Separation of $e^+e^- \to f\bar{f}$ with event-based ML : recap & CDR plans

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The Belle II collaboration

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Intro

Count $e^+e^- \to f\bar{f}$ events for A_{LR} **measurements** using a machine learning based classifier trained on **event variables.**

Attempt is to get **high purity discrimination** of $b\bar{b}$, $c\bar{c}$ without reconstruction to keep efficiency high.

Current results:

Sufficient for selecting $b\bar{b}$ events, but some **reconstruction may be needed** to select $c\bar{c}$ events from the $uds\tau$ background.

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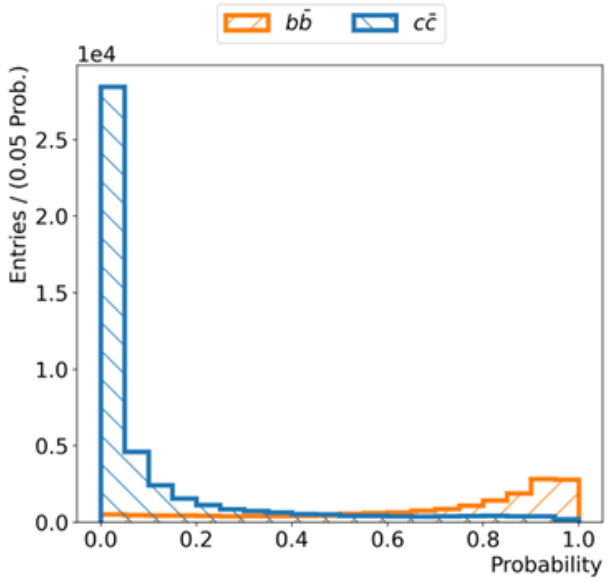
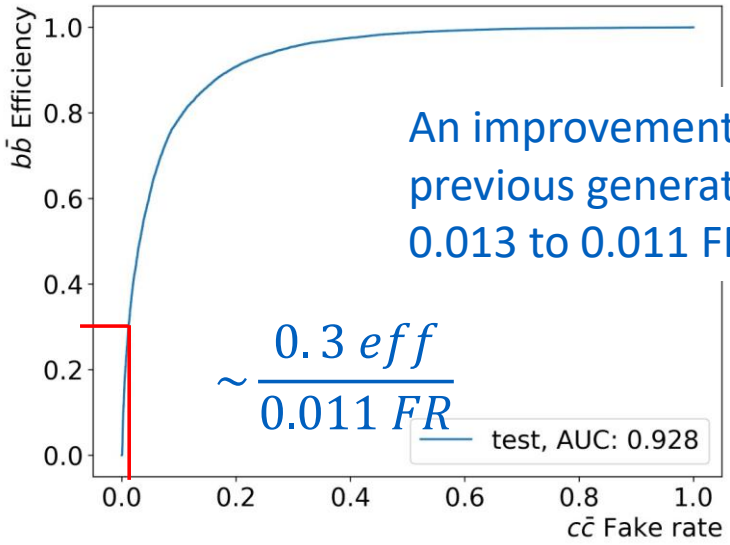
Selection $b\bar{b}$

$$b\bar{b}\ \text{Efficiency} = \frac{\#\ \text{of real}\ b\bar{b}\ \text{predicted as}\ b\bar{b}}{\#\text{total number of MC generated}\ b\bar{b}}$$

$$c\bar{c}\ \text{Fake rate} = \frac{\#\ \text{of real}\ c\bar{c}\ \text{misidentified as}\ b\bar{b}}{\#\text{total number of MC generated}\ c\bar{c}}$$





An improvement from the previous generation from 0.013 to 0.011 FR

$$\sim \frac{0.3\ eff}{0.011\ FR}$$

Good selection of $b\bar{b}$ with event variables.
$uds\tau$ Background is identified as $c\bar{c}$ by the model.

```
0. thrust (0.441)
1. foxWolframR2 (0.199)
2. missingEnergyOfEventCMS (0.054)
3. harmonicMoment__bo2__cm__spcollision__bc (0.045)
4. nTracks (0.036)
5. ne (0.027)
6. harmonicMomentThrust2 (0.023)
7. foxWolframR1 (0.022)
8. nmu (0.015)
9. harmonicMomentThrust0 (0.012)
10. missingMomentumOfEventCMS_theta (0.008)
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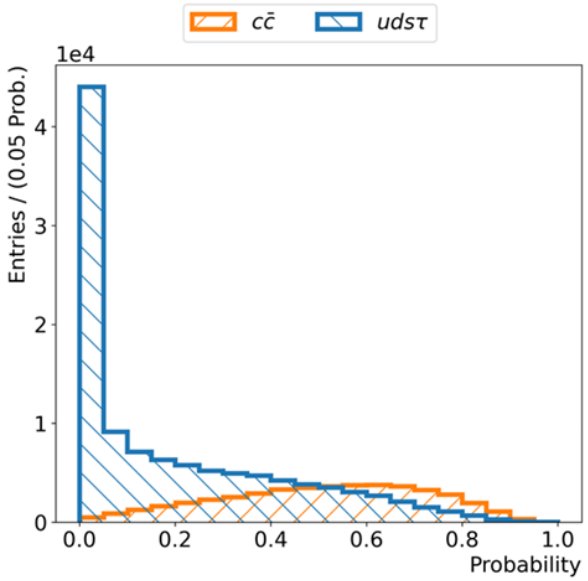
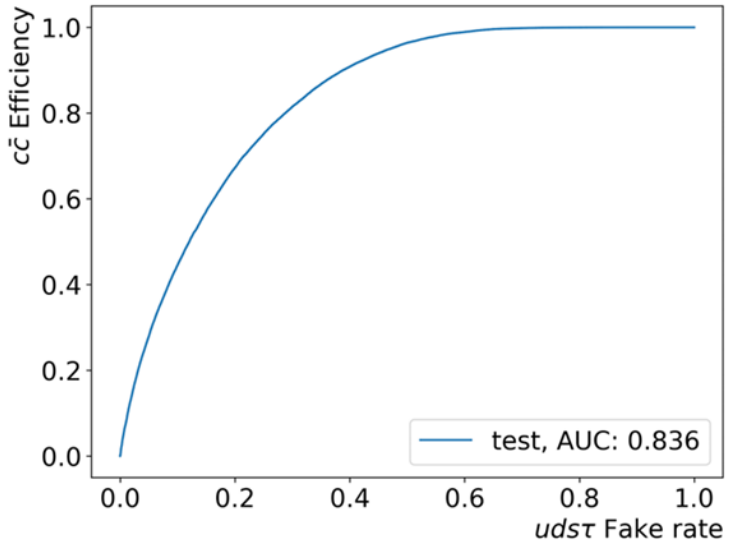
Selection $c\bar{c}$

$$c\bar{c}\text{ Efficiency} = \frac{\#\text{ of real } c\bar{c} \text{ predicted as } c\bar{c}}{\#\text{total number of MC generated } c\bar{c}}$$

$$uds\tau\text{ Fake rate} = \frac{\#\text{ of real } uds\tau \text{ misidentified as } c\bar{c}}{\#\text{total number of MC generated } uds\tau}$$





Better results than cut based approach, but reconstruction may be needed.

```
0. nTracks (0.425)
1. foxWolframR4 (0.109)
2. nK (0.097)
3. harmonicMomentThrust0 (0.055)
4. totalPhotonsEnergyOfEvent (0.040)
5. ne (0.029)
6. foxWolframR3 (0.023)
7. aplanarity (0.022)
8. cleoConeThrust0 (0.018)
9. nmu (0.012)
10. thrust (0.011)
```

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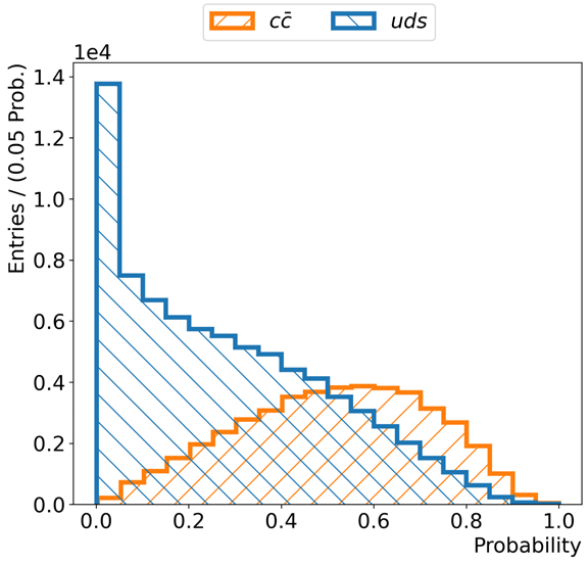
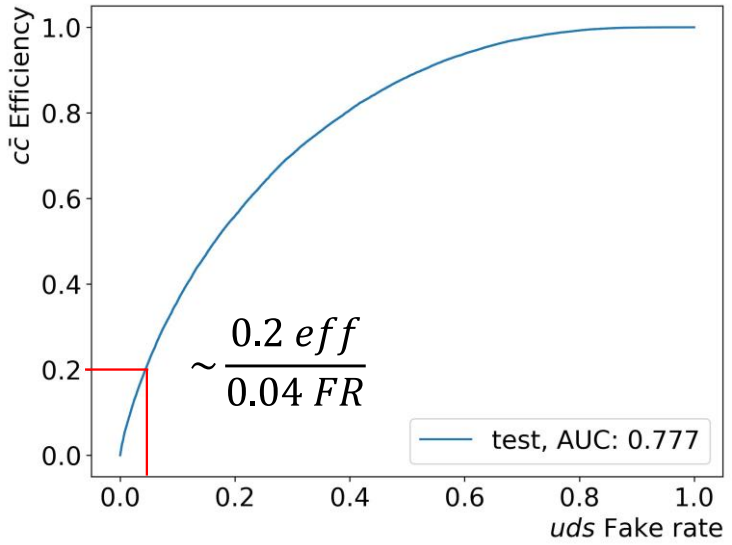
Selection $c\bar{c}$

```
0. foxWolframR4 (0.201)
1. nK (0.138)
2. nTracks (0.129)
3. harmonicMomentThrust0 (0.060)
4. ne (0.053)
5. visibleEnergyOfEventCMS (0.040)
6. foxWolframR3 (0.033)
7. totalPhotonsEnergyOfEvent (0.027)
8. nmu (0.022)
9. foxWolframR1 (0.020)
10. missingMass2OfEvent (0.018)
11. backwardHemisphereEnergy (0.014)
12. harmonicMomentThrust4 (0.014)
13. missingMomentumOfEvent_theta (0.014)
14. cleoConeThrust0 (0.013)
15. thrust (0.012)
16. cleoConeThrust7 (0.011)
17. cleoConeThrust2 (0.011)
18. nExtraCDCHitsPostCleaning (0.010)
19. cleoConeThrust6 (0.010)
20. npi (0.009)
```





Better results than cut based approach, but reconstruction may be needed.

As expected, uds is the harder part to discriminate.

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In Progress for CDR

1. To **improve event selection**, add variables & cuts
    1. Key variables of particles lists (max momentum, max energy, largest distance of closes approach, largest impact parameters…)
2. Add **minimal reconstruction** require a $D^{\pm}$ or D^{0} in the event
    1. Use “partial FEI” to minimize efficiency lost
3. Producing new **efficiency**/rake rate **tables**
    1. From MC & from data (exp 14)
    2. Off-res data set (exp 12) to capture background

Experiment	Beam Energy	Offline luminosity fb^{-1}	
		proc12 & prompt	proc13 & prompt
14	4S	16.385 +/- 0.005	16.405 +/- 0.005 +/- 0.115
12	4S	54.388 +/- 0.004	54.368 +/- 0.004 +/- 0.381
	4S_offres	8.716 +/- 0.002	8.679 +/- 0.002 +/- 0.061
10	4S	3.635 +/- 0.001	3.647 +/- 0.001 +/- 0.026

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