$\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$ through inclusive $D^{*+}\rightarrow\pi^* D^0$

- Method
- Preselection
- ℓ tagging
- Selection , Signal , Background
- Simulation Studies
- Vertexing
- τ_{B^0} Measurement

M.Margoni,M.Piemontese,F.Simonetto
INFN & Universita' di Padova

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Method (I)

- High Statistics selection of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$
- Do not attempt D^0reconstruction ;
- tag soft π^* from $D^{*+}{\rightarrow}D^0\pi^*$ through kinematics ;
- access ALL D^0final states ;
- gain O(10) wrt exclusive final states

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Method (II)

- D^{*+} dynamics :

$$\theta,\phi = \theta,\phi(\pi^*) \qquad (\sigma \sim 15\,\mathrm{deg})$$
$$p^* = 12.3p^*(\pi^*) + 0.2 \qquad (\sigma \sim 0.4\ GeV/c)$$

- $\bar{B}^0_d$ at rest in Υ rest frame
- Determine ν mass :

$$M_\nu{}^2 = \mathcal{P}_B^2 - (\mathcal{P}_\ell + \mathcal{P}_{D^{*+}})^2 = 0$$

- Background spread over a wide M_ν^2range

inclusive tag of $\bar{B}^0_d \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Pre-Selection

- Event Selection:
  - DATA: hadron skims runs 6485 $\Rightarrow$10322 (so far ...)
  - MC: SP2 400×10^3 $B^0\bar{B}^0 + 400 \times 10^3$ B^+B^-
  - $3 \leq$ N(charged tracks) ≤ 20 + F.W.(2) < 0.5
- π^* : $0.05 < p^* < 0.25$ GeV/c
- ℓ : $1 < p^* < 2.5$ GeV/c
  - e : $0.5 < E_{cal}/p < 2.0$ + Zernike(42) < 0.5
  - μ : $0.050 < E_{cal} < 1$ GeV ("mip") +
    $N_{Lay} > 8,\ N_{strip} < 9 \cdot N_{Lay}$ (Ifr)
- Pair $\ell\pi^*$ with $-10 < {M_\nu}^2 < 5\ GeV^2/c^4$
- $\Rightarrow$ Ntuple

inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

Ntuple Selection

- Enforce cuts:
  - $1.4 < p^*_\ell < 2.50$ GeV/c
  - $0.0 < p^*_{\pi^*} < 0.19$ GeV/c
- e tag:
  - $Z(42) < 0.1$
  - Lateral Momentum < 0.6
  - tune on data & combine E/p, dE/dX
- μ tag:
  - $E_{cal} < 0.4$ GeV
  - $N_{lay} \geq 10$,$N_{strips} < 6 \cdot N_{lay}$

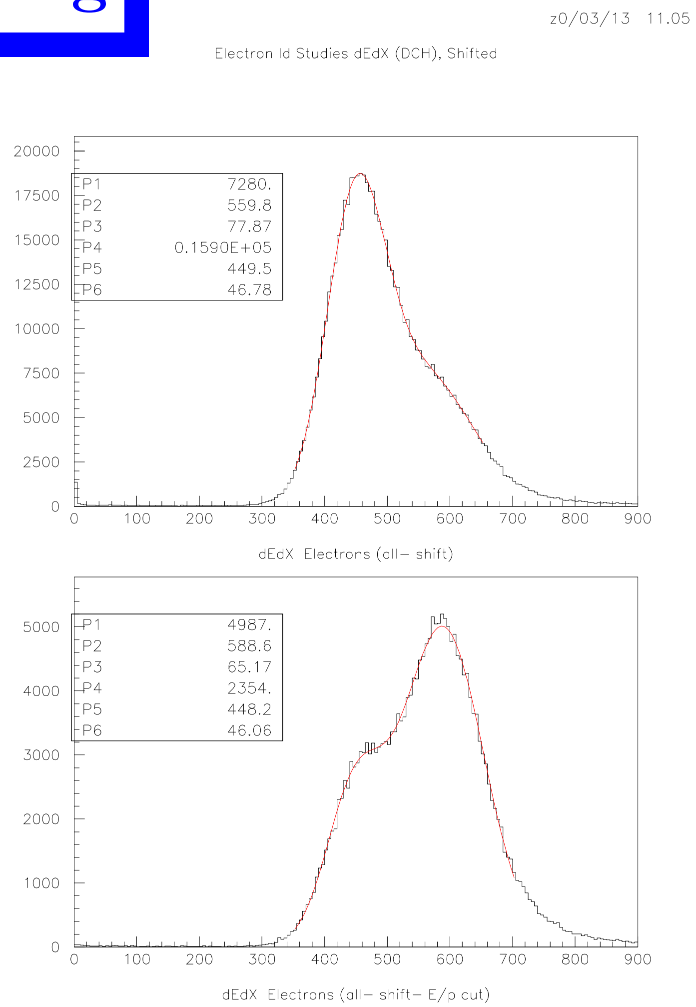
inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

e tag

- Run by Run (coarse) $E/P, dE/dX$ calibration ;
- Study dE/dX : use E/p to define
  - e enriched : $E/p > 0.8$
  - π enriched : $E/p < 0.8$
- fit dE/dX separately for π and e.
- Study E/p the same way
  - e enriched sample : $dE/dX > 500$
  - π enriched sample : $dE/dX < 500$

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

dE/dX **tuning**



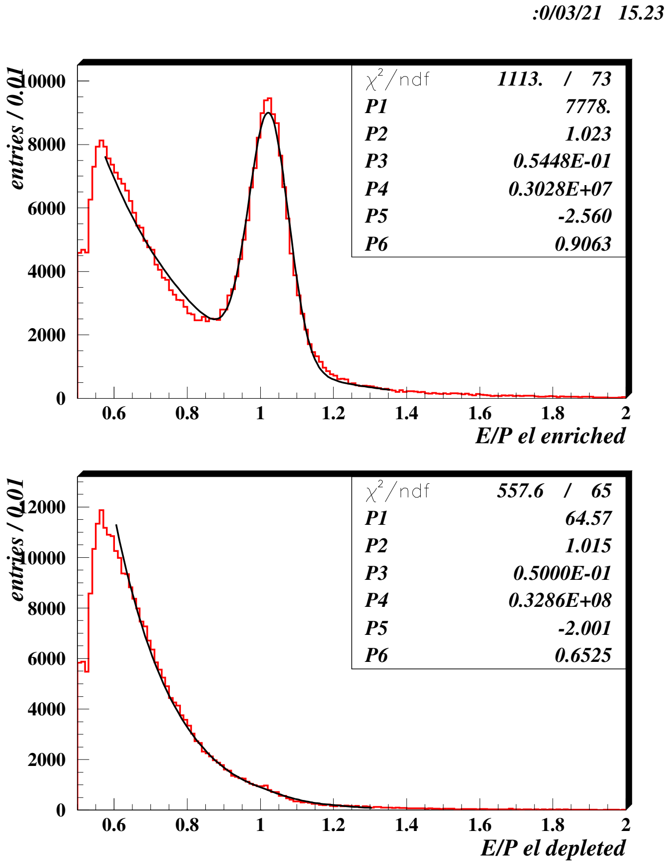
- Upper Plot : dE/dX π enriched
- Lower Plot : dE/dX e enriched
- In each sample fit two Gaussians, determine:
  - $N_\pi, < dE/dX >_\pi, \sigma(dE/dX)_\pi$
  - $N_e, < dE/dX >_e, \sigma(dE/dX)_e$
- Find :

Sample	$< dE/dX >$	σ
e	588	65
π	450	46

inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

E/P tuning (I)

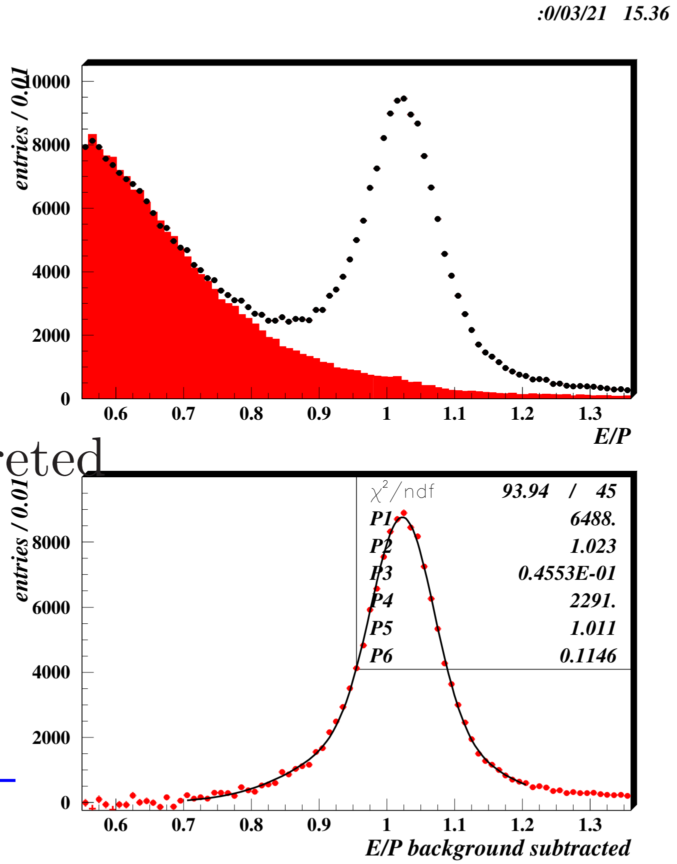
- Upper Plot : E/p e enriched
- Lower Plot : E/p π enriched. Less than 100 electrons are left in this sample.
- Also in this case both plots are fitted with two Gaussian.
- The fit for the π sample is good in the tagging range (0.65 $\rightarrow$1.30)
- The fit for the e sample is bad
  $\Rightarrow$Apply another approach



inclusive tag of $\bar{B}^0_d \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

E/P tuning (II)

- Upper plot : π (red area) superimposed to e (dots) normalised for 0.55< E/p <0.65
- The π sample is subtracted from the e sample (lower plot).
- The resulting distribution is interpreted as a 100 % pure e sample.
- It is fitted with two Gaussians.



	$< E/p >$	σ	frac (%)
narrow	1.023	0.045	52
wide	1.011	0.115	48

inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

Comparison to the Monte Carlo

Data (left columns) vs Monte Carlo expectation (right)

	$< E/p >$	σ	frac (%)	$< E/p >$	σ	frac (%)
e narrow	1.023	0.045	54	0.99	0.024	70
e wide	1.011	0.115	46	0.97	0.076	30

	$< dE/dX >$	$\sigma(\%)$	$< dE/dX >$	$\sigma(\%)$
e	590	11.0	550	6.8
π	450	10.2	440	9.1

Monte Carlo too optimistic !

Going to look at 8.6.X

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

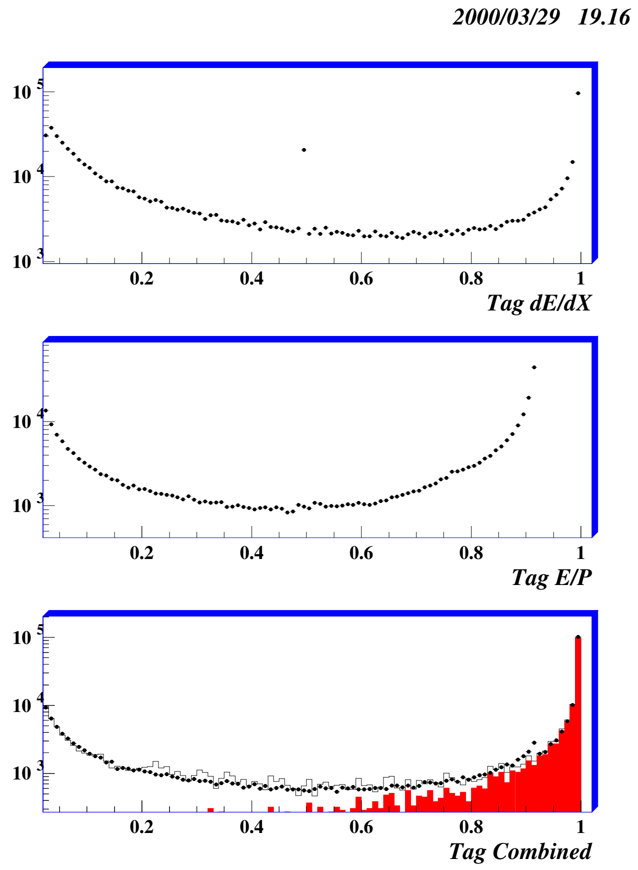
Combined Tag

- Combine the likelihood ratios:

$$\mathcal{R} = \frac{\mathcal{L}_e}{\mathcal{L}_\pi}\left(\frac{E}{p}\right) \cdot \frac{\mathcal{L}_e}{\mathcal{L}_\pi}\left(\frac{dE}{dX}\right)$$

- Plot : $X = \mathcal{R}/(\mathcal{R}+1)$
- The cut $X > 0.51$ leaves:
  - 95% of pre-selected e
  - 3 % of pre-selected π

  (Red area in last plot shows electron contribution)
- Actual efficiencies must also account for pre-selection cuts. (π rejection O(10^{-3}))



inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

μ Tag

- Could not apply official selection
- (Ifr dept info. is only present in MC Ntuple:)
- Ask old recipe :

$$\begin{aligned} E_{cal} &< 0.4 \\ N_{layers} &\geq 10 \\ N_{strips} &< 6 \cdot N_{layers} \end{aligned}$$

- in fact a loose selection

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Signal e sample

Upper plots. $M_\nu{}^2$ distribution with:

- $p^*_{\pi^*} < 0.190$
- $1.4 < p^*_\ell < 2.3$
- $\mathrm{X}_e > 0.51 + Z(42) < 0.1 + LM < 0.6$

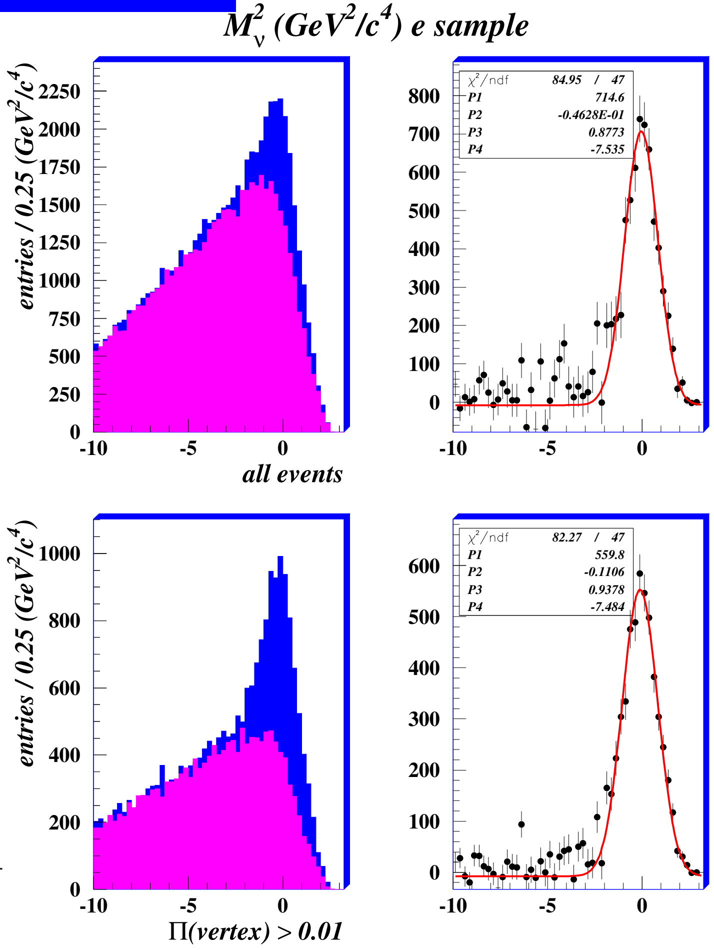
Lower plots. Add vertexing :

- $\mathrm{Prob}(\ell\pi^*)$ Vertex $> 1\%$

Signal (blue): $\ell^\mp\pi^{*\pm}$

Combinatorial (pink) : $\ell^\mp\pi^{*\mp}$

Right plots: background subtraction fitted with a Gaussian + Constant



Vertexing : gain ~ 3 on Signal/Noise

inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

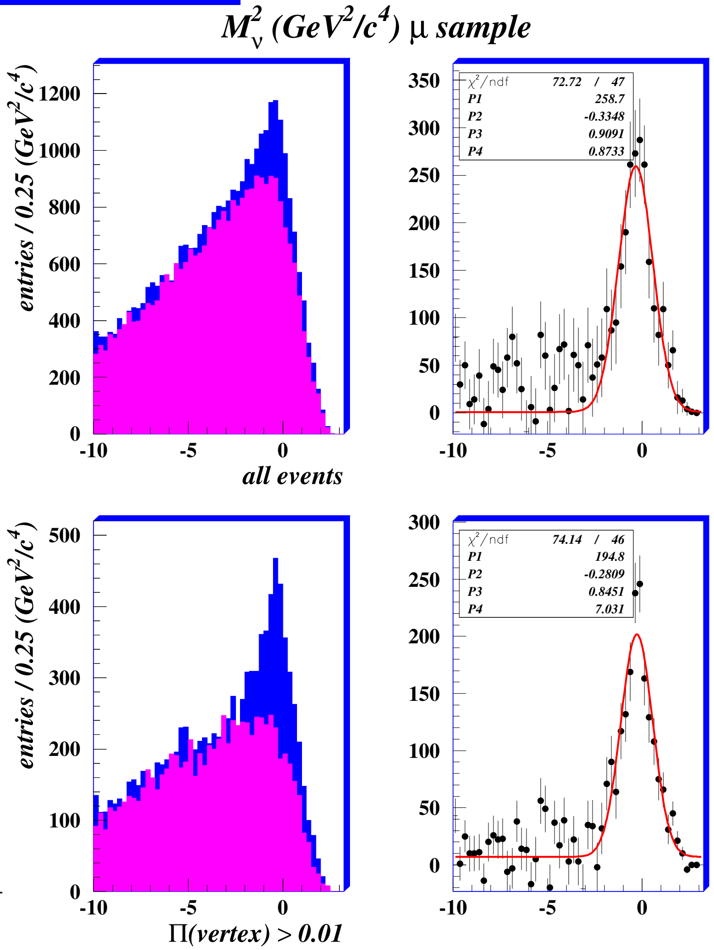
Signal μ sample

Upper plots. ${M_\nu}^2$ distribution with:

- $p^*_{\pi^*} < 0.190$
- $1.4 < p^*_\ell < 2.3$
- $E_{cal} < 0.4 +$ $N_{lay} \geq 10 + N_{str} < 6 \cdot N_{lay}$

Lower plots. Add vertexing :

- Prob($\ell\pi^*$) Vertex $> 1\%$



Signal (blue): $\ell^\mp\pi^{*\pm}$

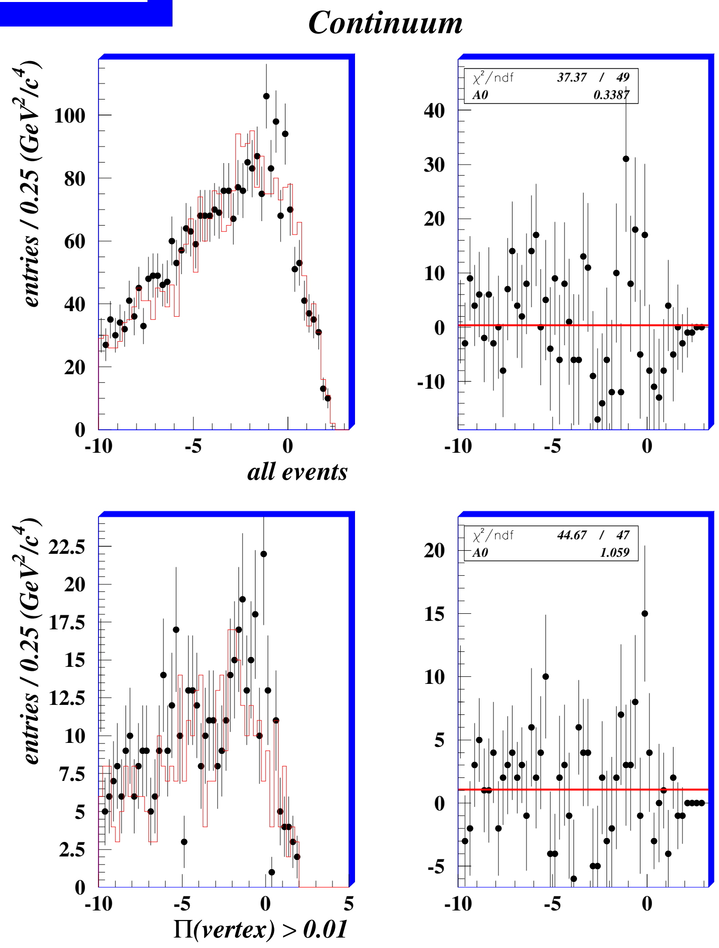
Combinatorial (pink) : $\ell^\mp\pi^{*\mp}$

Right plots: background subtraction fitted with a Gaussian + Constant

inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

Continuum

- Combinatorial was computed from events with wrong charge combination.
- Check with off peak events applying the same selection
- Dots show good charge, red line wrong charge, before (upper plots) and after (lower plots) the cut on vertex probability.
- Good agreement is found for all the M_ν^2range.
- See also the background subtracted plots on the right hand side (fitted by a Constant)

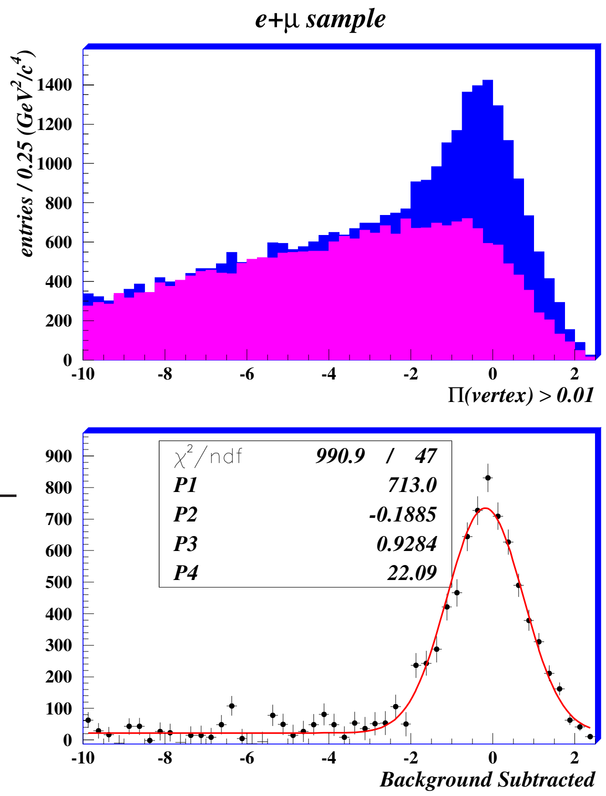


inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Signal ℓ sample

Asking $M_\nu{}^2 > -2\ GeV^2/c^4$, find:

$\mathcal{N}_{evt} = 8200 \pm 250$
$\mathcal{N}_{vtx} = 6600 \pm 150$ (plot $\Rightarrow$
$\epsilon(Vtx) = 80 \pm 2\%$ (MC 82%)



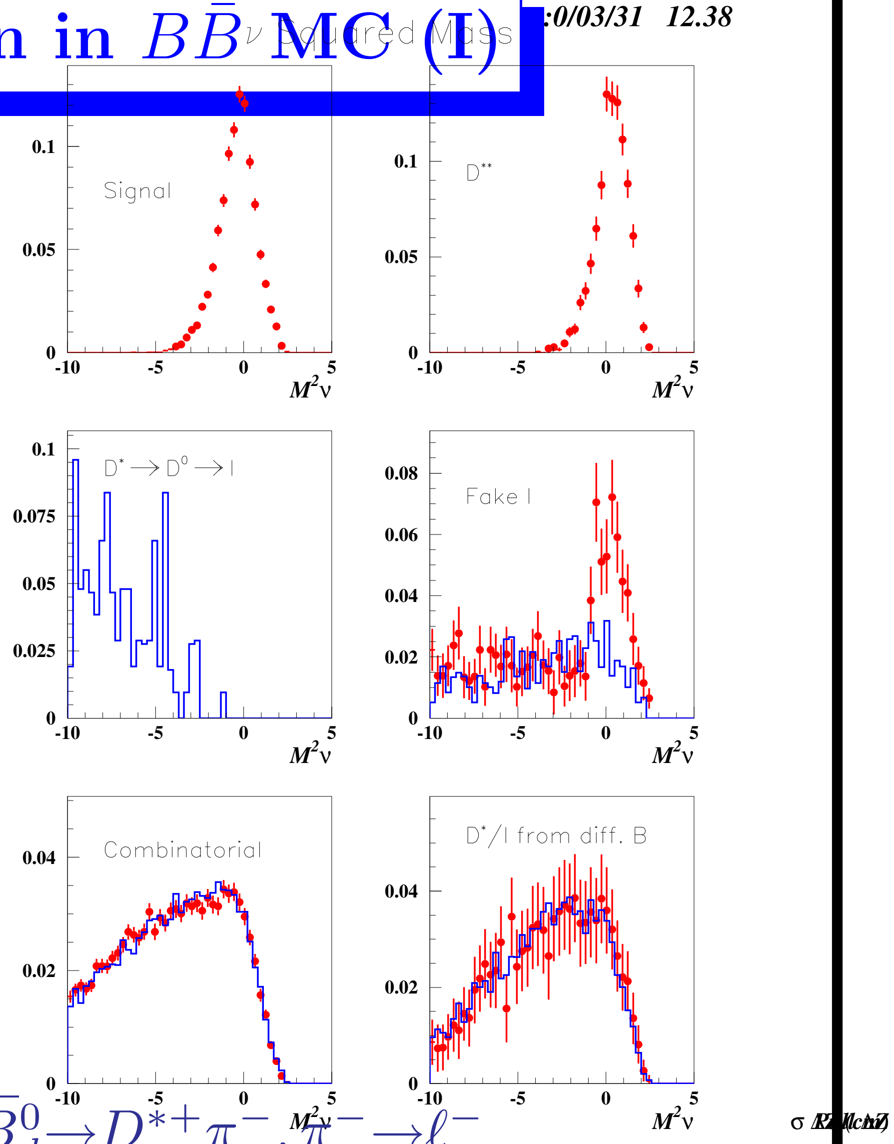
Sample	$e^\pm\pi^{*\mp}$	$e^\pm\pi^{*\pm}$	Signal
e all	23640	17640	6000± 200
$e(Vtx)$	9759	4839	4920± 121
μ all	11950	9734	2216± 147
$\mu(Vtx)$	4197	2497	1700± 82

inclusive tag of $\bar{B}^0_d \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Sample Composition in $B\bar{B}$ MC (I)

Dots : $\ell^{\pm}\pi^{*\mp}$ Line : $\ell^{\pm}\pi^{*\pm}$,
normalised in the side band.
Events sampled as :

1. $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$
2. $B \to D^{**}\ell^-\bar{\nu}_\ell,\ D^{**}\to D^{*+}X$
3. $D^{*+}\to\pi^* D^0,\ D^0\to\ell^+X$
4. D^{*+} + fake $\ell^{(\pm)}$
5. combinatorial
6. $B\to D^{*+}X$, $\bar{B}\to\ell^{(\pm)}Y$



Excess in class (4) is Physical, eg: $\bar{B}^0_d\to D^{*+}\pi^-,\ \pi^-\to\ell^-$

inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

Sample Composition in $B\bar{B}$ MC (II)

Conclusions:

- Wrong Charge data reproduce well the combinatorial.
- Distorsions are induced by Physical processes :
  1. $D^{*+} \rightarrow \pi^* D^0 \rightarrow \ell X$ (class (3))
  2. $B \rightarrow D^{*+} + \ fake\ \ell$ (class (4))
- which are however very small:
  - 1^{st} is negligible due to kinematic cuts;
  - 2^{nd} is small and only due to fake muons
    $\rightarrow$will decrease with improved μ tagging

inclusive tag of $\bar{B}^0_d \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Sample Composition in $B\bar{B}$ MC (III)

... however ...

Class (6) $(B \rightarrow D^{*+}X\ ,\ \bar{B} \rightarrow \ell Y\ )$ gives a bias as well :

- its M_ν^2shape is different from the one of the combinatorial
- $\mathcal{N}(D^{*\pm}\ell^{\pm})\ \sim\ 3 \times \mathcal{N}(D^{*\pm}\ell^{\mp})$
  $\longrightarrow$ they do not fully compensate.

These events account for :

$\sim$ 30% of the wrong charge combinatorial

$\sim$ 10% of the good charge combinatorial

... studies going on ...

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Flavour Tagging

Aim : Use all tags (ℓ, K, Q_{jet})

"Inclusive " problem:

Discriminate tagging tracks from D^0daughters

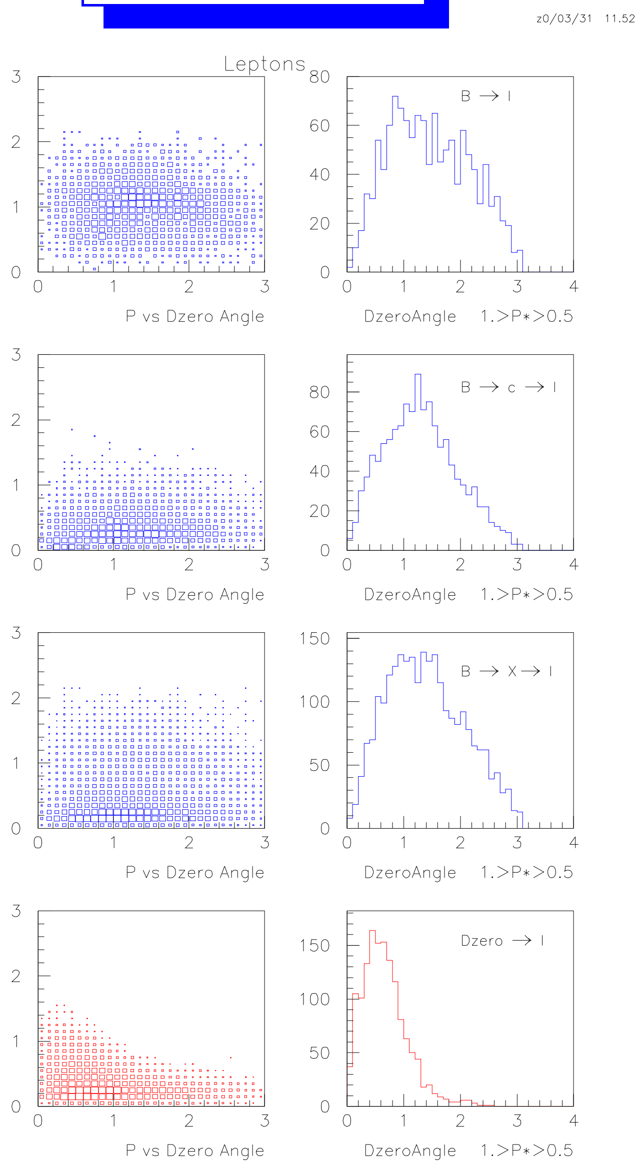
Exploit correlation between p^* and angle w.r.t. D^0

Do it separately for ℓ, K , π

Tagging leptons are further divided into $B \rightarrow \ell$, $B \rightarrow D\ell$,$B \rightarrow uds\ell$

inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

ℓ Tagging



Six upper histos: B tagging tracks.

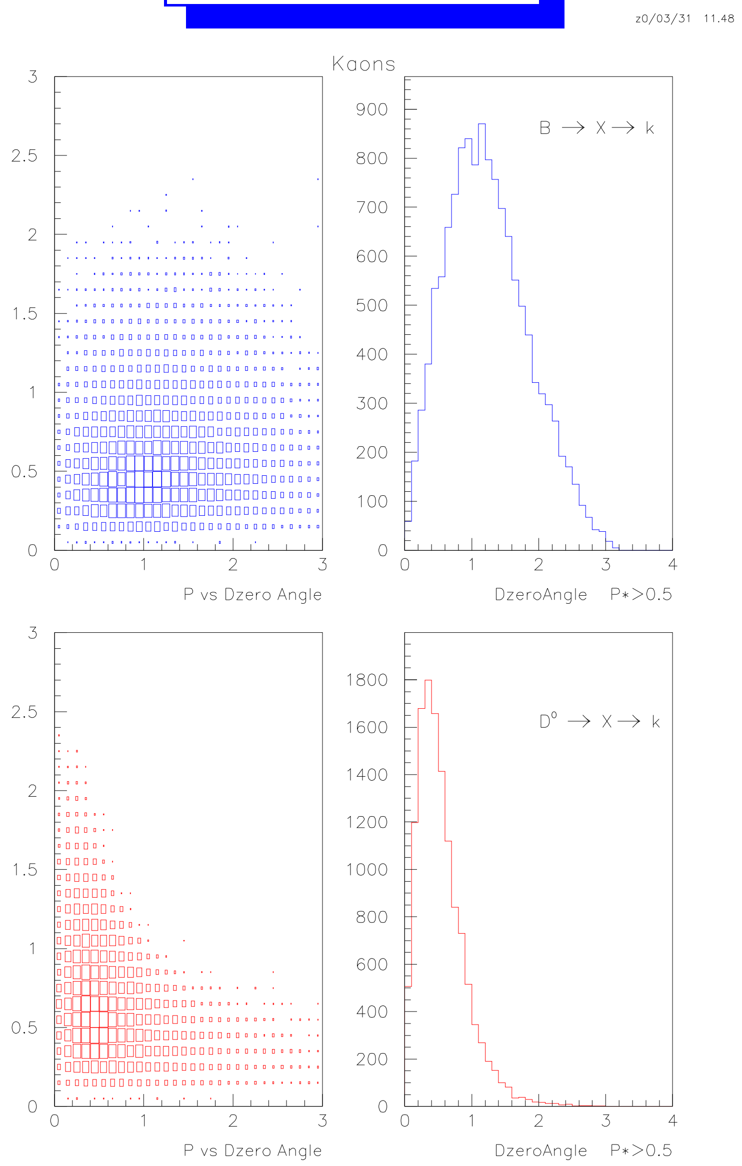
Lower histos : D^0 daughters

The cut $p^* > 1GeV$ leaves a pure $B \to \ell$ sample.

Right histos show angle for $0.5 < p^* < 1.0$ GeV.

inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

K Tagging



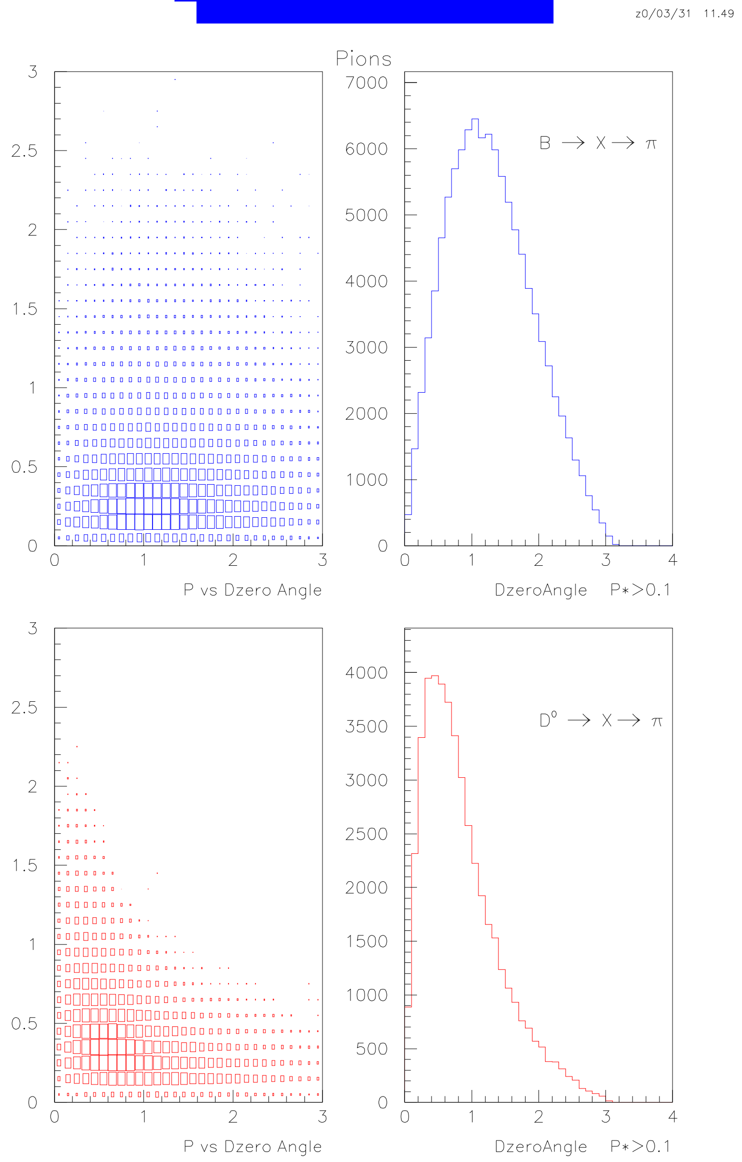
Upper histos: B tagging tracks.

Lower histos : D^0 daughters

Right histos show angle for $p_K^* > 0.5$ GeV.

inclusive tag of $\bar{B}_d^0 \to D^{*+} \ell^- \bar{\nu}_\ell$

π Tagging



Upper histos: B tagging tracks.

Lower histos : D^0 daughters

Right histos show angle for $p^*_\pi > 0.5$ GeV.

inclusive tag of $\bar{B}^0_d \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Vertex Reconstruction

Algo from Marco Zito's πD^{*+} analysis (many thanks !).

"Decay" vertex

- intersect the ℓ and π^* tracks
- impose beam spot (???)
- ask $\Pi(vtx) > 1\%$

"Tag" vertex

- collect tracks outside 1 rad cone about the π^* (remove $\sim 60\%$ D^0daughters).
- constrain X and Y to the Decay vertex to reduce residual bias

Next Slide: X,Y,Z (up to bottom), for "Decay"(left) and "Tag" (rigth) vertices

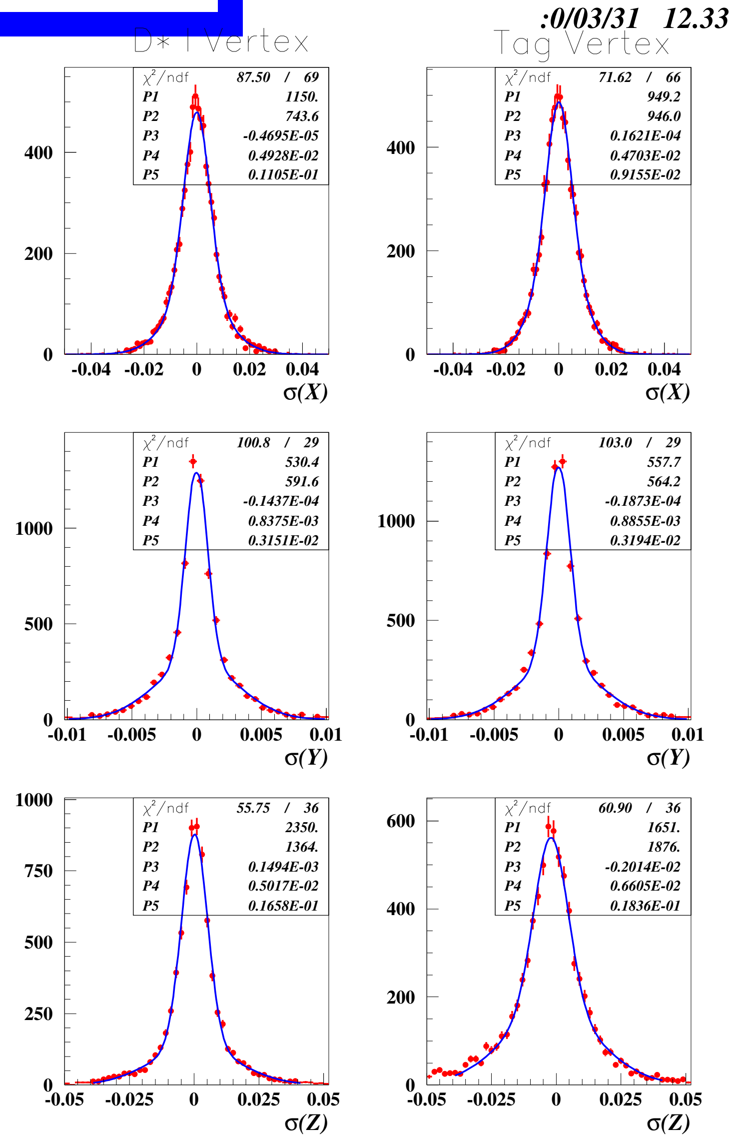
inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

Vertex Resolution

Fit resolution with two Gaussians.

	Decay	Tag
Z bias (μm)	0	20
$\sigma_1(Z)$ (μm)	50	66
$\sigma_2(Z)$ (μm)	160	180
$f(narrow)$	63 %	47 %

The resolution is comparable to fully reconstructed events. Still a small residual bias for the tag vertex.



inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

$\Delta(Z)$

Upper plot:

$\Delta(Z)_{reco}$ vs $\Delta(Z)_{gen}$

Lower plots:

$\Delta(Z)$ resolution (left)

$\Delta(Z)$ pull (rigth)

Find:

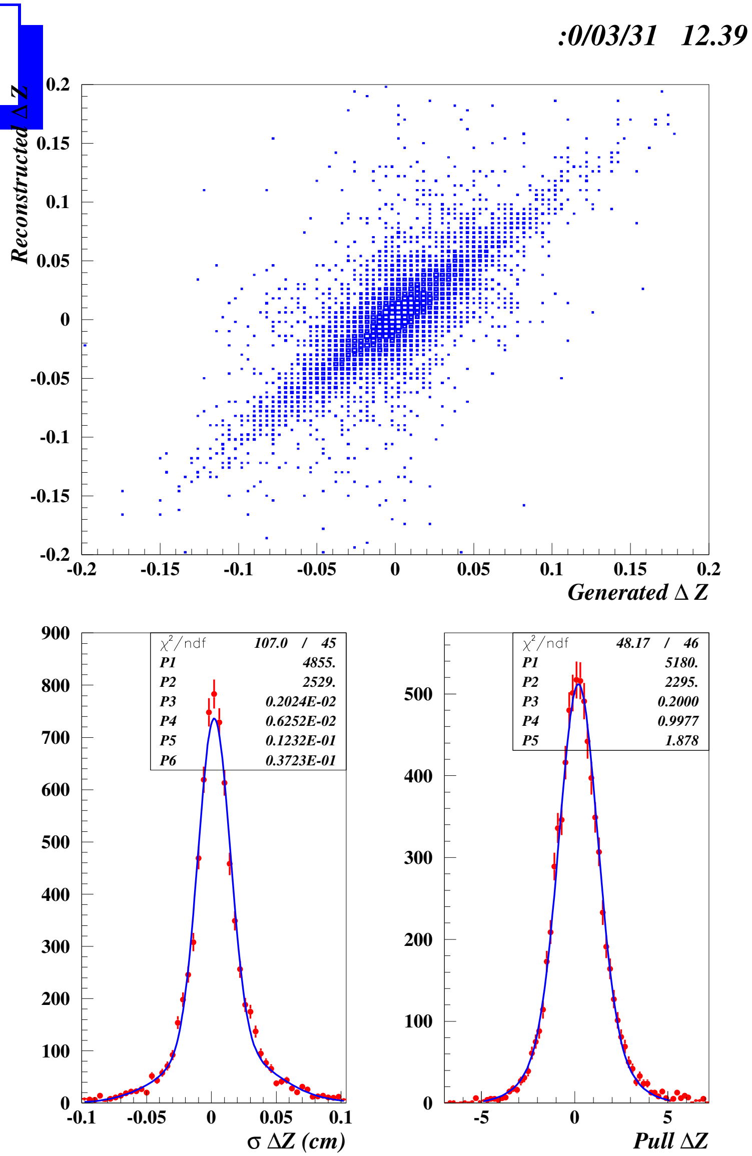
$\sigma(narrow) = 123\mu m$

$f(narrow) = 65\%$

$\sim 70\%$ of evts. with pull $= 1$

$\sim 30\%$ of evts. with pull ~ 2

$\Delta(Z)$ bias is $\sim 0.2\sigma$



inclusive tag of $\bar{B}_d^0 \rightarrow D^{*+}\ell^-\bar{\nu}_\ell$

τ_{B^0} Measurement (I)

Used Runs = 8474-10322; ($\mathcal{L} = 768.4\ pb^{-1}$);

Analysed with Version 8.5.2

Asking $M_\nu^2 > -2\ GeV^2/c^4$ (r.c.), find (MC):

$D^* l$	$35.5 \pm 0.2\%$
$D^{**} l$	$8.0 \pm 0.1\%$
D^*+ fake l	$1.7 \pm 0.1\%$
D^*/l from different Bs	$3.5 \pm 0.1\%$
Combinatorial	$48.0 \pm 0.3\%$

- τ_{B^0} from a fit to ΔZ using an Unbinned Maximum Likelihood (many thanks to M. Zito)

inclusive tag of $\bar{B}_d^0 \to D^{*+} \ell^- \bar{\nu}_\ell$

τ_{B^0} Measurement (II)

Three components considered:

1. Signal ($D^* + D^{**}(B^0) + D^*$ fake lept (B^0)):

   Described by an exponential convoluted with the Resolution Function from MC;

2. B^+ background ($D^{**}(B^+) + D^*(B^+)$ fake lept):

   Fraction of resonant sample from MC:

   $$f^e_{B^+} = 12.4 \pm 0.5\%, \; f^\mu_{B^+} = 14.5 \pm 0.6\%$$

   ΔZ shape from $\tau_{B^+} = 1.65 \pm 0.04$ ps and the same Resolution Function as the signal;

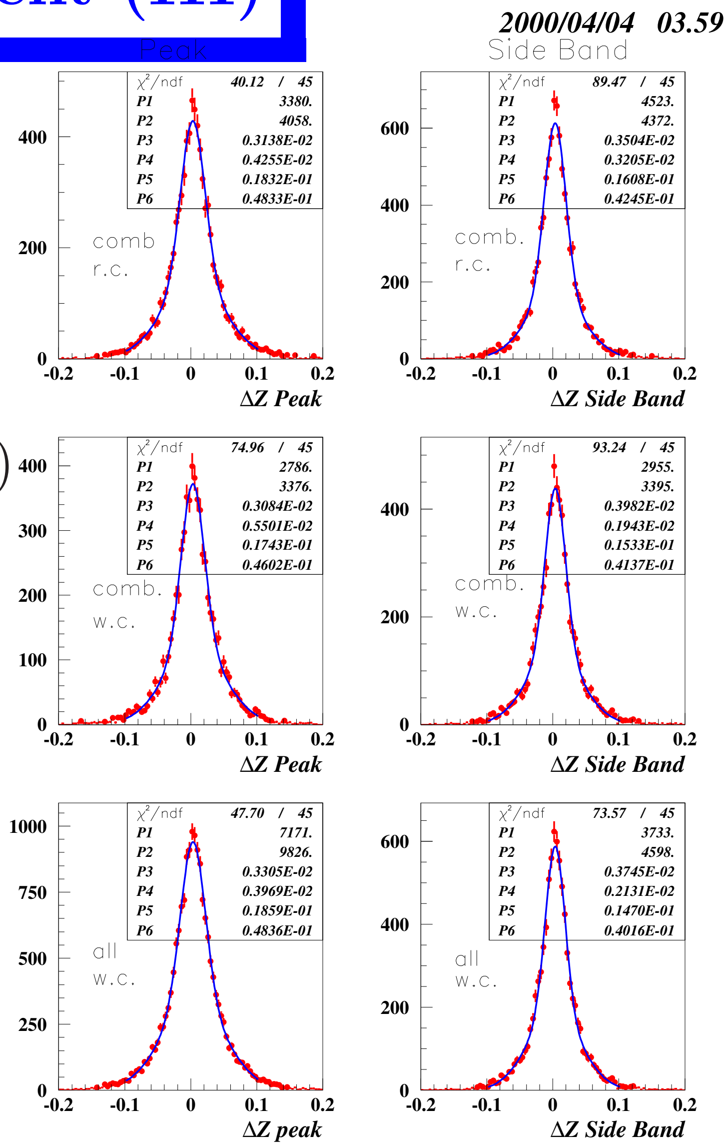
3. Combinatorial Background

inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

τ_{B^0} Measurement (III)

Combinatorial Study on MC:

- r.c. / w.c. combinatorial in good agreement;
- Combinatorial in side band (right) $\sim$ 10% narrower then below peak (left);
- Peak region: r.c. combinatorial (upper left) well reproduced by inclusive w.c. (lower left).



inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

τ_{B^0} Measurement (IV)

Combinatorial Study on DT:

- Upper Plots:

  Side Band r.c. / w.c.

  in good agreement.

- ΔZ shape from w.c. events

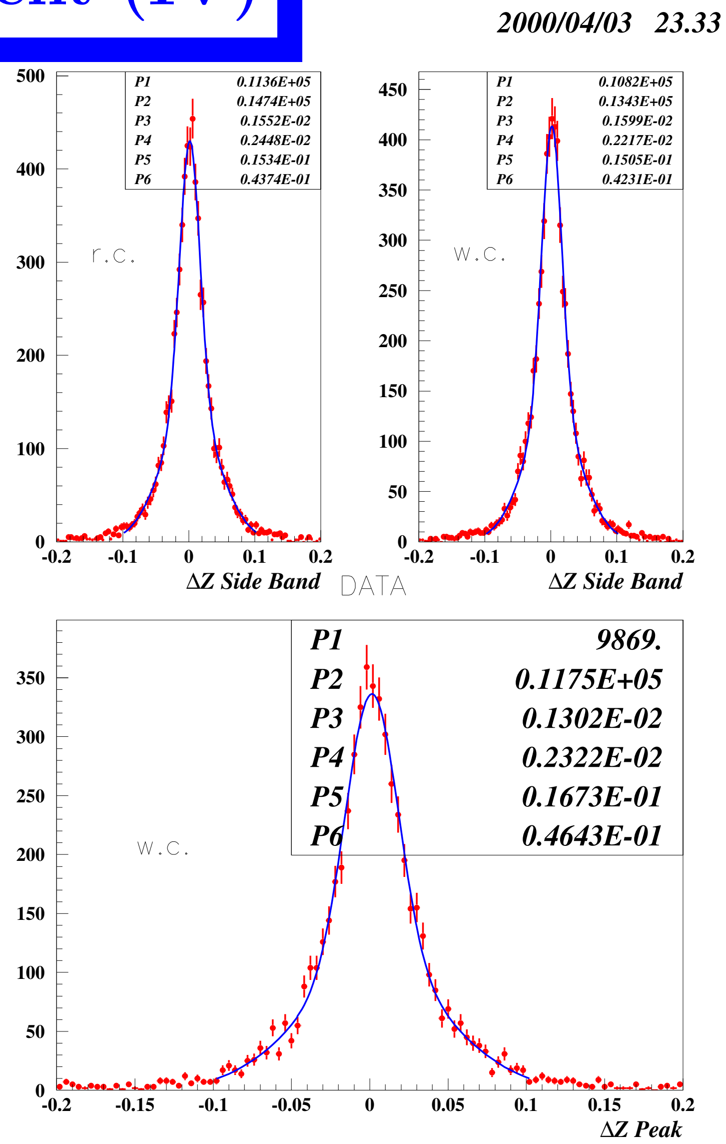
  below peak (Lower Plot).

- Fraction from w.c.

  normalized to r.c. in Side Band:

  $f^e_{comb} = 53.1 \pm 1.5\%$

  $f^\mu_{comb} = 60.6 \pm 1.0\%$



inclusive tag of $\bar{B}^0_d \to D^{*+}\ell^-\bar{\nu}_\ell$

τ_{B^0} Measurement (V)

Combinatorial Study: DT vs MC

- Side Band ΔZ Width

Width	MC r.c.	DT r.c.	MC w.c.	DT w.c.
narrow (cm)	0.016	0.015	0.015	0.015
wide (cm)	0.042	0.044	0.041	0.042

- Mass Band ΔZ Width

Width	MC r.c.	MC w.c.	DT w.c.
narrow (cm)	0.018	0.017	0.017
wide (cm)	0.048	0.046	0.046

inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

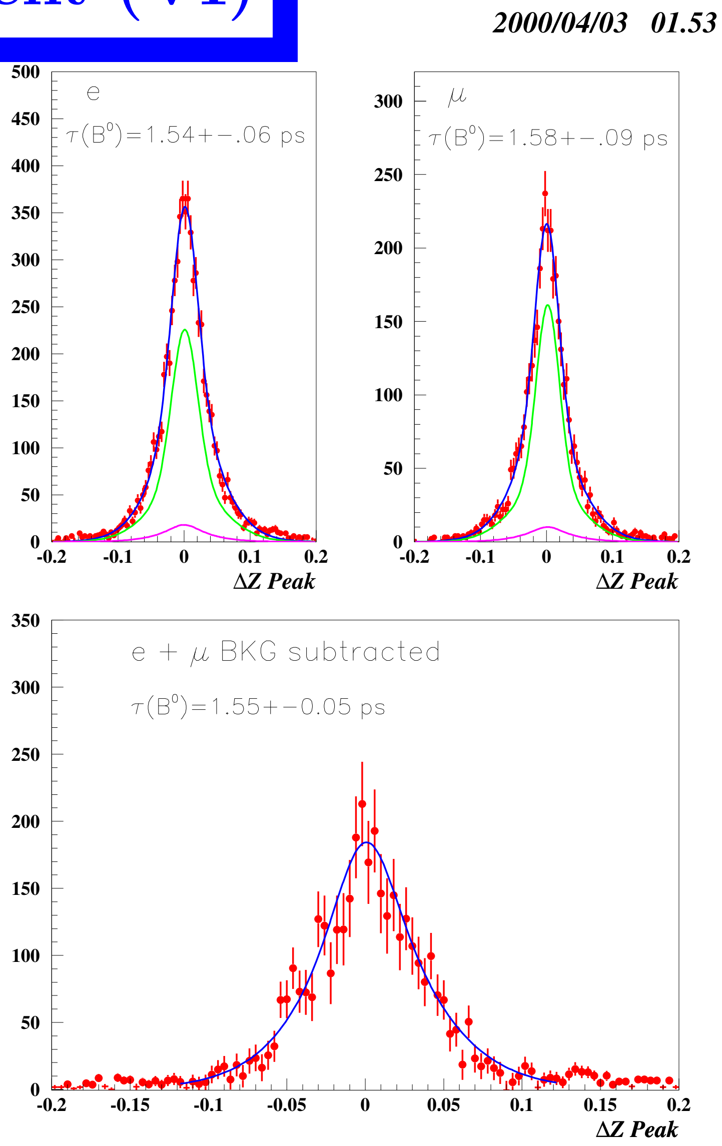
τ_{B^0} Measurement (VI)

- Signal Fraction:

  $$f_{sign} = (1. - f_{comb}) \times (1. - f_{B^+})$$

- Preliminary Results:

$\tau_{B^0}(e)$	$1.54 \pm 0.06(stat)\ ps$
$\tau_{B^0}(\mu)$	$1.58 \pm 0.09(stat)\ ps$
$\tau_{B^0}(e+\mu)$	$1.55 \pm 0.05(stat)\ ps$



inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

τ_{B^0} Measurement (VII)

Systematics:

Source	Variation	$\delta(\tau_{B^0})$
Combinatorial Fraction	$\pm 10\%$	$\pm 0.04\ ps$
D^{**} Fraction	$\pm 20\%$	$\mp 0.01\ ps$
Fake leptons Fraction	$\pm 20\%$	-
$\tau(B^+)$	$\pm 0.04\ ps$	$\mp 0.01\ ps$
M_ν^2 cut	$-2.5/-2.0/-1.5$	$\pm 0.03\ ps$

- Combinatorial to be controlled at a few% level

inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

τ_{B^0} Measurement (VIII)

Stability Check

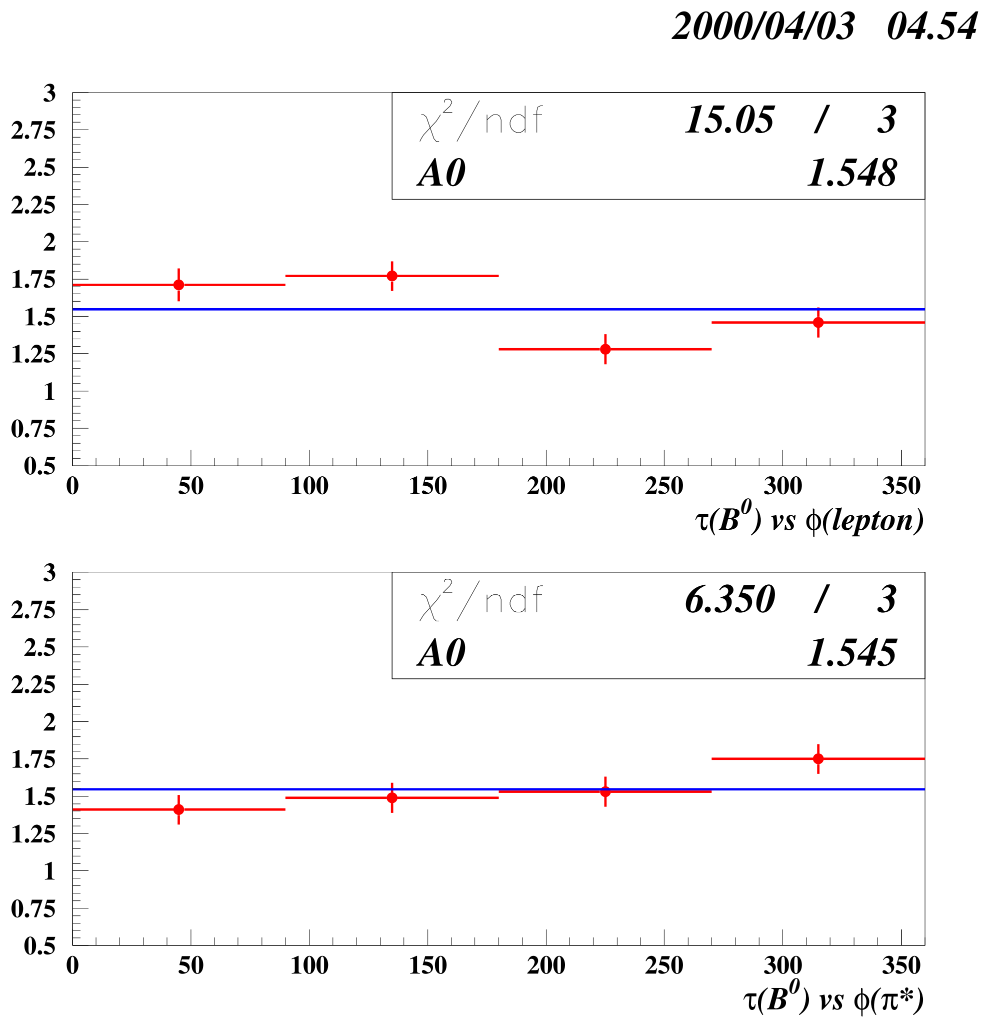
- Upper Plot:

  $\tau(B^0)$ versus $\phi(lept)$

- Lower Plot:

  $\tau(B^0)$ versus $\phi(pion)$

SVT (mis)alignment?



inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$

A first look at Mixing

- Same Data sample as for τ_{B^0}
- Used only lepton tag up to now...

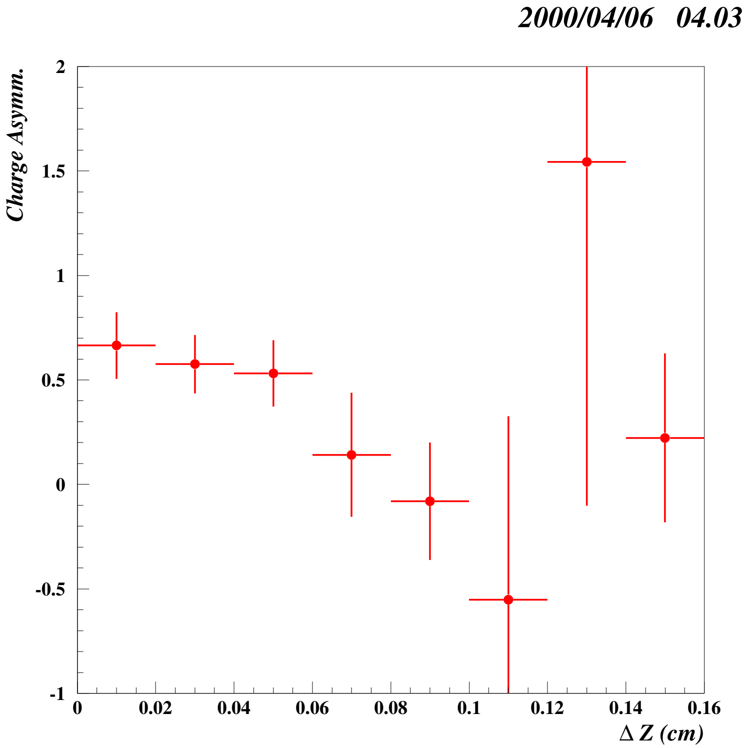
  $B \to \ell$ sample selected by $p^* > 1\ GeV$

  D^0 daughters removed requiring:

  $\ell - \pi^*$ angle > 1 rad;
- Computed Charge Asimmetry:

  $\frac{\ell^\pm \ell^\mp - \ell^\pm \ell^\pm}{\ell^\pm \ell^\mp + \ell^\pm \ell^\pm}$ vs ΔZ

  after BKG subtraction.



inclusive tag of $\bar{B}_d^0 \to D^{*+} \ell^- \bar{\nu}_\ell$

Conclusions

A very encouraging start

- resonant / combinatorial $\sim 1/1$
- 65 % evts. with $\sim 120\mu m$ resolution
- data analysis well advanced
- first $\tau_{\bar{B}_d^0}$ measurement already performed
- $B^0 - \bar{B}^0$ Mixing coming soon...
- Abstract for Osaka Available tomorrow.

inclusive tag of $\bar{B}_d^0 \to D^{*+}\ell^-\bar{\nu}_\ell$