Lab meeting

Yonsei University

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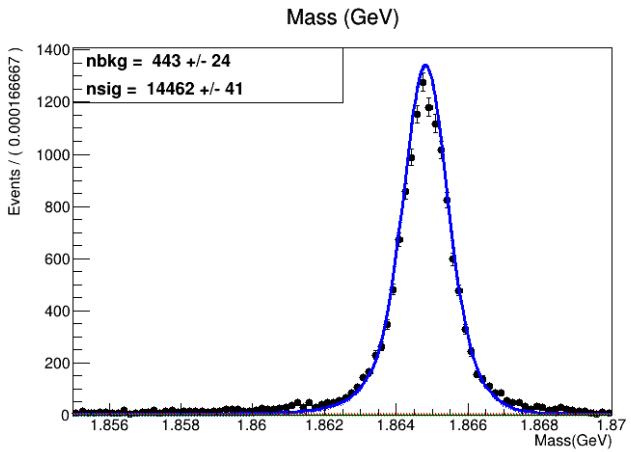
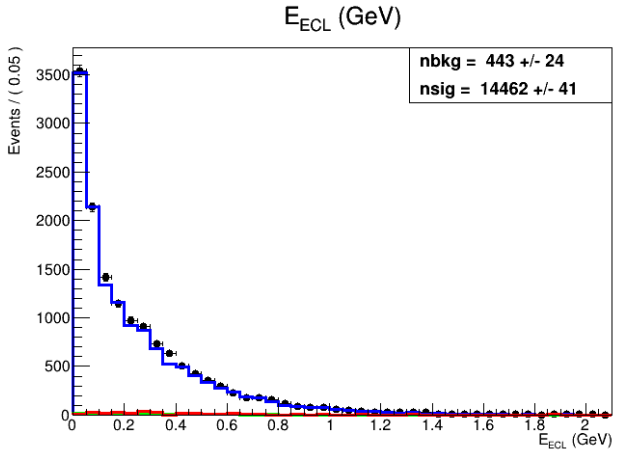
Recap of previous status

- Analysis tool Charm Tagger Development
  - 56 BDTs were trained for tag side reconstruction
  - Inclusive D reconstructed and fit was done
  - Toy MC(Linearity test & checking Pull distribution) test for inclusive D fitting was performed

- Signal extraction
  - 2D fitting on (M_{D^0}, E_{ECL})
  - BF of Control sample($D^0 \to K^-\pi^+$) was measured as validation of charm tagger
    => But this fit has some problem on fit status : maybe the cause of background seems to be histogram PDF from small amount of background events
  - CL UL of BF for signal mode($D^0 \to \nu\bar{\nu}$) on generic MC is estimated

Reminder : The result of measurement of $Br(D^0 \to K^-\pi^+)$ on generic MC





- BF formula : $Br(D^0 \to K^-\pi^+) = \frac{N_{exclusive}}{N_{inclusive} * \varepsilon_{sig}}$ (pdg value : 0.0395)
- Measurement of BF :

$$Br(D^0 \to K^-\pi^+) = \frac{14462 \pm 41}{(704597 \pm 1169) * (0.51826 \pm 0.00556)} = 0.039604 \pm 0.000444$$

Minor details : retraining tag side channels

- New skimming of generic ccbar MC by myself is done
- Slightly change in charm tagger
  - I used the angle between 2 daughters of Λ^0, K_S^0 as training variable
  - But it seems that I need to set DautherUpdate as True for using angle between daughters (refering to belle II software wiki)

> The momenta of the daughters are updated only if `updateAllDaughters` is set to `True` (i.e. **not** by default). Some variables, e.g. `daughterAngle`, will only return meaningful results if the daughters momenta are updated.
> This happens because variables like `daughterAngle` assume the direction of the daughers momenta *at the Ks vertex* to be provided, while non-updated daughters will provide their momenta direction at the point-of-closest-approach (POCA) to the beam axis.

  - This is about updating dauthers kinematics after vertex treefit
  - The default is False

Reminder : fastBDT training for Charm Tagging

- Input Variables of fastBDT
  - For D_{tag} training

    M, p, dr(flight length), dz, chiProb, Q, E, cosToThrustOfEvent,

    cosAngleBetweenMomentumAndVertexVectorInXYPlane, ImpactXY,

    xp, PID of daughters, cosHelicityAngle(2 body or 3 body decays),

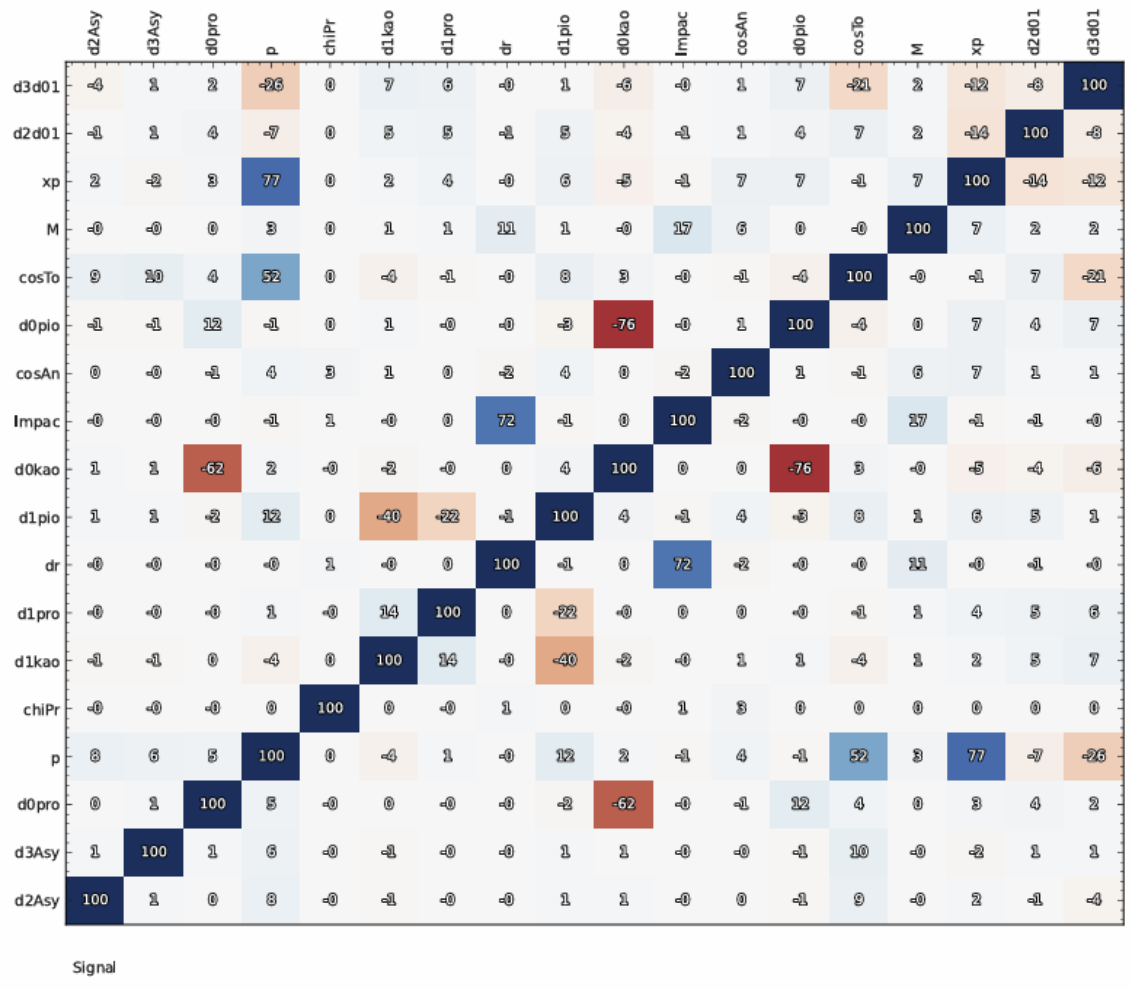
    angle between 2 daughters of $\pi^0(\rightarrow \gamma\gamma), K_S^0(\rightarrow \pi^+\pi^-), \Lambda^0(\rightarrow p^+\pi^-), \Sigma^+(\rightarrow p^+\pi^0)$,

    $|\frac{E_{d_1}-E_{d_2}}{E_{d_1}+E_{d_2}}|$ of $\pi^0(\rightarrow \gamma\gamma), K_S^0(\rightarrow \pi^+\pi^-), \Lambda^0(\rightarrow p^+\pi^-), \Sigma^+(\rightarrow p^+\pi^0)$ etc…
  - For D_{tag}^* training

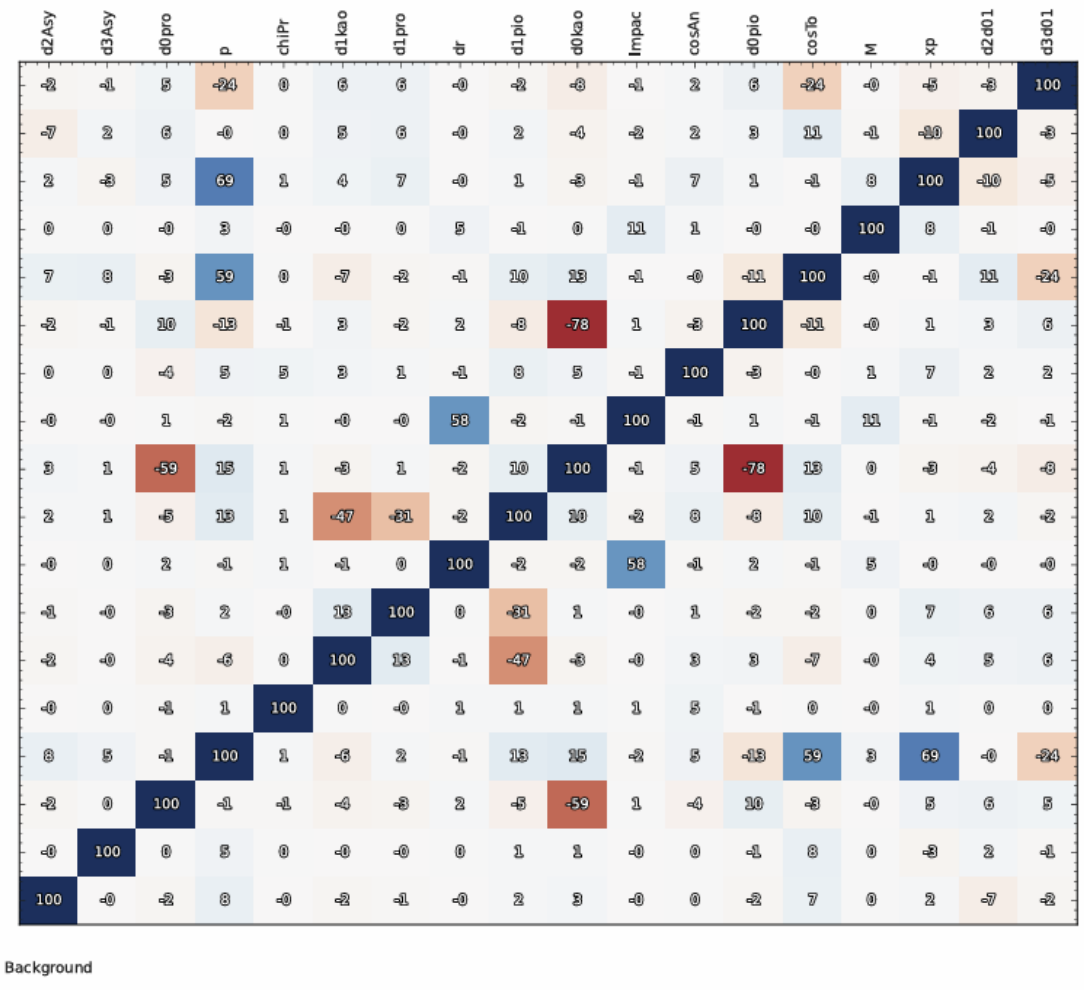
    $\Delta M(= M_{D_{tag}^*} - M_{D_{tag}})$, momentum of $\pi_s^{\pm}, \gamma, \pi^0$,

    angle between D_{tag} and $\pi_s^{\pm}, \gamma, \pi^0$ etc…
- Hyper Parameters of BDT was optimized by applying grid search for each tag training

Check on correlation between previous BDT variables

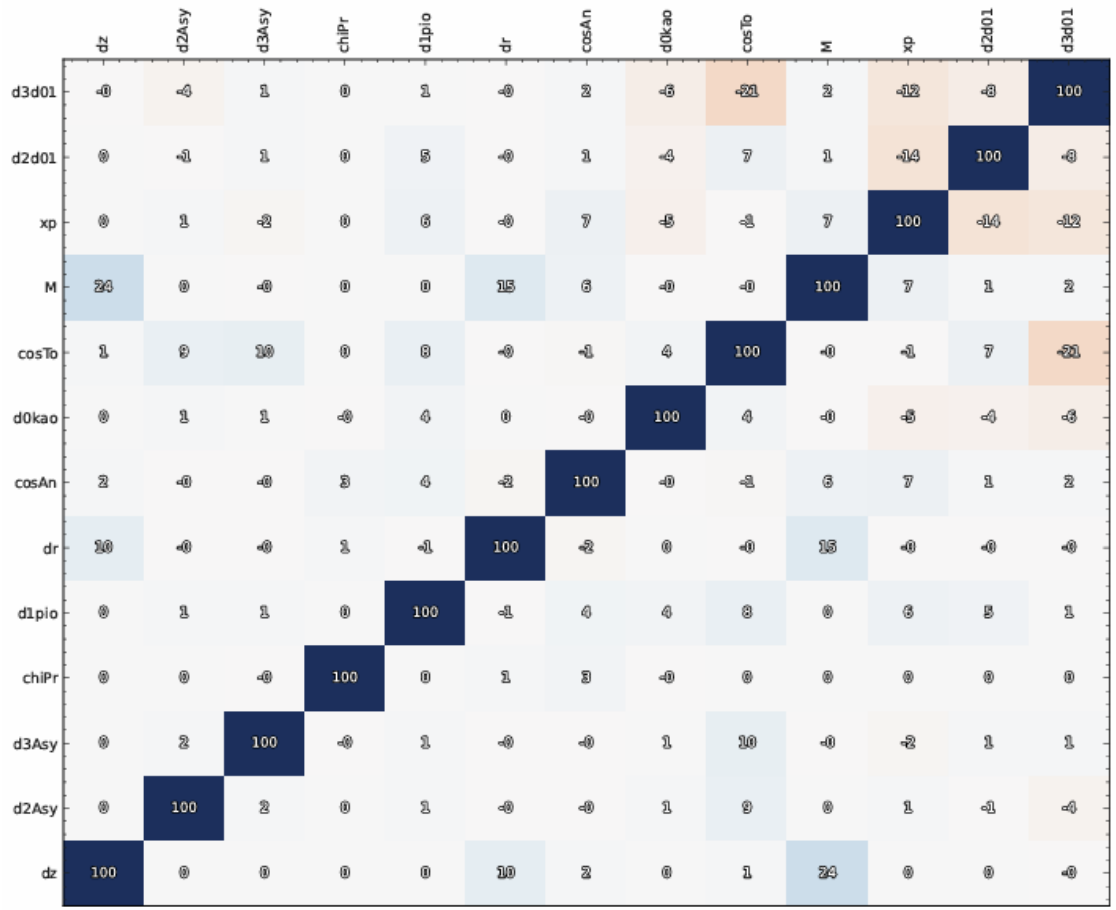


Signal

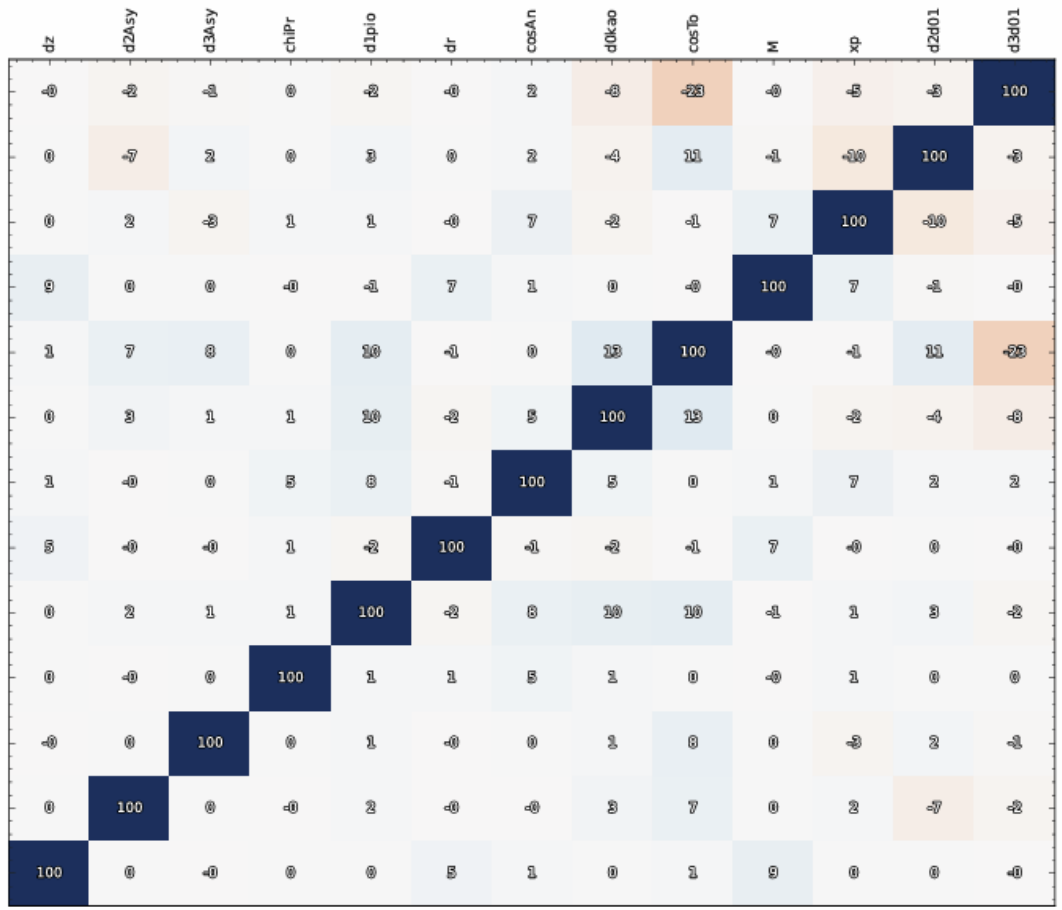


Background

Check on correlation between BDT variables



Signal



Background

Reminder : Investigation of background event in exclusive $D^0 \to K^-\pi^+$ in generic MC with TopoAna

Table 17: Exclusive components of $D^0 \to \pi^+ K^- + anything$.

rowNo	exclusive component of $D^0 \to \pi^+ K^- + anything$	iDcyBrIncDcyBr	nCase	nCcCase	nAllCase	nCCase
1	$D^0 \to \pi^+ K^-$	0	4427	4485	8912	8912
2	$D^0 \to \pi^0 \pi^+ K^-$	1	933	909	1842	10754
3	$D^0 \to \pi^+ K^- \gamma^F$	2	814	724	1538	12292
4	$D^0 \to \pi^0 \pi^+ K^- \gamma^F$	6	95	79	174	12466
5	$D^0 \to \pi^0 \pi^0 \pi^+ K^-$	7	76	59	135	12601
6	$D^0 \to \pi^+ \pi^+ \pi^- K^-$	3	72	57	129	12730
7	$D^0 \to \pi^+ K^- \gamma^F \gamma^F$	5	59	50	109	12839
8	$D^0 \to \pi^+ \omega K^-$	4	51	56	107	12946
9	$D^0 \to \rho^0 \pi^+ K^-$	8	44	52	96	13042
10	$D^0 \to \pi^+ \pi^+ \pi^- K^- \gamma^F$	11	11	12	23	13065
11	$D^0 \to \pi^+ \eta K^-$	12	4	8	12	13077
12	$D^0 \to \pi^+ \omega K^- \gamma^F$	13	4	4	8	13085
13	$D^0 \to \pi^0 \pi^0 \pi^+ K^- \gamma^F$	10	4	3	7	13092
14	$D^0 \to \rho^0 \pi^+ K^- \gamma^F$	9	3	2	5	13097
15	$D^0 \to \pi^+ K^- \gamma^F \gamma^F \gamma^F$	14	4	1	5	13102
16	$D^0 \to \pi^+ K_S^0 K^-$	15	1	1	2	13104
17	$D^0 \to \pi^+ \eta K^- \gamma^F$	17	1	1	2	13106
18	$D^0 \to \pi^+ \pi^+ \pi^- K^- \gamma^F \gamma^F$	18	1	1	2	13108
19	$D^0 \to \pi^0 \pi^+ K^- \gamma^F \gamma^F$	19	0	2	2	13110
20	$D^0 \to \rho^0 \pi^+ K^- \gamma^F \gamma^F$	16	1	0	1	13111

- Change of exclusive selection :
  - 2 remaining tracks and 1 reconstructed $D^0(K^-\pi^+)$: kaonID > 0.01 / pionID > 0.01
  - no $\pi^0, K_L^0, K_S^0, \Lambda^0$
  - $|\Delta E| < 0.1\text{GeV}$

$D^0 \to K^-\pi^+ +$ anything information according to the **iDcyBrIncDcyBr** index

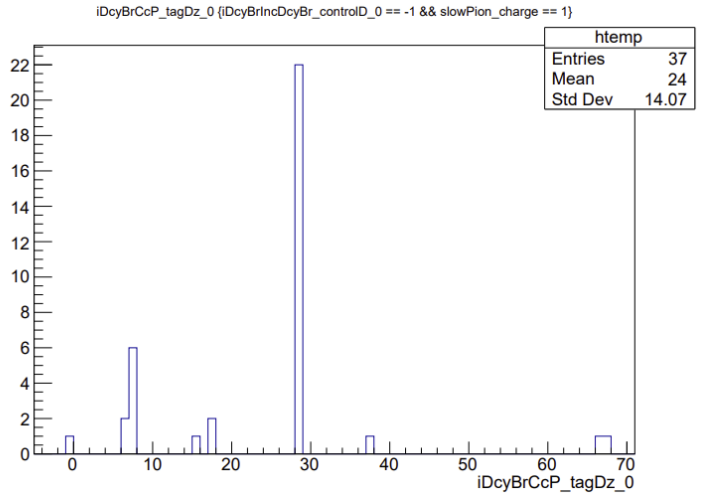
20 $D^0 \to K^-\pi^+\pi^0$ events of total 89 background events
- 89/9294 ~ 0.96%
- 20/9294 ~ 0.21%

1 $\bar{D}^0 \to K^+\pi^-\pi^+\pi^-\gamma^F$ event

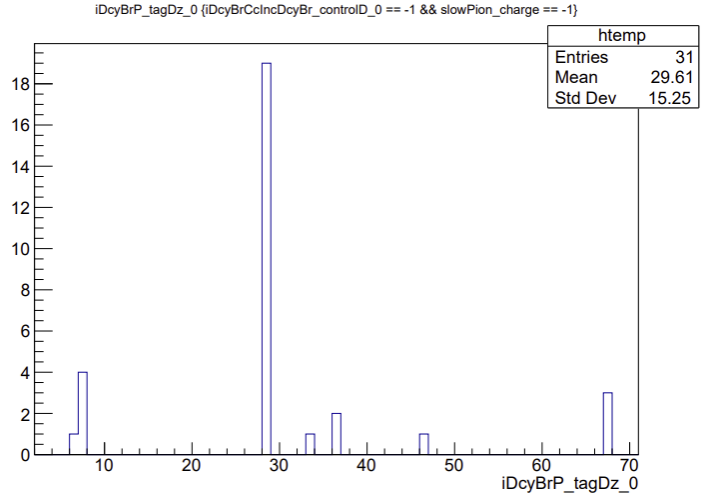
Reminder : Investigation about the cases of “iDcyBrIncDcyBr == -1”(68 events) with iDcyBrP index (1)

Table 14: Cascade decay branches of $\bar{D}^0$.

rowNo	cascade decay branch of $\bar{D}^0$	iCascDcyBrP	nCase	nCcCase	nAllCase	nCCase
1	$\bar{D}^0 \to \pi^- K^+$	0	4485	4427	8912	8912
2	$\bar{D}^0 \to \pi^0\pi^- K^+$	1	909	933	1842	10754
3	$\bar{D}^0 \to \pi^- K^+\gamma^F$	2	724	814	1538	12292
4	$\bar{D}^0 \to K^+ a_1^-, a_1^- \to \rho^0\pi^-, \rho^0 \to \pi^+\pi^-$	3	182	201	383	12675
5	$\bar{D}^0 \to \pi^+\pi^- K^*, K^* \to \pi^- K^+$	32	112	120	232	12907
6	$\bar{D}^0 \to \pi^+\pi^- K_S^0, K_S^0 \to \pi^+\pi^-$	11	102	123	225	13132
7	$\bar{D}^0 \to K^+ a_1^-, a_1^- \to \pi^+\pi^-\pi^-$	20	91	83	174	13306
8	$\bar{D}^0 \to \pi^0\pi^- K^+\gamma^F$	14	79	95	174	13480
9	$\bar{D}^0 \to \rho^0 K^*, \rho^0 \to \pi^+\pi^-, K^* \to \pi^- K^+$	30	73	86	159	13639
10	$\bar{D}^0 \to K^+ a_1^-, a_1^- \to \pi^- f_0(600), f_0(600) \to \pi^+\pi^-$	41	77	73	150	13789
11	$\bar{D}^0 \to \pi^0\pi^0\pi^- K^+$	19	59	76	135	13924
12	$\bar{D}^0 \to \pi^+\pi^-\pi^- K^+$	5	57	72	129	14053
13	$\bar{D}^0 \to \pi^0\pi^+\pi^-$	22	55	66	121	14174
14	$\bar{D}^0 \to \rho^- K^{*+}, \rho^- \to \pi^0\pi^-, K^{*+} \to \pi^0 K^+$	31	54	66	120	14294
15	$\bar{D}^0 \to K^+ K^-$	8	65	53	118	14412
16	$\bar{D}^0 \to K^+ a_1^-, a_1^- \to \pi^0\rho^-, \rho^- \to \pi^0\pi^-$	45	73	45	118	14530
17	$\bar{D}^0 \to \pi^- K^+\gamma^F\gamma^F$	12	50	59	109	14639
18	$\bar{D}^0 \to \pi^-\omega K^+, \omega \to \pi^0\pi^+\pi^-$	9	47	49	96	14735
19	$\bar{D}^0 \to \rho^0\pi^- K^+, \rho^0 \to \pi^+\pi^-$	43	43	39	82	14817
20	$\bar{D}^0 \to \pi^+\pi^+\pi^-\pi^-$	35	35	39	74	14891
21	$\bar{D}^0 \to \rho^- K^{*+}, \rho^- \to \pi^0\pi^-, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	33	27	38	65	14956
22	$\bar{D}^0 \to \pi^0\pi^+\pi^- K^*, K^* \to \pi^- K^+$	17	30	31	61	15017
23	$\bar{D}^0 \to K^+ a_1^-, a_1^- \to \rho^0\pi^-, \rho^0 \to \pi^+\pi^-\gamma^F$	28	25	28	53	15070
24	$\bar{D}^0 \to \pi^0 K_S^0, K_S^0 \to \pi^+\pi^-$	83	19	27	46	15116
25	$\bar{D}^0 \to K_S^0 K^+ K^-, K_S^0 \to \pi^+\pi^-$	64	22	22	44	15160
26	$\bar{D}^0 \to \pi^+ K^-$	39	19	22	41	15201
27	$\bar{D}^0 \to \pi^0\pi^0 K^*, K^* \to \pi^- K^+$	15	20	20	40	15241
28	$\bar{D}^0 \to \pi^+\pi^-$	26	16	23	39	15280
29	$\bar{D}^0 \to \pi^- K_1^+, K_1^+ \to \rho^0 K^+, \rho^0 \to \pi^+\pi^-$	36	21	16	37	15317
30	$\bar{D}^0 \to \omega K^*, \omega \to \pi^0\pi^+\pi^-, K^* \to \pi^- K^+$	47	19	16	35	15352
31	$\bar{D}^0 \to \pi^0\rho^- K^+, \rho^- \to \pi^0\pi^-$	50	15	18	33	15385
32	$\bar{D}^0 \to \omega K_S^0, \omega \to \pi^0\pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	16	11	19	30	15415



iDcyBrP distribution for D^0



iDcyBrP distribution for $\overline{D}^0$

Reminder : Investigation about the cases of “iDcyBrIncDcyBr == -1” with iDcyBrP index (2)

- Major components according to iDcyBrP information
  - 28 : $D^0 \to K^- a_1^+, a_1^+ \to \rho^0 \pi^+, \rho^0 \to \pi^+ \pi^-$
    (41 entries ~ 60% of “iDcyBrIncDcyBr == -1” cases)
    => now I have one example script about how to use apptainer (thanks to Jaeyoung)
    => test about generating with release-06

  - 7 : $D^0 \to K^- a_1^+, a_1^+ \to \rho^+(1450)\pi^0, \rho^+(1450) \to \pi^0 \pi^+$
    (10 entries ~ 15% of “iDcyBrIncDcyBr == -1” cases)
  - Other events (just 1 ~ 2 events) :
    $D^0 \to \pi^+ \pi^- K_S^0 (c.c),\ \pi^0 \pi^0 K^*(K^* \to \pi^- K^+)(c.c),$
    $\pi^0 \pi^+ \pi^- K^*(K^* \to \pi^- K^+), K^- K^{*+}(K^{*+} \to \pi^0 K^+),$
    $\rho^0 \pi^+ K^-(\rho^0 \to \pi^+ \pi^- \gamma^F)(c.c), \pi^0 \phi(\phi \to \pi^+ \rho^-, \rho^- \to \pi^0 \pi^-)(\mathrm{c.c})$
    $\bar{D}^0 \to \rho^- K^{*+}\left(\rho^- \to \pi^0 \pi^-, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0 \to \pi^+ \pi^-\right),$
    $\pi^- K_1^+(K_1^+ \to \rho^0 K^+, \rho^0 \to \pi^+ \pi^-),$
    $\pi^- K_1^+(K_1^+ \to \rho^+ K^0, \rho^+ \to \pi^0 \pi^+, K^0 \to K_S^0 \to \pi^+ \pi^-$

Background events : Data Production requested

total 400M events (D0 : 200M / anti-D0 : 200M)

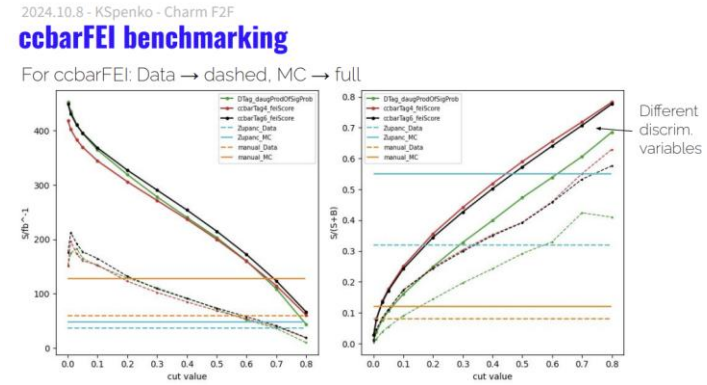
Background event	fraction
$D^{*+} \to D^0\pi^+, D^0 \to K^-\pi^+\pi^0$	64.9%
$D^{*+} \to D^0\pi^+, D^0 \to K^- a_1^+, a_1^+ \to \rho^0\pi^+, \rho^0 \to \pi^+\pi^-$	33.7%
$D^{*+} \to D^0\pi^+, D^0 \to K^- a_1^+, a_1^+ \to \rho^+(1450)\pi^0, \rho^+ \to \pi^0\pi^+$	1.4%

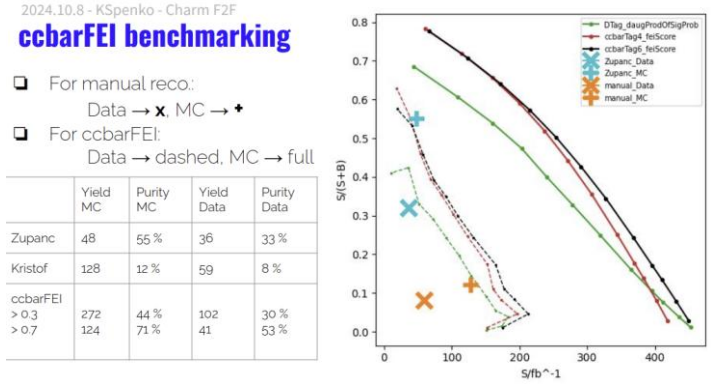
Expected background events number : 700 ~ 800 (~10%)
(previously 80 (~1%) background events in 9300 entries) => not sured whether it is enough or not

ccbarFEI in B2GM

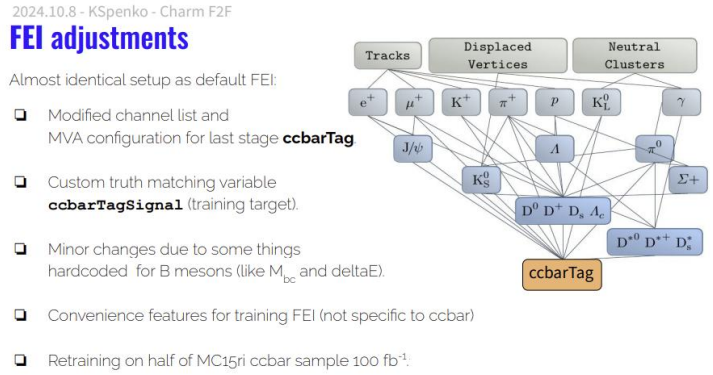
- In charm parallel session, there was presentation about “inclusive charm reconstruction using FEI”
  https://indico.belle2.org/event/13003/contributions/83007/attachments/30841/45560/charmF2F_oct24b2gm.pdf
- with modification of FEI code in basf2 and retraining, reconstruction of inclusive Λ_c^+
- Validation on the Data(10/fb) and MC(100/fb)
- Benchmarking charm tagging of Zupan (charm tagger idea from Zupan)
  (reminder)==========

- **Discussion with Kristof Spenko**
  - **He will add my 25 fragmentation channels for signal side D0 reconstruction and train in this week**
  - **He said he will send email soon**
  - **Chance to compare the result with my charm tagger result**





	Yield MC	Purity MC	Yield Data	Purity Data
Zupanc	48	55 %	36	33 %
Kristof	128	12 %	59	8 %
ccbarFEI > 0.3	272	44 %	102	30 %
ccbarFEI > 0.7	124	71 %	41	53 %



Plan and status about systematics…?

- Inclusive D^0
  - 1st Priority : Charm tagger (MC / Data difference …?)
    - FastBDT training output distribution (MC / Data difference …?) (Zupan…?)
    - Tagging efficiency…? (previous research and FEI) => systematics estimation with this
  - Fit model function (comparison about nominal fit & other model fit result) => Gauss / DSCB
  - Fit bias (ToyMC & Linearity test) => code prepared

- Exclusive D^0
  - Tracking efficiency
  - PID efficiency
  - $K_S^0, K_L^0, \Lambda^0, \pi^0$
  - Photon selection for E_{ECL} calculation…?
    (MVA based variable : beamBackgroundSuppression / fakePhotonSuppression cut)
  - Fitting model (comparison about nominal fit & other model fit result)
    - ECL histogram PDF (Data/MC difference
      => comparison with original histogram PDF & calibrated histogram PDF)
  - Fit bias (ToyMC & Linearity test) => code prepared

To do list

- Complete retraining of charm tagger with reduced variables and optimizing selection (on-going)
- Complete 2D (M_{D^0}, E_{ECL}) fitting for exclusive $D^0 \to K^-\pi^+$ with generation of background events
- Comparison about efficiency of charm tagger and ccbarFEI
- Keep going about systematics study and investigate how to estimate them