Update on same-side tagging for B_s-mixing

A. Rakitin

Lancaster University

June 15, 2006

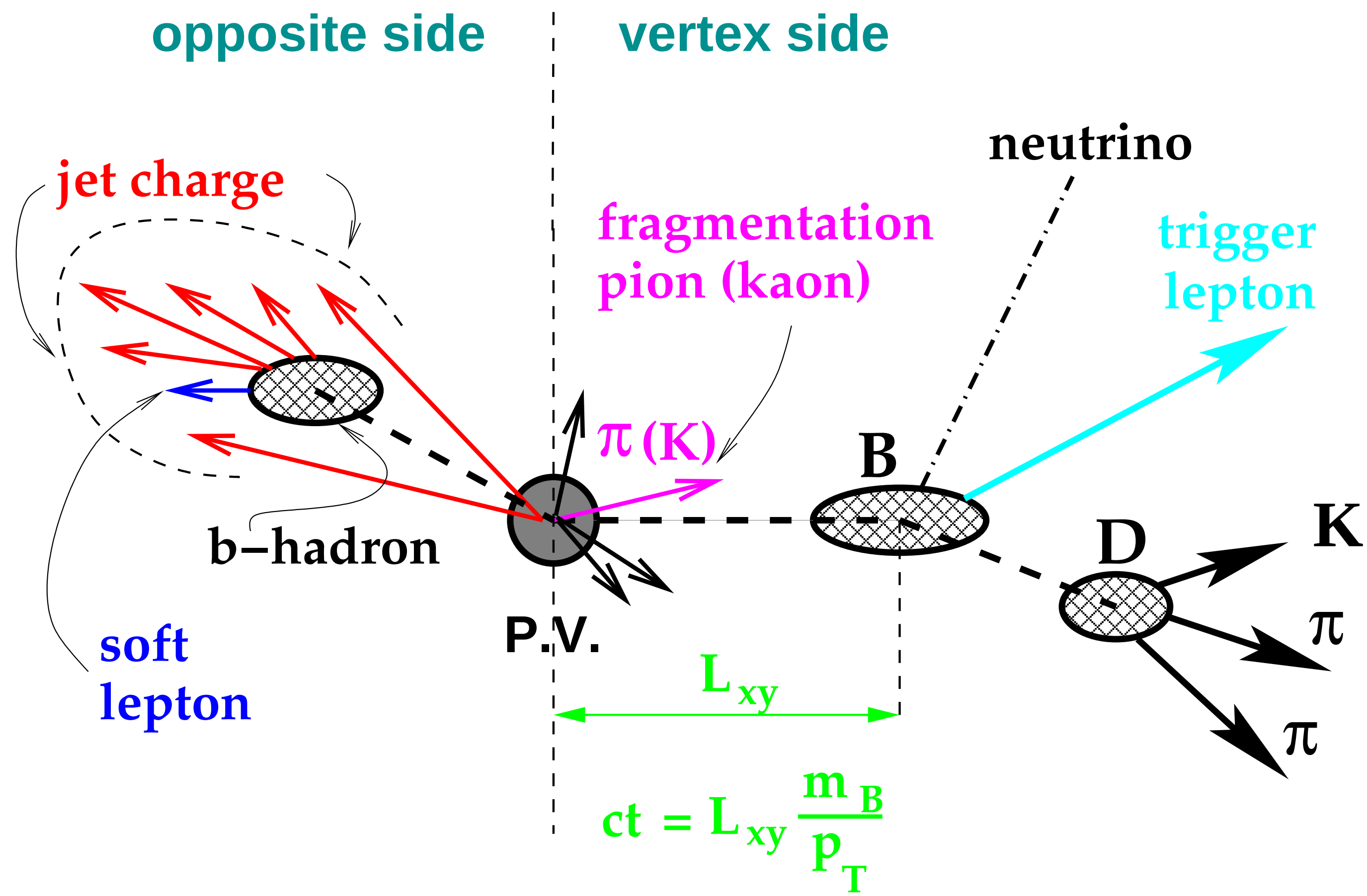
B-mixing and Lifetime Meeting

http://www-d0.fnal.gov/~rakitin/d0_private/tex/2006.Jun.15.Bmix/tr.pdf

Short introduction

To know if B-meson oscillated we need to know

- B-flavor at decay $\Longleftarrow$ can be inferred from trigger lepton charge
- B-flavor at production $\Longleftarrow$ obtained from OST (jet-charge, soft-lepton) or SST



I am going to talk about SST

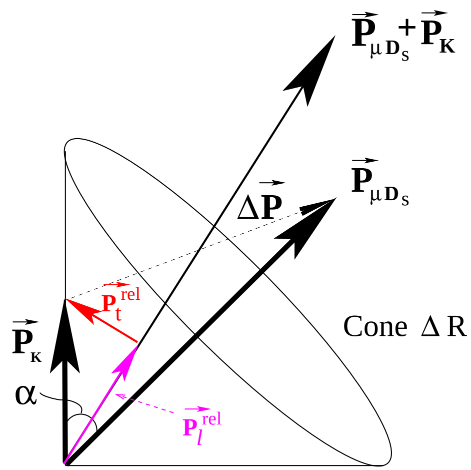
Outline of the analysis:

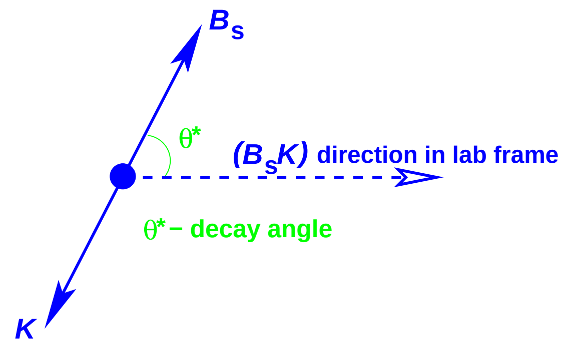
- Reconstruct B_s in p17 MC sample $B_s \to \mu D_s, D_s \to \phi\pi, (x_s = 25)$ (requests 29892, 29893)
- Look at tracks in cone $\cos\alpha < 0.8$ around $\vec{p}(B_s)$ (for consistency with OST)
- Use one of the following for same-side tagging:
  - Charge of one track, either selected with some kinematic algorithm or identified as kaon (from dE/dx)
  - Charges of kaons coming from K^{*0} or pions from Λ (two-track taggers)
  - Average charge of all tracks around $\vec{p}(B)$, like "jet-charge" (many-track taggers)
- Choose a few best same-side taggers
- Compute *combined dilution* d for them

One-track taggers:

Eleven taggers are used:

- ☞ Min. p_t^{rel}
- ☞ Max. p_L^{rel}
- ☞ Max. p_t
- ☞ Min. $|\Delta\vec{P}| \equiv |\vec{p}(B_s) - \vec{p}(K)|$
- ☞ Min. ΔR
- ☞ Max. $\cos\alpha$
- ☞ Min. $\cos\theta^*$
- ☞ Max. $\cos\theta^*$
- ☞ Min. $m(B_sK)$
- ☞ Highest kaon prob
- ☞ Random track
- ☞ . . .





- p_t^{rel} and p_L^{rel} are $\perp$ and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_sK)$
- $\Delta R \equiv \sqrt{\Delta\phi^2 + \Delta\eta^2}$ and angle α are taken between $\vec{p}(B_s)$ and $\vec{p}(K)$
- θ^* – 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
- Probability for a track to be a kaon, rather than pion, is taken from dE/dx (thanks to D. Strom)

Two-track taggers:

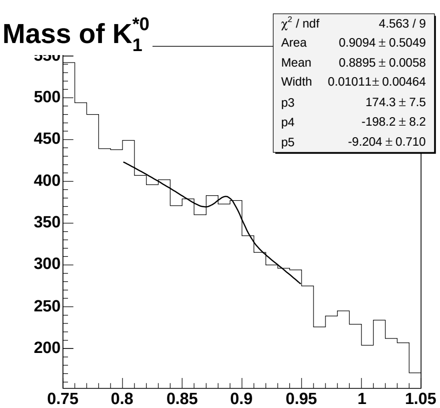
Using charge of kaon coming from $K^{*0} \to K\pi$ and $\Lambda \to p\pi$:

- ☞ Reconstruct $0.842 < m(K^{*0} \to K\pi) < 0.942$ with auto-reflection being outside of this mass window, so that we know which track is kaon
- ☞ Apply cuts to reconstruction of $K^{*0} \to K\pi$ – see if they improve tagging performance
- ☞ Reconstruct $\Lambda \to p\pi^-$ and $\bar{\Lambda} \to \bar{p}\pi^+$

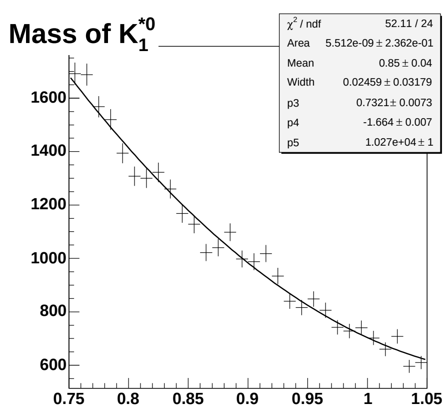
– Particles reconstructed out of tracks in cone $\cos\alpha > 0.8$

– B_s daughters are, obviously, excluded

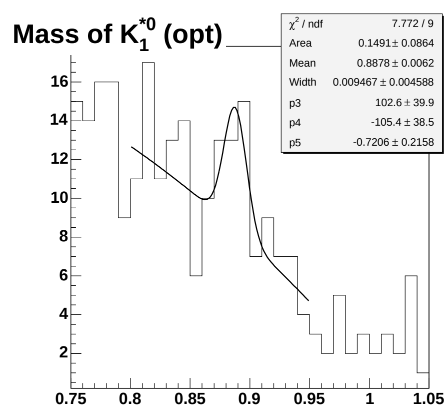
Monte Carlo



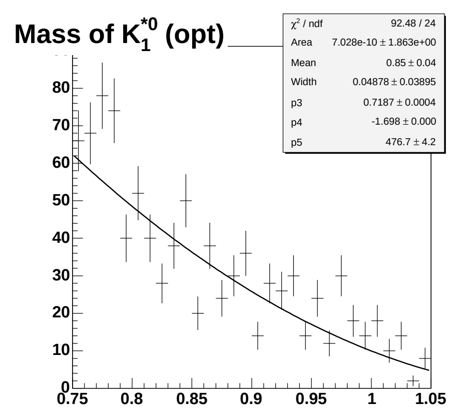
Data



Monte Carlo



Data



Many-track taggers:

Using weigted-average charge of all the tracks around $\vec{p}(B_s)$

Thirty-one tagger used:

☞ $Q_{jet}(p_t, \kappa) = \frac{\sum q \cdot p_t^\kappa}{\sum p_t^\kappa}$

☞ $Q_{jet}(p_t^{rel}, \kappa) = \frac{\sum q \cdot (p_t^{rel})^\kappa}{\sum (p_t^{rel})^\kappa}$

☞ $Q_{jet}(p_L^{rel}, \kappa) = \frac{\sum q \cdot (p_L^{rel})^\kappa}{\sum (p_L^{rel})^\kappa}$

- $\kappa = 0.0, 0.1, 0.2, ...1.0$
- p_t^{rel} and p_L^{rel} here are $\perp$ and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_s)$

Obtaining *true* dilution in MC

For each tagger we measure numbers of events in which:

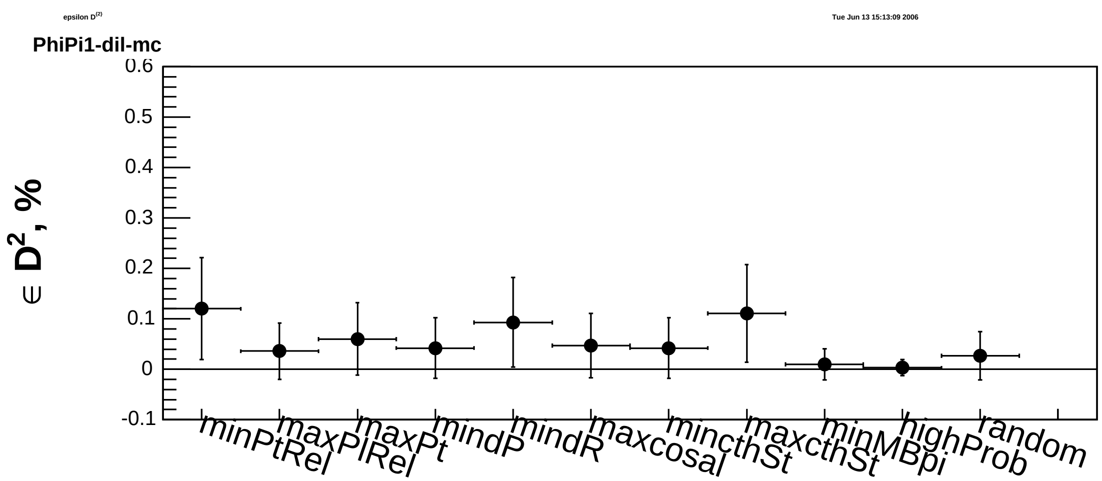
- tag charge corresponds to true B_d-flavor at production ("Right Tag")
- tag charge is opposite to true B_d-flavor at production ("Wrong Tag")
- no tag was found ("No Tag")

Mistag rate $p = \frac{N_{WT}}{N_{RT}+N_{WT}}$

True dilution D $= 1 - 2p = \frac{N_{RT}-N_{WT}}{N_{RT}+N_{WT}}$

True dilutions in MC - one-track taggers

Tagger	RT	WT	NT	ε, %	D, %	εD^2, %
Min. p_t^{rel}	1043 $\pm$ 32	941 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	5.1 $\pm$ 2.2	0.120 $\pm$ 0.101
Max. p_L^{rel}	1020 $\pm$ 32	964 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	2.8 $\pm$ 2.2	0.036 $\pm$ 0.056
Max. p_t	1028 $\pm$ 32	956 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	3.6 $\pm$ 2.2	0.060 $\pm$ 0.072
Min. ΔR	1037 $\pm$ 32	947 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	4.5 $\pm$ 2.2	0.093 $\pm$ 0.089
Max. $\cos\alpha$	1024 $\pm$ 32	960 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	3.2 $\pm$ 2.2	0.047 $\pm$ 0.064
Min. $\lvert\Delta\vec{P}\rvert$	1022 $\pm$ 32	962 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	3.0 $\pm$ 2.2	0.042 $\pm$ 0.060
Min. $m(B_sK)$	977 $\pm$ 31	1007 $\pm$ 32	2387 $\pm$ 49	45.4 $\pm$ 0.8	-1.5 $\pm$ 2.2	0.010 $\pm$ 0.031
Min. $\cos\theta^*$	1022 $\pm$ 32	962 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	3.0 $\pm$ 2.2	0.042 $\pm$ 0.060
Max. $\cos\theta^*$	1041 $\pm$ 32	943 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	4.9 $\pm$ 2.2	0.111 $\pm$ 0.097
High kaon prob.	141 $\pm$ 12	135 $\pm$ 12	4095 $\pm$ 64	6.3 $\pm$ 0.4	2.2 $\pm$ 6.0	0.003 $\pm$ 0.016
Random track	1016 $\pm$ 32	968 $\pm$ 31	2387 $\pm$ 49	45.4 $\pm$ 0.8	2.4 $\pm$ 2.2	0.027 $\pm$ 0.048

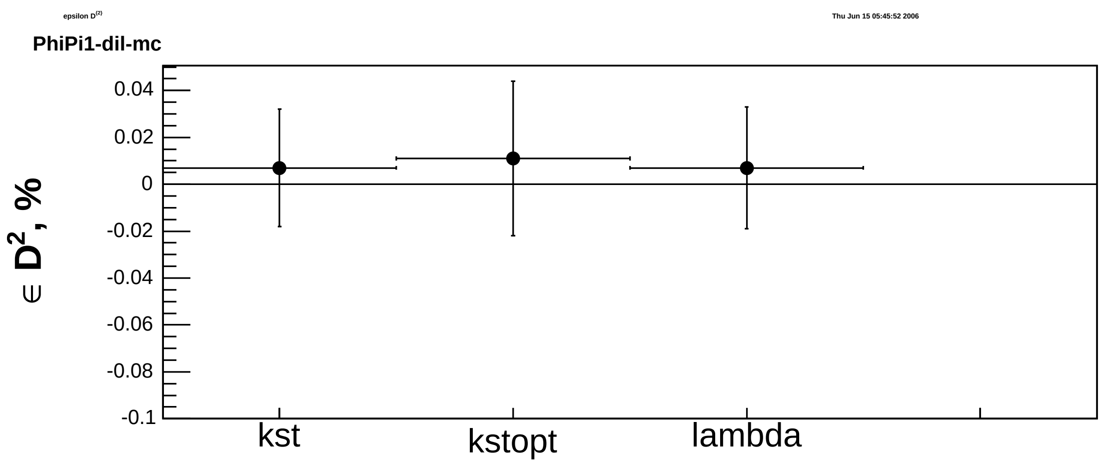


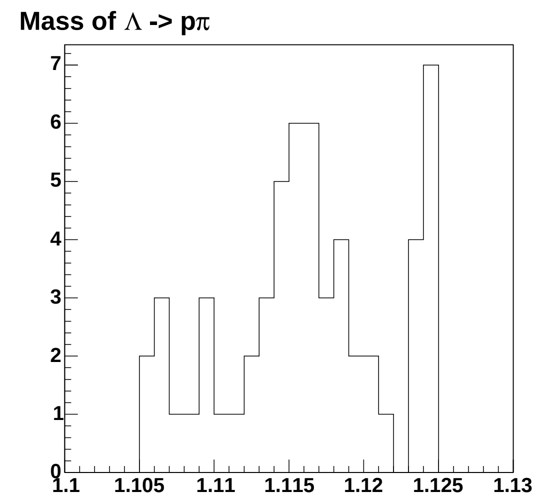
Found and fixed bug affecting "Min. p_t^{rel}" dilution $\Longrightarrow$ now "Min. p_t^{rel}" is the best one-track tagger

We will use "Min. p_t^{rel}", skipping the rest of the table

True dilutions in MC - two-track taggers

Tagger	RT	WT	NT	ε, %	D, %	εD^2, %
$K^{*0} \to K\pi$	439 $\pm$ 21	423 $\pm$ 21	3509 $\pm$ 59	19.7 $\pm$ 0.6	1.9 $\pm$ 3.4	0.007 $\pm$ 0.025
$K^{*0} \to K\pi$(opt)	48 $\pm$ 7	55 $\pm$ 7	4268 $\pm$ 65	2.4 $\pm$ 0.2	-6.8 $\pm$ 9.8	0.011 $\pm$ 0.033
Λ	6 $\pm$ 2	8 $\pm$ 3	4357 $\pm$ 66	0.3 $\pm$ 0.1	-14.3 $\pm$ 26.5	0.007 $\pm$ 0.026



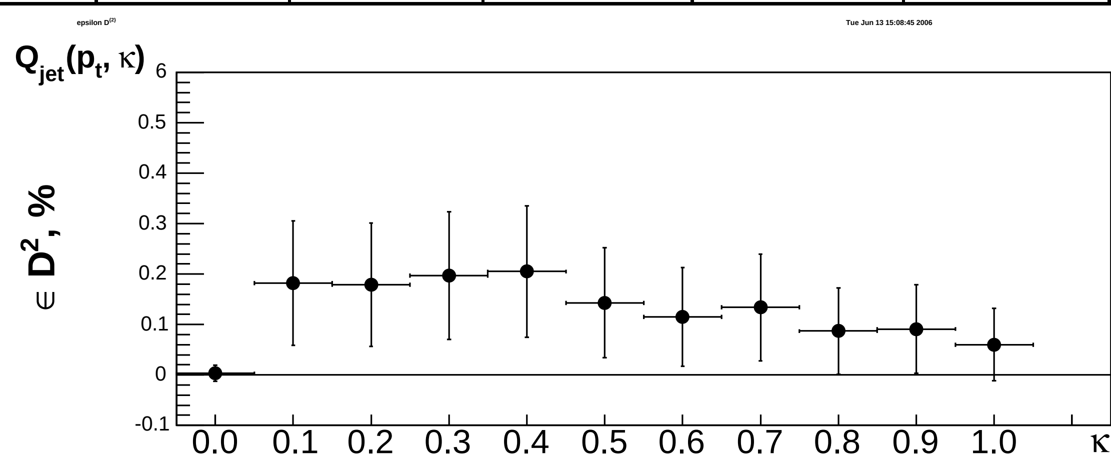


Let's choose "Lambda"

True dilutions in MC - many-track taggers

Weighted with p_t:

Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
$\sum Q$	703 ± 27	716 ± 27	2952 ± 54	32.5 ± 0.7	-0.9 ± 2.7	0.003 ± 0.016
$Q_{jet}(p_t, \kappa = 0.1)$	758 ± 28	652 ± 26	2961 ± 54	32.3 ± 0.7	7.5 ± 2.7	0.182 ± 0.123
$Q_{jet}(p_t, \kappa = 0.2)$	757 ± 28	652 ± 26	2962 ± 54	32.2 ± 0.7	7.5 ± 2.7	0.179 ± 0.122
$Q_{jet}(p_t, \kappa = 0.3)$	758 ± 28	648 ± 25	2965 ± 54	32.2 ± 0.7	7.8 ± 2.7	0.197 ± 0.127
$Q_{jet}(p_t, \kappa = 0.4)$	724 ± 27	608 ± 25	3039 ± 55	30.5 ± 0.7	8.7 ± 2.7	0.231 ± 0.137
$Q_{jet}(p_t, \kappa = 0.5)$	739 ± 27	646 ± 25	2986 ± 55	31.7 ± 0.7	6.7 ± 2.7	0.143 ± 0.109
$Q_{jet}(p_t, \kappa = 0.6)$	728 ± 27	645 ± 25	2998 ± 55	31.4 ± 0.7	6.0 ± 2.7	0.115 ± 0.098
$Q_{jet}(p_t, \kappa = 0.7)$	722 ± 27	633 ± 25	3016 ± 55	31.0 ± 0.7	6.6 ± 2.7	0.134 ± 0.106
$Q_{jet}(p_t, \kappa = 0.8)$	702 ± 26	631 ± 25	3038 ± 55	30.5 ± 0.7	5.3 ± 2.7	0.087 ± 0.086
$Q_{jet}(p_t, \kappa = 0.9)$	691 ± 26	619 ± 25	3061 ± 55	30.0 ± 0.7	5.5 ± 2.8	0.091 ± 0.088
$Q_{jet}(p_t, \kappa = 1.0)$	666 ± 26	608 ± 25	3097 ± 56	29.1 ± 0.7	4.6 ± 2.8	0.060 ± 0.072

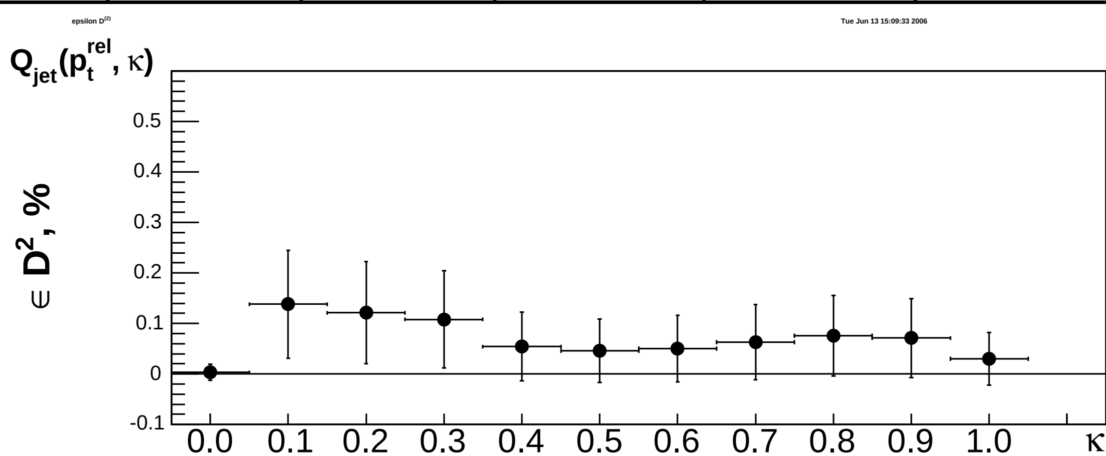


Best $\kappa = 0.4$

True dilutions in MC - many-track taggers

Weighted with p_t^{rel}:

Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	εD^2, %
$\sum Q$	703 ± 27	716 ± 27	2952 ± 54	32.5 ± 0.7	-0.9 ± 2.7	0.003 ± 0.016
$Q_{jet}(p_t^{rel}, \kappa = 0.1)$	750 ± 27	658 ± 26	2963 ± 54	32.2 ± 0.7	6.5 ± 2.7	0.138 ± 0.107
$Q_{jet}(p_t^{rel}, \kappa = 0.2)$	743 ± 27	657 ± 26	2971 ± 55	32.0 ± 0.7	6.1 ± 2.7	0.121 ± 0.101
$Q_{jet}(p_t^{rel}, \kappa = 0.3)$	736 ± 27	655 ± 26	2980 ± 55	31.8 ± 0.7	5.8 ± 2.7	0.108 ± 0.096
$Q_{jet}(p_t^{rel}, \kappa = 0.4)$	717 ± 27	660 ± 26	2994 ± 55	31.5 ± 0.7	4.1 ± 2.7	0.054 ± 0.068
$Q_{jet}(p_t^{rel}, \kappa = 0.5)$	705 ± 27	653 ± 26	3013 ± 55	31.1 ± 0.7	3.8 ± 2.7	0.046 ± 0.063
$Q_{jet}(p_t^{rel}, \kappa = 0.6)$	692 ± 26	638 ± 25	3041 ± 55	30.4 ± 0.7	4.1 ± 2.7	0.050 ± 0.066
$Q_{jet}(p_t^{rel}, \kappa = 0.7)$	682 ± 26	622 ± 25	3067 ± 55	29.8 ± 0.7	4.6 ± 2.8	0.063 ± 0.074
$Q_{jet}(p_t^{rel}, \kappa = 0.8)$	671 ± 26	606 ± 25	3094 ± 56	29.2 ± 0.7	5.1 ± 2.8	0.076 ± 0.080
$Q_{jet}(p_t^{rel}, \kappa = 0.9)$	654 ± 26	592 ± 24	3125 ± 56	28.5 ± 0.7	5.0 ± 2.8	0.071 ± 0.078
$Q_{jet}(p_t^{rel}, \kappa = 1.0)$	623 ± 25	583 ± 24	3165 ± 56	27.6 ± 0.7	3.3 ± 2.9	0.030 ± 0.052

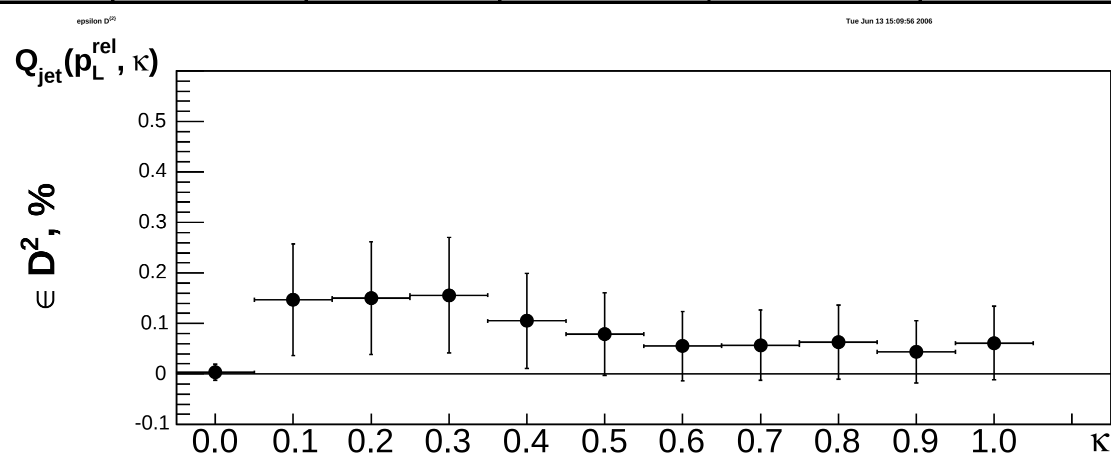


Best $\kappa = 0.1$

True dilutions in MC - many-track taggers

Weighted with p_L^{rel}:

Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
$\sum Q$	703 ± 27	716 ± 27	2952 ± 54	32.5 ± 0.7	-0.9 ± 2.7	0.003 ± 0.016
$Q_{jet}(p_L^{rel}, \kappa = 0.1)$	752 ± 27	657 ± 26	2962 ± 54	32.2 ± 0.7	6.7 ± 2.7	0.147 ± 0.111
$Q_{jet}(p_L^{rel}, \kappa = 0.2)$	753 ± 27	657 ± 26	2961 ± 54	32.3 ± 0.7	6.8 ± 2.7	0.150 ± 0.112
$Q_{jet}(p_L^{rel}, \kappa = 0.3)$	752 ± 27	654 ± 26	2965 ± 54	32.2 ± 0.7	7.0 ± 2.7	0.156 ± 0.114
$Q_{jet}(p_L^{rel}, \kappa = 0.4)$	736 ± 27	656 ± 26	2979 ± 55	31.8 ± 0.7	5.7 ± 2.7	0.105 ± 0.094
$Q_{jet}(p_L^{rel}, \kappa = 0.5)$	725 ± 27	656 ± 26	2990 ± 55	31.6 ± 0.7	5.0 ± 2.7	0.079 ± 0.082
$Q_{jet}(p_L^{rel}, \kappa = 0.6)$	710 ± 27	653 ± 26	3008 ± 55	31.2 ± 0.7	4.2 ± 2.7	0.055 ± 0.069
$Q_{jet}(p_L^{rel}, \kappa = 0.7)$	700 ± 26	642 ± 25	3029 ± 55	30.7 ± 0.7	4.3 ± 2.7	0.057 ± 0.070
$Q_{jet}(p_L^{rel}, \kappa = 0.8)$	688 ± 26	628 ± 25	3055 ± 55	30.1 ± 0.7	4.6 ± 2.8	0.063 ± 0.073
$Q_{jet}(p_L^{rel}, \kappa = 0.9)$	670 ± 26	620 ± 25	3081 ± 56	29.5 ± 0.7	3.9 ± 2.8	0.044 ± 0.062
$Q_{jet}(p_L^{rel}, \kappa = 1.0)$	658 ± 26	600 ± 24	3113 ± 56	28.8 ± 0.7	4.6 ± 2.8	0.061 ± 0.073



Best $\kappa = 0.3$

Best many-track tagger

- The best tagger is $Q_{jet}(p_t, \kappa = 0.4)$
- We will use this tagger only, skipping the remaining 30

Chosen taggers

- So, we've chosen three taggers: "Min p_t^{rel}", "Lambda" and "$Q_{jet}(p_t, \kappa = 0.4)$"
- Let's obtain one combined tagging variable for them

Combination of B-flavor taggers:

- Combination algorithm (developed by Guennadi *et al.* for OST):
  - Find uncorrelated discriminating variables x_i
    with p.d.f. $f_i^b(x_i)$ and $f_i^{\bar{b}}(x_i)$ being different for b and $\bar{b}$ quarks
  - Define tagging variables $y_i = \frac{f_i^b(x_i)}{f_i^{\bar{b}}(x_i)}$; $y_i > 1$ – b-quark, $y_i < 1$ – $\bar{b}$-quark
  - Define combined tagging variable $y = \prod y_i$
  - Compute *combined dilution* for each event $d = \frac{1-y}{1+y}$

☞ Where to obtain p.d.f.'s?
  - For OST they were taken from B_d sample
  - For SST we have to take them from Monte Carlo

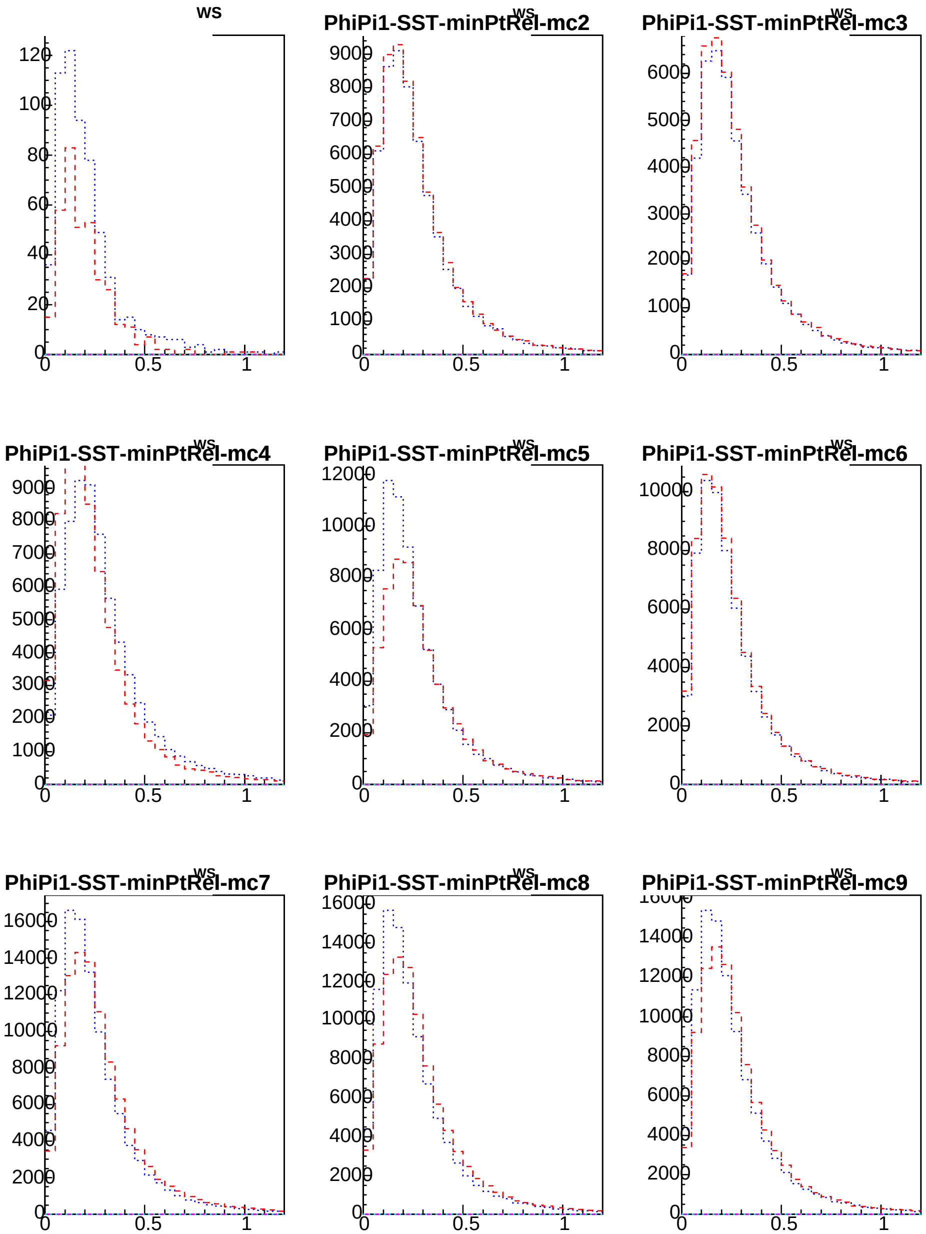
Monte Carlo samples used for p.d.f.'s:

Nine p17 Monte Carlo samples used:

- $B_s \to \mu D_s, D_s \to \phi\pi, (x_s = 25)$, requests 29892, 29893
- $B_s \to \mu^+\mu^-$, requests 29215, 29216, 29283
- $\overline{B_s} \to \mu^+\mu^-$, requests 29213, 29214, 29282
- $B^+ \to J/\psi K^+$, requests 29284, 29285
- $B^- \to J/\psi K^-$, requests 29286, 29287
- $B_s \to D_s \mu X$, request 23838
- $B_s \to D_s D_s X$, request 29865
- $B_s \to D_s^- D + X$, request 29866
- $B_s \to D_s^+ D - X$, request 29867

B^0 decays are not used because of possibility to select a B^0 daughter (π_{**}) as a tag

"Min. p_t^{rel}" p.d.f. in each MC sample:

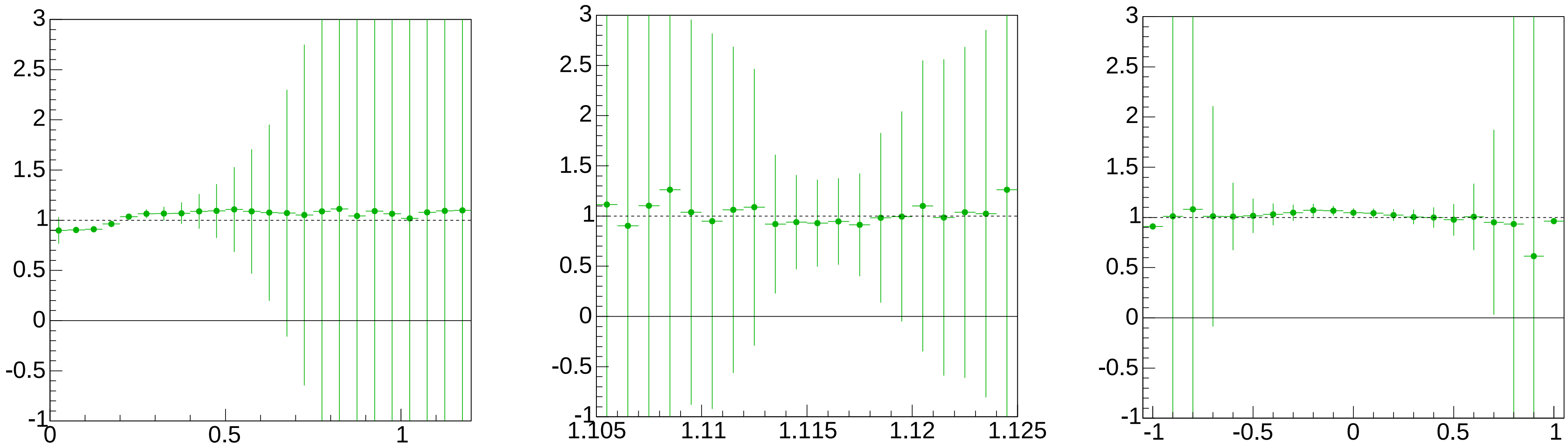


- Red - p.d.f.'s for $\bar{b}$-quark
- Blue - p.d.f.'s for b-quark

The total p.d.f. for "Min. p_t^{rel}" is the sum of all of them (to diminish stat. error)

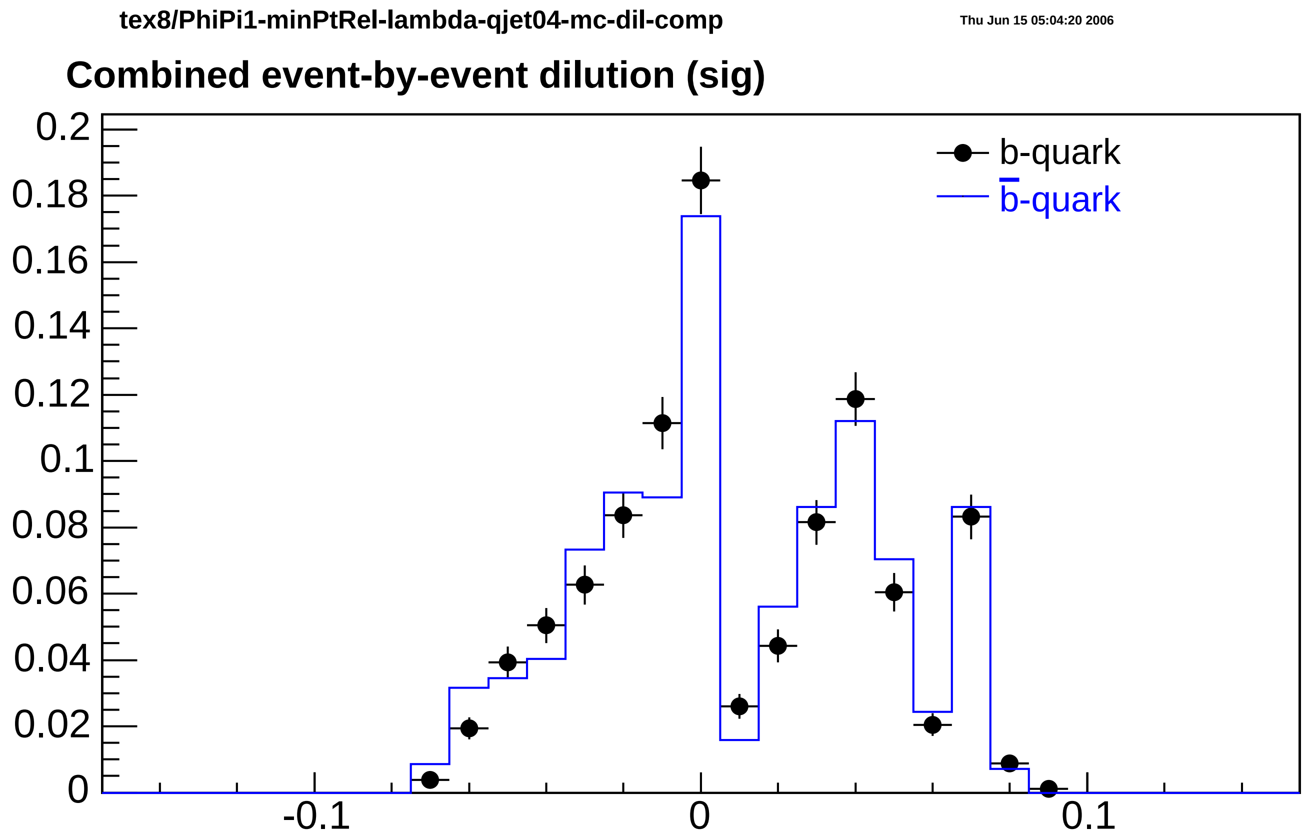
Total p.d.f's for chosen taggers:

"Min. p_t^{rel}" "Lambda" "$Q_{jet}(p_t, \kappa = 0.4)$"



- Green cricles - ratios of p.d.f.'s for $\bar{b}$-quark to p.d.f.'s for b-quark
- Combined variable y is a product of all the ratios
- Combined dilution d for each event computed as $d = \frac{1-y}{1+y}$
- Since y is close to one, d is close to zero (closer than for OST)

Combined dilution d



Unfortunately, d distributions for b and $\bar{b}$ quarks do not differ as much as for the OST $\Longrightarrow$

- Smaller discriminating power than OST
- Needs further improvement

Summary

- Investigated 45 SST algortihms for p17 Monte Carlo $B_s \to \mu D_s, D_s \to \phi\pi$ $(x_s = 25)$
- Divide taggers into three groups: 11 one-track taggers, 3 two-track taggers, 31 many track taggers
- Taggers in one group are correlated to each other $\Longrightarrow$ select one from each group:
  - Choose "Min. p_t^{rel}", "Lambda" and "$Q_{jet}(p_t, \kappa = 0.4)$" (the best ones)
- Combine these same-side taggers:
  - Combined dilution d doesn't have as much discrimination power for SST as for OST
  - Needs further work