Resistive Plate Chambers for PET

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LIP
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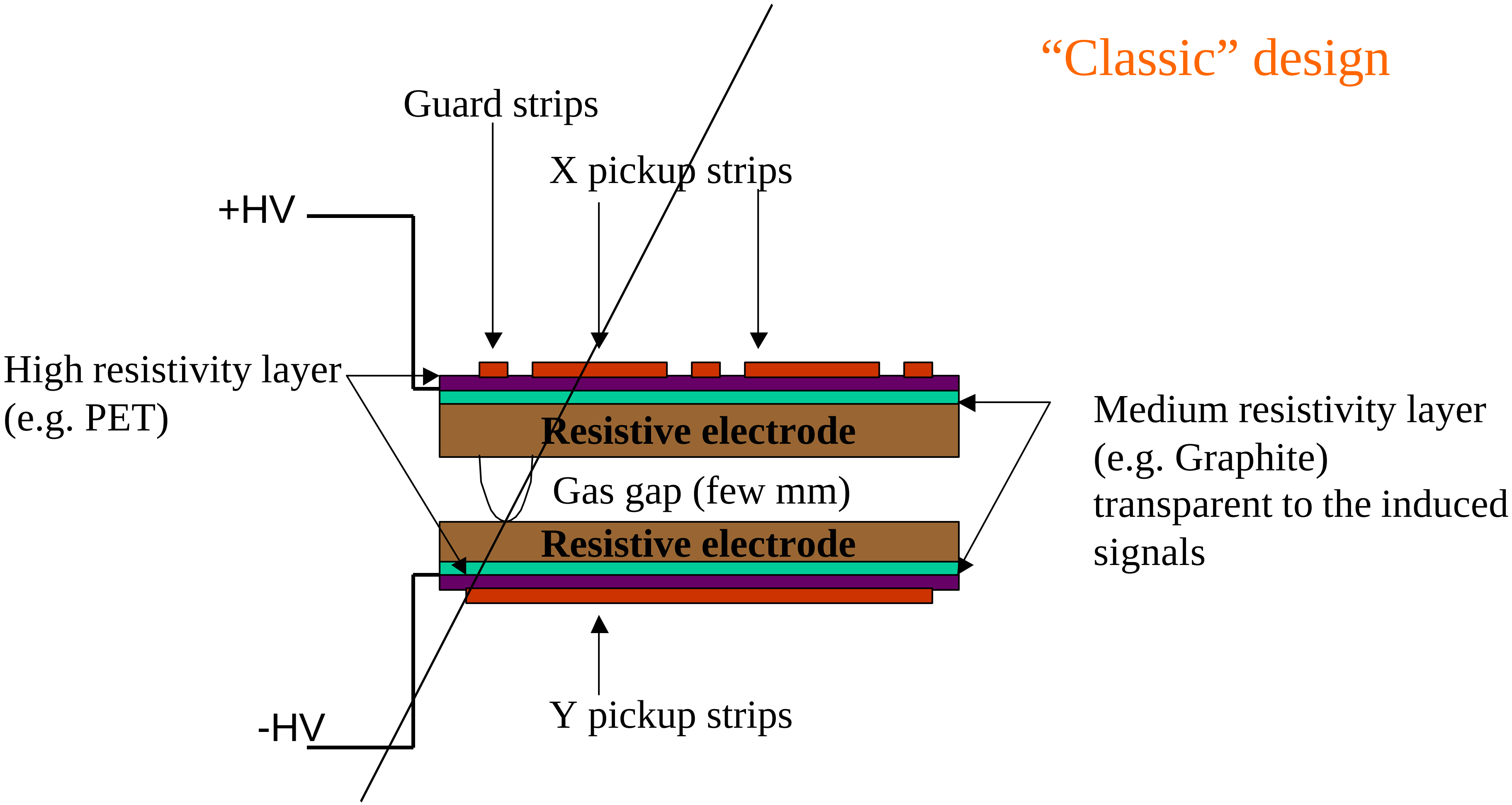
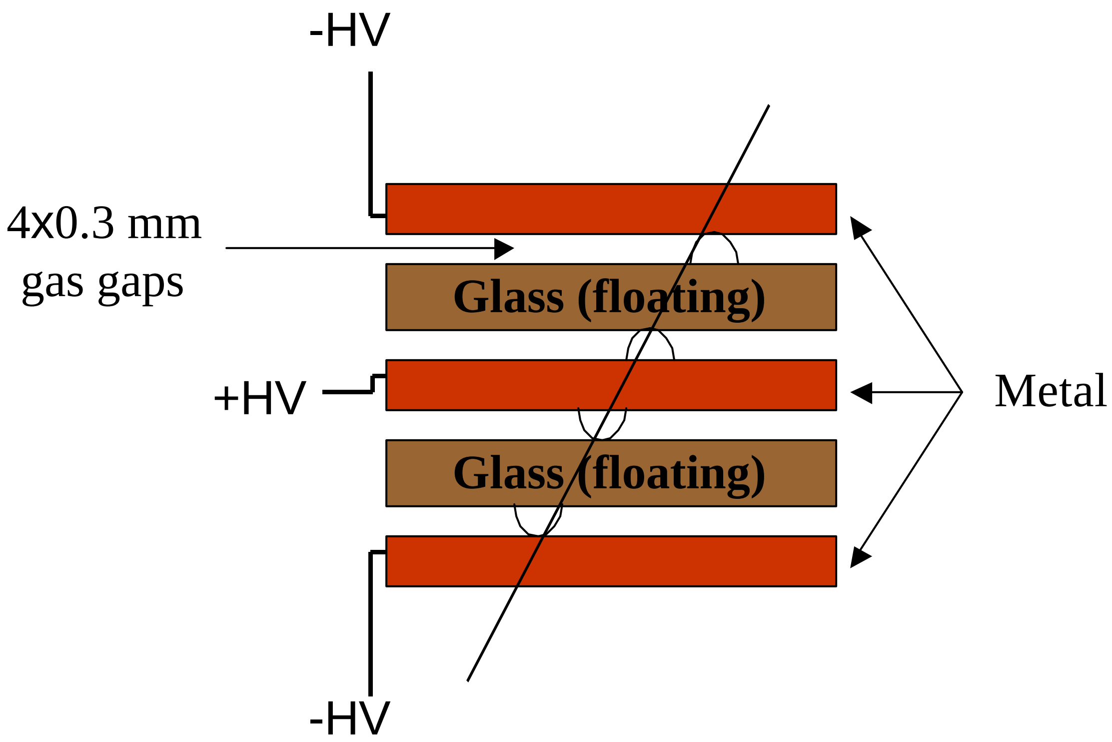
Resistive Plate Chambers:

planar gaseous counters made with resistive electrodes or metalic+resistive electrodes.

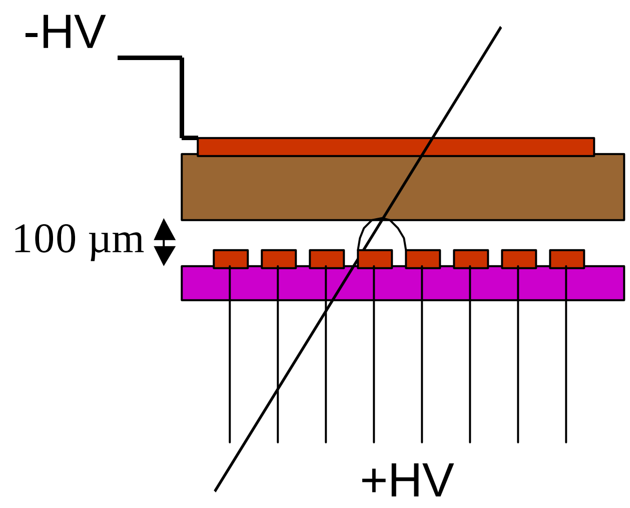
“Classic” design



Some novelties



Timing glass-metal RPC
for TOF measurements
σ=50 ps, ε=99%

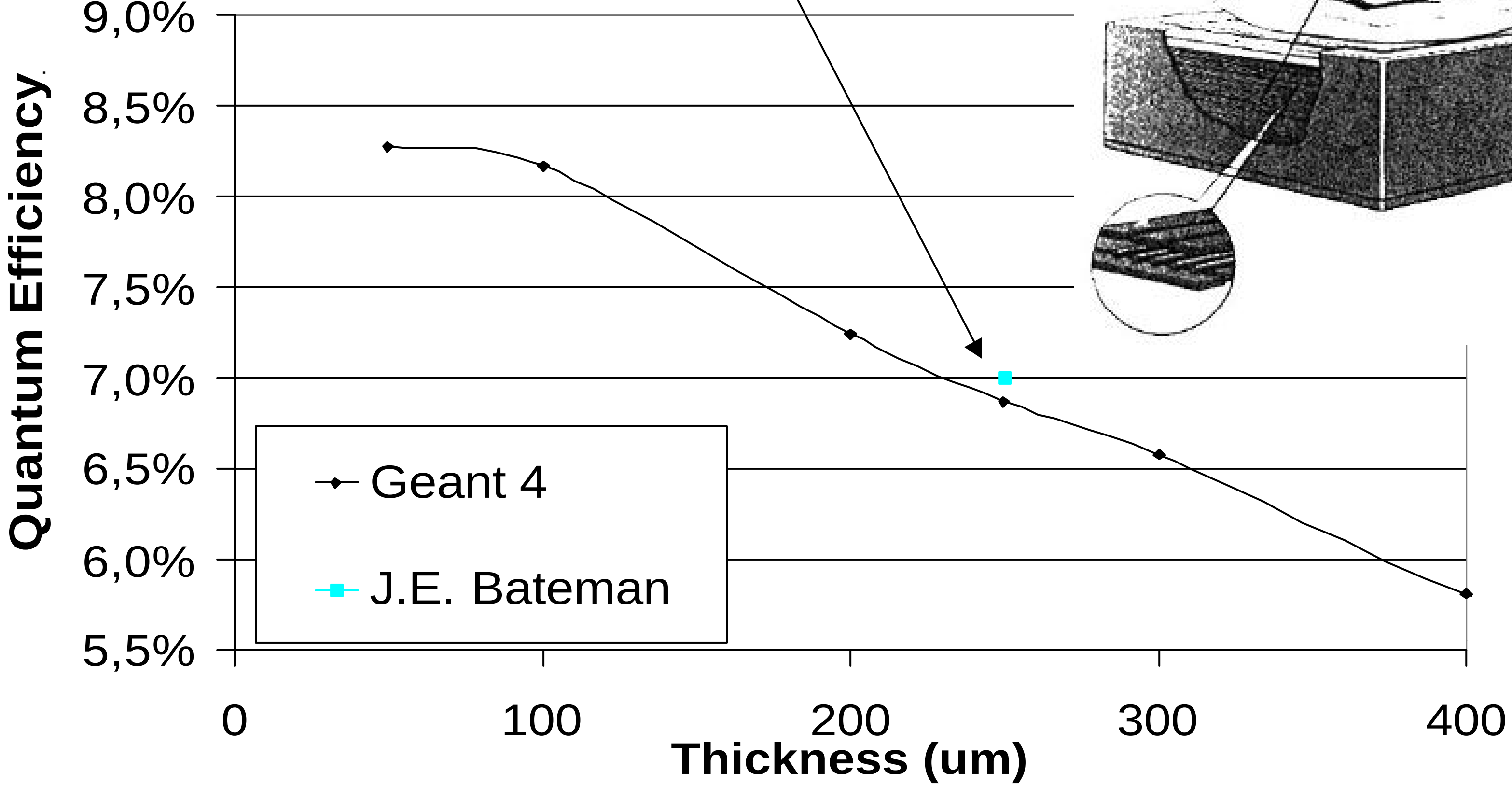


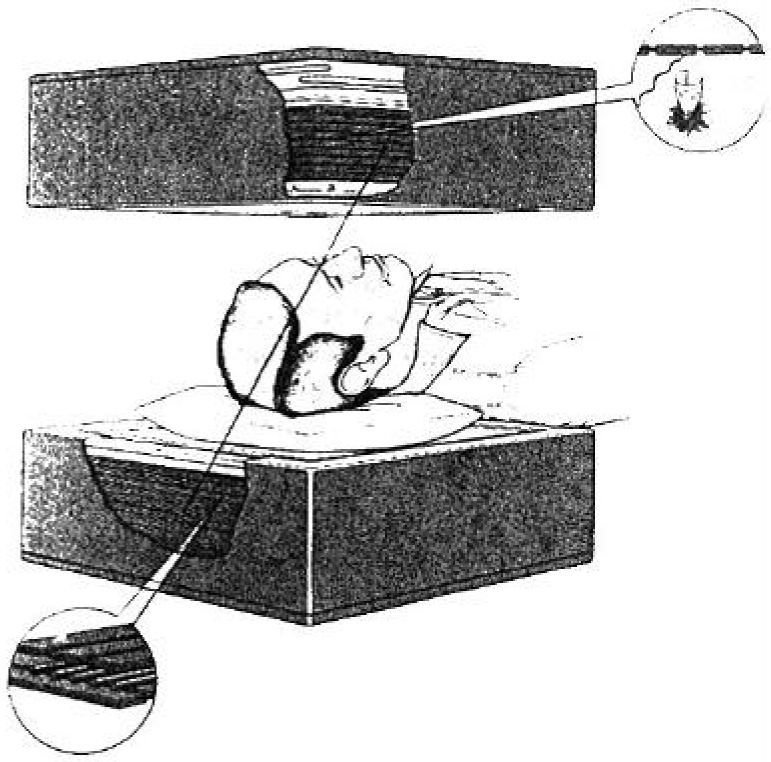
Micro-RPC
for accurate position
measurements
≈30 µm FWHM

Converter-plate principle

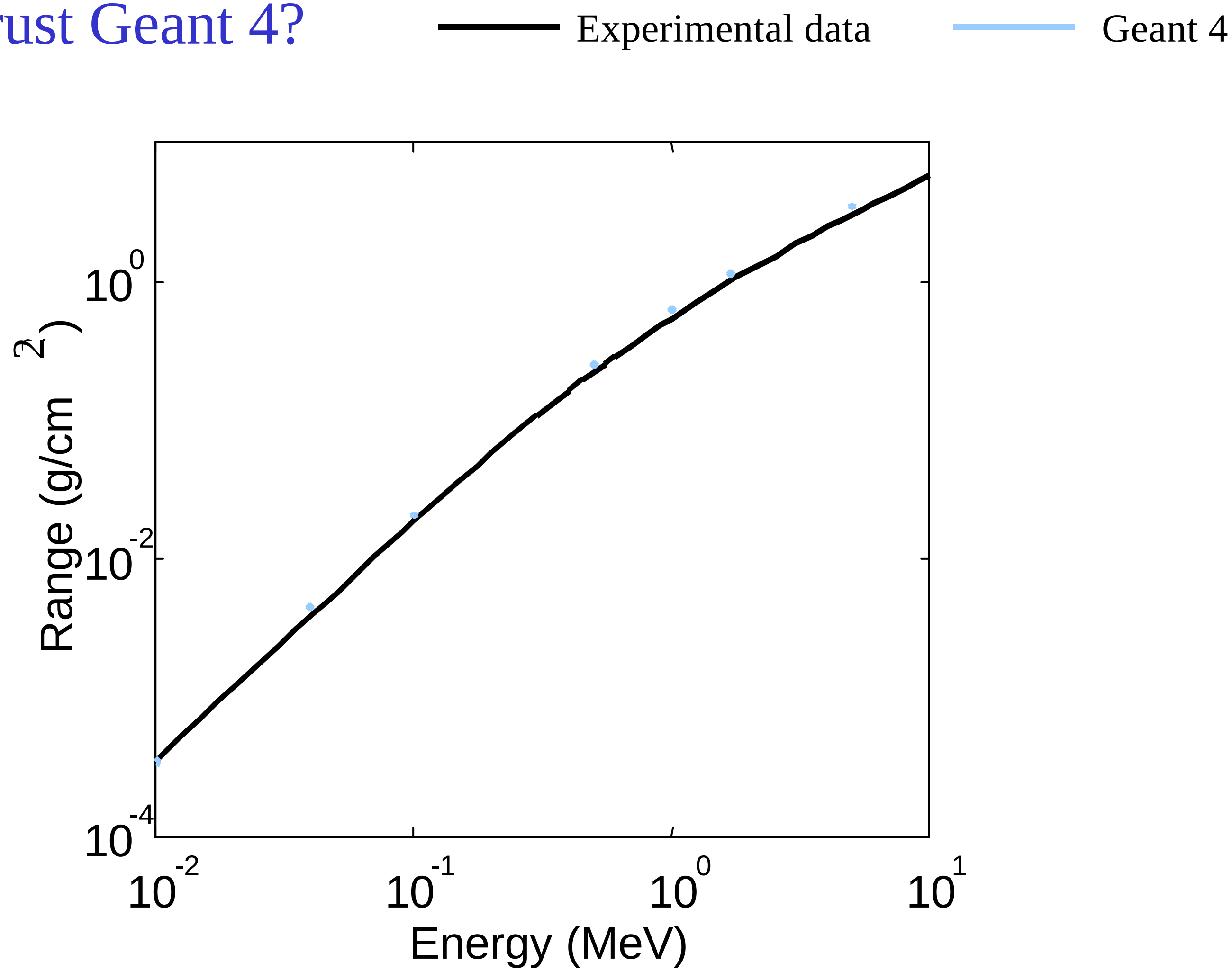
Efficiency of a MWPC with 21 lead plates (250 μm): 7%

[*J.E. Bateman NIM 221 (1984) 131*]





Can we trust Geant 4?

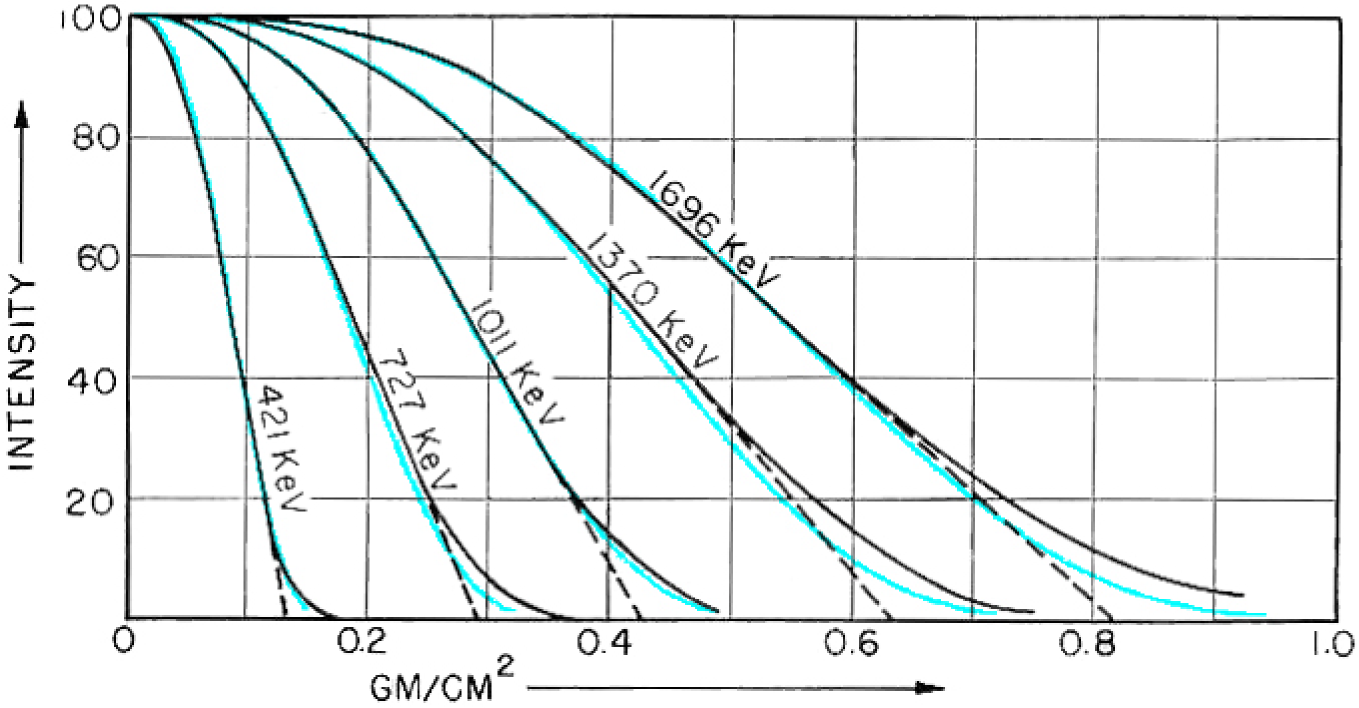


Ranges of electrons in Aluminium

From NIST (National Institute of Standards and Technology).

Can we trust Geant 4?

Experimental data — Geant 4

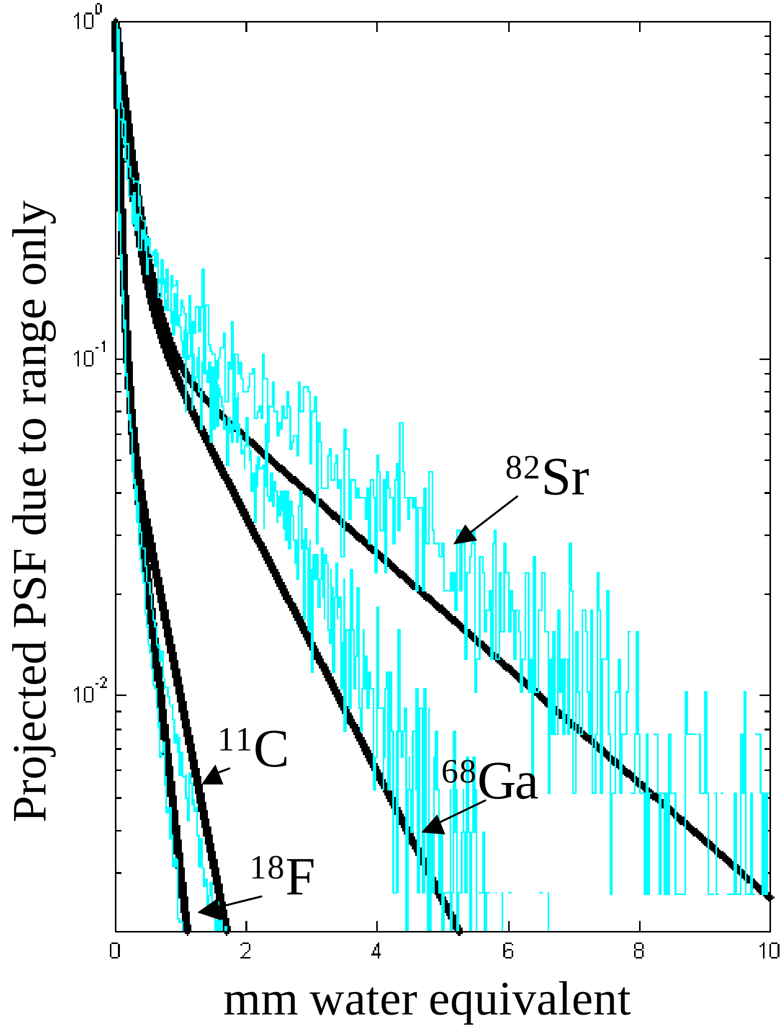


Absorption curves of monoenergetic electrons of various energies in aluminium.

[From *J. Marshall and A. G. Ward, Can. J. Research A15, 39 (1937)*]

Can we trust Geant 4?

Experimental data — Geant 4

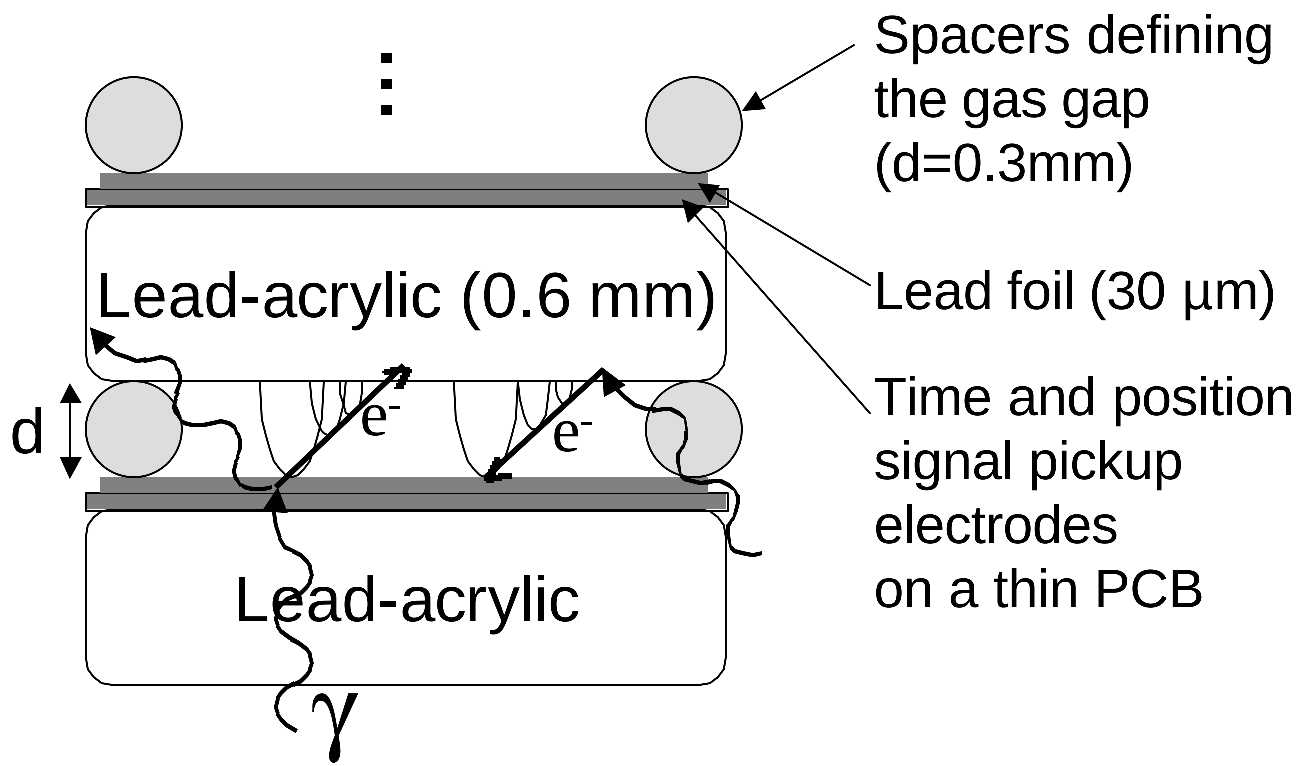


From "Mathematical removal of positron range blurring in high resolution tomography" Derenzo et all. IEEE NS, vol 33 No1"

Measured projected positron range distribution

Isotope	^{18}F	^{11}C	^{68}Ga	^{82}Rb
Maximun β^{+} energy (MeV)	0.64	0.96	1.90	3.35
FWHM (mm)	0.13	0.13	0.31	0.42

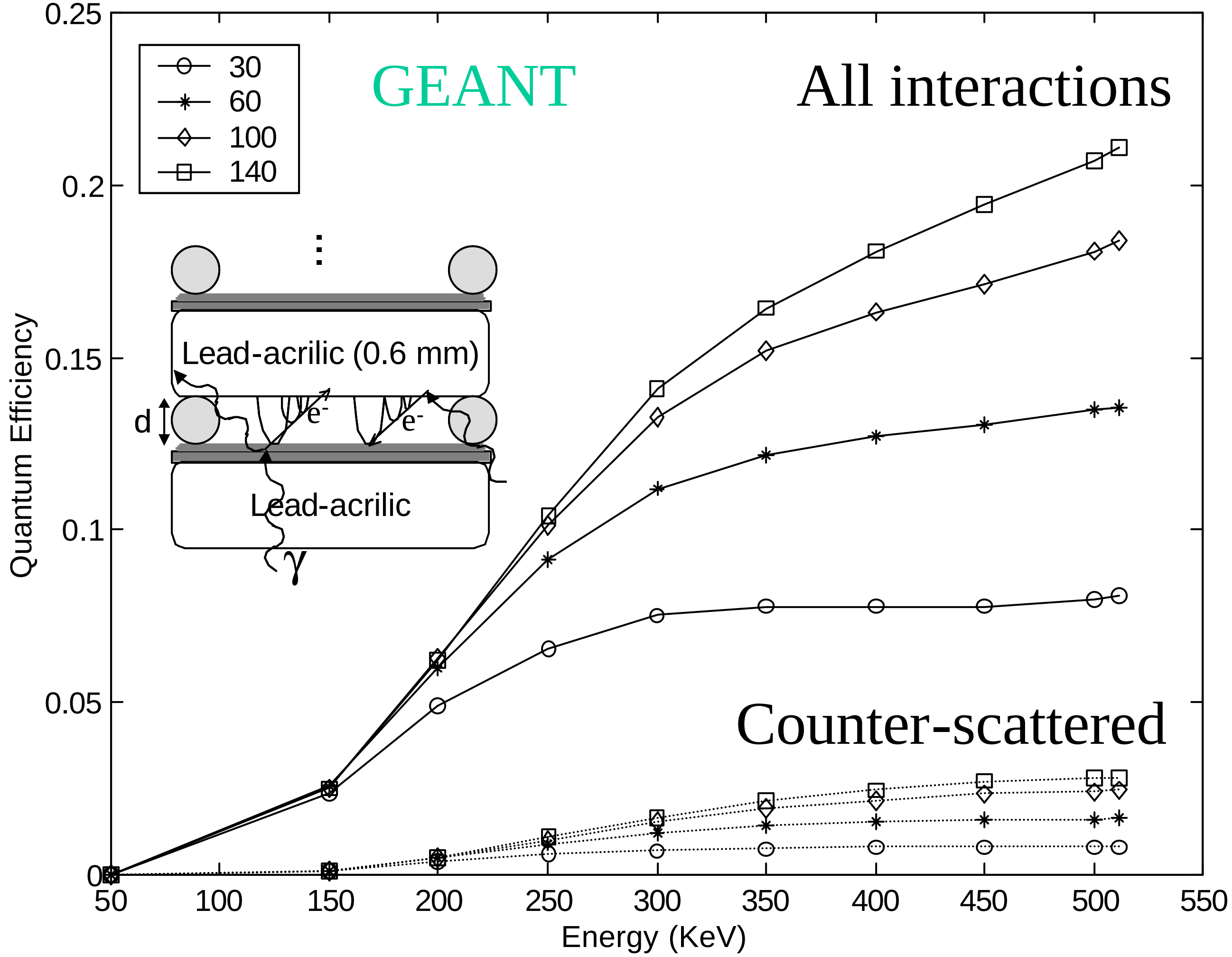
Application of RPCs to PET



Lead + lead-acrylic converter plates/electrodes

Simple assembly by stacking ⇒ many more layers possible

Efficiency of a lead + lead-acrylic stack



Scattered event rejection equivalent to a 300 keV threshold.
(Photon spectra calculated by the SIMSET program)

Possible applications

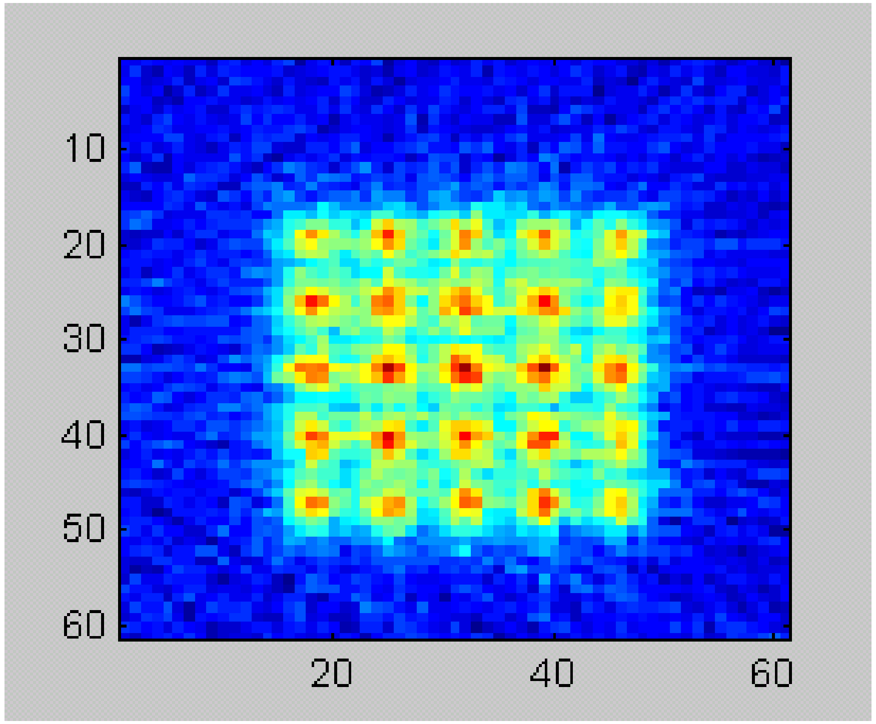
1 – Small animal PET:

excellent position resolution free of parallax
efficiency not so critical
inexpensive

2 – Whole body human PET:

low cost $\Rightarrow$ very wide FOV $\Rightarrow$ huge solid angle advantage
TOF capability $\Rightarrow$ more efficient reconstruction

Small animal PET



Full simulation in GEANT
Reconstruction by FBP

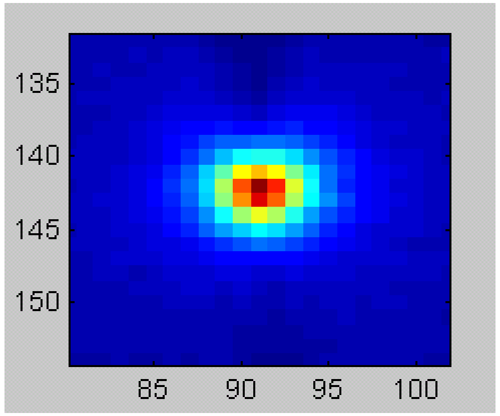
Pitch of 0.7 mm

Pixels of 0.1 mm

^{18}F

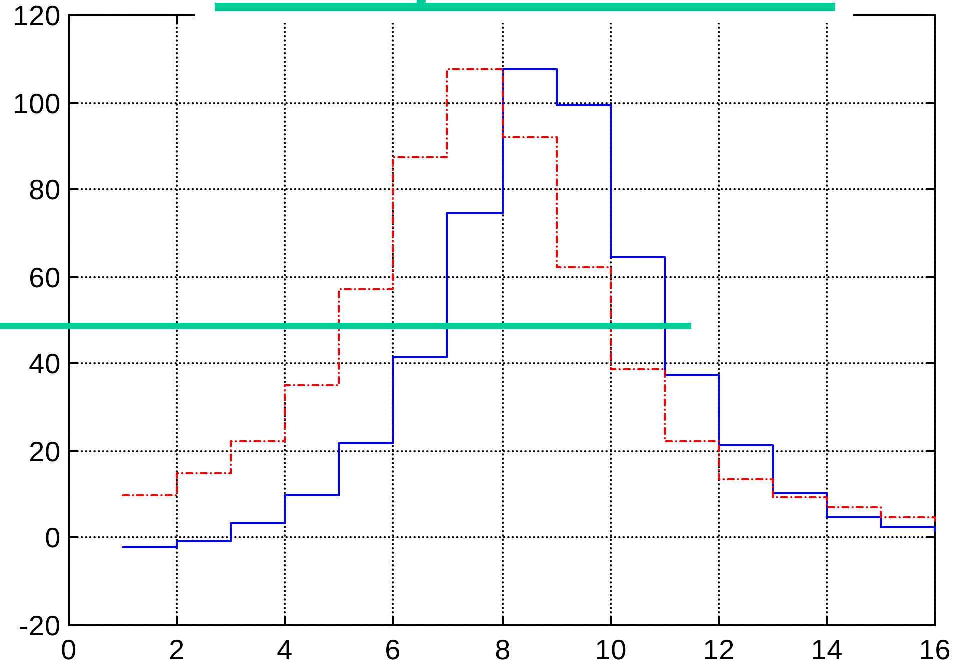
5 cm diameter ring

~1 M eventos



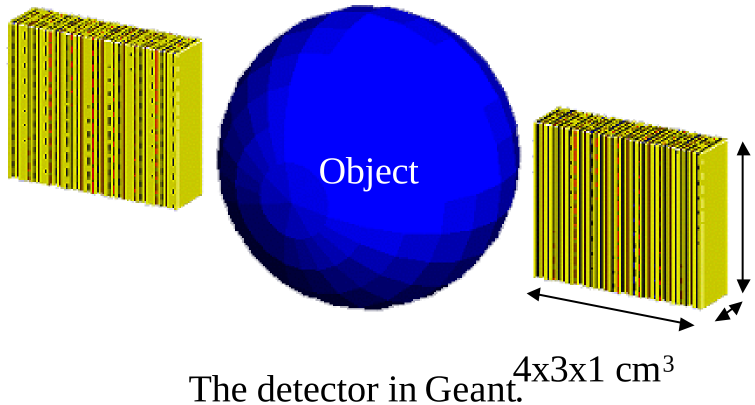
0.4mm FWHM

Point Spread Function

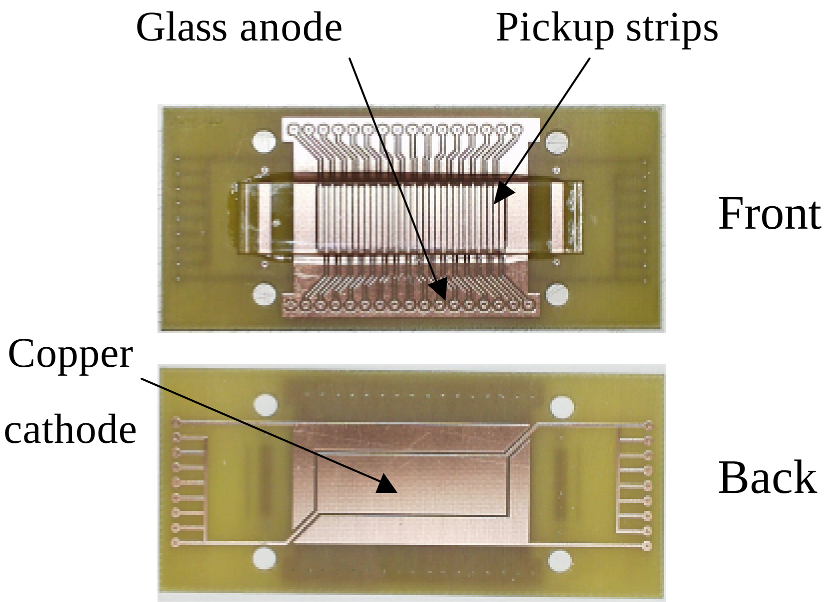


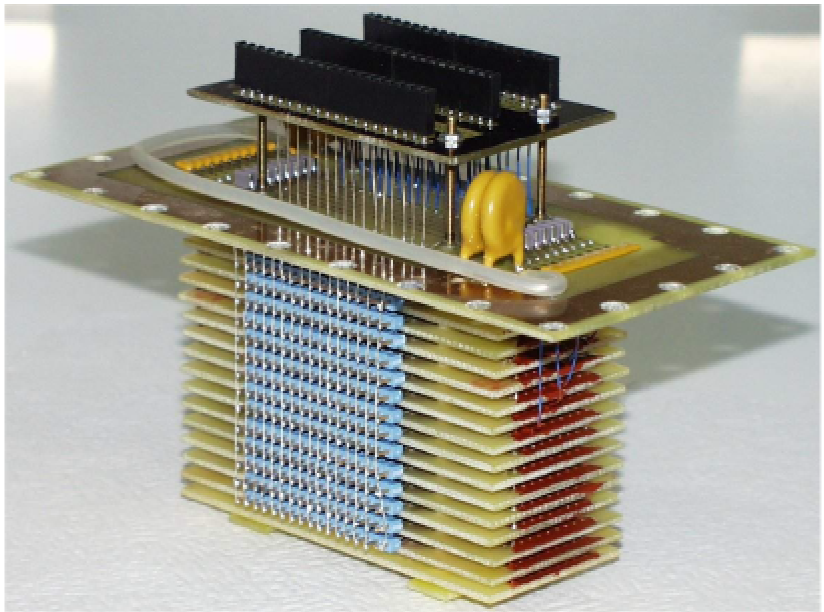
A RPC small-animal PET prototype

- 2 head rotatory system
- 16 stacked glass-metal counters → 2% ε
- 32 1mm wide X pickup strip

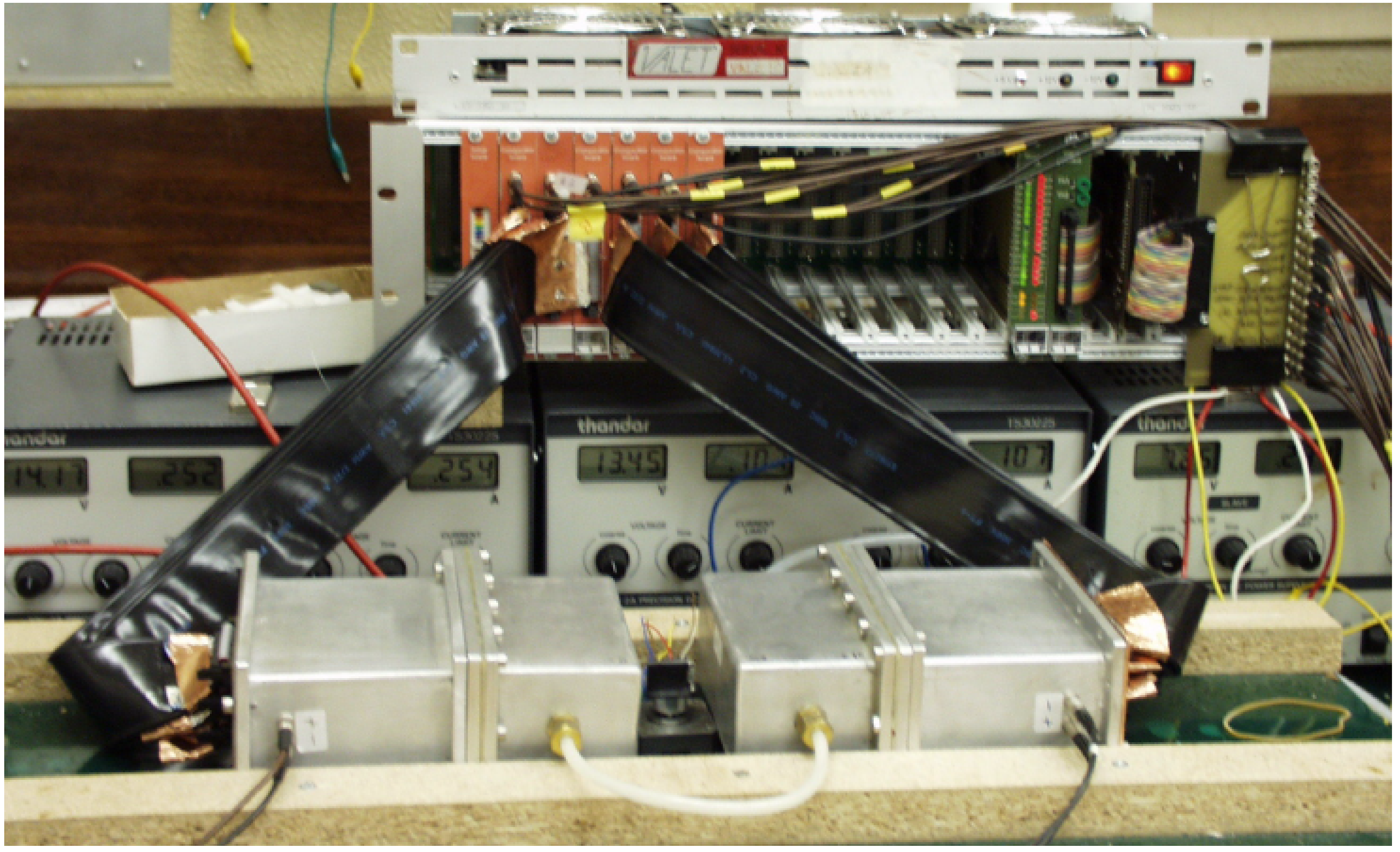


The detector in Geant.





The first prototype of an RPC small-animal PET

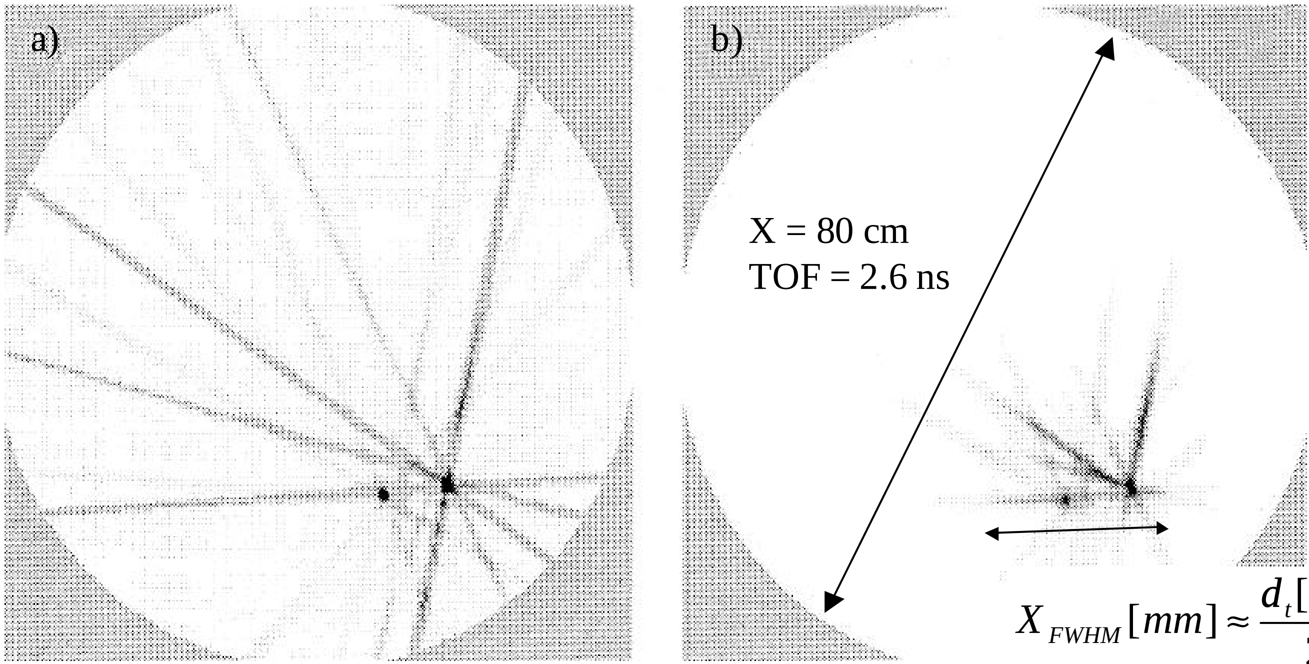


Comissioning in progress

Whole body FOV PET

TOF-PET

$$\textbf{Improvement of sensitivity} \approx \frac{d_t[ps]}{2 * \text{object size[mm]}} \approx \mathbf{10}$$



$$X_{FWHM}[mm] \approx \frac{d_t[ps]}{2}$$

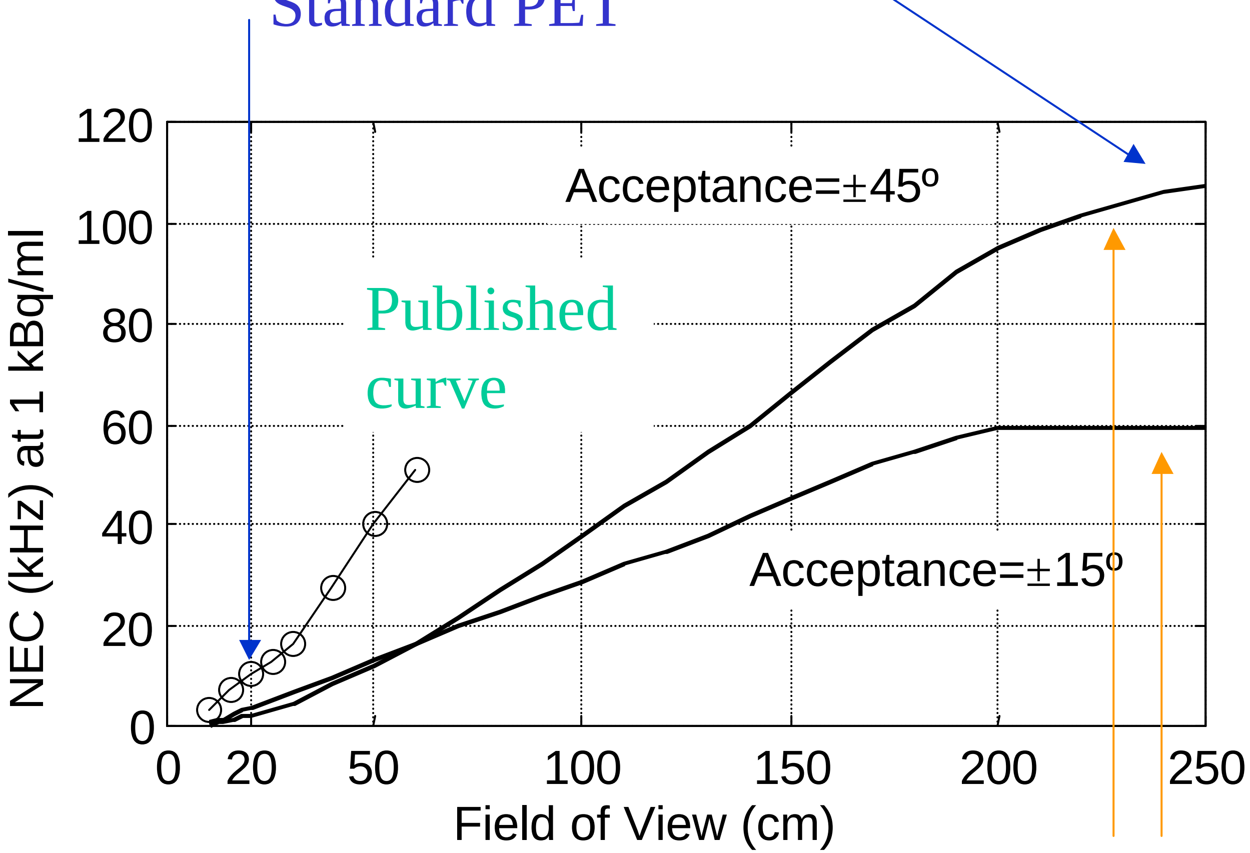
a) Reconstructed image without TOF. b) Reconstructed image using TOF information

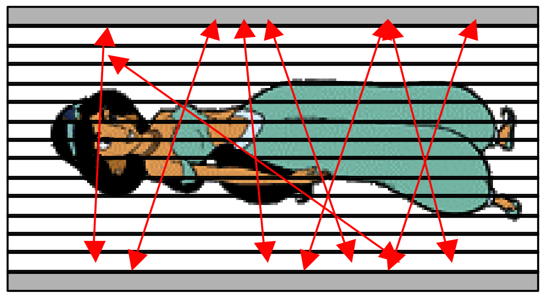
[NIM A 471(2001) 200-204]

Measured time resolution: σ_t= 90 ps ⇔ 300 ps FWHM

Whole body FOV PET

Tenfold increase in sensitivity





$$NEC = \frac{T^2}{T + S + 2R}$$

NEC=Noise-equivalent count rate
T=True coincidence rate
S=Scattered coincidence rate
R=Random coincidence rate (taken = 0)

Calculated using the SIMSET program
Eficiency= 20%, time resolution = 300 ps FWHM

Conclusions

Simulations suggest that PET with RPCs maybe interesting for:

- small animals providing an accuracy of 0.4 mm FWHM.
- human whole-body examinations providing a tenfold increase in system sensitivity, possibly for a lower price.

A first small-animal PET prototype is now being comissioned.