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Jet Charge at CEPC

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Flavor Physics Talk

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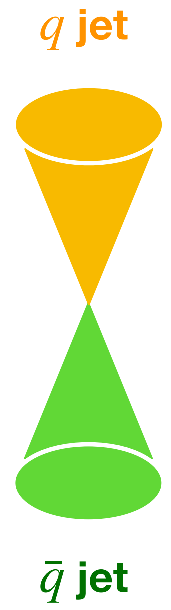
Outline

- **Methods:**
  - ★ **Leading Particle method (LPJC)**
  - ★ **Weighted Charge method (WCJC)**

- **Combination:**
  - ★ **Decision level combination**
  - ★ **Tagger level combination**

- **Conclusion**



Definition of effective tagging power

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

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

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

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

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

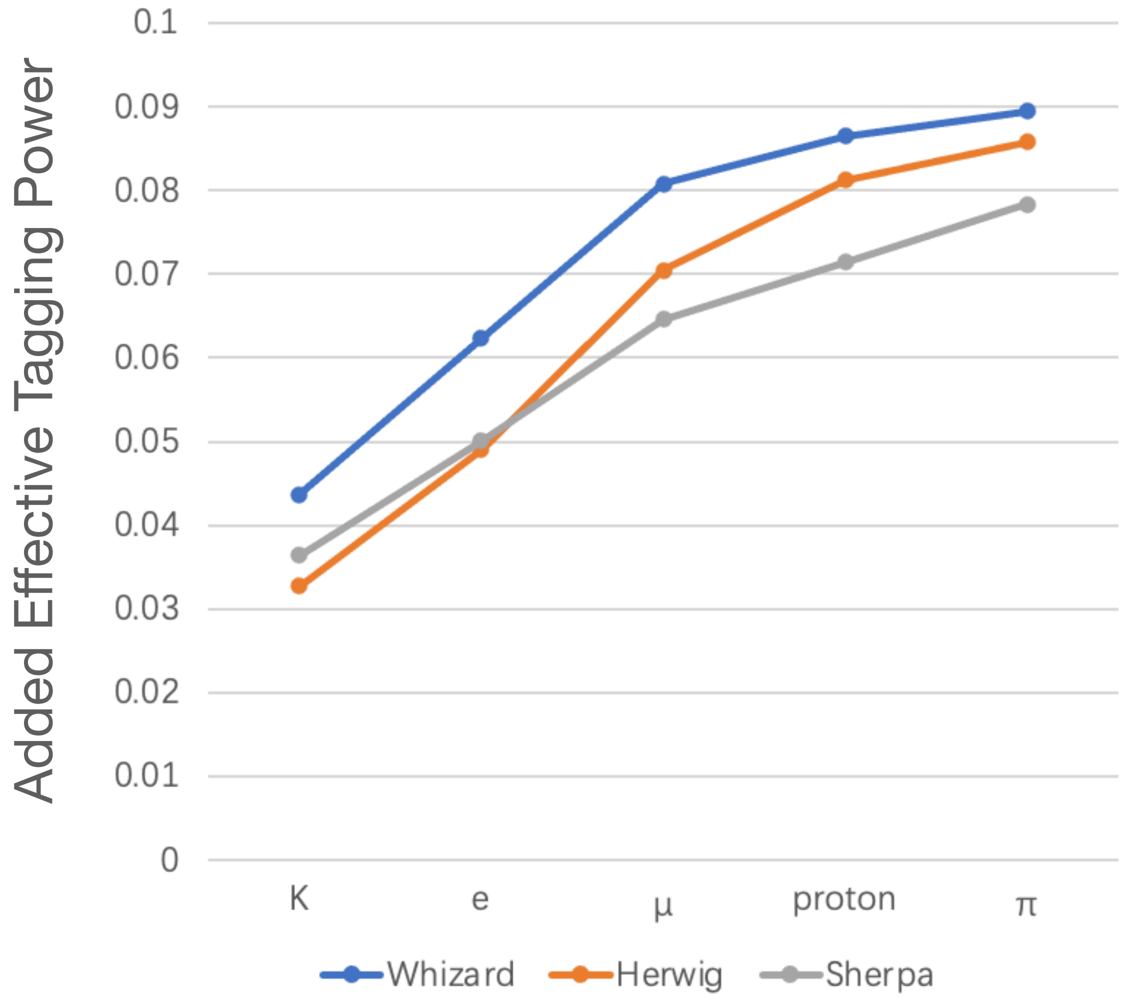
$$\delta a_{\text{CP}} = \frac{1}{\sqrt{N^{\text{tag}}}(1-2w)}$$

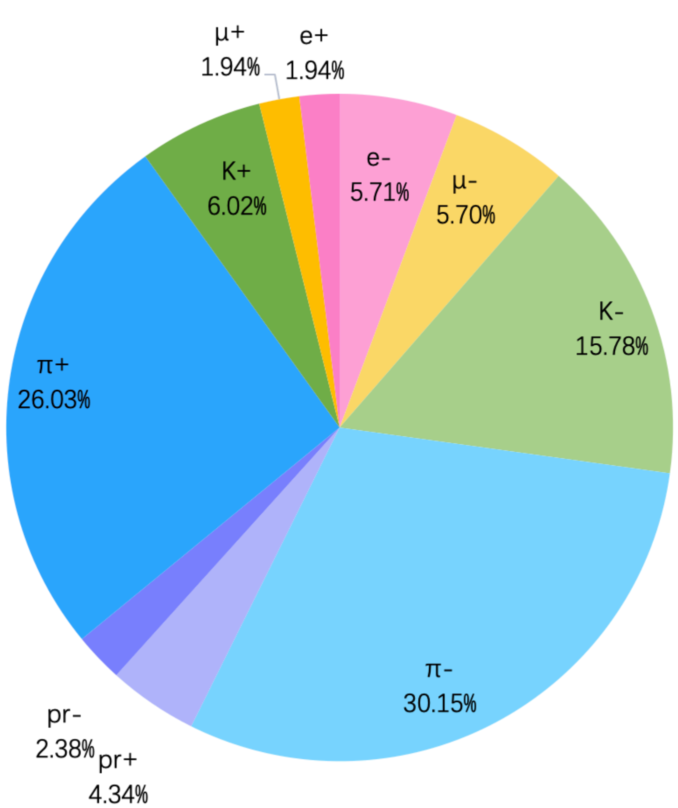
$$\varepsilon_{\text{eff}} = \frac{N^{\text{tag}}}{N}\cdot(1-2w)^2 = \varepsilon\cdot r^2$$

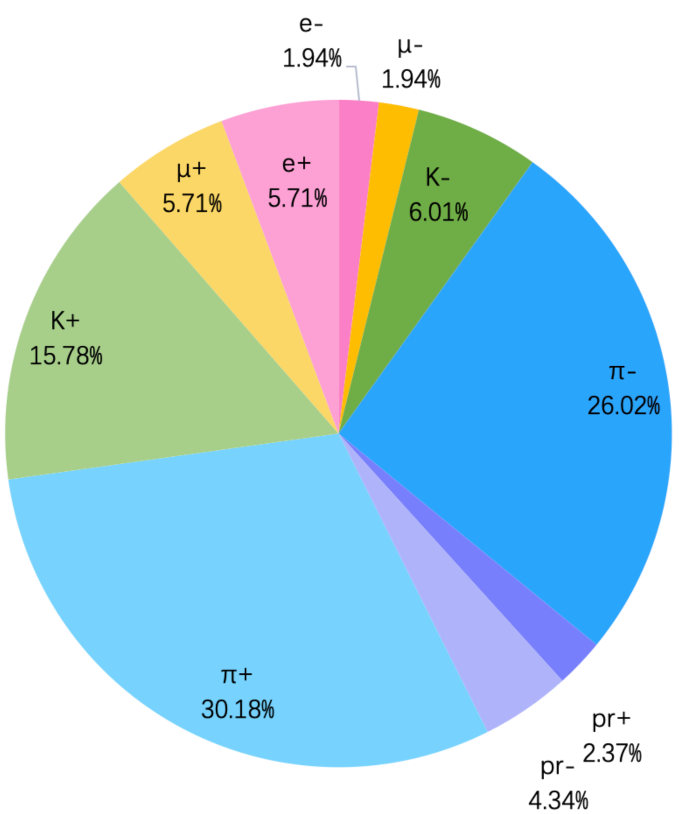
$$\varepsilon_{\text{eff}} = \sum_i \varepsilon_{\text{eff},i} = \sum_i \varepsilon_i \cdot (1-2w_i)^2$$

Leading particle method (LPJC)

LP	Whizard	Herwig	Sherpa
e	0.019	0.018	0.015
μ	0.018	0.021	0.015
K	0.045	0.033	0.036
π	0.003	0.005	0.006
p	0.005	0.007	0.006
Tot	0.089	0.084	0.078







Dependence on leading particle type

Dependence on b/c hadron type

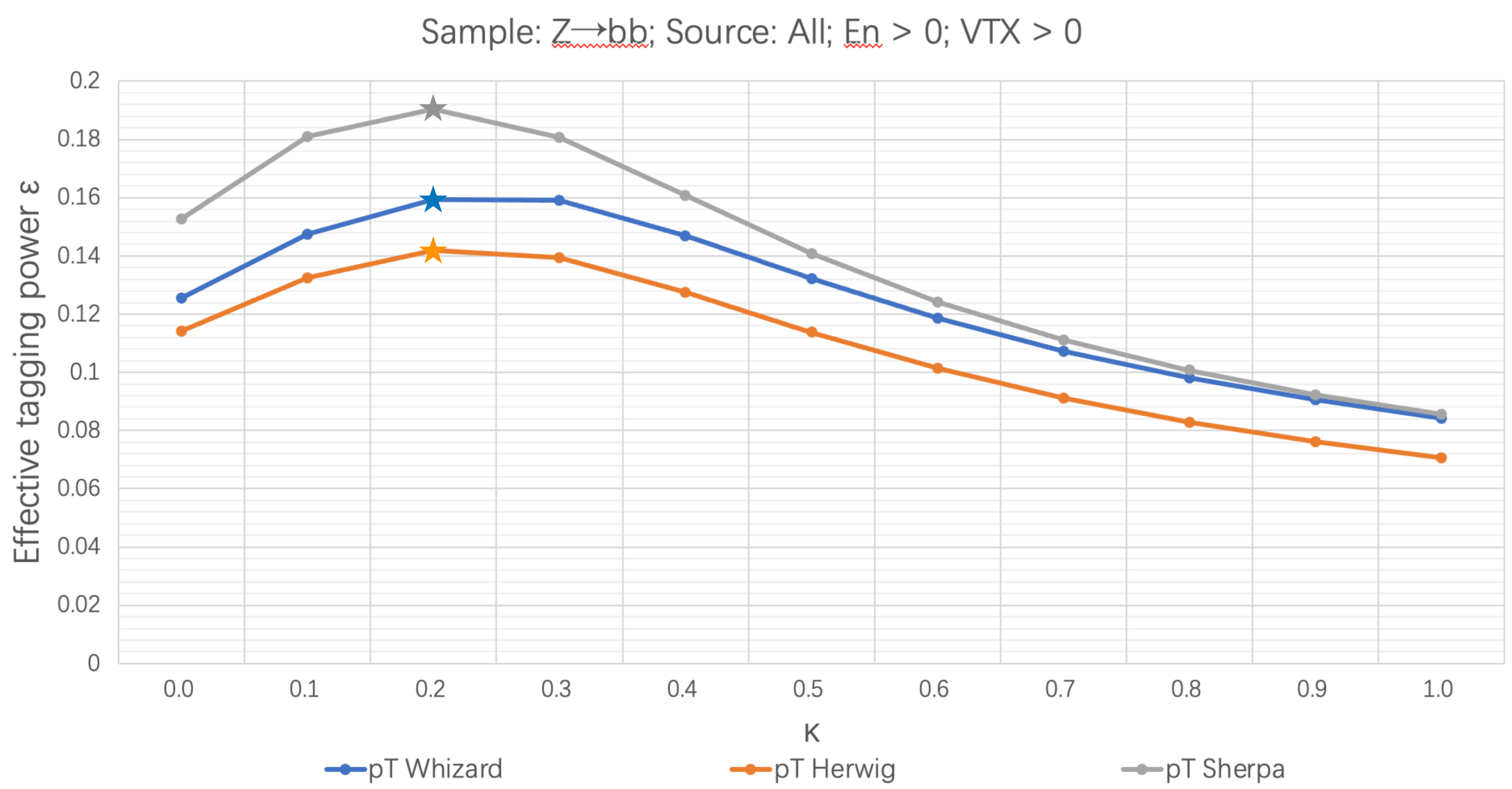
Dependence on decay source of leading particle: hadron or QCD.

Weighted charge method (WCJC)

Method:

- **Use the charge and momentum of all final charged particles in a jet with a weight parameter κ to calculate Q_{jet}^{κ}.**
- **the weight parameter κ is optimized for different decay modes.**
- **if $Q_{jet}^{\kappa}<0$, we consider this is a b quark, and vise versa.**

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



Methods	Optimized κ					
Generator	Whizard		Herwig		Sherpa	
source	all	from B/D	all	from B/D	all	from B/D
All b hadrons	(κ=0.2)	(κ=0)	(κ=0.2)	(κ=0)	(κ=0.2)	(κ=0)
B0/B0bar	(κ=0.2)	(κ=0.6)	(κ=0.2)	(κ=0.6)	(κ=0.3)	(κ=0.6)
B+/B-	(κ=0.3)	(κ=0)	(κ=0.4)	(κ=0)	(κ=0.3)	(κ=0)
Bs/Bsbar	(κ=0)	(κ=0)	(κ=0)	(κ=0)	(κ=0.2)	(κ=1.0)
Bc+/Bc-	(κ=0.2)	(κ=0)	(κ=0.7)	(κ=0)	(κ=0.6)	(κ=0)
Λb/Λbbar	(κ=0)	(κ=1.0)	(κ=0)	(κ=0.9)	(κ=0)	(κ=0)

Decision level combination of two methods

two methods decision percentage

LPJC		Per	ξ = +1	ξ = +1	ξ = -1	ξ = -1	ξ = +1	ξ = -1	Only two decisions			Only one dicision			Total
WCJC			ξ = +1	ξ = -1	ξ = +1	ξ = -1	ξ = 0	ξ = 0	ω	ε_{tag}	ε_{eff}	ω	ε_{tag}	ε_{eff}	ε_{eff}
b jet	e	7.65%	15.71%	9.64%	6.63%	68.03%	0.00%	0.00%	18.76%	6.40%	0.025				0.025
	μ	7.65%	15.68%	9.72%	6.62%	67.97%	0.00%	0.00%	18.75%	6.40%	0.025				0.025
	K	21.81%	15.53%	12.09%	10.93%	61.45%	0.00%	0.00%	20.18%	16.79%	0.060				0.060
	π	56.18%	20.55%	25.77%	11.17%	42.51%	0.00%	0.00%	32.59%	35.43%	0.043				0.043
	p	6.72%	6.09%	16.54%	11.49%	28.24%	12.81%	24.82%	17.75%	2.31%	0.010	34.04%	2.53%	0.003	0.012
	Total	100.00%	17.74%	19.70%	10.44%	49.58%	0.78%	4.11%	25.45%	67.32%	0.162	34.04%	2.53%	0.003	0.165
c jet	e	2.72%	91.76%	6.33%	0.35%	1.55%	0.01%	0.00%	1.66%	2.54%	0.024				0.024
	μ	2.73%	93.09%	6.44%	0.08%	0.39%	0.01%	0.00%	0.41%	2.55%	0.025				0.025
	K	28.38%	43.59%	10.32%	10.95%	2.60%	26.14%	6.41%	5.62%	13.11%	0.103	19.69%	9.24%	0.034	0.137
	π	57.28%	33.49%	7.84%	20.90%	5.23%	19.84%	12.70%	13.50%	22.18%	0.118	39.04%	18.64%	0.009	0.127
	p	8.88%	62.43%	9.65%	14.79%	13.13%	0.01%	0.00%	17.38%	6.71%	0.029				0.029
	Total	100.00%	42.14%	8.63%	16.41%	4.95%	18.05%	1.66%	10.17%	47.09%	0.299	30.38%	27.87%	0.043	0.342

Tagger level combination of two methods

Input final particle candidate i

get its PID

get $\omega_i(j=LPJC)$, $\omega_i(j=WCJC)$, decision $\xi_i(j=LPJC)$, $\xi_i(j=WCJC)$

for method j, if $\xi_{i,j} = 0$, $s_{i,j} = 0$

if two $\xi_{i,j}$!= 0, for smaller $\omega_{i,j}$, $s_{i,j}$ =1, for larger $\omega_{i,j}$, $s_i = 0$

put $s_{i,j}$, $\xi_{i,j}$, $\omega_{i,j}$ in this formula and get combined ε_{eff}

$$\epsilon_{ETP_{comb}} = \sum_{i=1}^{N_{candidate}} \sum_{j=1}^{N_{method}} s_{i,j} \, |\xi_{i,j}| \, (1 - 2\omega_{i,j})^2$$

$s_{i,j}$ is the decision weight of j-th method for i-th candidate.

$\omega_{i,j}$ is the mis-judgment rate ω of j-th method for i-th candidate.

$\xi_{i,j}$ is the tagging decision of j-th method for i-th candidate.

The tagging decision ξ_i takes the value of

- +1 when the candidate is tagged as $\bar{b}$ jet
- −1 when the candidate is tagged as b jet
- 0 when the candidate is untagged

Tagger level combination of two methods

Method	Tagger	κ	$\varepsilon_{tag}=N_{tag}/N$	$\omega_i=N_w/N_{tag}$	$\bar{\omega}$	r^2	ε_{eff}
LPJC	e		7.70%	25.45%		0.241	0.019
	μ		7.70%	25.53%		0.239	0.018
	K		21.97%	27.45%		0.203	0.045
	π		56.33%	46.34%		0.005	0.003
	p		6.30%	36.45%		0.073	0.005
	Total		100.00%	38.35%	35.06%	0.089	**0.089**
WCJC	All	2	100.00%	30.04%		0.159	**0.159**
WCJC combined with LP PID	e	4	7.70%	22.36%		0.306	0.024
	μ	4	7.70%	22.35%		0.306	0.024
	K	4	21.97%	26.32%		0.224	0.049
	π	2	56.33%	31.61%		0.135	0.076
	p	0	3.92%	27.94%		0.195	0.008
	Total		97.62%	28.13%	28.52%	0.185	**0.180**
Total Combined	e		7.65%	22.33%	22.36%	0.306	0.023
	μ		7.65%	22.31%	22.35%	0.306	0.023
	K		21.81%	26.46%	26.32%	0.224	0.049
	π		56.18%	31.72%	31.61%	0.135	0.076
	p		6.72%	30.40%	30.57%	0.151	0.010
	Total		100.00%	29.05%	28.68%	0.182	**0.182**

Tagger level combination of two methods

Method	Tagger	κ	$\varepsilon_{tag}=N_{tag}/N$	$\omega_i=N_w/N_{tag}$		r^2	ε_{eff}
LPJC	e		2.75%	1.90%		0.926	0.025
	μ		2.76%	0.47%		0.981	0.027
	K		28.70%	19.73%		0.367	0.105
	π		57.56%	38.79%		0.050	0.029
	p		8.22%	28.00%		0.194	0.016
	Total		100.00%	30.36%	27.49%	0.203	**0.203**
WCJC	All	0	67.39%	19.07%		0.383	**0.258**
WCJC combined with LP PID	e	10	2.75%	7.89%		0.709	0.020
	μ	10	2.76%	6.84%		0.745	0.021
	K	0	19.36%	18.99%		0.385	0.074
	π	0	38.80%	19.11%		0.382	0.148
	p	3	8.22%	22.77%		0.297	0.024
	Total		71.89%	13.37%	18.41%	0.399	**0.287**
Total Combined	e		2.72%	1.91%	1.90%	0.926	0.025
	μ		2.73%	0.46%	0.47%	0.981	0.027
	K		28.38%	19.32%	19.18%	0.380	0.108
	π		57.28%	25.77%	21.49%	0.325	0.186
	p		8.88%	22.78%	22.77%	0.297	0.026
	Total		100.00%	22.33%	19.49%	0.372	**0.372**

c jet by Whizard

Conclusion

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

★ *LPJC method:*

- *For $Z \to b\bar{b}$: Effective tagging power = 0.089*
- *For $Z \to c\bar{c}$: Effective tagging power = 0.203*

★ *WCJC method:*

- *For $Z \to b\bar{b}$: Effective tagging power = 0.159*
- *For $Z \to c\bar{c}$: Effective tagging power = 0.258*

★ *Decision level combination:*

- *For $Z \to b\bar{b}$: Effective tagging power = 0.165 (improve 3.8%)*
- *For $Z \to c\bar{c}$: Effective tagging power = 0.342 (improve 32.6%)*

★ *Tagger level combination:*

- *For $Z \to b\bar{b}$: Effective tagging power = 0.182 (improve 14.5%)*
- *For $Z \to c\bar{c}$: Effective tagging power = 0.372 (improve 44.2%)*

★ *Dependences:*

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

Future work:

Check the statistics.

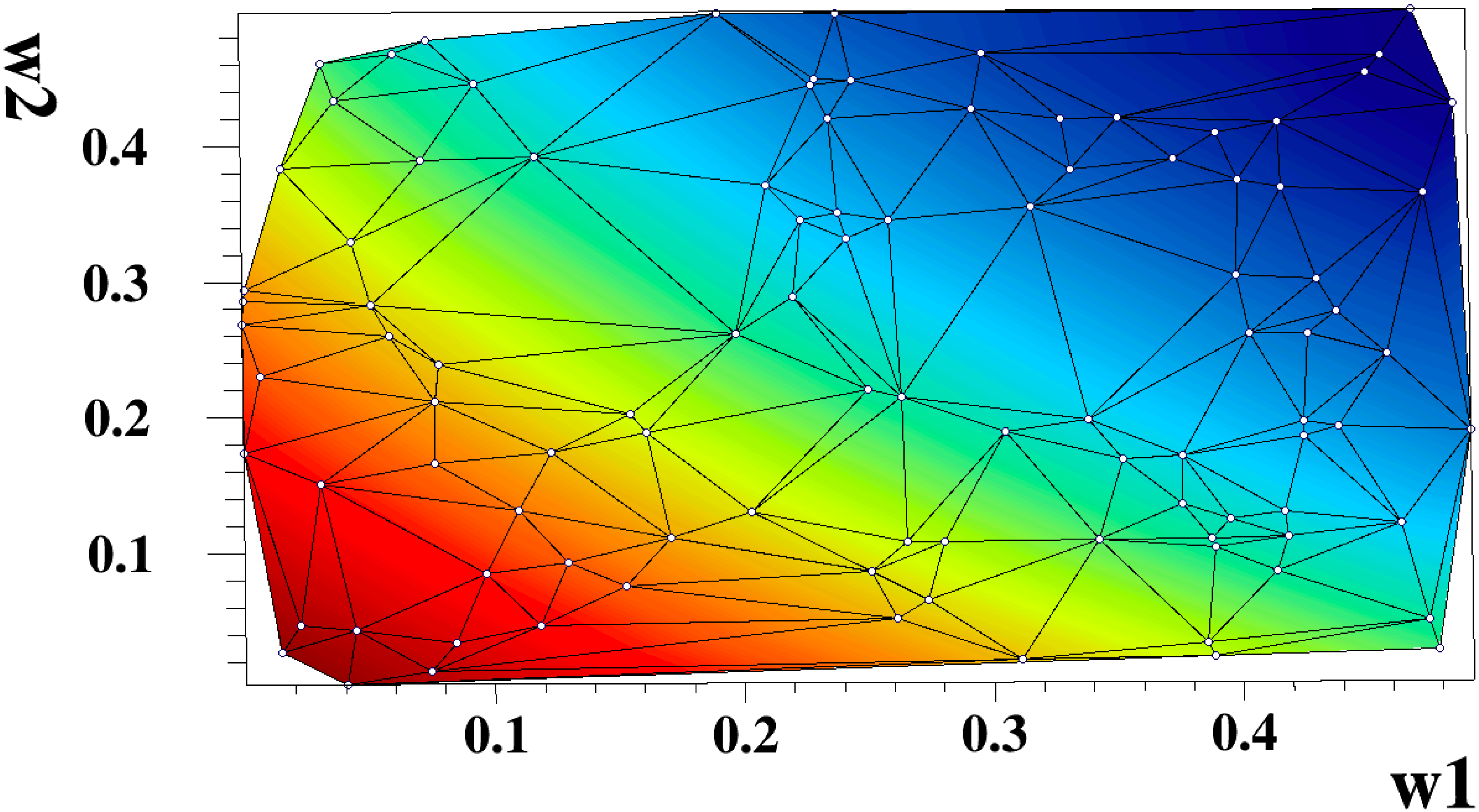
Write the paper.

More interesting work (better combination, jet flavor tagging, light jets…)

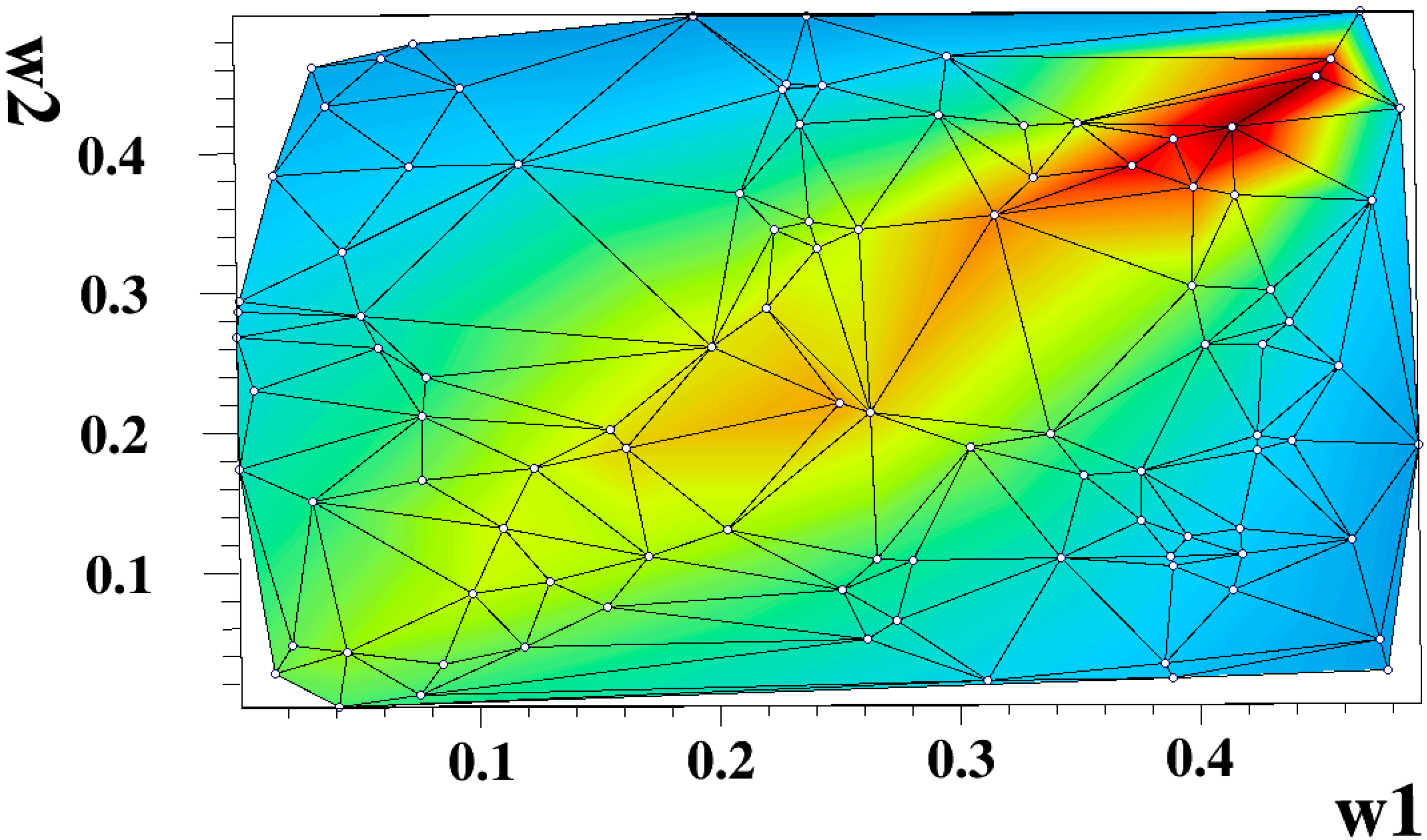
Thanks!

Back Up

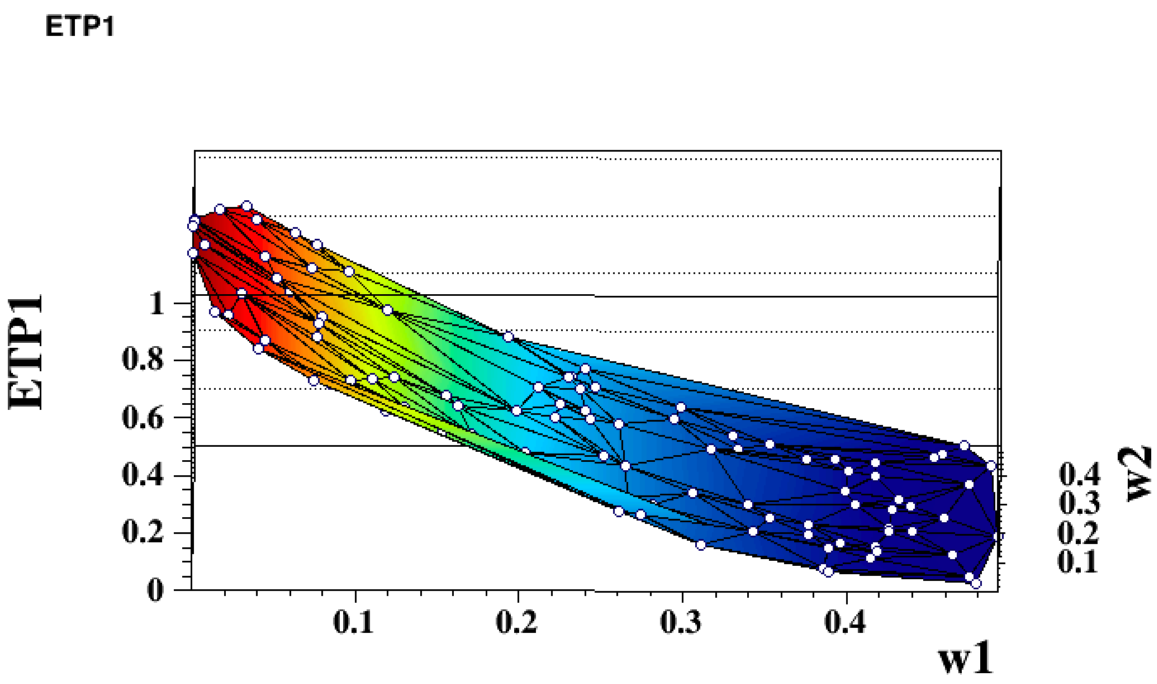
Decision level combined ε_{eff} vs ω_1 ω_2

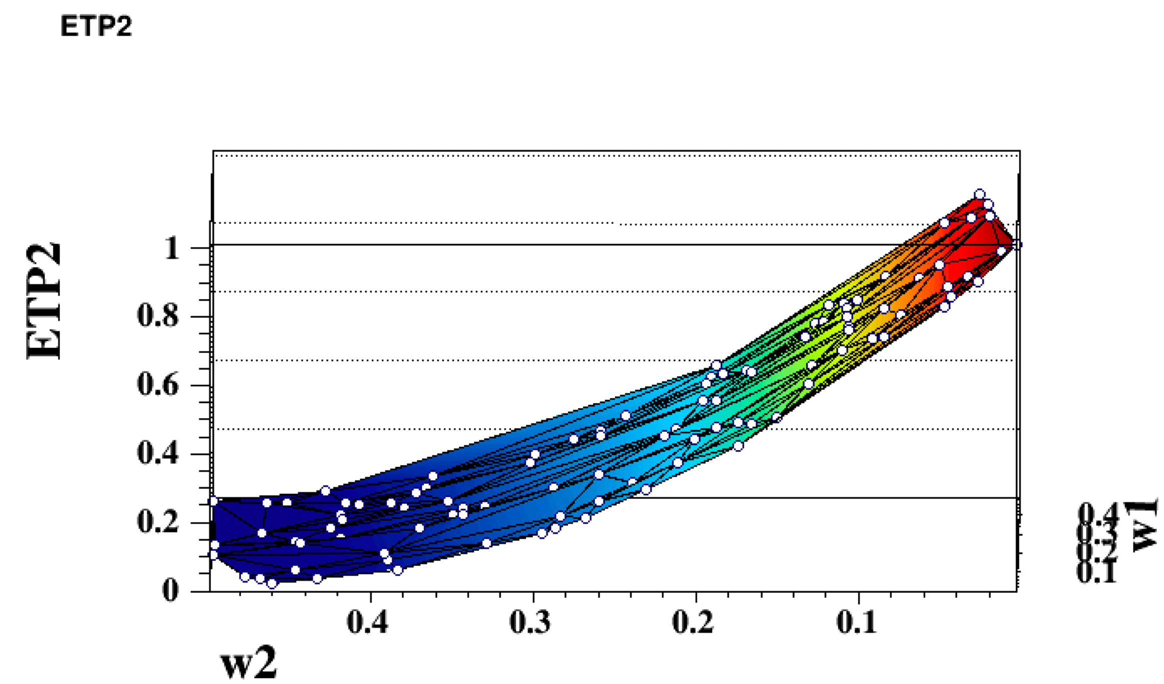


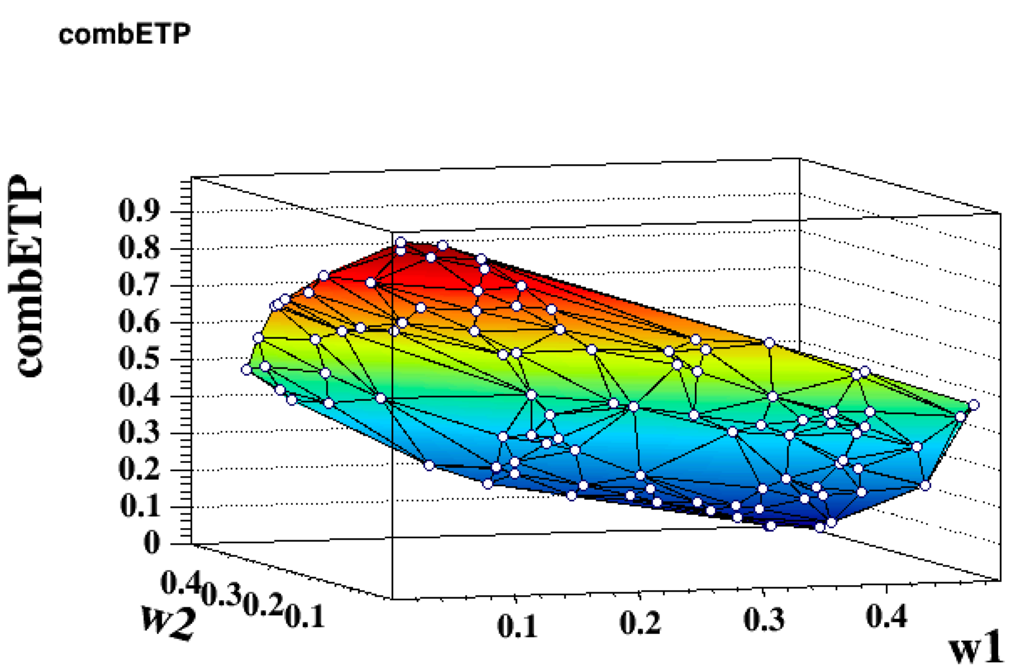
ε_{eff} ratio = ε_{eff}(combined)/ε_{eff}(better single method) vs ω_1 ω_2

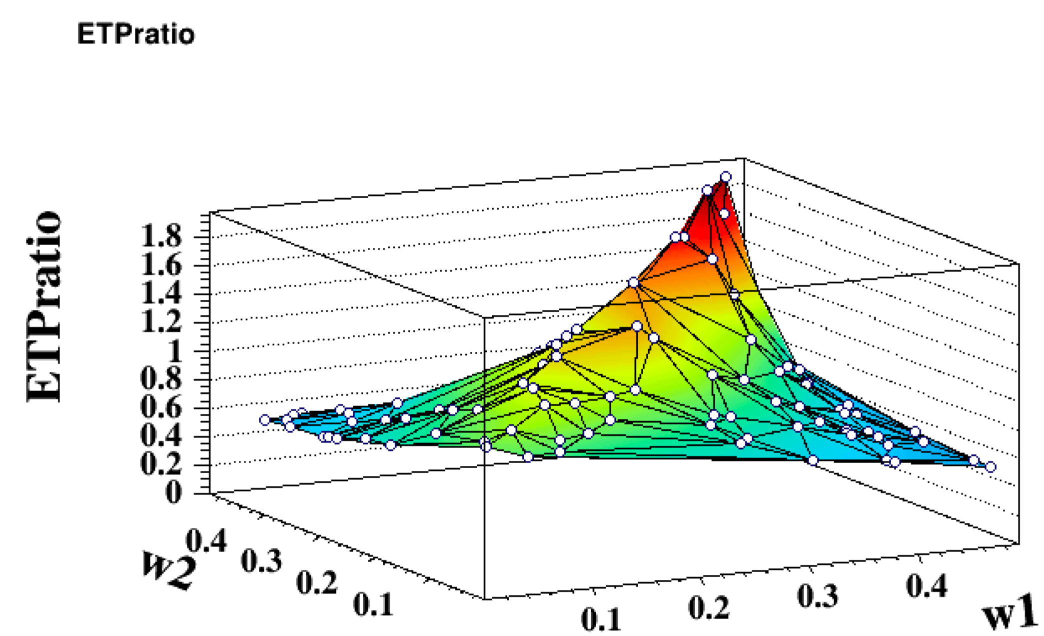


ε_{eff}(method1), ε_{eff}(method2), ε_{eff}(combined), ε_{eff} ratio vs ω_1 ω_2









Listen to which method

combination method listen to whom

	from b hadrons/QCD	from b hadrons	from c hadrons/QCD	from c hadrons
e	listen to weighted method	almost listen to weighted method	listen to LP method	almost listen to weighted method
μ	listen to weighted method	almost listen to weighted method	listen to LP method	listen to LP method
K	listen to weighted method	listen to LP method	most listen to weighted method	most listen to LP method
π	listen to weighted method	almost listen to weighted method	most listen to weighted method	most listen to LP method
p	most listen to weighted method	listen to LP method	listen to weighted method	almost listen to weighted method

by Whizard

blue： willing to listen to weighted method

pink： willing to listen to LP method

red frame： all source & only from hadron decay : listen to different method

TF percentage of two methods

b jet	ξ_{LP} -1 (right)	ξ_{LP} +1 (wrong)	Total
$\xi_{weighted}$ -1 (right)	50.87%	20.22%	71.09%
$\xi_{weighted}$ +1 (wrong)	10.71%	18.21%	28.92%
Total	61.58%	38.43%	100.01%

c jet	ξ_{LP} +1 (right)	ξ_{LP} -1 (wrong)	Total
$\xi_{weighted}$ +1 (right)	58.43%	11.96%	70.39%
$\xi_{weighted}$ -1 (wrong)	22.75%	6.86%	29.61%
Total	81.18%	18.82%	100%