Summary from KIT - top EWK coupling and |Vts|

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Outline

- EWK coupling measurement
- |Vts| measurement

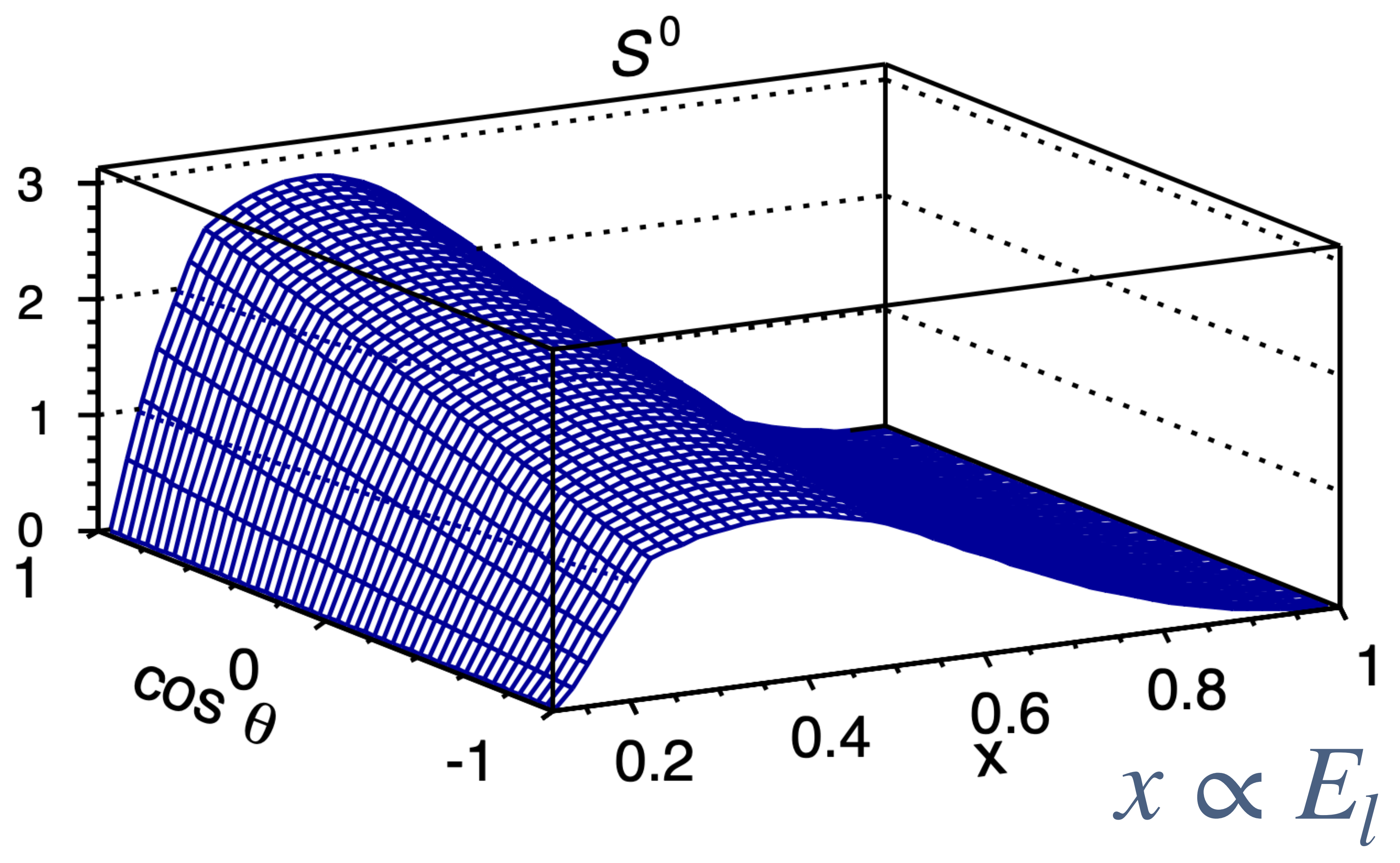
Top EWK couplings

(The following work is a bachelor thesis of Simon Keilbach)

Top EWK couplings parameters

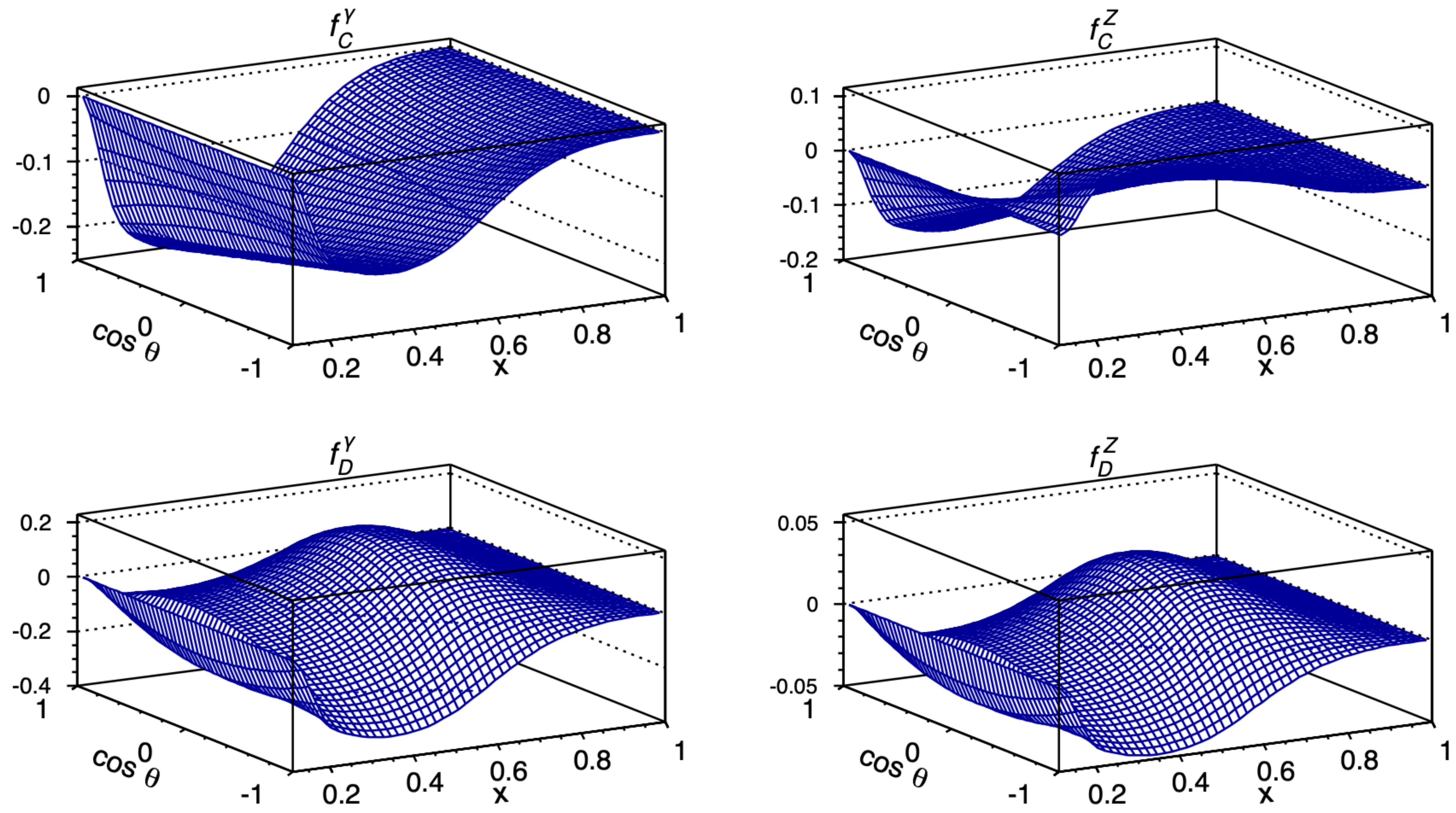
- Direct measurement of ttZ and ttγ couplings
  - Some BSM models can lead to significant deviations from SM
  - Traditionally more discussed in polarized e+e- collisions. For example at ILC (arXiv 1306.6352)
  - Study from FCC (10.1007/JHEP04(2015)182) also expects sensitivity without beam polarization.

SM case



$x \propto E_l$

examples of BSM contributions



Modified couplings

10.1007/JHEP04(2015)182

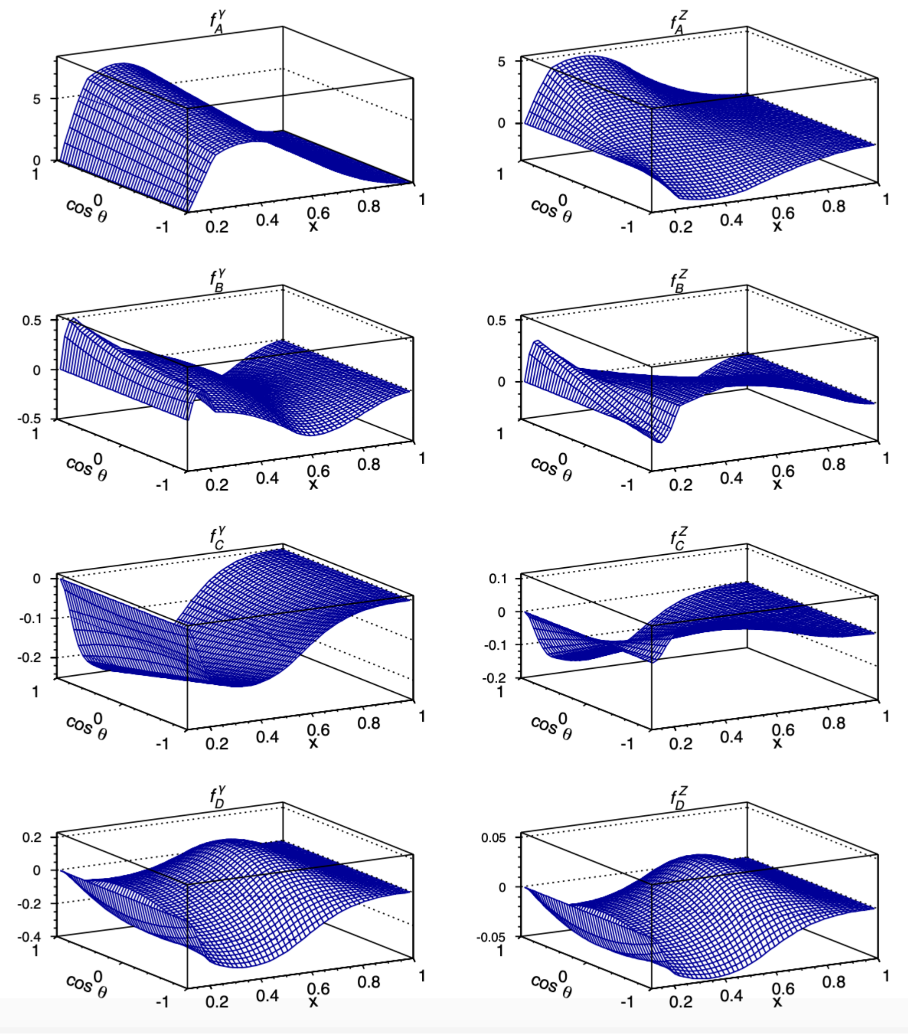
- coupling constants expressed in form factors

$$\Gamma_\mu^{ttX} = -ie\left\{\gamma_\mu\left(F_{1V}^X + \gamma_5 F_{1A}^X\right) + \frac{\sigma_{\mu\nu}}{2m_t}(p_t + p_{\bar{t}})^\nu\left(iF_{2V}^X + \gamma_5 F_{2A}^X\right)\right\},$$

- optimal observable parametrization

$$A_v + \delta A_v = -2i\sin\theta_W\left(F_{1V}^X + F_{2V}^X\right), \qquad B_v + \delta B_v = -2i\sin\theta_W F_{1A}^X,$$
$$\delta C_v = -2i\sin\theta_W F_{2V}^X, \qquad \delta D_v = -2\sin\theta_W F_{2A}^X.$$

- 8 independent modifications



Whizard setup (F. Bach thesis)

- Lagrangians

$$\mathcal{L}_{ttZ} = -\frac{g}{2c_w}\bar{t}\gamma^\mu\left(X_{tt}^L P_L + X_{tt}^R P_R - 2s_w^2 Q_t\right)t\,Z_\mu - \frac{g}{2c_w}\bar{t}\frac{\mathrm{i}\sigma^{\mu\nu}q_\nu}{m_Z}\left(d_V^Z + \mathrm{i}d_A^Z\gamma_5\right)t\,Z_\mu,$$

$$\Delta\mathcal{L}_{tt\gamma} = -\mathrm{e}Q_t\bar{t}\gamma^\mu t\,A_\mu - \mathrm{e}\bar{t}\frac{\mathrm{i}\sigma^{\mu\nu}q_\nu}{m_t}\left(d_V^\gamma + \mathrm{i}d_A^\gamma\gamma_5\right)t\,A_\mu$$

- Parameterization in Whizard SM_top_anom model

$$X_{tt}^L = \texttt{vl\_ttZ} \qquad X_{tt}^R = \texttt{vr\_ttZ}$$
$$d_V^Z = \texttt{tv\_ttZ} \qquad d_A^Z = \texttt{ta\_ttZ}$$
$$d_V^\gamma = \texttt{tv\_ttA} \qquad d_A^\gamma = \texttt{ta\_ttA}$$

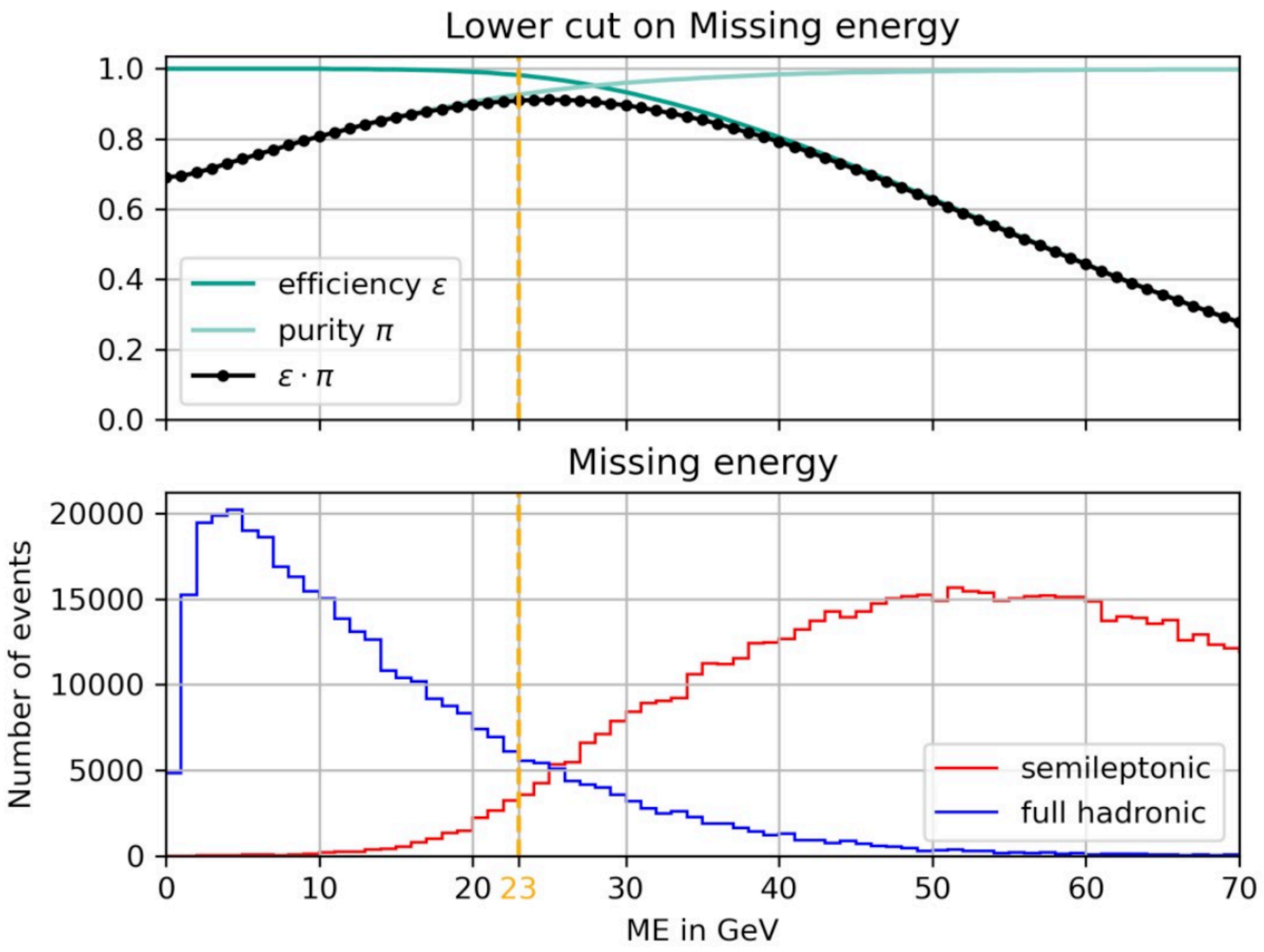
- Independent modifications
  - 6 parameters related to ttZ and ttγ couplings, 3 are constrained by gauge invariance
  - tv_ttZ fixed by tv_ttA, ta_ttZ fixed by ta_ttA, vl_ttZ fixed by vl_tbW
  - **In this work, use 3 independent modifications: tv_ttA, ta_ttA, vr_ttZ**

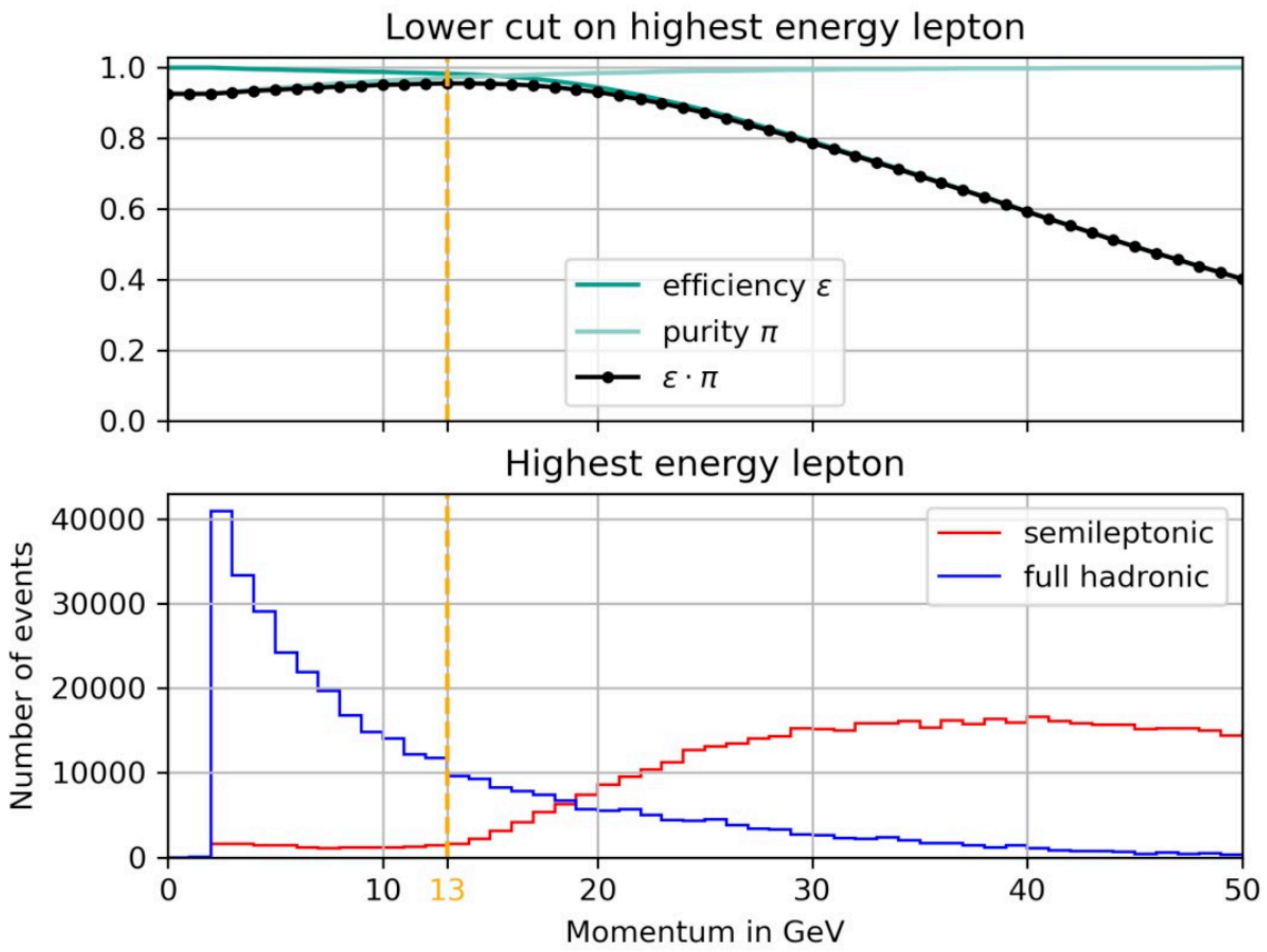
Event selection

- Selection for semileptonic decay:
  - $n_{\mu,e} > 0$ for leptons with $\Delta R(\ell, J) > 0.4$ or $E_\ell / E_J > 0.5$
  - missing energy $\not{E} > 23$ GeV
  - lepton momentum $p_{\text{lead}} > 13$ GeV
  - PV compatibility $d_0 < 0.05\ \text{mm}, \frac{\mathrm{d_0}}{\sigma(\mathrm{d_0})} < 50$

Jet definition at the moment:

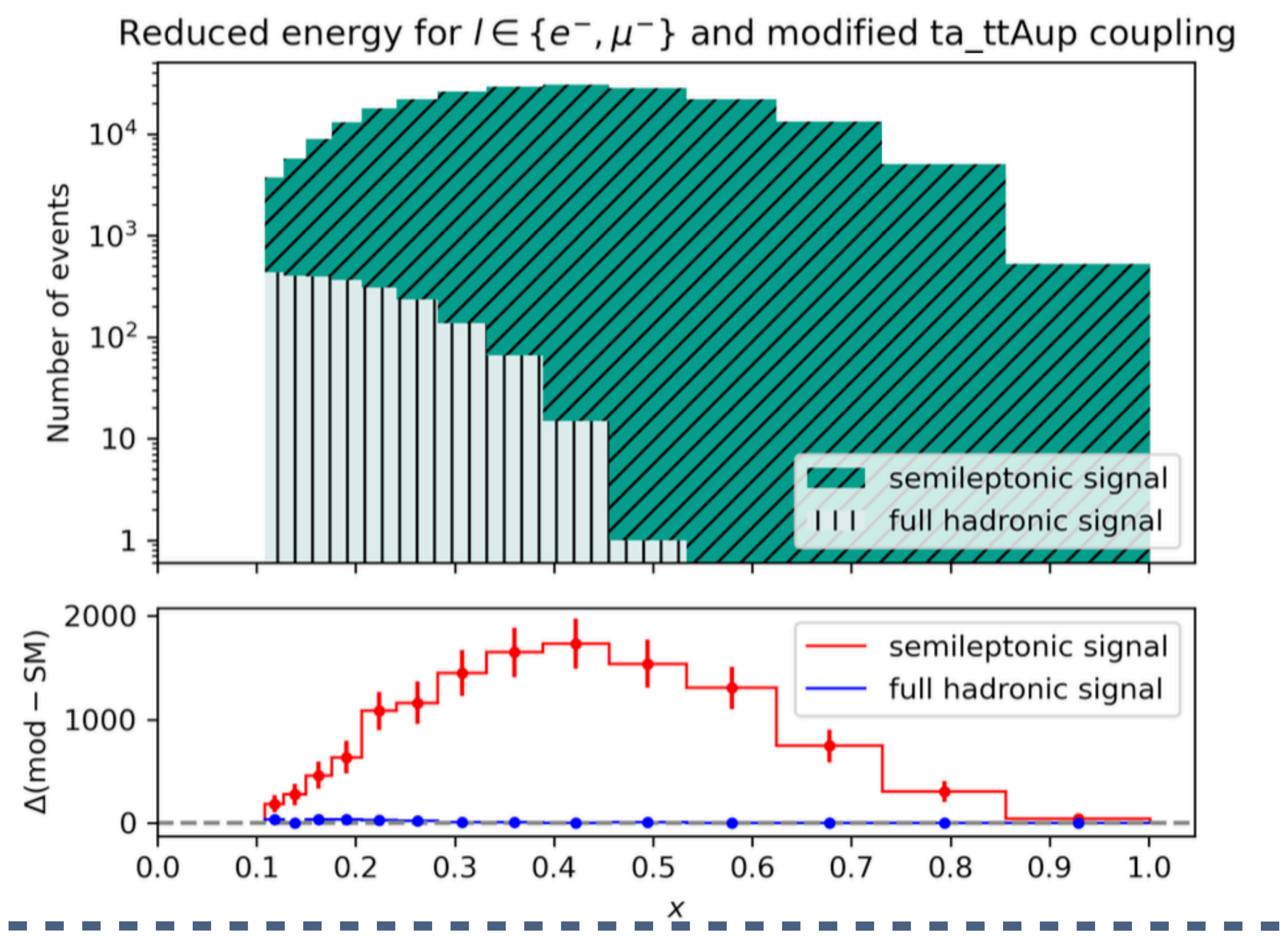
- kt, njet = 6, $E_J > 10$ GeV

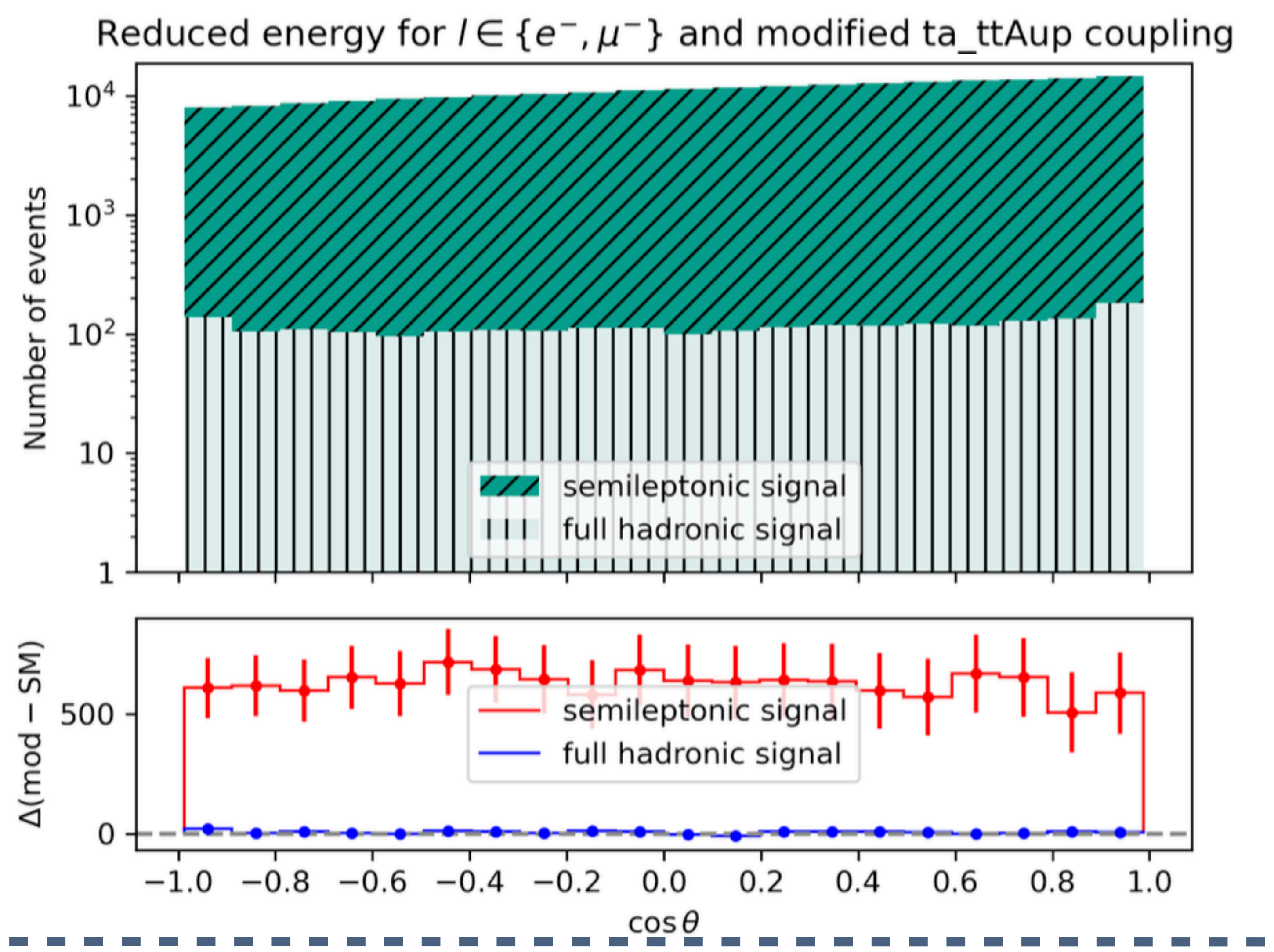




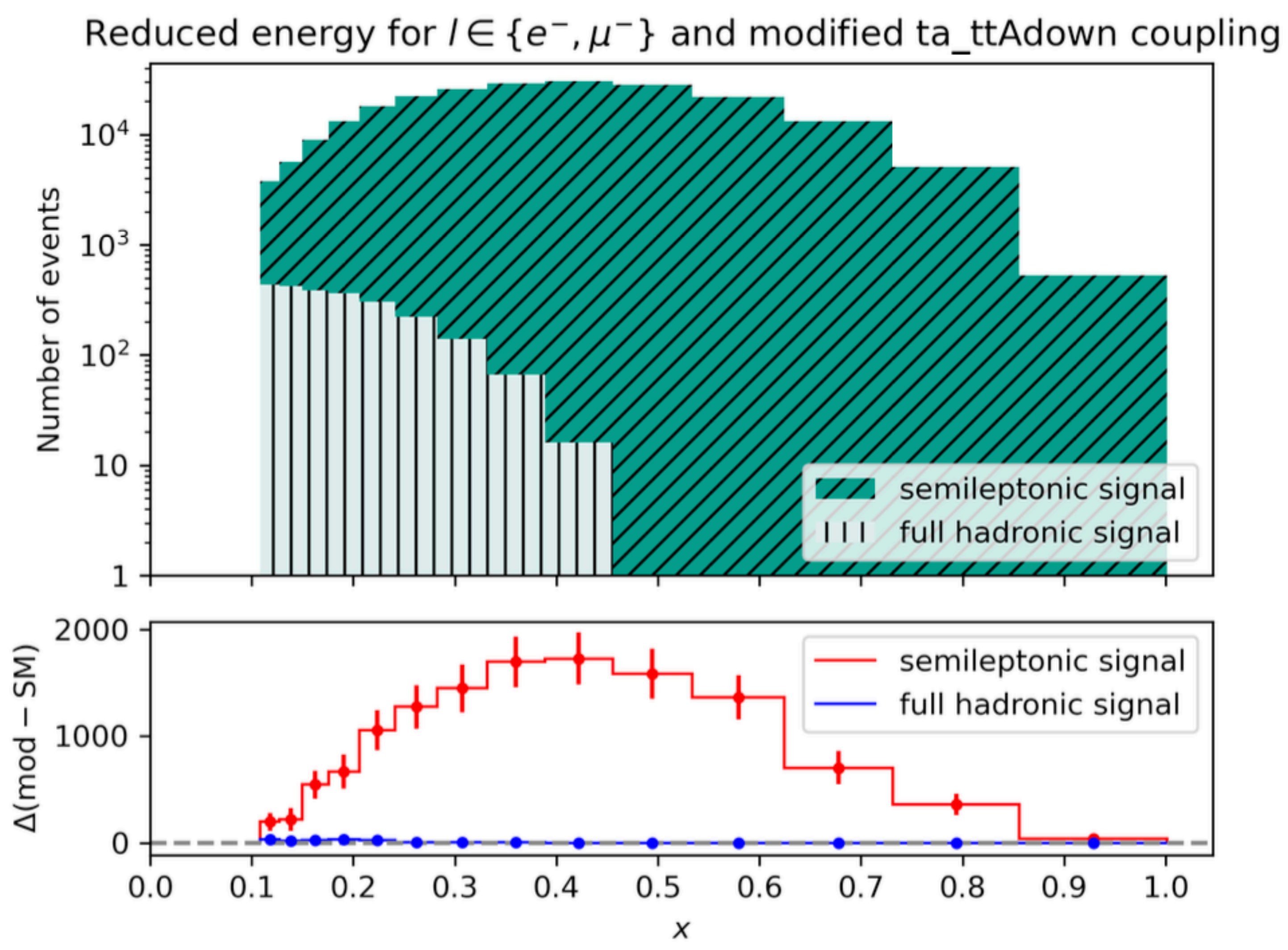
ta_ttA variation

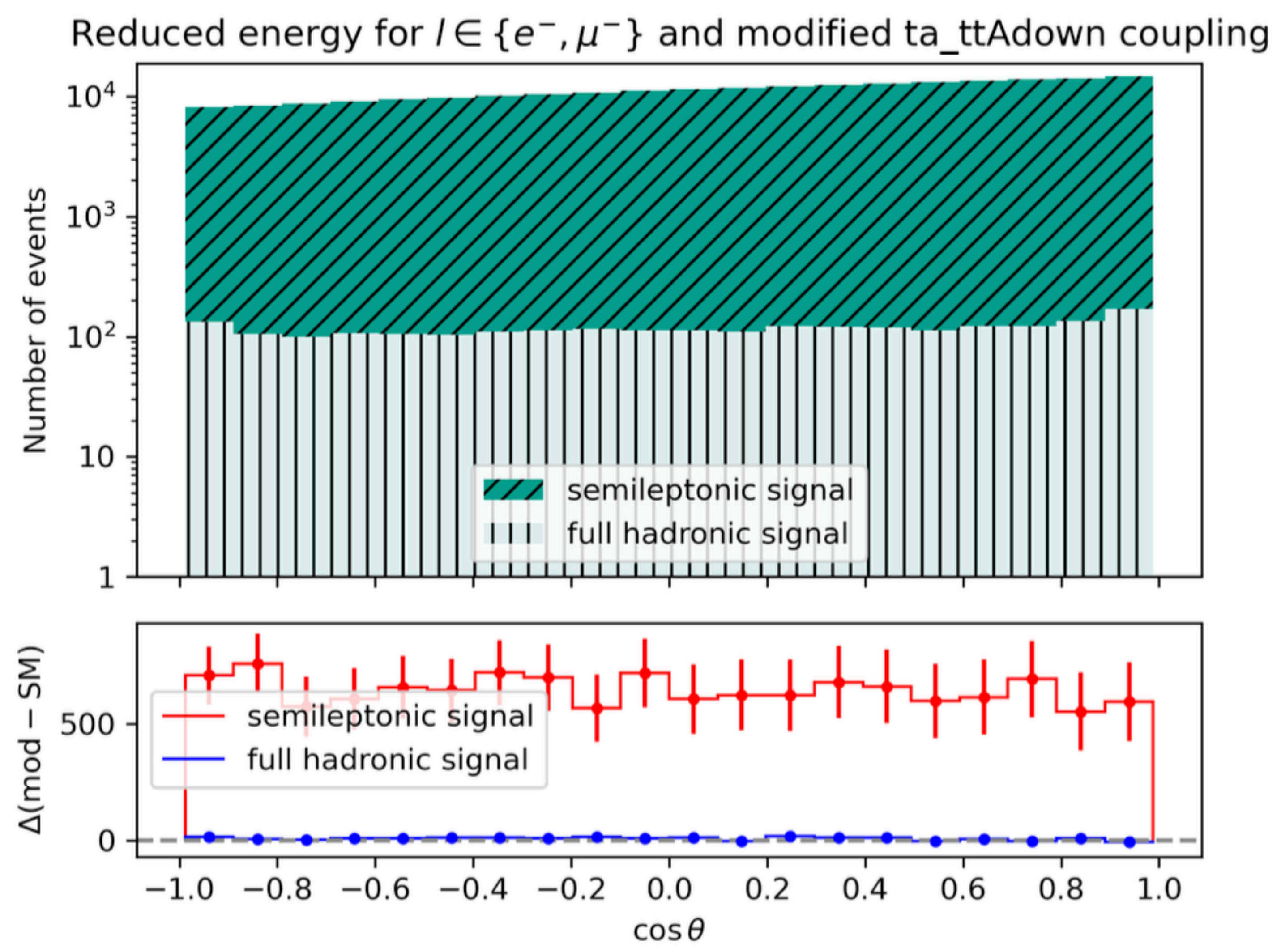
ta_ttA up variation





ta_ttA down variation

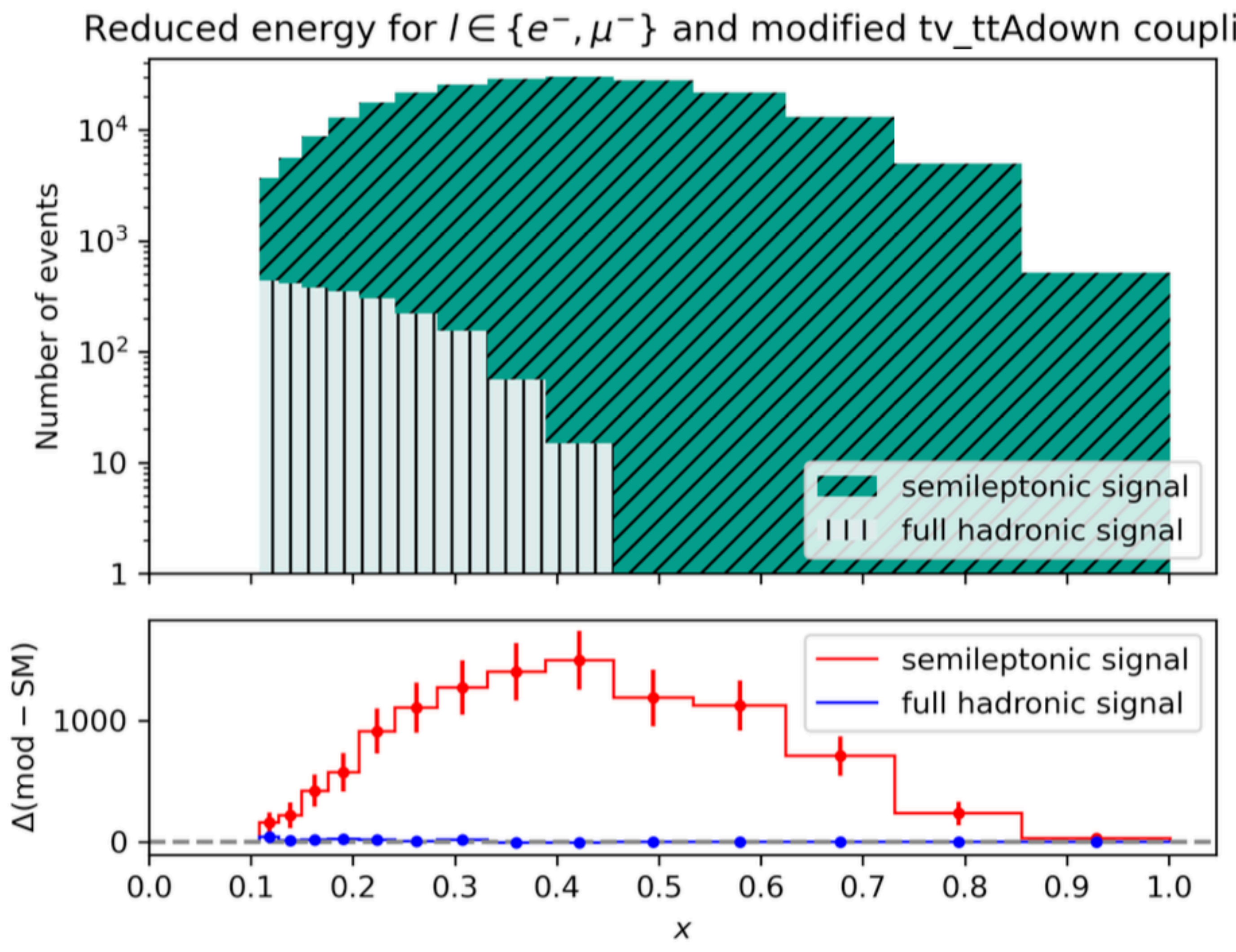


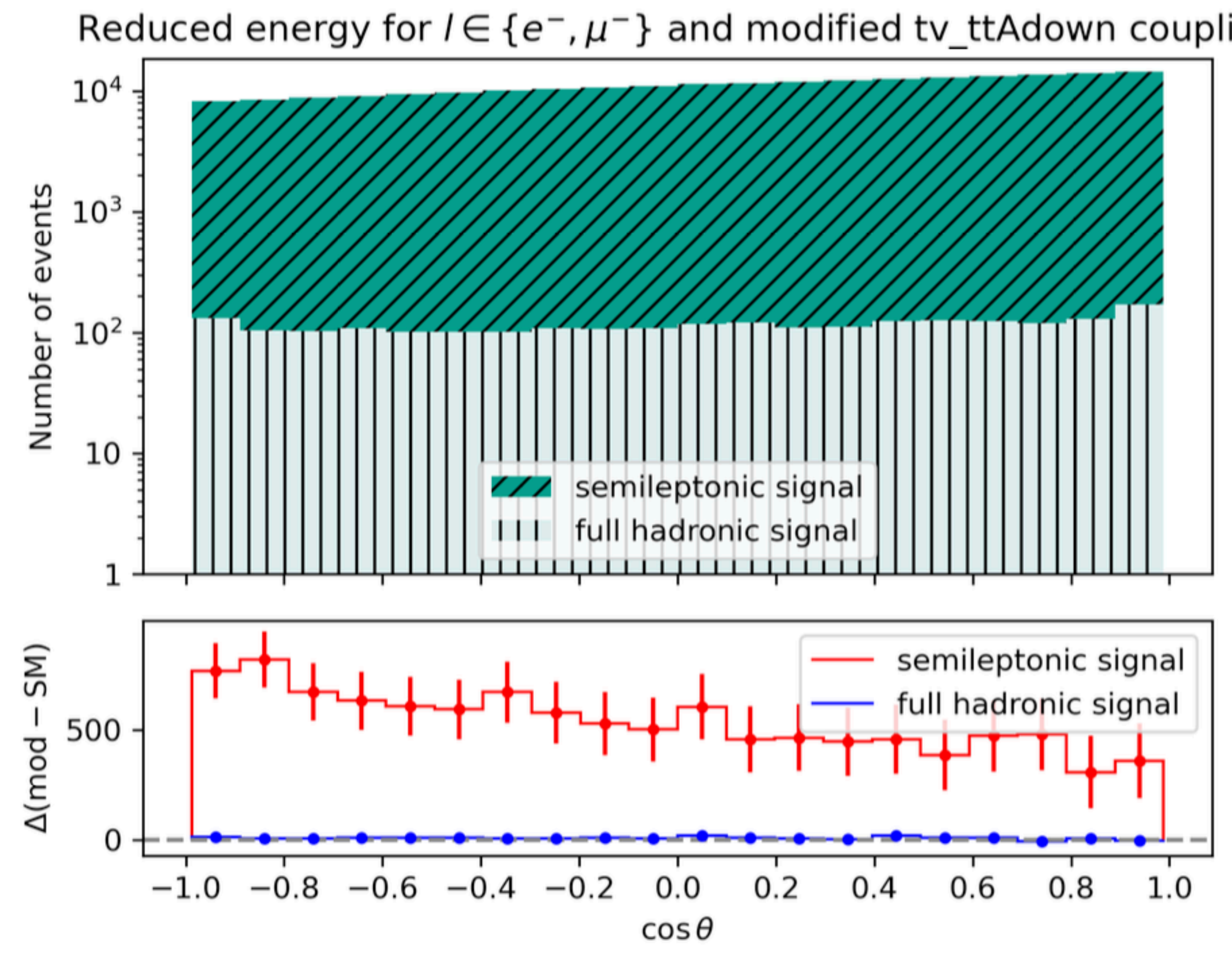


$x \propto E_l$ $\cos\theta$

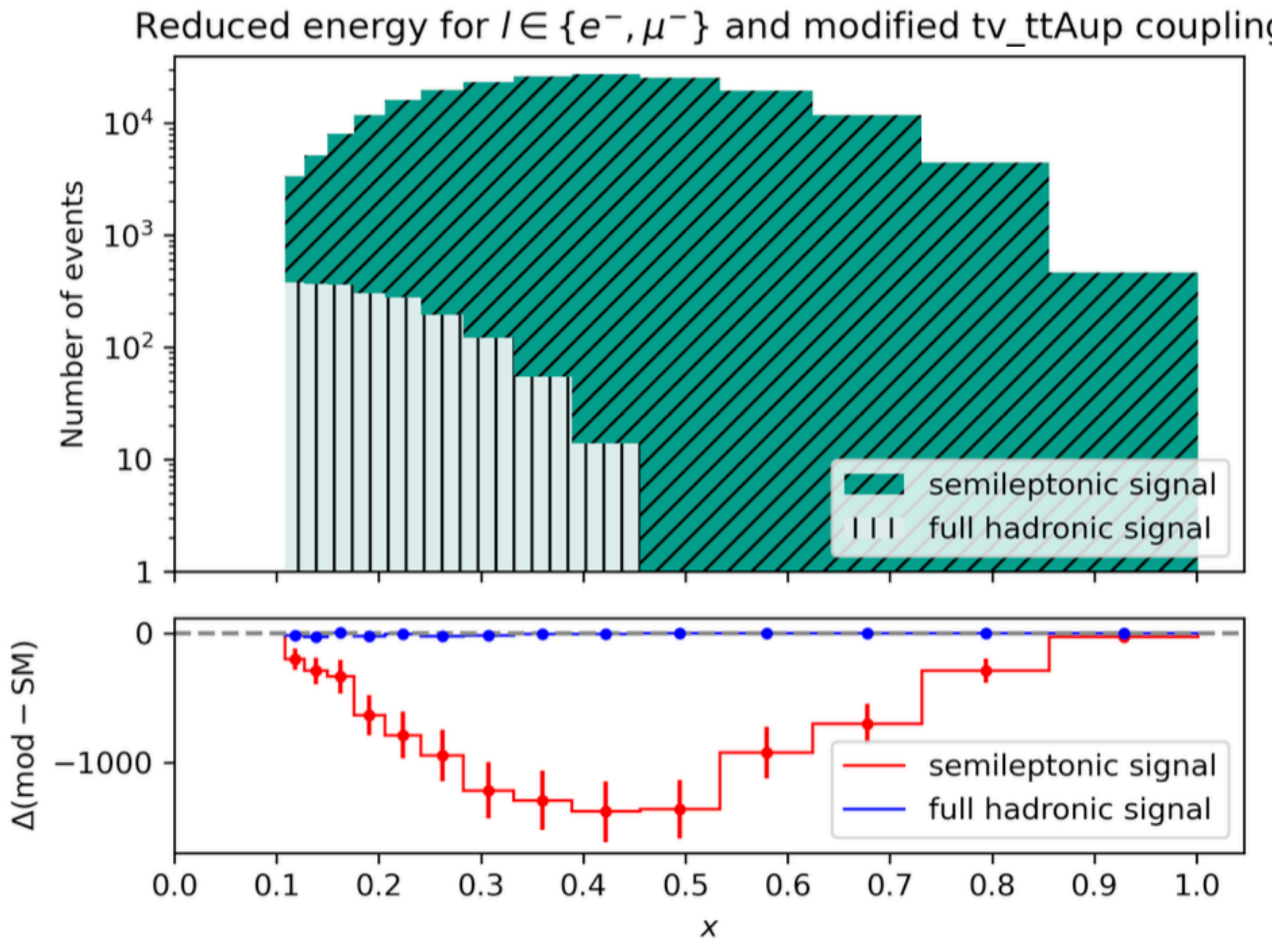
tv_ttA variation

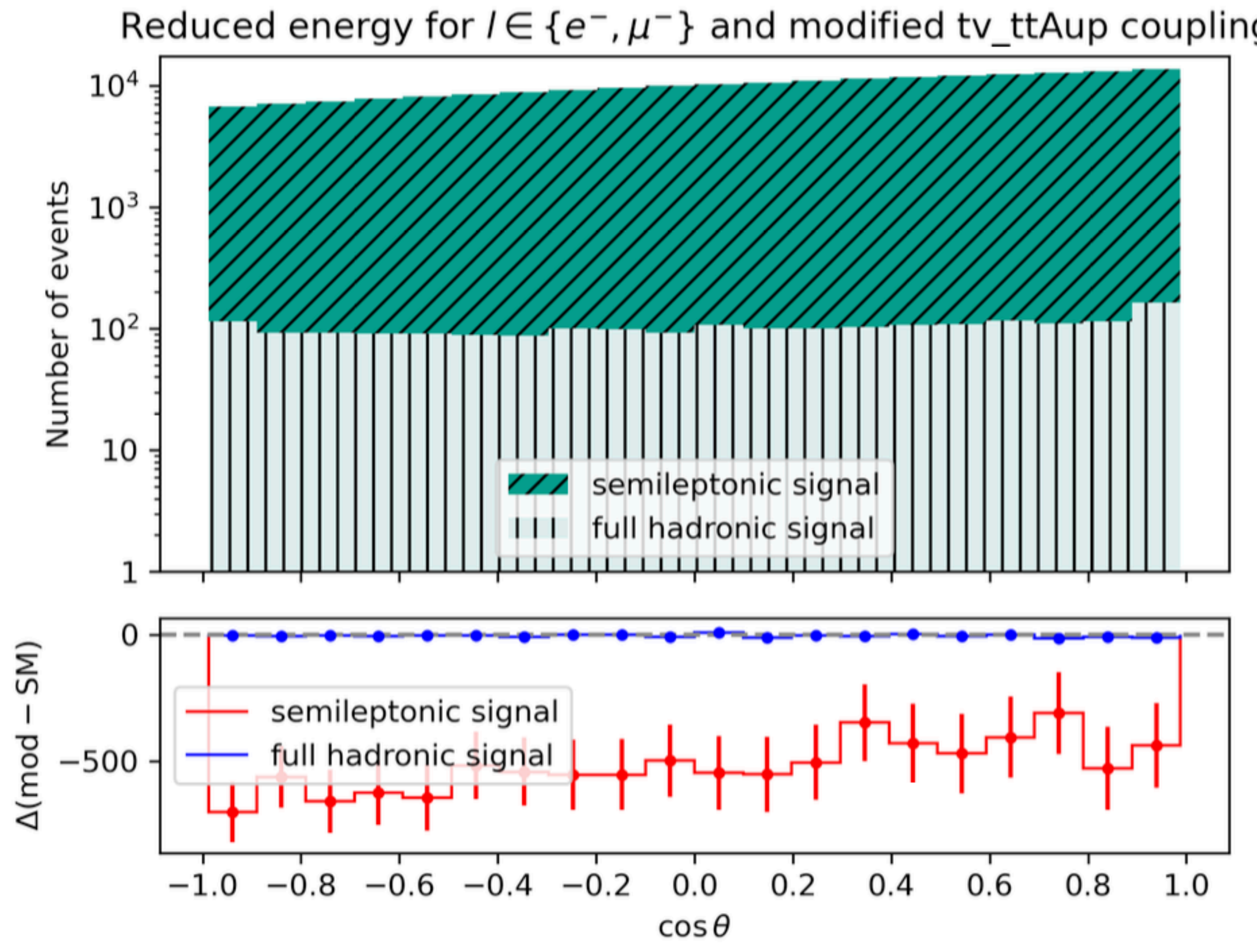
tv_ttA up variation





tv_ttA down variation

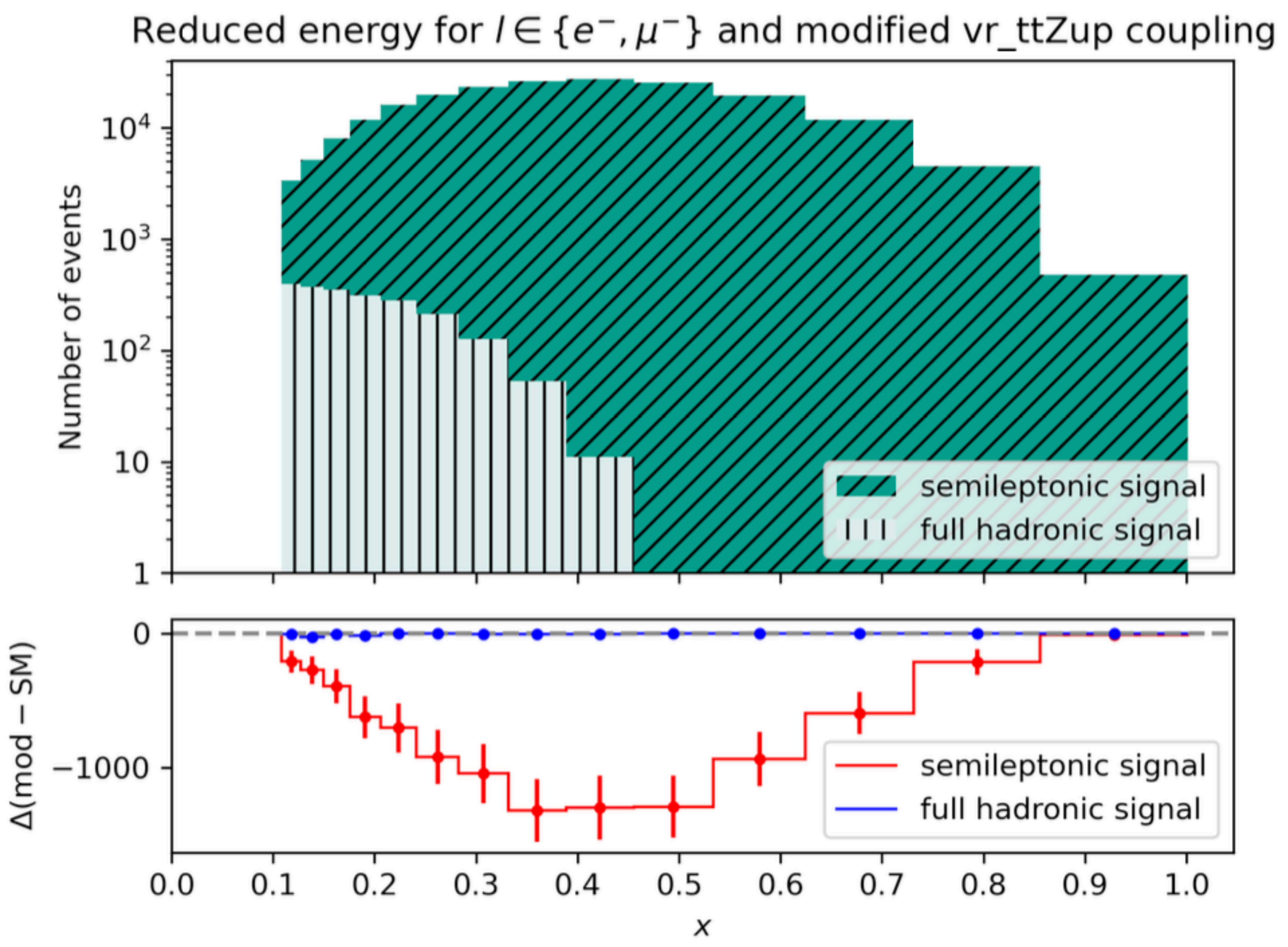


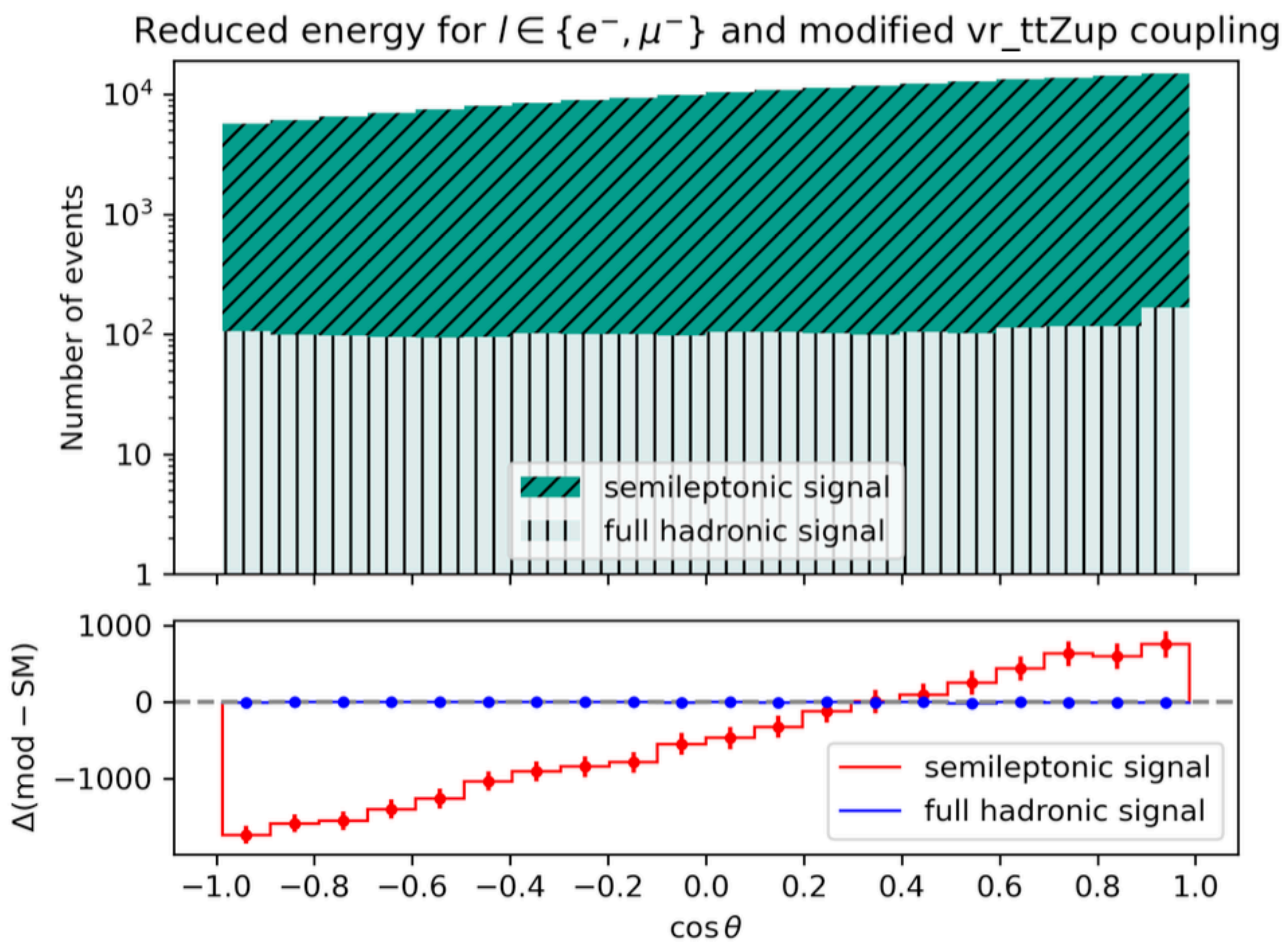


$x \propto E_l$ $\cos\theta$

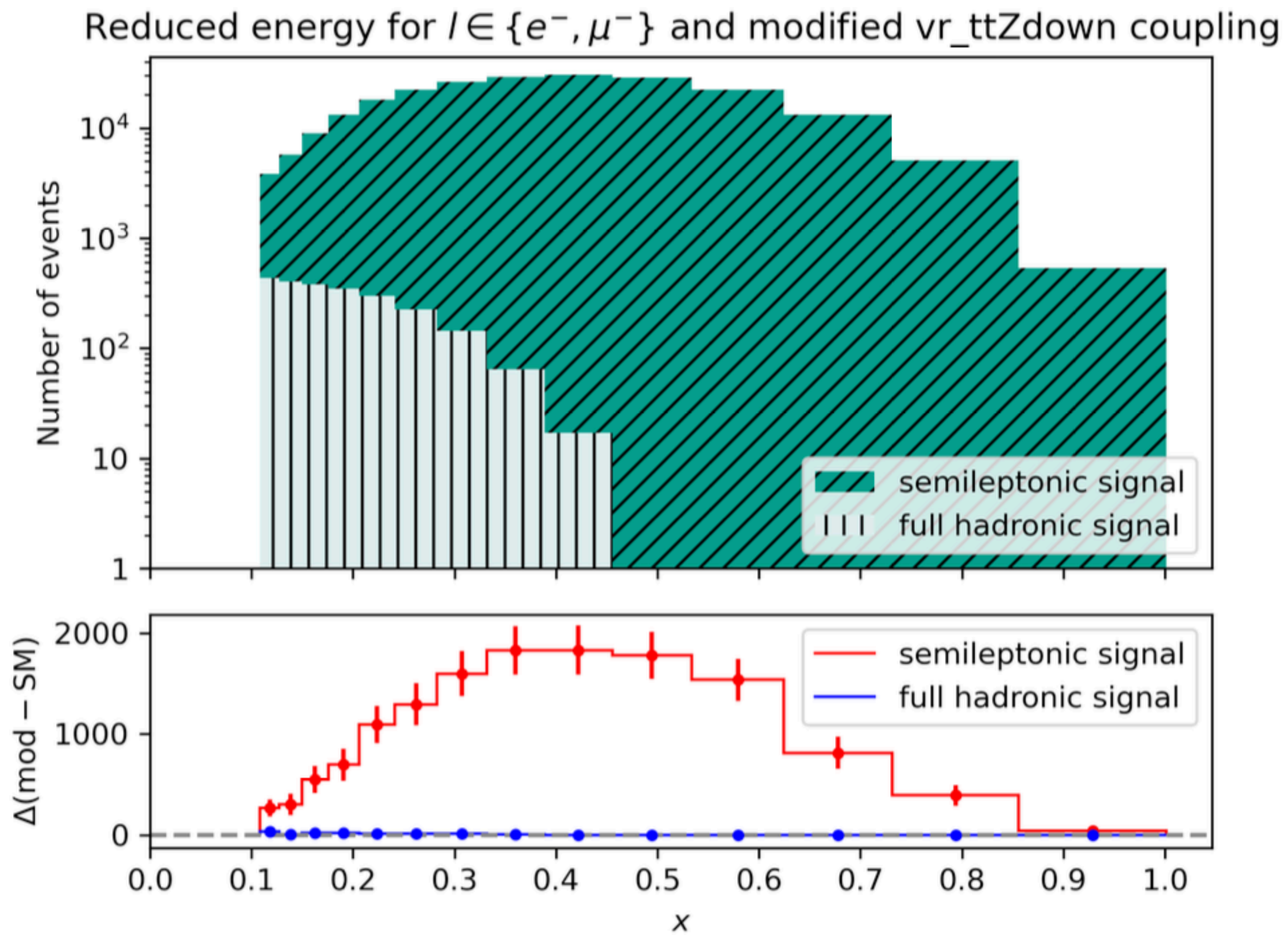
vr_ttZ variation

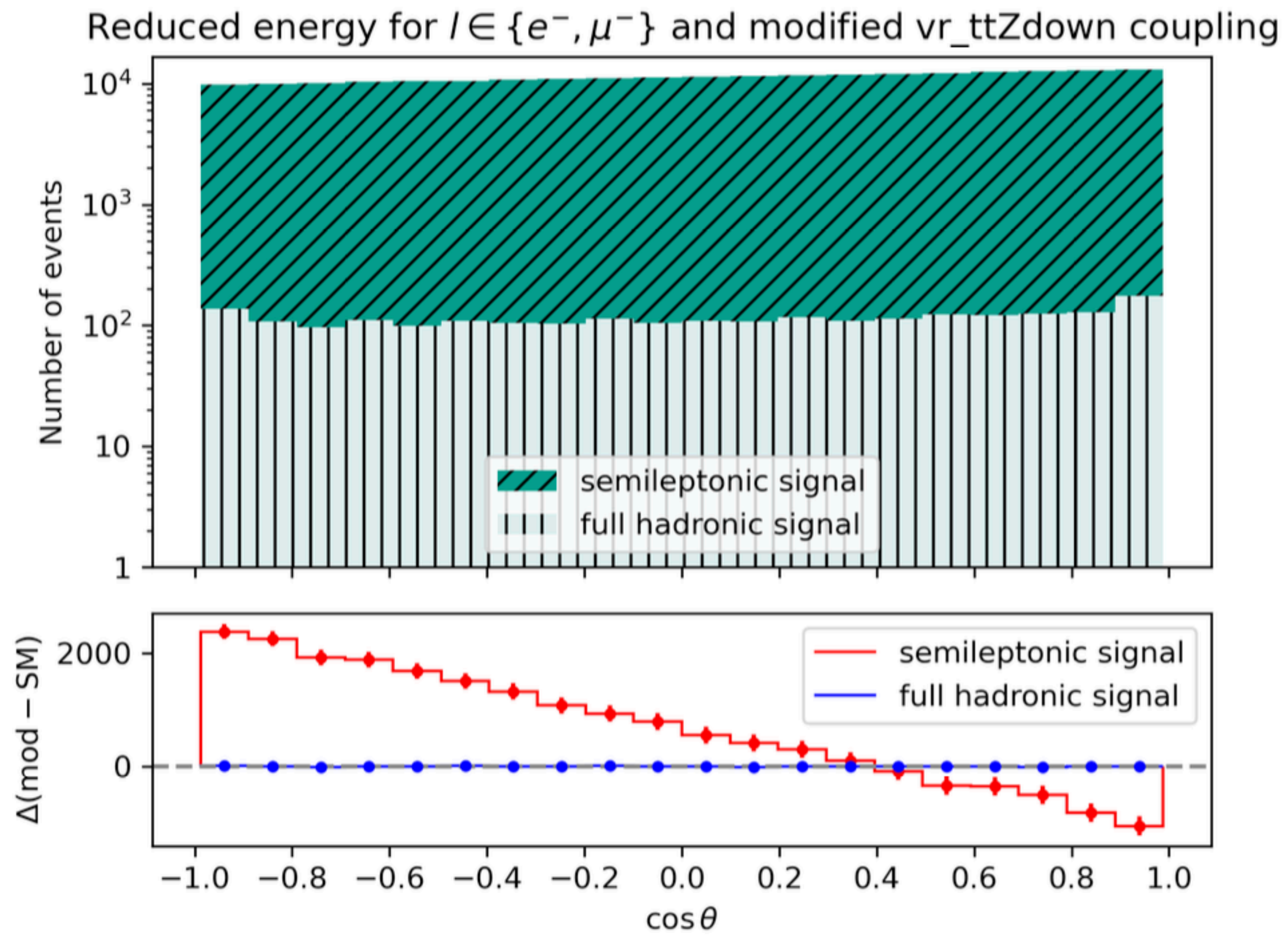
ta_ttA up variation





ta_ttA down variation





$x \propto E_l$ $\cos\theta$

Signal sensitivity

- Signal uncertainty extracted from binned chi^2 fit, assuming SM Asimov toy data
  - ta_ttA = $0.00^{+1.46\times10^{-2}}_{-1.40\times10^{-2}}$
  - tv_ttA = $0.00^{+4.20\times10^{-4}}_{-3.92\times10^{-4}}$
  - vr_ttZ = $0.00^{+3.86\times10^{-3}}_{-2.89\times10^{-3}}$
- Due to different parametrization, precisions not directly comparable to the ones in (10.1007/JHEP04(2015)182), except for one parameter

	WHIZARD framework		framework of [39]
F_{2V}^{γ}	-8.40×10^{-4}	$+7.85\times10^{-4}$	$\pm8.1\times10^{-4}$
F_{2A}^{γ}	2.91×10^{-2}	-2.81×10^{-2}	–

Discussions

- Performed data analysis with somewhat realistic experimental configuration
- Confirmed the sensitivity of FCC-ee to ttZ and ttγ coupling parameters
- In ballpark agreement with theory expectation in (10.1007/JHEP04(2015)182), albeit different parametrization
- Would be happy to hear suggestions from the theory community on the choice of parameter basis and how to compare them.

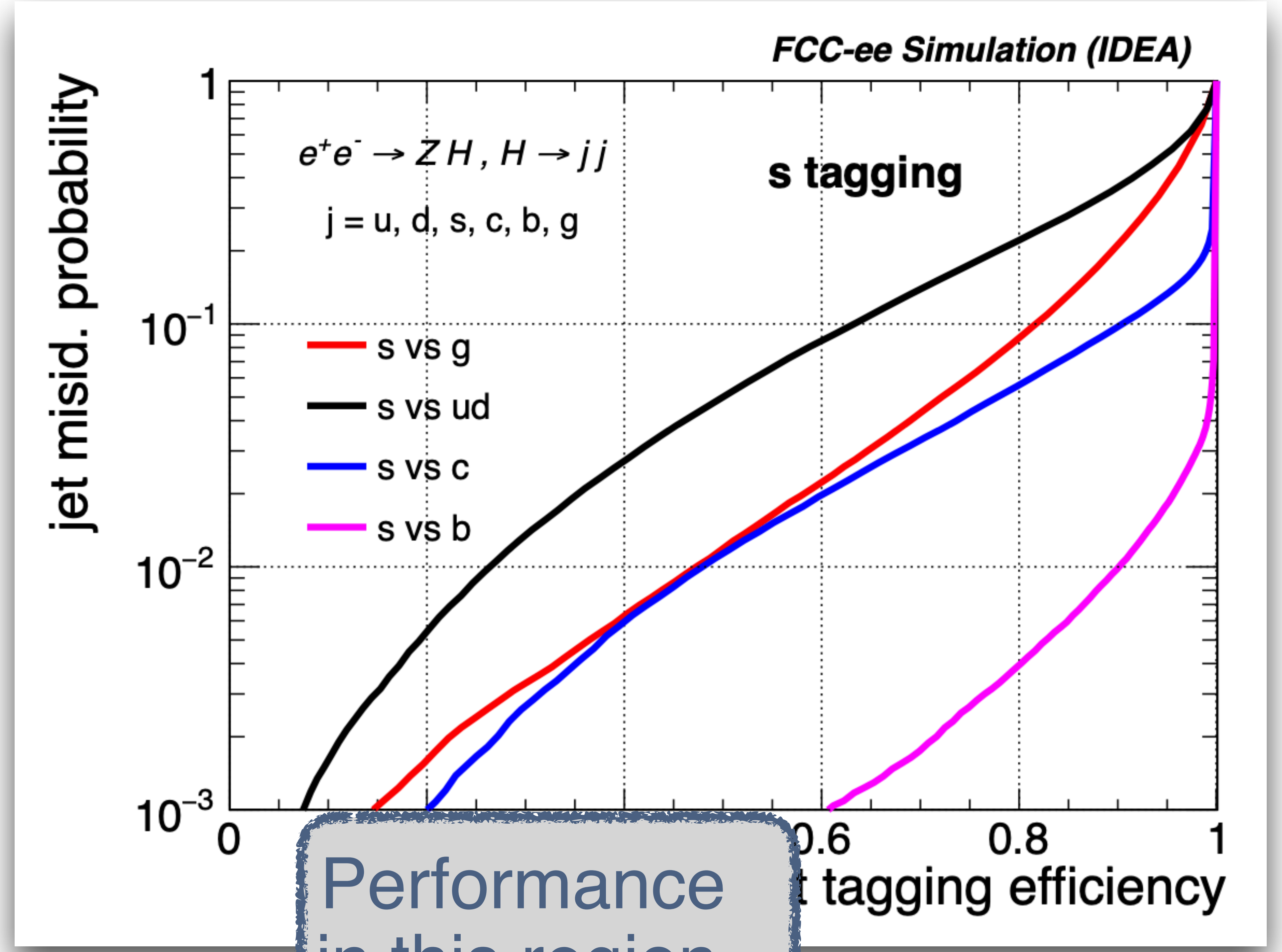
Probe of |Vts|

Context

- $t \to Ws$ decay as clean(est) probe of |Vts|
  - From PDG, $|V_{ts}| = (41.5 \pm 0.9) \times 10^{-3}$, measured from B_s mixing, dominated by theory uncertainty
  - $t \to Ws$ at FCC-ee is not going to have competitive precision, but it is free from theory inputs.

- Some basic numbers
  - $1.9 \times 10^6 \times 2 \times |V_{ts}|^2 \sim$ 6400 cases of $t \to Ws$
  - Assuming good s-tagging efficiency and correct reconstruction of W, still need b rejection below 0.1%

arxiv 2202.03285



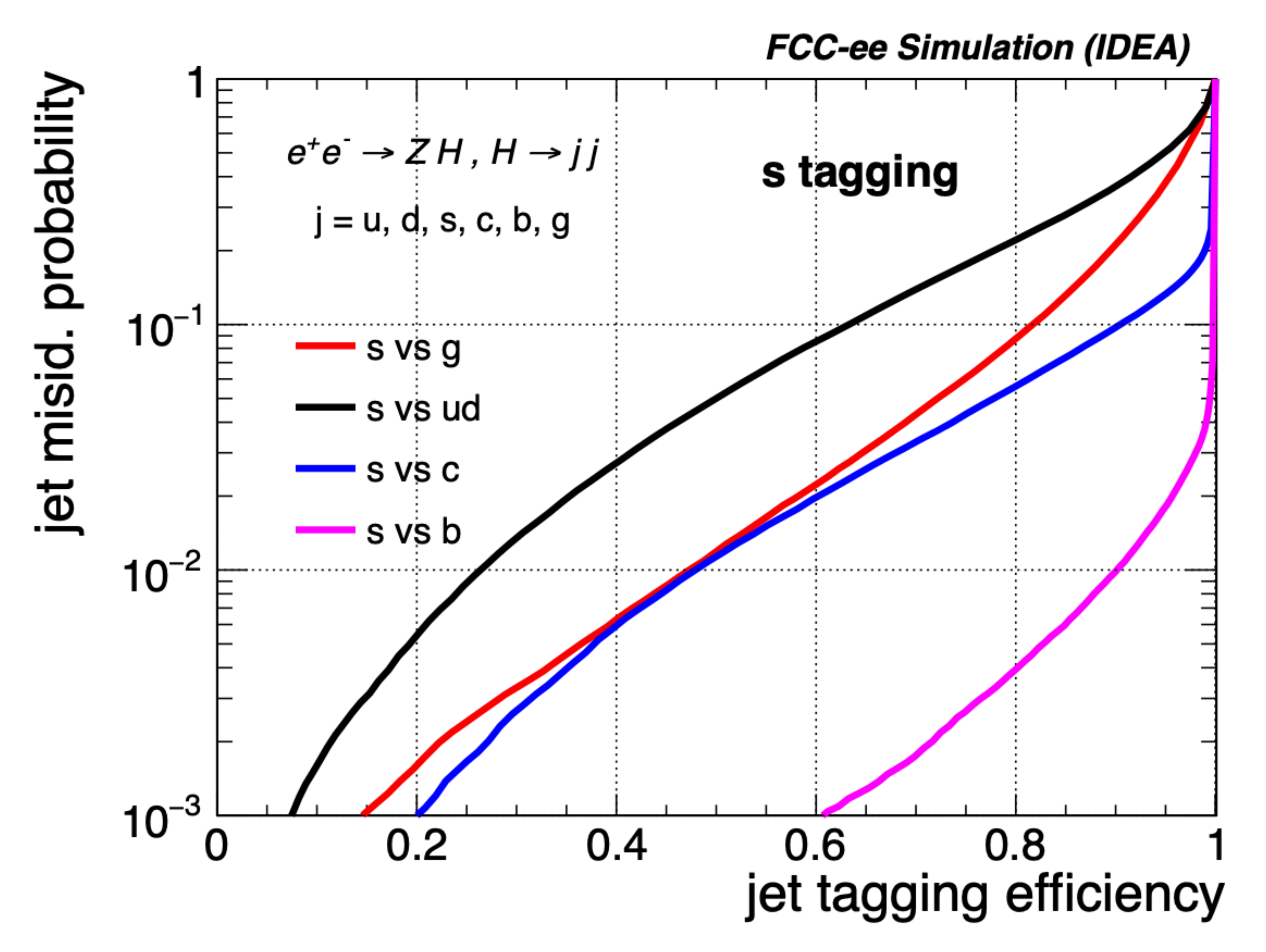
Performance in this region is crucial

s-tagging performance

- Training from arxiv 2202.03285
  - trained with $ZH \to \nu\nu jj$ events, with inclusive jets, R = 1.5
- Applied to $tt \to WWsb$ events, with different jet definitions
  - Exclusive (kt), njet = 2, 4, 6
  - Inclusive (anti-kt), R = 0.5, 1.0, 1.5

Very preliminary look, needs to be refined

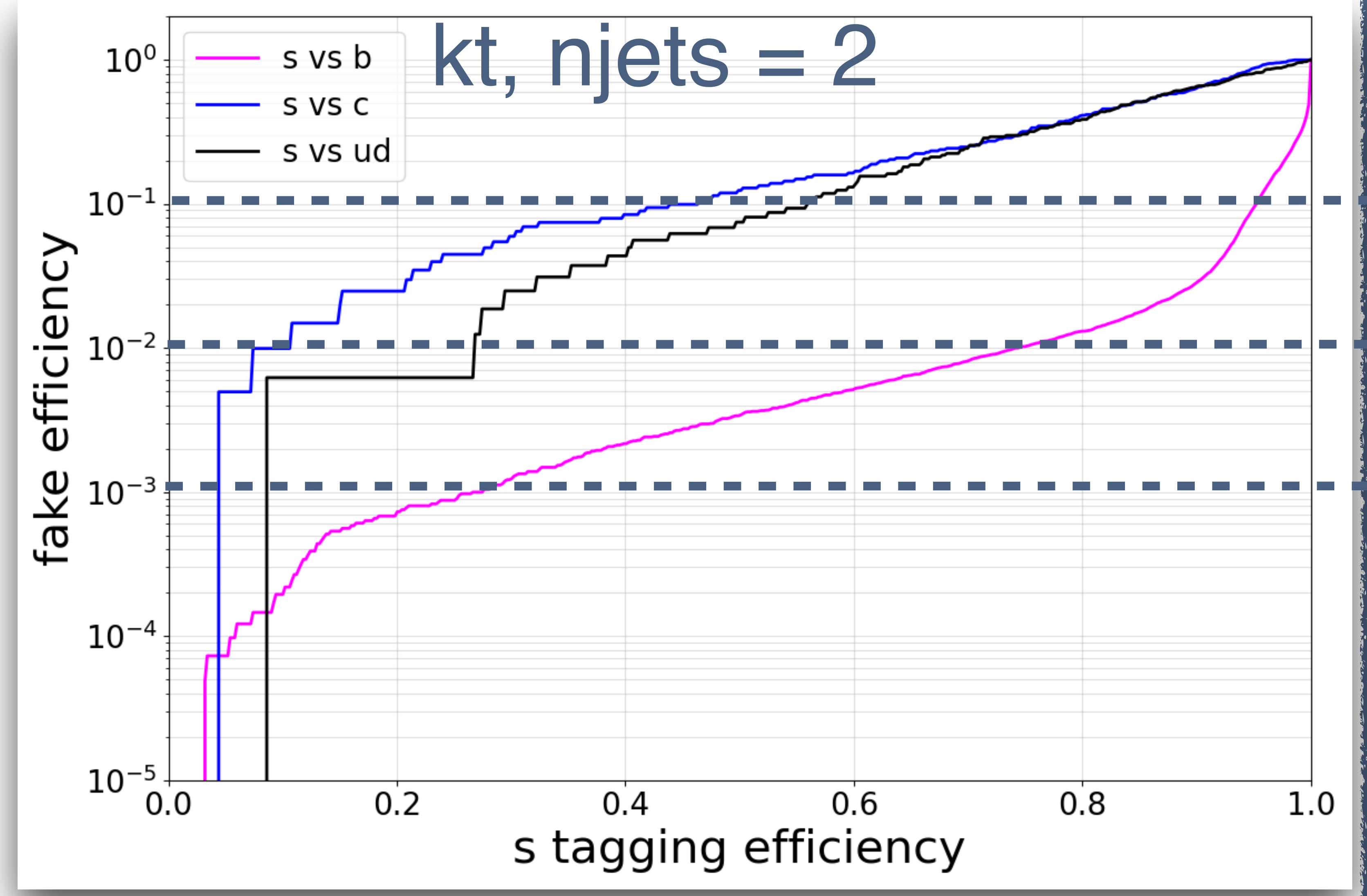
arxiv 2202.03285

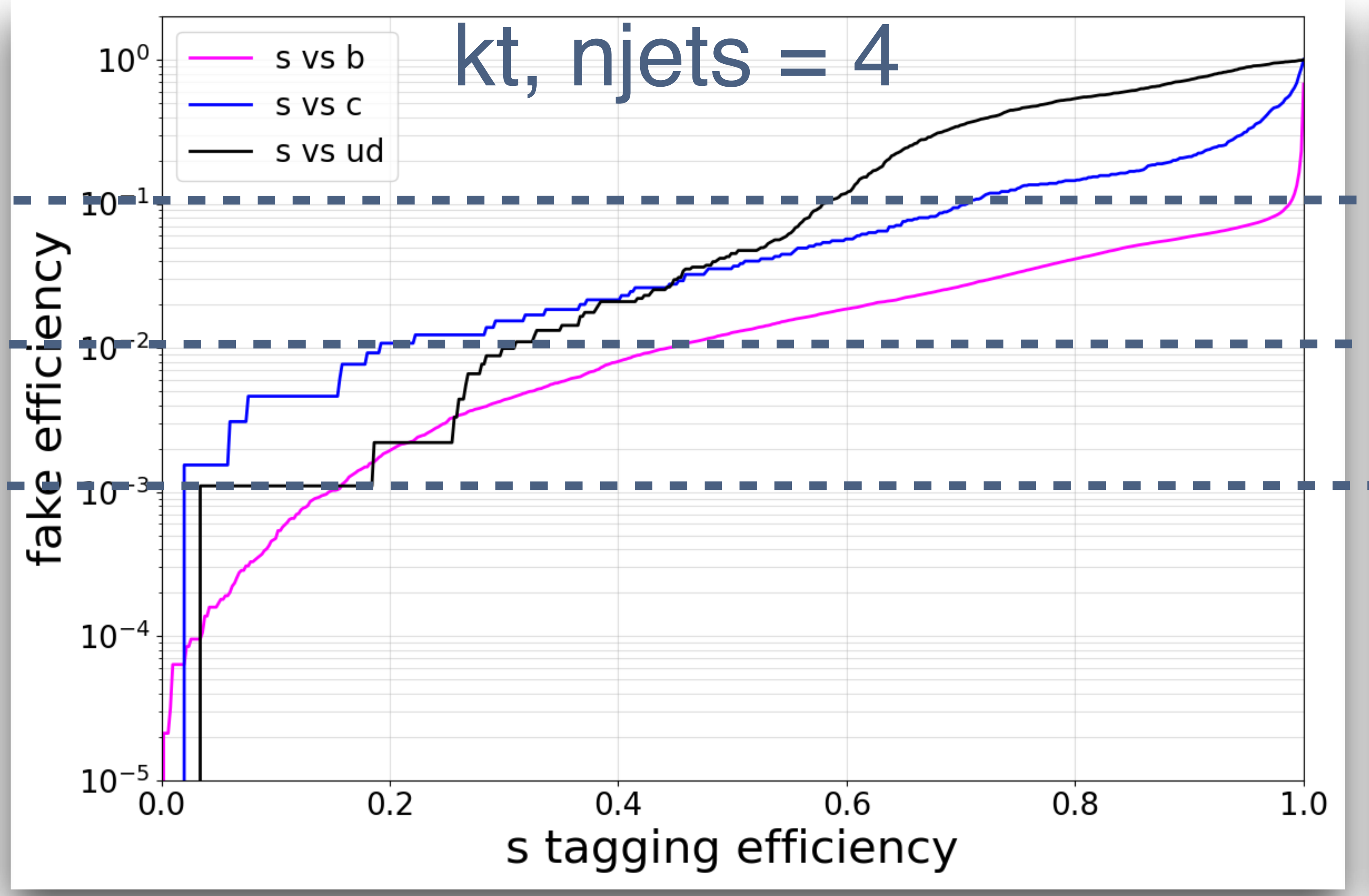


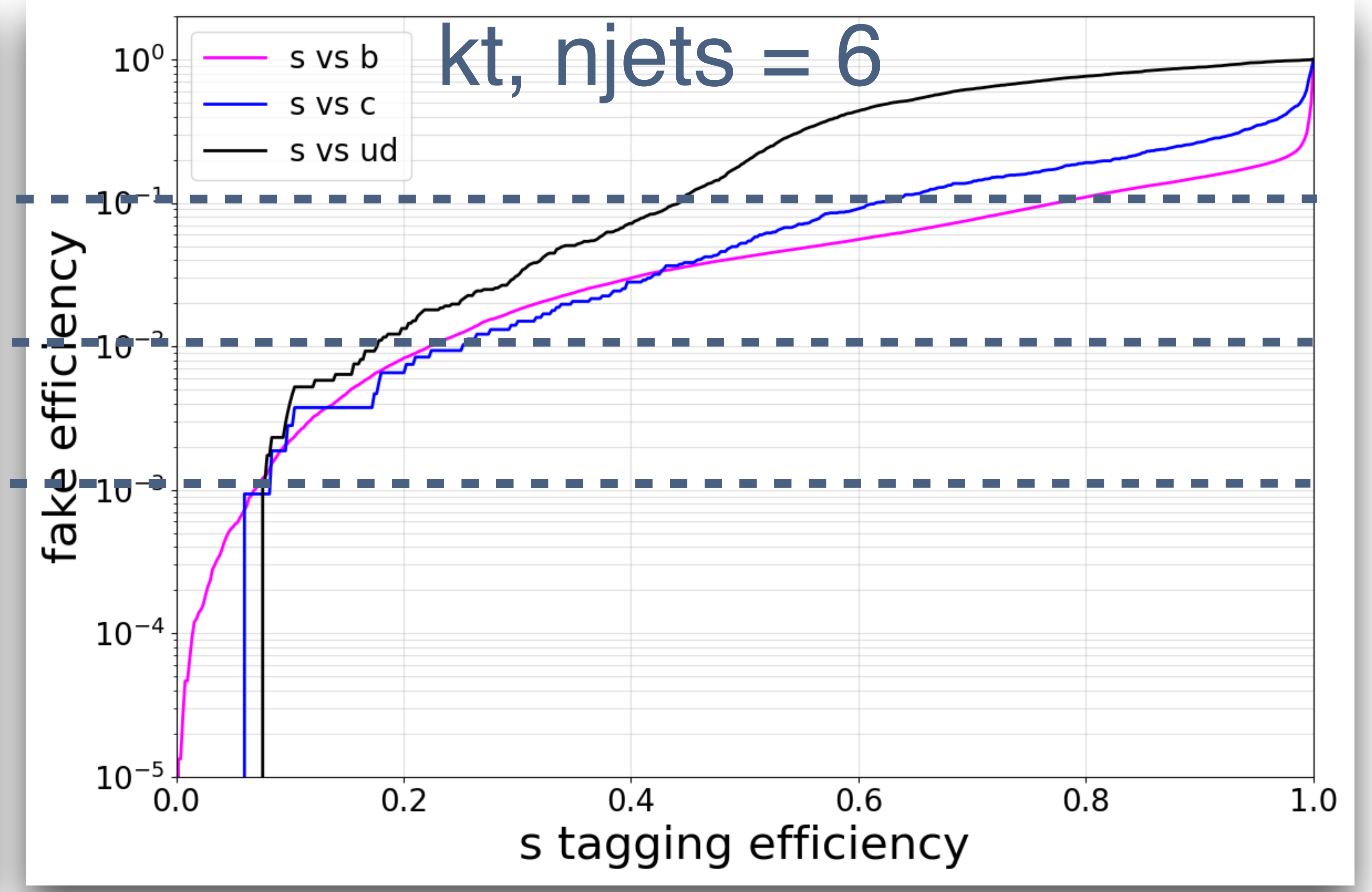
dileptonic events

- Compare exclusive clustering algo with different numbers of jets
- s-tagging performance is better if the jet reconstruction is more appropriate
- But not matching the performance from the training

correct jet assignment







semileptonic events

- Comparing inclusive clustering algo with different jet radii
- Performance with inclusive jets is in general better than those with exclusive jets
- Performance seems to be better with small R jets
  - Large jets may have multiple heavy-flavor constituents

Discussion

- No clear conclusion for the moment
- Further study on jet definition and flavor tagging performance for ttbar events
    - Synergy with other studies (involving ttbar reconstruction)

Backup

KIT group

- Group leader: Markus Klute
- Postdoc researchers: Jan Kieseler, Matteo Presilla, Xunwu Zuo
- PhD student: Sofia Giappichini
- Bachelor student: Lars Bogner, Simon Keilbach

Samples

All samples in winter2023 campaign,
Whizard ME + Pythia6 shower + Delphes IDEA simulation

SM t -> Wb samples

- wzp6_ee_SM_tt_tlepTlep_noCKMmix_keepPolInfo_ecm365
- wzp6_ee_SM_tt_thadThad_noCKMmix_keepPolInfo_ecm365
- wzp6_ee_SM_tt_tlepThad_noCKMmix_keepPolInfo_ecm365
- wzp6_ee_SM_tt_thadTlep_noCKMmix_keepPolInfo_ecm365

t -> Wb samples with **BSM EWK** couplings

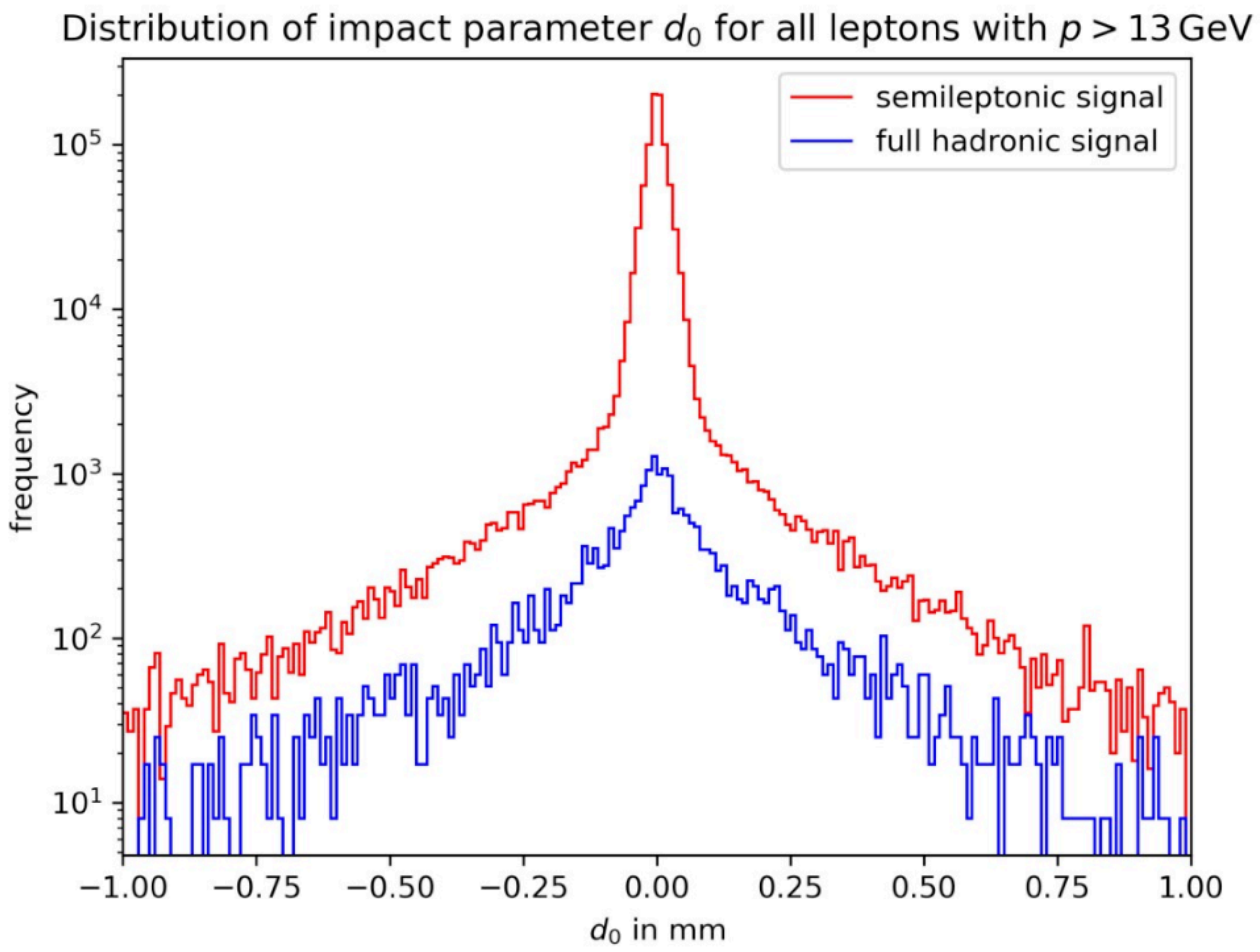
- wzp6_ee_SM_tt_tlepTlep_noCKMmix_keepPolInfo_{variation}_ecm365
- wzp6_ee_SM_tt_thadThad_noCKMmix_keepPolInfo_{variation}_ecm365
- wzp6_ee_SM_tt_tlepThad_noCKMmix_keepPolInfo_{variation}_ecm365
- wzp6_ee_SM_tt_thadTlep_noCKMmix_keepPolInfo_{variation}_ecm365

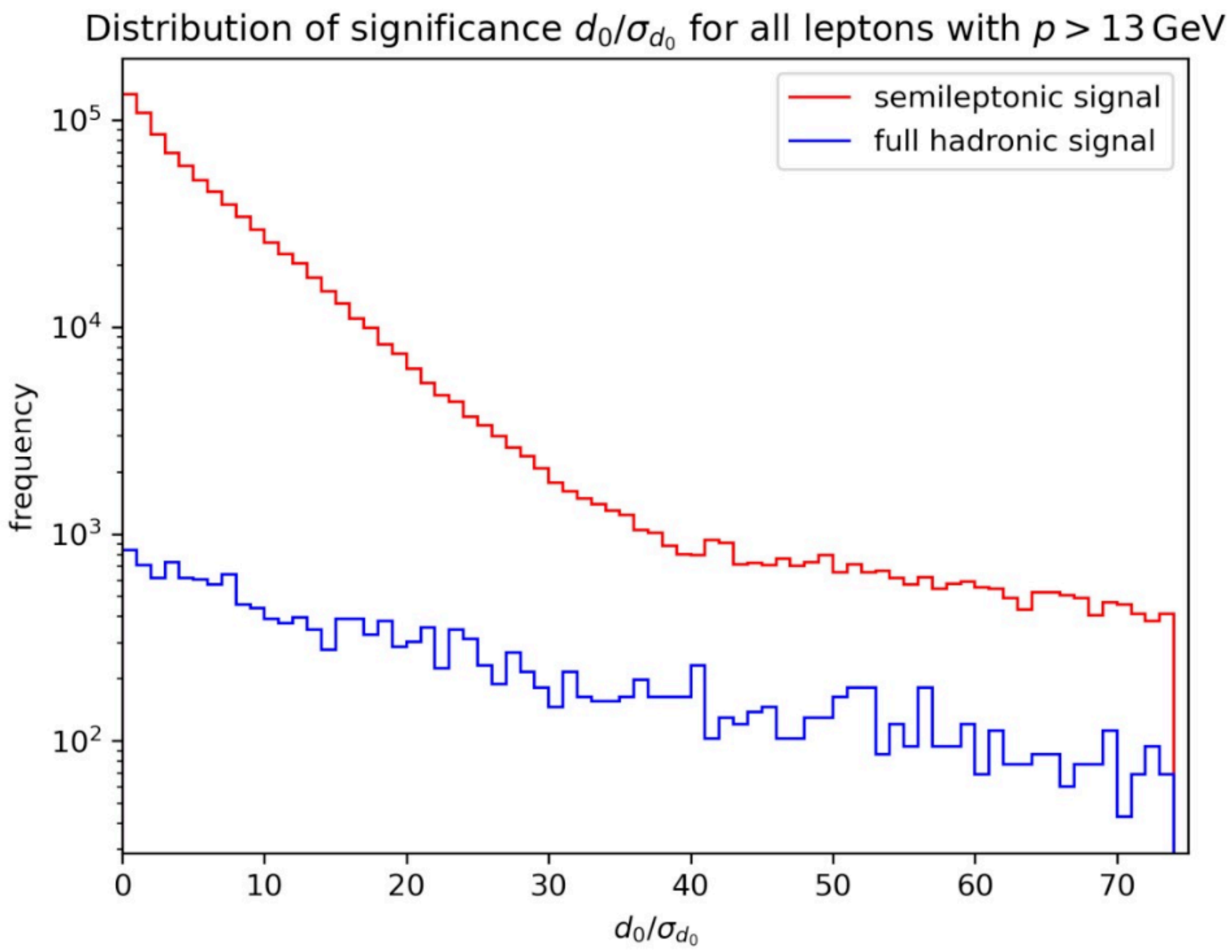
{variation} = ta_ttA, tv_ttA, vr_ttZ $\oplus$ up, down

SM samples with **t -> Ws** decay

- wzp6_ee_SM_tt_tWsTWb_tlepTall_ecm365
- wzp6_ee_SM_tt_tWsTWb_tlightTall_ecm365
- wzp6_ee_SM_tt_tWsTWb_theavyTall_ecm365
- wzp6_ee_SM_tt_tWbTWs_tallTlep_ecm365
- wzp6_ee_SM_tt_tWbTWs_tallTlight_ecm365
- wzp6_ee_SM_tt_tWbTWs_tallTheavy_ecm365

prompt vs nonprompt leptons





Signal efficiency and purity

- $\epsilon = \frac{S}{S_{\text{tot}}}$ (efficiency)
- $\pi = \frac{S}{S+B}$ (purity)

	semileptonic		full hadronic	
	ϵ [%]	π [%]	ϵ [%]	π [%]
$n_{\text{leptons}} > 0$	97.486 ± 0.017	69.212 ± 0.027	42.029 ± 0.053	30.789 ± 0.004
$\not{E} > 23$ GeV	95.686 ± 0.022	92.602 ± 0.026	7.409 ± 0.028	7.398 ± 0.002
$p_{\text{lead}} > 13$ GeV	94.035 ± 0.026	97.139 ± 0.018	2.684 ± 0.017	2.861 ± 0.001
PV selection	47.083 ± 0.055	98.886 ± 0.017	0.514 ± 0.008	1.114 ± 0.001

dihadronic events

- Compare exclusive clustering algo with different numbers of jets
- s-tagging performance is better if the jet reconstruction is more appropriate
  - s vs u,d,c is better for nets = 6, while s vs b is only better in high efficiency part
- But not matching the performance from the training

correct jet assignment

semileptonic events

- Compare exclusive clustering algo with different numbers of jets
- s-tagging performance is better if the jet reconstruction is more appropriate
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correct jet assignment