



Dose reduction in PET scans

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and the COST Action TD1401*

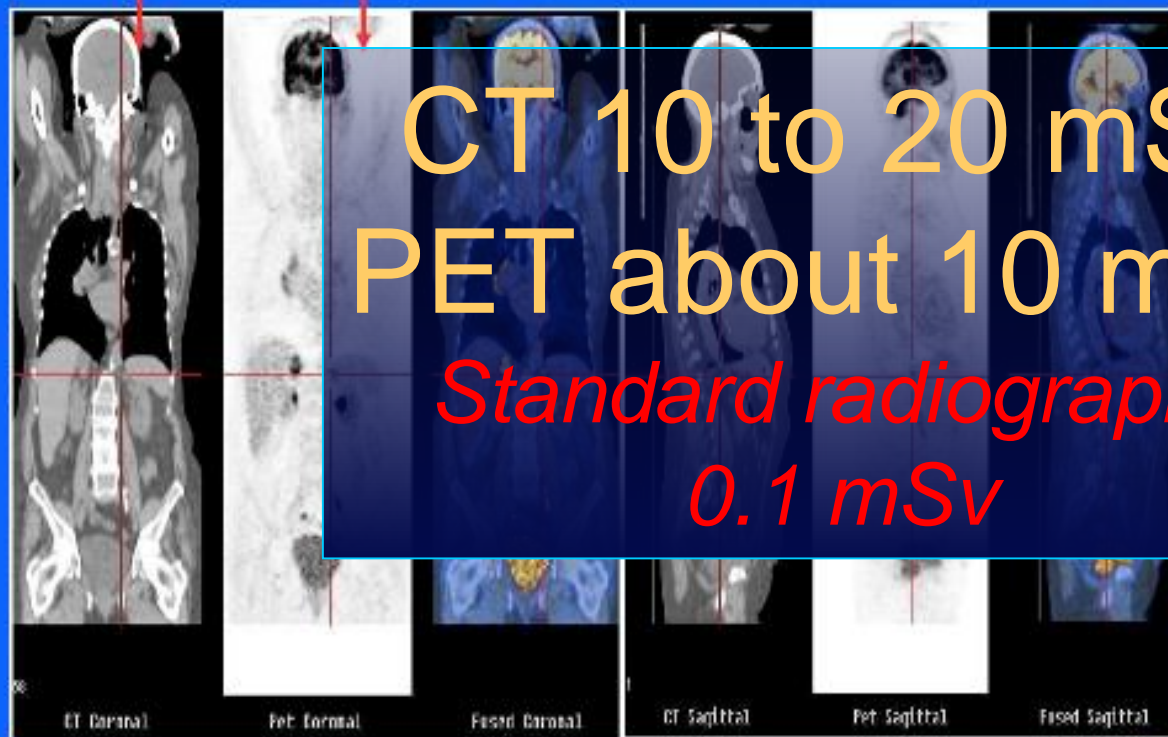


PET/CT Combine anatomic and functional/MI information

Invention of the PET/CT

morphology

metabolism



CT 10 to 20 mSv
 PET about 10 mSv
Standard radiography
0.1 mSv



David Townsend

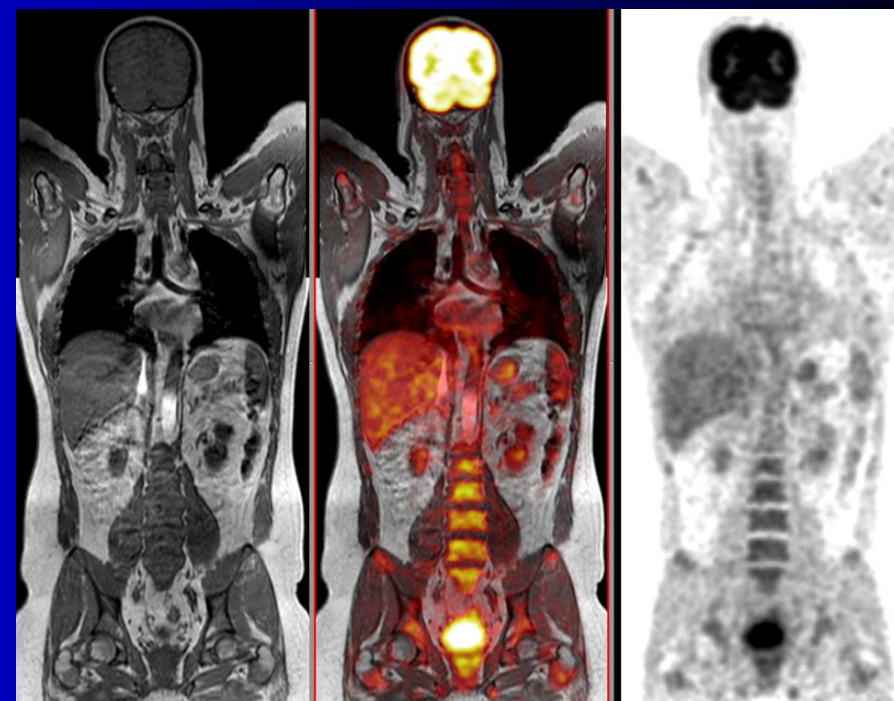
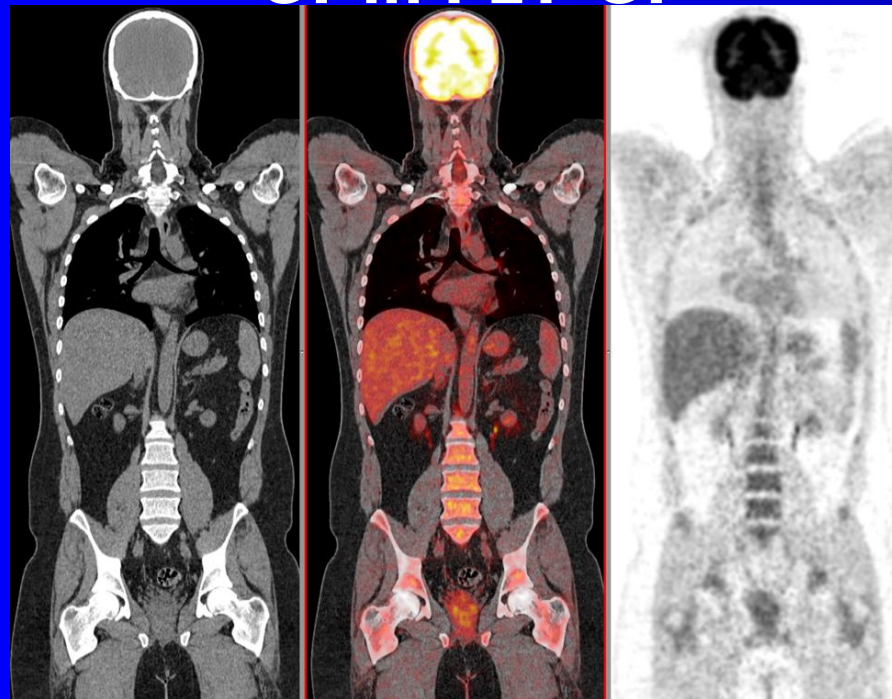
CERN: 1970-78
 Geneva University

UPM Pittsburgh
 and

Ronald Nutt
 (CTS - CTI)

CT in PET-CT

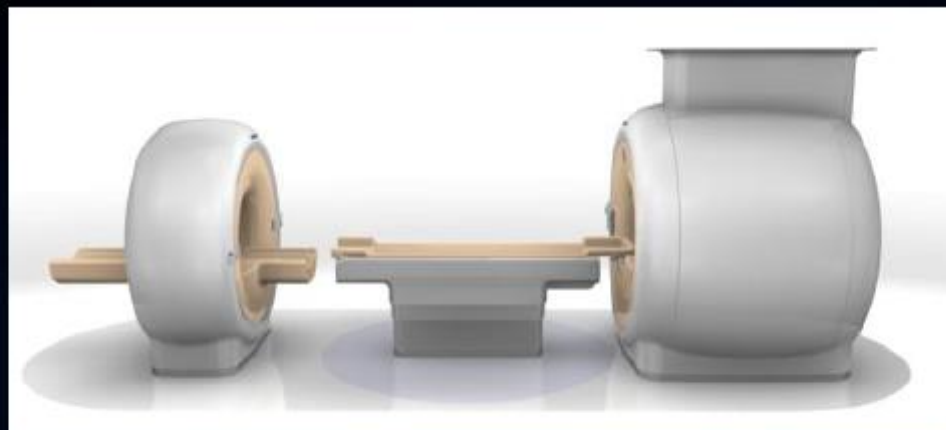
MR in PET-MR



- Anatomic
- Low soft tissue contrast
- Fast
- Attenuation correction
- 10 to 20mSv

- Anatomic + some functionality
- High soft tissue contrast
- Slow (depending on MR sequences)
- No attenuation correction
- **NO DOSE**

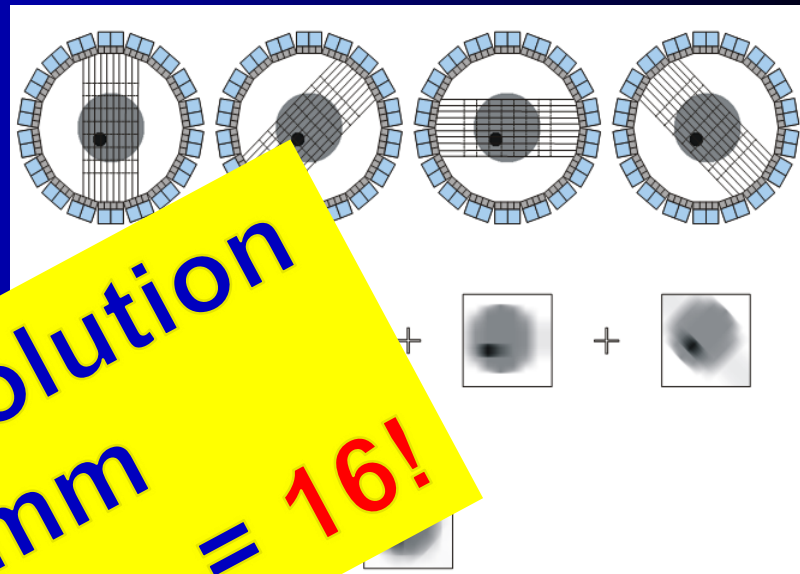
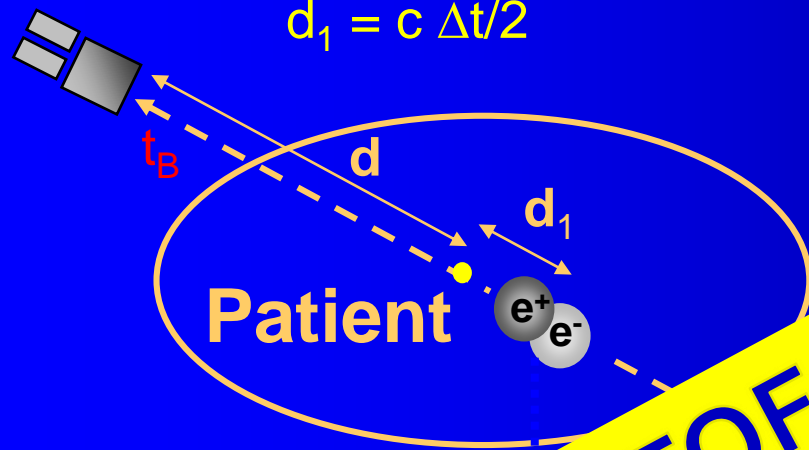
Commercial PET/MR scanners



Photographs courtesy
Siemens, Philips and Mediso

Time of Flight PET

Detector B $\Delta t = t_A - t_B = [(d+d_1) - (d-d_1)]/c$
 $d_1 = c \Delta t/2$



10ps TOF resolution
 $\delta x = 1.5\text{mm}$
 $\text{SNR}_{\text{TOF}}/\text{SNR}_{\text{conv}} = 16!$

$$\text{SNR}_{\text{TOF}} = \sqrt{(2D/cDt)} \cdot \text{SNR}_{\text{conv}}$$

δt (ps)	δx (cm)	SNR*
10	0.15	16
100	1.5	5.2
300	4.5	3.0
500	7.5	2.3

* SNR gain for 40 cm phantom

The 10ps challenge

1992: FAI raised a challenge for the first balloon circumnavigation

March 1999: Breitling Orbiter III circumnavigate the globe in 19 days 1 hour 49 minutes and won the Budweiser Cup

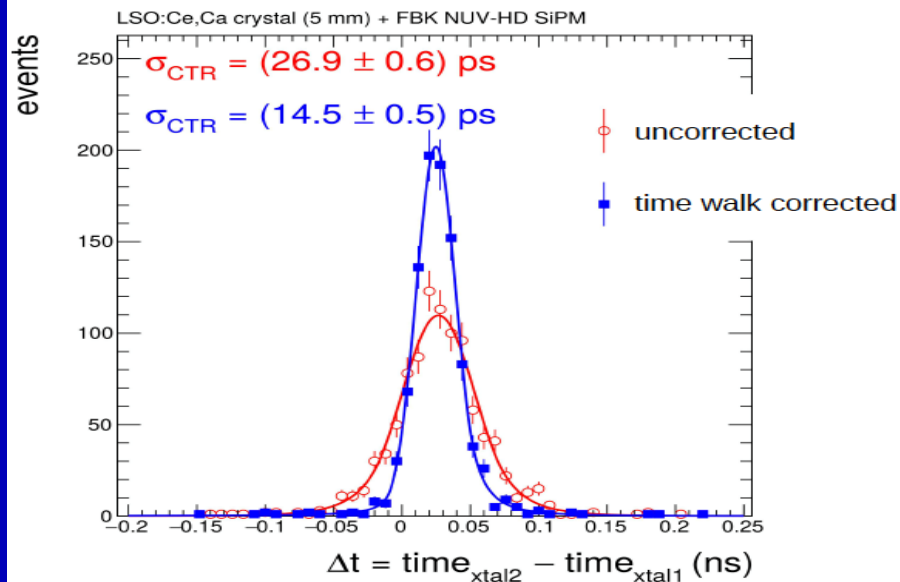
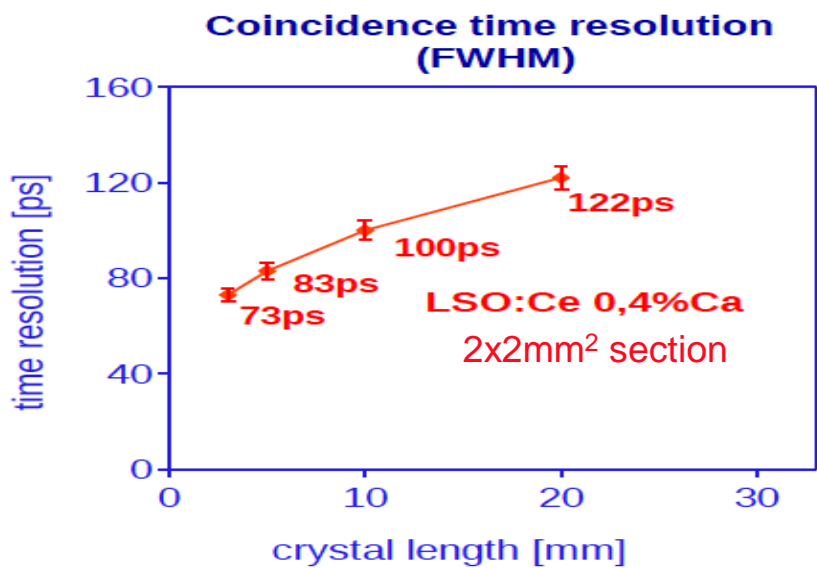
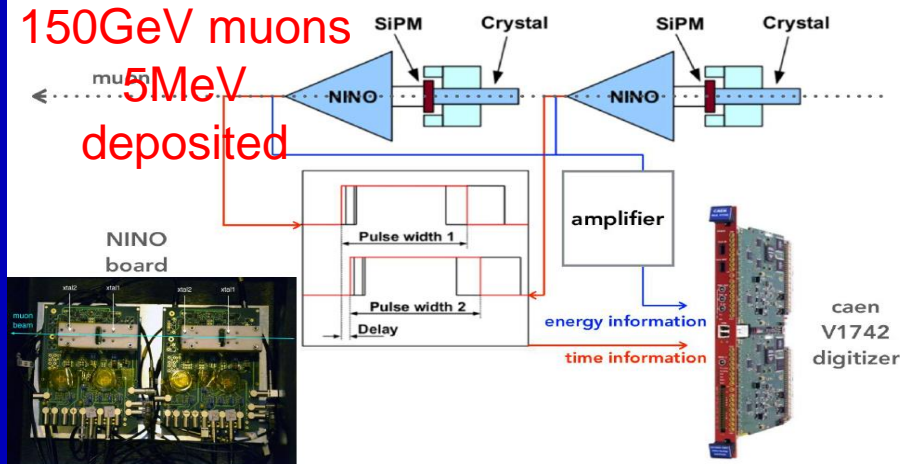
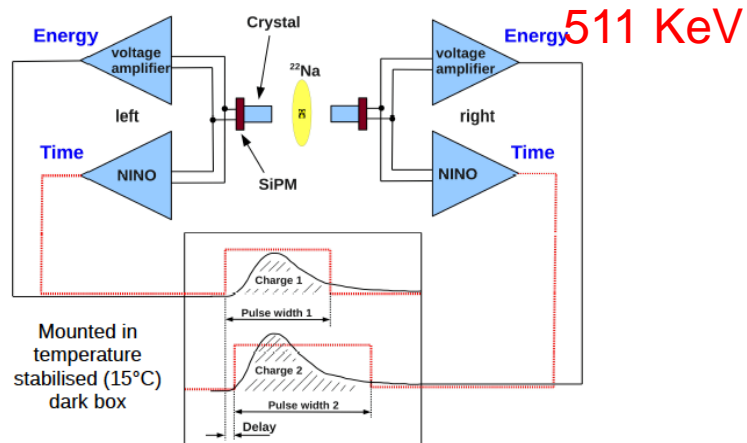
July 2016: Solar Impulse closed the loop of the Round-the-World without fuel attempt



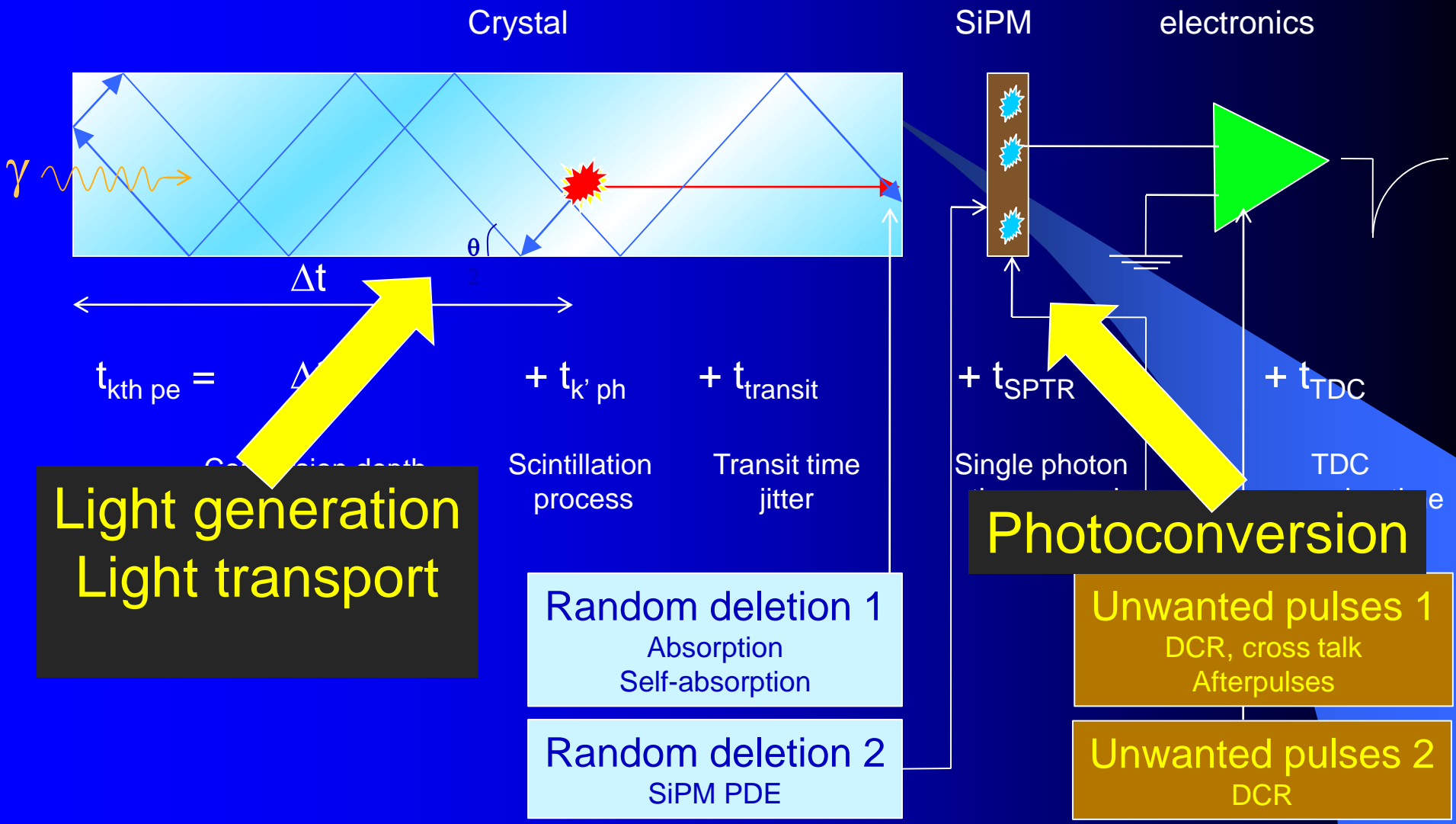
This is a clear-cut case to shed light on TOF-PET with $CTR < 10 \text{ ps FWHM}$ and raise a challenge on $\leq 1 \text{ mSv PET exposure} = 1 \text{ flight Paris-SF positron tomography}$

Courtesy of C. Morel, CPPM

LSO:Ce, 0.4%Ca, melmount coupled to 3x3mm² NUV SiPM from FBK, 55%PDE



The detection chain



Light generation
Light transport

Photoconversion

Unwanted pulses 1
DCR, cross talk
Afterpulses

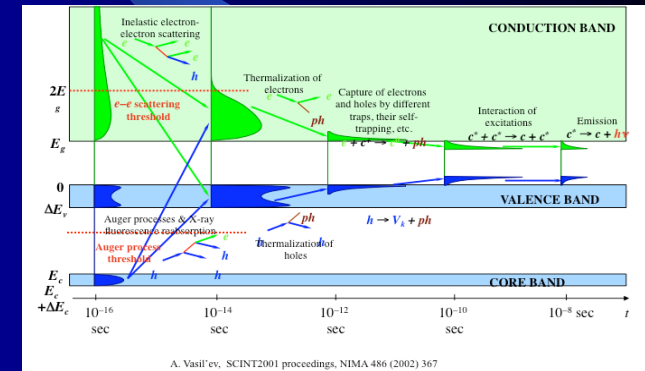
Unwanted pulses 2
DCR

P. Lecoq et al, IEEE Trans. Nucl. Sci. 57 (2010) 2411-2416

Besides all factors related to photodetection and readout electronics the scintillator contributes to the time resolution through:

1. The light production mechanism

- Light yield,
- Rise time,
- Decay time

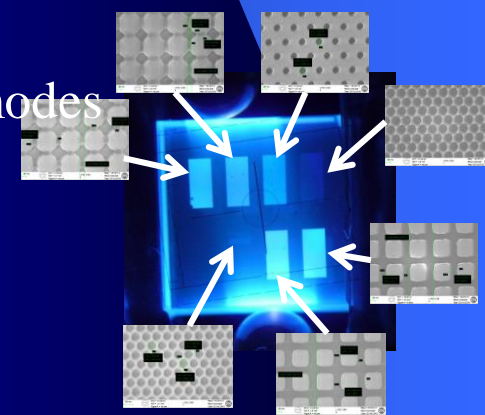


2. The light transport in the crystal

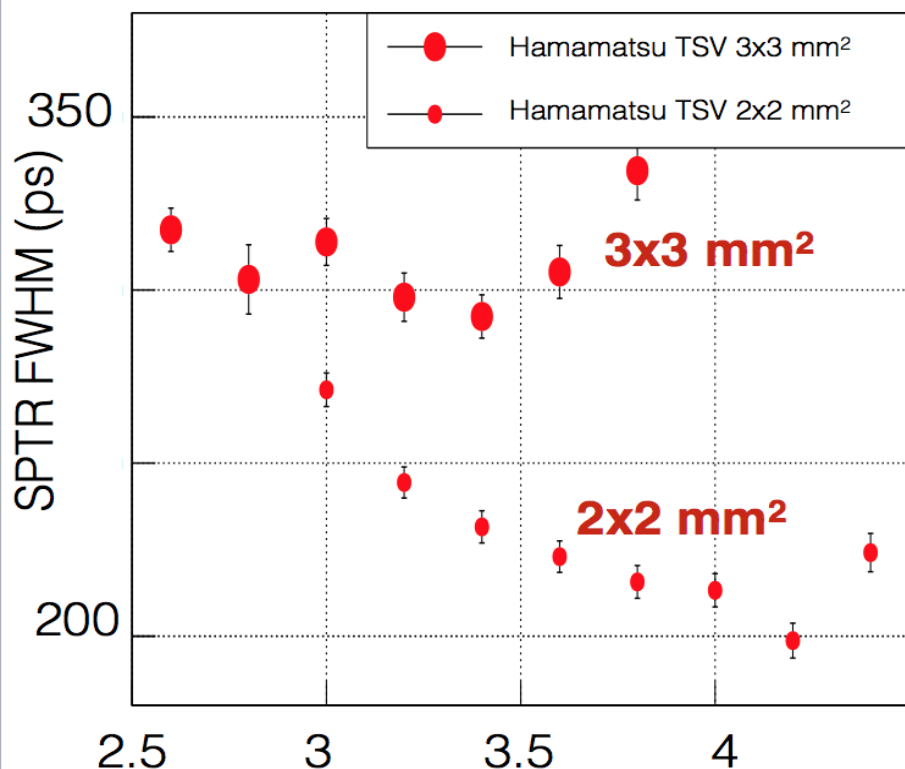
- Time spread related to different light propagation modes

3. The light extraction efficiency (LY → LO)

- Impact on photostatistics
- Weights the distribution of light propagation modes

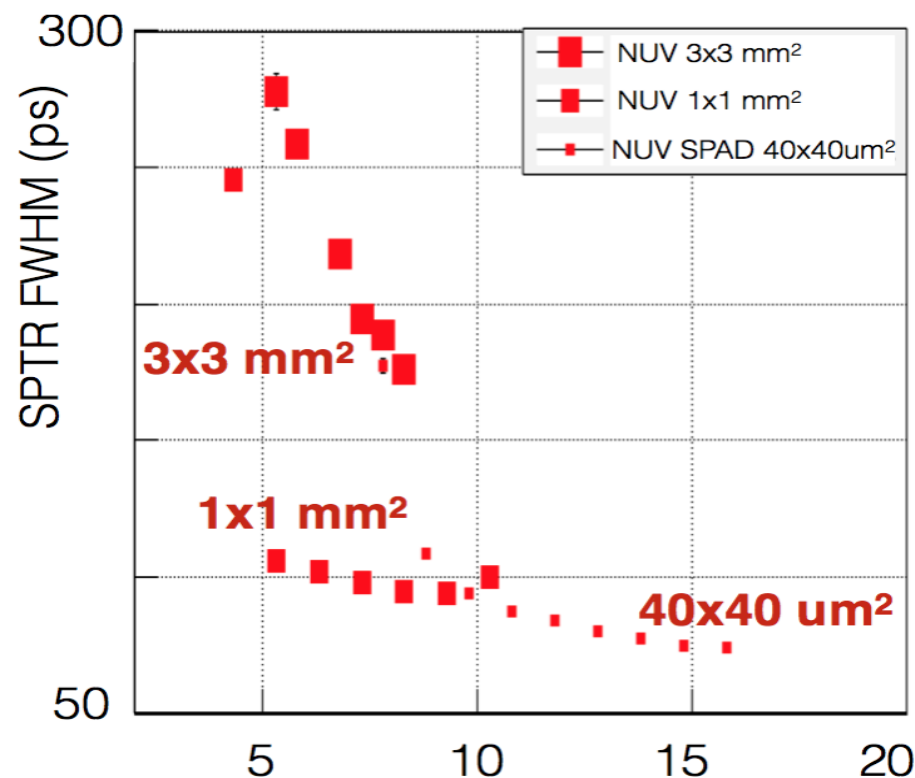


Hamamatsu TSV



SiPM bias overvoltage (V)

FBK NUV



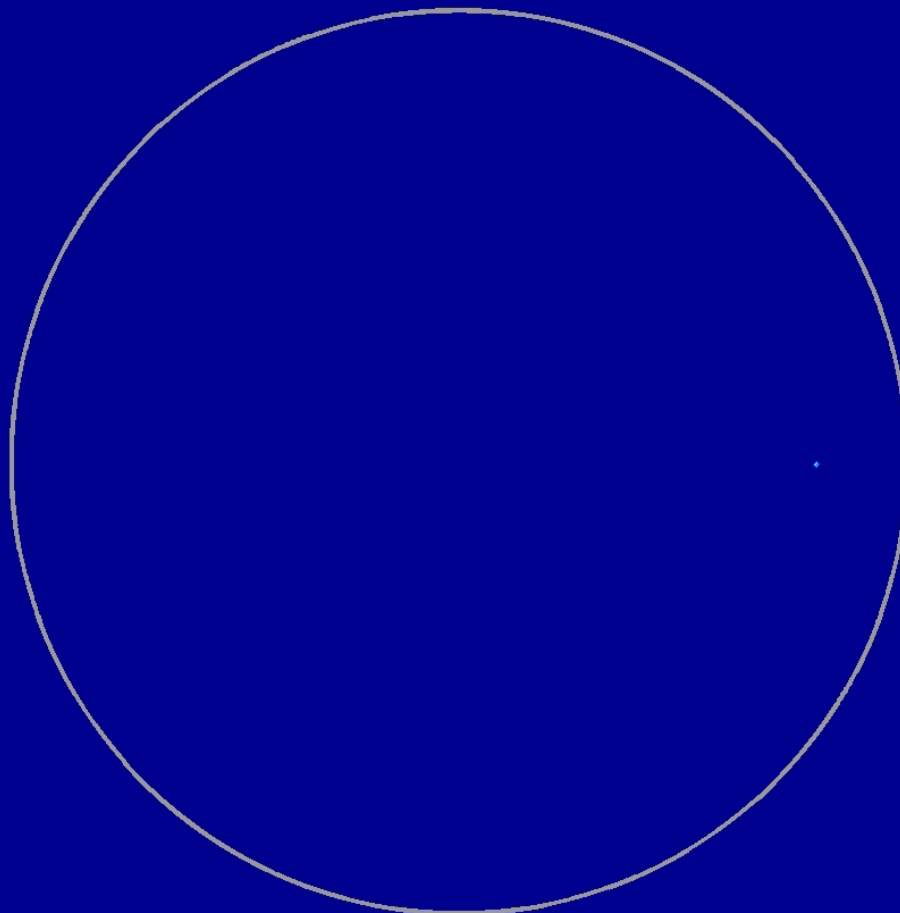
SiPM bias overvoltage (V)



Avalanche development in a 50 μm diameter SPAD



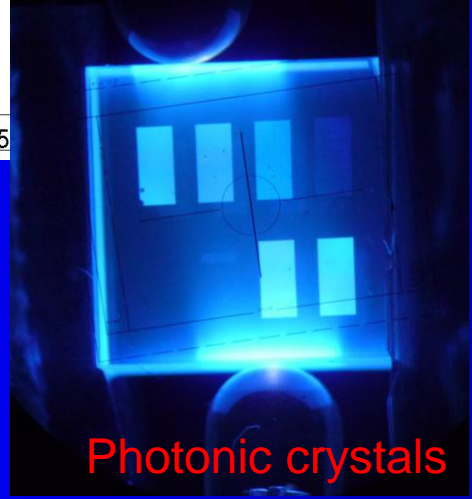
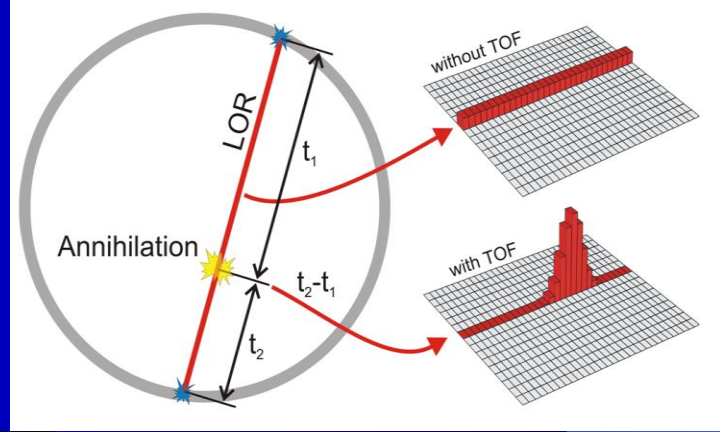
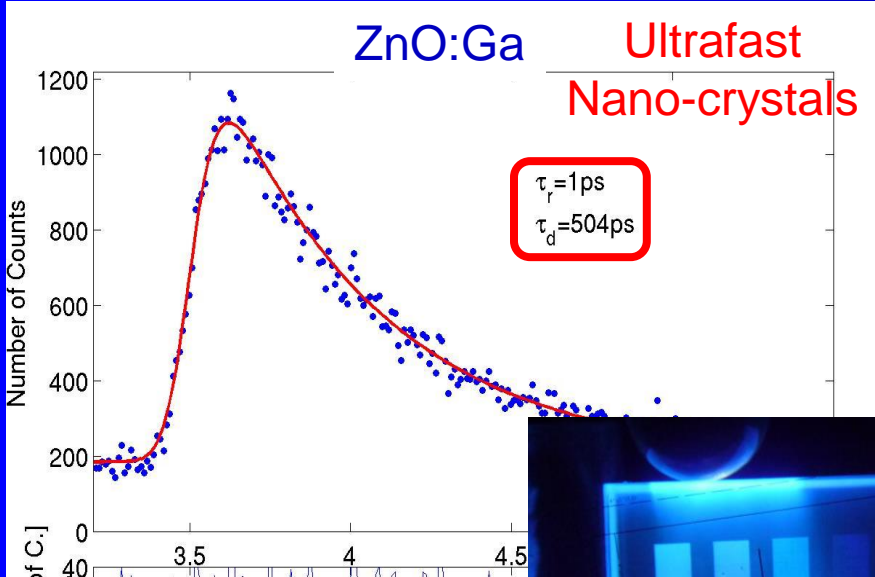
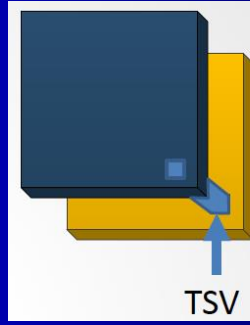
S44 Device - Time = 2 ps



Ivan Rech, Politecnico di Milano

Fast scintillation timing: the way to reconstructionless TOFPET

P Lecoq et al. Nucl. Instrum. Meth. A 718 (2013) 569

Digital 3D SiPM

- High fill factor - PDE
- Electronic flexibility
- Heterogeneous technologies
- The only way to eliminate the SPAD to TDC timing skew in the Single Photon Timing Resolution

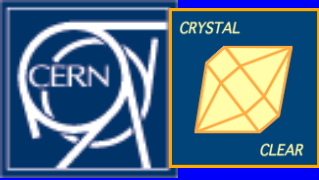
TSV

No TOF

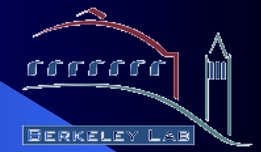
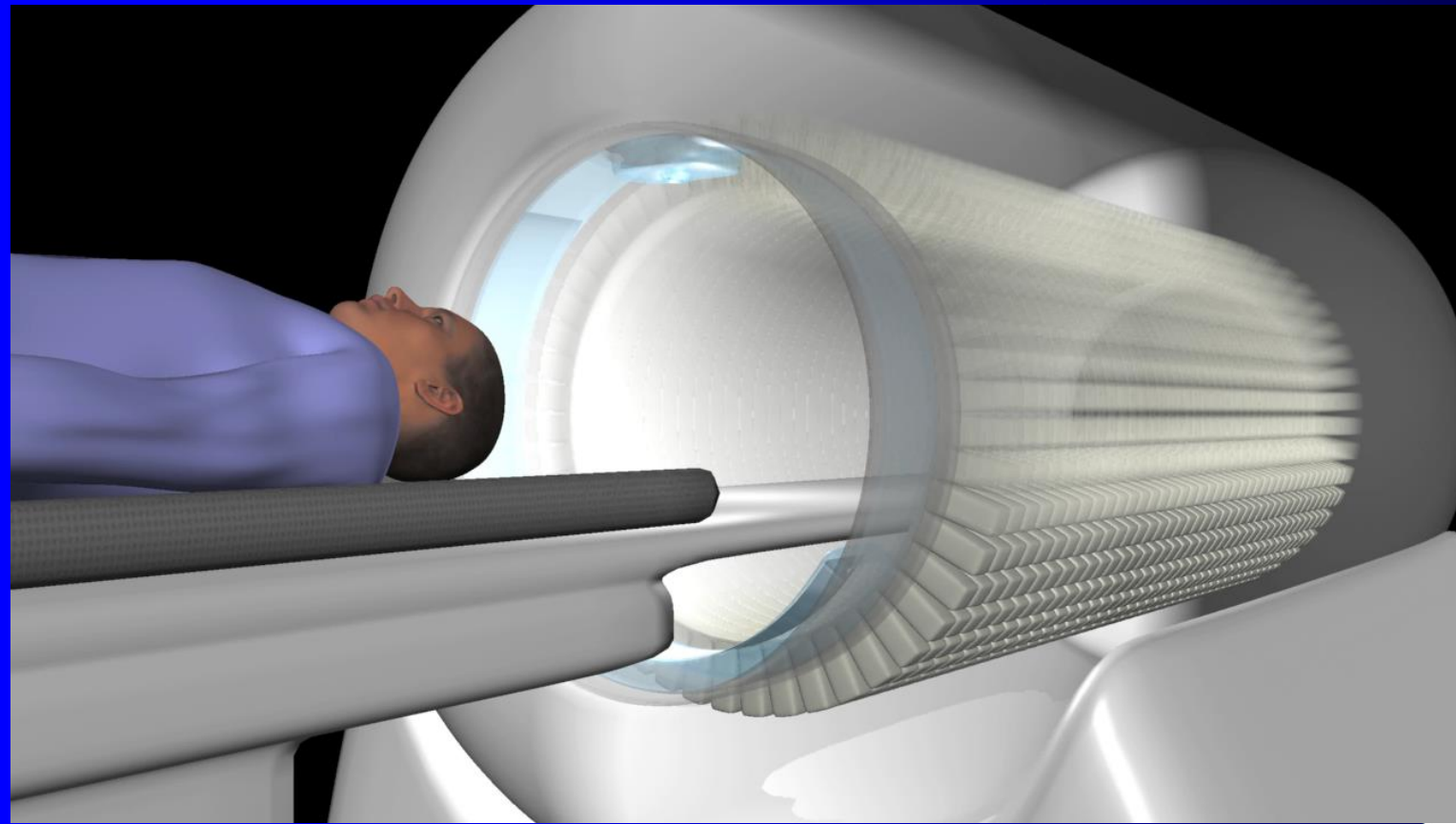
700 ps

500 ps

300 ps



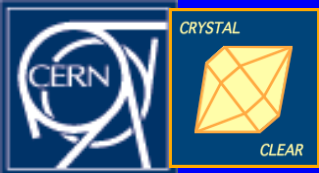
EXPLORER: A Total-Body PET Scanner



EXPLORER.ucdavis.edu

EURADOS WG9, 17 Oct, 2016

P. Lecoq CERN



EXPLORER: A Total-Body PET Scanner



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News > Researchers awarded \$15.5M to build first total-body PET scanner

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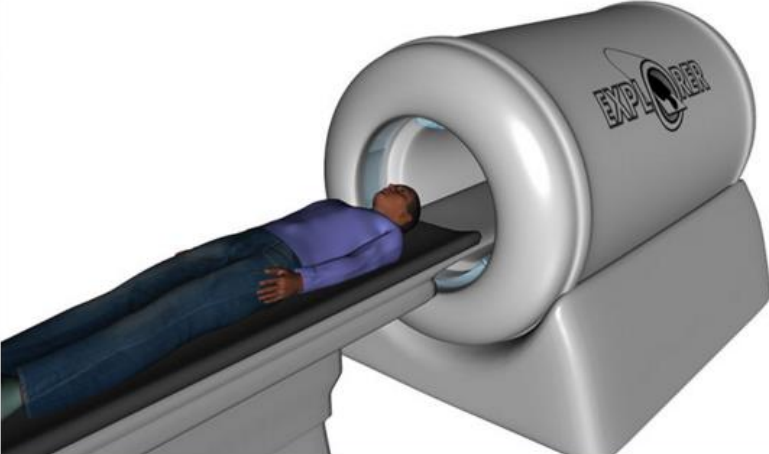
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Researchers awarded \$15.5M to build first total-body PET scanner

UC Davis
Tuesday, October 6, 2015



Credit: UC Davis

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Ramsey Badawi



Simon Cherry

EXPLORER: Design parameters

	Siemens mCT	
Axial FOV (cm)	21.8	200
Ring diameter (cm)	84.9	~80
Scintillator	LSO	LYSO
Spatial resolution (mm)	4.1	<4
TOF resolution (ps)	530	<400
Integrated CT unit?	Yes	Yes
DOI Measurement?	No	Yes No

- Up to 40-fold reduction in dose
 - Whole-body PET at ~ 0.15 mSv
 - Annual natural background is ~ 2.4 mSv
 - Return flight (SFO-LHR) is ~ 0.11 mSv
 - PET can be used with minimal risk – new populations



Conventional PET



**EXPLORER or
10ps TOFPET**

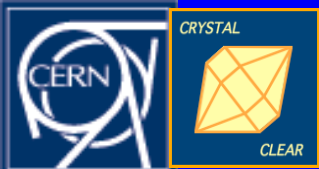


Image Gently (Low Dose) Maternal-Fetal interaction



- **Clinical Need**

- 15M babies born pre-term (< 37 weeks) / year
- 1.1M die because of pre-term complications / year
- Many surviving pre-term babies have problems as adults (disabled, diabetes, hypertension, heart disease, obesity)

- **Identify Problems *In Utero***

- Trace nutrient transport from mother to fetus (oxygen, glucose, amino acids, fatty acids)
- Image at < 0.05 mSv

The potential for low dose functional studies in maternal-fetal medicine using combined PET and MRI
Terry Jones and Thomas F. Budinger. Journal of Nuclear Medicine 2013, 54: 2017-2018

