Implementation, performance and physics impact of particle identification at Higgs factories

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The Future Collider Landscape & PID

Broad landscape of proposed future colliders

Need to focus personpower on common work, in particular software → key4HEP [1,2]

One big topic of common interest: particle identification (PID)

Here: common approach to combined PID at future colliders - Comprehensive PID (CPID) → [3]

References

[1] P. F. Declara et al.: *The Key4hep turnkey software stack for future colliders*, 2022, https://doi.org/10.22323/1.398.0844

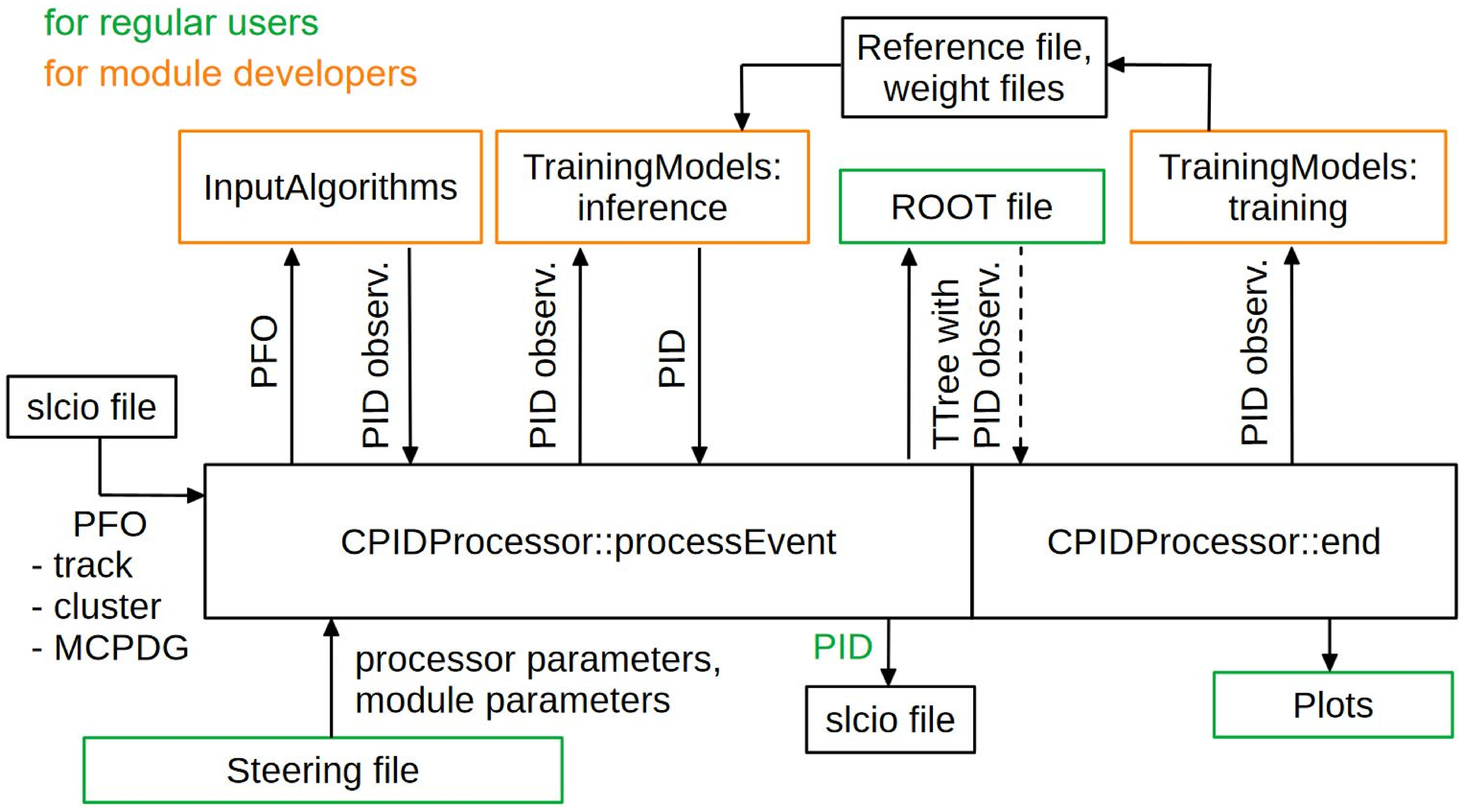
[2] key4HEP codebase: https://github.com/key4hep

[3] CPID (Marlinreco) codebase: https://github.com/iLCSoft/MarlinReco

[4] The ILD Collaboration: *International Large Detector: Interim Design Report*, 2020, https://arxiv.org/abs/2003.01116

[5] A. Albert et al.: *Strange quark as a probe for new physics in the Higgs sector*, 2022, https://arxiv.org/abs/2203.07535

CPID Structure

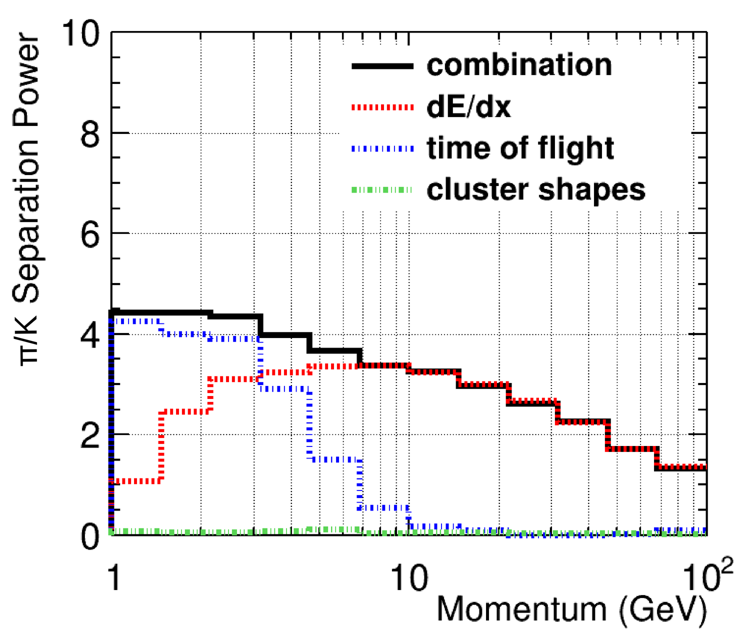


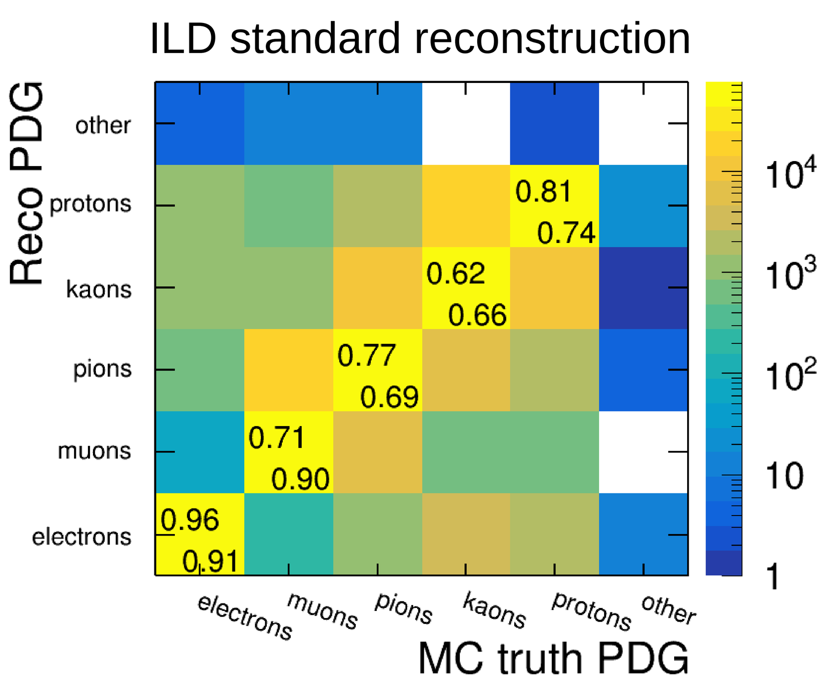
CPID Performance

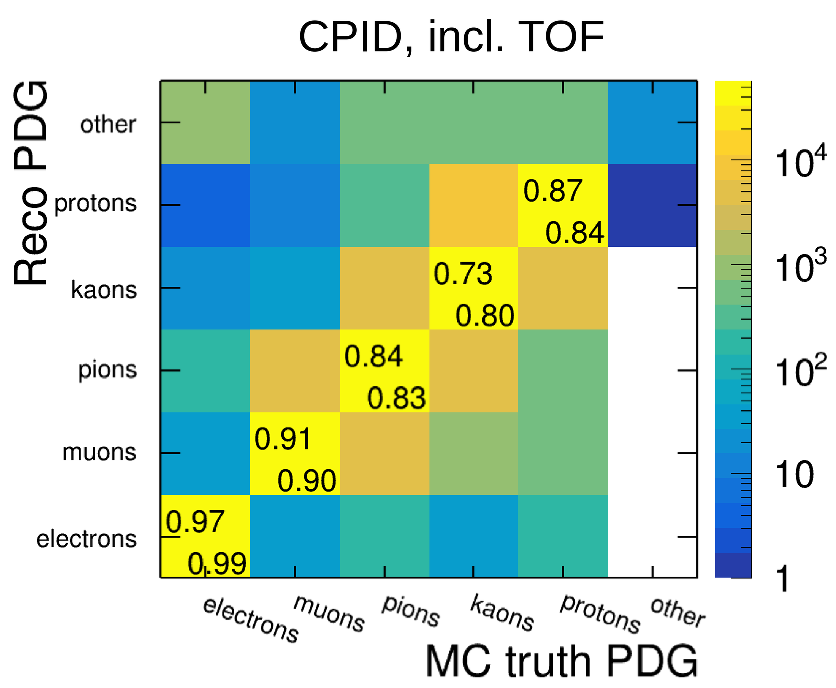
Based on ILD full simulation & reconstruction [4], single particles flat in log(p) and isotropic

Right: combination of different modules for pi/K separation

Below: improvement wrt. current tool in standard reco; numbers are effciency/purity for the diagonal







Current CPID Module Library

TrainingModels: so far simple sig/bkg BDT, and Multiclass BDT

InputAlgorithms are (mostly) based on full geant4 simulation

Performance: confusion matrix of charged detector-stable particles (e, μ, π, K, p), using 12 Multiclass BDTs split along log(p)

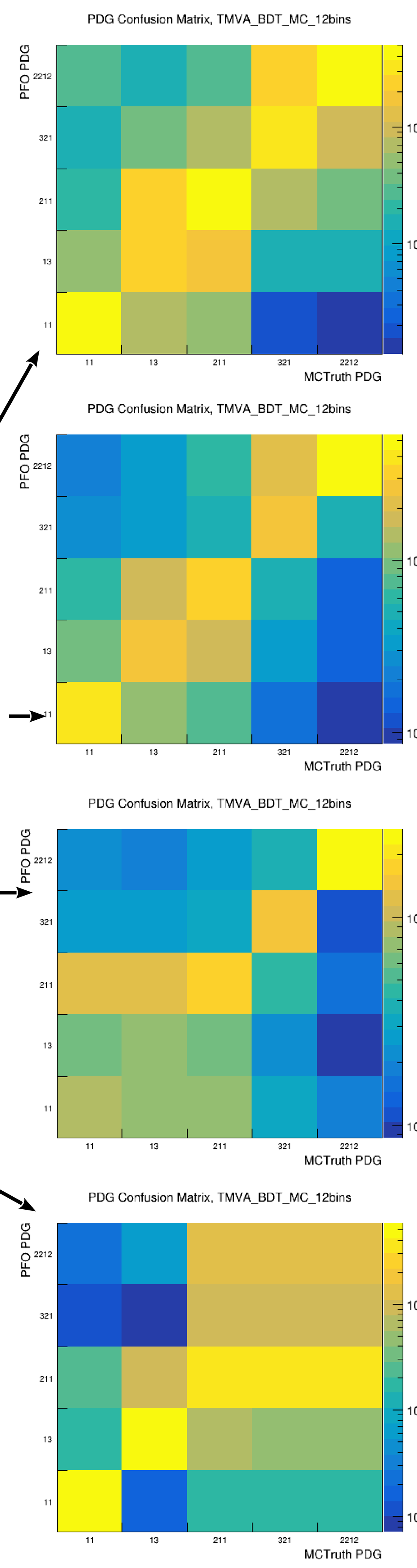
dE/dx: using distance to Bethe-Bloch curves

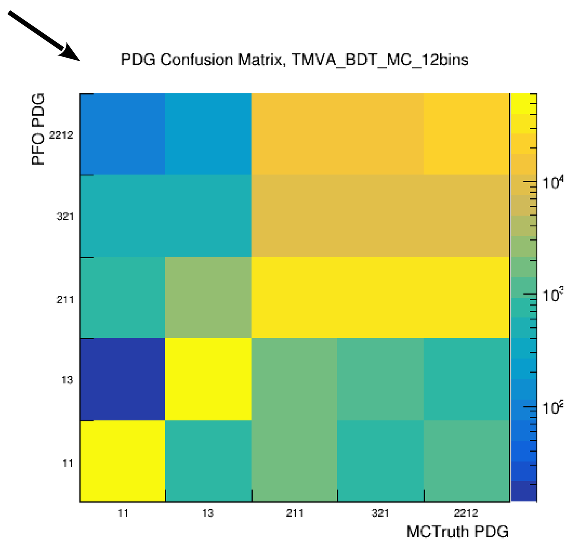
dN/dx: using distance to cluster-counting curves; based on Delphes parametrisation

Time-of-Flight (TOF): using reconstructed mass based on time resolution of 30 ps at the first ECal layer

Cluster shapes: 'side product' of particle flow algorithm (PandoraPFA)

LeptonID: dedicated BDT for electron and muon ID, using cluster shapes and dE/dx



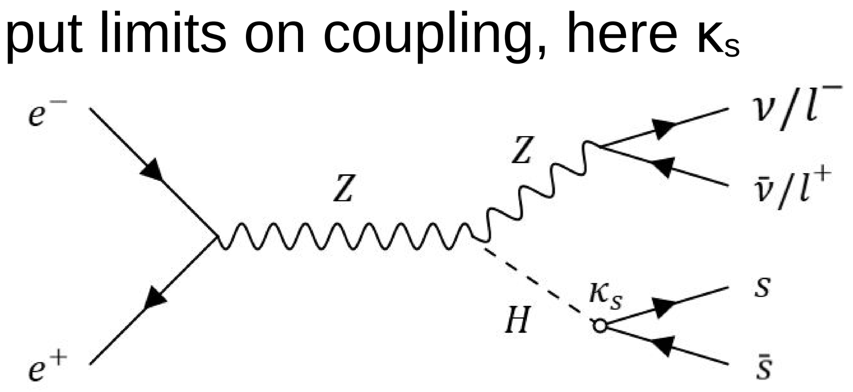


Physics Application Example: Strange Yukawa Coupling

Study of Higgs to $s\bar{s}$ decay [5]

Very rare in SM, can be enhanced in BSM

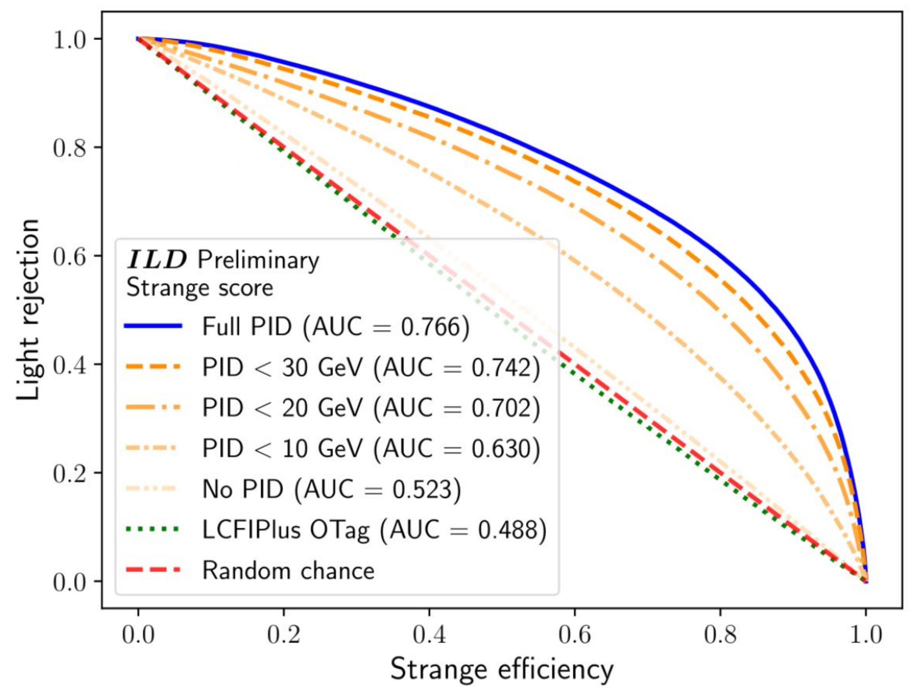
With PID-based strange tagging and clean environment at e+e- colliders will be able to put limits on coupling, here κ_s



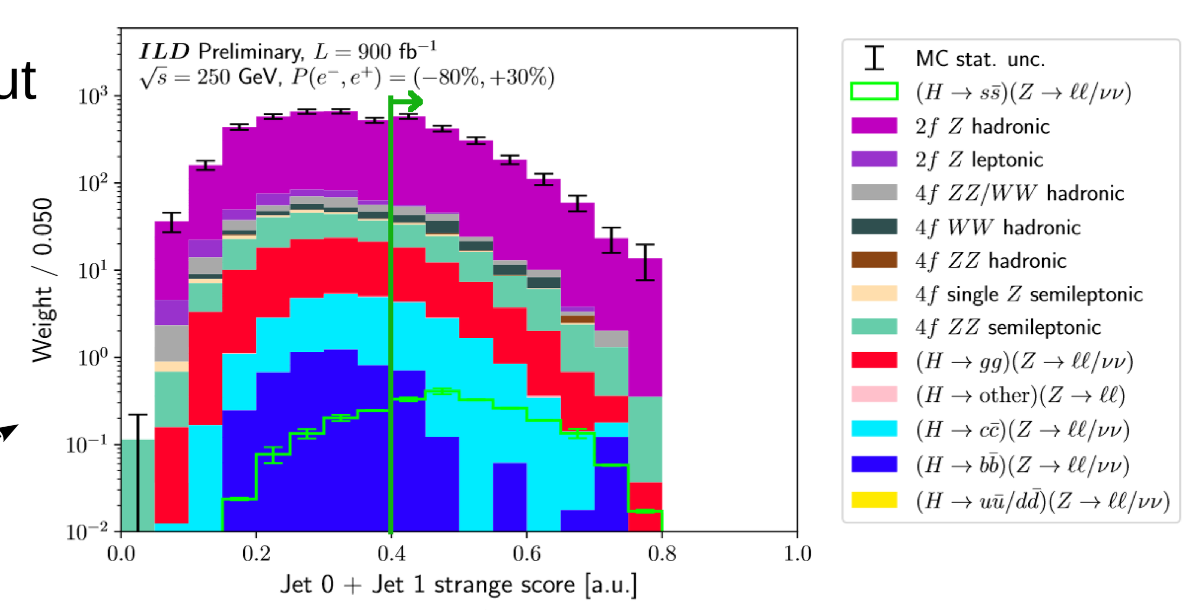
Jets originating from b- and c-quarks can be tagged via secondary vertex ID

Separation of s vs. u/d only possible via (mostly leading) strange jet constituents

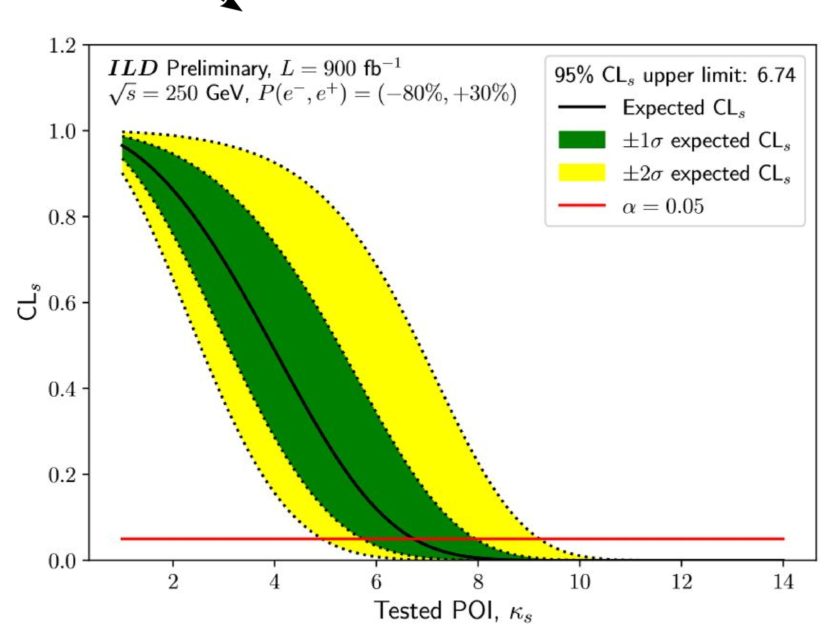
Impact of PID (kaons/pions, V^0s) on the separation between s- and u/d-jets:



Allows for cut on strange score to enhance sig/bkg:



Leading to upper limit for κ_s:



MC PID was used for now, but looking to apply CPID here and in other analyses