Crystal Clear Collaboration an example of multidisciplinary work and international cooperation

E. Auffray, CCC Spokesperson
CERN, EP-CMX

Crystal Clear Collaboration RD18 experiment

http://crystalclear.web.cern.ch/crystalclear/

An **international** collaboration
active on research and development
on **inorganic scintillating materials** for novel ionizing radiation detectors,
for high-energy physics, medical imaging and industrial applications.

History

- Initiated @CERN in 1990 by P. Lecoq
- Approved in April 1991 by DRDC @ CERN for R&D for future LHC detectors
- **Initial Aim:** develop scintillating materials suitable for use at the future LHC collider.

The Crystal Clear Collaboration

CERN / DRDC / 91-15
DRDC / P27
06 march 1991

R&D PROPOSAL FOR THE STUDY OF NEW FAST AND RADIATION HARD SCINTILLATORS FOR CALORIMETRY AT LHC

CERN , Geneva , Switzerland
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F. Allegretti , S. Pizzini

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Université Claude Bernard , Lyon , France
B. Moine , C. Pedrini

LAPP , Annecy , France
M. Lebeau , M. Schneegans , M. Vivargent

Leningrad Nuclear Physics Institute , Leningrad , USSR
V. Samsonov , V. Schegelski , V. Yanovski

Lund University
L. Jønsson

Physics Institute , RTWH Aachen , Germany
K. Lubelsmeyer , D. Schmitz , W. Wallraff

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T. Aziz , S. Banerjee , S.N. Ganguli , S.K. Gupta , A. Gurtu , P.K. Malhotra , K. Mazumdar , R. Raghavan , K. Shankar , K. Sudhakar , S.C. Tonwar

Abstract

In the recent past, several scintillating crystals have been developed and mass produced for large high resolution electromagnetic calorimeters, such as NaI, CsI, and BGO. In the new generation of ee and pp colliders, the very high design luminosities bring new constraints on the crystals : they must have a fast response, higher resistance to radiation, and be as dense as possible for calorimeter compactness. From our systematic studies of scintillation properties and radiation damage mechanisms in scintillators, several fluoride crystals or glasses should have the wanted properties. The purpose of this R&D program is to study these materials and the conditions of their mass production in order to find the best suited scintillator for calorimetry at future colliders.

Today

CCC: 31 institutes all over the world, mainly in Europe

With broad expertise in:

scintillator, crystal growth, photo-detection, electronics, detector design & realization for many applications

Crystal Clear Collaboration RD18 experiment

http://crystalclear.web.cern.ch/crystalclear/

Main Activities:

- Generic activities on inorganic scintillators
  - Scintillation mechanisms, timing properties, radiation hardness, crystal production
- Generic activities on photodetectors, electronic readout chain
- Detector Development for several applications,
  - in particular HEP and medical imaging

CCC Community

Community of experts

Industry partners

Crystal growth Companies

Photodetector Companies

Medical devices Integration, Production

Solid state physics
Luminescence
Crystallography
Instrumentation

31 Institutes
CCC
>100 Physicists

SCINT conferences

Crystal2000 (Chamonix 1992)
San Francisco 1994
Scint95 (Delft)
Scint97 (Shanghai)
Scint99 (Moscow)
Scint2001 (Chamonix)
Scint2003 (Valencia)
Scint2005 (Krimé)
Scint2007 (Wake forest)
Scint2009 (Jeju,)
Scint2011 (Giesen)
Scint2013 (Shanghai)
Scint2015 (Berkeley)
Scint2017 (Chamonix)
Scint2019 (SENDAI)

Communities of users

High Energy Physics
LCMS, Alice, Belle, BaBar
L3, Panda, FCC etc..

Medical Imaging

Industrial applications

Security systems

CERN

CERN (the European Organization for Nuclear Research) is the world's largest particle physics laboratory, where physicists and engineers probe the fundamental structure of the universe.

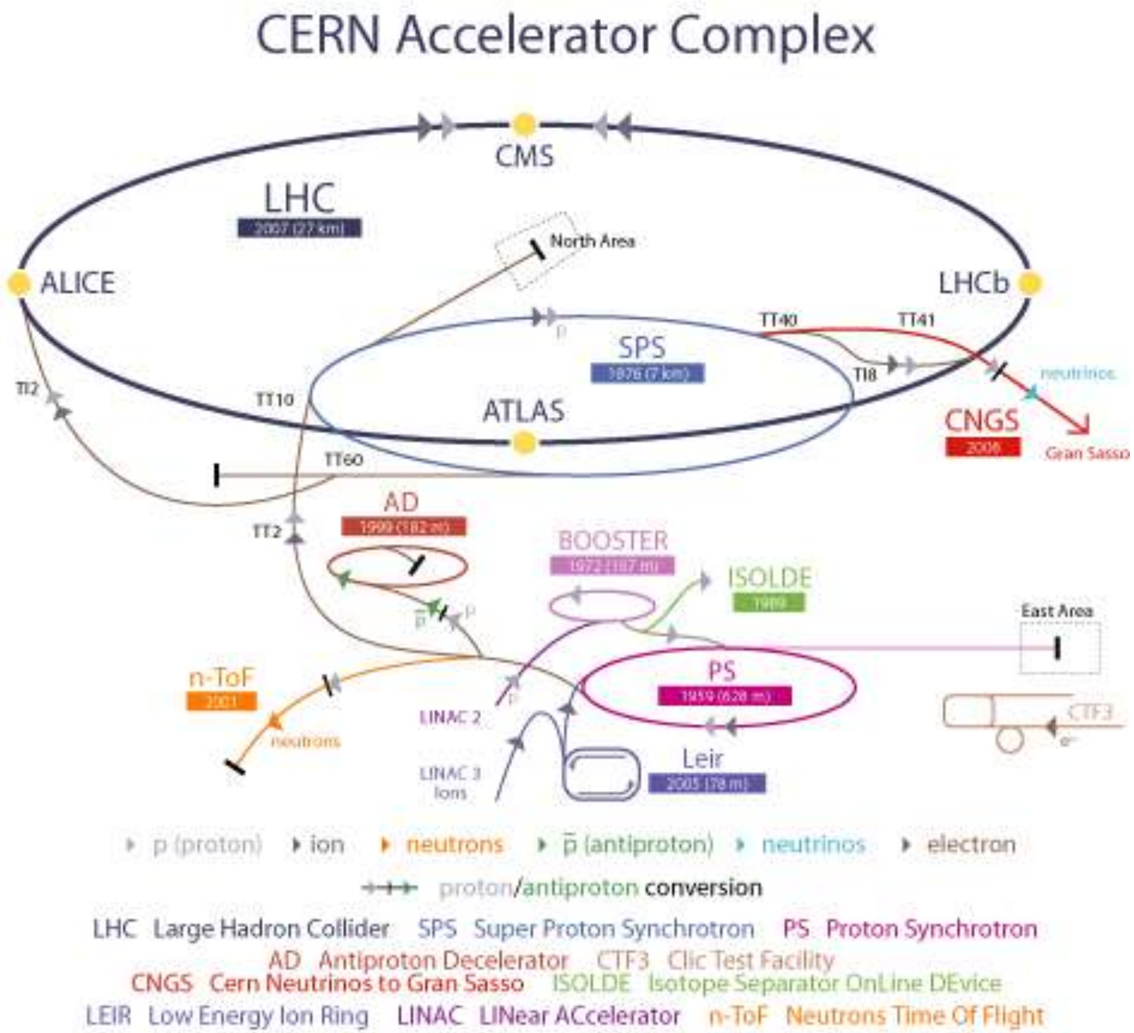
Seeking answers to questions about the Universe

Advancing the frontiers of technology

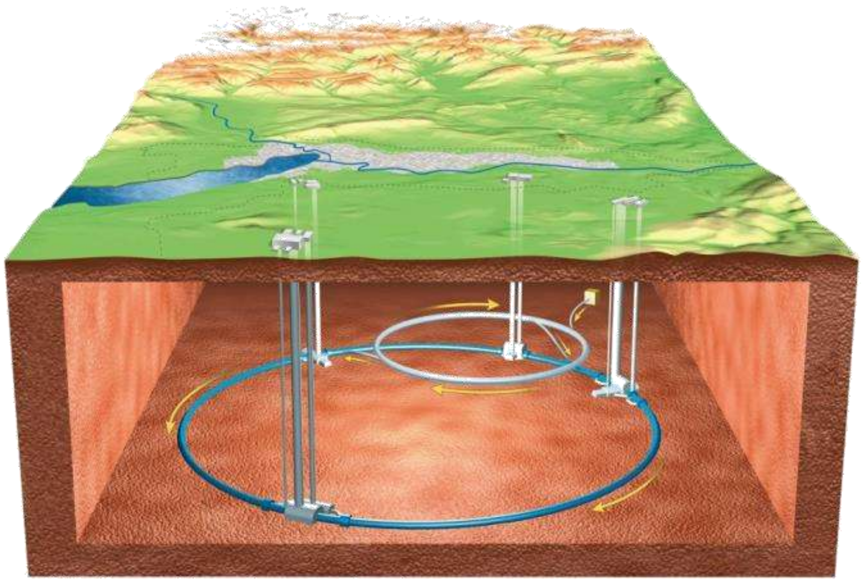
Training the scientists of tomorrow

Bringing nations together through science

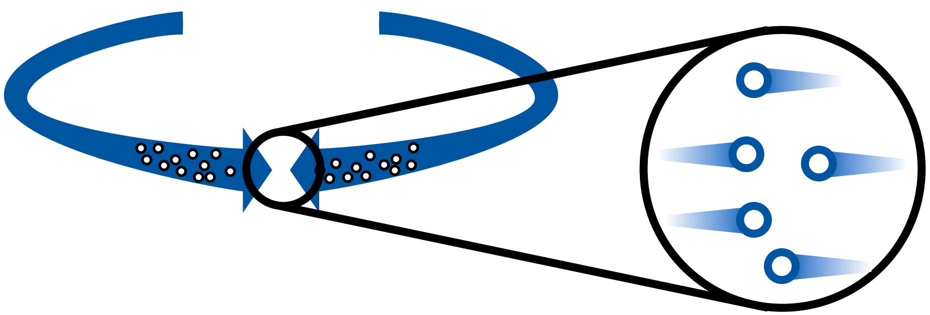
CERN Accelerator complex



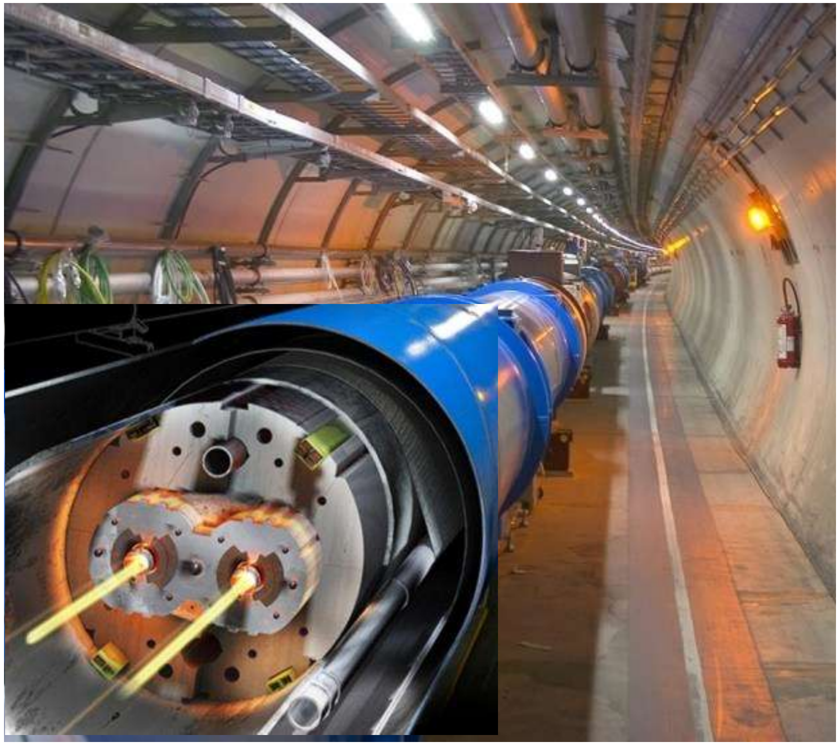
The Large Hadron Collider (LHC)



Length of ring: **27 km**
Collision energy: **8 TeV** (at present)



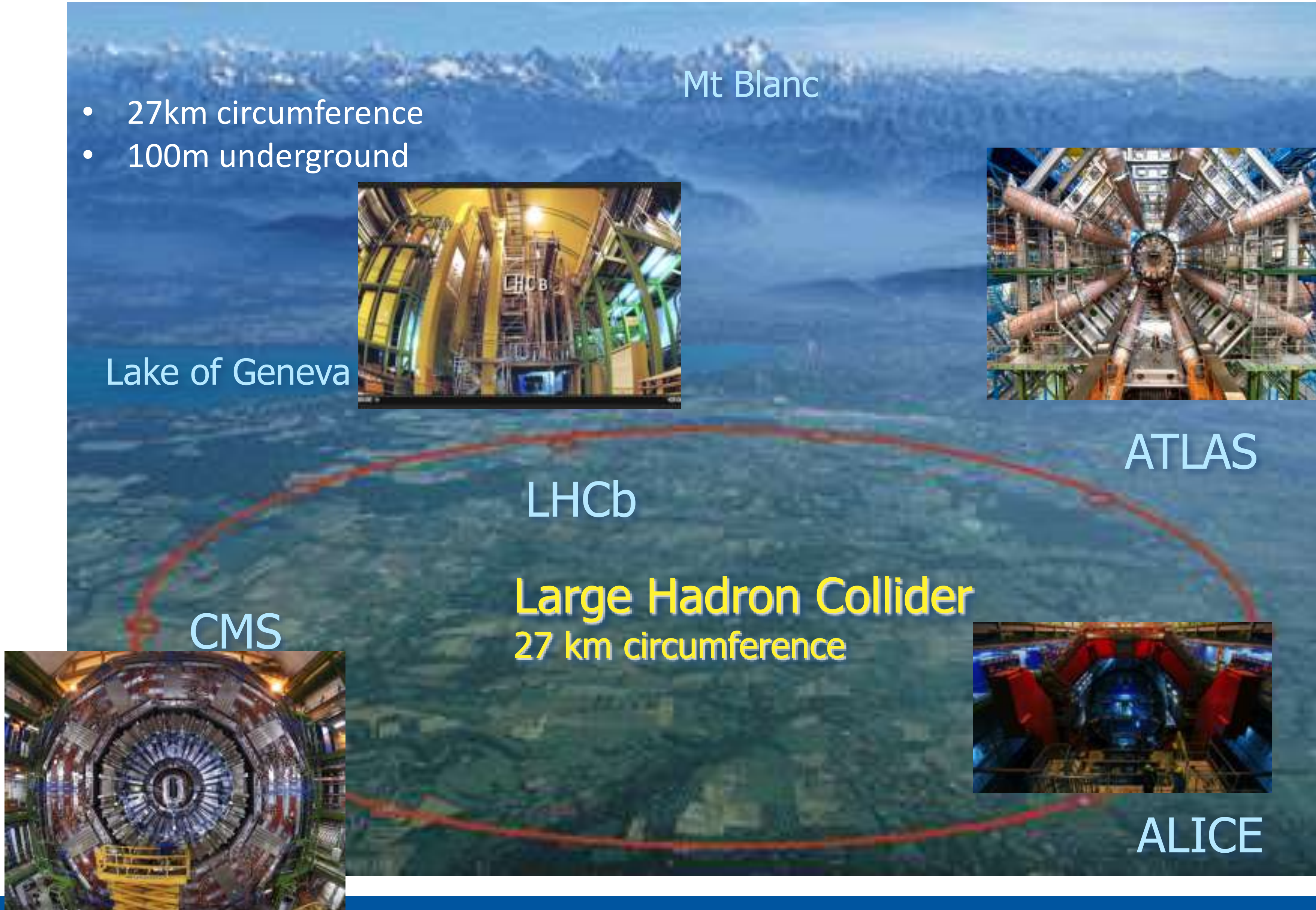
Protons or Lead ions



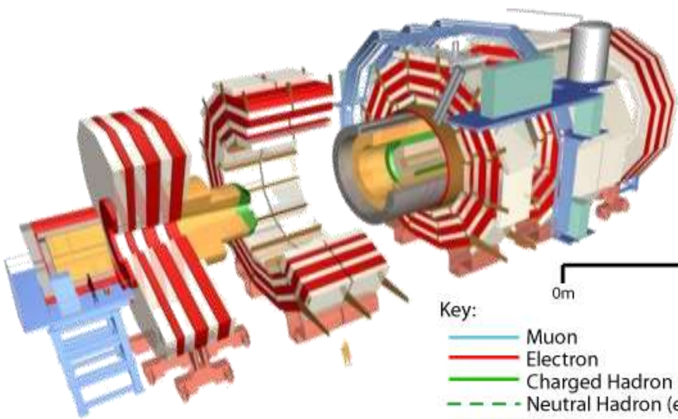
Based on superconducting magnets of Niobium-Titanium
Operating temperature:
1.9 K (−271.25 °C)

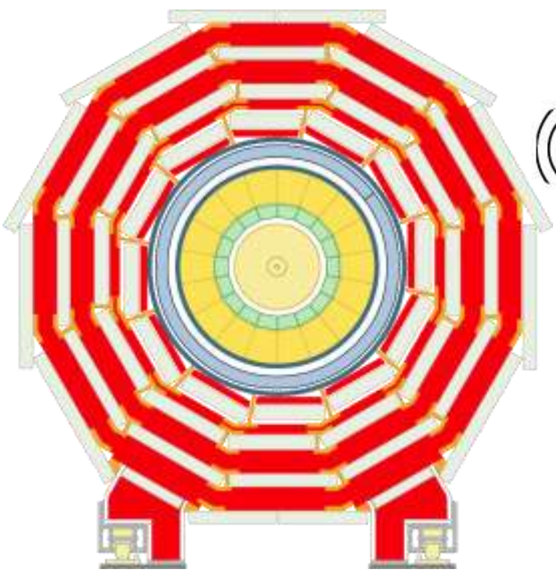
The Large Hadron Collider LHC

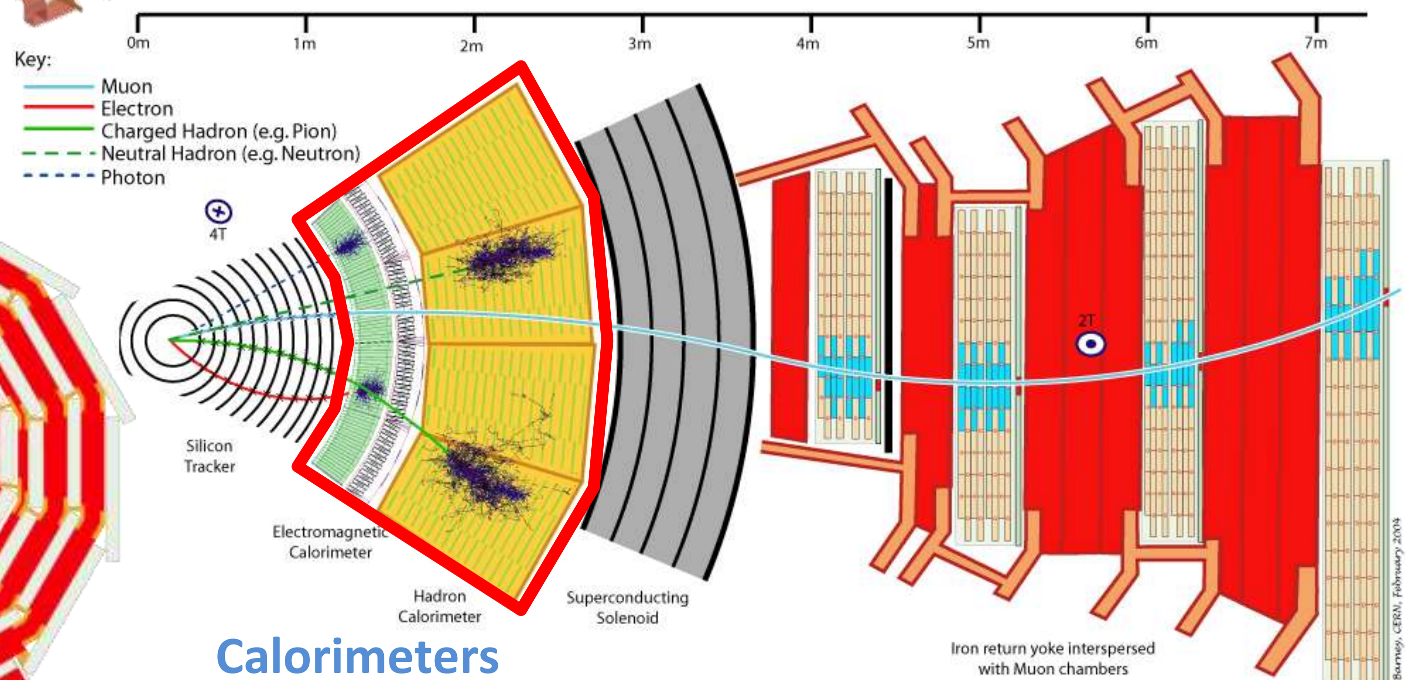
- 27km circumference
- 100m underground



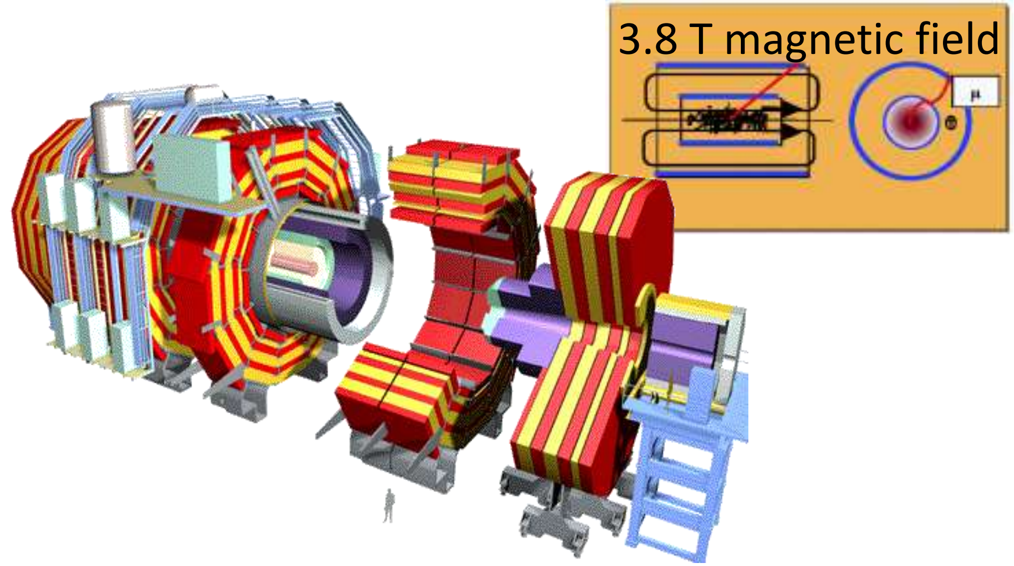
CMS: a multi-layer detector to reconstruct collision events





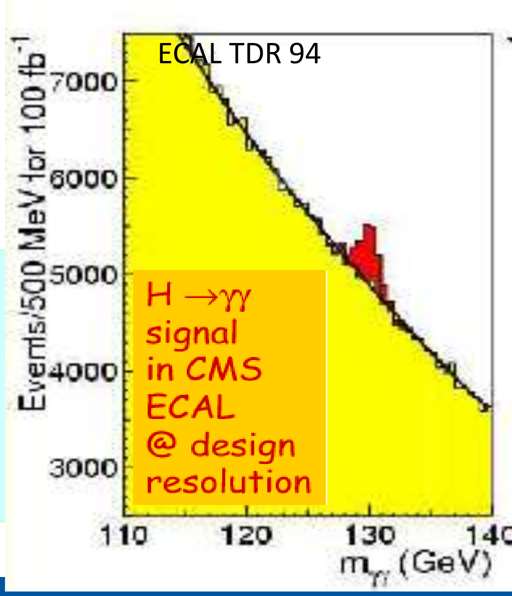


CMS : Compact Muon Solenoid @LHC



Length ~ 22 m
Diameter ~ 15 m
Weight ~ 14000 t

For a light Higgs
H→γγ best channel. Narrow width, but irreducible background:
Electromagnetic calorimeter (ECAL) resolution crucial !
=>Choice of homogeneous crystal calorimeter



Challenges for ECAL

Fast response (25ns between bunch crossings at LHC)

- High radiation doses and neutron fluences
  $500fb^{-1}$: 0.3 Gy/h & 4.10^{11} p/cm^2 at $|\eta| < 1.48$;
  6.5 Gy/h & 3.10^{13} p/cm^2 at $|\eta| = 2.6$

Strong magnetic field (3.8 teslas)

Long term stability monitoring capability

The Crystal Clear Collaboration

Initial Objective:

Develop scintillating materials suitable for use at the future LHC collider

From 1991 to 1994: R&D on several types of scintillator

Heavy fluoride glasses

R&D on new scintillators for LHC from 1991 to 1994

	Before 1990			Developed for LHC Crystal Clear/CMS		
	NaI(Tl)	CsI(Tl)	BGO $Bi_4Ge_3O_{12}$	**CeF_3**	**PWO $PbWO_4$**	**HFG Glass**
Xo [cm]	2.59	1.86	1.12	**1.66**	**0.89**	**1.6**
r [g/cm^3]	3.67	4.53	7.13	**6.16**	**8.2**	**6**
t [ns]	230	1050	340	**30**	**15**	**25**
l [nm]	415	550	480	**310 340**	**420**	**320**
Ref index n@l $_{max}$	1.85	1.80	2.15	**1.68**	**2.3**	**1.5**
LY [%NaI]	100	85	10	**5**	**0.5**	**0.5**

Crystal choice in 1994

From 1991 to 1994:

- Birth of the “scintillator community”
- Many progress in the understanding of the properties of 3 materials:
- CeF_3 had very good scintillation and radiation hardness properties **but no capability for large production**
- Heavy Glasses had good scintillation properties, **low cost but were not enough radiation hard for LHC**

⇒ **In 1994: Choice of PWO by CMS for the electromagnetic calorimeter**

⇒ **Choice of PWO for PHOs detector in ALICE**

	Developed for LHC Crystal Clear/CMS		
	CeF_3	PWO $PbWO_4$	HFG Glass
Xo [cm]	1.66	0.89	1.6
r [g/cm^3]	6.16	8.2	6
t [ns]	30	15	25
l [nm]	310 340	420	320
Ref index n@l $_{max}$	1.68	2.3	1.5
LY [%NaI]	5	0.5	0.5

INTERNATIONAL WORKSHOP ON HEAVY SCINTILLATORS FOR SCIENTIFIC AND INDUSTRIAL APPLICATIONS

CRYSTAL 2000

CHAMONIX, France, September 22-26, 1992

4 first papers on PWO for High Energy Physics applications at first conference on inorganic scintillators (SCINT conf)

STUDY OF CHARACTERISTICS OF REAL-SIZE $PbWO_4$ CRYSTAL CELLS FOR PRECISE EM-CALORIMETERS TO BE USED AT LHC ENERGIES

V.A. Kachanov IHEP Protvino, CIS

Y.D. Prokoshkin V.G. Vasilchenko L.L. Nagornaya

M.V. Korzhik

FAST SCINTILLATORS BASED ON LARGE "HEAVY" TUNGSTATE SINGLE CRYSTALS.

L.Nagornaya, V.Ryzhikov, ISC, Kharkov, Ukraine

$PbWO_4$ SCINTILLATOR AT ROOM TEMPERATURE

Masaaki KOBAYASHI[a], Mitsuru ISHII[b], Yoshiyuki USUKI[c] and Hiroshi YAHAGI[d]

a) KEK, National Laboratory for High Energy Physics, Tsukuba 305, Japan,
b) SIT, Shonan Institute of Technology, Fujisawa 251, Japan,
c) Furukawa Co., Kamiyoshima, Yoshima, Iwaki 970-11, Japan,
d) Fujitok Co., Kamijyujyo 1-9-16, Kitaku, Tokyo 114, Japan.

$PbWO_4$: A HEAVY, FAST AND RADIATION RESISTANT SCINTILLATOR FOR EM CALORIMETRY

L.V.Miassoedov, V.I.Selivanov, I.V.Sinitsin, V.D.Torokhov
Kurchatov National Center, Moscow 123182, Russia

L.L.Nagornaya, Y.Ia.Vostresov, I.A.Tupitsina
Monocrystal Institute, Kharkov, Ukraine

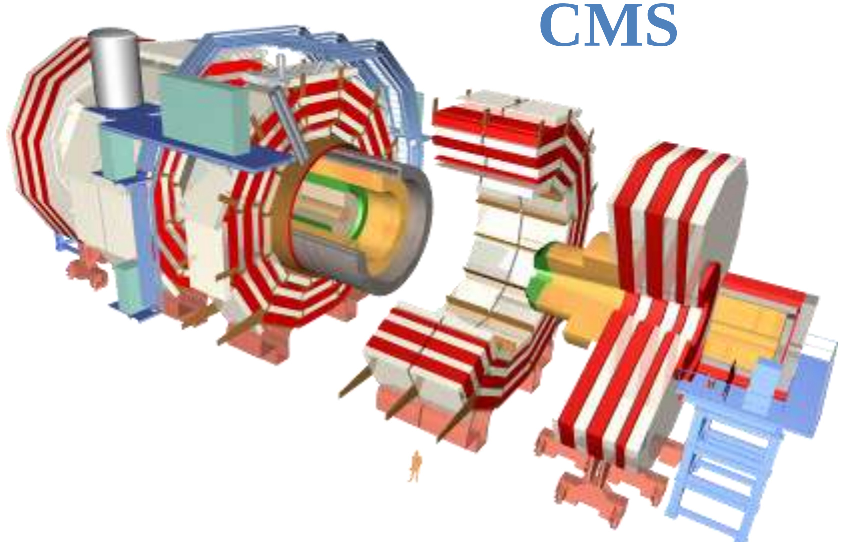
The promoters of PWO

@CERN in LHC

2 experiments use scintillating crystals : Lead tungstate crystals : $PbWO_4$

ALICE :17920 crystals

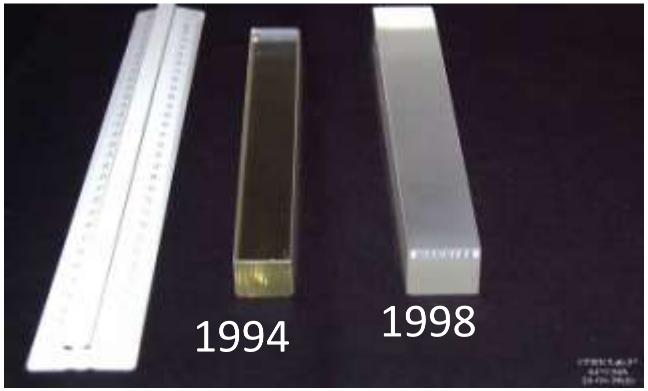
CMS



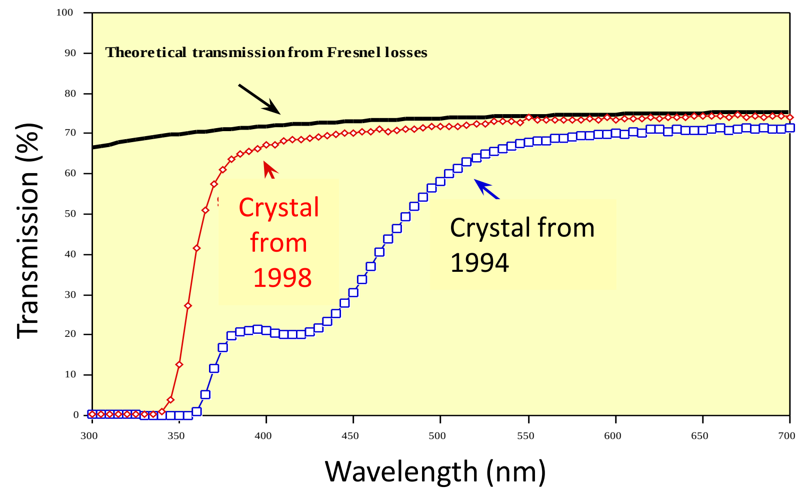
75848 crystals = 100 tons

From R&D to Production

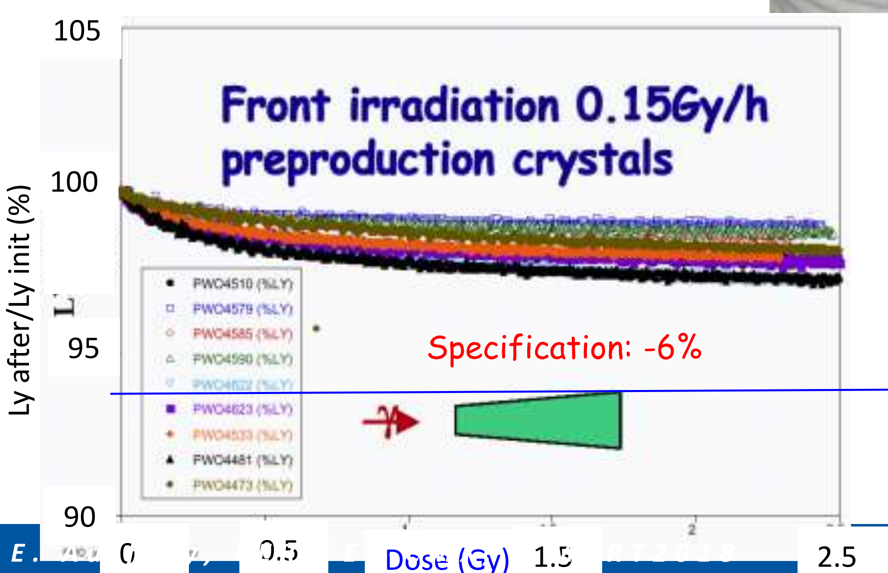
Optical properties improvement



Transmission improvement



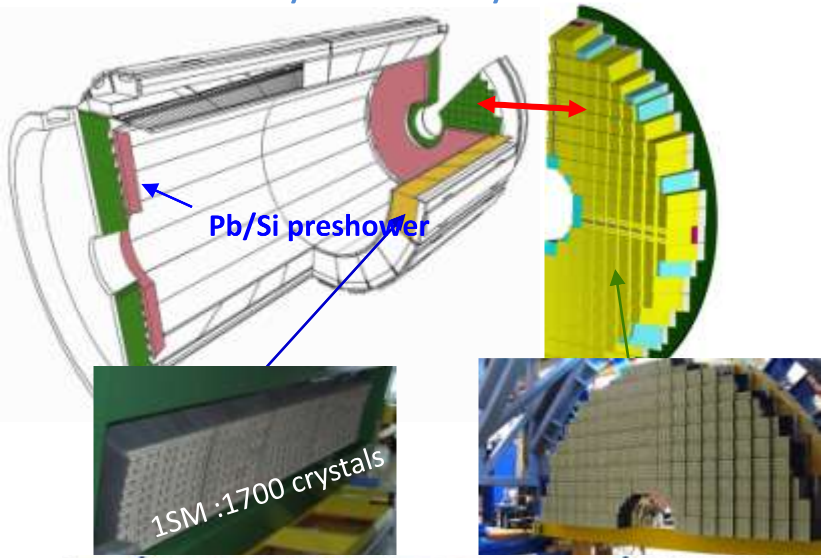
Radiation hardness improvement

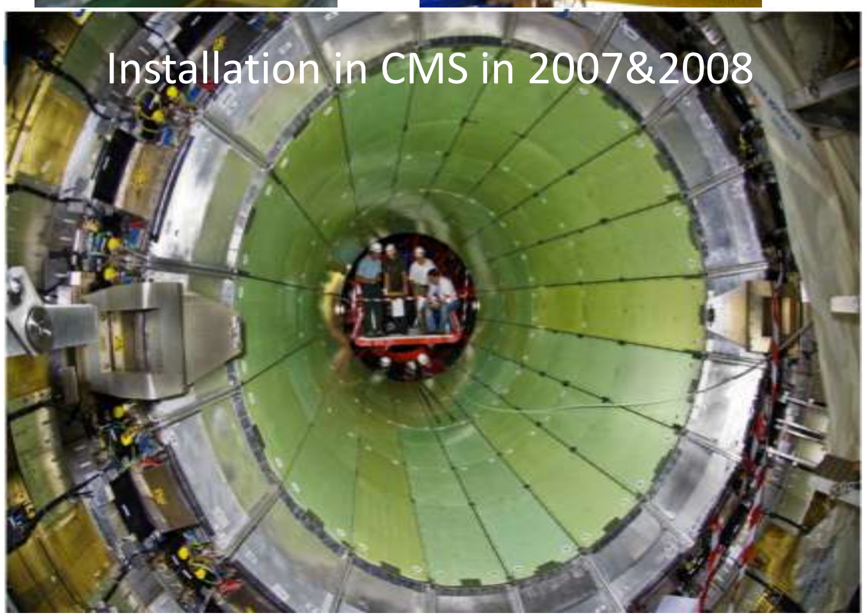


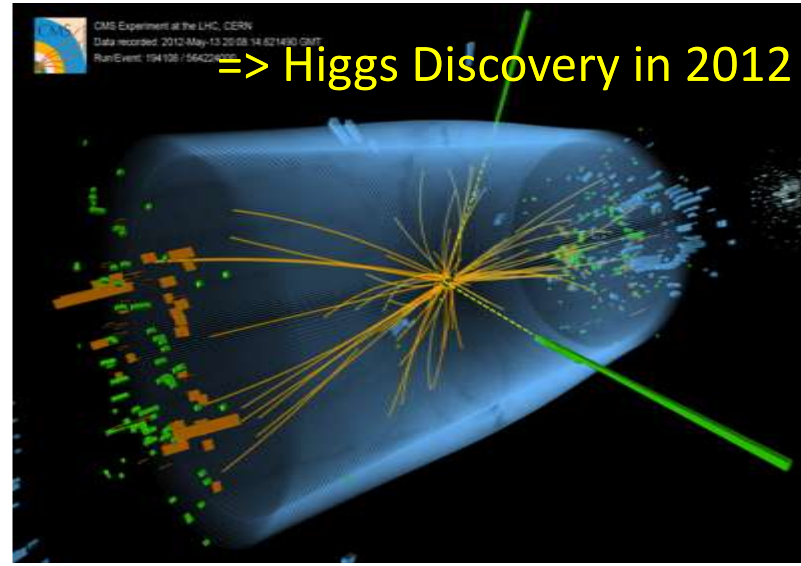
Delivery of the first 100 PWO Crystals Sept 98

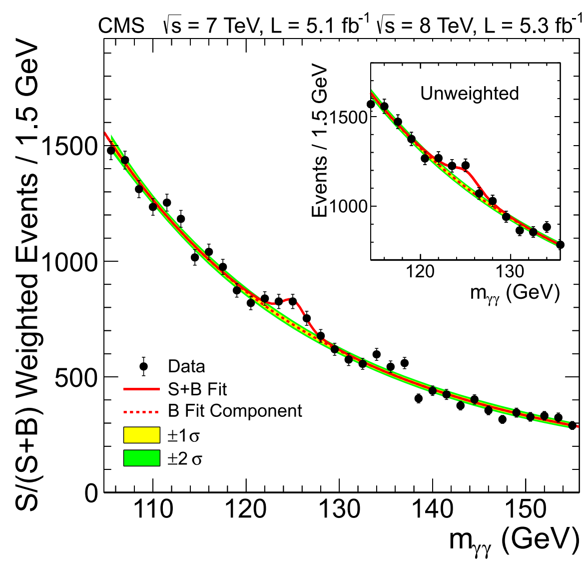
CMS ECAL: Higgs bosons

75848 PWO Crystals : 10 years of construction









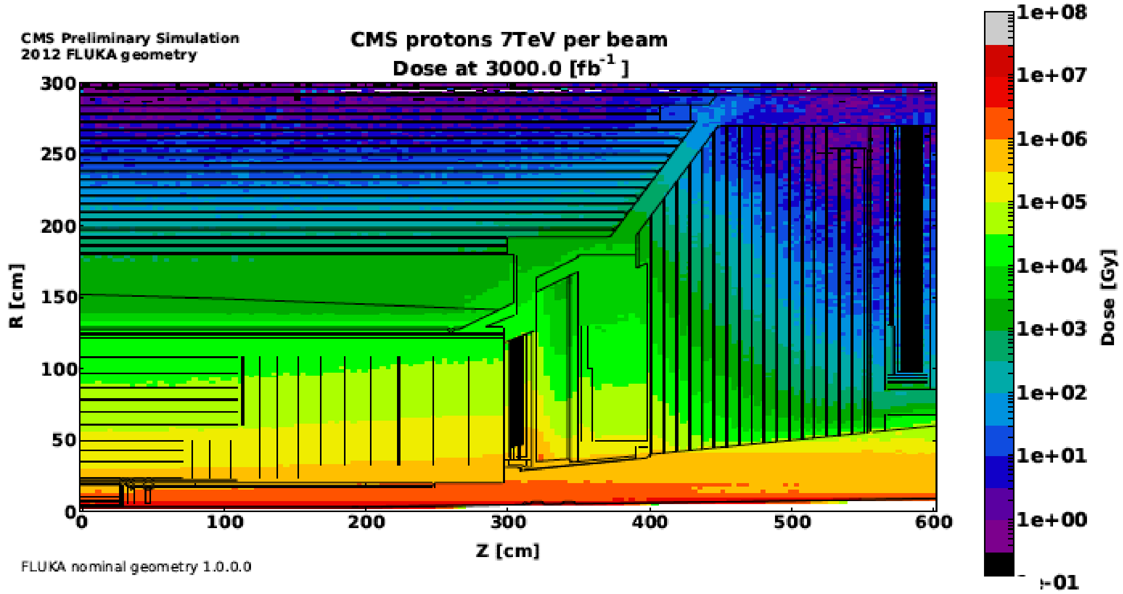
The calorimetry challenge in future High Energy colliders

- Precision Physics at future colliders required
  - High luminosity (high radiation level)
  - High granularity
  - Fast timing response

New challenge at High Luminosity LHC : radiation level

In CMS:

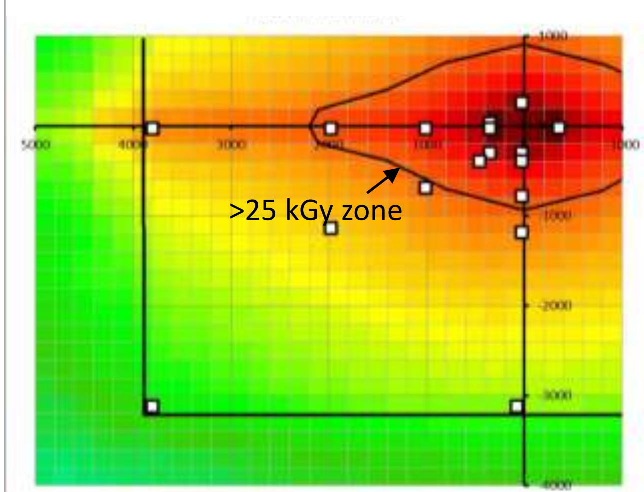
- ionizing radiation dose up to **1 MGy**
- charged hadron up to **2 10^{14} cm^2**



In LHCb:

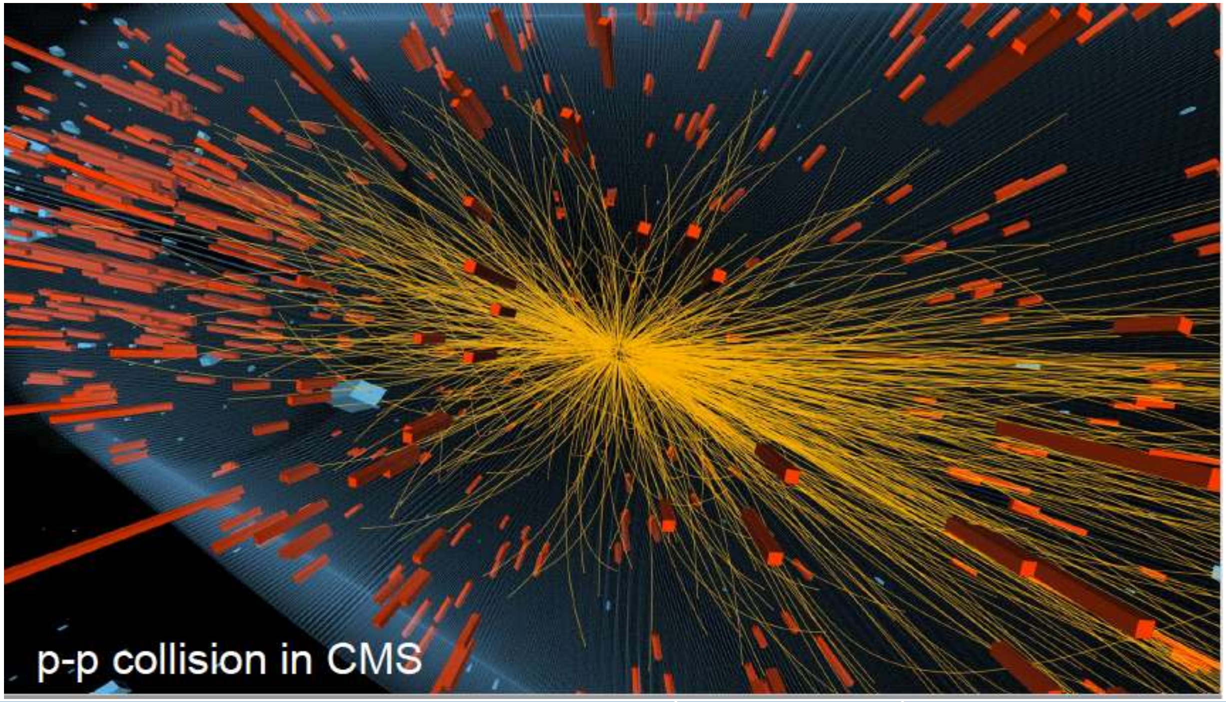
- Up to ~3 MGy and ~3·$10^{15}$$cm^2$ for 1 MeV n eq. at 300 fb^{-1} (in hottest region of the central part, decreasing quickly with distance from beam-pipe)

Radiation dose on LHCb ECAL front



=> Need for very radiation hard material

New challenge : high rate



	LHC	High Luminosity
Distance between bunch crossing (BX)	50ns	25ns
Number of proton collisions/BX	<40>	<200>
Spatial density of interaction vertices	$0.3mm^{-1}$	$1.9mm^{-1}$

=> Need for fast timing detector

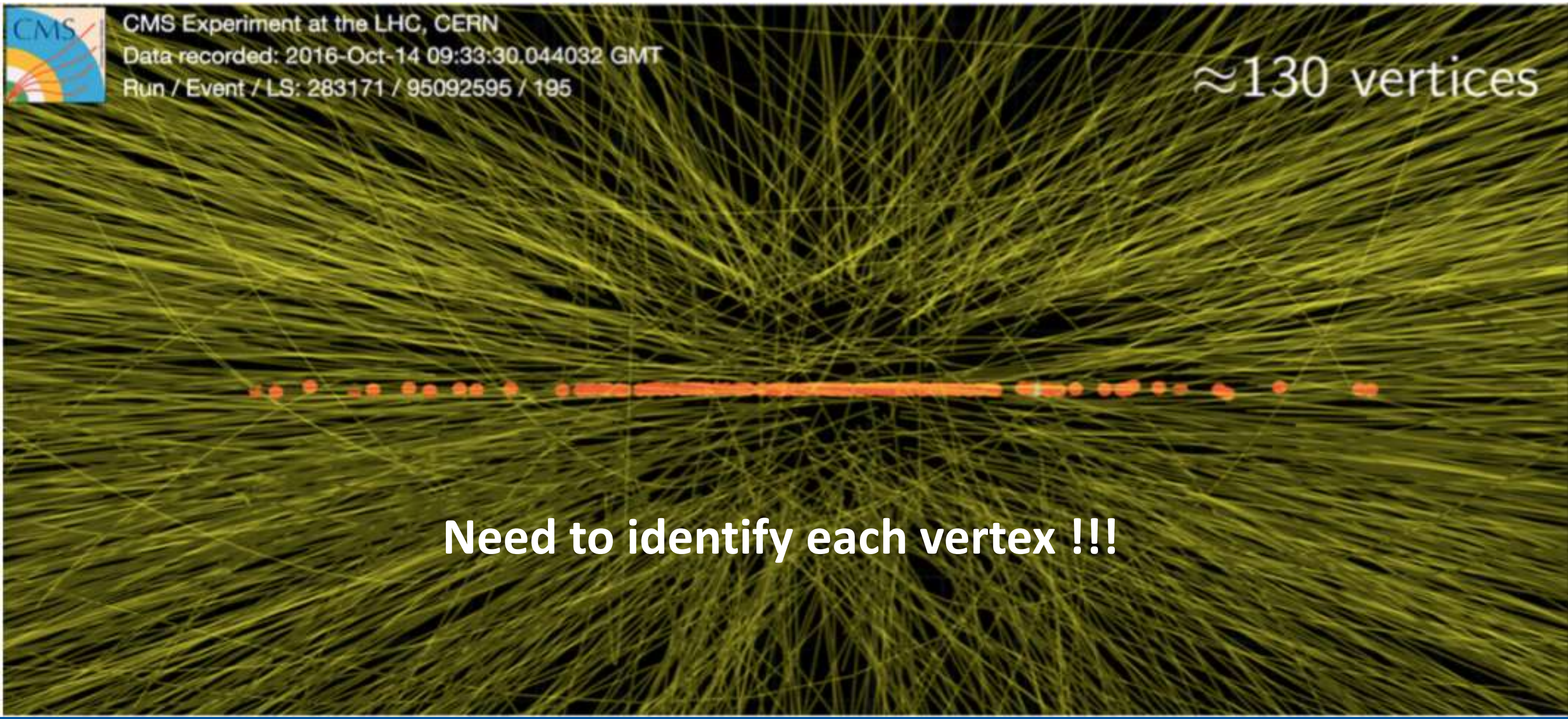
Request for FAST timing in HEP

Search for rare events implies high luminosity accelerators

→ Rate problems;

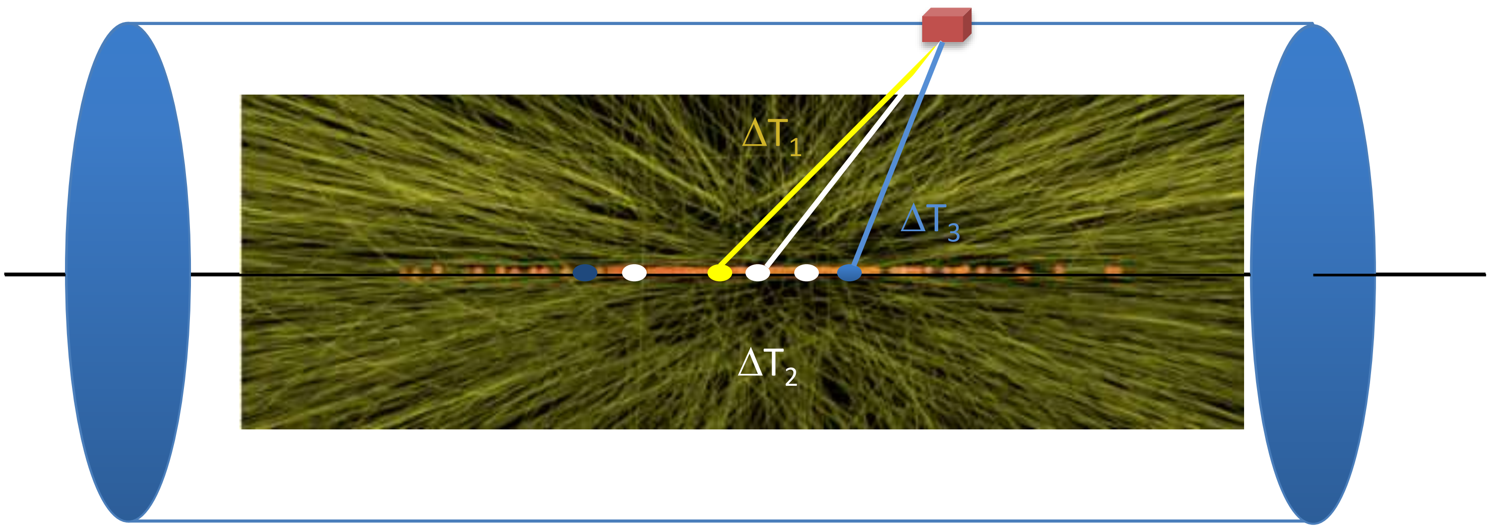
→ Pileup of >140 collision events per bunch crossing at *High Luminosity-LHC;*

→ Pileup mitigation via TOF requires TOF resolution < 50ps.



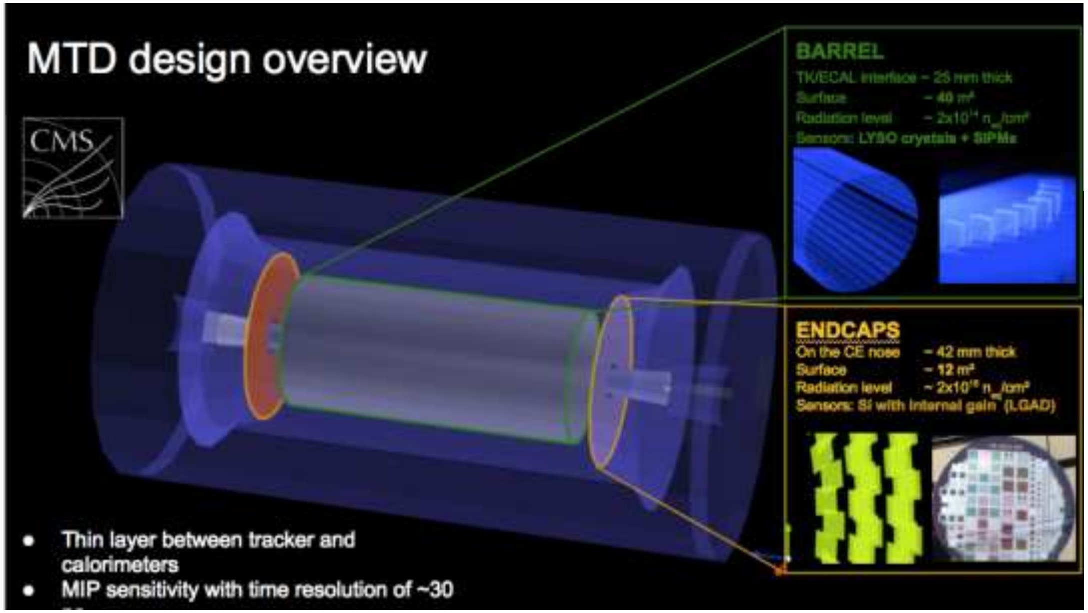
Need to identify each vertex !!!

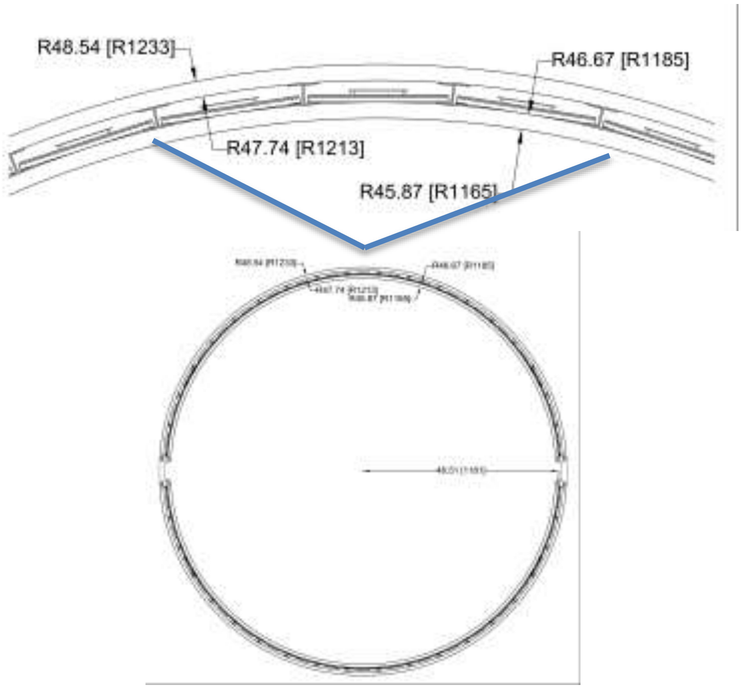
Request for FAST timing in HEP



The information of timing will allow to identify the vertex

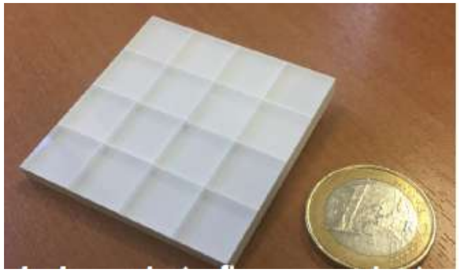
CMS Barel timing layer (BTL)





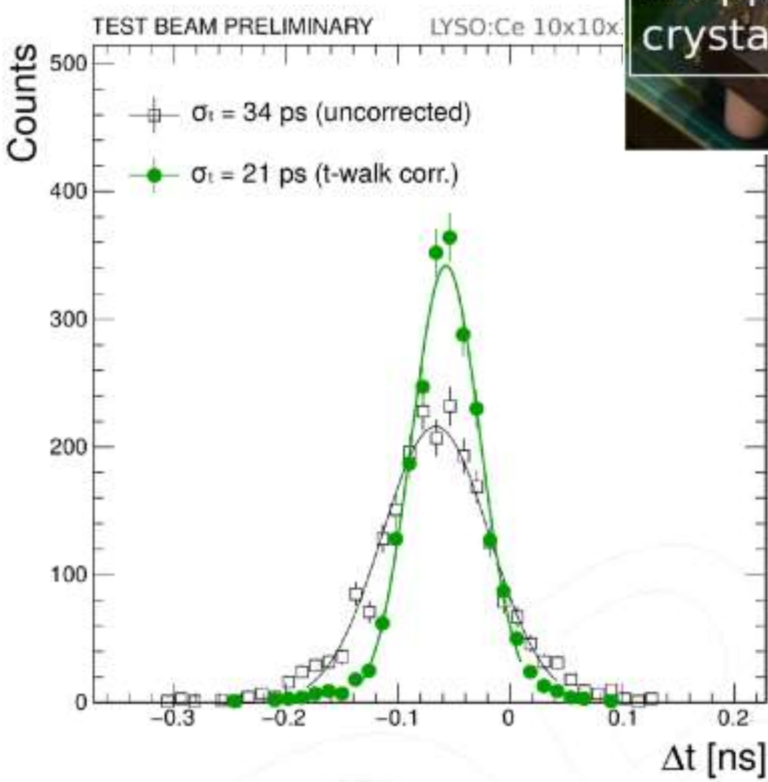
2 possible geometries

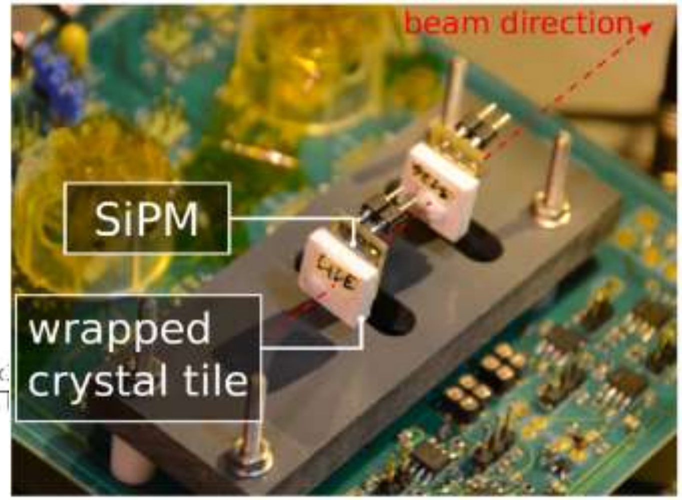
Plate 11.5*11.5*3mm^3

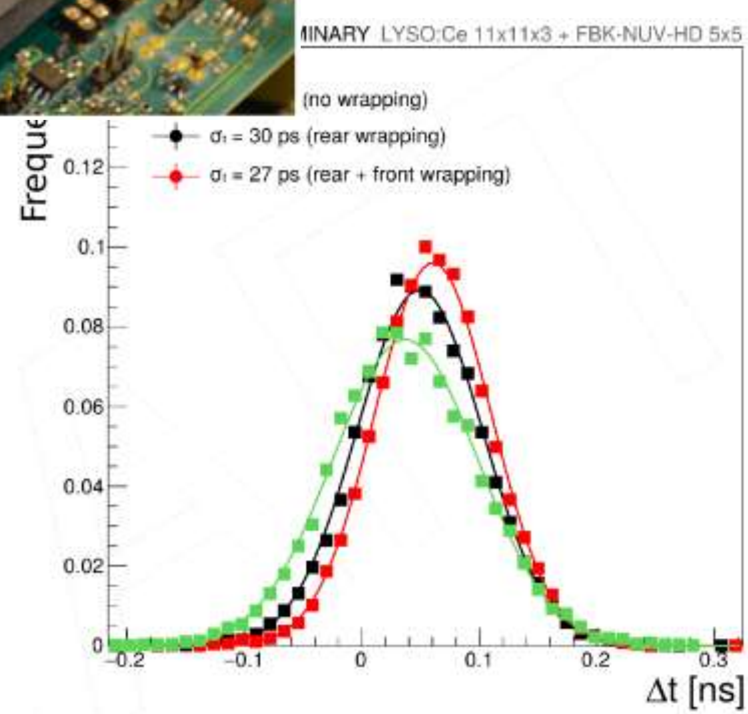


short fibers (3*3*50mmm^3)

Timing resolution Prototype BTL

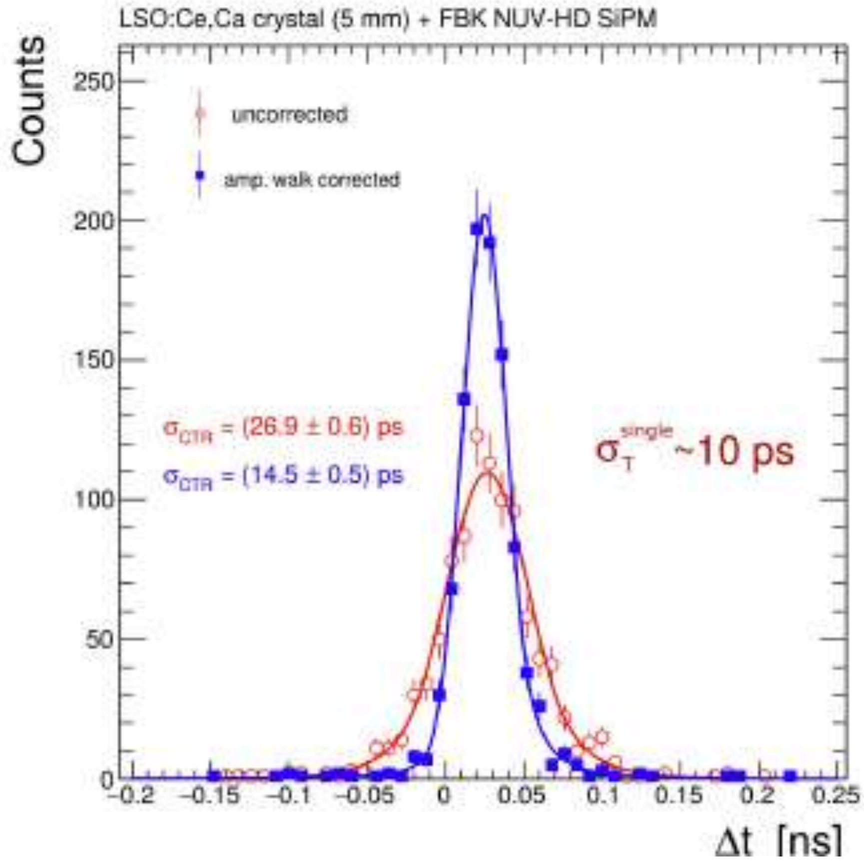






C. H. Pena, Calor 2018

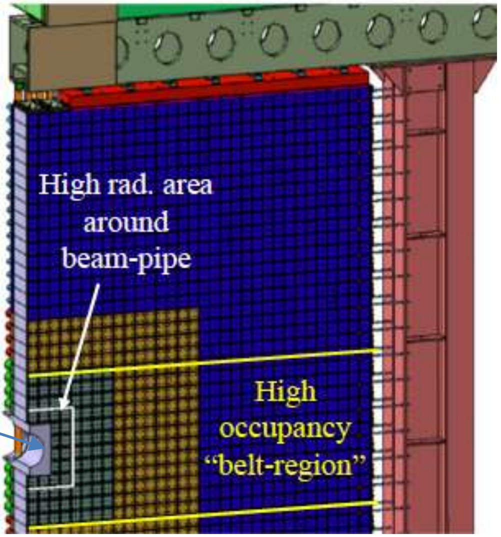
Best time resolution with mip

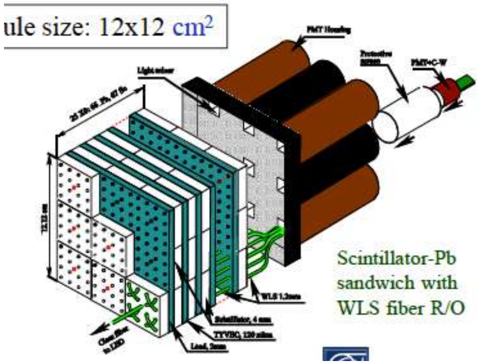


M.T. Lucchini et al., NIM A 852 (2017) 1-9

LHCb ECAL upgrade

LHCb calorimeter need to replace Shaslik calorimeter made of Pb/plastic scintillators) at least central part: 32 modules of 12x12 cm^2





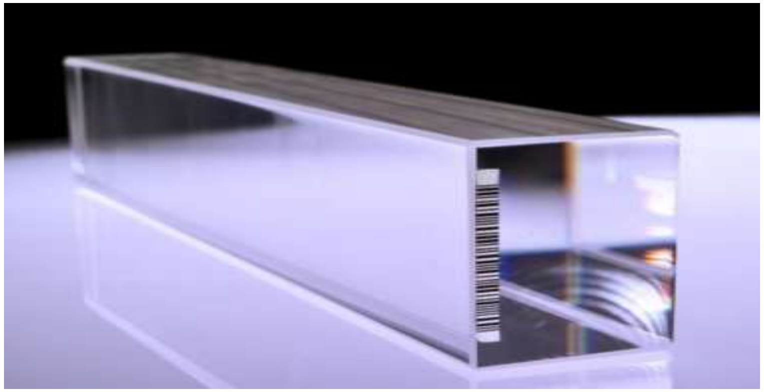
Possible envisaged options:

- Homogenous crystal calorimeter with
  fast and radiation hard crystal with small Moliere Radius and excellent σ(E)
- Shampling calorimeter: Shaslik or SPACAL
  - Tungsten or tungsten alloy as converter (RM ~ 1cm)
  - Radiation hard crystal as active medium with high light yield and fast response
  - Ø Radiation hard light-guide/fibre to transport light (for Shashlik type)
  - Ø Radiation hard photodetector
  - Ø Include a very fast (crystal) component (~20ps) into module (for pile-up mitigation)

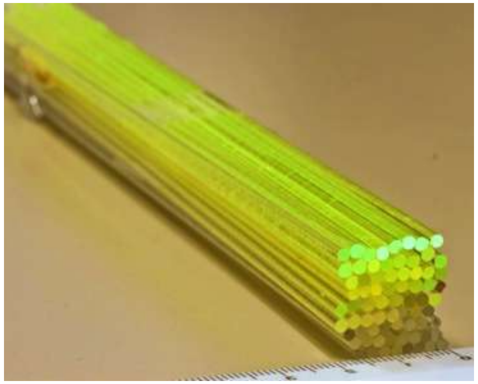
Scintillating crystal fibers: Flexibility for the calorimeter design

Homogeneous calorimeter

From bulk crystal



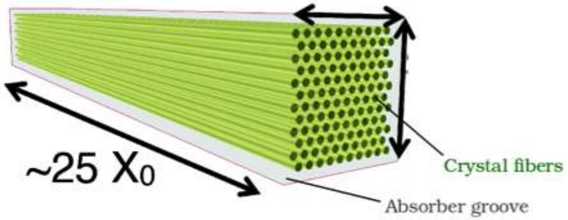
To bloc of fibers



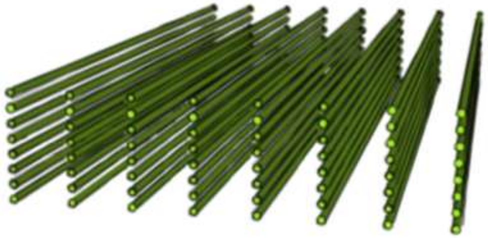
=> Need large volume of fibers with high density

Sampling calorimeter

Pointing Fibers
in a Spaghetti Calorimeter

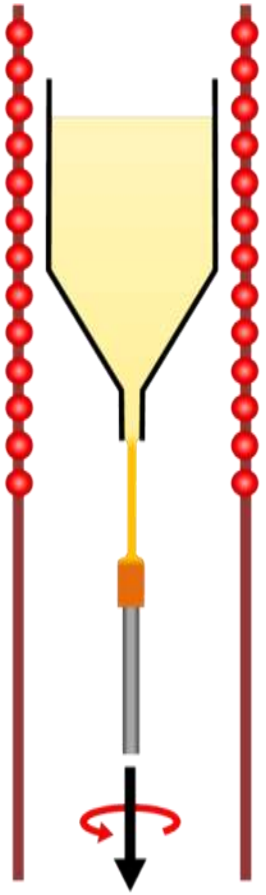


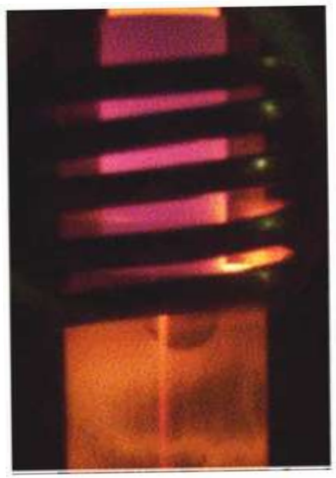
Layers of Crystal Fibers
in a sampling calorimeter



=> Need less fibers, possibility to use materials with lower density

Micro-Pulling down technology for crystal fiber growth

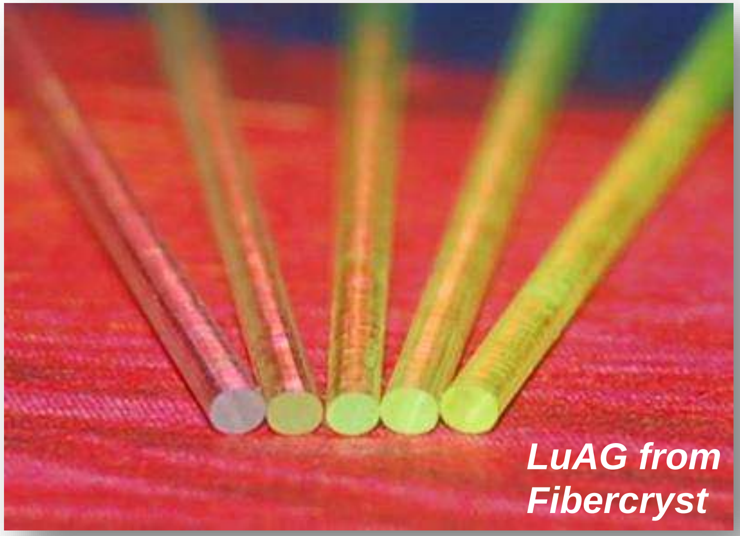




Courtesy Fibercryst

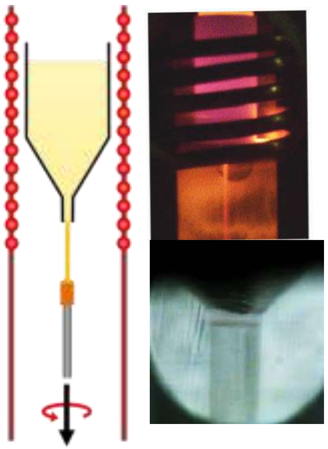
Micro-pulling down (µPD) : multiple advantages

- Wide range of diameters 300 µm – 3 mm
- Lengths up to 2 m
- Multiple geometries for capillary die
- Fast pulling rates
- Multi-fibers pulling possibilities (in parallel)

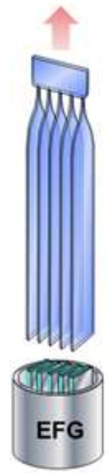


Crystal fiber productions

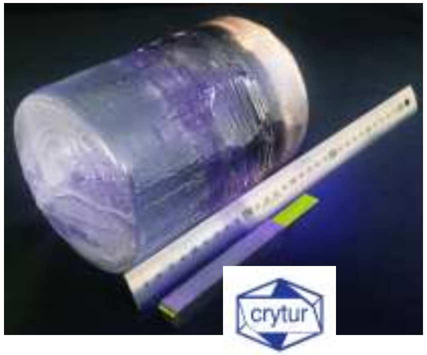
Micropulling down technique

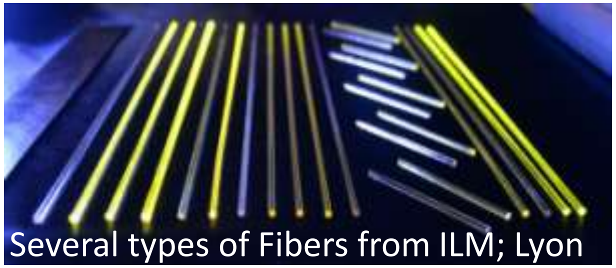


EFG

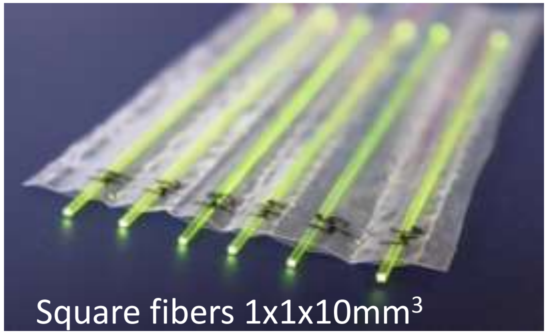


Czochralski method
Cut from large ingot




Several types of Fibers from ILM; Lyon

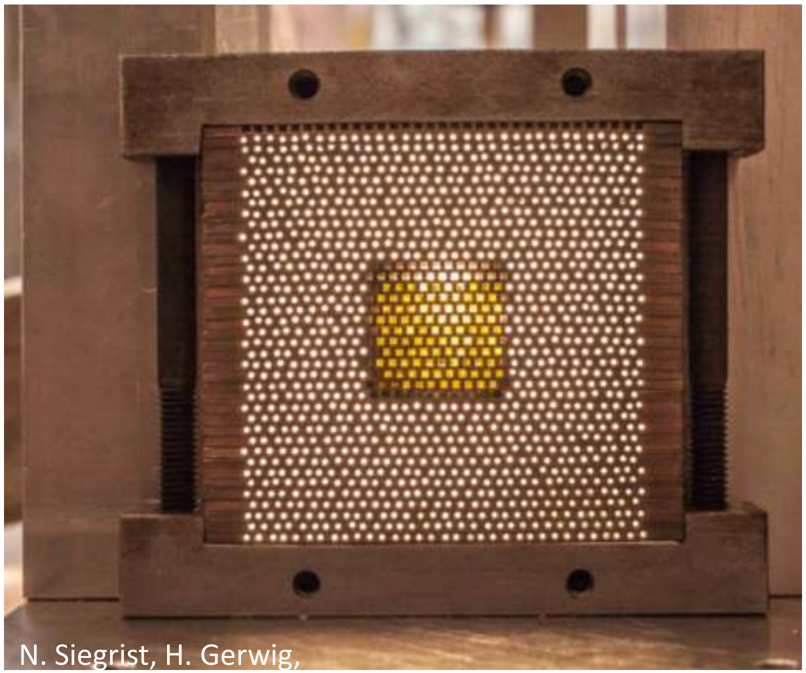

EFG-grown plate & fiber of LuAG:Ce from Adamant Namiki Co , Japan


Square fibers $1x1x10mm^3$

=> Feasibility study on going: main goal of Intelum project (European Rise project grant 644260) with 16 Partners (many from CCC) from 12 different countries: 11 academia and 5 companies

Intelum

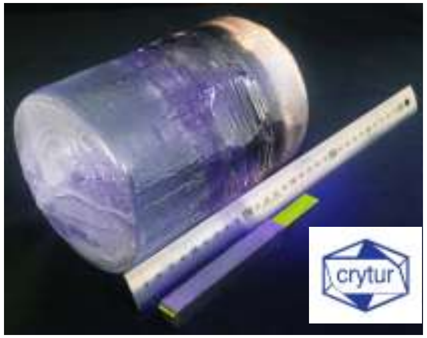
A SPACAL calorimeter unit developped at CERN

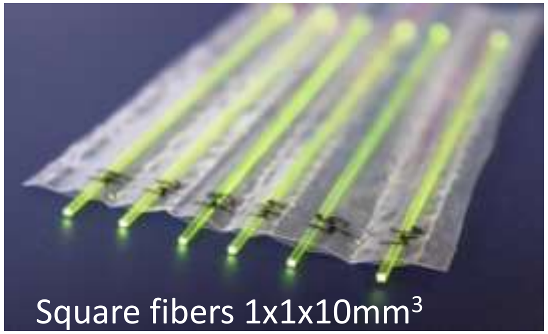


YAG square fibers
in a W-Cu Absorber
(stacked grooved plates)

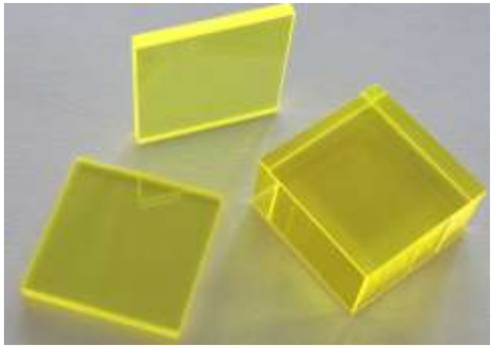
Garnet materials

YAG from From Crytur





GAGG: Ce, Mg, Ti From FOMOS



Properties of Garnet Ce doped crystal

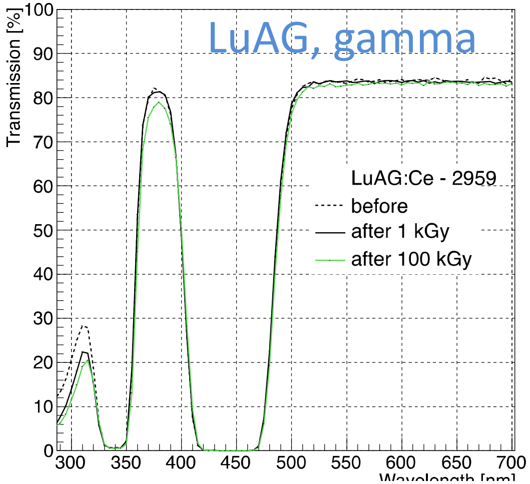
	$Y_3Al_5O_{12}$:Ce (YAG)*	$Lu_3Al_5O_{12}$: Ce (LuAG)*	$Gd_3Al_2Ga_3O_{12}$: Ce (GAGG)**	Lu_2SiO_5:Ce (LSO)
density (g/cm^3)	4.57	6.73	6.63	**7.4**
X_0 (cm)	3.5 cm	1.3	1.59	1.1
Refraction index	1.83	1.84	1.85	1.82
Λ_{max} (nm)	**550**	**535**	**520**	**420**
LY @ RT (ph/MeV)	**35000**	**25000**	**50000**	**30000**
decay time (ns)	70 + slow component	70 + slow component	60 + slow component	**40**

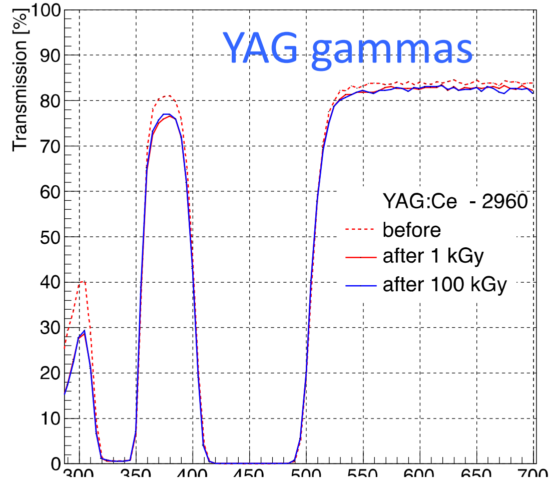
*http://www.crytur.cz/materials/

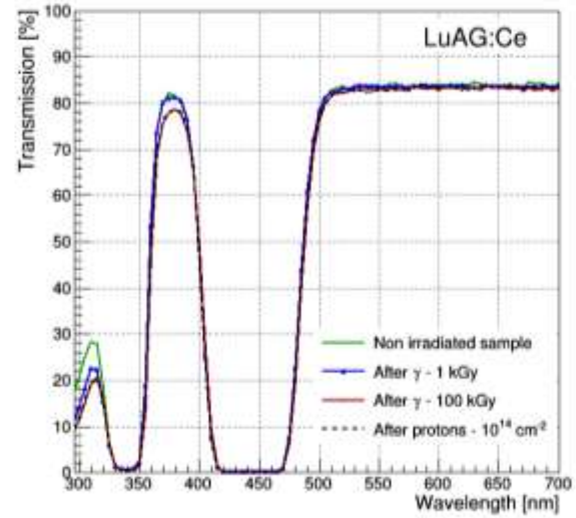
** K. Kamada et al. / Optical Materials 41 (2015) 63–66

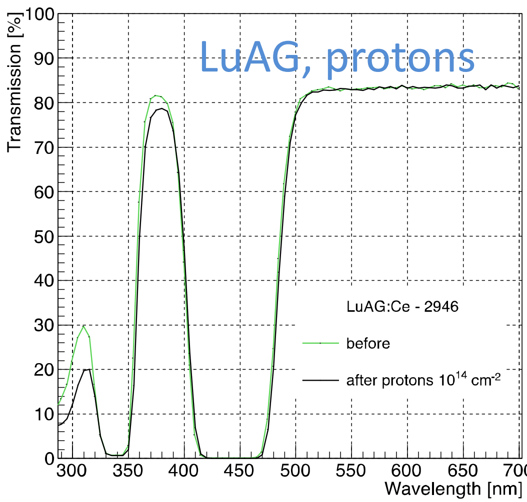
Radiation hardness of YAG/LuAG/GGAG material

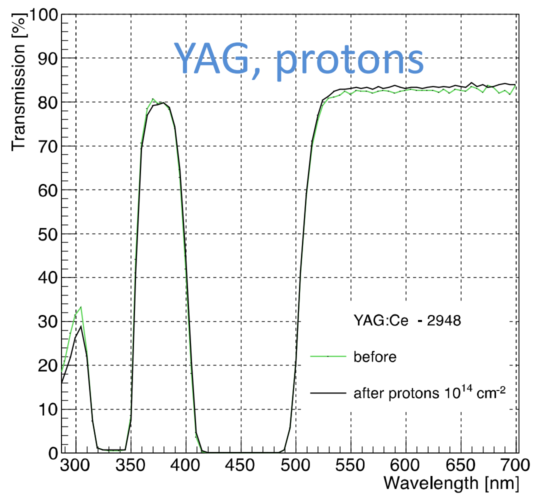
From Crytur 1cm³ | LuAG From Astharak (1x1x4cm³)

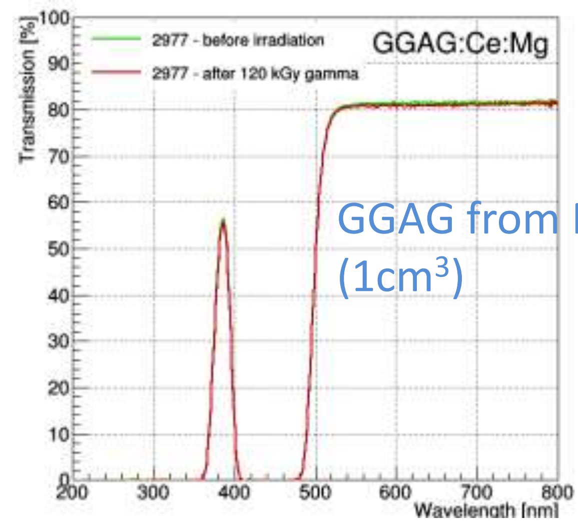












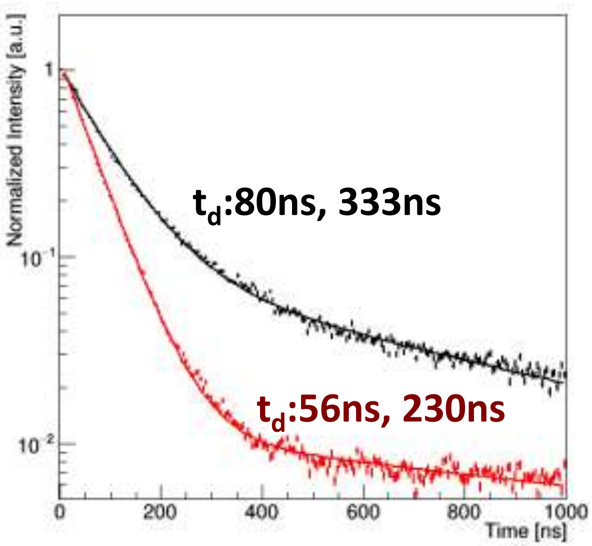
GGAG from Prague (1cm³)

Very Good radiation tolerance under gamma & proton

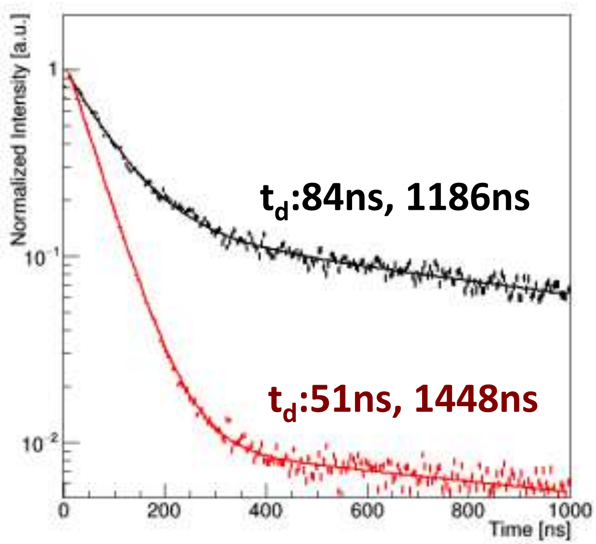
M. Lucchini,et al., IEEE TNS 63 (2) 586-590 ,
M. Lucchini et al, NIM A Volume 816, pp 176–183,

Influence of codoping on decay time

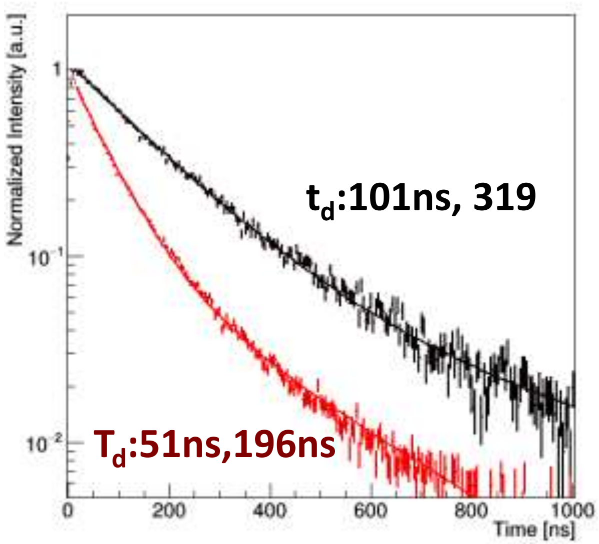
YAG



LuAG



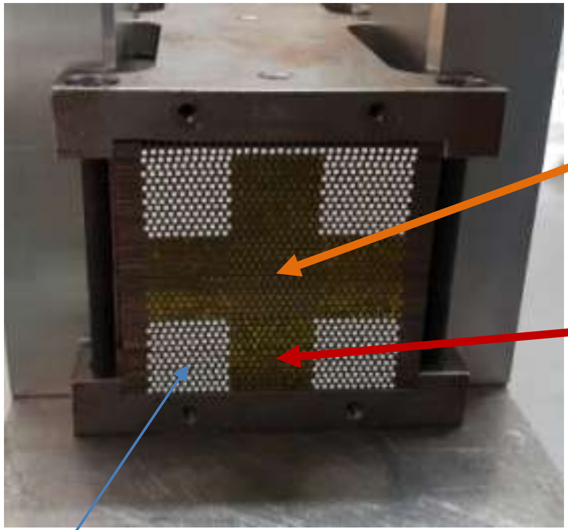
GAGG



with Mg codoping: shorter decay time and strong decrease of slow component

Kamada et al, O-14-3 at SCINT2015
M. Lucchini et al, NIM A Volume 816 (2016), pp 176–183,

SPACAL LHCb test beam Oct.2018 with square fibers YAG and GAGG

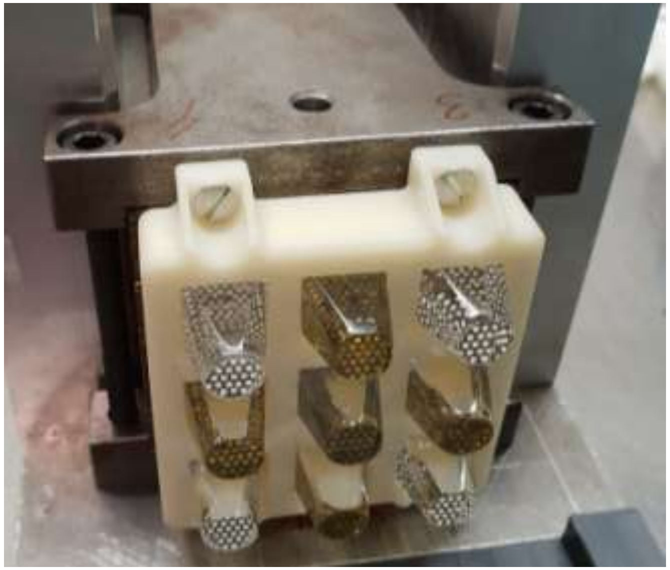


1 cell GaGG:ce, Mg, Ti fibers from FOMOS

4 cells YAG fibers from Crytur

Plastic fibers

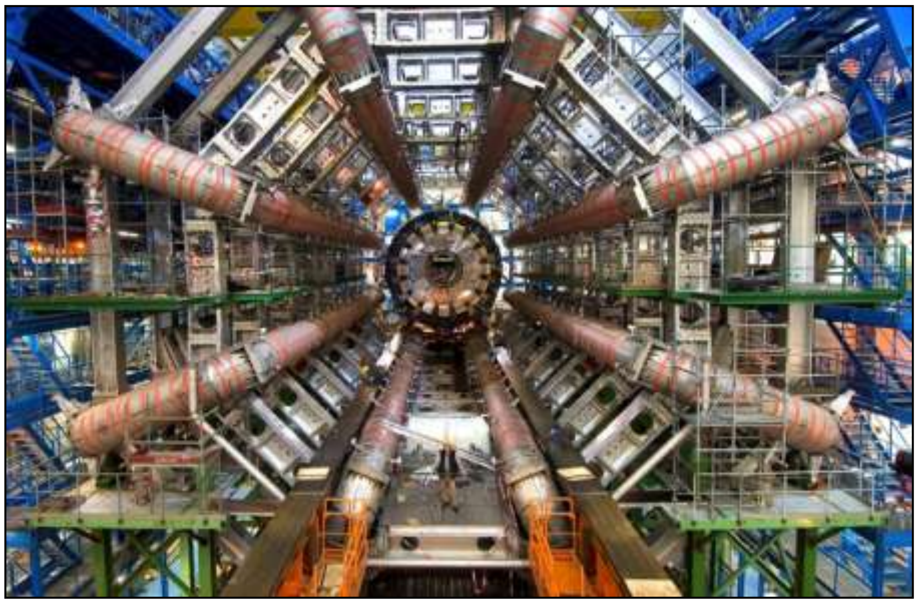
Readout with PMT
Coupling fiber to PMT with optical guide



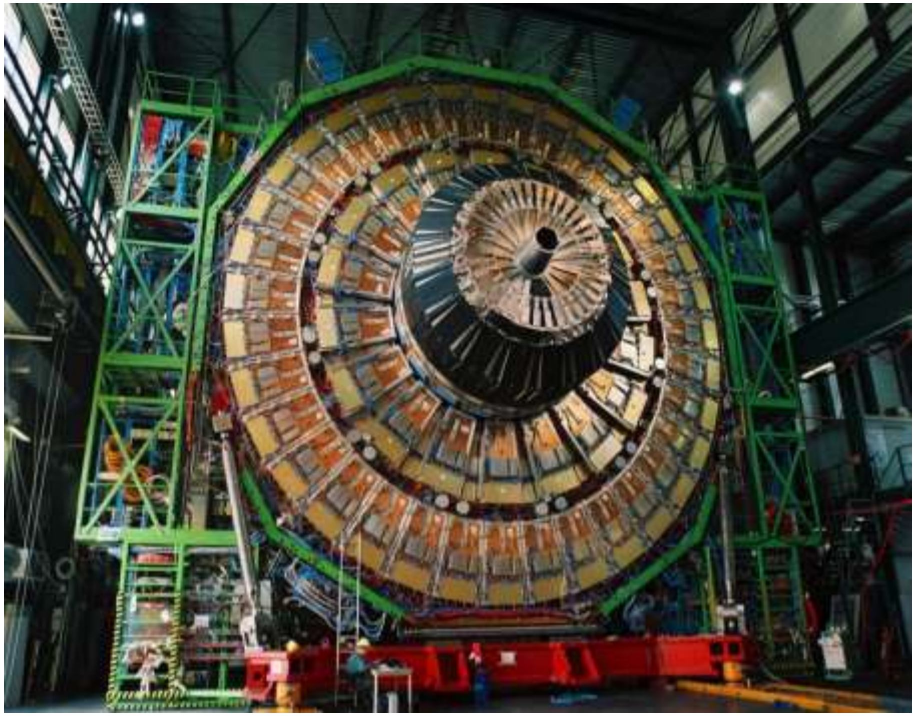
@ CERN development of leading edge technology

To build particles detectors like

ATLAS



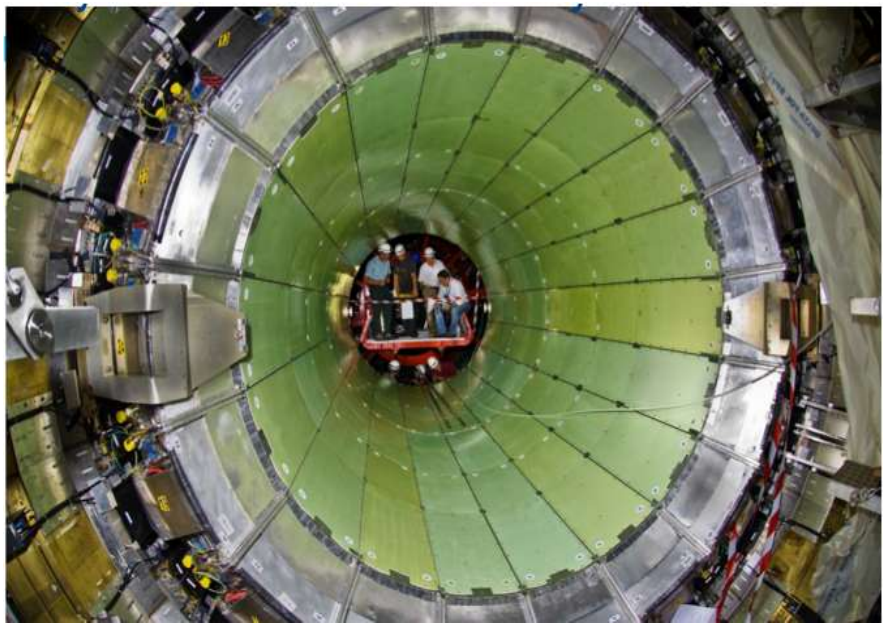
CMS



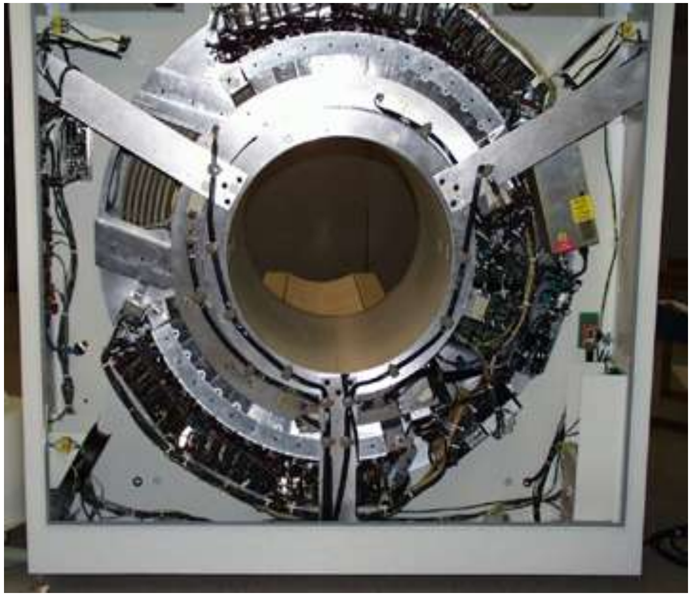
⇒ Application for medical imaging

Similar Challenges in HEP and medical imaging

CMS Electromagnetic calorimeter



Positron Emission Tomograph (PET)



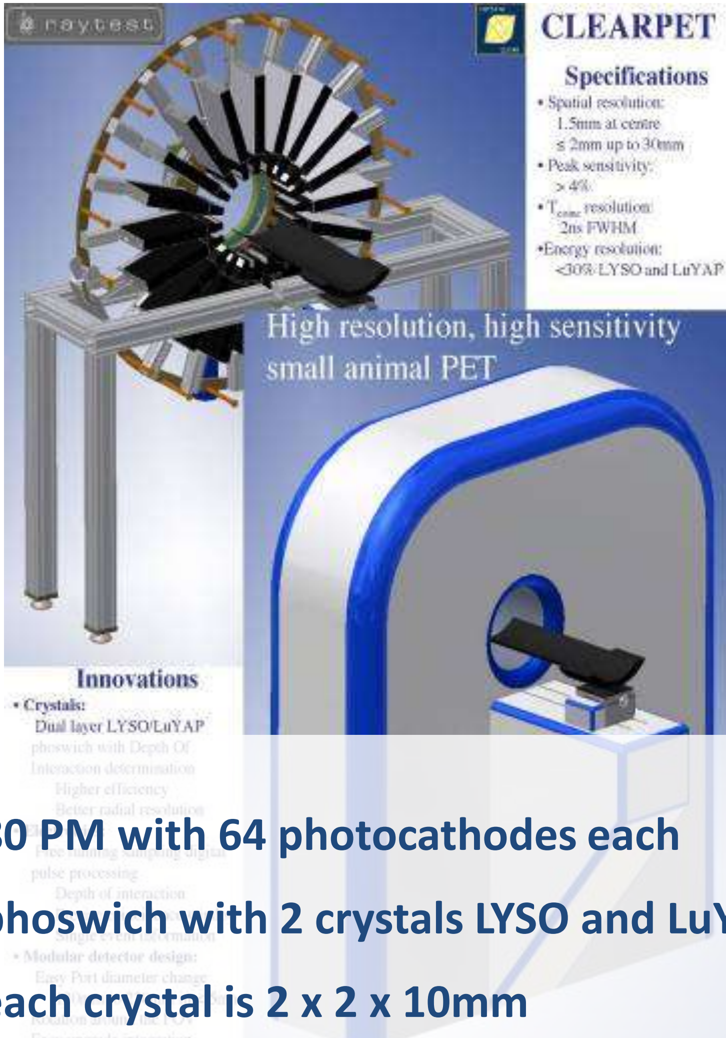
At LHC : Energy of particles < TeV

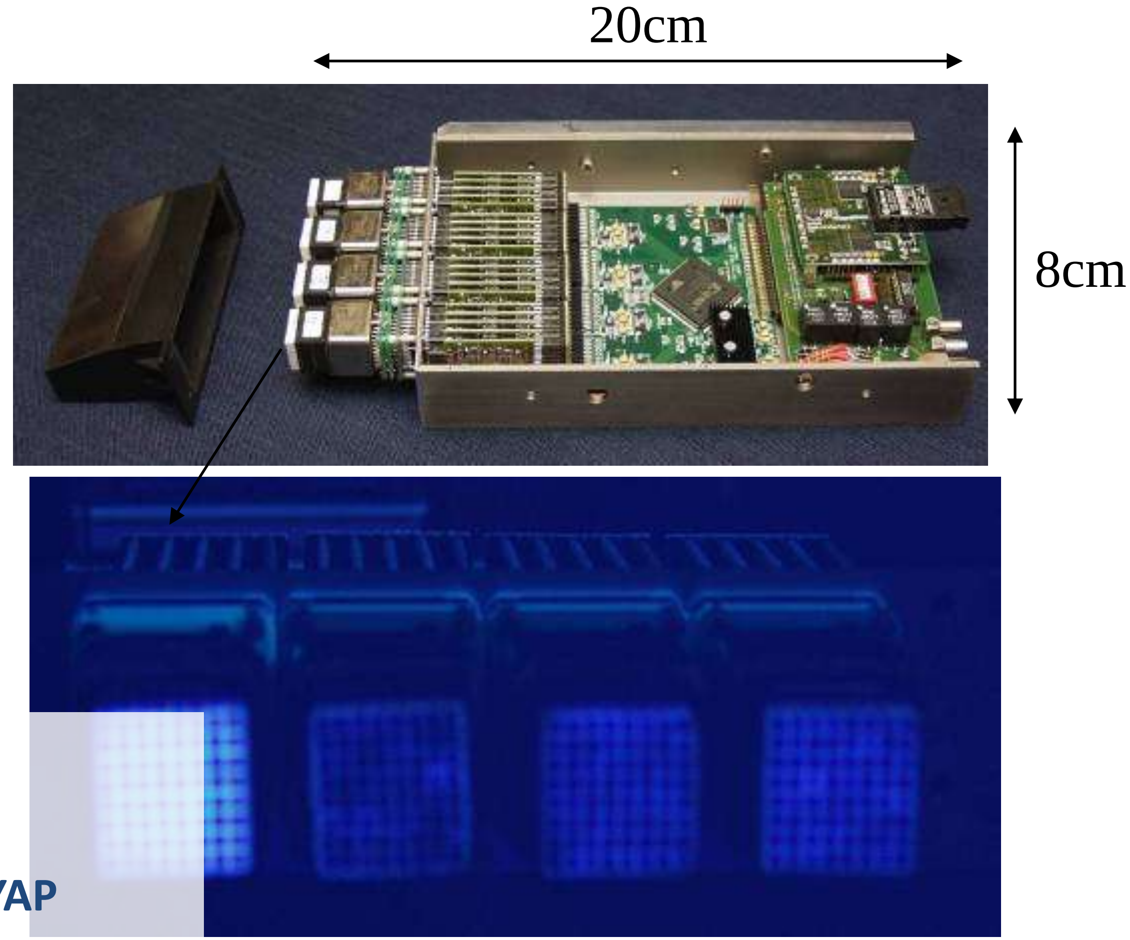
For PET: 0.000000511 TeV (511keV)Photons

Developed PET systems in Crystal Clear Since 1995

- **Since 1995: ClearPET: PET from small animal**
  - 4 Prototypes inside the CCC collaboration
  - Licence to a company Raytest (Germany)
  - Development ongoing in CPPM in Marseille & in Aachen
- **Since 2001: ClearPEM: PET dedicated to breast imaging**
  - 2 Prototypes installed in hospital for clinical tests
    - 1 in Coimbra
    - 1 in Marseille Hopital Nord -> San Gerardo hospital Milano
    - 1 start-up Petsys has been created in Portugal
  - New development on going to improve modules (KT Fund)
- **Since 2010: EndoTOFPET-US: endoscopic PET for pancreas and prostatic cancer**
  - European FP7 projects with 3 Hospitals as partners out of 11partners
- **2009-2013: Brain PET**
- **Since 2013: PhenoPET**
- **PET/MRI Activities in many groups**

Clear PET : small animal PET





80 PM with 64 photocathodes each

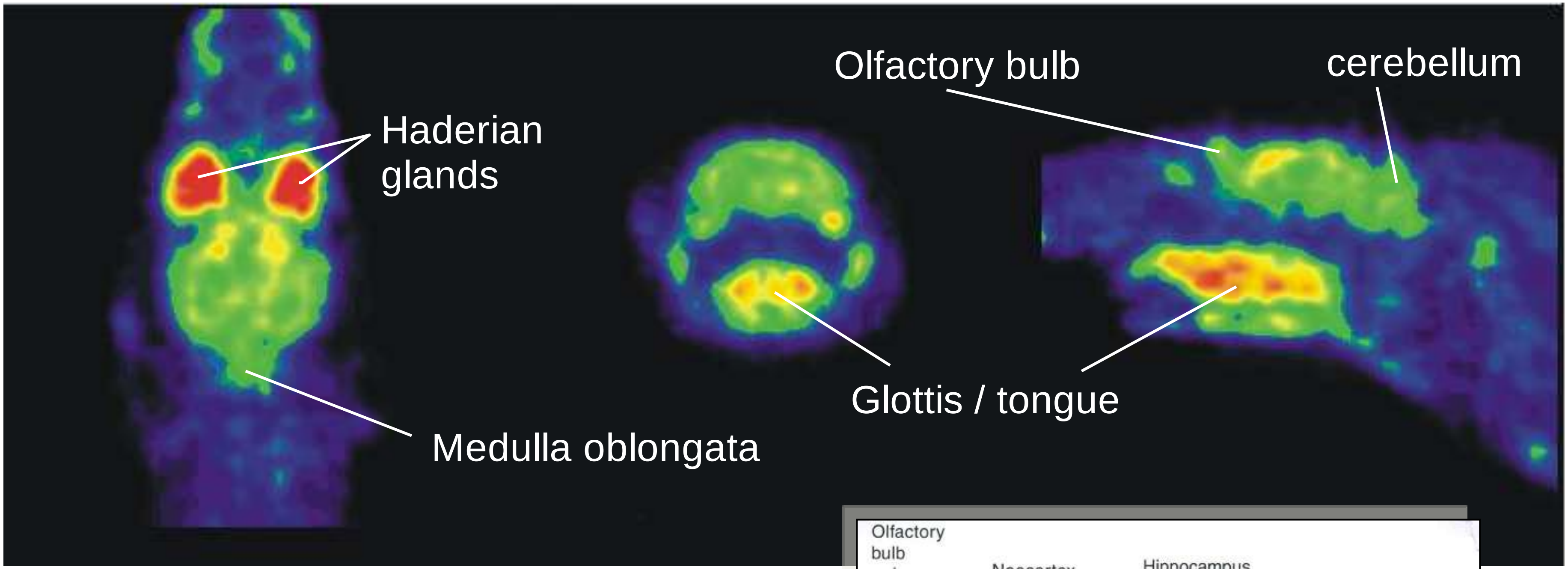
phoswich with 2 crystals LYSO and LuYAP

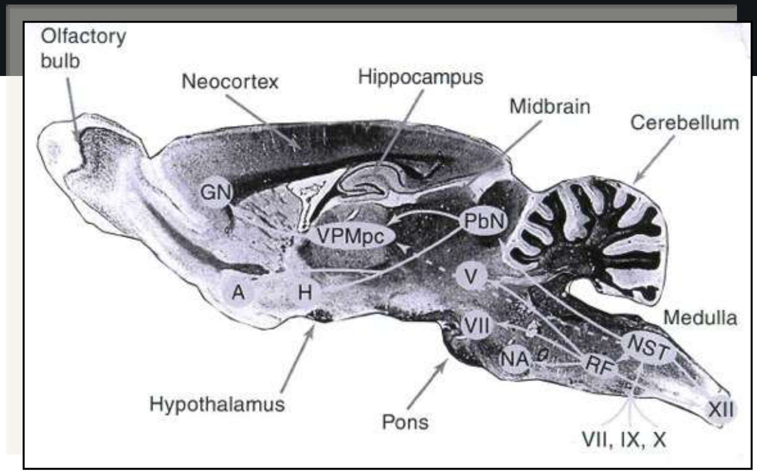
each crystal is 2 x 2 x 10mm

Spatial resolution 1.5 mm at centre

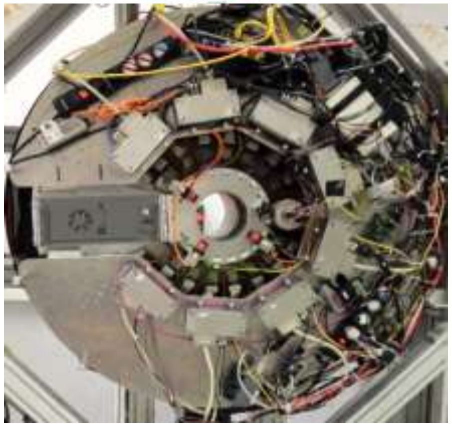
K. Ziemons et al., IEEE NSS/MIC conference record 2003
E. Auffray et al, (NIMA) (2004) 171
K. Ziemons et al, NIMA 537 (2005) 307

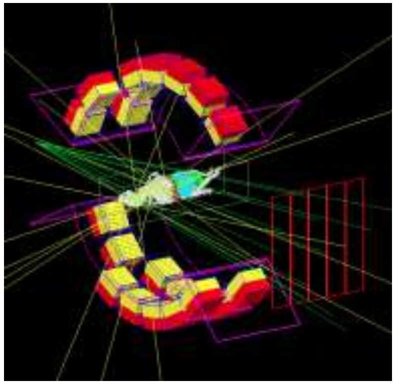
Rat Image with ClearPET Neuro

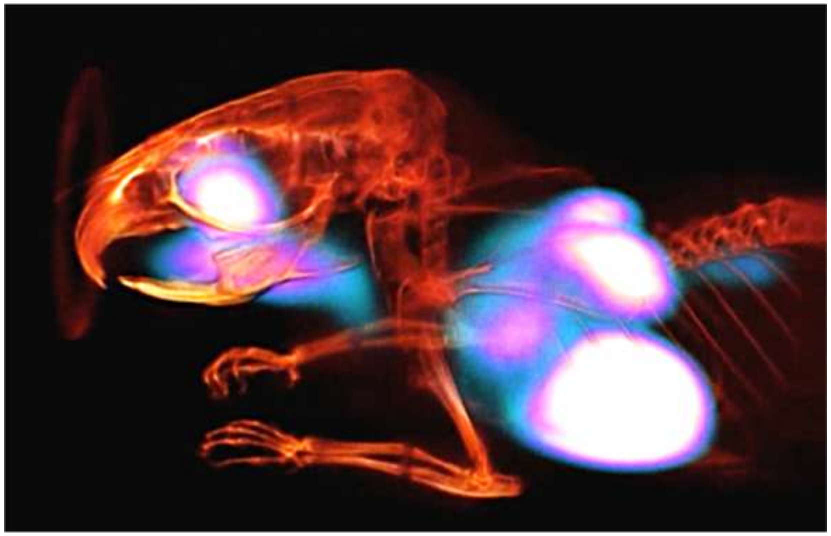




ClearPET/Xpad: A Simultaneous PET/CT developped in Marseilles



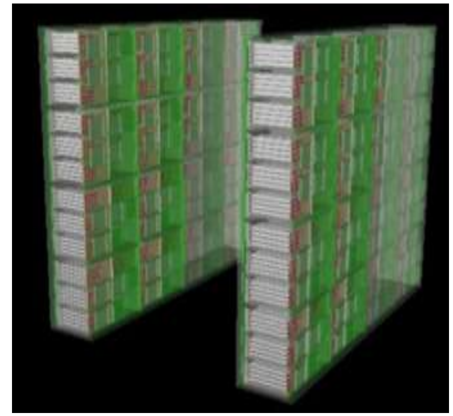




First simultaneous PET/CT scans of mice have been presented by M. Hamonet et al. at the 2015 IEEE NSS/MIC conference

ClearPEM & ClearpEM sonic

www.cern.ch/cerimed/



1 Plate 17,3x15,5x3cm =
16 SuperModules =
3072 crystals

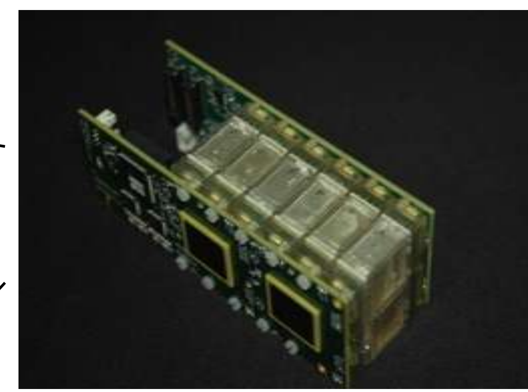
Technology :

- 2 plates
- 6144 LYSO:Ce crystals in 192 matrices
- Readout in both end with APD arrays
- Dedicated ASICs for fast readout

ClearPEM was the first PET using APDs !

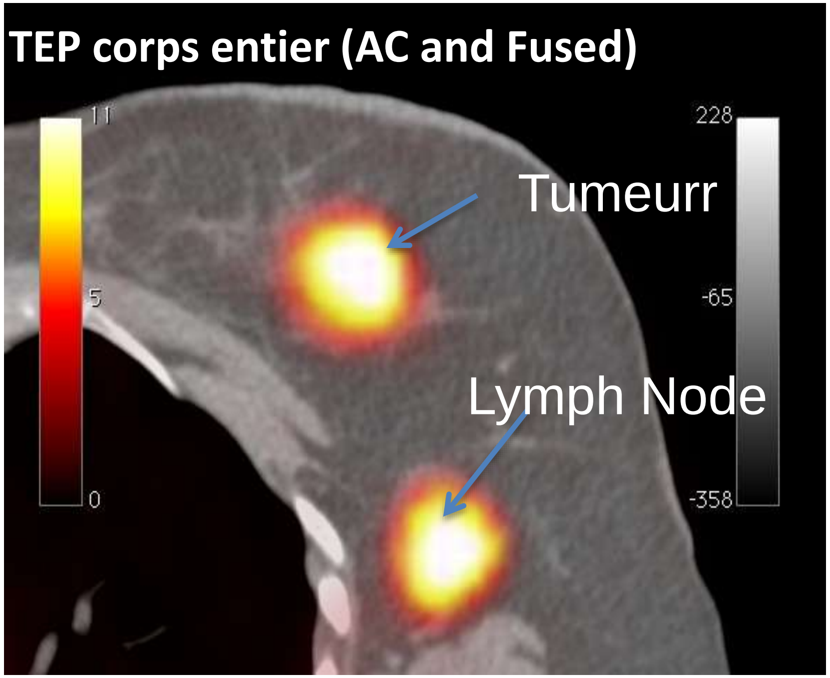
LYSO/BaSO$_4$ Matrice

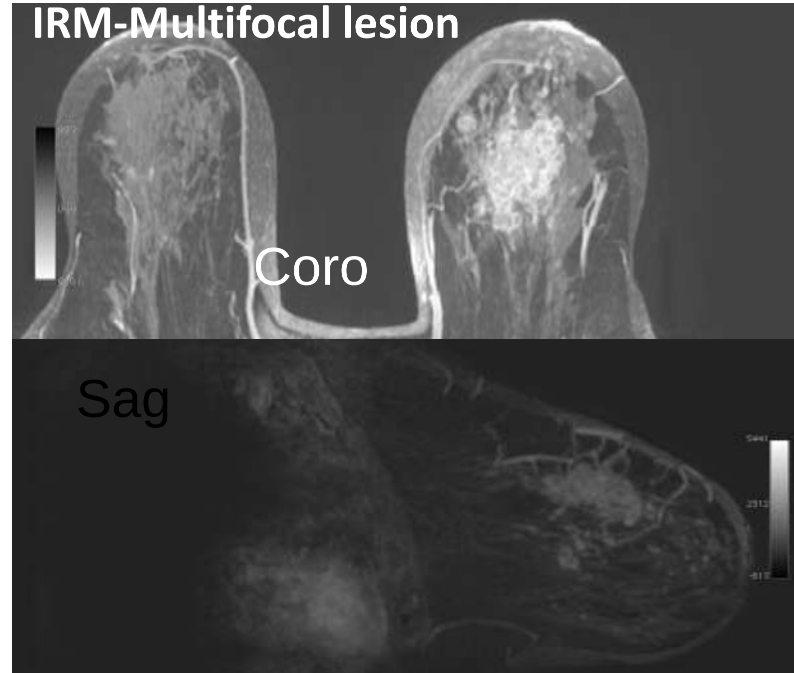
APD array

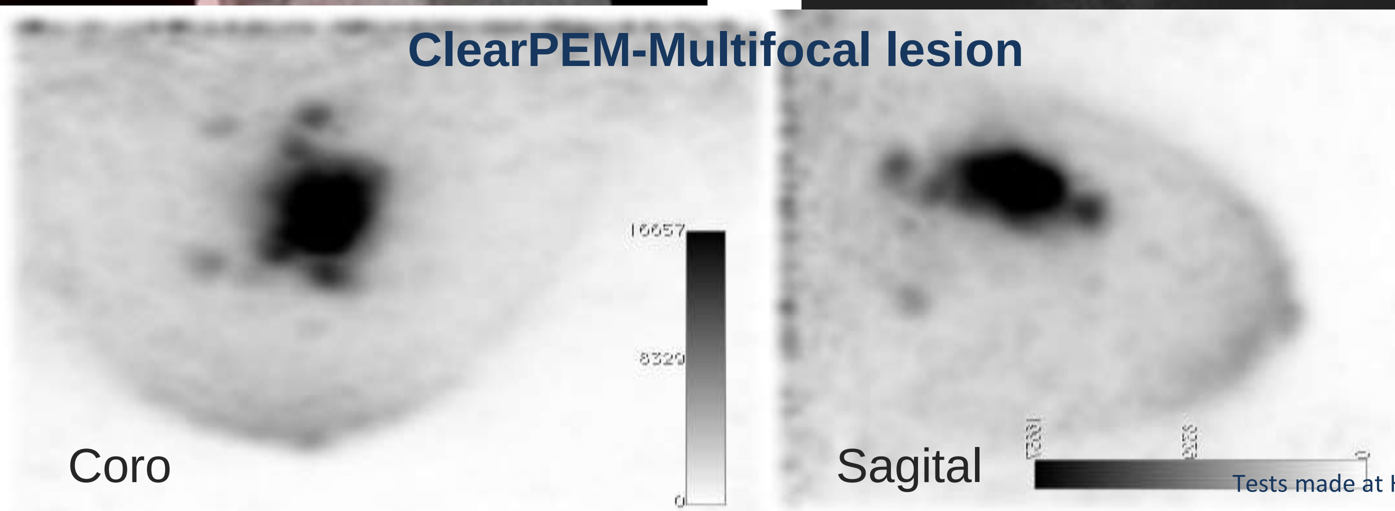


P. Lecoq, J. Varela. NIM. A 486 (2002) 1–6.
J Varela *et al.* NIMA. *A* **571** (2007) 81.
B. Frisch, CERN courrier Article, July.August2013

First images with ClearPEM



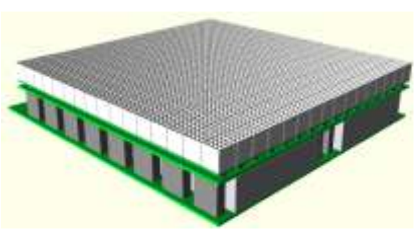


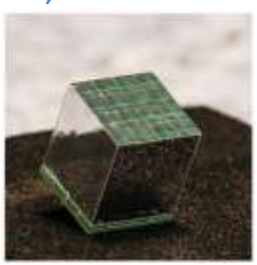


Tests made at Hospital Nord, Marseilles

EndoTOFPET-US project

4096 LYSO crystals 3.1x3,1X15mm^3





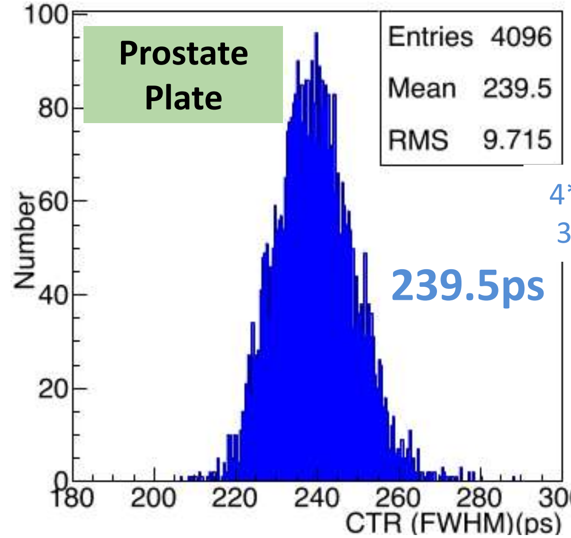
ENDO TOFPET US

Endoscopic TOFPET & Ultrasound

THE PICOSEC MC-NET PROJECT

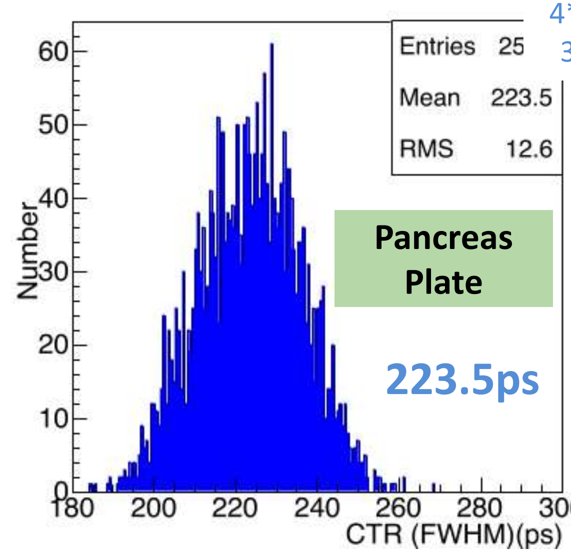
SEVENTH FRAMEWORK PROGRAMME

CTR

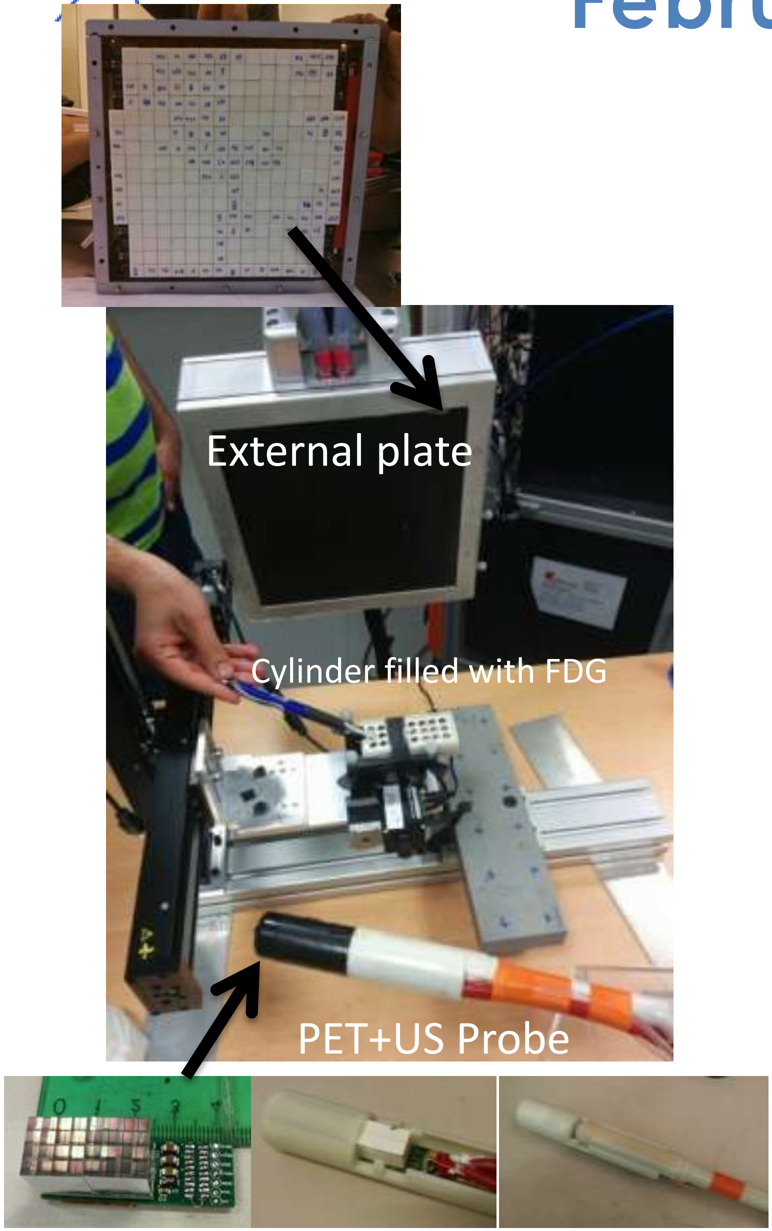


4*4 LYSO crystals 3.5*3.5*15mm^3

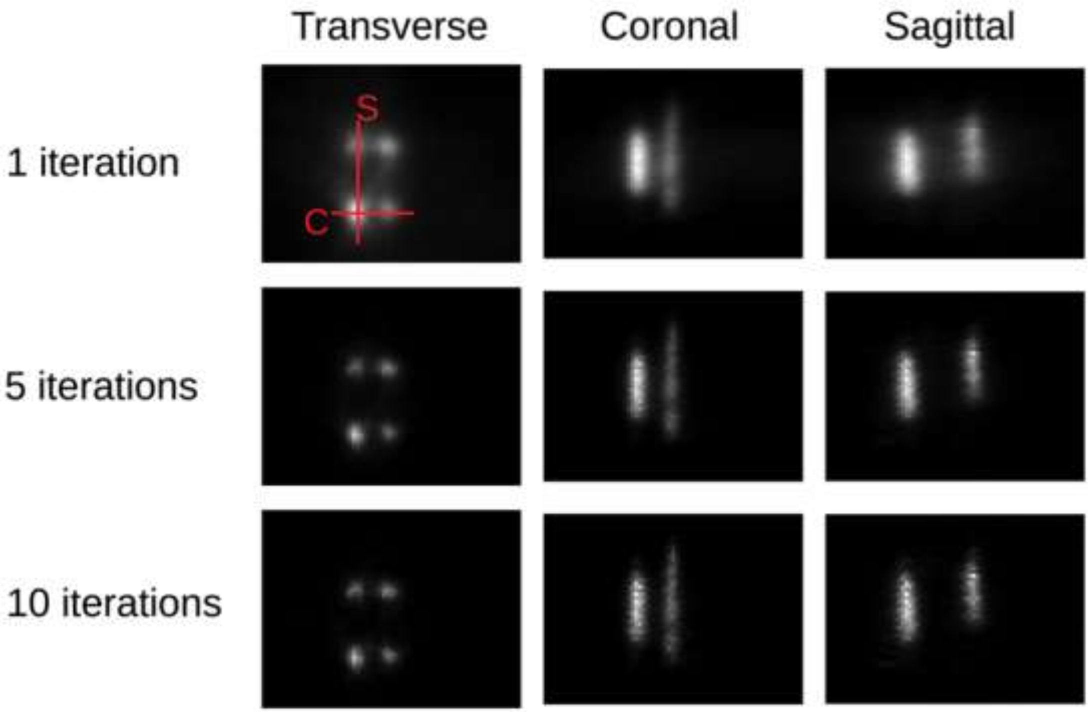
4*4 LYSO crystals 3.1*31*15mm^3



1st tests in CERIMED Marseille February- April2015

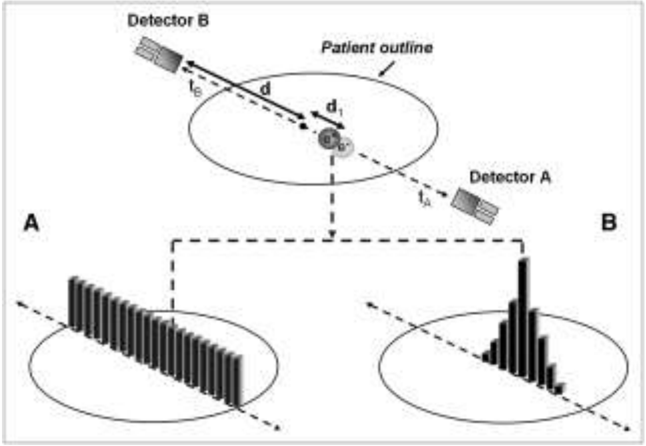


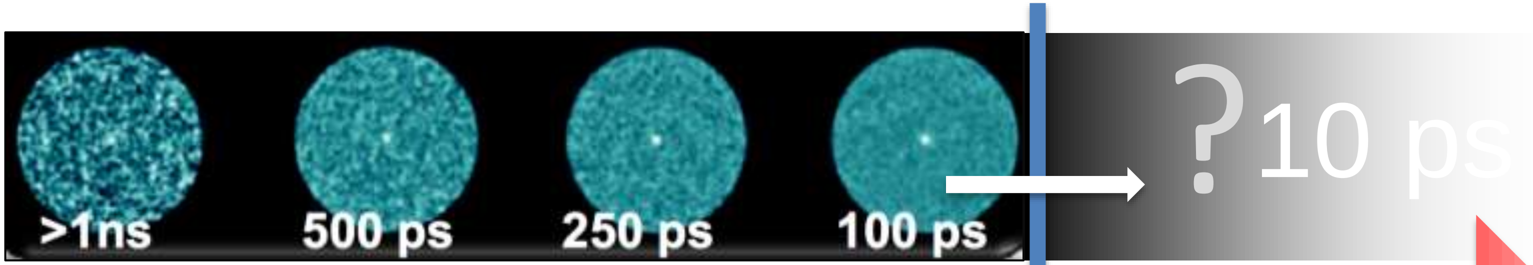
Preliminary images



The Merits of Time of Flight in PET (TOF-PET):

- In vivo: More precise, less invasive, more compact systems
- In vitro: Faster analysis of disease biomarkers
- Ultimatelly: Pave the way into precision medicine





Commercial systems

Effective event collimation
→ Background rejection
→ cm resolution along LOR (EndoTOFPET-US)

Five-fold S/N improvem.
→ Sensitivity gain of 25
→ Dose reduction

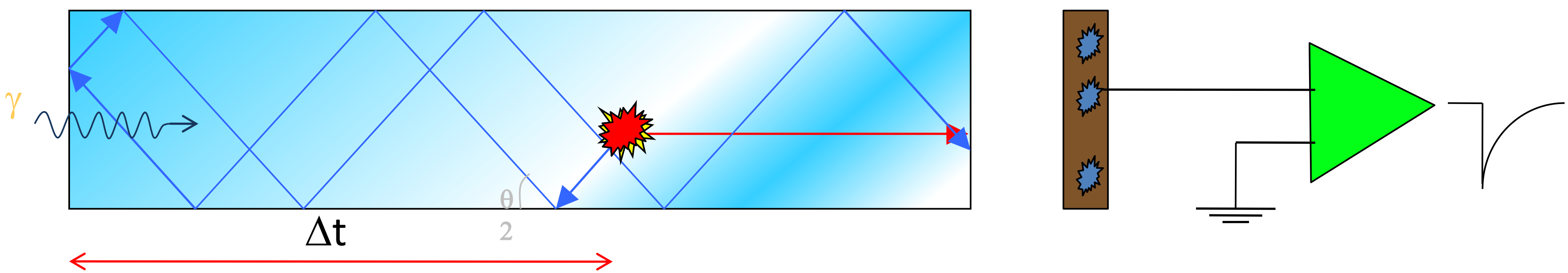
Direct 3D image reconstruction with:
→ mm resolution along LOR, and
→ Allow limited field of view

Commercial TOFPET today
550ps (250ps)

Lab today
100-200ps

Need to understand the photodetection Chain

Crystal **Photodetector** **Electronics**



$t_{kth\ pe} = \Delta t + t_{k'\ ph} + t_{transit} + t_{SPTR} + t_{TDC}$

- Δt: Conversion depth
- $t_{k'\ ph}$: Scintillation process
- $t_{transit}$: Transit time jitter
- t_{SPTR}: Single photon time spread
- t_{TDC}: TDC conversion time

Scintillator R & D
- Particule Interaction
- Light generation
- Light transport
- Light transfer
- Light collection

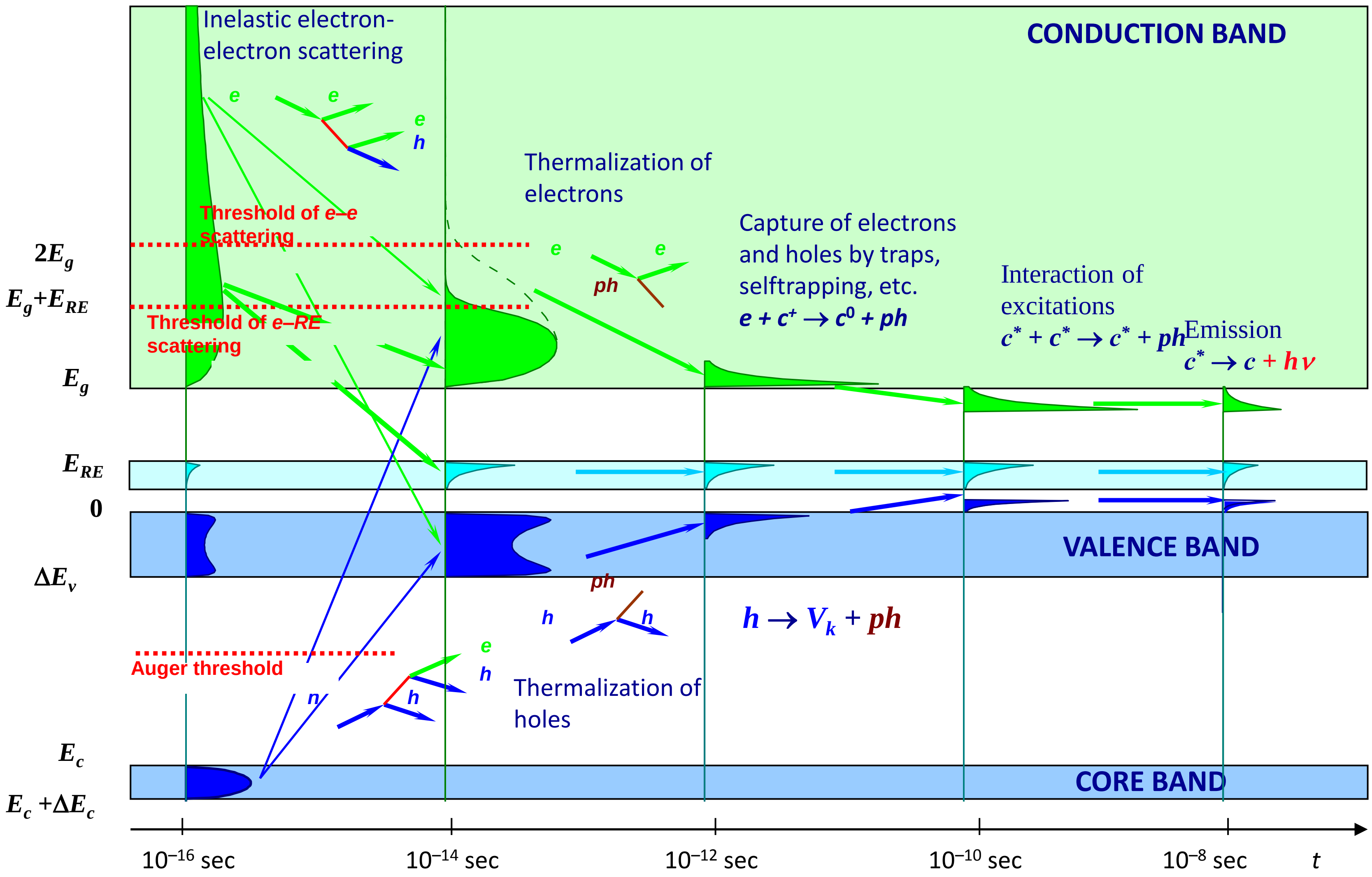
Photodetector R & D
- Reduce SPTR and DCR
- Increase fill factor (PDE)
- Digital SiPM
- MCP for PET & HEP

Electronics R & D
- TDC < 10ps bins
- Monolithic architecture
- High bandwidth
- Low noise
- Massive parallel data
- High number of channels

⇒ **Challenge: Understanding key factors of timing resolution**
Proposing routes toward 10ps
FAST Action TD1401

Understanding of the scintillation process chain

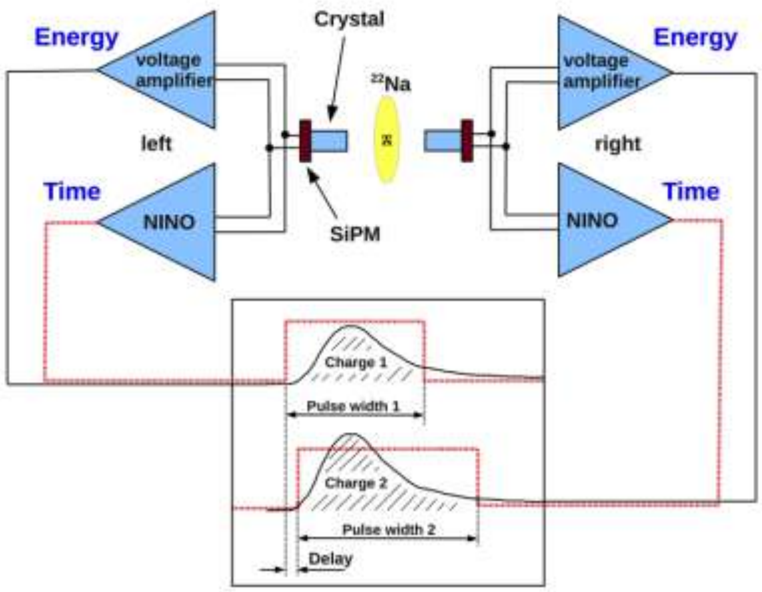
Case of Ce^{3+} doping

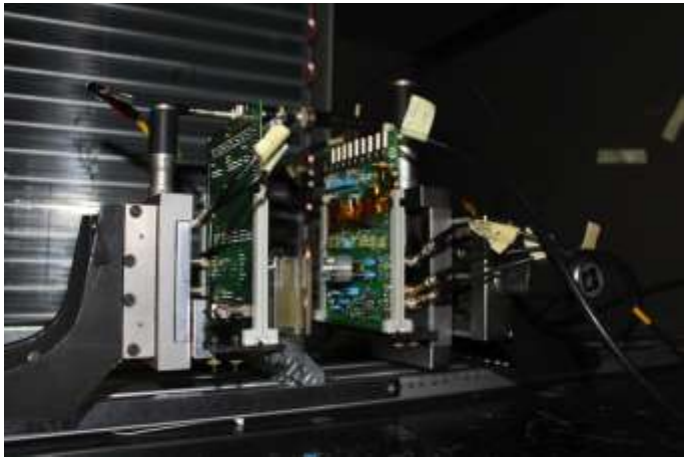


A. Vasiliev, Proceedings of The SCINT99 conference, Moscow, Faculty of Physics, Moscow State University, 2000, p. 43-52

Time coincidence resolution measurements

set-up at CERN



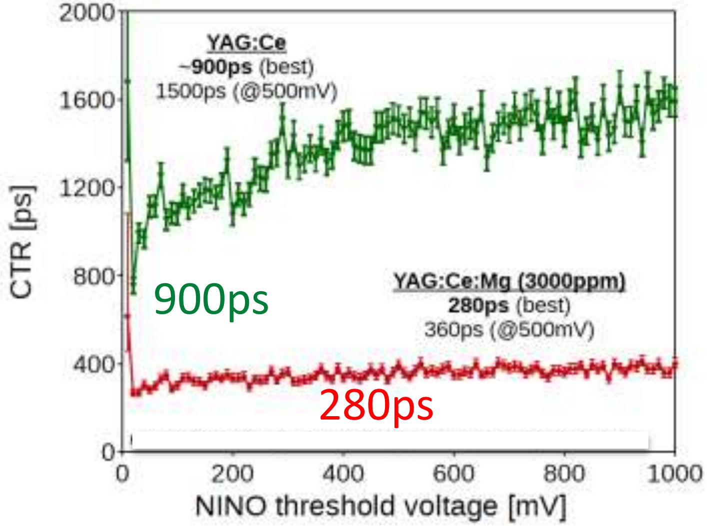


Data acquisition:
LeCroy Oscilloscope DDA 735Zi with 3.5GHz Bandwith and 40Gs/s

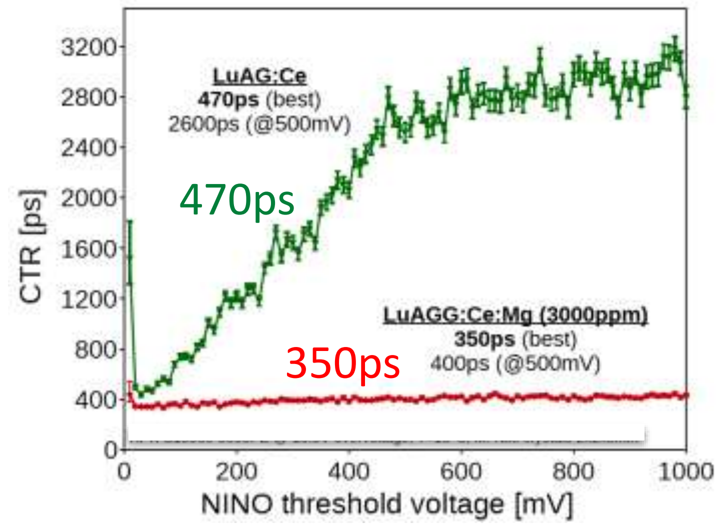
S. Gundacker, PhD thesis
S. Gundacker et al, JINST 8 P07014 2013

CTR results with 511 keV

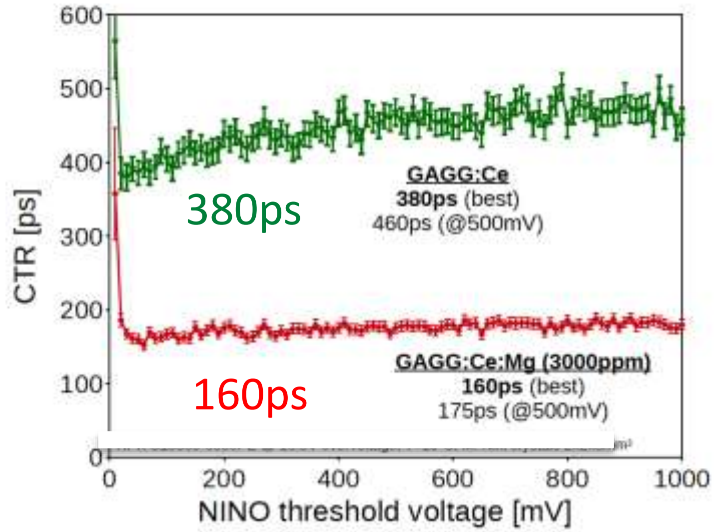
YAG



LuAG



GAGG



Very good CTR with GAGG

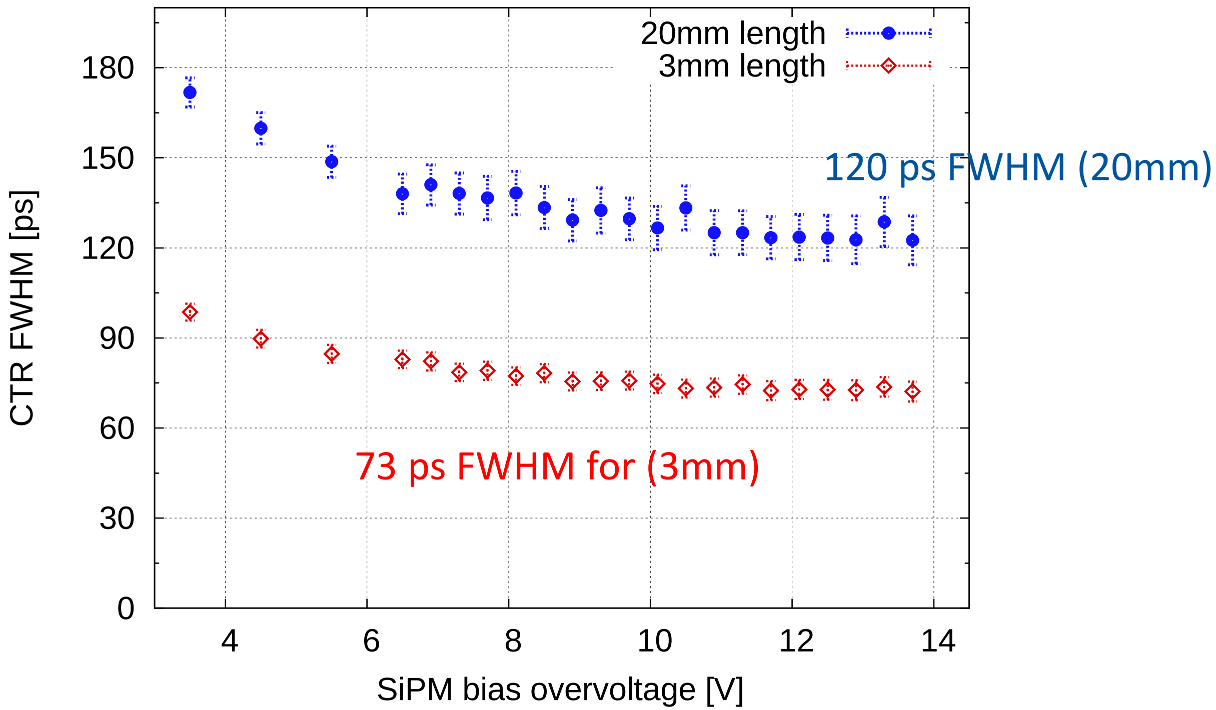
Measured with SiPM HPK S13360-3050PE, T15°C

S. Gundacker et al., to be published in NIMA

Current state of the art time resolution with bulk crystals

LSO:Ce:Ca crystal - FBK NUV-HD SiPMs

CTR results @511keV:

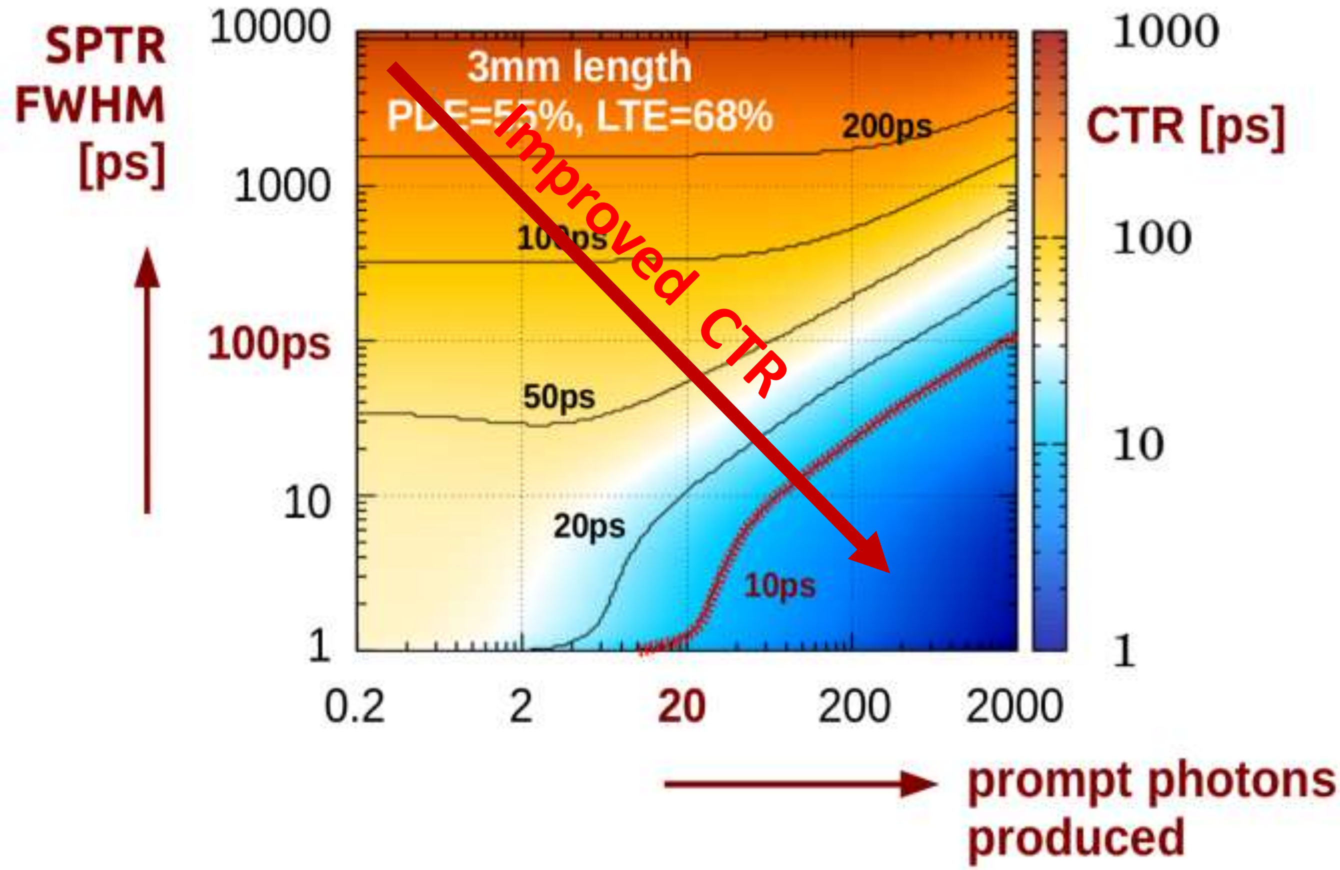


S. Gundacker et al, JINST 11P08008

Light transport, light collection improvement

- R&D on innovative ways to transport the light
- R&D on increase light collection
  - surface treatment,
  - photonic crystals,
  - light guide

Better time resolution with prompt photons



S. Gundacker, CERN-THESIS-2014-034
S. Gundacker et al, Phys. Med. Biol. 61 (2016) 2802-2837
S. Gundacker et al., JINST 11P08008

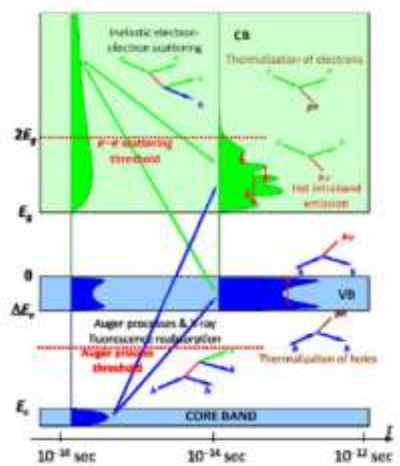
Study of fast emission process

- **Study and development of emission types:**
  - Excitonic emission (STE, excitations of anion complexes)
  - Emission of activators (Ce, Pr, …) Codoping:
  - **Cherenkov radiation**
  - **Crossluminescence**
  - **Hot intraband luminescence (HIL)**
  - **Quantum confinement driven luminescence:**

Slow → Ultra fast

Hot Intraband

HIB mechanisms

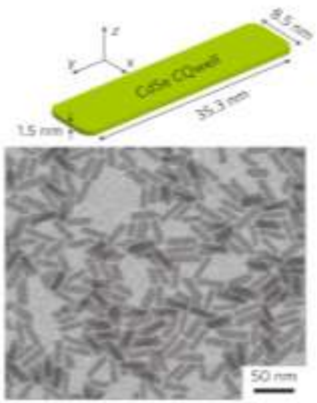


A. Vasiliev

Nanomaterials

Procházková et al., Radiat Meas 90, 2016, 59-63

J.Grim, ITT, Italy



FAST ASCIMAT TICAL

Conclusion

Since **27** years Crystal Clear has been very active in the development of scintillators for many applications in particular:

- In the understanding of scintillation mechanisms and radiation hardness
- The development of new materials

CCC has a worldwide recognition of collaboration activities,

The recent developments initiated in Crystal Clear:

- New production technology
- Engineering of the materials
- Fast timing

Open new promising perspectives for the future detectors in HEP, medical applications and others

Acknowledgment

Many thanks to my CERN Crystal Clear team at CERN EP.-CMX group and my colleagues from Crystal Clear Collaboration

This work is supported by : European Union's Horizon 2020 research and innovation programme under ERC TICAL (grant agreement 338953), the Marie Skłodowska-Curie Intelum project (grant agreement 644260), TWIN project ASCIMAT (Grant agreement no. 690599),
COST Action TD1401 (FAST),

Acknowledgement

I thank all CCC colleagues

15th Int. Conference on Scintillating Materials and their Applications (SCINT2019)

will be held at

Resilience, Harmony and Inspiration

SENDAI

School: Sept. 26 (Thu) to 28(Sat)
(μ-PD growth trial lessen will be planed at school.)
Conference :
Sept. 29 (Sun.) - October 4 (Fri.)

Today CCC partners: 31 Institutes (1)

Austria

- Stefan Meyer Institute Austrian Academy of Sciences (Contact: J. Marton)

Armenia

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