Simulation study of $B^0 \to K^{*0}\gamma$

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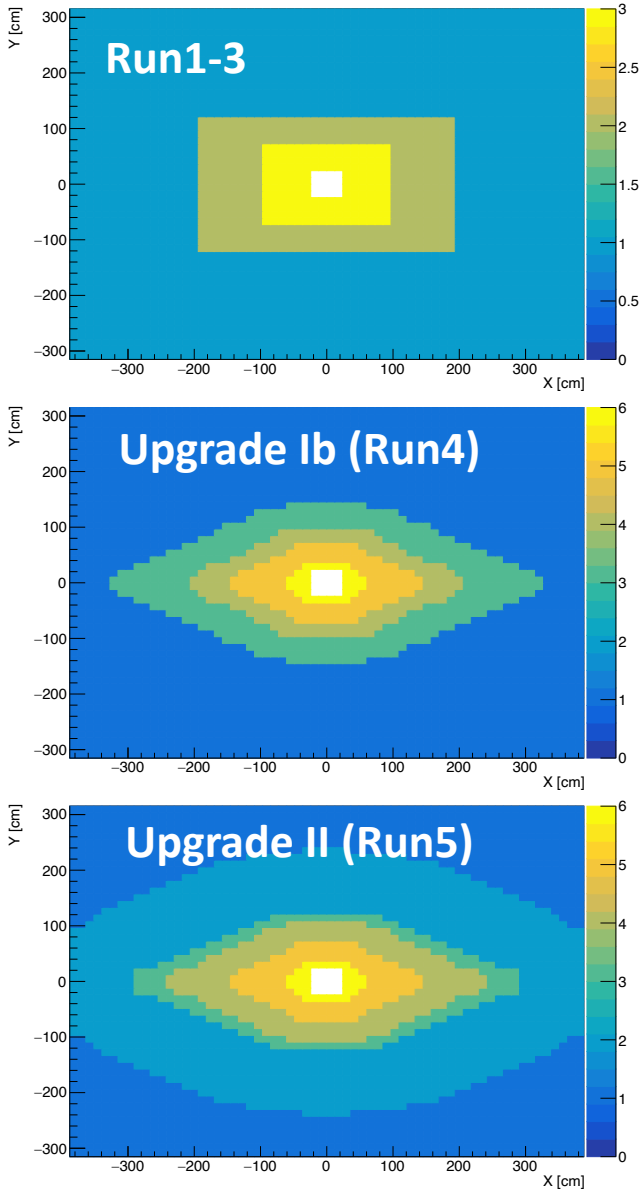
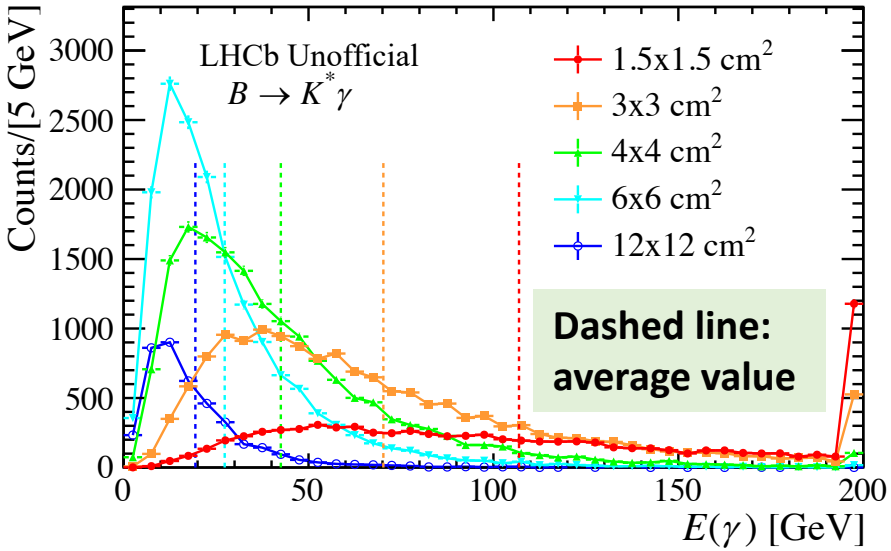
Simulation setup

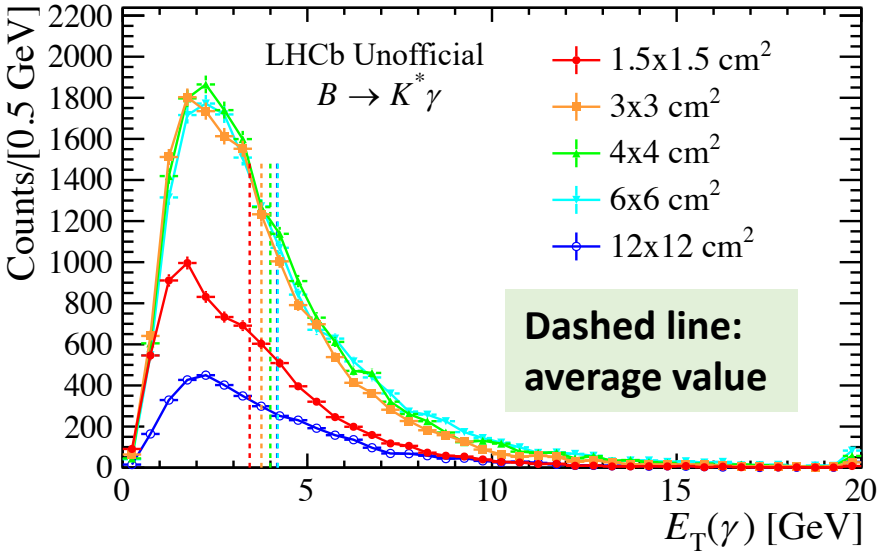
- Various ECAL scenarios are implemented in the hybrid-MC framework *[See Marco Pizzichemi' talk]*
- Upgrade II:
  - ✓Innermost: $1.5\times1.5\ \mathrm{cm}^2$ SPACAL W+GAGG
  - ✓Second inner: $3\times3\ \mathrm{cm}^2$ SPACAL Pb+Poly
  - ✓Outer: $4\times4/6\times6/12\times12\ \mathrm{cm}^2$ Shashlik
  - ✓With longitudinal segmentation
  - ✓Dual timing readout for all modules
- No tilt of SPACAL modules yet
- Pile-up is included in simulation
- Upgrade II luminosity configuration:
  peak $\mathcal{L} = 1.5\times10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ with
  $127\ \mathrm{fb}^{-1}@1.5 + 103\ \mathrm{fb}^{-1}@1.0$
  $+105\ \mathrm{fb}^{-1}@0.6 = 335\ \mathrm{fb}^{-1}$



$B^0 \to K^{*0}\gamma$

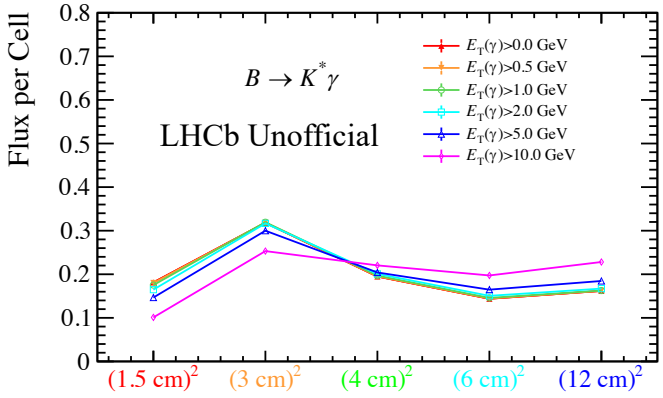
➢A typical high-energy photon channel





- Average E large and gets larger in inner region

- Average E_T similar and larger than 3 GeV for all regions

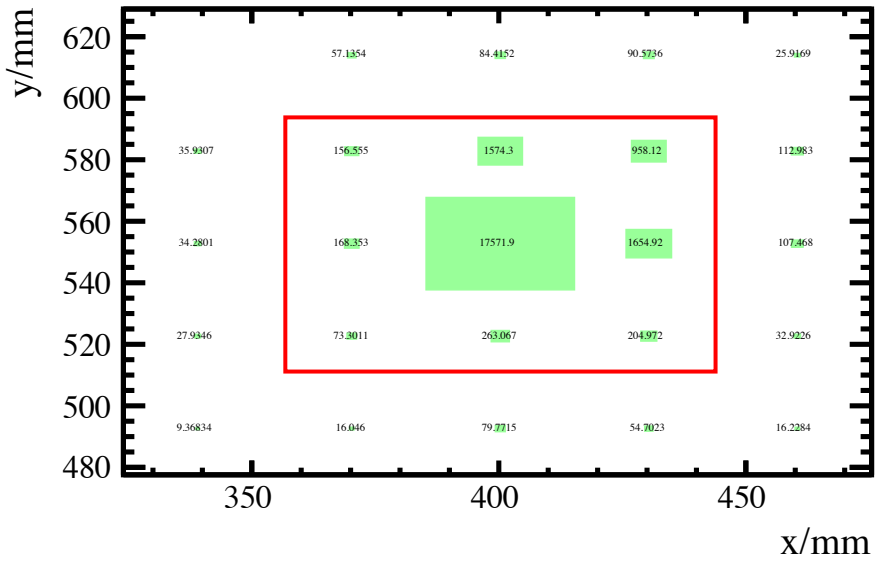


- Photon flux per cell is similar in all regions, and slightly larger for the 3×3 cm^2 cells

Clustering approach

➢3×3 cells clustering

✓cell with larger deposit energy than all its neighbor cells taken as **seed cell**; 3×3 cells surrounding seed cell taken as a cluster



✓Seed cell with E_{T} threshold of $50\ \mathrm{MeV}$

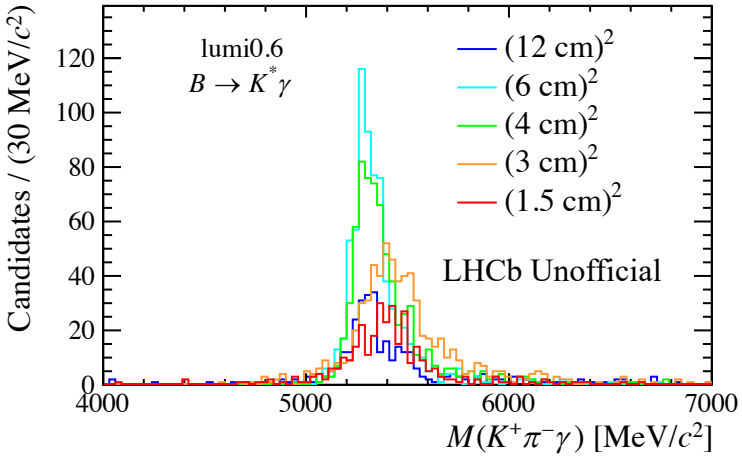
✓**Energy in front and back cell summed up; timing taken as that of seed cell**

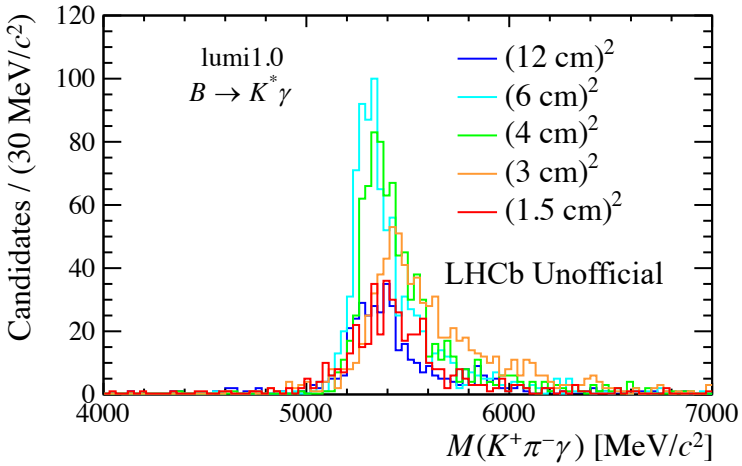
✓S, L and E corrections to position and energy of the clusters are implemented

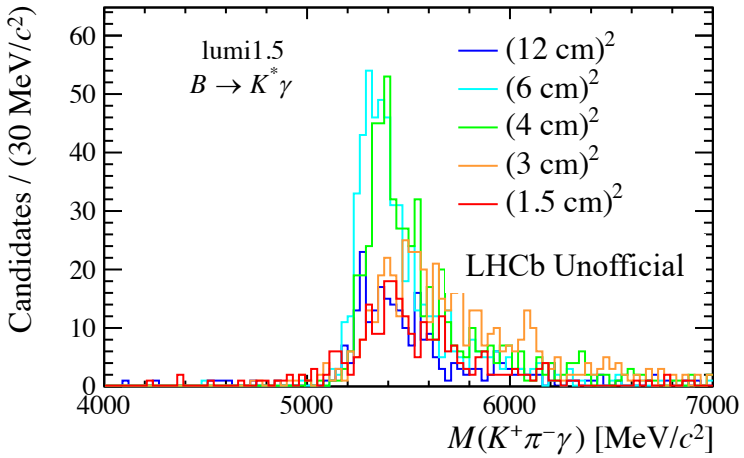
✓Algorithm to be improved: utilizing ***long. segmentation***, ***timing info*** etc.

$M(K^-\pi^+\gamma)$ distributions

- $M(K^-\pi^+\gamma)$ distributions with reconstructed photon energy for truth-matched photons
  - ✓Mass peaks well reproduced ⇒ photon reconstruction works well
  - ✓Pile-up effect gets more significant with larger luminosity as expected

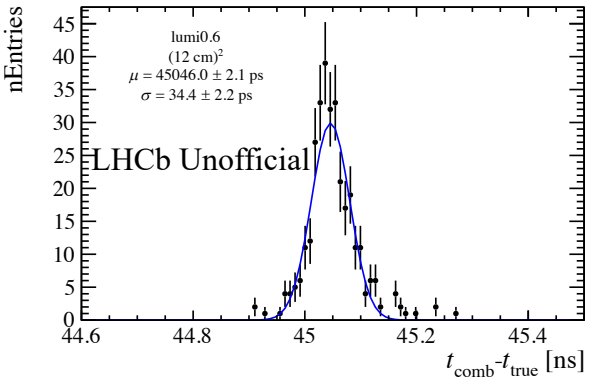


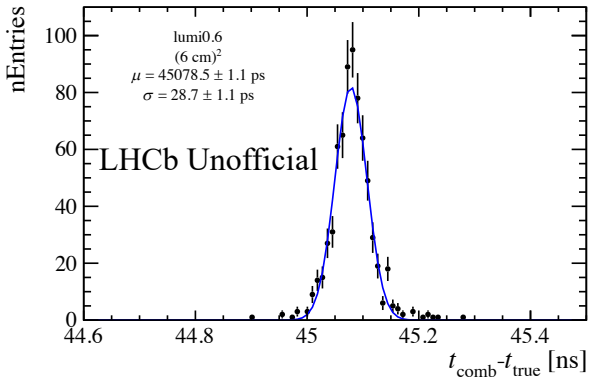


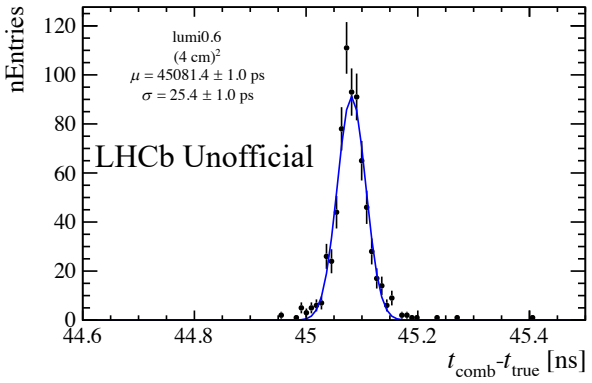


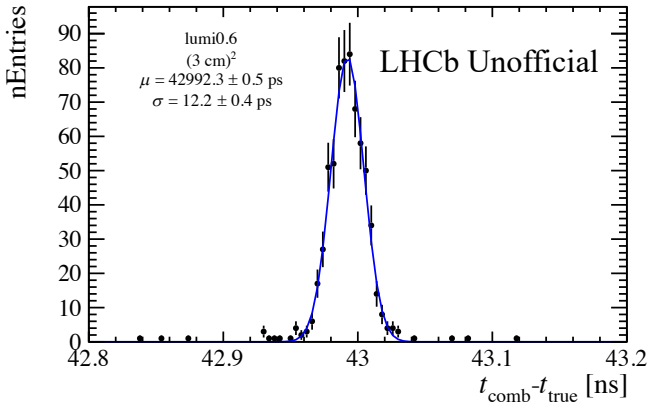
Timing resolution

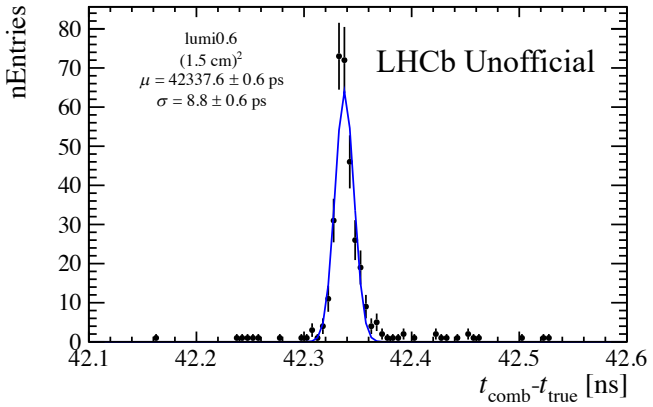
- Timing resolution obtained as weighted average of front & back section time
  - ✓Variation of timing resolution vs. photon energy not utilized yet





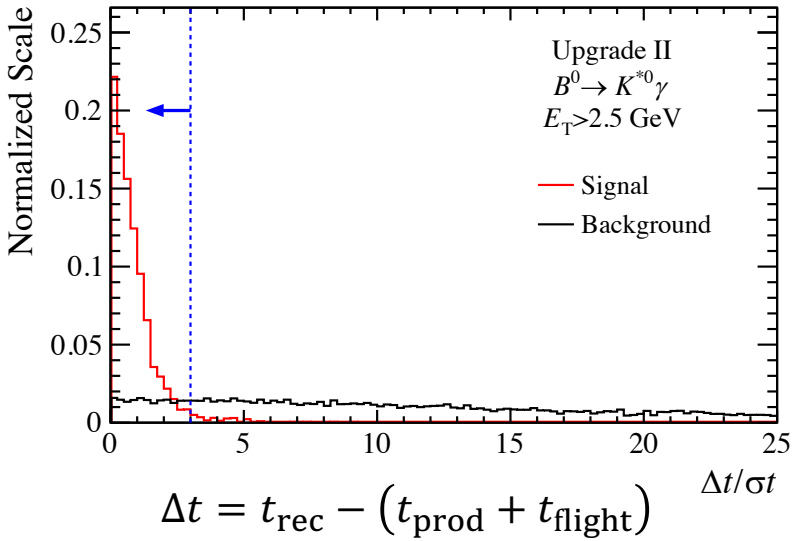




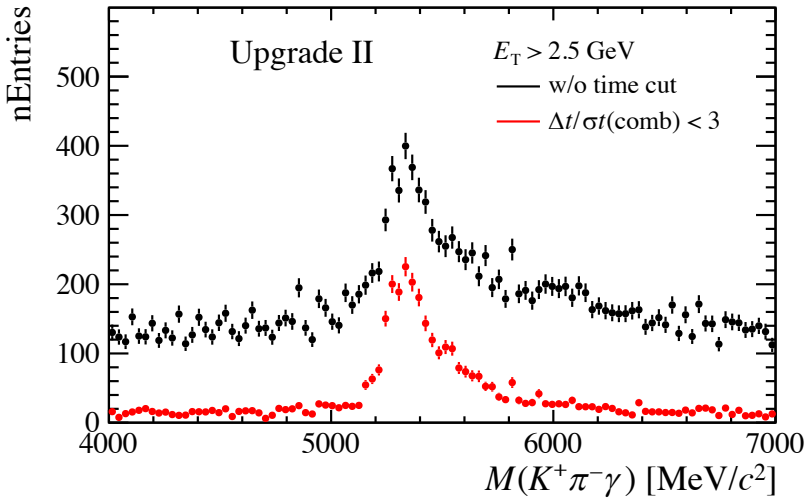


Timing cut

- The timing cut is effective in reducing background



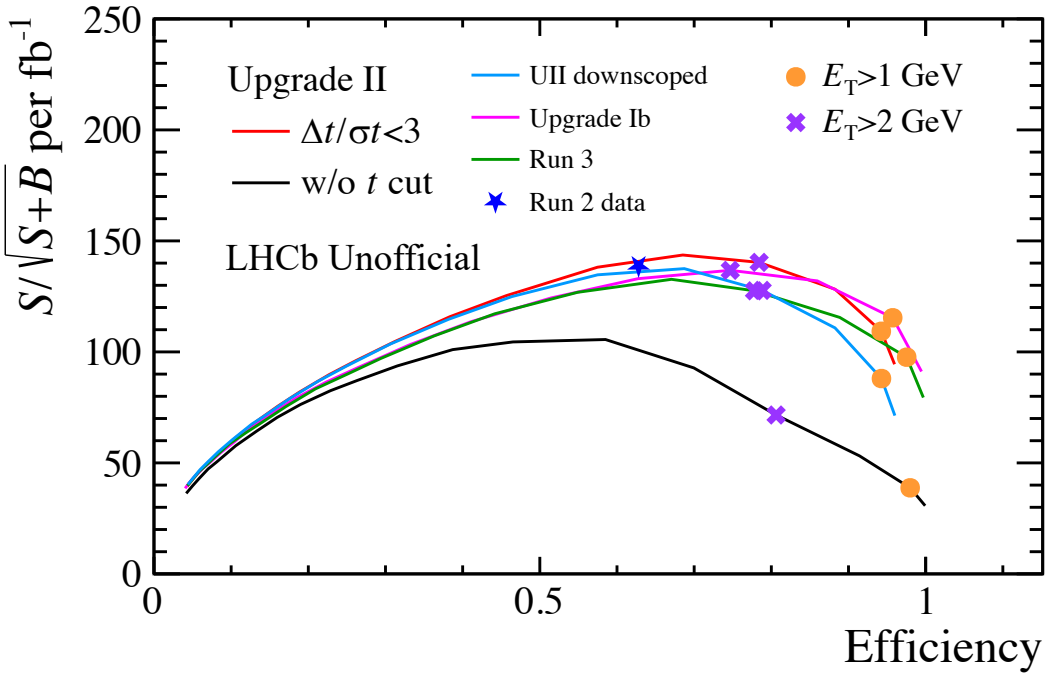
$$\Delta t = t_{\text{rec}} - (t_{\text{prod}} + t_{\text{flight}})$$



Performance comparison

✓The same bkg. level and tracking efficiency for K^{*0} are assumed for all setups

✓Timing resolution of K^{*0} vertex assumed to be 0

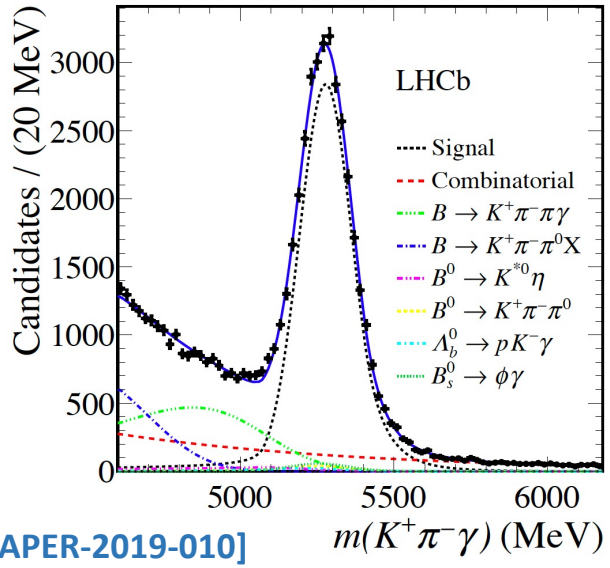


- Timing cut effective for Upgrade II
- With timing cut, Upgrade II performance can reach that of Run2
- Upgrade II downscoped option has a downscaled performance
- Upgrade Ib can improve performance wrt Run3

*UII downscoped: same setup as Upgrade II but w/o long. seg.
*Upgrade Ib: no timing info yet
*Run 3: radiation damage not considered yet

Mass fit

- Run 2 publication

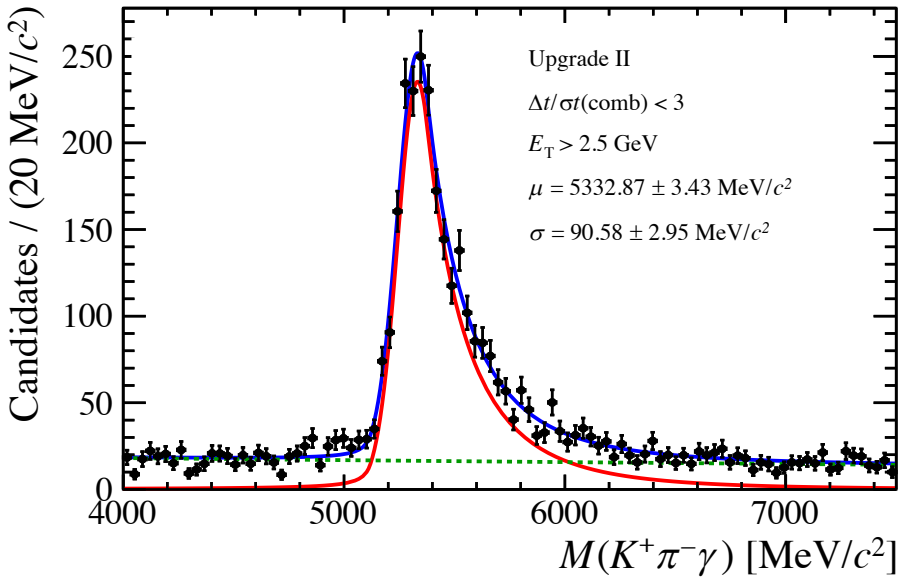


[LHCb-PAPER-2019-010]

$M = 5277.49 \pm 0.65$ MeV

$\sigma = 85.99 \pm 0.72$ MeV

- Upgrade II simulation

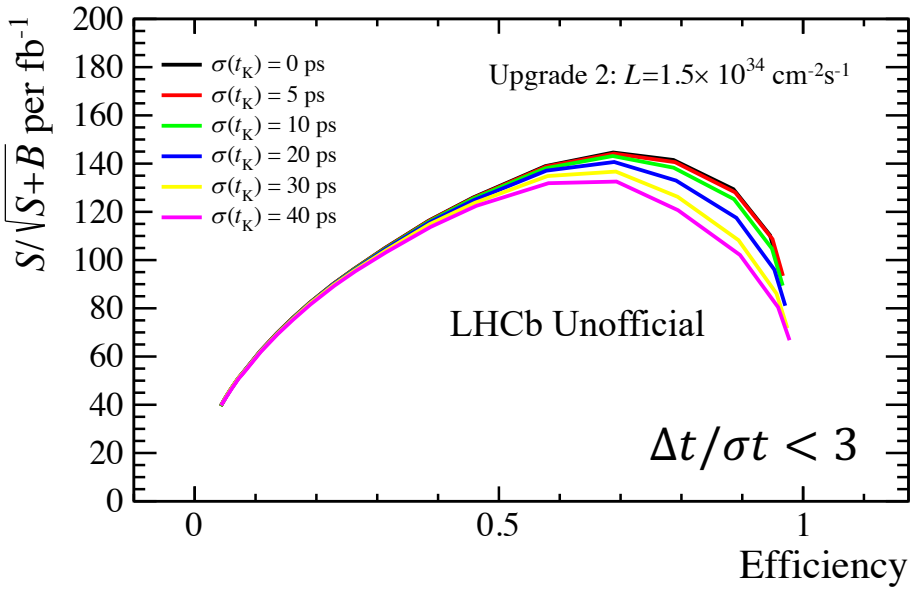


✓Core mass resolution close to that in Run2

✓Mass peak shifted upwards & large right tail due to pile-up; to be improved

Joint VELO/ECAL study

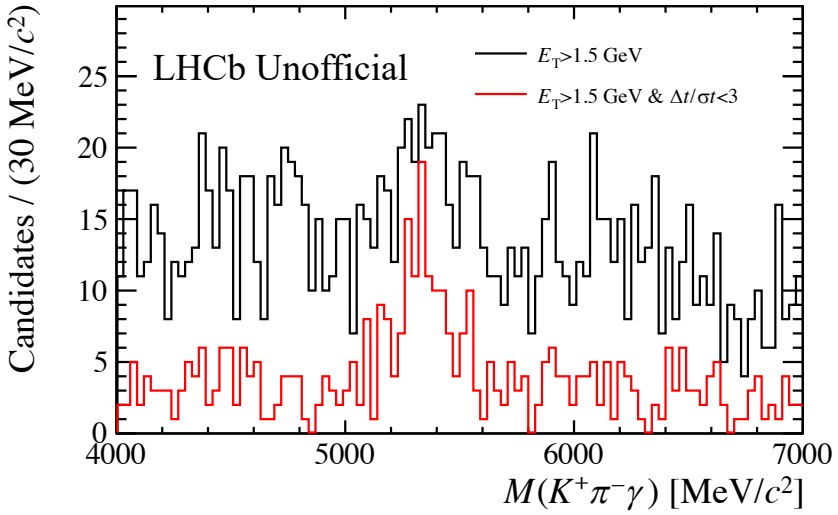
- Timing resolution from tracking system can largely affect the whole performance



- A joint VELO/ECAL performance study for Upgrade II is in preparation

  [See Laurent Dufour' talk for more details]

  - ✓Preliminary match of VELO&ECAL events works well
  - ✓Further studies to be performed



Summary and prospects

- The $B^0 \to K^{*0}\gamma$ decay is studied using hybrid-MC simulation for ECAL upgrade
  - ✓Good timing resolution is obtained and found to be efficient in reducing background
  - ✓Preliminary performance studies show that the upgrade ECAL design is promising in reaching a good performance
  - ✓There is still large room for improvement by utilizing long. segmentation, timing info etc.

- Prospects
  - ✓Rotation of SPACAL modules have been implemented for Upgrade Ib and II; S, L and E corrections for Upgrade II in place and ongoing for Upgrade Ib; performance study of $B^0 \to K^{*0}\gamma$ will follow up soon
  - ✓Extend the study to low-energy photon mode, e.g. $\chi_{c1} \to J/\psi\gamma$

- Joint VELO/ECAL study for Upgrade II is ongoing

Back up

Simulated Upgrade scenarios

- Run 1-3: $4\times4/6\times6/12\times12\ \mathrm{cm}^2$ Shashlik
- Run4 (Upgrade Ib):
  - ✓Innermost: $2\times2\ \mathrm{cm}^2$ SPACAL W+Poly.
  - ✓Second inner: $3\times3\ \mathrm{cm}^2$ SPACAL Pb+Poly
  - ✓Outer: $4\times4/6\times6/12\times12\ \mathrm{cm}^2$ Shashlik
  - ✓No longitudinal segmentation
  - ✓Timing readout for SPACAL only (option with timing in Shashlik will also be checked)
- Run5 (Upgrade II):
  - ✓Innermost: $1.5\times1.5\ \mathrm{cm}^2$ SPACAL W+GAGG
  - ✓Second inner: $3\times3\ \mathrm{cm}^2$ SPACAL Pb+Poly
  - ✓Outer: $4\times4/6\times6/12\times12\ \mathrm{cm}^2$ Shashlik
  - ✓With longitudinal segmentation
  - ✓Dual timing readout for all modules
- A hybrid-MC framework was built with all these scenarios implemented *[See Marco Pizzichemi' talk]*