The Role of Gas-Based Photon Detectors in Synchrotron Experiments

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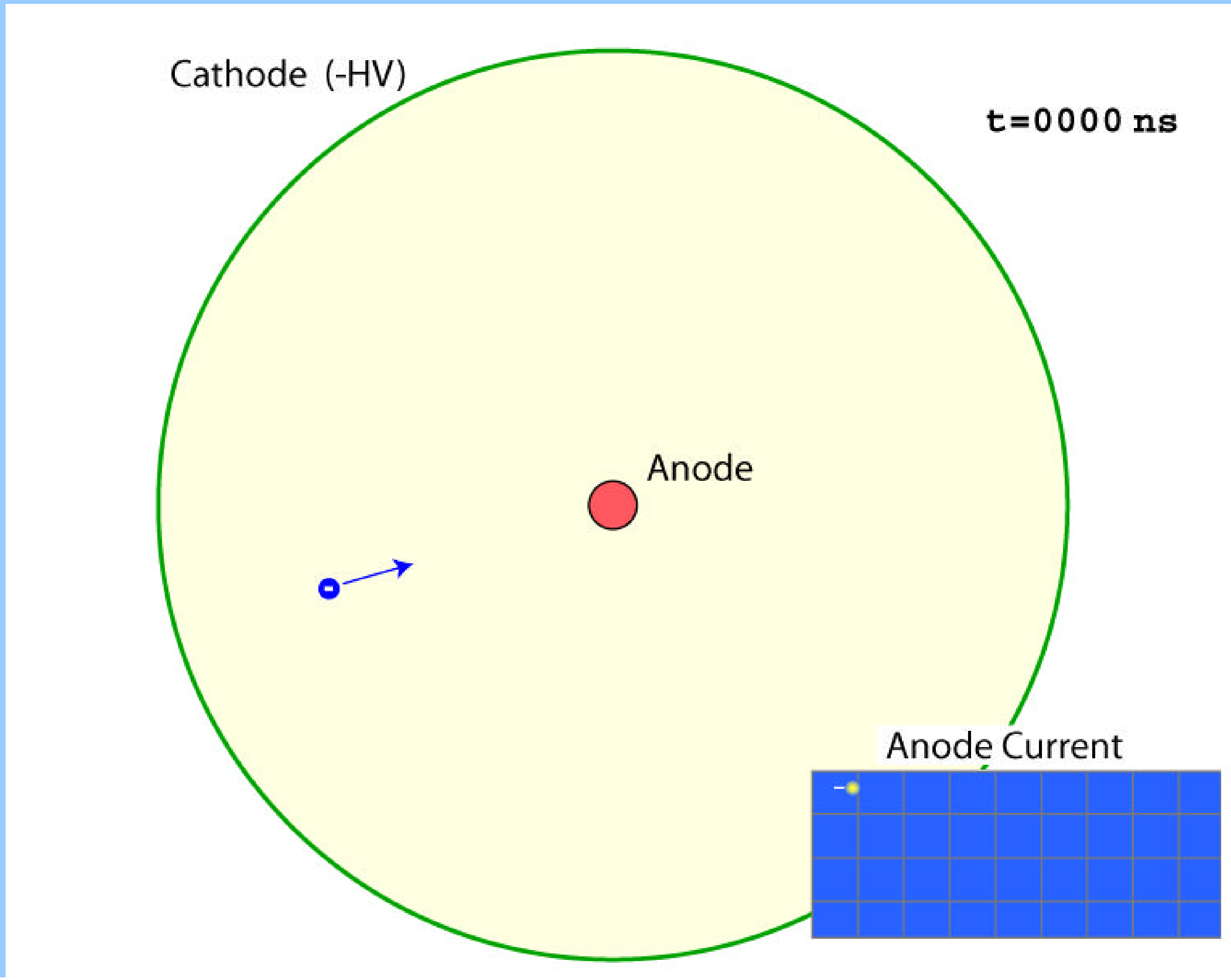
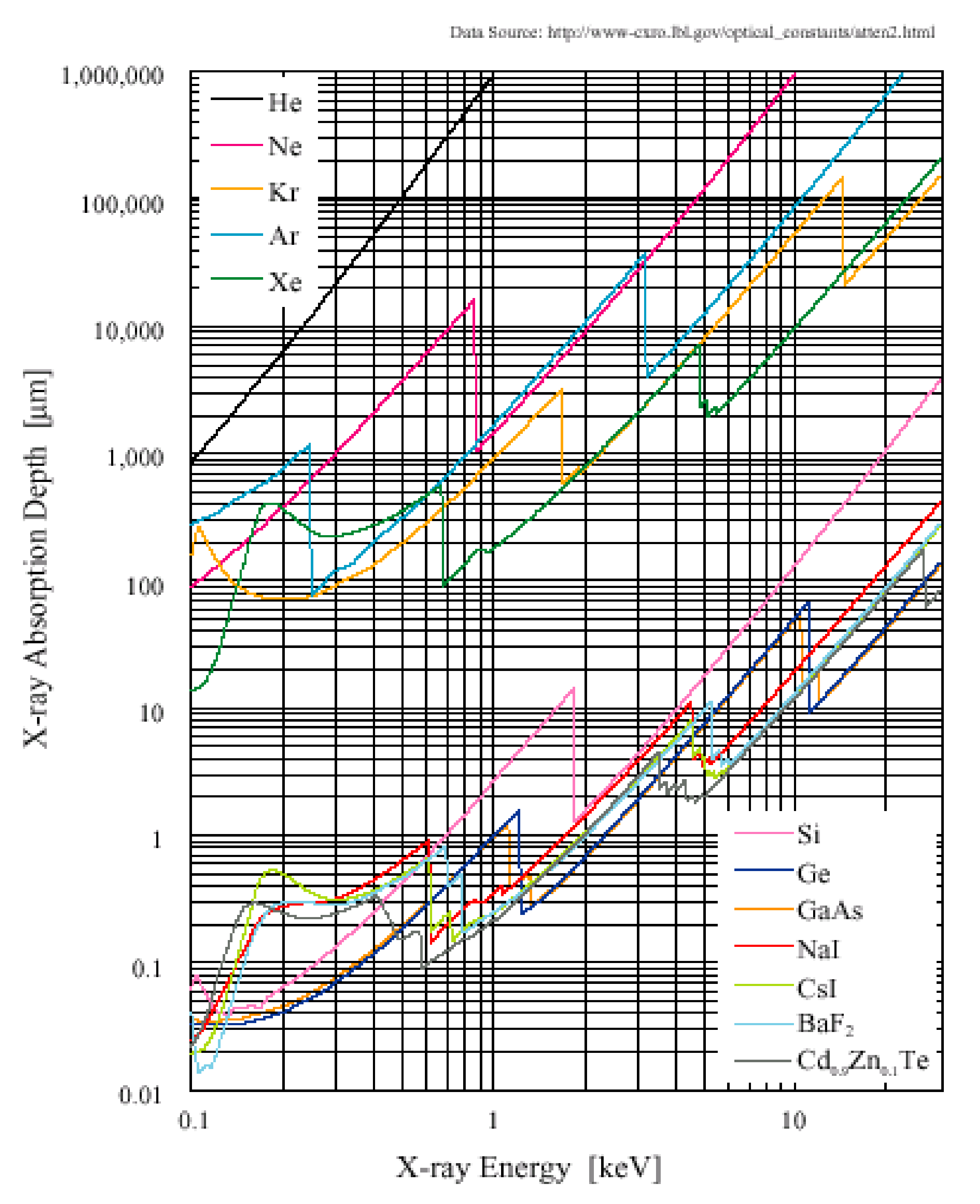
ESRF Detector Workshop. February 13-14, 2003

Brookhaven National Laboratory

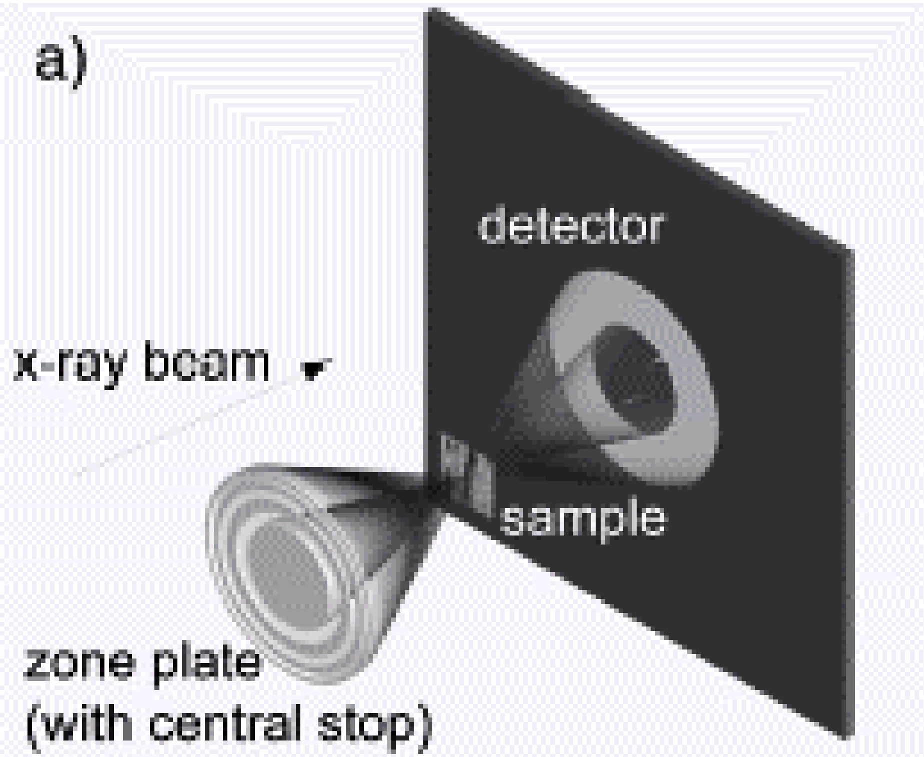
Operating Principle of a Proportional Counter

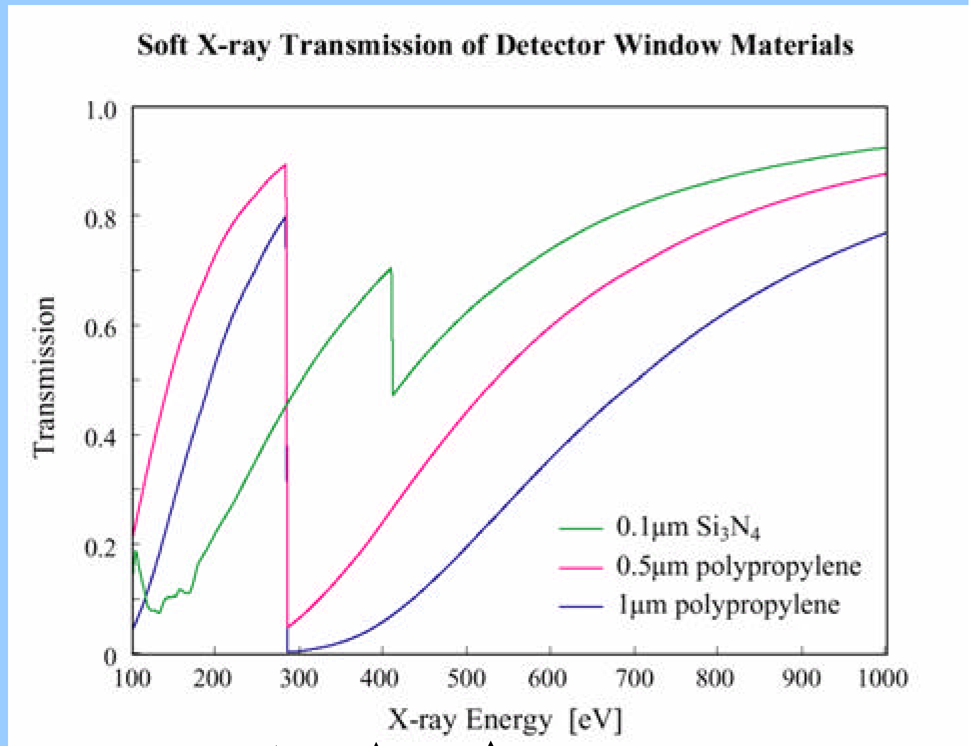


X-ray Absorption Depth in Various Media



Soft X-ray Microscopy with a Gas-based Photon Counter

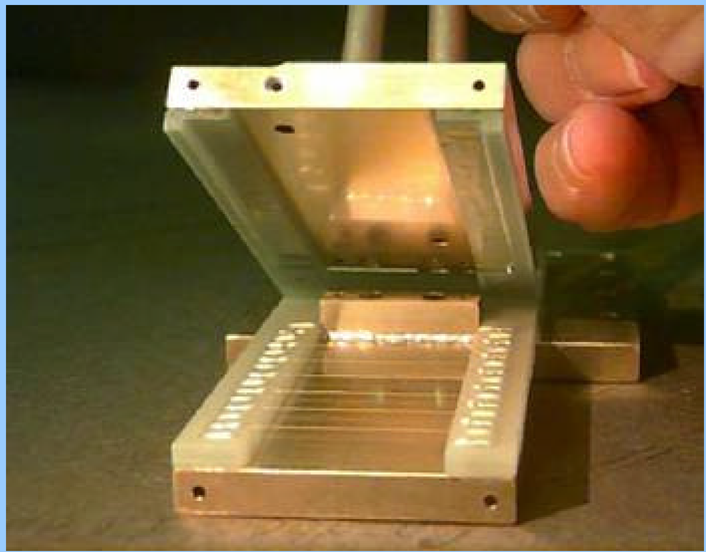


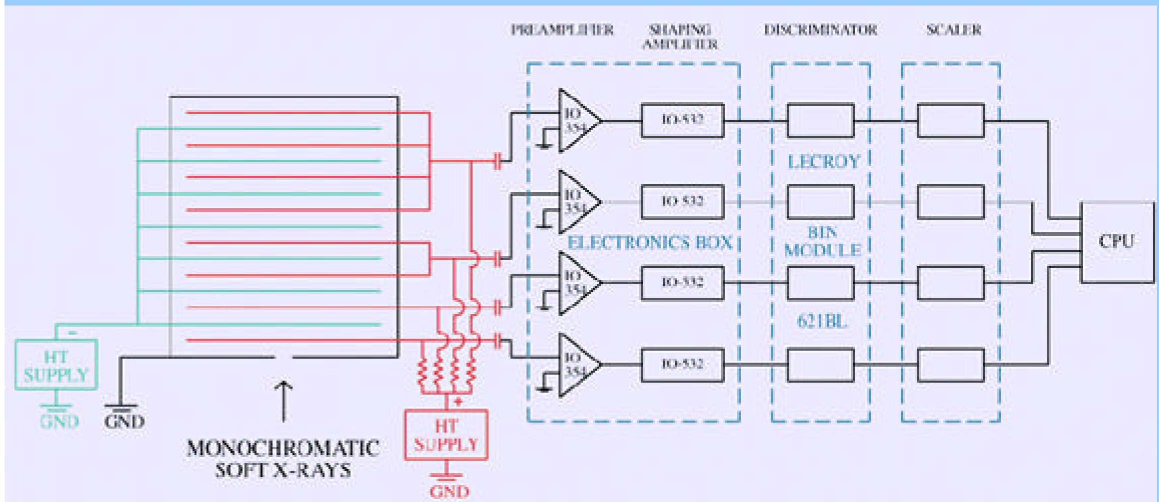


C_K N_K O_K

Soft X-ray Microscopy

Detector and Electronics

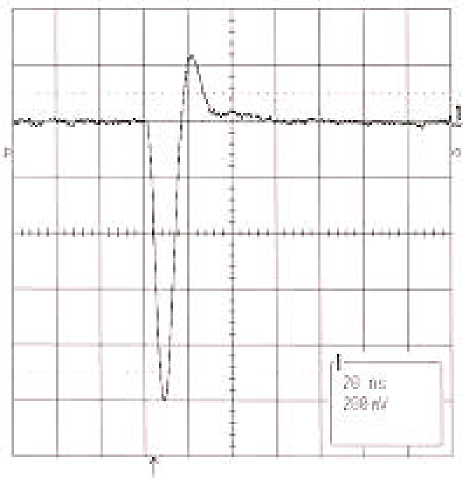




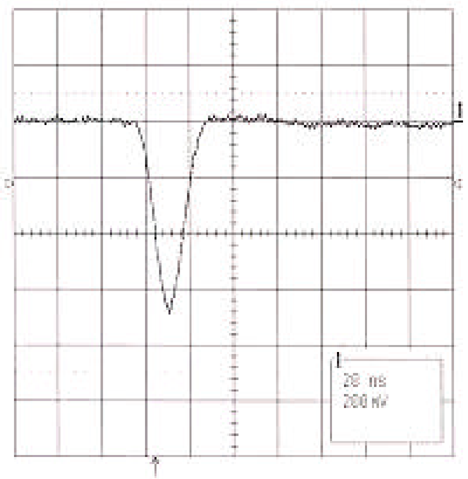
Complete Detector System

Soft X-ray Microscopy

Signal Waveforms



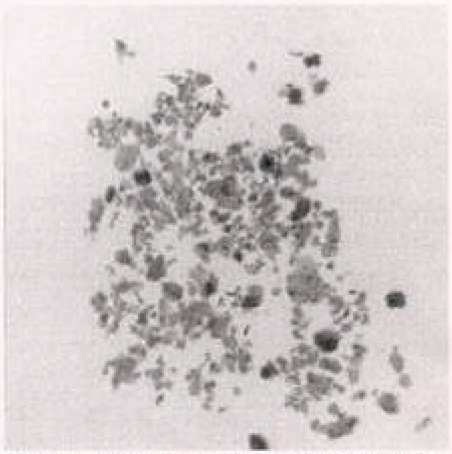
Step pulse response



X-ray response

Fast shaper outputs after pole-zero adjustment for positive-ion tail cancellation

Images from X1A of NSLS.

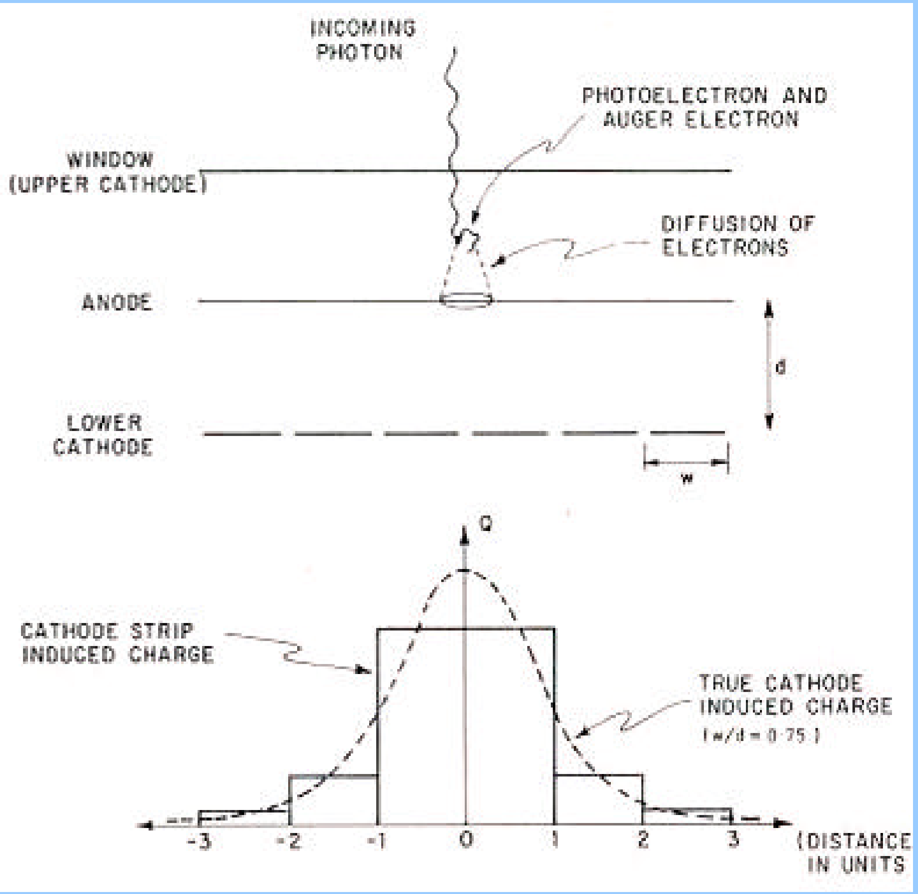


Flocculates in soil – study to reduce erosion in soil loam

Floculates in soil – study of erosion reduction in soil loam

Test pattern, using C_K X-rays. Line width at center is 25 nm

X-ray Conversion and Position Determination



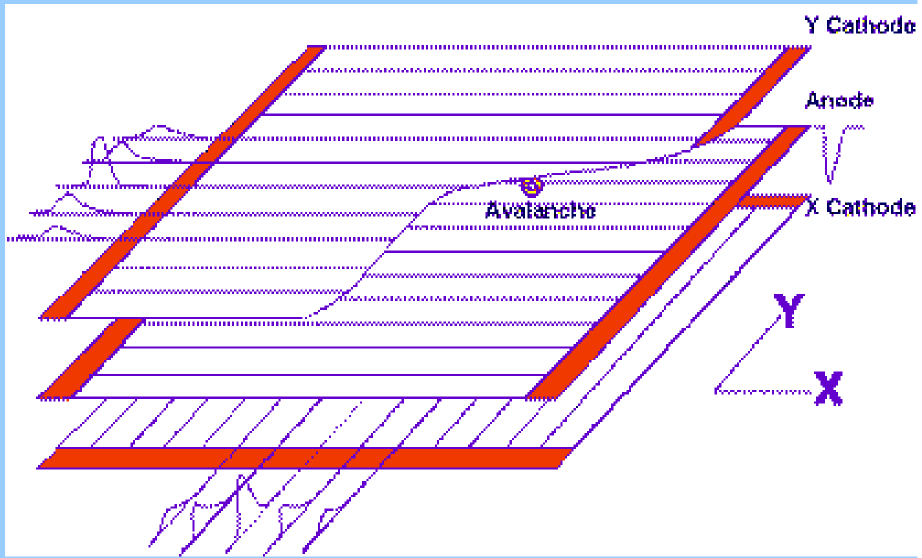
Key principles for stable gas detector operation:

? Low avalanche size (0.1 pC) – minimize gas gain

? Low noise elctronics

? Research grade purity

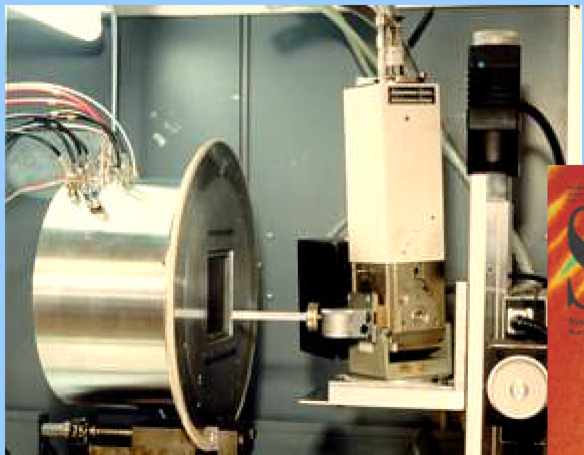
? Gas flow or circulation/purification

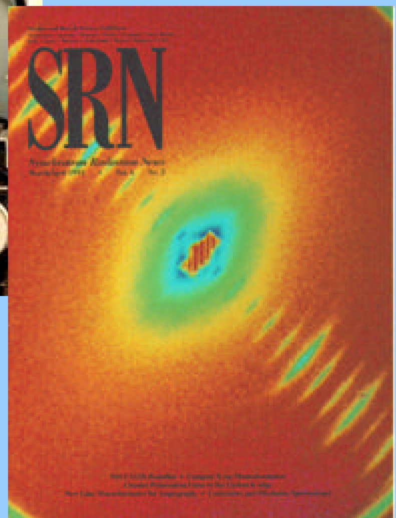


Position Readout Modes of Gas Detectors

Delay Line on Each Cathode

(Less complex electronics)





Developed in a number of Laboratories.

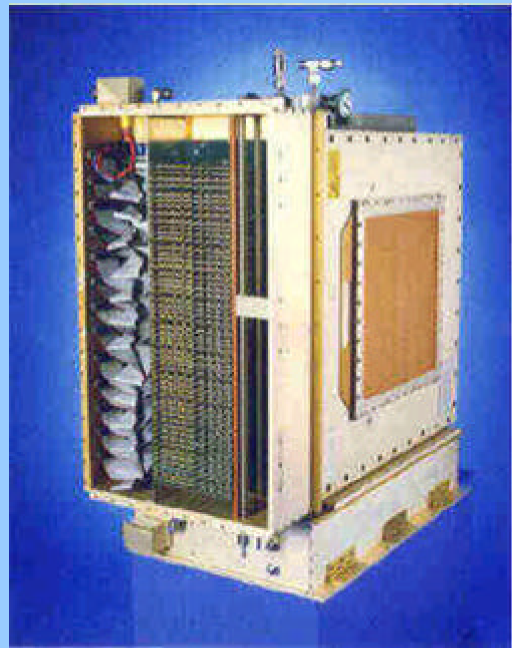
Position Accuracy: Photo-electron range

Rate Capability: 100-500 kHz

Dynamic studies down to 10^{-2} s

Amp/ADC on each cathode strip

(More complex electronics)



RAPID (Refined ADC Per Input Detector)

Developed by Darebury Laboratory

Position Accuracy: ? 200? m

Rate Capability: 10 –100 MHz

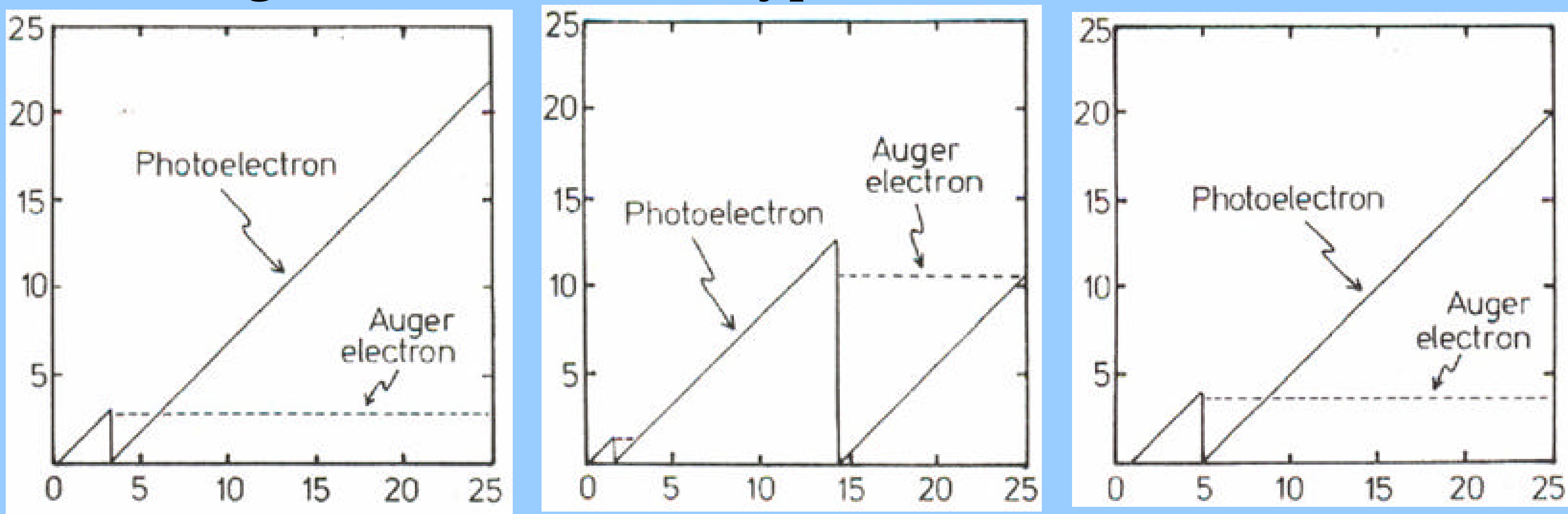
Dynamic studies down to 10^{-4} s

http://detserv1.dl.ac.uk/herald/detectors_rapid_movies.htm

Photoelectron/Auger Electron Energies

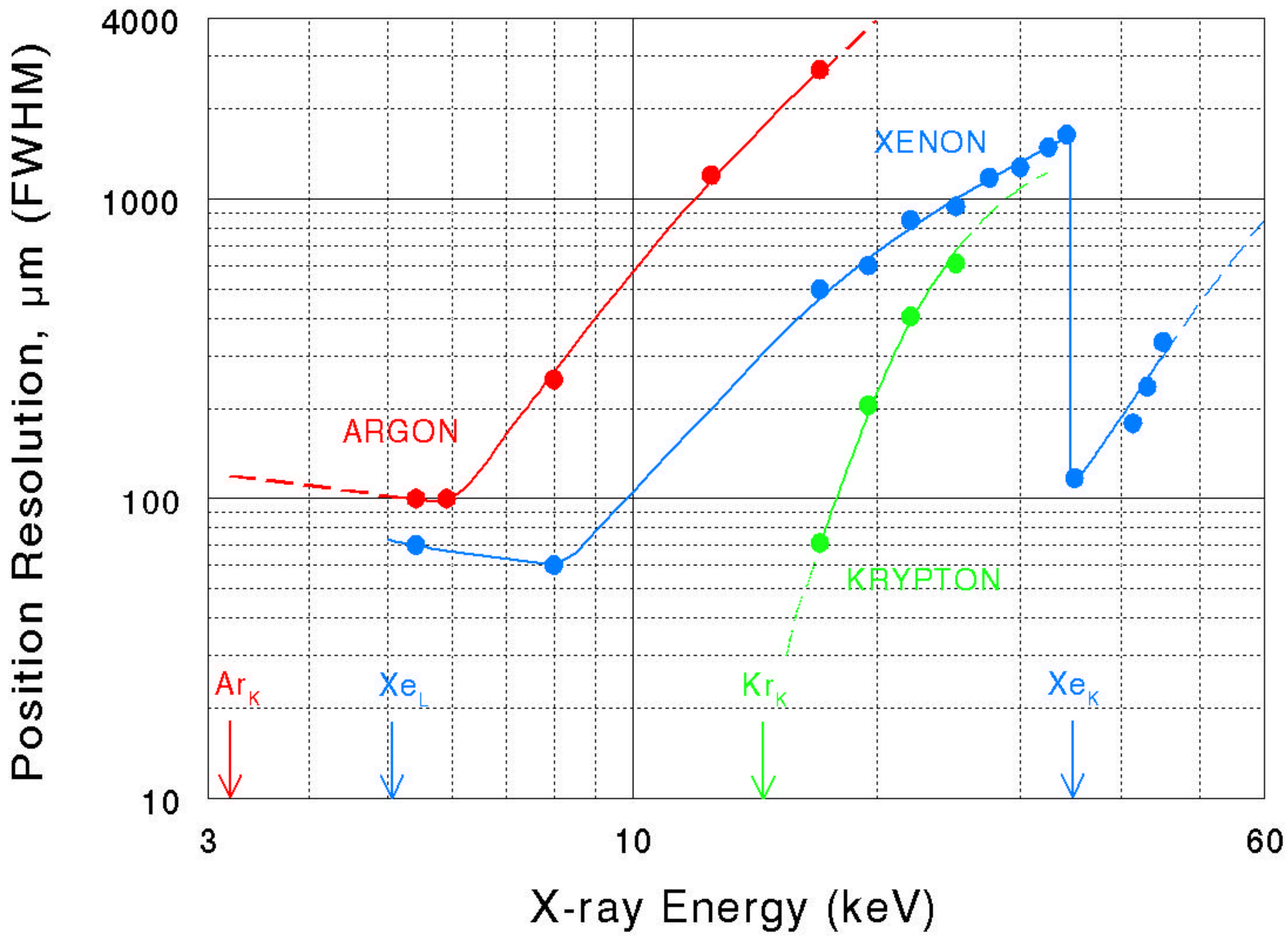
Argon Krypton Xenon

Electron Energy

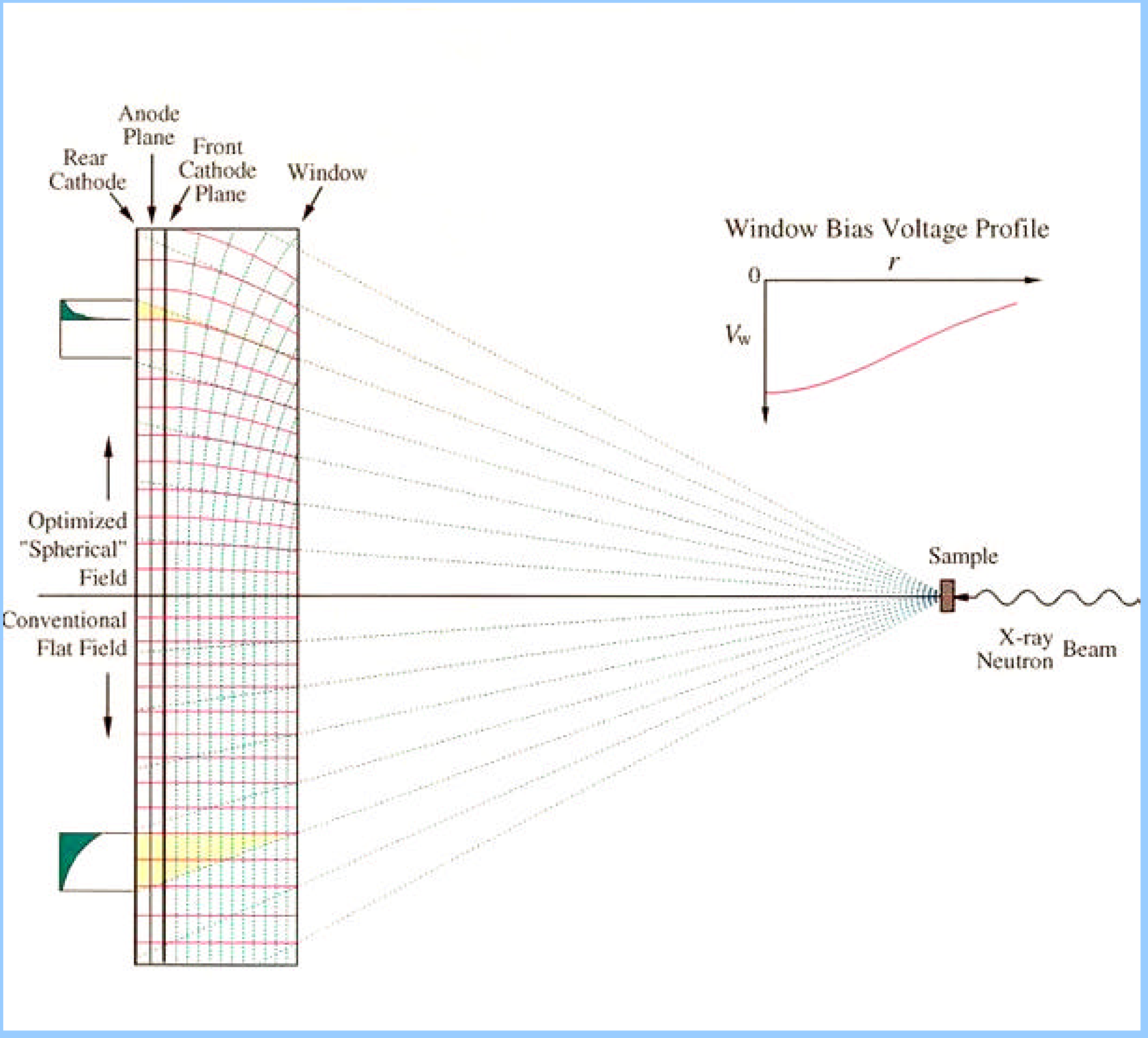


X-ray energy

X-ray Position Resolution, Limited Solely By Electron Range (1 bar operation)

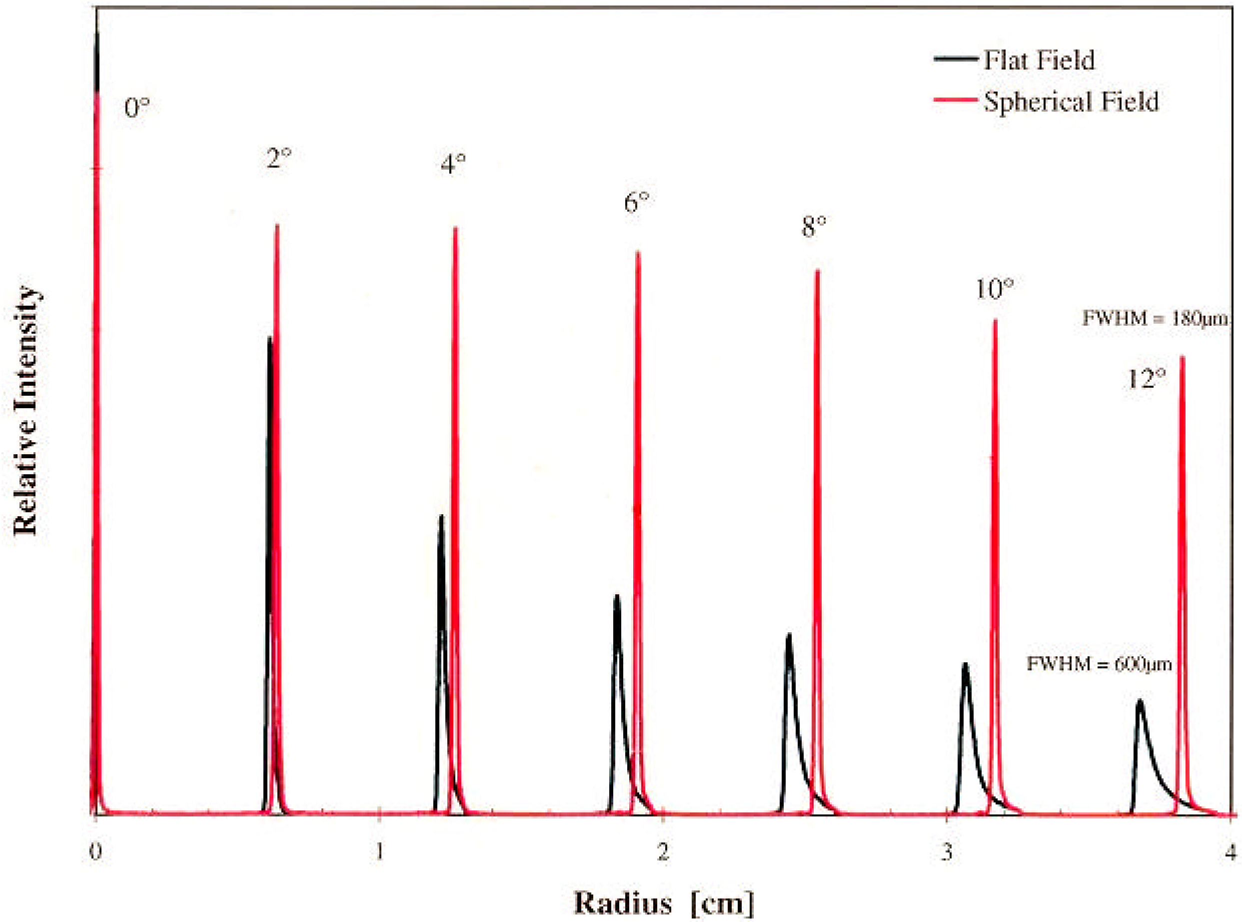


Technique for Reducing Parallax



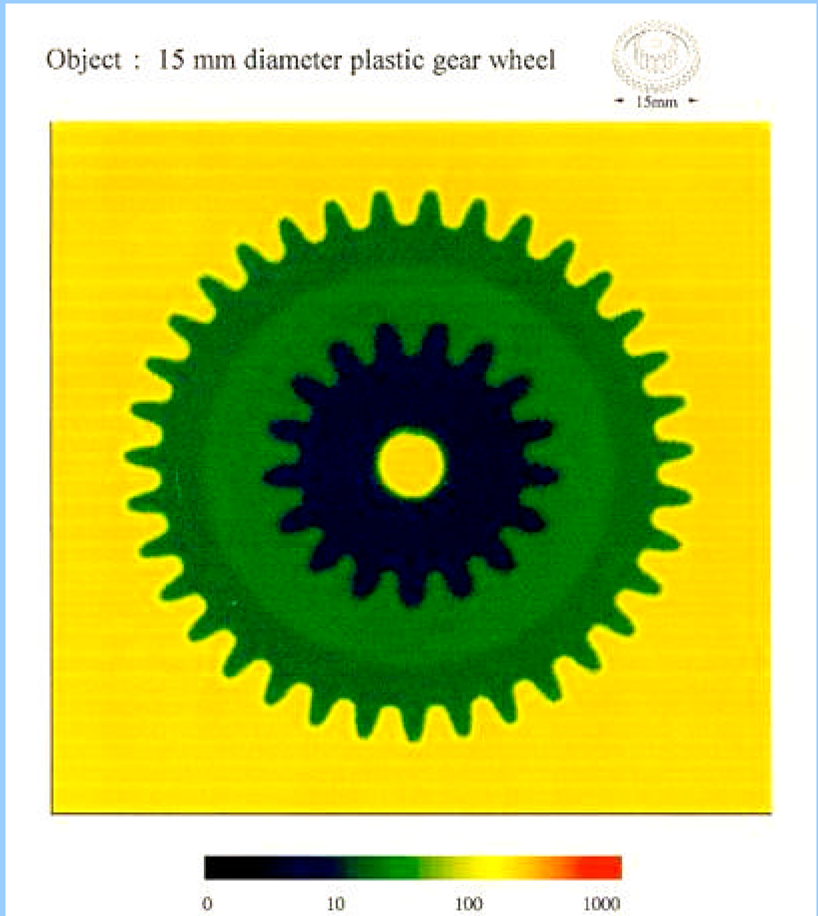
Detector Responses to Collimated Beam at Various Incident Angles

(5.4keV x-rays, Xenon+10%CO_2, 1.27cm Gas Depth, 18cm focal length)

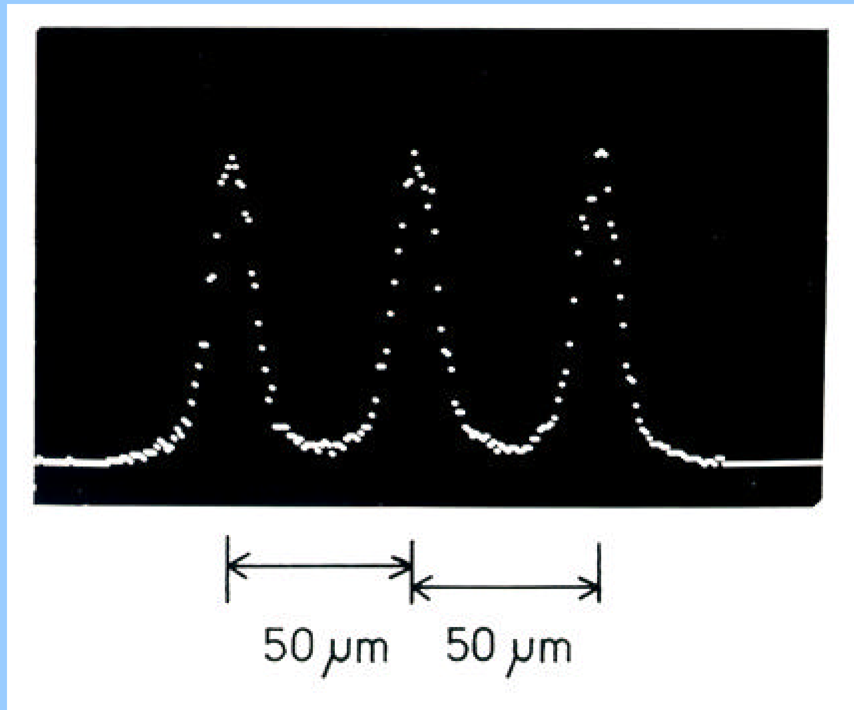


Some Unrivalled Performances

Linearity



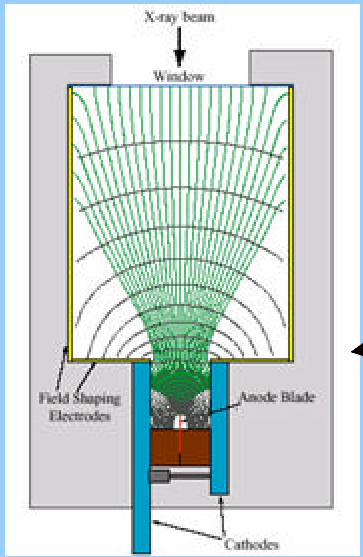
Position Resolution

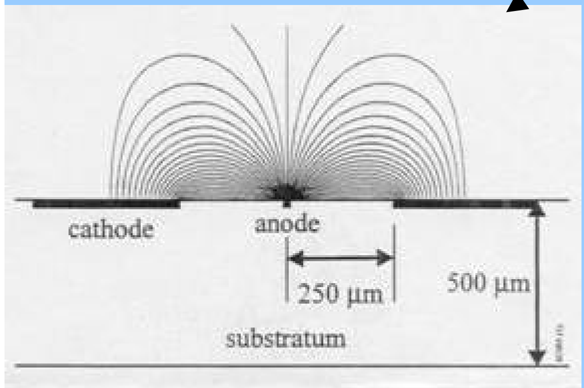


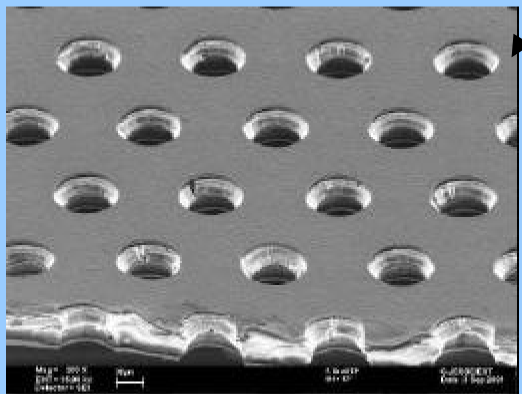
8keV conversion in
10bar Xe/10%CO_2
FWHM = 14 μm

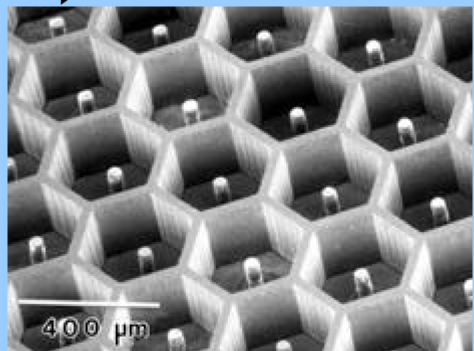
Micropattern Gaseous Detectors

Acronym	*Translation*	*Origination*
Blade	Blade	1980's
MSGC	Micro-Strip Gas Chamber	A. Oed, Grenoble, 1988
MGC	Micro-Gap	R. Bellazzini, Italy, 1995
CAT	Compteur A Trou	F. Bartol et al France 1995
GEM	Gas Electron Multiplier	F. Sauli, CERN 1996
Micromegas	MICRO-Mesh Gaseous Structure	Y. Giomataris, France 1996
MIPA	Micro-Pin Array	P. Rehak, BNL, 1999

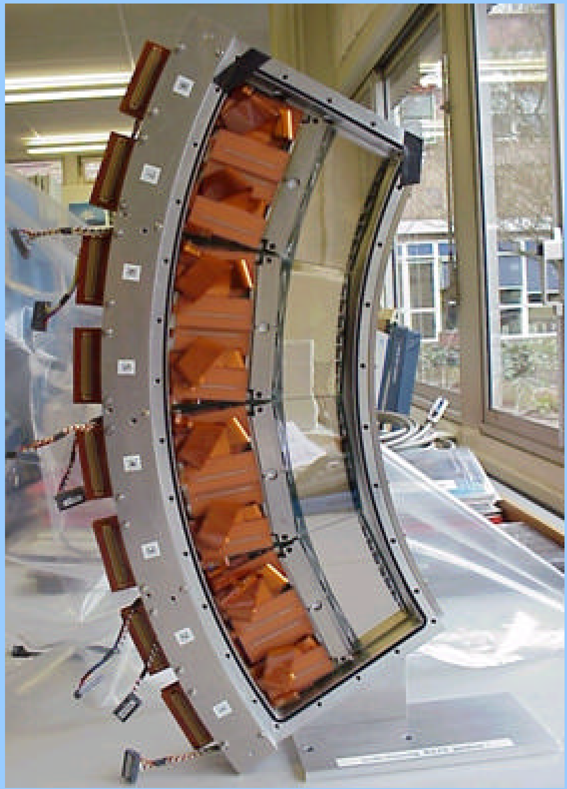








ESFR Beam Line X26

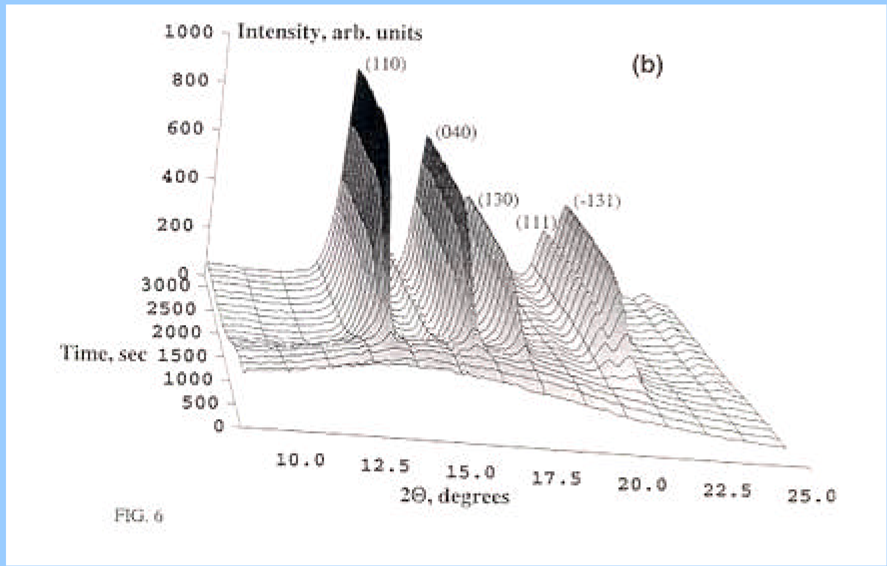


WAXS MSGC Detector	
Count Rate	4?10^{5} / s / channel
Time Resolution	1.5 ms / frame
Energy Range	5-25 keV
Opening Angle	60°
Angular Resn	0.03 °
Radius of curvature	360 mm (from anodes)

A Fast Position Sensitive Microstrip-Gas-Chamber Detector at High Count Rate Operation

I.P. Dolbnya, H. Alberda, F.G. Hartes, F. Udo, R.E. Bakker, M. Konijnenburg, E. Homan, I. Cerjak,, P. Goedtkindt and W. Bras

Rev. Sci Instrum. 73 (2002) 3754- 3758

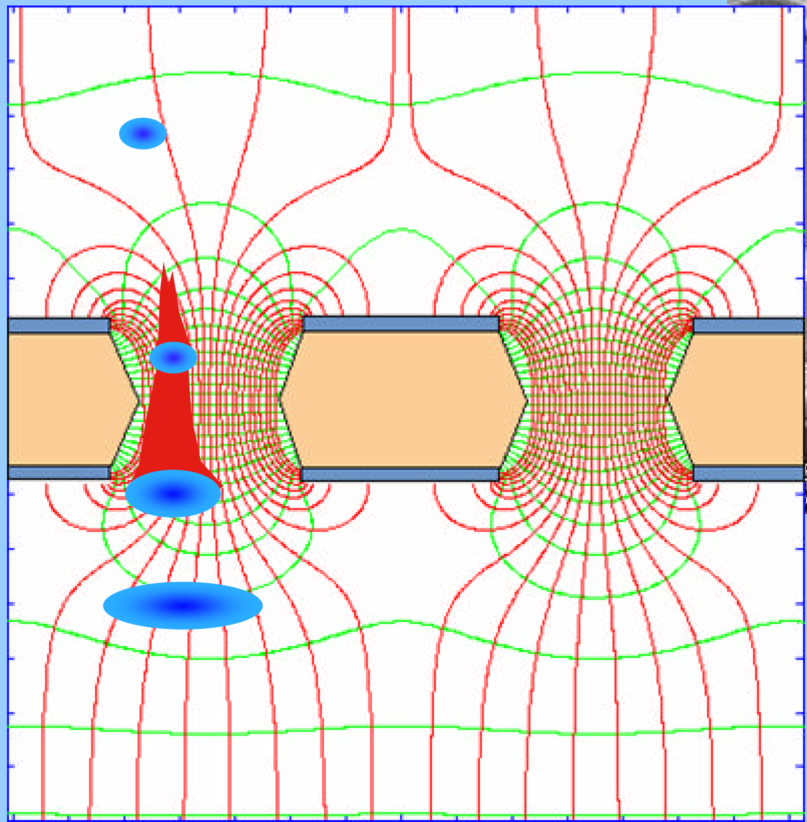


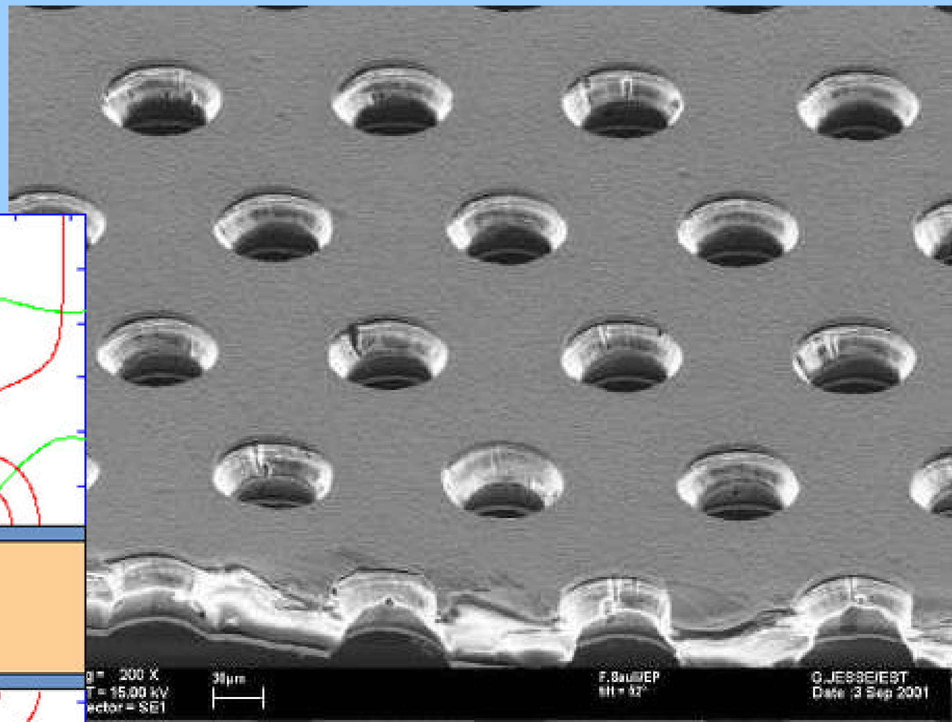
Time development of WAXS patterns of isothermally crystallizing iPP at 130° demonstrate different stages of the crystallization process (10 keV)

GEM
PRINCIPLE

GAS ELECTRON MULTIPLIER (GEM) F. SAULI (1996)

THIN, METAL-COATED POLYMER FOIL WITH A LARGE DENSITY OF HOLES (100 mm^{-2})

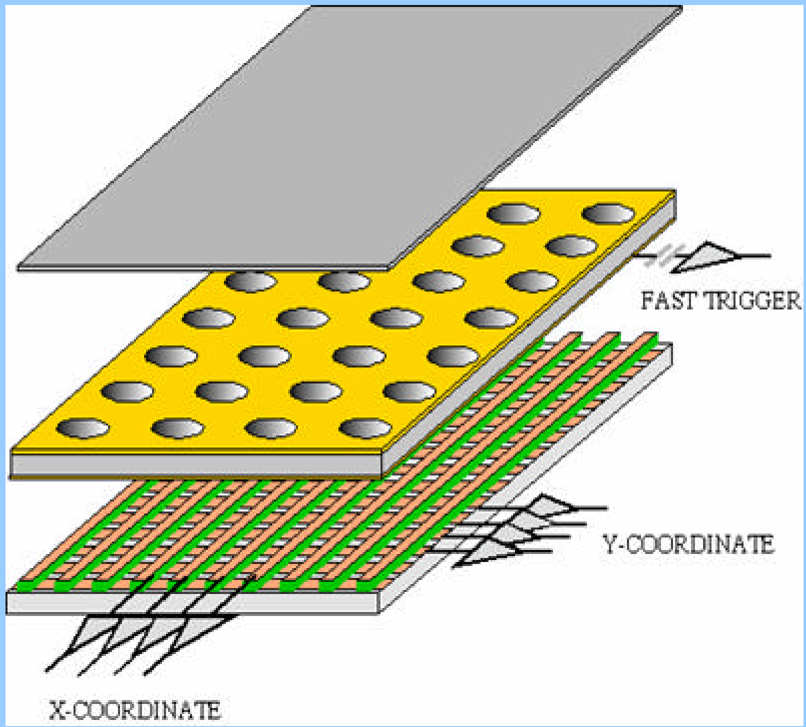




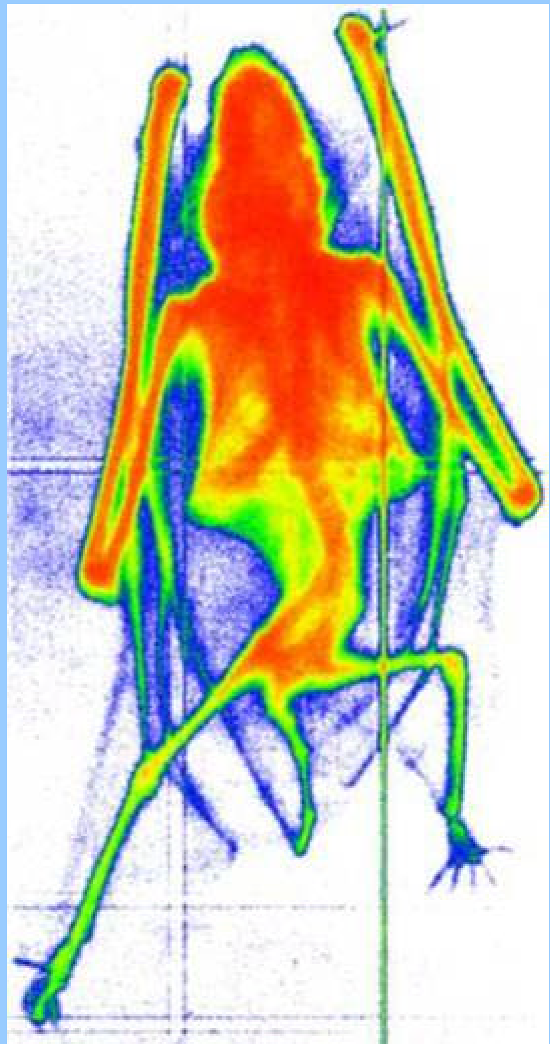
F. Sauli, Nucl. Instr. and Meth. A386 (1997) 531.

Absorption Radiograph of Small Mammal

Using the lower GEM signal, the readout can be self-triggered with energy discrimination:

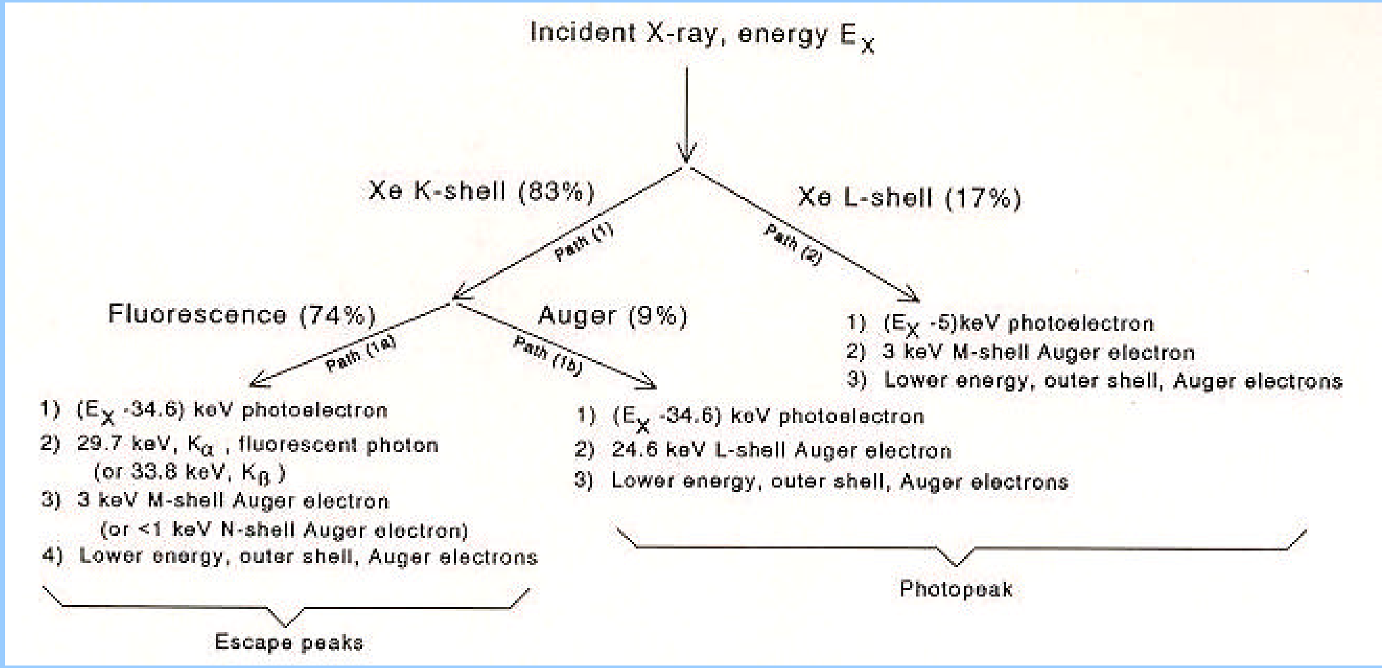


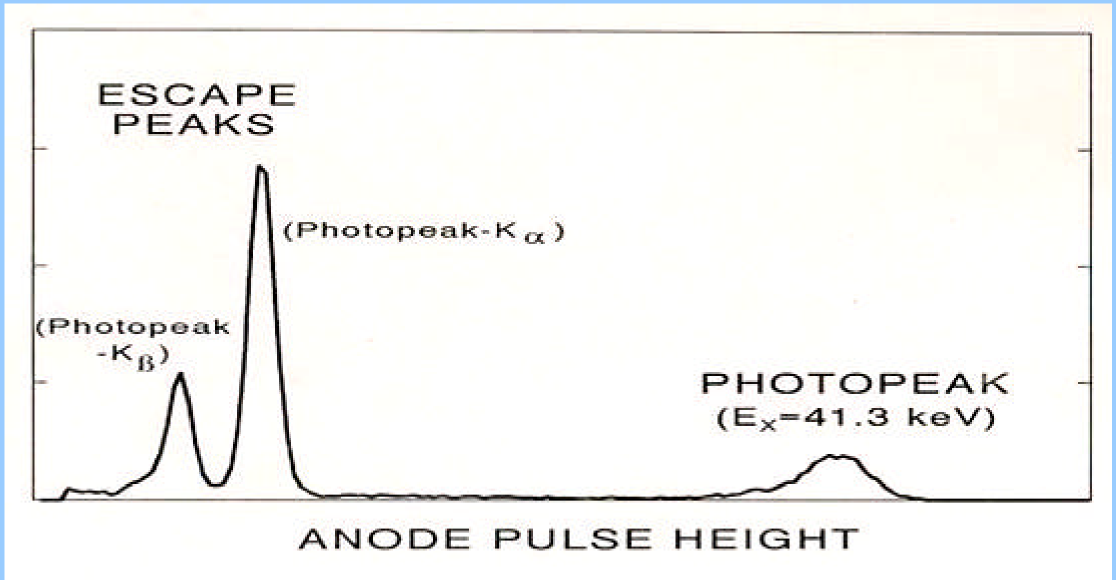
F. Sauli, Nucl. Instr. and Meth.A 461(2001)47



8 keV absorption radiography of a small mammal (image size ~ 60 x 30 mm^2)

X-ray Energies > 34.6 keV





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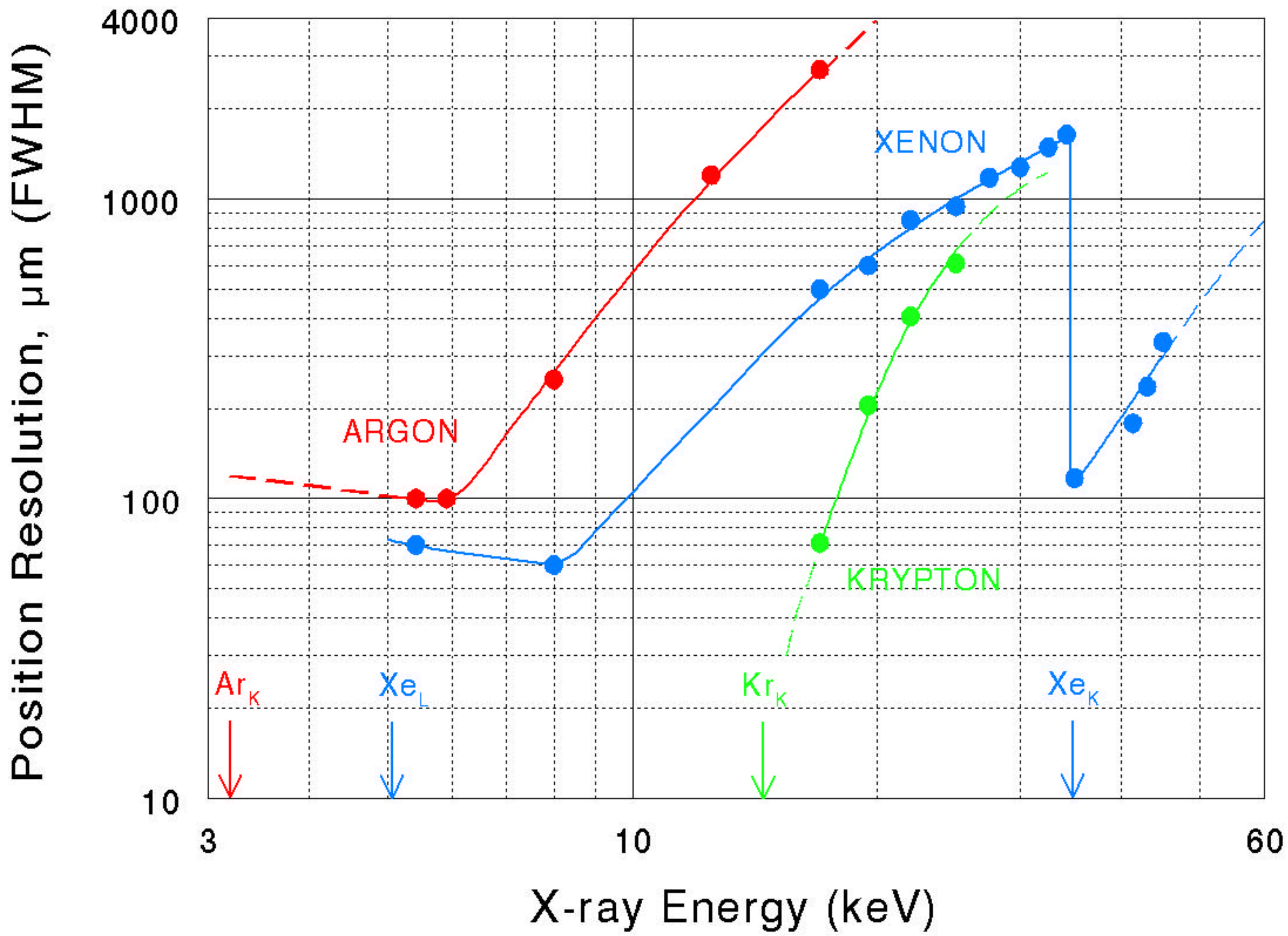


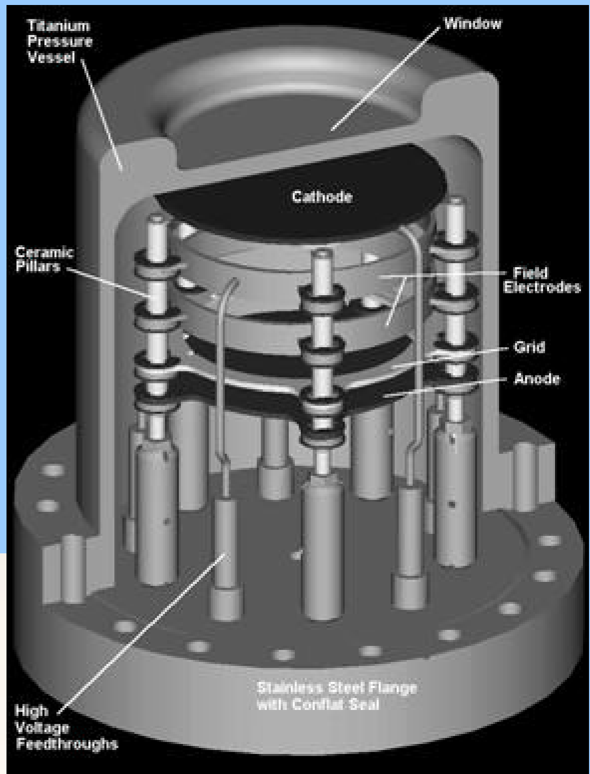
X-ray Energies of 100keV and Above

Compressed Xenon Ionization Detector

? = 0.55 g cm^{-3}

P ~ 800 psi

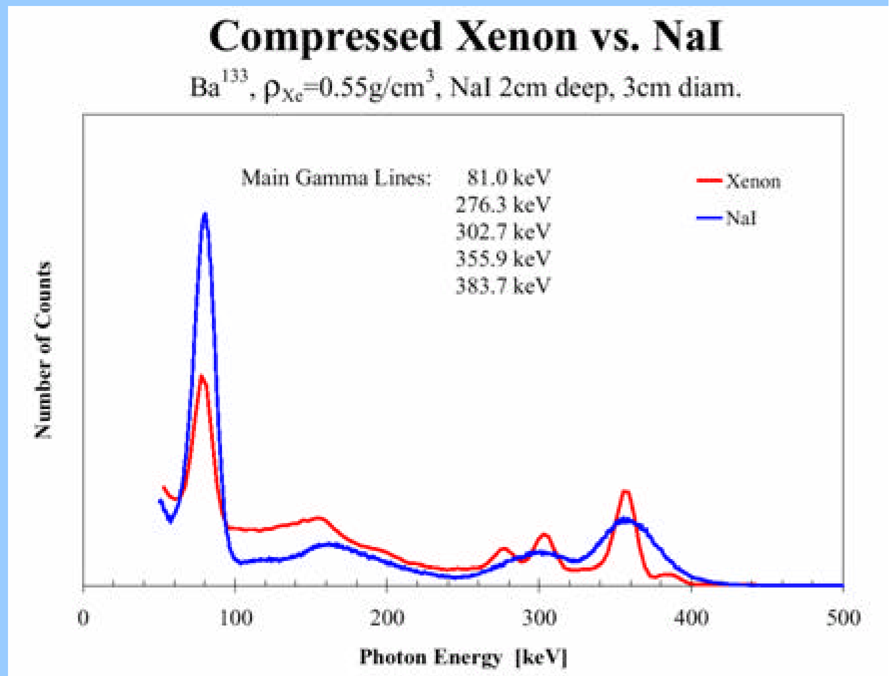
Purity: few ppb



$$\sigma_N^{\ 2} = FN$$

F = Fano Factor = 0.13 for xenon
N = No. of primary electrons = E_X / w
w = 22eV, energy per ion/pair

For E_X = 355 keV for example, **N = 16,100 electrons**
FWHM = 0.7 %



Main applications in Anti-terrorism and X-ray Astronomy

Summary

It is important for the community to support a continued role for gas detectors in synchrotron experiments:

? Versatile

? Wide energy range & area coverage, good position resolution (< 100 ? m)

? Count Rates: 10^5 s^{-1} to 10^7 s^{-1}

? Large Dynamic Range – counting mode

? Generally require less specialized infrastructure to fabricate

? Very reliable when fundamental characteristics are understood

? Provide an economic and appropriate solution in a number of applications