# $V_{us}$ measurement from $\tau \to K^0_L \pi X_{no_s}$

Status and plans

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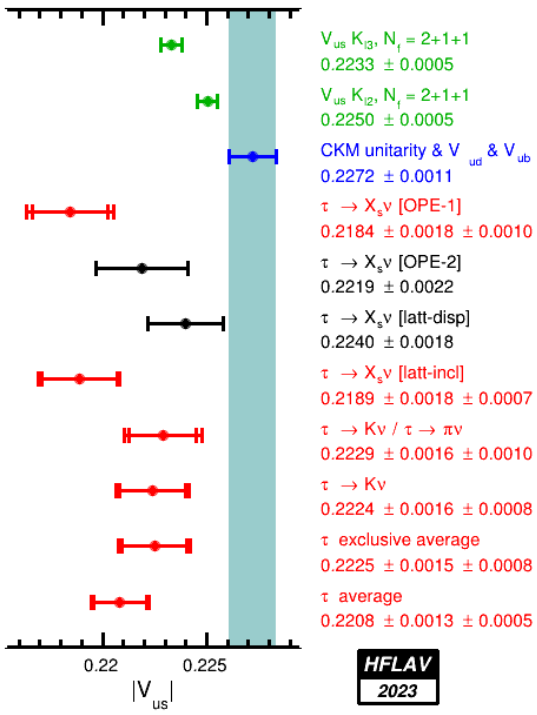
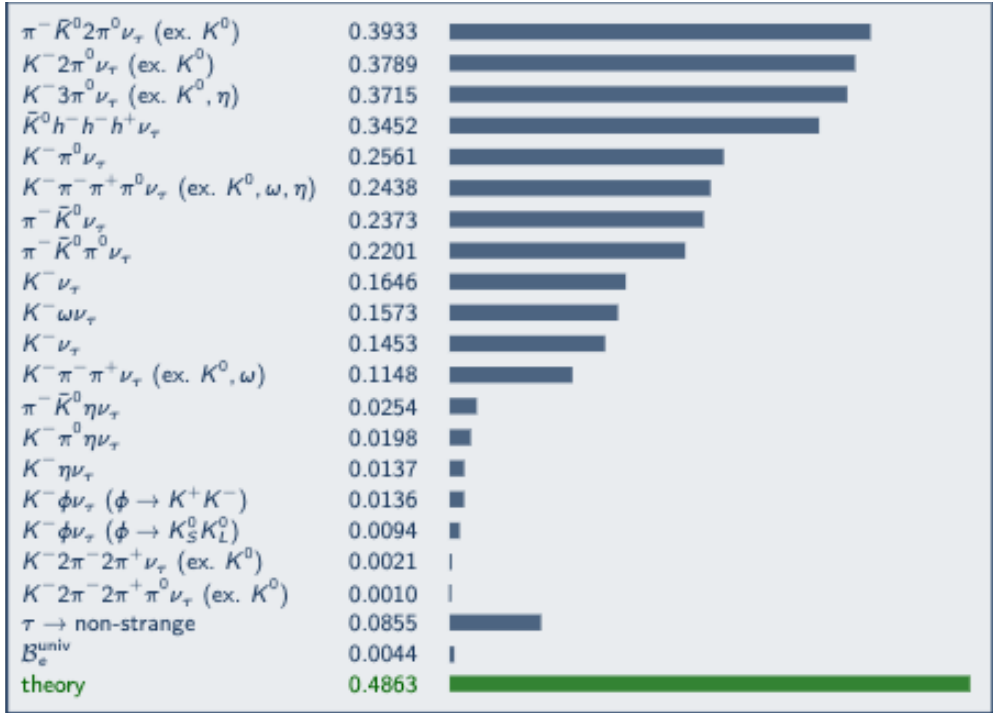
# Experimental status

- $V_{us}$ value below unitarity could be explained by underestimated $\mathscr{B}(\tau \to \mathrm{s})$ (at least for inclusive determination)




- The uncertainty on Vus determination is driven by experimental error on $\mathscr{B}(\tau \to \mathrm{s})$




Uncertainty budget on $V_{us}$ determination

# What to measure: inclusive decays $\tau \to s$

**Perform a measurement of the branching fraction $\tau \to X_s \nu_\tau$**

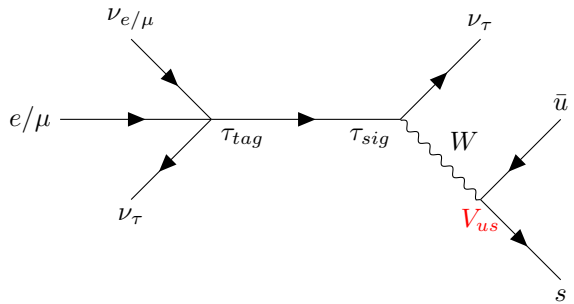
- « Inclusive » $V_{us}$ determinations until now are done using the sum of the exclusive modes

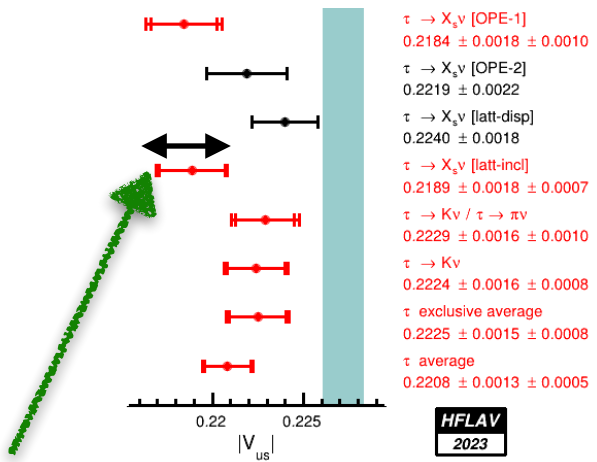
Our goal is an inclusive measurement: « $\tau$ decay + net strangeness»

→ no explicit requirements on the additional hadronic system

→ no dependency on singular modes

And improve precision!




Confirm/shift the central value for $V_{us}$ and $\mathcal{B}(\tau \to s)$

# Tracks & neutrals selection

Tracks:

- abs(dz) $< 3$
- dr $< 1$

To apply the corresponding mass hypothesis:

- e/$\mu$/$\pi$ IDNN $> 0.9$
- KIDNN $> 0.5$
- Brem correction for electrons

Photons & $\pi^0$:

- Std recommendations for $\tau$
- Photons orthogonal to ECL clusters for KL0

$K_S^0$ :

- Allows $\pi^+$ not from IP (in the ROE)

$K_L^0$:

KLM-only:

- klmClusterLayers <= 7
- KlmClusterInnermostLayer <= 10
- KlmClusterKlId $> 0.05$
- KlmClusterLayers $> 1$

ECL-only:

- clusterE $> 0.4$
- clusterE1E9 $< 0.85$ (ratio of central crystal and 3x3 crystals around)
- ECLKLID $> 0.9$

KLM-ECL pairs:

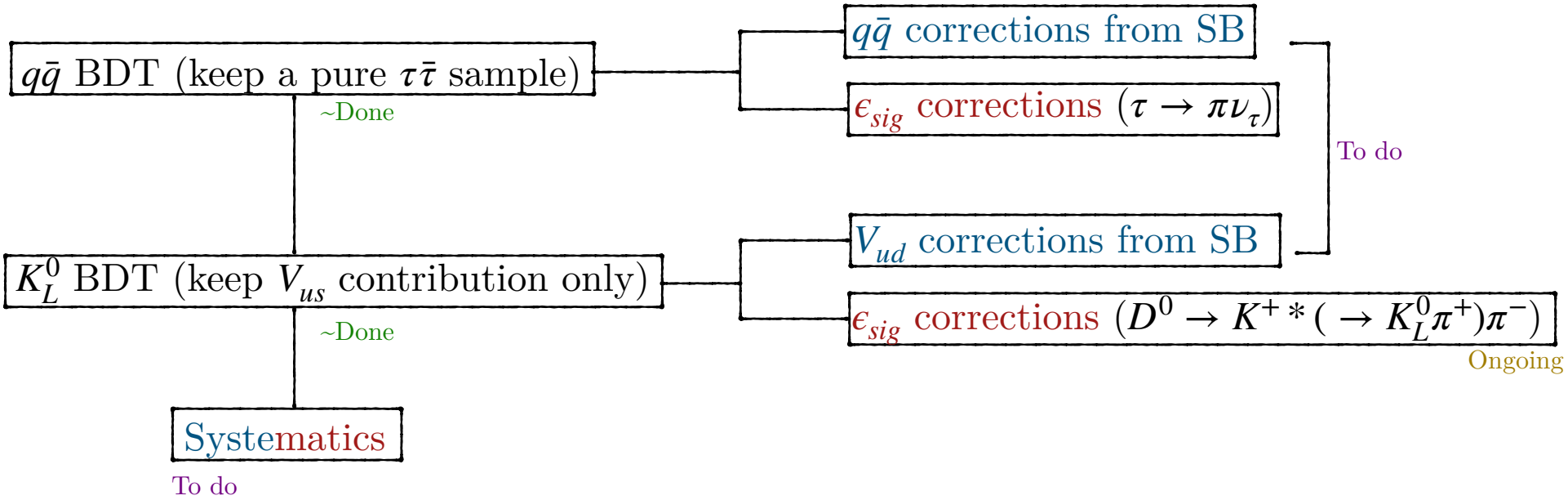
- Merge KLM and ECL clusters with angle $< 0.8$ rad
- Accept KLM clusters with **1 klmClusterLayers**

# Event reconstruction

- Tag: $\tau \to \ell \nu_\ell \nu_\tau$
- Signal: $\tau^- \to K_L^0 \pi^- \nu X_{no_s}$
- Hemisphere separation:
  - Signal and tag separated
  - $K_L^0$ and $\pi$ in the same hemisphere
- Additional selections:
  - Thrust $< 0.9$ & Pt* of tag lepton $> 0.4$

- ROE against virtual photon (signal +tag)
  - Using particle lists previously defined
  - Should be the $X_{no_s}$
- EventShape / EventKinematics with particle lists previously defined (in particular, $E_\gamma$>0.2 GeV)
- No trigger selection yet (trigger bits in the ntuples)
- Tau Generic OR tau thrust skim
- MC matching: K0L matched to a MC K0L or one of its (grand) daughters (+ tauola mode)

# Overview



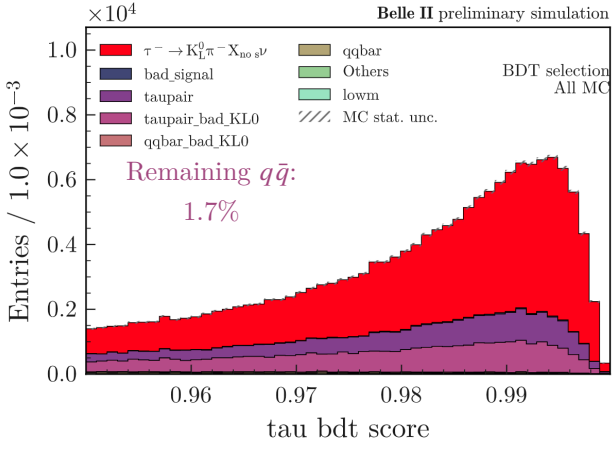

Extract $N_{sig}$ (from $\epsilon_{sig}$ and $N_{bg}^{MC}$) $\to B(\tau \to K_L^0 \pi X_{no_s})$

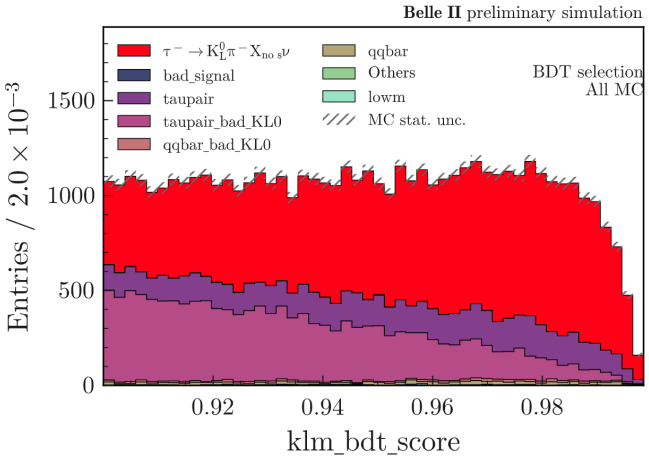
# BDTs

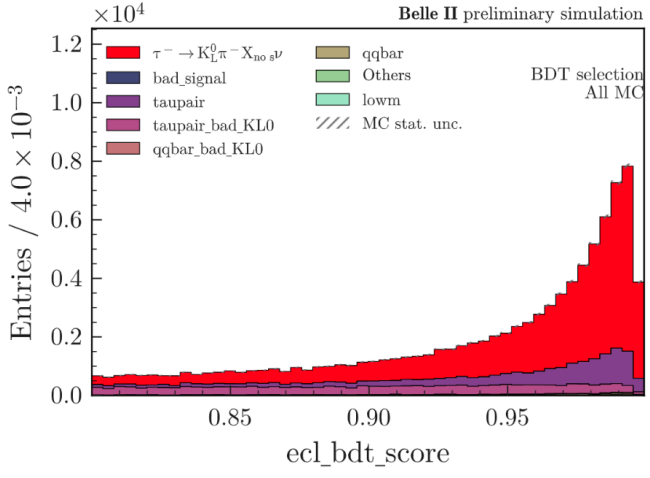
- $q\bar{q}$ BDT trained with signal events vs $q\bar{q}$ events, using event based variables (missing info / tag info / thrust)
- $K_L^0$ BDT trained on signal events vs $V_{ud}\ \tau\bar{\tau}$ background, using ECL/KLM info only
- 65% purity, ~100k signal events (per 0.5 $ab^{-1}$)

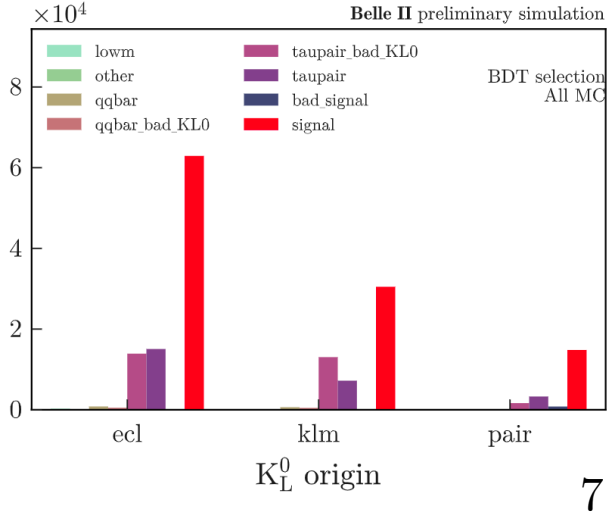
→ 0.2% uncertainty on signal yield coming from background stat. and ~ 0.2% stat. uncertainty on signal efficiency

→ still some « room » for more systematic uncertainty (PID and unfolding/ signal extraction) as we target 1% precision




*Plots to be updated, BDT optimization running

# Signal extraction

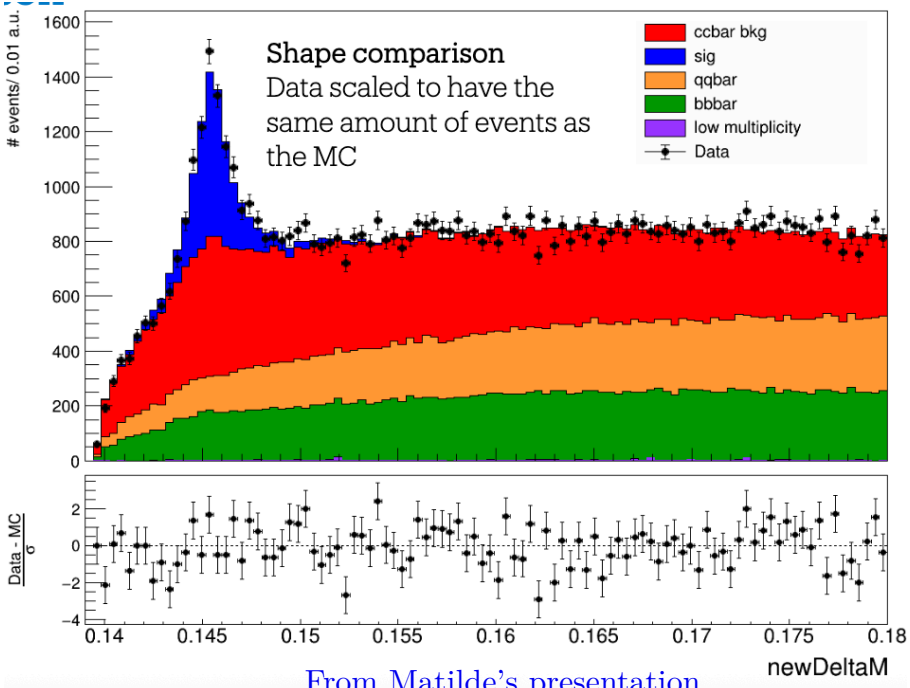
- We plan to combine all the modes together: $\tau \to K_L^0 X, \tau \to K_S^0 X, \tau \to K^+ X$
- Group in DESY are working on an unfolding matrix (unfold $V_{us}/V_{ud}$/ signal cross-feed)
  → cut and count the total number of events

- Maybe fit some distribution ($K_L^0$ BDT output) to extract signal yields
  - Considered by DESY for the measurement of $\tau \to K_S^0 K_L^0 \pi \nu$
  - Personnally not convinced by it, in particular for $\tau \to K_L^0 \pi X$
  - And it would make combining the modes harder
  - But if it works (and has low syst.) then why not

# $K_L^0$ control sample

Using $D^0 \to K^{+*}(\to K_L^0\pi^+)\pi^-)$ as a control sample for $K_L^0$s

- $K_L^0$ momentum around 1 GeV/c$^2$, close to the $K_L^0$ from $\tau$
- Fit the $D^0$ mass before and after applying the BDT to extract yields
- Reconstruct also the final state with $K_S^0$ for normalization and obtain absolute corrections
- Shared work with DESY: Matilde's producing the ntuples & fit, I'm working on the implementation in Sysvar

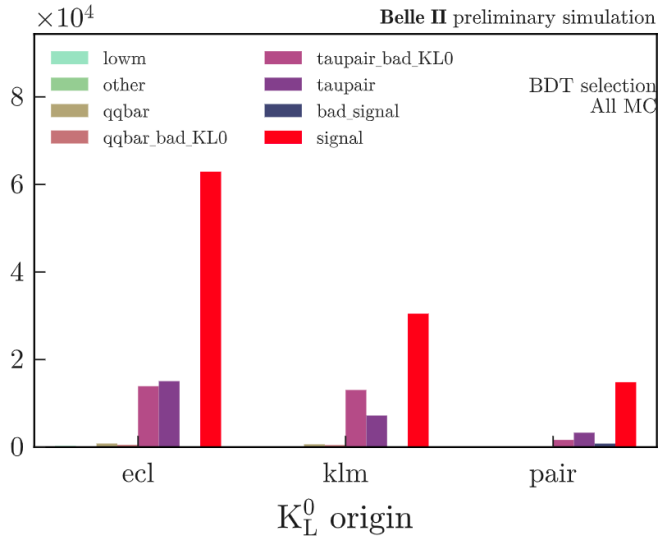



From Matilde's presentation

- I was investigating $D_s \to K_L^0 K_S^0 \pi$ (with $\phi$ or $K^{+*}$) resonance, but the resolution is worse and stat lower

# The KLM situation

- The KLM (proportionally) produces much more background than signal candidates,
- Currently (release-08) only provides 2 relevant variables (for true $K_L^0$ selection): cluster timing & layer depth / penetration (+ geometrical position of the cluster)
- Release-09 brings more useful variables, but most likely will be too late (at least wrt my contract)
- And might also come with high systematic uncertainty (pending $K_L^0$ control sample study)

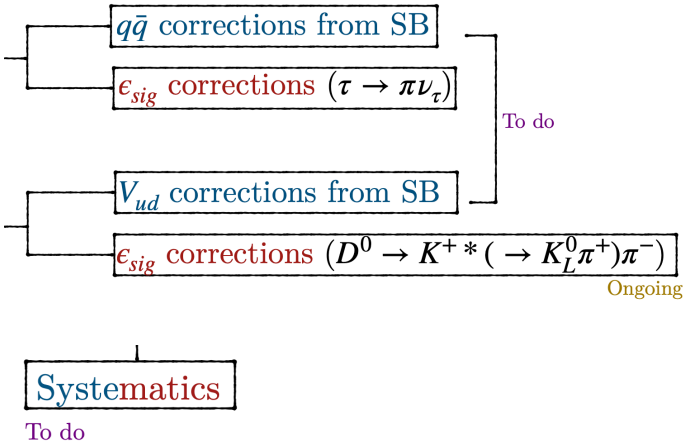



2 ideas:

- Antonio suggested it could be possible to first run some selection ( $q\bar{q}$ BDT, pre-selection on $K_L^0$) and reprocess the remaining ntuples to add the release-09 variables ← I've no idea on the feasibility
- Drop KLM candidates in $\tau \to \ell\nu\nu$ tag; also use $\tau \to 3\pi\nu$ tag and use the $3\pi$ system to constrain the cone in which the $K_L^0$ can be found; might reduce greatly the number of fake ← I have already minimal working code & I'm running some quick test to assess the idea

# Next

Finish the analysis (obviously🫠):




- Overall we have a clear plan toward $V_{us}$
- Additional workforce could be really beneficial to finish the project in my contract time
- The remaining work items are **well defined** and e.g. the $K^0_L$ corrections could serve as an entry point into the analysis for a **phD student interested** in contributing to $\tau$ analysis 👀