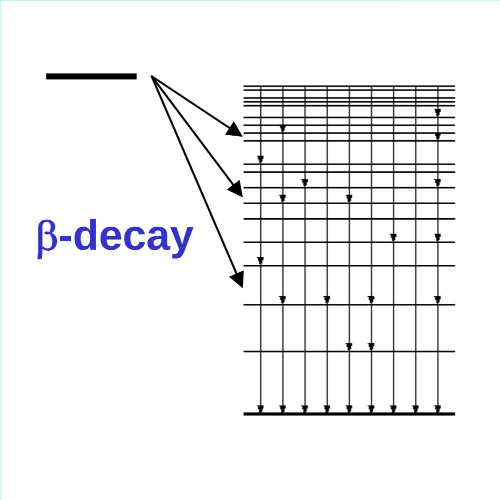
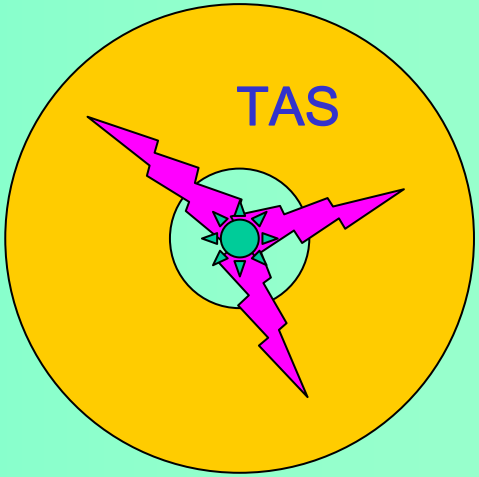
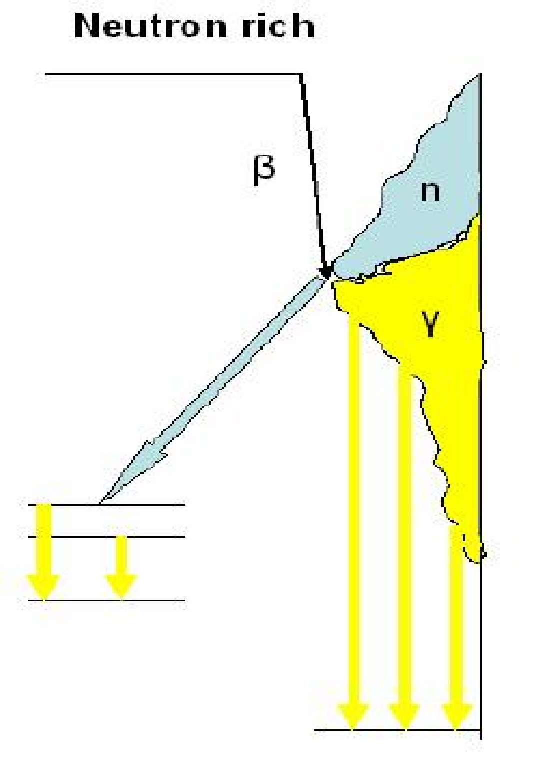
A Total Absorption Spectrometer for DESPEC

- Total Absorption Spectroscopy is the best method to measure beta strengths in β-decay (the only valid one far from stability)
- The highest possible efficiency and energy resolution of the spectrometer are important to minimize systematic errors in the de-convolution process
- The main source of systematic error is contamination/background signals

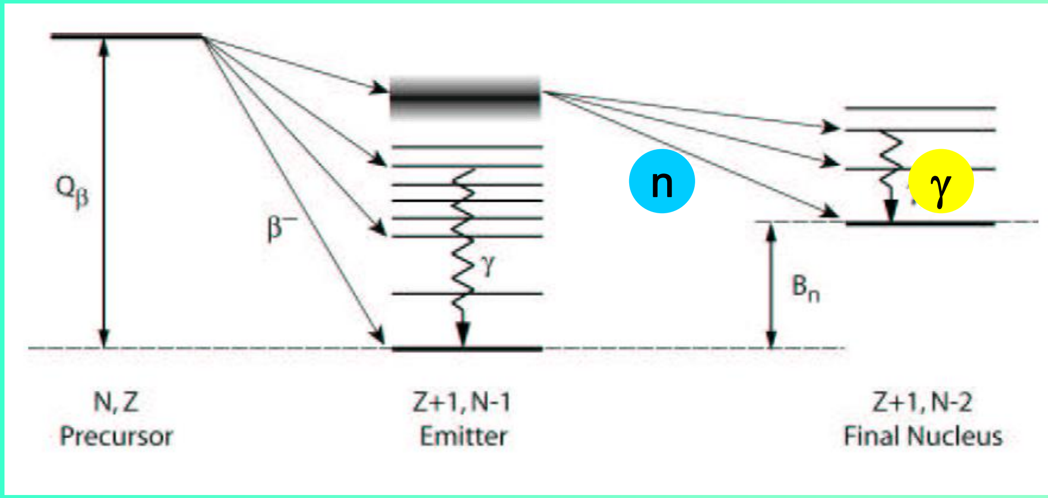




- At DESPEC there is a strong motivation to measure β^- -strength far from stability
- A particular challenge is the application of this technique at the neutron rich side, due to the beta delayed neutrons



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



1. The problem is related to the way the data analysis is performed:

$$d_i = \sum_j R_{ij} \cdot f_j$$

Inverse problem

d : spectrometer data
R : response to decay
f : beta feeding

R from MC simulations

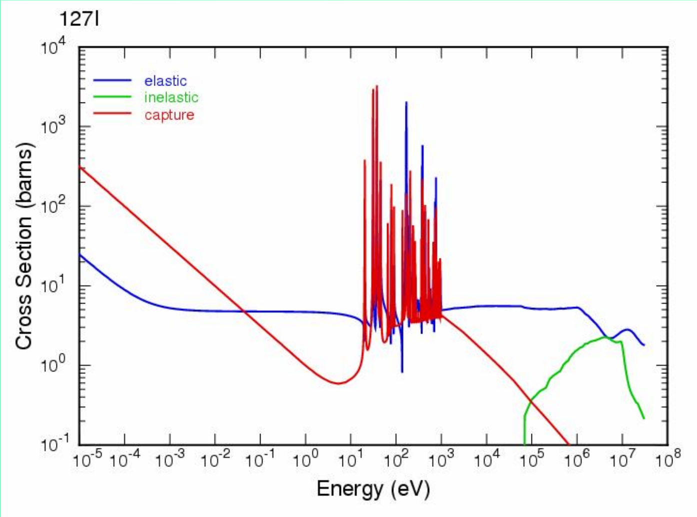
2. Grand-daughter γ-rays are prompt with daughter γ-rays

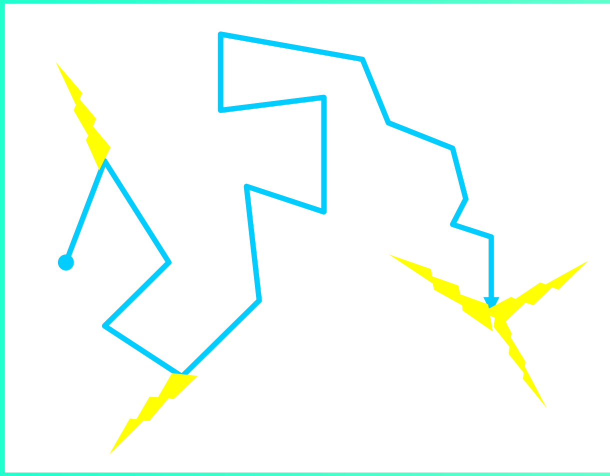
Solution: “subtract” from data

- Measure them with high resolution (Ge array + neutron-detector array)
- Measure them with low resolution (TAS + neutron detector)

3. Neutrons interact through:

- elastic scattering
- inelastic scattering $\rightarrow$ γ-rays
- capture $\rightarrow$ γ-rays





- Recoils have low energies ($E^{max} = (A-1)^2/(A+1)^2$) and their light is quenched (~3-5)
- Long interaction times (μs) $\rightarrow$ delayed signals

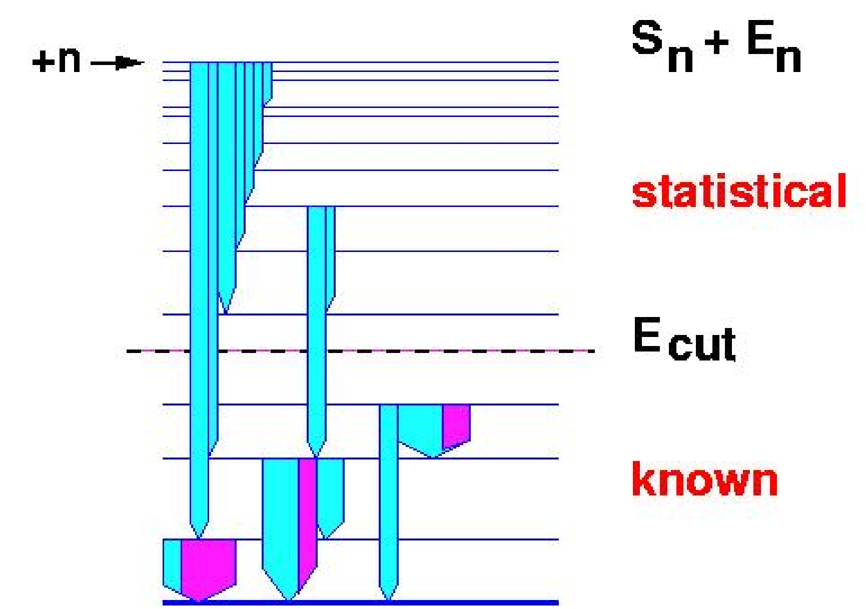
$\rightarrow$ neutrons are probably not the problem

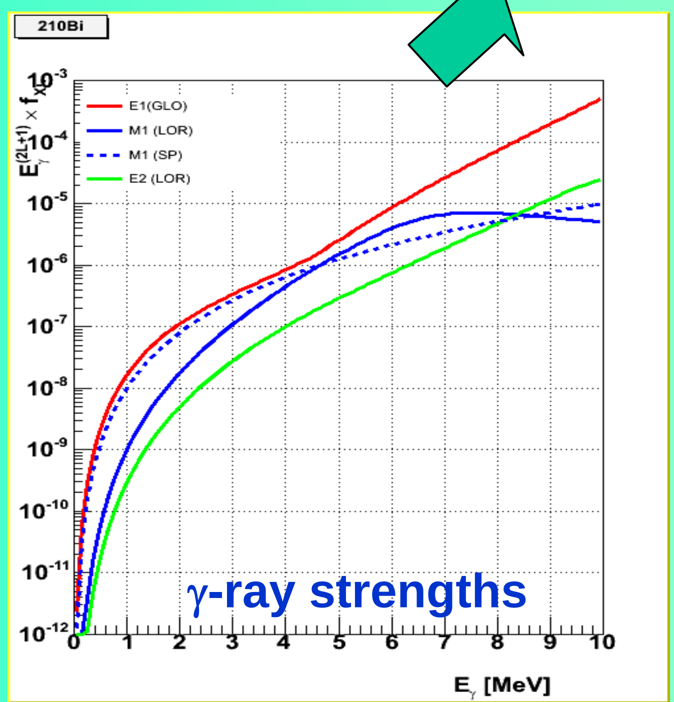
$\rightarrow$ MC simulations

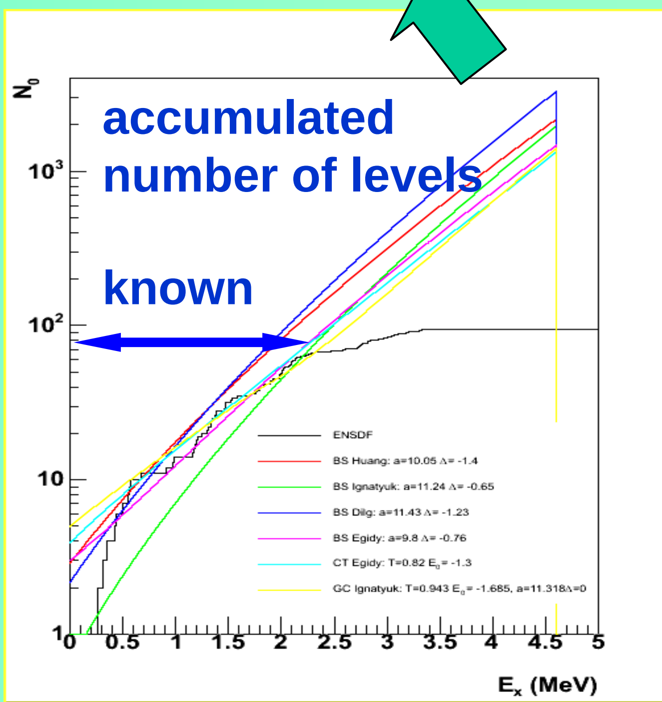
Statistical cascades

Neutron MC simulation codes have a simplified photon generation

→ Replace by cascades generated with the nuclear statistical model

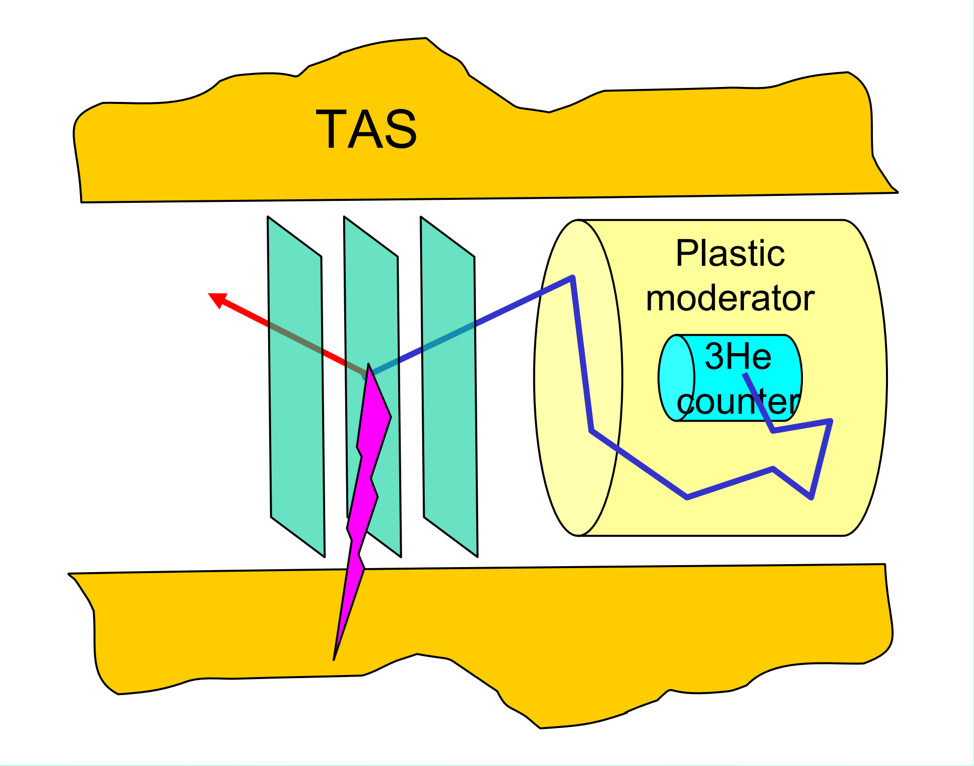






4. A ^{3}He counter placed inside a plastic moderator inside the TAS close to the source

→ MC simulation

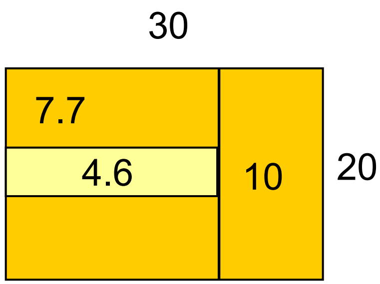


5. The penetration of the β-rays needs some consideration since their MC is less accurate → (plastic) absorber

→ MC simulation

Existing β-decay TAS:

St. Petersburg TAS

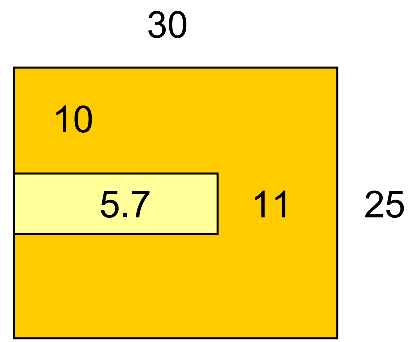


	ε^P	ε^T
1 MeV	**0.47**	**0.87**
5 MeV	**0.25**	**0.71**

cylindrical

NaI(Tl), 2 Crystals

INEL TAS

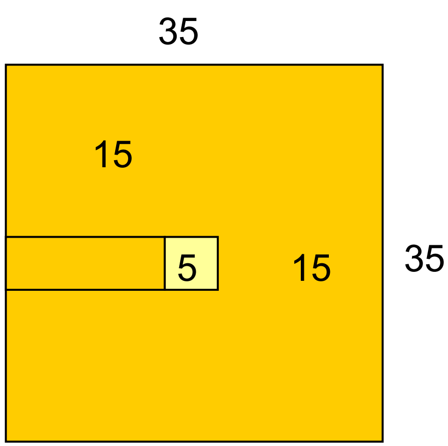


	ε^P	ε^T
1 MeV	**0.65**	**0.90**
5 MeV	**0.45**	**0.76**

cylindrical

NaI(Tl), 1 Crystal

LBL TAS @ GSI

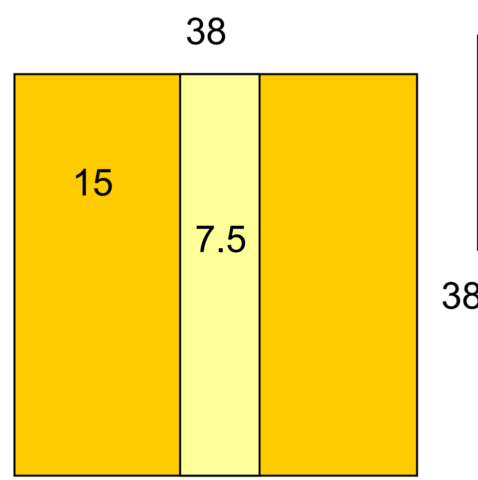


	ε^P	ε^T
1 MeV	**0.65**	**0.97**
5 MeV	**0.52**	**0.89**

cylindrical

NaI(Tl), 1 Crystal + Plug

Lucrecia @ ISOLDE

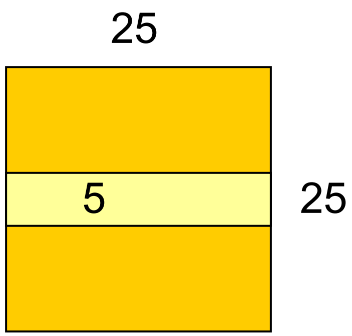


	ε^P	ε^T
1 MeV	**0.62**	**0.89**
5 MeV	**0.44**	**0.79**

cylindrical

NaI(Tl), 1 Crystal

Rocinante @ IFIC



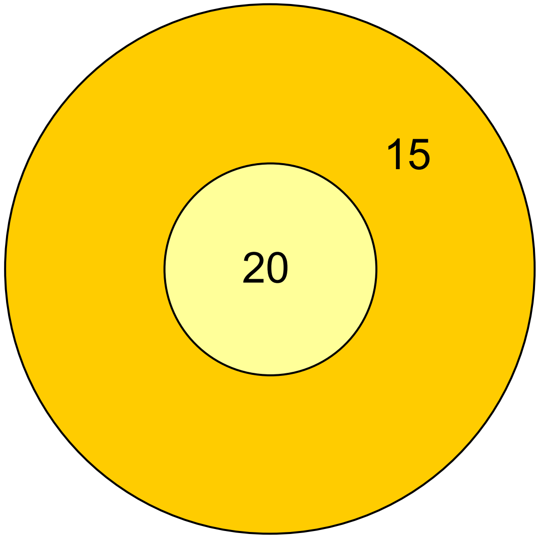
	ε^P	ε^T
1 MeV	**0.70**	**0.89**
5 MeV	**0.43**	**0.79**

cylindrical

BaF_2, 12 Crystals

TACs @ FZK and n_TOF

for (n,γ) !



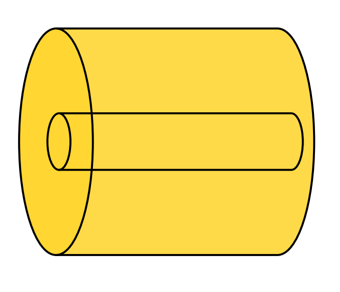
	ε^P	ε^T
1 MeV	**0.90**	**0.98**
5 MeV	**0.80**	**0.91**

spherical

BaF_2, 42 Crystals

6. Spectrometer design:

- Large opening for the ion beam. Eventual beta absorber at the other side. Eventual neutron detector at the other side $\rightarrow$ cylindrical geometry



- NaI $\rightarrow$ good energy resolution
- 15 cm of NaI make a good TAS, 20 cm a very good one (15 cm BaF2 ≈ 20 cm NaI)
- Large opening $\Rightarrow$ loss of solid angle $\rightarrow$ MC find length to maximize ε^T

R_{int}	R_{ext}	L	ε^P 1MeV	ε^T 1MeV	ε^P 5MeV	ε^T 5MeV	ε^T 1 + 5 MeV	
5	20	40	0.82	0.91	0.59	0.85	0.986	**1 Crystal ?**
10	25	60	0.82	0.90	0.59	0.81	0.981	**2× 8 crystals**
5	25	50	0.91	0.96	0.74	0.90	0.996	**2× 6 or 8 crystals**
10	30	70	o.90	0.94	0.73	0.89	0.993	**2× 8 crystals**

$\rightarrow$ Effect of dead material and ancillary detectors $\rightarrow$ MC simulations

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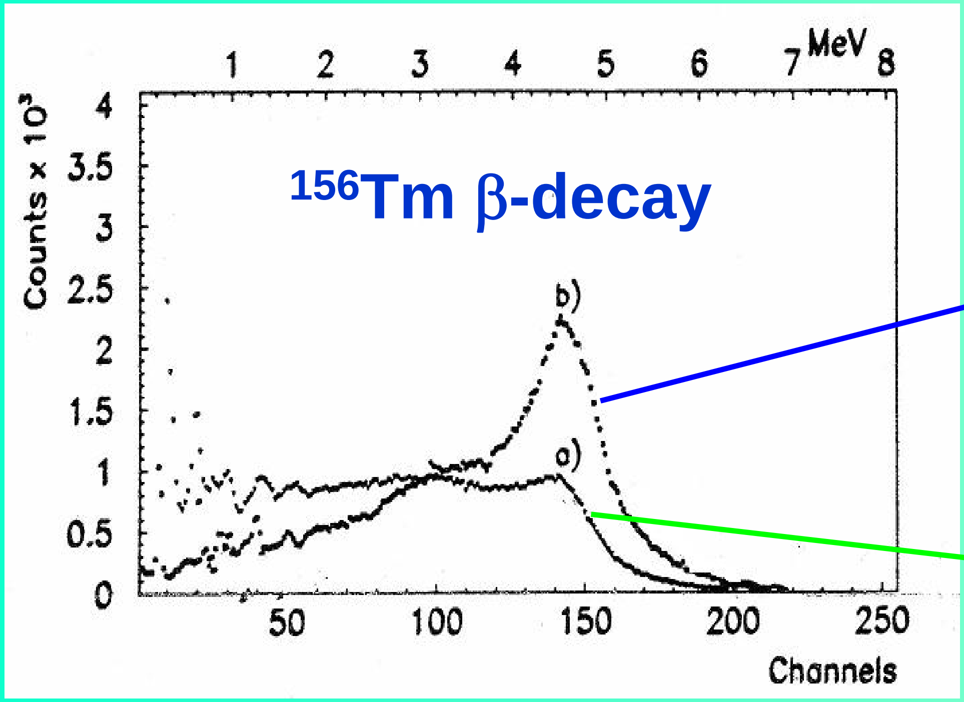
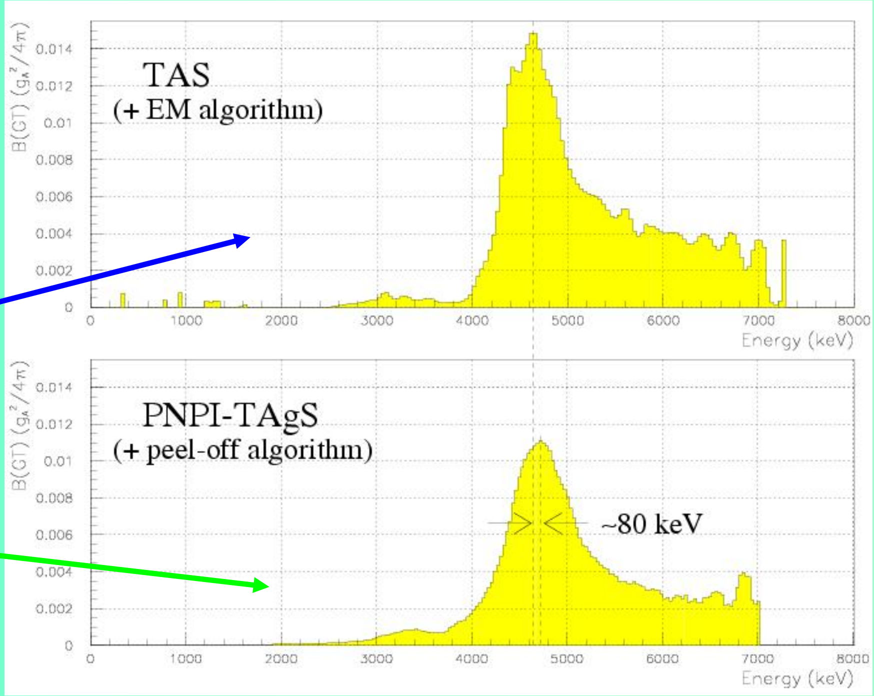
St. Petersburg TAS vs. LBL TAS @GSI





BaF_2	$\sigma^{th}_{(n,\gamma)}$ (b)	E_C (MeV)	E_{1stEx} (MeV)
^{19}F	0.0096	6.6	0.11
^{nat}Ba	1.15	4.7-9.1	0.2

NaI	$\sigma^{th}_{(n,\gamma)}$ (b)	E_C (MeV)	E_{1stEx} (MeV)
^{23}Na	0.53	6.9	0.44
^{127}I	6.2	6.8	0.06

$LaBr_3$	$\sigma^{th}_{(n,\gamma)}$ (b)	E_C (MeV)	E_{1stEx} (MeV)
$^{79,81}Br$	6.9	7.9,7.6	0.2
^{139}La	9.0	5.2	0.17