Timing for flavour tagging FCC-ee

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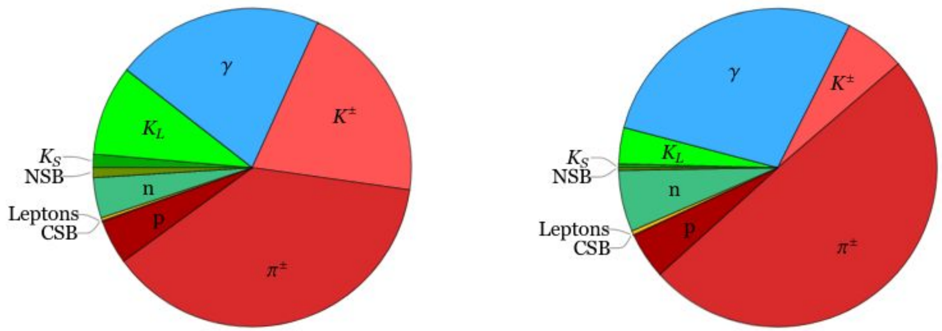
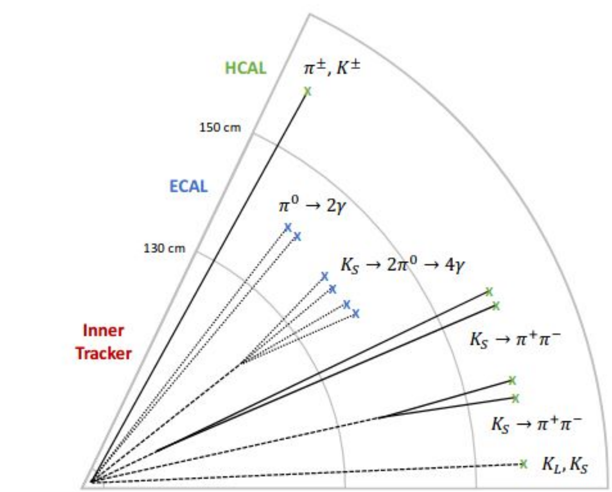
Basics of flavour tagging (strange)

[2003.09517] Momentum weighted fraction:



Strange $p_T = 45\,\mathrm{GeV}$

Down $p_T = 45\,\mathrm{GeV}$

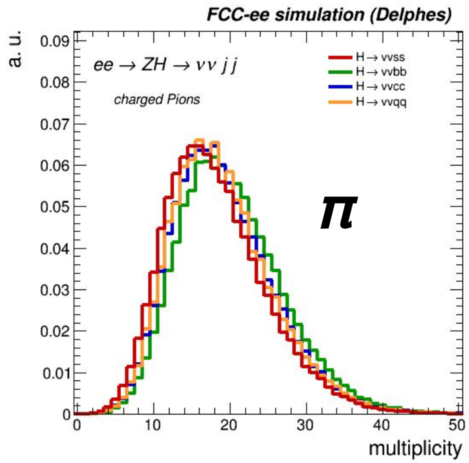


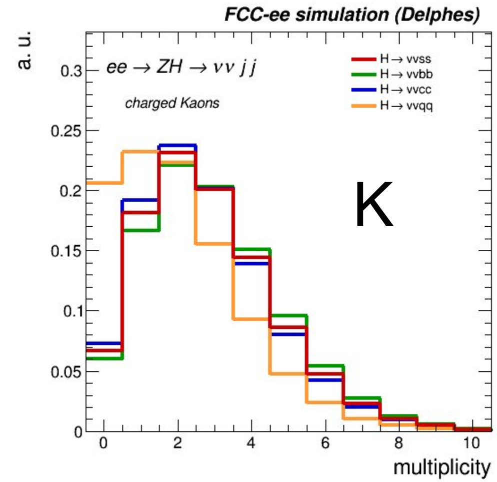
- Large Kaon content
  - Charged Kaon as track:
    - **K/pi separation**
      - TOF
      - dEdx/dNdx
  - Neutral Kaons:
    - $K_S \rightarrow \pi\pi$
      - Displaced 2 track vertex
      - 4 photons
    - **K_L vs n ?**
      - TOF vs n ?

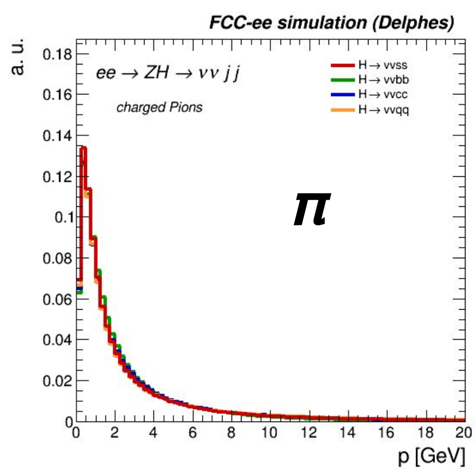
Detector constraints:

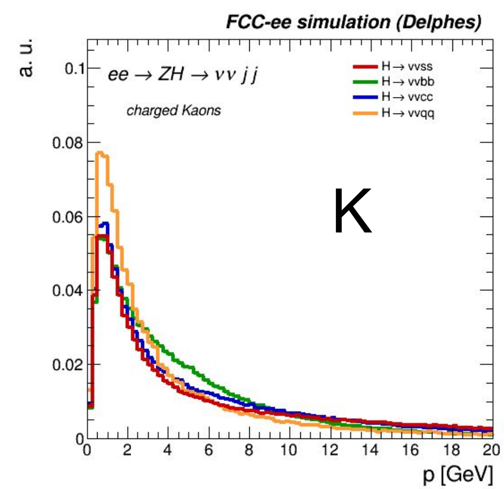
Need power pixel/tracking detectors
- good spatial resolution
- timing detectors
- charged energy loss (gas/silicon)

Particle content

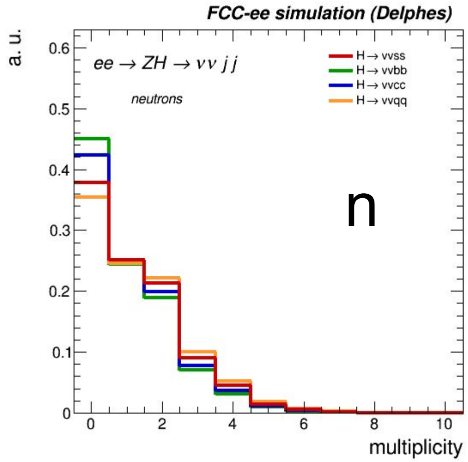


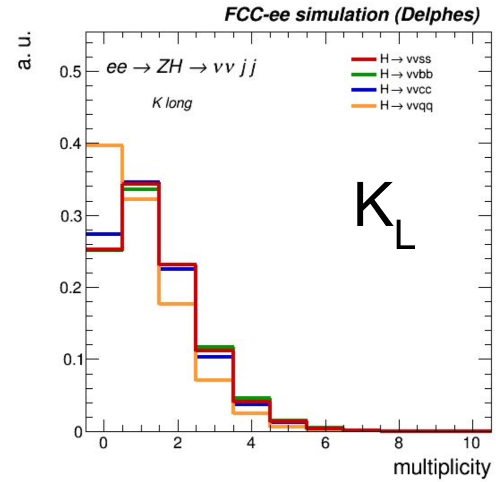


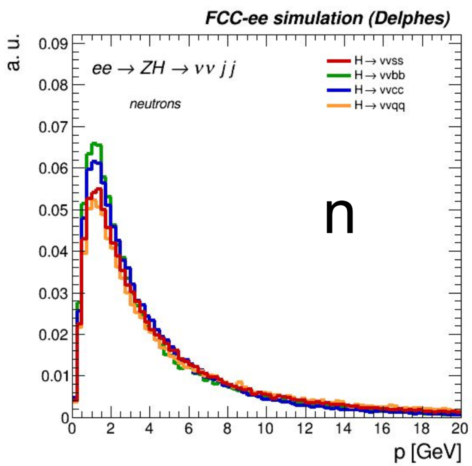


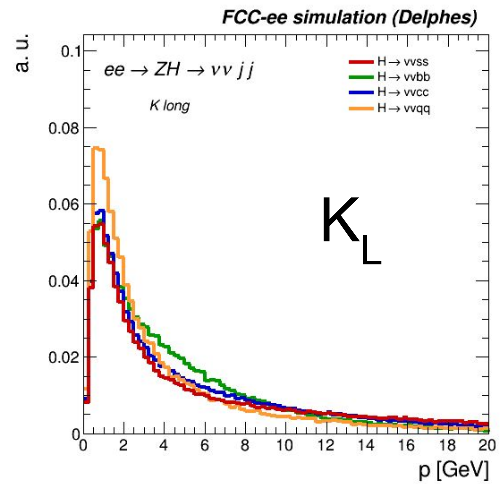


Particle content

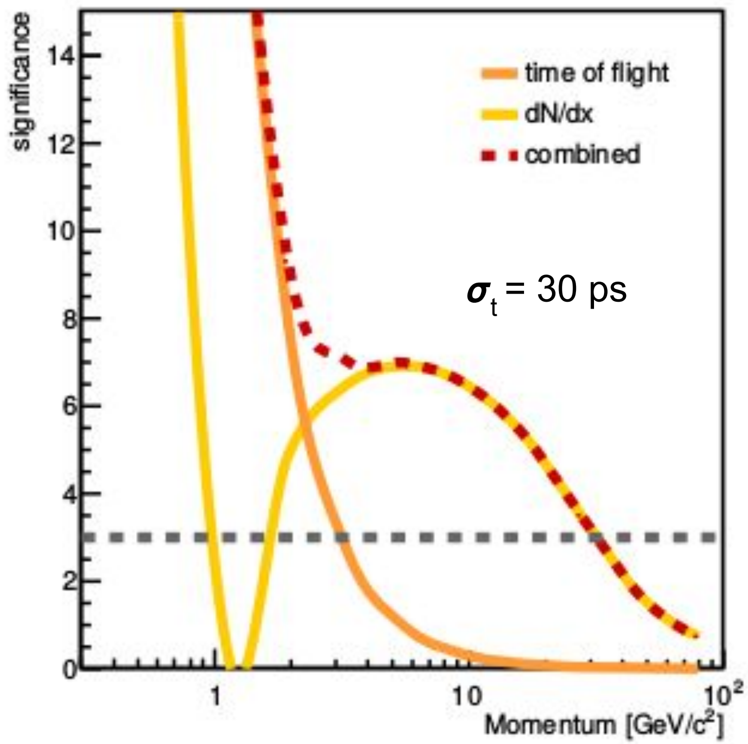








Particle ID



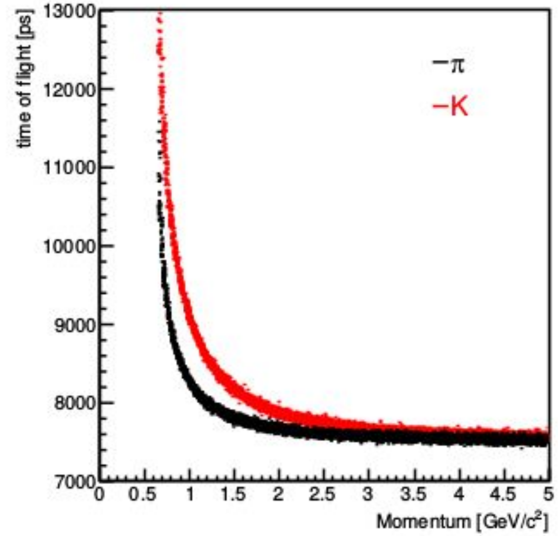
dN/dx (dE/dx) provides excellent PID for p > 2 GeV and p < 1 GeV

- blind spot 1 < p < 2 GeV can be covered by TOF
  - With 30 ps , 3**σ** for p < 3 GeV
  - With 3 ps , 3**σ** for p < 10 GeV

Time-of-flight (charged)

- Allows for good K/pi separation at low momenta:

$$t_{\mathrm{flight}} \equiv t_{\mathrm{F}} - t_{\mathrm{V}} = \frac{L}{\beta} = \frac{L\sqrt{p^2+m^2}}{p} = \frac{LE}{\sqrt{E^2-m^2}}$$



σ_t = 30 ps

- Can in principle get charged and neutral separation :

$$m^{(c)}_{\mathrm{t.o.f.}} = p\sqrt{(\frac{t_{\mathrm{flight}}}{L})^2 - 1} \qquad m^{(n)}_{\mathrm{t.o.f.}} = E\sqrt{1 - (\frac{L}{t_{\mathrm{flight}}})^2}$$

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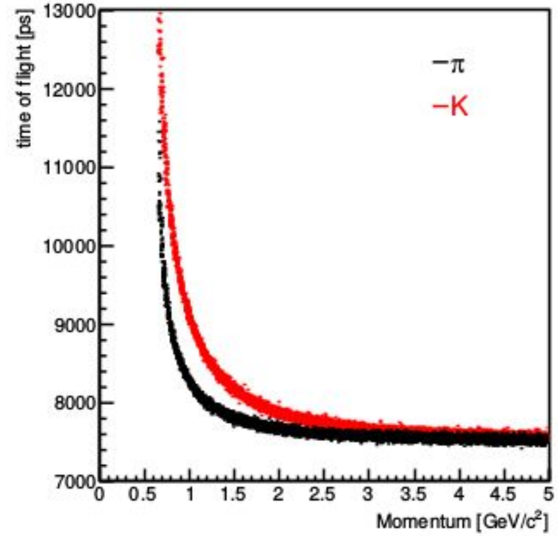
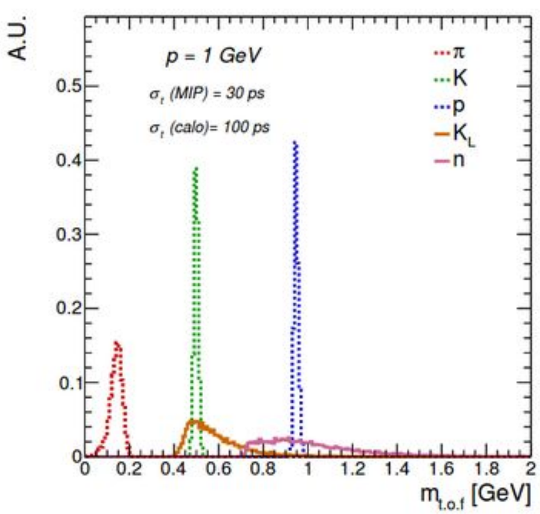
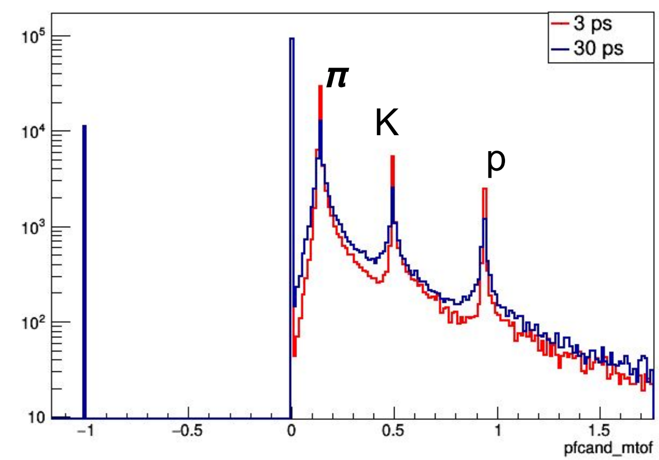


Worse for neutrals, due to energy resolution (calo) being poor at low momenta

σ_t = 30 ps





Comments and caveats

- TOF requires knowledge of:
  - t_{calo} and t_{vtx}, path length (X_{calo}, X_{vtx}) , momentum (tracks)/energy (neutrals)

    → mtof

    - t(final) will be measured with some timing layer at the entrance of the calorimeter
    - t(initial) ? requires precise knowledge of the vertex timing
      - with dedicated timing layer
        - reduces tracker transparency and downstream perf of ele/photons …
      - precise knowledge of event time will give a constraint of order bunch length
        - assuming clock from the machine:

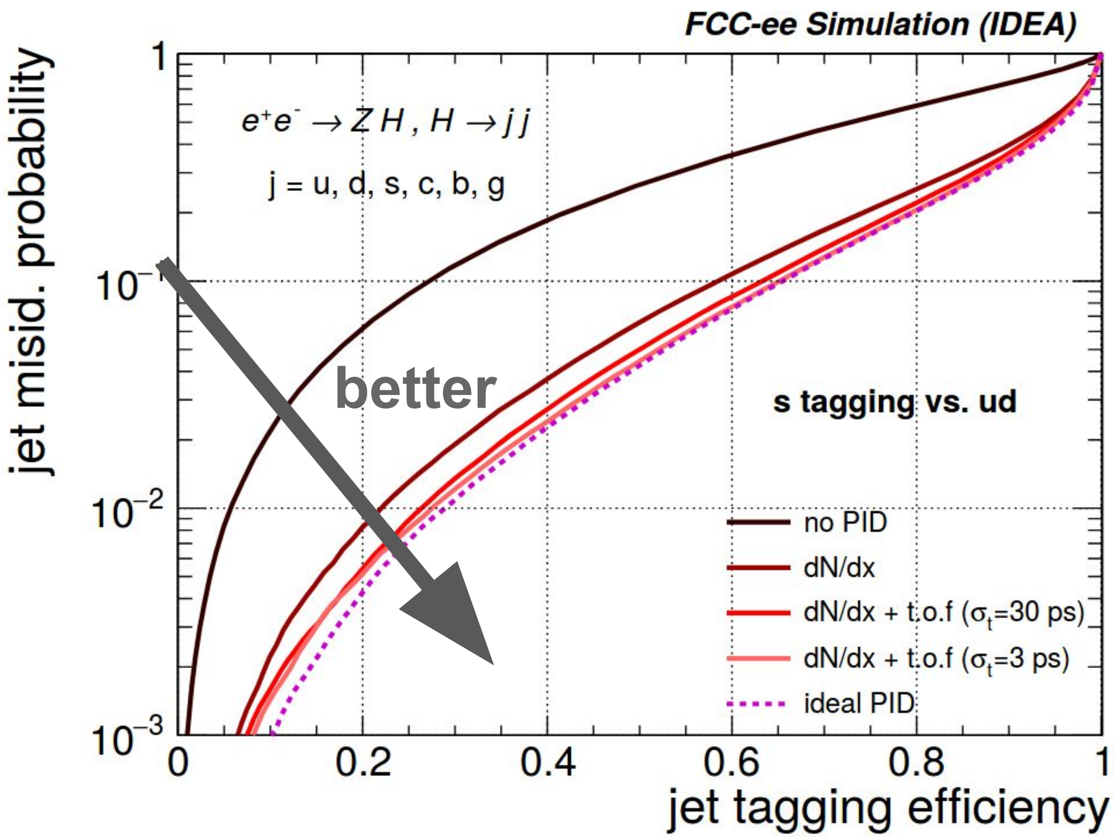
Ebeam (GeV)	45.6	80	120	175	182.5
σ_x (μm)	6.4	13.0	13.7	36.6	38.2
σ_y (nm)	28.3	41.2	36.1	65.7	68.1
σ_z (mm)	12.1	6.0	5.3	2.62	2.54
Vertex σ_x (μm)	4.5	9.2	9.7	25.9	27.0
Vertex σ_y (nm)	20	29.2	25.5	46.5	48.2
Vertex σ_z (mm)	0.30	0.60	0.64	1.26	1.27
Vertex σ_t (ps)	28.6	14.1	12.5	6.2	6.0

- **σ**t ~ 30-15 ps

- can also be fitted using all low momentum tracks in the event assuming they originate from same vtx

Strange tagging

assuming perfect knowledge of initial time…



assuming perfect knowledge of initial time…

Conclusion

- Timing can provide useful information for strange tagging
    - assuming initial time is known, 30 ps timing resolution seems to provide sufficient ID capabilities to fully exploit jet content

- To be understood:
    - How well can we measure initial time
        - how precise is event time (clock) given by the machine (for the constraint)
            - simultaneous fit of (tvtx, mass) implementation in 4D vertex fit needed
    - How much does neutral timing bring?

- Can we obtain similar PID perf at low momenta with other methods (e.g Cherenkov)