# Same-side and opposite-side tagging for $B_s \to J/\psi\phi$ decay mode

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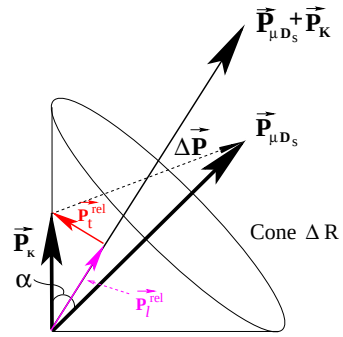
$B$ Mixing and Lifetime Meeting

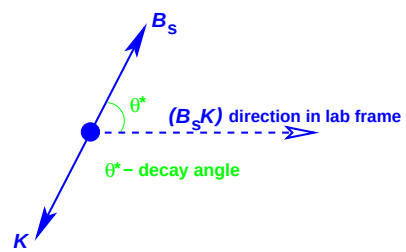
http://www-d0.fnal.gov/~rakitin/d0_private/tex/2007.May.24.Bmix/tr.pdf

# List of used same-side taggers:

We are using the following SSTs (one-track and many-track taggers):

- Min. $p_t^{\text{rel}}$
- Max. $p_L^{\text{rel}}$
- Max. $p_t$
- Min. $|\Delta\vec{P}| \equiv |\vec{p}(B_s) - \vec{p}(K)|$
- Best: Min. $\Delta R$
- Max. $\cos\alpha$
- Min. $\cos\theta^*$
- Max. $\cos\theta^*$
- Min. $m(B_sK)$
- Random track
- $Q_{jet}(p_t, \kappa) = \frac{\sum q \cdot p_t^{\kappa}}{\sum p_t^{\kappa}}$
- $Q_{jet}(p_t^{rel}, \kappa) = \frac{\sum q \cdot (p_t^{rel})^{\kappa}}{\sum (p_t^{rel})^{\kappa}}$
- $Q_{jet}(p_L^{rel}, \kappa) = \frac{\sum q \cdot (p_L^{rel})^{\kappa}}{\sum (p_L^{rel})^{\kappa}}$
- Best: $Q_{jet}(p_t, \kappa = 0.6)$



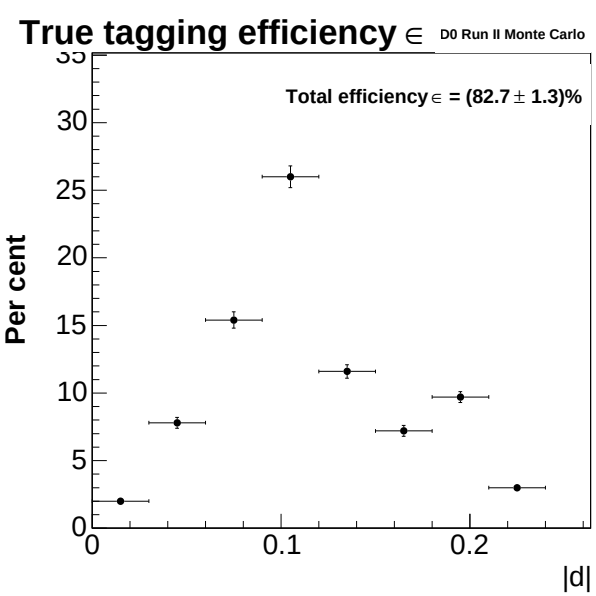



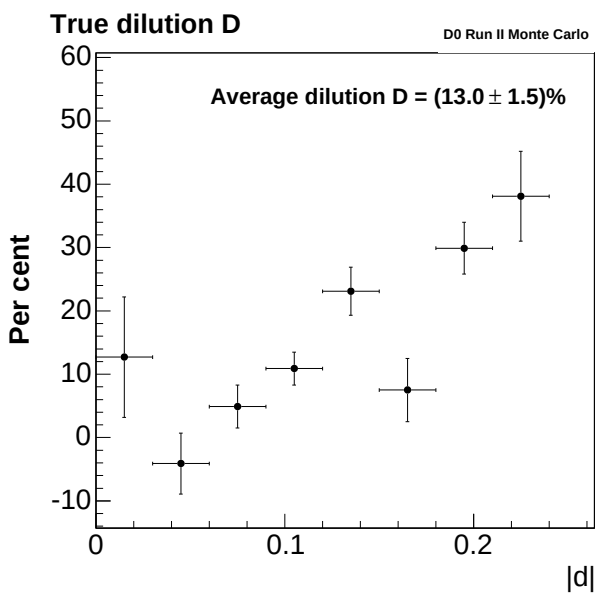

- One-track: $p_t^{\text{rel}}$ and $p_L^{\text{rel}}$ are $\perp$ and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_sK)$
- $\Delta R \equiv \sqrt{\Delta\phi^2 + \Delta\eta^2}$ and angle $\alpha$ are taken between $\vec{p}(B_s)$ and $\vec{p}(K)$
- $\theta^*$ – decay angle of $B_sK$-system, *i.e.* angle between directions of $\vec{p}(B_sK)$ and $\vec{p}(B_s)$ in reference frame of $B_sK$ system
- $\kappa = 0.0, 0.1, 0.2, ...1.0$
- $Q_{jet}$: $p_t^{rel}$ and $p_L^{rel}$ are $\perp$ and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_s)$

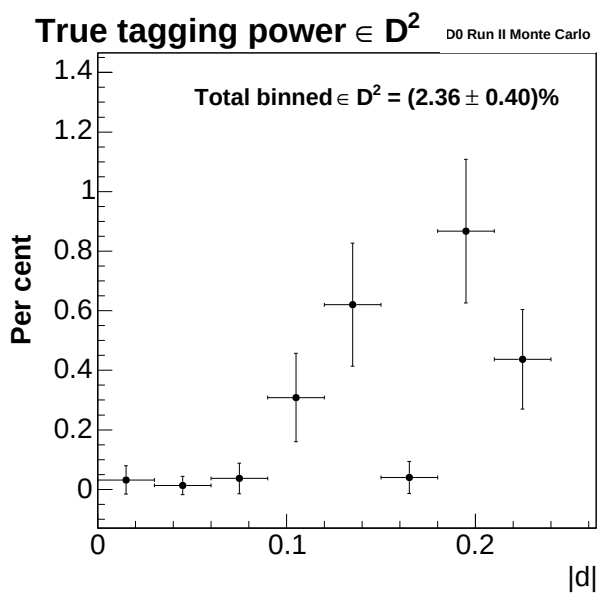
# Combined SST in $B_s \to J/\psi\phi$ MC

- Combining "Min. $\Delta R$" and "$Q_{jet}(p_t, 0.6)$"
- Implemented in class `TagCombinedSame` in `BANA` package
- **Combination improves results compared to individual taggers**

| Tagger | $\epsilon$, % | $D$, % | Unbinned $\epsilon D^2$, % | Binned $\epsilon D^2$, % |
|---|---|---|---|---|
| "Min. $\Delta R$" | 73.1±1.5 | 14.1±1.6 | 1.45±0.32 | 1.82±0.36 |
| "$Q_{jet}(p_t, 0.6)$" | 84.3±1.7 | 16.5±2.2 | 0.95±0.26 | 1.05±0.27 |
| "'Comb. SST' = "Min. $\Delta R$" + "$Q_{jet}(p_t, 0.6)$" | 84.3±1.7 | 13.0±1.5 | 1.41±0.32 | 2.36±0.40 |



# SST calibration curve

For reference we use standard $|d|$ bins:

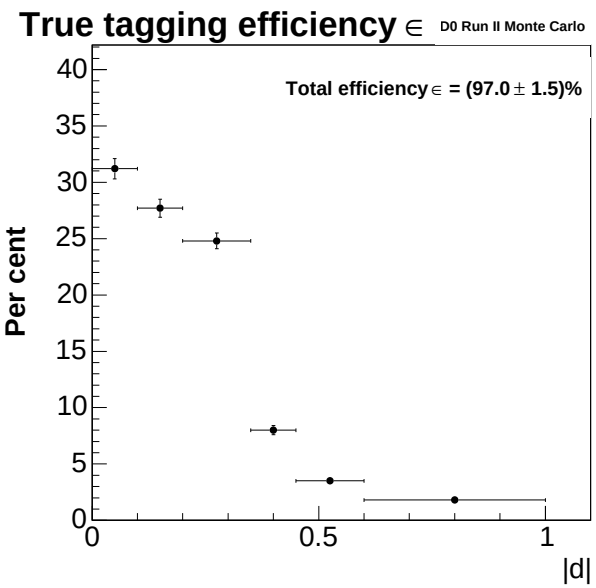
| $\|d\|$ | $D$, % | $\epsilon D^2$ |
|---|---|---|
| 0.00 - 0.10 | 2.9 $\pm$ 2.4 | 0.03 $\pm$ 0.04 |
| 0.10 - 0.20 | 16.9 $\pm$ 2.0 | 1.27 $\pm$ 0.30 |
| 0.20 - 0.35 | 37.3 $\pm$ 5.0 | 0.88 $\pm$ 0.24 |
| Total | – | **2.17 $\pm$ 0.38** |

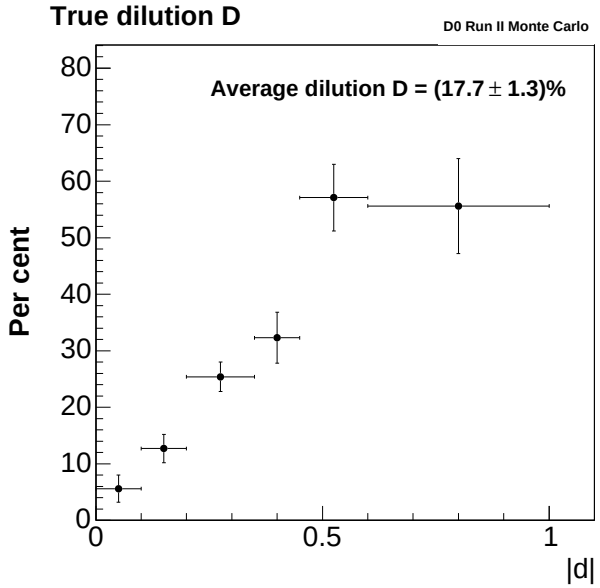
# Further tagger combination in MC

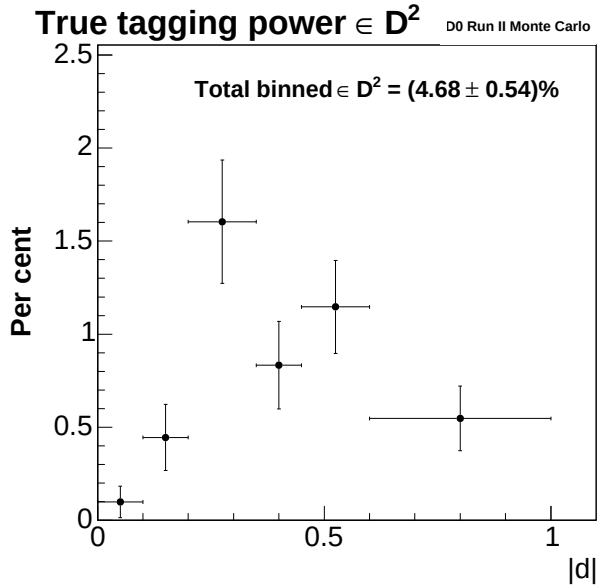
- Combine SST, OST and EventCharge taggers
- Implemented in class `TagCombinedAll`
- OST is a standard combination of $\mu$, $e$ and SV charge
- EventCharge is average charge of all tracks outside cone $\cos\alpha > 0.8$
- If there is no OST, we take EventCharge
- Again, **combination improves results compared to individual taggers**

| Tagger | $\epsilon$, % | $D$, % | Unbinned $\epsilon D^2$, % | Binned $\epsilon D^2$, % |
|---|---|---|---|---|
| "Comb. SST" = "Min. $\Delta R$" + "$Q_{jet}(p_t, 0.6)$" | 84.3±1.7 | 13.0±1.5 | 1.41±0.32 | 2.36±0.40 |
| "Comb. OST" | 7.1±0.4 | 49.7±4.3 | 1.76±0.32 | 1.95±0.33 |
| "Event Charge" | 96.9±1.8 | 11.2±1.4 | 1.22±0.29 | 2.05±0.38 |
| "Comb. SST" + "Comb. OST" + EventCharge | 97.0±1.9 | 17.7±1.3 | 3.03±0.46 | 4.68±0.54 |

# SST+OST calibration curve

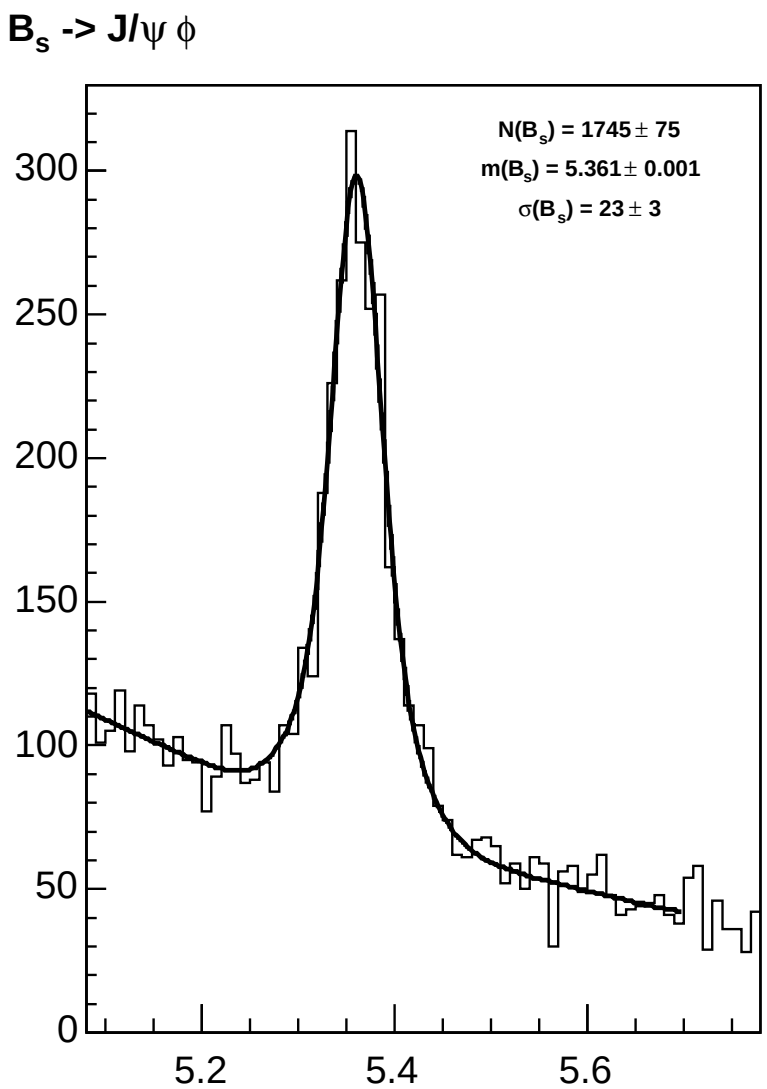


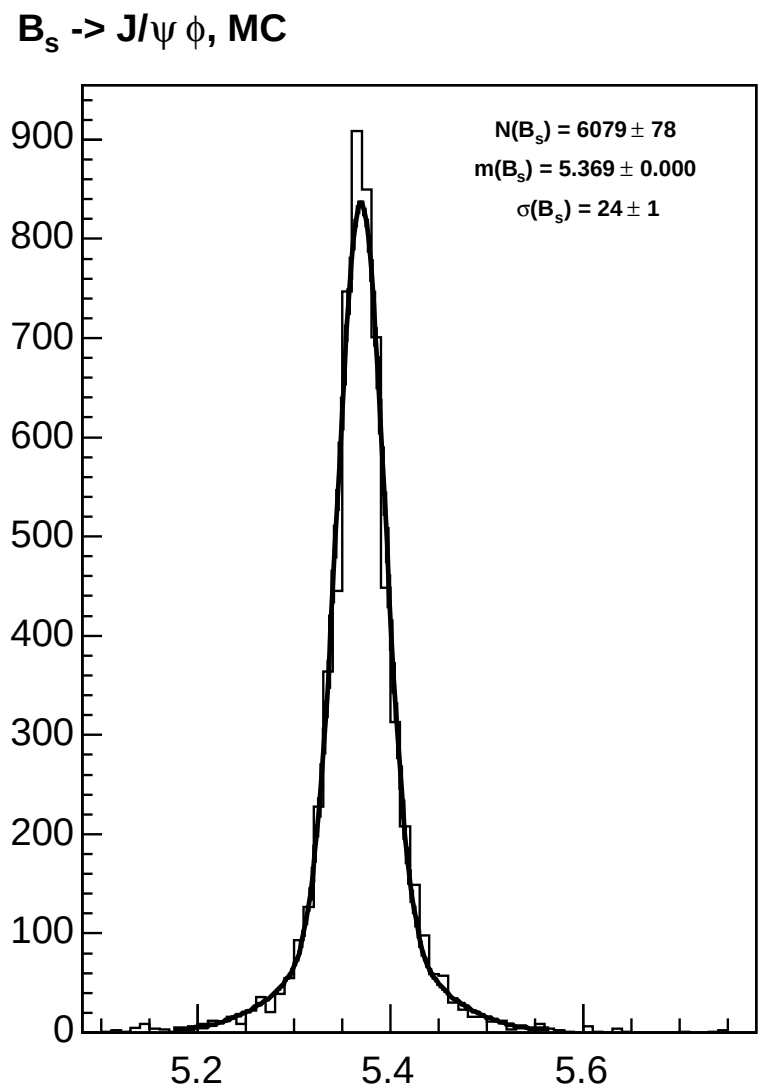




| $\|d\|$ | $D$, % | $\epsilon D^2$ |
|---|---|---|
| 0.00 - 0.10 | 5.60 ± 2.40 | 0.10 ± 0.08 |
| 0.10 - 0.20 | 12.70 ± 2.50 | 0.45 ± 0.18 |
| 0.20 - 0.35 | 25.40 ± 2.60 | 1.60 ± 0.33 |
| 0.35 - 0.45 | 32.30 ± 4.50 | 0.83 ± 0.23 |
| 0.45 - 0.60 | 57.10 ± 5.90 | 1.15 ± 0.25 |
| 0.60 - 1.00 | 55.60 ± 8.40 | 0.55 ± 0.17 |
| Total | – | **4.68±0.54** |

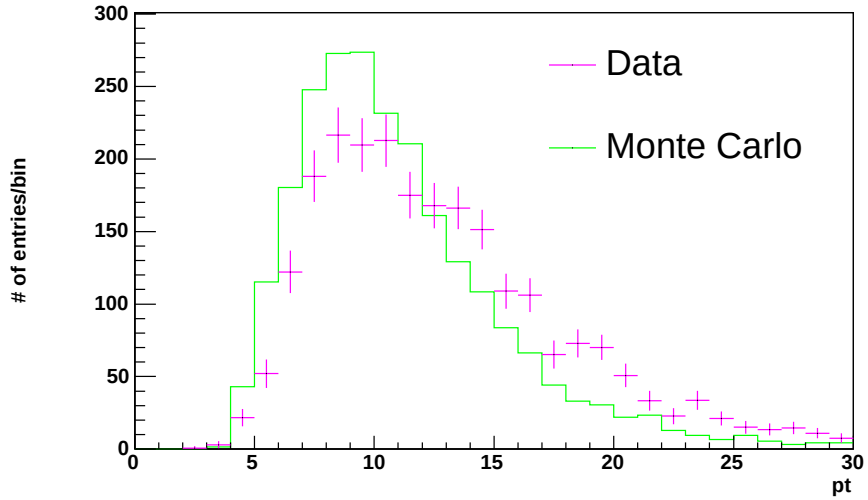
# Data-MC comparison

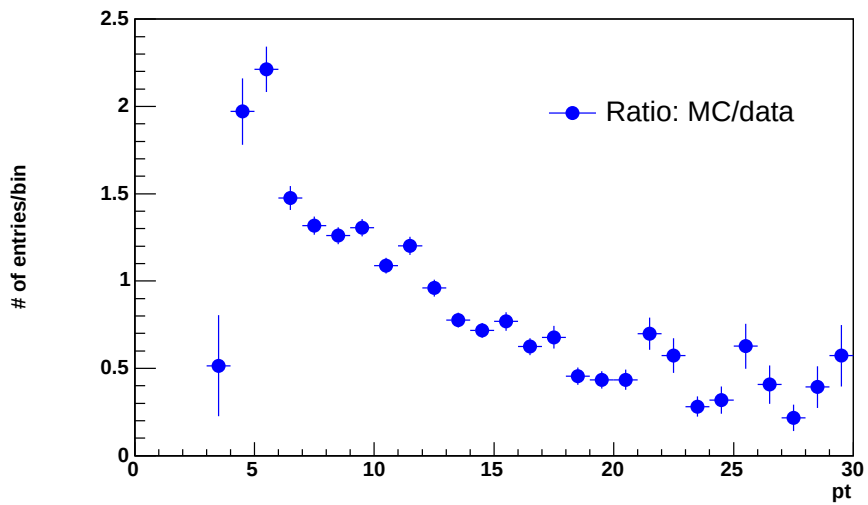


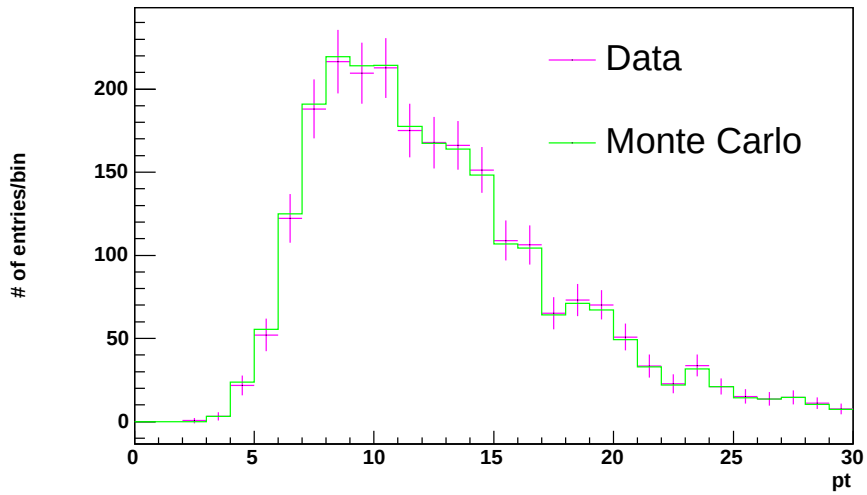
# Data-MC comparison

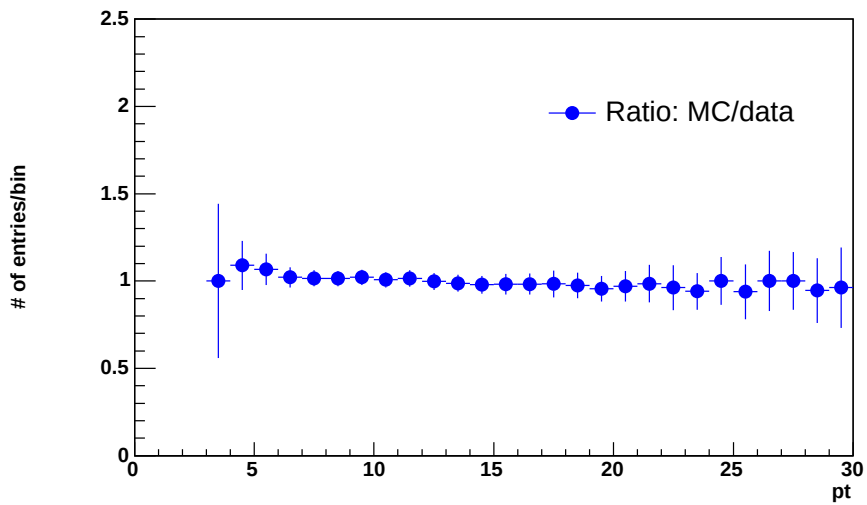
Before re-weighting



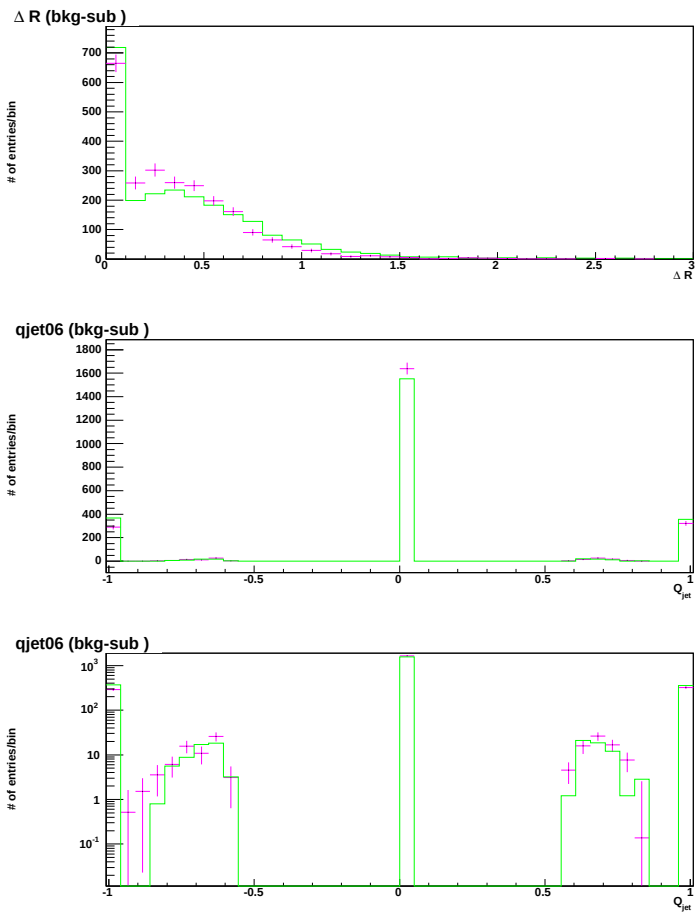

After re-weighting



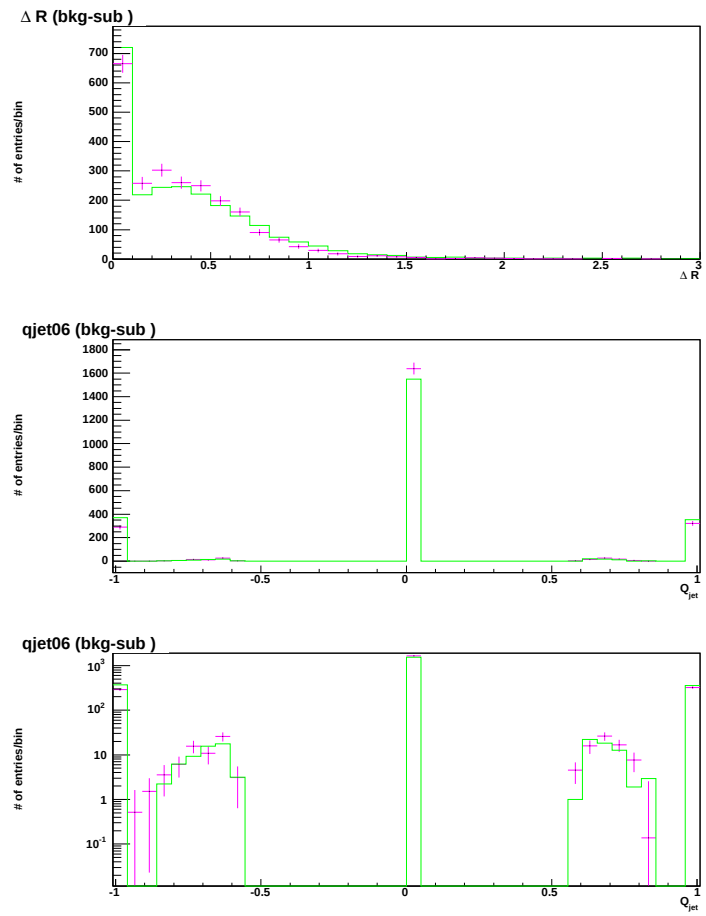



# "Min. $\Delta R$" and "$Q_{jet}(p_t, \kappa = 0.6)$"

Before re-weighting




After re-weighting




- Peak at zero - no-tag events
- Overall change is small, matching improves a little bit

# Tagger performance

| Tagger | $\epsilon$, % | $D$, % | Unbinned $\epsilon D^2$, % | Binned $\epsilon D^2$, % |
|---|---|---|---|---|
| SST before re-weighting | 84.3±1.7 | 13.0±1.5 | 1.41±0.32 | 2.36±0.40 |
| SST after re-weighting | 84.3±1.7 | 14.2±1.5 | 1.68±0.34 | 2.91±0.44 |
| SST+OST before re-weighting | 97.0±1.9 | 17.7±1.3 | 3.03±0.46 | 4.68±0.54 |
| SST+OST after re-weighting | 97.1±1.9 | 18.9±1.3 | 3.46±0.49 | 5.26±0.57 |

- Re-weighting slightly improves results
- Small difference, can be used for systematics

# Conclusion

- SST works for $B_s \to J/\psi\phi$
- Monte Carlo for $B_s \to J/\psi\phi$ needs to be re-weighted
- Re-weighting slightly affects (improves) SST and SST+OST performance
- Combination SST + OST has expected value of $\epsilon D^2$ ($\sim 4.7\%$)
- $B_s \to \mu\phi\pi$ is under study

# Backup

# SST-OST correlations in $B \to J/\psi\phi$ MC

| Tagger | $D_{SST}$ with OST | $D_{SST}$ without OST | $D_{OST}$ with SST | $D_{OST}$ without SST |
|---|---|---|---|---|
| "Comb. SST" + "Comb. OST" | 13.9±5.3 | 13.0±1.5 | 49.6±4.6 | 51.1±12.8 |
| "Min. $\Delta R$" + "Comb. OST" | 11.6±5.6 | 14.3±1.6 | 48.4±5.0 | 54.5±8.9 |
| "$Q_{jet}(p_t, \kappa = 0.6)$" + "Comb. OST" | 21.6±8.0 | 16.1±2.3 | 49.6±4.6 | 51.1±12.8 |

- There is **no correlations** observed, but the errors are quite large...

# SST-OST correlations in $B \to J/\psi K$ MC sample

| Tagger | $D_{SST}$ with OST | $D_{SST}$ without OST | $D_{OST}$ with SST | $D_{OST}$ without SST |
|---|---|---|---|---|
| "Comb. SST" + "Comb. OST" | 15.9±1.6 | 18.6±0.5 | 36.9±1.5 | 49.1±3.9 |
| "Min. $\Delta R$" + "Comb. OST" | 14.9±1.7 | 19.3±0.5 | 36.0±1.6 | 47.6±3.0 |
| "$Q_{jet}(p_t, \kappa = 0.6)$" + "Comb. OST" | 17.0±1.6 | 20.3±0.5 | 37.1±1.5 | 48.7±4.1 |
| "Min. $p_t^{rel}$" + "Comb. OST" | 10.7±1.7 | 15.3±0.5 | 36.0±1.6 | 47.6±3.0 |
| "Min. $\Delta R$" + "$\mu$ OST" | 13.7±3.0 | 19.1±0.5 | 38.4±2.8 | 36.2±6.1 |
| "$Q_{jet}(p_t, \kappa = 0.6)$" + "$\mu$ OST" | 19.5±2.8 | 20.1±0.4 | 38.7±2.7 | 32.3±8.3 |
| "Min. $p_t^{rel}$" + "$\mu$ OST" | 6.4±3.0 | 15.2±0.5 | 38.4±2.8 | 36.2±6.1 |

- We observe some correlation
- Presence of OST **decreases** SST dilution
  - The effect does not vanish even for "Min. $p_t^{rel}$" SST and "$\mu$ OST"
- Presence of SST decreases "Comb. OST" dilution but increases "$\mu$ OST" dilution

# SST-OST correlations in $B \to J/\psi K$ data sample

| Tagger | $D_{SST}$ with OST | $D_{SST}$ without OST | $D_{OST}$ with SST | $D_{OST}$ without SST |
|---|---|---|---|---|
| "Comb. SST" + "Comb. OST" | 22.6±1.8 | 20.1±0.5 | 34.8±1.7 | 50.0±5.0 |
| "Min. $\Delta R$" + "Comb. OST" | 24.0±1.8 | 21.0±0.5 | 34.0±1.8 | 47.0±3.8 |
| "$Q_{jet}(p_t, \kappa = 0.6)$" + "Comb. OST" | 20.7±1.8 | 20.0±0.5 | 35.2±1.7 | 47.2±5.4 |
| "Min. $p_t^{rel}$" + "Comb. OST" | 20.5±1.9 | 18.1±0.5 | 34.0±1.8 | 47.0±3.8 |
| "Min. $\Delta R$" + "$\mu$ OST" | 21.5±2.8 | 21.2±0.5 | 35.8±2.7 | 51.6±5.7 |
| "$Q_{jet}(p_t, \kappa = 0.6)$" + "$\mu$ OST" | 18.7±2.7 | 20.1±0.5 | 37.1±2.5 | 54.8±8.7 |
| "Min. $p_t^{rel}$" + "$\mu$ OST" | 20.7±2.8 | 18.2±0.5 | 35.8±2.7 | 51.6±5.7 |

- Presence of OST **does not change** SST dilution
- Presence of SST **decreases** OST dilution
  - The effect does not vanish even for "Min. $p_t^{rel}$" SST and "$\mu$ OST"