TOF-PET for Proton Therapy

ST @ PETsys electronics

Portugal will have a proton therapy centre in Lisbon in a 5 years.

In preparation of that the Portuguese government made a call for proposals to to create more scientific and technological know-how in this area in Portugal.

We submitted a project to this call for proposals , and the project was accepted.

It is a joint project with the MD Anderson centre in Austin Texas, and the University of Texas in Austin.

The MD Anderson centre is one of the main medial centres in the US and has proton therapy centre since several years.

Participants

- PETsys Electronics, Portugal, (PI)

- University of Texas at Austin, Austin, Texas

- UT MD Anderson Cancer Center Proton Therapy Center, Texas

- C2TN Centro de Ciências e Tecnologias Nucleares, Portugal

- ICNAS, Instituto de Ciências Nucleares Aplicadas à Saúde,

-LIP, Laboratório de Instrumentação e Física Exp. de Partículas,

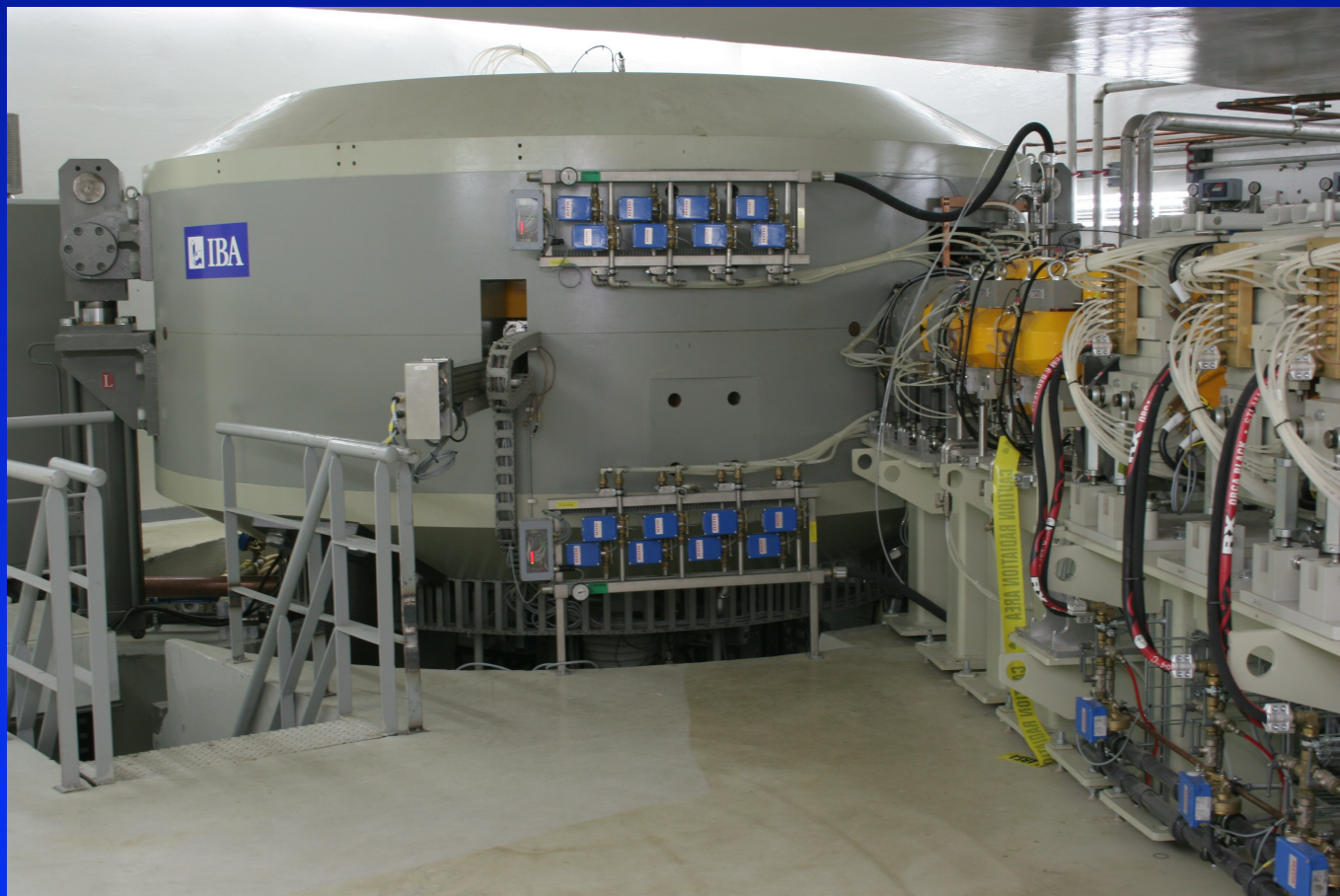
Scientific motivation for the project

Today the most commonly used method of ration therapy is based on the use of gamma rays

It uses gamma beams in the few MeV range

Scientific motivation for the project

I proton therapy ne uses a proton beam to irradiate the patient
That needs protons of up to 230 MeV , an this needsa big accelerator such as a cyclopron

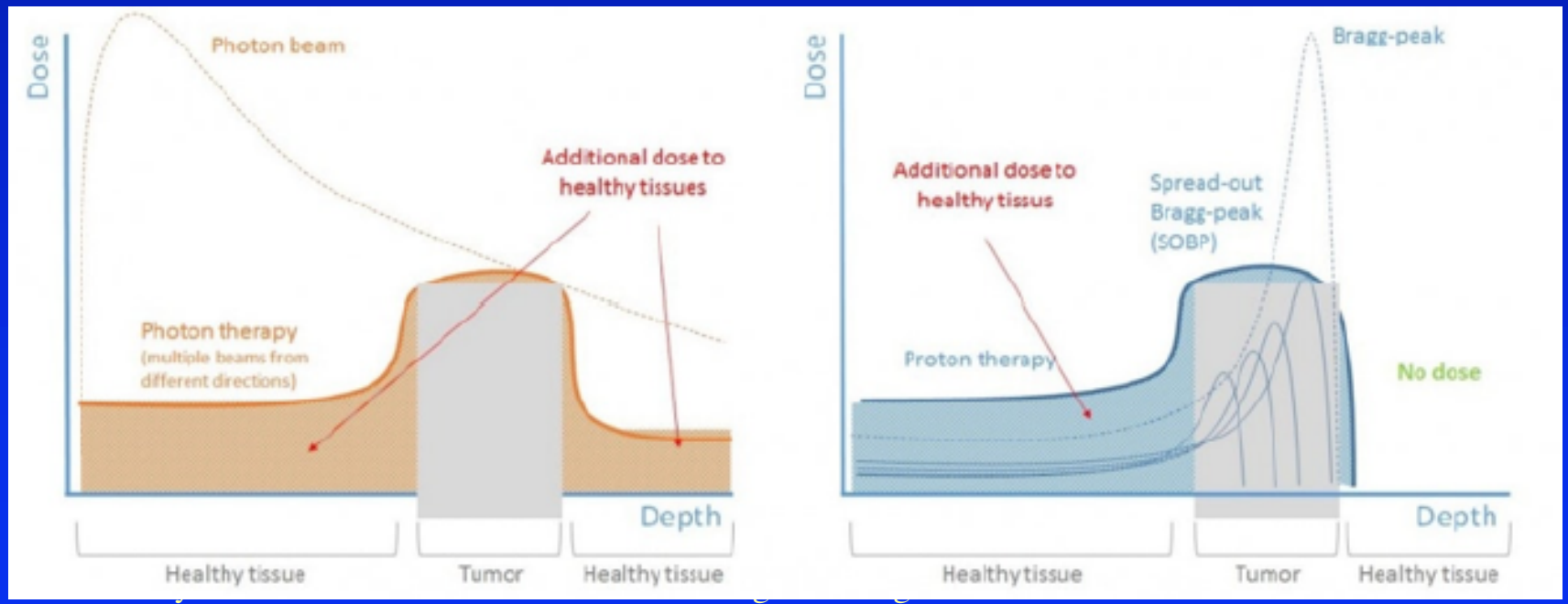


January 2020

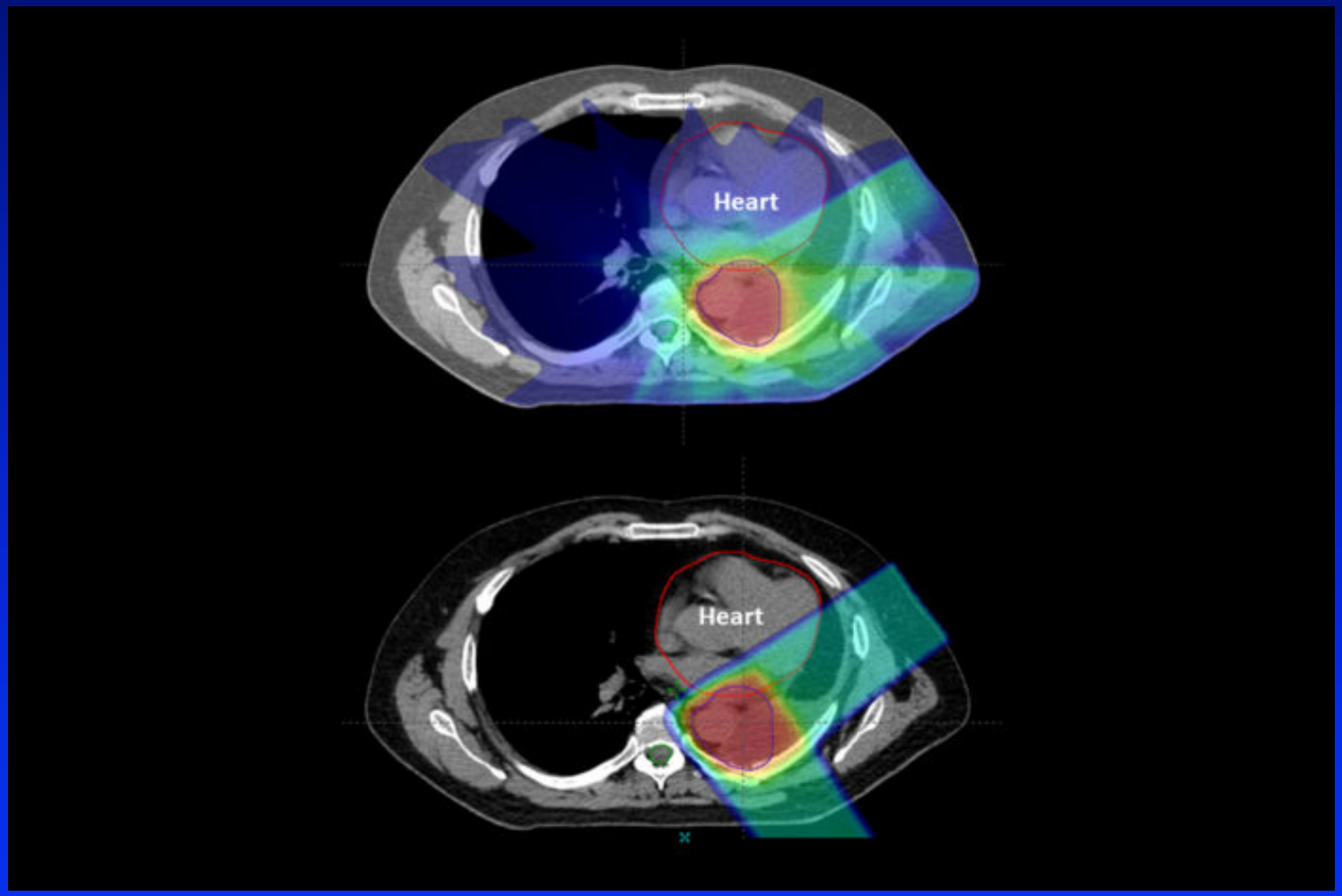
Scientific motivation for the project

Unlike gamma rays, protons travel until they have lost all their energy and stop. The maximum radiation dose is delivered in the last few millimeters at the end of the range.

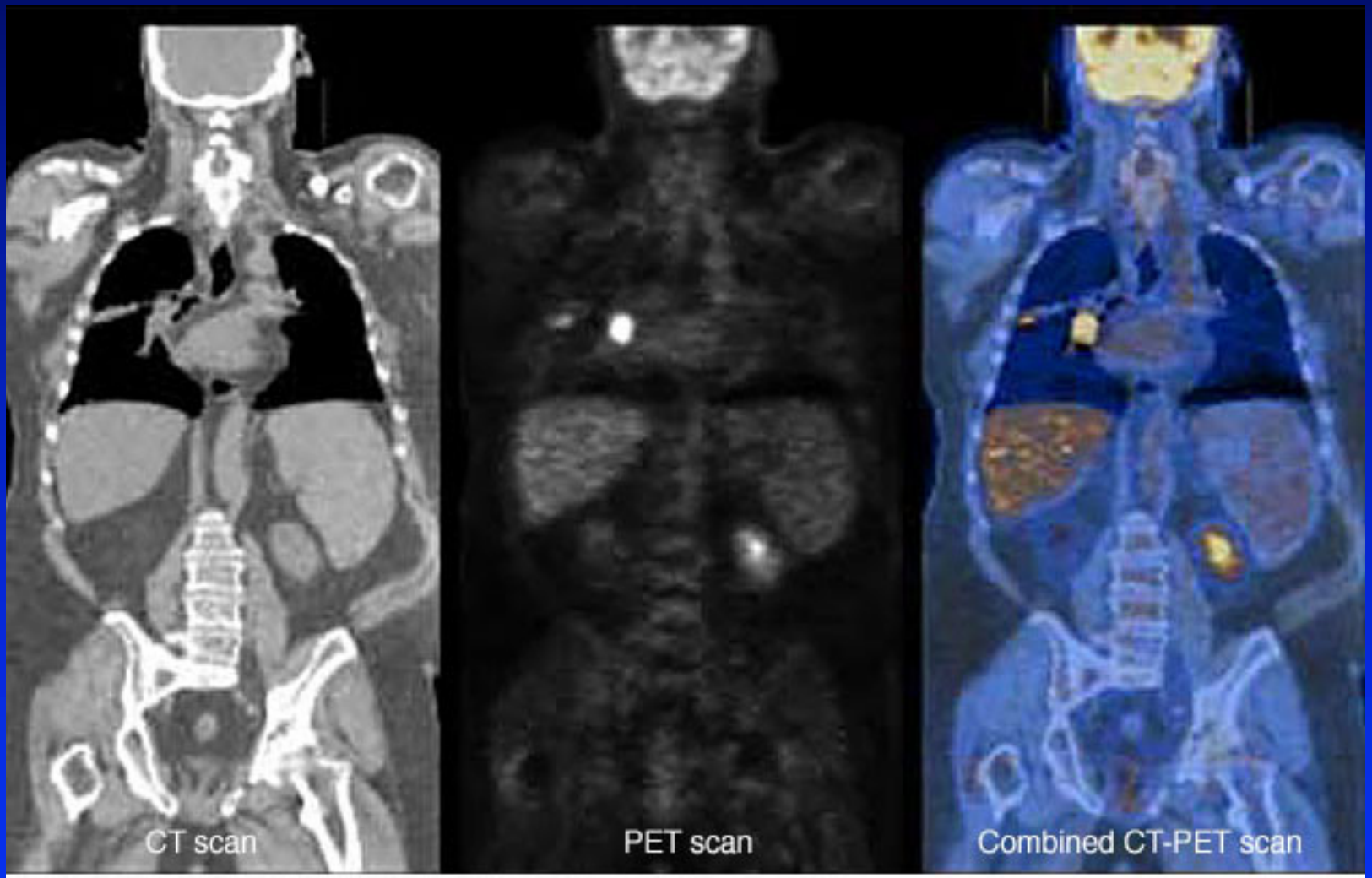
No dose is delivered beyond the end point of the beam. Proton radiation therapy is mainly use when the area to be irradiated is close to some very vital organ that absolutely must be spared.



Scientific motivation for the project



Patient positioning is based on the CT- image
There is usually a CT incorporated in the radiation cite



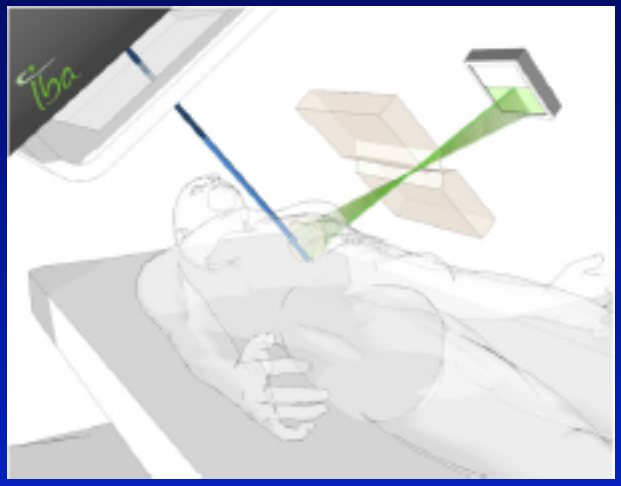
Scientific motivation for the project

The precision of the irradiation is limited by uncertainties on proton range. It is highly desirable to reduce the effect range uncertainties, and to verify that the treatment was delivered as intended.
Several methods to monitor the proton range are being considered

- prompt gamma rays
- prompt charged particle emission
- neutron emission
- Positron Emission Tomography. (PET)

In this project we want to prove the value of PET in proton range verification.

Comparing prompt gamma and PET



- The prompt gamma rays 4-7 MeV are emitted in nuclear reactions induced by protons

- emitted within ns of the beam

- Cyclotron beam structure depends on the type of cyclotron used. If it is a Synchro cyclotron, it has pulses of about 1 microsec, 1 msec appart.

- No image is obtained, only the range is measured

- You need a detailed simulation to connect the emission of prompt gammas to the radiation dose deposition

Comparing prompt gamma and PET

- In PET you will need two detectors around the patient. It is in practice very difficult to have a full ring. A partial ring is mandatory, and therefor excellent timing is mandatory

- The isotopes produced are

C11 20 min decay time

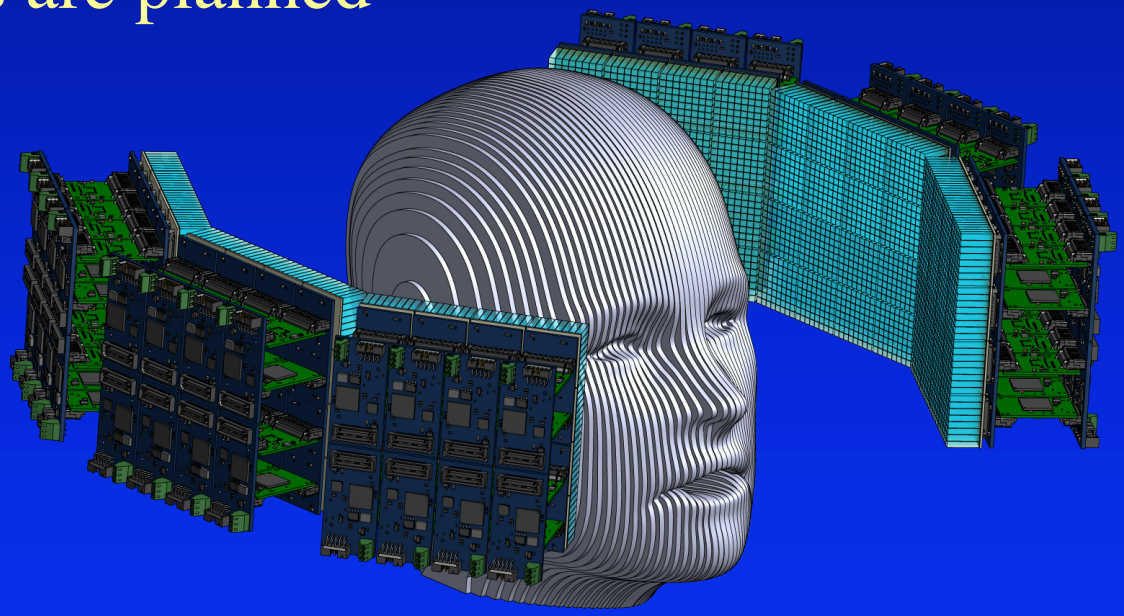
O15 2 min decay time

- the PET image must be made immediately > wash out

- But the PET image has much more information.
Eventually it may even be possible to make the tumor itself , and the proton image visible in the same image.

TPPT Portugal Austin project :

- Duration 3 years,
- Start 2020-01-01
- Partial ring setup that could be used for brain irradiations
- we assume a brain system to save on detector cost
- No patients studies are planned



Activities

- Build the PET detector / PETsys + UT Austin

- Simulations & image reconstruction:
  LIP, ICNAS and MD Anderson

- Beam tests at MD Anderson / MD Anderson

- Biological studies / C2TN + ICNAS

Our main task is to build the PET detector

Time line

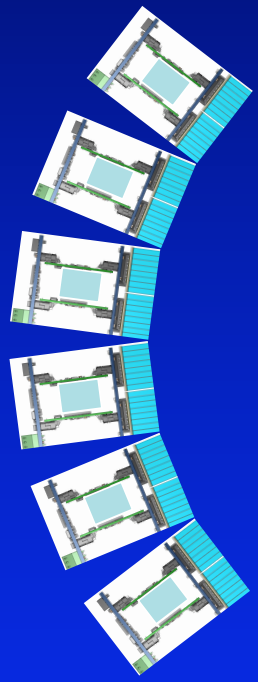
- Finalise the design	M1 > M6
- construction PET scanner	M7 > M14
- Commissioning in Lisbon	M15 > M20
- Ship to Austin	M21
- provide remote support	till end project

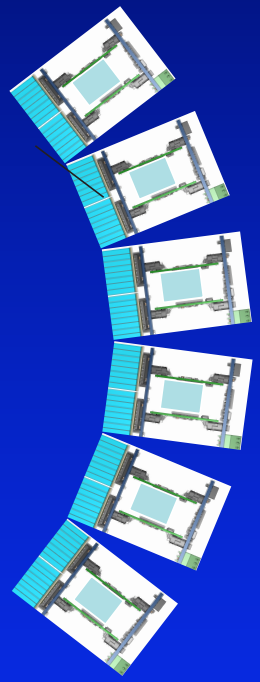
Our main task is to build the PET detector

- We are considering Hamamatsu 8x8 array
  3x3 mm pixel SiPM

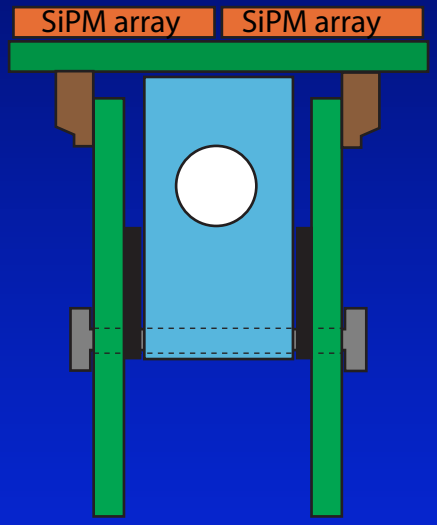
- LYSO 3x3x15 mm crystals

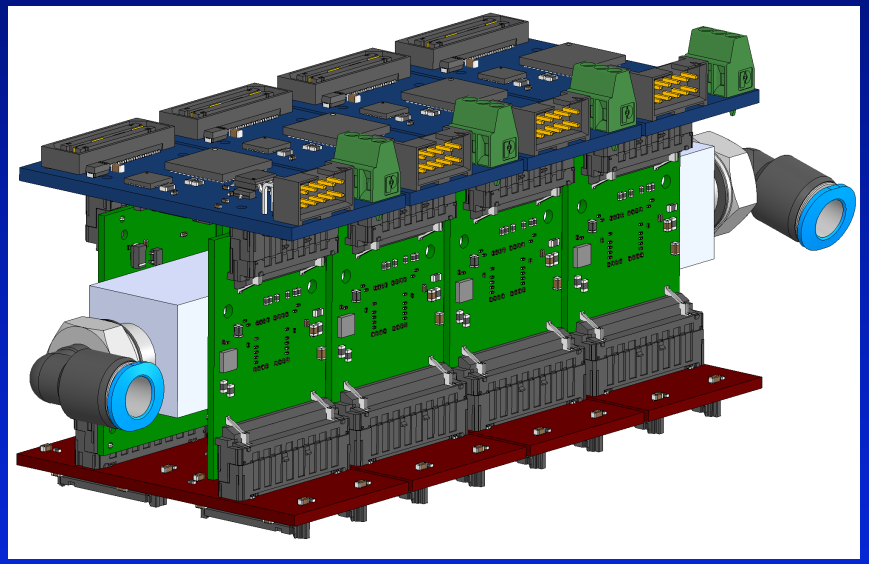
Preliminary design ideas





For rings deep
≈10 cm


SiPM array
SiPM array



It is mandatory to carefully optimize the front-end module for best timing, which crystals, which separation, way to glue etc.

I see no reason to significantly change anything in the rest of the readout . Possibly we want to use the new FEB/2000.

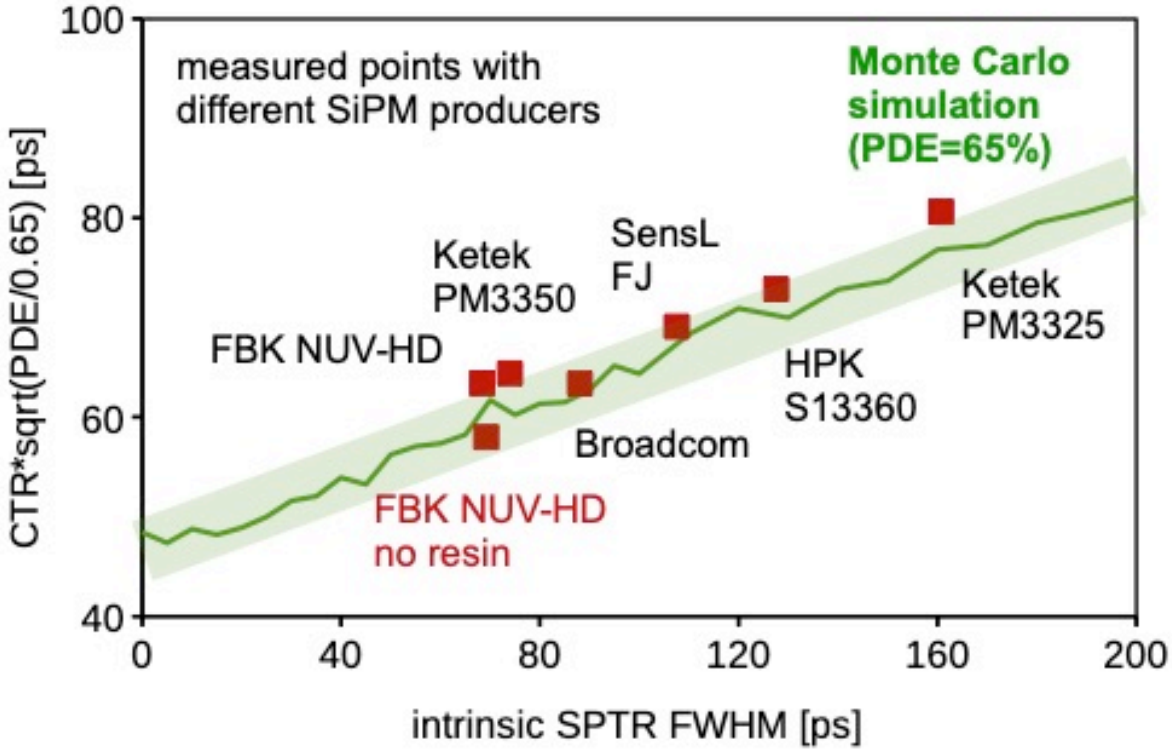
Overall mechanics and cooling will be designed by UT Austin.

We should keep a partial system (2000 channels?) in Lisbon

That’s it

Thank you for your attention

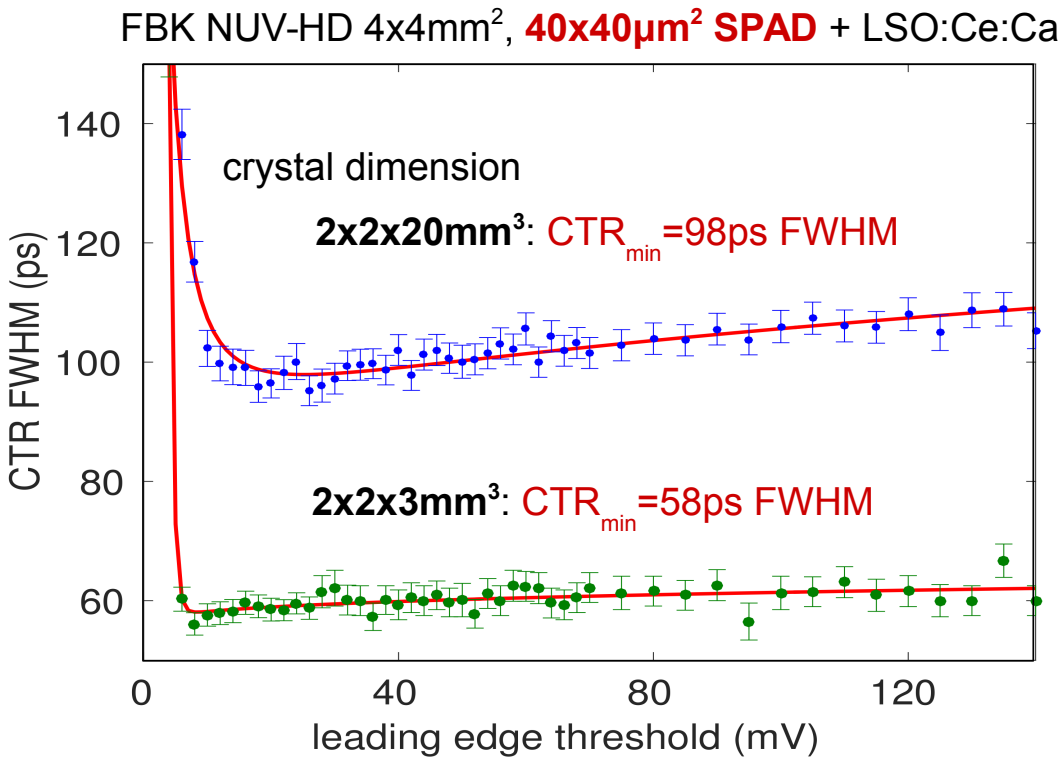
PDE adjusted CTR as function of the SPTR



CTR measured with 2x2x3mm³ LSO:Ce codoped 0.4%Ca corrected for measured PDE as if 65%

Slide from Stefan Gundacker

FBK NUV-HD 40µm SPAD breaks CTR records

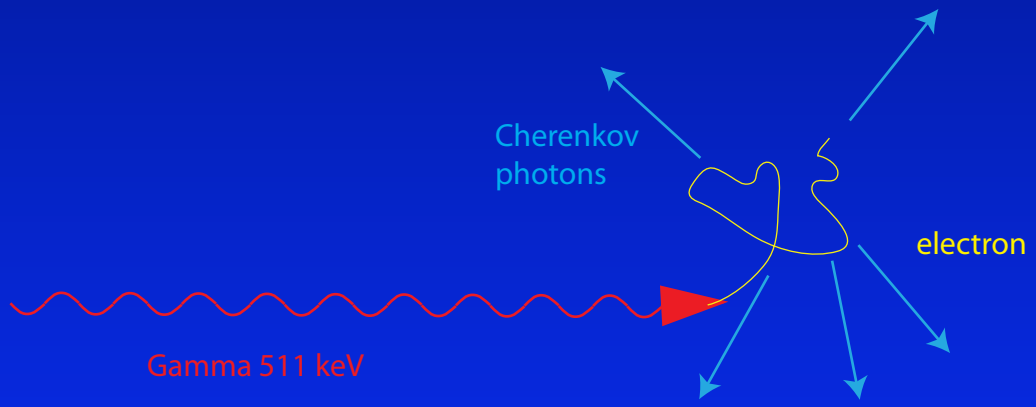


High PDE and good SPTR of FBK NUV-HD with 40µm SPAD size leads to record CTR.

Slide from Stefan Gundacker

Is there any mechanism producing prompt photons ?

- Cherenkov effect. Gives prompt photons,
but only 10-20 are produced



Spare slides

Spare slides

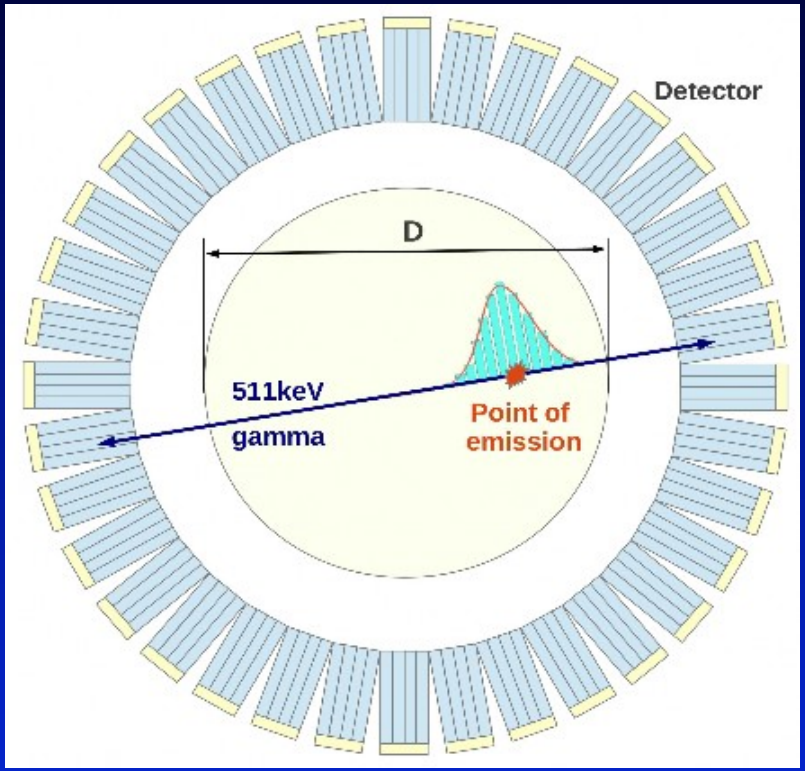
Principe de détection des Gammas de 511 keV
Scintillateur dense + photo-détecteur

	Densité	Long Attenu. [mm]	Photo fraction [%]	Rend. Lumin. [ph/MeV]	Temps de Déclin [ns]	Longueur d'onde Emission [nm]
BGO	**7,1**	**10,4**	**40**	**9000**	**300**	**480**
LSO	**7,4**	**11,4**	**32**	**32000**	**40**	**420**

$BGO = Bi_4Ge_3O_{12}$

$LSO = Lu_2SiO_5$

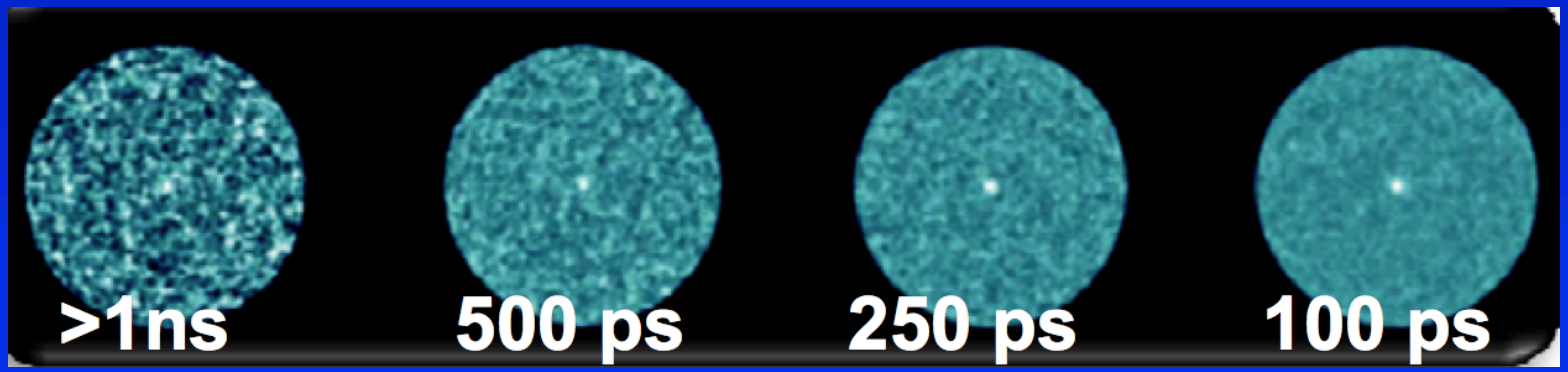
$LYSO = Lu_{1.6}Y_{0.4}SiO_5$



Le temps de vol donne un gain de « sensibilté effective »

$\approx$ 2 ns / CTR

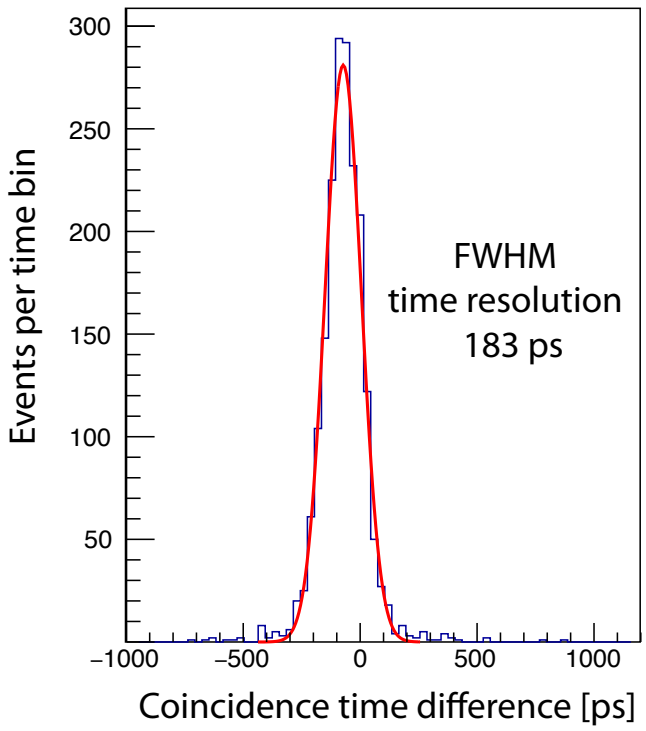
Une meilleure résolution Temporelle réduit considérablement le bruit dans l'image



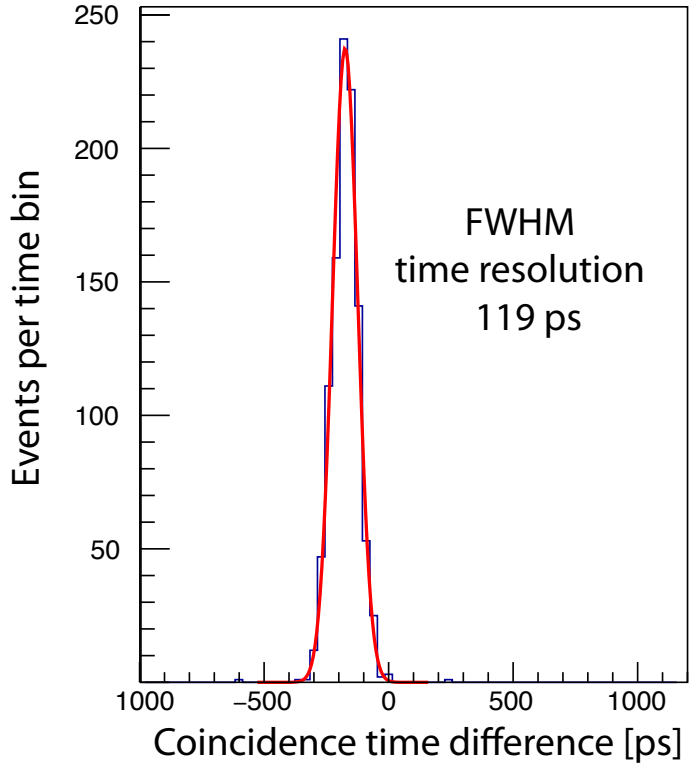
From Surti and Karp

Le mieux qu'on peut faire aujourd'hui pour des amplis d'un coût abordable (PETsys TOFPET ASIC)

LYSO 3x3x20 mm^2

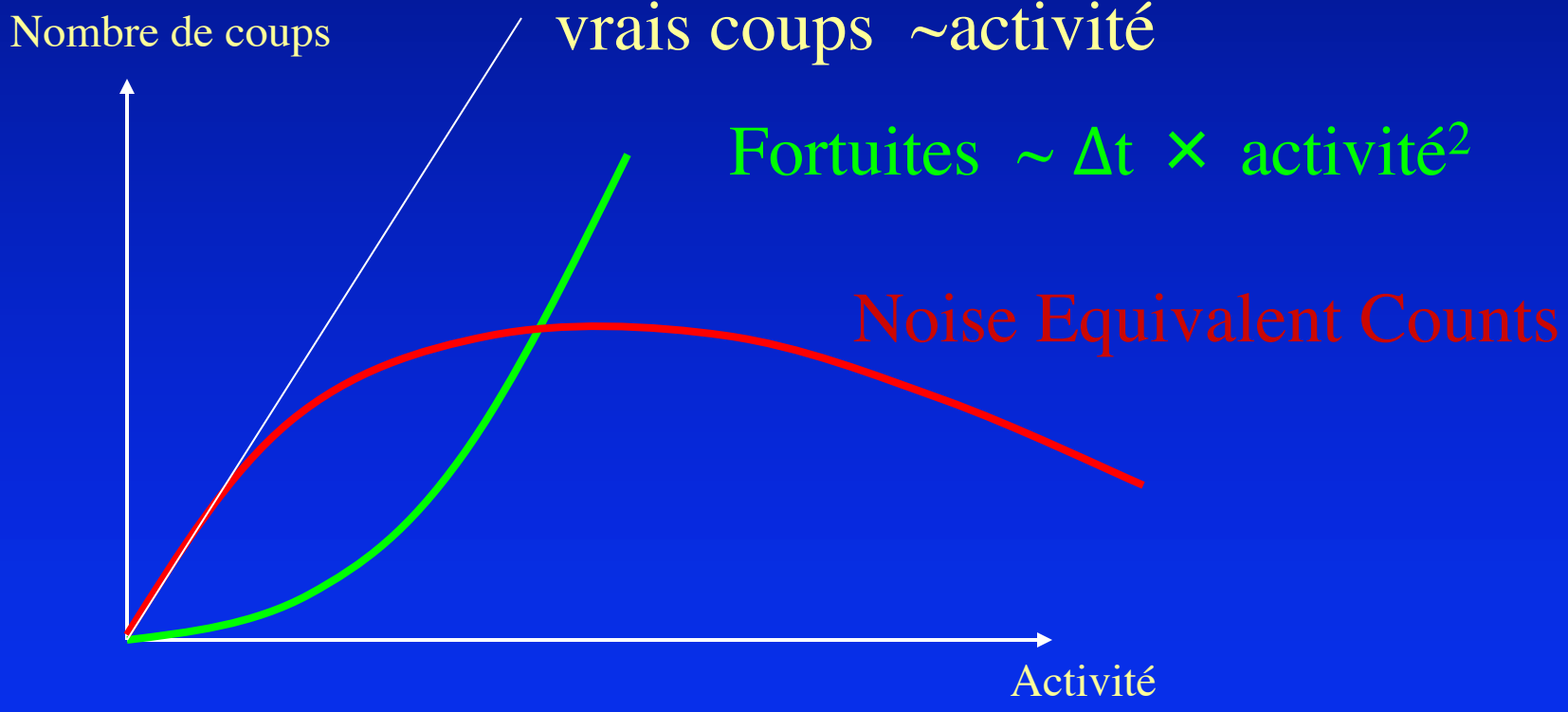


LYSO 2x2x3 mm^2

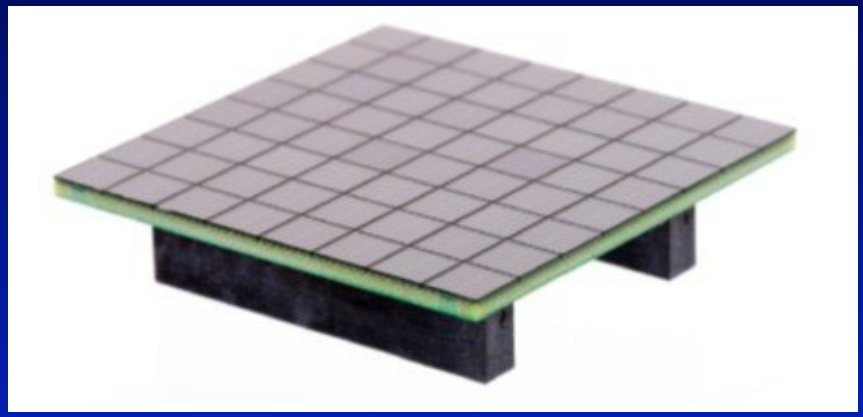


La résolution temporelle est essentielle

Les taux de comptage en TEP sont importants ($\geq 10^7$ / s)



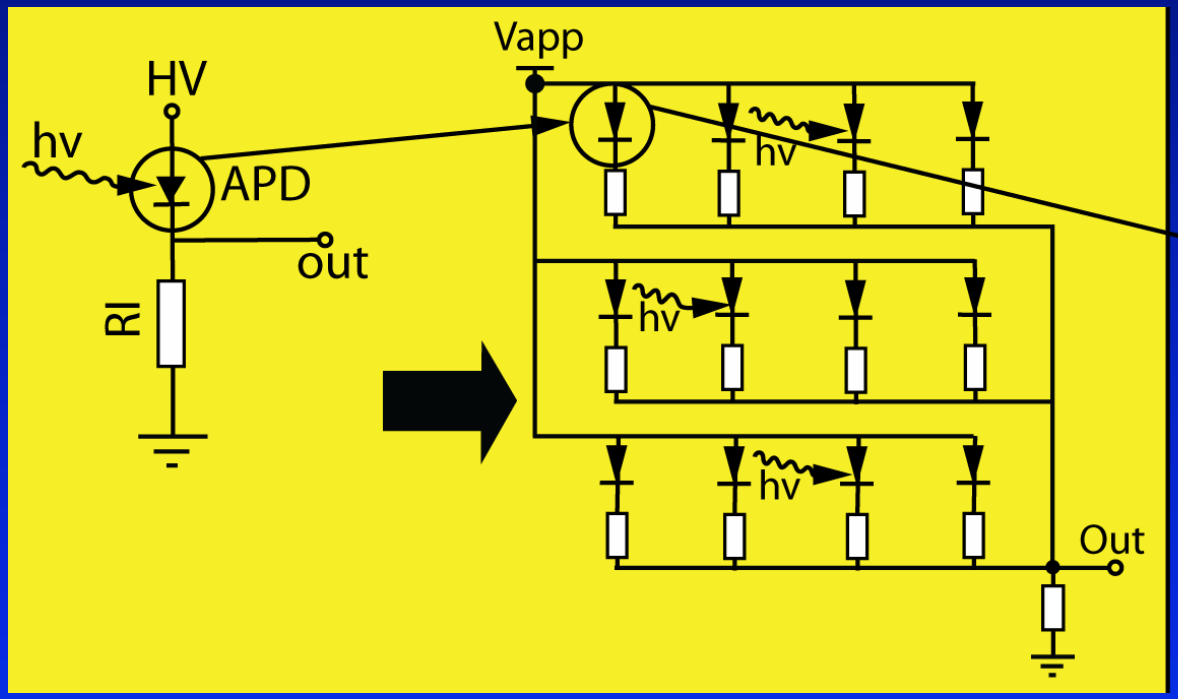
Maintenant, les PMT sont de plus en plus remplacés par des SiPM



- meilleure résolution temporelle
- insensible aux champs magnétiques
- un SiPM se divise facilement en petits pixels
- le coût des SiPM a baissé
  (20 USD / cm^2) / en très grand volume!

Maintenant les PMT sont de plus en plus remplacés par des SiPM

SiPM = Silicon PhotoMultiplier



Micro cellule (SPAD)