# Rb measurement in CEPC

# Why measure Rb

$$R_b = \frac{\Gamma(Z \to b\bar{b})}{\Gamma(Z \to \text{had})}$$

- One of fundamental parameters in Standard Model
- Rb measurement is sensitive to new physics models (e.g. SUSY)
- Benchmark to reflect vertex detector performance

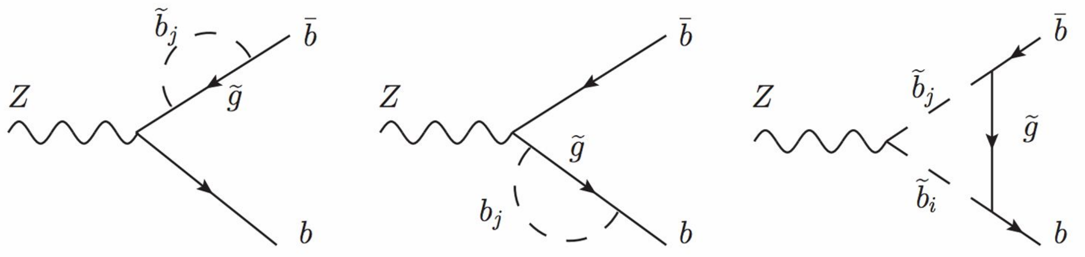
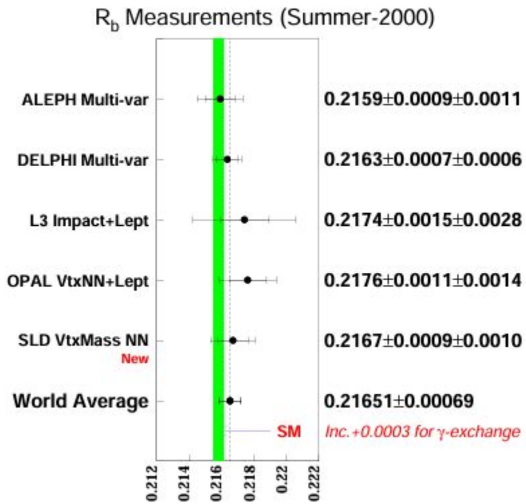



FIG. 1: One-loop Feynman diagrams of gluino correction to $Z \to \bar{b}b$

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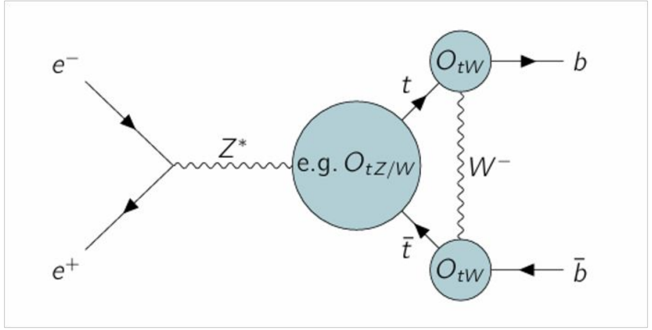
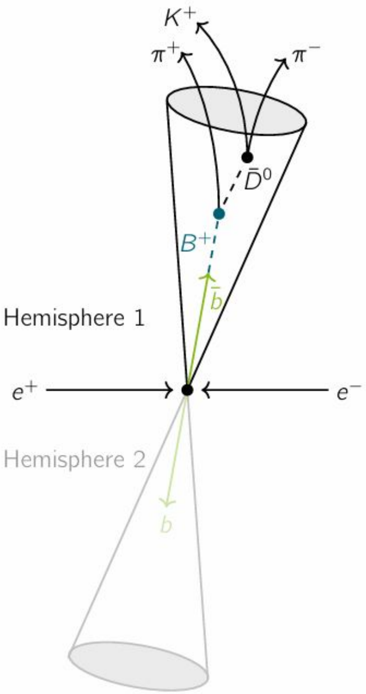
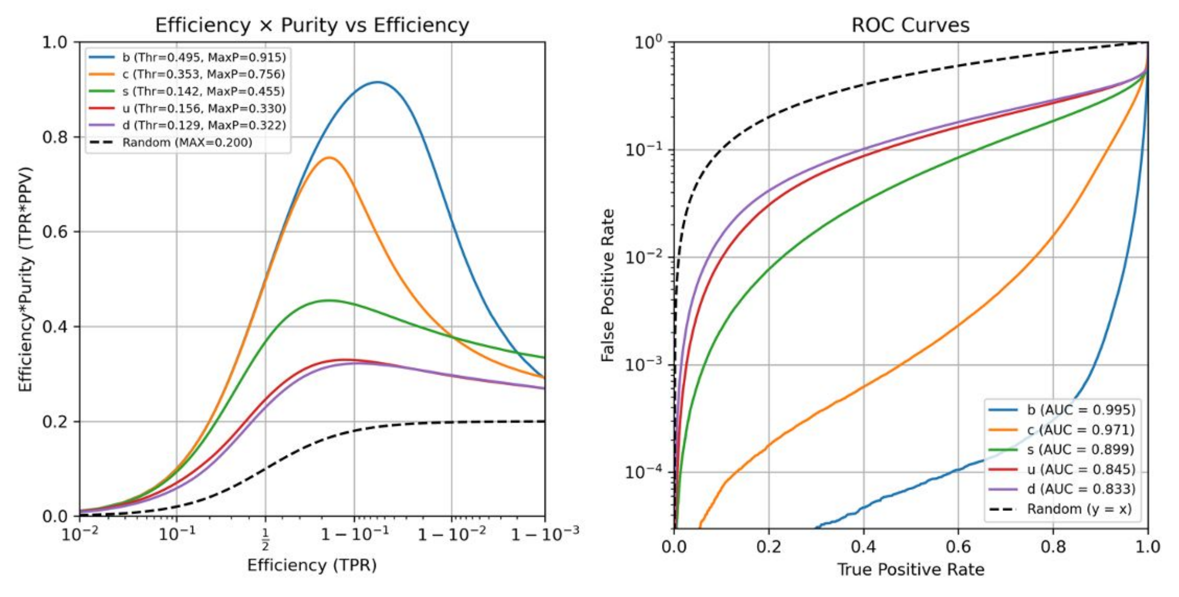
# Method of Measurement



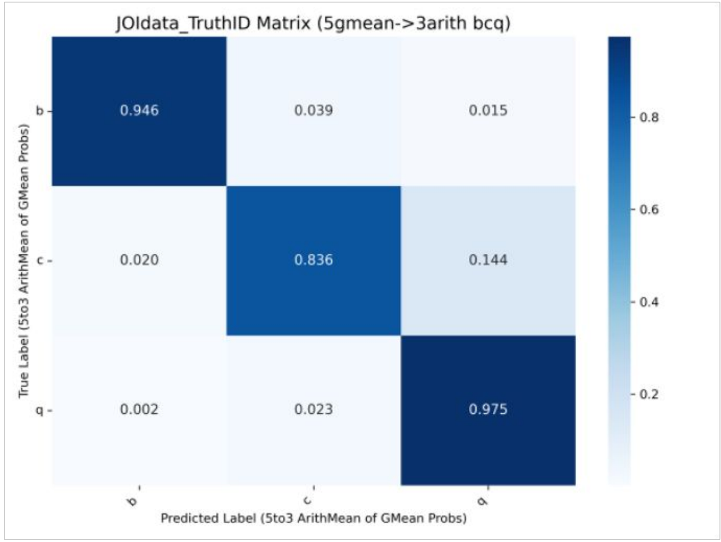

- Event topology: two back to back particle sprays
- Produce Z to qqbar events at Z pole
- Training the JOI model
- With total 1e12 events (1e11 for low Z), estimate the mean value of Rb and the error σ
- Flavor tagging
- Get Ri and σi (i = b, c, q) by solving the overdetermined simultaneous system of equations using LSM



# Model performance




With H pole samples

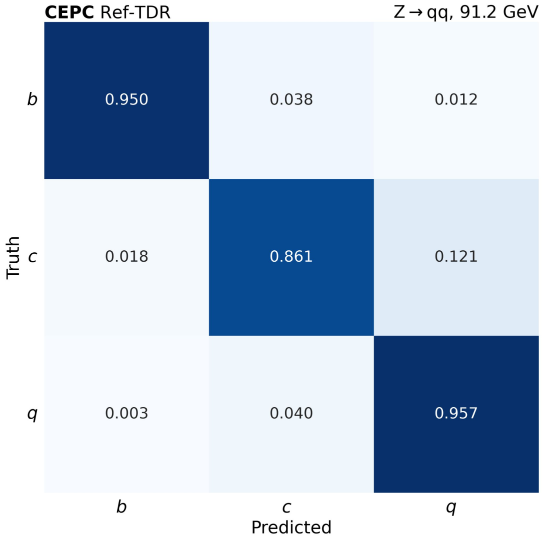


# Current results

| | Error of Rb | Error of Rc | Error of Rc | Flavor tagging method |
|---|---|---|---|---|
| LEP+SLC | 659 | 3015 | - | - |
| FCCee | 2.1(0.3) | - | - | - |
| Template fit | 1.2 | 2.3 | 2.1 | LCFIPlus |
| Double + single 3 categories | 1.3 | 1.4 | - | ParticleNet 1e11 events |
| Double + single 2 categories | 0.52 | - | - | ParT(PFOAna) 1e10 events |
| Double + single 3 categories | 1.32 | 1.51 | - | ParT(PFOAna) 1e10 events |

# Current results

With Z pole samples




- Result is better than previous work (with 1e11 toy MC events)
- By optimizing the confusion matrix will further reduce the error
- Model used in previous table is based on Higgs pole data, newest model will bring better results

Good enough, but still lots of room to improve

# Systematic uncertainty

- In current analysis, the systematic uncertainty is not included yet.
- Based on previous template fit results. Following uncertainty will be included
    - Hemisphere correlation
    - Gluon splitting
    - Charm modelling
        - This affect JOI performance

| Error source | $\Delta R^b$ ($10^{-5}$) |
|---|---|
| Statistics | 1 |
| Tracking resolution | 1 |
| Charm modeling | 3 |
| Gluon spliting | 1 |
| Hemisphere correlation | 6 |
| Total | 7 |

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| $\Delta R_b$ from Internal Error Sources | |
|---|---|
| MC statistics | 0.00092 |
| Resolution | 0.00056 |
| Vertex effects on $c_b$ | 0.00125 |
| $\theta$ effects on $c_b$ | 0.00006 |
| $\phi$ effects on $c_b$ | 0.00021 |
| Total Internal | 0.00166 |
| **$\Delta R_b$ from External Error Sources** | |
| $R_c$ uncertainty | −0.00094 |
| $D^+$ fraction | −0.00128 |
| $D_s$ fraction | −0.00017 |
| $\Lambda_c$ fraction | +0.00045 |
| $D^+$ lifetime | −0.00020 |
| $D^0$ lifetime | −0.00013 |
| $D_s$ lifetime | −0.00012 |
| $\Lambda_c$ lifetime | −0.00008 |
| $D^+$ 1-prong decay multiplicity | +0.00045 |
| $D^+$ 5-prong decay multiplicity | −0.00006 |
| $D^0$ 0-prong decay multiplicity | −0.00004 |
| $D^0$ 4-prong decay multiplicity | −0.00024 |
| $D^0$ 6-prong decay multiplicity | 0.00000 |
| $D_s$ 1-prong decay multiplicity | +0.00028 |
| $D_s$ 5-prong decay multiplicity | +0.00055 |
| $D \to K^0_S$ multiplicity | −0.00025 |
| $< x_E(c) >$ | −0.00086 |
| $g \to c\bar{c}$ in $c\bar{c}$ events | −0.00001 |
| $g \to b\bar{b}$ in $c\bar{c}$ events | −0.00003 |
| $K^0_s$ and $\Lambda$ production | −0.00176 |
| $g \to c\bar{c}$ in uds events | −0.00018 |
| $g \to b\bar{b}$ in uds events | −0.00015 |
| B fragmentation $< x_E(b) >$ | +0.00032 |
| B lifetimes | +0.00018 |
| B decay multiplicity | +0.00009 |
| Hard gluon fragmentation | 0.00010 |
| Total External | 0.00271 |

L3 results: arXiv:hep-ex/9909045

# Hemisphere correlation

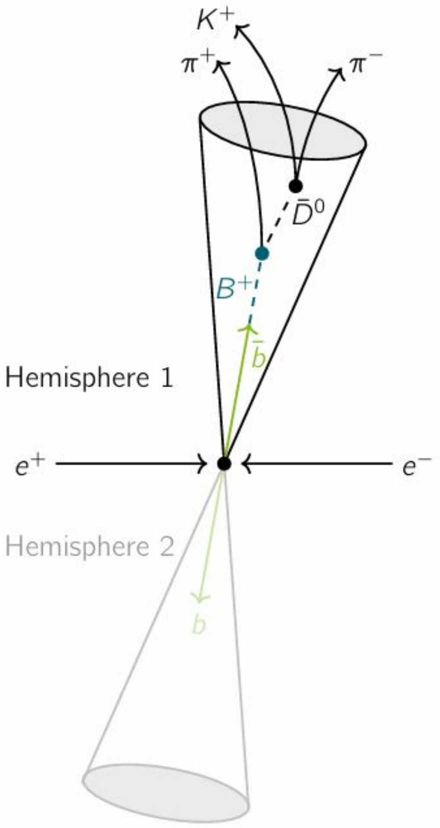
- Key parameter in double tag equation

**Single tag:** $N_1 = 2N_Z \cdot (R_b\, \varepsilon_b + R_c\, \varepsilon_c + R_{uds}\, \varepsilon_{uds})$

**Double tag:** $N_2 = N_Z \cdot (R_b\, \varepsilon_b^2\, C_b + R_c\, \varepsilon_c^2\, C_c + R_{uds}\, \varepsilon_{uds}^2\, C_{uds})$

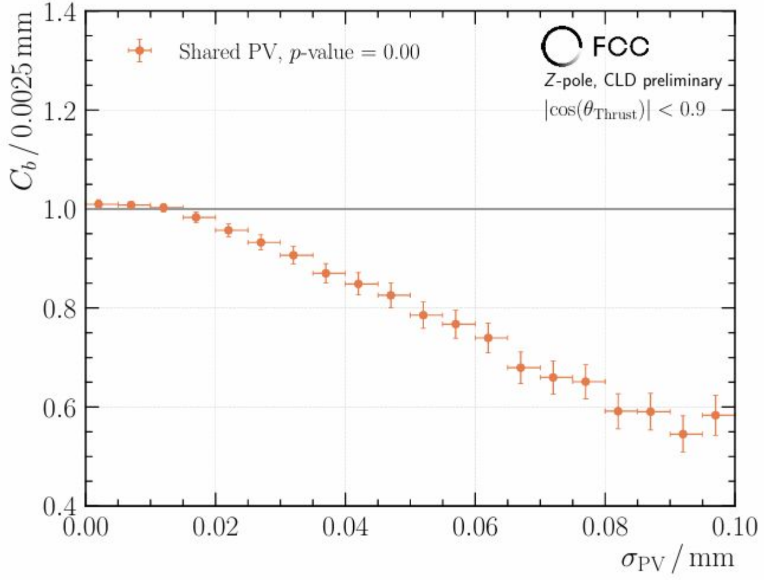
- Need to be study with MC samples and a fixed tagging working point
- Since JOI can distinguish b and bbar, probably the correlation can be different.

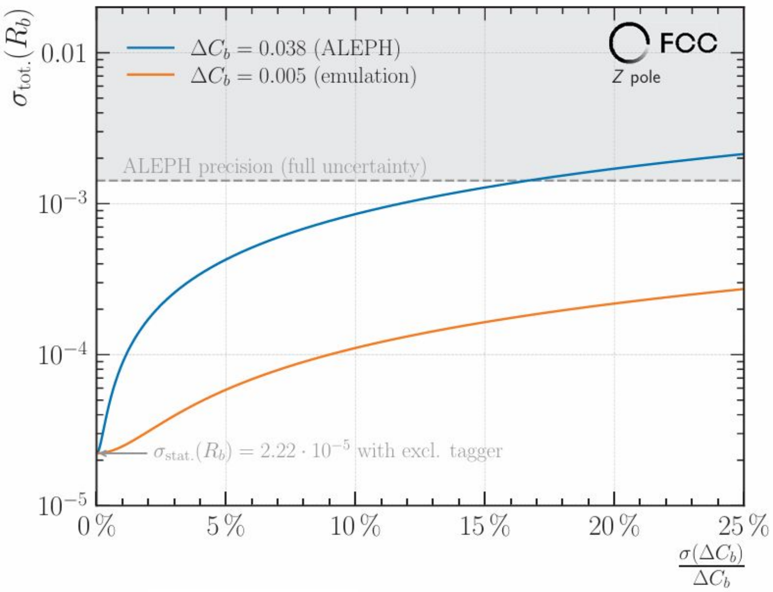
$$C_i = \frac{\varepsilon_{i_1} \varepsilon_{i_2}}{\varepsilon_{i_{1,2}}^2}$$



# Impact of Hemisphere correlation

- Recent FCCee study shows the *Cb* has dependence on PV resolution
  - CEPC would have similar performance as FCCee
  - High related to vertex detector performance




arXiv:2502.17281

# Summary

- A Rb (Rc) measurement at Z pole with JOI tagger is performed
- Using the double tag method
- Statistical uncertainty is quite similar to previous studies (template fit and ParTNet)
- Next Step: to evaluate systematic uncertainties.