B^+/B^0 Lifetime Ratio

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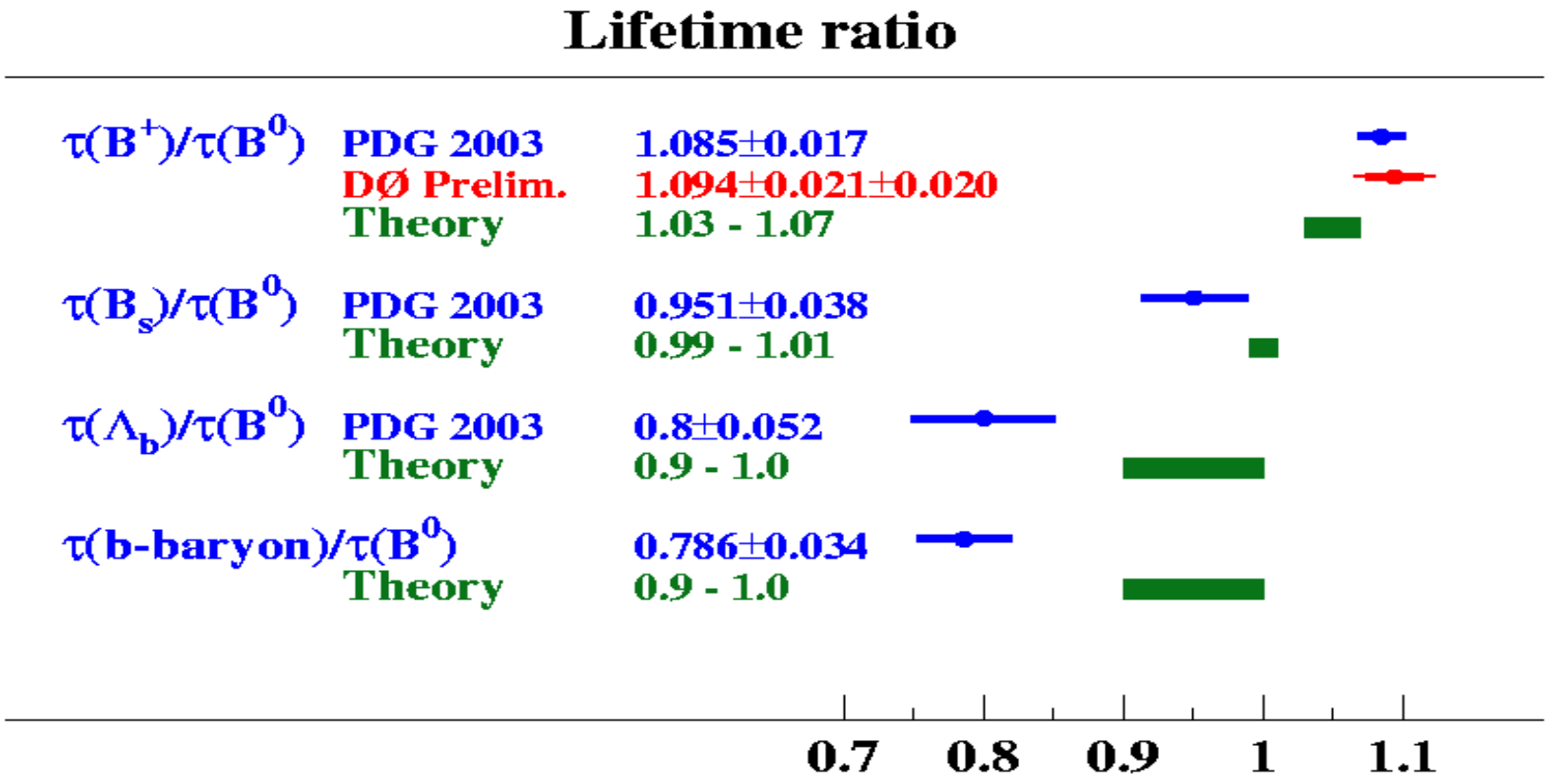
- B^+ and B^0 lifetimes should be the same in naïve spectator model and even down to $O(1/m_b^2)$ level
- However there are differences at $O(1/m_b^3)$ level explained by Weak Annihilation (for B^0) and Pauli Interference (for B^+) diagrams

- In general theory prefers to deal with ratios
- Recent progress in NLO Lattice QCD improved precision of theoretical prediction on the lifetime ratio

$$\tau(B^+)/\tau(B^0) = 1.053 \pm 0.016 \pm 0.017\ (m_B, V_{cb}, f_B)$$

Need improvements in experimental accuracy

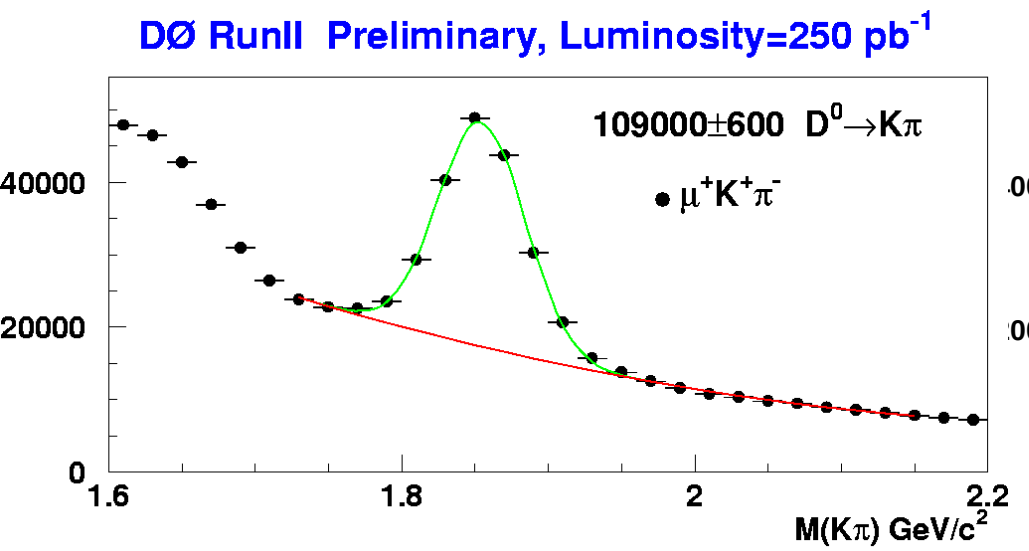
Theory Predictions vs Experiment

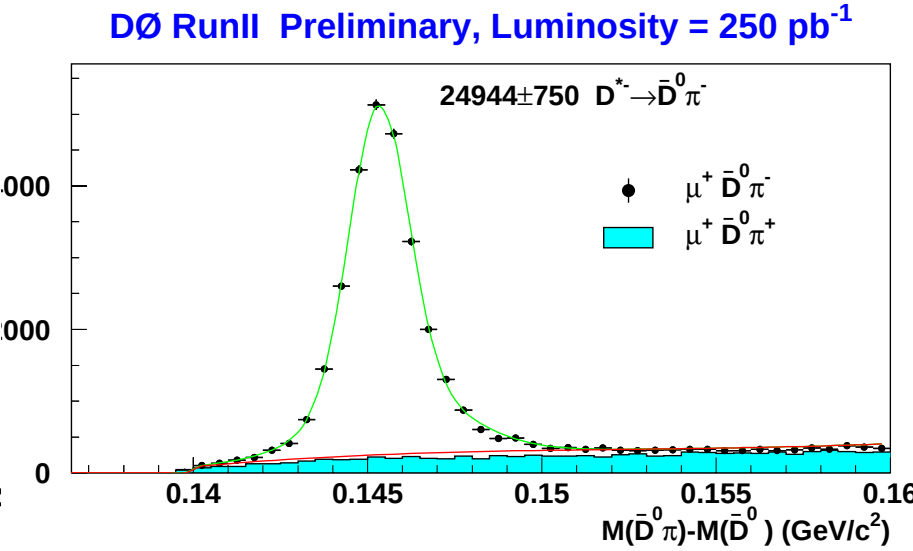


DZero Semileptonic B_d sample

- 109k $B \to \mu \nu D^0$ candidates
- 25k $B \to \mu \nu D^*$ candidates

$$B \to \mu \nu D^0 X, \quad D^0 \to K^+\pi^-$$





Dominated by B^+ decays
B^+ 82% / B^0 16%

Dominated by B^0 decays
B^0 86% / B^+ 12%

Above estimates take into account $B \to \mu \nu \{D, D^*, D^{**}\}$ contributions

Analysis : Novel Technique

Three important points :

1) Measure directly ratio of lifetimes instead of measuring absolute lifetimes

- Group events into 8 bins of Visible Proper Decay Length (VPDL):

$VPDL = L_T / p_T(\mu D^0) \cdot M_B$ $\quad$ L_T = transverse decay length

2) Measure $r = N(\mu D^*)/N(\mu D^0)$ in each bin

- Number of events is extracted from the fit of mass peak

  $\Rightarrow$ no need to know VPDL distribution for background

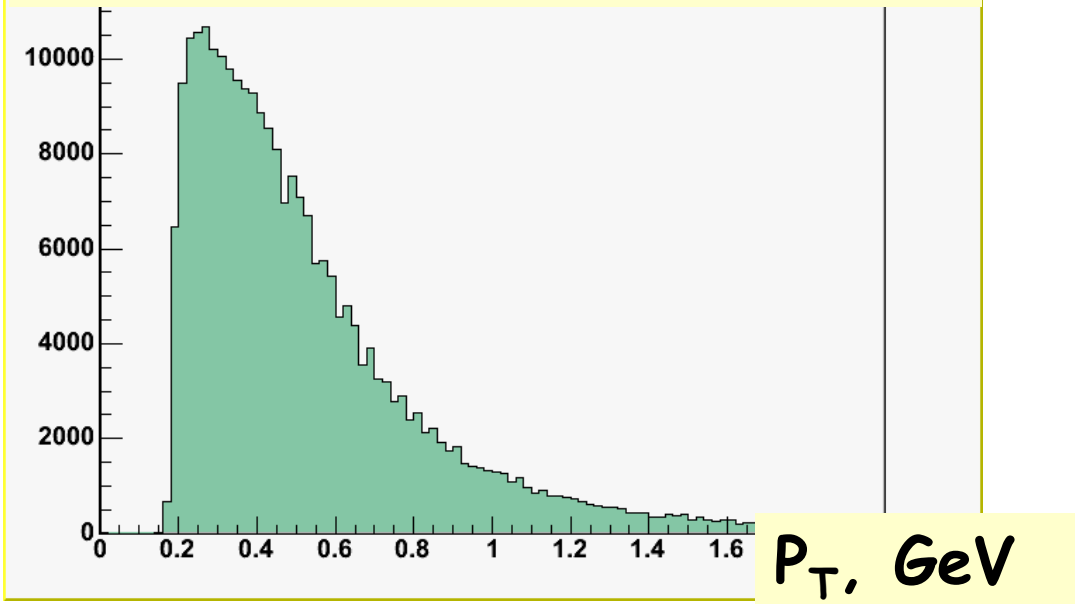
3) If relative D^*/D^0 efficiency does not depend on VPDL it does not affect the lifetime ratio =>

- Reconstruct slow pion from D* without biasing lifetime

D* Selections

- Reconstruct slow pion from D* without biasing lifetime
  - Only requirement on slow pion is to give correct m(D*)-m(D^0) value
  - Slow pion is NOT used for calculation of VPDL
    NOT used in B-vertex
    NOT used in k-factors

p_T spectrum of soft pion candidate in $D^* \to D^0 \pi$

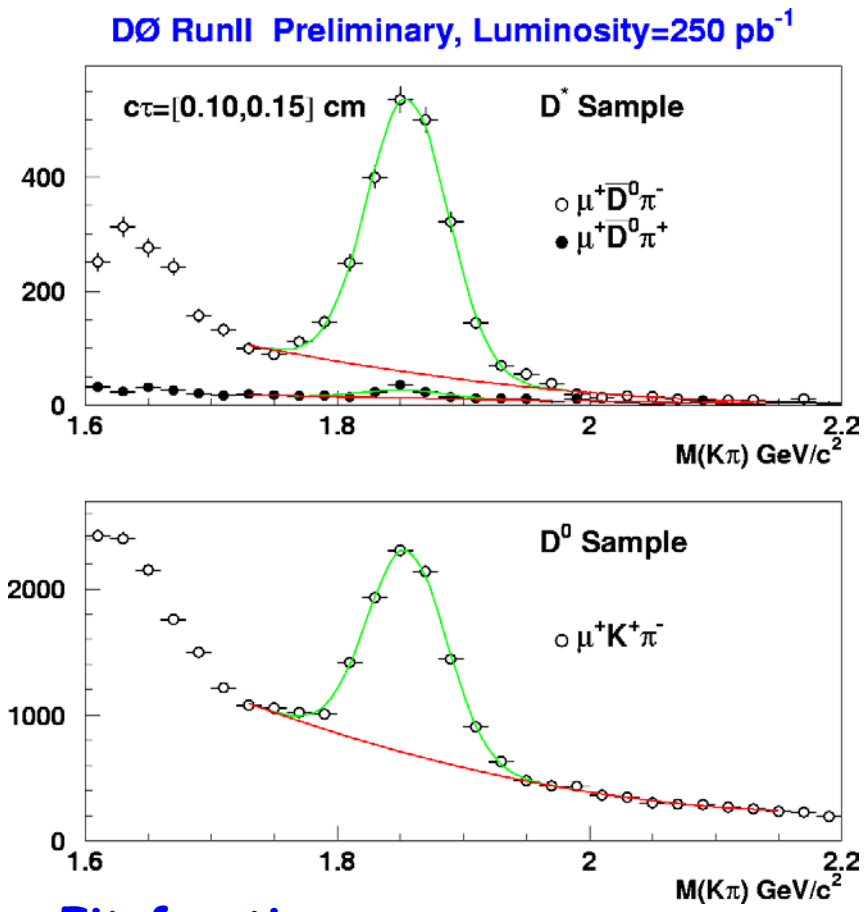


D^0 and D* Samples

- D* sample :
  - all identified D* candidates
- D^0 sample :
  - D^0 candidates with removed D* candidates

Ratio of D^0 and D* events

one example : VPDL bin [0.10 - 0.15 cm]



Fit function :

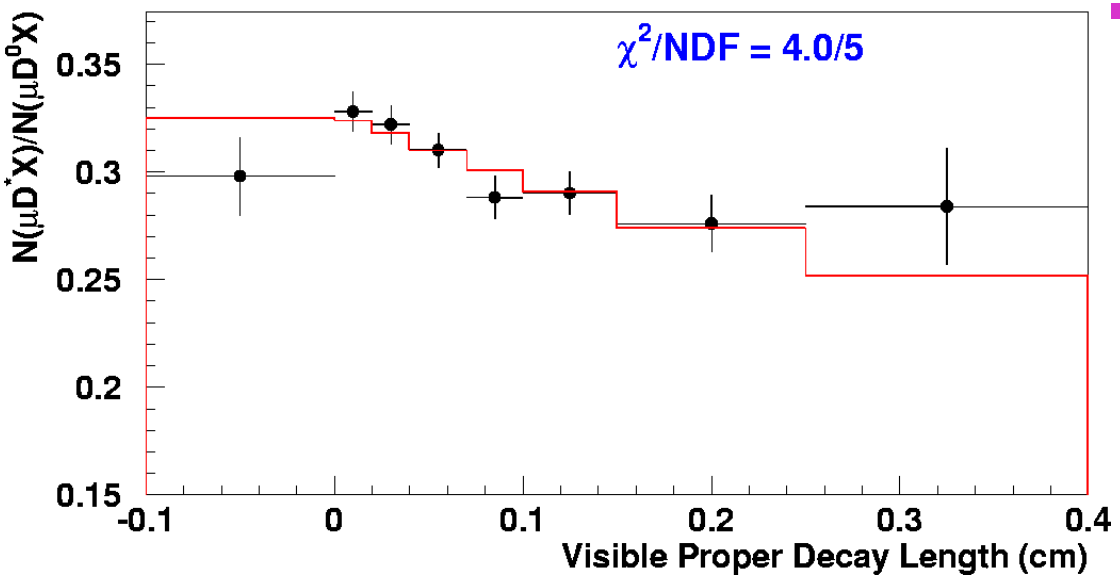
Gaussian + 2nd order polynomial

$$r_i = \frac{N_i(\mu^+ D^{*-})}{N_i(\mu^+ \bar{D}^0)} = \frac{N_i^{*R} - C \cdot N_i^{*W}}{N_i^0 + (1+C) \cdot N_i^{*W}}$$

- Fit D^0 mass peak in both cases in exactly same way
  - Decreases fit systematics
- Number of D* events is corrected to account for combinatorial bkg
  - Estimated from wrong sign D* combinations
  - Small correction because D* S/B is good
- Number of D^0 events is corrected to account for genuine D^0's lost due to D* window cut
  - Small correction as well

Measured Ratio vs VPDL

DØ RunII Preliminary, Luminosity = 250 pb^{-1}



Errors are statistical, derived from the fit of mass peaks

i	VPDL range	N_i^{*R}	N_i^{*W}	$N_i^0 + N_i^{*W}$	r_i	r_i^e
1	-0.1÷0.0	1016 ± 39	43 ± 18	3175 ± 109	0.298±0.018	0.325
2	0.0÷0.02	3482 ± 69	129 ± 22	9973 ± 162	0.328±0.009	0.324
3	0.02÷0.04	3350 ± 67	111 ± 18	9850 ± 152	0.322±0.009	0.318
4	0.04÷0.07	3593 ± 70	114 ± 18	10995 ± 155	0.310±0.008	0.310
5	0.07÷0.10	2175 ± 55	75 ± 13	7144 ± 126	0.288±0.010	0.301
6	0.10÷0.15	1932 ± 51	57 ± 13	6349 ± 120	0.290±0.010	0.291
7	0.15÷0.25	1212 ± 42	36 ± 11	4189 ± 102	0.276±0.013	0.274
8	0.25÷0.40	298 ± 21	5 ± 6	1022 ± 51	0.284±0.027	0.252

Fitting Procedure

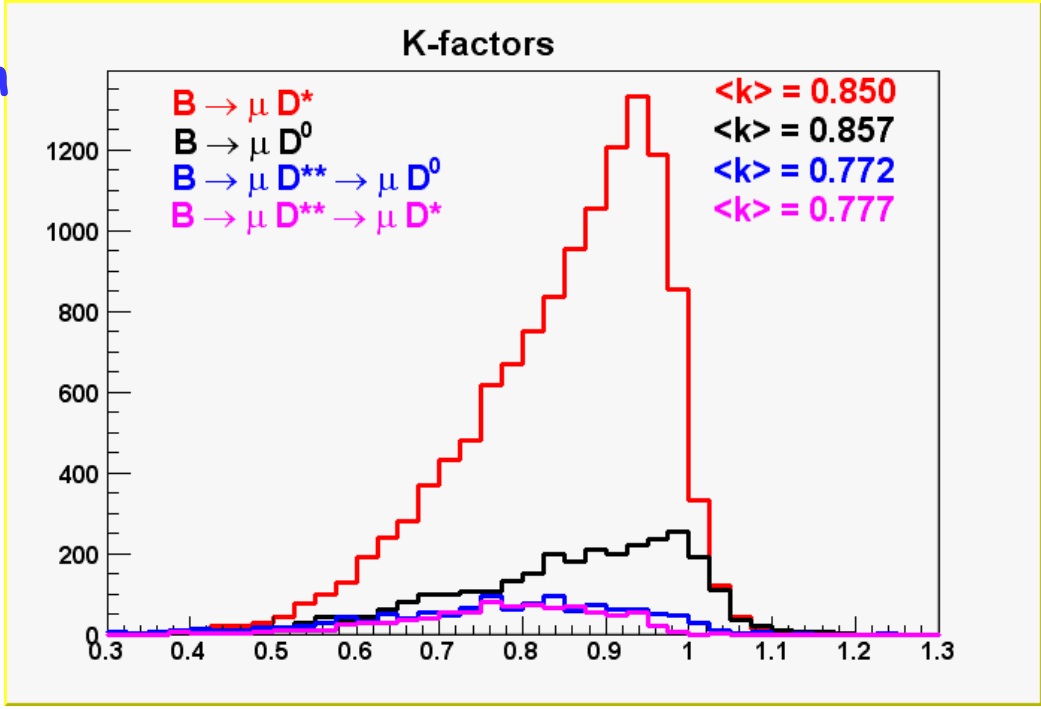
$k \equiv \tau^+/\tau^0 - 1$ **is determined from** $\chi^2(N,k)$ **minimisation:**

$$\chi^2(N,k) = \sum_i \frac{(r_i - N \cdot r_i^e(k))^2}{\sigma^2(r_i)}$$

- **Norm** N **and** k **are free parameters in minimisation;**
- $\tau^+ = 1.674 \pm 0.018$ **ps is taken from PDG;**
- $\tau^0 = \tau^+/(1+k)$**;**
- Br_j **are taken from PDG;**
- $D_j(K)$, $Res_j(x)$ **are taken from simulation;**
- $Eff_{D^0}(x)$ **is taken from simulation;**
- $Eff_{D^*}(x) = C \cdot Eff_{D^0}(x)$ **- verified in simulation;**

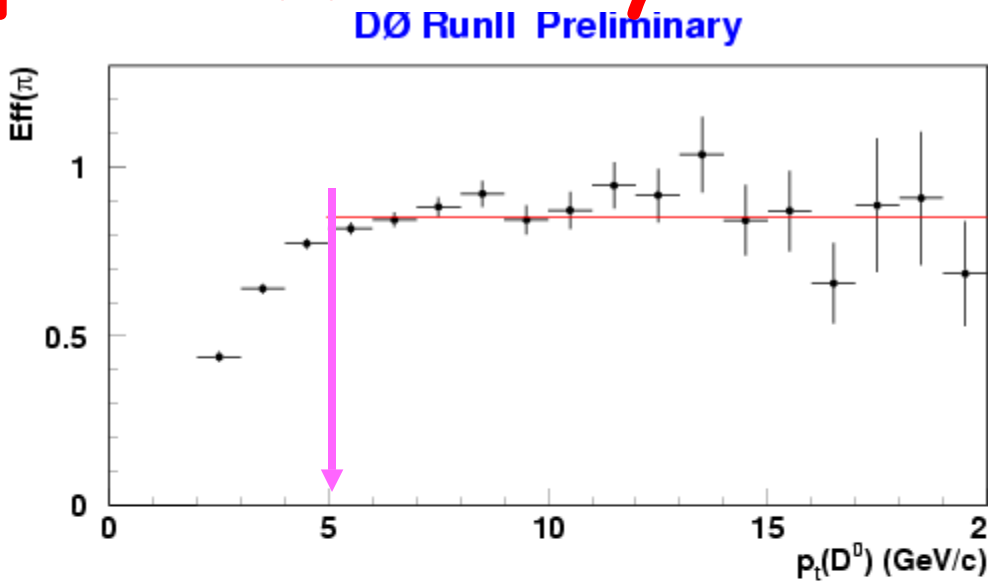
K-factors

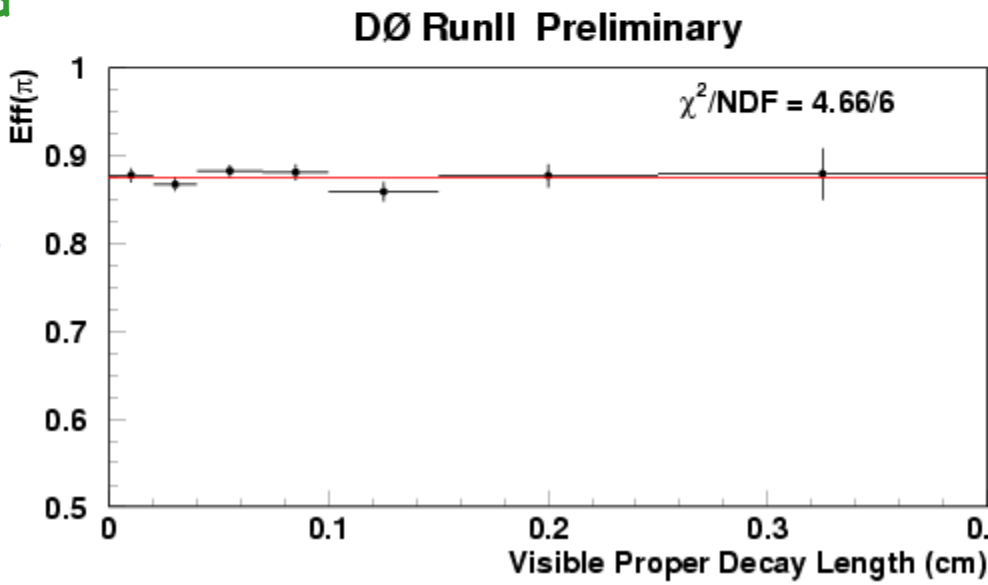
- K-factor accounts for missing decay products like neutrino in calculation of proper lifetime
- Production $B \to D^{*(0,+)} \mu \nu X$ dominates both D^0 and D^* samples
- We always compute k-factors as : K = $P_T(\mu D^0) / P_T(B)$ even for D^{*+} sample
  - Same K-factor for D^{*+} and D^{*0}
  - Reduce systematic error
- K-factors are grouped into 4 categories



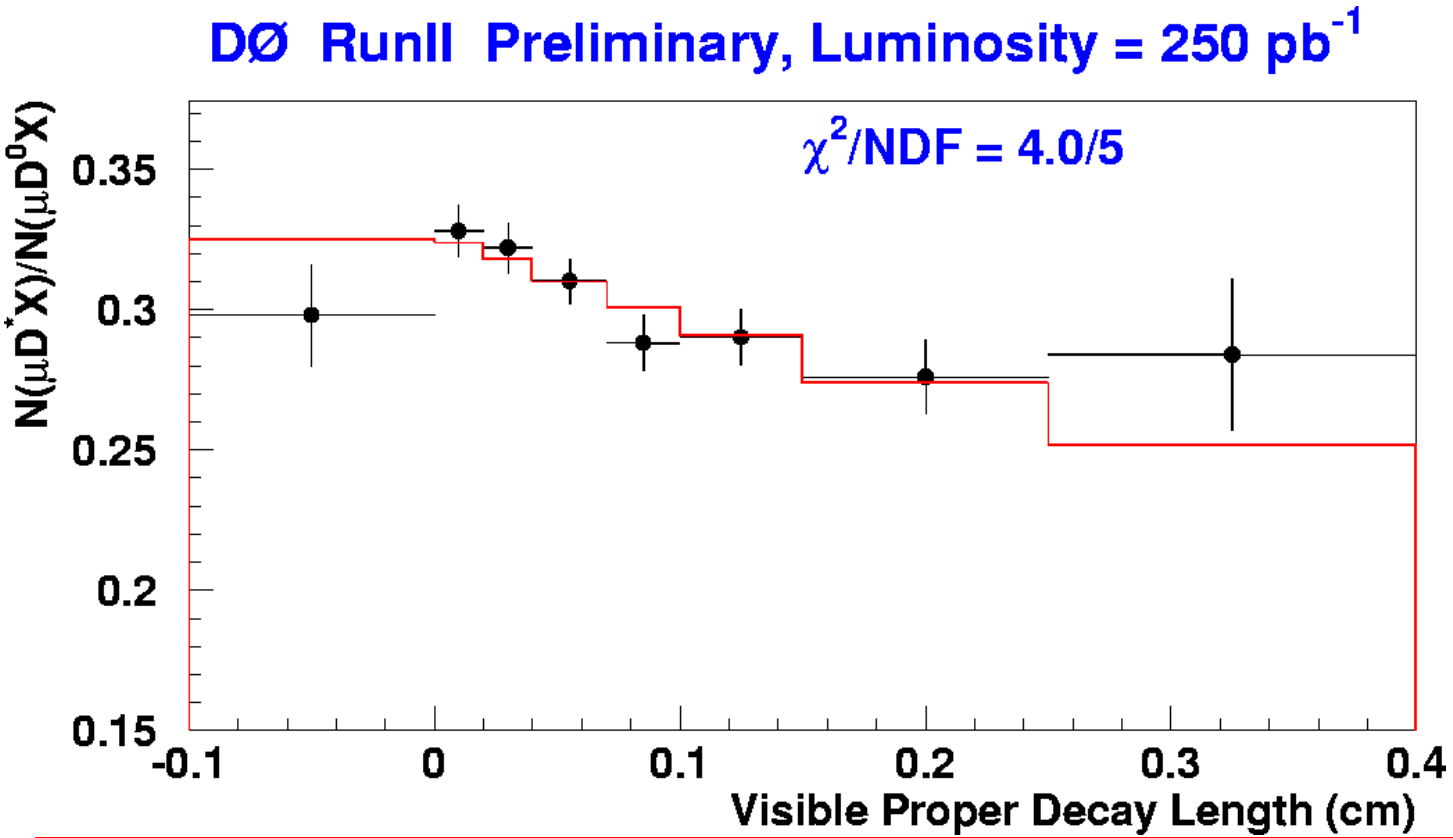
Slow pion efficiency

- Key point : Want to avoid lifetime bias
- Eff depends on $P_T(D^0)$ because of tracking cutoff at P_T=0.183 GeV
  - May induce VPDL dependence
  - Cut at 5 GeV
    - Removes 35% of events
    - Should help to remove ccbar and $B \rightarrow D_s D$ contributions
- After that Eff = 88% and does not depend on VPDL in MC
- Error on possible slope was used to estimate systematics
- Investigating ways to double check it in data





$\tau(B^+)/\tau(B^0)$: Result



Preliminary result:

$\tau(B^+)/\tau(B^0) = 1.093 \pm 0.021$ (stat) ± 0.022 (syst)

$N = 1.001 \pm 0.012$

Systematic errors

source	variation range	$\Delta(\tau^+/\tau^0)$
$Br(B_d^0 \to \mu^+\nu \mathrm{D}^{*-})$	$5.53 \pm 0.23\%$	0.0015
$Br(B^+ \to \mu^+\nu \bar{\mathrm{D}}^{*0})$	$6.50 \pm 0.5\%$	0.0001
$Br(B^+ \to \mu^+\nu \bar{\mathrm{D}}^{**0})$	$2.67 \pm 0.37\%$	0.0005
$Br(B^+ \to \mu^+\nu \mathrm{D}^{*-}\pi^+ X)$	$1.06 \pm 0.25\%$	0.0074
$Br(B_s^0 \to \mu^+\nu D_s X)$	$7.9 \pm 2.4\%$	0.0025
R_s^{**}, see (11)	$0 \div 1$	0.0007
$Eff(x; B^+ \to \mu^+\nu \bar{\mathrm{D}}^{*0})$	set $Eff(x) = const$	0.0012
$Eff(\pi)$	0.876 ± 0.04	0.0012
Time dependence of $Eff(x;\pi)$	slope ± 0.12 [1/cm]	0.0132
C_Y	$C_Y = 1$	0.0086
VPDL resolution	MC resolution $\times(0.2 \div 4.0)$	0.0042
difference in resolution between D^* and D^0	$r_1^e \to r_1$	0.0060
K-factors	average value $\pm$ 2%	0.0021
K-factors	$Z(K; \mathrm{D}^{**}) = Z(K; \mathrm{D}^0, \mathrm{D}^*)$	0.0072
Fitting procedure	see section 10	0.0060
C from eqn. (2)	1.22 ± 0.04	0.0004
Total		0.0215

- Work in progress to understand (and hopefully decrease) main contributors

Consistency Checks

- Split data sample in two parts wrt various parameters – all looks good

Consistency test	k
$\|Z_{PV}\| < 15cm$	0.099 ± 0.028
$\|Z_{PV}\| > 15cm$	0.091 ± 0.031
$\eta(muon) > 0$	0.107 ± 0.031
$\eta(muon) < 0$	0.079 ± 0.030
$p_T(\mathrm{D}^0) < 7.5$ GeV/c	0.105 ± 0.031
$p_T(\mathrm{D}^0) > 7.5$ GeV/c	0.083 ± 0.030
μ^+ only	0.088 ± 0.030
μ^- only	0.111 ± 0.031
$p_T(\mu) < 5.5$ GeV/c	0.104 ± 0.033
$p_T(\mu) > 5.5$ GeV/c	0.083 ± 0.028
Different intervals	0.086 ± 0.021
Without last VPDL interval	0.107 ± 0.024
Additional VPDL interval 0.4-0.8 cm	0.092 ± 0.021

- Measured ratio in MC = 0.073 ± 0.030 (input 0.070)

Summary

- Performed precise measurement of B^+/B^0 lifetime ratio
  - Competitive with B-factories

Preliminary result:

$\tau(B^+)/\tau(B^0) = 1.093 \pm 0.021\ (stat) \pm 0.022\ (syst)$

- Working on final systematic errors
- Statistics is flowing in
  - Proposal to increase L3 BW and write more B-mesons on tape is on the table