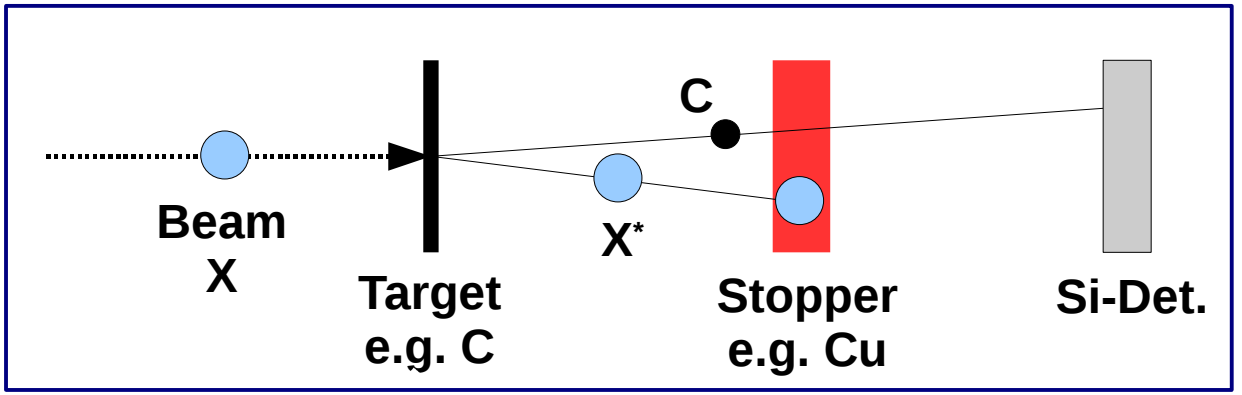
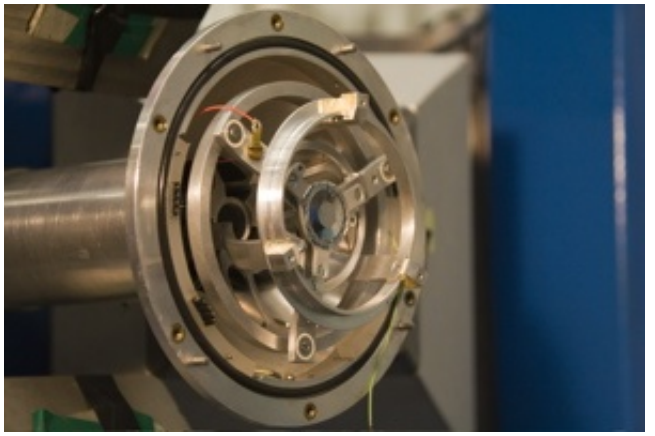
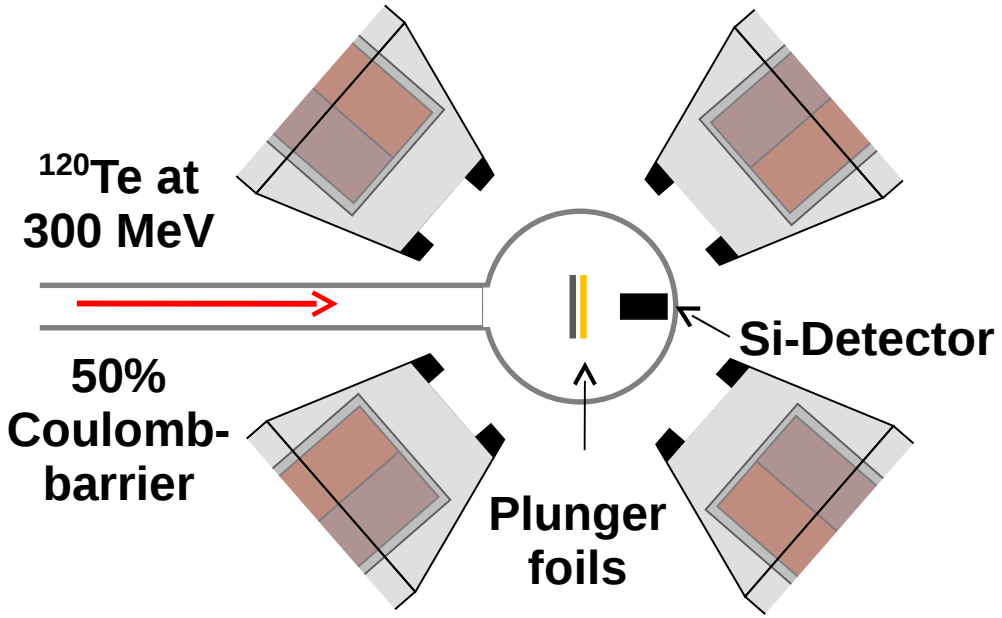
Lifetime measurements in inverse kinematics Coulex

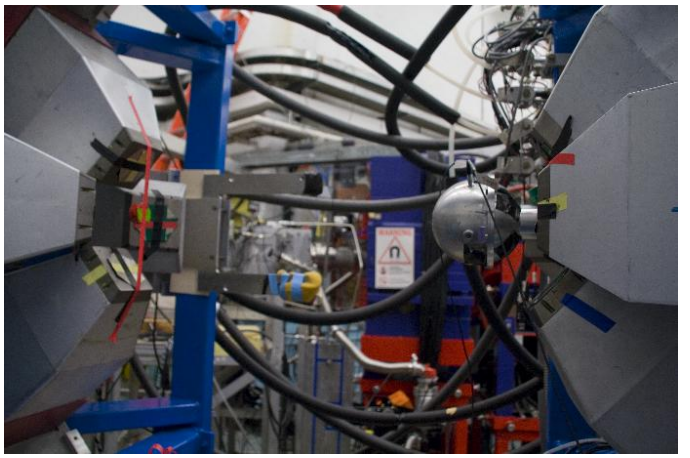
Yale Plunger







Compton-suppressed
Clover detectors (8)



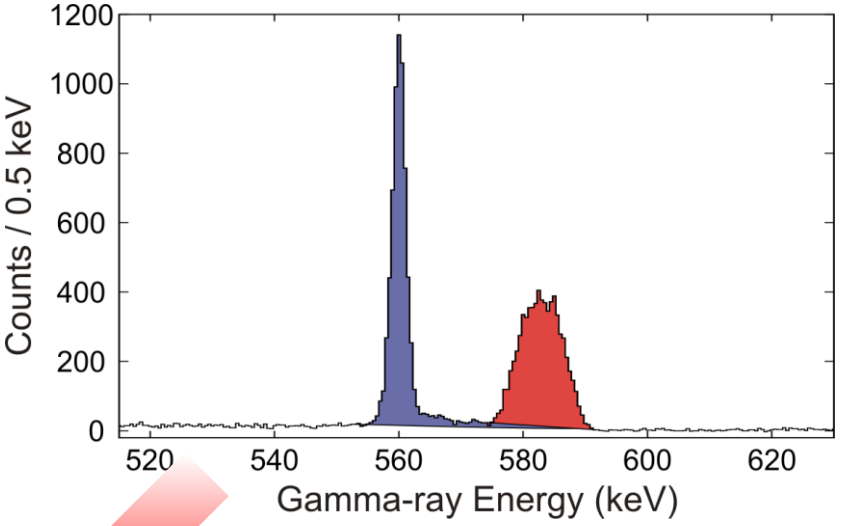
Lifetime analysis

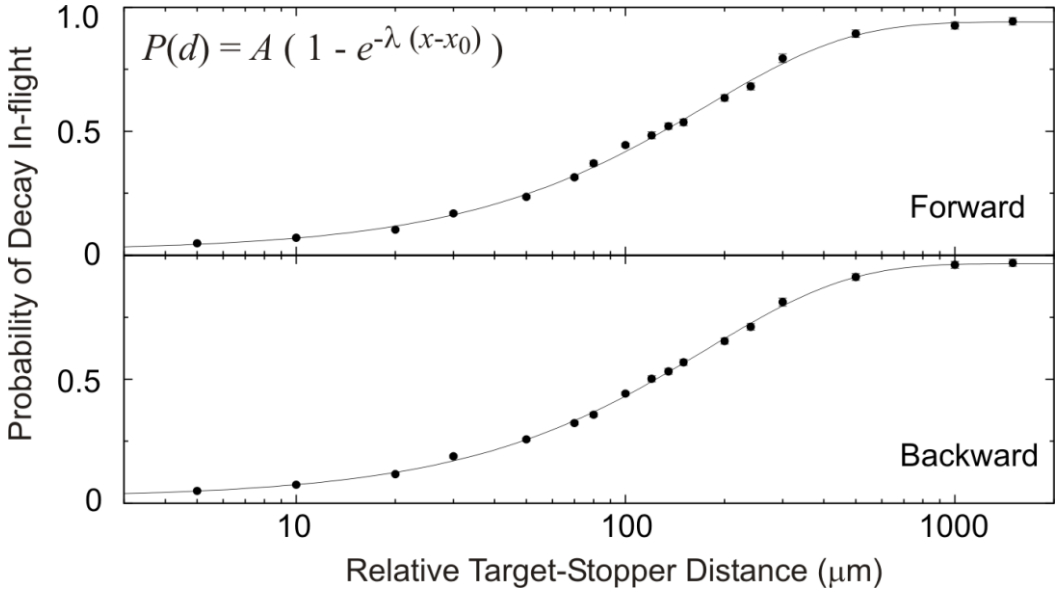
Probability of emitting gamma-ray while in-flight:

$$P(d) = 1 - \exp[-\lambda(d - d_0)]$$

From data:

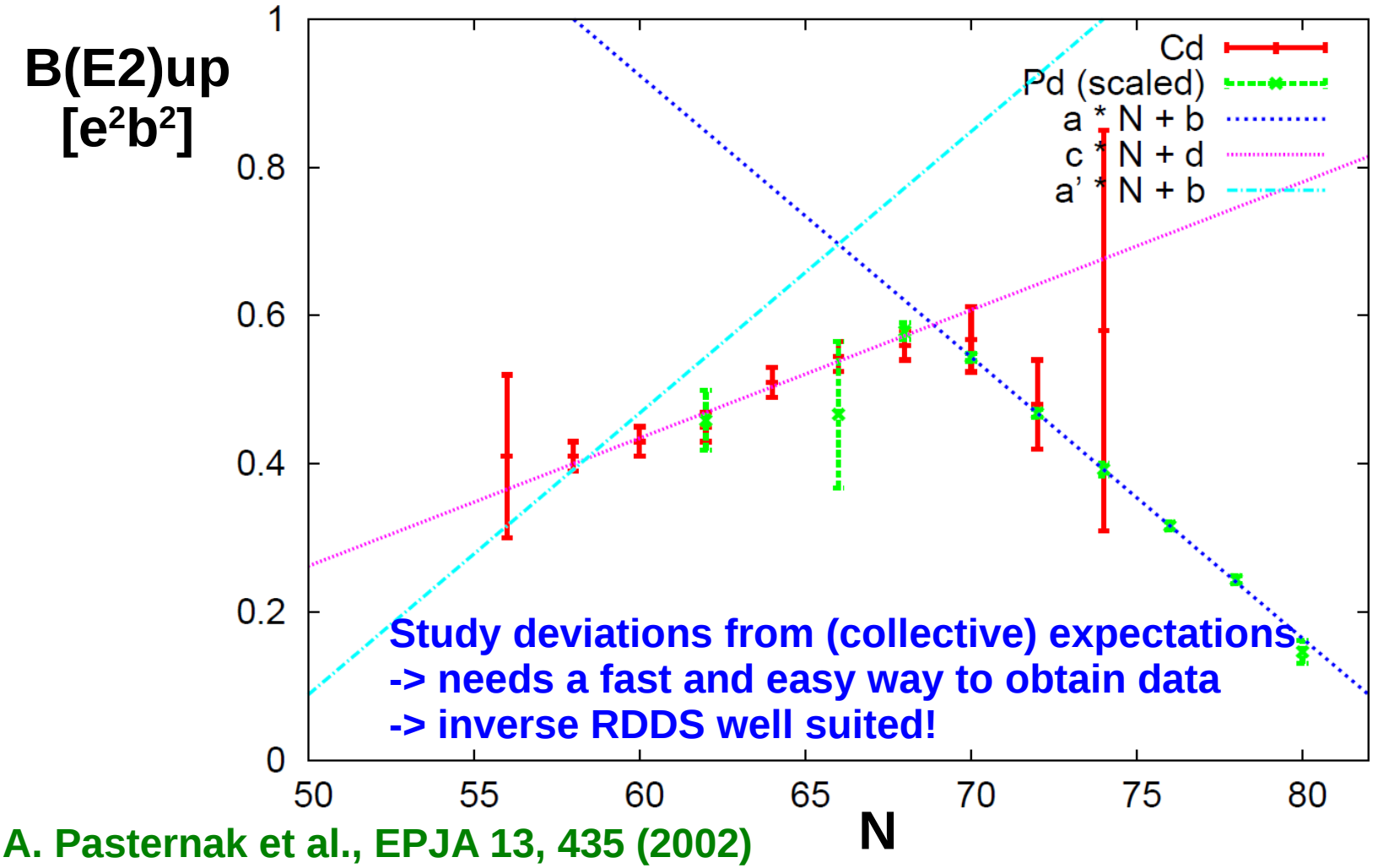
$$P(d) = \frac{I_\gamma^{(shifted)}(d)}{I_\gamma^{(total)}(d)} \quad \text{where} \quad I_\gamma = \frac{N_\gamma}{\varepsilon(E_\gamma)W(\theta_\gamma)}$$





For example: Valence proton symmetry

Data from NNDC, WNSL (^{120}Te), NBI group (^{116}Te), Cologne (^{114}Te)



A.A. Pasternak et al., EPJA 13, 435 (2002)
O. Möller et al., PRC 71, 064324 (2005)

Important in inverse kinematics: Deorientation

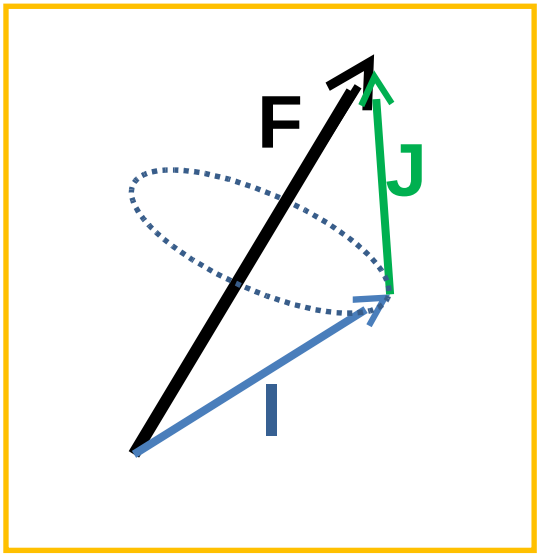
Large v/c => except for relativistic corrections: significant hyperfine-interaction between nucleus and electrons!

⇒Precession of the **nuclear spin I** and the **electron spin J** about the **total spin F**

Ensemble of may different electron configurations, spins are randomly oriented

⇒Attenuation of the asymmetry in $W(\theta_\gamma)$

⇒Attenuation coefficient $G_k(t)$ drops approximately exponentially with time:



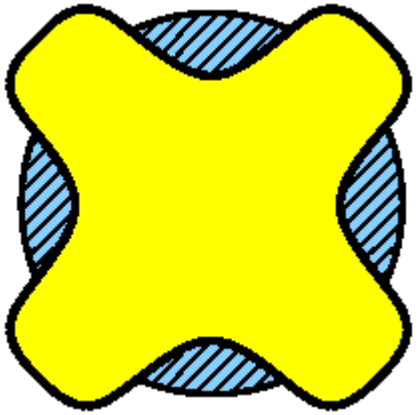
A. E. Stuchbery and N. J. Stone, Phys. Rev. C **76** (2007) 034307

$$G_k(t) = \alpha_k + (1-\alpha_k)\exp\left(-\frac{|g|t}{C_k}\right)$$

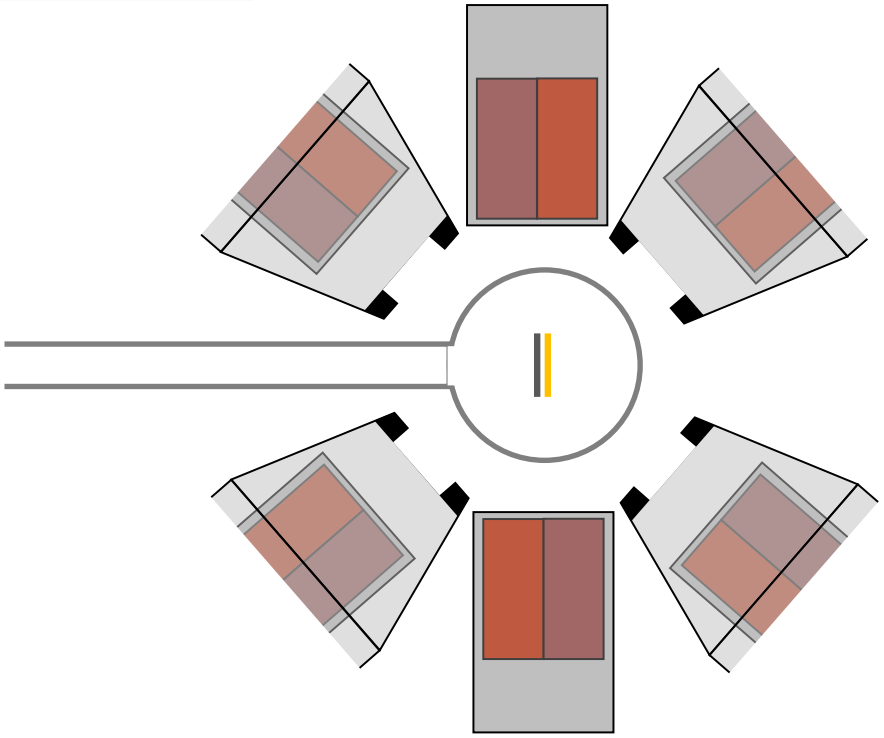
g – g-factor of the state

C_k, α_k – Parametrization of the hyperfine interaction

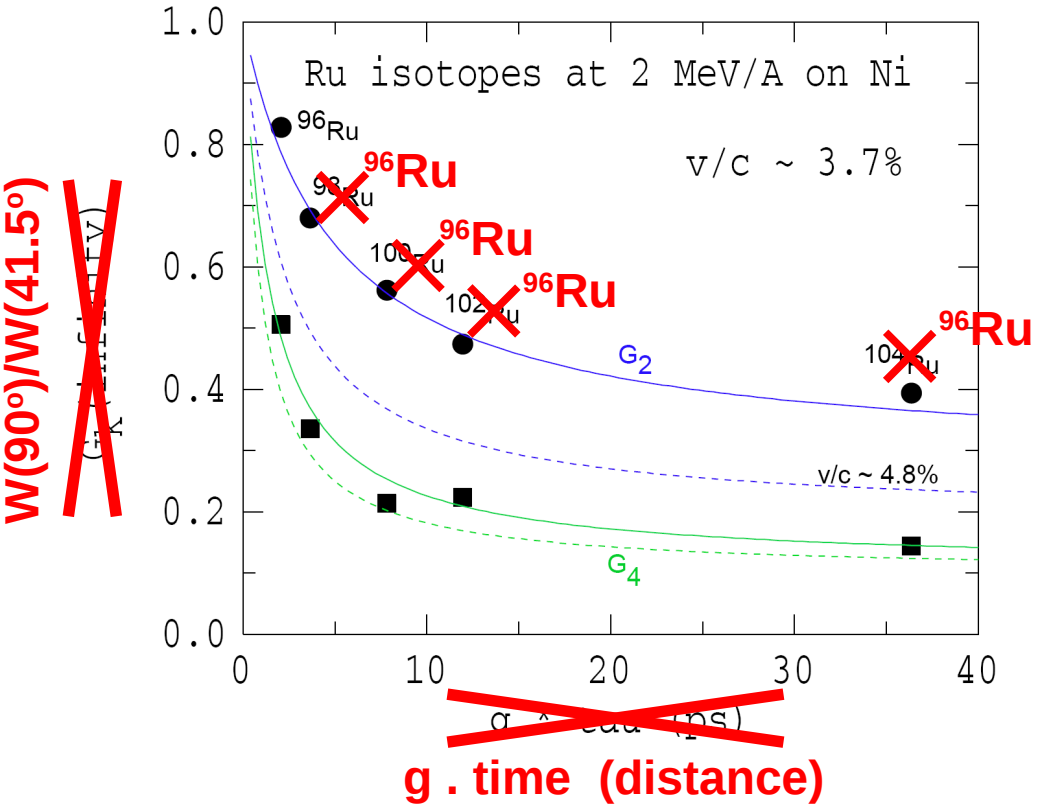
$$W(\theta)=1+\sum_{i=2,4} G_i(t)\, Q_i\, B_i\, F_i\, P_i(\cos\theta)$$



Plunger Method for g Factors



- Measure deorientation as function of distance
- Calibrate deorientation parameters in ONE isotope, 2_1^+
- Measure other states or neighbor isotope using those parameters



g . time (distance)

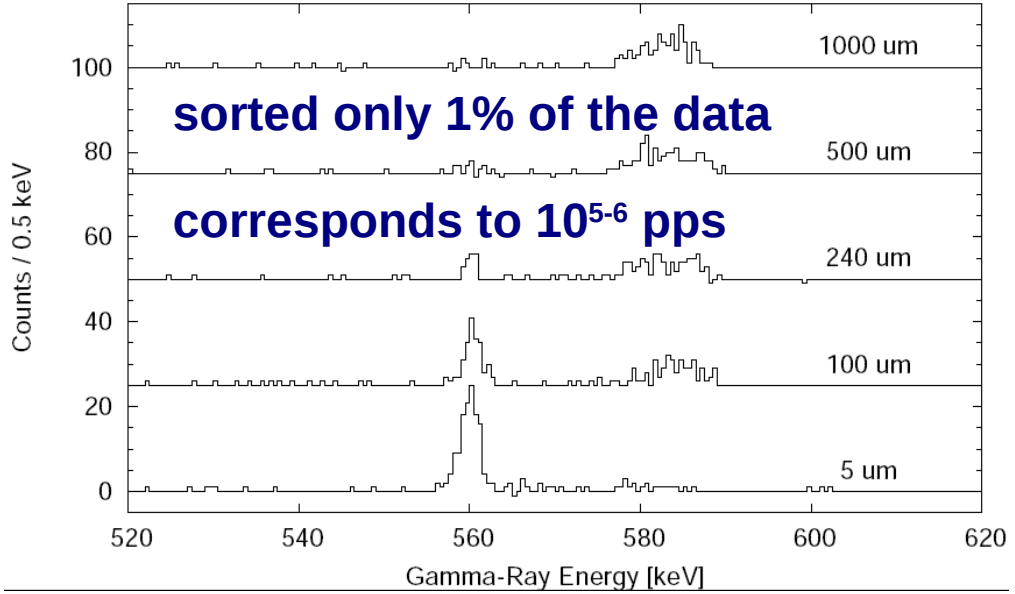
- Add detectors at 90° to measure angular distribution
- Make use of rings of individual leafs

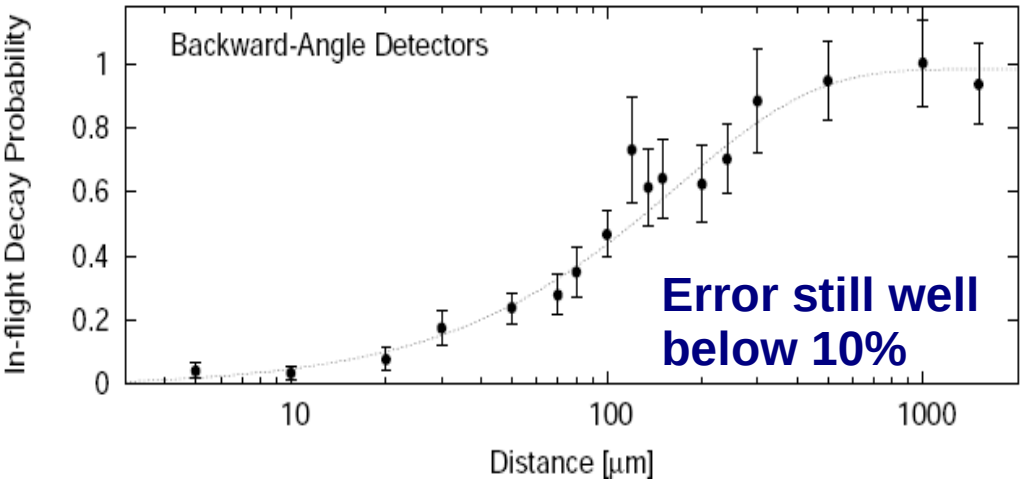
Example future prospects: (stable and unstable)

Structural evolution

- **along important isotopic (-tonic) chains (e.g., Zr, Ru, or Mo) from stable into radioactive isotopes -> transition spherical-deformed, indications for new (sub)-shells?**

- **along shell closures -> e.g., details on shifts of sp-orbitals, formation of proton-neutron symmetric (p + n) and mixed-symmetric (p – n) configurations, in inverse Coulex / reactions.**





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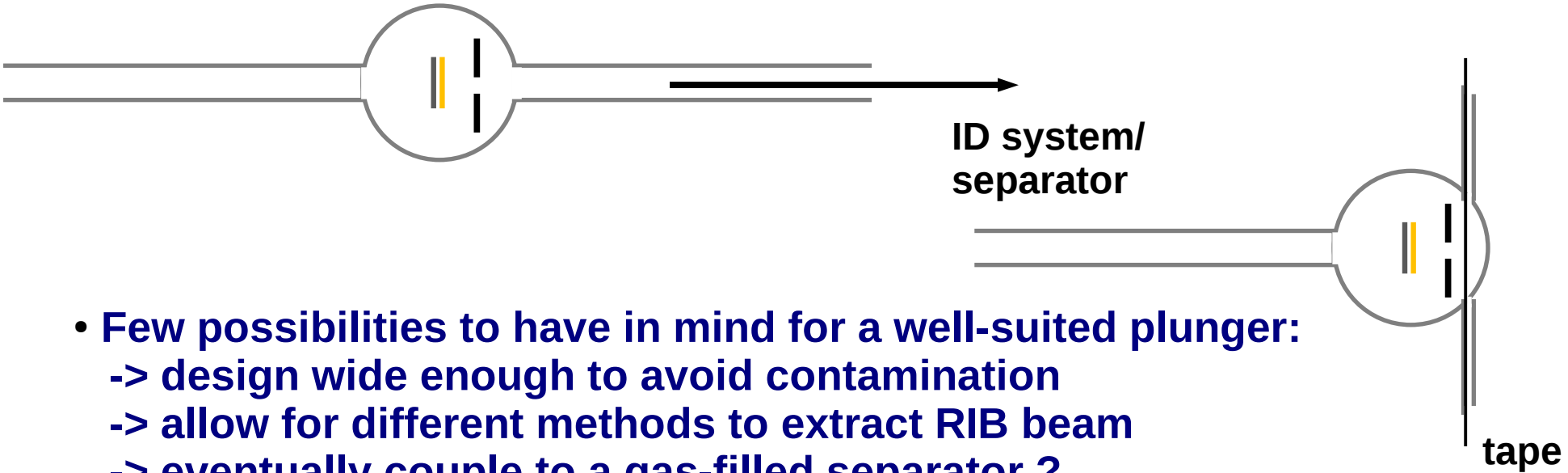
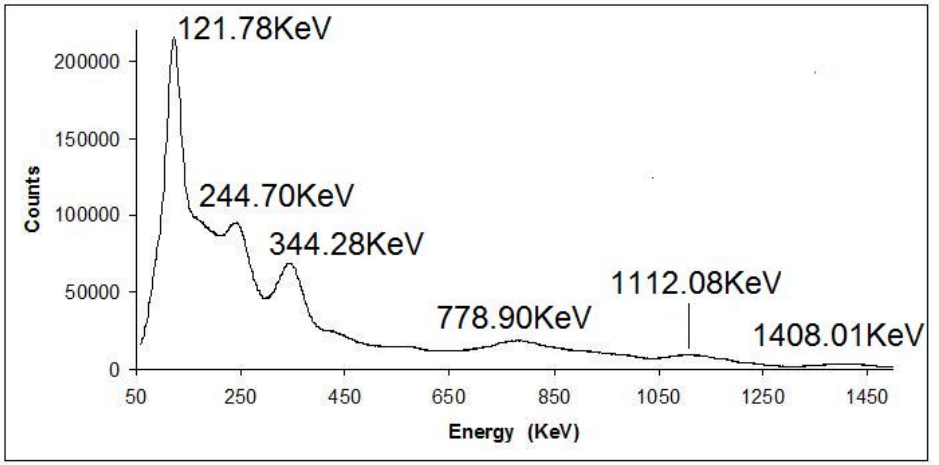
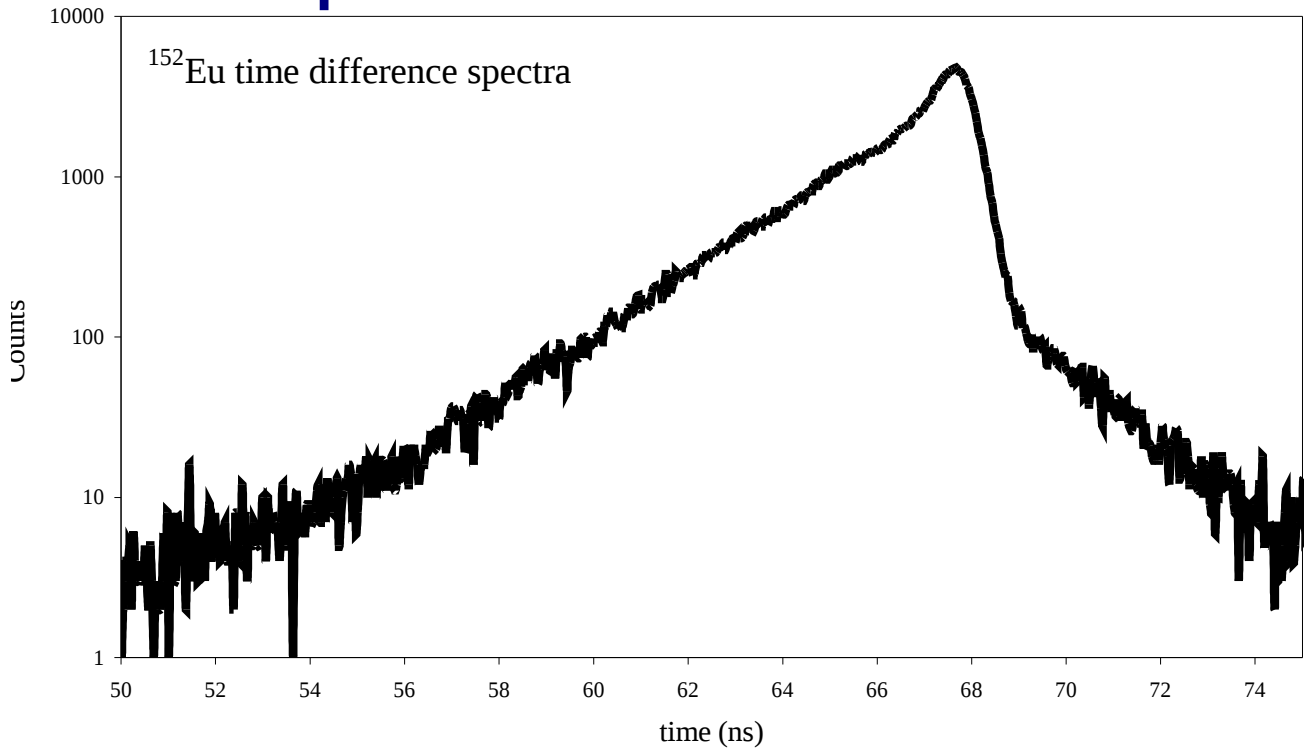


- **Few possibilities to have in mind for a well-suited plunger:**
  - **-> design wide enough to avoid contamination**
  - **-> allow for different methods to extract RIB beam**
  - **-> eventually couple to a gas-filled separator ?**

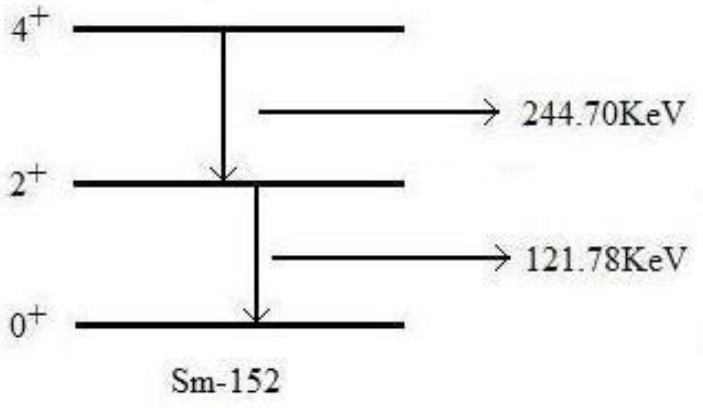
Fast timing measurements

- **BaFl2 scintillators**
- **very good time resolution :)**
- **Very poor energy resolution :(**
- **Alternative has been developed: LaBr3 !**



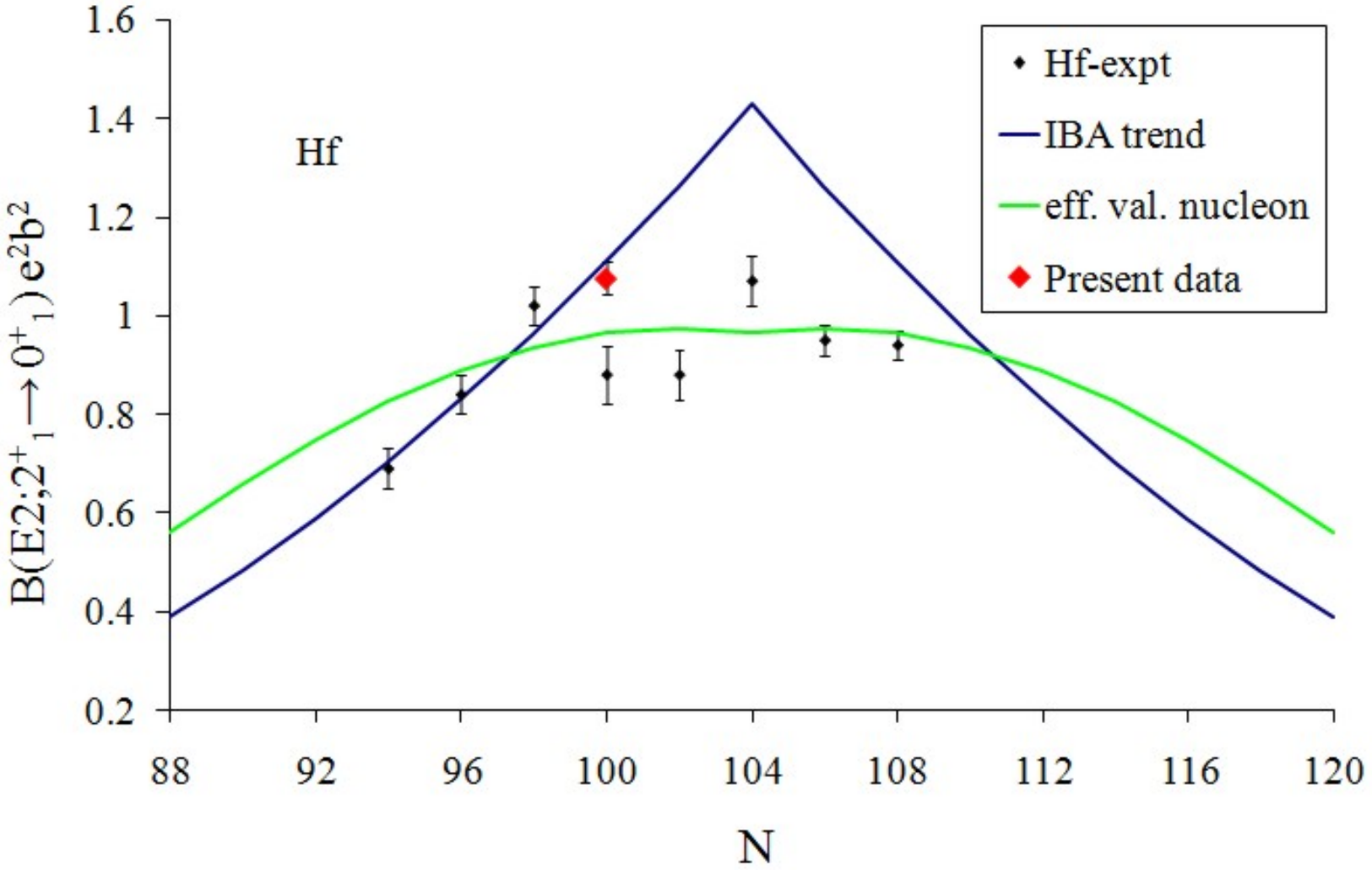


τ from simple line-fit



Revised Hf systematics

^{172}Hf: $\tau = 1.844(55)\,ns$ $B(E2; 2_1^+ \rightarrow 0_1^+) = 1.08(3)\,e^2b^2$



Fast timing γ-spectroscopy: LaBr3

- Energy resolution ~ 3%
- Timing similar to BaFl2
- High efficiency of a scintillator
- Commercially available

Wishlist:

- array of LaBr3
- Versatile:
  use for in-beam measurements / evtl. “sphere” config:
  -> at large v/c the loss in resolution can be tolarated
  -> timing can give advantage for RIBs
  use for decay spectroscopy:
  -> cluster config to be placed, e.g., behind a focal plane
  -> combine with high-res Ge detectors for clean coninc.

Physics: e.g., study of isomers > 1ns,
study of deformation (neutron-rich) mid-shell regions