



Lab meeting

Yonsei University

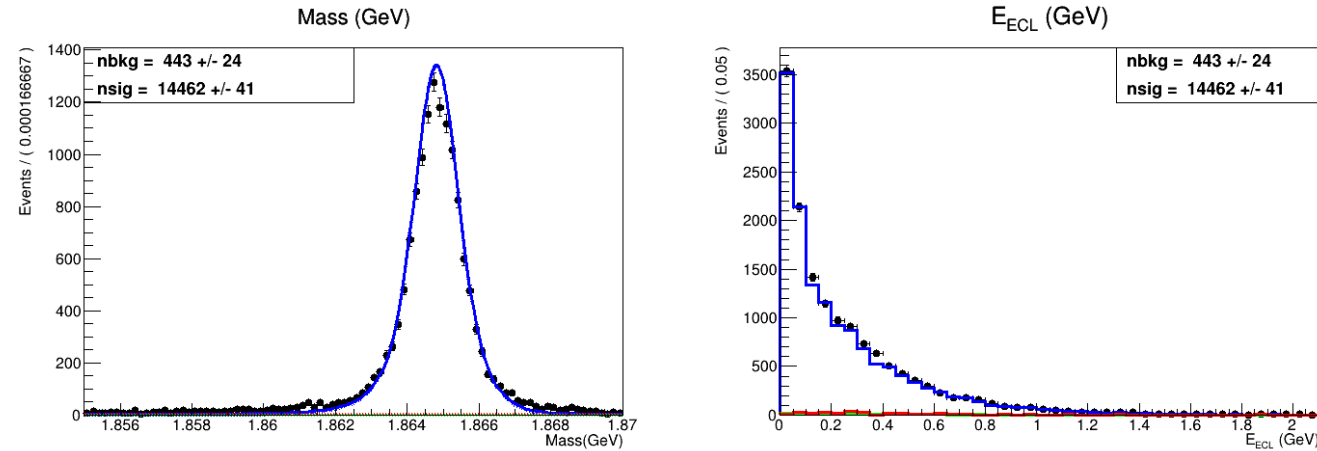
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2024-10-16

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($D^0 \rightarrow K^- \pi^+$) 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($D^0 \rightarrow \nu \bar{\nu}$) on generic MC is estimated

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



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

- Measurement of BF :

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

Minor details : retraining tag side channels

- New skimming of generic c \bar{c} bar 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 (referring 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 daughters 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), 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 π_S^\pm , γ , π^0 ,

angle between D_{tag} and π_S^\pm , γ , π^0 etc...

- Hyper Parameters of BDT was optimized by applying grid search for each tag training

Minor error fixing in basf2 package..?

- basf2_mva_merge_mc :
 - This is used for splitting data into training set and test set with fixing signal and background ratio and applying some selections
 - But this command had some error probably due to python package uproot version
 - Originally, I used light-2311 version for this command (there are no errors at that time)
 - light-2311 also show similar errors
 - So, I need to fix the error in basf2 package directly

```
Traceback (most recent call last):
  File "/gpfs/home/belle2/chankim/localB2/BASF2/basf2/bin/Linux_x86_64/opt/basf2_mva_merge_mc", line 112, in <module>
    df_sig = uproot.concatenate(data_sig[0], columns, cut=cut_sig, library='pd')
    ~~~~~
  File "/cvmfs/belle.cern.ch/el9/externals/v02-02-01/Linux_x86_64/common/lib/python3.11/site-packages/uproot/behaviors/TBranch.py", line 374, in concatenate
    arrays = library.global_index(arrays, global_start)
    ~~~~~
  File "/cvmfs/belle.cern.ch/el9/externals/v02-02-01/Linux_x86_64/common/lib/python3.11/site-packages/uproot/interpretation/library.py", line 922, in global_index
    index = arrays.index.arrays
    ~~~~~
AttributeError: 'Index' object has no attribute 'arrays'. Did you mean: 'array'?
AttributeError: 'DataFrame' object has no attribute 'append'. Did you mean: '_append'?
Load data
loading signal
loading background
- 8928 signal candidates selected.
- 1223982 background candidates selected.
Adjusting signal/background ratio from 0.007241 to 0.500000.
Warning: sampling down background
Traceback (most recent call last):
  File "/gpfs/home/belle2/chankim/localB2/BASF2/basf2/bin/Linux_x86_64/opt/basf2_mva_merge_mc", line 154, in <module>
    df = df_bkg.append(df_sig, ignore_index=True)
    ~~~~~
  File "/cvmfs/belle.cern.ch/el9/externals/v02-02-01/Linux_x86_64/common/lib/python3.11/site-packages/pandas/core/generic.py", line 6299, in __getattr__
    return object.__getattr__(self, name)
    ~~~~~
AttributeError: 'DataFrame' object has no attribute 'append'. Did you mean: '_append'?
Load data
```

- Using basf2 with modifying the code and compiling, it seems that this command worked properly at now (but it looks very slow...)

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

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

| rowNo | exclusive component of $D^0 \rightarrow \pi^+ K^- + anything$ | iDcyBrIncDcyBr | nCase | nCcCase | nAllCase | nCCase |
|-------|---|----------------|-------|---------|----------|--------|
| 1 | $D^0 \rightarrow \pi^+ K^-$ | 0 | 4427 | 4485 | 8912 | 8912 |
| 2 | $D^0 \rightarrow \pi^0 \pi^+ K^-$ | 1 | 933 | 909 | 1842 | 10754 |
| 3 | $D^0 \rightarrow \pi^+ K^- \gamma^F$ | 2 | 814 | 724 | 1538 | 12292 |
| 4 | $D^0 \rightarrow \pi^0 \pi^+ K^- \gamma^F$ | 6 | 95 | 79 | 174 | 12466 |
| 5 | $D^0 \rightarrow \pi^0 \pi^0 \pi^+ K^-$ | 7 | 76 | 59 | 135 | 12601 |
| 6 | $D^0 \rightarrow \pi^+ \pi^+ \pi^- K^-$ | 3 | 72 | 57 | 129 | 12730 |
| 7 | $D^0 \rightarrow \pi^+ K^- \gamma^F \gamma^F$ | 5 | 59 | 50 | 109 | 12839 |
| 8 | $D^0 \rightarrow \pi^+ \omega K^-$ | 4 | 51 | 56 | 107 | 12946 |
| 9 | $D^0 \rightarrow \rho^0 \pi^+ K^-$ | 8 | 44 | 52 | 96 | 13042 |
| 10 | $D^0 \rightarrow \pi^+ \pi^+ \pi^- K^- \gamma^F$ | 11 | 11 | 12 | 23 | 13065 |
| 11 | $D^0 \rightarrow \pi^+ \eta K^-$ | 12 | 4 | 8 | 12 | 13077 |
| 12 | $D^0 \rightarrow \pi^+ \omega K^- \gamma^F$ | 13 | 4 | 4 | 8 | 13085 |
| 13 | $D^0 \rightarrow \pi^0 \pi^0 \pi^+ K^- \gamma^F$ | 10 | 4 | 3 | 7 | 13092 |
| 14 | $D^0 \rightarrow \rho^0 \pi^+ K^- \gamma^F$ | 9 | 3 | 2 | 5 | 13097 |
| 15 | $D^0 \rightarrow \pi^+ K^- \gamma^F \gamma^F \gamma^F$ | 14 | 4 | 1 | 5 | 13102 |
| 16 | $D^0 \rightarrow \pi^+ K_S^0 K^-$ | 15 | 1 | 1 | 2 | 13104 |
| 17 | $D^0 \rightarrow \pi^+ \eta K^- \gamma^F$ | 17 | 1 | 1 | 2 | 13106 |
| 18 | $D^0 \rightarrow \pi^+ \pi^+ \pi^- K^- \gamma^F \gamma^F$ | 18 | 1 | 1 | 2 | 13108 |
| 19 | $D^0 \rightarrow \pi^0 \pi^+ K^- \gamma^F \gamma^F$ | 19 | 0 | 2 | 2 | 13110 |
| 20 | $D^0 \rightarrow \rho^0 \pi^+ K^- \gamma^F \gamma^F$ | 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 $\pi^0, K_L^0, K_S^0, \Lambda^0$
- $|\Delta E| < 0.1 \text{ GeV}$

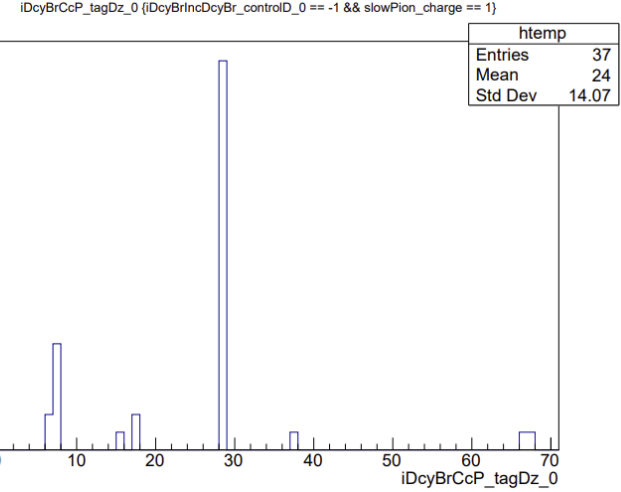
$D^0 \rightarrow K^- \pi^+ + anything$ information according to the **iDcyBrIncDcyBr** index

20 $D^0 \rightarrow K^- \pi^+ \pi^0$ events of total 89 background events
- 89/9294 ~ 0.96%
- 20/9294 ~ 0.21%
1 $\bar{D}^0 \rightarrow K^+ \pi^- \pi^+ \pi^- \gamma^F$ event

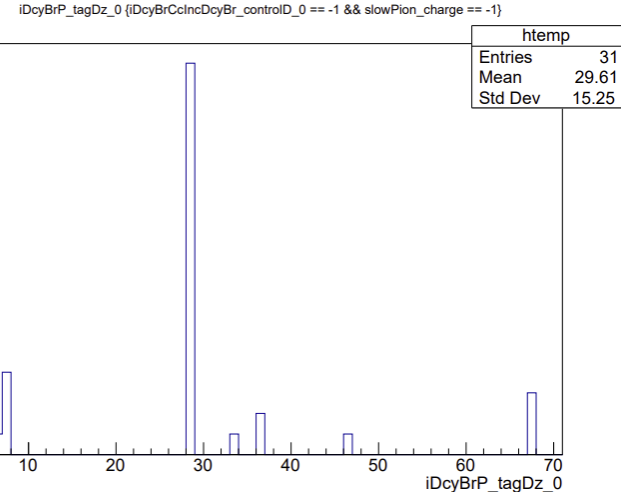
Investigation about the cases of “iDcyBrIncDcyBr == -1”(68 events) with iDcyBrP index (1)

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

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



iDcyBrP
distribution for D^0



iDcyBrP
distribution for \bar{D}^0

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

- Major components according to iDcyBrP information

- 28 : $D^0 \rightarrow K^- a_1^+, a_1^+ \rightarrow \rho^0 \pi^+, \rho^0 \rightarrow \pi^+ \pi^-$
 (41 entries ~ 60% of “iDcyBrIncDcyBr == -1” cases)
 => generation of 50M(D^0) + 50M(\bar{D}) is on-going... (some problems...)
 => advise from expert to contact DP liason

- 7 : $D^0 \rightarrow K^- a_1^+, a_1^+ \rightarrow \rho^+(1450) \pi^0, \rho^+(1450) \rightarrow \pi^0 \pi^+$
 (10 entries ~ 15% of “iDcyBrIncDcyBr == -1” cases)

- Other events (just 1 ~ 2 events) :

$D^0 \rightarrow \pi^+ \pi^- K_S^0 (c.c), \pi^0 \pi^0 K^*(K^* \rightarrow \pi^- K^+) (c.c),$
 $\pi^0 \pi^+ \pi^- K^*(K^* \rightarrow \pi^- K^+), K^- K^{*+} (K^{*+} \rightarrow \pi^0 K^+),$
 $\rho^0 \pi^+ K^- (\rho^0 \rightarrow \pi^+ \pi^- \gamma^F) (c.c), \pi^0 \phi (\phi \rightarrow \pi^+ \rho^-, \rho^- \rightarrow \pi^0 \pi^-) (c.c)$
 $\bar{D}^0 \rightarrow \rho^- K^{*+} (\rho^- \rightarrow \pi^0 \pi^-, K^{*+} \rightarrow \pi^+ K^0, K^0 \rightarrow K_S^0 \rightarrow \pi^+ \pi^-),$
 $\pi^- K_1^+ (K_1^+ \rightarrow \rho^0 K^+, \rho^0 \rightarrow \pi^+ \pi^-),$
 $\pi^- K_1^+ (K_1^+ \rightarrow \rho^+ K^0, \rho^+ \rightarrow \pi^0 \pi^+, K^0 \rightarrow K_S^0 \rightarrow \pi^+ \pi^-)$

Background

| Background event | fraction |
|---|----------|
| $D^{*+} \rightarrow D^0\pi^+, D^0 \rightarrow K^-\pi^+\pi^0$ | 28.2% |
| $D^{*+} \rightarrow D^0\pi^+, D^0 \rightarrow K^-a_1^+, a_1^+ \rightarrow \rho^0\pi^+, \rho^0 \rightarrow \pi^+\pi^-$ | 57.7% |
| $D^{*+} \rightarrow D^0\pi^+, D^0 \rightarrow K^-a_1^+, a_1^+ \rightarrow \rho^+(1450)\pi^0, \rho^+ \rightarrow \pi^0\pi^+$ | 14.1% |

Print generated MC particles

```
[INFO] Content of MCParticle list
├── e- (11)
│   ├── gamma (22)
│   ├── gamma (22)
│   └── gamma (22)
├── e+ (-11)
├── Z0 (23)
│   ├── D** (413)
│   │   ├── D0 (421)
│   │   │   ├── a_1+ (20213)
│   │   │   │   ├── rho0 (113)
│   │   │   │   │   ├── pi+ (211)
│   │   │   │   │   └── pi- (-211)
│   │   │   │   └── pi+ (211)
│   │   │   │       ├── nu_mu (14)
│   │   │   │       ├── mu+ (-13)
│   │   │   │       ├── anti-nu_mu (-14)
│   │   │   │       ├── nu_e (12)
│   │   │   │       └── e+ (-11)
│   │   │   └── K- (-321)
│   │   │       ├── nu_mu (14)
│   │   │       ├── mu+ (-13)
│   │   │       ├── anti-nu_mu (-14)
│   │   │       ├── nu_e (12)
│   │   │       ├── e+ (-11)
│   │   │       ├── pi- (-211)
│   │   │       └── p+ (2212)
│   │   └── pi+ (211)
│   │       ├── nu_mu (14)
│   │       ├── mu+ (-13)
│   │       ├── anti-nu_mu (-14)
│   │       ├── nu_e (12)
│   │       └── e+ (-11)
│   └── pi- (-211)
│       ├── n0 (2112)
│       ├── pi0 (111)
│       │   ├── gamma (22)
│       │   └── gamma (22)
│       └── anti-D*0 (-423)
```

```
[INFO] Content of MCParticle list
├── e- (11)
│   └── gamma (22)
├── e+ (-11)
├── Z0 (23)
│   ├── D** (413)
│   │   ├── D0 (421)
│   │   │   ├── K- (-321)
│   │   │   │   ├── gamma (22)
│   │   │   │   ├── gamma (22)
│   │   │   │   ├── pi- (-211)
│   │   │   │   └── p+ (2212)
│   │   │   └── omega (223)
│   │   │       ├── pi- (-211)
│   │   │       │   ├── gamma (22)
│   │   │       │   └── gamma (22)
│   │   │       ├── pi+ (211)
│   │   │       │   ├── n0 (2112)
│   │   │       │   ├── pi0 (111)
│   │   │       │   │   ├── gamma (22)
│   │   │       │   │   └── gamma (22)
│   │   │       └── pi+ (211)
│   │   └── pi+ (211)
│   │       ├── gamma (22)
│   │       └── gamma (22)
│   └── pi0 (111)
│       ├── gamma (22)
│       ├── gamma (22)
│       ├── e- (11)
│       └── e+ (-11)
└── D*- (-413)
    └── anti-D0 (-421)
```

Naive arrangement of systematics

- Inclusive D^0
 - Charm tagger efficiency (MC / Data difference ...?)
 - FastBDT training output distribution (MC / Data difference ...?)
 - Fit model function (comparison about nominal fit & other model fit result)
 - Fit bias (ToyMC & Linearity test)
- Exclusive D^0
 - Tracking efficiency
 - PID efficiency
 - $K_S^0, K_L^0, \Lambda^0, \pi^0$
 - 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)