Fast simulation of ECAL for LHCb UpgradeII

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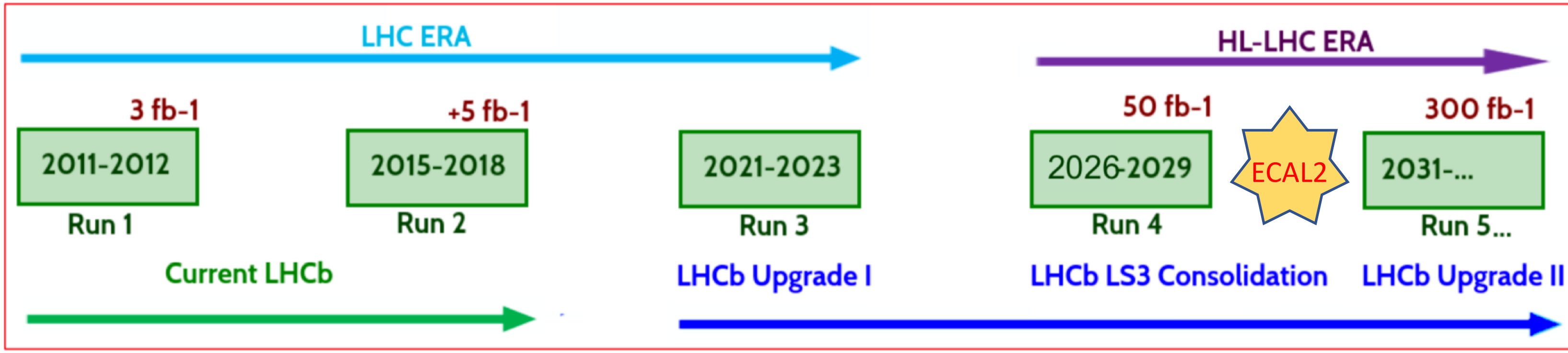
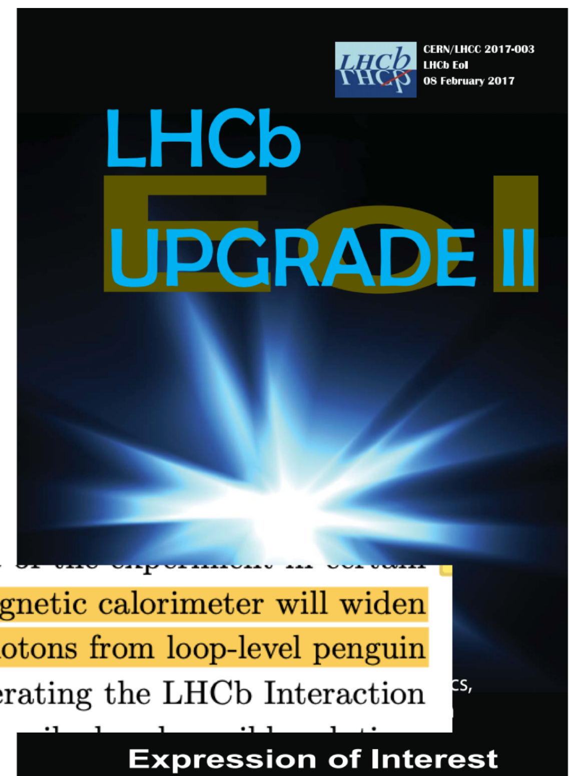
Introduction



LHCb Upgrade II will exploit the flavour-physics opportunities of the HL-LHC.

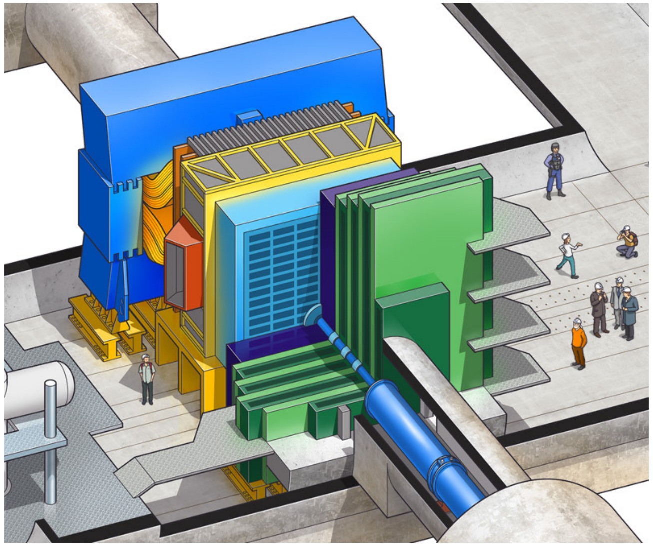
Use GAUSS event generator and DELPHES simulation framework to study:

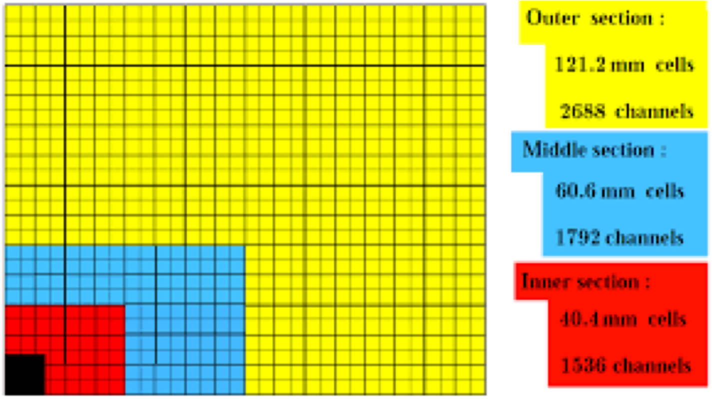
1. High luminosity effect, e.g. pile up
2. Different ECAL cell size
3. Including time information

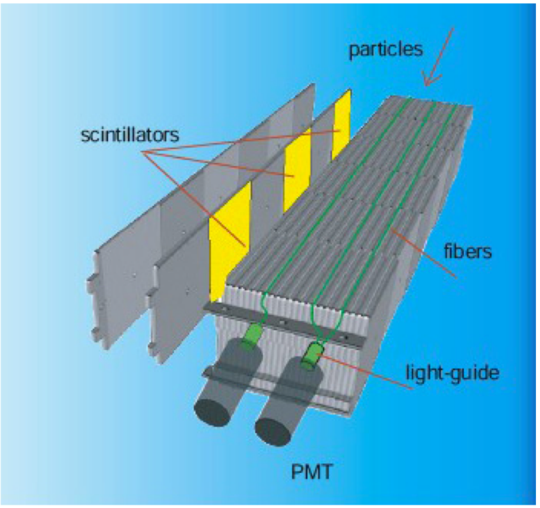


key areas. In particular the installation of a tungsten sampling electromagnetic calorimeter will widen LHCb's capabilities for decays involving π^0 and η mesons, electrons, and photons from loop-level penguin processes. The physics motivation is presented, and the prospects for operating the LHCb Interaction

Introduction



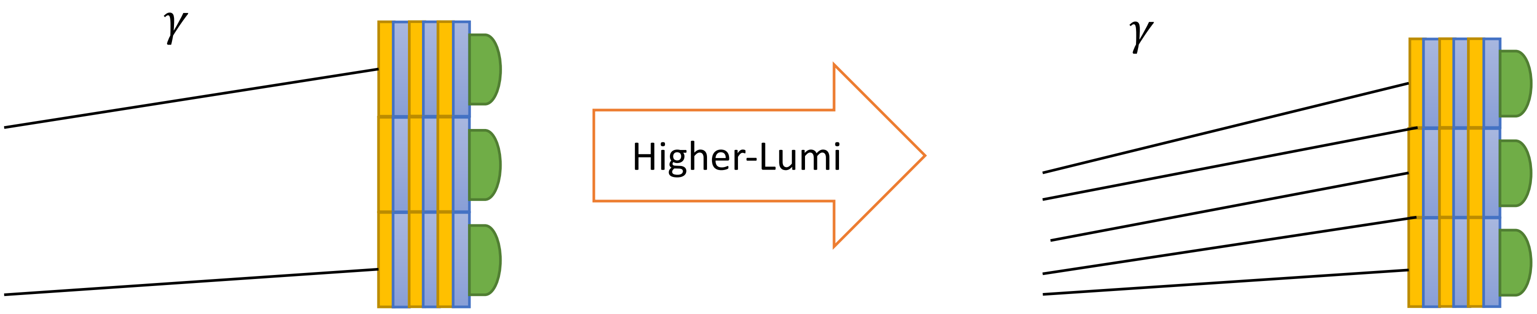




Present LHCb ECAL has three sections, with different cell size.
Put after the tracking and RICH system.
Preliminary simulation study in this phase:

1. Test general optimization scheme
2. Naïve clustering reconstruction algorithm
3. Assuming no energy deposition by charged μ, π, K and p by now

Energy resolution at different Luminosity

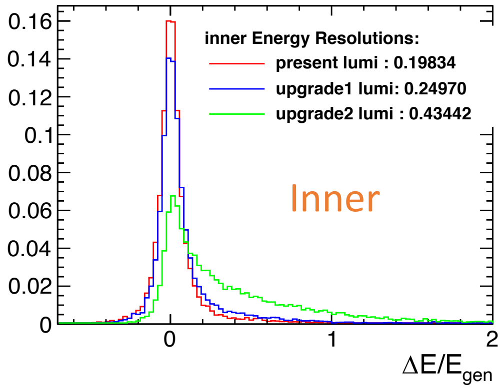


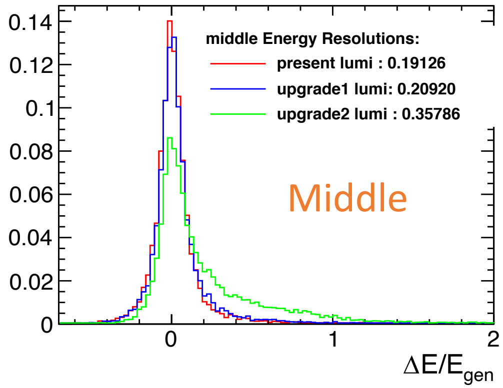
The reconstructed cluster is matched with highest energy photon that hits seed cell
Energy resolution defined as:

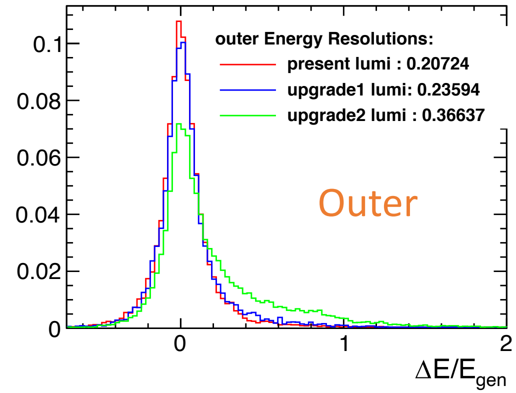
$$Res(E) = (E_{rec} - E_{gen})/E_{gen}$$

No fitting, standard deviation here:

With current ECAL configuration





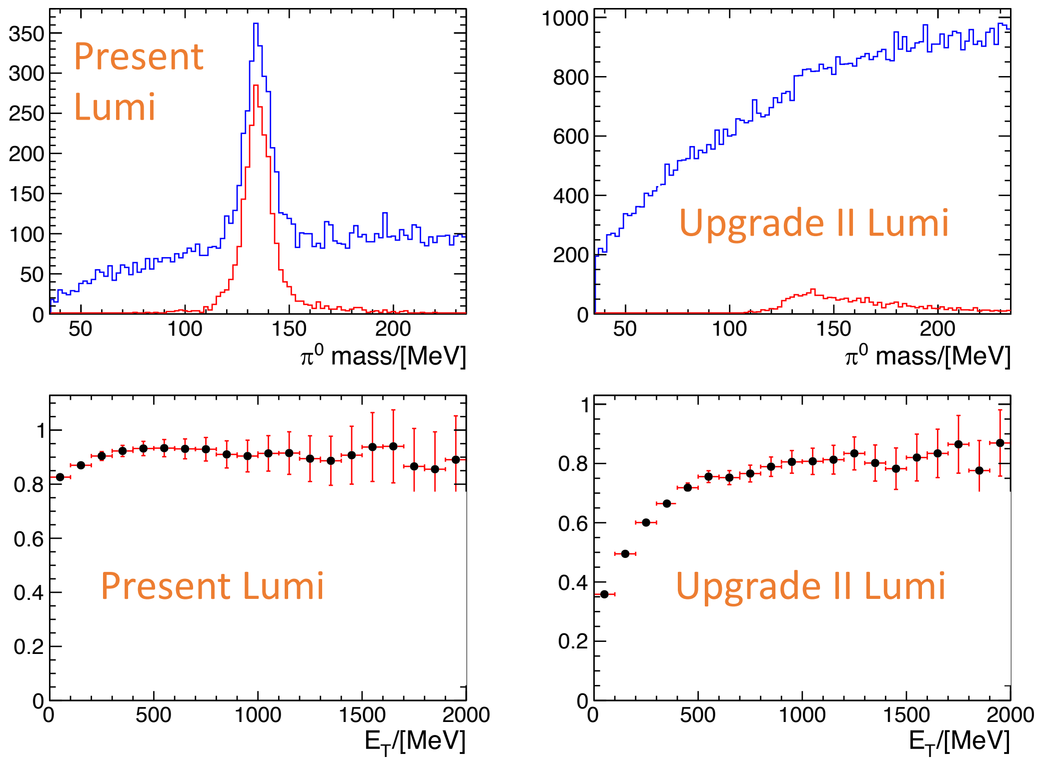


π^0 and γ performance

Reconstruct π^0 in minimum bias sample, combine two γ in one events:

1. $p_T(\gamma) > 0.2\text{GeV}$
2. $p_T(\pi^0) > 2\text{GeV}$

γ reconstruction efficiency, including matching efficiency.



1. Higher Luminosity causes worse energy resolution.
2. More background in π^0 mass spectrum.
3. Worse π^0 mass resolution.
4. Worse photon reconstruction efficiency.

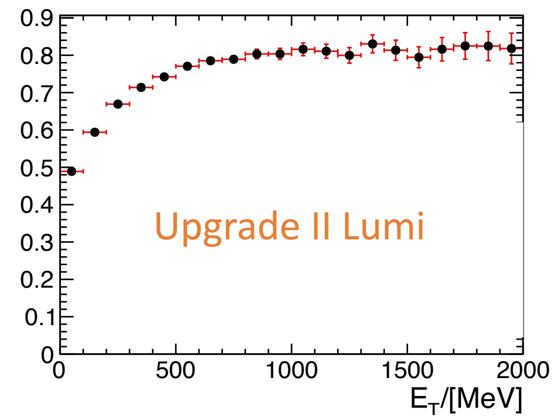
Overlapping effect is the biggest challenge with higher luminosity.

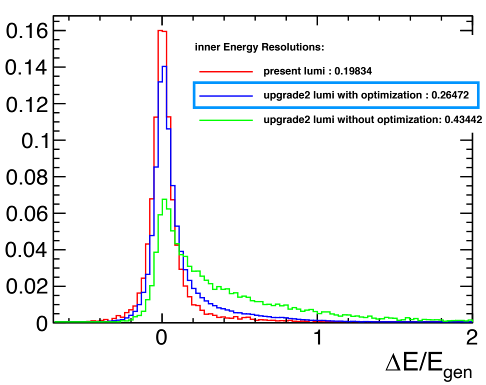
Cell size effect

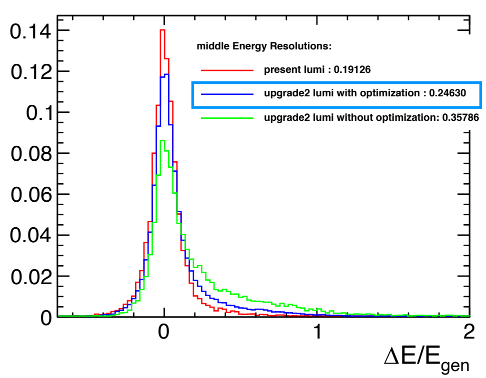
Change the cell size:

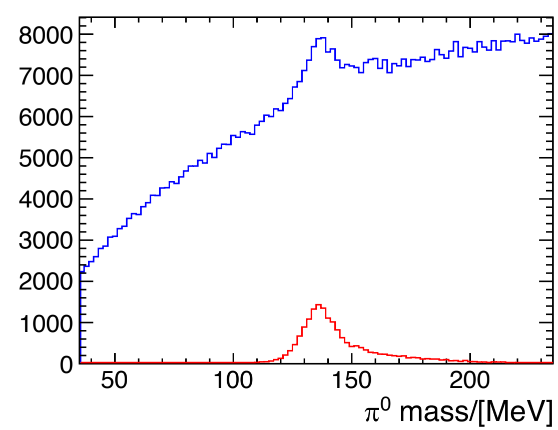
Different Region	Present size	Present Num	New size	New Num
Inner	40×40	1472	20×20	5888
Middle	60×60	1792	40×40	4032
Outer	120×120	2688	120×120	2688

1. Inner and middle section energy resolution becomes better.
2. π^0 mass resolution get better.
3. Photon efficiency becomes higher.
4. Still high level of background from π^0 mass spectrum.



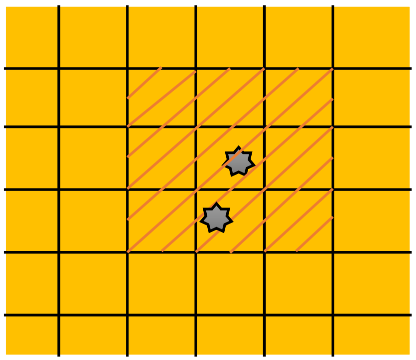






Time information in clustering

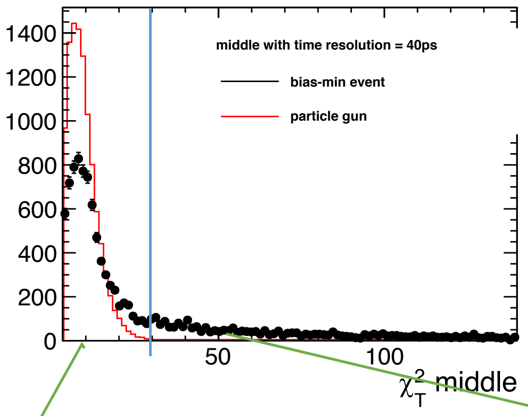
Cluster reconstruction including time information, construct a new variable to describe the time fluctuation in one cluster:



$$\chi_T^2 = \sum_i^N \frac{(T_i - \bar{T})^2}{\sigma^2\,(E_i, x_i, y_i)}$$

N is the total cells used in one cluster reconstruction.
In this preliminary study, we assumed σ_T is known.

The distribution of χ_T^2 with σ_T equal to $40ps$.
Red line got from particle gun, black line from minimum bias event with upgrade2 lumi.



Using time information to choose overlapping clusters:

1. Better time resolutions lead to better energy resolution.
2. Better time resolution can help to choose cleaner cluster, which bring about smaller clean cluster efficiency.
3. Better time resolution also helps to improve π^0 mass resolution.

This kind of cluster contains only one photon?

This kind of cluster contains more than one photons?

Time information for particle identification

Particle identification to reject electron hypothesis

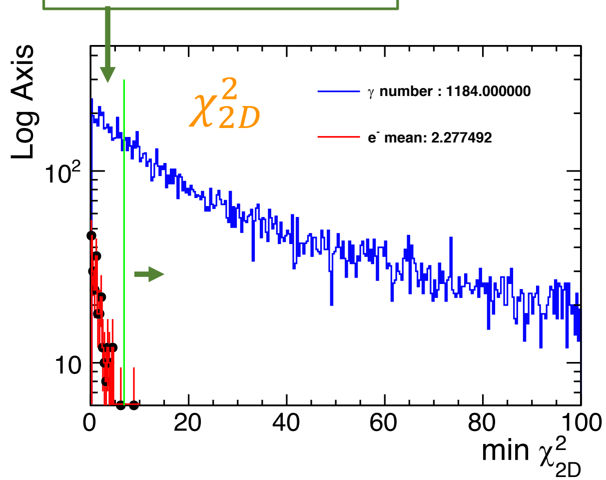
The simple form of χ^2_{2D}:

$$\chi^2_{2D} = \frac{(x_{cluster} - x_{tr})^2}{\sigma_x^2} + \frac{(y_{cluster} - y_{tr})^2}{\sigma_y^2}$$

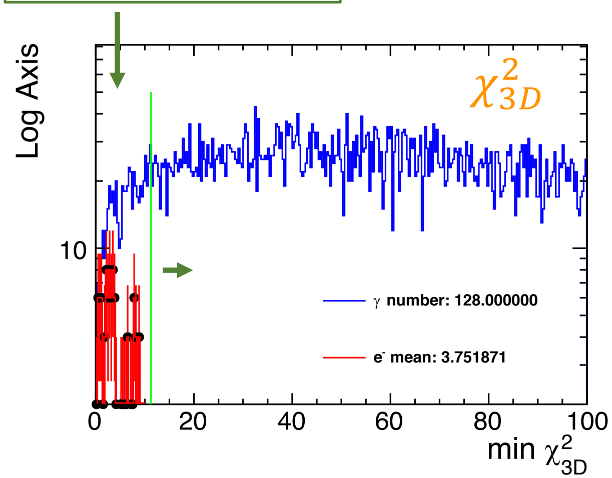
The simple form of χ^2_{3D} including time:

$$\chi^2_{3D} = \frac{(x_{cluster} - x_{tr})^2}{\sigma_x^2} + \frac{(y_{cluster} - y_{tr})^2}{\sigma_y^2} + \frac{(T_{cluster} - T_{tr})^2}{\sigma_T^2}$$

Reject 1184 photons



Reject 128 photons

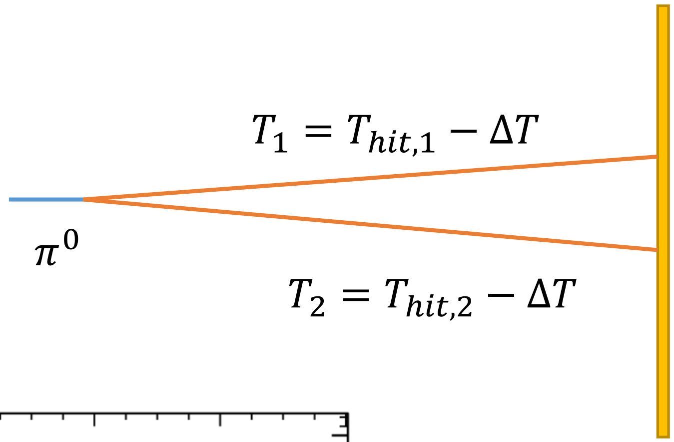


The particle identification variable has better performance including time information

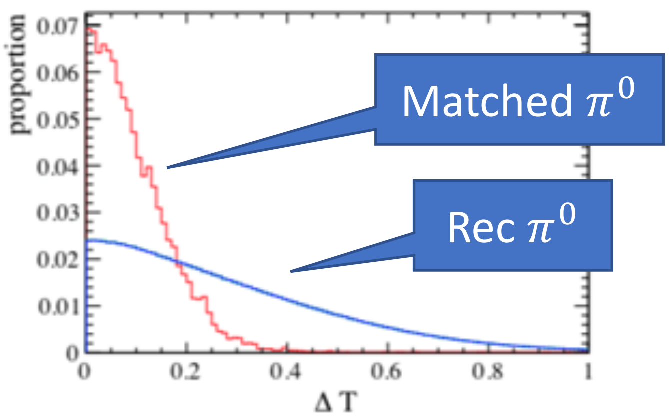
Time information to suppress combinatorics

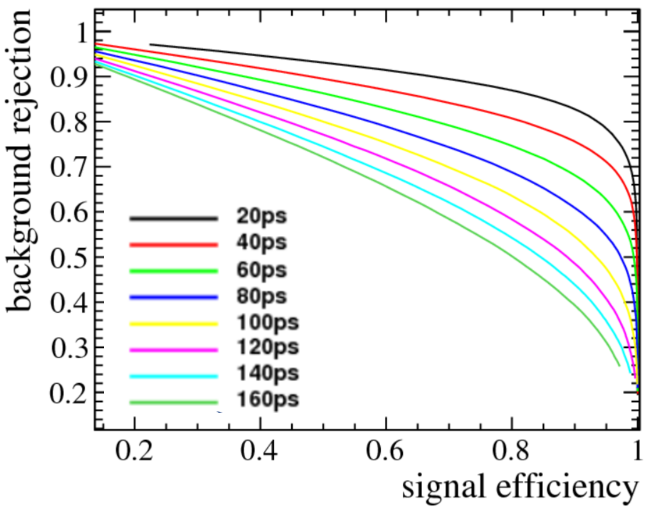
π^0 reconstruction including time:
Building new variable based on time information can help to increase the significance:

$$\Delta T_{1,2} = |T_1 - T_2|$$



Minimum bias event sample.





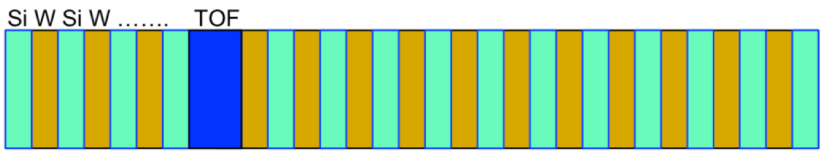
1. Applying $\Delta T_{1,2}$ can help reject more background candidates.
2. If background rejection is the same, with the time getting smaller, the efficiency increases.
3. If the momentum of π^0 is very large, it's difficult to estimate $\Delta T(x, y)$.

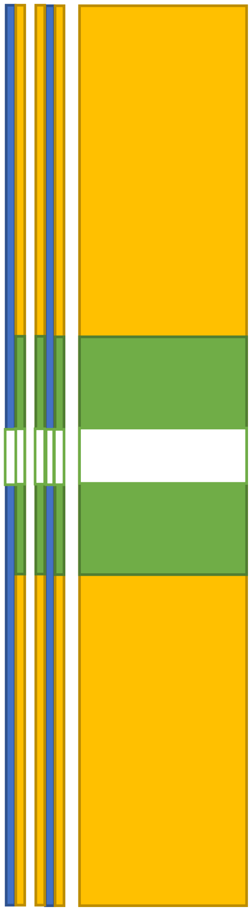
How to measure time

Shashlik or Spaghetti

Some possible choice:

1. From PMT in the shashlik or spaghetti cell. (or two PMTs)
2. Timing layer behind a pre-shower plate.
3. Insert silicon sensor in a reasonable position.





PMT or Silicon Sensor?

1. We cannot expect a very good time resolution from PMT, especially if the deposited energy is small.
2. Silicon detector is very sensitive, and anti-radiation character is not very bad. But it is very expensive.

Conclusion and Outlook

Summary:

1. Overlapping effect is the biggest obstacle with high-lumi for present ECAL.
2. Smaller cell size is really helpful to conquer the huge barrier.
3. Precision timing ECAL can help to optimize energy resolution and reduce background candidates.
4. The final technology choice is not sure yet.

Smaller cell and precision timing can help to handle the high luminosity challenge.

Outlook:

1. Detailed simulation can really help to study the future reconstruction algorithms. (In the view of software.)
2. Beam testing for shashlik and spaghetti prototype is ongoing, we will get more time information from recent test.
   (in the view of technology.)

Thanks for your listening!

Backup