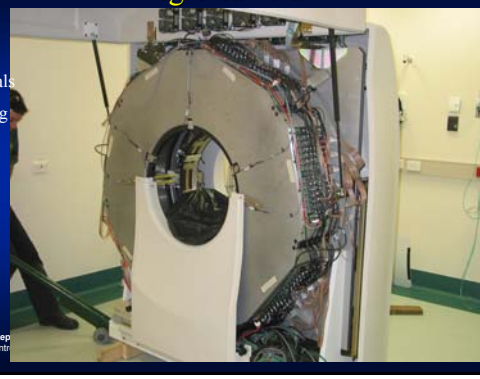
Initial Experience with Allegro GSO Scanner

Graeme O'Keefe, PhD
Centre for PET
Austin & Repatriation Medical Centre
Heidelberg
Victoria

Austin & Repatriation Medical Centre

Allegro camera

2-day install
3-days setup/cals
3-days training



Austin & Rep Medical Centr

Allegro GSO Scanner

- Integration
- Characteristics
- Performance
- Operational
- Future Developments

Austin & Repatriation Medical Centre

Allegro Integration

- Shielding - Radiation Protection
- Ergonomics
- Heat Load, Room Cooling
- Power
- Floor loading
- Infusion rooms
- Acute services (Anaesthetics)
- Network, DICOM

Austin & Repatriation Medical Centre

Allegro Integration

- A&RMC installation – July 2002
  - 3 month room preparation period.
  - Initial 2-week period of followup comparison scans from ECAT-951
  - Clinical @ 3½ days/week
    - 12 scans/day on Allegro - Wholebody
    - 3 scans/day on ECAT 951 – Brain/Head-Neck
    - 750 scans/6 months
  - PM/QA
    - 1/2-day cyclotron + scanner PM/QA
  - Research
    - 1-day – MPPF, Flumazenil, Nicotinic, FMISO, H_20

Austin & Repatriation Medical Centre

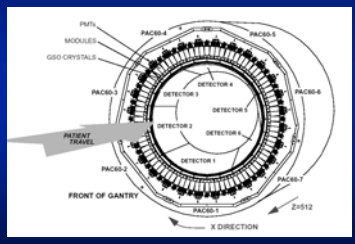
Allegro Characteristics

- Power, Weight, Environment
- Scanner design
  - PMT's
  - Triggers
  - Transmission
  - Acquisition system
  - Crystals

Austin & Repatriation Medical Centre

Characteristics
Scanner Design

- Gantry
  - Continuous light-guide
  - dedicated 3D, septaless
  - 180 mm axial extent
  - 800 mm diameter ring
  - 6 'virtual detectors'
  - 740 MBq ^{137}Cs singles transmission source.
  - 165 cm bed travel

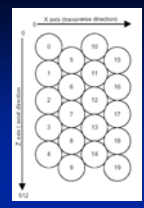


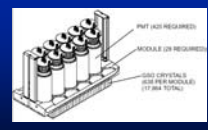
Austin & Repatriation Medical Centre

Graphic from Allegro User/Service Manual
Courtesy of Philips Medical Systems

Characteristics
Scanner Design

- Detection system
  - 17864 GSO crystals = 29 rings * 616
    - 4mm * 6mm * 20mm (Tangential, Axial, Radial)
  - 420 PMT's
  - 6 virtual detectors, 28 modules
    - 6, 4, 4, 4, 6 trigger modules
  - Trigger modules
    - 15 PMT's per module, neighbouring overlap
    - Timing, Pulse height processed on module basis
  - $29^2 = 841$ ring-pairs interpolated to 7 tilts.

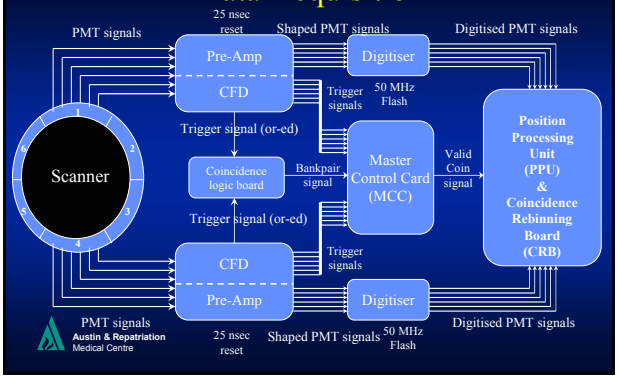




Austin & Repatriation Medical Centre

Graphic from Allegro User/Service Manual
Courtesy of Philips Medical Systems

Data Acquisition



Austin & Repatriation Medical Centre

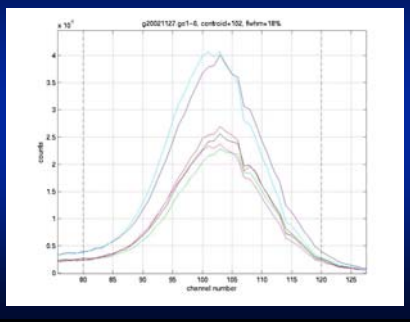
Allegro Performance

- Resolution – Energy, Timing, Spatial
- NEMA measurements
  - Countrate
  - Scatter
  - Deadtime
- Attenuation

Austin & Repatriation Medical Centre

Characteristics
Energy Resolution

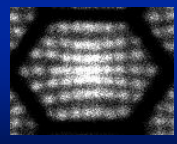
- Specification: 15%
- Measured: 17-18%
  - Daily check
  - Warning > 20 %
  - Failure > 25 %



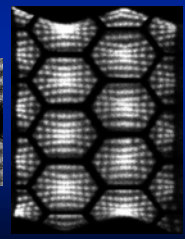
Austin & Repatriation Medical Centre

Characteristics
Spatial Resolution

- Geometric Distortion Removal
  - Delineation of Crystal boundaries
- Measured
  - Transverse
    - 1 cm - 4.73 mm
    - 10 cm – 5.59 mm
  - Axial
    - 1 cm – 4.74 mm
    - 10 cm – 5.89 mm



Trigger module



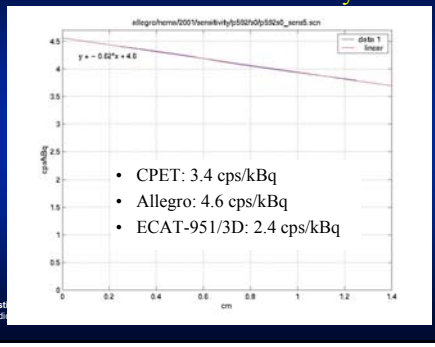
Austin & Repatriation Medical Centre

Performance
NEMA-2001 Sensitivity

- 5 sleeves
  - thickness= [0.25, 0.50, 0.75, 1.00, 1.25];
  - Central sleeve filled with ~ 5 MBq
    - randoms/deadtime < 1%
- Total counts vs. thickness
  - Determine cps/kBq for extrapolated zero thickness

Austin & Repatriation Medical Centre

Performance
NEMA-2001 Sensitivity



- CPET: 3.4 cps/kBq
- Allegro: 4.6 cps/kBq
- ECAT-951/3D: 2.4 cps/kBq

Austin & Repatriation Medical Centre

Performance
NEMA-94/2001 Sensitivity

- NEMA-94
  - Allegro: 19.7 kcps.kBq^{-1}.mL (728 kcps.µCi^{-1}.mL)
  - ECAT-951
    - 2D = 2.97 kcps.kBq^{-1}.mL (110 kcps.µCi^{-1}.mL)
    - 3D =
- NEMA-2001
  - Allegro: 4.6 cps.kBq^{-1}
  - CPET^{+}: 3.5 cps.kBq^{-1}
  - ECAT-951/3D: 2.4 cps.kBq^{-1}

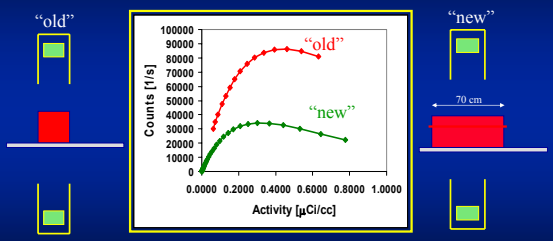
Austin & Repatriation Medical Centre

Performance
NEMA-2001 Countrate

- Phantom
  - Line source - 70 cm length, 8.85 ml
  - 22 litre uniform cylinder 70 cm length * 20 cm diameter
  - Line source offset by 45 mm
- Initial activity > 600 MBq
  - > 28 kBq/ml (0.75 µCi/ml)
  - 11 hour acquisition
    - 8*15 min + 6*30 min + 6*60 min
    - Add extra 1-hr frame for every extra 300 MBq
- Scatter fraction determined when randoms rate < 1%
  - Different from NEMA-94 where SF = $\frac{R_0^{Scatt} + 8*R_{45}^{Scatt} + 10.75*R_{90}^{Scatt}}{R_0^{Tot} + 8*R_{45}^{Tot} + 10.75*R_{90}^{Tot}}$

Austin & Repatriation Medical Centre

Performance
NEC Measurements



Austin & Repatriation Medical Centre

Graphic Courtesy of Steve Meikle, RPAH

Performance
NEMA-2001 Countrate

20 cm diameter

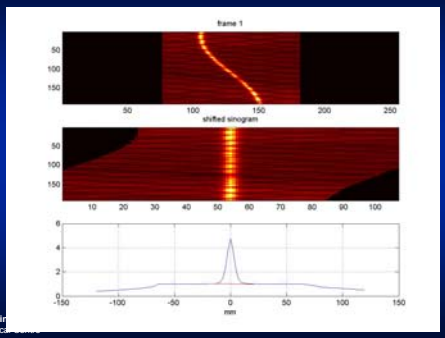
70 cm length

Line source offset by 45 mm

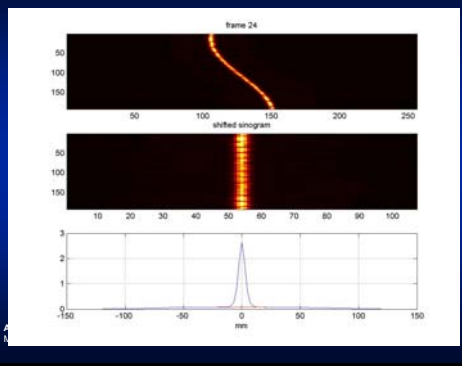
Scatter fraction determined when randoms rate < 1%

Austin & Repatriation Medical Centre

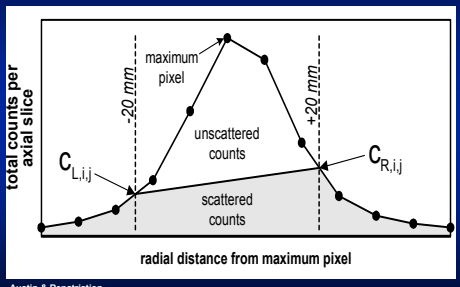
Performance -Scatter Fraction



Performance - Scatter Fraction



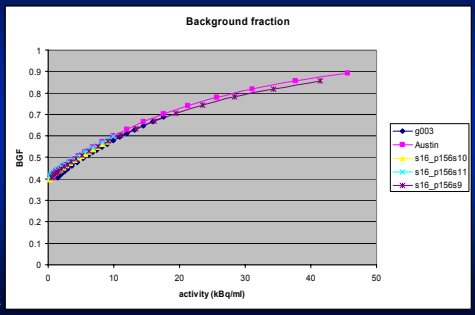
Performance
NEMA-2001 Countrate



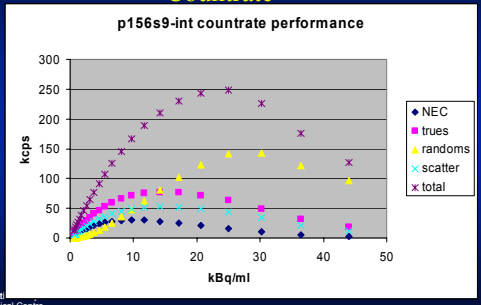
Austin & Repatriation Medical Centre

Graphic from NEMA-NU2-2001 document

Performance
Scatter Fraction



Performance
Countrate



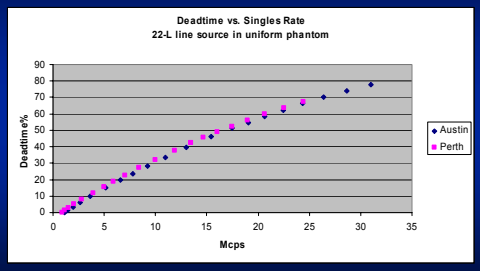
Performance
Scatter fraction

$$\frac{R_0^{Scatt} + 8 * R_{45}^{Scatt} + 10.75 * R_{90}^{Scatt}}{R_0^{Tot} + 8 * R_{45}^{Tot} + 10.75 * R_{90}^{Tot}}$$

- NEMA-94
  - Allegro = 28%
  - ECAT-951 @ 250 keV
    - 2D = 15%
    - 3D = 48%
- NEMA-2001
  - Allegro = 40%
  - ECAT-951 @ 350 keV = 44%

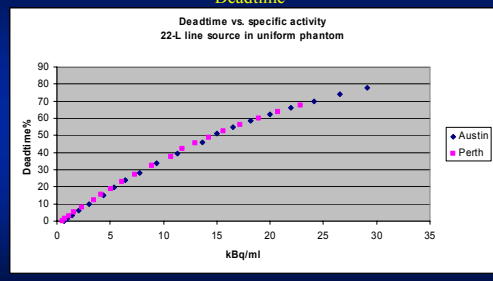
Austin & Repatriation Medical Centre

Performance
Deadtime



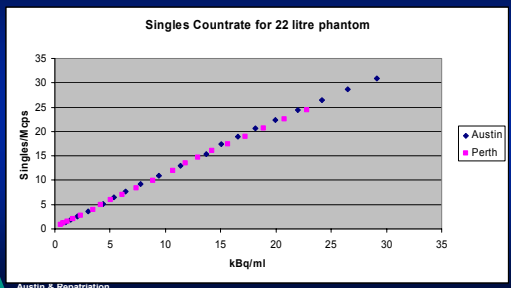
Austin & Repatriation Medical Centre

Performance
Deadtime



Austin & Repatriation Medical Centre

Performance
Countrate



Austin & Repatriation Medical Centre

Allegro Operational

- Daily QC
- Routine Calibrations
- Clinical
  - Scan protocols
  - Issues

Austin & Repatriation Medical Centre

Allegro Operational

- Daily QC
  - PreAmp/SumAmp baseline measurement.
  - Photopeak centroid and FWHM ~ 5 min
  - Emission/Transmission ~ 5 min.
  - Pass/Warning/Fail status
- Routine Calibrations
  - Quarterly
    - PreAmp/SumAmp
    - CFD Thresholds
    - Timing
  - 6-monthly
    - Normalisation – SUV/Deadtime
    - Spatial Resolution
    - Countrate performance.

Austin & Repatriation Medical Centre

Operational
Clinical

- Typical 8-bed scan = 76 cm
  - 576 mm FOV
  - 9 cm overlap
  - 8 * 4-min/bed emission
  - 10 * 45-sec/bed transmission
  - 10 * 12-sec/bed emission contamination
- Scan time breakdown
  - Counting duration = 41:20
  - Overheads = 8:40
  - Total = 50:00

Austin & Repatriation Medical Centre

Operational
Clinical

- Reconstruction (concurrent)
  - FBP
  - OSEM
  - RAMLA2d + 3d Attenuation
  - RAMLA3d + 3d Attenuation
- – Attenuation correction
  - Measured
  - Calculated
  - Histogram/Remapped

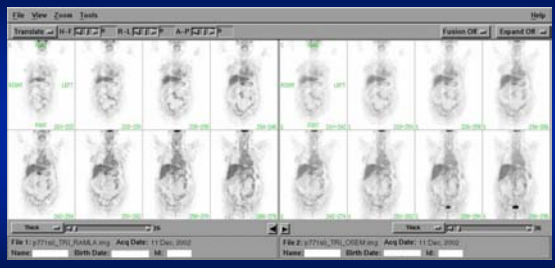
Austin & Repatriation Medical Centre

Operational
Clinical

- RAMLA vs OSEM
  - – Row Action Maximum Likelihood Algorithm
    - similar to the OS-EM algorithm but has a relaxation parameter incorporated into the algorithm
    - like OS-EM, it converges an order of magnitude faster than ML in early iterations
    - for a certain class of relaxation parameters, it converges to the true ML solution for emission tomography and does not exhibit cycling

Austin & Repatriation Medical Centre

Comparison of reconstructed images



OSEM: 2 inter-update smooths.

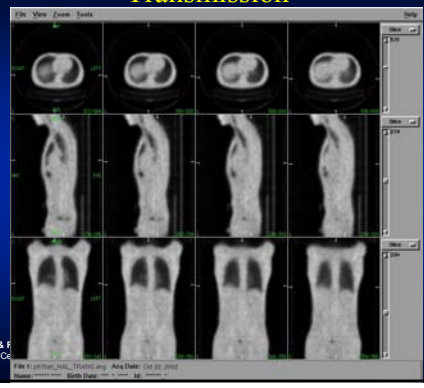
Austin & Repatriation Medical Centre

Graphic courtesy of Centre for PET

Transmission

370 MBq FDG
45 min. PI

T:45 sec/bed
EC: 15 sec/bed
8 beds

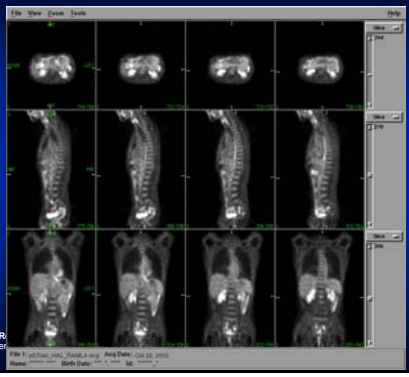


Austin & Repatriation Medical Centre

Emission

370 MBq FDG
45 min. PI

E: 4 min/bed
T: 45sec/bed
8 beds



Austin & Repatriation Medical Centre

Operational
Clinical

- Background subtraction
  - Corrects for Randoms/Scatter
  - Choice of:
    - – None
    - – Uniform
    - – Non-uniform
  - 50 % counts arise from randoms/scatter
  - Uniform/Non-Uniform correction require background region to fit.
  - Problematic with large patients or Arms-down.

Austin & Repatriation Medical Centre

Background subtraction

370 MBq FDG
45 min. PI

E:4 min/bed
T:45 sec/bed
8 beds

Austin & Repatriation Medical Centre

Bacground subtraction

370 MBq FDG
45 min.

E:4 min/bed
T:45 sec/bed
8 beds

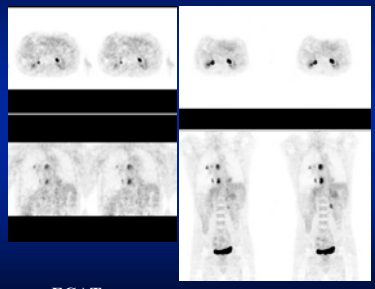
Austin & Repatriation Medical Centre

Allegro Image Quality
Patient Studies

Injection time - 8:10
Dose - 426.9 MBq

ECAT/2D
Scan time - 8:40
4 beds @ 10 mins
AW-OSEM

Allegro
Scan time - 9:40
8 beds @ 4 mins
RAMLA2d



ECAT **Allegro**

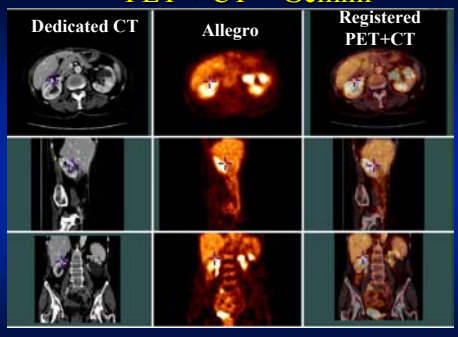
Austin & Repatriation Medical Centre

Operational
Clinical

- Issues
  - Datasizes
    - Single bed emission > 80 Mb.
    - Typical 8-bed scan + image data ~ 0.8 Gb
    - All data archived to DDS-3.
    - Patient image data transferred to Department RAID.
  - Large patients & Arms down scanning
    - Problems with background subtraction.
    - Require 2-3 transmission source revs.
  - Low countrate studies (large patients, diabetics)
  - RAMLA3d vs RAMLA2d
    - Time penalty for small gain in image quality.

Austin & Repatriation Medical Centre

PET + CT = Gemini



Austin & Repatriation Medical Centre

Future developments

- Overheads reduction
  - Elimination of EC measurement
  - Continuous 'spiral' transmission
- Delayed Randoms measurement
  - Smoothed randoms subtraction
- Energy, timing window optimisation
- Single Scatter Simulation

Austin & Repatriation Medical Centre

Conclusion

- Allegro commissioned July 2001
  - 600 scans/6 months
  - Typical wholebody scan 45 minutes
    - Further overheads reduction
  - 1 day downtime
  - Scatter/Randoms
    - Arms up scanning mandatory
    - Large patient problematic
  - Image quality