



A study of scintillating crystals and bolometers at 20 mK

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**Scintillation is detected on all
materials tested !**

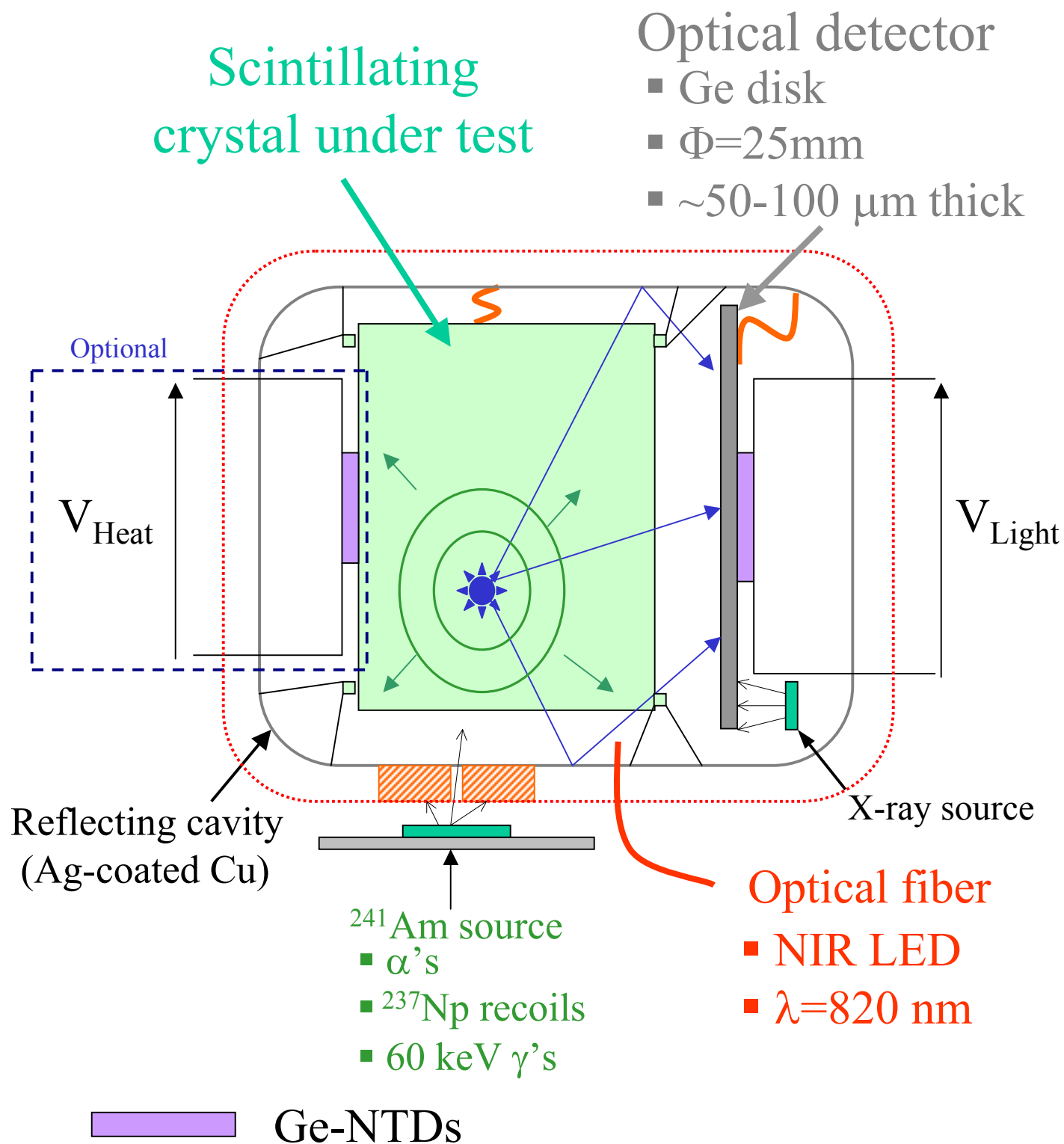
Crystals (~1cc)

- YAP:Ce
- GSO:Ce
- CaF₂:Eu
- Al₂O₃:Ti

Bolometers

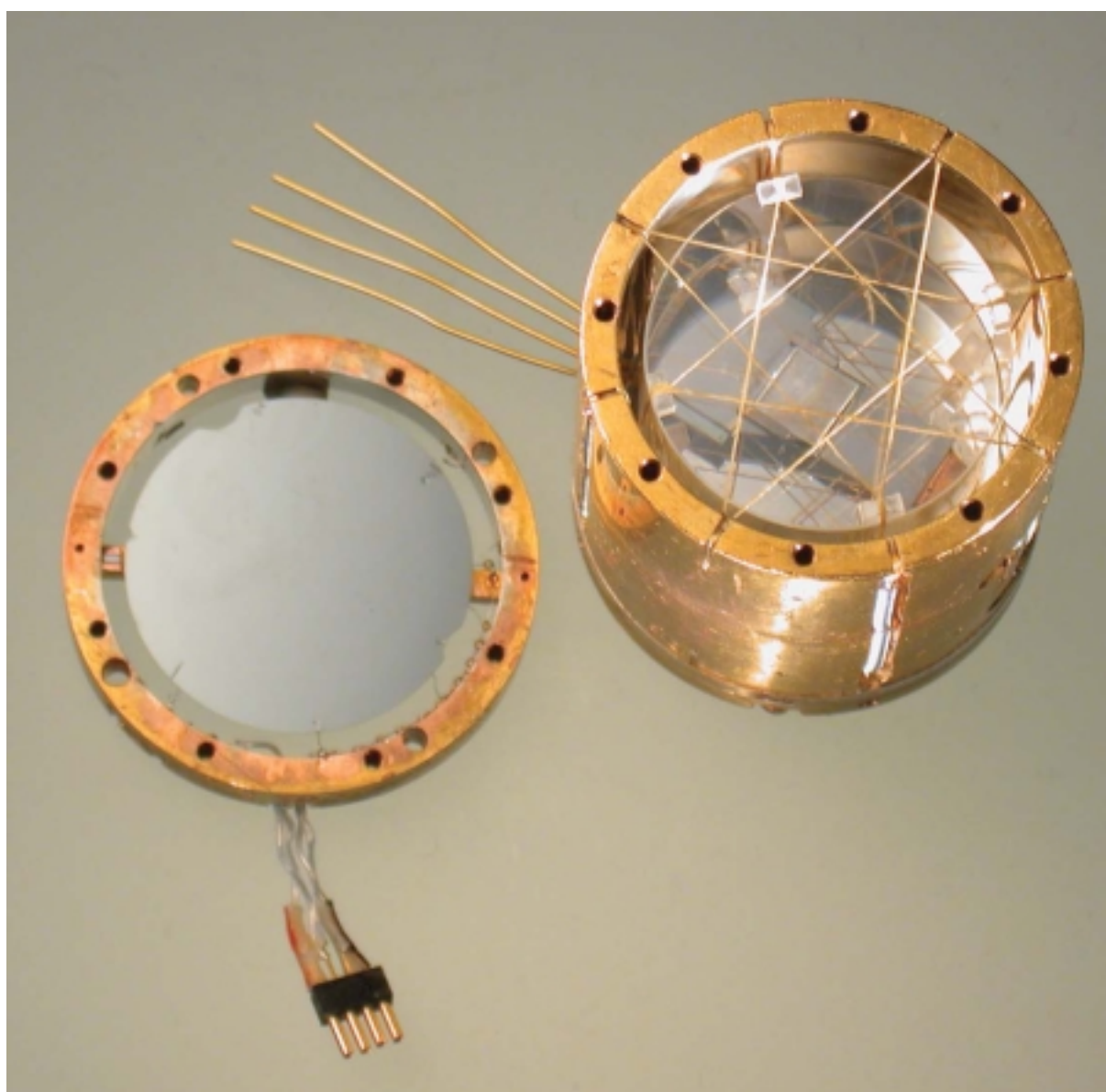
- CaWO₄ (ROSEBUD)
- BGO
- LiF
- TeO₂
- Al₂O₃

Light and Heat bolometers





A 91g BGO bolometer with its Germanium-Light detector ($\varnothing=25\text{mm}$)



New 20 mK scintillation data:



	Crystals				Bolometers				
	CaF ₂	YAP YAlO ₃	GSO Gd ₂ SiO ₅	Al ₂ O ₃	CaWO ₄	BGO Bi ₄ Ge ₃ O ₁₂	LiF	TeO ₂	Al ₂ O ₃
Doping agent	Eu	Ce	Ce	Ti					
Mass	20g	6g	7g	4g	54g	46g	16g	25g	50g
Light yield keV/MeV γ	~14		3	13	6	7.5	0.38	0.05	12.7
Light yield keV/MeV α	2.6	1.3	0.43	1.7	1.5	1.3	0.11	0.002	1.13
Qf γ/α	~5.4		7	7.6	4	5.8	3.5	25	11.2
Qf γ/recoil					10	12-15	6.5		21.5

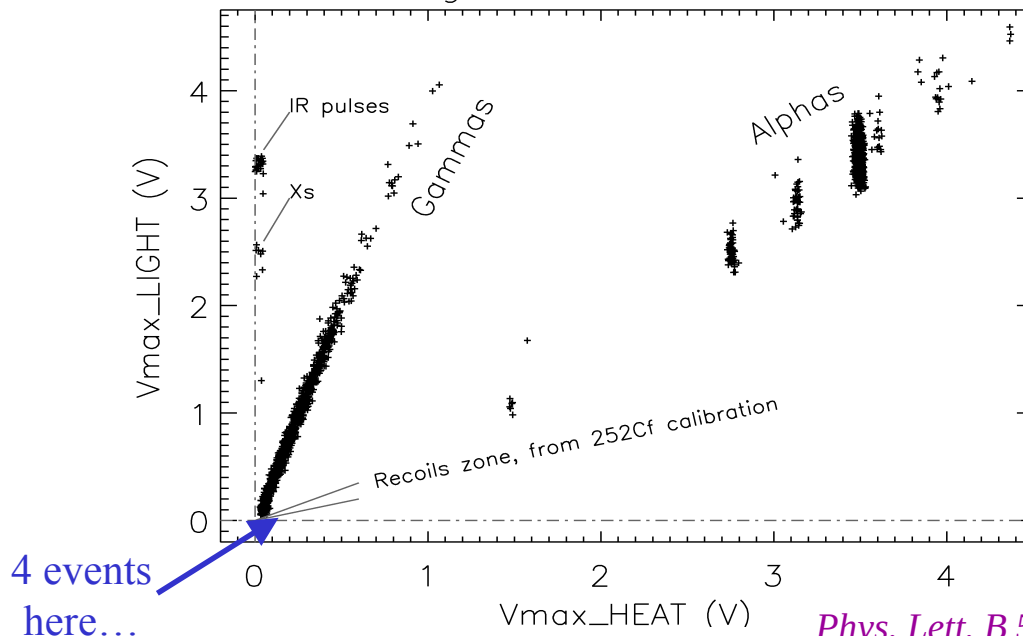
Origin	Aries	SGCD	Hitachi	Rubicon	Pi-Kem	SGCD	Aries	Crystal Technology	Sorem
Year of purchase	1993	2000	2002	2001	2000	1997		1989	1995
Cost k€/kg	8.5	33	40	56	33	2		10	2.5
α decay			¹⁵² Gd 0.2%		¹⁸⁰ W 0.1%	²⁰⁹ Bi			
$\beta\beta$ decay	⁴⁸ Ca 0.2%		¹⁶⁰ Gd 22%		⁴⁸ Ca 0.2%	⁷⁶ Ge 7%		¹³⁰ Te 34%	
Neutrons			¹⁵⁵ Gd ¹⁵⁷ Gd				⁶ Li		
Radioactivity					U, Th	²⁰⁷ Bi, U, Th		See Cuore	
Spin and interest for dark matter detection	¹⁹ F 1/2 highest rate	⁸⁹ Y 1/2	¹⁵⁵ Gd 15% ¹⁵⁷ Gd 16% 3/2	²⁷ Al 5/2 low threshold	¹⁸³ W 14% 1/2	²⁰⁹ Bi 9/2 highest A		¹²⁵ Te 7% 1/2	²⁷ Al; 5/2 low threshold
Comments		short run !				Low ²⁰⁷ Bi quality exists !		Crystal broke at end !	Kyropoulos grown

54g CaWO_4 bolometer at Canfranc [ROSEBUD]; 24h



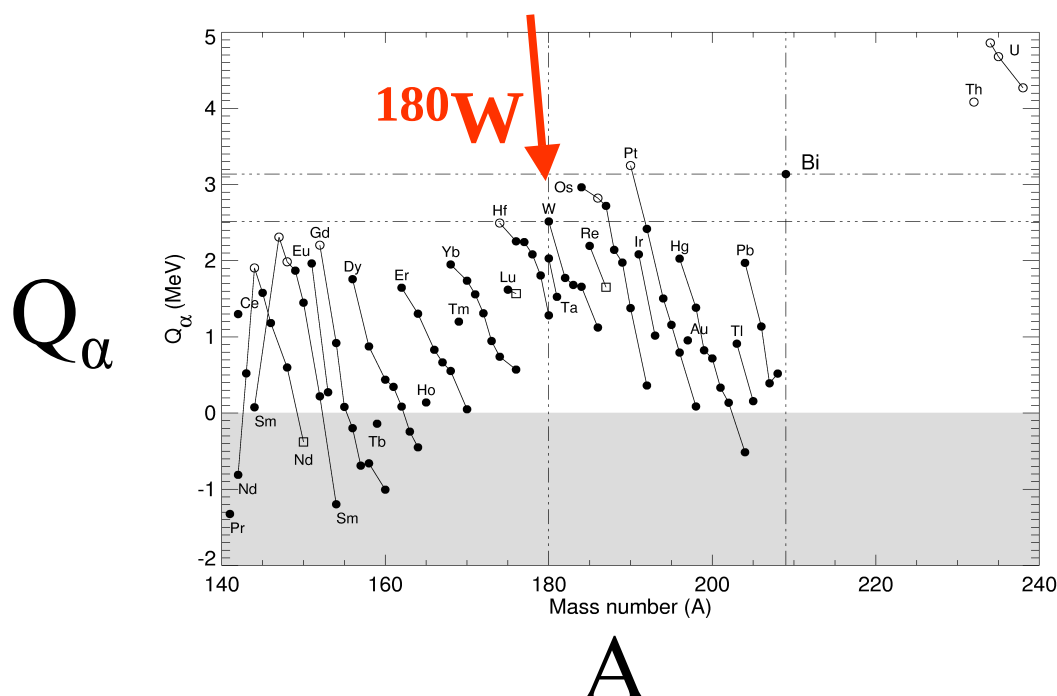
U daughters & ^{147}Sm contaminations used...

54 g CaWO_4 @ Canfranc

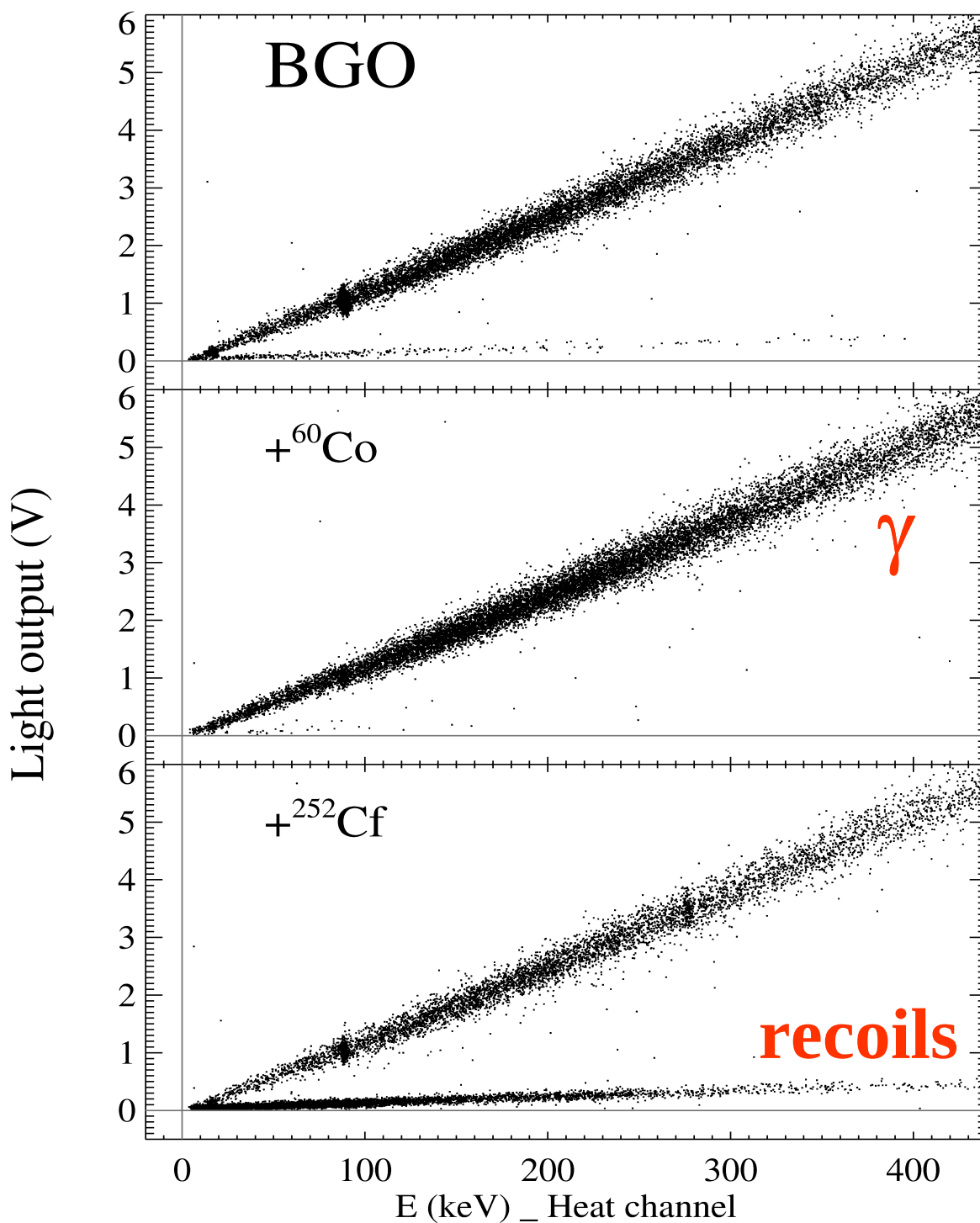


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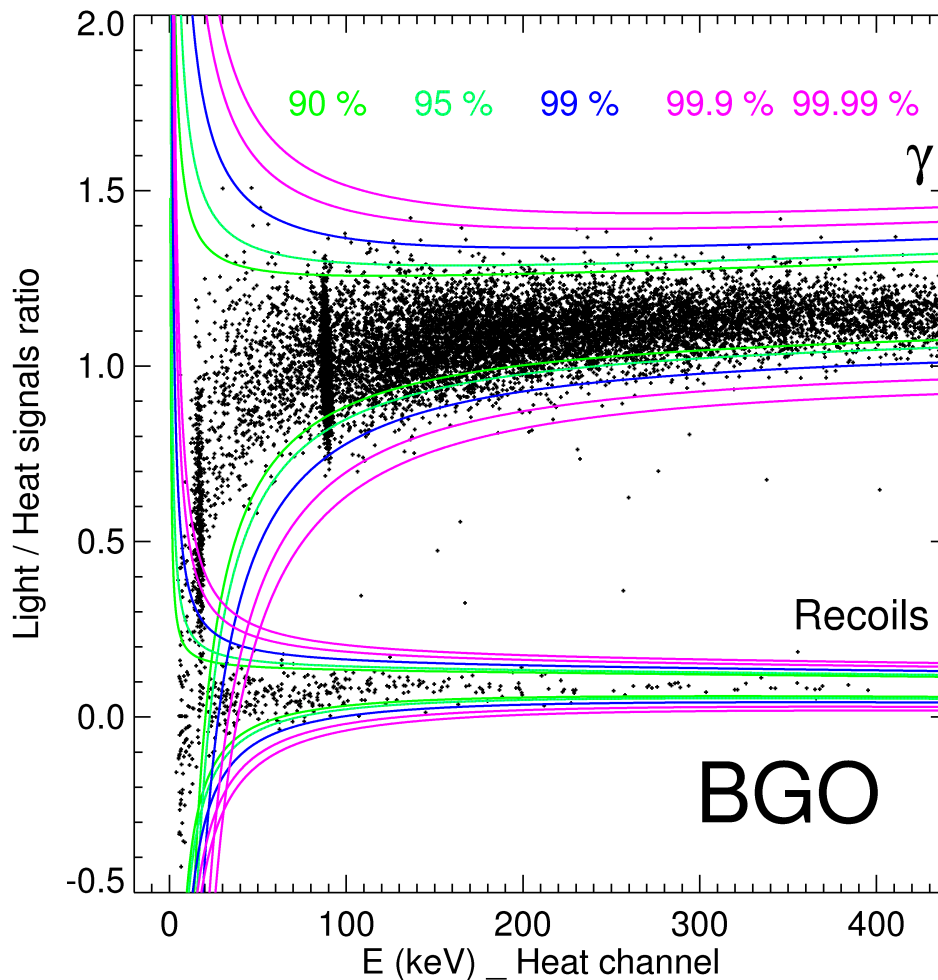
...to improve ^{180}W α decay limits $T_{1/2} (>2.7 \cdot 10^{17} \text{ y})$



Runs on 46g BGO bolometer at IAS

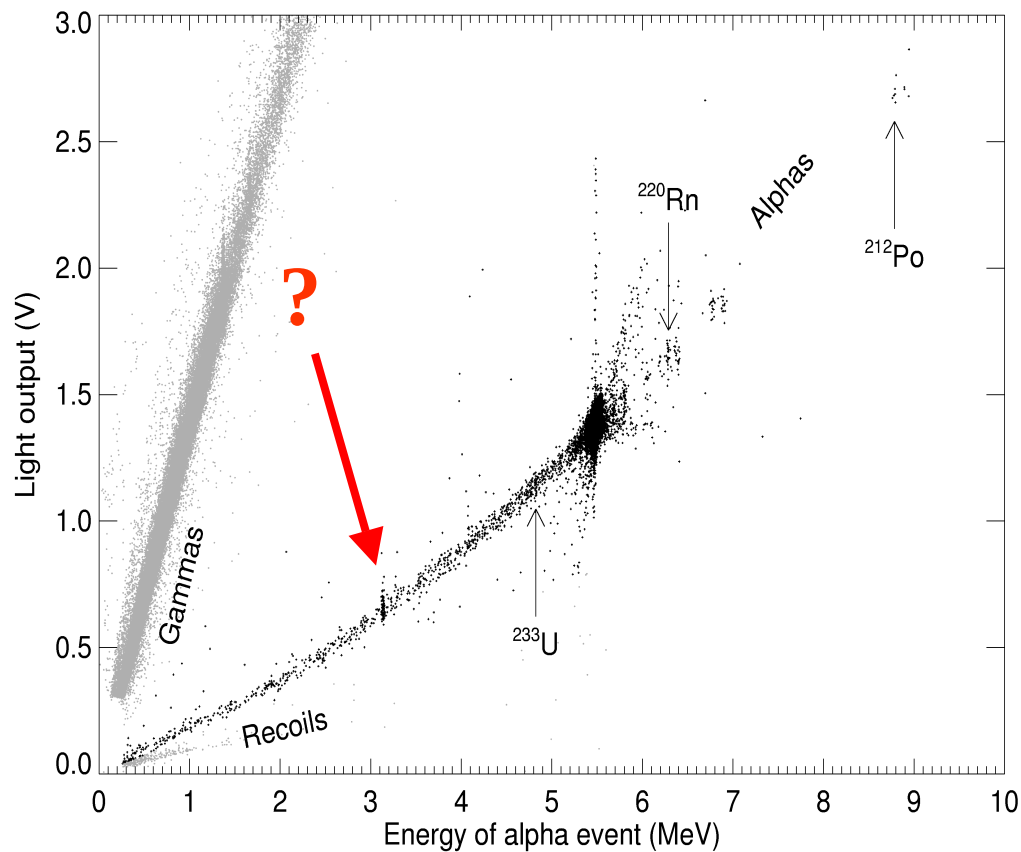


Discrimination factor on a 46g BGO bolometer



- Particle identification with
 - 90% CL at $E > 23$ keV
 - 99.99% CL at $E > 51$ keV
- BGO is qualified for dark matter experiments
 - ROSEBUD (with low ^{207}Bi quality)
- ^{209}Bi : highest A and σ_{SI} factor + 100% spin ($J=9/2$)

BGO tells more on ^{209}Bi ...

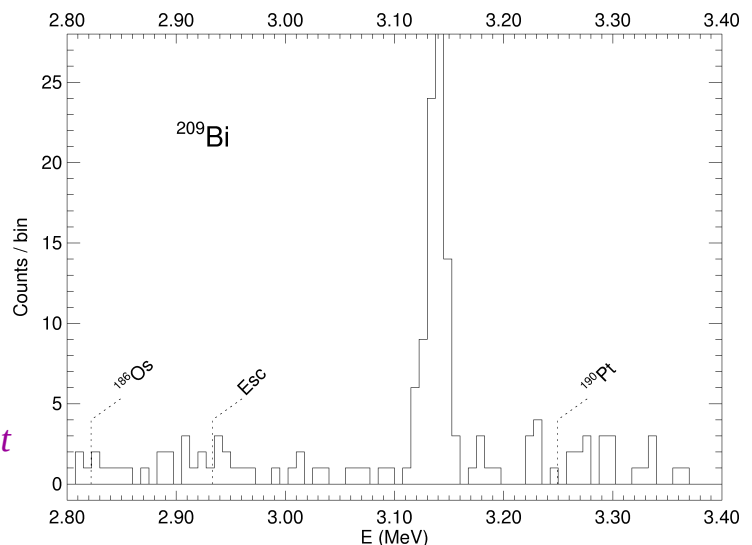


First detection of the natural radioactivity of bismuth

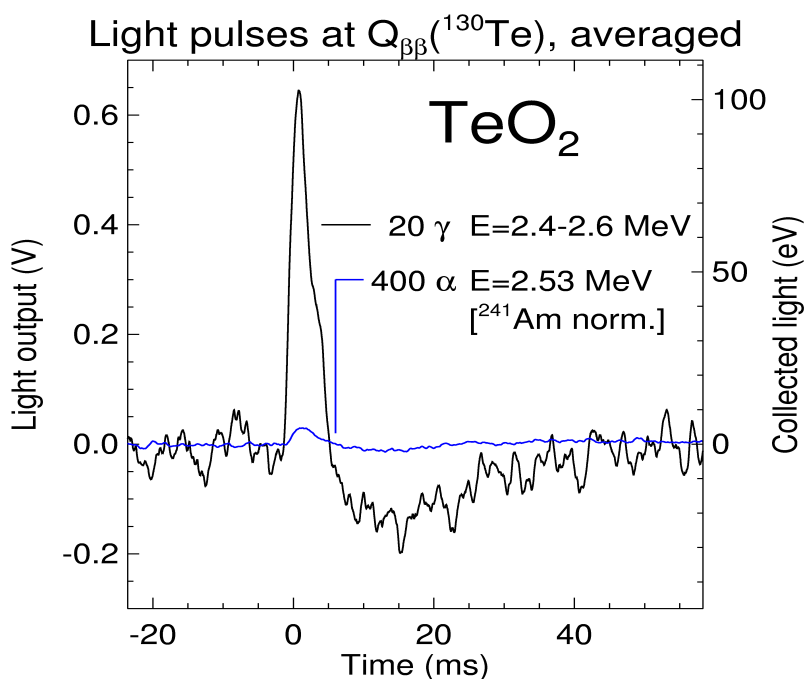
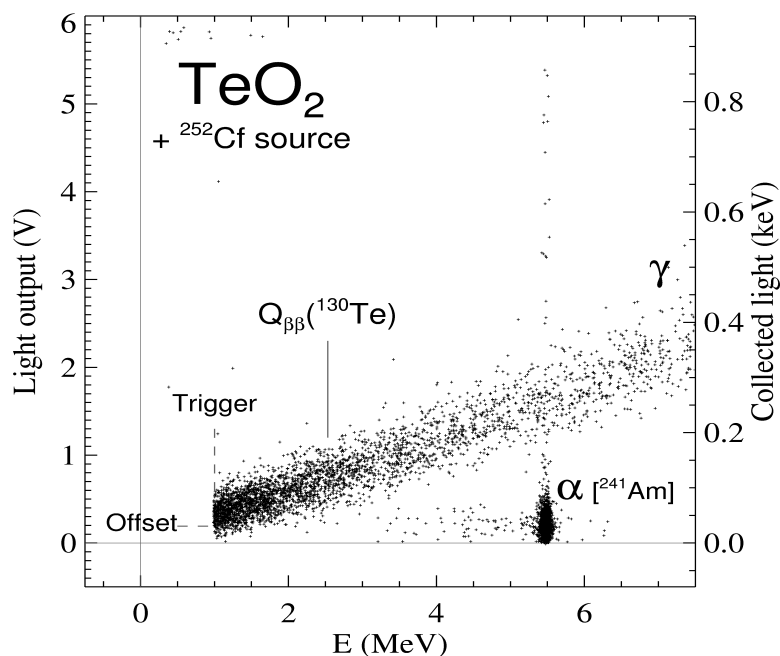
- $Q_\alpha = 3137 \text{ keV}$
- $T_{1/2} \sim 2 \cdot 10^{19} \text{ years}$!

*Nature 422 (2003)876-878
for a full description of this experiment*

^{209}Bi α decay line

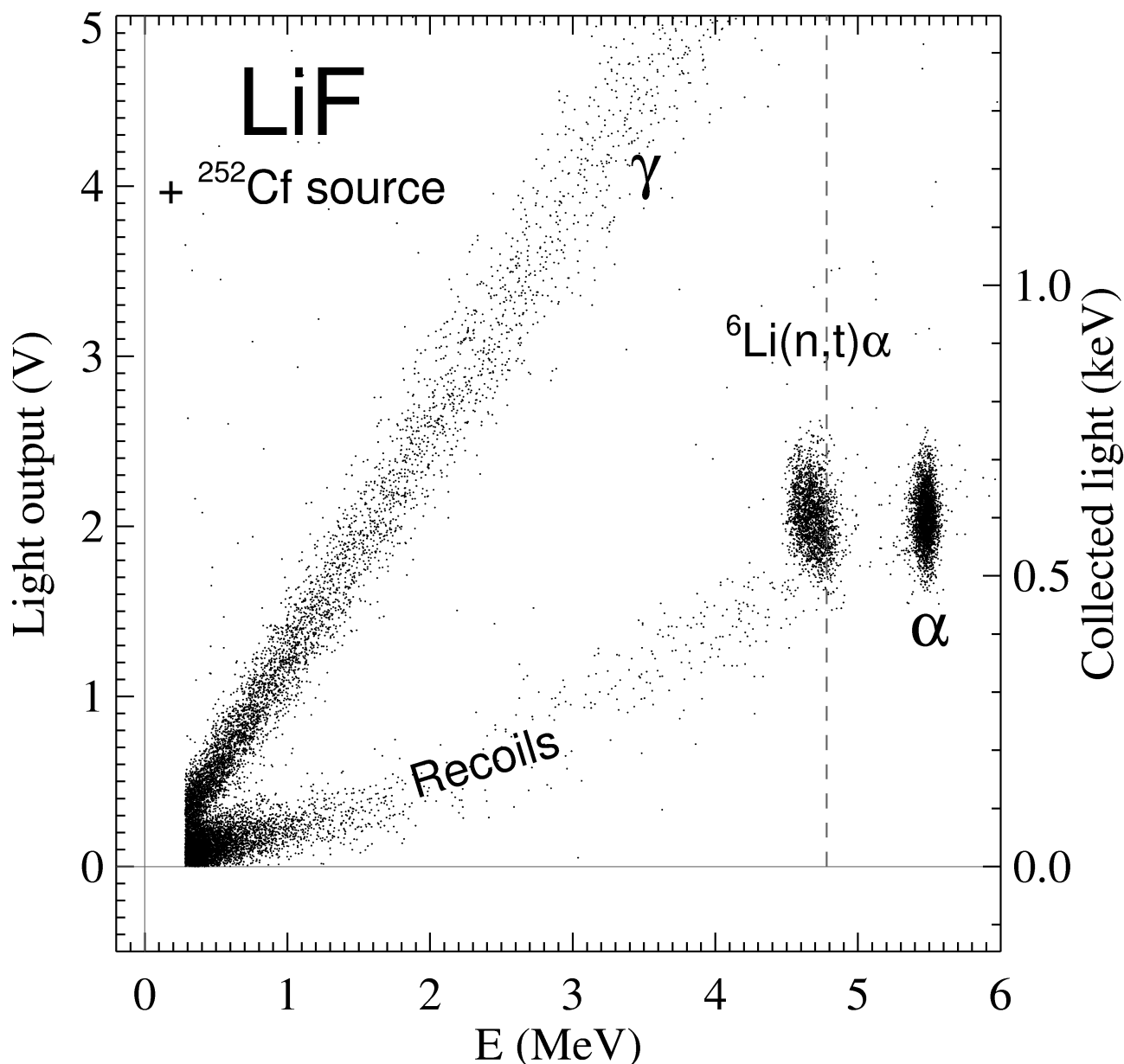


a 25g TeO_2 bolometer



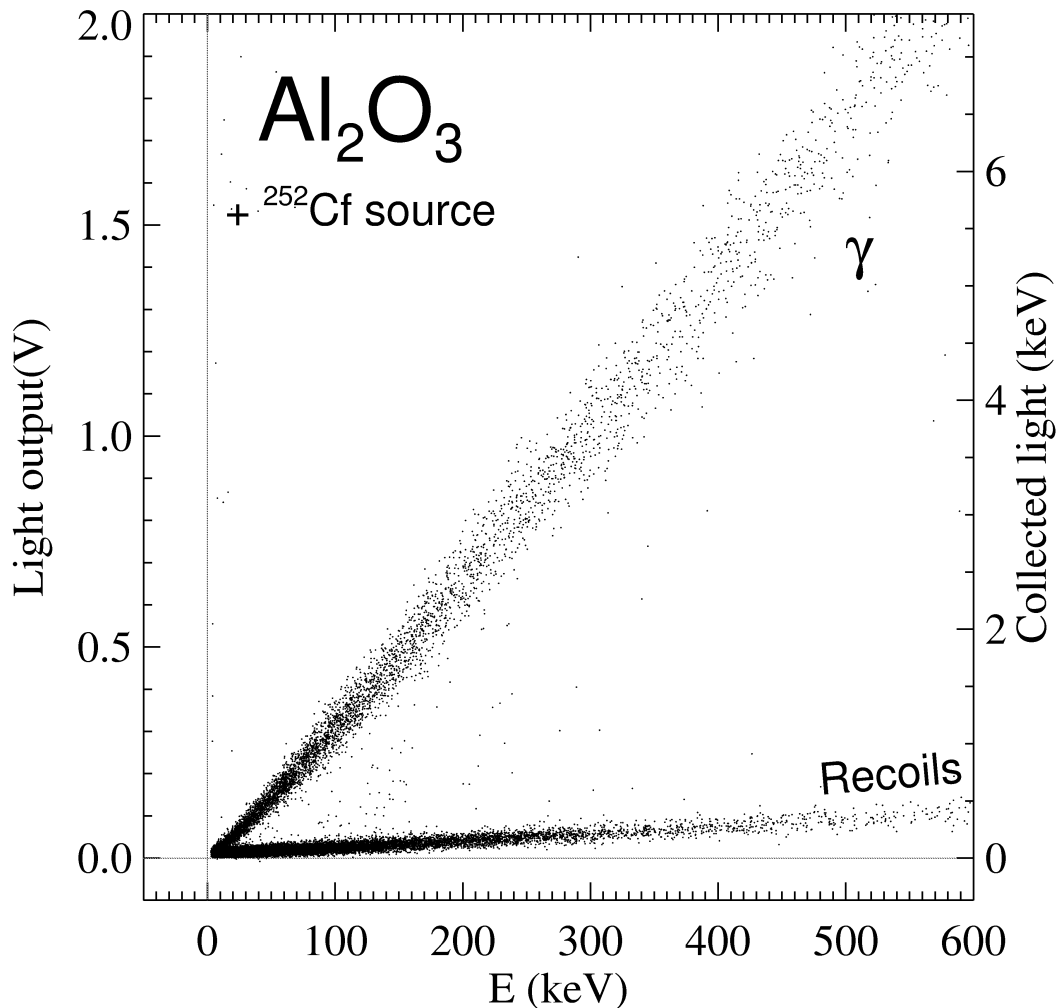
Scintillation (weak) separates alphas and gammas at $E \approx Q_{\beta\beta}(^{130}\text{Te})$ level !

a 16g LiF bolometer



- Separation of α / (${}^6\text{Li}+\text{n}$) events
→ detection of very rare neutrons
- Separation of γ / nuclear recoils

a 50g pure sapphire bolometer

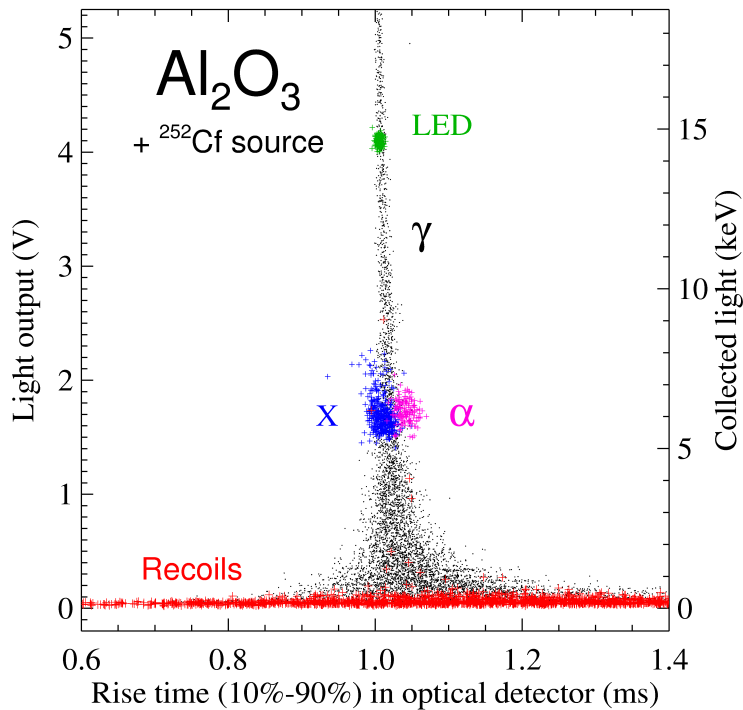


- A **strong light emission** is detected ($\sim$ BGO) !
- a **very good γ /recoils separation** is achieved
→ **very good news** for ROSEBUD & CRESST !
- possible interpretation: Cr³⁺ R1-line of ruby excited, even at the trace (ppm) level...[*A. Bettioli et al., NIM B 130 (1997) 734-739*]

Time constants

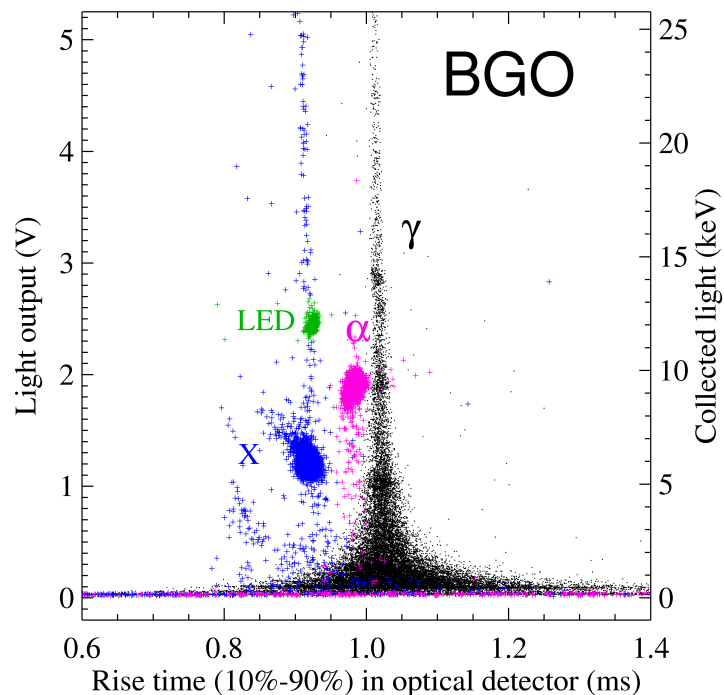


~ 2 classes found (/gamma scintillation)
analysis → future insights in the mechanisms ?



« prompt »

- Sapphire
- CaF_2



« delayed »

- BGO
- YAP
- GSO
- CaWO_4
- LiF



Conclusions

- **Scintillating bolometers:** a bright and rewarding tool to help the rarest events search: combine high resolution of bolometers with a high discrimination power on particles

+ a broad palette of targets.

- dark matter: Al_2O_3 (!), CaF_2 , ...
- alpha decays: ^{209}Bi , ^{180}W , ...
- neutron physics: LiF , GSO , ...
- double beta decay: TeO_2 , ...

[+ Anticorrelations Light / Heat are noted in the data: we will learn where the energy goes, and correct for energy losses in « hidden » branches → **higher resolutions to be expected in transparent crystals**]