

Physique médical et le projet HPD-PET

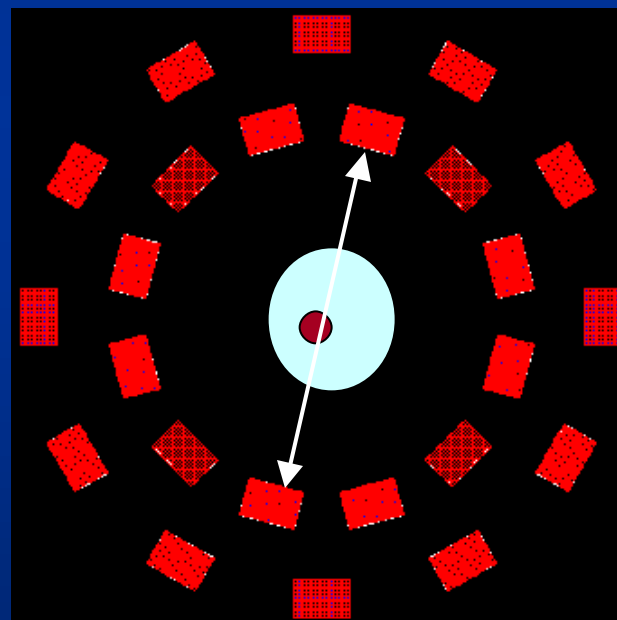
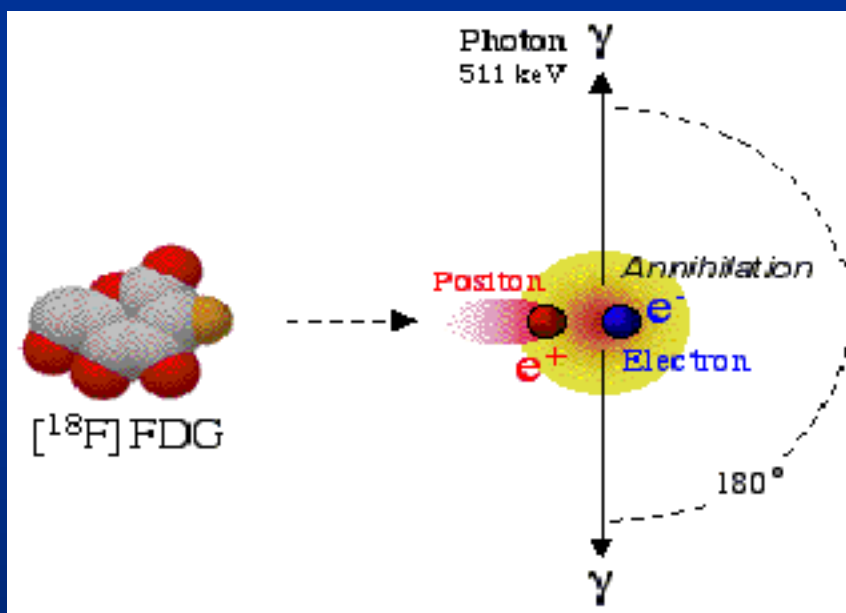
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Bossey 12 July 2002

Outlook

- Positron Emission Tomography (PET)
- Hybrid Photo-Detectors (HPD)
- The HPD-PET project

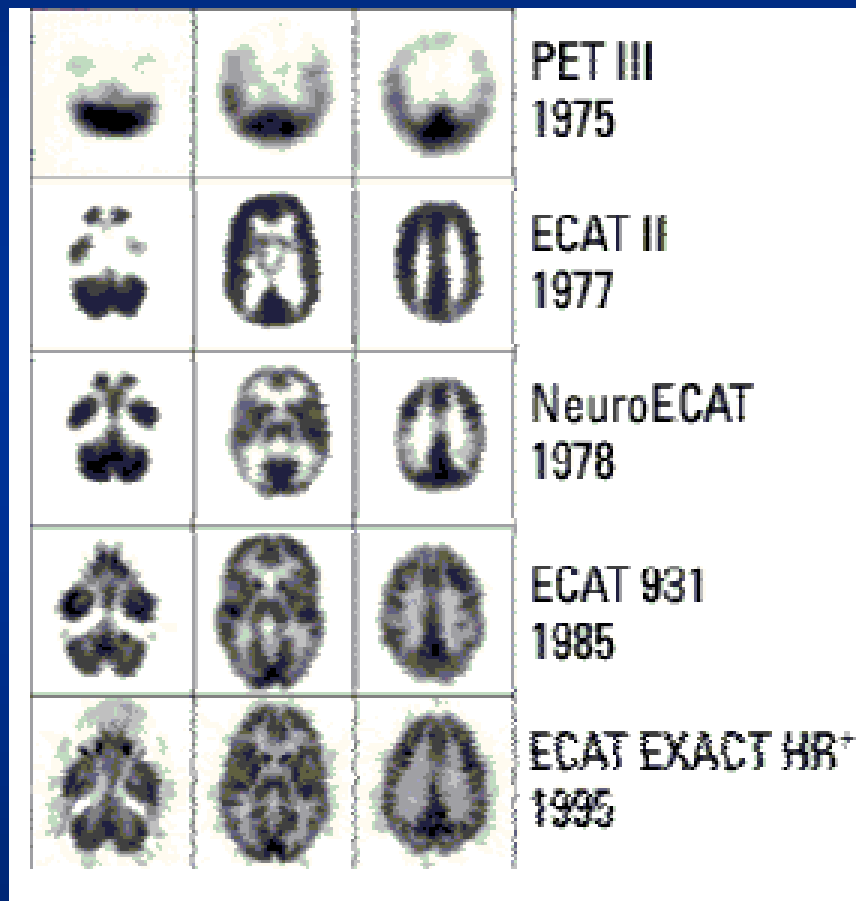
Positron Emission Tomography

- Diagnosis in vivo
- Patient is injected a radio-nuclides
 - ^{18}F , ^{11}C , ^{13}N , ^{15}O ...emits positrons
 - Annihilates with electrons inside the body



AIM: reconstruct the interaction point

Image reconstruction



Limits and deterioration factors:

- e^+ flight
- γ acollinearity
- Detector resolution
- Background events
- ...

HPD-PET project

- Use of particle physics expertise
- Build a PET detector providing:
 - High statistics
 - High spatial and energy resolution
 - Full 3D γ reconstruction
 - Free of parallax errors

Technology

- Scintillating crystals : YAP:Ce, LSO:Ce or LuAP:Ce
- Photo-detectors: Hybrid Photo-Diodes (R&D for LHCb)

CRYSTALS	HPD	
Hight light output	Energy resolution	Good energy resolution
Short decay time constant	Fast trigger	Short coincidences intervals

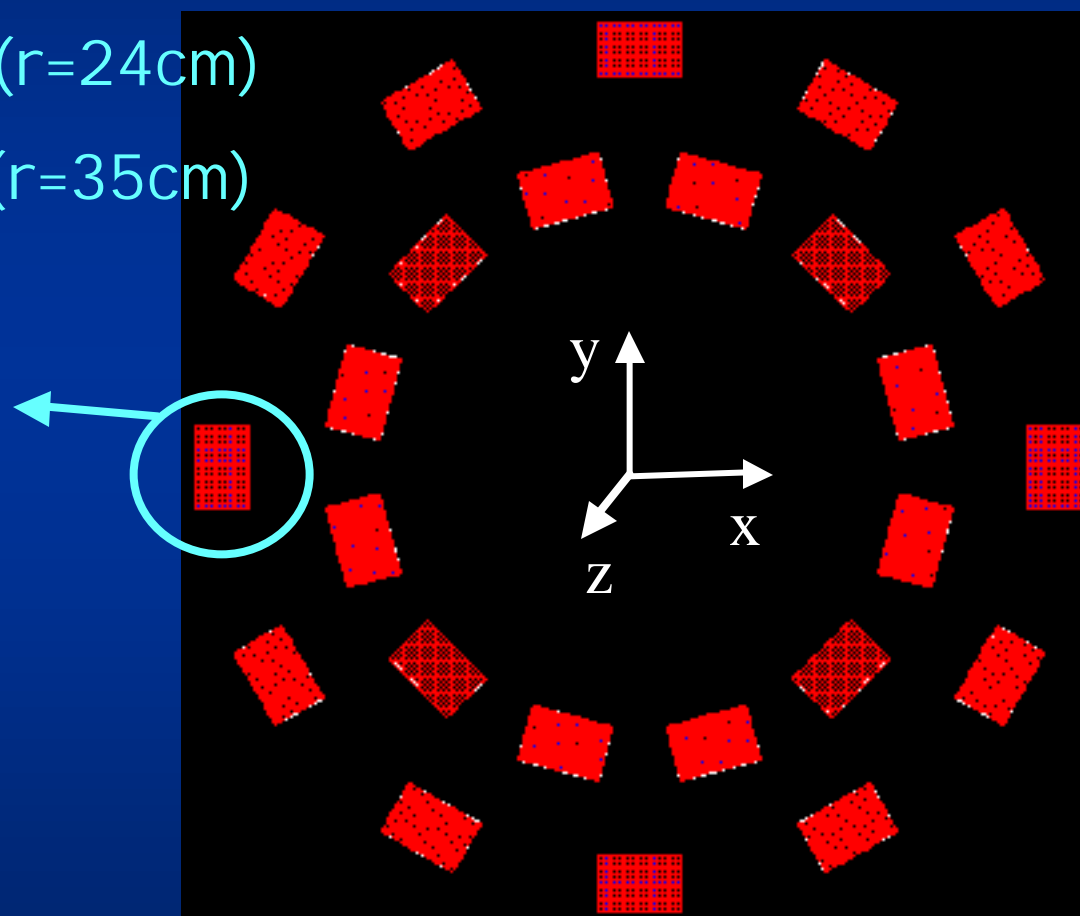
HPD-PET project

Brain PET scanner

- 12 inner modules ($r=24\text{cm}$)
- 12 outer modules ($r=35\text{cm}$)

Each module:

- ❑ Matrix of Scintillator crystals
- ❑ 2 Hybrid Photo-Diodes (HPD)



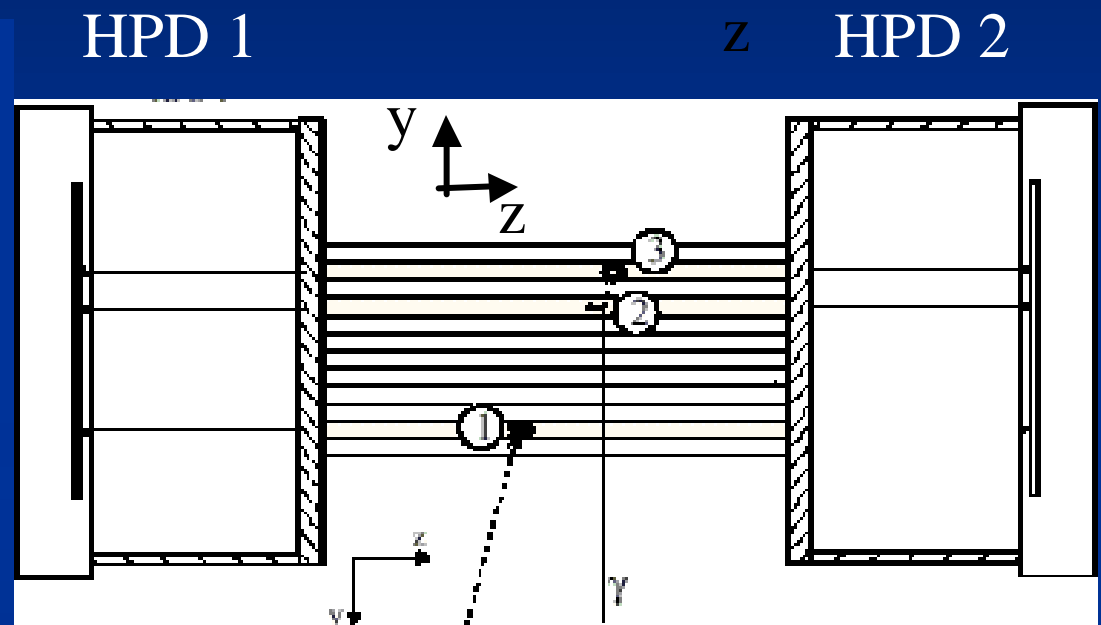
Module Section

Each module:

- matrix of 12x18 crystals
- 2 HPD tubes with segmentation matching the crystals

Each crystal:

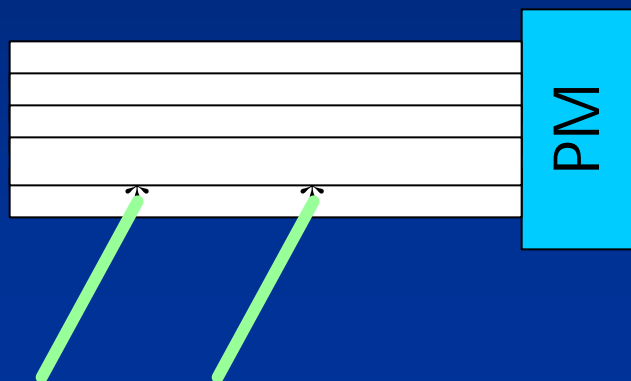
- 3.2x3.2x100 mm
- YAP:Ce first try



The fine segmentation of the crystals and the matching to the HPD silicon sensors → very good resolution in the XY plane ~2.5 mm (FWHM)

Depth Of Interaction

Standard PET:

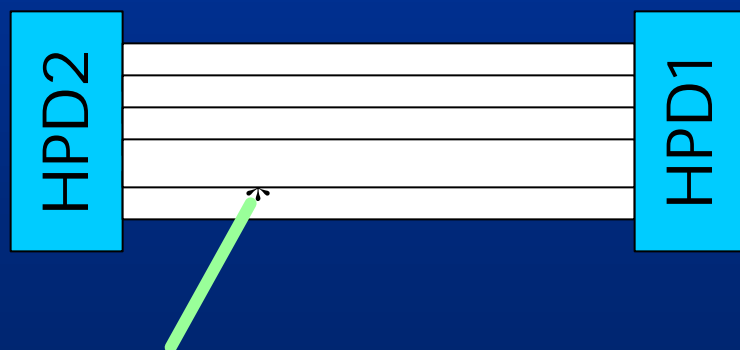


→ No measurement of the Depth Of Interaction

→ Parallax error in the reconstruction

New with this geometry:

□ Measurement of the Depth Of Interaction (DOI)



$$z = \frac{L}{2} \frac{Q_1 - Q_2}{Q_1 + Q_2}$$

→ X, Y and Z measured for each event

Zresol ~ 5mm

Crystals

Properties	BGO	YAP:Ce	LuAP:Ce	LSO:Ce
Density(g/cm ³)	7.1	5.55	8	7.4
Z (effective)	74	32	63	66
t (ns)	300	27	150	40
photons/MeV	9700	18000	14000	32000
l (nm) of max. emission	480	370	360	420
photo- fraction(%)	42	4	19	33

➤ YAP:Ce used as a first trial thought low photo-fraction

➤ Increase sensitivity using Compton events possible thanks to:

➤ full 3D reconstruction

➤ large detection volume

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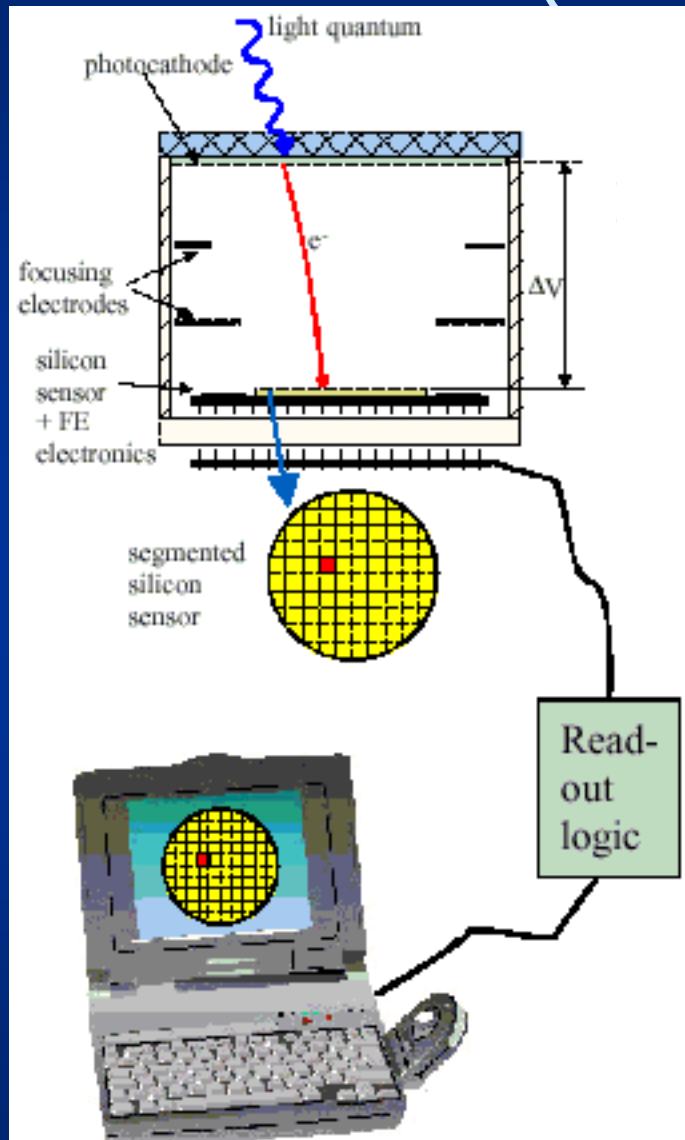
❑ LSO: will be considered but...

▪ too expensive

▪ not easy to cut 10cm.

❑ LuAP: studied at a later stage

HPD (designed for LHCb)

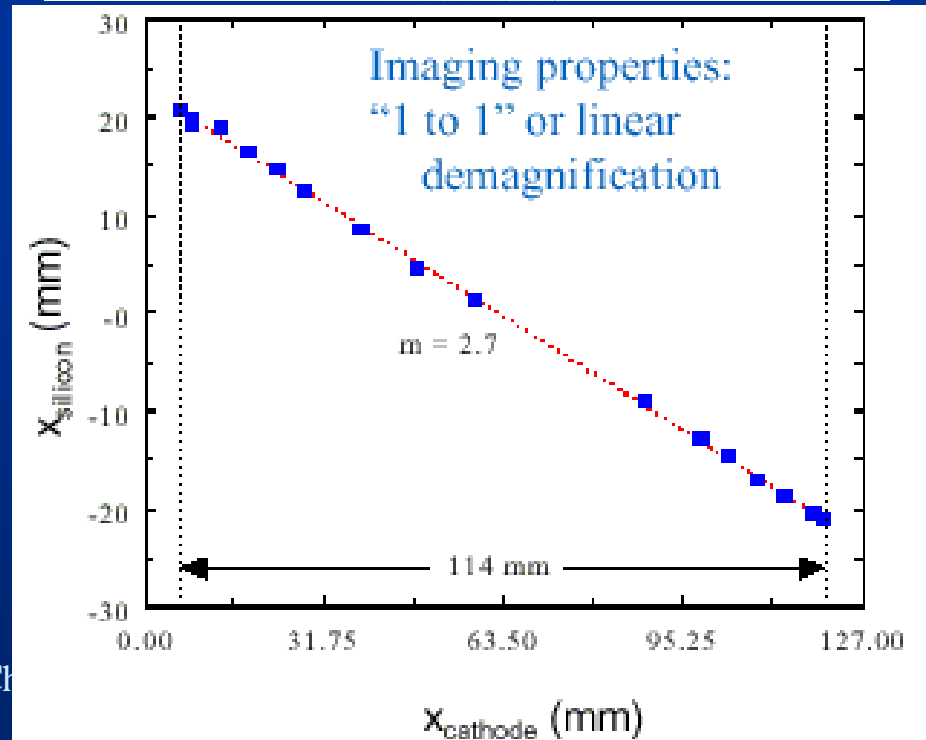
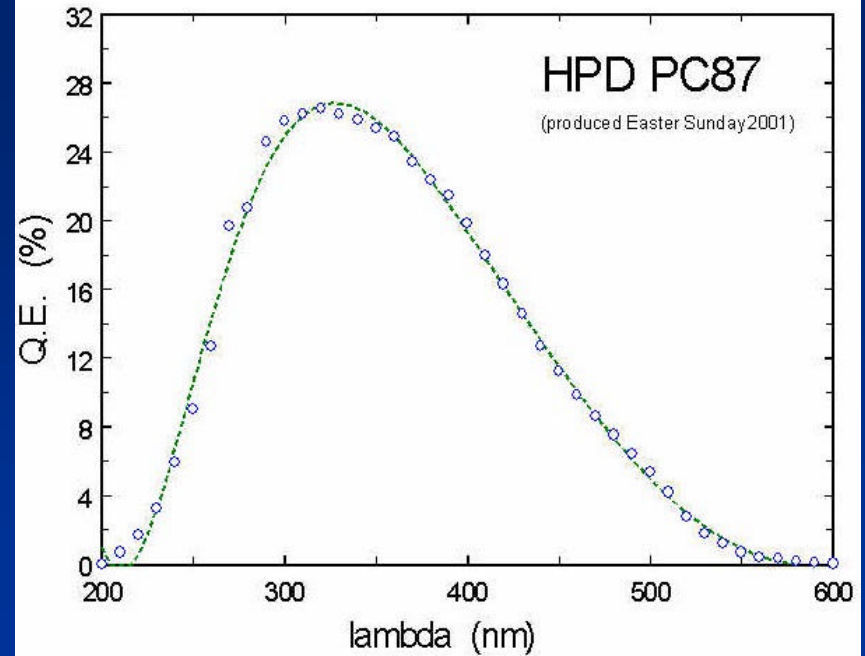


Developed
and built @



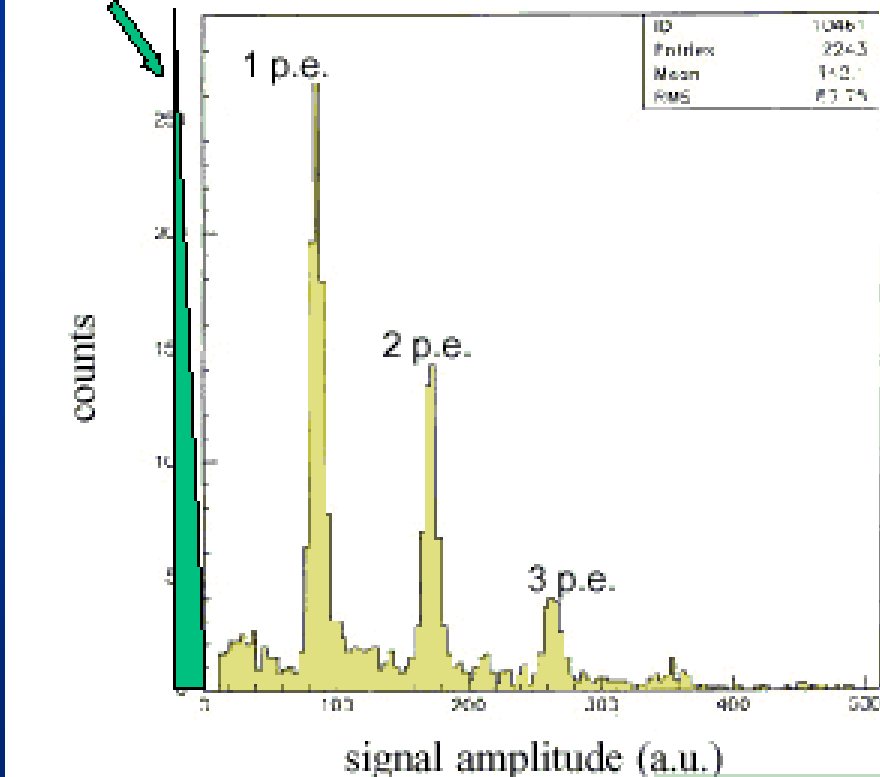
- Gain of HPD ~3000
- Design is modified for HPD-PET
 - Ceramic body
 - Flat entrance window

HPD combines single photon sensitivity of PMT with spatial and energy resolution of silicon sensors



Electronics noise well separated from signal

Signal definition and energy resolution

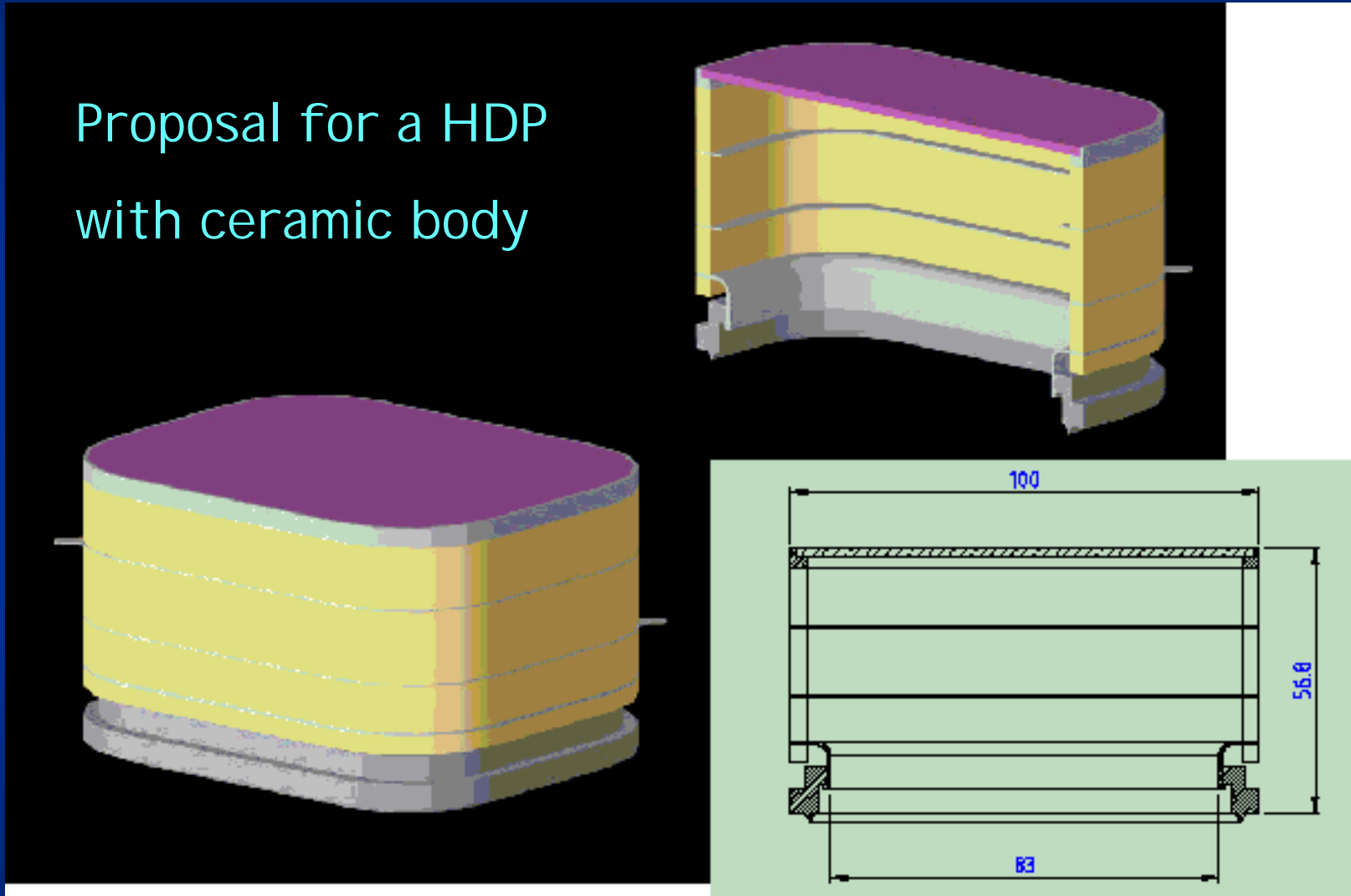


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New HPD design

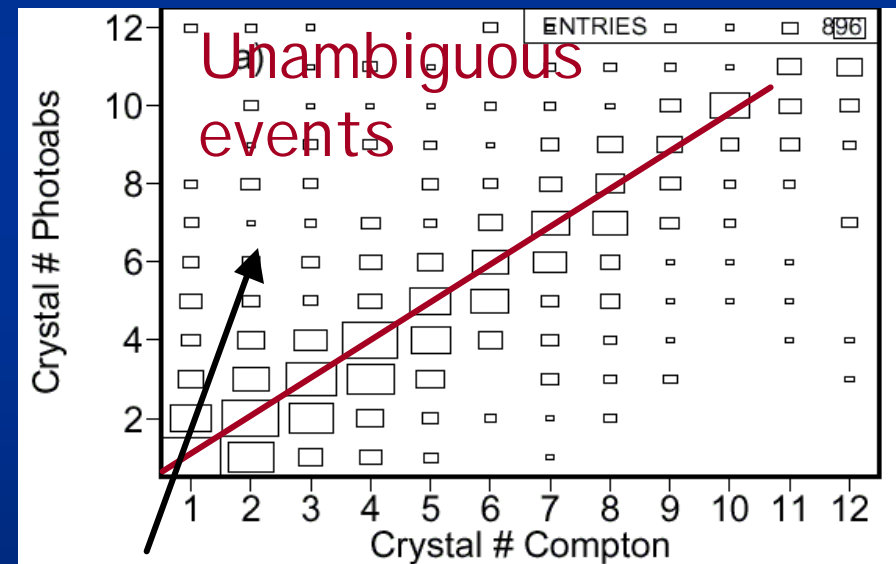
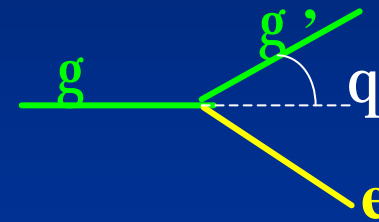
Proposal for a HDP
with ceramic body



Geant4 LowEnergy

- Simulates interaction of 511 KeV γ s with YAP (LSO)

	YAP	LSO
photoabs.	4%	34%
1Compton+ photoabs	10%	35%
1Compton+ Photoabs. Unambig.	2.5%	12%
Probability Detection in coincidence	0.45%	21%



Unambiguous events: the photo-absorption takes place in a crystal after the Compton

Collaboration and Funding

- **Institutes participating**
 - Bari
 - Rome
 - CERN
 - HUG
 - Univ. Geneva
- **Possible collaborators**
 - Ohio univ.
 - Ljubljana
- **The HPD-PET project is part of the CIMA collaboration (Compton Imaging for Medical Applications)**
- **Funding**
 - Bari
 - Rome
 - CERN HPD project
 - Univ. Geneva (own resources)
 - CERN ETT division has expressed intention to substantially contribute
- **Expression Of Interest sent to the EU**

Conclusions

- A novel concept of PET is proposed
 - 3D parallax-free PET with Compton enhancement
- R&D going on to optimize the design and materials of the modules
- First samples of crystals and slightly modified HPDs before end 2002