ATHENA
Charged Particle Diverter

Jakub Zlámal (BUT), Richard Hynek (L.K.Engineering)
• Large X-ray observatory

• Second L-class mission in ESA “Cosmic Vision” program

• Addresses Science Theme “The Hot and Energetic Universe”:
  • How does ordinary matter assemble in large structures as seen today? Most ordinary matter in the universe is in the form of hot gas at X-ray temperatures
  • How do black holes grow and shape the universe? A significant fraction of the luminous energy in the universe is from accretion

• Periodic L2 “Halo orbit ”
• Protons impinging X-ray detectors cause decrease of signal to noise ratio – they should be deflected away
• Deflection of protons by magnetic field of permanent magnets – no power consumption
• Protons with energies up to 76 keV (WFI detector) and 66 keV (X-IFU detector)
• Magnets cannot shield X-ray photons focused by mirror
• Working temperature range +/- 35 °C, survive range +/- 50 °C

WFI detector
(Wide field imager)

X-IFU detector
(integral field – superconducting calorimeters) cooled to 50 mK
• Technology preparation of Charged Particle Divertor

• Cooperation of experienced science and industrial entities in Brno
  
  • Frentech Aerospace s.r.o. – prime contractor and manufacturer
  • Brno University of Technology – magnetic design of the diverter
  • L.K.Engineering s.r.o. – structural design of the diverter
ATHENA CPD – design process

Subsystem Requirements (ESA)

Structural design tradeoff (LKE)  <->  Magnetic design tradeoff (BUT)

Tradeoff study winner (LKE+BUT)

Preliminary Design (LKE+BUT)

Detailed Design (LKE+BUT)

Engineering Model production (Frentech Aerospace)
PRINCIPLE OF MAGNETIC DIVERTER

X-IFU detector

proton

X-ray photons envelope
PRINCIPLE OF MAGNETIC DIVERTER

- Permanent magnets
- X-ray photons envelope
- Force
- Magnetic field
- Velocity
- WFI detectors
- WFI pear-shape Halbach Array

- X-IFU detector
- X-IFU Halbach Array
Circular Halbach Array

- Permanent magnets
- Strong magnetic field inside
- Small magnetic field outside

Uniform field
ATHENA CPD – magnetic design

Circular Halbach Array

- Permanent magnets
- Strong magnetic field inside
- Small magnetic field outside
- Weight of magnets 6 kg

Nonuniform field – better performance
• In front of WFI detector
• Inner diameter of 35 cm
• Weight of magnets 21 kg
Pear-shape Halbach Array optimization

Entrance of Halbach Array

WFI detector plane
Pear-shape Halbach Array optimization

Entrance of Halbach Array

WFI detector plane
Pear-shape Halbach Array optimization

Entrance of Halbach Array

WFI detector plane
Pear-shape Halbach Array optimization

Entrance of Halbach Array

WFI detector plane
STRUCTURAL SOLUTION SHOULD:

Be compliant to magnetic requirements
Be as light as possible
Be as stiff as possible
Survive all loads with margin
Be economically feasible
Be feasible to test in Czech facilities

TRADEOFF STUDY
10 semi-final configurations

- Mass performance
- Modal performance
- Strength performance
- Test feasibility

Mass mark = 3.0
Mass mark = 2.3
Mass mark = 1.7
Mass mark = 1.5
Mass mark = 1.8
Mass mark = 1.7
Mass mark = 2.5
Mass mark = 1.3
Mass mark = 1.5
Mass mark = 1.0
Trade-off winning configuration – Mass mark 1.3 | compliant eigenfrequency | feasible for test and production.

ATHENA CPD – structural design story
Vibration loads

BREAD BOARD MODEL

Copyright: LKE
BREAD BOARD MODEL
Optimized sandwich panel

X-IFU

CFRP strut system

WFI

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ATHENA CPD – next steps

- Preliminary magnetic & structural design
- Preliminary Design Review **January 2019**
- Critical Design Review **Spring 2019**
- Engineering qual. model **Summer 2019**
- Qualification tests late 2019 ➞ Roadmap to flight model
Thank you for your attention

Ask us

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