

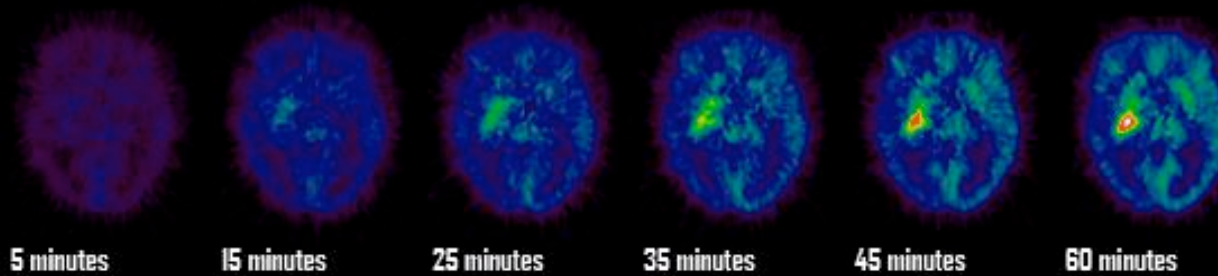
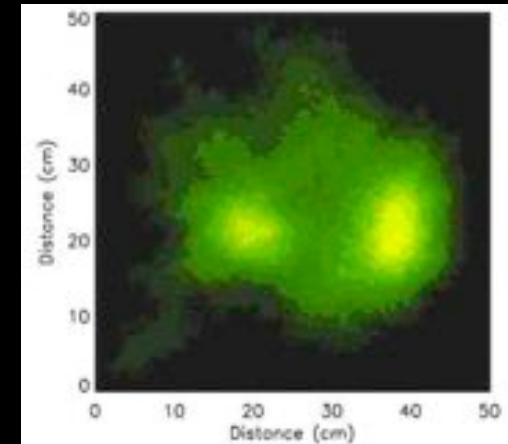
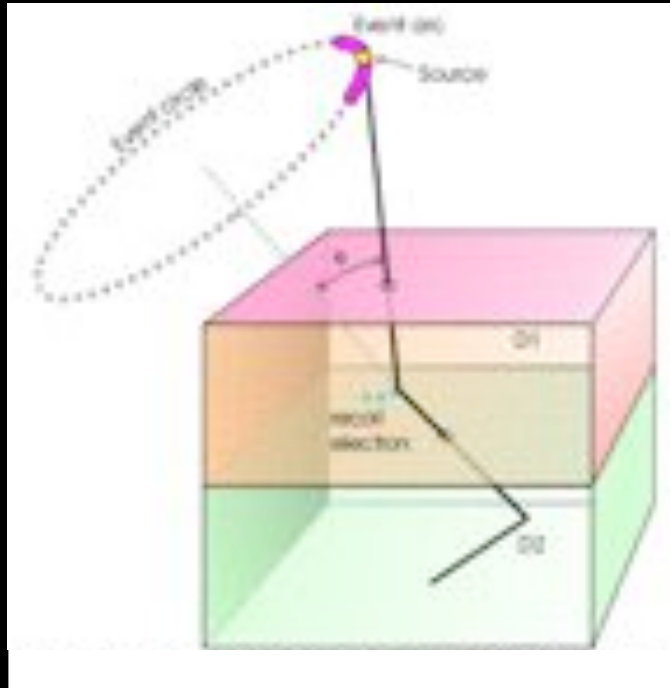
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# L'IA pour la détection en physique nucléaire

# Objectifs

- Etat du tracking gamma pour AGATA
- Algorithmes développés et applications
- L'I.A. à l'IPNO et au CSNSM
- Analyse mathématique de la fonction de transfert du système de détection


# Tracking gamma



DOE/SC-0062

**Report on the Workshop on the Role of  
the Nuclear Physics Research Community  
in Combating Terrorism**

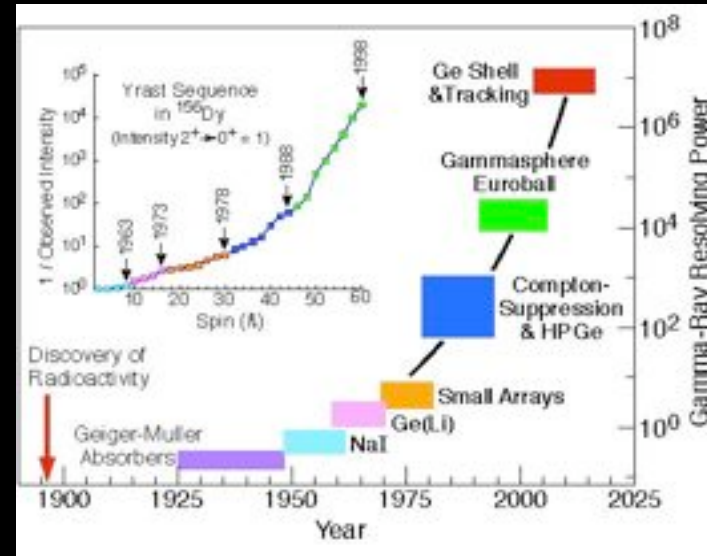
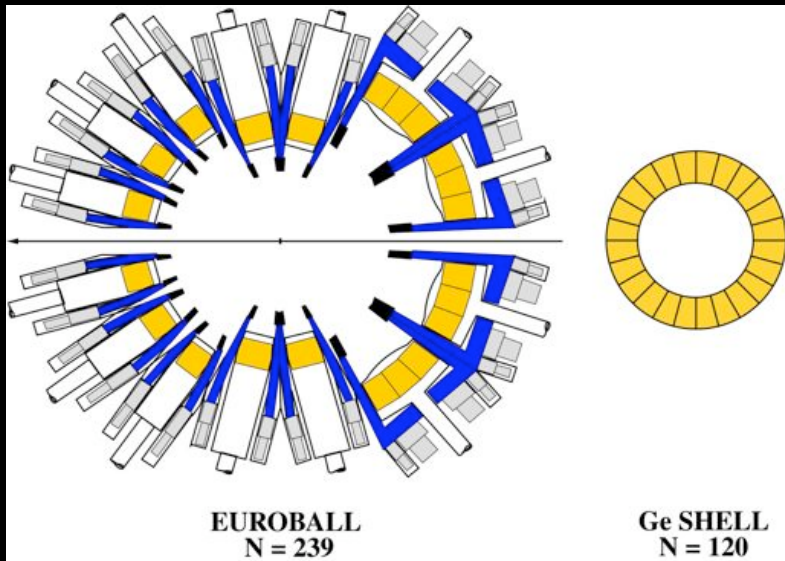
Washington, D.C.  
11–12 July 2002



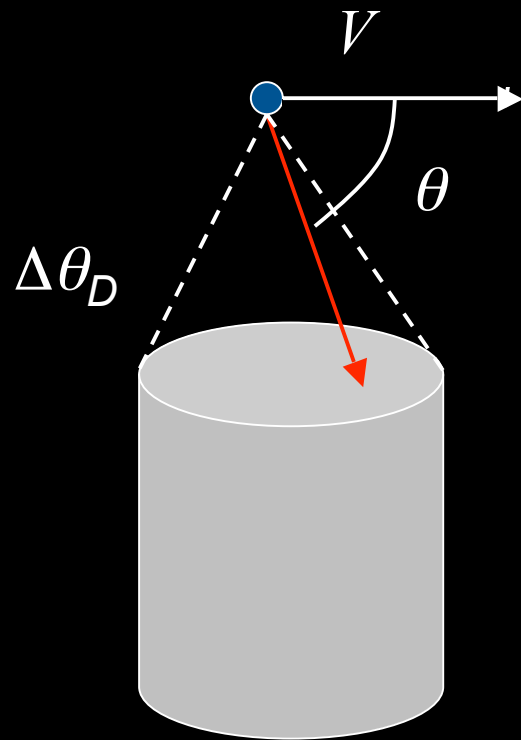
Editors:  
Joel Moss, Los Alamos National Laboratory  
Donald Grossman, Argonne National Laboratory  
Lee Schneider, Lawrence Berkeley National Laboratory  
Johanne Simon-Gilles, Department of Energy/Division of Nuclear Physics  
Bradley Keister, National Science Foundation/Physics Division

U.S. Department of Energy  
Office of Science, SC-23, 617N  
1000 Independence Avenue, SW  
Washington, D.C. 20585-1290

# Avant le tracking

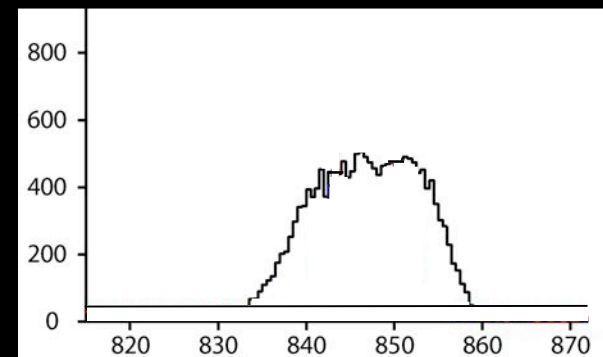


# Élargissement Doppler

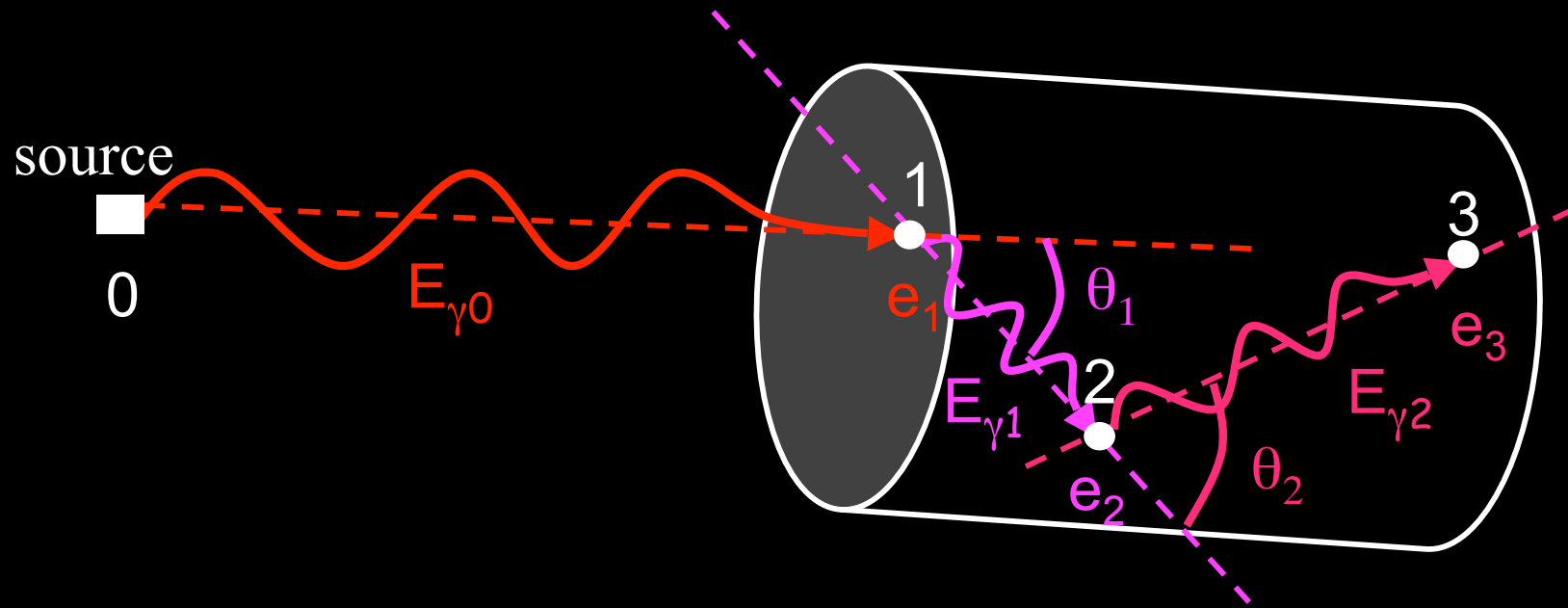


$$E_{\gamma} = E_0 \frac{\sqrt{1 - \frac{V^2}{c^2}}}{1 - \frac{V}{c} \cos \theta}$$

Élargissement raie 847 keV : 16,5 keV (FWHM)



# tracking



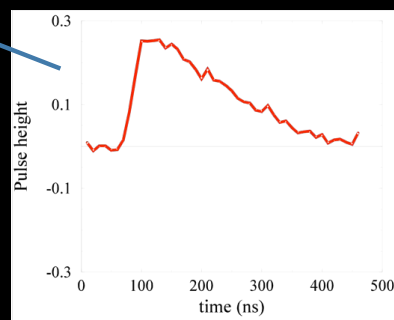
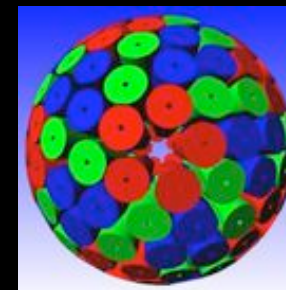
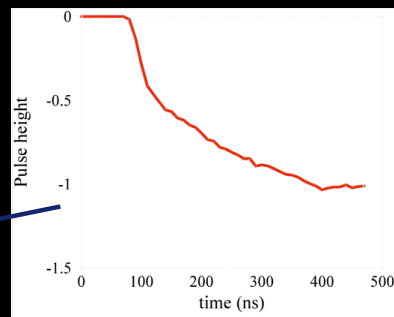
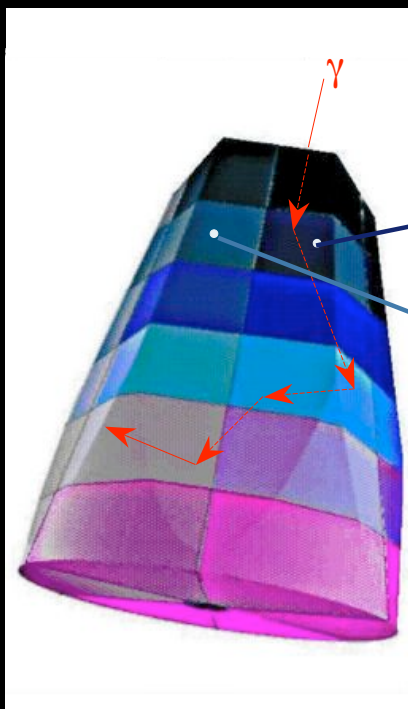
énergie incidente de  $i$

$$\cos(\theta_i) = 1 - m_e c^2 \left( \frac{1}{E_{\gamma i}} - \frac{1}{E_{\gamma(i-1)}} \right)$$

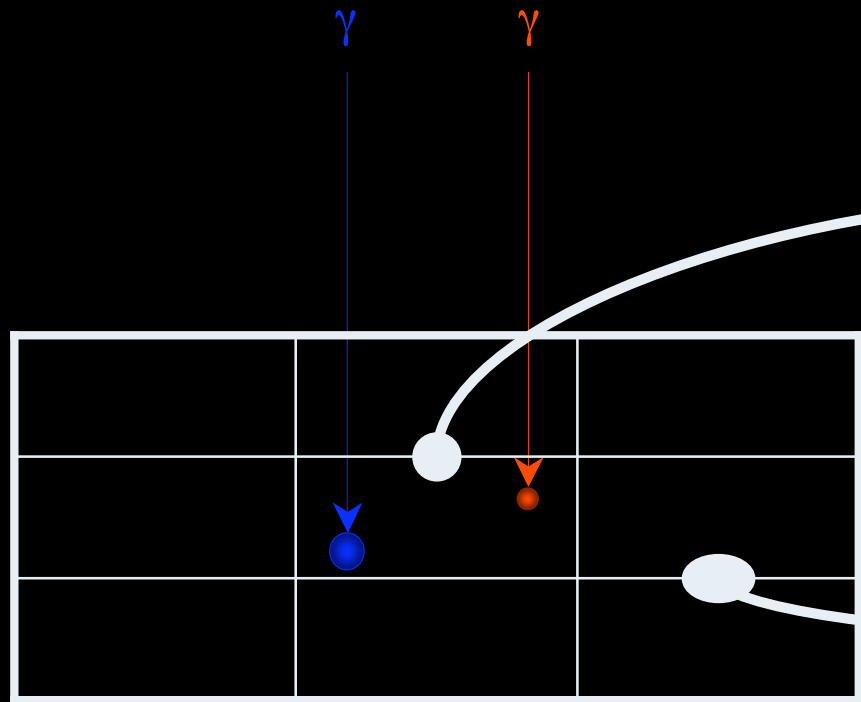
énergie diffusée par  $i = E_{\gamma(i-1)} - e_i$

A. Lopez

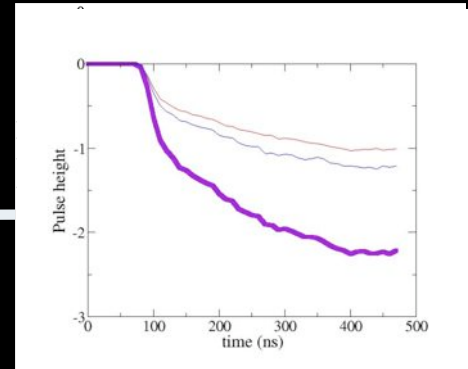
# Le tracking gamma dans AGATA



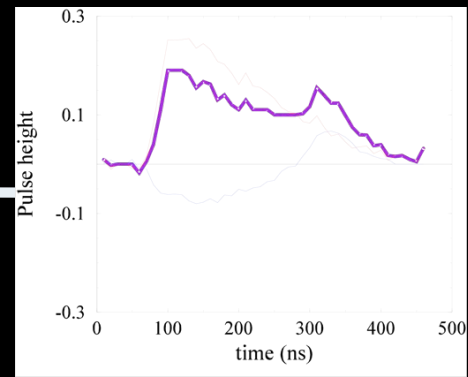
# Additivité des signaux



Segments du détecteur



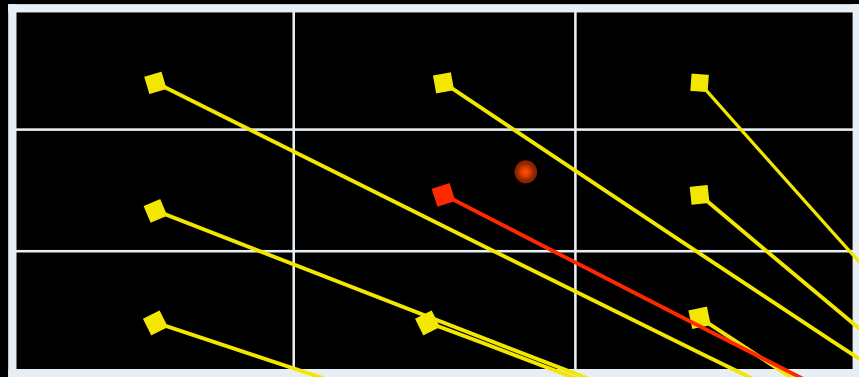
Signal de charge



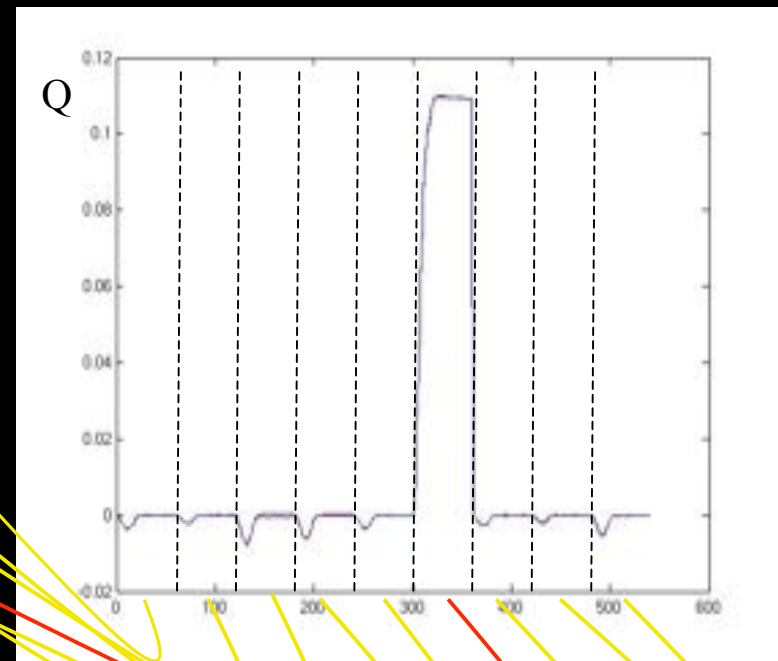
Signal induit

→ Le signal délivré est la somme des signaux

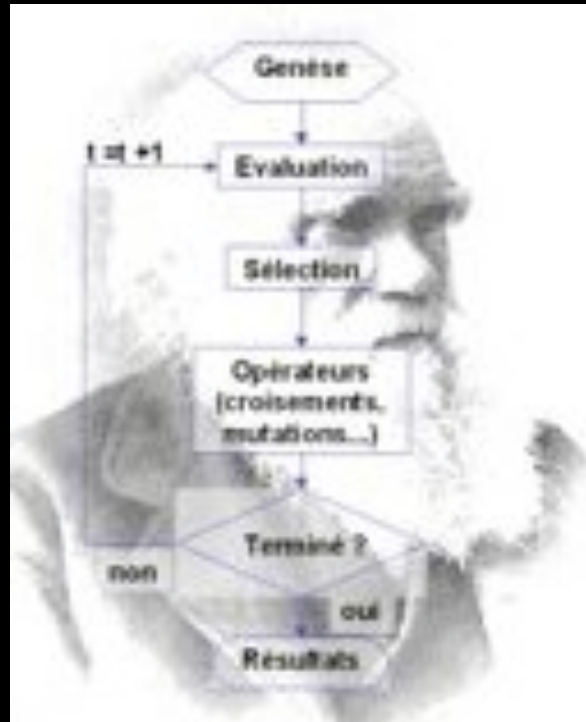
# Les meta-signaux



Segments du détecteur



# Les algorithmes génétiques

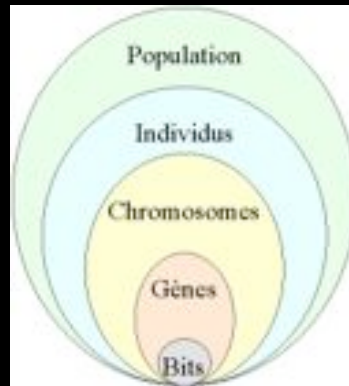


# Les chromosomes

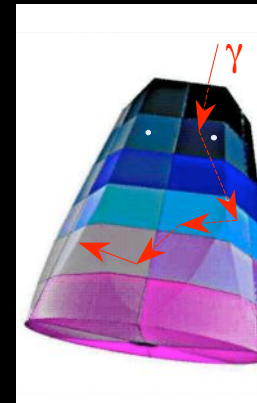
biologique

binaire

Gène 1	G	0
	T	1
	A	1
	G	1
	C	0
Gène 2	A	1
	T	0
	T	0
	C	1
	A	0

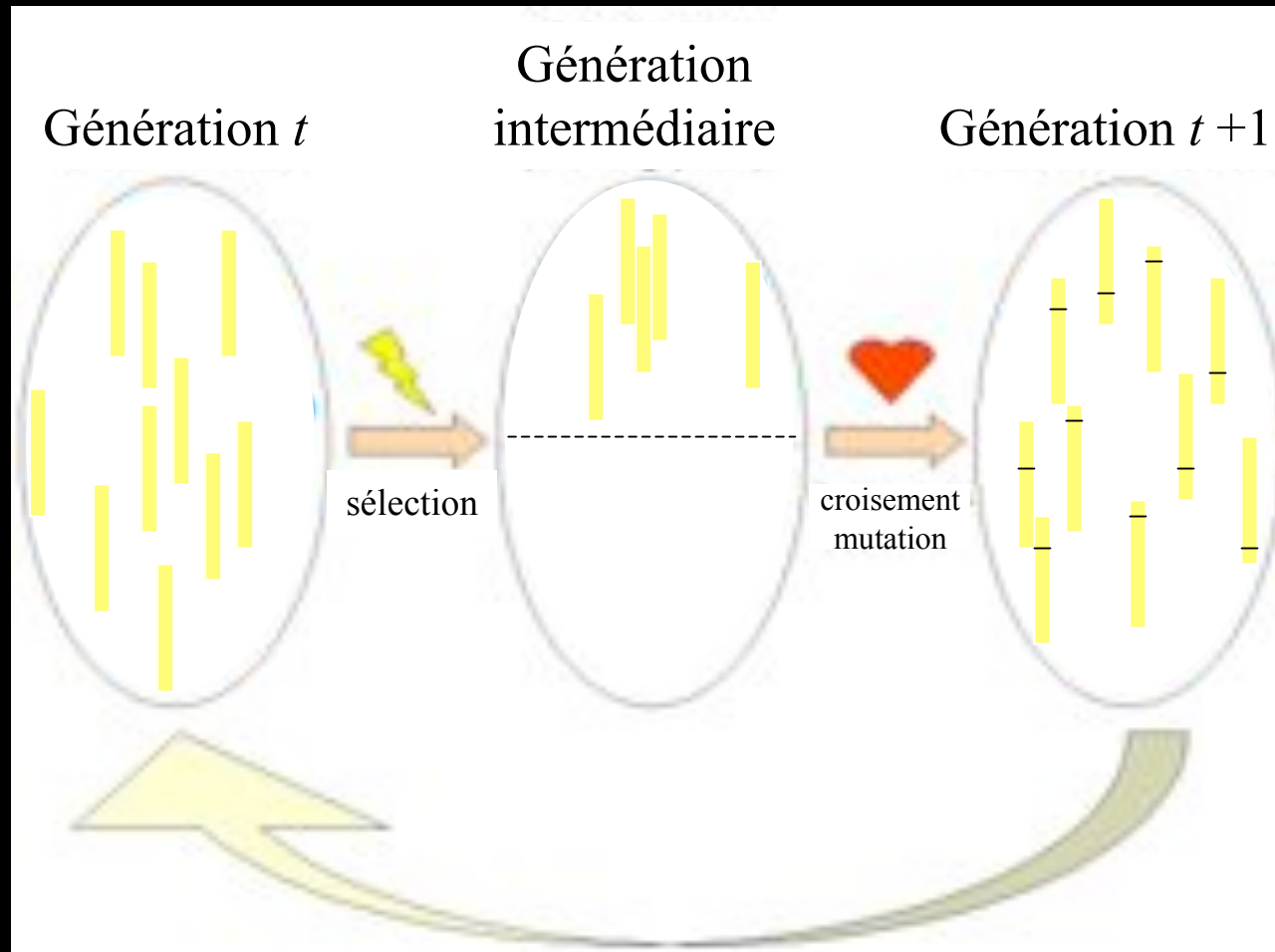


## Chromosome AGATA



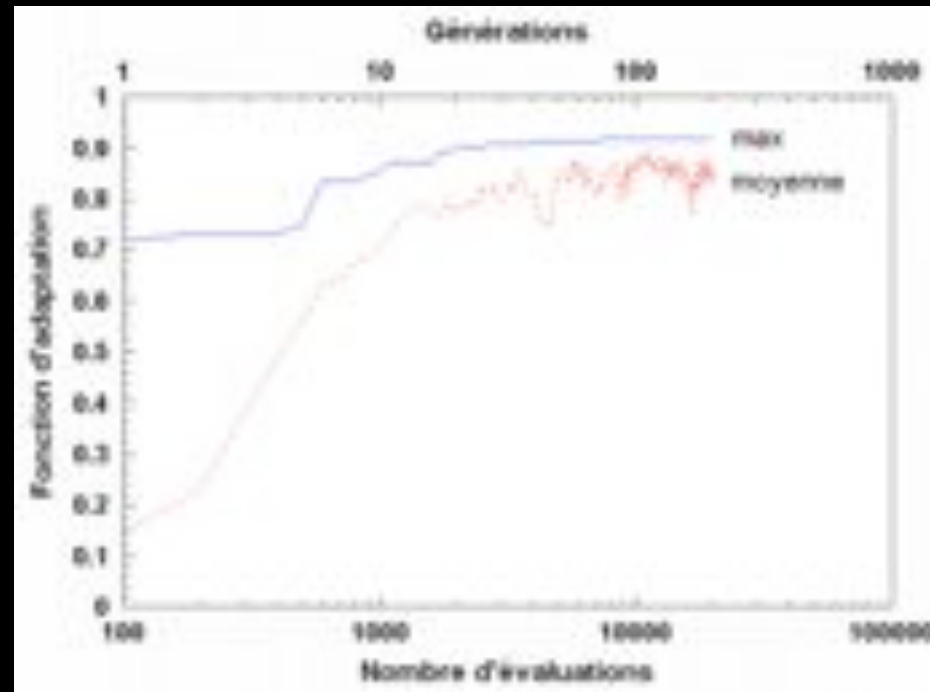
Gène 1	$x_1$
	$y_1$
	$z_1$
	$e_1$
Gène 2	$x_2$
	$y_2$
	$z_2$
Gène 3	$e_2$
	$x_3$
	$y_3$
Gène 4	$z_3$
	$e_3$
	$x_4$
	$y_3$
	$z_3$
	$e_3$

# Sélections et croisements



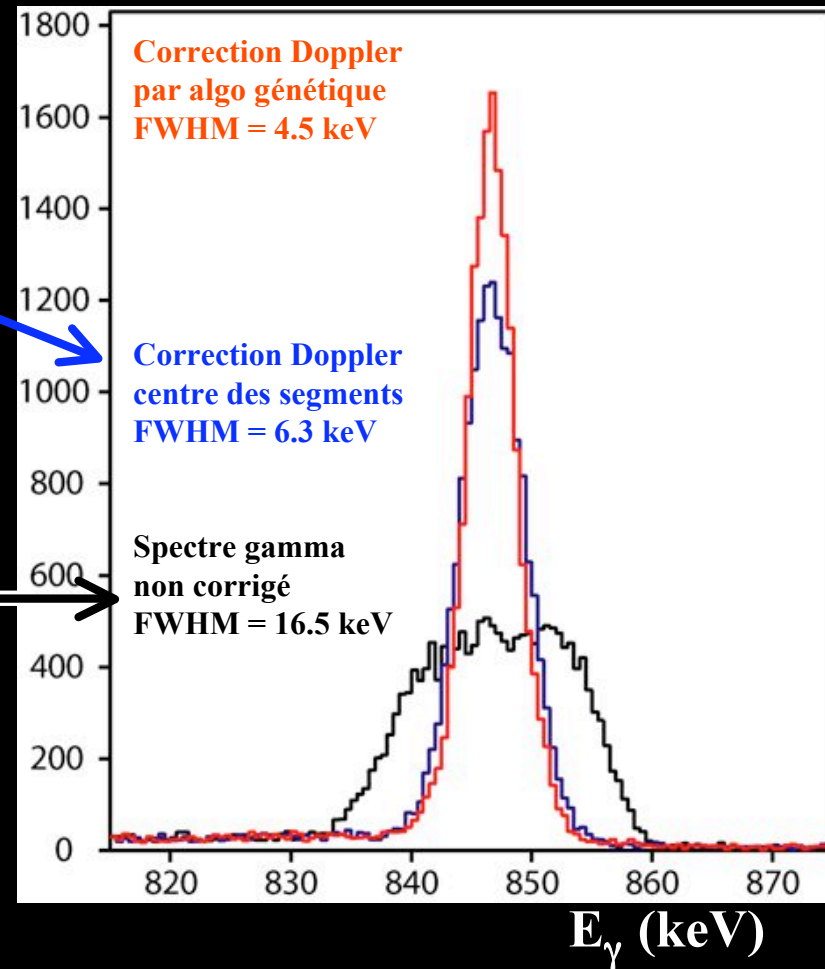
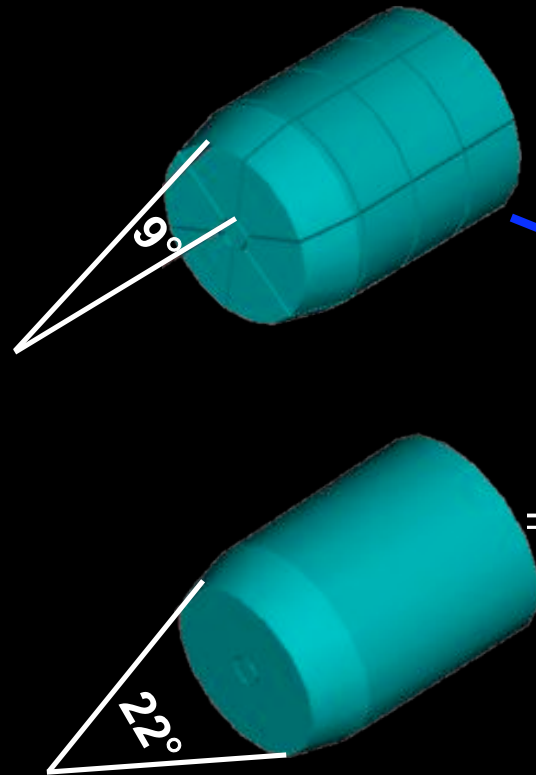
# Convergence

## Test d'arrêt



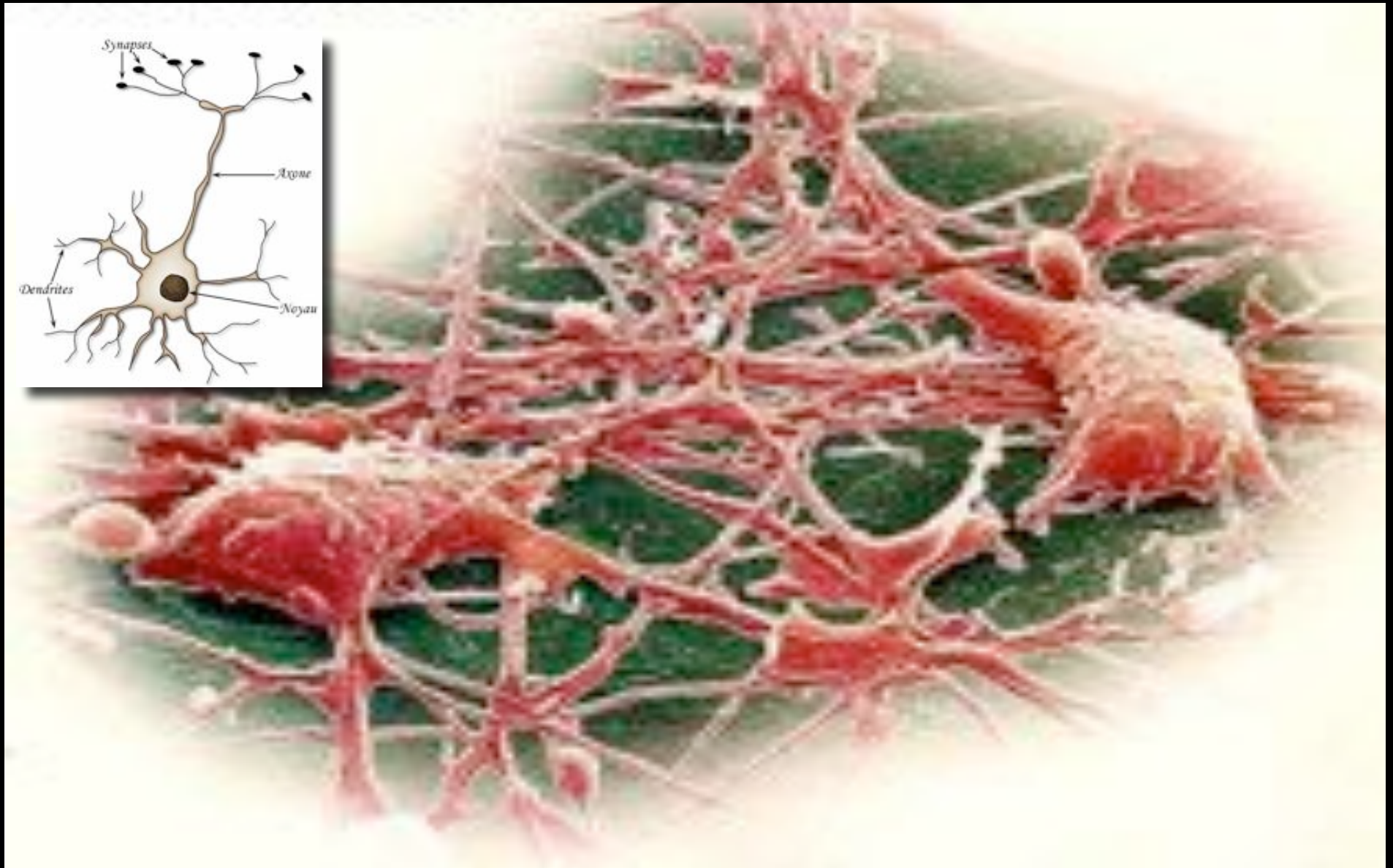
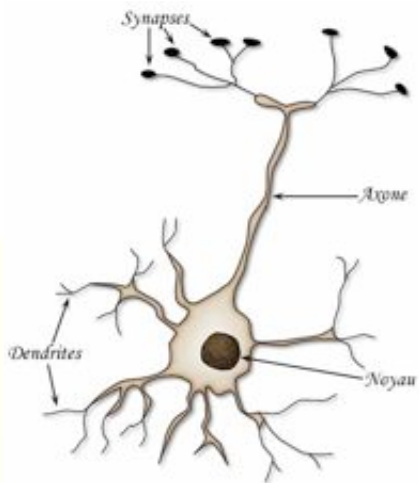
# Résultats

Résultats finals attendus :  
Tracking parfait:  
3.4 keV  
Erreur position 5 mm:  
4.2 keV

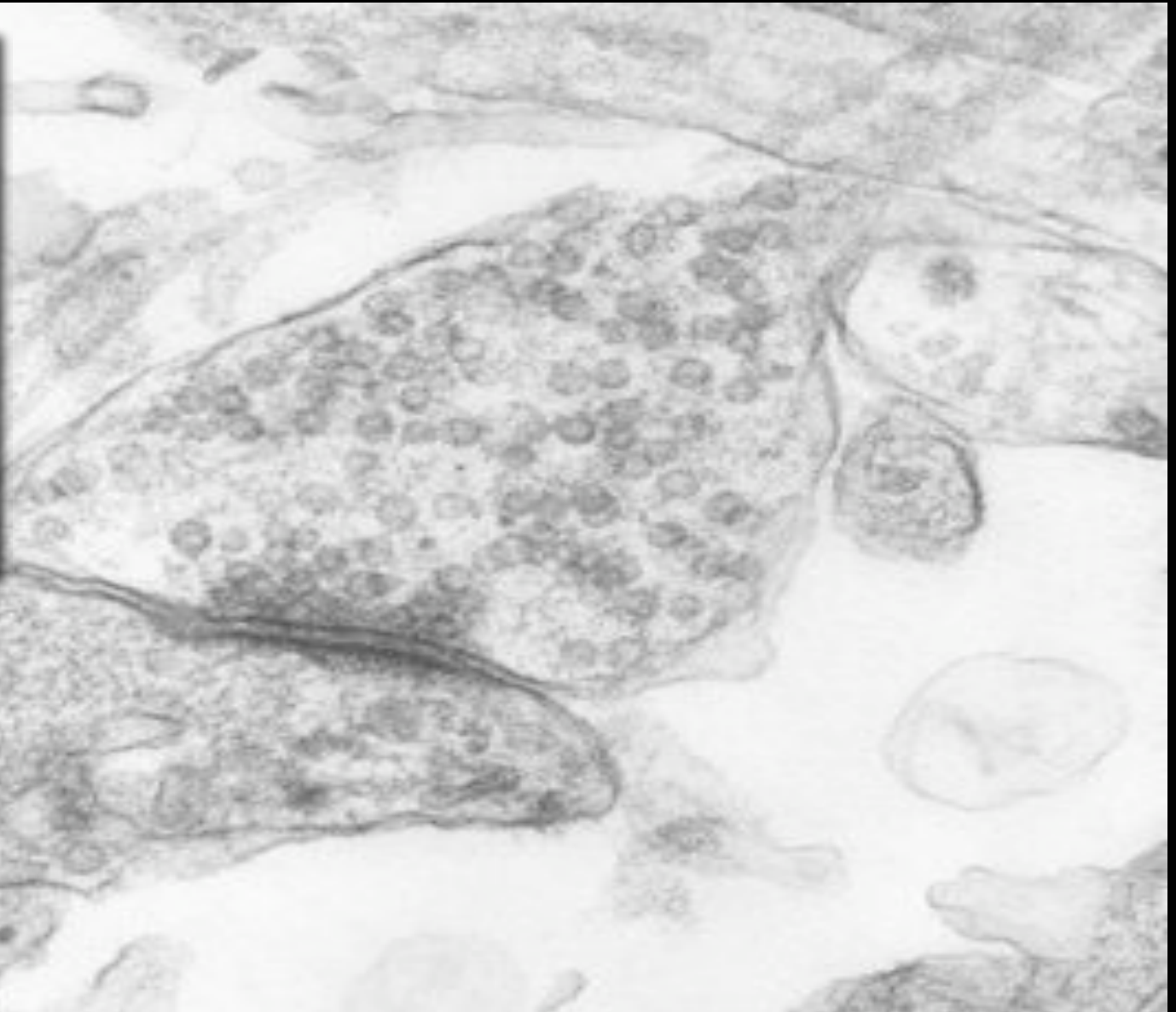
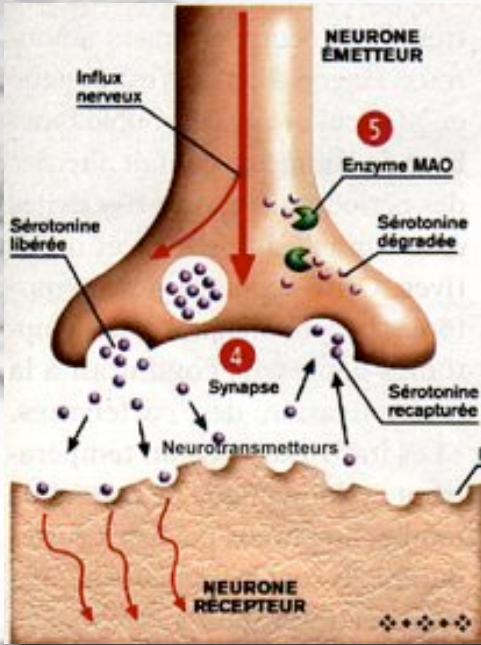


Algo génétique : erreur de 5 mm sur la position

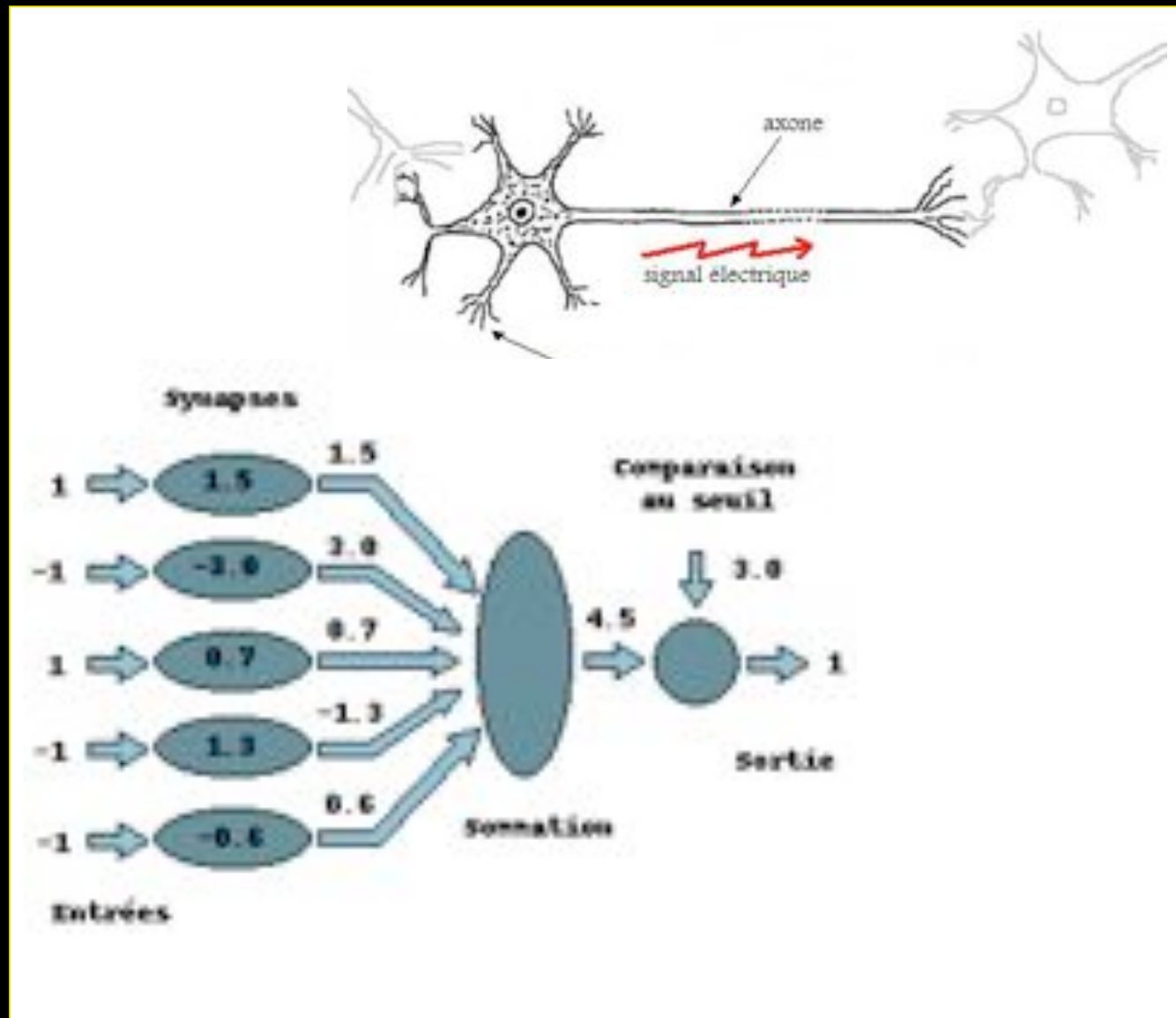
# Les neurones



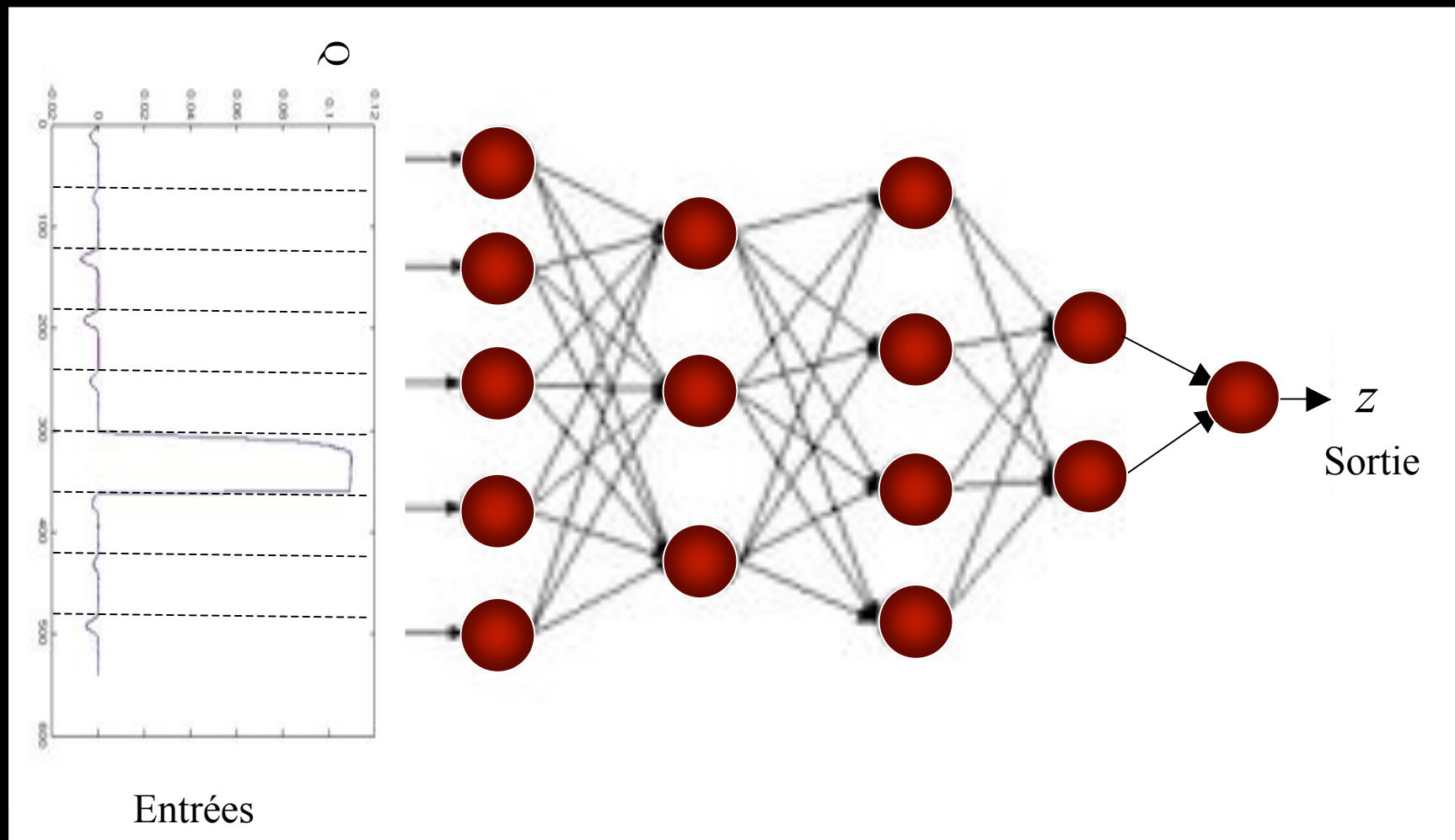
# Une synapse



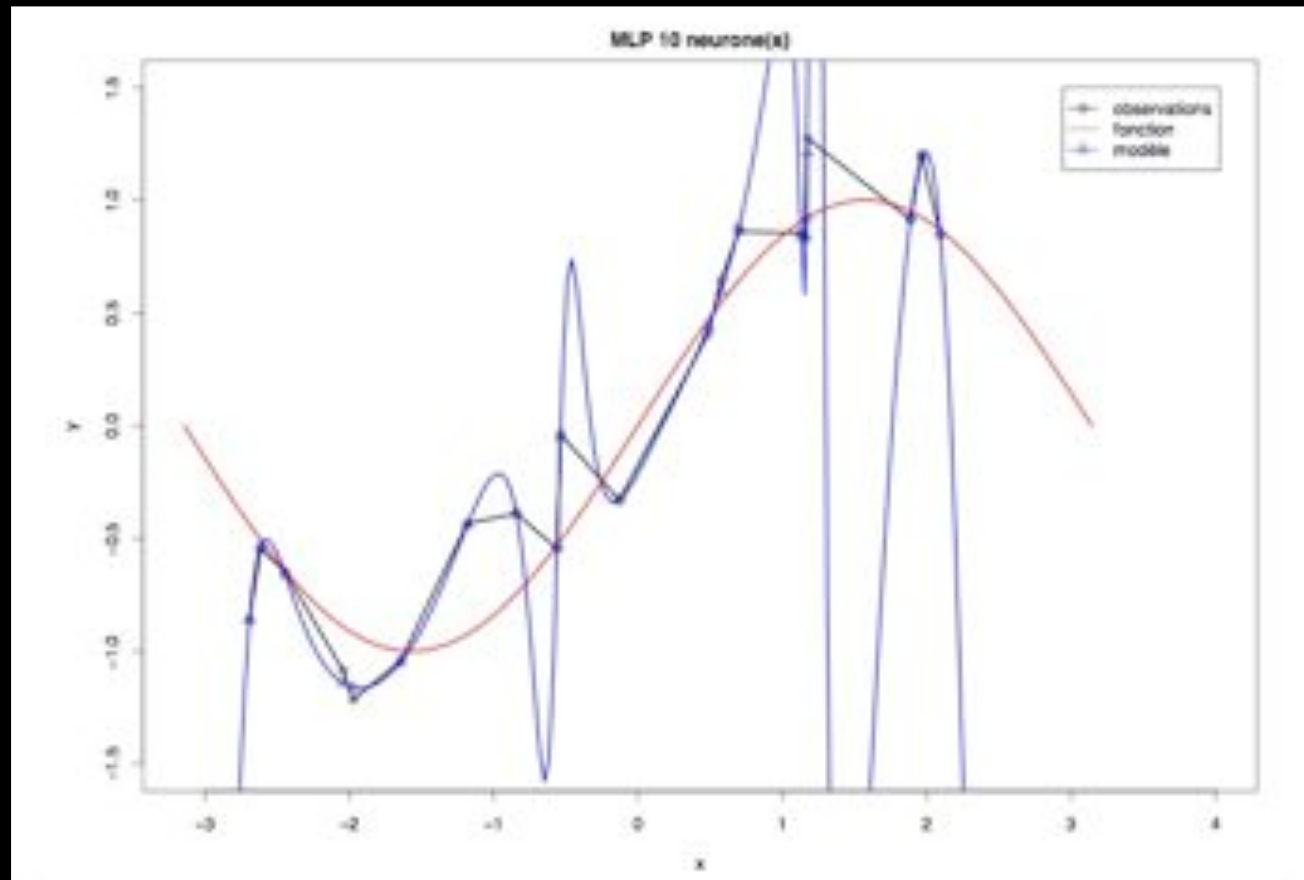
# Du neurone au perceptron



# Réseau multicouche

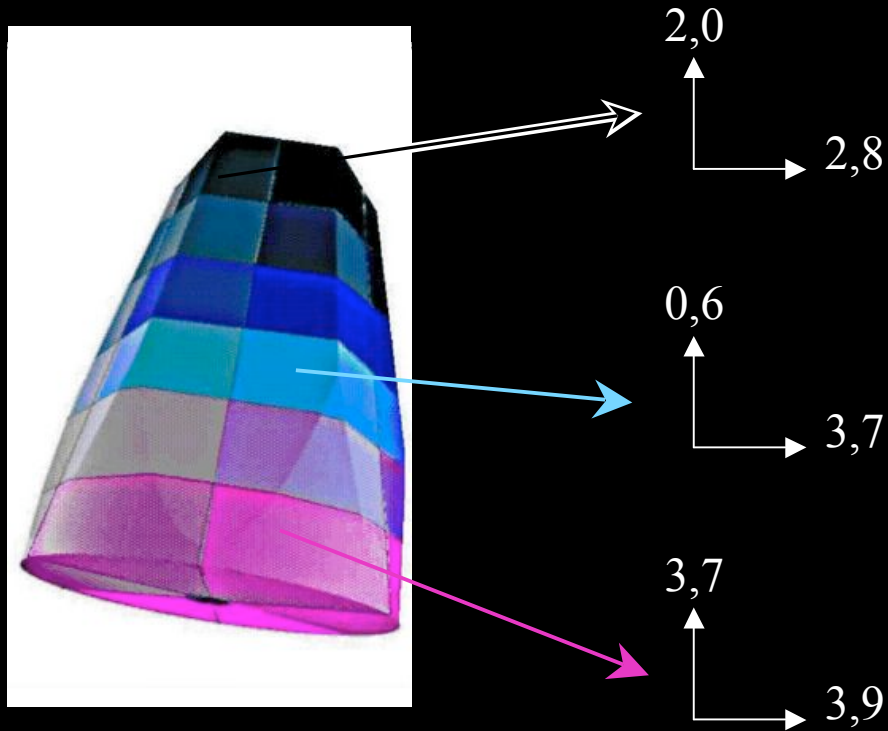


# Evolution avec le nombre de neurones



# Résultats AGATA

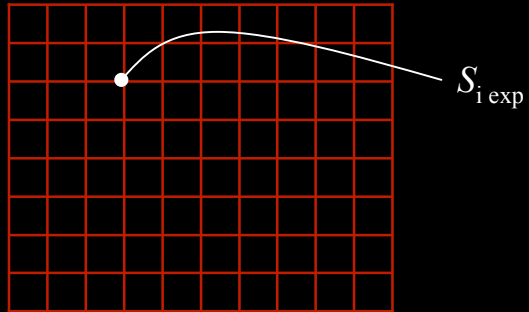
Erreur position (mm)



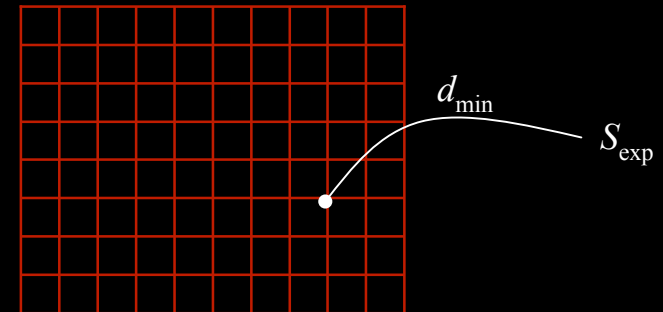
C. Diarra

# Kohonen

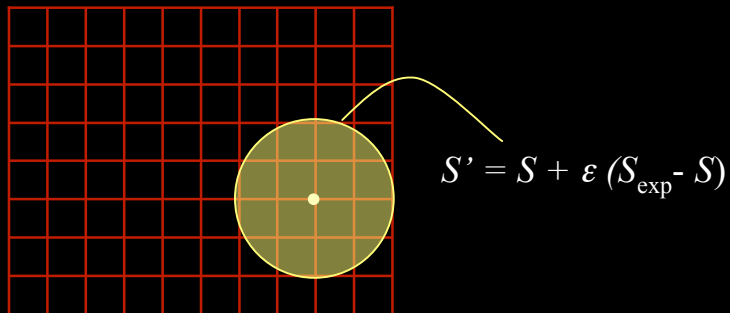
- initialisation



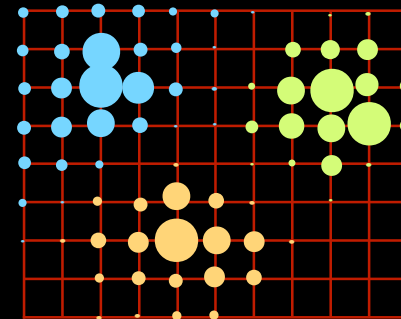
- affectation



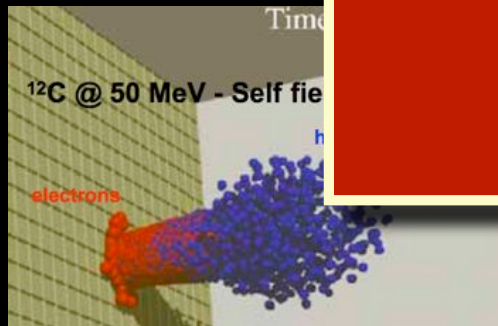
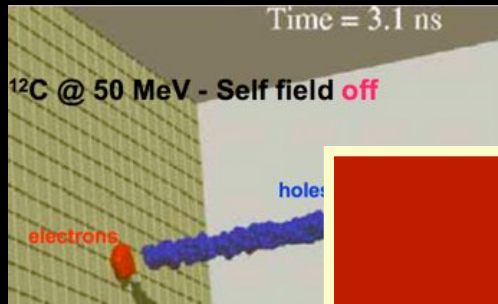
- adaptation du voisinage



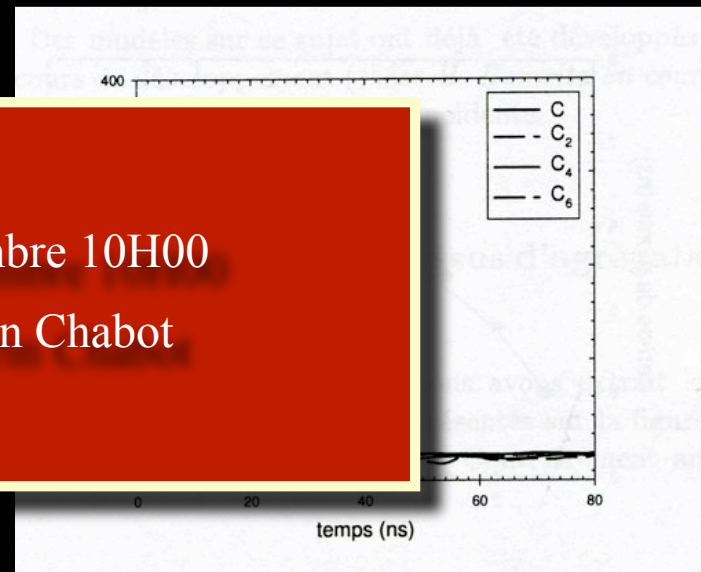
- résultats



# Classement de partitions de $C_n$



Le 19 décembre 10H00  
HDR Marin Chabot

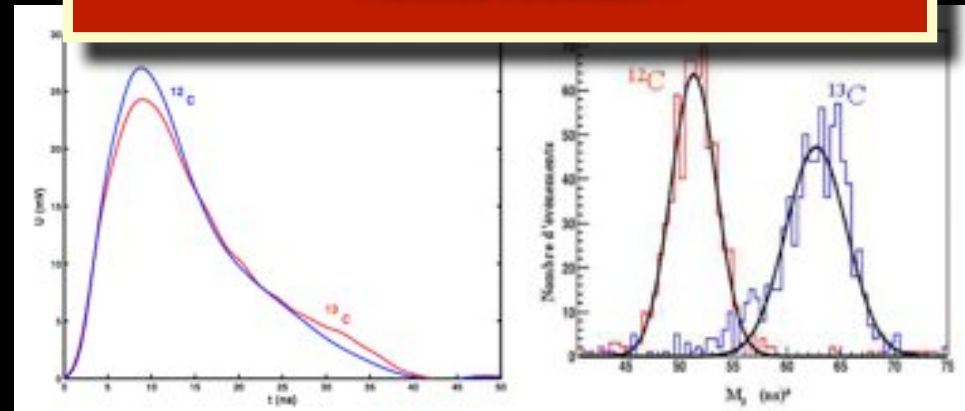


# Projet FAZIA : A, Z, E

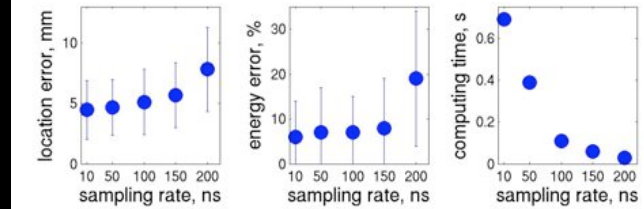
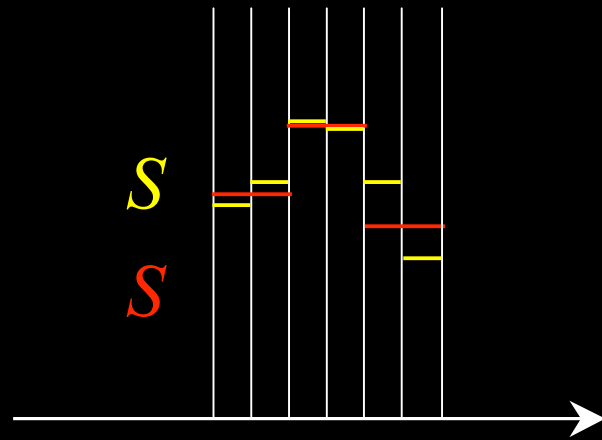


Le 15 décembre 13H30  
Caf'info Marie-France Rivet :

« Le projet FAZIA, R&D de pointe et  
vieilles recettes »



# Compactage de l'information



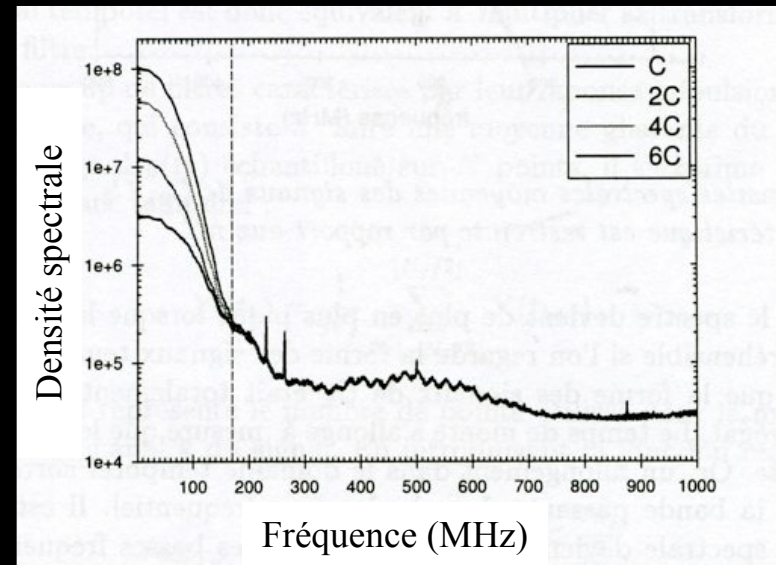
⇒ resolution is not worsen up to 150 ns bins !

# Compactage : transformée de Fourier

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(\omega) e^{i\omega t} d\omega$$
$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-i\omega t} dt = F\{x(t)\}$$

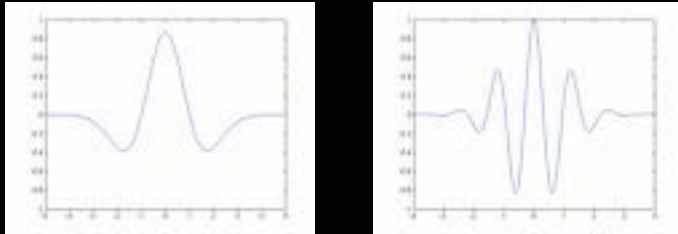
Since  $X(\omega)$  contains both imaginary and real parts, it can be written as

$$X(\omega) = |X(\omega)| e^{i\phi(\omega)}$$



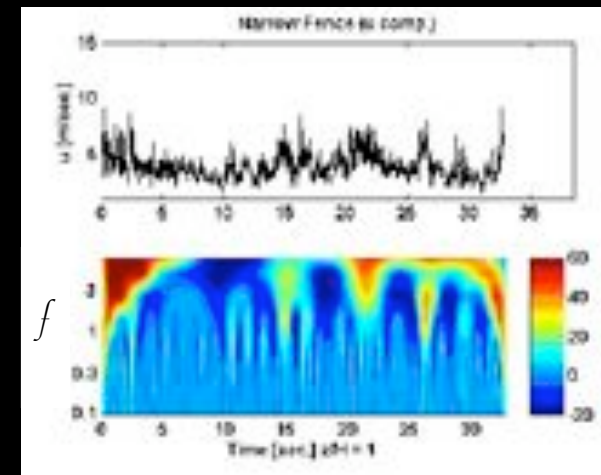
M. Chabot et al.

# Compactage : ondelettes



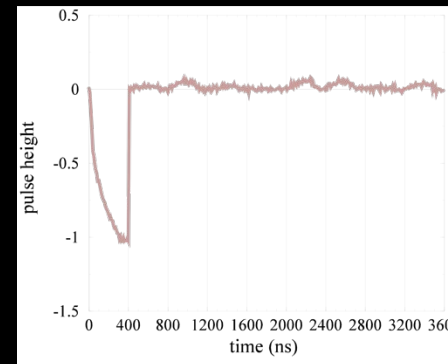
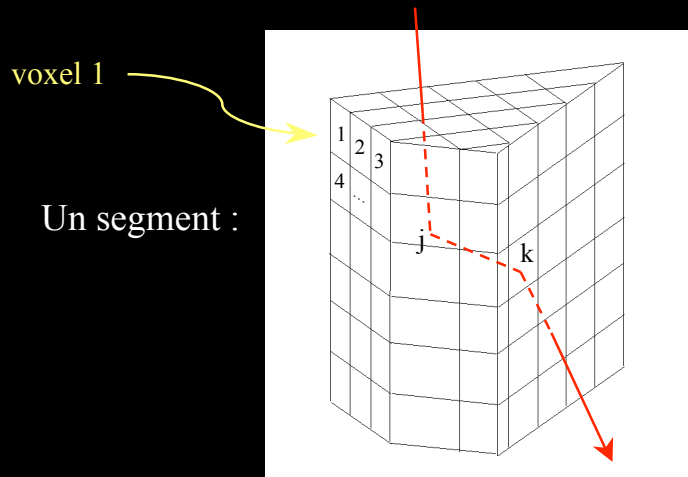
Ondelettes mères ( $\Psi$ )

$$\begin{aligned} f(t) &= \sum_{j,n \in \mathbb{Z}} \langle f, \psi_{j,n} \rangle \psi_{j,n}(t) \\ &= \sum_{n \in \mathbb{Z}} \langle f, \phi_{j,n} \rangle \phi_{j,n}(t) \\ &+ \sum_{k \leq j, n \in \mathbb{Z}} \langle f, \psi_{k,n} \rangle \psi_{k,n}(t) \end{aligned}$$



F. Lefebvre et al.

# Comment trouver la position des interactions ?



$e_j$  : dépôt d'énergie dans le voxel j

$$\begin{array}{c} 0 \\ \vdots \\ e_j \\ \vdots \\ 0 \\ \vdots \\ e_k \\ \vdots \\ 0 \end{array} \xrightleftharpoons[\mathbf{T}^{-1} ?]{\mathbf{T}} \begin{array}{c} S_1 \\ \vdots \\ S_j \\ \vdots \\ S_k \\ \vdots \end{array} = e_j S_j + e_k S_k$$

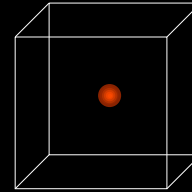
$S_j$  : signal pour un dépôt 1 dans le voxel j (donné par MGS)

→ trouver  $e_1 \dots e_n$  tel que  $S = \sum_i e_i S_i$

↔ trouver  $X$  tel que  $S = \mathbf{T} X$

# Propriétés de $S = T X$

- bruit sur  $S$  et incertitudes sur  $T$



→ réduction statistique

- $T$  mal conditionnée, problème *mal posé* (plusieurs solutions)

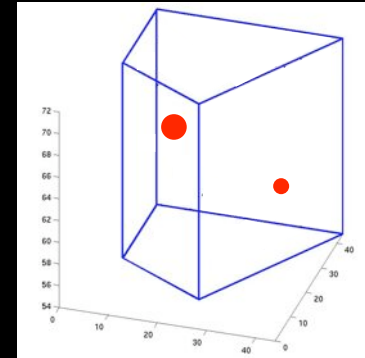
→ d.v.s.

- $X \geq 0$  (surtout des 0)

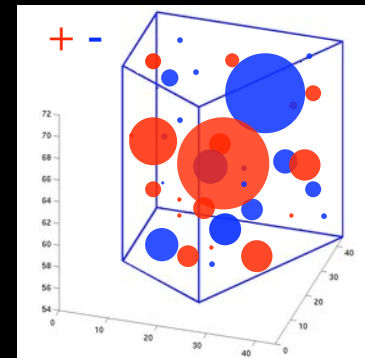
→ méthode des moindres carrés non négatifs.

# T mal conditionnée

$$\mathbf{T} X = S \longrightarrow X =$$



$$\mathbf{T} X = S + \text{bruit} (.1\%) \longrightarrow X =$$

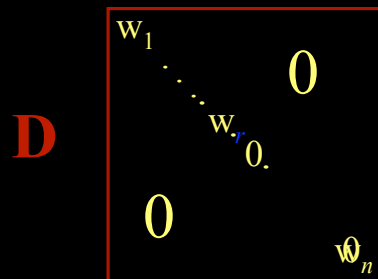
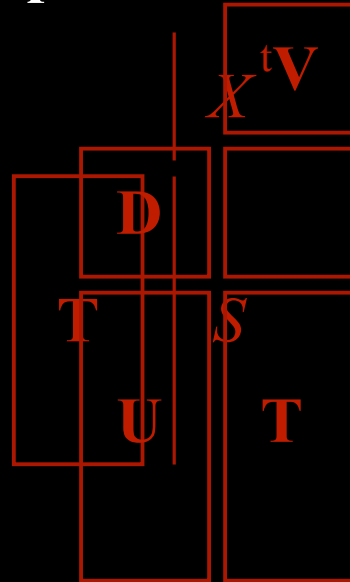


$$\Delta X \propto \text{conditionnement} \times \text{bruit}$$

# Le conditionnement

La décomposition en valeurs singulières :  $T = U D^t V$

$T, X, S, S :$

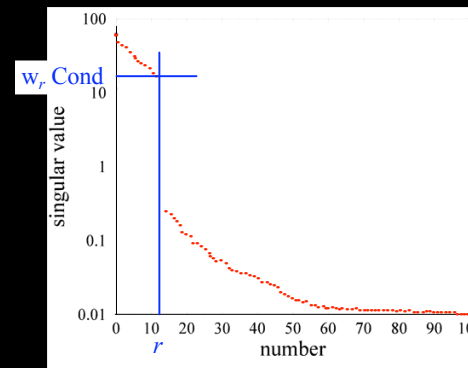


$$w_1 > \dots > w_n$$

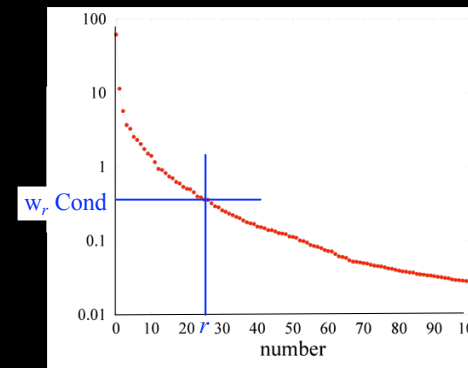
$$\text{Cond} = w_1/w_r$$

Comment choisir  $r$  ?

- rang déficient :



- mal posé (AGATA) :



# Comment utiliser la d.v.s. ?

## équations

$$TX = S$$

$$T = U D V^t \quad (\text{d.v.s.})$$

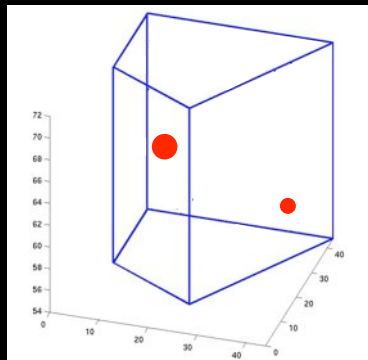
$$T'X = S$$

$$U'U'D'V^tUX = U'S$$

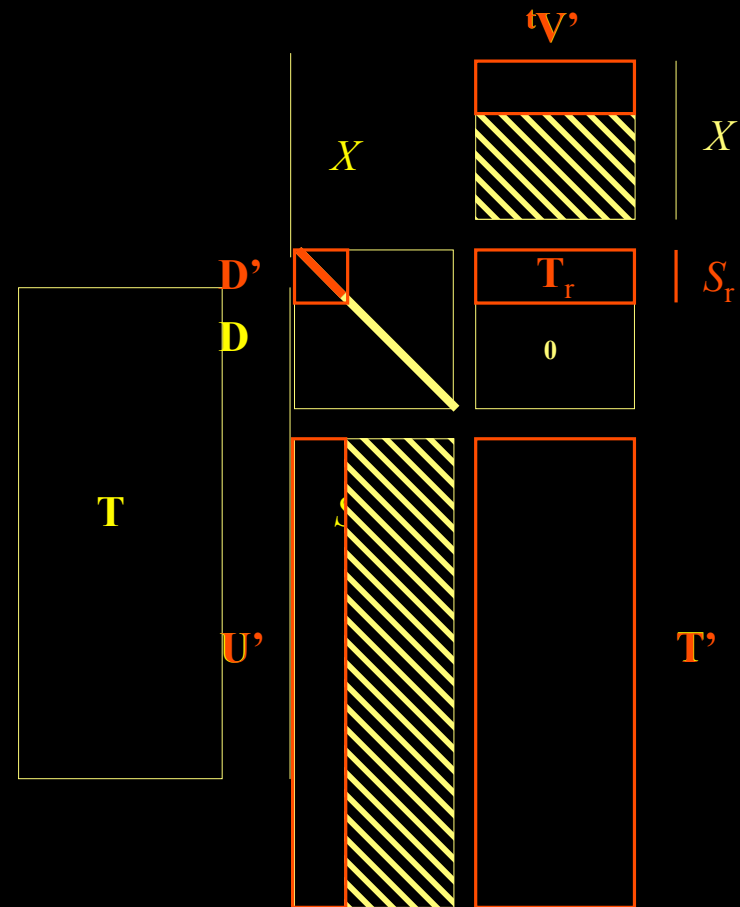
$$T_r X = S_r$$

## résultats ( $S$ bruité .1%)

$X =$

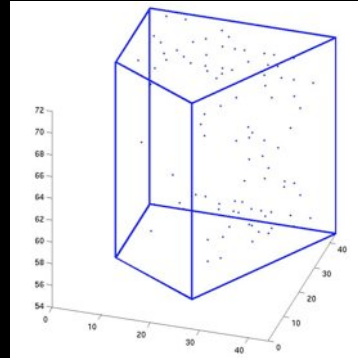


## matrices

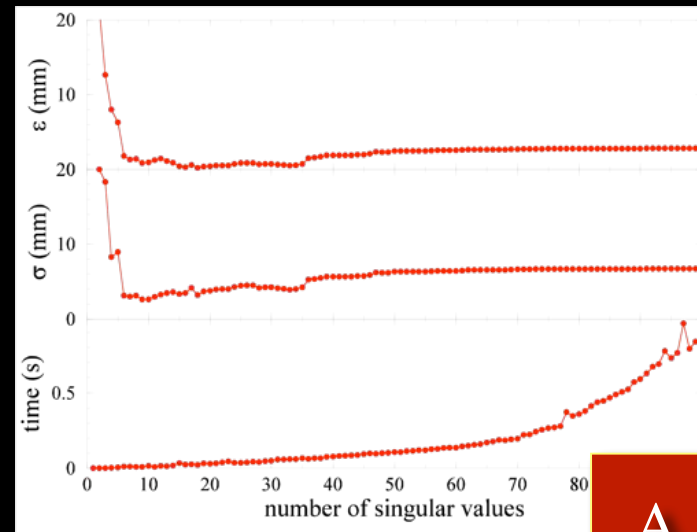
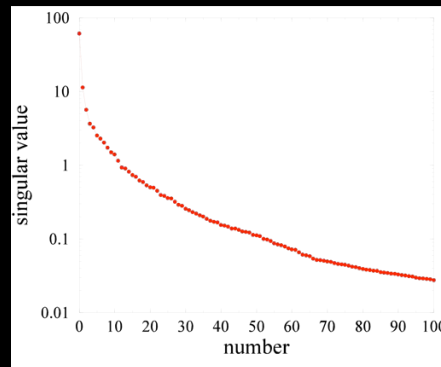


# Améliorations de T

Réseau irrégulier (adapté à la sensibilité) :



Décomp. en valeurs singulières de T :

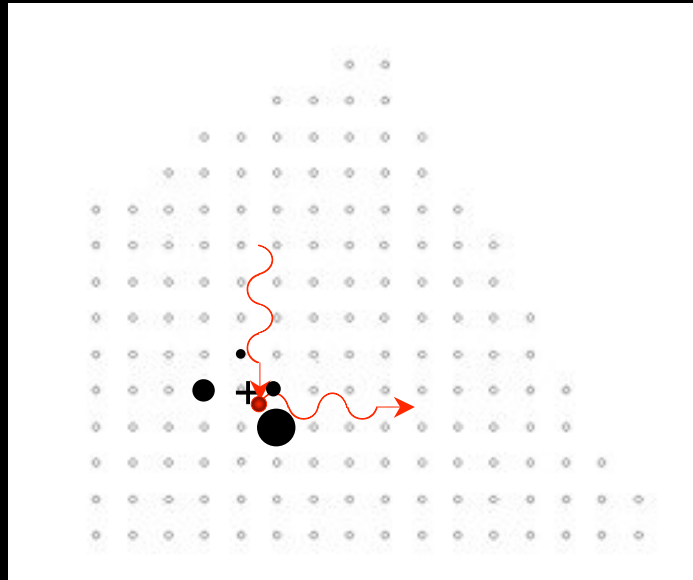


A. Olariu

→ Ne garder qu'environ 20 valeurs singulières

# Résultats avec des signaux simulés (MGS)

Une seule interaction :

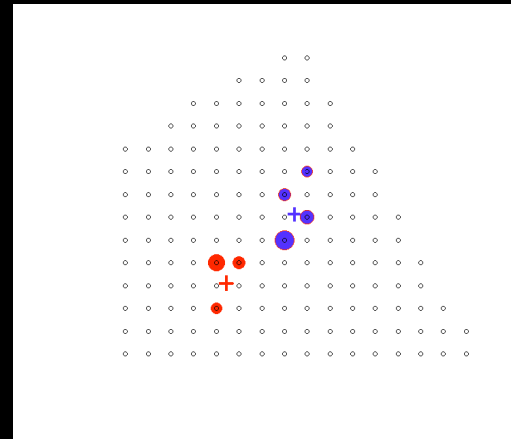


Performances :

- $\delta$  (localisation) = 2 mm
- $\delta$  (énergie) = 0.1 %
- $t$  (Matlab) = 20 ms

# Résultats pour deux interactions

méthode des centres mobiles :

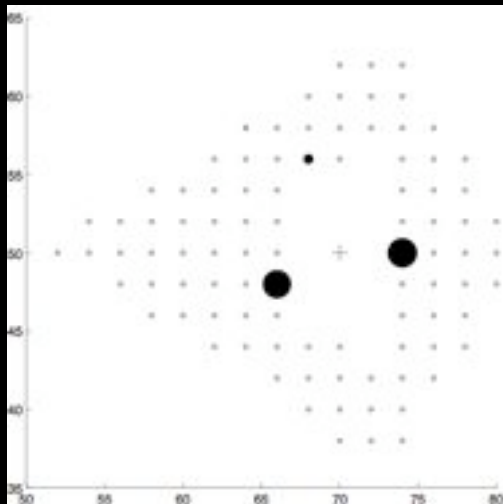
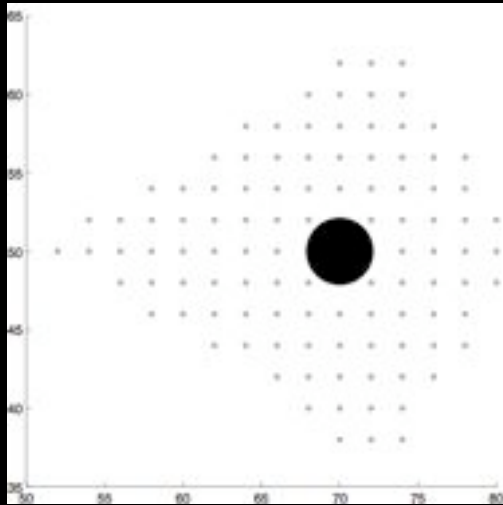


Performances :

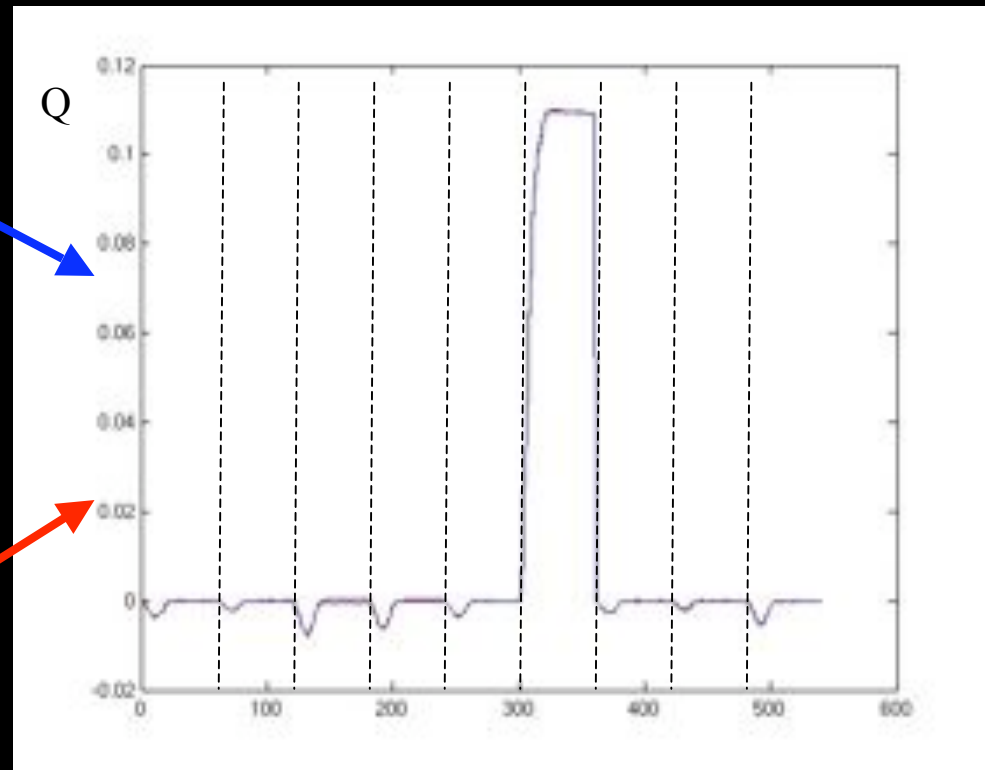
- $\delta$  (location) = 7 mm
- $\delta$  (energy) = 5 %
- $t$  (Matlab) = 100 ms

# Linéarité $\Rightarrow$ indétermination

localisation

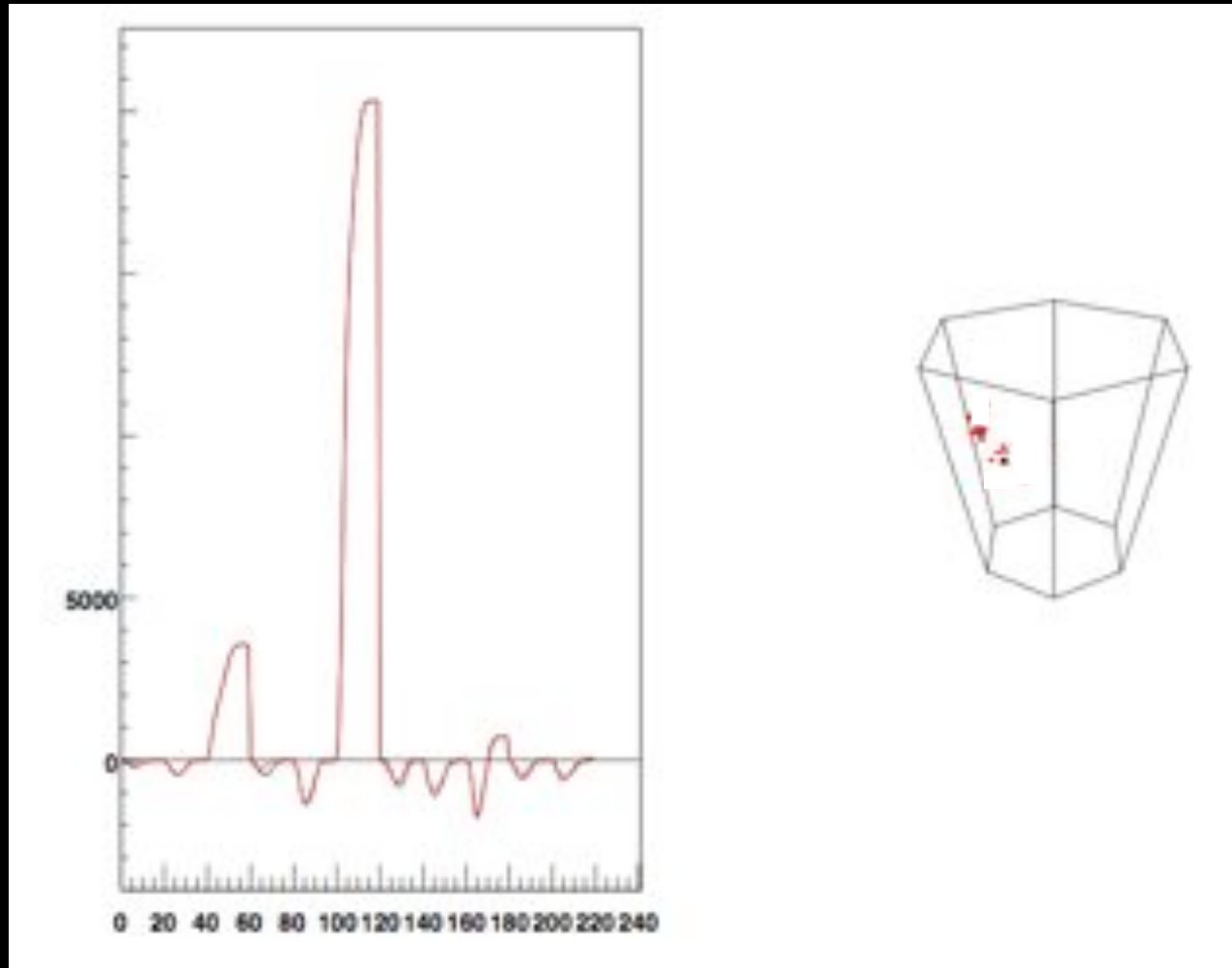


signaux



Problème indéterminé

# Résultat typique



# Conclusions

- Ne pas sur-estimer l'IA
- Traitement mathématique avant I.A.
- AGATA, problème difficile résolu sans I.A.