Assessing the potential of quantum annealers for track reconstruction at LUXE

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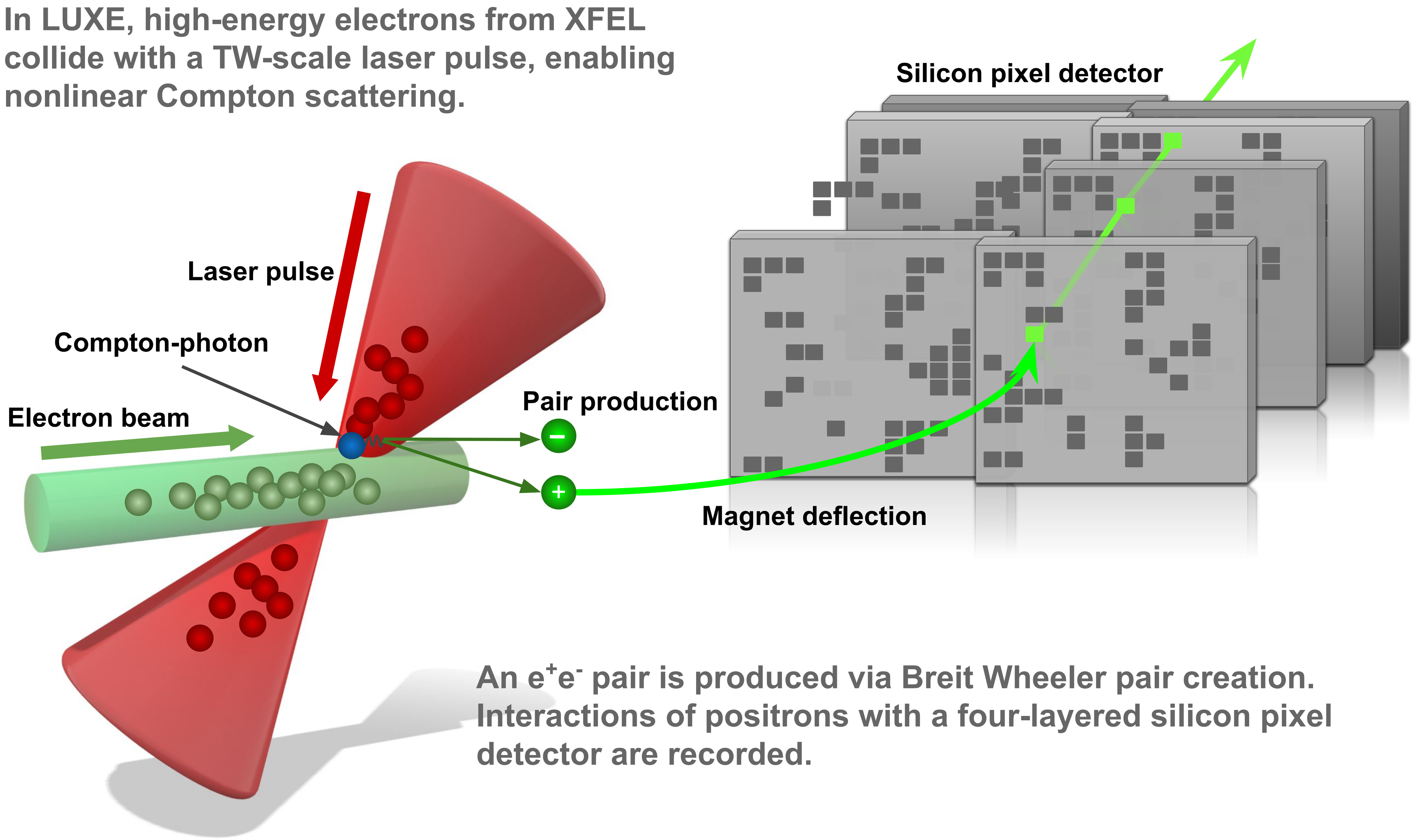
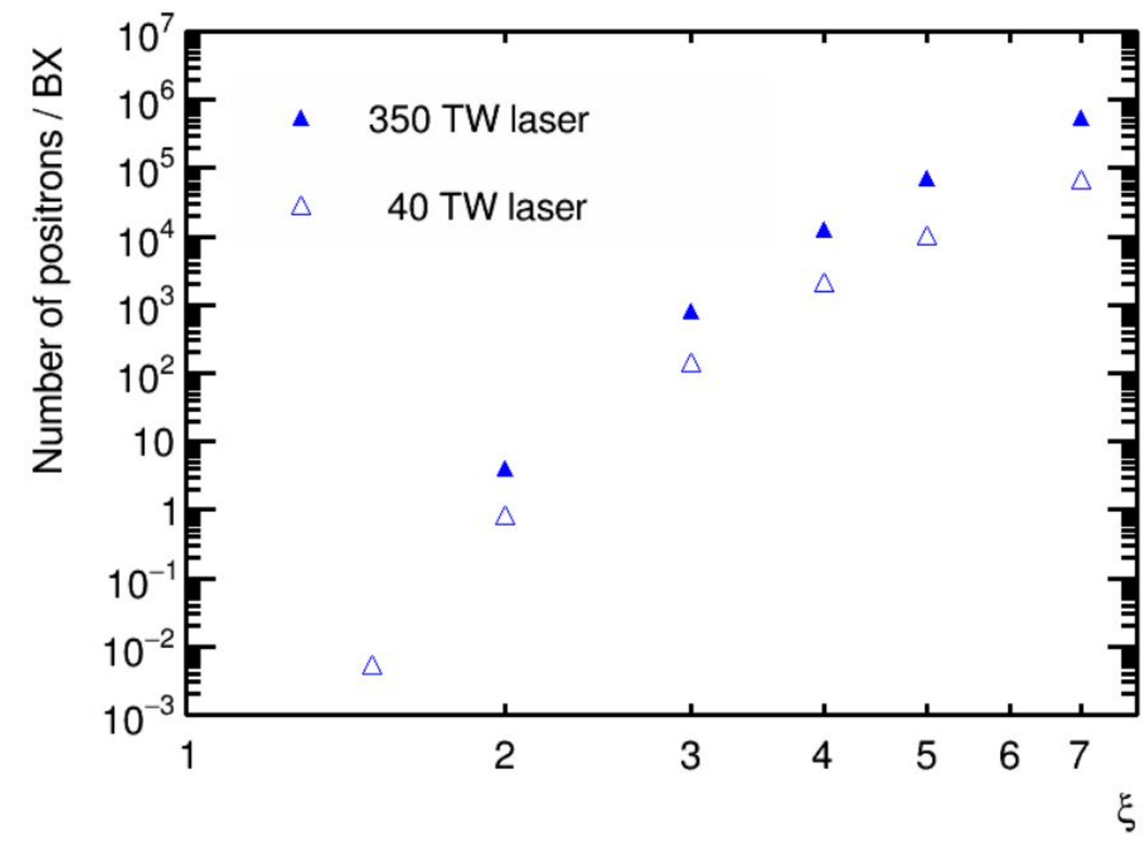
In LUXE, high-energy electrons from XFEL collide with a TW-scale laser pulse, enabling nonlinear Compton scattering.



An e^+e^- pair is produced via Breit Wheeler pair creation. Interactions of positrons with a four-layered silicon pixel detector are recorded.



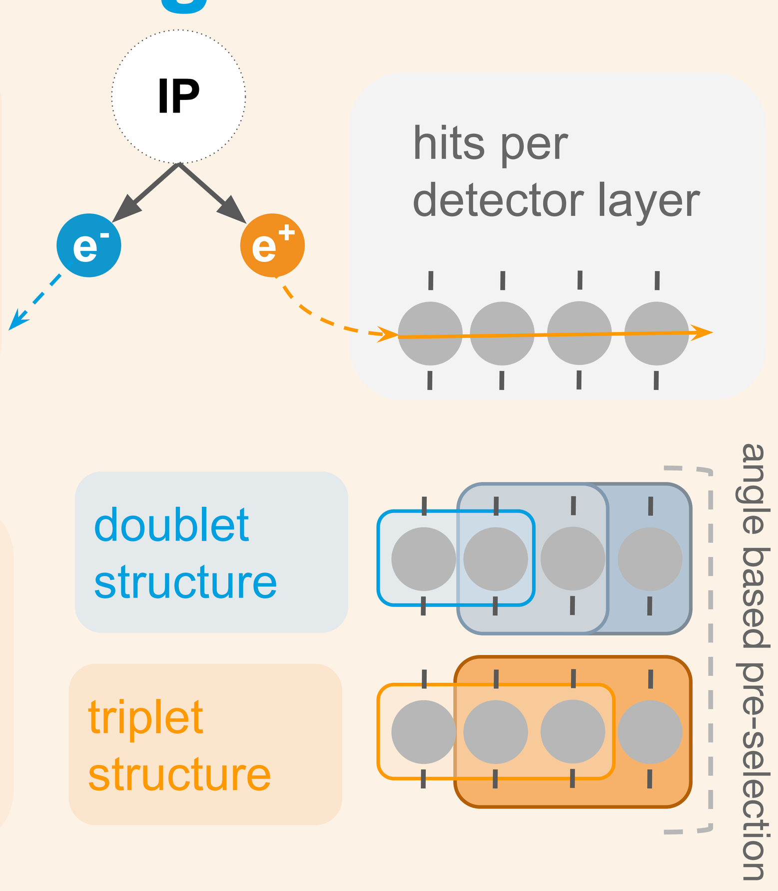
A key measurement is to quantify the positron rate as a function of the intensity parameter ξ.

$$\xi = \frac{m_e E_L}{\omega_L E_{crit}}$$

m_e : electron mass
ω_L : laser frequency
$E_{L,cr}$: laser/critical field strength

LUXE Model Building.

Custom Monte Carlo event generation + simulation



Forming patterns from hits of consecutive layers:

- Two hits combined to a doublet
- Two doublets combined to a triplet

Triplets as QUBO variables.

Quadratic Unconstrained Binary Optimisation

$$O(a,b,T) = \sum_{i=1}^{N} a_i T_i + \sum_{i}^{N} \sum_{j<i}^{N} b_{ij} T_i T_j \quad T \in \{0,1\}$$

Quality a_i of a triplet

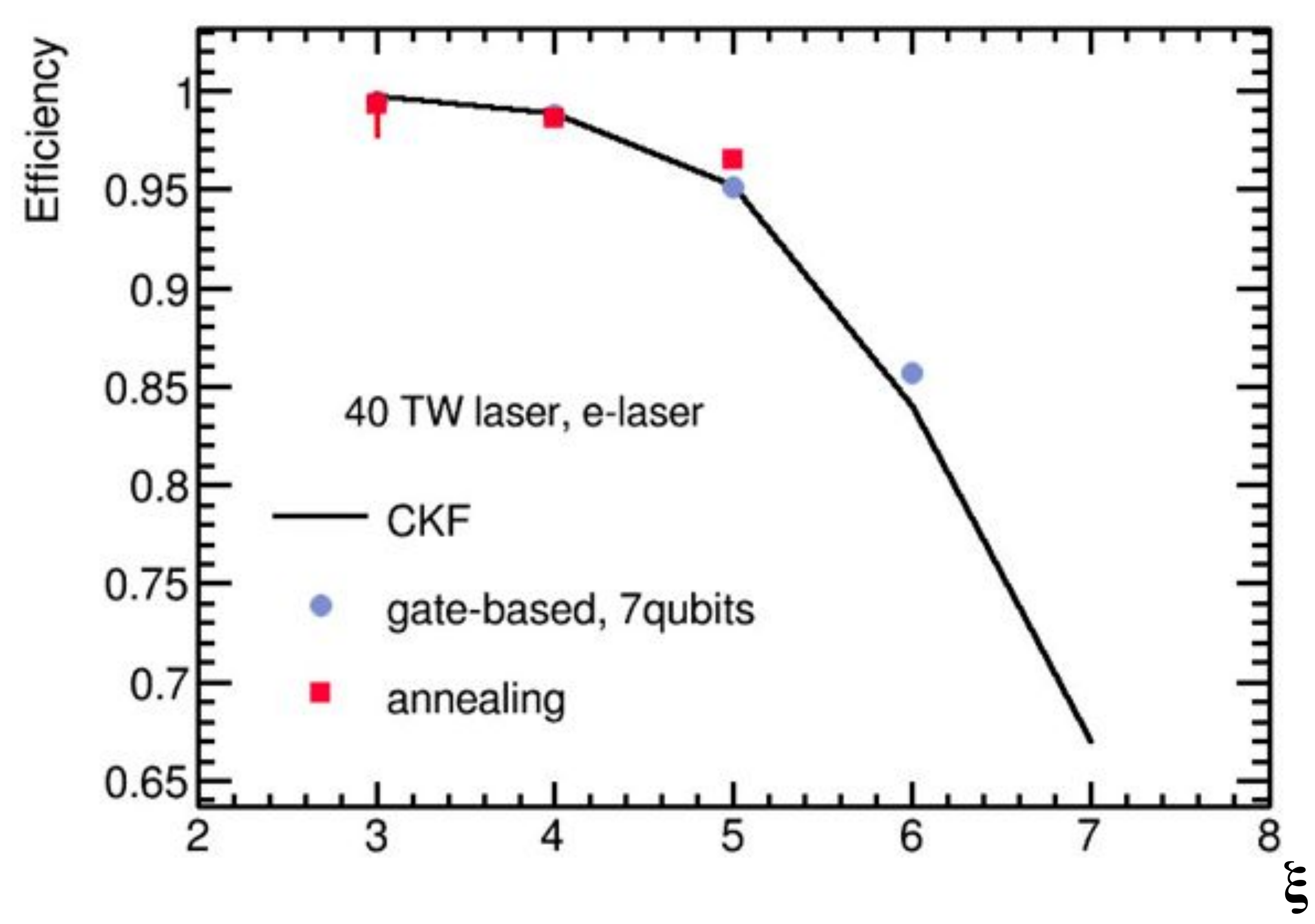
Compatibility b_{ij} of two triplets

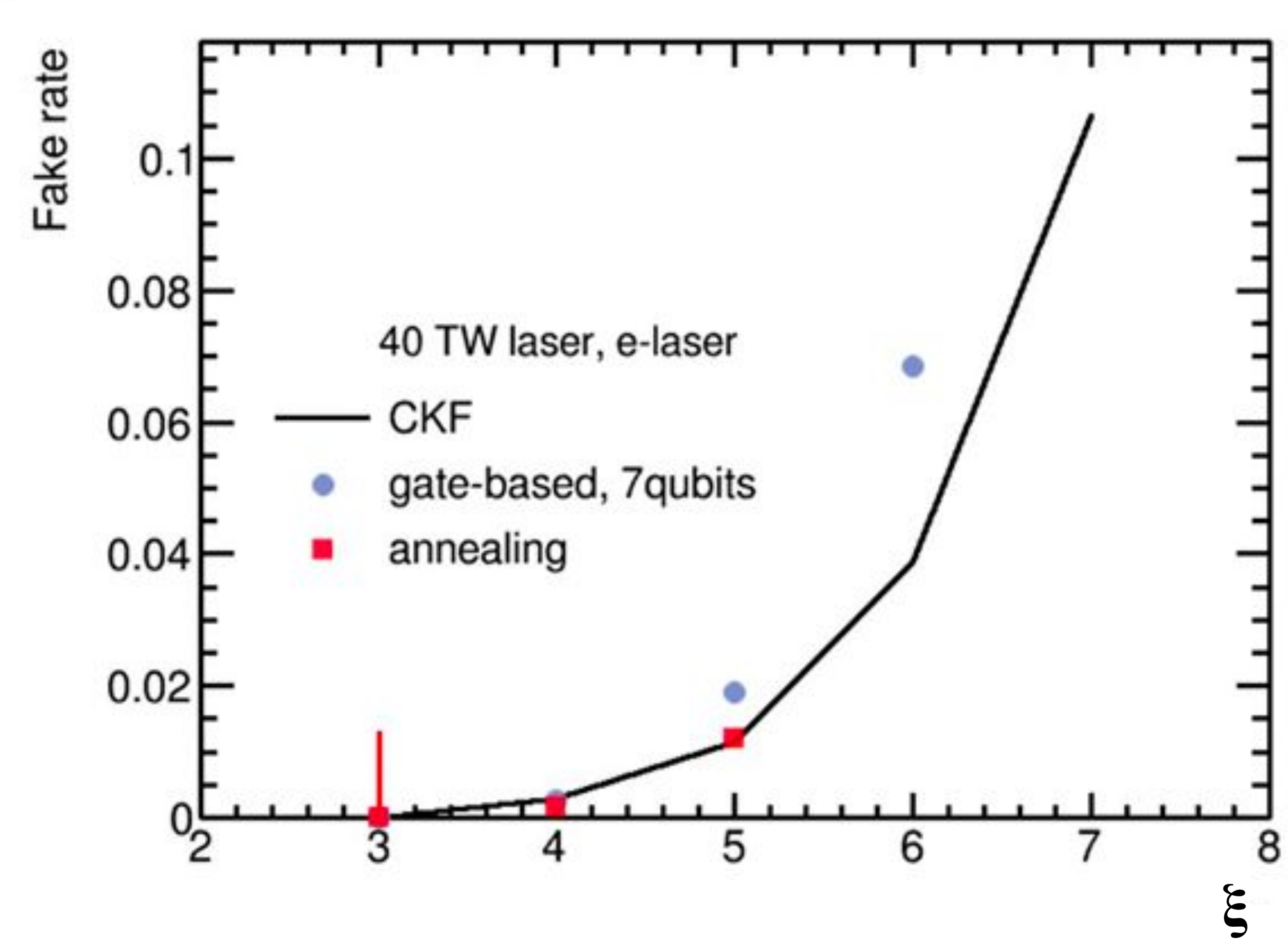
$$b_{ij} = \begin{cases} -S(Ti, Tj), & \text{if } (T_i, T_j) \text{ form a quadruplet,} \\ \zeta & \text{if } (T_i, T_j) \text{ are in conflict,} \\ 0 & \text{otherwise.} \end{cases}$$

Results.

$$\text{Efficiency} = \frac{N_{tracks}^{matched}}{N_{tracks}^{generated}}$$

$$\text{Fake rate} = \frac{N_{tracks}^{fake}}{N_{tracks}^{reconstructed}}$$





Key questions.

- How does the performance depend on ξ?
- What quantum algorithm is optimal?
- What are the requirements (noise, size,…) on a real quantum device as a backend?

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Quantum algorithms for charged particle track reconstruction in the LUXE experiment

Technical Design Report for the LUXE Experiment

HELMHOLTZ