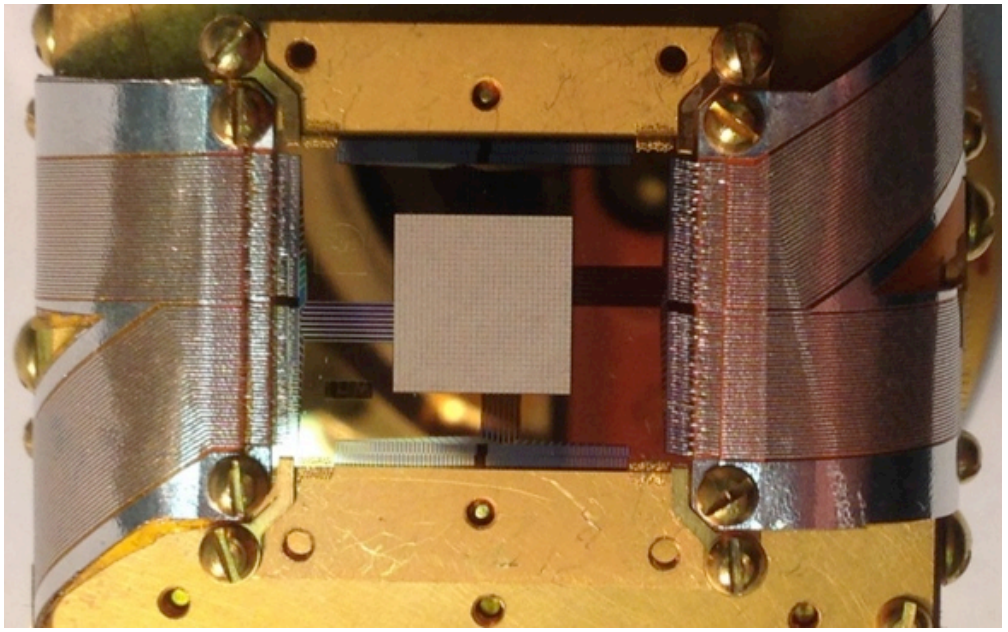
NASA Contributions to the X-IFU

Simon Bandler
- *TES microcalorimeter project manager*
- *on behalf of the team developing X-IFU microcalorimeter arrays*

- Consortium membership
- DM Array development
- Array fabrication processing development
- Studies of TESs under AC bias
- X-IFU array configuration trade
- X-IFU scale array test platform build-up
- Multiplexing developments
- Updated schedule details



Now formally part of the X-IFU “Proto-consortium”

- Richard Kelley: *Member of the X-IFU consortium board*
- Simon Bandler: *TES microcalorimeter project manager*
- Caroline Kilbourne: *Member of X-IFU system team as detector scientist*

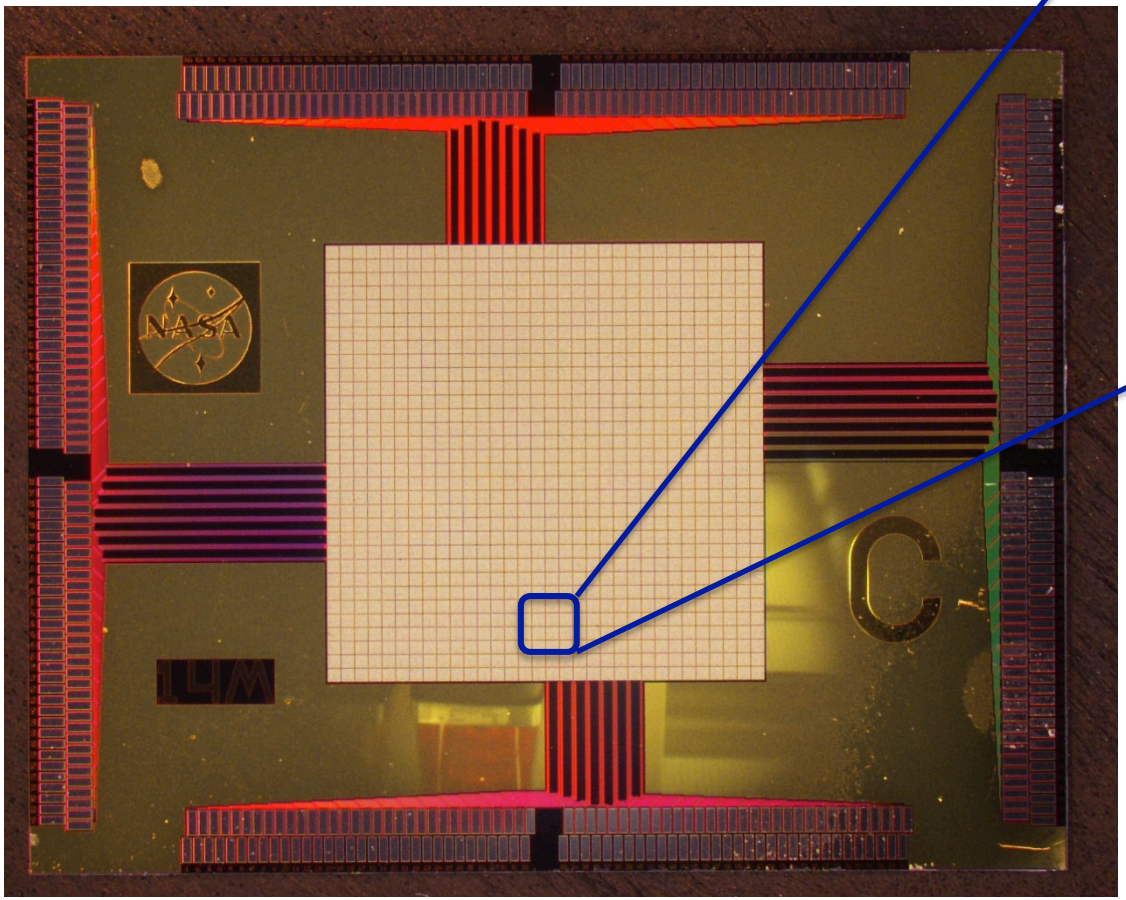
R. Kelley, S. Bandler & C. Kilbourne attended the third X-IFU consortium meeting (10/26-10/28), including the following splinter meetings:

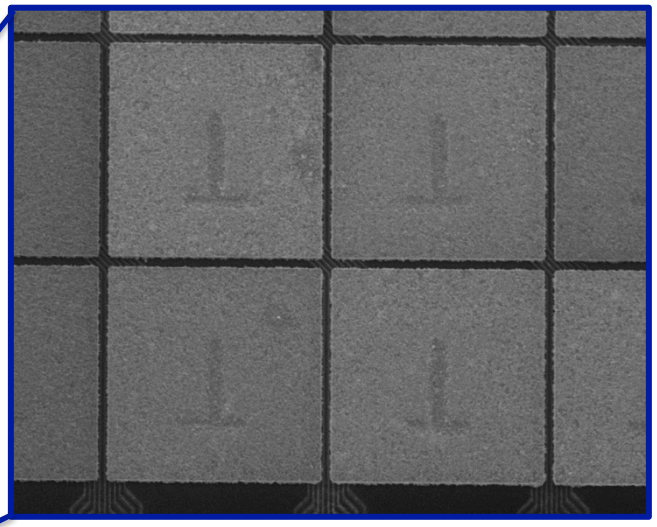
- Consortium board meeting (RK)
- National project manager meeting (SB)
- Sensor array configuration meeting (SB, CK & RK)
- Informal aperture assembly meeting (CK & RK)

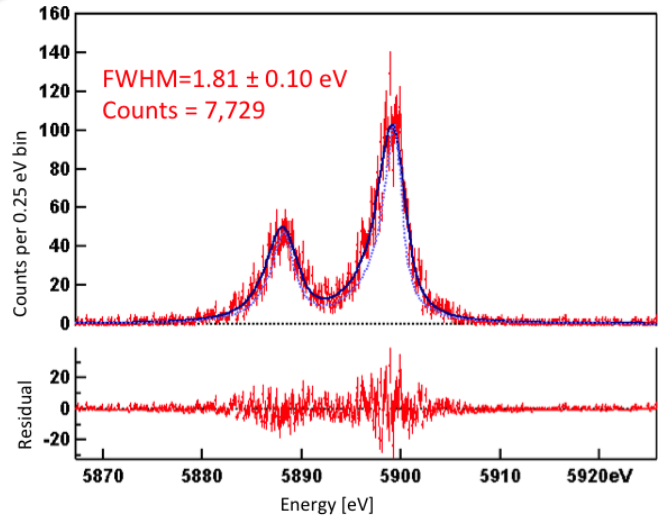
Demonstration model (DM) kilo-pixel arrays

- being fabricated and tested

- 32 x 32 array – close-packed microstrip wiring
- Absorbers: Au: 1.5 μm, Bi: 3.0 μm, on 250 μm pitch





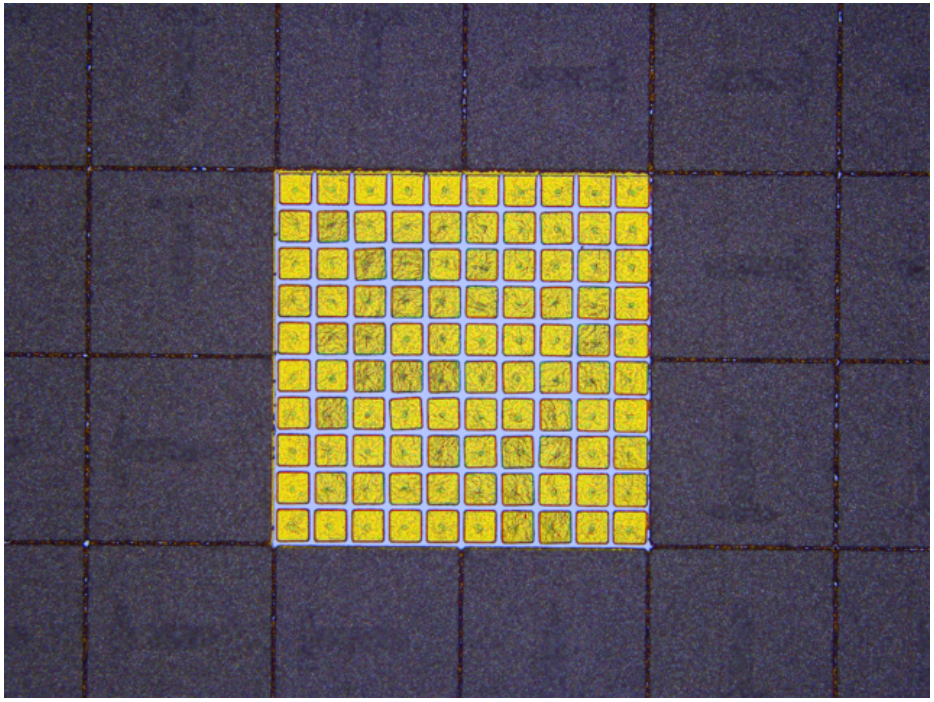


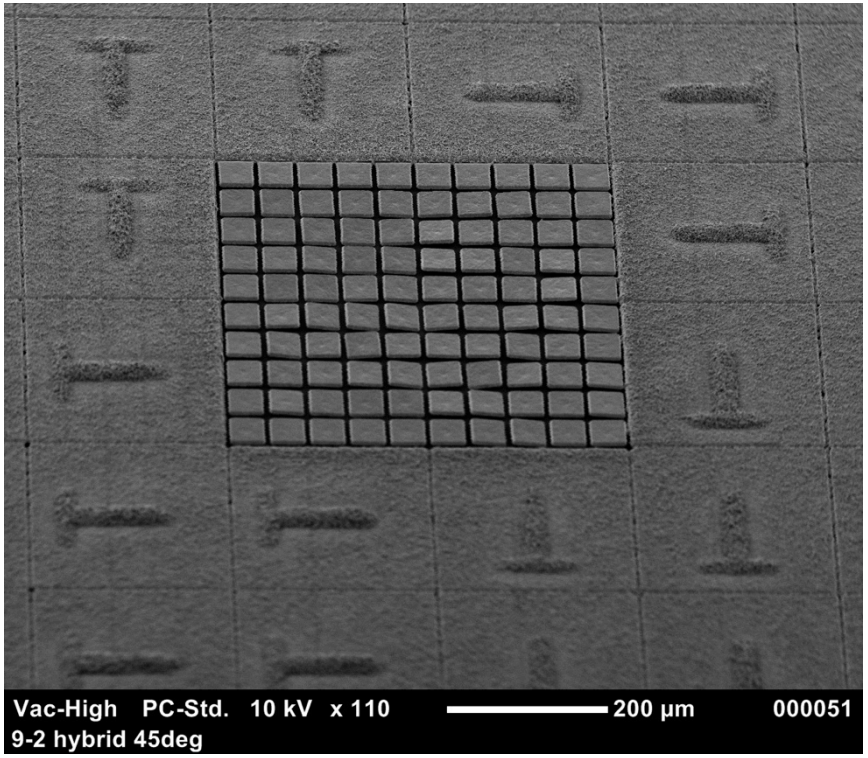
Uniformity of Tc / performance is improving

- continued studies of transition properties, heat capacity & noise

Developing microfabrication techniques for fabricating “hybrid” arrays

Photograph & SEMimage of two types of absorbers fabricated on single Si substrate

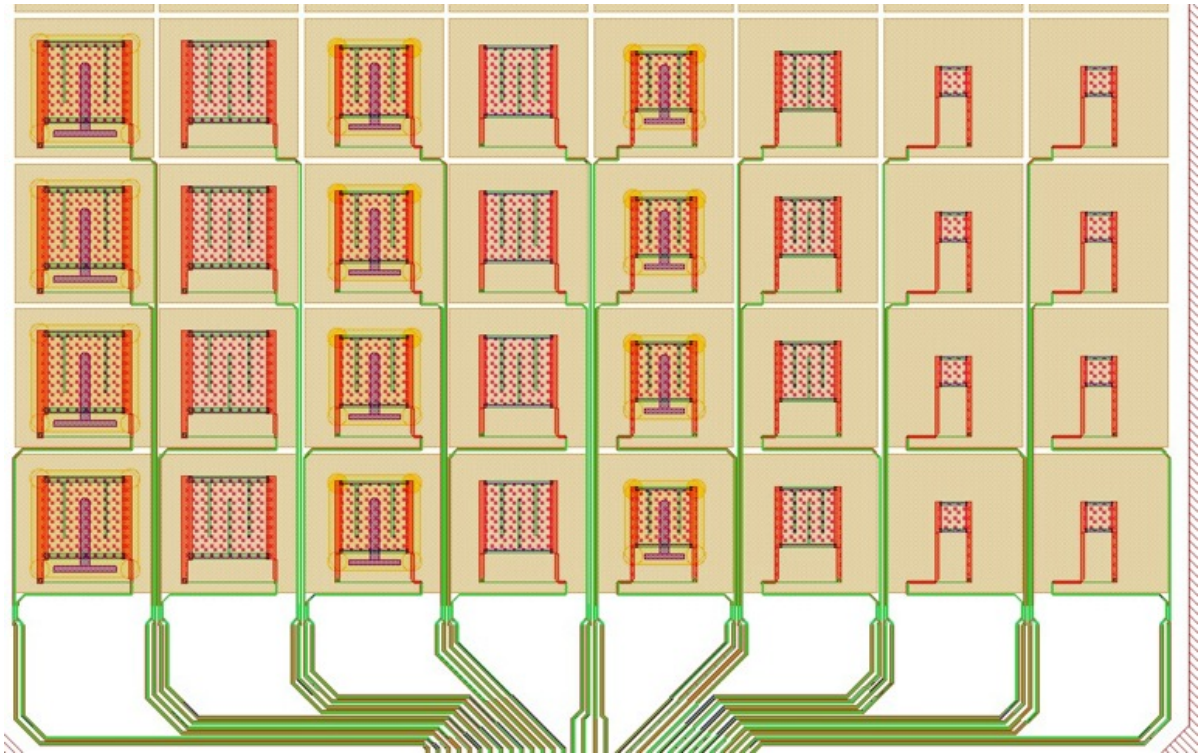




Central 5x5 array of free-standing absorbers: all-Au on a 50 μm pitch, 4.0 μm thick.
Surrounding large absorbers: AuBi on a 250 μm pitch, 2.5 μm Au, 3 μm Bi.

TESs under AC bias

- New detector sent to SRON for AC bias tests after extensive characterization at GSFC.
- Purpose: to study different geometric configuration under AC bias
  - Different pixel sizes: 50 µm, 100 µm, 120 µm, 140 µm.
  - Different stem contact geometries.
  - Micro-strip wiring.
- Stephen Smith from GSFC visited SRON for 2 weeks to participate in testing/data interpretation and learn AC measurement techniques.



- GSFC building up dedicated AC bias read-out capability, supported by SRON.
- Electronics and resonator components being kindly provided by SRON, SQUIDs by VTT.

X-IFU sensor array configuration trade

Motivation:

• Athena L2 proposal: "uniform" sensor array with equal performance (sensitivity, count-rate) over a 5' FoV (goal = 7').

- realizing all requirements in uniform array is challenging
- achieving one or more goals is unrealistic.
- configuration unnecessarily requires point-source-driven count-rate requirements met in all pixels.

• Past development at GSFC of a range of TES pixel geometries includes arrays combining multiple pixel types.

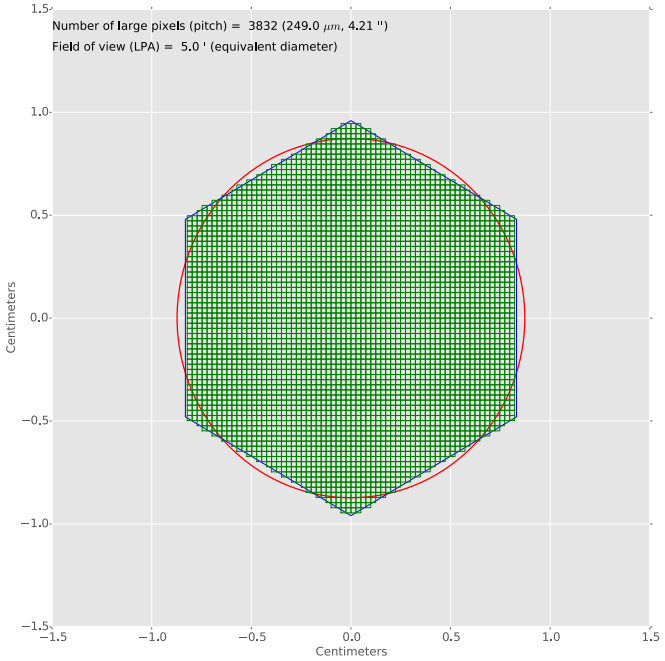
=> X-IFU could benefit from a configuration that combines:

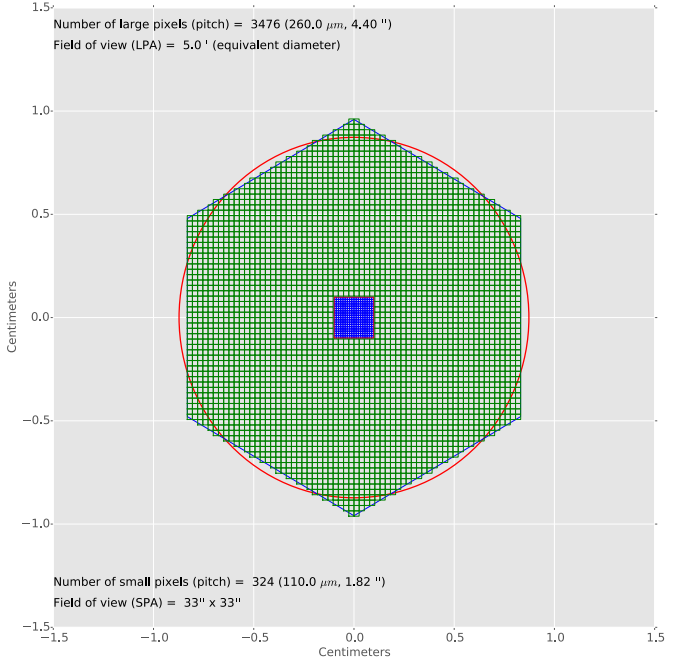
- a sub-array of pixels optimized for (bright) point-sources
- main array optimized for a larger field of view.

• Athena science study team reviewed the science and performed series of simulations to evaluate the science implications of "hybrid" sensor array.

- concluded that hybrid array offers significant improvement in X-IFU science capabilities compared to uniform array

• In parallel, a review of the implementation aspects of the sensor array is also needed.





Study timeline:

July-Oct.: first drafts of chapters 3-7

Oct. 28: presentations & discussions in consortium splinter meeting

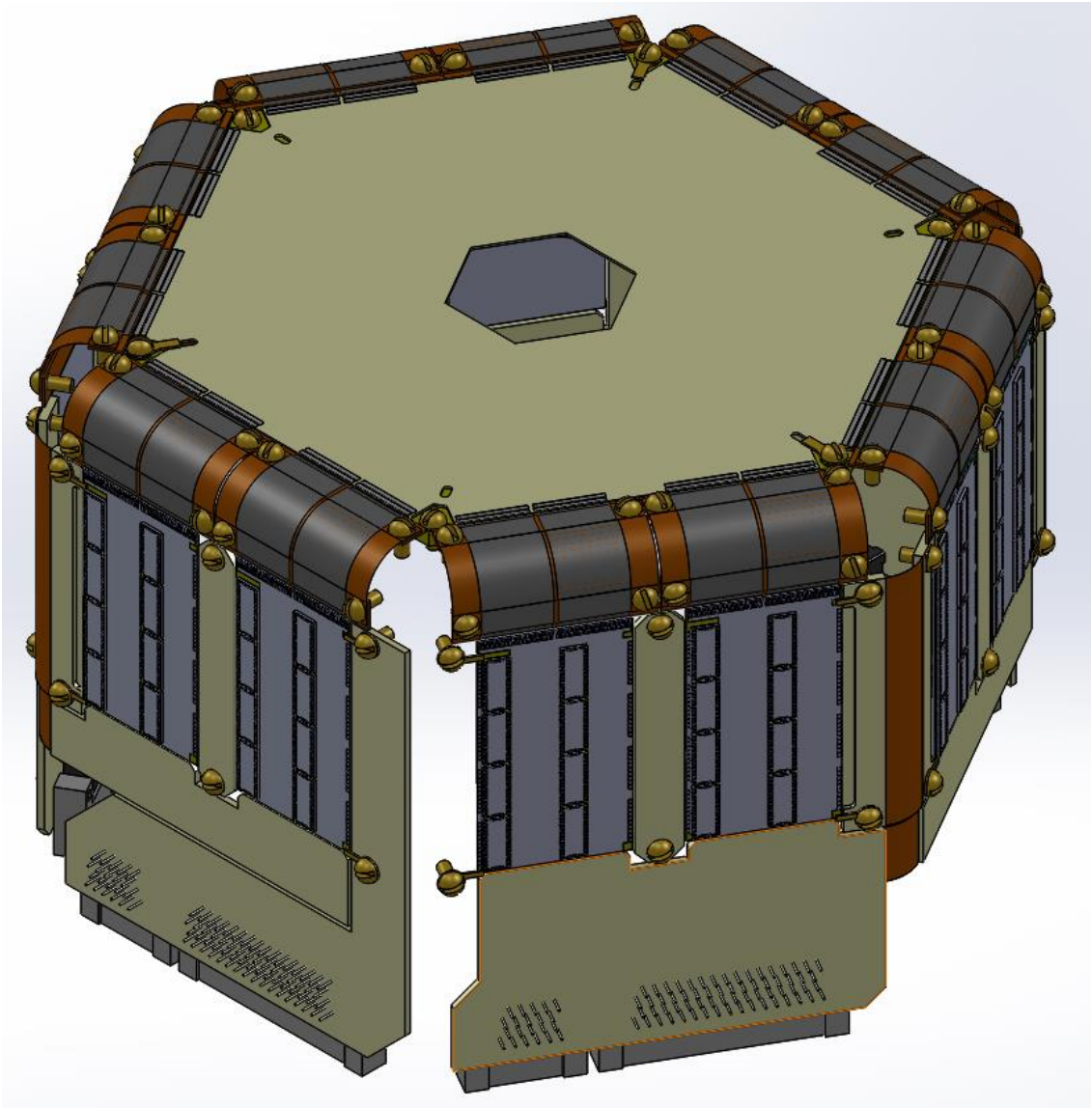
Nov..: review & updates, submit to X-IFU management team

Version 1.0 of document just issued and submitted to X-IFU management team.

Version includes:

- summary of related science goals and requirements
- 2 (key) chapters from GSFC about the sensor array configurations and implementation issues
- summary on impact on the energy resolution budget of the SPA pixels
- conclusions of the impact on the readout electronics
- summary of the "other implementation issues" discussed at splinter meeting
- preliminary conclusions and recommendations

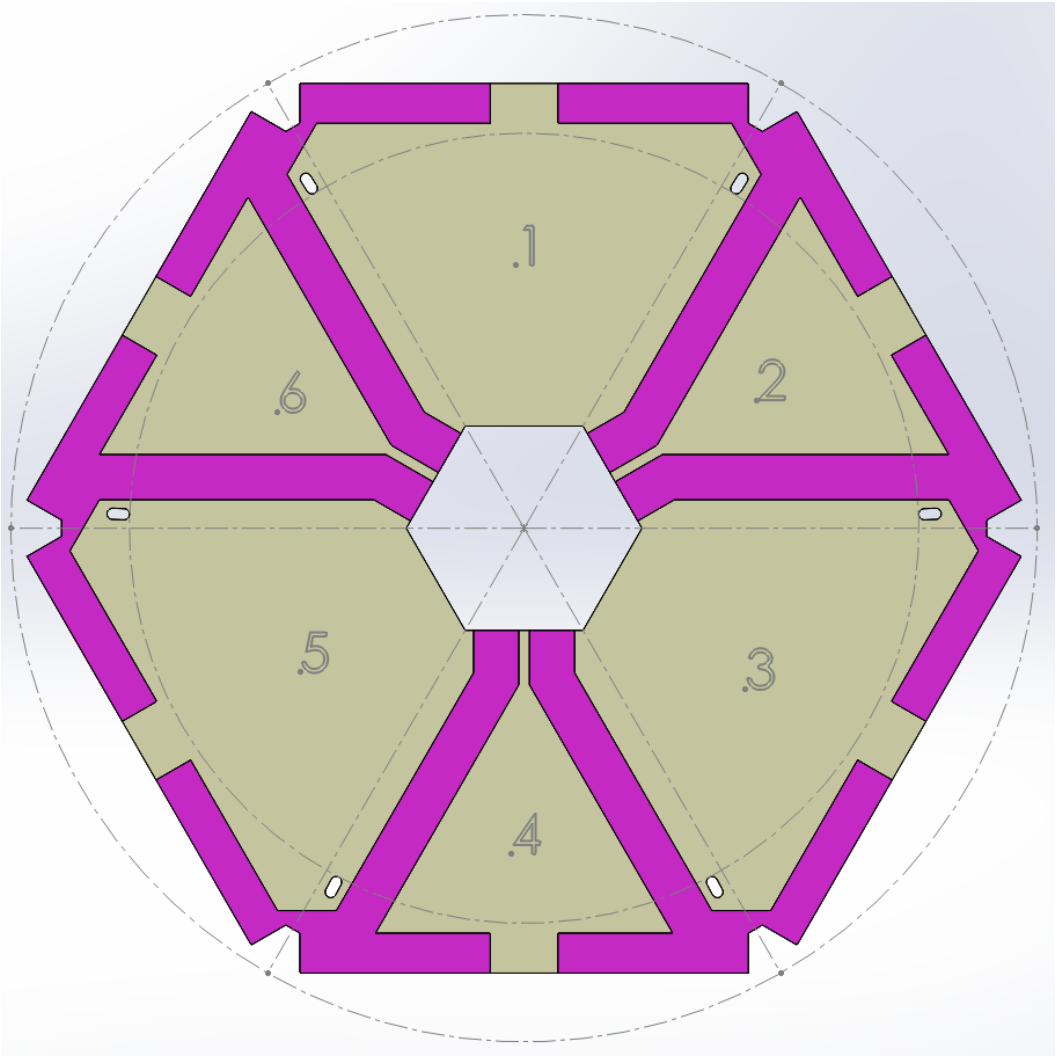
Architecture for kilo-pixel scale characterization of arrays with 3840 TESs



Some features:

- 40-row architecture
- 24 Columns (4/side)
  => 960 pixel characterization
- 6 side panels
- Heat-sinking to rear side of array wafer available via ribbon/wire-bonds
- Kinematic mounting of wafers
- Hexagonal TES chip is 91mm on diagonal

TES array wafer layout for kilo-pixel level testing/demonstrations



Working, towards wafer size, shape & layout for future kilo-pixel level testing of X-IFU style arrays, via:

- Wire-bonding & DC-biased testing
- Coil coupling and AC-biased tests

Converging on solution with:

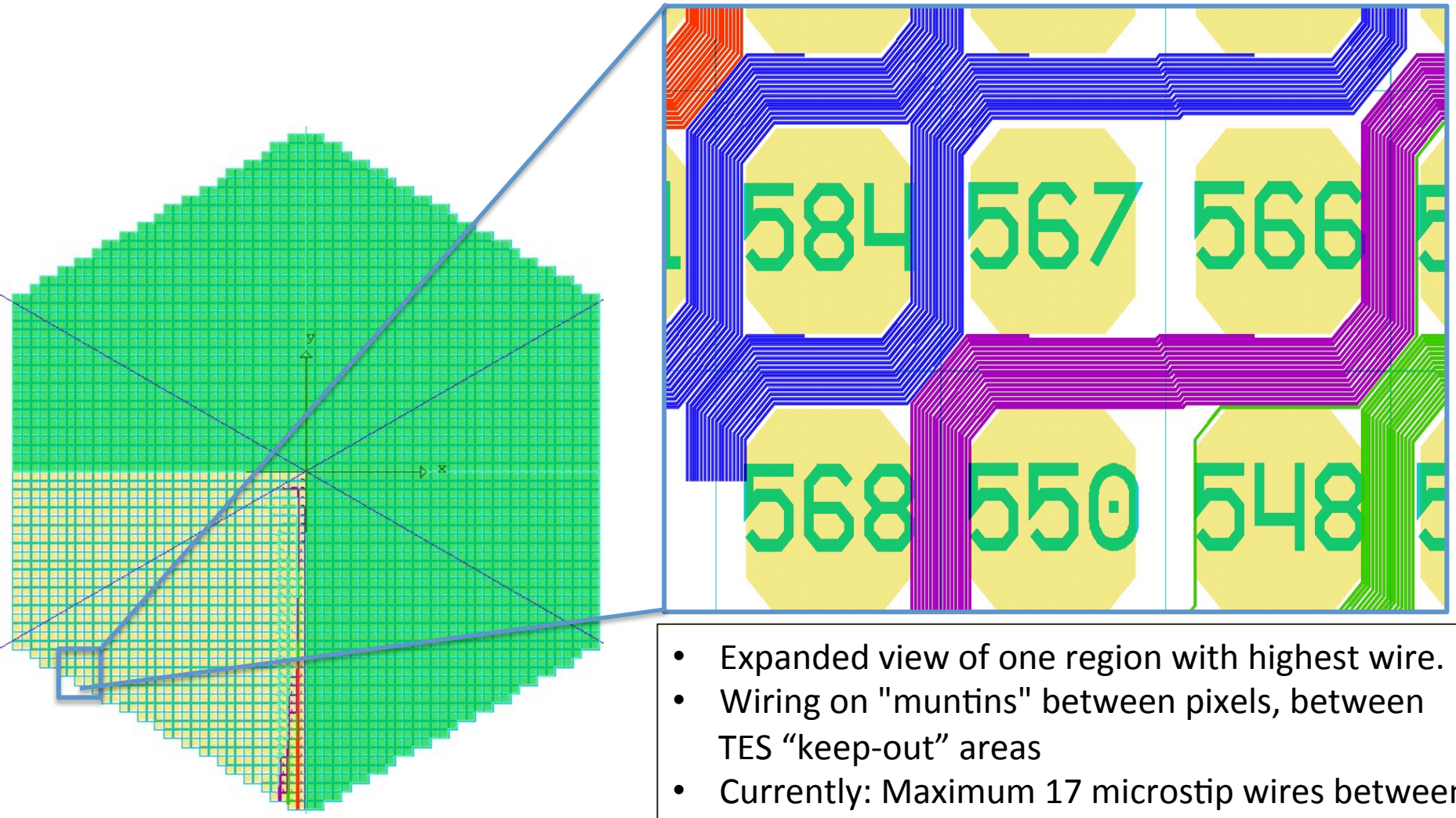
- DC-biased pixels in sectors 1, 3, 5,
- AC-biased pixels with transformer coils in sectors 2,4,6

Still TBD:

- Locations of glue spots for flexures to mount into SRON module.
- Removal of bond-pads in sectors 1, 3, 5

Wire-routing development: towards 3840 TESs

Preliminary wire-routing within the 3840 pixel TES array.



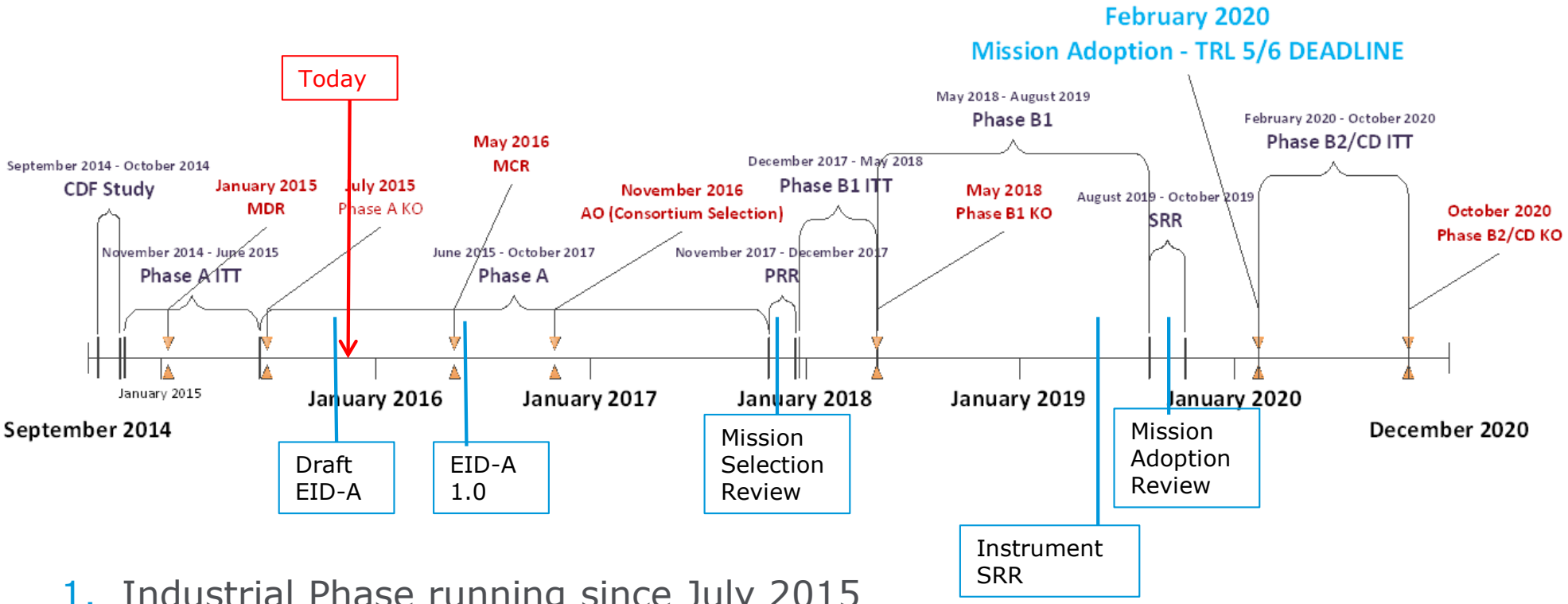
Full hexagonal array with 3840 square pixels on a square grid.

- Expanded view of one region with highest wire.
- Wiring on "muntins" between pixels, between TES “keep-out” areas
- Currently: Maximum 17 microstip wires between pixels on a muntin, & 32 along diagonal
- Version of wiring with “hybrid” array “Option-2” wiring now worked out in principle – masks just starting to be drawn

Athena mission timeline

- **Phase A: 2015-2017**
  - Phase A1 industry study kickoffs (parallel contracts) – August 2015
  - Mission Concept Review (MCR) data package (2 configurations) - March 2016
  - MCR completed - May 2016
    - **Agreements for non-ESA contributions in place**
  - Mission baseline selection - June 2016
  - Phase A2 kickoff - June 2016
  - AO for science instruments - July 2016
  - Selection of instrument consortia - November 2016
  - Preliminary Requirements Review (PRR) data package - November 2017
  - PRR completed (end phase A) - December 2017
- **Phase B1: 2018-2019**
  - Technology developments (mirror, detectors) at TRL > 5-6 - 2019
  - System Requirements Review - End 2019
  - Mission adoption by the ESA Science Program Committee - Feb 2020
- **Phase B2/C/D kickoff - Nov 2020**
- **Launch - 2028**

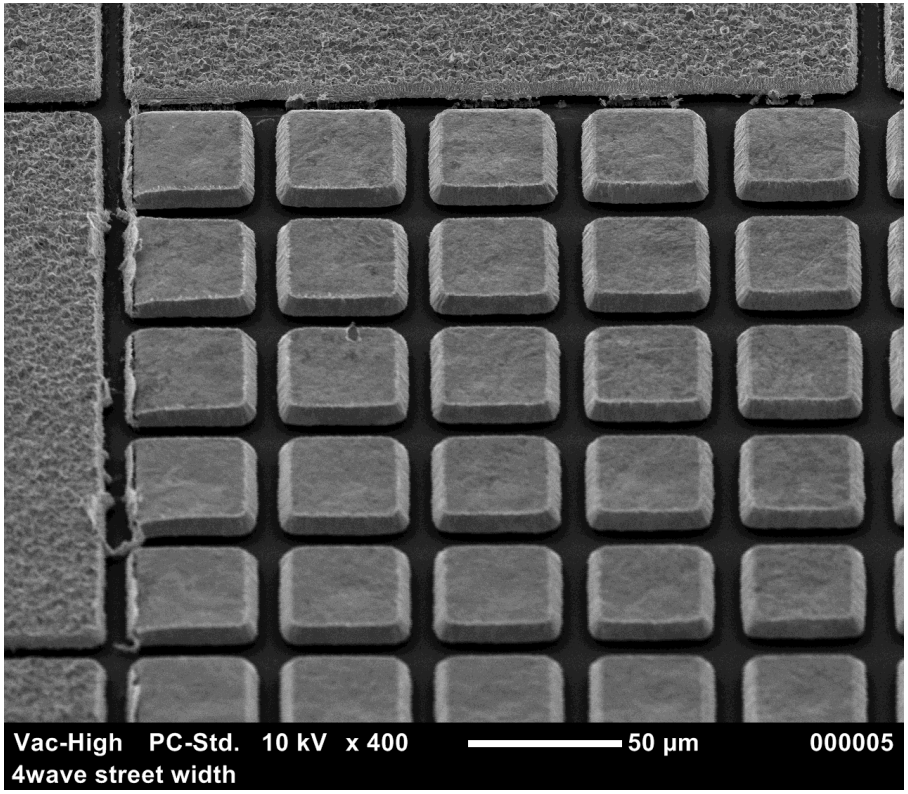
Athena Reference schedule A/B1

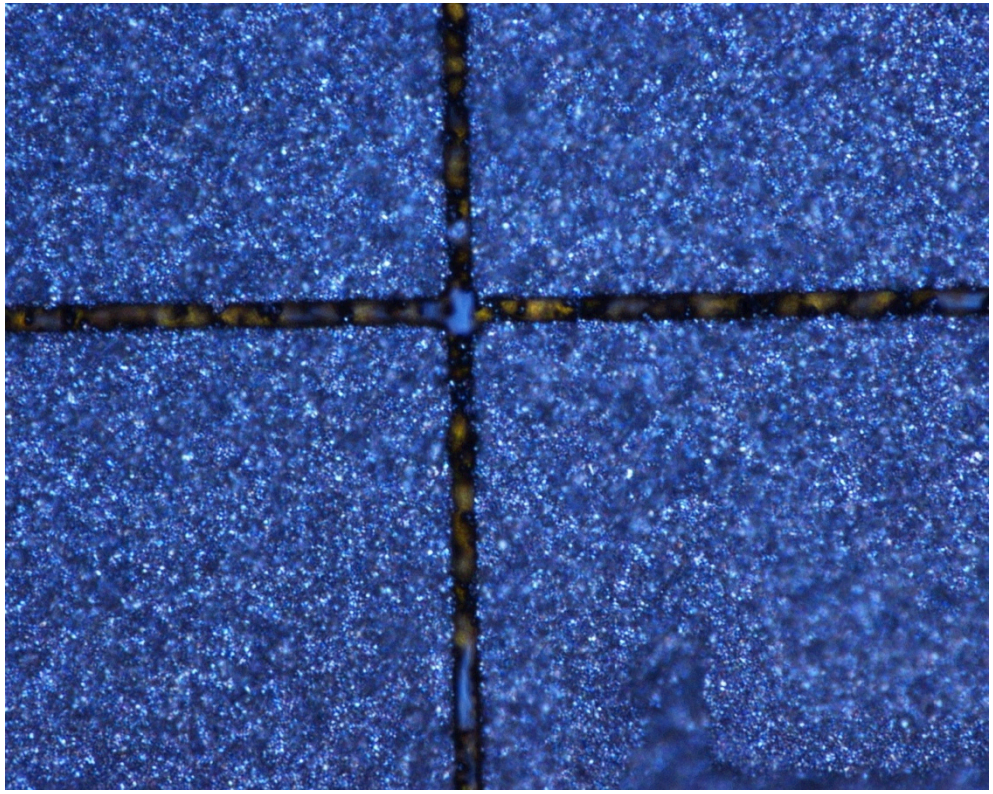


1. Industrial Phase running since July 2015
2. MCR still planned to be finalized in May 2016 to freeze the baseline
3. Draft EID-A under preparation to define Instrument baseline for MCR
4. Around MCR, first issue of the EID-A with final budgets for AO
5. Mission Adoption ~2020: need to demonstrate TRL5/6 on critical technologies

Developing microfabrication techniques for fabricating “hybrid” arrays

Zoomed in image of two absorber types:





Need to optimize process for defining narrow gaps between pixels of different composition – ion-milling.

Hybrid Array Implications

Implications for fabrication and testing (not readout, FPA)

1) Tc of bilayer for SPA pixels may be different to Tc for LPA pixels ✔

2) Absorber composition desired for SPA different to LPA ✔

3) Ion-milling processing needed for minimum gaps between pixels in LPA & SPA ✔

4) Heat-sinking SPA different heat-sinking LPA. (✔)

5) More processing steps, therefore high yield needed. ✔

6) Routing of wires within arrays and to the transformer coils requires different algorithm. ✔

7) The count rate requirements/goals are different ✔

8) Properties of pixels under AC bias may be different for LPA & SPA. **?**

9) Pre-flight and in-flight calibration more time-consuming & challenging – need to make X-ray rates on both pixel types similar **(✔)**

Programmatic and personnel developments:

- CNES has a new management team and a new program schedule (see later slides).
  - We now have 6 additional months before the delivery of the microcalorimeters for the X-IFU development model (DM) (Dec. 2016).
  - There is no longer a need for calorimeters for an engineering model June 2017. This has been replaced with the need for a calorimeter array for the “DM-2” FPA, now Dec. 2017, essentially identical what was previously being developed for the EM.
  - These changes have almost no effect on our research program, as deliverables are still essentially the same, and previous schedule was extremely aggressive.

Other development activities taking place:

- TDM multiplexing (3 x 32) demonstration system (Lisa) evolved to allow observe X-ray through side-window.
  - System will ship to EBIT in early 2016.

- New TDM multiplexing demonstration being built and assembled
  - two new heat-switch types being developed
  - new salt pill being built
  - focal plane assembly "snout" identical to one in Lisa being purchased
  - new planar focal plane assembly also being developed

- High-speed TDM electronics developed at NIST, but needs further modifications to improve stability for use at GSFC

- Flight TDM electronics/firmware under development at GSFC

- Instrument control and data acquisition software continues to evolve