

complex structure in even-odd staggering in fission fragment yields

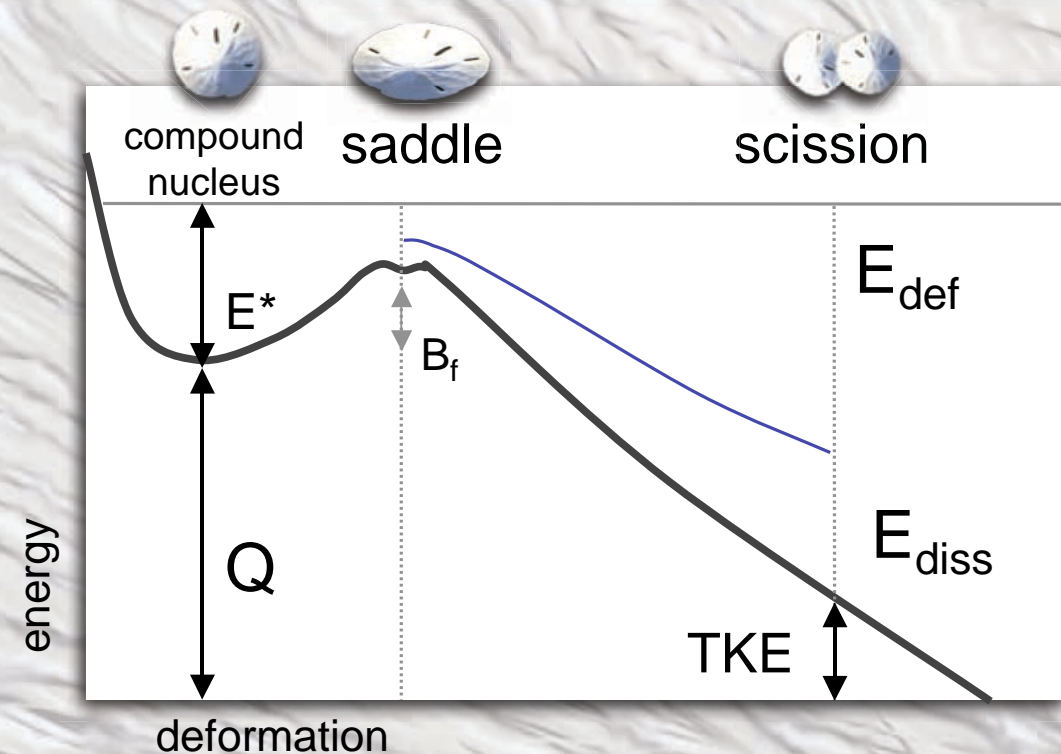
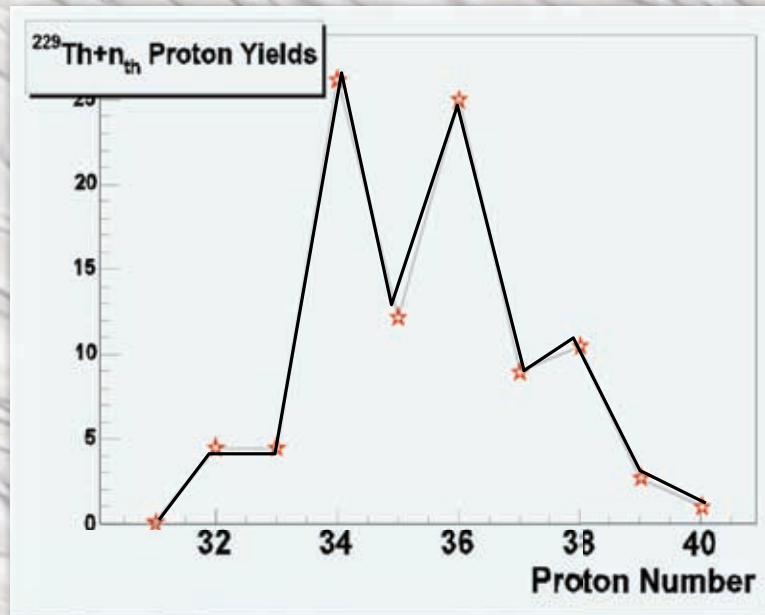
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even-odd effect in fission fragment yields



part of the available excitation energy is **dissipated in breaking pairs** with a certain probability.

even-odd effect reflects the **survival probability** of the pairs along the saddle to scission path.

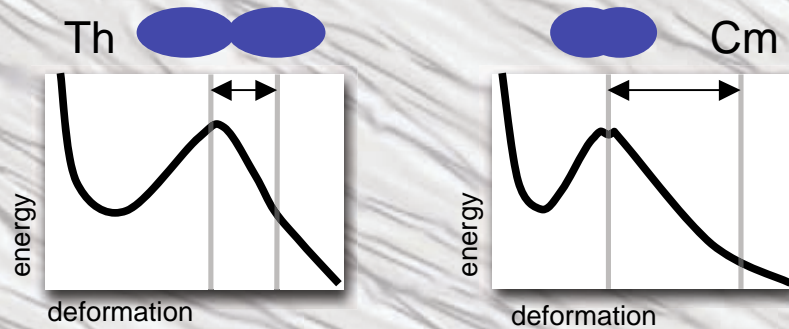
the amplitude of the even-odd effect contains information about the **saddle to scission process**.



global proton even-odd effect and fissility

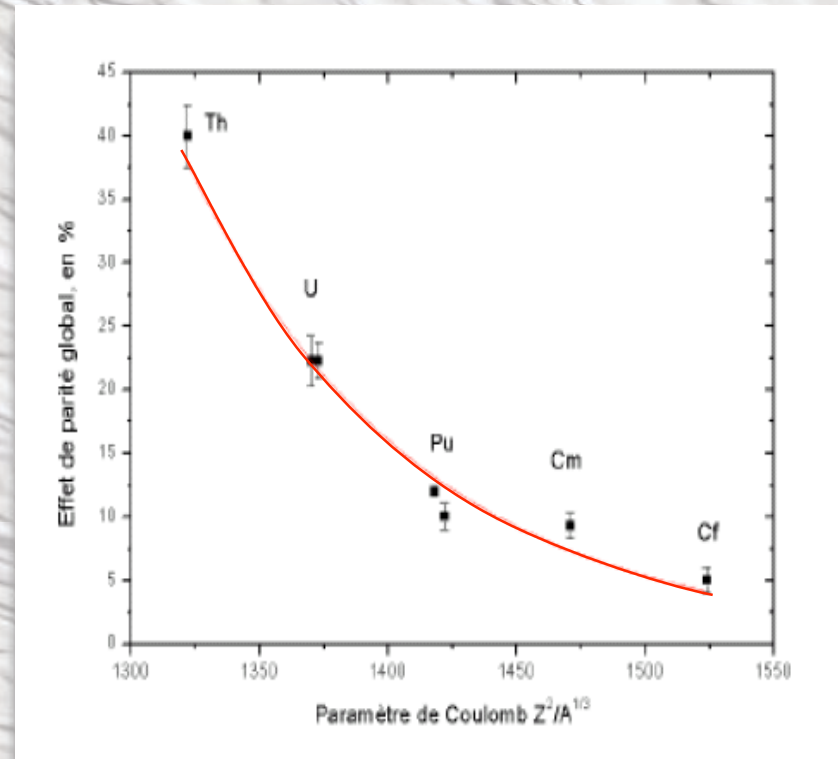
Coulomb repulsion makes more compact systems at saddle.

$$\delta_p^{\text{global}} = \sum Y_Z^{\text{even}} - \sum Y_Z^{\text{odd}}$$



E_{diss} increases with **fissility** as saddle to scission path is longer

probability of breaking proton pairs is higher and **even-odd effect is lower**



description of even-odd effect:

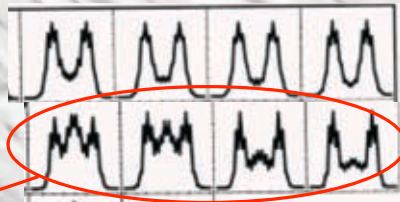
$$E_{\text{diss}} \propto -\ln(\delta_p)$$

$$E_{\text{diss}} \leftrightarrow \text{even-odd effect} \leftrightarrow \text{fissility}$$



global proton even-odd effect and charge split

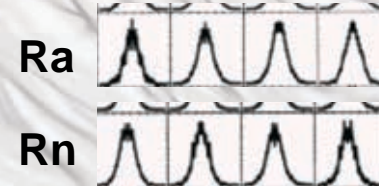
electro-magnetic induced fission in inverse kinematics



U

Th

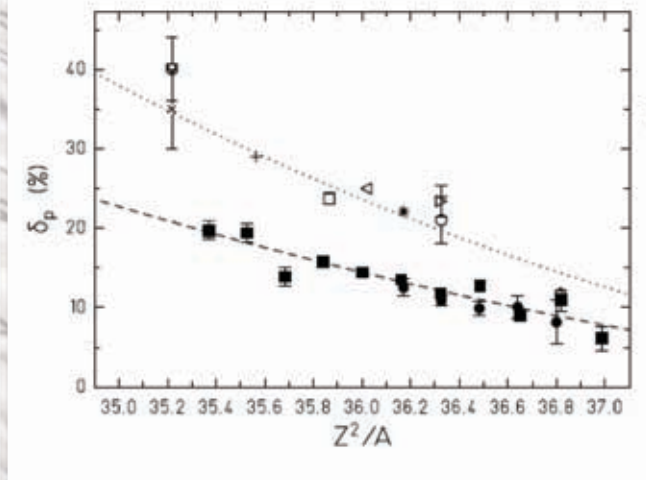
complete charge distributions



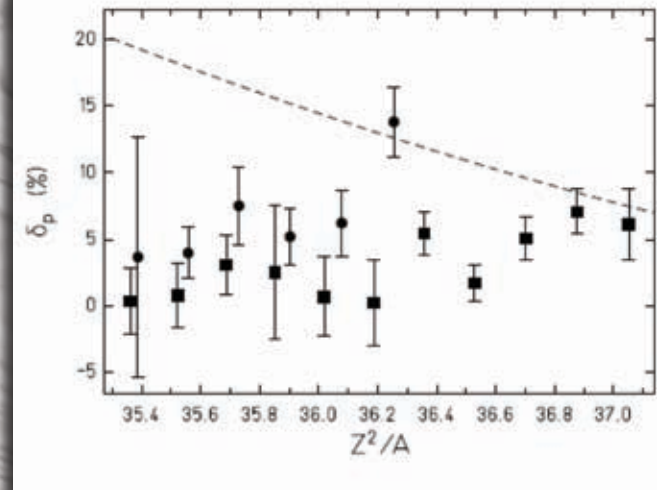
Ra

Rn

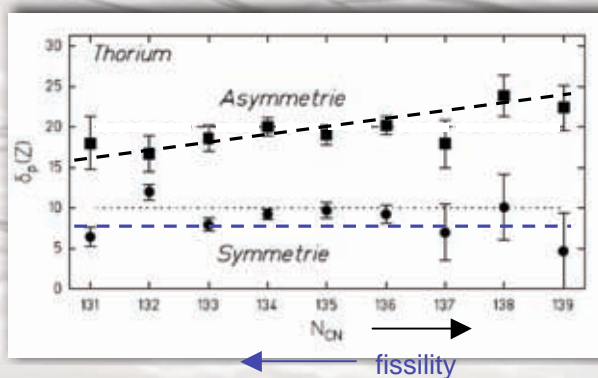
mainly **asymmetric** splits



mainly **symmetric** splits



S. Steinhäuser,
PhD thesis 1997



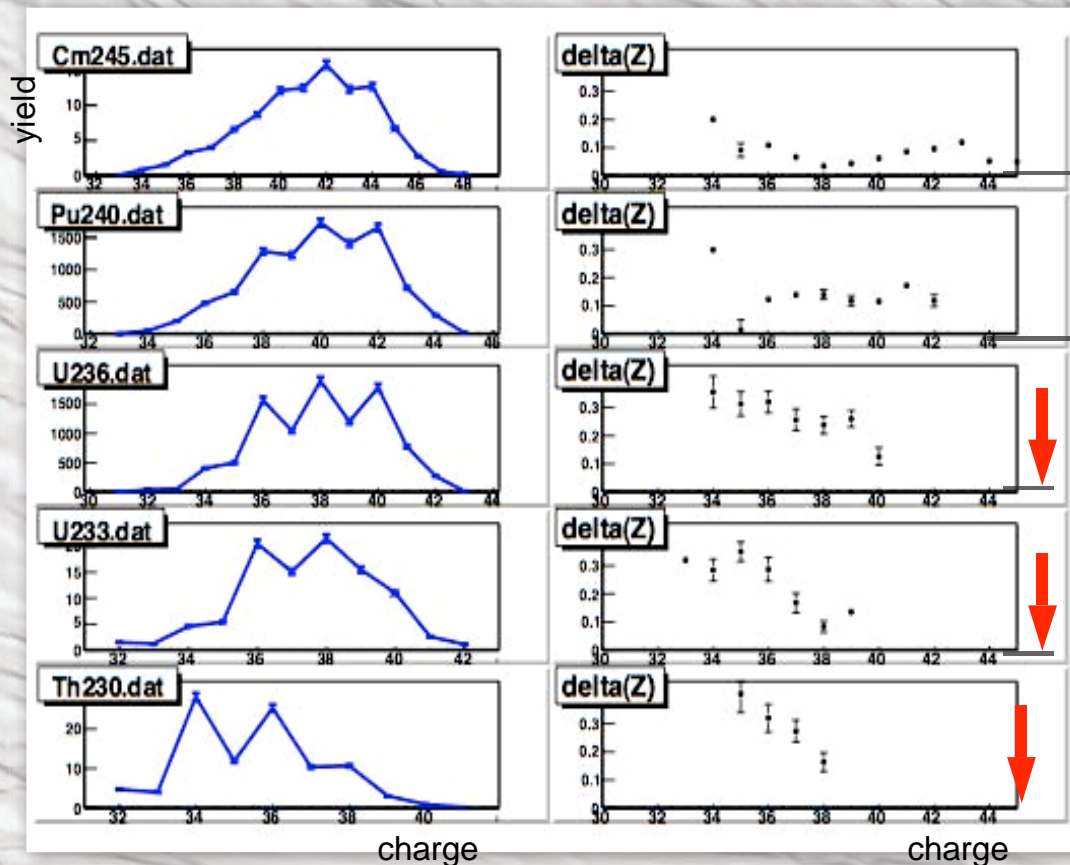
a **constant even-odd effect**, with no dependence on fissility, is suggested for **symmetric** charge splits.



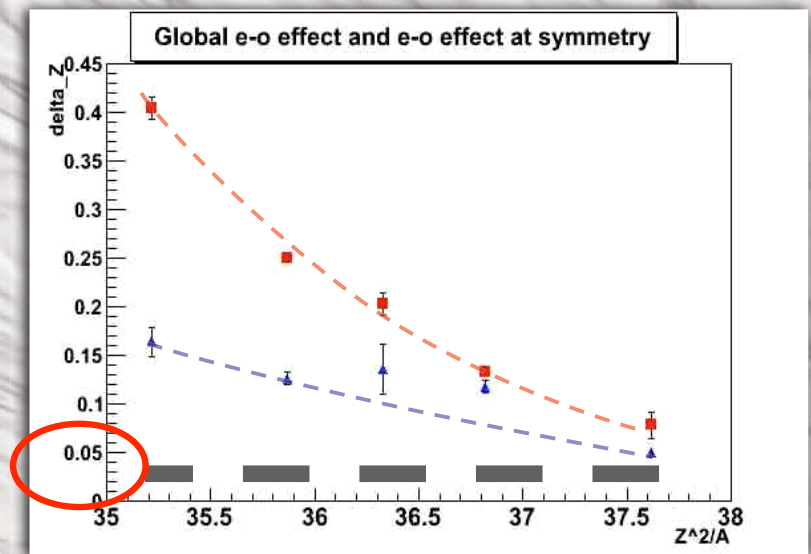
local proton even-odd effect and charge split

thermal neutron induced fission

$$\Delta(Z) = 1/8(-1)^{Z+1} (\ln Y_{Z+3} - \ln Y_Z - 3 \ln Y_{Z+2} + 3 \ln Y_{Z+1})$$



local even-odd effect
lower towards symmetry
(more data needed)



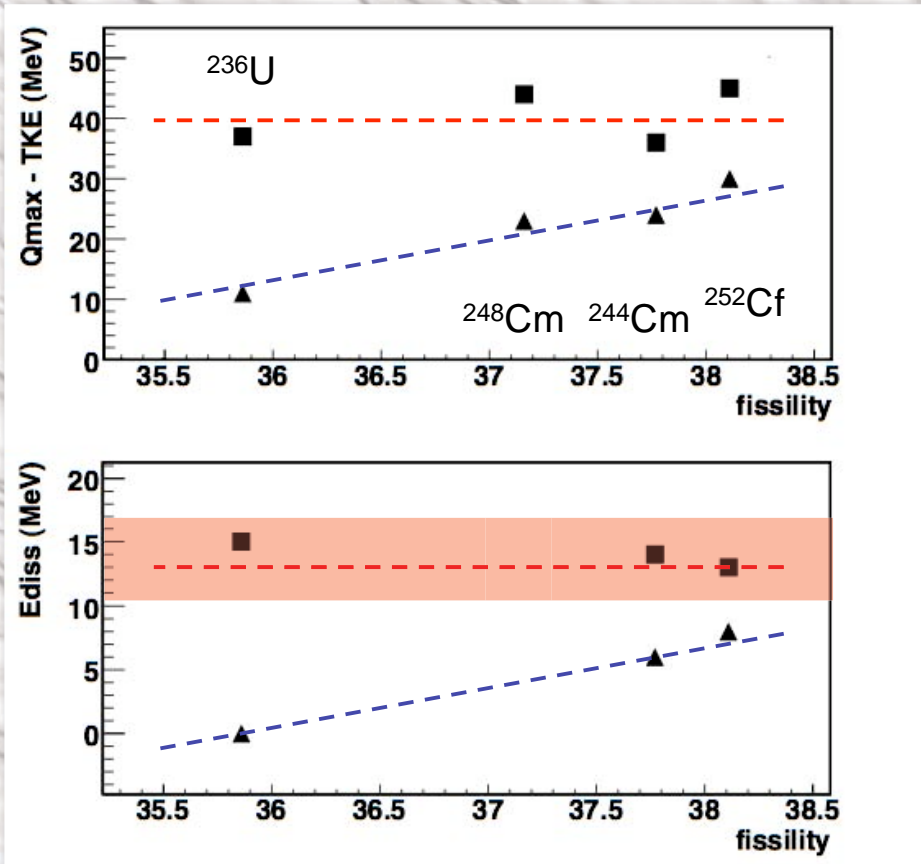
- - - global effect
- - - closest to symmetry
- - - extrapolation to symmetry (~3%)

NPA 425 (1984) 120, NPA 345 (1980) 34, NPA 487 (1988) 1,
NPA 430 (1984) 21, NPA 710 (2002) 3

local even-odd effect **constant** for symmetric charge splits.



energy dissipation and fissility



$$Q_{\max} - \text{TKE} = E_{\text{diss}} + E_{\text{def}}$$

the maximum energy available for dissipation remains **constant** with fissility at symmetry.

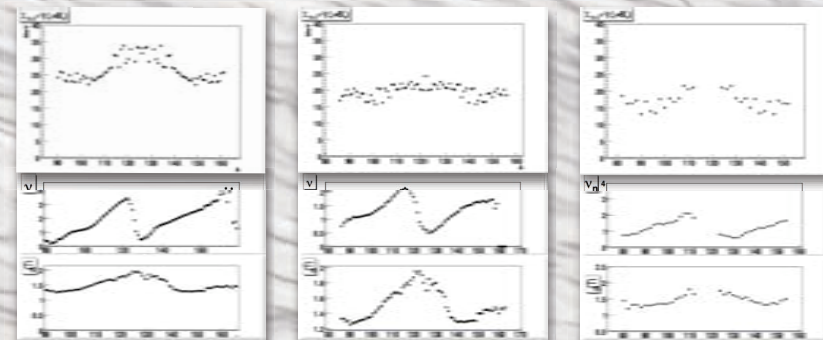
prompt neutrons: $E_{\text{def}} \approx \sum_{\text{fragments}} \nu(\epsilon + B_n)$

$$E_{\text{diss}} \approx Q_{\max} - \text{TKE} - \sum_{\text{fragments}} \nu(\epsilon + B_n)$$

^{252}Cf

^{244}Cm

^{236}U



NPA 632 (1998) 540
 NPA 789 (2007) 55
 PR 141 (1966) 1146
 NPA 490 (1988) 307

asymmetry: - - - symmetry: - - -

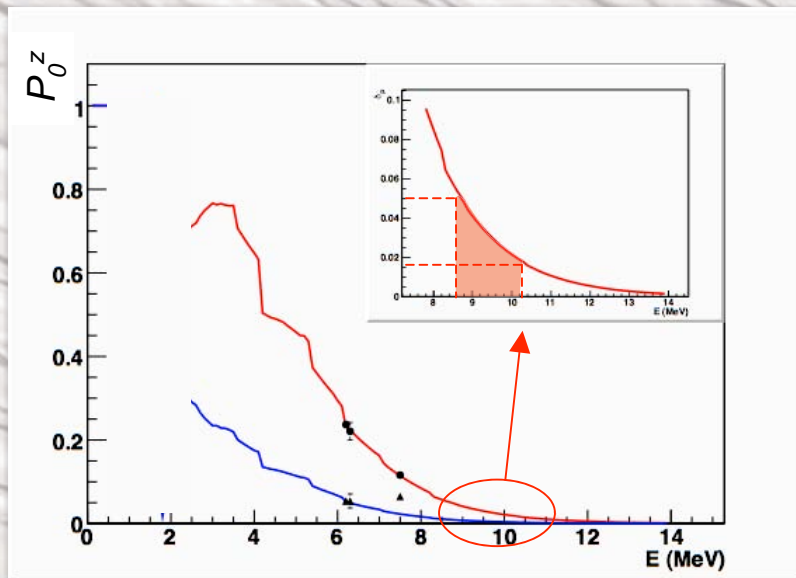
$$E_{\text{diss}}^{\text{sym}} > E_{\text{diss}}^{\text{asym}}$$

the dissipation energy remains **constant** with fissility for symmetric splits.



even-odd effect for symmetric charge splits

the even-odd effect is directly related to E_{diss}



the probability of breaking **only** neutron pairs depends on the level density

$$P_0^Z = \frac{\sum \rho_{n_Z=0, n_N}(E_{diss})}{\sum \rho_{n_Z, n_N}(E_{diss})} \quad \rho_n(E_{diss}) = \frac{g^n (E_{diss} - n\Delta)^{n-1}}{(n/2)!^2 (n-1)!}$$

proton and neutron even-odd effects are reproduced with the **same description**

F. Rejmund et al. NPA678 (2000)215

with ~ 10 MeV of E_{diss} the code predicts an even-odd effect of $\sim 3\%$, in good agreement with the extrapolation to symmetric charge split.



even-odd effect for symmetric charge split summary

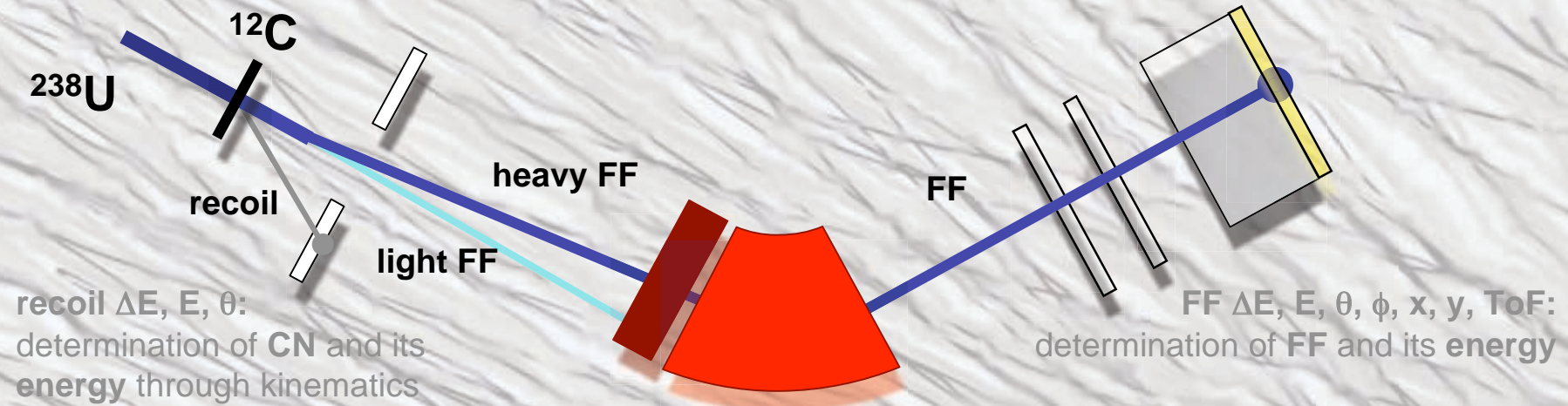
even-odd effect: useful tool for measuring E_{diss}

different sets of data (e.m., n_{th} fission) give a coherent picture of an even-odd effect with no dependence on fissility at symmetric split.

these experimental approaches provide an insight to even-odd effect for symmetric split. More data of this kind (yields of symmetric splits, information on E^* , neutrons, etc) is needed.



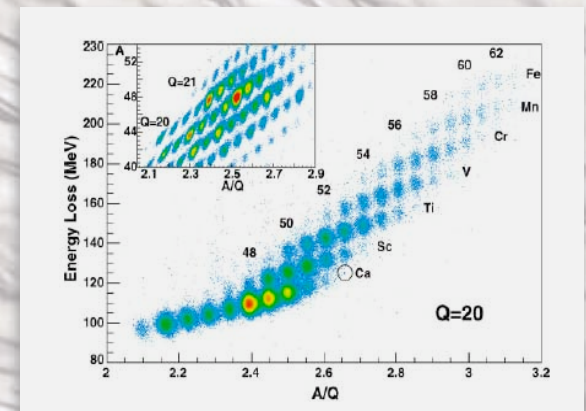
transfer induced fission in inverse kinematics with VAMOS at GANIL



a collection of fissioning systems from Cm to Ra are expected with different E^*

precise determination of **Z** and **A** of the fission fragments.

Isotopic fission **yields** in complete fragment distribution.



study of **structure** and **even-odd effects** as a function of fissility, excitation energy and charge splits.

