The IXO WFI, HXI and HTR

Overview over the WFI and HXI concepts and activities

Lothar Strüder, MPE, HLL

Outline:

WFI

- The DePFET active pixel sensor
- The WFI layout and properties
- The WFI status and technology development plan

HXI

- The double sided CdTe and DSSD hard X-ray Imager
- The HXI concept and the expected properties

HTRS

- The high speed SDD
- The expected properties

with input from

WFI (Lothar Strüder)

- MPI-HLL (MPE and PNSensor)
- Universties of Tübingen, Darmstadt and Nürnberg-Erlangen
- University of Leicester
- Politecnico di Milano
- University of Osaka
- MIT, CfA and Penn State University

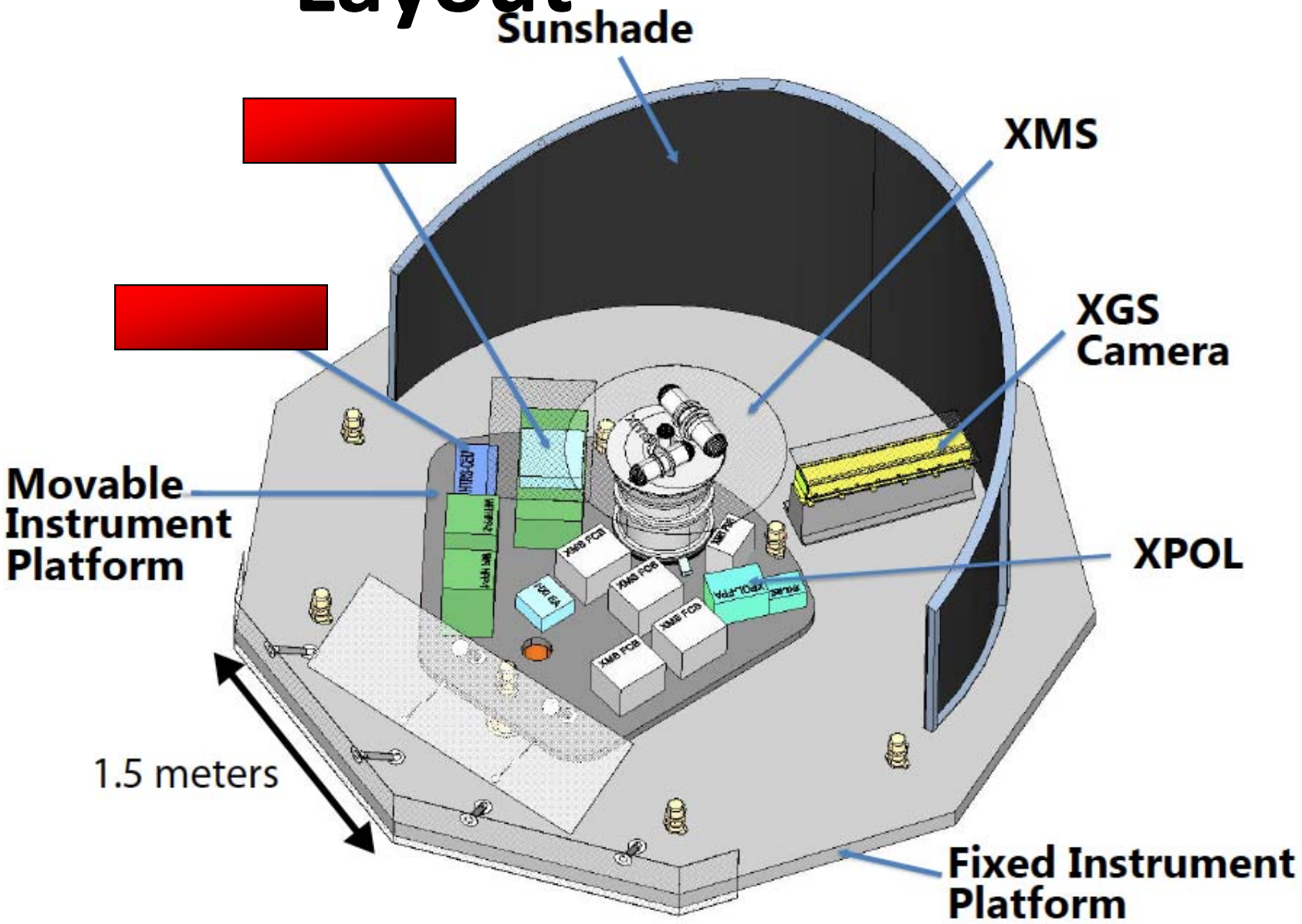
HXI (Tad Takahashi)

- JAXA, ISAS
- CEA, CNES
- University of Tokio

HTRS (Didier Barret)

- CESR, CNES, MPE/PNS
- University of Tübingen,
- University de Genève
- Univ. of Nürnberg-Erlangen
- Politecnico di Milano

Focal Plane Layout



Mirror Effective Area	**3 m^2 @1.25 keV** **0.65 m^2 @ 6 keV with a goal of 1 m^2** **150 cm^2 @ 30 keV with a goal of 350 cm^2**	**Black hole evolution, large scale structure, cosmic feedback,** **Strong gravity, EOS** **Cosmic acceleration, strong gravity**
Spectral Resolution **(FWHM)**	**ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV)** **ΔE = 10 eV within 5 x 5 arc min (0.3 – 7 keV)** **ΔE =150 eV at 6 keV within 18 arc min diameter (0.1 - 15 keV)** **E/ΔE = 3000 (0.3–1 keV) with an area of 1,000 cm^2 and a goal of 3000 cm^2 for point sources** **ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)**	**Black Hole evolution,** **Large scale structure** **Missing baryons using tens of background AGN**
Angular Resolution	**≤5 arc sec HPD (0.1 – 7 keV)** **30 arc sec HPD (7 - 40 keV); goal of 5 arc sec**	**Large scale structure, cosmic feedback, black hole evolution, missing baryons**
Count Rate	**1 Crab with >90% throughput. ΔE < 150 eV @ 6 keV (0.1 – 15 keV)**	**Strong gravity, EOS**
Polarimetry	**1% MDP on 1 mCrab,100 ksec, 3σ, 2 - 6 keV**	**AGN geometry, strong gravity**
Astrometry	**1 arcsec at 3σ confidence**	**Black hole evolution**
Absolute Timing	**50 μ sec**	**Neutron star studies**

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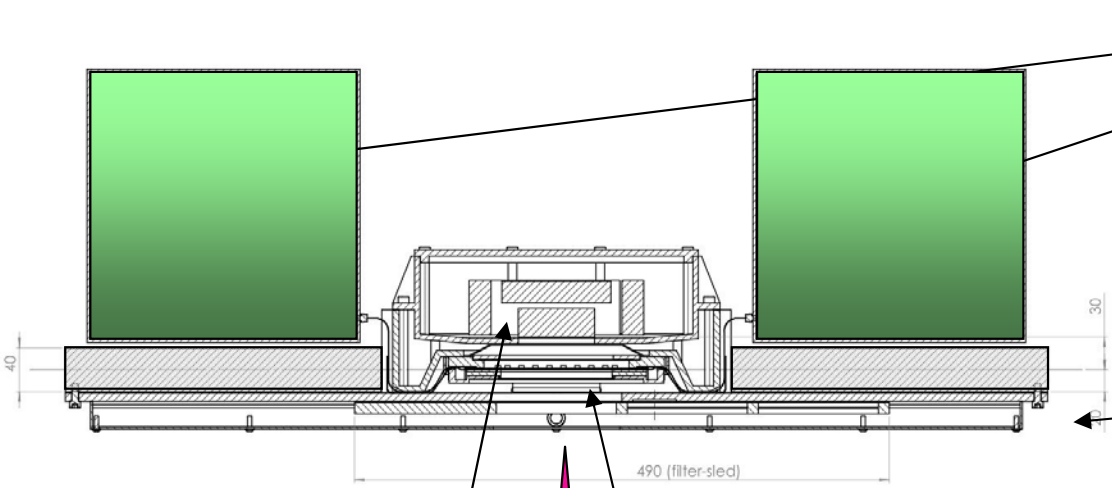
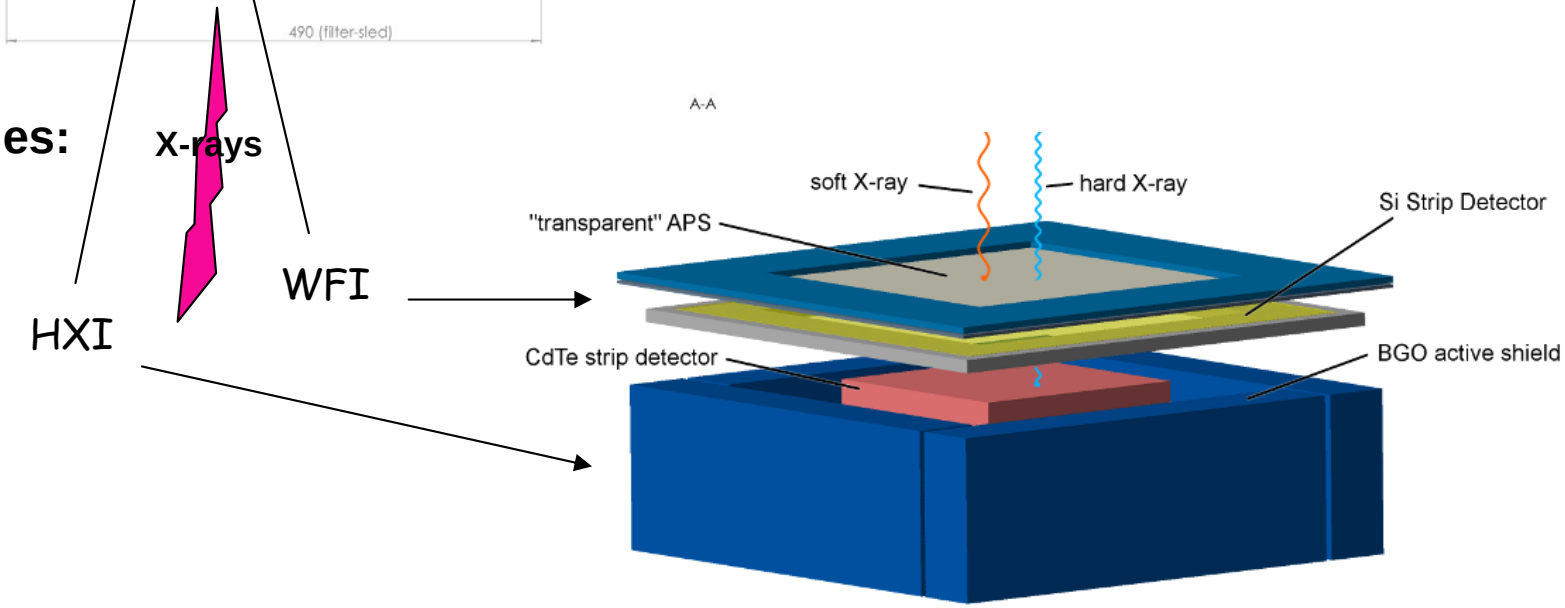
WFI/HXI Mechanical Layout



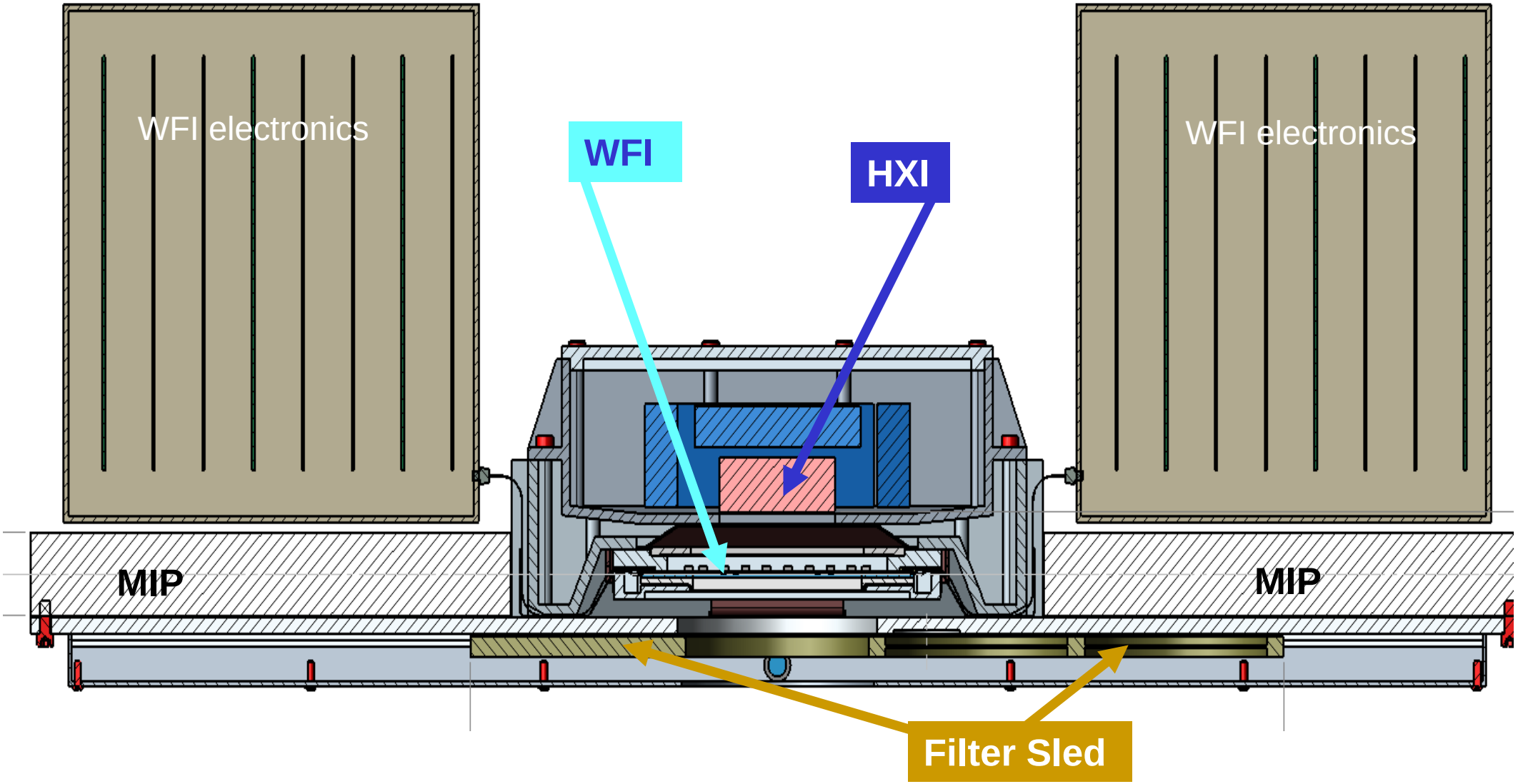
Wide field imagers for two energy ranges:

WFI: 0.05 – 15 keV
FOV: 18x18 arcmin

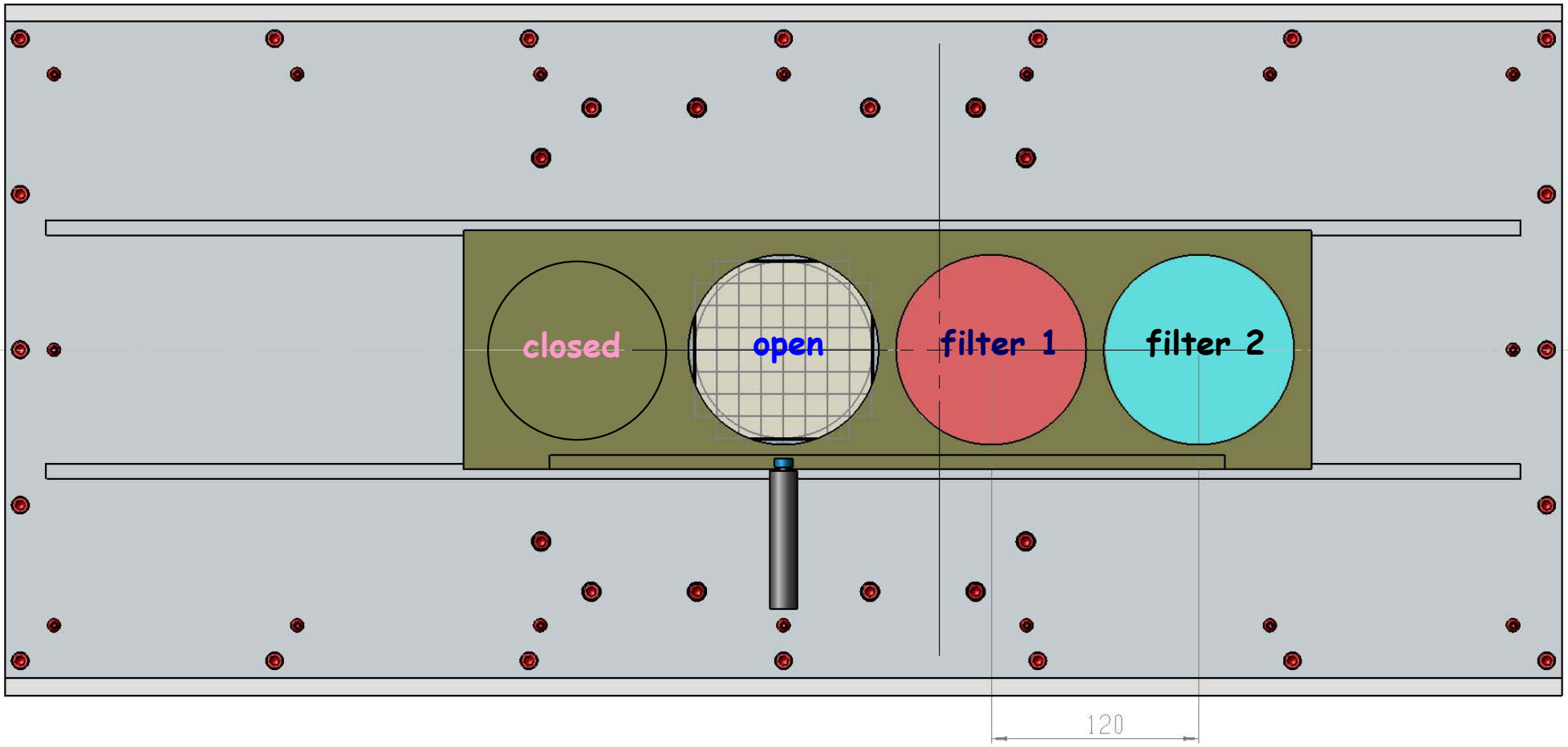
HXI: 5 – 50 keV
FOV: 8x8 arcmin



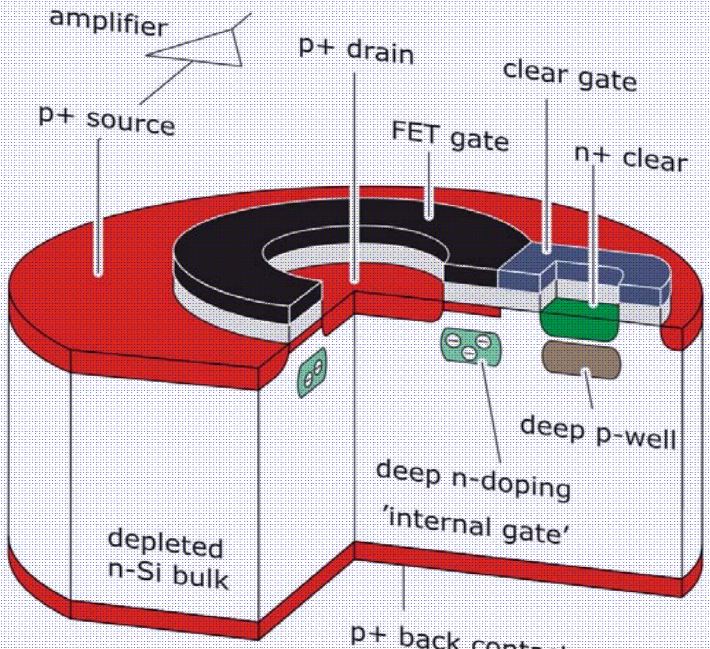
Thermal & Mechanical Concept

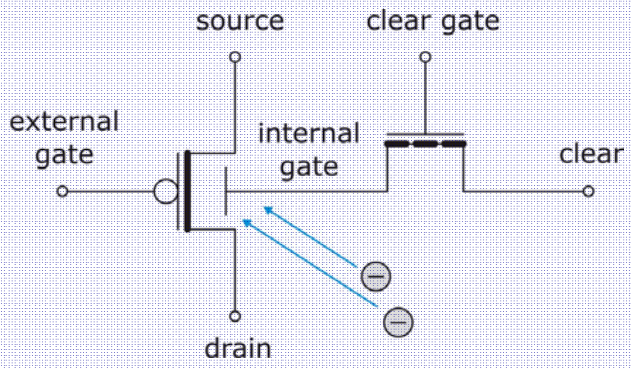


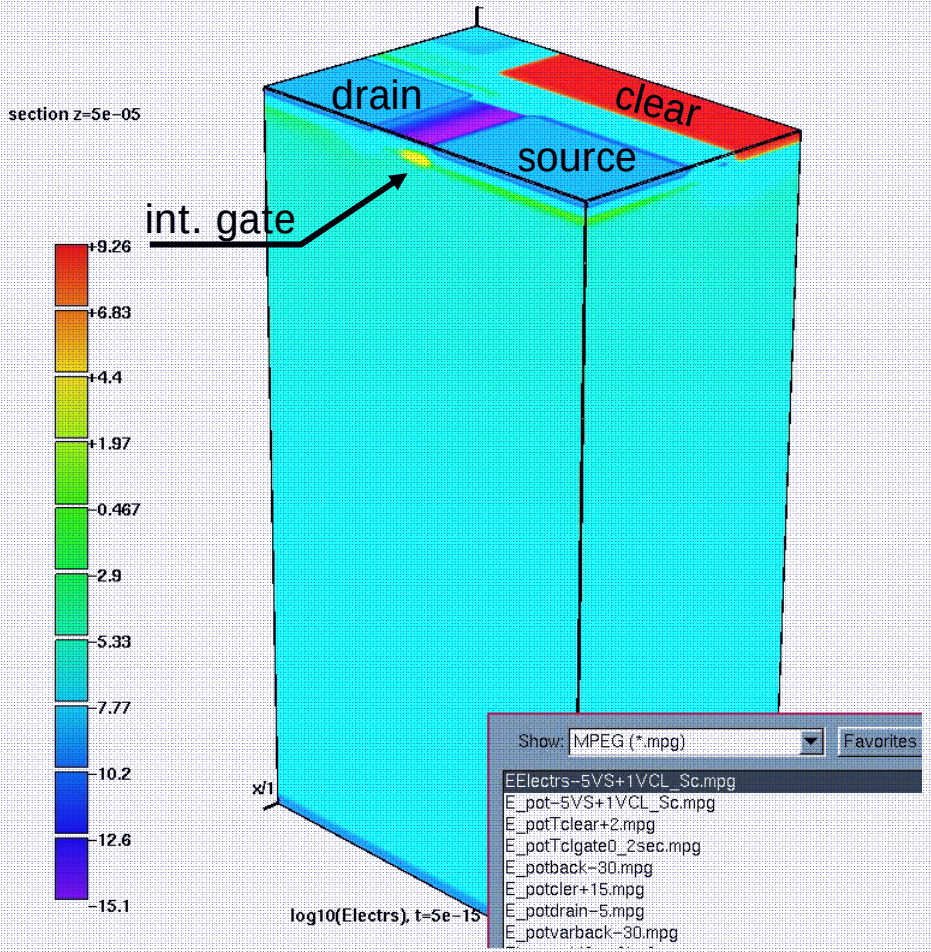
Filter Sled



3-dim simulation of the DEPFET

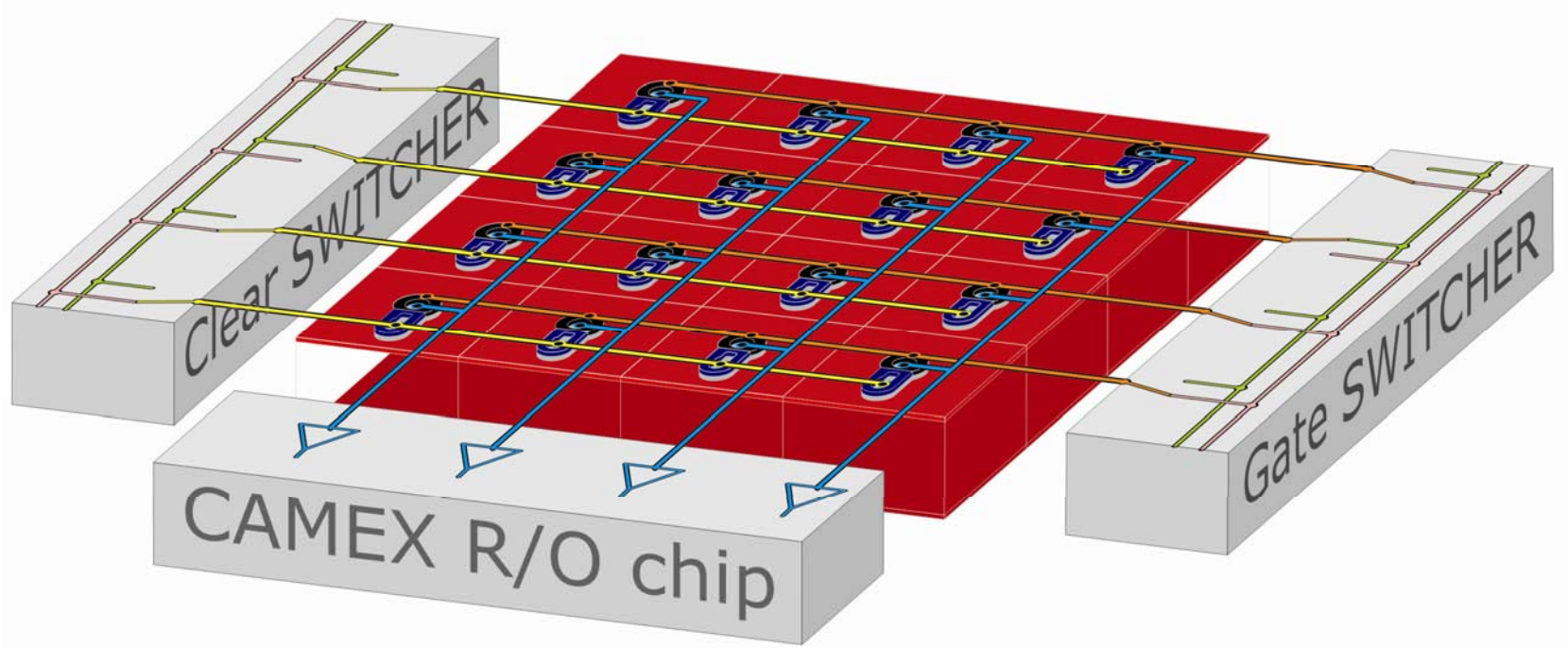






TeSCA 3D Simulation by K.Gärtner, WIAS, Berlin

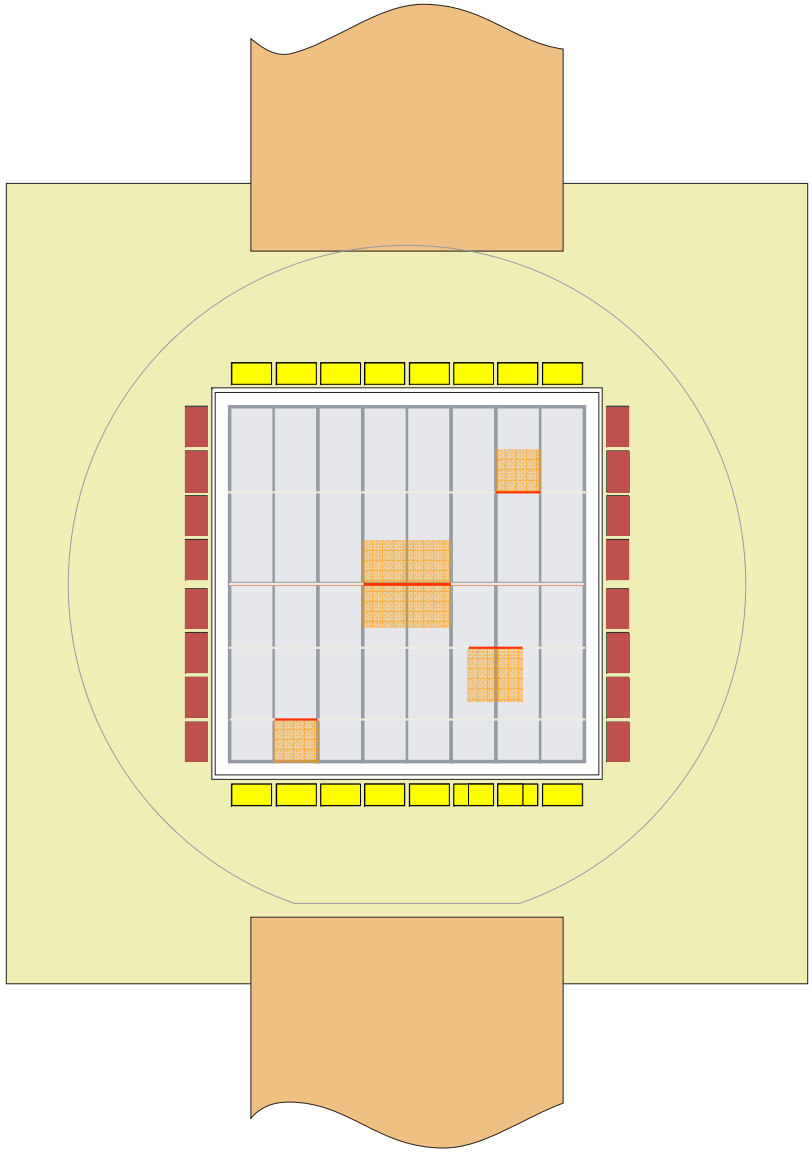
DEPFET Active Pixel Sensor Array



- **matrix organisation**
- - common back contact
- » **thin, homogeneous entrance window**
- » **fill factor 100 %**
- - row-wise connection of gate, clear, clear gate
- - column-wise connection of source / drain
- » **individually addressable pixels**
- » **windowing option**

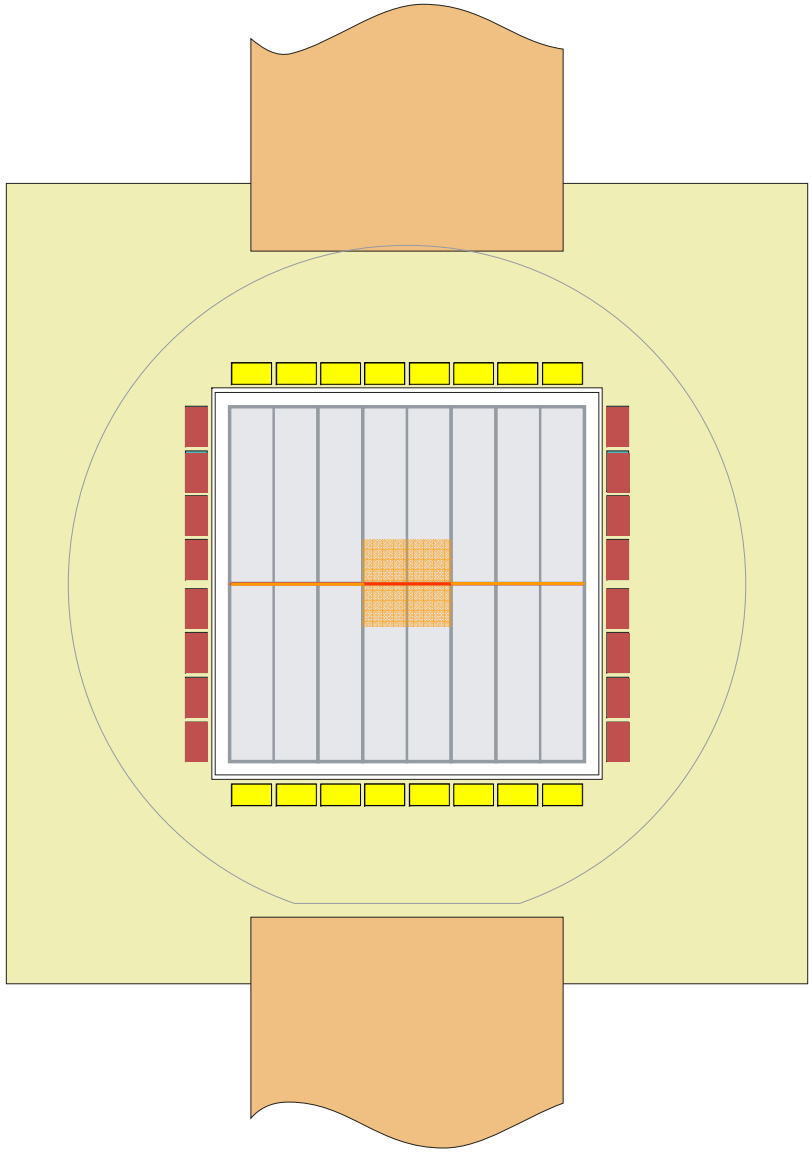
- **operation philosophy**
  - one active row
  - all other pixels turned off
    - » **low power consumption**
  - all operations in a row in parallel
    - » **fast processing**

WFI readout concept



- *Readout modes:*
  - **Full frame mode**: Parallel readout of both hemispheres on full width
  - **ROI mode**: Define ROI, read out repetitively with high framelet rate
  - Information of entire row is acquired, but information from outside ROI is discarded in preprocessing
  - Arbitrary position anywhere on the sensor
  - Simultaneous readout of disjunkt ROIs on different hemispheres
  - With next generation of ICs:
  - On-the-fly selection of ROIs / switch between ROIs
  - ROIs exceeding sector borders

WFI readout concept



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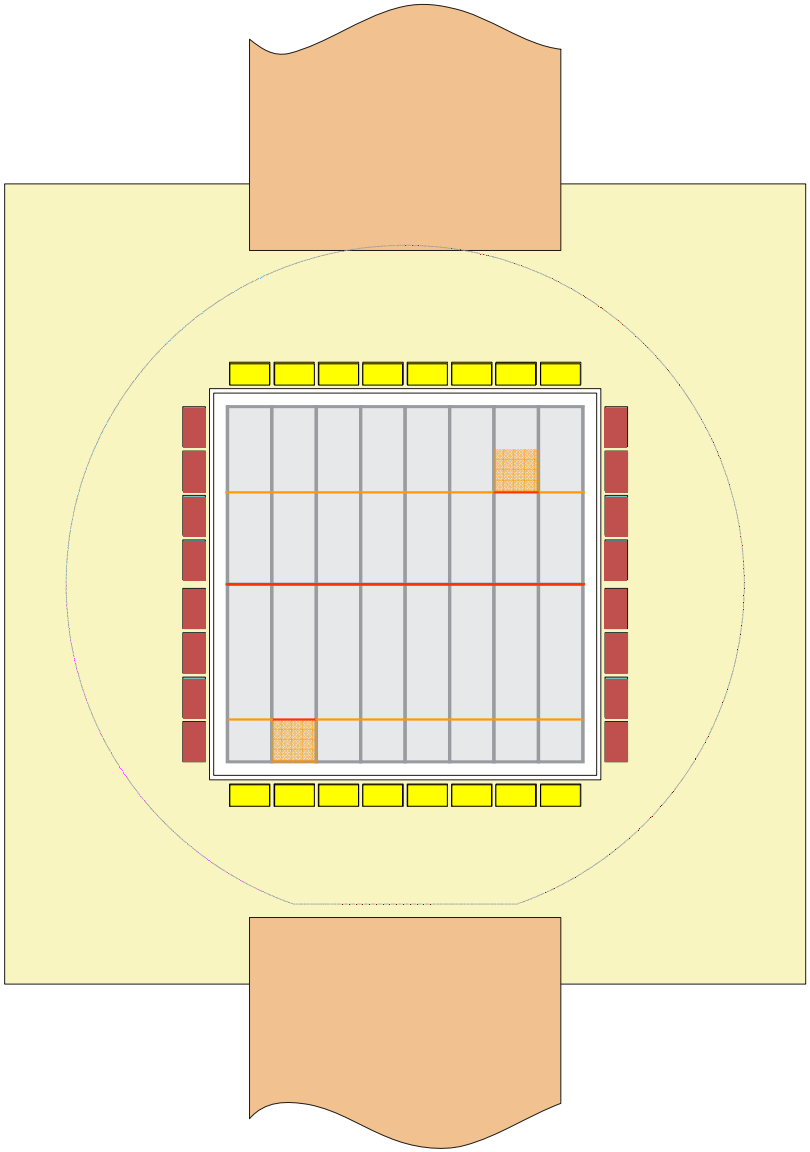
  - **Window mode:** Acquire fully sized window strip (anywhere on FPA) repetitively
  - Read rest of frame with reduced framerate

WFI readout concept



- *Readout modes:*
  - **Window mode:** Acquire fully sized window strip (anywhere on FPA) repetitively
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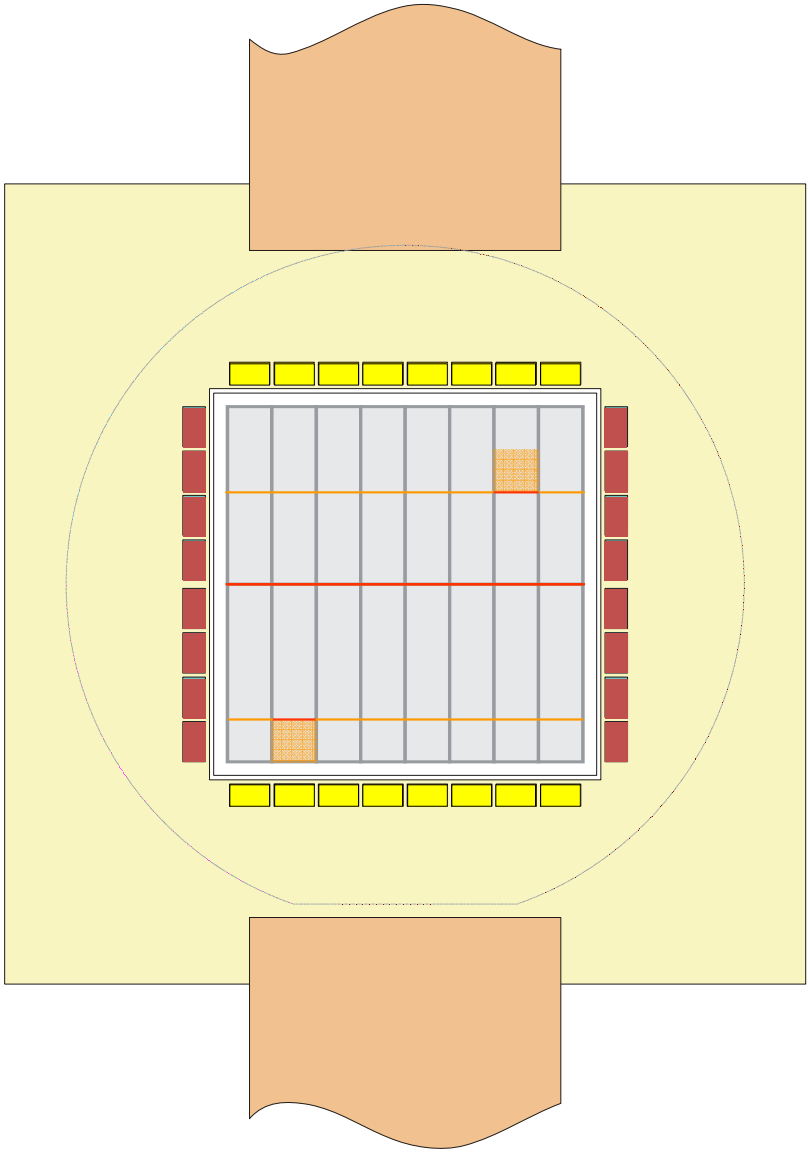
  - Different ROIs on arbitrary positions on FPA

WFI readout concept



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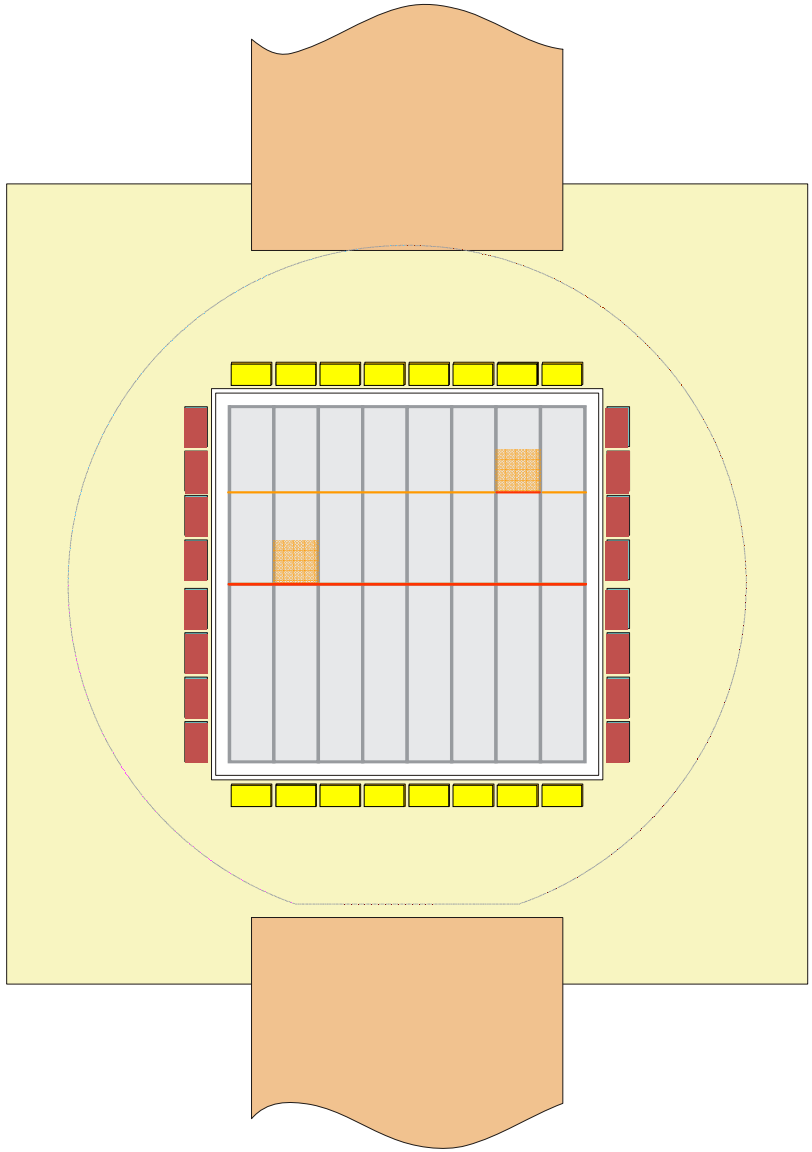

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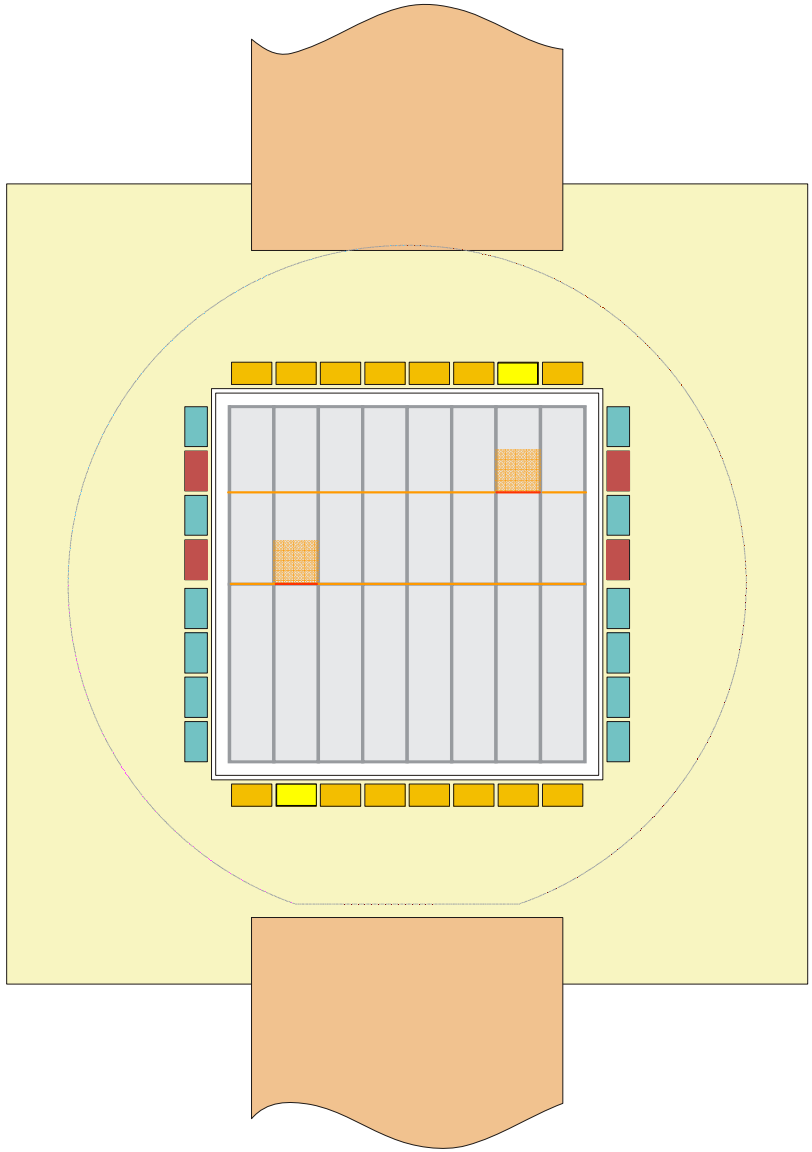
  - Even different non-overlapping ROIs on same Hemisphere possible (subsequent readout)

WFI readout concept



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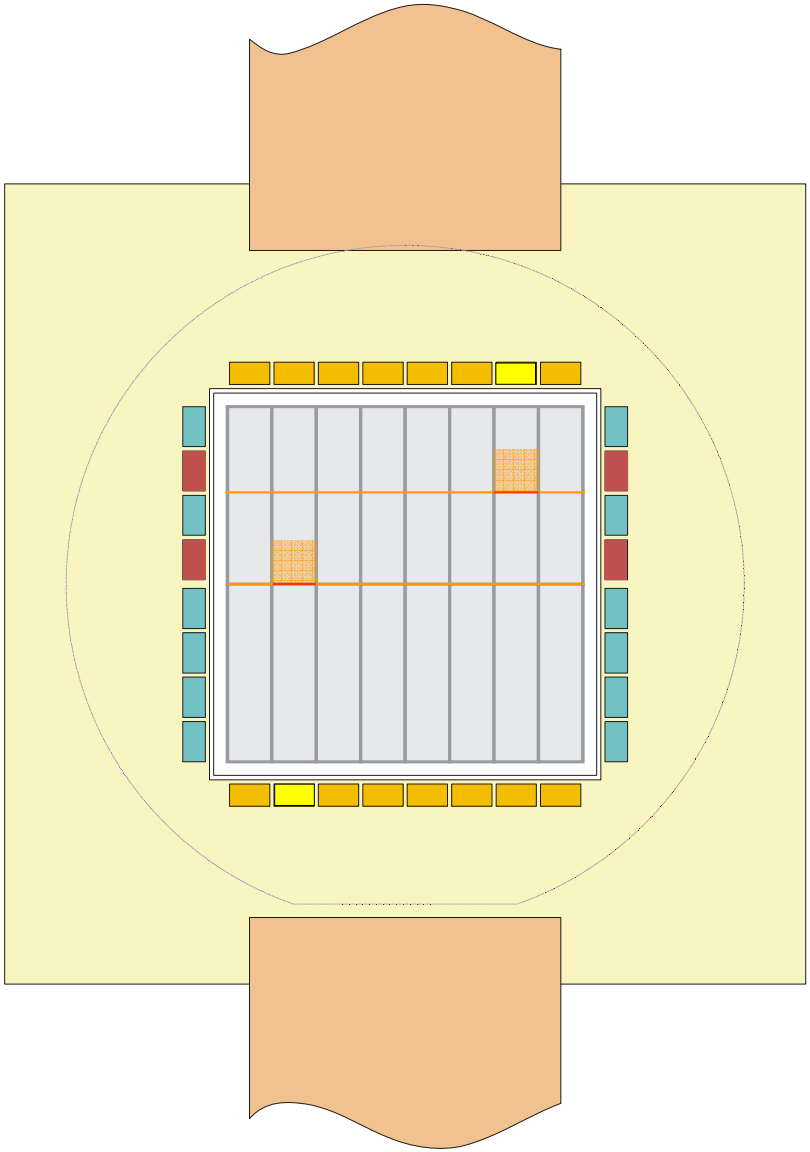

- *Readout modes:*
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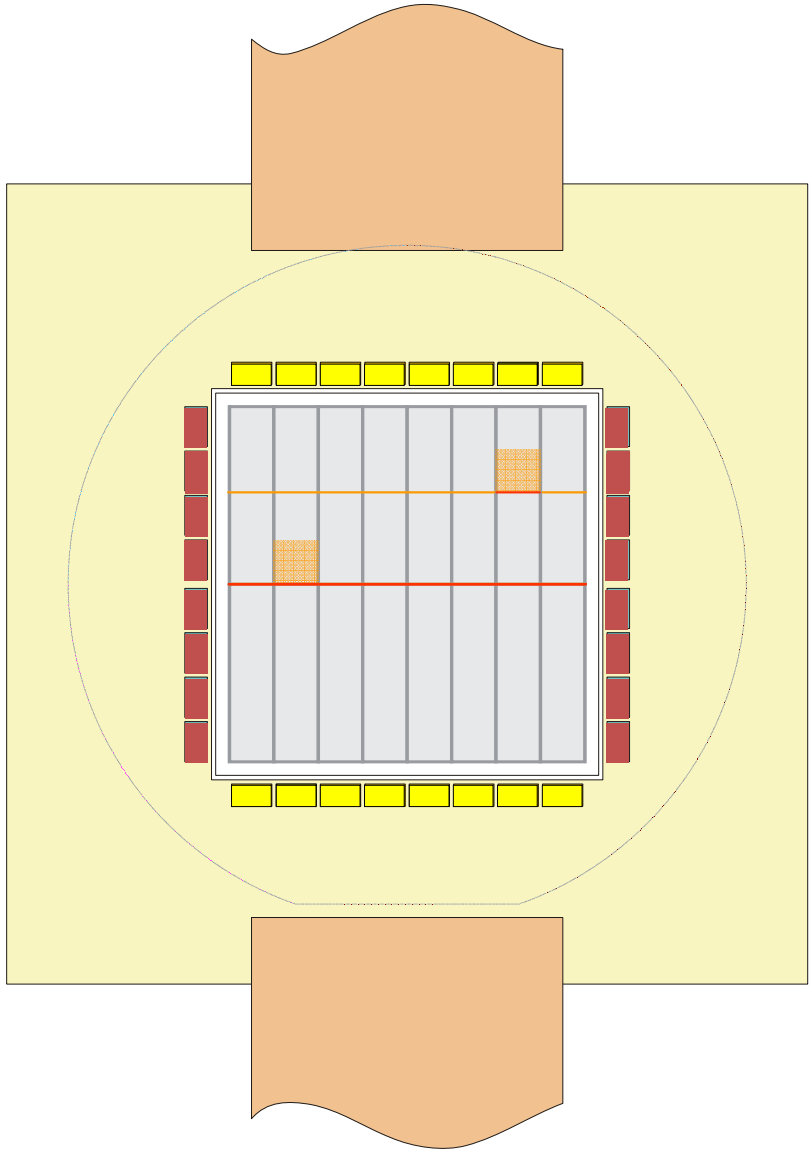
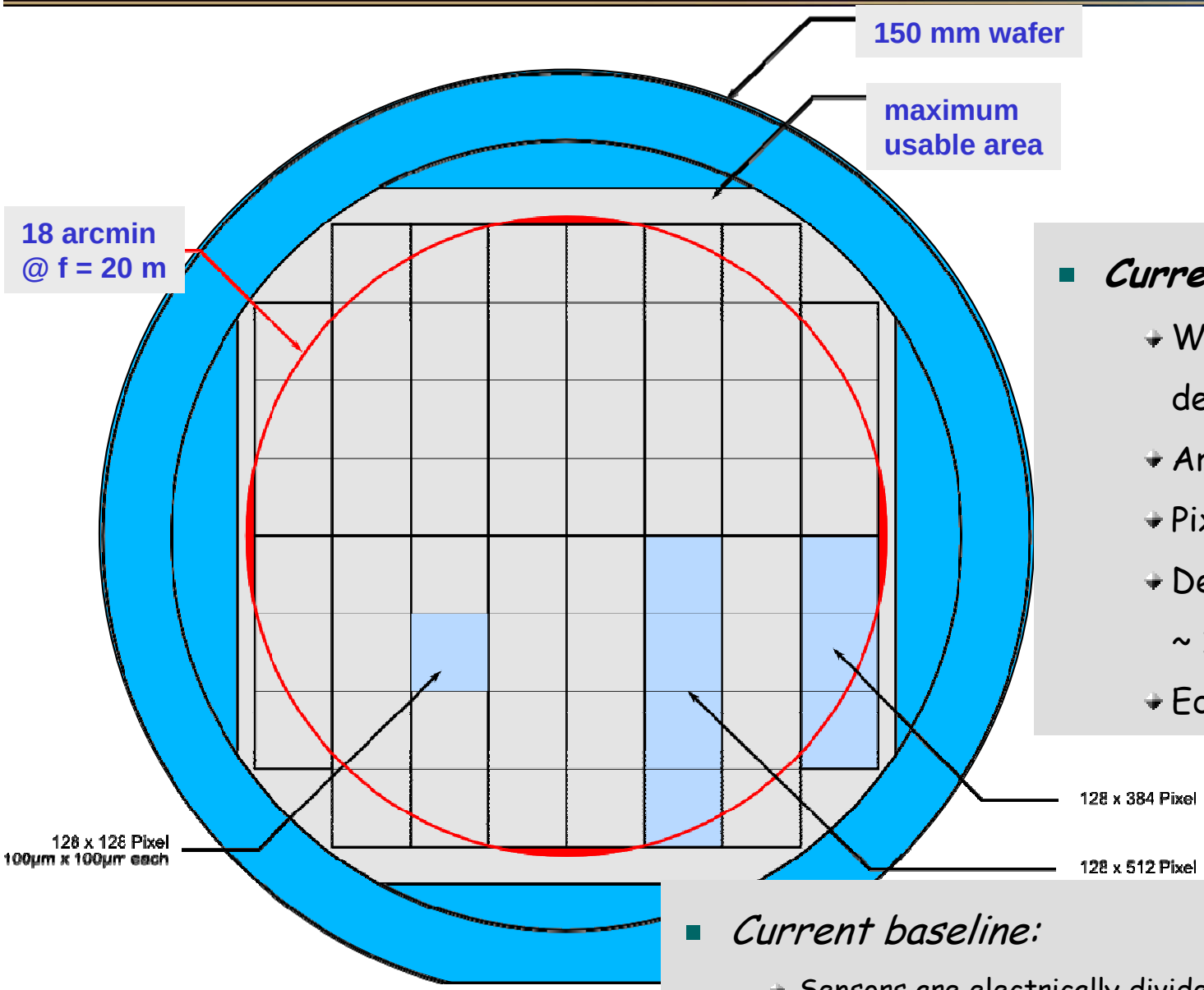
WFI readout concept



- *Readout modes:*
  - **Window mode (cont.):** Acquire fully sized window strip (anywhere on FPA) repetitively
  - Read rest of frame with reduced framerate
  - Different ROIs on arbitrary positions on FPA
  - Even different non-overlapping ROIs on same Hemisphere possible (subsequent readout)

Concept



- ***Current baseline:***
  - WFI will consist of monolithic device integrated on 150 mm wafer
  - Array format: 1024 x 1024
  - Pixel size of ~100 x 100 μm^2
  - Device will occupy an area of about ~ 102.4 x 102.4 mm^2
  - Edge regions require special care!

- ***Current baseline:***
  - Sensors are electrically divided into two hemispheres and 16 sectors
  - Division is purely electrical, Processing time ~ 2 μs / row
  - Common entrance window homogeneous & without dead regions
  - Hemispheres are read out in parallel (factor 2 in parallelization)

Expected and experimentally verified WFI properties

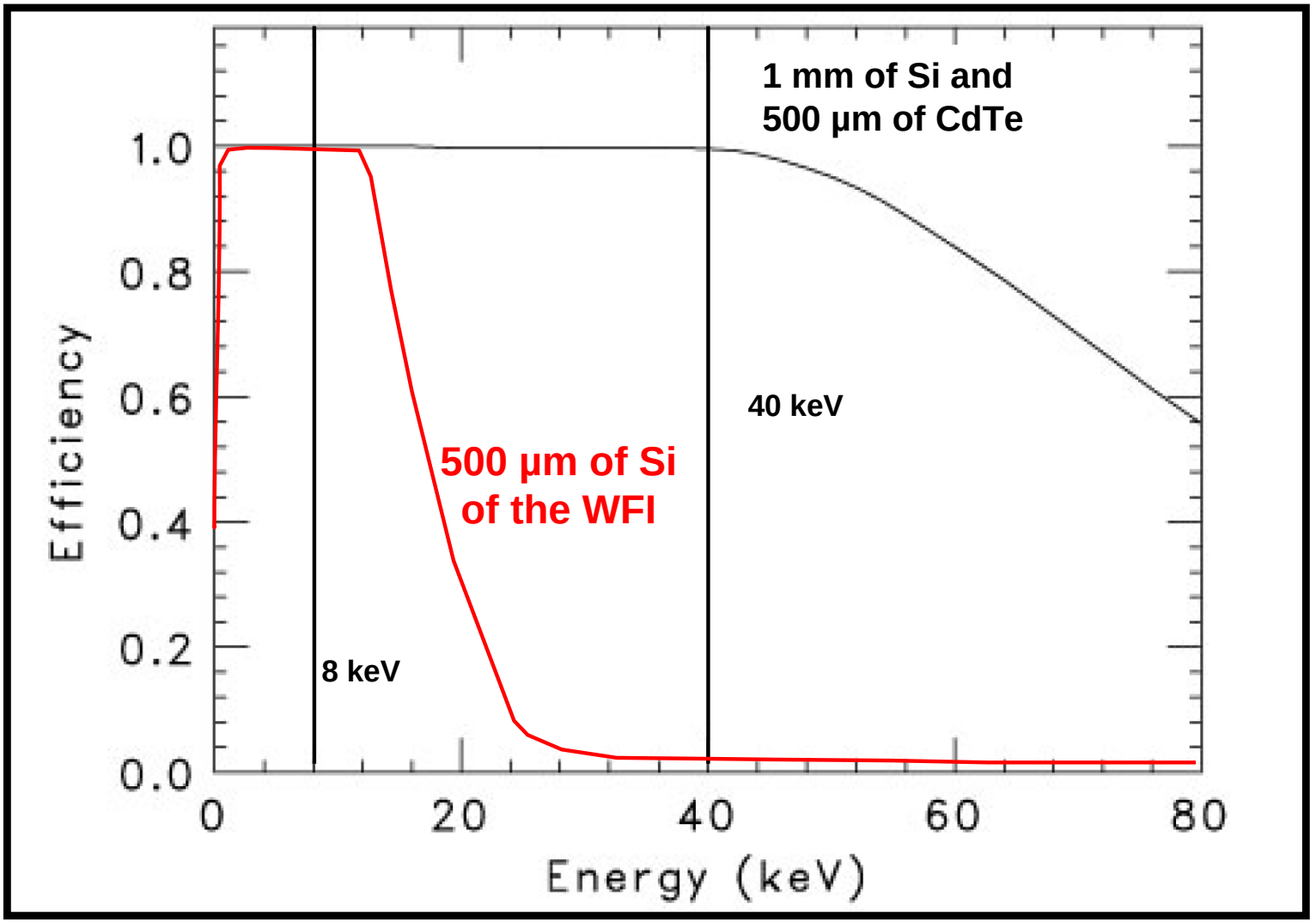
1.	Energy bandwidth:	0.1 keV up to 20 keV
2.	Electronic noise:	3 electrons (rms)
3.	Energy resolution:	130 eV (FWHM) @ 6 keV 45 eV (FWHM) @ 0.2 keV
4.	Format:	1024 x 1024 pixels
5.	Pixel (FP) size:	100 x 100 μm^2 (10 x 10 cm^2)
6.	Position resolution:	$\sigma_{x,y} \leq 40$ µm
7.	Readout speed	2 µs/pix , 2048 pix. in parallel
8.	Time resolution:	1 ms in FF, down to 16 µs in WM
9.	Integrated optical filter:	10^5 optical light reduction
10.	Windowing modes:	adjustable according to target
	Depleted thickness:	480 µm

TRL schedule summary

Topic	2009 1. half	2009 2. half	2010 1. half	2010 2. half	2011 1. half	2011 2. half	2012 1. half	2012 2. half
DePFET sensor fabrication								
CAMEX ASIC								
VELA & ASTEROID								
Switcher ASIC								
Camera mechanics And HXI I/F								
Cooling								
optical blocking Filters								
Filter sled								
DAQ Electronics								

TRL	3	4	5	6	>6

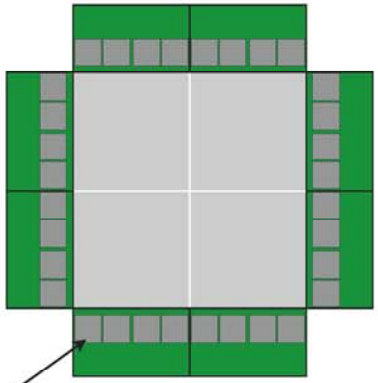
Quantum efficiency of WFI and HXI



Hard X-ray imaging detector

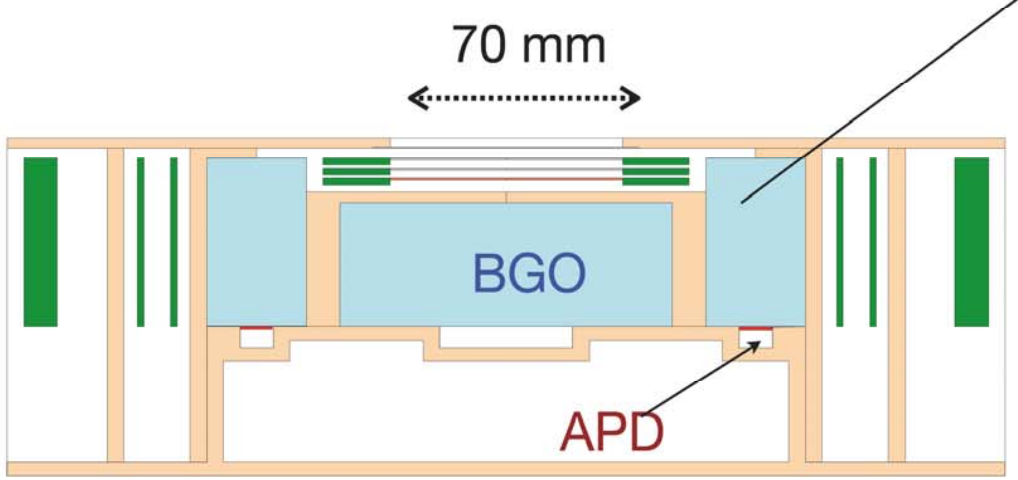
Main detection part consists of 2-layers of Double-Sided Silicon Strip (DSSD) and 1 layer of Double-sided CdTe strip (DS-CdTe). Each layer contains 2x2 devices.

Top-view
(imager part)



Readout ASICs are directly coupled with devices within the same plate.

Cross-section-view



Active shield :
2 cm thick BGO
(default)

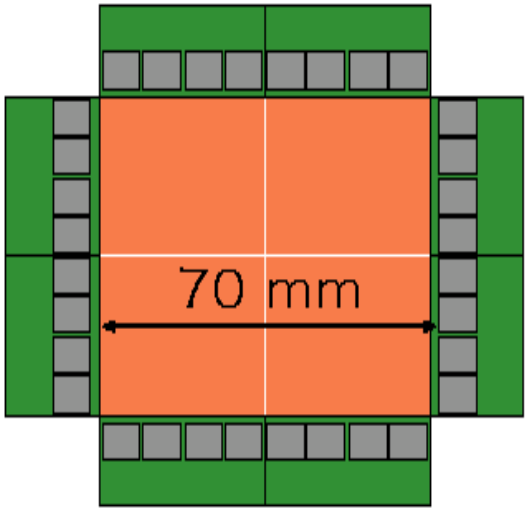
Total Weight : 24 kg
Total Power : ~32W
(including electronics)

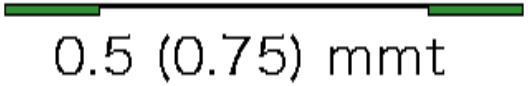
Heritage from Suzaku-HXD

Status of the CdTe imager

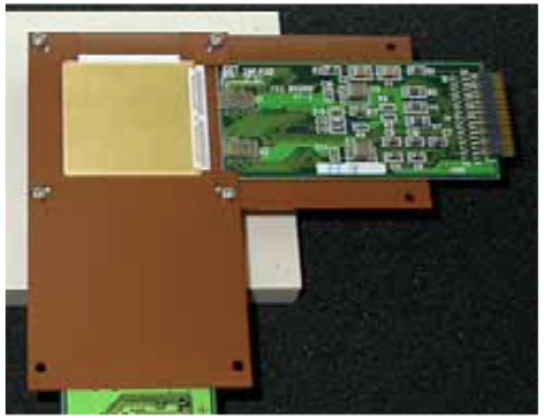
Double-sided CdTe strip detector from ACRORAD

IXO HXI goal

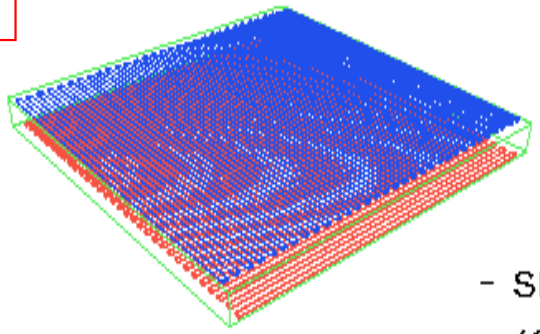




Laboratory experiment

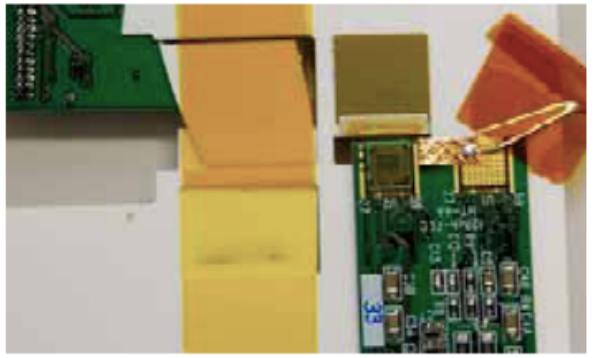


2.5 cm DS-CdTe



Strip detector

- smaller read-out channels (2n instead of n^2)
- 1-dimensional ASIC
- relatively large leak and C

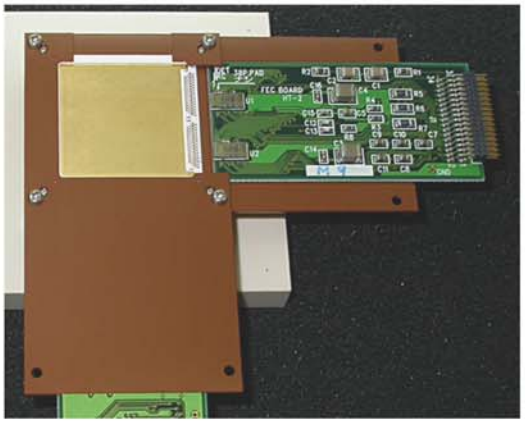


1.3 cm DS-CdTe

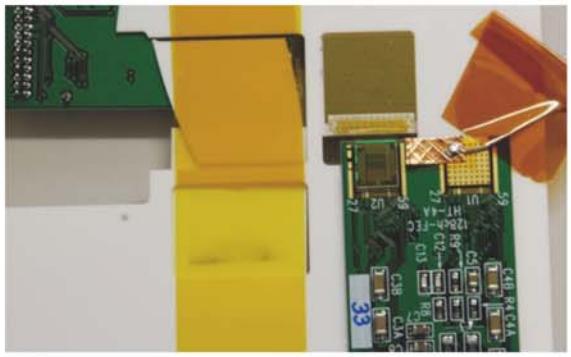
Status of HXI development: DS CdTe

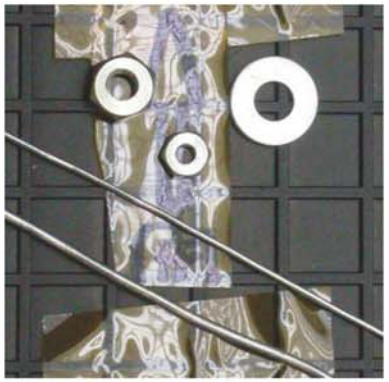
Double-sided strip detector based on CdTe diode devices from ACRORAD

2.5 cm DS-CdTe

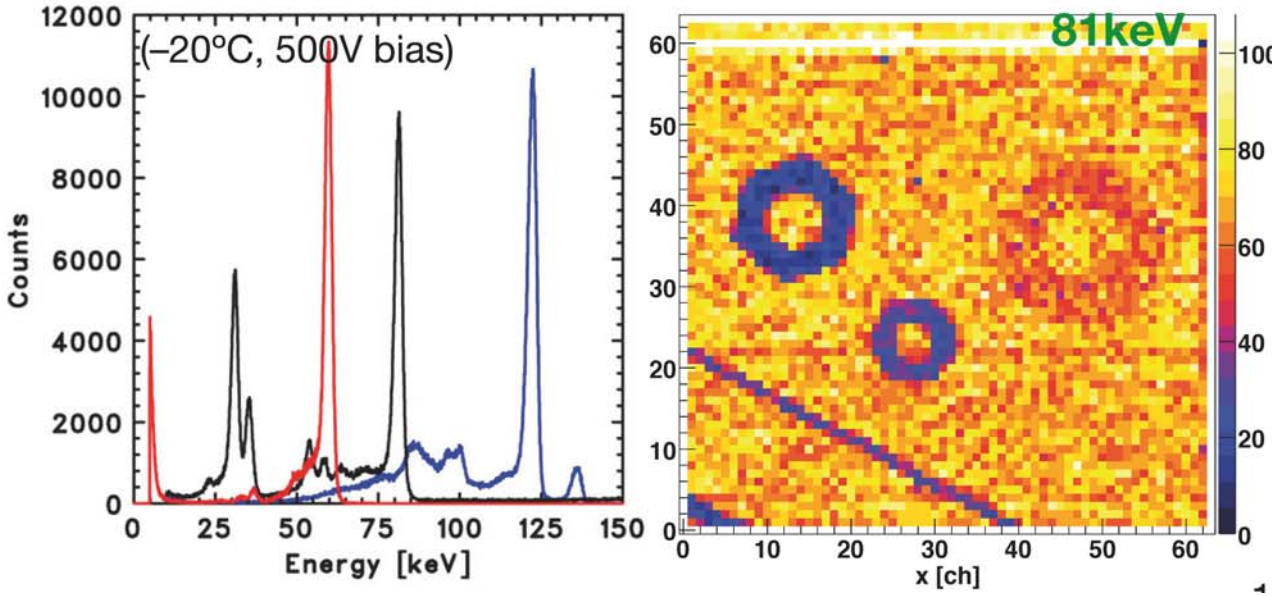


1.3 cm DS-CdTe





Shadow Image with various RIs (^{241}Am, ^{133}Ba, ^{57}Co)



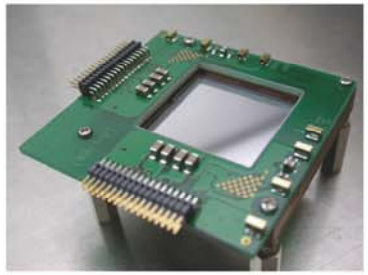
Comparisons of strip with Pixel

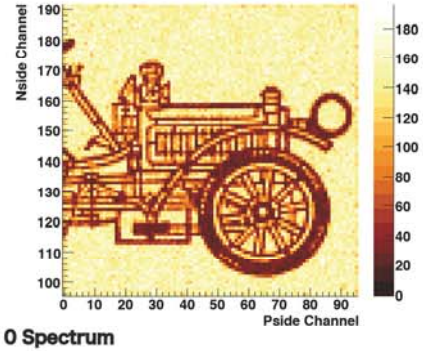
- smaller read-out channels (2n instead of n^2)
- 1-dimensional ASIC
- relatively large leak and C

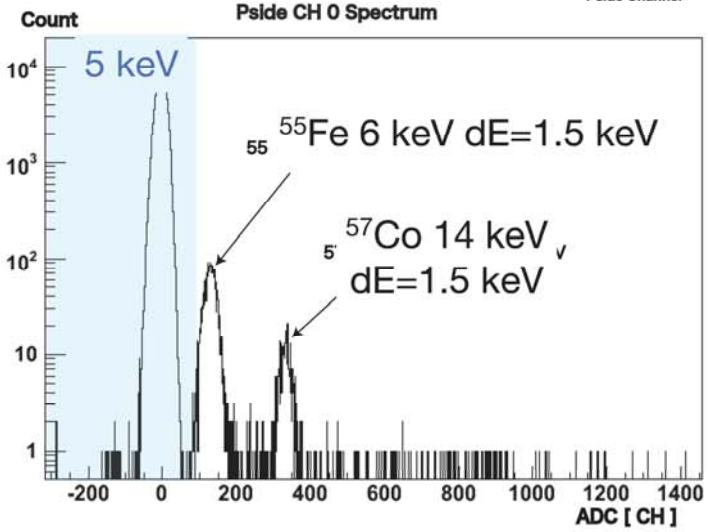
Status of HXI development: DS SSD

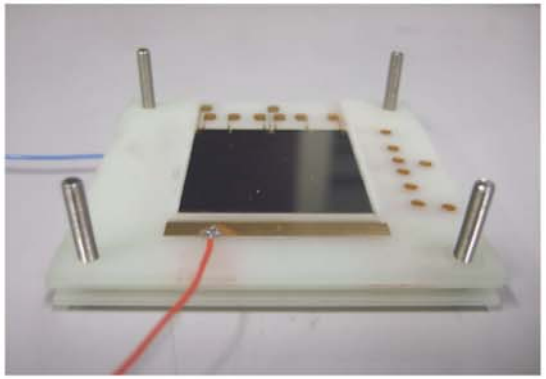
Lower intrinsic background can be achieved than CdTe thanks to its small atomic number. Also act as a "fluorescent X-ray shield" for WFI located between CdTe and WFI. Background reduction with anti-coincidence can be also utilized.

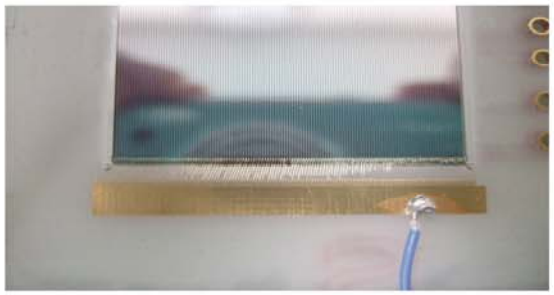
Engineering model Strip pitch: 400um
Size : 40 x 40 mm^2











Low noise performance has been verified with a lower energy threshold of ~5 keV.

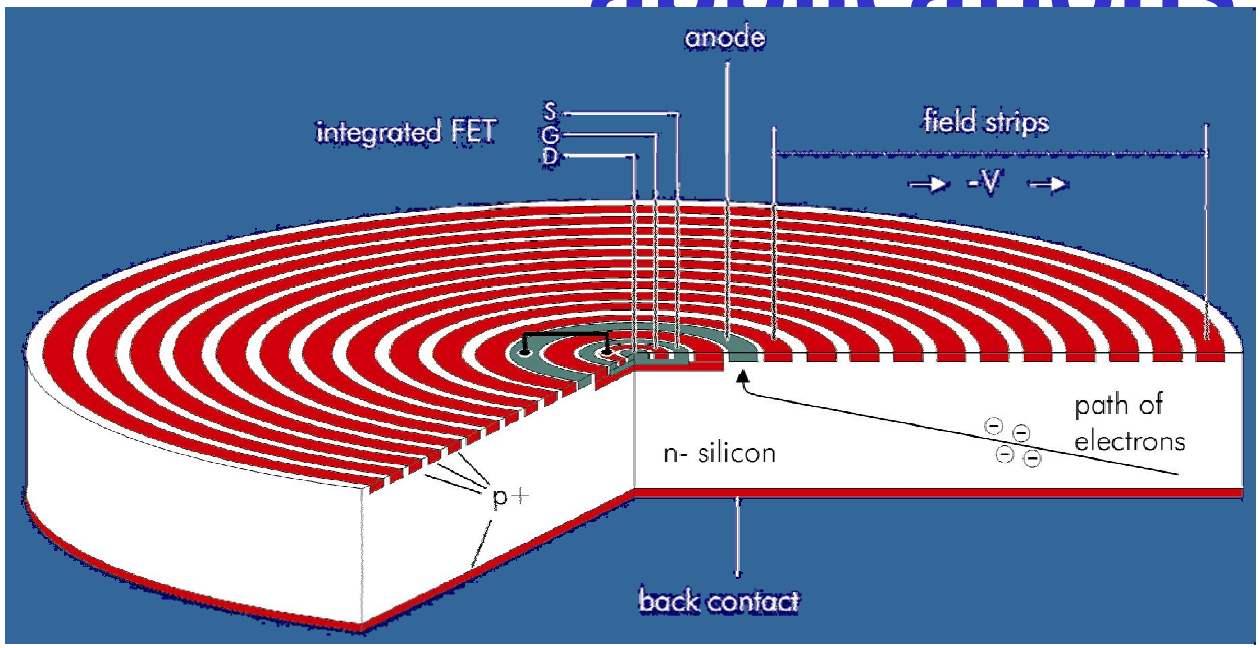
ASTRO-H flight model

Strip pitch: 250 µm
Thickness: 500 µm
Area: 32 x 32 mm
(128 channels for each side)

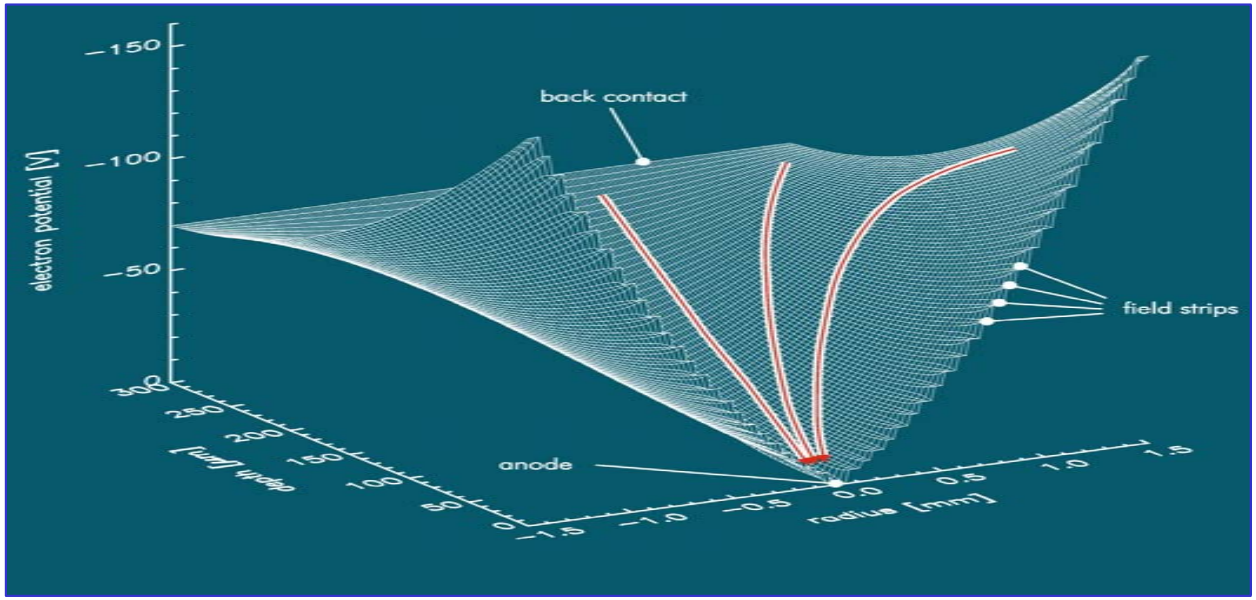
SDDs for scientific applications

time to drift from device edge to readout node:

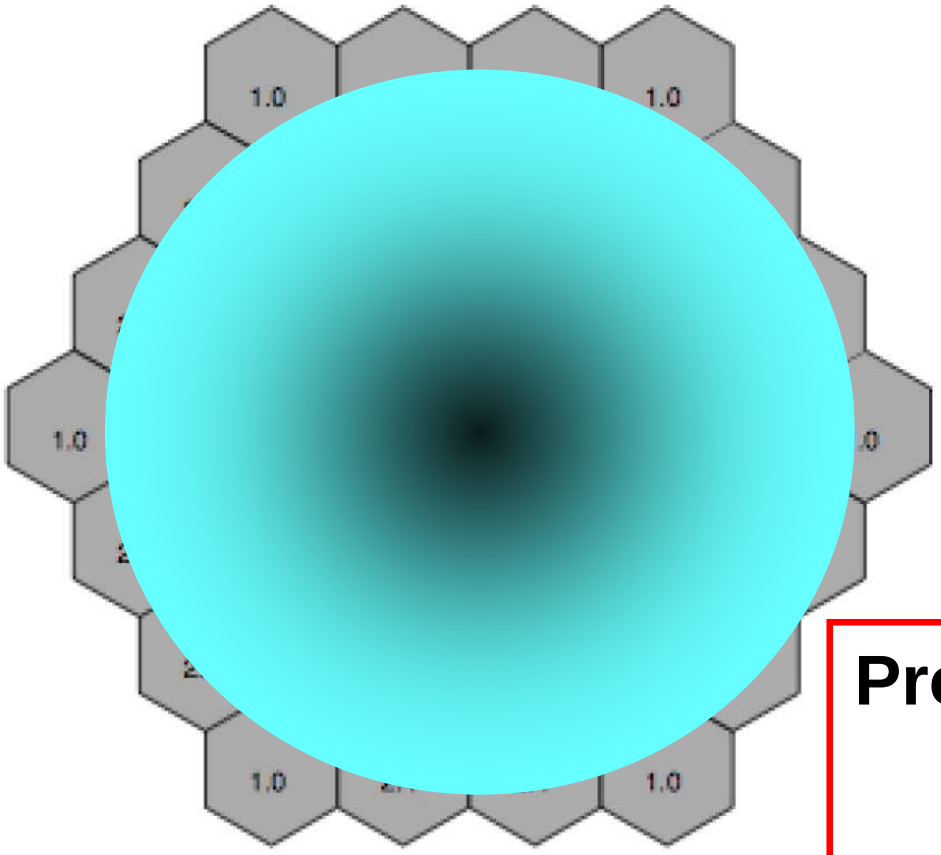
$\Delta t = \Delta x / \mu E$
$= 200$ ns
for $\Delta r = 2$ mm
i.e. $A = 13$ mm²
and $E = 800$ V /cm

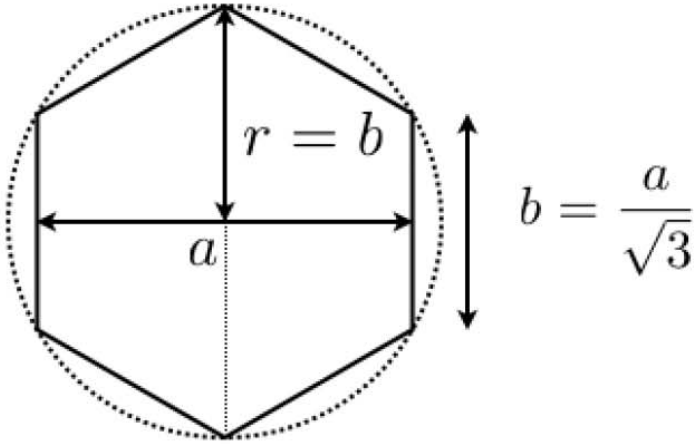


SDD with integrated SSJFET



Electrical Potential in a circular SDD





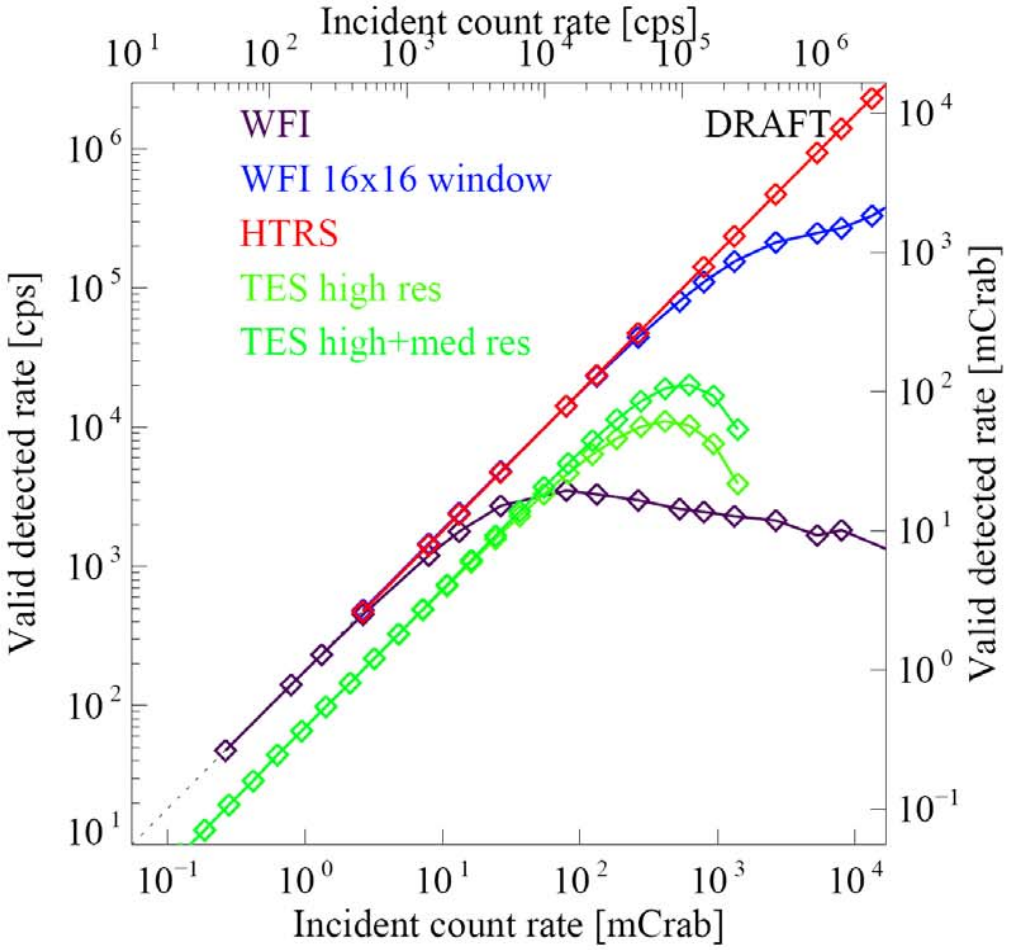
Proposal: array of 37 SDD cells

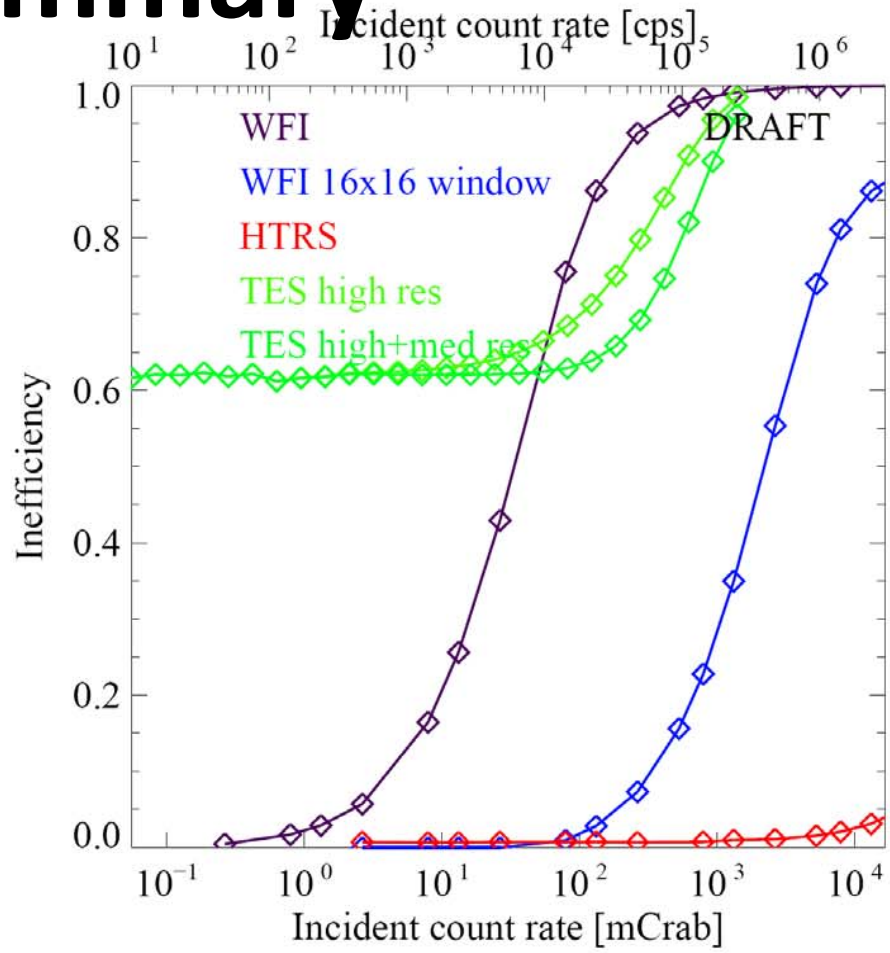
12 cm out-of-fo
typ. 10 mm² of
"adaptive pixel
75 ns shaping
up to 500.000 c
ΔE < 200 eV (F

500 µm thick s

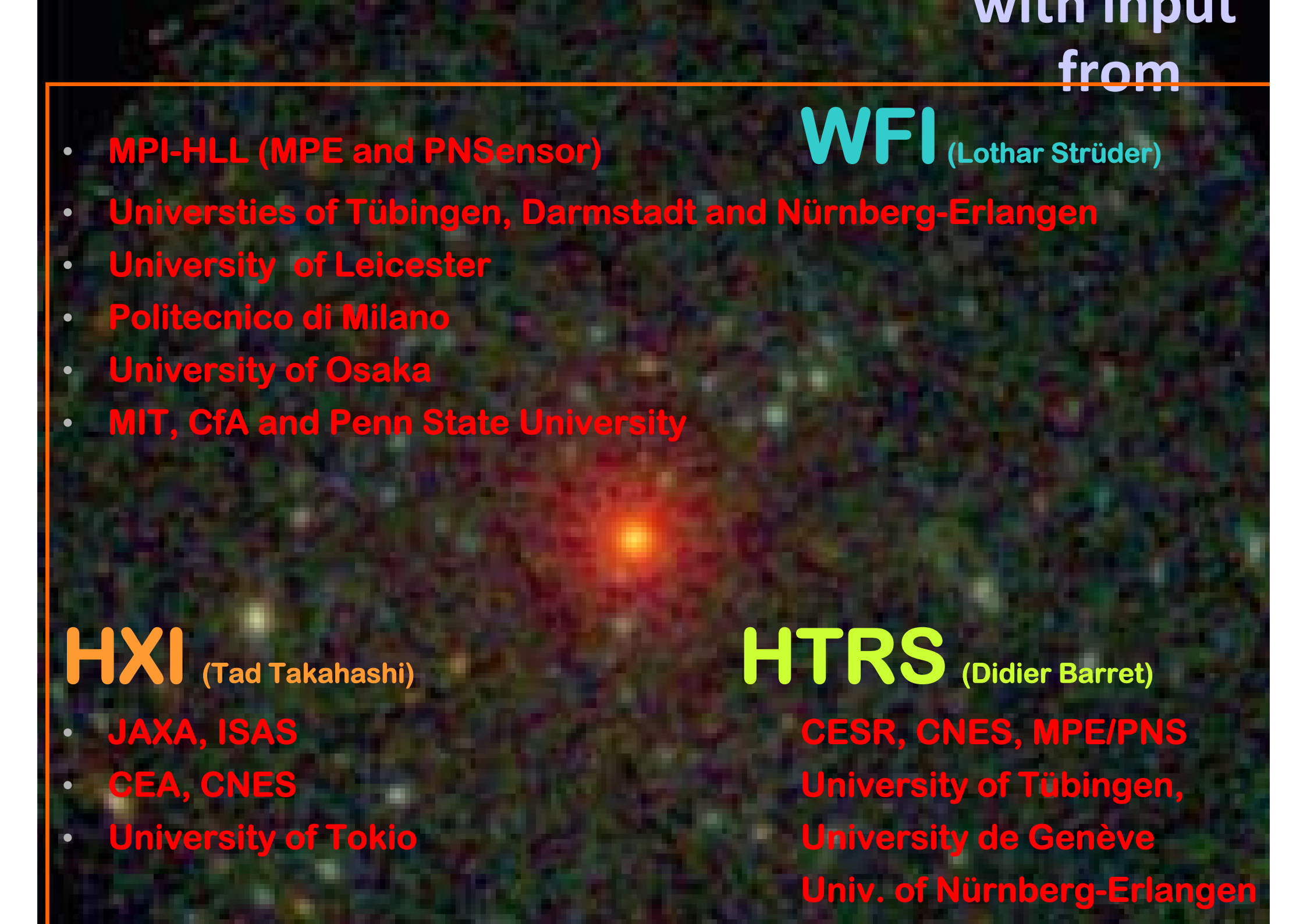
0.1 keV < E < 2

Count rate capability: Summary





Calculations performed by Jörn Wilms et al.


with input from
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MPI-HLL (MPE and PNSensor)
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University of Leicester
Politecnico di Milano
University of Osaka
MIT, CfA and Penn State University
HXI (Tad Takahashi)
JAXA, ISAS
CEA, CNES
University of Tokio
HTRS (Didier Barret)
CESR, CNES, MPE/PNS
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