Materials of interest for IN2P3

Christophe Dujardin

Institute of Light and Matter, University Lyon1, CNRS, France.

christophe.dujardin@univ-lyon1.fr

Website
http://ilm.univ-lyon1.fr/luminescence

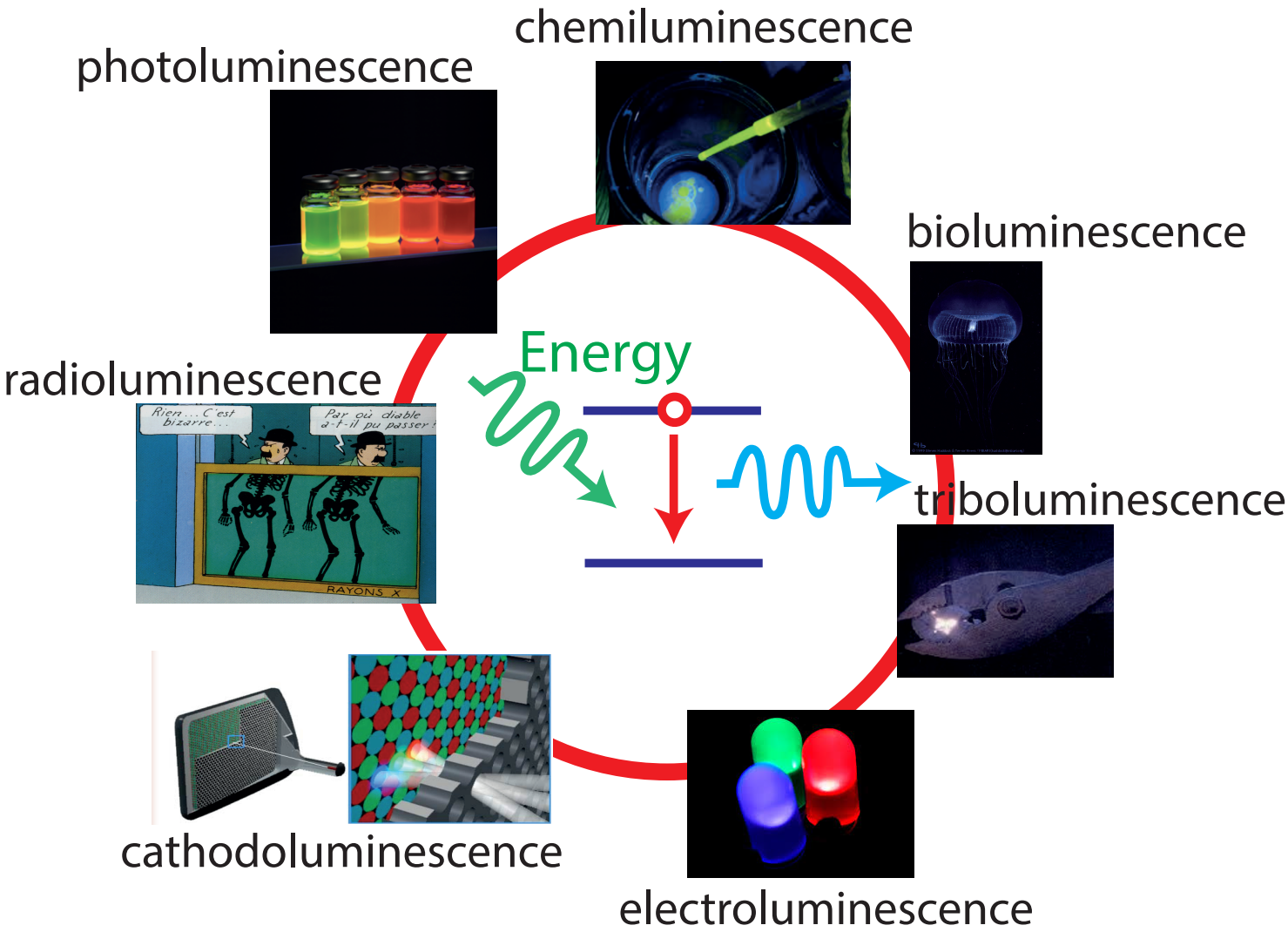
Why materials?

Materials contribute to transform

- ideas into reality
- hypothesis into theories

$PbWO_4$ @ CERN

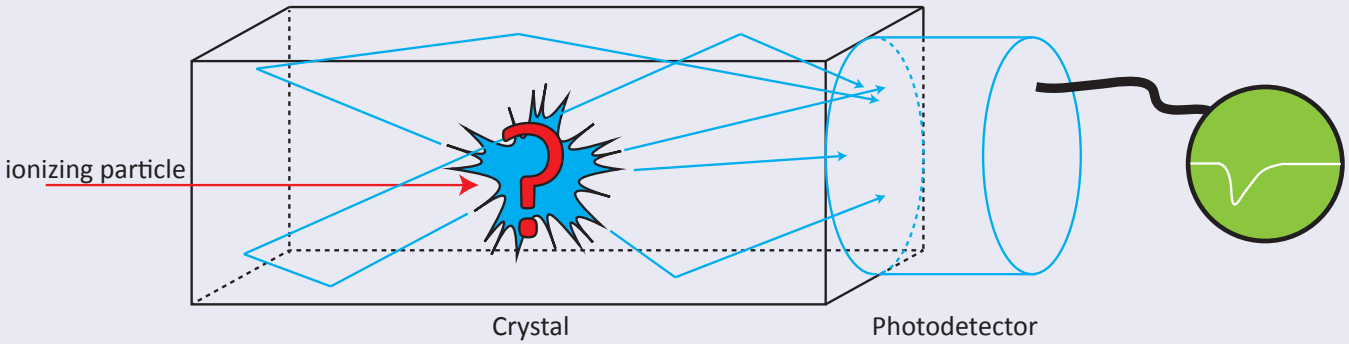
Introduction/Luminescence/Scintillation



Scintillation is one of the luminescence types

Scintillator: processes and materials developments

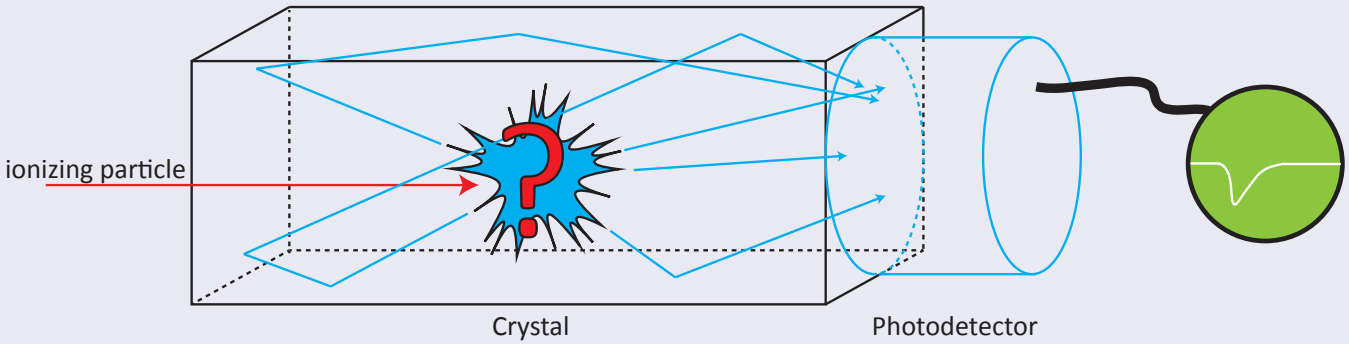
Huge relaxation of Energy



1 high energy photon (keV-MeV) $\rightarrow$ thousands of IR-Vis photons (eV)

Scintillator: processes and materials developments

Huge relaxation of Energy



1 high energy photon (keV-MeV) $\rightarrow$ thousands of IR-Vis photons (eV)

Multiscale Physics

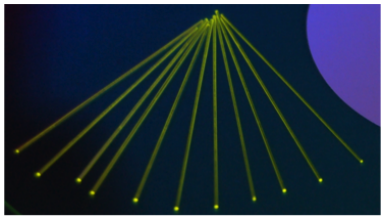
- As cutting a 10km string in pieces of a few cm!
- First steps in the ps range, last ones can be in the s time range
- Energy deposition is structured at the nm and mm scale

Material side: many shapes are existing

Single Crystal

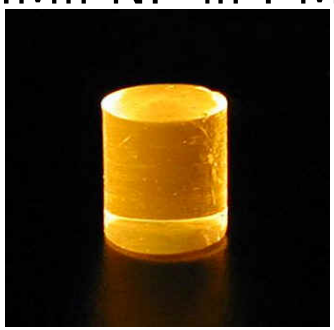
Many applications

Inorganic Fibers



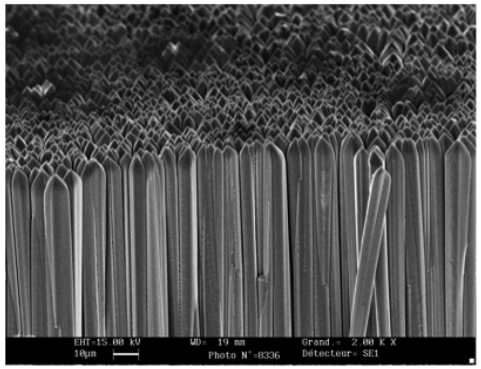
Calorimetry, other?

ZnS:Mn NP in PMMA



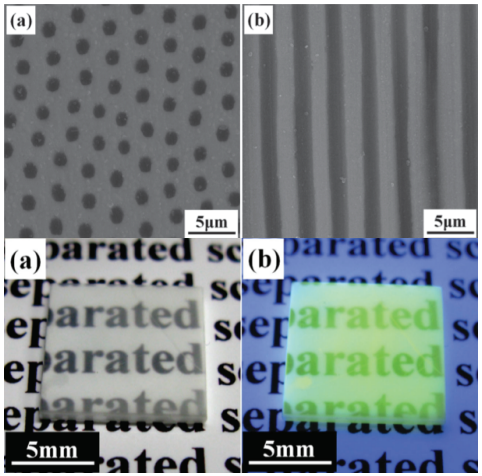
http://chm.tu-dresden.de

CsI:Tl Needles



Medical x-ray imaging

CsI-NaCl eutectic



@Canon, Adv. Mat. 2012

Thin films

High resolution x-ray imaging

Phosphor powder

x-ray imaging

Crystal growth at ILM (K.Lebbou)

The aim is to develop new phases, to optimize them up to the functional product. It includes the process and scale up.

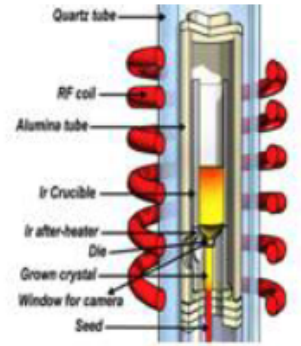
Application fields: laser materials, substrates, piezo... and scintillating materials

Illustration with inorganic scintillating fibers (K.Lebbou)

It allows to grow shaped fibers of many compositions including garnets diameters 300μm up to 2 mm, lengths up to 1 m

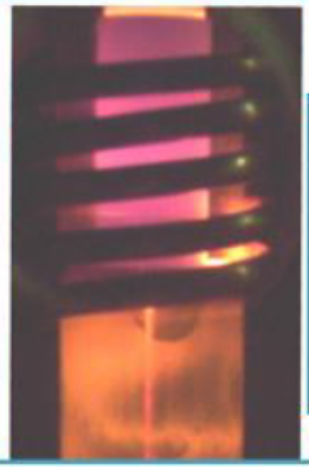
circular, square, plates, hollow, multi-fiber-pulling....

RF Machine using metal chamber

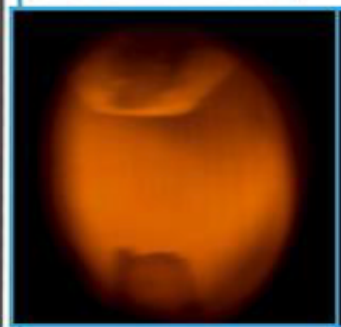


RF machine using Quartz tube chamber

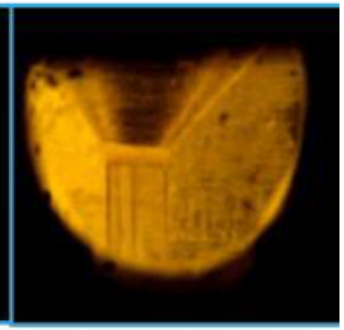
Seed, crucible and thermal insulation



RF Heating



Seeding



Connection and fiber growth

Illustration with inorganic scintillating fibers

interest for fibers emerged more than 10 years ago

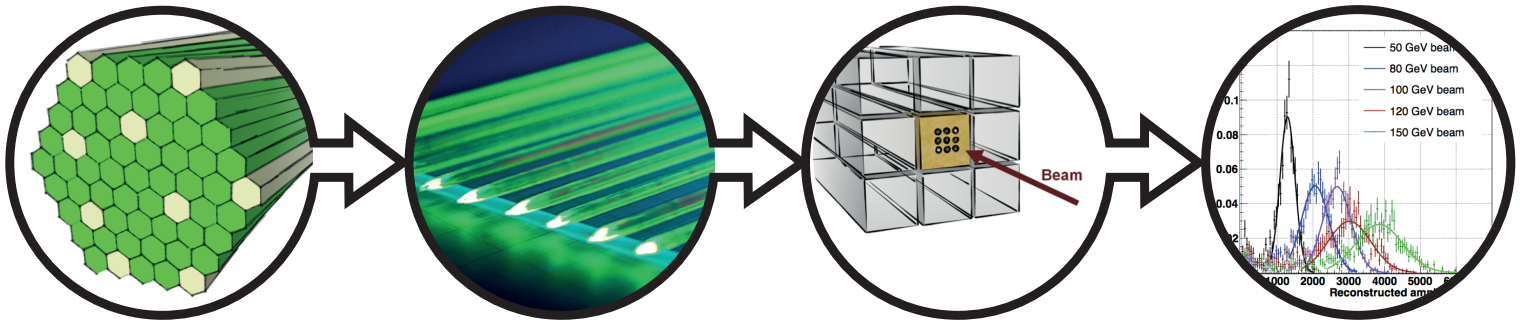
JOURNAL OF APPLIED PHYSICS **108**, 013510 (2010)

LuAG:Ce fibers for high energy calorimetry

C. Dujardin,[1] C. Mancini,[1] D. Amans,[1] G. Ledoux,[1] D. Abler,[2] E. Auffray,[2] P. Lecoq,[2] D. Perrodin,[3] A. Petrosyan,[4] and K. L. Ovanesyan[4]
[1]*Université Lyon 1, CNRS, UMR5620, Laboratoire de Physico-Chimie des Matériaux Luminescents, Université de Lyon, F-69622 Villeurbanne Cedex, France*
[2]*CERN, 1211 Geneva 23, Switzerland*
[3]*Fibercryst, La Doua, Bat. Atrium, Bd Latarjet, F- 69616 Villeurbanne, France*
[4]*Laboratory of Crystal Growth of Luminescent Materials, Institute for Physical Research, Armenian National Academy of Science, 0203 Ashtarak-2, Armenia*

$\rightarrow$ It led to the ANR project "INFHINI"

concept fiber growth prototype beam test results



tracking the defects

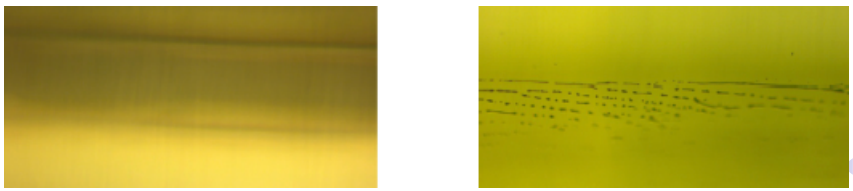
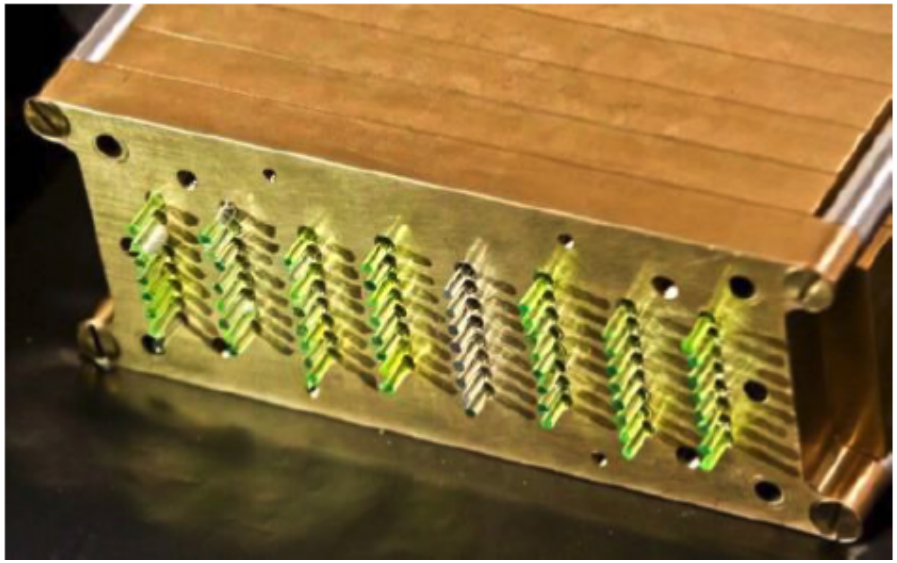
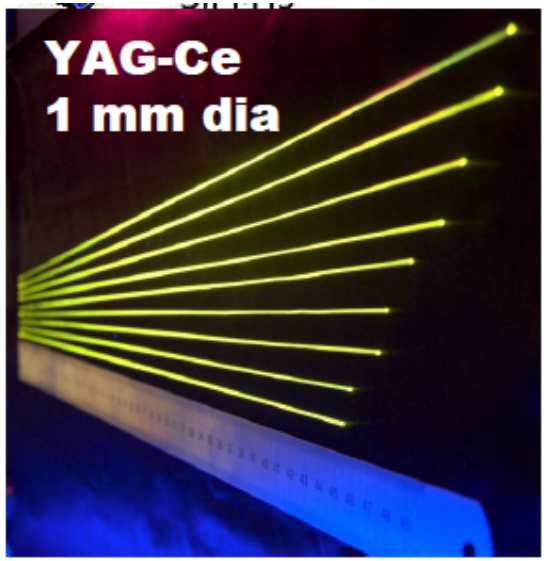


Illustration with inorganic scintillating fibers

And then a EU-Rise project led by E. Auffray (CERN) has been granted

$\rightarrow$ first "real" tests in beam





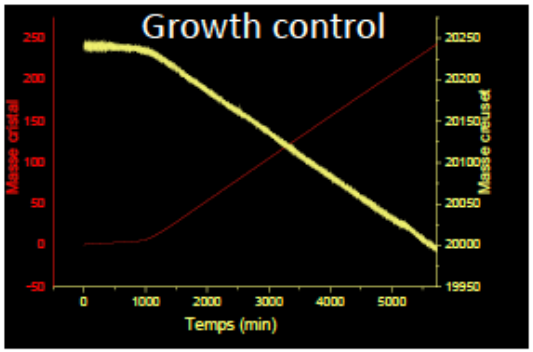
Benaglia et al. JINST 2016

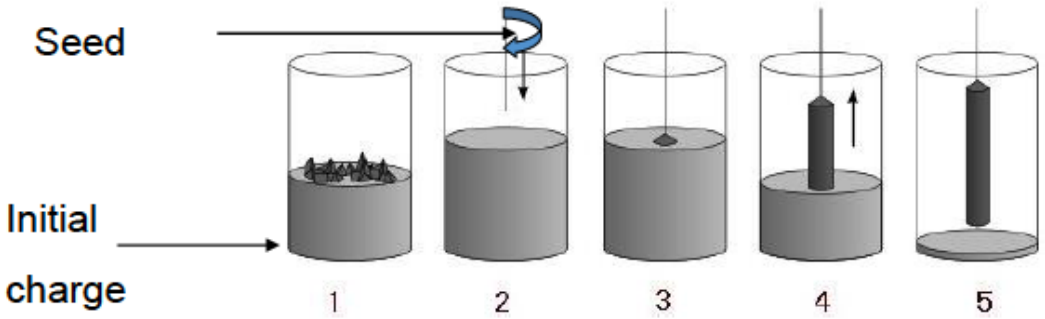
Illustration with inorganic scintillating fibers

Alternative process, fibers from the bulk (better light transmission)

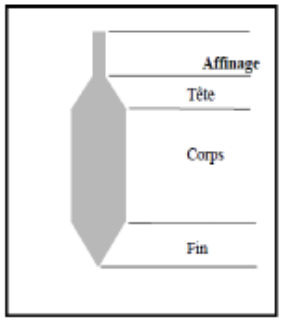
Machine Czochralski

Ir Crucible





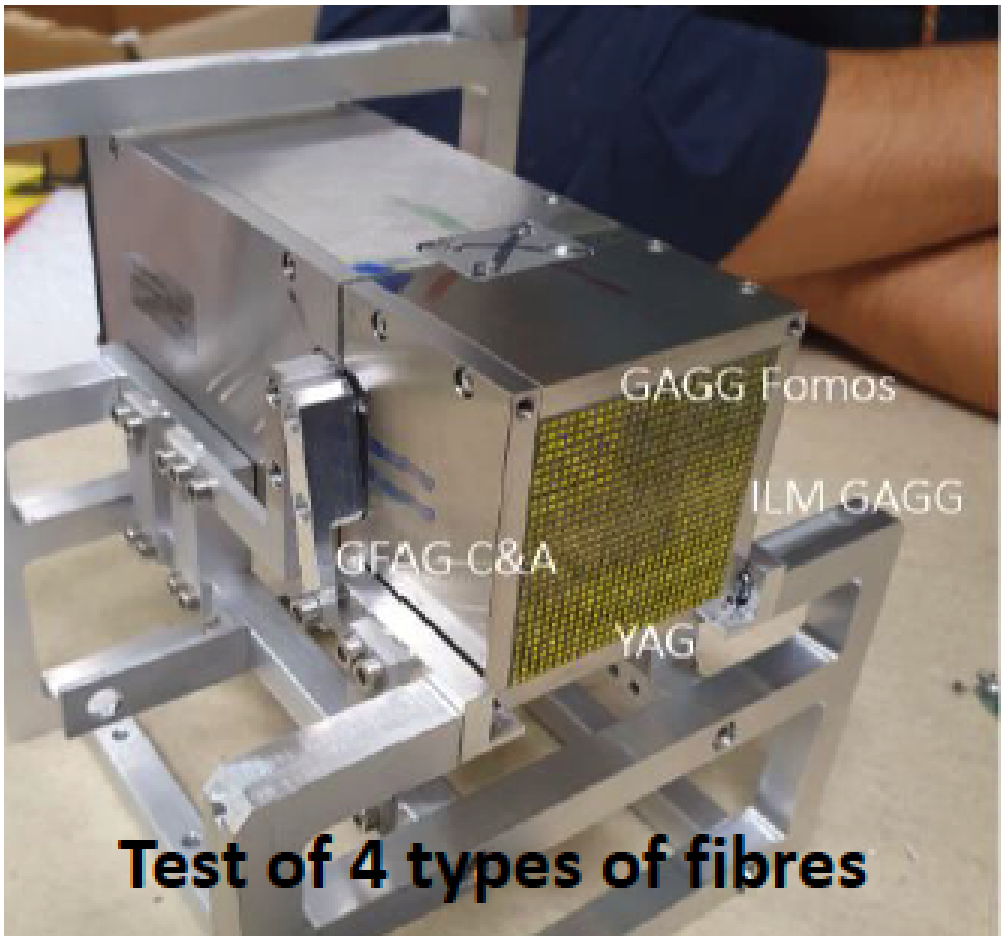
Growth steps using CZ technique

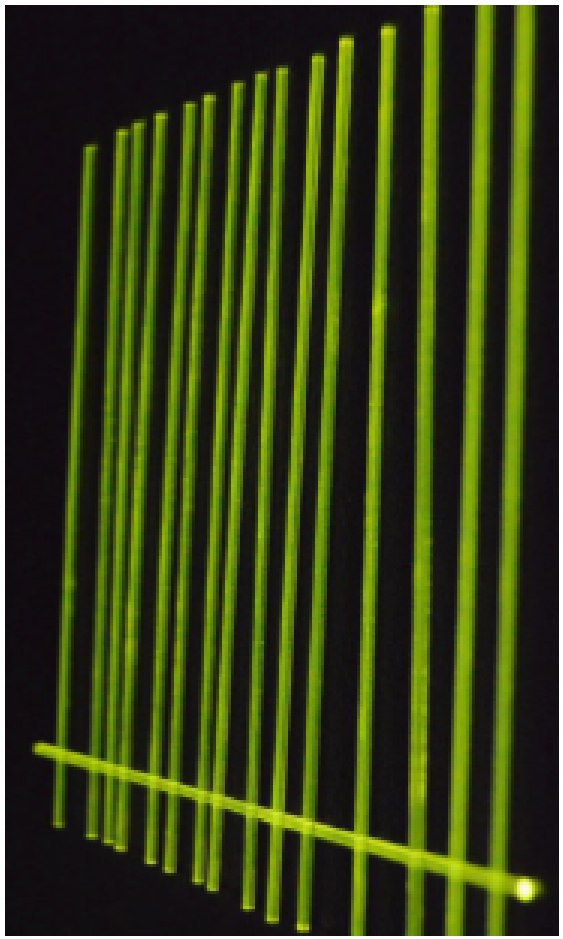


Final crystal shape

about crystals for scintillation

Fibers cut from the boule



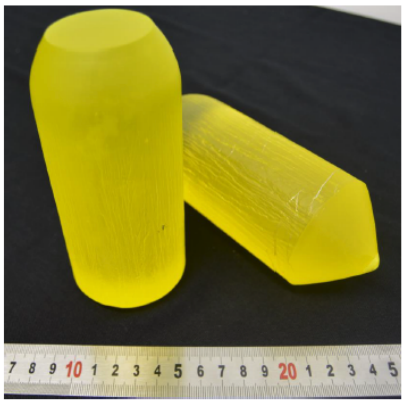


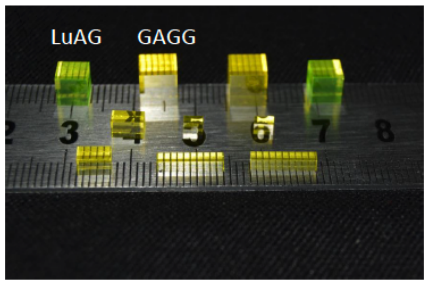
See M.Lucchini's talks for the latest results

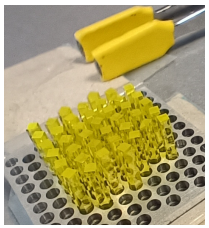
growth technology, radiation hardness, performance, cost, ... and reducing the decay (today's work)

about crystals for scintillation (K.Lebbou)

Concluding remark for crystals







samples to I.Laktineh (IP2I)

- possibilities to develop projects (activity rather costly)
- discussions with S.Gascon, also with the C.Morel for the PEPR I2S2, project Chronography
- LMO for rare events search (M.Valasquez, ANR CLYMENE)

Thin scintillating films - A.Pereira (ILM) & ESRF

Journal of Materials Chemistry C

ROYAL SOCIETY OF CHEMISTRY

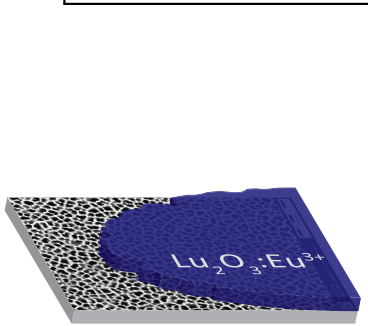
PAPER

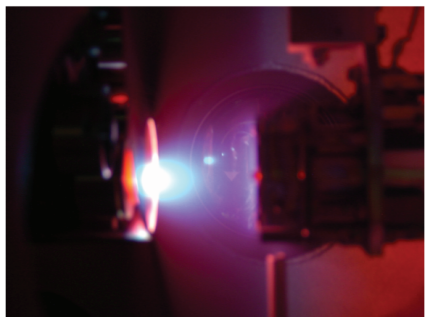
CrossMark click for updates

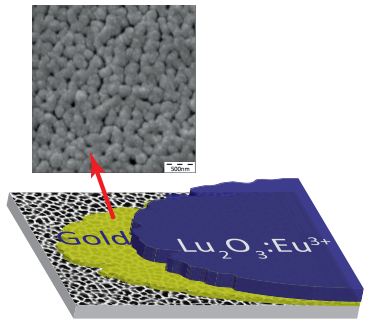
Cite this: J. Mater. Chem. C, 2015, 3, 4954

Low-absorption, multi-layered scintillating material for high resolution real-time X-ray beam analysis

Antonio Pereira,[a] Thierry Martin,[b] Mariana Levinta[a] and Christophe Dujardin*[a]







Thin scintillating films - A.Pereira (ILM) & ESRF

Journal of Materials Chemistry C

ROYAL SOCIETY OF CHEMISTRY

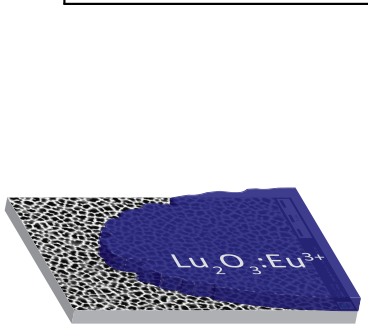
PAPER

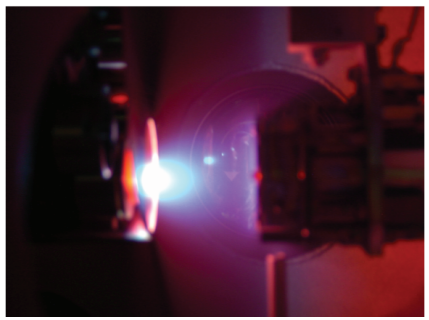
CrossMark click for updates

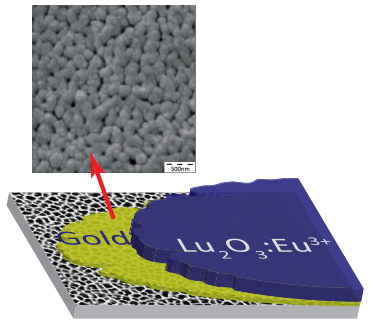
Cite this: J. Mater. Chem. C, 2015, 3, 4954

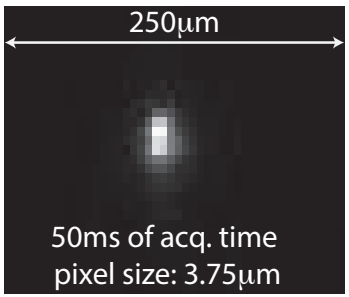
Low-absorption, multi-layered scintillating material for high resolution real-time X-ray beam analysis

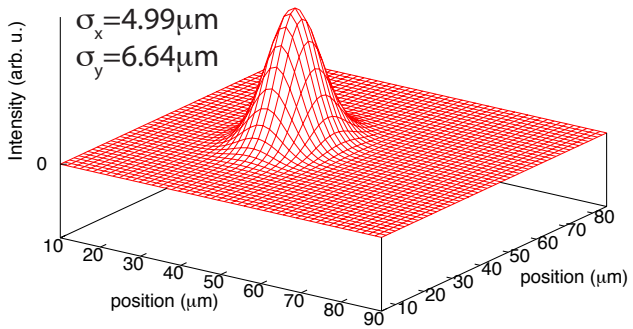
Antonio Pereira,[a] Thierry Martin,[b] Mariana Levinta[a] and Christophe Dujardin*[a]











Thin scintillating films - PhD L.Wollensen (ILM & ESRF)

Journal of Materials Chemistry C

ROYAL SOCIETY OF CHEMISTRY

PAPER

View Article Online
View Journal | View Issue

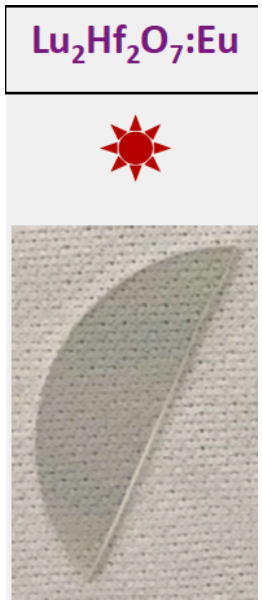
Check for updates

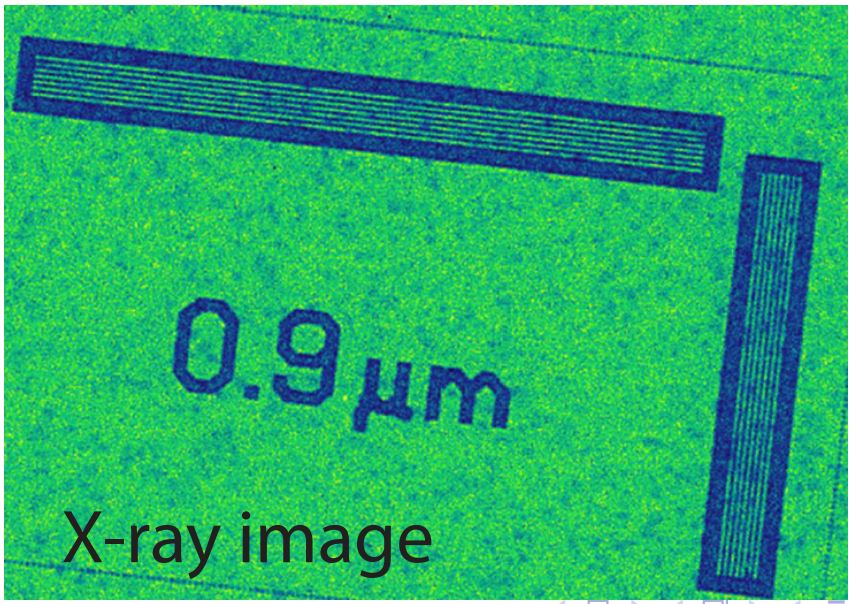
Cite this: *J. Mater. Chem. C*, 2022, **10**, 9257

Scintillating thin film design for ultimate high resolution X-ray imaging†

Laura Wollesen,[ab] Federica Riva,[ab] Paul-Antoine Douissard,[a] Kristof Pauwels,[a] Thierry Martin[a] and Christophe Dujardin *[b]

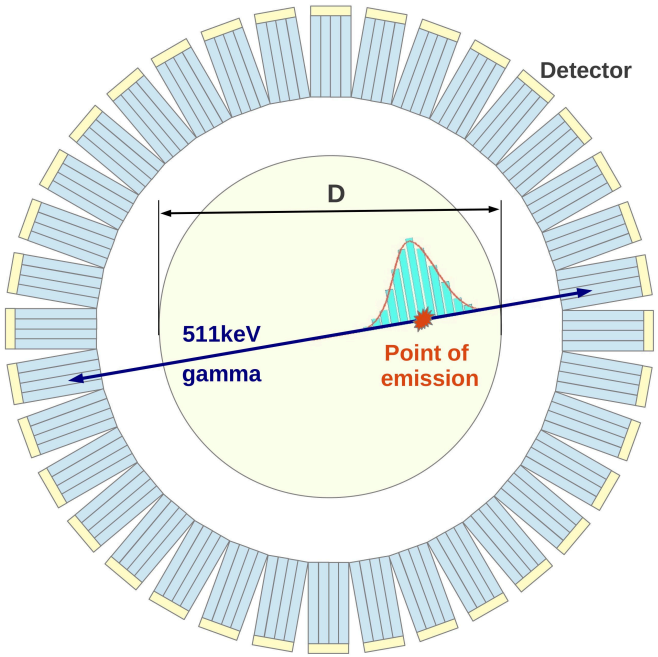
Prepared with Liquid Phase Epitaxy; density ≈ 10; thickness $= 2.8\mu$m





combining materials

Interest for ultra-fast scintillators



Coincidence time resolution as fast as possible (CTR$_{1st}$=2.18 $\sqrt{\frac{\tau_r \tau_f}{n_{PE}}}$)

S.Gundacker et.al.

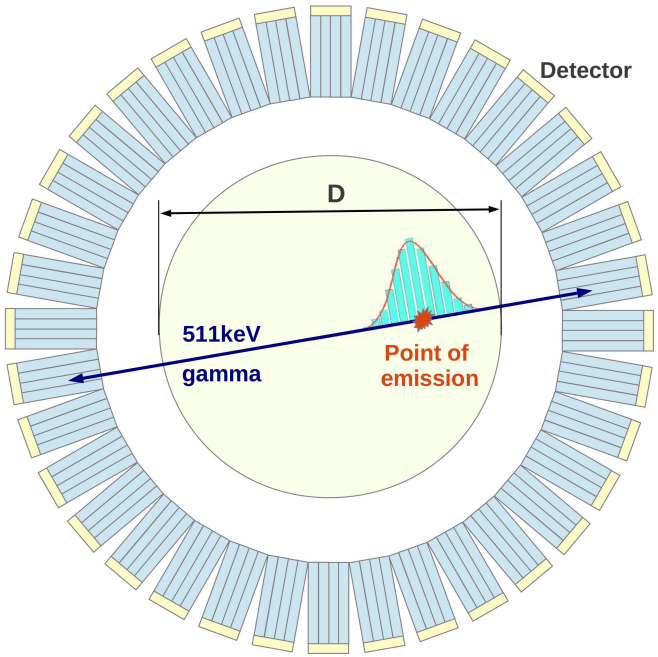
Toward hybrid materials

combining the best of several materials

→density, light and SPEED

combining materials

Interest for ultra-fast scintillators



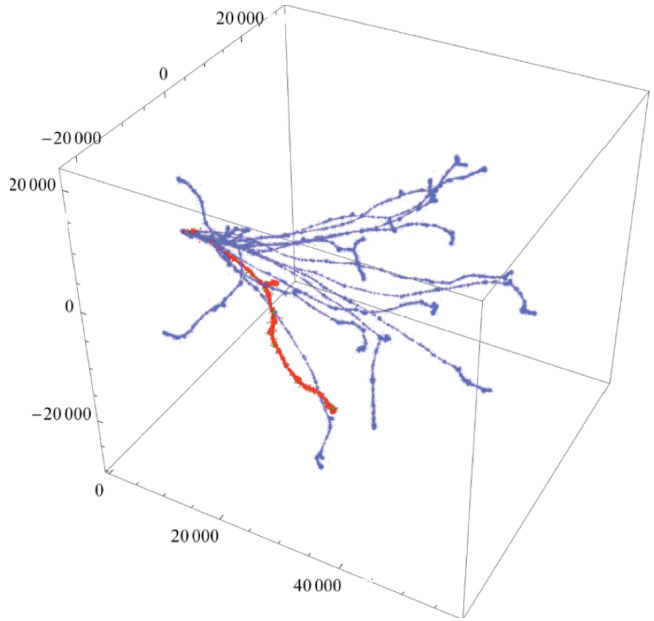
Coincidence time resolution as fast as possible (CTR$_{1st}$=2.18 $\sqrt{\frac{\tau_r \tau_f}{n_{PE}}}$)

S.Gundacker et.al.

Toward hybrid materials

combining the best of several materials

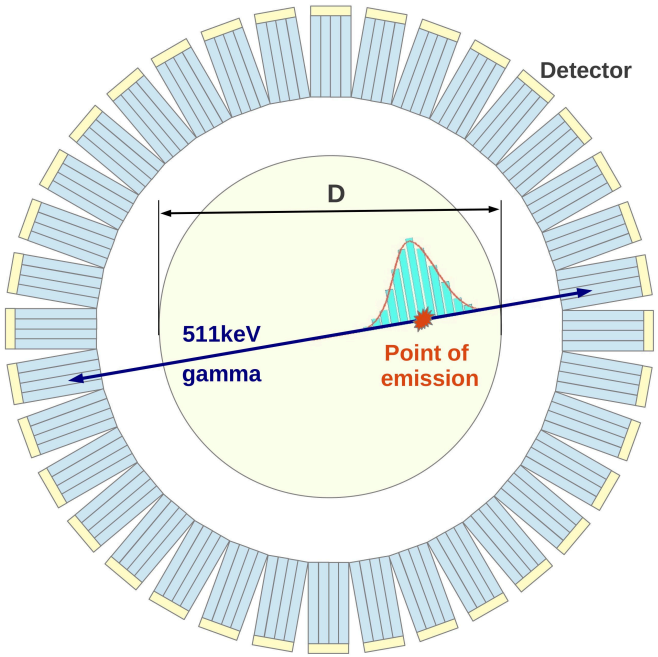
→density, light and SPEED



A.Gektin and A. Vasil'ev, Functional Materials (2017)

combining materials

Interest for ultra-fast scintillators



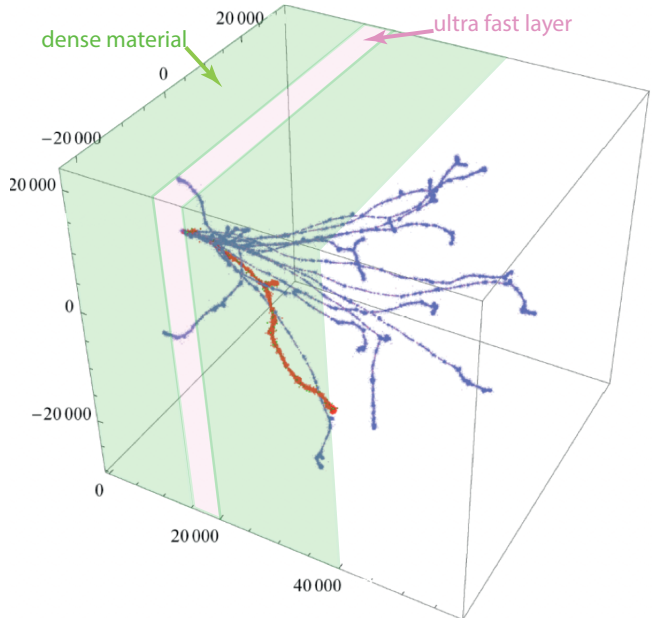
Coincidence time resolution as fast as possible (CTR_{1st}=2.18 $\sqrt{\frac{\tau_r \tau_f}{n_{PE}}}$)

S.Gundacker et.al.

Toward hybrid materials

combining the best of several materials

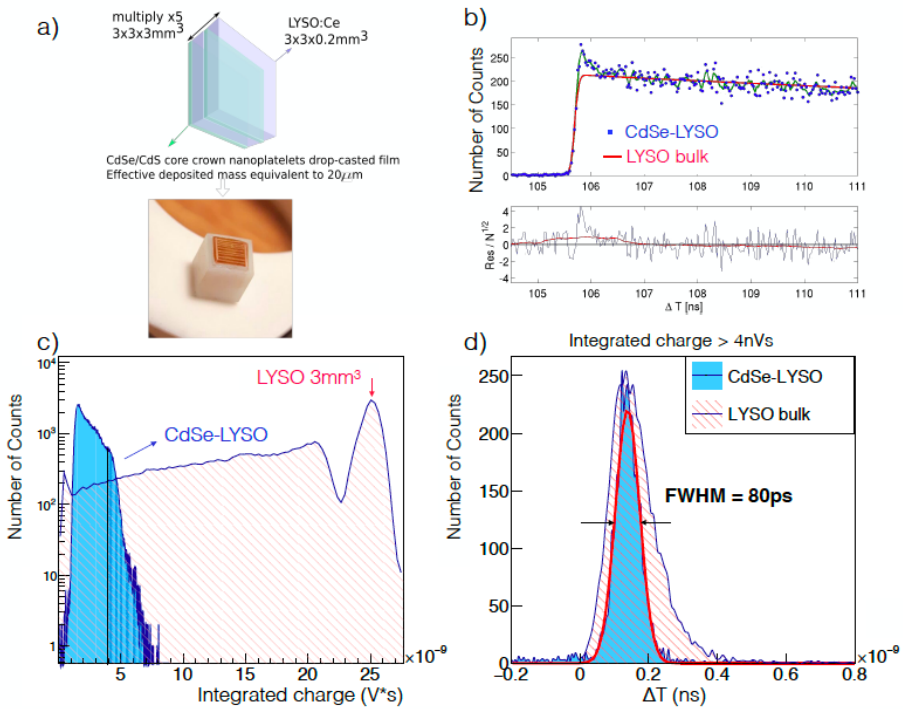
$\rightarrow$ density, light and SPEED



A.Gektin and A. Vasil'ev, Functional Materials (2017)

combining materials

An illustration with CdSe-CdS nanoplatelets



npj | 2D Materials and Applications

www.nature.com/npj2dmaterials

ARTICLE OPEN

On the use of CdSe scintillating nanoplatelets as time taggers for high-energy gamma detection

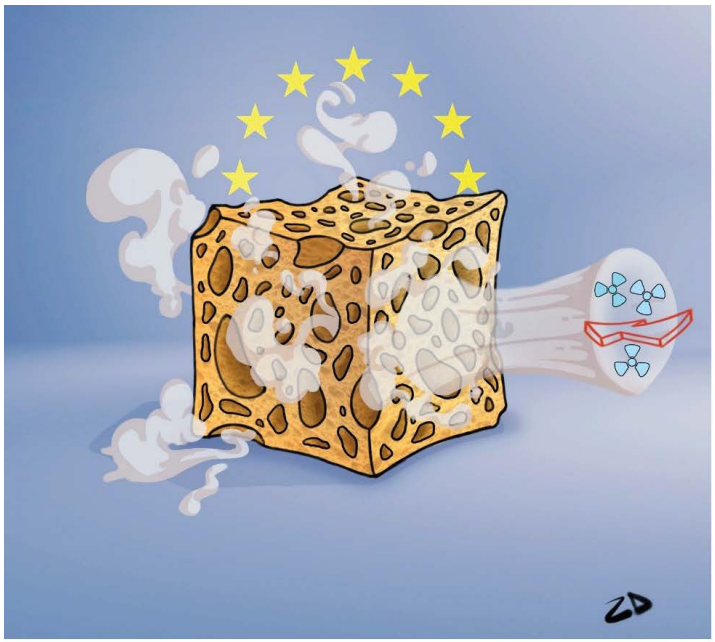
R. M. Turtos[1*], S. Gundacker[1,2], S. Omelkov[3], B. Mahler[4], A. H. Khan[5], J. Saaring[3], Z. Meng[4], A. Vasil'ev[6], C. Dujardin[4], M. Kirm[3], I. Moreels[5], E. Auffray[1] and P. Lecoq[1]

Another unusal material: porous scintillators

Target: detecting β radioactivity in gas (^{85}Kr, ^{133}Xe, ^{3}H, ^{37}Ar)

$\rightarrow$ The concept of the scintillating sponge
(H2020 FET-OPEN granted in oct 2020)

Requirements: Porous, transparent, bright and fast

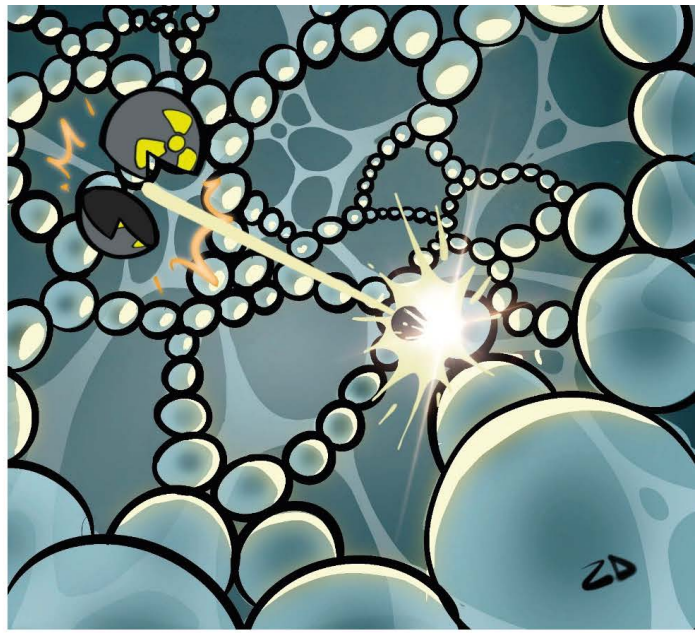


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 899293

Another unusal material: porous scintillators

Target: detecting β radioactivity in gas (^{85}Kr, ^{133}Xe, ^{3}H, ^{37}Ar)

$\rightarrow$ aerogel made of scintillating nanoparticles

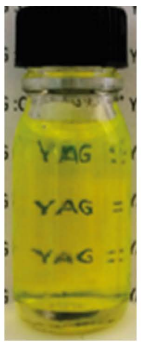


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 899293

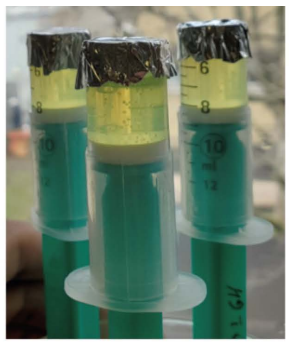
Another unusual material: porous scintillators

Target: detecting β radioactivity in gas (^{85}Kr, ^{133}Xe, ^{3}H, ^{37}Ar)

The process: supercritrical drying of a gel



Colloidale solution of YAG:Ce



gels of YAG:Ce

aerogels of YAG:Ce

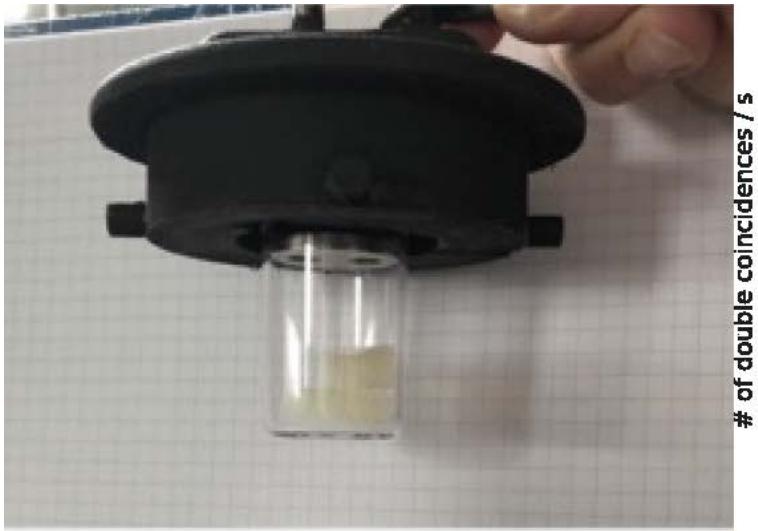
F.Chaput
LC-ENS-Lyon

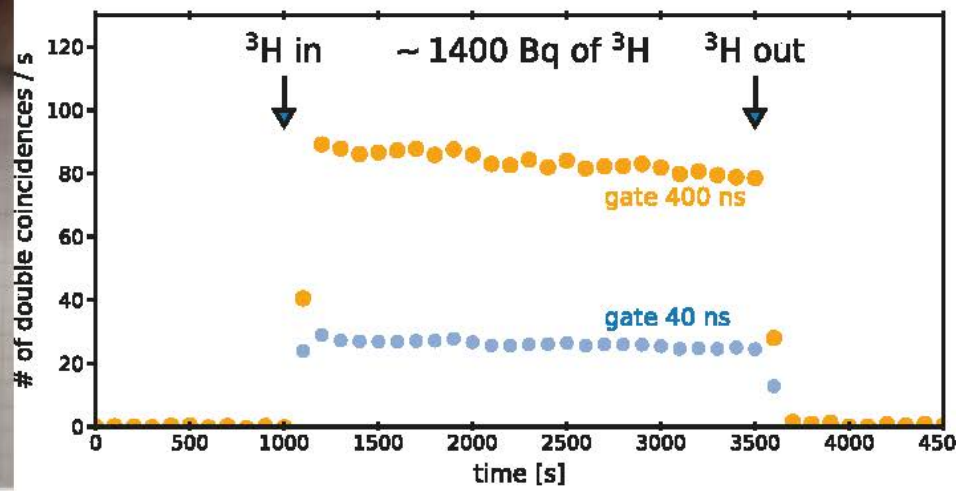
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 899293

Another unusual material: porous scintillators

Target: detecting β radioactivity in gas (^{85}Kr, ^{133}Xe, ^{3}H, ^{37}Ar)

The first real time ^{3}H measurement with an aerogel
estimated detection efficiency 7%
(With B.Sabot, CEA-LNE)





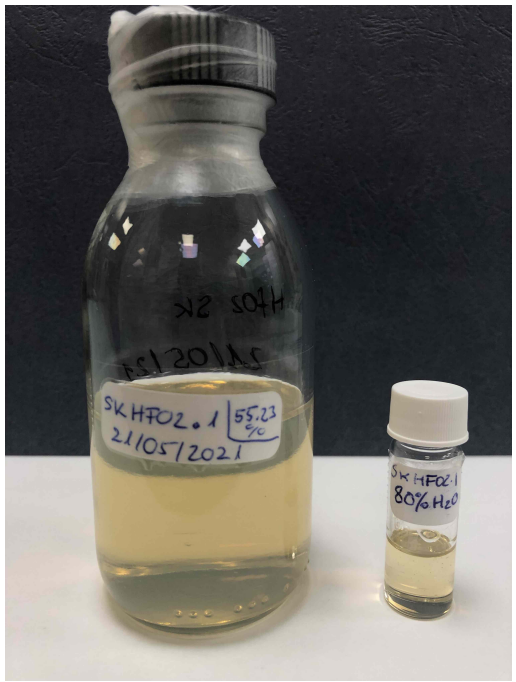
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 899293

follow the project: https://www.sparte-project.eu

still some open areas

An illustration with a new "object"

Water loaded with HfO_2 nanoparticles at 55 wt% and 80 wt%
(resp. densities: 1.83 and 2.86!)



(F.Chaput, LC-ENS-Lyon)

Any interest as liquid scintillator for high energy physics?

conclusion

→ The "landscape" of scintillating materials is very large

→ The Scintillating materials community is active, organized and ready to go beyond $PbWO_4$ for the next generation of experiments

conclusion

→ The "landscape" of scintillating materials is very large

→ The Scintillating materials community is active, organized and ready to go beyond $PbWO_4$ for the next generation of experiments

A "recent" open access review paper

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 65, NO. 8, AUGUST 2018

Needs, Trends, and Advances in Inorganic Scintillators

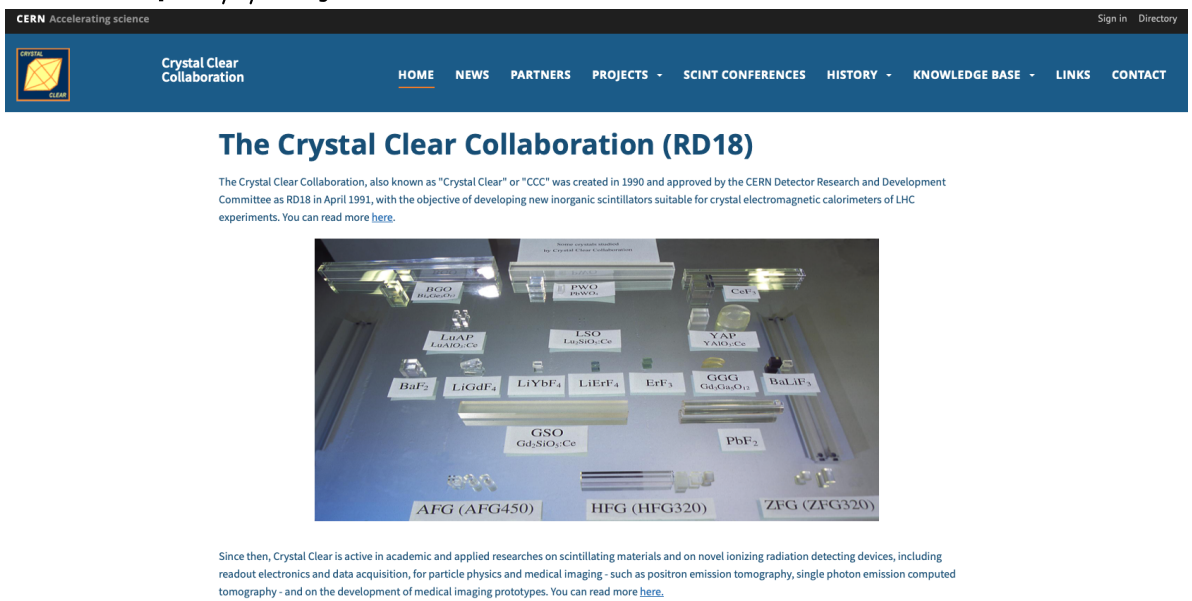
C. Dujardin, E. Auffray, E. Bourret-Courchesne, P. Dorenbos, P. Lecoq, M. Nikl, A. N. Vasil'ev, A. Yoshikawa, and R.-Y. Zhu

A community

And then a community is needed.
We are lucky, it is already well organized

- The "Crystal Clear Collaboration", spokesperson E.Auffray, CERN
- more than 30 partners in EU
- gathering skills from chemistry to modeling and end users
- addressing various applications including HEP

https://crystalclearcollaboration.web.cern.ch



A community

We also have an international conference series

- Every 2 years
- 200-300 attendees
- gathering skills from chemistry to modeling and end users
- addressing materials, mechanisms and applications including HEP

https://scint.univ-lyon1.fr

Beyond Scintillators

IDEX Breakthrough OSAG project (coord. G.Cagnoli)

Giant sapphire substrates - low T gravitational wave interferometry optics
(K.Lebbou, G.Cagnoli & Collaboration IP2I)

target: ∅ 450mm x 200mm; C-axis
no diffusive defects and absorption $<$ 50ppm/cm