Application of CMOS Monolithic Active Pixel Sensors (MAPS) to Compton Telescopes

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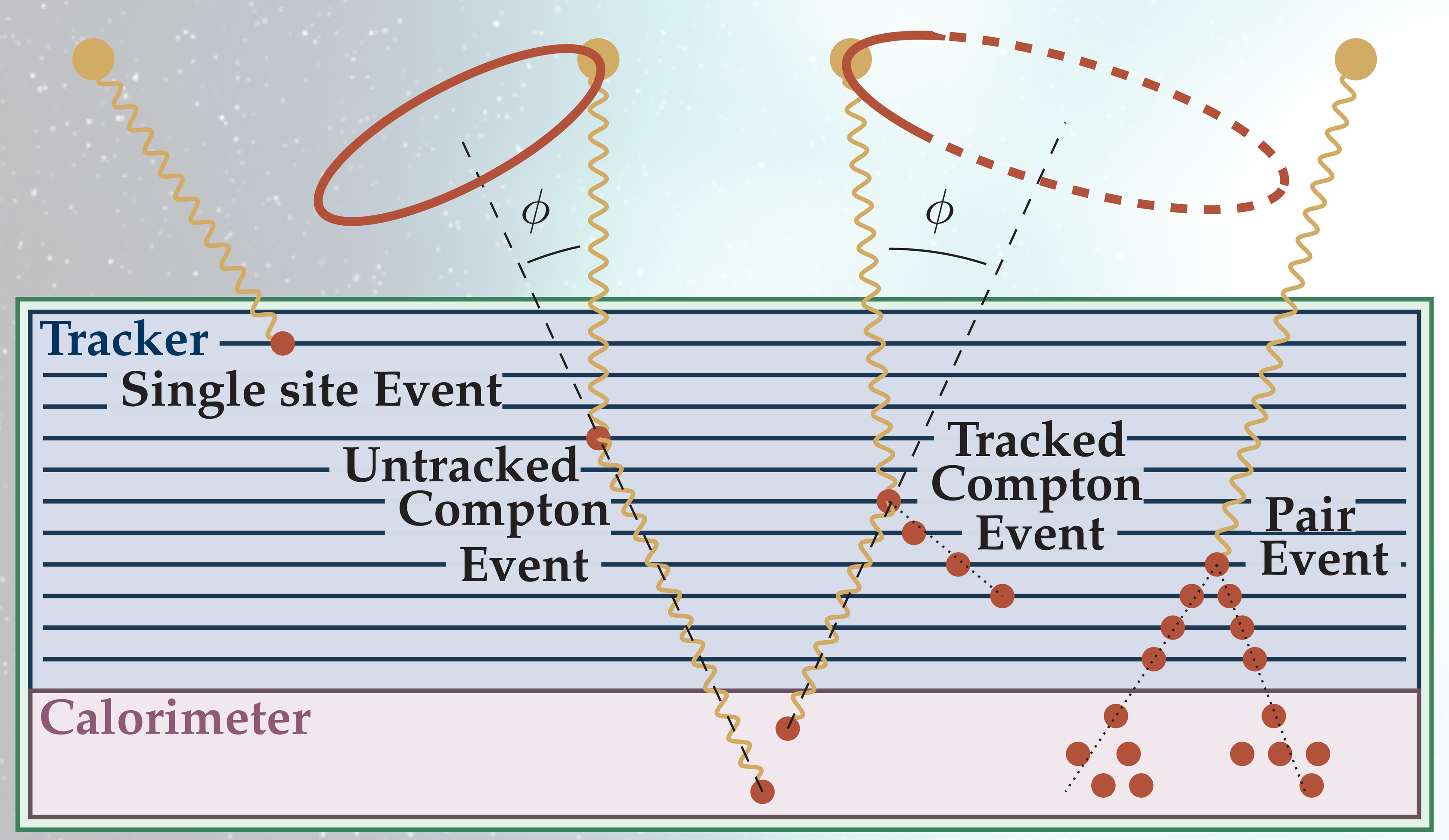
Introduction

Gamma-ray observations – in the MeV range (100 keV – 1 GeV) – are central to **probing high-energy phenomena and advancing multi-messenger studies**. **Compton scattering is the dominant interaction in this regime**, and so advanced tracking is essential for precise source reconstruction in the next-generation explorer-class missions. To overcome current limitations in the tracker spatial resolution, **new Monolithic Active Pixel Sensors (MAPS), under development within the SIU! Spoke 4 (WP 4.2), provide a promising solution**.

Principle of Compton Telescopes

Compton telescopes typically consist of a **tracker** on top of a **calorimeter** surrounded by an **anticoincidence detector** to veto background from charged particles. In the MeV range they need to allow **photon-by-photon reconstruction across three energy regimes** [1]:

Low energies: $E_\gamma \lesssim 100\,\text{keV}$ | Compton Regime: $100\,\text{keV} \lesssim E_\gamma \lesssim 10\,\text{MeV}$ | Pair Production: $E_\gamma \gtrsim 10\,\text{MeV}$



To maximize sensitivity, the next-generation of Compton telescopes must achieve **high-precision energy and spatial reconstruction** while minimizing inactive material.

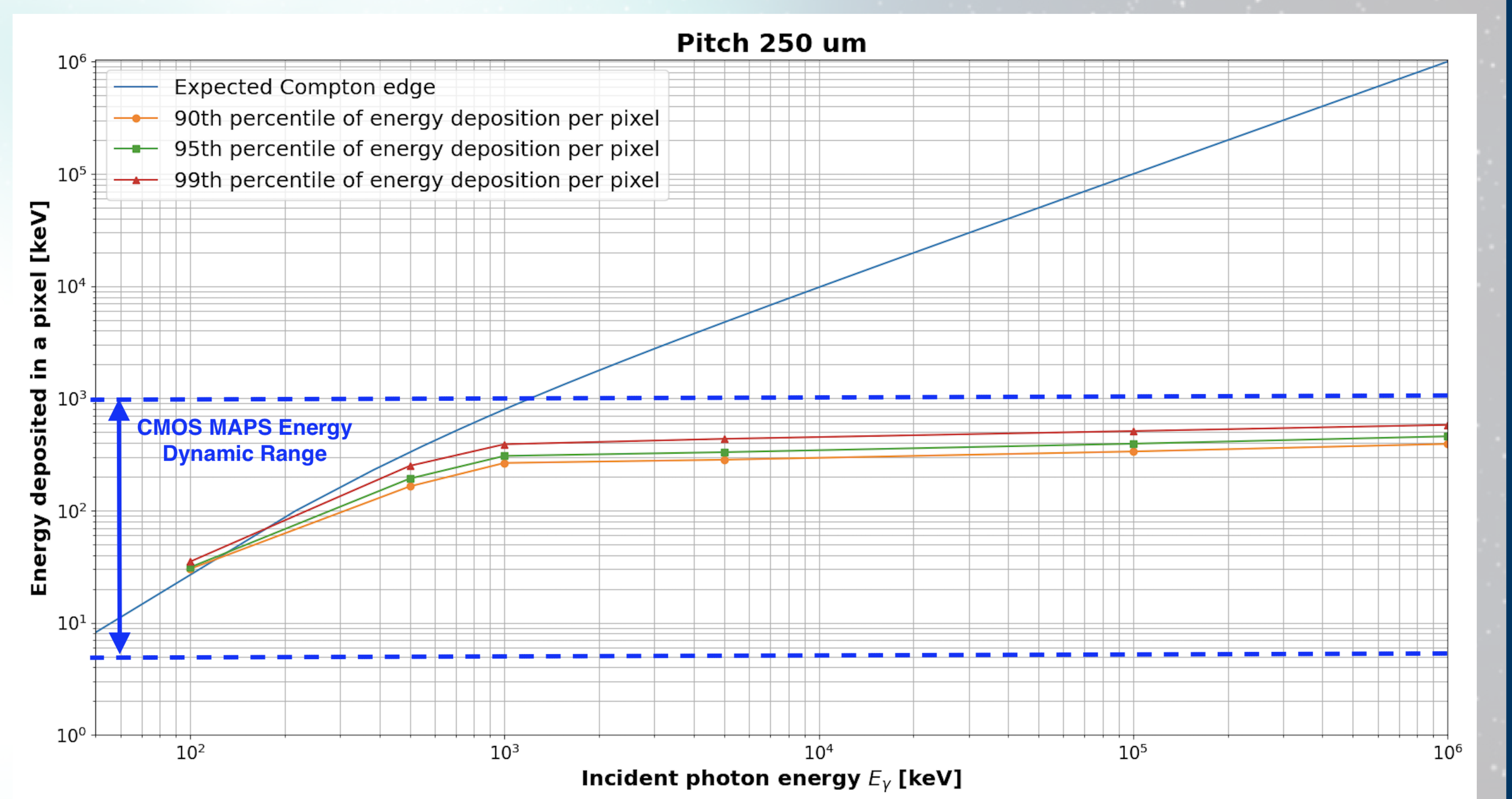
A new CMOS MAPS design

SIU! Spoke 4, WP 4.2 group is designing and producing **arrays of large-area, low-power, high-granularity monolithic radiation sensors (MAPS)** using a commercially standard 110 nm CMOS. See posters [2], [3] and [4] for details.

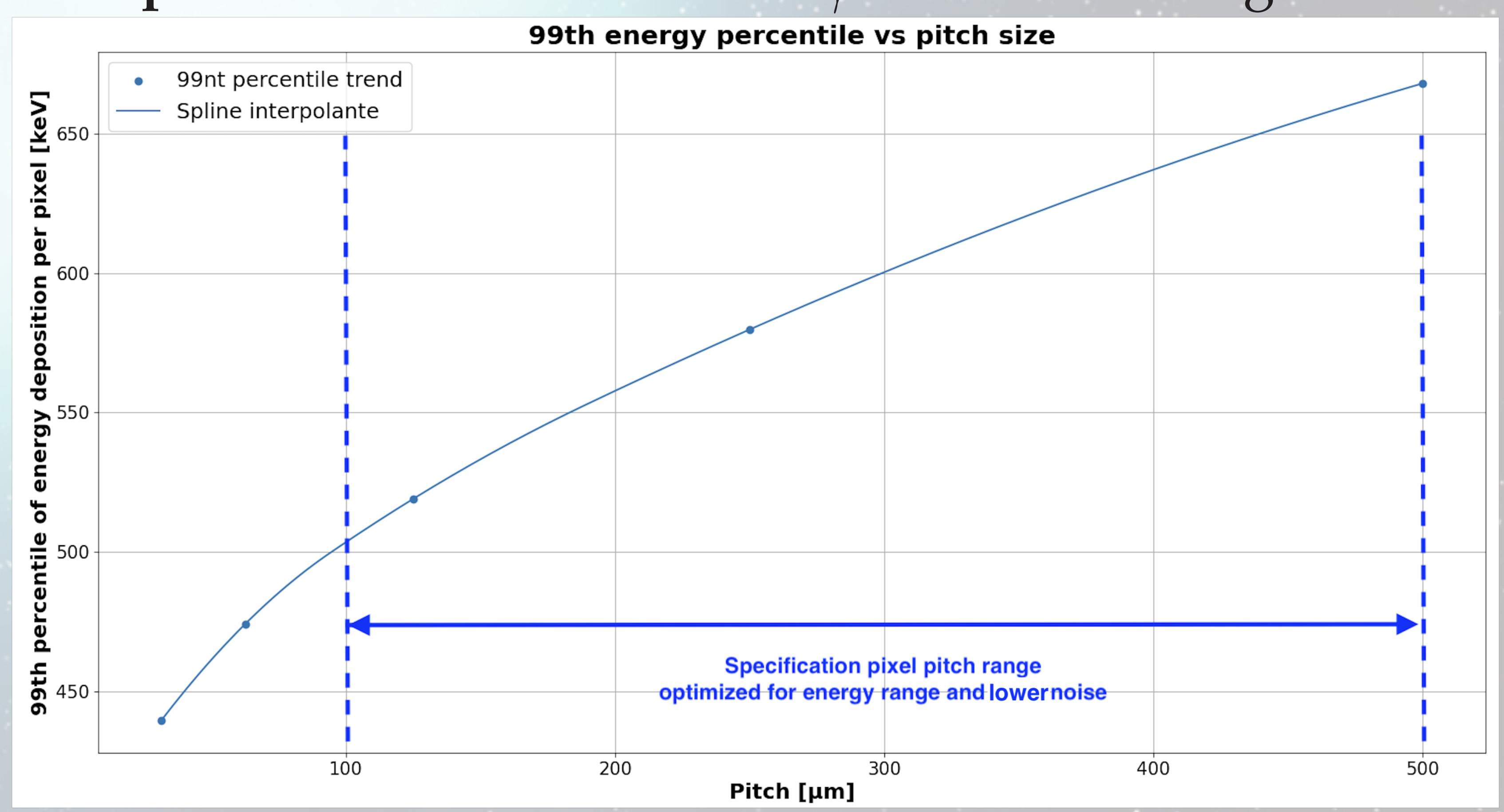
Simulations of a MAPS-based Tracker

SIU! Spoke 4, WP 4.2 group is starting to investigate the **application of this new MAPS sensors in Compton Telescopes** by using the MEGAlib software [5]:

- Deposited energy in **250×250×700** μm^3 pixel vs. E_γ:



- Asymptotic energy deposited in a single pixel **vs. different pixel sizes** with incident E_γ in the MeV-range:



Conclusions

SIU! Spoke 4, WP 4.2 group is establishing a **supply chain for low-power MAPS and back-end electronics featuring space-qualified components**, key for future astrophysics missions. Next-generation **Compton telescopes** will precisely reconstruct photon paths by employing **MAPS-based trackers**, offering **an unprecedented view of the high-energy universe**.

References

[1] K. Engel, *et al.* "The Future of Gamma-Ray Experiments in the MeV-EeV Range", [arXiv:2203.07360 [astro-ph.HE]].

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[5] A. Zoglauer, R. Andritschke, and F. Schopper., "MEGAlib – The Medium Energy Gamma-ray Astronomy Library", New Astronomy Rev., 50(7-8):629–632, 2006.

Acknowledgements

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Background Picture: Artist's impression of a gamma-ray burst (Credit: ESA/CC BY-SA 3.0 IGO)