The relative decay width measurement in hadronic Z decays by template method

Bo Li

Outline

- **Relative decay widths**
- **template method**
- **IO test**
- **statistical uncertainty**
- **quantitative effect of the differential distribution**

Relative decay widths

- Relative decay width in hadronic Z decays

$$R_{q(q=b,c,uds)} = \frac{\Gamma_{Z\to qq}}{\Gamma_{Z\to had}}$$

- Traditional method: double-tagging method

$$\frac{N_t}{2N_{had}} = R_b\varepsilon_b + R_c\varepsilon_c + (1 - R_b - R_c)\varepsilon_{uds}$$

$$\frac{N_{tt}}{N_{had}} = C_bR_b\varepsilon_b^2 + C_cR_c\varepsilon_c^2 + C_{uds}(1 - R_b - R_c)\varepsilon_{uds}^2$$

- Introduce a template method for cross-check and differentical measurement

$$N_{had}(\lambda) = R_b \cdot N_{bb}(\lambda) + R_c \cdot N_{cc}(\lambda) + R_{uds} \cdot N_{uds}(\lambda)$$

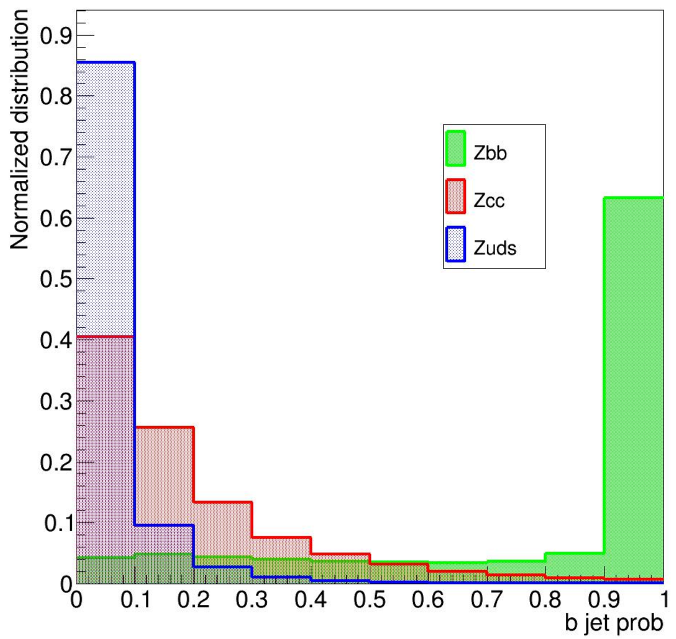
Template method

- **Retrieving physics observables from a sensitive variable λ distribution in real data by fitting with the distribution of MC templates**

$$N_{had}(\lambda) = R_b \cdot N_{bb}(\lambda) + R_c \cdot N_{cc}(\lambda) + R_{uds} \cdot N_{uds}(\lambda)$$

- **λ: b-jet probability**
  - ✓ **retrieved from the flavour-tagging algorithm in the LCFIPlus framework**
  - ✓ **by using BDTs method in TMVA with input variables related to the information on the tracks and vertices**

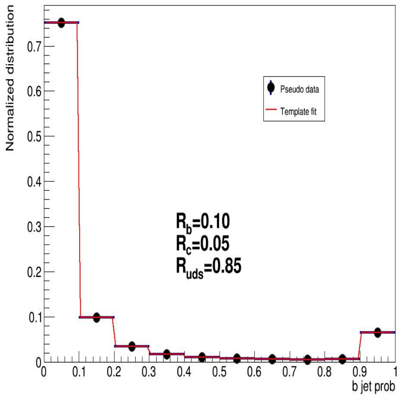
a good discriminative power between different decay channels

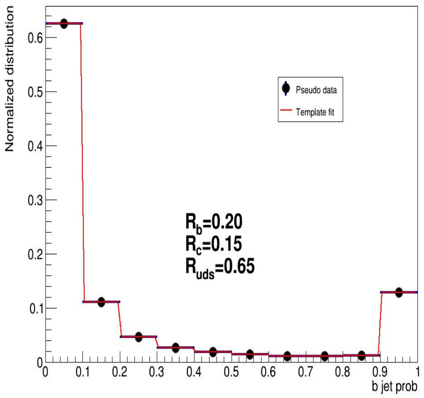


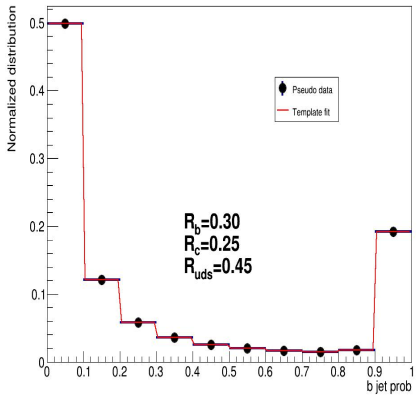
closure test

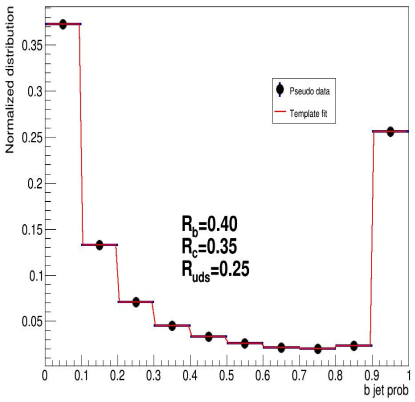
- **Pseudo-data** samples are mixed by using the $Z \rightarrow b\bar{b}$, $Z \rightarrow c\bar{c}$ and Z→uds MC samples with different fraction **frac{Rb, Rc, Ruds}**
- **by fitting with the b-jet prob templates**

frac{0.1, 0.05, 0.85}
frac{0.2, 0.15, 0.65}
frac{0.3, 0.25, 0.45}
frac{0.4, 0.35, 0.25}

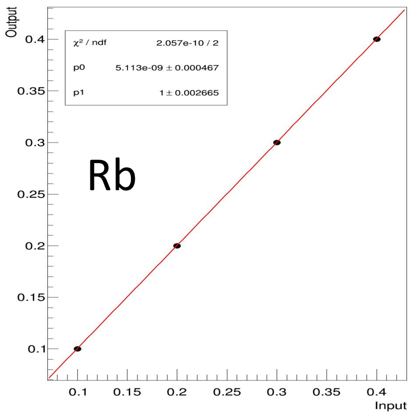


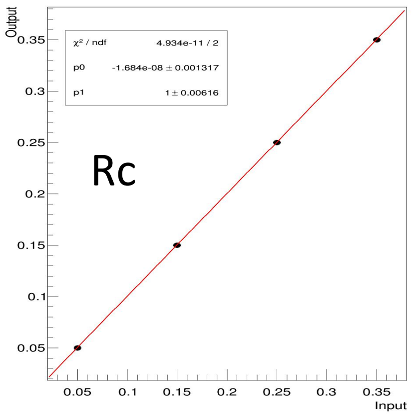


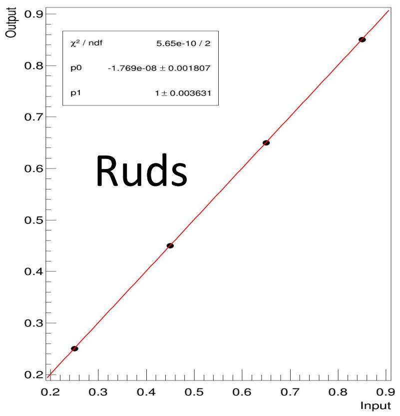




Input/output have good agreement





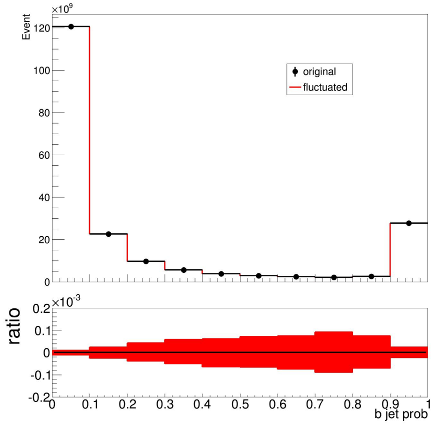


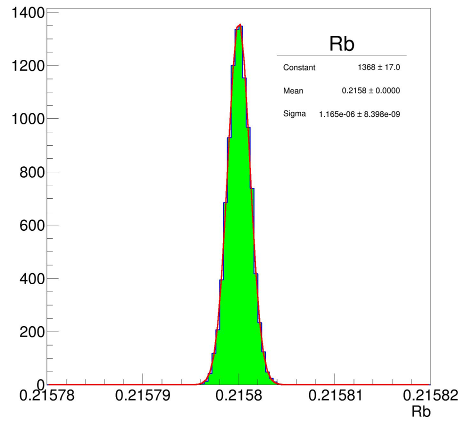
statistical uncertainty

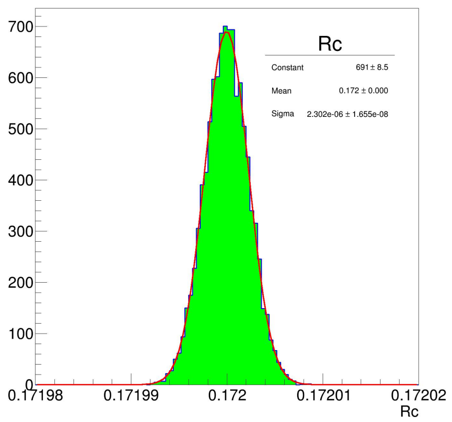
- **Pseudo-data are mixed by MC samples with the relative decay widths in SM:**

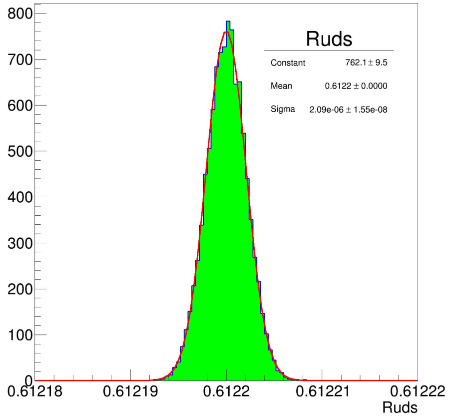
  Rb=0.2158, Rc=0.172 and Ruds=0.6122

- **The contents and errors of the b-jet prob distribution are reset according to the expected statistics 10^{11}.**
- **Ensemble test: the original distribution of the pseudo-data will fluctuate 10,000 times randomly according to the statistical error**









Ratio in down plot: $(\text{Content}_{\text{flucated}} - \text{Content}_{\text{original}})/\text{Content}_{\text{original}}$

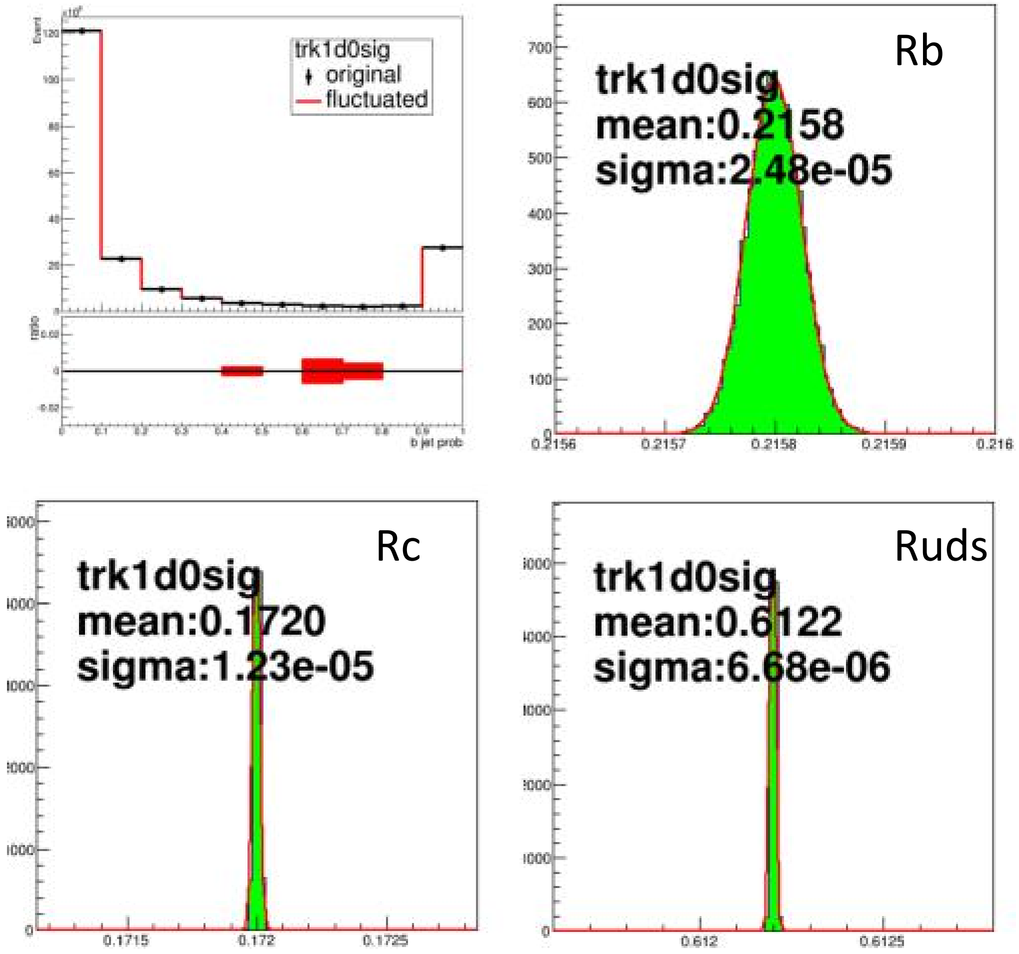
the estimated statistical error of Rb, Rc and Ruds are all approximately 10^{-6}

quantitative effect from input variables

- The b-jet prob are computed from input variables related to tracks and vertices

- by varying the input variables by 0.1%, the bias between the varied and original distributions is taken as the effect of the input variable.

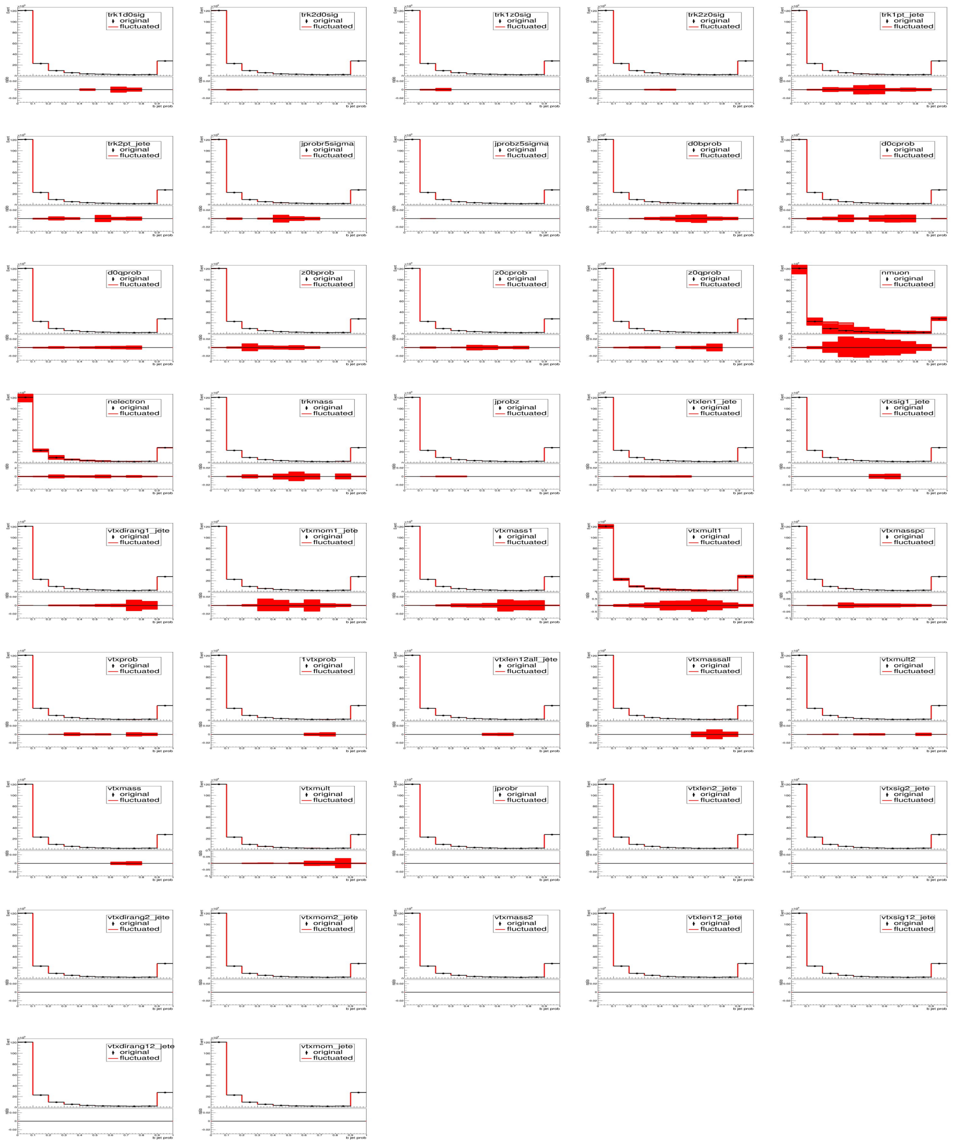
- Similar to the ensemble test in the statistical uncertainty study, the original statistics at each bin of the pseudo-data distribution will fluctuate 10,000 times according to the bias between the varied and original distributions.



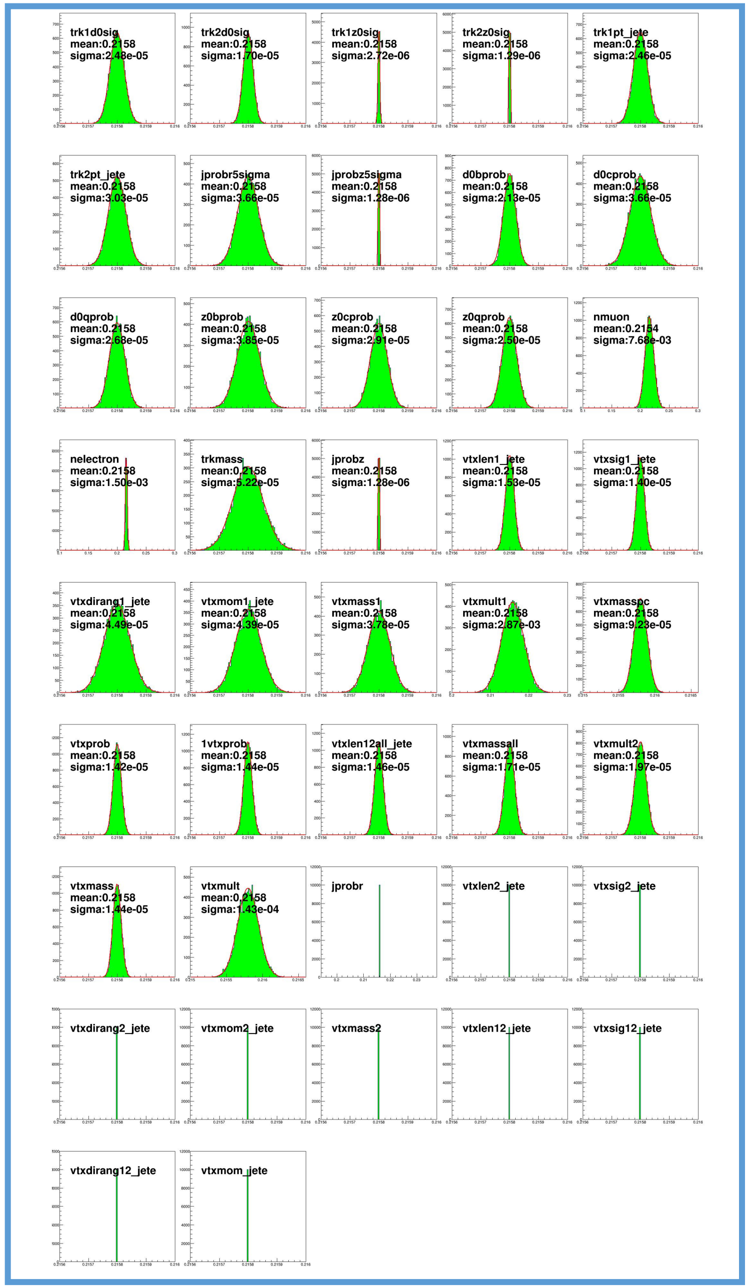
quantitative effect from input variables

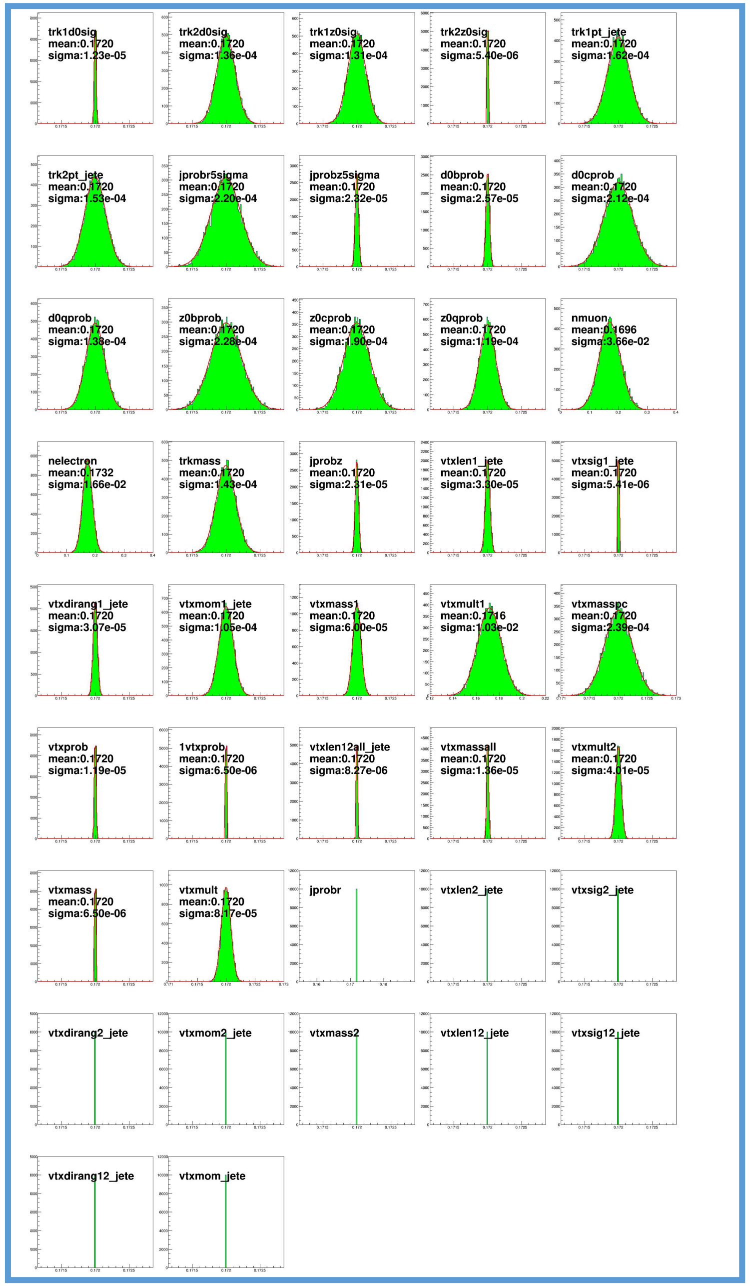
Table 1. The quantitative effect on the uncertainty from ~ 0.1% bias of each variable.

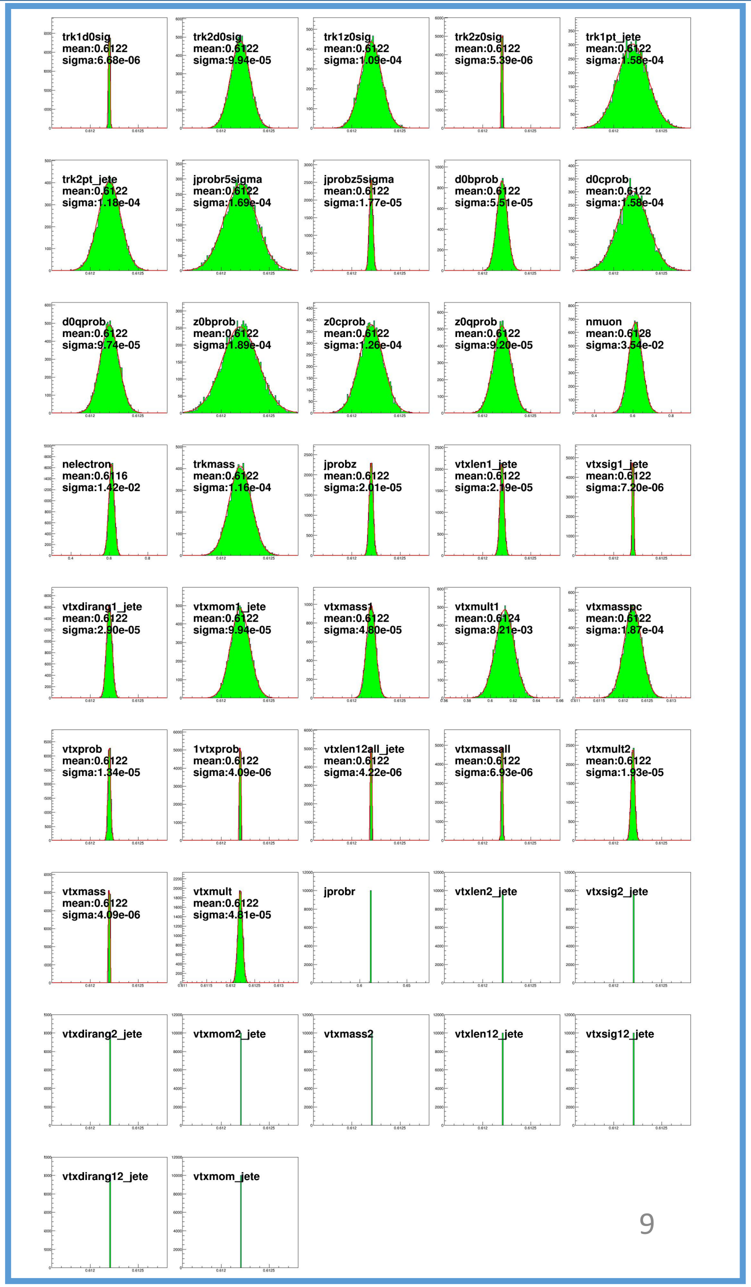
Input variables	$\triangle R_b(10^{-5})$	$\triangle R_c(10^{-5})$	$\triangle R_{uds}(10^{-5})$
trk1d0sig	2.5	1.2	0.7
trk2d0sig	1.7	14	9.9
trk1z0sig	0.3	13	11
trk2z0sig	0.1	0.5	0.5
trk1pt_jete	2.5	16	16
trk2pt_jete	3.0	15	12
jprobr5sigma	3.7	22	17
jprobz5sigma	0.1	2.3	1.8
d0bprob	2.1	2.6	5.5
d0cprob	3.7	21	16
d0qprob	2.7	14	9.7
z0bprob	3.9	23	19
z0cprob	2.9	19	13
z0qprob	2.5	12	9.2
trkmass	5.2	14	12
jprobz	0.1	2.3	2.0
vtxlen1_jete	1.5	3.3	2.2
vtxsig1_jete	1.4	0.5	0.7
vtxdirang1_jete	4.5	3.1	2.9
vtxmom1_jete	4.4	11	9.9
vtxmass1	3.8	6.0	4.8
vtxmasspc	9.2	24	19
vtxprob	1.4	1.2	1.3
1vtxprob	1.4	0.7	0.4
vtxlen12all_jete	1.5	0.8	0.4
vtxmassall	1.7	1.4	0.7
vtxmult2	2.0	4.0	1.9
vtxmass	1.4	0.7	0.4
vtxmult	14	8.2	4.8
jprobr	0	0	0
vtxlen2_jete	0	0	0
vtxsig2_jete	0	0	0
vtxdirang2_jete	0	0	0
vtxmom2_jete	0	0	0
vtxmass2	0	0	0
vtxlen12_jete	0	0	0
vtxsig12_jete	0	0	0
vtxdirang12_jete	0	0	0
vtxmom_jete	0	0	0
Input variables	$\triangle R_b$	$\triangle R_c$	$\triangle R_{uds}$
nmuon	7.7×10^{-3}	3.7×10^{-2}	3.5×10^{-2}
nelectron	1.5×10^{-3}	1.7×10^{-2}	1.4×10^{-2}
vtxmult1	2.9×10^{-3}	1.0×10^{-2}	0.8×10^{-2}



quantitative effect from input variables





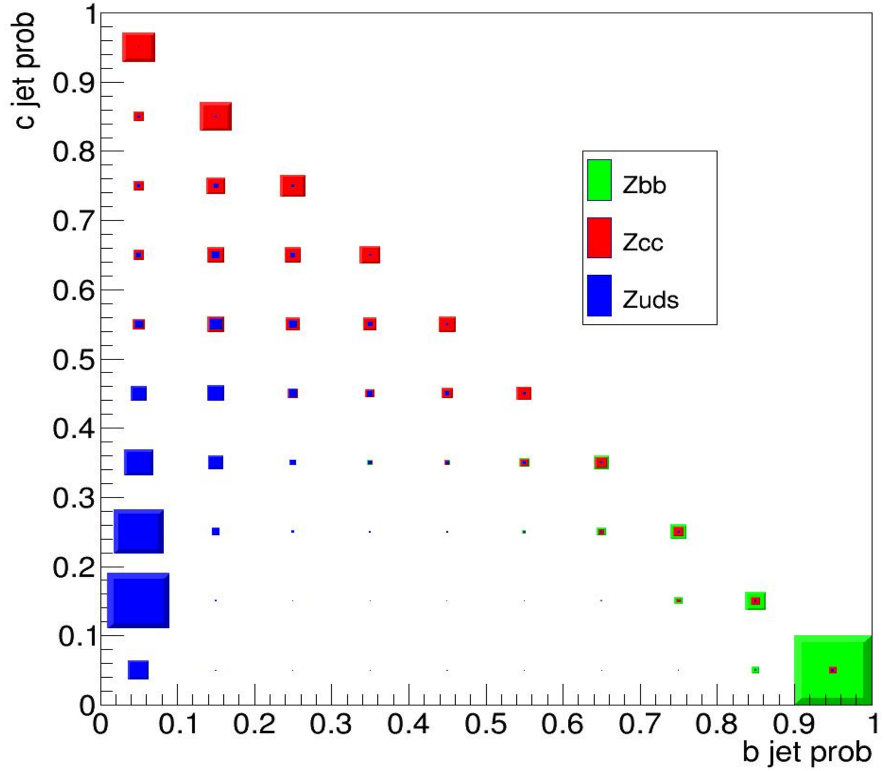


quantitative effect from input variables

- For some of the input variables that are based on the information of the second vertex in the jet, such as the variable *vtxlen2*, the effect is negligible with a 0.1% bias.
  - the reason is that the statistics of jets with two vertices inside are rather small after the Jet Vertex Refiner step, and the related input variables will be set to zero if no second vertex is found.
- The effect from input variables refers to the number of leptons and tracks, such as *nmuon*, *nelectron* and *vtxmult1* are larger
  - since we preliminarily vary the original number(in general less than 10) by integer 1.
- For most of the input variables, the effect on the relative decay widths are $\Delta Rb \sim 10^{-5}$, $\Delta Rc \sim 10^{-4}$ and $\Delta Ruds \sim 10^{-4}$ with a 0.1% bias on input variables.
  - the reason is that b-jet prob is dedicated to the bottom jet identification, so the discrimination power between charm jet and light jet is relatively smaller compared with the bottom jet
- A future plan in our study is to increase the discrimination power between the charm and light jet by introducing another charm-jet probability (c-jet prob) to the jet. For example, the 2D template distribution of b-jet prob and c-jet prob based on the flavour-tagging algorithm in the LCFIplus

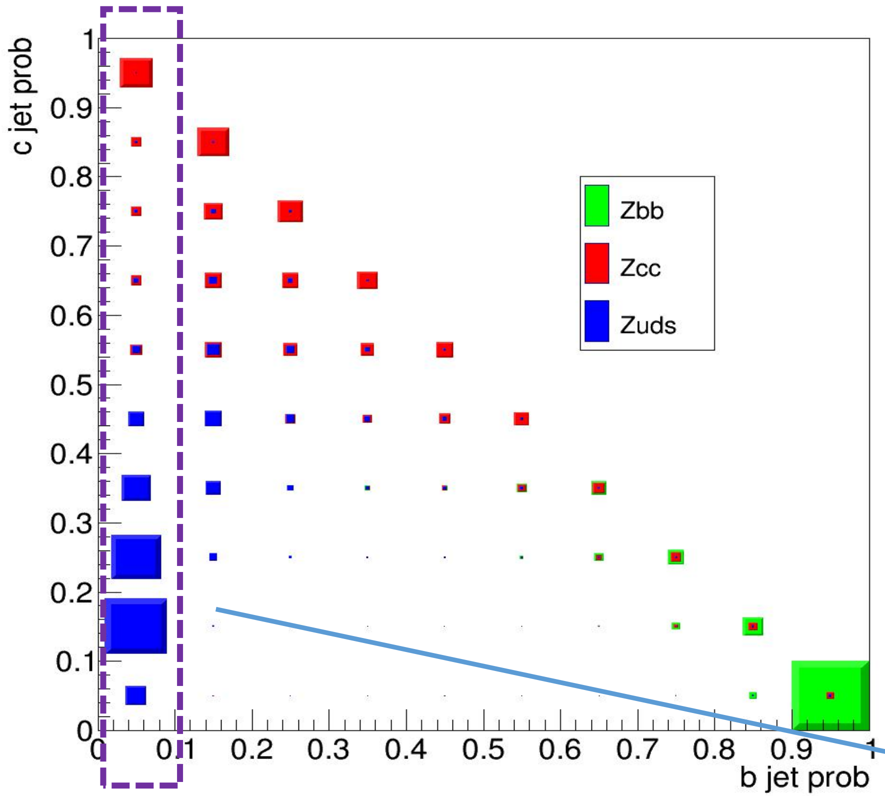
quantitative effect from input variables

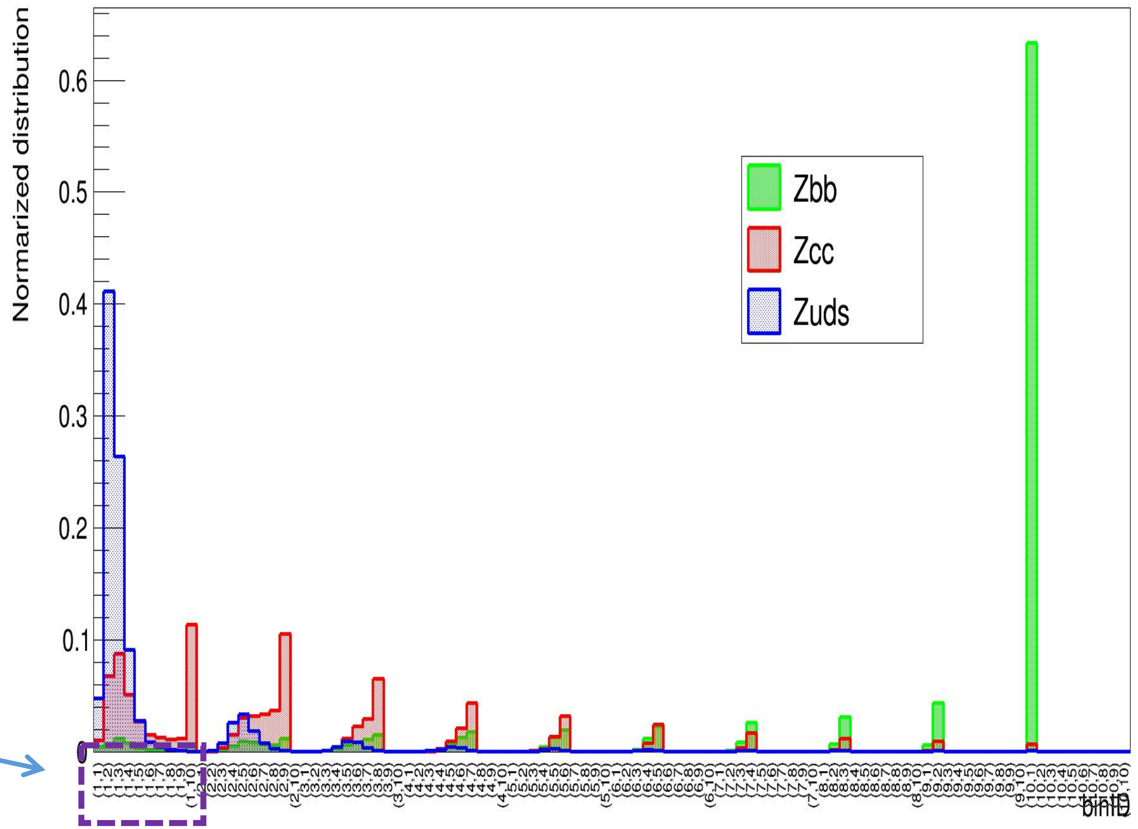
- A future plan in our study is to increase the discrimination power between the charm and light jet by introducing another charm-jet probability (c-jet prob) to the jet. For example, the 2D template distribution of b-jet prob and c-jet prob based on the flavour-tagging algorithm in the LCFIplus



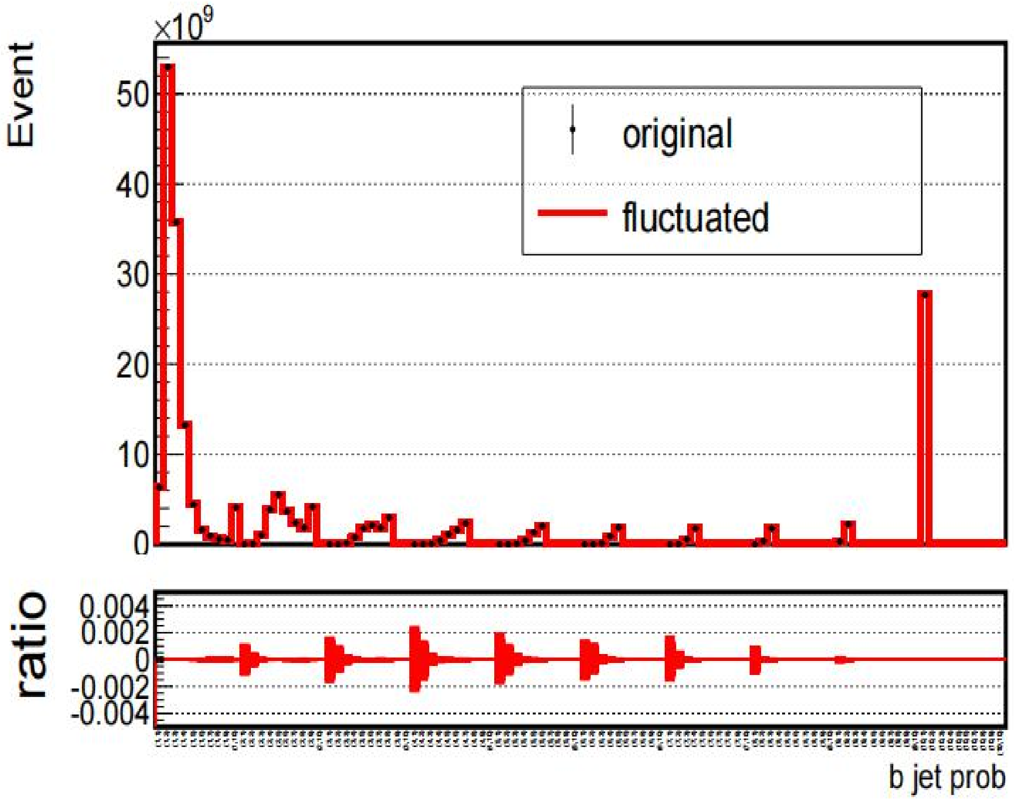
quantitative effect from input variables

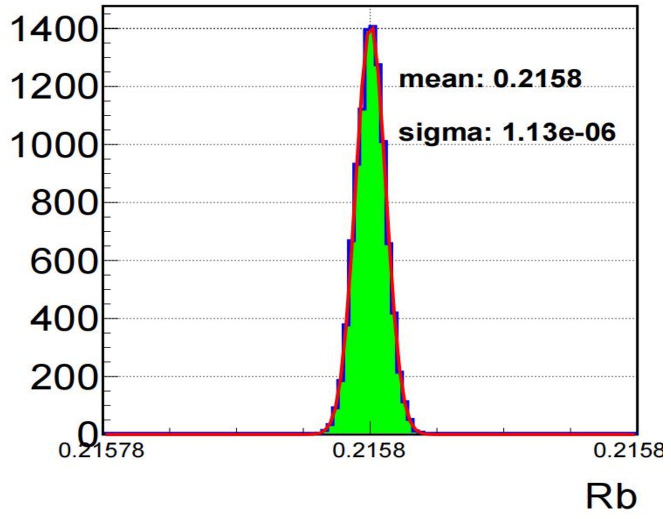
- A future plan in our study is to increase the discrimination power between the charm and light jet by introducing another charm-jet probability (c-jet prob) to the jet. For example, the 2D template distribution of b-jet prob and c-jet prob based on the flavour-tagging algorithm in the LCFIplus

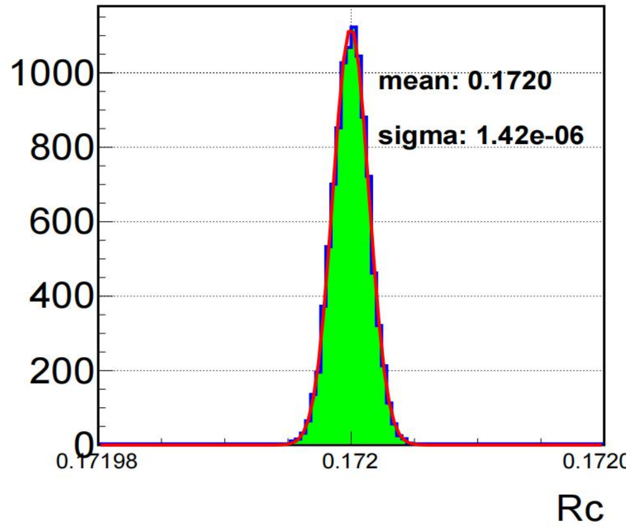


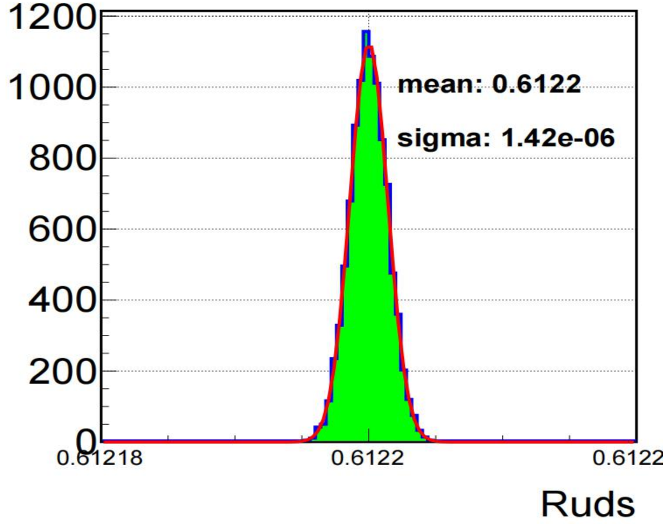


statistical uncertainty





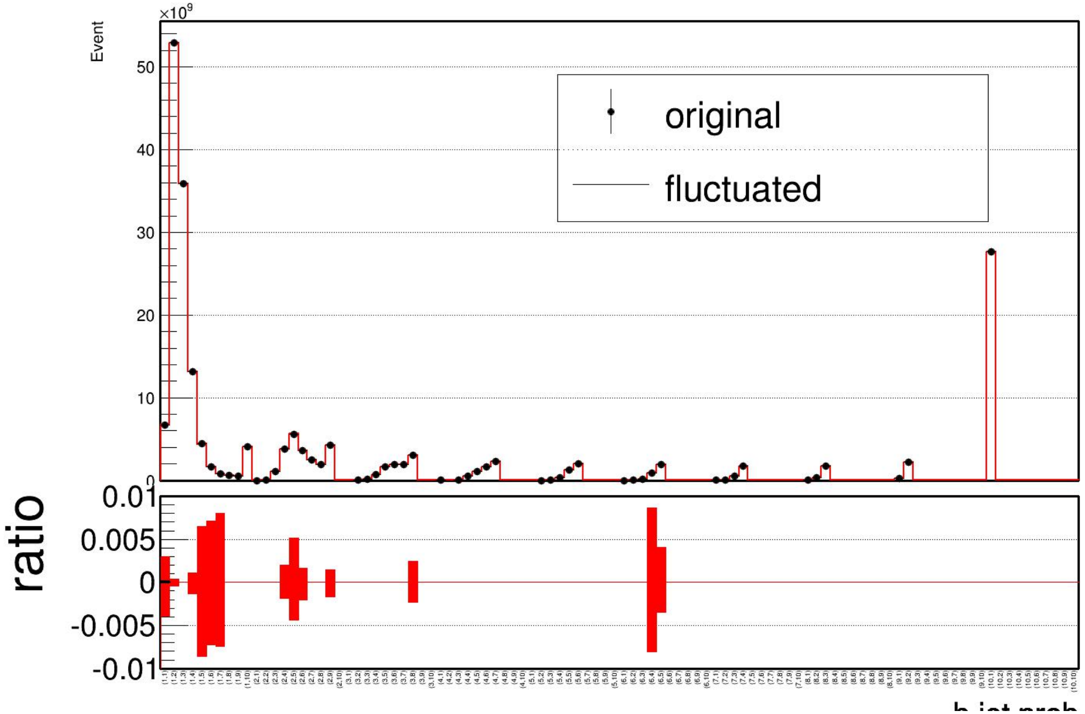


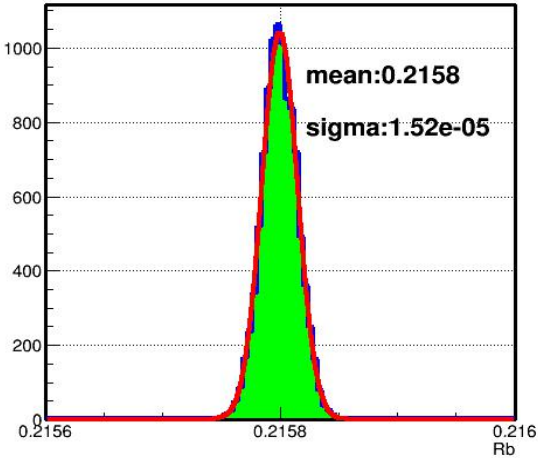


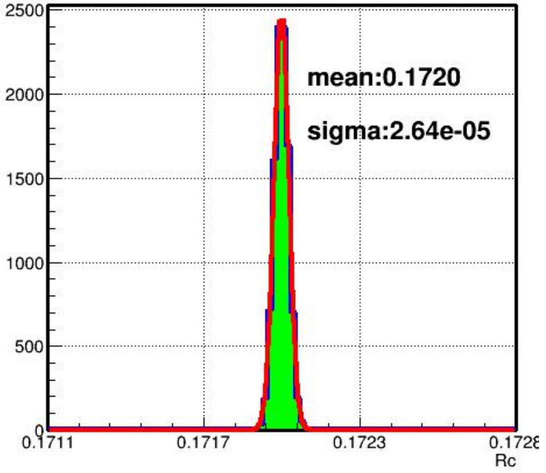
systematic uncertainty

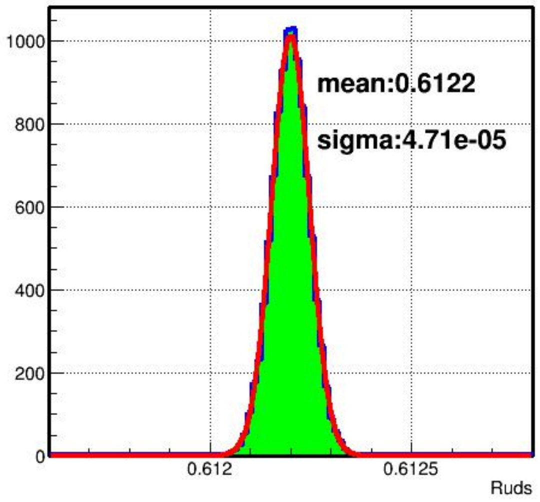
Table 1. The quantitative effect on the uncertainty from ~ 0.1% bias of each variable.

Input variables	$\triangle R_b (10^{-5})$	$\triangle R_c (10^{-5})$	$\triangle R_{uds} (10^{-5})$
trk1d0sig	2.5	1.2	0.7
trk2d0sig	1.7	14	9.9
trk1z0sig	0.3	13	11
trk2z0sig	0.1	0.5	0.5
trk1pt_jete	2.5	16	16
trk2pt_jete	3.0	15	12
jprobr5sigma	3.7	22	17









Conclusion

- B-tagging method provides a possible template distribution
- Precedure works well in our study
- Statistical uncertainty will not be limit factor in the measurment
- A feasible way to investigate the effect on systematic errors at the differential distribution level