Challenges on ASTRO-H Calibration Plans

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R. Petre (NASA's Goddard)
J.-W. den Herder (SRON)

ASTRO-H Calibration Advisory Board

Calibration Advisory Board is established for ASTRO-H in order to help facilitate complex calibration plans which are to be executed in proper and efficient manner by instrument teams.

Three of us are appointed to serve for the purpose.

Software / Calibration Team (SCT led by Terada and Angelini) is established for the same concept.

Unofficial Remark: We are here to make the lives of instrument teams easier by providing advices on calibration when and where needed (on occasion, provide hard, physical labor…[→ Bish]).

ASTRO-H Calibration Plans

Having four instruments covering the energy range from 0.3 ~ 600keV, it is *crucial* for ASTRO-H to have good cross-calibration plans among instruments, as well as good calibration goals for each instrument.

We are here at this IACHEC to "give" you excellent opportunities to provide us insights on what you might do (differently) if you are to plan calibration activities for ASTRO-H.

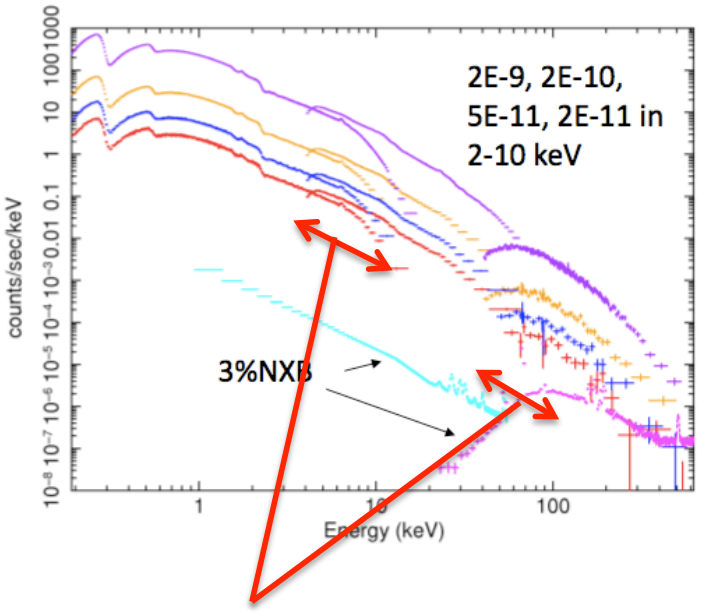
ASTRO-H Calibration Plans

How accurately can we cross-calibrate between SXI-SXS-HXI-SGD?

What actions are needed on ground and in flight to ensure high accuracies of calibration in the overlap regions?

Courtesy of Terashima-san

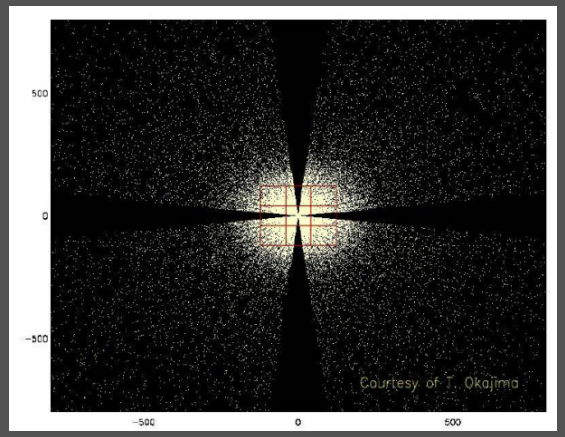
SXI + HXI + SGD simulation
Unabsorbed AGN

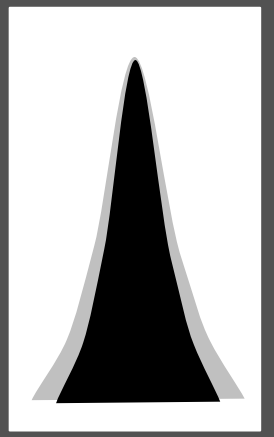


Cross-calibrate better to 5%? 10%?

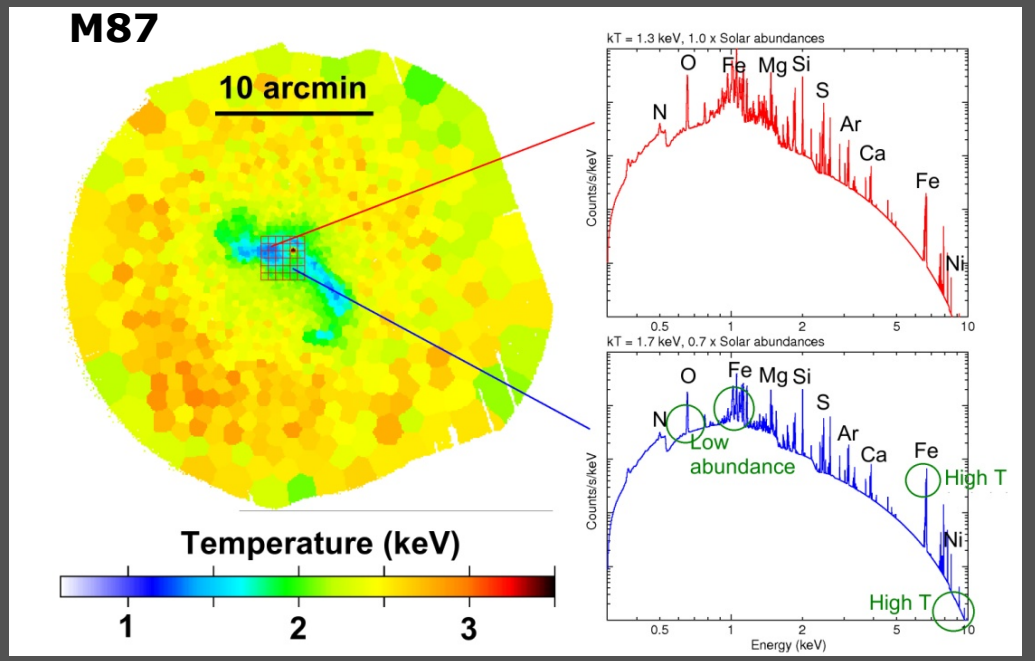
Convolution spatial & spectral response

- Spatial distribution not radial symmetric
- spectral & spatial redistribution not fully separated
- Fully exploit spectral response: know PSF with comparable accuracies; assess accuracy levels by modeling
- How to exploit accurate knowledge about source morphology (Chandra)





Broad PSF & RMF coupled in A-H



Energy Scale of Calorimeter

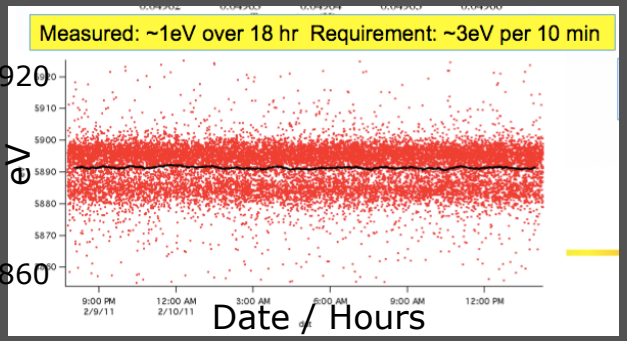
New challenge: < 2 eV accuracy

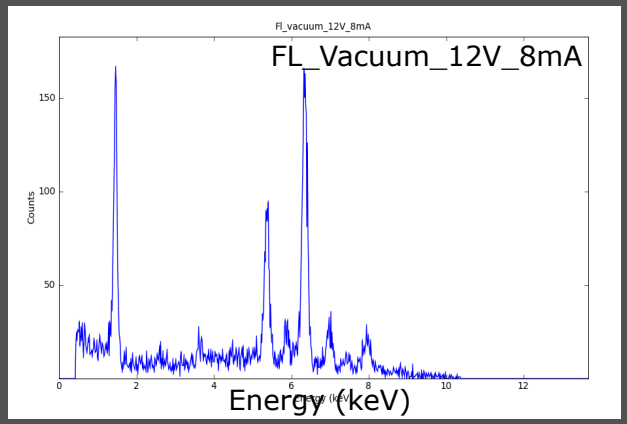
- Varies from pixel to pixel (thermal load on pixels)
- Accuracy of electronics at this level is also not guaranteed
- Time variable?

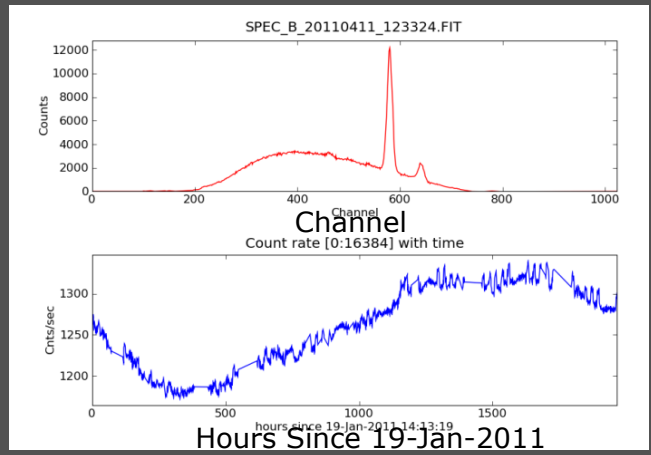
- XRS data show stability
- Modeling shows variations > 2 eV

New calibration source (MXS)

- Time modulated, high flux
- Employs image intensifier and 10 kV for electron impact on Cu (Ti/Cu, Cr/Cu) source
- Use same source for multiple lines from fluorescence target







SRON

Critical Cal to be done on ground (per instrument)

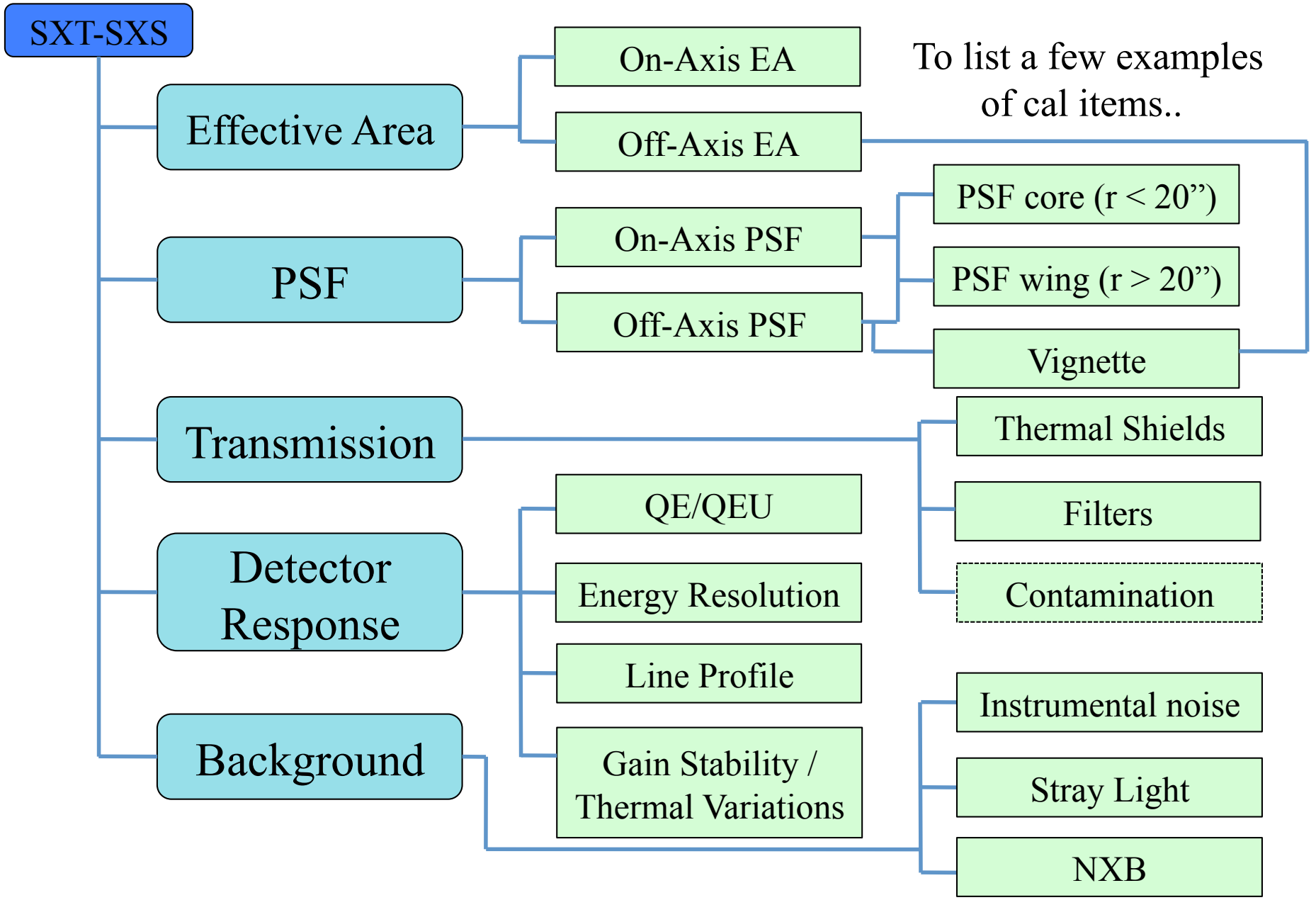
- Where do you like to spend more time for ground calibrations?
  - Detector mixed-grade (pile-up) model (high-res/mid-res for SXS) (it is easy to tune flux on ground instrument for testing)
  - Calorimeter gain versus system parameters (Telectronics, ..)
  - Mirror PSF shape (combining data with different flux to get good accuracy over full wings) for on and off-axis PSF
  - Energy dependence of PSF (monochromatic lines but at what low energies)
  - EXAFs (where they play a role)
  - Instrument cross calibrations: requires cal standard or a lot of time/work in orbit (source spectrum / mode dependent?)???
- Was there any ground calibration for XMM/Chandra which was a waste of time/resources?
- Which part of the ground calibration shouldn't we miss?

SRON

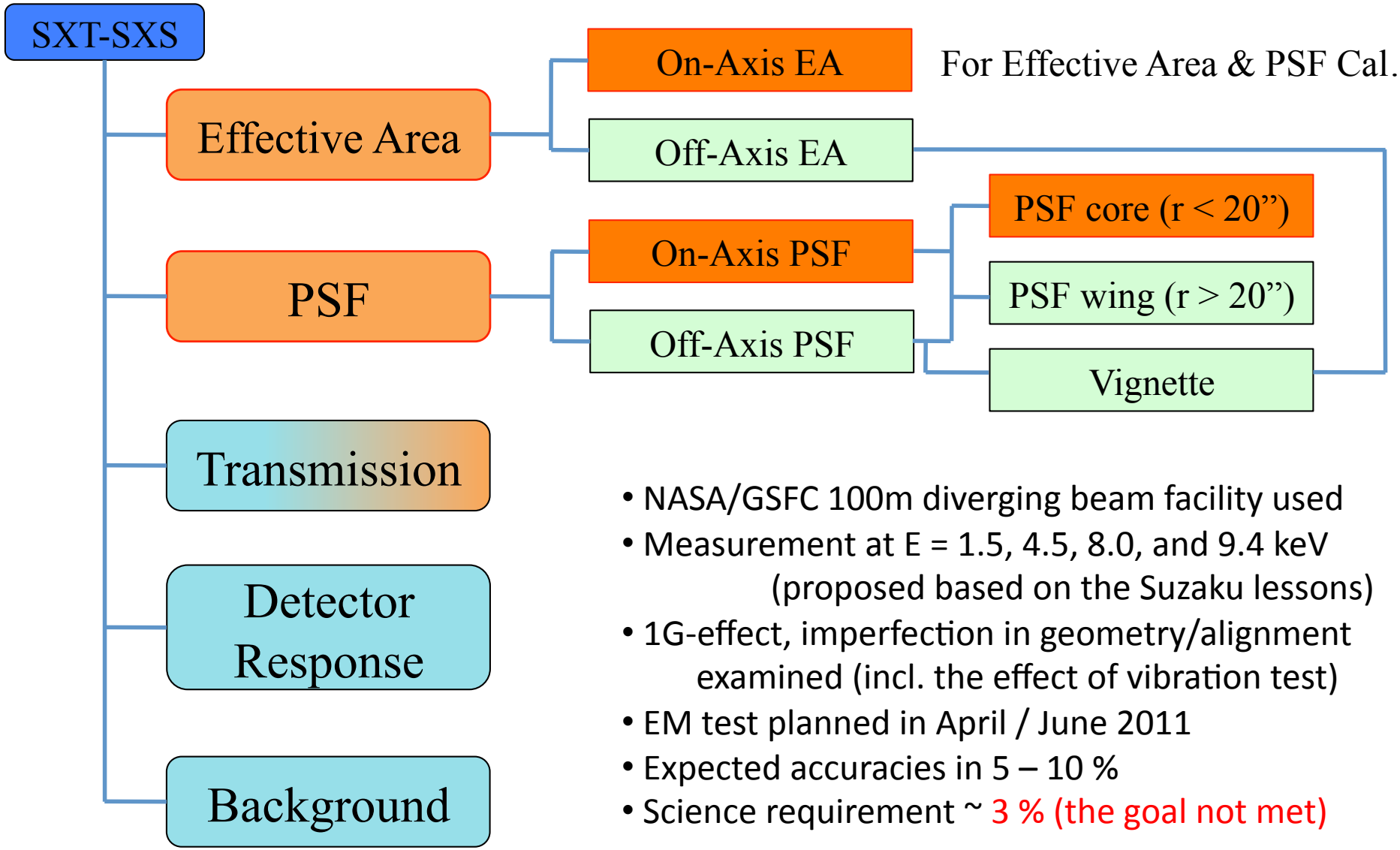
ASTRO-H Calibration Plan

Graphic Representation
of
ASTRO-H Calibration Plans

ASTRO-H: SXT – SXS Calibration Items

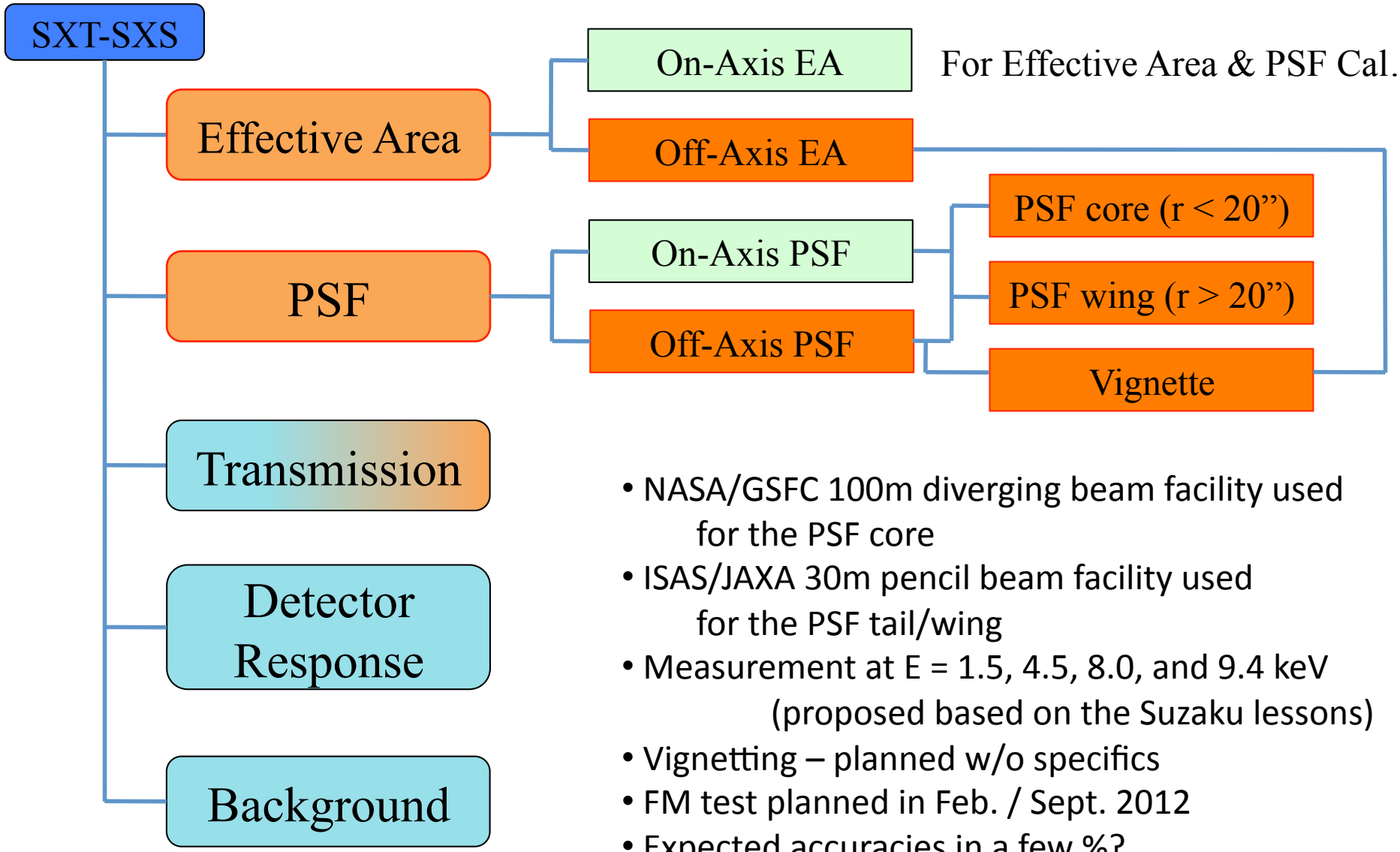


ASTRO-H: SXT – SXS Calibration Items



- NASA/GSFC 100m diverging beam facility used
- Measurement at E = 1.5, 4.5, 8.0, and 9.4 keV (proposed based on the Suzaku lessons)
- 1G-effect, imperfection in geometry/alignment examined (incl. the effect of vibration test)
- EM test planned in April / June 2011
- Expected accuracies in 5 – 10 %
- Science requirement ~ 3 % (the goal not met)

ASTRO-H: SXT – SXS Calibration Items

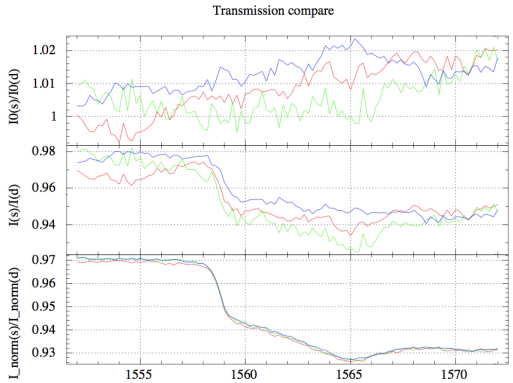


- NASA/GSFC 100m diverging beam facility used for the PSF core
- ISAS/JAXA 30m pencil beam facility used for the PSF tail/wing
- Measurement at E = 1.5, 4.5, 8.0, and 9.4 keV (proposed based on the Suzaku lessons)
- Vignetting – planned w/o specifics
- FM test planned in Feb. / Sept. 2012
- Expected accuracies in a few %?
- Science requirement ~ 3 % (the goal not met)

ASTRO-H: SXT – SXS Calibration Items

- SXT-SXS
  - Effective Area
  - PSF
  - Transmission
    - Thermal Shields
    - Filters
    - Contamination
  - Detector Response
  - Background

- SPring-8 BL25SU measurement conducted
- C-K, N-K, O-K, Al-K edges sampled at 0.2eV (see example at Al-K below); in 0.8 – 1.8keV at 10eV; otherwise (in 0.12 – 1.8keV) at 5 eV
- Measured accuracies: better than 1% in general

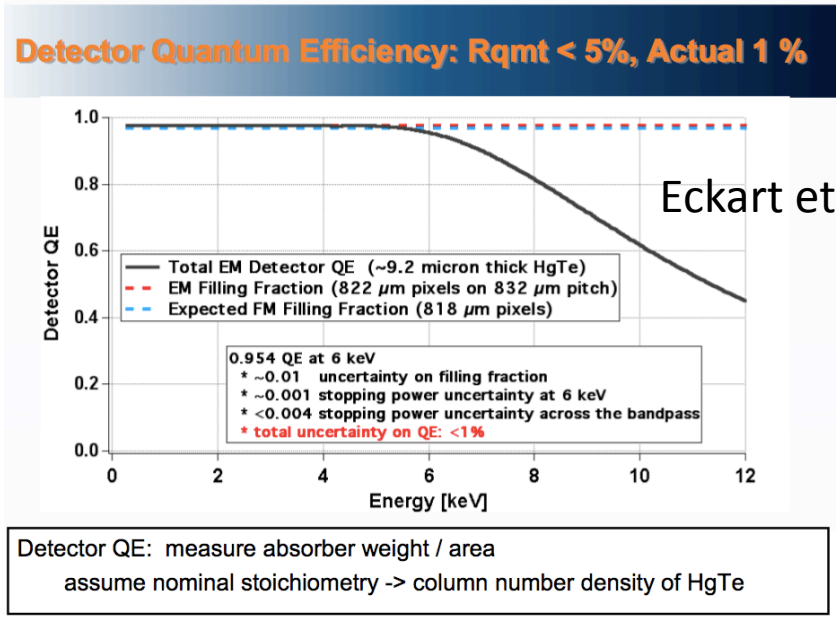


- Brookhaven/NSLS facility & LLNL/EBIT used for filter transmission
- Thickness verification & edge structure examined
- EM test in Apr 2011; FM test in Nov 2011
- Expected accuracies: < 5%

Uncertainty in transmission would affect that of EA.

ASTRO-H: SXT – SXS Calibration Items

- SXT-SXS
  - Effective Area
  - PSF
  - Transmission
  - Detector Response
    - QE/QEU
    - Energy Resolution
    - Line Profile
    - Gain Stability / Thermal Variations
  - Background



Eckart et al. 2011

Detector QE: measure absorber weight / area
assume nominal stoichiometry -> column number density of HgTe

EM absorbers: areal density 76 μg/mm^2 (<1% error)
Measured by Detectors Subsystem (Caroline Kilbourne et al.) prior to absorber attachment.

- NASA/GSFC facility used
- QE = Absorber weight / area
- Uncertainty in QE < 1 %
- Mission Requirement: < 5 %

ASTRO-H: SXT – SXS Calibration

- SXT-SXS
  - Effective Area
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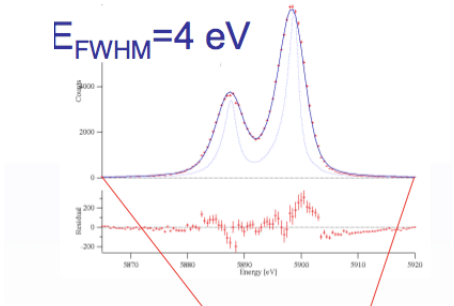
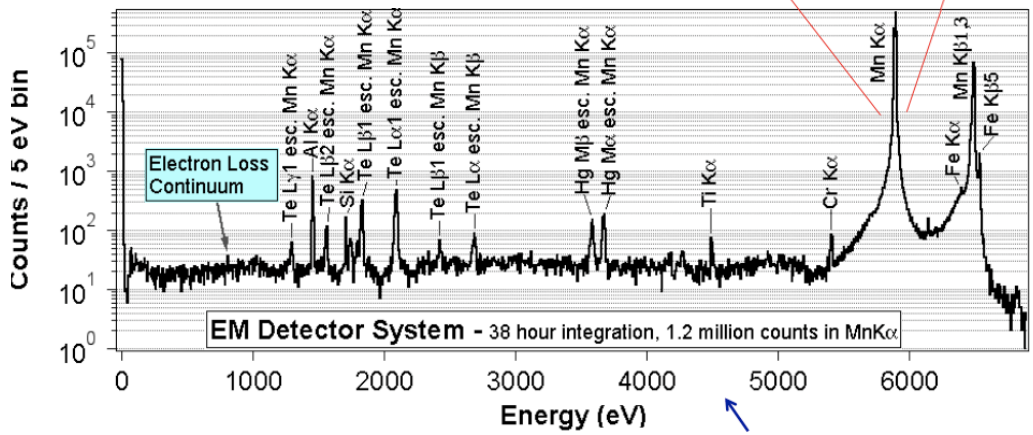


Eckart et al. 2011



- NASA/GSFC facility used
- σ_{FWHM} ~ +/-1eV (Goal 0.2eV)
- Gaussianity of profile expected
- Spectral redistribution
- Measure several energies in EM integration in May 2011
- Science Requirement: < 1.6eV

ASTRO-H: SXT – SXS Calibration Items

- SXT-SXS
  - Effective Area
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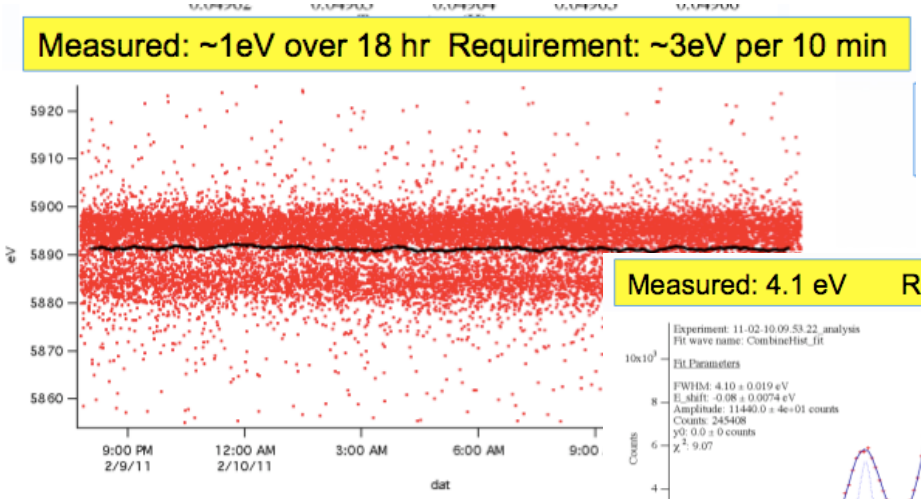
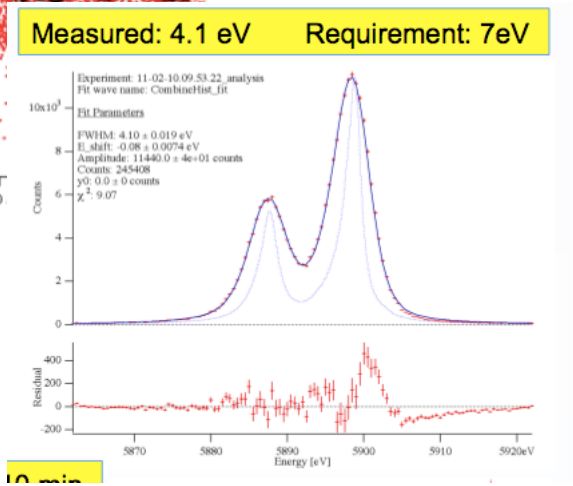
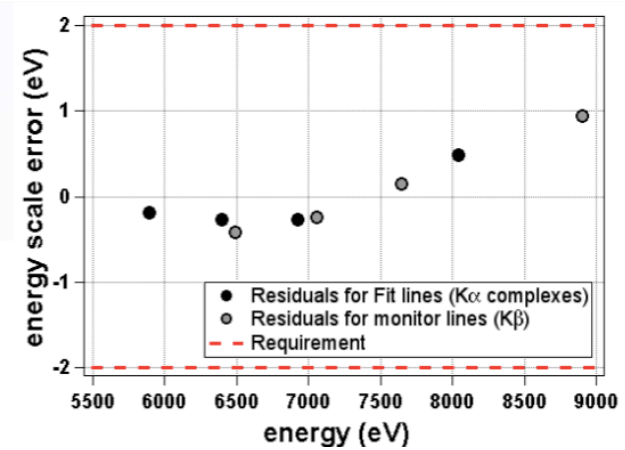


Kelley et al. 2011

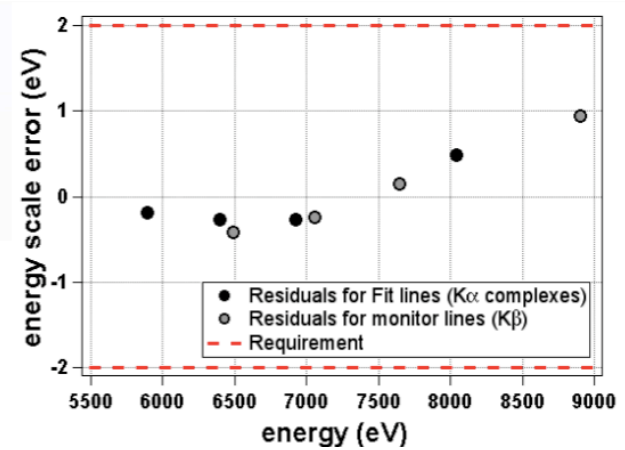




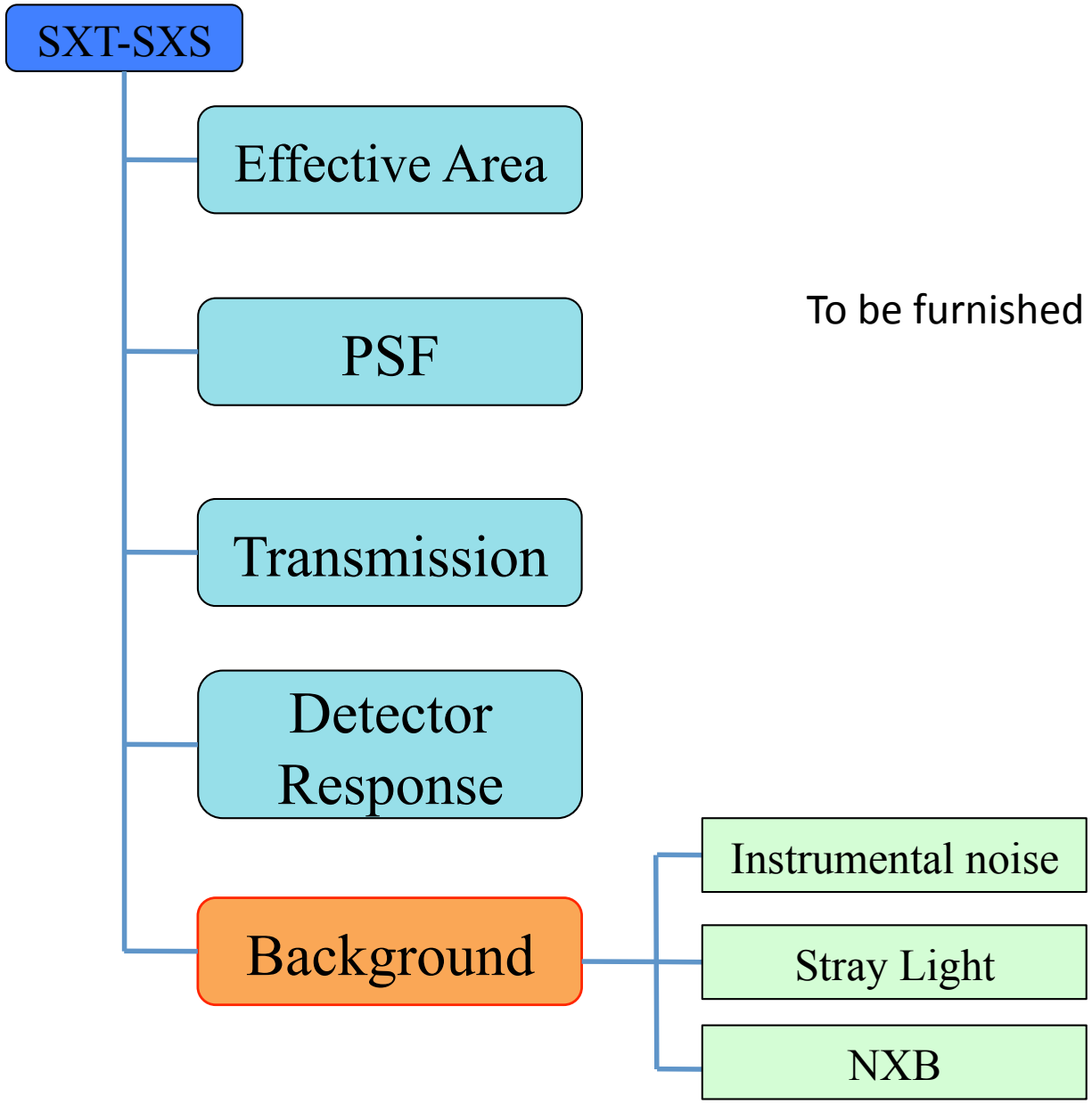
ASTRO-H: SXT – SXS Calibration Items

- SXT-SXS
  - Effective Area
  - PSF
  - Transmission
  - Detector Response
    - QE/QEU
    - Energy Resolution
    - Line Profile
    - Gain Stability / Thermal Variations
  - Background

- NASA/GSFC facility used (ISAS in later EM test)
- ΔE ~ +/-2eV (Goal 0.5 – 1 eV)
- Measure several energies in EM integration test in May / June 2011
- FM test planned in the same manner; more extensive in large matrix of operating conditions
- Use of Modulated X-ray Sources (MXS) in flight
- Science Requirement: 0.5 – 1 eV (marginally OK)

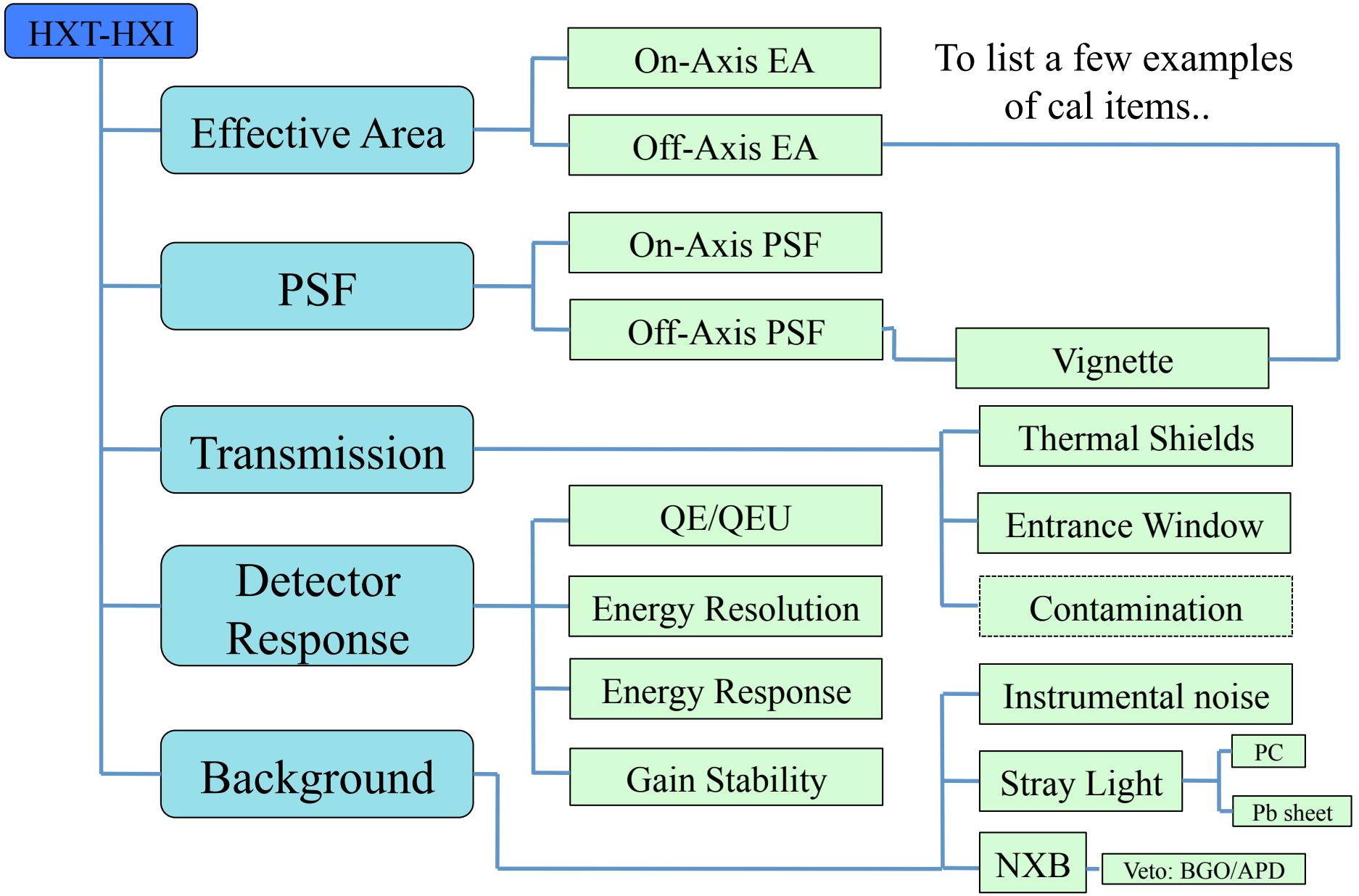


ASTRO-H: SXT – SXS Calibration Items

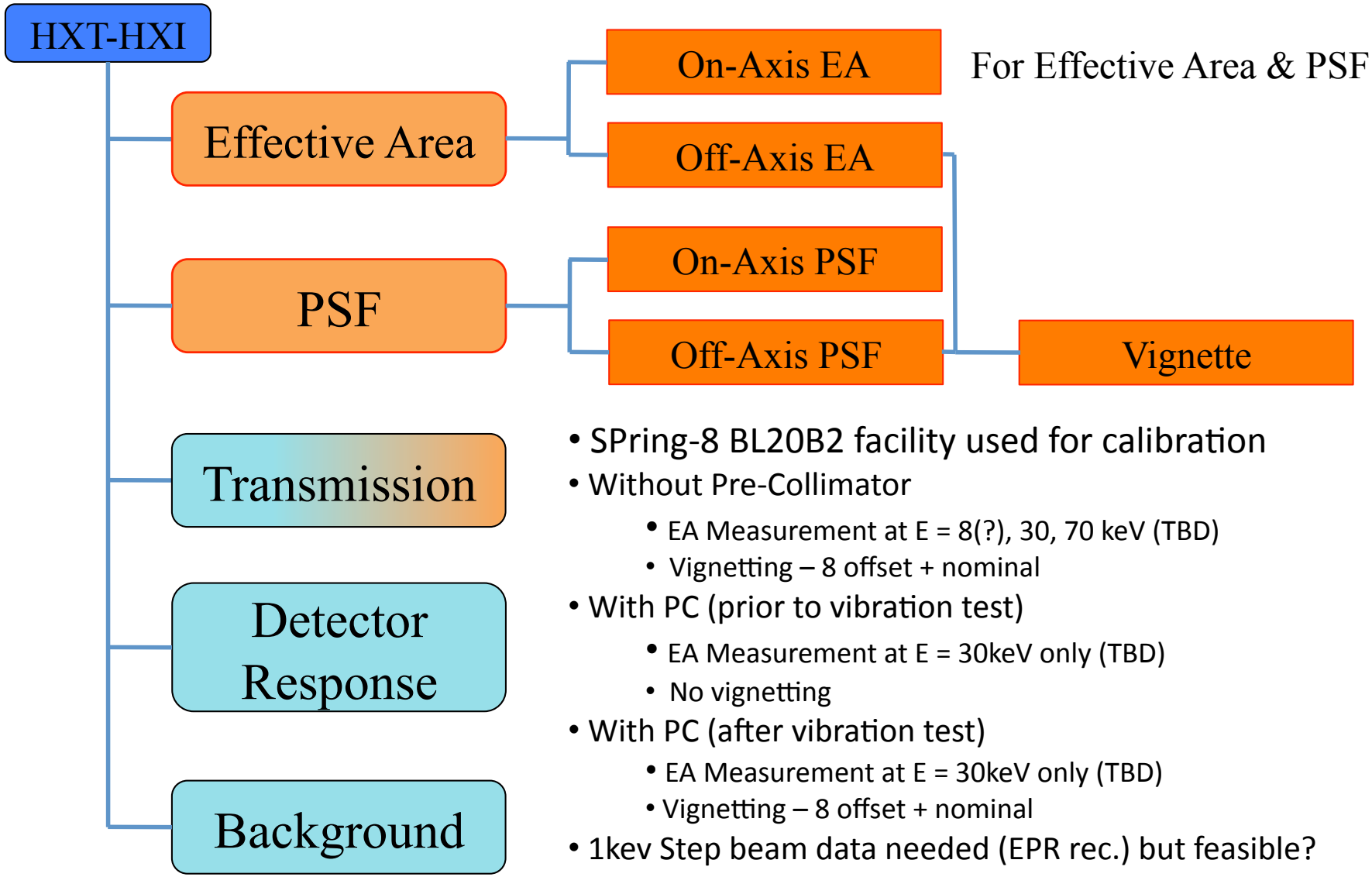


To be furnished later.

ASTRO-H: HXT – HXI Calibration Items



ASTRO-H: HXT – HXI Calibration Items



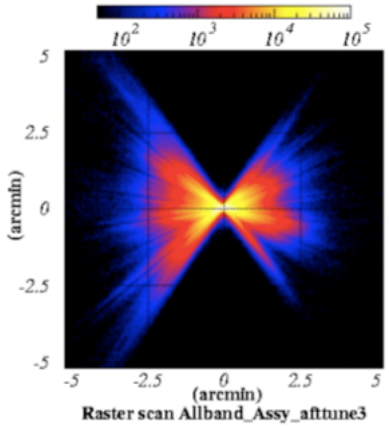
For Effective Area & PSF Cal…

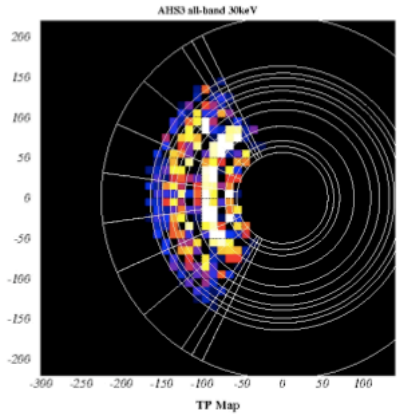
- SPring-8 BL20B2 facility used for calibration
- Without Pre-Collimator
  - EA Measurement at E = 8(?), 30, 70 keV (TBD)
  - Vignetting – 8 offset + nominal
- With PC (prior to vibration test)
  - EA Measurement at E = 30keV only (TBD)
  - No vignetting
- With PC (after vibration test)
  - EA Measurement at E = 30keV only (TBD)
  - Vignetting – 8 offset + nominal
- 1kev Step beam data needed (EPR rec.) but feasible?
- Expected accuracies in 5 – 10 % (TBD in flight)
- Science requirement ~ 5 % (marginal)

ASTRO-H: HXT – HXI Calibration Items

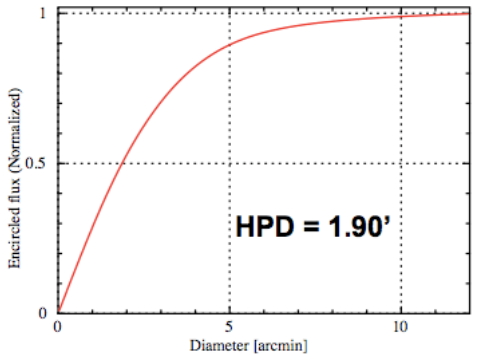
- HXT-HXI
  - Effective Area
    - On-Axis EA
    - Off-Axis EA
  - PSF
    - On-Axis PSF
    - Raster Scan All band 2ref. II
  - Transmission
  - Detector Response
  - Background

For Effective Area & PSF Cal…





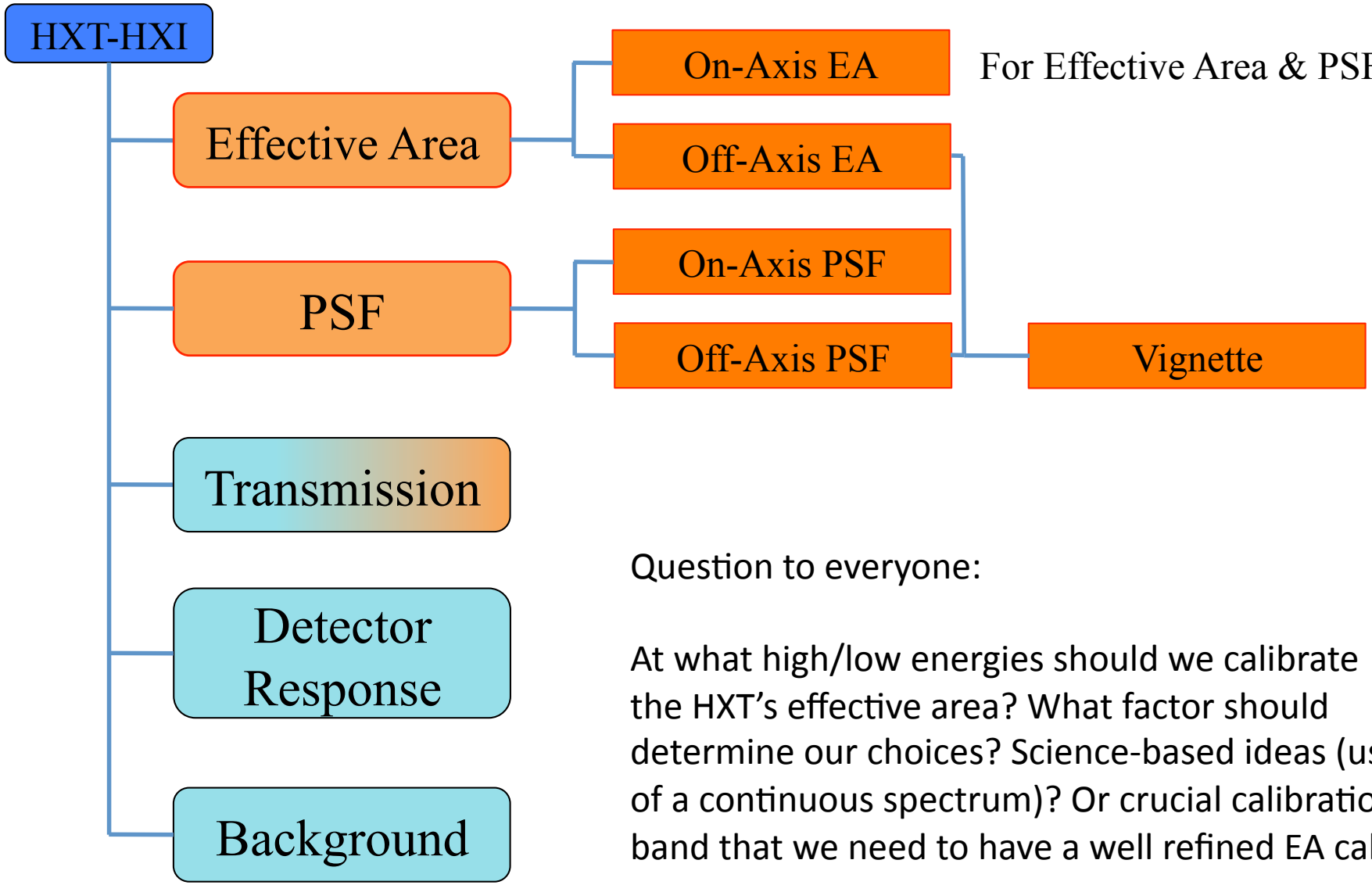
EEF Raster scan Allband Assy_afttune3 II



Preliminary Result From SPring-8:

Partial Raster Scan at 30 keV.

ASTRO-H: HXT – HXI Calibration Items

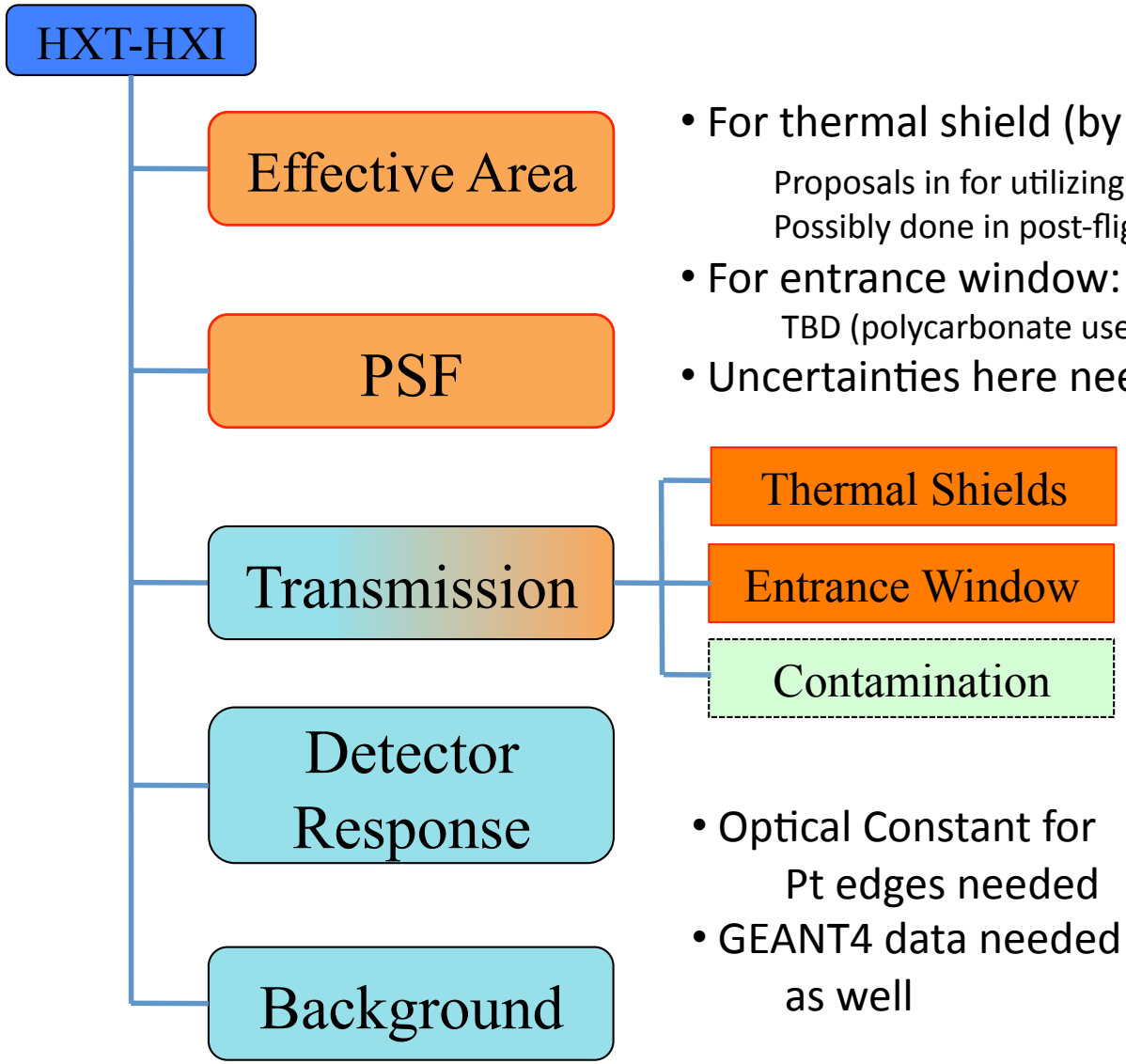


For Effective Area & PSF Cal…

Question to everyone:

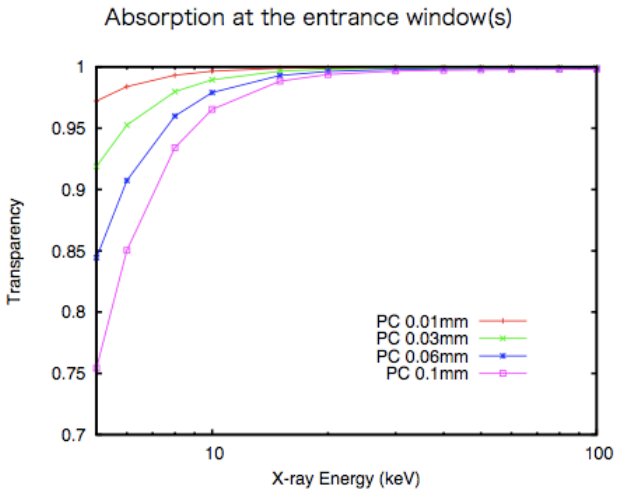
At what high/low energies should we calibrate the HXT's effective area? What factor should determine our choices? Science-based ideas (use of a continuous spectrum)? Or crucial calibration band that we need to have a well refined EA cal?

ASTRO-H: HXT – HXI Calibration Items



- For thermal shield (by Toh-Ray):
  - Proposals in for utilizing SPring-8 BL25SU and/or KEK/PF
  - Possibly done in post-flight with the same sample?
- For entrance window:
  - TBD (polycarbonate used in EM; evapolated Al in FM)
- Uncertainties here need to be accounted in EA

- Optical Constant for Pt edges needed
- GEANT4 data needed as well



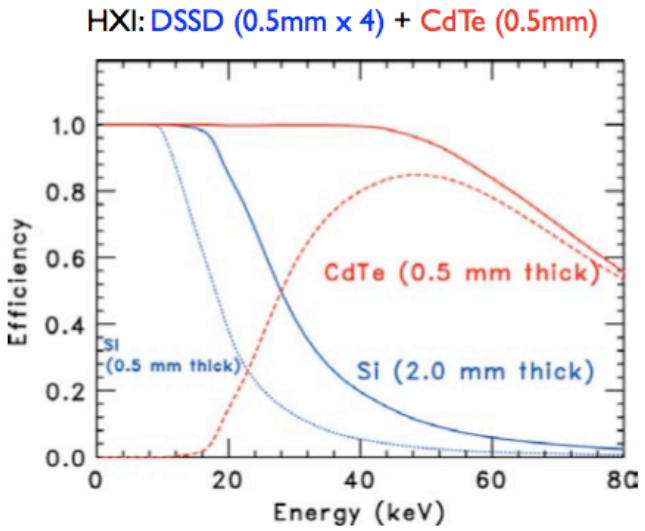
The current thickness of PC (30 um) is determined based on the calculation of probability of MMOD hitting in orbit.

ASTRO-H: HXT – HXI Calibration Items

- HXT-HXI
  - Effective Area
  - PSF
  - Transmission
  - Detector Response
    - QE/QEU
    - Energy Resolution
    - Energy Response
    - Gain Stability
  - Background

- ISAS/JAXA facility used

- Uncertainty in QE: TBD
- Science Requirement in EA: 5 %



We have changed the thickness of CdTe to 0.75 mm. This results higher efficiency at the high energy range, together with an increase of background.

ASTRO-H: HXT – HXI Calibration Items

- HXT-HXI
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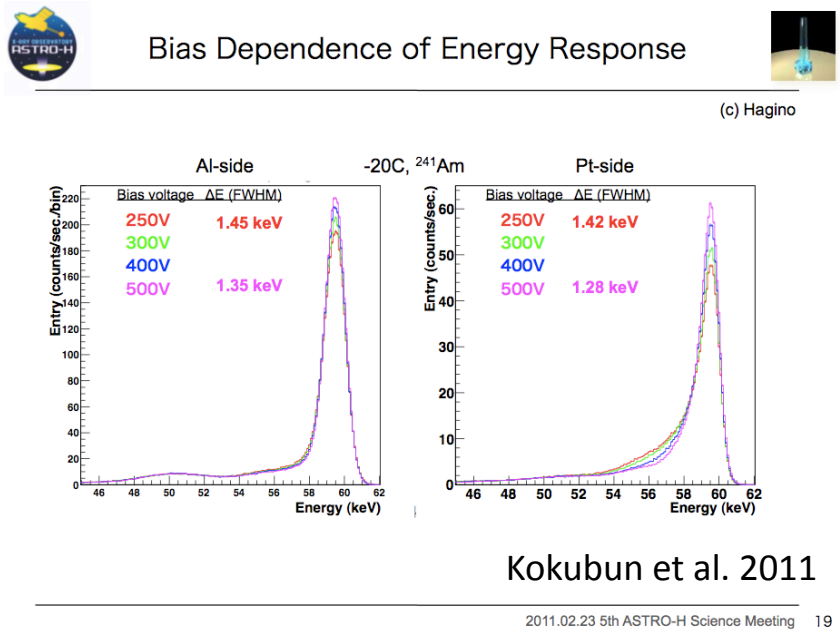
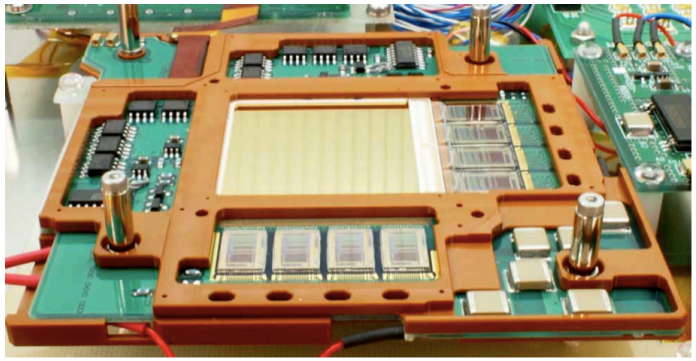


- ISAS/JAXA facility used
- E_{FWHM} at 60keV:
  - Si ~ 1.1 keV
  - CdTe ~ 1.4 (Al) & 1.3 (Pt) keV
- Science Requirement: ~ 1keV?

ASTRO-H: HXT – HXI Calibration Items

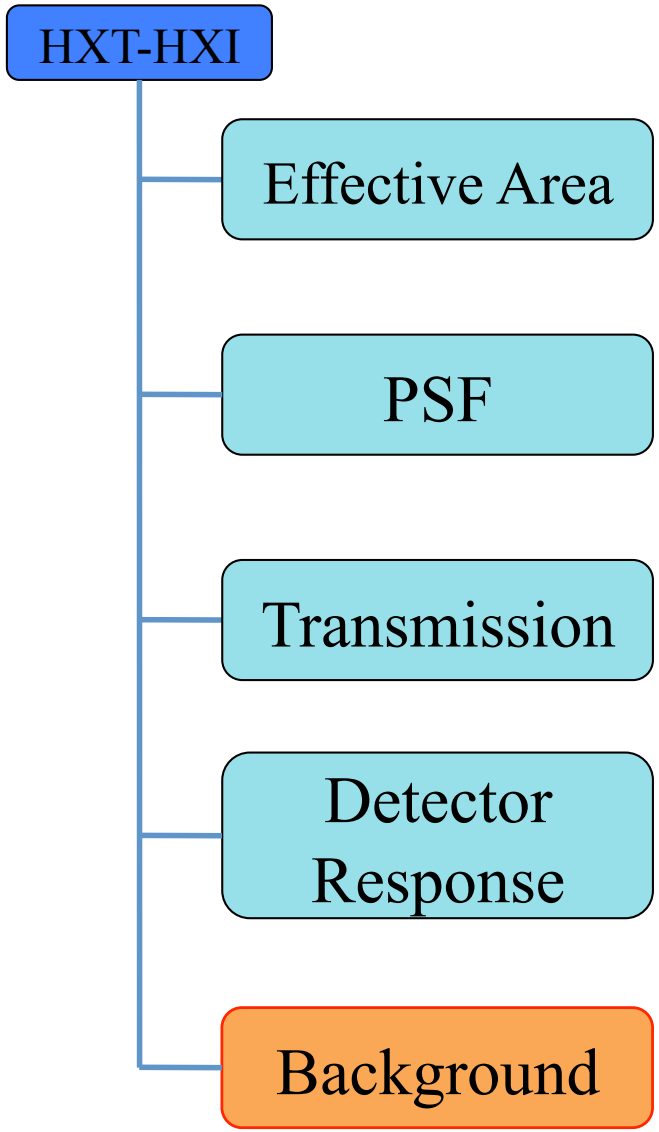
- HXT-HXI
  - Effective Area
  - PSF
  - Transmission
  - Detector Response
    - QE/QEU
    - Energy Resolution
    - Energy Response
    - Gain Stability
  - Background

- ISAS/JAXA facility used
- Test Pulse Injector in ASIC to monitor gain variations in the HXI-DE
- Uncertainty in gain: TBD
- Science Requirement: 3 %? (seems poor)



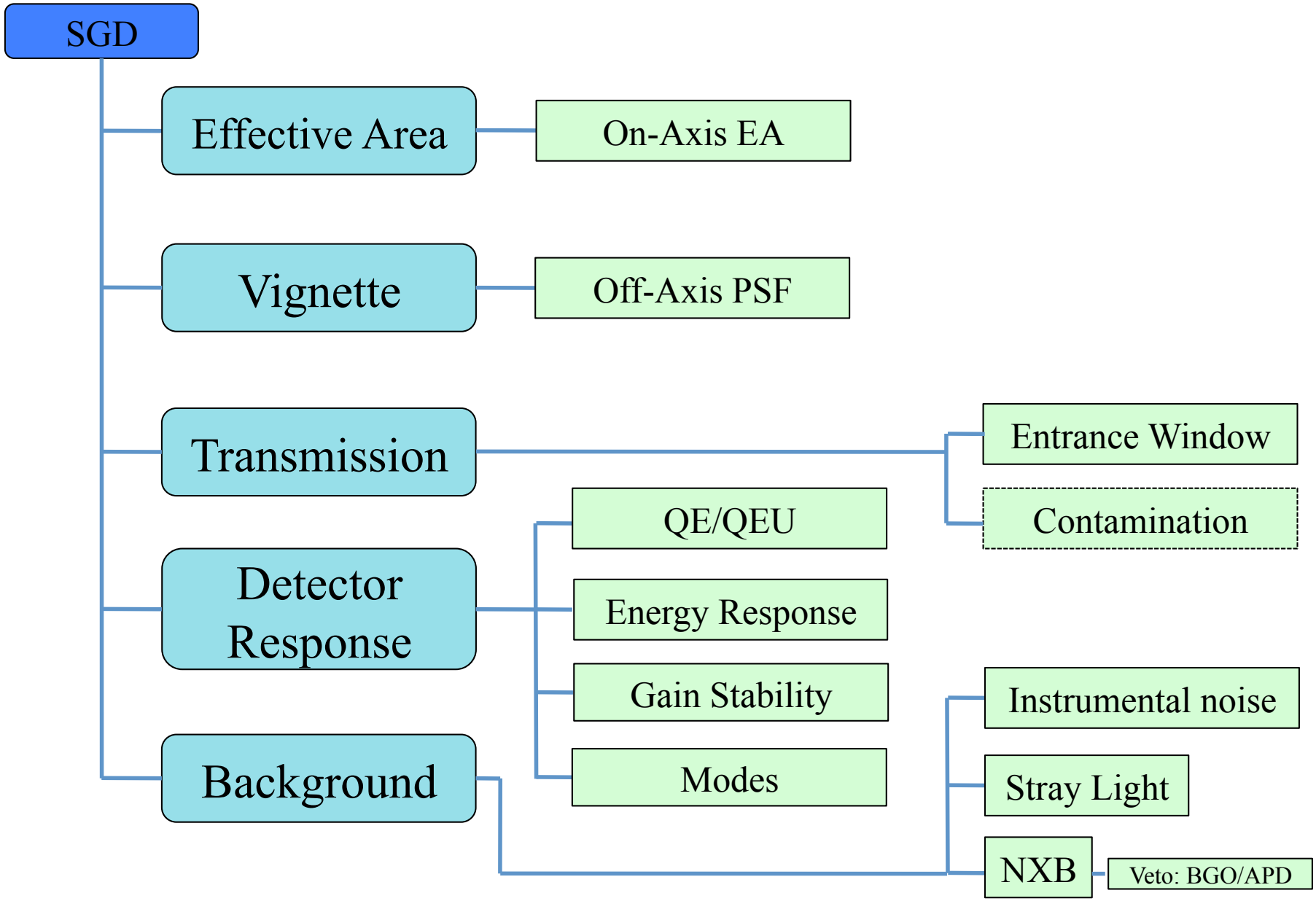
3.4 cm wide CdTe diode detector (Al/CdTe/Pt type), 0.75 mm thick
250μm strip pitch, 200μm wide strip electrodes
128 strips on each side, imaging area 3.2 cm x 3.2 cm

ASTRO-H: Calibration Items



To be furnished later.

ASTRO-H: Calibration Items



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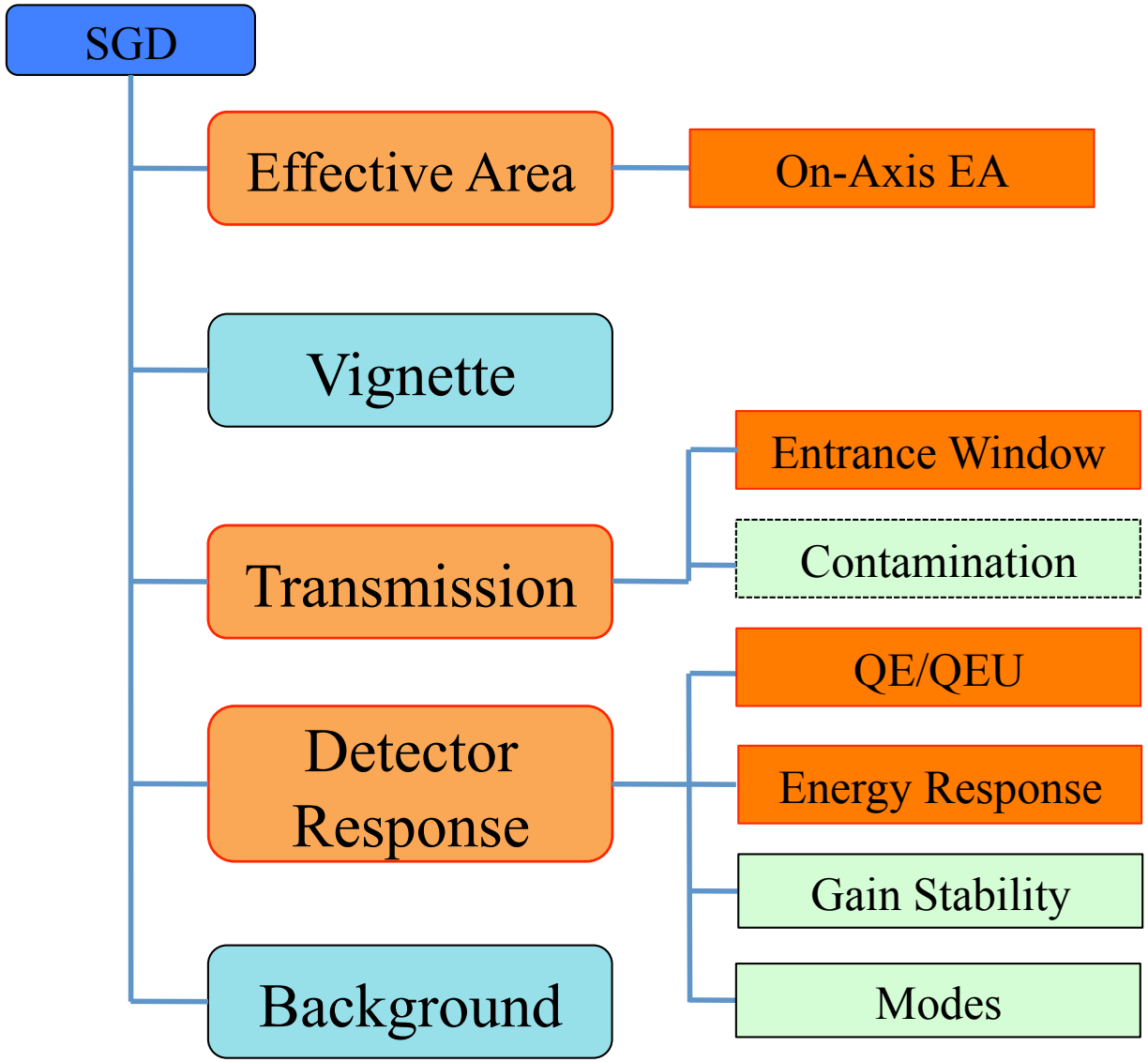


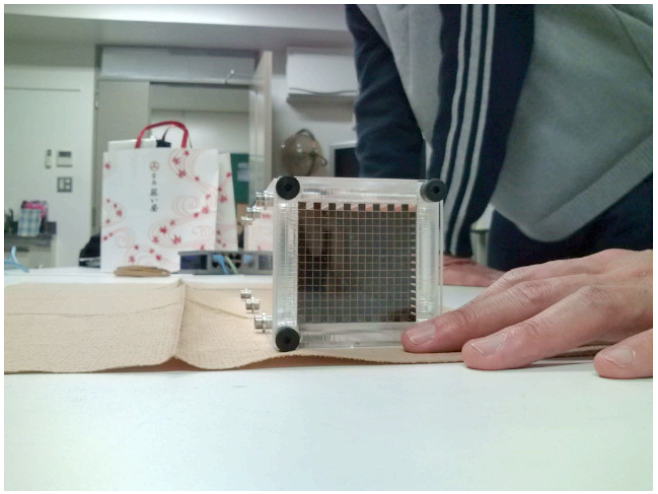
- 36864 channels to be calibrated
  - Each detector pad to be calibrated separately with radioactive sources (^{241}Am, ^{57}Co, ^{22}Na, ^{137}Cs).
  - line channel checked for each pixel to correct for gain
  - line strength checked for effective EA (+ QE).
  - Can be done at any site with radioactive sources, clean room, etc.
- The whole 36864 channels after integration
  - Ditto as above, but with difficulties in reduction of flux by fine-collimator…
- Test pulse injection in ASIC used for gain correction in electronics.

ASTRO-H: Calibration Items

- SGD
  - Effective Area
  - Vignette
    - Off-Axis PSF
  - Transmission
  - Detector Response
  - Background

- Fine Collimator
  - Structural measurements (distortion, gap / shift in welding points, etc)
  - Precise 3-D info to be fed into GEANT4 model

Fine Collimator (BBM)



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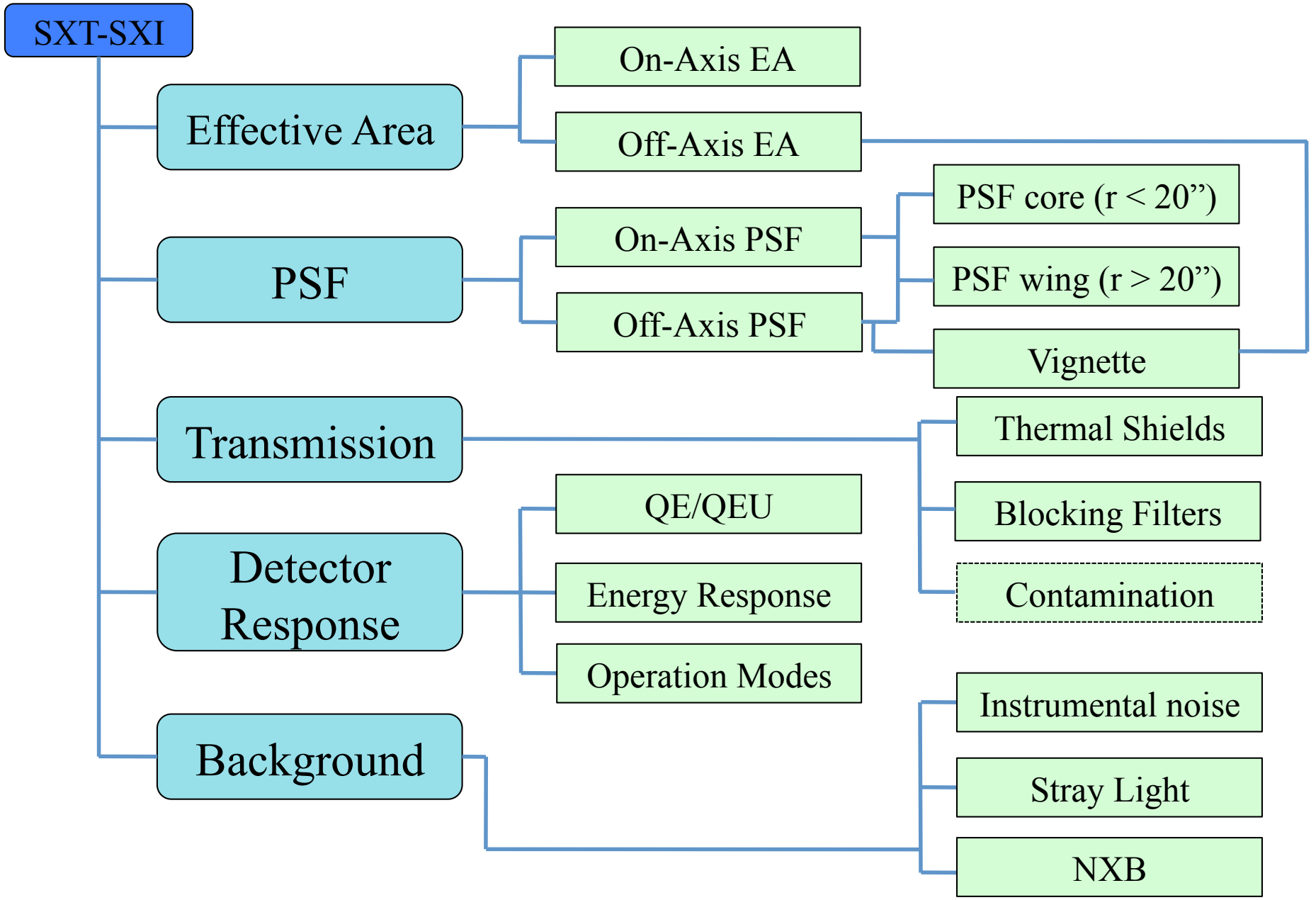

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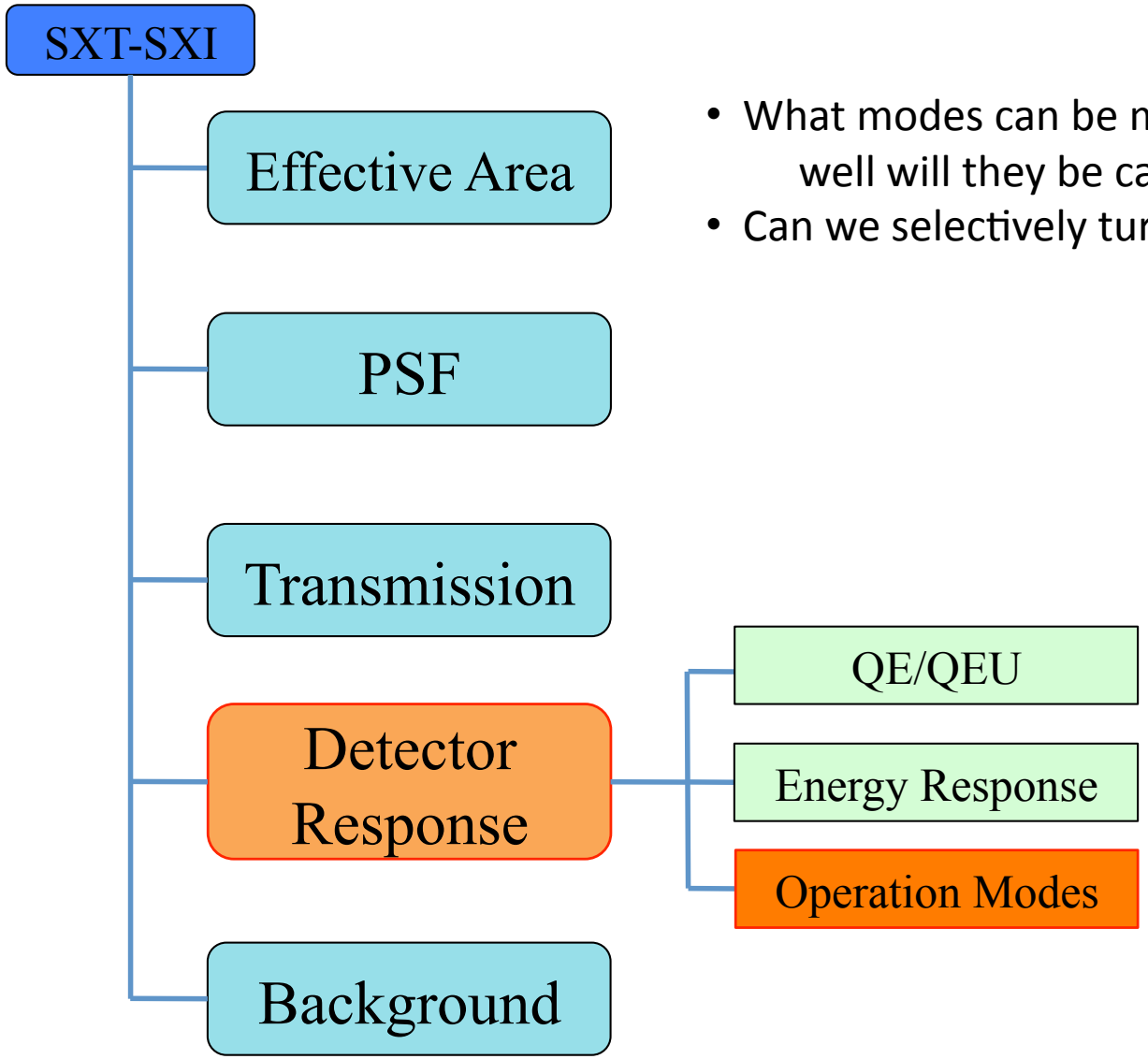

- What modes can be made available and how well will they be calibrated prior to or in flight.
- Can we selectively turn off CCD chips not needed?

ASTRO-H Calibration Plan

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