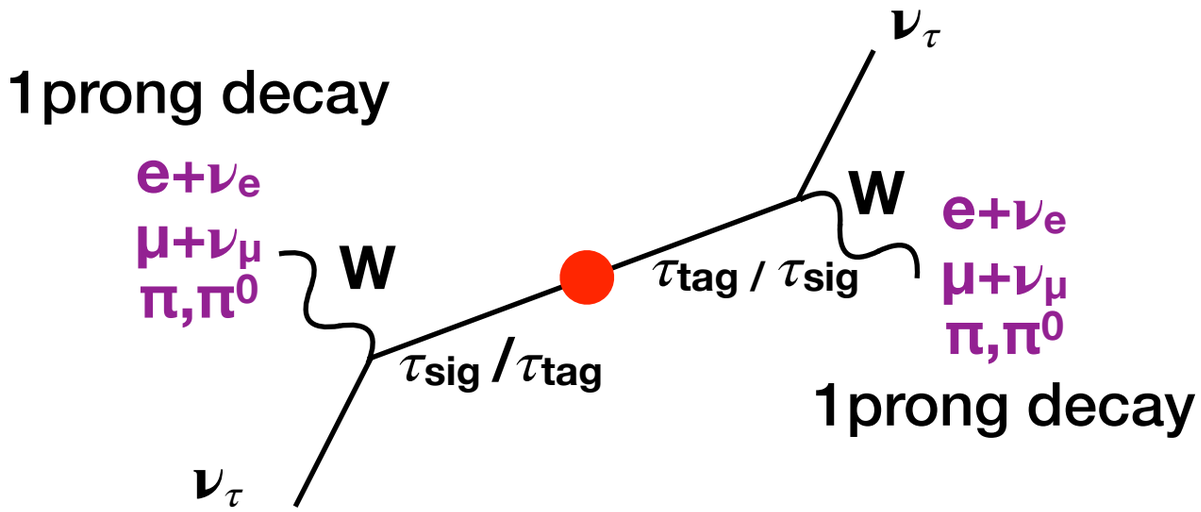
Status of L1 trigger for the τ group

Alberto Martini — DESY

Trigger workshop, 29 Nov. - 2 Dec. 2022

Studied τ topologies: features

tau1x1



Pure leptonic cases:

Expected 2 ~back-to-back cluster energy

Missing energy

Very similar to bhabhas

Hadronic cases:

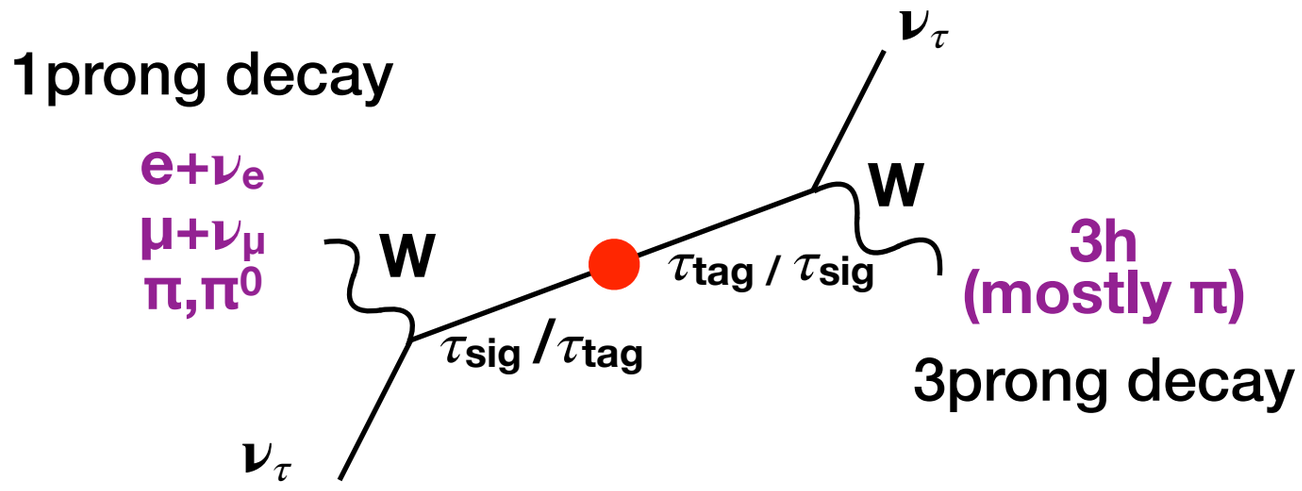
Expected at least 1 ~back-to-back cluster energy pair

Missing energy

Possibly >2 clusters

Similar to bhabhas

tau3x1



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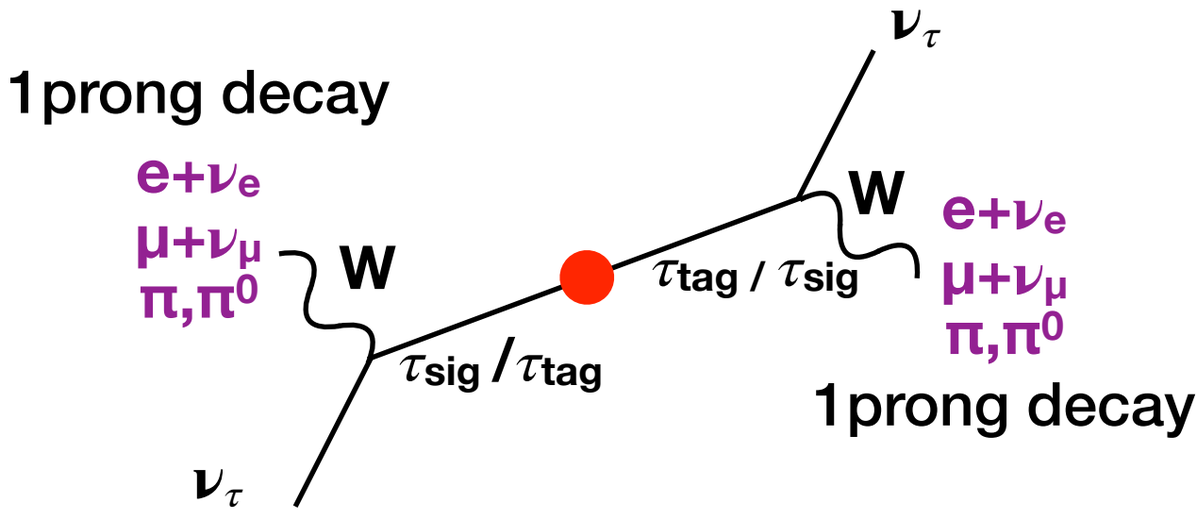

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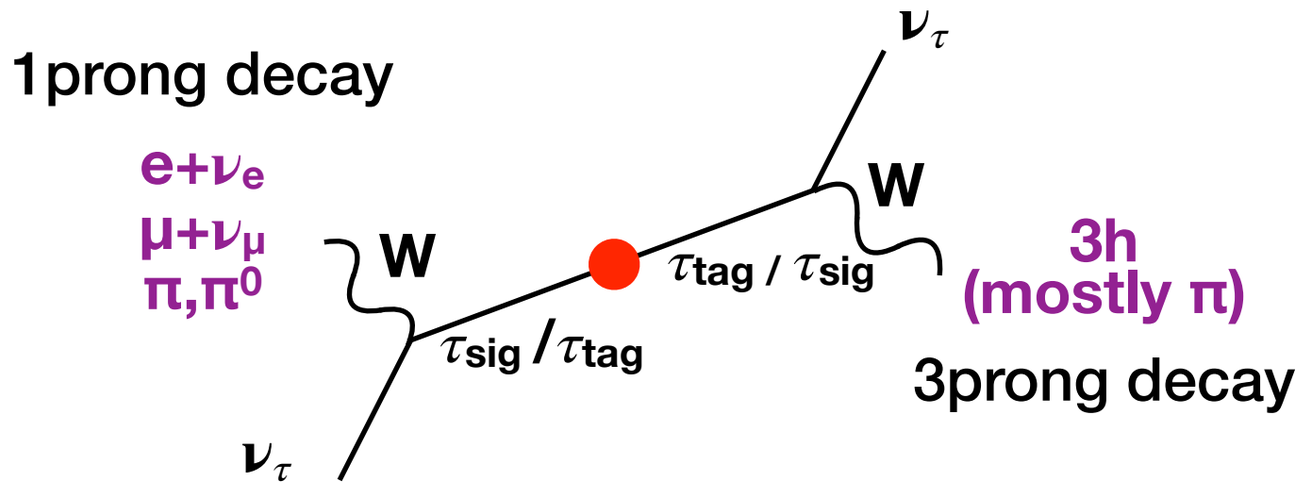

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Usable bits used for τ physics

Reference detector	Name	Definition	Topology(ies)
CDC	**ffy** **fyo** **syo** **stt**	Different combinations of track based triggers. Pro: very effective with all different topologies Cons: high performances restricted to the CDC only acceptance → generally not good in the endcaps	**tau3x1** **tau3x1+tau1x1** **tau3x1+tau1x1** **tau3x1+tau1x1**
ECL	**c4** **hie** **lml**	Different combinations of number of clusters and energy deposited. Pro: useful for specific topologies and coverage of endcaps regions Cons: very poor for specific topologies	**tau3x1** **tau3x1+tau1x1** **tau3x1+tau1x1**
CDC-KLM + KLM	**cdc_klm** **mu_b2b** **mu_eb2b** **eklm2** **beklm**	Geometrical combinations of signals identified in the KLM, some with CDC matching. Pro: good for muons Cons: High rate for line that only target muons	**tau3x1+tau1x1** **tau1x1** **tau1x1** **tau1x1** **tau1x1**

Usable bits used for τ physics

Reference detector	Name	Definition	Topology(ies)
CDC	**ffy**	#full trk>=3, |z|<20cm	**tau3x1**
	fyo	#full trk>=2, $\Delta\phi$>90°, |z|<20cm	**tau3x1+tau1x1**
	syo	#full trk>=1 + #short trk>=1, $\Delta\phi$>90°, |z|<15cm	**tau3x1+tau1x1**
	stt	#full tracks>=1, |z|<15cm, p>0.7GeV	**tau3x1+tau1x1**
ECL	**c4**	#CL >=4, 18.5° < θ_{LAB} < 129.5°	**tau3x1**
	hie	Total E>1GeV, 18.5° < θ_{LAB} < 139.3°	**tau3x1+tau1x1**
	lml	lml are defined in backup slide here	**tau3x1+tau1x1**
CDC-KLM + KLM	**cdc_klm**	#full/short trk matching in KLM-Barrel/endcap>=1	**tau3x1+tau1x1**
	mu_b2b	back-to-back matching in KLM-Barrel sectors	**tau1x1**
	mu_eb2b	back-to-back matching in KLM-Endcap sectors	**tau1x1**
	eklm2	Endcap KLM sectors >=2	**tau1x1**
	beklm	Endcap-KLM sectors >=1 + Barrel-KLM sectors >=1	**tau1x1**

Efficiency evaluation

Standard performance studies:

$$\varepsilon_{\mathrm{CDC-trigger}} = \frac{(\mathrm{hie\ or\ lmlX})\ \&\ \mathrm{CDC-trigger}}{\mathrm{hie\ or\ lmlX}}$$

$$\varepsilon_{\mathrm{KLM-trigger}} = \frac{(\mathrm{hie\ or\ lmlX})\ \&\ \mathrm{KLM-trigger}}{\mathrm{hie\ or\ lmlX}}$$

$$\varepsilon_{\mathrm{ECL-trigger}} = \frac{(\mathrm{ffy\ or\ fyo\ or\ stt})\ \&\ \mathrm{ECL-trigger}}{\mathrm{ffy\ or\ fyo\ or\ stt}}$$

stt could have larger efficiency since we might lost events with tracks in the endcaps

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stt could have larger efficiency since we might lost events with tracks in the endcaps

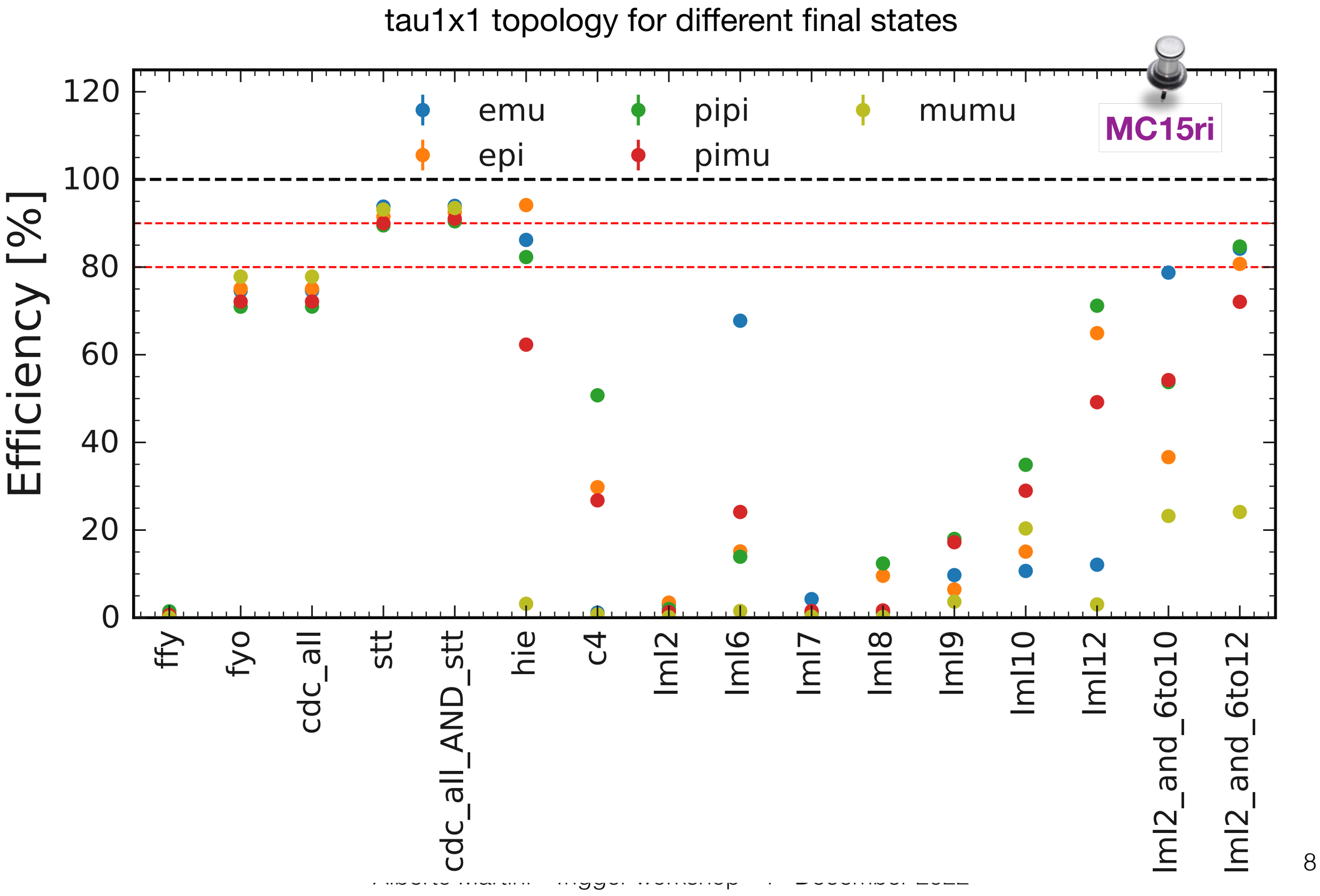
Absolute efficiency studies:

$$\varepsilon_{\mathrm{CDC-trigger}} = \frac{\mathrm{CDC-trigger}}{\mathrm{Initial\ events}}, \qquad \varepsilon_{\mathrm{KLM-trigger}} = \frac{\mathrm{KLM-trigger}}{\mathrm{Initial\ events}}$$

$$\varepsilon_{\mathrm{ECL-trigger}} = \frac{\mathrm{ECL-trigger}}{\mathrm{Initial\ events}}$$

Important caveat:
this is made on MC only, as soon as we consider TSIM reliable

Standard performance studies: tau1x1



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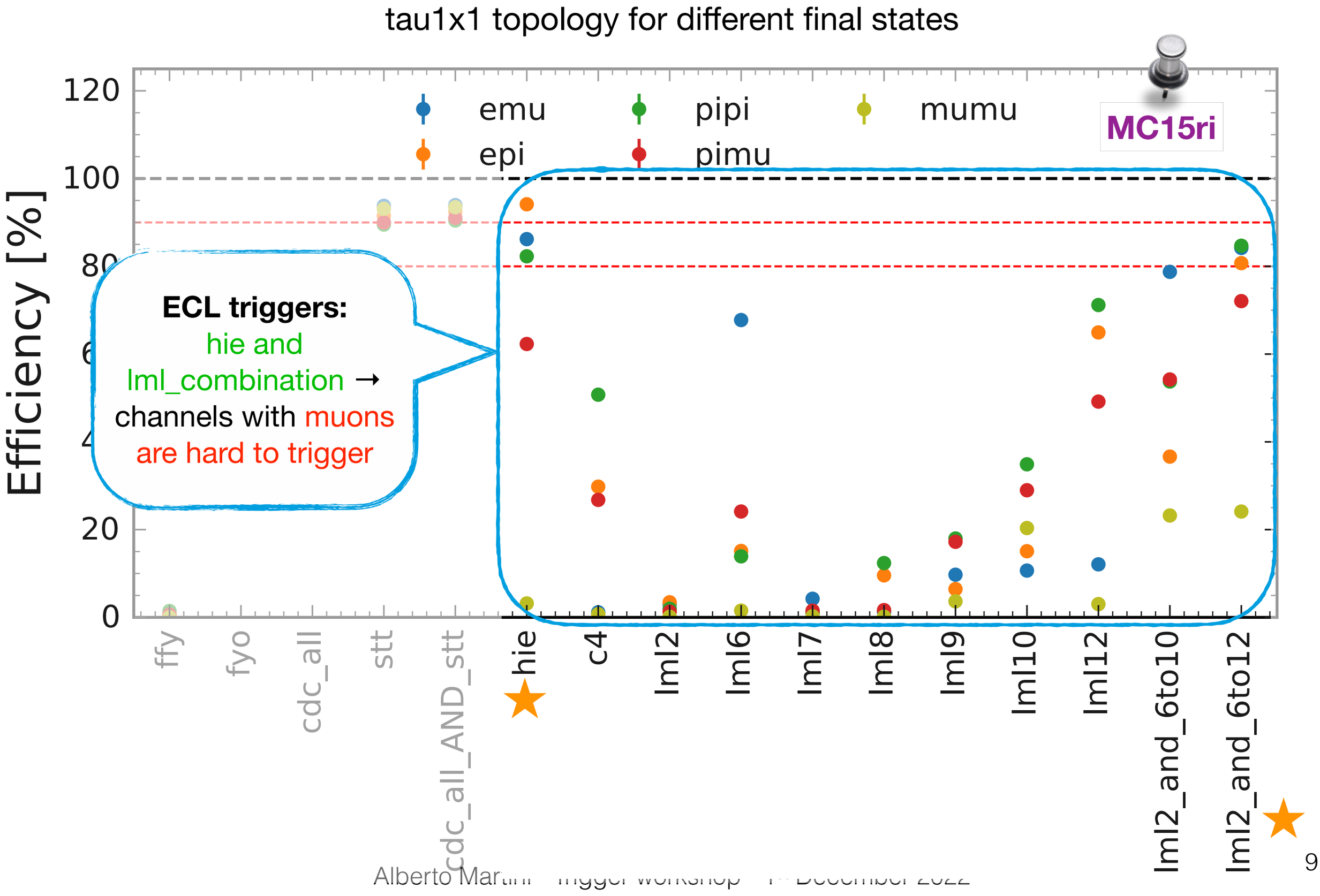

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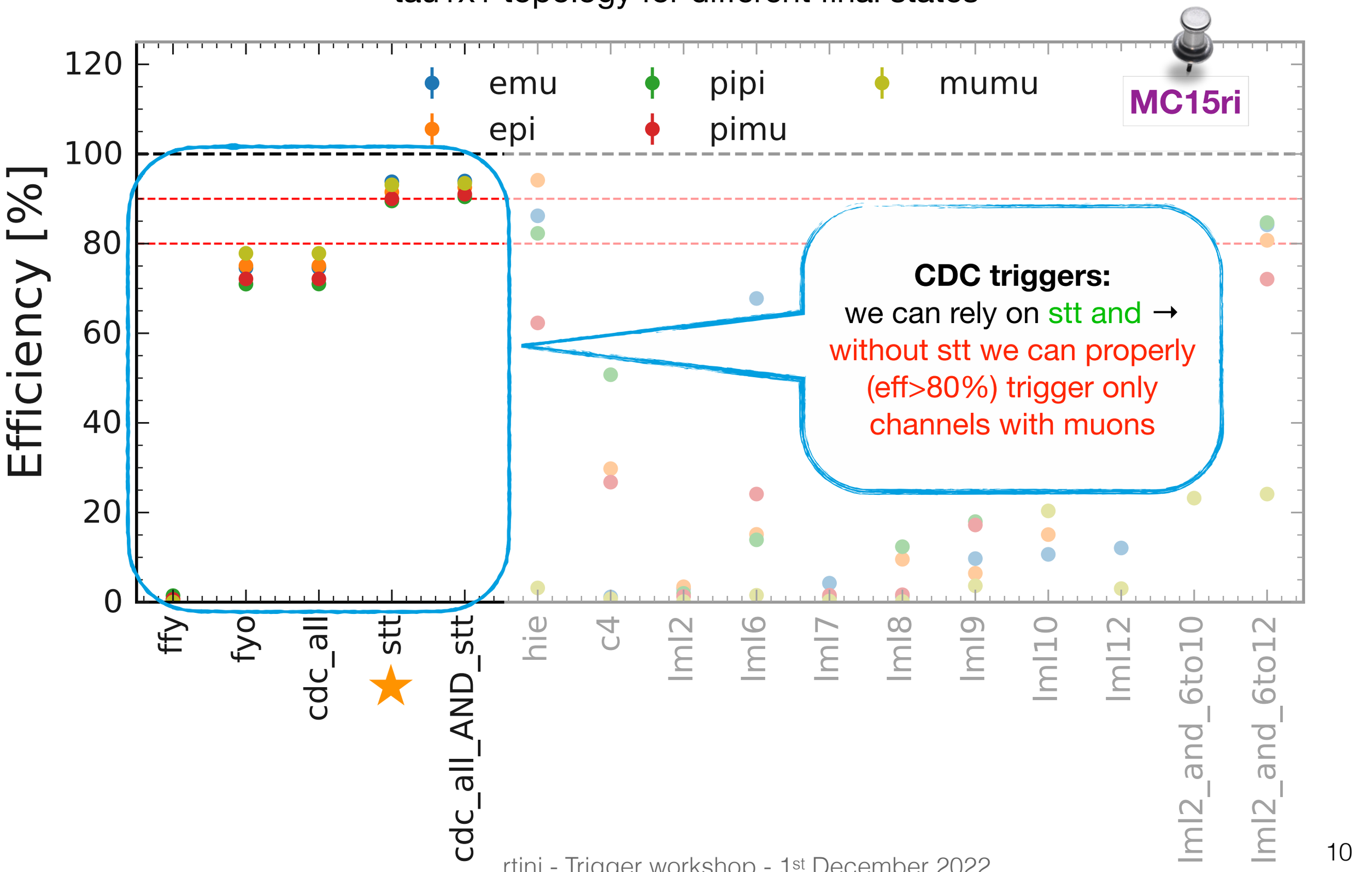
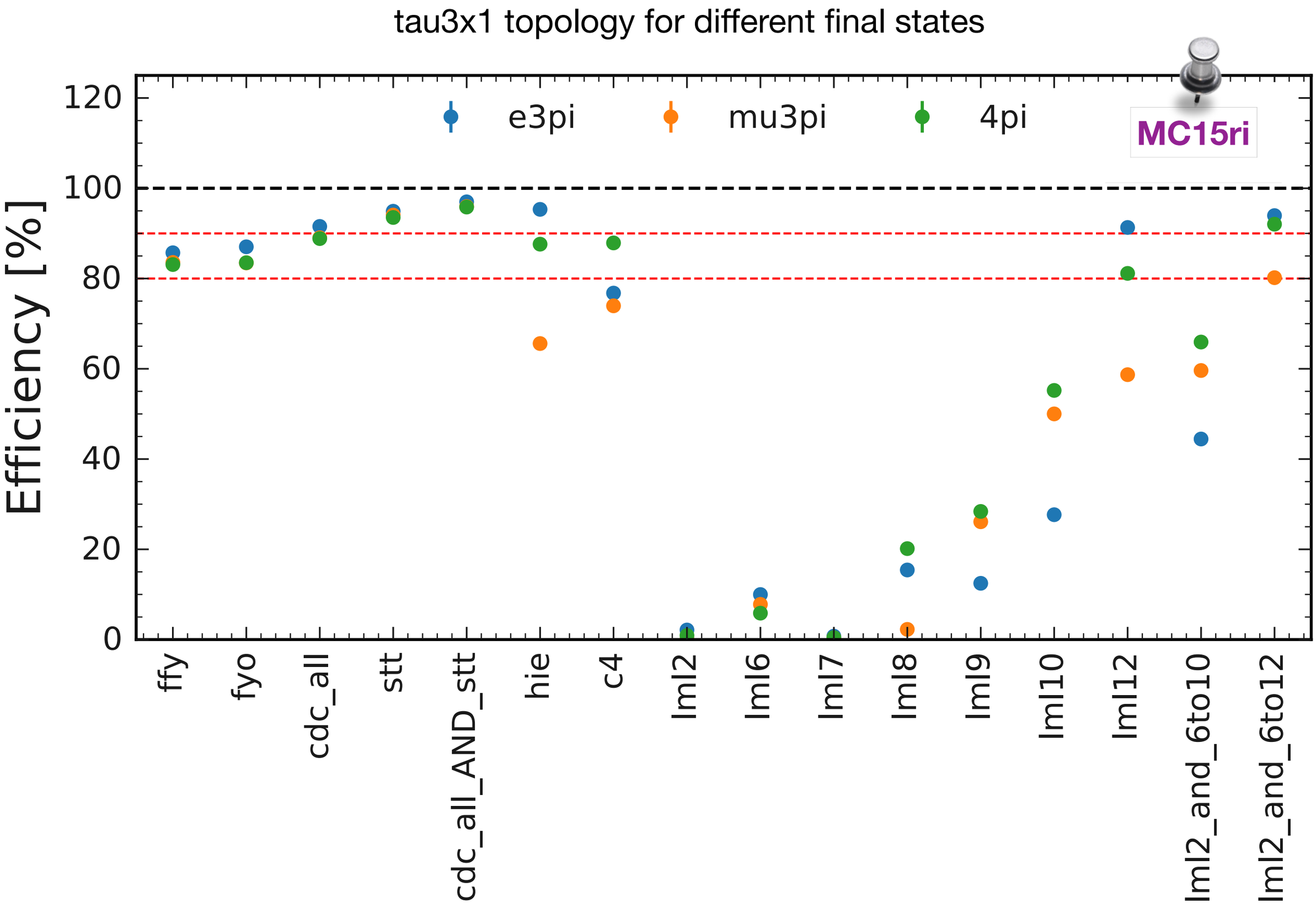
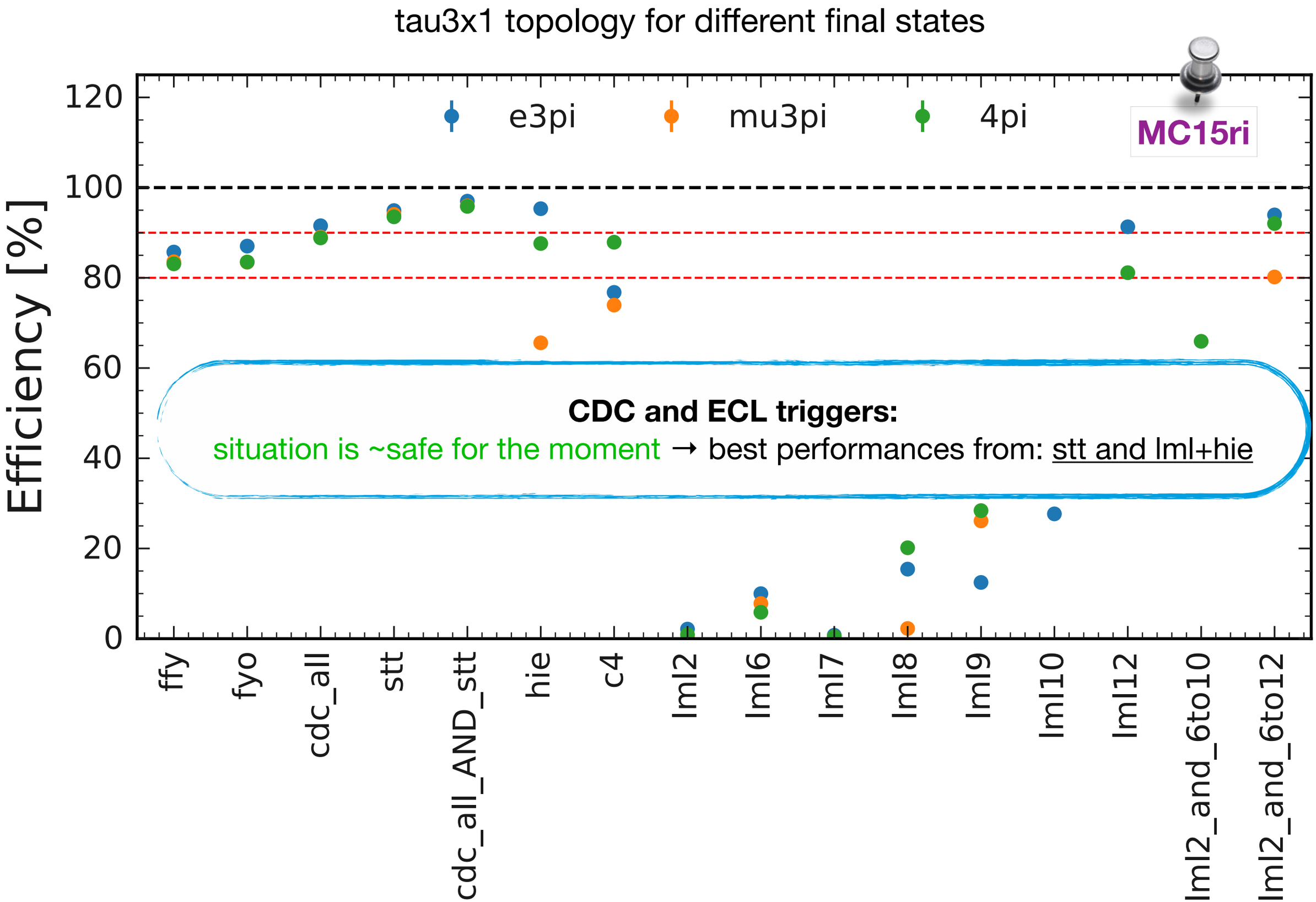


Standard performance studies: tau3x1

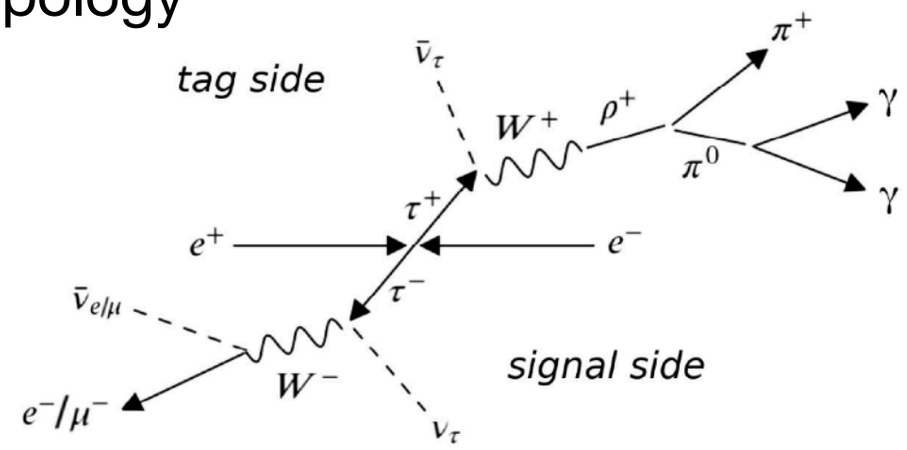


Standard performance studies: tau3x1

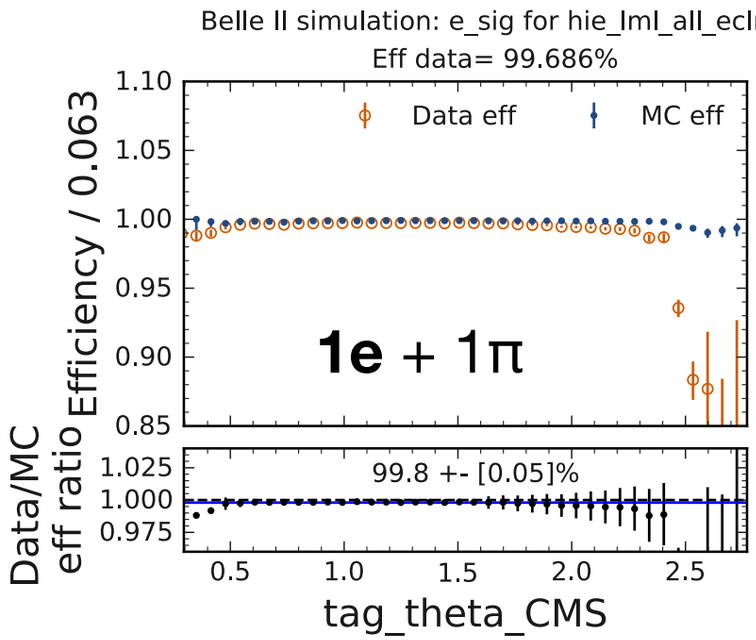


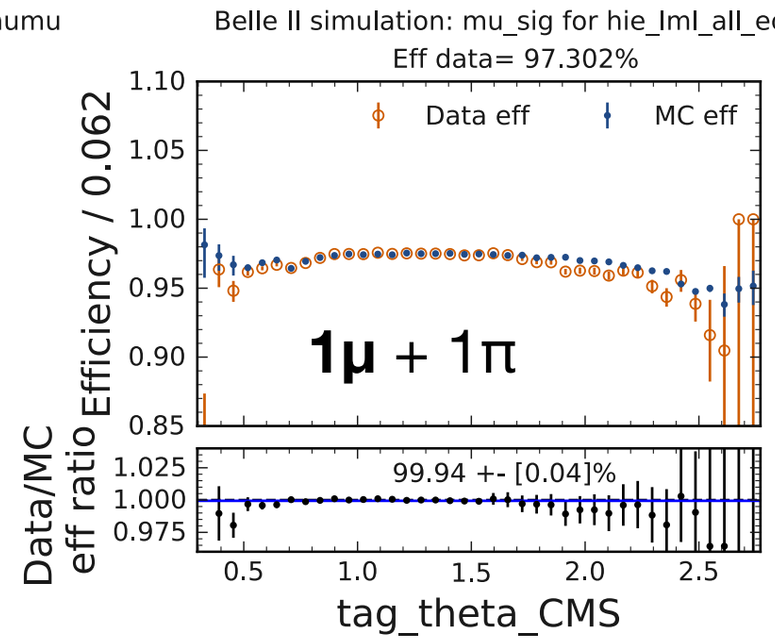
Ongoing efforts in the τ group (I)

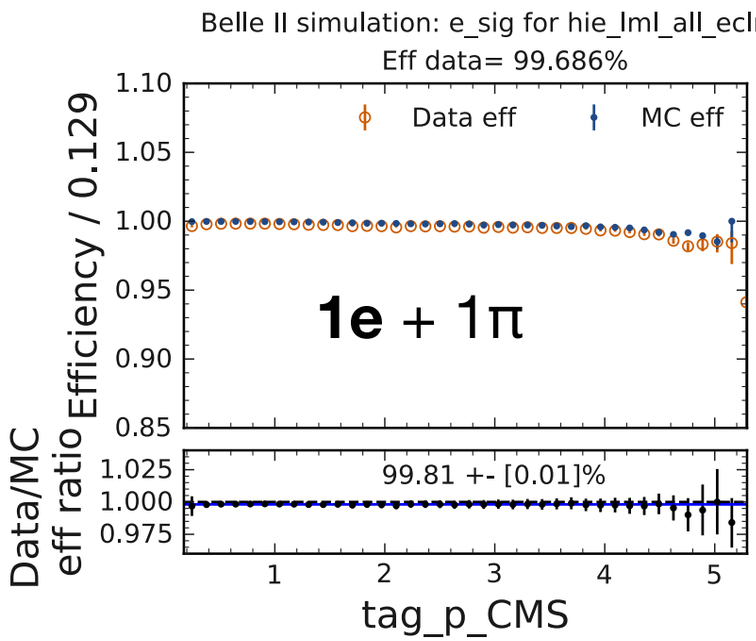
τ LFUV preliminary studies: 1x1 topology

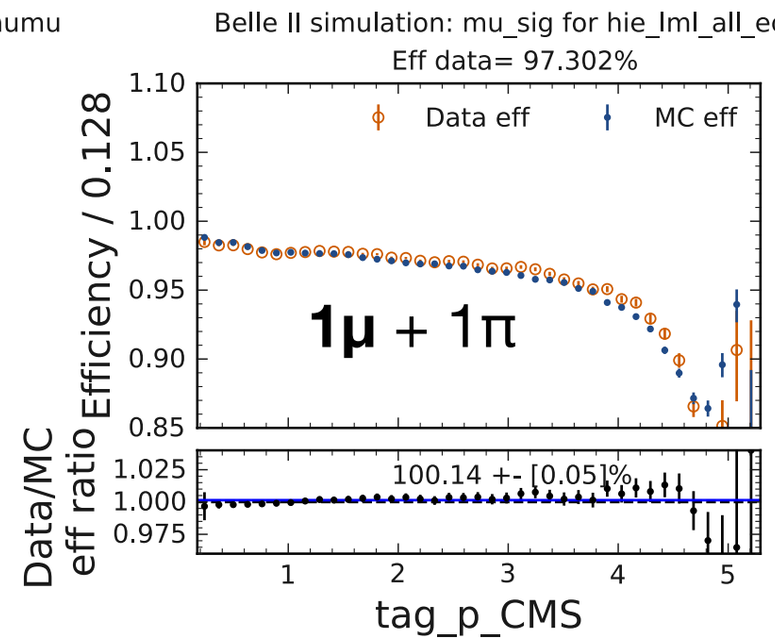


Preliminary data proc12-MC14 good agreement









Analysis strategy: application of a correction factor separately for e and μ channels

↓

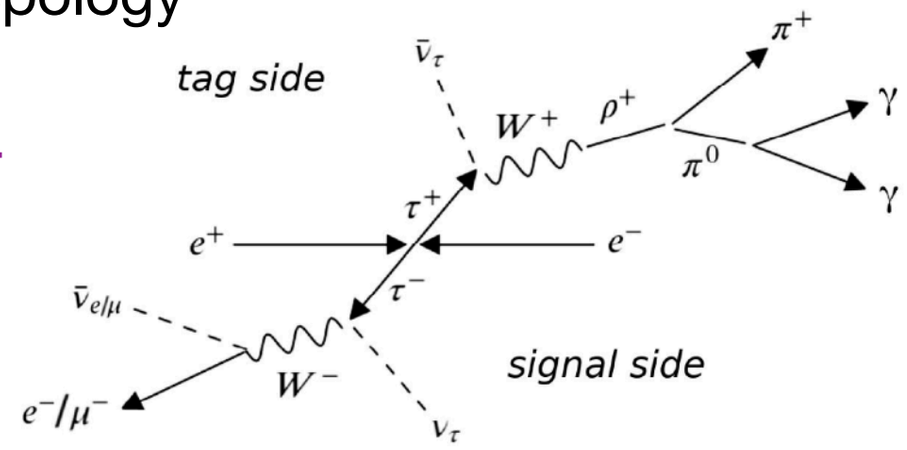
Reduced systematics uncertainties

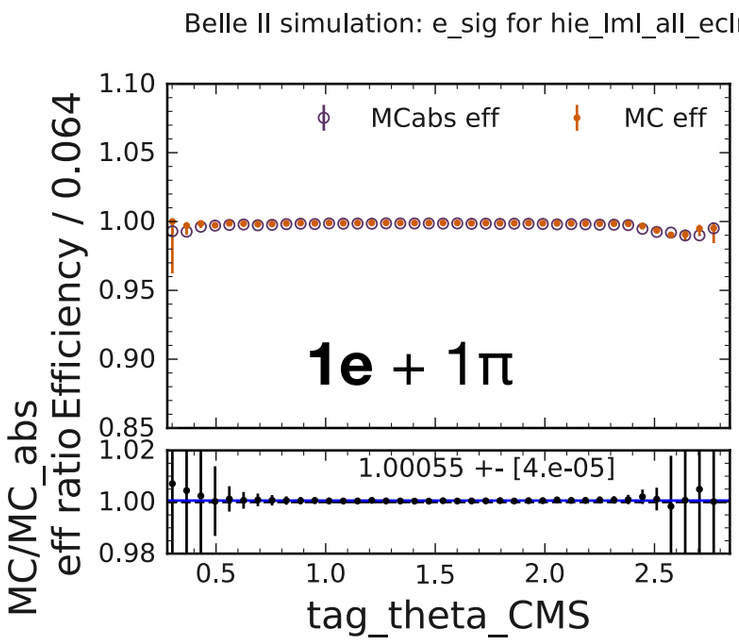
ref: https://indico.belle2.org/event/7804/contributions/46223/attachments/18616/27665/Trigger_systematics.pdf

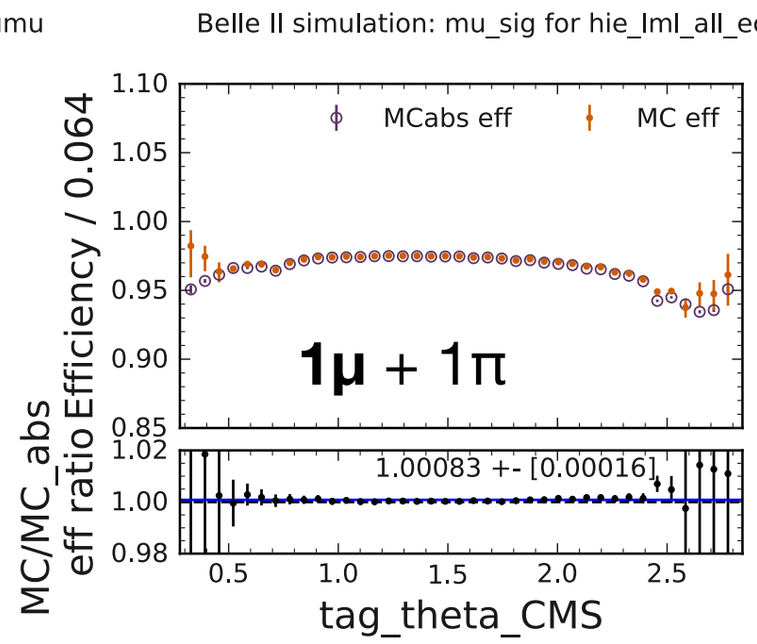
Ongoing efforts in the τ group (I)

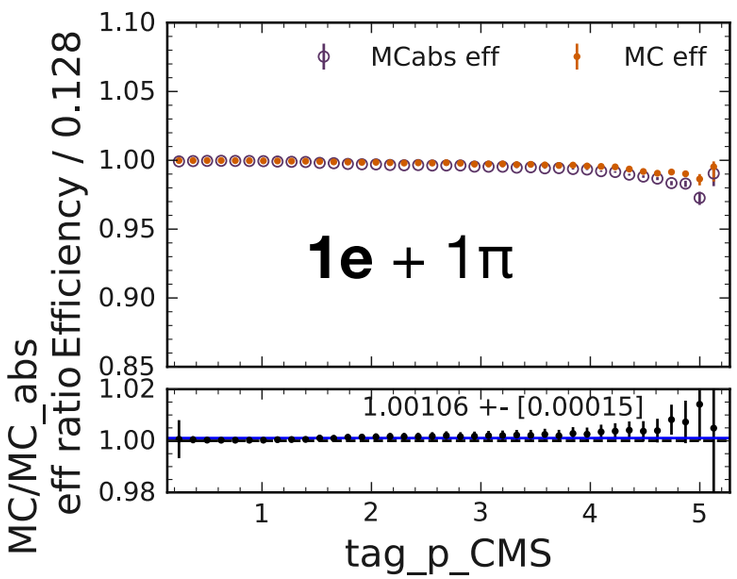
τ LFUV preliminary studies: 1x1 topology

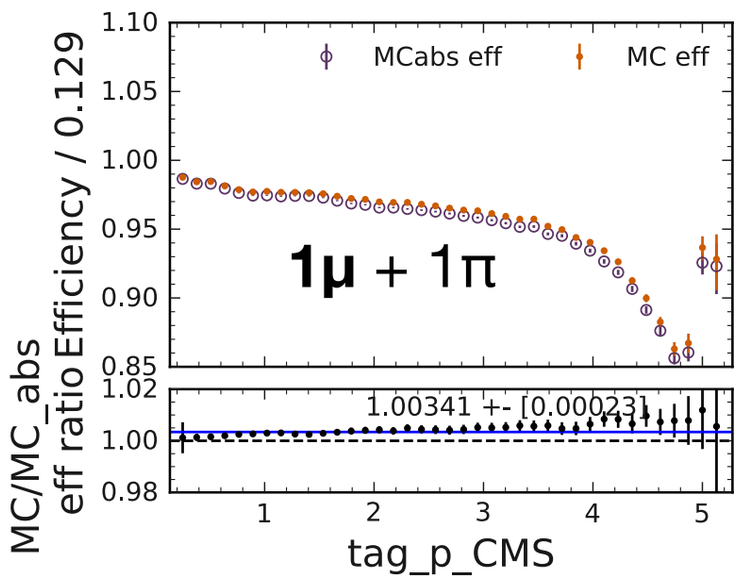
$$\varepsilon_{\text{abs}} = \frac{\text{ECL trigger}}{\text{Selected events}}$$ → estimate bias due to reference trigger











ffo+fso used as reference

↓

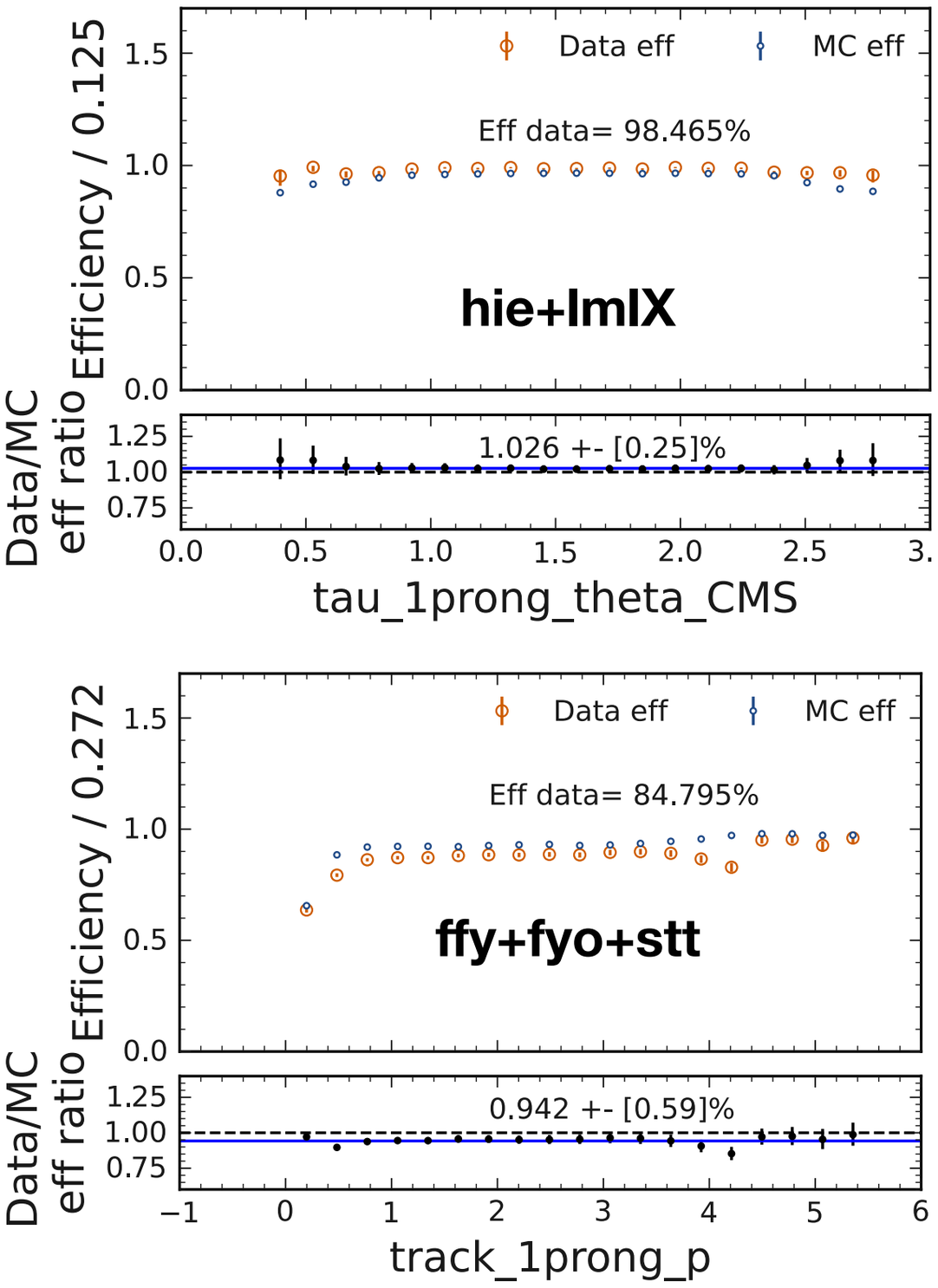
Bias introduced by using a trigger reference is small

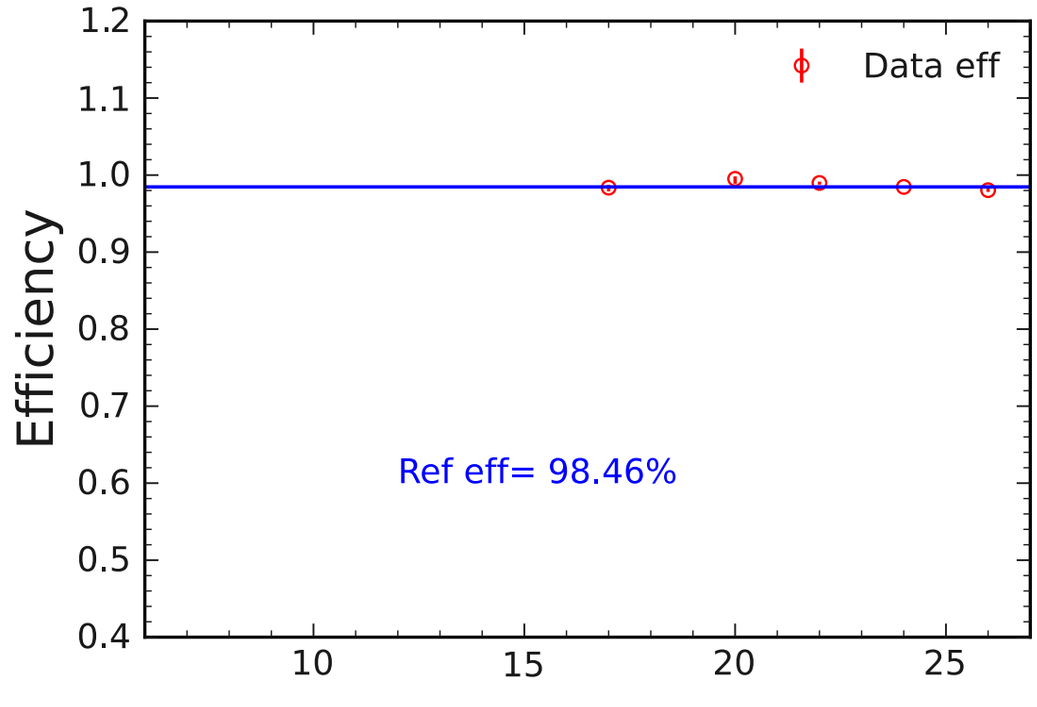
Not negligible for the μ case but still <%

ref: https://indico.belle2.org/event/7804/contributions/46223/attachments/18616/27665/Trigger_systematics.pdf

Ongoing efforts in the τ group (II)

$\tau \rightarrow$ 3μ LFV preliminary studies: 3x1 topology with specific kinematics constraints



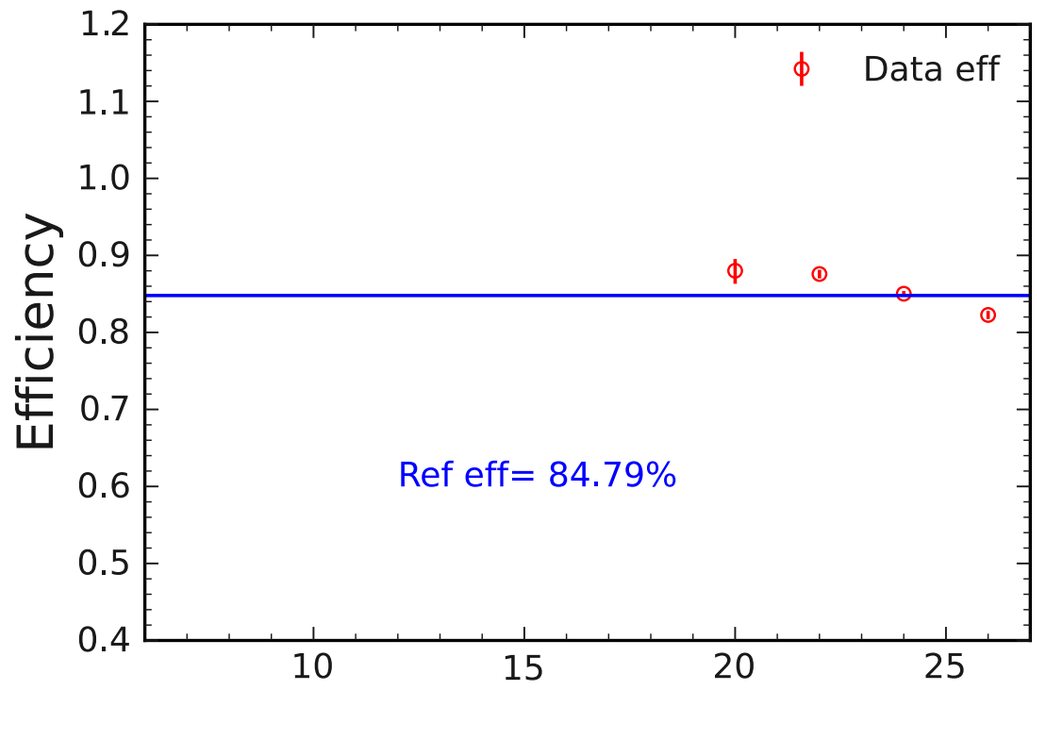


ref: https://indico.belle2.org/event/7743/contributions/44326/attachments/18482/27504/AlbertoMartini_tau3mu.pdf

Control channel: 3π+1e/μ/π

↓

ECL triggers are better performing



Data exp22-MC15 agree well and stably

Ongoing efforts in the τ group (III)

Study trigger efficiency for: $\tau \rightarrow$ e/μ rho $\rightarrow$ control channel used to avoid unblinding: $\tau \rightarrow 3\pi$

L. Zani

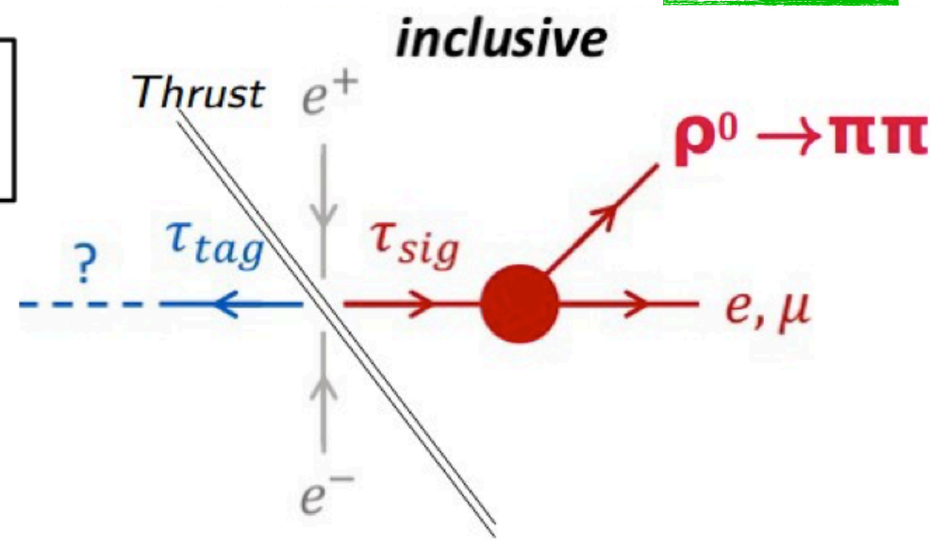
Relative (to CDC reference lines) efficiency

$$\epsilon_{LML} = \frac{(fff \text{ or } ffs \text{ or } ffo \text{ or } ff30) \; AND \; lmlX}{(fff \text{ or } ffs \text{ or } ffo \text{ or } ff30)}$$

Syst. Uncertainty:

$$1 - \frac{\varepsilon_{lml}^{Data}}{\varepsilon_{lml}^{MC}} = 0.7\,\%$$

Inclusive reco, No LID corrections applied (only pions in final state). Applied selection: *offline TauLFV skim && M_IRho0 < 1.5 & DeltaE<0.*



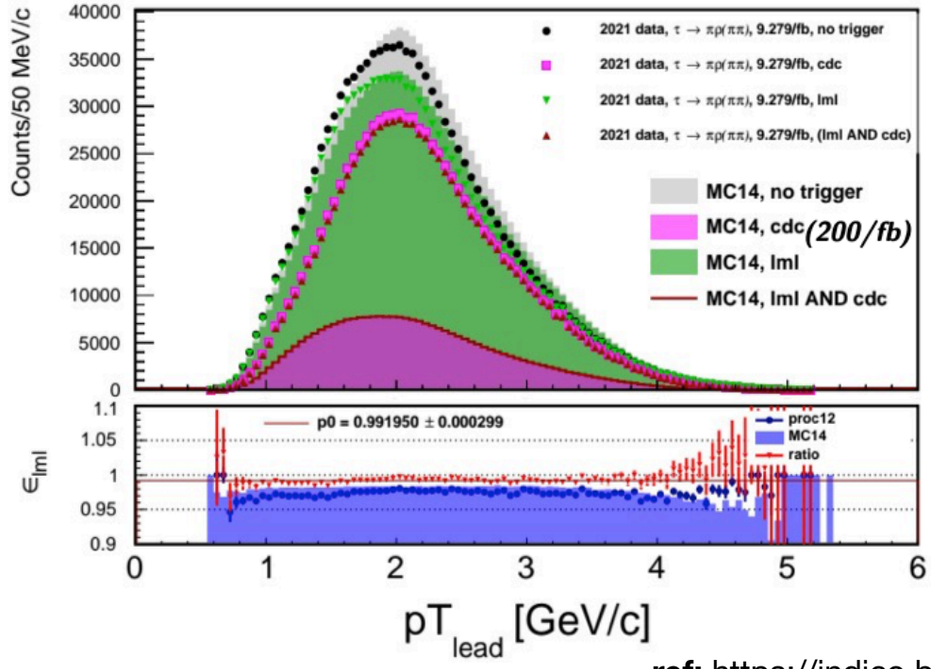
Absolute trigger efficiency (TSIM)

$$\varepsilon_{lmlX}^{TSIM} = \frac{lmlX}{tot.\,generated}$$

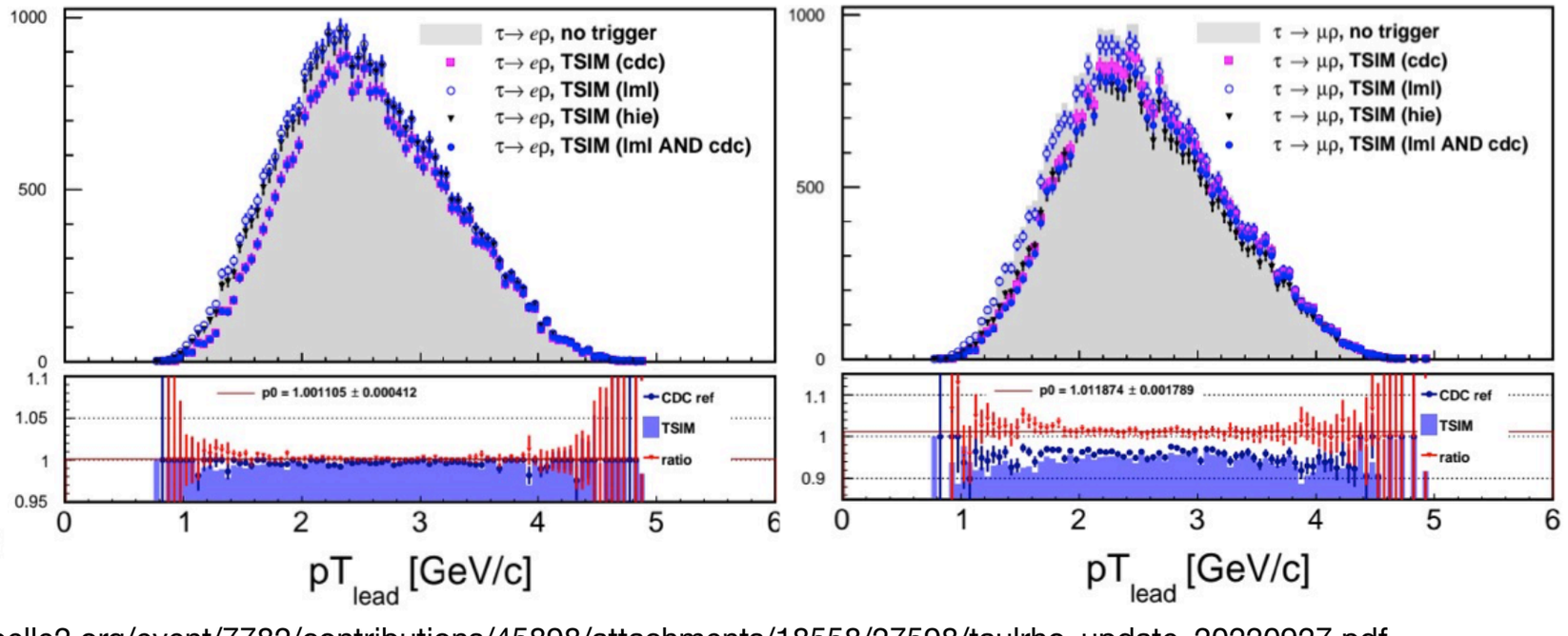
Bias:

$$1 - \frac{\varepsilon_{lml}^{MC}}{\varepsilon^{TSIM}} = 0.1\,(0.9)\,\%\; for\; electron\,(muon)$$

Data: exp 12, run 5888-6427, 9.27/fb (proc12)



Signal MC14 (TauolaBelle II), TSIM



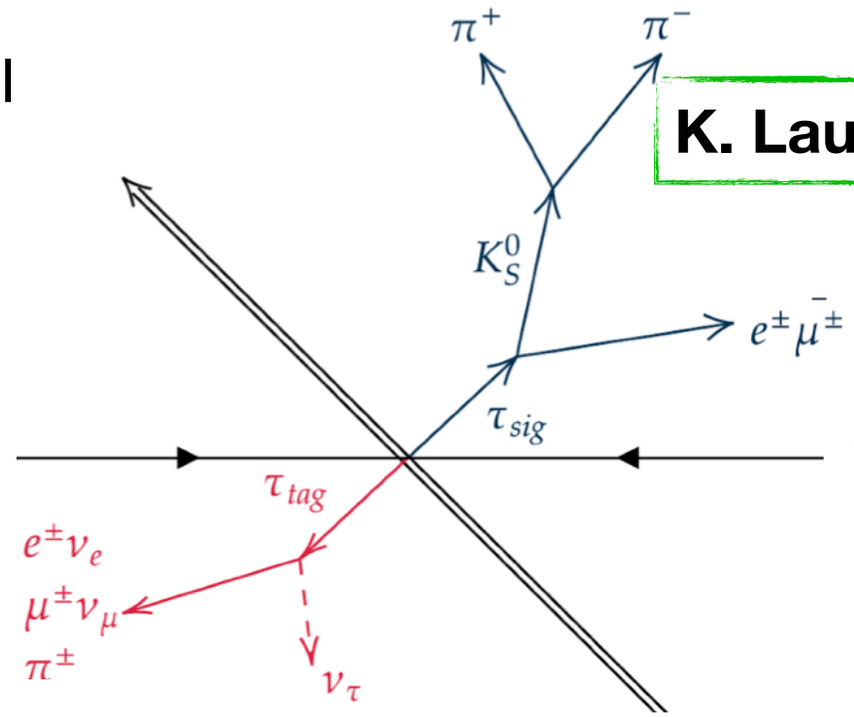
ref: https://indico.belle2.org/event/7782/contributions/45898/attachments/18558/27598/taulrho_update_20220927.pdf

Ongoing efforts in the τ group (IV)

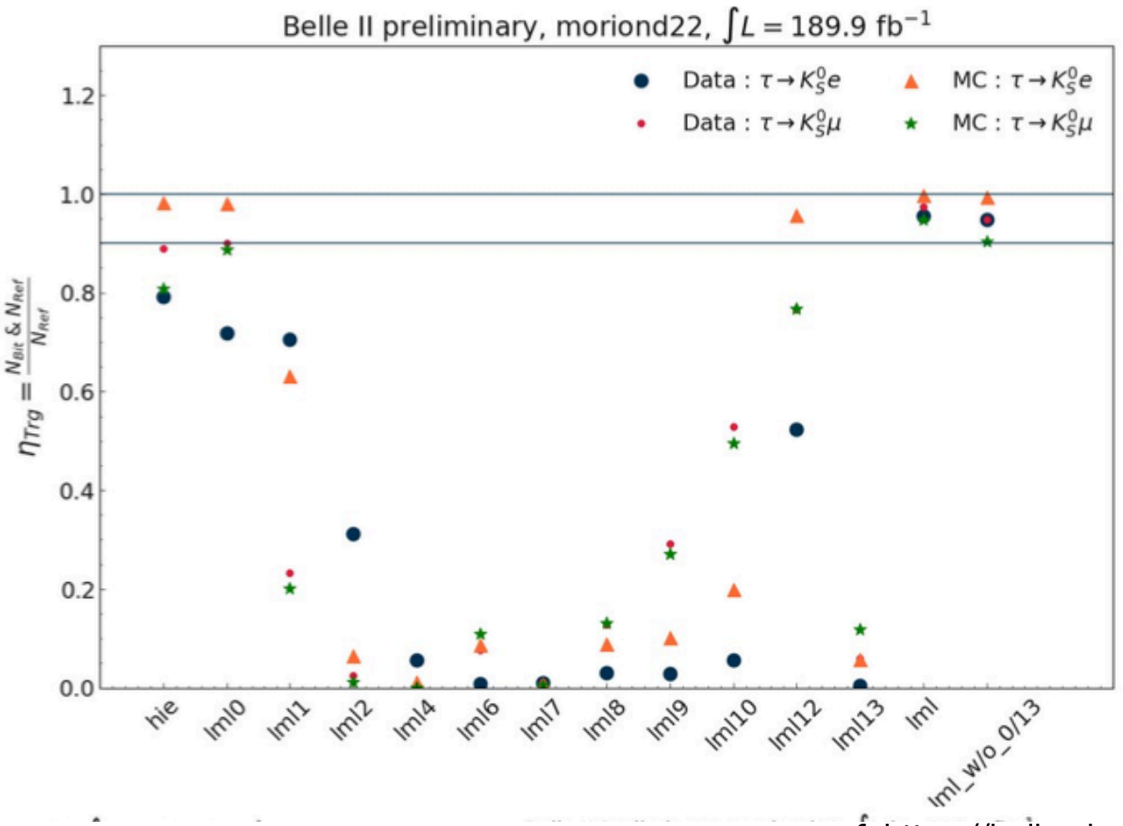
Study trigger efficiency for: $\tau \rightarrow K_S^0$ e/μ → control channel used to avoid unblinding: $\tau \rightarrow K_S^0$ π

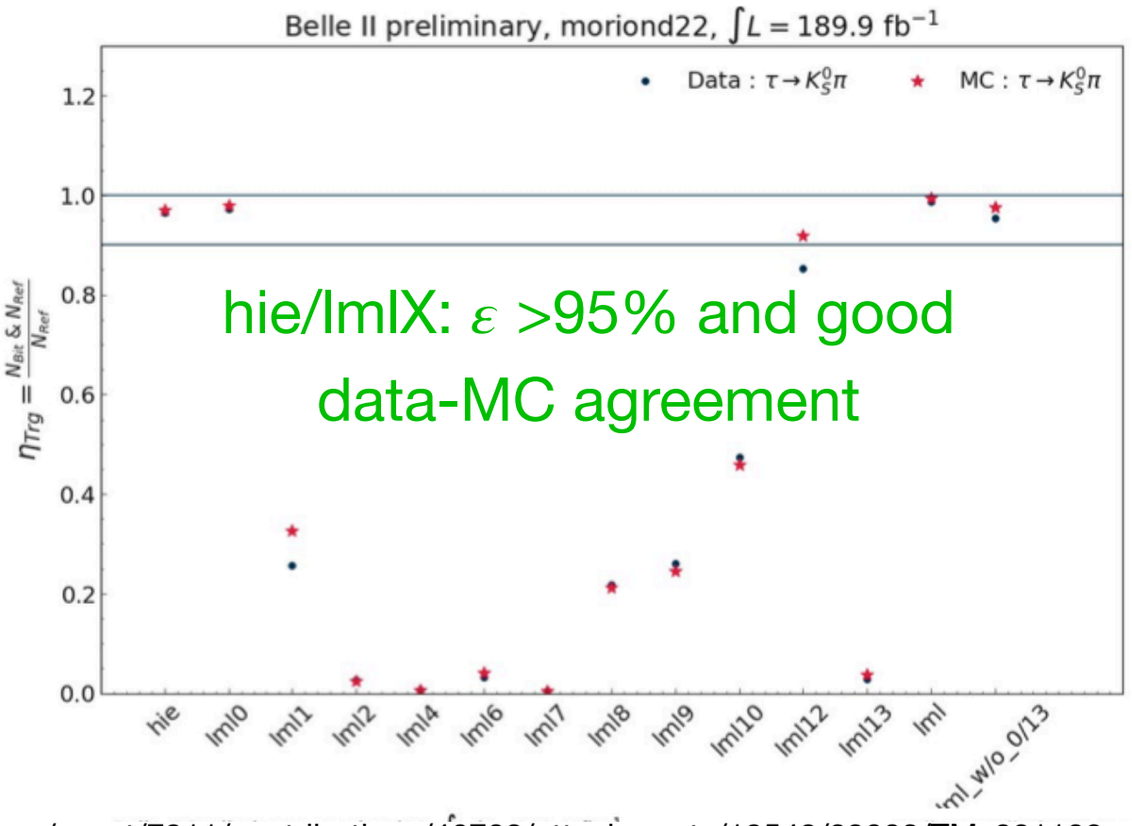
Trigger efficiency: $\varepsilon = \dfrac{(N_{bit}\ \&\ N_{ref})}{N_{ref}}$

with $N_{ref} = fff$ or fso or ffo or f30



K. Lautenbach





hie/lmlX: ε >95% and good data-MC agreement

ref: https://indico.belle2.org/event/7911/contributions/46703/attachments/19549/29003/TM_221122.pdf

Summary table

Trigger bit	Prescale (today)	Raw Rate	Physics analysis	Physics analyzer	Physics note,slide (of TRG efficiency)	Comments, priority
stt	1	🧐	τ 1x1 τ 3x1	CDC trigger for τ group	LFV_tau3mu	**priority: high**
fy30	1	🧐	—	—	General checks only This presentation (backup slides)	**priority: low**
hie, hie3	1	🧐	τ 1x1 τ 3x1	τ group	LFUV , LFV_tau3mu, LFV_tauerho, LFV_taulKS	**priority: high**
lml2	1	🧐	τ 1x1 τ 3x1	τ group	LFUV , LFV_tau3mu, LFV_tauerho, LFV_taulKS	**priority: low**
lml6	1	🧐	τ 1x1	τ group	LFUV , LFV_tau3mu, LFV_tauerho, LFV_taulKS	**priority: medium**

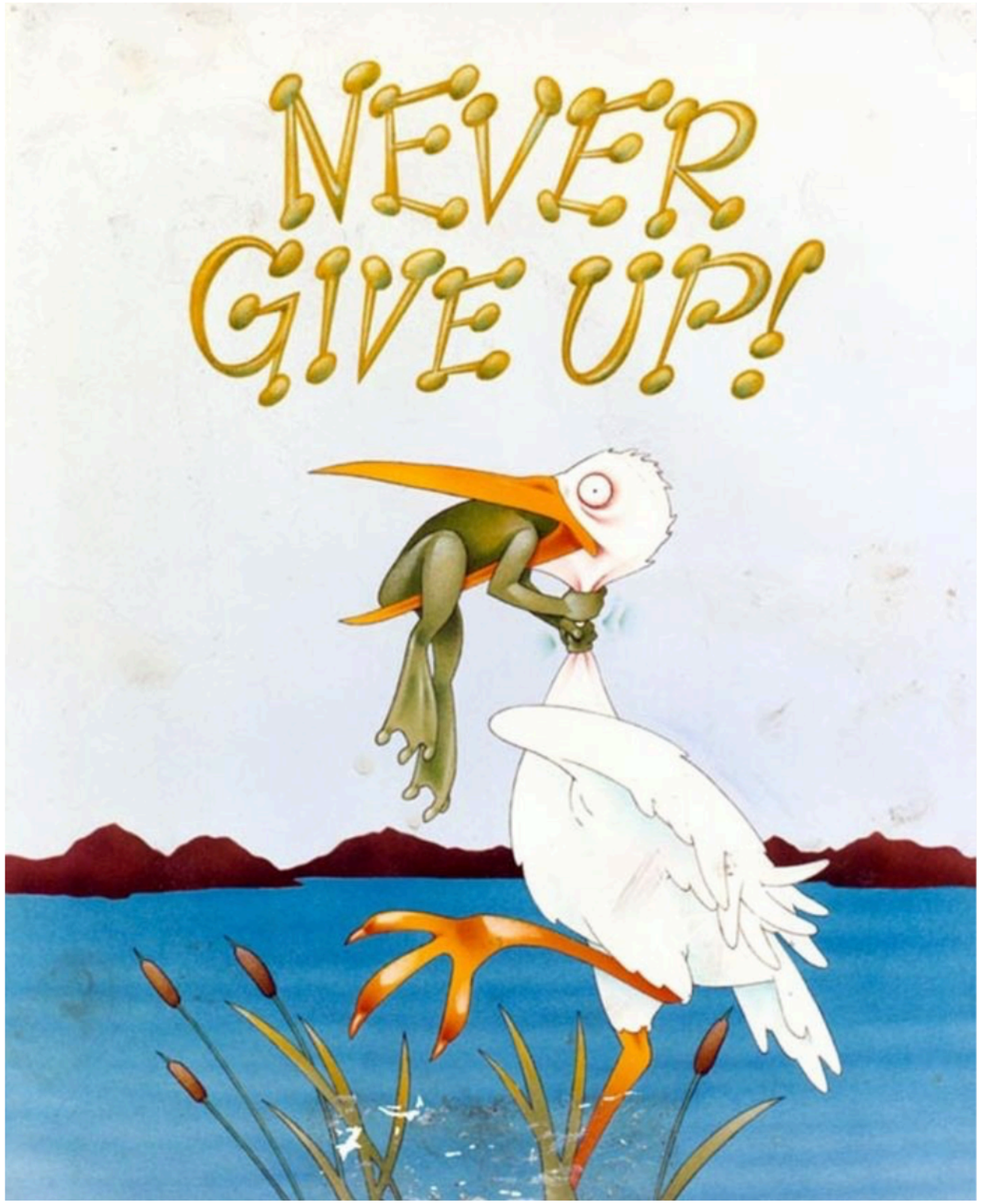
Conclusion

- As of today, ~all the active analysis in the τ group rely only on ECL triggers
  - Data and MC agreement are good and performances are rather stable

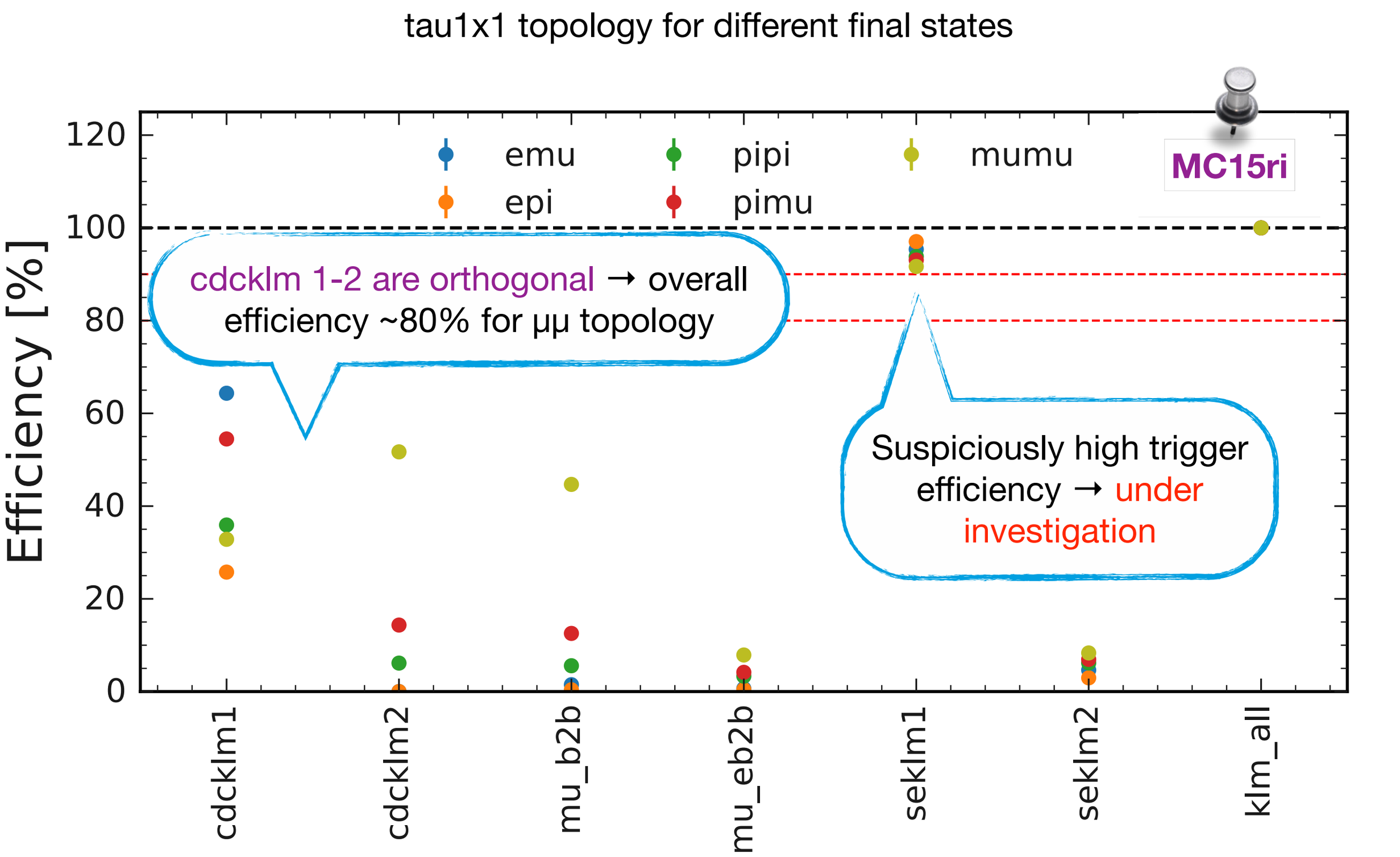
- stt, hie and lml are crucial bits for τ physics
  - performances for tau1x1 topology is in danger if stt or lmlX will be prescaled
  - tau3x1 performances are stable

- klm related triggers can play an important role
  - performances are still to be properly estimated by the group (few hints in the backup slides)

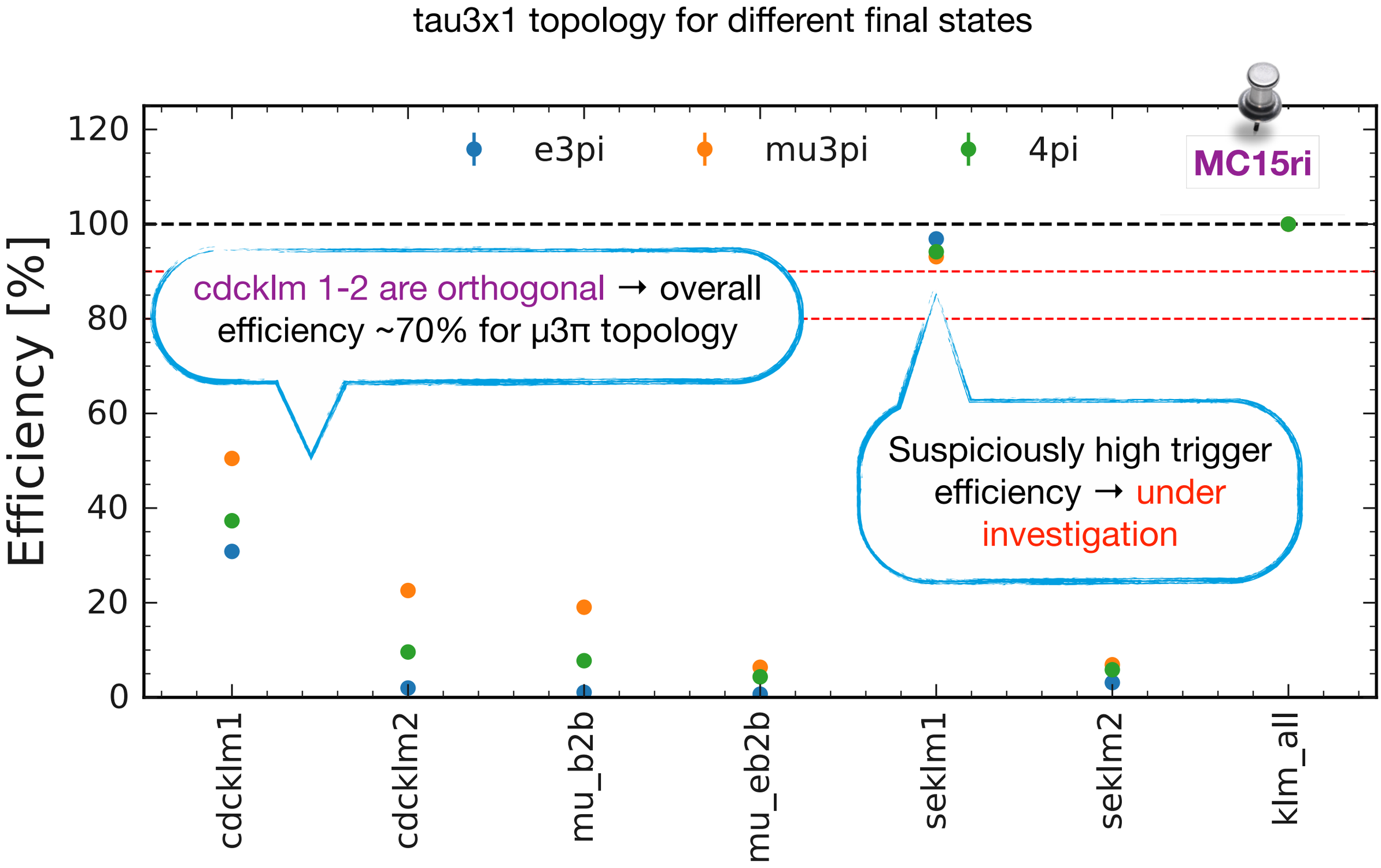
Emergency slides!!



Hints on klm-related triggers



Hints on klm-related triggers



Taupair selection for the general study

Cuts applied to data samples:

- Event based cuts:
  - nGoodPhotons<3 && nPi0<2
  - thrust>0.85 + 0.52 rad <θ_p_{miss}<2.8 rad + 1 GeV^2/c^4<M^2_{miss}<49 GeV^2/c^4

- Particle identification cuts: PID global variables to separate the different τ channels for both topologies → different cuts are due to different statistical samples.
  - tau1x1: PID>0.9
  - tau3x1: eID>0.5 + μID>0.5 + πID>0.2 on 3 prong tracks + πID>0.5 on 1 prong track

Cuts applied to MC samples:

- Event based cuts:
  - nGoodPhotons<3 && nPi0<2
  - thrust>0.85 + 0.52 rad <θ_p_{miss}<2.8 rad + 1 GeV^2/c^4<M^2_{miss}<49 GeV^2/c^4

- Different τ channels separated using MC truth variables in TauolaBelleII:
  - 1prong e: tauMCMode==1
  - 1prong μ: tauMCMode==2
  - 1prong π: tauMCMode==4,110,163,164,303
  - 3prong decay: tauMCMode==3,4,13,14,22to28,32,33,24,41to47,63,66,70,85,112

lml trigger bits definition

Low multiplicity definition from the trigger confluence page:

- lml[0]: (NCL ≥ 3, at least 1 CL ≥ 300 MeV(Lab)) (with θ_{id}= 1 ~ 17), **not** an ECL 3D Bhabha
- lml[1]: one CL ≥ 2 GeV(CM) with θ_{id} = 4~ 14
- lml[2]: one CL ≥ 2 GeV(CM) with θ_{id} =2, 3, 15 or 16 and **not** an ECL 3D Bhabha
- lml[3]: ECL one CL ≥ 2 GeV(CM) with θID = 2, 3, 15 or 16 and an ECL 3D Bhabha
- lml[4]: one CL ≥ 2 GeV(CM) with θ_{id} =1 or 17 and **not** an ECL 3D Bhabha
- lml[5]: ECL one CL ≥ 2 GeV(CM) with θID = 1 or 17
- lml[6]: only one CL≥1 GeV(CM) with θ_{id}= 4 ~ 15 and no other CL≥300 MeV(Lab) anywhere
- lml[7]: only one CL≥1 GeV(CM) withθ_{id}= 2, 3, or 16 and no other CL≥300 MeV(Lab) anywhere
- lml[8]: 170°<ΔϕCM<190°, both CL > 250 MeV(Lab), no 2GeV(CM) CL in an event
- lml[9]: 170°<ΔϕCM<190°, one CL > 250 MeV(Lab), the other CL > 250 MeV(Lab), no 2GeV(CM) CL in an event
- lml[10]: 160°<ΔϕCM< 200°, 160°<ΣθCM< 200°, no 2GeV(CM) CL in an event
- lml[12]: (NCL≥3, at least 1 CL ≥500 MeV(Lab)) (withθ_{id}= 2 ~ 16), **not** an ECL 3D Bhabha

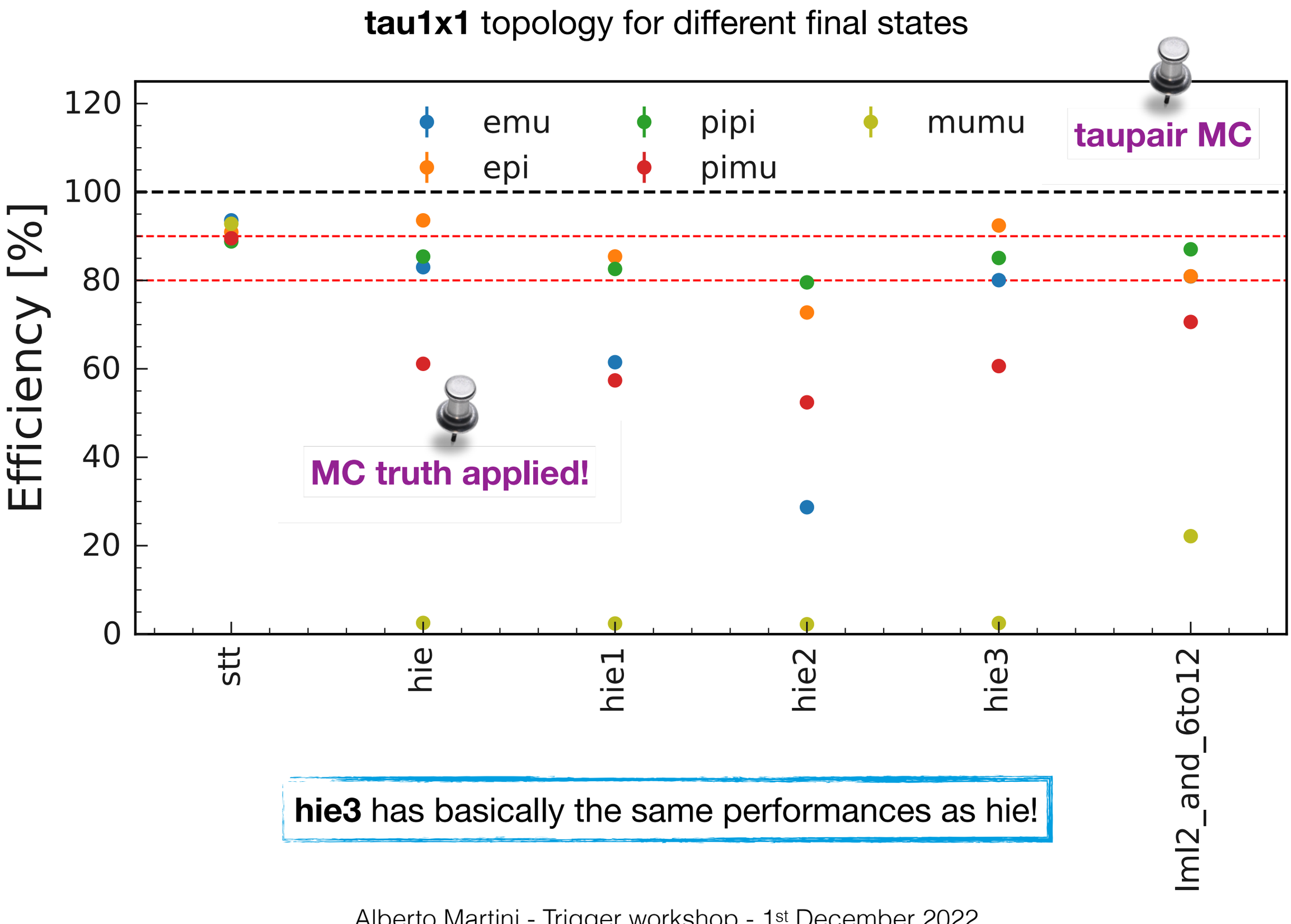
- **Red bits are already prescaled**

Performance of new bits: bhabha veto on hie

hie bits definitions w/ new bhabha vetoes

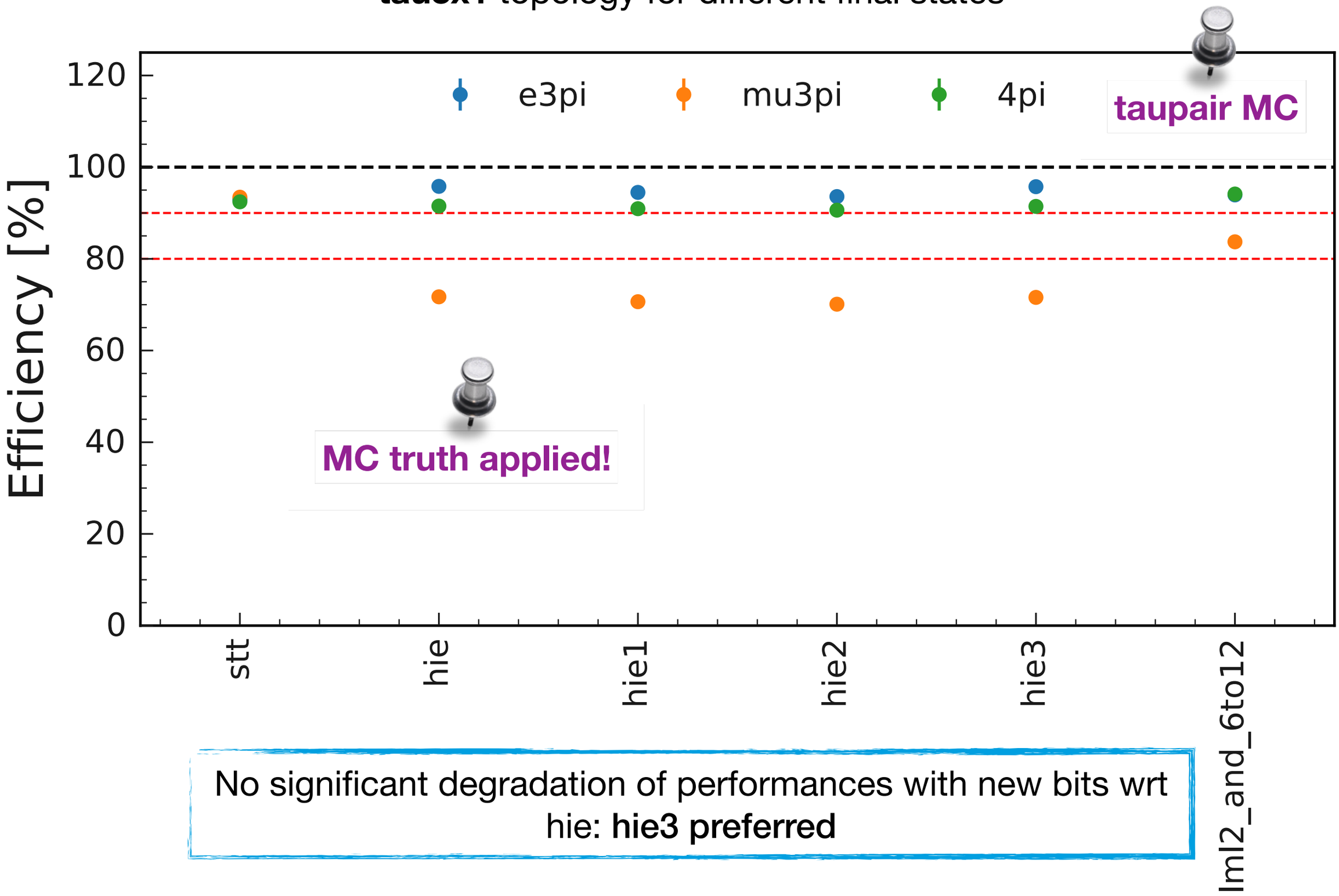
hie w/ additional **Bhabha veto 1**	**hie1**	• New hie to reduce Bhabha contribution(condition-1) • hie && 1CL veto && 2CL veto • 1CL veto = not (N(CL)=1 && θ_{CM} in FW) • 2CL veto = not (N(CL)=2 && (160°< $\Sigma\theta_{CM}$< 200° && 150°< $\Delta\phi_{CM}$< 250°) • See (link) for details
hie w/ additional **Bhabha veto 2**	**hie2**	• New hie to reduce Bhabha contribution(condition-2) • hie && 1CL veto && 2CL veto • 1CL veto = not (N(CL)=1 && θ_{CM} in FW) • 2CL veto = not (N(CL)=2 && (160°< $\Sigma\theta_{CM}$< 200° || 150°< $\Delta\phi_{CM}$< 250°) • See (link) for details
hie w/ additional **Bhabha veto 3**	**hie3**	• New hie to reduce Bhabha contribution(condition-3) • hie && 1CL veto && 2CL veto • 1CL veto = not (N(CL)=1 && θ_{CM} in FW) • 2CL veto = not (N(CL)=2 && CL_{LowerE} in FW or BW) • See (link) for details

Performance of new bits: bhabha veto(I)



hie3 has basically the same performances as hie!

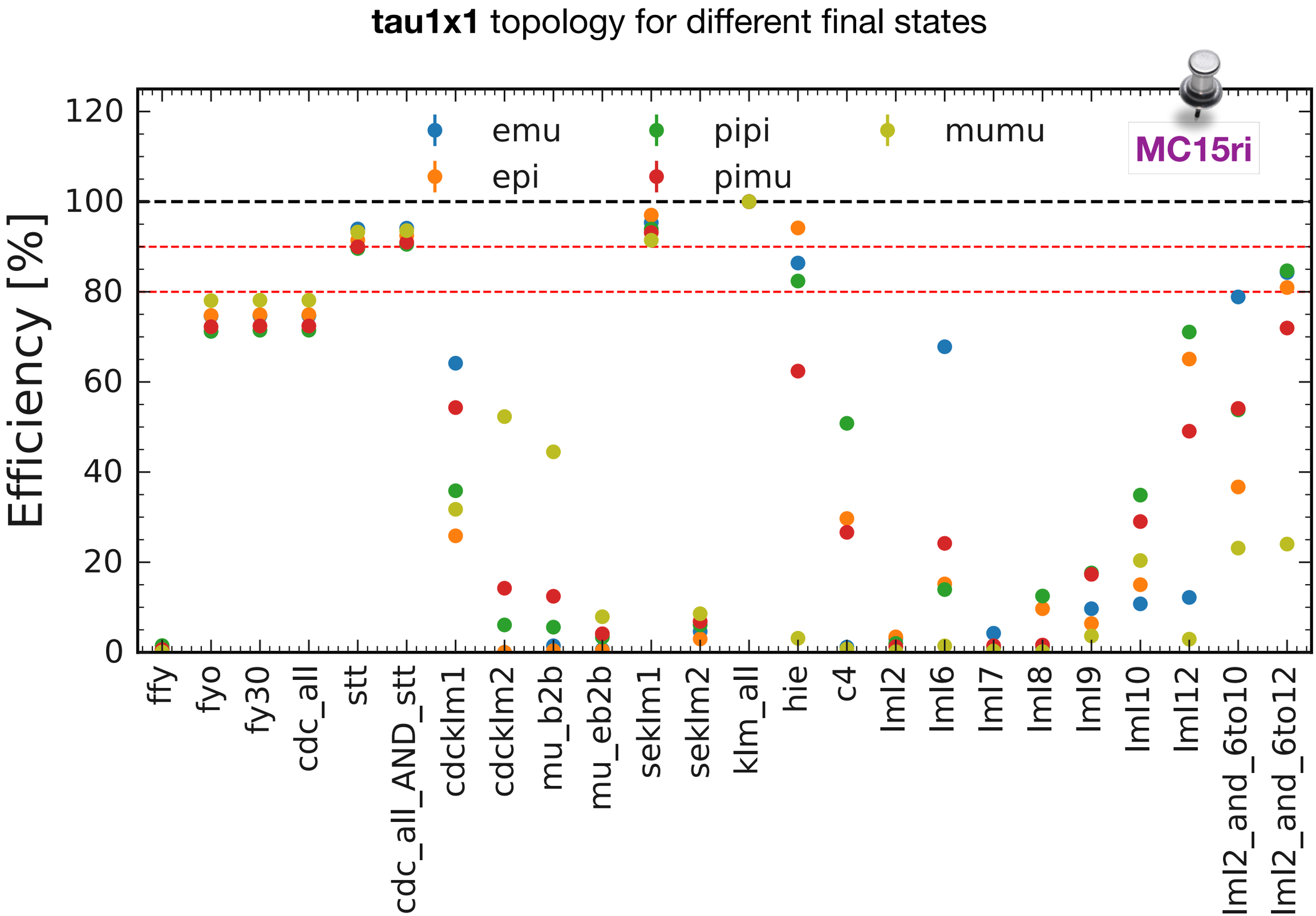
Performance of new bits: bhabha veto(I)



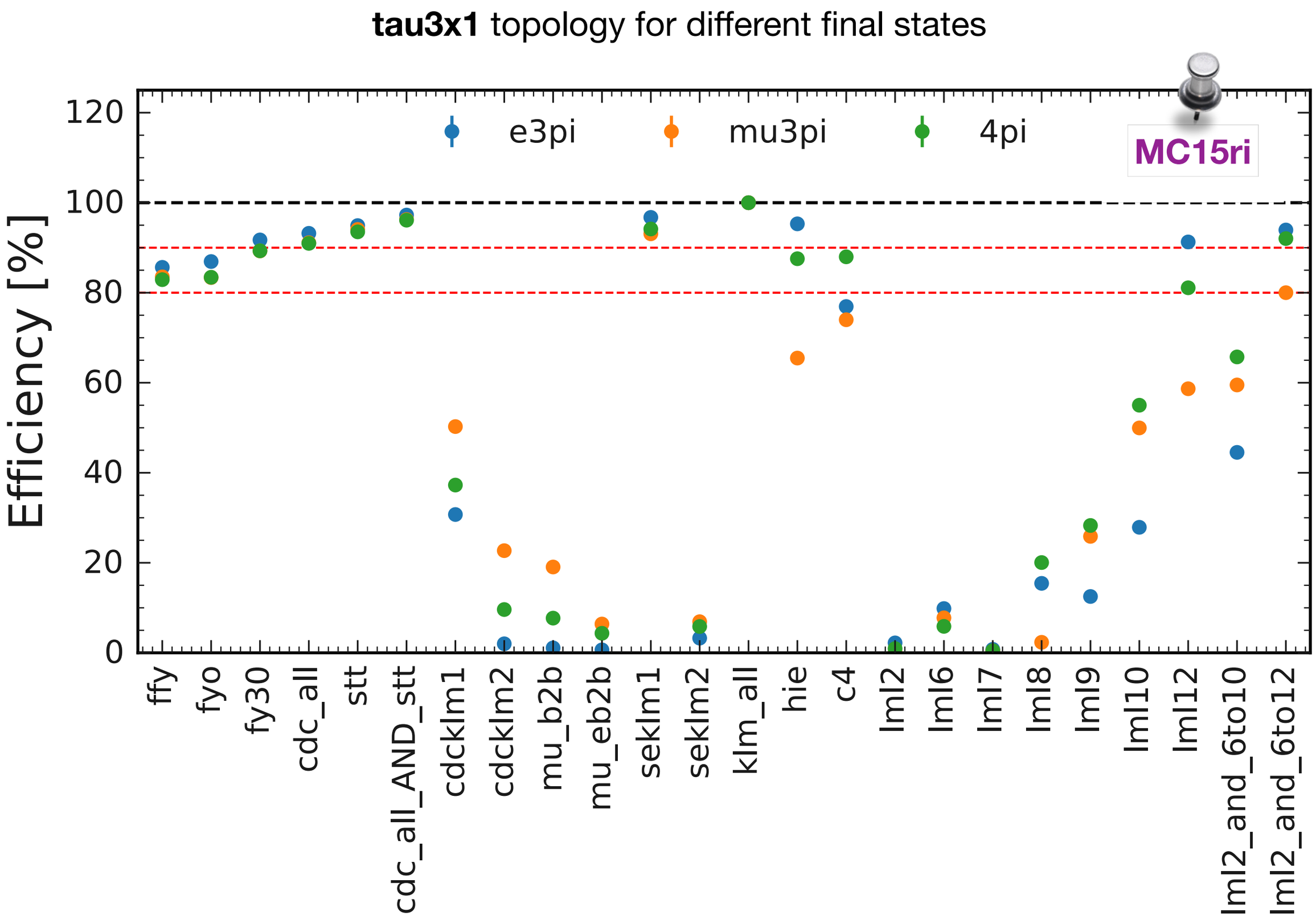
No significant degradation of performances with new bits wrt hie: **hie3 preferred**

MC additional checks

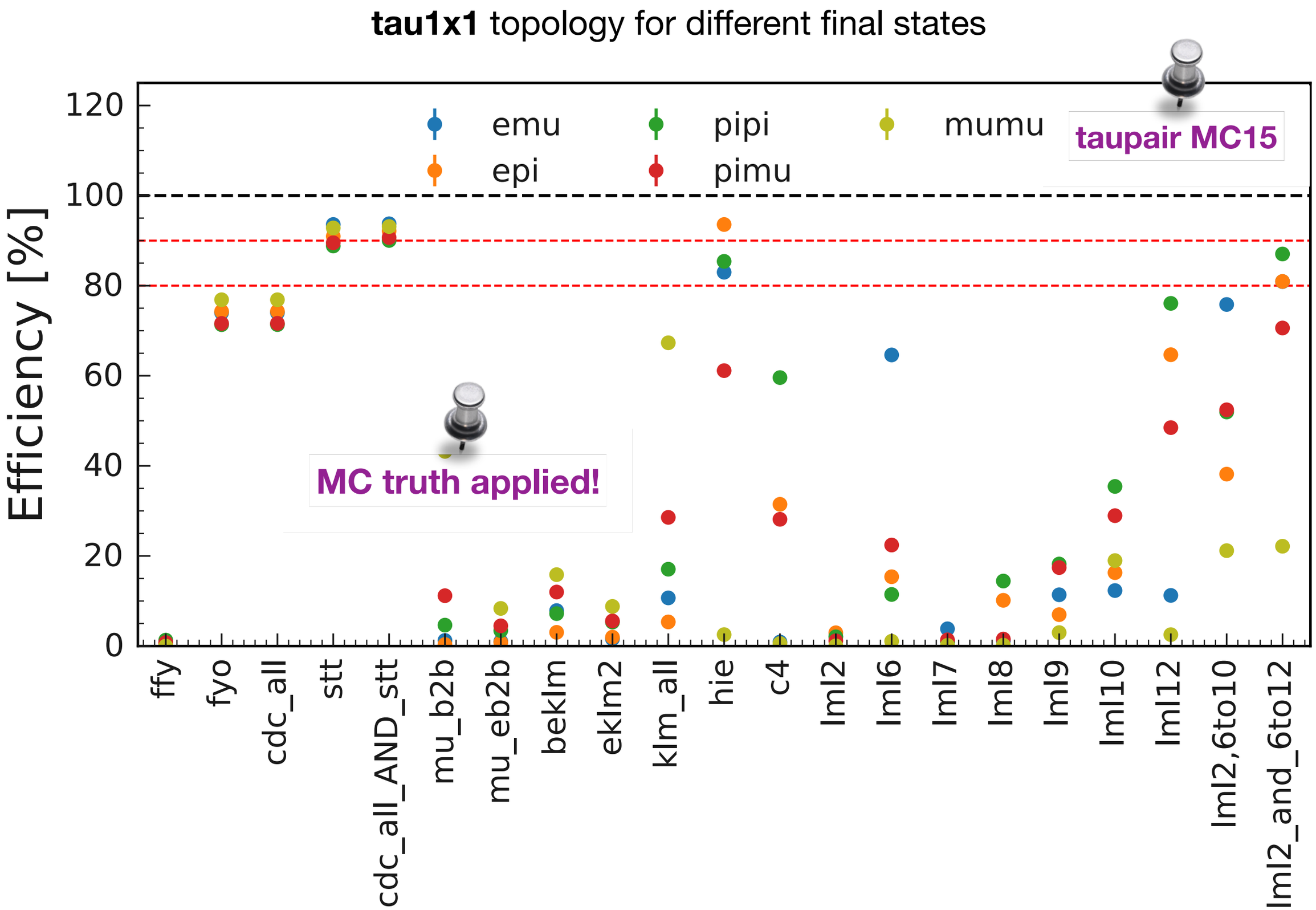
Overall performances



Overall performances



Overall performances



Overall performances