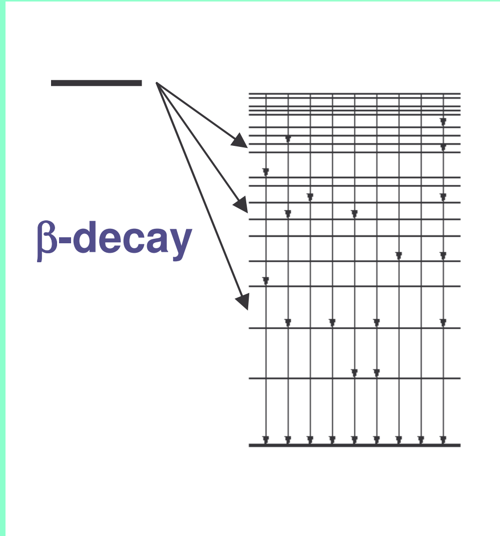
Neutron MC simulations for Total Absorption Gamma-ray Spectroscopy

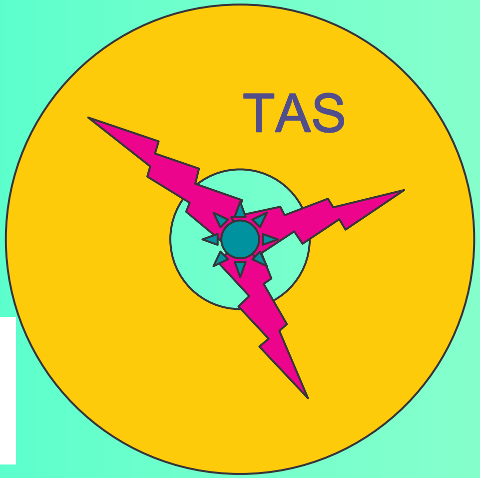
- Total Absorption Spectroscopy is the best method to measure beta strengths in β-decay (the only valid one far from stability)

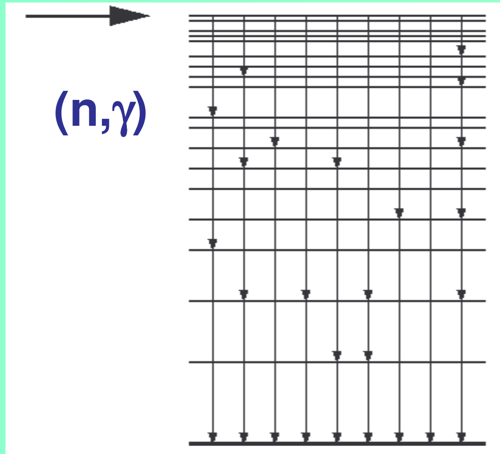
- It is also a powerful method to measure neutron capture cross-sections (the only useful for rare or radioactive samples)



- A mayor source of systematic error is contamination/ background signals

TAS: large 4π scintillation detector





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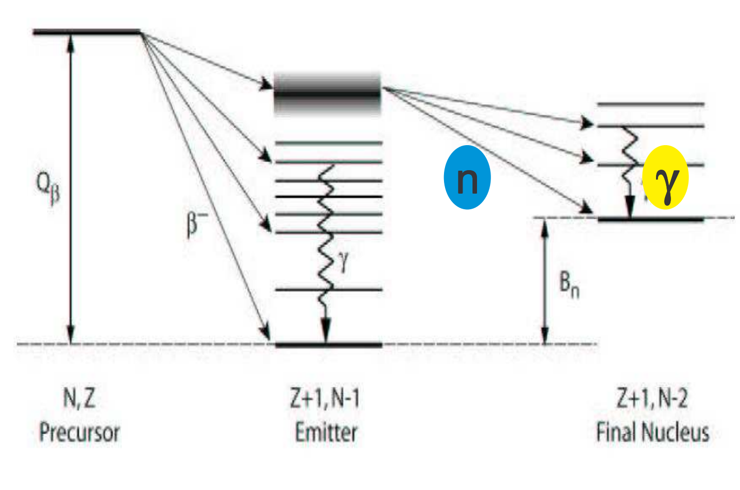
- A particular challenge is the application of the TAS technique in β-decay at the neutron rich side, due to the beta delayed neutrons

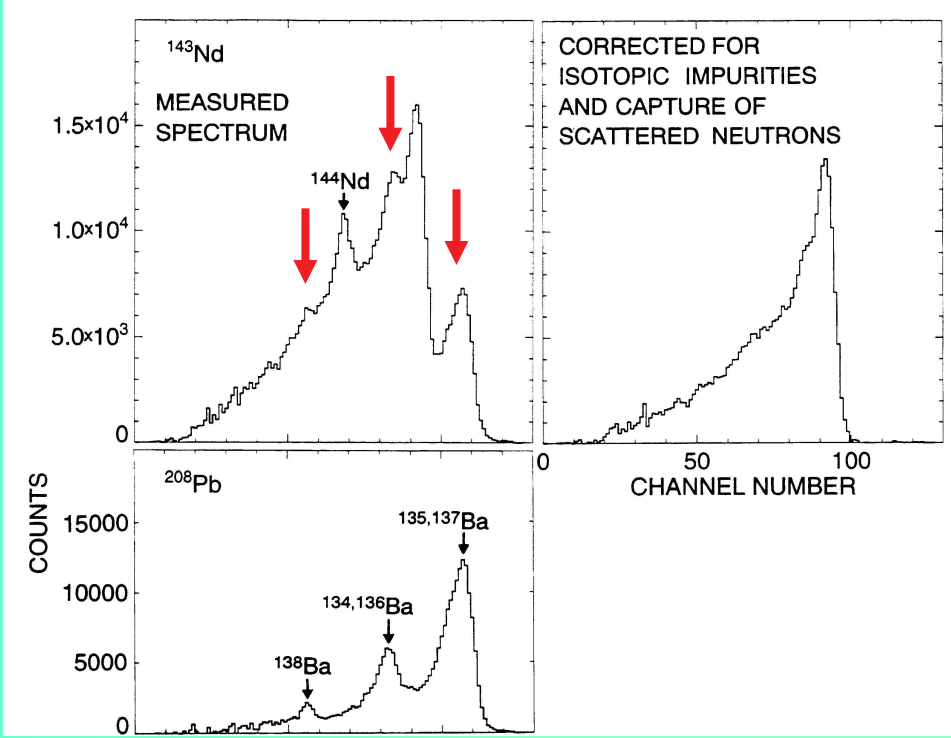


The beta-delayed **neutrons** and the subsequently emitted **gamma-rays** (may) become a contamination source

Grand-daughter γ-rays are prompt with daughter γ-rays → solution: "subtract" from data

- **What will be the effect of the emitted neutrons?**
- **How can we correct for it?**

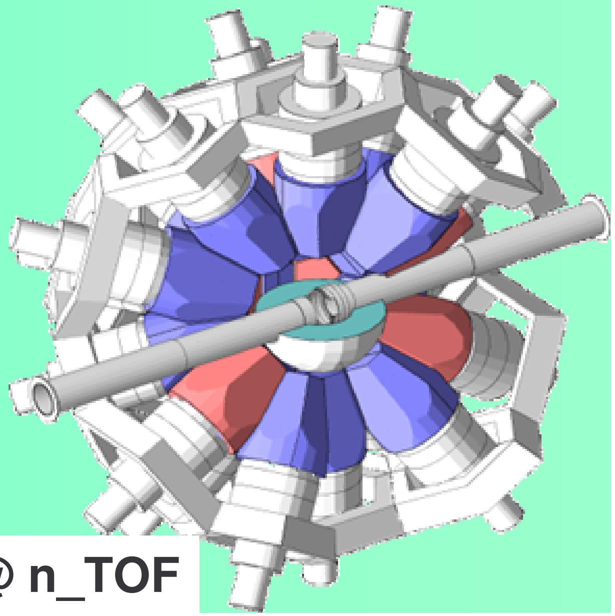
• A particular challenge is the application of the TAS technique to the measurement of low (n,γ) cross sections, due to the high scattering/capture ratio



The sample scattered **neutrons** can be captured in the detector and the subsequently emitted **gamma-rays** become a contamination source

→ solution: “subtract” from data

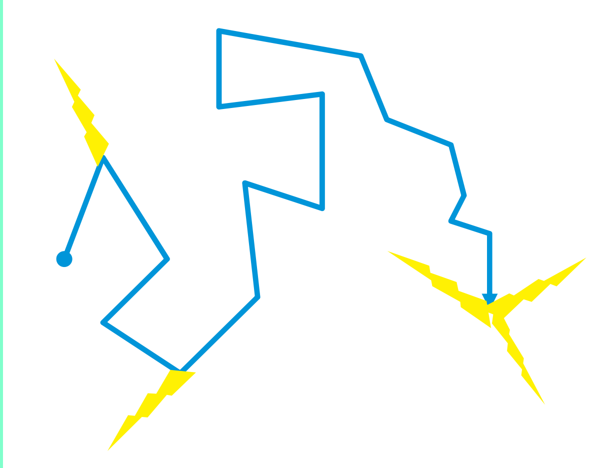
• **Can we obtain a good estimation of the correction?**



TAS @ n_TOF

Neutrons interact through:

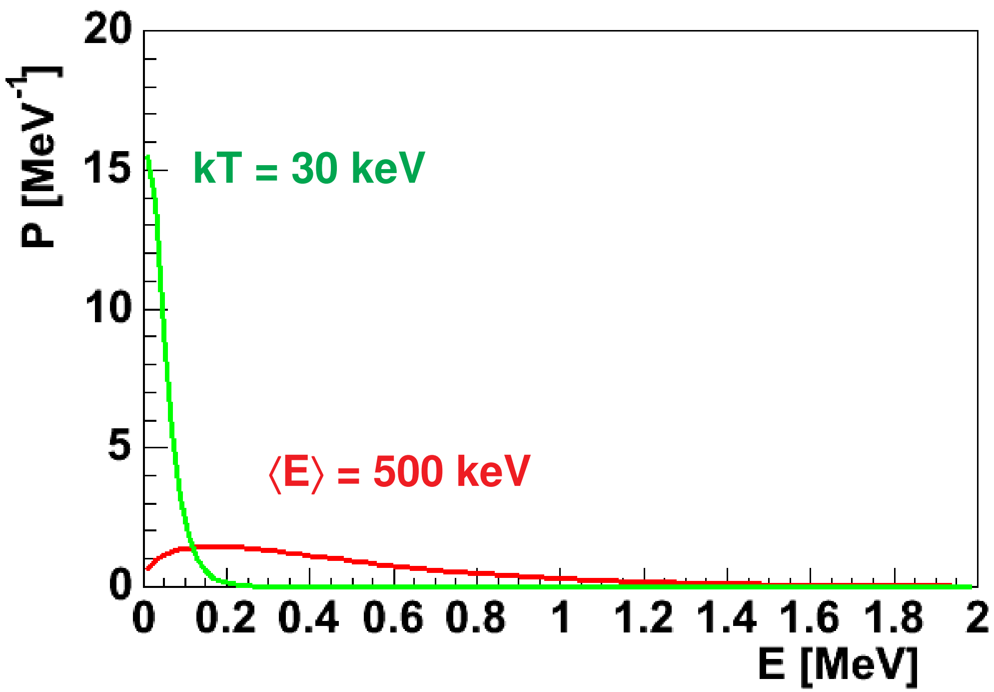
- elastic scattering
- inelastic scattering → γ-rays
- capture → γ-rays
- other: (n,p), (n,α)… → γ-rays



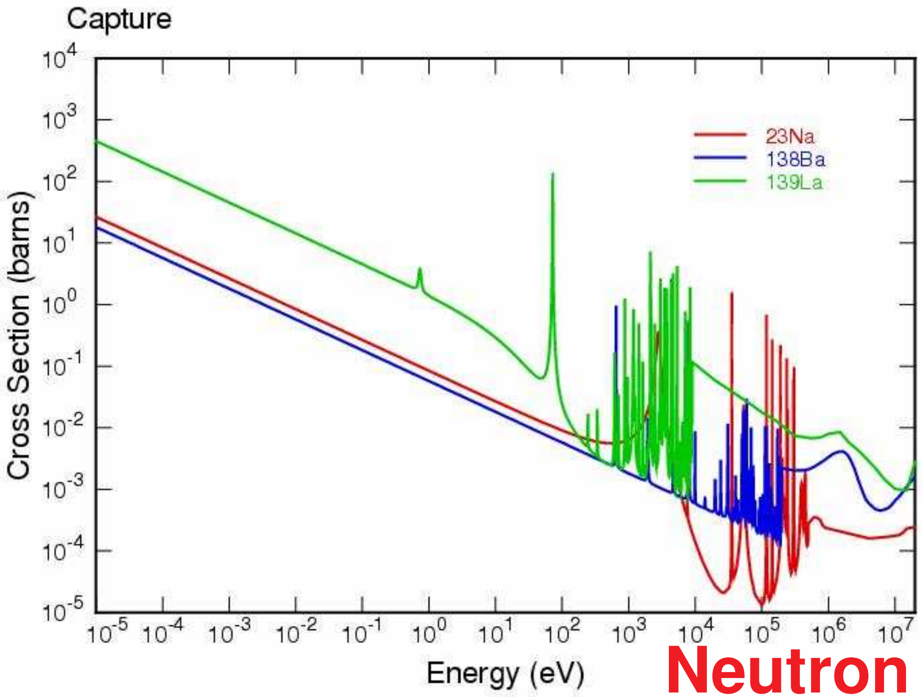
Neutron energy distribution

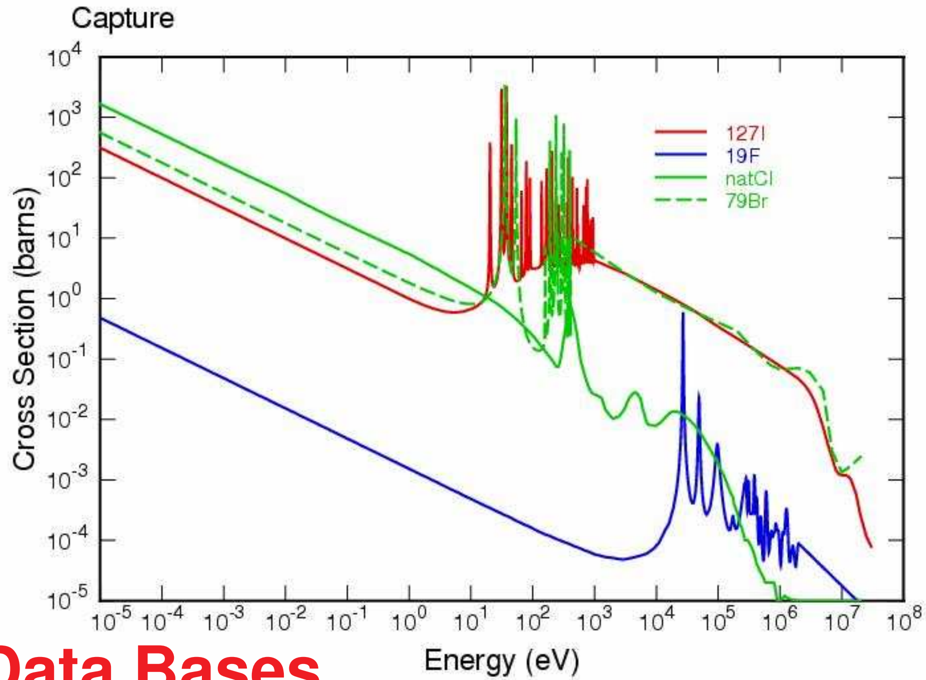
Maxwell distribution of neutrons at a typical stellar temperature kT = 30 keV

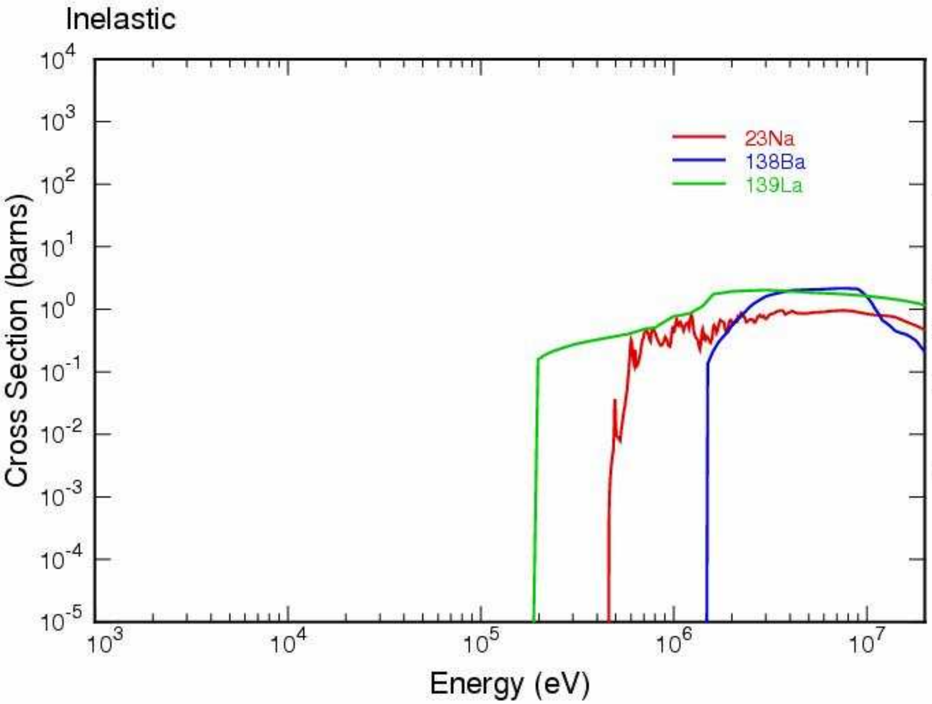
Average energy distribution of delayed neutrons from ^{235}U thermal fission products: ~ Maxwell distribution with ⟨E⟩ = 500keV

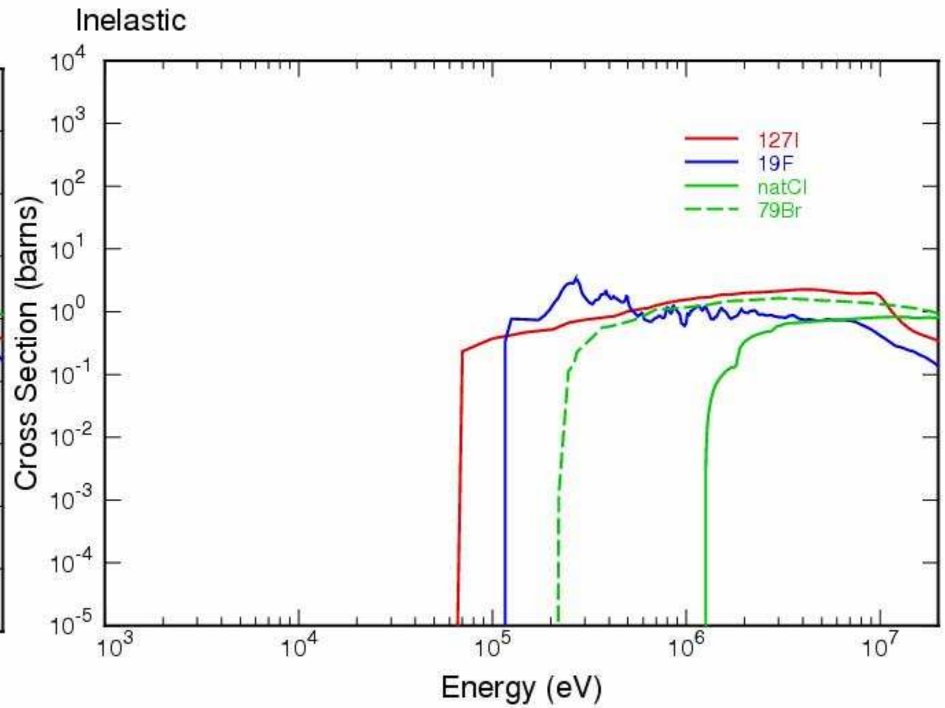


Neutron Data Bases







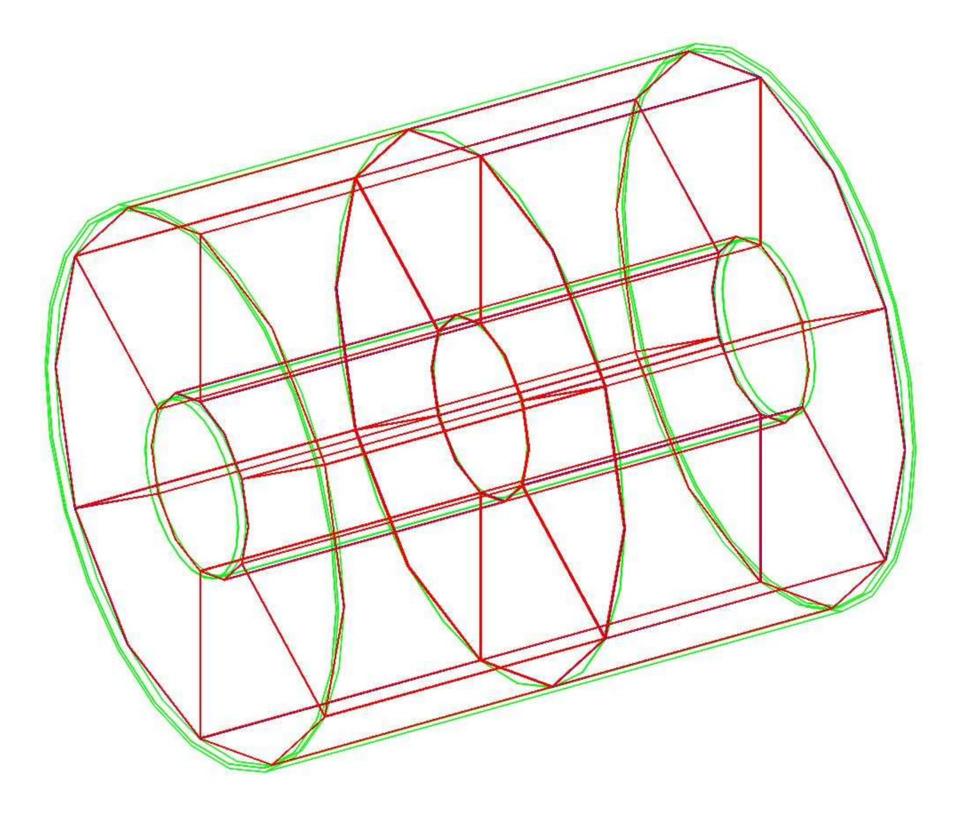


Investigated scintillation materials

σ in mb		CAPTURE				INELASTIC			
MATERIAL	ISOTOPES	σ THERMAL	σ MXW kT=30keV	σ FP ⟨E⟩=500keV	S_n (MeV)	σ THERMAL	σ MXW kT=30keV	σ FP ⟨E⟩=500keV	E_{1stEx} (MeV)
NaI(Tl)	^{127}I ^{23}Na	6730	767	205	6.8 6.9	0	183	1053	0.06 0.44
BaF_2	^{19}F $^{134-138}Ba$	1170	57	18	6.6 4.7-9.1	0	328	2350	0.11 0.2-1.44
$LaBr_3$(Ce)	$^{79,81}Br$ ^{139}La $^{140,142}Ce$	29700	1335	397	7.9,7.6 5.2 5.4,5.2	0	4	772	0.2 0.17 1.6,0.64
$LaCl_3$(Ce)	$^{35,37}Cl$ ^{139}La $^{140,142}Ce$	108300	63	17	8.6,6.1 5.2 5.4,5.2	0	3	378	1.2 0.17 1.6,0.64

Work started:

- Simulations with Geant4 with recommended hadronic package: LHEP_PRECO_HP.
- Testing of package is in progress
- Some “problems” detected
- No cross-section data for La, Ce, Br and Cl isotopes

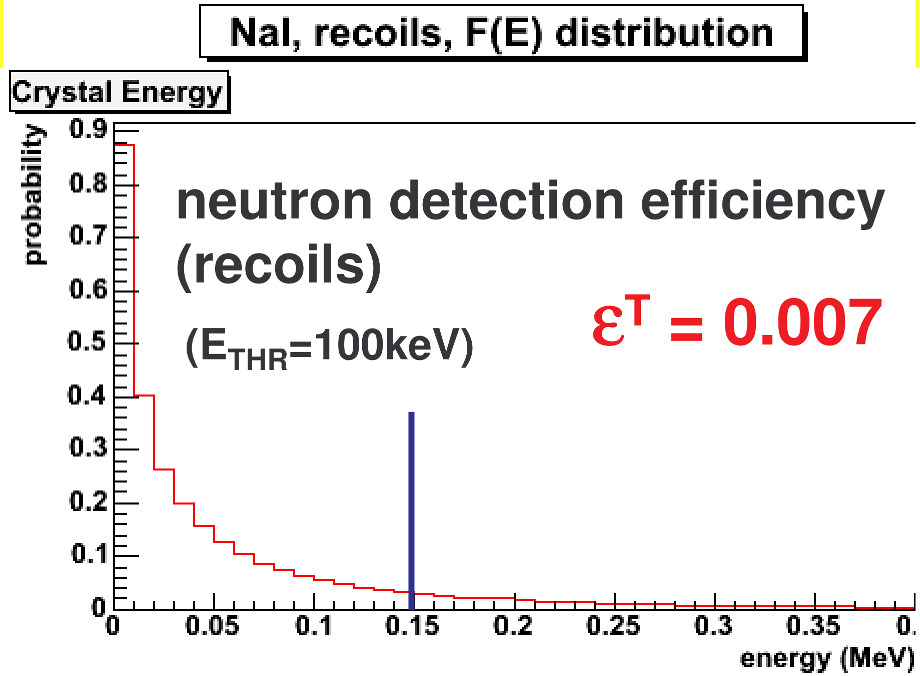


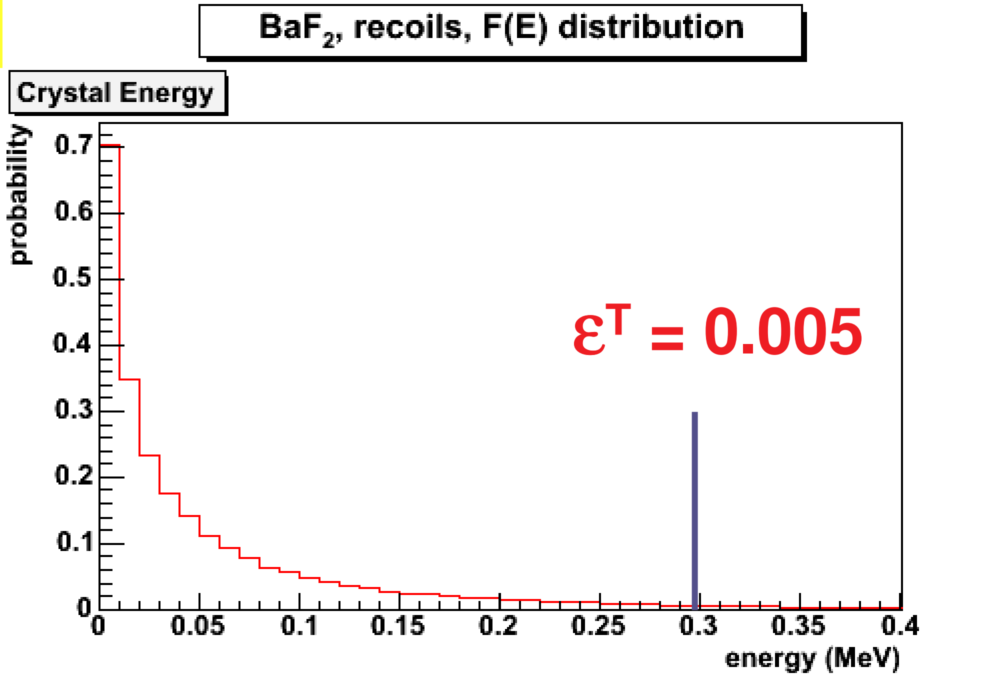
Simulation geometry:

NaI(Tl): R_{in}=10cm, R_{ext}=30cm, L=70cm
BaF_2 : R_{in}=10cm, R_{ext}=25cm, L=60cm

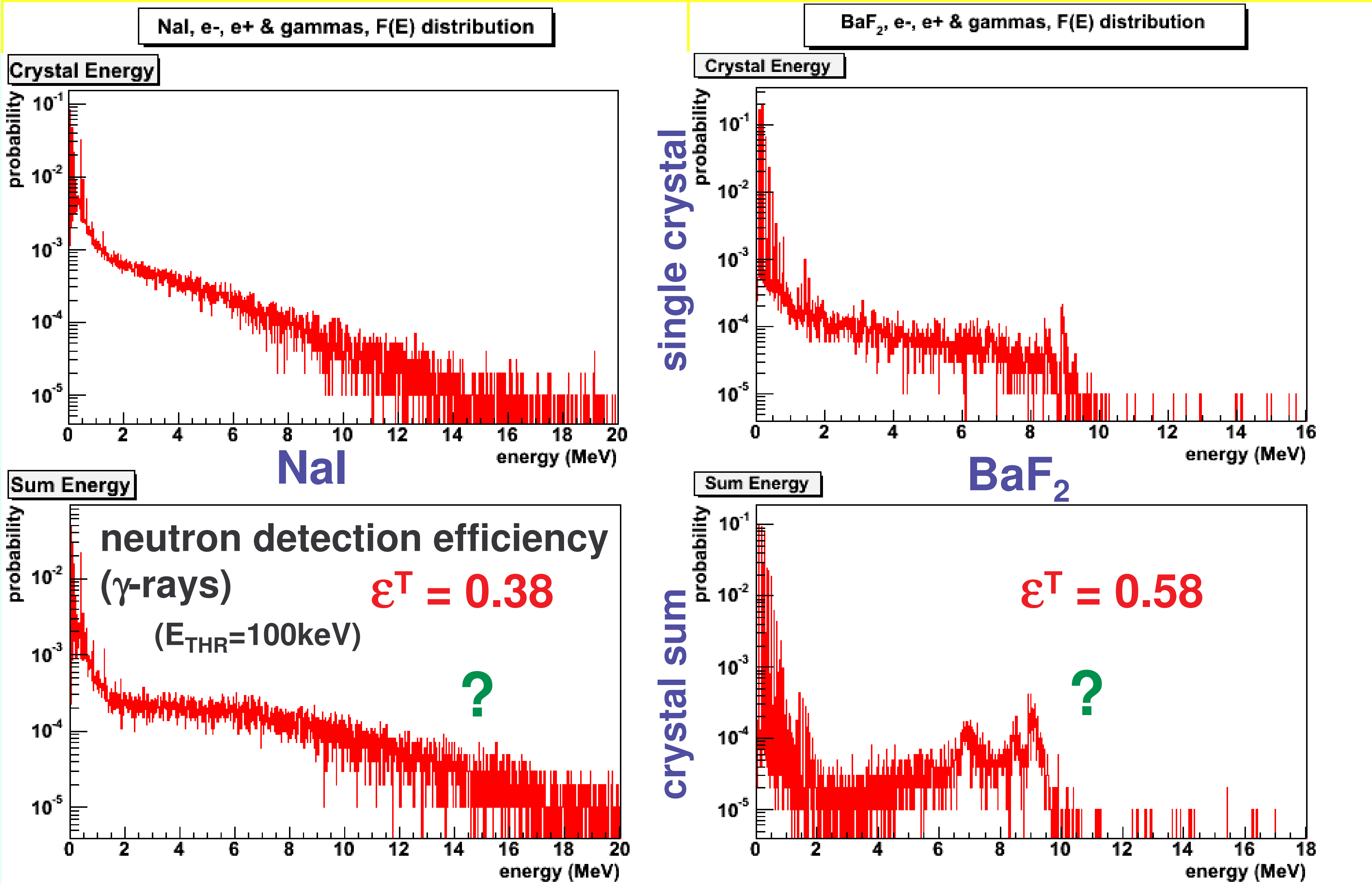
Material	ε^P 1MeV	ε^T 1MeV	ε^P 5MeV	ε^T 5MeV
NaI(Tl)	0.85	0.94	0.69	0.89
BaF_2	0.84	0.92	0.68	0.87

Energy deposited in TAS by recoils





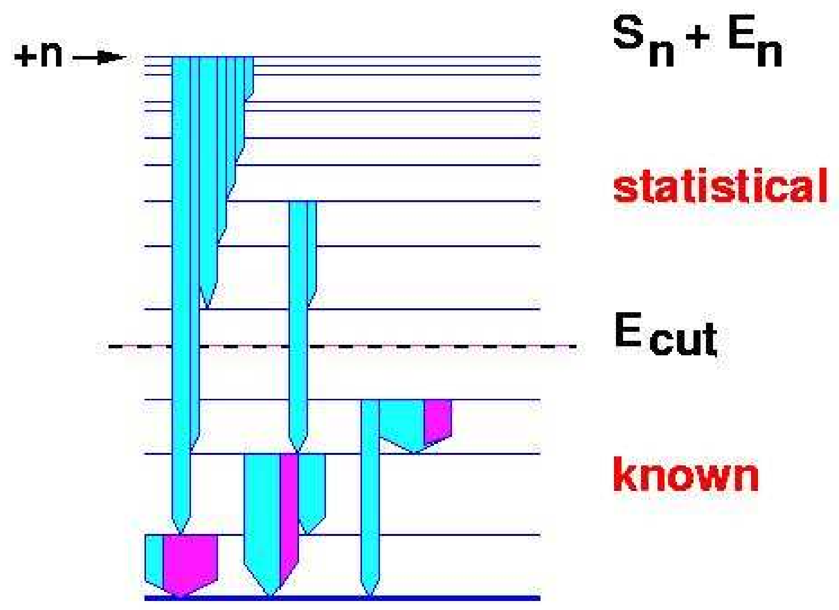
Energy deposited in TAS by FP delayed neutron energy distribution



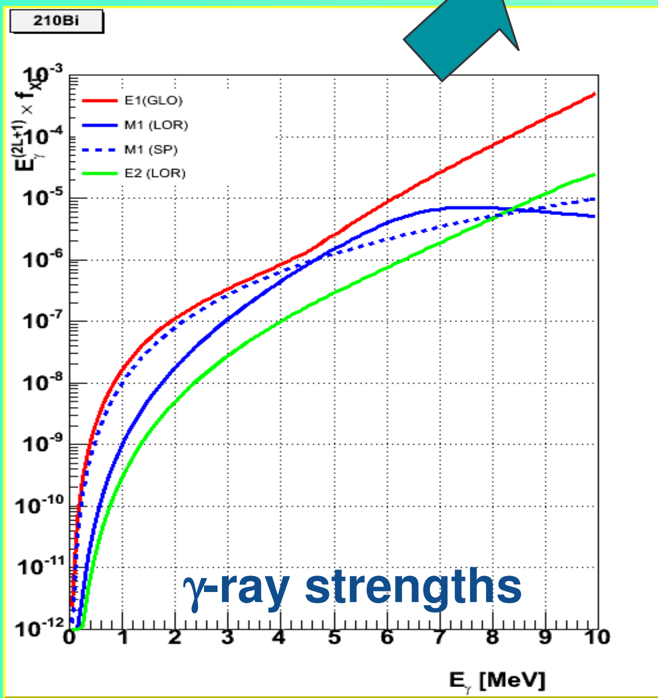
Neutron MC simulation codes have a simplified photon generation

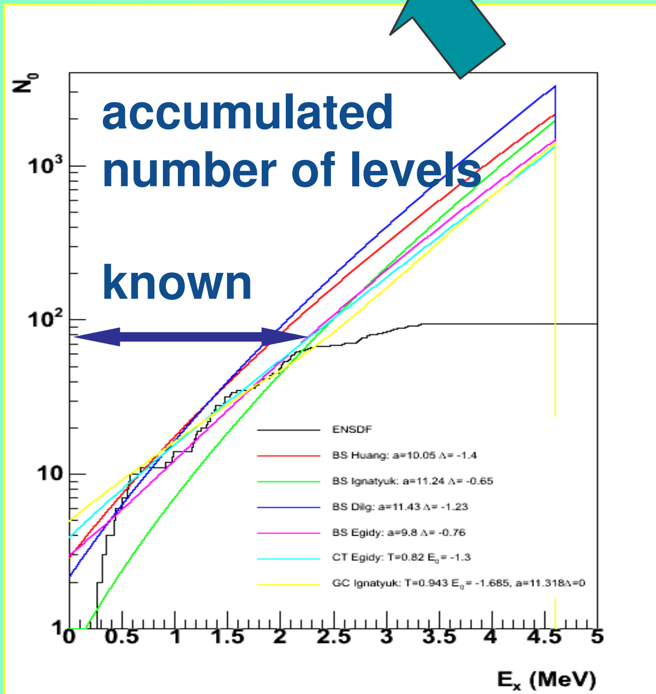
→ Replace by cascades generated with the nuclear statistical model and/or from detailed level schemes

Statistical cascades

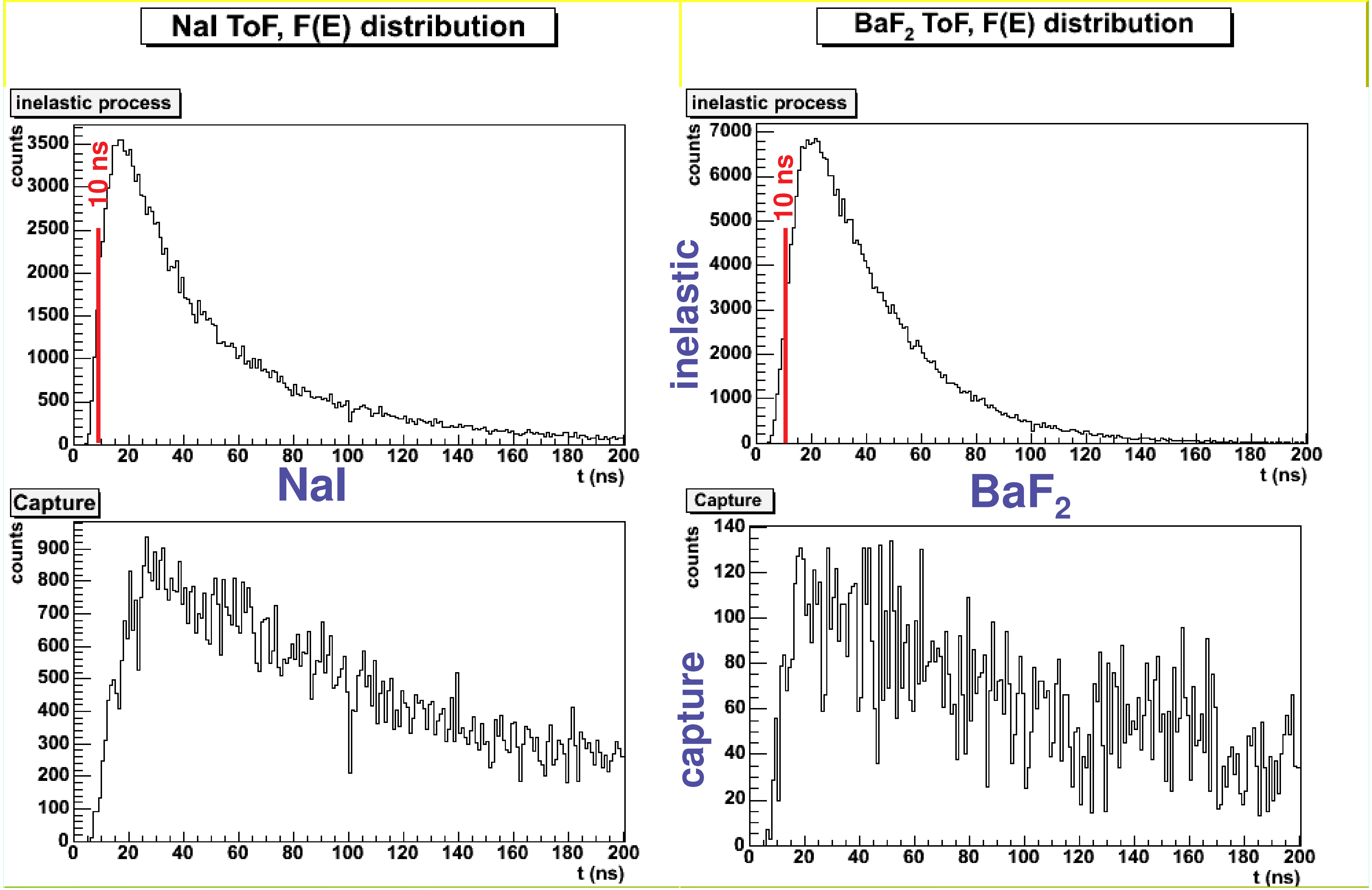


For capture, we have done this work already for GEANT3/GCALOR and D.Cano@CIEMAT for Geant4





Interaction time in TAS by FP delayed neutron energy distribution



Summary-Conclusions:

- We have presented examples of measurements where an adequate estimation of low energy neutron interactions is essential to improve their accuracy
- Although test measurements will be useful, only MC simulations can provide the necessary generality
- Many other fields (therapy, dosimetry, radiation protection,…) will profit from accurate MC simulations of low energy neutrons
- Although several codes exist, still it is missing a general purpose code that simulates response to neutrons
- From the very nature of the low energy neutron data bases it is essential to allow for flexibility in their use
- Although it is not our aim, we can dedicate some effort, mainly in testing-debugging if we find some help