FUTURE CIRCULAR COLLIDER

4th FCC Physics and Experiments Workshop

Use cases for precise timing information at FCC-ee

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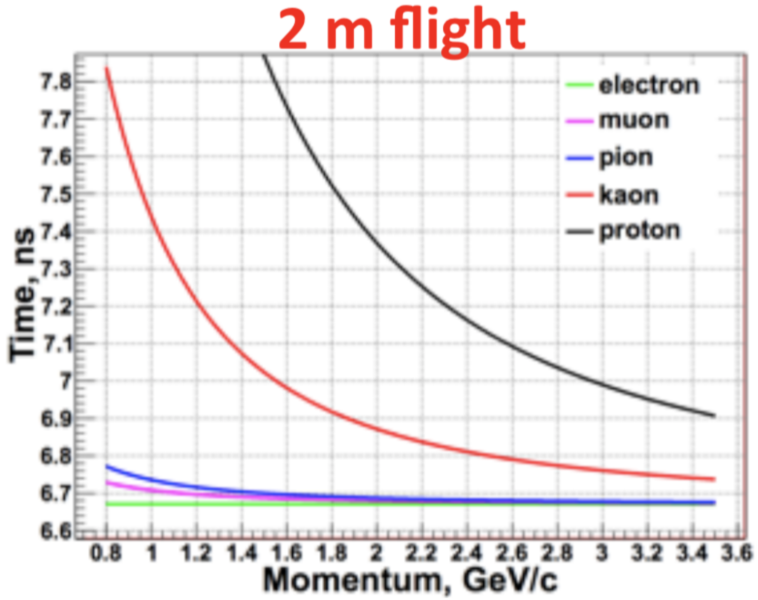
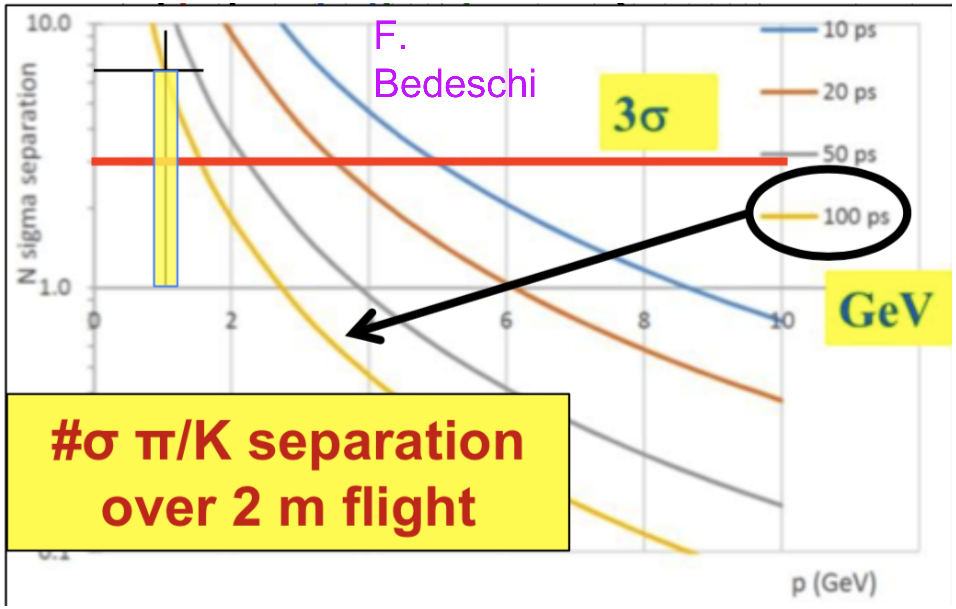
Introduction

- HL-LHC experiments will make use of precise timing information
  - ATLAS and CMS : primary goal is to limit the effects of very large pile-up
  - Target precision: up to O(30ps)
- Timing measurements could be provided
  - By dedicated “timing layers”, or embedded in other sub-detectors
  - Different technologies exist and active R & D
- We have started to collect use cases for precise timing at FCC-ee
  - No pile-up at FCC-ee, small beam backgrounds
  - What should be the requirements from physics on the timing resolution ?

Timing for Particle Identification

- Of course !
- Particle ID via dE/dx or $dN_{cluster}/dx$ in the IDEA drift chamber : provides K / π separation in most of the p range, apart from a blind area around 1 GeV





K / π separation in this area could easily be recovered by TOF @ 2m, with an unchallenging resolution of 100 ps.

- For a 3σ K / π separation from TOF alone at 2m, up to O(5 GeV) : would need O(10 ps). Already smaller than the T(BX).

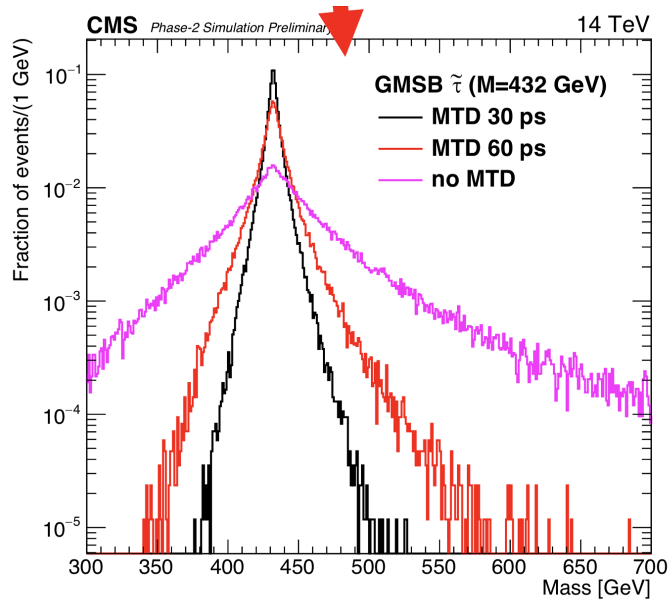
- See dedicated session on Particle ID this afternoon
  - Talks from J. Vavra (TOF review) and C-H Yeh (Timing layers)

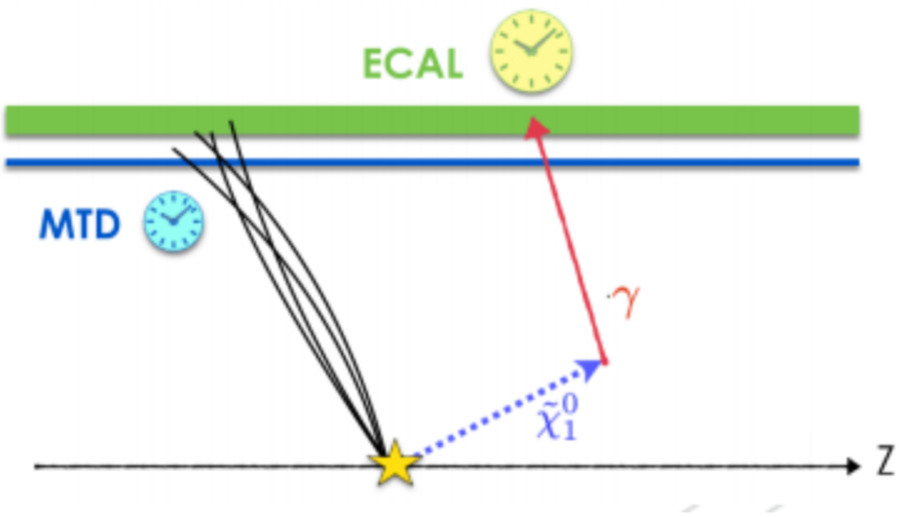
Timing for Long-lived particles, HSCP

- Well-known use-case too

- LLPs, HSCPs : these particles travel with a low velocity, because of their mass. Timing information e.g. in the tracker or in (front of) the calorimeter, would allow to tag these late arriving particles.

  Measurement of p and of β (TOF) give access to the mass of the new particle (as for standard PID).





- Or one could have late arriving charged particles or photons, that come from the decay of a long-lived particle.

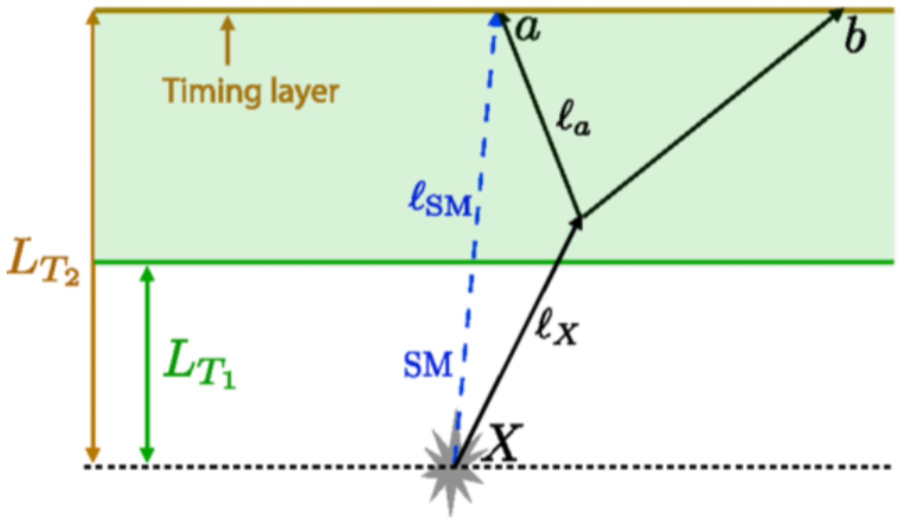
Benchmarks and corresponding requirements will be studied by the LLP group.

Timing for improved reconstruction

- A precise timing of the energy deposits in the EM Calorimeter could also tell the position, at the ECAL entrance, of photons that come from the IP (with a precision of up to √2 x 3 mm for a timing resolution of 10 ps – depending on the angle. That's the best case, at 45 degrees). This could be used in the clustering algorithm that will reconstruct the photon.

  Alternatively, if the timing and position informations are not consistent with a particle coming from the IP, it tells you that the photon comes from a displaced vertex.

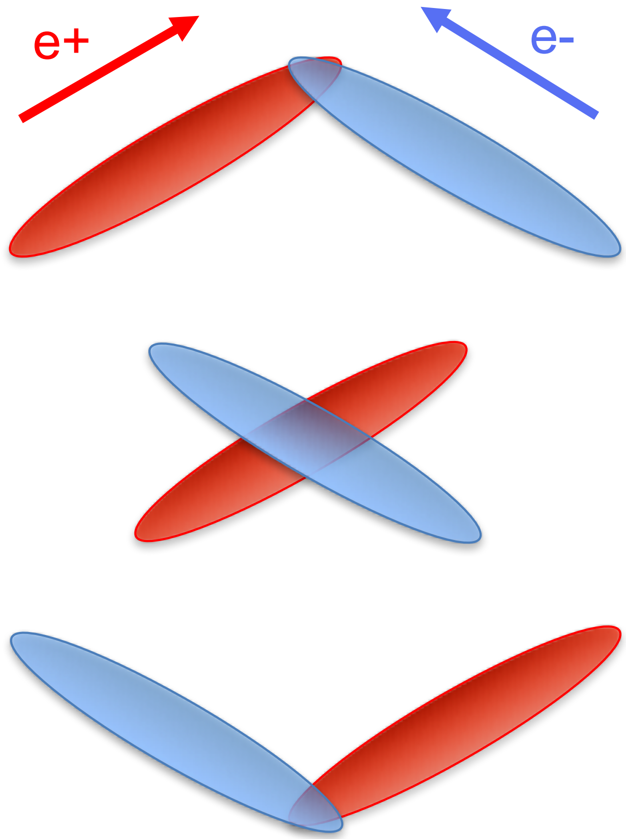
- More generally: timing information could contribute to improvements in the reconstruction in other places too, deserves more thought.



$$\Delta t = t_{signal} - t_{SM}$$

Timing of the collisions

Because of the crossing angle: there is a correlation between the “time” of the collision and the longitudinal position of the colliding particles within their respective bunch.



Early collisions: between particles in the heads of both bunches.

Central collisions: between particles in the middle of both bunches.
$t_0 = 0$ (def) : when the centers of the bunches coincide with the IP.

Late collisions: between particles in the tails of both bunches.

Time distribution: $\sigma_t = \sigma_z / (c \sqrt{2})$

At the Z peak:	σ_z = 12 mm,	σ_t = 30 ps
At $\sqrt{s}$ = 240 GeV:	σ_z = 5.3 mm,	σ_t = 12 ps

Longitudinal position / time correlation

If one could determine the time of the collision (w.r.t. the t0) to better than the duration of the interaction, say $\sigma t/2$, one could separate head-head from tail-tail collisions.
- the largest the multiplicity, the easiest: resolution on the event time ~ $\sigma / \sqrt{N}$

Potential use cases :

- Control of the systematic uncertainty of $\sqrt{s}$: check that there is no unexpected difference of $< \sqrt{s} >$ between "head" and "tail" collisions
  - For example, di-muon events in several timing bins, compare the $< M_{\mu\mu} >$
- Make some further checks of the beam-beam effects, exploiting the fact that the BB effects strongly depend on the longitudinal position
- for the run at the Higgs pole, in a "chromatization" scheme which leads to a dependence of the $< E >$ of the particles in the bunch on their longitudinal position.
  - Measuring the timing of the interaction, event by event, would be equivalent to binning the events in $\sqrt{s}$ bins, so this would offer a scan of the Higgs resonance within a single run. Would need a resolution of O(6 ps) to make 5 $\sqrt{s}$ bins.