3D vs. 2D PET

The main advantage of the 3-D acquisition in PET is an improved sensitivity of ~5-7 times the 2-D sensitivity.

The drawback is that the scatter fraction increases by a factor of 3.

Non-uniform axial sensitivity

Higher Randoms Rates → Increased Noise

Dead-time problems

Image reconstruction is more complex

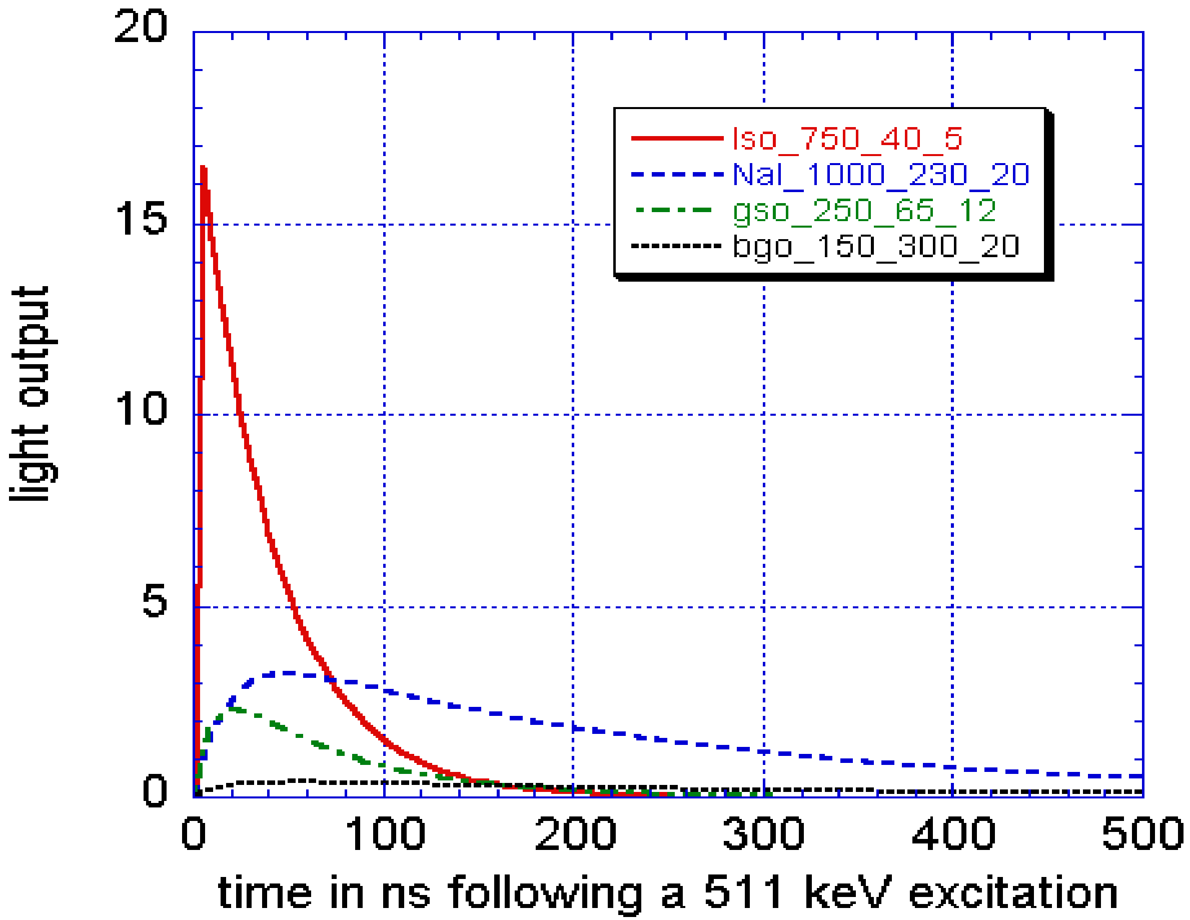
More data

Scintillator Materials

	NaI (Tl)	BGO	GSO	LSO	LYSO	$LaBr_3$
Density [g/ml]	3.67	7.13	6.71	7.35	7.1	5.29
1/μ [cm]	2.88	1.05	1.43	1.16	1.2	~2
Index of Refraction	1.85	2.15	1.85	1.82	1.81	1.9
Hygroscopic	Yes	No	No	No	No	Yes
Rugged	No	Yes	No	Yes	Yes	Yes
Peak Emission [nm]	410	480	430	420	420	380
Decay Constant [ns]	230	300	60	40	41	25
Light Output	100	15	35	75	75	>100
Energy Resolution	7.8	20	8.9	<9	11	7.5

Why LSO is Optimal as a PET Detector?

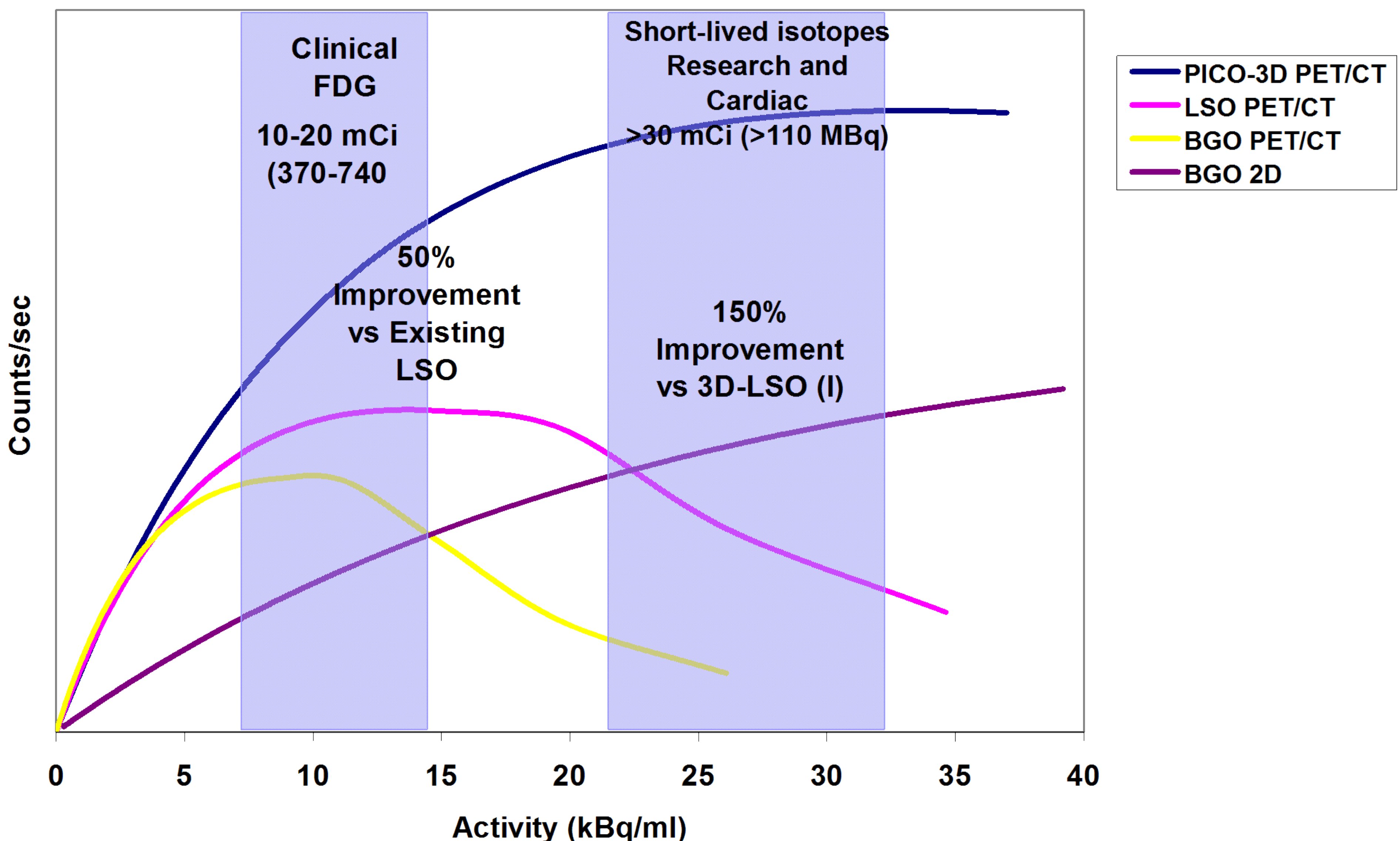
Light emitted during the first 100 ns:
LSO 69%; NaI 35%; GSO 19.8%; BGO 4.3%



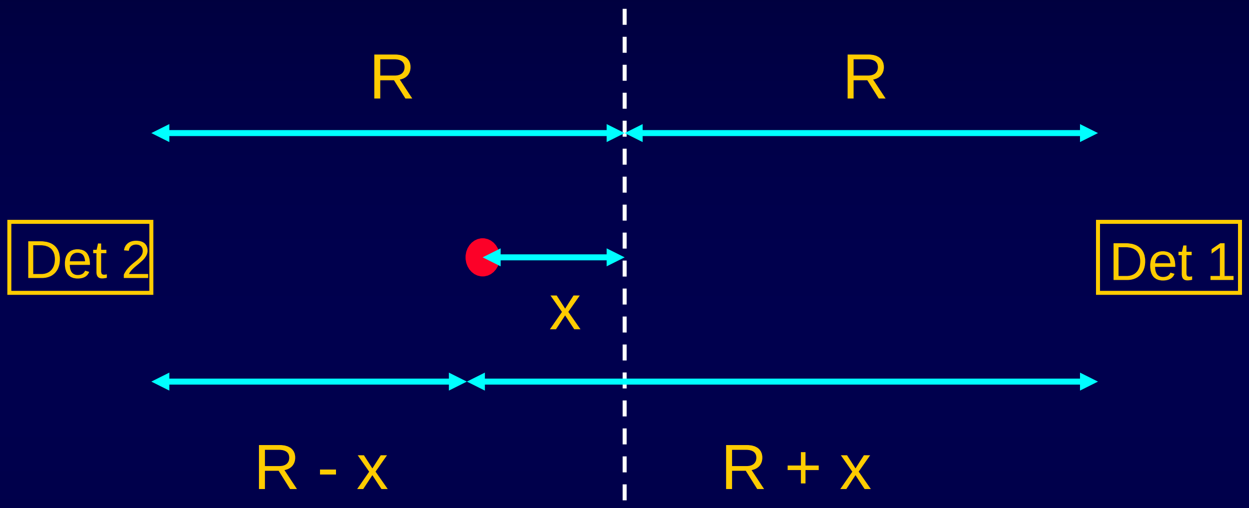
Improved NEC Performance

Bernard Bendriem, Ph.D.
Vice-President, R&D
March 19, 2004

NEMA 2001 Noise Effective Count Rate



Time-of-flight PET



$$R + x = vt_1$$

$$R - x = vt_2$$

$$2x = v(t_2 - t_1) \Rightarrow x = {c\Delta t}/{2}$$

Time-of-flight PET

For ideal detectors, TOF would eliminate the need for image reconstruction, since the measurement would allow each event to be accurately positioned in space.

All detectors have a finite time resolution, or uncertainty in timing. This translates to an uncertainty in positioning.

BGO ~ 5 ns	75 cm
NaI ~ 1.5 ns	22.5 cm
CsF, $LaBr_3$ ~ 0.45 ns	6.7 cm
BaF_2, LSO, LYSO ~ 0.3 ns	4.5 cm

Time-of-flight PET

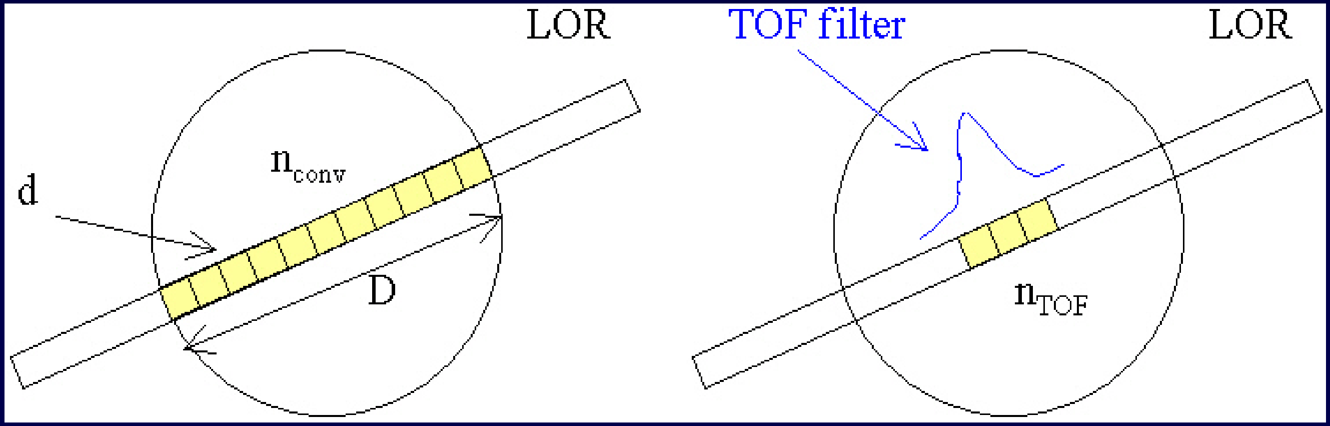


Figure 1. Image elements contributing to a LOR, for conventional PET (left) and TOF PET (right).

Time-of-flight PET

Even with a finite time resolution, using the TOF information an improvement in signal-to-noise ratio (S/N) can be achieved:

$$SNR_{TOF} \cong \sqrt{\frac{D}{\Delta x}} SNR_{conv.} = \sqrt{\frac{2D}{c\Delta t}} SNR_{conv.}$$

workshop on TIME-OF-FLIGHT TOMOGRAPHY

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Time-of-flight PET – 1980's

Problems with TOF in the 80's

Poor detection efficiency of available scintillators

TOF Gain did not offset the poor efficiency

To improve the efficiency, large detector modules were used

A more significant gain in S/N could be achieved by using high resolution detectors and conventional detection methods (Phelps, Hoffman, Huang, 1982).

Time-of-flight PET today

Scintillators:
CsF, BaF_2 → LSO, LYSO - *fast, high light, and dense*

Detectors/PMTs:
1:1 coupling → 100:1 crystal encoding - *spatial resolution*

Geometry:
2D (septa) → 3D with large axial FOV - *sensitivity*

Reconstruction:
Analytic (FBP) → iterative (list-mode) - *system modeling*

Electronics:
Accurate and stable

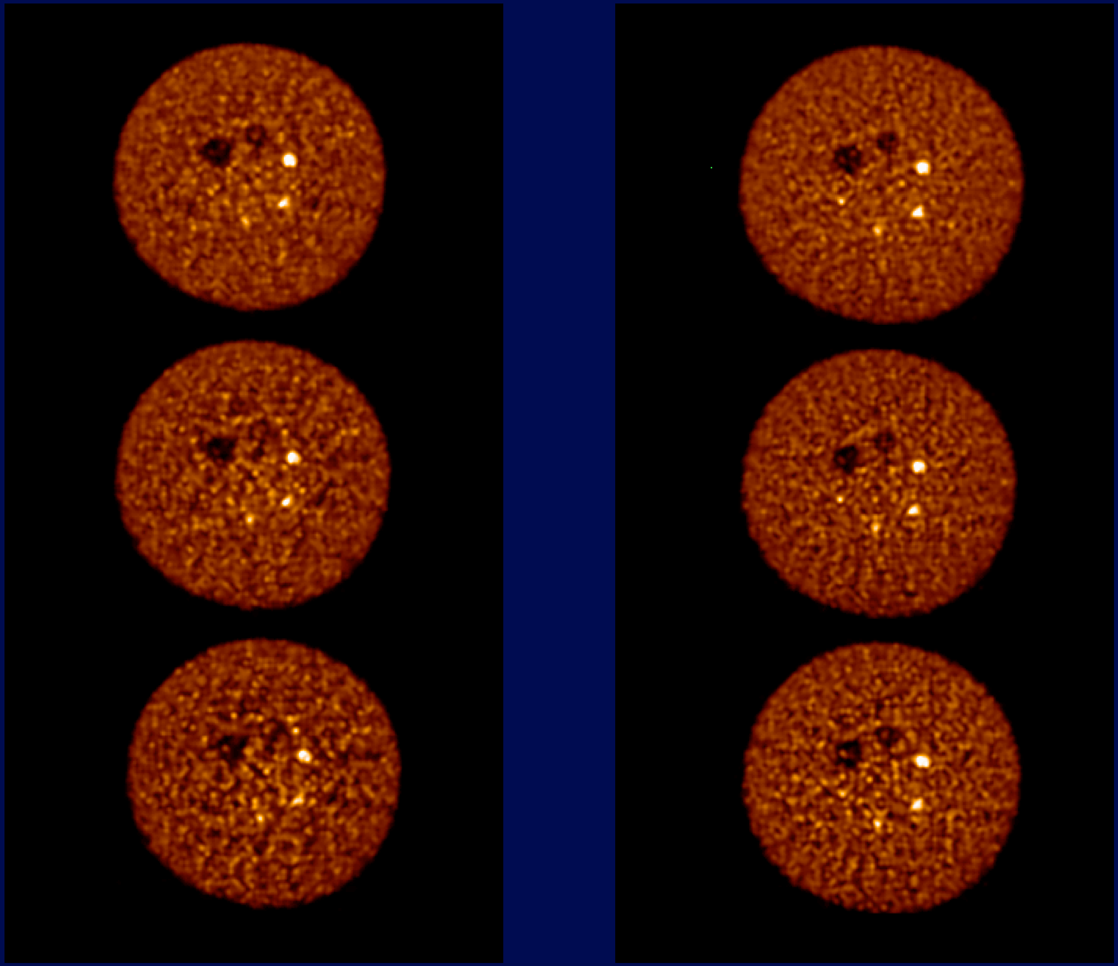
Can we see TOF improvement?

non TOF | TOF

5 min

3 min

1 min



6-to-1 contrast; 35-cm phantom

J. Karp, U of Penn

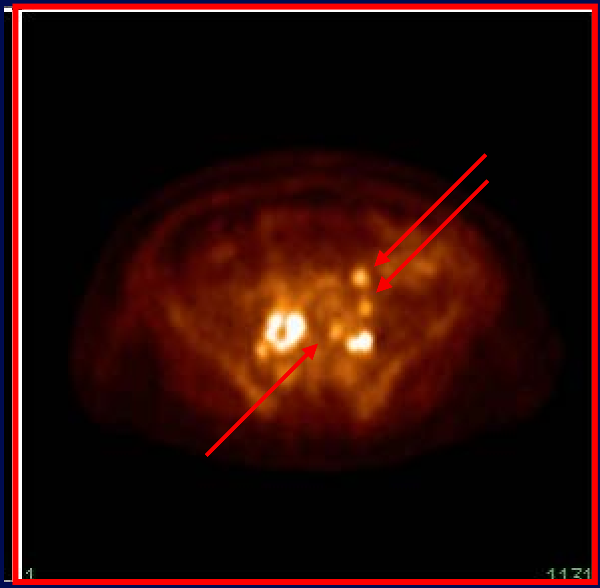
Noticeable improvement with TOF with large size phantom

Gemini TF - patient study

Rectal carcinoma, metastases in mesentery and bilateral iliac chains

114 kg; BMI = 38.1
12 mCi; 2 hr post-inj
3min/bed

non-TOF



TOF

J. Karp, U of Penn

Lesion contrast (SUV) improves with TOF reconstruction