Development of new inorganic thermal-neutron scintillators

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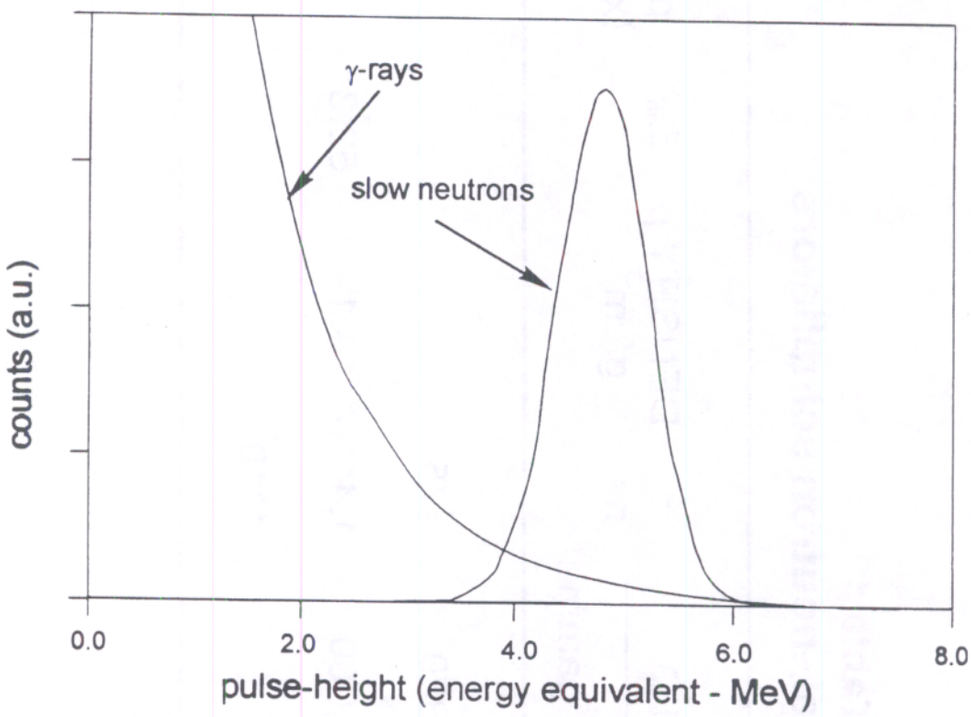


Typical pulse-height spectrum recorded with a ^{6}Li-glass scintillator-photomultiplier system

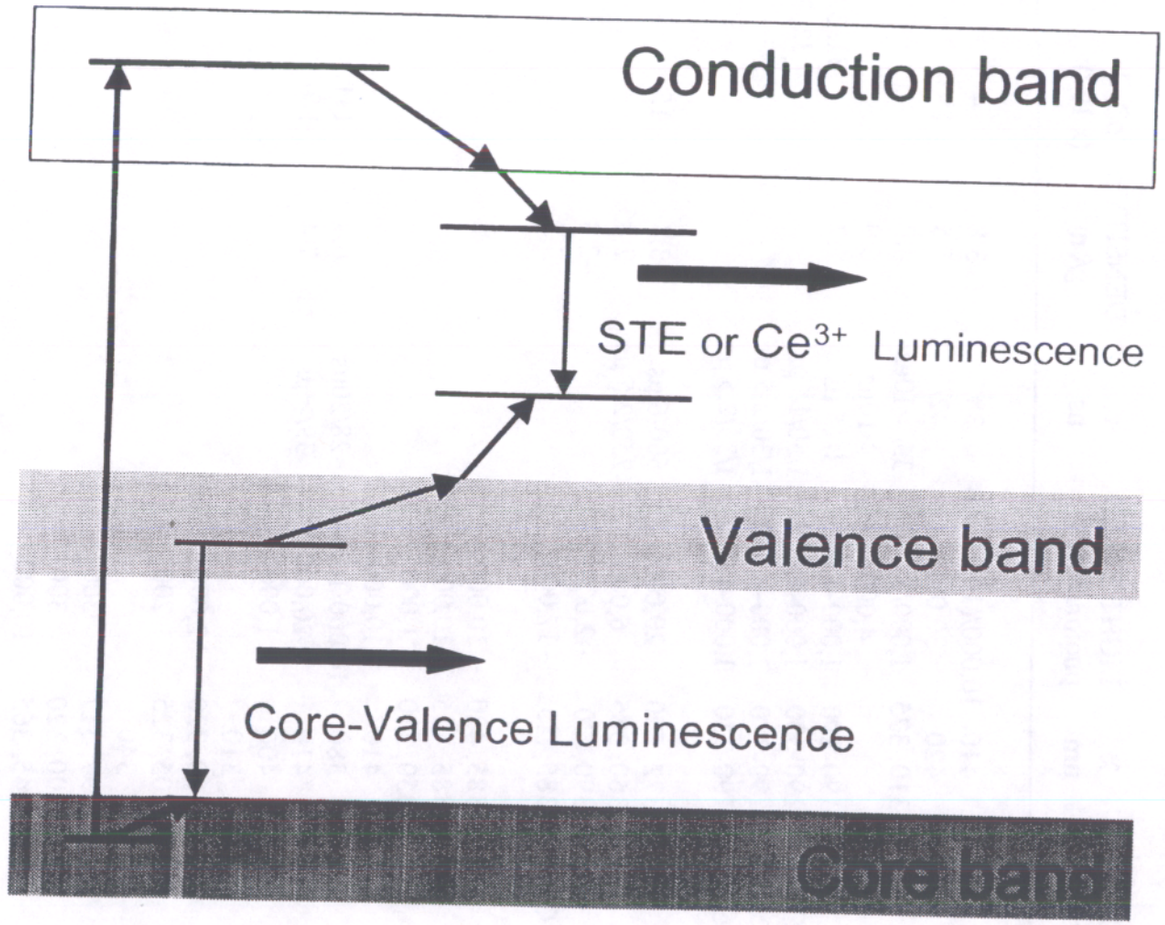
Table 1
Traditional thermal–neutron scintillators

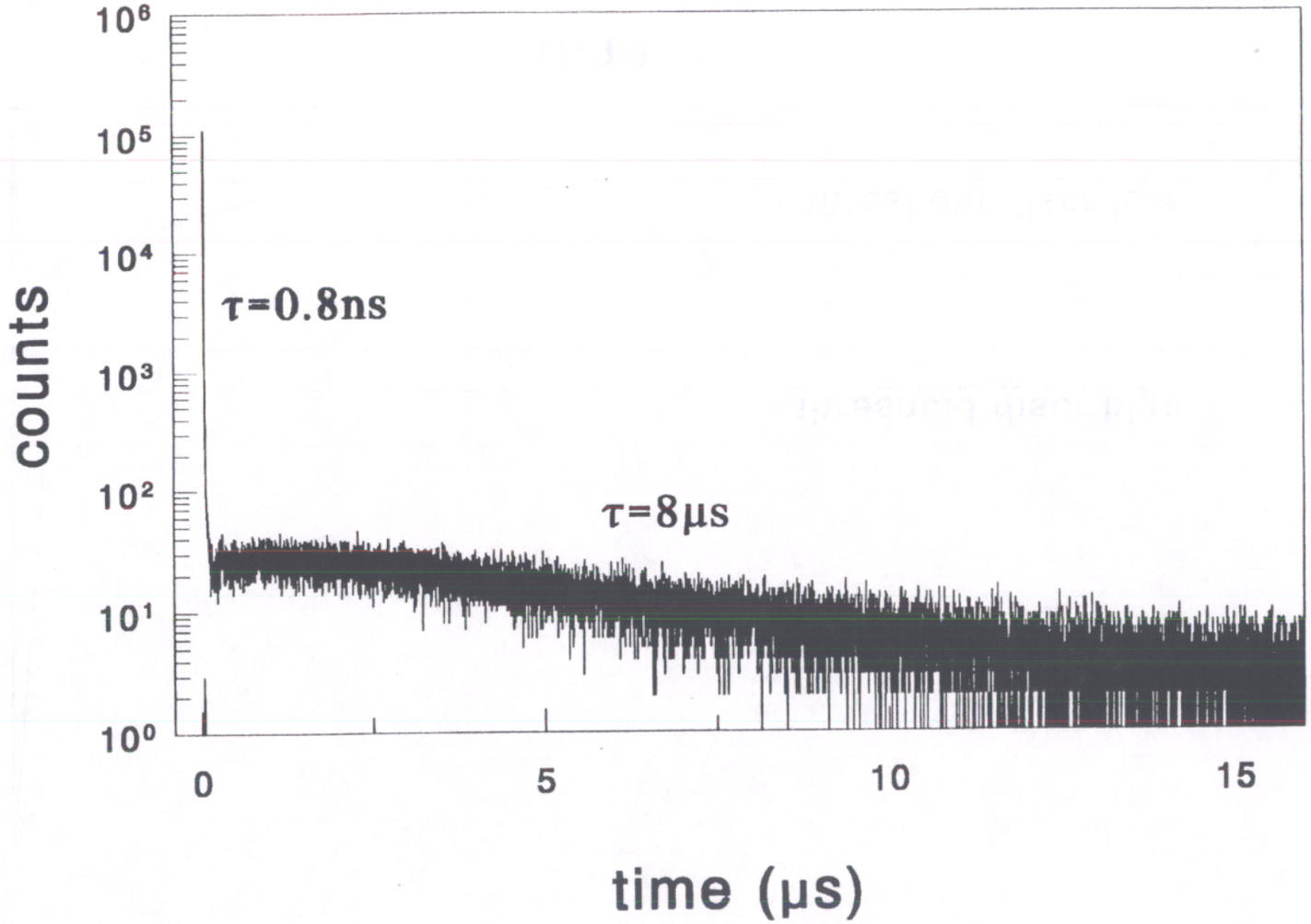
SCINTILL.	λ_{em} nm	LIGHT YIELD		τ ns	DENSITY ρ g/cm^3	Z_{eff}	ρZ_{eff}^4 ($\times 10^{-6}$)
		phot/neut	/MeV gamma				
^{6}Li-glass:Ce	395	~6,000	~4,000	75			
^{6}LiI:Eu	470	50,000	12,000	$1.4*10^3$	4.1	52.3	31
^{6}LiF/ZnS:Ag	450	160,000		$1*10^3$			

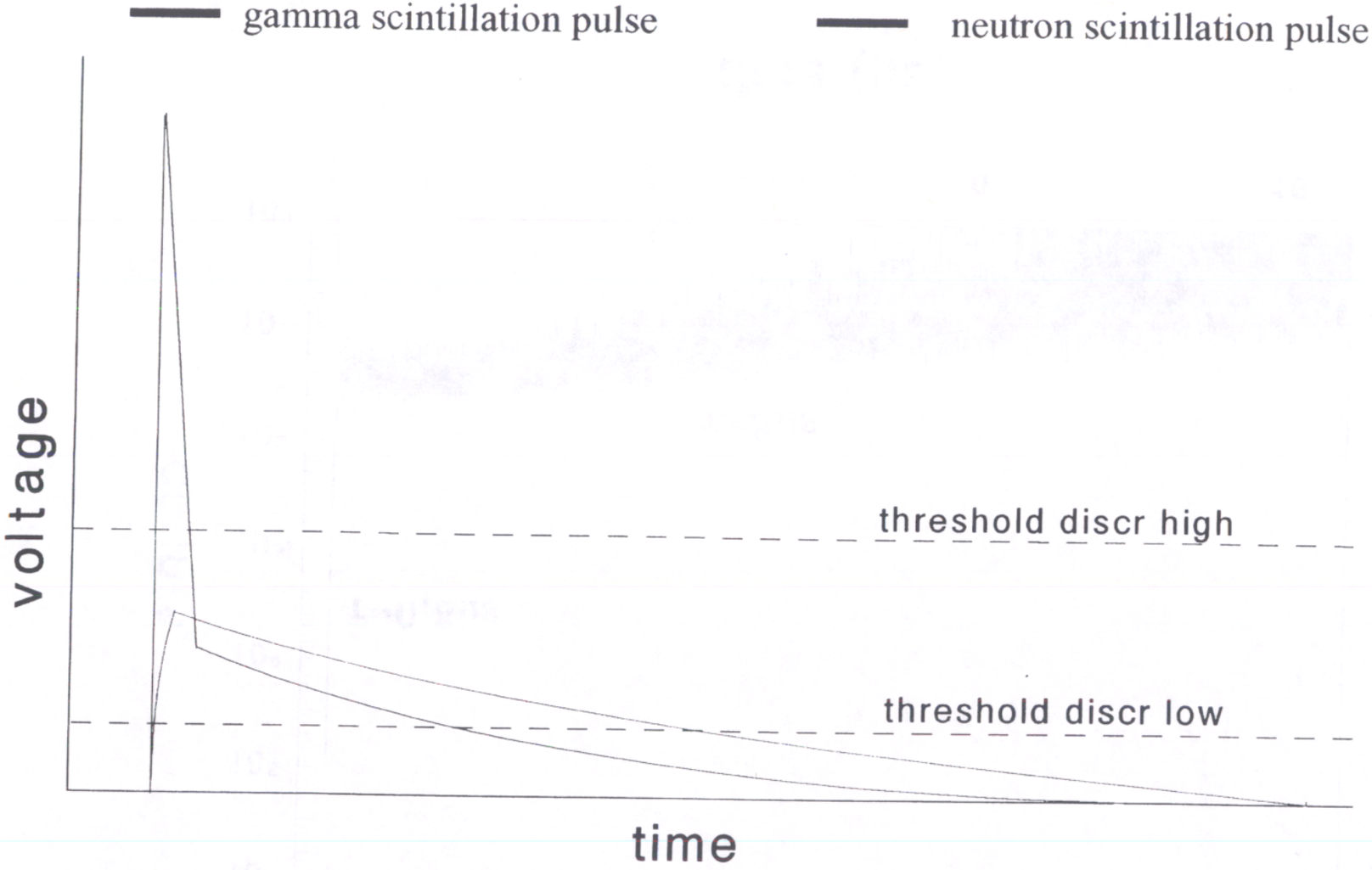
Table 2
Some Gd, B and Li containing Ce doped scintillators

HOST	DOPANT/ Ce conc-mol%	λ nm	LIGHT YIELD photons/MeV	τ ns	DENSITY ρ g/cm^3	ρZ_{eff}^4 (x 10^{-6})	REF.
$LiYSiO_4$	5	410	10,000/(10,000/n)	38	3.8	4	11
$LiLuSiO_4$	~1	420	30,000	42/ ...	5.5	89	12
$LiYF_4$	0.1	310, 325	1,000/5,000	35/ >10μs	4.0		
$LiLuF_4$	0.1		4,000	>10μs	6.0		
$LiBaF_3$	-	190-290	1,000-4,000	1/15 μs	5.2		31, 32, 33, 34, 35, 36
$LiBaF_3$	Ce/0.08	190-330	1,000-4,000	1/50/15 μs			32, 33, 34, 35, 36
$LiBaF_3$	Ce/0.3;K	190-330	1,000-4,000	1/30/2.5 μs			33, 34
$LiBaF_3$	Ce/0.3;Rb	190-330	1,000-4,000	1/35/2.5 μs			33, 34
$Li_{1-x}Cs_xCl$	-						
Cs_2LiYCl_6	0.5	372, 400	20,000	600/6 μs	3.3	15	
Li_3YCl_6	0.2	360, 385	6,000	250/2.5 μs	2.45		
$Li_6Y(BO_3)_3$	Ce	390,420	~2,000		~2.8		24, 30
$Li_6Gd(BO_3)_3$	Ce/1-4	385,415	~17,000		3.5		30
$ScBO_3$	1	385, 420	10,000				23, 24
YBO_3	1	385, 415	10,000				23, 24
$LaBO_3$	1	350, 380	1,000				23, 24
$GdBO_3$	1	410	10,000				23, 24
$LuBO_3$ (calc)	1	380	10,000/10,000	~28/20μs	6.9	131	13, 15
$LuBO_3$(vate)	0.1	410	~20,000	39/> μs	7.4	140	13,15
$CaYBO_4$	1	400	1,000				24,25
LiB_3O_5	-	310					26, 27
LaB_3O_6	1	300, 320	2,000				28
GdB_3O_6	1	305, 325	200				24
$Li_2B_4O_7$	-	340					29
$YMgB_5O_{10}$	1	297, 317	300				28
$LaMgB_5O_{10}$	1	300, 320	300				28
$YAl_3B_4O_{12}$	1	345, 365	10,000				23, 24
$CaLaB_7O_{13}$	1	290-360	200				24
Gd_2O_2S	Tb			ms	7.3	101	
Gd_2O_2S	Pr,Ce,F						
Gd_2SiO_5	Ce	440	800/n	60/600	6.7	81	
$RbGd_2Cl_7$	1	400	16,500/18,000/ 10,000	455/1.3+4.4μs/ long	3.7	31	19
	5	400	24,200/15,000				
$RbGd_2Br_7$	1	420	25,900/6,500	80+0.7μs/long	4.7	31	19,20
	5		43,900/11,000	60/0.6+1.6μs			

$BaLiF_3$


Conduction band
STE or Ce^{3+} Luminescence
Valence band
Core-Valence Luminescence
Core band


counts
10^6
10^5
10^4
10^3
10^2
10^1
10^0
τ=0.8ns
τ=8μs
0
5
10
15
time (μs)



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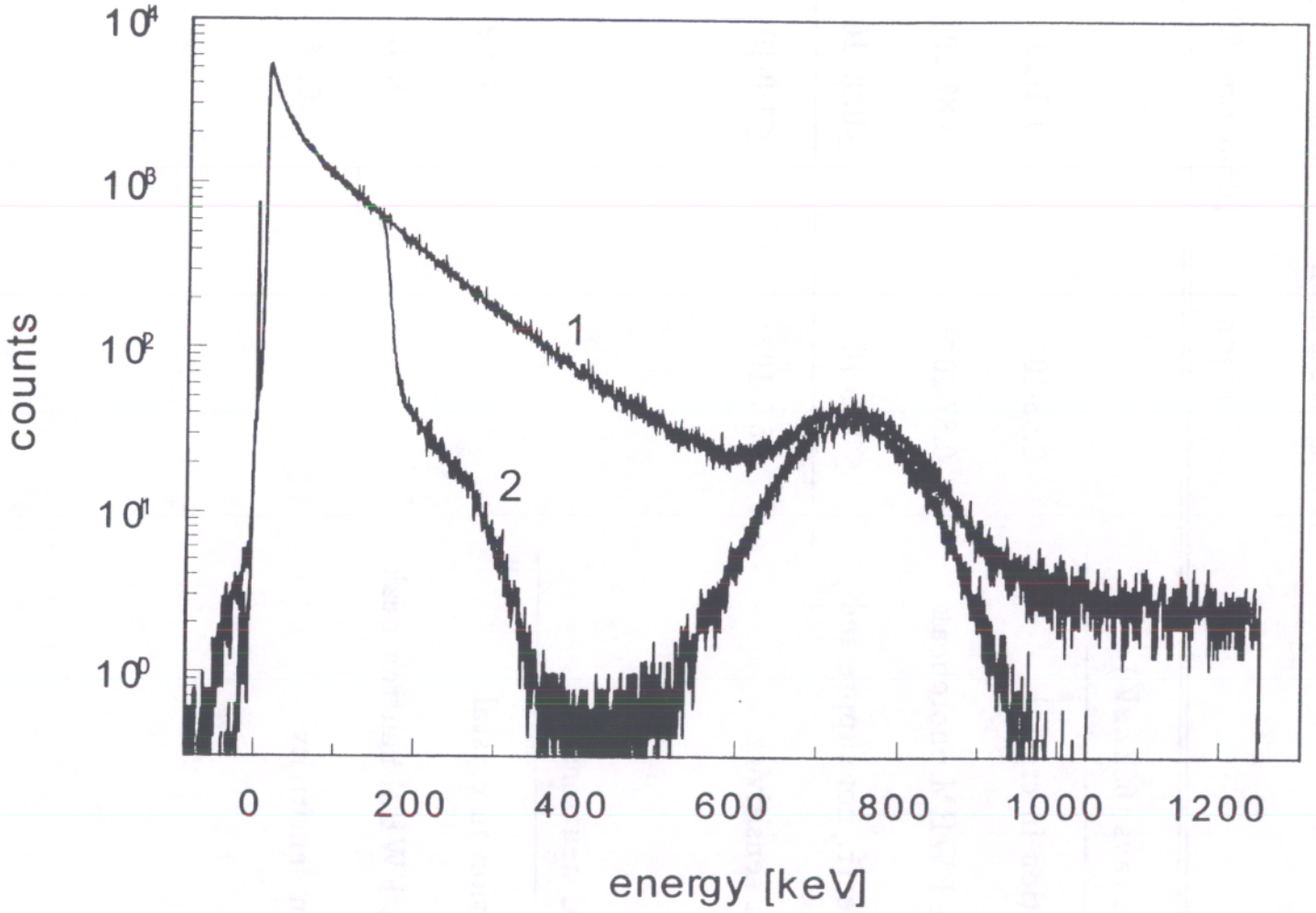

counts
10^4
10^3
10^2
10^1
10^0
1
2
0
200
400
600
800
1000
1200
energy [keV]

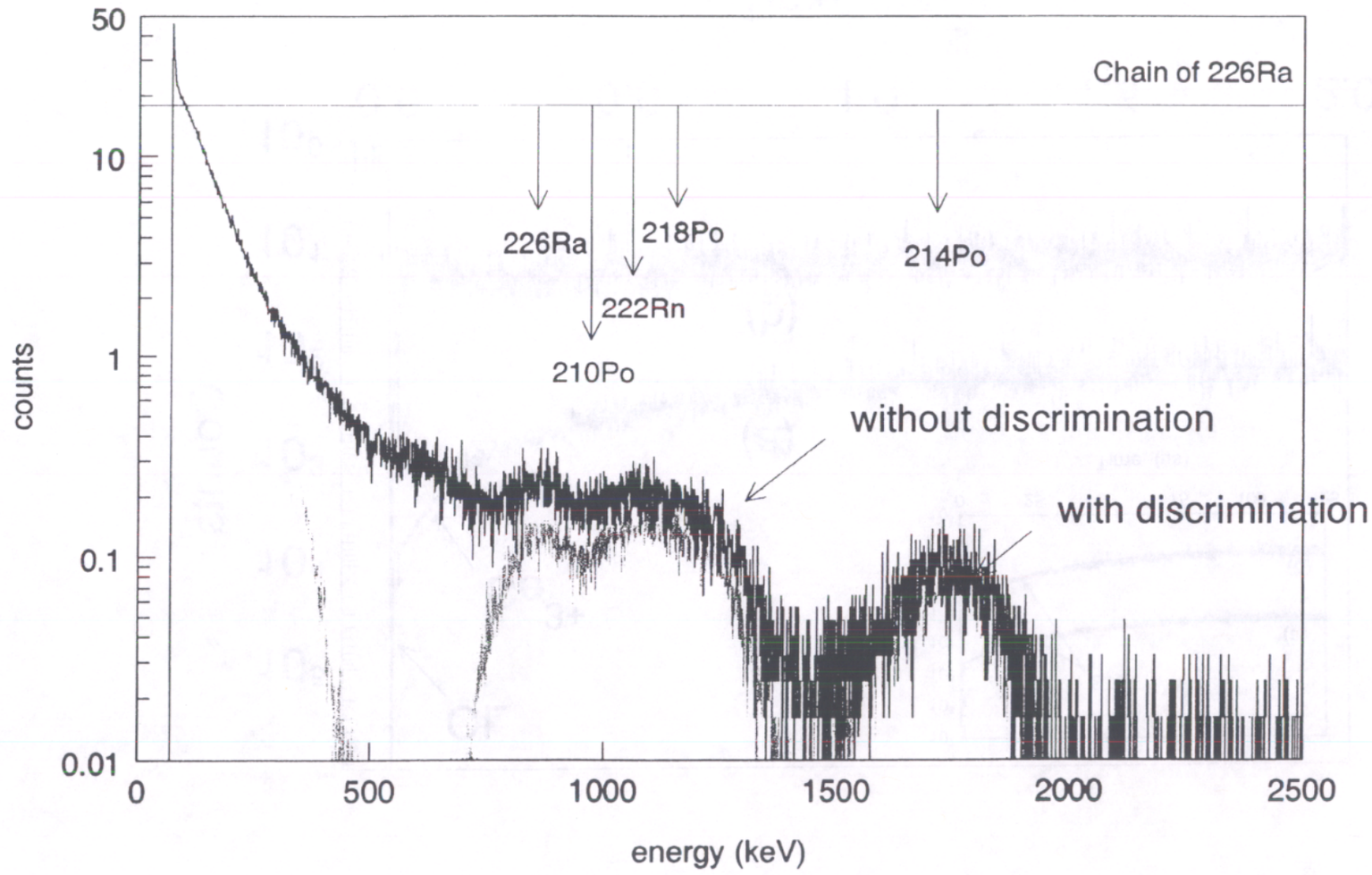
Table 1: gamma sensitivity and thermal neutron sensitivity for the crystal experimented with and an 96% ^{6}Li enriched crystal.

	crystal experiment (d=1.75 mm)	crystal proposed (d=3 mm, 96%^{6}Li)
gamma rays (662 keV)		
absorption in crystal	$0.68 \cdot 10^{-1}$	$1.1 \cdot 10^{-1}$
part in FWHM photopeak	$0.87 \cdot 10^{-1}$	$0.87 \cdot 10^{-1}$
part electr. not suppressed	$\leq 0.96 \cdot 10^{-4}$	$\leq 0.96 \cdot 10^{-4}$
gamma sensitivity	$\leq 5.7 \cdot 10^{-7}$	$\leq 1.0 \cdot 10^{-6}$
thermal neutrons		
absorption in crystal		>0.99
part in FWHM neutron peak		0.76
neutron sensitivity		0.76

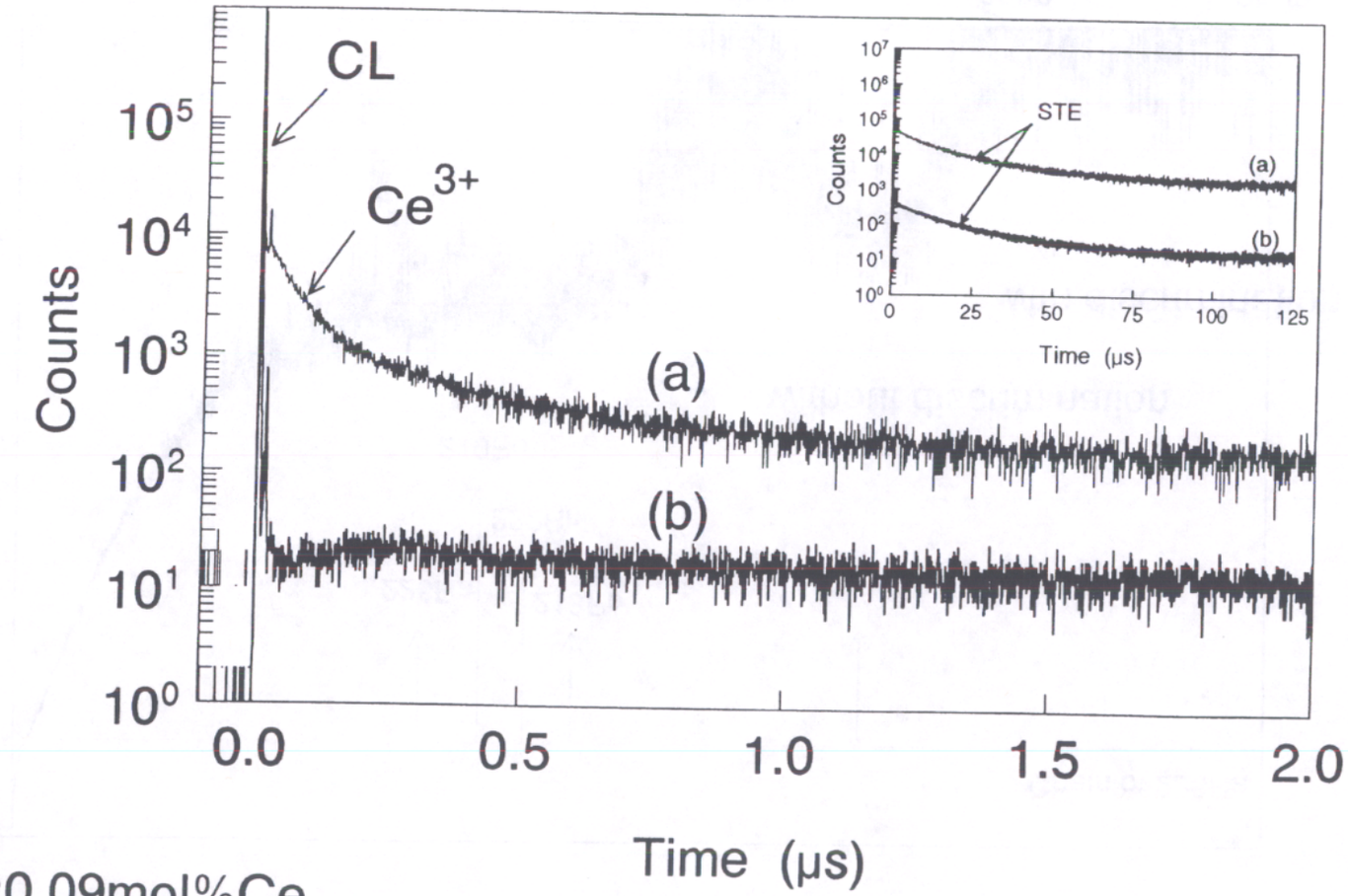
Intrinsic α activity : 612 counts/cm^3/hour

80 counts/cm^3/hour in FWHM neutron peak

Background

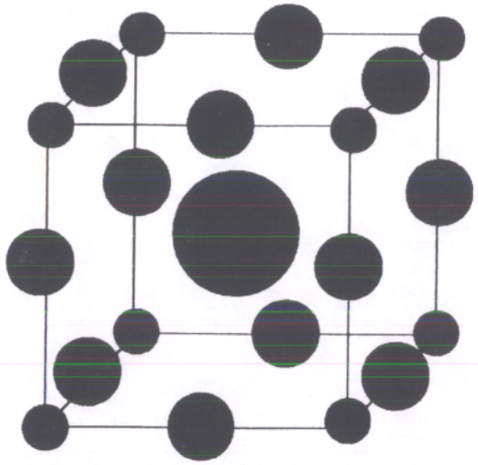

Chain of 226Ra
226Ra
222Rn
218Po
214Po
210Po
without discrimination
with discrimination
counts
energy (keV)
50
10
1
0.1
0.01
0
500
1000
1500
2000
2500

Decay time spectra



(a) LiBaF3:0.09mol%Ce

(b) LiBaF3 pure



LiBaF3

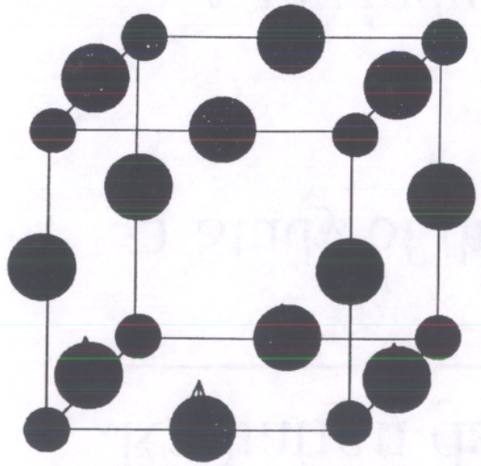
Cubic site symmetry

Ba^{2+}

Ce^{3+}

F^-

Li^+



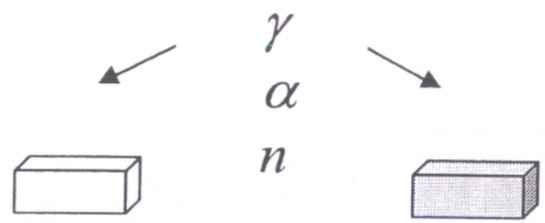
LiBaF3: Ce^{3+}

Li^+ replaces Ba^{2+}

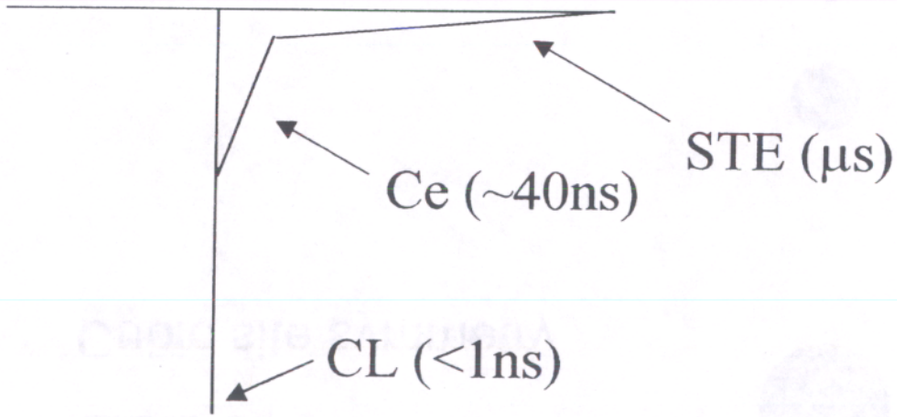
C4v symmetry > experimental splitting

Radiation damage/scint. pulse shape

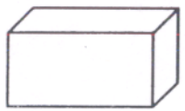
- Study of the scint. pulse shape

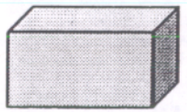


- γ-ray induced pulse



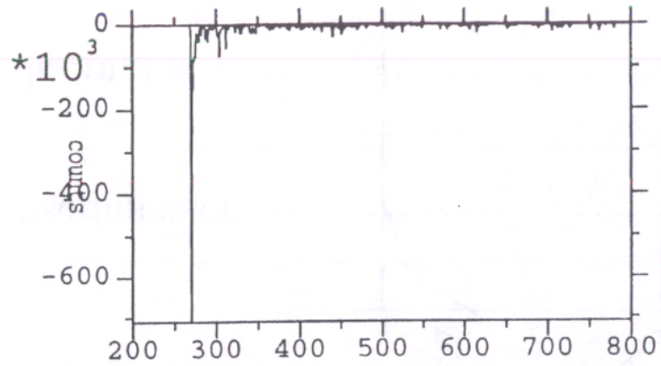
LeCroy LS140-$LiBaF_3$:Ce,Rb

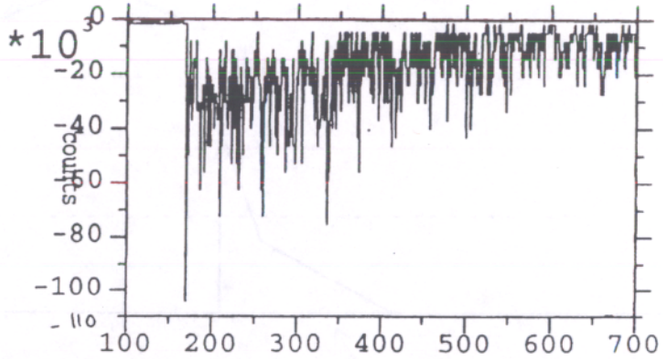


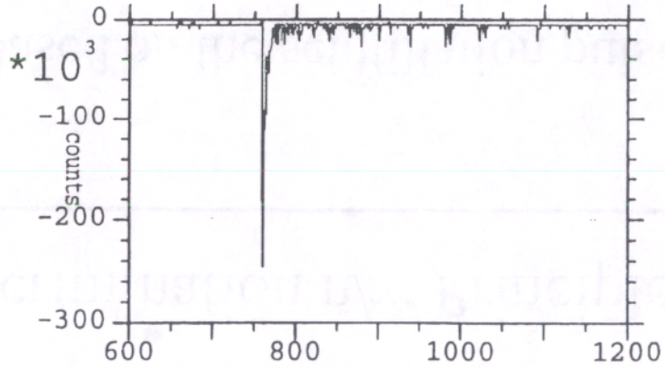


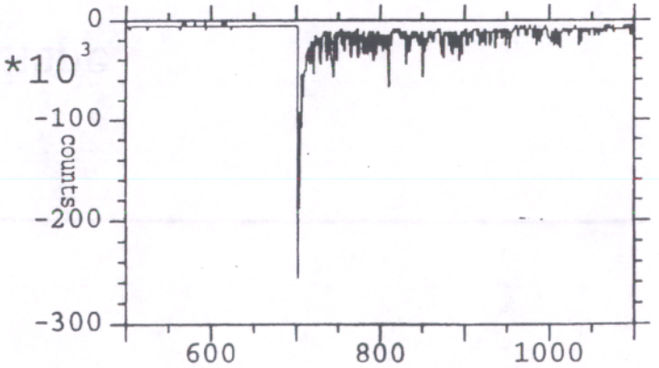
γ

α,n



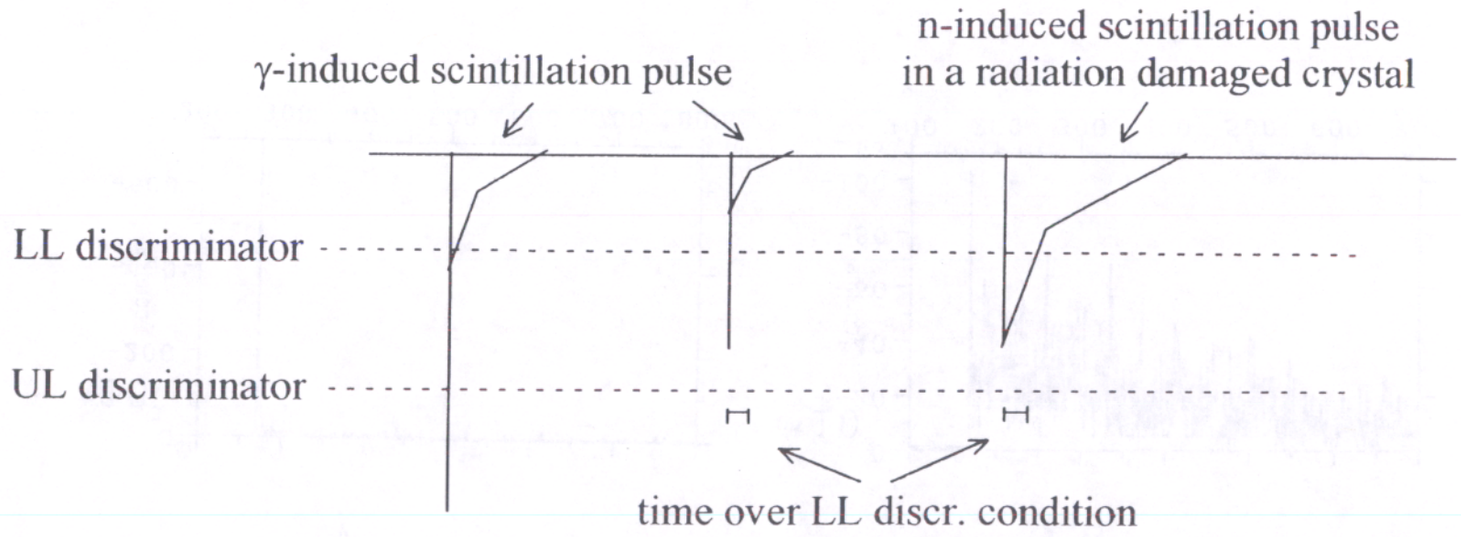




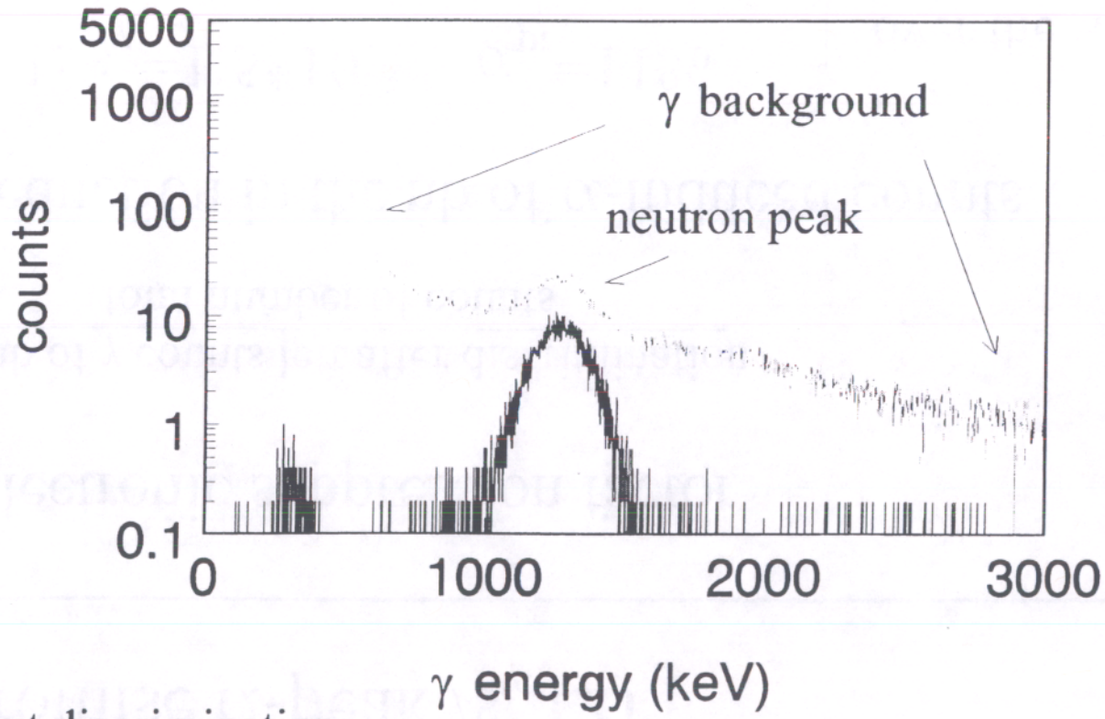


Discrimination n/γ: Principle

- Based on the scintillation pulse shape



Phs of a Pu/Be source + paraffine



——without discrimination

—— with discrimination

Compromise α-peak /s_γ (2)

- s_γ= electronic suppression factor

$$= \frac{\text{nb of } \gamma \text{ counts left after discrimination}}{\text{total number of counts}}$$

- α_{pr}=reduction in the nb of α-induced counts
- discr. 1: $s_\gamma = 1.5*10^{-3}$ $\alpha_{pr}=11\%$
  discr. 2: $s_\gamma = 3.6*10^{-4}$ $\alpha_{pr}=33\%$

} over the whole energy range