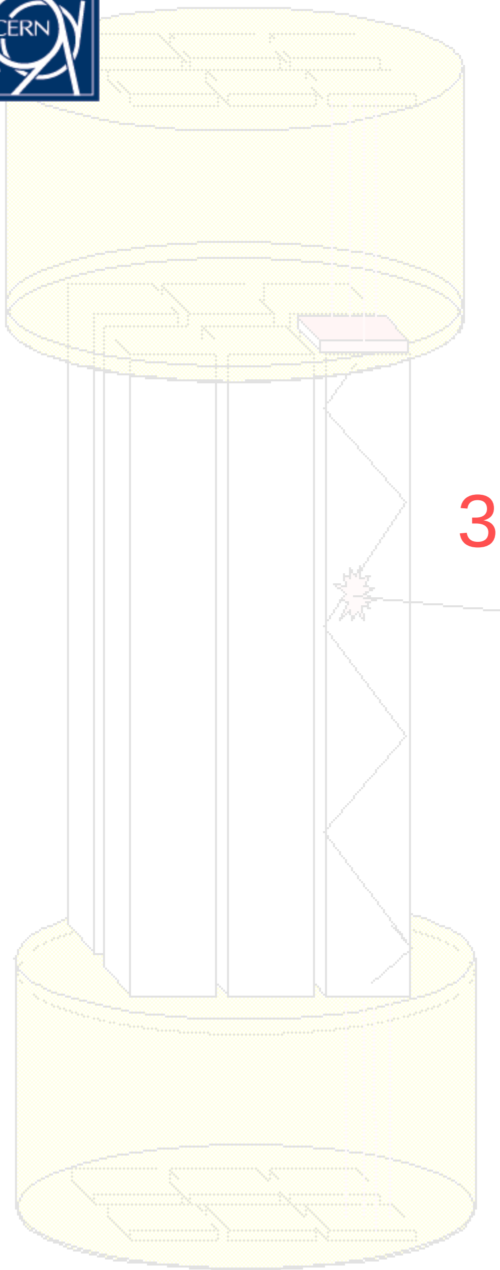
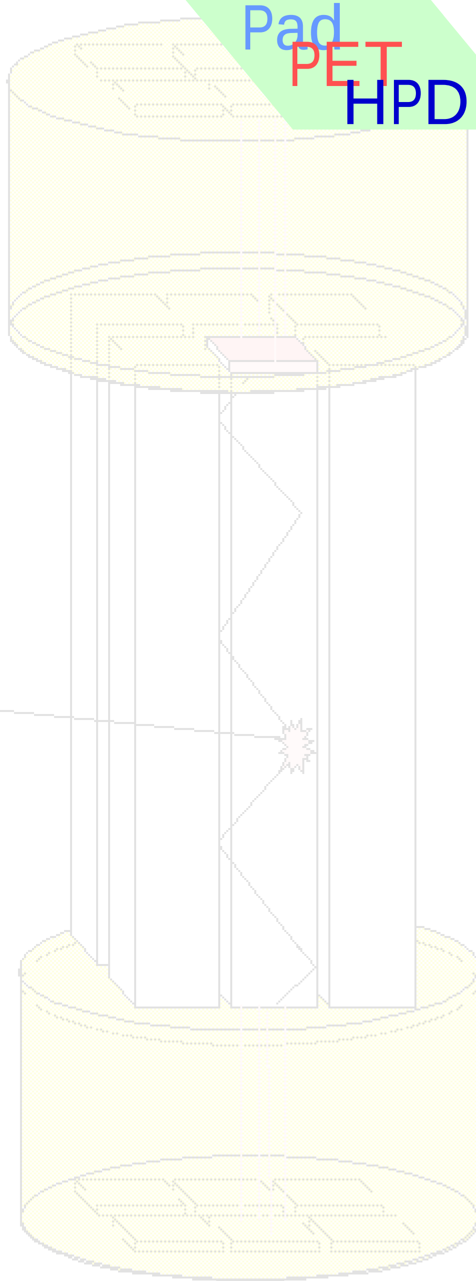
Pad PET HPD

PET Detector
with
Parallax-free
Compton Enhanced
3D Gamma Reconstruction





Bari Polytechnicum & Univ. – CERN -

Univ. Cracow - Univ. Erlangen -

Univ. Hospital Geneva –

Univ. Geneva – Lisbon CFNUL & ITN -

ISS Rome

§§ Patent application filed under PCT/EP 02/07967 §§

Background

Pad PET HPD

Our collaboration has...

- Expertise and experience in development and construction of Si sensors and Hybrid Photon Detectors
- Expertise and experience in development of front-end electronics / data acquisition hardware

Motivation

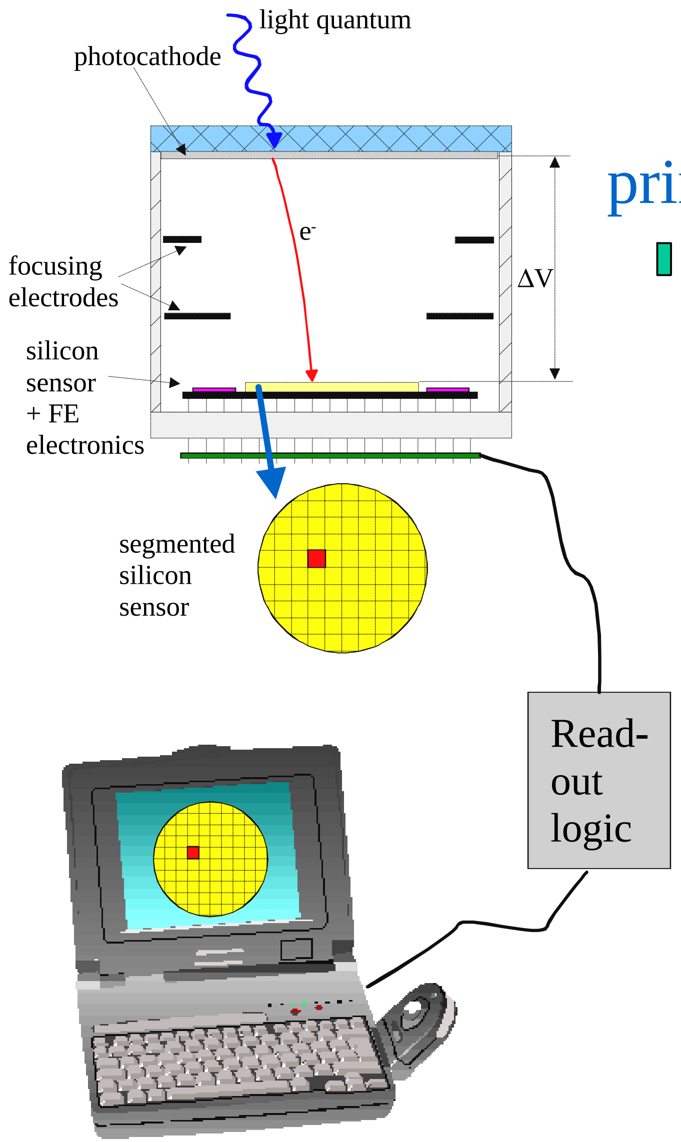
We propose to apply some of the developed technologies to medical imaging, in particular to a high resolution (brain) PET system

Goal

We want to implement a novel geometrical concept which allows for a full 3D reconstruction, free of any parallax error. The concept allows to enhance the sensitivity by recovering also Compton scattered gammas.

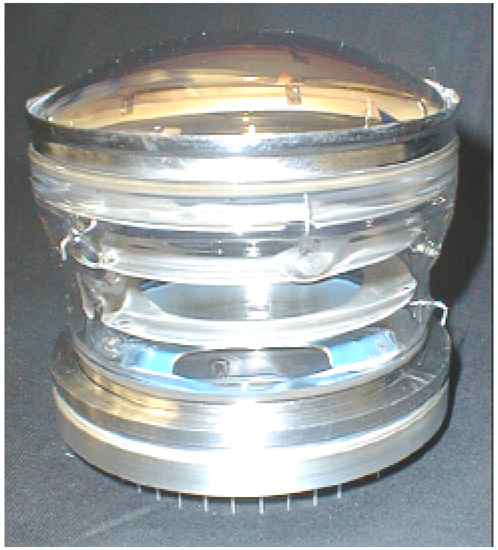
HPD Principle

Pad PET HPD



principle

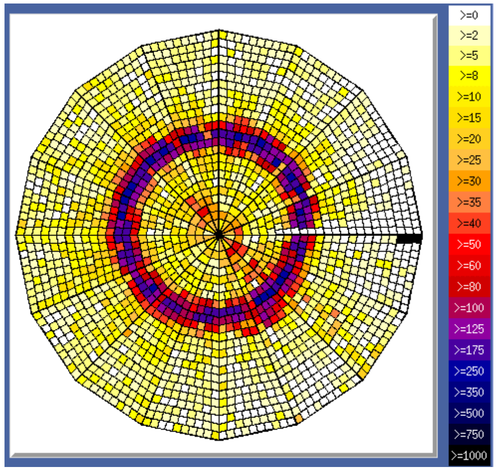
real device



Developed and built @

Pad HPD 127mm Ø

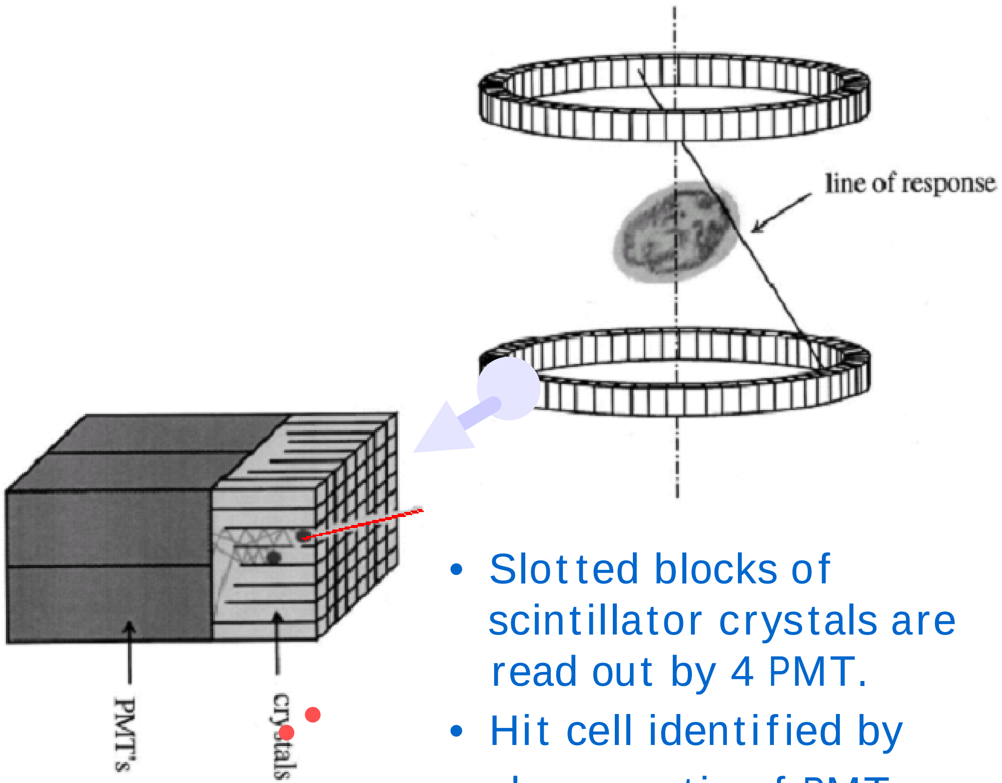
Single photon imaging with 2048 Channels. S/N ~ 10.



The proposed PET concept

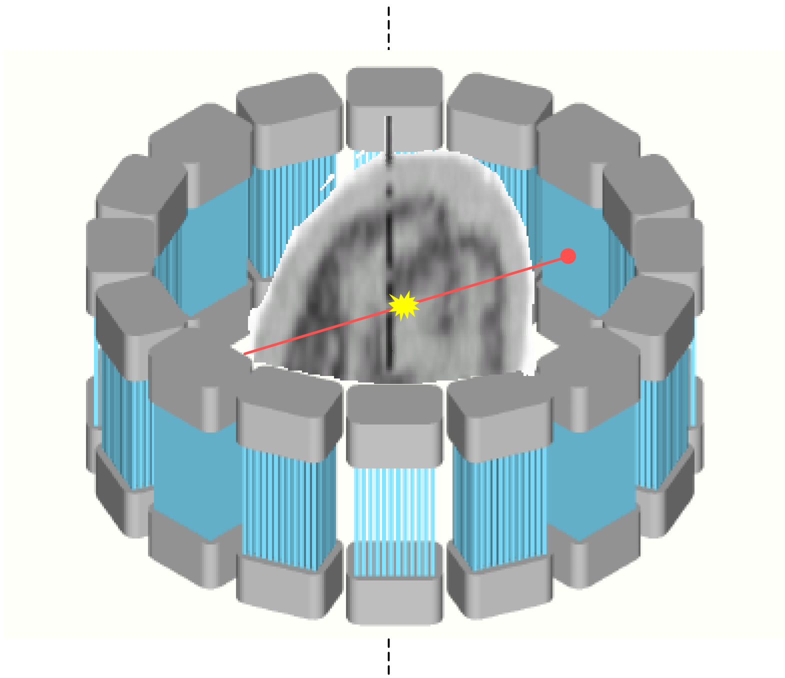
Pad PET HPD

["Conventional" PET geometry]



- Slotted blocks of scintillator crystals are read out by 4 PMT.
- Hit cell identified by charge ratio of PMTs.
- Limited detector thickness
- No DOI …

[Our new PET geometry]



- Axial arrangement of individual long scint. Crystals
- Readout by HPDs on both sides.
- 1 crystal = 1 HPD channel

Main advantages of the concept

Pad PET HPD

- Full 3D reconstruction of γ quanta without parallax error
  - x,y from silicon pixel address
  - z from amplitude signal ratio of the 2 HPD's

➔ Precise Depth of Interaction DOI measurement

➔ No limitation in detector thickness ➔ improved sensitivity.

- Measurement of light yield on both sides of crystals
- Negligible statistical fluctuations in HPD

➔ Very good γ energy resolution

- 3D reconstruction provides possibility to recuperate part of γ's which underwent Compton scattering in the detectors

➔ Compton enhanced sensitivity

Scintillation crystals

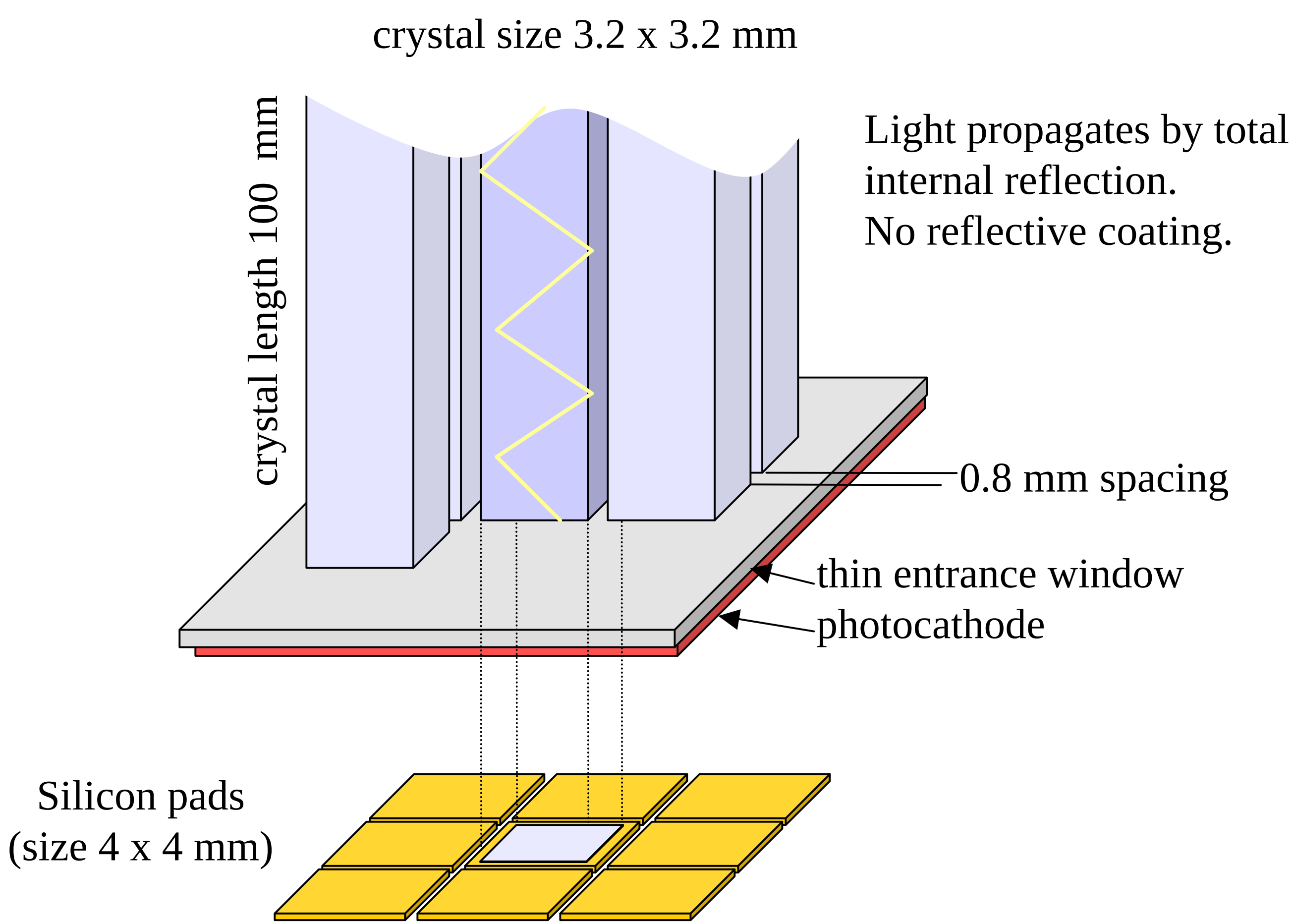
Pad PET HPD

- Criteria to be taken into account: light yield, absorption length, photo fraction, self absorption, decay time, availability, machinability, price.
- All preliminary performance estimates are based on YAP:Ce (availability!)

	YAP:Ce	LSO:Ce	LuAP:Ce	$LaBr_3$:Ce
Density r (g/cm^3)	5.55	7.4	8.34	5.3
Effective atomic charge Z	34	66	65	46.9
Scintillation light output (photons / MeV)	18000	23000	≈ 10000	≈ 61000
Wavelength of max. emission (nm)	370	420	370	356
Refractive index n at max. emission	1.94	1.82	1.95	~ 1.88
Bulk light absorption length l_a (cm)	14	20		
Principal decay time (ns)	27	40	38	30±5
γ attenuation length at 511 keV (mm)	22.4	11.5	10.5	11.8
Photofraction at 511 keV (%)	4.5 !	32.5	30.6	15
Energy resolution at 662 keV (FWHM, %)	4.5	8		2.9

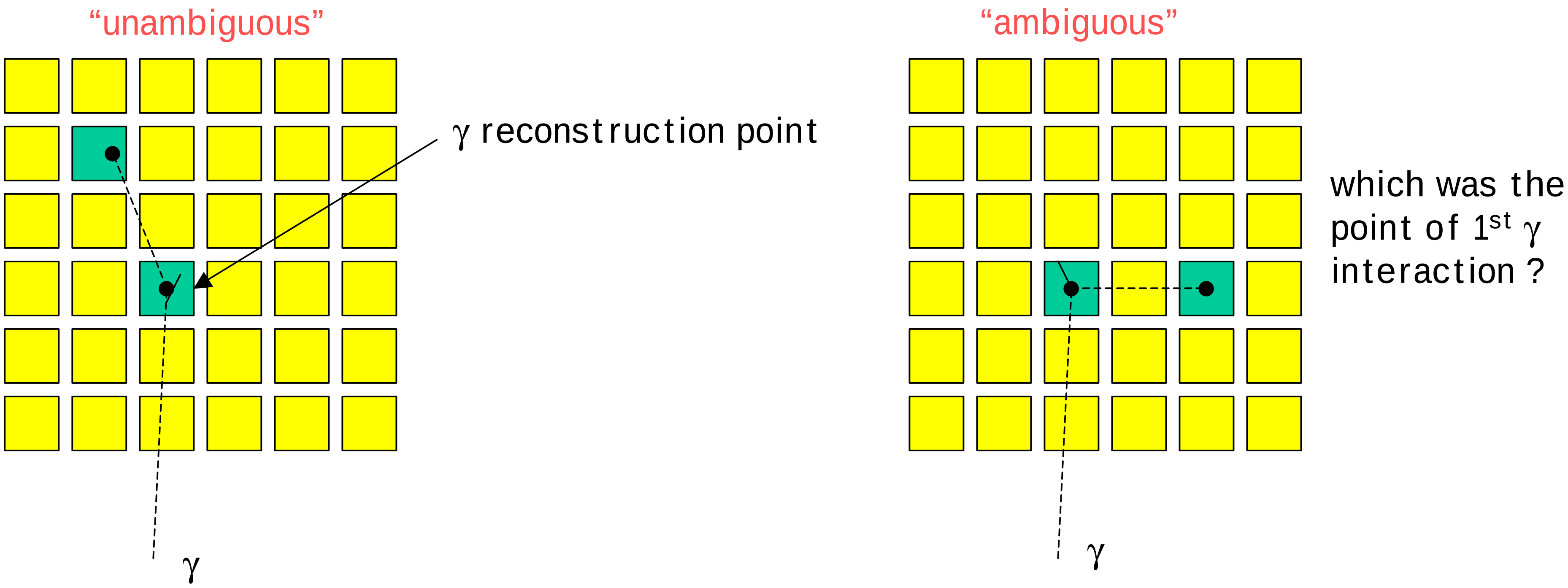
- YAP is OK for proof of principle, however suffers from low Z (high absorption length, low photo fraction)
- $LaBr_3$, LSO and LuAP are the really interesting candidates.

The crystal matrix



Compton enhanced reconstruction

Fine 3D segmentation and large volume make it possible…

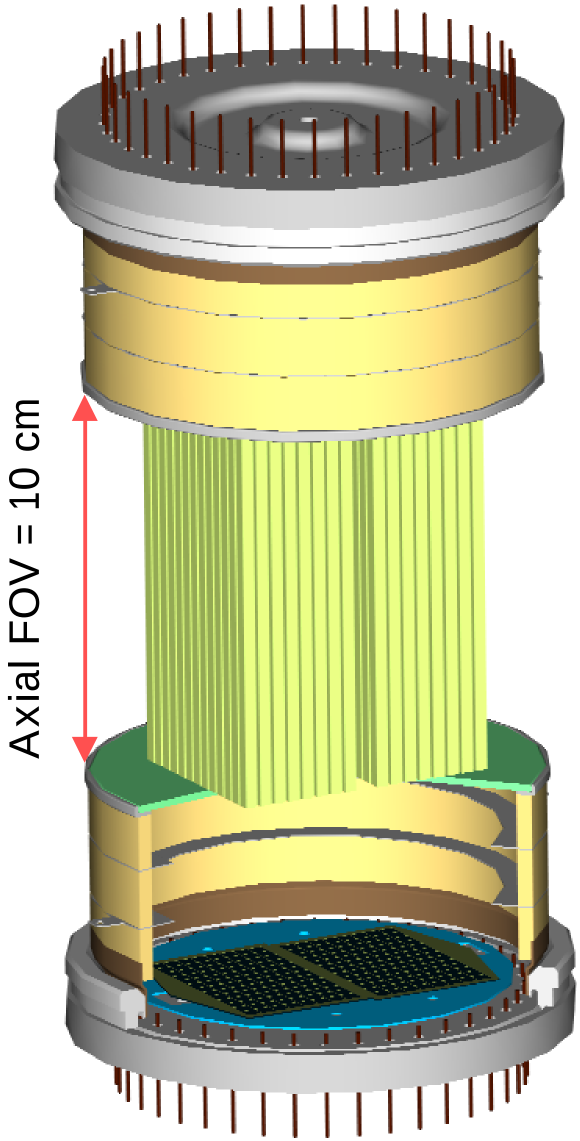


- ➔ Select only events in which Compton scattering happens in forward hemisphere
- ➔ Restrict to Compton angle $10° \leq \theta \leq 60°$
- ➔ Ask for energy deposit in first interaction $E \leq 170$ keV

Pad PET HPD

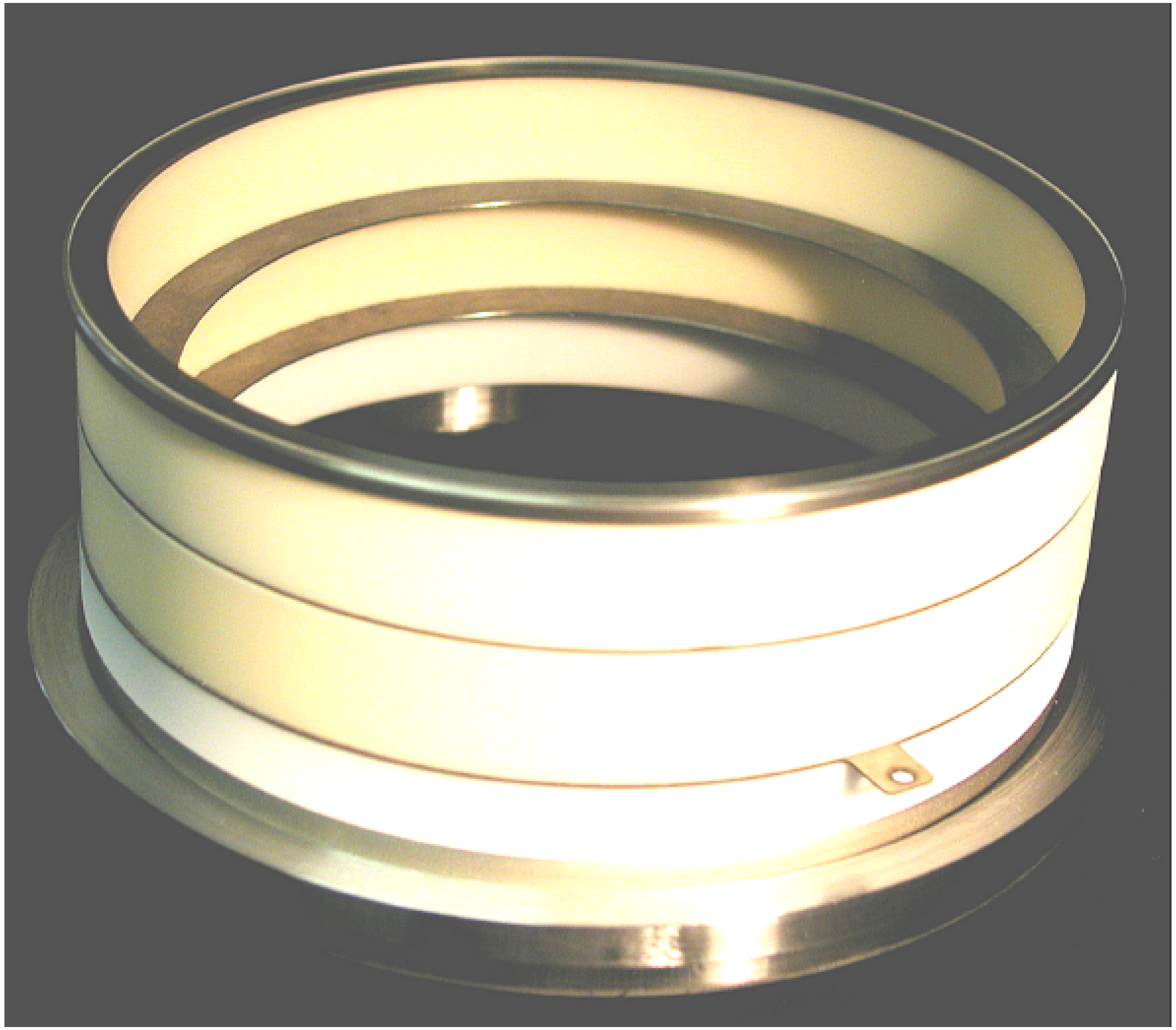
PET camera prototype module

- 2 HPD PCR5
- Scintillator array (208 crystals)



PCR5 envelope assembled (Ø127 mm)

Pad PET HPD



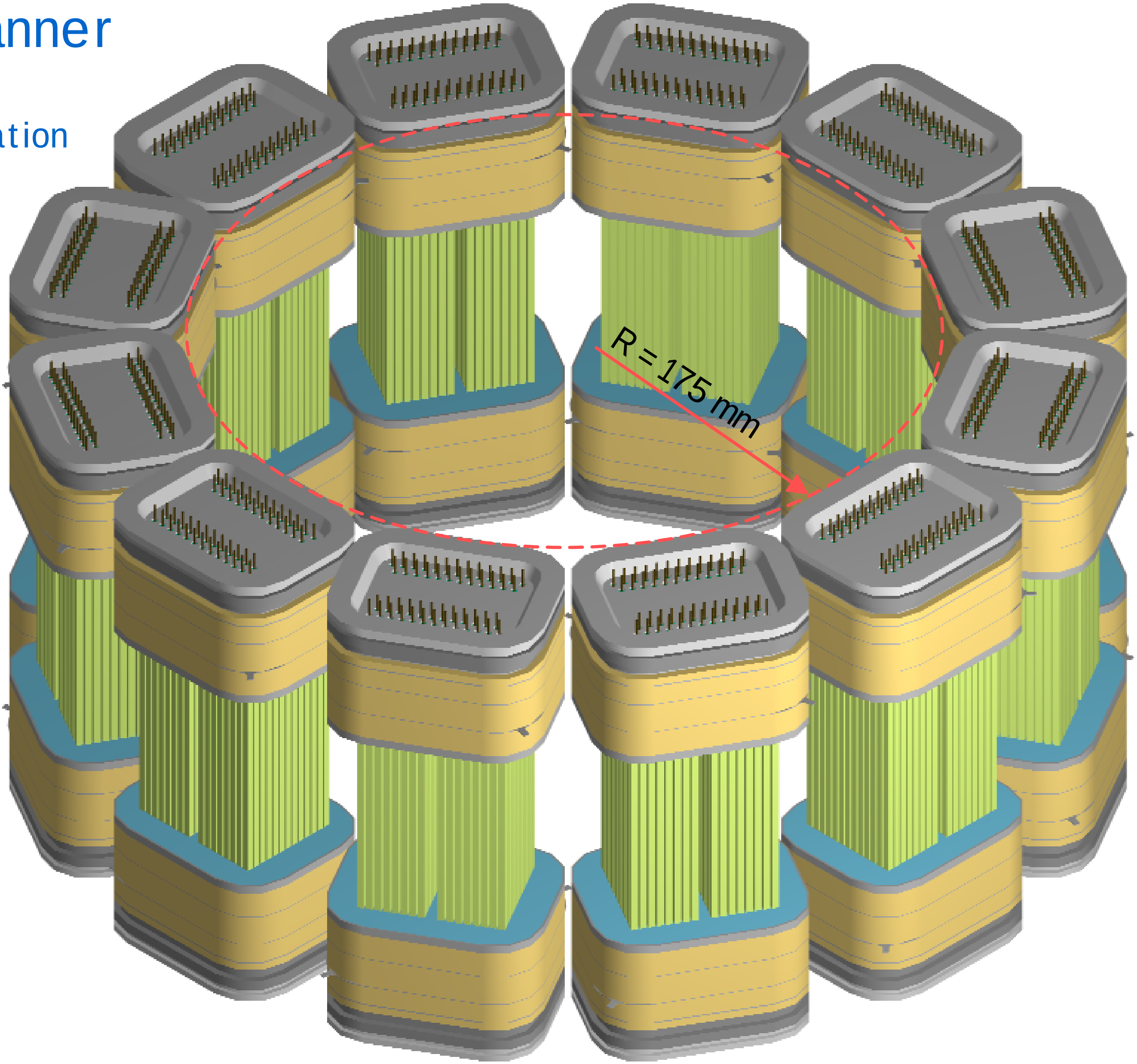
Ceramic body

1.8mm sapphire window

fabricated at CERN

Full ring scanner

Possible configuration
for a Brain PET



- 34 cm inner diameter
- 10 cm axial length
- 2496 crystals
- 24 HPDs
- Optimized HPD design
- total detection volume
  2556 cm^3
- Φ coverage 66%
- Ω coverage 18%