light yield description

for scintillating cryogenic calorimeters

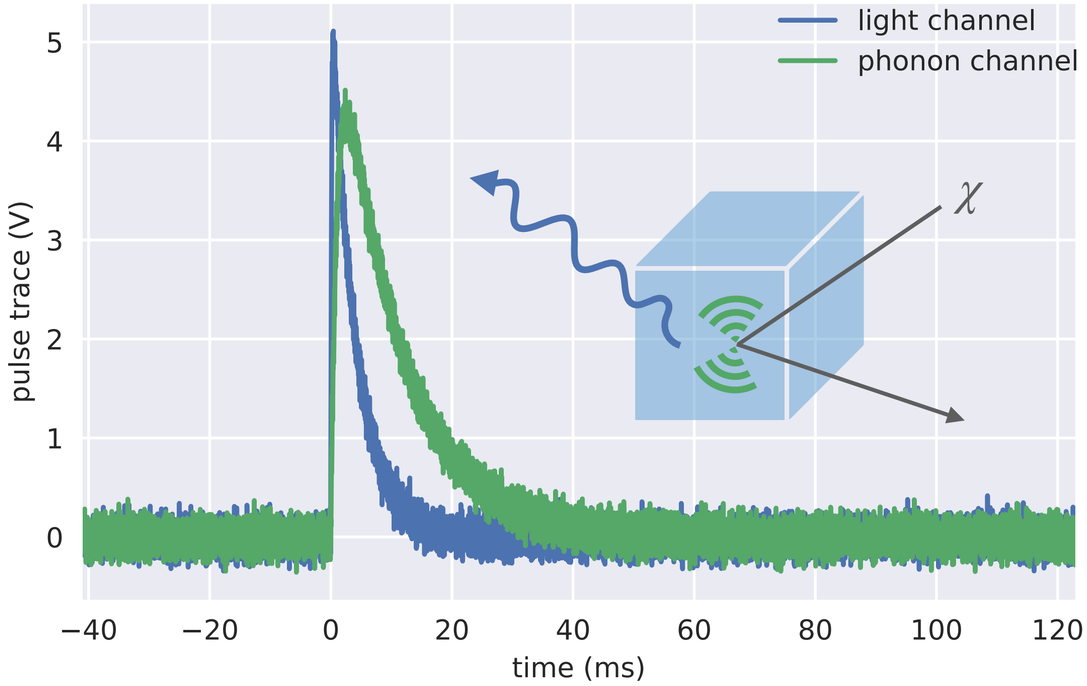
Philipp Schreiner

April 5, 2024

TU WIEN
TECHNISCHE UNIVERSITÄT WIEN
HEPHY
INSTITUTE OF HIGH ENERGY PHYSICS

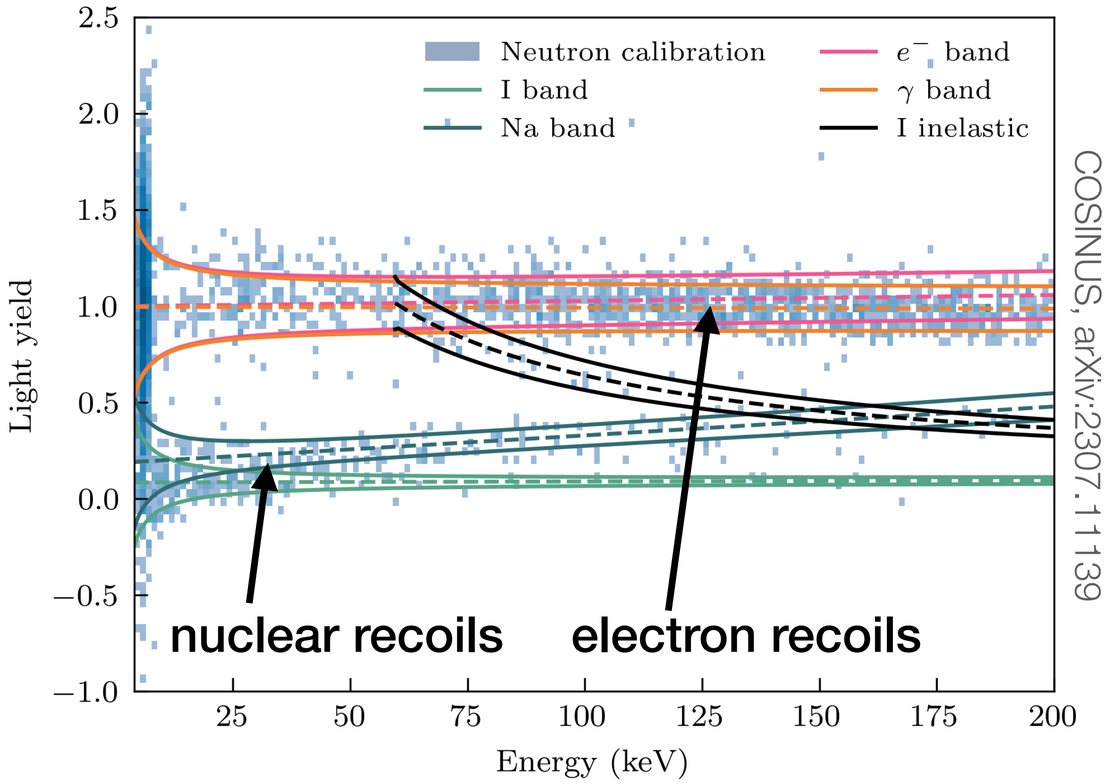
Scintillating Cryogenic Calorimeters

- Particles interacting with detector produce **phonons** and **scintillation light**
- Ratio between phonon and light energy, called **light yield**, depends on type of recoil (electronic or nuclear)
- Allows for **particle discrimination** on event-by-event basis



The Light Yield Plane

- Drawing light yield as a function of total deposited energy reveals **recoil bands**
- Bands are well modelled semi-empirically (CRESST, arXiv:2403.03824)
- Parametric fit allows **hypothesis testes** (limit setting and discovery analysis)
- Discrimination: increased sensitivity
- Width of bands follows **energy-dependant Gaussian**



Caveats and Motivation for Extension

- Scintillators with low light output and at low energies only produce $\mathcal{O}(1)$ photons
- Width of bands will be inaccurate (Gaussian assumptions is conservative)
- Discrimination power suffers
- Scintillation process is better modelled by **Poisson process** (# of photons emitted)
- **Gaussian resolution** of phonon and light detector needs to be incorporated

$$F(E,L) = \int_{-\infty}^{\infty} \frac{dE'}{1-\eta} \sum_{k=0}^{\infty} \frac{\lambda(E')^k \mathrm{e}^{-\lambda(E')}}{k!} \mathcal{N}_{0,\sigma_L}(L-\alpha k) \mathcal{N}_{0,\sigma_P}\left(\frac{E'-E}{1-\eta}\right)$$

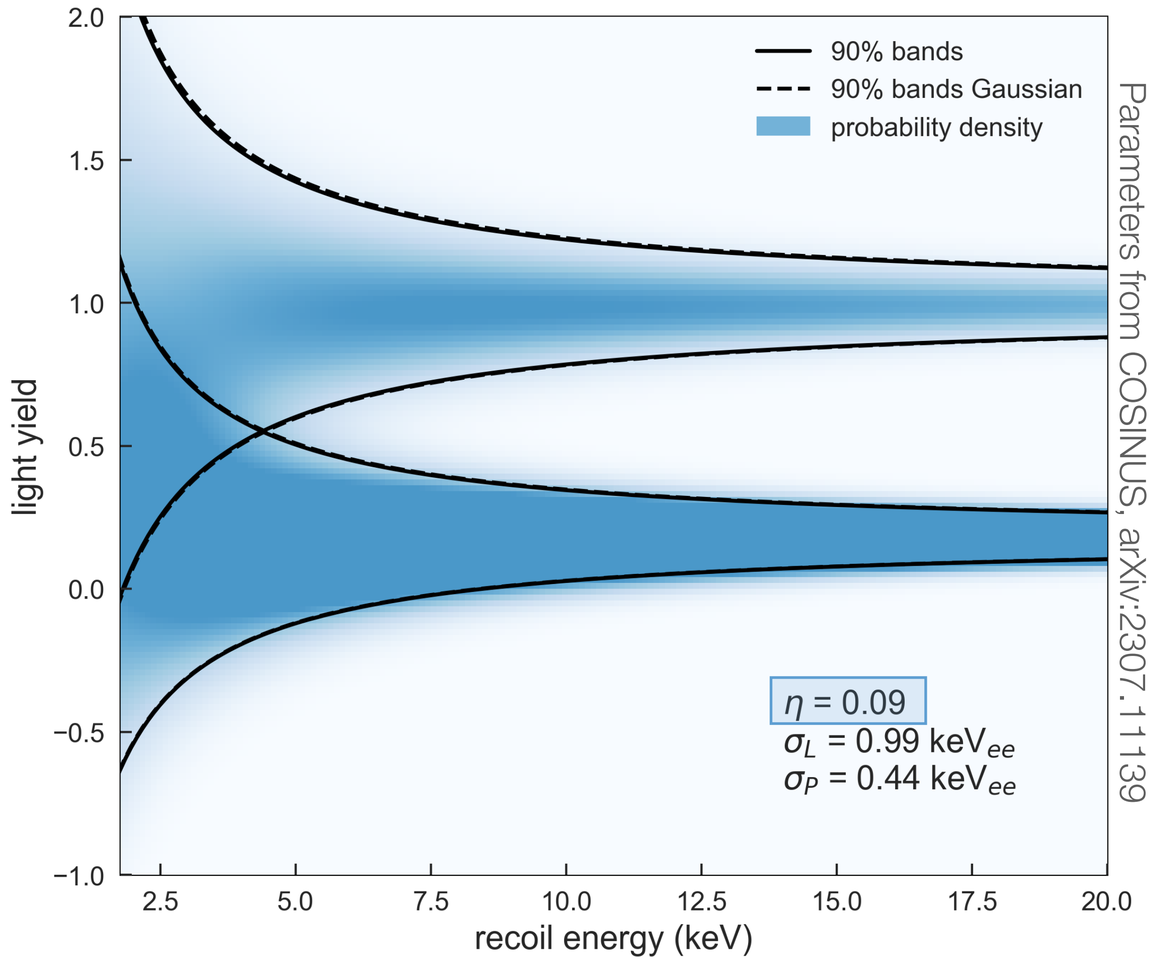
Poissonian light output

light detector resolution

phonon detector resolution

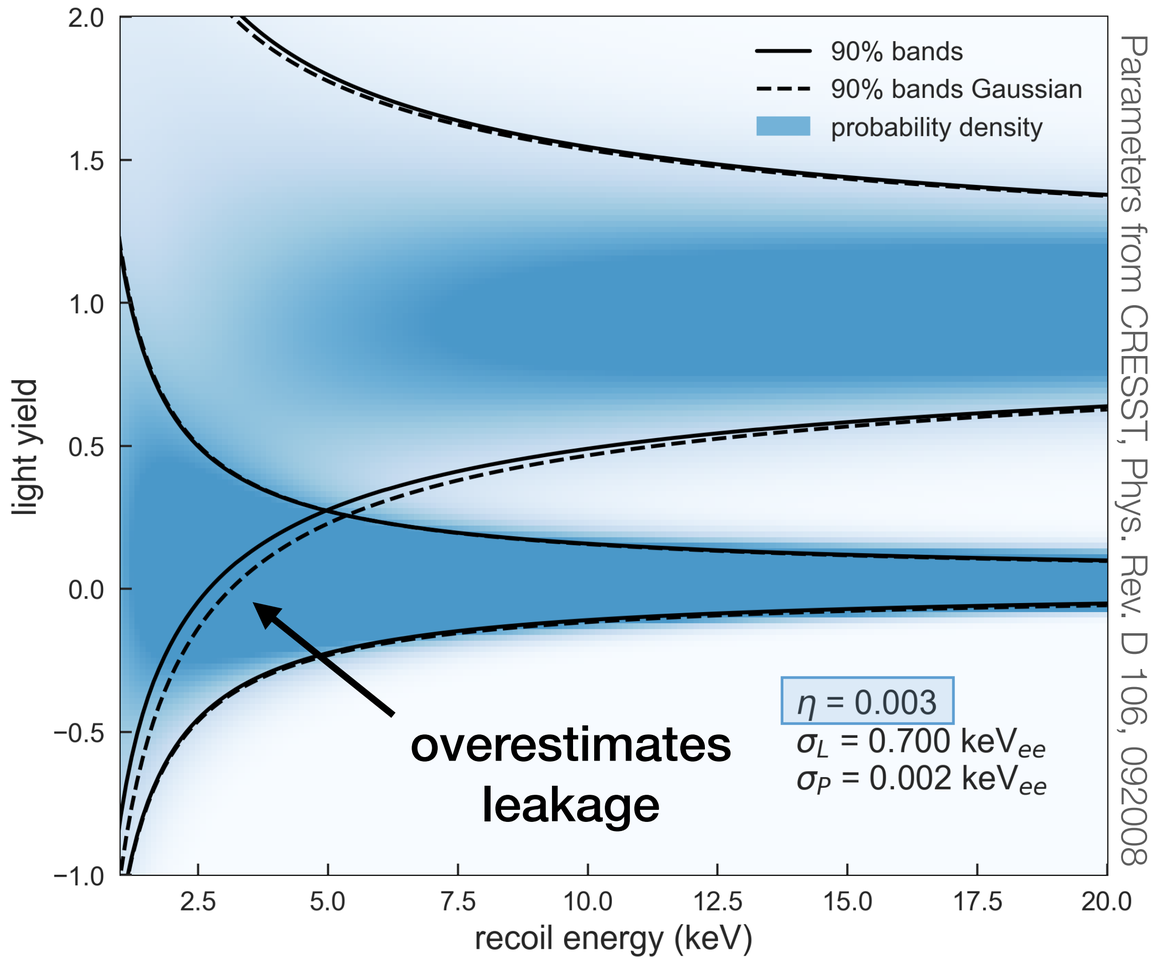
Observations

- As expected (and as a sanity check) we observe no difference for high light output and low resolutions
- Effect visible for **low light output** crystals
- Will be visible for **better light** detector **resolutions**



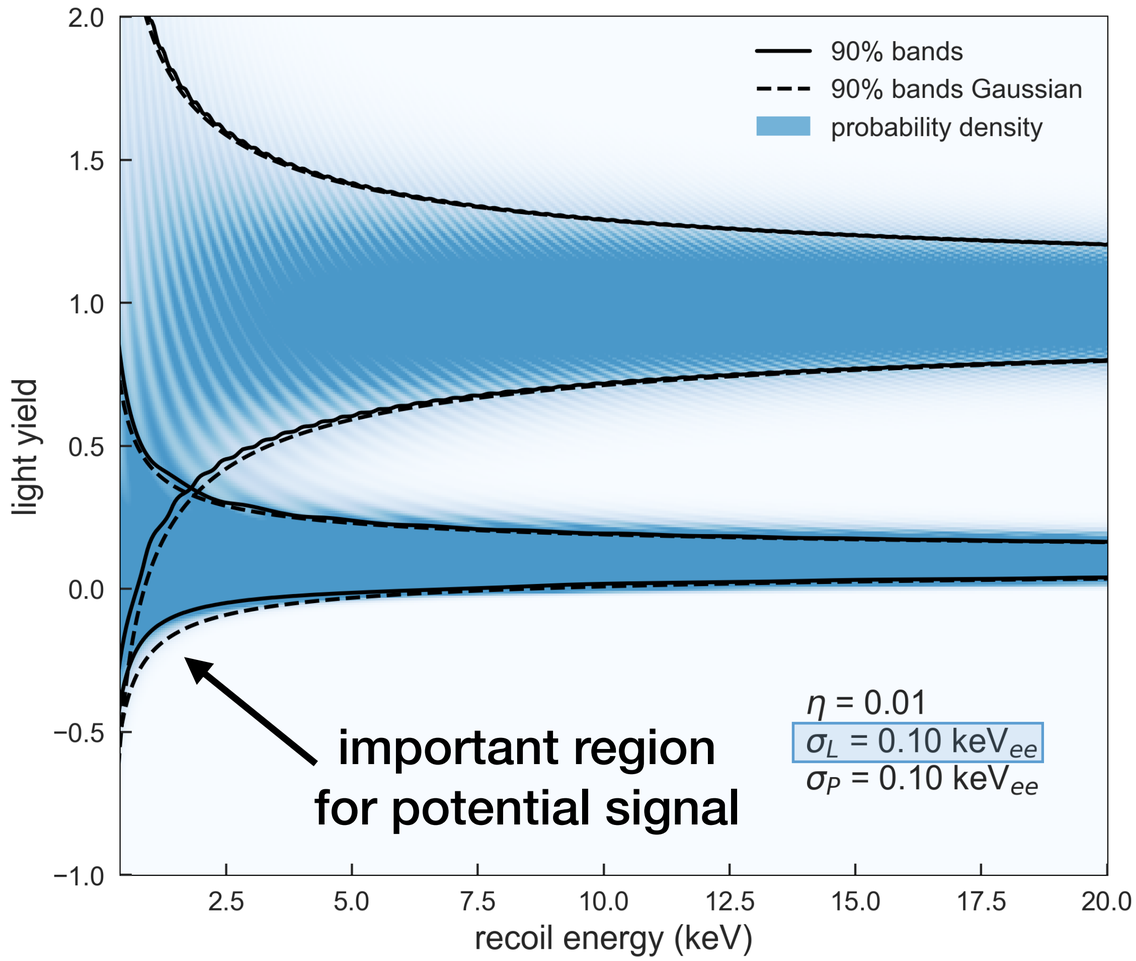
Observations

- As expected (and as a sanity check) we observe no difference for high light output and low resolutions
- Effect visible for **low light output** crystals
- Will be visible for **better light** detector **resolutions**



Observations

- As expected (and as a sanity check) we observe no difference for high light output and low resolutions
- Effect visible for **low light output** crystals
- Will be visible for **better light** detector **resolutions**



What's next

- Include functionality in already existing likelihood fit python framework
- Assess impact on dark matter **limits** by fitting to **real data**