

# SYSTEMATIC STUDY OF THE DIFFERENT QUENCHING PHENOMENA IN ORGANIC SCINTILLATORS

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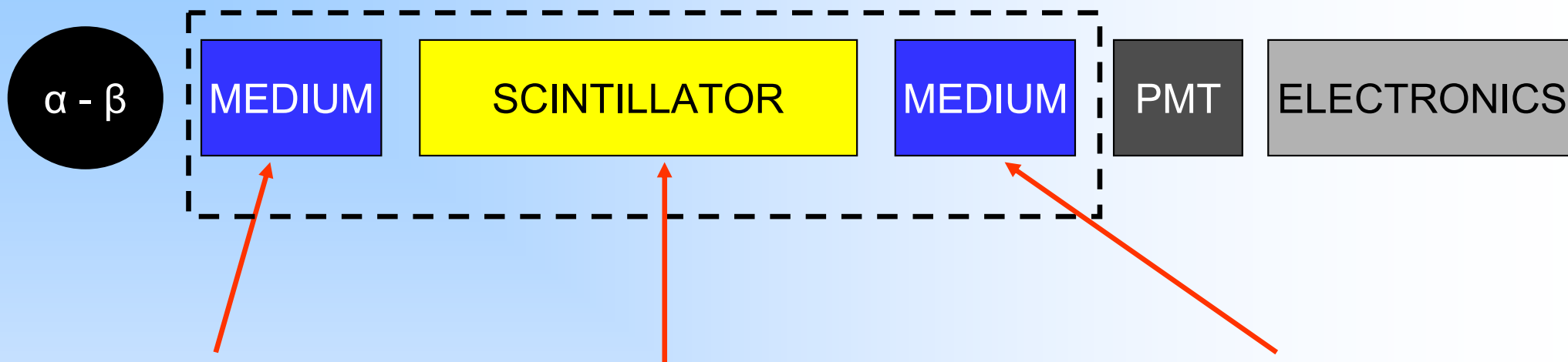


## Development of Organic Scintillators (Plastic and Liquid)

- . Start at 50's and mainly in 60's-80's.
- . Main development in LS (routine technique with great number of applications)
  - . Description of theoretical methods
  - . Systematic studies of the experimental conditions
  - . Establishment of measuring protocols

## Development of Plastic Scintillators (spheres or blocks)

- . Extrapolation from LS theories
- . Lack of experimental confirmation about mechanism of scintillation



- Lost of energy due to interactions of the particles with the medium (PARTICLE QUENCHING)

- Lost of energy due to ionization (IONIZATION QUENCHING)
- Lost of energy due to non effective electronic transfer (CHEMICAL QUENCHING)

- Absorption of photons (COLOR QUENCHING)
- Optical effects (OPTICAL QUENCHING)

- Medium
- Compounds with high atomic number or high density

- Scintillator
- Molecules with high electroaffinity, ...

- Colored compounds
- Compounds that change the optical conditions of the medium

## OBJECTIVE OF THE WORK

Evaluation of different quenching mechanism taking place in the measurement with organic scintillators (plastic microspheres and liquid).

. Measure of different beta radionuclide solutions with different quenching agents using PS microspheres of two different diameters and liquid scintillation in a commercial detector

**PS microspheres:** UPS-89, From Detec-Rad (Canada)

- PS1: PS microspheres with a diameter around  $120 \leq \phi \leq 180 \mu\text{m}$
- PS2: PS microspheres with a diameter around  $400 \leq \phi \leq 500 \mu\text{m}$

**LS cocktail:** Optiphase SuperMix, From Perkin Elmer

**Radionuclides:**

- $^3\text{H}$  (18.6 keV)
- $^{36}\text{Cl}$  (708.6 keV)

**Sample preparation and measuring conditions:**

- 2.4g of scintillator (plastic or liquid) in 6 mL PE-vials
- active solution or carrier solution plus quenching agent: 1.2 g
- 10 minutes in ultra sonic bath (only PSm)
- Centrifugation: about 10 min at 5000 RPM
- Counting time: 45 min.

**Detector:**

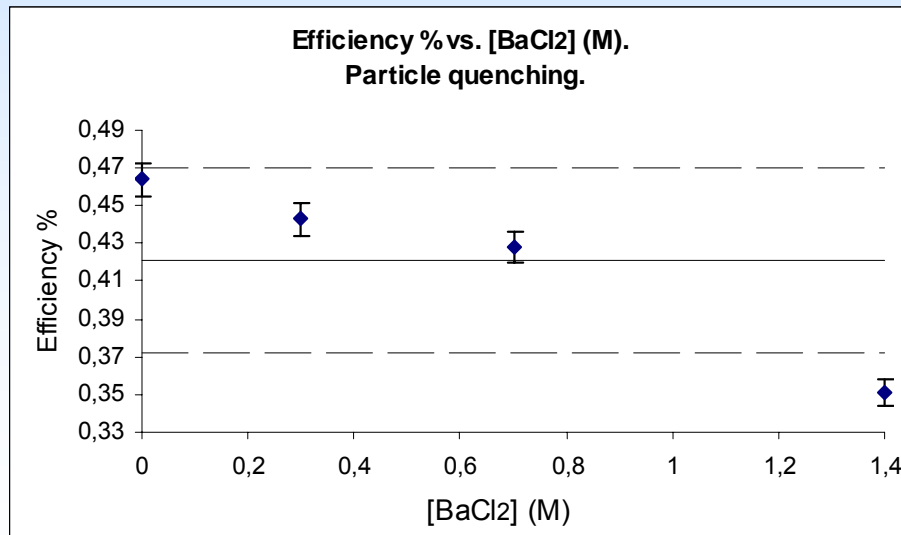
- Quantulus 1220

Quenching agent	Concentration range	Quenching effect	Index of refraction	Absorption between 300-500 nm	Density
BaCl <sub>2</sub>	0-1.4 M	Particle	1.33-1.37	NO	1.00-1.25
Nitromethane	0-7.57 µl/ml	Chemical	1.33	NO	1.00
Glycerin	0-72 % (w/v)	Optical	1.33-1.45	NO	1.00-1.22
Methyl orange	0-0.0138 g/l	Color	1.33	YES	1.00

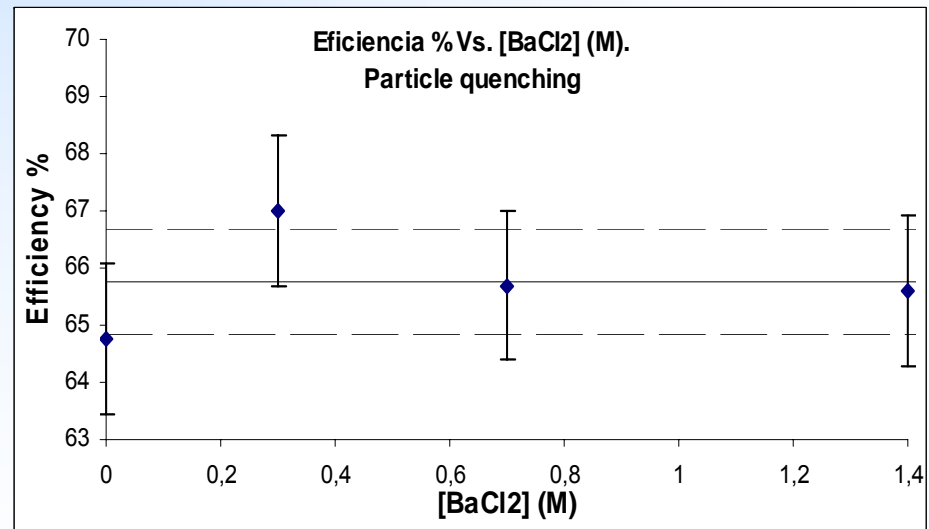
## Quenching agents: BaCl<sub>2</sub>

- Slight decrease of the detection efficiency in case of <sup>3</sup>H
- No variation on the SQP (671 ± 3; 739 ± 2)
- Spectra is always at the same position
- <sup>36</sup>Cl is not affected by the presence of BaCl<sub>2</sub> due to its high energy

### <sup>3</sup>H by PS1 with BaCl<sub>2</sub>

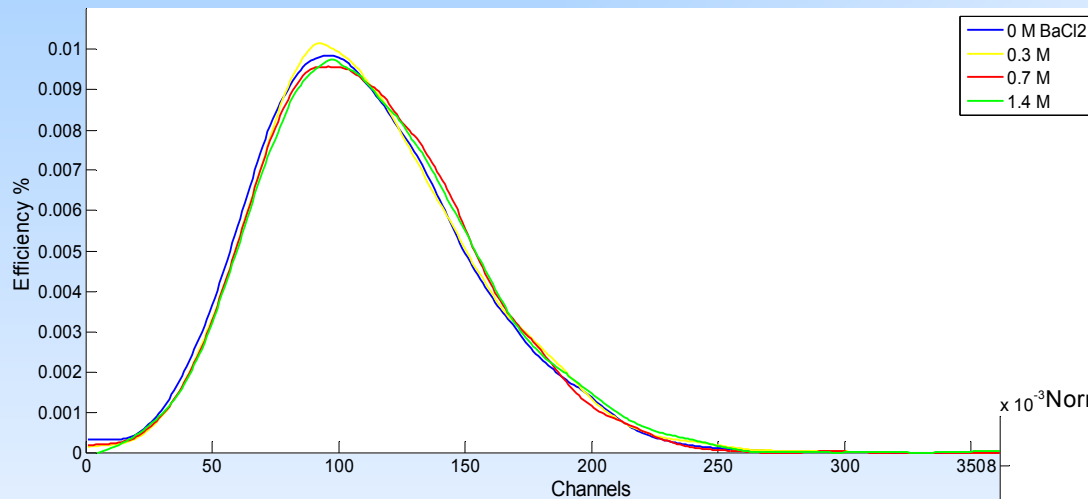


### <sup>36</sup>Cl by PS2 with BaCl<sub>2</sub>

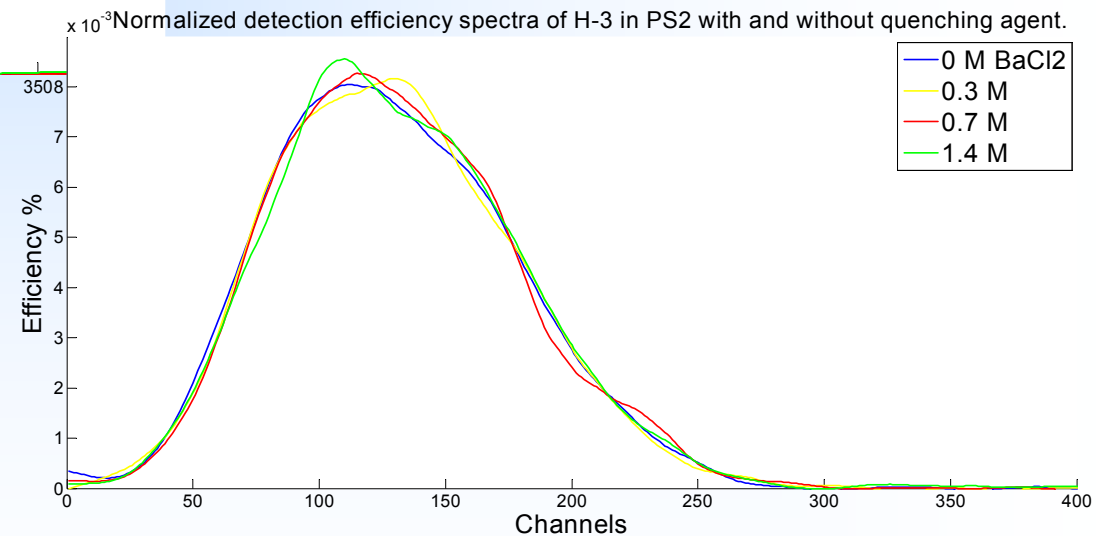


Quenching agents: BaCl<sub>2</sub>

<sup>3</sup>H by PS1 with BaCl<sub>2</sub>

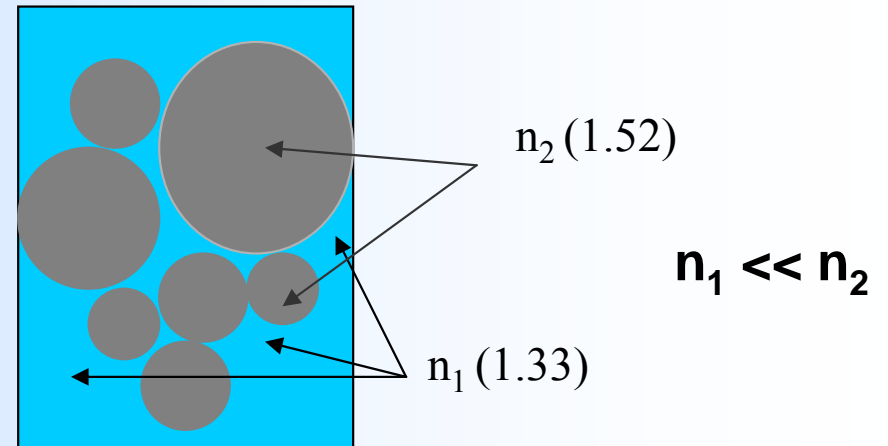


<sup>3</sup>H by PS2 with BaCl<sub>2</sub>

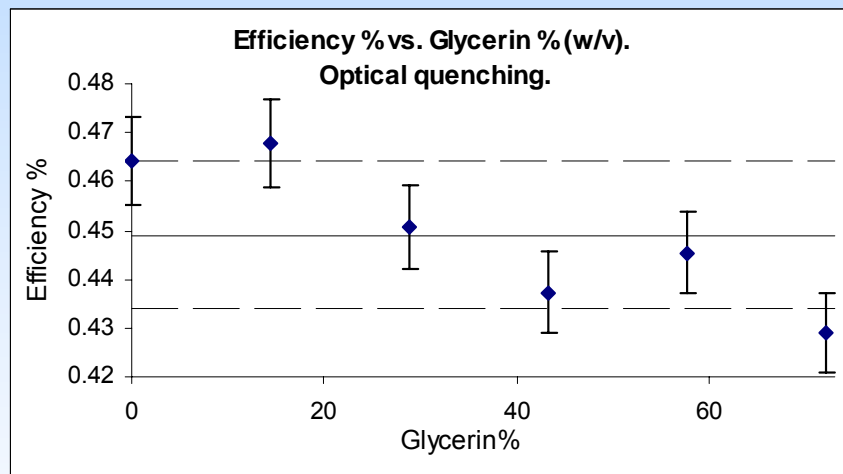


## Quenching agents: Glycerin

Concentration range	Index of refraction	Density
0-72.17 % (w/v)	1.33-1.45	1.00-1.22



## $^3\text{H}$ by PS1 with Glycerin



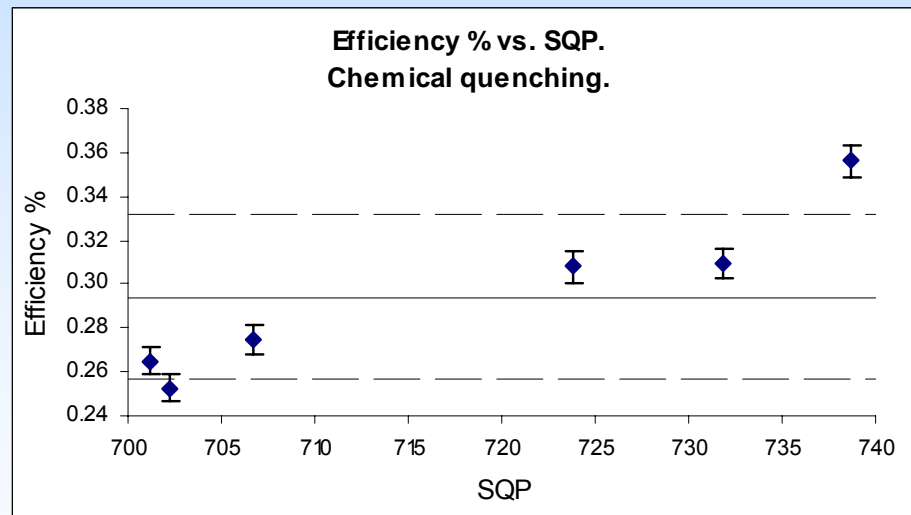
- Slight decrease of the detection efficiency in case of  $^3\text{H}$
- No variation in the SQP ( $676 \pm 2$  ;  $736 \pm 4$ )
- Spectra is always at the same position
- $^{36}\text{Cl}$  is not affected by the presence of glycerin

- The changes in the index of refraction does not produced the expected effect
- Variations can be attributed to density changes and to Particle Quenching

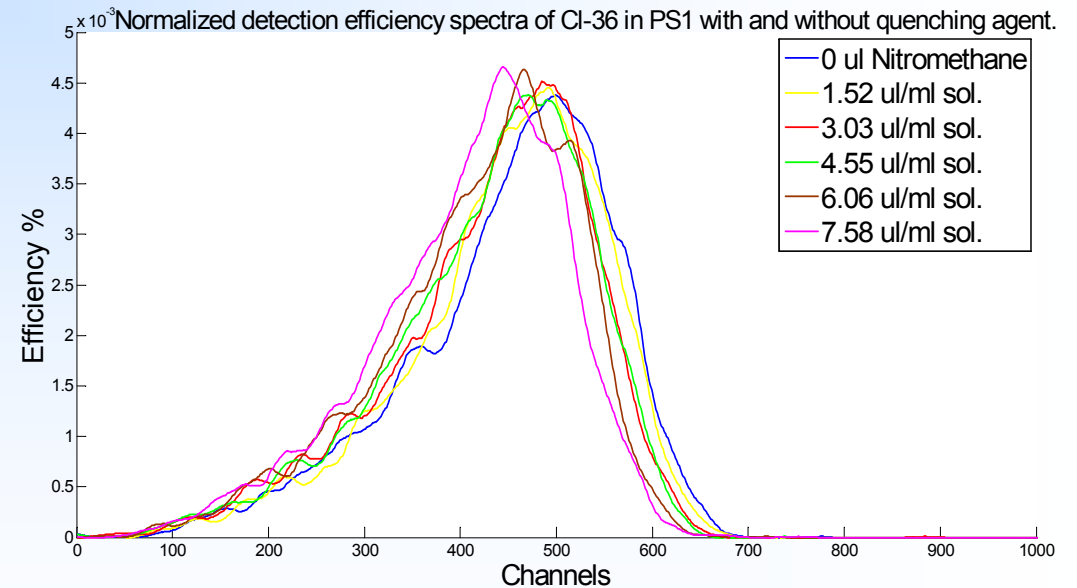
## Quenching agent: Nitromethane

- Classical quenching curve. Decrease of the efficiency correlated with a decrease of the SQP
- Spectra shifted to low energies with the increase of the Nitromethane concentration

### $^3\text{H}$ by PS2 with Nitromethane

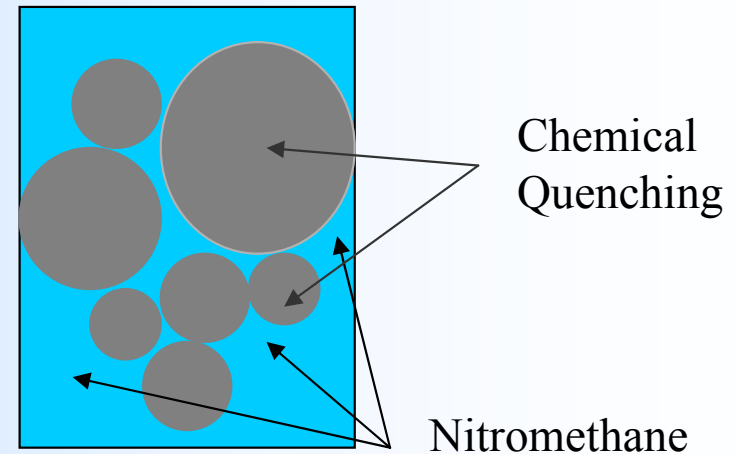


### $^{36}\text{Cl}$ by PS1 with Nitromethane



## Unexpected Results:

Solution and spheres are only in contact in the surface and not in the scintillator (Chemical Quenching)



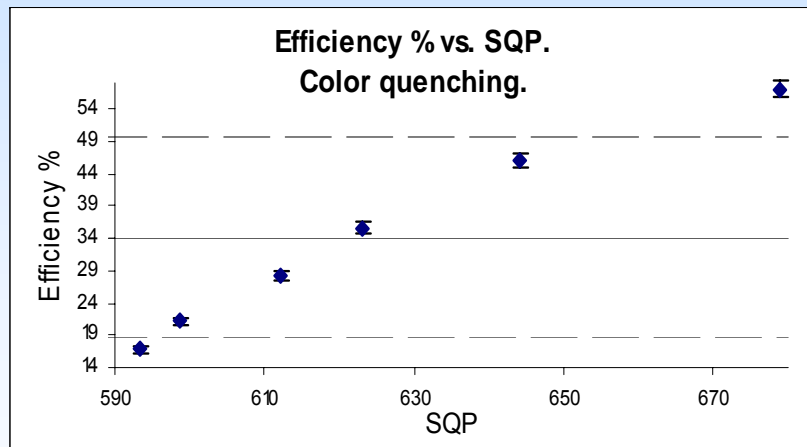
## Hypothesis

- Nitromethane is solved into the PSm
- Electronic transfer takes place in the sphere surface

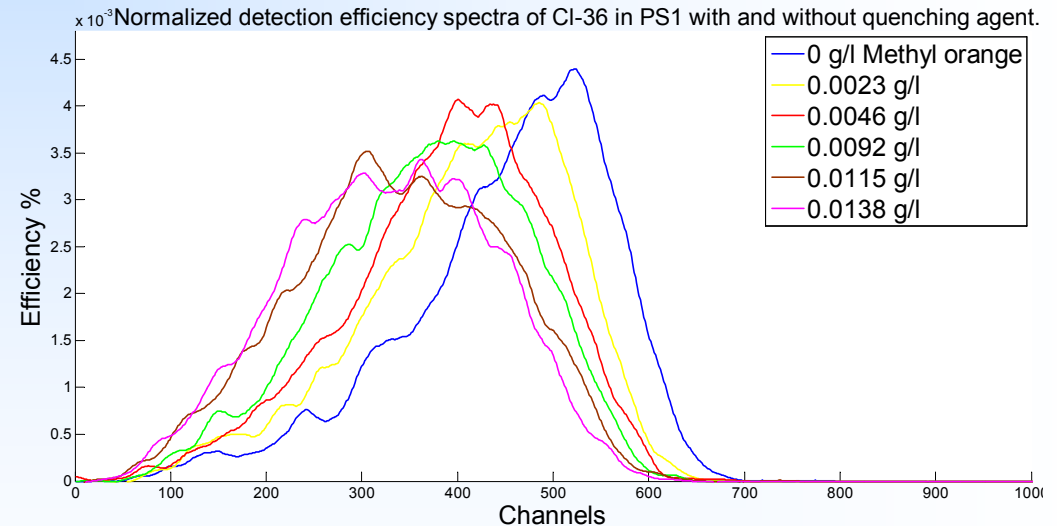
## Quenching agent: methyl orange

- Classical quenching curve. Decrease of the efficiency correlated with a decrease of the SQP
- Spectra shifted to low energies with the increase of the methyl orange concentration

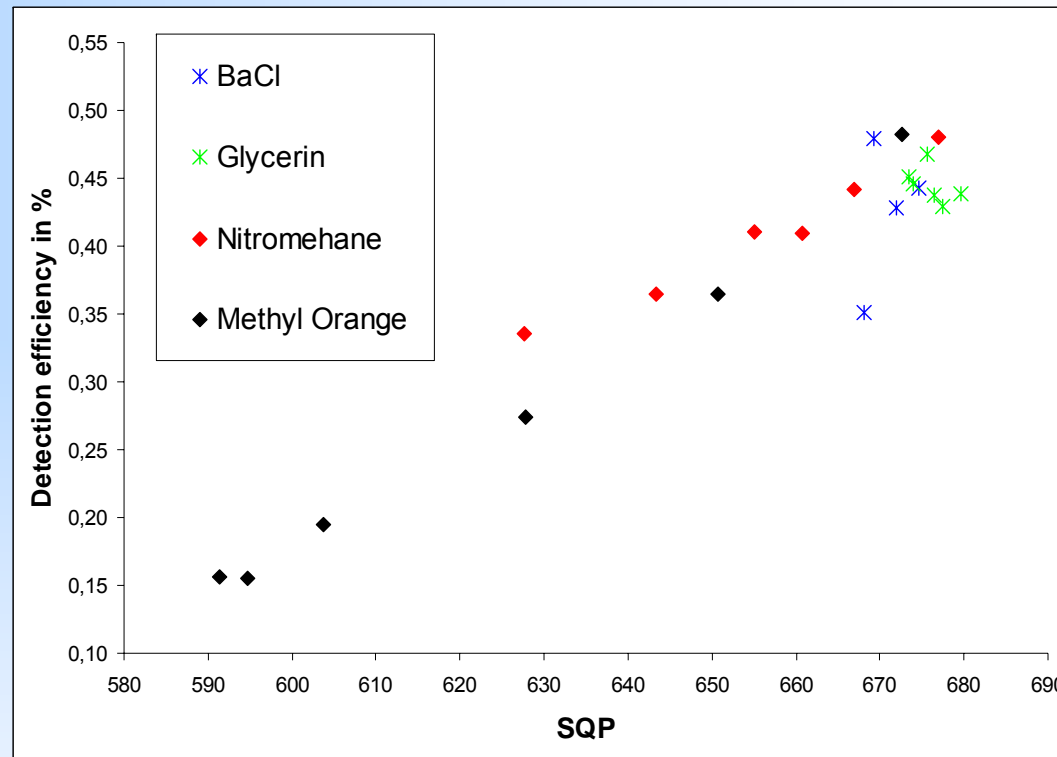
### $^{36}\text{Cl}$ by PS1 with methyl orange



### $^{36}\text{Cl}$ by PS1 with methyl orange



$^3\text{H}$  by PS1 (3:176)



**PARTICLE QUENCHING:** Lost of energy due to interactions of the particle with the medium before the particle reach de scintillator.

Quenching agents: BaCl<sub>2</sub> and glycerin



**PHASE HETEROGENITY**

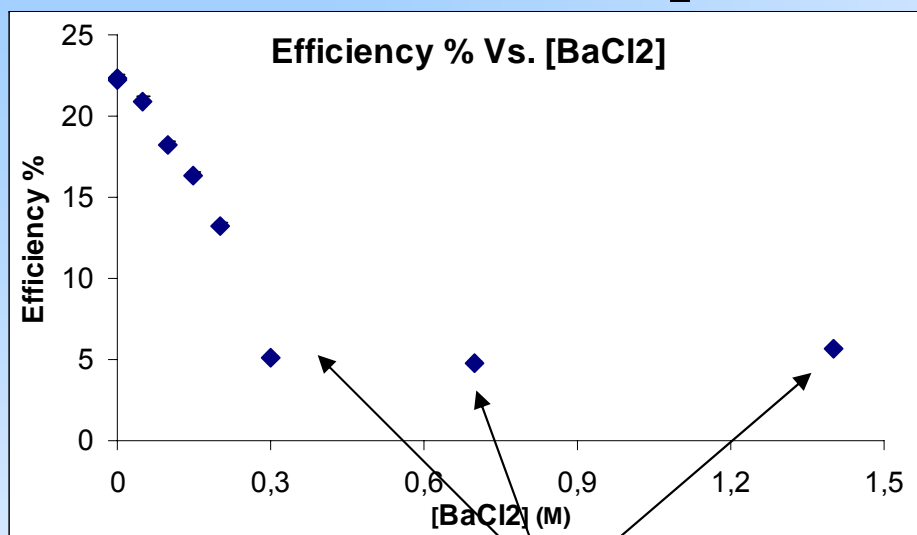
## BaCl<sub>2</sub> (0.05-1.4M)

- All are milky after preparation. Turbidity is proportional to concentration
- After 24h formation of white colloidal precipitate
- 2 clear phases at concentrations higher than 0.3M

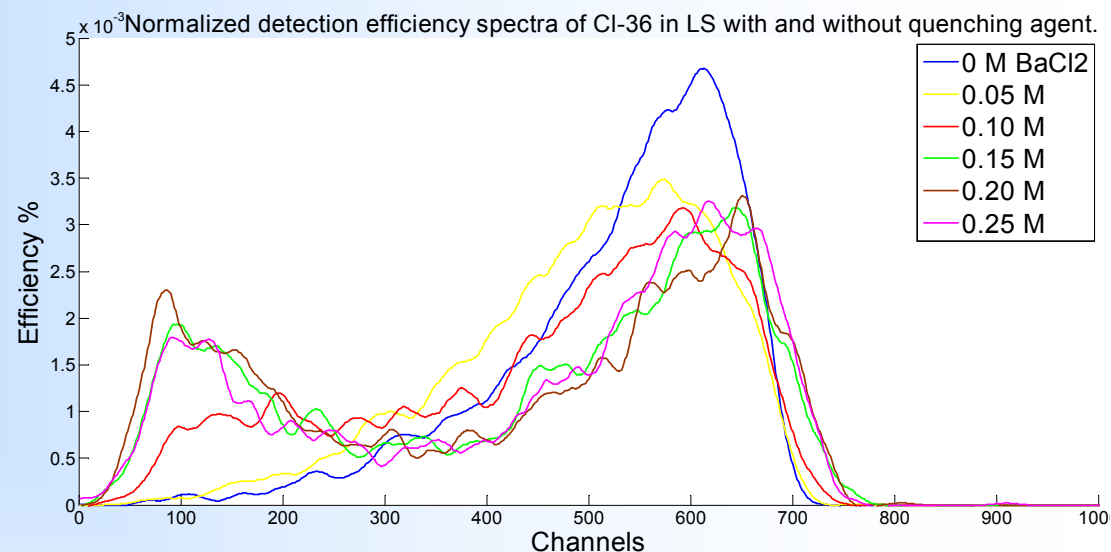
## Glycerin (14-72%)

- Clear after preparation, except concentration higher than 58% (slight turbidity)
- After 24 hours only 72% sample presents phase separation

## $^3\text{H}$ by LSC with $\text{BaCl}_2$



## $^{36}\text{Cl}$ by LSC with $\text{BaCl}_2$

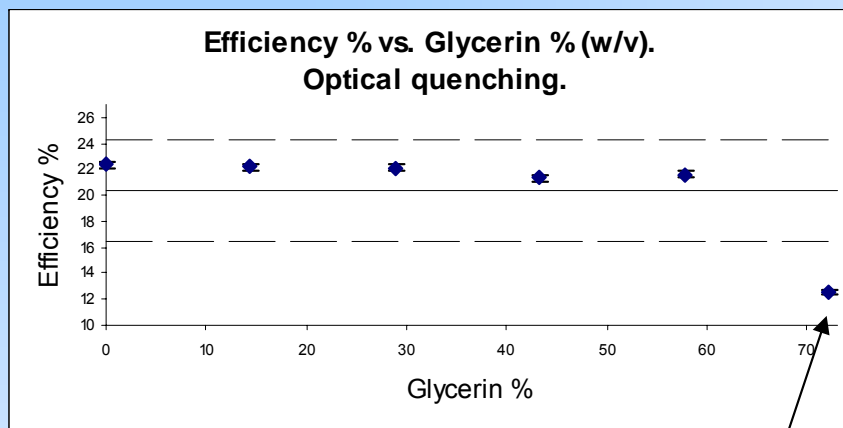


PHASE SEPARATION ( $[\text{BaCl}_2] > 0.3$ )

- Important decrease of the detection efficiency ( $^3\text{H}$  and  $^{36}\text{Cl}$ )
- Increase of the SQP
- Spectra at high energies is at the same position

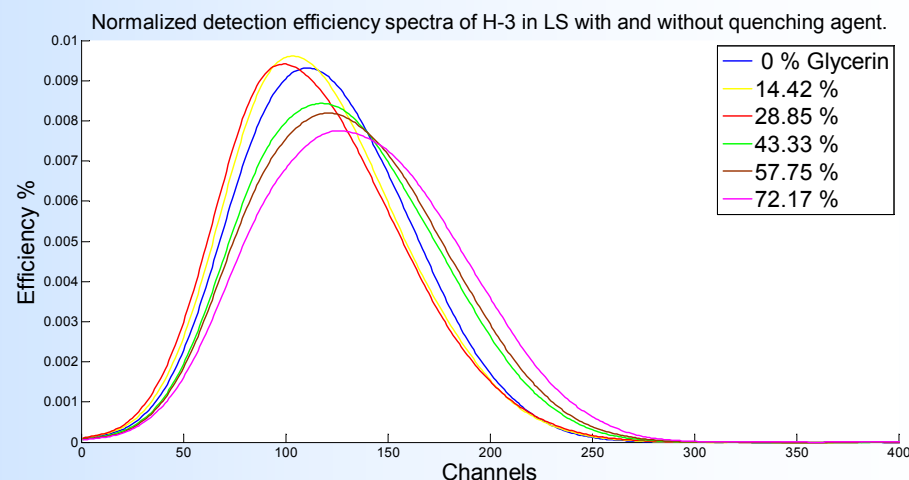
$\text{BaCl}_2$ (M)	$^3\text{H}$ Efficiency (%)	SQP
0	22,37	739,7
0,05	20,91	753,0
0,15	16,34	774,9
0,3	5,13	798,7
0,7	4,80	807,6
1,4	5,66	803,3

## $^3\text{H}$ by LSC with Glycerin



PHASE SEPARATION ([Glycerin]=72%)

## $^3\text{H}$ by LSC with Glycerin



More stopped particles at low energies

- increase of the density
- increase of the micelle size

- Dramatically decrease of the efficiency when phase separation takes place
- Slight decrease of  $^3\text{H}$  efficiency with the Glycerin proportion (22.3, 22.1, 21.8, 21.7, 21.3)
- No evident in  $^{36}\text{Cl}$
- SQP constant ( $747 \pm 6$ ) expect when phase separation (791)
- $^3\text{H}$  spectra moves to high energies.  $^{36}\text{Cl}$  spectra only moves when phase separation

## Effect of increasing amounts of BaCl<sub>2</sub> and Glycerin

- INCREASE OF THE MICELLE SIZE:

- . Organic phase with non saturated water micelles of higher diameter
- . Low beta emitters are affected by density changes
- . Similar situation to PS (PARTICLE QUENCHING)

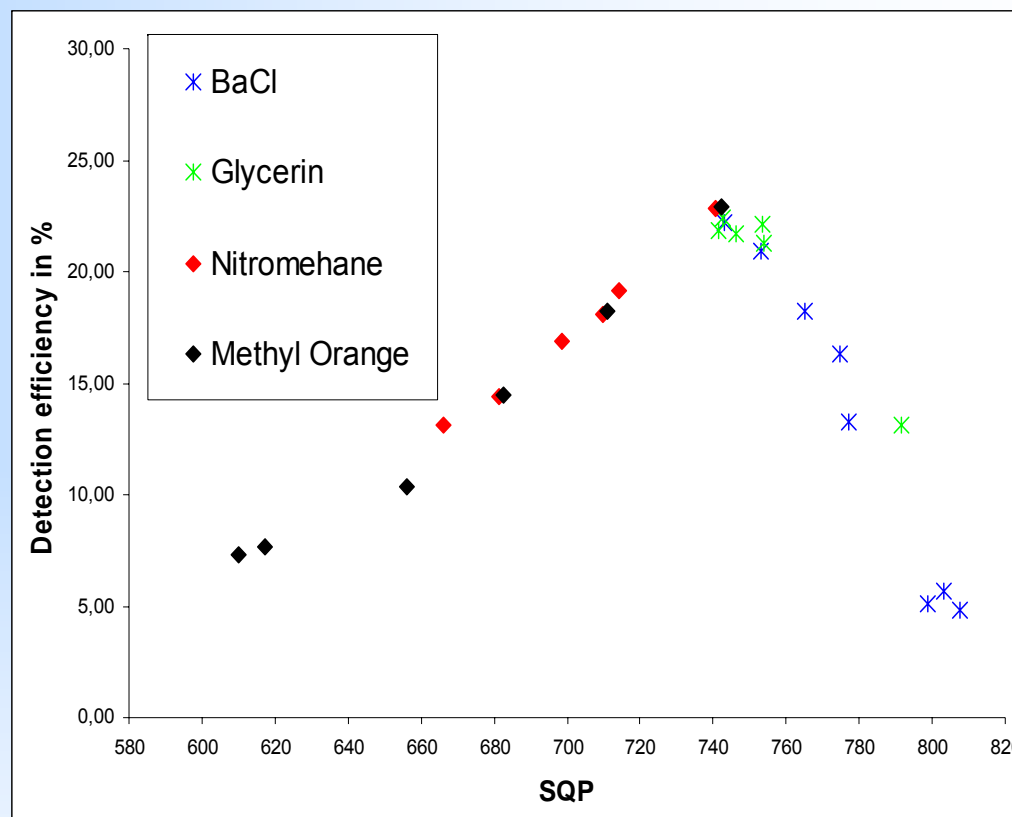
- PHASE SEPARATION:

- . Organic phase with saturated micelles (higher energetic part of the spectra)
- . Water phase with the organic scintillator solved (lower energetic part of the spectra)
- . Radionuclides are distributed in both phases
- . Organic phase becomes saturated and efficiency and SQP remain constant

## Quenching agents: Nitromethane and Methyl orange

- Classical quenching curve. Decrease of the efficiency correlated with a decrease of the SQP
- Spectra shifted to low energies with the increase of the quencher concentration

## $^3\text{H}$ by LSC (1:175)



- **Classical Quenching**
- **Particle Quenching.**
- **Phase Separation**

- $\text{BaCl}_2$  and Glycerin affect the measure of  $^3\text{H}$  with PSm as some particles are stopped and detection efficiency decreases.  $^{36}\text{Cl}$  is too energetic and no effects are detected.
- Presence of nitromethane in the PSm measurements causes a decrease of the efficiency correlated with the SQP (classical chemical quenching)
- Measure of  $^3\text{H}$  with LS in presence Glycerin is affected by particle quenching (increase of the density or the micelle size) as the decrease of the efficiency observed is similar to that of PSm.

- Ministerio de Ciencia e Innovacion (CTM2008-01178/TECNO)

THANK YOU FOR  
YOUR  
ATTENTION