Discussion topics for H → ss focused study

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Actually, we miss discussion on plans, slides here may not reflect other members' perspective…

H → ss: target by organizers (1)

Theoretical, phenomenological and MC generator targets

- BSM models predicting deviations in $h \to s\bar{s}$, e.g. SUSY
- BSM models predicting for example charged Higgs boson with large branching ratios in final states including strange quarks, e.g. 2HDM $H^+ \to cs$ BR $\approx 50\%$
- $s\bar{s}$ vs. $b\bar{b}$ in BSM models: gain from $s\bar{s}$?
- flavor assumptions in EFTs: decouple 3rd from 1st/2nd family? Partially looked at in the context of the Spontaneous Flavour Violating framework.

No serious model discovered so far?

TBD?

No serious model discovered so far?

Works exist

Target physics observables

- $e^+e^- \to Zh$ with $h \to ss$ ($Z \to$ anything) at $\sqrt{s} = 240/250$ GeV (higher center of mass energies still unexplored)
- projected precision on branching fraction, and differential cross-section in $\cos\theta_s$
- Flavour changing decays are very rare in the SM , for example BR$(h \to bs) \simeq 10^{-7}$. NP models, which can be encapsulated by an EFT, allow larger values.

Done with some concepts: to be collected and compared?

TBD?

Target methods to be developed

- charged hadron ID from dN/dx, dE/dx, ToF, RICH, study complementarity in momentum reach.
- reconstruction of in-flight decays, e.g. $K^0_S \to \pi^+\pi^-$
- strangeness-tagging
- s vs $\bar{s}$ separation
- control of strange-tagging related systematic uncertainties

Work in progress

TBD?

Some works exist, some ongoing

TBD (some ongoing)?

TBD?

H → ss: target by organizers (2)

Target analysis techniques

- diboson background suppression
- signal extraction (fit discriminant variables, counting experiement etc)

Done in ILD study, more to come?

Target detector performance aspects

- dependence of the precision on physics observables on particle ID and reconstruction capabilities

Some works exist, more to come?

MC samples needed

full SM and $e^+e^- \to f\bar{f}h$ at $\sqrt{s} = 240/250$ GeV and 350...380 GeV available in general samples listed in Section

Existing tools / examples

- similar ILD analysis for $h \to b\bar{b}/c\bar{c}/s\bar{s}$: https://github.com/ILDAnaSoft/ILDbench_Hbbccgg
- similar SiD analysis ...
- similar CLICdp analysis ...
- similar IDEA analysis ...
- similar CLD analysis ...

List of active works (ongoing and planned)

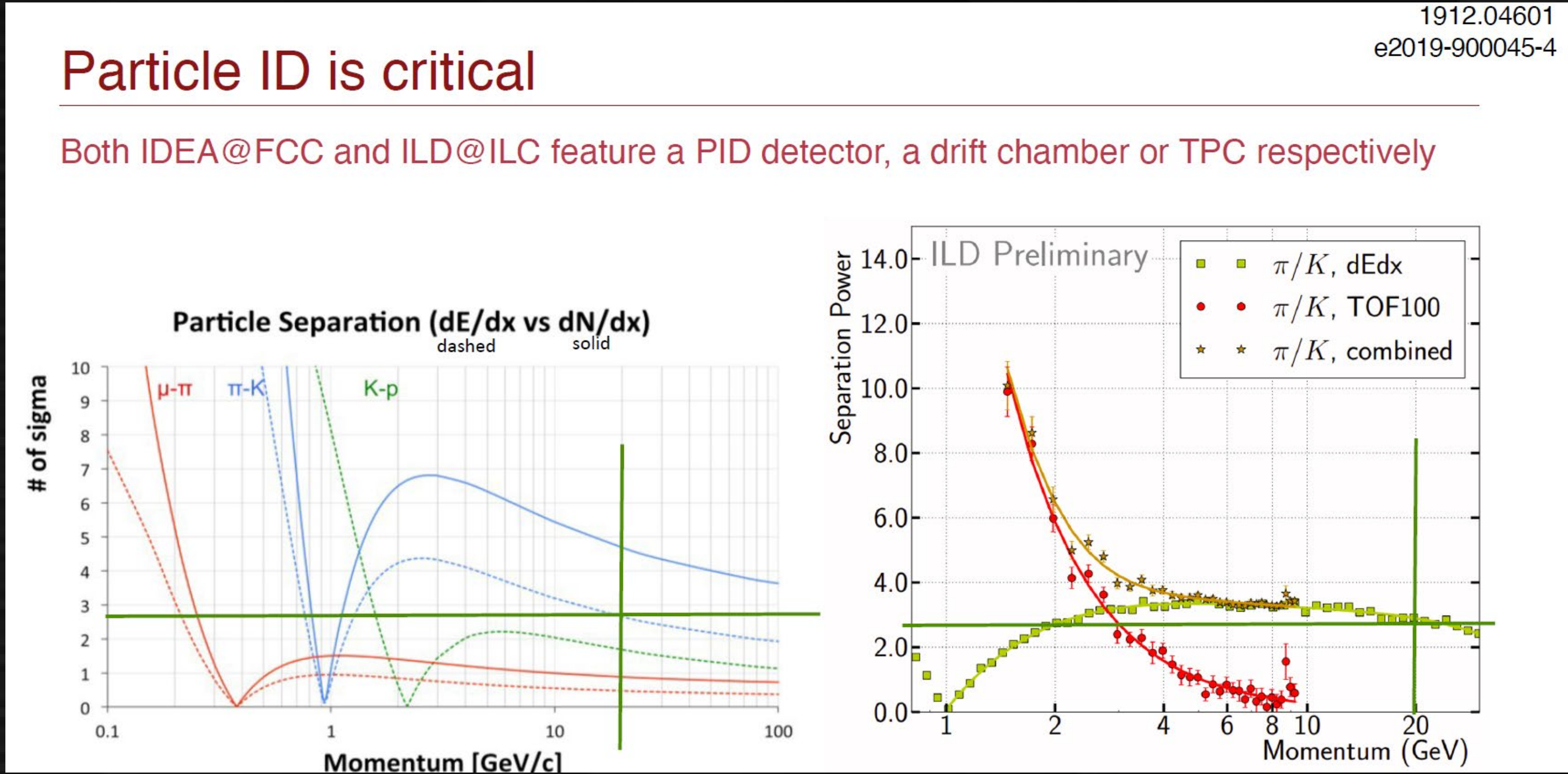
- ILD: Comprehensive H → ss paper exists, including discussion on additional RICH on detector (maybe good to replace with latest strange tagging) arxiv:2203.07535
- IDEA: strange tagging with ParticleNet etc. gives good results, real H → ss analysis to be done? arxiv:2202.03285
- CEPC: work ongoing based on ParticleNet arxiv:2310.03440
- Others?

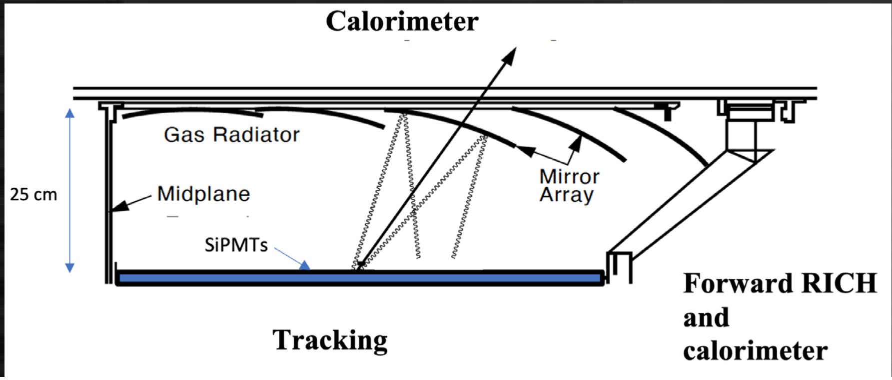
Common topics

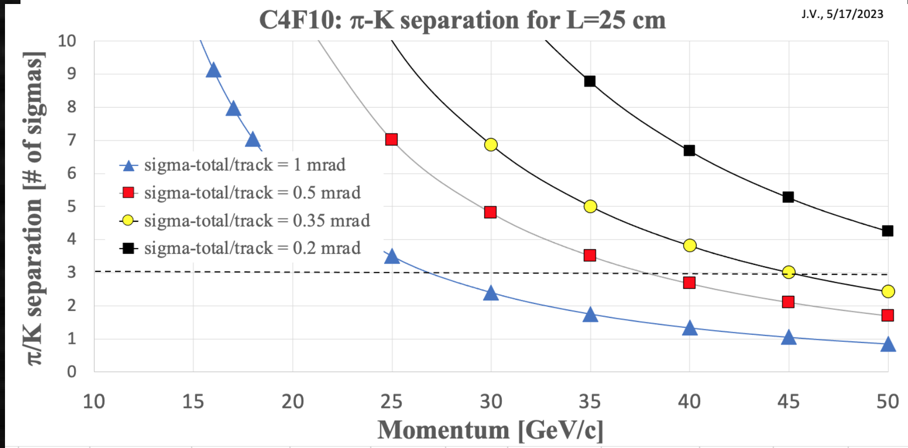
- Demonstration of technologies (dE/dx or dN/dx, large-scale picosec timing detectors, RICH)
  - Clarify difference of the performance between detector concepts
- Reconstruction algorithm
  - GNN/Transformer seems promising, dependence on detector performance to be seen
  - Common framework to use ML-based algorithm to analysis
  - Difference between fast and full sim identified
- Physics analysis – comparison of results
- Interpretation (BSM sensitivity?)

Difference on PID (e.g. ILD and FCCee)

arXiv: 2307.01929







How the performance should be validated? Detector prototype available?
Picosec detectors at calorimeter practical? Power consumptions?
RICH to be included? Impact on detector design/performance?
Other technologies?

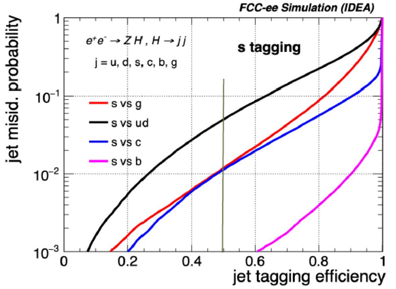
Current status of strange tagging

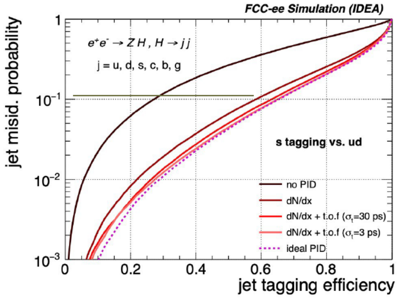
PRD 101 056019 (2020)
EPJ C 82 646 (2022)
L. Gouskos @FCC week

Strange tagging performance 1/2

IDEA-like detector and Particle cloud graph neural network (fast sim)

- Both TOF and dN/dx ($3\sigma < 30$ GeV) included as inputs
- No PID to PID with dN/dx → at fixed mistag, efficiency doubles





WP	Eff (s)	Mistag (g)	Mistag (ud)	Mistag (c)	Mistag (b)
Loose	90%	20%	40%	10%	1%
Medium	80%	9%	20%	6%	0.4%

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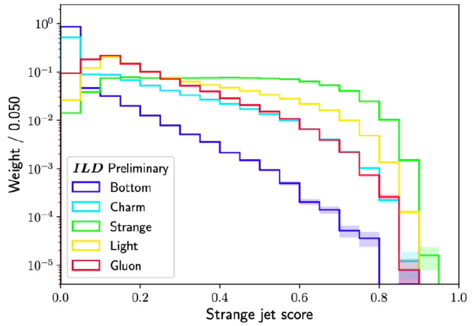
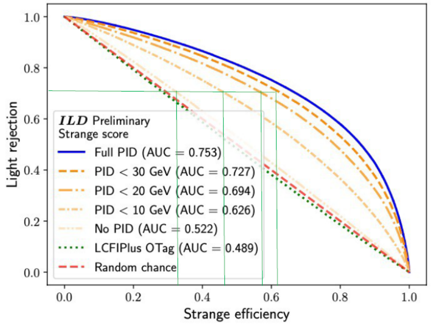
2203.07535

Strange tagging performance 2/2

ILD-like detector with full simulation and Recurrent NN

- Includes PDG-based PID → assuming perfect detector capability
- At 50% s-tag efficiency, 90% background rejection
- No PID to PID < 10 (30) GeV → at fixed mistag, 1.5x (2x) efficiency





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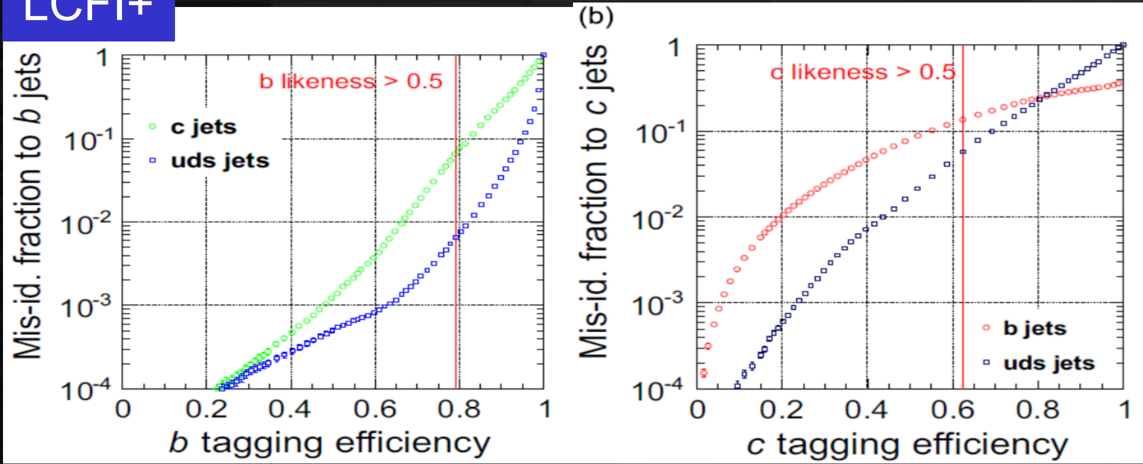
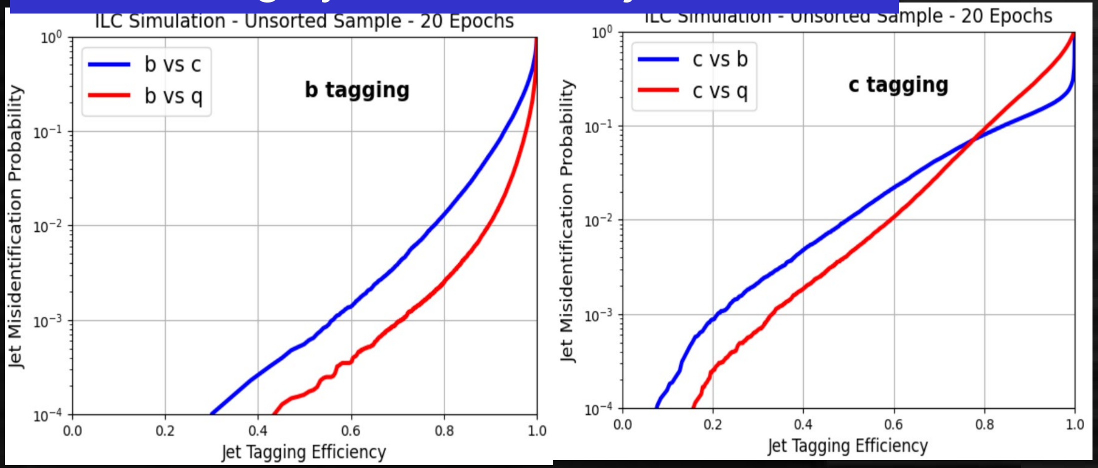
ILD: b/c tagging with Particle Transformer
strange tagging to be investigated

LCFI+



ParT – roughly 10x better rejection ratio



Analyses to be compared

- Strange tag need to be fixed first
  - DNN-based tagger seems to be baseline
  - Need to incorporate into (common?) analysis framework
- Analyses are usually difficult to compare
  - Detector different
  - Simulation details different
  - Analysis method different

  Difficult to disentangle those – common framework / analysis would help (to be discussed)

Issues on H → ss (apart from strange tag)

- Higgs with other decays (bb/cc/gg): main background
  - Need to clarify Z/W background for some channels though
- Separation of H → bb/cc is relatively easy (H → bb: clear signature, H → cc: statistically less demanding) → the critical part is discrimination of H → gg/ss (if we ignore H → light quarks / exotic)
- "Gluon tagging" may be rather essential
  - Included in the current tagger (in part of multiclass)
  - Different from e^+e^- → ss (where strange tag is essential)

Investigating more issues

- Jet charge of strange?
- Exotic decay of Higgs like H → bs?
- Differential cross section of H → ss?
- Decay of K0 short?
- Heavy Higgs decay e.g. H^+ → cs?
- Systematic effects?
  - Esp. serious for DNN-based algorithms

Interpretation?

- Theory colleagues would propose way to go…
  - Sorry, not available today

- Some quasi-personal comments:
  - Physics case for H → ss is not very strong
    (not the first 2nd generation quark, not easy to reach SM…)
    Worthwhile to separate from 1st generation in case of large deviation?
  - How about H → bs, H^+ → cs, other exotics?

Caterina's summary

Conclusions and next steps

s-tagging & PID would allow for a complete exploration of the 2nd generation Yukawa couplings

- First simulations with some assumptions on detector performance show promise to test κ_s
- Moving forward we want to:
  - map this into phenomenological targets
    - i.e. BSM models predicting deviations in $h \rightarrow ss$, or $h \rightarrow cs$
  - refine the analysis for $e^+e^- \rightarrow Zh$ with $h \rightarrow ss$ ($Z \rightarrow X$) at 240/250 GeV
    - higher center of mass energies still unexplored
  - study detector benchmarks:
    - the complementarity in momentum reach of charged hadron ID from dN/dx, dE/dx, ToF, RICH
    - reconstruction of in-flight decays, $K^0_S \rightarrow \pi^+\pi^-$
    - strangeness-tagging and s/sbar separation
    - ***Important to evaluate simultaneously other Higgs benchmarks***

Timeline

- To be discussed…

- Possible timescale (?)
  - November 2023: call for ongoing/planned work issued
  - Mid 2024: collect ongoing and planned work and missing work identified
  - 3Q 2024: complete works to be done
  - End 2024: assemble the results and summarize to a document

Discussions

Targets / goals

Topical issues

Procedure / way to go / timeline

Others?