Development of the Gamma tracking algorithm for SuperNEMO

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CPPM

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Summary

I) The SuperNEMO experiment

II) Different kind of background noise

III) The GammaTracking

IV) Estimation of the errors

V) Ongoing analysis of ^{208}Tl

VI) Conclusion and perspective

I) The SuperNEMO experiment

International Collaboration

SuperNEMO

Modane's Underground laboratory

Objectives:

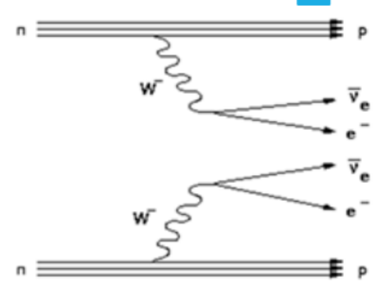
Neutrinos nature
Mass hierarchy

Rare decay:

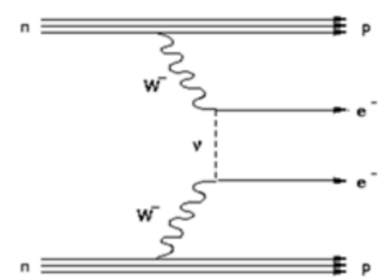
$T_{1/2} > 10^{25}$ years

Need a deep understanding of the background

Neutrinoless double beta decay



Désintégration Double béta « classique »

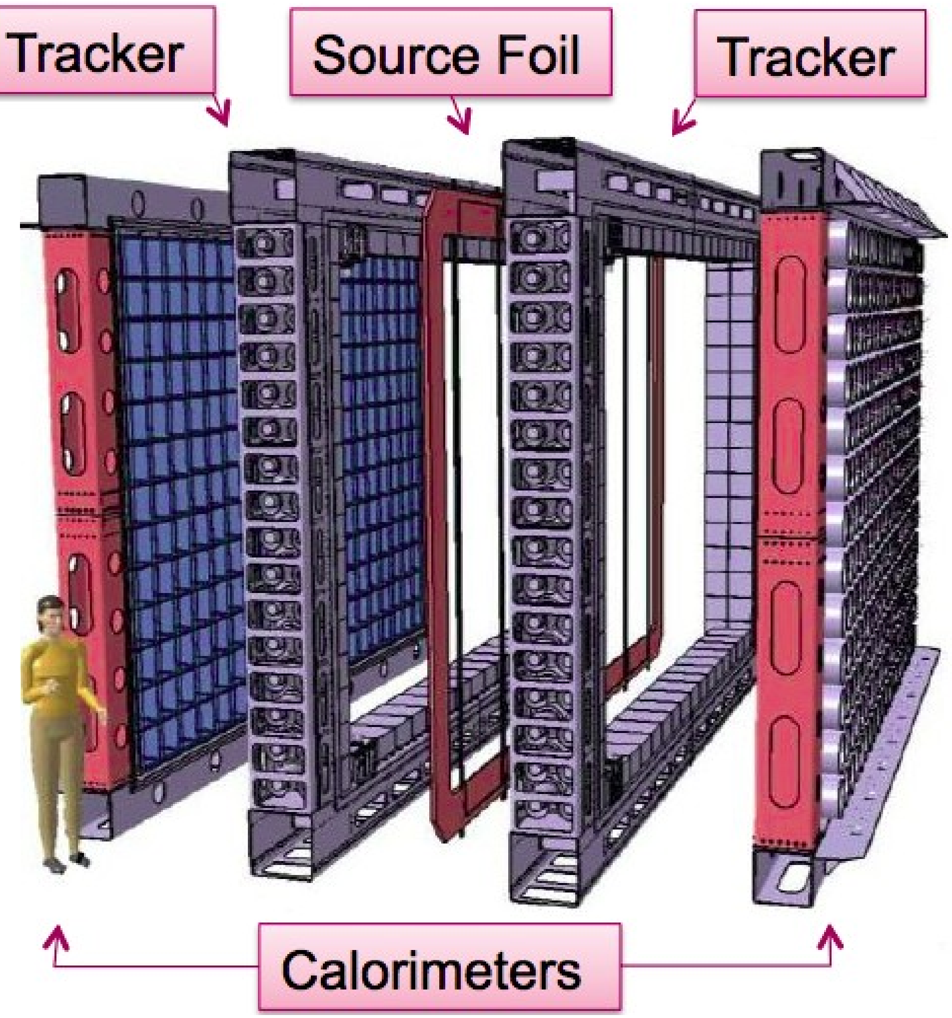


Désintégration Double béta sans neutrinos

I) The SuperNEMO experiment

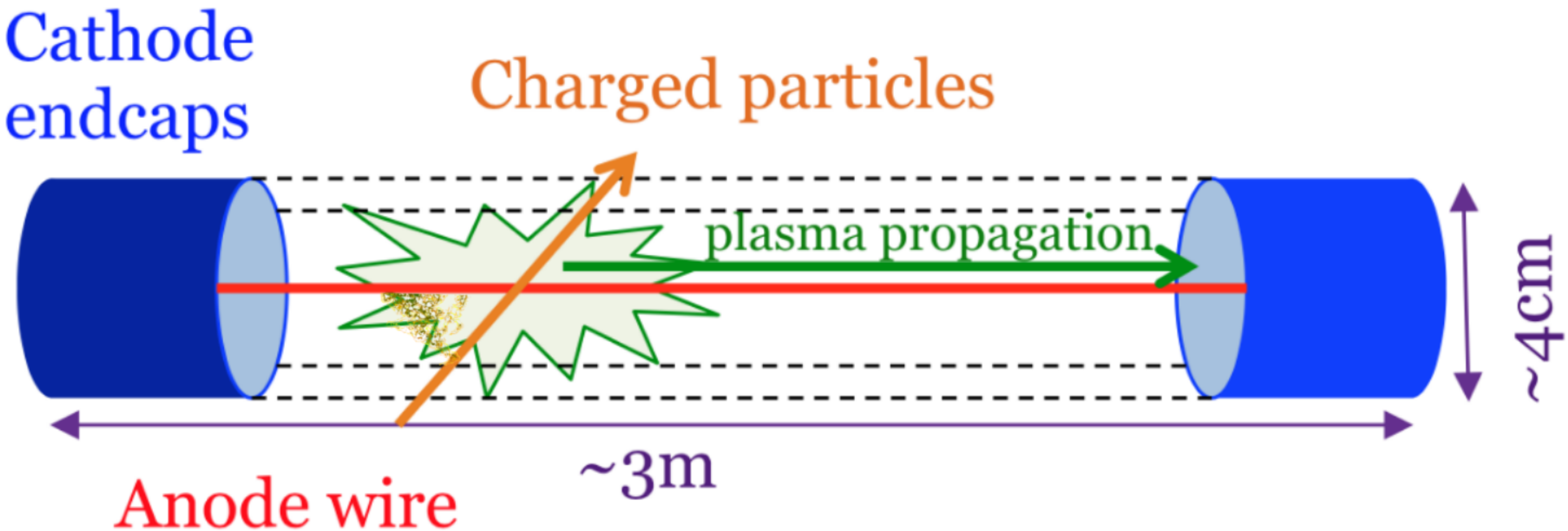
International Collaboration
SuperNEMO
Modane's Underground laboratory

Neutrinoless double beta decay



I.1) SuperNEMO tracker

Made of multiple Wire chambers



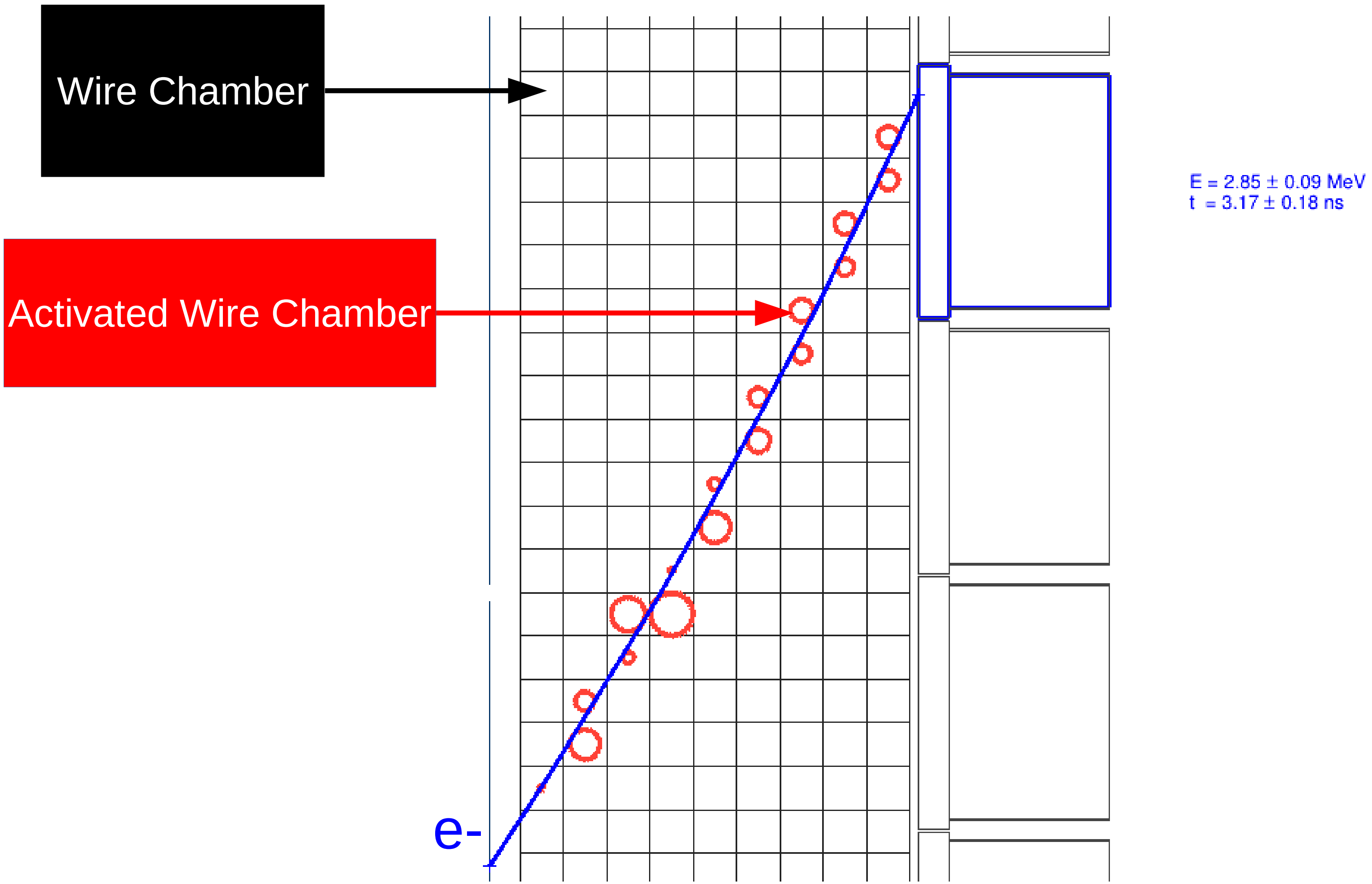
Gas: 94% Helium + 5% Alcohol + 1% Argon

Mode: Geiger

No energy measurement
3D position measurement

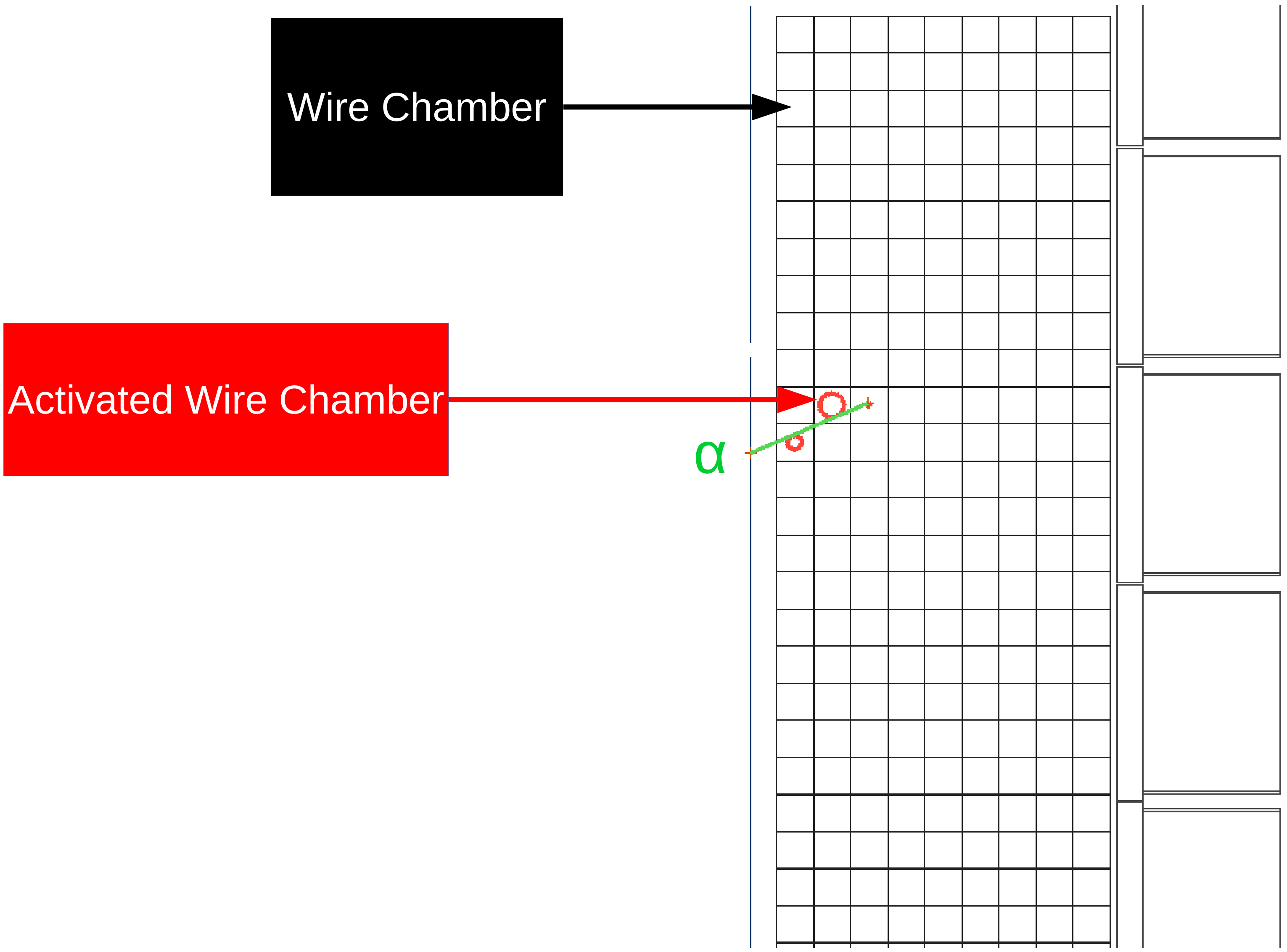
I.1) SuperNEMO tracker

Simulation of an e- from the source foil



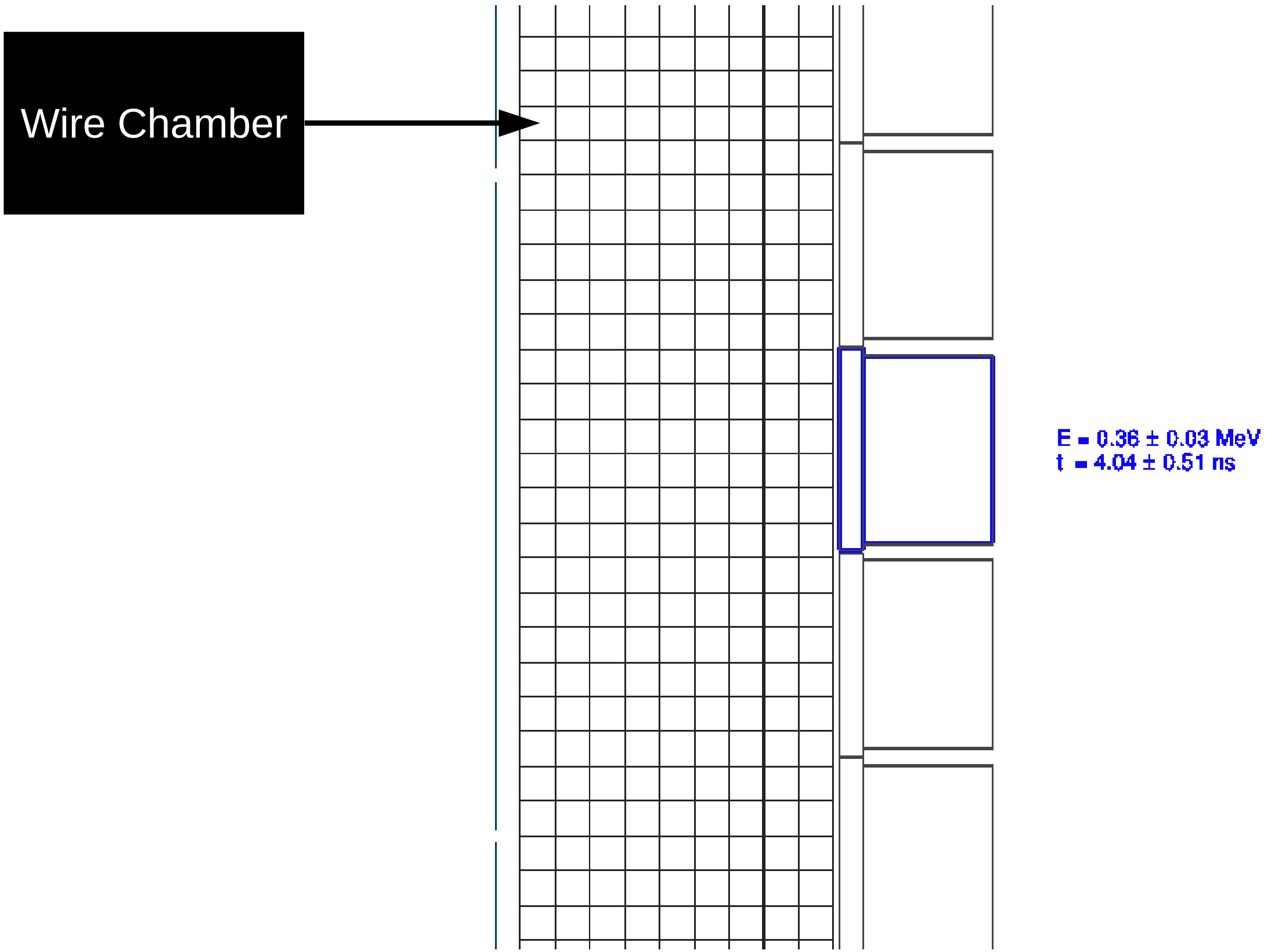
I.1) SuperNEMO tracker

Simulation of an alpha from the source foil



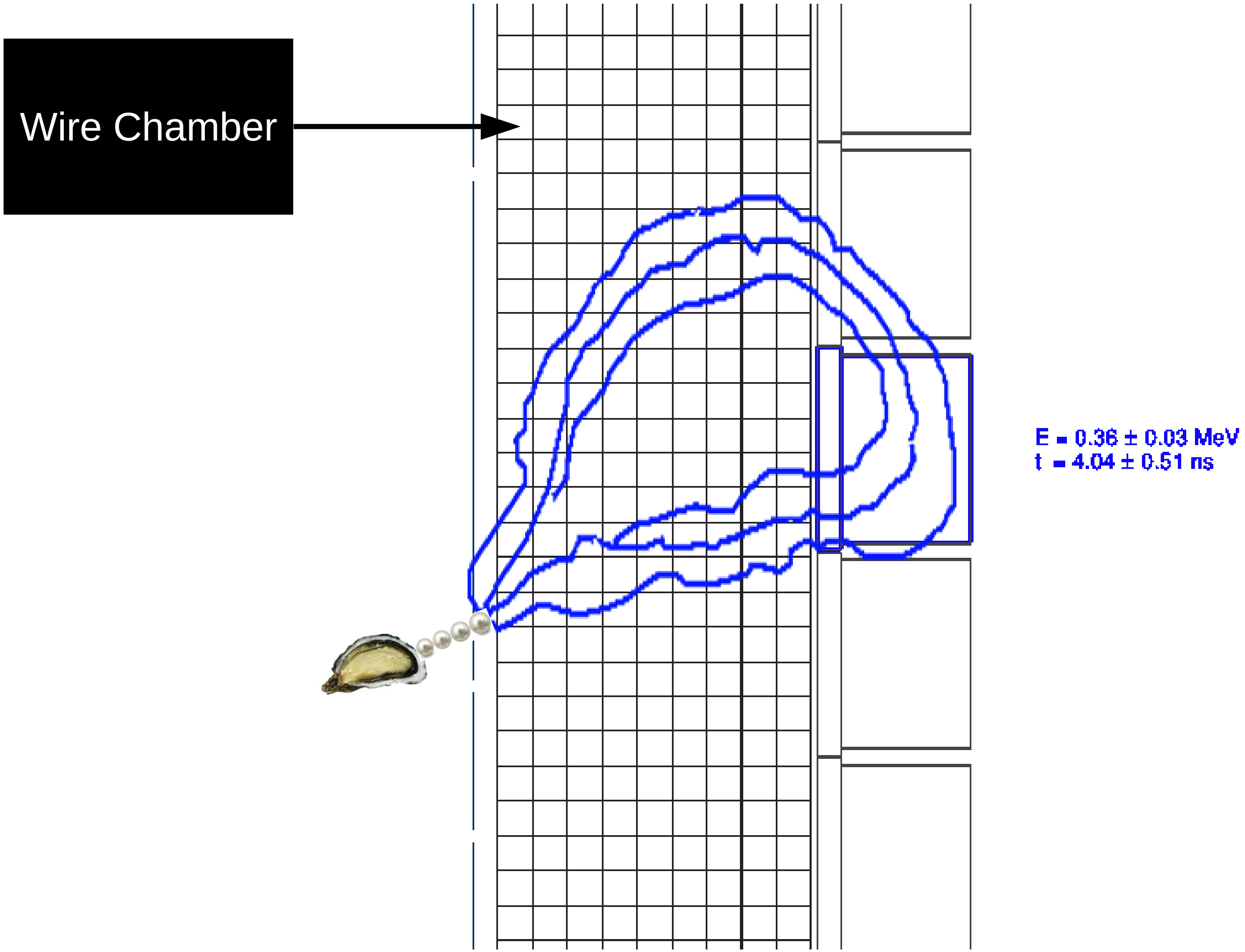
I.1) SuperNEMO tracker

Simulation of a gamma from the source foil



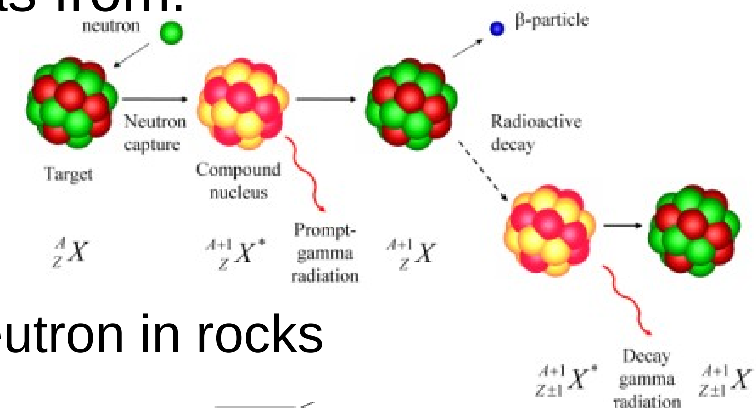
I.1) SuperNEMO tracker

Simulation of an oyster from the source foil



II) Different kind of background noise

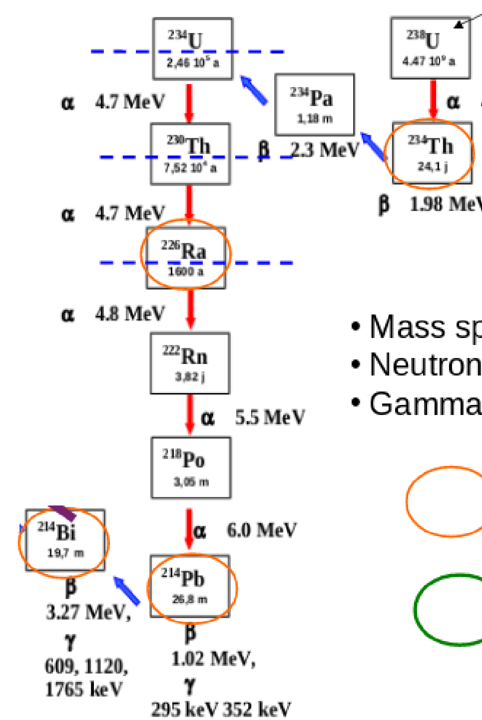
External Background mainly composed of gammas from:



Neutron capture (6-10 MeV)
Uranium & Thorium decay chain (4-6 MeV)
Weak muon cosmic rays flux producing thermal neutron in rocks

Internal Background:

^{208}Thallium (2.6 MeV)
^{214}Bismuth (0.6, 1.12 & 1.76 MeV)
^{222}Radon

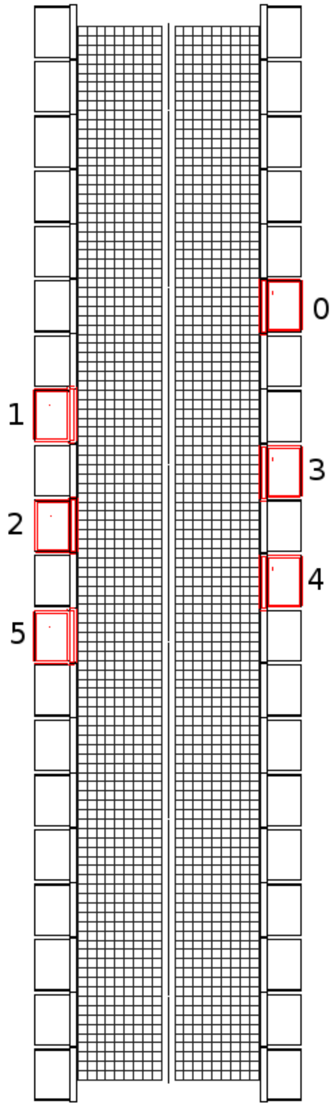


- Mass spectrometry
- Neutron Activation Analysis
- Gamma spectrometry

Gamma active nuclide

Sub-chains

III) The GammaTracking



Calcul of X_{12}^2

$$\chi^2 = \frac{\left(\left(t_2^{exp} - t_1^{exp}\right) - \frac{l_{1\to 2}}{c}\right)^2}{\sigma_{t_1}^2 + \sigma_{t_2}^2 + \sigma_l^2}$$

Calcul of P_{12}

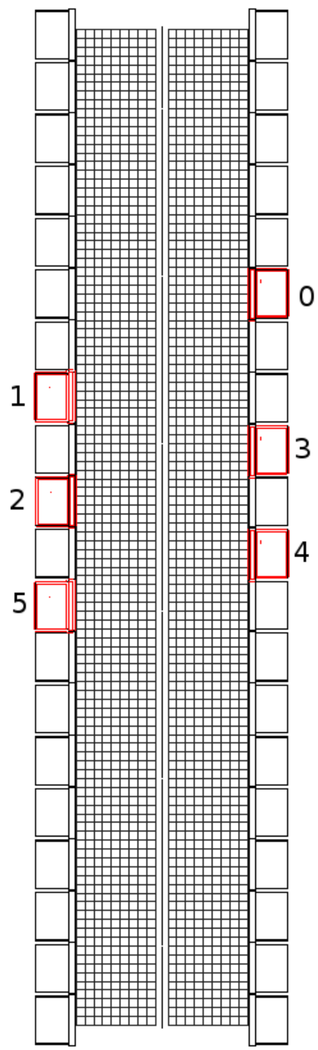
$$P(\chi^2) = 1 - \frac{1}{\sqrt{2\pi}} \int_0^{\chi^2} x^{-1/2}\, e^{-x/2}\, dx$$

0

!=0

III) The GammaTracking

Probability is not necessary and only indicative of the errors’ estimation



Calcul of P_{12}

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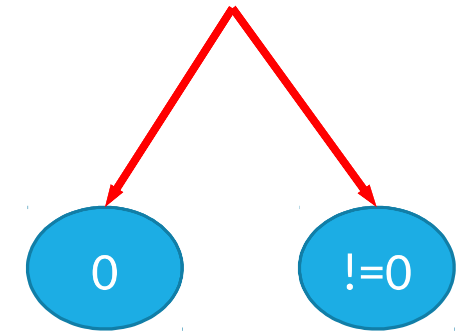


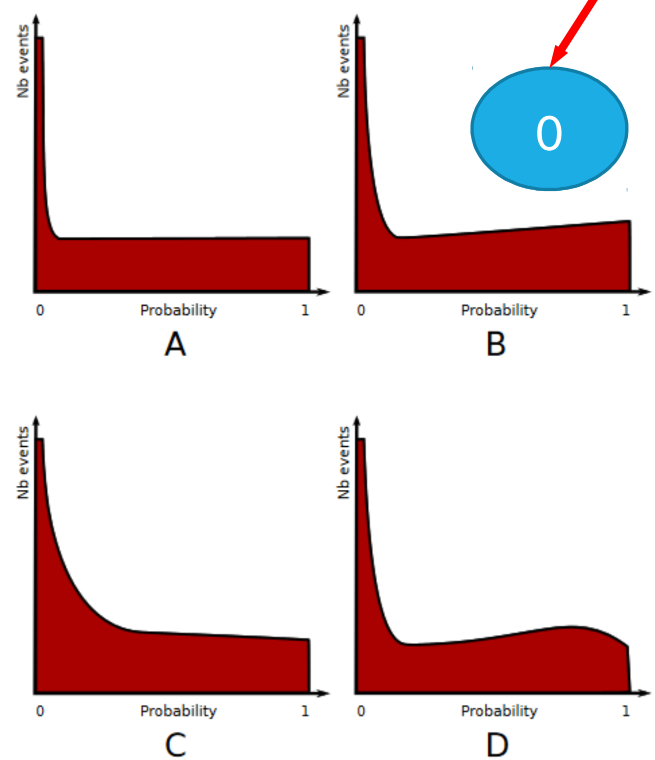


FIGURE 4.4.4: Probabilités pour une hypothèse donnée d’un jeu de données. Normal (A), surestimation de σ_{tot} (B), erreur dépendante d’un paramètre pour le calcul de σ_{tot} (C), erreur structurelle et dépendante du temps pour le calcul de σ_{tot} (D).

III.1) How does it work

I) Initialization

calculation of the χ^2 and probability of all the calorimeter pair

$$\chi^2_{12} = \frac{((t_2 - t_1) - t_{th})^2}{\sigma^2_{t1} + \sigma^2_{t2} + \sigma^2_{l}}$$

II) Combination

calculation of all the combination χ^2 and probability

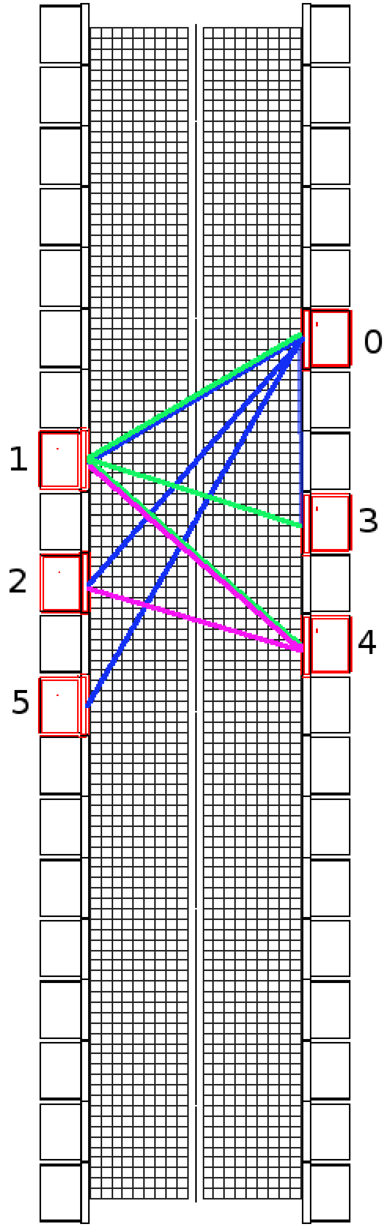
$$\chi^2_{123} = \chi^2_{12} + \chi^2_{23}$$

$$P(\chi^2) = \frac{1}{2\Gamma(\nu/2)} \int_{\chi_0}^{\infty} (x/2)^{\nu/2-1} exp(-x/2) dx$$

With ν = ndf

III) Selection

III.2) GammaTracking: Initialization



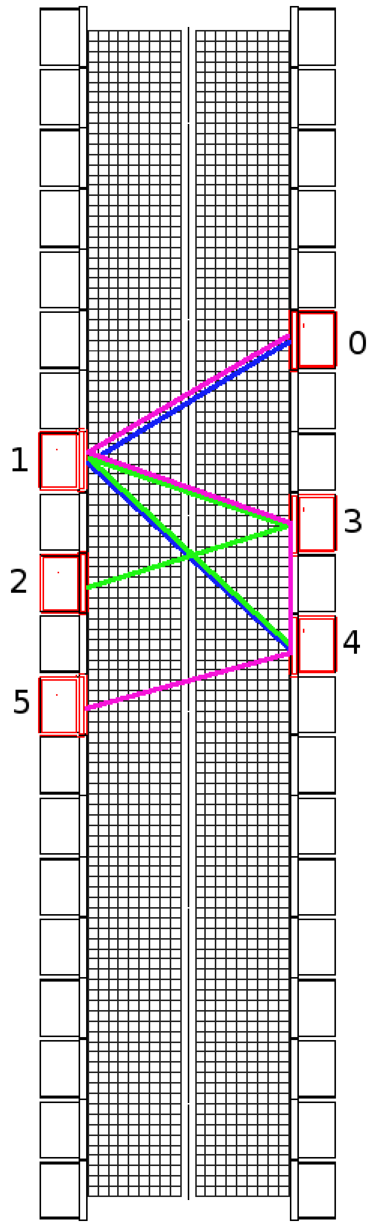
- Calculation of all pairs χ^2

$$\chi^2_{12} = \frac{((t_2 - t_1) - t_{th})^2}{\sigma^2_{t1} + \sigma^2_{t2} + \sigma^2_l}$$

$\sigma^2_{t1} \rightarrow$ is the error given by falaise (get_time_error())

$\sigma^2_l \rightarrow$ is the error due to the geometry

III.3) GammaTracking: Combination



- Calculation of all the combinations χ^2

$$\chi^2_{123} = \chi^2_{12} + \chi^2_{23}$$

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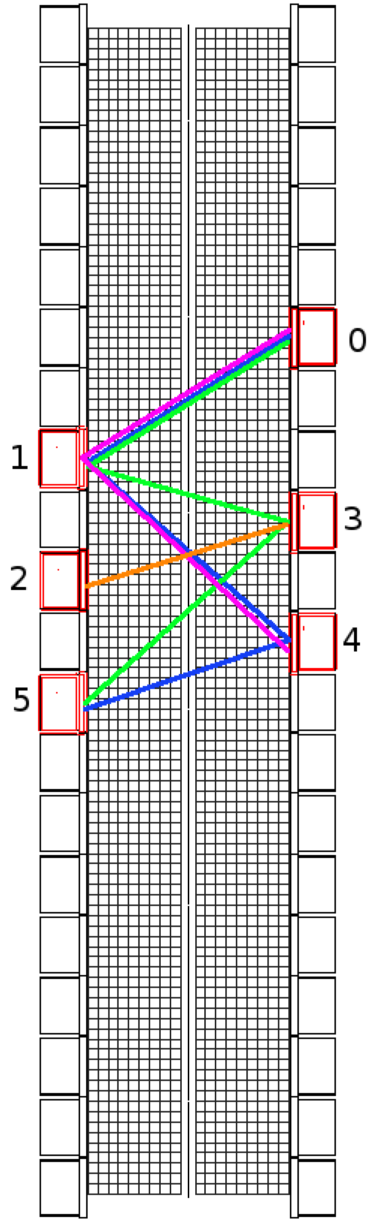
With ν = ndf

III.4) GammaTracking: Selection

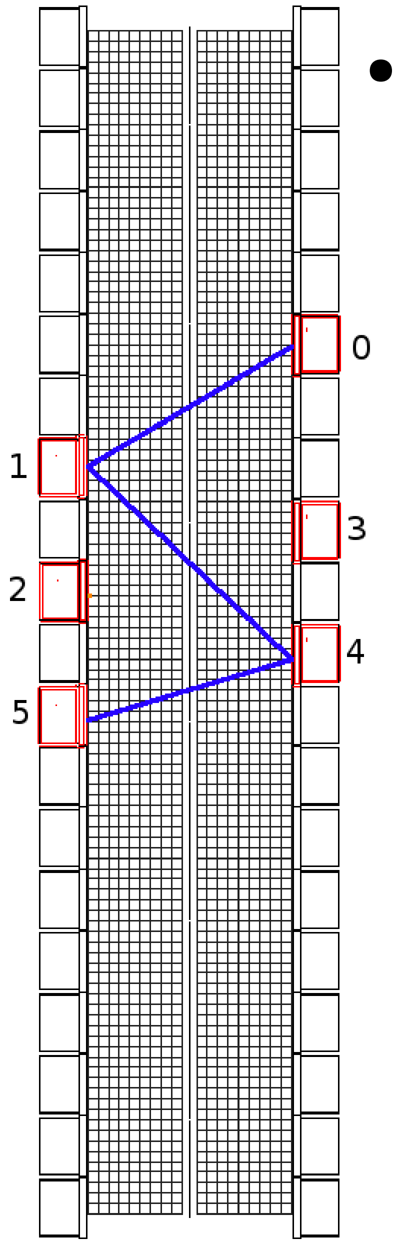


- Criteria of selection:
    1) Probability > User Probability cut
    2) Length of the combination
    3) Probability

Possible combination :

<0 1 4 5> → Most probable
<0 1 3 5>
<0 1 4>
<1 4 5>
<2 3>
<0 1>
<1 3>
<4 5>
...

III.4) GammaTracking: Selection



- Criteria of selection:
  1) Probability > User Probability cut
  2) Length of the combination
  3) Probability

Possible combination :

<0 1 4 5> Selected

~~<0 1 3 5>~~

~~<0 1 4>~~

~~<1 4 5>~~

Exclusion of combination with used calorimeter

<2 3>

~~<0 1>~~

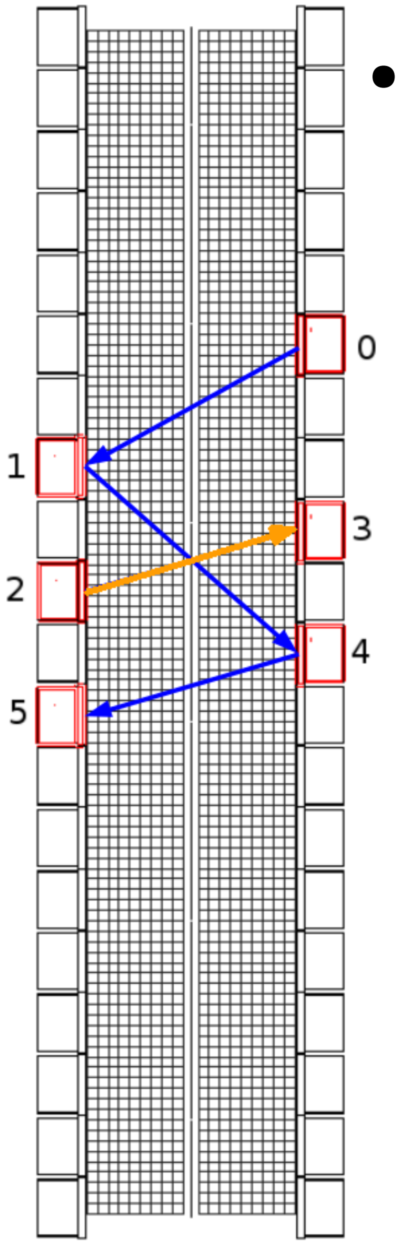
~~<1 3>~~

~~<4 5>~~

...

Selection of the next longest and highest probability combination

III.4) GammaTracking: Selection



- Criteria of selection:
  1) Probability > User Probability cut
  2) Length of the combination
  3) Probability

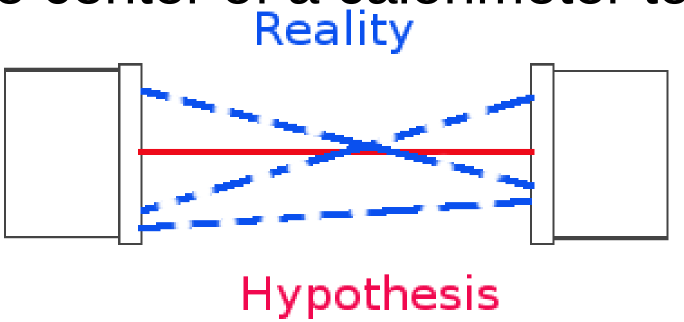
Selected combination :

<0 1 4 5>
<2 3>

IV) Estimation of the errors

I) Hypothesis:

Gammas goes from the center of a calorimeter to another



II) Estimation of the geometrical error σ_L

Purely geometrical calculation of the error

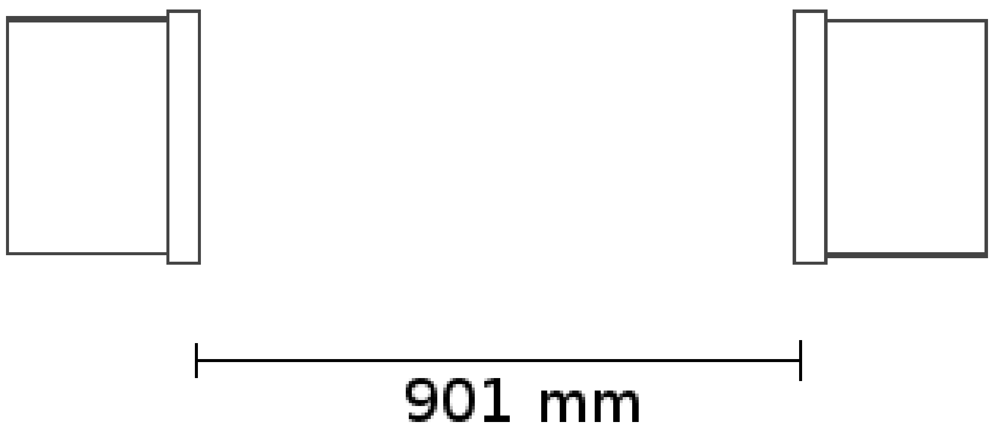
in function of the transverse distance between two calorimeters

III) Estimation of the total error σ_{tot}

in function of the Energy and θ the impact angle

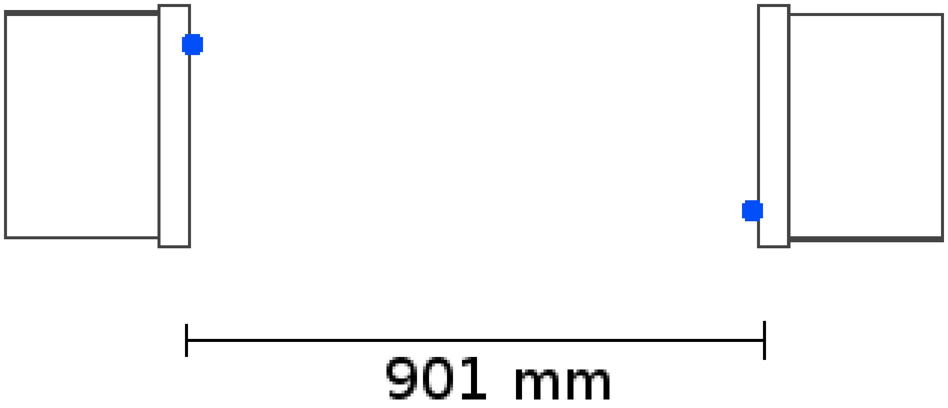
IV.1) Geometric errors (σ_L)

Simulate the surface of a calorimeter on each wall

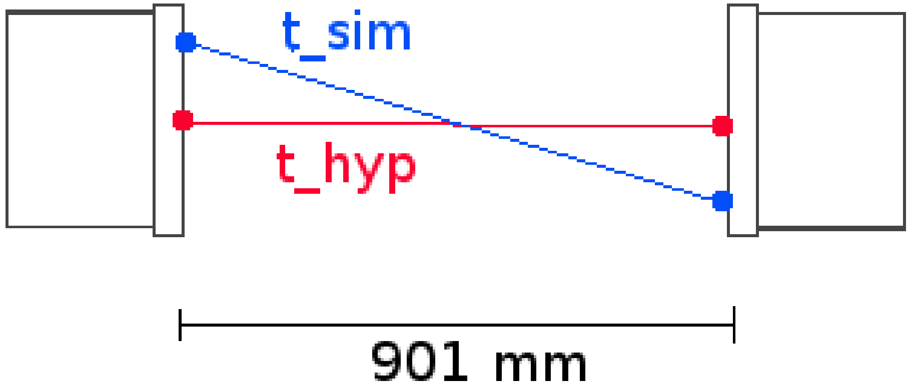


IV.1) Geometric errors (σ_L)

Generate randomly a pair of point on each calorimeter

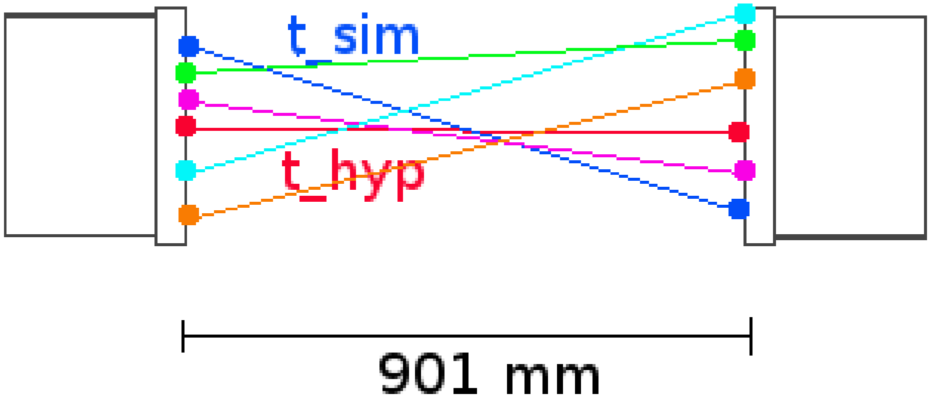


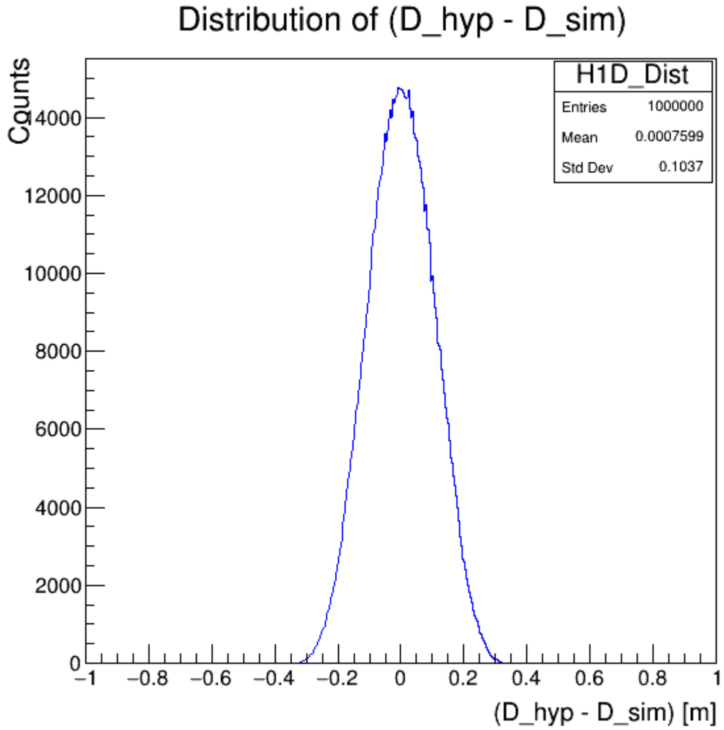
Calcul of (t_{hyp} - t_{sim})



IV.1) Geometric errors (σ_L)

We repeat this process N time

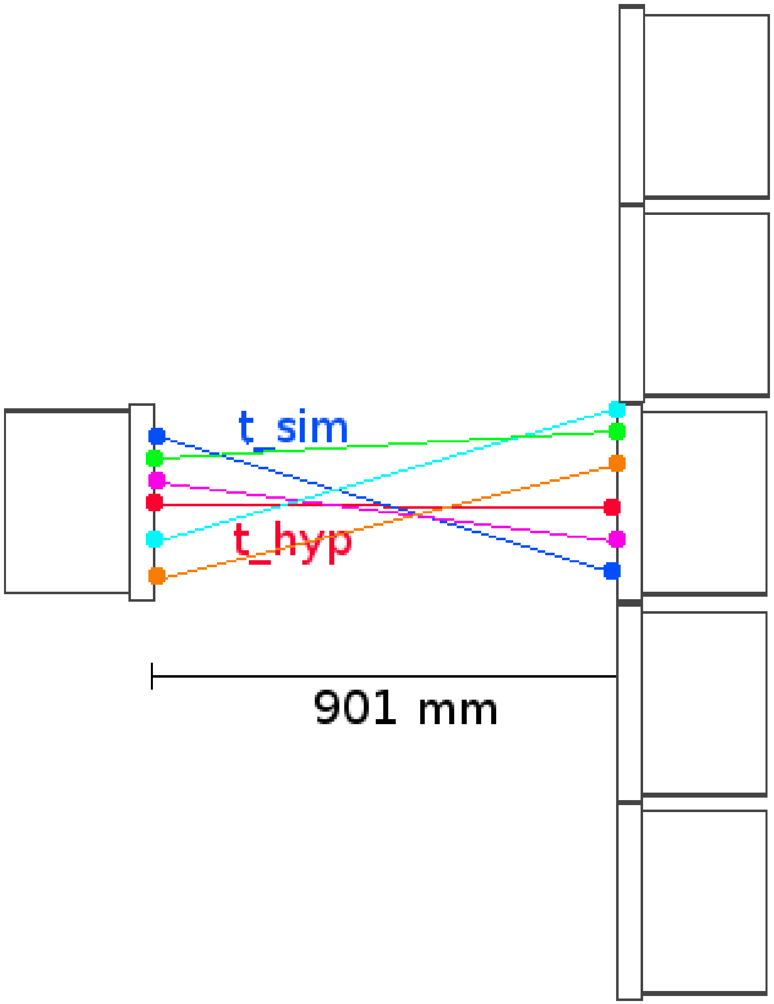




Estimate σ_L for a pair of calorimeter in front of each other

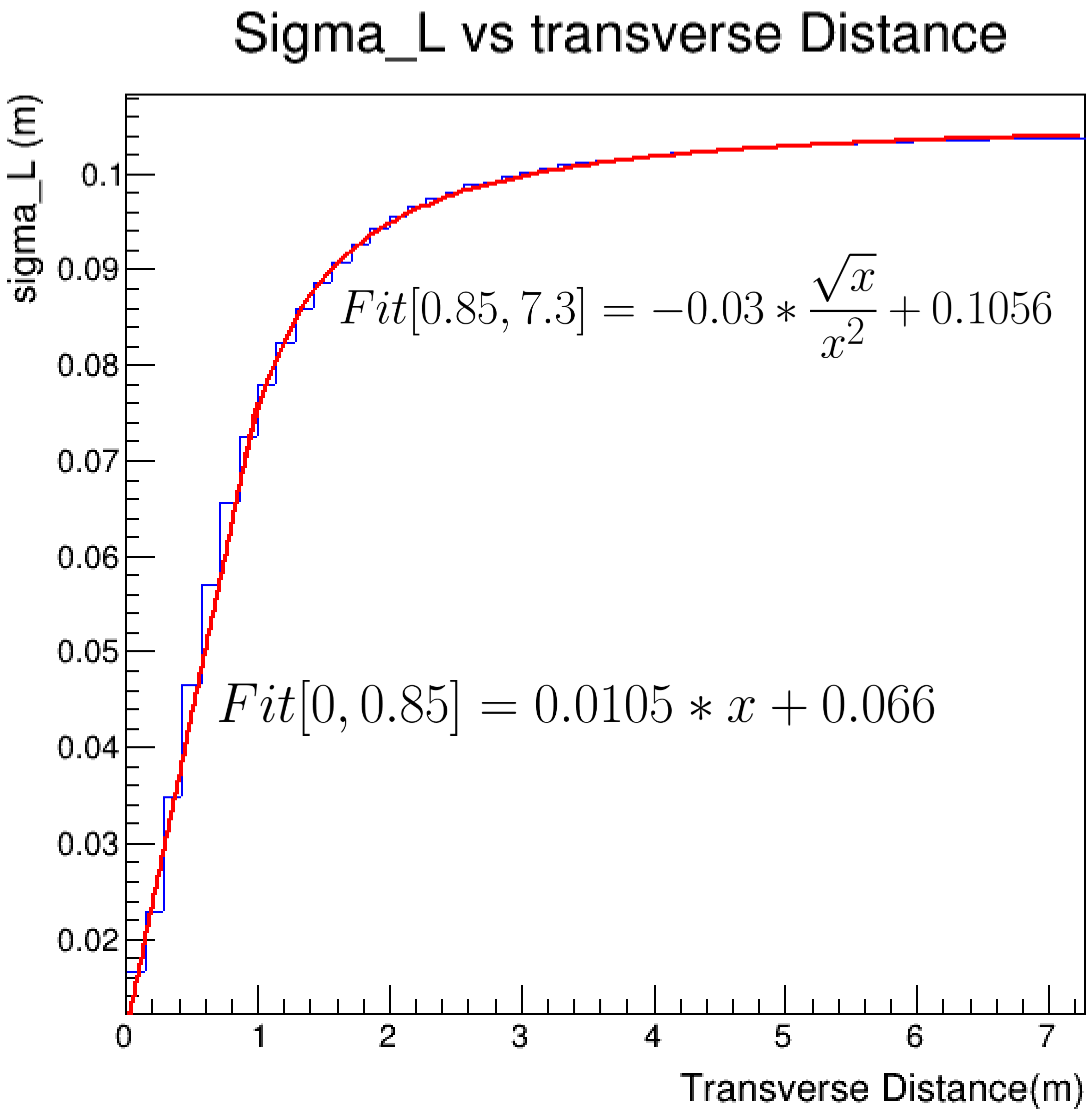
IV.1) Geometric errors (σ_L)

We repeat this simulation for all the possible pair of calorimeter in SuperNemo



Estimate σ_L wrt the transverse distance between two calorimeter

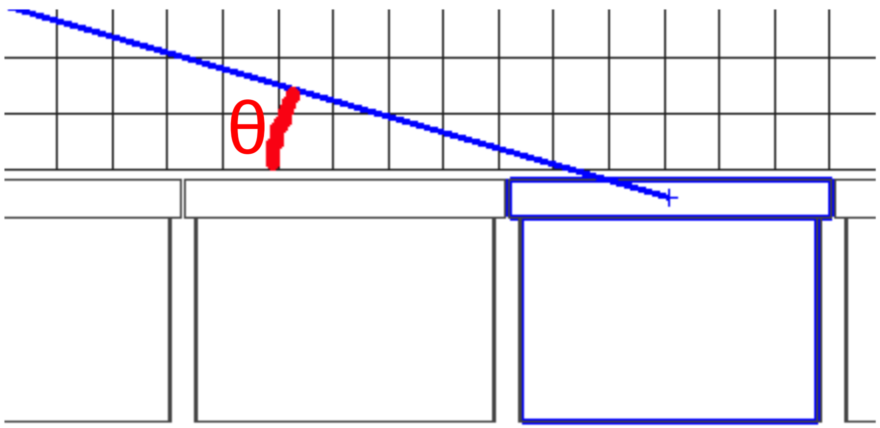
IV.1) Geometric errors (σ_L)

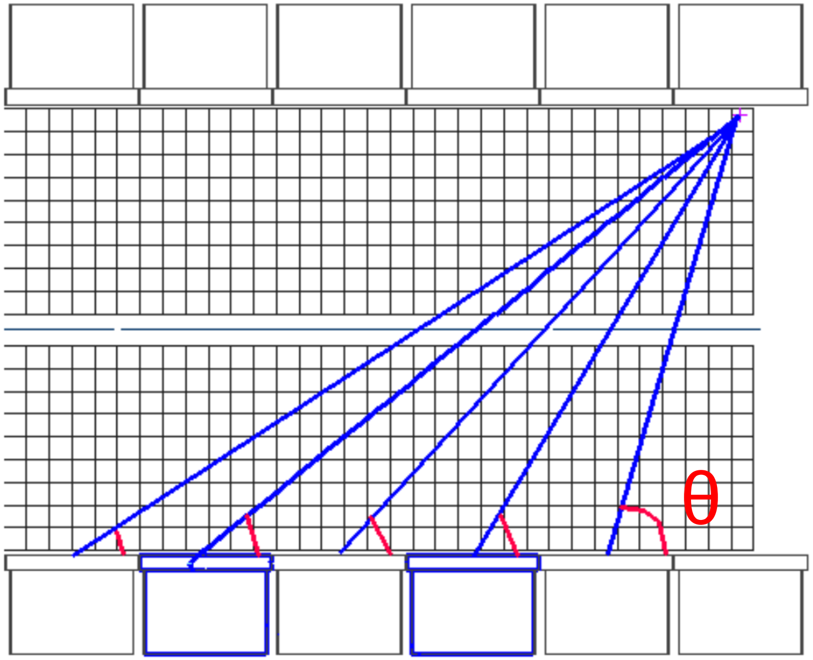


IV.2) Error candidates: Impact angle and interaction depth

We miss:

- The error due to the impact angle θ





- The error related to the deposited energy
- And the correlation between the two
- Problematic: No direct study possible

IV.2) Solution: estimation of the total error

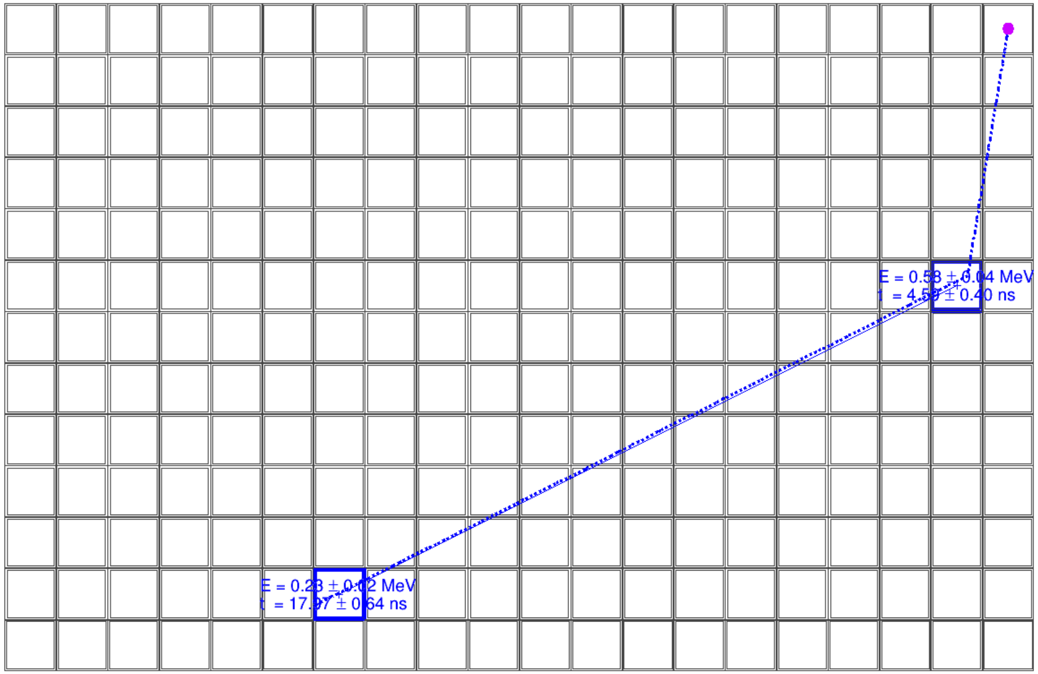
We simulate a gamma source in the corner of the detector

Energy of the source:

- 0.1 to 5 MeV

Objective:

- Comparison between estimated and total error



Selection of event with:

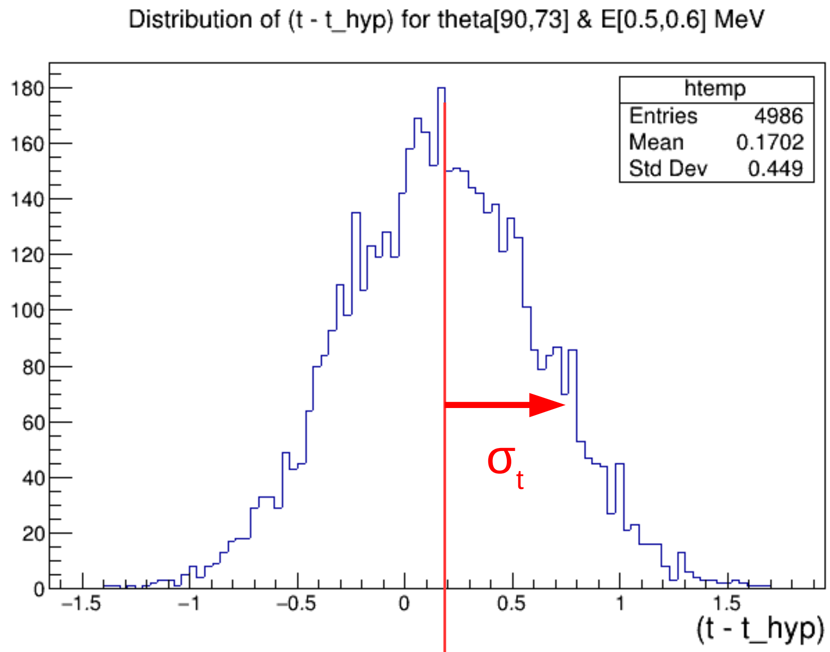
- No interaction in the tracker
- 1st calorimeter in the opposed wall
- Straight trajectory from the source to the 1st calorimeter

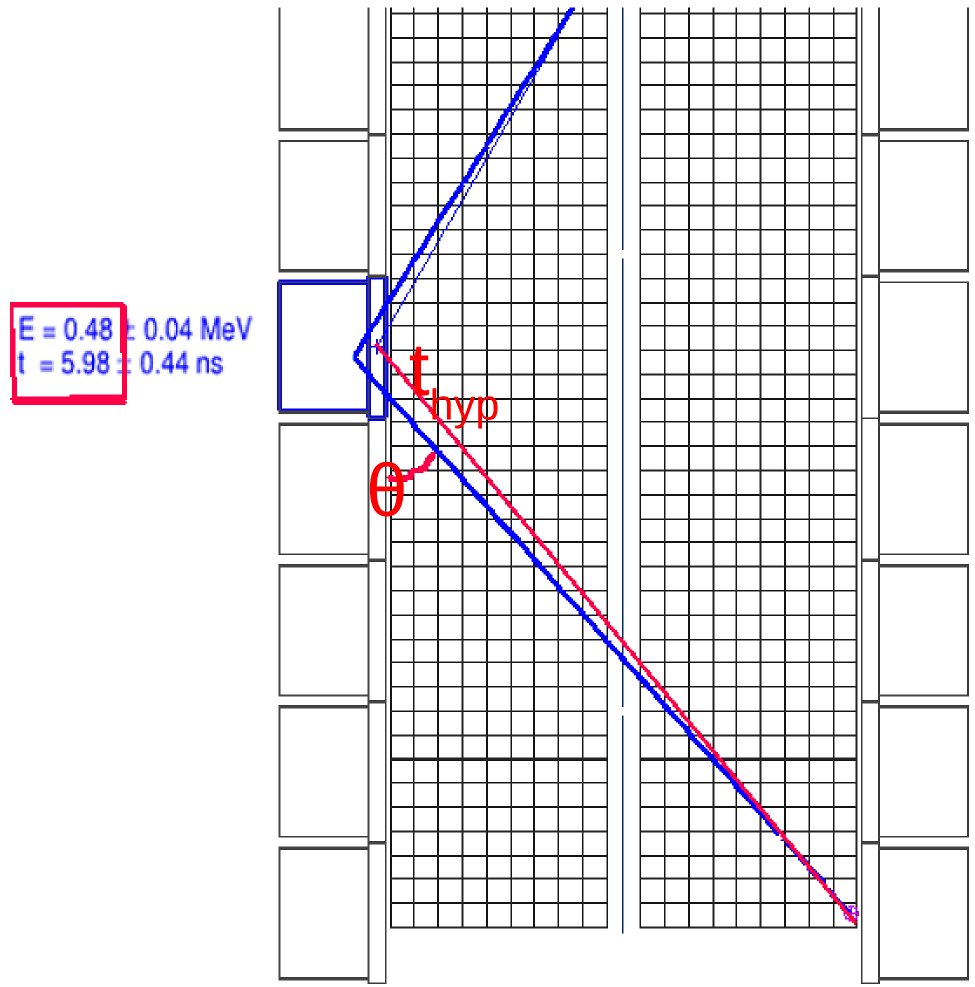
IV.2) Solution: estimation of the total error

We retrieve the impact angle, the deposited energy and the time of arrival

We calculate (t-t_{hyp})

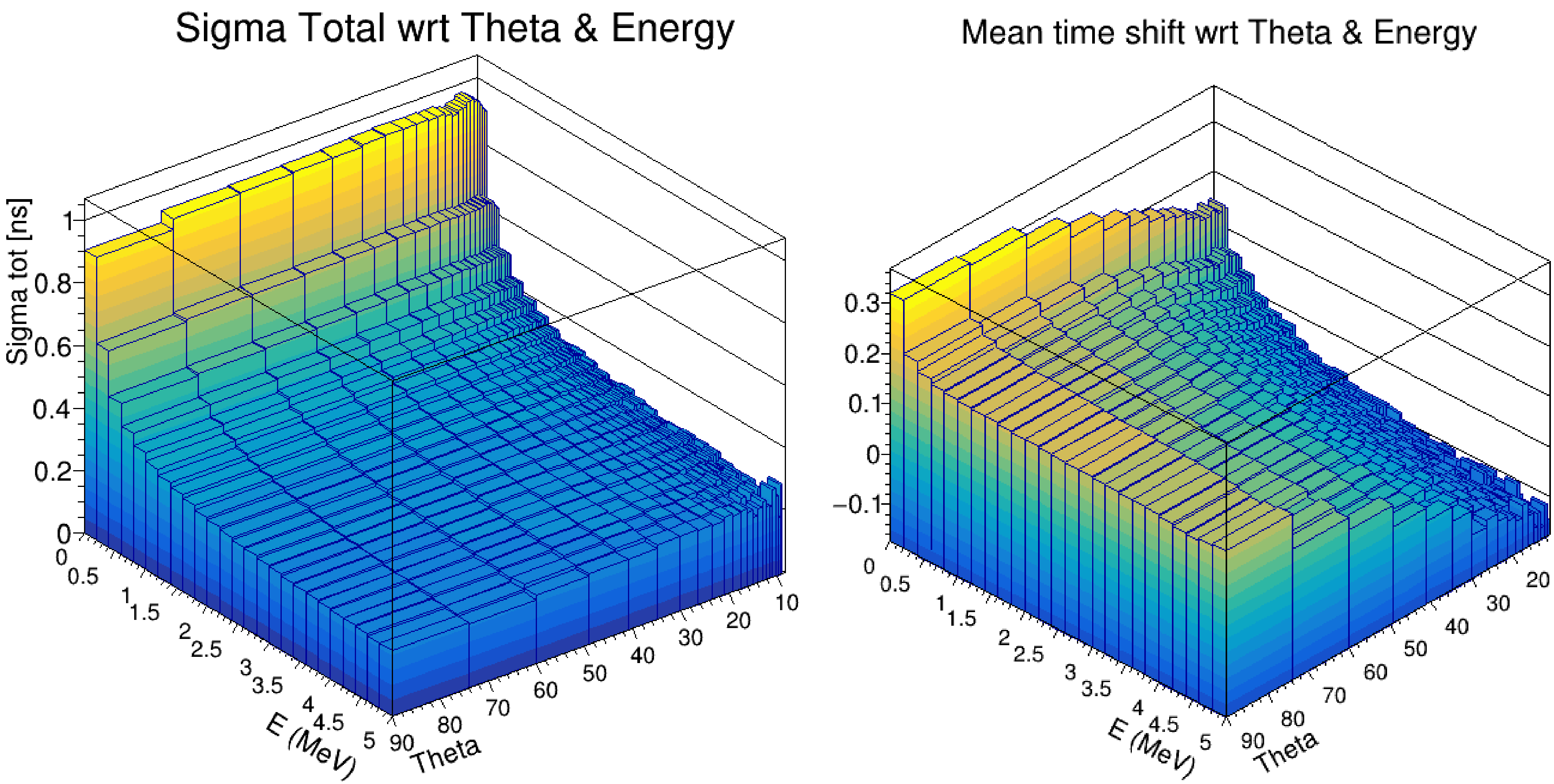
for each θ and $E_{measured}$



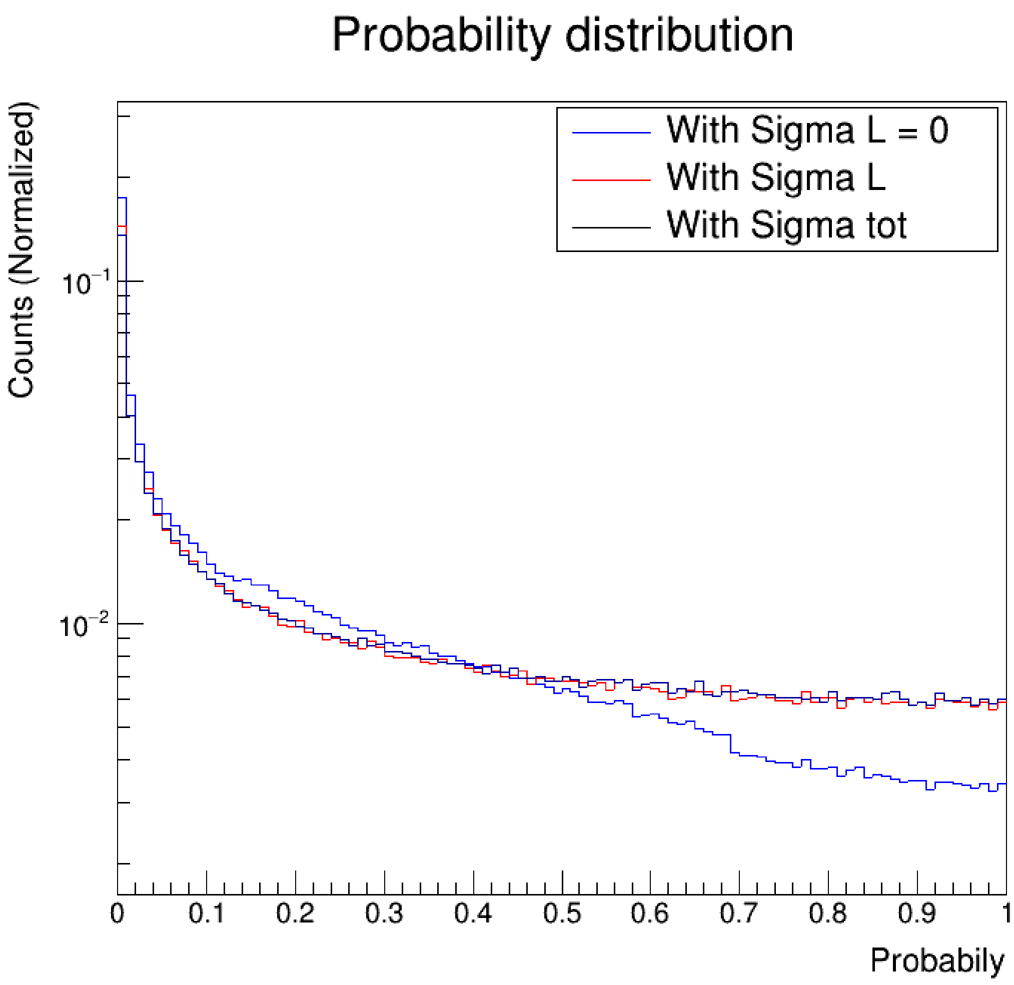


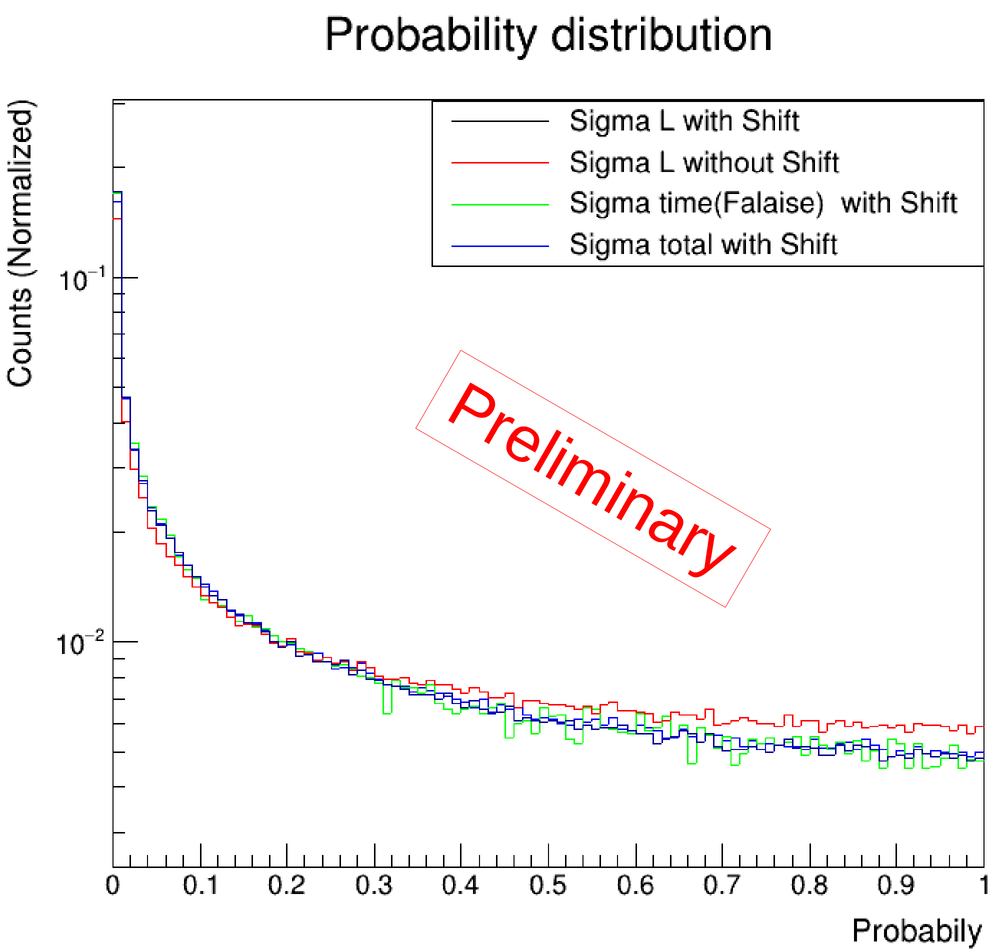
IV.2)Estimation of the total error

5.10[7] simulated event per 100keV



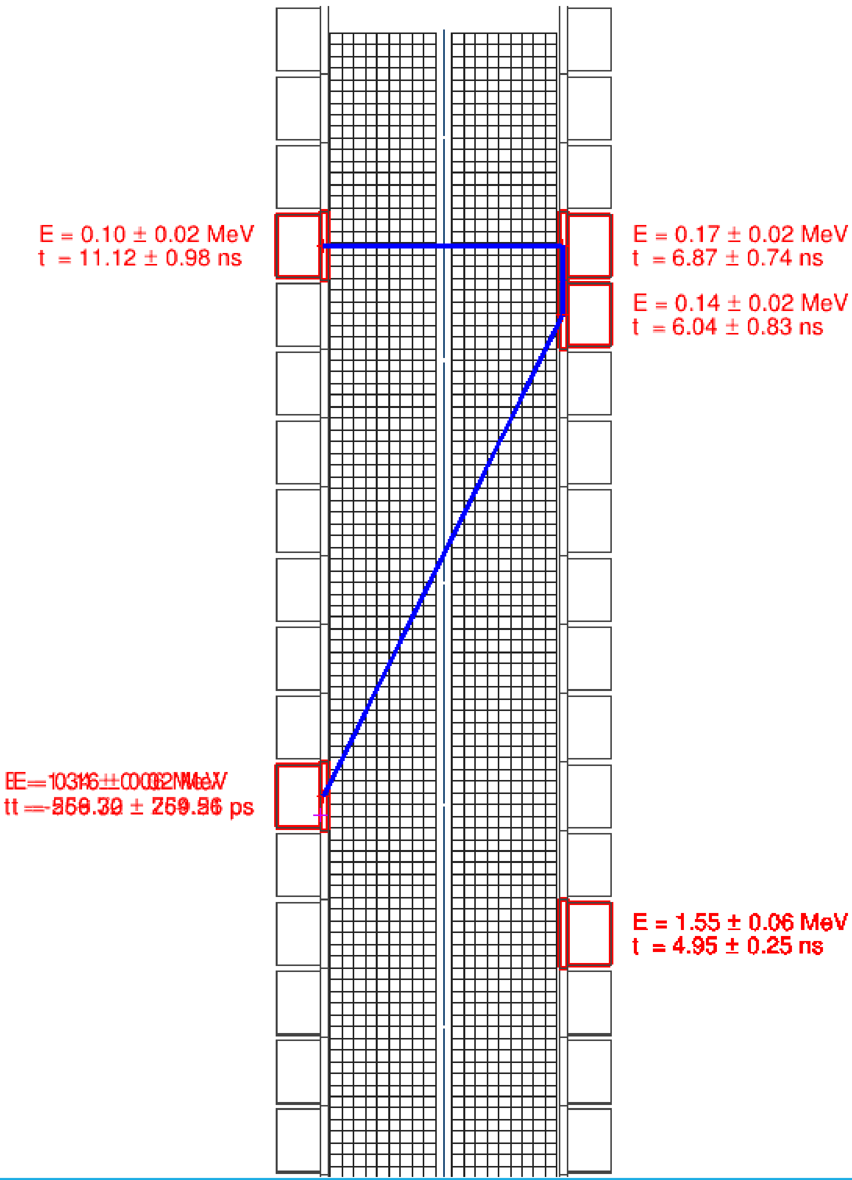
IV.3) Influence on the probability distribution



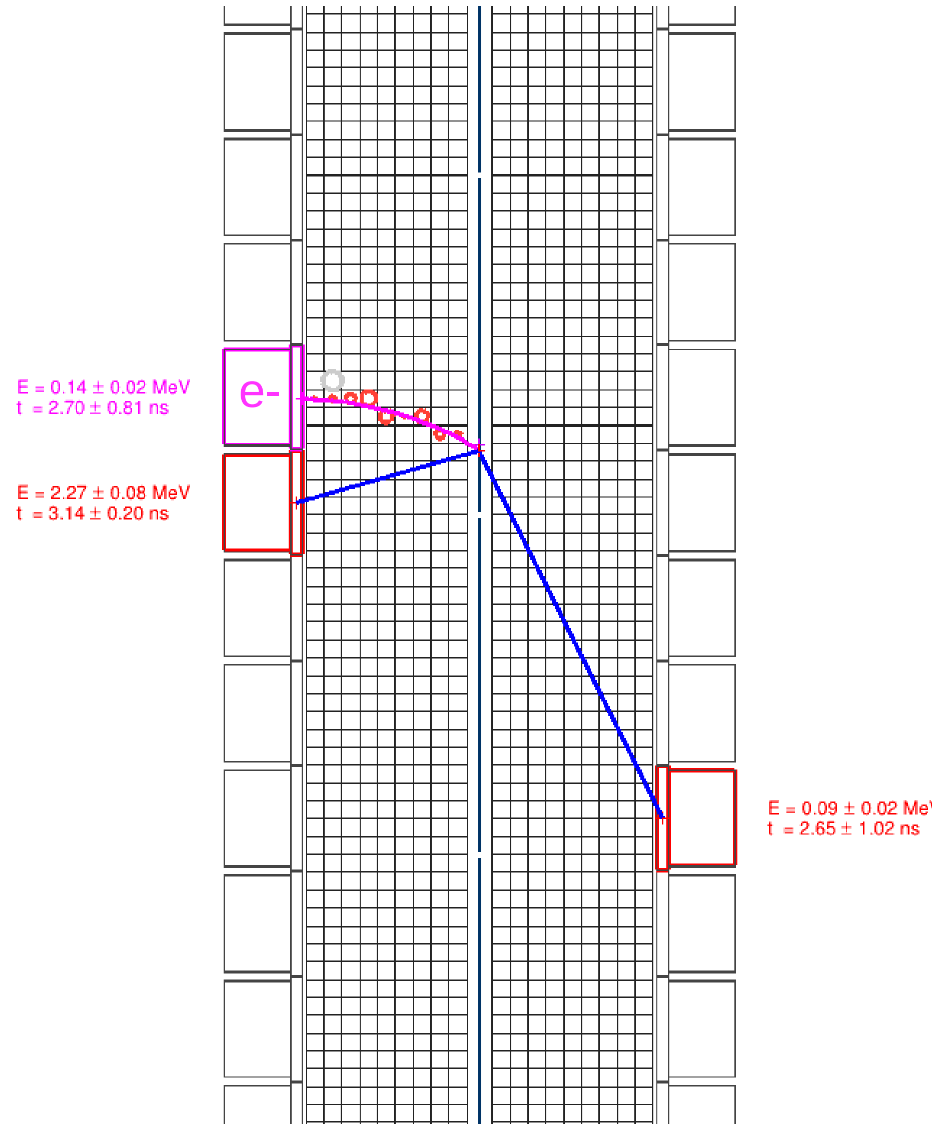


V) Ongoing analysis of ^{208}Tl

^{208}Tl in scintillator



^{208}Tl in source foil



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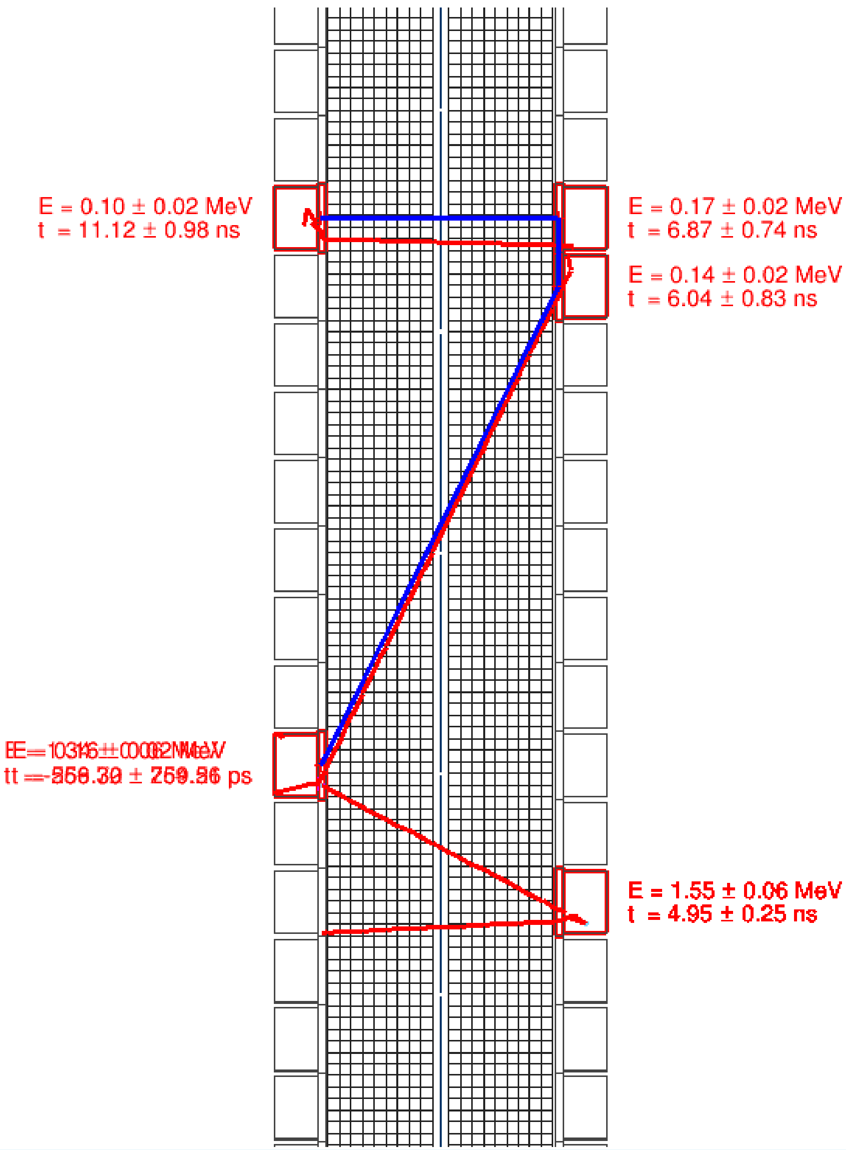
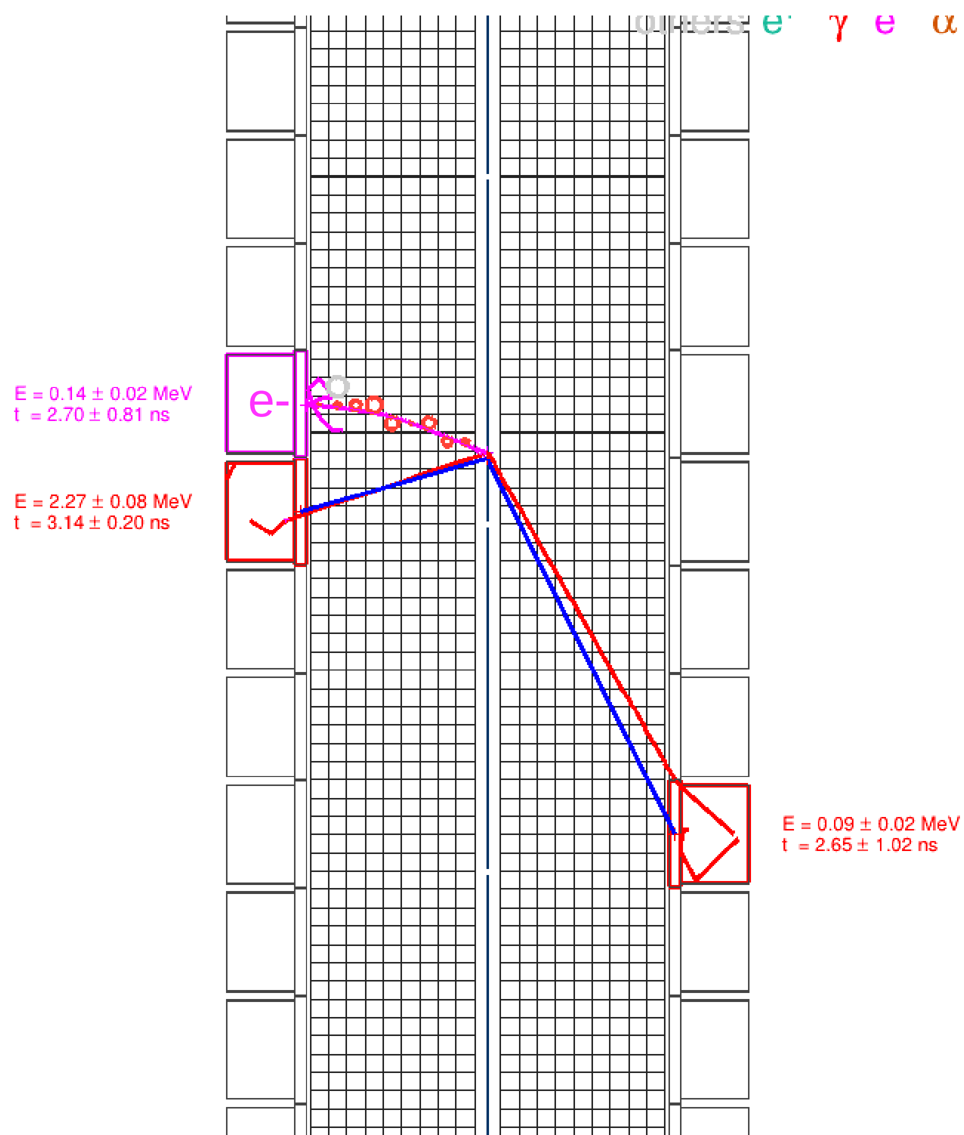
^{208}Tl in scintillator



^{208}Tl in source foil



V) Conclusion and perspective

The GammaTracking module reconstruct the gamma track in the detector

We understood and estimated the errors

On going:

Estimation of the GammaTracking performance with Talium

Next:

Analysis of external background and ^{82}Se decay into excited state

There is a lot of work to be done but as Alain Juppé said:

“La défaite est orpheline.”

Thank you for your attention