Workshop on Detectors for Synchrotron Research
30-31, 2000, in Washington, DC

Pixel and Microstrip Detectors for Synchrotron Radiation Applications: Digital Systems

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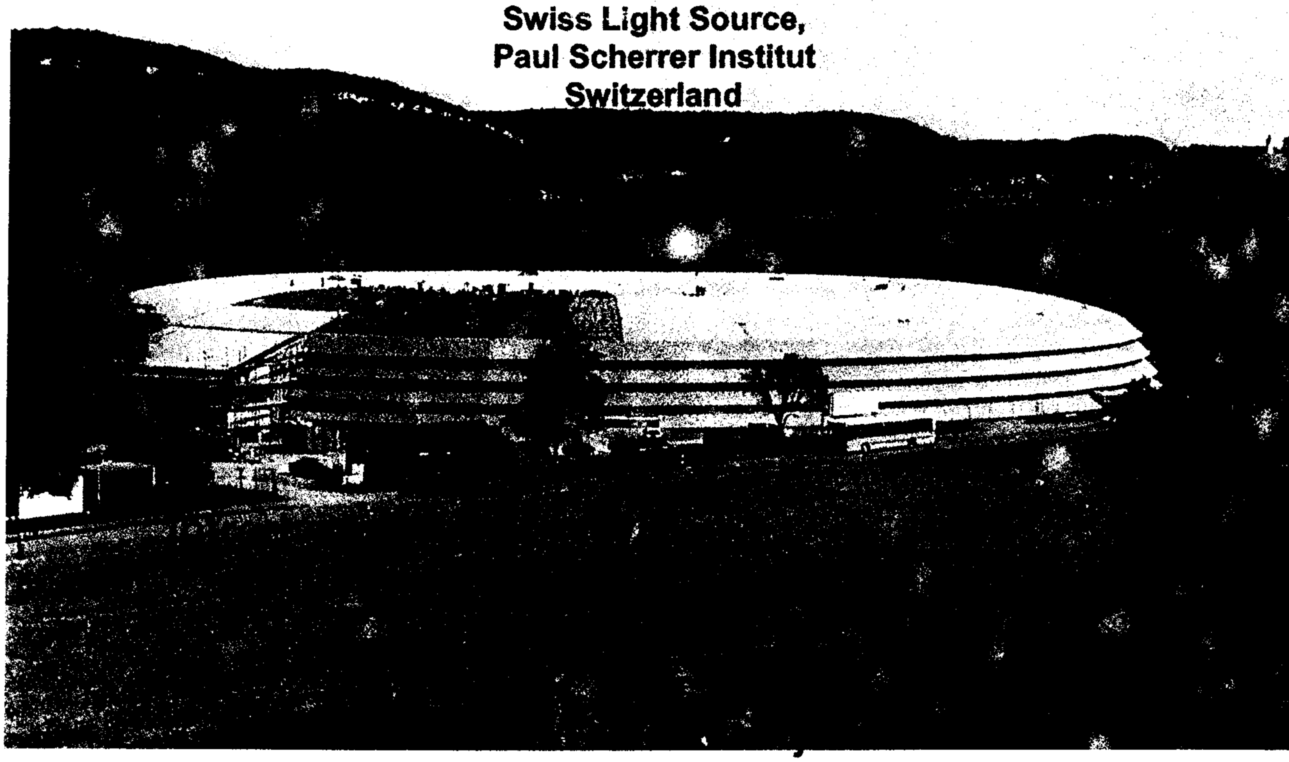

Summary and Conclusions

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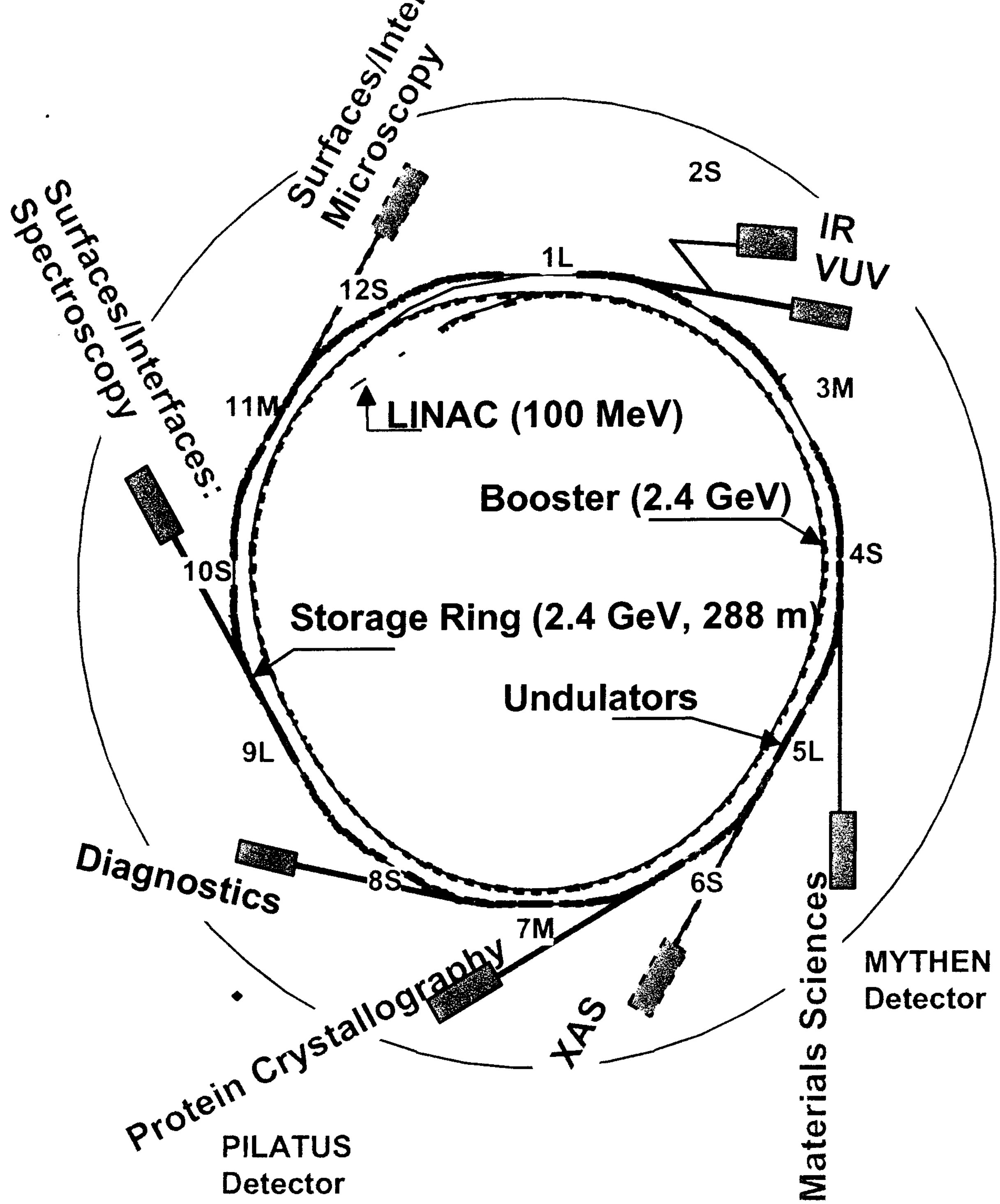
Ch. Bühler[2], U. Greuter[2], M. Näf[1], S. Streuli[2], R. Brun[1]
[1] Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen-PSI
[2] Paul Scherrer Institut, CH-5232 Villigen-PSI

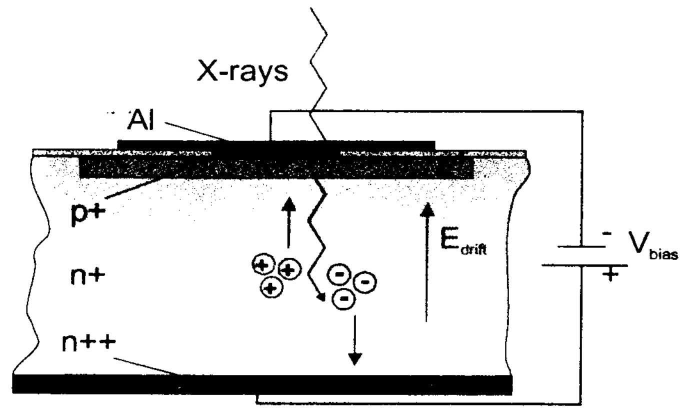
SLS: The Beamlines



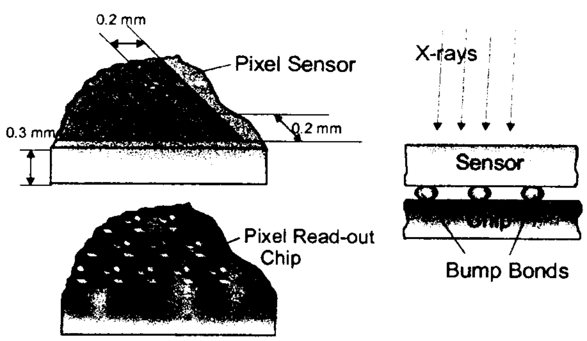
Pixel and Microstrip Detectors

Si pn-junction

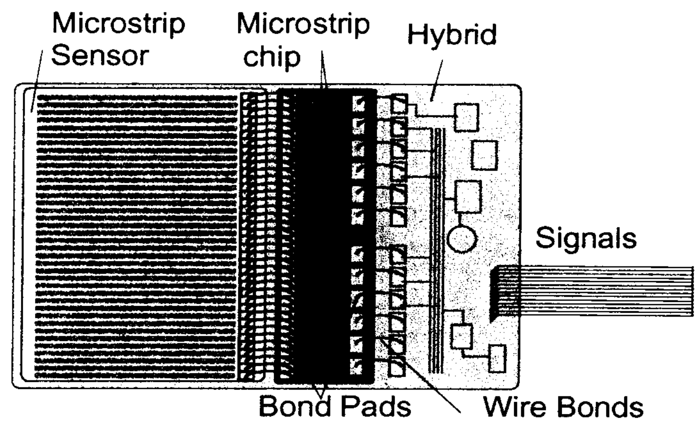
3.6 eV to create
1 eh-pair



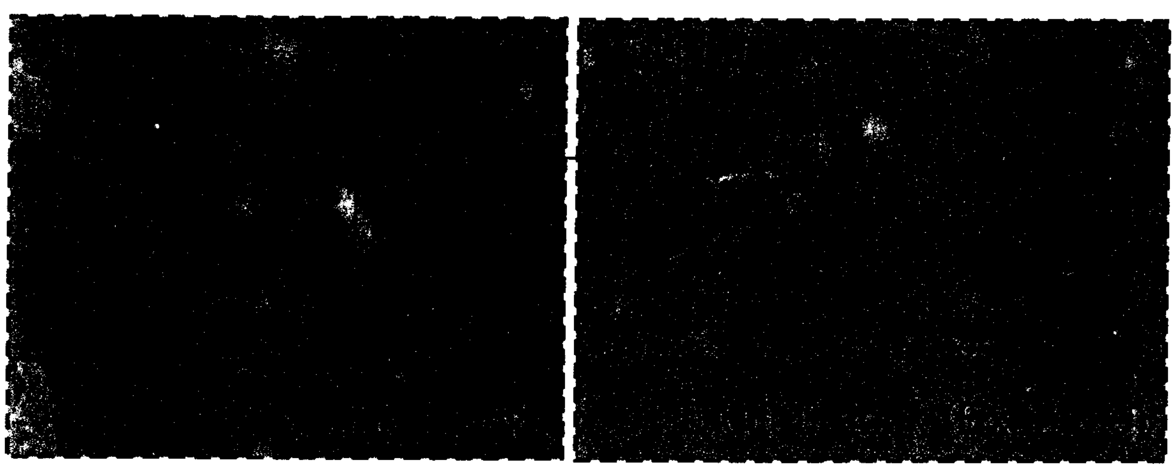
Pixel Detector



Microstrip Detector

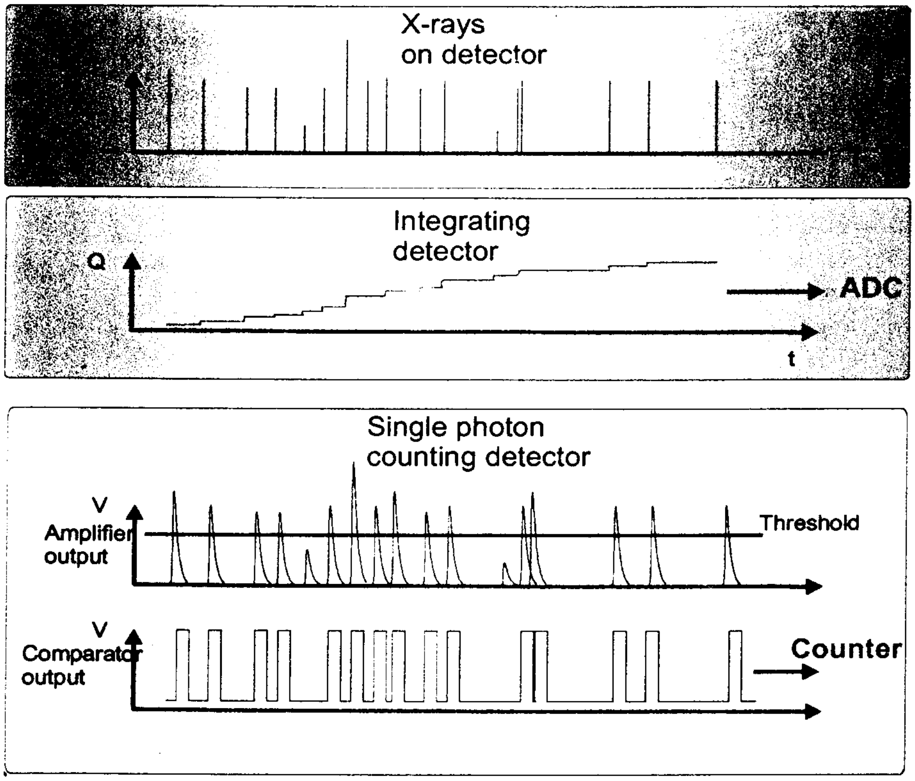


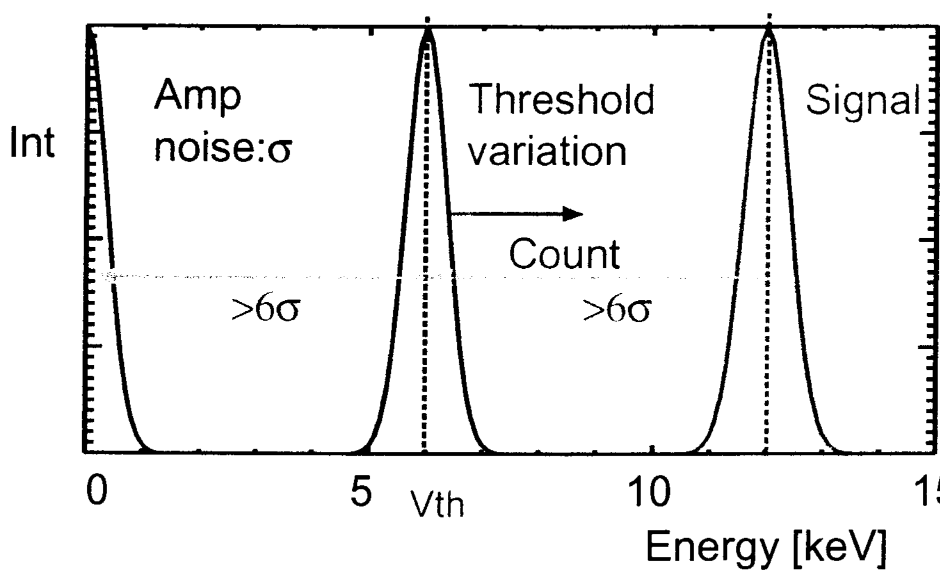
Electronics for each pixel (strip)



Earliest possible digitization !

Integrating Detector vs Single Photon Counting Detector





Low Noise Amplifier (σ<100e)

Low Threshold Variation (σ<100e)

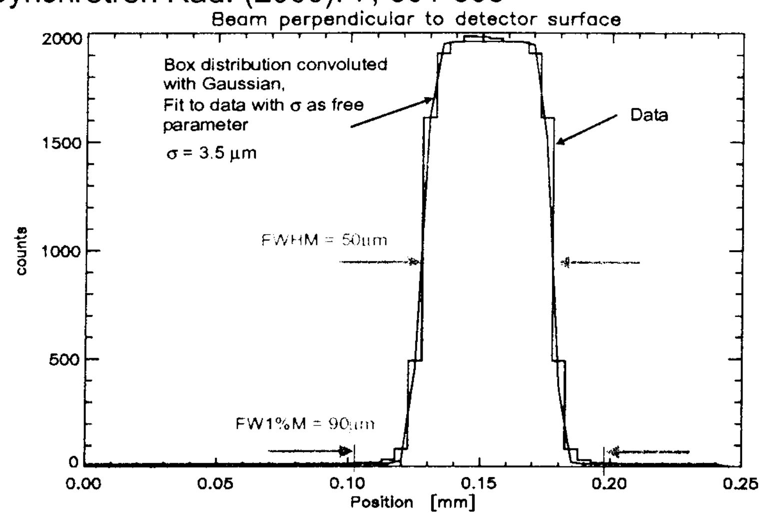
Very high dynamic range

(But: Very dense mixed signal circuit in each pixel and on chip)

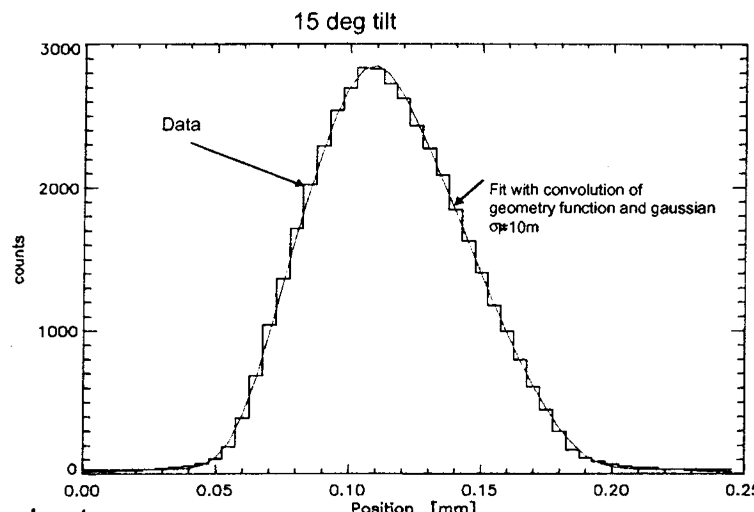
Single Photon Counting Detectors: Properties

Ch. Brönnimann et al, J. Synchrotron Rad. (2000). 7, 301-306

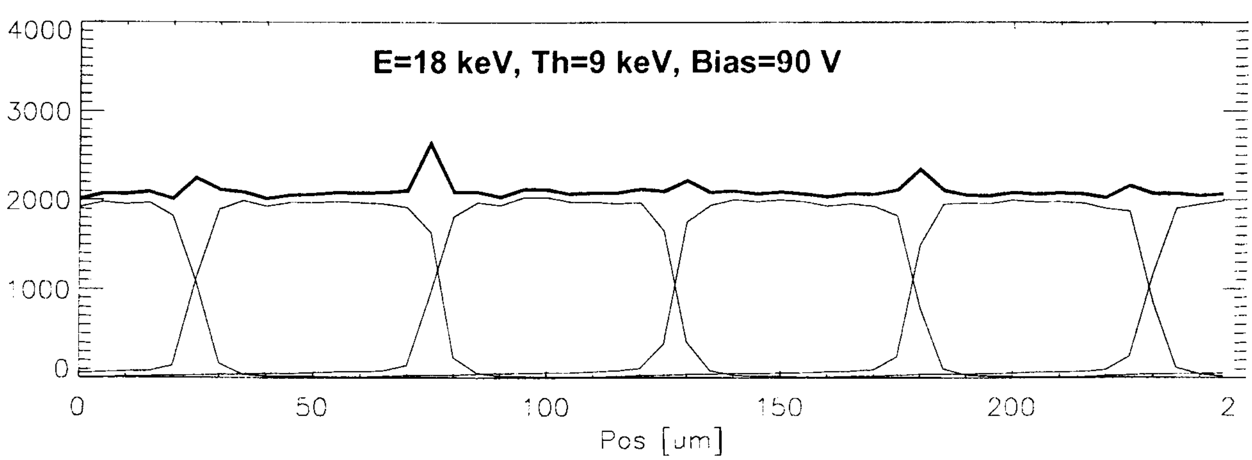
Excellent PSF:
Direct detection of X-rays



Parallax Effect:
Dependent on energy and angle of incidence of X-rays

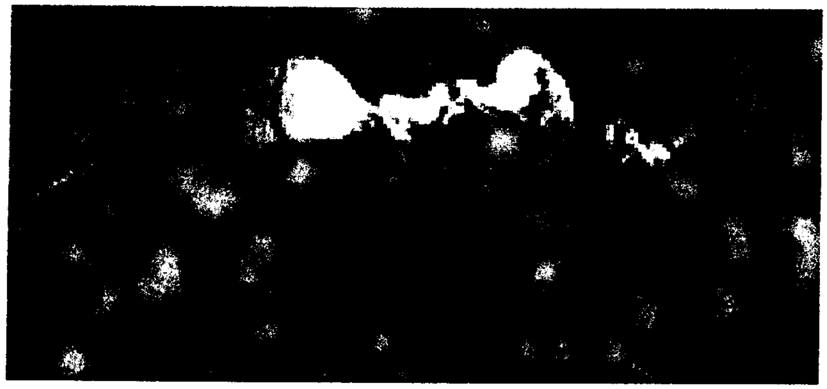


Charge Sharing:
Energy and threshold dependent



The Pilatus Detector

Pixel Apparatus for the SLS



Pixel Detector for the Protein Crystallography Beamline 6S

PSI

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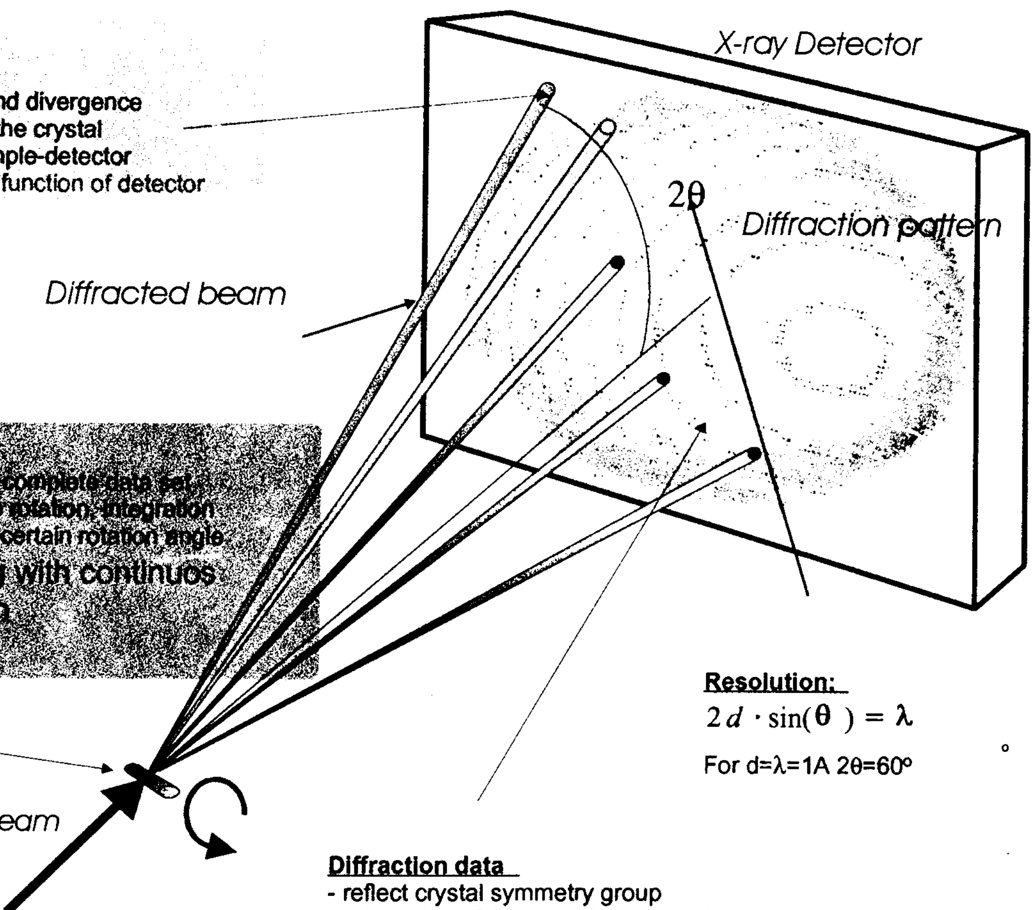
Pixel Detectors for Protein Crystallography

Spot size:

- Beam size and divergence
- Mosaicity of the crystal
- Distance sample-detector
- Point spread function of detector



Crystal rotation:
- 30-180 degrees for complete data set.
- Currently: Discrete rotation, integration over certain rotation angle.
- Fine φ-slicing with continuos sample rotation

Resolution:

$$2d \cdot \sin(\theta) = \lambda$$

For d=λ=1A 2θ=60°

Beam
Energy: 5-17.5 keV
Intensity: $>10^{12}$/s
Focal spot size: Adjustable to $>75 \times 30\ \mu m^2$
Divergency: $<375 \times 70\ \mu rad^2$ (FWHM)

Diffraction data
- reflect crystal symmetry group
- orientation of the crystal-> orientation matrix
- High dynamic range: $>10^4$ between strong and weak reflections
- Intensities need to be determined accurately (1%)
- Determination of amplitudes and phases leads to electron density maps

Main Detector Requirements:

1) Large area (40 x 40 cm) and/or large number of pixels to detect a high number of reflection orders (>500)

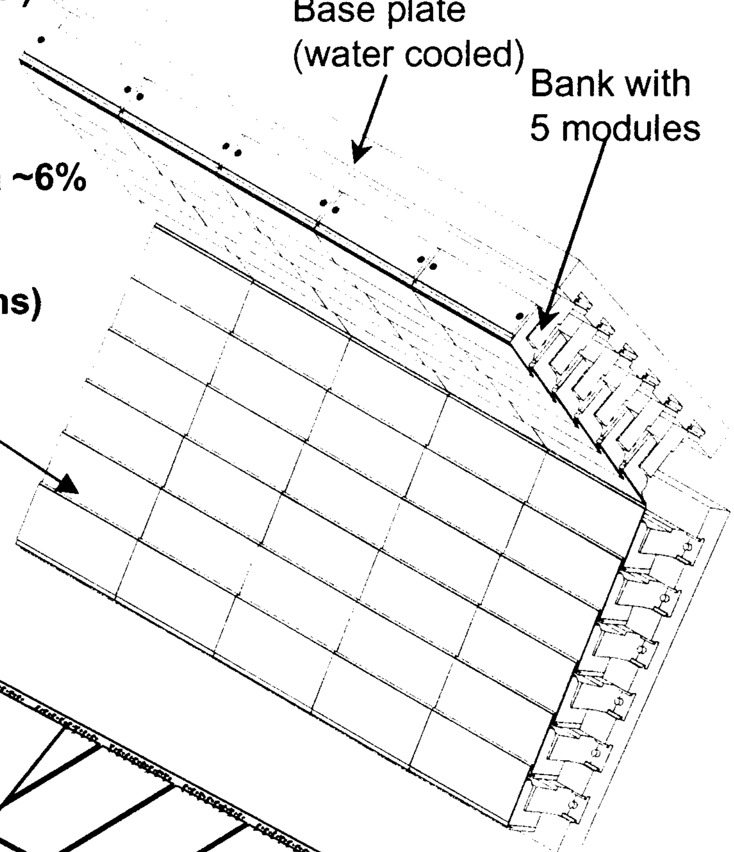
2) Accurate determination of integrated intensities (1%) and wide dynamic range (>16 bit), single photon counting detector

3) Fast readout (<<0.1s)

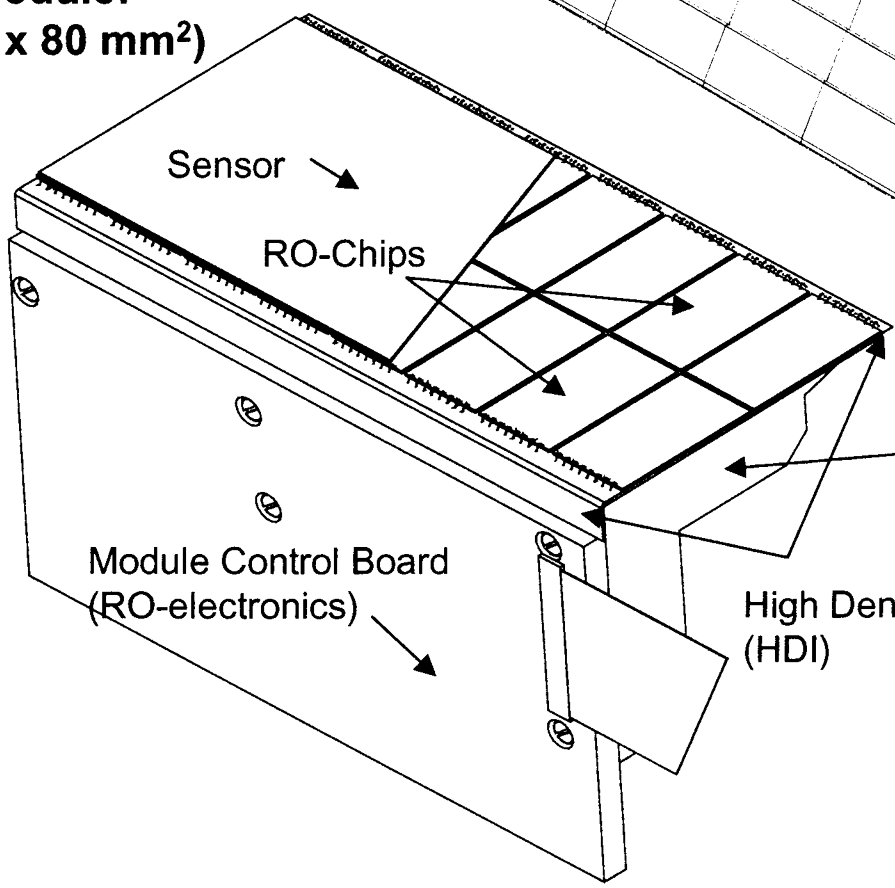
PILATUS Detector

- Final size: 40 x 40 cm^2 (0.16m^2)
- 2000 x 2000 pixels
- Pixel size: 217 x 217 μm^2
- Modular detector -> dead area ~6%
- High frame rate: 10Hz
- High duty cycle: >95% (T_{ro}~5ms)

Full Detector:

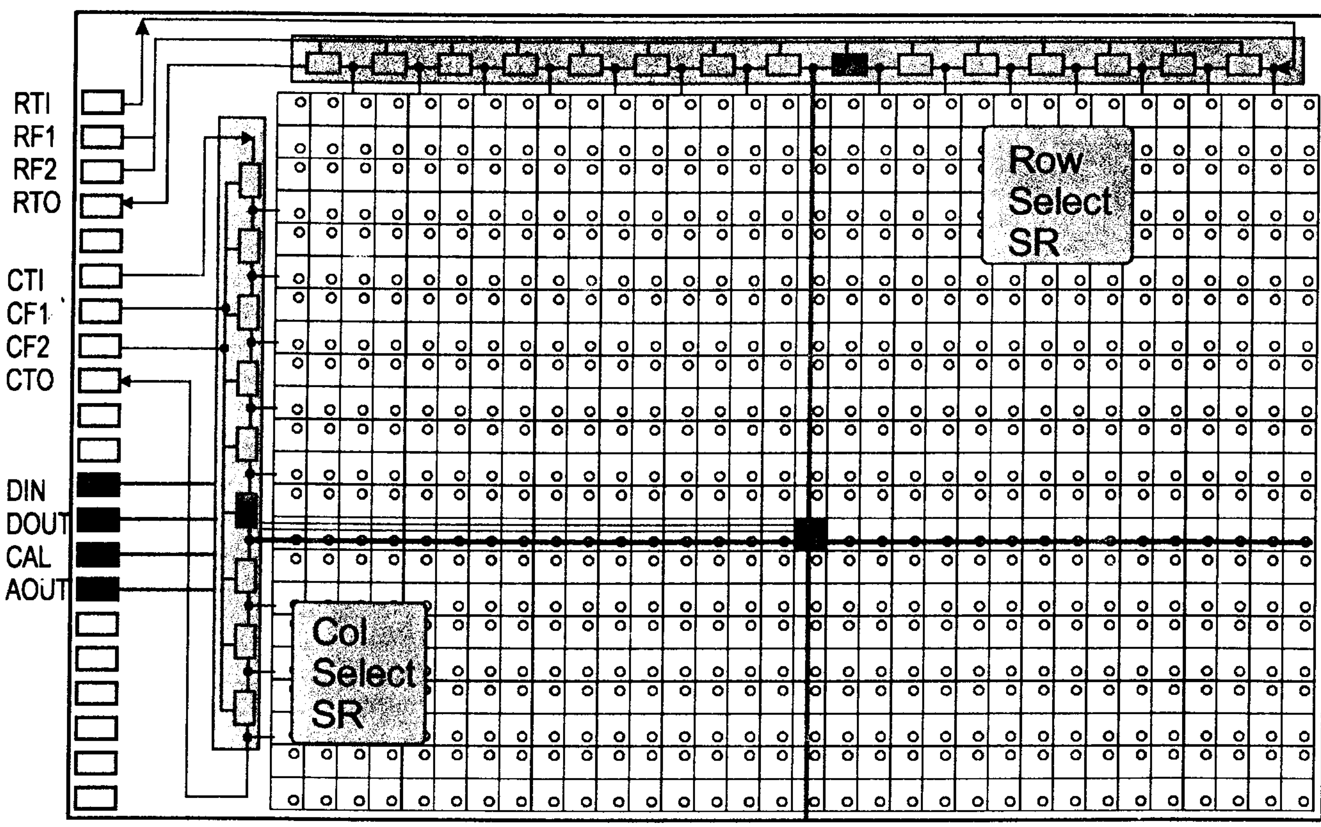


1 Module:
(35 x 80 mm^2)



PILATUS Chip: Specifications

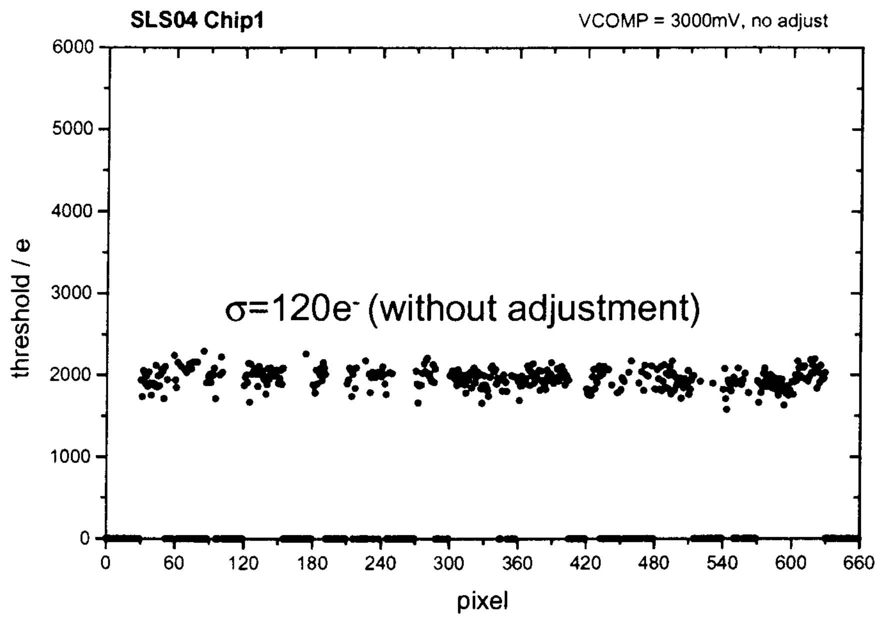
- Radiation tolerant DMILL technology
- Low noise analog block (ENC tot < 100 e-)
- Shaping time t_{sh} = 100 ns -> 1MHz
- Individual threshold adjustment
- Low overall threshold variation (σ < 100e-)
- 15 bit pseudo random counter
- Large size 44 x 78 pixels (20 x 10 mm²)
- Each pixel is XY-addressable
- Read-out time: 5ms (at 10 MHz)



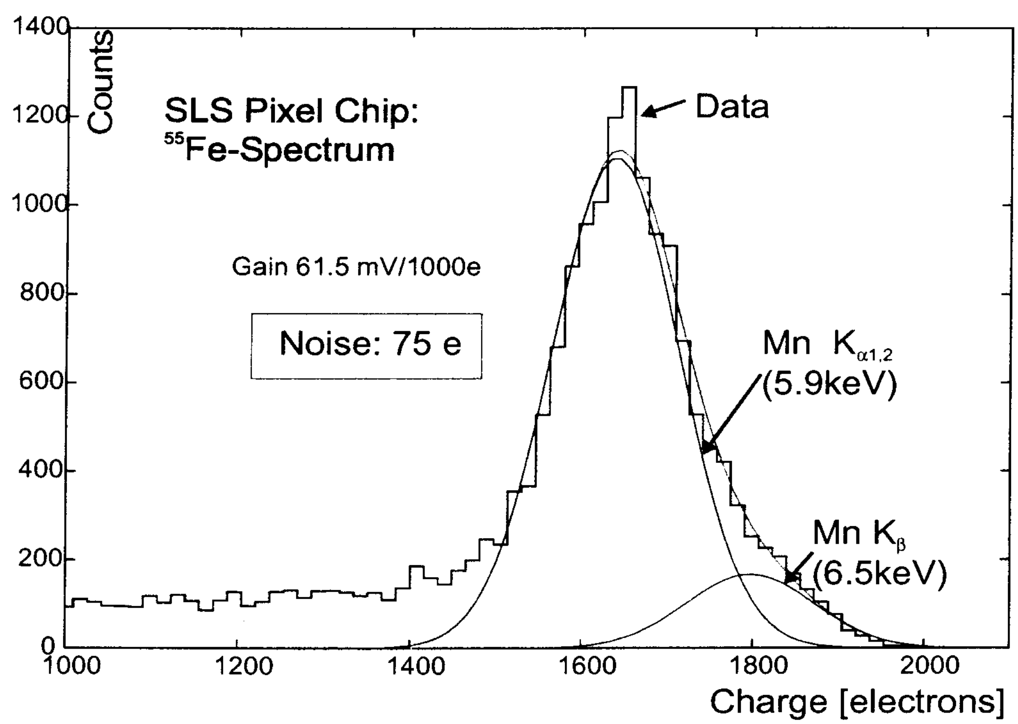
Submitted in Nov 2000

Results from SLS04 prototype readout chip (22 x 30 pixels)

Threshold values from scan of 660 pixels



^{55}Fe spectrum measured at the analog output of one pixel:



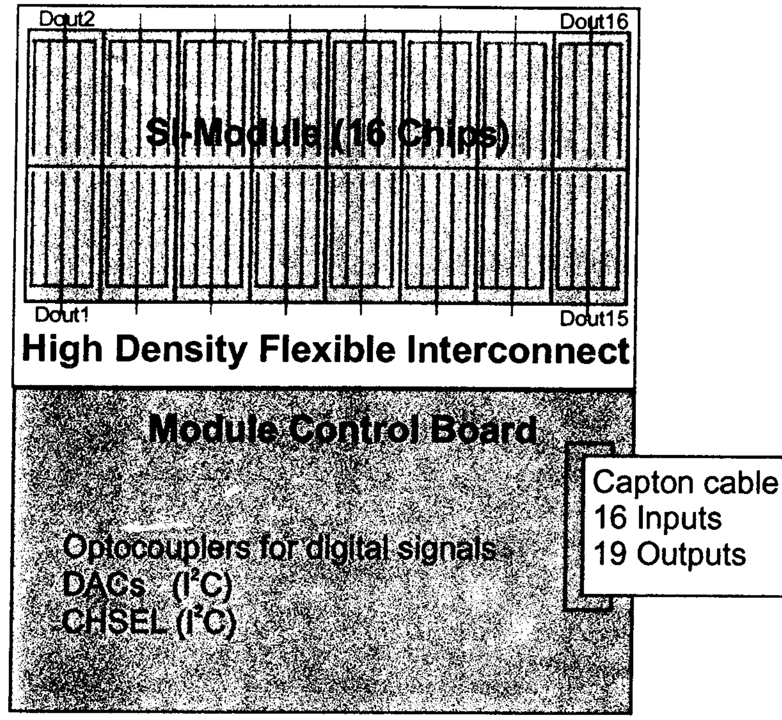
Read-out Electronics

Read-out clock:
F_{RO}=10 MHz

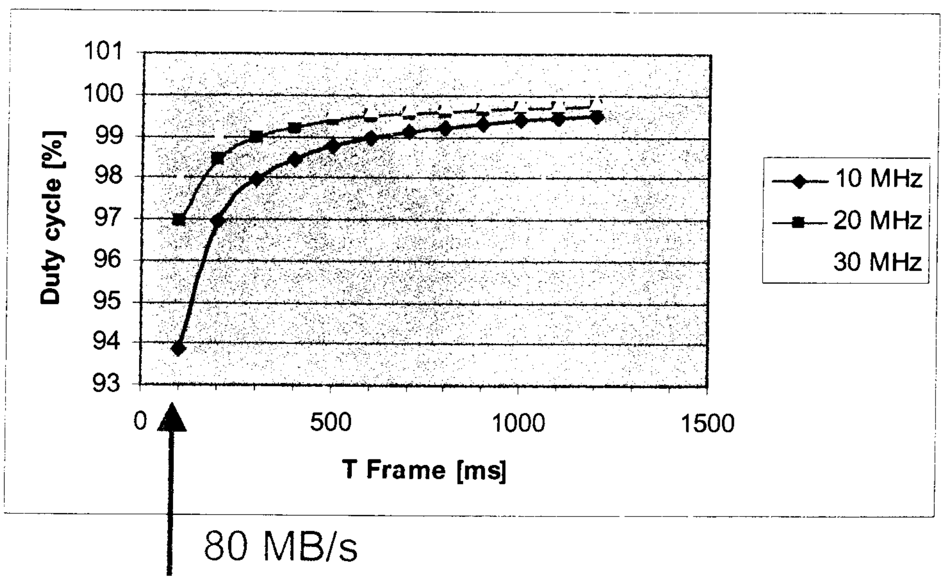
Serial read-out of the 15 bits on each chip (3432 pixel)

Parallel readout of 16 chips

Total read-out time/module:
T_{RO}=5 ms

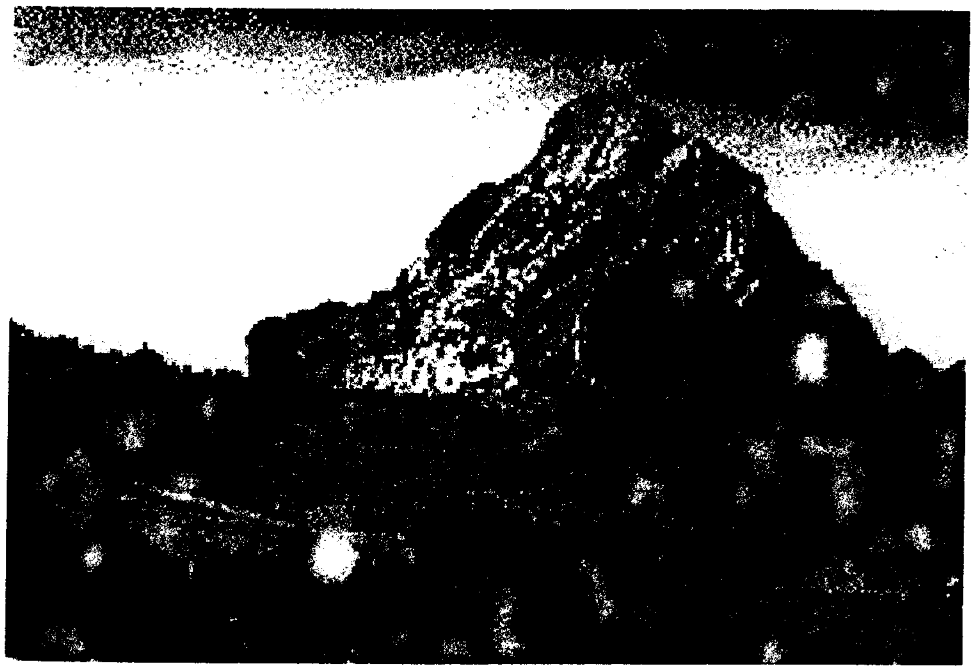


Duty Cycle [in %] = $(T_{Fr}-T_{RO})/T_{Fr}$



The SLS Mythen Detector

Microstrip System for Time-Resolved Experiments



Microstrip Detector for the Powder Diffraction Station of the Material Science Beamline 4s

B. Schmitt[1] , Ch. Brönnimann[1], E. Eikenberry[1], R. Baur[2] and R.Horisberger[2]

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[2] *CMS-Project, Paul Scherrer Institut, CH-5232 Villigen-PSI*

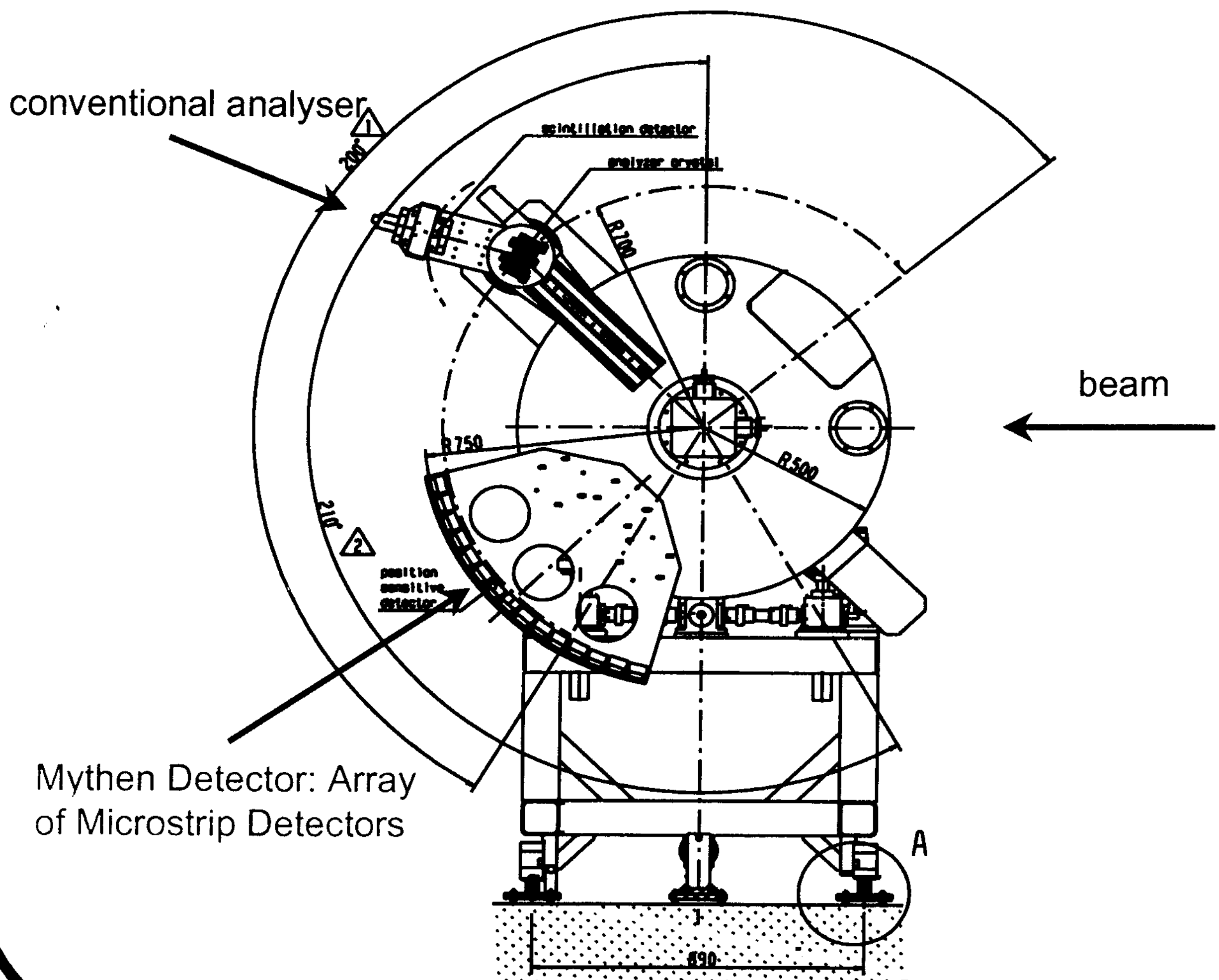
Powder Diffraction Station of the SLS Material Science Beamline 4S

Mythen: Array of microstrip detectors

Angular coverage:	**60°**
No of channels:	**15000**
Angular resolution :	**0.004°**
Read-out time:	**244 μs**

→ time resolved powder diffraction

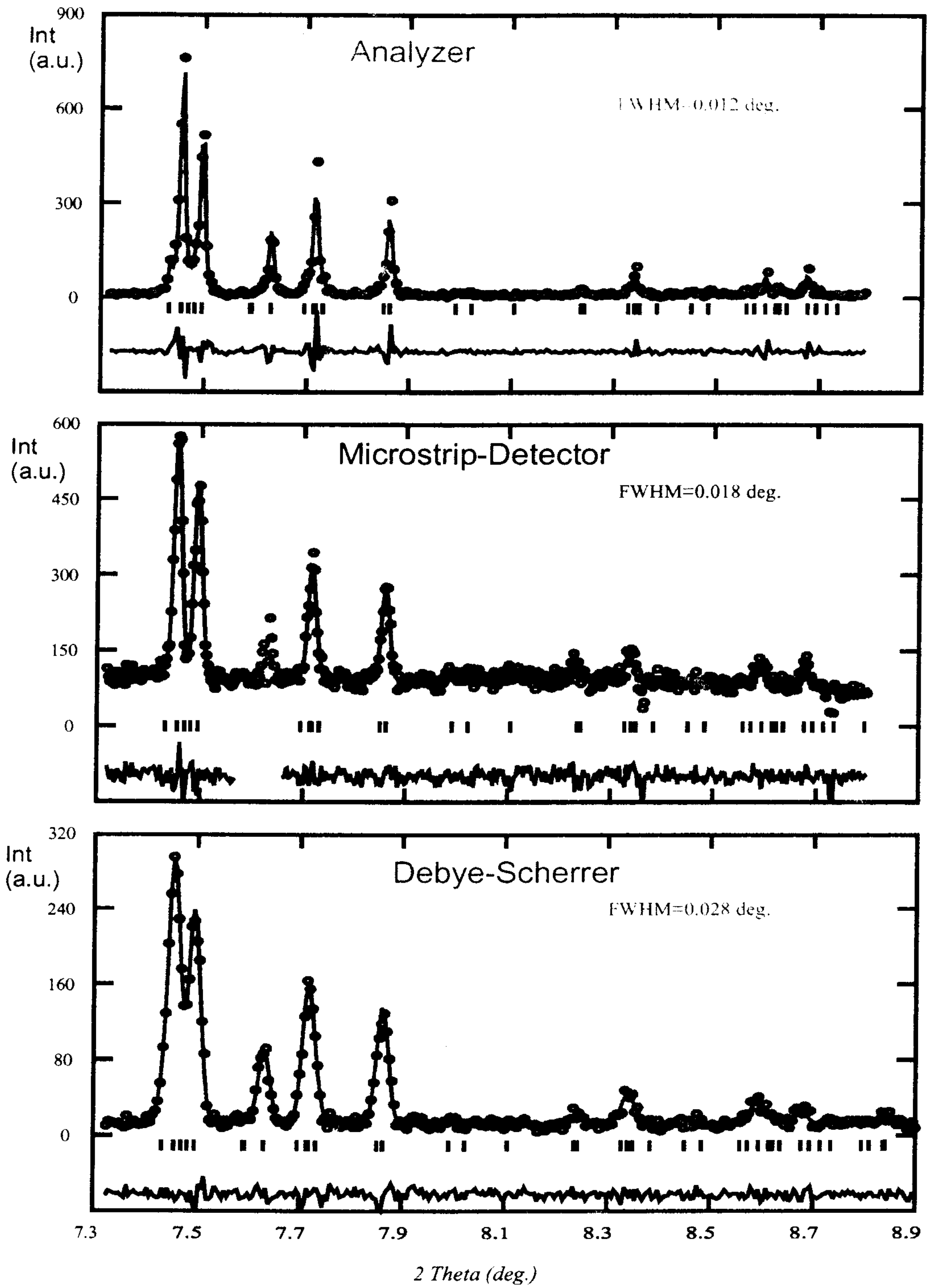
Experimental Set-up



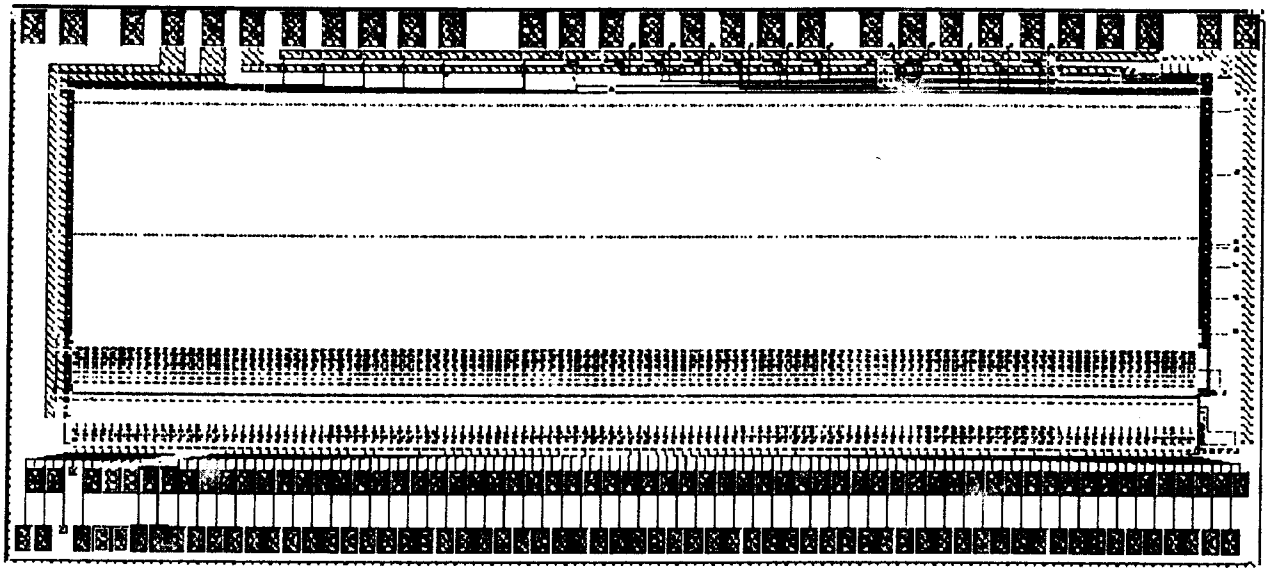
Comparison of analyzer and microstrip data

(F.Fauth et al, Nucl. Instr. Meth. A (2000), 439, no.1, p.138-46.

ZSM-5



The Mythen Readout Chip



Chip features:

Designed in 0.8μm DMILL process

128 channels, 50 μm pitch

18 bit counter per pixel

Count rate 1MHz

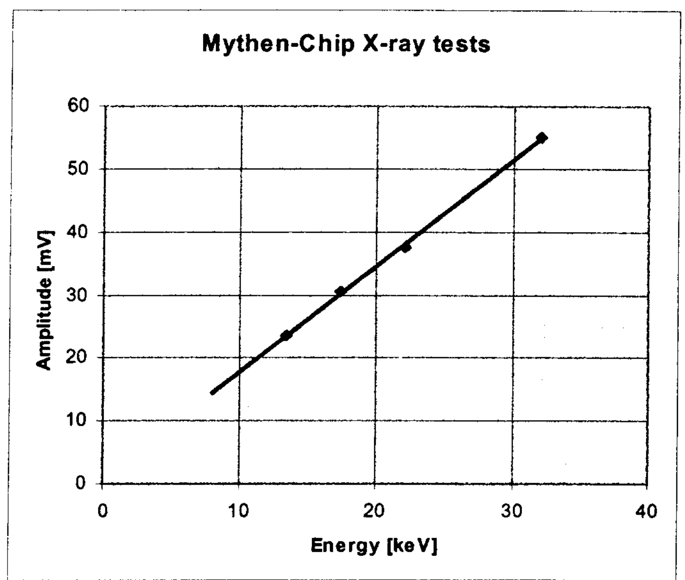
Readout time: 244 μs

Threshold correction in each pixel

Low noise: 150 electrons

Single strip counting (ssc)

Fast Gate: 10ns



Pixel and Microstrip Detectors for Synchrotron Radiation Applications: Digital Systems

Summary and Conclusions

•Technologies of microstrip and pixel detectors so far driven by high rate HEP Experiments.

• 80% of the development time and costs for new detectors are put into ASIC-design and readout electronics.
-> need of good ASIC design teams

• Pixel detectors have a brilliant future. However, the needed efforts are sometimes underestimated...

• Microstrip detectors (although "old fashioned") are believed to have a impact on synchrotron radiation applications. They are relatively easy and cheap to fabricate.