Overview of Neutron Detectors

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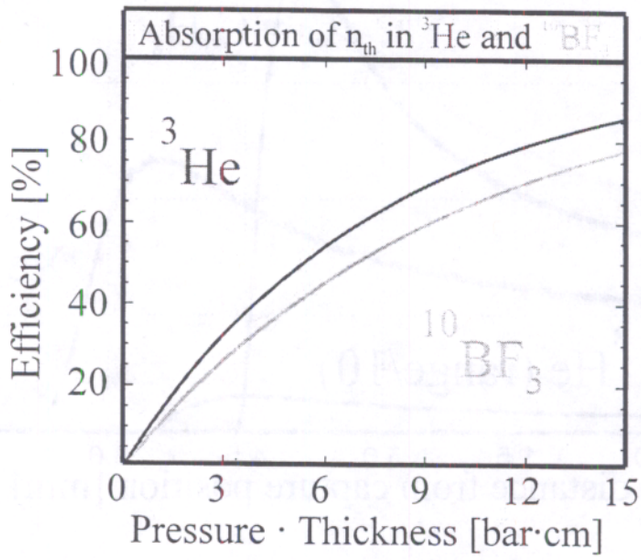
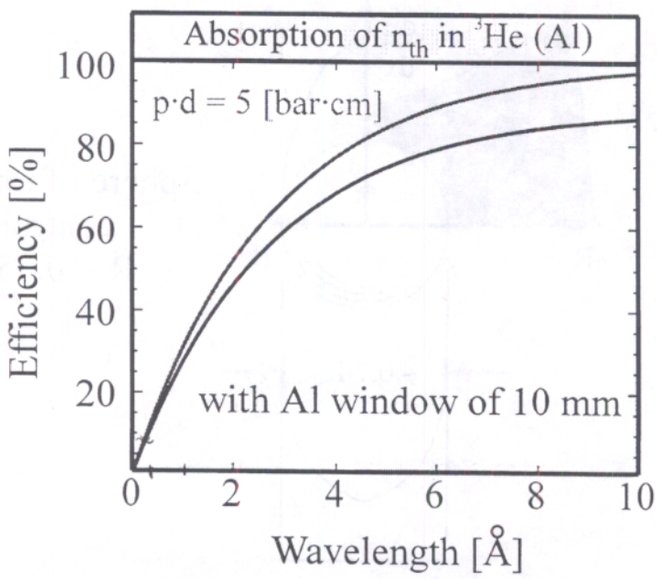
Table of Neutron Converters

Isotope	State	Reaction	Cross Section	Abs. length	Ejectile energies [keV]	Ejectile atten. length/range
^{3}He	gaseous	$^{3}He(n,p)t$	5 333 b	7.59 bar·cm	p: 573, t: 191	R_p = 0.43 bar·cm CF_4!
^{6}Li	solid	$^{7}Li(n,\alpha)t$	940 b	230 µm	t: 2727, α: 2055	R_t = 130 µm
^{10}B	solid	$^{10}B(n,\alpha)^{7}Li$	3 836 b	19.9 µm	α: 1472, ^{7}Li: 840	R_α = 3.14 µm
$^{10}BF_3$	gaseous	$^{10}B(n,\alpha)^{7}Li$	3 836 b	9.82 bar·cm	α: 1472, ^{7}Li: 840	R_α = 0.42 bar·cm
^{nat}Gd	solid	$^{nat}Gd(n,\gamma)$	49 122 b	6.72 µm	ce: 29 - 191 (86.5%)	λ_{ce} = 12.3 µm
^{157}Gd	solid	$^{157}Gd(n,\gamma)^{158*}Gd$	255 000 b	1.30 µm	ce: 29 - 182 (87.3%)	λ_{ce} = 11.6 µm

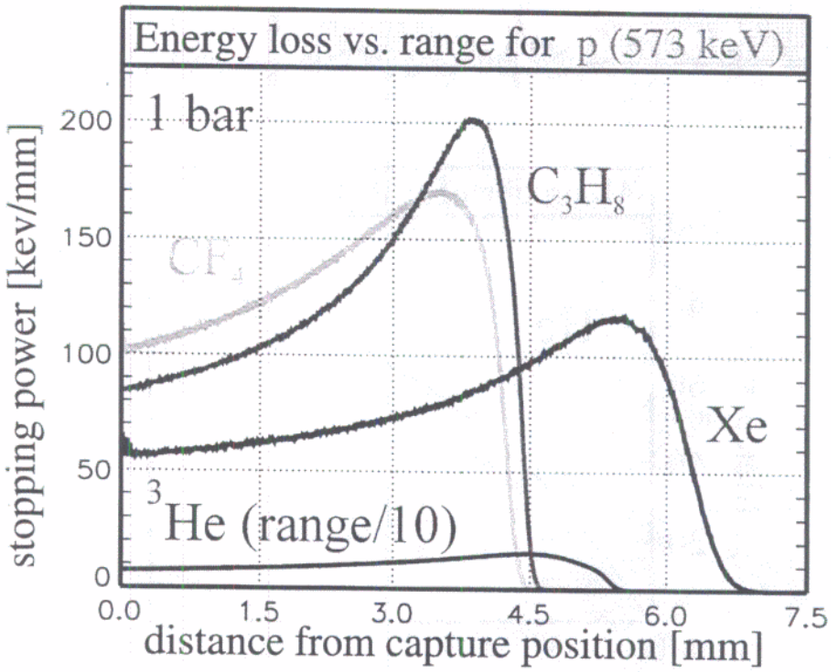
Absorption of Neutrons in Gases

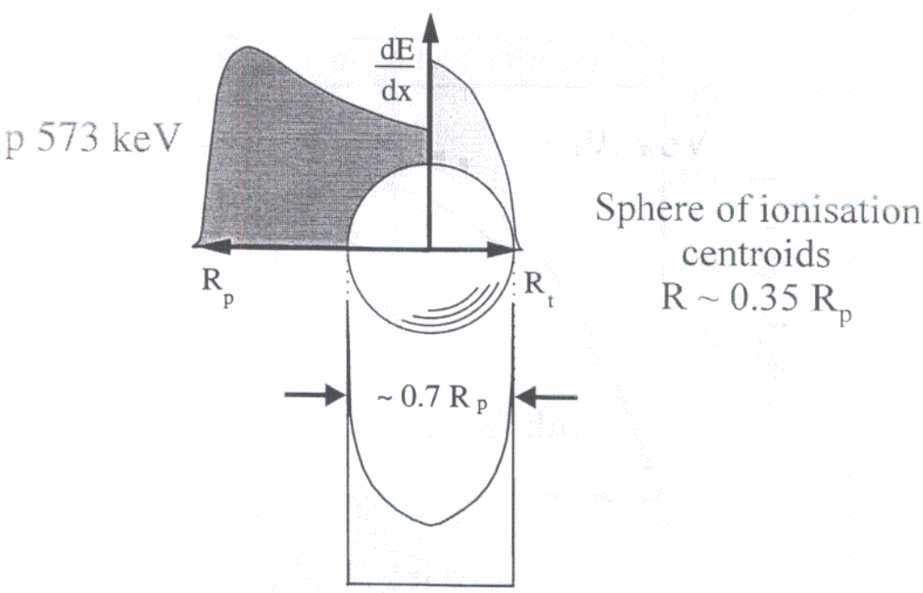
$$\varepsilon = (1 - \exp(-\rho \cdot L \cdot \sigma \cdot d \cdot p \cdot \lambda / A))$$



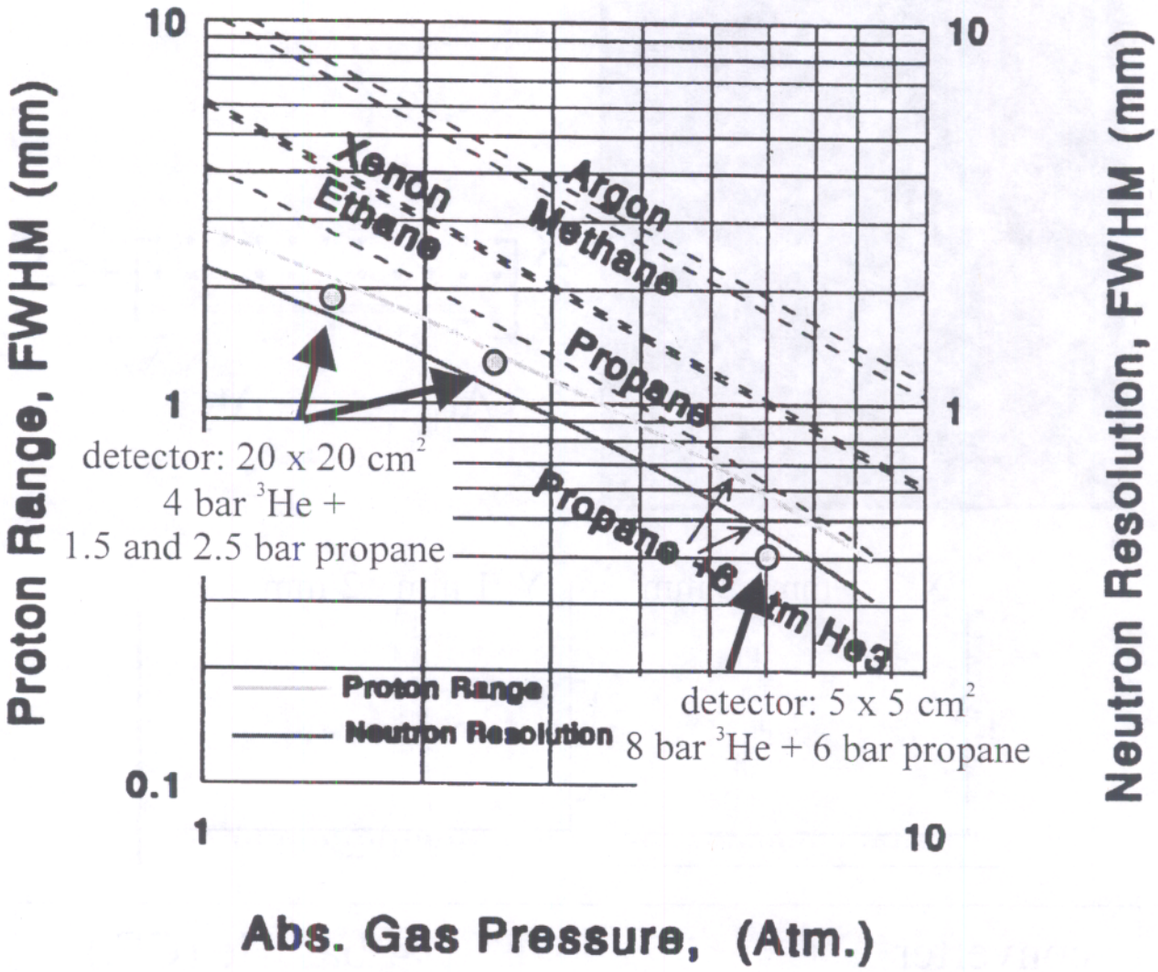


Range of Secondaries in Gases





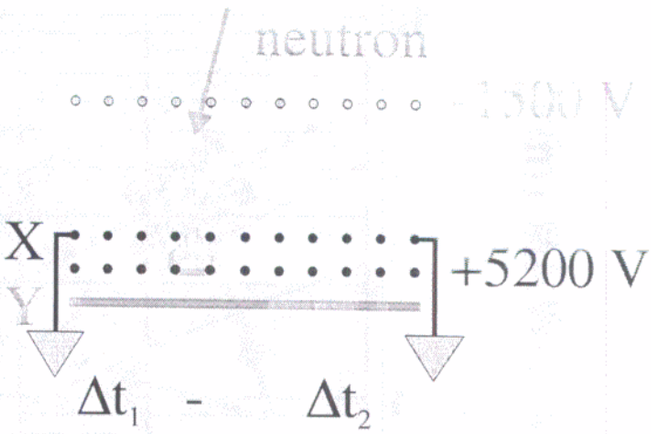
Position Resolution with Gas Detectors

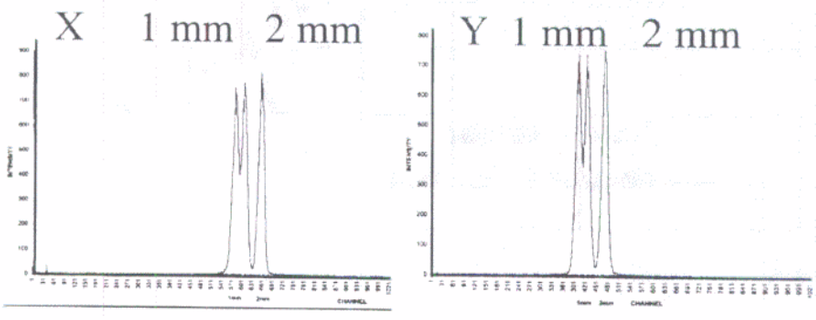


best position resolution with gas detectors:
0.4 mm at BNL

http://www.inst.bnl.gov/GasDetectorLab/NeutronDetectors/Brochure/Brochure.html

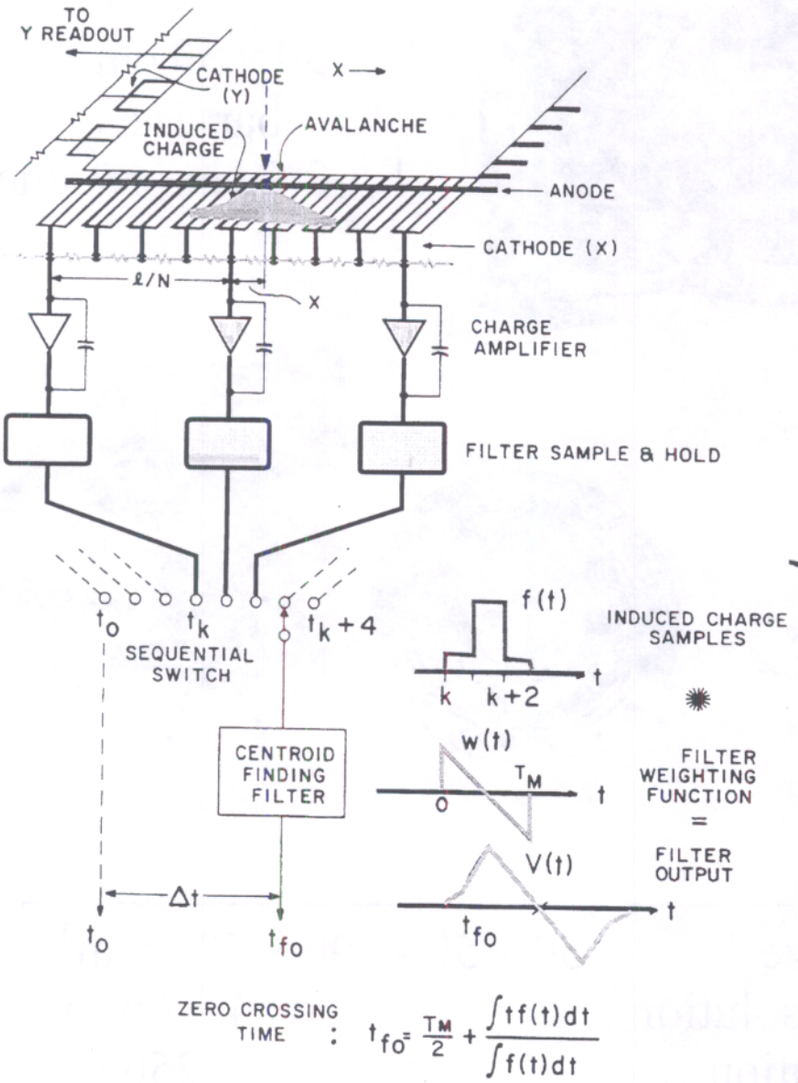
2D MWPC for Neutrons (EMBL)





converter	4 bar ^3He (CF_4)
detector size	90 x 90 - 300 x 300 mm^2
position resolution	1-2 mm
time resolution	<100 ns
efficiency @ 1.8 Å	28%
counting rate	0.5 MHz

Readout Method of BNL 2D Detectors



cathode wires

resistor chain

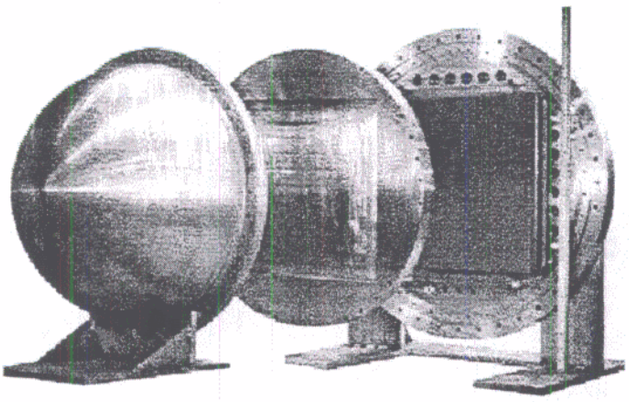
amplifier
shaper
stretcher

centroid
finding
filter

$$\text{fwhm} \propto \ell/N^{3/2}$$

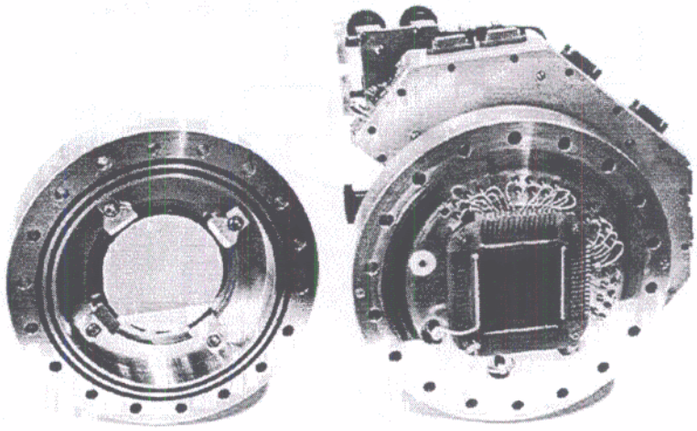
V. Radeka and R.A. Boie NIM 178 (1980) 543-554

2D Detectors at BNL



50 x 50 cm^2
bar ^3He +
1.5-2.5 bar propane

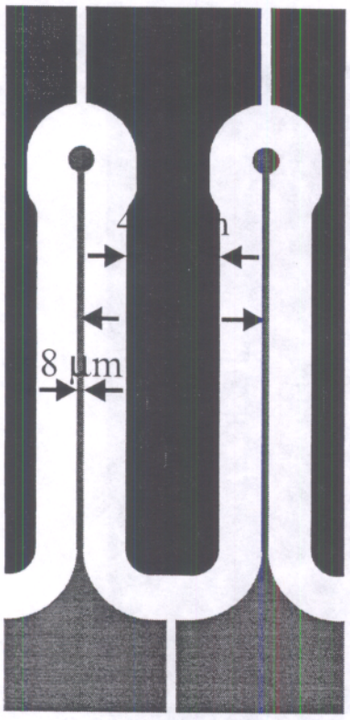
5 x 5 cm^2
8 bar ^3He
6 bar propane

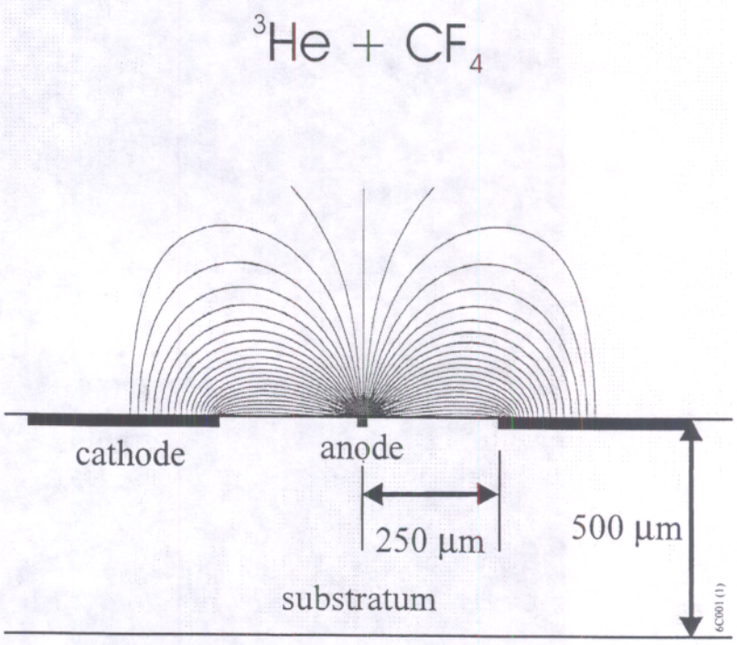


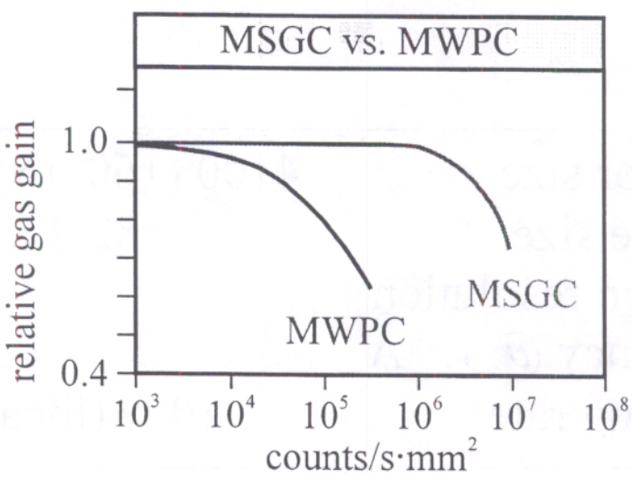
detector size	50 x 50 - 500 x 500 mm^2
position resolution	<0.4 - 2 mm
time resolution	250 ns
efficiency @ 1.8 Å	<80%
counting rate	$5 \cdot 10^{-4} s^{-1}$

http://www.inst.bnl.gov/GasDetectorLab/NeutronDetectors/Brochure/Brochure.html

Micro Strip Gas Chambers for Neutrons (ILL)

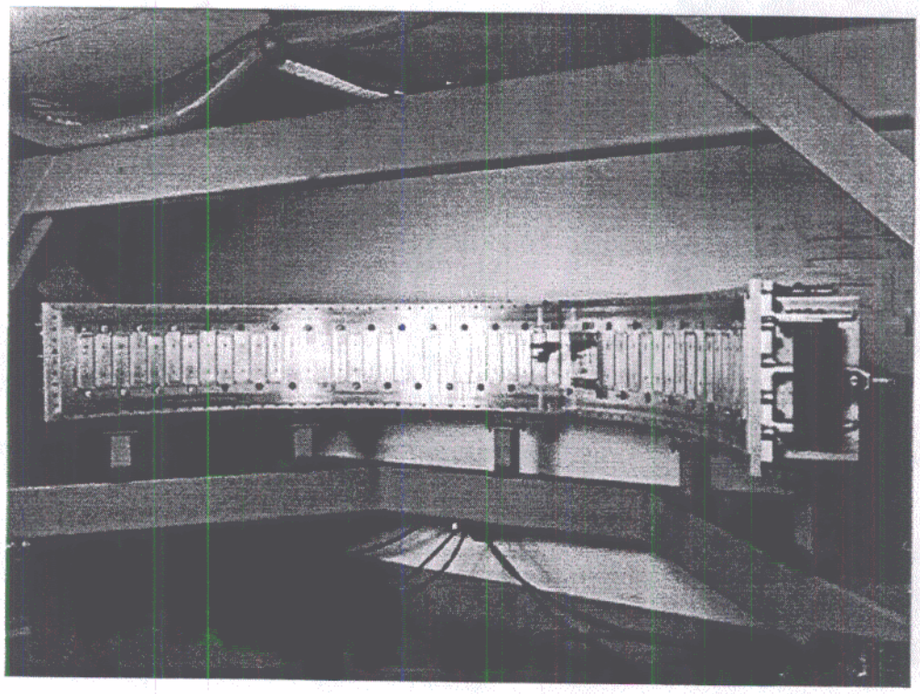






A. Oed NIM A 263 (1988) 351, A. Oed NIM A 367 (1995) 34

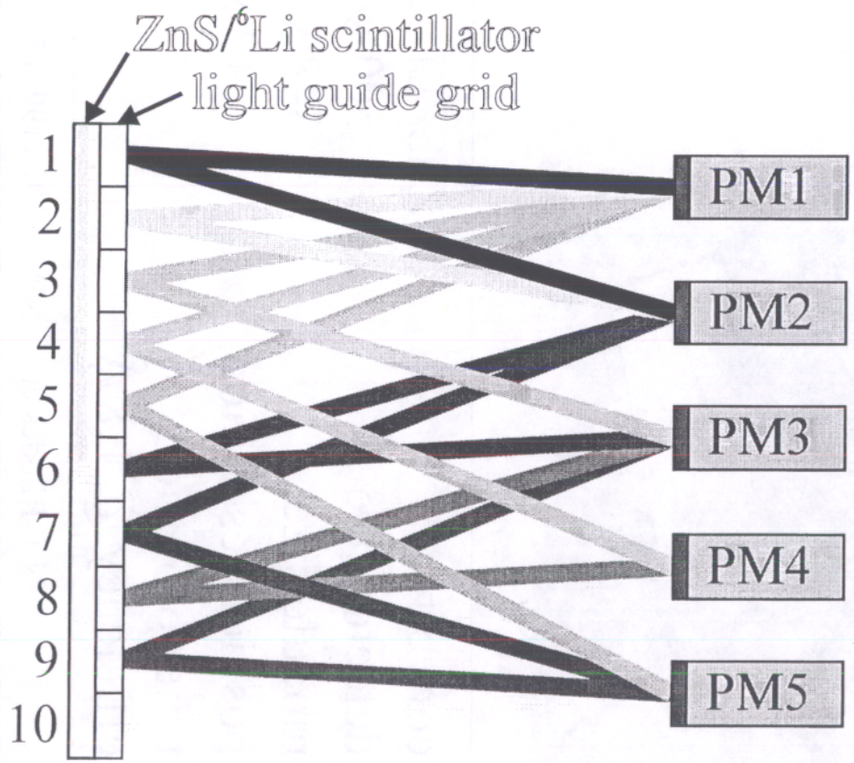
Banana Detector with MSGCs: D20 at ILL



detector size	4100 (160°) x 150 mm^2
module size	82.2 x 150 mm^2
position resolution	~3 mm
efficiency @ 1.8 Å	<85%
counting rate	$10^7 s^{-1}$ (local $5 \cdot 10^4 s^{-1}$)

A. Oed NIM A 263(1998) 351, A. Oed NIM A 367 (1995) 34

Scintillation Pixel Detectors Principle (ISIS)

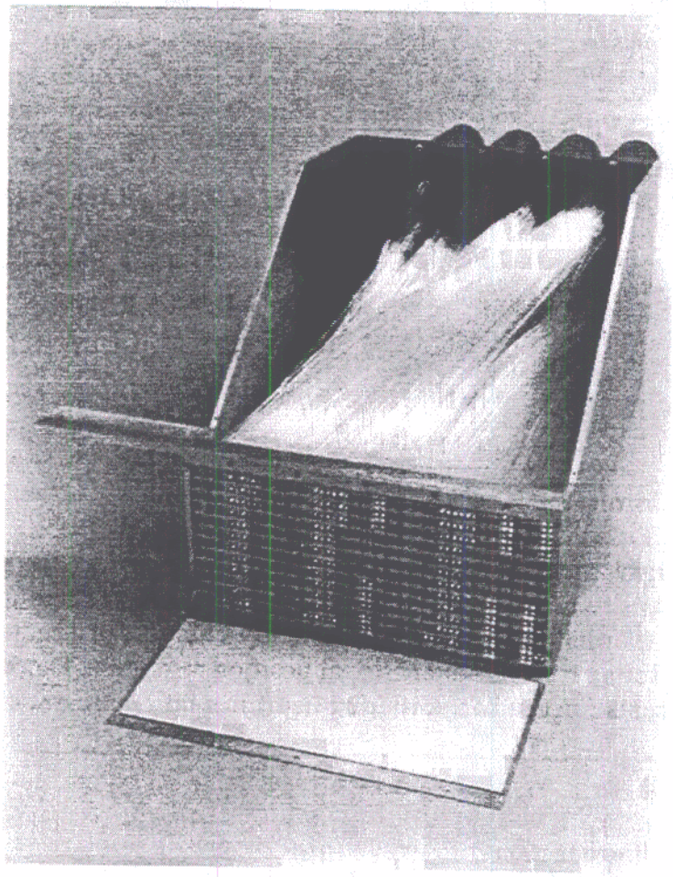


coincidence scheme

PM1 + PM2	pixel	1
PM1 + PM3	pixel	2
PM1 + PM4	pixel	3
.....		
PM3 + PM4	pixel	8
PM3 + PM5	pixel	9
PM4 + PM5	pixel	10

12 PMs (^4C_n) → 495 pixel

Detector at LOQ Diffractometer (ISIS)



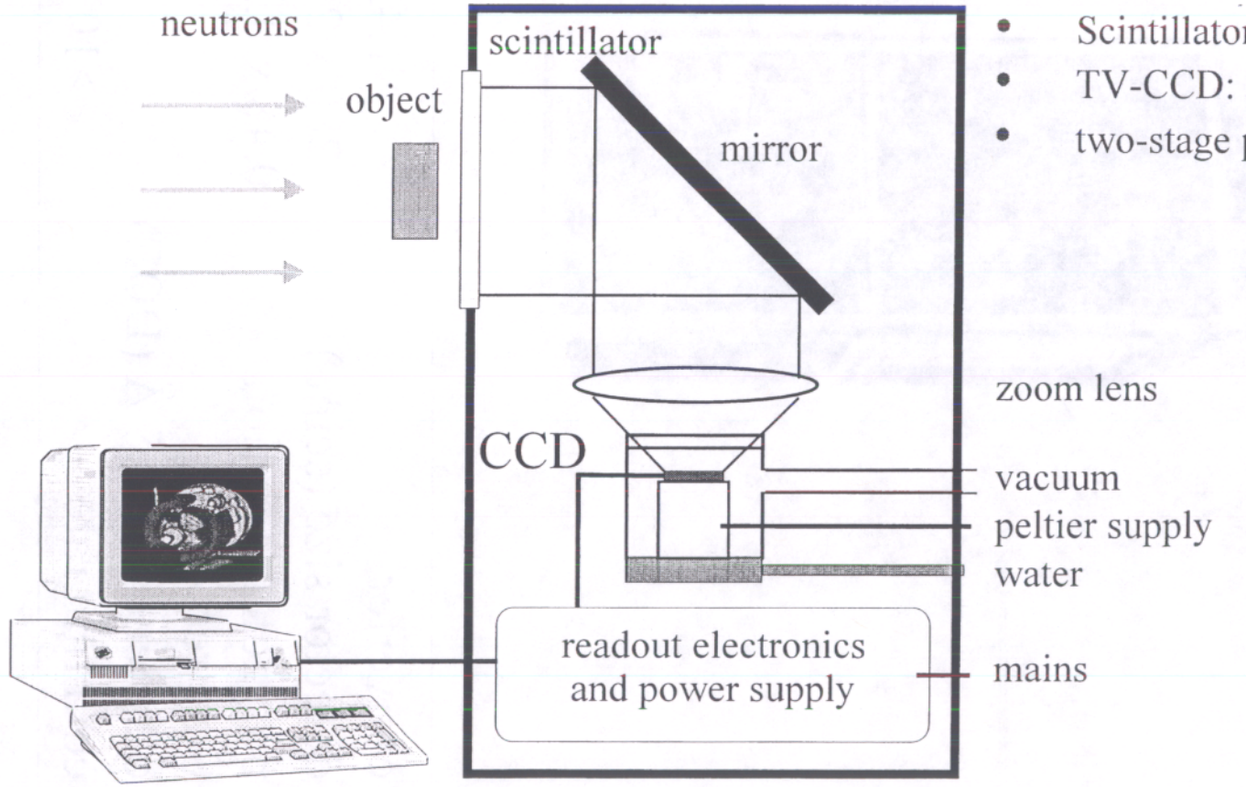
detector modul:

each pixel 12mm x 12mm viewed by 16 fibre optic light guides 1.5 mm diam.

converter	$ZnS/^{6}Li$ scintillator
detector size	500 x 500 mm^2
module size	348 x 144 mm^2
position resolution	12 x 12 mm^2
time resolution	2.5 µs
efficiency @ 1.8 Å	33%

N.J. Rhodes et al. NIM A392 (1997) 315-318

CCD Camera Detector (TU Munich)

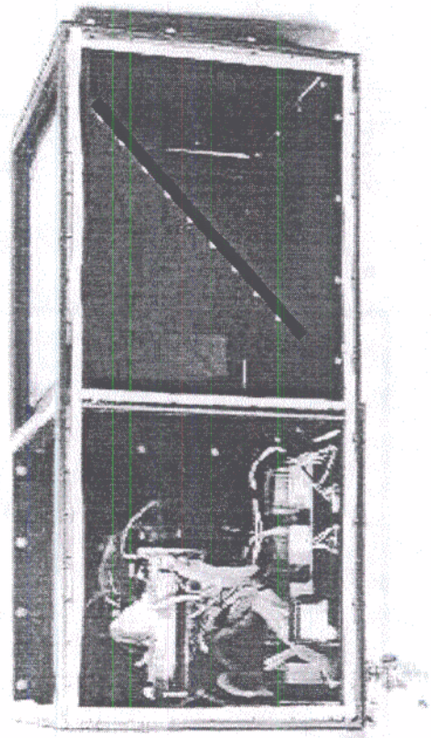


- Scintillator: NE426 (blue)
- TV-CCD: 512 x 512 pixel
- two-stage peltier cooler (-50°C)

C. Rausch, B. Schillinger et al. http://www.tu-muenchen.de/lehrstuehle/E21/Projects/NNews/nnews.html

Cooled CCD Camera Detector

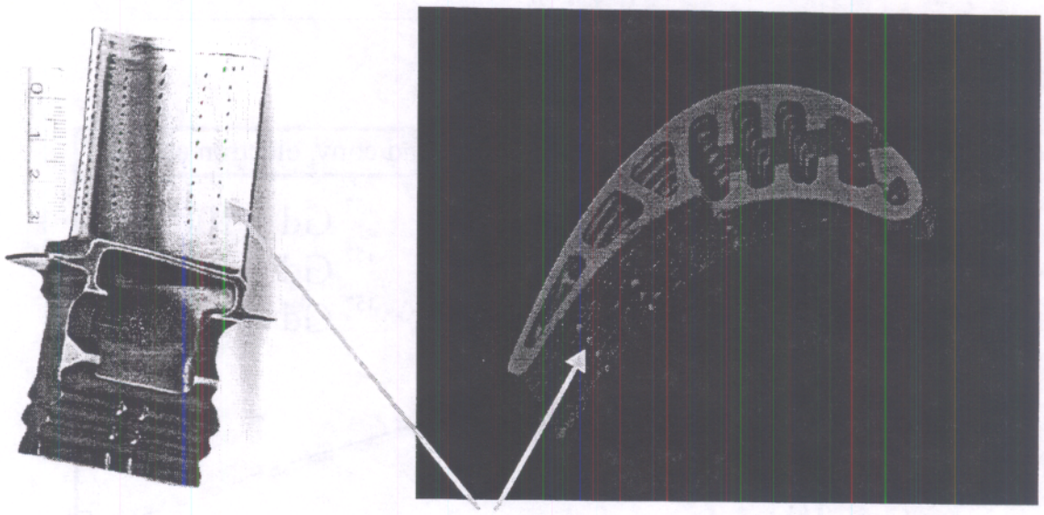
Neutrons



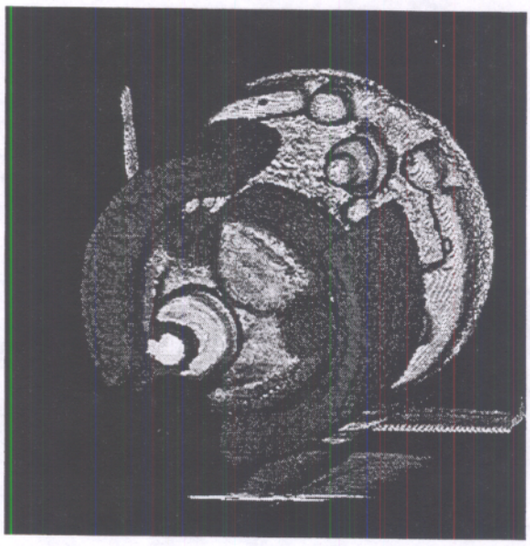
converter	NE426 (^{6}Li)
detector size (scint.)	280 x 280 mm^2
position resolution	0.48 x 0.34 mm^2
time resolution	no
efficiency @ 1.8 Å (DQE)	12%
counting rate	>10^5/s pixel

C. Rausch, B. Schillinger et al. http://www.tu-muenchen.de/lehrstuehle/E21/Projects/NNews/nnews.html

CCD Camera Detector: Examples of 3D Radiography



aviation turbine blade (holes of ~300 μm diam.)

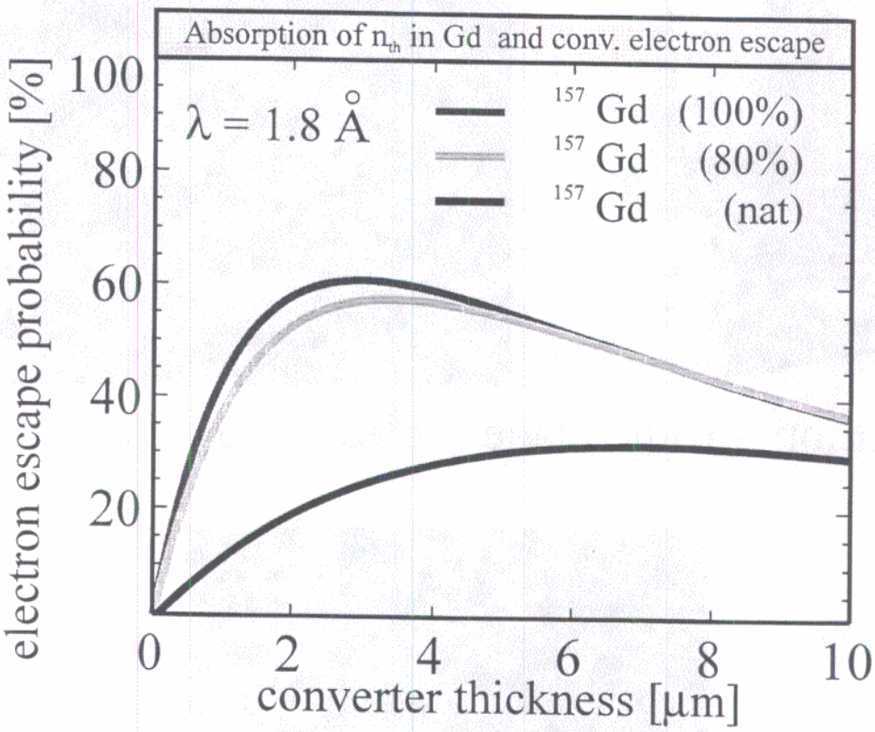


electric motor ~ 20 mm diameter)

C. Rausch, B. Schillinger et al. http://www.tu-muenchen.de/lehrstuehle/E21/Projects/NNews/nnews.html

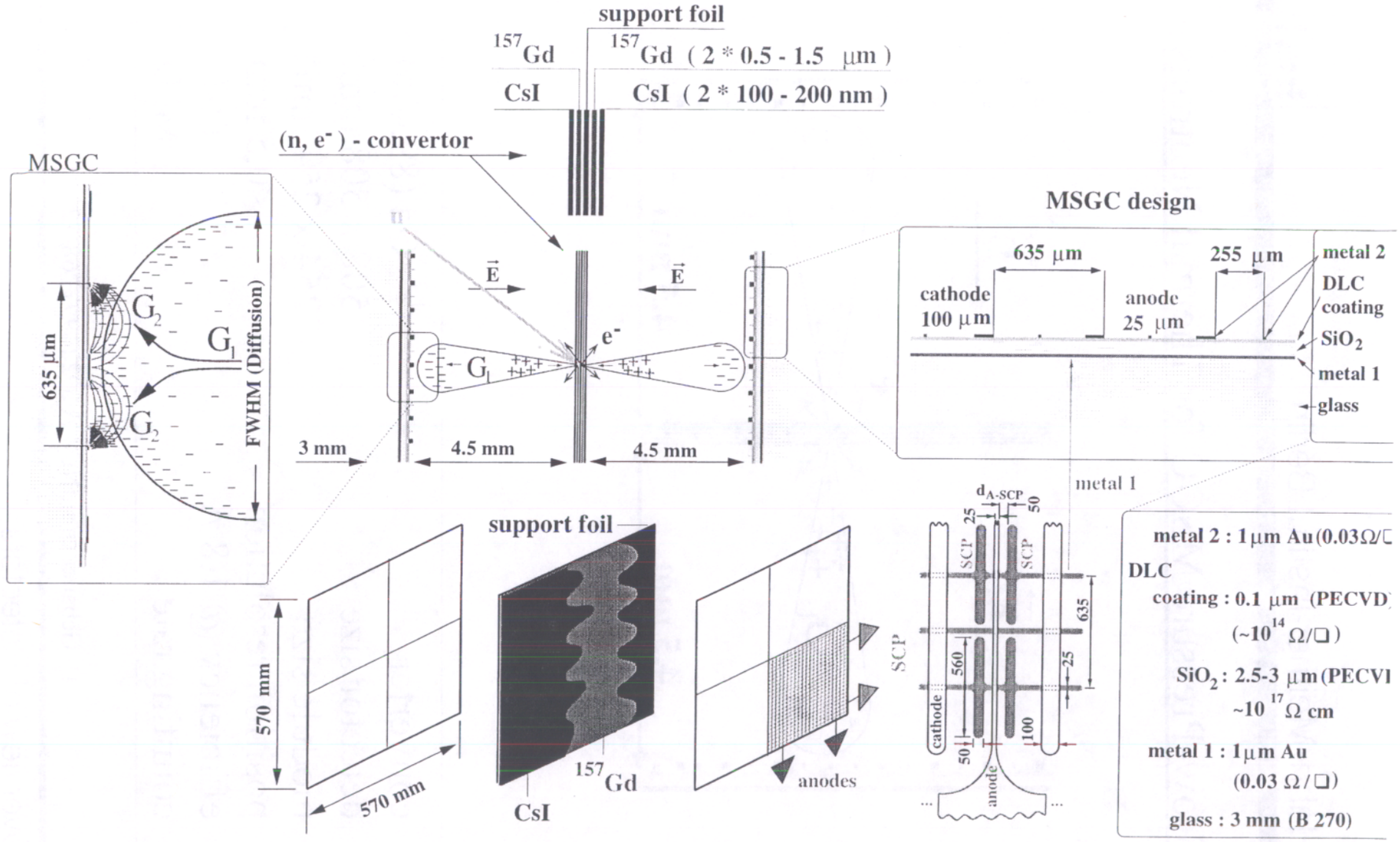
Gd Converter for Thermal Neutrons

$$\varepsilon = \{1 - \exp(-\mu_n \cdot d \cdot \lambda)\} \cdot E_0 \cdot \exp(-\mu_e \cdot d)$$

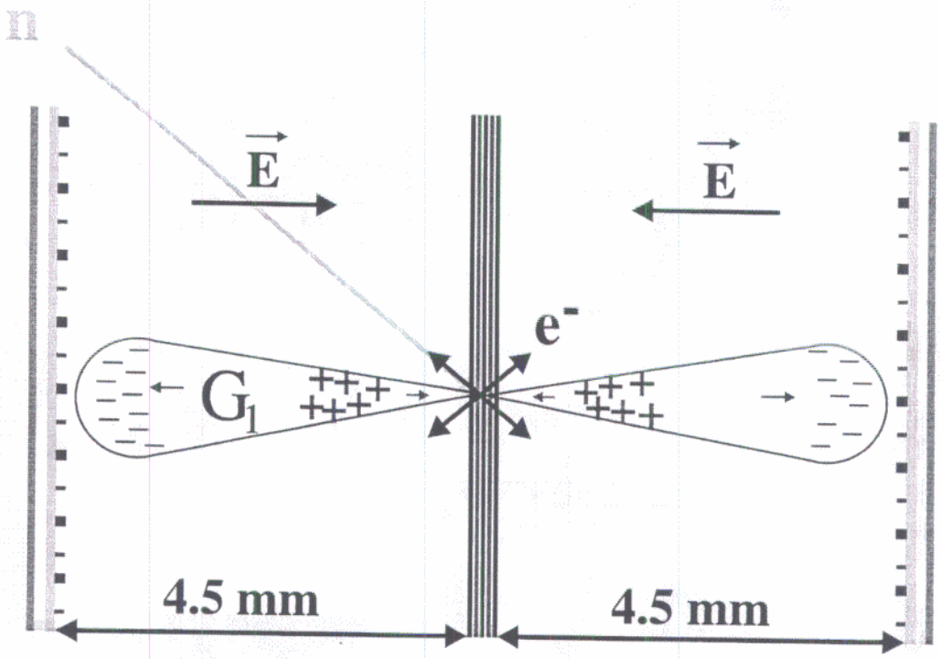


$^{157}Gd(n,\gamma)^{158}Gd^*$

electron conversion energies and fractions					
	$4^+ \longrightarrow 2^+$		$2^+ \longrightarrow 0^+$		E_0
K	131.7	68.8%	29.3	32.6%	· 87.3%
L	173.6	24.7%	71.2	54.2%	
M	180.6	6.4%	78.2	13.2%	


support foil
157Gd
157Gd (2 * 0.5 - 1.5 μm)
CsI
CsI (2 * 100 - 200 nm)
(n, e⁻) - convertor
MSGC
635 μm
G2
G1
G2
FWHM (Diffusion)
E
E
e⁻
G1
3 mm
4.5 mm
4.5 mm
MSGC design
635 μm
255 μm
cathode
100 μm
anode
25 μm
metal 2
DLC
coating
SiO2
metal 1
glass
metal 1
dA-SCP
25
50
SCP
SCP
635
560
25
cathode
100
50
anode
SCP
metal 2 : 1 μm Au (0.03 Ω/□)
DLC
coating : 0.1 μm (PECVD)
(~10^14 Ω/□)
SiO2 : 2.5-3 μm (PECVD)
~10^17 Ω cm
metal 1 : 1 μm Au
(0.03 Ω/□)
glass : 3 mm (B 270)
support foil
570 mm
570 mm
157Gd
CsI
anodes

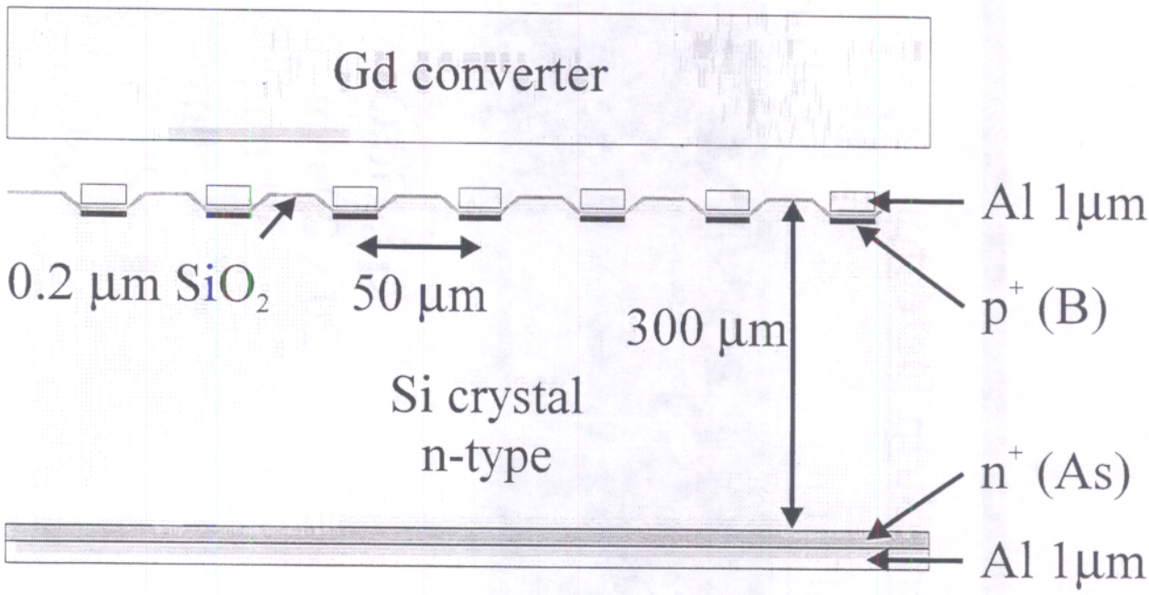
Low-Pressure MSGC for Thermal Neutrons



converter	^{157}Gd (89.4%)
detector size	508 x 508 mm^2
module size	254 x 254 mm^2
position resolution	<0.5 mm
efficiency @ 1.8 Å	~60%
counting rate	>1 MHz

B. Gebauer et al. NIM A 392 (1997) 68-72

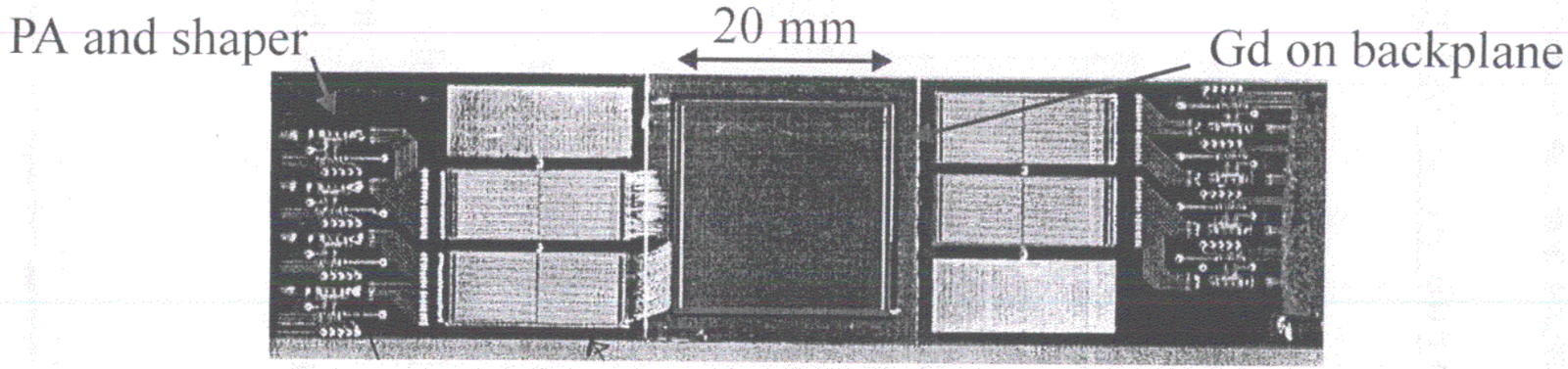
Solid State Neutron Detectors



- silicon micro strip detectors (like in HEP) in combination with Gd-converters
- high position resolution is possible
- low noise front end electronics is necessary
- different converter configurations have been tested

C. Petrillo et al. NIM A 378 (1996) 541 - 551

Silicon Micro Strip Detector



converter	Gd, Gd_2O_3
detector size (Si)	20 x 20 mm^2
position resolution	<1 mm
time resolution	< 50ns
efficiency @ 1.8 Å	20 %
counting rate	$>10^6$/s

C. Petrillo et al. NIM A 378 (1996) 541 - 551