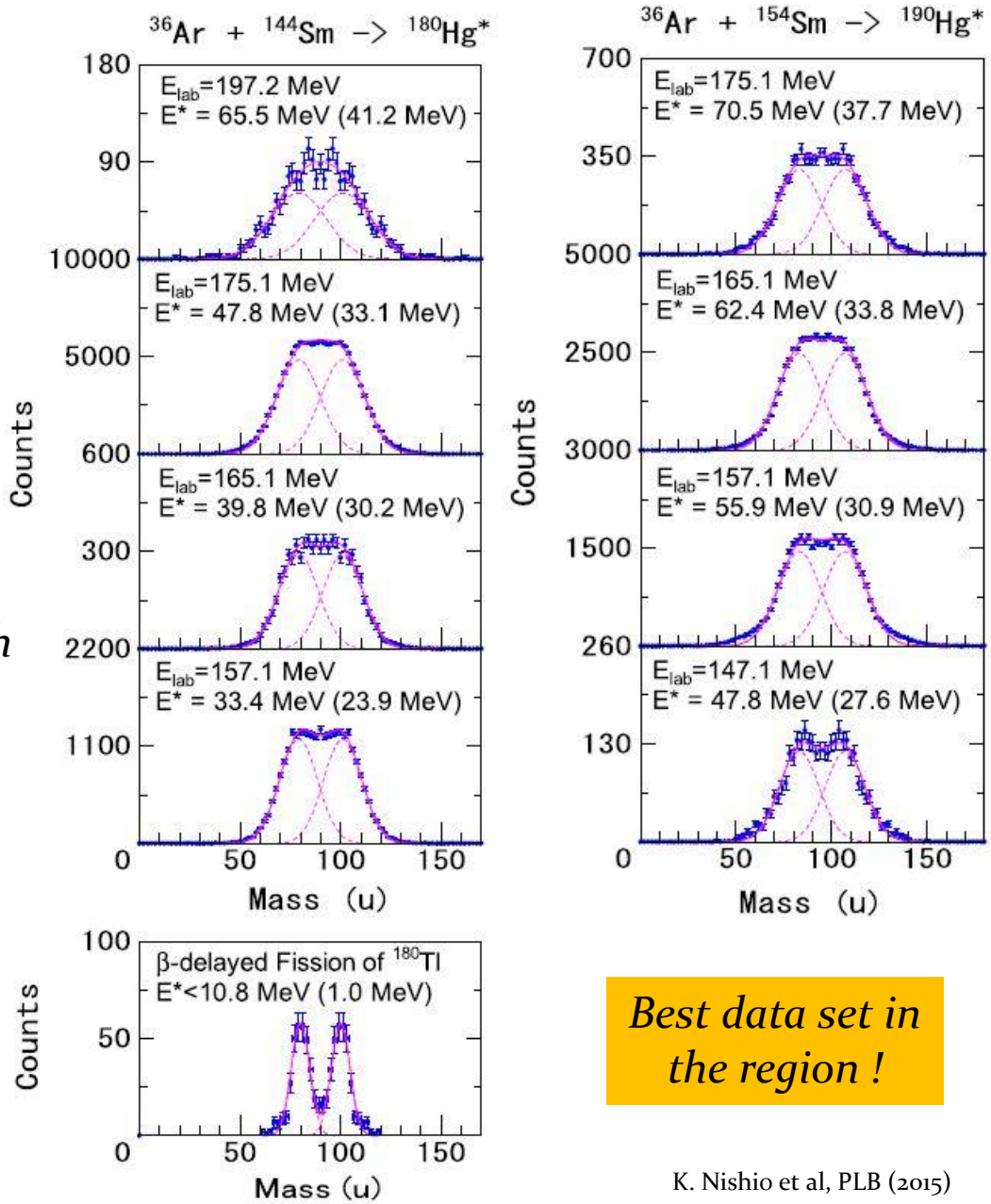
- E* = 34-71 MeV
- 2010-2014: JAEA,Tokai

✓ **Robustness with Eexc :**

Asymmetric MD up to E*= 70 MeV

"The mass distributions for both Hg isotopes could be well reproduced with a single asymmetric fission mode"

➢ **No symmetric mode ?**



Best data set in the region !

K. Nishio et al, PLB (2015)

Actinides : MD – TKE correlation

PHYSICAL REVIEW C **93**, 034603 (2016)

Fragment-mass, kinetic energy, and angular distributions for ^{234}U(n, f) at incident neutron energies from E_n = 0.2 MeV to 5.0 MeV

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(Received 19 August 2015; published 3 March 2016)

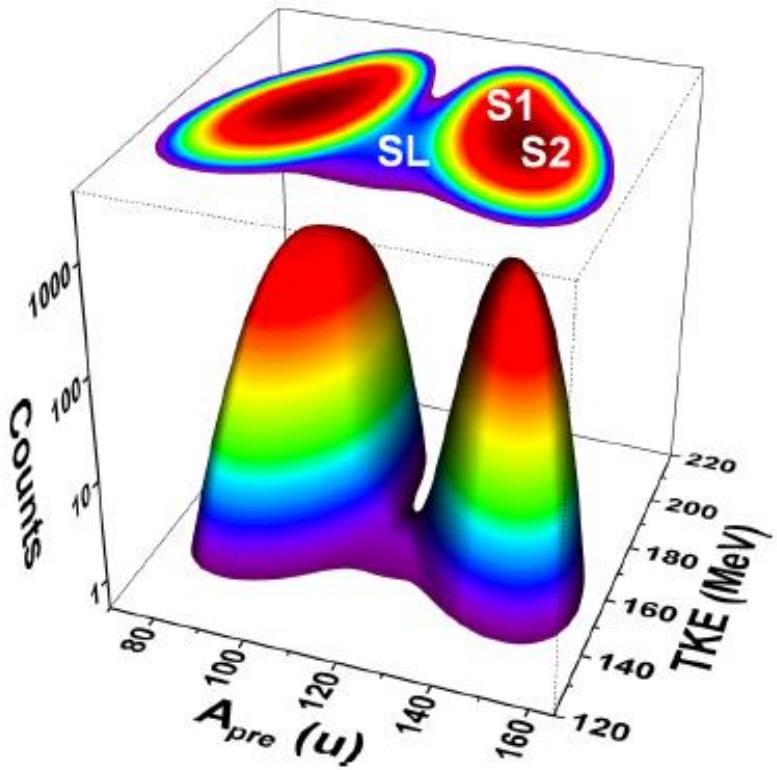


FIG. 9. The experimental two-dimensional TKE vs mass data is fitted with three modes. Equation (12) was used to parametrize the data. In total, three fission modes (S1, S2, and SL) were taken into account.

$$\overline{TKE}_{symm} < \overline{TKE}_{asymm}$$

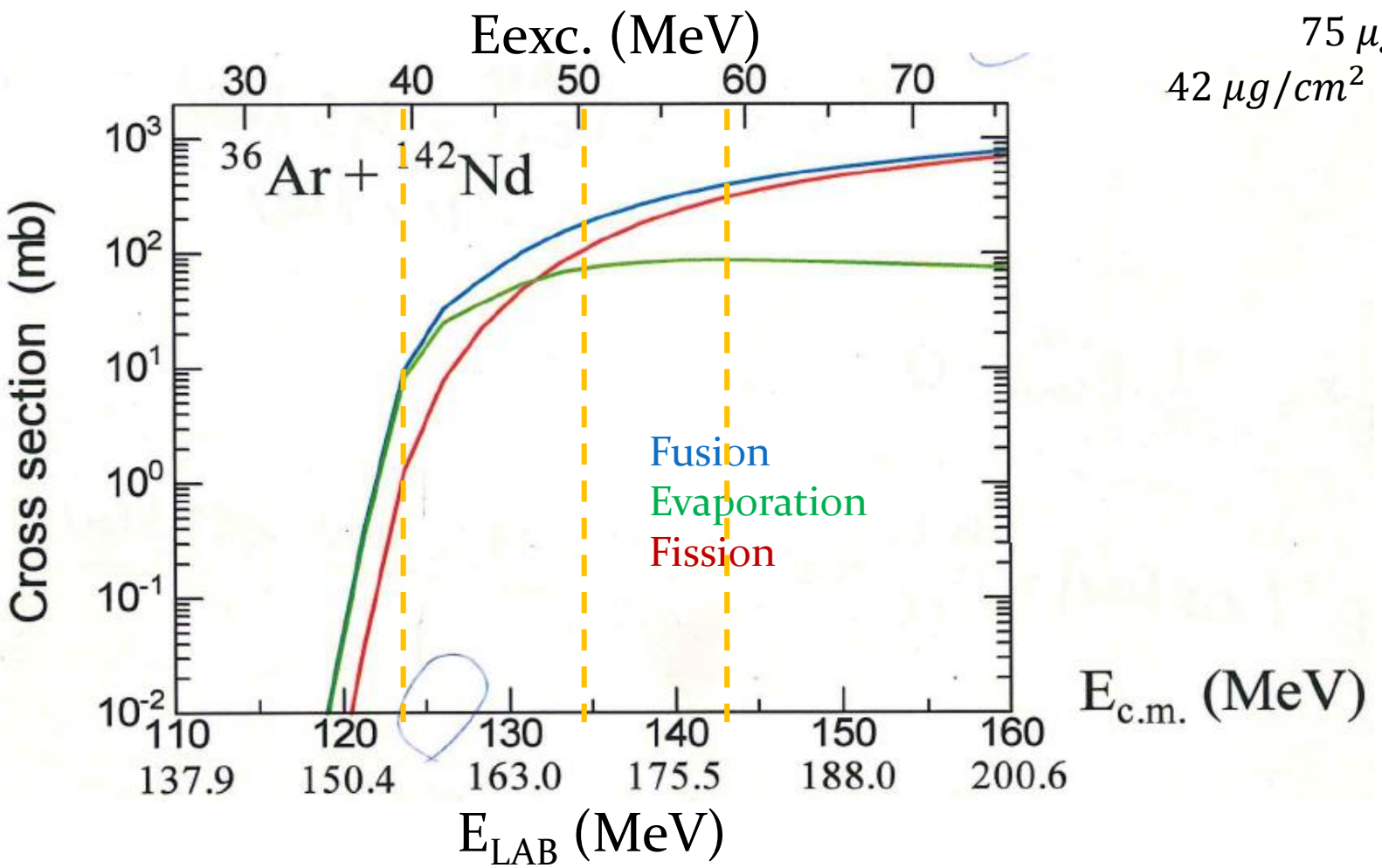
$$\sigma^{A}_{symm} > \sigma^{A}_{asymm}$$

^{178}Pt Experiment : - July 2016, JAEA : $^{36}Ar + {}^{142}Nd \rightarrow {}^{178}Pt$

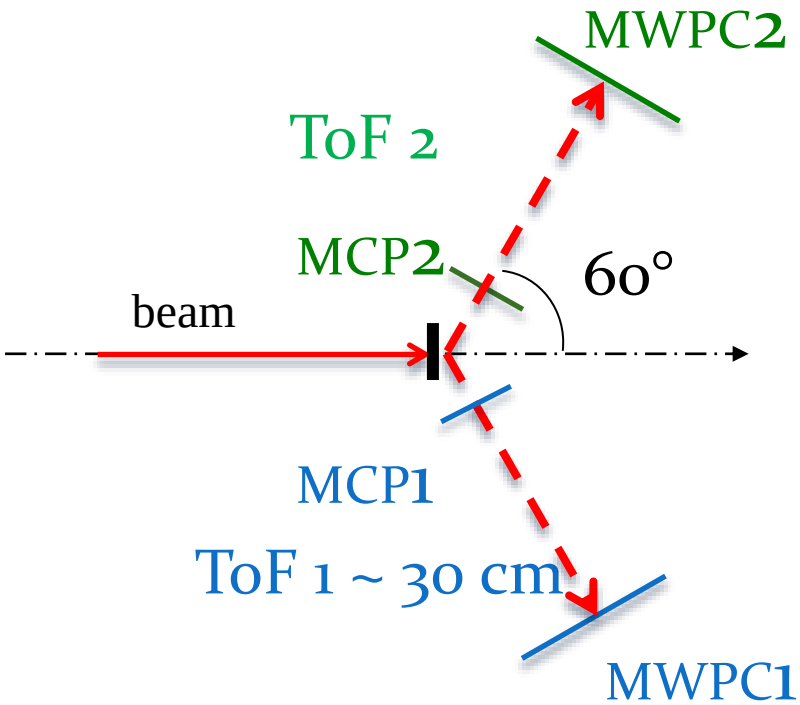
Target: C + **Nd**F_3

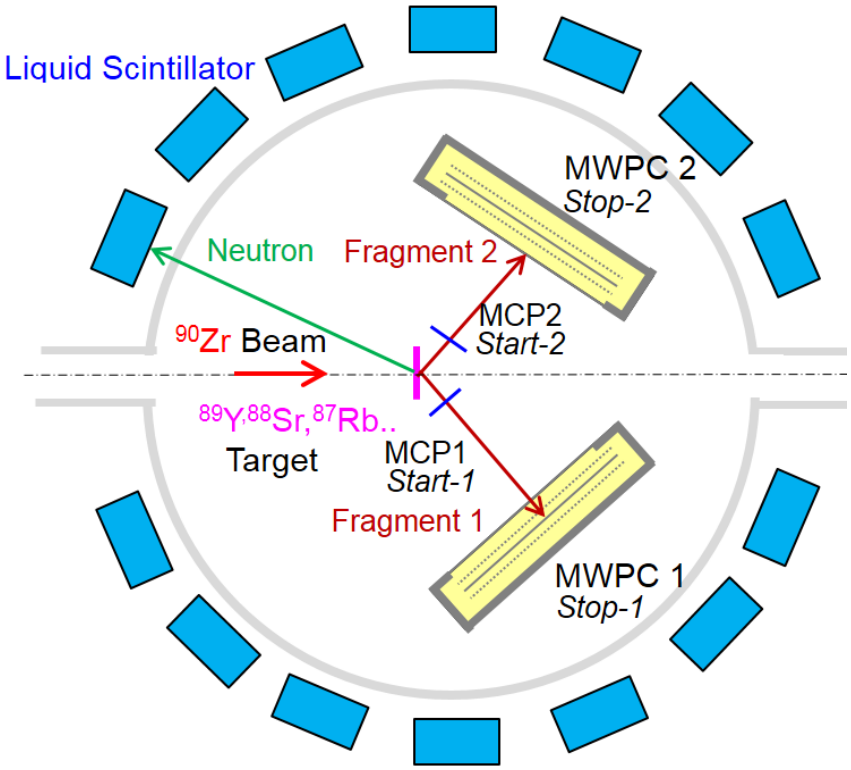
$75\ \mu g/cm^2$

$42\ \mu g/cm^2$



JAEA Experimental Setup





✓ ***2 independent TOF arms***

$$A_L \cdot v_L = A_H \cdot v_H$$

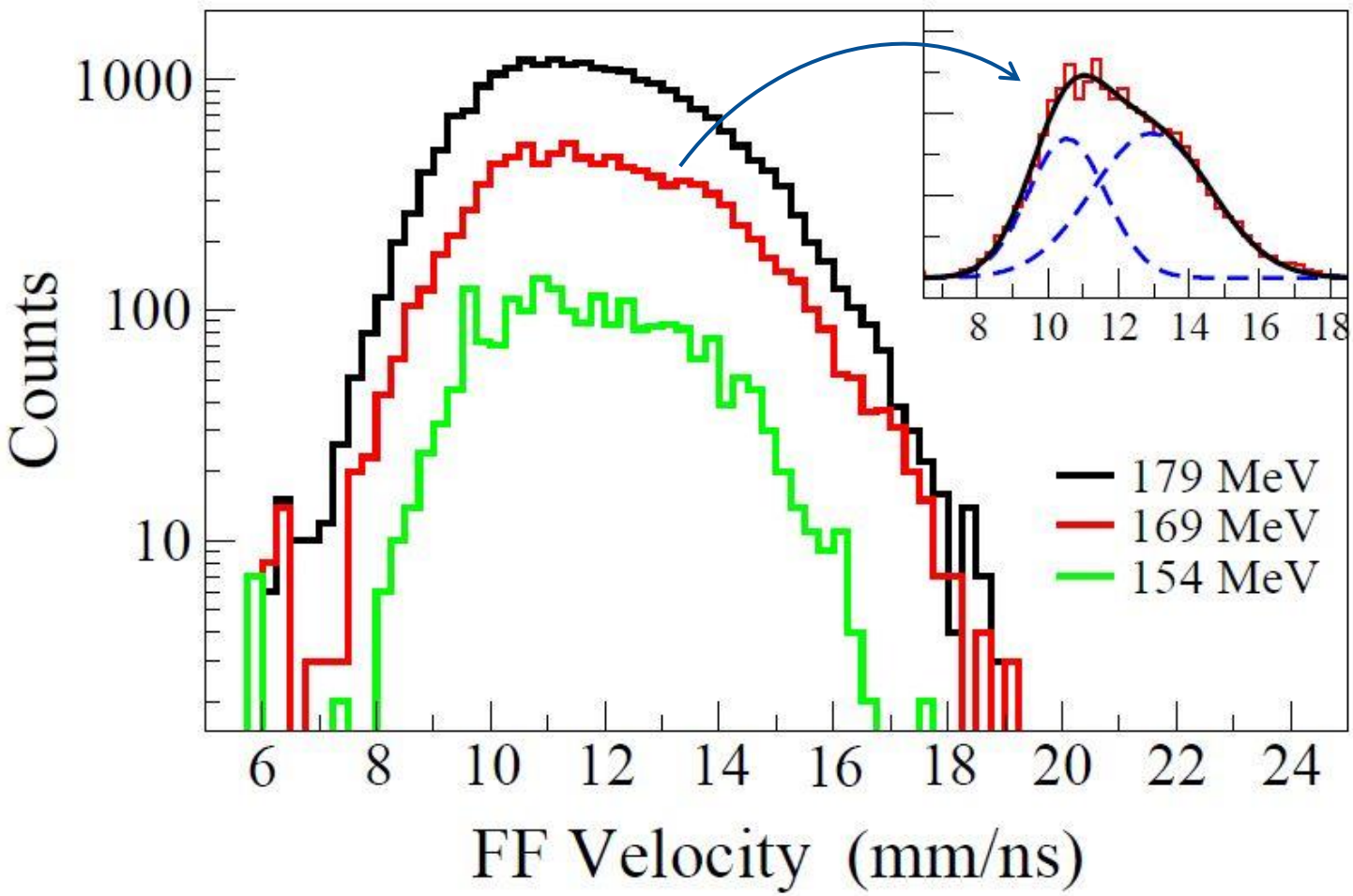
$$TKE = 0.5 \cdot A_{CN} \cdot v_L \cdot v_H$$

✓ ***44 n/γ detectors***

(TOF and PSD)

DAQ: digital triggerless

Results : Fission-Fragment Velocities (TOF2)

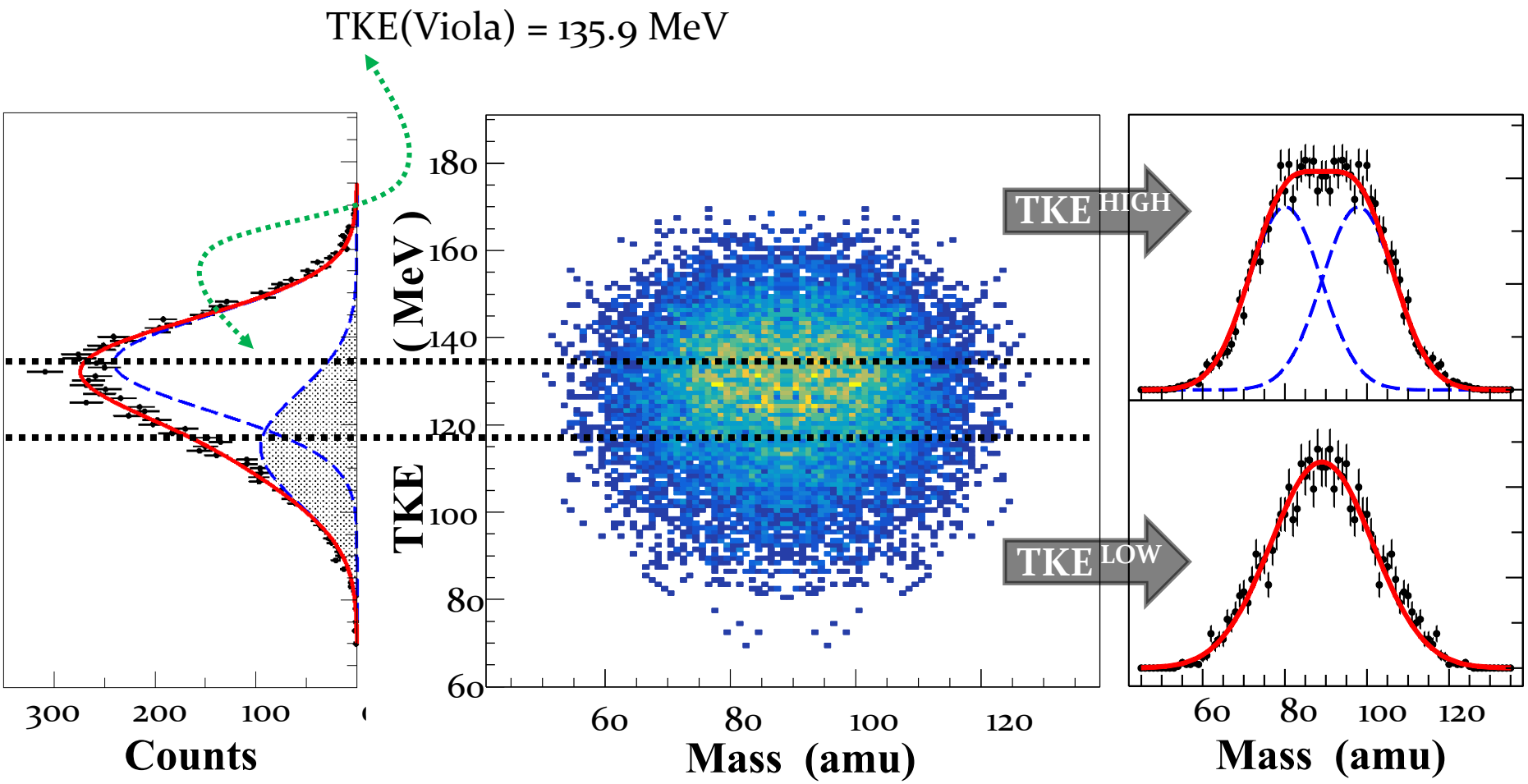


Expected :

- MDs : predominantly asymmetric
- MDs : must contain the symmetric component

I. Tsekhanovich *et al*, arXiv: 1804.01832

Mode position : Partial Mass Distributions



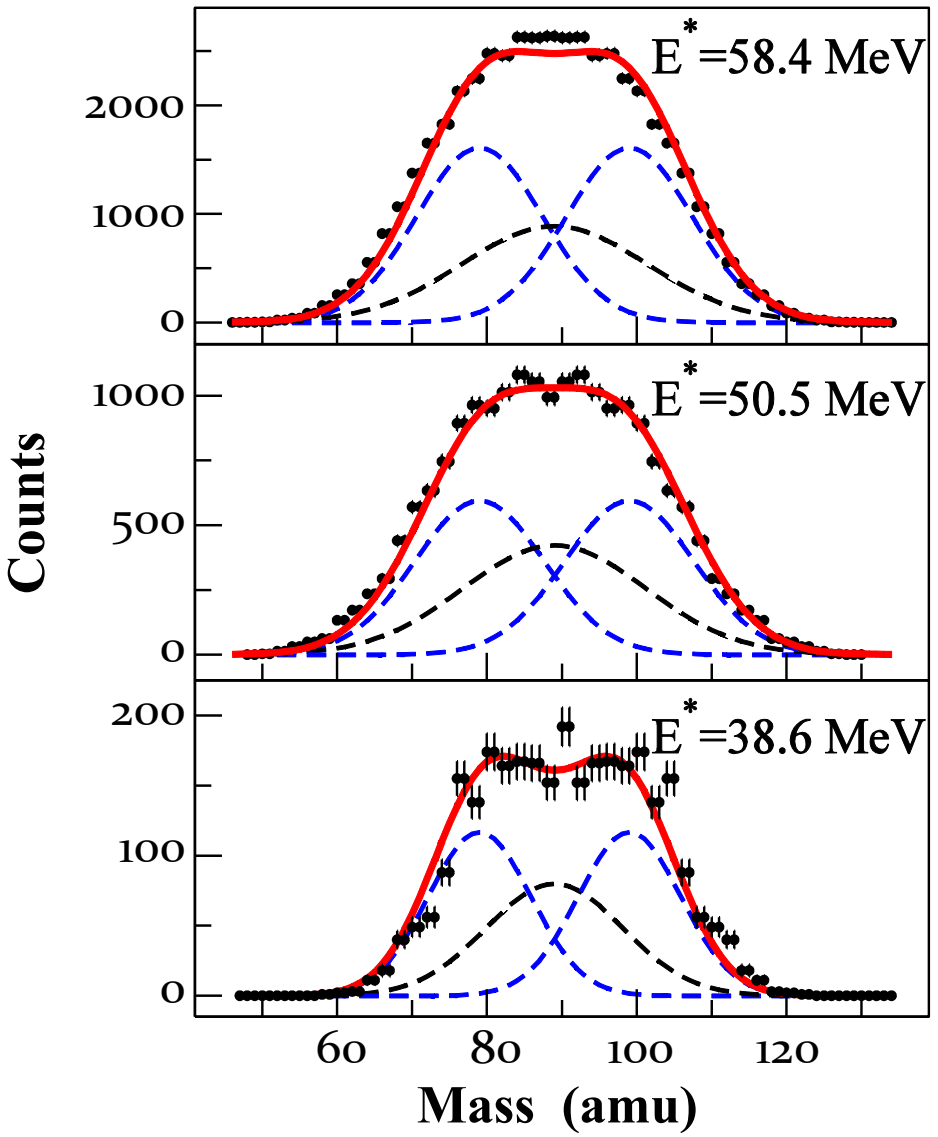
Symmetric mode : $\frac{A_{CN}}{2}$

Asymmetric mode : $A_L = 79$

$A_H = 99$

I. Tsekhanovich *et al*, arXiv: 1804.01832

Results : Fission-Fragment Mass Distributions



(fit with fixed peak positions)

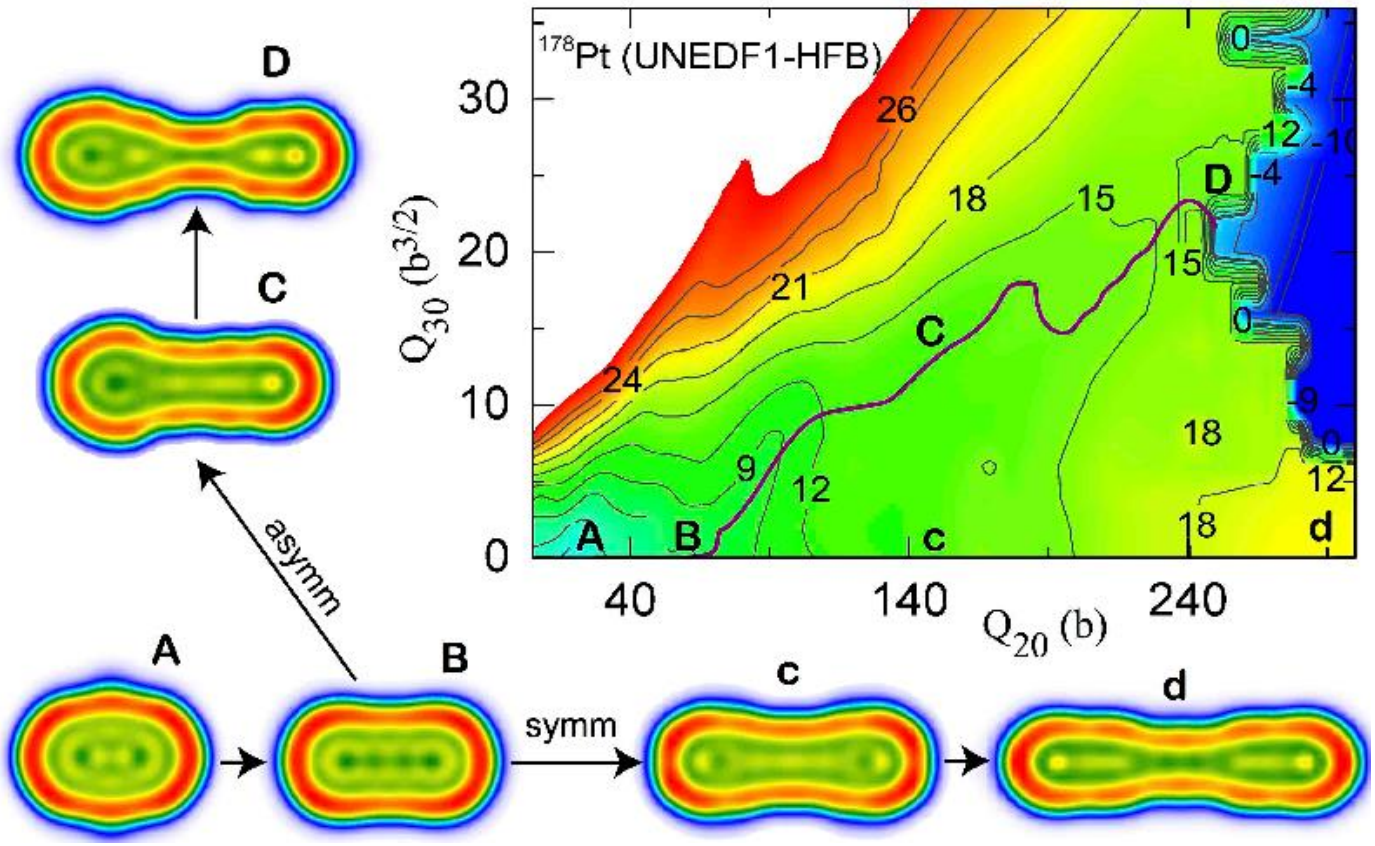
- MD shapes well reproduced
- Symmetric mode is wider

- Symmetric mode yield ~ 30 %

I. Tsekhanovich *et al*, arXiv: 1804.01832

Fission of ^{178}Pt : PES

Nuclear Density Functional Theory results :



- ☑ *Most probable division :* **^{80}Br + ^{98}Tc**
- ☑ *Symmetric division :* **in competition**

I. Tsekhanovich *et al*, arXiv: 1804.01832

Summary for ^{178}Pt :

- New MED data : apparently insensitive to Eexc
- Predominantly asymmetric mass distribution
- Co-existing fission modes
- Fission mode properties as in actinides: insensitivity to isospin

Work to do :

- Need for more experimental data in the new island of asymmetric fission :
  i. To establish systematics on yields
  ii. Fission mode competition, as function of *N*, *Z* and *Eexc* of CN

New Challenge :

fission studies at ***Eexc ~ Sn***

symmetric fusion reactions :

^{90}Zr + ^{90}Zr → ^{180}Hg*
^{90}Zr + ^{89}Y → ^{179}Au*
^{90}Zr + ^{88}Sr → ^{178}Pt*
^{90}Zr + ^{87}Rb → ^{177}Ir*

JAEA tandem :
Zr beams available !!

Who is involved :

CENBG :

- **S. Czajkowski**
- **B. Jurado**
- **I. Tsekhanovich**

JAEA :

- **K. Nishio**
- **K. Hirose**
- **H. Makii**
- **R. Orlandi**
- **M. Vermeulen**

York University :

- **A. Andreyev**

RIKEN :

- **K. Morimoto**
- **T. Tanaka (& Kyushu University)**
- **K. Morita (& Kyushu University)**

Theory :

- W. Nazarewich (MSU/FRIB, USA)
- M. Matheson (MSU/FRIB, USA)
- M. Warda (Lublin, Poland)
- J. Sadhukhan (Kolcata, India)

Thank you for your attention !