Monte Carlo based ray tracing for CAST and BabyIAXO

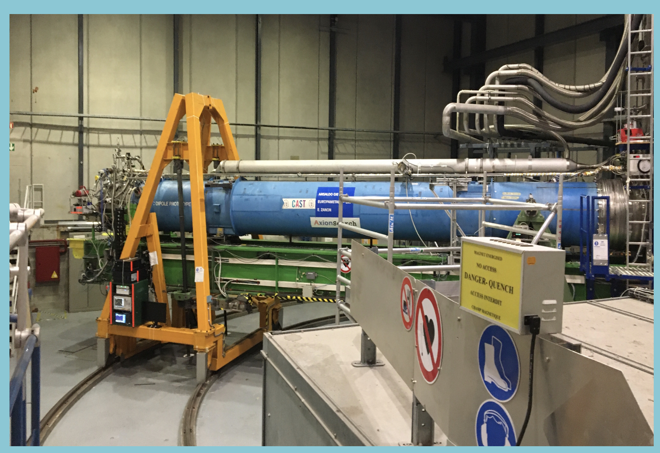
Physikalisches Institut

UNIVERSITÄT BONN

CAST

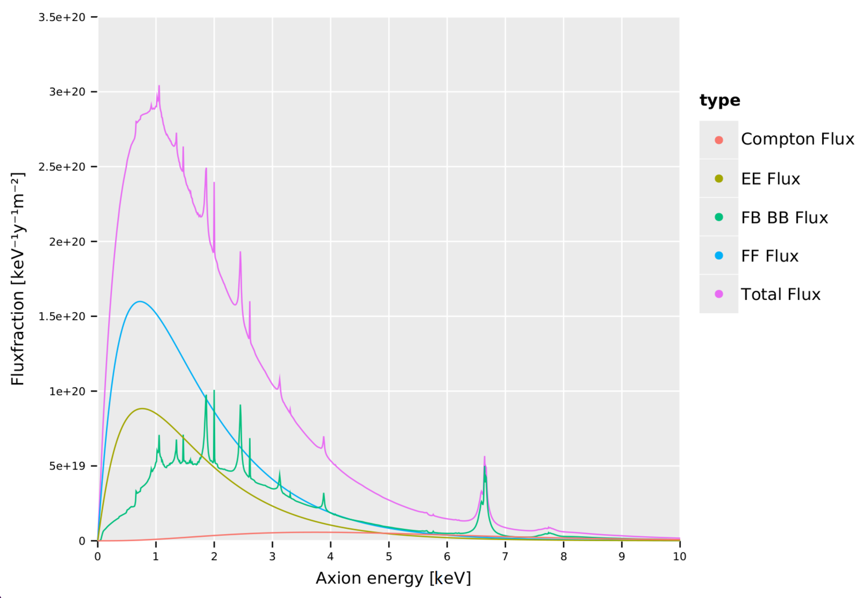
Ray tracing

BabyIAXO



→ The axions arriving at one of the CAST magnet bores with $A = 1.452 \times 10^{-3}\,\mathrm{m}^2$ in a three month run would be $\sim 1.7 \times 10^{16}$

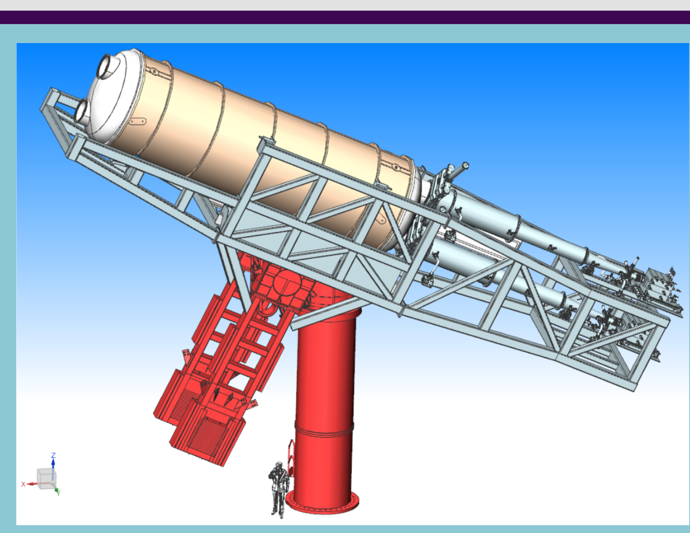
Simulation of the emission rates of solar axions



- DFSZ axions are produced in the sun via different mechanisms
- In a step preceding the raytracer, the solar emission rates are calculated depending on the point of origin of the axion in the sun and its energy
- Values used here:

  $g_{ae} = 10^{-13}$

  $g_{a\gamma} = 10^{-12}\,\mathrm{GeV}^{-1}$
- The total axion flux: $\Phi_a = 7.785 \times 10^{20} \frac{1}{\mathrm{year\ m}^2}$



→ The axions arriving at one of the BabyIAXO magnet bores with $A = 0.385\,\mathrm{m}^2$ in a three month run would be $\sim 3.7 \times 10^{19}$

The CAST magnet:
Length magnetic field: $L = 9.26\,\mathrm{m}$
Magnetic field: $B = 9\,\mathrm{T}$
Diameter of the bore: $d = 4.3\,\mathrm{cm}$

Conversion to X-ray photons in the magnet

Conversion probability in vacuum:

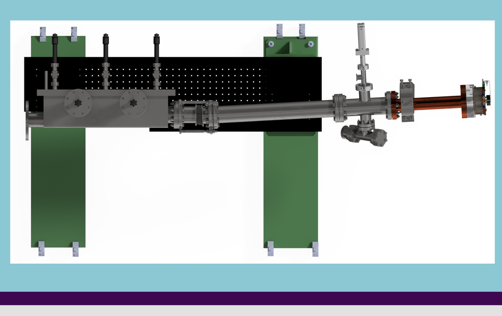
$$P_{a\to\gamma} = \frac{1}{4}(g_{a\gamma\gamma}BL)^2$$

For axion masses below $10\,\mathrm{meV}$

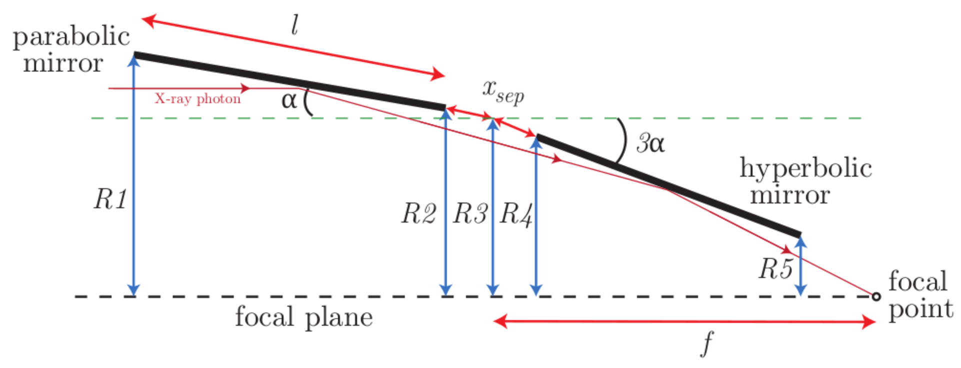
Conversion and transmission probability in gas:
- Increases with lower mass difference $m_\gamma - m_a$
- m_γ rises with higher p_{gas} and lower T_{gas}
- Increases with the axion energy

The BabyIAXO magnet:
Length magnetic field: $L = 10\,\mathrm{m}$
Magnetic field: $B = 2 - 3\,\mathrm{T}$
Diameter of the bore: $d = 70\,\mathrm{cm}$

The LLNL optics from one of the 2017/2018 setups:
Focal length: $f = 1.5\,\mathrm{m}$
Number of mirror layers: $N = 13$
Length per mirror: $l = 225\,\mathrm{mm}$
Reflective coating: Pt/C

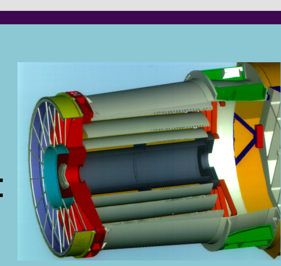


Reflection path and probability in the X-ray telescope

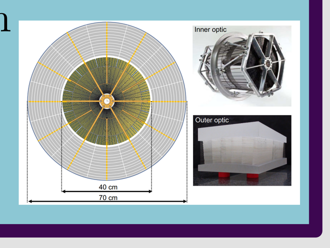


The geometrics of the Wolter I optics and the reflective coating give the change of path of the X-ray as well as its reflection probability

The XMM telescope:
Focal length: $f = 7.5\,\mathrm{m}$
Number of mirror layers: $N = 58$
Reflective coating: $250\,\mathrm{nm}$ gold

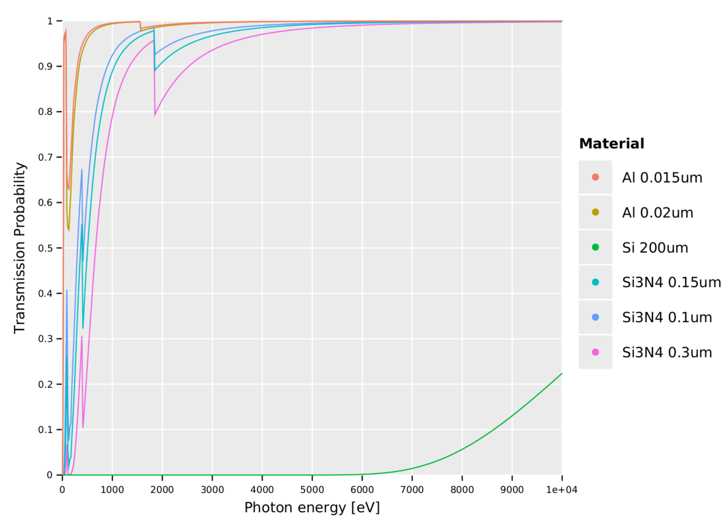


The BabyIAXO telescope:
Focal length: $f = 5.0\,\mathrm{m}$
Number of mirror layers: $N = 123$

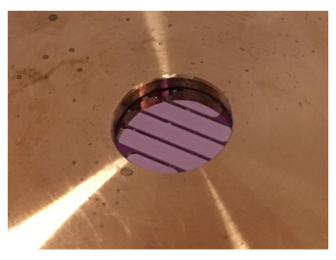


The 2017/18 GridPix detector:
Window properties:
$0.3\,\mu\mathrm{m}$ Si3N4, radius $= 7\,\mathrm{mm}$
Material 4 window strips:
$200\,\mu\mathrm{m}$ Si
Cathode related window coating:
$20\,\mathrm{nm}$ Al
Material detector gas: $3\,\mathrm{cm}$ Ar

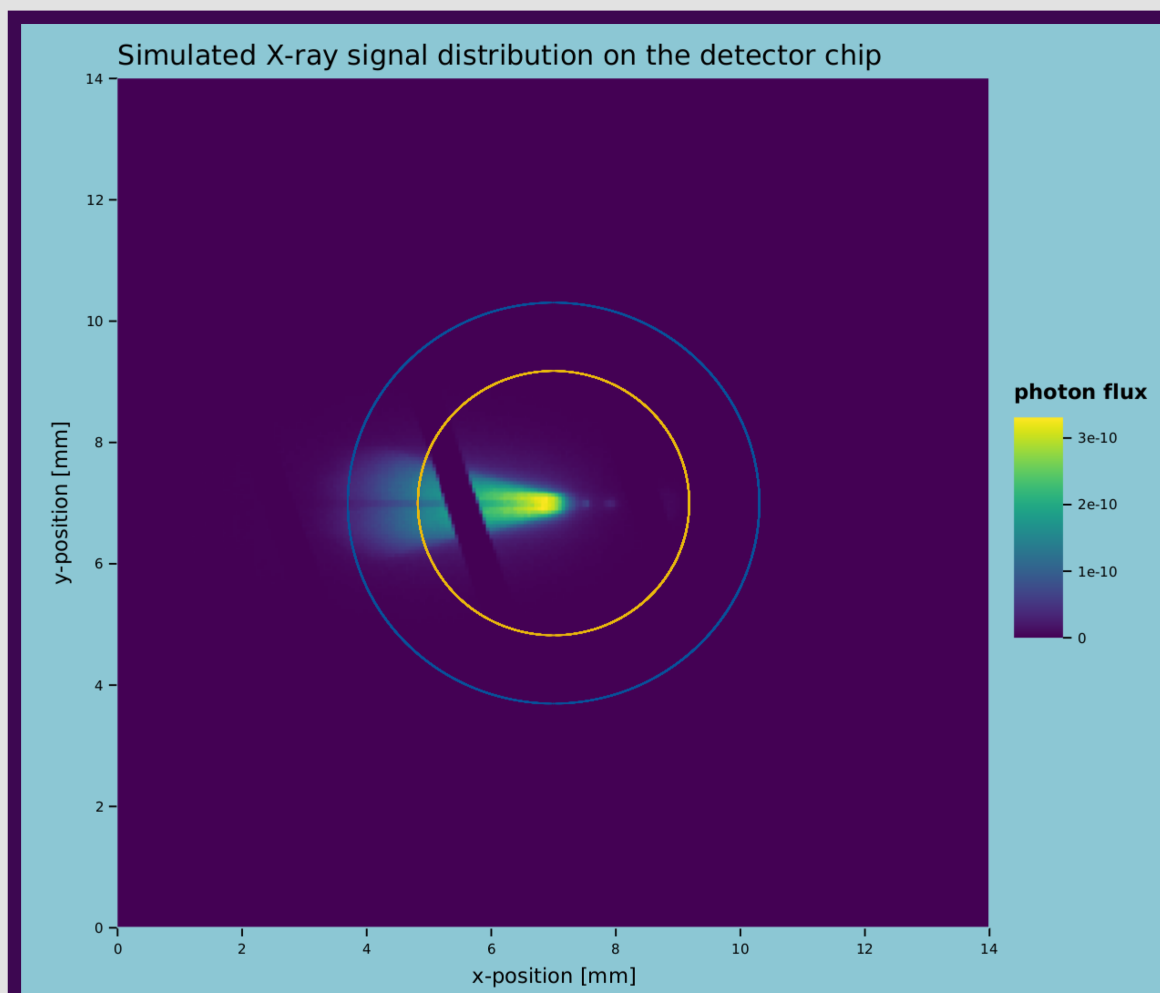
Transmission probability through the detector window

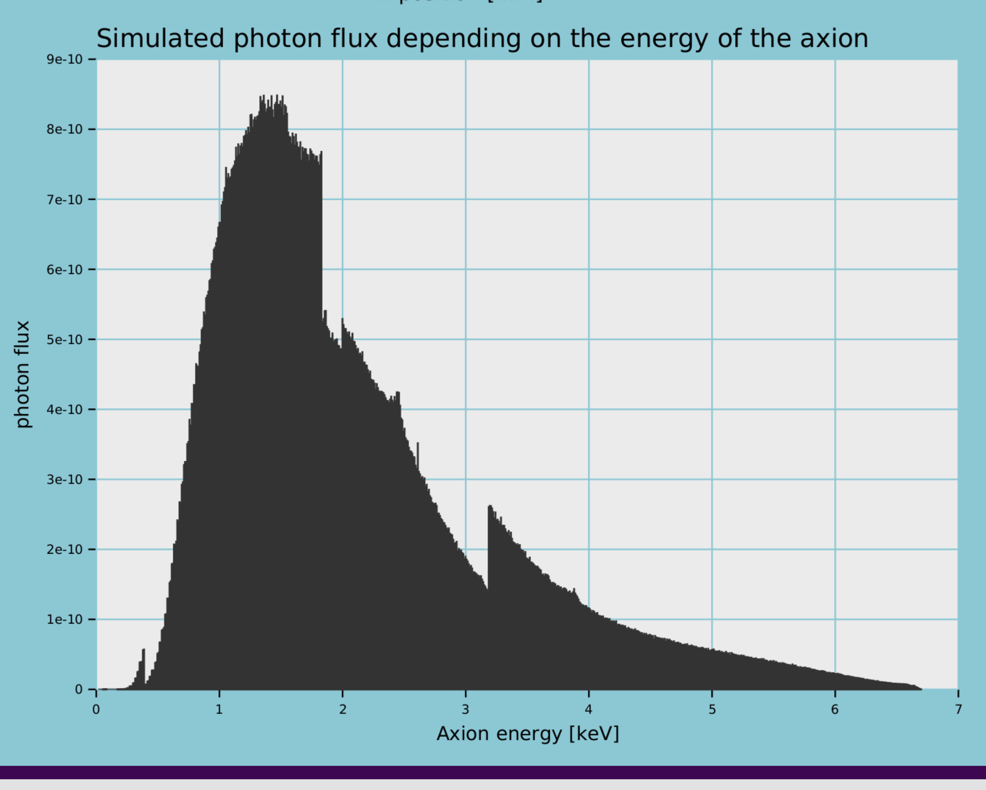


- A higher $p_{\mathrm{gas,\ det}}$ allows for a better absorption but requires a thicker window towards the vacuum
- A thinner window raises the transmission probability
- More strips can allow a thinner window but reduce the open window area



A possible multistriped window GridPix detector:
Window properties:
$0.1\,\mu\mathrm{m}$ Si3N4, radius $= 4\,\mathrm{mm}$
Material ~ 20 window strips: $200\,\mu\mathrm{m}$ Si
Cathode related window coating:
$15\,\mathrm{nm}$ Al
Material detector gas: $3\,\mathrm{cm}$ Ar





The ray tracer outcome informations

- Example outcome plots have been generated for both experiments for the described setups in vacuum phase and for BabyIAXO with the XMM telescope
- The σ_1 and σ_2 surroundings in the chip simulation plots are displayed in yellow and blue respectively

view the code!

Conclusion

- The simulated X-ray flux arriving at the detector chip can be used as a comparison to the taken data
- The variability of different values can help determine the parameters of future experimental setups
- The quantitative flux depends heavily on the assumed coupling strengths