Detector Development at the UK Diamond Light Source and Interactions with other Light Sources i.e. reflections of what is going on for SR in Europe

SRI APS meeting December 2005

Gareth Derbyshire

CCLRC and diamond

Structure of talk

A UK based view of SR detectors

UK current status

Interactions with Europe

UK current landscape

The Diamond Light Source will be operational in January 2007 at the Rutherford Campus

The SRS will close in December 2008.

UK involvement in XFEL being discussed.

4GLS is being developed with an ERL being built at Daresbury

UK current landscape

Into this arena are significant underpinning technology from the Research Councils UK in BASIC TECHNOLOGY

£4M for Monolithic Active Pixel Sensors

£2.5M for CZT development (just announced)

PLUS in DLS

£5M Diamond Detector Development

UK current landscape

Diamond

Although targeted development funds of £5M a further £5M approx. is available in beamline budgets for building final versions of detectors.

Development and Final Build have different funding

(Point raised by Heinz on final version)

Further underpinning research funds are accessible through CCLRC Centre for Instrumentation.

UK current landscape

CCLRC CFI funding has been key to obtaining the funds from RCUK in two basic technology areas.

Both of these areas for development were linked to the strategy documents of an SR detector roadmap which was updated in 2004.

i.e. Although funding covers areas outside the SR community the documents immediately include SR in the bigger picture.

UK current landscape

Without these strategy documents
Funding could not have been obtained.

Low Energy workshop held this year and roadmap will be out soon.

Watch www.srs.ac.uk

Diamond Building Site- ***Aug. 2005***

Science Division

Life Sciences Director
Louise Johnson

Physical Sciences Director
Colin Norris

Macromolecular Crystallography
I02, I03,I04, I24

Liz Duke
Gwyndaf Evans
Katherine McAuley
Ralf Flaig
Thomas Sorensen
Jose Brandao-Neto
Armin Wagner

Soft Condensed Matter
I22, B24

Nick Terrill
Giuliano Siligardi
Marc Malfois
Rohanah Hussein

Spectroscopy
I18, I20

Sofia Diaz-Moreno
Fred Mosselmans

Divisional Office
Andy Dent   Sue Gill
Veronique Saunal
Kathryn Spencer
Mike Smith
Simon Martin
Simon Alcock
Sara Fletcher
Brian Fosh

User Office

Theory & e-science

Support from Technical Division
Controls
Engineering
Health Physics
Installation
Survey & Alignment
Vacuum

Computing & Data Acquisition Group
Bill Pulford
Richard Woolliscroft
Fajin Yuan
Alun Ashton
Stuart Cavill
Stuart Campbell
Adrian Mirea
Wesley Armour
Jason Roche

Laboratory & Services

Optics & Metrology
Kawal JS Sawhney
Lucia Alianelli
Ulrich Wagner
Thomas Roth

Detectors
Gareth Derbyshire
Nicola Tartoni
Victoria Wight
Brian Willis

Engineering & Environmental Science
I11, I12, I15

Chiu Tang
Michael Drakopoulos
Andrew Jephcoat
Stephen Thomson

Materials
I16, B16, I19

Steve Collins
Kawal JS Sawhney
Simon Teat
Alessandro Bombardi
Harriott Nowell
Igor Dolbnya

Surface & Interface Science
I06, I07

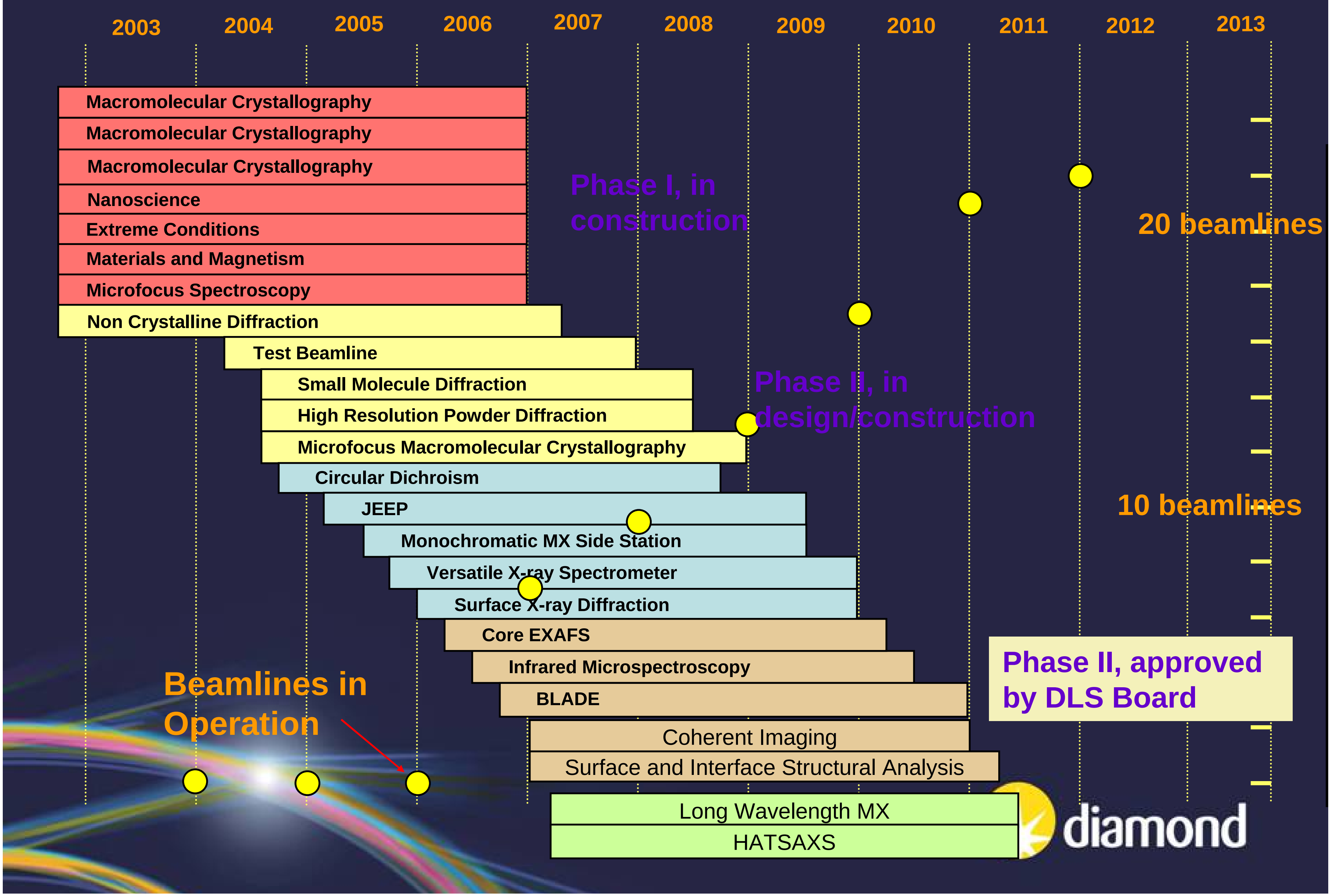
Sarnjeet Dhesi
Chris Nicklin
Paul Steadman

Total staff Sept 05: 89

Planned July 2011: 192

diamond

Phases I and II beamline construction



Diamond Detector Development

- Current Plans
- Update on Progress, Specific example I22
- Wider interactions

Schedule of work

➢ **Start enabling works**	**3rd Mar. ‘03** ✓
➢ **Completion of enabling works**	**29th Sep ‘03** ✓
➢ **Start main construction work**	**13th Oct. ‘03** ✓
➢ **Handover 1st Section Tunnel**	**8th Oct ‘04** ✓
➢ **Office block available**	**10th Jan ‘05** ✓
➢ Buildings Completion	Dec ‘05 / Jan ‘06
➢ First beam in Storage ring	Mar ‘06
➢ Start Beamline commissioning	Jun ‘06
➢ Start of Operations	Jan ‘07

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Experimental Hall & Beamline Hutches – May 2005

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Detector Group

Now consists of:-

- Victoria Wright (detector scientist)
- Nicola Tartoni (detector scientist)
- Gareth Derbyshire (50/50 with CCLRC)
- Brian Willis (detector technician)
- Another detector technician just recruited
- Electronics Engineer next recruitment
- Plus currently 4 CCLRC staff on various projects

Methodology

- Purchase
- Adapt or Collaborate
- Develop

Current Plans Phase 1(day 1)

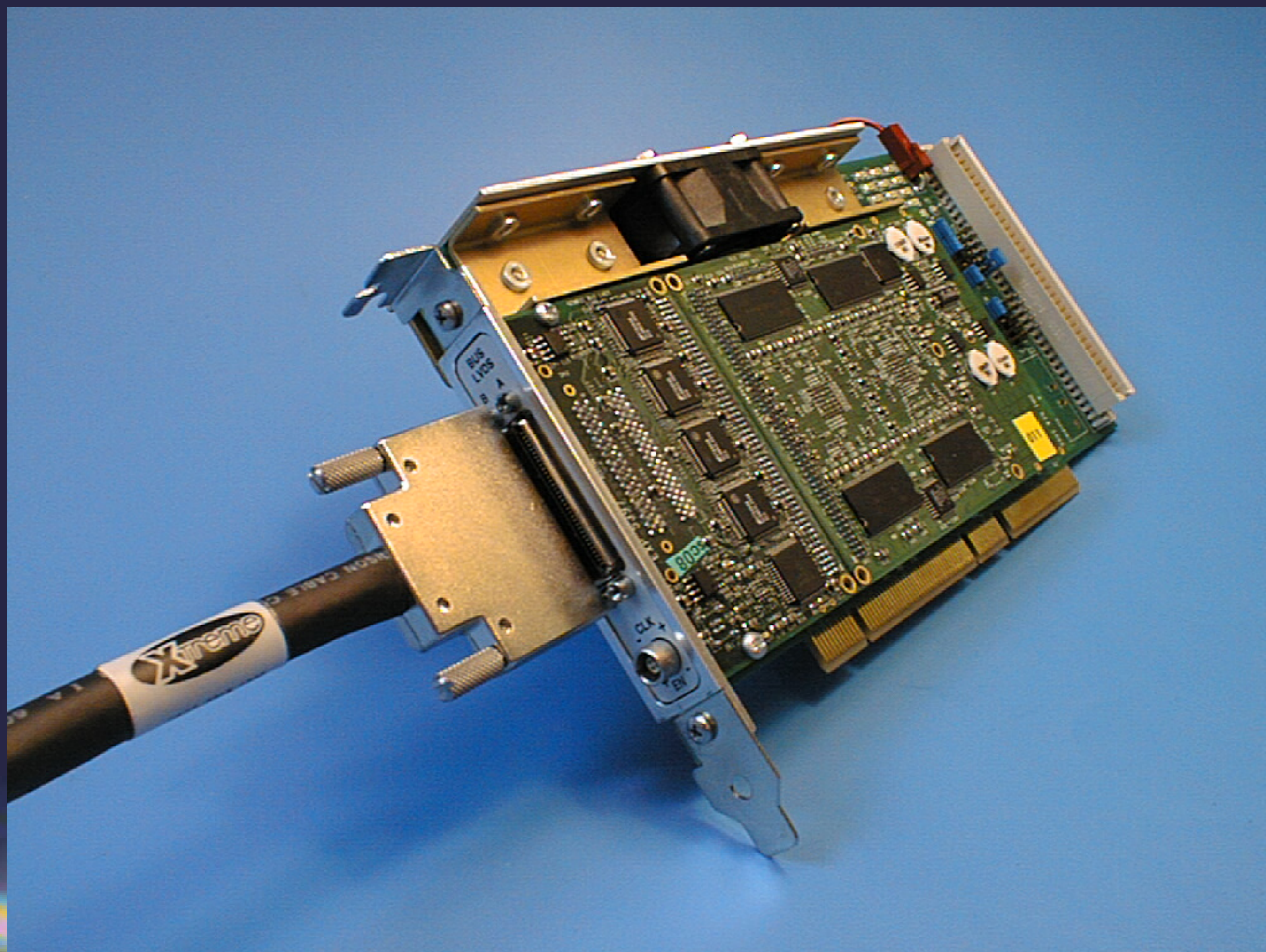
- Little development for Day 1 beamlines due to timescales and budgets. Some moving of DAQ designs between platforms and a “belt and braces” approach to all stations.
- Development for Phase 2. Any prototypes from phase 2 projects that are useful to phase 1 will be made available.

Current Plans Phase 1(day 1) 7 stations Jan 07

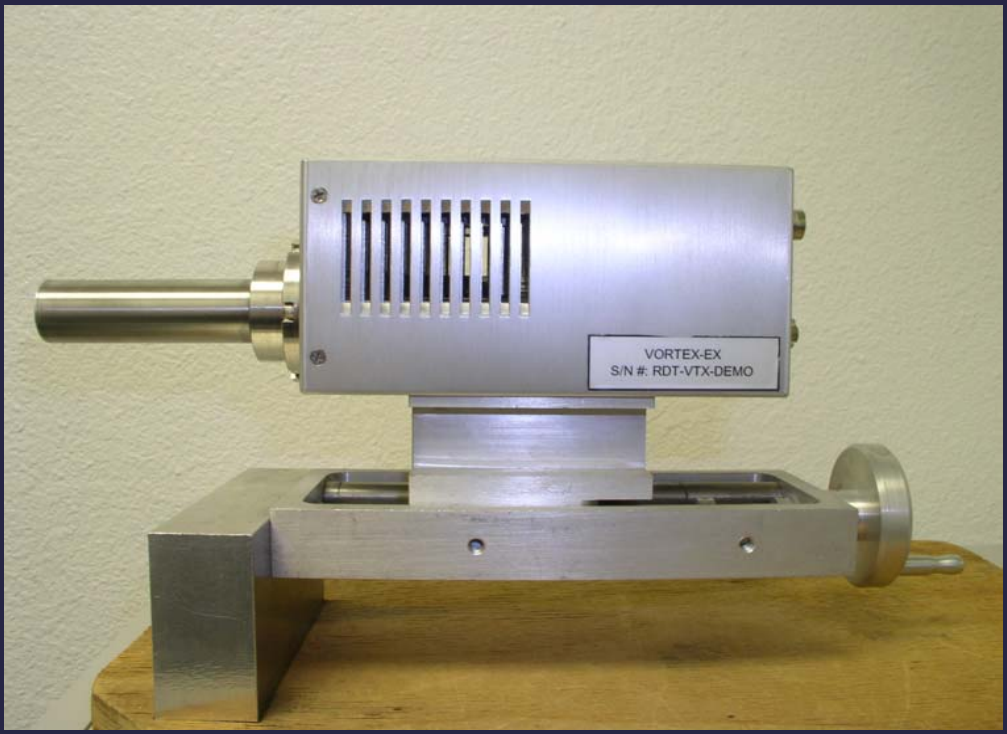
- I18 X-SPRESS (GDAQ) and C-TRAIN 9 element Ge monolithic.
- I06 MCP CCD as bought with PEEM
- 3 MX Beamlines ADSC plus Vortex
- Extreme Conditions Ge detector (3 elements?) and image plate plus CCD
- Magnetic Diffraction APD or / and Vortex

Current Plans Phase 1 I18

Current Plans Phase1 I18

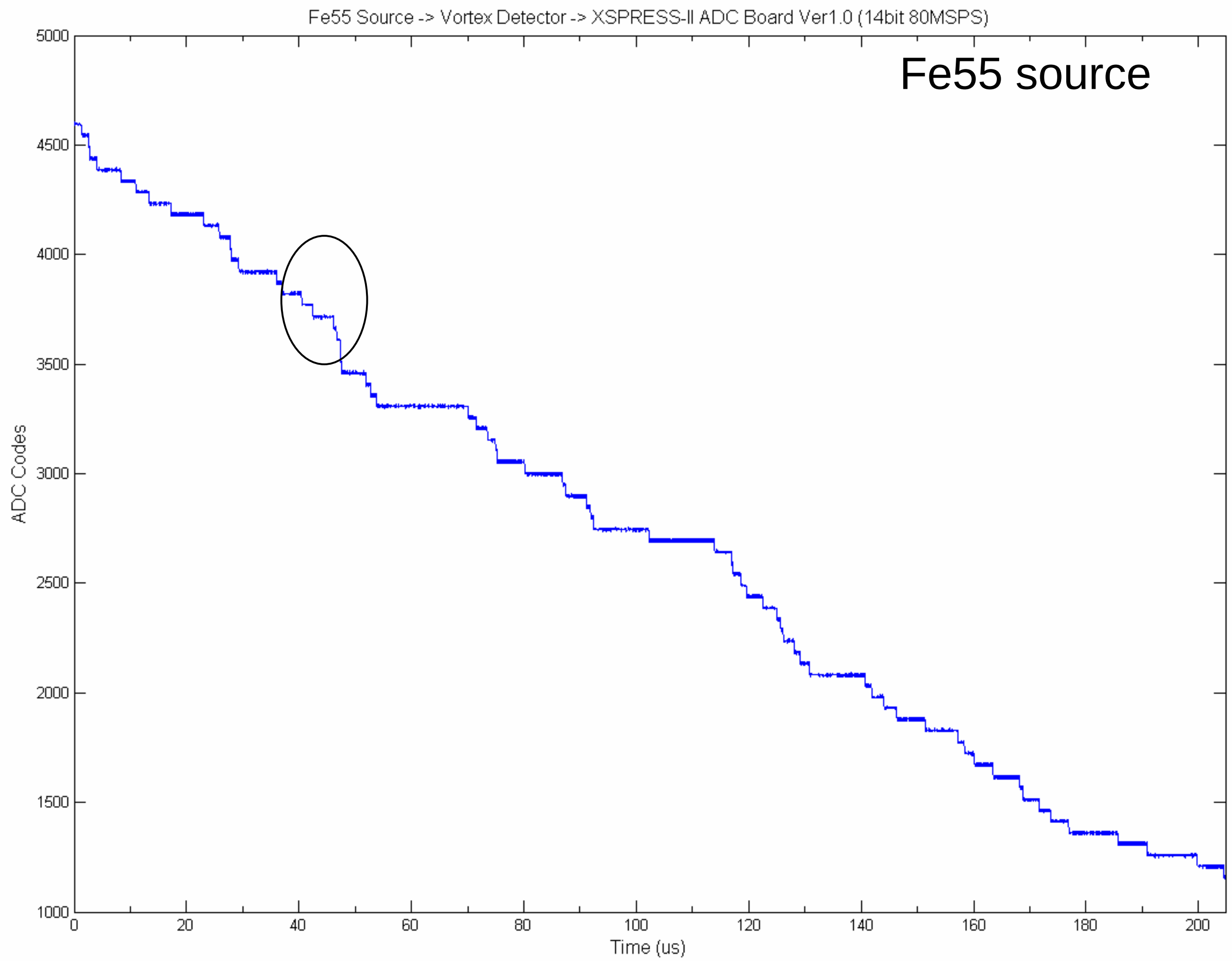


Current Plans Phase 1 MX

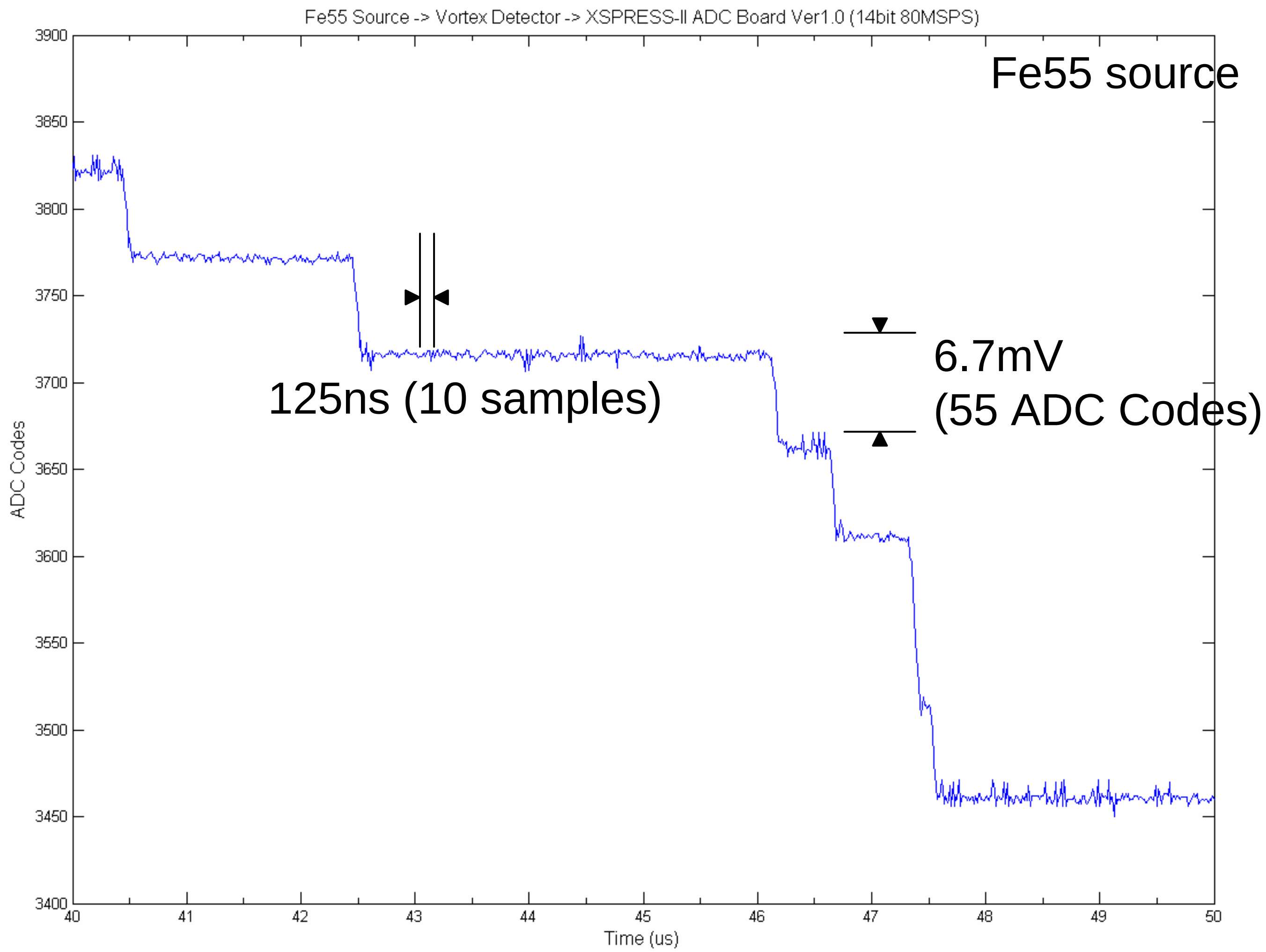


Tests at SSRL on several diodes showed that the Vortex was the best choice for what we wanted.

Vortex Detector & XSPRESS-II plus new ADC



Vortex Detector & XSPRESS-II plus new ADC (zoomed)



Current Plans Phase 1(day 2)

- I18 XSPRESS and N>20 element Ge Pos. Si
- I06 e-MAPS prototype tests through access to MI3 MAPS consortium. Prof Allinson Sheffield University (first test prototype May 2006)
- MX Beamlines ADSC plus Vortex plus XSPRESS (GDAQ)
- Extreme Conditions Ge detector 3? elements plus photon counting area array
- Magnetic Diffraction PENELOPE Prototype

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Early Phase 2

- I22 is the first experimental station in phase 2.
- Hence this is the first station to have a detector specifically designed to meet the science requirements. This is high rate detector for time resolved SAXS.

Early Phase 2

- I22 has had a detailed suite of detectors planned in from the start with tight specs. These are now underway.
- Very good interaction with CCLRC is necessary and is being obtained.
- Key links to CCLRC facility development funds.
- Very good interaction with user community.

Gas Detectors

Gas detectors still have a place on Diamond at least. GMSD and RAPID (wire detector currently)

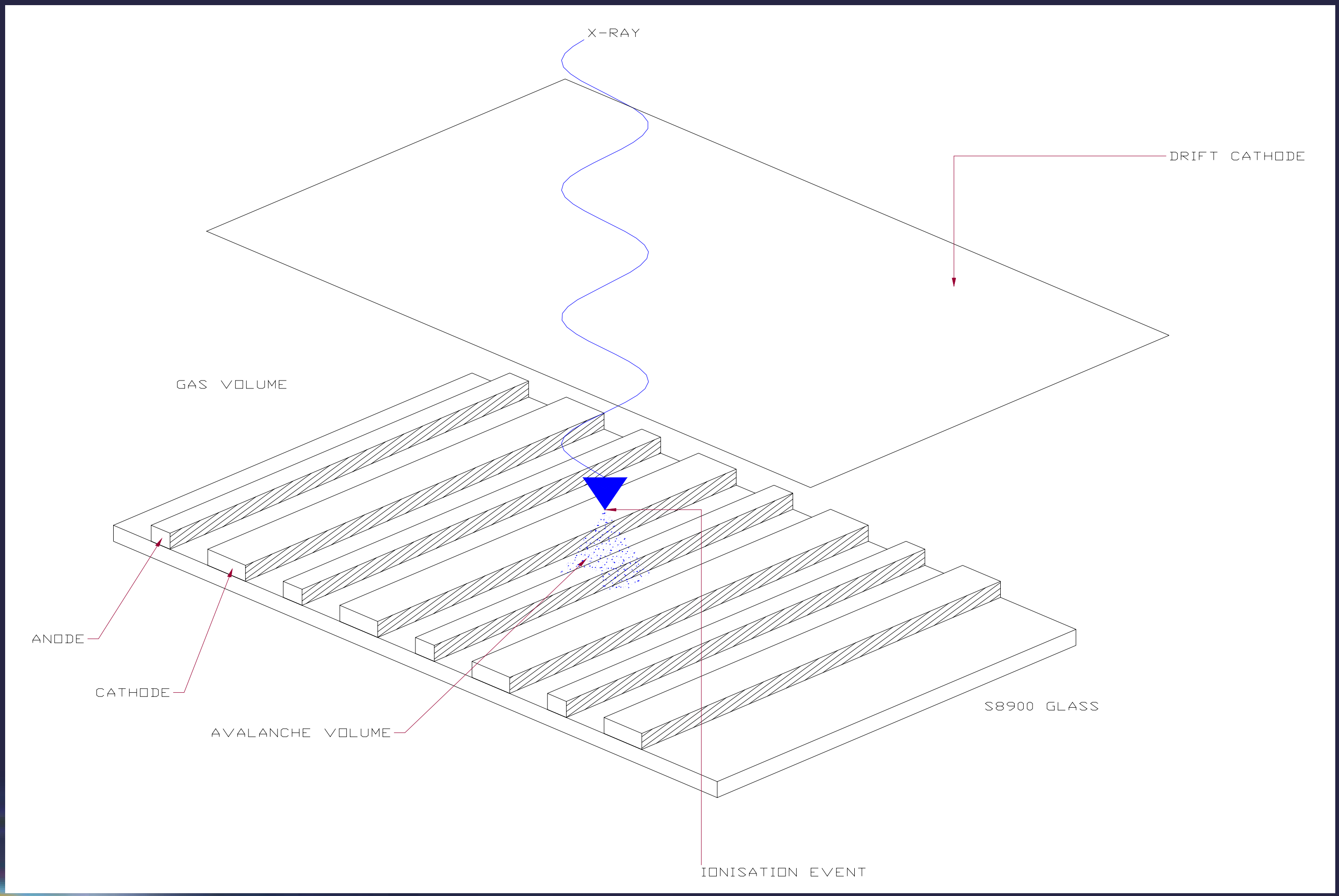
Also Soleil is developing similar CAT based detectors.

ALBA has a gas detector programme for 2D wire based detectors.

I 22

- I22 will initially have a matched pair of 1D detectors HOTWAXS and HOTSAXS for day one.
- Each detector capable of 500Mcps global counting rate. HOTSAXS specifically developed for I22.
- Time frame resolution will be set by the TFG (TFG2). 1 to 10 microsecond time framing min.
- This station will also have a new 2D RAPID detector built by CCLRC's Daresbury Lab.

GMSD operating concept



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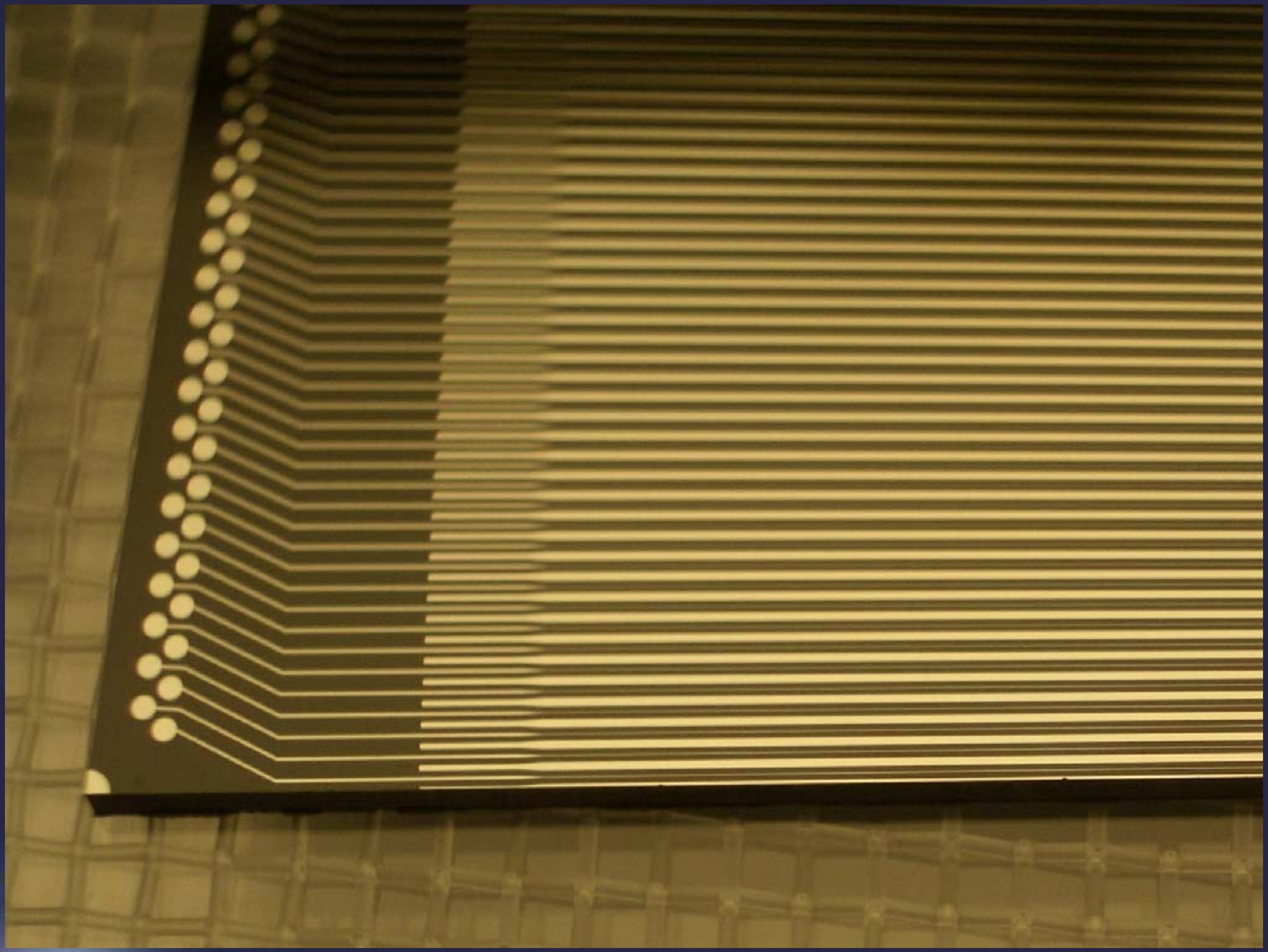
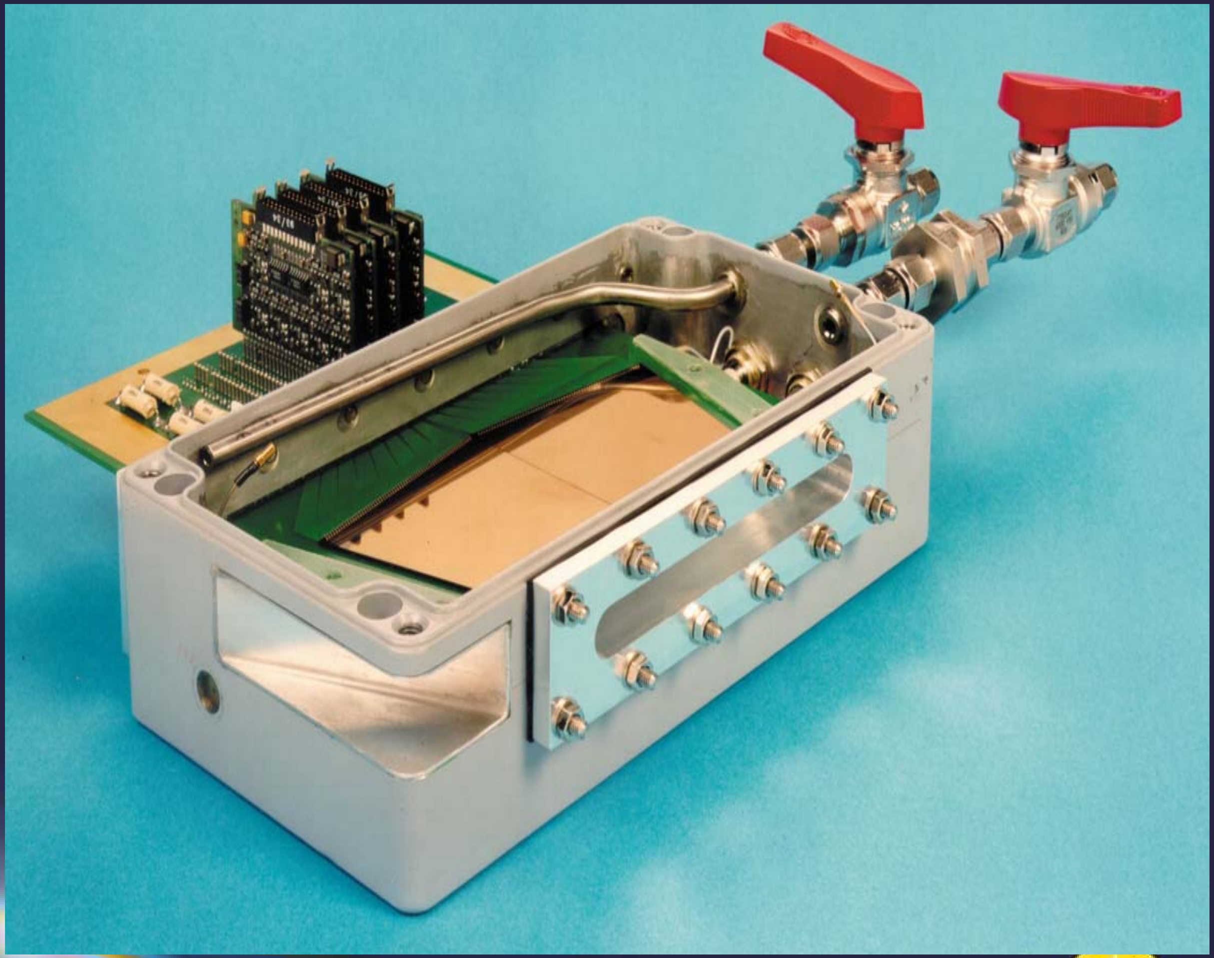
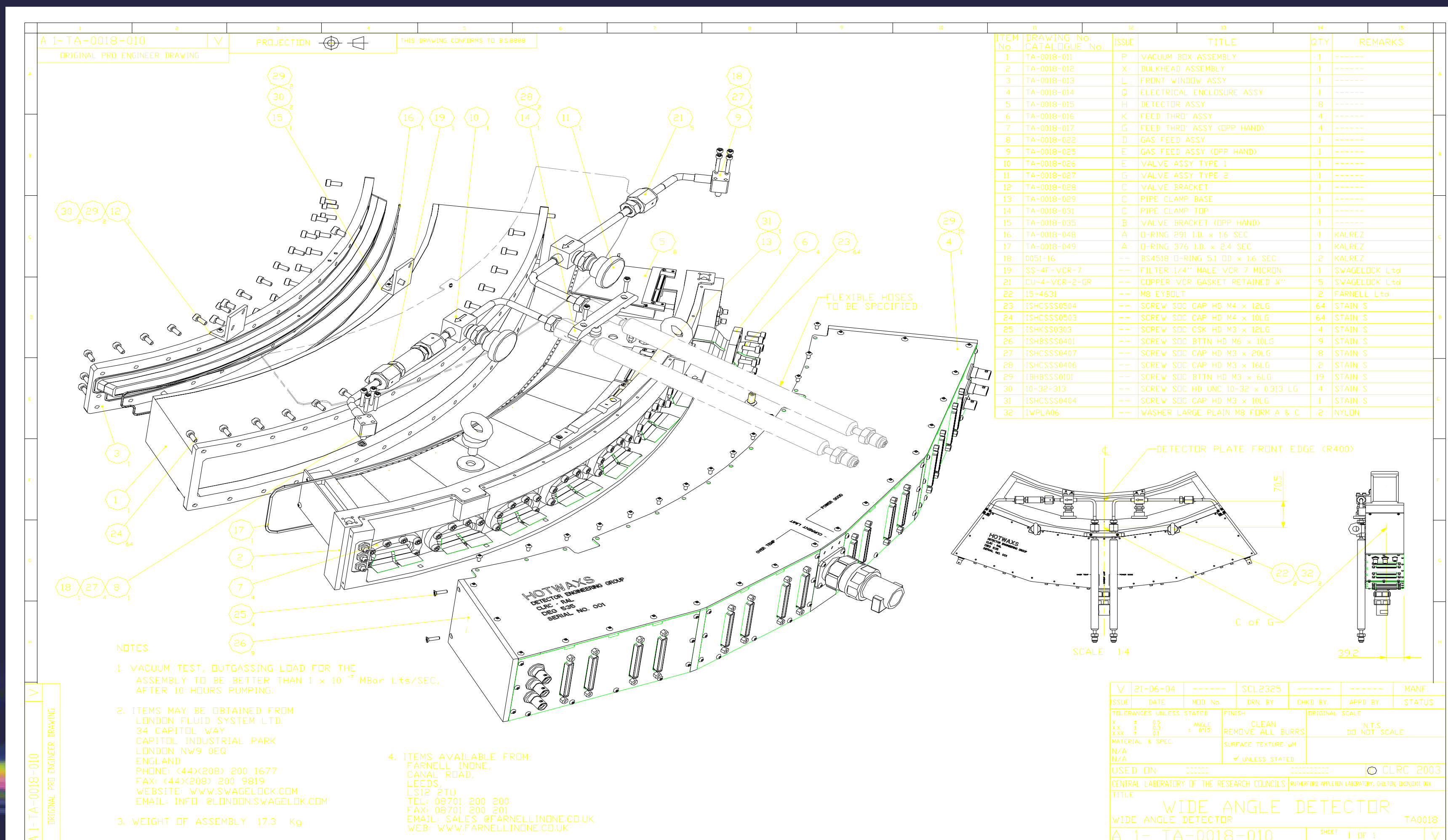
HOTWAXS Glass Plates



HOTWAXS PROTOTYPE



HOTWAXS G.A.



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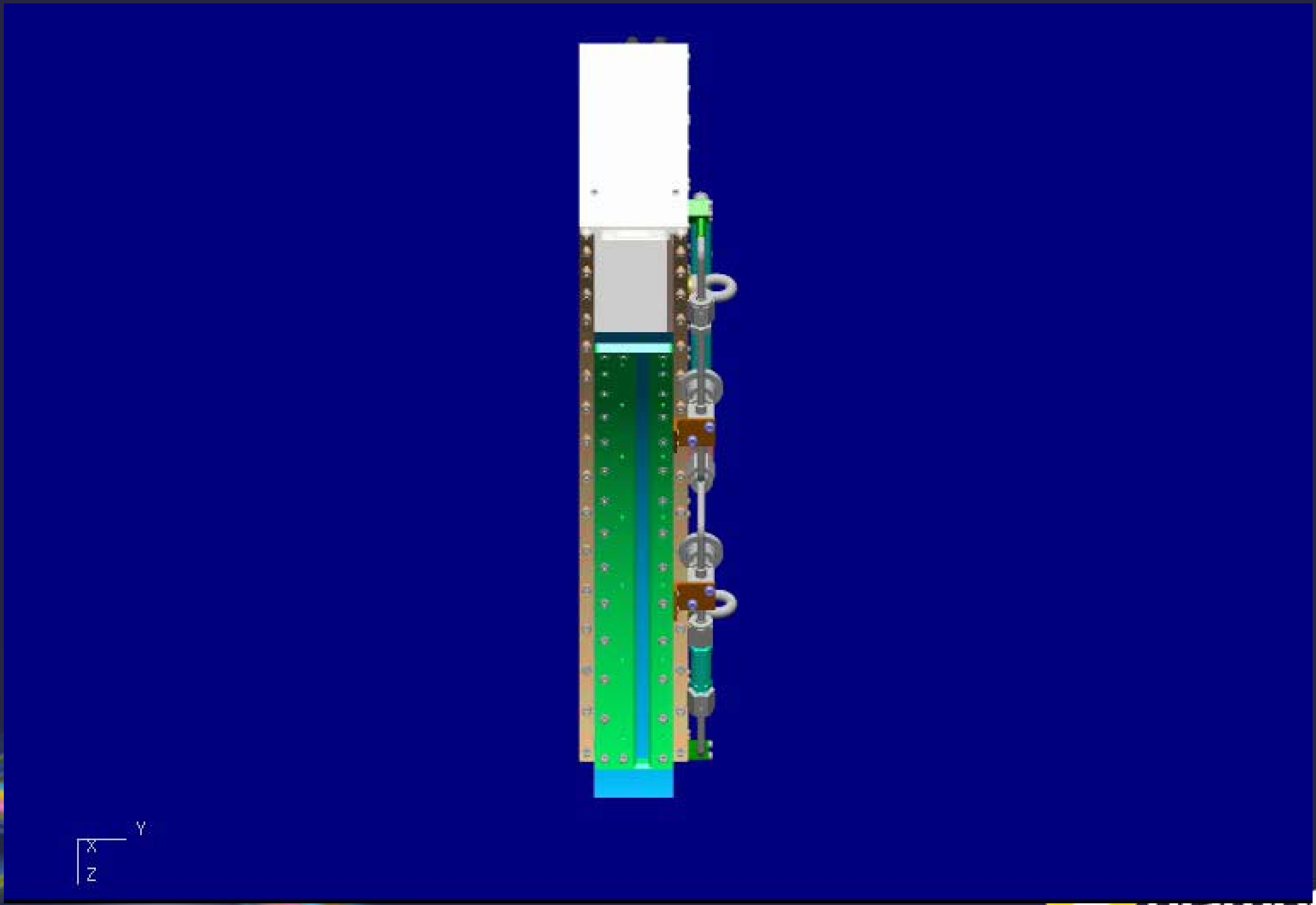
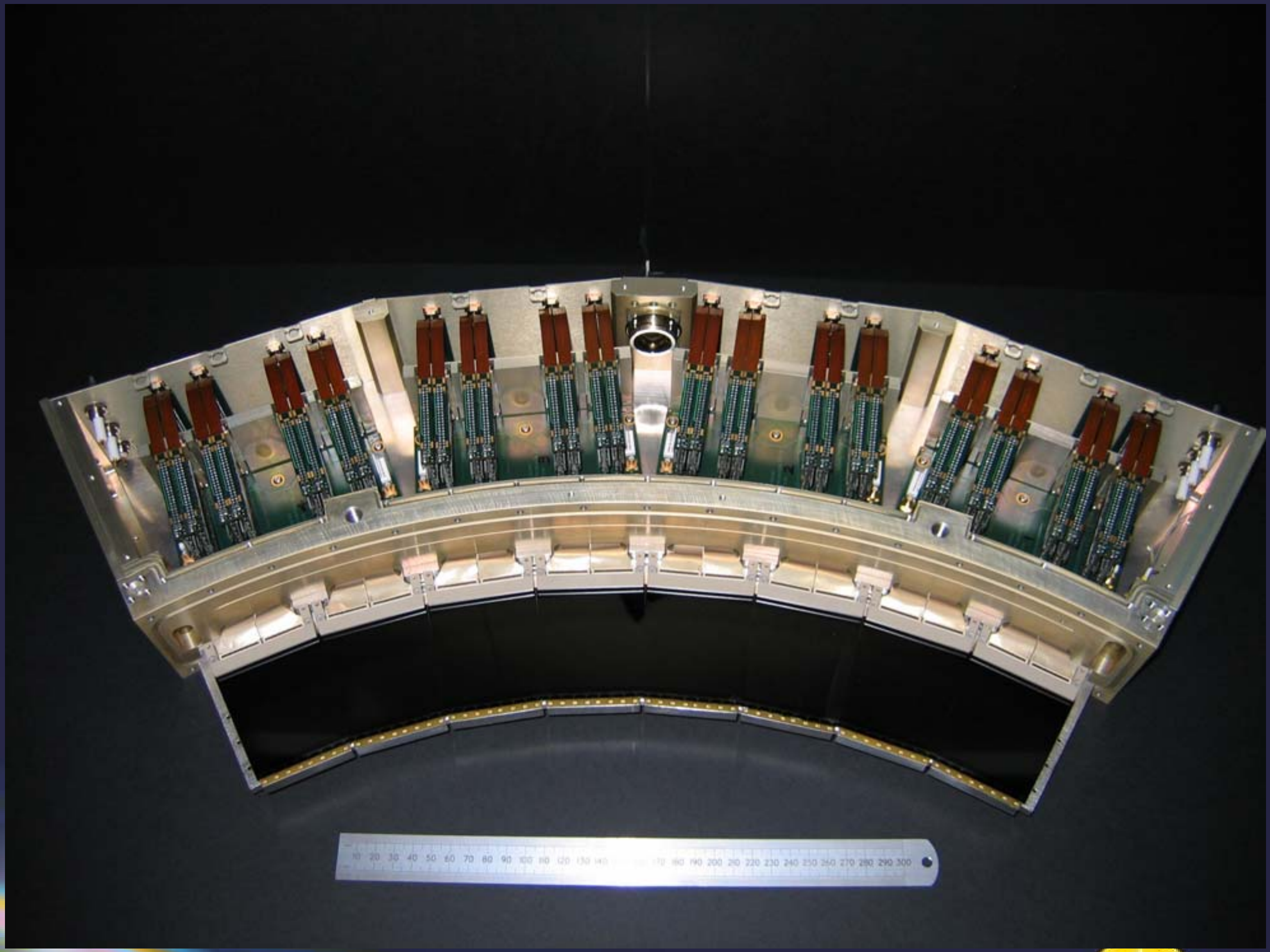
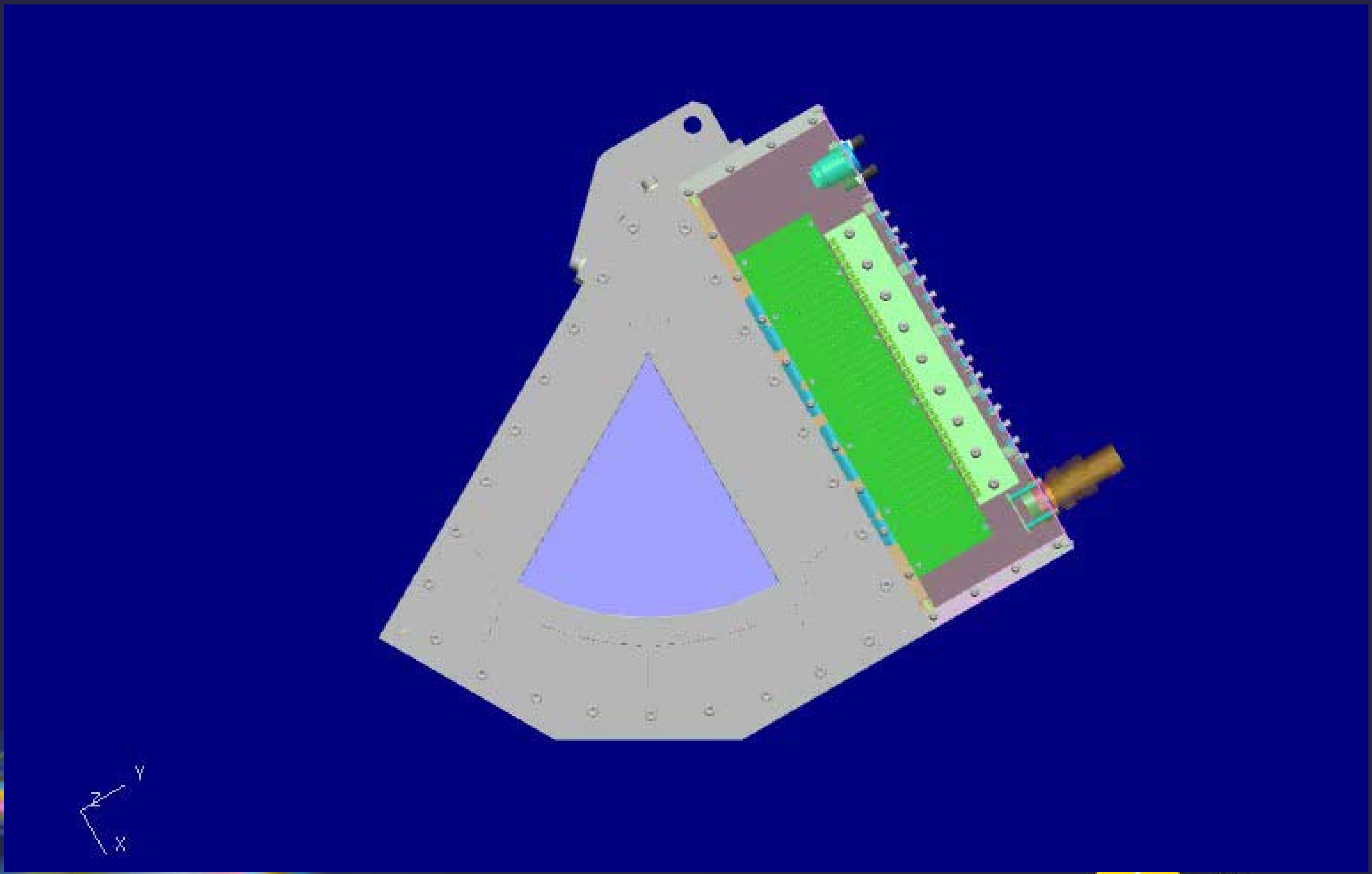
HOTWAXS G.A.



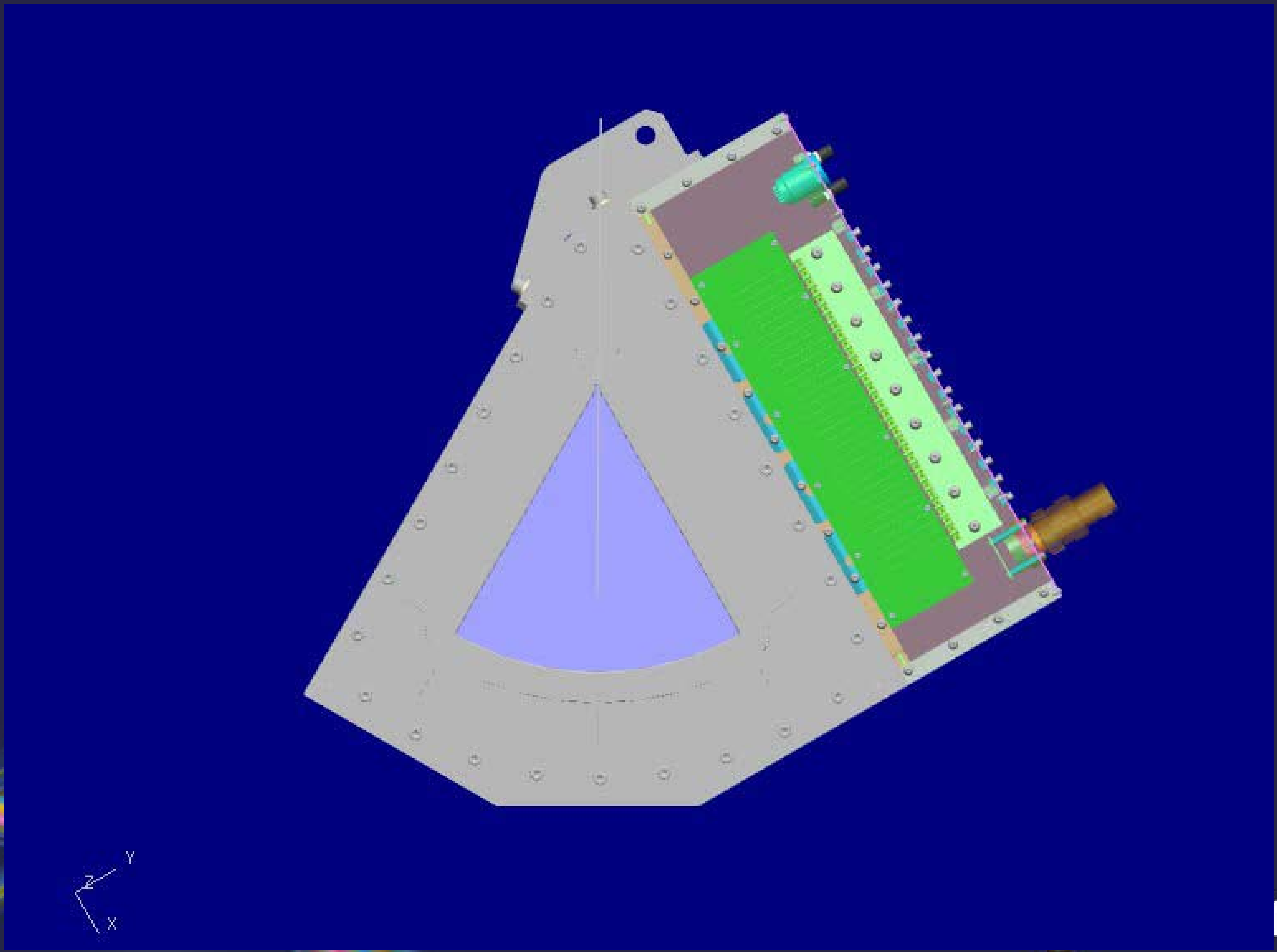
HOTWAXS detector



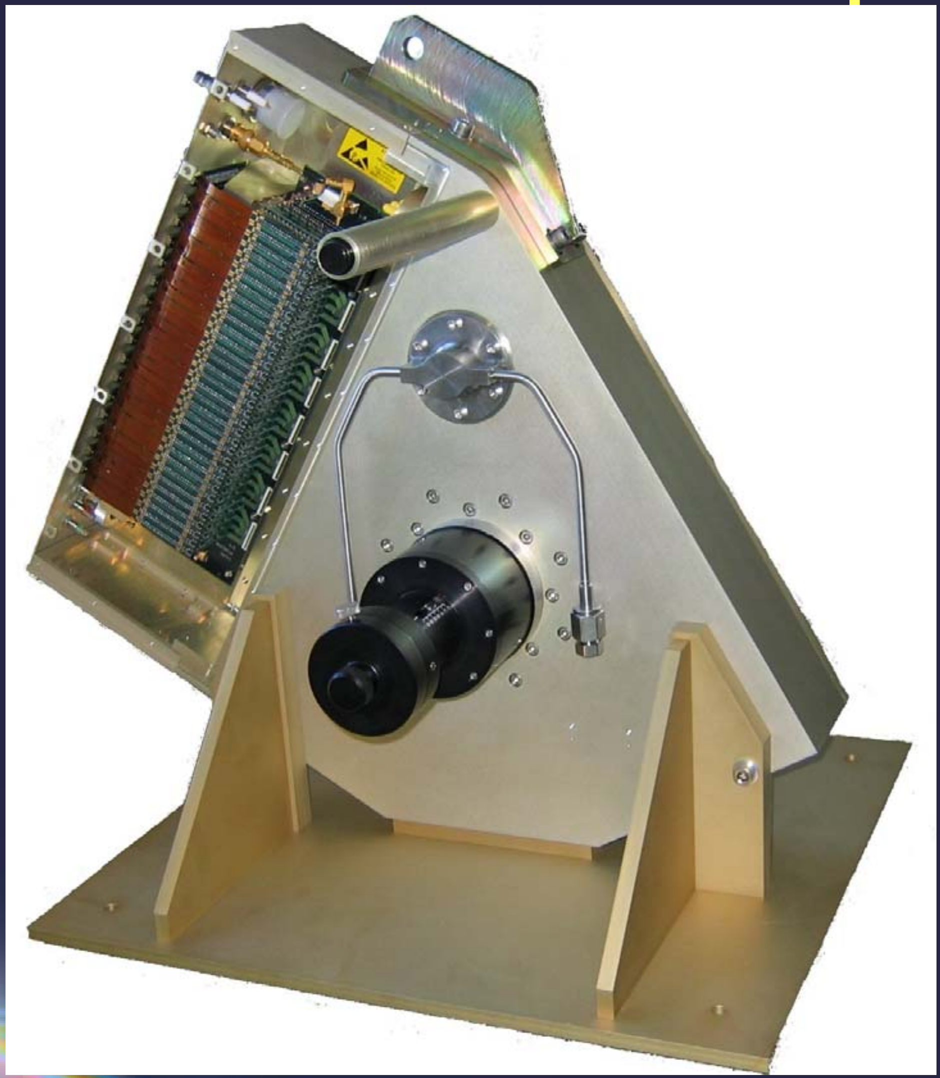
HOTSAXS G.A.



HOTSAXS G.A.



HOTSAXS development



Delivery Schedules

- HOTSAXS:- Already in development phase. Delivery of detector March 2006.
- HOTWAXS:- Started April 2005. Delivery to I22 Sept. 2006: copy of CCLRC detector following existing CCLRC facility development programme.

Common Data Acquisition

- A VME based 32 channel discriminator has been designed as a front-end data acquisition card. Common to ISIS neutron detector front end.
- The VME discriminator feeds into a scaler/ memory bank based on GDAQ.
- Interconnection cables are industry standard SCSI cables.

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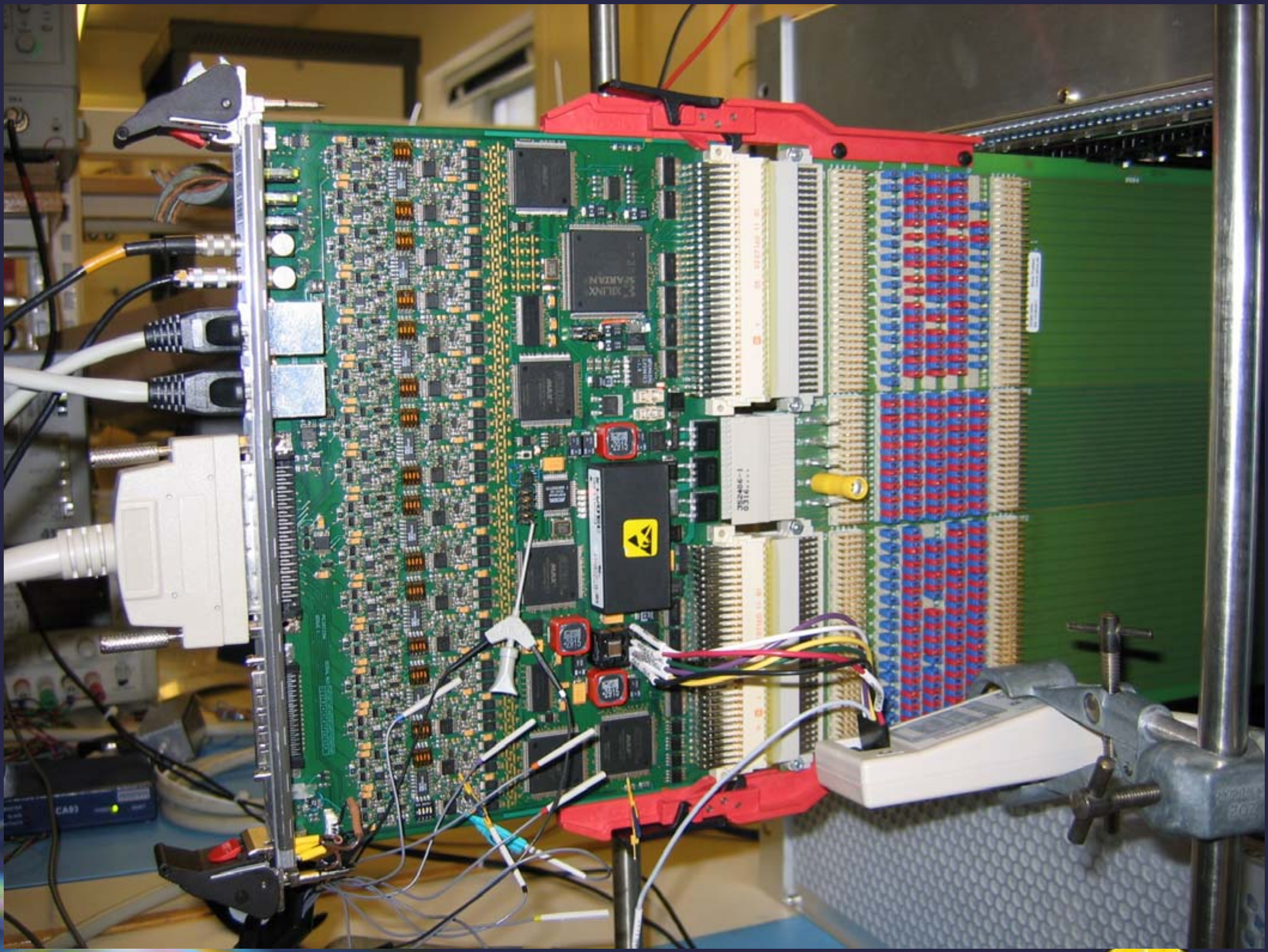
DAQ VME Discriminator



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Support of HOT detectors

- HOTWAXS:- 8 keystone gas microstrip plates. Each plate can be removed and changed so easy to support. Keep plates in a dry environment. Few £100 per plate.

- HOTSAXS:- Plates larger but still removable and replaceable. Approx. £2k per replacement.

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Future upgrade paths

- HOTWAXS can be upgraded to 1024 channels with the use of FREDA chip (CCLRC CFI Project) which will be available 2008.
- HOTRAP is currently being worked on by CCLRC CFI which will give a 2D HOT GMSD/ wire hybrid type detector interfaced to RAPID electronics. Prototype planned for April 2006. Reason to decrease manufacturing costs and increase supportability of RAPID.

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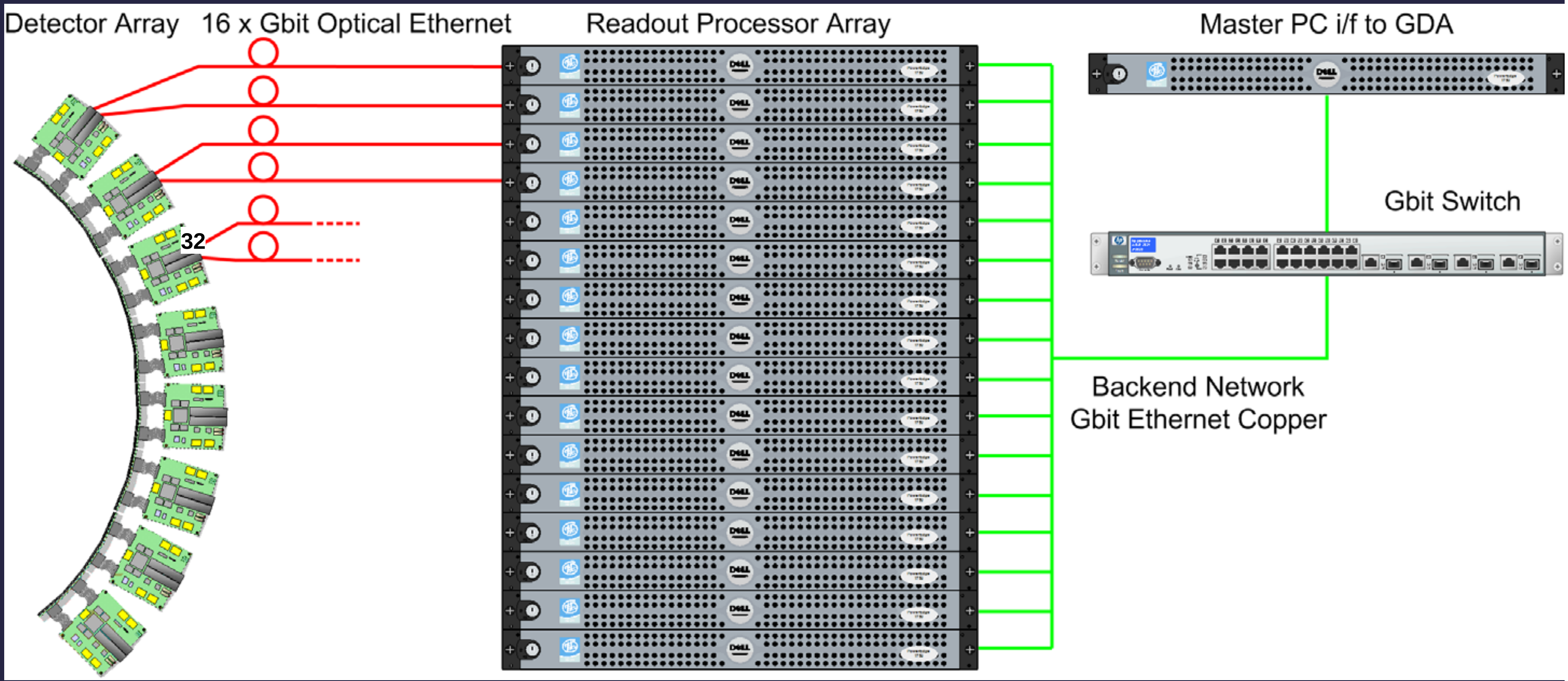
Pixels PENELOPE project

A pixel detector project is proposed for phase 2 programme.

This will have a degree of energy resolution and and fast time framing. The project will take advantage of the DIFFEX project currently being undertaken by CCLRC and other detector programmes such as IMPACT and PILATUS etc. However first iteration will be with HERMES.

PENELOPE



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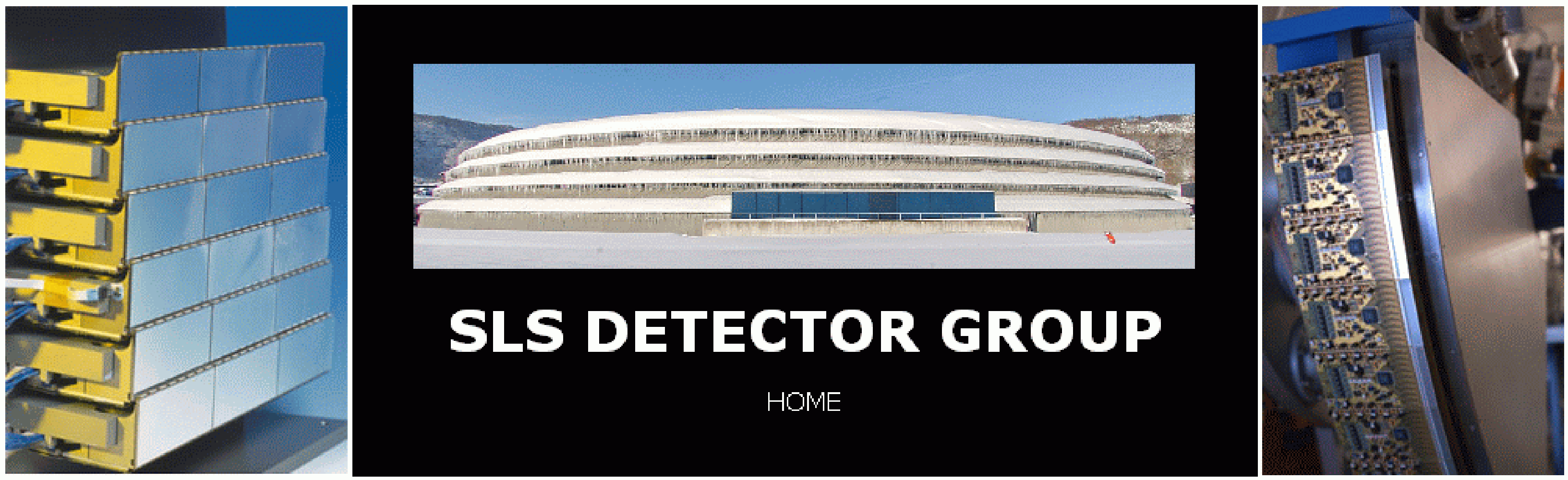
pilatus.web.psi.ch



A. Bergamaschi, Ch. Broennimann, R. Dinapoli, E.F. Eikenberry, B. Henrich, G. Hülsen, M. Kobas, P. Kraft, M. Naef, H. Rickert and B. Schmitt
PSI, SLS Detector Group, Villigen-PSI, Switzerland

R. Horisberger, H.K. Kaestli, B. Meier*, S. Streuli*, et al…
*PSI, CMS-Pixel, Villigen-PSI, Switzerland, *IPP ETH-Zuerich*

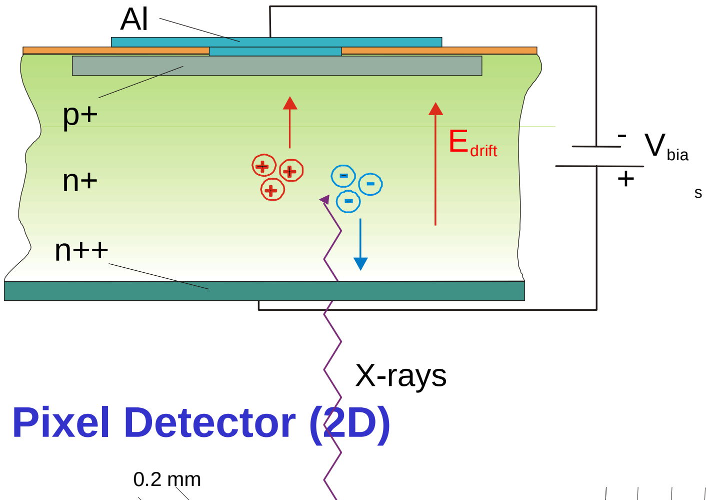
D. Luethy, E. Schmid, G. Theidel, et al…
PSI, Electronics Departement, Switzerland

F. Glaus, J. Lehmann, et al…
PSI, LMN, Villigen-PSI, Switzerland

H. Toyokawa, M. Suzuki
JASRI, Spring 8, Japan

Solid State Pixel and Microstrip Detectors
Spin off from HEP

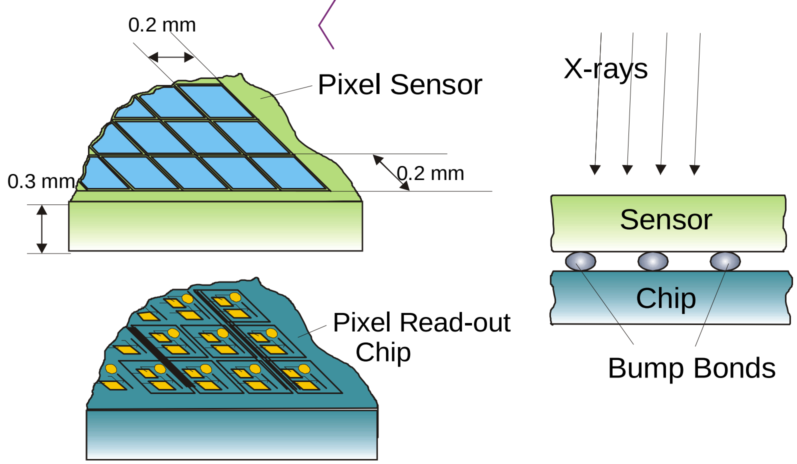
Sensor: Si pn-junction



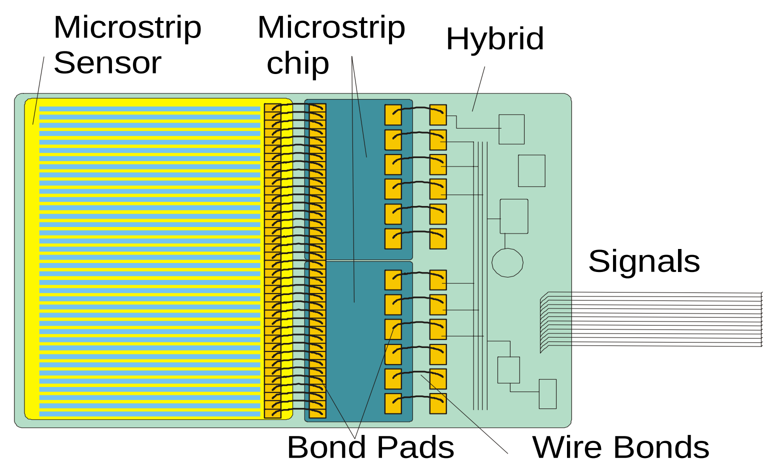
3.6 eV to create 1 eh-pair

Sensor 0.32mm Silicon

Pixel Detector (2D)

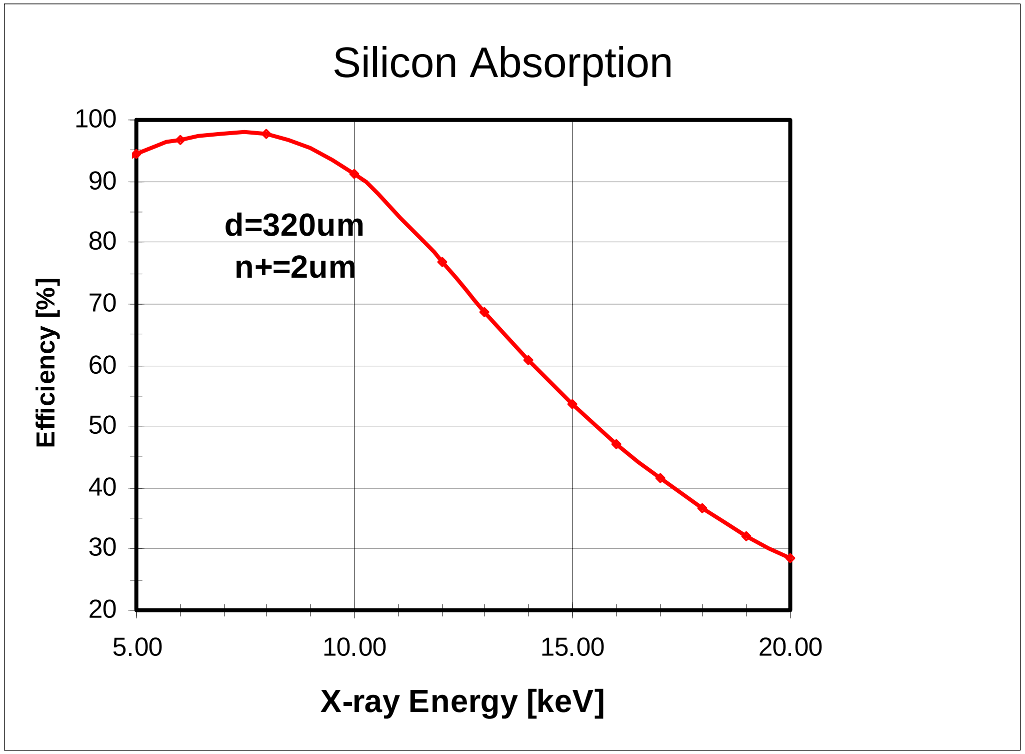


Microstrip Detector (1D)



Single photon counting hybrid pixel/strip detectors

Properties:
Energy range 4 – 30 keV
No dark current
No readout noise
Excellent point spread function
Short readout times: ms
Suppression of fluorescent background
Very good signal/noise ratio

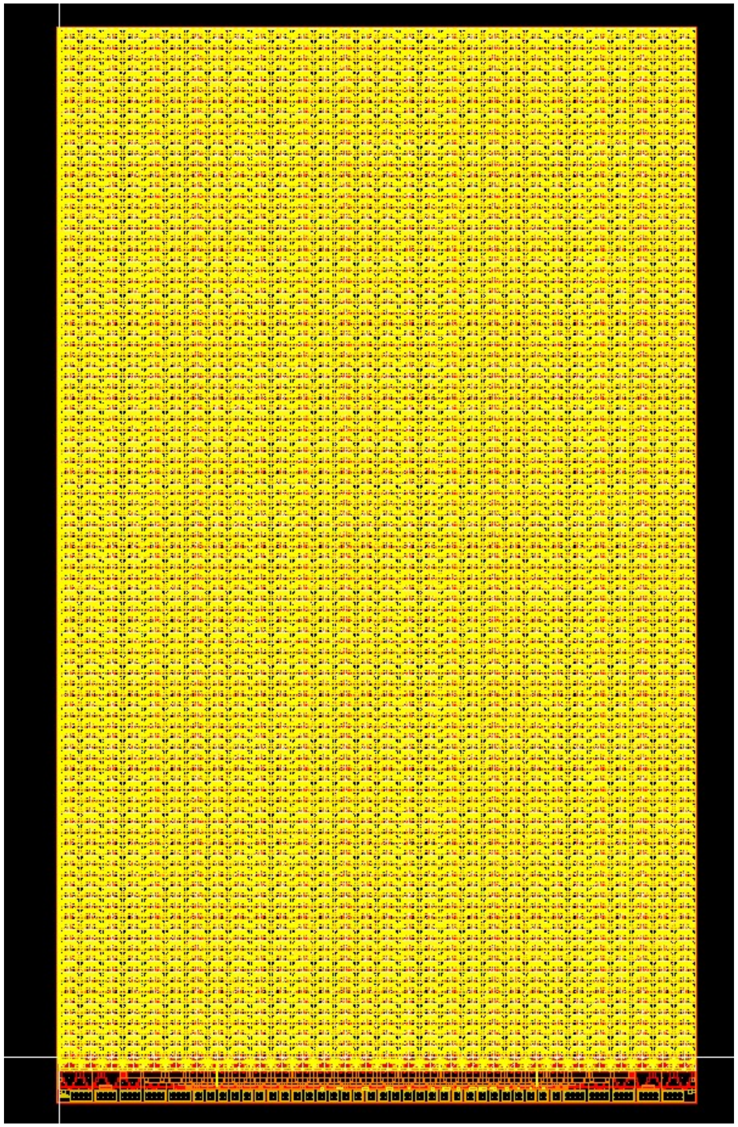


Applications:
Protein Crystallography
Powder Diffraction
Surface Diffraction
Small Angle Scattering

Challenges:
Quality
Stability
Calibrations, i.e. the precision of the data

Silicon is the optimal choice for SLS-Detectors

PILATUS II Chip



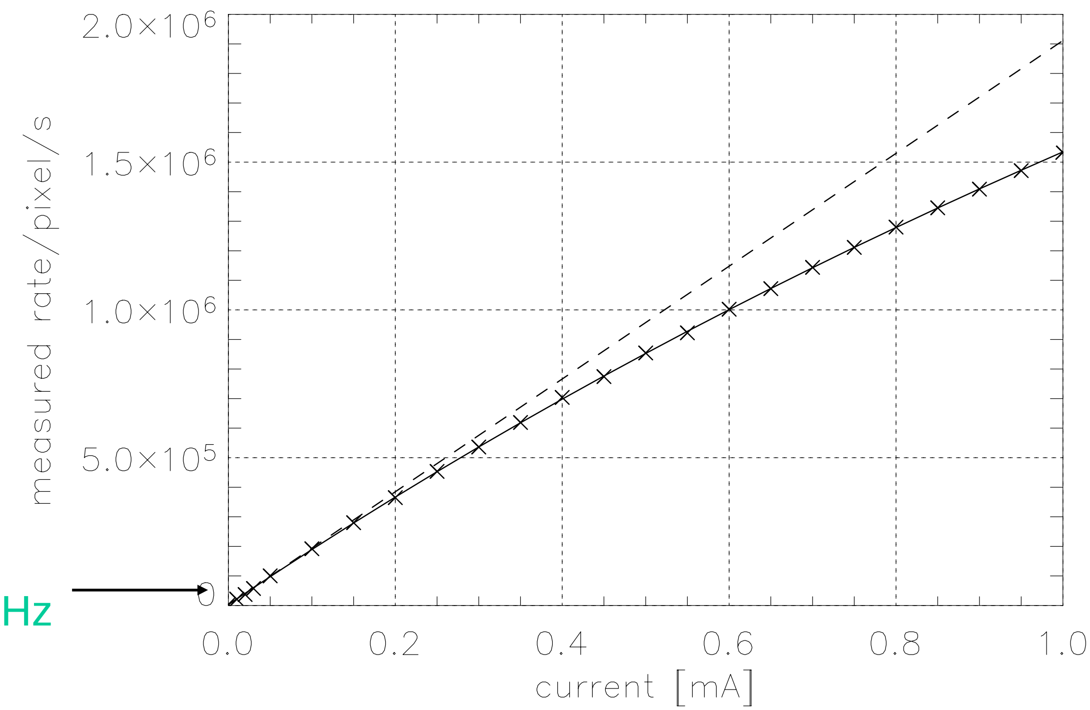
- **UMC_25_MMC process; Radiation hard design**
- **60 x 97 pixels = 5820 pixels**
- **Pixel size 172 x 172 um^2**
- **17.540 x 10.450 mm^2**
- **Count rate: 1MHz/pixel**
- **20 bit counter**
- **Counting timer circuit**
- **6 bit DAC for threshold adjustment**
- **XY-adressable**
- **Analog output**
- **75 MHz LVDS readout (T_{ro} = 2 ms)**
- **Submitted 29.09.04**
- **Received 1.12.04**

$4*10^6$ Transistors

Philipp Kraft, Characterization of the Readout Chip for the PILATUS 6M Detector, ETHZ-IPP Internal Report 2005-03 (March 2003)
Available on-line soon

PILATUS II Rate Tests

8keV X-rays, avg rate of 20 pixels



Paralyzable counter:

$$R' = a \cdot x \cdot e^{(-a\tau x)}$$

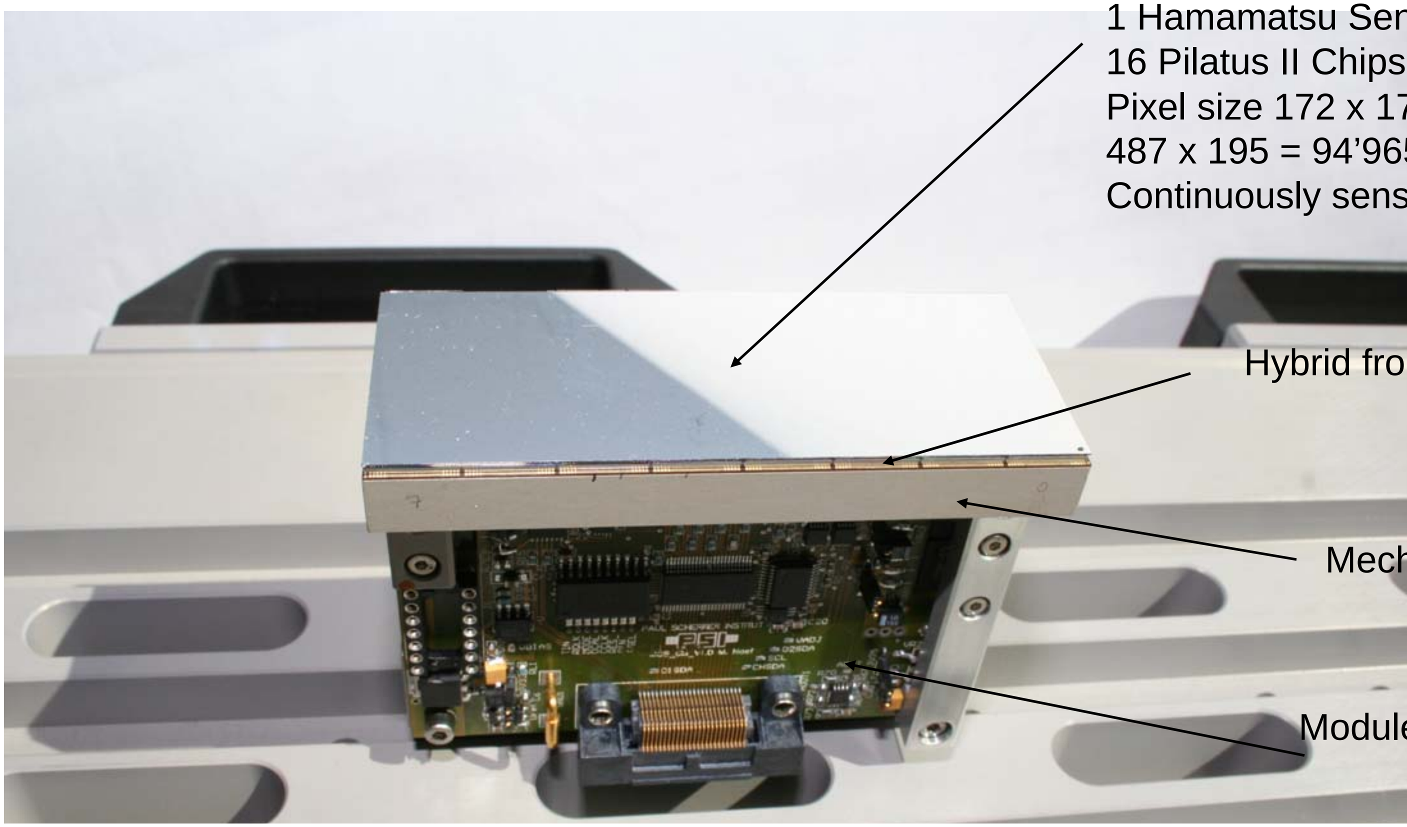
$$\tau = 113ns$$

Count Rate capability:

- max local $3*10^6$ X-rays/s/pixel
- max global 10^8 X-rays/s/mm^2

PILATUS II: Single Module (1)

Module:
1 Hamamatsu Sensor, 85 x 35 mm^2,
16 Pilatus II Chips
Pixel size 172 x 172 μm^2
487 x 195 = 94’965 pixel
Continuously sensitive



PILATUS II Single Module (SM) Detector System

Complete system
(incl. Powersupply, DAQ, PC)

No of pixels: 487 x 195 = 94’965 pixel

Pixel size: 172 x 172 μm^2

Read out time: T_{ro} = 2 ms

Energy Range: 3 – 30 keV

Total Power Consumption: 15 W

Air cooled, very simple operation

Electronic shutter, external synchronisation

Frame Rates:

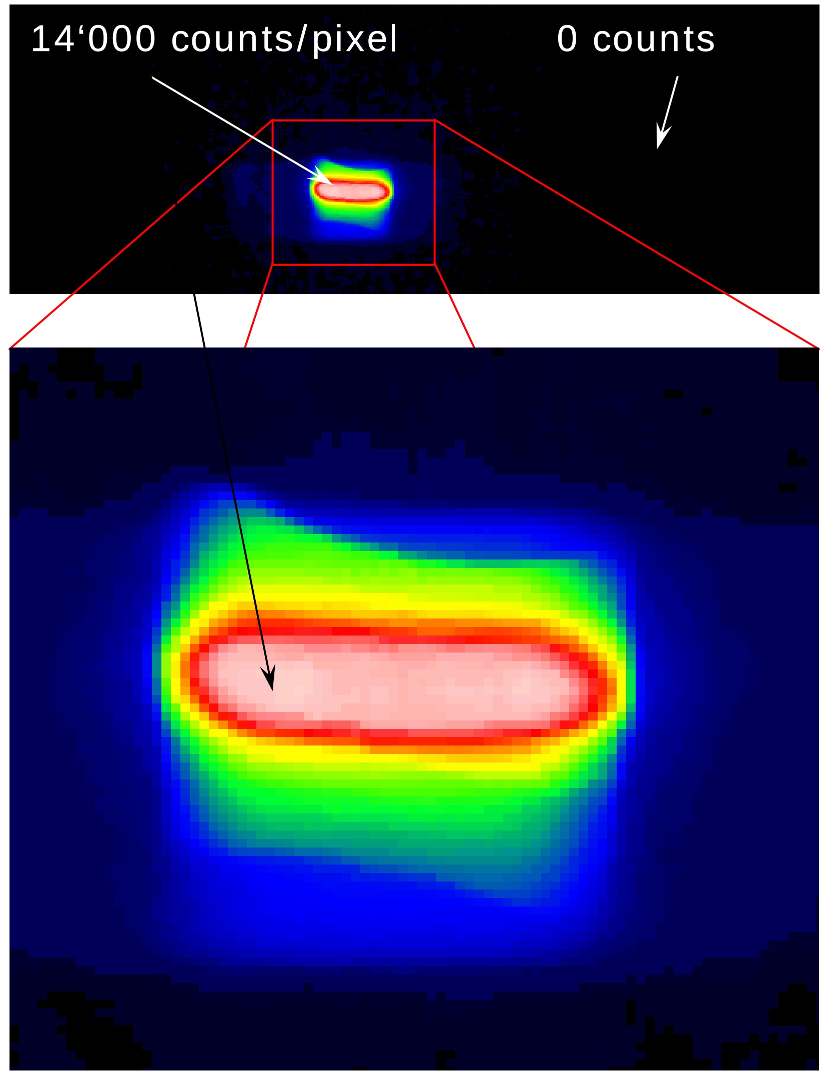
At the Beamline (VME- DAQ): 1Hz

In the Lab (PCI-VME): 16Hz

Expected Frame Rate (PCI only): 150 Hz

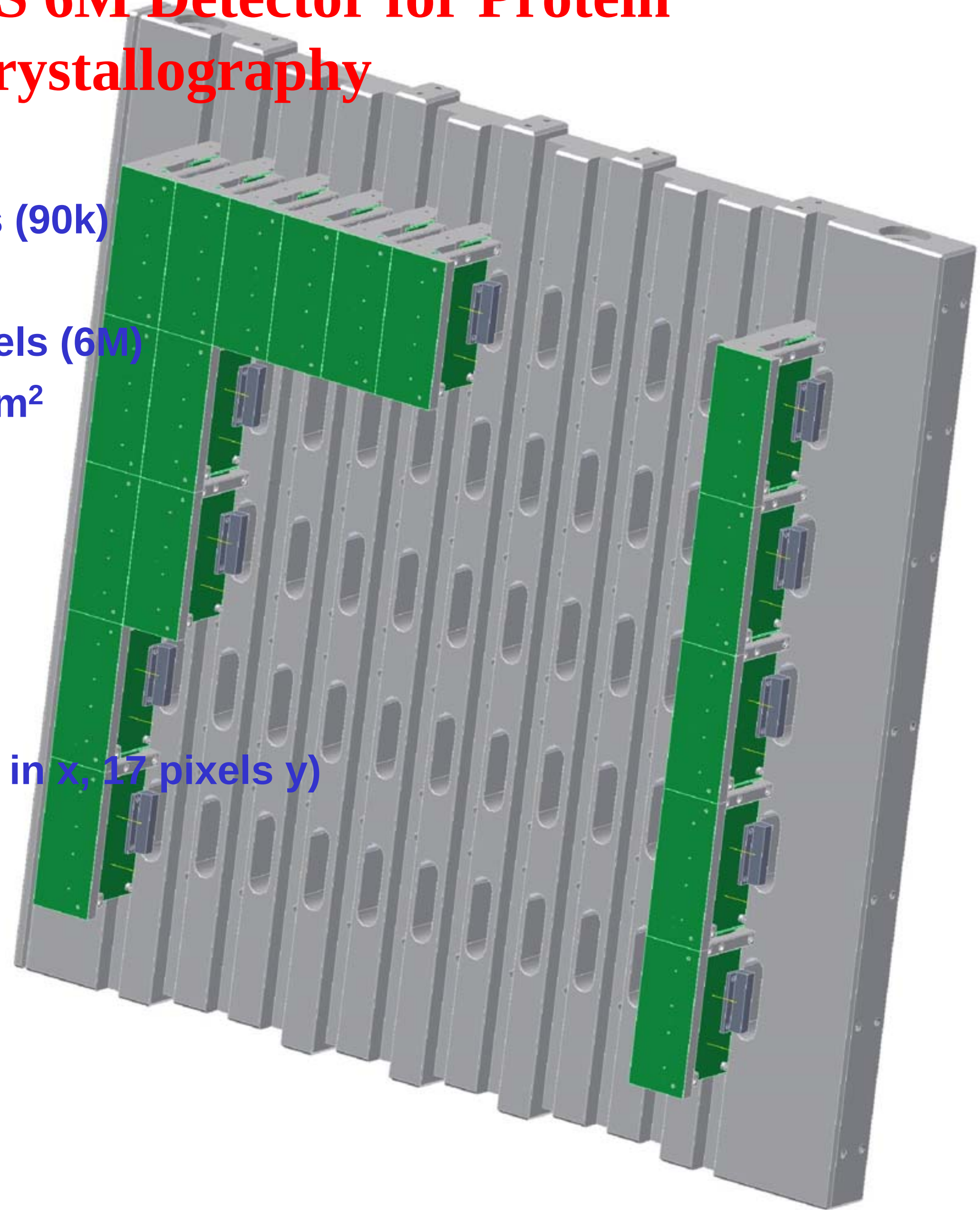
Direct synchrotron beam (12 keV) on the detector

- Looking at defocussed direct beam
- Integrated signal of 9.6 Mcounts in 5 ms
- Count rate = 2.7 Mcounts/s/pixel



The PILATUS 6M Detector for Protein Crystallography

No of Modules	60
Module size	487 x 195 pixels (90k)
Detector Size	431 x 448 mm^2
No of Pixels	2527 x 2463 pixels (6M)
Spatial resolution	0.172 x 0.172 mm^2
Dynamic range:	20bits
Readout time	~2ms
Frame rate	5-10 Hz
Rate	1 MHz/pixel
Spatial distortion	Flat geometry
Dead area	~8.4 % (7 pixels in x, 17 pixels y)



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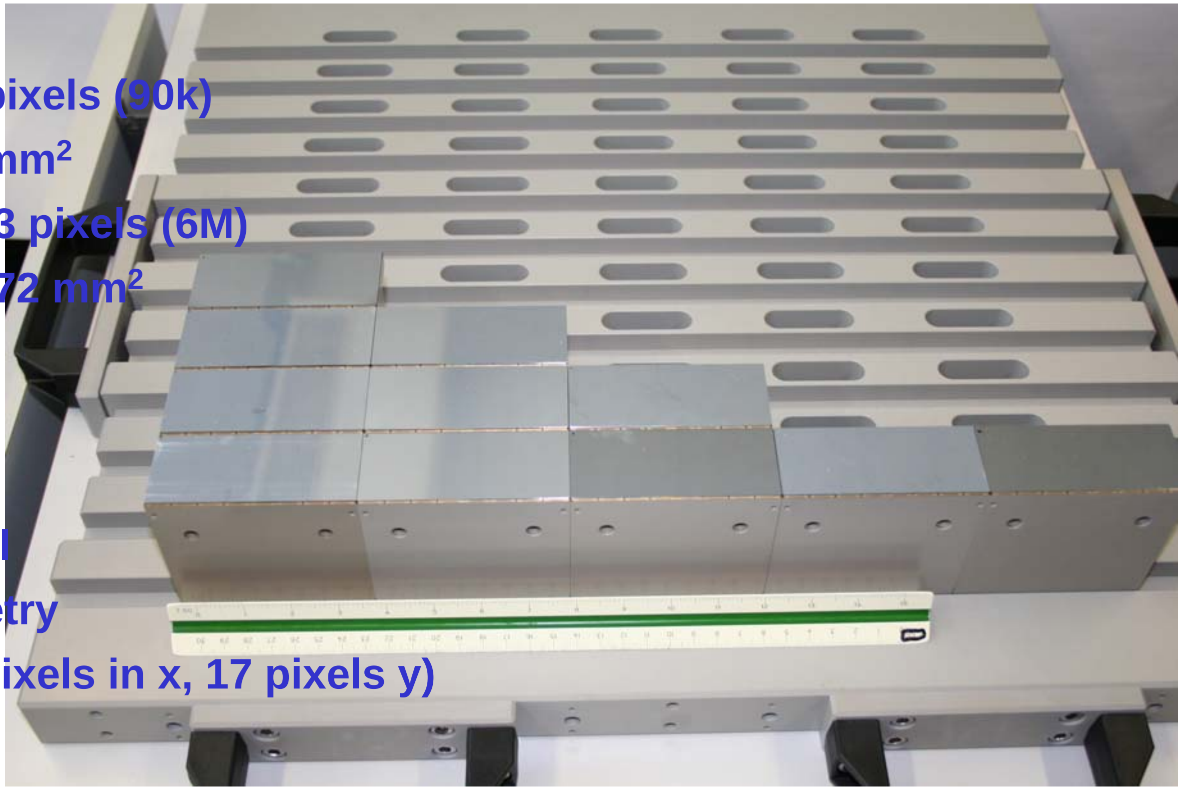


The PILATUS Project

For more information : http://pilatus.web.psi.ch

Contact: christian.broennimann@psi.ch

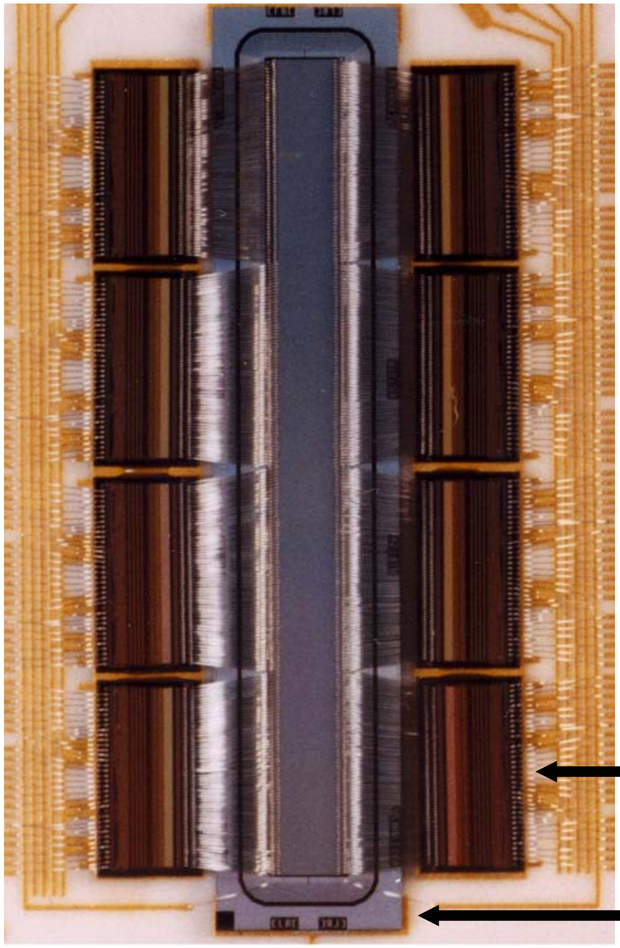
XSTRIP strip detectors

- Integrating strip detector for EDE.
- 10 microseconds continuous shot rate.
- GaAs and Ge versions being worked on for higher energy.

Required for diamond in 2009.

Little development as chips already available DAQ may be modified.

XSTRIP – Fast linear detector for EDE



- Custom designed 25mm long, 500μm thick Si detector containing 1024 x 25μ strips
- Back illumination
- 8 XCHIPs, full custom ASICs with 128 c.s. pre-amps.

XCHIP ASIC

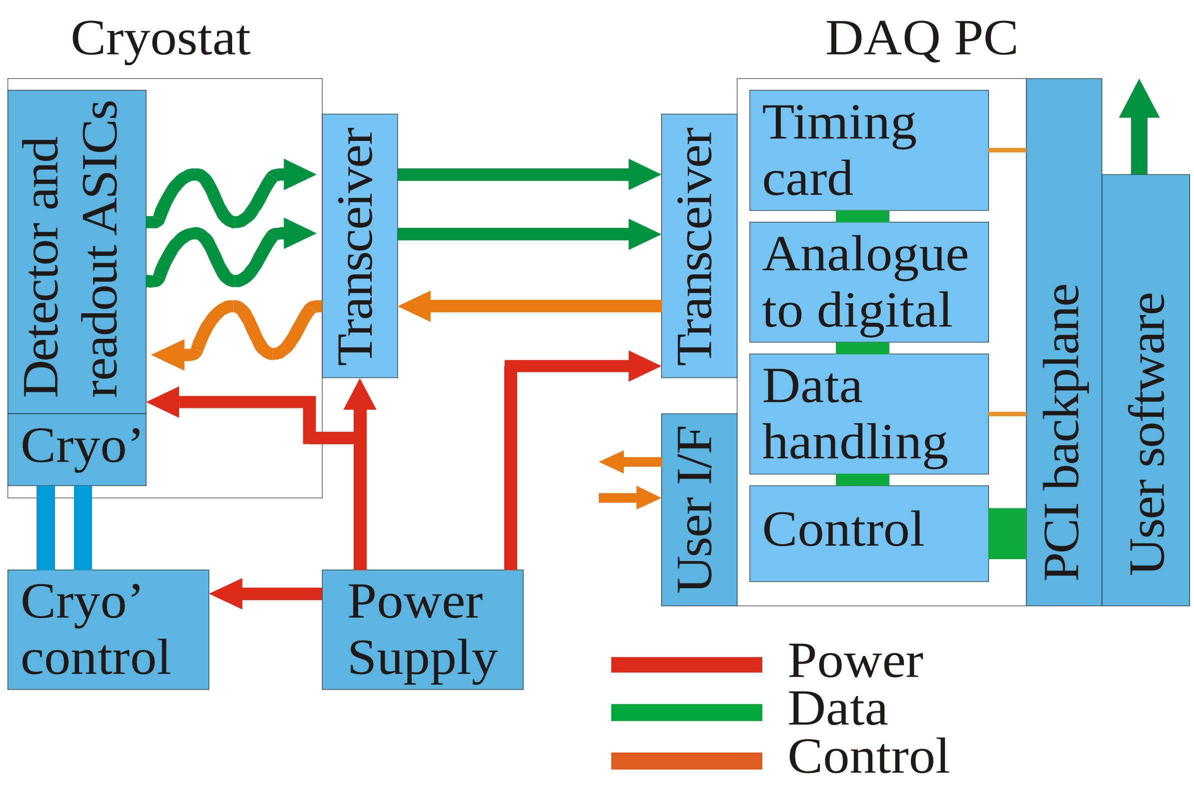
XSTRIP Detector

XSTRIP – Fast linear detector for EDE

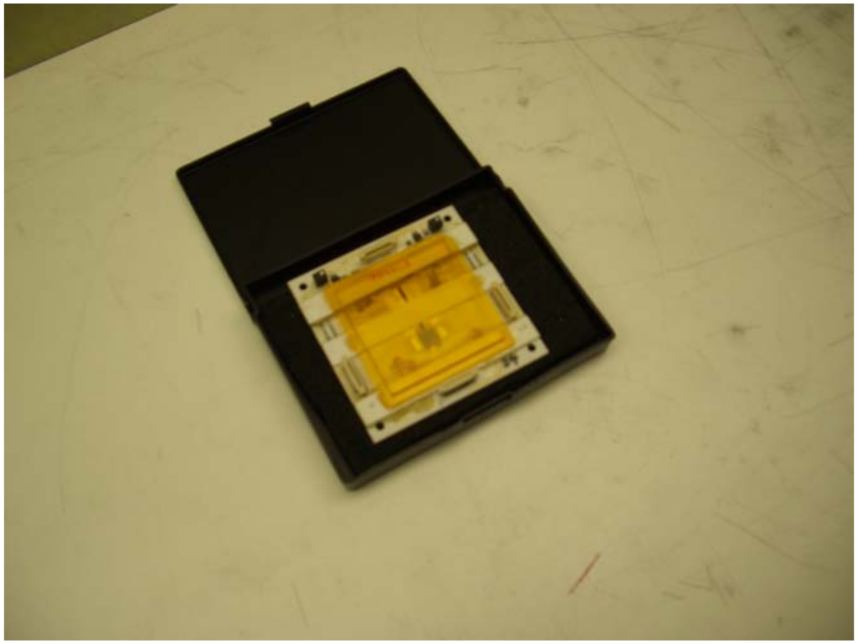
Collaboration with ESRF in testing and looking at damage.

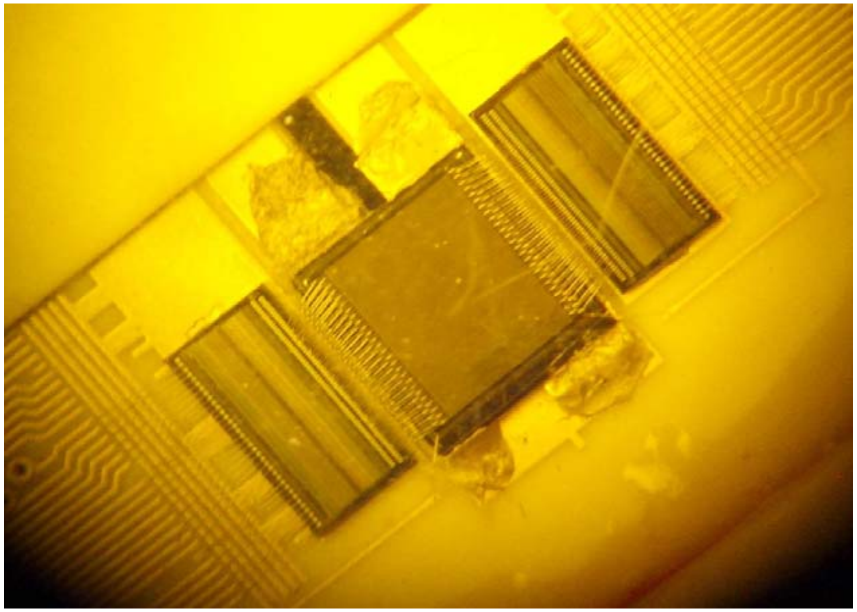
Radiation tolerance is an issue

XSTRIP-Block diagram



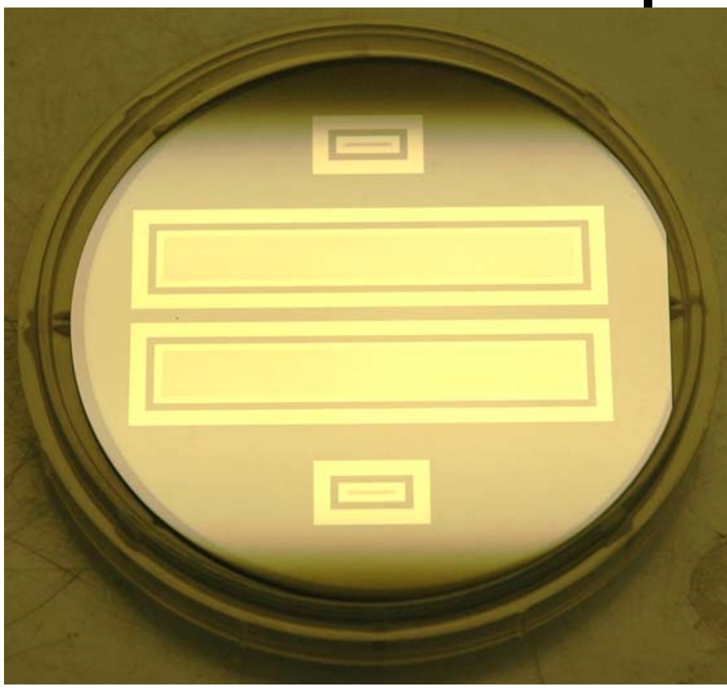
Metorex GaAs latest detector

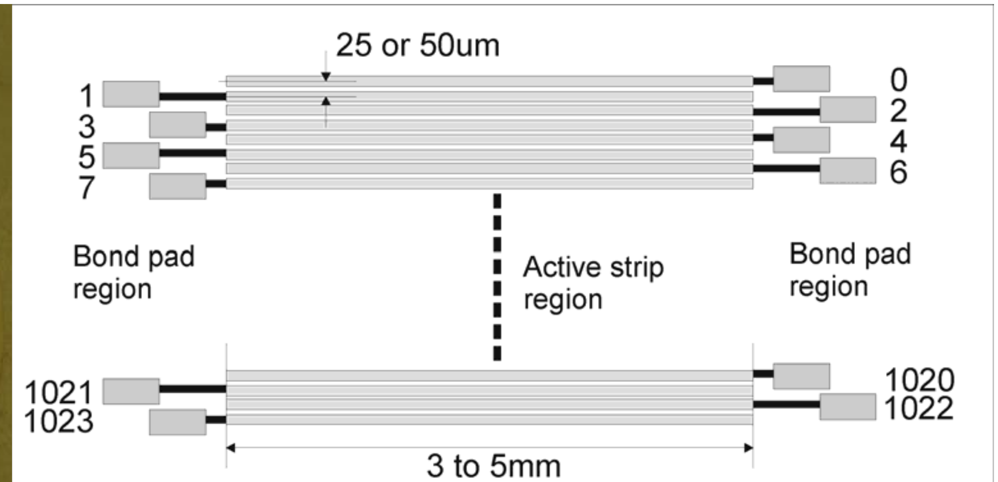


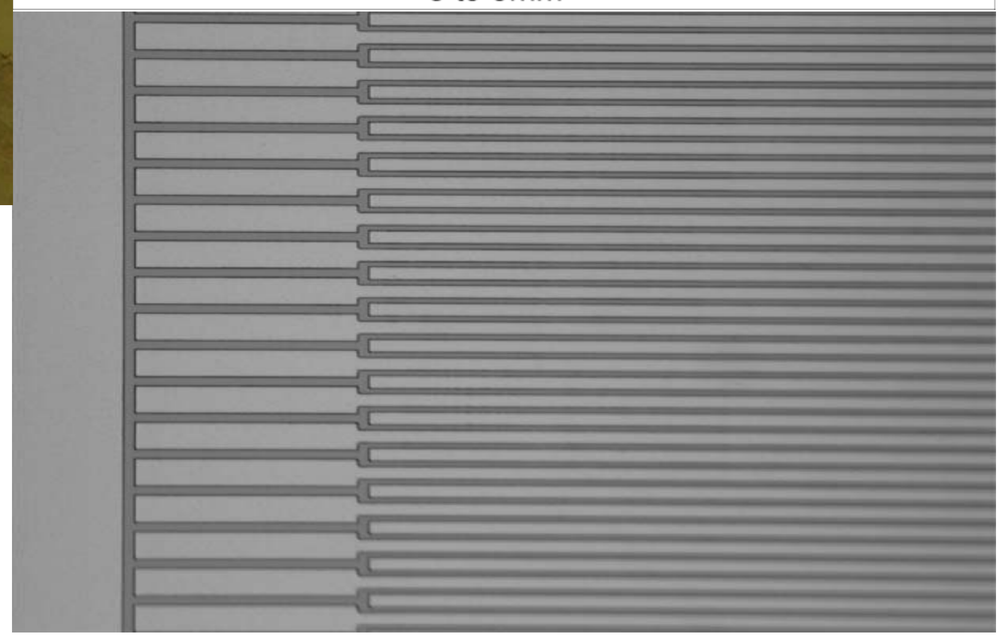


- Presently awaiting full tests.

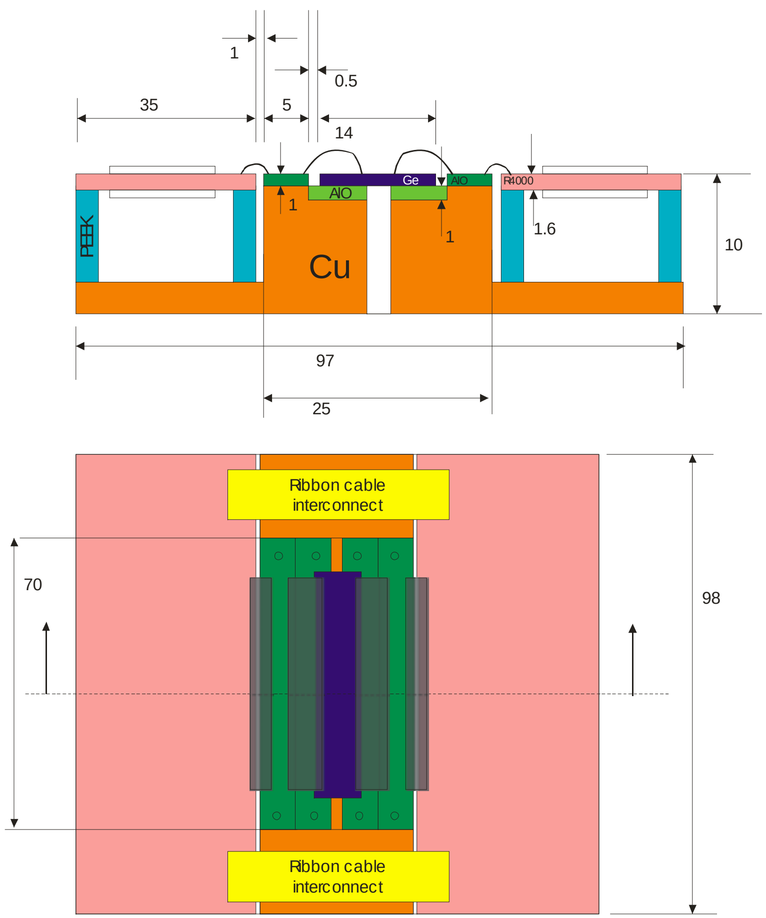
XH – Fine pitch Ge. Test wafer.

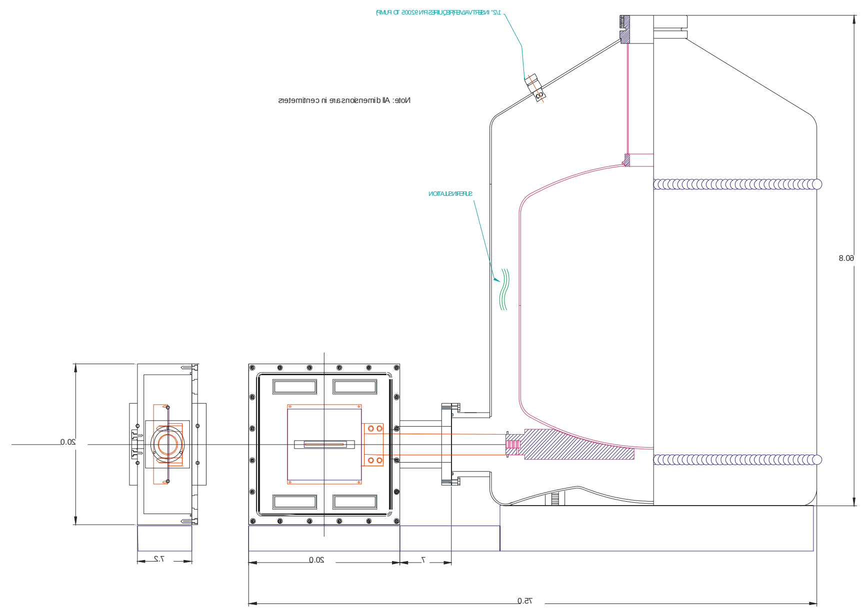






XH – Fine pitch build and cryo.





Wider Issues

- To do things like XSTRIP you need access to the best technologies.
- Forces collaboration…. HEP plus other labs
- Radiation damage
- Programme now being put together for CCLRC funding.
- Some of the materials issues already covered but needs more.

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Wider Issues

- Bump Bonding for Pixel detectors.
- Key technology not just for SLS but for DLS and many SR sources.
- DLS/CCLRC now have an industry standard Bump Bonder.
- Installed in CCLRC clean room.
- Commissioning underway with input and help from SLS/PSI and CHESS.

diamond

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European Collaboration specifically for SR detectors.

"Collaboration is the only way forward"

1st PIXEL detector meeting was held in early 2005 at Diamond and organised jointly by ESRF and Diamond.

2nd meeting held in October at SLS organised by SLS

Attendees:-

ALBA, SLS/PSI, Diamond/CCLRC, ESRF, Soleil, DESY

Specific work packages are now being defined and funding committed.

The aim of the SR Pixel group is to develop a joint approach and to make relevant technology and know-how available to each other to move forward pixel detectors in light source.

We intend to pool things that we would be doing anyway and get more out as a result.

The membership is made up of the New European Light Sources and the European central facility of the ESRF.

European SR Pixel group

- Initially “pay as you go” but already the group is forming ideas to engage politically for funding.
- The aim is undertake developments only targeted for beamline use.
- The beamline science and not the detector development will drive this forward as funding is coming from within each facility where a common development is identified this will be tensioned against the beamline demands.

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Conclusions

- The UK scene in detectors is changing due to Diamond and there are opportunities for Europe to collaborate and develop. This is due to key developments and progress such as those at SLS/PSI.
- UK experience has shown that underpinning funding for research can be achieved as part of a bigger landscape / roadmap process that has significant science input. Needs revisiting frequently.
- Targeted funding for development is facility specific but there is significant commonality and opportunities for collaboration between facilities. Facilities must have the cash to do it.

…The total being greater than the sum of the parts.

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