# Future Missions of Space X-ray Astronomy in China

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# Outlines

- My career-long connections with Ruediger Staubert
- The Hard X-ray Modulation Telescope (HXMT) satellite mission
- The Wide-field Imaging Multi-band Spectrometer (WIMS) mission aboard China's future spacelab
- China's mid-long term plan for science and technology Sciences

# My Career-Long (short) Connections with Ruediger

- I first met Ruediger in 1988 in Beijing, China, when I was called back from Southampton to meet “special guests”
  - I guided Ruediger and his wife to tour the Forbidden City and several other places; after the tour I said goodbye and see you soon!
- Then I visited Tuebingen several months later and learnt what a laboratory should be.
- After retuning to astronomy in 1992 as a BATSE team member from my postdoc research in particle physics, I have been running into Ruediger frequently at various meetings.
  - The most exciting one was our exploration of the mountains/beaches at Port Douglas in 1998.
- Some quotes from Ruediger:
  - “I don’t know hoe close this beach is to heaven, but very close!”
  - “Snorkeling is the second best thing in the universe after ?????.”
  - “Instrumentalists deserve and are qualified doing science”

# Congratulations and thanks to Ruediger from China

- Ruediger has helped China's experimental X-ray astronomy since mid-1980's when China just started developing scientific ballooning and flying simple hard X-ray detectors.
  - The HXMT mission is a direct consequence of that program.
- My colleagues (Li, Gu, Wu, Ma and many others) in China ask me to express our
  - Warmest regards for his 65$^{th}$ birthday
  - Sincere congratulations for his exciting and distinguished achievements
  - Deep appreciations for his help to China
- On behalf of the Laboratory for Particle Astrophysics (IHEP, Chinese Academy of Sciences) and Center for Astrophysics (Tsinghua University), I would like to invite Ruediger to spend more time in China after his "retirement" from Tuebingen.
  - To promote and work on future Germany-China collaborations on space X-ray astronomy

# Current Status of the HXMT Mission

- Hard X-ray Modulation Telescope (HXMT)
  - 973 Major State Basic Research Project in China since April 2000 (Scientific Definition and Technology Demonstration Phase)
    - Total about $5M
  - Principal Investigator: Prof. Li, Tipei
    - Assistant Principal Investigator: myself since 2002
  - Main participating institutions:
    - Chinese Academy of Sciences:
      - *Institute of High Energy Physics*
      - *Center for Space Science and Application Research*
    - Tsinghua University: *Astrophysics Center*, *Physics Department*, *Engineering Physics Department*, *Space Center*
  - Currently applying for full satellite mission
    - Full mission cost about $50M

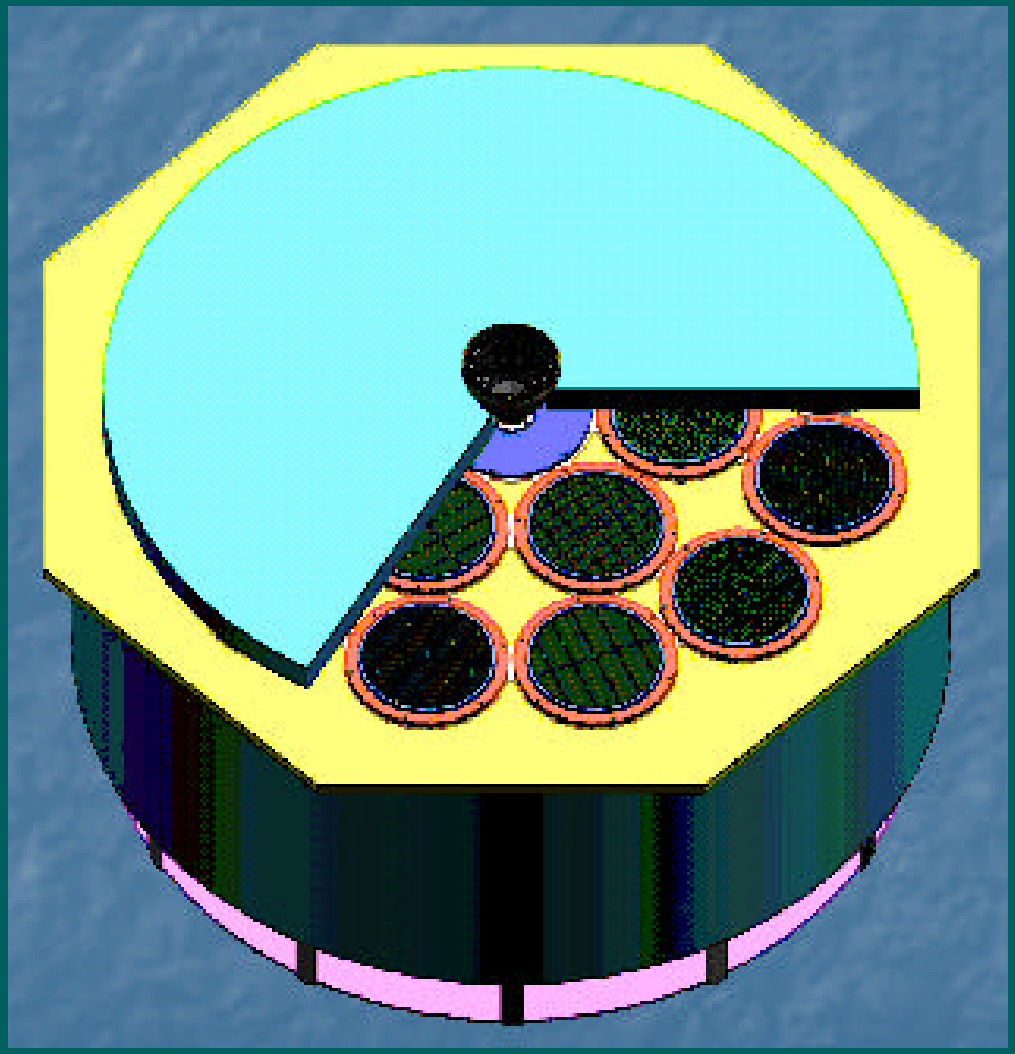
# Main Scientific Goals

- Main Scientific Goals
  - Deep hard X-ray all-sky survey between 20-250 keV
    - Seyfert II AGNs
    - Quasars
    - Galactic Plane Diffuse X-ray Emission
  - Pointed observations of faint objects
    - Seyfert AGNs
    - Quasars
    - X-ray binaries
  - High sensitivity timing studies
    - X-ray binaries

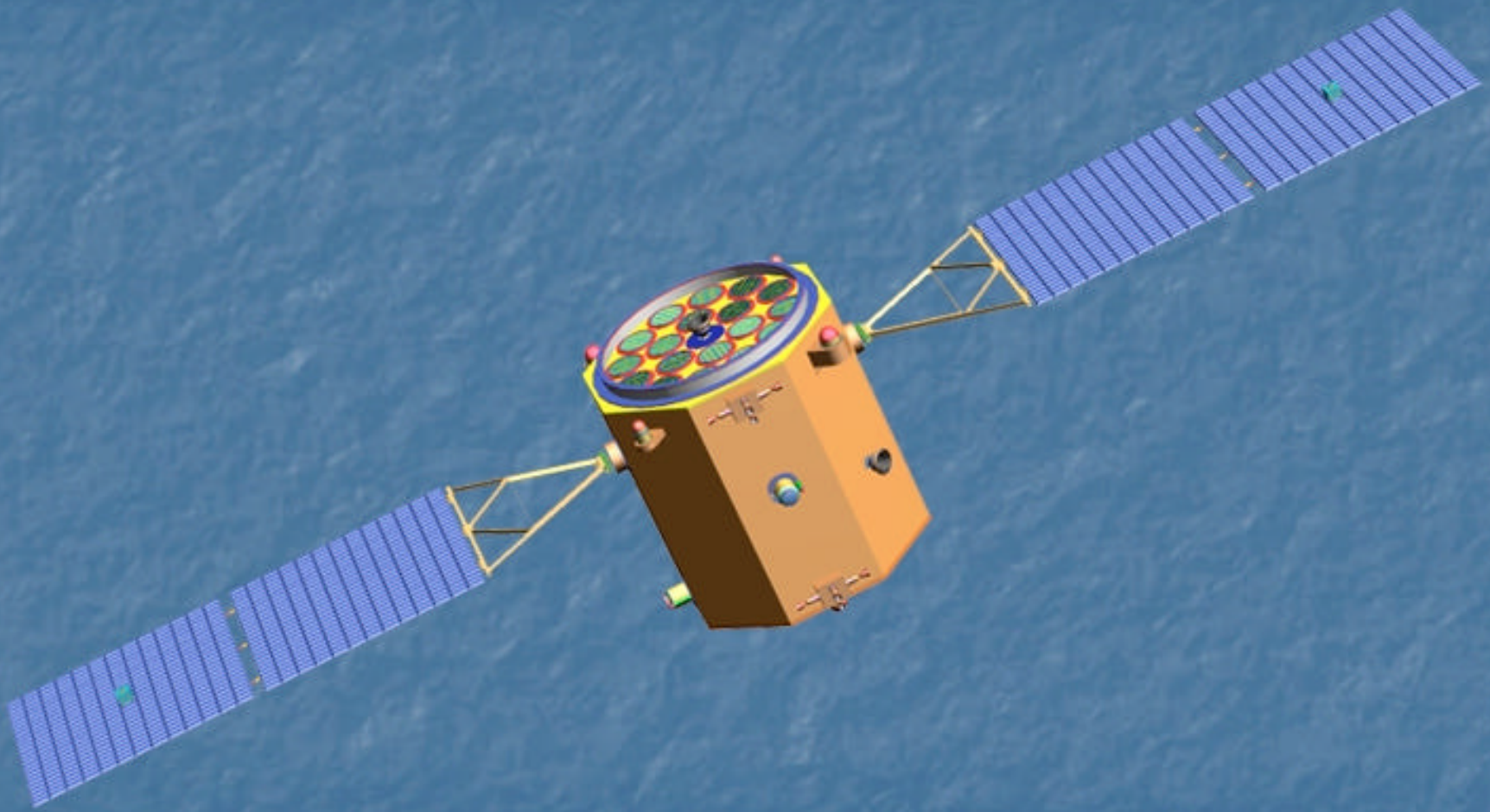
# Characteristics of the HXMT Mission

- Main Detector NaI(Tl)/CsI(Na) Phoswich
- Total Detect Area ~5000 $cm^2$
- Energy Range 20~250 keV
- Energy Resolution ~22% (@60keV)
- Continuum Sensitivity ~3.0×10-7 ph cm-2 s-1 keV-1 (3s@100keV,$10^5$s)
- Field of View 5.7°x 5.7°( FWHM)
- Source Location =1 arcmin(20σ)
- Angular Resolution =5 arcmin(20σ)
- Mass ~1100kg (payload ~700 kg)
- Dimension 1.7×1.7×1.2m (L×W×H)
- Nominal Mission lifetime 2 years
- Orbit Altitude 550km, Inclination 43°
- Attitude Three-axis stabilized
  Control precision: ±0.25°
  Stability: 0.005 °/s
  Measurement accuracy: <0.01°

# HXMT Telescope

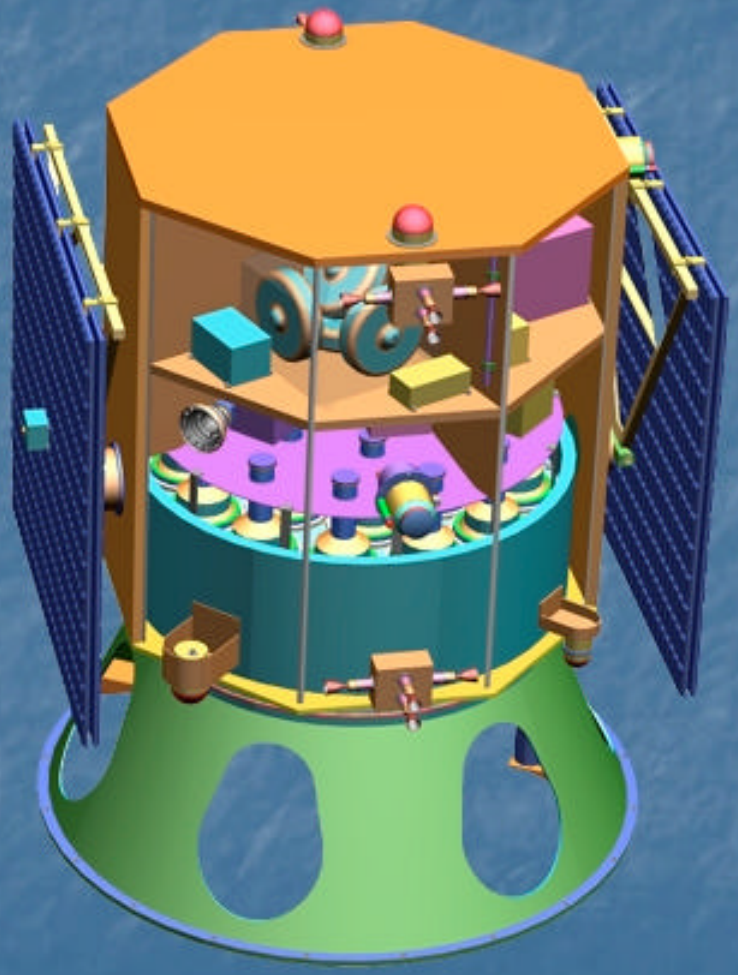


# Structural Configuration (In the orbit)



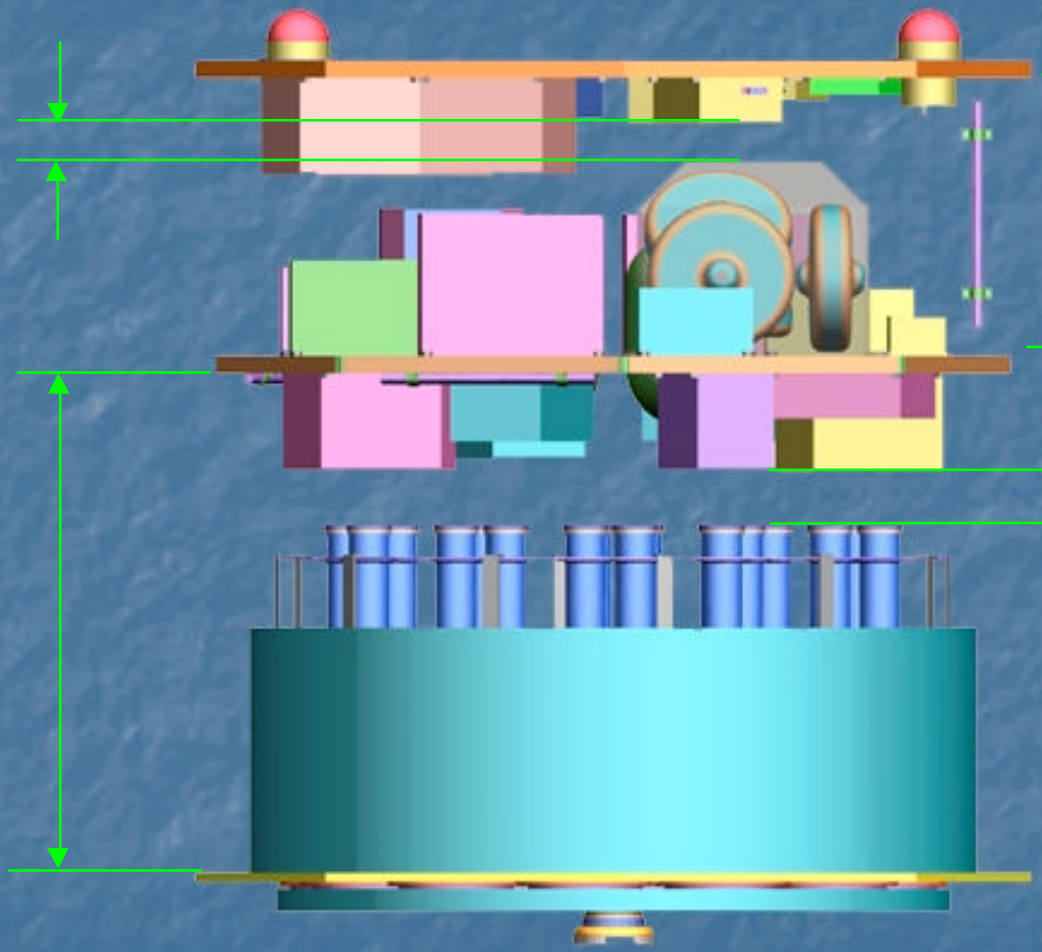
# Structural Configuration

## Launch State with 3 Side-Plates Removed



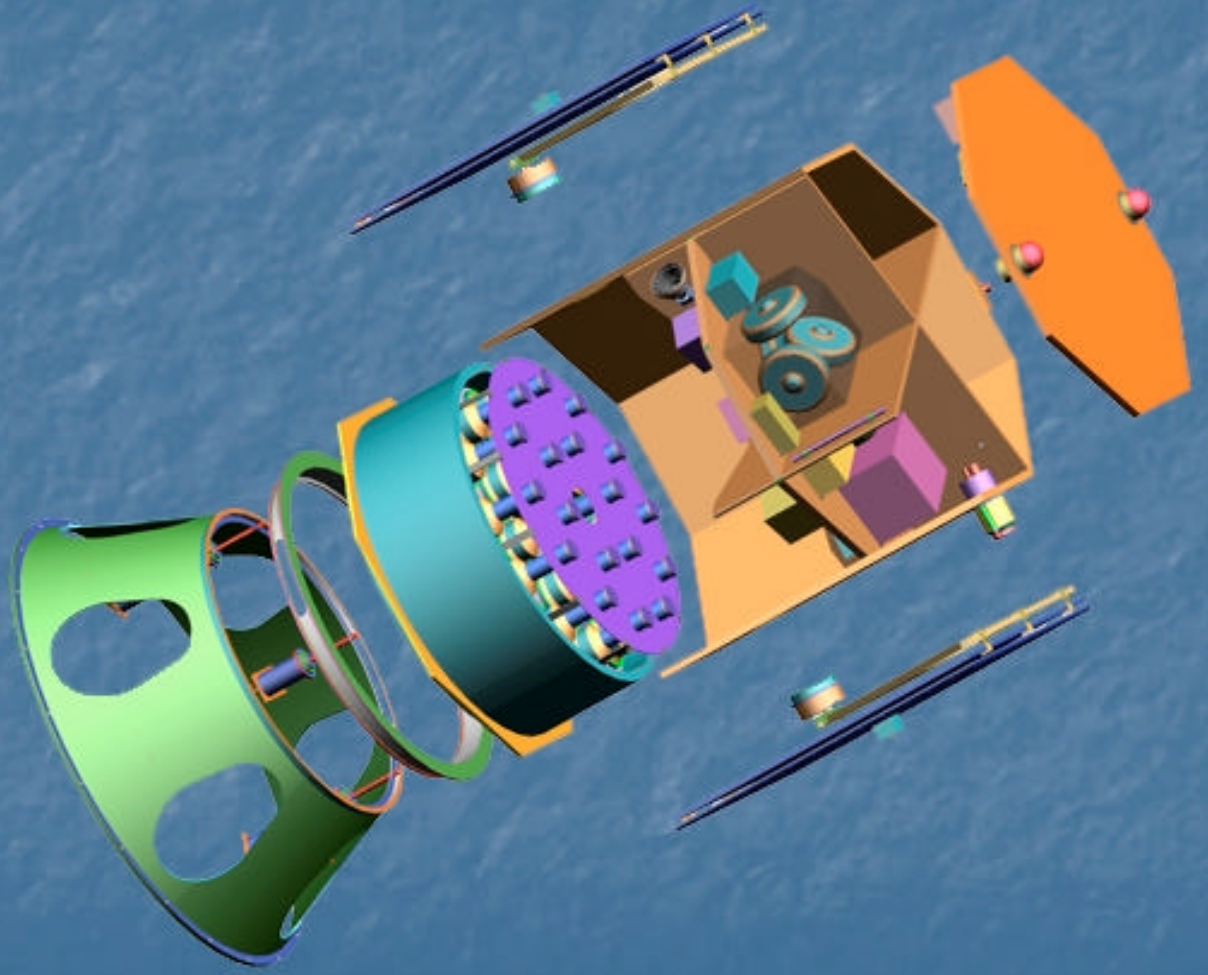
# Structural Configuration

## Instruments Arrangement and 2-D Dimensions



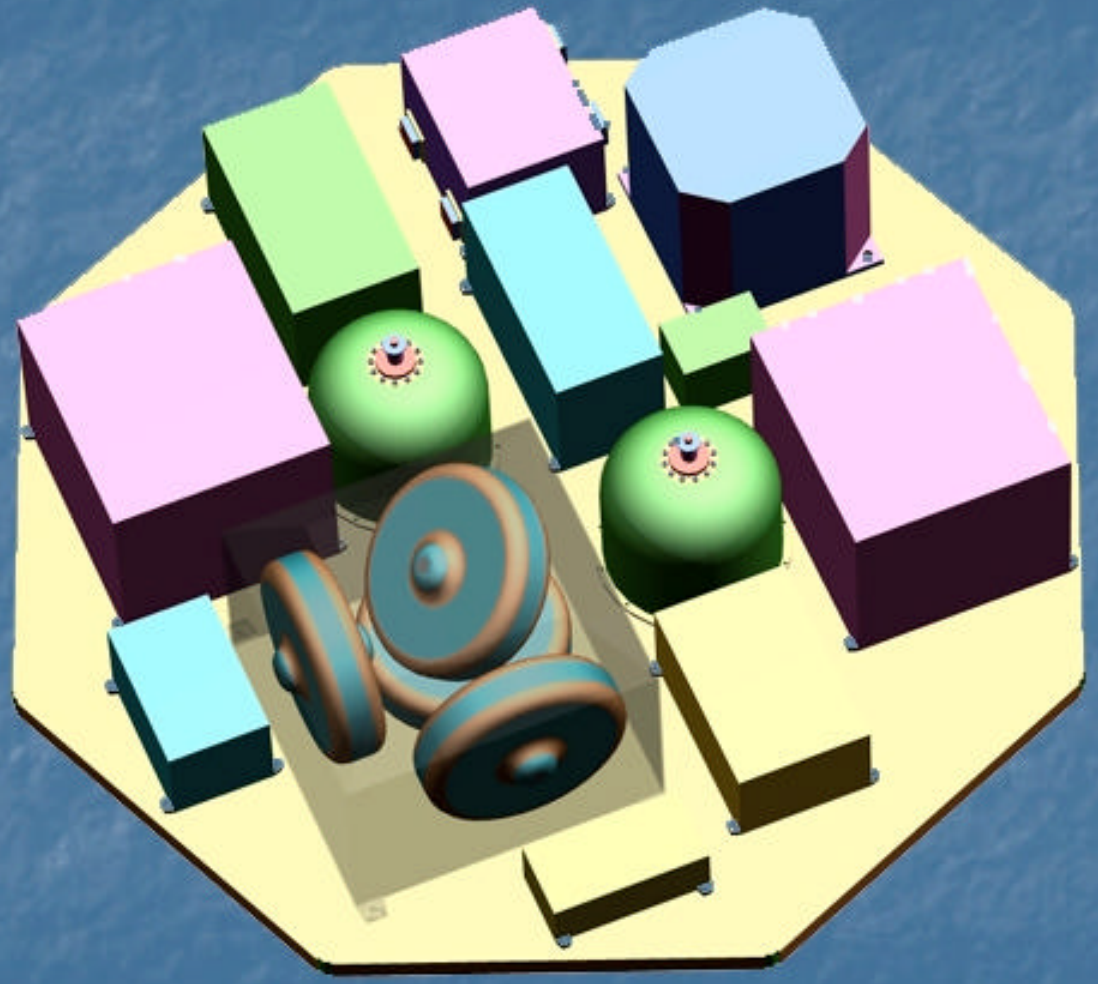
# Structural Configuration

## Exploded View



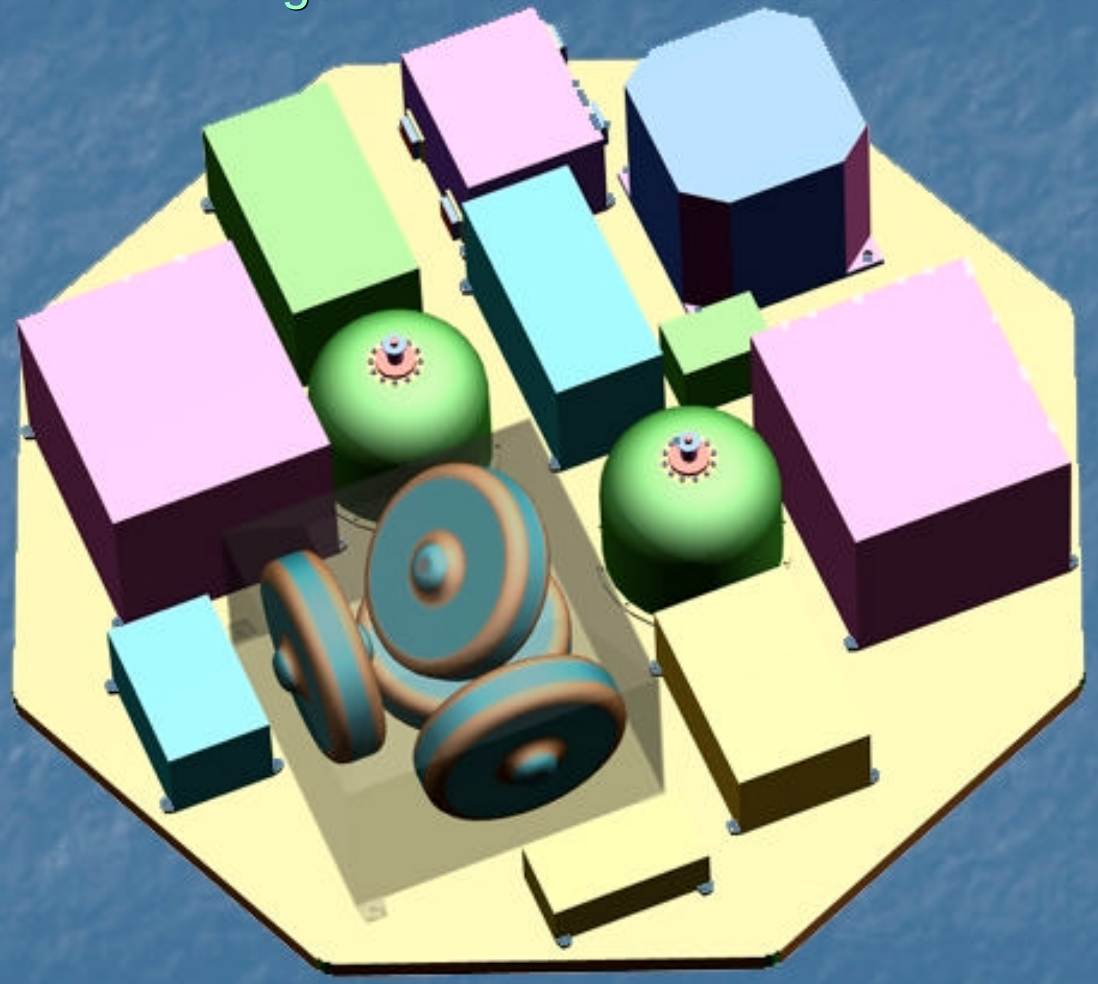
# Structural Configuration

## Instruments Arrangement on Top Surface of Mid-Plate



# Structural Configuration

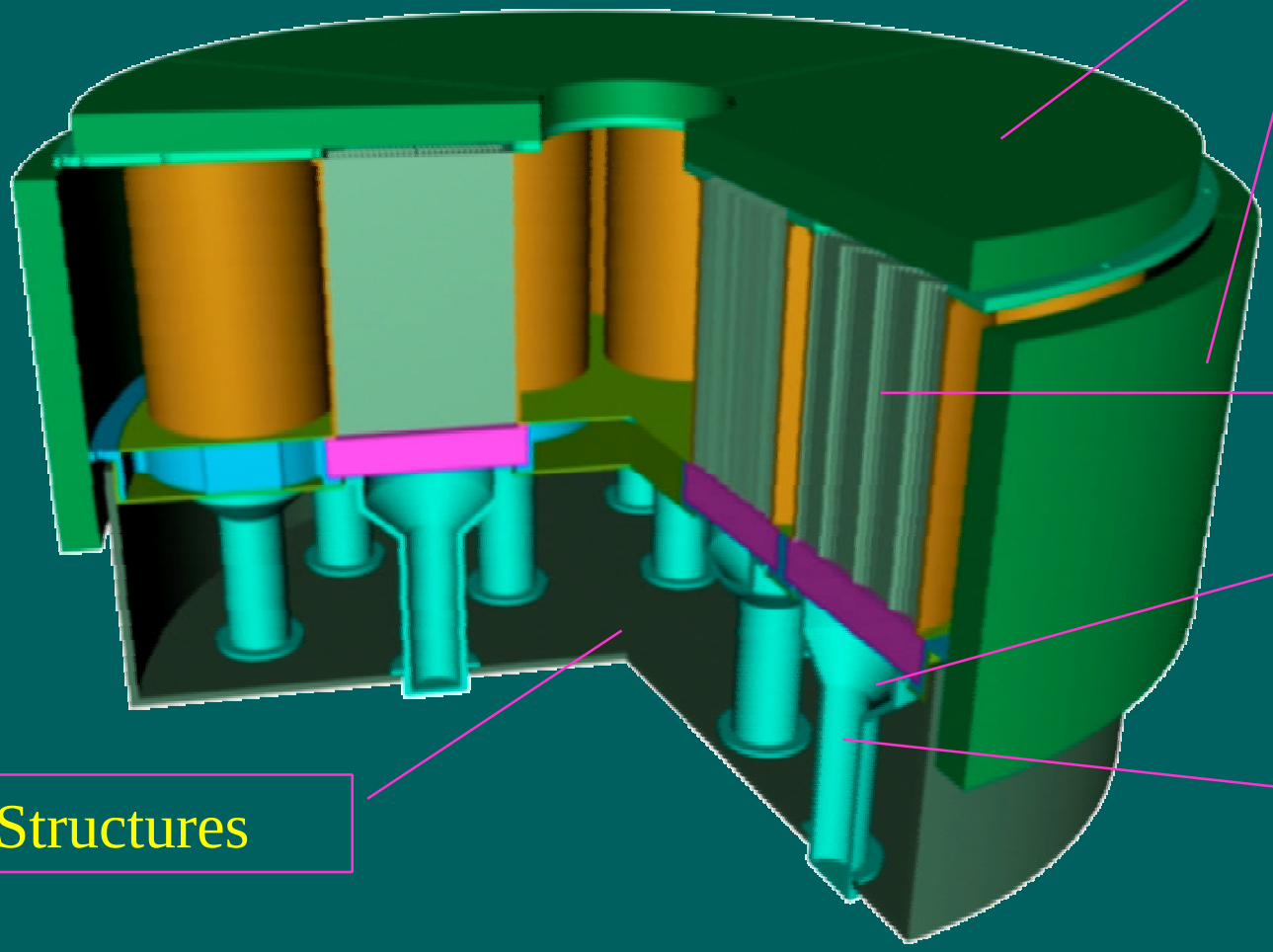
## Instruments Arrangement on Bottom Surface of Mid-Plate



# Structural Configuration

## Instruments Arrangement on Top Plate

# The Configuration of the HXMT



**Active Shield**

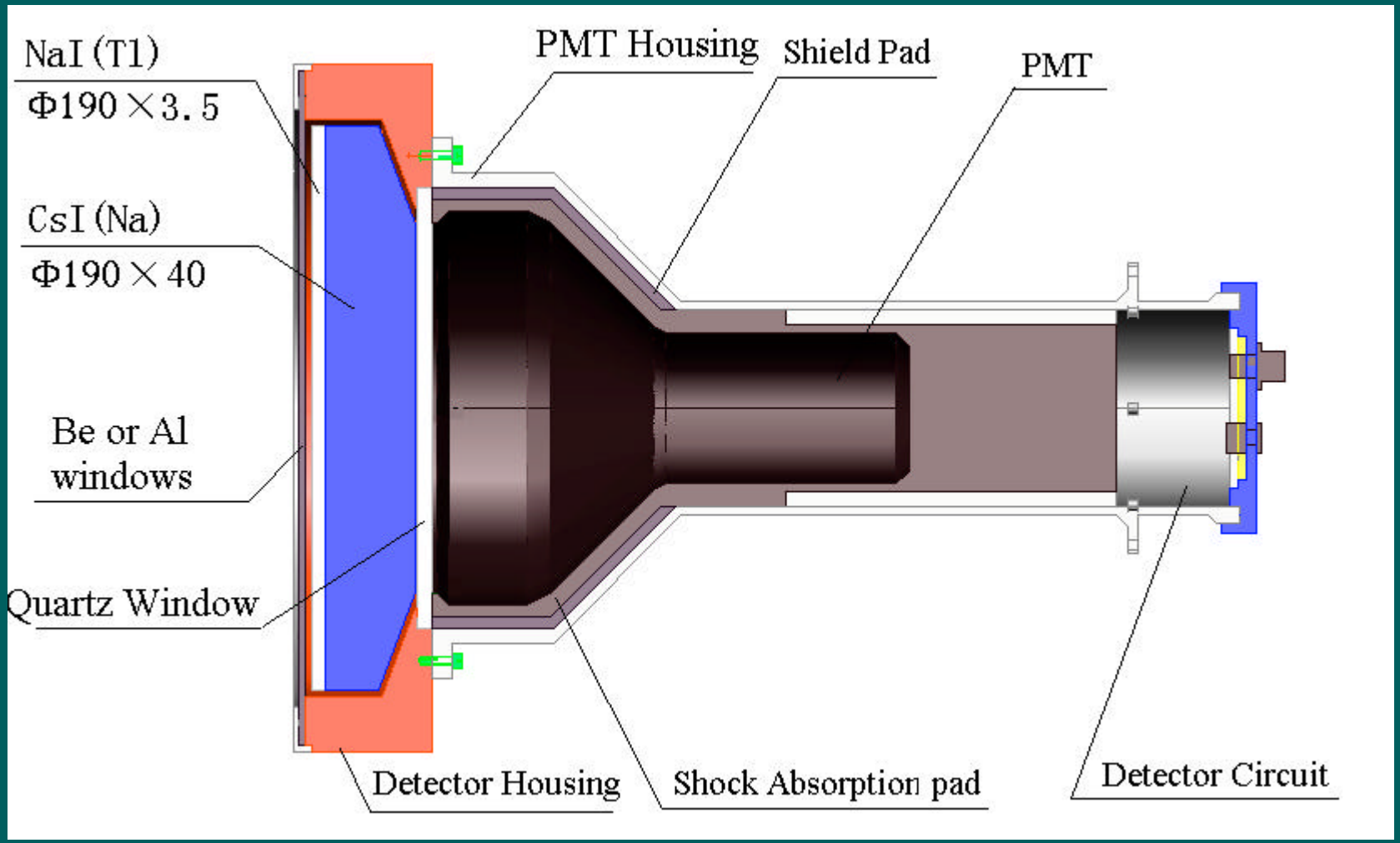
**Collimator**

Phoswich detector

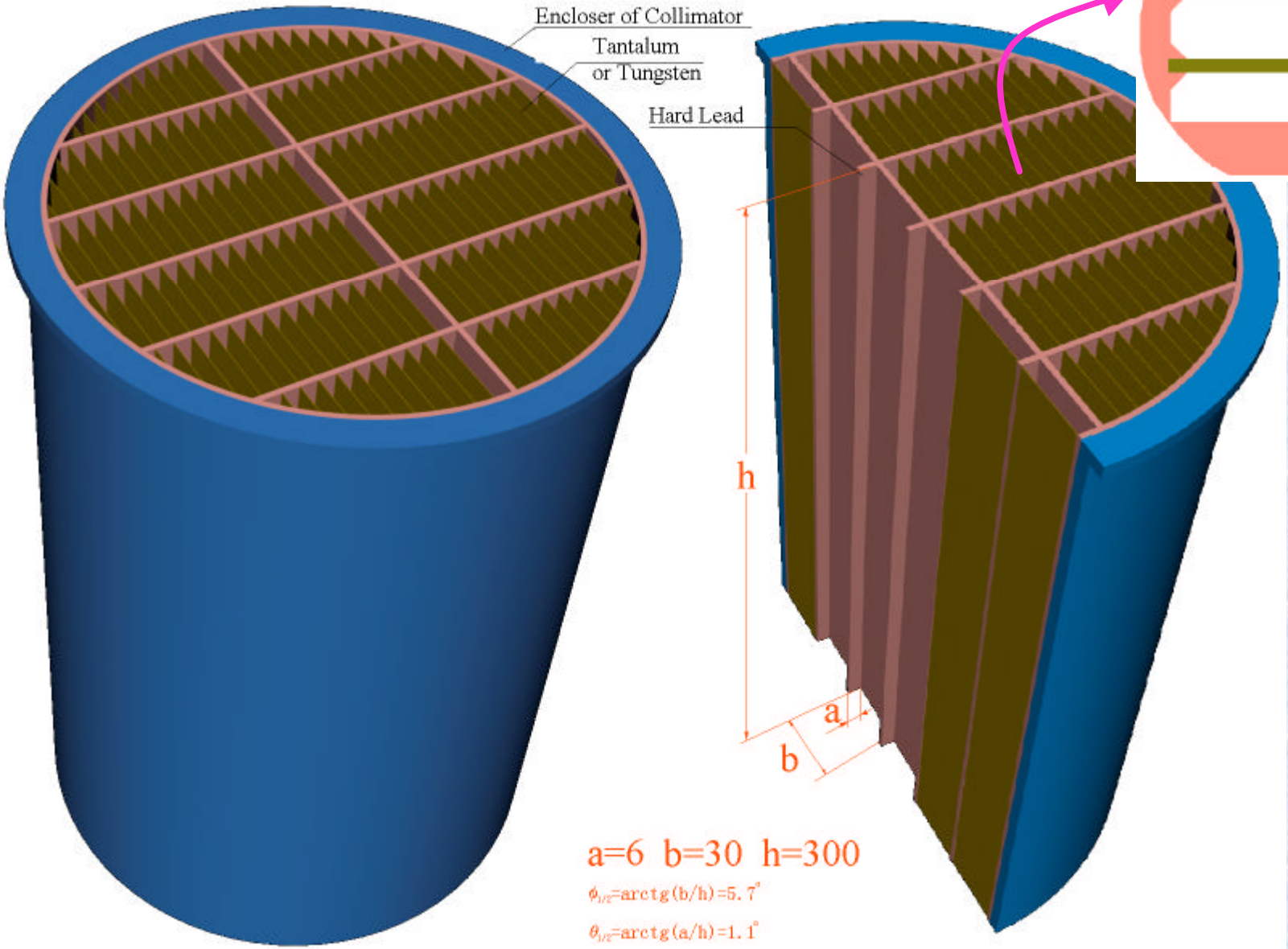
Structures

PMT

# The Main Detector system of the HXMT



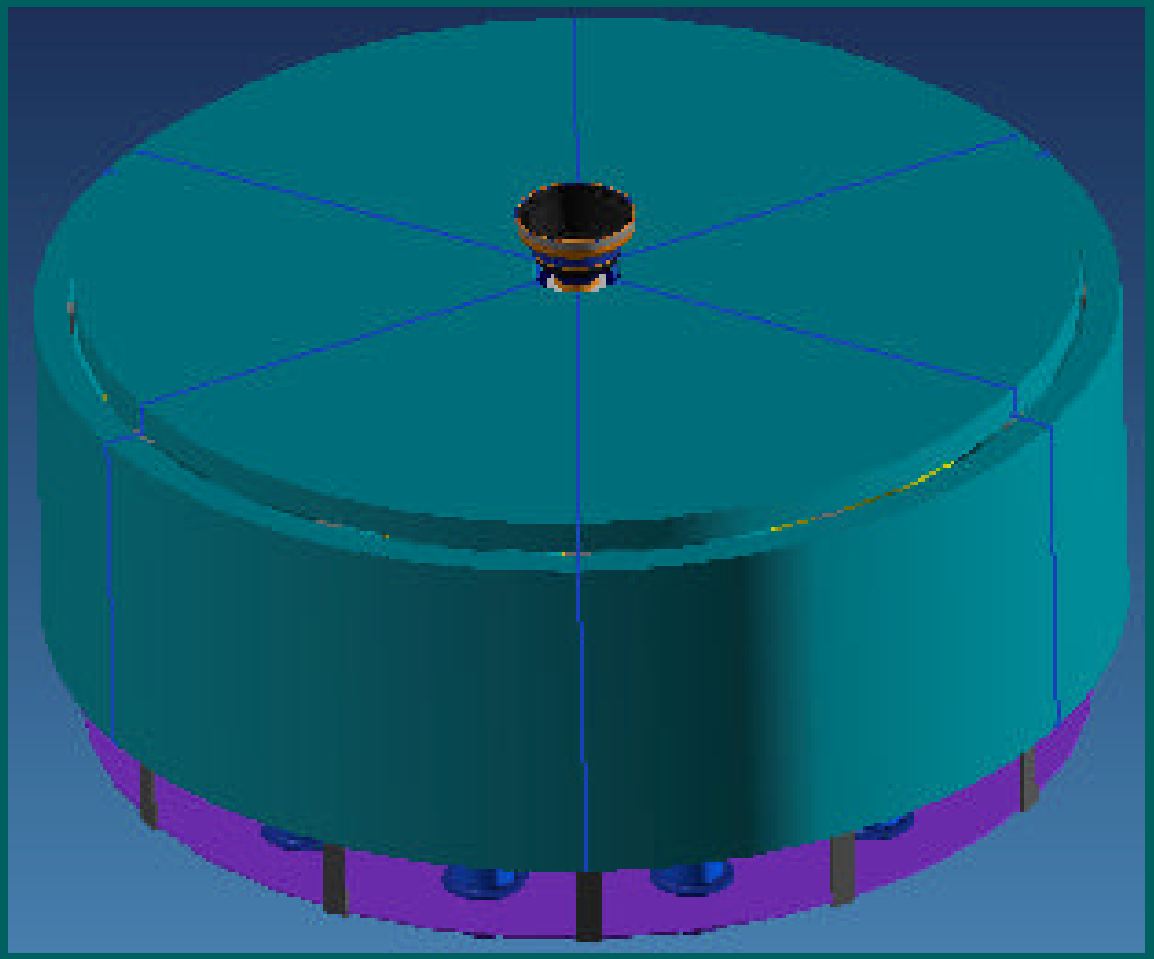
# The Collimator of the HXMT




局部放大图

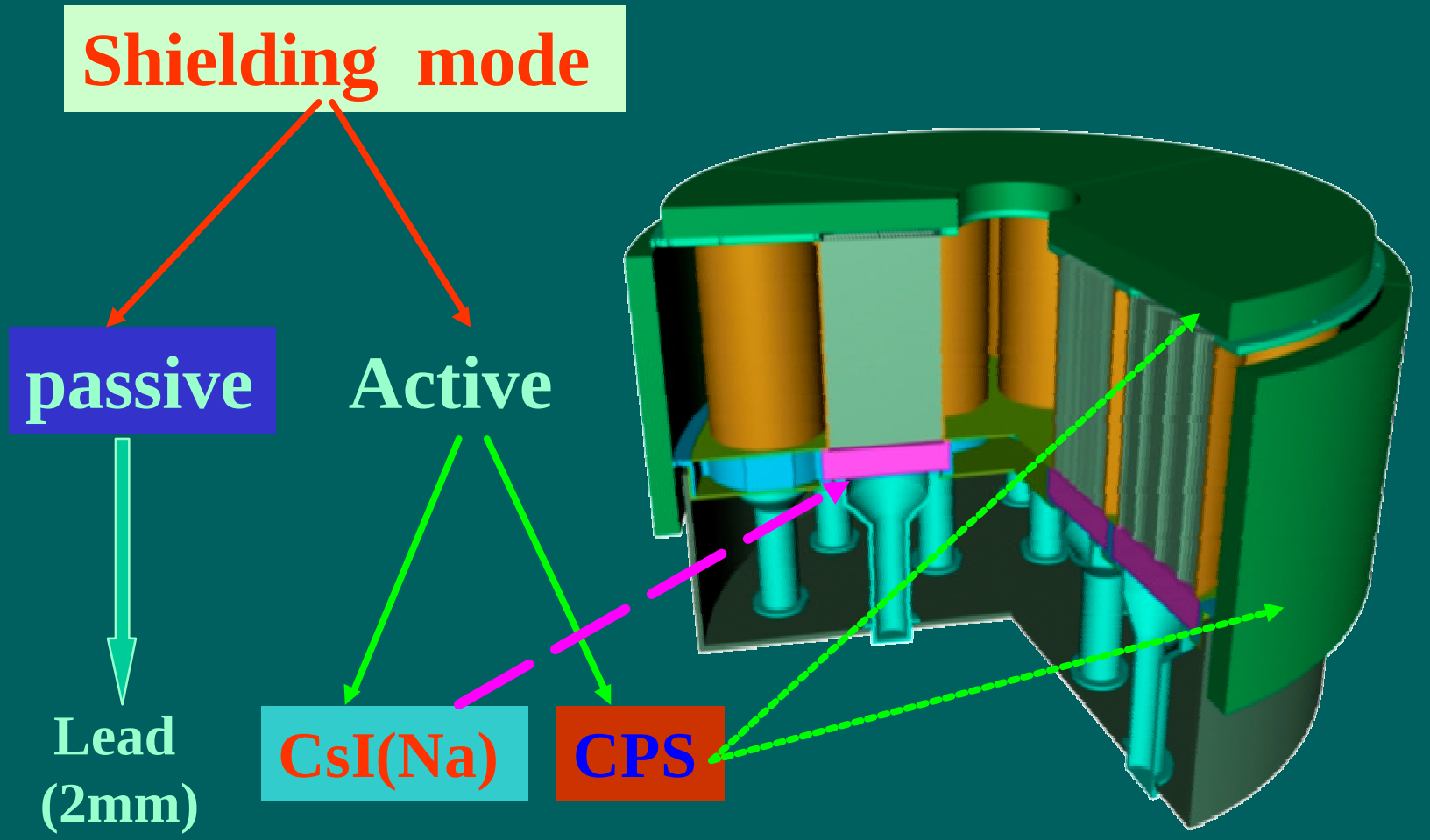
# Charged particle anti-coincidence shield

- There are 12 anti-coincidence shield detectors in the HXMT, 6 are on the top and 6 surrounding the HXMT.
- The detectors are plastic scintillation crystals.
- When a charged particle enters the detector, a interaction will occur and create a “scintillation”(pulse of light).
- The light produced by the interaction is viewed through optical fiber light guide in both ends by two PMT.

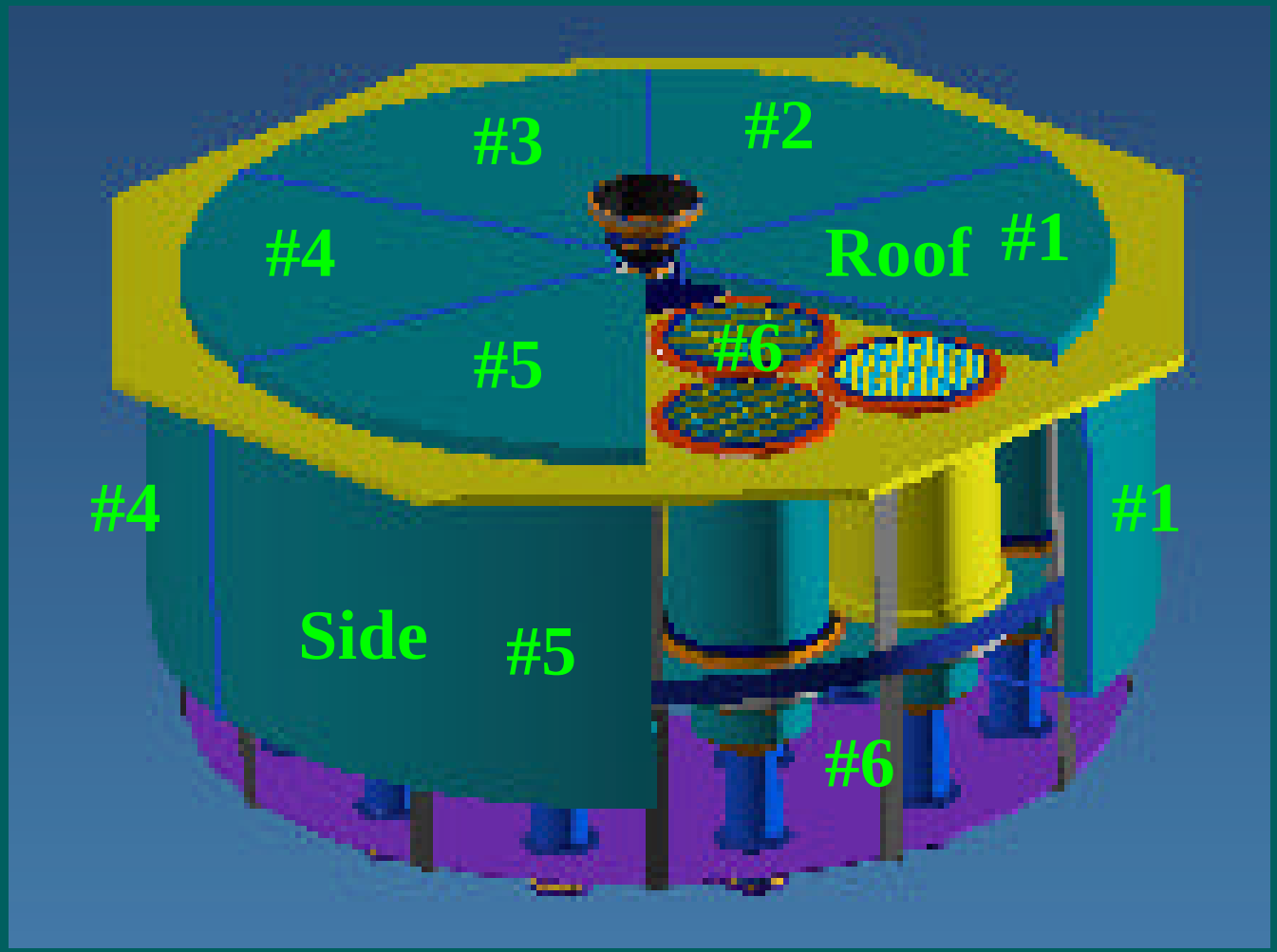


# Outside profile

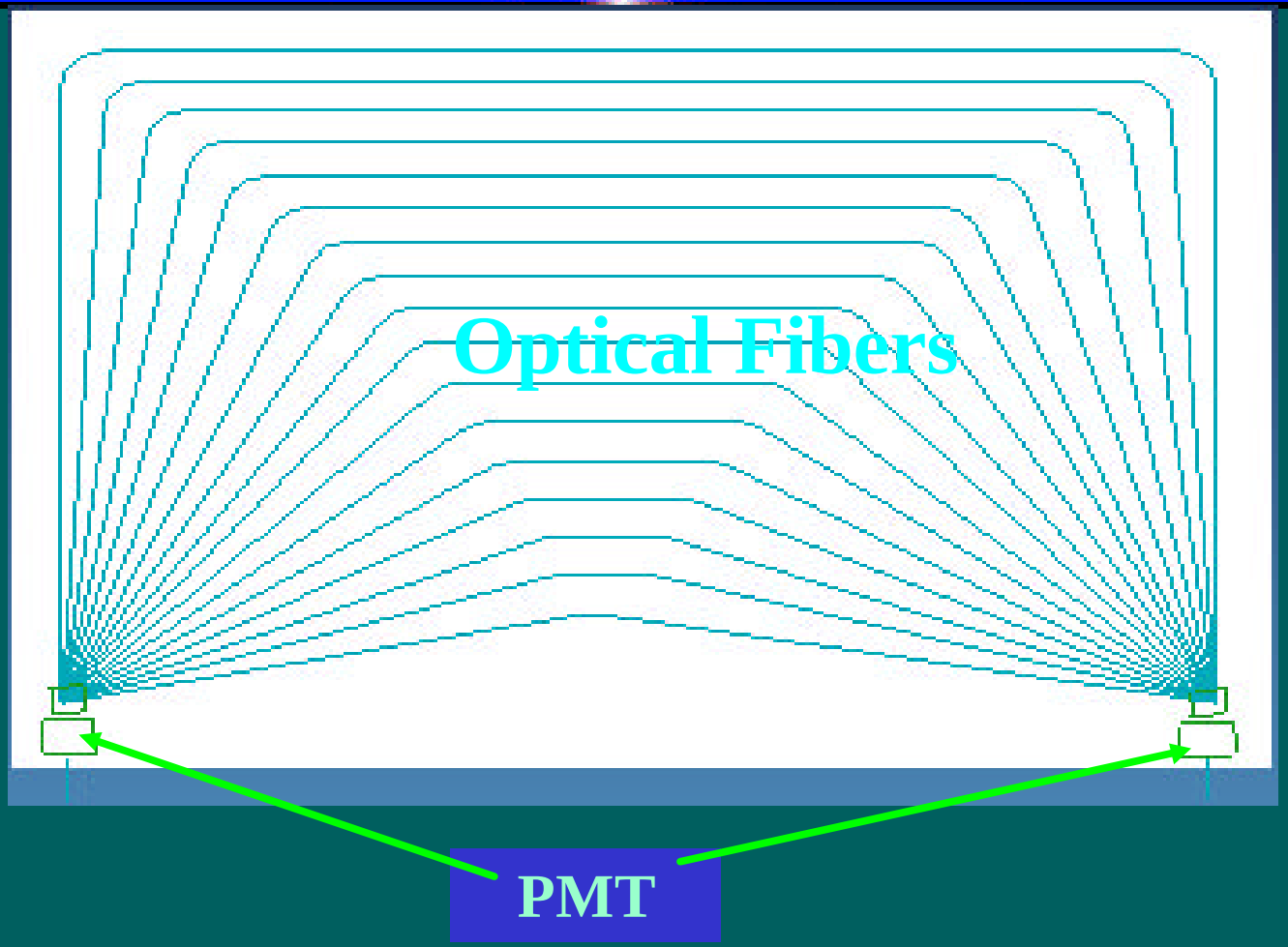
# ☞ Shielding consist of



# The structure of CPS



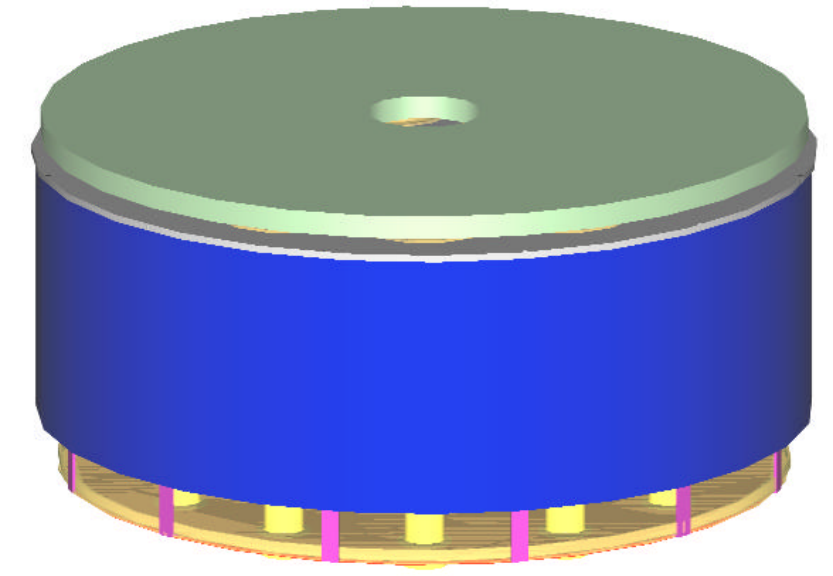
# The fibers distribution in PS board

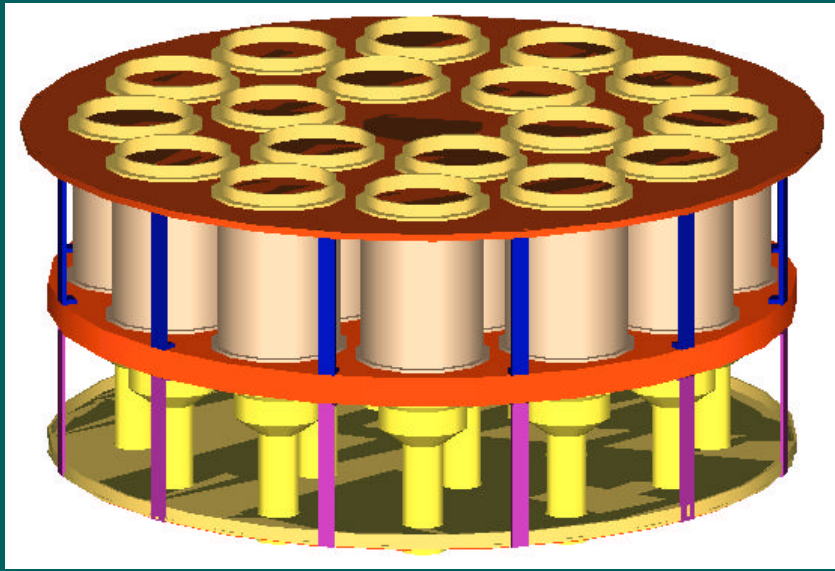


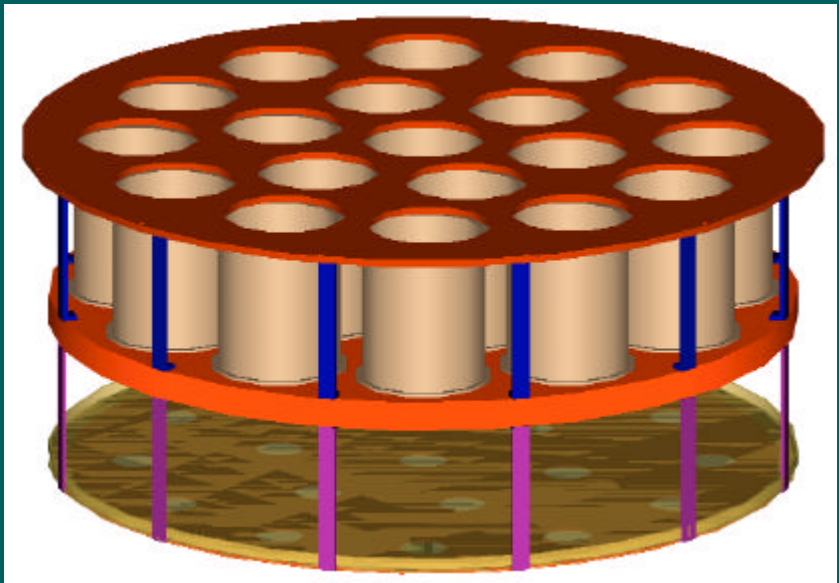

Maximum photo collection: >99.8%

Minimum photo collection: >99.5%

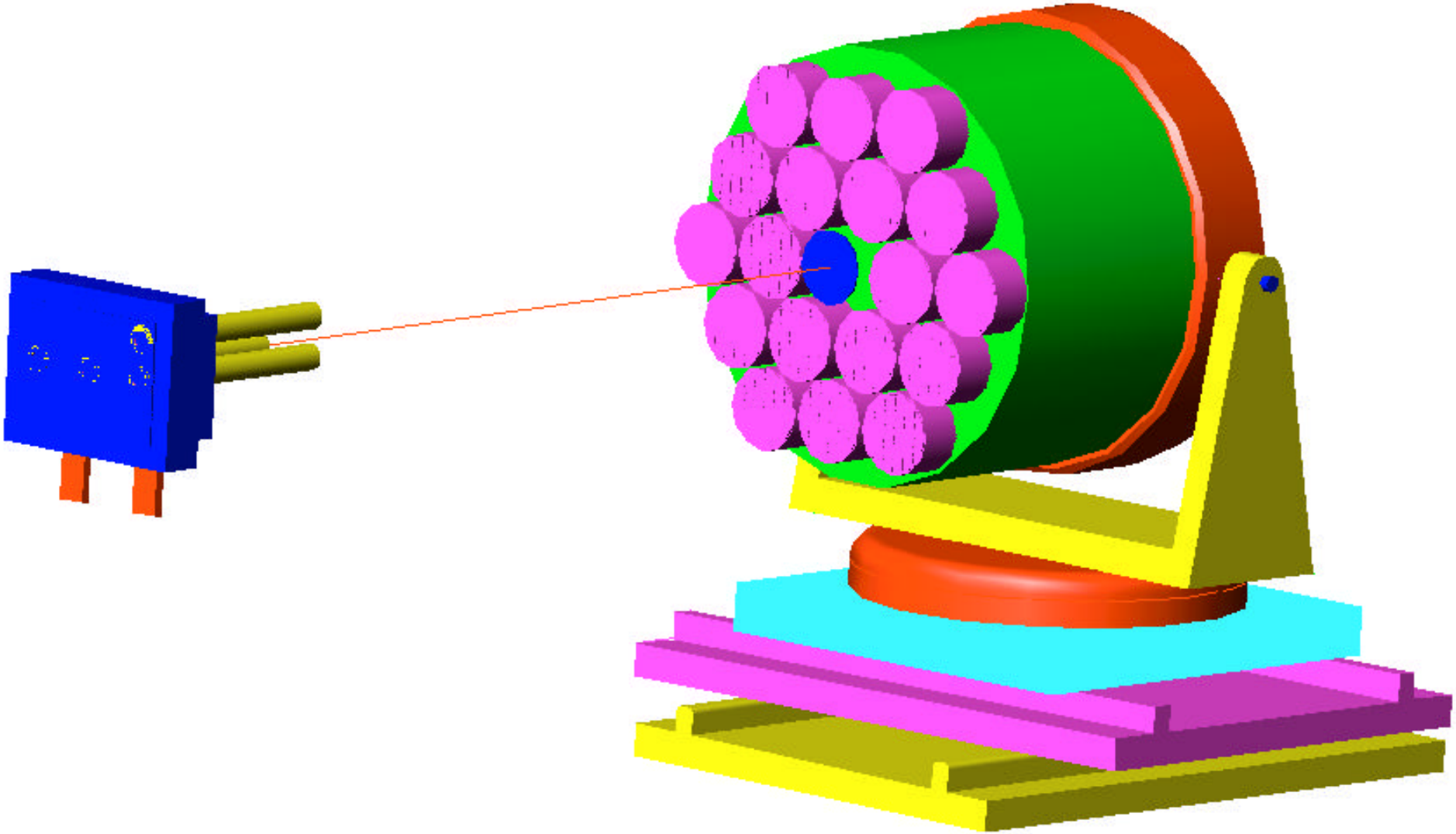
# The structure of the HXMT



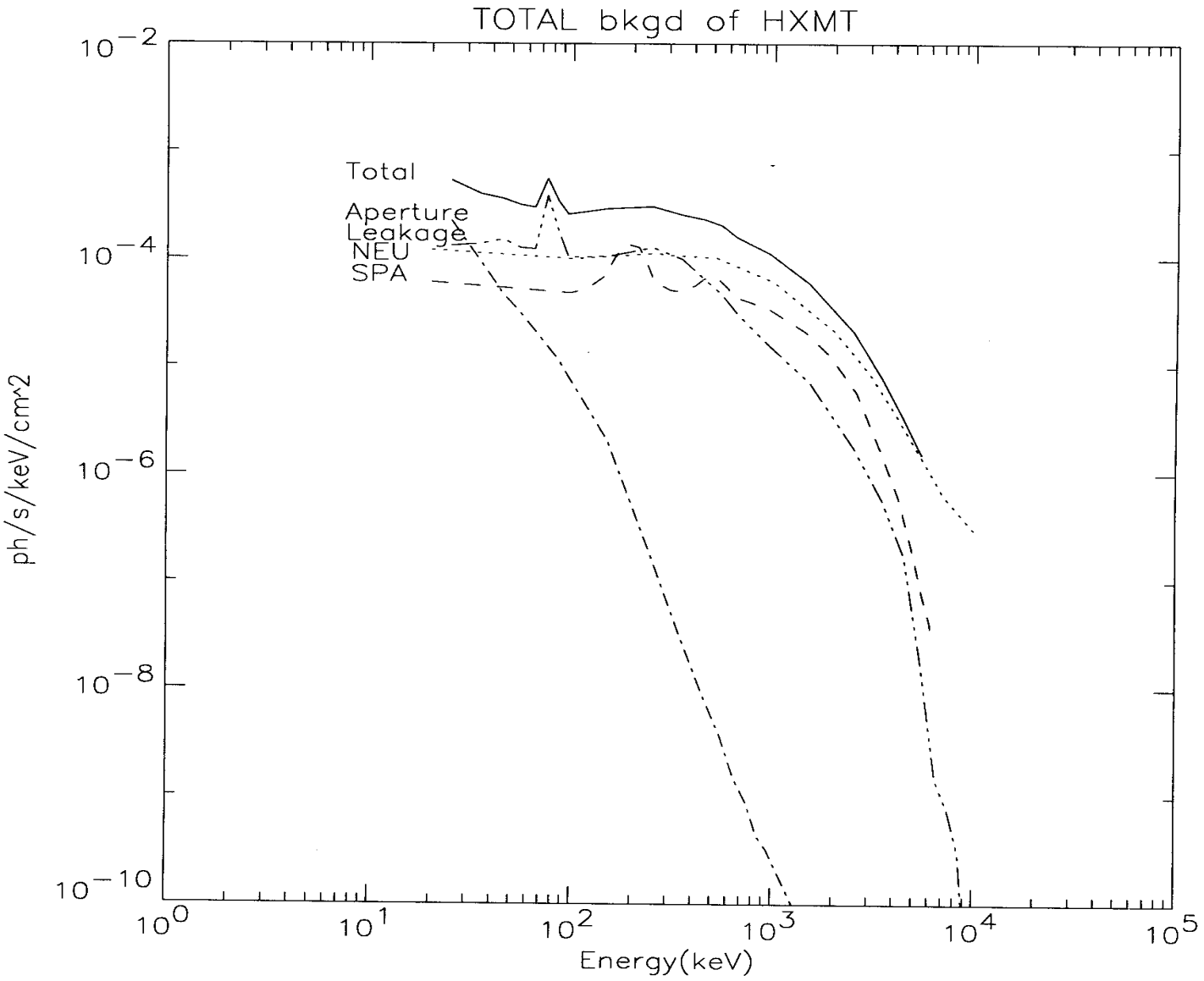




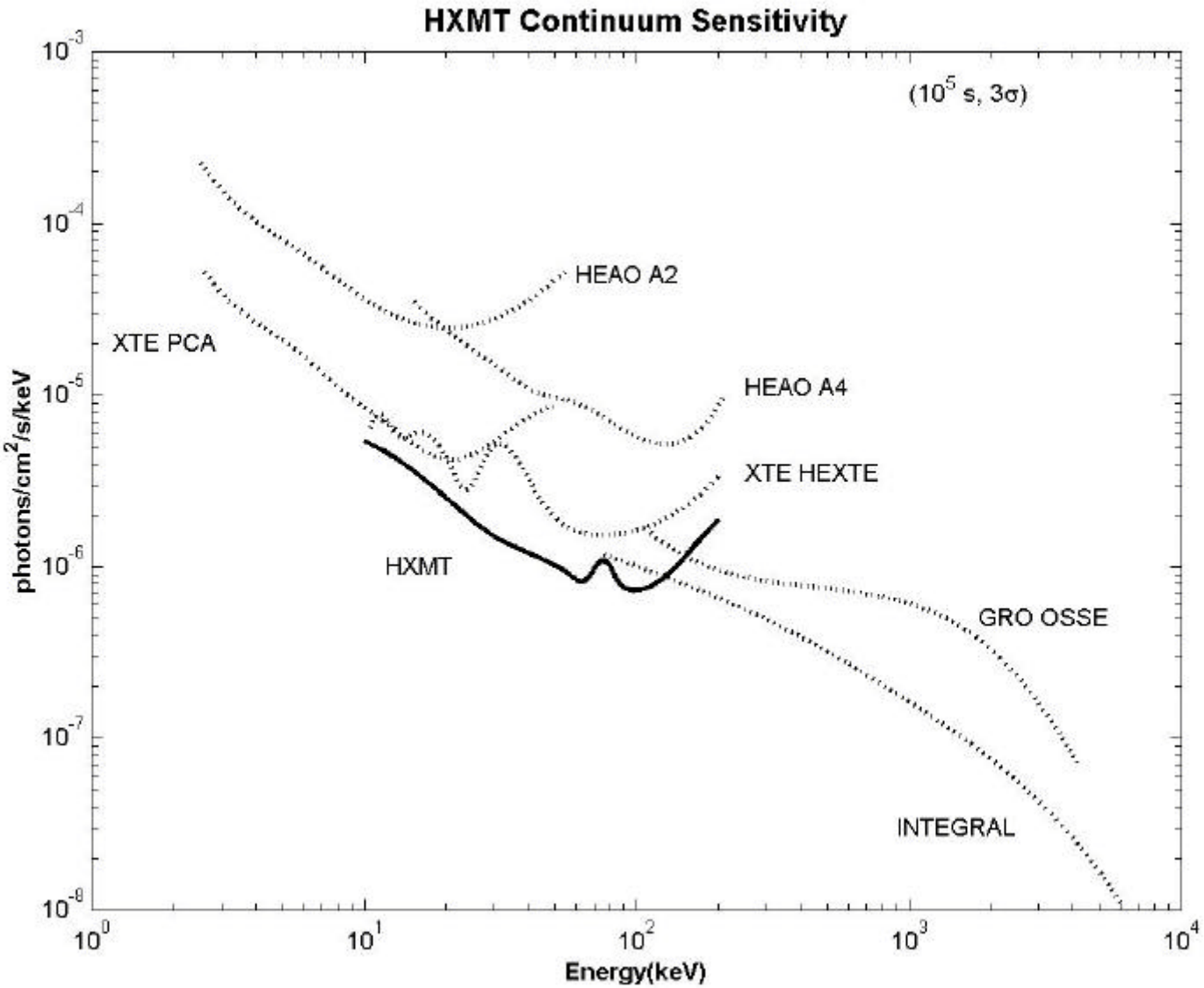
# The ground examination system



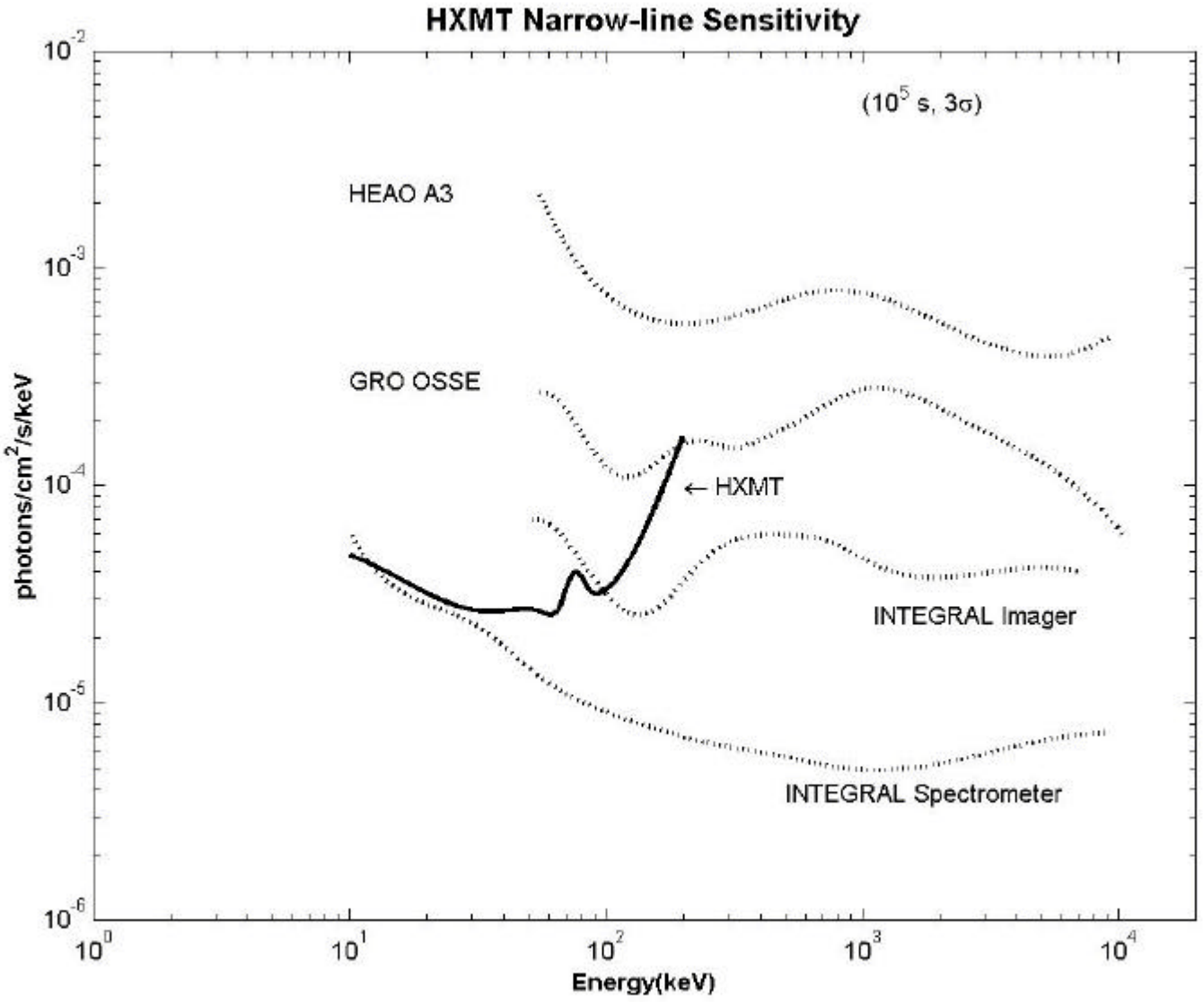
# The Background simulation of the HXMT



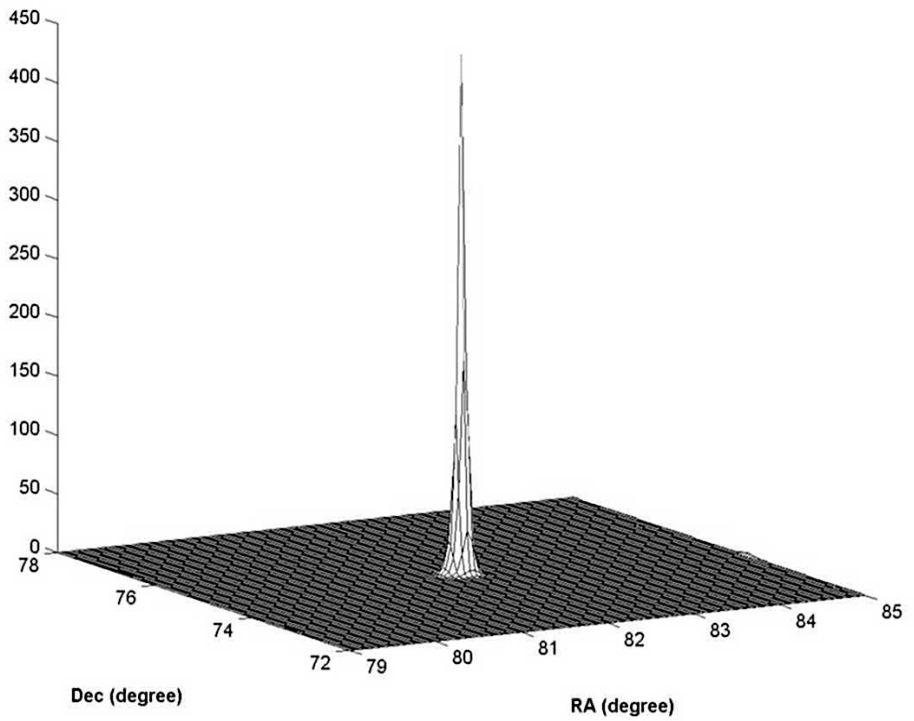
# The sensitivity of the HXMT

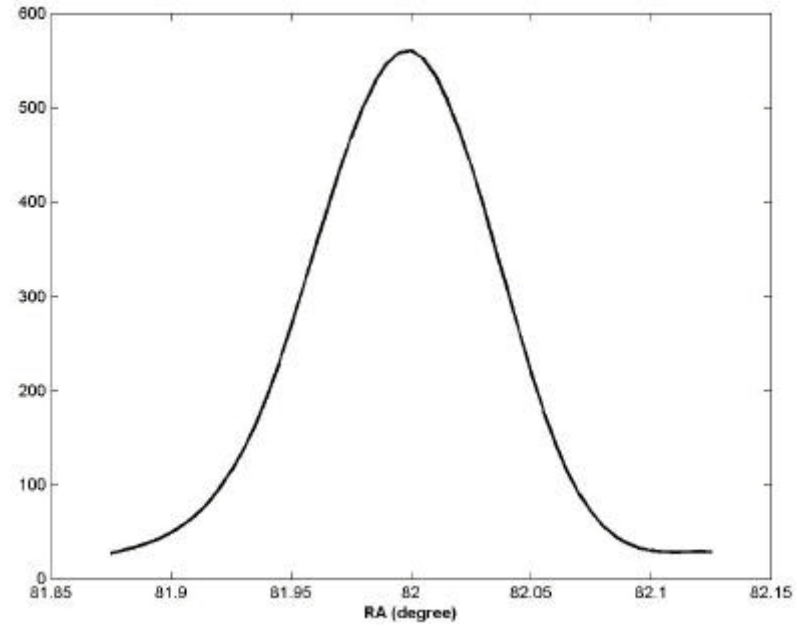


# The sensitivity of the HXMT



# The imaging performance of the HXMT



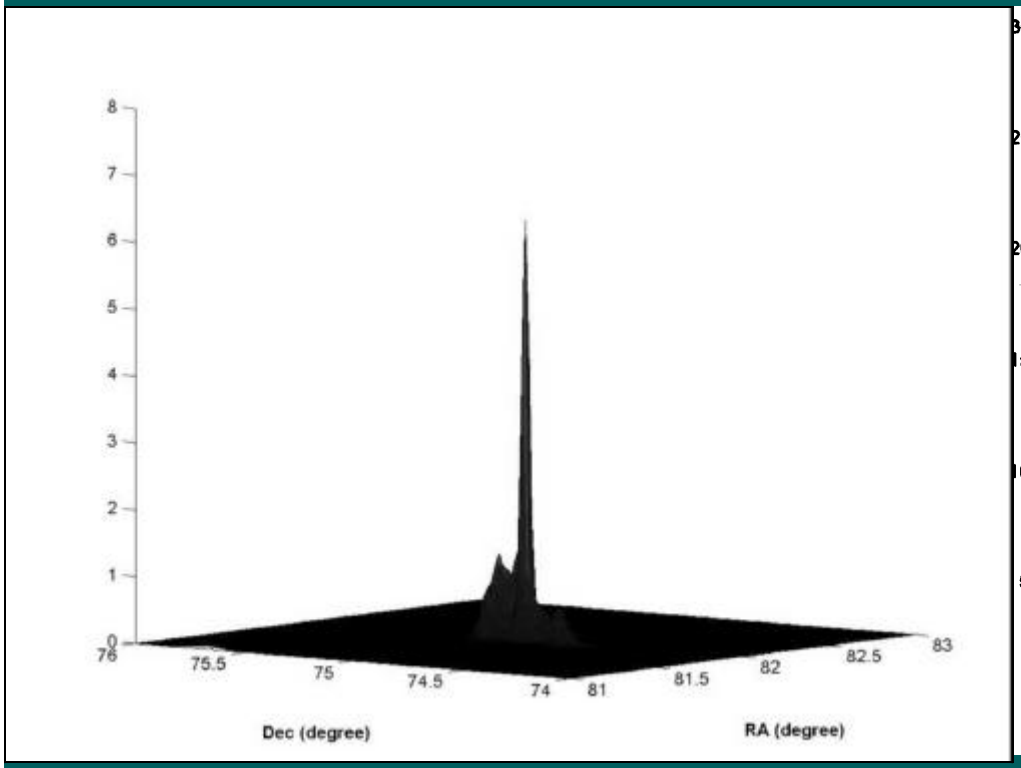



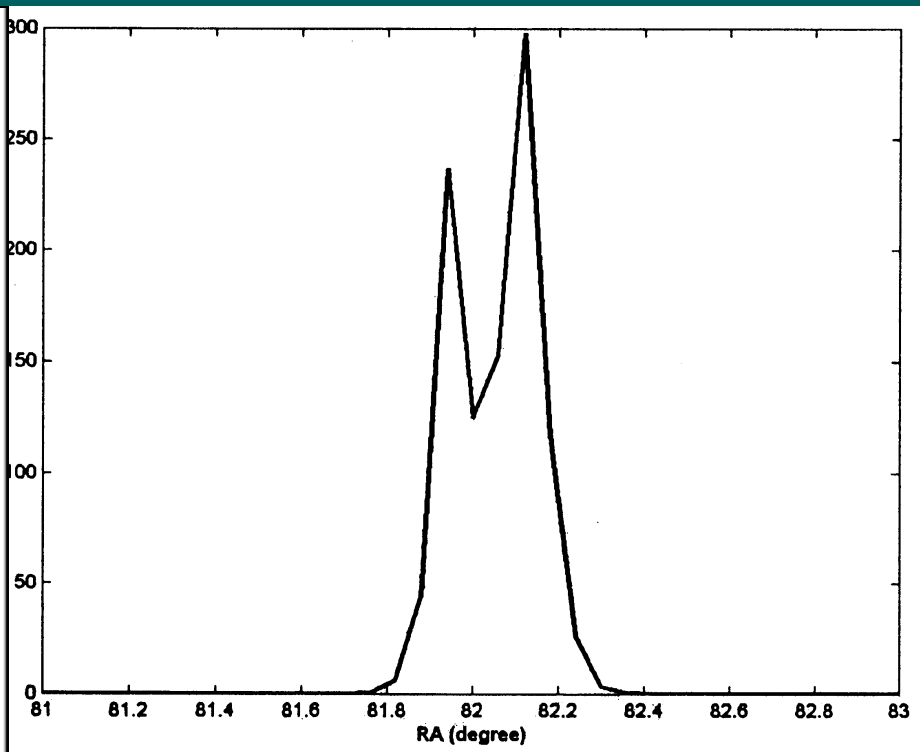

20 sigma source

Source Location <0.5 arcmin

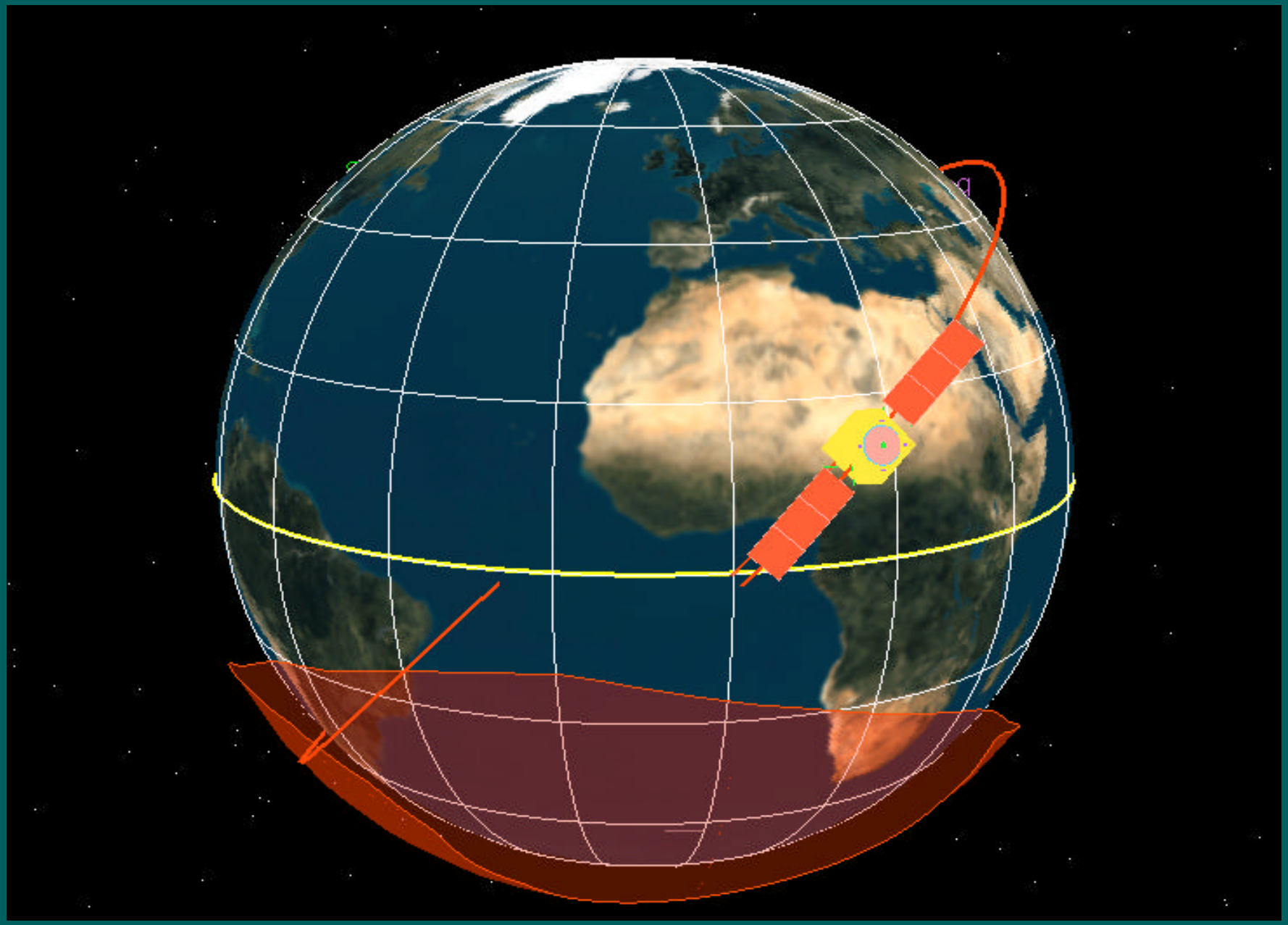
Angular resolution<5 arcmin

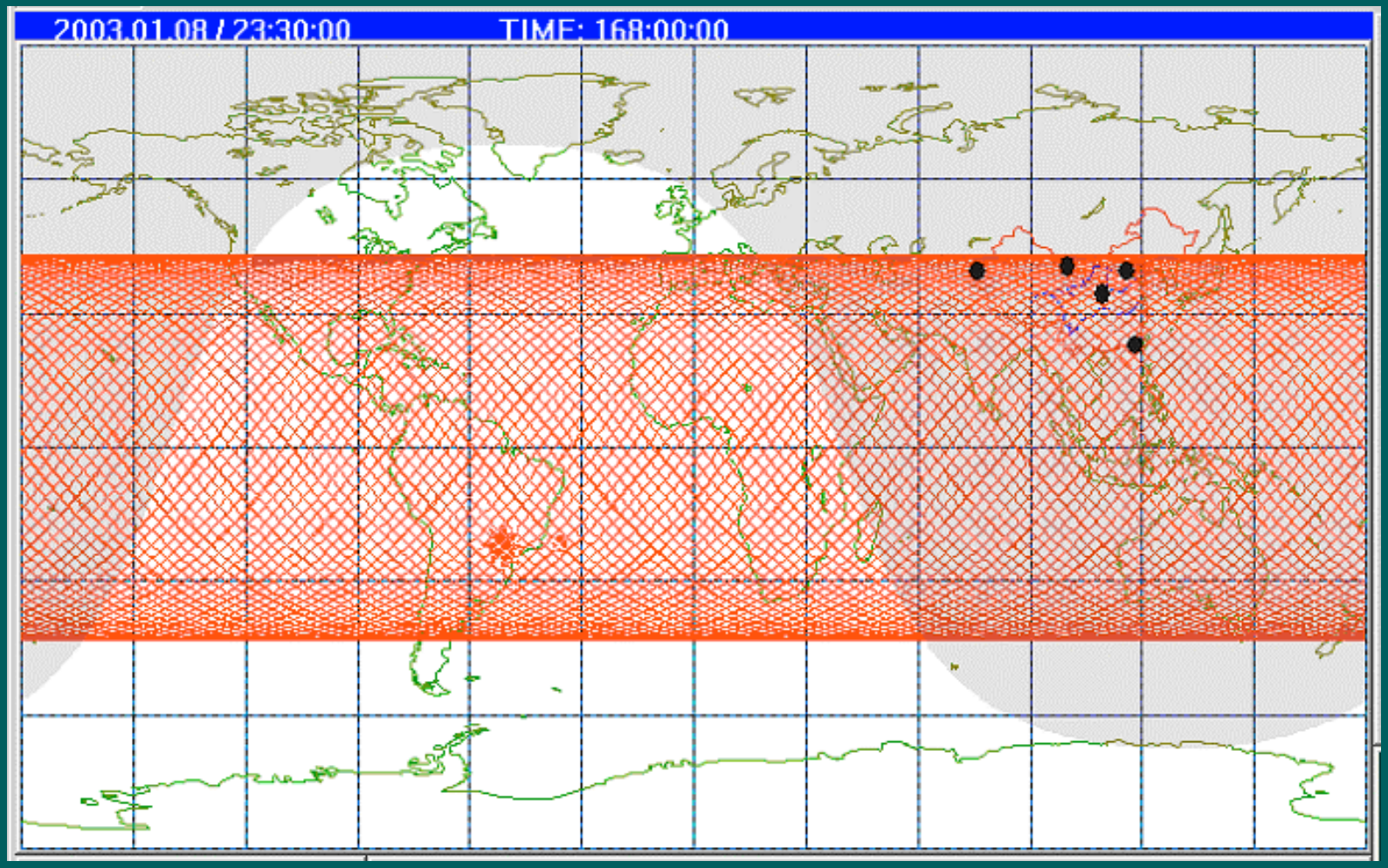
# The imaging performance of the HXMT




- Two point sources separated by 17 arcmin




2003.01.08 / 23:30:00
TIME: 168:00:00

# Observation modes

- Survey mode of HXMT
  - All sky scan mode
  - 3-axis stabilized earth oriented:
    - roll angle=0º , region span=-43º-43º, 66days
    - roll angle=30º , region span=-13º-73º, 66days
    - roll angle=-30º , region span=-73º-13º, 66days
- Pointing and deep scanning of selected sky region

# Possible secondary instruments

- Through international collaborations
  - Soft X-ray telescope
  - Wide field X-ray monitor
  - etc

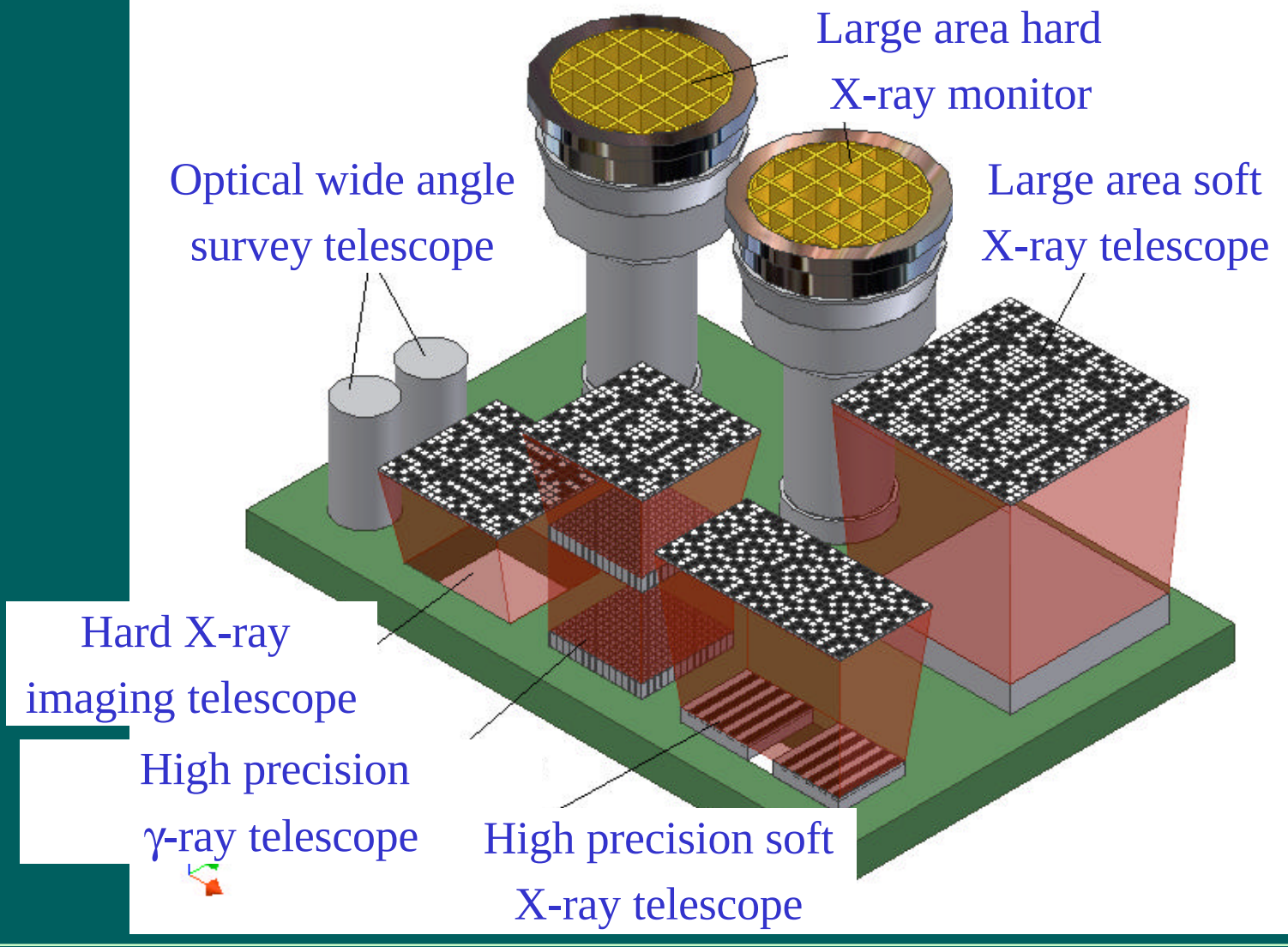
# The Wide-field Imaging Multi-band Spectrometer (WIMS) aboard China's Spacelab

- Three steps in China's manned flight program
  - Manned launch and return: successful last year (eight years since the start)
  - Spacelab (around 2010): periodically serviced by astronauts
  - Space station (depending upon the success of spacelab program): astronauts living on-board
- For the spacelab mission, only one astronomy proposal is selected
  - Wide-field Imaging Multi-band Spectrometer (WIMS)
    - Constantly pointed away from the center of the earth
    - Simultaneous multi-band, imaging and spectroscopic capability for bright transient events

# Conceptual design

| **Instrument** | Weight (kg) | Power (W) | Area ($cm^2$) | Energy ( keV) | Cost ($M) |
|---|---|---|---|---|---|
| Wide-angle optical survey telescope | 7.5X2 | 2 | 20X2 | 0.002-0.005 | 1 |
| High precision soft X-ray telescope | 7.5X2 | 18X2 | 100X2 | 0.5-20 | 3 |
| Large area soft X-ray telescope | 20 | 10 | 500 | 2-20 | 2 |
| Large area hard X-ray monitor | 15X2 | 5X2 | 280X2 | 15-250 | 2 |
| Hard X-ray imaging telescope | 15 | 10 | 200 | 20-300 | 2 |
| High precision γ-ray telescope | 20 | 10 | 200 | 20-1000 | 3 |
| Total | 115 | 80 | 1700 | 0.002-1000 | 13 |

# Schematic view of the system



# Wide angle optical survey telescope

- Two cameras of 50mm lens, f/0.8: Marconi CCD 47-20 back thinned AR coating peaked at 550nm 1024 × 1024 frame-transfer CCD as detector
- Field of view: each 20 ×20 degree$^2$
  - Combined field 20 ×40 degree$^2$
    - Covers the whole 20 ×40 degree$^2$ field in every 5 minutes
- Sensitivity

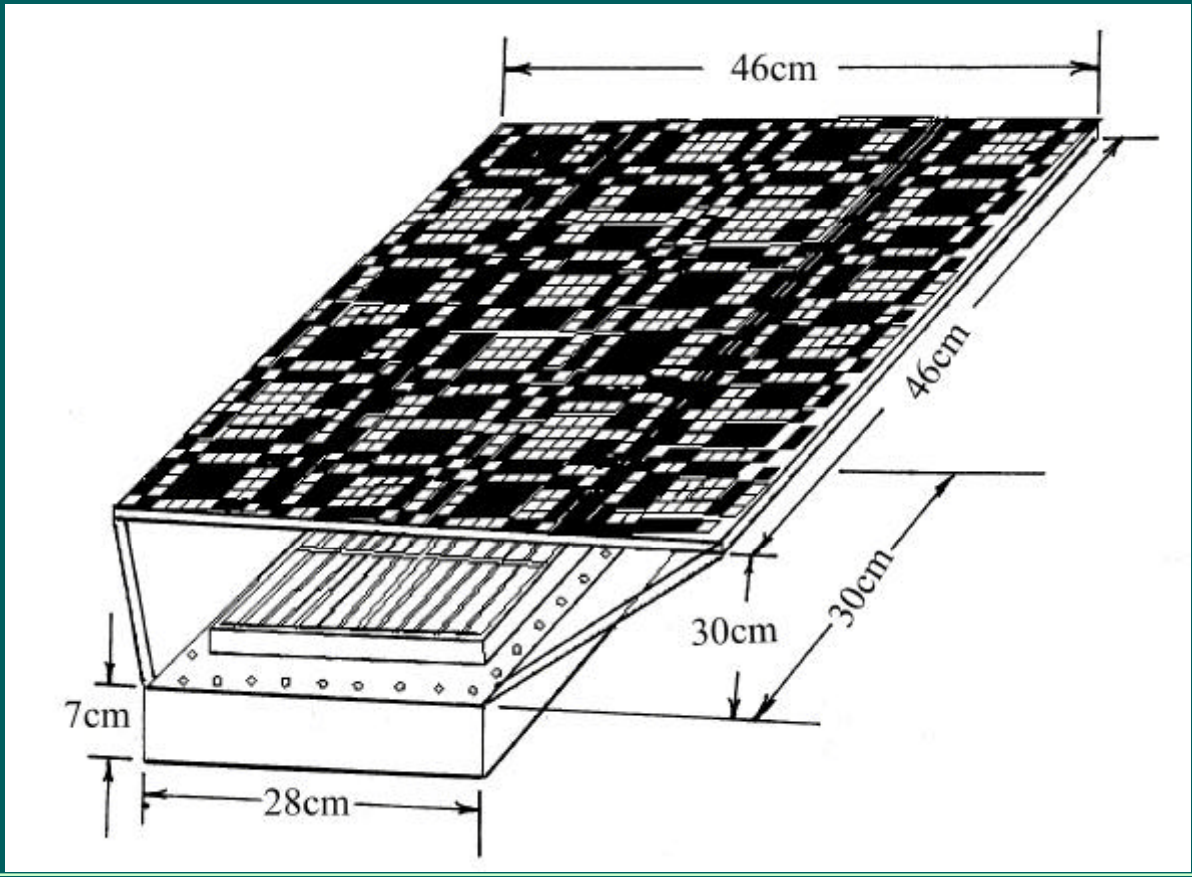
| V | S/N in 1 second | S/N in 5 minutes |
|---|---|---|
| V= 5 | $4.0\times10^5$ | $1.2X10^8$ |
| V= 10 | $4.0\times10^3$ | $1.2X10^6$ |
| V= 15 | 4.0×10 | $1.2X10^4$ |
| V= 16 | ----- | $4.8X10^3$ |

# High precision soft X-ray telescope

- $40^o$x$40^o$ coded mask: point source location accuracy~2-5 arcmin
- Silicon semiconductor: DEPFET (DEpleted P-channel Field Effect Transistor)?
  - Energy range: 0.15-20 keV
  - Energy resolution: 150-200 eV
- Two modules, each 100 $cm^2$
  - 3-5 sigmas in one second for bright galactic X-ray binaries
  - 30-50 GRBs in one year
- Total weight 15 kg
- Total power: 20W

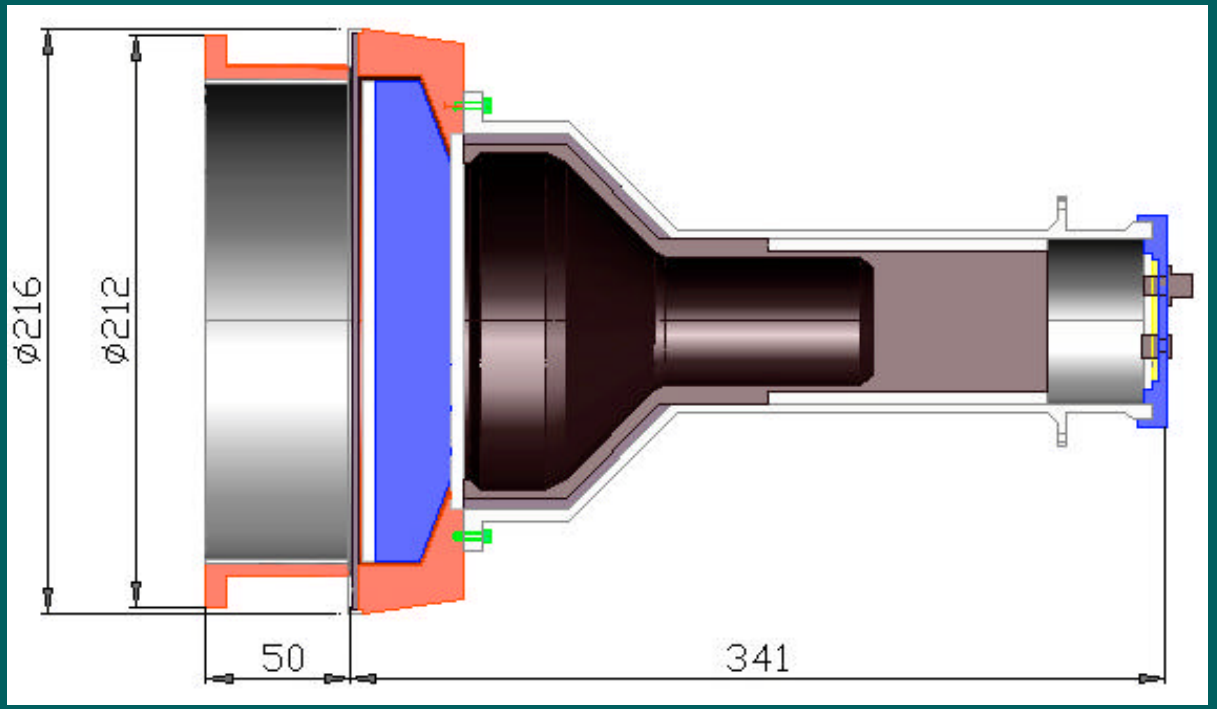
# Large area soft X-ray telescope

- Gas drift chambers with coded mask: 500 cm2
- $40^{o}$x$40^{o}$ coded mask: angular resolution better than 1 degree
- Energy range: 2-20 keV
- Weight: 20 kg
- Power: <10 W



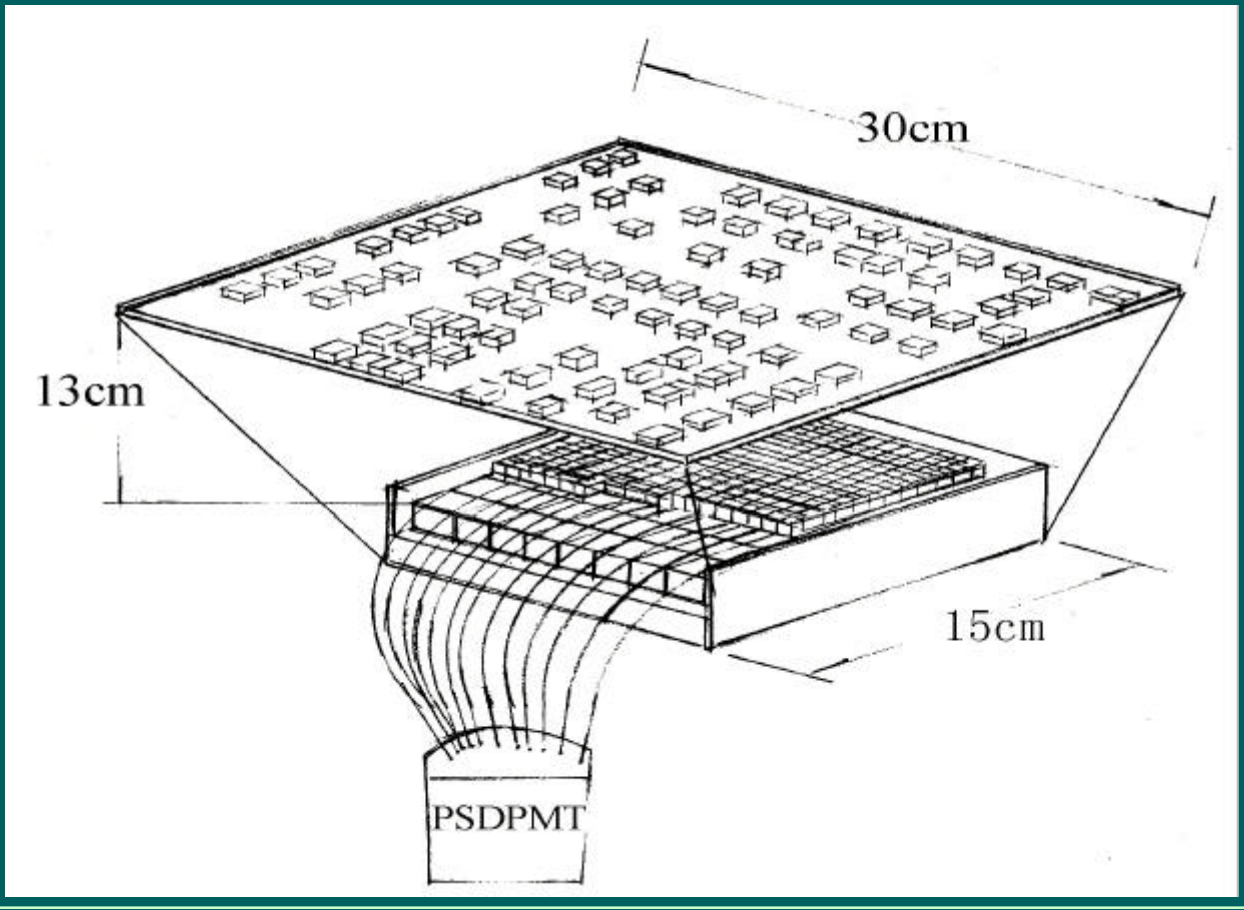
# Large area hard X-ray monitor

- Two detectors: 3mm NaI(Tl) +40mm CsI(Na), each 300cm$^2$
- Energy range: 15-250 keV
- Collimator field of view: 40° x 40°
- Total weight: 15kg x 2
- Power: <5W x 2



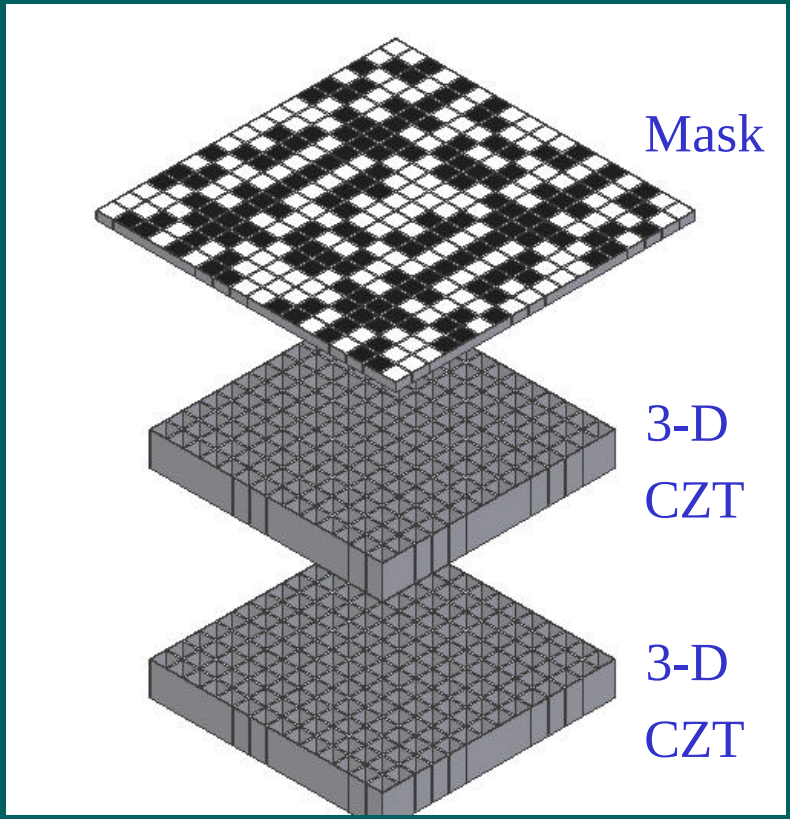
# Hard X-ray imaging telescope

- Detector: CsI + optical fibers + position sensitive PMTs, 200cm$^2$
- Energy range: 20-300 keV
- Coded mask field of view: 40° x 40° (Angular resolution: < 1 degree)
- Weight: 15kg
- Power: <10W



# High precision gamma-ray telescope

- Coded mask and double-layered Compton telescope
  - 20-300 keV coded mask (40° x 40°)
    - Location: 2-5 arcmin
  - 300-1000 keV Compton
    - Location: 1°-3°
- CZT detector area: 200cm$^2$
- Weight: 20 kg
- Power: 10W



# Challenges and difficulties

- Need international collaborations on
  - Silicon semiconductor detector
  - 3-D CZT detector

# China's mid-long term plan for science and technology

- Time range covered: 2006-2020
- Seven high priority areas of basic science identified
  - I am a member of the basic science planning board.
- The 3rd area is: "basic structures of matter, large scale laws of physics, the creation and evolution of the universe"
- A scientific satellite series is proposed as a national major research plan
  - Space astronomy is a main component
    - Deep hard X-ray sky survey is a high priority topic
  - In each five-year period, 2-3 astronomy satellites are launched
    - Eventually launch an observatory class astronomy satellite

# The fifth microquasar workshop

- Science topics: microquasar and related astrophysics
  - Jets, intermediate mass blackholes, GRBs, etc.
- Location: Beijing, China
- Dates: June 7-13, 2004 (including two day sightseeing programs)
- Registration deadline: March 31st, 2004
- Home page: jet.uah.edu/microquasar
- E-mail: microquasar@jet.uah.edu

# Thank you

Center for Astrophysics, Tsinghua University