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Jet Charge at CEPC

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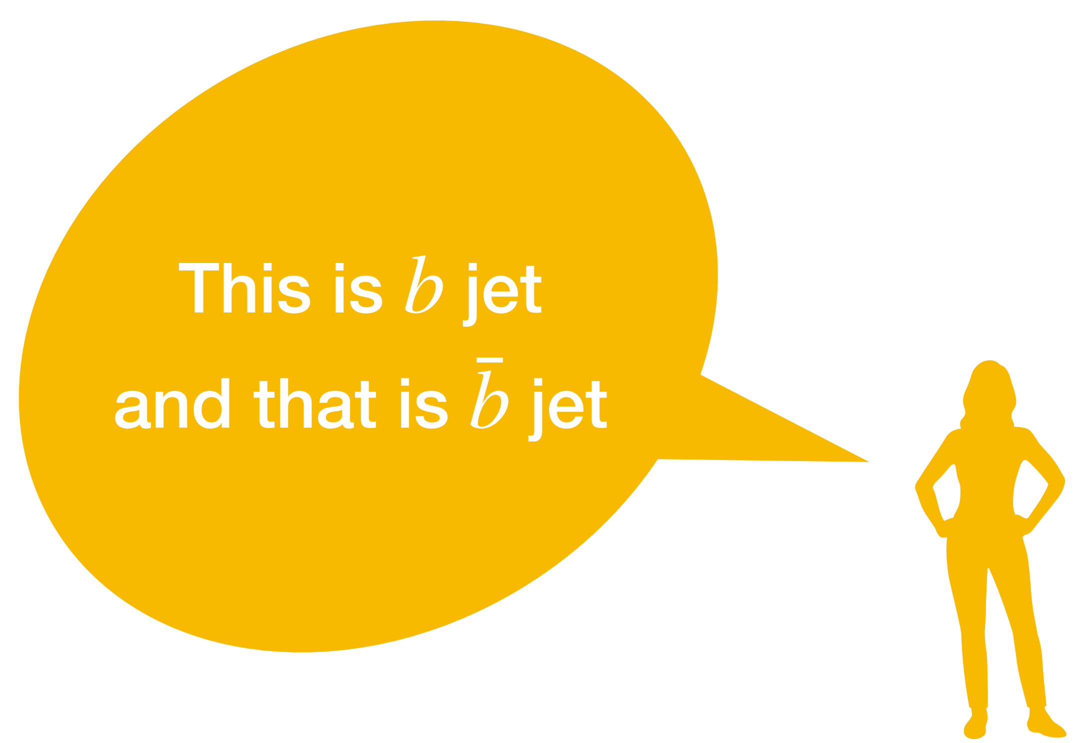
Outline

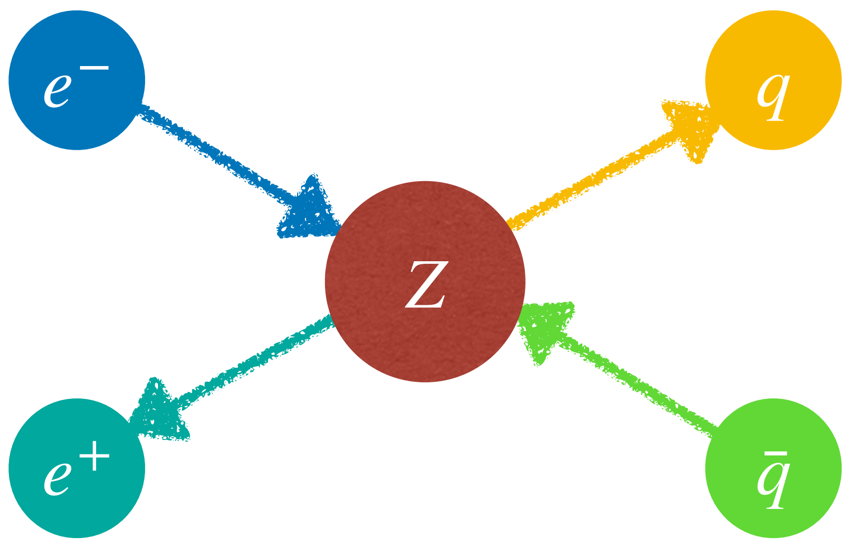
- Introduction
- Samples
- Method
- Results
- Conclusion

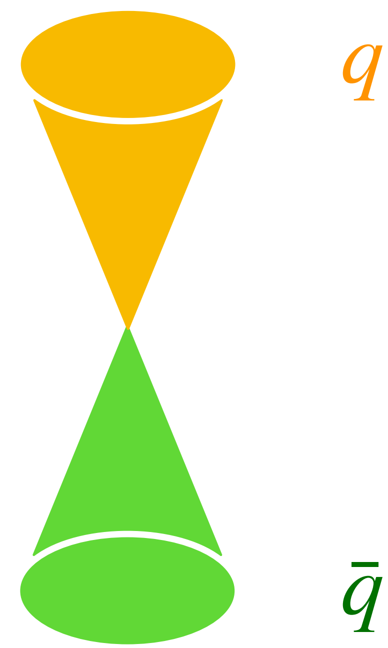


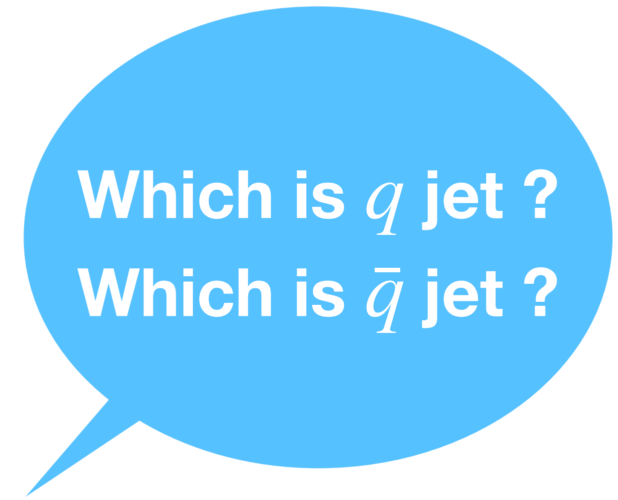
Introduction

Introduction of Jet Charge

We already have flavor tagging algorithm, Jet Charge can help find more physics







What is Jet Charge?

- *To determine initial jet charge, namely b quark v.s. $\bar{b}$ quark / c quark v.s. $\bar{c}$ quark*

Application of Jet Charge:

- *The measurements of specific heavy hadrons channel*
- *The electroweak precision measurements*

  e.g. - A_{FB}*(Forward and Backward Asymmetry);*
  - $\sin^2\theta_W$*(electroweak mixing angle);*
  - *CP Violation measurement*
- *...*

Jet Charge Algorithm

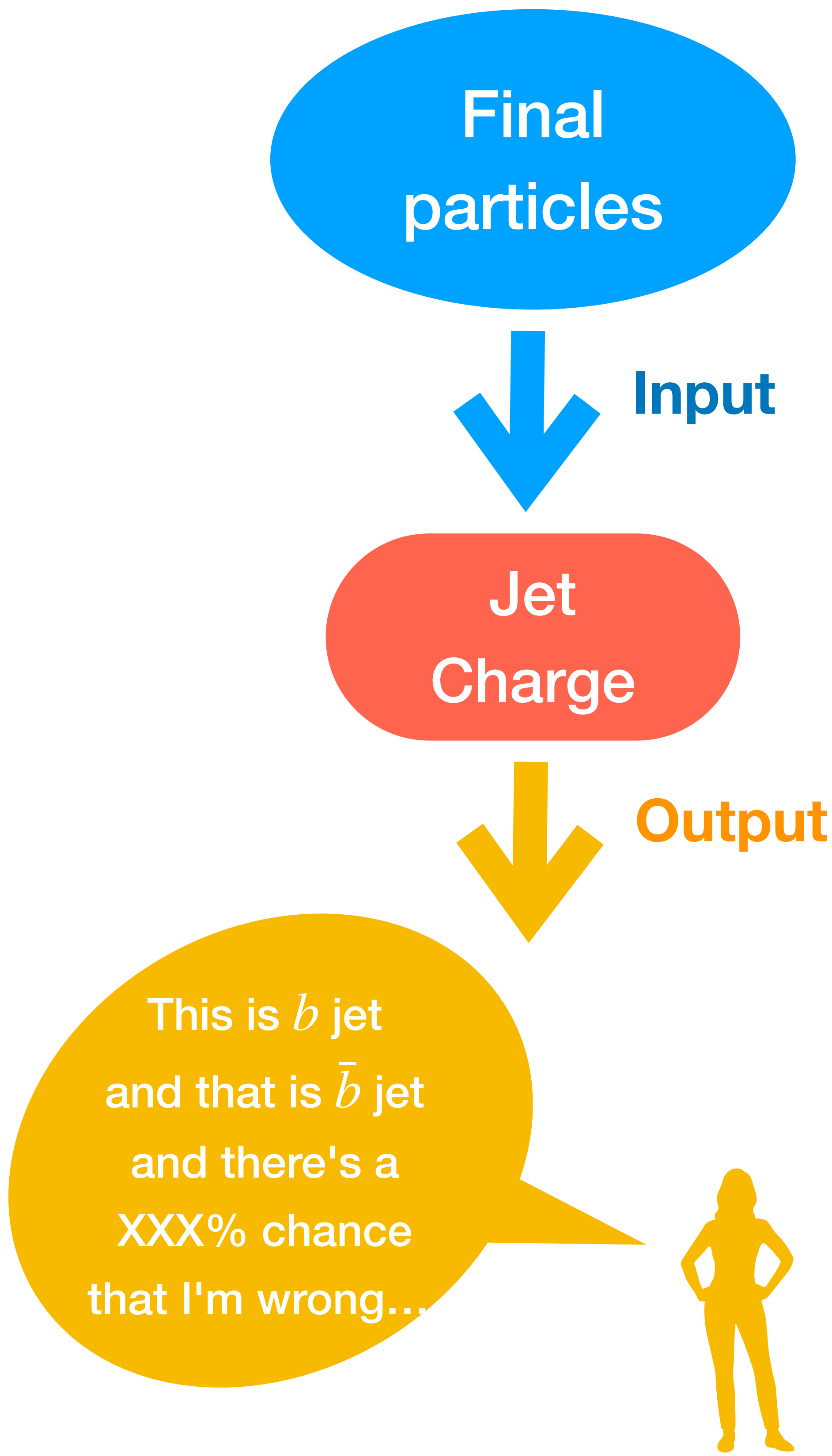
Jet Charge Algorithm at Truth Level:

Input:

- *Information of final particles:*
    - *Charge*
    - *Energy*
    - *Momentum*
    - *…*

Output:

- *Jet charge*
- *Description of Jet Charge*
    - *Misjudgment rate ω*
    - *Effective tagging power*



Jet Charge at CEPC

Why CEPC?

High productivity

- *3 x 10^{11} - 10^{12} Z bosons in 2 years*
- $b\bar{b}$ *branching fraction: 15.2%*
- *0.152 × 10^{11} - 10^{12}* $b\bar{b}$

Good detector system

- *Good VTX reconstruction*
- *Good PID system*

Clean environment

Different particle flavors

- $Z \to b\bar{b}$ *events*
- $Z \to c\bar{c}$ *events*

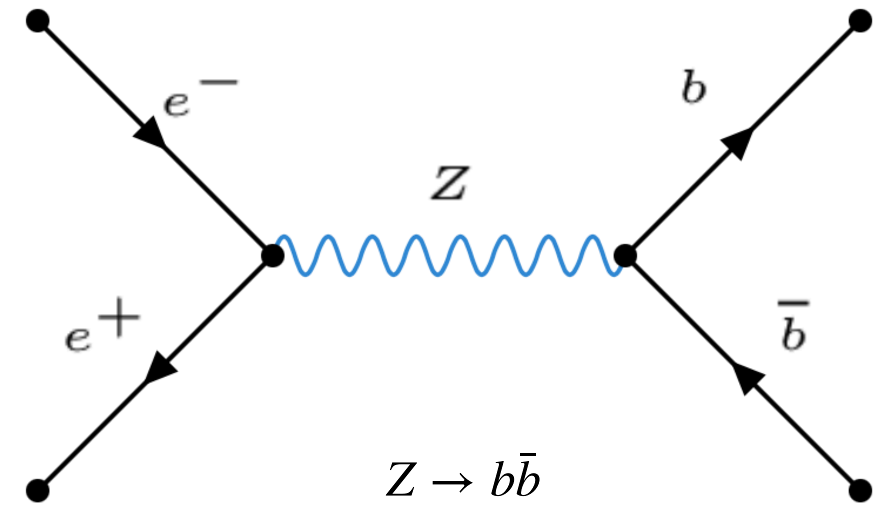
Flavor production at different experiments

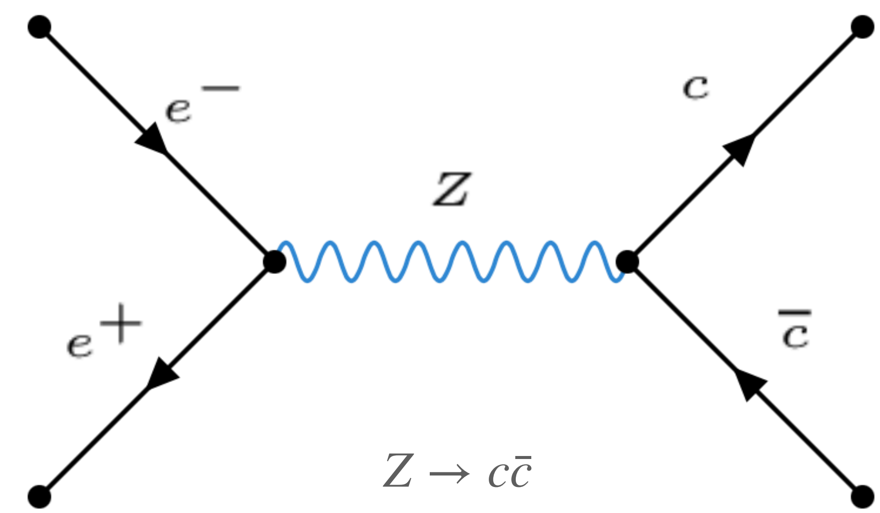
Particle	**Tera-Z**	**Belle II**	**LHCb**
***b* hadrons**			
B^+	6×10^{10}	3×10^{10} ($50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S)$)	3×10^{13}
B^0	6×10^{10}	3×10^{10} ($50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S)$)	3×10^{13}
B_s	2×10^{10}	3×10^{8} ($5\,\mathrm{ab}^{-1}$ on $\Upsilon(5S)$)	8×10^{12}
b baryons	1×10^{10}		1×10^{13}
Λ_b	1×10^{10}		1×10^{13}
***c* hadrons**			
D^0	2×10^{11}		
D^+	6×10^{10}		
D_s^+	3×10^{10}		
Λ_c^+	2×10^{10}		
τ^+	3×10^{10}	5×10^{10} ($50\,\mathrm{ab}^{-1}$ on $\Upsilon(4S)$)	

From CEPC CDR 2018

Samples

Samples



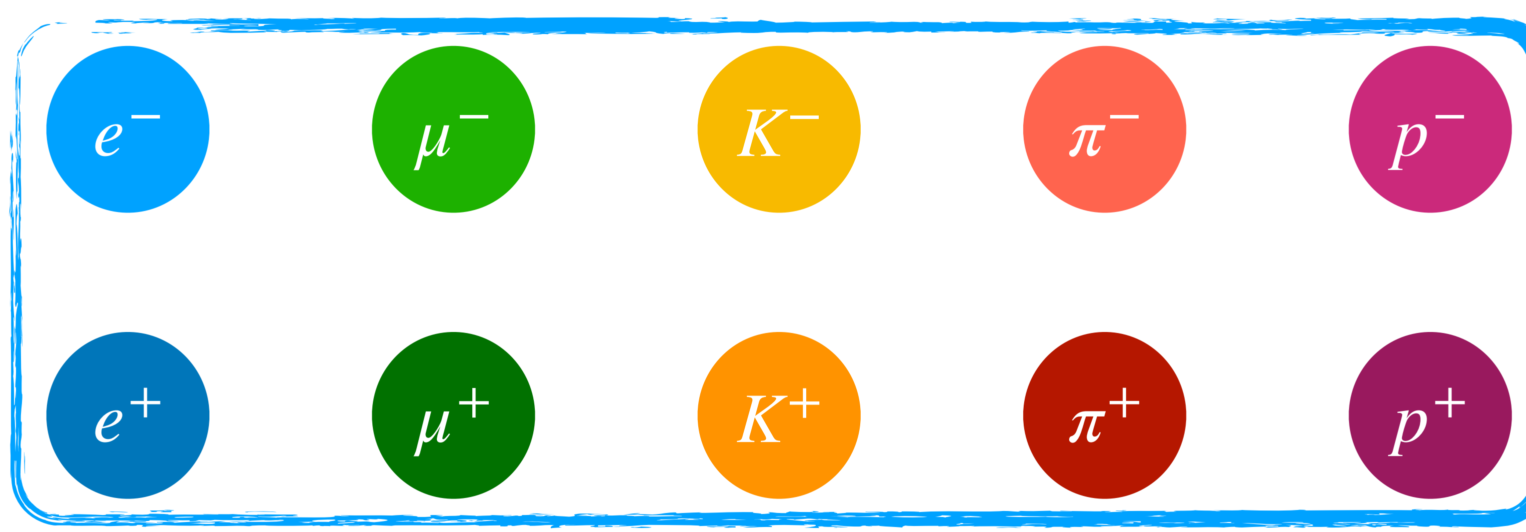


Samples:

- ***WHIZARD195***
- *CEPC Z pole (91.2 GeV) at Truth level*
  - *16 million $Z \to b\bar{b}$ events:*
    - *easy to select*
  - *16 million $Z \to c\bar{c}$ events:*
    - *simpler decay behavior*

Final particles we consider:

- *leptons: e^+e^-, $\mu^+\mu^-$*
- *Kaons: K^+K^-*
- *pions: $\pi^+\pi^-$*
- *protons: p^+p^-*



Method

How to develop Jet Charge?

Jet Charge Algorithm:

- *Use Jet Clustering to divide final leading particles into two jets*
- *Find the relationship between observables(charge, energy) of final leading particles and jet charge:*
  - *For $Z \to b\bar{b}$ samples:*
    - $e^-, \mu^-, K^-, \pi^-, p^+$ are closer to b jet
    - $e^+, \mu^+, K^+, \pi^+, p^-$ are closer to $\bar{b}$ jet
  - *For $Z \to c\bar{c}$ samples:*
    - $e^+, \mu^+, K^-, \pi^+, p^+$ are closer to c jet
    - $e^-, \mu^-, K^+, \pi^-, p^+$ are closer to $\bar{c}$ jet
  - *Combine the information of two jets*
- *Use those observables(charge, energy) to measure jet charge*
- *Use Misjudgment rate ω and effective tagging power to describe Jet Charge*

How to describe Jet Charge?

Misjudgment rate ω:

- *To describe the probability of misjudging the jet charge*

$$\omega = \frac{\text{Number of selected final particles that incorrectly reflect the charge flow of b jet to } \bar{\text{b}} \text{ jet}}{\text{Number of selected final particles}}$$

Efficiency:

- *To describe the selection efficiency of $Z \to b\bar{b}$ or $Z \to c\bar{c}$ samples:*

$$\text{Efficiency} = \frac{\text{Number of selected final particles}}{\text{Number of all final particles}}$$

Effective tagging power ETP:

- *To consider both misjudgment rate ω and efficiency to describe the total performance of Jet Charge*

$$\text{Effective tagging power} = \text{Efficiency} \; * \; (1 - 2 * \omega)^2$$

Steps of studying Jet Charge

1. Because the lepton and Kaon can deliver better misjudgment rate ω than pion and proton. → Categorize the final leading particles:

$$(e, \mu, K)\ \&\ (\pi, proton)$$

Misjudgment rate ω

bbar jet → / b jet ↓	e, μ, K	π,proton
e, μ, K	11.73%	23.05%
π,proton	23.05%	40.41%

Misjudgment rate ω

cbar jet → / c jet ↓	e, μ, K	π,proton
e, μ, K	4.03%	10.87%
π,proton	10.86%	26.30%

Second best case

Best case

Worst case

Steps of studying Jet Charge

1. Because the lepton and Kaon can deliver better misjudgment rate ω than pion and proton. → Categorize the final leading particles:

$$(e, \mu, K) \ \& \ (\pi, proton)$$

2. Misjudgment rate ω and effective tagging power of each category
3. Impact of energy threshold of the final leading particles

4. Distribution of each B/C hadron
5. Effective tagging power of each B/C hadron
6. The "same charged" samples

7. Samples only decayed to leading particles

8. Typical channels: Bs, Bc, Λ_b, …
9. More information from final particles
10. Different generators (e.g. Evtgen, …)

Steps of studying Jet Charge

1. Because the lepton and Kaon can deliver better misjudgment rate ω than pion and proton. → Categorize the final leading particles:

$$(e, \mu, K) \,\&\, (\pi, proton)$$

Yangzhou, April

2. Misjudgment rate ω and effective tagging power of each category
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CEPC flavor, September

7. Samples only decayed to leading particles

This Report

8. Typical channels: Bs, Bc, Λ_b, …
9. More information from final particles
10. Different generators (e.g. Evtgen, …)

Future Plans

Steps of studying Jet Charge

1. Because the lepton and Kaon can deliver better misjudgment rate ω than pion and proton. → Categorize the final leading particles:

$\{e, \mu, K\}\{e, \mu, K\}$ can deliver better results

Yangzhou, April

$Z \to b\bar{b}$ Total Effective Tagging Power = 0.127

$Z \to c\bar{c}$ Total Effective Tagging Power = 0.282

2. Misjudgme … each category
3. Impact of energ … particles

No energy threshold is the best case

4. Distribution of each … Symmetric between two jets
5. Effective t … High dependence of different hadron combination
6. The "same charged … Some small improvements

flavor, September

7. Samples only decayed to leading particles

This Report

8. Typical channels: Bs, Bc, Λ_b, …
9. More information from final particles
10. Different generators (e.g. Evtgen, …)

Future Plans

Results

Firstly, we have to understand the distribution of samples

Multiplicity of B/C hadrons

Num_B bbar jet → b jet ↓	0	1	2	3
0	0.02%	1.25%	0.61%	1E-05
1	1.25%	96.08%	0.03%	0.05%
2	0.61%	0.03%	0.03%	2E-07
3	8E-06	0.05%	3E-07	2E-07

each jet has one B

Num_C cbar jet → c jet ↓	0	1	2	3
0	0.02%	1.24%	0.76%	6E-05
1	1.24%	94.74%	0.03%	0.46%
2	0.75%	0.03%	0.21%	6E-05
3	6E-05	0.46%	5E-05	2E-05

each jet has one C

by WHIZARD195

Multiplicity of B/C hadrons

Num_B bbar jet → b jet ↓	0	1	2	3
0	0.02%	1.25%	0.61%	1E-05
1	1.25%	96.08%	0.03%	0.05%
2	0.61%	0.03%	0.03%	2E-07
3	8E-06	0.05%	3E-07	2E-07

Num_C cbar jet → c jet ↓	0	1	2	3
0	0.02%	1.24%	0.76%	6E-05
1	1.24%	94.74%	0.03%	0.46%
2	0.75%	0.03%	0.21%	6E-05
3	6E-05	0.46%	5E-05	2E-05

82.4% decayed to leading particle

66.2% decayed to leading particle

by WHIZARD195

Multiplicity of B/C hadrons

Num_B bbar jet → b jet ↓	0	1	2	3
0	0.02%	1.25%	0.61%	1E-05
1	1.25%	96.08%	0.03%	0.05%
2	0.61%	0.03%	0.03%	2E-07
3	8E-06	0.05%	3E-07	2E-07

Num_C cbar jet → c jet ↓	0	1	2	3
0	0.02%	1.24%	0.76%	6E-05
1	1.24%	94.74%	0.03%	0.46%
2	0.75%	0.03%	0.21%	6E-05
3	6E-05	0.46%	5E-05	2E-05

Divided into: both all cases & the case only decayed to leading particles

by WHIZARD195

$Z \to b\bar{b}$ Percent of B hadrons of b jet and $\bar{b}$ jet

percent bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar	others	all
B^0bar	17.360%	17.350%	3.369%	0.022%	2.759%	0.688%	41.548%
B^-	17.350%	17.359%	3.364%	0.022%	2.765%	0.689%	41.550%
B_s^0bar	3.355%	3.362%	0.652%	0.004%	0.545%	0.144%	8.062%
B_c^-	0.022%	0.022%	0.004%	0.00003%	0.004%	0.001%	0.052%
Λ_b	2.762%	2.762%	0.543%	0.004%	0.451%	0.121%	6.644%
others	0.653%	0.655%	0.136%	0.001%	0.119%	0.579%	2.144%
all	41.503%	41.511%	8.068%	0.053%	6.641%	2.225%	100% ★

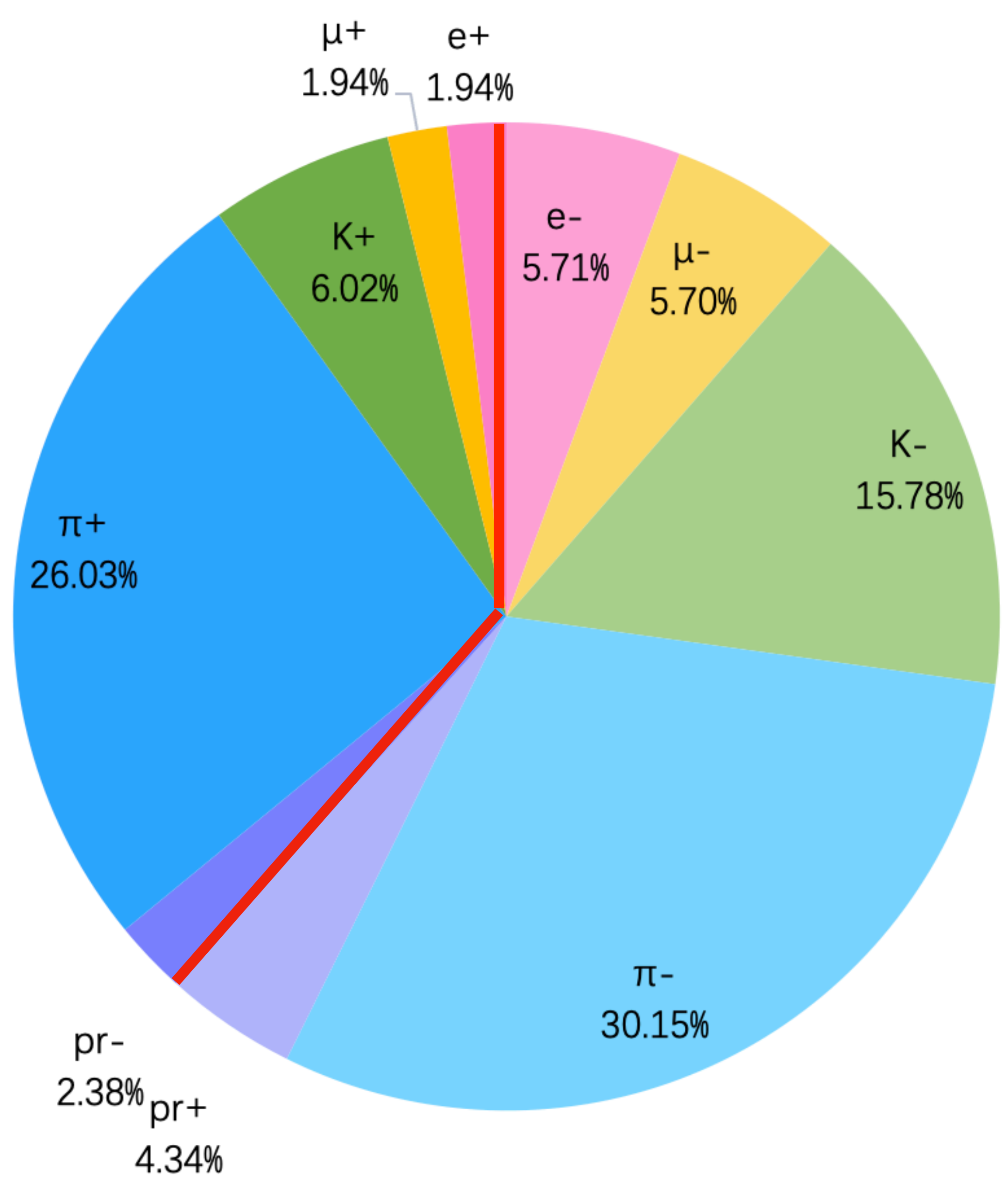
by WHIZARD195

$Z \to c\bar{c}$ **Percent of C hadrons of c jet and $\bar{c}$ jet**

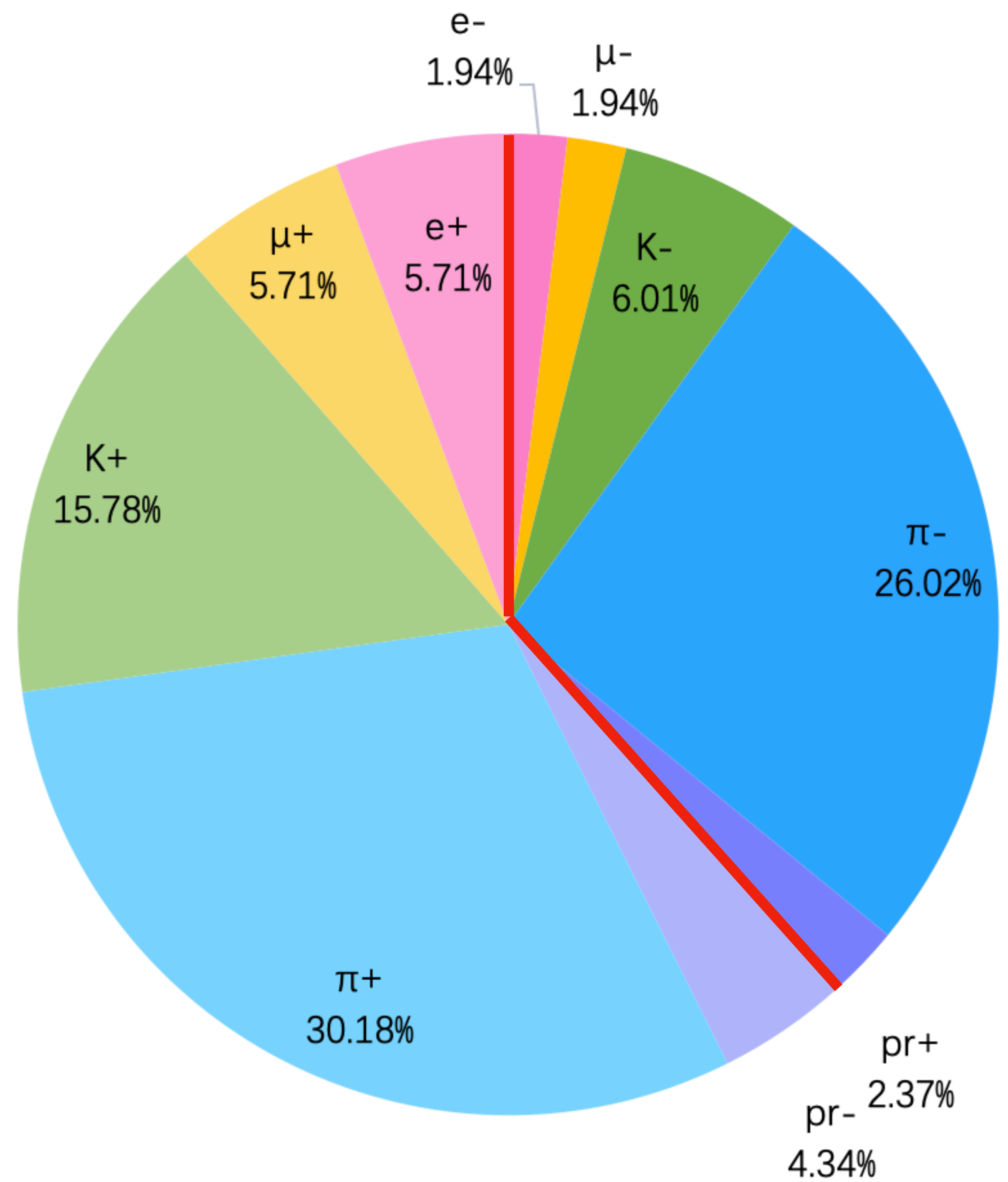
percent cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-	others	all
D^0	4.654%	13.302%	1.717%	1.444%	0.529%	21.532%
D^+	13.290%	37.933%	4.887%	4.110%	1.122%	61.342%
D_s^0	1.712%	4.894%	0.631%	0.533%	0.159%	7.929%
Λ_c^+	1.442%	4.111%	0.533%	0.449%	0.141%	6.676%
others	0.402%	1.066%	0.148%	0.135%	0.656%	2.521%
all	21.500%	61.306%	7.916%	6.671%	2.607%	100%

by WHIZARD195

$Z \to b\bar{b}$ Percent of final charged leading particles of b jet and $\bar{b}$ jet



b jet

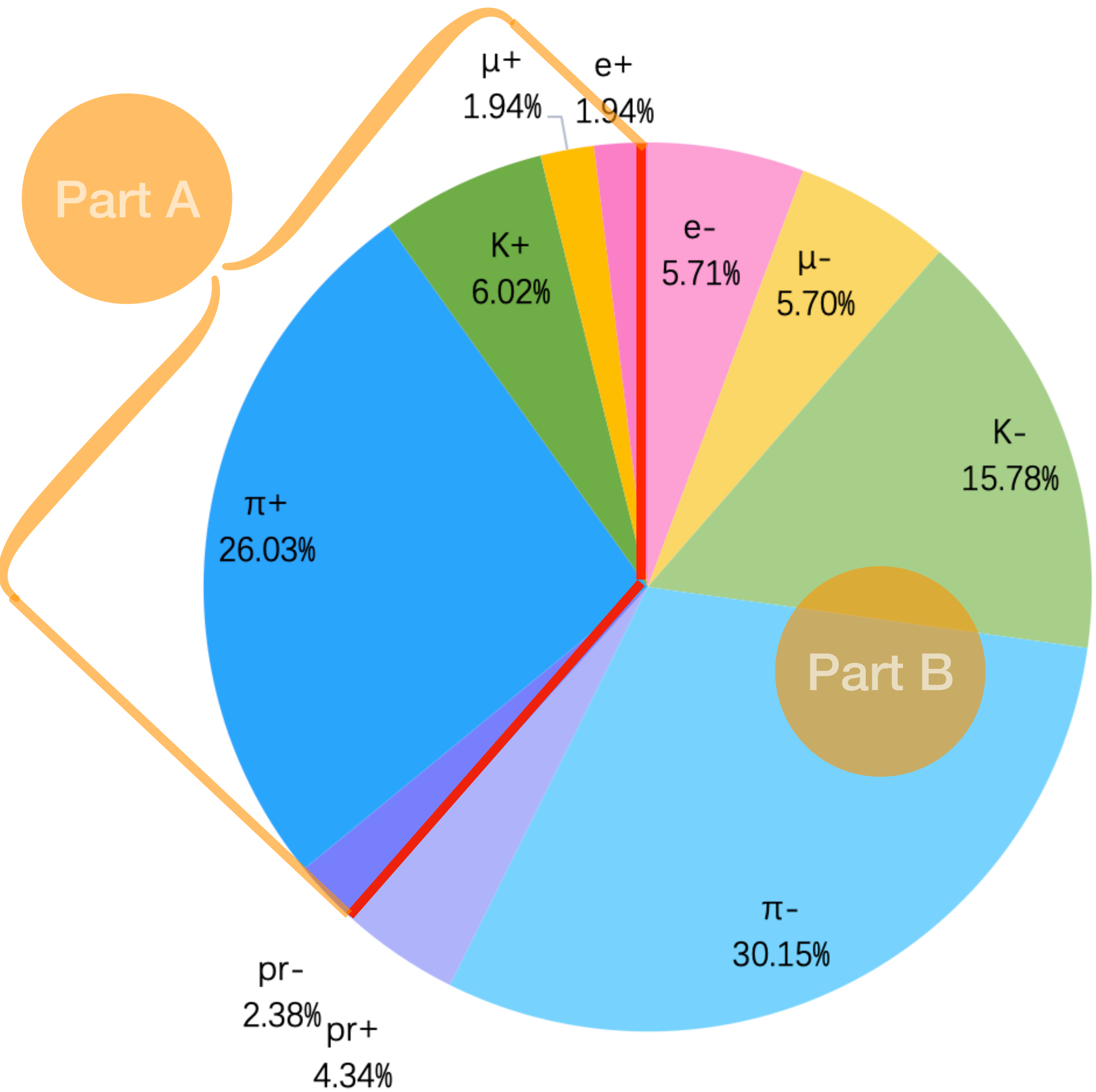


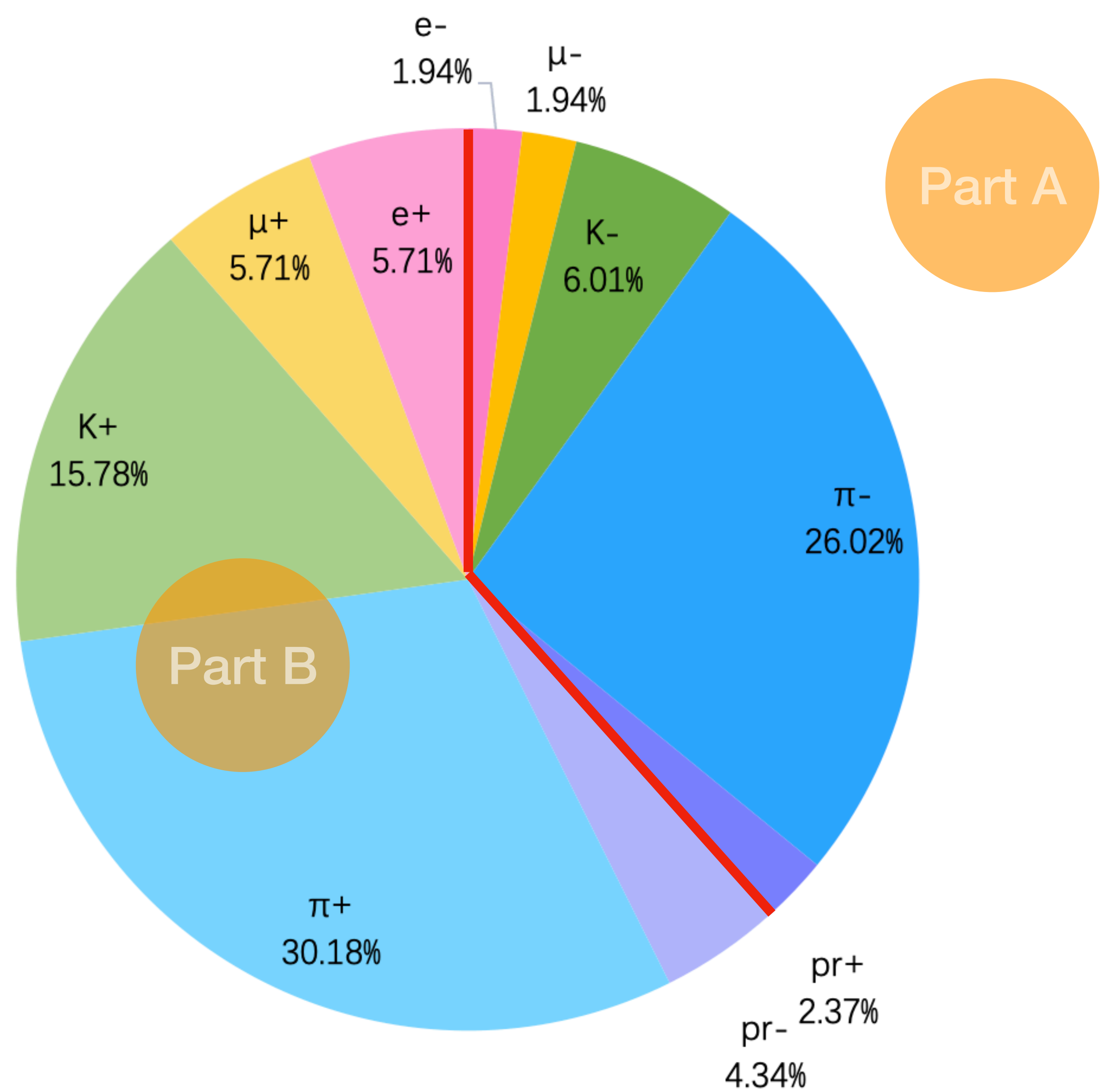
$\bar{b}$ jet

☞ *The distribution of each charged particle of two jets is asymmetry*

Secondly, let us explore the misjudgment rate ω

$Z \to b\bar{b}$ Percent of final charged leading particles of b jet and $\bar{b}$ jet





b jet

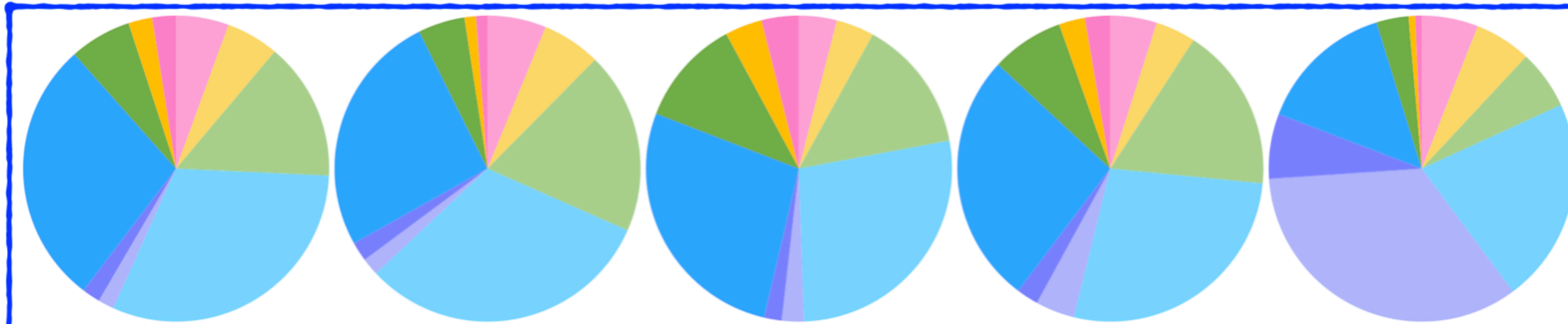
$$\omega = \frac{\text{Number of Part A}}{\text{Number of Part (A + B)}}$$

$\bar{b}$ jet

☞ ***The distribution of each charged particle of two jets is asymmetry***

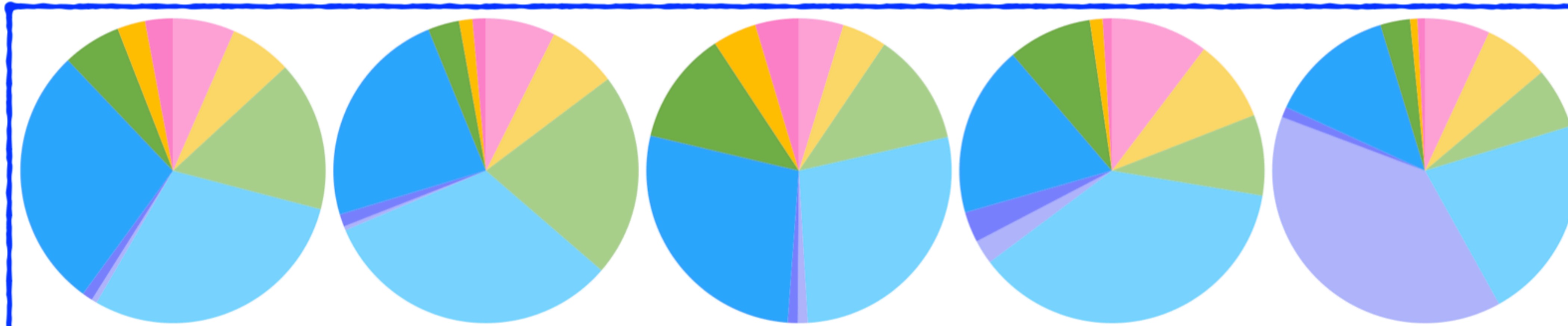
$Z \to b\bar{b}$

Percent of leading particles of each B hadron of b jet



$\bar{B}^0$ * 0.415 | B^- * 0.416 | $\bar{B}_s^0$ * 0.081 | B_c^- * 0.0005 | Λ_b * 0.066

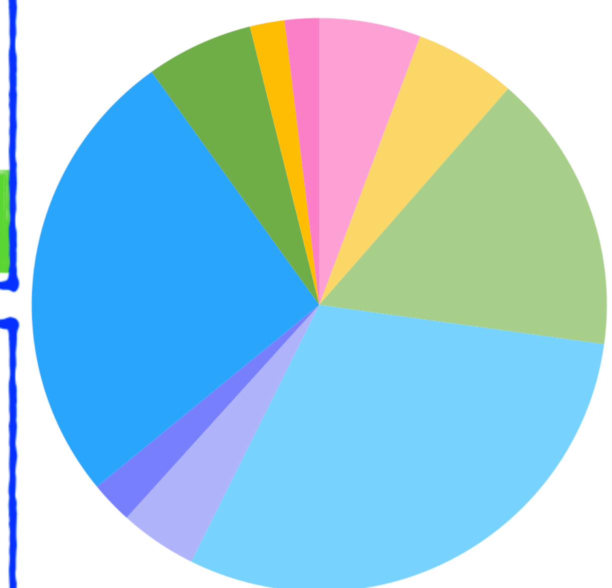
all cases



$\bar{B}^0$ * 0.353 | B^- * 0.350 | $\bar{B}_s^0$ * 0.068 | B_c^- * 0.0002 | Λ_b * 0.057

the case only decayed to leading particles

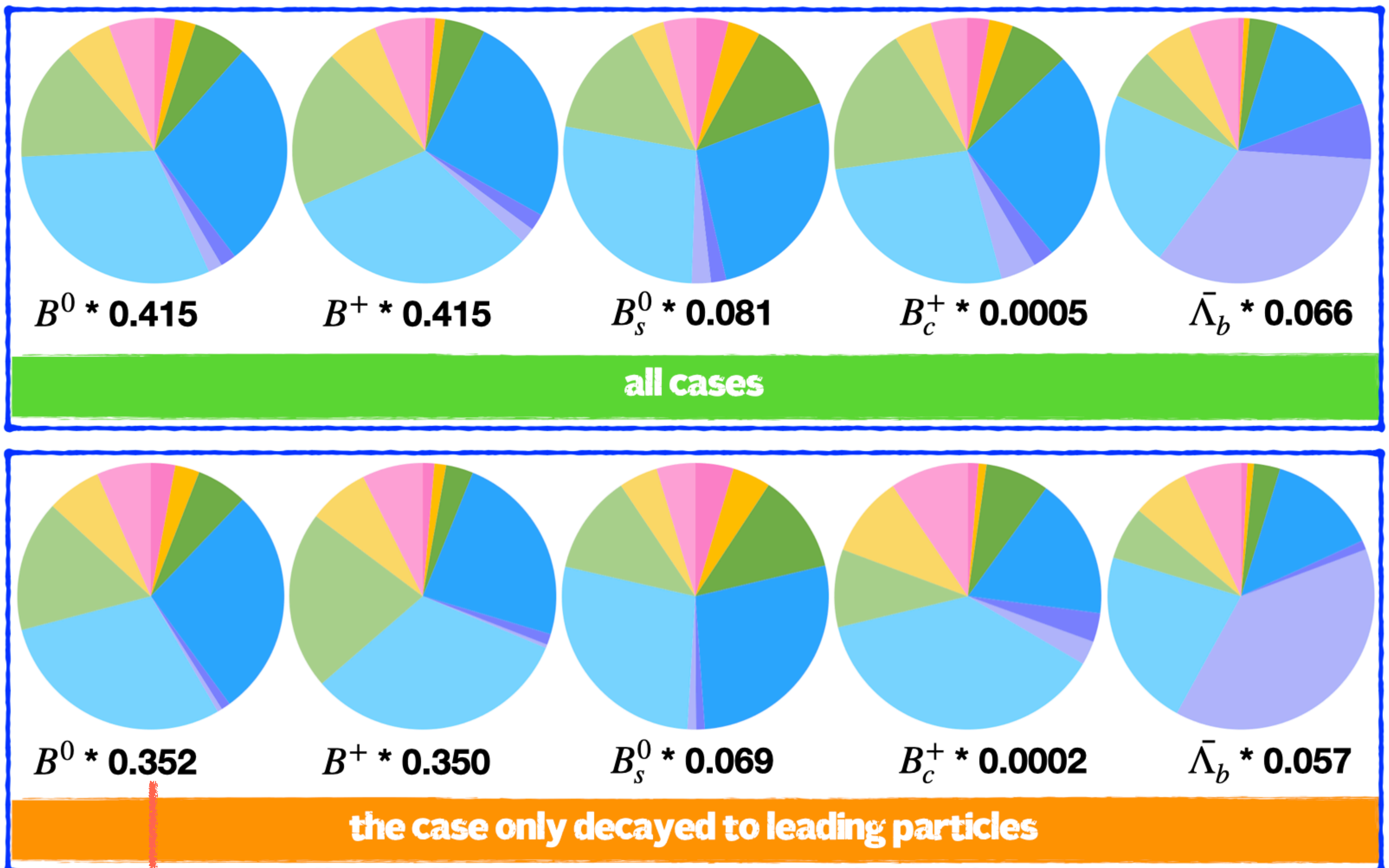
Percent of All B hadrons

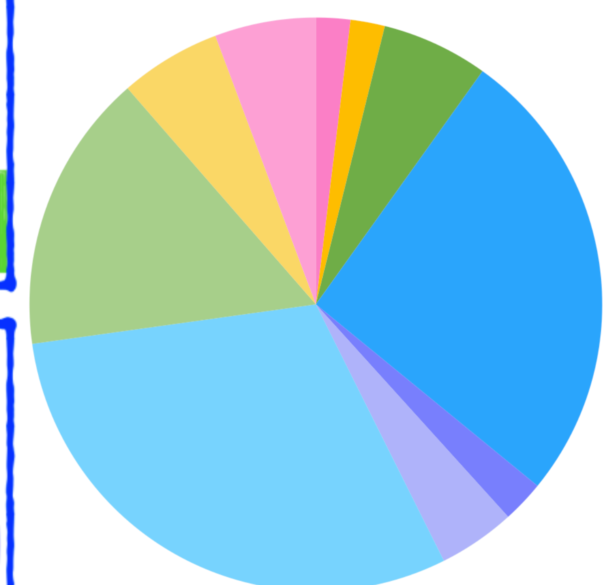


All B, b jet

$Z \to b\bar{b}$

Percent of leading particles of each B hadron of $\bar{b}$ jet

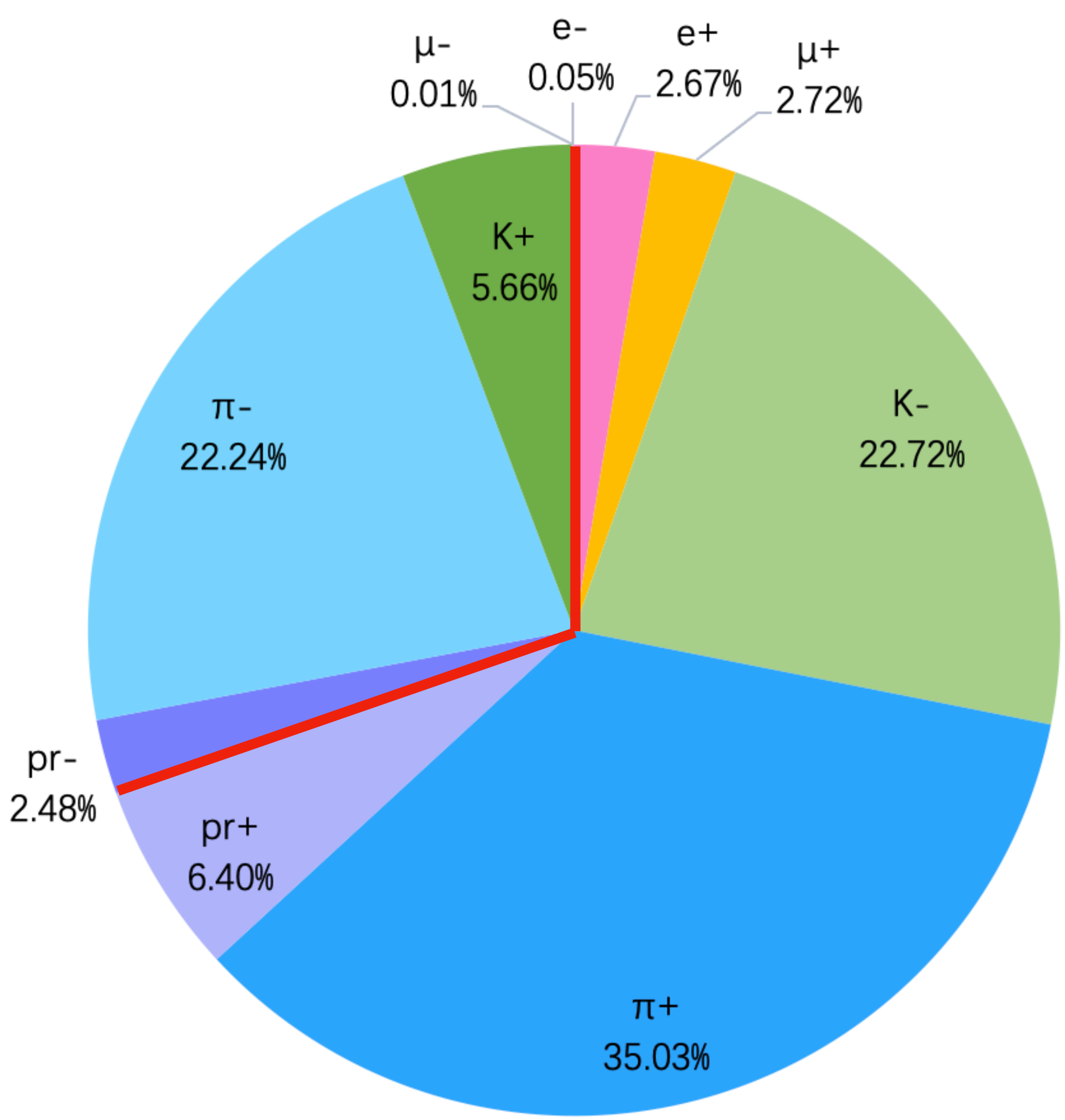




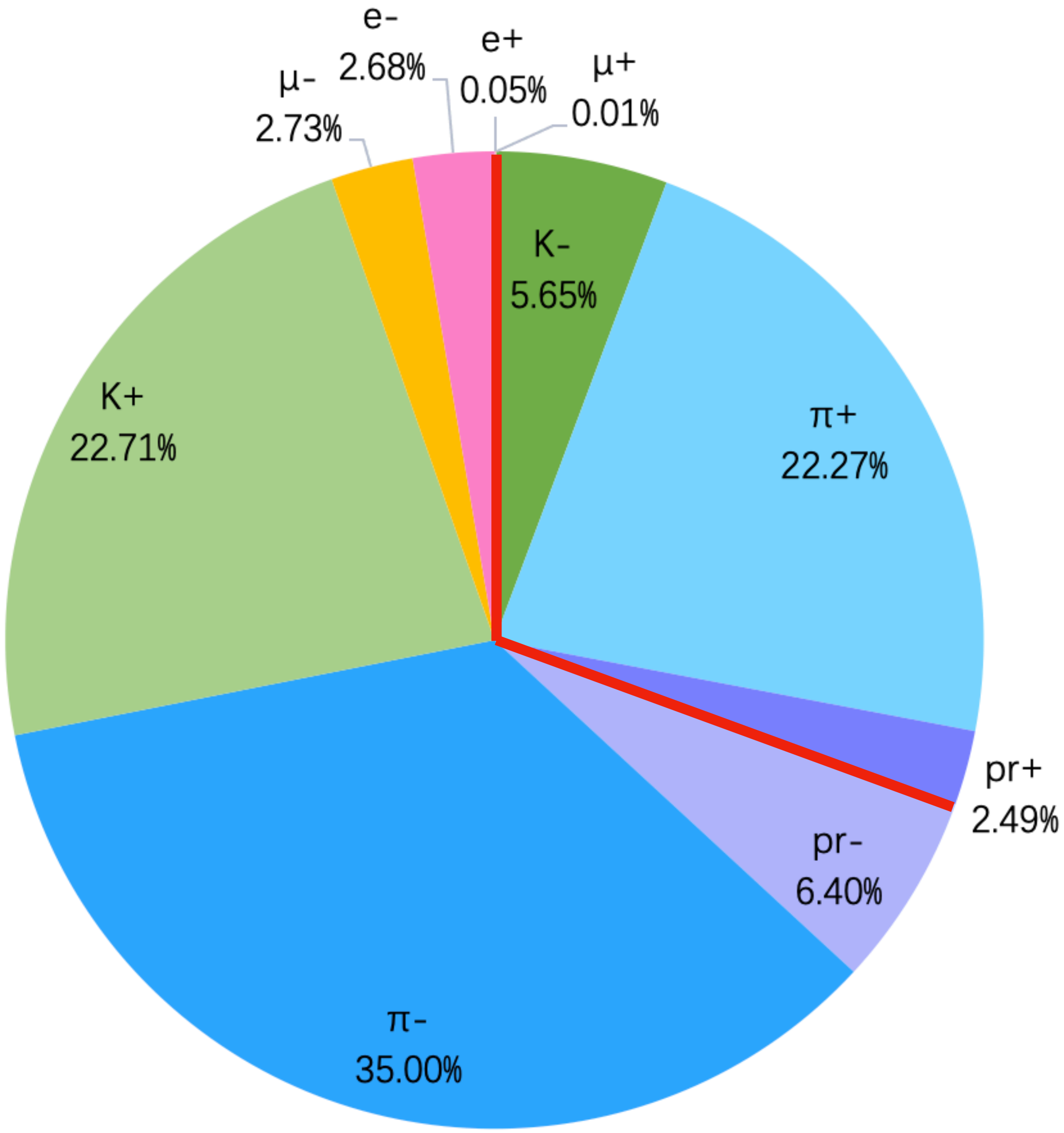
All B, $\bar{b}$ jet

Percent of All B hadrons

$Z \to c\bar{c}$ Percent of final charged leading particles of c jet and $\bar{c}$ jet



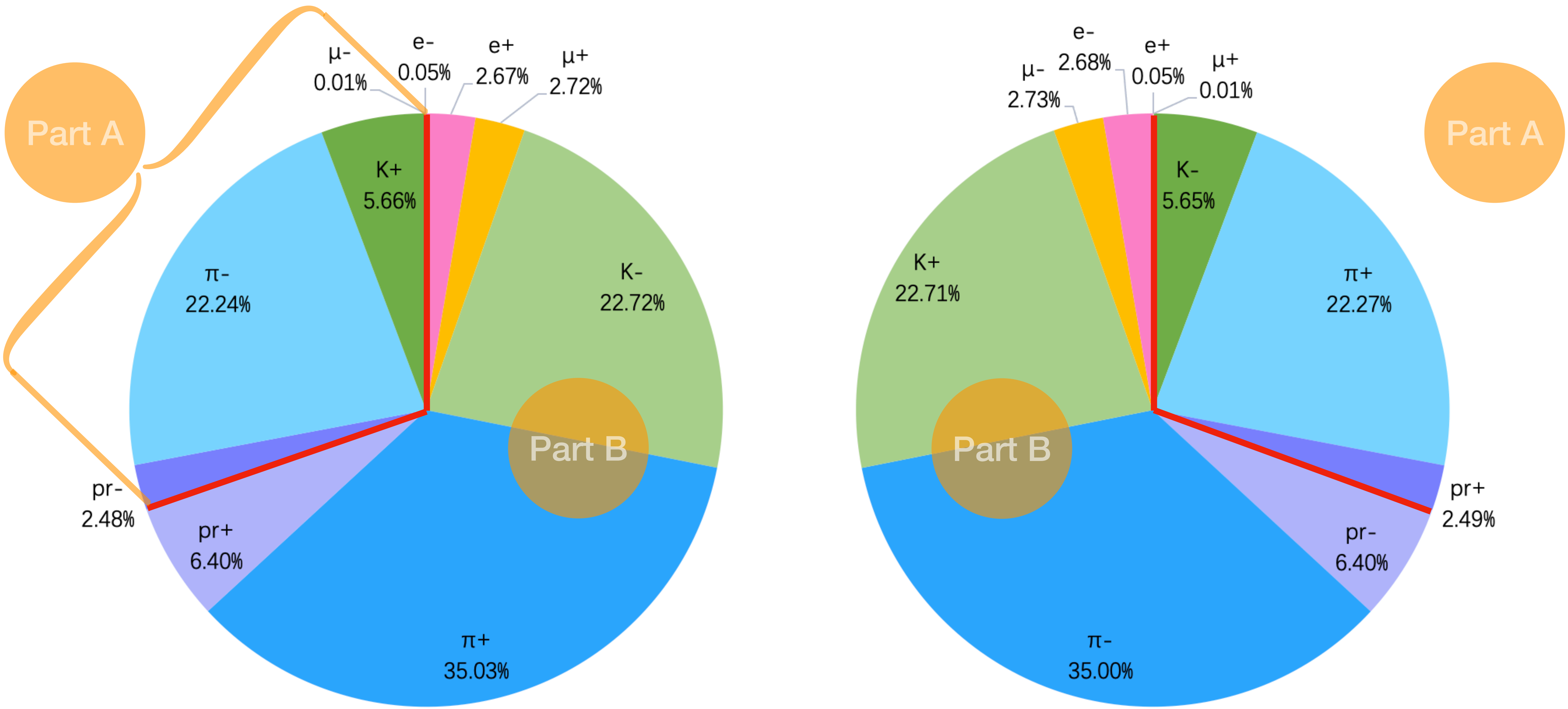
c **jet**



$\bar{c}$ **jet**

☞ *The distribution of each charged particle of two jets is asymmetry*

$Z \to c\bar{c}$ Percent of final charged leading particles of c jet and $\bar{c}$ jet

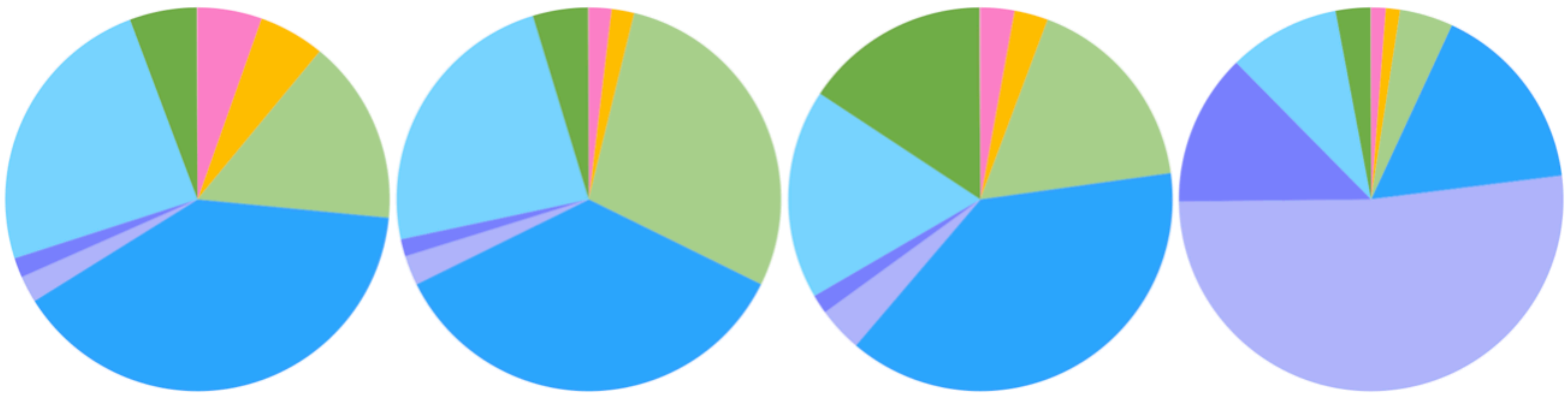


c **jet** $\qquad \omega = \dfrac{\text{Number of Part A}}{\text{Number of Part (A + B)}} \qquad$ $\bar{c}$ **jet**

☞ ***The distribution of each charged particle of two jets is asymmetry***

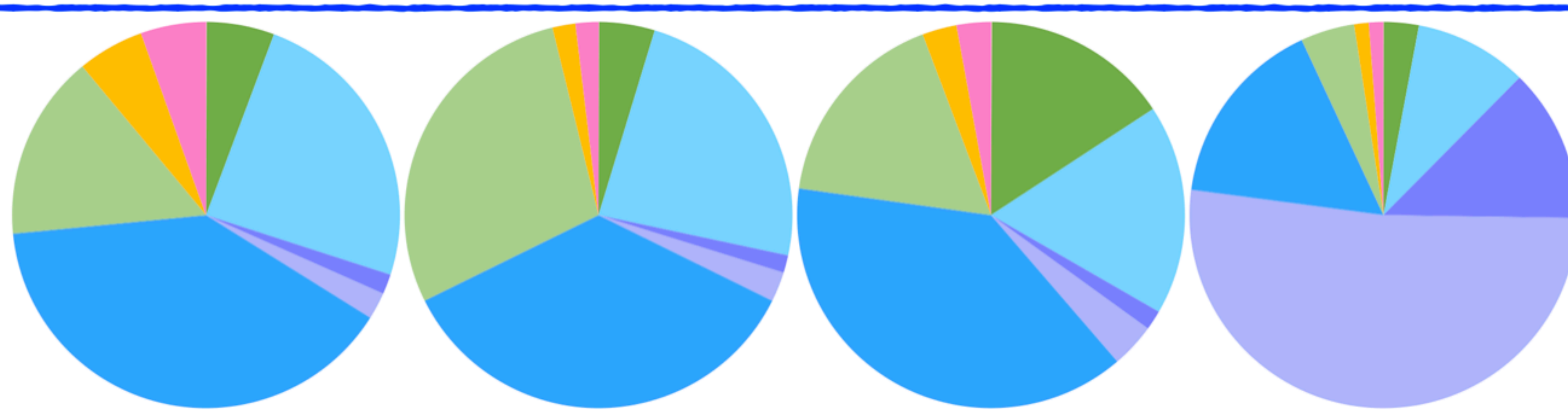
$Z \to c\bar{c}$

Percent of leading particles of each C hadron of c jet



D^0 * 0.215 D^+ * 0.613 D_s^0 * 0.079 Λ_c^+ * 0.067

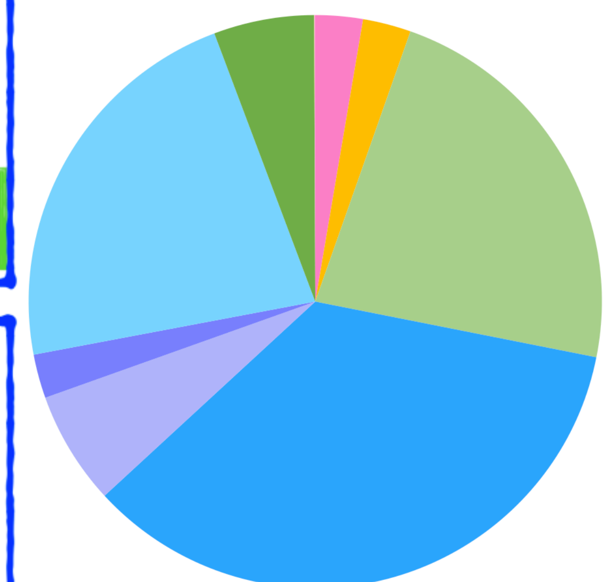
all cases



D^0 * 0.142 D^+ * 0.426 D_s^0 * 0.054 Λ_c^+ * 0.049

the case only decayed to leading particles

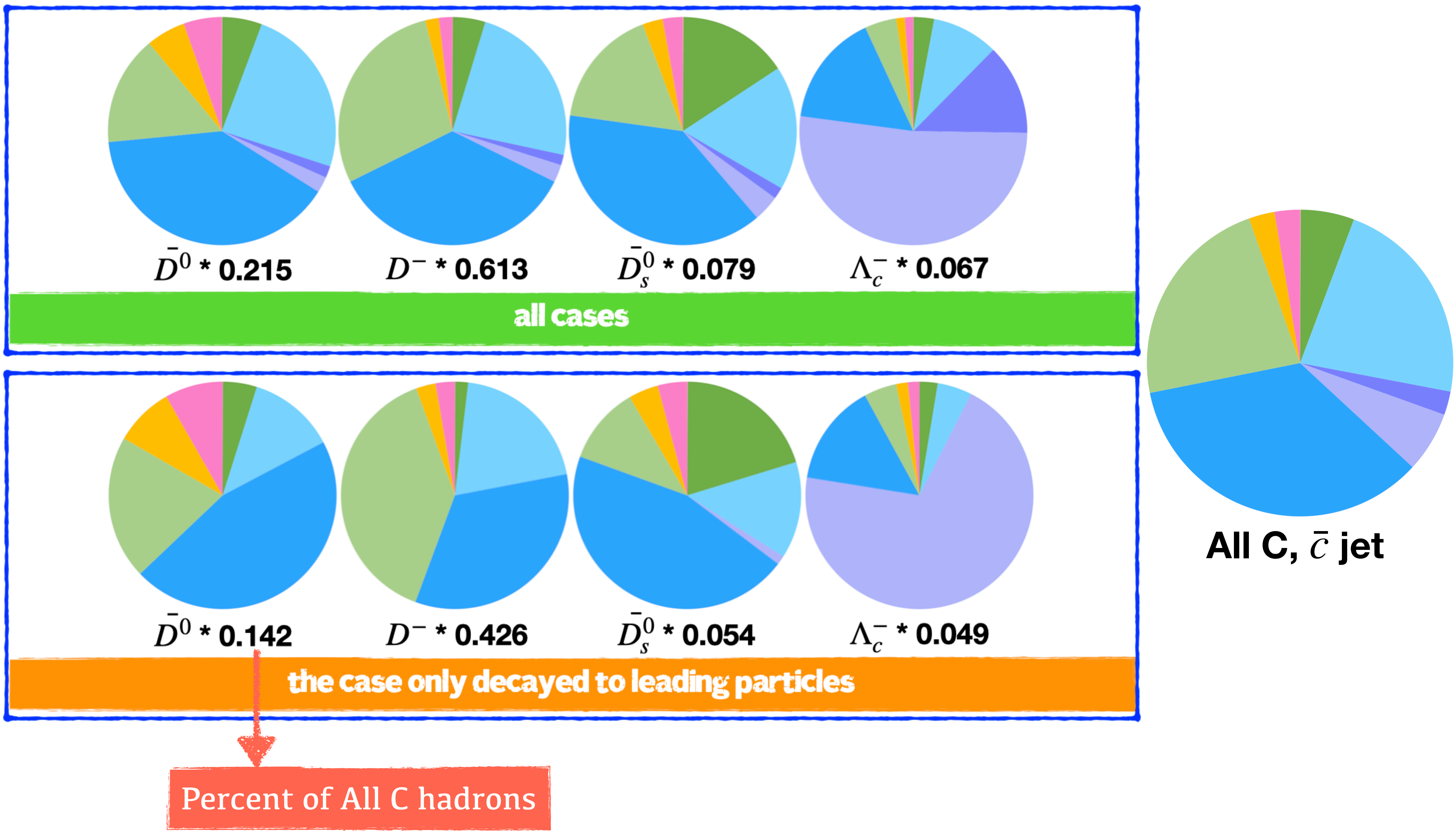
Percent of All C hadrons



All C, c jet

$Z \to c\bar{c}$

Percent of leading particles of each C hadron of $\bar{c}$ jet



$Z \to b\bar{b}$

Misjudgment rate ω of $\{e, \mu, K\}\{e, \mu, K\}$

Total Misjudgment rate ω = 11.73%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	16.73	9.42	27.80	12.80	10.51
B^-	9.51	5.09	17.08	9.55	5.78
B_s^0bar	28.07	16.59	43.62	36.21	19.09
B_c^-	19.74	7.30	46.81	-	11.43
Λ_b	10.63	5.52	19.20	3.85	6.11

All B hadrons

Total Misjudgment rate ω = 9.20%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	14.74	6.55	29.20	7.22	8.67
B^-	6.62	2.74	14.74	3.77	3.89
B_s^0bar	29.29	14.41	50.47	27.27	19.61
B_c^-	14.56	4.63	50.00	-	18.18
Λ_b	8.99	3.59	19.80	0	4.80

B hadrons that decayed to leading particles

$Z \to c\bar{c}$

Misjudgment rate ω of $\{e, \mu, K\}\{e, \mu, K\}$

Total Misjudgment rate ω = 4.03%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	4.53	2.98	12.90	8.50
D^+	3.03	2.05	8.80	6.29
D_s^0	12.64	9.13	31.45	21.65
Λ_c^+	8.32	5.96	23.37	15.07

All C hadrons

Total Misjudgment rate ω = 1.11%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	1.80	0.55	11.78	4.16
D^+	0.57	0.17	4.08	1.26
D_s^0	11.87	4.32	51.86	25.84
Λ_c^+	4.27	1.37	26.06	10.57

C hadrons that decayed to leading particles

Besides, add energy information of same charged samples

Charge verse, Charge same, Charge correct

For leading e, μ, K ***of*** b ***jet and*** $\bar{b}$ ***jet***

charge bbar jet → b jet ↓	+	-
+	19.54%	7.15%
-	53.81%	19.50%

Charge verse

Charge correct

For leading e, μ, K ***of*** c ***jet and*** $\bar{c}$ ***jet***

charge cbar jet → c jet ↓	+	-
+	13.96%	69.12%
-	2.90%	14.01%

Charge verse, Charge same, Charge correct

For leading e, μ, K ***of*** b ***jet and*** $\bar{b}$ ***jet***

charge bbar jet → b jet ↓	+	-
+	19.54%	7.15%
-	53.81%	19.50%

For leading e, μ, K ***of*** c ***jet and*** $\bar{c}$ ***jet***

charge cbar jet → c jet ↓	+	-
+	13.96%	69.12%
-	2.90%	14.01%

Charge verse

Charge correct

Charge same

Two methods of using same charge samples

About 7.9% and 6.7% improvement for $Z \to b\bar{b}$ & $Z \to c\bar{c}$ samples

1. **For the two leading particles of two jets, measure jet charge by the charge of the leading particle with higher energy.**

   For $Z \to b\bar{b}$: Improve Effective Tagging Power from 0.127 to 0.137

   For $Z \to c\bar{c}$: Improve Effective Tagging Power from 0.127 to 0.136

2. **For the two leading particles and two sub-leading particles of two jets, measure jet charge by the charge of the leading particle which has higher energy difference with the sub-leading particle.**

   For $Z \to b\bar{b}$: Improve Effective Tagging Power from 0.282 to 0.301

   For $Z \to c\bar{c}$: Improve Effective Tagging Power from 0.282 to 0.294

Two methods of using same charge samples

The first method is better

1. For the two leading particles of two jets, measure jet charge by the charge of the leading particle with higher energy.

   For $Z \to b\bar{b}$: Improve Effective Tagging Power from 0.127 to 0.137

   For $Z \to c\bar{c}$: Improve Effective Tagging Power from 0.127 to 0.136

2. For the two leading particles and two sub-leading particles of two jets, measure jet charge by the charge of the leading particle which has higher energy difference with the sub-leading particle.

   For $Z \to b\bar{b}$: Improve Effective Tagging Power from 0.282 to 0.301

   For $Z \to c\bar{c}$: Improve Effective Tagging Power from 0.282 to 0.294

The effective tagging power

$Z \to b\bar{b}$ Effective Tagging Power of B Hadrons

Total Effective Tagging Power = 12.736%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	7.792	14.044	3.491	8.346	20.179
B^-	13.965	20.604	8.734	14.568	27.854
B_s^0bar	3.486	8.882	0.363	3.046	13.346
B_c^-	7.820	14.426	0.774	-	23.294
Λ_b	20.268	27.788	13.064	22.841	37.460

charge verse

Total Effective Tagging Power = 13.716%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	8.403	15.213	3.775	8.961	22.144
B^-	15.137	22.434	9.500	16.784	30.450
B_s^0bar	3.730	9.673	0.382	3.406	14.756
B_c^-	8.639	15.817	1.061	-	25.021
Λ_b	22.224	30.313	14.518	26.729	40.840

charge verse & same

$Z \to b\bar{b}$ Weighted Effective Tagging Power of B Hadrons

Total Effective Tagging Power = 12.736%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	1.353	2.437	0.118	0.002	0.557
B^-	2.423	3.577	0.294	0.003	0.770
B_s^0bar	0.117	0.299	0.002	0.0001	0.073
B_c^-	0.002	0.003	0.00003	-	0.0008
Λ_b	0.560	0.768	0.071	0.0008	0.169

charge verse

Total Effective Tagging Power = 13.716%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	1.459	2.640	0.127	0.002	0.611
B^-	2.627	3.895	0.320	0.004	0.842
B_s^0bar	0.125	0.325	0.003	0.0001	0.080
B_c^-	0.002	0.003	0.00005	-	0.0009
Λ_b	0.614	0.837	0.079	0.001	0.184

charge verse & same

$Z \to c\bar{c}$ Effective Tagging Power of C Hadrons

Total Effective Tagging Power = 28.214%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	25.605	28.561	21.514	32.280
D^+	28.544	31.285	24.395	34.759
D_s^0	21.452	24.252	17.423	28.135
Λ_c^+	32.148	34.849	27.635	39.511

charge verse

Total Effective Tagging Power = 30.116%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	27.184	30.702	22.353	35.202
D^+	30.644	33.779	25.816	37.813
D_s^0	22.287	25.670	18.006	30.236
Λ_c^+	35.135	37.930	29.543	42.924

charge verse & same

$Z \to c\bar{c}$ Weighted Effective Tagging Power of C Hadrons

Total Effective Tagging Power = 28.214%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	1.192	3.800	0.370	0.466
D^+	3.794	11.870	1.1925	1.429
D_s^0	0.367	1.187	0.110	0.150
Λ_c^+	0.464	1.433	0.147	0.177

charge verse

Total Effective Tagging Power = 30.116%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	1.265	4.085	0.384	0.508
D^+	4.074	12.817	1.262	1.554
D_s^0	0.382	1.257	0.114	0.161
Λ_c^+	0.507	1.560	0.157	0.193

charge verse & same

Conclusion

Main results:

For $Z \to b\bar{b}$ & $Z \to c\bar{c}$ samples at CEPC Z pole:

★ *Distribution*

- *Percent & Multiplicity of B/C hadrons*

★ *Misjudgment rate ω*

- *Distribution of final charged leading particles*
- *Distribution of final charged leading particles of each B/C hadrons*
- *All Hadrons v.s. Hadrons that decayed to leading particles*

★ *Effective tagging power*

- *High dependence between different hadron channels*
- *Potential of typical B/C hadrons(See Next…)*

★ *Charge verse + Charge same*

- *For $Z \to b\bar{b}$ at Truth level:*
  - *Using only charge verse: effective tagging power = 0.127*
  - *Using also charge same: effective tagging power = **0.137***
- *For $Z \to c\bar{c}$ at Truth level:*
  - *Using only charge verse: effective tagging power = 0.282*
  - *Using also charge same: effective tagging power = **0.301***

Next…

☞ *Jet Charge in typical channels*

- *B_s hadrons: prompt Kaon*
- *B_c hadrons: prompt D meson*
- *Λ_b hadrons: prompt proton*
- *…*

☞ *More information from final particles*

- *from primary vertex / secondary vertex*
- *each flavor select one leading particle*
- *leading particles + sub-leading particles*
- *charged particles + neutral particles(e.g. K_S, K_L, …)*

☞ *Model cross checking*

- *Using different generators (e.g. Evtgen, …)*

☞ *ML(BDT) to train input informations*

☞ *Event level → Jet level*

☞ *Truth level → Full simulated level*

- *CEPC detector performance*

Thanks!

Back Up

$Z \to b\bar{b}$ Effective Tagging Power with Uncertainty

Total Effective Tagging Power = (13.716 ± 0.014)%

% bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	8.403 ±0.026	15.213 ±0.037	3.775 ±0.037	8.961 ±0.768	22.144 ±0.110
B^-	15.137 ±0.047	22.434 ±0.062	9.500 ±0.063	16.784 ±1.071	30.450 ±0.134
B_s^0bar	3.730 ±0.037	9.673 ±0.063	0.382 ±0.024	3.406 ±0.954	14.756 ±0.187
B_c^-	8.639 ±0.732	15.817 ±1.063	1.061 ±0.495	-	25.021 ±3.309
Λ_b	22.224 ±0.110	30.313 ±0.134	14.518 ±0.186	26.729 ±3.322	40.840 ±0.3915

charge verse & same

$Z \to c\bar{c}$ Effective Tagging Power with Uncertainty

Total Effective Tagging Power = (30.116 ± 0.022)%

% cbar jet → c jet ↓	D^0bar	D^-	D_s^0bar	Λ_c^-
D^0	27.184 ±0.098	30.702 ±0.062	22.353 ±0.144	35.202 ±0.200
D^+	30.644 ±0.062	33.779 ±0.039	25.816 ±0.093	37.813 ±0.124
D_s^0	22.287 ±0.144	25.670 ±0.093	18.006 ±0.204	30.236 ±0.298
Λ_c^+	35.135 ±0.200	37.930 ±0.124	29.543 ±0.295	42.924 ±0.395

charge verse & same

$Z \to b\bar{b}$

Correlation of b jet and $\bar{b}$ jet

σ bbar jet → b jet ↓	B^0	B^+	B_s^0	B_c^+	$\Lambda_b$bar
B^0bar	12.475	11.195	4.459	0.612	0.069
B^-	11.216	11.930	3.359	0.670	1.456
B_s^0bar	1.424	2.830	0.749	-0.185	4.988
B_c^-	-0.658	-0.598	-0.181	0.200	0.537
Λ_b	0.848	0.829	3.774	0.537	5.644

$$\sigma = \frac{Residual}{Uncertainty}$$