Positron Emission Tomography based on Resistive Plate Chambers

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SYMPOSIUM ON APPLIED NUCLEAR PHYSICS AND INNOVATIVE TECHNOLOGIES, JAGIELLONIAN UNIVERSITY CRACOW

June 4, 2013

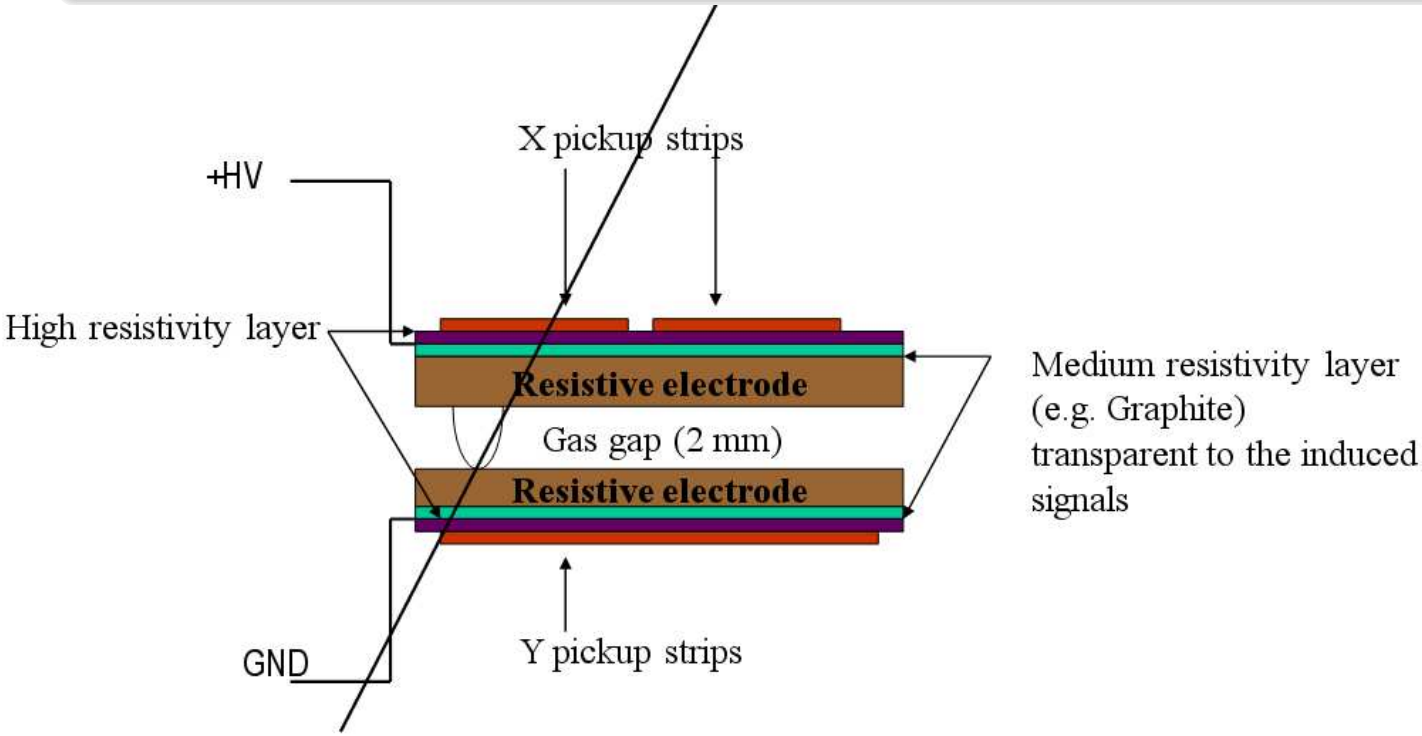
LIP · U · C · FCT Fundação para a Ciência e a Tecnologia MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR · QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007-2013 · Ciência.Inovação 2010 · Programa Operacional Ciência e Inovação 2010 MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR · União Europeia · Fundo Europeu de Desenvolvimento Regional

Outline

1. Introduction to resistive plate chambers

What are resistive plate chambers?

- Initially developed for high energy physics (HEP).
- Single-gap streamer-mode RPC used by the BABAR experiment:

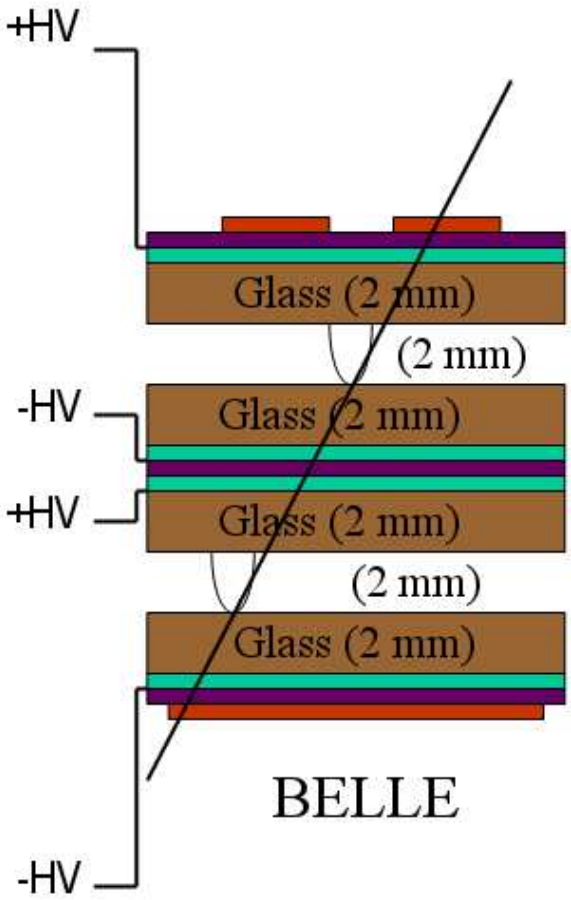


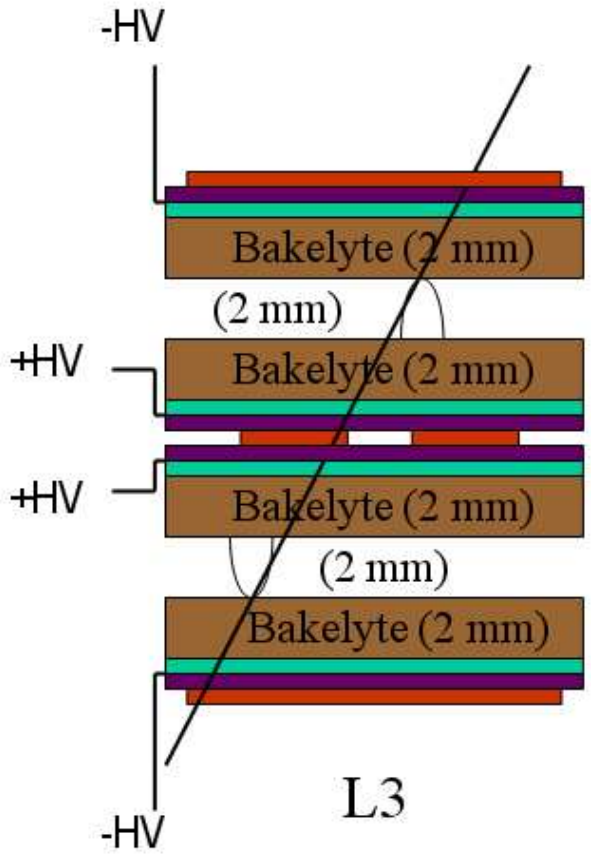
Fonte IEEE TNS 2002

1. Introduction to resistive plate chambers

What are resistive plate chambers?

- Initially developed for high energy physics (HEP).
- Double-gap RPCs used by the L3 and Belle exps.:





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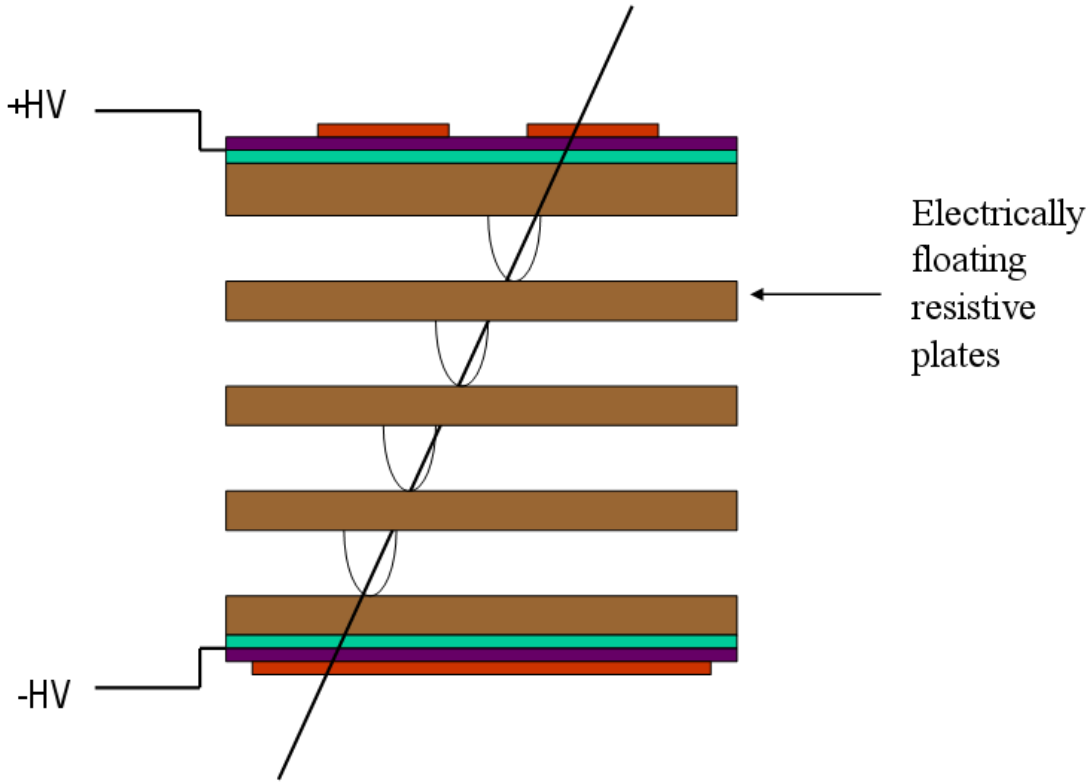
1. Introduction to resistive plate chambers

What are resistive plate chambers?

- Initially developed for high energy physics (HEP).
- Multigap RPC first proposed by Cerron Zeballos et al NIMA 1996:

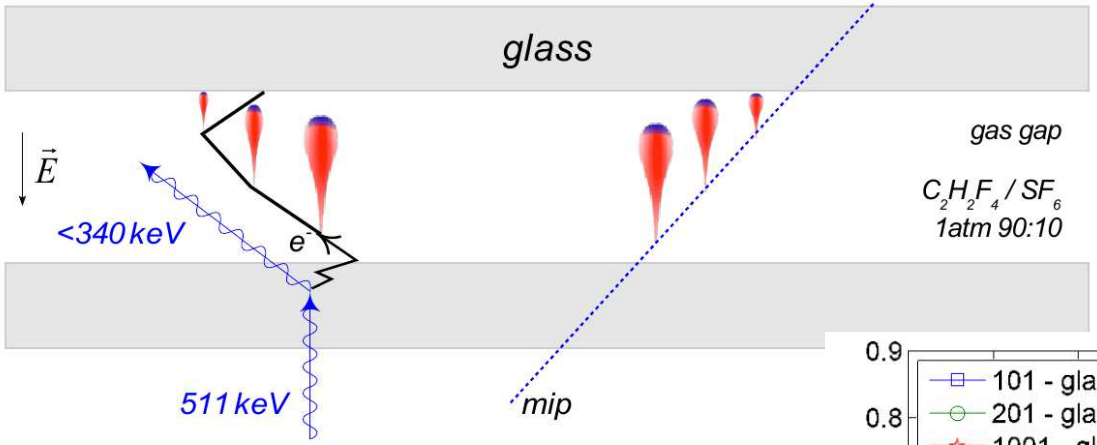


Fonte IEEE TNS 2002

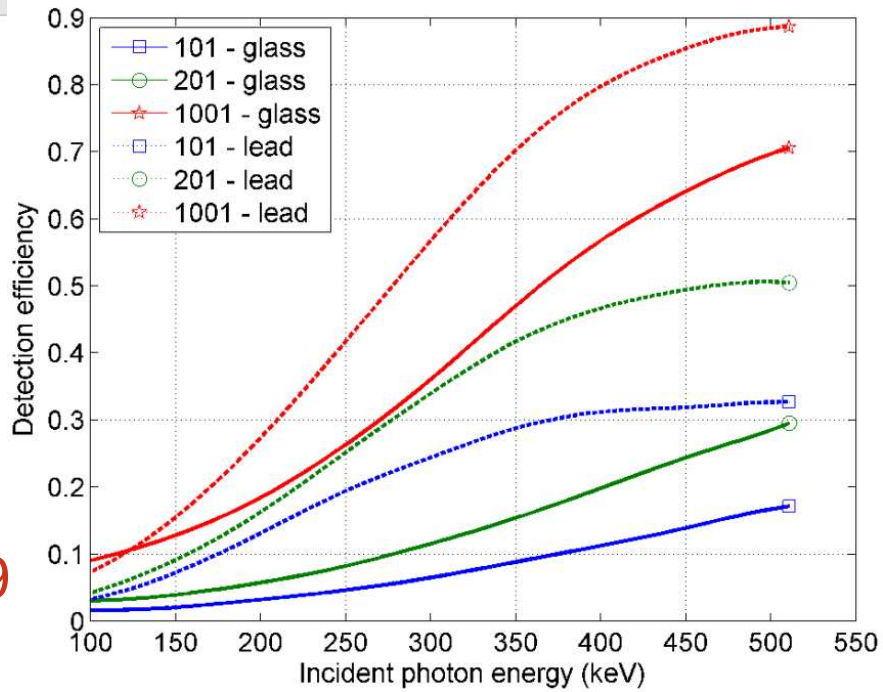
1. Introduction to resistive plate chambers

Converter plate principle

- Detecting electromagnetic irradiation (mostly γ-rays):



Neves MSc 2008

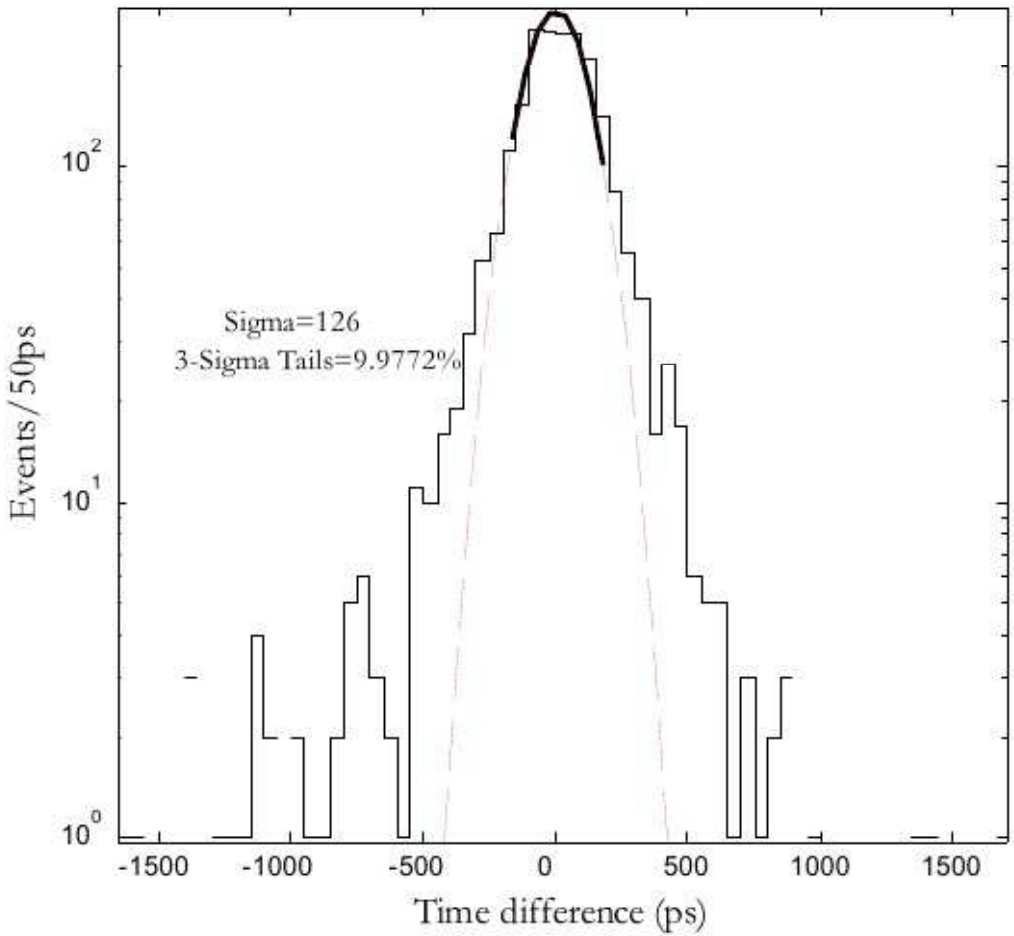


Blanco et al NIMA 2009

1. Introduction to resistive plate chambers

Coincidence time resolution

- Experimental time resolution obtained between two RPC detectors with 6 gaps each (Gouvêa MSc 2007)



2. Small-animal RPC-PET: preclinical

State-of-the-art small-animal PET:

- Technique experiences worldwide exponential growth supported e.g. by pharmaceutical industry and biomedical, fundamental science.

Raytest, Germany

Inveon DPET, Siemens

- Coming soon:
  aRPCPET, LIP, Portugal

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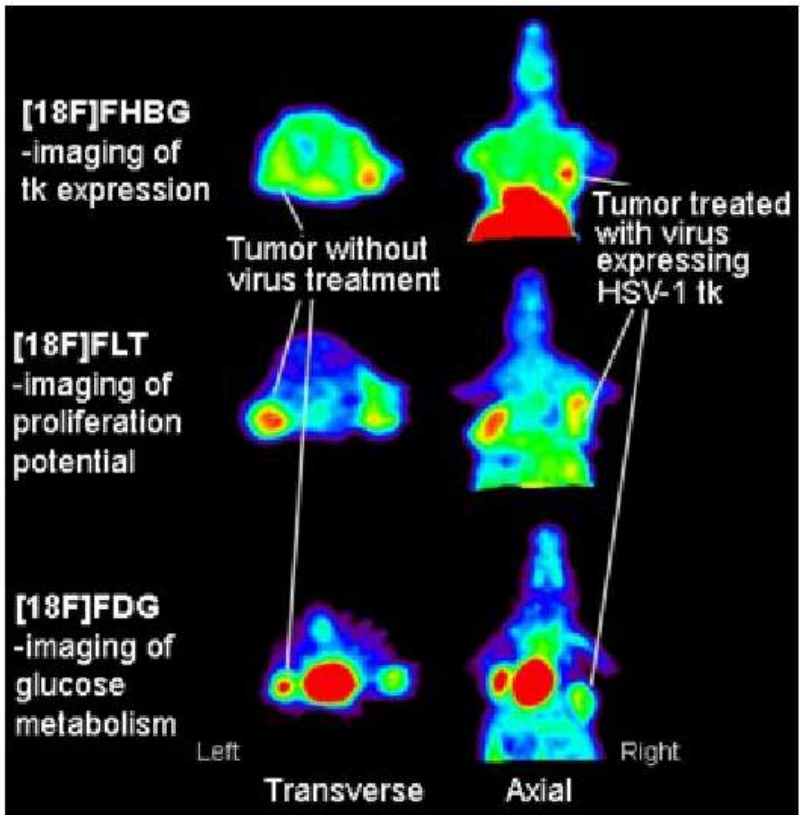
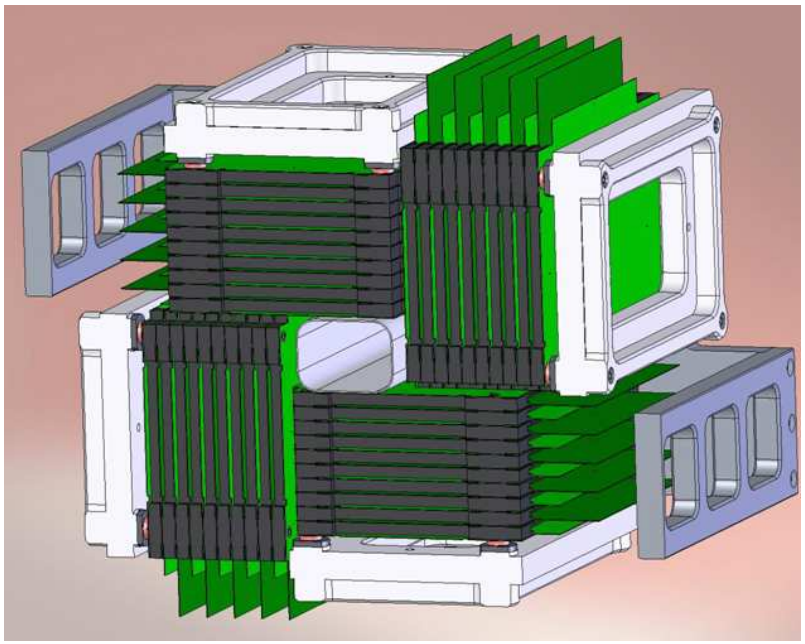


- From Athinoula Martinos Center for Biomedical Imaging
- FHBG = fluoro-hydroxy-metil-butil-guanine.
- HSV-1 = Herpes simplex virus-1.
- FDG = fluoro-desoxy-glucose.
- FLT = desoxy-fluorothymidine.

2. Small-animal RPC-PET: preclinical

Concept:

- LIP proposes innovative preclinical, small-animal RPC-PET (e.g. Blanco et al. TNS 2006) based on knowledge acquired from its developments within high energy physics projects.

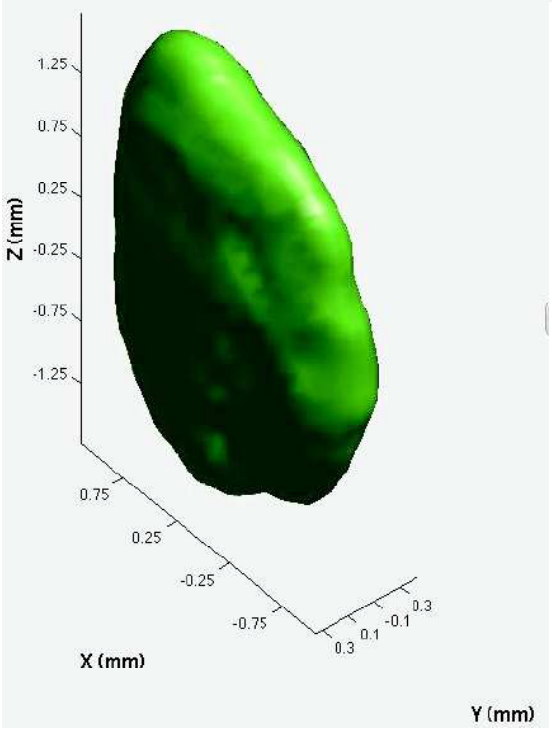


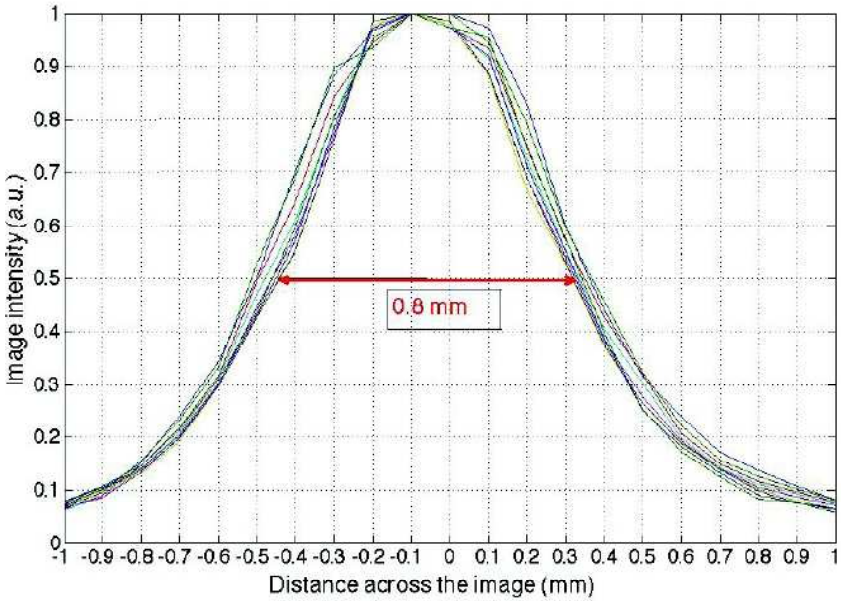
Full head, now being commissioned

2. Small-animal RPC-PET: pre-clinical

Implementation: ongoing experimental results surpass the spatial resolution of the state of the art for animal PET

- Imaging a disk-shaped radioactive source: sub-millimetric resolution achieved



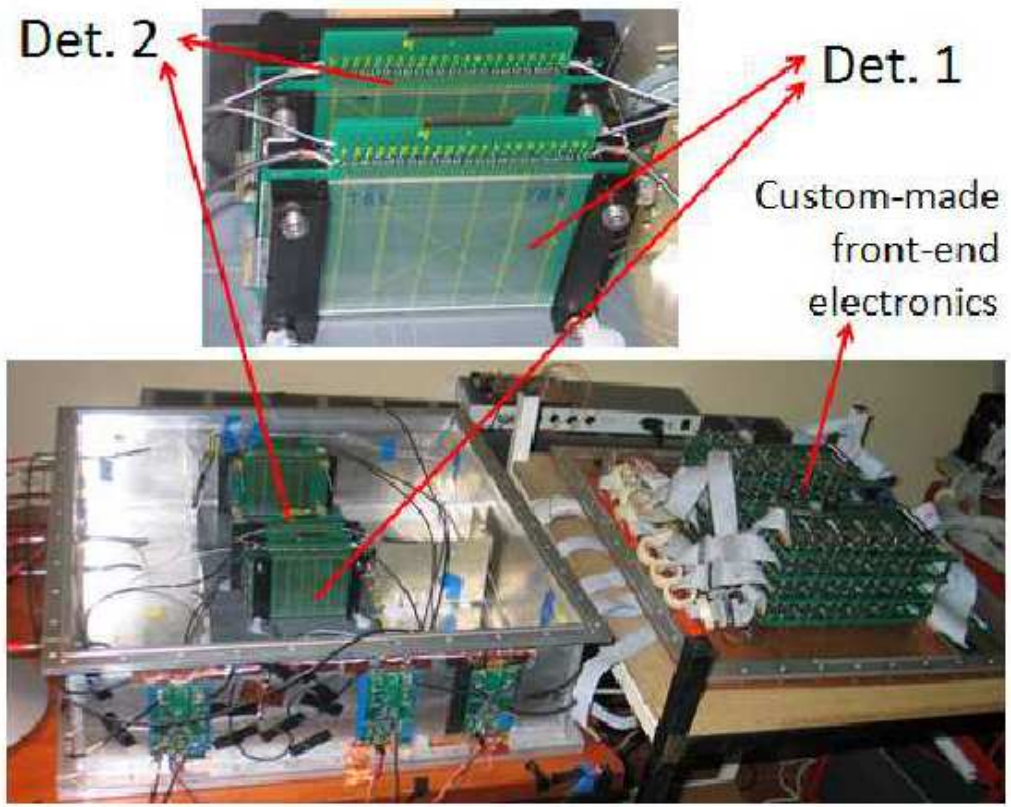


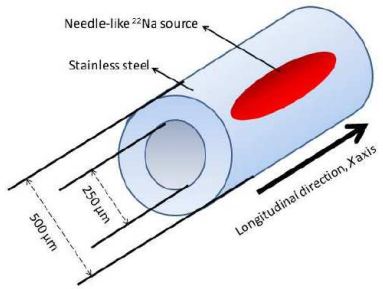
Martins et al 2012 IEEE NSS/MIC

2. Small-animal RPC-PET: pre-clinical

Implementation: ongoing experimental results surpass the spatial resolution of the state of the art for animal PET

- Imaging a needle-like radioactive source: sub-millimetric resolution achieved





Martins et al 2013 IEEE NSS/MIC, submitted

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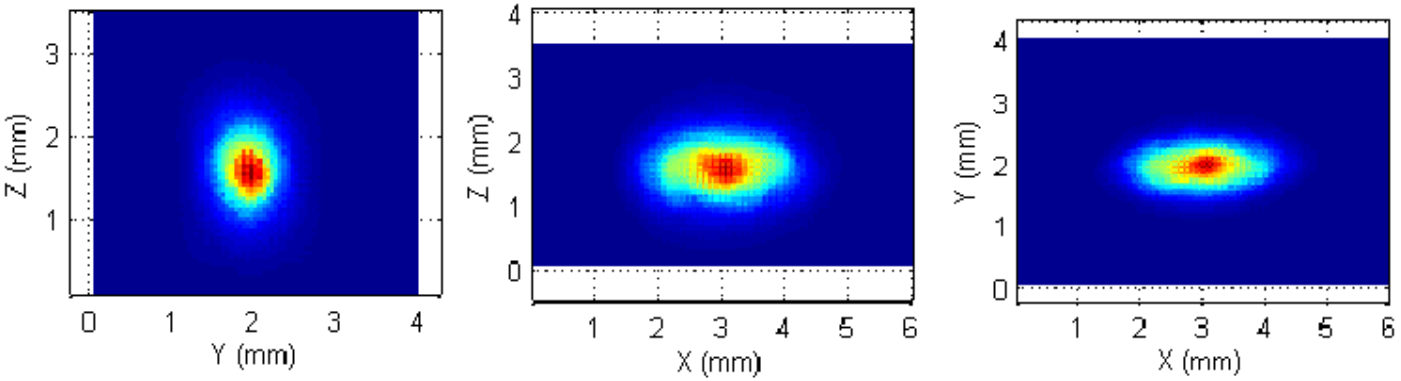

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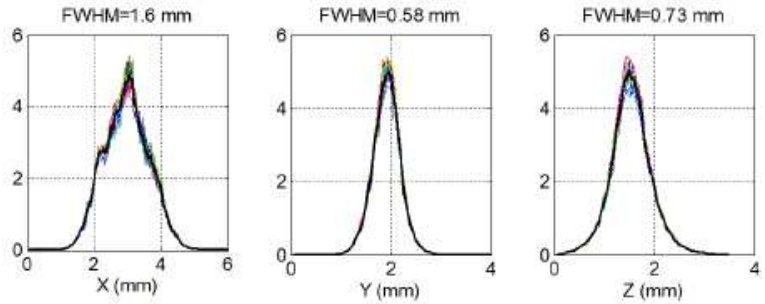
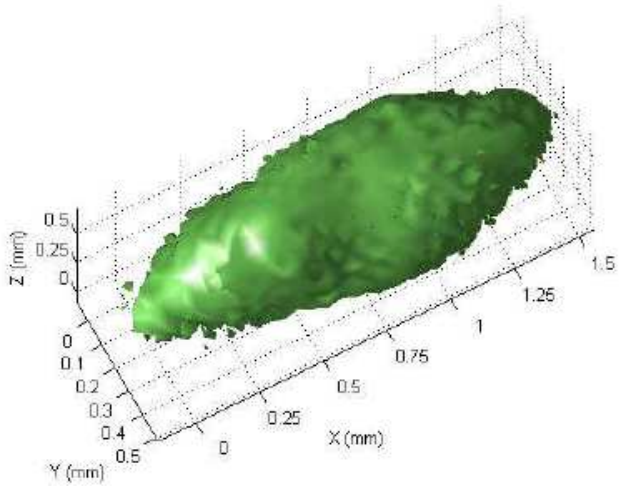


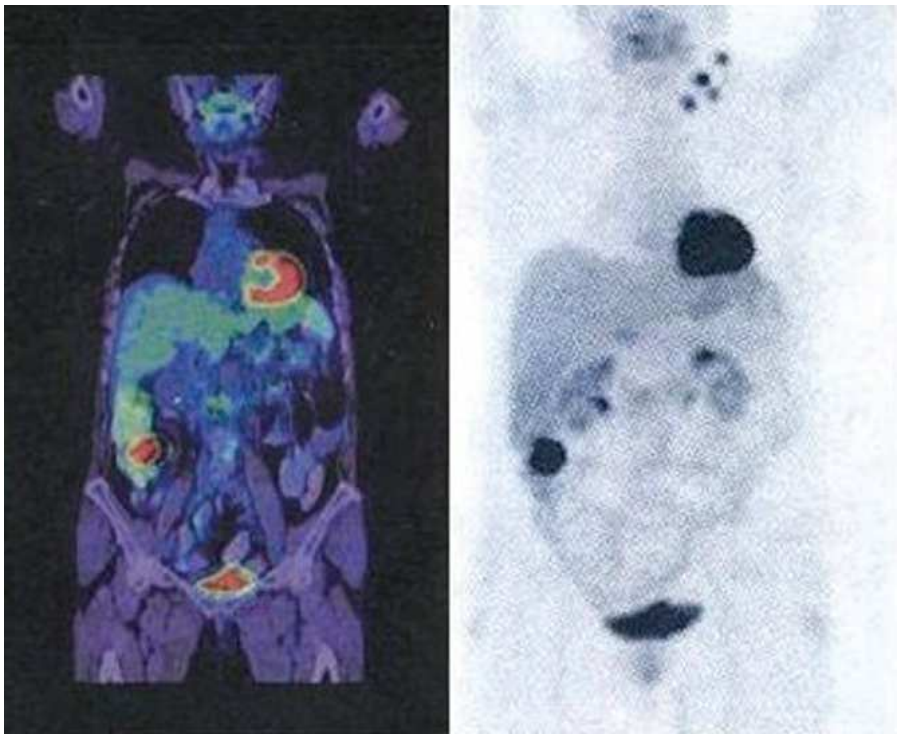


Martins et al 2013 IEEE NSS/MIC, submitted

3. Human single-bed whole-body RPC-PET

Rationale is based on state-of-the-art of PET (positron emission tomography):

- Technique experiences growing utilization in nuclear medicine, e.g. for diagnostic/screening/staging of oncologic, neurologic, and cardiac disease.

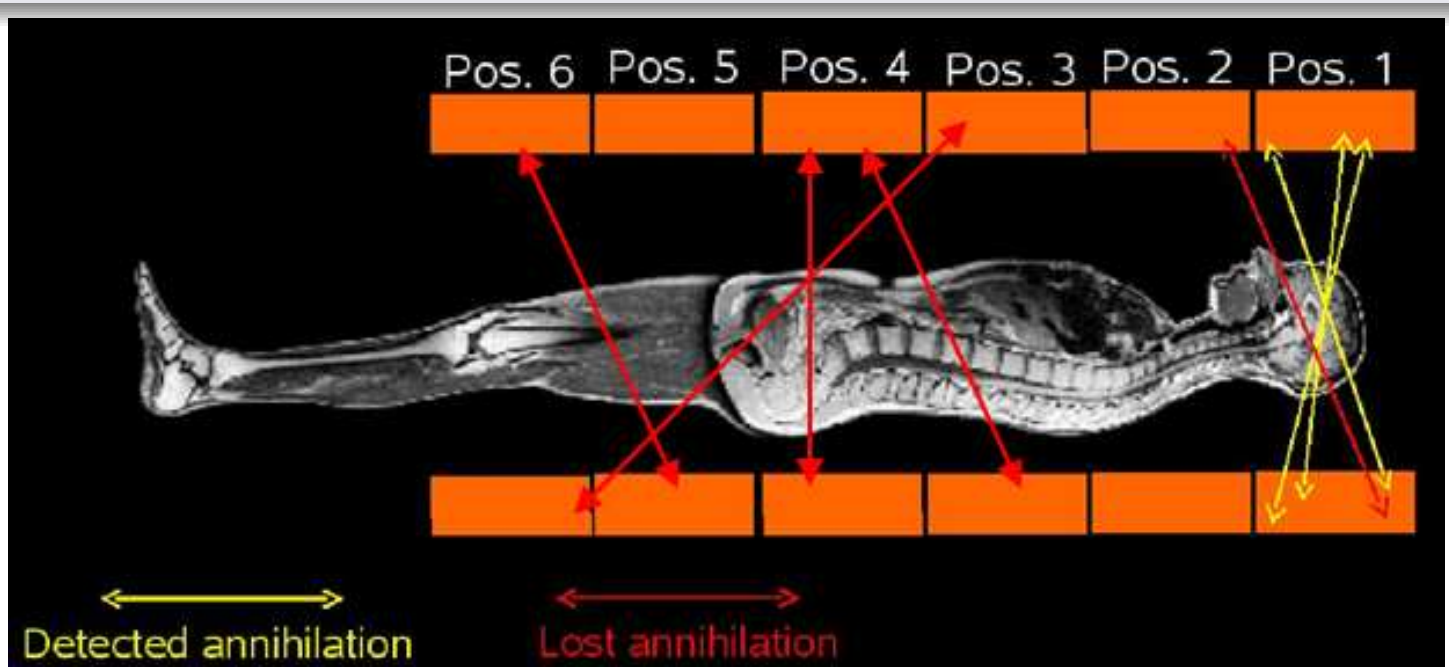


- E.g. Palmisano et al. Saudi J Gastroenterol 2011
- F, 64 a., symptoms: palpable supracavicular, ganglionic adenopathies, asthenia, anorexia.
- PET-based diagnostic: adenocarcinoma of the ascendent colon.

3. Human single-bed whole-body RPC-PET

Rationale:

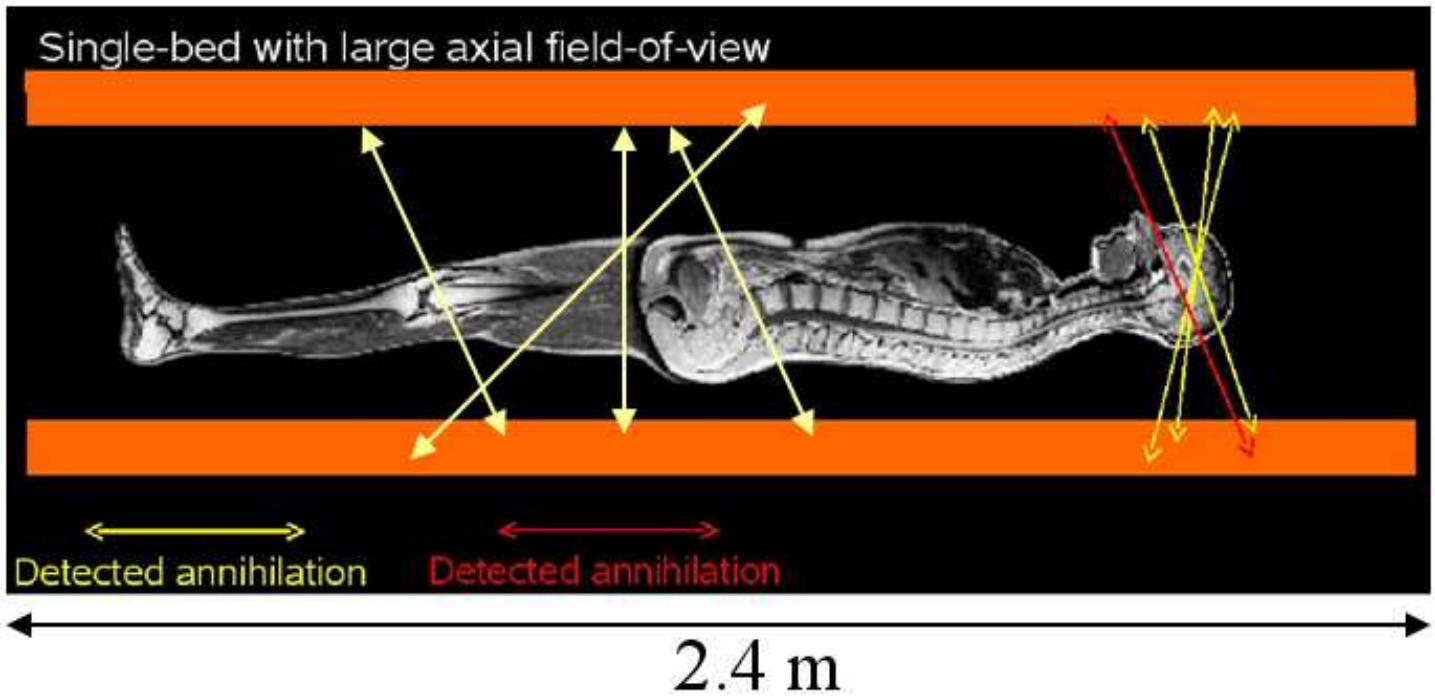
- PET technology is extremely costly (millions of €); patient examinations are equally costly (ca. 4000 €), lengthy in time, morphologically imprecise, often inconclusive when imaging small lesions (detectability, sensitivity, and specificity); and the patient bears a non-negligible amount of radiation dose.



3. Human single-bed whole-body RPC-PET

Rationale:

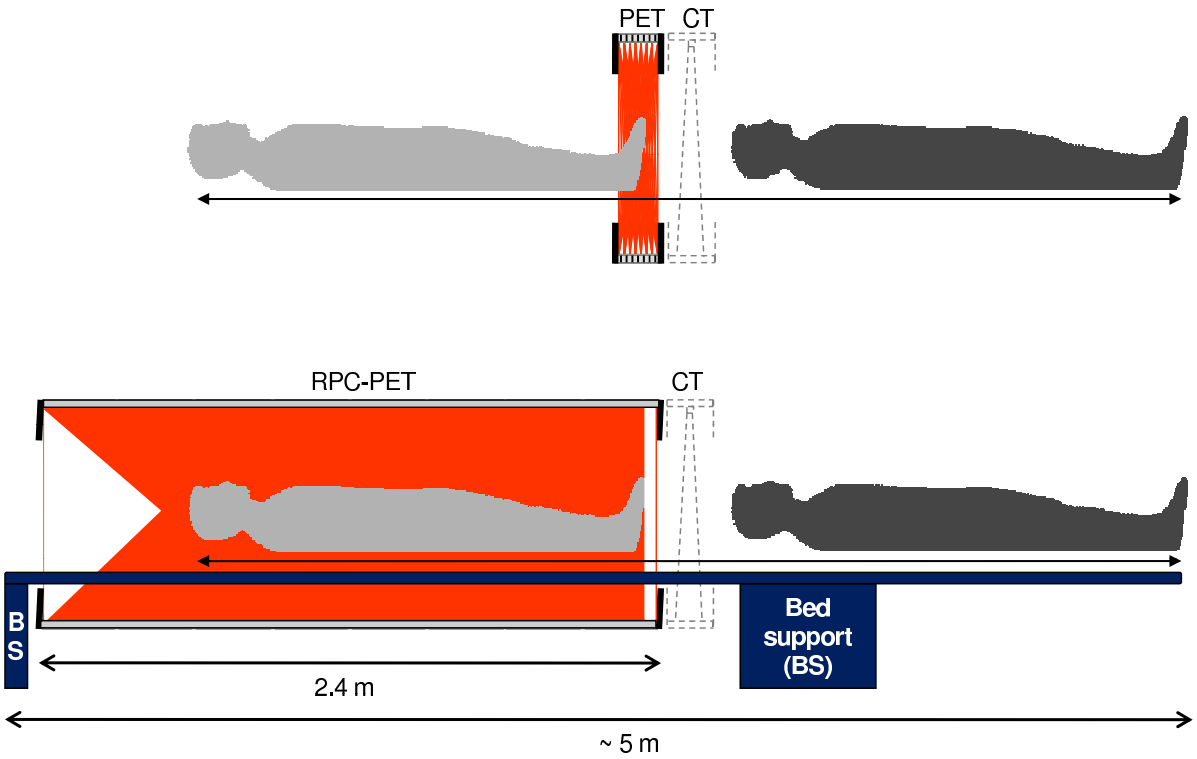
- Prohibitive price of scintillator crystals, and the enormous complexity of a full body system prevent its fabrication.
- But RPC (*resistive plate chamber*) technology already provides detectores covering areas of ca. m^2.



3. Human single-bed whole-body RPC-PET

Concept:

- LIP proposed totally innovative, whole-body RPC-PET system by applying to nuclear medicine its knowledge in detectors from high-energy physics (Fonte et al, Portuguese patent).



3. Human single-bed whole-body RPC-PET

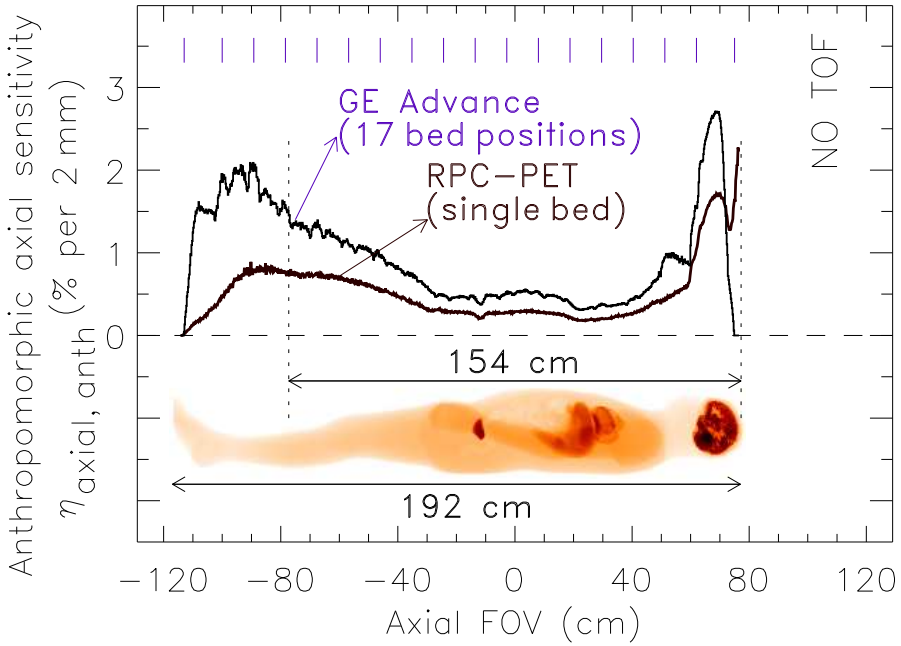
Implementation (hardware):

- Project PTDC/SAU-BEB/104630/2008: *RPC-PET – A novel technology for single-bed whole-body human molecular imaging with higher sensitivity and resolution*. Leader: Prof. João José Pedroso de Lima
- R&D in detectors and electronics

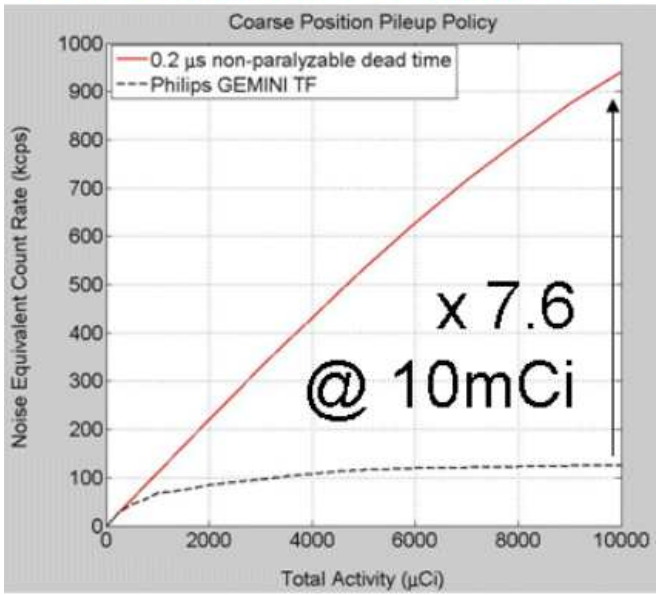
3. Human single-bed whole-body RPC-PET

Implementation (software):

- R&D in Monte Carlo (simulation)



NEMA 2001 **full simulation**
Noise-equivalent counting rate



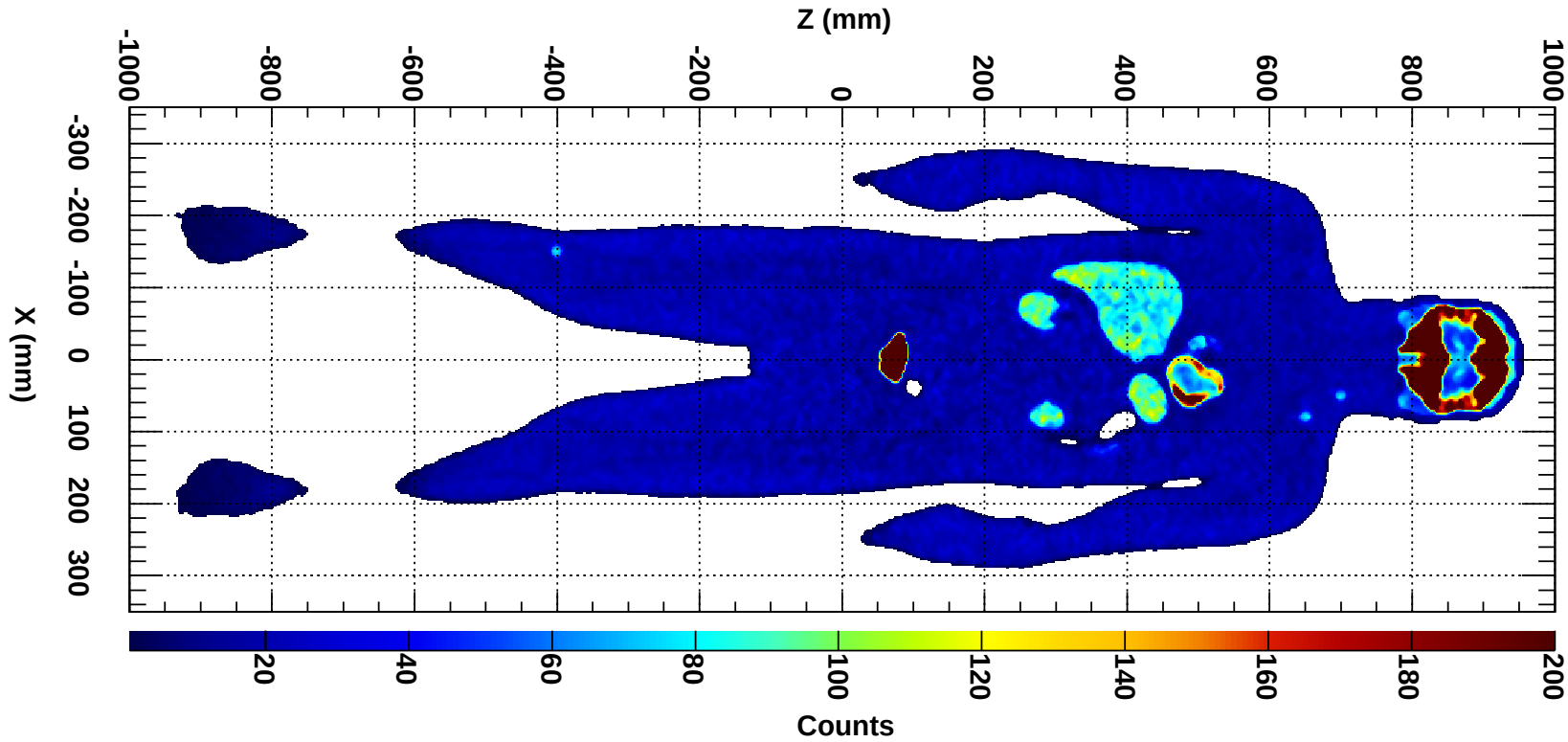
- Studies suggest increase in system sensitivity larger than 7 in respect to top tomographs on the market

Crespo et al TNS 2012, Couceiro et al 2012 IEEE NSS/MIC

3. Human single-bed whole-body RPC-PET

Implementation (software):

- R&D in simulation and reconstruction



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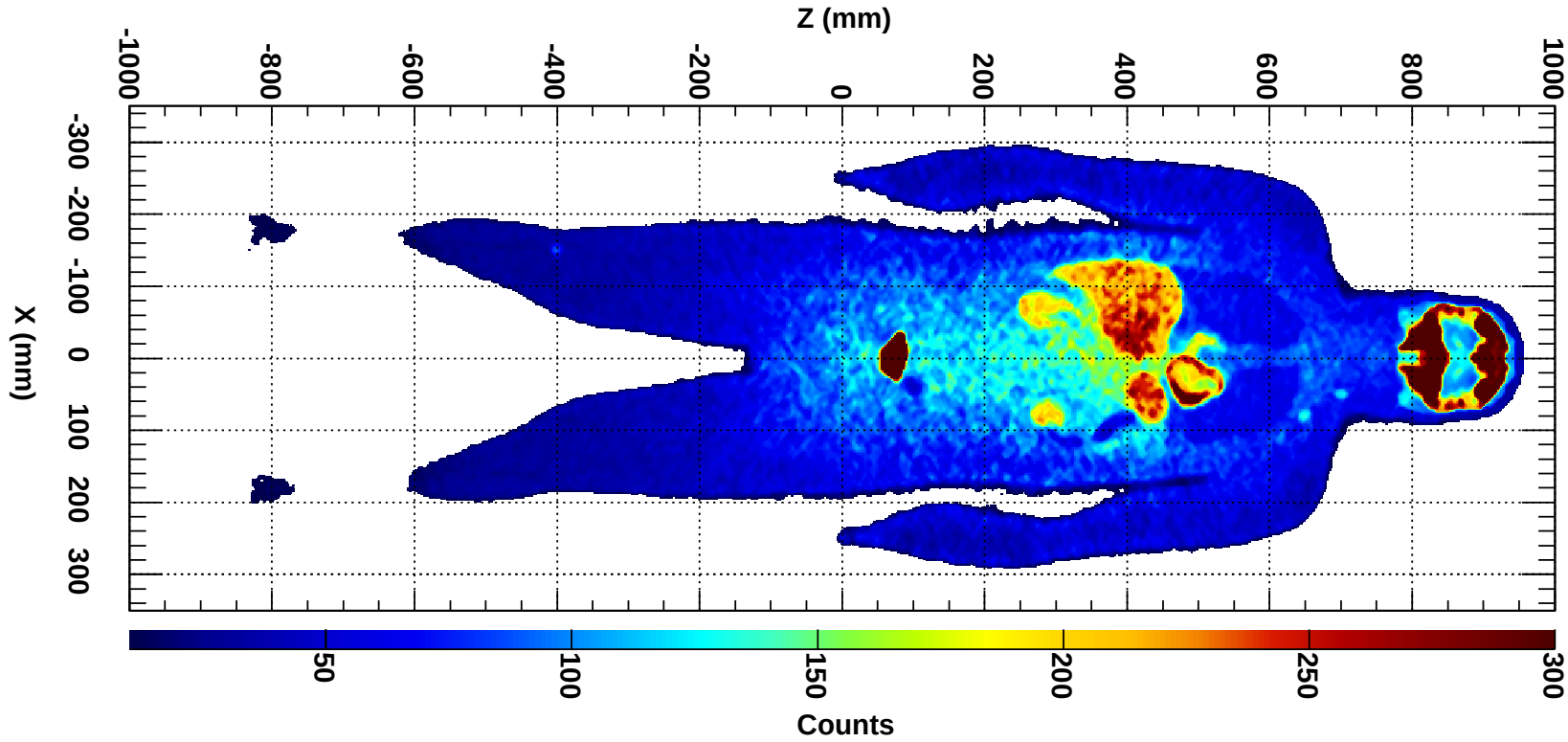

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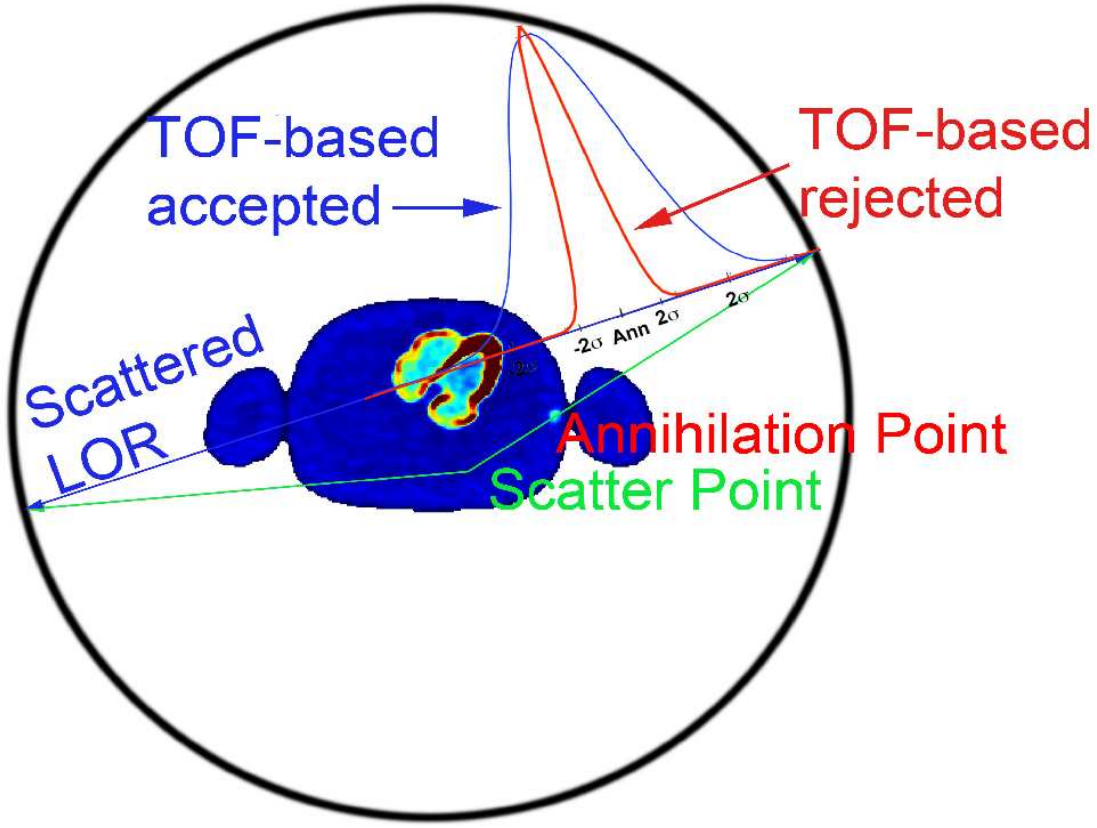
3. Human single-bed whole-body RPC-PET

Implementation (software):

- R&D in simulation and reconstruction based on the time-of-flight capabilities of RPC detectors for PET:



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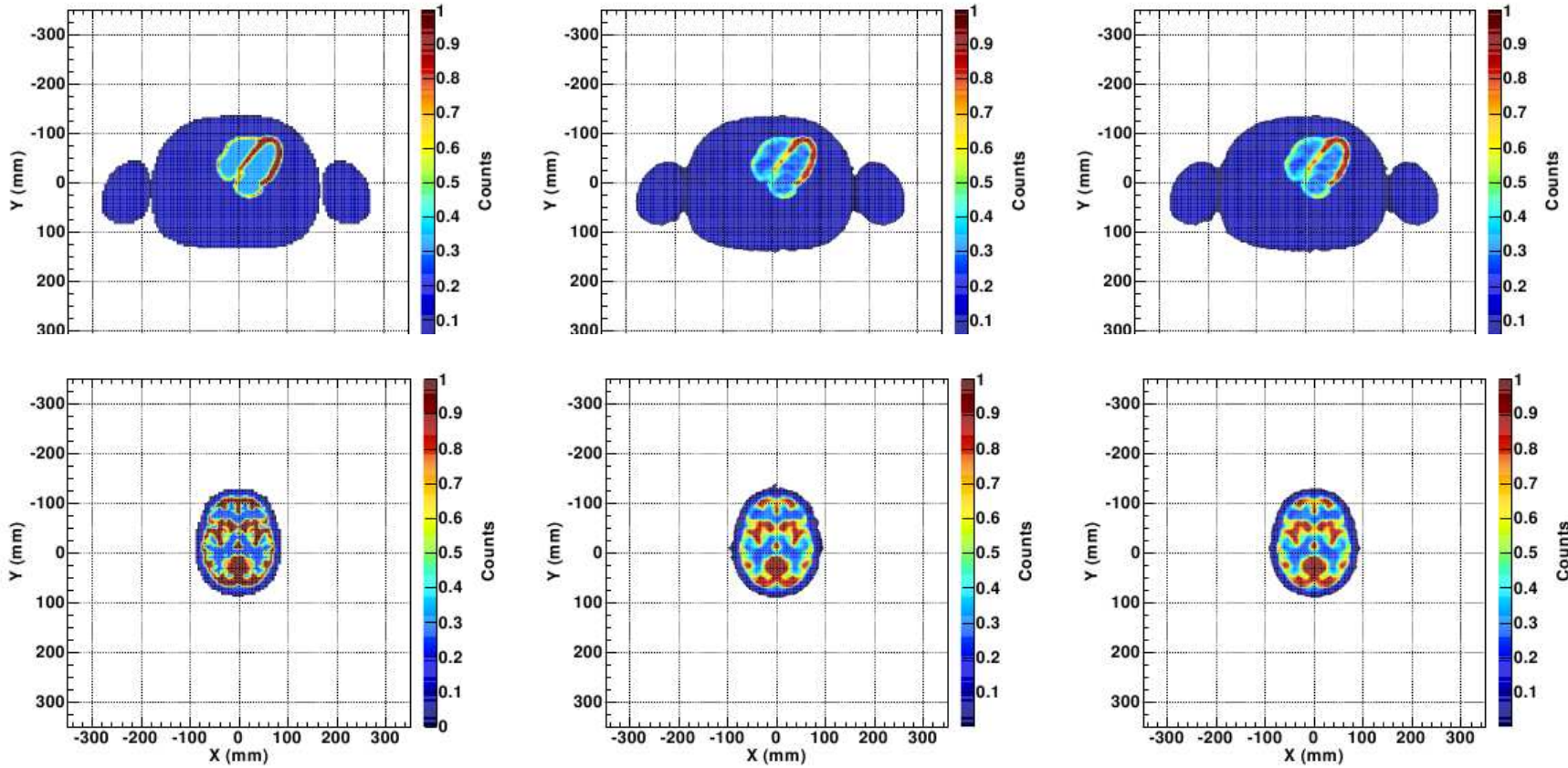

Martins PhD, in submission

Acknowledgment (RPC-PET):

A equipa de RPC-PET

Researchers and engineers				*Technicians*	
Name	**Institute**	**Name**	**Institute**	**Name**	**Institute**
Adriano Rodrigues	ICNAS/FMUC	Luís Mendes	FMUC	Americo Pereira	LIP
Alberto Blanco	LIP	M. Kajetanowicz	NE	Carlos Silva	LIP
Antero Abrunhosa	ICNAS	Marek Palka	IKF	João Silva	LIP
Carlos Silvestre	ISEC	Michael Traxler	GSI	Joaquim Oliveira	LIP
Custódio Loureiro	FCTUC	Miguel Couceiro	LIP/ISEC/FCTUC	Nuno Carolino	LIP
Durval Costa	HPP	Miguel Oliveira	LIP	Ricardo Caeiro	LIP
Filomena Clemêncio	FCTUC	Nuno Chichorro	ICNAS/FMUC		
Francisco Caramelo	FMUC	Orlando Oliveira	LIP		
Grzegorz Korcyl	JU	Paulo Crespo	LIP		
Isabel Prata	IBILI	Paulo Fonte	LIP/ISEC		
Jan Michel	IKF	Paulo Martins	LIP		
J.J. Pedroso Lima	LIP	Rui Alves	LIP		
Jorge Landeck	FCTUC	Rui F. Marques	LIP/FCTUC		

FCTUC: Departamento de Física da Faculdade de Ciências e Tecnologia da Universidade de Coimbra.
FMUC: Faculdade de Medicina da Universidade de Coimbra.
GSI: Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany
HPP: Hospitais Privados do Porto, Porto, Portugal
IBILI: Instituto Biomédico de Investigação da Luz e Imagem da Faculdade de Medicina da Universidade de Coimbra
ICNAS: Instituto de Ciências Nucleares Aplicadas à Saude da Universidade de Coimbra, Coimbra, Portugal.
IKF: Institut für Kernphysik, Goethe-Universität, Frankfurt, Germany
ISEC: Instituto Superior de Engenharia de Coimbra, Coimbra, Portugal.
JU: Jagiellonian University of Cracow, Cracow, Poland.
LIP: Laboratório de Instrumentação e Física Experimental de Partículas, Coimbra, Portugal.
NE: Nowoczesna Elektronika, Crakow, Poland

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C.M.B.A. Correia[2], L. Fazendeiro[1], M.F. Ferreira Marques[4,5], C. Gil[4], M. P. Macedo[2,5]

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4 ICEMS, Departamento de Física, Universidade de Coimbra, 3004-516 Coimbra, Portugal.
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Thank you

for your attention