Physics motivation and requirements for a timing layer

Zhenwei Yang @ Peking University

on behalf of the LHCb ECAL Upgrade II R&D group

14 Dec 2022

Great thanks for inputs from all the colleagues, especially Marina, Matthew, Jiale, and Jike.

ECAL Upgrade II Workshop (in a hybrid mode)

12-14 Dec 2022, IJCLab, Orsay

Outline

➤ Introduction

➤ Benefits from timing layer

➤ Summary

ECAL is essential to many physics

➢ Photon polarization in the $b \rightarrow s\gamma$ process

➢ CP violation in $B^0 \rightarrow K^+\pi^0$ decays

➢ Lepton universality tests through the reconstruction of $b \rightarrow se^+e^-$ transitions

➢ ……

See talks in the *Physics benchmarking of baseline* session on Tuesday morning
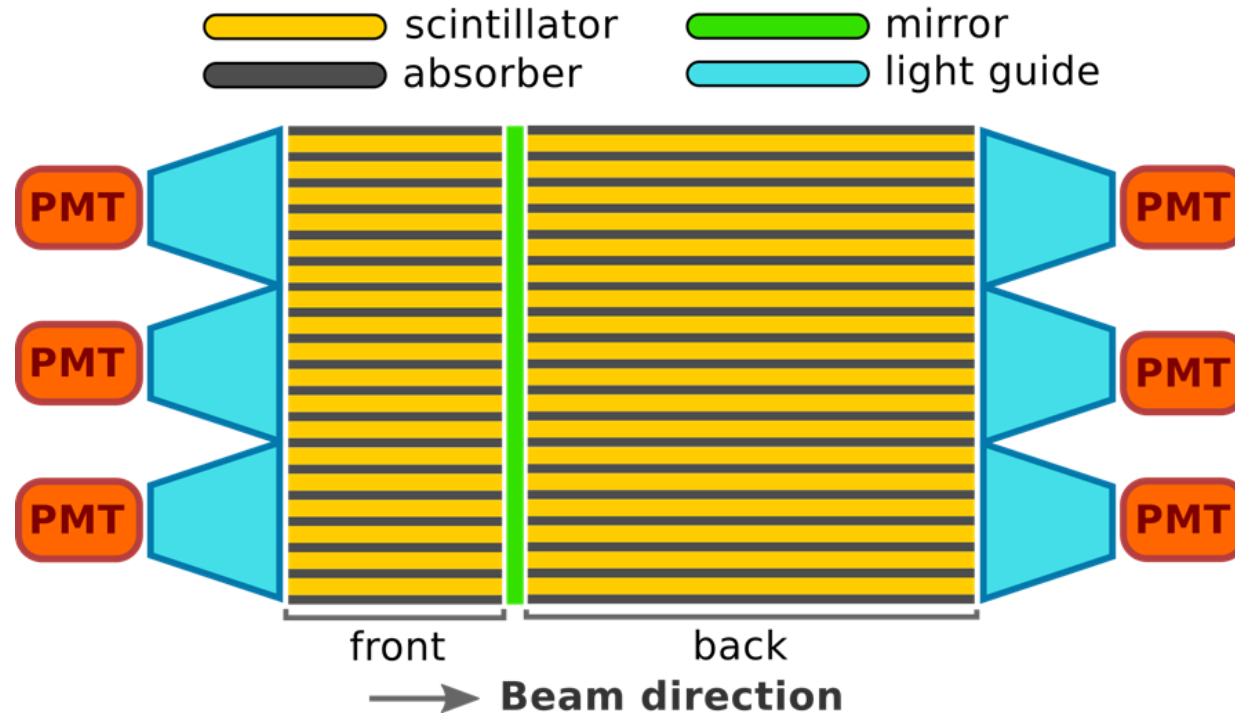
ECAL run conditions & requirements

➢ Run 3: data taking at 2×10^{33} cm^{-2}s^{-1}

➢ Run 5: data taking at 1.5×10^{34} cm^{-2}s^{-1}
- Pile-up: 50-60

➢ Requirements
- Good radiation tolerance
- Good timing resolution ⎫
- Good granularity   ⎬ to mitigate pile-up
- Good energy resolution
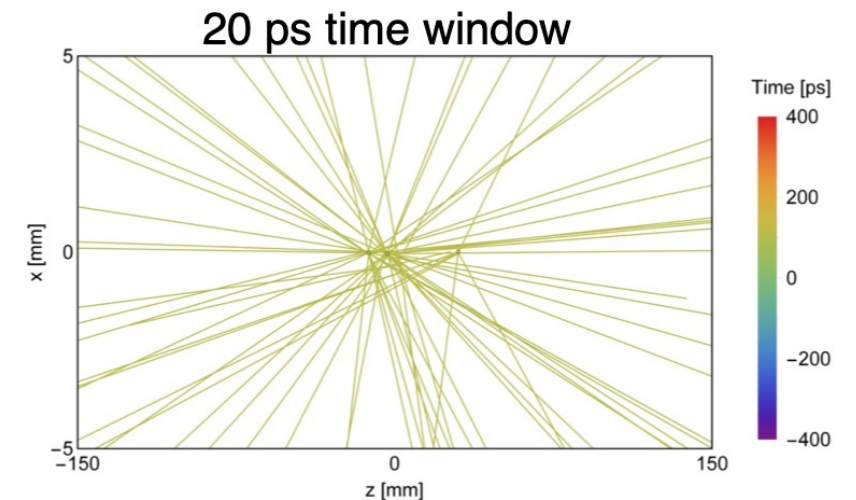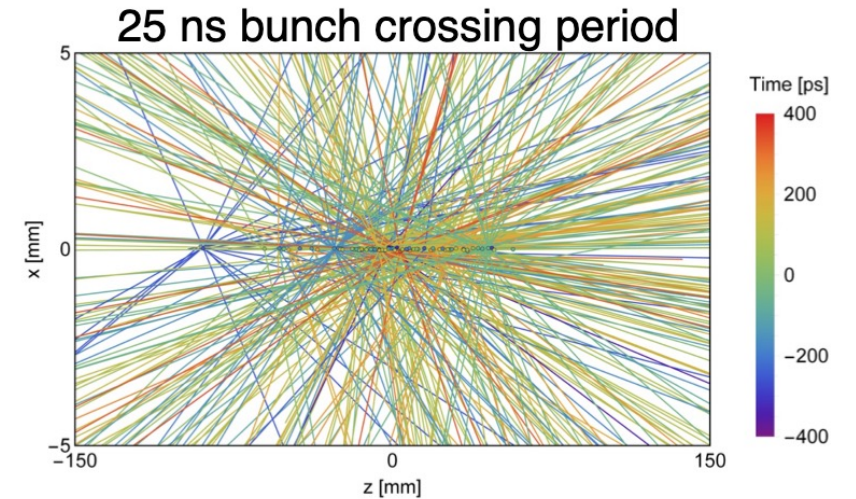
Baseline scenario

Additional timing layer could provide special benefits

Different technologies under consideration (see talk by Vincenzo):
LAPPD, LGADs, SiW ⋯

A timing layer is more than timing

Better granularity and position ➔ imaging

Timing measurements

➢ Layer may achieve close to 20 ps resolution per measurement

➢ For all technologies: need to understand how time resolution will vary with irradiation

➢ Increased segmentation allows for many measurements per shower

  • For instance, more inputs for machine learning

➢ Less impact from spillover in time measurement

➢ May have potential for TOF measurement for MIPs in a particle flow type reconstruction

Benefits of high granularity

➢Improved spatial and angular resolution

- direct impact on mass resolution
- Could benefit SPACAL energy corrections

➢Shower shape

- Better overlap removal
- Resolving merged objects

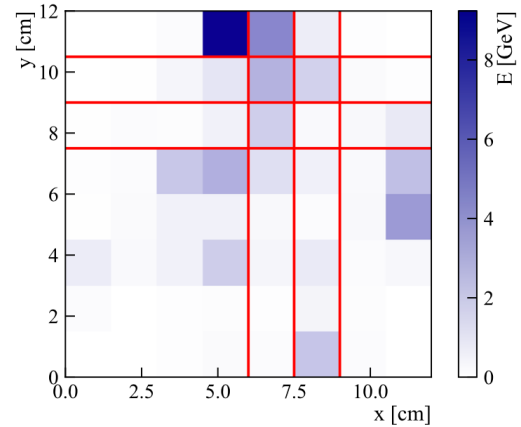# Energy deposition in SPACAL and Si layer

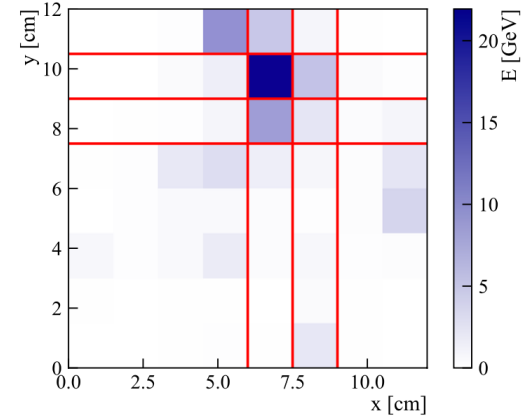Matthew Rudolph

SPACAL F

SPACAL B
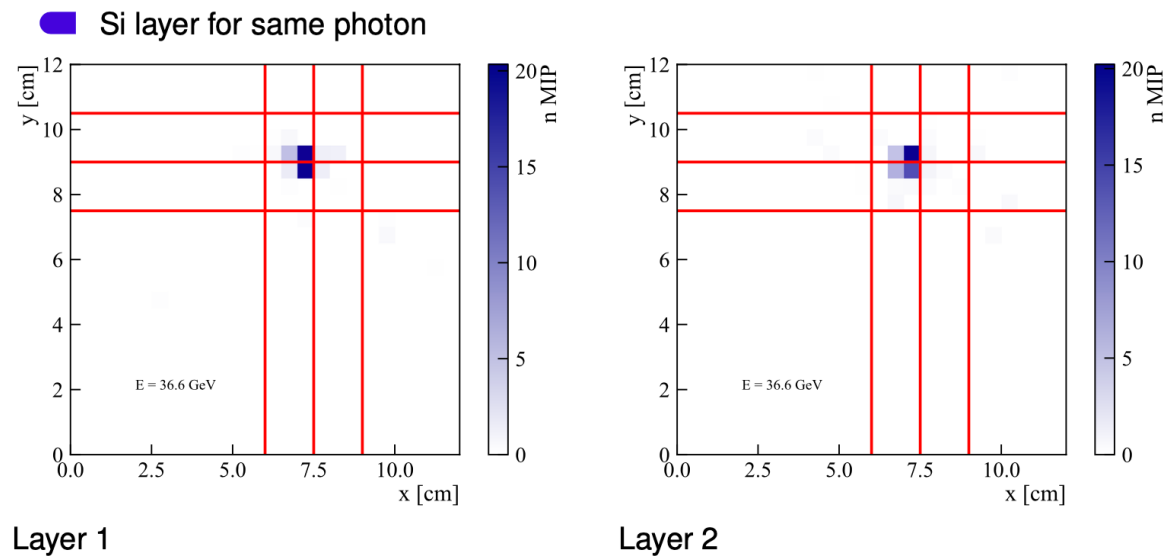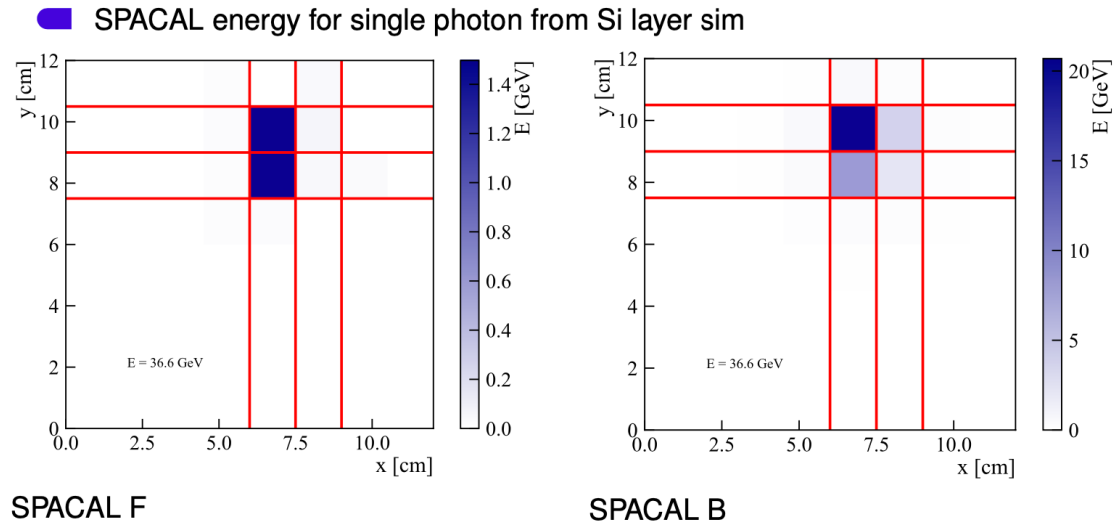
Layer 1

Layer 2

Energy deposition in SPACAL w/o Si layer

Matthew Rudolph

- Sum of energies: would even identify as two clusters?
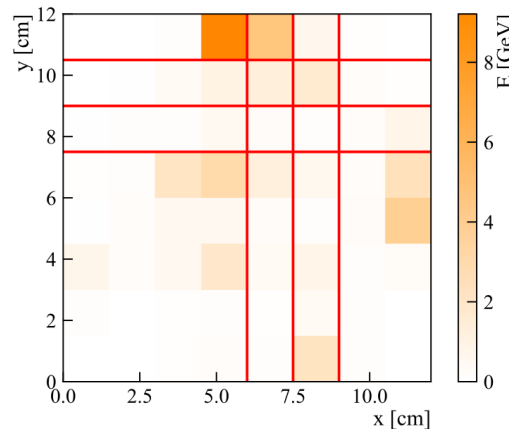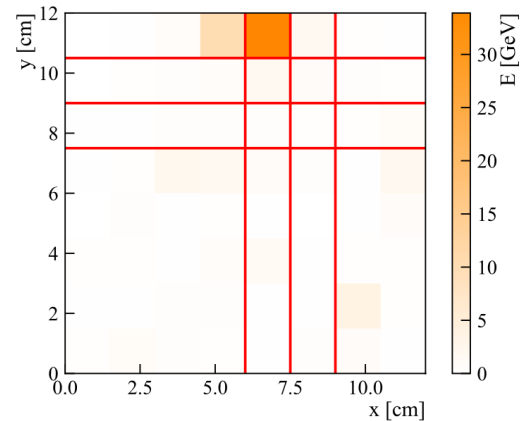- Would be clearly separate in Si layers

SPACAL F

SPACAL B

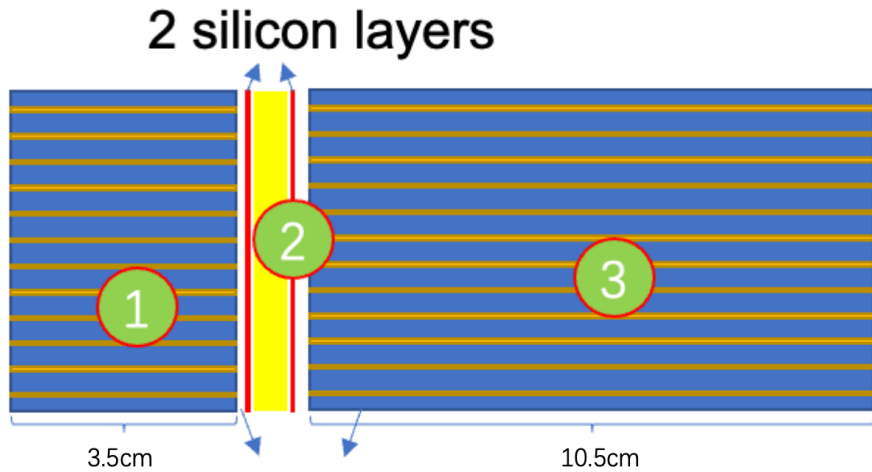- Same module in random Minbias event (sim w/o timing layer)

SPACAL F

SPACAL B

Time resolution with Si layer

Jiale Fei

2 silicon layers

3.5cm   10.5cm

A lot of simulation studies are under way
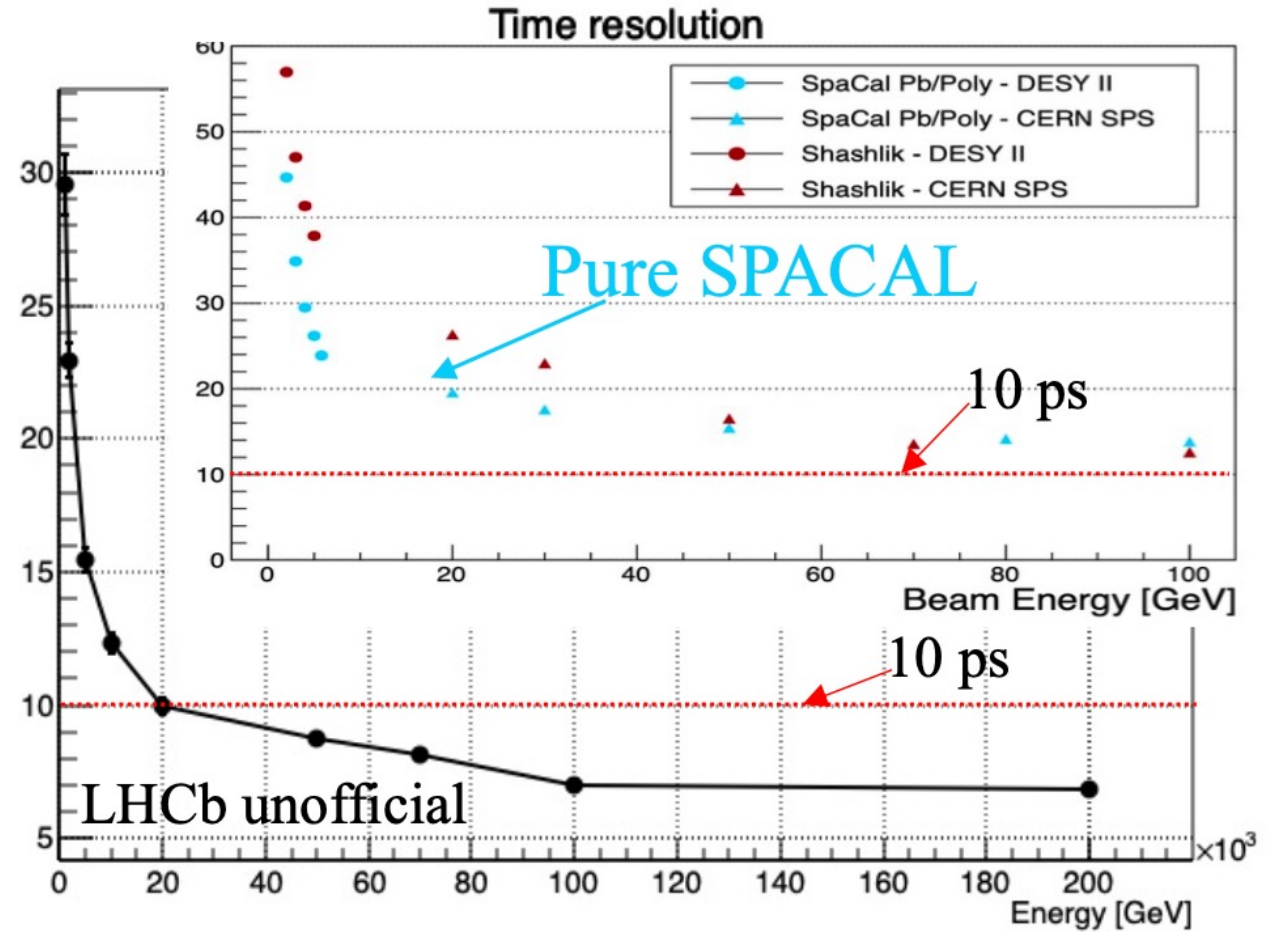
Studies to do

➢ Add pile-up to simulation with timing layer (can stick with single-photon "signals" at first)

➢ How well can we separate pile-up showers using spatial segmentation?

- Both in Si along and using to help SPACAL

➢ Identification of merged π^0 showers

Planned R&D

➢ Simulation studies to identify the optimum cell size/tile size to achieve the best spatial/temporal resolution

➢ Timing/spatial resolution performance before and after irradiation validated in test beam studies

➢ Investigation of alternative technologies/substrate materials

Summary

➢ Time information is essential for Upgrade II

➢ A timing layer could provide great benefits
  - Timing, granularity, and imaging

➢ Some various technologies are under investigation and more studies are needed

➢ An excellent ECAL is needed for flavour physics in 2030s