Si-DIODE/Gd DETECTORS FOR THERMAL NEUTRONS

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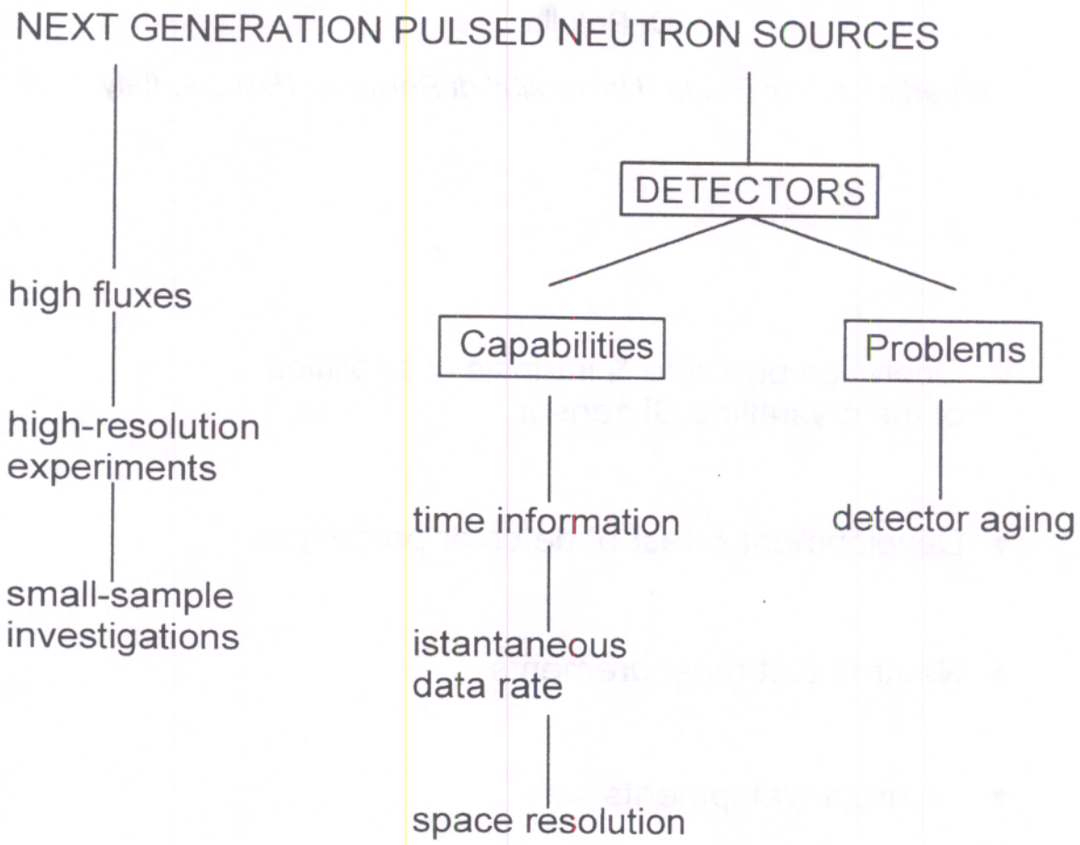
- Operation principle & intrinsic capabilities of the crystalline Si sensor
- Development & test of detector prototypes
- Neutron test measurements
- Future developments

Research program developed under the E.U. Project XENNI



CRYSTALLINE Si SENSORS ARE KNOWN FOR THEIR UNRIVALLED SPACE RESOLUTION AT HIGH COUNTING RATES (HEP-Trackers)

Si SENSOR coupled to VLSI READOUT ELECTRONICS

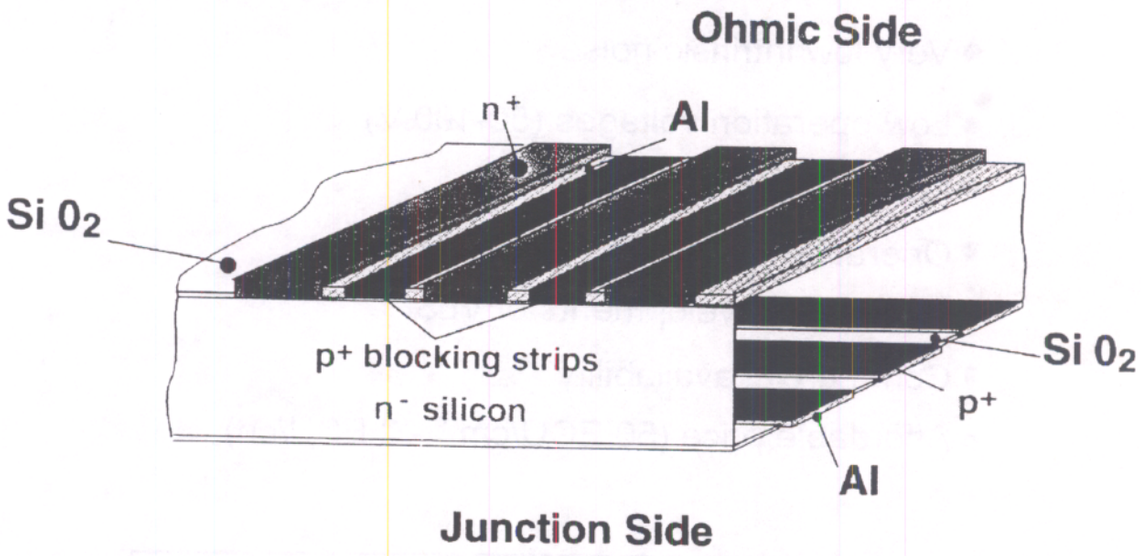
CAPABILITIES

- Count rates > 10^{6} s^{-1}
- Position resolution < 50 μm
- Flexibility in shape & size
- Very low intrinsic noise
- Low operation voltages (50-100 V)
- Low power VLSI
- Operation under vacuum possible
- Rad-hard developments of VLSI
- Commercial availability
- Affordable price (50 ECU/cm^{2} - 2 ECU/ch)

AS NEUTRON DETECTORS/MONITORS

- Converter required → efficiency over a wide energy range
- γ-sensitivity (<1MeV)
- Radiation damage

The Double Side Silicon Wafer

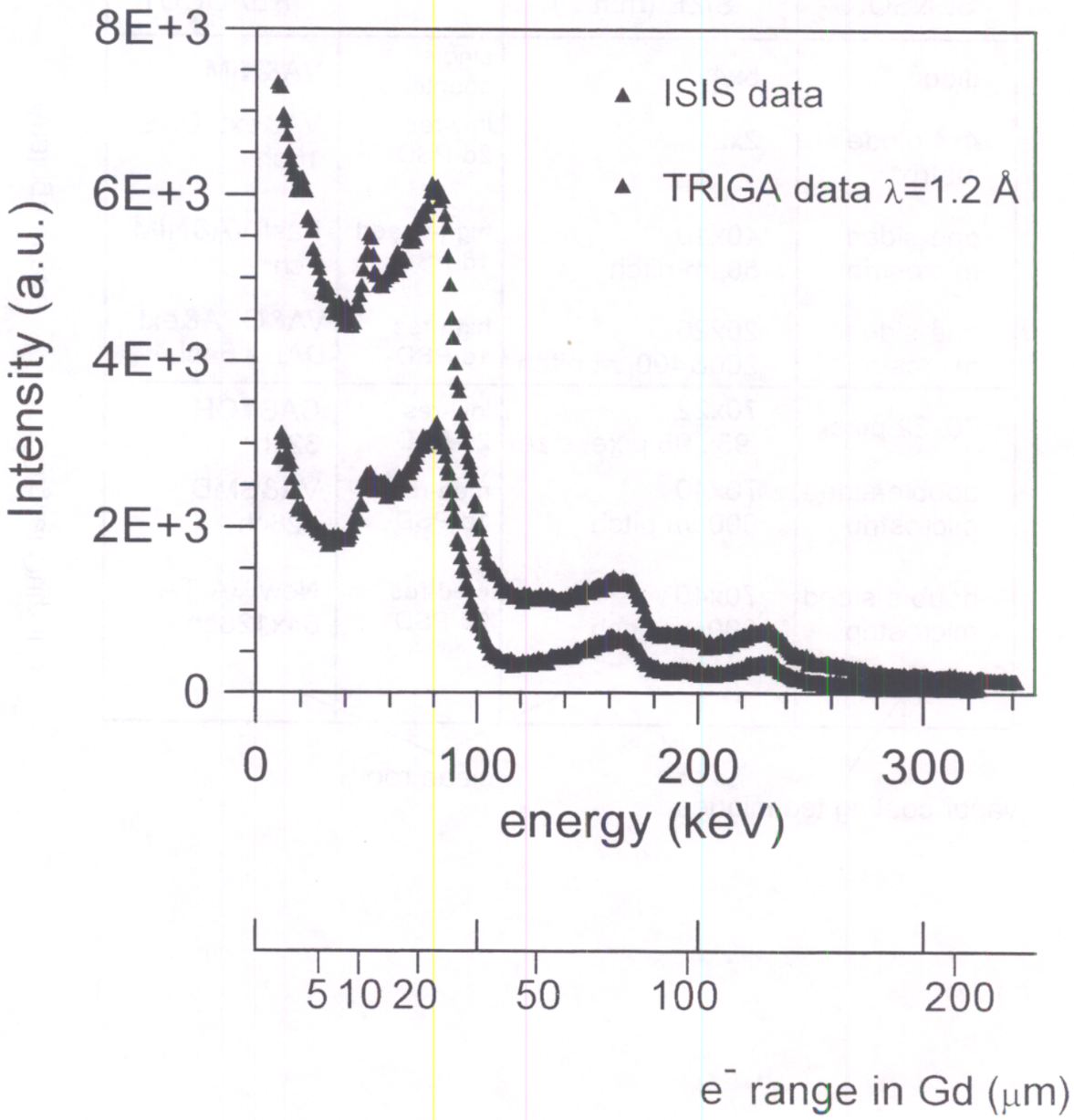


Schematic view of a double-sided silicon detector

Converter: natural Gd - 10μm & 250μm thick

$n + {}^{155}Gd \rightarrow Gd^* \rightarrow \gamma$-spectrum

$\rightarrow$ conversion e^- spectrum



PROTOTYPES DEVELOPED under XENNI

developed & tested

under development

SENSOR	300μm thickness SIZE (mm^2)		PARALLEL READOUT
diode	5x4	single counter	VA&NIM
4x4 diode matrix	2x2	low-res 2d-PSD	VA&ext. DAE 16ch
one-sided microstrip	40x10 50μm pitch	high-speed 1d-PSD	Fast-VA&NIM 4ch
one-sided microstrip	20x20 200&400μm pitch	high-res 1d-PSD	VA&OPA&ext. DAE - 64ch
70x22 pixel	70x22 .95x.95 pixel size	low-res 2d-PSD	CASTOR 32ch
double-sided microstrip	70x40 600μm pitch	med-res 1d-PSD	VA&SMD 128ch
double-sided microstrip	70x40 600μm pitch	med-res 2d-PSD	New VA-TA 64x128ch

Analog Output

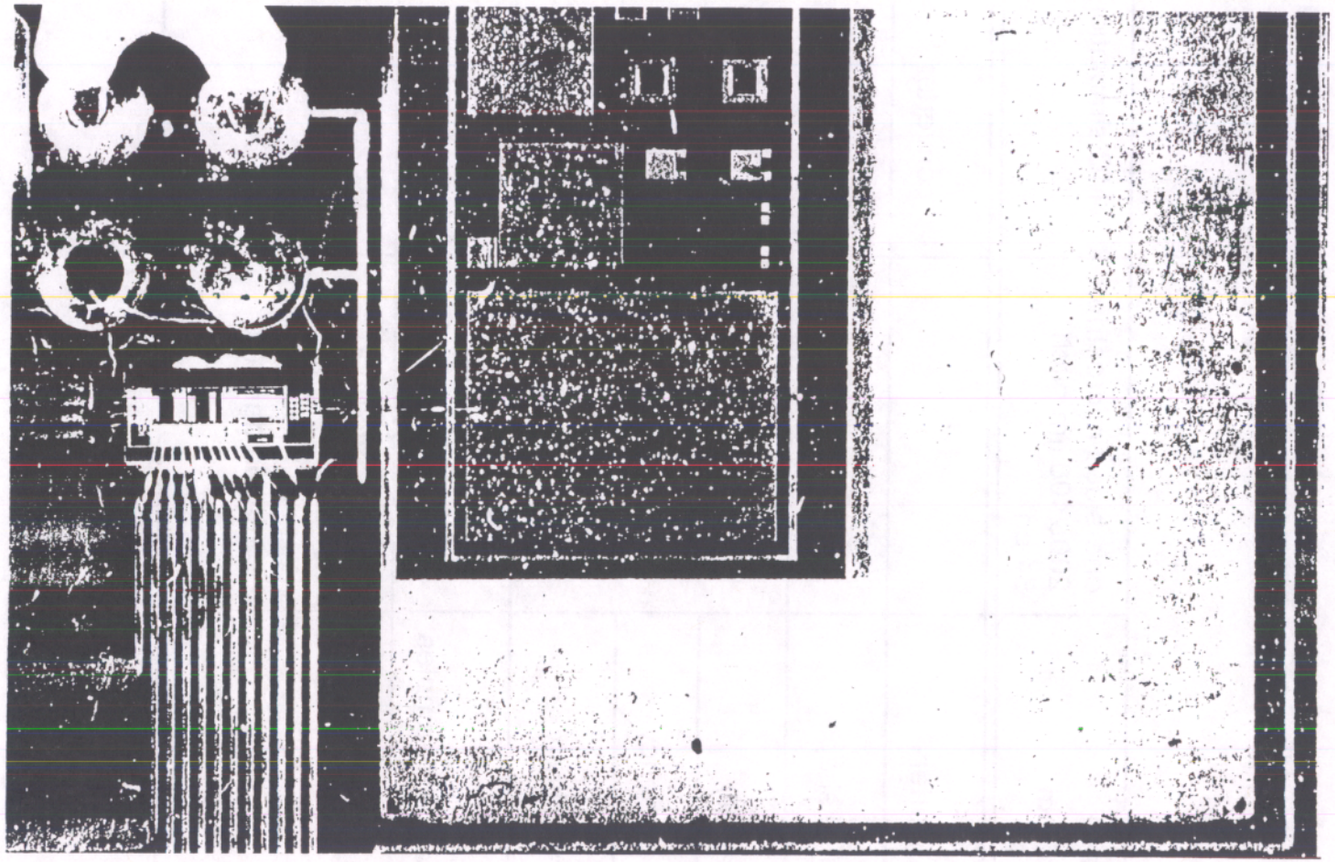
Digital Output

vapor coating techniques

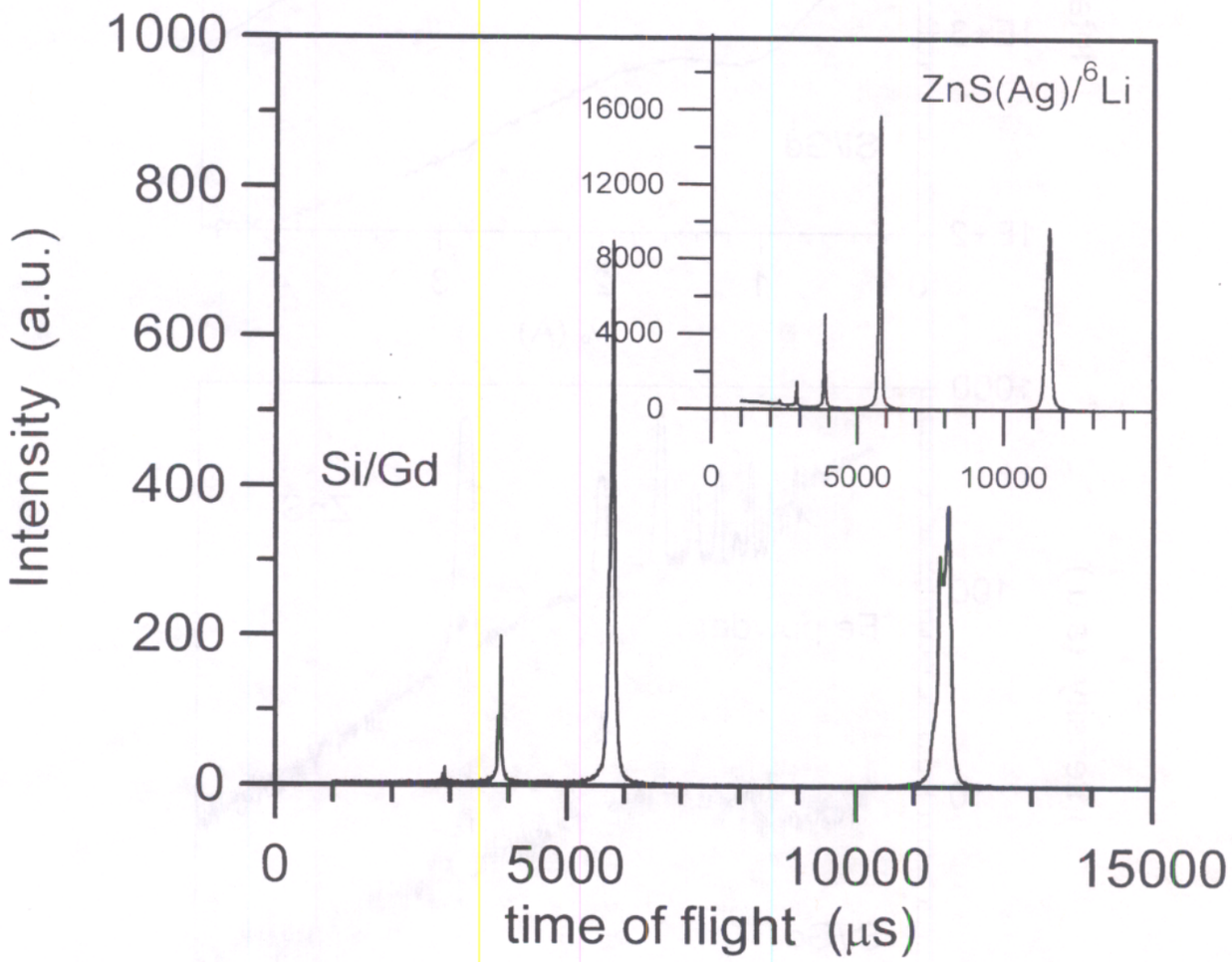
clean room

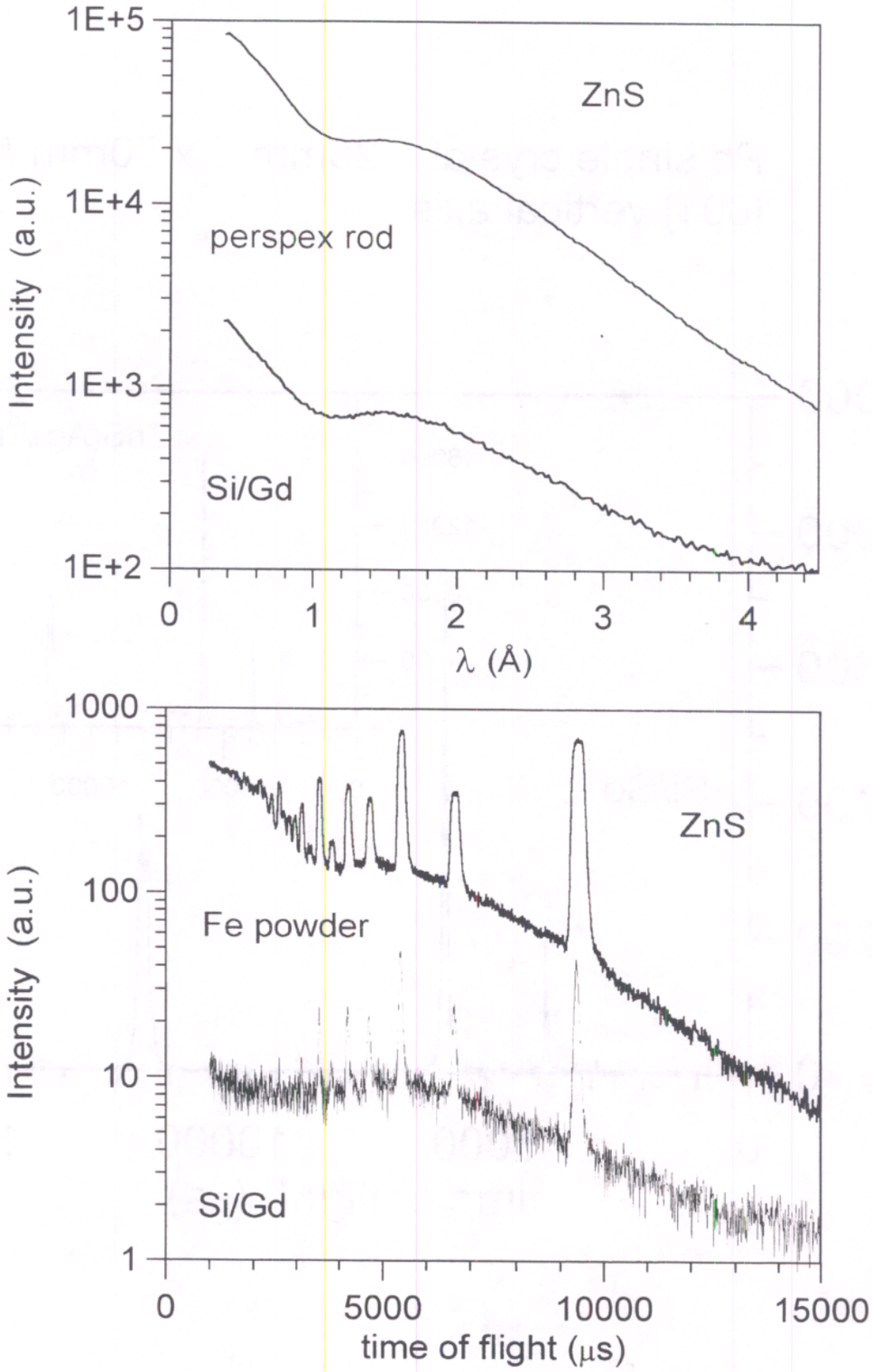
TEST MEASUREMENTS & MONTE CARLO SIMULATION

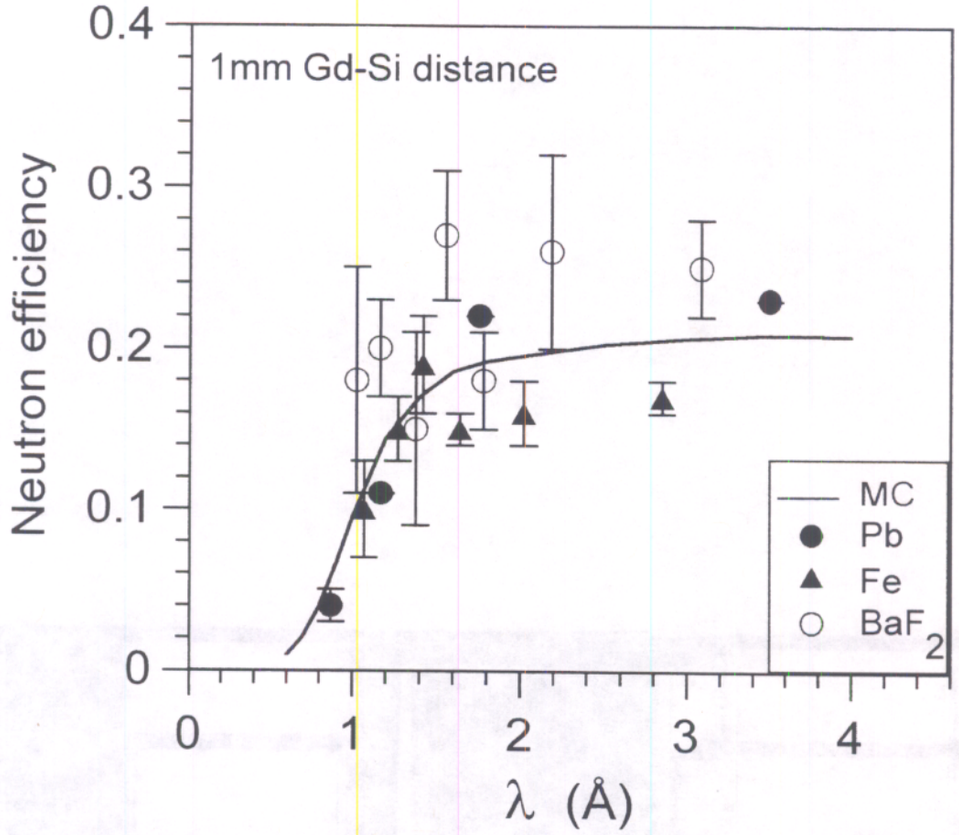
diode $5x4mm^2$	one-sided microstrip 200&400 μm pitch 64 ch	MC simulation
converter		converter
pulse shape	pulse shape	
stability		
n-efficiency		n-efficiency
γ-sensitivity		γ-sensitivity
spectra of standard samples	small-size samples	
	space resolution	space resolution
	radiation damage	

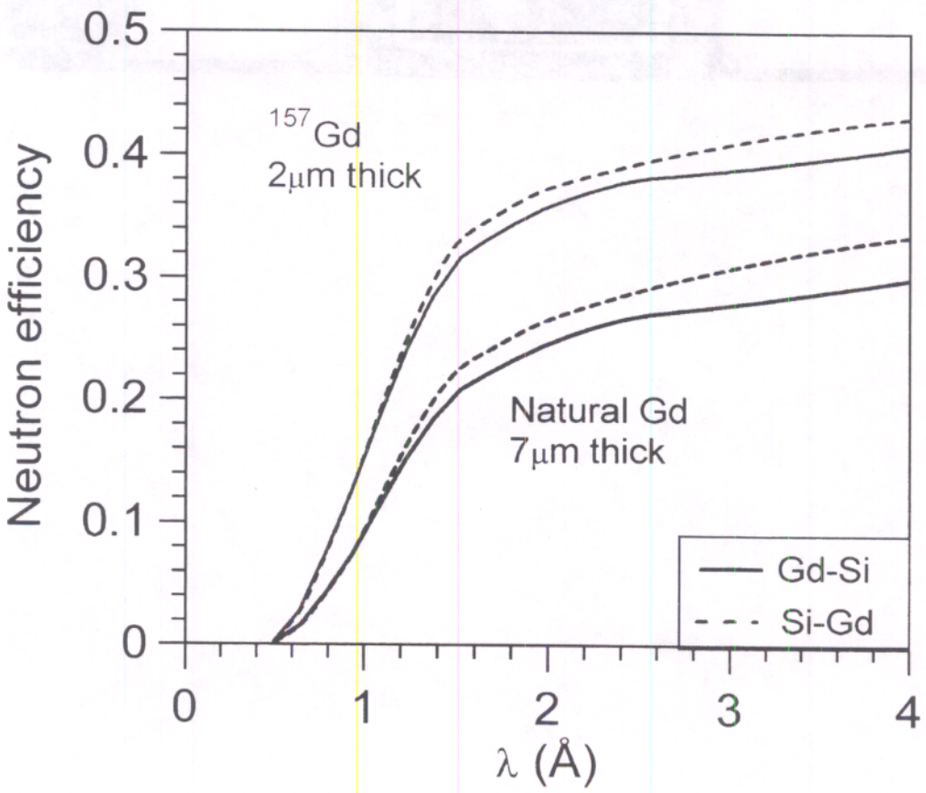


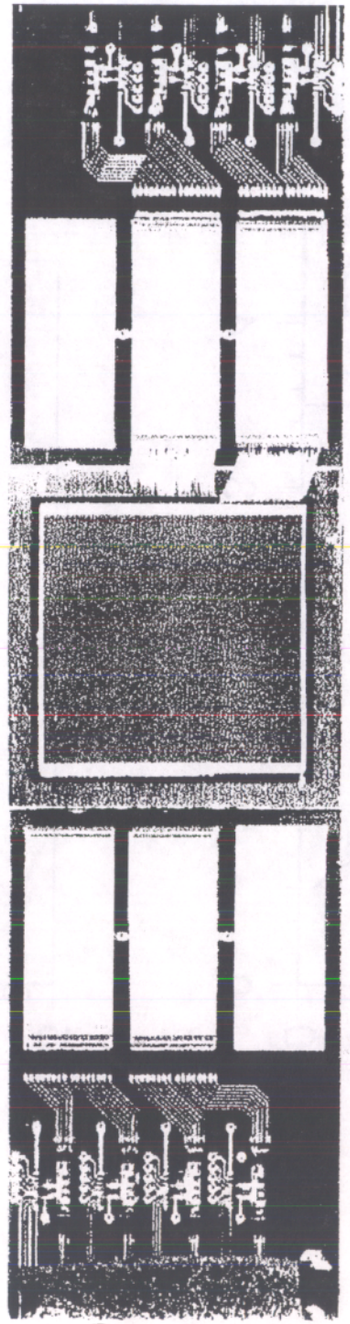
Pb single crystal - 25mm x 50mm *h*
[001] vertical axis

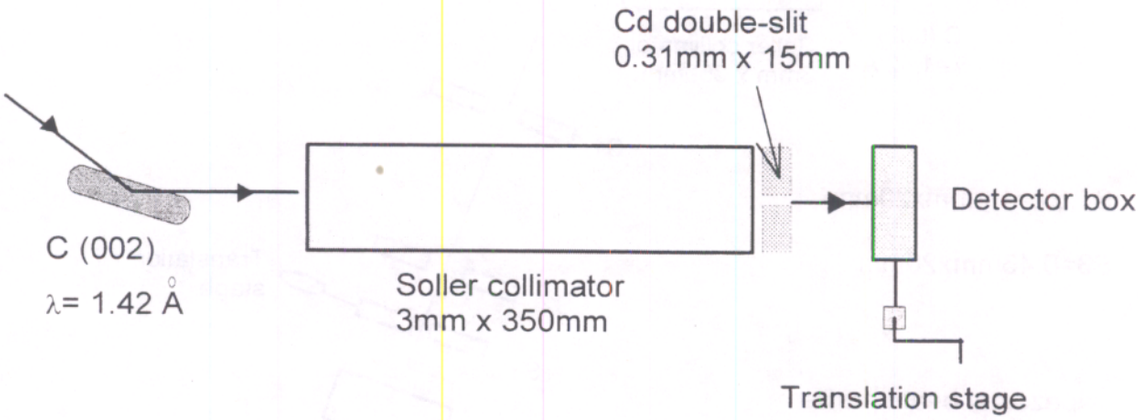


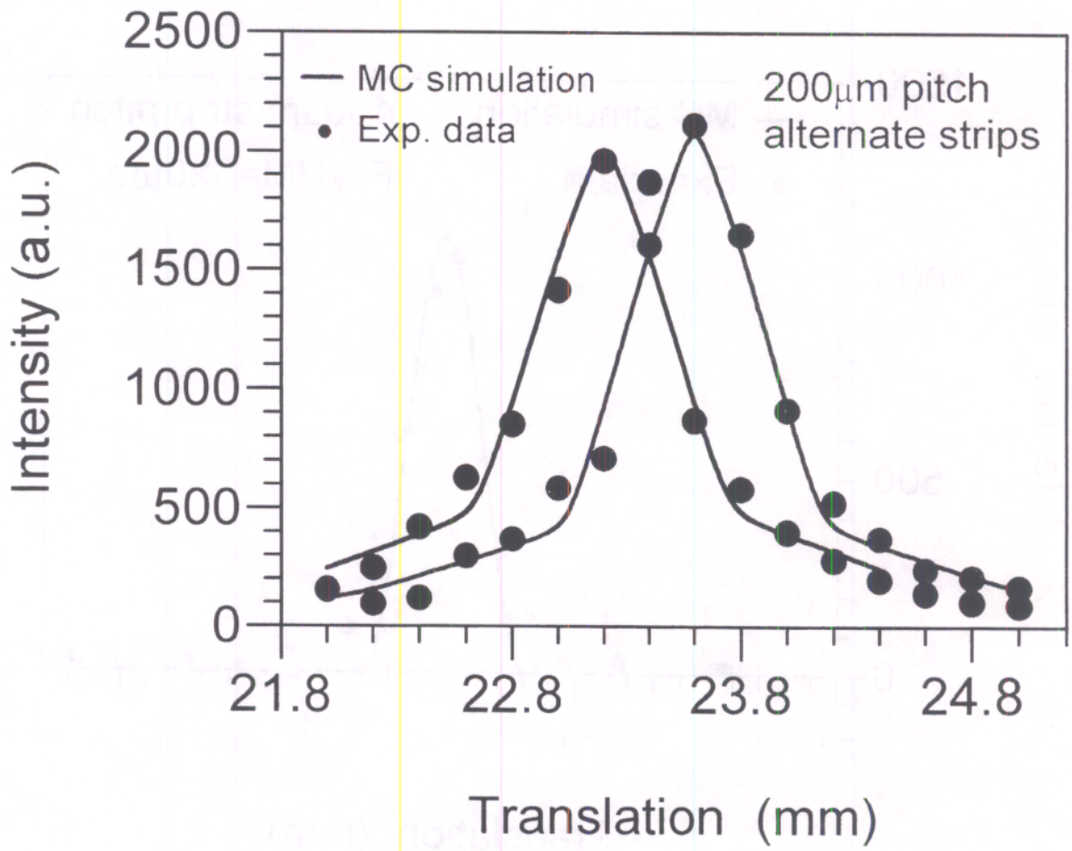

1E+5
1E+4
1E+3
1E+2
Intensity (a.u.)
ZnS
perspex rod
Si/Gd
0
1
2
3
4
λ (Å)
1000
100
10
1
Intensity (a.u.)
ZnS
Fe powder
Si/Gd
0
5000
10000
15000
time of flight (μs)

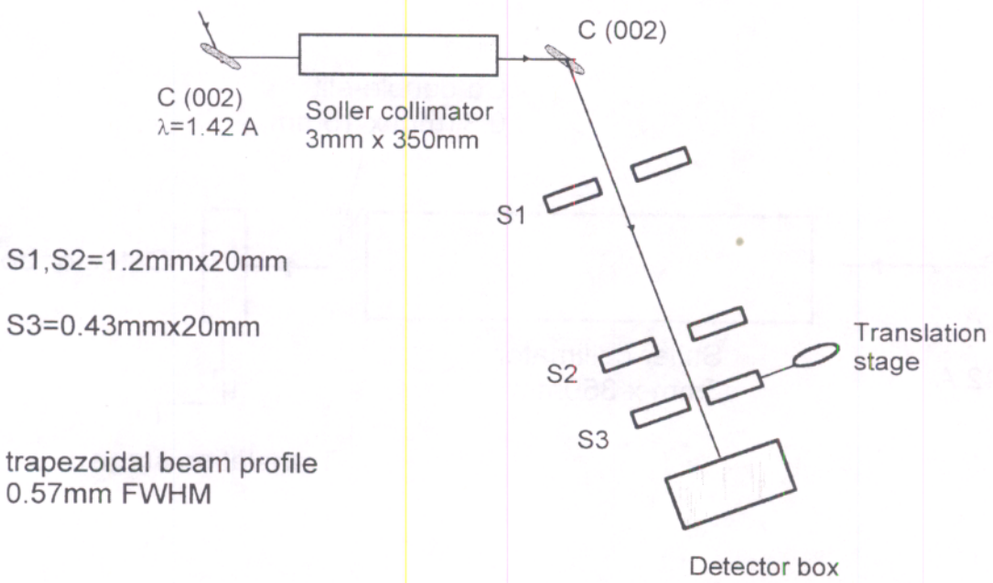

1mm Gd-Si distance
Neutron efficiency
λ (Å)
MC
Pb
Fe
BaF2


157Gd
2μm thick
Natural Gd
7μm thick
Gd-Si
Si-Gd
Neutron efficiency
λ (Å)




Cd double-slit
0.31mm x 15mm
Detector box
C (002)
λ= 1.42 Å
Soller collimator
3mm x 350mm
Translation stage

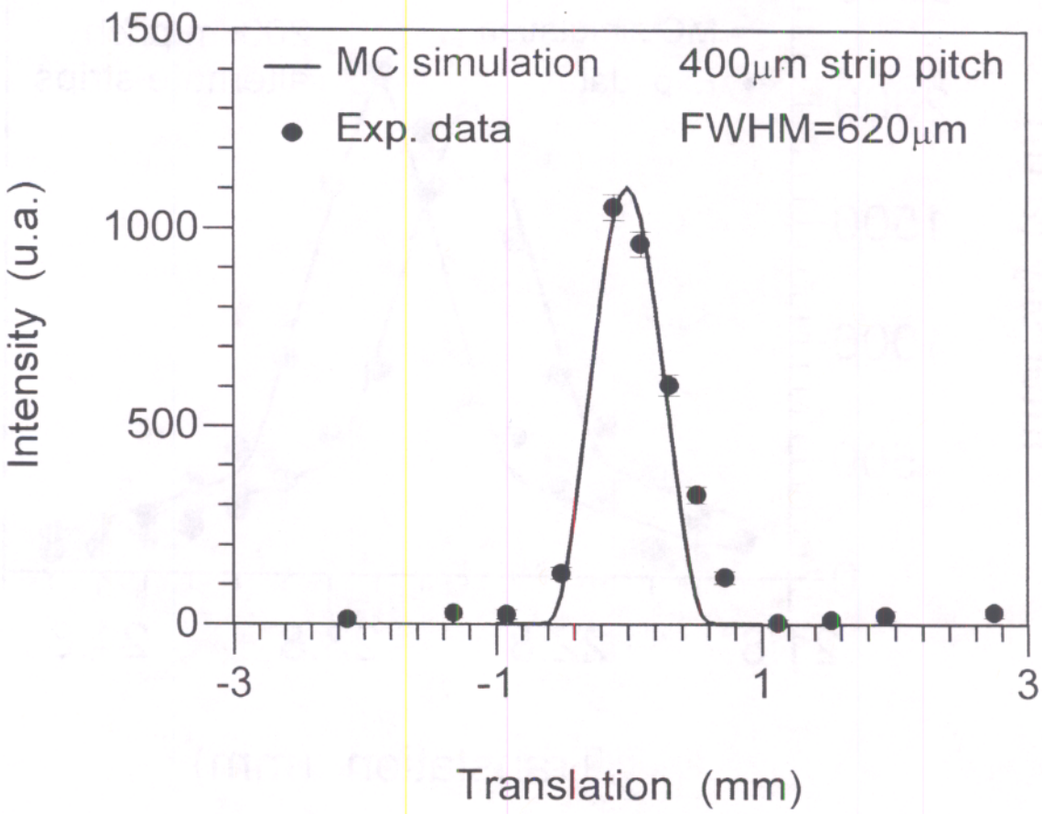

MC simulation
Exp. data
200μm pitch
alternate strips
Intensity (a.u.)
2500
2000
1500
1000
500
0
21.8
22.8
23.8
24.8
Translation (mm)

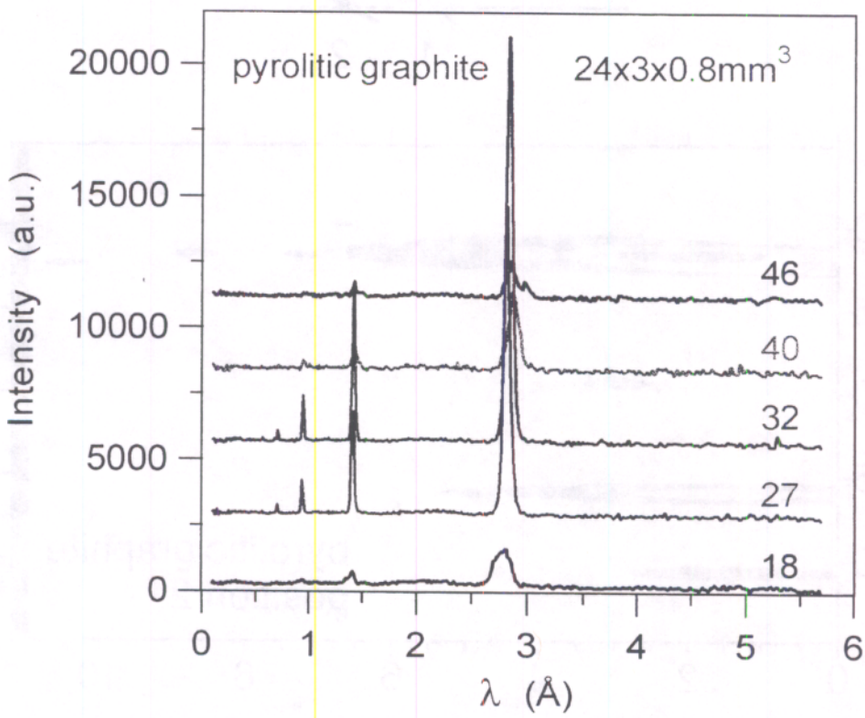


S1,S2=1.2mmx20mm

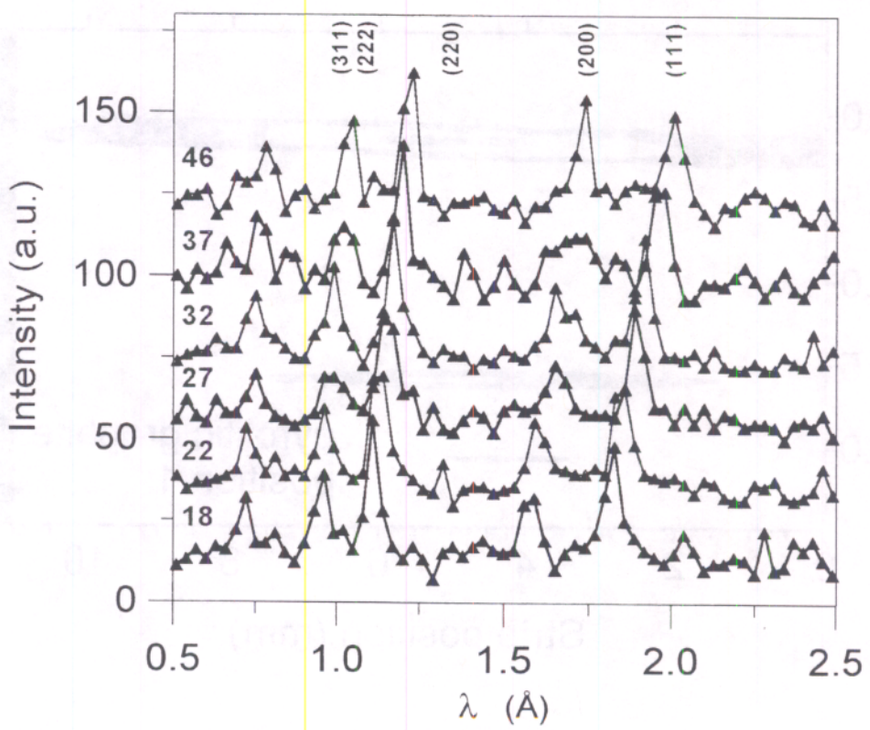
S3=0.43mmx20mm

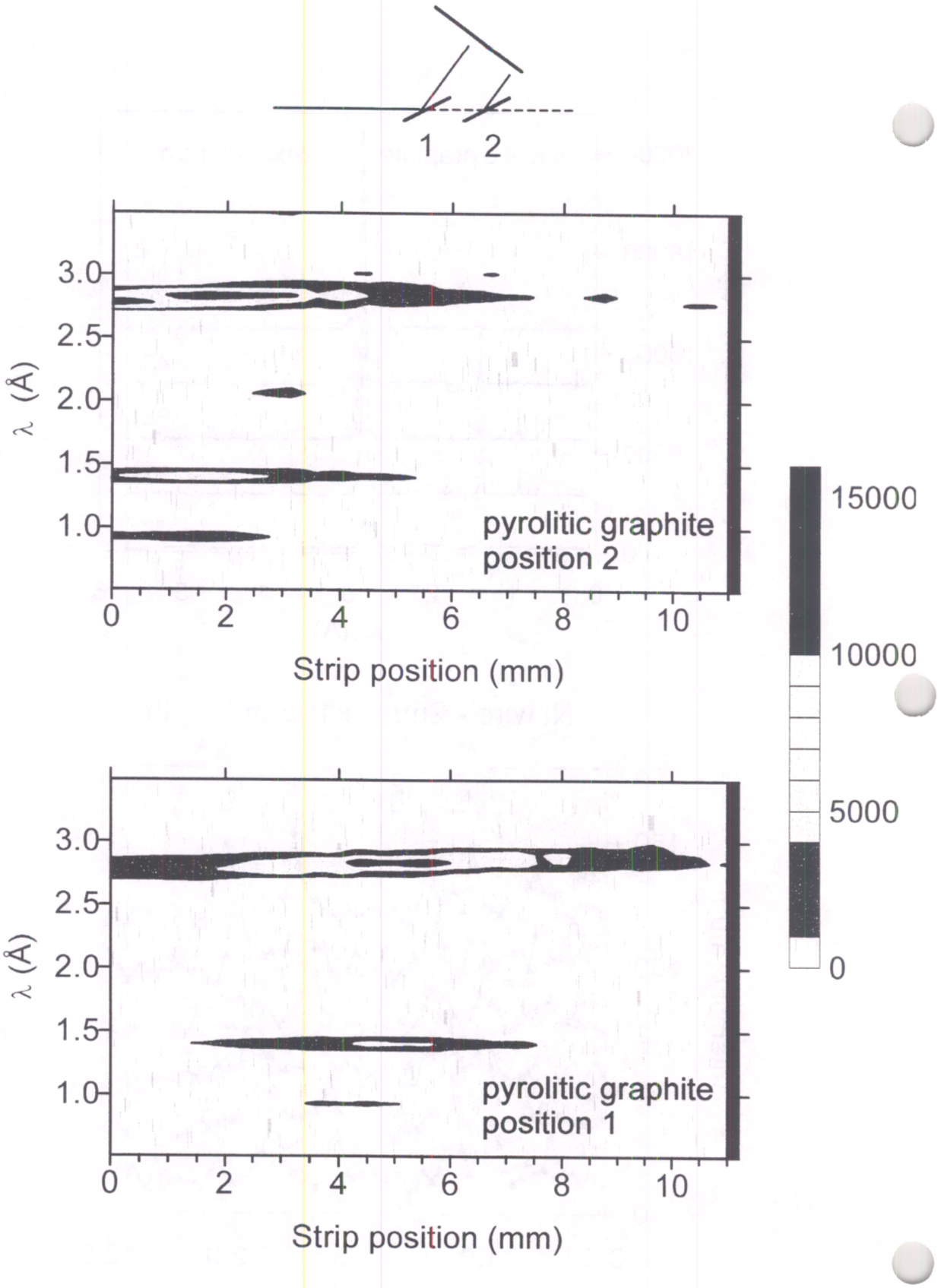
trapezoidal beam profile
0.57mm FWHM

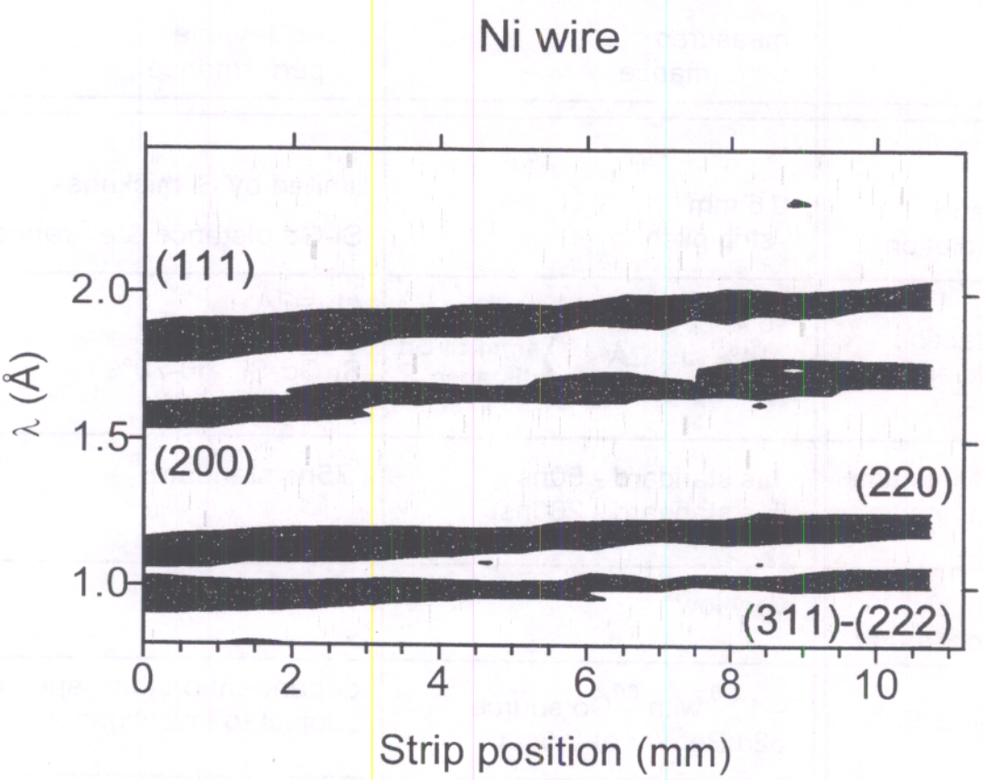




Ni wire - 2mm x10mm length




1
2
3.0
2.5
2.0
1.5
1.0
λ (Å)
pyrolitic graphite
position 2
0
2
4
6
8
10
Strip position (mm)
15000
10000
5000
0
3.0
2.5
2.0
1.5
1.0
λ (Å)
pyrolitic graphite
position 1
0
2
4
6
8
10
Strip position (mm)

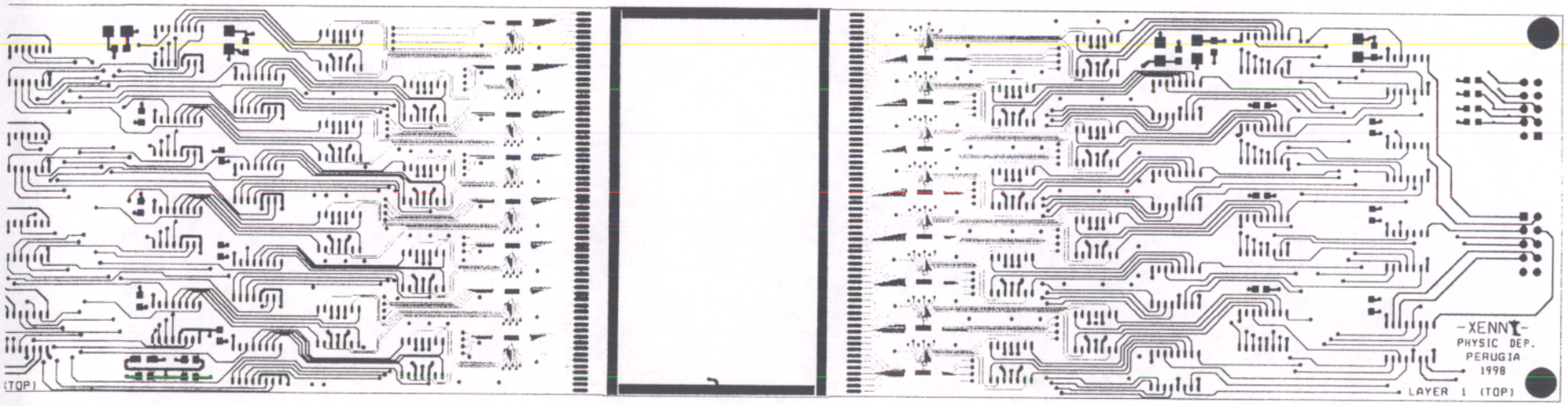

Ni wire
(111)
(200)
(220)
(311)-(222)
λ (Å)
2.0
1.5
1.0
0
2
4
6
8
10
Strip position (mm)

CRYSTALLINE Si DIODE/NATURAL Gd CONVERTER

	measured performance	achievable performance
space resolution	0.6 mm ~strip pitch	limited by Si thickness, Si-Gd distance & e^- range
detection efficiency	~6% at 0.9Å ~14% at 1.2Å ~20% at 2Å } **1mm Si-Gd distance**	at λ=2Å Gd-Si 30% Si-Gd-Si 60-70% Gd-Si-Gd 50%
peaking time shaping time	1μs standard - 50ns 5μs standard - 200ns	75ns standard
intrinsic background	very low	
γ-sensitivity	~ 10^{-5} with ^{60}Co source 32mRem/hr at 2.5cm	dependent on the γ-spectrum subject to investigation
stability	excellent over 3 months continuous operation	dependent on radiation damage
radiation damage	$1x10^{14}$n/cm^2& $2x10^{14}$n/cm^2 2MeV neutron fluences -leakage current increase -type-inversion -depletion voltage increase	performances recovered by lowering sensor temperature (0°,-10°C) & increasing bias (LHC-collaboration)

-XENNI-
NEUTRON DETECTOR BOARD

1 LAYER TOP



ELECTRONIC SERVICE
INFN & PHISIC DEP.
PERUGIA
(August 1998)