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Update of AFB measurement @ Z--> qqbar

Libo Liao

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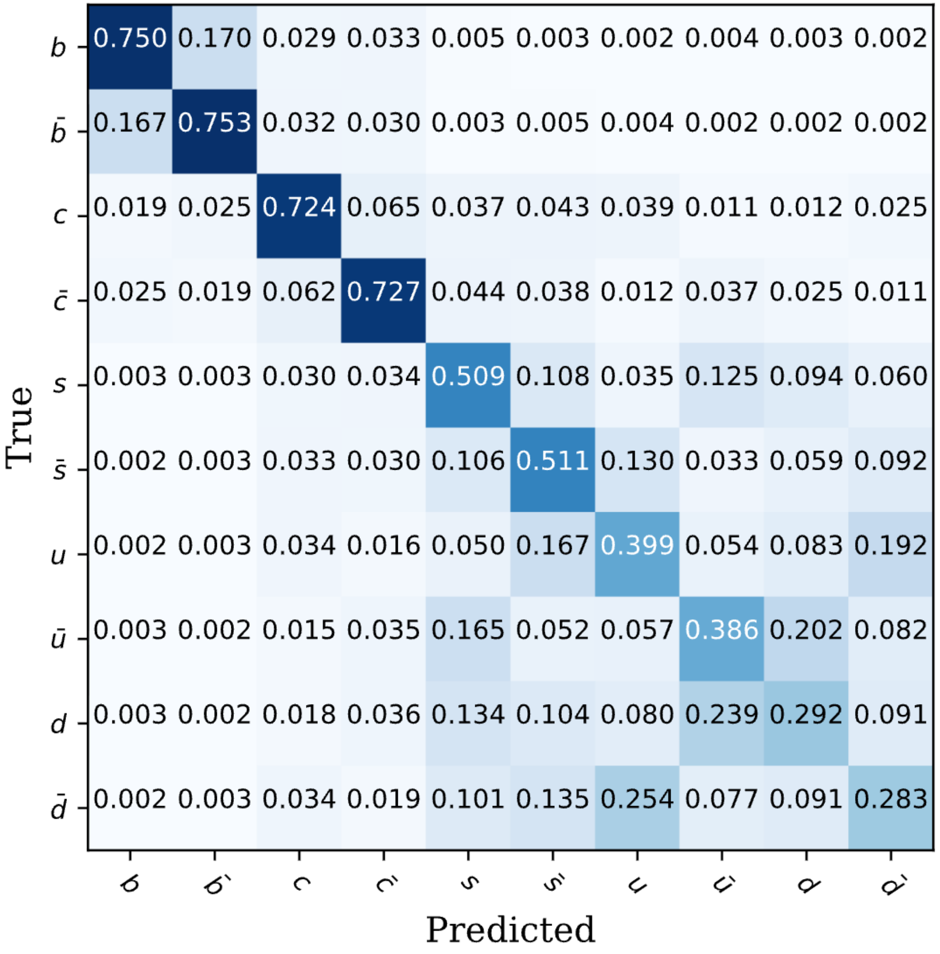
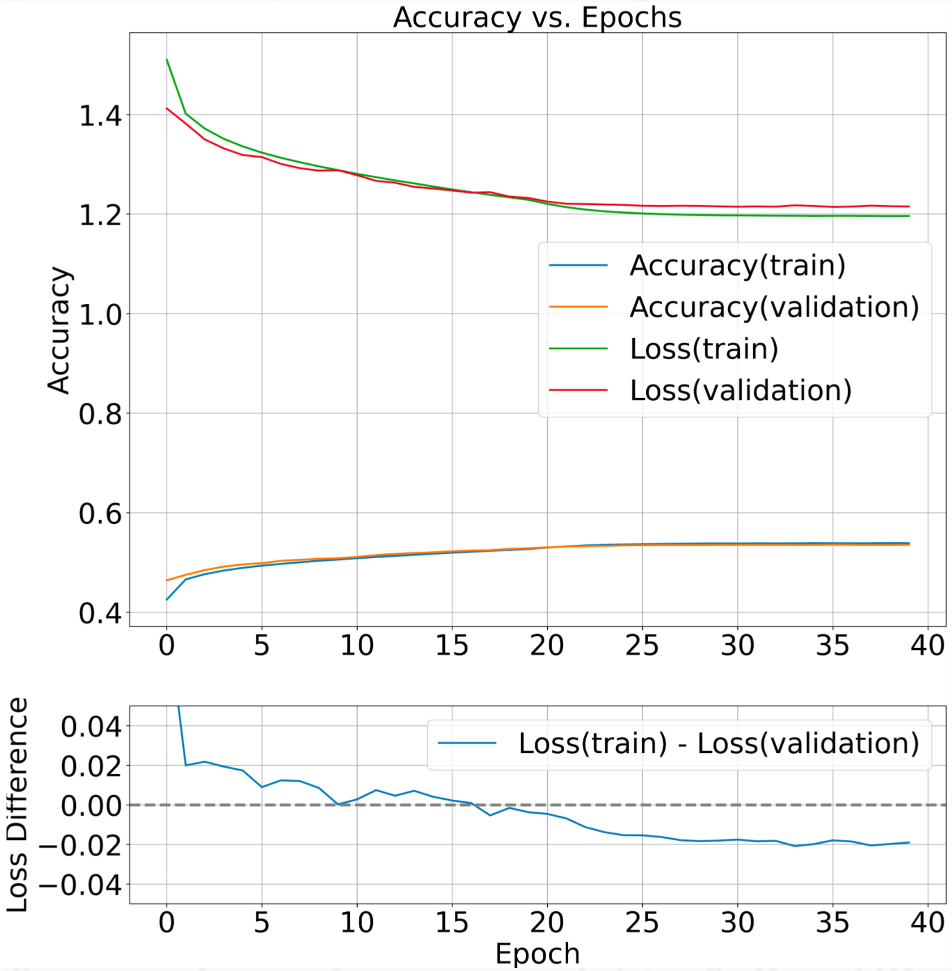
Transformer - zqq





- stable training
- no obvious over-fiting

Compared to TDR

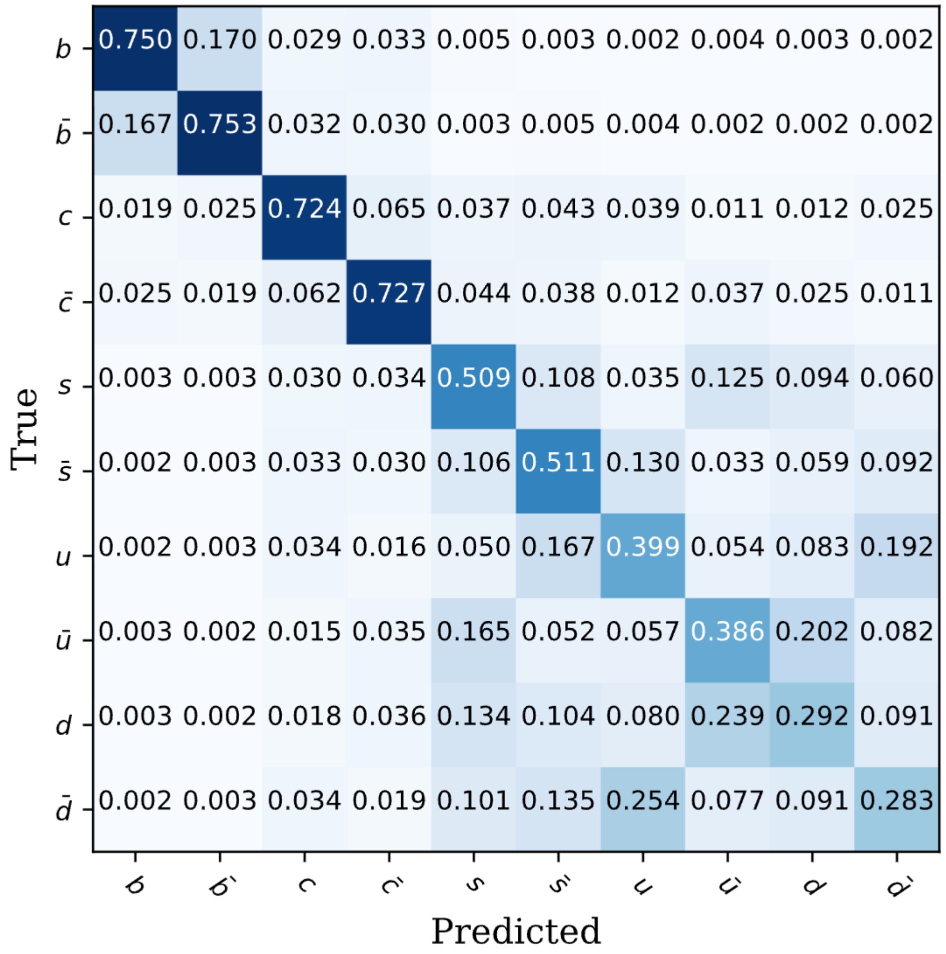
True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$
b	0.750	0.170	0.029	0.033	0.005	0.003	0.002	0.004	0.003	0.002
$\bar{b}$	0.167	0.753	0.032	0.030	0.003	0.005	0.004	0.002	0.002	0.002
c	0.019	0.025	0.724	0.065	0.037	0.043	0.039	0.011	0.012	0.025
$\bar{c}$	0.025	0.019	0.062	0.727	0.044	0.038	0.012	0.037	0.025	0.011
s	0.003	0.003	0.030	0.034	0.509	0.108	0.035	0.125	0.094	0.060
$\bar{s}$	0.002	0.003	0.033	0.030	0.106	0.511	0.130	0.033	0.059	0.092
u	0.002	0.003	0.034	0.016	0.050	0.167	0.399	0.054	0.083	0.192
$\bar{u}$	0.003	0.002	0.015	0.035	0.165	0.052	0.057	0.386	0.202	0.082
d	0.003	0.002	0.018	0.036	0.134	0.104	0.080	0.239	0.292	0.091
$\bar{d}$	0.002	0.003	0.034	0.019	0.101	0.135	0.254	0.077	0.091	0.283

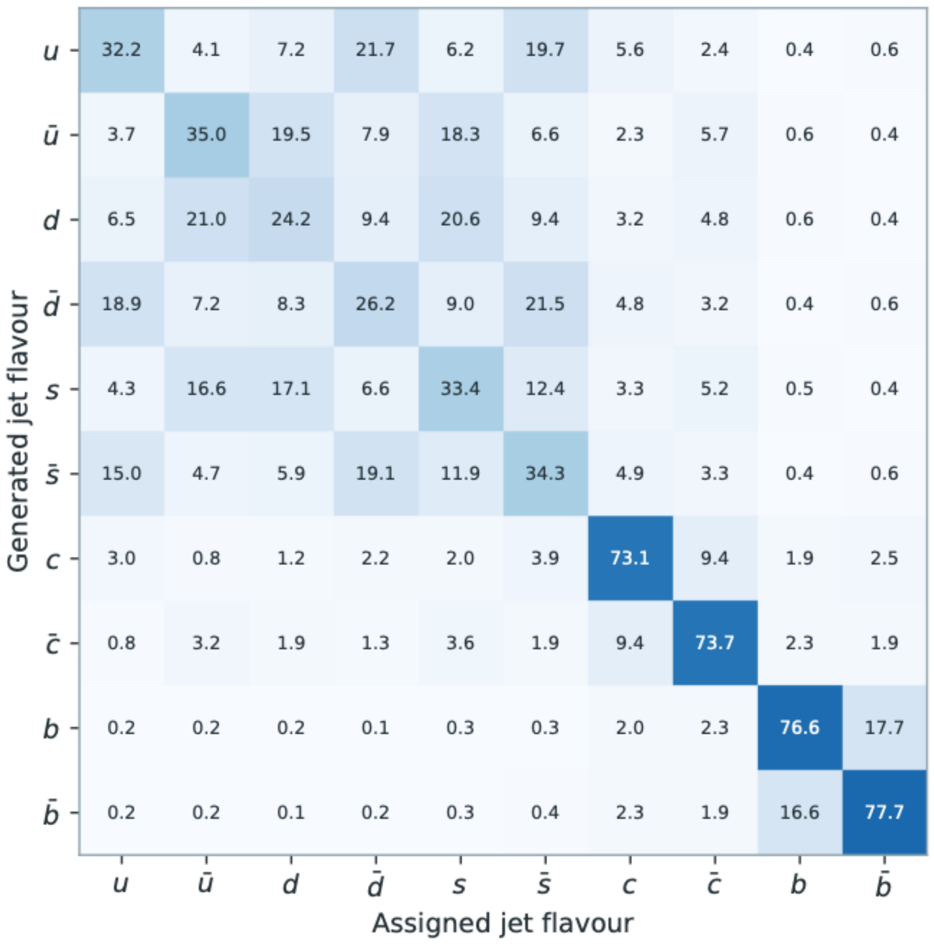
CEPC Ref-TDR $ZH\to\nu\nu jj$, $\sqrt{s}$ = 240 GeV

Truth \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$	g
b	0.811	0.132	0.019	0.016	0.002	0.001	0.001	0.002	0.002	0.001	0.013
$\bar{b}$	0.124	0.819	0.017	0.018	0.001	0.002	0.002	0.001	0.001	0.002	0.014
c	0.009	0.012	0.798	0.042	0.019	0.027	0.027	0.006	0.007	0.017	0.035
$\bar{c}$	0.013	0.011	0.049	0.790	0.027	0.022	0.006	0.026	0.016	0.007	0.033
s	0.002	0.001	0.016	0.019	0.488	0.095	0.028	0.119	0.093	0.053	0.084
$\bar{s}$	0.001	0.002	0.020	0.015	0.084	0.508	0.124	0.024	0.049	0.091	0.082
u	0.001	0.002	0.021	0.008	0.035	0.146	0.413	0.037	0.068	0.178	0.092
$\bar{u}$	0.002	0.001	0.008	0.021	0.139	0.040	0.045	0.391	0.189	0.070	0.093
d	0.002	0.001	0.011	0.019	0.124	0.088	0.066	0.218	0.296	0.080	0.096
$\bar{d}$	0.001	0.002	0.020	0.009	0.078	0.132	0.239	0.059	0.076	0.289	0.095
g	0.011	0.012	0.029	0.029	0.074	0.077	0.072	0.066	0.057	0.057	0.514

- comparable misclassification distributions.
- different samples, Based on Z pole and ZH

Compared to Z->ss analysis





- ☐ comparable results in each elements

Compared to ParticleNet

True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$
b	0.750	0.170	0.029	0.033	0.005	0.003	0.002	0.004	0.003	0.002
$\bar{b}$	0.167	0.753	0.032	0.030	0.003	0.005	0.004	0.002	0.002	0.002
c	0.019	0.025	0.724	0.065	0.037	0.043	0.039	0.011	0.012	0.025
$\bar{c}$	0.025	0.019	0.062	0.727	0.044	0.038	0.012	0.037	0.025	0.011
s	0.003	0.003	0.030	0.034	0.509	0.108	0.035	0.125	0.094	0.060
$\bar{s}$	0.002	0.003	0.033	0.030	0.106	0.511	0.130	0.033	0.059	0.092
u	0.002	0.003	0.034	0.016	0.050	0.167	0.399	0.054	0.083	0.192
$\bar{u}$	0.003	0.002	0.015	0.035	0.165	0.052	0.057	0.386	0.202	0.082
d	0.003	0.002	0.018	0.036	0.134	0.104	0.080	0.239	0.292	0.091
$\bar{d}$	0.002	0.003	0.034	0.019	0.101	0.135	0.254	0.077	0.091	0.283

True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$
b	0.682	0.188	0.047	0.059	0.007	0.005	0.003	0.005	0.003	0.002
$\bar{b}$	0.192	0.677	0.058	0.048	0.005	0.007	0.005	0.003	0.002	0.002
c	0.027	0.043	0.656	0.076	0.051	0.056	0.042	0.013	0.012	0.025
$\bar{c}$	0.042	0.027	0.074	0.659	0.059	0.048	0.014	0.042	0.026	0.011
s	0.004	0.003	0.031	0.039	0.514	0.128	0.031	0.131	0.067	0.052
$\bar{s}$	0.003	0.004	0.038	0.031	0.133	0.513	0.126	0.031	0.054	0.068
u	0.002	0.004	0.036	0.018	0.067	0.206	0.369	0.058	0.077	0.164
$\bar{u}$	0.004	0.002	0.018	0.037	0.209	0.063	0.054	0.381	0.153	0.079
d	0.003	0.003	0.021	0.038	0.173	0.124	0.076	0.272	0.204	0.085
$\bar{d}$	0.003	0.004	0.037	0.021	0.127	0.169	0.261	0.082	0.084	0.213

- slight improved in b, c identification

Update physics results

AFB (1e-3)	PN	ParT
b	0.013	0.012
c	0.023	0.022
s	0.019	0.017

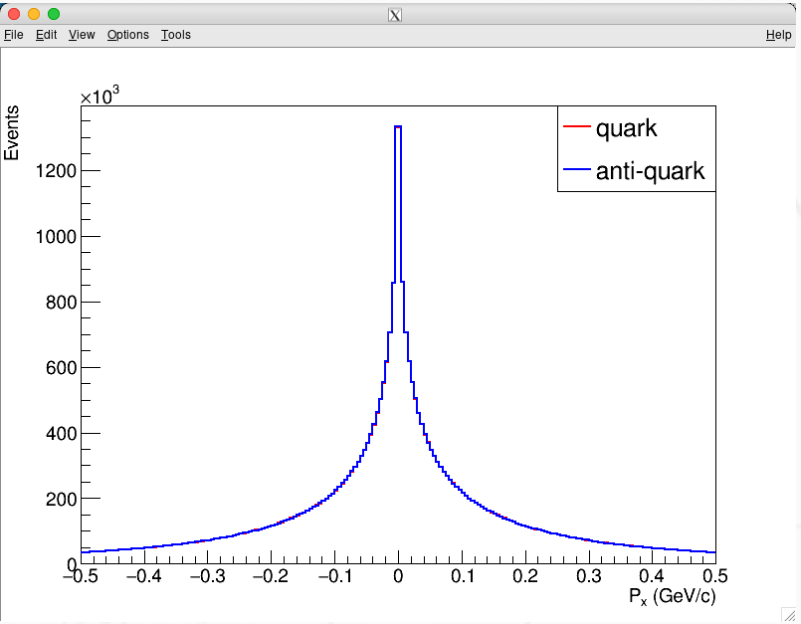
sinW (1e-6)	fast sim	PN	ParT
b	1.0	1.1	1.0
c	1.5	1.7	1.6
s	1.4	1.5	1.4

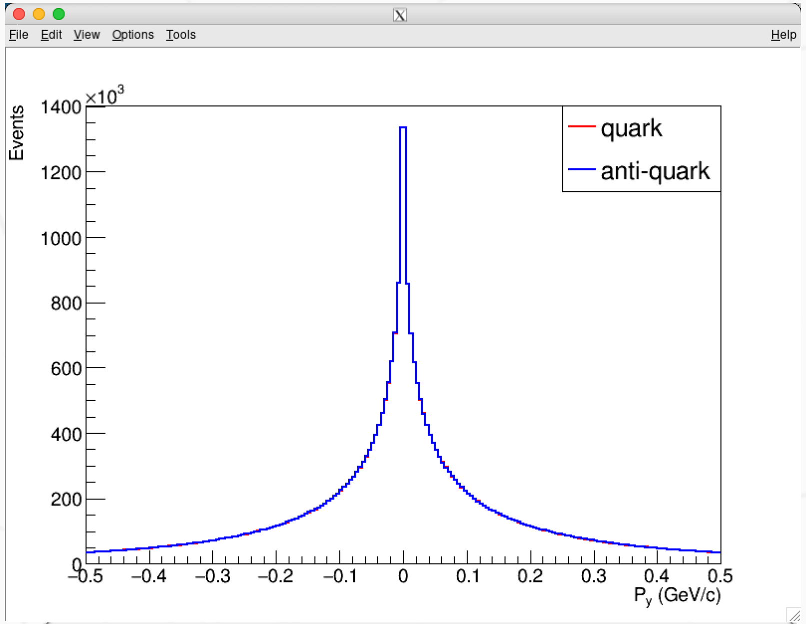
Pe	0.5		0.6		0.7		0.8	
sinW(1e-6)	PN	ParT	PN	ParT	PN	ParT	PN	ParT
b	0.57	0.54	0.56	0.53	0.54	0.51	0.52	0.50
c	0.81	0.72	0.79	0.71	0.77	0.69	0.75	0.67
s	0.93	0.88	0.92	0.87	0.91	0.86	0.89	0.84

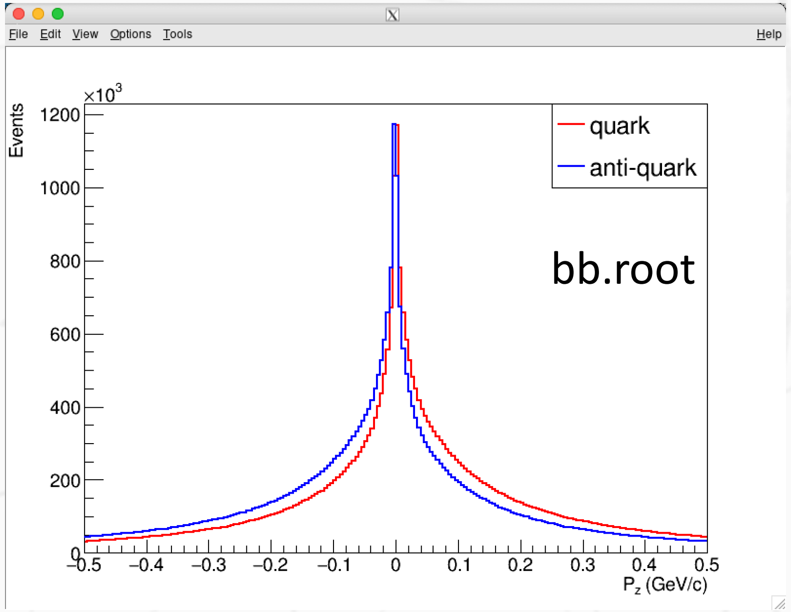
- Comparable results
- Dominant by statistics

BACKUP

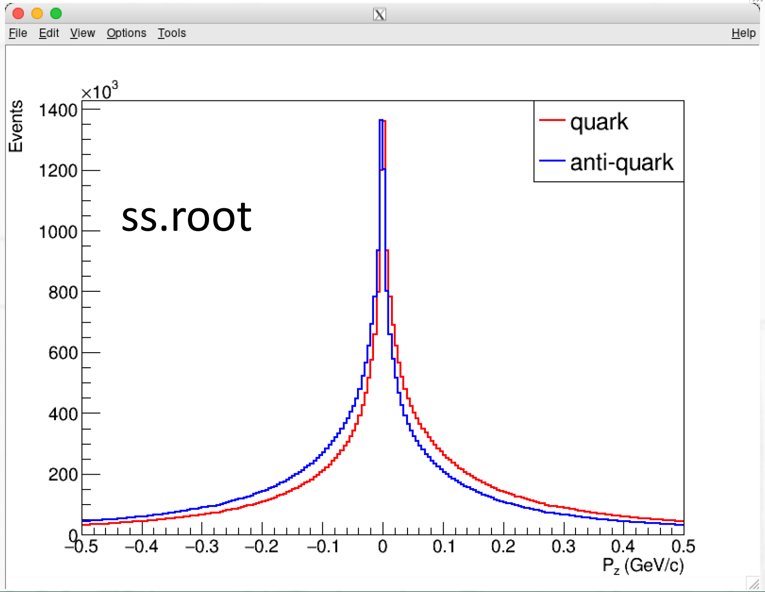
unforeseen issue

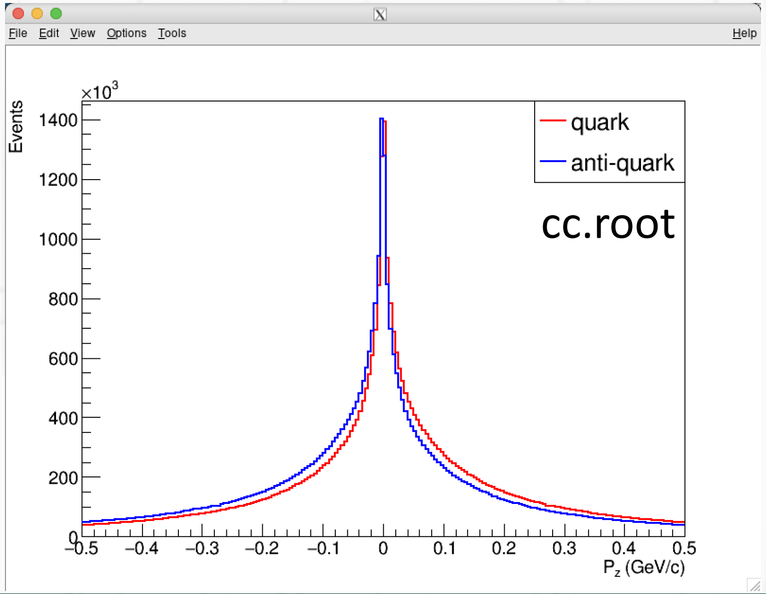






The momentum is not consistent in Pz

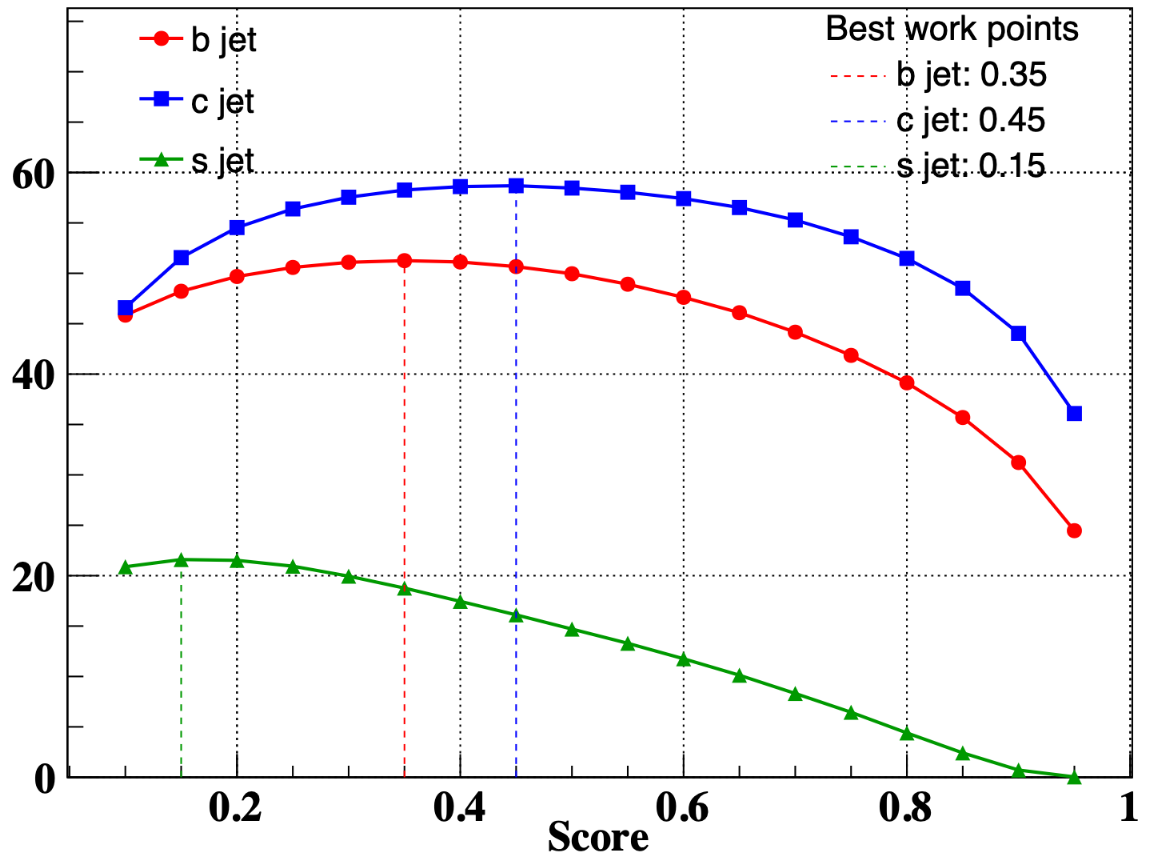




Determination of working points

- The working point is chosen to maximize the overall jet charge identification performance, weighted by the production cross sections

$$\mathrm{FoM} = \sum_i \sigma_i \times \epsilon_i \times \rho_i \times \left(\frac{1}{\sigma_i}\frac{\partial \sigma_i}{\partial A_{\mathrm{FB}}}\right)^2$$
$$= \sum_i \epsilon_i \times \rho_i \times \frac{1}{\sigma_i}\left(\frac{8}{3}\cos\theta_i\right)^2,$$



- The results are consistent with expectation.
  - The lower threshold for s-jets reflects the greater challenge in distinguishing strange quarks due to the absence of a heavy quark decay vertex.

Efficiency curves

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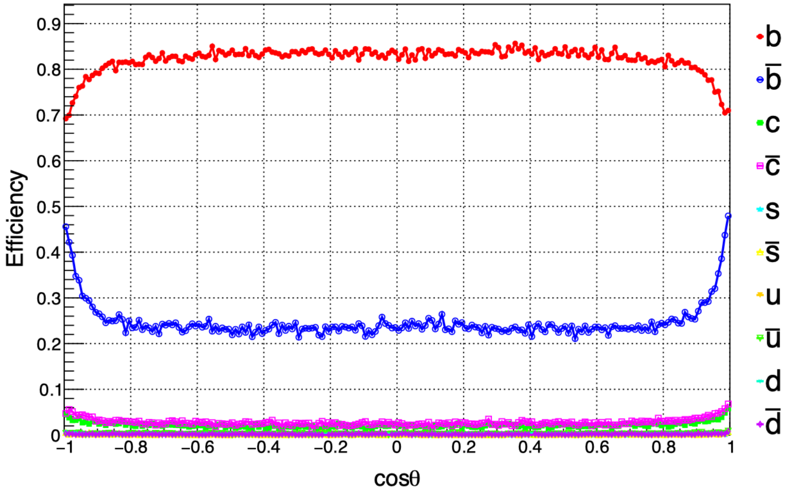
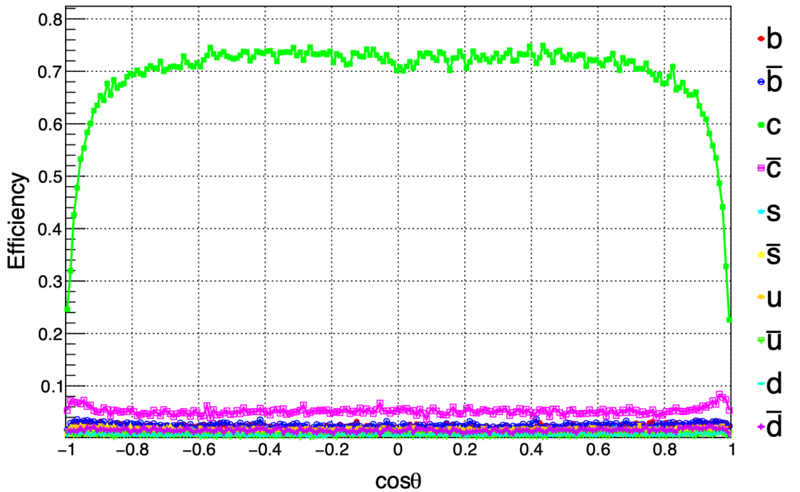
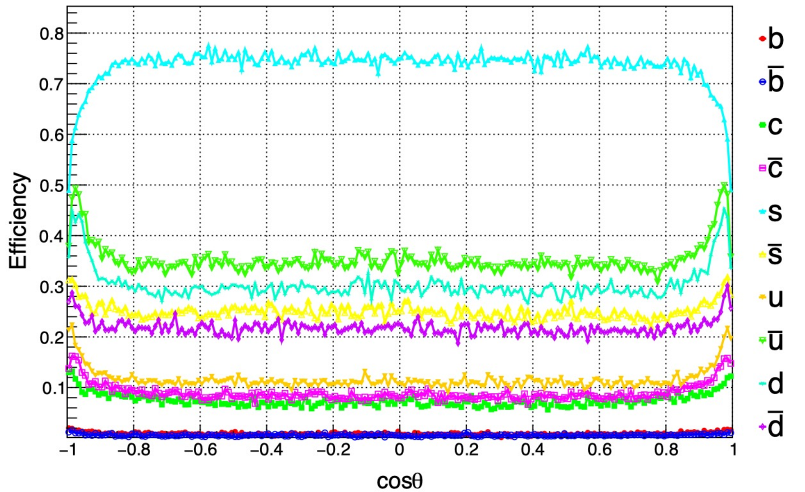
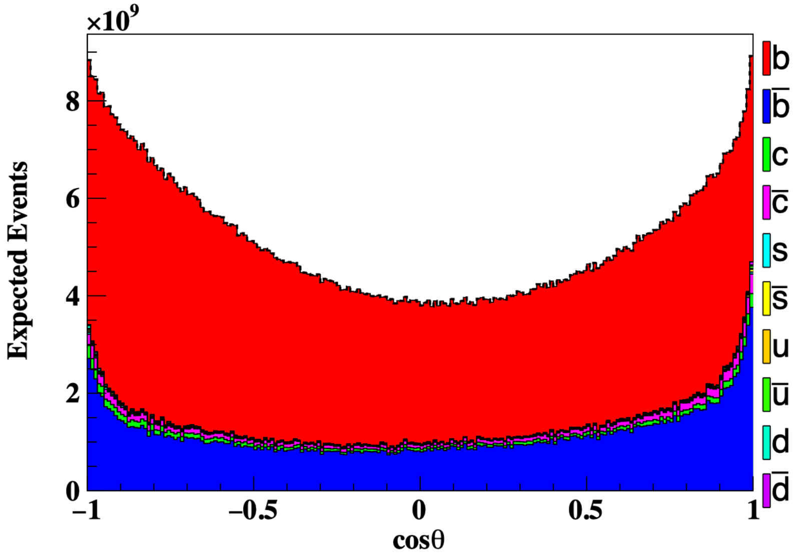
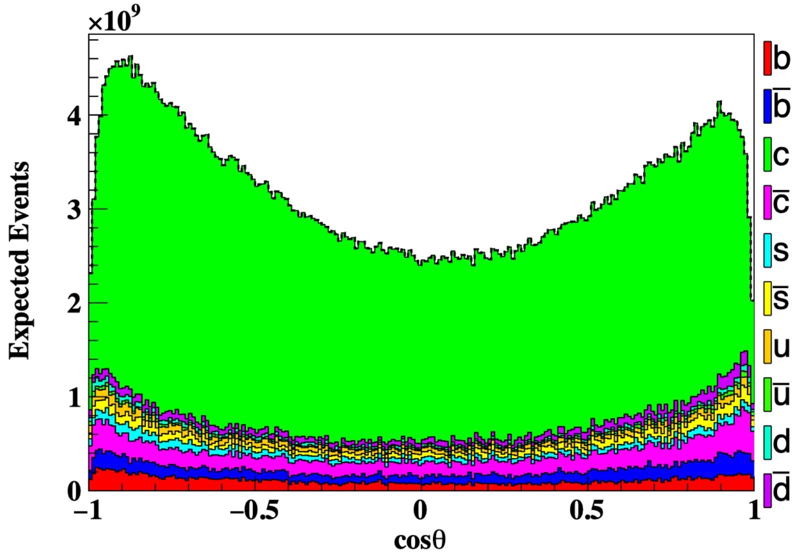
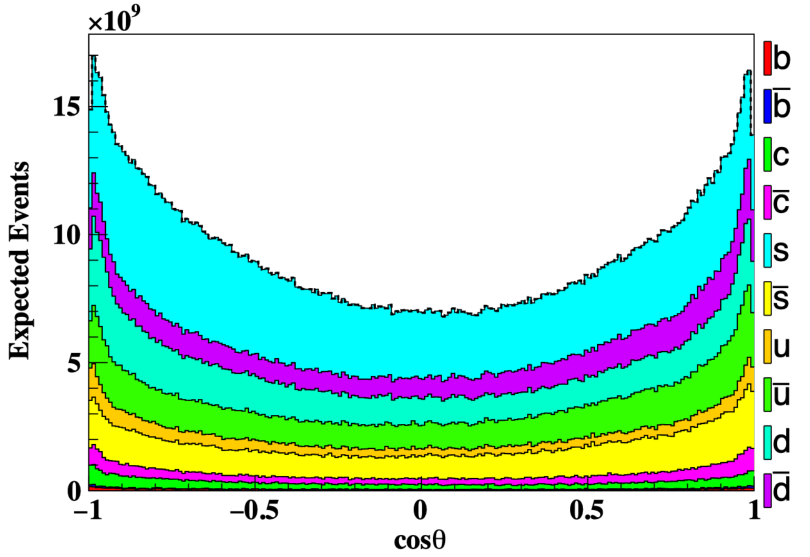












Measurement of A_{FB}

- The expected number of events for reconstructed flavor j (5 flavor) in bin i (200) is:

$$N_{i,j}^{\exp} = \mathcal{L}\sum_k \sigma_{i,j}\epsilon_{i,j,k},$$

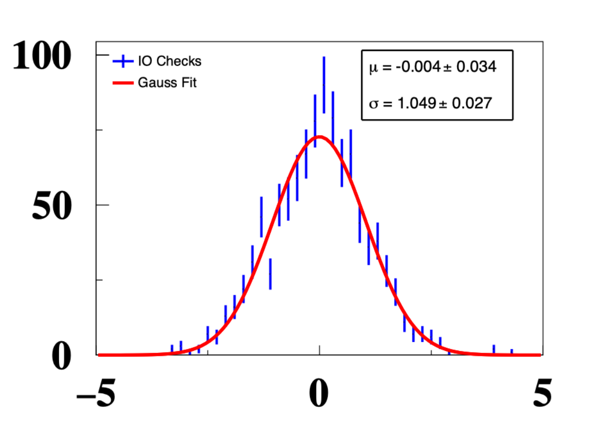
$$\sigma_{i,j} = (1+\cos^2\theta_i + \frac{8}{3}A_{FB,j}\cos\theta_i)\Delta,$$

- A_{FB} could be extracted via a binned maximum likelihood fit

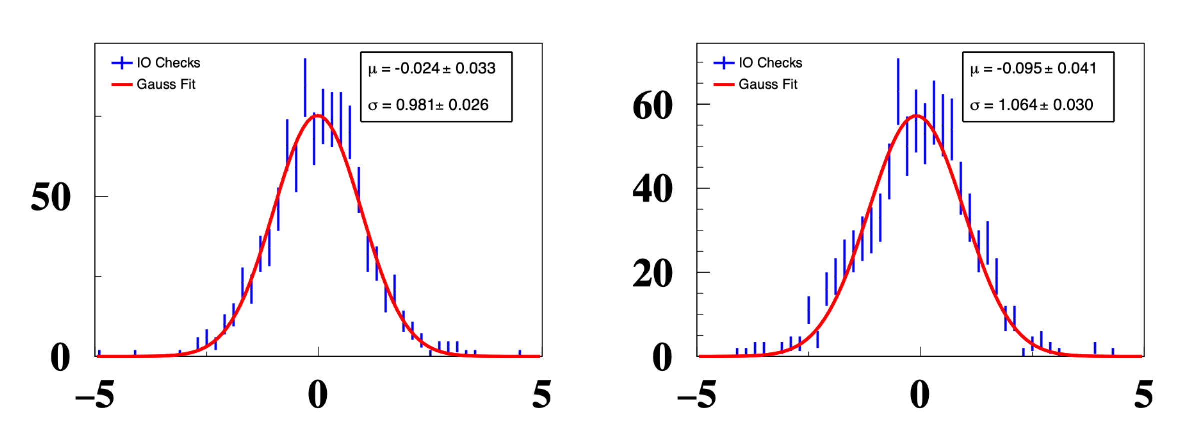
$$\mathcal{L}(A_{FB,j}, N_j^{\text{prod}}) = \prod_i \frac{\mu_{i,j}^{n_{i,j}} e^{-\mu_{i,j}}}{n_{i,j}!},$$

- To estimate the statistical precision, and joint flavor and charge identification
  - Generate 1000 toy Monte Carlo samples.
- The results are listed below:

	This work (10^{-3})	PDG values(10^{-3})
ΔA_{FB}^b	0.013	16
ΔA_{FB}^c	0.021	50
ΔA_{FB}^s	0.018	148



Pull = (O - I) / error



Measurement of $\sin^2 \theta_W^{eff}$

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- The published sensitivities of $\sin^2 \theta_{\mathrm{eff}}^{\mathrm{lept}}$ are at the 10^{-3} level
  - The sensitivity obtained from $A_{FB}^{0,b}$ is better than that from $A_{FB}^{0,l}$, because the cross section for quark final states is larger than that for leptonic decays.

	$\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$	$\Delta\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ (10^{-3})
LEP, $A_{FB}^{0,b}$	0.23221±0.00029	1.3
LEP, $A_{FB}^{0,l}$	0.23099±0.00053	2.3
SLC, A_{LR}	0.23098±0.00026	1.2
LEP+SLC	0.23153±0.00016	0.70

- To extract $\sin^2 \theta_W^{\mathrm{eff}}$ from the simulated CEPC data, a similar binned extended maximum likelihood is performed
- 1000 toy Monte Carlo samples, pull distributions are also standard
- The results (10^{-6}) are listed
  - Improvements in both statistical precision and analysis methods

	b	c	s
$\Delta\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$	1.0	1.5	1.4

Extension to polarization scenario

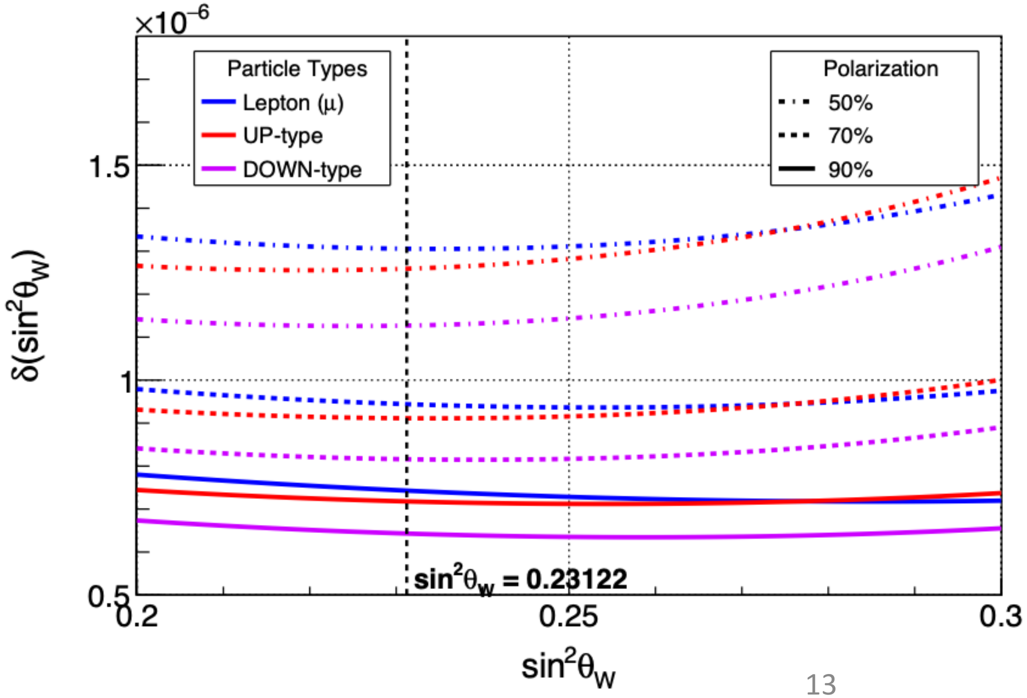
- The power of beam polarization for electroweak precision measurements was convincingly demonstrated by the SLC experiment
  - With less statistics using a polarized electron beam
  - A precision comparable to — and in some respects exceeding

	$\sin^2\theta_{\rm eff}^{\rm lept}$	$\Delta\sin^2\theta_{\rm eff}^{\rm lept}$ (10^{-3})
LEP, $A_{FB}^{0,b}$	0.23221 ± 0.00029	1.3
LEP, $A_{FB}^{0,l}$	0.23099 ± 0.00053	2.3
SLC, A_{LR}	0.23098 ± 0.00026	1.2
LEP+SLC	0.23153 ± 0.00016	0.70

- The statistical advantage of the polarized measurement could be estimated using Fisher Information
  - The factor $\sqrt{2}$ accounts for the fact that the total integrated luminosity is split between the left-handed and right-handed polarization states.

$$\frac{\Delta(\sin^2\theta_W^{\rm eff})_{\rm pol}}{\Delta(\sin^2\theta_W^{\rm eff})_{\rm unpol}} = \frac{\sqrt{2}}{P_e}\cdot\frac{|\partial A_{\rm FB}/\partial\sin^2\theta_W^{\rm eff}|}{|\partial A_{\rm LR}/\partial\sin^2\theta_W^{\rm eff}|},$$

- The expected precision of $\sin^2\theta_W^{\rm eff}$ measurements using the Fisher information method



Extension to polarization scenario

- The expected bin-by-bin number of left(right)-handed events

$$N^{\mathrm{exp}}_{L(R),i,j} = \mathcal{L}\Delta \sum_k \sigma_{L(R),i,j}\epsilon_{i,j,k},$$

- $\sin^2\theta_W^{\mathrm{eff}}$ could be extracted via a binned maximum likelihood fit

$$\mathcal{L}(\sin^2\theta_W^{\mathrm{eff}}, N^{\mathrm{prod}}_{L,j}, N^{\mathrm{prod}}_{R,j}) = \prod_i \frac{\mu_{L,i,j}^{n_{L,i,j}} e^{-\mu_{L,i,j}}}{n_{L,i,j}!} \times \frac{\mu_{R,i,j}^{n_{R,i,j}} e^{-\mu_{R,i,j}}}{n_{R,i,j}!},$$

- 1000 toy Monte Carlo samples, pull distributions are also standard
- The results (10^{-6}) are listed

	$P_e = 0.5$	$P_e = 0.6$	$P_e = 0.7$	$P_e = 0.8$
b	0.55	0.54	0.52	0.51
c	0.71	0.69	0.68	0.65
s	0.83	0.82	0.81	0.79