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CEPC

Heavy Flavor Jet Charge @ Z factory

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Flavor Talking

05, 05, 2023

Outline

- **Jet Charge Introduction & Samples**

- **Methods & Dependences**
  - ★ **Leading Particle Jet Charge (LPJC)**
  - ★ **Weighted Jet Charge (WJC)**

- **Combination**
  - ★ **Improved Weighted Jet Charge (IWJC)**
  - ★ **Heavy Flavor Jet Charge (HFJC)**

- **Detector Performance**
  - ★ **Energy Threshold**
  - ★ **PID**

- **Comparison & Summary & Outlook**

Introduction

Jet charge

Applications:

- *Electroweak measurements of* A_{FB} *,* $\sin^2\theta_W$
- *CP measurements in neutral B/D system*
- *Differential measurements*

$$\delta a_{\mathrm{CP}} = \frac{1}{\sqrt{N^{\mathrm{tag}}}(1-2w)}$$

$$\varepsilon_{\mathrm{eff}} = \frac{N^{\mathrm{tag}}}{N} \cdot (1-2w)^2 = \varepsilon \cdot r^2$$

How to measure:

- *Jet charge performance is quantified by effective tagging power*

Misjudgment rate ω:

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

$$\omega = \frac{\mathrm{N_W}}{\mathrm{N_{tag}}}$$

Efficiency:

➡ *To describe the selection efficiency of all samples:*

$$\epsilon_{\mathrm{tag}} = \frac{\mathrm{N_{tag}}}{\mathrm{N_{all}}}$$

Effective tagging power:

➡ *Considering both misjudgment rate ω and efficiency to describe the total performance of jet charge*

$$\epsilon_{\mathrm{eff}} = \epsilon_{\mathrm{tag}}(1-2\omega)^2$$

Experiments & Methods

Experiments	Measureme	Methods	Performance
LEP Experiments	A_{FB}, $\sin^2\theta_W$	prompt lepton weighted jet charge c hadron, vtx, Kaon	b purity = 90%
ATLAS CMS	q&g jet charge	weighted jet charge	ε_{eff} = 1.49% (Bs)
LHCb	b jet charge	opposite side e, μ, K, c hadron, Q_{vtx} same side π, p, K BDT & QML	ε_{eff} = 8% (pT>60GeV)
CEPC	b/c jet charge	leading particle weighted jet charge (for Bs: kaon)	ε_{eff} = 20% (b jet) ε_{eff} = 39% (c jet) ε_{eff} = 20% (Bs)
BABAR	B tagging	hadronic B decay products with NN	ε_{eff} = 31.2%
Belle II	B tagging	hadronic B decay products & DNN	ε_{eff} = 30.0%

Details and references are listed in back up

Z pole operation & Samples

Process	Br	Tera-Z yield
$Z \to d\bar{d}$	15.84%	1.584×10^{11}
$Z \to u\bar{u}$	11.17%	1.117×10^{11}
$Z \to s\bar{s}$	15.84%	1.584×10^{11}
$Z \to c\bar{c}$	12.03%	1.203×10^{11}
$Z \to b\bar{b}$	15.12%	1.512×10^{11}

CEPC Advantages:

- **High productivity of b/c hadrons**
- **Clean collision environment**
- **Good VTX/tracking and PID system**

Our work:

Jet charge performance at Z pole

- *Leading Particle Jet Charge LPJC*
- *Weighted Jet Charge WJC*
- *combine → Heavy Flavor Jet Charge HFJC*

and dependencies - test of principle

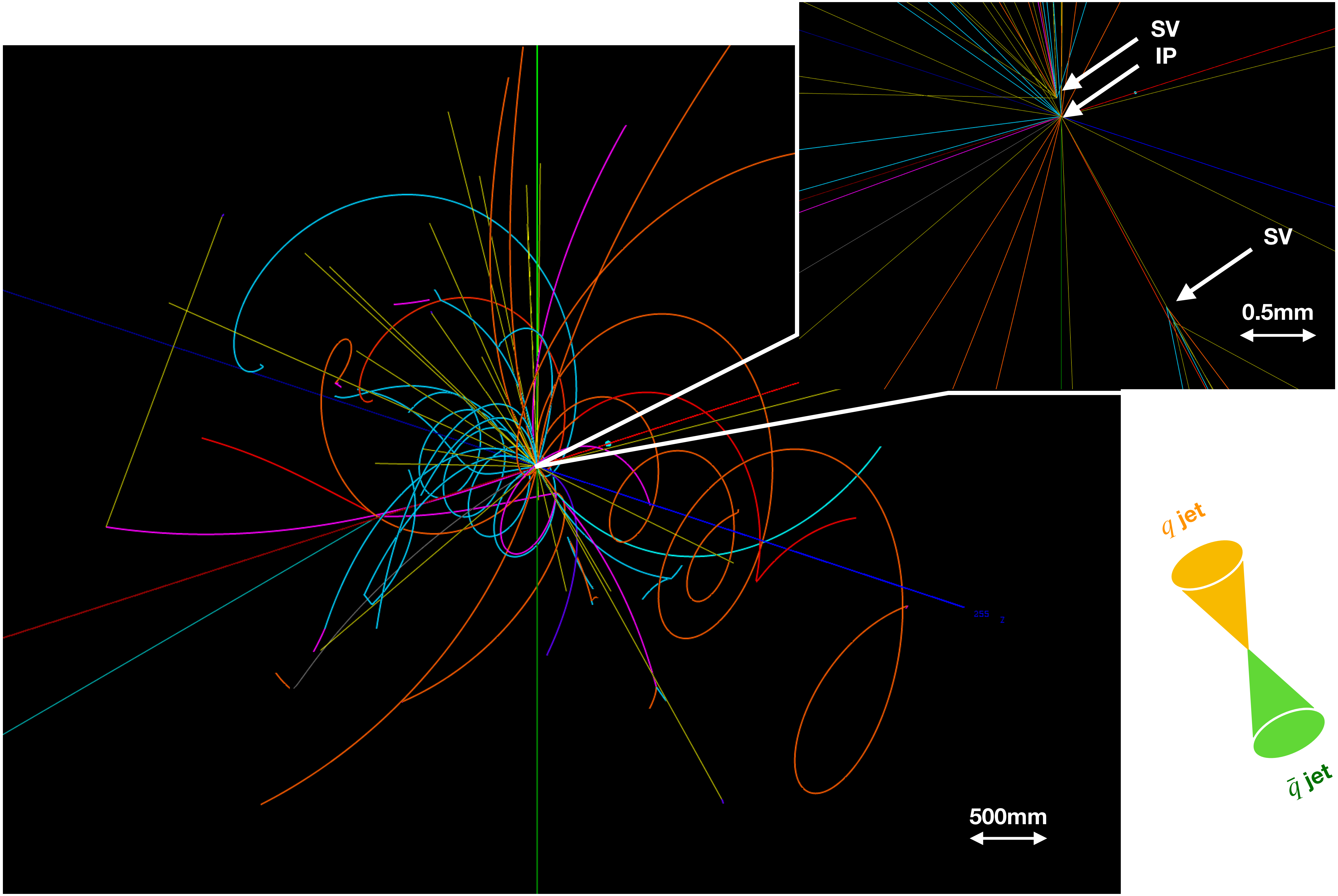
Software:

Three generators: Whizard195, Herwig, Sherpa

Samples:

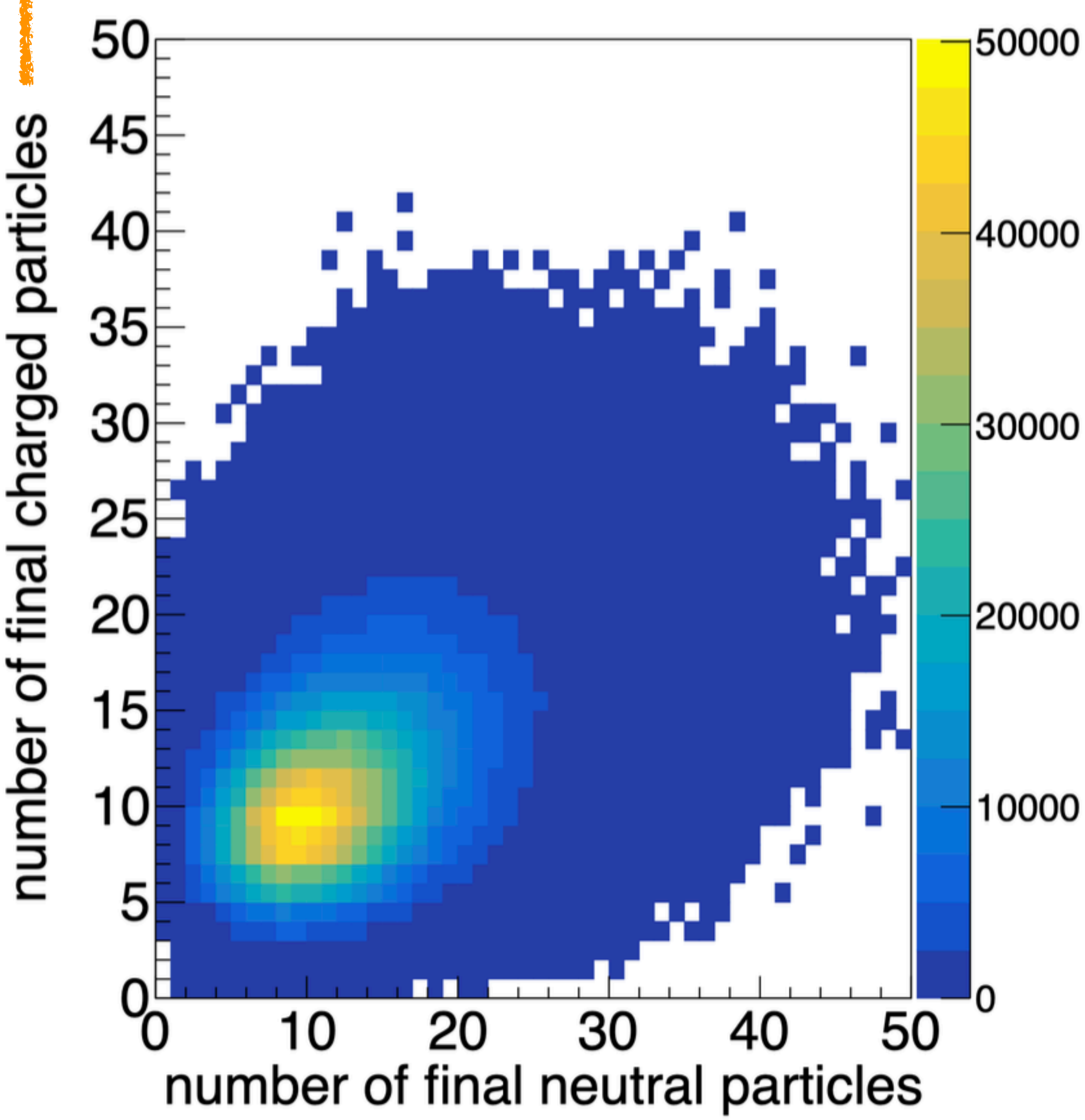
Samples ~ 10^{-4} Z→bb/cc events
Statistical uncertainty ~ 10^{-4} and can be omitted

Z→bb event display

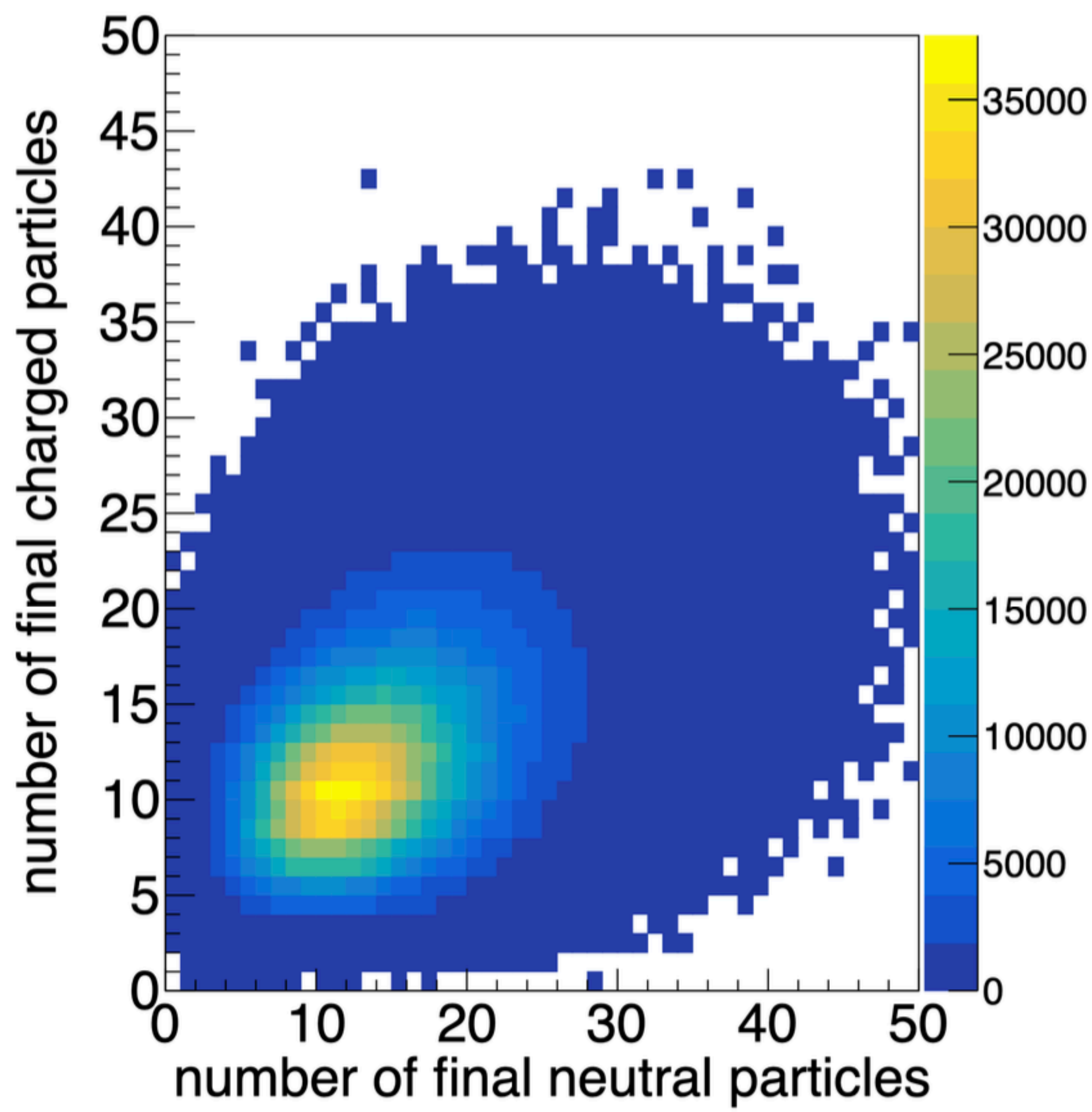


b/c jet multiplicity & final charged particles

	Mass(MeV)	τ(s)	cτ(m)
e	0.51	6.6E+28	
μ	105.66	2.197E-06	658.6
K	493.68	1.238E-08	3.711
π	139.57	2.603E-08	7.804
p	938.27	3.6E+29	



c jet



b jet

LPJC

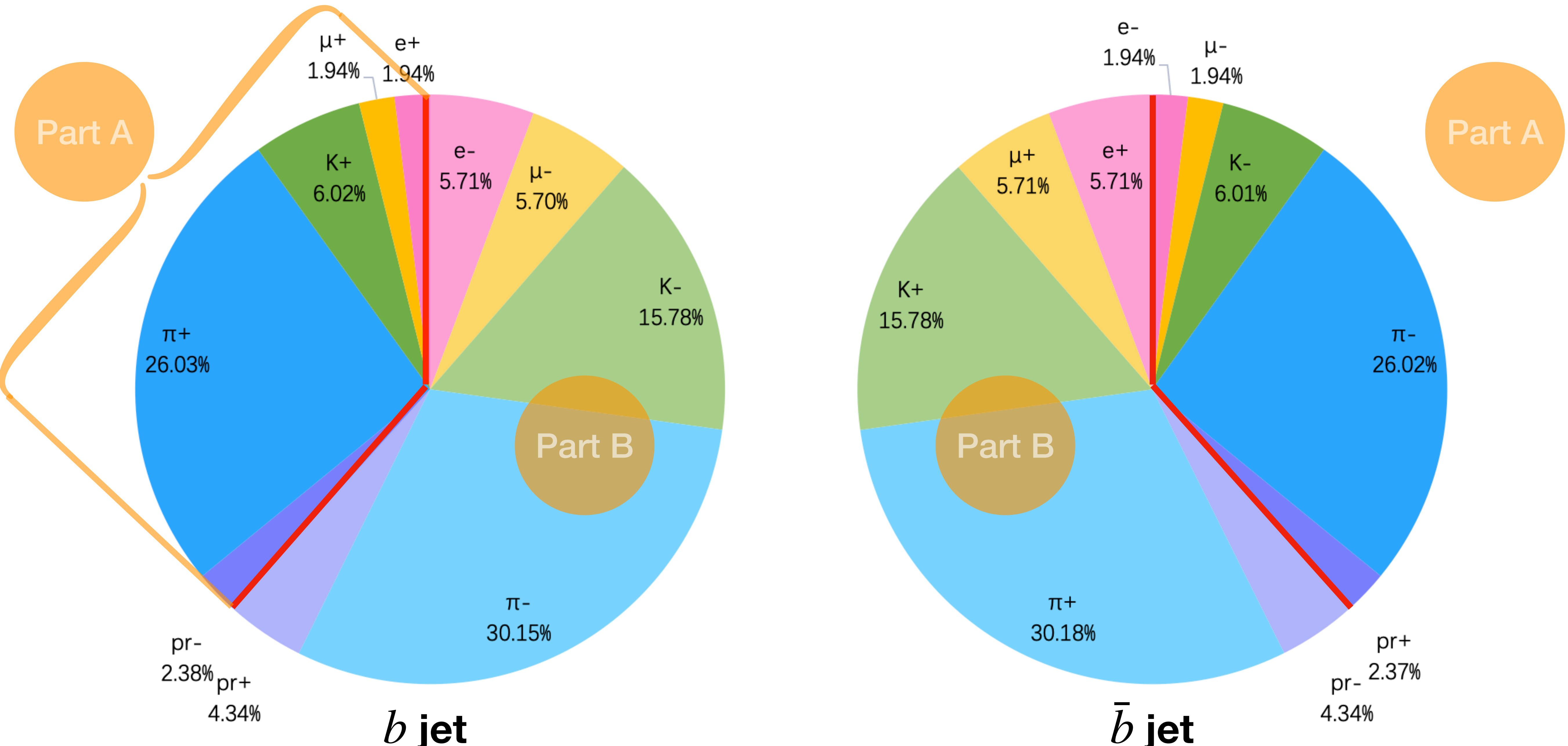
Leading Particle Jet Charge LPJC

Steps of LPJC:

- *Divide final state charged particles into two back-to-back jets.*
- *Select the highest energy state particle in each jet, identified as leading particle LP.*
- *Classify LP into sub-groups based on their types.*
- *Use the charge asymmetry and PID information to determine jet charge.*

corresponding misjudgment rate ω.

Use charge asymmetry to calculate misjudgment rate ω

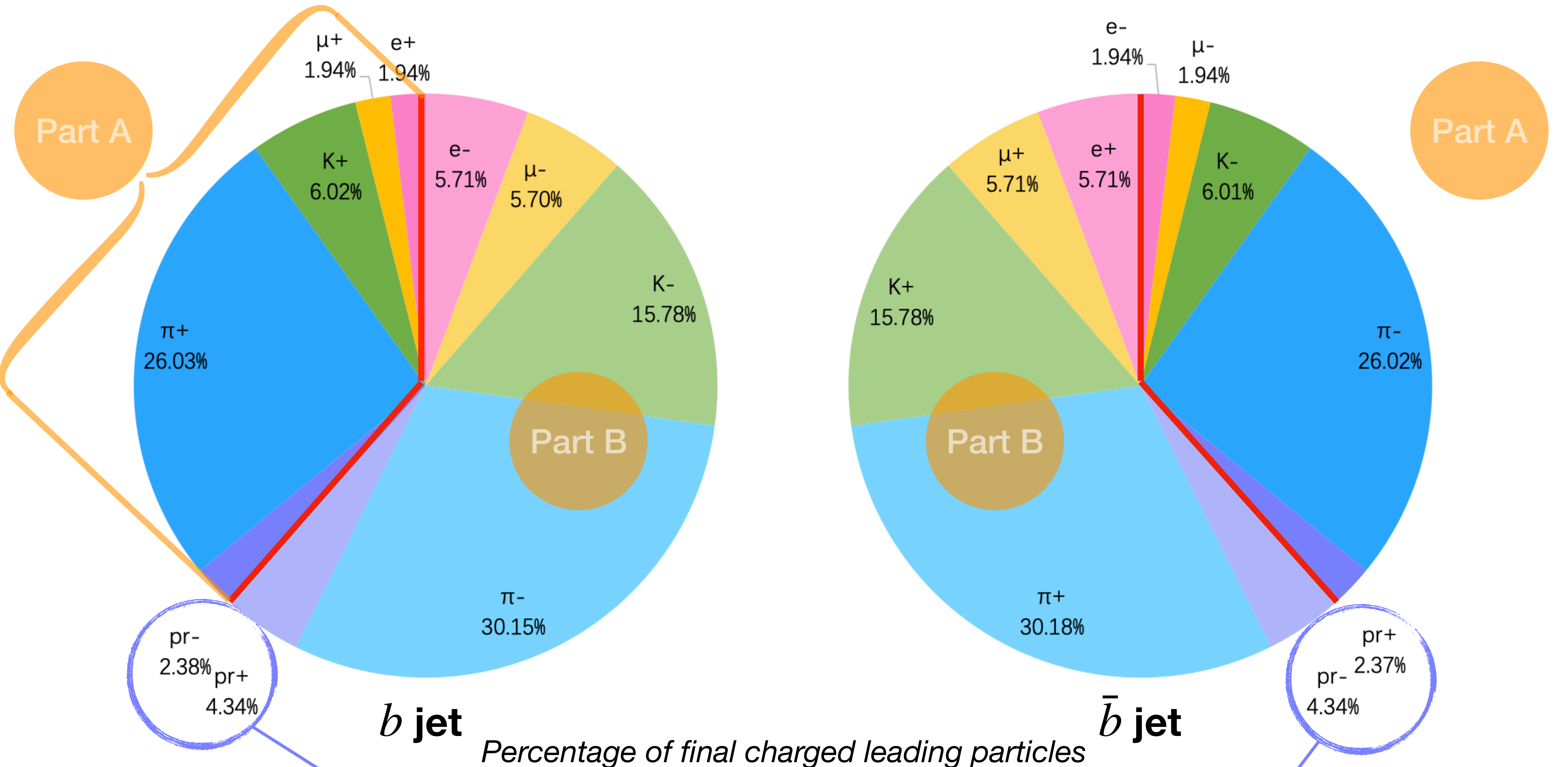


Percentage of final charged leading particles

$$P(b\,|\,\text{final}_i) = \frac{P(\text{final}_i\,|\,b)}{P(\text{final}_i\,|\,b) + P(\text{final}_i\,|\,\bar{b})}$$

$$\omega = 1 - P(b\,|\,\text{final}_i) = \frac{P(\text{final}_i\,|\,\bar{b})}{P(\text{final}_i\,|\,b) + P(\text{final}_i\,|\,\bar{b})} = \frac{\text{Number of Part A}}{\text{Number of Part }(A+B)}$$

Use charge asymmetry to calculate misjudgment rate ω



Percentage of final charged leading particles

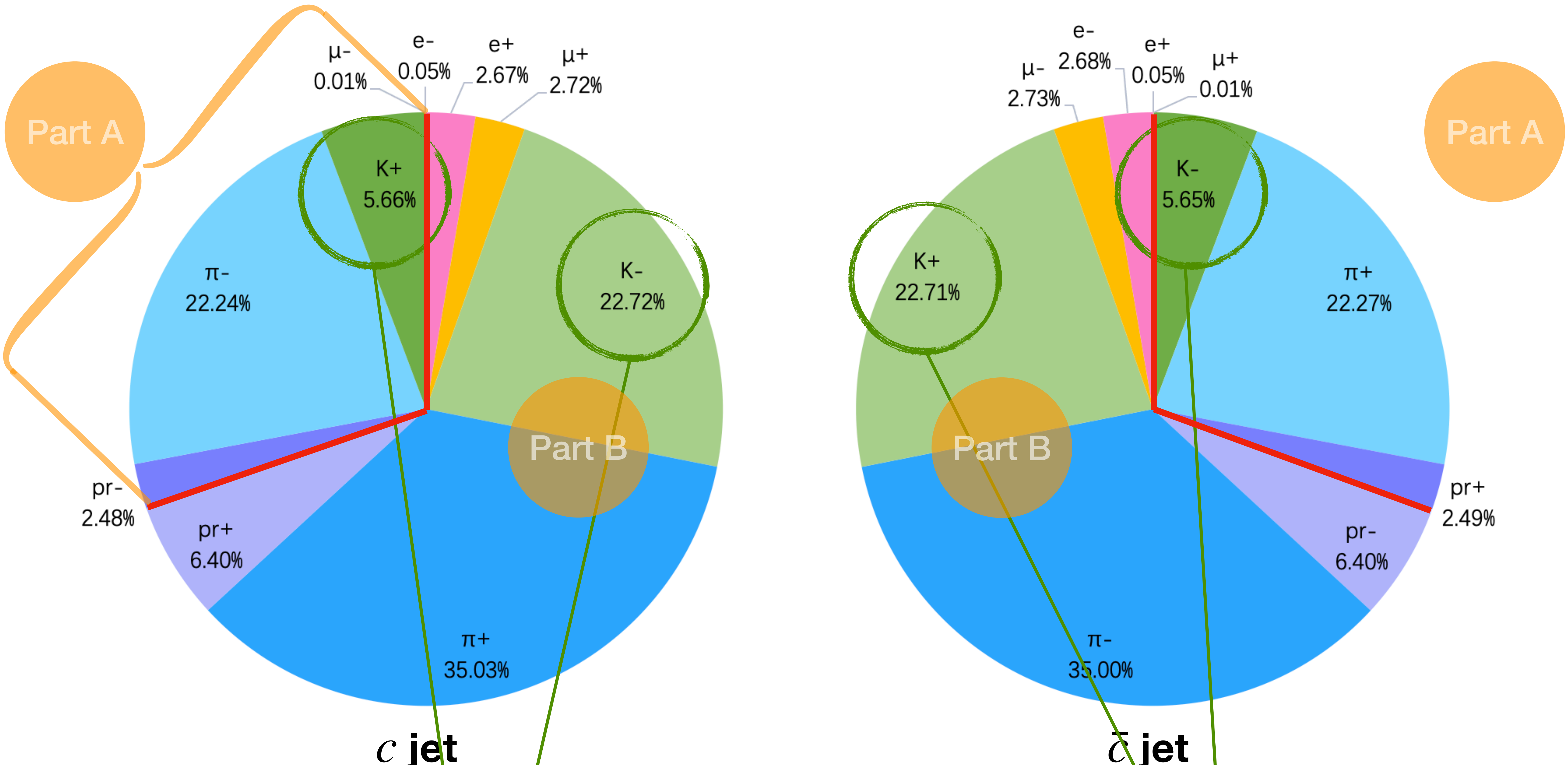
ω(using only charge) = 0.403

ω(using charge & PID) = 0.383

ω(using only charge) = 0.402

ω(using charge & PID) = 0.383

Use charge asymmetry to calculate misjudgment rate ω



Percentage of final charged leading particles

ω(using only charge) = 0.473
ω(using charge & PID) = 0.304

ω(using only charge) = 0.475
ω(using charge & PID) = 0.305

ε_{tag}, ω, ε_{eff} of LPJC

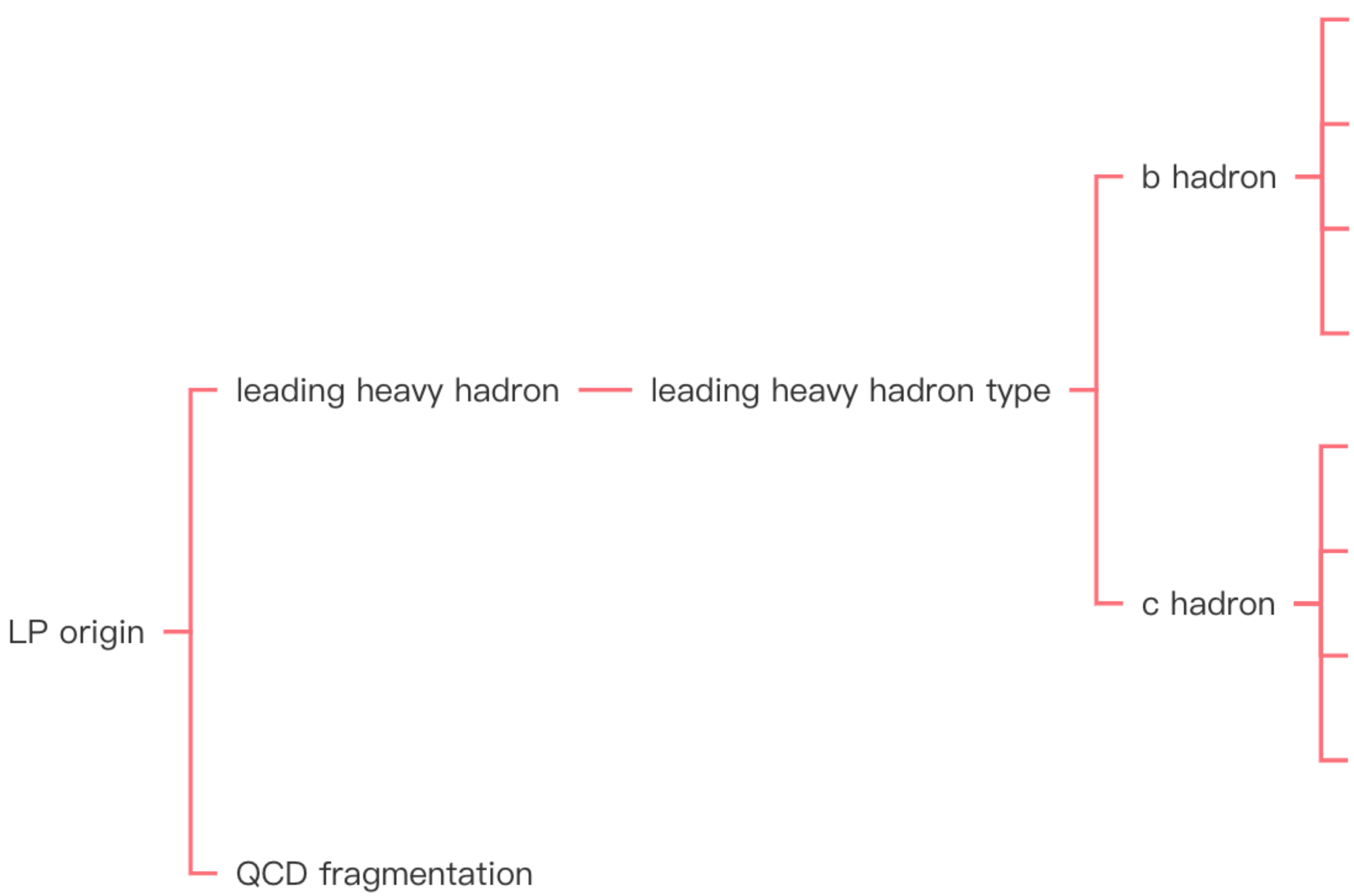
	b jet									c jet								
	Whizard			Herwig			Sherpa			Whizard			Herwig			Sherpa		
	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
e	7.6%	25.5%	1.8%	7.3%	25.1%	1.8%	7.8%	28.0%	1.5%	2.7%	1.9%	2.5%	3.6%	1.5%	3.4%	3.3%	2.4%	3.0%
μ	7.6%	25.5%	1.8%	7.0%	22.7%	2.1%	7.8%	28.1%	1.5%	2.7%	0.5%	2.7%	3.0%	0.2%	3.0%	3.3%	0.4%	3.2%
K	21.8%	27.5%	4.4%	21.3%	30.3%	3.3%	22.9%	30.2%	3.6%	28.4%	19.7%	10.4%	28.5%	17.8%	11.8%	30.0%	19.7%	11.0%
π	56.2%	46.3%	0.3%	53.2%	45.2%	0.5%	56.8%	44.9%	0.6%	57.3%	38.8%	2.9%	58.0%	37.9%	3.4%	58.1%	39.0%	2.8%
p	6.7%	36.5%	0.5%	11.2%	37.5%	0.7%	4.7%	32.1%	0.6%	8.9%	28.0%	1.7%	6.9%	31.8%	0.9%	5.4%	23.8%	1.5%
sum	100.0%	35.1%	8.9%	100.0%	35.5%	8.4%	100.0%	36.0%	7.8%	100.0%	27.5%	20.2%	100.0%	26.3%	22.5%	100.0%	26.8%	21.5%

Jet charge performance dependences

1. Dependence on leading particle type

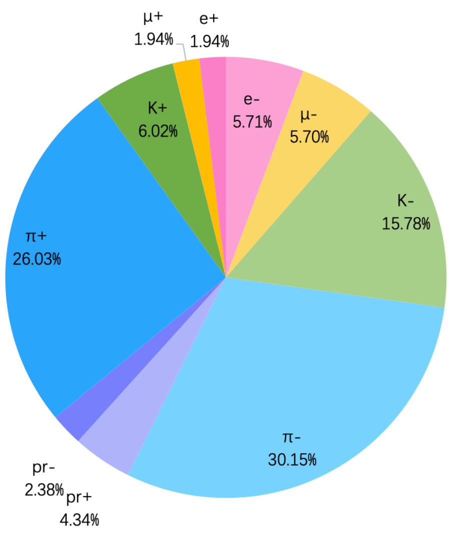
2. Dependence on b/c hadron type

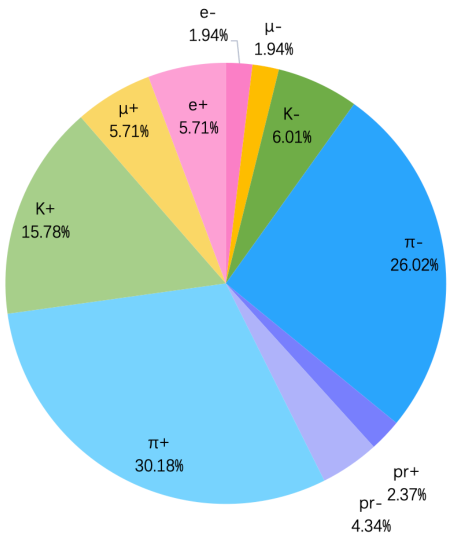
3. Dependence on decay source of leading particle: from b/c hadron or QCD.



	Mass(MeV)	τ(s)	cτ(μm)
$\bar{B}^0$	5279.66	1.519E-12	455.4
B^-	5279.34	1.638E-12	491.1
$\bar{B}_s^0$	5366.92	1.520E-12	455.7
Λ_b	5619.60	1.471E-12	441.0
D^+	1869.66	1.033E-12	309.8
D^0	1864.84	4.100E-13	123.0
D_s^+	1968.35	5.040E-13	151.2
Λ_c^+	2286.46	2.015E-13	60.4

What will



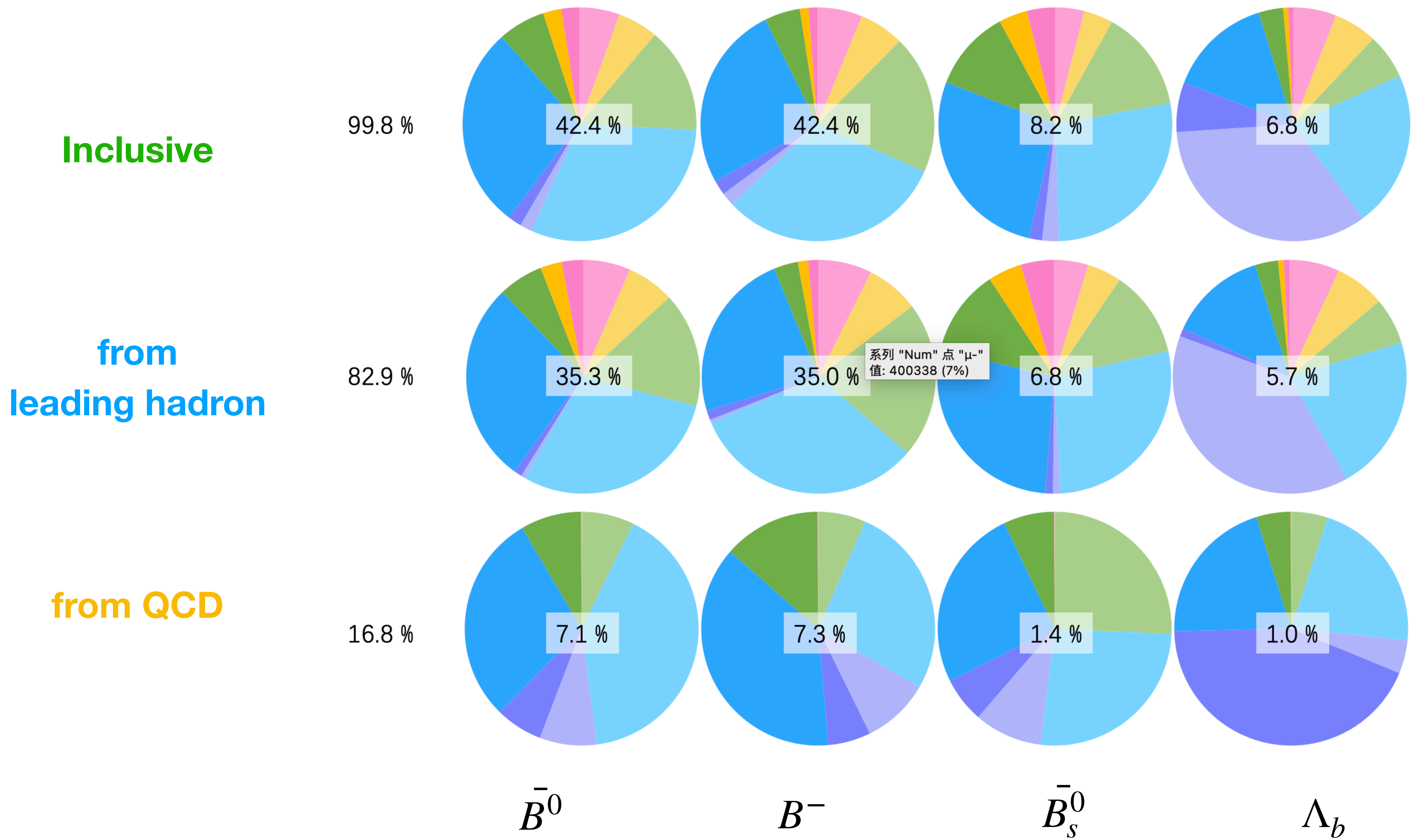


change

if decayed from typical hadron?

b jet

Percentage of leading particles



by WHIZARD195

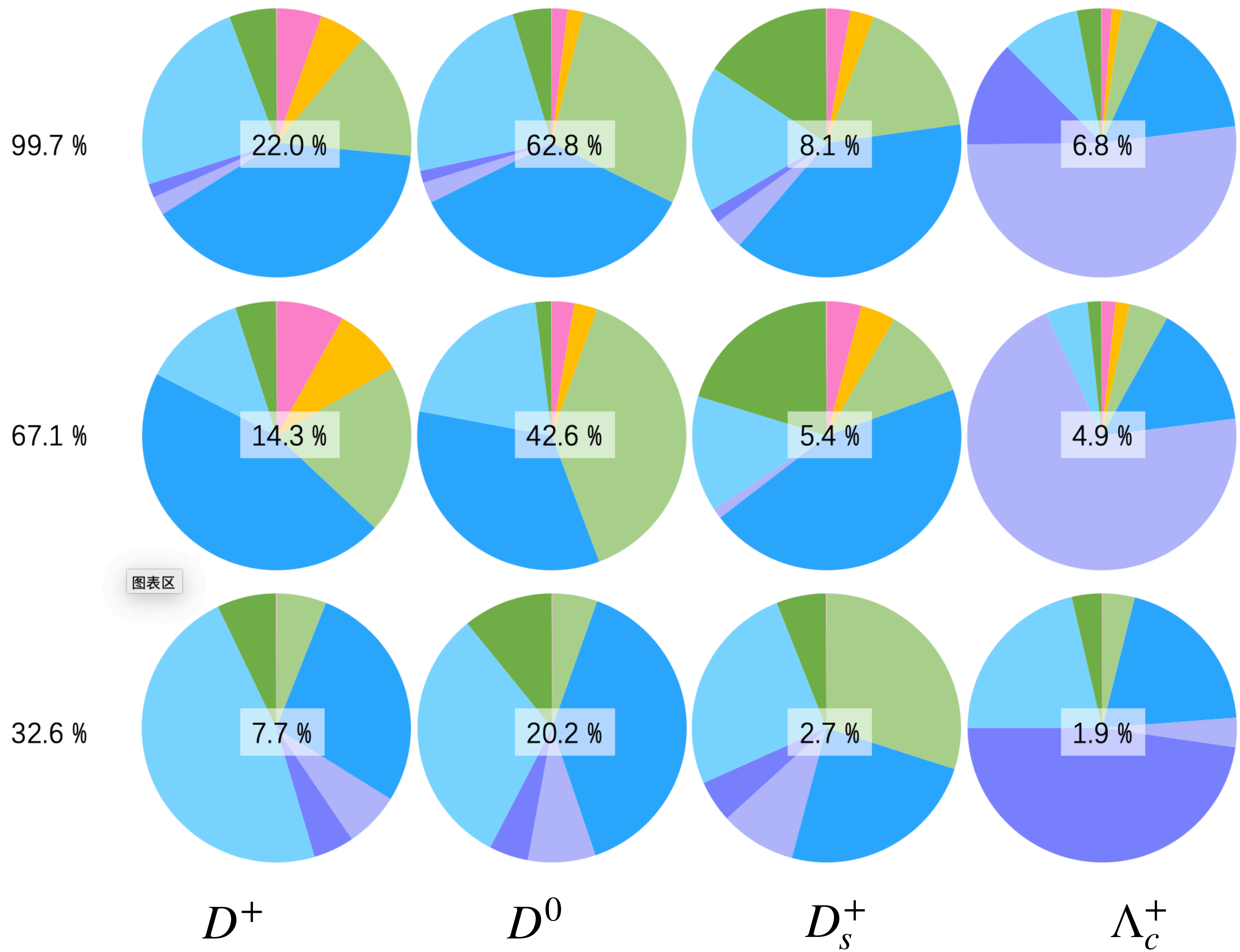
c jet

Percentage of leading particles

Inclusive

from
leading hadron

from QCD



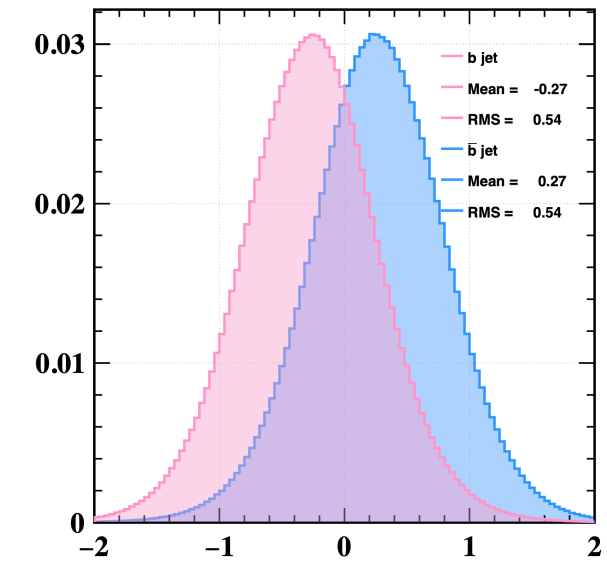
by WHIZARD195

ε_{tag}, ω, ε_{eff} of LPJC(distinguish leading heavy hadron)

		Whizard			Herwig	Sherpa
		ε_{tag}	ω_i	ε_{eff}	ε_{eff}	ε_{eff}
b jet	$\bar{B}^0$	42.4%	38.3%	5.6%	3.1%	13.7%
	B^-	42.4%	30.2%	15.8%	16.6%	14.6%
	$\bar{B}_s^0$	8.2%	47.0%	0.4%	0.2%	10.8%
	Λ_b	6.8%	23.1%	28.9%	26.1%	16.4%
	Total	99.8%	34.5%	11.0%	10.1%	14.0%
c jet	D^+	22.0%	23.9%	19.3%	26.2%	19.7%
	D^0	62.8%	19.0%	23.5%	24.4%	25.9%
	D_s^+	8.1%	22.2%	14.1%	17.1%	17.5%
	Λ_c^+	6.8%	20.0%	28.1%	26.1%	35.1%
	Total	99.7%	20.3%	22.1%	24.3%	24.4%

WJC

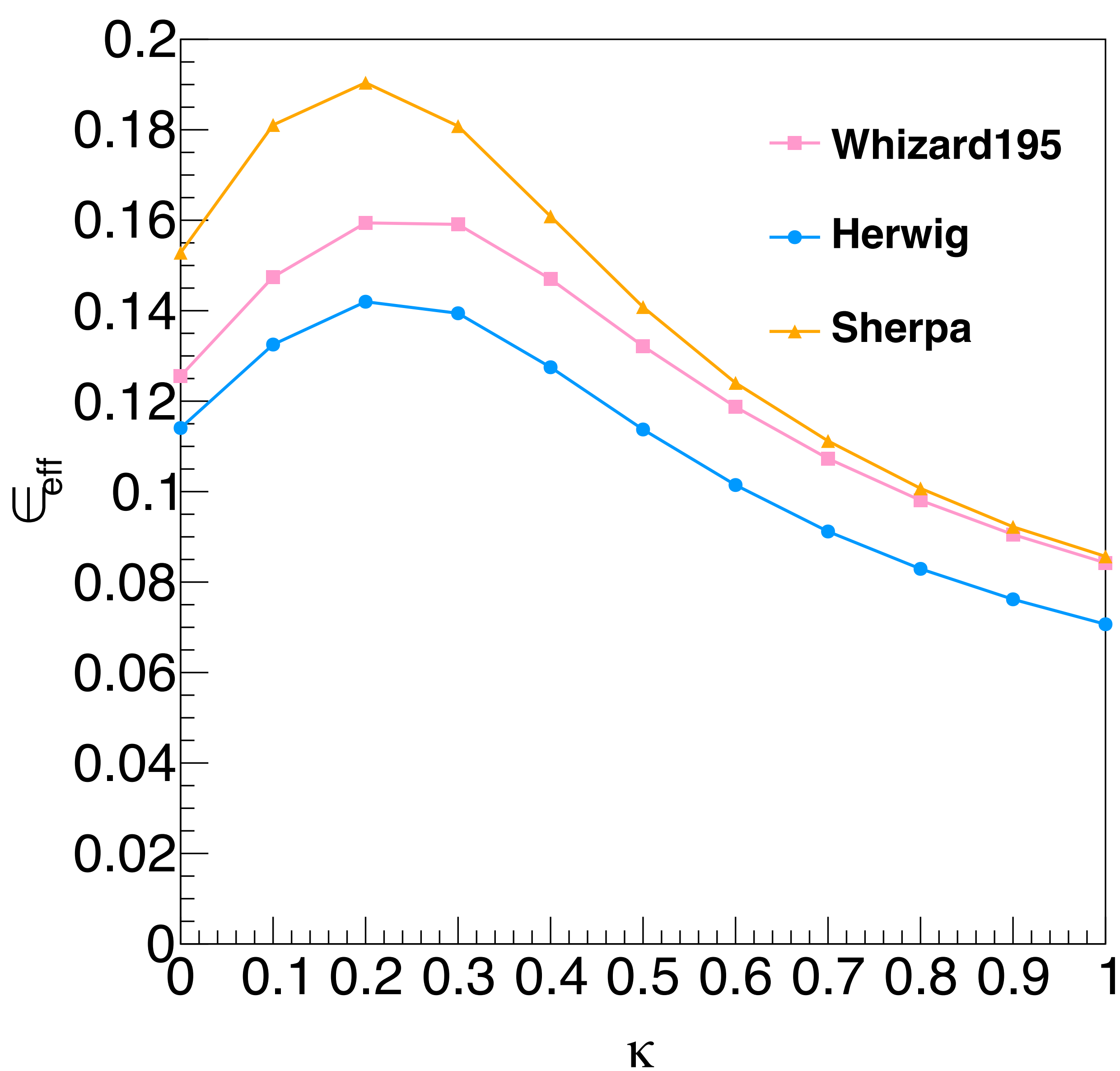
Weighted Jet Charge (WJC)



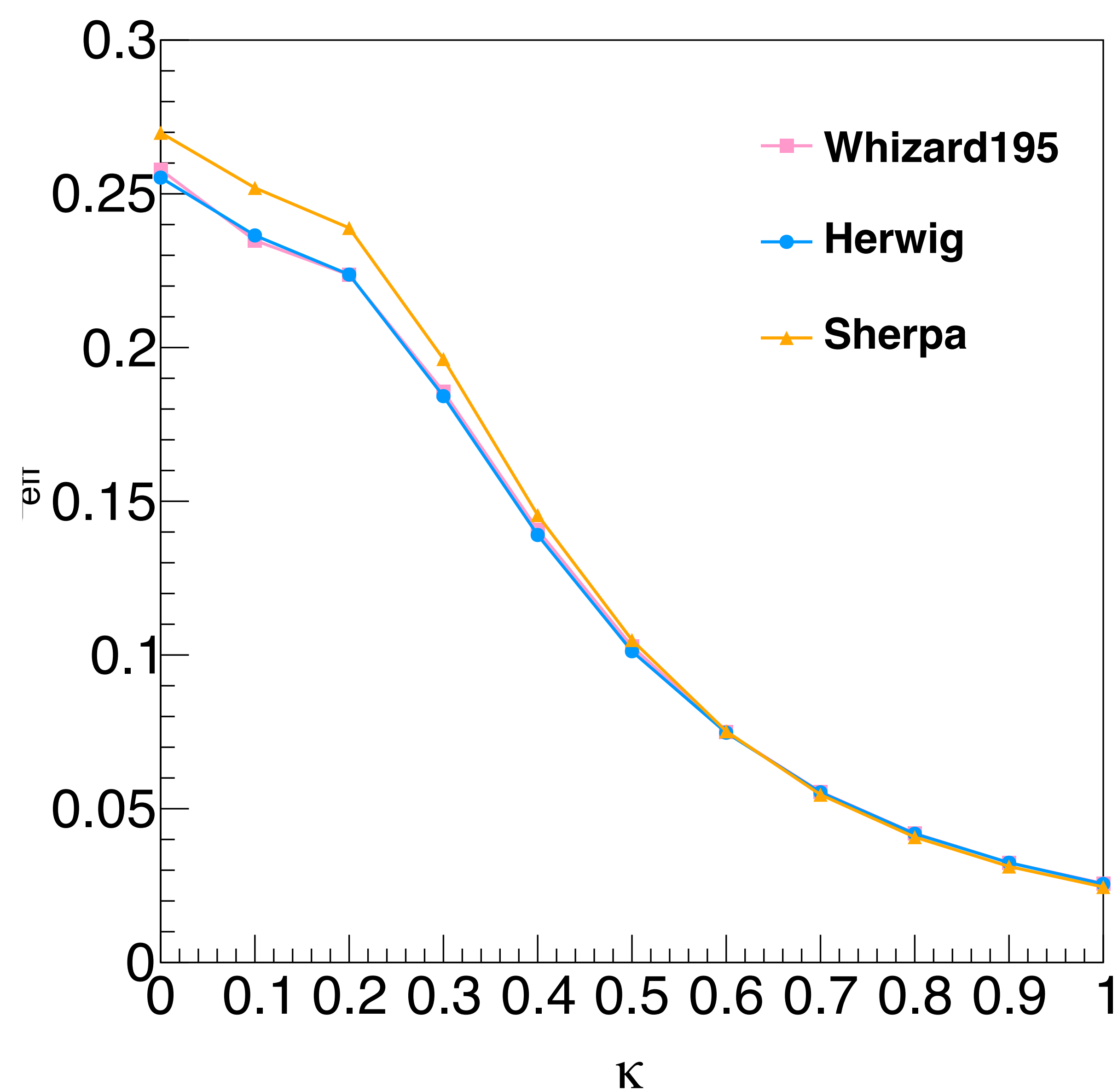
$b\bar{b}$ jet charge with κ=0.2

- **Use the charge and energy of all final charged particles in a jet with a weight parameter κ to calculate Q_{jet}^{κ}.**

$$Q_{jet}^{\kappa} = \frac{\Sigma_i (E_i)^{\kappa} \, Q_i}{\Sigma_i (E_i)^{\kappa}}$$



b **jet**

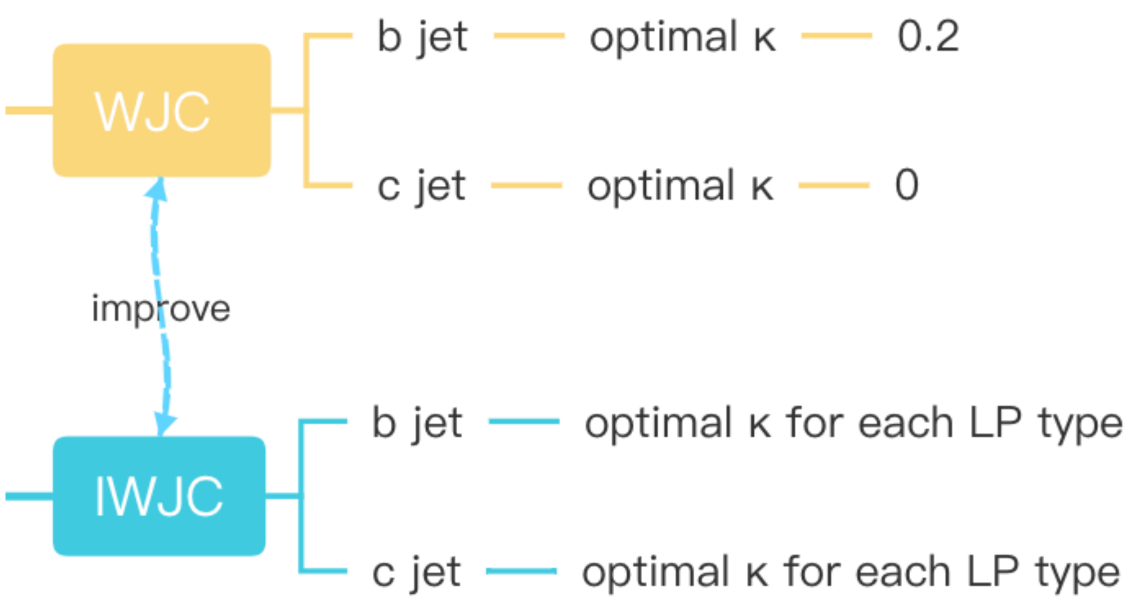


c **jet**

IWJC

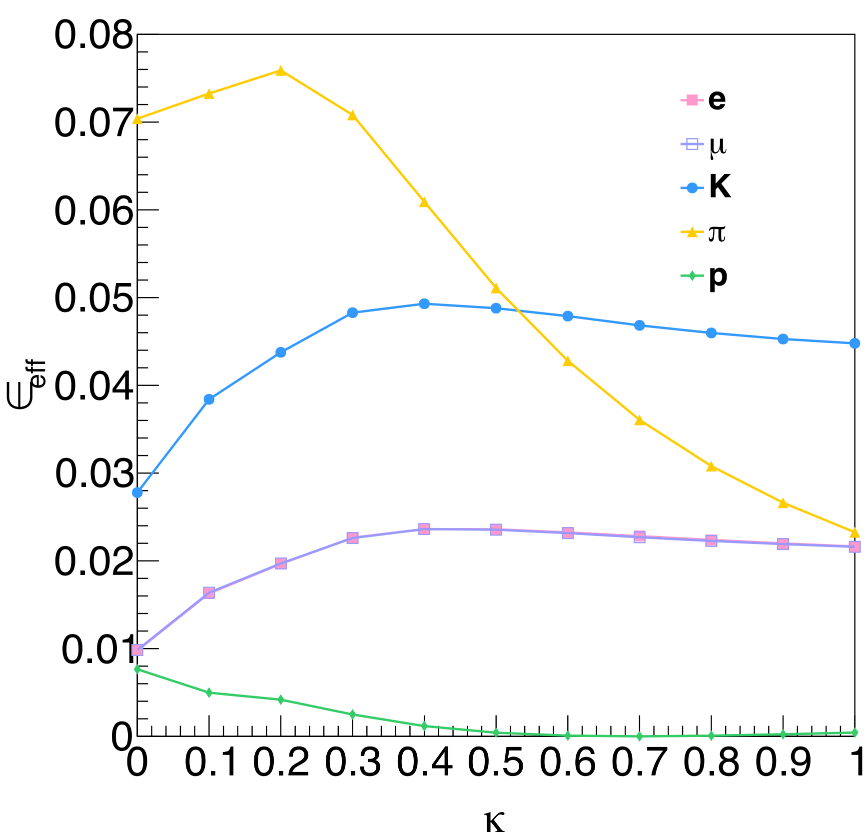
Improved Weighted Jet Charge (IWJC)

Optimal κ vs leading particle type

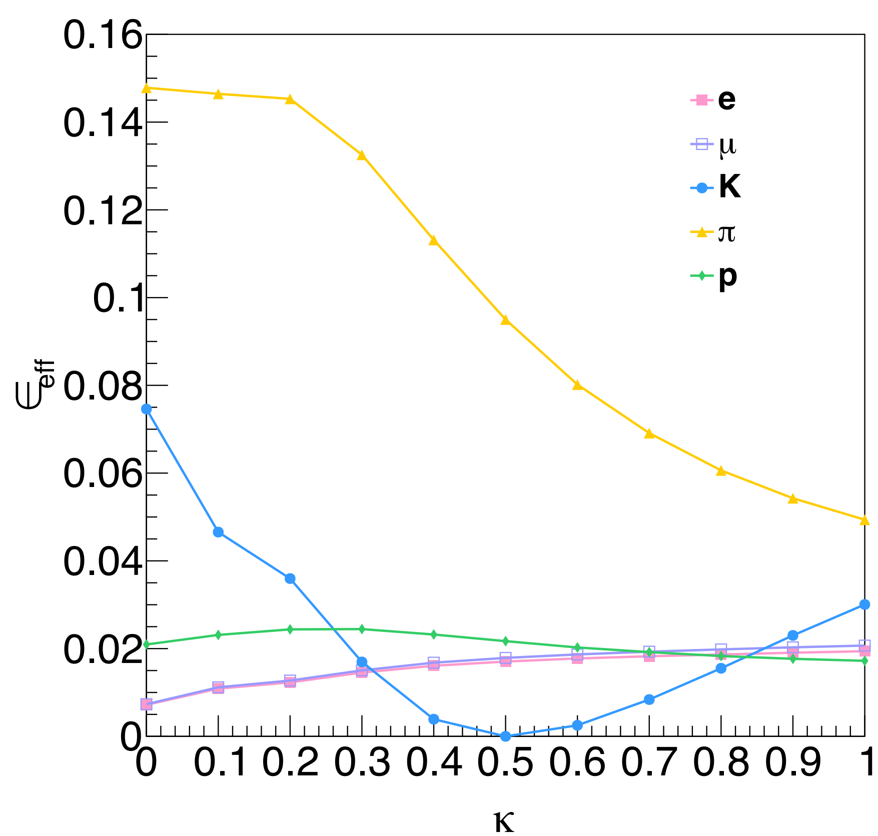


The optimized parameter κ varies with final state leading particles type and the decay sources.

The overall optimized κ depends on the balance between hadron decay and QCD factorization.



***b* jet**



***c* jet**

		inclusive	heavy hadron	QCD
c jet	e	$+\infty$	$+\infty$	-
	μ	$+\infty$	$+\infty$	-
	K	$+\infty$	$+\infty$	0.3
	π	0	0	0
	p	0.3	$+\infty$	0
b jet	e	0.4	0	-
	μ	0.4	0	-
	K	0.4	0	$+\infty$
	π	0.2	0	0
	p	0	$+\infty$	0.1

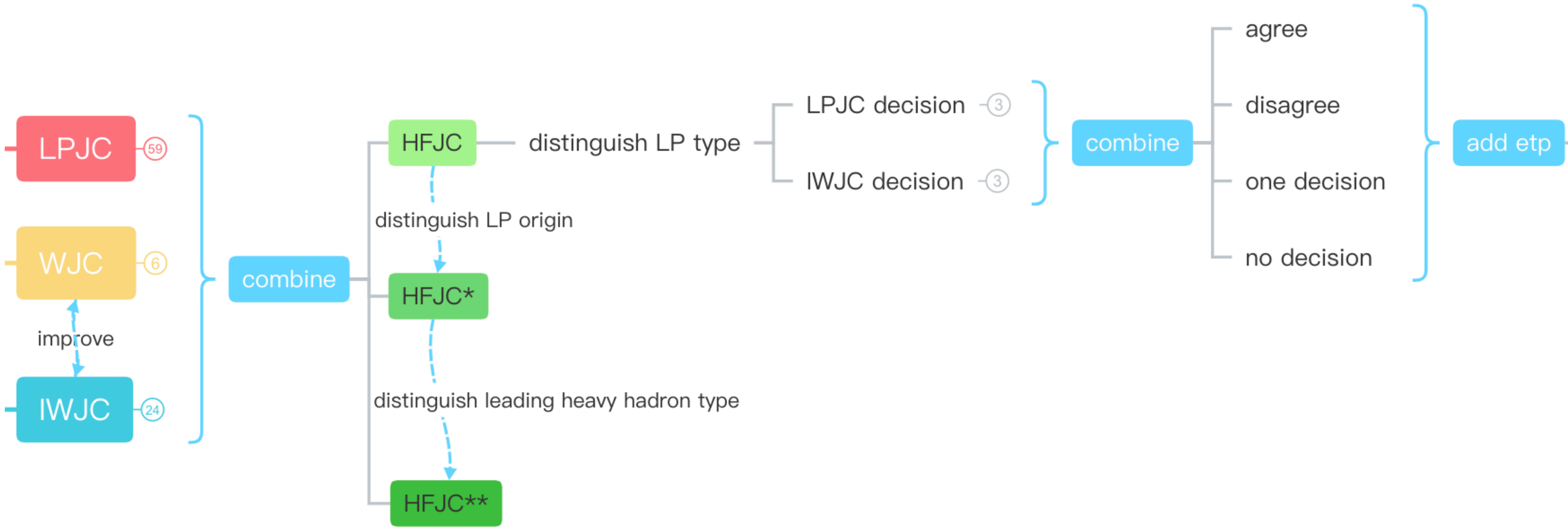
Consider the optimal κ=100 as +∞ , which corresponds to LCJC method.

ε_{tag}, ω, ε_{eff} of IWJC

	b jet									c jet								
	Whizard			Herwig			Sherpa			Whizard			Herwig			Sherpa		
	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
e	7.6%	22.3%	2.3%	7.3%	22.5%	2.2%	7.8%	22.9%	2.3%	2.7%	7.9%	1.9%	3.6%	7.1%	2.7%	3.3%	7.7%	2.3%
μ	7.6%	22.3%	2.3%	7.0%	21.4%	2.3%	7.8%	23.5%	2.2%	2.7%	6.8%	2.0%	3.0%	6.5%	2.3%	3.3%	6.1%	2.5%
K	21.8%	26.5%	4.8%	21.3%	29.7%	3.5%	22.9%	27.2%	4.8%	28.4%	22.4%	8.6%	28.5%	22.4%	8.7%	30.0%	22.0%	9.4%
π	56.2%	31.2%	7.9%	53.2%	32.0%	6.9%	56.8%	29.1%	10.0%	57.3%	23.7%	15.9%	58.0%	23.7%	16.1%	58.1%	23.0%	17.0%
p	6.7%	32.1%	0.9%	11.2%	32.4%	1.4%	4.7%	30.1%	0.7%	8.9%	22.5%	2.7%	6.9%	23.5%	1.9%	5.4%	20.6%	1.9%
sum	100.0%	28.6%	18.3%	100.0%	29.8%	16.3%	100.0%	27.7%	20.0%	100.0%	22.1%	31.1%	100.0%	21.9%	31.7%	100.0%	21.2%	33.1%

HFJC
(combine above methods)

Combination→Heavy Flavor Jet Charge (HFJC)



$$\epsilon_{\mathrm{tag}_{\mathrm{comb}}} = \sum_{i=1}^{\mathrm{N}_{\mathrm{method}}} s_i \, |\xi_i| \, (1 - 2\omega_i)^2$$

for each input candidate,

s_i is the decision weight of i-th method.

ω_i is the mis-judgment rate ω of i-th method.

ξ_i is the jet charge decision of i-th method.

ε_{tag}, ω, ε_{eff} of HFJC

	b jet									c jet								
	Whizard			Herwig			Sherpa			Whizard			Herwig			Sherpa		
	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
e	7.6%	21.6%	2.5%	7.3%	21.3%	2.4%	7.8%	21.9%	2.4%	2.7%	1.9%	2.5%	3.6%	1.8%	3.4%	3.3%	2.7%	2.9%
μ	7.6%	21.2%	2.5%	7.0%	20.2%	2.5%	7.8%	22.5%	2.4%	2.7%	0.5%	2.7%	3.0%	0.4%	3.0%	3.3%	0.7%	3.2%
K	21.8%	23.8%	6.0%	21.3%	25.6%	5.1%	22.9%	23.9%	6.2%	28.4%	15.2%	13.8%	28.5%	14.3%	14.5%	30.0%	15.0%	14.7%
π	56.2%	31.1%	8.1%	53.2%	31.8%	7.1%	56.8%	28.9%	10.2%	57.3%	22.9%	16.8%	58.0%	22.8%	17.2%	58.1%	22.4%	17.7%
p	6.7%	28.1%	1.3%	11.2%	28.4%	2.1%	4.7%	24.0%	1.3%	8.9%	19.8%	3.2%	6.9%	21.5%	2.2%	5.4%	17.0%	2.3%
sum	100.0%	27.4%	20.4%	100.0%	28.2%	19.1%	100.0%	26.3%	22.5%	100.0%	18.8%	39.0%	100.0%	18.3%	40.3%	100.0%	18.1%	40.8%

Effective tagging power of each method

		LPJC	WJC	IWJC	HFJC	HFJC*	HFJC**
c jet	Whizard	20.2%	25.8%	31.1%	39.0%	45.5%	56.1%
	Herwig	22.5%	25.5%	31.7%	40.3%	46.5%	57.3%
	Sherpa	21.5%	27.0%	33.1%	40.8%	48.6%	59.4%
b jet	Whizard	8.9%	15.9%	18.3%	20.4%	36.9%	47.8%
	Herwig	8.4%	14.2%	16.3%	19.1%	36.0%	46.6%
	Sherpa	7.8%	19.0%	20.0%	22.5%	35.8%	48.9%

HFJC* distinguish LP origin (b/c hadron / QCD)

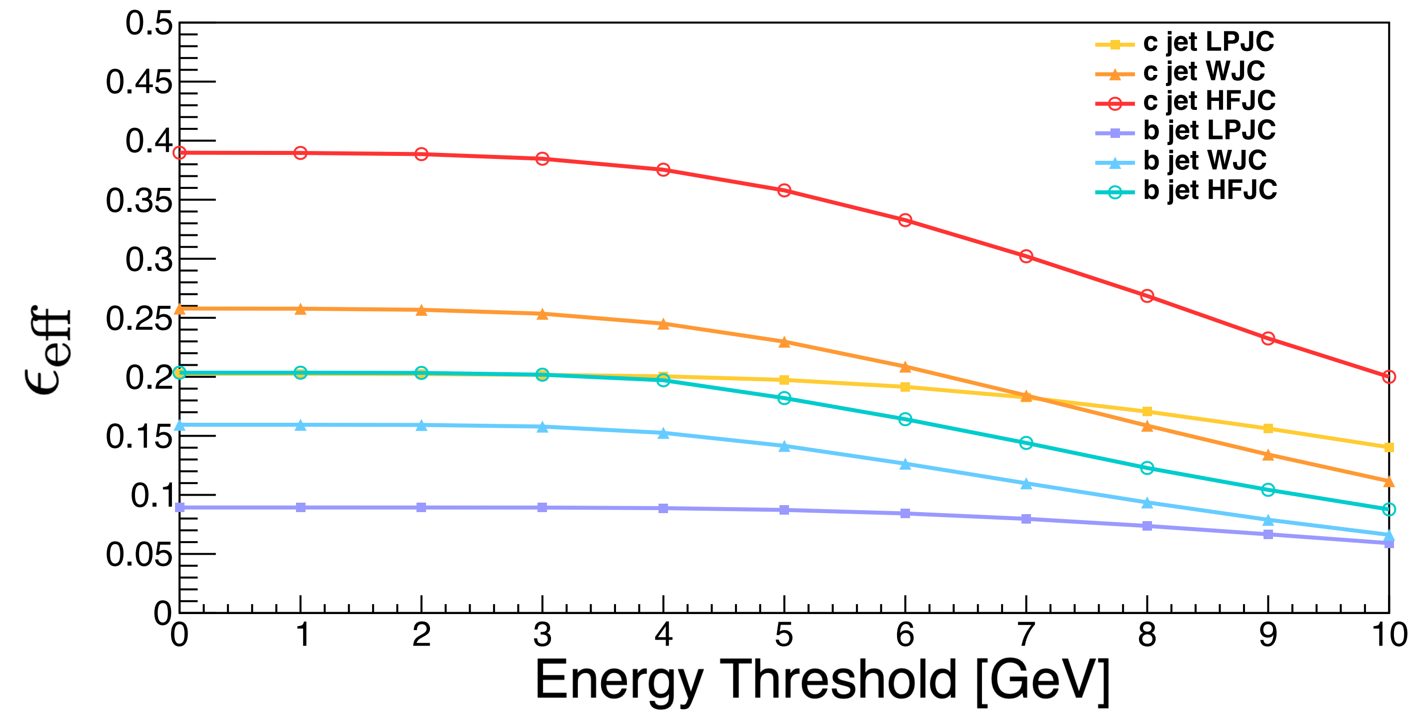
HFJC** distinguish LP origin & leading heavy hadron type

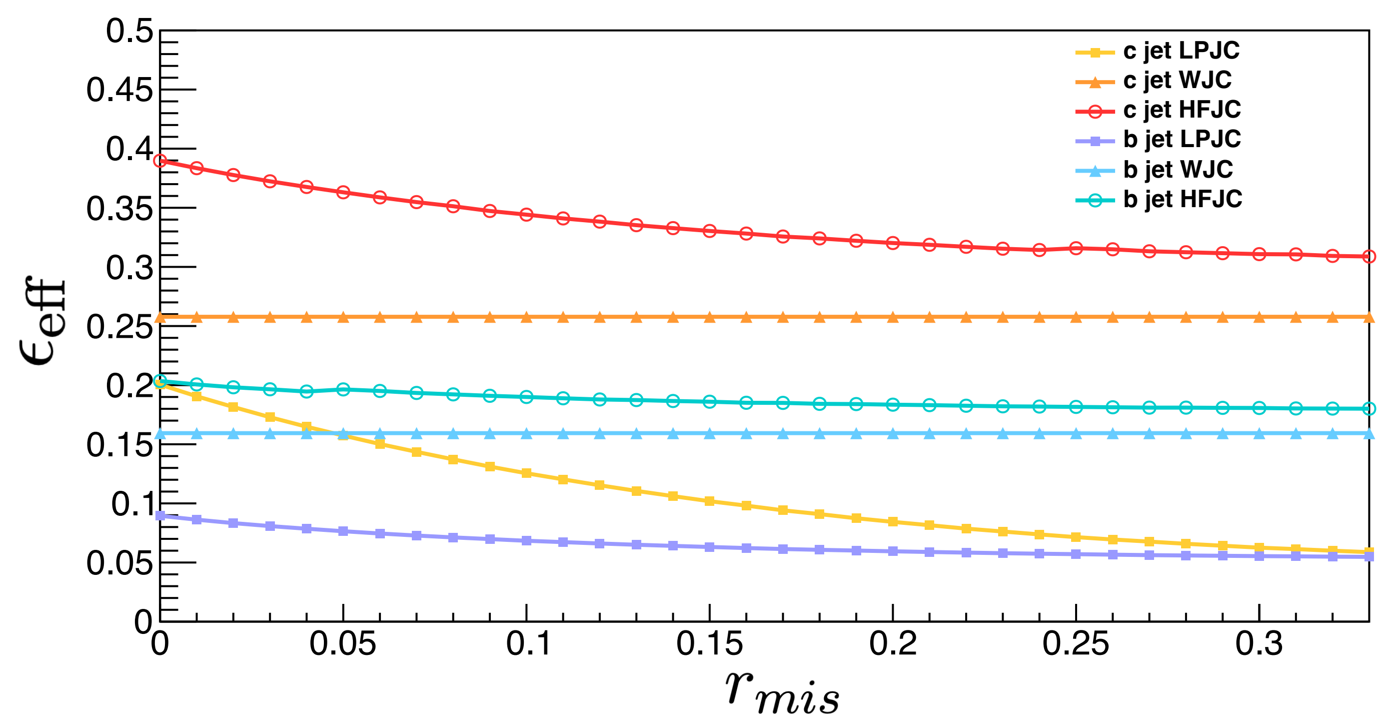
Detector Performance Impact

Related detector performance impact

- Flavor tagging (see back up)
- Energy threshold < 1GeV
- PID
  - Lepton identification $r_{mis} < 1\%$
  - Hadron identification dE/dx resolution < 3%
- Momentum resolution $\delta p/p$ ~0.1%
- Polar angle acceptance $|\cos(\theta)|$ ~0.99
- Track reconstruction …

- Although jet charge performance is sensitive to some effects such as PID performance, for a conceptual detector, the impact is relatively small.
- Therefore, jet charge performance at the reconstruction level will not differ significantly from the truth-level.



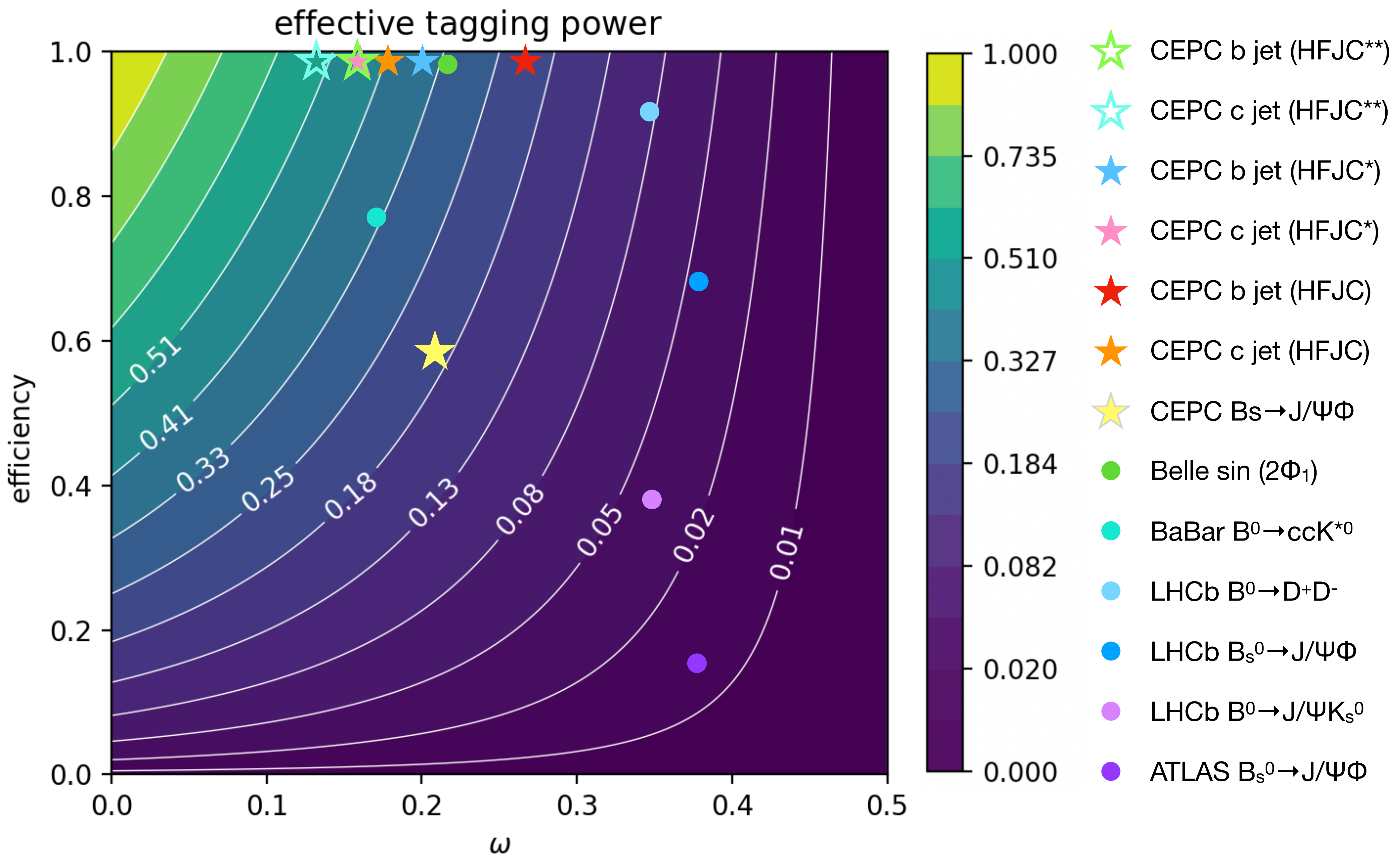


p, K, pi mis-id matrix

$$\begin{pmatrix} r_T & r_{mis} & r_{mis} \\ r_{mis} & r_T & r_{mis} \\ r_{mis} & r_{mis} & r_T \end{pmatrix} \qquad r_T = 1\text{-}2r_{mis}$$

Comparison

Comparison with other experiments



Summary & Future work

Analysis of jet charge performance for single jet at Z pole:

★ *Effective tagging power: 20% / 39% for b/c jet*

★ *Dependences:*

- *High dependency on leading particle type.*
- *High dependency on b/c hadrons type, especially for B_s (Mingrui), Λ_b, Λ_c, …*
- *High dependency on the decay source of leading particle.*

★ *Detector Performance:*

- *Energy threshold*
- *PID*

Future work:

Include charged 2rd/3rd vertex

Take into account hadron decay, Bs, Λb/c…

Jet charge vs c.m.s energy

Jet charge vs jet shape, thrust

Full simulation

Fragmentation model of different generator

ML

…

Thanks!

Back Up

Related detector performance impact

- **Flavor tagging impact**
- **flavor tagging algorithm (FT) for b/c jet is characterized by**

$$\begin{pmatrix} b^{reco} \\ c^{reco} \end{pmatrix} = \begin{pmatrix} r_{\mathrm{FT}}^{bb} & r_{\mathrm{FT}}^{bc} \\ r_{\mathrm{FT}}^{cb} & r_{\mathrm{FT}}^{cc} \end{pmatrix} \begin{pmatrix} b^{T} \\ c^{T} \end{pmatrix}$$

- **Efficiency of FT:**

$$\epsilon_{\mathrm{tag,FT}}^{b} = \frac{r_{\mathrm{FT}}^{bb}}{r_{\mathrm{FT}}^{bb} + r_{\mathrm{FT}}^{bc}}, \qquad \epsilon_{\mathrm{tag,FT}}^{c} = \frac{r_{\mathrm{FT}}^{cc}}{r_{\mathrm{FT}}^{cc} + r_{\mathrm{FT}}^{cb}}.$$

- **Purity of FT:**

$$p_{\mathrm{FT}}^{b} = \frac{r_{\mathrm{FT}}^{bb}}{r_{\mathrm{FT}}^{bb} + r_{\mathrm{FT}}^{cb}}, \qquad p_{\mathrm{FT}}^{c} = \frac{r_{\mathrm{FT}}^{cc}}{r_{\mathrm{FT}}^{cc} + r_{\mathrm{FT}}^{bc}}.$$

- **An algorithm combining the jet flavor tagging and jet charge identification (FC)**
- **is characterized by a parameter matrix, defined in**

$$\begin{pmatrix} b^{reco} \\ \bar{b}^{reco} \\ c^{reco} \\ \bar{c}^{reco} \end{pmatrix} = \begin{pmatrix} r_{\mathrm{FC}}^{bb} & r_{\mathrm{FC}}^{b\bar{b}} & r_{\mathrm{FC}}^{bc} & r_{\mathrm{FC}}^{b\bar{c}} \\ r_{\mathrm{FC}}^{\bar{b}b} & r_{\mathrm{FC}}^{\bar{b}\bar{b}} & r_{\mathrm{FC}}^{\bar{b}c} & r_{\mathrm{FC}}^{\bar{b}\bar{c}} \\ r_{\mathrm{FC}}^{cb} & r_{\mathrm{FC}}^{c\bar{b}} & r_{\mathrm{FC}}^{cc} & r_{\mathrm{FC}}^{c\bar{c}} \\ r_{\mathrm{FC}}^{\bar{c}b} & r_{\mathrm{FC}}^{\bar{c}\bar{b}} & r_{\mathrm{FC}}^{\bar{c}c} & r_{\mathrm{FC}}^{\bar{c}\bar{c}} \end{pmatrix} \begin{pmatrix} b^{T} \\ \bar{b}^{T} \\ c^{T} \\ \bar{c}^{T} \end{pmatrix}$$

Related detector performance impact

- **The elements in FC matrix can be calculated from FT matrix and misjudgment rate ω of jet charge algorithm:**

$$\begin{pmatrix} r^{bb}_{\rm FT}(1-\omega^b_{\rm JC})/2 & r^{bb}_{\rm FT}\omega^b_{\rm JC}/2 & r^{bc}_{\rm FT}\xi\omega^b_{\rm JC}/2 & r^{bc}_{\rm FT}(1-\xi\omega^b_{\rm JC})/2 \\ r^{bb}_{\rm FT}\omega^b_{\rm JC}/2 & r^{bb}_{\rm FT}(1-\omega^b_{\rm JC})/2 & r^{bc}_{\rm FT}(1-\xi\omega^b_{\rm JC})/2 & r^{bc}_{\rm FT}\xi\omega^b_{\rm JC}/2 \\ r^{cb}_{\rm FT}\xi\omega^c_{\rm JC}/2 & r^{cb}_{\rm FT}(1-\xi\omega^c_{\rm JC})/2 & r^{cc}_{\rm FT}(1-\omega^c_{\rm JC})/2 & r^{cc}_{\rm FT}\omega^c_{\rm JC}/2 \\ r^{cb}_{\rm FT}(1-\xi\omega^c_{\rm JC})/2 & r^{cb}_{\rm FT}\xi\omega^c_{\rm JC}/2 & r^{cc}_{\rm FT}\omega^c_{\rm JC}/2 & r^{cc}_{\rm FT}(1-\omega^c_{\rm JC})/2 \end{pmatrix}$$

correct charge correlation:

	b	$\bar{b}$	c	$\bar{c}$
e	-	+	+	-
μ	-	+	+	-
K	-	+	-	+
π	-	+	+	-
p	+	-	+	-

→ for e, μ, π, ξ=-1; for K, p, ξ=1.

The misjudgment rate ω of jet charge with flavor tagging, ω_{FC}:

$$\omega^b_{\rm FC} = \frac{r^{bb}_{\rm FT}\omega^b_{\rm JC} + r^{cb}_{\rm FT}(1-\xi\omega^c_{\rm JC})}{r^{bb}_{\rm FT} + r^{cb}_{\rm FT}}\,, \qquad \omega^c_{\rm FC} = \frac{r^{cc}_{\rm FT}\omega^c_{\rm JC} + r^{bc}_{\rm FT}(1-\xi\omega^b_{\rm JC})}{r^{cc}_{\rm FT} + r^{bc}_{\rm FT}}\,.$$

The corresponding effective tagging power ε_{eff} :

$$\epsilon^b_{\rm eff,FT} = \epsilon^b_{\rm tag,FT}(1-2\omega^b_{\rm FC})^2\,, \qquad \epsilon^c_{\rm eff,FT} = \epsilon^c_{\rm tag,FT}(1-2\omega^c_{\rm FC})^2\,.$$

Related detector performance impact

Flavor tagging matrix of b c u d s by Yongfeng:

	b	c	u	d	s
b	0.92813847	0.05349302	0.00523912	0.00427207	0.00885732
c	0.03278909	0.81605705	0.02867341	0.02832364	0.09415682
u	0.0035225	0.02041253	0.38276848	0.39610872	0.19718777
d	0.00361637	0.02051501	0.31427264	0.45391248	0.2076835
s	0.00366069	0.03068756	0.07769855	0.11526544	0.77268777

Overview

Jet charge at LEP & SLD

use jet charge to determine A_{FB}:

In every $A_{\mathrm{FB}}^{\mathrm{qq}}$ analysis the measured asymmetry is given by

$$A_{\mathrm{FB}}^{\mathrm{meas}} = \sum_{\mathrm{q}} (2\omega_{\mathrm{q}} - 1)\eta_{\mathrm{q}} A_{\mathrm{FB}}^{\mathrm{q\overline{q}}}, \tag{5.13}$$

where η_{q} is the fraction of $\mathrm{q\overline{q}}$ events in the sample, ω_{q} is the probability to tag the quark charge correctly and the sum is taken over all quark flavours. It should be noted that the tagging methods often tag the quark charge and not the flavour, so that in these cases $(2\omega_{\mathrm{q}} - 1)$ is close to -1 for charm if it is constructed to be positive for b-quarks. Similar flavour composition and quark charge tag factors also apply to corresponding equation for $A_{\mathrm{LRFB}}^{\mathrm{q\overline{q}}}$ analyses.

cuts on the final electron and muons, are applied. On the one hand, the lepton-based analyses determine the b-quark charge from that of the hardest charged lepton in the event, and then extract $A_{\mathrm{FB}}^{obs,b}$ by fitting the corresponding distribution of polar angles θ between the e^- and the thrust axis, $dN/d\cos\theta = 3/8\ [1+\cos^2\theta + 8/3\, A_{\mathrm{FB}}^{obs,b}(1-2\chi_B)\cos\theta]$, where $\chi_B \approx 0.12$ is the $B^0\overline{B^0}$ effective mixing parameter. On the other, in the jet-charge-based analyses, $b, \bar{b}$-quarks are identified via their measured jet charge $Q_{\mathrm{jet}} = \sum p_L^\kappa Q / \sum p_L^\kappa$ (where p_L is the longitudinal momentum of the final-state particles, with charge Q, with respect to the thrust axis, and the power κ varies between 0.4 and 0.6), and $A_{\mathrm{FB}}^{obs,b}$ is derived by fitting the distribution $\langle Q_F - Q_B\rangle / \langle Q_b - Q_{\bar{b}}\rangle = 8/3\, A_{\mathrm{FB}}^{obs,b}(1+C)\cos\theta/(1+\cos^2\theta)$, where Q_F (Q_B) are the jet charges in the forward (backward) hemisphere, and the C factor is a ~3.5% correction for missing higher-order QCD terms and for the difference between the thrust axis and the b-quark direction [1,3].

https://arxiv.org/abs/1806.00141v2

https://arxiv.org/abs/hep-ex/0509008v3

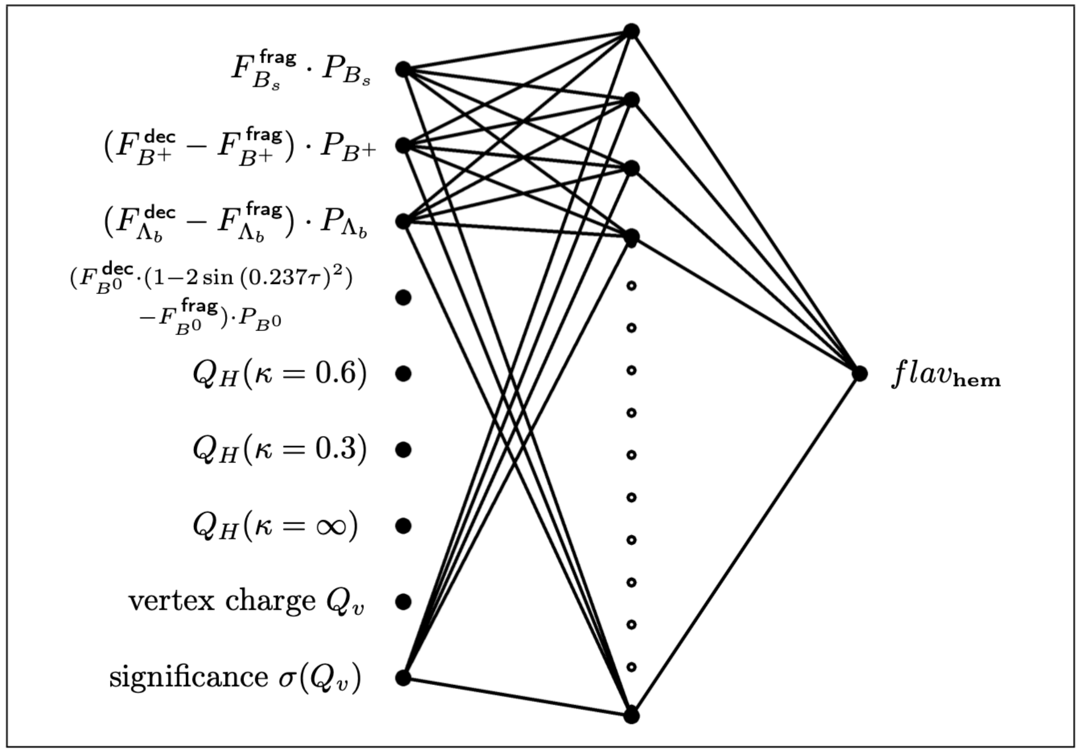
Jet charge at LEP & SLD

Method:

In order to measure a quark asymmetry two ingredients are needed. The quark flavour needs to be tagged and the quark has to be distinguished from the antiquark. For the flavour tagging the methods described in Sections 5.2.1 to 5.2.4 can be used. For the charge tagging essentially five methods have been used, relying on leptons, D-mesons, jet-charge, vertex-charge and kaons. Some analyses also combine the information from the different methods.

For B- and D-mesons the meson charge is correlated with the flavour of the b- or c-quark. If all charged particles of a jet can be uniquely assigned to the primary or the decay vertex, the charge sum of the decay vertex, if non-zero, uniquely tags the quark charge. At SLD the $\mathcal{A}_b$ measurement with vertex charge is the most precise measurement of this quantity. At LEP the vertex charge has also been used in conjunction with other tags, however the impact parameter resolutions at LEP limit the efficiencies in comparison with SLD.

- Measurements of $\mathcal{A}_b$ and $\mathcal{A}_c$ using leptons [152];
- A measurement of $\mathcal{A}_c$ using D-mesons [153];
- A measurement of $\mathcal{A}_b$ using jet charge [154];
- A measurement of $\mathcal{A}_b$ using vertex charge [155];
- A measurement of $\mathcal{A}_b$ using kaons [156];
- A measurement of $\mathcal{A}_c$ using vertex charge and kaons [155].



https://arxiv.org/abs/hep-ex/0509008v3

Jet charge at DELPHI

Method:

a high purity b sample. For event hemispheres with a reconstructed secondary vertex the charge of the corresponding quark or anti-quark is determined using a neural network which combines in an optimal way the full available charge information from the vertex charge, the jet charge and from identified leptons and hadrons. The probability of correctly identifying b-quarks and anti-quarks is measured on the data themselves comparing the rates of double hemisphere tagged like-sign and unlike-sign events. The b-quark forward-backward asym-

To discriminate fragmentation from decay tracks, a Neural Network called TrackNet separates particles originating from the event primary vertex from those starting at a secondary decay vertex. The separation uses the impact parameter measurement and additional kinematic information. Particles from the primary vertex lead to TrackNet values close to 0, while particles from a secondary vertex get values close to 1.

Dedicated Neural Networks are trained for each of the four b-hadron types, and for each set two separate versions are produced: one trained only on tracks originating from the fragmentation process, and the other trained only on tracks originating from the weak b-hadron decay. This construction makes the final charge tagging Network explicitly sensitive to information that is specific to a particular B hadron type. Various effects, such as the proton charge in the fragmentation tracks of b baryon jets often being anticorrelated to the b charge, or $B - \overline{B}$ oscillations between neutral B production and decay, are taken into account automatically. The Networks themselves are defined such that the target output value is +1 (−1) if the charge of a particle is correlated (anti-correlated) to the b-quark charge. A set of predefined input variables is used to establish the correlation:

https://arxiv.org/abs/hep-ex/0412004

Jet charge at DELPHI

Result:

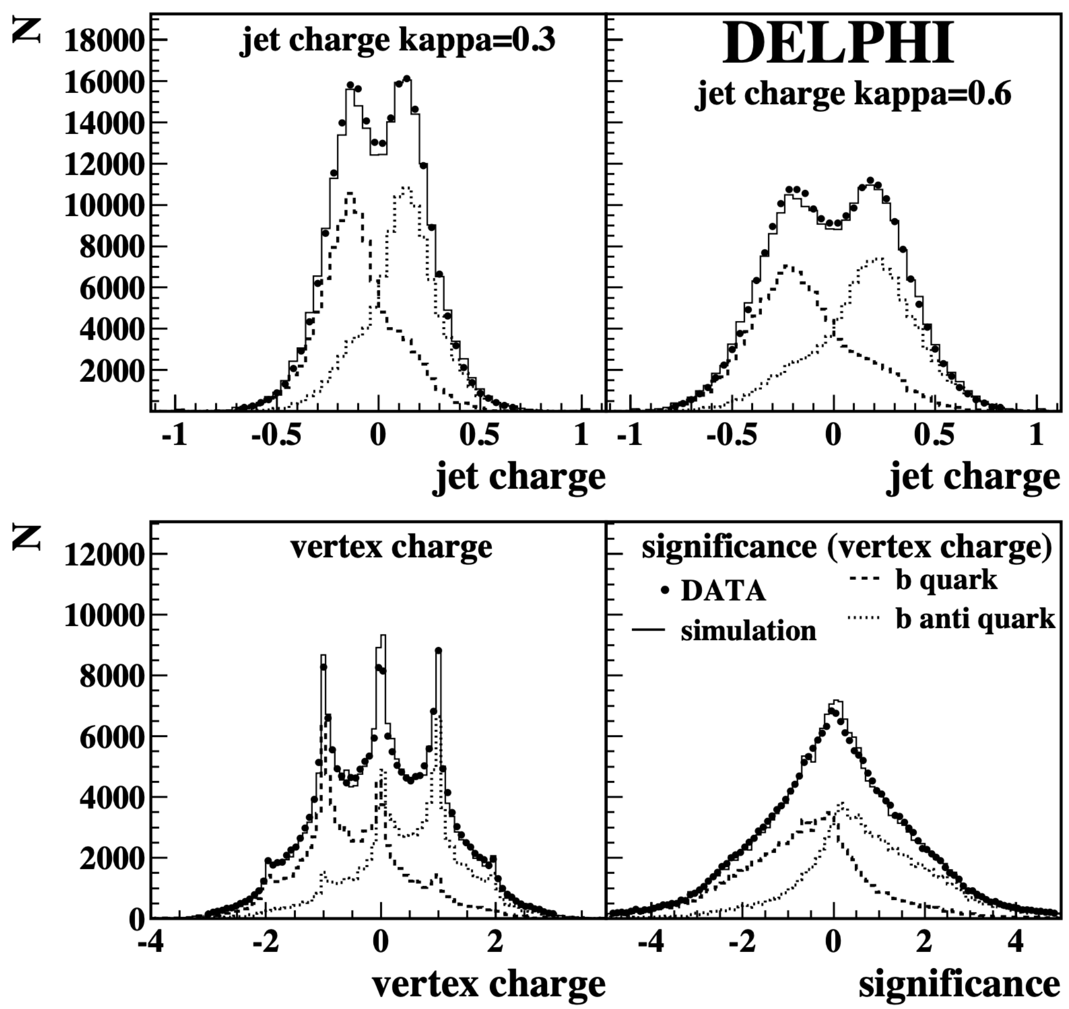


Figure 5: *The jet charge information for $\kappa = 0.3$ and 0.6 (upper plots) and the vertex charge and its significance (lower plot). Shown is the comparison between 1994 data and simulation for all hemispheres that are both b and charge tagged.*

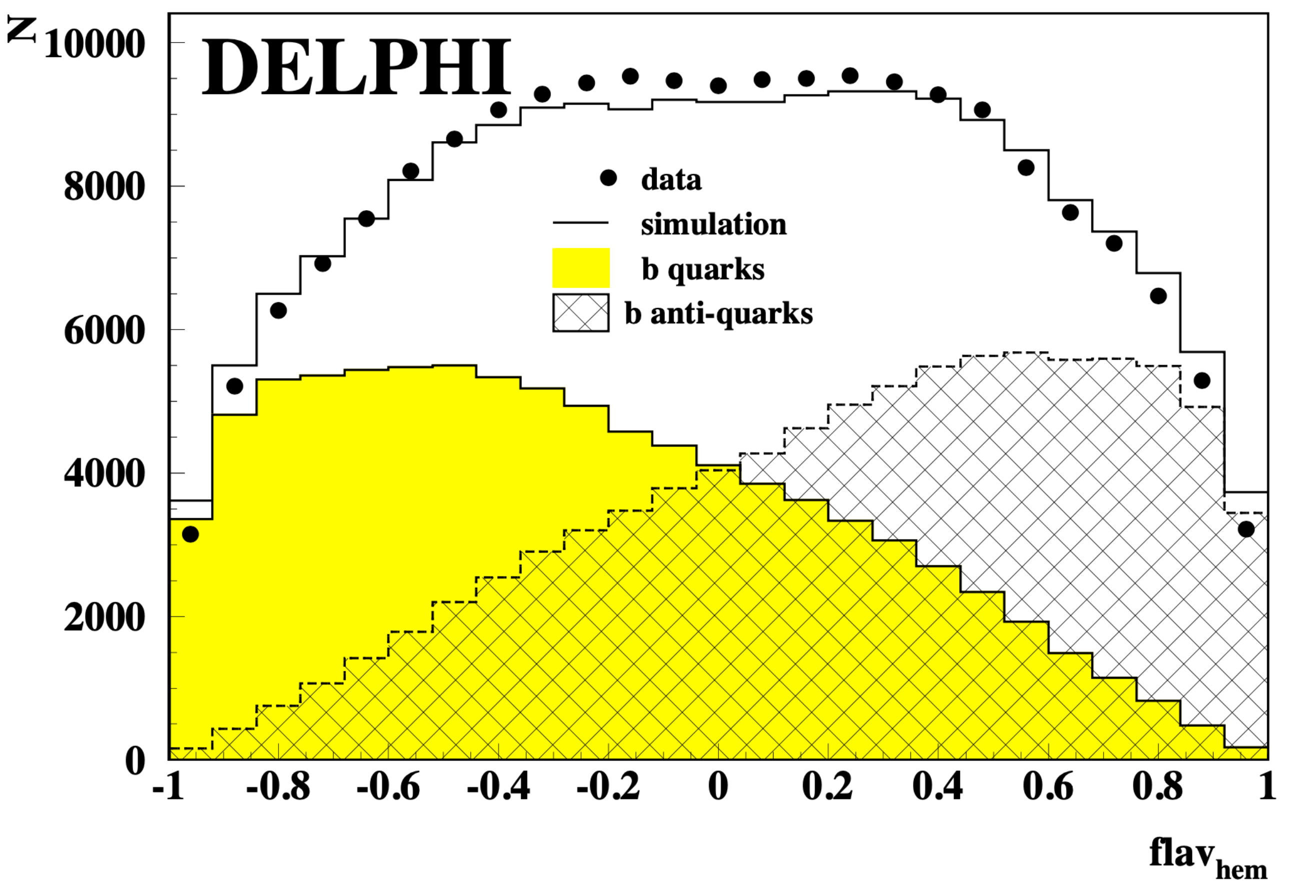


Figure 6: *Comparison between data and simulation for the hemisphere charge tag Neural Network output, $flav_{hem}$, for the data of 1994. Hemispheres from all b-enhanced samples were used, resulting in a b purity of 90 %.*

https://arxiv.org/abs/hep-ex/0412004

Jet charge at DELPHI

Result:

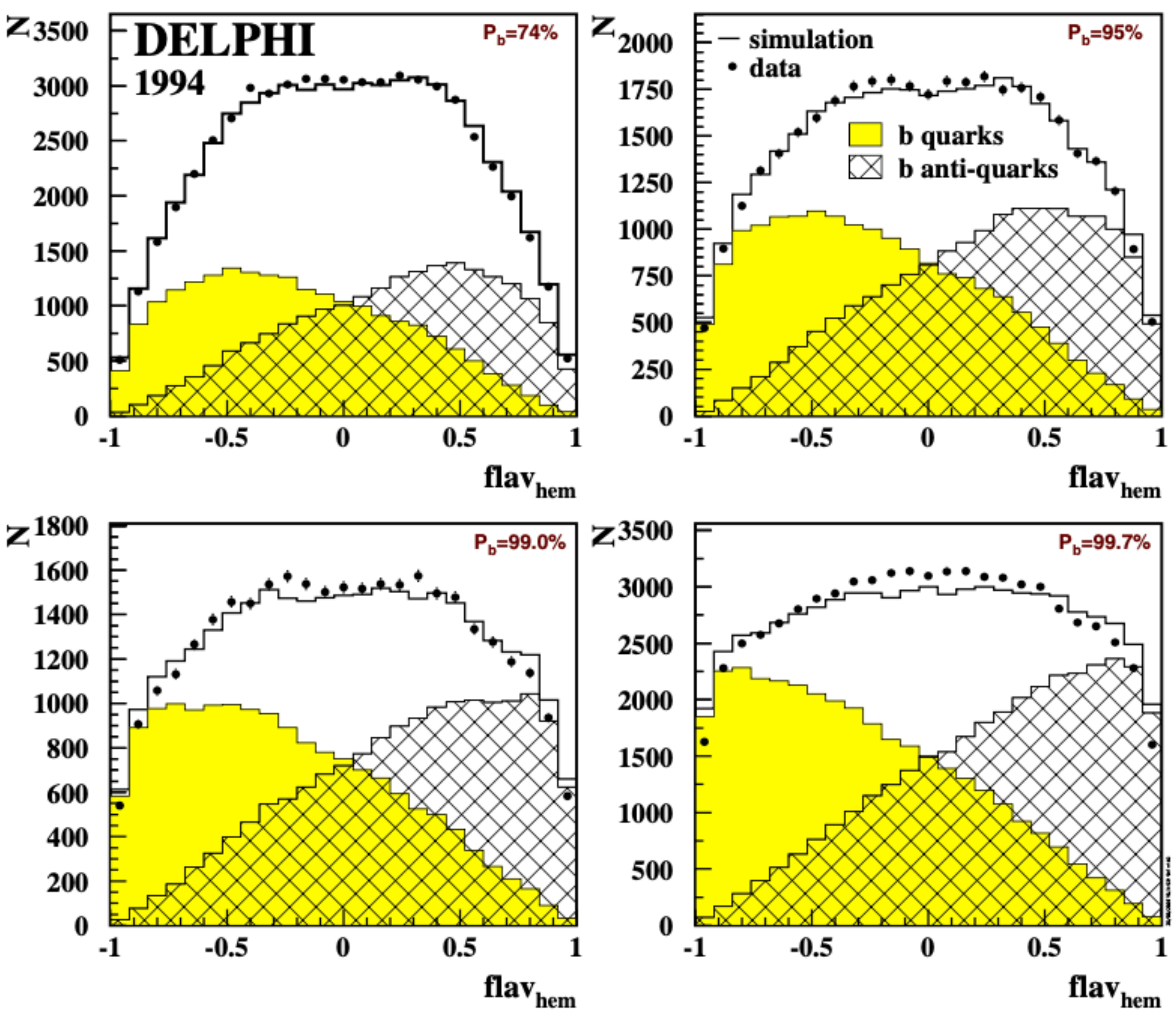


Figure 7.9: Comparison between data and simulation for the hemisphere charge taggin Network output, $flav_{hem}$, for the data of 1994. The distribution is shown for each of the four b-purity enhanced samples. The b/$\bar{\mathrm{b}}$ contributions are normalised to the b purity.

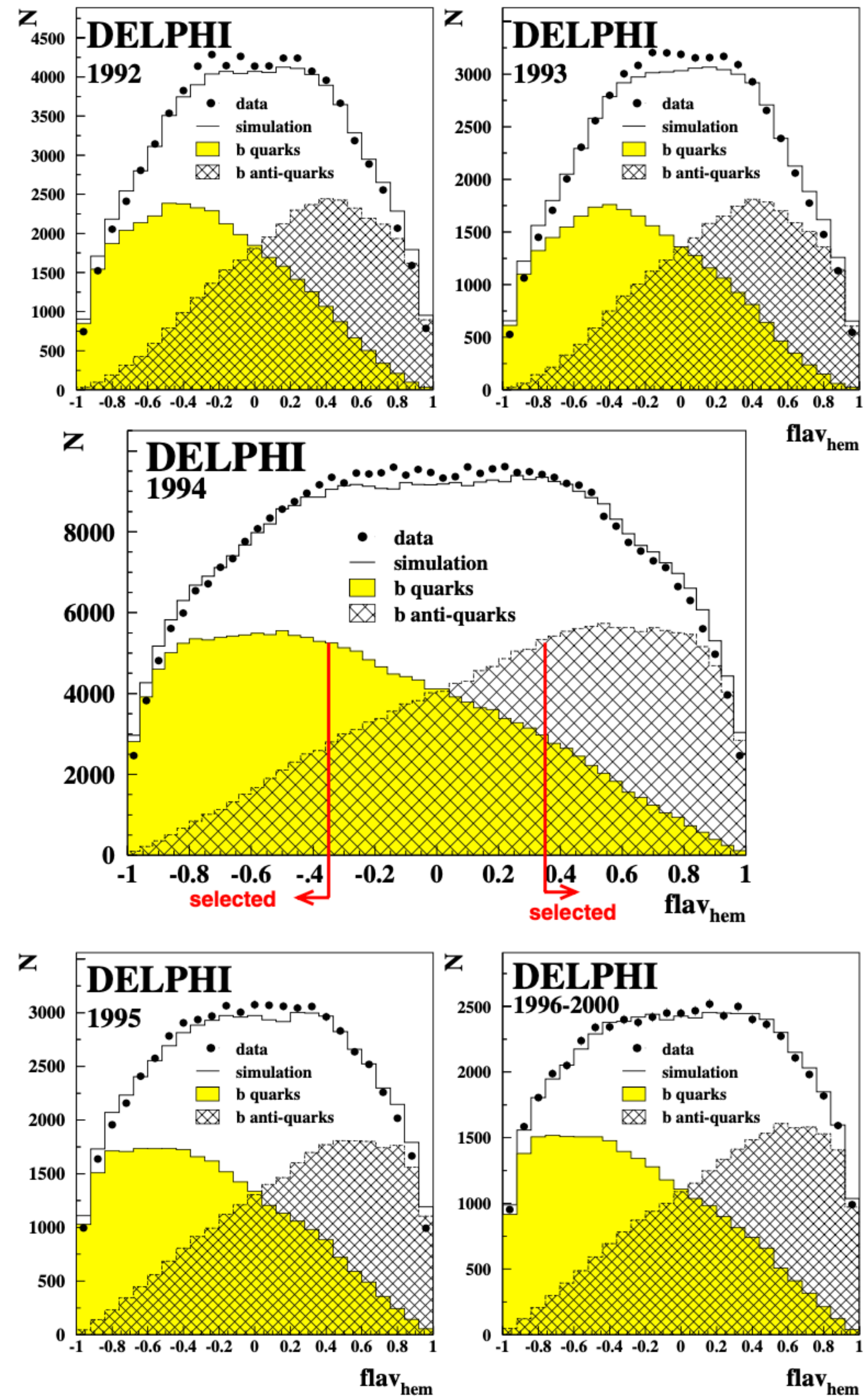
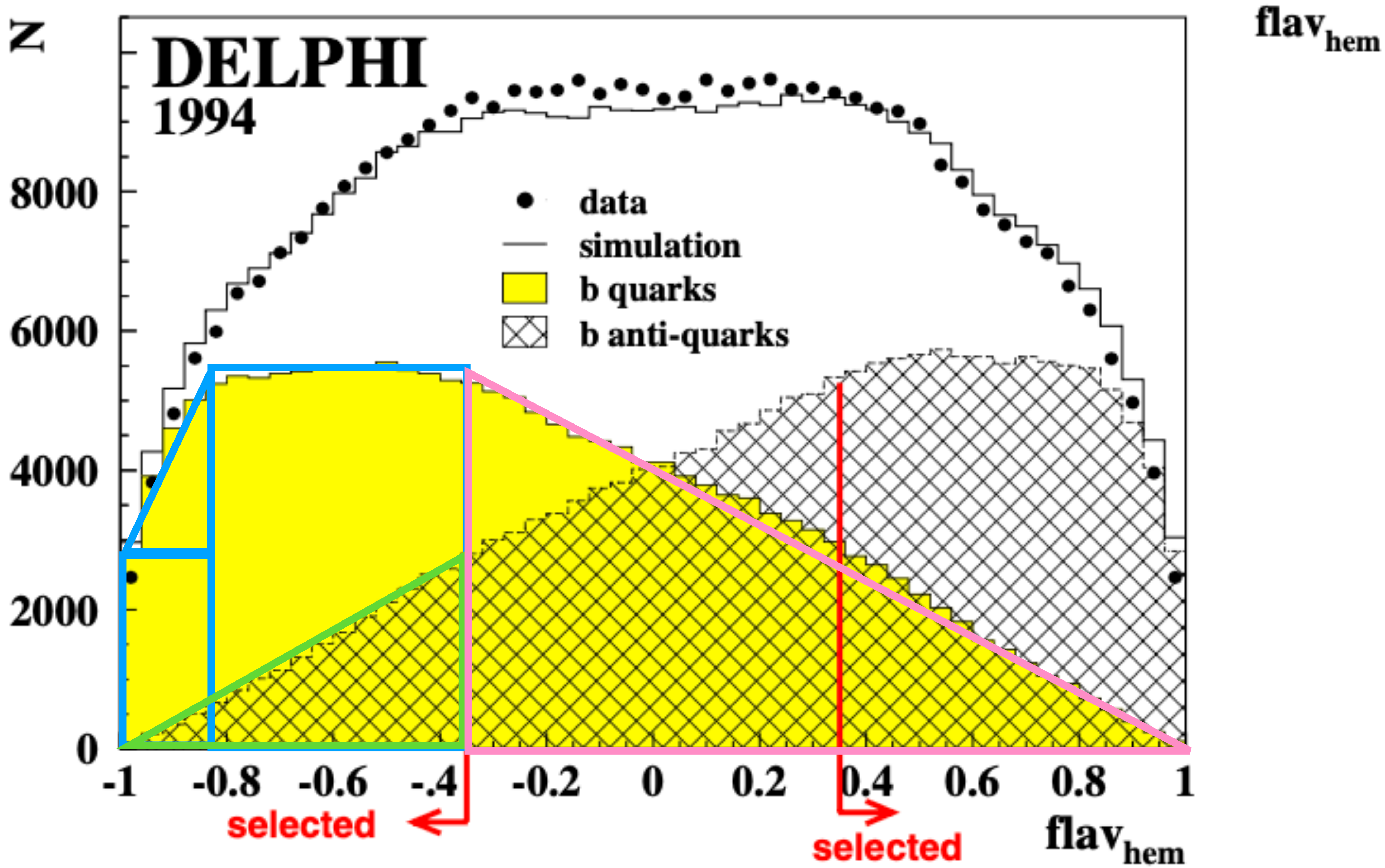


Figure 7.10: Comparison between data and simulation for the hemisphere charge tagging Neural Network output, $flav_{hem}$, for the years 1992 to 2000. Hemispheres from all b-enhanced samples were integrated, resulting in a b purity of 90%.

https://arxiv.org/abs/hep-ex/0412004



Pink: untagged b quarks: 473*248/2=58652

Blue: tagged b quarks: 167*249+58*125+56*117/2=52109

Green: tagged b anti-quarks: 218*123/2=13407

ω=13407/(52109+13407)=0.205

efficiency ε_{tag} =52109/(52109+58652)=0.470

Effective tagging power ε_{eff} =0.470*(1-2*0.205)*(1-2*0.205)=0.164

Jet charge at DELPHI

Result:

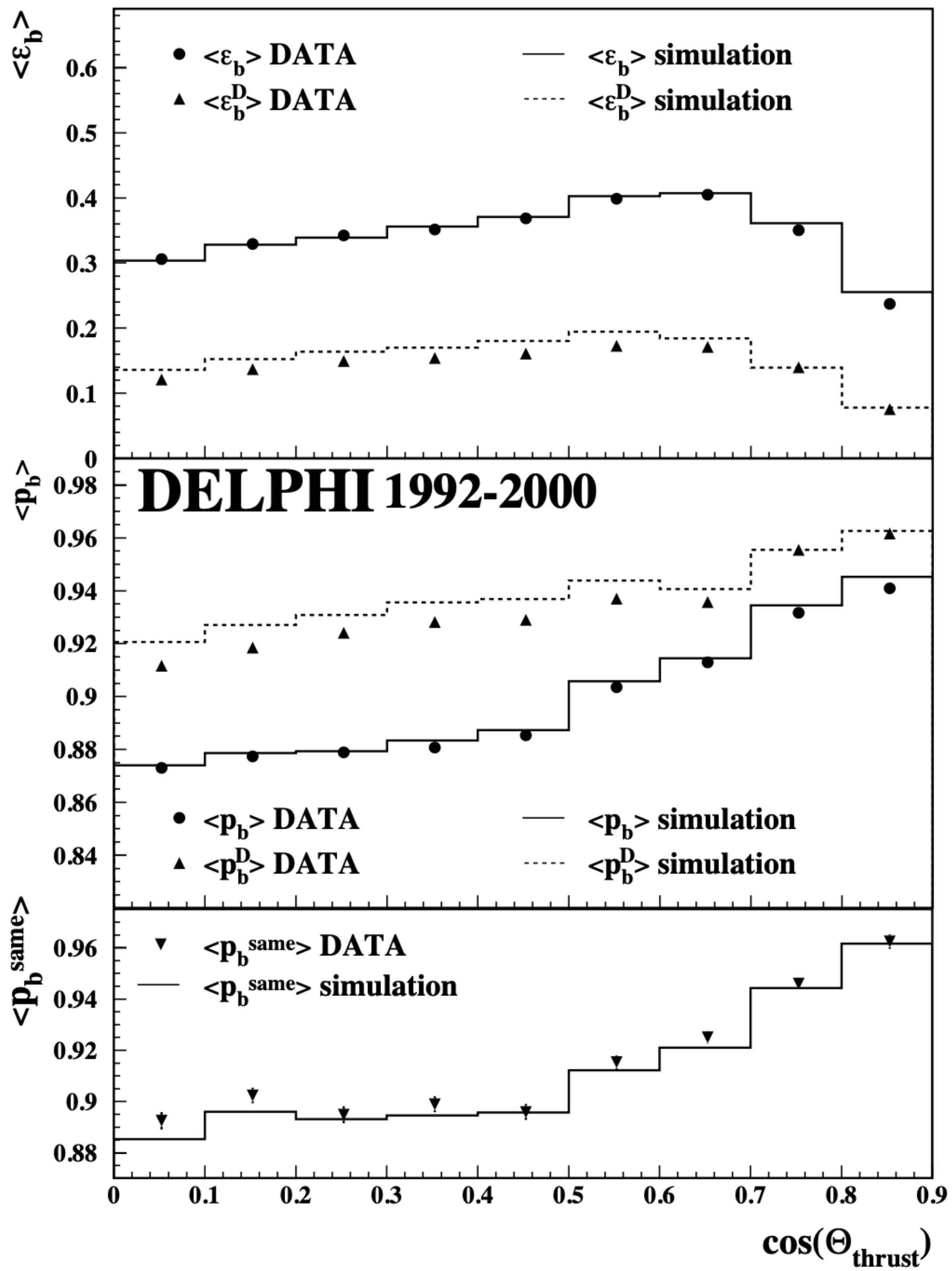


Figure 7: The b efficiencies ϵ_b and ϵ_b^D and the purities p_b and p_b^D for single and double unlike-sign tagged events as a function of the polar angle. The full sample of all four bins in b-tag has been used. The purity p_b^{same} for double like-sign tagged events is relevant for measuring the charge tagging probability, $w_b^{(D)}$.

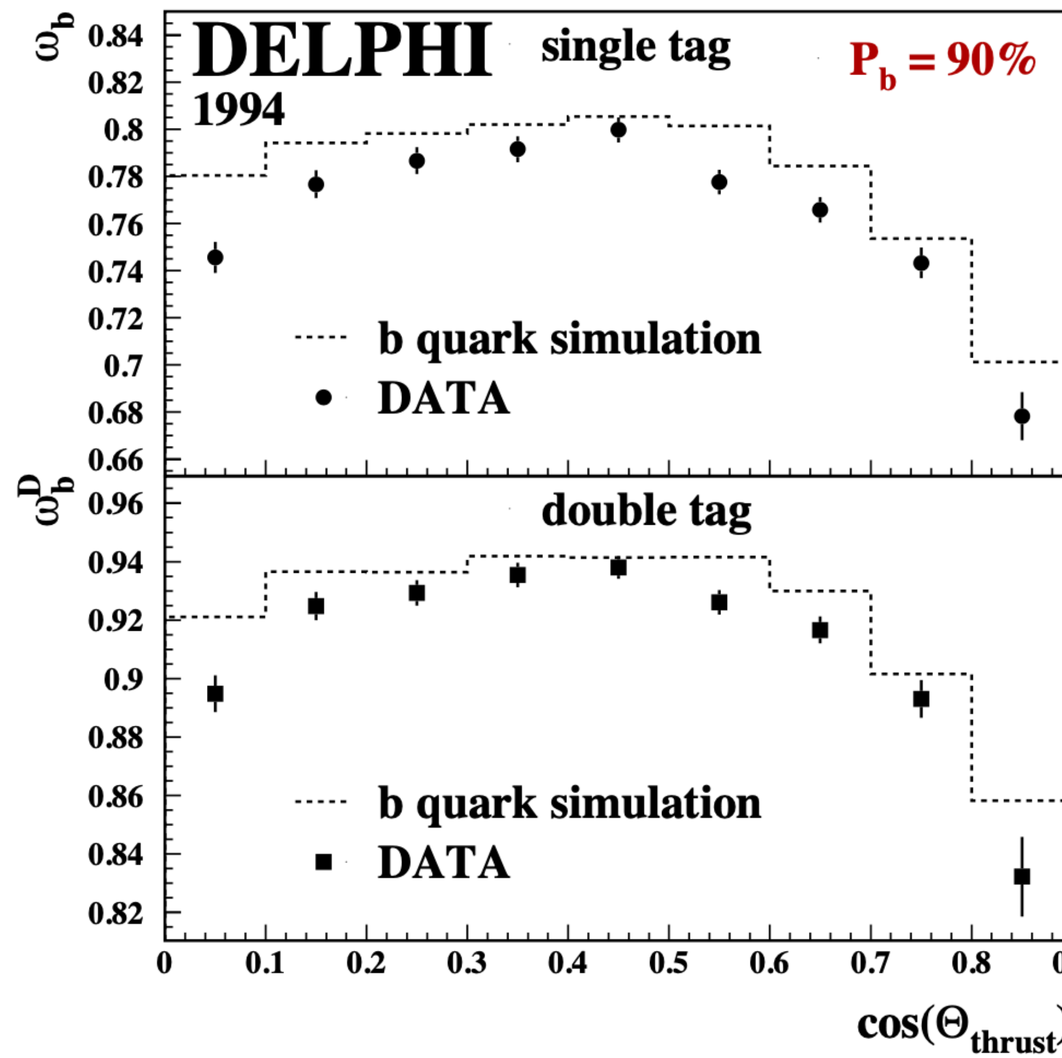


Figure 8: The probability to identify b-quarks correctly for data and simulation for the year 1994. The upper plot shows the result for single tagged events, the lower for double tagged events. See text for details.

https://arxiv.org/abs/hep-ex/0412004

Jet charge at ALEPH

Result:

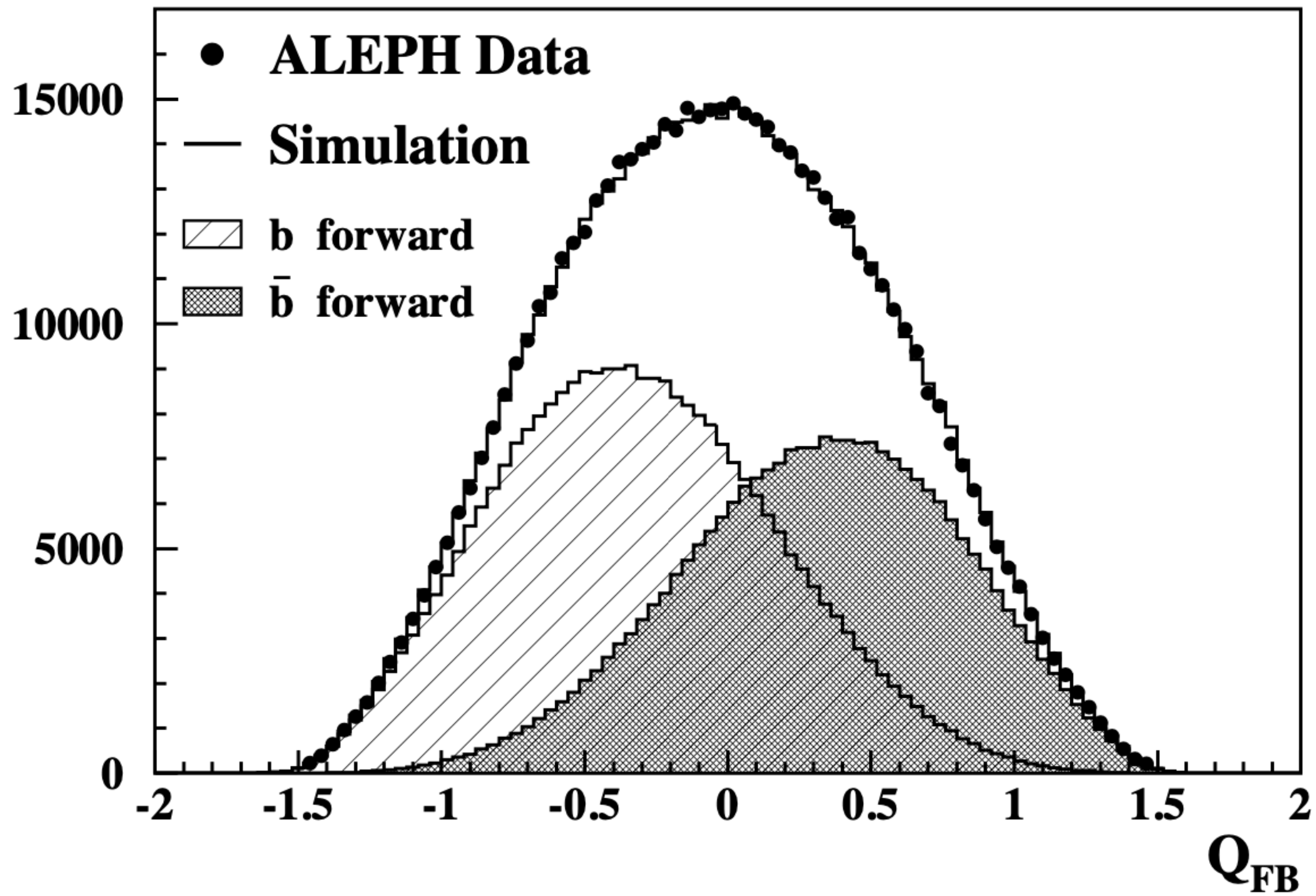
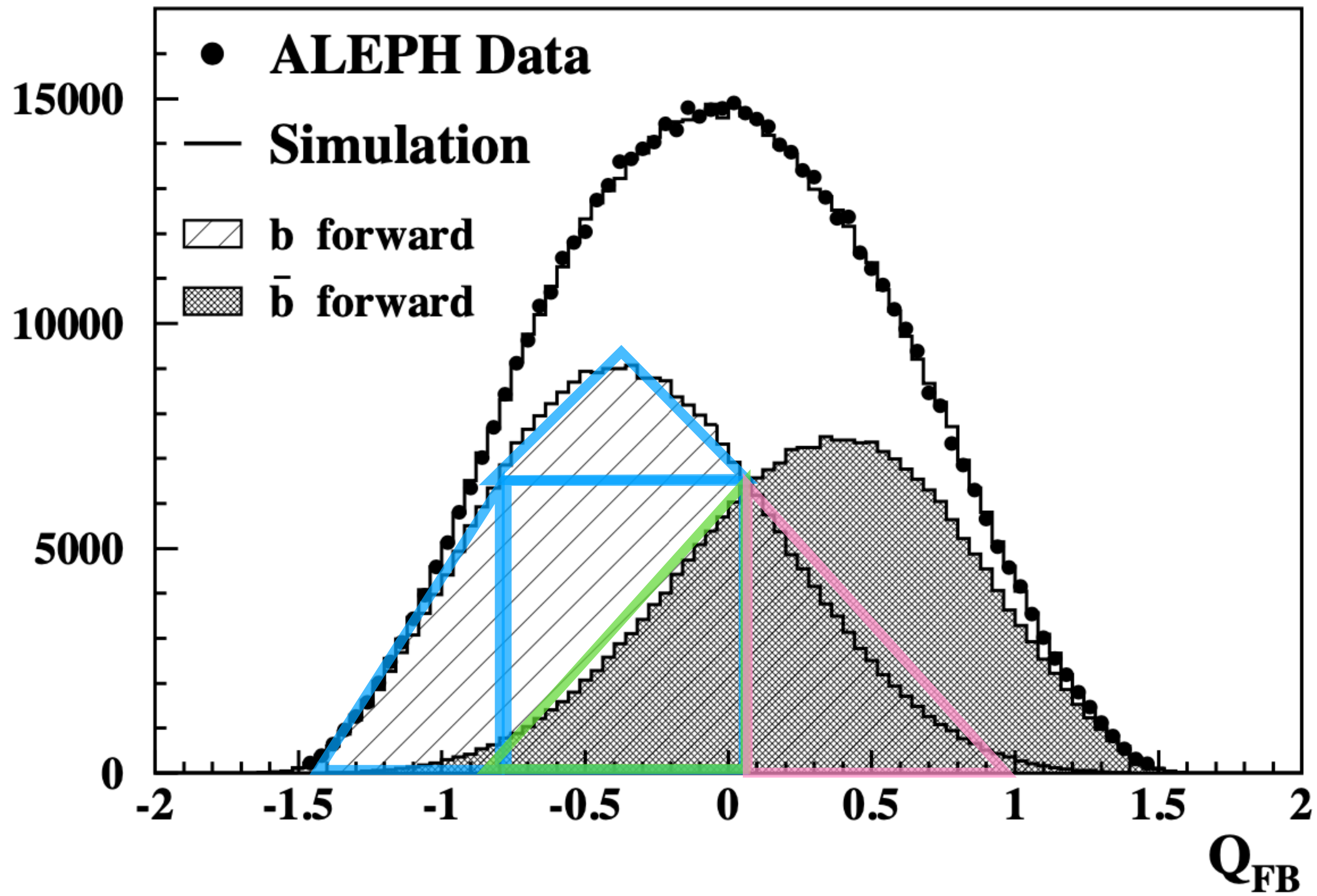


Figure 5.12: Charge separation of the ALEPH neural net tag using jet charge, vertex charge and charged kaons [142]. The asymmetry reflects $A_{FB}^{b\bar{b}}$ diluted by the non-perfect charge tagging.

https://arxiv.org/abs/hep-ex/0509008v3

Jet charge at ALEPH

Result:



Pink: untagged b quarks: 105*116/2=6090

Blue: tagged b quarks: 96*117+72*74/2.+74*115/2.=18151

Green: tagged b anti-quarks: 105*116/2=6090

ω=6090/(6090+18151)=0.251

efficiency ε_{tag} =18151/(18151+6090)=0.749

Effective tagging power ε_{eff} =0.749*(1-2*0.251)*(1-2*0.251)=0.186

https://arxiv.org/abs/hep-ex/0509008v3

Jet charge at L3

Result:

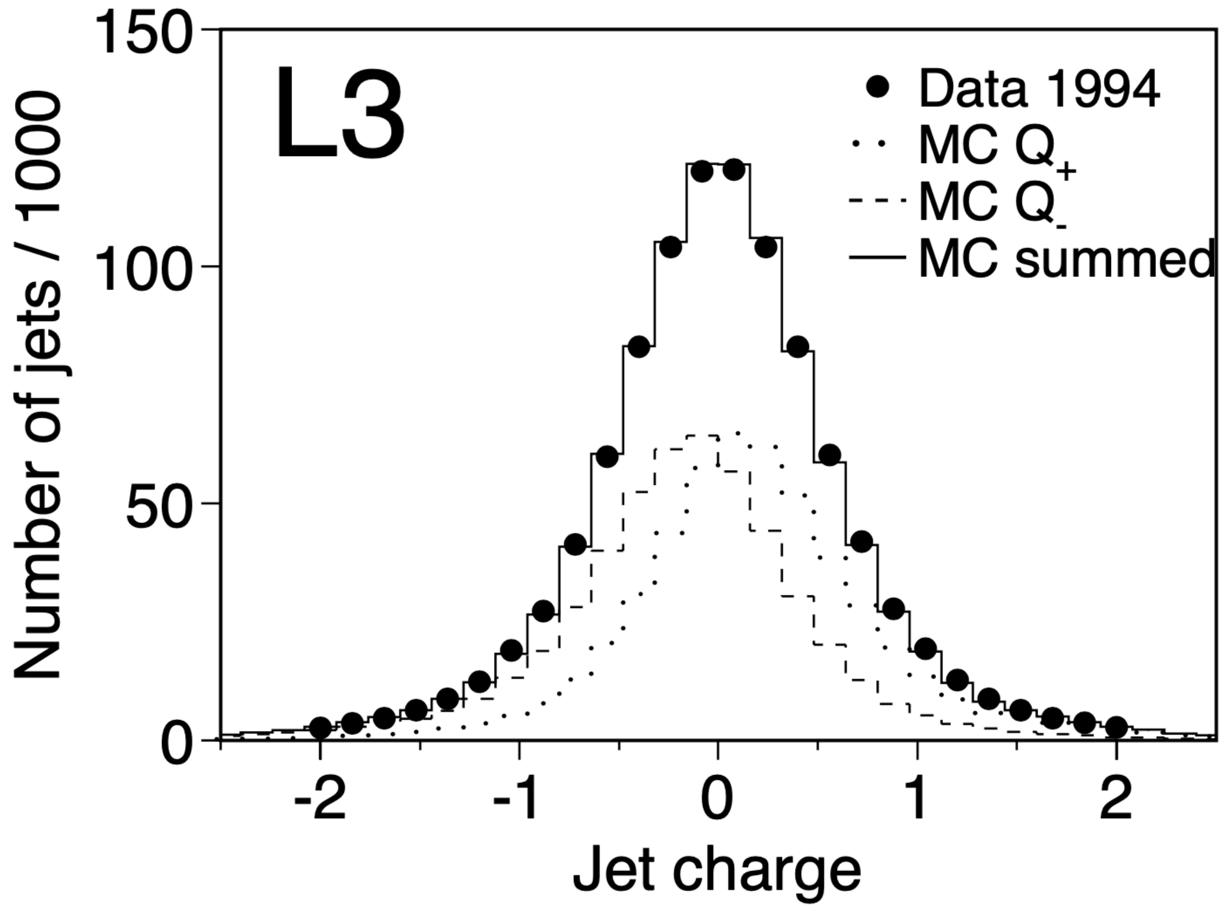


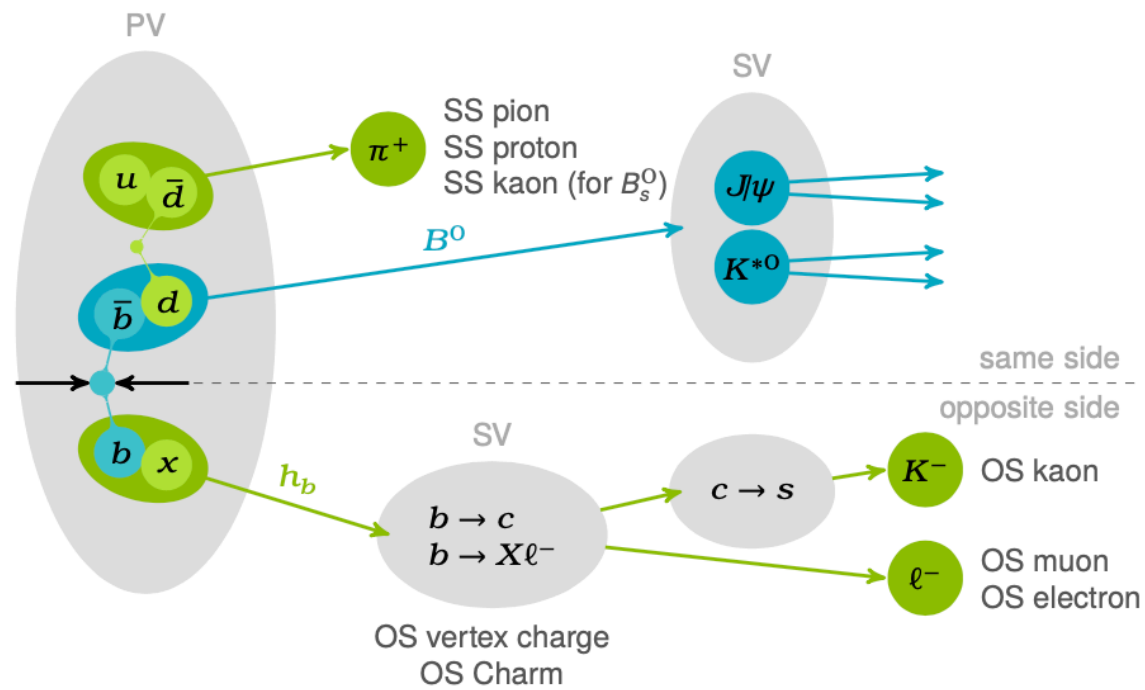
Figure 6.1: The Q_+ and Q_- distributions obtained from Monte Carlo simulation by L3. Their sum is compared to the sum of the $Q_F + Q_B \equiv Q_+ + Q_-$ distributions for 1994 data.

https://arxiv.org/abs/hep-ex/0509008v3

Jet charge at LHCb

Method:

Flavour Tagging Algorithms . . . .
- Opposite Side Single Track Taggers .
- Vertex Charge Tagger . . . .
- Charm Tagger . . . .
- Same Side Proton and Pion Tagger . .
- Same Side Kaon Tagger . . . .



Result:

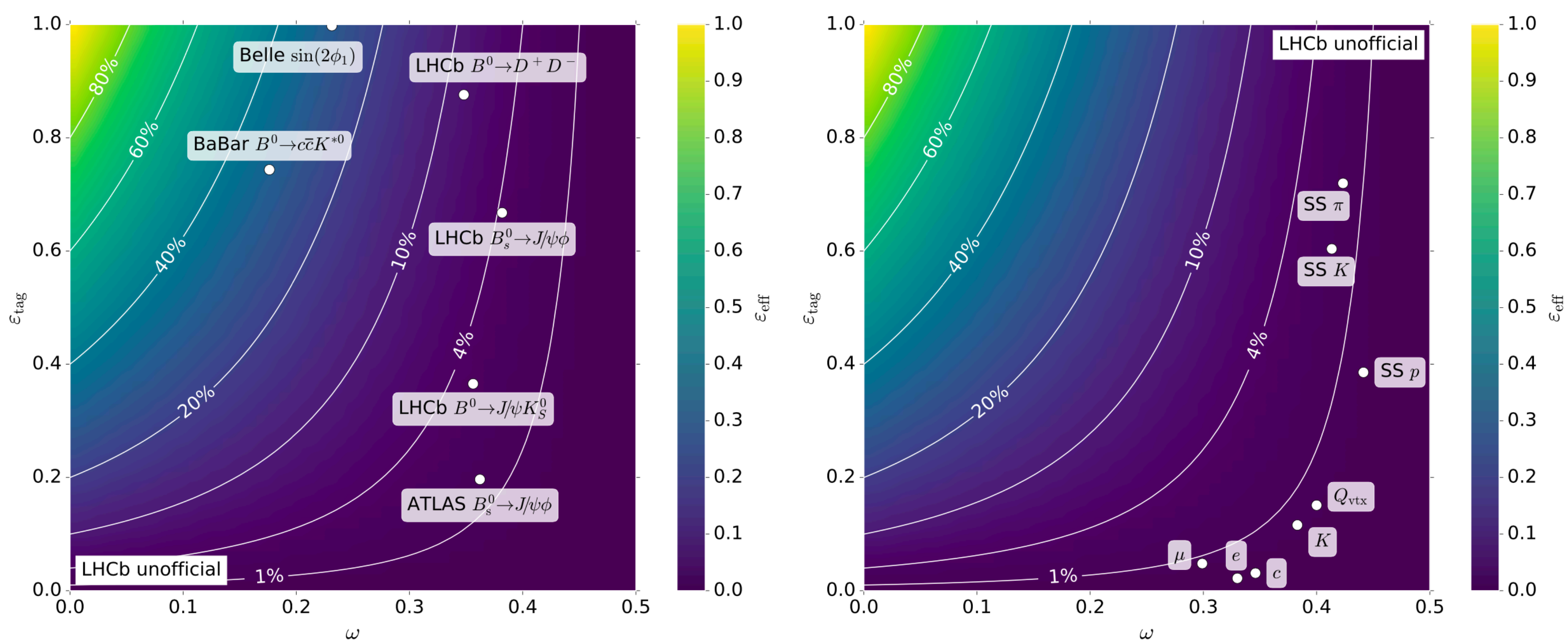


Figure 3.1: Effective tagging efficiency of (left) different HEP experiments and (right) LHCb flavour tagging algorithms [40]. The white lines indicate contours of constant tagging power.

https://cds.cern.ch/record/2229990/

Jet charge at LHCb

Method:

produced in the $pp \to b\bar{b}X$ event. At LHCb, these algorithms fall into one of two categories: those that involve measuring the flavour of the other b hadron produced in the event (referred to as Opposite-Side tagging) [36, 37] and those based on information from other particles associated with the hadronisation of the signal b or $\bar{b}$ quark (Same-Side tagging) [38, 39]. These algorithms typically combine various sources of information using multivariant techniques, and provide as output:

- a discrete decision indicating whether the initial flavour is more likely to be B or $\overline{B}$, or if it cannot be tagged ($q = +1, -1, 0$, respectively);
- an estimated probability, η, that the decision of q (if non-zero) is wrong, known as the mistag fraction.

Result:

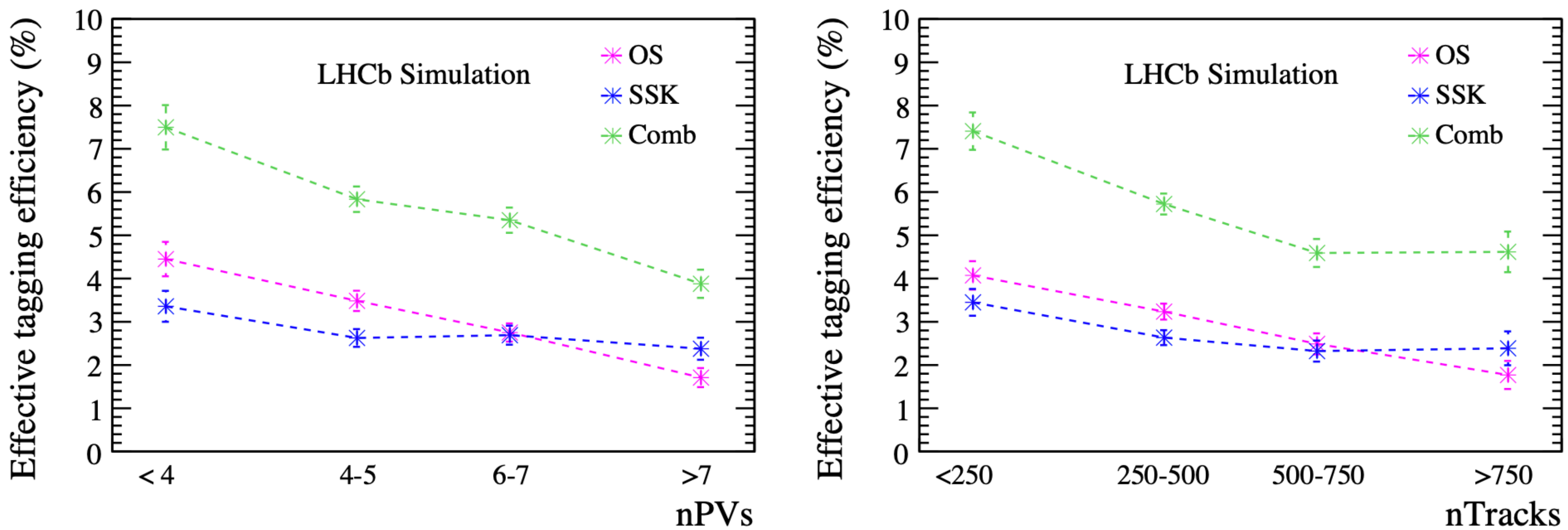


Figure 3.2: Effective tagging efficiency of OS and SS kaon taggers, and their combination, (left) in bins of pile-up vertices and (right) in bins of track multiplicity. These results are obtained from Upgrade I simulation of $B_s^0 \to D_s^- \pi^+$ decays. The OS performances correspond to those obtained from combination of the individual OS taggers.

https://arxiv.org/abs/1808.08865

Jet charge at LHCb

Method:

$$Q = \frac{\sum_i (p_{\mathrm{T}}^{\mathrm{rel}})_i q_i}{\sum_i (p_{\mathrm{T}}^{\mathrm{rel}})_i}$$

A quantum algorithm is implemented by means of a quantum circuit, namely a collection of linked quantum gates acting on a n-qubit quantum state: the measurements on the final state represent the outcome of the quantum algorithm. Parametrised Quantum Circuits (PQCs) [42] are a type of circuit that contains adjustable gates with tunable parameters. The Variational Quantum Classifier (VQC) [43] is a hybrid quantum-classical algorithm to perform classification tasks using a Machine Learning model based on a PQC with the following structure:

Result:

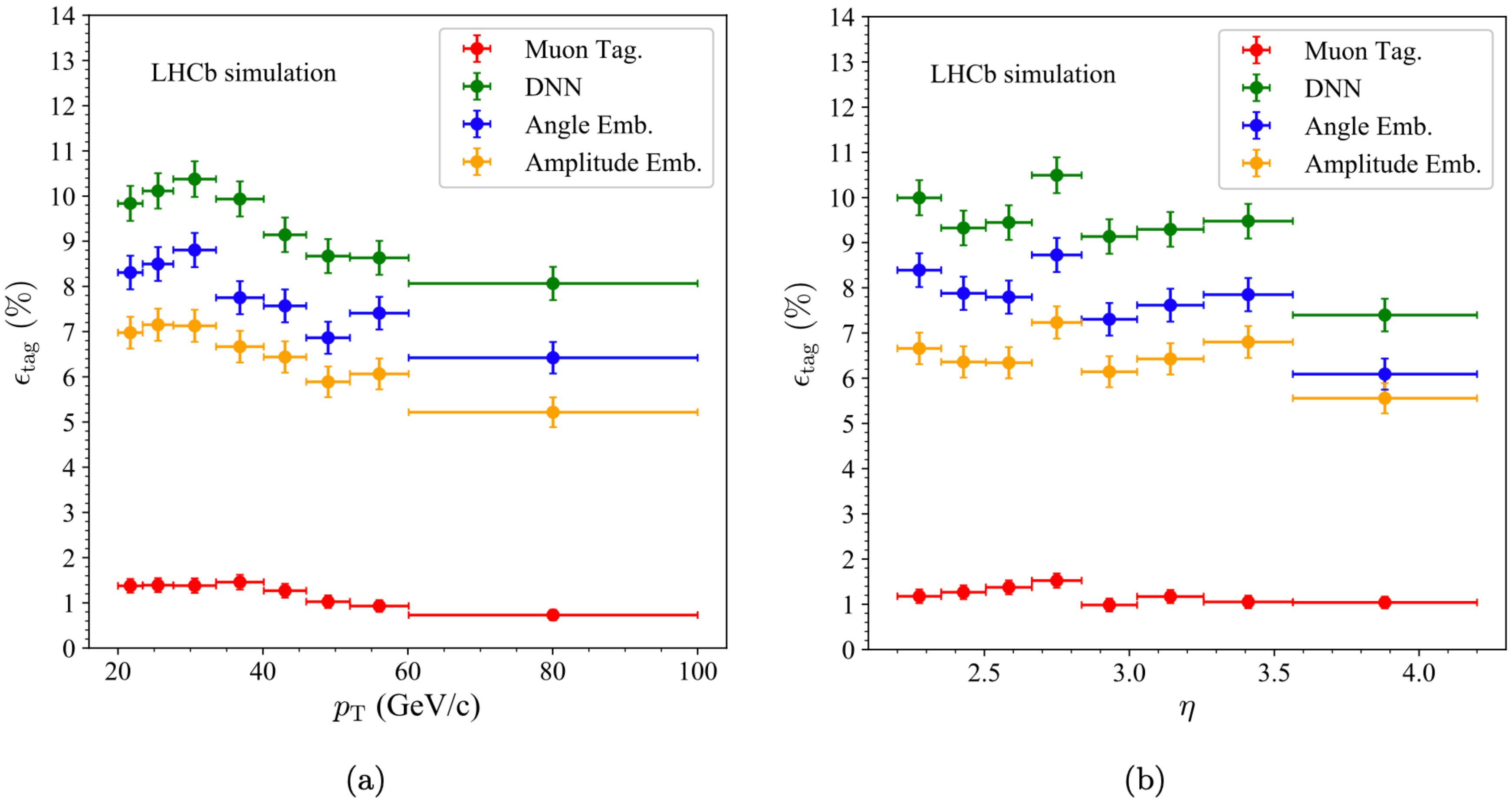


Figure 8. Tagging power ϵ_{tag} with respect to (a) jet p_{T} and (b) jet η for the *complete dataset*. The quantum algorithms perform slightly worse than the DNN, with the Angle Embedding circuit performing better than the Amplitude Embedding circuit.

https://link.springer.com/article/10.1007/JHEP08(2022)014

B tagging at BABAR

Method:

The tagging algorithm we employ [5, 13] analyzes tracks on the tag side to assign a flavor and associated probability to B_{tag}. The flavor of B_{tag} is determined from a combination of nine different tag signatures, such as isolated primary leptons, kaons and pions from B decays to final states containing D^* mesons, and high momentum charged particles from B decays. The properties of those signatures are used as inputs to a single neural network

Result:

TABLE I: Efficiencies ϵ_i, average mistag fractions w_i, mistag fraction differences between B^0 and $\overline{B}^0$ tagged events Δw_i, and effective tagging efficiency Q_i extracted for each tagging category i from the B_{flav} sample.

Category	ϵ_i (%)	w_i (%)	Δw_i (%)	Q_i (%)
Lepton	8.96 ± 0.07	2.8 ± 0.3	0.3 ± 0.5	7.98 ± 0.11
Kaon I	10.82 ± 0.07	5.3 ± 0.3	-0.1 ± 0.6	8.65 ± 0.14
Kaon II	17.19 ± 0.09	14.5 ± 0.3	0.4 ± 0.6	8.68 ± 0.17
KaonPion	13.67 ± 0.08	23.3 ± 0.4	-0.7 ± 0.7	3.91 ± 0.12
Pion	14.18 ± 0.08	32.5 ± 0.4	5.1 ± 0.7	1.73 ± 0.09
Other	9.54 ± 0.07	41.5 ± 0.5	3.8 ± 0.8	0.27 ± 0.04
All	74.37 ± 0.10			31.2 ± 0.3

https://arxiv.org/abs/0902.1708v2

B tagging at BABAR

Method:

We use a multivariate technique [33] to determine the flavor of the B_{tag}. Separate neural networks are trained to identify leptons from B decays, kaons from D decays, and soft pions from D^* decays. Events are assigned to one of seven mutually exclusive tagging categories (one category being untagged events) based on the estimated average mistag probability and the source of the tagging information. The quality of tagging is expressed

Result:

TABLE I: Average tagging efficiency ϵ, average mistag fraction w, mistag fraction difference $\Delta w = w(B^0) - w(\overline{B}^0)$, and effective tagging efficiency Q for signal events in each tagging category (except the untagged category).

Category	ϵ (%)	w (%)	Δw (%)	Q (%)
Lepton	8.96 ± 0.07	2.9 ± 0.3	0.2 ± 0.5	7.95 ± 0.11
Kaon I	10.81 ± 0.07	5.3 ± 0.3	0.0 ± 0.6	8.64 ± 0.14
Kaon II	17.18 ± 0.09	14.5 ± 0.3	0.4 ± 0.6	8.64 ± 0.17
Kaon Pion	13.67 ± 0.08	23.3 ± 0.4	-0.6 ± 0.7	3.91 ± 0.12
Pion	14.19 ± 0.08	32.6 ± 0.4	5.1 ± 0.7	1.73 ± 0.09
Other	9.55 ± 0.07	41.5 ± 0.5	3.8 ± 0.8	0.28 ± 0.04
Total				31.1 ± 0.3

https://arxiv.org/abs/1206.3525v2

B tagging at Belle

Method:

(1) high-momentum leptons from $B^0 \to X\ell^+\nu$ decays,
(2) kaons, since the majority of them originate from $B^0 \to K^+X$ decays through the cascade transition $\bar{b} \to \bar{c} \to \bar{s}$,
(3) intermediate momentum leptons from $\bar{b} \to \bar{c} \to \bar{s}\ell^-\bar{\nu}$ decays,
(4) high momentum pions coming from $B^0 \to D^{(*)}\pi^+X$ decays,
(5) slow pions from $B^0 \to D^{*-}X, D^{*-} \to \overline{D}^0\pi^-$ decays, and
(6) $\overline{\Lambda}$ baryons from the cascade decay $\bar{b} \to \bar{c} \to \bar{s}$.

Result:

We describe a flavor tagging algorithm used in measurements of the CP violation parameter $\sin 2\phi_1$ at the Belle experiment. Efficiencies and wrong tag fractions are evaluated using flavor-specific B meson decays into hadronic and semileptonic modes. We achieve a total effective efficiency of $28.8 \pm 0.6\%$.

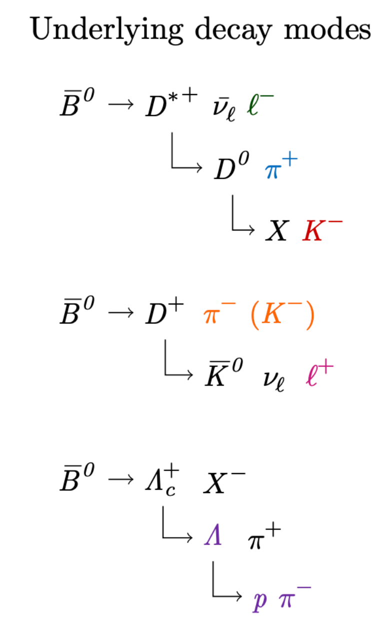
https://arxiv.org/abs/hep-ex/0403022v1

B tagging at Belle2

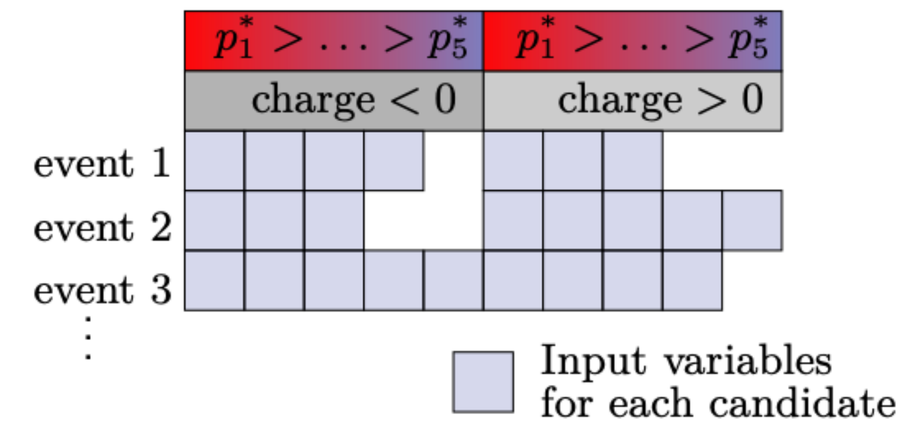
Method:

THE CATEGORY-BASED FLAVOR TAGGER

Categories	Targets for $\bar{B}^0$
Electron	e^-
Intermediate Electron	e^+
Muon	μ^-
Intermediate Muon	μ^+
Kinetic Lepton	ℓ^-
Intermediate Kinetic Lepton	ℓ^+
Kaon	K^-
Kaon-Pion	K^-, π^+
Slow Pion	π^+
Maximum p^*	ℓ^-, π^-
Fast-Slow-Correlated (FSC)	ℓ^-, π^+
Fast Hadron	π^-, K^-
Lambda	Λ



THE DEEP-LEARNING FLAVOR TAGGER



Result:

$$\varepsilon_{\text{eff}} = \left(30.0 \pm 1.2(\text{stat}) \pm 0.4(\text{syst})\right)\%$$

for a category-based algorithm and

$$\varepsilon_{\text{eff}} = \left(28.8 \pm 1.2(\text{stat}) \pm 0.4(\text{syst})\right)\%$$

for a deep-learning-based algorithm.

https://arxiv.org/abs/2110.00790v1

B tagging at Belle2

Method:

For the analysis procedure, the signal side B meson is reconstructed in one of the two aforementioned decay channels. The tag side B meson is not reconstructed explicitly, instead unique signatures of the event are used, to infer the B meson flavor from its decay products. This so-called flavor tagging is performed with a deep neural network algorithm that develops its own representation of the data during the training process. Since potential difference between Monte Carlo data and recorded data could have a significant influence on the algorithm, a careful validation on data was performed.

Result:

The effective tagging efficiency is determined for both channels. Here, the extraction fit is repeated in 14 bins of the classifier output, respectively. The deep neural network based algorithm achieves an effective tagging efficiency on data

$$\mathcal{Q}_{B^+} = 0.3937 \pm 0.0040 \pm 0.0001$$

for the charged B meson channel and

$$\mathcal{Q}_{B^0} = 0.2930 \pm 0.0161 \pm 0.0021$$

for the neutral B meson channel

https://docs.belle2.org/record/2423

B tagging at Belle2

Method:

Belle II MC			
Category	Variable	$\varepsilon_{\text{eff}} \pm \delta\varepsilon_{\text{eff}}$	$\Delta\varepsilon_{\text{eff}} \pm \delta\Delta\varepsilon_{\text{eff}}$
Electron	$q \cdot y$	5.58 ± 0.01	0.25 ± 0.02
	$(q \cdot y)_{\text{eff}}$	5.68 ± 0.01	0.30 ± 0.02
Int. Electron	$q \cdot y$	1.40 ± 0.01	-0.22 ± 0.01
	$(q \cdot y)_{\text{eff}}$	1.43 ± 0.01	-0.18 ± 0.01
Muon	$q \cdot y$	5.64 ± 0.01	0.27 ± 0.02
	$(q \cdot y)_{\text{eff}}$	6.04 ± 0.01	0.30 ± 0.03
Int. Muon	$q \cdot y$	0.30 ± 0.01	-0.02 ± 0.01
	$(q \cdot y)_{\text{eff}}$	0.28 ± 0.01	0.00 ± 0.01
Kin. Lepton	$q \cdot y$	11.44 ± 0.02	0.43 ± 0.03
	$(q \cdot y)_{\text{eff}}$	12.05 ± 0.02	0.51 ± 0.04
Int. Kin. Lep.	$q \cdot y$	1.31 ± 0.01	-0.11 ± 0.01
	$(q \cdot y)_{\text{eff}}$	1.03 ± 0.01	-0.03 ± 0.01
Kaon	$q \cdot y$	17.57 ± 0.01	-0.56 ± 0.03
	$(q \cdot y)_{\text{eff}}$	21.19 ± 0.02	-0.76 ± 0.04
Kaon-Pion	$q \cdot y$	14.52 ± 0.01	-0.25 ± 0.03
	$(q \cdot y)_{\text{eff}}$	15.43 ± 0.01	-0.35 ± 0.03
Slow Pion	$q \cdot y$	9.89 ± 0.01	0.06 ± 0.02
	$(q \cdot y)_{\text{eff}}$	10.82 ± 0.01	0.10 ± 0.03
FSC	$q \cdot y$	13.74 ± 0.02	-0.17 ± 0.03
	$(q \cdot y)_{\text{eff}}$	14.64 ± 0.02	-0.11 ± 0.03
Maximum p^*	$q \cdot y$	12.99 ± 0.01	1.40 ± 0.03
	$(q \cdot y)_{\text{eff}}$	12.54 ± 0.01	0.93 ± 0.03
Fast Hadron	$q \cdot y$	4.70 ± 0.01	1.14 ± 0.01
	$(q \cdot y)_{\text{eff}}$	6.22 ± 0.01	1.46 ± 0.01
Lambda	$q \cdot y$	3.05 ± 0.01	0.79 ± 0.01
	$(q \cdot y)_{\text{eff}}$	2.41 ± 0.01	0.62 ± 0.01

Result:

Table 4.10: Effective efficiencies of the category-based flavor tagger and the deep-learning flavor tagger on Belle II MC and on Belle MC. All values are given in percent.

	Belle II MC	Belle MC
Approach	$\varepsilon_{\text{eff}} \pm \delta\varepsilon_{\text{eff}}$	$\varepsilon_{\text{eff}} \pm \delta\varepsilon_{\text{eff}}$
Category-based	36.64 ± 0.05	34.18 ± 0.06
Deep-learning [122]	40.69 ± 0.03	34.42 ± 0.09

https://edoc.ub.uni-muenchen.de/23003/

Jet charge at ATLAS

Method: The *jet charge* is defined as

$$Q_{\text{jet}} = \frac{\sum_i^{N\ \text{tracks}} q_i \cdot (p_{\text{T}i})^\kappa}{\sum_i^{N\ \text{tracks}} (p_{\text{T}i})^\kappa},$$

where $\kappa = 1.1$ and the sum is over the tracks associated with the jet, excluding those tracks associated with a primary vertex other than that of the signal decay and tracks from the signal candidate. Figure 4 shows the distribution of the opposite-side jet-charge for $B^\pm$ signal candidates.

Result:

Tagger	Efficiency [%]	Dilution [%]	Tagging Power [%]
Combined μ	4.12 ± 0.02	47.4 ± 0.2	0.92 ± 0.02
Electron	1.19 ± 0.01	49.2 ± 0.3	0.29 ± 0.01
Segment-tagged μ	1.20 ± 0.01	28.6 ± 0.2	0.10 ± 0.01
Jet-charge	13.15 ± 0.03	11.85 ± 0.03	0.19 ± 0.01
Total	19.66 ± 0.04	27.56 ± 0.06	1.49 ± 0.02

Table 1. Summary of tagging performance for the different flavour tagging methods described in the text. Uncertainties shown are statistical only. The efficiency and tagging power are each determined by summing over the individual bins of the charge distribution. The effective dilution is obtained from the measured efficiency and tagging power. For the efficiency, dilution, and tagging power, the corresponding uncertainty is determined by combining the appropriate uncertainties in the individual bins of each charge distribution.

https://link.springer.com/content/pdf/10.1007/JHEP08(2016)147.pdf

Jet charge at ATLAS

Method: There are a few approaches used for calculation of jet charge:

$$Q_J^{(1)} = \frac{1}{p_{T,J}^{\kappa}} \sum_{h \in \mathrm{Jet}} q_h \times (p_{T,h})^{\kappa}, \quad Q_J^{(2)} = \frac{\sum_{h \in \mathrm{Jet}} q_h |\vec{j} \cdot \vec{p}_h|^{\kappa}}{\sum_{h \in \mathrm{Jet}} |\vec{j} \cdot \vec{p}_h|^{\kappa}}, \quad Q_J^{(3)} = \sum_{h \in \mathrm{Jet}} z_h^{\kappa} q_h, \quad z_h = \frac{E_h}{E_J} \tag{1}$$

where q_h, $p_{T,h}$, E_h and $\vec{p}_h$ are the hadron (h) track charge, transverse momentum, energy and momentum, respectively, κ is an exponent (a free parameter), E_J is the jet energy, and $\vec{j}$ is the jet direction unit vector.

Result:

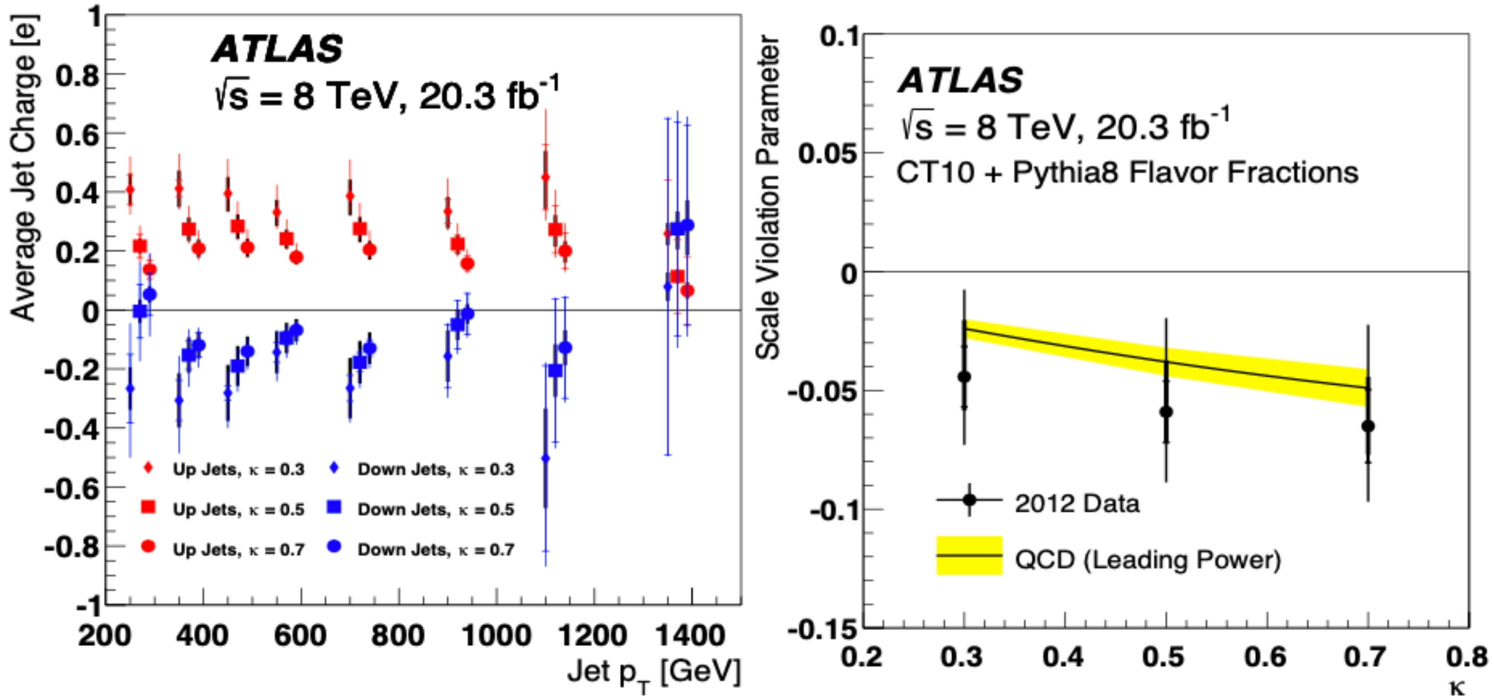


Figure 4: The extracted average u and d quark jet charges in bins of jet p_T for κ=0.3, 0.5, and 0.7 (left) and the extracted scale violation parameter c_κ from the data compared to theoretical calculations [5]. The error bars include statistical, experimental systematic, and PDF uncertainties added in quadrature (right).

https://cds.cern.ch/record/2255823/files/ATL-PHYS-PROC-2017-017.pdf

Jet charge at CMS

Method:

$$Q^\kappa = \frac{1}{(p_T^{\text{jet}})^\kappa} \sum_i Q_i (p_T^i)^\kappa,$$

$$Q_L^\kappa = \sum_i Q_i \left(p_\parallel^i\right)^\kappa \Big/ \sum_i \left(p_\parallel^i\right)^\kappa, \qquad p_\parallel^i = \vec{p}^i \cdot \vec{p}_{\text{jet}} / |\vec{p}_{\text{jet}}|$$

$$Q_T^\kappa = \sum_i Q_i \left(p_\perp^i\right)^\kappa \Big/ \sum_i \left(p_\perp^i\right)^\kappa. \qquad p_\perp^i = |\vec{p}^i \times \vec{p}_{\text{jet}}| / |\vec{p}_{\text{jet}}|$$

Result:

Table 1: Systematic uncertainties in terms of their corresponding inverse-variance-weighted mean in the fractional deviation as defined in Eq. (4) in percent (%).

Sources of uncertainty	$\kappa = 1.0$			$\kappa = 0.6$			$\kappa = 0.3$		
	Q^κ	Q_L^κ	Q_T^κ	Q^κ	Q_L^κ	Q_T^κ	Q^κ	Q_L^κ	Q_T^κ
Jet energy scale	0.7	<0.1	<0.1	0.4	<0.1	<0.1	0.3	<0.1	<0.1
Jet energy resolution	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Track reconstruction	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.4	0.4
Track p_T resolution	1.4	1.0	0.8	1.0	0.6	0.7	1.5	0.4	0.4
Pileup	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Response matrix modeling	1.6	1.6	1.8	1.0	0.8	1.3	1.5	1.3	1.3
Response matrix statistics	0.9	0.9	0.6	0.6	0.6	0.5	0.6	0.5	0.4

https://arxiv.org/abs/1706.05868v2

Jet charge at CEPC for B_s^0

Using the WHIZARD [16] generator, about 6000 $Z \to b\bar{b} \to B_s(\bar{B}_s)$

$$B_s^0 \to J/\psi\,\phi \to \mu^+\mu^- K^+K^- \quad (e^+e^-K^+K^-)$$

Method:

A simple algorithm is developed to identify the initial flavor of the particle. The idea of the algorithm is as follows:

The $b(\bar{b})$ quarks are predominantly produced in $b\bar{b}$ pairs that fly to the opposite side in space. The flavor of the opposite b quark can be used to determine the initial flavor of the interested B_s. To judge the flavor of this opposite b quark, we take a lepton and a charged kaon with maximum momentum in the opposite direction of the B_s. The charge of the lepton and the kaon provides the flavor of the opposite b quark. Furthermore, when the b quark is hadronized to a B_s meson, another s quark is spontaneously created, which then has the chance to become a charged kaon, flying in the similar direction as the B_s. Based on this kaon, one can identify the flavor of the particle. The algorithm simply takes the particle with the largest momentum. If these particles provide different determinants for the flavor, the algorithm simply says that it cannot identify the flavor.

Result:

The algorithm is applied to a Monte Carlo truth-level simulation, assuming perfect particle identification. With the tagging algorithm, the tagging efficiency is estimated as 67%. The miss-tagging rate is 22.5%. Thus, the tagging power is estimated to be 20.2%.

https://arxiv.org/abs/2205.10565v1

Effective tagging power

Definition of effective tagging power

Number, efficiency, and misjudgment rate ω:

$$\varepsilon = \frac{N^{\text{tag}}}{N}$$

$$N_{B^0}^{\text{tag}} = \varepsilon(1-w)N_{B^0} + \varepsilon w N_{\bar{B}^0}$$

$$N_{\bar{B}^0}^{\text{tag}} = \varepsilon(1-w)N_{\bar{B}^0} + \varepsilon w N_{B^0}$$

a_{CP}:

$$a_{\text{CP}}^{\text{obs}} = \frac{N_{B^0}^{\text{tag}} - N_{\bar{B}^0}^{\text{tag}}}{N_{B^0}^{\text{tag}} + N_{\bar{B}^0}^{\text{tag}}} = (1-2w)\cdot\frac{N_{B^0} - N_{\bar{B}^0}}{N_{B^0} + N_{\bar{B}^0}} = (1-2w)\cdot a_{\text{CP}} \qquad r \equiv |1-2w|$$

accuracy of a_{CP}:

$$\delta a_{\text{CP}} = \frac{\delta a_{\text{CP}}^{\text{obs}}}{1-2w} \qquad \delta a_{\text{CP}}^{\text{obs}} \overset{N_{B^0}^{\text{tag}} \approx N_{\bar{B}^0}^{\text{tag}}}{=} \frac{1}{\sqrt{N^{\text{tag}}}}$$

use effective tagging power to measure the accuracy:

$$\delta a_{\text{CP}} = \frac{1}{\sqrt{N^{\text{tag}}}(1-2w)} \qquad \varepsilon_{\text{eff}} = \frac{N^{\text{tag}}}{N}\cdot(1-2w)^2 = \varepsilon\cdot r^2$$

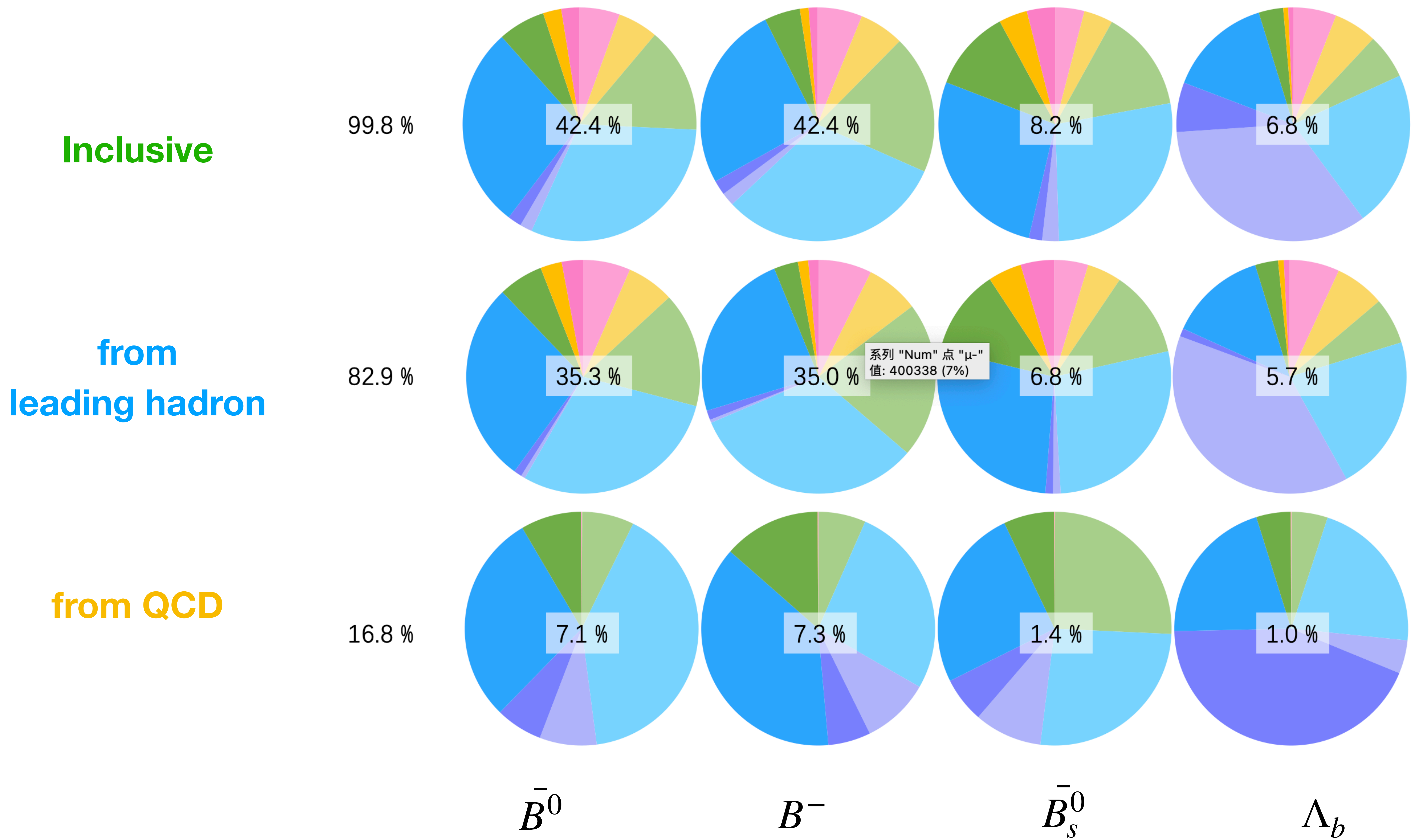
Total effective tagging power for independent sub-groups:

$$\varepsilon_{\text{eff}} = \sum_i \varepsilon_{\text{eff},i} = \sum_i \varepsilon_i\cdot(1-2w_i)^2$$

LPJC pie plots

b jet

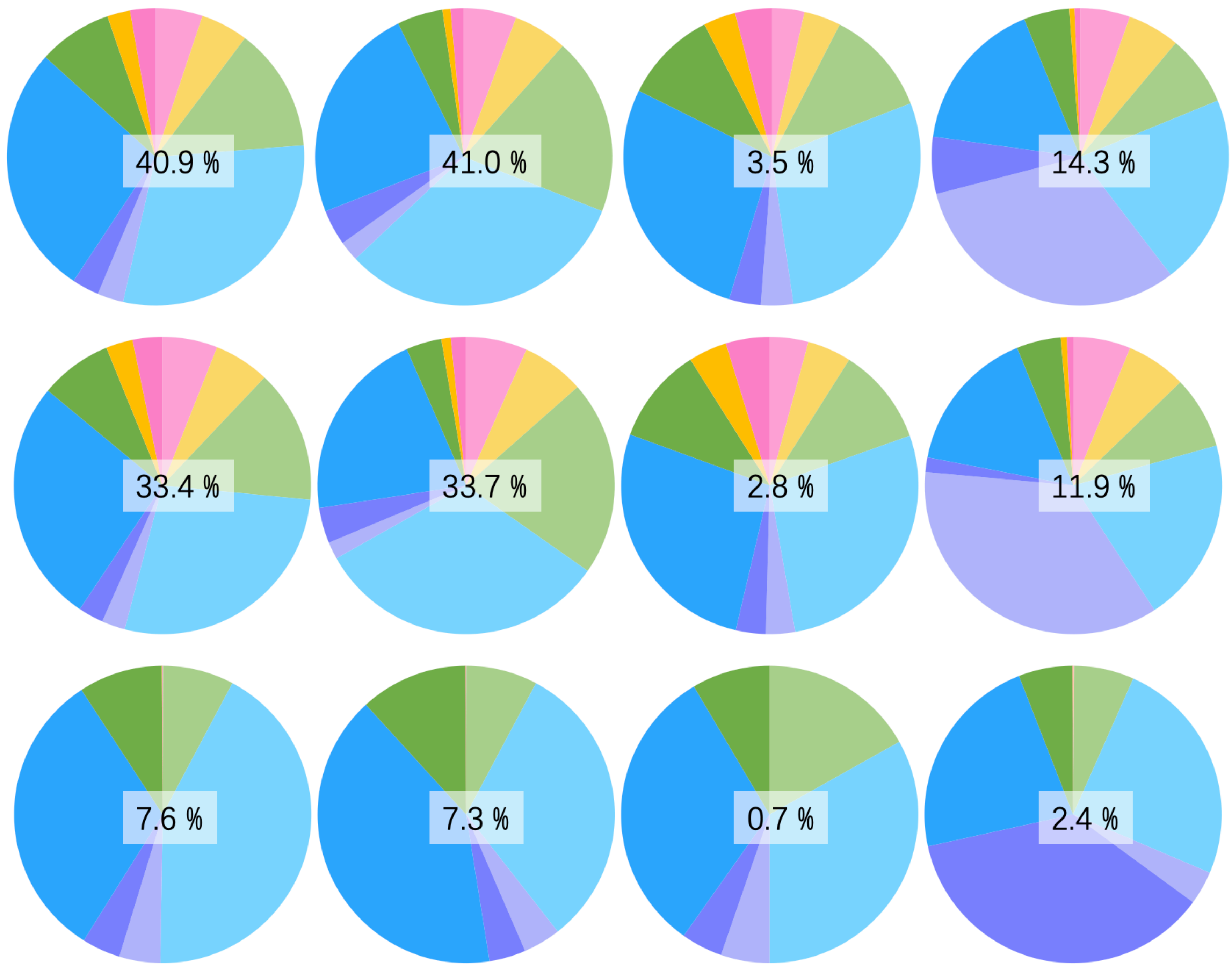
Percentage of leading particles



by WHIZARD195

b jet

Percentage of leading particles

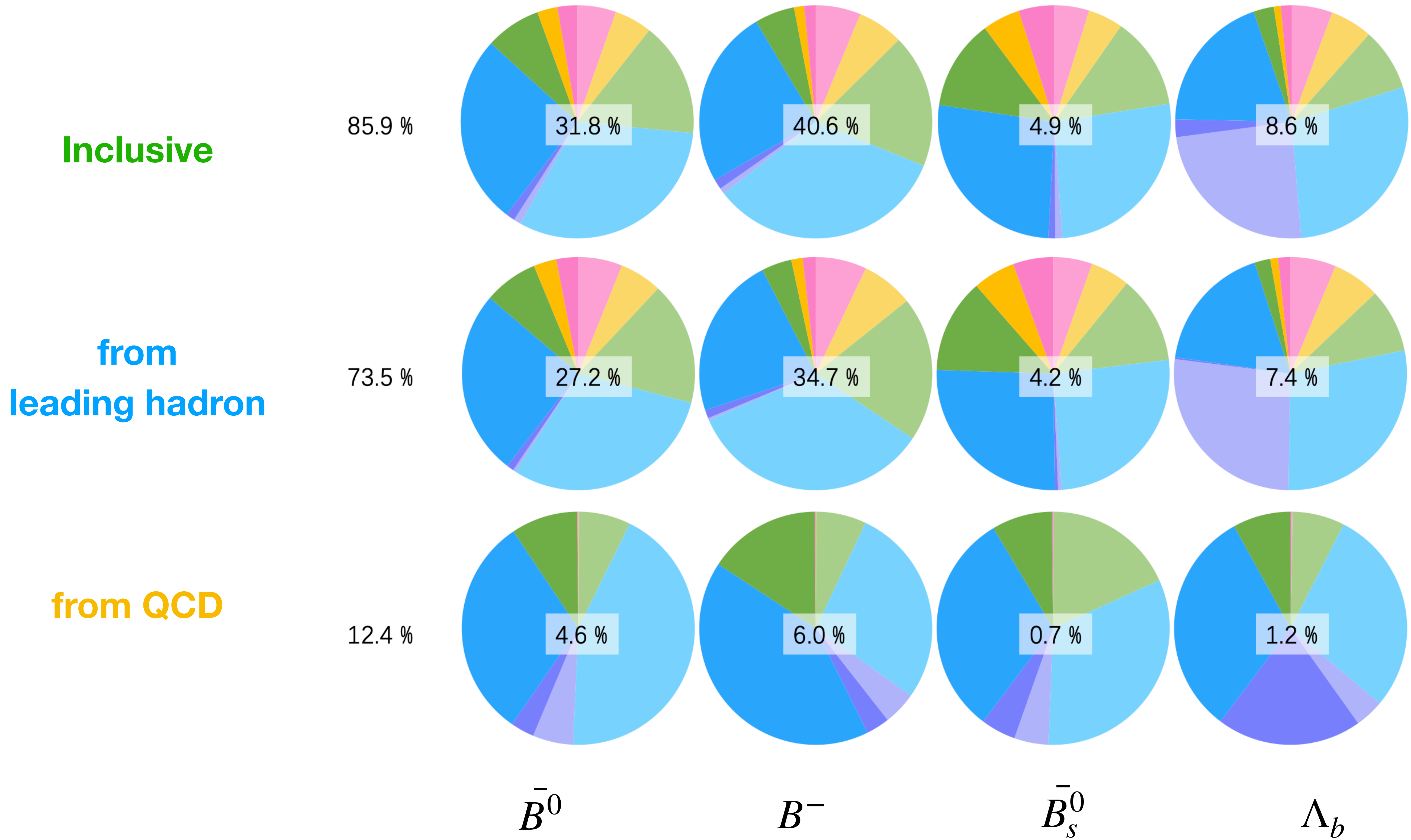


		$\bar{B}^0$	B^-	$\bar{B}_s^0$	Λ_b
Inclusive	99.7 %	40.9 %	41.0 %	3.5 %	14.3 %
from leading hadron	81.8 %	33.4 %	33.7 %	2.8 %	11.9 %
from QCD	17.9 %	7.6 %	7.3 %	0.7 %	2.4 %

by Herwig

b jet

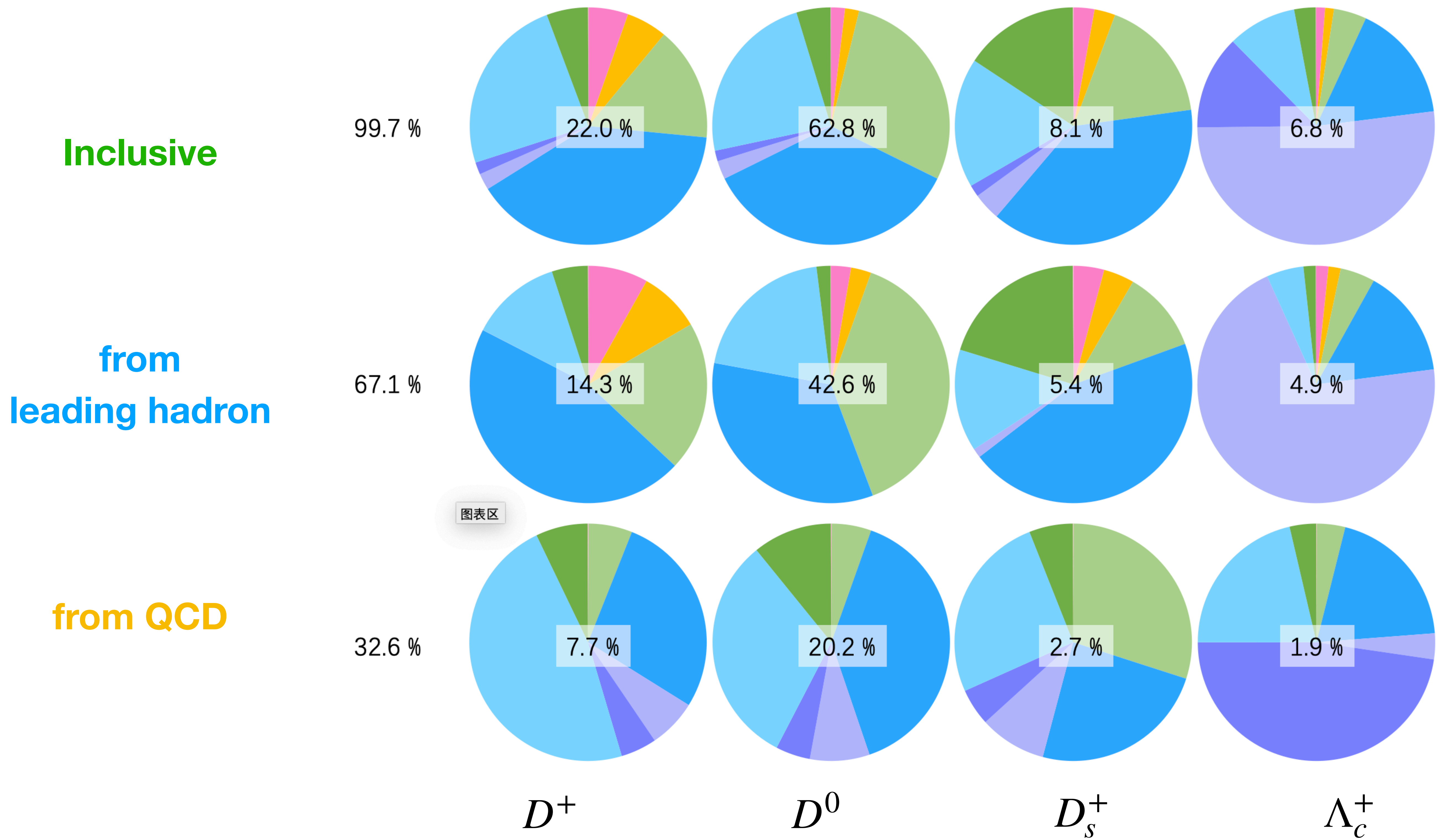
Percentage of leading particles



by Sherpa

c jet

Percentage of leading particles



by WHIZARD195

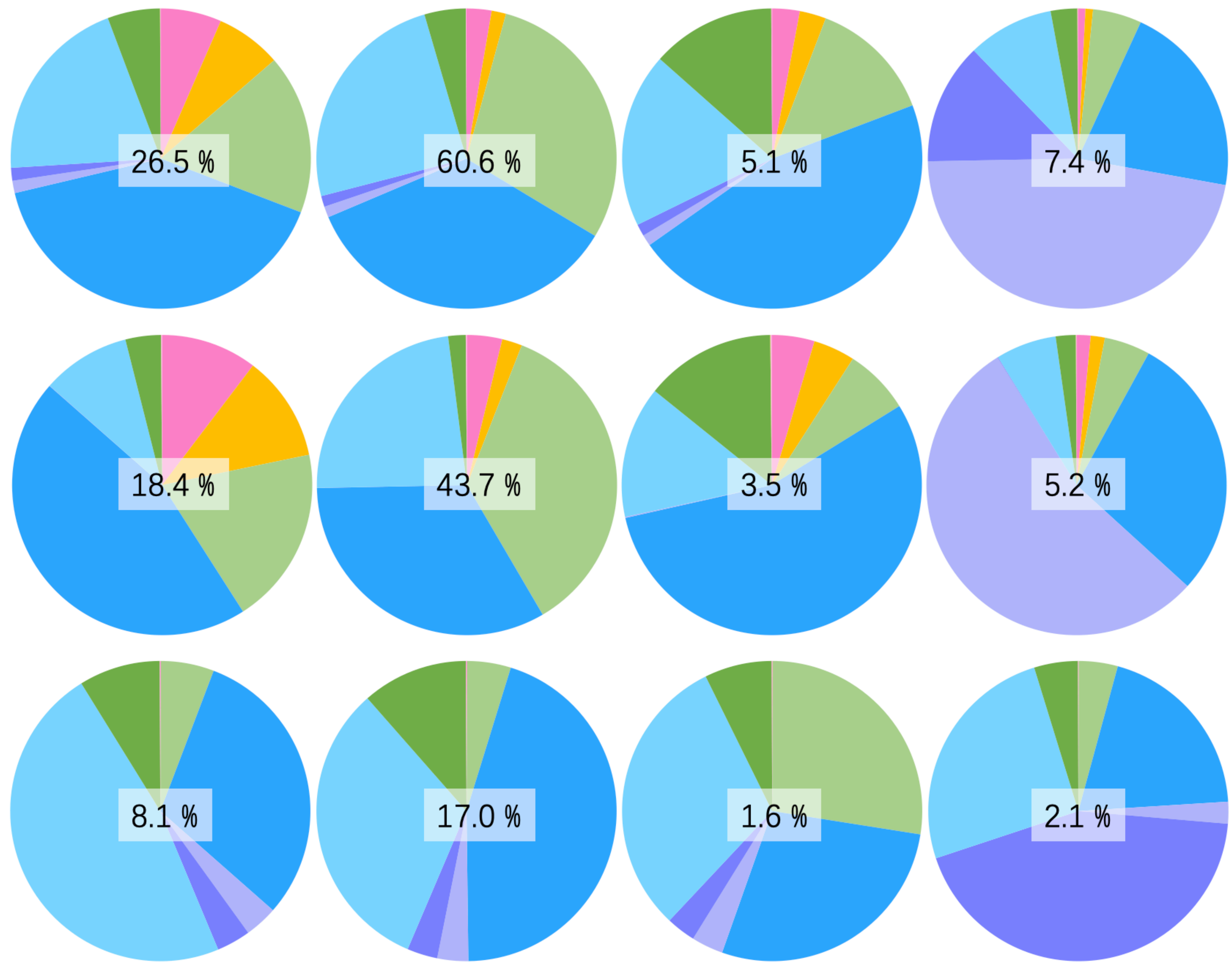
c jet

Percentage of leading particles

Inclusive 99.6 %

from leading hadron 70.8 %

from QCD 28.8 %

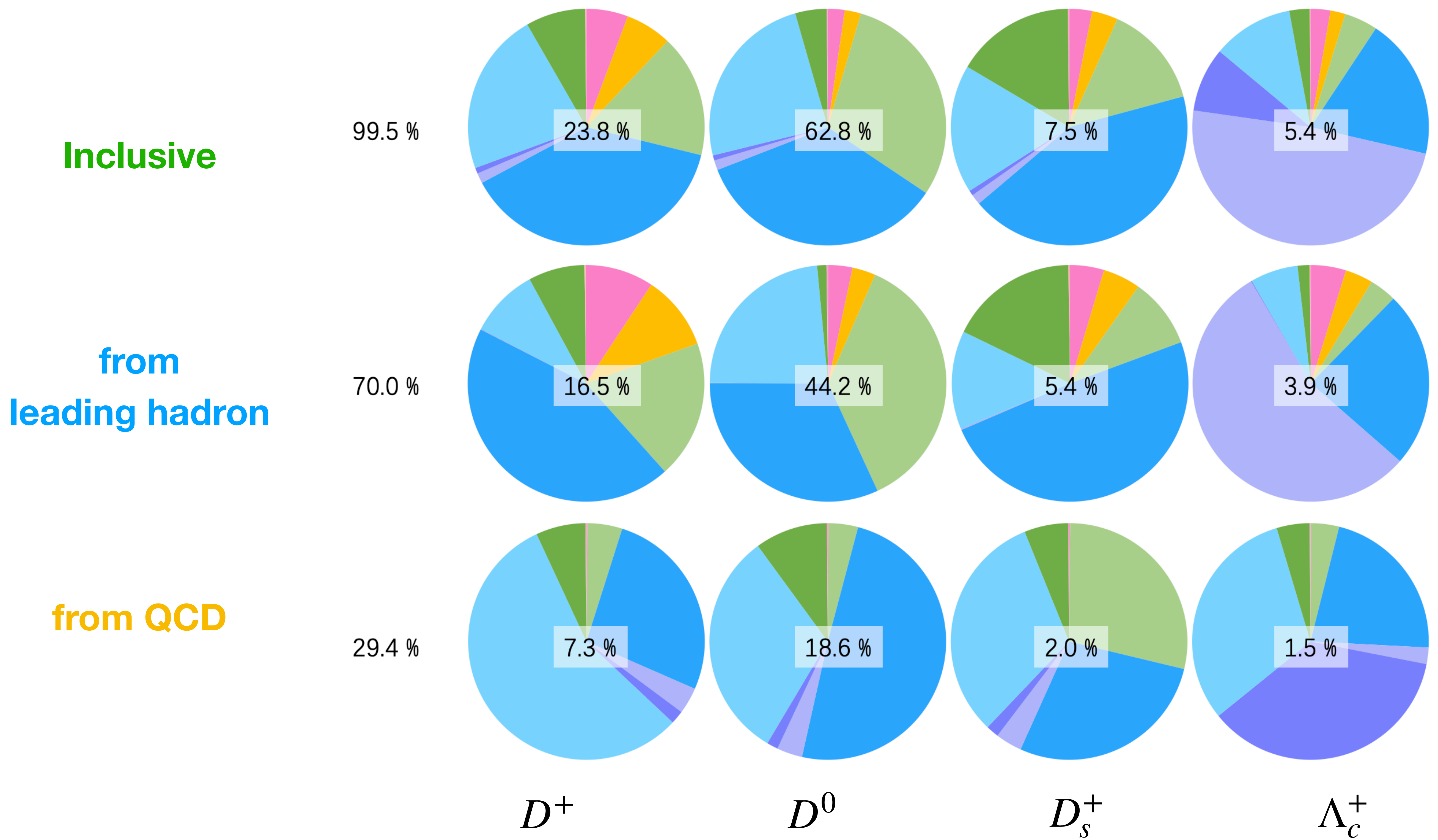


D^+ D^0 D_s^+ Λ_c^+

by Herwig

c jet

Percentage of leading particles



by Sherpa

HFJC*
distinguish LP origin
(b/c hadron / QCD)

source	leading particle	b jet									c jet								
		Whizard			Herwig			Sherpa			Whizard			Herwig			Sherpa		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	7.6%	21.6%	2.5%	7.3%	21.3%	2.4%	7.8%	21.9%	2.4%	2.7%	1.9%	2.5%	3.6%	1.8%	3.4%	3.3%	2.7%	2.9%
	μ	7.6%	21.2%	2.5%	7.0%	20.2%	2.5%	7.8%	22.5%	2.4%	2.7%	0.5%	2.7%	3.0%	0.4%	3.0%	3.3%	0.7%	3.2%
	K	21.8%	23.8%	6.0%	21.3%	25.6%	5.1%	22.9%	23.9%	6.2%	28.4%	15.2%	13.8%	28.5%	14.3%	14.5%	30.0%	15.0%	14.7%
	π	56.2%	31.1%	8.1%	53.2%	31.8%	7.1%	56.8%	28.9%	10.2%	57.3%	22.9%	16.8%	58.0%	22.8%	17.2%	58.1%	22.4%	17.7%
	p	6.7%	28.1%	1.3%	11.2%	28.4%	2.1%	4.7%	24.0%	1.3%	8.9%	19.8%	3.2%	6.9%	21.5%	2.2%	5.4%	17.0%	2.3%
	sum	100.0%	27.4%	20.4%	100.0%	28.2%	19.1%	100.0%	26.3%	22.5%	100.0%	18.8%	39.0%	100.0%	18.3%	40.3%	100.0%	18.1%	40.8%
heavy hadron	e	7.5%	15.9%	3.5%	7.1%	15.6%	3.3%	7.6%	17.0%	3.3%	2.7%	1.1%	2.6%	3.6%	1.2%	3.4%	3.2%	1.8%	3.0%
	μ	7.6%	15.9%	3.5%	6.8%	15.7%	3.2%	7.7%	17.3%	3.3%	2.7%	0.4%	2.7%	3.0%	0.3%	3.0%	3.3%	0.6%	3.2%
	K	18.8%	14.3%	9.6%	18.1%	15.6%	8.6%	20.1%	16.4%	9.0%	23.1%	4.3%	19.2%	23.5%	4.4%	19.5%	24.9%	3.2%	21.8%
	π	45.6%	18.2%	18.5%	41.8%	18.6%	16.5%	47.0%	18.8%	18.3%	35.4%	19.5%	13.2%	37.6%	19.4%	14.1%	36.5%	20.2%	12.9%
	p	3.6%	15.5%	1.7%	8.2%	15.6%	3.9%	3.1%	14.0%	1.6%	3.5%	0.4%	3.4%	3.4%	0.4%	3.3%	2.6%	0.7%	2.5%
	sum	83.1%	16.7%	36.8%	82.0%	17.1%	35.6%	85.5%	17.7%	35.6%	67.3%	10.9%	41.1%	71.1%	10.9%	43.4%	70.4%	10.7%	43.4%
QCD	e	0.1%	20.9%	0.0%	0.2%	14.7%	0.1%	0.2%	15.8%	0.1%	0.1%	25.8%	0.0%	0.0%	29.1%	0.0%	0.1%	36.5%	0.0%
	μ	0.1%	17.9%	0.0%	0.2%	12.4%	0.1%	0.1%	14.2%	0.1%	0.0%	8.8%	0.0%	0.0%	17.0%	0.0%	0.0%	24.2%	0.0%
	K	3.0%	45.5%	0.0%	3.2%	46.6%	0.0%	2.8%	46.0%	0.0%	5.3%	40.3%	0.2%	5.0%	39.8%	0.2%	5.1%	37.3%	0.3%
	π	10.6%	49.3%	0.0%	11.4%	48.3%	0.0%	9.8%	48.1%	0.0%	21.9%	39.6%	0.9%	20.3%	41.2%	0.6%	21.6%	39.6%	0.9%
	p	3.1%	44.0%	0.0%	3.0%	38.4%	0.2%	1.6%	38.2%	0.1%	5.4%	41.5%	0.2%	3.5%	38.0%	0.2%	2.8%	41.7%	0.1%
	sum	16.9%	45.3%	0.1%	18.0%	42.4%	0.4%	14.5%	43.1%	0.3%	32.7%	39.9%	1.3%	28.9%	40.4%	1.1%	29.6%	39.3%	1.4%
sum	e	7.6%	16.0%	3.5%	7.3%	15.5%	3.5%	7.8%	17.0%	3.4%	2.7%	1.5%	2.6%	3.6%	1.4%	3.4%	3.3%	2.1%	3.0%
	μ	7.6%	16.0%	3.5%	7.0%	15.6%	3.3%	7.8%	17.2%	3.4%	2.7%	0.5%	2.7%	3.0%	0.3%	3.0%	3.3%	0.7%	3.2%
	K	21.8%	16.9%	9.6%	21.3%	18.2%	8.6%	22.9%	18.6%	9.1%	28.4%	8.6%	19.4%	28.5%	8.4%	19.7%	30.0%	7.0%	22.1%
	π	56.2%	21.3%	18.5%	53.2%	22.1%	16.5%	56.8%	21.6%	18.3%	57.3%	25.1%	14.2%	58.0%	24.8%	14.8%	58.1%	25.6%	13.9%
	p	6.7%	24.3%	1.8%	11.2%	19.9%	4.0%	4.7%	19.8%	1.7%	8.9%	18.2%	3.6%	6.9%	14.2%	3.5%	5.4%	15.3%	2.6%
	sum	100.0%	19.6%	36.9%	100.0%	20.0%	36.0%	100.0%	20.1%	35.8%	100.0%	17.4%	42.4%	100.0%	16.7%	44.4%	100.0%	16.5%	44.8%
comb	e	7.6%	16.0%	3.5%	7.3%	15.5%	3.5%	7.8%	17.0%	3.4%	2.7%	1.5%	2.6%	3.6%	1.4%	3.4%	3.3%	2.1%	3.0%
	μ	7.6%	16.0%	3.5%	7.0%	15.6%	3.3%	7.8%	17.2%	3.4%	2.7%	0.5%	2.7%	3.0%	0.4%	3.0%	3.3%	0.7%	3.2%
	K	21.8%	16.9%	9.6%	21.3%	18.2%	8.6%	22.9%	18.6%	9.1%	28.4%	8.6%	19.4%	28.5%	8.4%	19.7%	30.0%	7.0%	22.1%
	π	56.2%	21.3%	18.5%	53.2%	22.1%	16.5%	56.8%	21.6%	18.3%	57.3%	22.9%	16.8%	58.0%	22.8%	17.2%	58.1%	22.4%	17.7%
	p	6.7%	24.3%	1.8%	11.2%	19.9%	4.0%	4.7%	19.8%	1.7%	8.9%	18.2%	3.6%	6.9%	14.2%	3.5%	5.4%	15.3%	2.6%
	sum	100.0%	19.6%	36.9%	100.0%	20.0%	36.0%	100.0%	20.1%	35.8%	100.0%	16.4%	45.0%	100.0%	15.8%	46.8%	100.0%	15.1%	48.6%

HFJC**
distinguish LP origin
&
leading heavy hadron type

source	leading particle	b jet by Whizard																	
		inclusive			$\bar{B}^0$			B^-			$\bar{B}_s^0$			Λ_b			sum		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	7.6%	21.6%	2.5%	3.4%	25.3%	0.8%	3.1%	13.1%	1.7%	0.6%	32.3%	0.1%	0.4%	10.3%	0.3%	7.6%	41.5%	2.9%
	μ	7.6%	21.2%	2.5%	3.4%	25.3%	0.8%	3.1%	13.1%	1.7%	0.7%	32.3%	0.1%	0.4%	10.2%	0.3%	7.6%	41.5%	2.9%
	K	21.8%	23.8%	6.0%	8.9%	25.6%	2.1%	10.1%	18.2%	4.1%	2.1%	31.6%	0.3%	0.7%	28.5%	0.1%	21.7%	37.1%	6.6%
	π	56.2%	31.1%	8.1%	25.0%	31.8%	3.3%	24.2%	29.7%	4.0%	4.5%	32.7%	0.5%	2.5%	30.6%	0.4%	56.1%	35.7%	8.2%
	p	6.7%	28.1%	1.3%	1.7%	32.3%	0.2%	1.8%	31.4%	0.3%	0.4%	31.6%	0.1%	2.8%	15.1%	1.3%	6.7%	43.2%	1.9%
	sum	100.0%	27.4%	20.4%	42.4%	29.2%	7.3%	42.4%	23.7%	11.7%	8.2%	32.3%	1.0%	6.8%	20.2%	2.4%	99.8%	26.3%	22.5%
heavy hadron	e	7.5%	15.9%	3.5%	3.4%	29.9%	0.5%	3.1%	0.4%	3.0%	0.6%	48.8%	0.0%	0.4%	10.3%	0.3%	7.5%	40.2%	3.9%
	μ	7.6%	15.9%	3.5%	3.4%	30.0%	0.5%	3.1%	0.4%	3.0%	0.6%	48.6%	0.0%	0.4%	10.2%	0.3%	7.5%	40.2%	3.9%
	K	18.8%	14.3%	9.6%	7.8%	27.7%	1.6%	8.7%	0.3%	8.6%	1.6%	49.0%	0.0%	0.5%	32.2%	0.1%	18.7%	34.0%	10.2%
	π	45.6%	18.2%	18.5%	20.2%	43.7%	0.3%	19.5%	0.5%	19.2%	3.8%	48.9%	0.0%	2.0%	37.9%	0.1%	45.5%	27.9%	19.6%
	p	3.6%	15.5%	1.7%	0.6%	33.6%	0.1%	0.6%	0.4%	0.6%	0.1%	49.0%	0.0%	2.3%	2.8%	2.0%	3.6%	41.8%	2.7%
	sum	83.1%	16.7%	36.8%	35.3%	35.4%	3.0%	35.0%	0.4%	34.5%	6.8%	48.9%	0.0%	5.7%	15.2%	2.8%	82.9%	15.2%	40.3%
QCD	e	0.1%	20.9%	0.0%	0.0%	19.2%	0.0%	0.0%	21.0%	0.0%	0.0%	19.1%	0.0%	0.0%	29.2%	0.0%	0.1%	49.0%	0.0%
	μ	0.1%	17.9%	0.0%	0.0%	16.5%	0.0%	0.0%	18.0%	0.0%	0.0%	17.1%	0.0%	0.0%	27.0%	0.0%	0.1%	49.0%	0.0%
	K	3.0%	45.5%	0.0%	1.1%	33.1%	0.1%	1.4%	23.9%	0.4%	0.4%	20.6%	0.1%	0.1%	32.2%	0.0%	3.0%	45.9%	0.7%
	π	10.6%	49.3%	0.0%	4.8%	31.2%	0.7%	4.6%	26.8%	1.0%	0.7%	32.6%	0.1%	0.4%	32.3%	0.1%	10.6%	43.3%	1.8%
	p	3.1%	44.0%	0.0%	1.1%	30.6%	0.2%	1.2%	28.1%	0.2%	0.2%	28.9%	0.0%	0.5%	13.3%	0.3%	3.1%	45.8%	0.7%
	sum	16.9%	45.3%	0.1%	7.1%	31.2%	1.0%	7.3%	26.3%	1.7%	1.4%	27.5%	0.3%	1.0%	21.6%	0.3%	16.8%	28.0%	3.3%
sum	e	7.6%	16.0%	3.5%	3.4%	29.8%	0.6%	3.1%	0.6%	3.1%	0.6%	46.2%	0.0%	0.4%	10.1%	0.3%	7.6%	14.3%	3.9%
	μ	7.6%	16.0%	3.5%	3.4%	29.8%	0.6%	3.1%	0.6%	3.1%	0.7%	46.2%	0.0%	0.4%	10.0%	0.3%	7.6%	14.3%	3.9%
	K	21.8%	16.9%	9.6%	8.9%	28.3%	1.7%	10.1%	2.9%	9.0%	2.1%	36.7%	0.1%	0.7%	32.2%	0.1%	21.7%	14.6%	10.9%
	π	56.2%	21.3%	18.5%	25.0%	40.0%	1.0%	24.2%	4.3%	20.2%	4.5%	43.0%	0.1%	2.5%	36.7%	0.2%	56.1%	19.1%	21.4%
	p	6.7%	24.3%	1.8%	1.7%	31.6%	0.2%	1.8%	16.3%	0.8%	0.4%	33.4%	0.0%	2.8%	4.4%	2.3%	6.7%	14.4%	3.4%
	sum	100.0%	19.6%	36.9%	42.4%	34.6%	4.0%	42.4%	3.8%	36.1%	8.2%	40.7%	0.3%	6.8%	16.0%	3.1%	99.7%	17.0%	43.5%
comb	e	7.6%	16.0%	3.5%	3.4%	25.3%	0.8%	3.1%	0.6%	3.1%	0.6%	32.3%	0.1%	0.4%	10.3%	0.3%	7.6%	12.7%	4.2%
	μ	7.6%	16.0%	3.5%	3.4%	25.3%	0.8%	3.1%	0.6%	3.1%	0.7%	32.3%	0.1%	0.4%	10.2%	0.3%	7.6%	12.7%	4.2%
	K	21.8%	16.9%	9.6%	8.9%	25.6%	2.1%	10.1%	2.9%	9.0%	2.1%	31.6%	0.3%	0.7%	28.5%	0.1%	21.7%	13.6%	11.5%
	π	56.2%	21.3%	18.5%	25.0%	31.8%	3.3%	24.2%	4.3%	20.2%	4.5%	32.7%	0.5%	2.5%	30.6%	0.4%	56.1%	17.0%	24.4%
	p	6.7%	24.3%	1.8%	1.7%	31.6%	0.2%	1.8%	16.3%	0.8%	0.4%	31.6%	0.1%	2.8%	4.4%	2.3%	6.7%	14.3%	3.4%
	sum	100.0%	19.6%	36.9%	42.4%	29.2%	7.3%	42.4%	3.8%	36.1%	8.2%	32.3%	1.0%	6.8%	14.8%	3.4%	99.8%	15.4%	47.8%

source	leading particle	b jet by Herwig																	
		inclusive			$\bar{B}^0$			B^-			$\bar{B}_s^0$			Λ_b			sum		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	7.3%	21.3%	2.4%	3.1%	27.1%	0.7%	2.9%	14.8%	1.5%	0.3%	32.8%	0.0%	0.9%	9.1%	0.6%	7.3%	41.7%	2.8%
	μ	7.0%	20.2%	2.5%	3.1%	26.5%	0.7%	2.8%	11.7%	1.6%	0.2%	33.1%	0.0%	0.9%	8.7%	0.6%	7.0%	41.4%	2.9%
	K	21.3%	25.6%	5.1%	8.8%	29.5%	1.5%	9.8%	19.7%	3.6%	0.8%	32.7%	0.1%	1.9%	31.6%	0.3%	21.2%	38.4%	5.4%
	π	53.2%	31.8%	7.1%	23.1%	32.3%	2.9%	22.6%	30.2%	3.6%	2.0%	33.4%	0.2%	5.4%	33.1%	0.6%	53.1%	36.5%	7.3%
	p	11.2%	28.4%	2.1%	2.8%	32.5%	0.3%	2.9%	31.3%	0.4%	0.3%	32.8%	0.0%	5.2%	15.1%	2.5%	11.1%	40.9%	3.3%
	sum	100.0%	28.2%	19.1%	40.9%	30.8%	6.0%	41.0%	24.5%	10.6%	3.5%	33.1%	0.4%	14.3%	21.5%	4.7%	99.7%	26.7%	21.7%
heavy hadron	e	7.1%	15.6%	3.3%	3.1%	32.9%	0.4%	2.8%	0.4%	2.8%	0.2%	48.2%	0.0%	0.9%	9.1%	0.6%	7.0%	40.3%	3.8%
	μ	6.8%	15.7%	3.2%	3.0%	32.4%	0.4%	2.7%	0.4%	2.6%	0.2%	48.8%	0.0%	0.9%	8.7%	0.6%	6.8%	40.5%	3.6%
	K	18.1%	15.6%	8.6%	7.5%	34.6%	0.7%	8.5%	0.4%	8.3%	0.6%	49.1%	0.0%	1.5%	37.4%	0.1%	18.1%	34.9%	9.1%
	π	41.8%	18.6%	16.5%	18.1%	45.2%	0.2%	17.8%	0.5%	17.4%	1.6%	48.8%	0.0%	4.3%	42.3%	0.1%	41.7%	29.0%	17.7%
	p	8.2%	15.6%	3.9%	1.8%	46.4%	0.0%	1.9%	0.4%	1.9%	0.2%	49.0%	0.0%	4.3%	4.3%	3.6%	8.2%	38.3%	5.5%
	sum	82.0%	17.1%	35.6%	33.4%	39.0%	1.6%	33.7%	0.5%	33.1%	2.8%	48.8%	0.0%	11.9%	17.6%	5.0%	81.8%	15.2%	39.7%
QCD	e	0.2%	14.7%	0.1%	0.1%	14.9%	0.0%	0.1%	14.7%	0.0%	0.0%	24.8%	0.0%	0.0%	13.7%	0.0%	0.2%	48.3%	0.1%
	μ	0.2%	12.4%	0.1%	0.1%	12.3%	0.0%	0.1%	12.4%	0.0%	0.0%	24.4%	0.0%	0.0%	12.0%	0.0%	0.2%	48.3%	0.1%
	K	3.2%	46.6%	0.0%	1.3%	34.6%	0.1%	1.3%	30.3%	0.2%	0.2%	27.8%	0.0%	0.3%	34.9%	0.0%	3.2%	46.8%	0.4%
	π	11.4%	48.3%	0.0%	5.1%	33.3%	0.6%	4.8%	31.2%	0.7%	0.4%	34.8%	0.0%	1.1%	35.4%	0.1%	11.4%	44.1%	1.4%
	p	3.0%	38.4%	0.2%	1.0%	29.0%	0.2%	1.0%	34.5%	0.1%	0.1%	30.3%	0.0%	0.9%	19.6%	0.3%	3.0%	46.1%	0.6%
	sum	18.0%	42.4%	0.4%	7.6%	32.2%	1.0%	7.3%	30.8%	1.1%	0.7%	31.6%	0.1%	2.4%	27.6%	0.5%	18.0%	30.9%	2.6%
sum	e	7.3%	15.5%	3.5%	3.1%	32.1%	0.4%	2.9%	0.8%	2.8%	0.3%	43.6%	0.0%	0.9%	9.2%	0.6%	7.3%	13.5%	3.9%
	μ	7.0%	15.6%	3.3%	3.1%	31.5%	0.4%	2.8%	0.7%	2.7%	0.3%	43.7%	0.0%	0.9%	8.8%	0.6%	7.0%	13.5%	3.7%
	K	21.3%	18.2%	8.6%	8.8%	34.6%	0.8%	9.8%	3.3%	8.5%	0.8%	39.2%	0.0%	1.9%	36.9%	0.1%	21.2%	16.5%	9.5%
	π	53.2%	22.1%	16.5%	23.1%	41.1%	0.7%	22.6%	5.2%	18.1%	2.0%	43.0%	0.0%	5.4%	40.4%	0.2%	53.1%	20.0%	19.1%
	p	11.2%	19.9%	4.0%	2.8%	36.9%	0.2%	2.9%	8.7%	2.0%	0.3%	38.6%	0.0%	5.2%	6.5%	3.9%	11.1%	13.0%	6.1%
	sum	100.0%	20.0%	36.0%	40.9%	37.5%	2.6%	41.0%	4.4%	34.1%	3.5%	41.7%	0.1%	14.3%	19.0%	5.5%	99.7%	17.4%	42.3%
comb	e	7.3%	15.5%	3.5%	3.1%	27.1%	0.7%	2.9%	0.8%	2.8%	0.3%	32.8%	0.0%	0.9%	9.1%	0.6%	7.3%	12.2%	4.1%
	μ	7.0%	15.6%	3.3%	3.1%	26.5%	0.7%	2.8%	0.7%	2.7%	0.2%	33.1%	0.0%	0.9%	8.7%	0.6%	7.0%	12.2%	4.0%
	K	21.3%	18.2%	8.6%	8.8%	29.5%	1.5%	9.8%	3.3%	8.5%	0.8%	32.7%	0.1%	1.9%	31.6%	0.3%	21.2%	15.1%	10.4%
	π	53.2%	22.1%	16.5%	23.1%	32.3%	2.9%	22.6%	5.2%	18.1%	2.0%	33.4%	0.2%	5.4%	33.1%	0.6%	53.1%	17.9%	21.8%
	p	11.2%	19.9%	4.0%	2.8%	32.5%	0.3%	2.9%	8.7%	2.0%	0.3%	32.8%	0.0%	5.2%	6.5%	3.9%	11.1%	12.5%	6.3%
	sum	100.0%	20.0%	36.0%	40.9%	30.8%	6.0%	41.0%	4.4%	34.1%	3.5%	33.1%	0.4%	14.3%	17.5%	6.0%	99.7%	15.8%	46.6%

source	leading particle	b jet by Sherpa																	
		inclusive			$\bar{B}^0$			B^-			$\bar{B}_s^0$			Λ_b			sum		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	7.8%	21.9%	2.4%	2.5%	16.7%	1.1%	3.1%	14.9%	1.5%	0.5%	12.5%	0.3%	0.6%	16.2%	0.3%	6.7%	41.1%	3.2%
	μ	7.8%	22.5%	2.4%	2.5%	17.1%	1.1%	3.1%	15.0%	1.5%	0.5%	14.1%	0.2%	0.6%	15.0%	0.3%	6.7%	41.1%	3.1%
	K	22.9%	23.9%	6.2%	7.4%	18.8%	2.9%	9.8%	18.8%	3.8%	1.2%	28.3%	0.2%	1.0%	20.7%	0.4%	19.5%	36.5%	7.3%
	π	56.8%	28.9%	10.2%	18.6%	28.1%	3.6%	23.5%	27.6%	4.7%	2.7%	29.6%	0.4%	4.0%	28.1%	0.8%	48.8%	34.6%	9.5%
	p	4.7%	24.0%	1.3%	0.8%	29.0%	0.1%	1.1%	30.3%	0.2%	0.1%	29.9%	0.0%	2.3%	8.9%	1.5%	4.3%	43.2%	1.9%
	sum	100.0%	26.3%	22.5%	31.8%	23.7%	8.8%	40.6%	23.1%	11.8%	4.9%	25.4%	1.2%	8.6%	19.2%	3.2%	85.9%	23.0%	25.0%
heavy hadron	e	7.6%	17.0%	3.3%	2.4%	19.3%	0.9%	3.1%	0.4%	3.0%	0.5%	13.0%	0.2%	0.6%	17.7%	0.2%	6.5%	39.5%	4.4%
	μ	7.7%	17.3%	3.3%	2.5%	20.3%	0.9%	3.0%	0.4%	3.0%	0.5%	14.8%	0.2%	0.6%	15.6%	0.3%	6.6%	39.6%	4.4%
	K	20.1%	16.4%	9.0%	6.7%	17.8%	2.8%	8.6%	0.4%	8.4%	1.0%	42.9%	0.0%	0.8%	19.4%	0.3%	17.1%	33.0%	11.5%
	π	47.0%	18.8%	18.3%	15.3%	37.0%	1.0%	19.5%	0.5%	19.1%	2.2%	44.9%	0.0%	3.3%	39.6%	0.1%	40.4%	27.5%	20.3%
	p	3.1%	14.0%	1.6%	0.4%	18.8%	0.1%	0.5%	0.3%	0.5%	0.0%	22.9%	0.0%	2.0%	1.1%	1.9%	2.9%	42.0%	2.6%
	sum	85.5%	17.7%	35.6%	27.2%	27.1%	5.7%	34.7%	0.5%	34.0%	4.2%	32.2%	0.5%	7.4%	18.5%	2.9%	73.5%	11.7%	43.2%
QCD	e	0.2%	15.8%	0.1%	0.1%	15.5%	0.0%	0.1%	16.0%	0.0%	0.0%	24.3%	0.0%	0.0%	19.0%	0.0%	0.1%	48.7%	0.1%
	μ	0.1%	14.2%	0.1%	0.0%	12.7%	0.0%	0.1%	15.8%	0.0%	0.0%	27.1%	0.0%	0.0%	17.8%	0.0%	0.1%	48.8%	0.1%
	K	2.8%	46.0%	0.0%	0.8%	32.0%	0.1%	1.3%	28.8%	0.2%	0.2%	26.0%	0.0%	0.2%	31.0%	0.0%	2.4%	46.8%	0.4%
	π	9.8%	48.1%	0.0%	3.3%	31.4%	0.5%	4.0%	28.6%	0.7%	0.4%	31.8%	0.1%	0.7%	31.4%	0.1%	8.4%	44.2%	1.3%
	p	1.6%	38.2%	0.1%	0.4%	27.0%	0.1%	0.6%	28.5%	0.1%	0.1%	26.8%	0.0%	0.3%	22.5%	0.1%	1.4%	47.3%	0.3%
	sum	14.5%	43.1%	0.3%	4.6%	30.5%	0.7%	6.0%	28.3%	1.1%	0.7%	29.5%	0.1%	1.2%	28.7%	0.2%	12.5%	29.2%	2.2%
sum	e	7.8%	17.0%	3.4%	2.5%	19.2%	0.9%	3.1%	0.7%	3.0%	0.5%	13.4%	0.3%	0.6%	17.7%	0.2%	6.7%	9.0%	4.5%
	μ	7.8%	17.2%	3.4%	2.5%	20.2%	0.9%	3.1%	0.7%	3.0%	0.5%	15.1%	0.2%	0.6%	15.6%	0.3%	6.7%	9.3%	4.4%
	K	22.9%	18.6%	9.1%	7.4%	19.0%	2.9%	9.8%	3.1%	8.7%	1.2%	38.9%	0.1%	1.0%	21.1%	0.3%	19.5%	10.9%	11.9%
	π	56.8%	21.6%	18.3%	18.6%	35.9%	1.5%	23.5%	4.1%	19.8%	2.7%	41.3%	0.1%	4.0%	37.8%	0.2%	48.8%	16.7%	21.6%
	p	4.7%	19.8%	1.7%	0.8%	22.9%	0.2%	1.1%	12.5%	0.6%	0.1%	25.1%	0.0%	2.3%	3.1%	2.0%	4.3%	9.1%	2.9%
	sum	100.0%	20.1%	35.8%	31.8%	27.5%	6.4%	40.6%	3.5%	35.1%	4.9%	31.8%	0.7%	8.6%	19.8%	3.1%	86.0%	13.7%	45.3%
comb	e	7.8%	17.0%	3.4%	2.5%	16.7%	1.1%	3.1%	0.7%	3.0%	0.5%	12.5%	0.3%	0.6%	16.2%	0.3%	6.7%	8.2%	4.7%
	μ	7.8%	17.2%	3.4%	2.5%	17.1%	1.1%	3.1%	0.7%	3.0%	0.5%	14.1%	0.2%	0.6%	15.0%	0.3%	6.7%	8.3%	4.6%
	K	22.9%	18.6%	9.1%	7.4%	18.8%	2.9%	9.8%	3.1%	8.7%	1.2%	28.3%	0.2%	1.0%	20.7%	0.4%	19.5%	10.6%	12.1%
	π	56.8%	21.6%	18.3%	18.6%	28.1%	3.6%	23.5%	4.1%	19.8%	2.7%	29.6%	0.4%	4.0%	28.1%	0.8%	48.8%	14.5%	24.6%
	p	4.7%	19.8%	1.7%	0.8%	22.9%	0.2%	1.1%	12.5%	0.6%	0.1%	25.1%	0.0%	2.3%	3.1%	2.0%	4.3%	9.1%	2.9%
	sum	100.0%	20.1%	35.8%	31.8%	23.5%	8.9%	40.6%	3.5%	35.1%	4.9%	25.3%	1.2%	8.6%	17.1%	3.7%	85.9%	12.3%	48.9%

source	leading particle	c jet by Whizard																	
		inclusive			D^+			D^0			D_s^+			Λ_c^+			sum		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	2.7%	1.9%	2.5%	1.2%	0.8%	1.1%	1.2%	2.3%	1.1%	0.2%	2.3%	0.2%	0.1%	1.9%	0.1%	2.7%	42.0%	2.5%
	μ	2.7%	0.5%	2.7%	1.2%	0.1%	1.2%	1.2%	0.3%	1.2%	0.2%	0.4%	0.2%	0.1%	0.5%	0.1%	2.7%	41.8%	2.7%
	K	28.4%	15.2%	13.8%	4.6%	18.5%	1.8%	20.5%	11.6%	12.1%	2.6%	23.1%	0.8%	0.5%	22.4%	0.2%	28.3%	30.7%	14.9%
	π	57.3%	22.9%	16.8%	14.0%	22.3%	4.3%	36.9%	23.3%	10.5%	4.5%	20.2%	1.6%	1.8%	22.1%	0.5%	57.1%	29.4%	16.9%
	p	8.9%	19.8%	3.2%	1.0%	24.4%	0.3%	3.0%	23.2%	0.9%	0.5%	20.5%	0.2%	4.4%	15.6%	2.1%	8.8%	40.8%	3.4%
	sum	100.0%	18.8%	39.0%	22.0%	18.5%	8.7%	62.8%	18.0%	25.8%	8.1%	19.7%	3.0%	6.8%	17.2%	2.9%	99.7%	18.2%	40.4%
heavy hadron	e	2.7%	1.1%	2.6%	1.2%	0.1%	1.2%	1.2%	1.6%	1.1%	0.2%	0.2%	0.2%	0.1%	0.2%	0.1%	2.7%	42.0%	2.6%
	μ	2.7%	0.4%	2.7%	1.2%	0.0%	1.2%	1.2%	0.1%	1.2%	0.2%	0.1%	0.2%	0.1%	0.1%	0.1%	2.7%	41.8%	2.7%
	K	23.1%	4.3%	19.2%	3.6%	0.2%	3.6%	17.3%	4.6%	14.3%	1.7%	0.2%	1.7%	0.4%	0.3%	0.3%	23.0%	27.7%	19.9%
	π	35.4%	19.5%	13.2%	8.3%	0.2%	8.2%	22.9%	37.2%	1.5%	3.2%	0.2%	3.2%	1.0%	0.2%	0.9%	35.3%	31.4%	13.8%
	p	3.5%	0.4%	3.4%	0.0%	7.2%	0.0%	0.0%	28.5%	0.0%	0.1%	0.4%	0.1%	3.4%	0.0%	3.4%	3.5%	40.7%	3.5%
	sum	67.3%	10.9%	41.1%	14.3%	0.2%	14.1%	42.6%	17.4%	18.1%	5.4%	0.2%	5.3%	4.9%	0.1%	4.9%	67.1%	10.2%	42.4%
QCD	e	0.1%	25.8%	0.0%	0.0%	30.5%	0.0%	0.0%	19.8%	0.0%	0.0%	25.2%	0.0%	0.0%	21.2%	0.0%	0.1%	49.4%	0.0%
	μ	0.0%	8.8%	0.0%	0.0%	7.1%	0.0%	0.0%	7.9%	0.0%	0.0%	9.8%	0.0%	0.0%	9.2%	0.0%	0.0%	49.3%	0.0%
	K	5.3%	40.3%	0.2%	1.0%	33.4%	0.1%	3.2%	21.9%	1.0%	0.9%	16.4%	0.4%	0.2%	34.6%	0.0%	5.3%	43.7%	1.6%
	π	21.9%	39.6%	0.9%	5.7%	29.5%	1.0%	14.0%	24.3%	3.7%	1.3%	32.7%	0.2%	0.8%	33.1%	0.1%	21.8%	38.9%	4.9%
	p	5.4%	41.5%	0.2%	1.0%	34.8%	0.1%	2.9%	22.6%	0.9%	0.4%	30.5%	0.1%	1.0%	10.2%	0.6%	5.4%	43.6%	1.7%
	sum	32.7%	39.9%	1.3%	7.7%	30.5%	1.2%	20.2%	23.6%	5.6%	2.7%	25.5%	0.6%	1.9%	19.3%	0.7%	32.6%	25.0%	8.2%
sum	e	2.7%	1.5%	2.6%	1.2%	0.3%	1.2%	1.2%	2.0%	1.1%	0.2%	0.5%	0.2%	0.1%	0.7%	0.1%	2.7%	1.1%	2.6%
	μ	2.7%	0.5%	2.7%	1.2%	0.1%	1.2%	1.2%	0.3%	1.2%	0.2%	0.2%	0.2%	0.1%	0.3%	0.1%	2.7%	0.2%	2.7%
	K	28.4%	8.6%	19.4%	4.6%	5.3%	3.7%	20.5%	6.8%	15.3%	2.6%	5.3%	2.1%	0.5%	7.6%	0.4%	28.3%	6.4%	21.5%
	π	57.3%	25.1%	14.2%	14.0%	9.5%	9.2%	36.9%	31.3%	5.2%	4.5%	7.2%	3.3%	1.8%	11.5%	1.0%	57.1%	21.4%	18.7%
	p	8.9%	18.2%	3.6%	1.0%	34.7%	0.1%	3.0%	22.6%	0.9%	0.5%	24.2%	0.1%	4.4%	2.1%	4.0%	8.8%	11.9%	5.1%
	sum	100.0%	17.4%	42.4%	22.0%	8.3%	15.3%	62.8%	19.3%	23.7%	8.1%	7.0%	6.0%	6.8%	4.7%	5.6%	99.7%	14.4%	50.6%
comb	e	2.7%	1.5%	2.6%	1.2%	0.3%	1.2%	1.2%	2.0%	1.1%	0.2%	0.5%	0.2%	0.1%	0.7%	0.1%	2.7%	1.1%	2.6%
	μ	2.7%	0.5%	2.7%	1.2%	0.1%	1.2%	1.2%	0.3%	1.2%	0.2%	0.2%	0.2%	0.1%	0.3%	0.1%	2.7%	0.2%	2.7%
	K	28.4%	8.6%	19.4%	4.6%	5.3%	3.7%	20.5%	6.8%	15.3%	2.6%	5.3%	2.1%	0.5%	7.6%	0.4%	28.3%	6.4%	21.5%
	π	57.3%	22.9%	16.8%	14.0%	9.5%	9.2%	36.9%	23.3%	10.5%	4.5%	7.2%	3.3%	1.8%	11.5%	1.0%	57.1%	17.6%	24.0%
	p	8.9%	18.2%	3.6%	1.0%	24.4%	0.3%	3.0%	22.6%	0.9%	0.5%	20.5%	0.2%	4.4%	2.1%	4.0%	8.8%	11.1%	5.3%
	sum	100.0%	16.4%	45.0%	22.0%	8.0%	15.5%	62.8%	16.0%	29.0%	8.1%	6.8%	6.0%	6.8%	4.7%	5.6%	99.7%	12.5%	56.1%

source	leading particle	c jet by Herwig																	
		inclusive			D^+			D^0			D_s^+			Λ_c^+			sum		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	3.6%	1.8%	3.4%	1.7%	0.9%	1.7%	1.6%	2.0%	1.5%	0.2%	2.8%	0.1%	0.1%	2.8%	0.1%	3.6%	40.8%	3.4%
	μ	3.0%	0.4%	3.0%	1.9%	0.1%	1.9%	0.9%	0.3%	0.9%	0.1%	0.4%	0.1%	0.1%	0.0%	0.1%	3.0%	41.4%	3.0%
	K	28.5%	14.3%	14.5%	6.0%	17.8%	2.5%	20.4%	11.2%	12.3%	1.4%	22.7%	0.4%	0.6%	20.8%	0.2%	28.4%	30.4%	15.4%
	π	58.0%	22.8%	17.2%	16.1%	21.0%	5.4%	36.1%	23.6%	10.0%	3.3%	18.6%	1.3%	2.3%	21.2%	0.7%	57.8%	29.1%	17.5%
	p	6.9%	21.5%	2.2%	0.8%	24.8%	0.2%	1.6%	27.9%	0.3%	0.1%	30.4%	0.0%	4.4%	15.7%	2.1%	6.9%	41.9%	2.6%
	sum	100.0%	18.3%	40.3%	26.5%	16.8%	11.6%	60.6%	17.8%	25.1%	5.1%	18.6%	2.0%	7.4%	17.4%	3.1%	99.6%	17.6%	41.9%
heavy hadron	e	3.6%	1.2%	3.4%	1.7%	0.1%	1.7%	1.6%	1.7%	1.5%	0.2%	0.2%	0.2%	0.1%	0.0%	0.1%	3.6%	40.7%	3.5%
	μ	3.0%	0.3%	3.0%	1.9%	0.0%	1.9%	0.9%	0.2%	0.9%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	3.0%	41.4%	3.0%
	K	23.5%	4.4%	19.5%	4.7%	0.2%	4.7%	17.5%	4.7%	14.3%	0.8%	0.3%	0.8%	0.4%	0.3%	0.4%	23.4%	27.5%	20.2%
	π	37.6%	19.4%	14.1%	10.1%	0.2%	10.0%	23.7%	38.9%	1.2%	2.4%	0.1%	2.4%	1.4%	0.2%	1.4%	37.5%	30.7%	14.9%
	p	3.4%	0.4%	3.3%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	3.4%	3.4%	40.8%	3.4%
	sum	71.1%	10.9%	43.4%	18.4%	0.2%	18.3%	43.7%	18.0%	17.9%	3.5%	0.1%	3.5%	5.2%	0.1%	5.2%	70.8%	10.2%	44.9%
QCD	e	0.0%	29.1%	0.0%	0.0%	26.6%	0.0%	0.0%	18.4%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	49.5%	0.0%
	μ	0.0%	17.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.4%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	49.7%	0.0%
	K	5.0%	39.8%	0.2%	1.3%	31.7%	0.2%	2.9%	24.0%	0.8%	0.5%	22.1%	0.2%	0.2%	29.8%	0.0%	5.0%	44.6%	1.2%
	π	20.3%	41.2%	0.6%	6.0%	30.8%	0.9%	12.4%	25.5%	3.0%	0.9%	35.5%	0.1%	0.9%	32.5%	0.1%	20.3%	39.9%	4.1%
	p	3.5%	38.0%	0.2%	0.8%	38.0%	0.0%	1.6%	27.5%	0.3%	0.1%	32.7%	0.0%	1.0%	6.8%	0.8%	3.5%	44.6%	1.1%
	sum	28.9%	40.4%	1.1%	8.1%	31.5%	1.1%	17.0%	25.4%	4.1%	1.6%	29.7%	0.3%	2.1%	17.3%	0.9%	28.8%	26.4%	6.4%
sum	e	3.6%	1.4%	3.4%	1.7%	0.2%	1.7%	1.6%	1.9%	1.5%	0.2%	0.2%	0.2%	0.1%	0.0%	0.1%	3.6%	0.9%	3.5%
	μ	3.0%	0.3%	3.0%	1.9%	0.0%	1.9%	0.9%	0.2%	0.9%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	3.0%	0.1%	3.0%
	K	28.5%	8.4%	19.7%	6.0%	5.1%	4.9%	20.4%	7.0%	15.1%	1.4%	7.5%	1.0%	0.6%	8.6%	0.4%	28.4%	6.6%	21.4%
	π	58.0%	24.8%	14.8%	16.1%	8.9%	10.9%	36.1%	33.0%	4.2%	3.3%	6.9%	2.5%	2.3%	9.7%	1.5%	57.8%	21.3%	19.0%
	p	6.9%	14.2%	3.5%	0.8%	37.5%	0.0%	1.6%	27.5%	0.3%	0.1%	30.7%	0.0%	4.4%	1.5%	4.1%	6.9%	9.4%	4.5%
	sum	100.0%	16.7%	44.4%	26.5%	7.2%	19.4%	60.6%	19.9%	22.0%	5.1%	7.1%	3.8%	7.4%	4.4%	6.1%	99.6%	14.1%	51.3%
comb	e	3.6%	1.4%	3.4%	1.7%	0.2%	1.7%	1.6%	1.9%	1.5%	0.2%	0.2%	0.2%	0.1%	0.0%	0.1%	3.6%	0.9%	3.5%
	μ	3.0%	0.4%	3.0%	1.9%	0.0%	1.9%	0.9%	0.2%	0.9%	0.1%	0.0%	0.1%	0.1%	-0.0%	0.1%	3.0%	0.1%	3.0%
	K	28.5%	8.4%	19.7%	6.0%	5.1%	4.9%	20.4%	7.0%	15.1%	1.4%	7.5%	1.0%	0.6%	8.6%	0.4%	28.4%	6.6%	21.4%
	π	58.0%	22.8%	17.2%	16.1%	8.9%	10.9%	36.1%	23.6%	10.0%	3.3%	6.9%	2.5%	2.3%	9.7%	1.5%	57.8%	17.2%	24.8%
	p	6.9%	14.2%	3.5%	0.8%	24.8%	0.2%	1.6%	27.5%	0.3%	0.1%	30.4%	0.0%	4.4%	1.5%	4.1%	6.9%	8.8%	4.7%
	sum	100.0%	15.8%	46.8%	26.5%	7.1%	19.5%	60.6%	16.1%	27.9%	5.1%	7.1%	3.8%	7.4%	4.4%	6.1%	99.6%	12.1%	57.3%

source	leading particle	c jet by Sherpa																	
		inclusive			D^+			D^0			D_s^+			Λ_c^+			sum		
		ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}	ε_{tag}	ω	ε_{eff}
all	e	3.3%	2.7%	2.9%	1.4%	1.1%	1.3%	1.5%	3.5%	1.3%	0.2%	2.7%	0.2%	0.1%	1.7%	0.1%	3.2%	41.4%	3.0%
	μ	3.3%	0.7%	3.2%	1.5%	0.2%	1.5%	1.4%	0.5%	1.4%	0.3%	0.7%	0.3%	0.1%	0.8%	0.1%	3.3%	41.0%	3.2%
	K	30.0%	15.0%	14.7%	5.9%	19.7%	2.2%	21.3%	10.3%	13.4%	2.2%	22.2%	0.7%	0.4%	21.5%	0.1%	29.8%	29.7%	16.4%
	π	58.1%	22.4%	17.7%	14.5%	21.4%	4.7%	37.2%	22.8%	11.0%	4.5%	18.8%	1.8%	1.6%	21.8%	0.5%	57.8%	28.8%	18.0%
	p	5.4%	17.0%	2.3%	0.6%	22.8%	0.2%	1.5%	22.3%	0.5%	0.2%	19.5%	0.1%	3.1%	12.5%	1.7%	5.3%	42.2%	2.4%
	sum	100.0%	18.1%	40.8%	23.8%	17.8%	9.9%	62.8%	16.9%	27.5%	7.5%	18.3%	3.0%	5.4%	15.1%	2.6%	99.5%	17.1%	43.0%
heavy hadron	e	3.2%	1.8%	3.0%	1.4%	0.2%	1.3%	1.5%	2.6%	1.3%	0.2%	0.0%	0.2%	0.1%	0.0%	0.1%	3.2%	41.3%	3.0%
	μ	3.3%	0.6%	3.2%	1.5%	0.1%	1.5%	1.4%	0.3%	1.4%	0.3%	0.1%	0.3%	0.1%	0.0%	0.1%	3.3%	41.0%	3.2%
	K	24.9%	3.2%	21.8%	4.9%	0.4%	4.8%	18.0%	2.6%	16.2%	1.6%	0.4%	1.6%	0.2%	0.6%	0.2%	24.7%	26.1%	22.8%
	π	36.5%	20.2%	12.9%	8.8%	0.3%	8.7%	23.3%	39.9%	1.0%	3.3%	0.3%	3.3%	0.9%	0.4%	0.9%	36.3%	31.4%	13.8%
	p	2.6%	0.7%	2.5%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%	0.8%	0.0%	2.5%	0.1%	2.5%	2.6%	42.0%	2.5%
	sum	70.4%	10.7%	43.4%	16.5%	0.3%	16.3%	44.2%	16.5%	19.9%	5.4%	0.3%	5.4%	3.9%	0.2%	3.9%	70.0%	9.7%	45.4%
QCD	e	0.1%	36.5%	0.0%	0.0%	34.3%	0.0%	0.0%	27.3%	0.0%	0.0%	30.7%	0.0%	0.0%	37.3%	0.0%	0.1%	49.5%	0.0%
	μ	0.0%	24.2%	0.0%	0.0%	11.0%	0.0%	0.0%	26.6%	0.0%	0.0%	21.1%	0.0%	0.0%	31.1%	0.0%	0.0%	49.7%	0.0%
	K	5.1%	37.3%	0.3%	1.0%	32.8%	0.1%	3.3%	21.6%	1.1%	0.6%	21.4%	0.2%	0.2%	32.8%	0.0%	5.1%	44.1%	1.4%
	π	21.6%	39.6%	0.9%	5.7%	26.9%	1.2%	13.9%	23.6%	3.9%	1.2%	31.5%	0.2%	0.8%	30.6%	0.1%	21.5%	38.4%	5.4%
	p	2.8%	41.7%	0.1%	0.6%	29.9%	0.1%	1.5%	21.7%	0.5%	0.2%	30.2%	0.0%	0.5%	10.5%	0.3%	2.8%	45.2%	0.9%
	sum	29.6%	39.3%	1.4%	7.3%	27.9%	1.4%	18.6%	23.1%	5.4%	2.0%	27.7%	0.4%	1.5%	21.9%	0.5%	29.4%	24.4%	7.7%
sum	e	3.3%	2.1%	3.0%	1.4%	0.4%	1.3%	1.5%	3.0%	1.3%	0.2%	0.4%	0.2%	0.1%	0.3%	0.1%	3.2%	1.6%	3.0%
	μ	3.3%	0.7%	3.2%	1.5%	0.1%	1.5%	1.4%	0.4%	1.4%	0.3%	0.2%	0.3%	0.1%	0.2%	0.1%	3.3%	0.3%	3.2%
	K	30.0%	7.0%	22.1%	5.9%	4.3%	4.9%	21.3%	5.0%	17.3%	2.2%	5.3%	1.8%	0.4%	11.4%	0.2%	29.8%	4.9%	24.2%
	π	58.1%	25.6%	13.9%	14.5%	8.7%	9.9%	37.2%	32.0%	4.8%	4.5%	6.3%	3.4%	1.6%	11.2%	1.0%	57.8%	21.2%	19.1%
	p	5.4%	15.3%	2.6%	0.6%	29.7%	0.1%	1.5%	21.7%	0.5%	0.2%	27.3%	0.0%	3.1%	1.7%	2.9%	5.3%	9.7%	3.5%
	sum	100.0%	16.5%	44.8%	23.8%	6.9%	17.7%	62.8%	18.3%	25.3%	7.4%	6.0%	5.8%	5.4%	5.0%	4.3%	99.5%	13.5%	53.1%
comb	e	3.3%	2.1%	3.0%	1.4%	0.4%	1.3%	1.5%	3.0%	1.3%	0.2%	0.4%	0.2%	0.1%	0.3%	0.1%	3.2%	1.6%	3.0%
	μ	3.3%	0.7%	3.2%	1.5%	0.1%	1.5%	1.4%	0.4%	1.4%	0.3%	0.2%	0.3%	0.1%	0.2%	0.1%	3.3%	0.3%	3.2%
	K	30.0%	7.0%	22.1%	5.9%	4.3%	4.9%	21.3%	5.0%	17.3%	2.2%	5.3%	1.8%	0.4%	11.4%	0.2%	29.8%	4.9%	24.2%
	π	58.1%	22.4%	17.7%	14.5%	8.7%	9.9%	37.2%	22.8%	11.0%	4.5%	6.3%	3.4%	1.6%	11.2%	1.0%	57.8%	16.9%	25.3%
	p	5.4%	15.3%	2.6%	0.6%	22.8%	0.2%	1.5%	21.7%	0.5%	0.2%	19.5%	0.1%	3.1%	1.7%	2.9%	5.3%	9.1%	3.6%
	sum	100.0%	15.1%	48.6%	23.8%	6.8%	17.8%	62.8%	14.7%	31.4%	7.5%	5.8%	5.8%	5.4%	5.0%	4.3%	99.5%	11.4%	59.4%

Commonly Used

ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ

αβγδεζηθικλμνξοπρστυφχψω

A_{FB} $\sin^2\theta_W$

$Z \to b\bar{b}$ $Z \to c\bar{c}$

b jet $\bar{b}$ jet

c jet $\bar{c}$ jet

$e^-, \mu^-, K^-, \pi^-, p^+$

$e^+, \mu^+, K^+, \pi^+, p^-$

(e, μ, K) $(\pi, proton)$

$\bar{B}^0$ B^0 B^- B^+ $\bar{B}_s^0$ B_s^0 B_c^- B_c^+ Λ_b $\bar{\Lambda}_b$

D^0 $\bar{D}^0$ D^+ D^- D_s^0 $\bar{D}_s^0$ Λ_c^+ Λ_c^-

Misjudgment rate ω, Effective tagging power