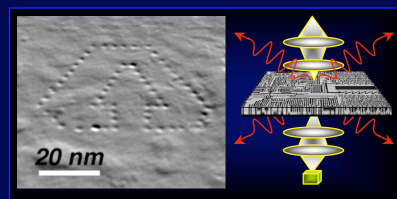
Performance of a High Count Rate Silicon Drift X-ray Detector on The ANL 300 KV AAEM



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- Photon Imaging Inc.

Office of Science - BES Program
US Department of Energy

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Why are we still working on XEDS systems?

Modern nanoscale characterization using x-ray energy dispersive spectroscopy in the Analytical Electron Microscope is limited by a number of factors

- Foremost among these is the inability of an investigator to detect all characteristic x-ray emission from the region of interest of the specimen.
- Experimental operating condition of the microscope dictate the physics of the generation of x-ray emission from the sample
- To maximize sensitivity of the technique, only improvements in the detector can accomplish this task. This improvements can be achieved by optimizing the detector to maxmize the :

1. the subtending solid angle of the collected x-rays
2. the conversion (detection) efficiency for x-rays
3. the count rate (pulse) efficiency

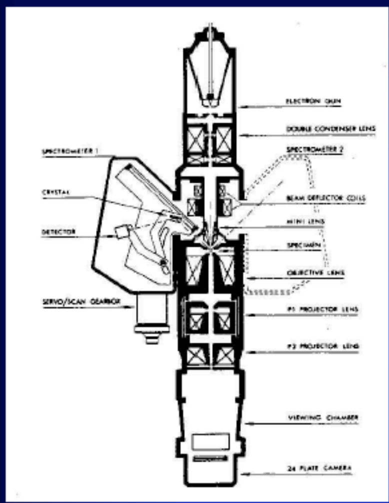
ANL Applications

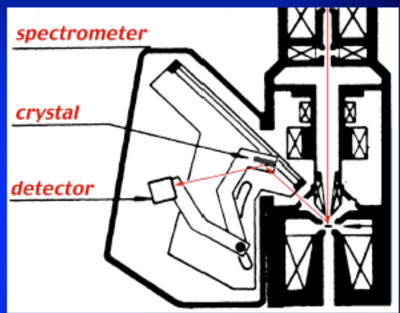
- DoE TEAM Project : Next Generation Medium Voltage FEG AEM's…
  Aberration correction increase probe current!
- Scanning Confocal Electron MIcroscopy

Others:
Conventional BULK specimen SEM data (Mapping)
Conventional FEG AEM TEM's

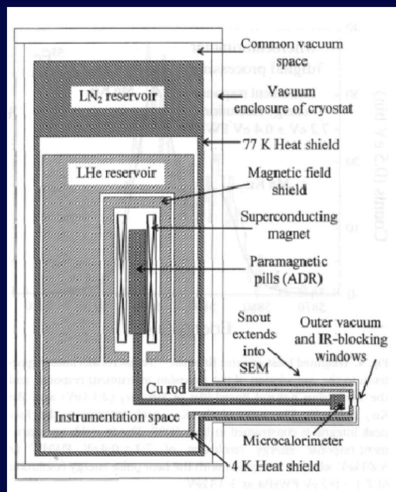
X-ray Detector Systems for the AEM

- Wavelength Dispersive Spectrometers (WDS)
- Energy Dispersive Spectrometers (EDS)
  - Si(Li) Detectors
  - HPGe Detectors
- Superconducting Calorimeters/Bolometers
- Silicon Drift Detectors





Installation of a Crystal Spectrometer in a TEM - EMMA-4 System

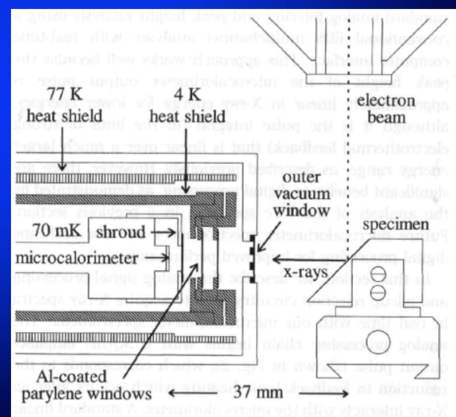


Microcalorimeter Solid Angle

$\Omega = A/R^2$

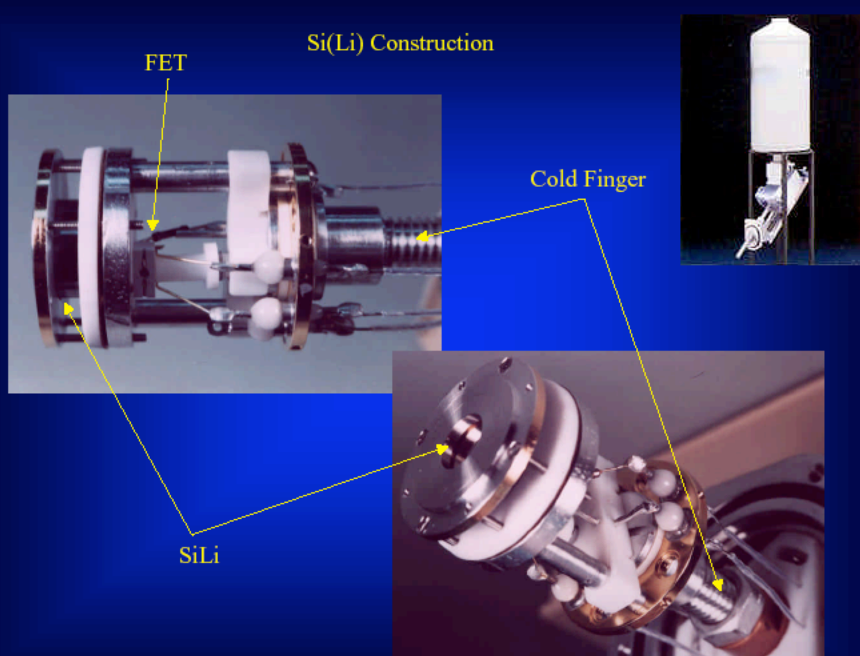
$= (0.5x0.5\ mm)/(37mm)^2$

$= 0.00018\ sr$



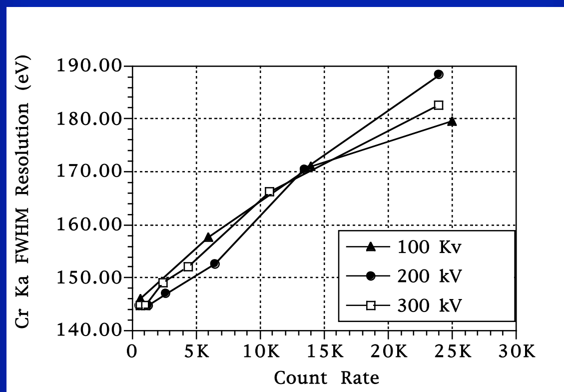
Courtesy of D. Newbury

Si(Li) Construction

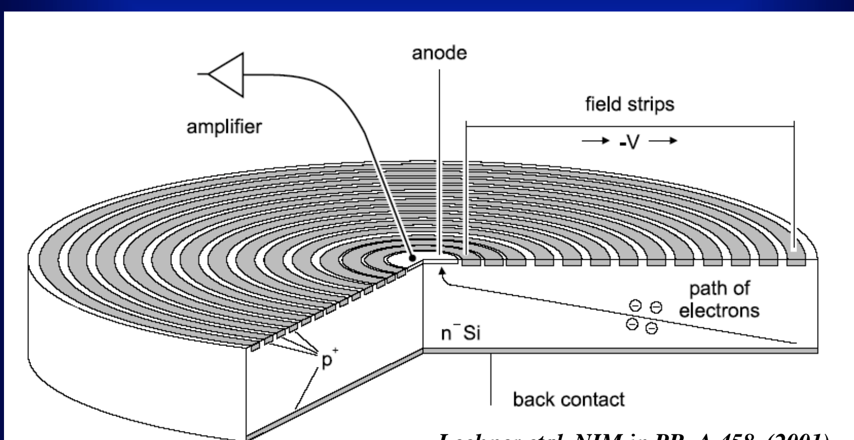


Components of a Stnd Si(Li)

Resolution Loss with Count Rate



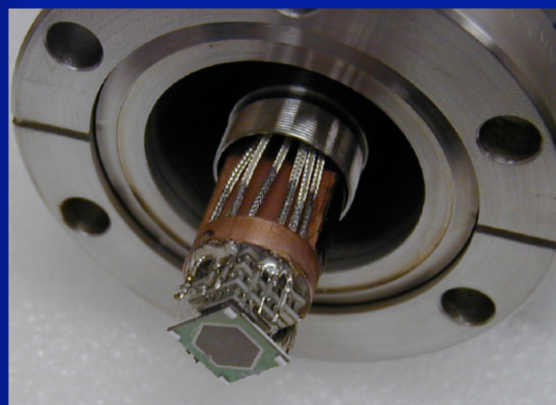
Silicon Drift Detector Construction



Lechner etal NIM in PR. A 458, (2001)

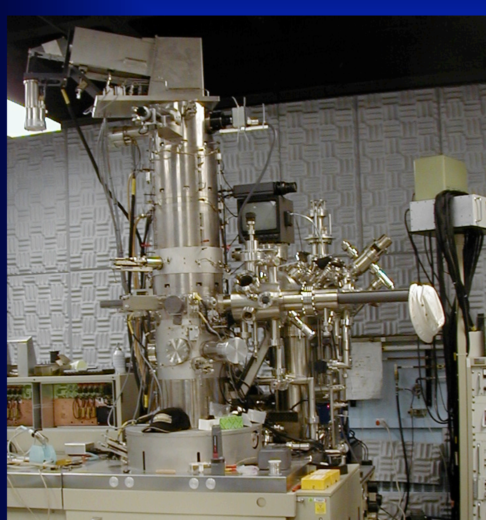
Thinner devices -> Low Capacitance -> High Count Rates

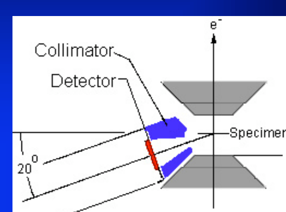
Silicon Drift Detector Construction

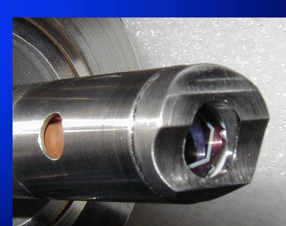


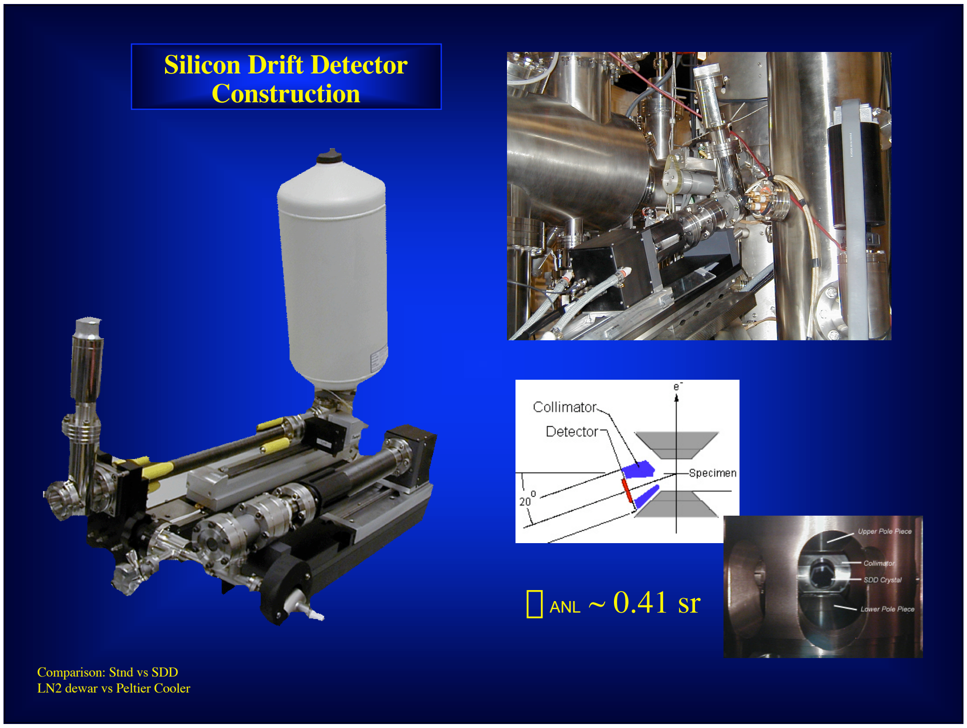
Detector Area = 50 mm^2
Peltier Cooled -> No LN_2
Low Capacitance (250 fF)-> High Count Rates

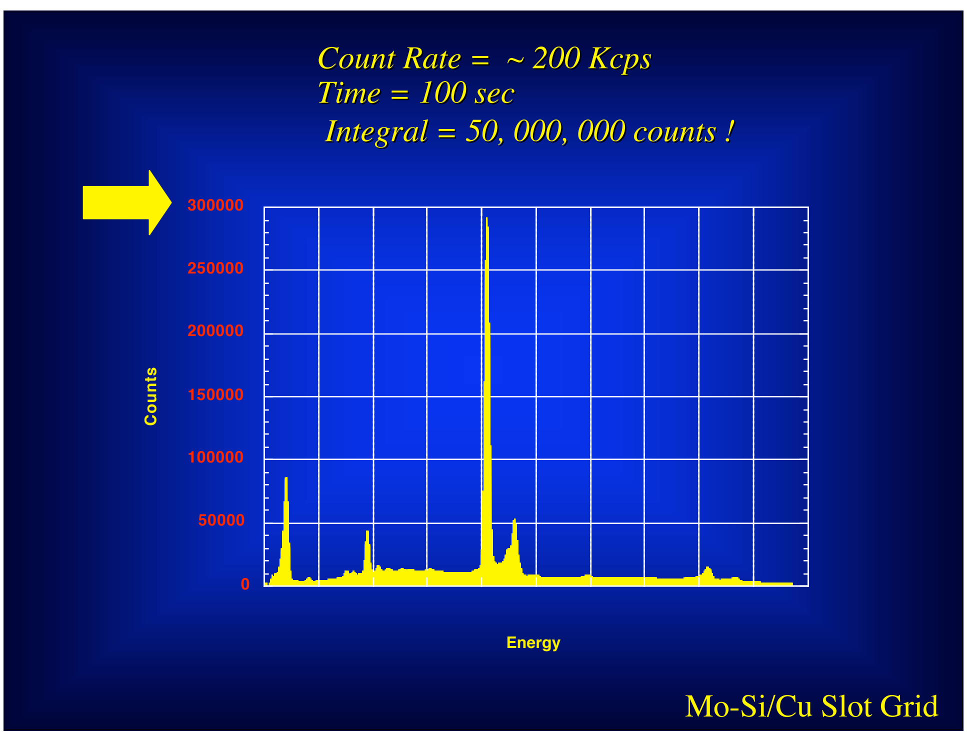
ANL Experimental Configuration

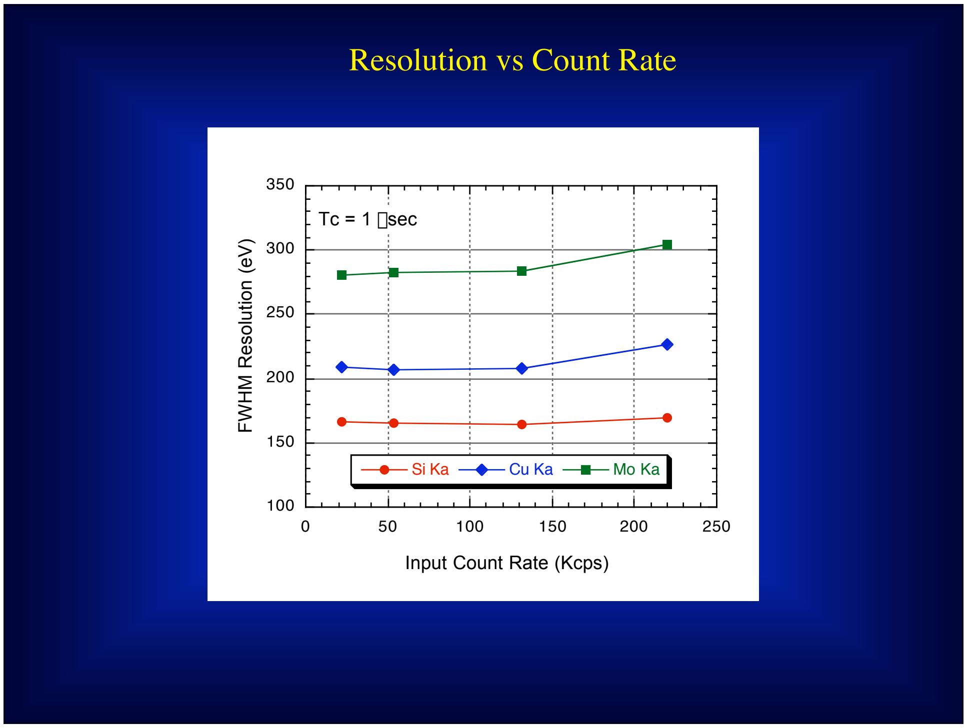


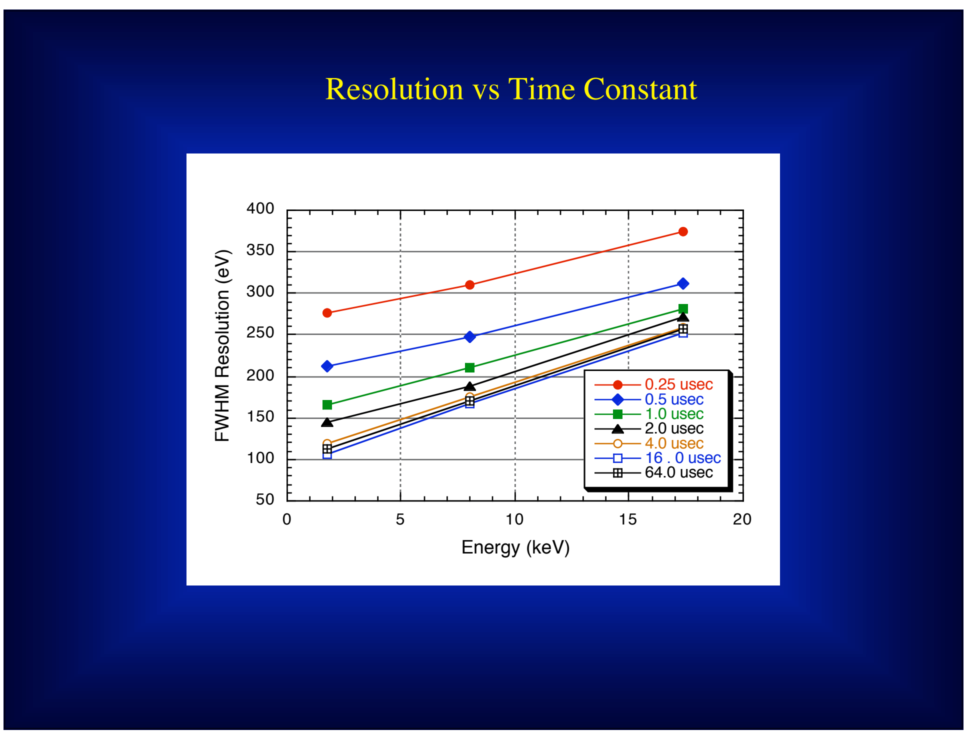




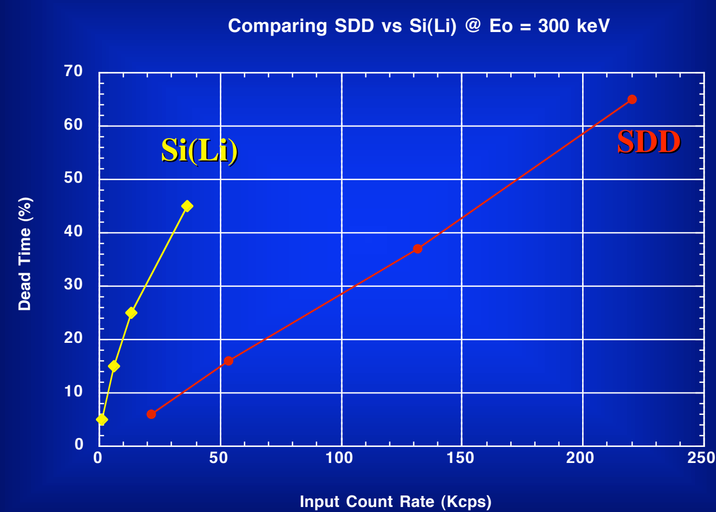

Silicon Drift Detector Construction
Collimator
Detector
Specimen
e⁻
20°
Upper Pole Piece
Collimator
SDD Crystal
Lower Pole Piece
ANL ~ 0.41 sr
Comparison: Stnd vs SDD
LN2 dewar vs Peltier Cooler


Count Rate = ~ 200 Kcps
Time = 100 sec
Integral = 50, 000, 000 counts !
300000
250000
200000
150000
100000
50000
0
Counts
Energy
Mo-Si/Cu Slot Grid

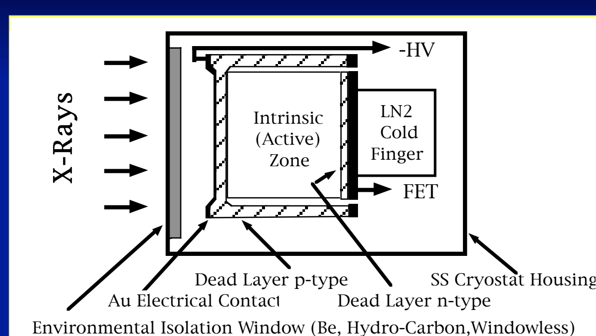

Resolution vs Count Rate
Tc = 1 □sec
FWHM Resolution (eV)
350
300
250
200
150
100
0
50
100
150
200
250
Input Count Rate (Kcps)
Si Ka
Cu Ka
Mo Ka


Resolution vs Time Constant
FWHM Resolution (eV)
400
350
300
250
200
150
100
50
0
5
10
15
20
Energy (keV)
0.25 usec
0.5 usec
1.0 usec
2.0 usec
4.0 usec
16 . 0 usec
64.0 usec

Dead Time vs Count Rate

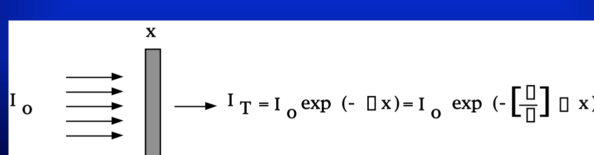


Solid State Detector Construction



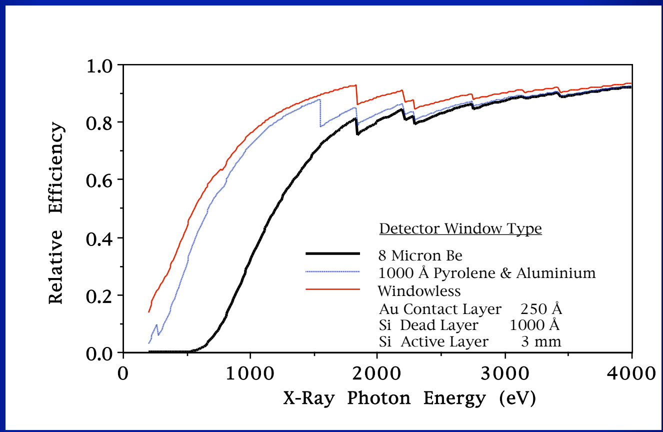
Relative Detection Efficiency

Solid State Detectors: Si(Li) or Instrinsic (High Purity) Ge
Using a simple absorption model define the relative detector efficiency $\varepsilon(E)$
by the following procedure:

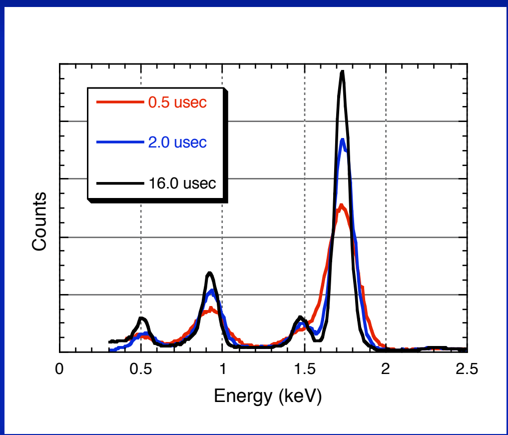


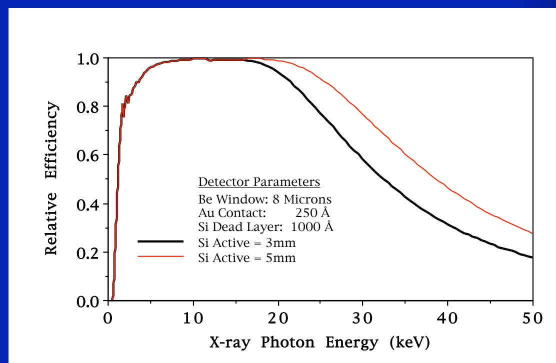
$$I_T = I_o \exp(-\mu x) = I_o \exp\left(-\left[\frac{\mu}{\rho}\right]\rho x\right)$$

Relative Detector Efficiency

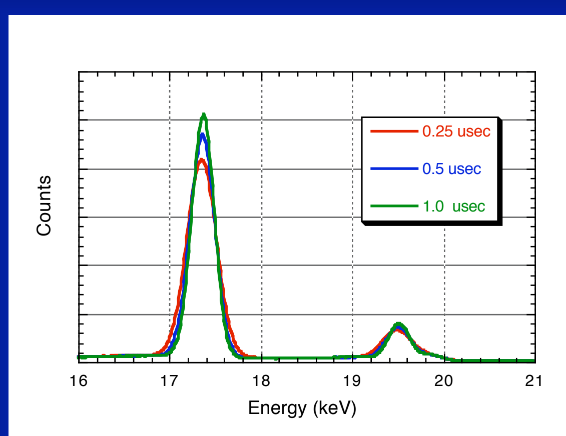


Resolution vs Tc and Energy

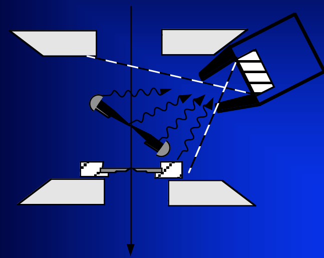




Resolution vs Tc and Energy

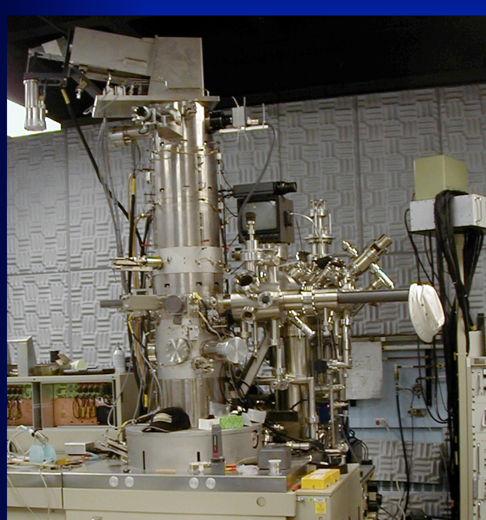


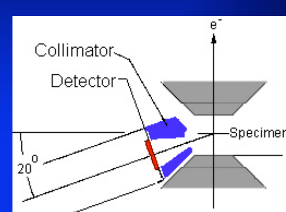
Subtending Solid Angle

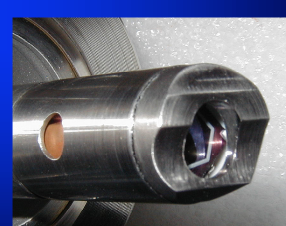


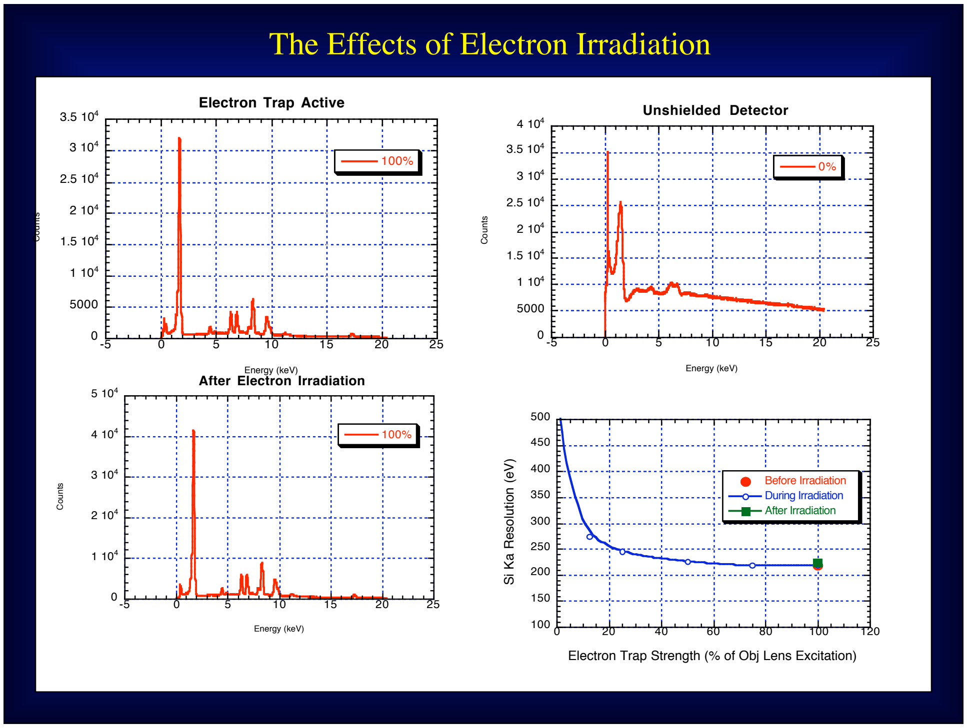
Large Solid Angles
Are Important for the
Next Generation of AEM

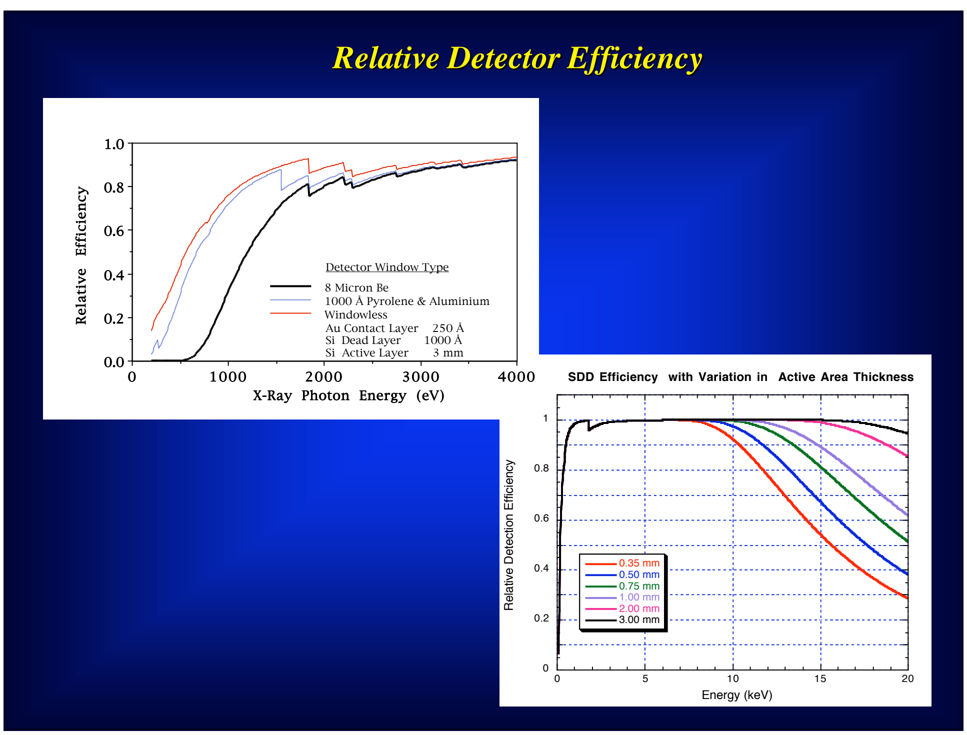
Electron Damage Effects

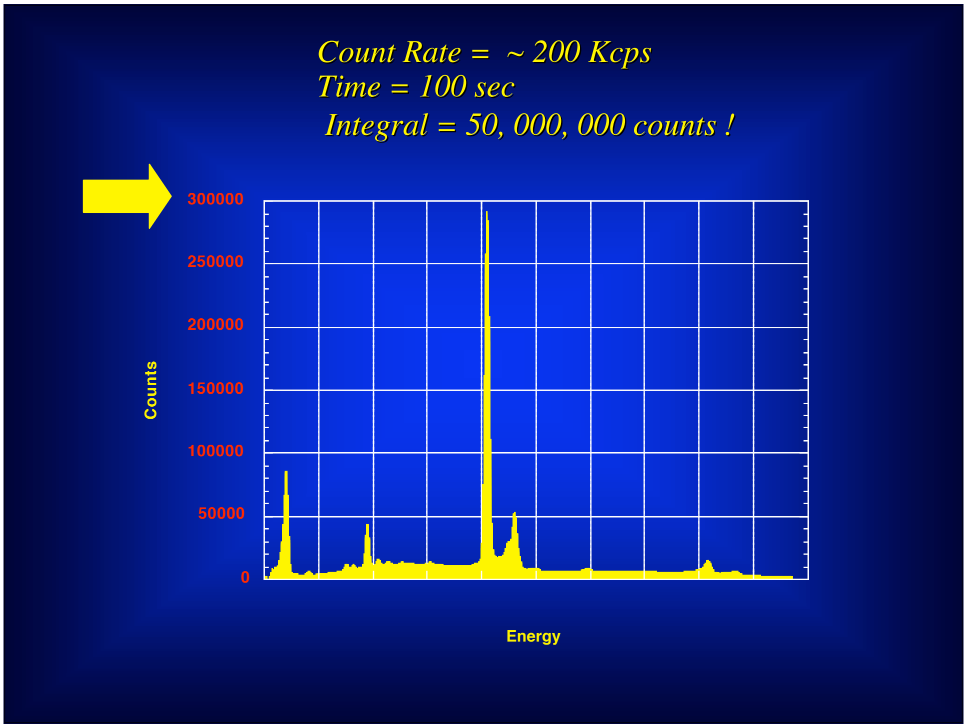


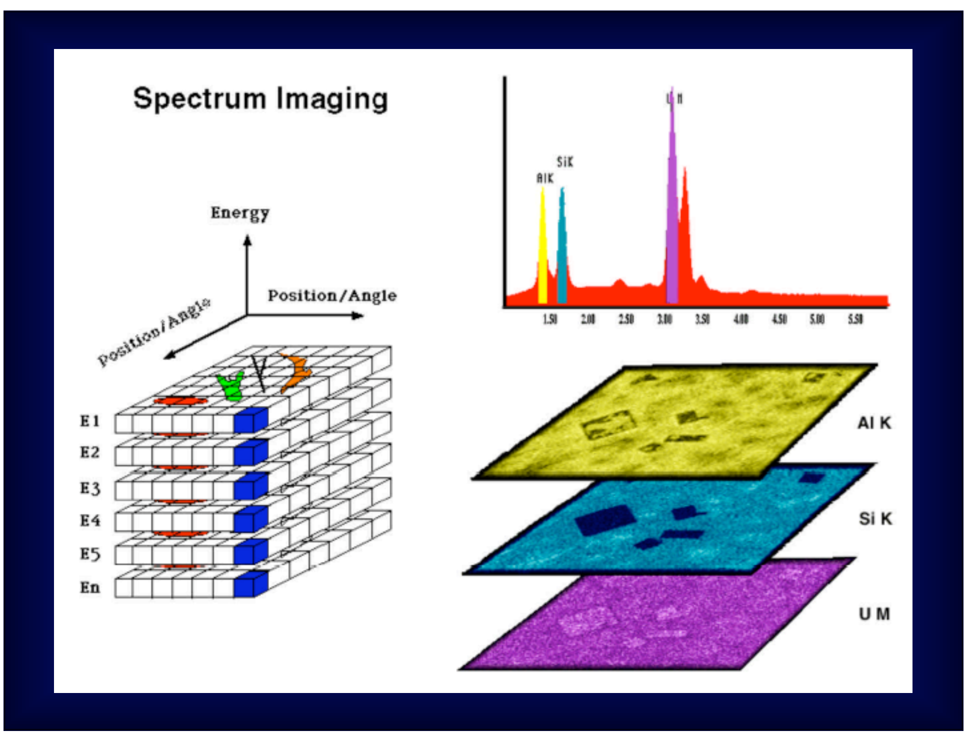


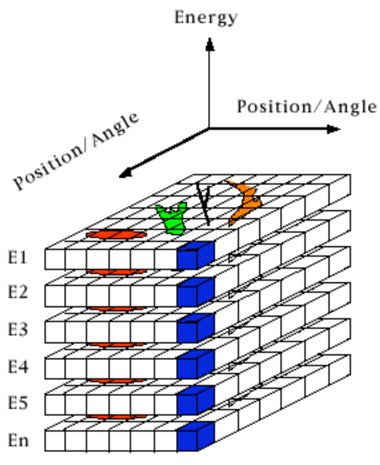



The Effects of Electron Irradiation
Electron Trap Active
100%
Counts
Energy (keV)
Unshielded Detector
0%
Counts
Energy (keV)
After Electron Irradiation
100%
Counts
Energy (keV)
Si Ka Resolution (eV)
Before Irradiation
During Irradiation
After Irradiation
Electron Trap Strength (% of Obj Lens Excitation)


Relative Detector Efficiency
Relative Efficiency
X-Ray Photon Energy (eV)
Detector Window Type
8 Micron Be
1000 Å Pyrolene & Aluminium
Windowless
Au Contact Layer 250 Å
Si Dead Layer 1000 Å
Si Active Layer 3 mm
SDD Efficiency with Variation in Active Area Thickness
Relative Detection Efficiency
0.35 mm
0.50 mm
0.75 mm
1.00 mm
2.00 mm
3.00 mm
Energy (keV)

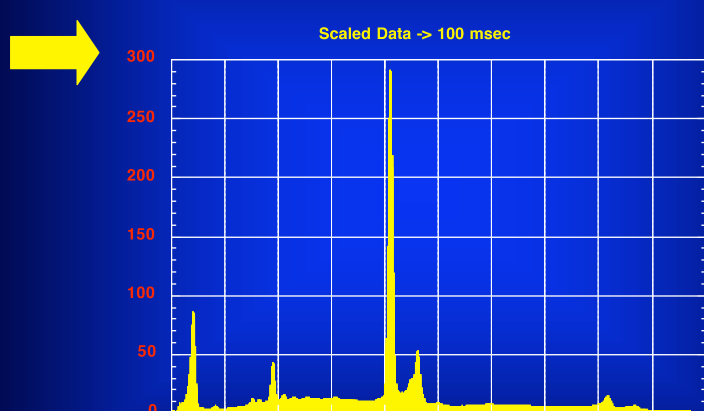

Count Rate = ~ 200 Kcps
Time = 100 sec
Integral = 50, 000, 000 counts !
300000
250000
200000
150000
100000
50000
0
Counts
Energy


Spectrum Imaging
Energy
Position/Angle
Position/Angle
E1
E2
E3
E4
E5
En
Al K
Si K
U M
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
Al K
Si K
U M



Spectrum Imaging

t \ XY	128^2	256^2	512^2	1024^2
1 μs	16 ms	65 ms	0.26 s	1.05 s
1 ms	16 s	65 s	4.4 min	17.5 min
1 s	~4.5 hrs	~18 hrs	~3 days	~12 days
1 min	~11 days	~1.5 mnths	~ 6 mnths	~2 yrs



Thanks

Questions?