PHILIPS

Allegro

*Enhancing PET to a new level of performance*

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ANZSNM Physics Workshop 2002
Outline

• Allegro technology
  – Clinical goals of PET
  – 3D Imaging to meet clinical goals
  – GSO ideal for 3D imaging
  – Detector design to optimize performance

• Cs-137 attenuation correction benefits

• 3D RAMLA benefits
If you cannot see the lesion you cannot localize it

Clinical Goal

*Image the smallest possible lesion with a low contrast in a background of radioactivity*

- Large number of counts in the image – high sensitivity
- 3D imaging maximizes Sensitivity
Allegro is the only PET System designed for 3D imaging from the beginning

- 3D imaging maximizes the sensitivity for oncology patients

![Graph showing 2D and 3D imaging comparison](image)

Counts

Activity Concentration

2D 3D

w/Septa No/Septa
3D Imaging provides 5 times Sensitivity vs. 2D

- 2D Imaging is limited by the Septa for FDG Whole-Body scans

<table>
<thead>
<tr>
<th></th>
<th>2D</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>1x</td>
<td>5x</td>
</tr>
<tr>
<td>Count rate</td>
<td>1x</td>
<td>5x</td>
</tr>
<tr>
<td>Throughput</td>
<td>1 hour</td>
<td>~ 30 mins.</td>
</tr>
<tr>
<td>Scatter</td>
<td>20%</td>
<td>40%</td>
</tr>
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</table>

# 3D Imaging Requirements

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
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<tbody>
<tr>
<td>Fast decay time</td>
<td>Permits high singles rate</td>
</tr>
<tr>
<td>Good energy resolution</td>
<td>Limits randoms and scatter</td>
</tr>
<tr>
<td>High stopping power</td>
<td>Gives high coinc. fraction</td>
</tr>
<tr>
<td>Good timing resolution</td>
<td>Reduces randoms</td>
</tr>
</tbody>
</table>

*These 3D imaging requirements are fulfilled by the GSO - Fast, High Density Scintillator*
GSO is the Material of Choice for 3D PET

<table>
<thead>
<tr>
<th></th>
<th>BGO</th>
<th>NaI</th>
<th>LSO</th>
<th>GSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decay Time</td>
<td>300</td>
<td>230</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Deadtime (nsec)</td>
<td>700</td>
<td>240</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>Energy Res. (%)</td>
<td>15</td>
<td>8</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Stopping Power</td>
<td>11.6</td>
<td>30.7</td>
<td>12.3</td>
<td>16.0</td>
</tr>
<tr>
<td>Light Output</td>
<td>15%</td>
<td>100%</td>
<td>75%</td>
<td>25%</td>
</tr>
</tbody>
</table>

- GSO combines high stopping power of BGO with excellent energy resolution of NaI
- Fast decay time of GSO is necessary to keep up with the increased photon flux in 3D and reduce detector deadtime

GSO Improves Systems Reliability due to High Temperature Stability

- Temperature stability of GSO is much better than LSO or BGO
- LSO and BGO based scanners require special water cooling systems
- Makes GSO the material of choice for combined PET/CT tomographs


System down time for detector calibrations is minimized
LSO systems have compromised Transmission capabilities

- Coincidence transmission imaging is a poor second choice
  - Ge-68 source
    - Source needs to be replaced about once/year
    - Maximum data rate limited to maximum true rate, i.e. ~100-400 Kcps

- Long acquisition times for Transmission scans due to coincidence mode acquisitions

- Poor image quality of the transmission images due to radioactive background from LSO
  - Radioactivity increases the background counts in Transmission images
  - particularly high attenuation regions
  
  Source: Radioisotope decay data; SNM proceedings (2001); internal analysis
GSO Advantages versus LSO/BGO

- Excellent energy resolution
- Short decay time
- Good stopping power
- Very good temperature stability
- Not radioactive

The design of the system is as important as the selection of the scintillator
Detector Designs

- Different crystal/PMT schemes are used in designing PET scanners
- Trade-off between count rate capability, system energy resolution and complexity
  - Continuous Positioning Detector Design
  - Block Design
Continuous Positioning Detector Technology optimizes use of GSO for 3D imaging

Combining single crystals with continuous light guide

- Much better system energy resolution
- High count rate capability
- Small crystal size for excellent spatial resolution
- Better 3D imaging capabilities

# Allegro PIXELAR Detector vs Competitor Block Detectors

<table>
<thead>
<tr>
<th>Continuous Positioning</th>
<th>Block Detector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PIXELAR Detector - Allegro</strong></td>
<td><strong>All competitor systems</strong></td>
</tr>
<tr>
<td>• New technology</td>
<td>• &gt; 20 year old technology</td>
</tr>
<tr>
<td>• Designed for 3D imaging</td>
<td>• Designed for 2D imaging</td>
</tr>
<tr>
<td>• Variation of light collection &lt;20%</td>
<td>• Variation of light collection ~300%</td>
</tr>
<tr>
<td>• Excellent energy resolution: &lt;18%</td>
<td>• Poor energy resolution: 25-35%</td>
</tr>
</tbody>
</table>
Crystal & detector design determines system energy resolution

<table>
<thead>
<tr>
<th>Crystal Type</th>
<th>Detector Design</th>
<th>System Energy Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens Accel LSO</td>
<td>Block</td>
<td>&gt;25 %³)</td>
</tr>
<tr>
<td>Siemens Accel LSO</td>
<td>Continuous pixelated</td>
<td>&lt; 18 %⁵)*</td>
</tr>
<tr>
<td>Allegro GSO</td>
<td>Continuous pixelated</td>
<td>&lt; 18 %⁵)*</td>
</tr>
</tbody>
</table>

5) Philips measurements
Good Energy Resolution is Essential to Reduce Randoms

Singles rates are very high in 3-D mode

Singles and coincidence energy spectra for 20 cm Ø, 70 cm long phantom

Relative Randoms Fraction

Randoms Fraction decreases exponentially with increased LLD

An LLD setting of 410 keV on the Allegro enables excellent image quality

Data courtesy of J. Karp, Ph.D. University of Pennsylvania
Good Energy Resolution is Essential to Reduce Scatter

Scatter fraction as a function of LLD for 20 cm Ø, 20 cm long phantom with line source

Scatter Fraction decreases linearly with increased LLD

An LLD setting of 410 keV on the Allegro enables excellent image quality
Allegro is Designed for 3D Imaging to Provide High Image Quality

Allegro $\rightarrow$ GSO + Continuous Positioning Detectors $\rightarrow$ Optimum for 3D Imaging

GE
Siemens $\rightarrow$ BGO/LSO + Block Detectors $\rightarrow$ Designed for 2D Compromised 3D
Allegro design allows use of Cs-137 for transmission for **better throughput, image quality and cost**

<table>
<thead>
<tr>
<th>Allegro (Cs-137 source)</th>
<th>LSO &amp; BGO Block Detectors (Ge-68 coincidence source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High count rates in excess of 3Mcps</td>
<td>10X lower count rates than Cs-137</td>
</tr>
<tr>
<td>Fast Acquisition times (45 sec)</td>
<td>Long acquisition times</td>
</tr>
<tr>
<td>High quality transmission images</td>
<td>Need for image segmentation</td>
</tr>
<tr>
<td>No need to replace source (30 yr half life)</td>
<td>Need to replace source annually (271 day half life -&gt; $10K/year)</td>
</tr>
</tbody>
</table>
ALLEGRO™
Example of Cs-137 transmission image

- 43 sec. acquisition per step
- Transmission count rates > 3 Mcps

Ability to see bone structure and the Pelvis provide the anatomical landmarks required to perform image fusion accurately

Images courtesy of J. Karp, Ph.D.
University of Pennsylvania
Why 3D RAMLA?

Acquire in 3D -> Reconstruct in 3D for best image quality

3D RAMLA Benefits

• Accurate reconstruction for 3D imaging
• Improves image quality
• Reduces artifacts
• Minimizes noise
Fully 3D iterative recon improves image quality

Key Differentiator

FORE + OSEM

- No bladder artifact
- Sharper edges and definition of the Liver
- Uniform distribution
- Much better definition at the edge of the FOV

3D RAMLA

University of Pennsylvania PET Center
Fully 3D iterative recon improves image quality

FORE + OSEM

3D RAMLA

- No bladder artifact
- No artifacts
- Better definition of structure

University of Pennsylvania PET Center
Fully 3D iterative recon improves spatial resolution

University of Pennsylvania PET Center

2D

FORE + OSEM

3D

3D RAMLA

Much better definition of structure
Allegro High Performance PET System

- Capture Events
- Process Events
- Reconstruct Image
- Display & Review

GSO
PIXELAR
3D RAMLA
SYNTEGRA
Allegro Key Benefits

- High quality PET images through 3D mode data acquisition that optimizes sensitivity
- Excellent energy resolution of the PIXELAR detector technology provides optimum contrast resolution to detect small low contrast lesions
- High Density, fast scintillator GSO for high patient throughput
- Accurate full 3D image reconstruction to visualize low contrast lesions provided by the unique 3D RAMLA software
- Seamless integration with Radiation Oncology through Syntegra image fusion and multi modality connectivity