Prospects of Charged Kaon Mass Measurement via TOF at ILD

But can we *quantify* that?

Uli Einhaus
ILD Software & Analysis Meeting
09.09.2020

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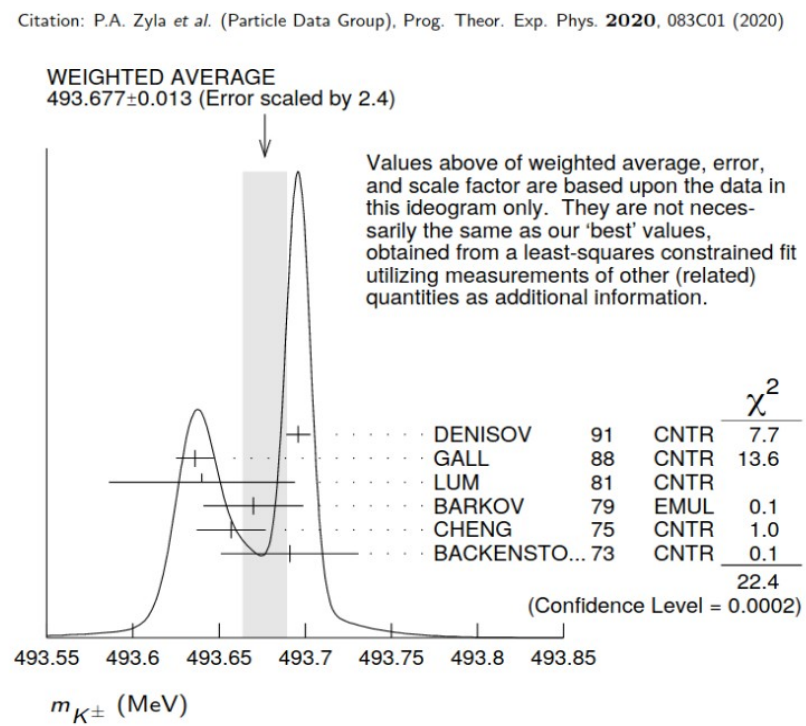
RESEARCH FOR GRAND CHALLENGES

The Question

- Motivated by Graham's ICHEP talk, back up slide: charged kaon mass
- m_K = 493.677 ± 0.013 MeV
- " With ILC detectors and precision momentum-scale calibration, ILC should be able to help resolve this! This would also help lots of D, B masses etc. "
- How can we get a high-purity kaon sample and measure the mass?



https://indico.cern.ch/event/868940/contributions/3816411/

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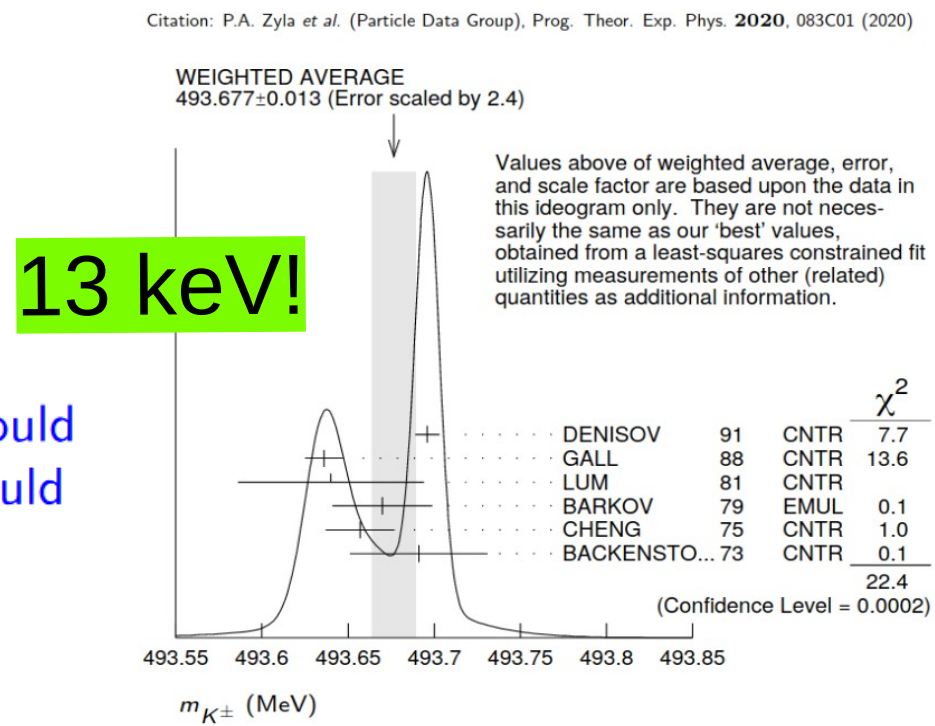

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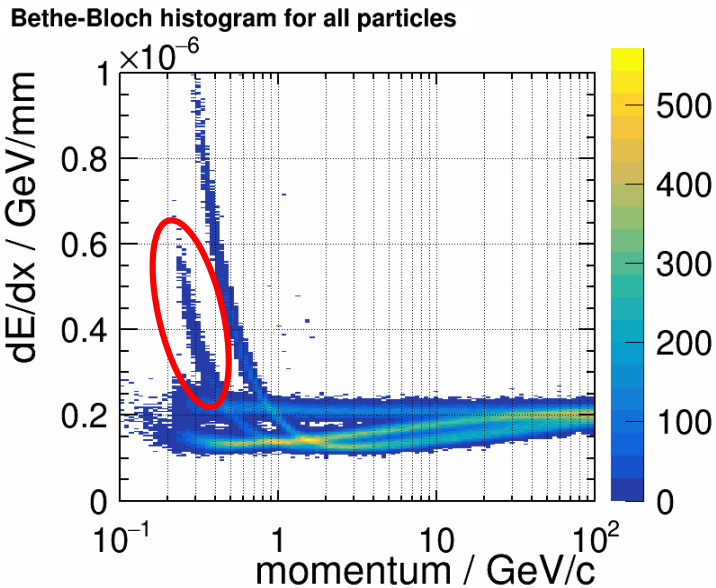
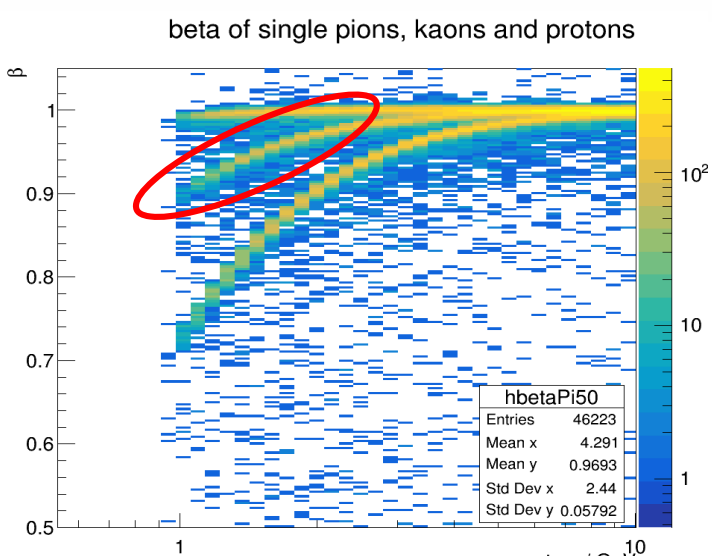
The Idea



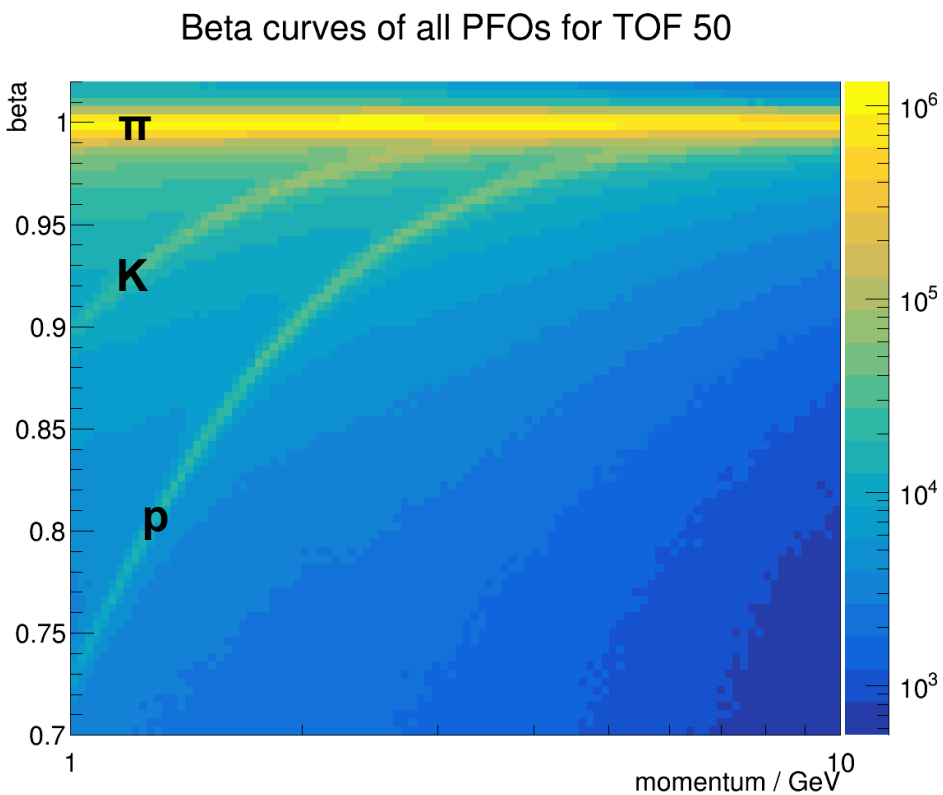


- Use dE/dx and TOF to select low-momentum kaons from a random particle collection!
  Use these to extract their mass via β from a large sample!
- TOF is measuring β directly, while in dE/dx the position of the non-relativistic rise is proportional to β.
- dE/dx would be effective at a few 100 MeV, but is not set up for curlers (yet).

  → Use TOF for now!
  (and a bit of dE/dx for refining)

The Procedure – Kaon Selection

- Big issue: large backgrounds
- Cut on track properties to reduce:
  - #(Hits) <= 200 (TPC: max. 220)
  - $|d_0| < 10$ mm
  - $|z_0| < 20$ mm



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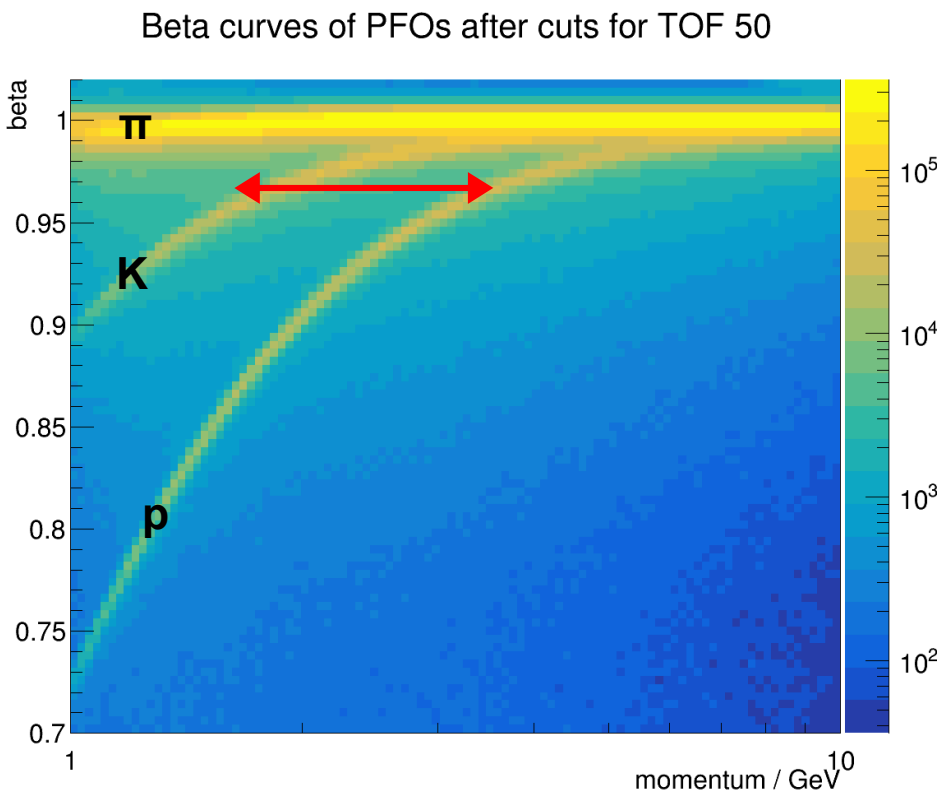
- Use momentum window from 1 GeV to a variable maximum between 1.6 GeV and 3.6 GeV
- Reconstruct mass of each PFO:

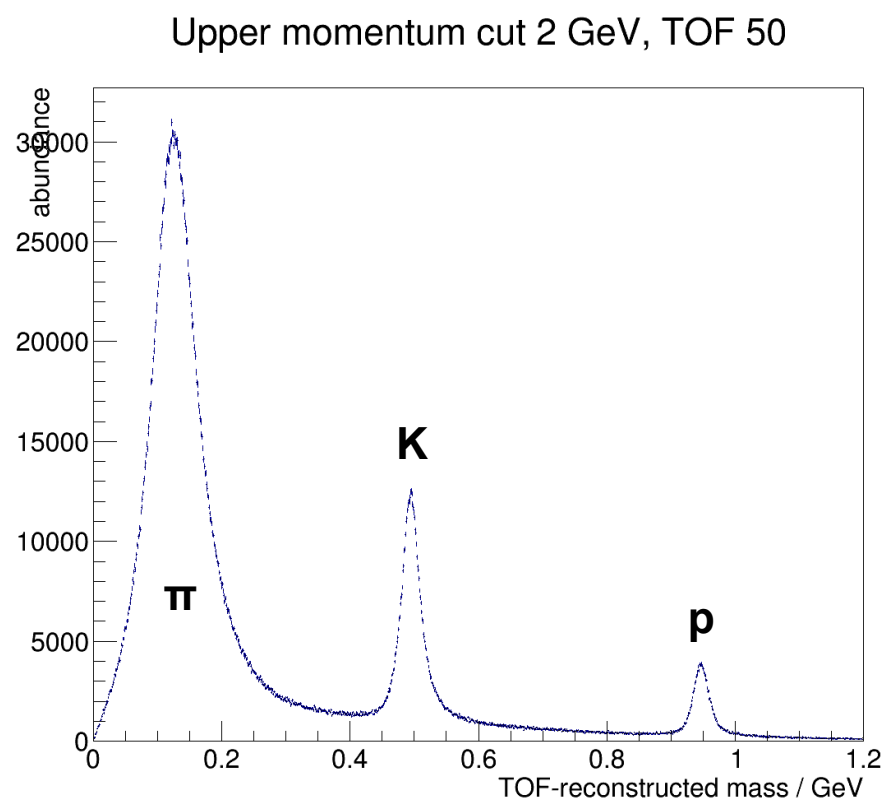
$$m = \mathrm{sqrt}(p^2/\beta^2 - p^2)$$

→ equals projection along TOF-bands



The Procedure – Mass Fit

- Select kaons by requiring
  0.36 GeV < m < 0.7 GeV
- Fit kaon mass peak with Breit-Wigner + Exponential (to cover background)
- Fit mean of Breit-Wigner is estimate for reconstructed mass, uncertainty of mean is the achievable statistical error



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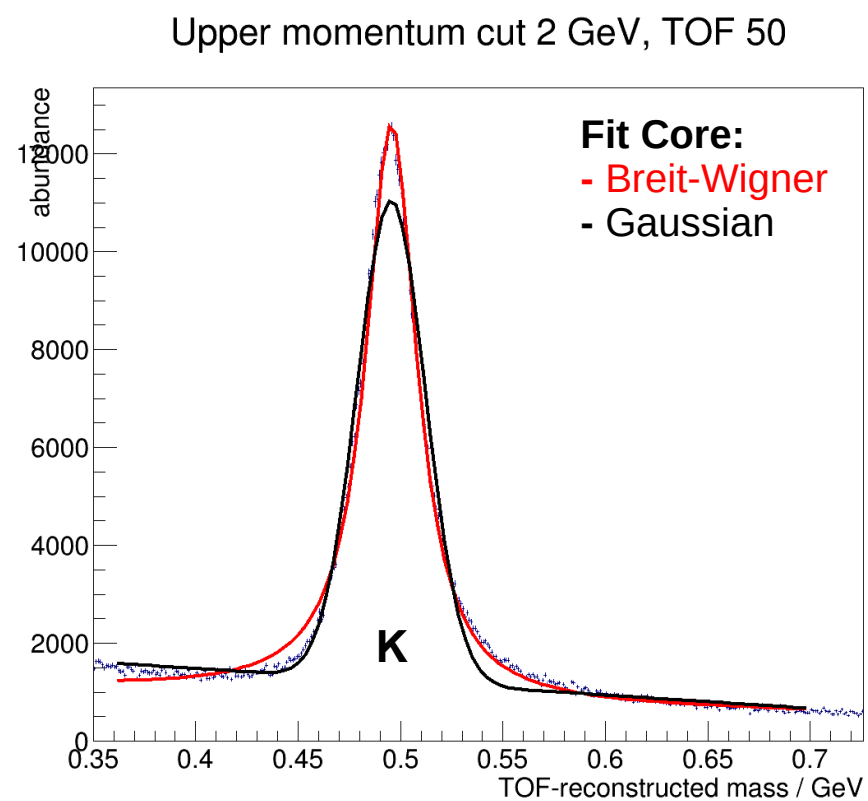
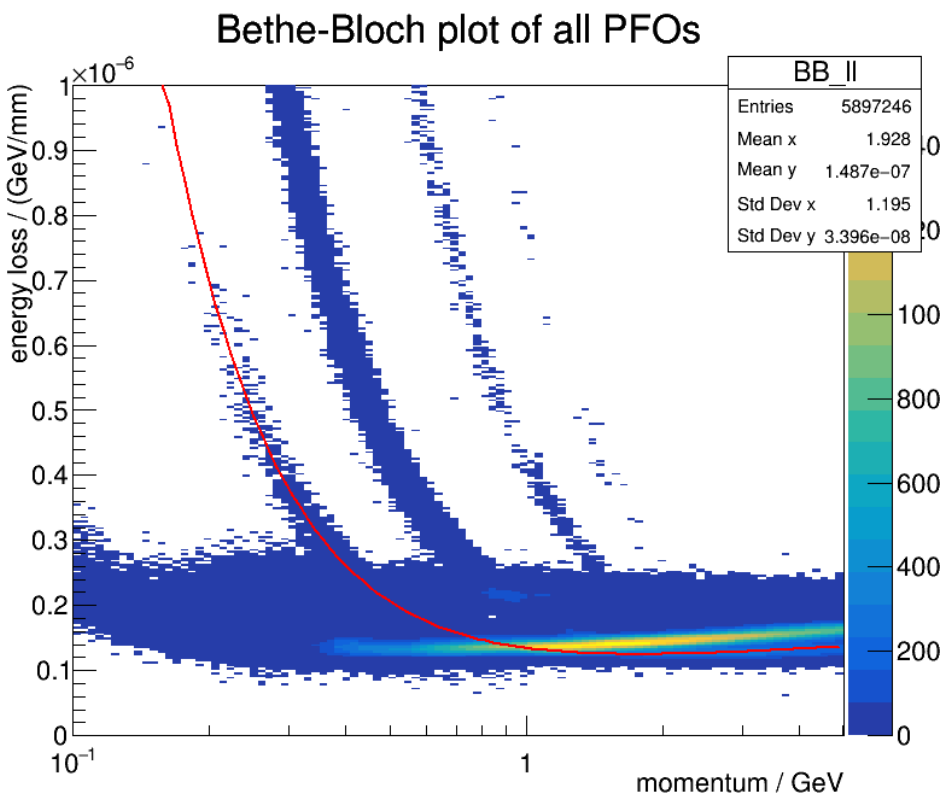
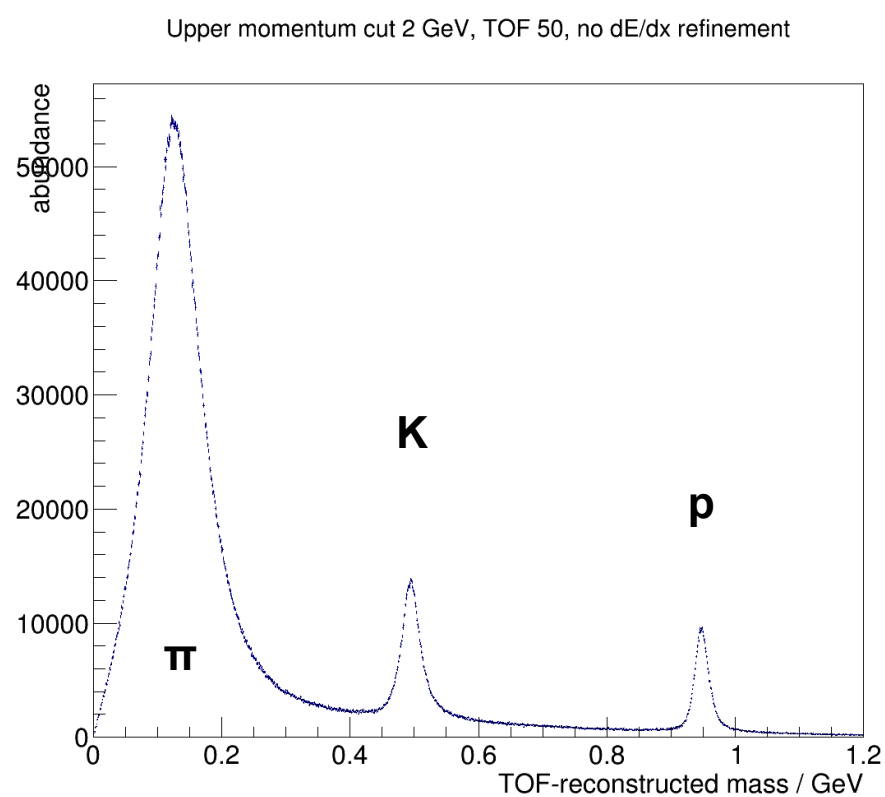
- Here: $m_K = (495.579 \pm 0.032)$ MeV
- Initial observation: interesting order of magnitude of statistical error, but large systematic offset!



Apply dE/dx Cut

- Require PFOs to have reasonably consistent dE/dx value (± 2.5 σ; optimised by hand) compared to single-particle fit curve





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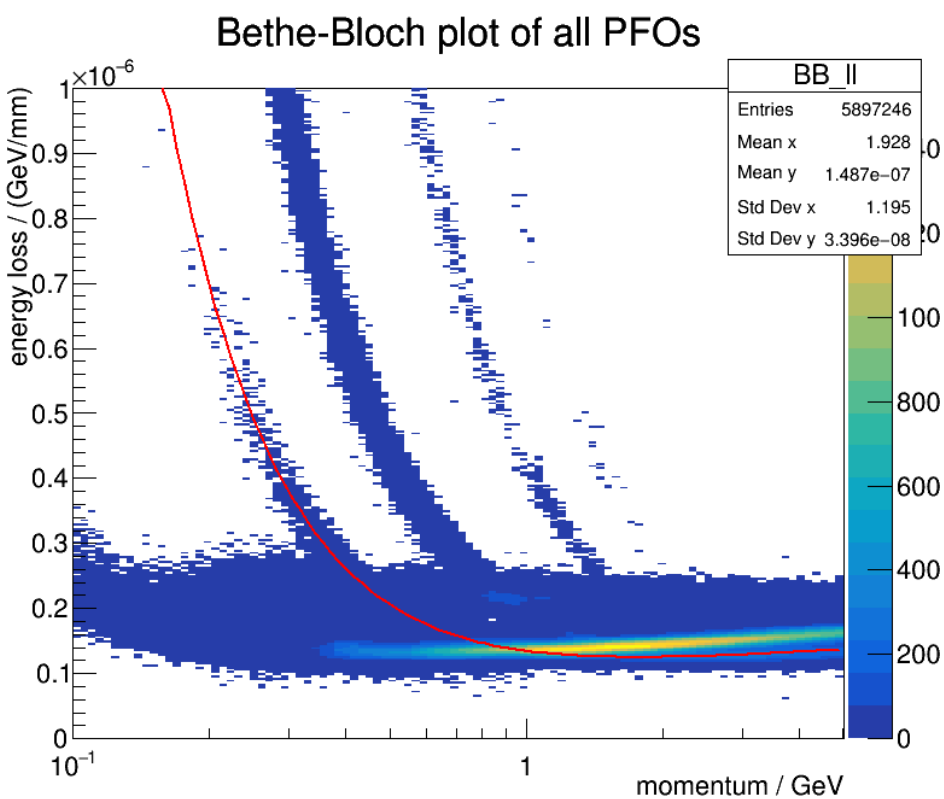
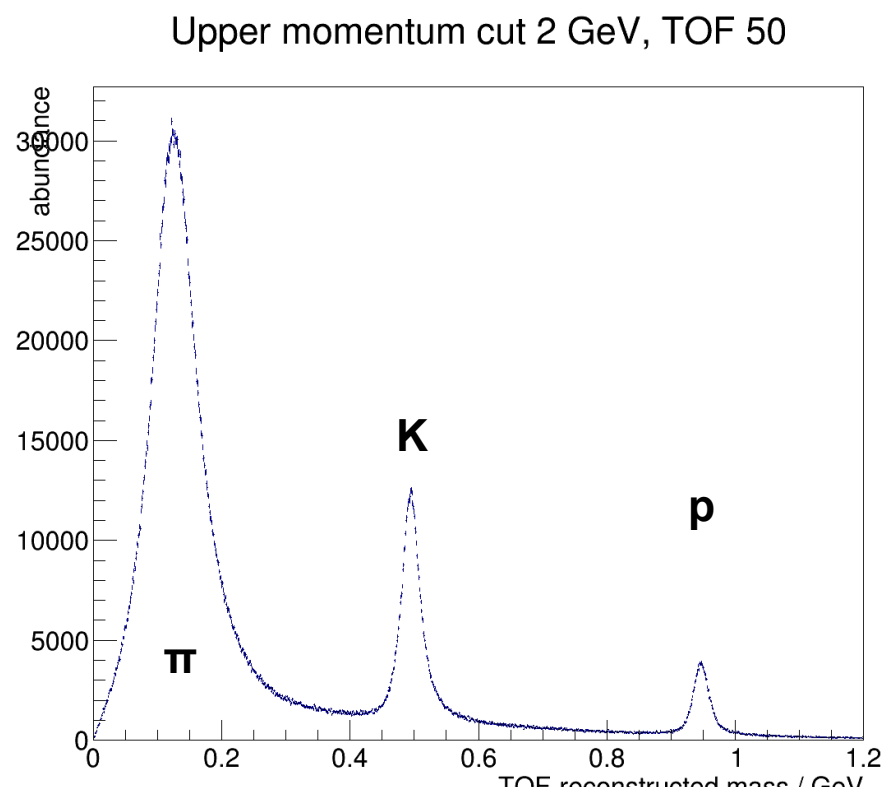




Data Used

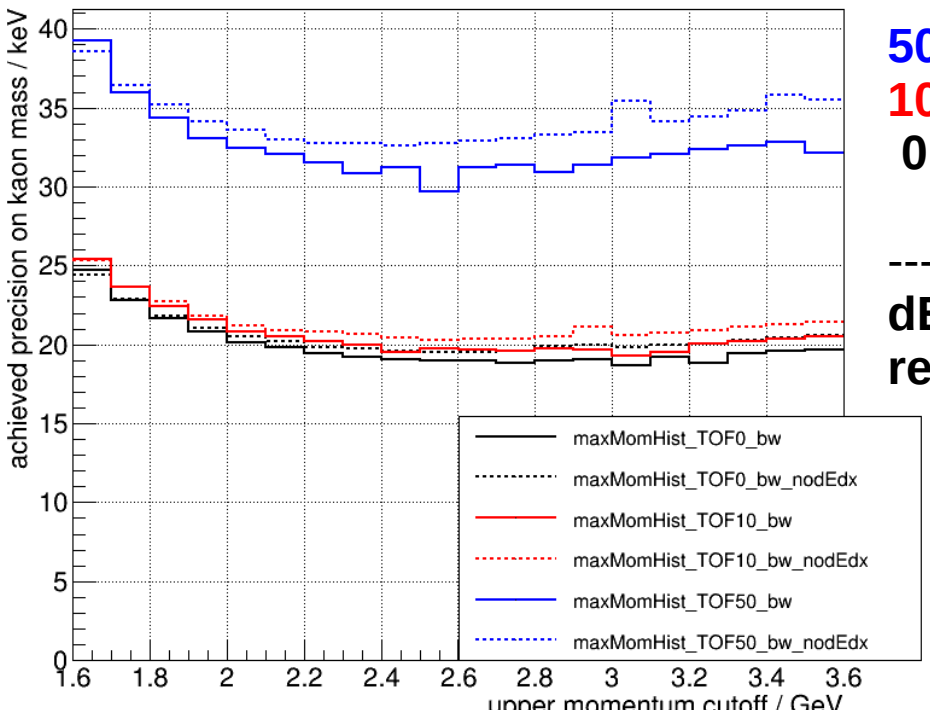
- Available data with TOF: IDR production, 500 GeV only
- Files used:
  - 2f-Z-hadronic
  - 4f-WW-hadronic
  - 4f-ZZ-hadronic
  - 6f-ttbar (all)
- Looked at 2 luminosity scenarios:
  - H20: 1600 fb^{-1} (-,+), 1600 fb^{-1} (+,-), 400 fb^{-1} (-,-), 400 fb^{-1} (+,+)
  - 2x200: 200 fb^{-1} (-,+), 200 fb^{-1} (+,-) ~ before lumi upgrade

ILC Operating Scenarios, T. Barklow e. a., ILC-NOTE-2015-068

(-,+) : $\{P_{e-} = -0.8, P_{e+} = 0.3\}$

Results

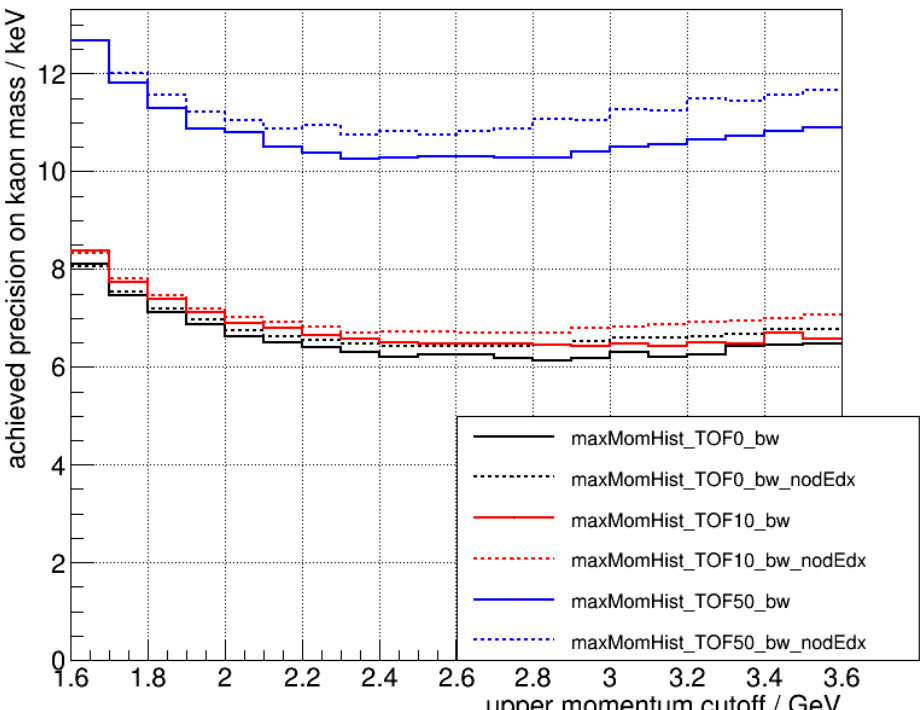
2x200



50 ps
10 ps
0 ps

--- no dE/dx refine

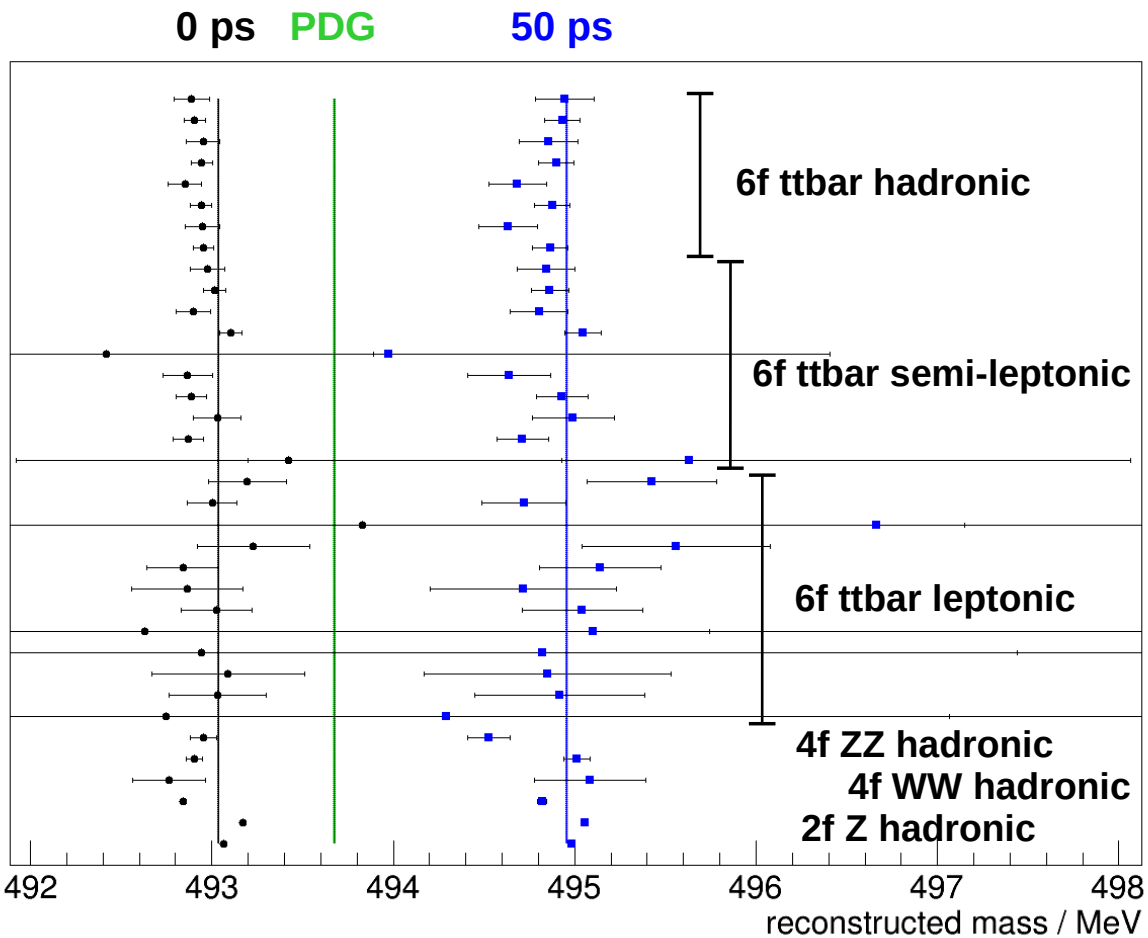
H20



10 keV resolution (stat.) achievable, would be decisive on kaon mass question!

Open Questions

- Systematic error needs investigation
- Large offset between reconstructed mass and PDG/MC value
- Consistent between processes, but different between timing resolutions



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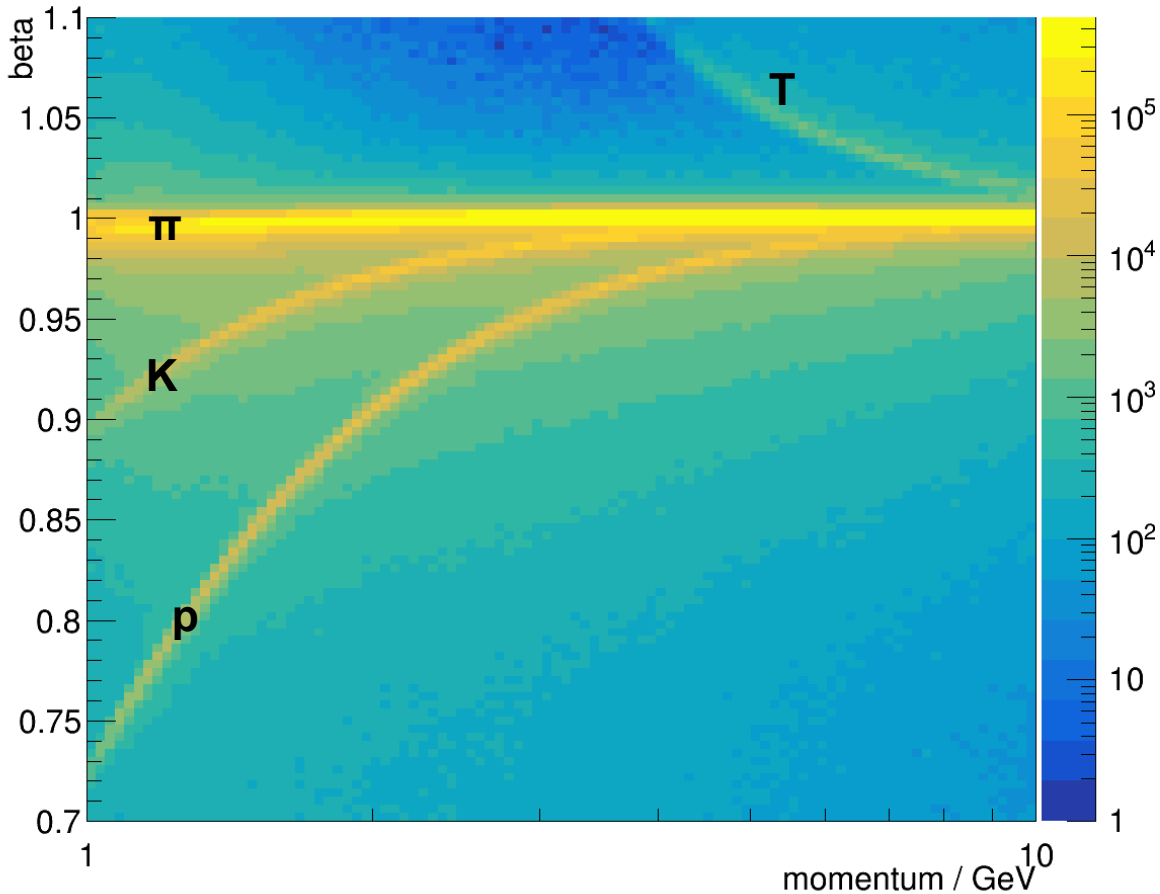
- Large offset between reconstructed mass and PDG/MC value
- Consistent between processes, but different between timing resolutions
- Also… tachyons?!



Conclusion

- With a TOF timing resolution of 50 ps, ILD can make a significant impact on the kaon mass measurement statistical resolution:
  Before the luminosity upgrade up to 30 keV, which would be a relevant contribution.
  In the full H20 scenario up to 10 keV, which would be decisive on the problem.
- Improvements can be made by including all processes, adding 250 GeV and optimising the analysis, probably leading to ~ 2-3 keV better final resolution.
- The systematical error O(MeV) remains an open issue and will be addressed by a new PhD student at DESY, Bohdan Dudar, who will work on TOF and hopefully improve reconstruction and resolve various questions.
- Other observables, like dE/dx, can be utilized to improve on the TOF result or make an independent measurement.