

ENSAR

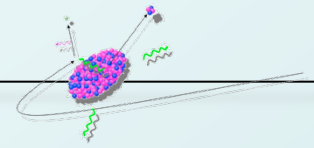
**HIGH INTENSITY
STABLE ION BEAMS
in EUROPE**



ECOS: European Collaboration on Stable ion beams



NuPECC is an Expert Committee of the European Science Foundation



FUSHE 2012

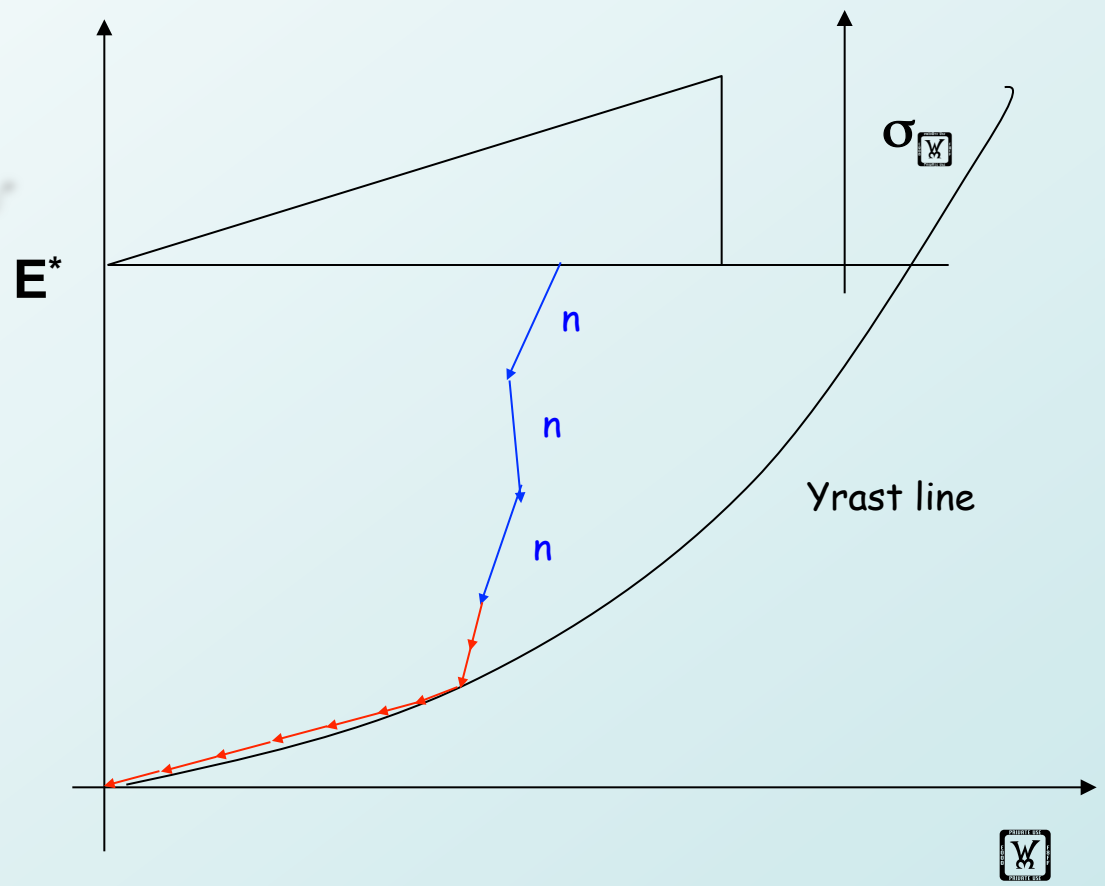
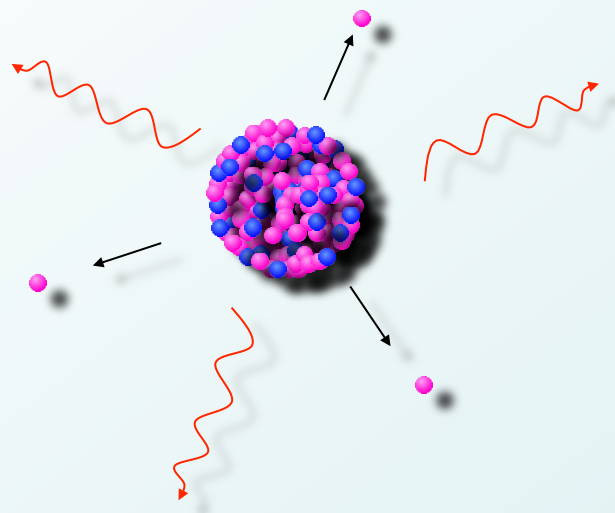
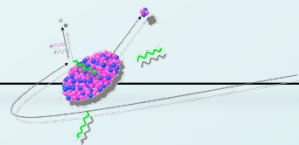
Workshop on

FUture **Super-Heavy Element Strategy**

ENSAR ECOS task 2
*synergies in the field of
SHE research*

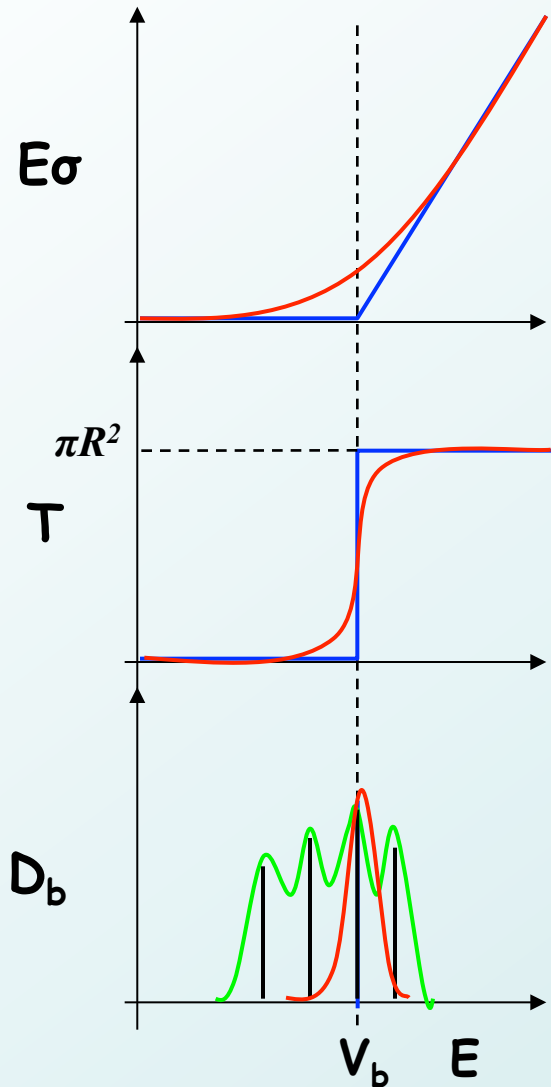
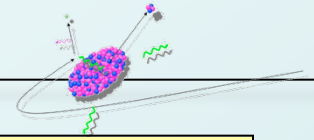
The Statistical Model

- de-excitation of the Hot Compound System



Fusion Barrier Distribution

- the Concept



$$\sigma E(E, V_b) = \pi R^2 \left(1 - \frac{V_b}{E}\right) \quad , E > V_b$$

$$\sigma E(E, V_b) = 0 \quad , E < V_b$$

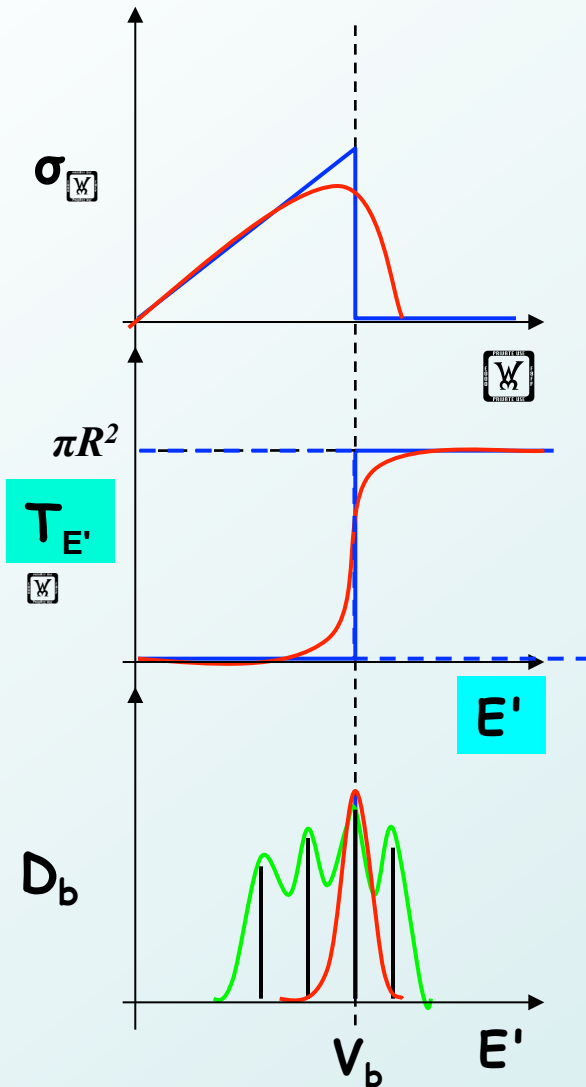
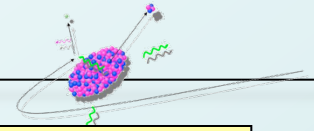
$$\frac{d(E\sigma(E, V_b))}{dE} = \pi R^2 \quad , E > V_b$$

$$\frac{d(E\sigma(E, V_b))}{dE} = 0 \quad , E < V_b$$

$$\frac{d^2(E\sigma(E, V_b))}{dE^2} = \pi R^2 \delta(E - V_b)$$

Fusion Barrier Distribution

- Partial Wave Cross sections: the CN Spin Distribution



$$\sigma_\ell(E) = T_\ell(E, \ell)(2\ell + 1)\pi\hat{\lambda}^2$$

$$\hat{\lambda} = \frac{\hbar}{\sqrt{2\mu E}} \rightarrow \text{de Broglie wave length}$$

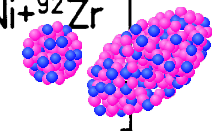
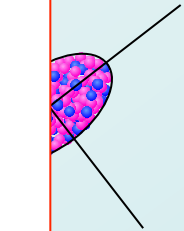
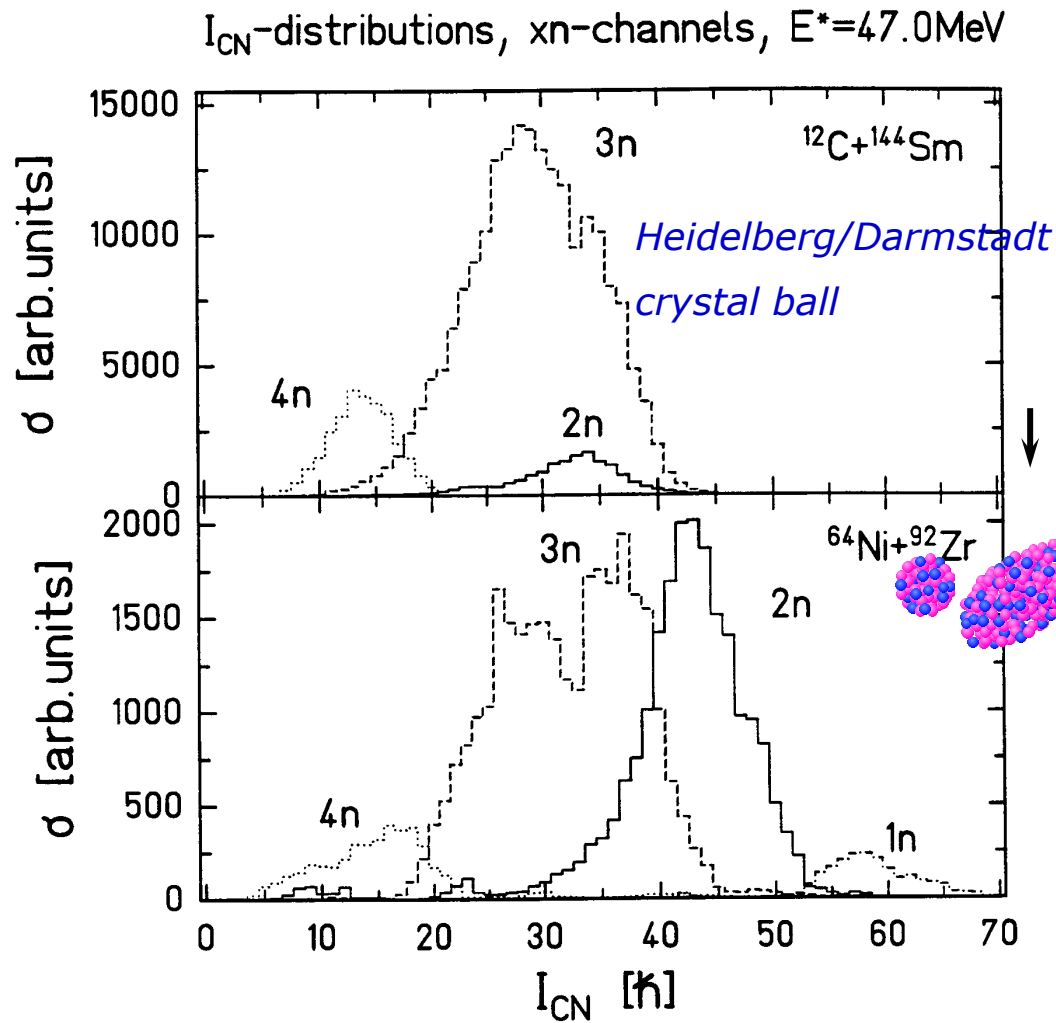
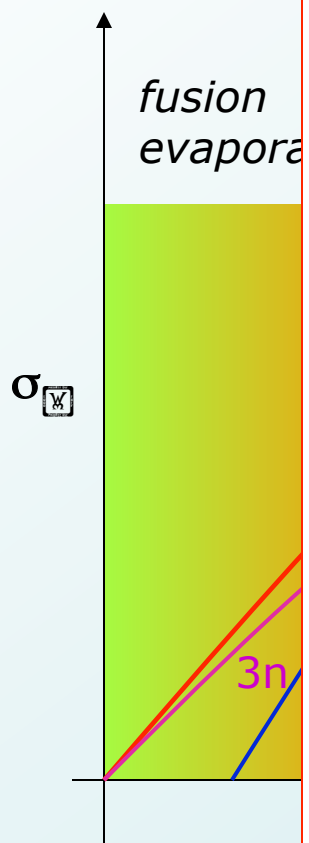
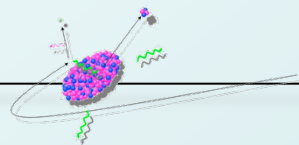
$$T_\ell(E, \ell) = \frac{\sigma_\ell(E)}{(2\ell + 1)\pi\hat{\lambda}^2}$$

$$\ell \rightarrow E' \text{ with } E' = E - E_{rot}, \quad E_{rot}(\ell) = \frac{\ell(\ell + 1)}{2\mu R_b^2}$$

$$T_\ell \rightarrow T_{E'}$$

$$T_{E'} = \frac{1}{\pi R_b} \frac{d(E' \sigma(E', V_b))}{dE'} = \frac{\sigma(E')}{(2\ell + 1)\pi\hat{\lambda}^2}$$

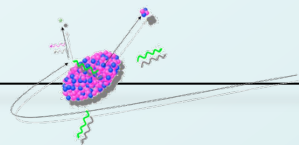
Fusion Dynamics and the Spin Distribution



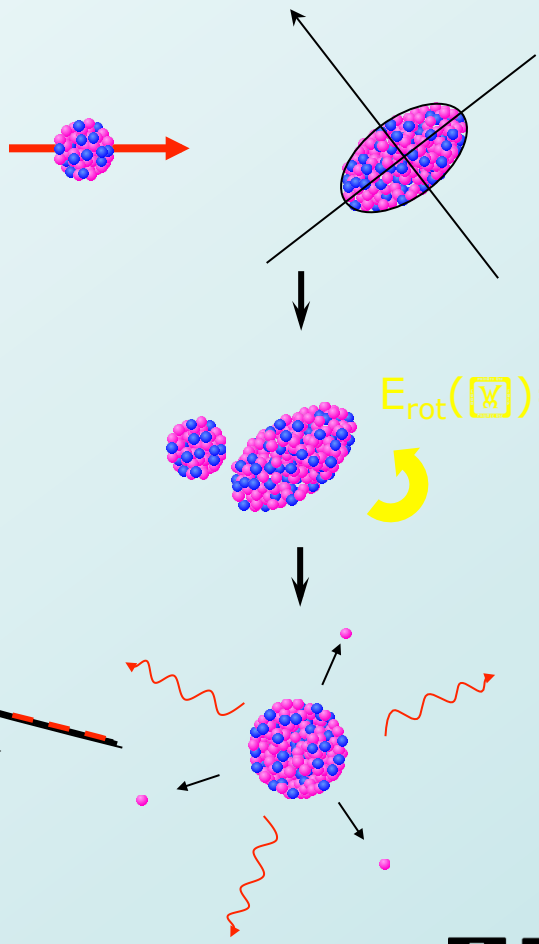
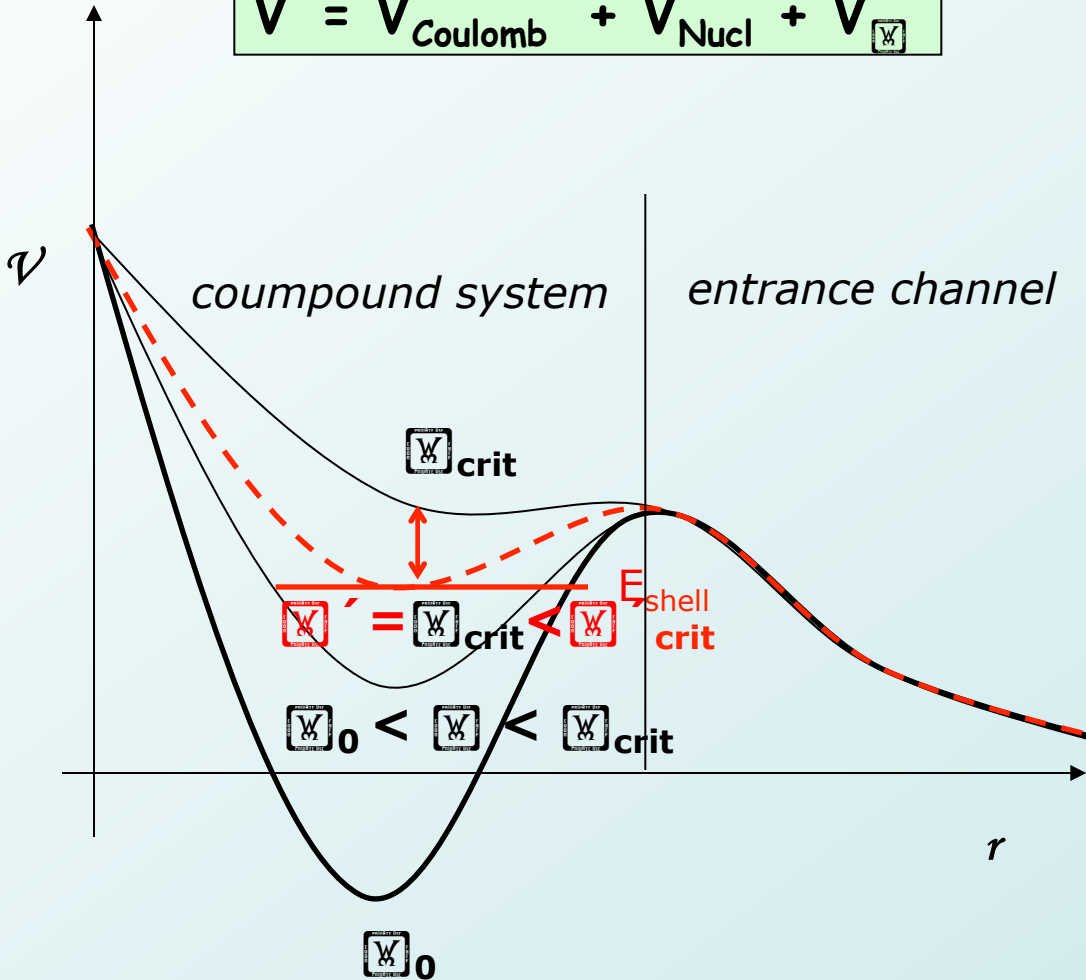
$$E_{rot}(\mathbb{N}) = \frac{\mathbb{N}(\mathbb{N}+1)\hbar^2}{2\mu R_b^2}$$

Abbildung 4.33. Die I_{CN} -Verteilungen der ungeladenen Kanäle der beiden Eingangskanäle.
 F. Heller, Ph.D. thesis, University of Heidelberg, 1995)

Fusion Dynamics and the Spin Distribution

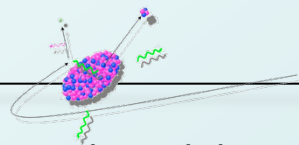


$$V = V_{\text{Coulomb}} + V_{\text{Nucl}} + V_{\text{rot}}$$

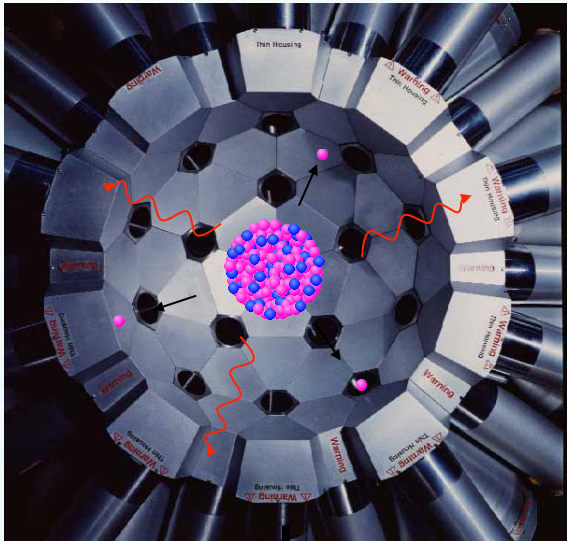


$$E_{\text{rot}}(I) = \frac{I(I+1)\hbar^2}{2\mu R_b^2}$$

Experimental Approach to the Spin Distribution with GASP



1 GASP – inner ball (80 BGO-crystals)



2 GASP – high resolution Ge-detectors

3 statistical model (codes like PACE, EVAP, HIVAP...)



E_γ



ER identification



evaporation parameters



spin removed by particles and statistical γ -rays

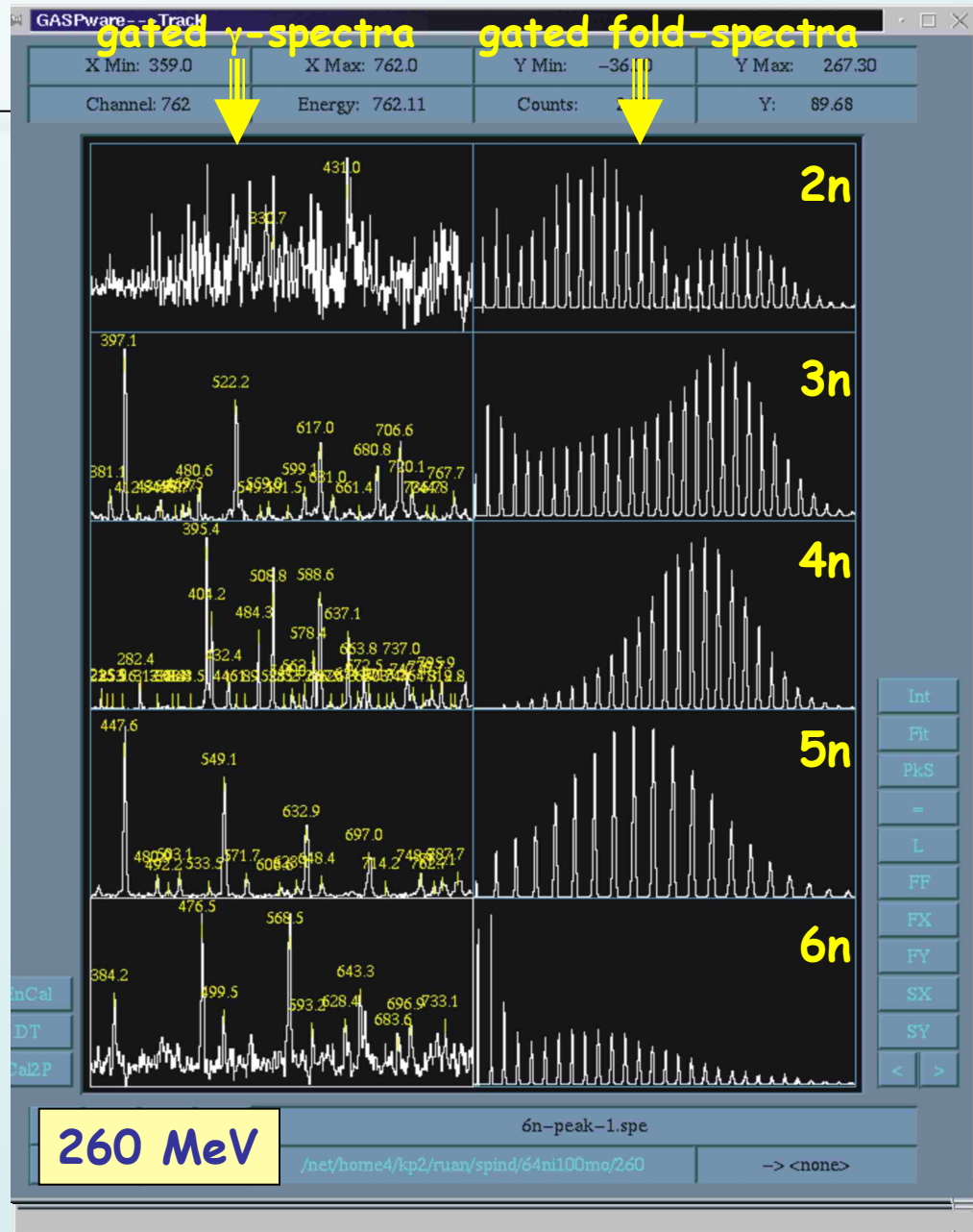
γ -ray fold
GASP response function

M_γ

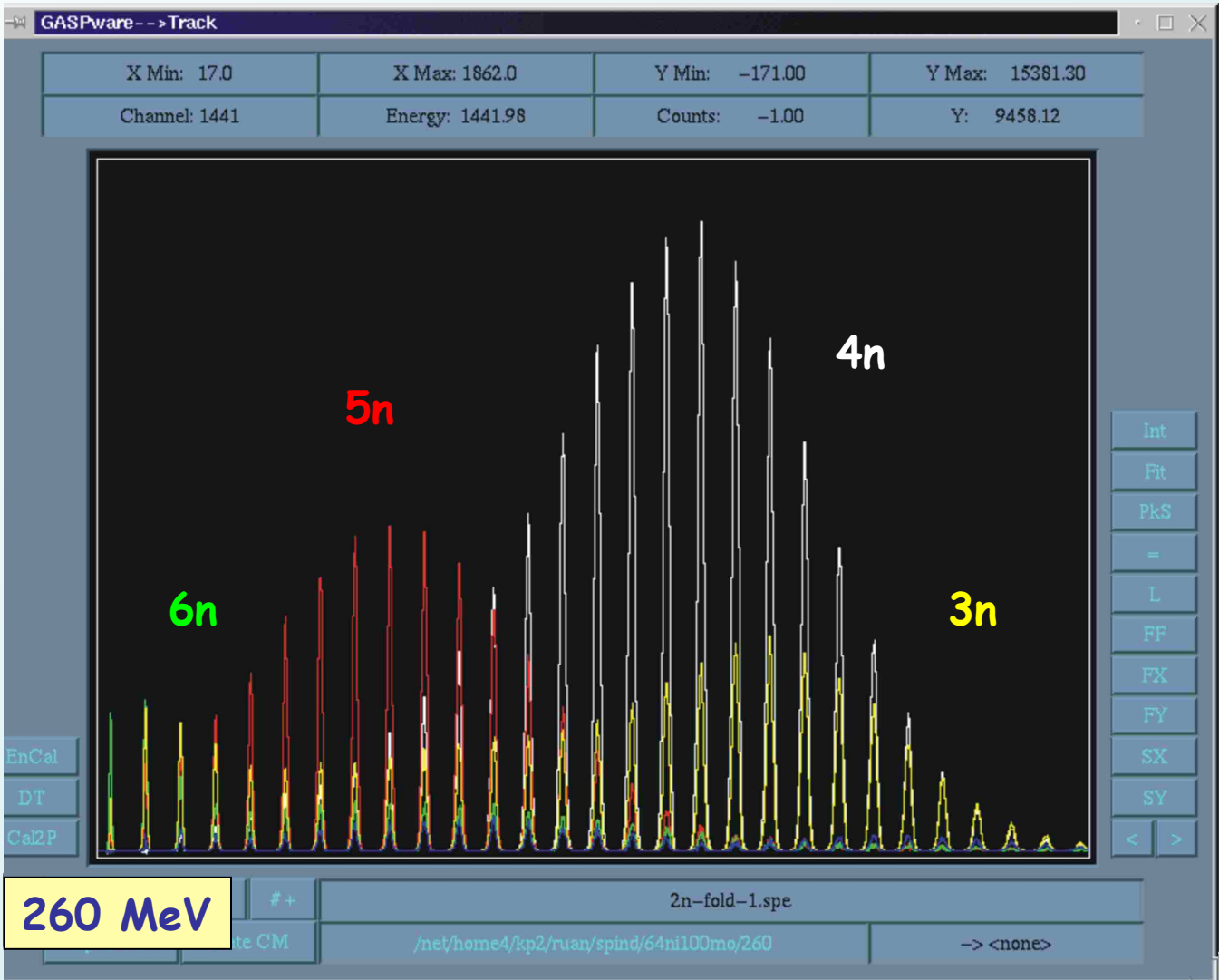
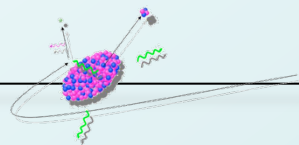
$$\left[\begin{matrix} \text{W} \\ \text{CN} \end{matrix} \right] = (M_\gamma - M_{\gamma s}) \Delta \left[\begin{matrix} \text{W} \\ \gamma \end{matrix} \right] + M_{\gamma s} \Delta \left[\begin{matrix} \text{W} \\ \gamma s \end{matrix} \right] + \left[\begin{matrix} \text{W} \\ i \end{matrix} \right] M_i \Delta \left[\begin{matrix} \text{W} \\ i \end{matrix} \right] + \Delta \left[\begin{matrix} \text{W} \\ \text{gs/m} \end{matrix} \right]; i$$

= p, n, α

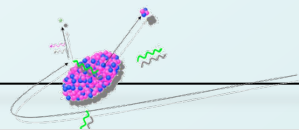
Fold Distributions with GASP for $^{64}\text{Ni}+^{100}\text{Mo}$



Fold Distributions with GASP for $^{64}\text{Ni}+^{100}\text{Mo}$



Fold Distributions with GASP for $^{64}\text{Ni}+^{100}\text{Mo}$



X Min: 14.0	X Max: 2130.0	Y Min: -167.00	Y Max: 15352.70
Channel: 2130	Energy: 2130.18	Counts: 0.00	Y: 270.74

X Min: 17.0	X Max: 1862.0	Y Min: -171.00	Y Max: 15381.30
Channel: 1441	Energy: 1441.98	Counts: -1.00	Y: 9458.12

4n

Experimentally probing the fusion barrier distribution

$\Delta \Psi \approx 20 \Psi$

$\Delta \Psi \approx 10 \Psi$

1171

fold ≈ 9

4n

3n

246 MeV

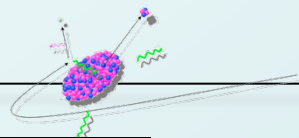
$^{64}\text{Ni}+^{100}\text{Mo}$
 ANL/Notre Dame BGO array

$V_B < E \sim E_{\text{Fiss}}$

Figure 4. Comparison of the spin distributions at the two higher energies (figures 3(e) and (f)). The shaded area in the bottom figure illustrates the truncation of the distribution by fission.

D.Ackermann et al., J. Phys. G 23 (1997)

Fold Distributions with GASP for $^{34}\text{S}+^{170}\text{Er} \rightarrow ^{204}\text{Po}^*$



GASP – inner ball (80 BGO-crystals)

