CaLIPSO

Calorimètre Liquide Ionisation Position Scintillation Organométallique

Un nouveau Calorimètre pour photons énergétiques

En vue des TEPs

Mais aussi de la spectrométrie des positrons

D. Yvon, CEA Saclay, IRFU

Plan de l'exposé

Groupe et collaborateurs

Principe de la TEP

Intérêt Biomédical

Principe du détecteur CaLIPSO

Détection Optique

- Propriétés Physiques
- Instrumentation et mesure sur détecteur

Détection Ionisation

- Propriétés Physiques
- Instrumentation du détecteur

Financement

CaLIPSO à l'IRFU

Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

D. Yvon

Responsable scientifique

G. Tauzin

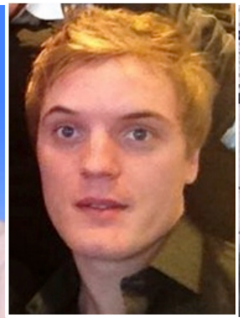
Chef de projet

P. Verrecchia

Physique du détecteur

S. Sharyy

Physique du détecteur



X. Mancardi

Thèse Démons. ionisation

O. Kolchebina

Post. Doc. Simu. PET Optimisée

J.P. Mols

Mécanique

P. Starzynski

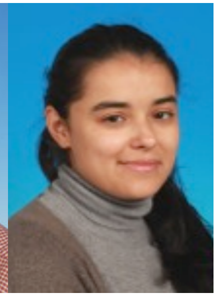
Mécanique et Ultra-Vide

J.P. Bard

Électronique et labo

Ph. Abbon

Elec. Analog. Rapide



M. Kebbiri

Techno. Détec. Avancées

? + ?

Thèse Détec. Opt. rapide.

Colaborateurs

IRFU SPP et SEDI

Le groupe présenté précédemment

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CEA/DEN - DANS/DPC/SECR

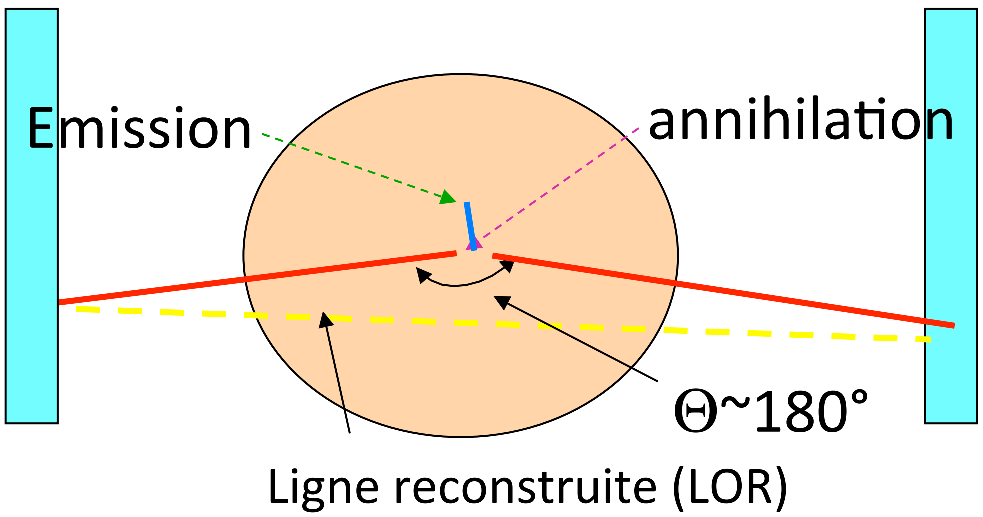
D. Doizi, V. Dauvois, G. Plancque, A. Turban, S. Legan

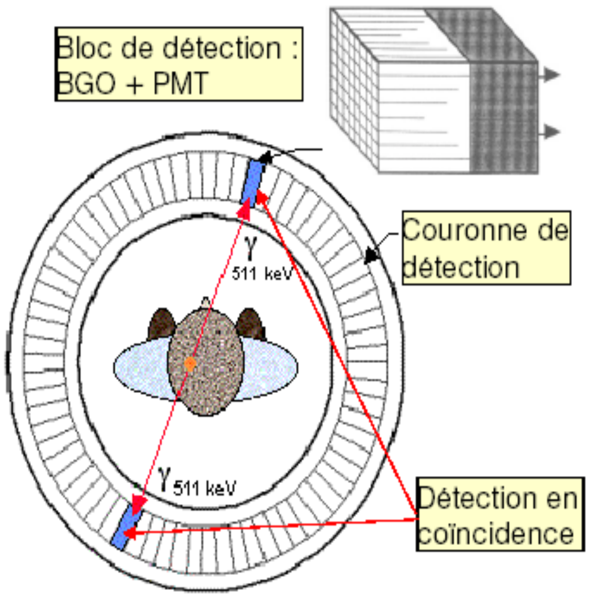
Principe de la TEP

- Traceur ^{18}**F**DG => fixation sur cellules d'intérêt
- Emission β^{+}, => annihilation ~ qq MHz
- Parcours 0,5 mm => 2 γ de 511 keV à ≈ 180°

Coïncidences:

Line Of Response => Reconstruction de l'image

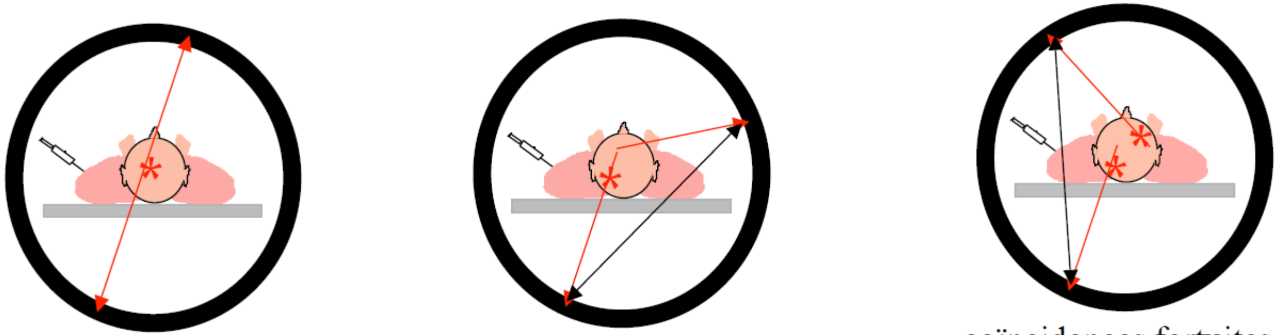




Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Mécanismes de Bruits de fonds

Les signaux reçus en TEP :



coïncidences vraies
⇨ bien localisés sur la ligne de projection
⇨ information utile

coïncidences diffusées
⇨ mauvaise localisation
⇨ diminution du contraste
⇨ biais quantitatif

coïncidences fortuites
⇨ mauvaise localisation
⇨ réduction des capacités de comptage
⇨ biais quantitatif

Master RIA - Tomographie d'émission de positons - Irène Buvat – octobre 2010 - 47

Examen TEP corps adulte : rendement < 6%

But : Rejeter fortuites + diffusées

Détecter efficacement les vraies coïncidences

Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Intérêt Biomédical

Why a Brain PET Scan?

MRI Assets/Challenges

Visualize the **brain structure**

Matter density.

Great spatial resolution

1 mm^3 *full brain* -> $(50\mu m)^3$ zoom

Poor sensitivity to biochemical cellular activity

~ 10^{-4} mol.

Good blood flow Imaging.

PET Scans Assets/Challenges

Visualize the **biological activity**

Modest spatial resolution

~ $(2.2\ mm)^3$

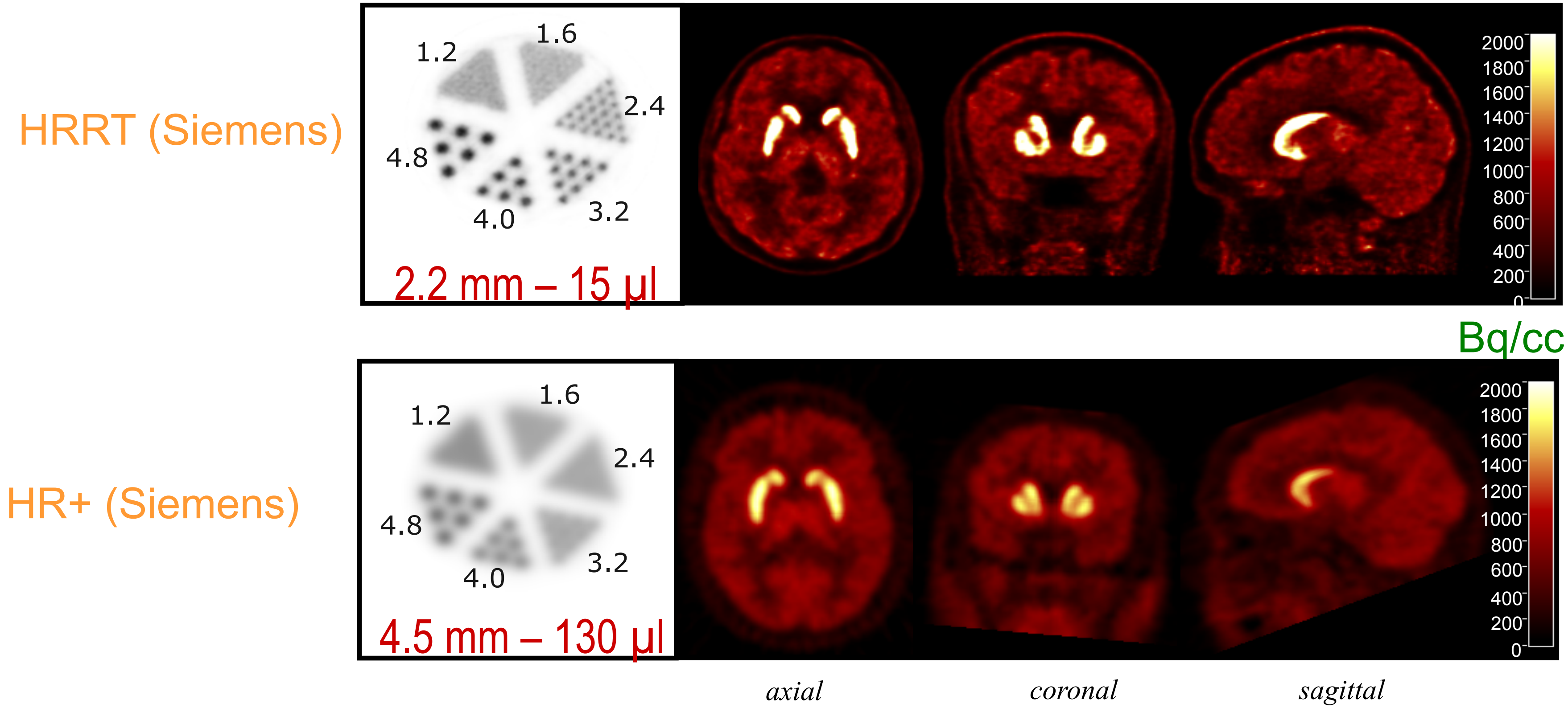
Great Sensitivity to biochemical cellular activity

Down to 10^{-12} mol.

The patient is irradiated

lower exam **dose welcome**

Why High resolution Brain PET imaging?



Brain neuro-transmitter work at **very low concentration**

Brain structures are small.

- **Better definition** of the structures of interest in the brain.
- **Better recovery of contrast**
  - Better quantification of regions of interest and biological parameters.

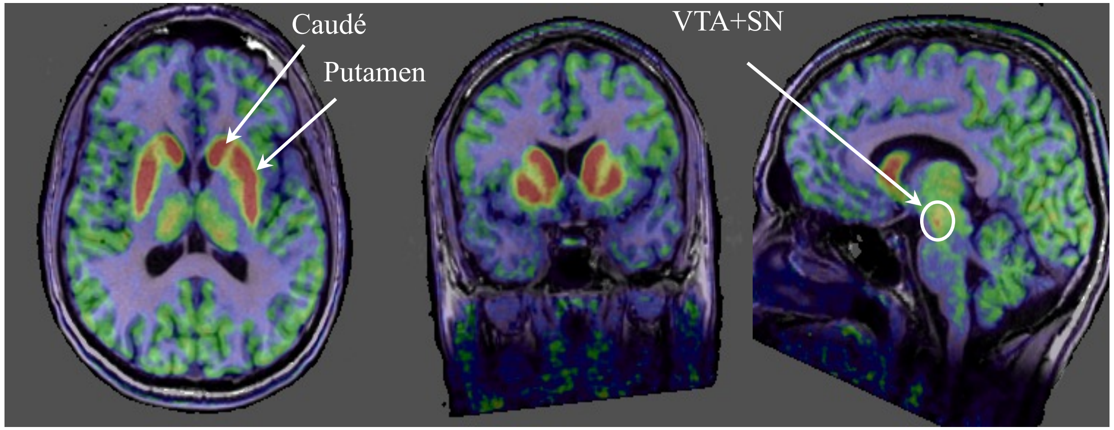
This is our main goal

Leroy *et al, JNM, 2007*

Medicine with *High Res.* Brain PET imaging ?

C. Leroy, J. Nucl Med 48 (4), 2007 ; FC Sureau, J. Nucl Med 49 (6), 2008

E. Artiges, Psychiatrist
R. Trebossen,
R. Boisgard, SHFJ



Access to **fine structures activity**: the substantia nigra (SN), basal ganglia

- Fine study of dopaminergic circuits in patient populations

Cellular biochemistry involved in **Neurodegenerative diseases**

- Parkinson's, Huntington, Alzeimer diseases
- **Before any structural effect can be seen.**

Attention Deficit-Hyperactivity, Autism Spectrum Disorders, Psychiatric disorders (Bipolar, Addictions ...)

- **« See » drugs at work.**

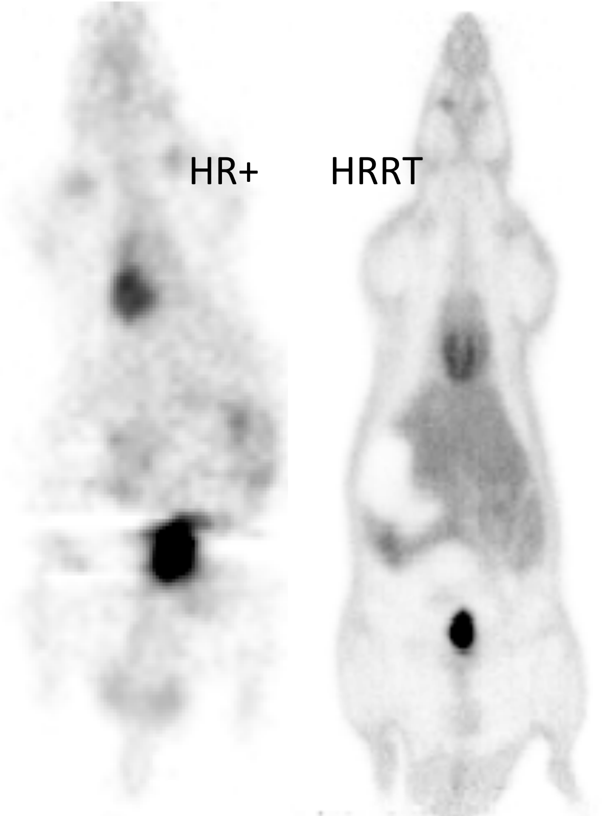
High-Resolution PET, large volume
Speeding up drug testing?

Rodent Model => Measurement of target/drug bioactivity.
But, ***variability of radio-tracers*** and ***biological variability***

Need to increase statistics in a single measurement

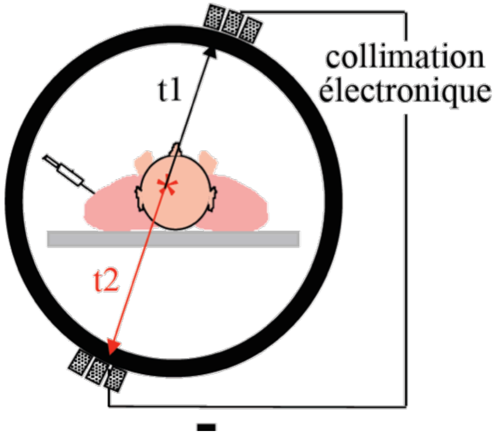
Multi-Rodent: simultaneous acquisition
=> Tracer variability reduced + Save time (x6 !).

Ph. Hantraye, MIRCEN + R. Trébossen, R. Boisgard, SHFJ



Quel détecteur pour un imageur TEP haute résolution?

Detector Specifications List



Timing accuracy

Few ns (PET random coincidence)

to few 100 ps (TOF PET, Lifetime Spec.)

γ interaction positioning accuracy

Down to $1mm^3$

(ACAR Spec. – PET High Spatial Res.)

Detection efficiency

Att. Length : 1 -> few cm

Photoelectric Efficiency: 30% → ??.

Energy resolution

15% to few % (FWHM)

In vivo scattering rejection (PET-scan)

« Plug and play »

What are current PET technologies?

Properties / *Detector*	Atten Length (cm)	Coinc . PhotElecE Eff.(%)	Timing Resolution (ps, FWHM)	Energy Resolution (% FWHM)	G Interac. Postion. (mm)	End user friendly
LSO/LYSO	1.23	12	300 - 500	10	10 - 2	YES
$LaBr_3$	2.3	1.9	100 - 300	3	10 - 4	YES
CdTe/CZT	2.0	2.2	slow	1- 3	0.1	YES
CaLIPSO	2.9	22	?150? - 380	10	0.15	Will be !

LSO/LYSO : The reference detector. No big drawback.

LaBr3 : Excellent timing, poor PE Efficiency, fair positionning.

Only relevant for full body, Time of Flight PET config.

CdTe/CZT : Excellent position reconstruction, poor PE Efficiency.

Only relevant for single mouse PET imaging

CaLIPSO : Best PE efficiency, Excellent positioning, very good timing.

Take the best of all technologies – *Needed* for high-res efficient Brain PET

CaLIPSO Detector Basics (1)

TriMethyl Bismuth (TMBi), Bi(CH_3)$_3$

Bi, Z = 83, highest Z non radioactive element.

Phot. Electric Efficiency 47%

Limpid, dielectric, Chem. stable.

***Double** Detection*

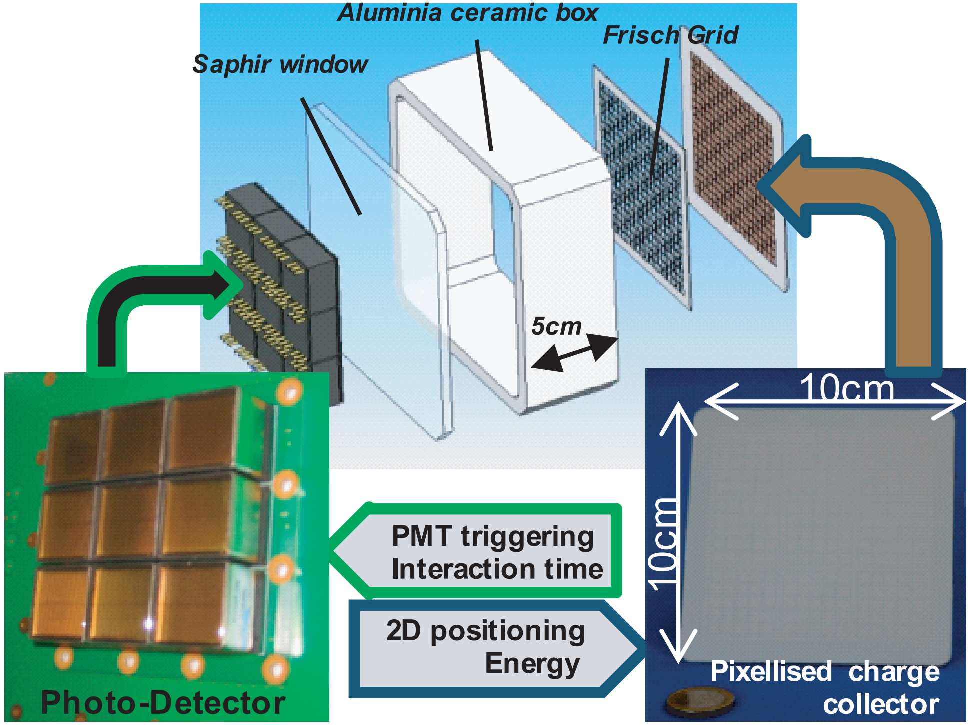
Photo-detectors

Fast! => Trigger, timing.

Ionization chamber

Pixelated detector, Frisch Grid

Energy, positioning 2D



Patent: γ detector

D. Yvon, PCT/EP2011/054153

D. Yvon, J-Ph. Renault, G. Tauzin et al. , IEEE TNS, vol. 61 (2014) 60.

CaLIPSO Detector Basics (2)

γ interacts in TMBi : $R_{PE} = \dfrac{\sigma_{PE}}{\sigma_{PE} + \sigma_{Comp}}$ = 47 %

$\Rightarrow$ **e^-_{PE} ~ 420 keV**

=> Light Production : Cherenkov

Low yield (~20 - 40 γ), **Very Fast (~ 10 ps)**

Photomultipliers.

=> Ions pairs production

Modest Yield (~10 pairs/keV)

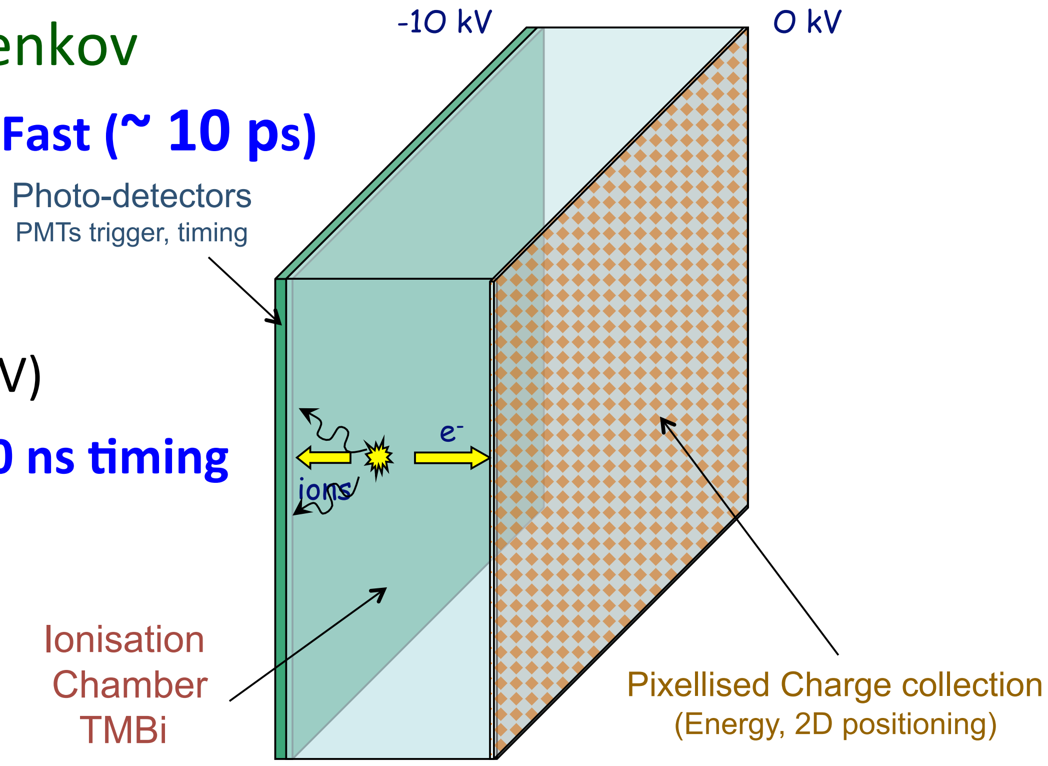
=> **Energy 10% FWHM, 100 ns timing**

Slow Drift :1 cm/μs/10kV/cm

=> Drift time

Pixels => 2D positioning

Drift Time => **3D positioning, 1mm^3**



Etat d’avancement du projet

Propriétés optiques du TMBi

Détecteurs Optiques

Vers un détecteur ionisation

CaLIPSO technological challenges (1)

TMBi properties for particle detection

Now known, *but Gfi*.

Light Collection efficiency

Timing on a single PE γ

Ultra-purification, cleaness

better than 1 ppb eq. O_2

Needed for charge drift

Known: TMSi, TMGe, TMP

Readout electronic density

1 amplifier every mm^2

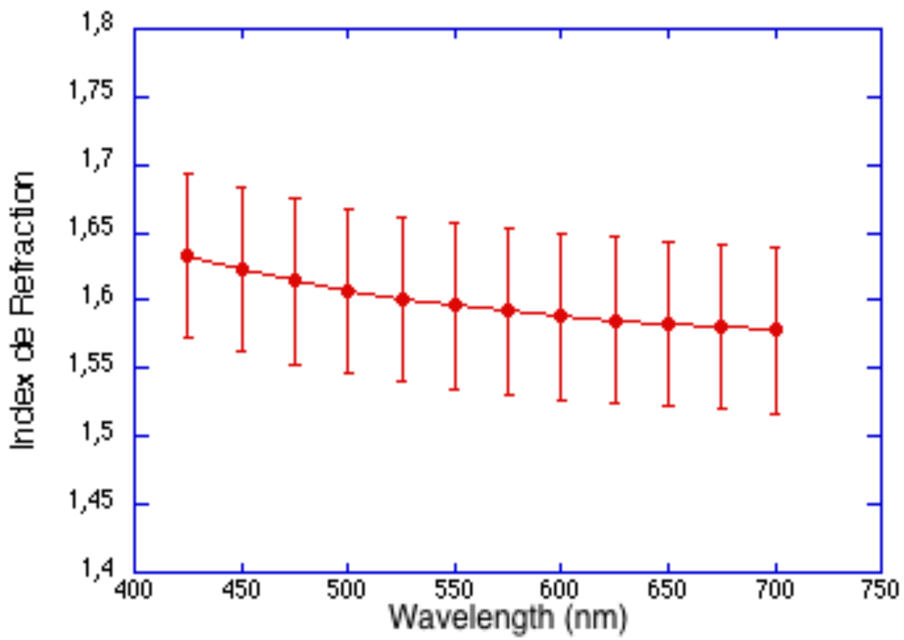
=> *ASICs IDeF-X*, CaLISTE

TMBi Ultra-purification apparatus

Propriétés optiques du TMBi

Indice de réfraction du TMBi

Daniel Desforge
Emilie Ramos



Mesure au goniomètre

Cellules prismatiques étanches

Mesure sur le TMBi

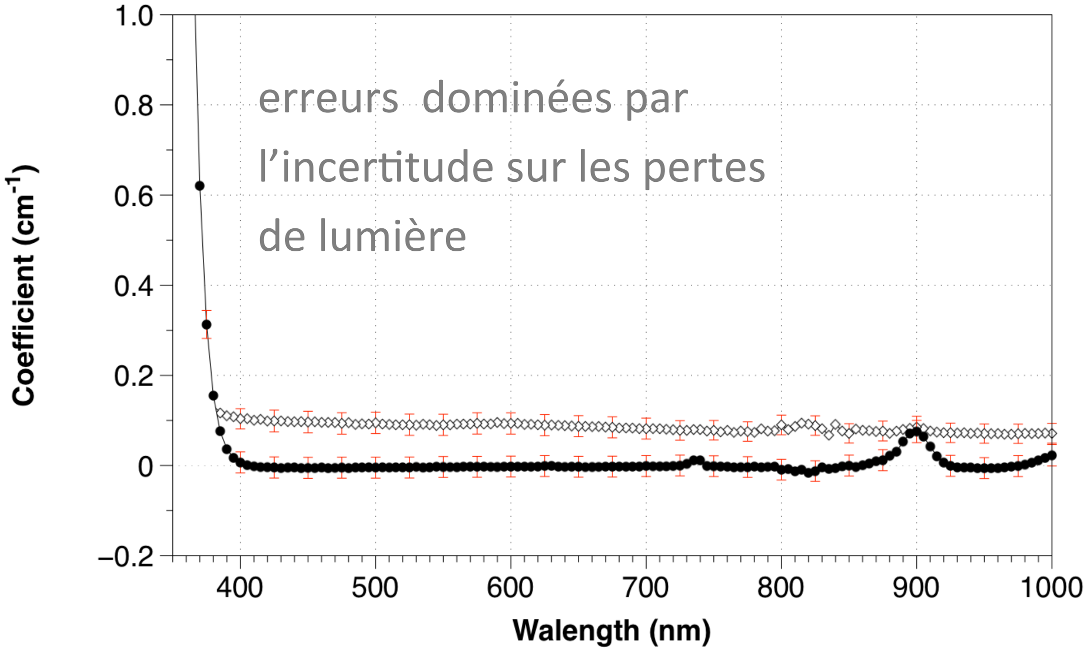
Erreurs :
géométrie
de la cuve

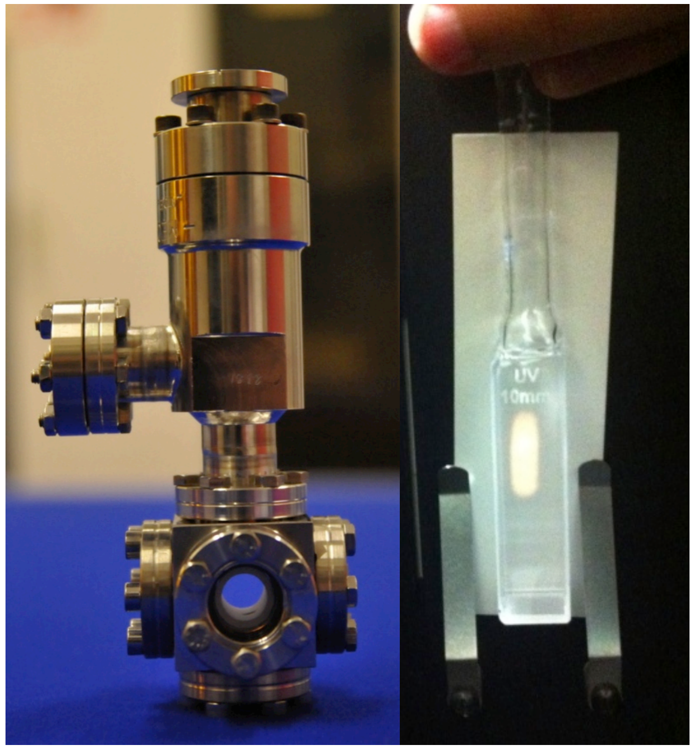
Absorption / Diffusion du TMBi

Cuves en verre à faces parallèles étanches

Tenir compte des différentes pertes lumineuses:

- Absorption dans le verre
- Réflexions de Fresnel



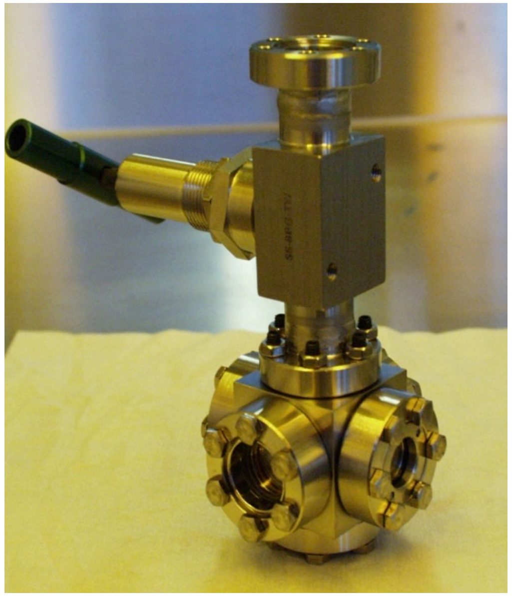


Production de lumière

Cellule optique

Fenêtres MgF_2

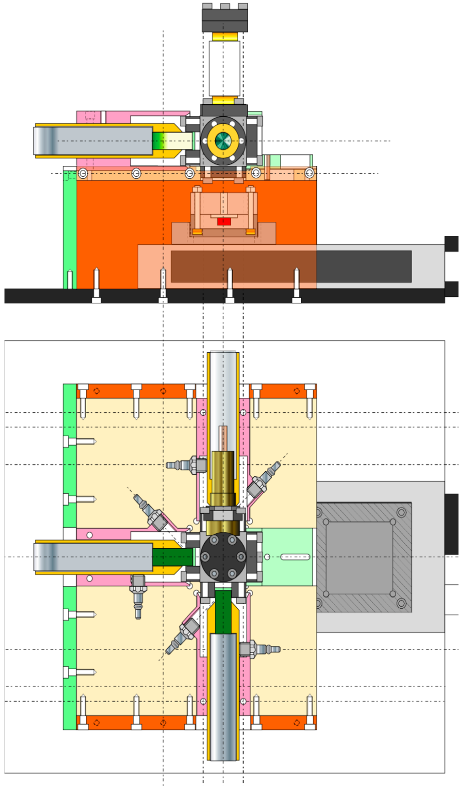
120 nm - 800 nm

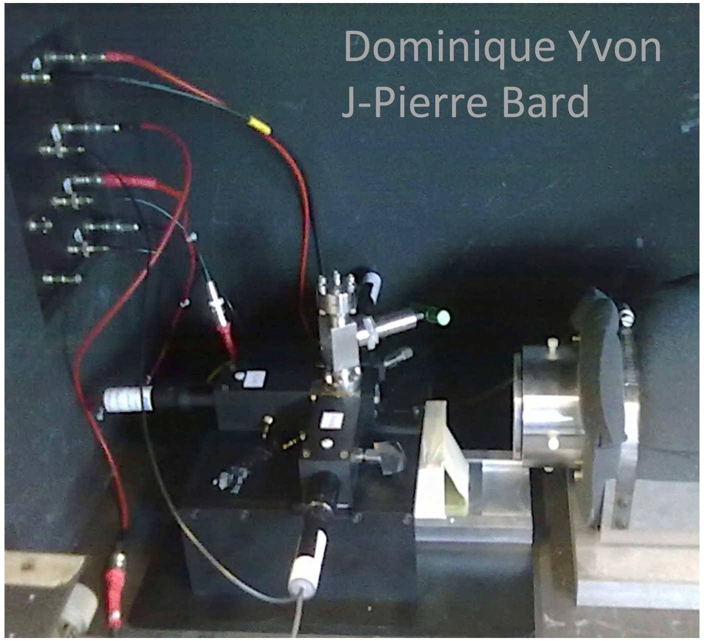


P. Cassette et al. [2003]

Banc de mesure du rendement production lumière

dessins Daniel Desforge



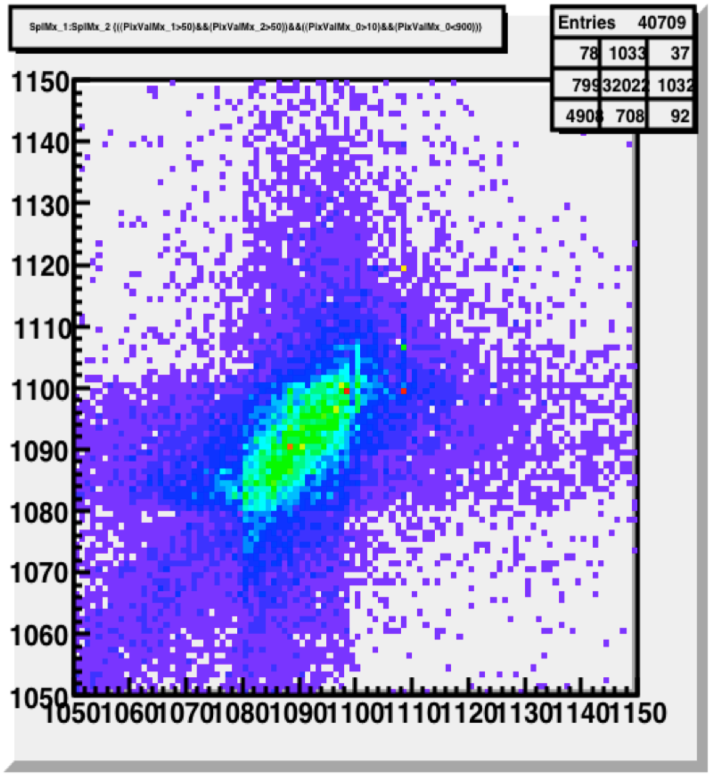


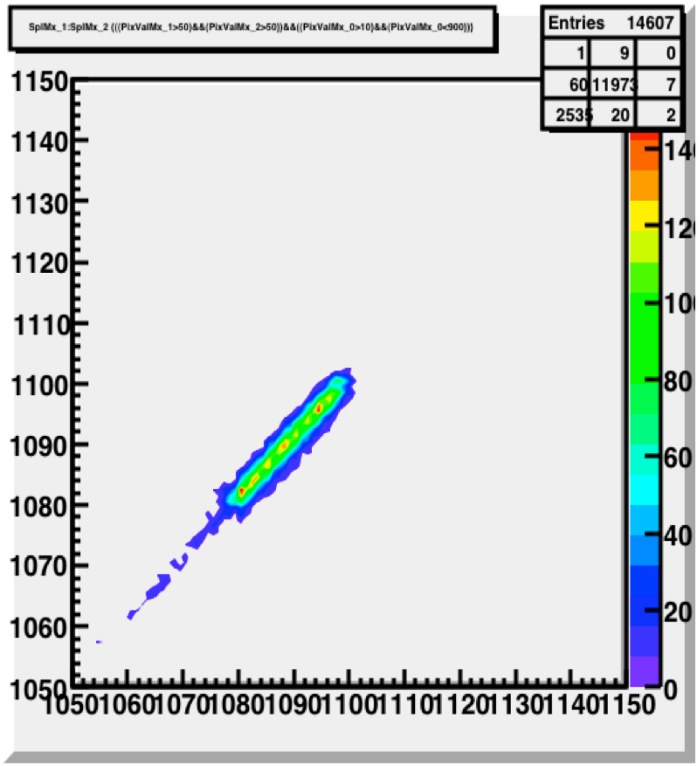
Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Temps de décroissance de scintillation

LAB+PPO, *LAB-Pb+PPO*,

TMBi, TMSi





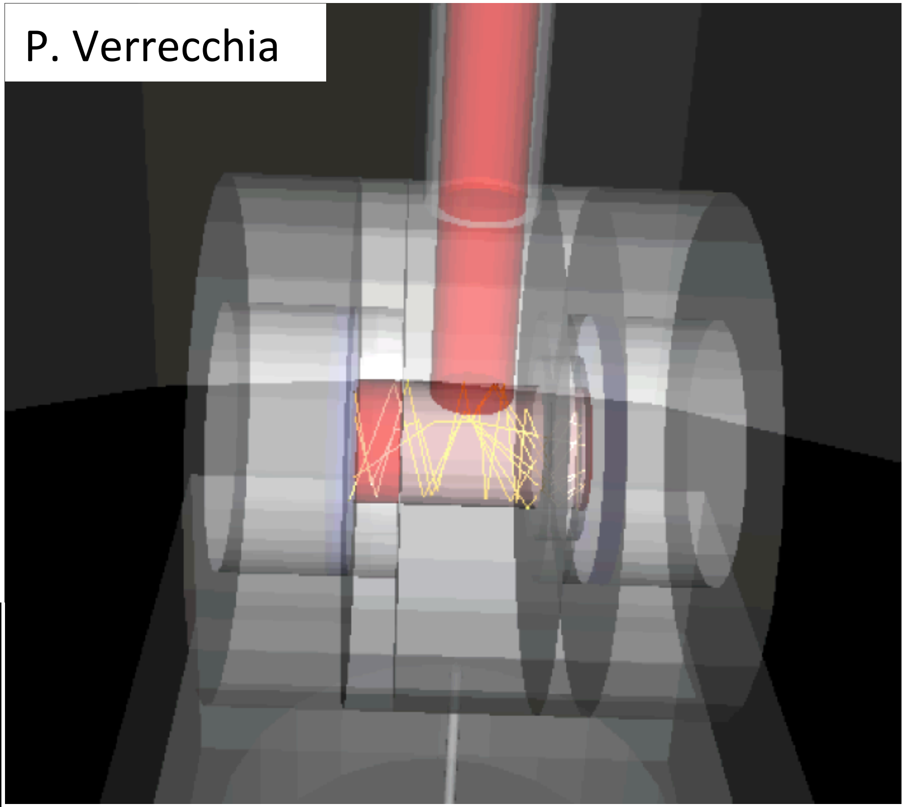
Temps de décroissance scintillation LAB
~ 5 ns

Temps de décroissance scintillation
TMBi et TMSi *Rapide! < 1.5 ns*

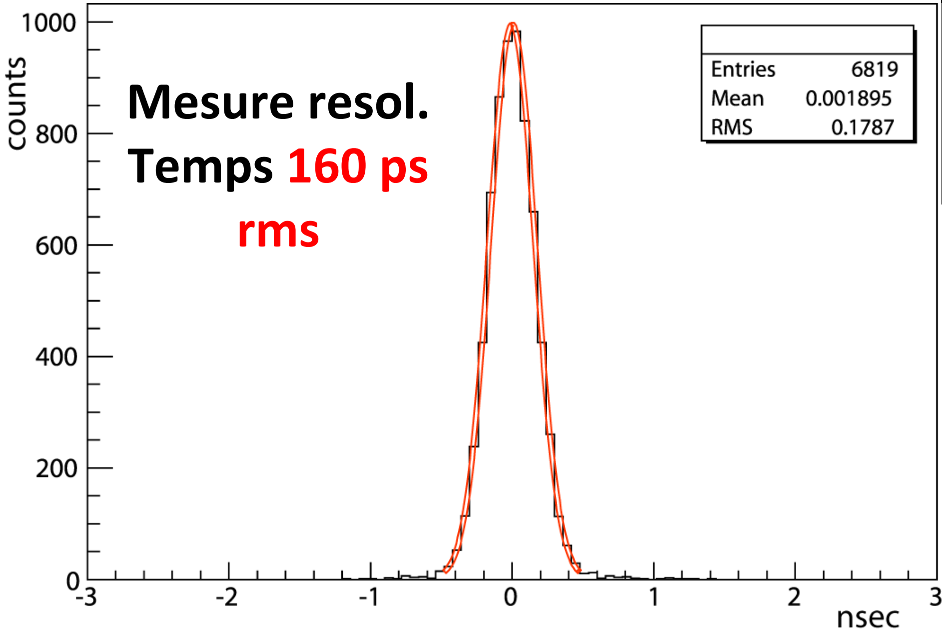
Etude cellule Temps-Scintillation

Cellule
Temps-Scintillation +
PMT R9880U-100.

D. Desforges



Simulation Optique Géant 4



Résolution en temps dominée par les PMTs

TMBi properties for particle detection

60 IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 61, NO. 1, FEBRUARY 2014

CaLIPSO: An Novel Detector Concept for PET Imaging

D. Yvon, J.-Ph. Renault, G. Tauzin, P. Verrecchia, C. Flouzat, S. Sharyy, E. Ramos, J.-P. Bard, Y. Bulbul, J.-P. Mols, P. Starzynski, D. Desforge, A. Marcel, J.-M. Reymond, S. Jan, C. Comtat, and R. Trébossen

***Abstract*—The CaLIPSO project focuses on the development of an innovative energetic-photon detector. The detector uses a "heavy" organometallic liquid: the TriMethyl Bismuth (TMBi), 82% by weight of Bismuth. TMBi efficiently converts through the photo-electric effect photons of energies below 1 MeV. The ionisation signal and light produced in the liquid are both detected. Beyond the measurement of gamma photon energies, this detector will allow locating photon interactions in the detector in three dimensions down to 1 mm^3 and a sub nanosecond timing accuracy. All these desirable properties can be obtained simultaneously with liquid TMBi detector.**

***Index Terms*—Biomedical imaging, calorimetry, gamma ray detectors, position sensitive particule detectors, positron emission tomography.**

I. Introduction

PET imaging is used for diagnosis, clinical research and in vivo small animal research to study molecular processes associated with cancer, neurological and neurodegenerative diseases, psychiatry and cardiology. Since the early 1990 when PET was recognized as a powerful diagnosis tool, major technological advances have been made mainly in the five following directions: 1) sensitivity improvement, 2) spatial resolution gain, 3) uniformity of the spatial resolution across the field of view, 4) corrections for the main effects degrading the quantification, and 5) reconstruction algorithms so as to improve the signal to noise ratio and the spatial resolution of images.

These efforts have translated to the advent of dedicated small animal imaging devices, TOF PET and high spatial resolution whole body PET systems. In addition to these improvements, an

TABLE I
Main Recent Scintillator Cristals Properties

		LSO	LYSO	$LaBr_3$
Density	$g.cm^{-3}$	7.4	7.1	5.3
RapPE	%	30	30	15
Att. Coeff.	cm^{-1}	0.87	0.86	0.47
Light Yield	MeV^{-1}	30000	32 000	63 000
Dec. time	ns	40	41	25
Hydroscopic		No	No	Yes

effort toward multimodalities imaging systems including PET is ongoing.

Most PET detectors use Lutetium-based crystals such as LSO and/or LYSO scintillator crystals [1], [2], [3]. Recently $LaBr_3$ scintillation crystal has been proposed as an alternative to lutetium based crystals. Table I summarizes the main properties of those crystals. Those detectors have opened the way to advanced performance PET systems in the early 2000s. Roger Lecomte has detailed in reference [3] the performance requirements for clinical PET and described the detection technologies and their assembly into systems.

The state of the art commercially available PET systems exhibit nearly 10% efficiency. This moderate value mainly results from the limited solid angle coverage. Indeed, most of PET systems are cylindrical and their axial extension is limited to 20 to 25 cm at best.

Furthermore 511 keV-photons that enter an LSO scintillating crystal have 70% chance to Compton scatter. If the crystal is large enough, double interactions are likely to occur and ensure the full conversion of photon energy. However these events introduce an ambiguity in the interaction positioning and will also impact the spatial resolution. As a consequence a detector material with a high **photo fraction** is valuable for PET imaging [2] as it will enable the development of a compact system with optimal spatial resolution and preserved detection efficiency.

Improvement of the spatial resolution and its uniformity across the Field of View (FOV) were proposed with the measurement of the photon depth of interaction and the 3D positioning of the photon interactions in the detectors [2], [3]. However, in most of commercially available systems, intrinsic spatial resolution is limited by detector crystal size, photon noncolinearity and to a less extent to the positron range.

A *detector time resolution* of a few 100 ps allows localizing the position of the positron annihilation with several-cm accuracy along the Line Of Response. This time resolution efficiently reduces the random background impact on the image

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D. Yvon, G. Tauzin, P. Verrecchia, C. Flouzat, S. Sharyy, E. Ramos, J.-P. Bard, Y. Bulbul, J.-P. Mols, P. Starzynski, D. Desforges, A. Marcel, and J.-M. Reymond are with CEA Saclay, Institut de Recherche sur les lois Fondamentales de l'Univers, Bat. 141, F-91191 Gif sur Yvette Cedex (e-mail: dominique.yvon@cea.fr).

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Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

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Trimethyl Bismuth optical properties for particle detection and the CaLIPSO detector

E. Ramos, D. Yvon, P. Verrecchia, G. Tauzin, D. Desforge, V. Reithinger, D. Dubreuil, M. Hamel, C. Flouzat, S. Sharyy, J-P. Bard, Y. Bulbul, J-P. Mols, P. Starzynski, A. Marcel, R. Granelli.

Abstract— **Trimethyl bismuth (TMBi) is a "heavy" transparent and dielectric organometallic liquid. Charge and light produced in the liquid are both detected in the CaLIPSO detector. This paper focuses on the measurement of the TMBi optical properties relevant for particle detection. We measured the TMBi transmission curve and refraction index versus wavelength, as well as the light production yield and the timing performance on a small size cell.**

***Index Terms*— Gamma ray detectors, Position sensitive particle detectors, Calorimetry, Biomedical Imaging, Positron emission tomography.**

I. Introduction

The CaLIPSO project focuses on the development of an innovative energetic-photon detector. The qualities of this detector are particularly highlighted in demanding measurements on the properties of positron annihilations. Such device would be welcome in solid state physics on slow positrons beams (Positron Annihilation Lifetime Spectroscopy, or ACcolinearity Annihilation Reconstruction methods, so called PALS or ACAR), or in the context of medical imaging by positron emission tomography. Motivations, context, technological assets and challenges for the CaLIPSO project (french acronym for liquid ionization calorimeter with positionning and light detection) are described in detail in references [1, 2]. The detector uses an

Fig.1: Measurement setup of the TMBi refraction index. A prismatic cell filled with water is placed at the center of the goniometer plateau for a systematic check.

Manuscript received October 9, 2001. (Write the date on which you submitted your paper for review.)

This work was supported in part by the Neuropole de Recherche Francilien (NeRF), Ile de France, under the Grant n° RPH10014DDA.

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innovative "heavy" organometallic liquid: the TriMethyl Bismuth (TMBi), 82% by weight of Bismuth. TMBi efficiently converts through the photo-electric effect, photons of energies below 1 MeV. The ionisation signal and light produced in the liquid are both detected. Beyond the measurement of gamma photon energies, this detector will allow locating photon interactions in the detector in three dimensions down to 1 mm^3 and a sub nanosecond timing accuracy.

Liquid TMBi had never been used for particle detection so far. This paper focuses on measurements of TMBi optical properties relevant for particle detection. Several TMBi properties have to be measured in order to be able to compute the CaLIPSO detector performances. Knowledge of the TMBi *refraction index* (Chapter II), *absorption* properties (Chapter III) and *light production yield* (Chapter IV) are mandatory to parameterize, optimize and in the end understand propagation and collection of optical photons in the CaLIPSO detector.

Then Chapter V details our first attempt to build a device that triggers on the light produced through 511 keV gamma interactions in TMBi.

Unfortunately, TMBi is a pyrophoric liquid. We cannot use in measurement device that expose the liquid to air. Thus we adapted a CF16 flange (from Composants Technique Verre Metal) to vacuum tight optical cells. For these measurements, optical cells were filled with "Electronic" grade TMBi, from JSC Alkyl, 99.9995% pure.

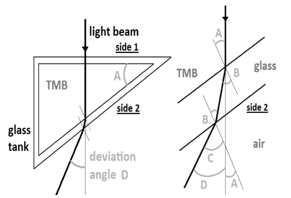


Fig. 2: Beam path and angle names at the prismatic cell boundaries.

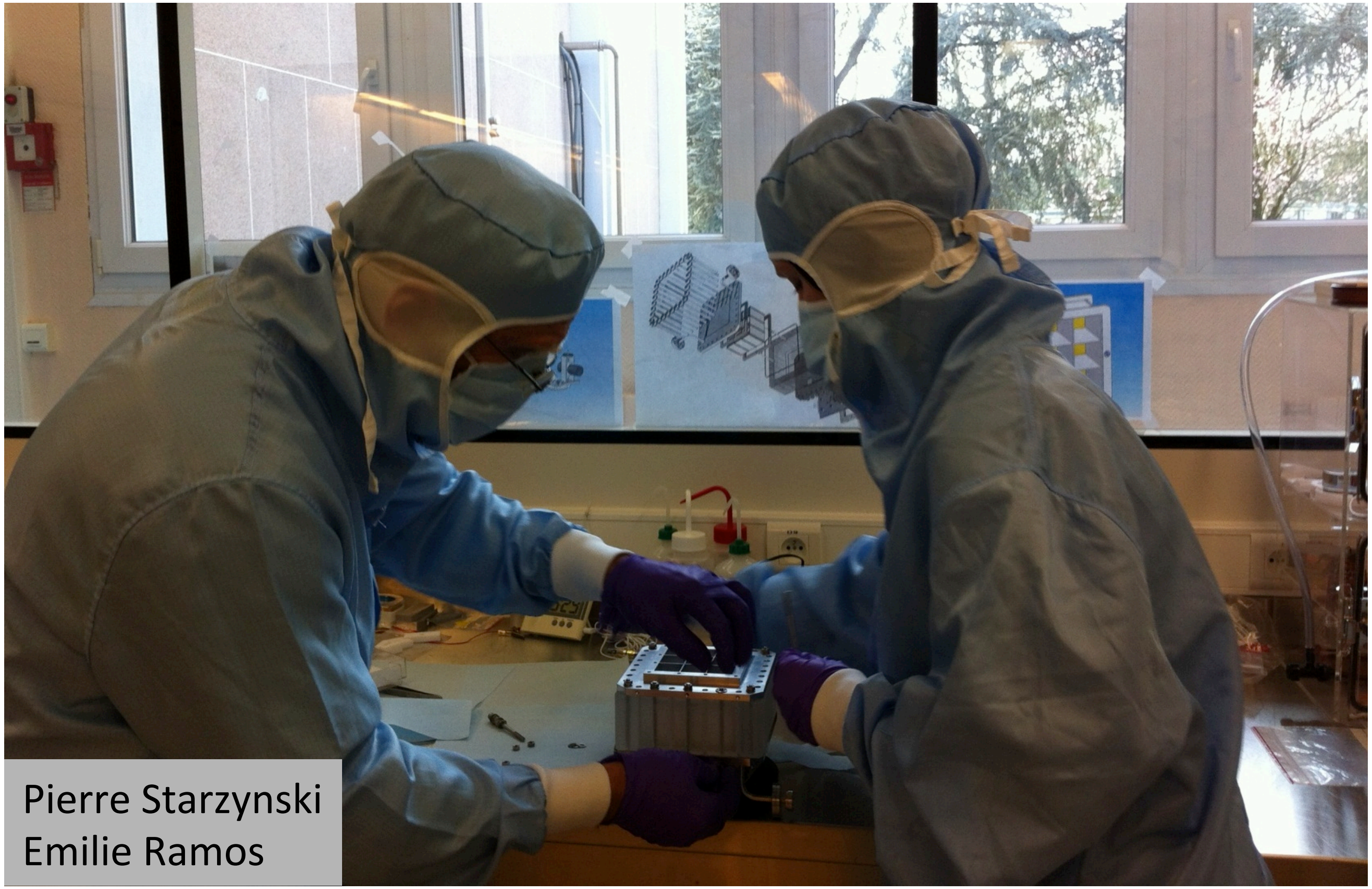
II. Refractive Index

A. Experimental setup

For its measurement, we used vacuum tight prismatic glass

Instrumentation du Détecteur Optique

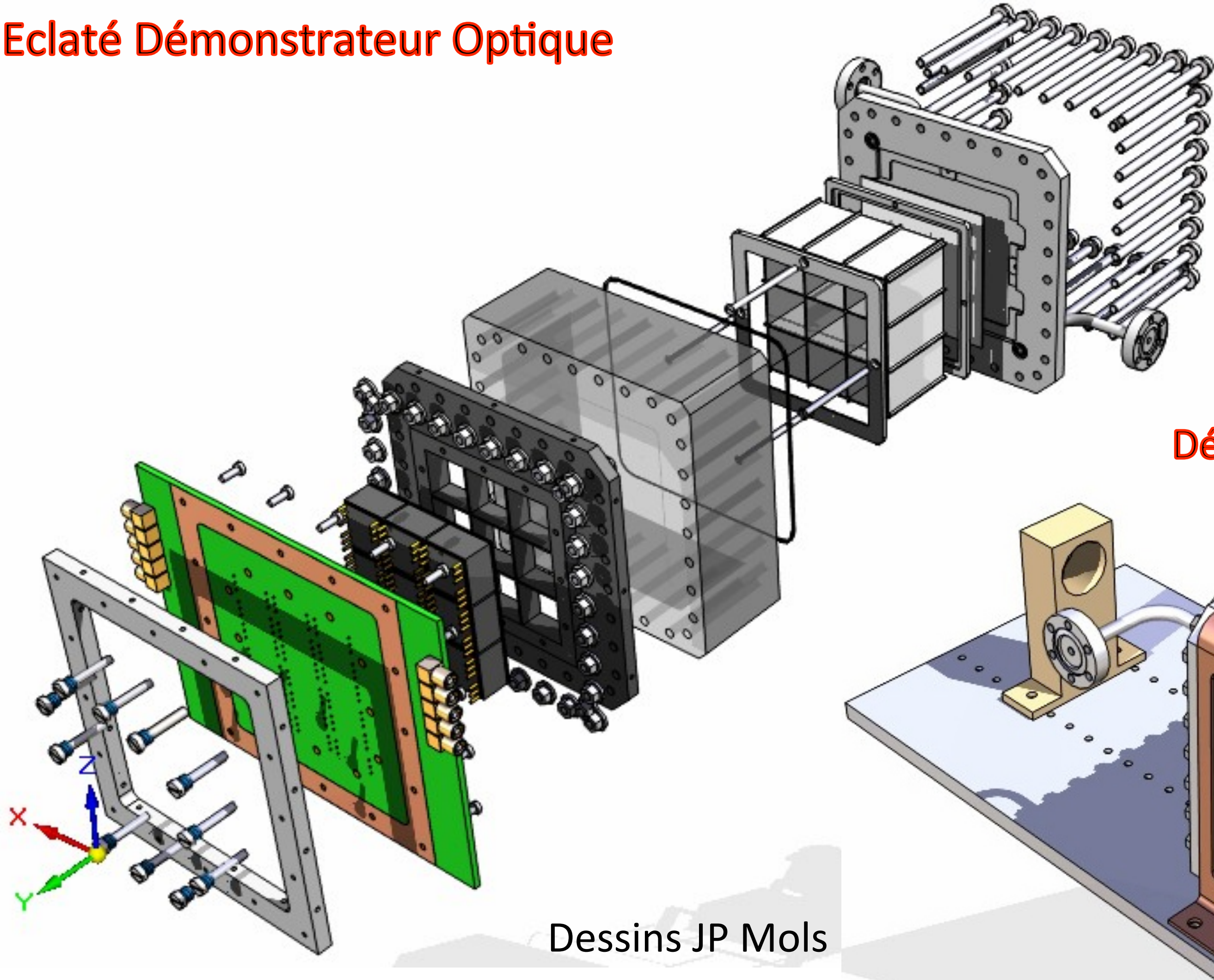
Démonstrateur optique



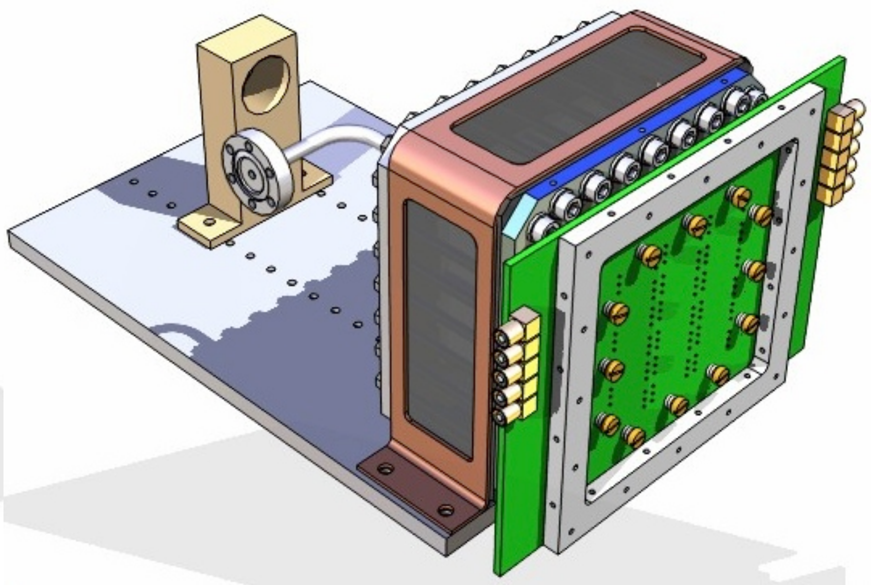
Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Conception Mécanique et Vide

Eclaté Démonstrateur Optique

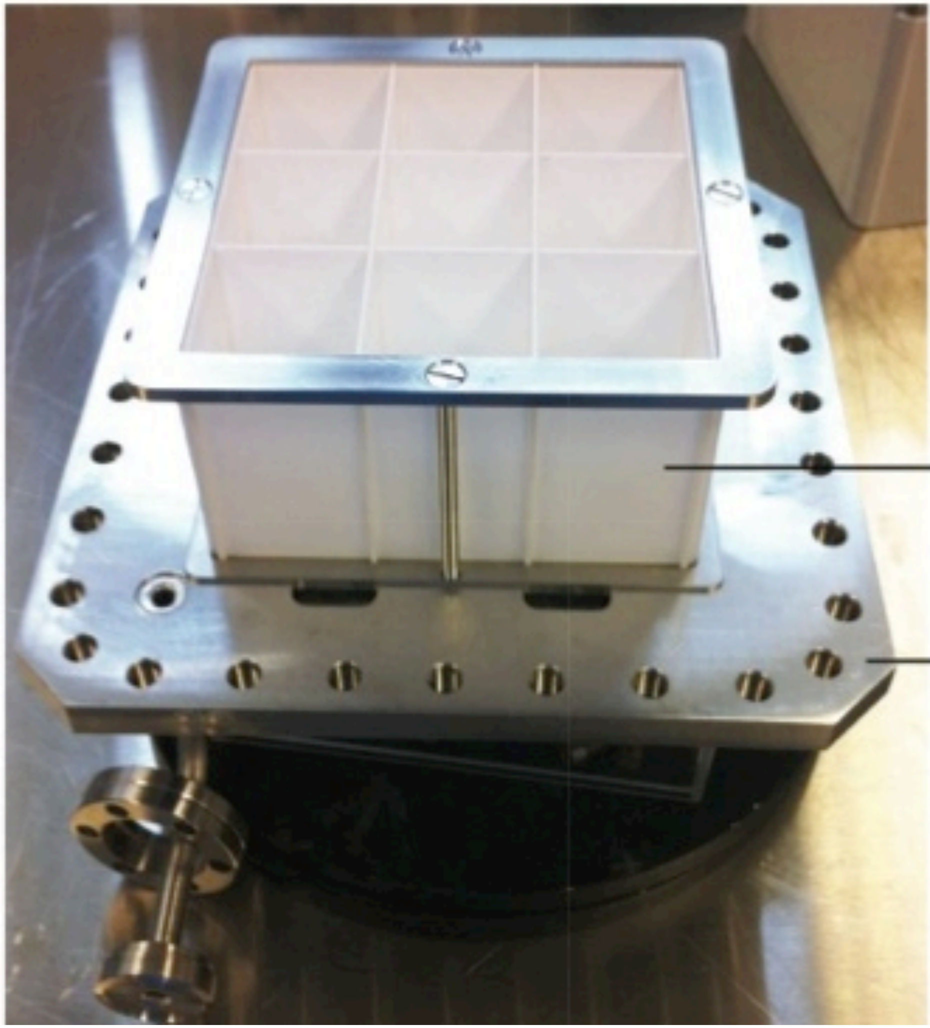


Démonstrateur Monté



Dessins JP Mols

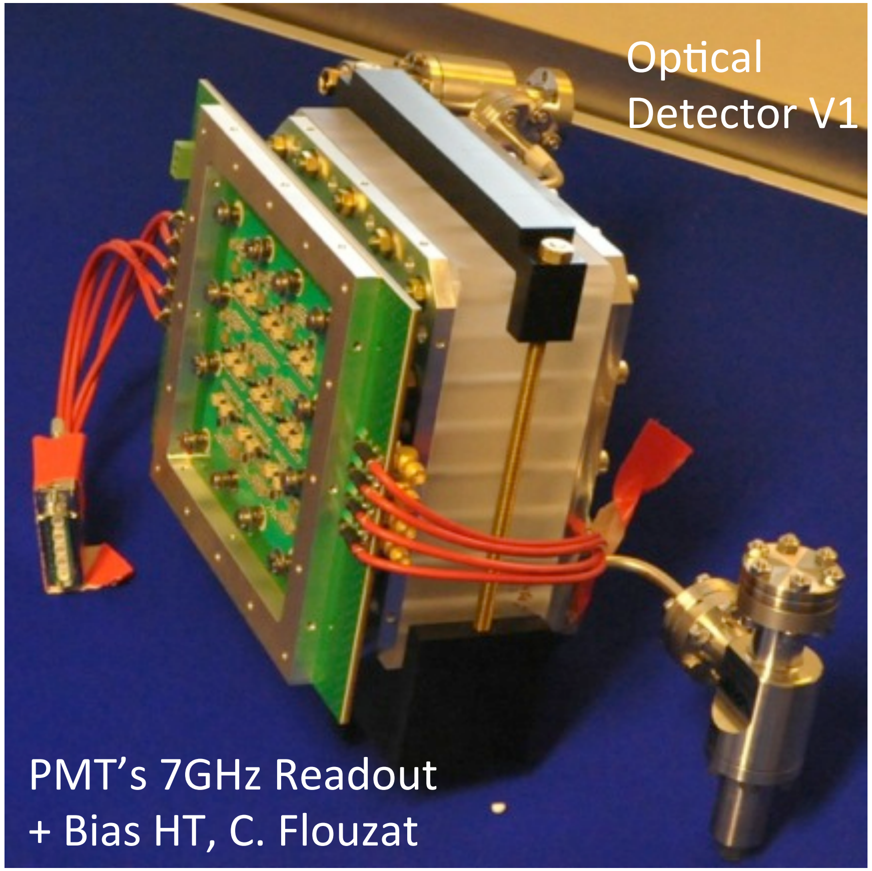
Guide de Lumière DO1 CaLIPSO

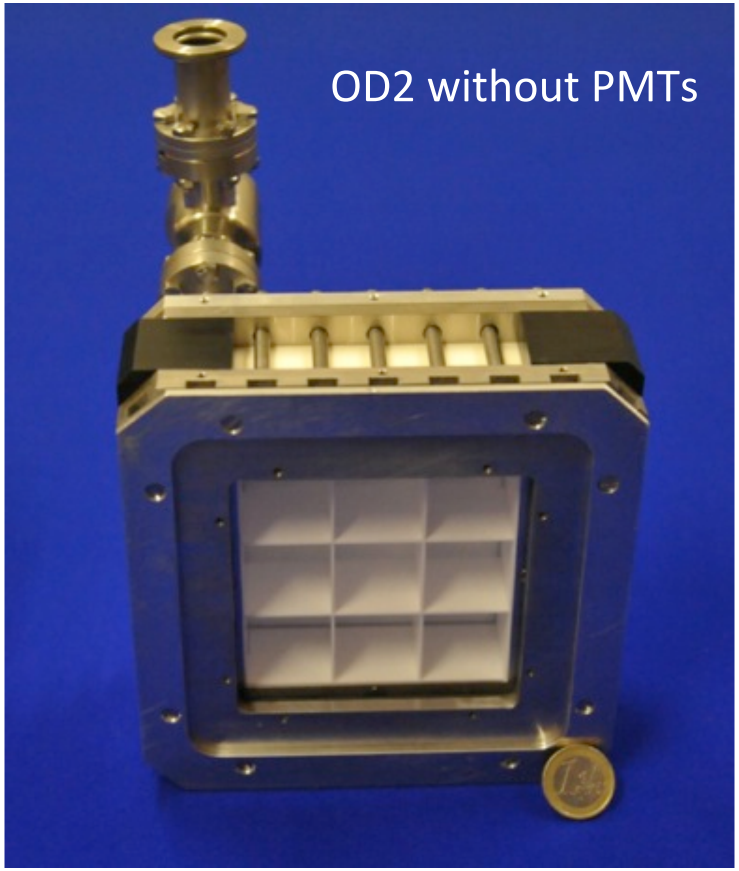


Guide de lumière

Bride servant à fermer le corps de chambre

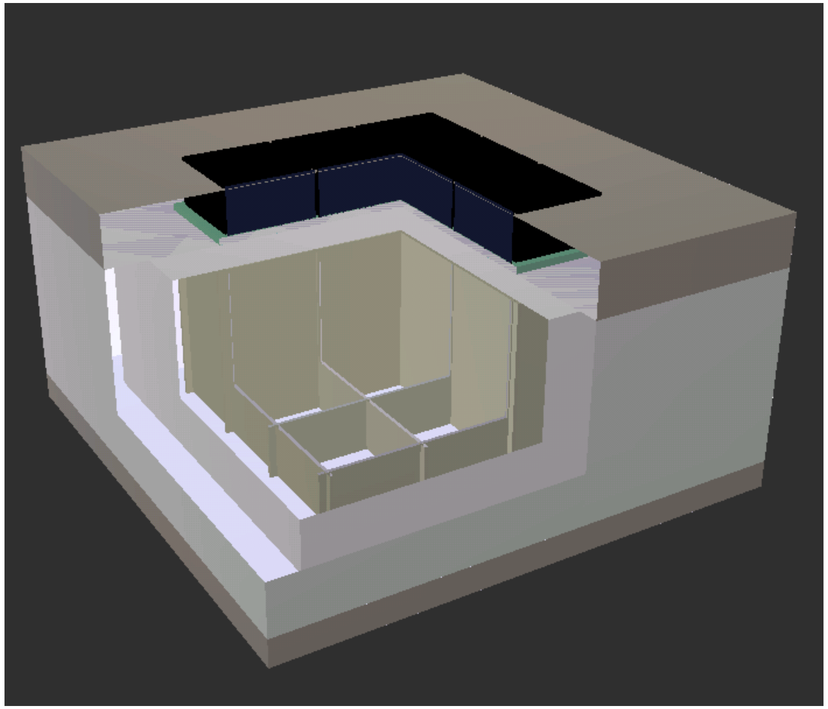
First and Second Optical Detector

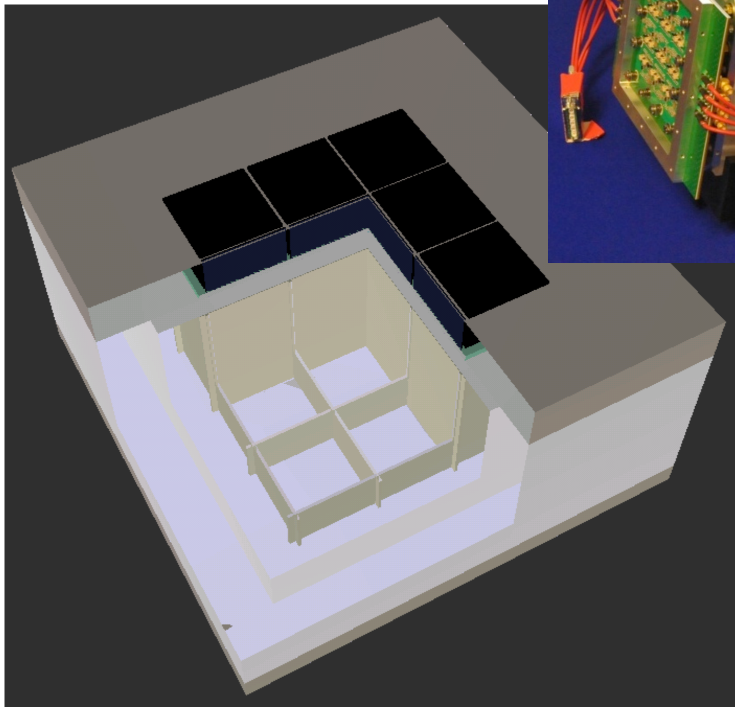


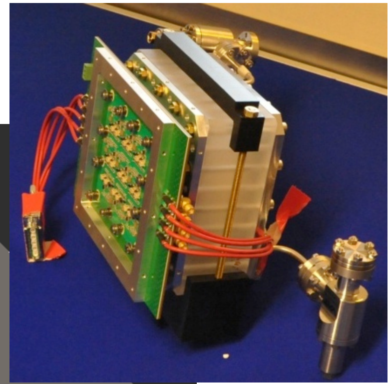


Démonstrateur optique simulé

Géométrie du démonstrateur optique dans Geant4



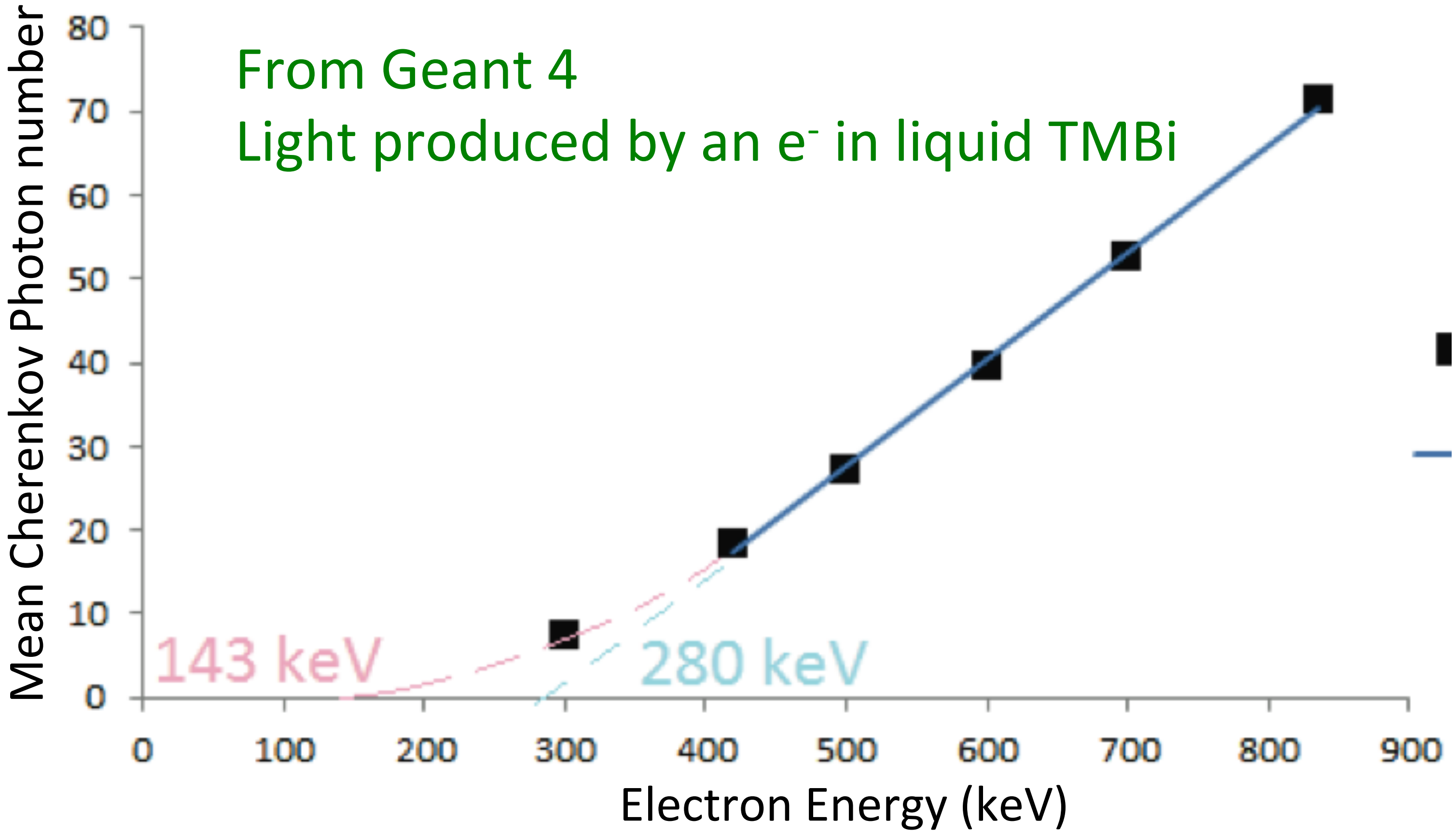




- Valider le modèle
- S’en servir pour comprendre et optimiser le démonstrateur

Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Cherenkov light production



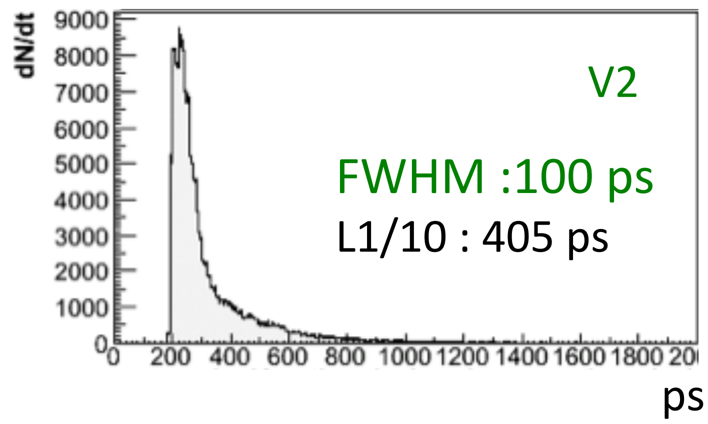
~ 20 Cherenkov Photons produced for a 420 keV PE electron

Supported by a single measurement at 836 keV

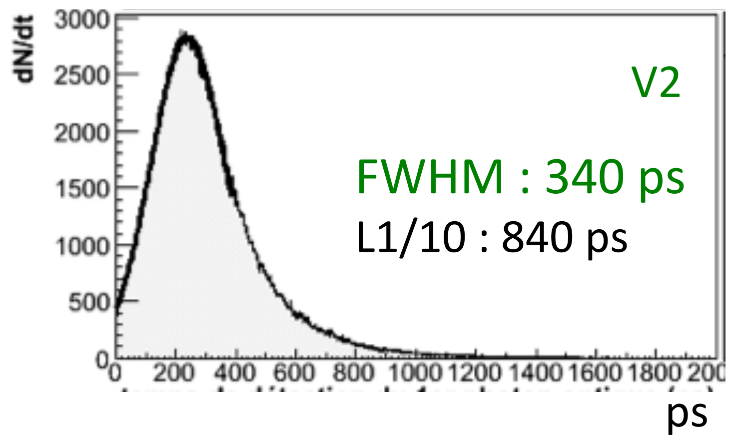
E. Ramos, et al. "Trimethyl Bismuth optical properties ……", IEEE TNS. – sub.

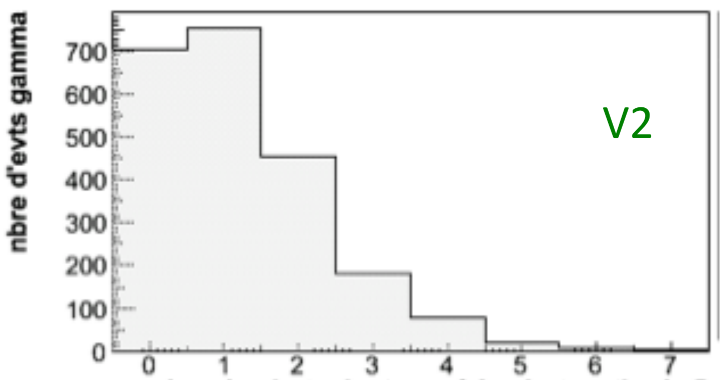
Optical Detec. V2 simulations.

PhotElec. Time Distrib

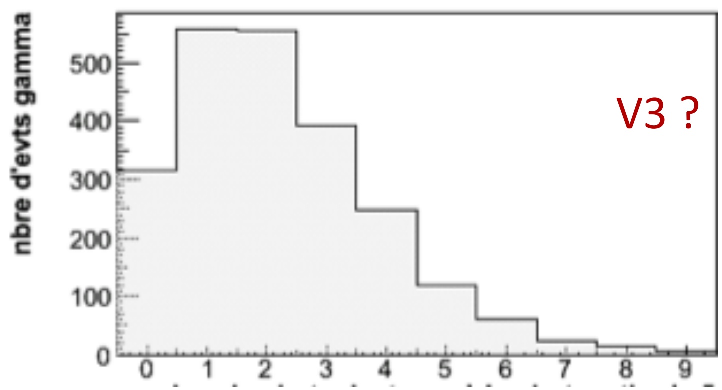


Expected Mes. Time Distrib – R11265



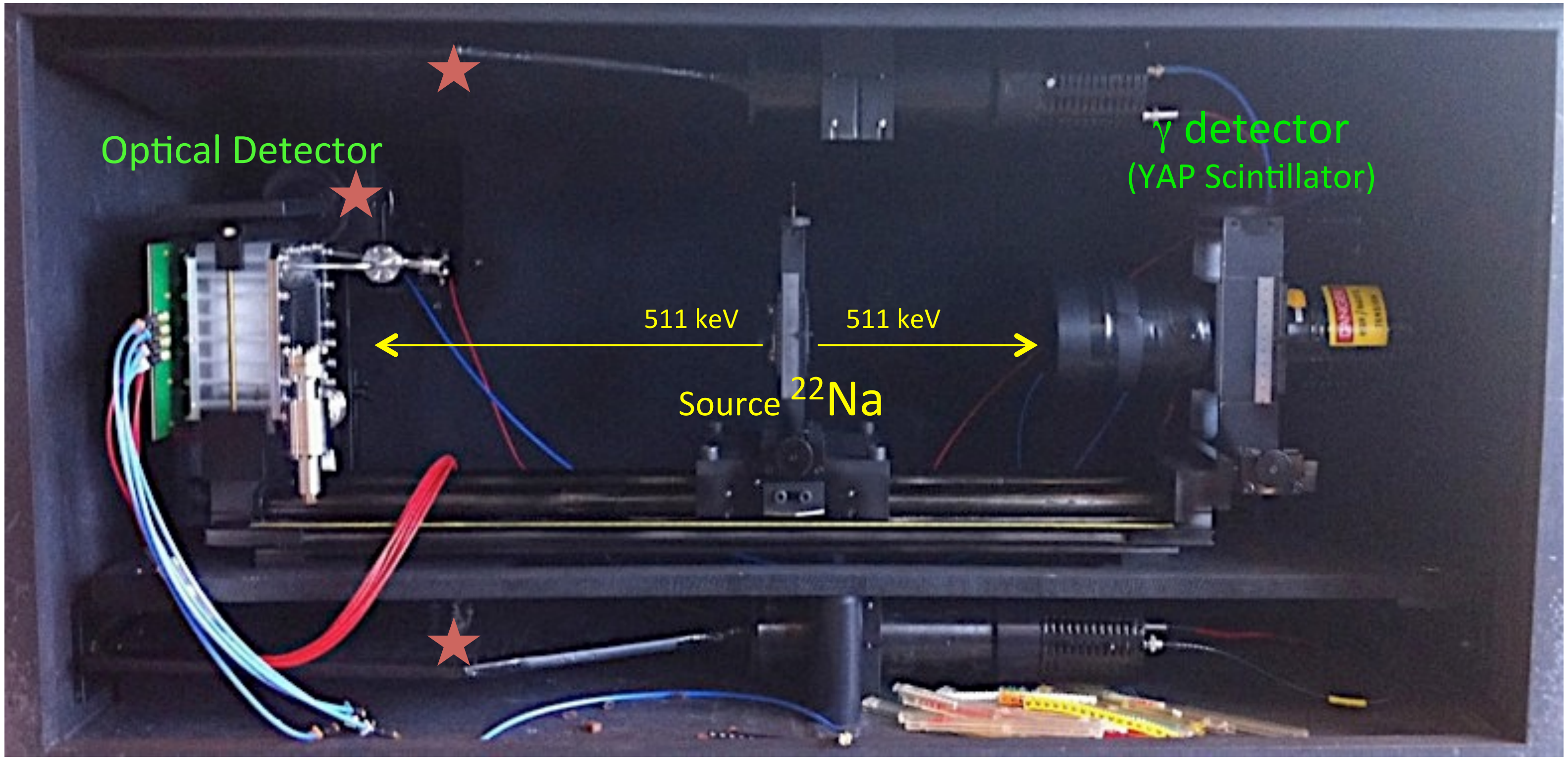


Calc. PhotElec Number Distribution



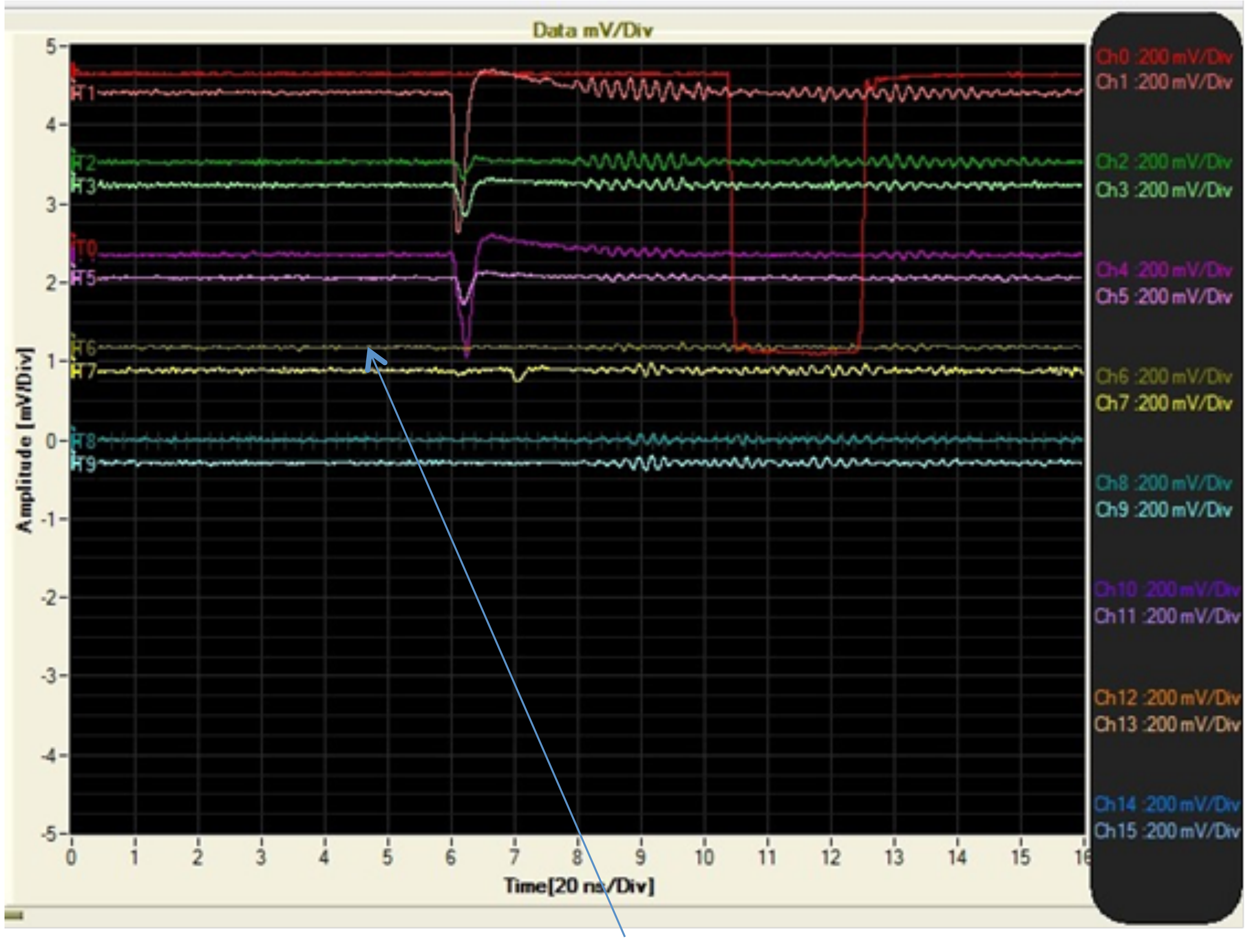
Opt. PhotElec Number Distribution
High efficiency Photocathode.

Optical Detector Test Setup



- Data acquisition triggered by a YAP scintillator pulse.
- Geometry/threshold chosen to select 511 keV γ pointing in centered Cell.
- Measurement of the **detector's efficiency** and **speed** on 511 keV γ.

First Signal on Optical Detector



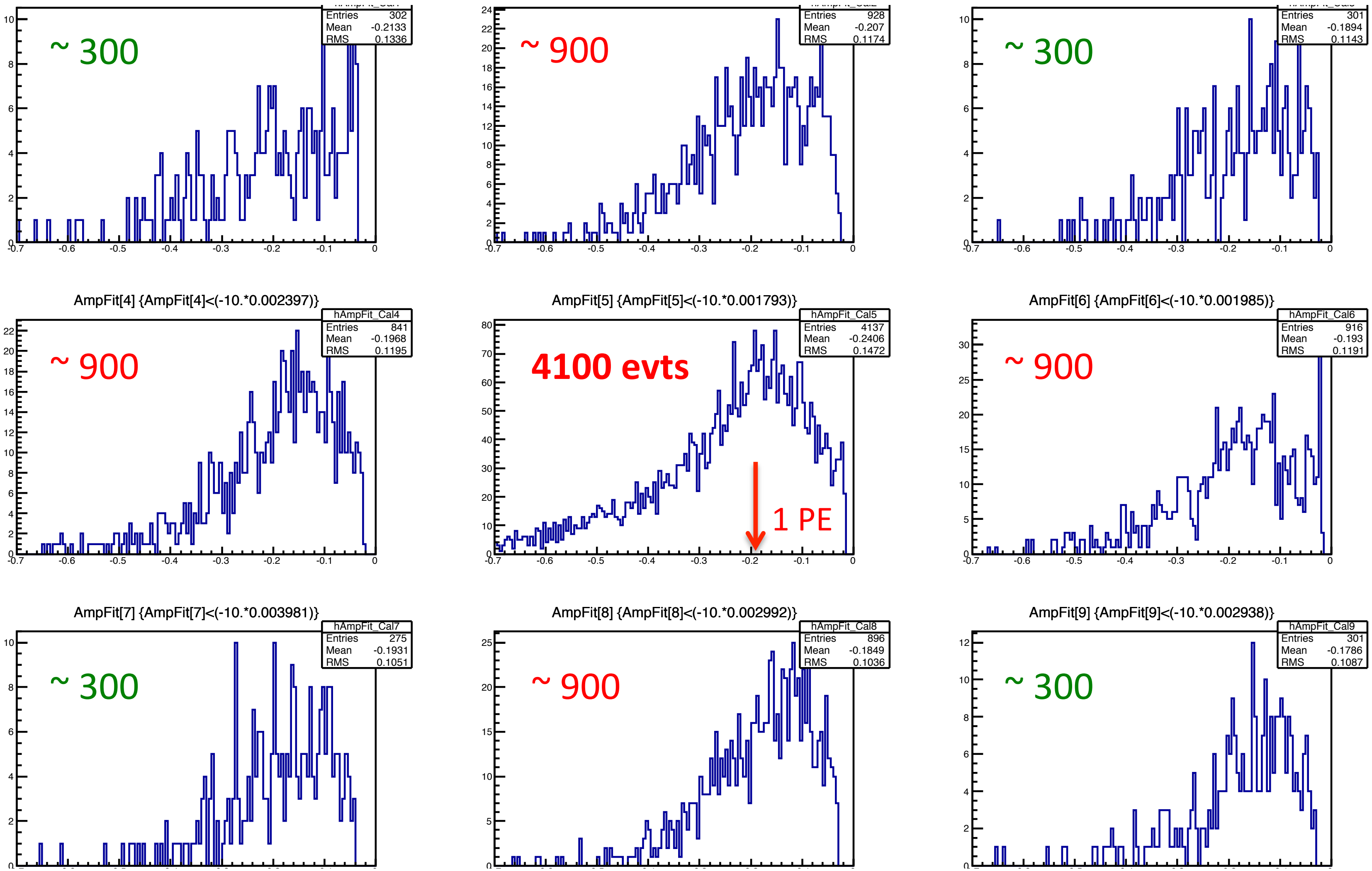
D.Yvon
JP Bard

Cosmic rays => coincidences on 5 channels, strong signal => lower HT on PMT.

Using a 16 Ch., 3.2 GHz, WaveCatcher (D. Breton et al., NIM A, 2011)

Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Pulse Amplitude Distribution

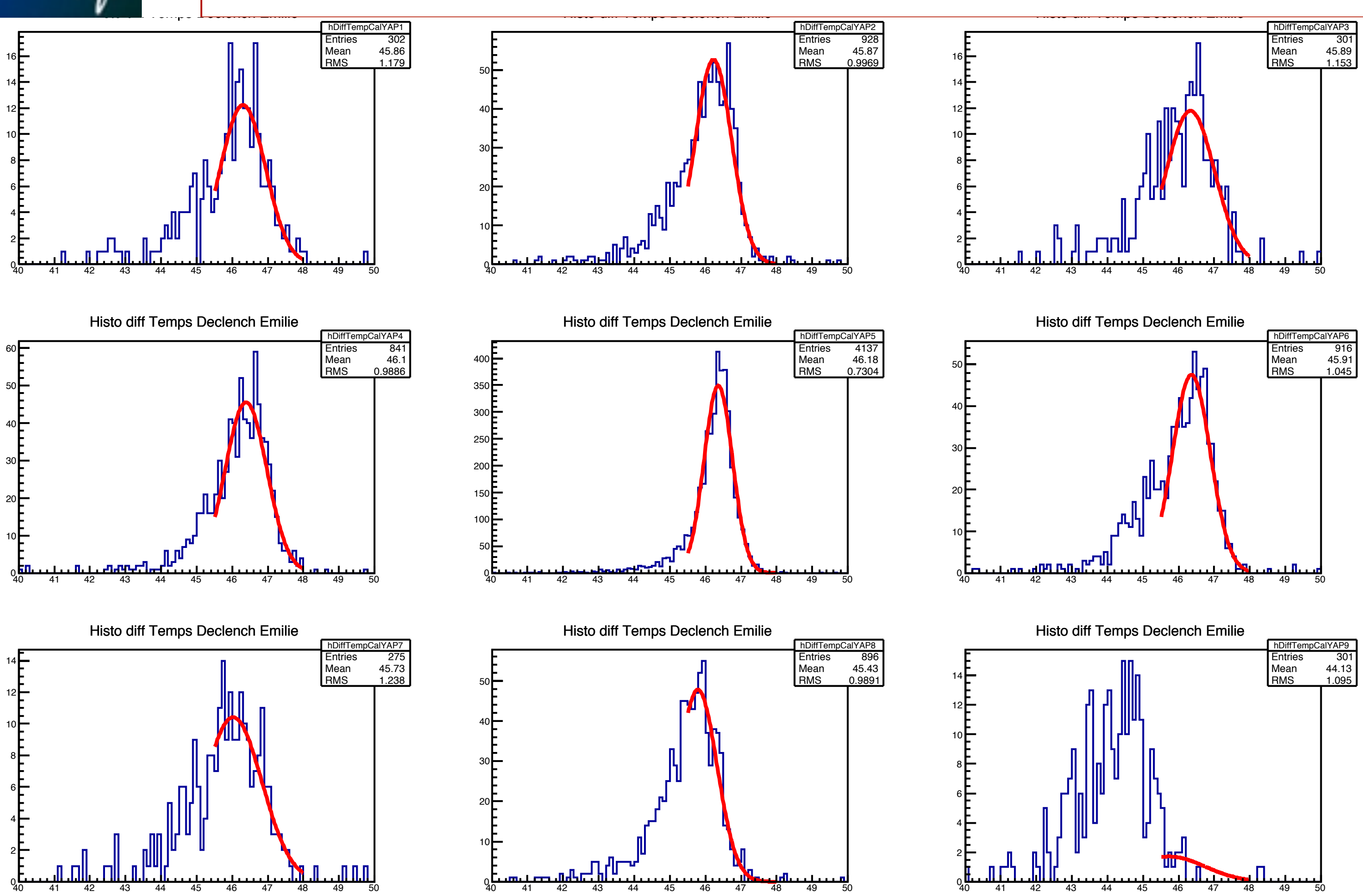


We mainly trigger on Single Photo-Electrons

Centered cell rate >> neighbor cells rates but *crosstalk*

YAP-OD2 Measured ΔT

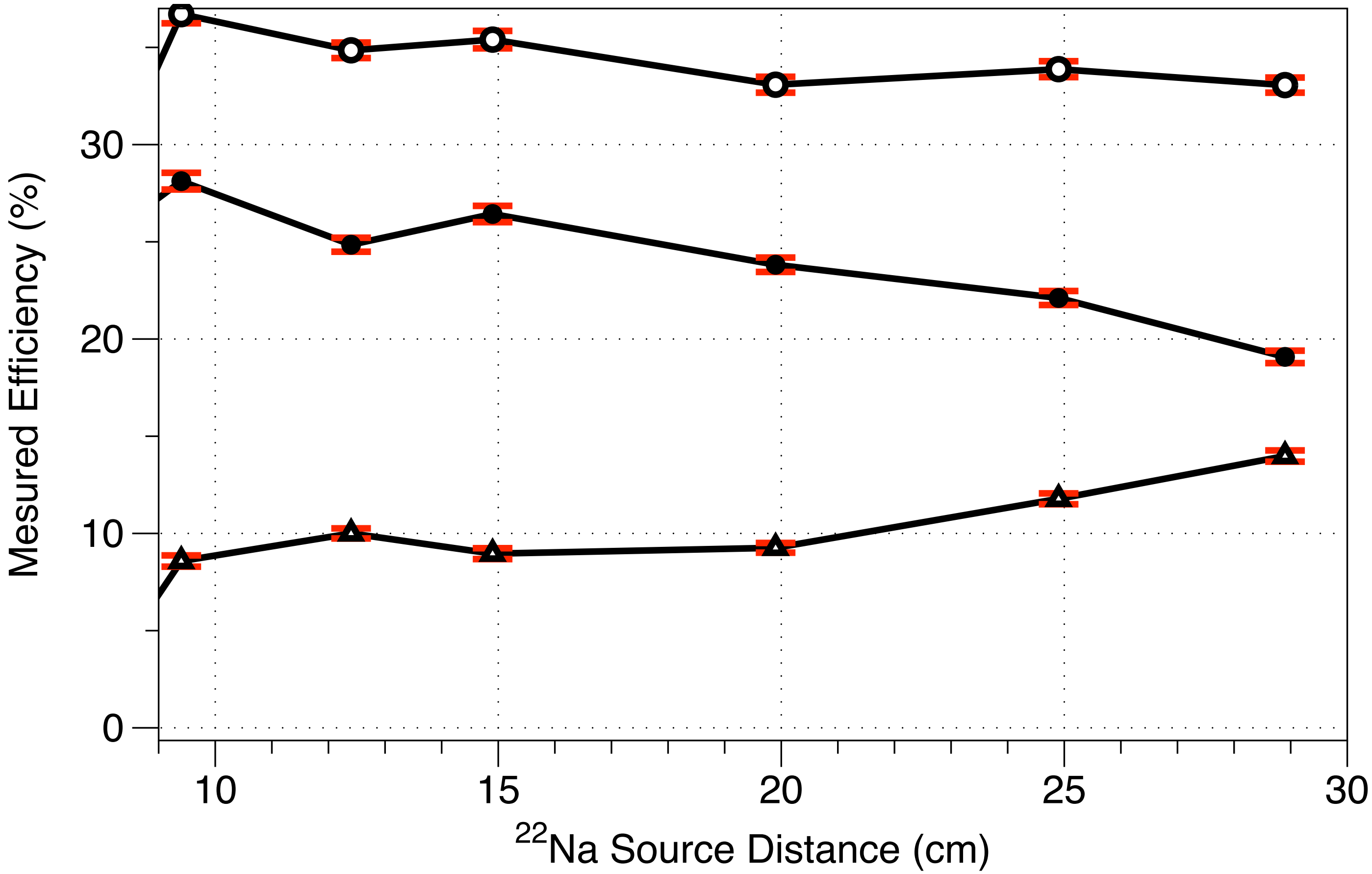
D.Y.



Centric cell time distribution is the narrowest

=> Increased optical path for neighbor cells triggering photons

511-keV γ Detec. Efficiency



D.Y.

Circles: Total detection efficiency Flat ~ 34.5 %

Black Dots: Centric cell detection efficiency

Triangles: Neighbor cells detection efficiency

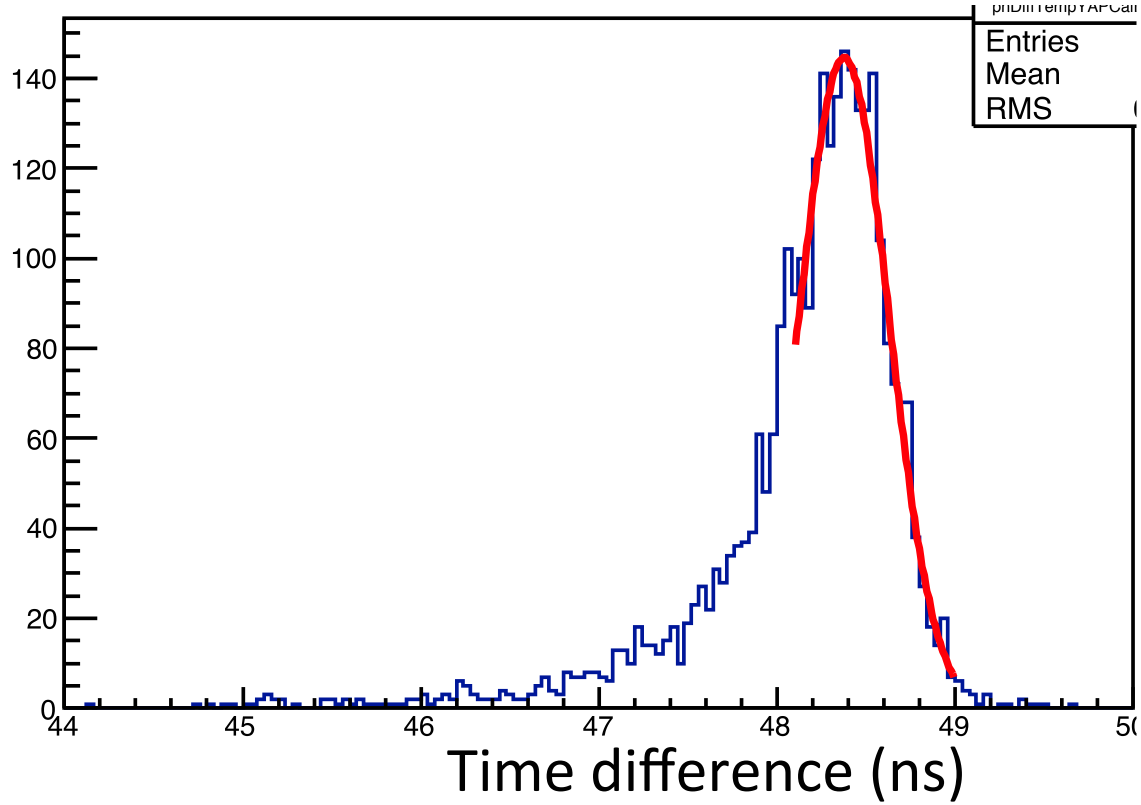
Dist. >20 cm => 511 keV Photons imping on neighbor cells too

YAP - OD2 measured ΔT

Fitted Time Width :
592 ± 18 ps (FWHM)

YAP γ Detector :
245 ± 11 ps (FWHM)

OD2 Time Res. :
539 ± 25 ps (FWHM)



Dominated by R11265 PMT Time Transit Spread:

Biasing network ***not tappered***

*Working at **Gain = 0.4 10^6*** ***….. But ……***

MCP-PMTs needed in order to optimise CaLIPSO time resolution.

Summary DO2 Tests

Detection Efficiency on 511 keV γ through PE conversion :

Expected: 0.90* 65.7% * 47% *= 27%*

We measure: **34.5 %.**

Fully efficient ☺ => We detect few Compton interactions

Timing on 511 keV: 539 ± 25 ps (FWHM),

Timing correlated to PMT Gain

MCP-PMT needed in order to get closer to nominal 100 ps FWHM.

E. Ramos PhD Thesis, December 2014.

Next Step (DO3):

Optimize Light *Guides design* to minimize Cross-Talk.

Optimize Timing with MCP-PMT => MCP-PMT ordered.

Vers un Démonstrateur Ionisation

Etudes Détecteurs

Etude électronique multipixéllisée

Ultrapurification.

Enjeux pour un détecteur Ionisation

Propriétés de dérive de charge dans le TMBi

Technologie Détecteur

- Chambre à ionisation liquide
- Herméticité/Porosité/absorption eau: Zéro
- Compatibilité Chimie TMBi
- Grande densité de pixels
  - ➔ *Plancher de détection résistif*
  - ➔ *Détection par influence capacitive*
- Electronique ASICs IdeF-X

Ultrapurification du TMBi

- *Objectif ~ 0.1 ppb O_2 eq.*
- Ultra-propreté
- *Détection de contaminants*
- *Ultra-purification*

Ionisation dans les liquides

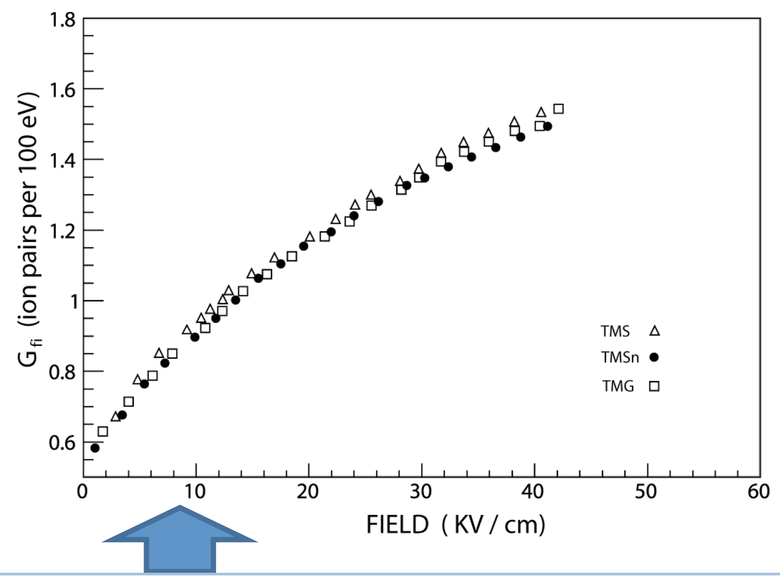
Principales propriétés:
- **Rendement de production de charge**
- **Mobilité des électrons**
- **Durée de vie des électrons**

Free ion yield Nombre de paires échappant à la recombinaison Pour 100 eV déposés dans le liquide $\equiv G_{fi}$

G_{tot} Nombre total de paires d'ions formées dans le liquide pour 100 eV d'énergie

	Chemical formula	ε	d (g/cm³)	$G_{fi}(0)$	μ (cm²/V s)
TMS	$(CH_3)_4Si$	1.92	0.645	0.65	100
TMG	$(CH_3)_4Ge$	2.01	1.006	0.63	90
TMSn	$(CH_3)_4Sn$	2.25	1.31	0.64	70
TMB	$(CH_3)_3Bi$	2.65	2.30	>0.4	50 ?

Pour les liquides à température ambiante : G_{tot} ~ 3.5.



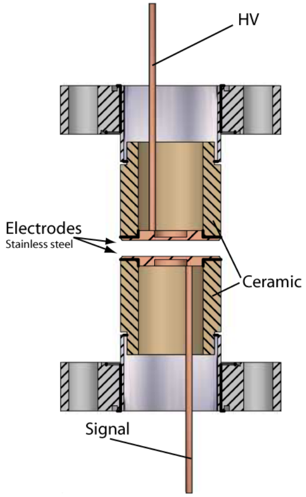
A bas champs les paires d'ions se recombinent

Nos premières cellules / mesures

Montée sur le banc d'ultrapurification

Tous les appareillages sont assemblés sous procédure UHV

P. Verrecchia
G. Tauzin



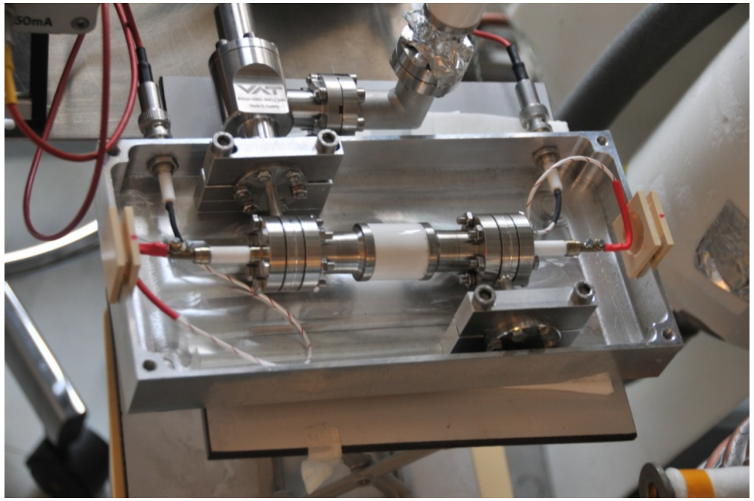
Gap : entre 2 et 2.35mm
HV max : between -1500 and -1800 Volts
Validation : R > 10^{16} Ω

Mesures

- **Mobilité des ions**
- **Constante diélectrique**
- **Rendement production de charge : G_{fi}**
- **Compatibilités chimiques**

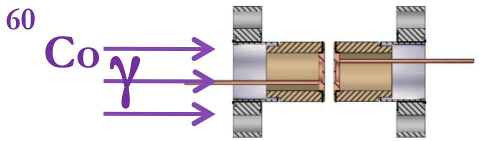
Mesures de pureté du TMBi

A base de matériel standard UHV

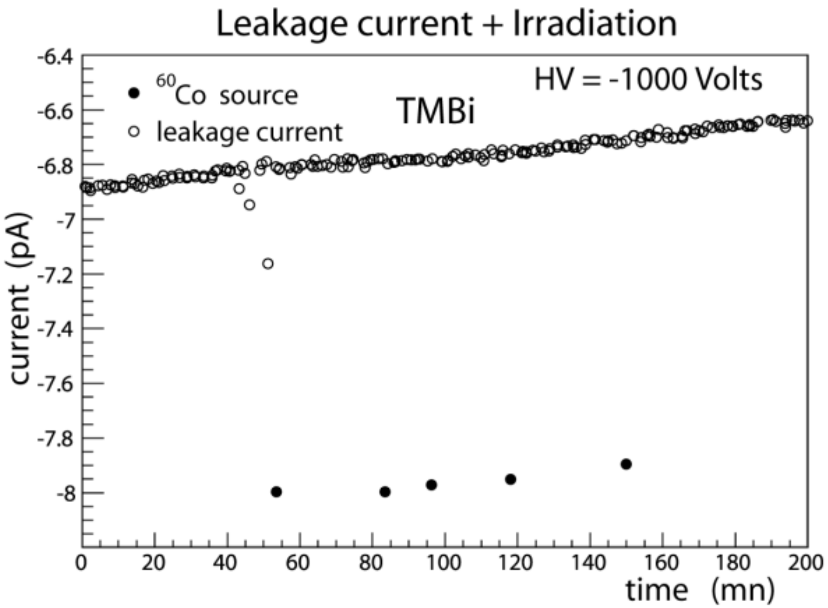


Premiers résultats sur l'ionisation

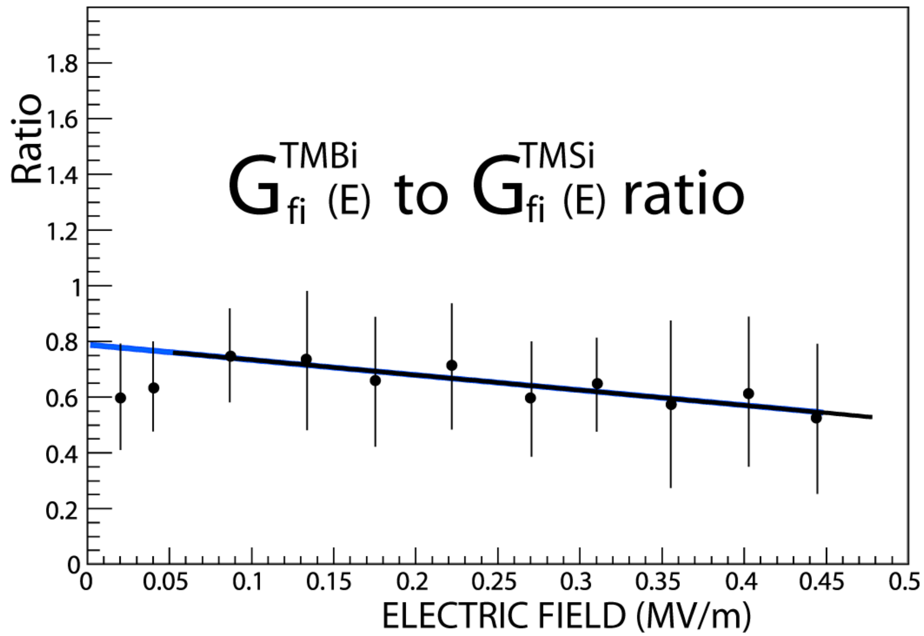
Pas d'ultrapurification



Dose rate ≈ 300 μGy/s
2 identical cells filled with TMS and TMB same purity



Les charges sont mobiles dans le TMBi.

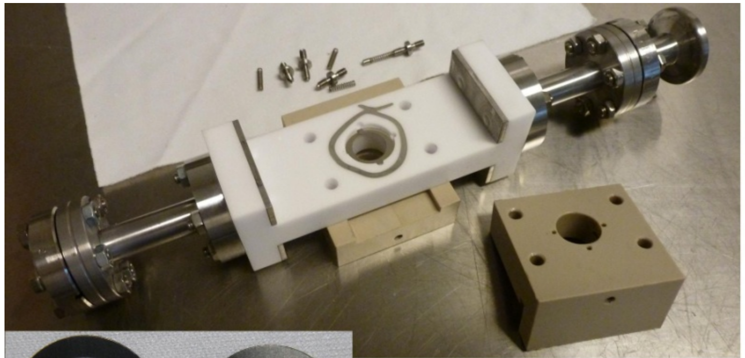


G_{fi}(E=0) for TMB > 0.4

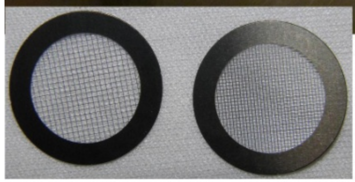
Mesure de la durée de vie des électrons libres

Prototype *Monopixel* du détecteur ionisation

avec les technologies prévues pour la grille de Frisch et L'électronique de lecture.



Exploded view of the "TVie" cell



Two types of Frisch grid

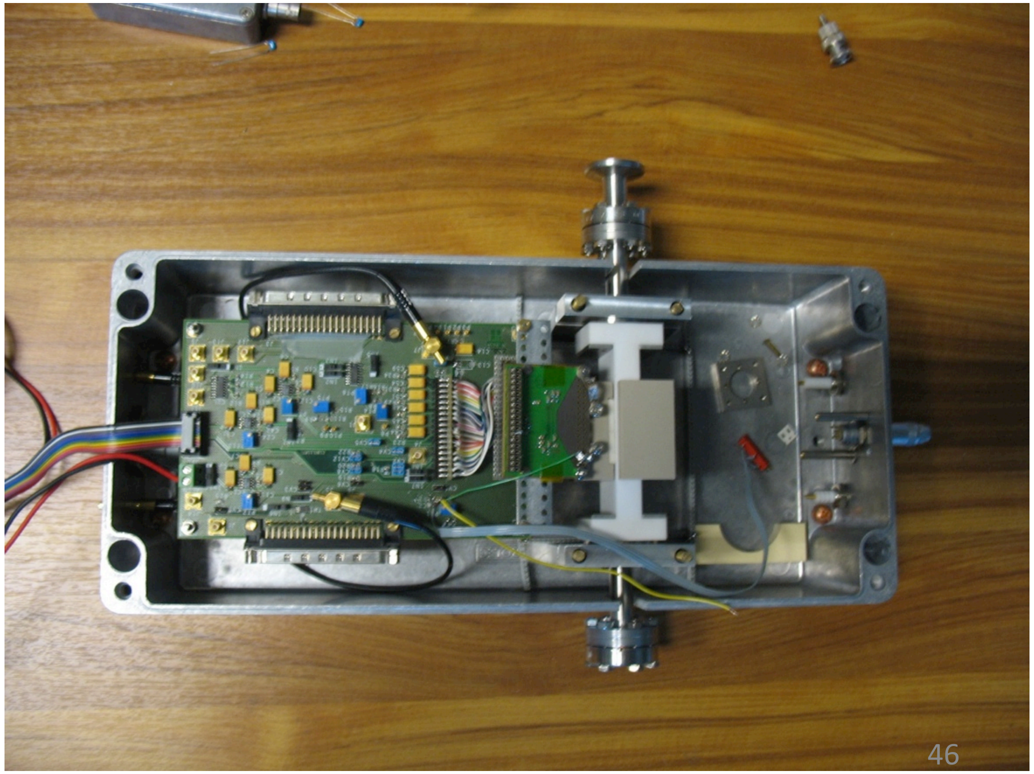
Left : Nickel wires of 0.040mm at an interval of 0.5mm

Right : Nickel wires of 0.040mm at an interval of 0.3mm

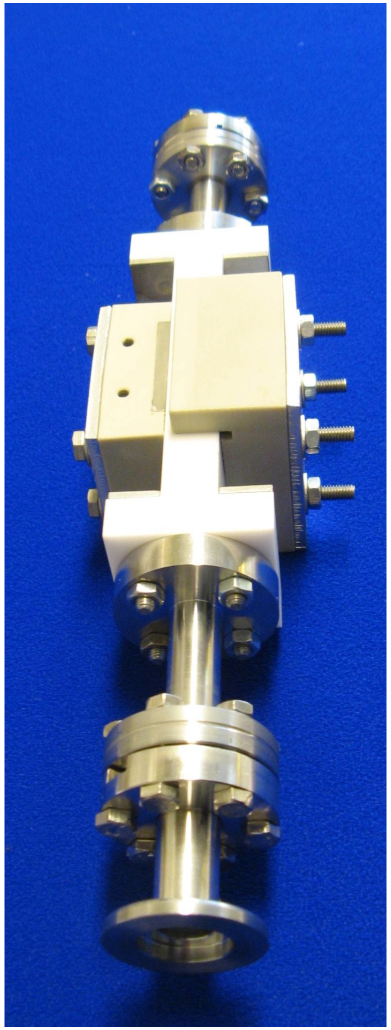
L'épaisseur de la chambre à dérive est réduite à 1 cm

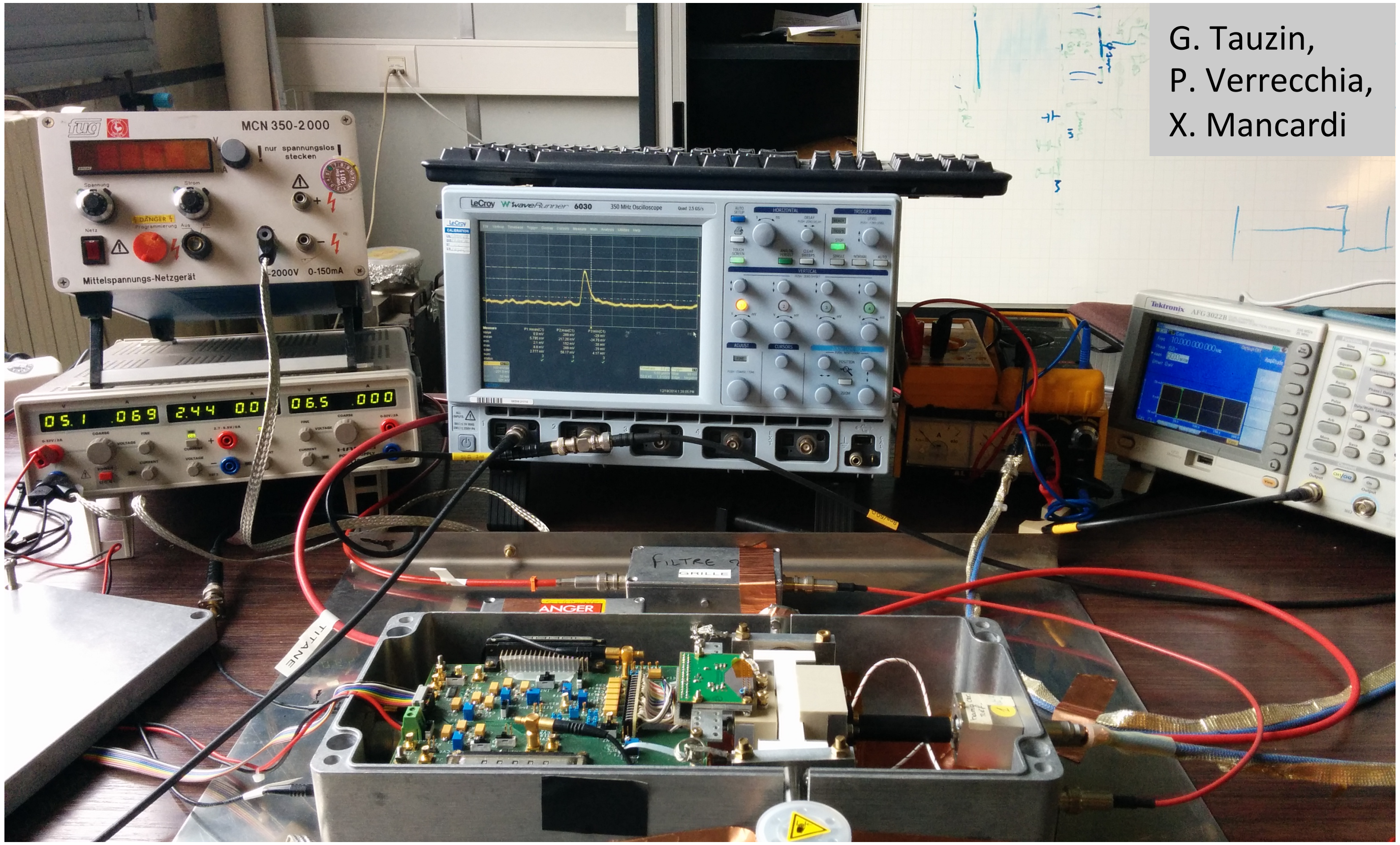
Premiers tests d'adaptation de l'électronique de lecture IdeF-X

(32 voies)



Cellule TVie





G. Tauzin,
P. Verrecchia,
X. Mancardi

Premières impulsions muons du détecteur de charge CaLIPSO

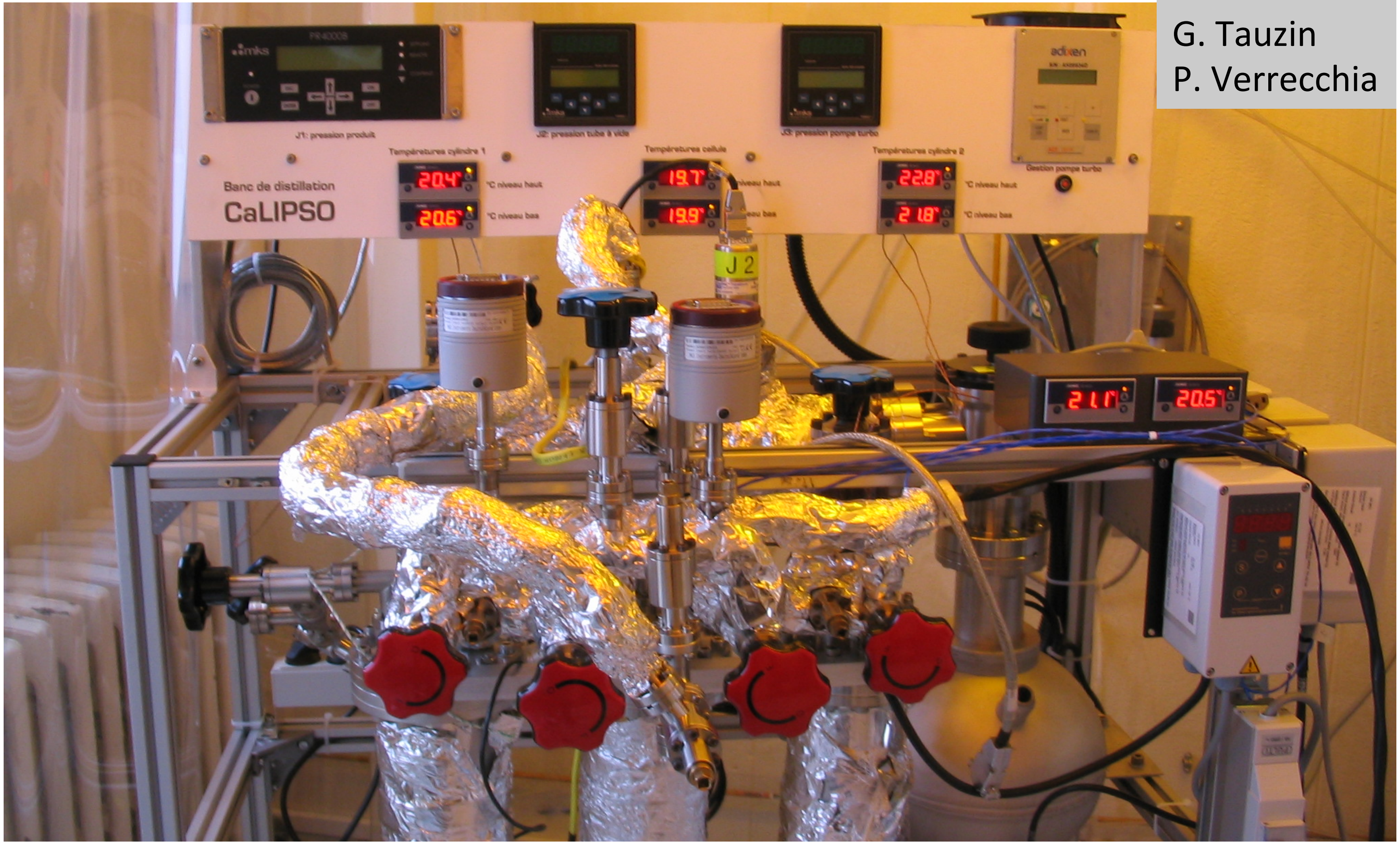
Seuil ~ 1000 electrons, avec ASICs IdeF-X.

Charge attendue γ 511 keV ~ 4500 electrons

=> Electronique de lecture validée ☺

La question de l'Ultra-Purification

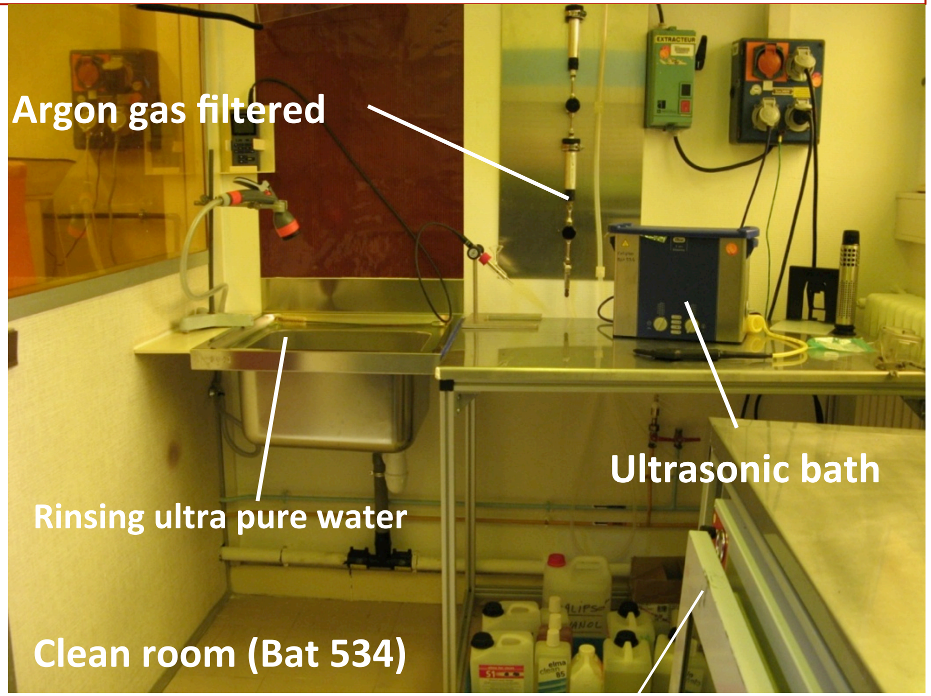
G. Tauzin
P. Verrecchia



Ultra - Propreté

Procédures de nettoyage ultravide standard :

➔ Nettoyage de toutes les surfaces exposées au vide



Etuvage "sec" à 150°C

Assemblage en salles Blanches :

Tout éléments sous vide,
Détecteurs,
Flux classe 100.

Taux de Fuite:

$< 10^{-11}$ mbar.l/s

Dégazage sous pompage sec:

Vide limite

⇩

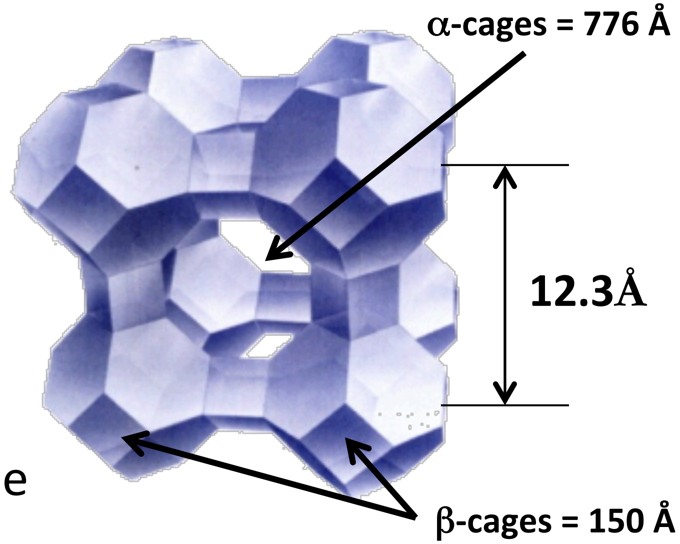
Vide sans contamination.

Ultra purification par tamis moléculaire

Solide micro-poreux ≡ Adsorbent

Adsorption : Piègeage des molécules de tailles inférieures à l'ouverture des micropores.

Aluminosilicate = ***Zeolites***
Les tamis moléculaires sont des matériaux de synthèse



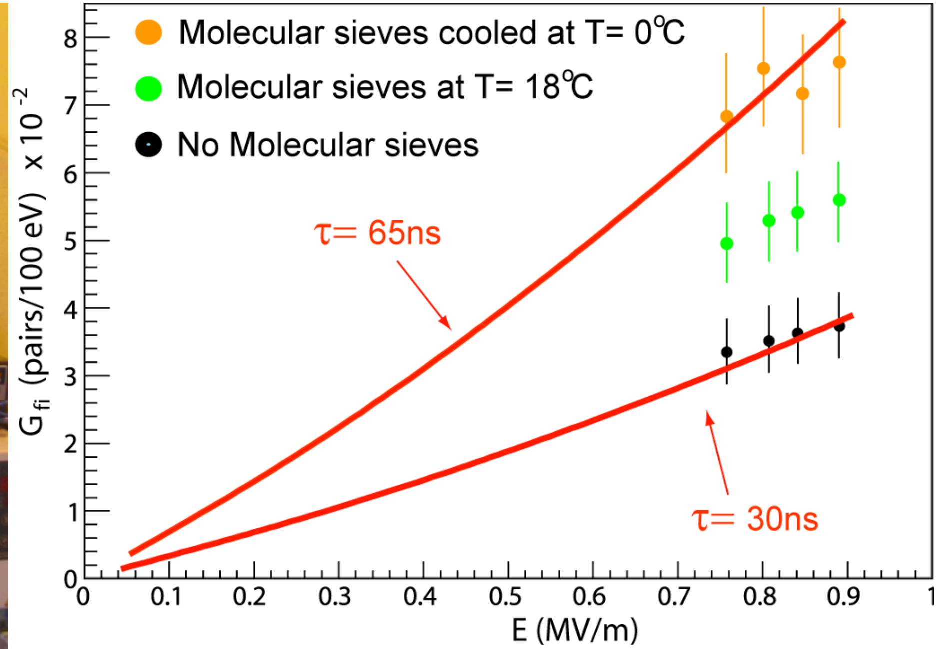
Structure d'une Zeolite A
➔ piègeage des molécules polaires

Pellets

Les zéolites sont agglomérées en "Pellets" de taille macroscopique

Dans lesquels sont aménagés des "macropores".

Travail sur le tamis moléculaire



Electrons life time fitted using the Onsager model with the parameters:

ε= 2.65 Gfi(E=0)= 0.408 μ= 50cm2/V·s

Réussir est indispensable pour permettre d'acquérir des signaux 511 keV en ionisation.

C'est notre première priorité de travail

Identification des contaminants

Guidance de J-Ph. Renault (IRAMIS)

=> CEA/DEN - DANS/DPC/SECR

D. Doizi, V. Dauvois, G. Plancque, A. Turban, S. Legan

Chimie analytique,

Recherche de ***traces*** de contaminants electronégatifs dans le TMBi.

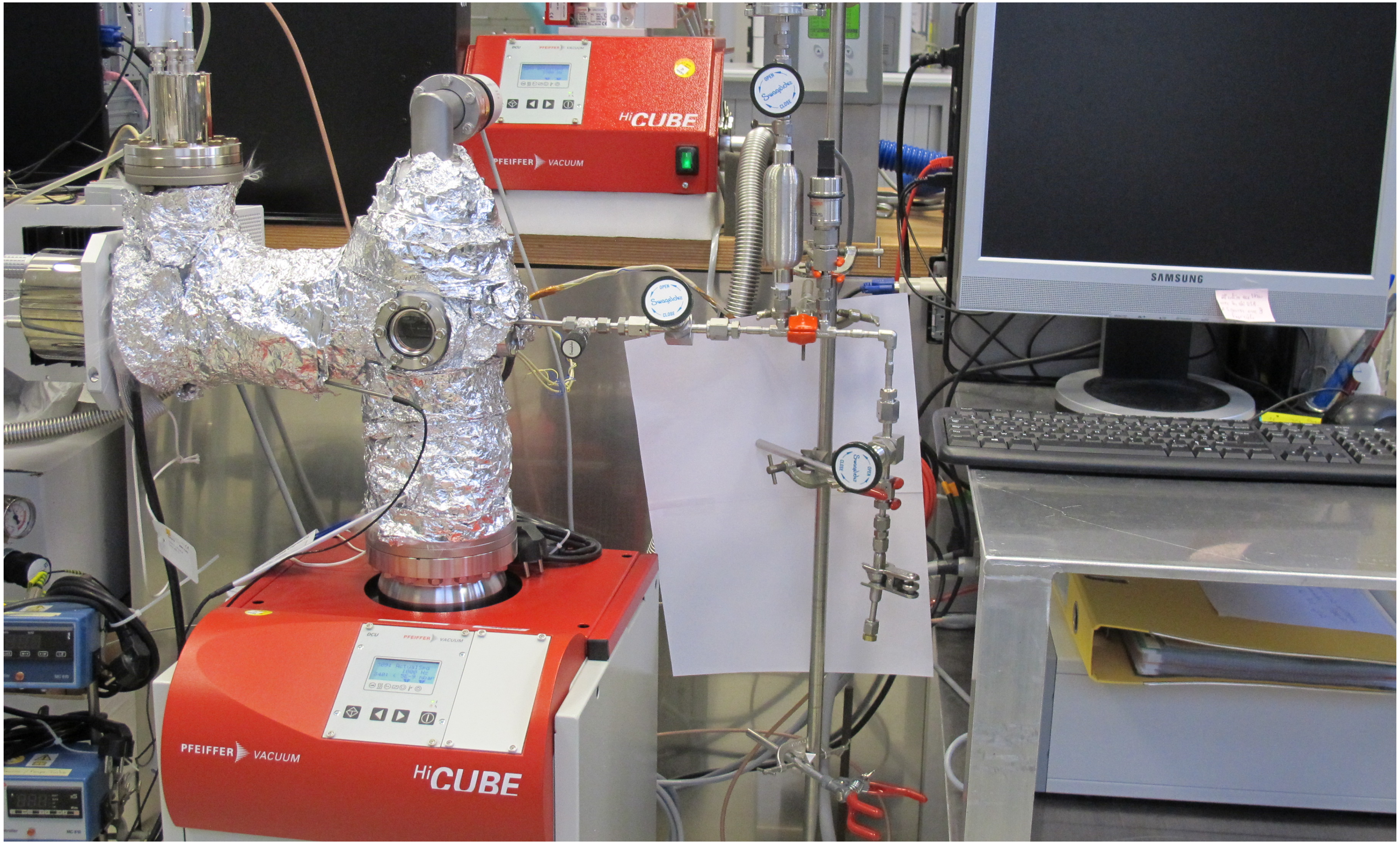
Si identification,

le choix d'un tamis efficace sera facilité.

Défi expérimental.

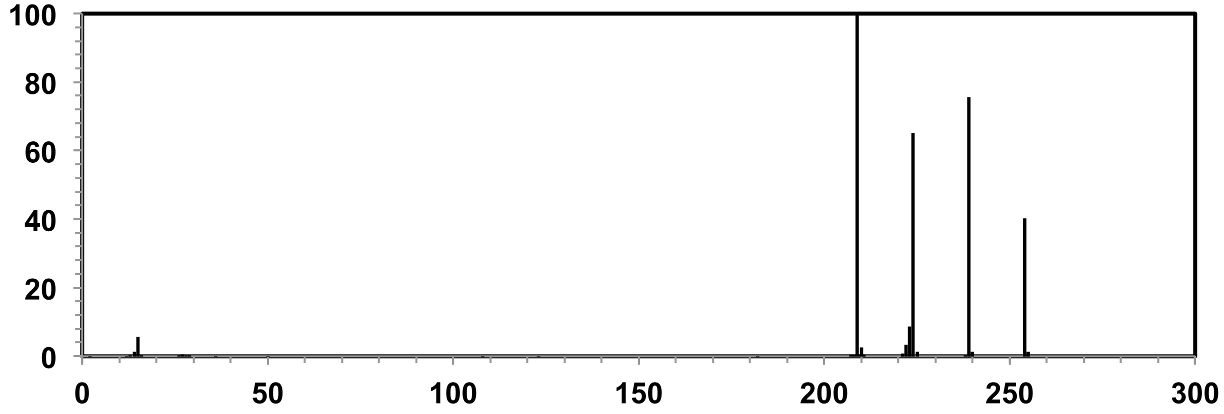
D. Doizi, V. Dauvois.

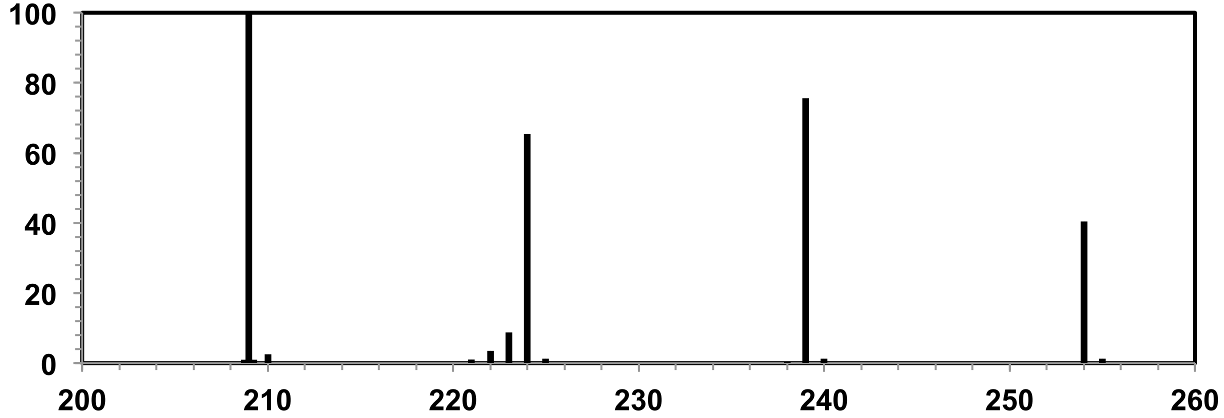
Spectro Masse Quadripolaire (GMS, industrie)



Spectro de Masse Gaz (GMS, Secteur Magnétique)

Spectro. Masse Gaz TMBi pur.

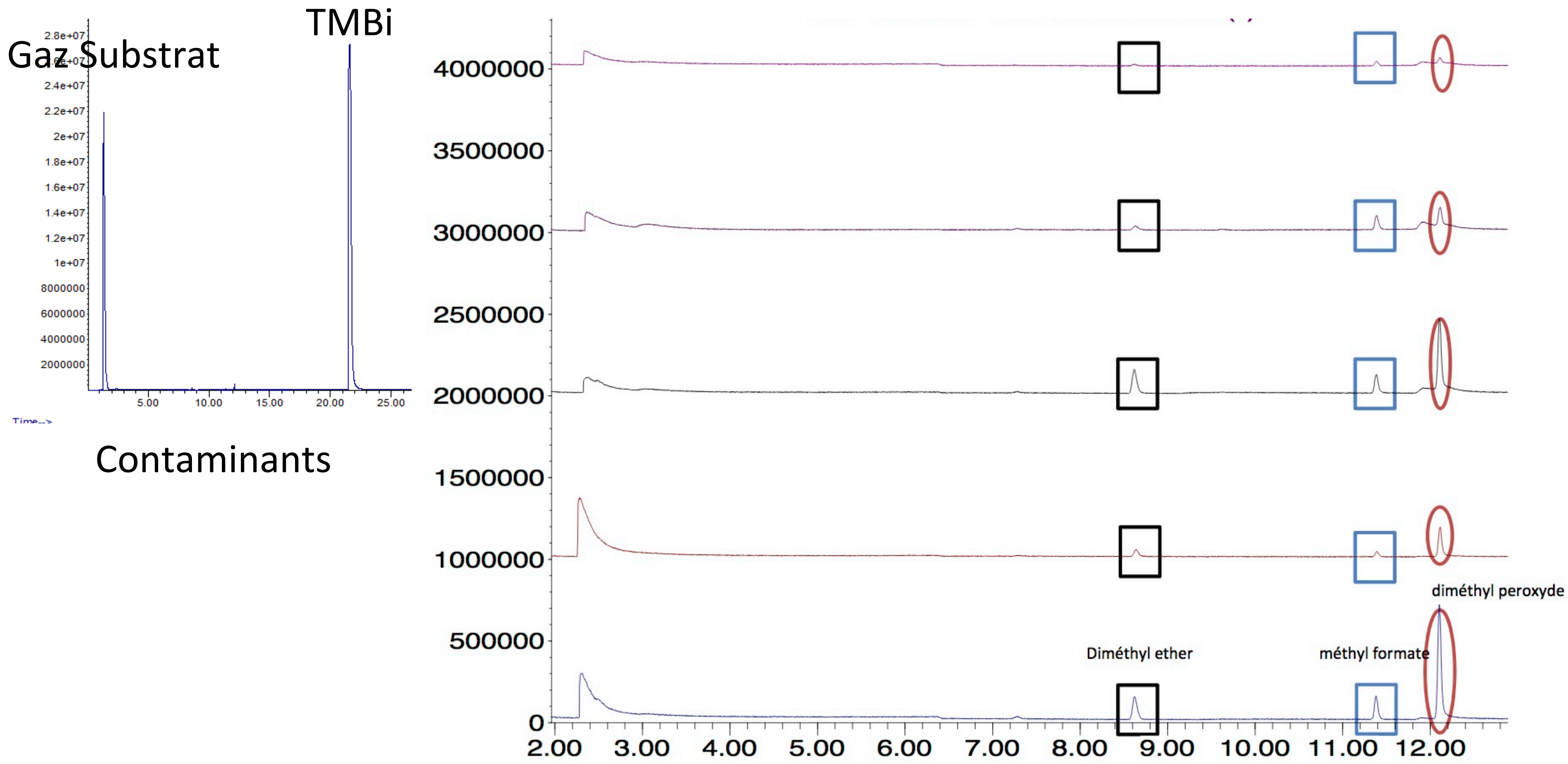




C’est ce que l’on mesure. Notre Liquide est très pur…

Chromatographe + Spectro de Masse Gaz

Chromatographie - GMS

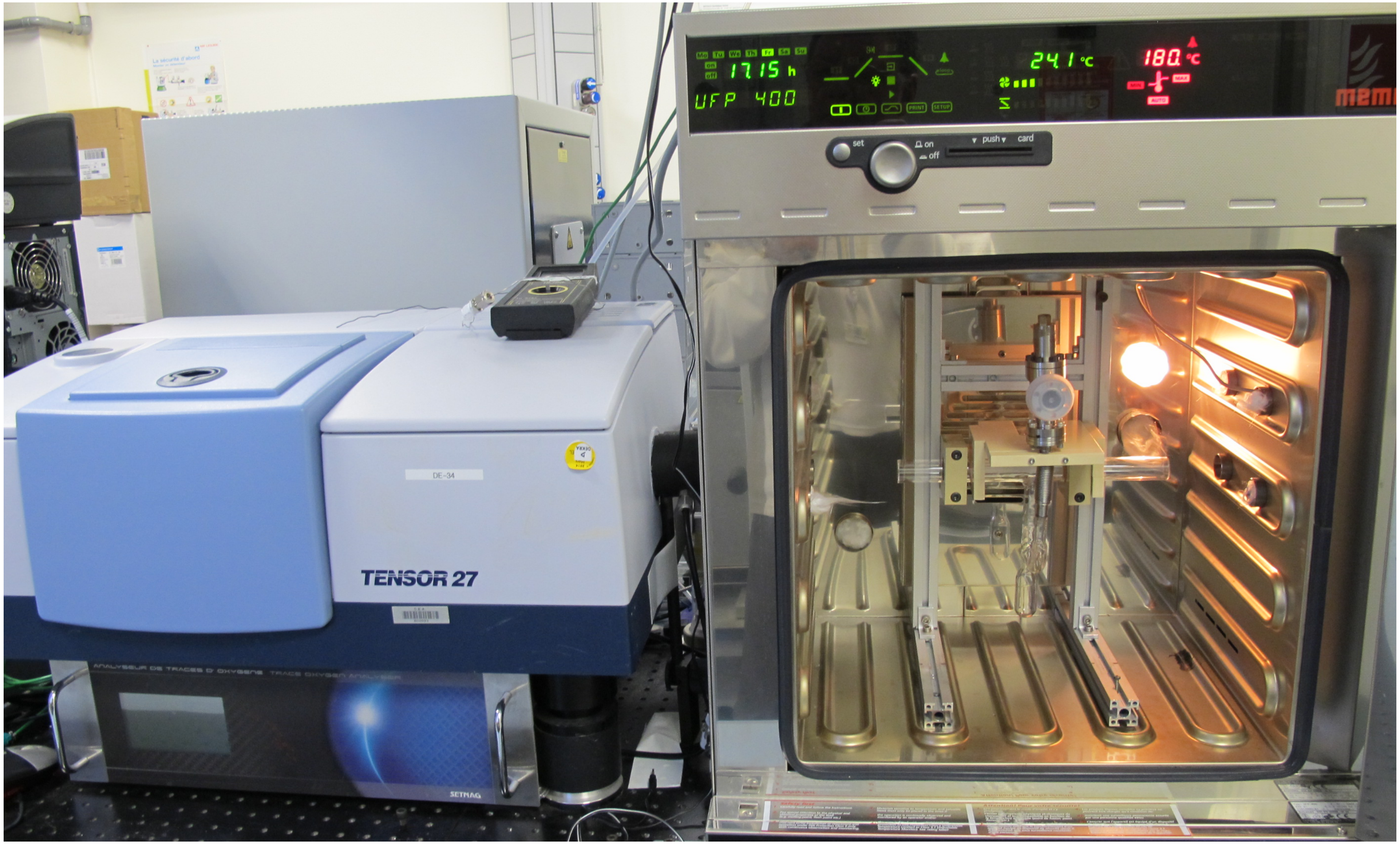


Contaminants détectés, mais …..

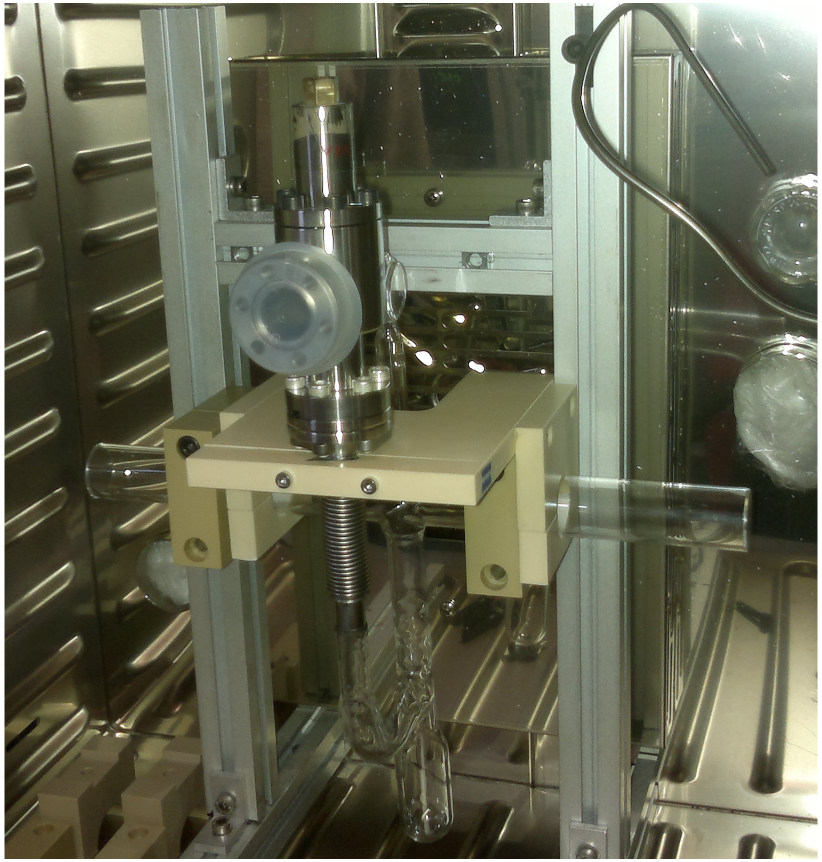
Répétition de la mesure, les pics de contaminants *disparaissent*

⇒ TMBi excellent nettoyant de l'appareillage de mesure

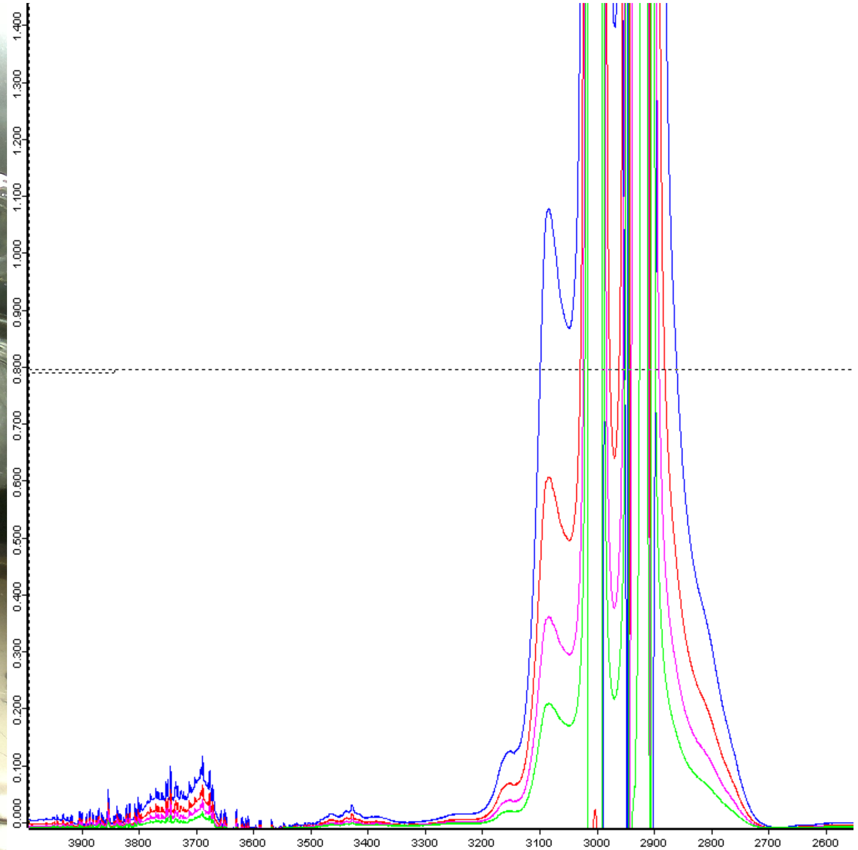
Spectromètrie Infra-Rouge



Mesures sur Spectromètre Infra Rouge



Cellule de mesure à l'intérieur de l'étuve.

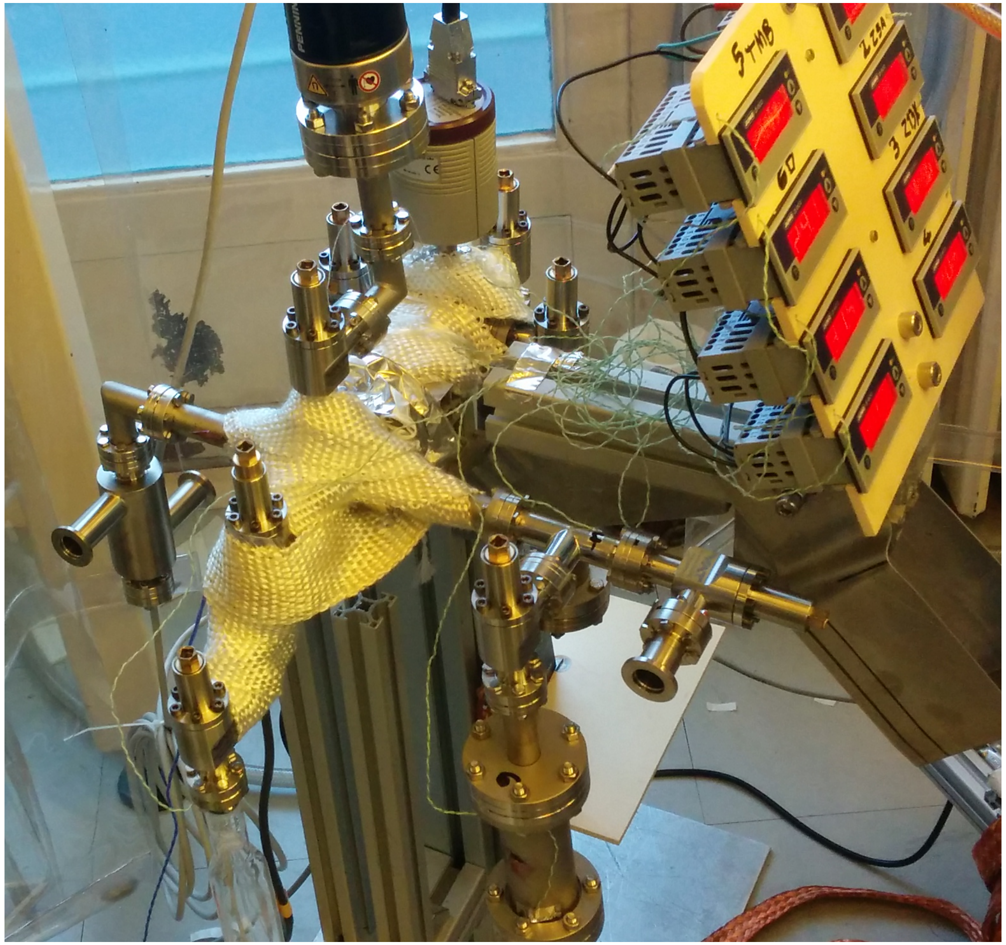


Spectres de raies d'absorption

• Zone saturée correspondant au TMBi.

• Zone faible pouvant correspondre à une Contamination => A confirmer.

Mini-Banc Ultra-Purif (Hydre)



Permet de tester plus rapidement le potentiel d'une technologie de Tamis sur le TMBi.

Financements CaLIPSO

Salaires Instituts

La contribution majeure.

Investissements (sur 5 ans)

Investissements IRFU ~ 50 k€.

Prog. Trans. TechnoSanté ~ 60 k€

+ 18 mois de Post-Doc.

R&T CNES (Bolomètres) ~ 25 k€

DIM NeRF Ile de France ~ 200 k€

LabEx P2IO R&D ~ 40 k€

IdEx Prématuration ~ 55 k€

24 Dossiers Déposés

Instance	Date	Montant (HT)	Statut
Financement IRFU	2009	30 k€	Financement initial
DGA Proposition REI	Janv. 2010	263 k€	Refus: Guichet fermé en 2010
DIM NeRF	Avril 2010	373 k€ Demandé	Accepté pour 200 k€
CNES R&T	2010	25 k€	Produit lié Olimpo
CoPil TechnoSanté 2010	Printemps 2010	~200 k€	En maturation. Trop Amont
Emergence 2010		Non déposé	Ne cadre plus avec l'appel
CoPil TechnoSanté 2011	Printemps 2011	~200 k€	En maturation. Trop Amont
LabEx IPhyMed	Hiver 2011-2012	Soutien de base	Refus
AVieSan FLI	2011	?	Accepté sans financement CaLIPSO
ANR Blanc SVSE5	2011	554.4 k€	Refus
INCa/PhysiCancer	2012	222.5 k€	Refus
LabEx P2IO	2012	100 k€	Accepté pour 40 k€
PANDORA Faisceau positrons	2012 (Europe)	~ 200 k€	Refus
INCa/PhysiCancer	2013	217 k€	Refus
TechnoSanté	2013	30 k€	Accepté
ANR Blanc SIMI5	2013	507 k€	Refus
HEPTech (CERN)	2013	A négocier	En attente
ANR Santé et Bien être. CaLIPSO LS7_2	2014	520 k€	Refus
ANR Défis de tous les savoir PE2_3 + Photonis	2014	430 k€	Refus
IDex Prématuration	2014	55 k€	En cours d'Evalutaion

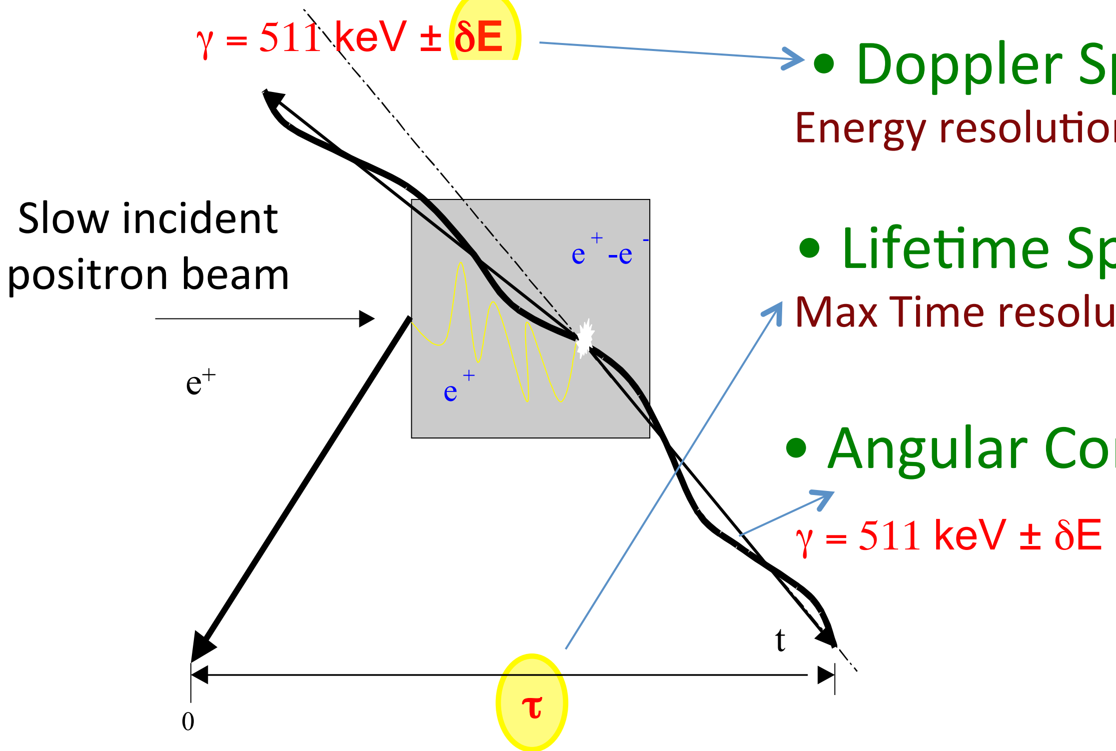
+2 ANR et 1 ERC

Materials science analysis

Positron Annihilation Spectroscopy

Material-specific information, **e^+ annihilation kinematics**

Lattice defects (vacancies, voids), **Cavities** (< few 10 nm range),
Electron momentum (Fermi surface), others…..



- Doppler Spectroscopy
  Energy resolution better than ~1.2 keV FWHM
- Lifetime Spectroscopy (**PALS**)
  Max Time resolution : 250 ps FWHM
- Angular Correlation Annihilation Reconstruction, (**ACAR**)
  Goal Accuracy: 16 mrad

Lazslo Liskay
J-Michel Rey

Positron annihilation spectroscopy
Why CaLIPSO ?

High-resolution gamma calorimetry (ie Doppler Spectroscopy)

Technically simple - **Difficult to extract quantitative information**

Lifetime measurements (ie Lifetime Spectroscopy, PALS)

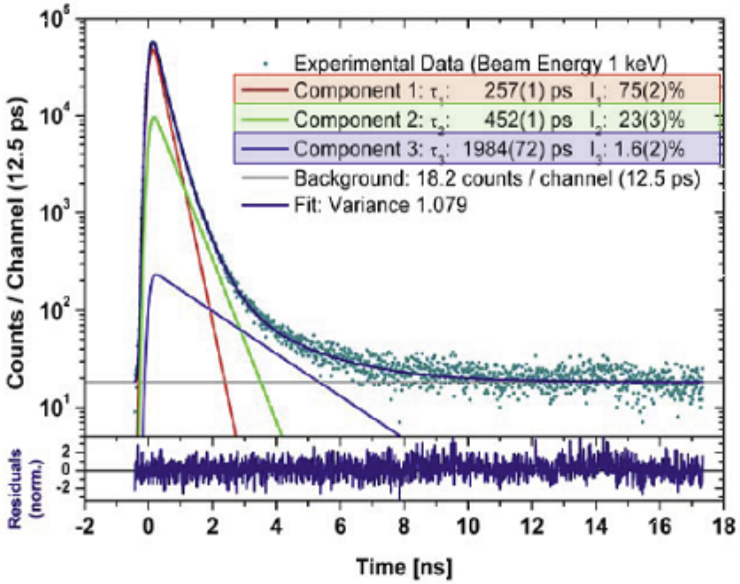
From 100 ps to 142 ns, **High Resolution/Rate.** => **Cherenkov γ detector**

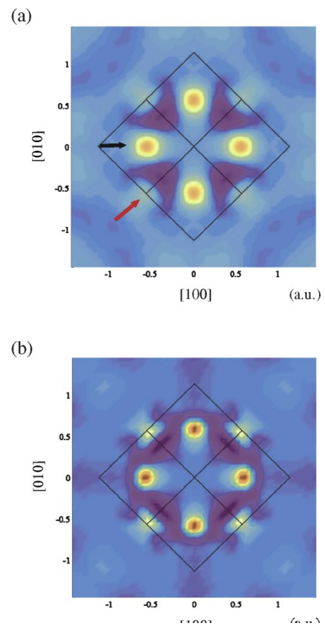
High sensitivity – Allows defect types identification

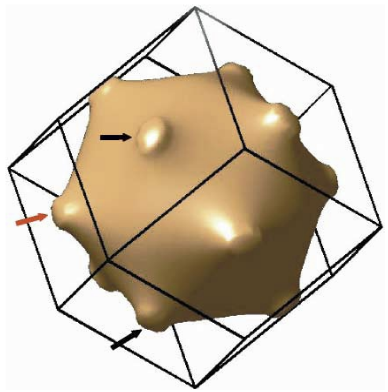
Angular correlation of the γ annihilations (ACAR, 2D-ACAR)

Requires very good position reconstruction (--> angular resolution) **=> CaLIPSO**

Information on the electron structure?







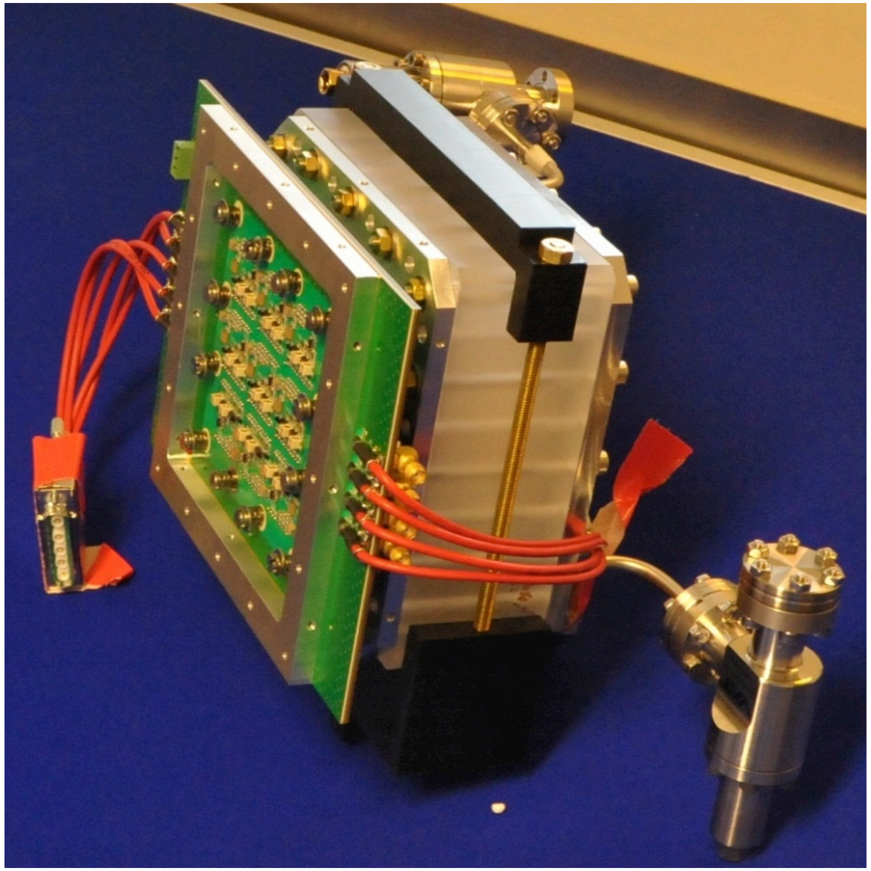
bcc Cu
Fermi surface

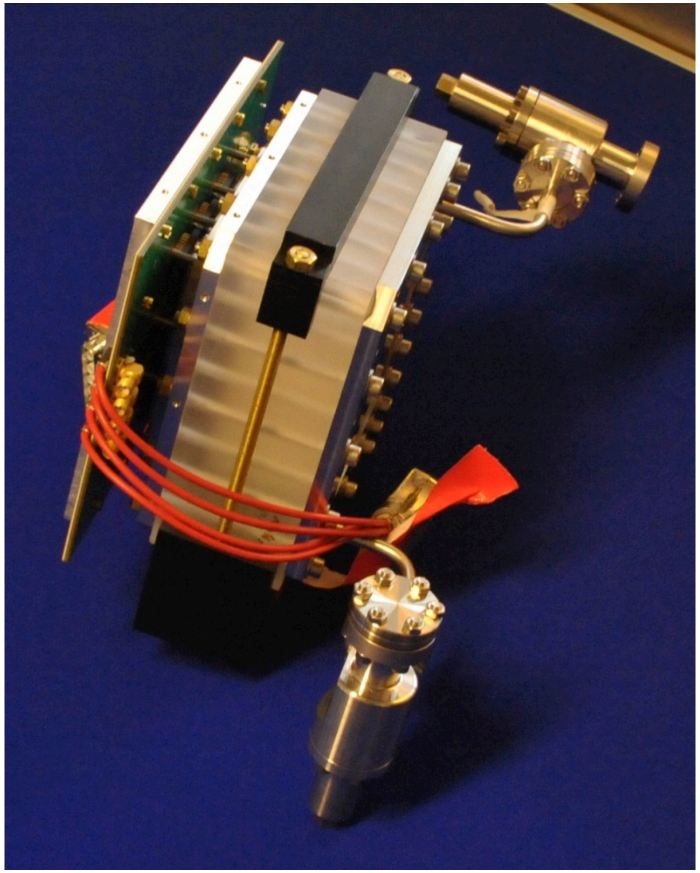
Lazslo Liskay

Conclusions

- CaLIPSO, une rupture technologique vers des imageurs TEP haute résolution spatiale.
- Un détecteur « héritage » de la communauté des liquides chauds et du Xénon liquide.
- Une double détection: Cherenkov et chambre à ionisation.
- Trois des quatre verrous technologiques sont maintenant dépassés.
- Détection efficace de γ 511 keV par effet Cherenkov démontrée
- Les premières impulsions lues par le détecteur de charge
- Reste l'enjeux de l'ultra-purification (et encore du travail ☺) pour aboutir…….
- Le financement de l'investissement est un enjeux en soi.

Merci de votre écoute.





Calorimètre **L**iquide **I**onisation **P**osition **S**cintillation **O**rganométallique

Hadronthérapie, TEP « en ligne »?

Aveuglé pendant l'irradiation (qq s?). ?Après?

Emetteur β+ produits en hadronthérapie: (K. Parodi)

6.86 10^4 pour 10^6 protons, 6.25 10^5 pour 10^6 ^{12}C

Isotope	demi-vie (s)	λ (mm)	Fais. Proton Abondance (%)	Fais. ^{12}C Abondance (%)
^{15}O	122	~ 2.	30	27
^{11}C	1223	~ 1.2	66.6	68
^{10}C	19	?	3.2	4.8

Ordre de grandeur de flux, cas ^{12}C

5 à 10 Gy, tumeur de 2 cm, ==> 10^9 ^{12}C. (S. Jan, SHFJ)

1.5 10^8 ^{16}O, en deux minutes, 1 à qq MHz => validation faisceau rapide

4 10^8 ^{11}C en 40 minutes, 170 kHz => Dosimétrie tumeur à postériori

Enjeux : Efficacité, résolution spatiale

Plus généralement: Radiologie

Tumeurs cérébrales ou autres:

Suivi post-opératoire

Recherche de métastases.

L'hyper-insulinisme du nourisson

Diagnostique de l'épilepsie

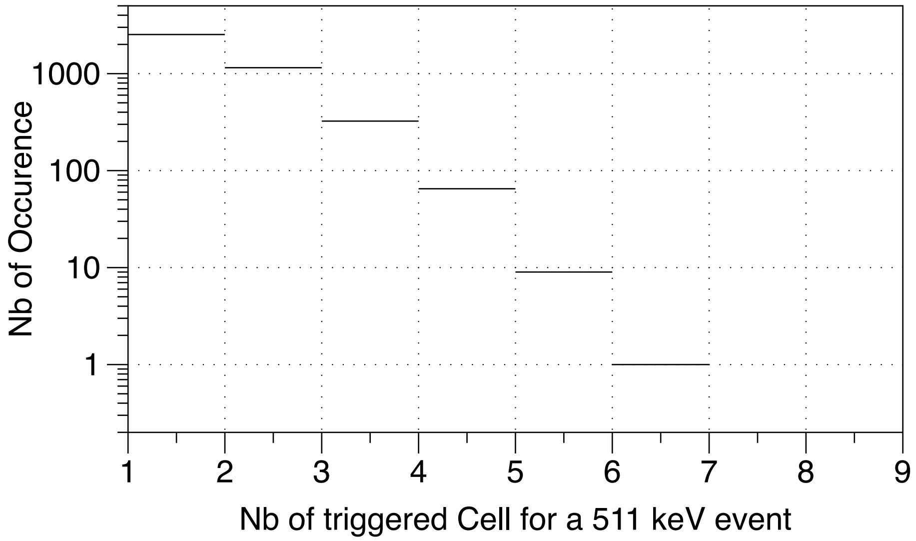
Et plus généralement des hypo-métabolismes (efficacité, résolution mm^3!)

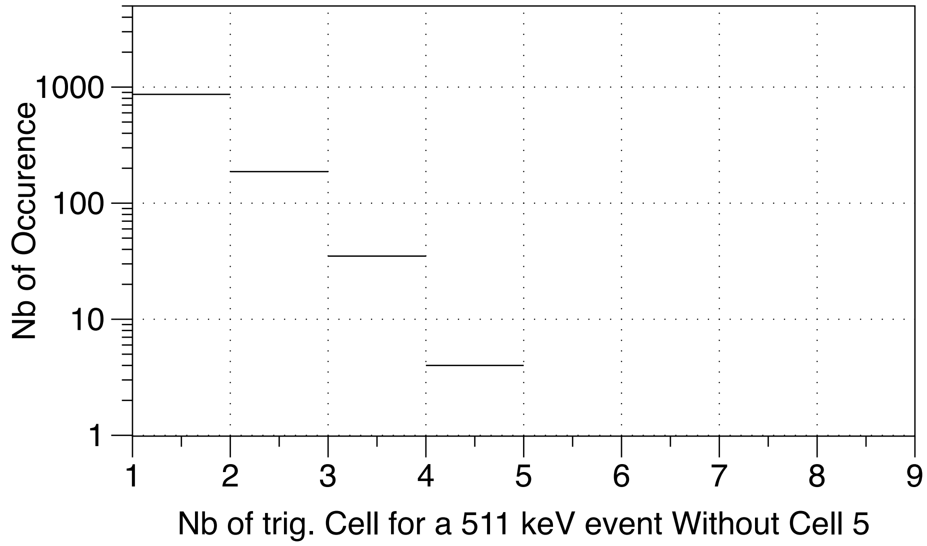
Souvent Image IRM Normale:

=> Accès à l'activité métabolique indispensable.

Prof. Boddaert (Radiologie Pédiatrique, Hopital. Necker)

Nb of triggered cells on 511 keV Evts





Most events trigger centric Cell

Some of then trigger many cells

1/3 of them do not trigger the centric Cell

These event have lower triggered cell multiplicity.

Light leakage within the detector, larger than expected

But these are ***true* detections**