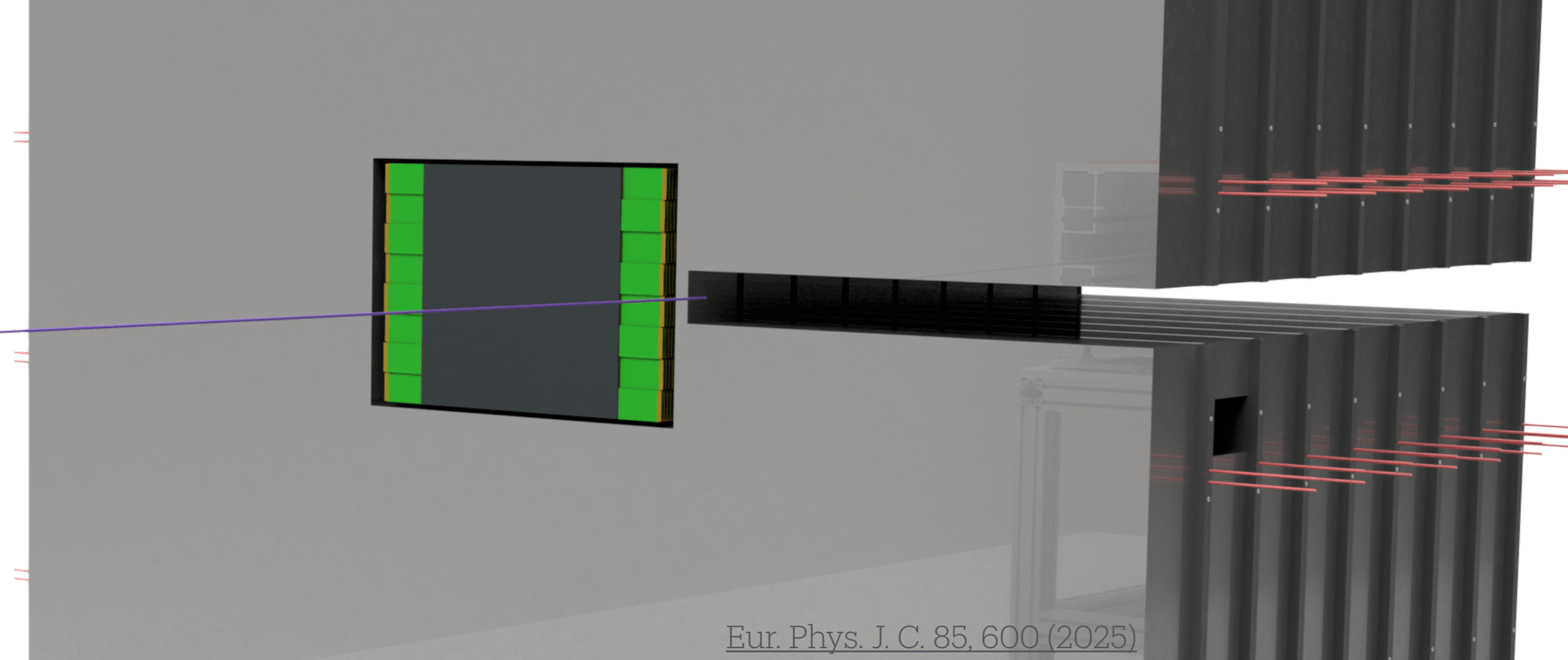
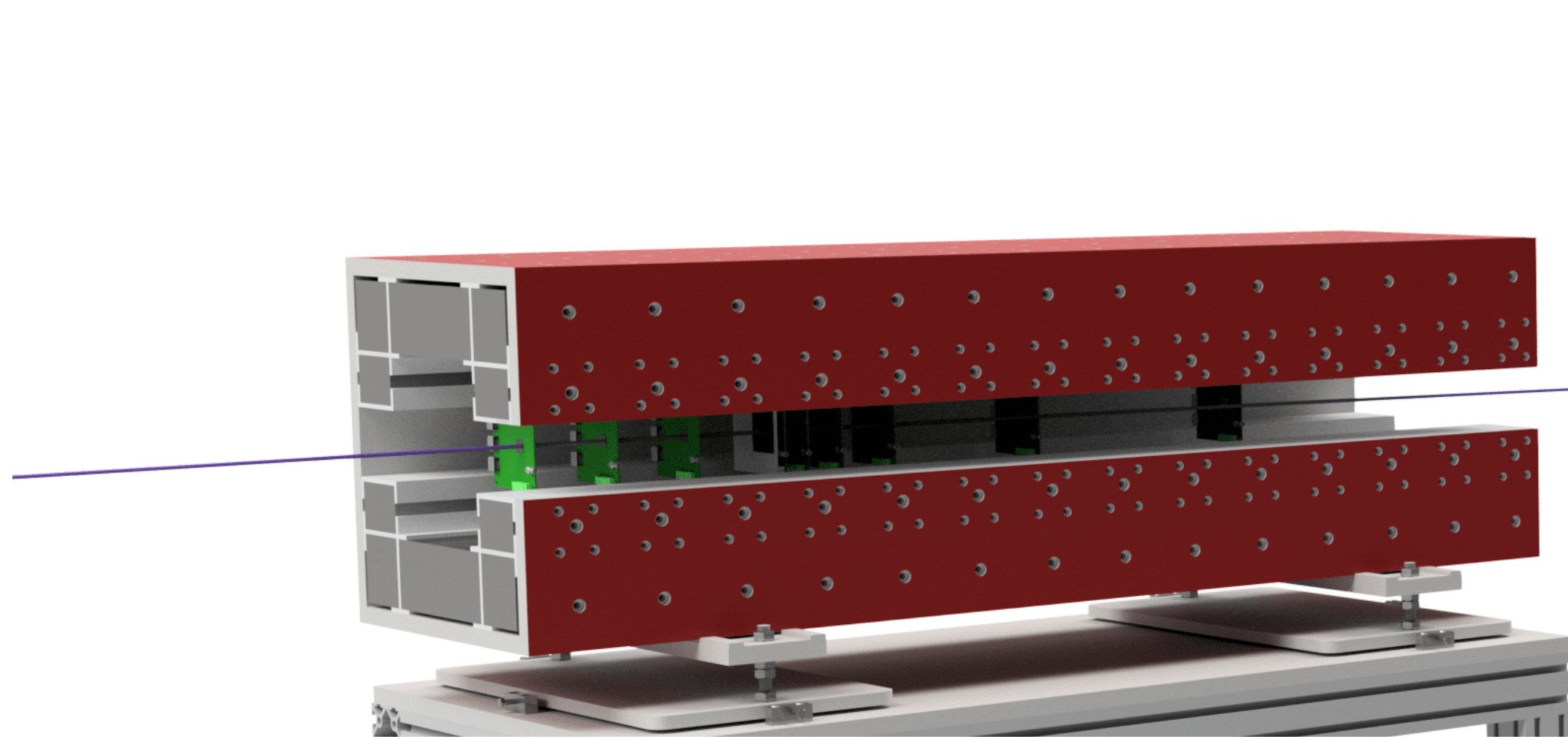


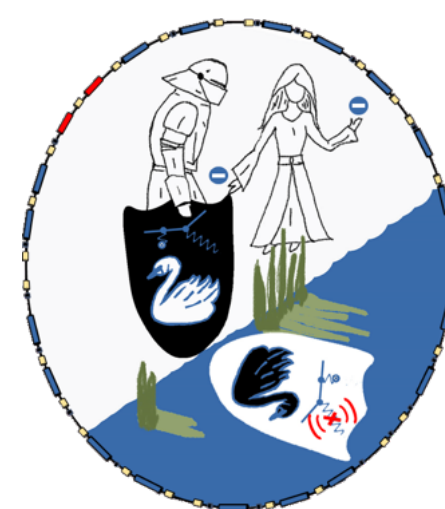


Updates on the Lohengrin Experiment

Cedric Breuning for the Lohengrin Study Group
22.10.2026 — DMLab 2026 — Paris

Philip Bechtle¹, Christian Bepin¹, Dominique Breton², Cedric Breuning¹, Carlos Orero Canet⁴, Klaus Desch¹, Herbi Dreiner¹, Oliver Freyermuth¹, Rhorry Gauld^{1,3}, Markus Gruber¹, Cesar Blanch Gutierrez⁴, Hayem Hajjar¹, Matthias Hamer¹, Jan-Eric Heinrichs¹, Adrian Irles⁴, Jochen Kaminski¹, Laney Klippfahn¹, Nico Klein¹, Hans Krüger¹, Cemre Kurt, Michael Lupberger¹, Jihane Maalmi², Roman Pöschl², Dennis Proft¹, Leonie Richarz^{1,6}, Tobias Schiffer¹, Patrick Schwäbig¹, Martin Schürmann¹, Mika Thein¹, Emma Thier¹, Carla Vermöhlen¹, Dirk Zerwas⁵

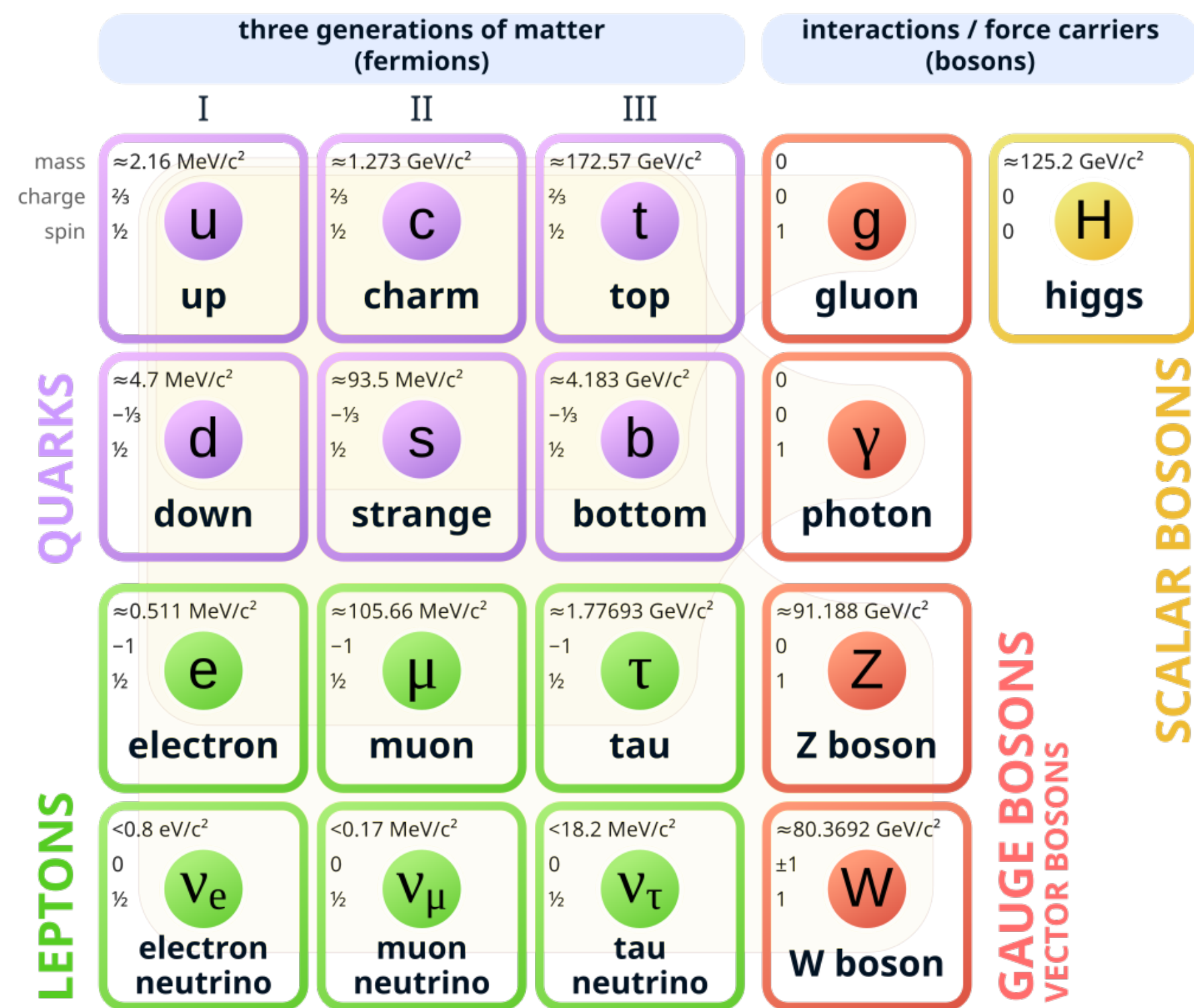
¹ Physikalisches Institut, University of Bonn | ² IJCLab Orsay | ³ Werner-Heisenberg-Institute, MPP Garching | ⁴ IFIC, Valencia | ⁵ DMLab, DESY/IN2P3/CNRS | ⁶ NTNU Norway



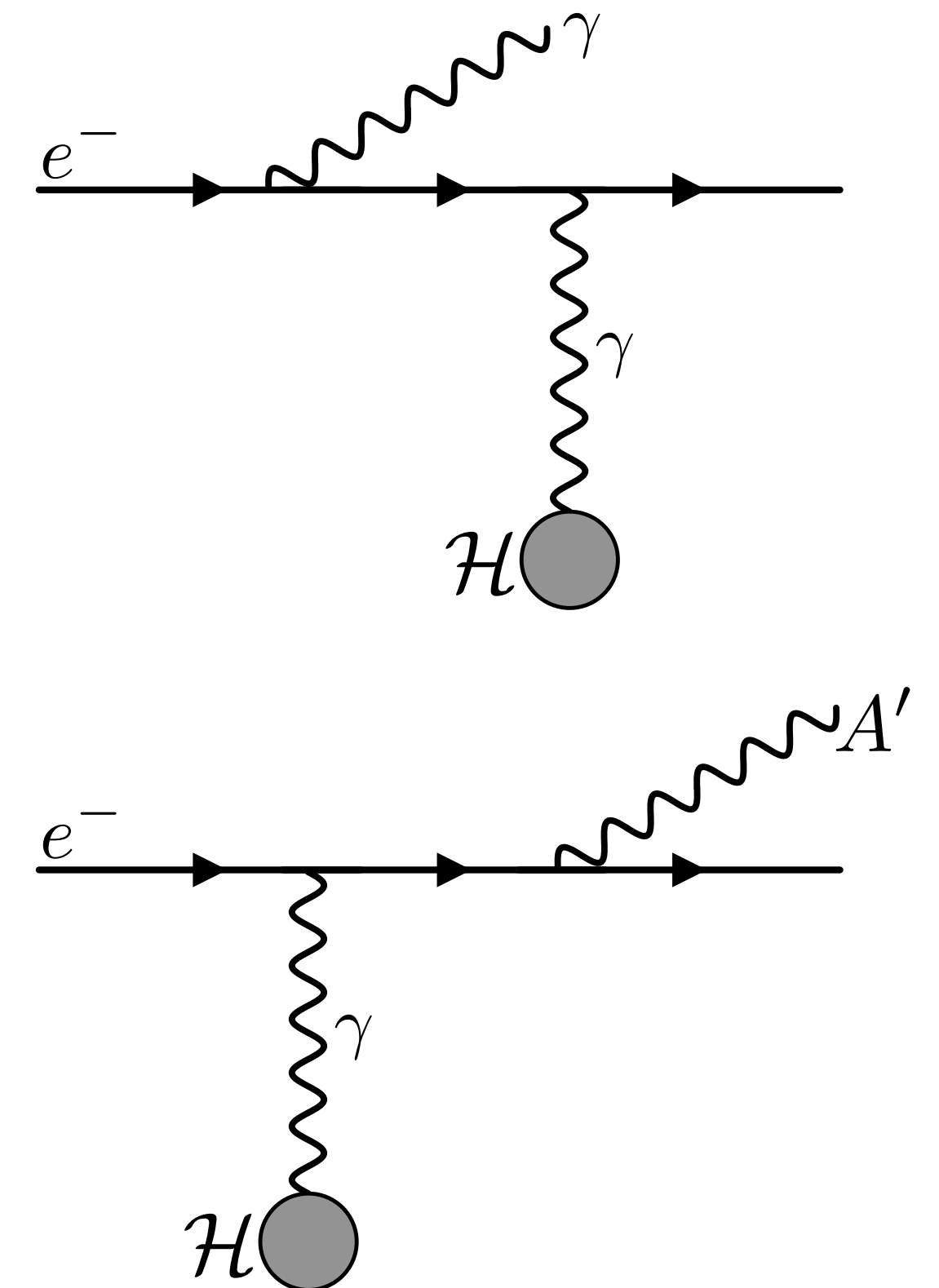
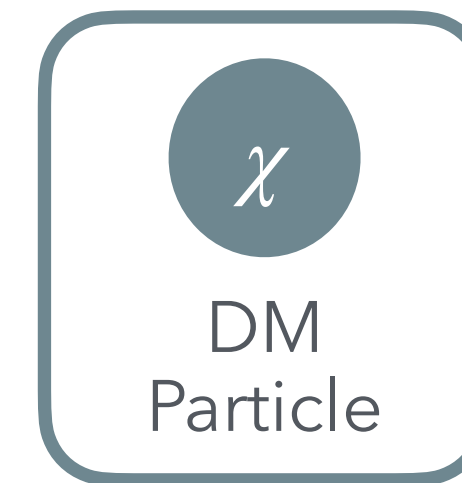
color meets flavor

Light Dark Matter Portal Interaction

Standard Model of Elementary Particles



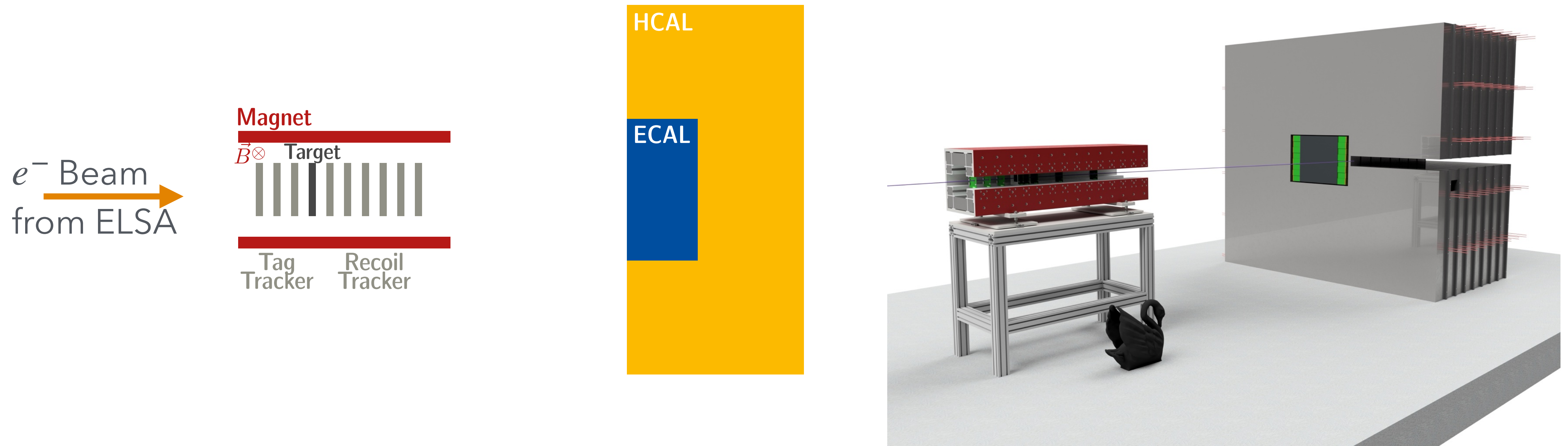
Dark Sector



$$\mathcal{L} \supset -\frac{1}{4}F_{D\mu\nu}F_D^{\mu\nu} + \frac{1}{2}m_{A_D}^2 A_{D\mu}A_D^\mu - \frac{\sin \epsilon_Y}{2}F_D^{\mu\nu}B_{\mu\nu} - g_D A_{D\mu}J_D^\mu$$

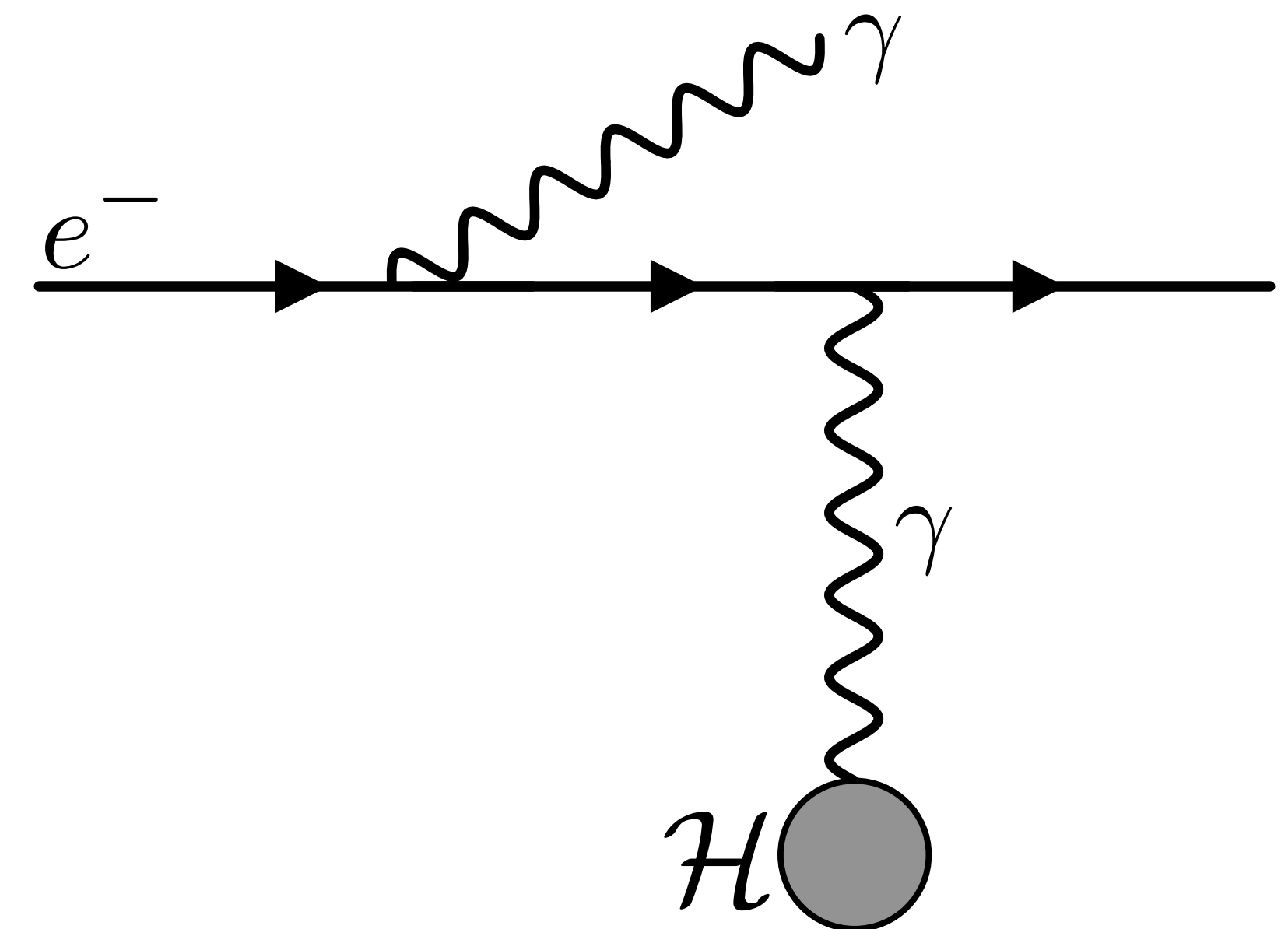
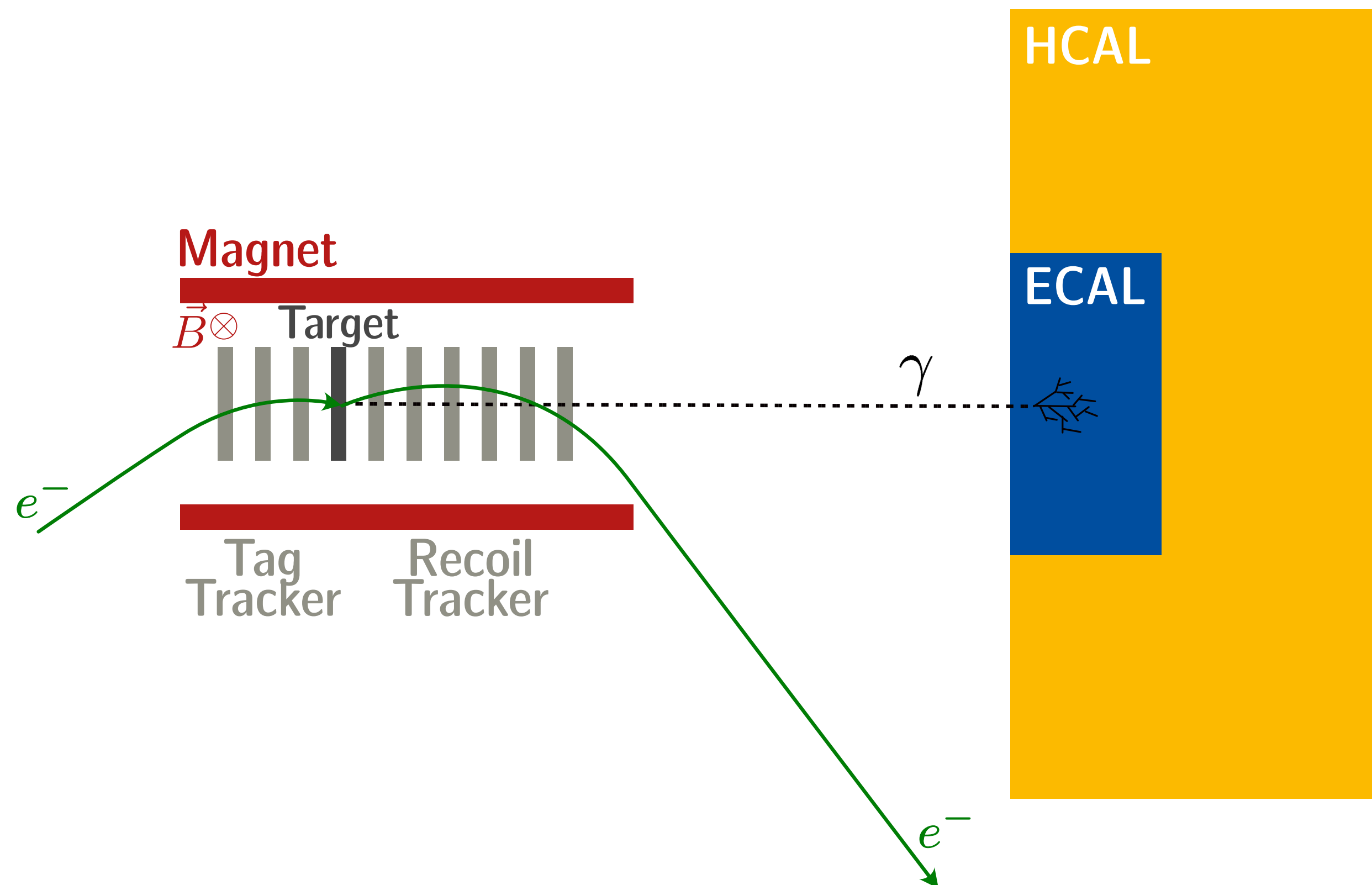
The Lohengrin Experiment

Sketch — Inspired by the LDMX proposal [arXiv:2508.11833](https://arxiv.org/abs/2508.11833)



Lohengrin Experiment Concept

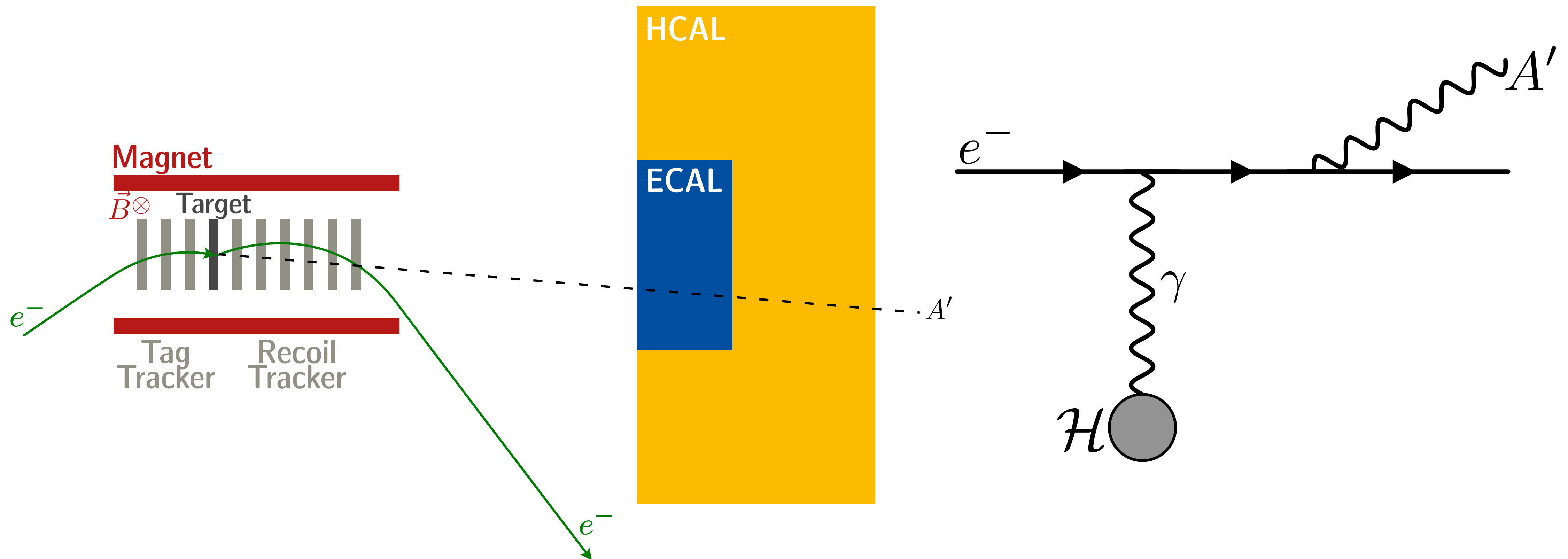
QED Bremsstrahlung



→ Low energetic recoil electron + ECAL Signal

Lohengrin Experiment Concept

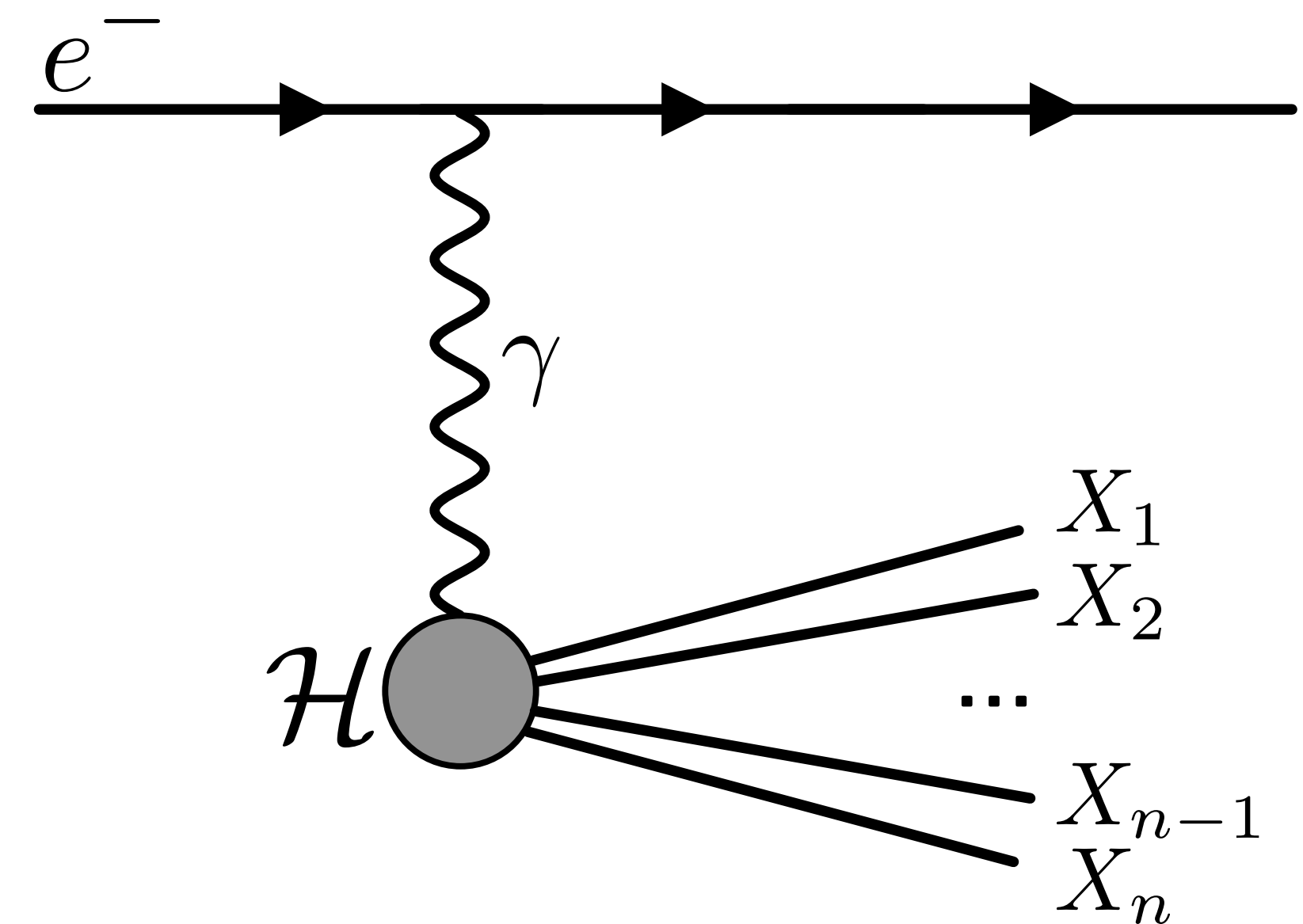
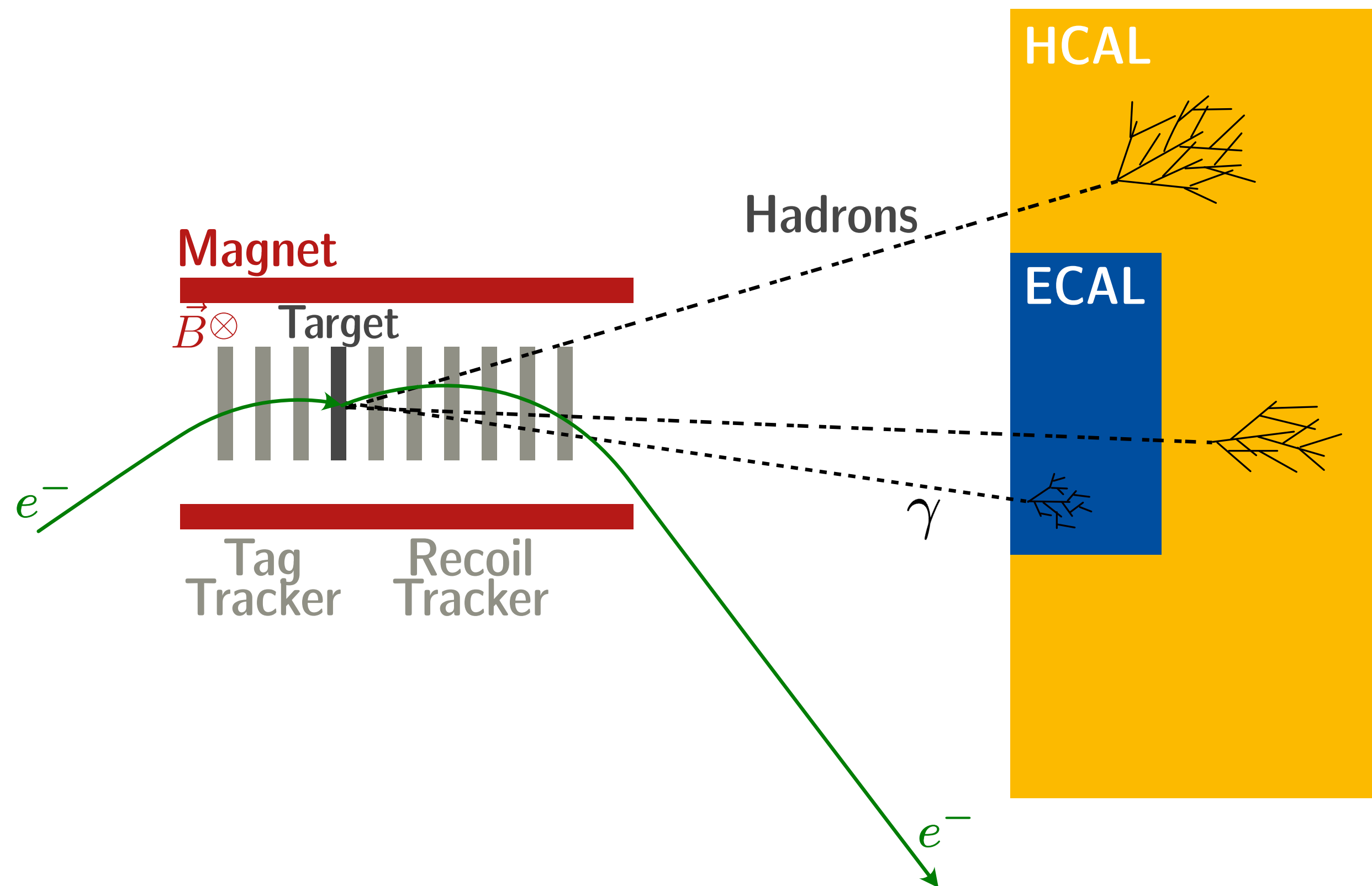
Dark Bremsstrahlung



→ Low energetic recoil electron

Lohengrin Experiment Concept

Electro Nuclear Reactions



→ Low energetic recoil electron + ECAL/HCAL Signal

ELSA

$$\frac{\langle N_e \rangle}{\text{Event}} \leq 1$$

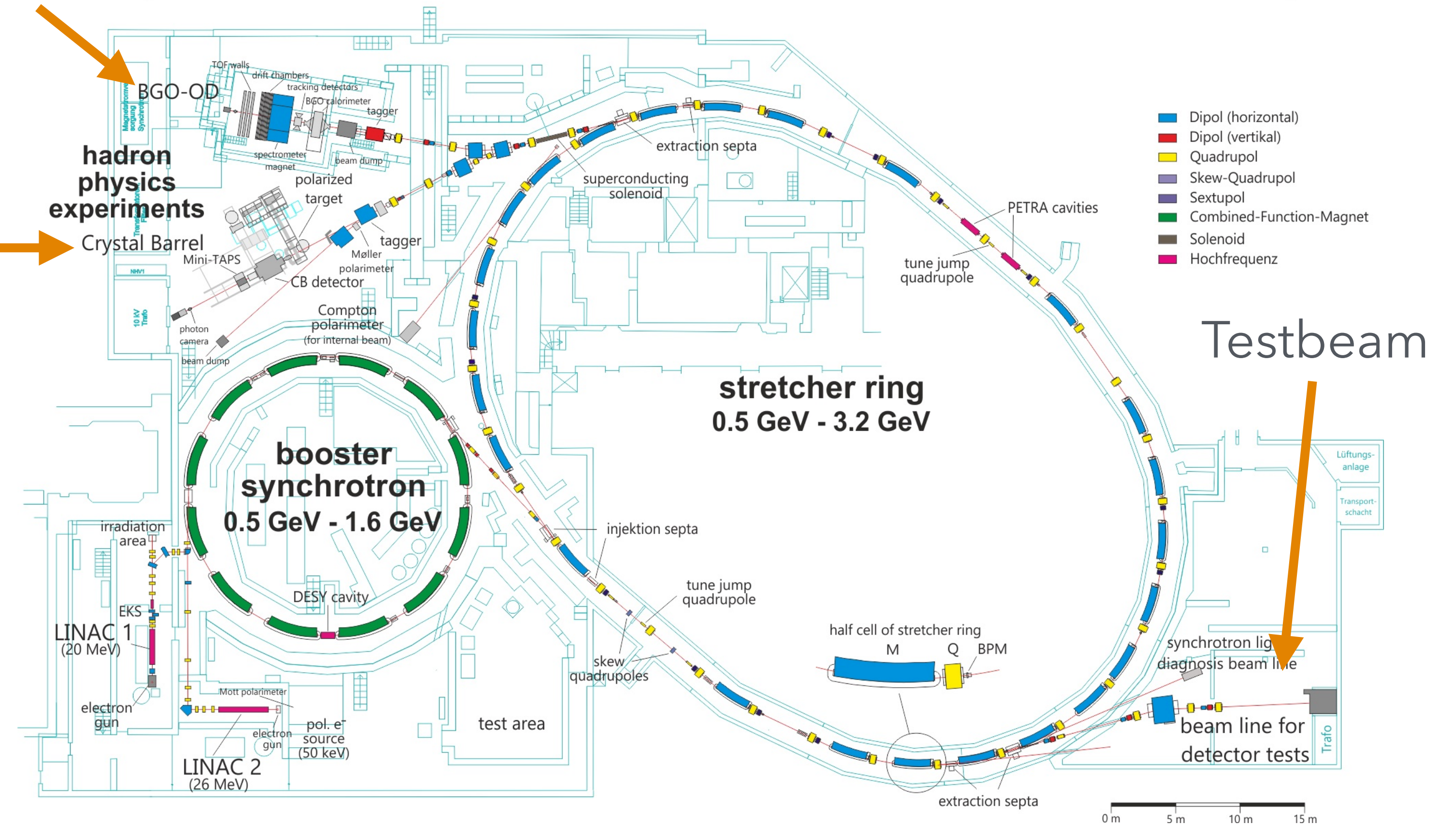
$$R_e = 500 \text{ MHz} \\ \rightarrow \frac{\langle N_e \rangle}{2 \text{ ns}} = 0.2$$

$$E_e \leq 3.2 \text{ GeV} \\ \sigma_E = 0.08 \%$$

Decomission

Insight
@ ELSA

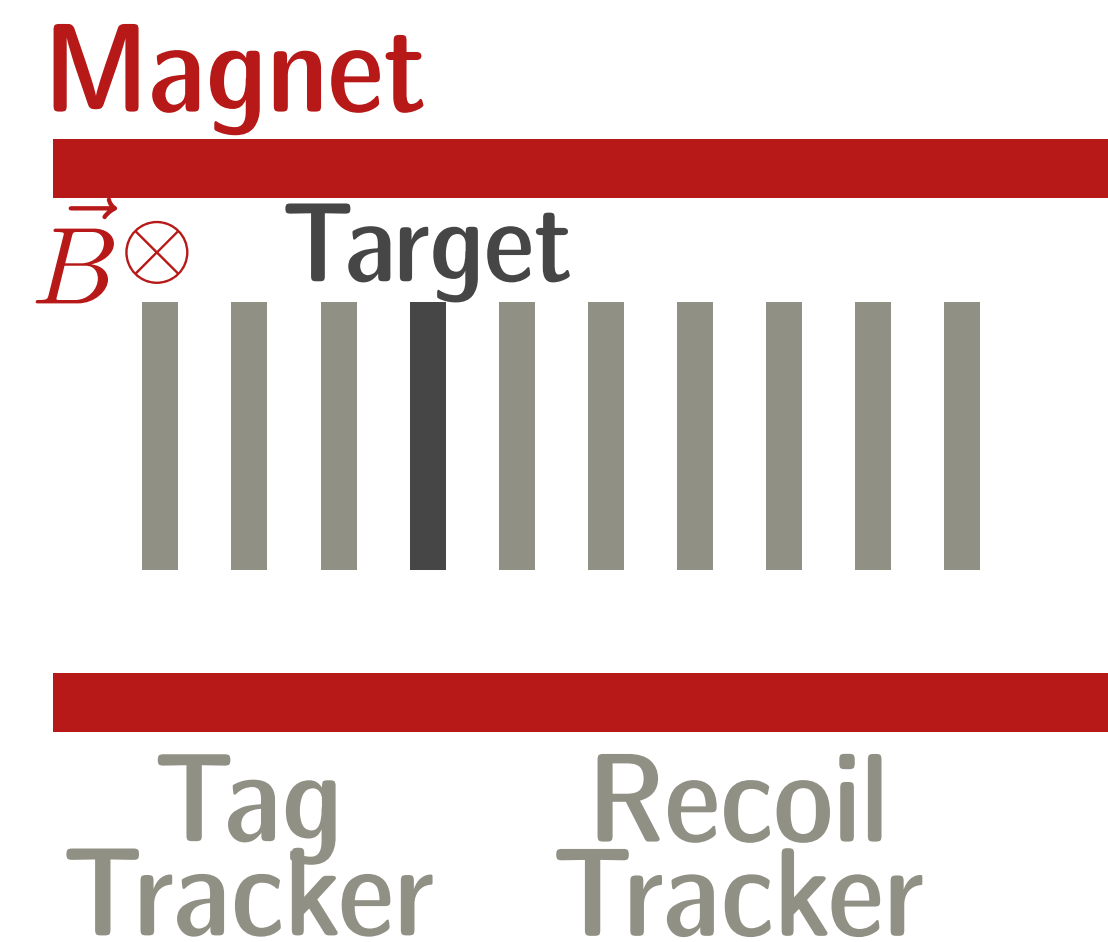
Electron Stretcher Accelerator (ELSA)



ELSA Gruppe, ELSA homepage (2019)

The Lohengrin Experiment

Simulation

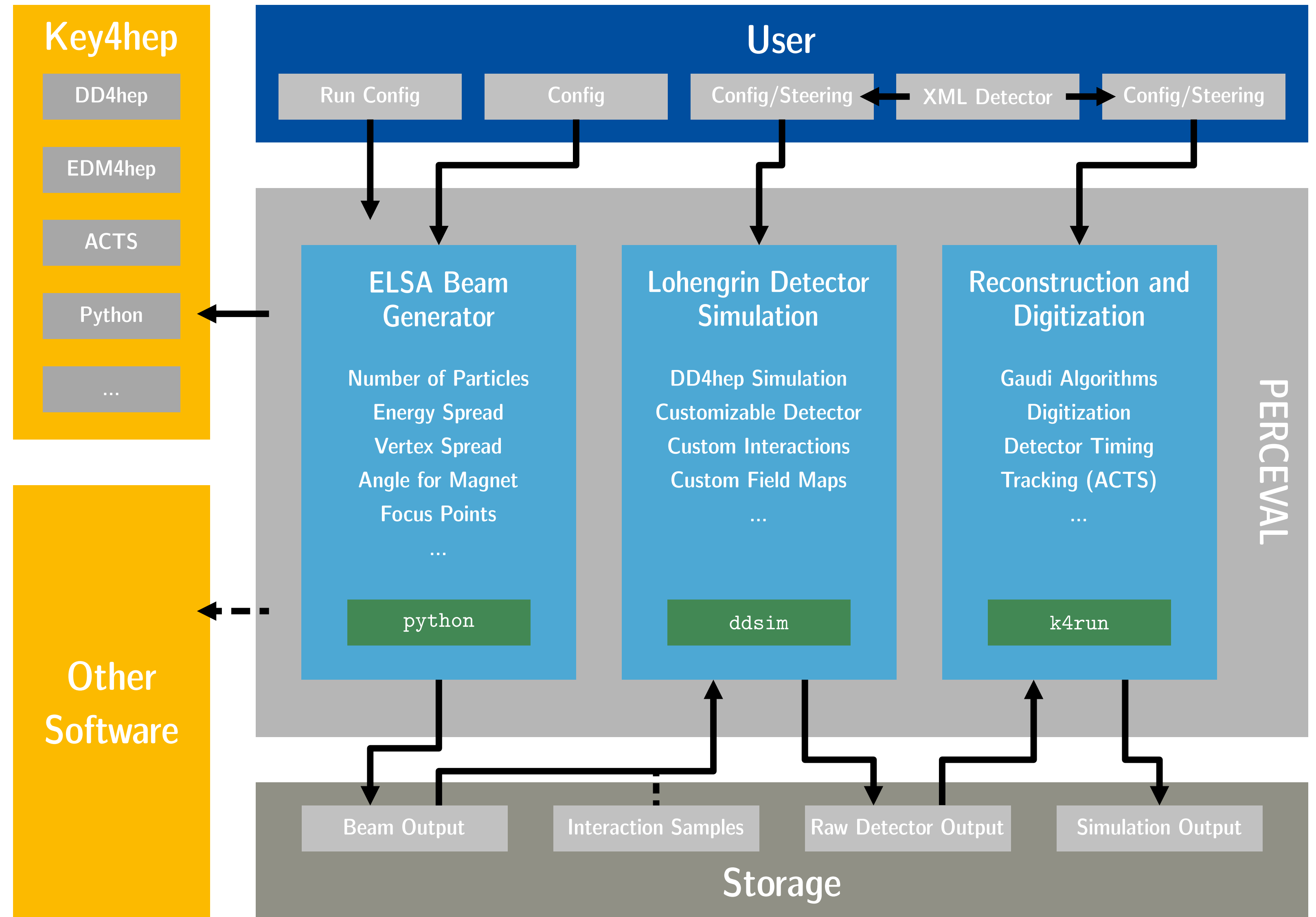


PERCEVAL

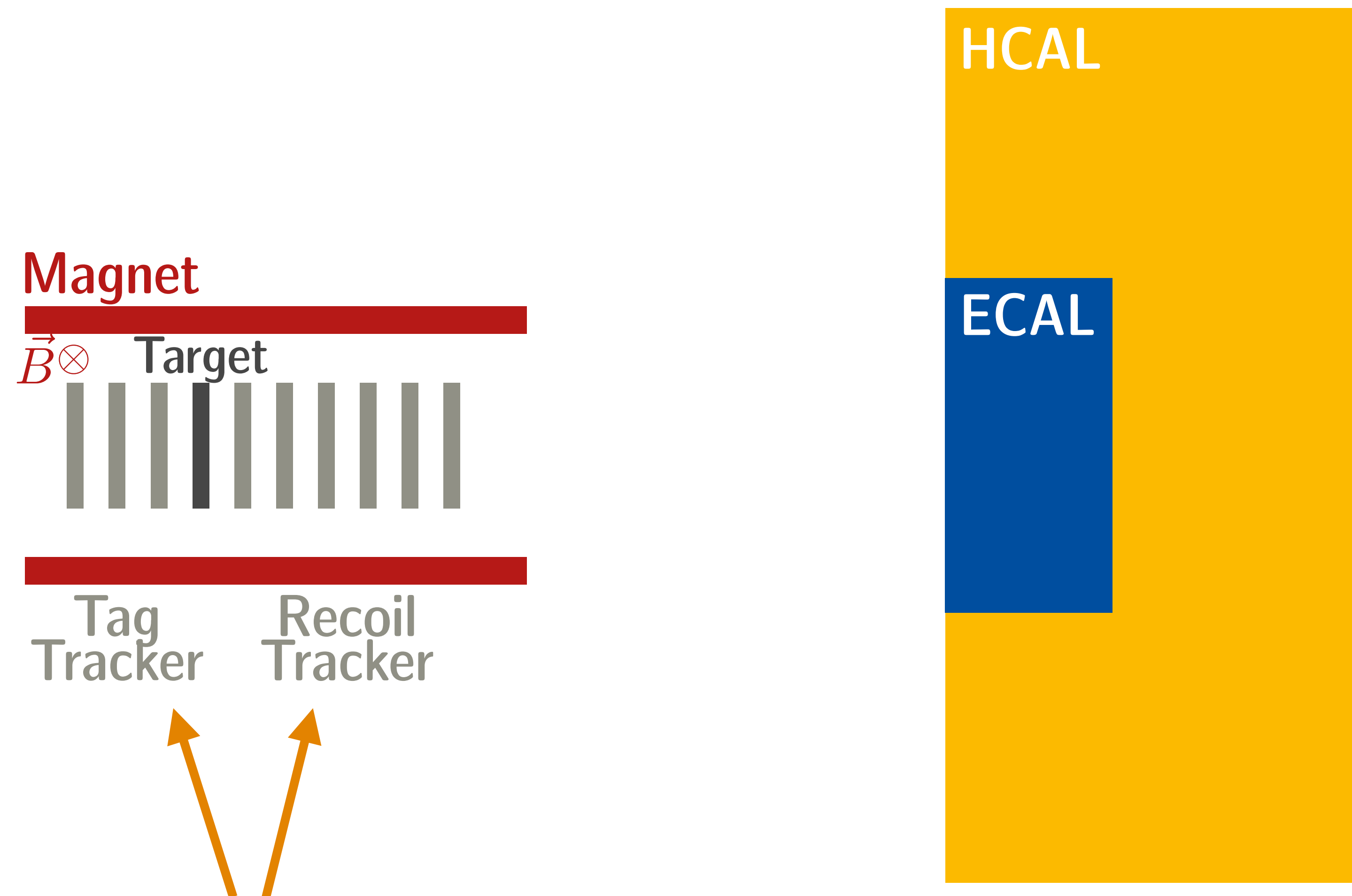
Requirements:

- Use existing solutions where possible
- Allow flexible changes in the setup
- Plugin custom interactions
- ...

→ Key4hep, ACTS, ...

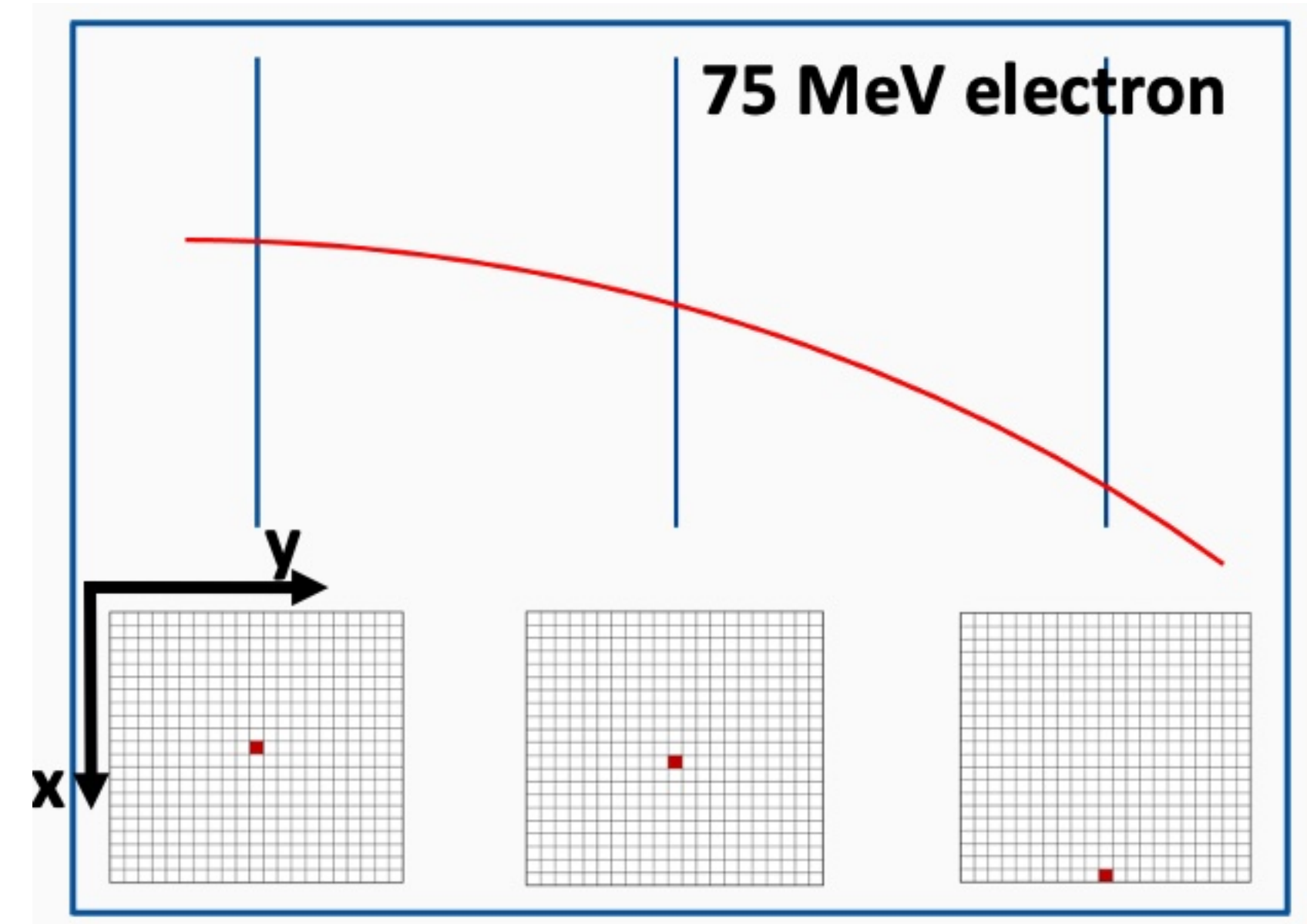
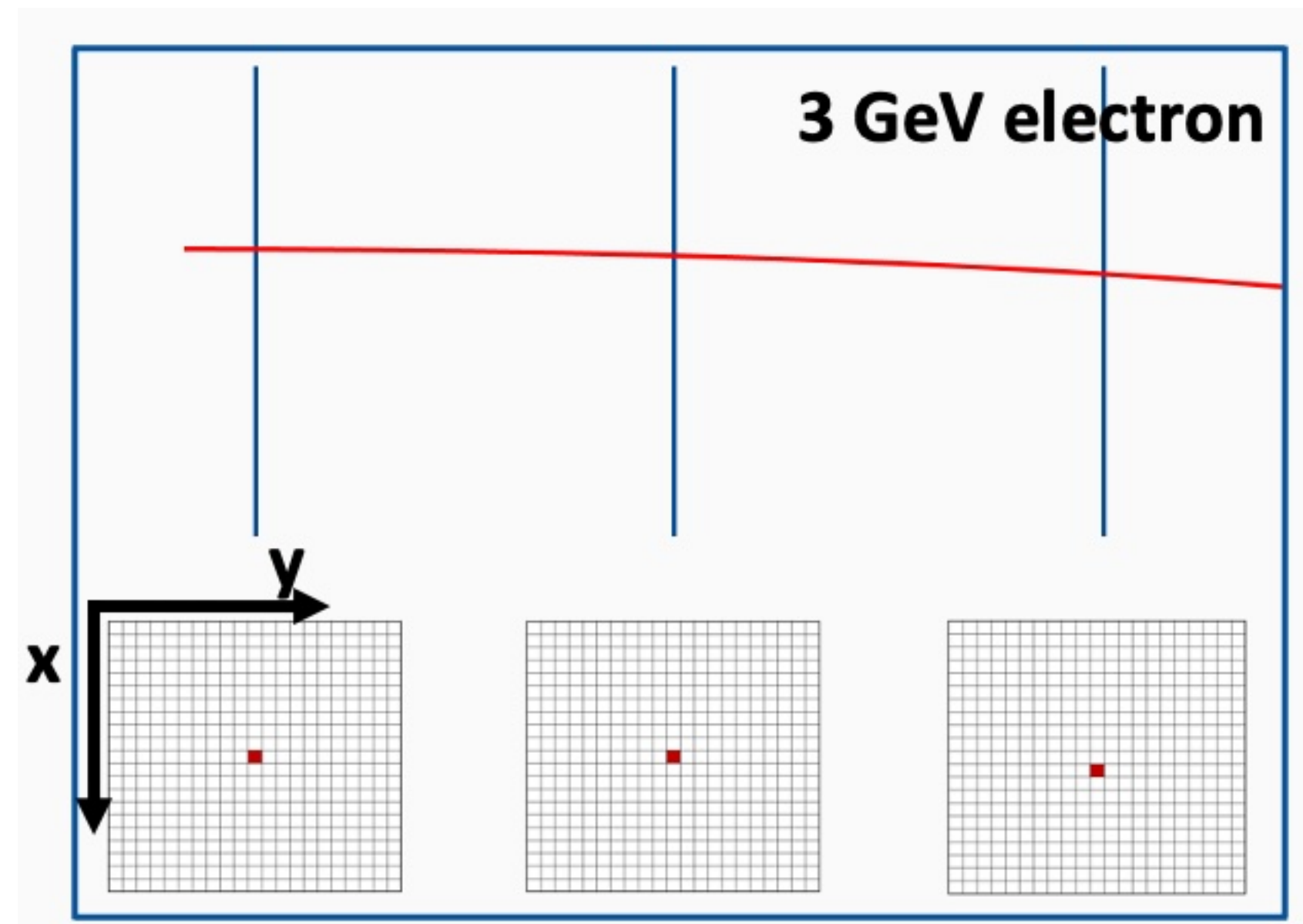


The Lohengrin Experiment



Lohengrin L0-Trigger

L0-Trigger: Event reduction by factor 10-20

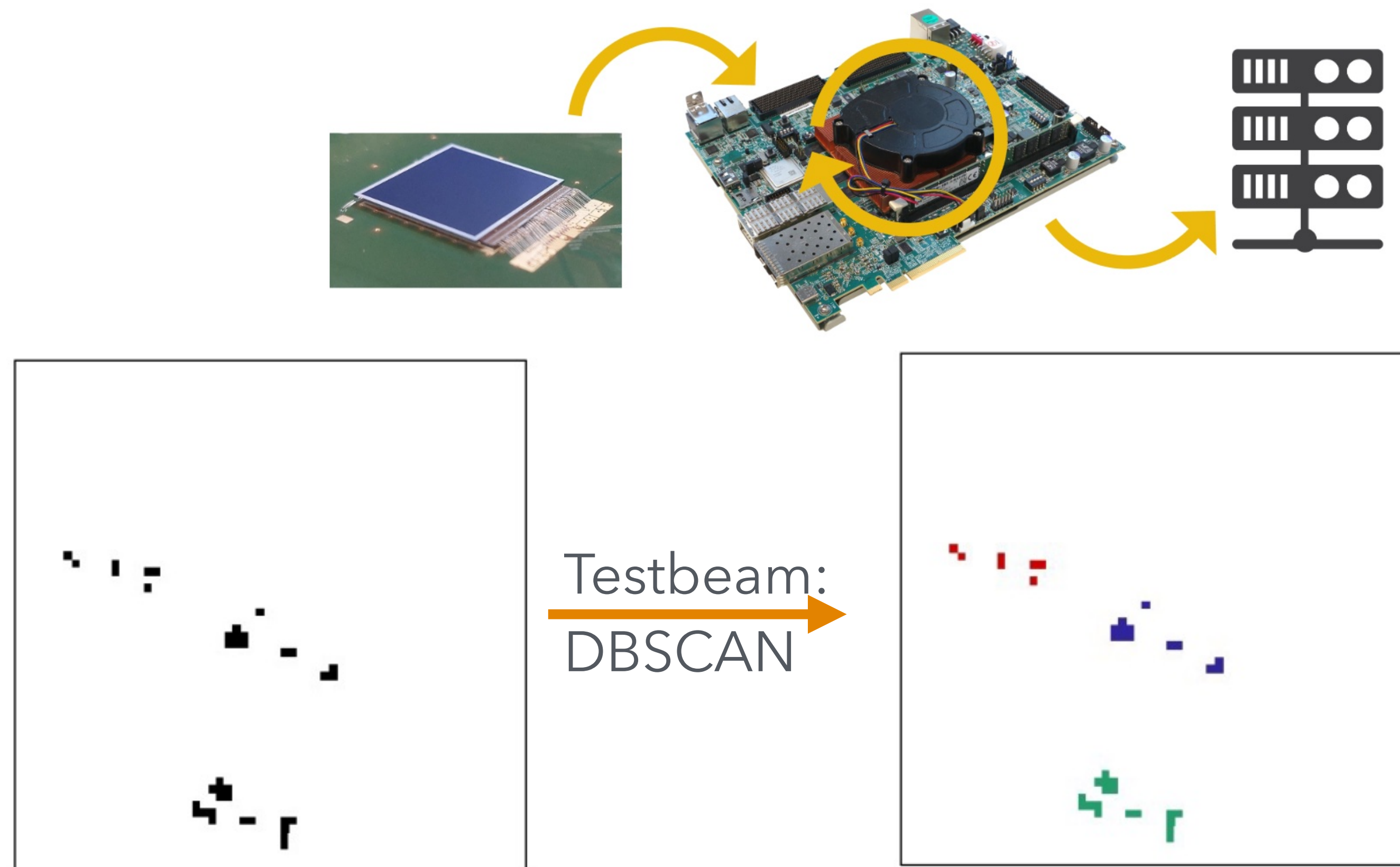


Column	Rows	chip0 → chip1	chip1 → chip0
5	400, 200	29.89 ns	21.68 ns
100	329, 160	23.59 ns	19.71 ns
219	480, 48	62.63 ns	54.31 ns
220	128, 124	2.54 ns	-0.36 ns

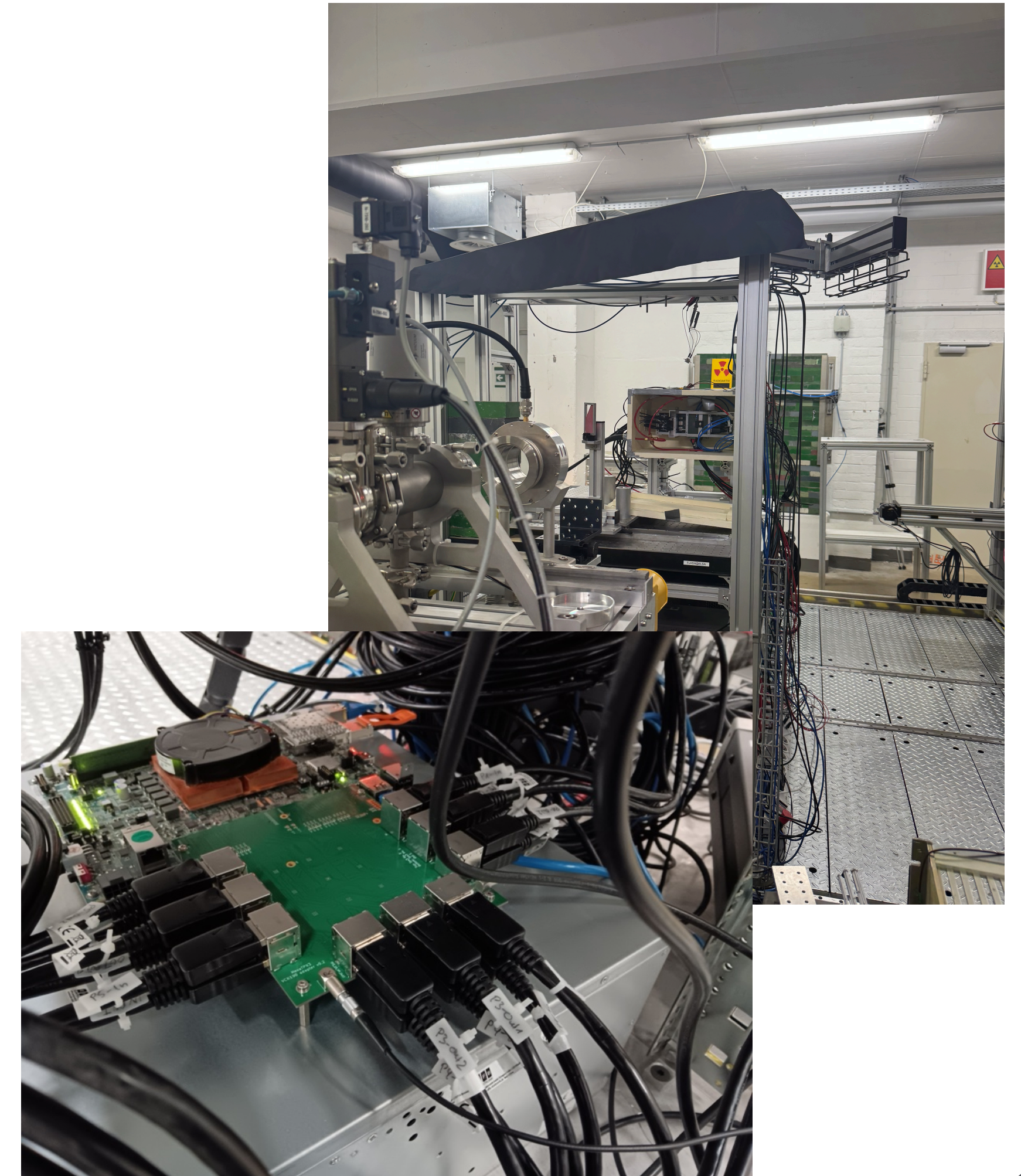
→ Difference between multiple chips (Hit-Or) needs improvement (here: TJ-Monopix2)

AI engine driven track trigger

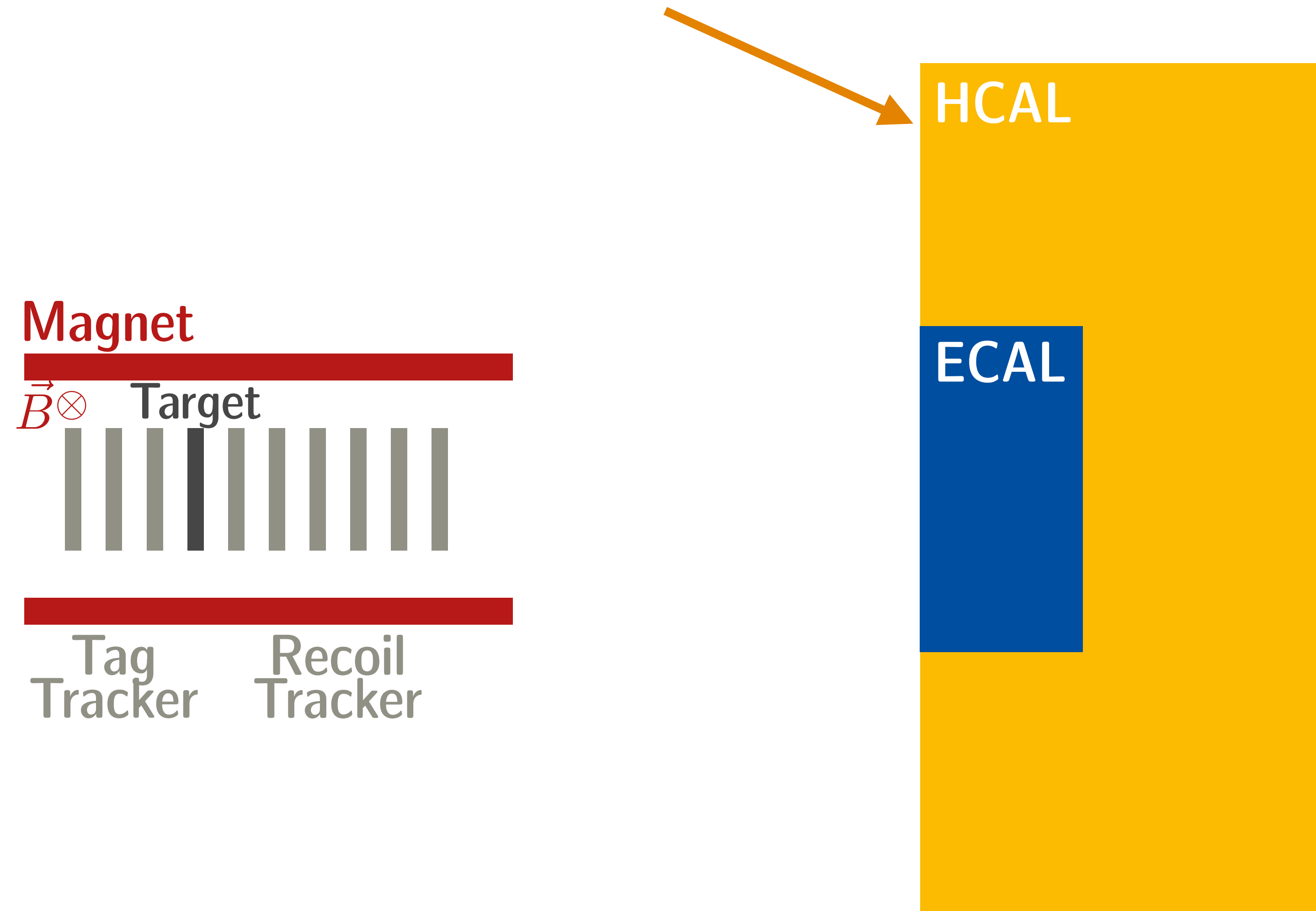
2 successful testbeams in 2025



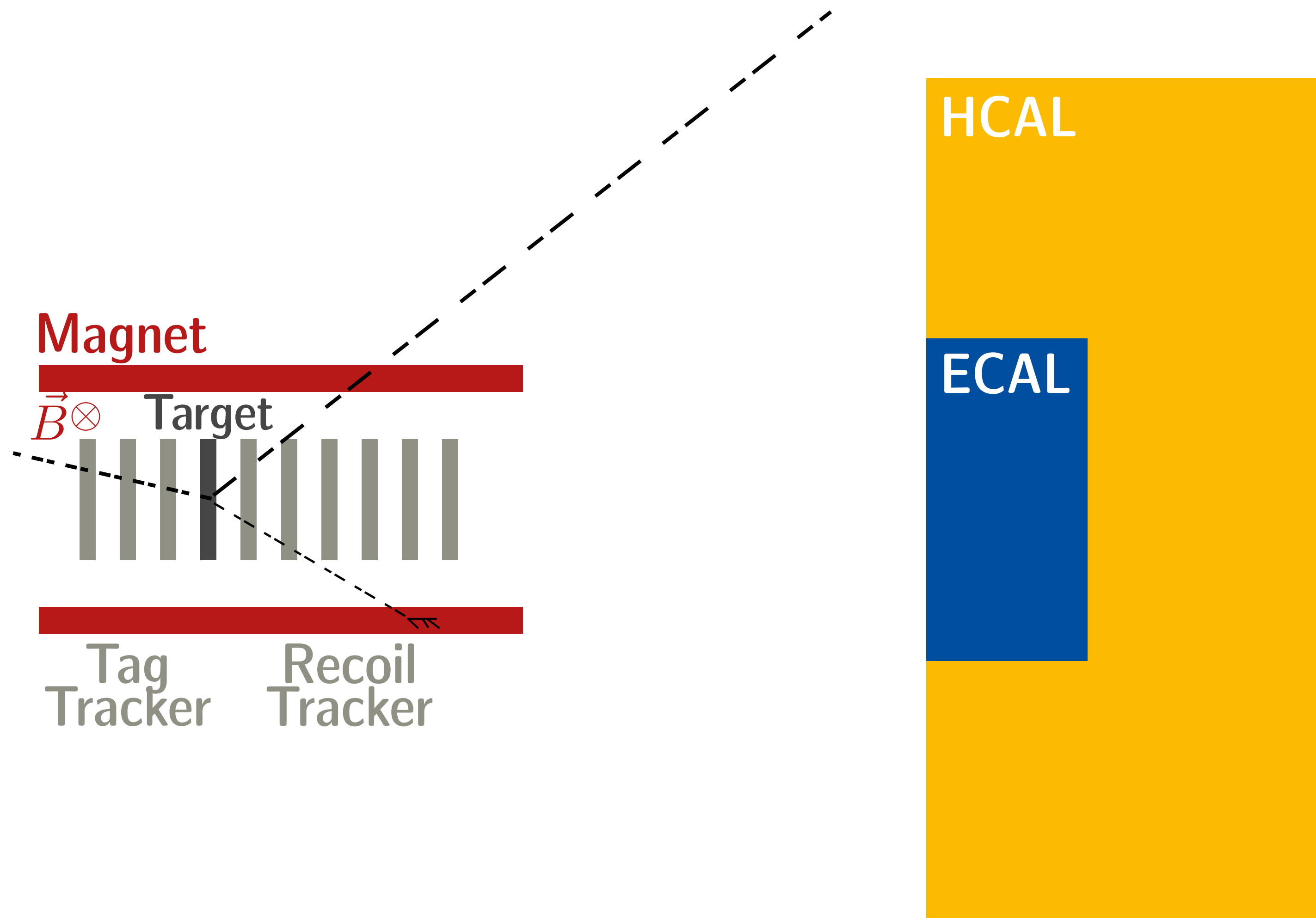
Goal: Graph Neural Network with coarse track fit



The Lohengrin Experiment



Problematic Hadronic Backgrounds



How problematic is this?

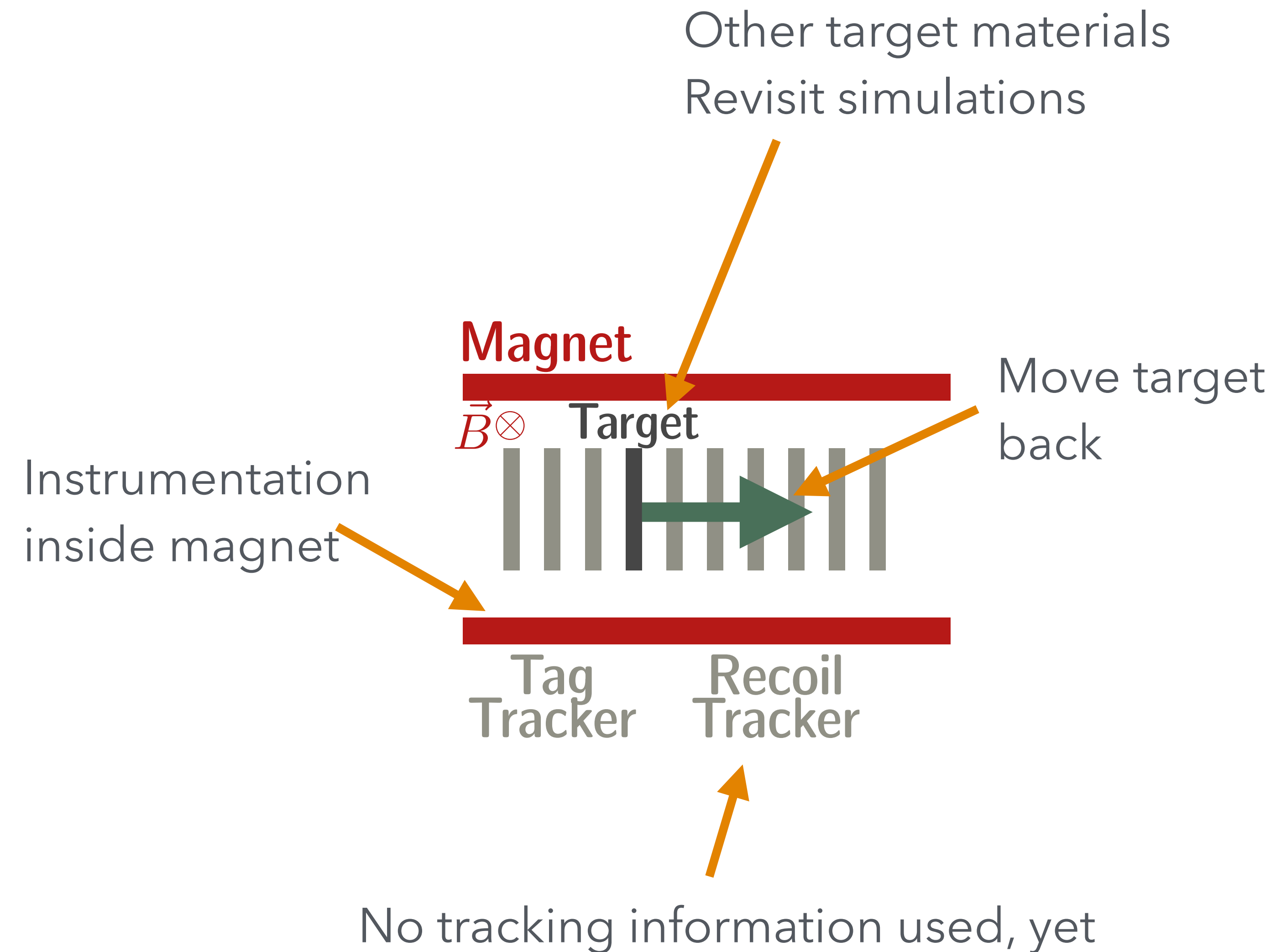
Signal: $10^2 - \mathcal{O}(10^3)$

Background

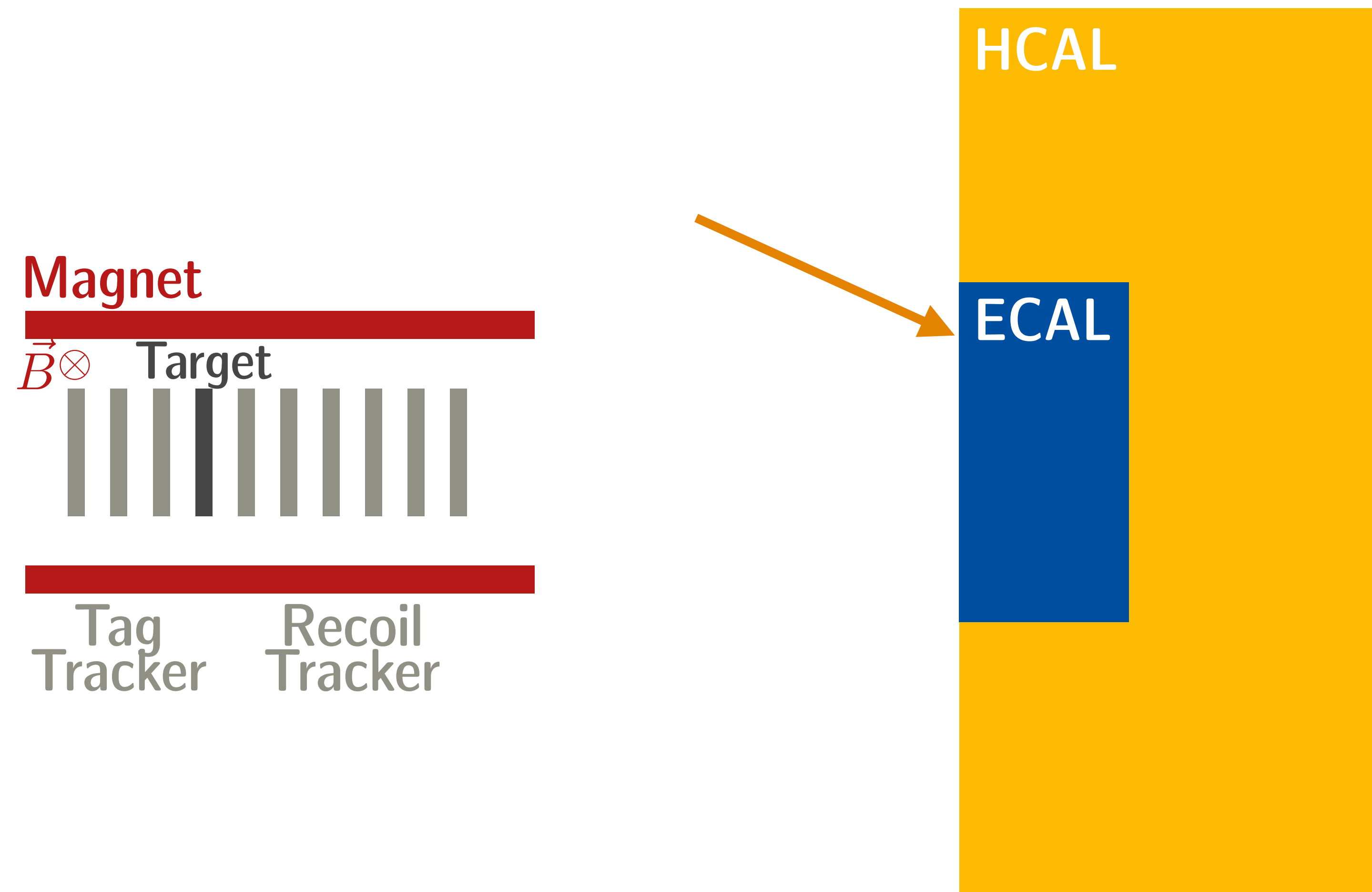
Only geometric: $\mathcal{O}(10^3) - \mathcal{O}(10^4)$

Incl. components: $\mathcal{O}(10^6)$

How to solve these background problems

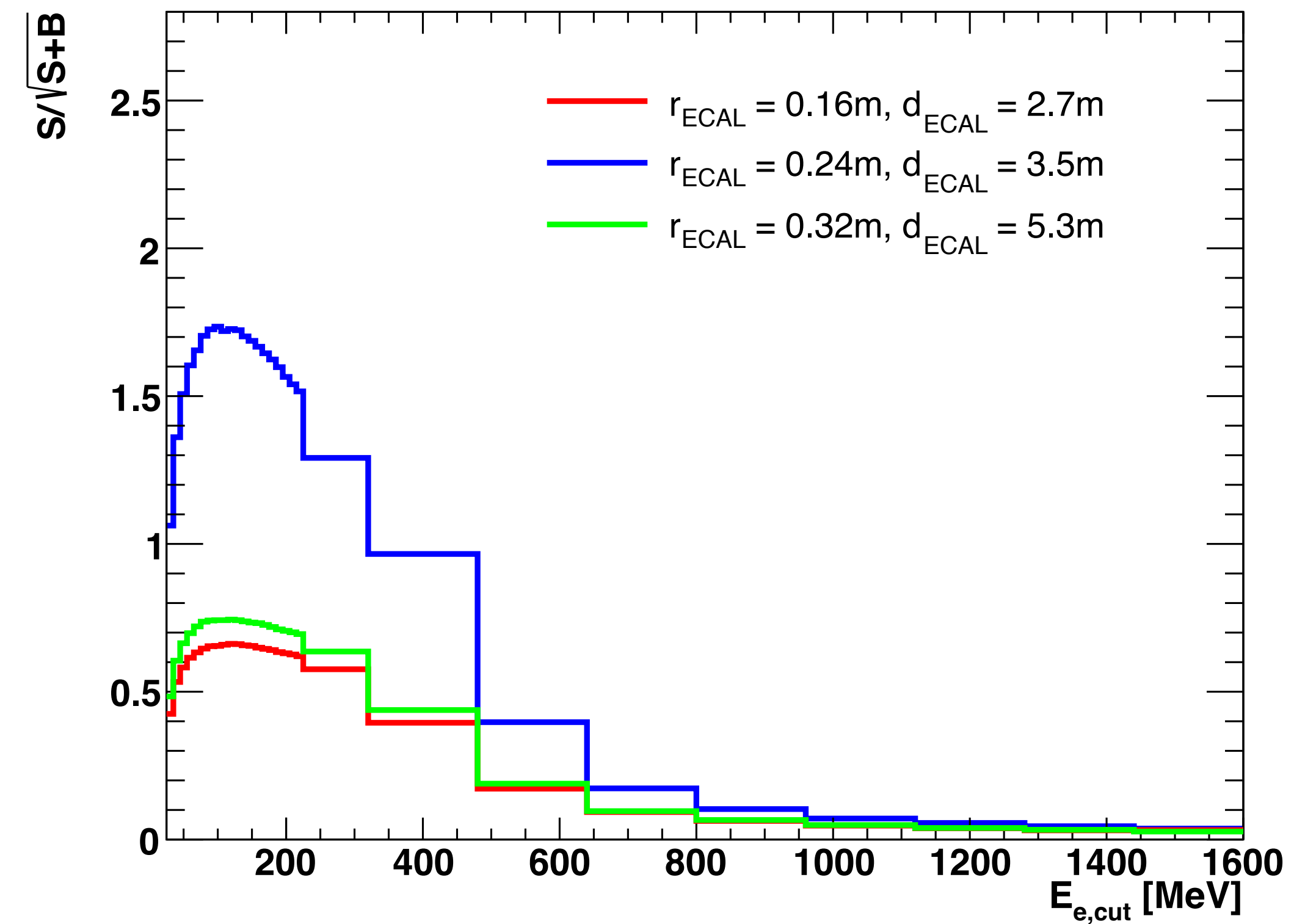
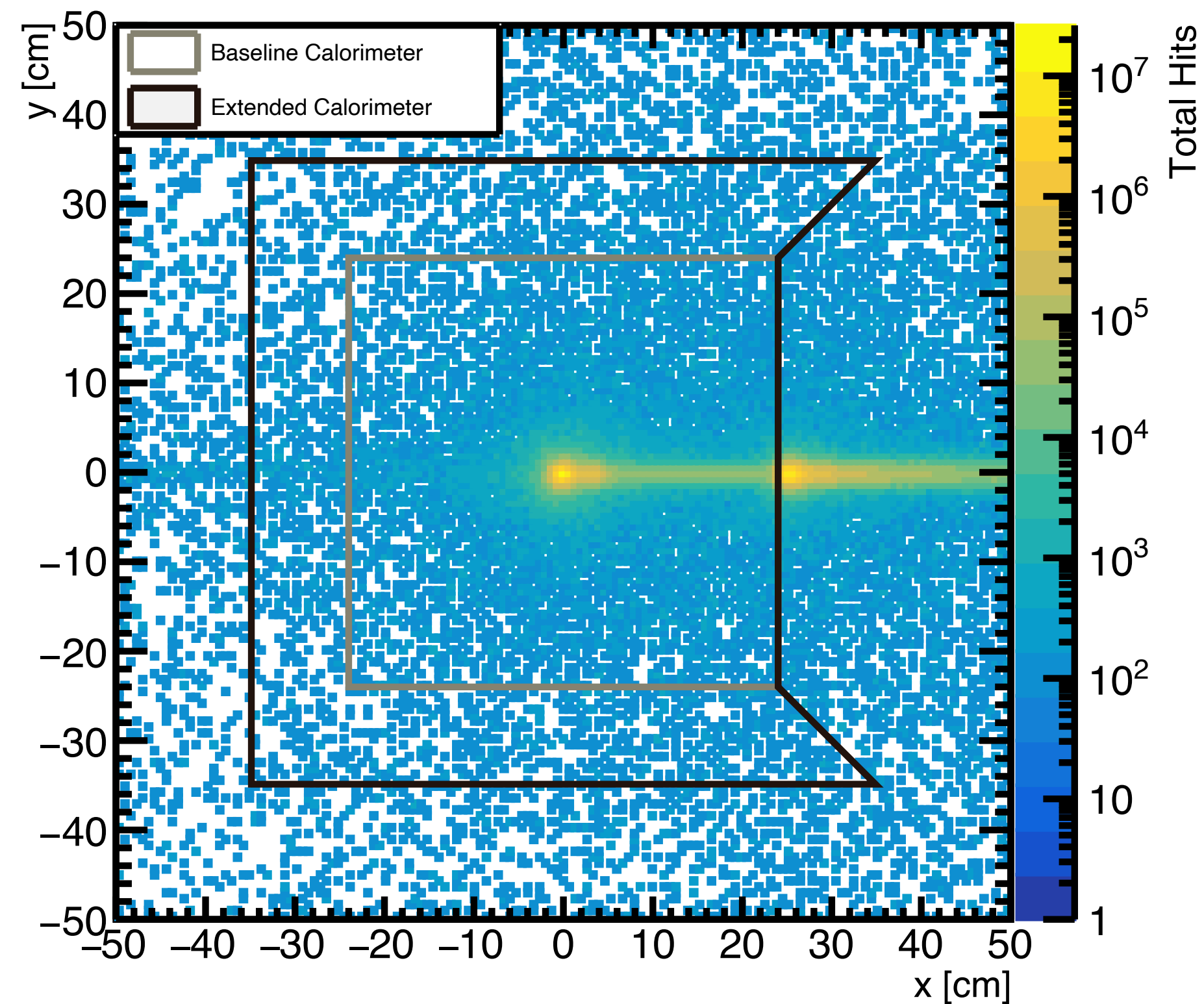


The Lohengrin Experiment



Whitepaper ECAL Setup

CALICE SiW ECAL → sampling calorimeter with 30 layers of Si and W



→ Bend e^- out of ECAL, find high energetic γ on top of low energy QED background

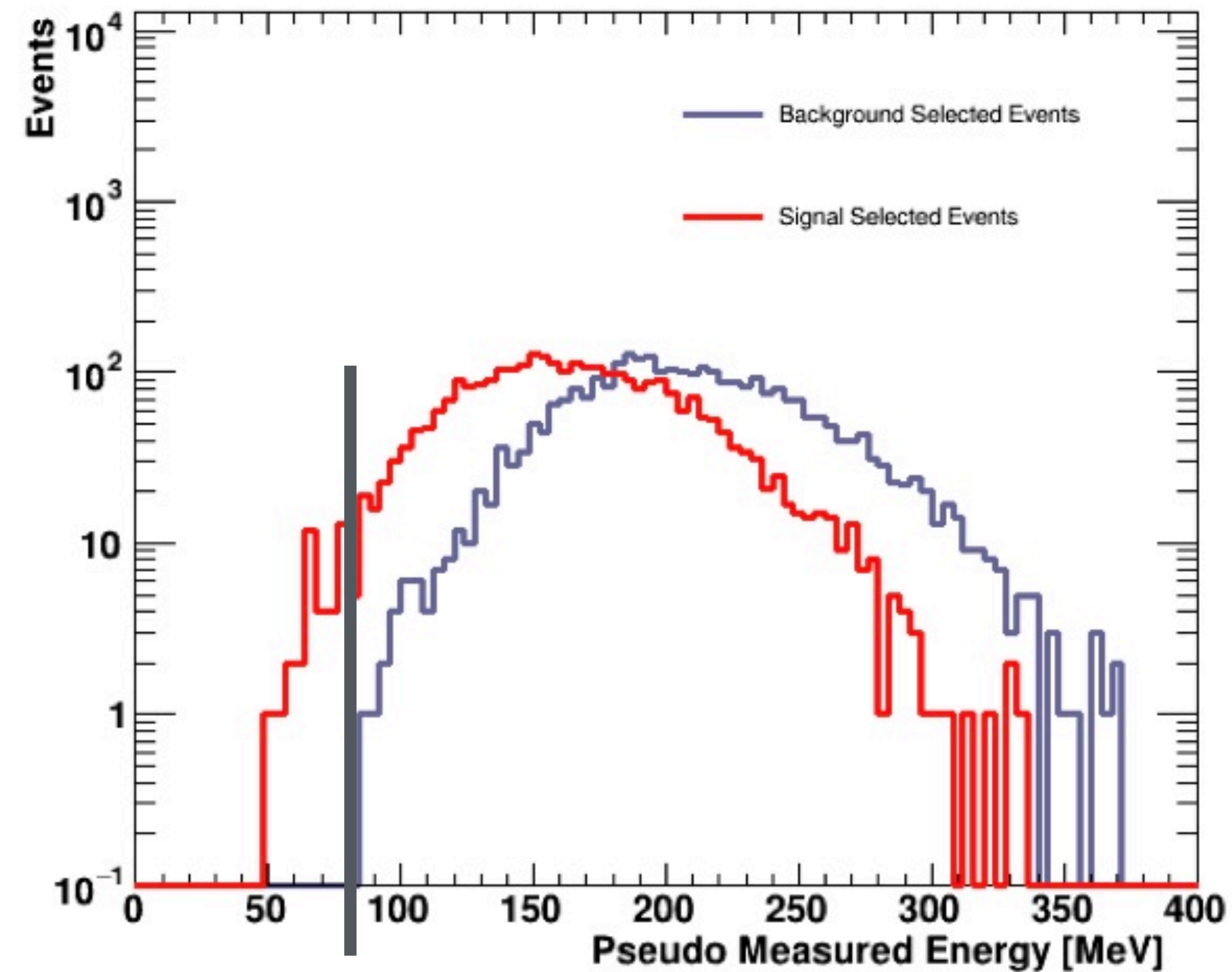
→ Most sensitive for $E_e \leq 100\text{ MeV}$

ECAL Timing

Current technology

$\tau = 180 \text{ ns}$

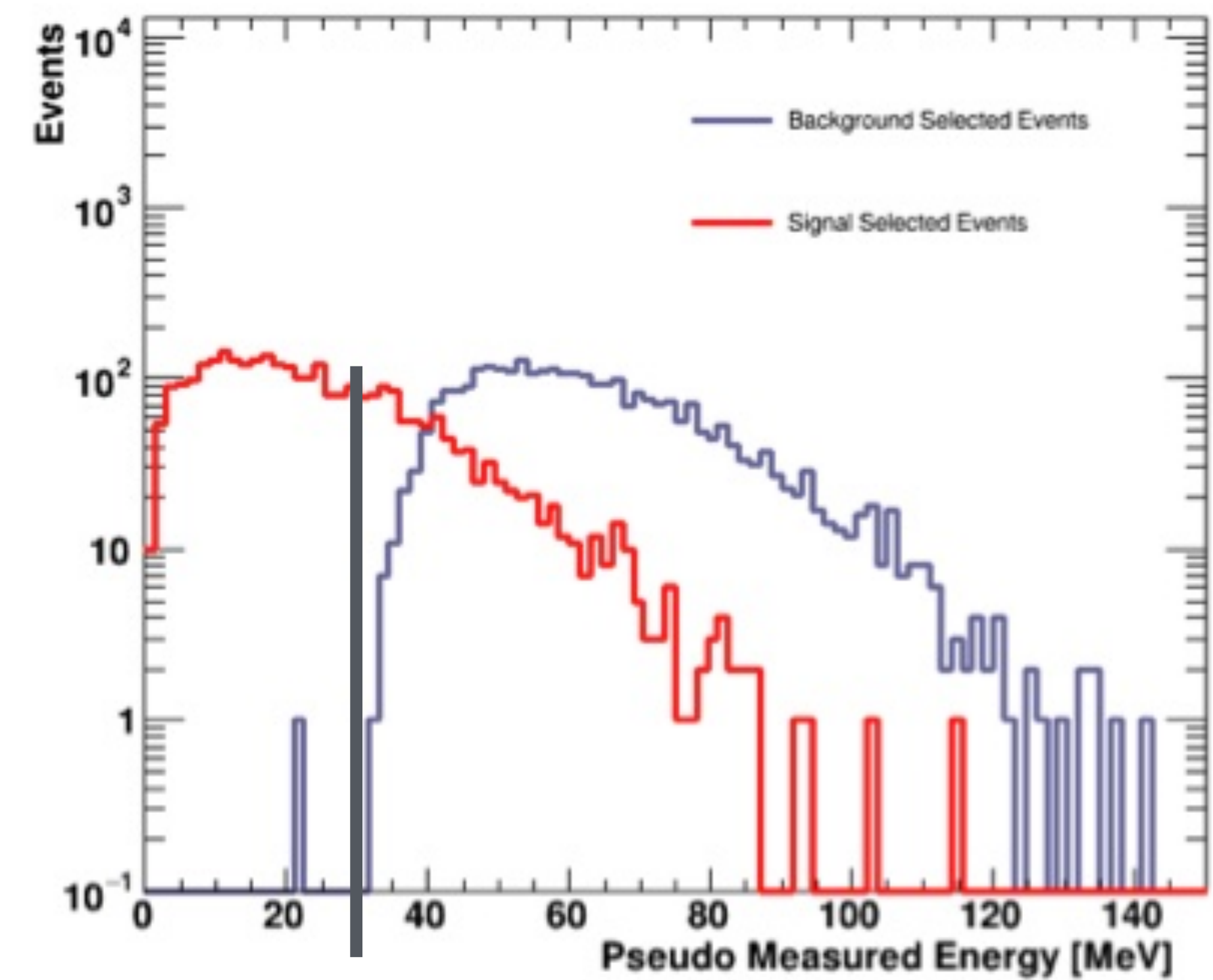
Signal efficiency $\rightarrow 0 \%$



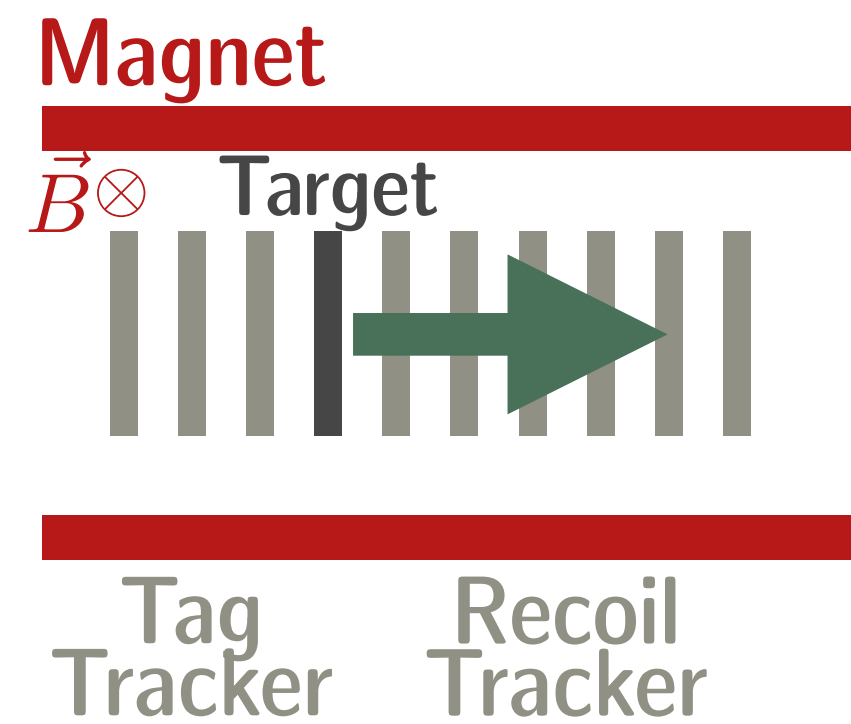
Faster ECAL

$\tau = 30 \text{ ns}$

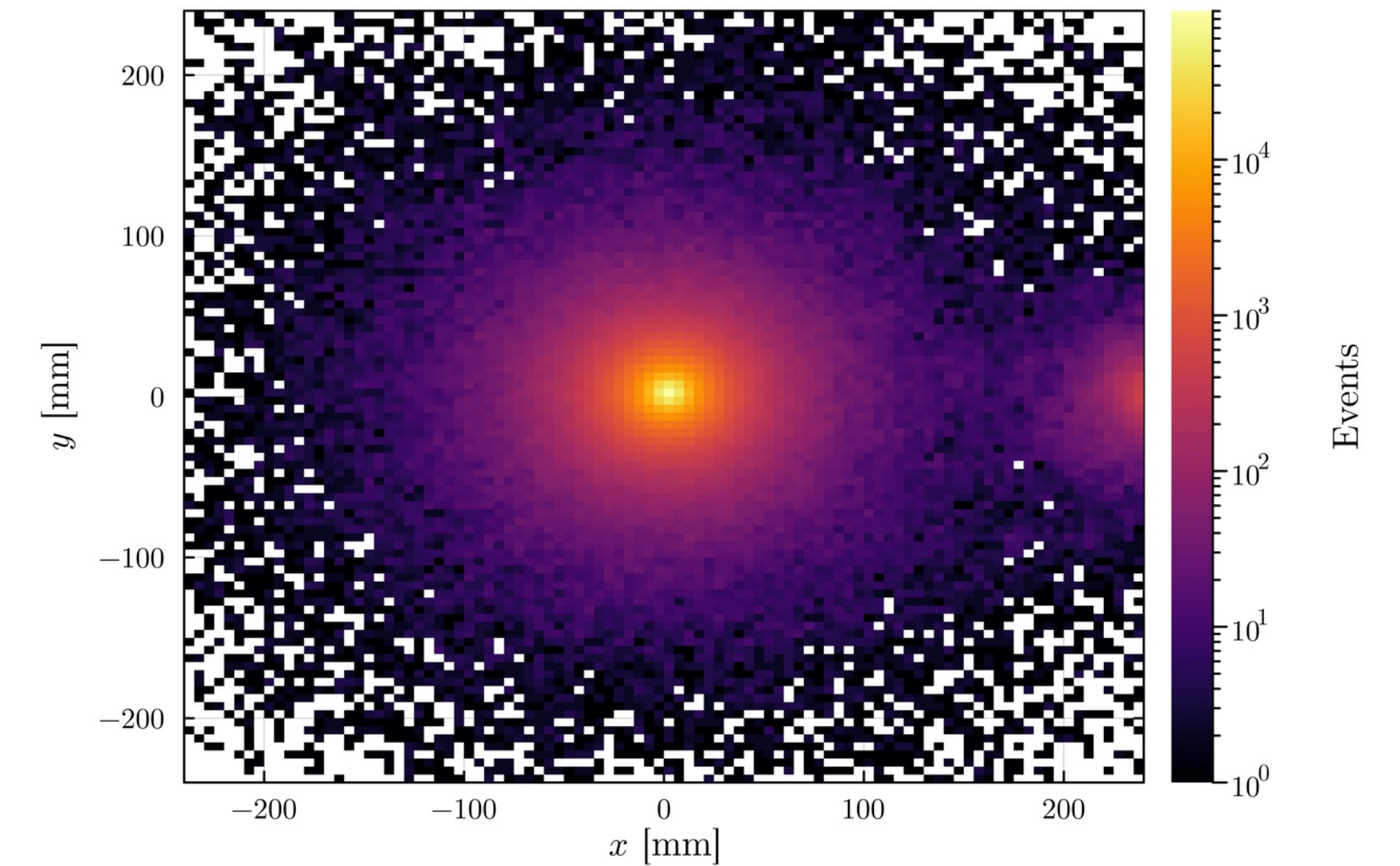
Signal efficiency $\rightarrow 68 \%$



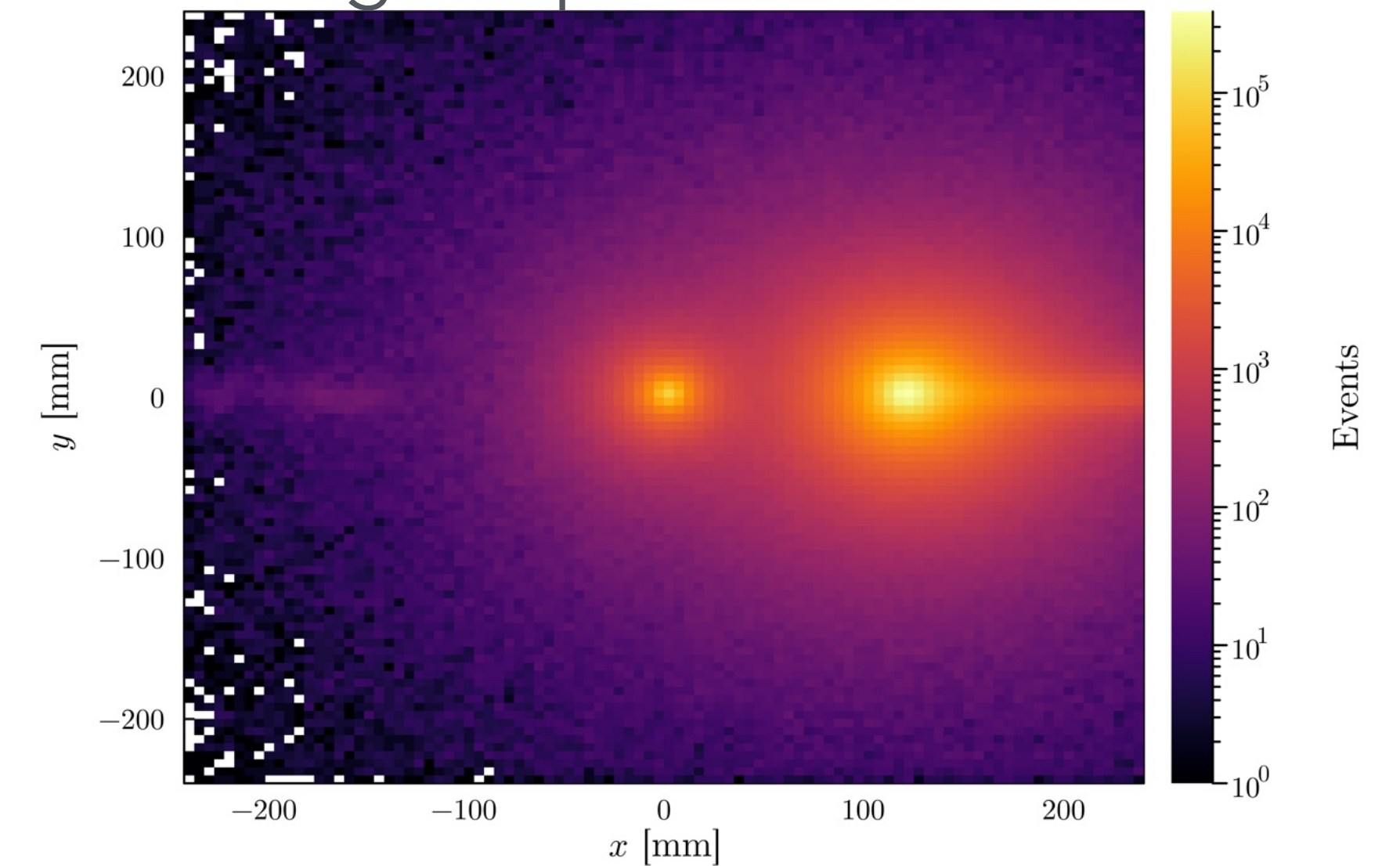
Moving the target back



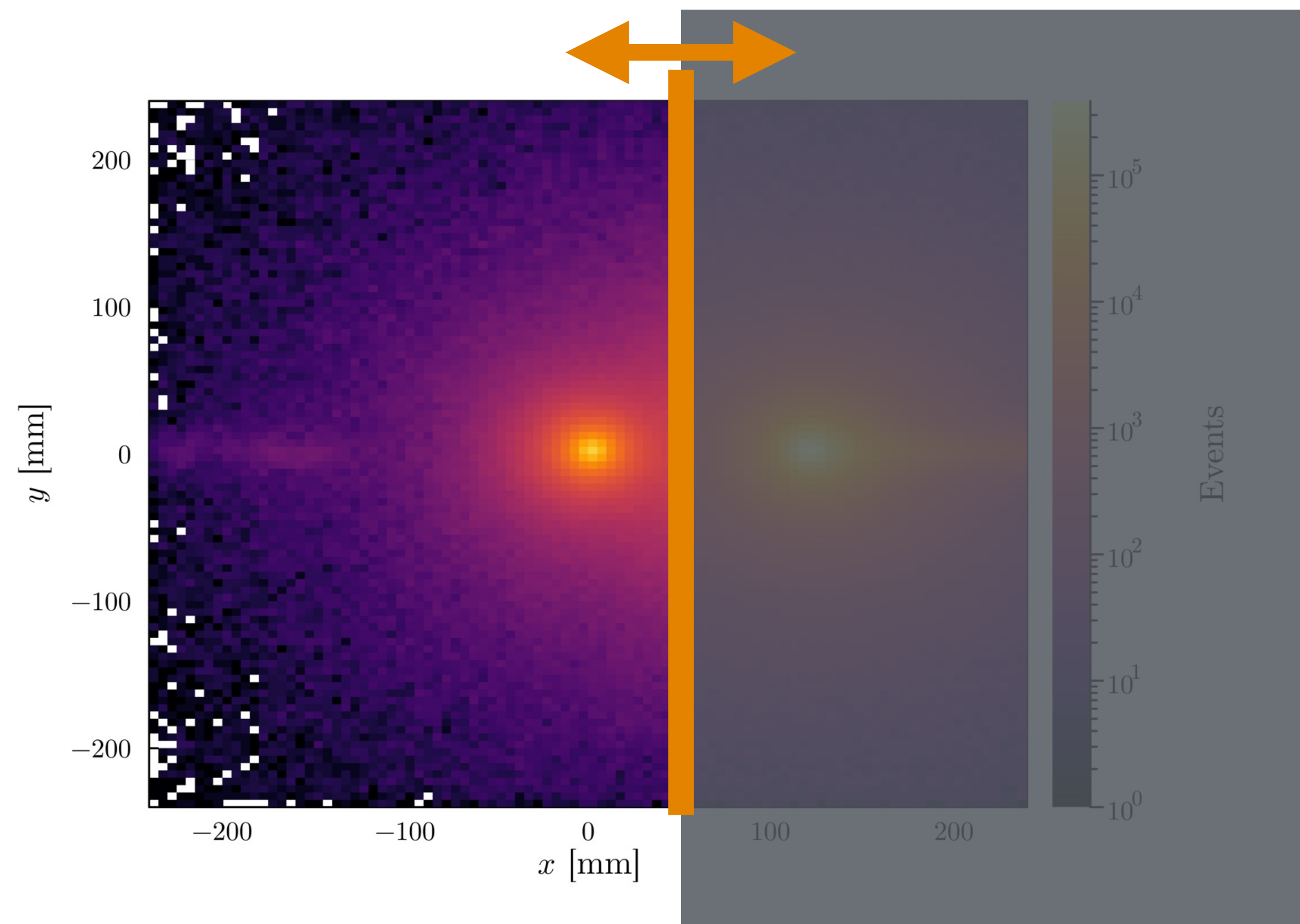
Original position



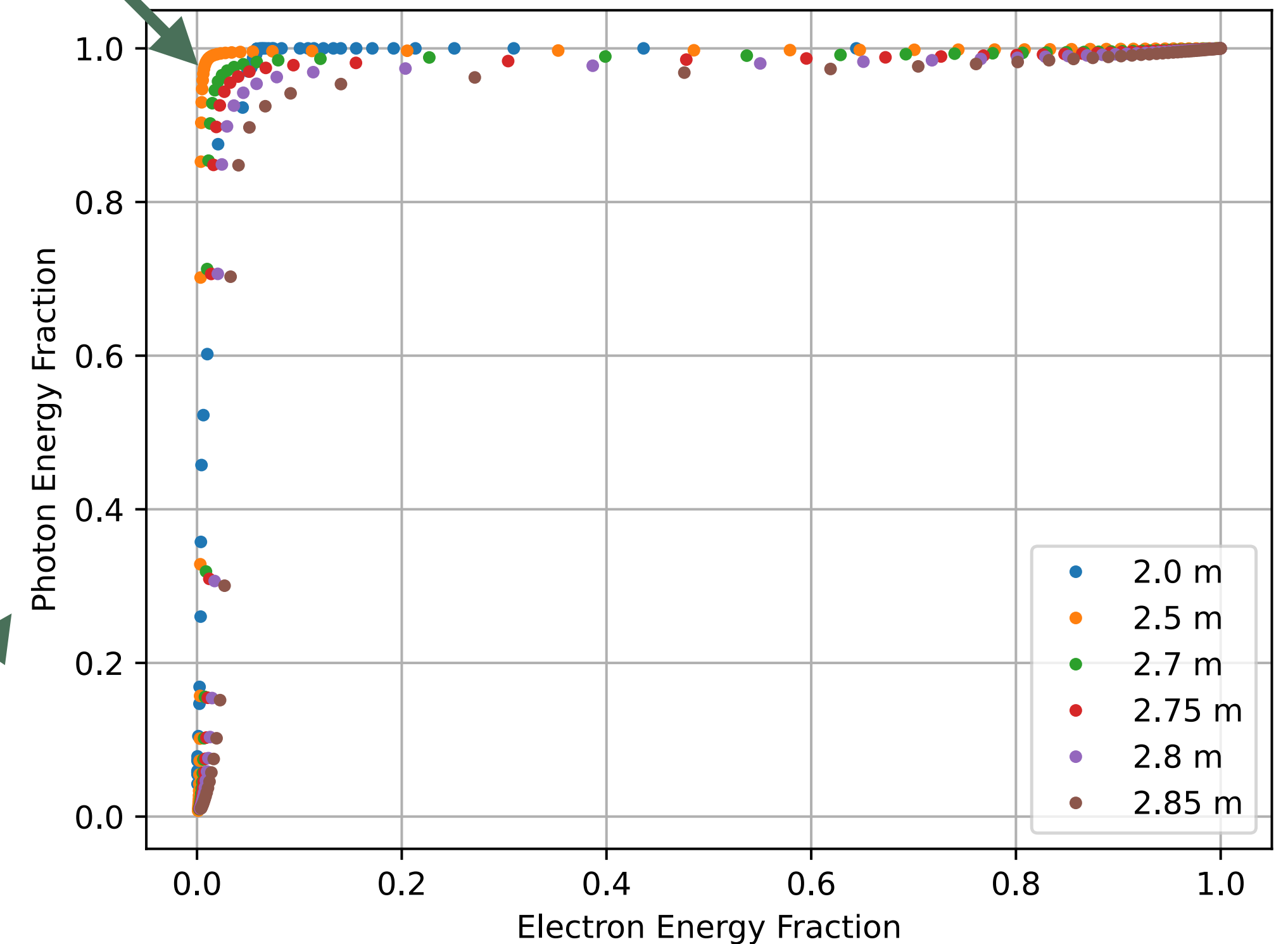
Original position + 0.5 m



Removing electrons in the ECAL



Choose Working Point

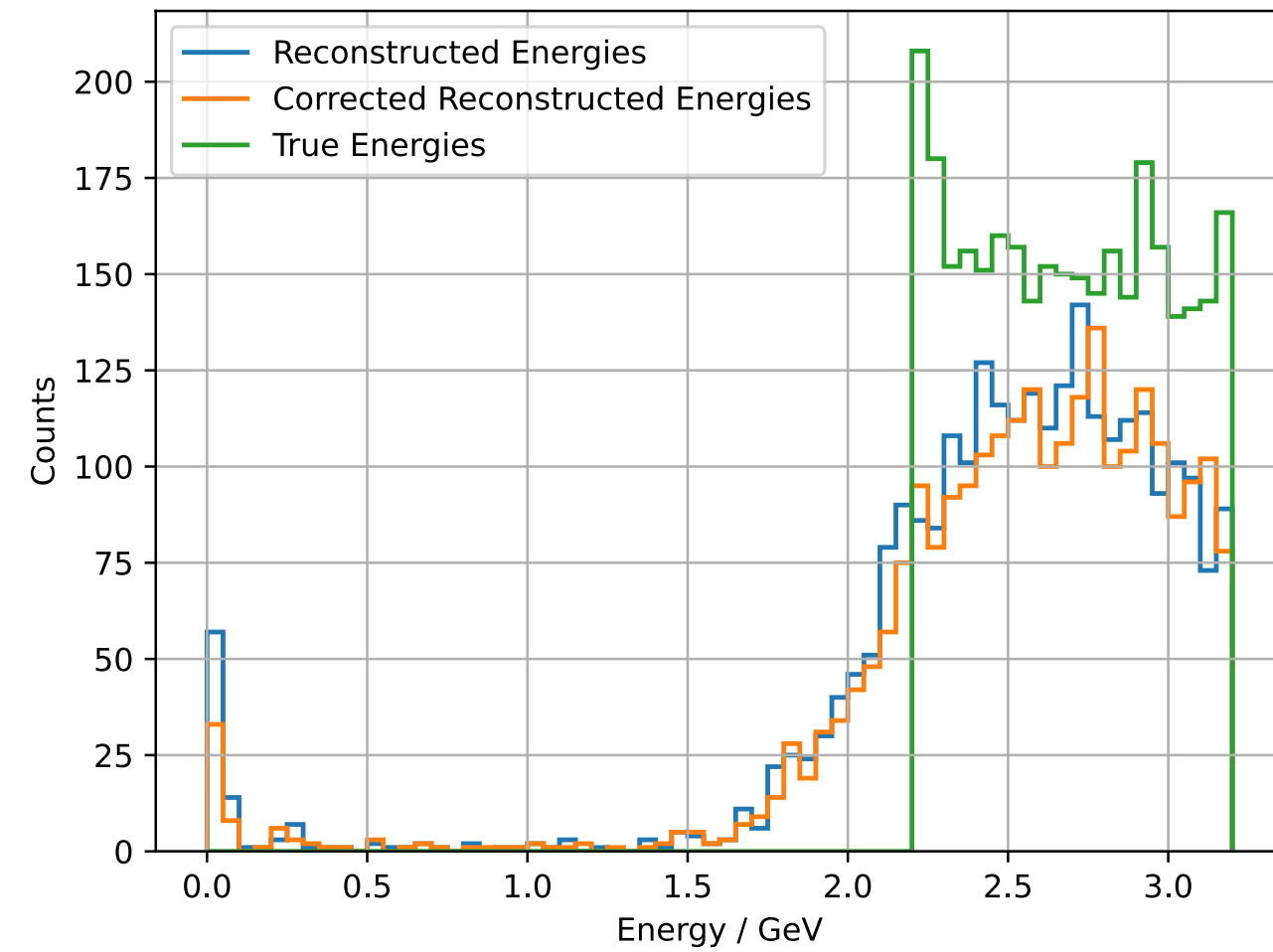


Photon Energy Fraction: $\langle \underline{E_{\gamma, \text{left}}} / E_{\gamma, \text{total}} \rangle$ for E in ECAL

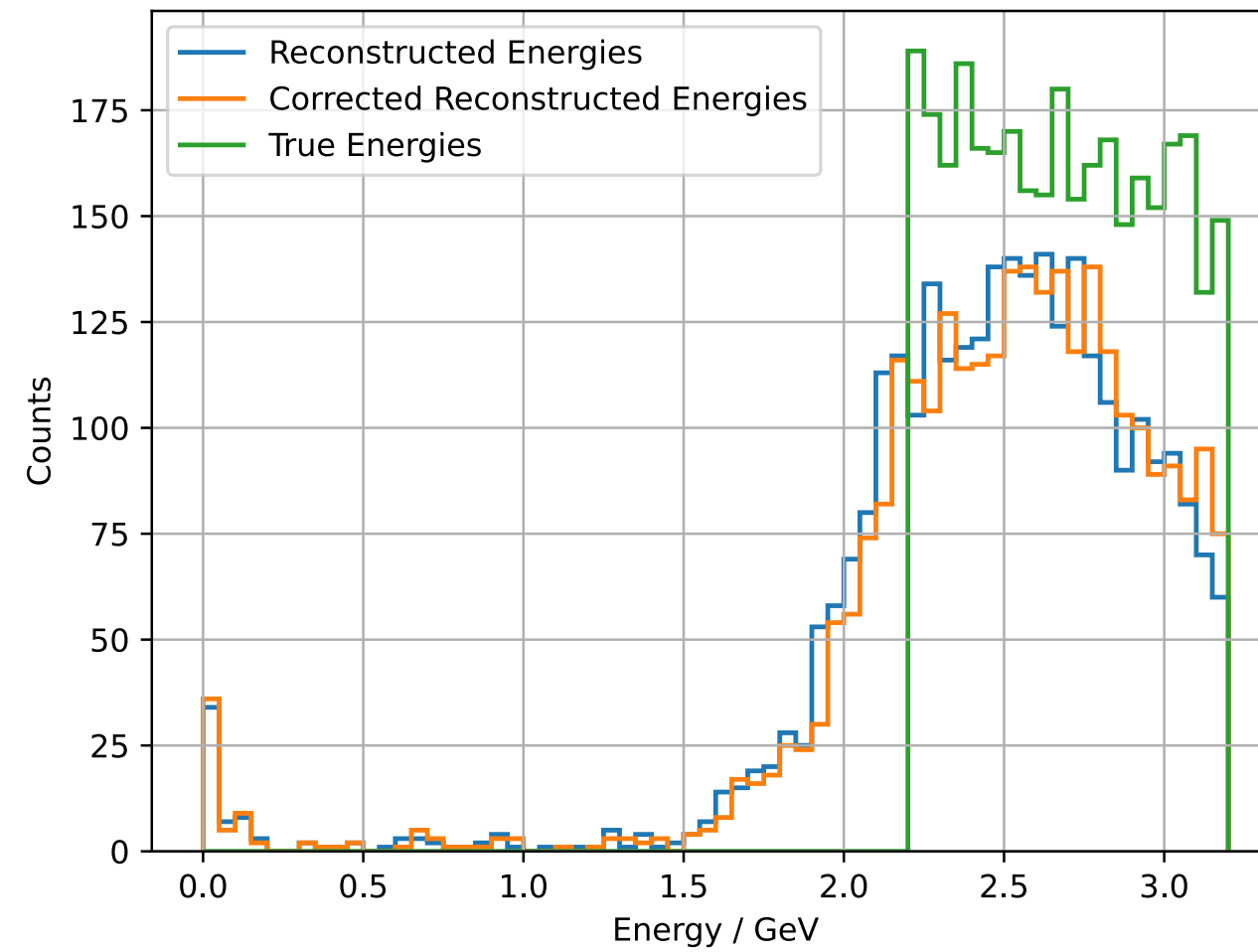
Recoil Electron Energy Fraction: $\langle \underline{E_{e', \text{left}}} / E_{e', \text{total}} \rangle$ for E in ECAL

Photon reconstruction in the ECAL

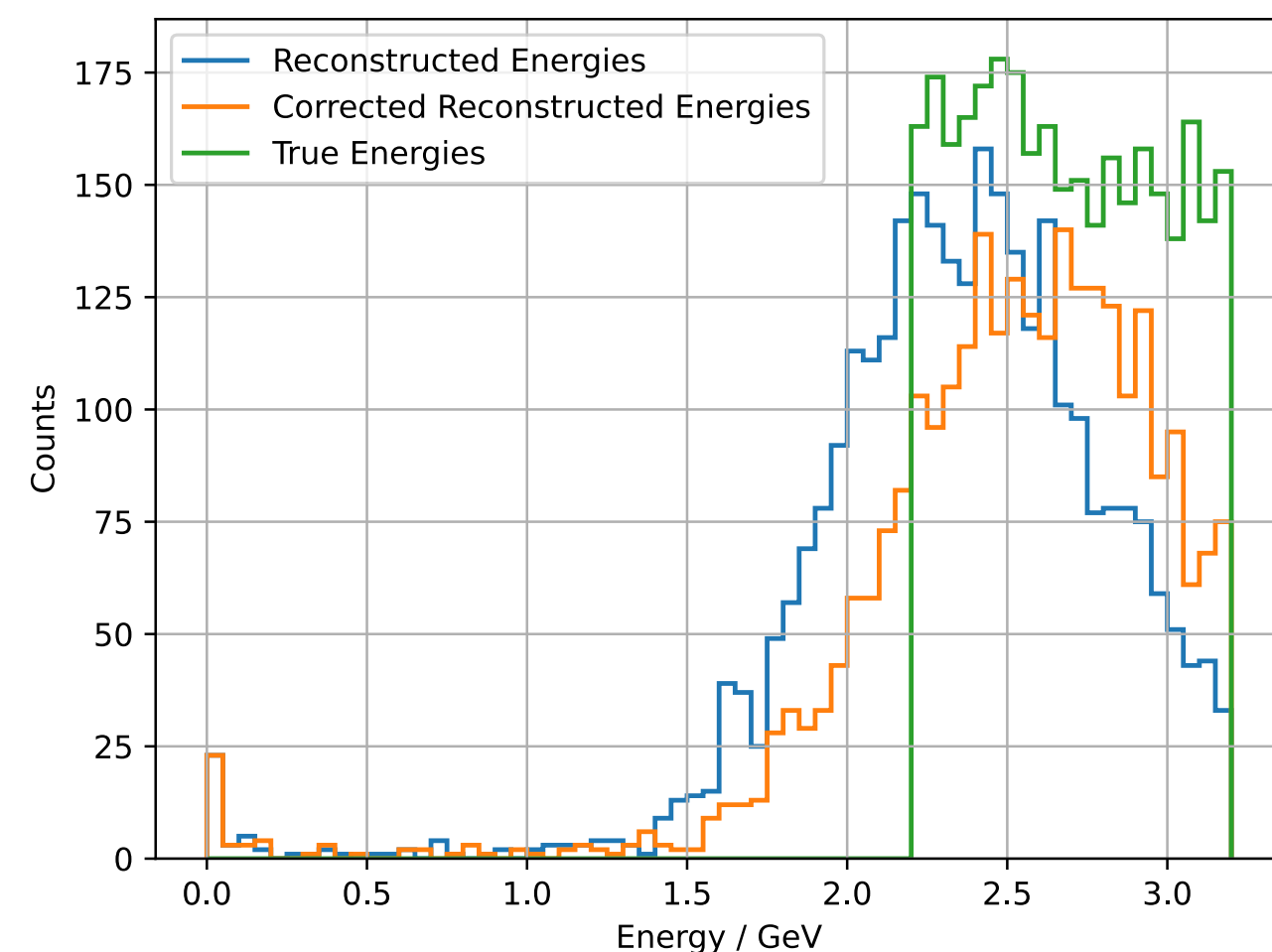
$z_t = 2 \text{ m}$



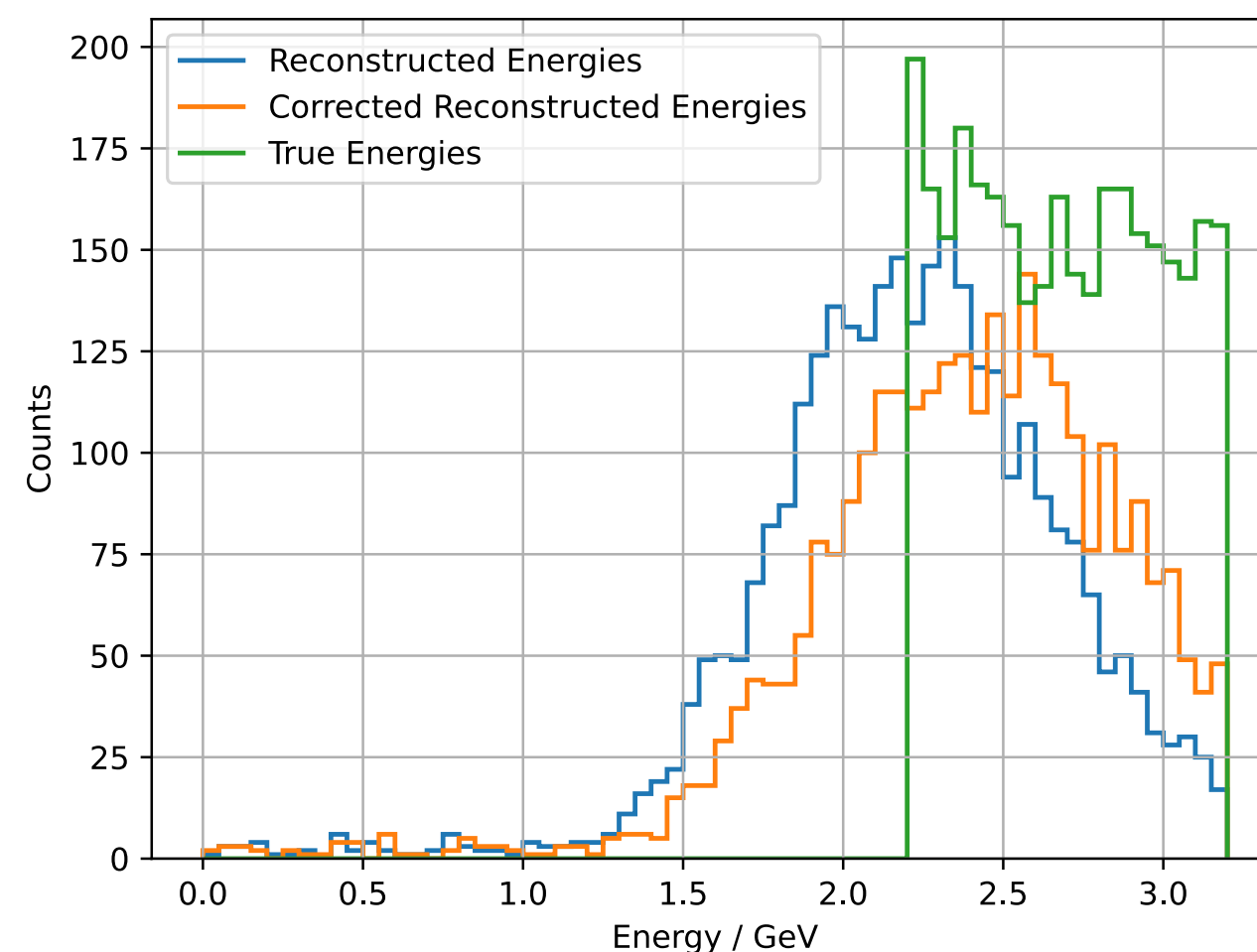
$z_t = 2.5 \text{ m}$



$z_t = 2.7 \text{ m}$



$z_t = 2.85 \text{ m}$



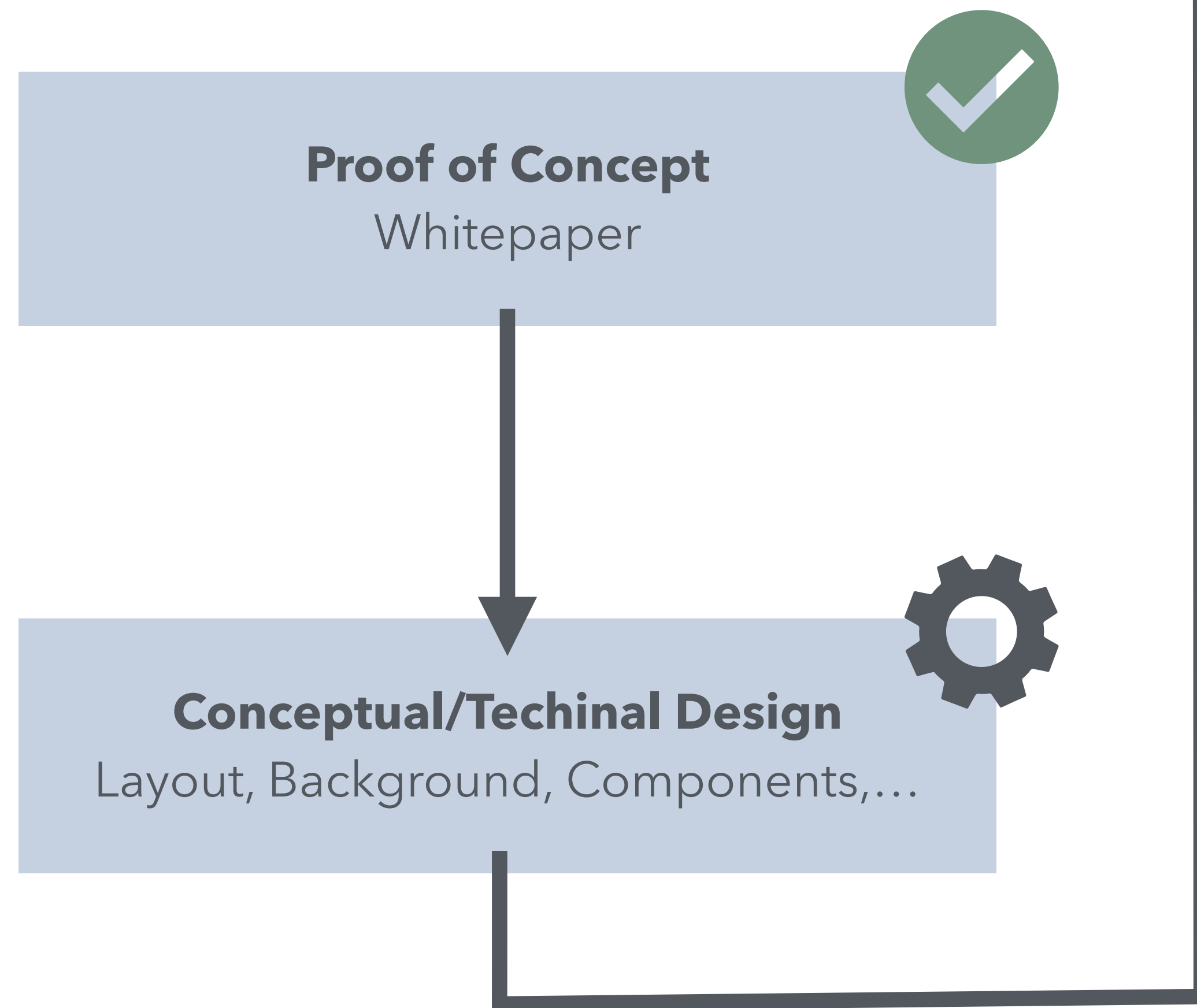
From Working Point

$$E_{\text{det}} = f_{\gamma} E_{\gamma} + f_e E_e$$

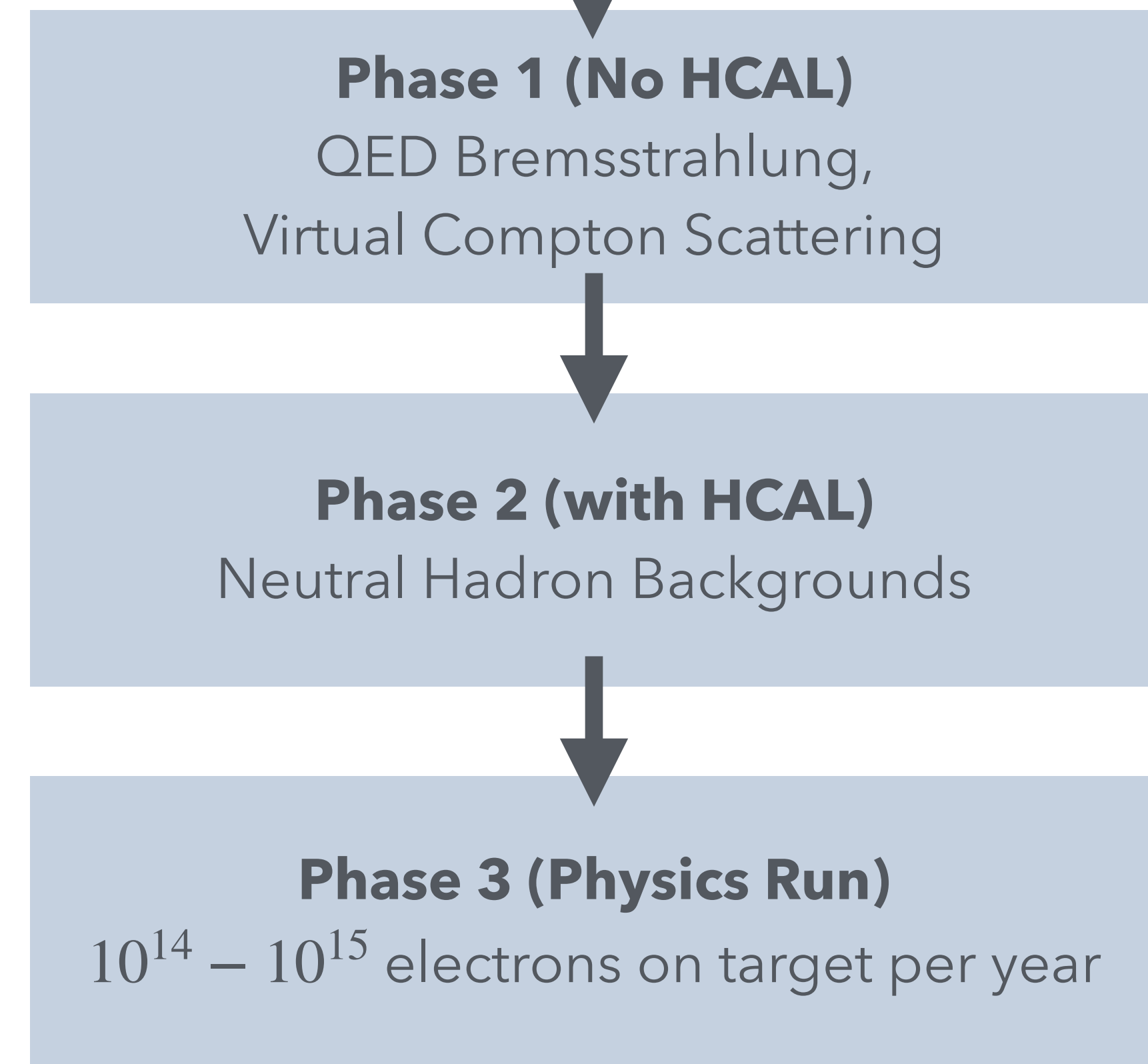
Track Info

$$E_{\gamma} = \frac{E_{\text{det}} - f_e E_e}{f_{\gamma}}$$

Roadmap

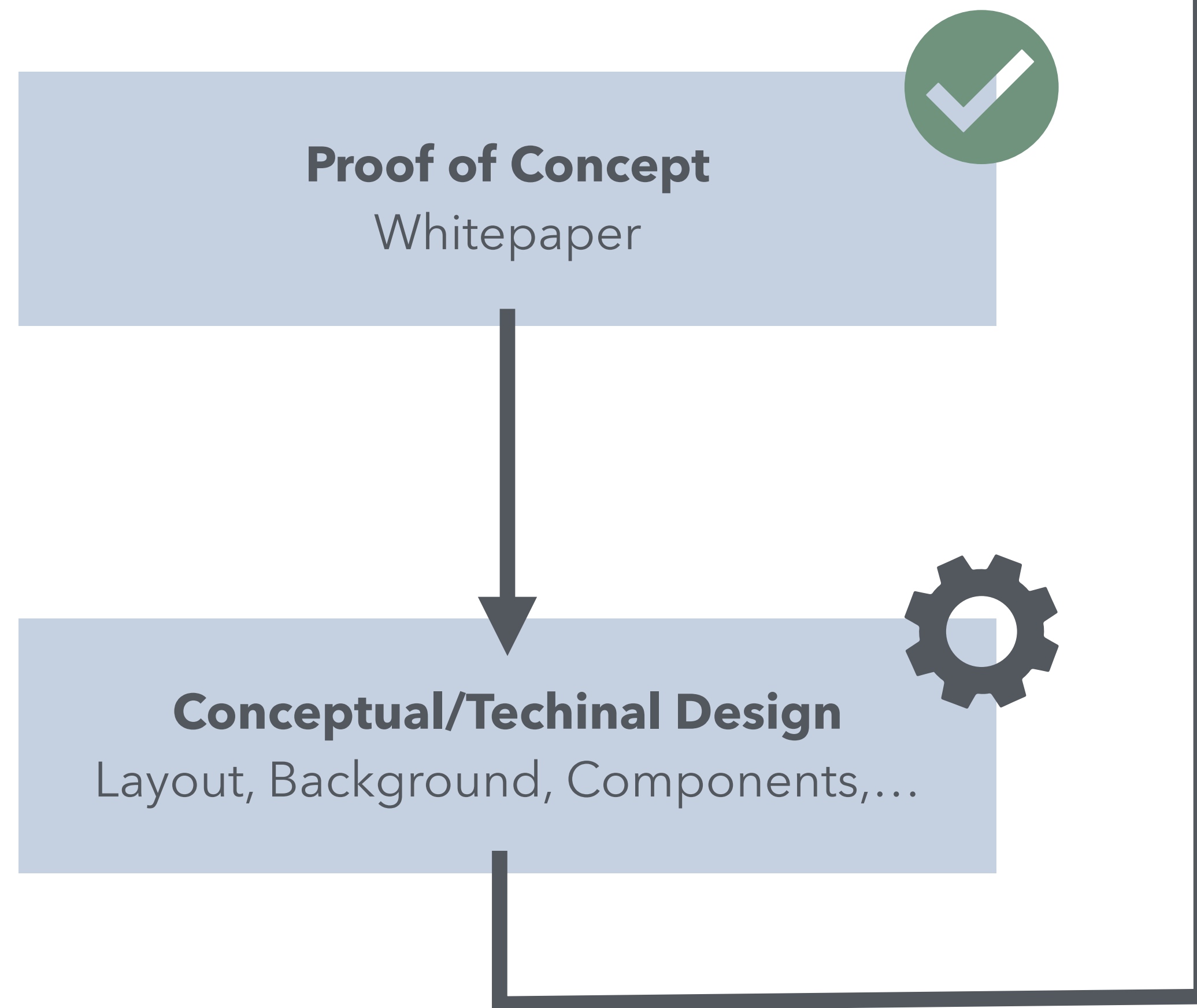


Conceptual Studies

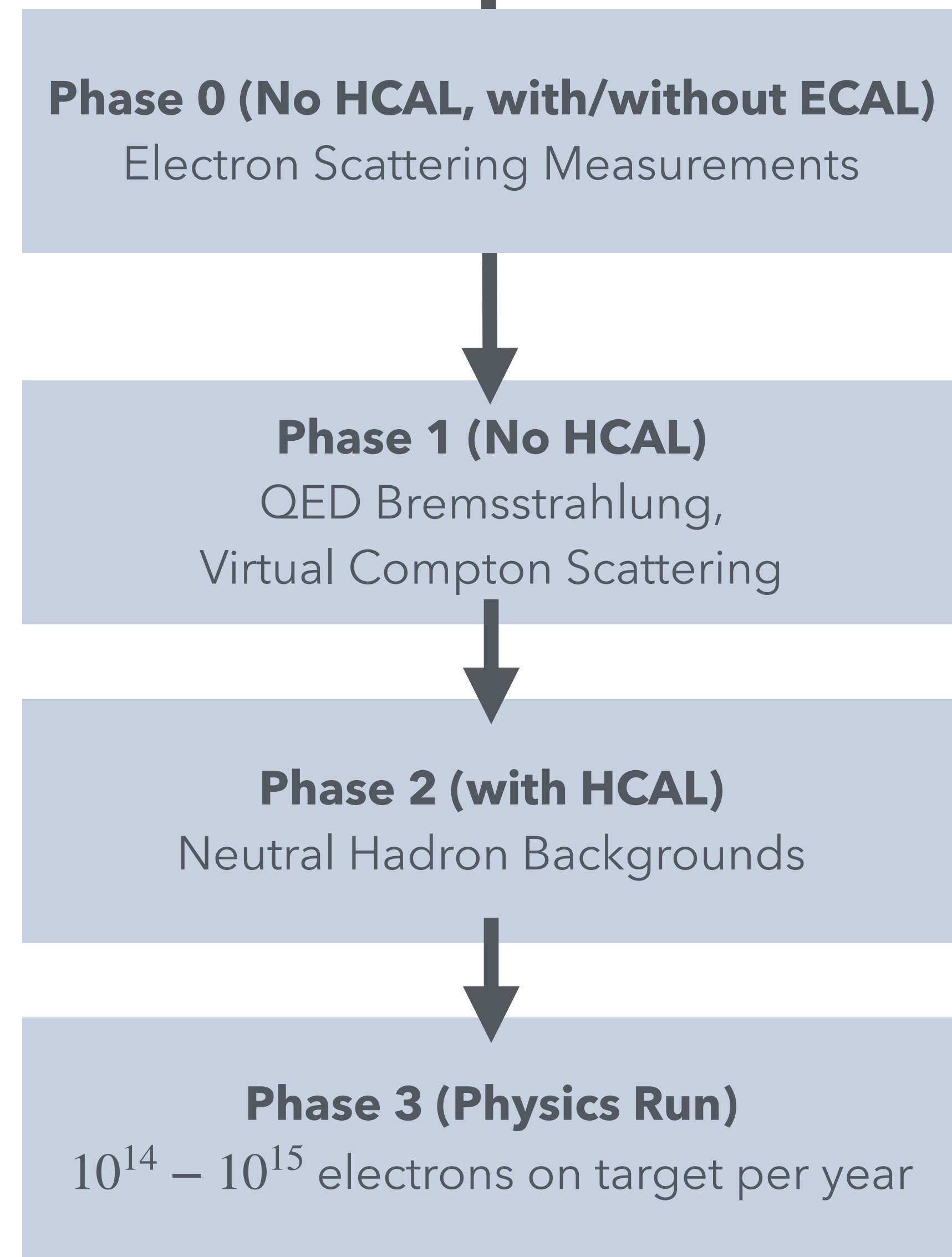


Experimental Phases

Roadmap



Conceptual Studies



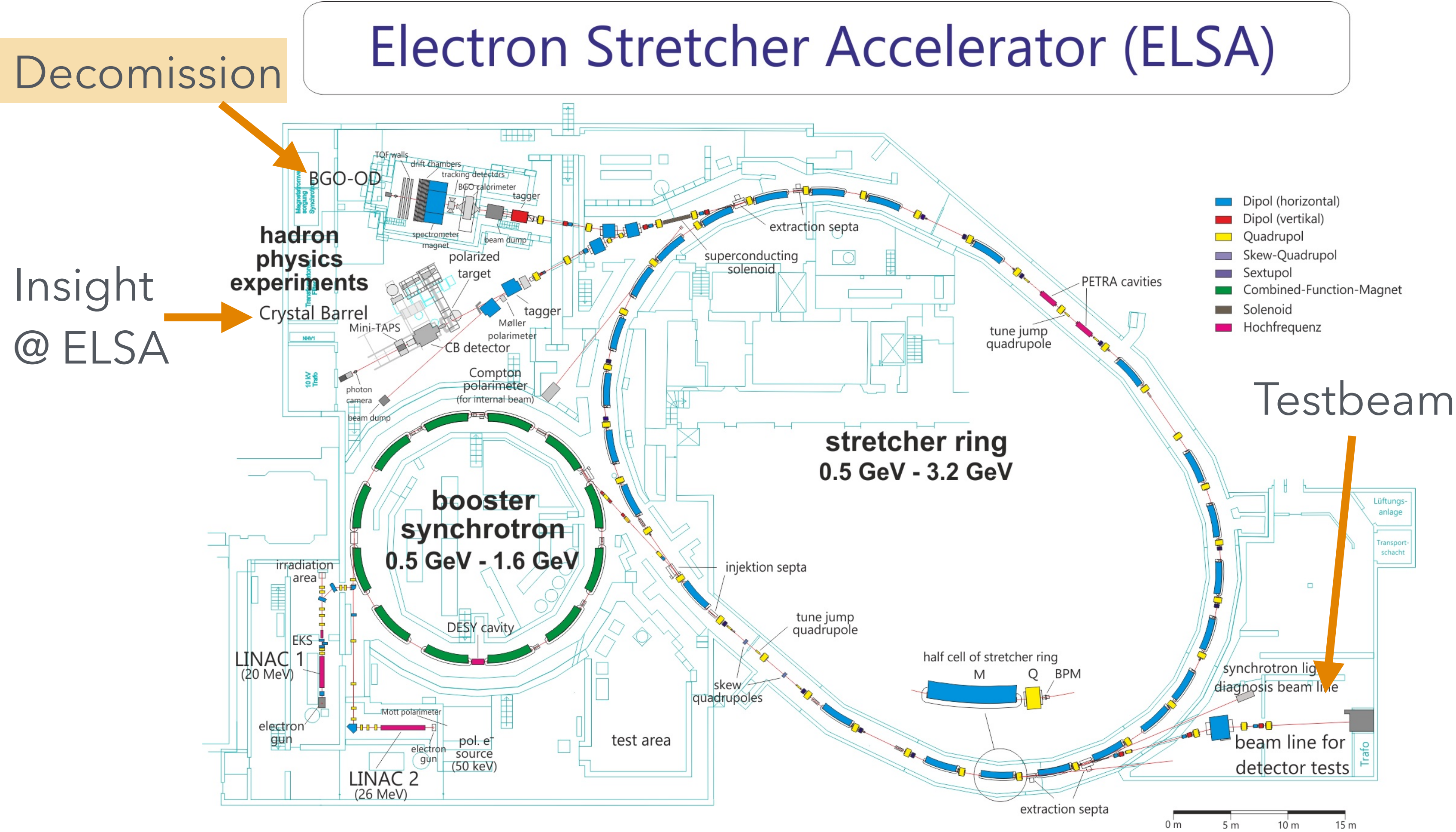
Experimental Phases

Beginning of the talk: ELSA

$$\frac{\langle N_e \rangle}{\text{Event}} \leq 1$$

$$R_e = 500 \text{ MHz} \rightarrow \frac{\langle N_e \rangle}{2 \text{ ns}} = 0.2$$

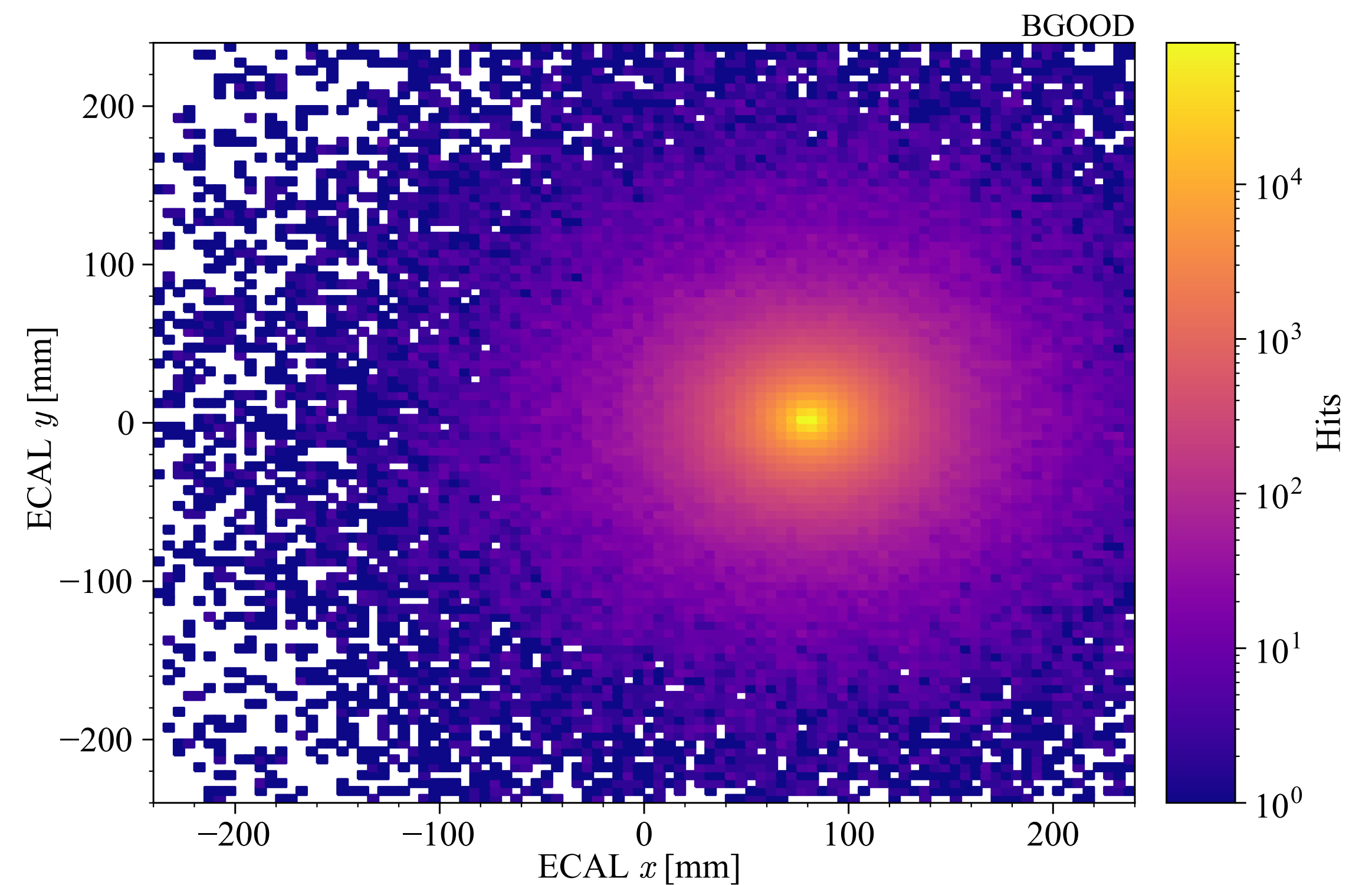
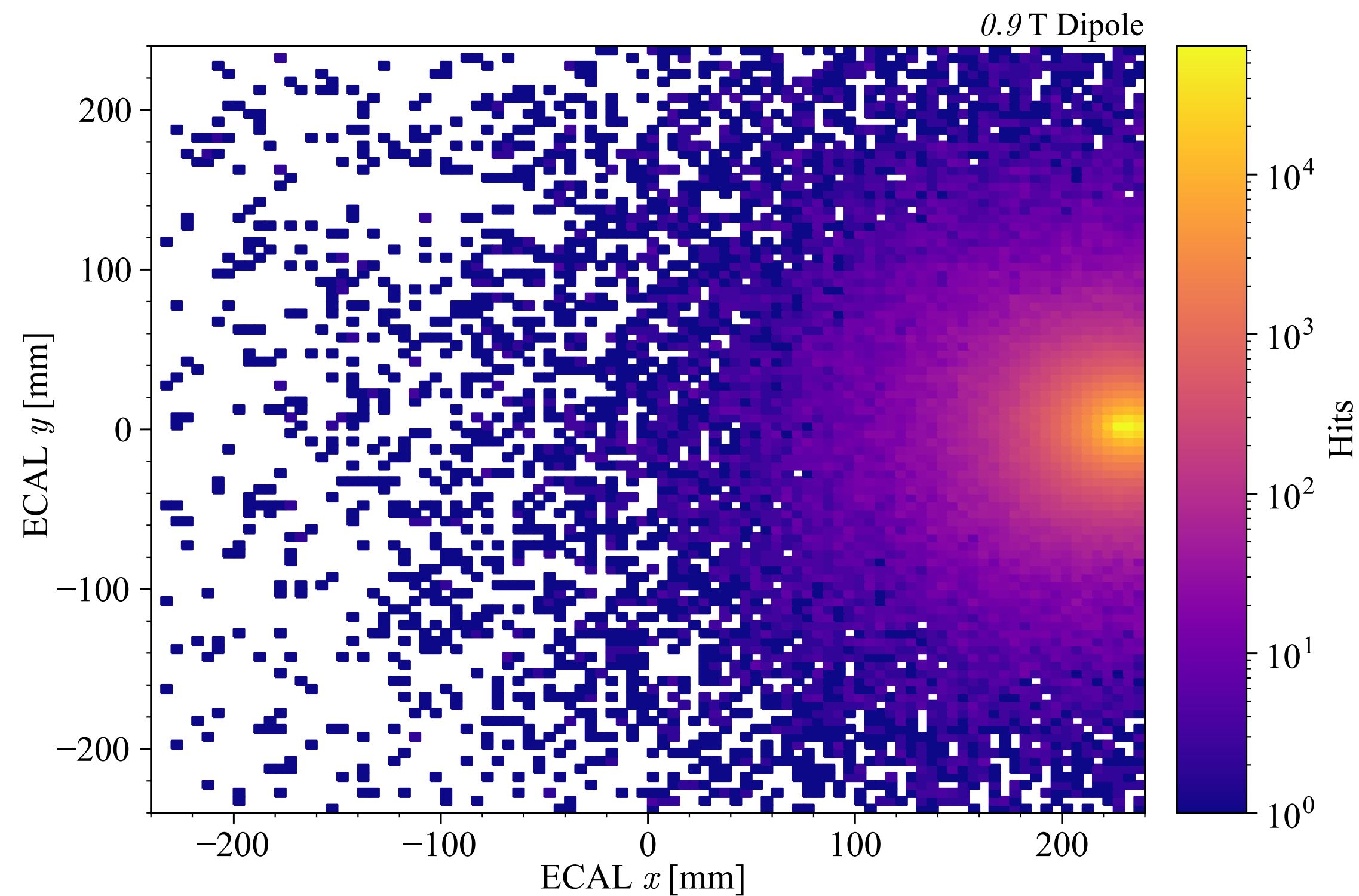
$$E_e \leq 3.2 \text{ GeV}$$
$$\sigma_E = 0.08 \%$$



Existing magnets

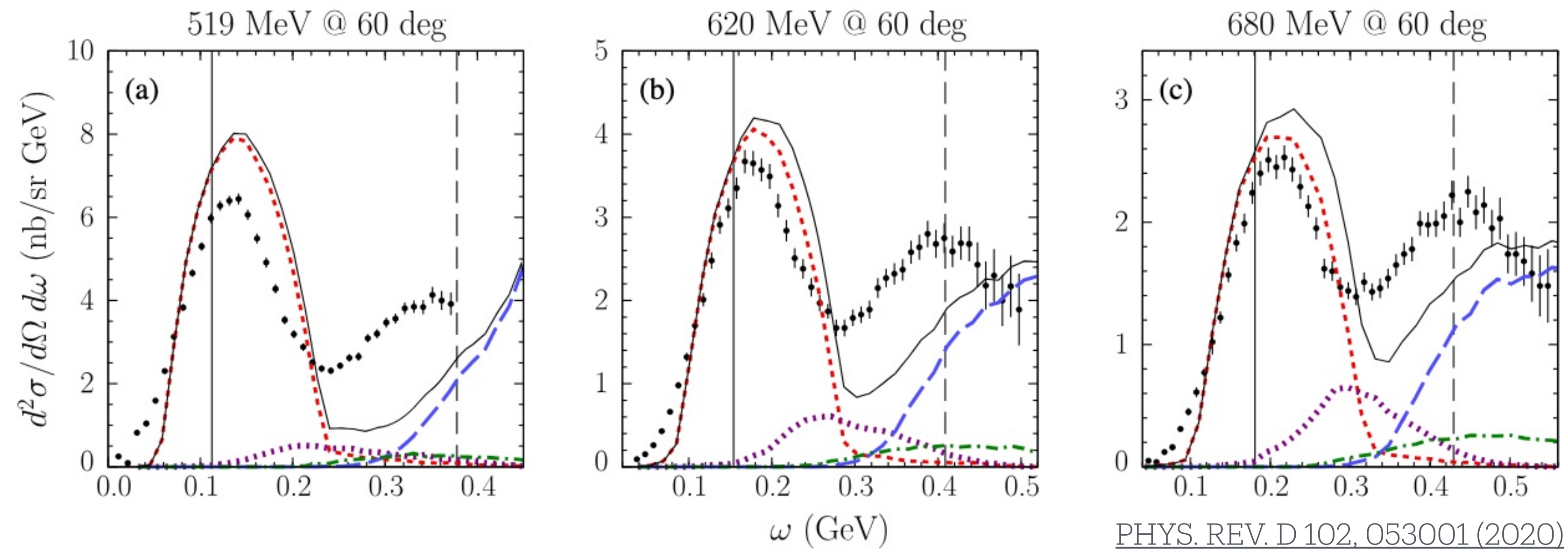
Simulation: Electron gun + magnet + ECAL

Only $\approx 0.5 - 0.7$ T



→ resolving the electron in the ECAL would become necessary anyways

Electron Nucleus Scattering Cross Section



- MC Generators not accurate enough
- No data available at low angles
- Important for ν scattering (e.g. DUNE)
- We can cover part of that!

What do we need?

Tracker 

Target 

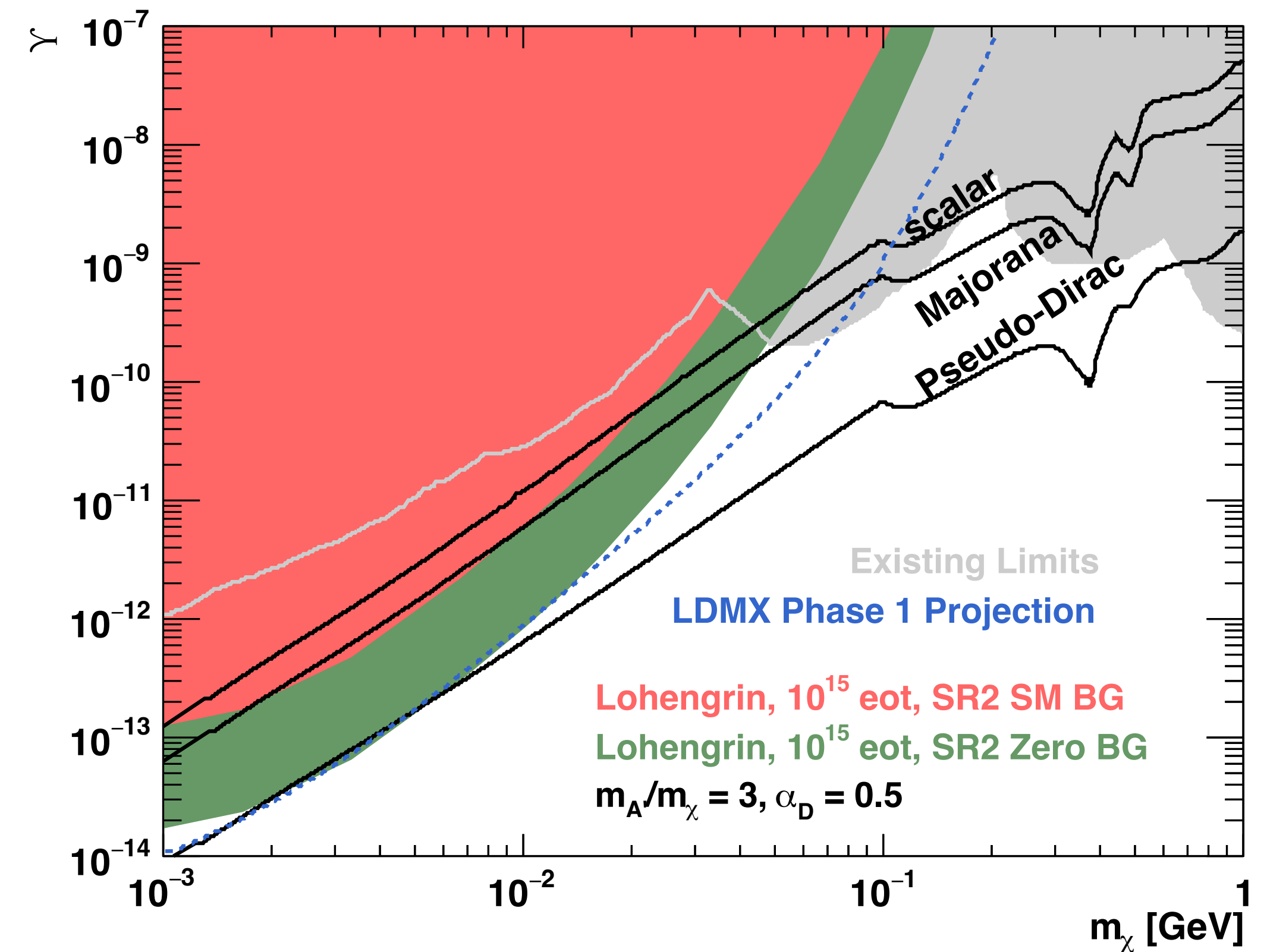
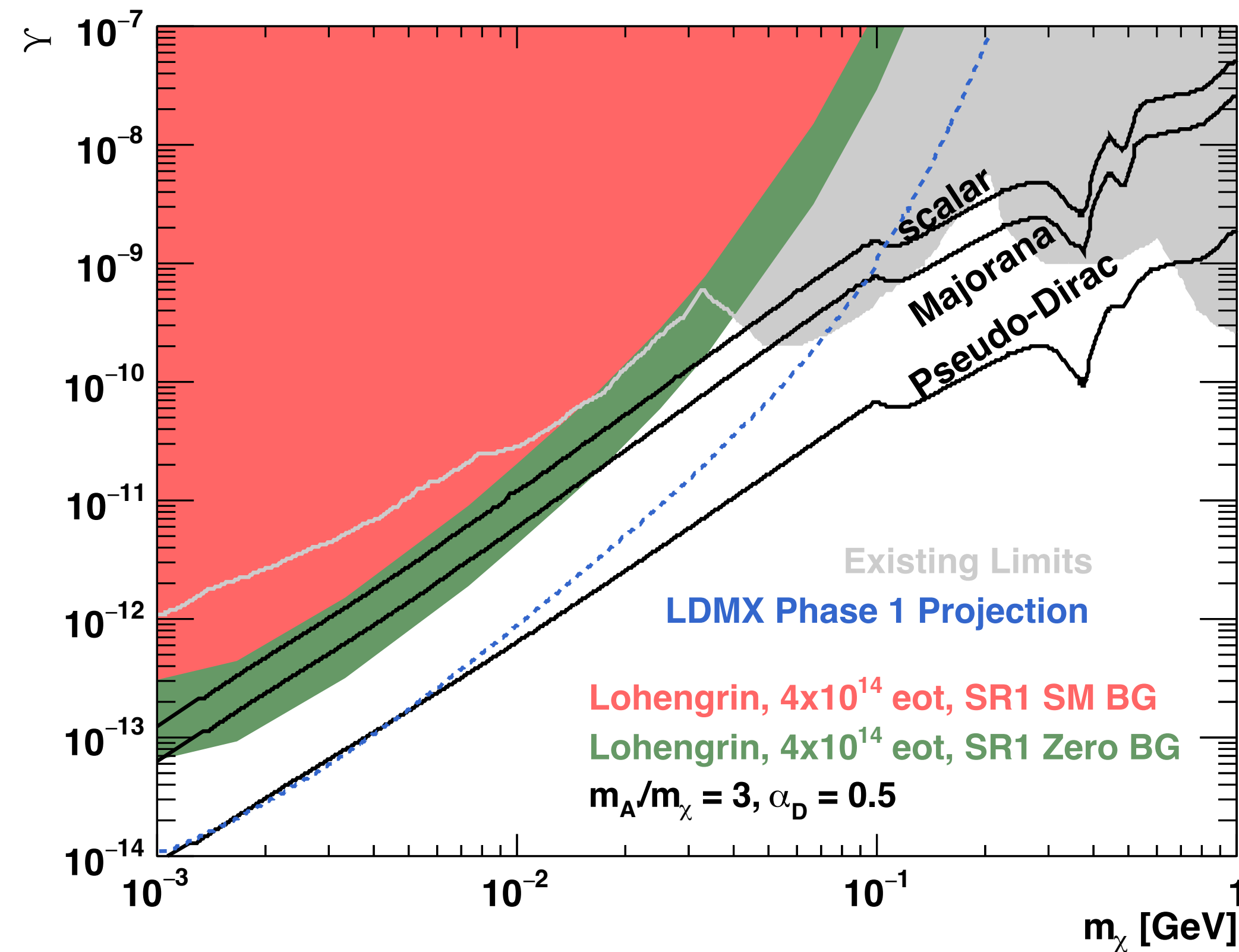
Magnet 

(ECAL) 

→ TJ-Monopix2/Timepix3

→ BGOOD

The goal



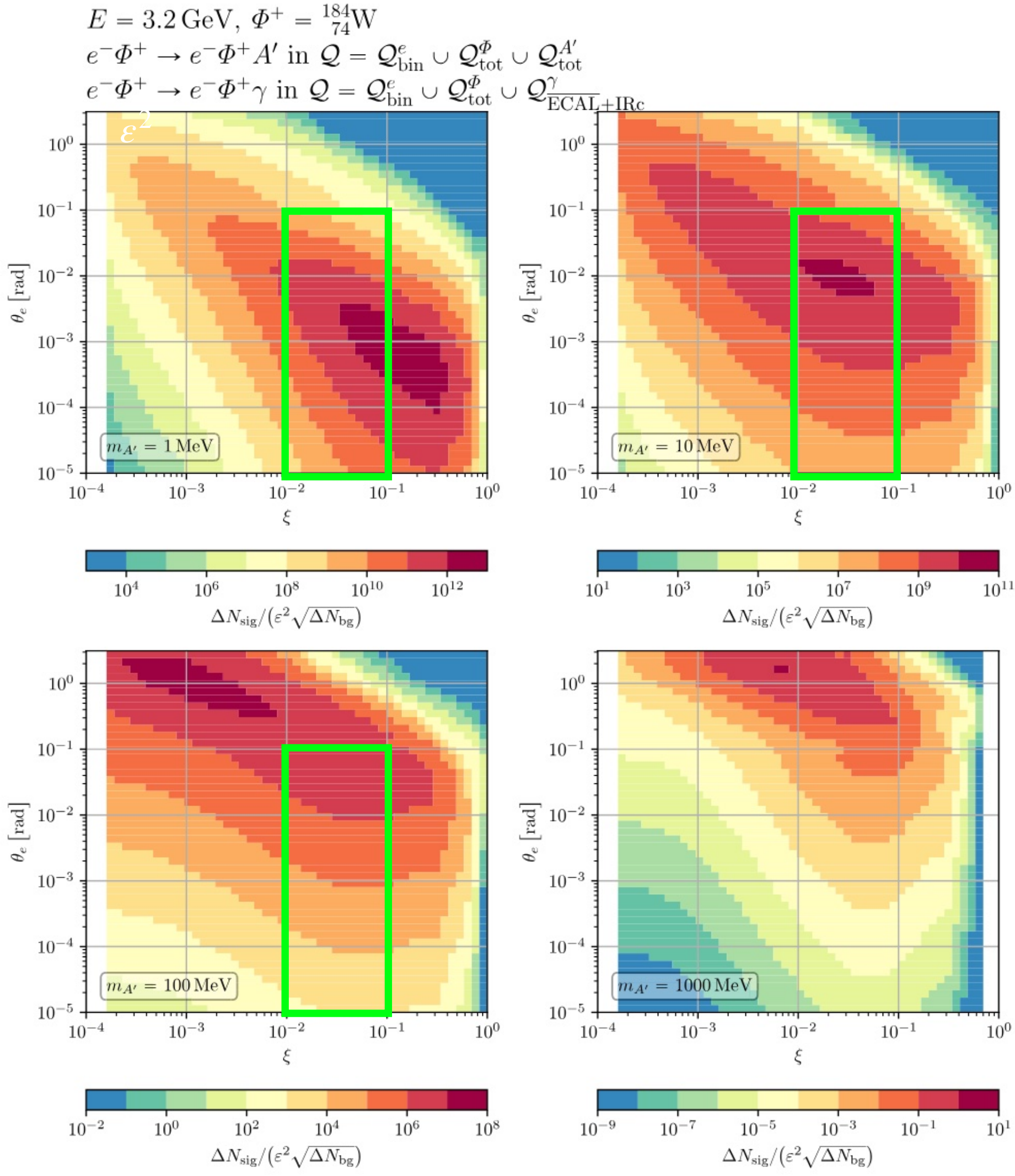
More aggressive SR, more eot
Lower E_e threshold can be lowered

Backup

Where are we looking



Recoil e^- polar angle



Assuming a perfect detector...

Green Area: promising for $m_{A'} \in [1,100] \text{ MeV}$

A' Mass [MeV]	ε^2	Run Days to produce 100 A'
4.5	$O(10^{-11})$	$O(10^2) - O(10^3)$
10	$O(10^{-10})$	$O(10^2) - O(10^3)$
100	$O(10^{-8})$	$O(10^2) - O(10^3)$
1000	$O(10^{-7})$	$O(10^8) - O(10^9)$

Lohengrin Tracker

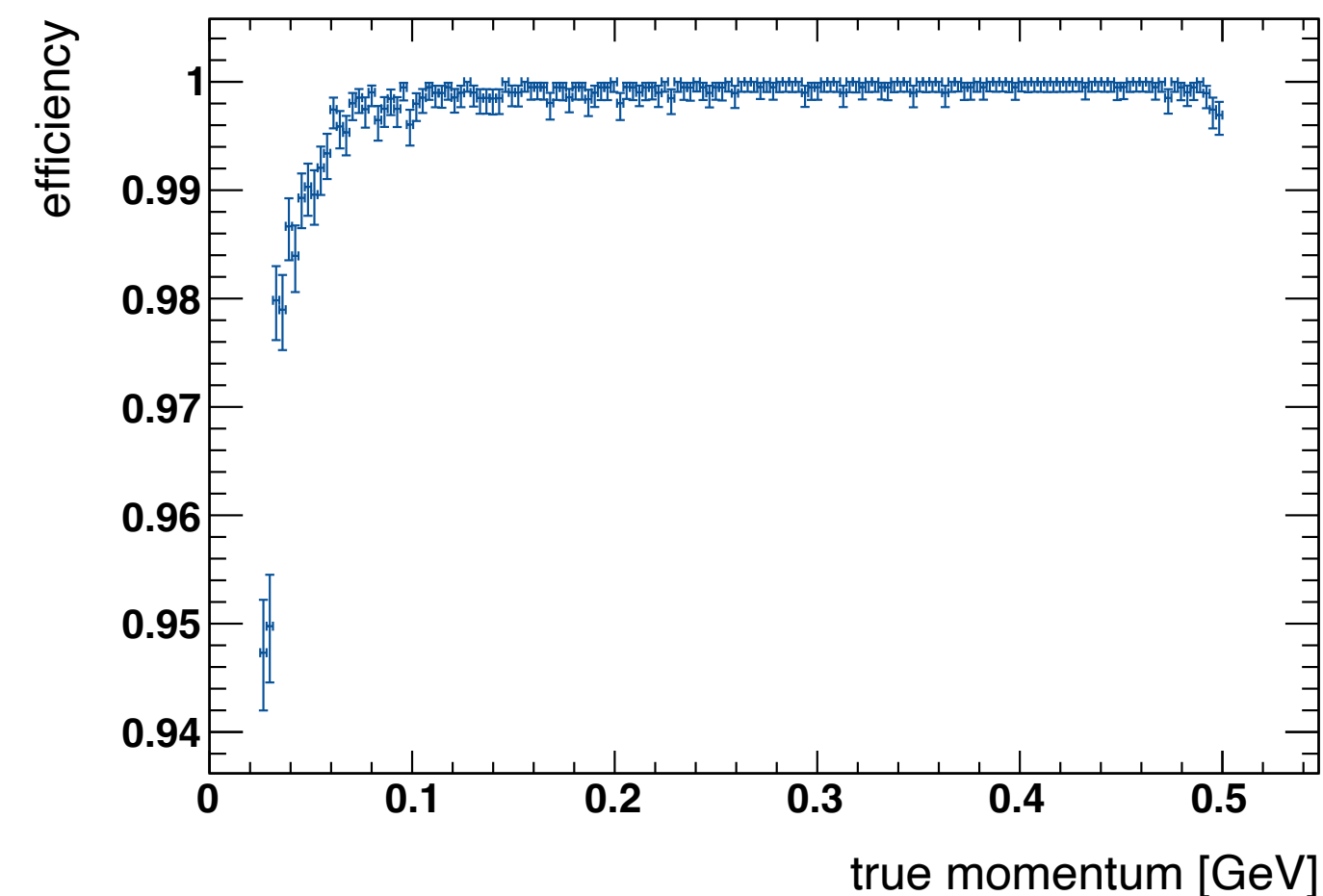
Requirements:

Reasonable hit rate per pixel
Low material budget

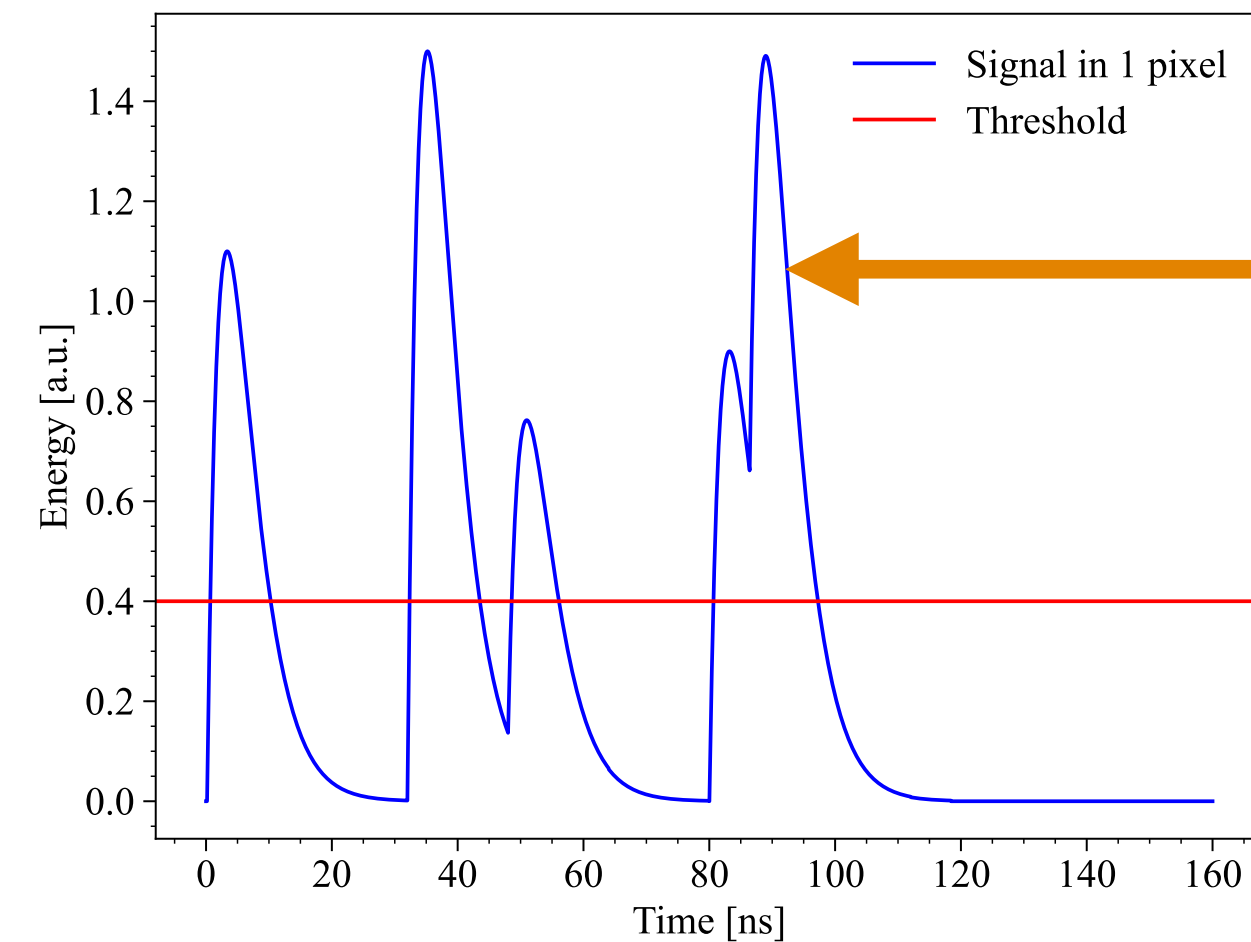
Current Studies:

TJ Monopix, Obelix like tracking ASICs

Need good tracking to low momenta



Need a fast tracker

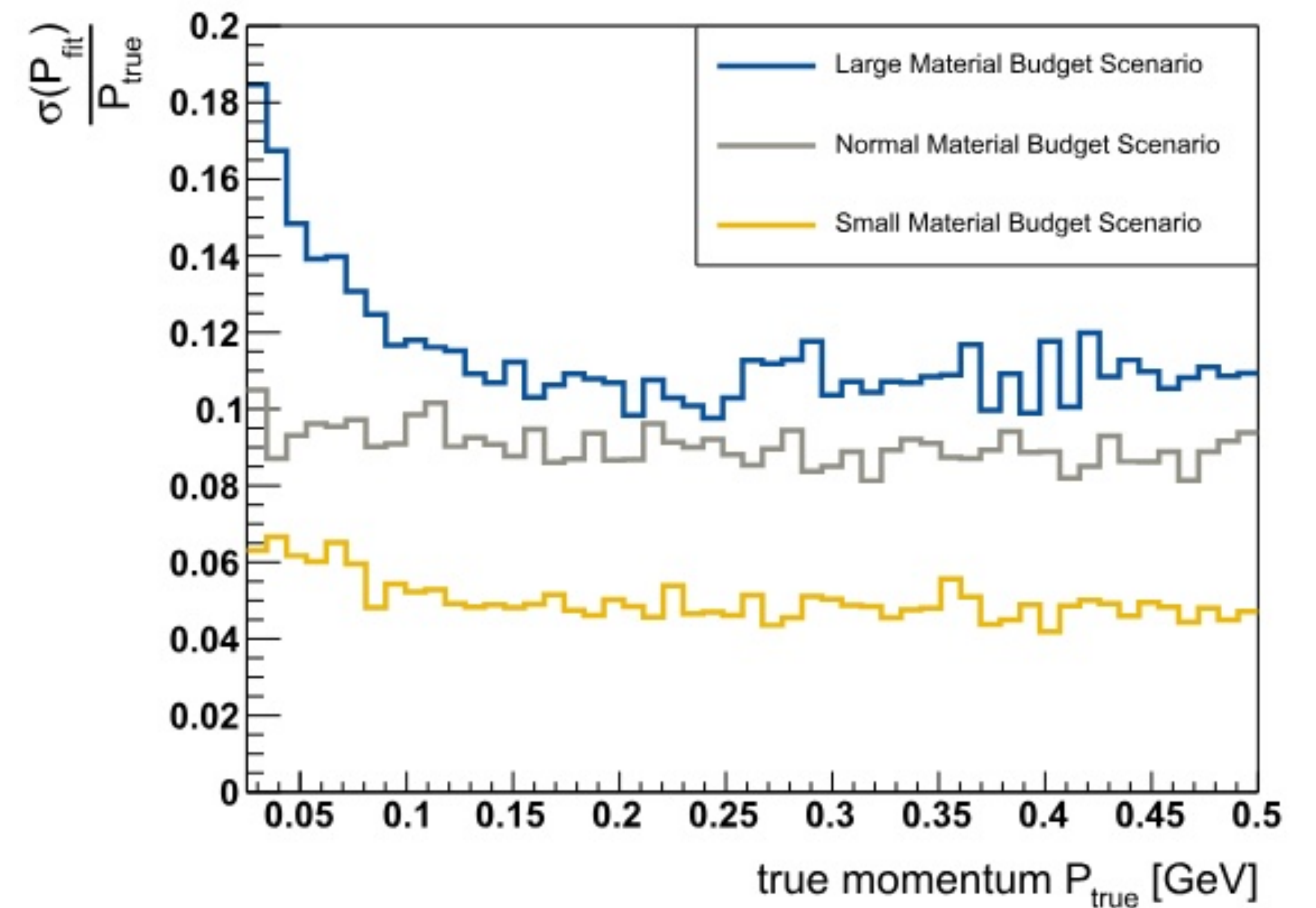
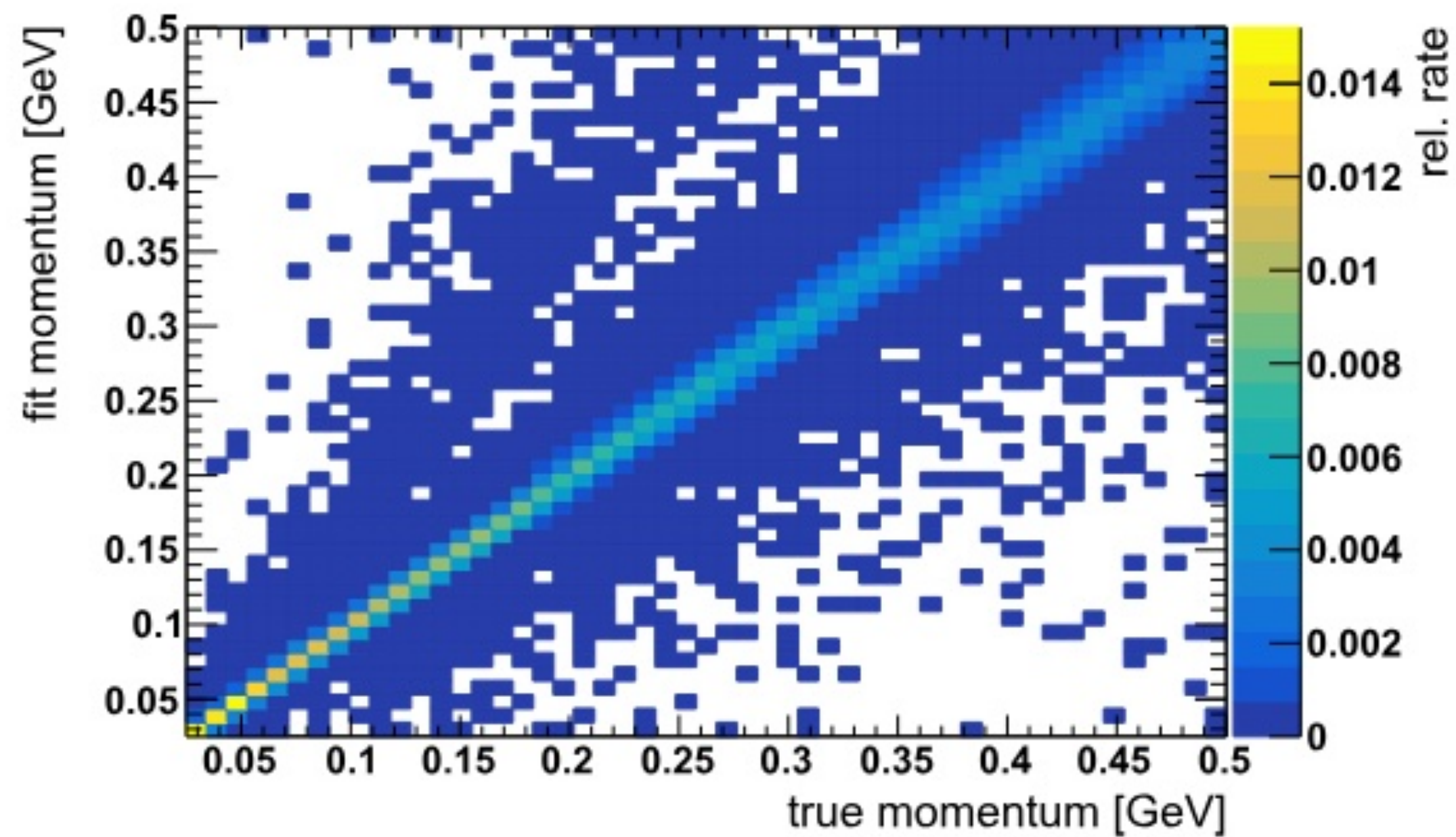


Hit not
registered

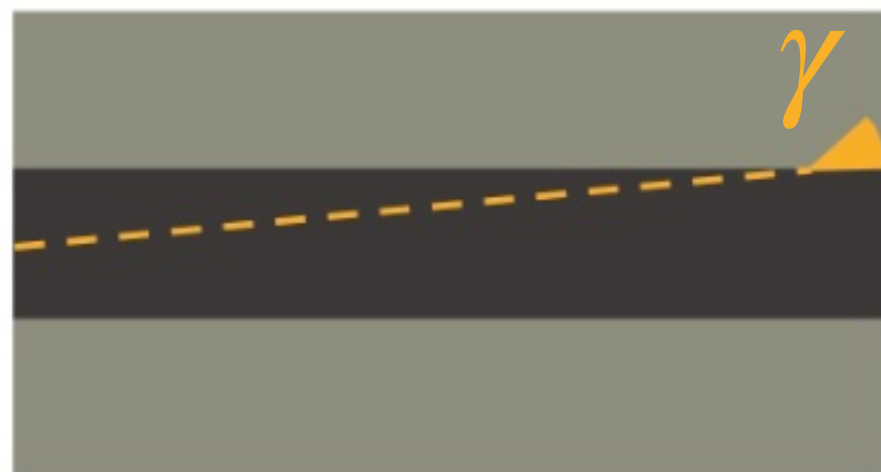
Chips themselves need to be fast

Tracking

Whitepaper Simulations, ACTS



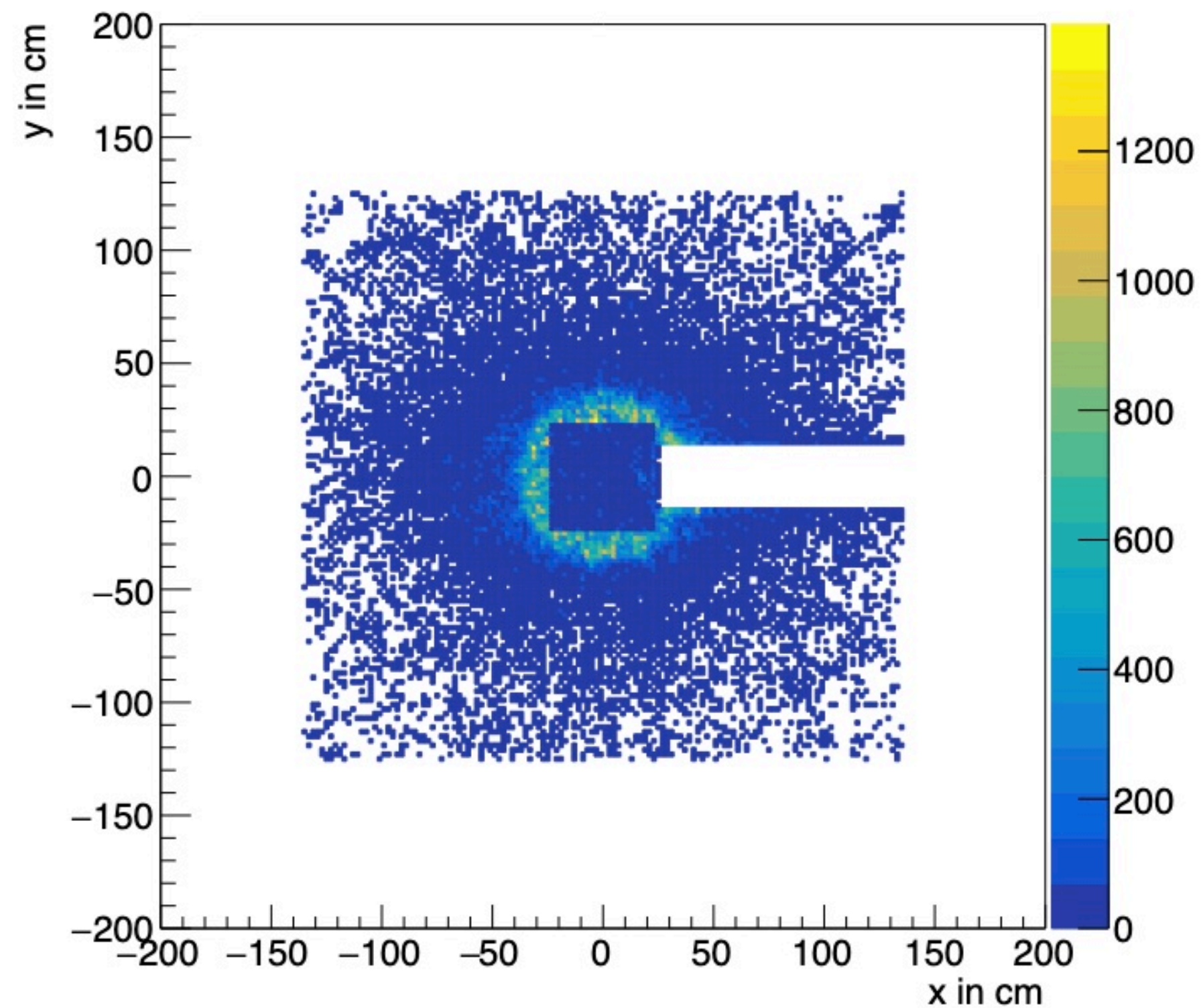
The magnet bulk



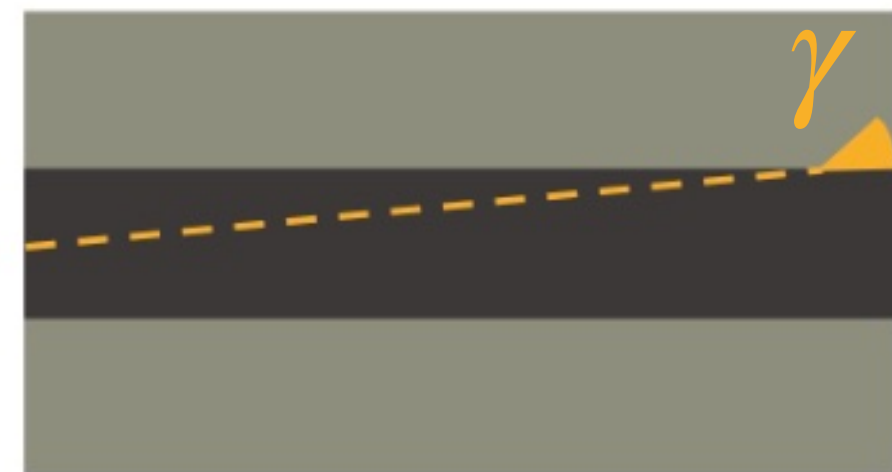
n, p, π^+, γ with
variable E

variable d

Fe



The magnet bulk



n, p, π^+, γ with
variable E

variable d

