B_d oscillations with muon tags

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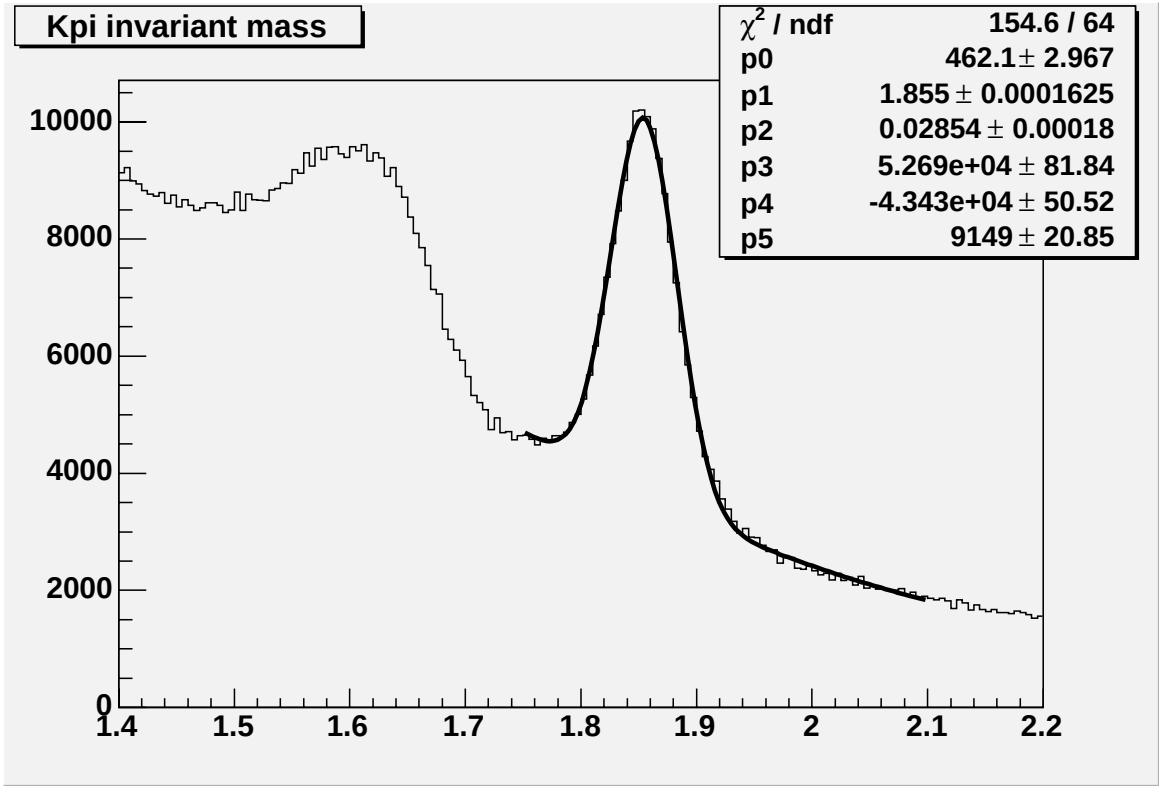
- Looked for B_d oscillations using this process
  - $B^0 \to D^* \mu$
    - $D^* \to D^0 \pi \to (K \pi) \pi$
- Limit sample to the selections of lifetime ratio analysis (see D0note 4280) to recycle all studies done with the sample
- Add to the sample
  - Opposite Side Muon tagging
  - Asymmetry fit procedure
- Results
- Plans

D^0 signal

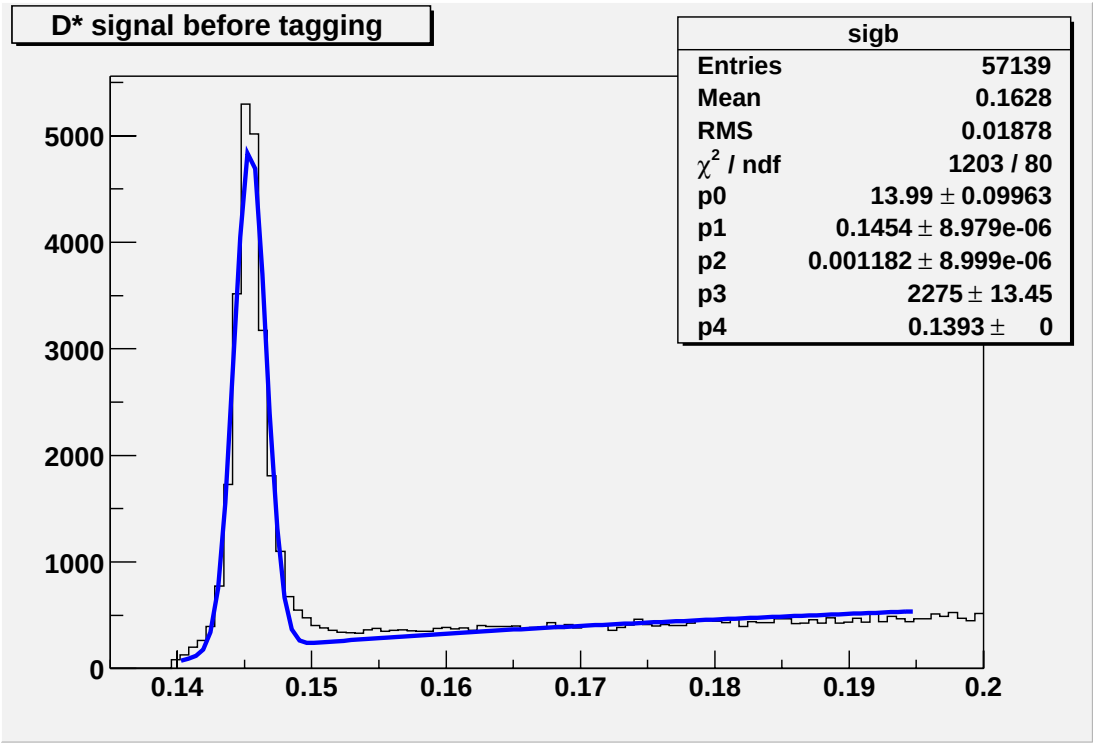
- ~225 pb^{-1} p14 data
- 92400 D^0 candidates, see D0note 4280 for selections



K π invariant mass, GeV

D* signal

- Slow pion selections
  - Any track with >1 SMT and > 1 CFT hits with correct charge correlation
  - D0 mass window [1.75-1.95 GeV]
- 21400 D* candidates



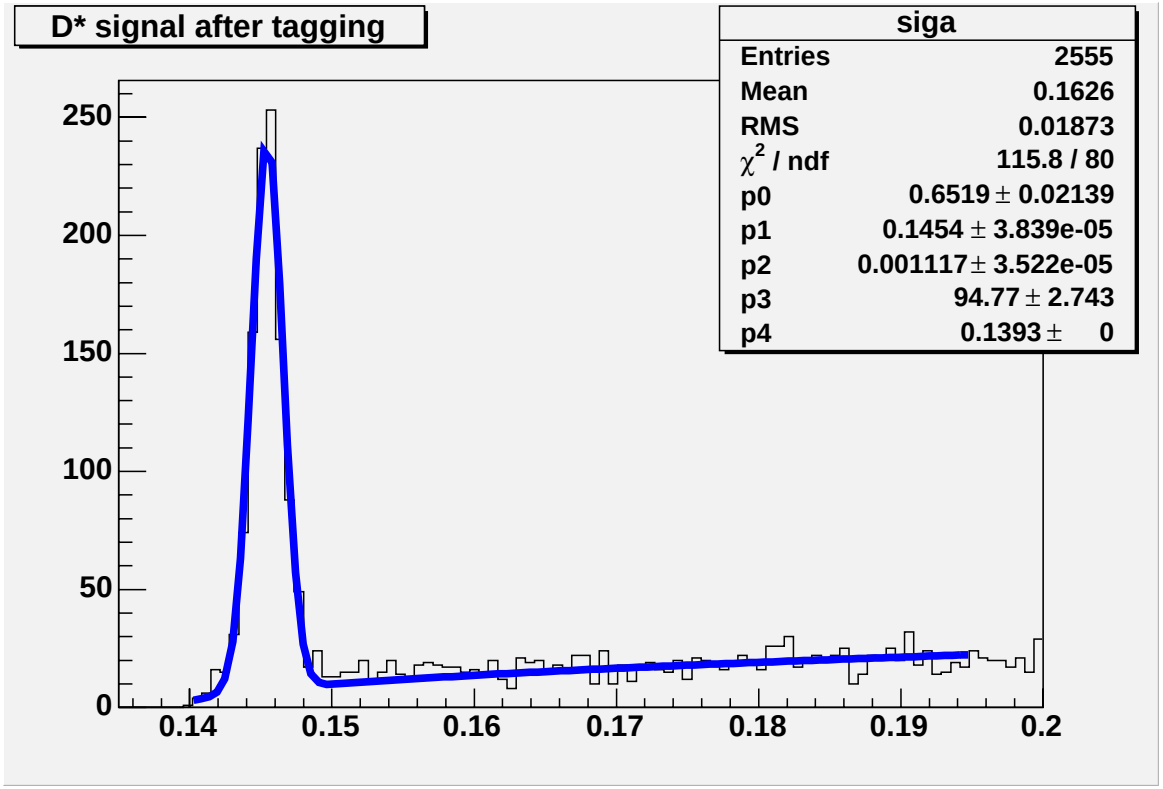
m(D*)-m(Kπ), GeV

Tag muon selections

- For tag optimization used
  - Semileptonic B^+ sample
  - B^+ -> J/psi K^+ sample
  - See AN talk at B meeting 12/4/2003
- Adopted the following tagging procedure
  - Select certified muons
    - Track with # SMT hits > 1, # CFT hits > 1
    - Pt > 2.5 GeV
    - Nseg = 2 or 3
    - Not from the same jet as B candidate
    - cos (ϕ angle between B and tag muon) < 0.5
    - Not from J/psi
  - If more than one candidate – choose muon with max Pt

D* signal after tagging

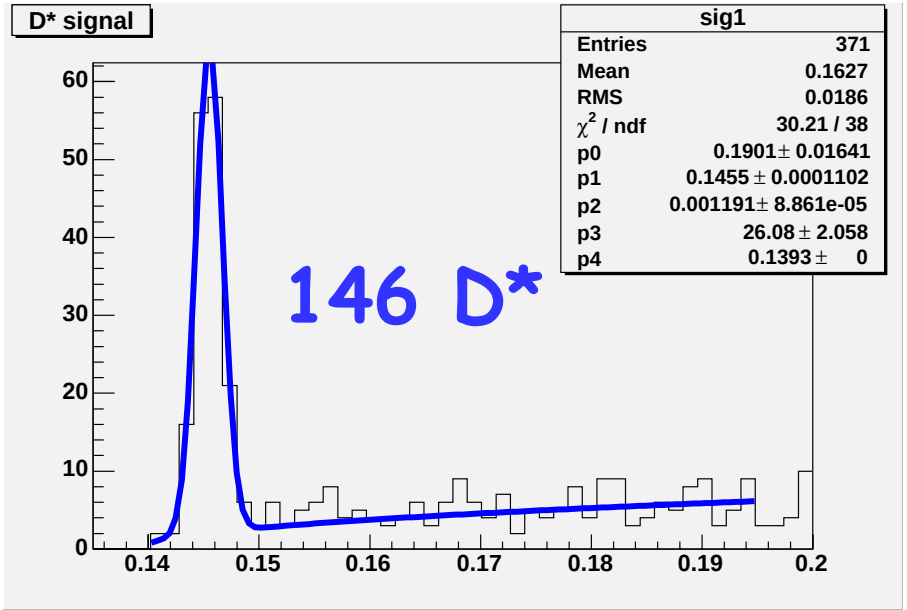
- Fit D* peak with (gauss + sqrt) function
- Total 1003 D* candidates after tagging
- Eff of tagging = 4.7%

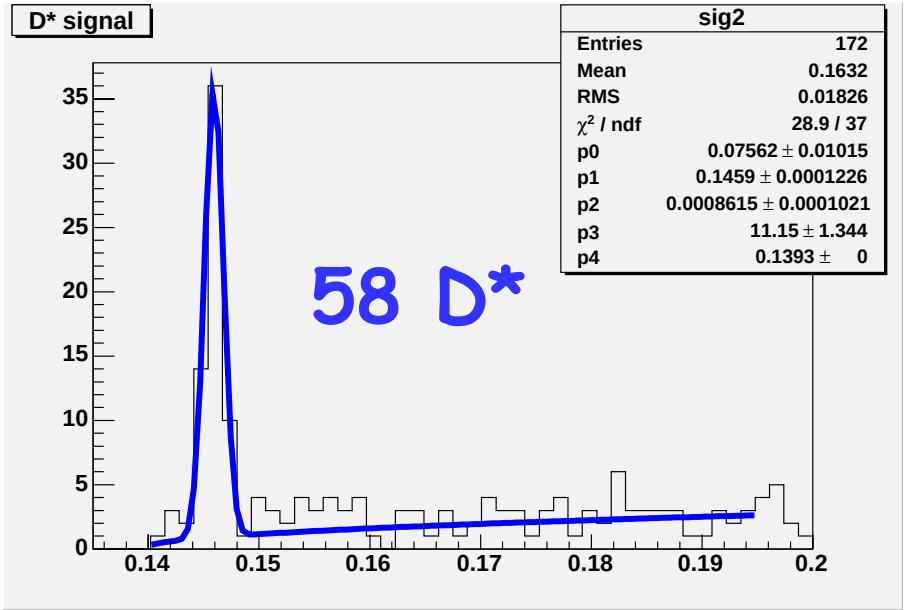


Visible Proper Decay Length

- VPDL = $x = \frac{L_{xy}}{P_T^{\mu D^0}} \cdot M_B$

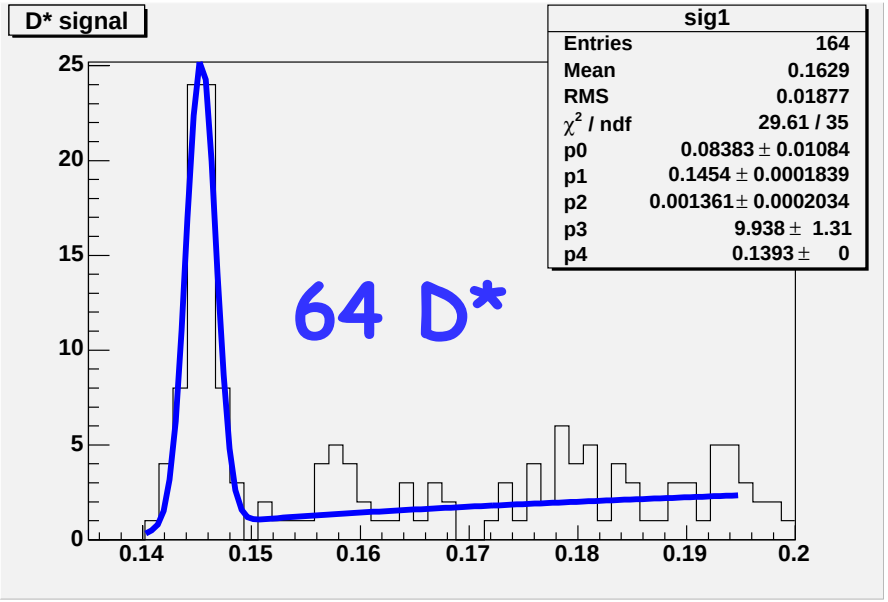
- Defined 7 bins of VPDL
- Example : "Not oscillated" and "oscillated" samples for bin VPDL = [0-0.025 cm]

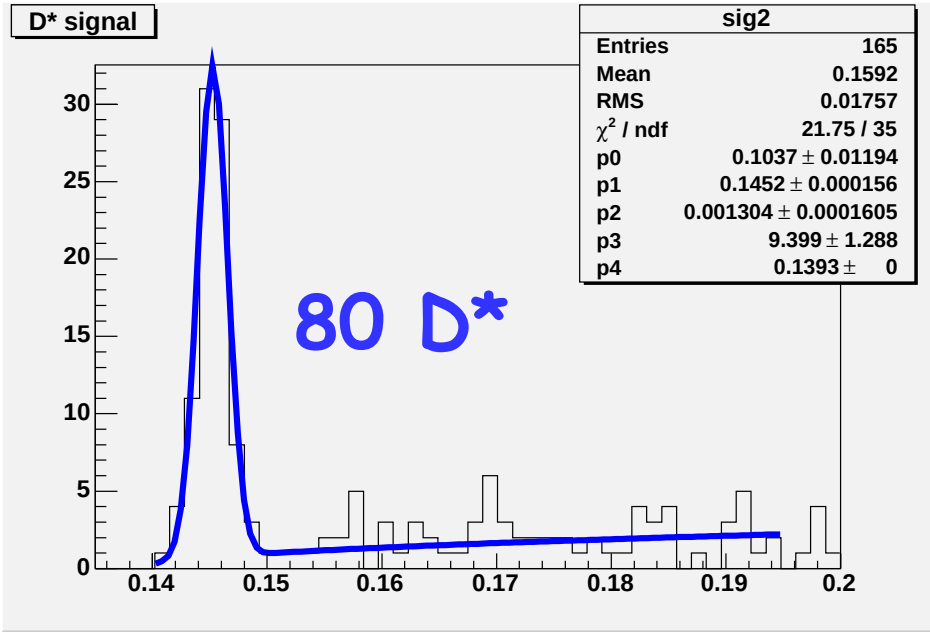




Visible Proper Decay Length

- Another example : "Not oscillated" and "oscillated" samples for last bin VPDL = [0.125-0.25cm]



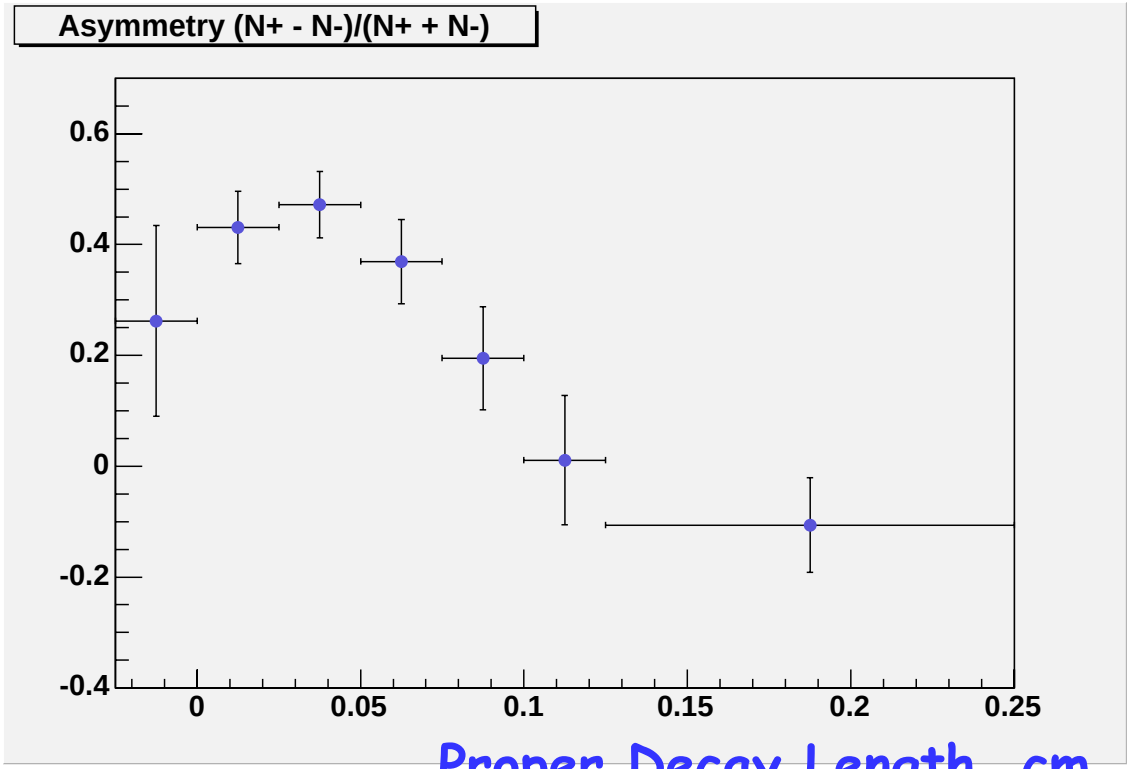


Observable : Asymmetry

- For each VPDL bin define

$A_i = (N_i^{non-osc} - N_i^{osc}) / (N_i^{non-osc} + N_i^{osc})$

- Expect to see oscillations



Proper Decay Length, cm

Fit procedure

- Need expression for expected asymmetry
  - Use exactly the same approach as in the lifetime ratio analysis
- First sort out how different B meson species behave wrt oscillation/tagging
  - Bd tagged as oscillated

$$n_d^+ = \frac{K}{c\tau_{B_d}} \exp(-\frac{Kx}{c\tau_{B_d}}) \cdot 0.5 \cdot (1 + (2\eta - 1)\cos(\Delta m \cdot Kx / c))$$

  - Bd tagged as non-oscillated

$$n_d^- = \frac{K}{c\tau_{B_d}} \exp(-\frac{Kx}{c\tau_{B_d}}) \cdot 0.5 \cdot (1 - (2\eta - 1)\cos(\Delta m \cdot Kx / c))$$

    - Bd oscillates with frequency Δm
    - x is VPDL
    - η is tagging purity = fraction of correctly tagged events / total

Fit procedure (cnt'd)

- B_u tagged as oscillated

$$n_u^+ = \frac{K}{c\tau_{B_u}} \exp(-\frac{Kx}{c\tau_{B_u}}) \cdot (1-\eta)$$

- B_u tagged as non-oscillated

$$n_u^- = \frac{K}{c\tau_{B_u}} \exp(-\frac{Kx}{c\tau_{B_u}}) \cdot \eta$$

  - i.e. B_u does not oscillate

- B_s tagged as oscillated

$$n_s^+ = 0.5 \cdot \frac{K}{c\tau_{B_s}} \exp(-\frac{Kx}{c\tau_{B_s}})$$

- B_s tagged as non oscillated

$$n_s^- = 0.5 \cdot \frac{K}{c\tau_{B_s}} \exp(-\frac{Kx}{c\tau_{B_s}})$$

i.e. B_s oscillation frequency is taken infinite

Fit procedure (cnt'd)

- Integration over K-factors and resolution functions

$$N_{d,u,s}^{+,-}(x^M) = \int dx \cdot \mathrm{Res}\ (x - x^M) \cdot Eff\ (x) \int dK \cdot D\ (K) \cdot n_{d,u,s}^{+,-}(x,K)$$

  - $n_{d,u,s}^{+,-}(x,K)$ were defined above

- "Oscillated" events

$$N_i^{osc} = \int_i dx^M \left(\sum Br \cdot N_d^+ + \sum Br \cdot N_u^+ + \sum Br \cdot N_s^+\right)$$

- "Not oscillated" events

$$N_i^{non-osc} = \int_i dx^M \left(\sum Br \cdot N_d^- + \sum Br \cdot N_u^- + \sum Br \cdot N_s^-\right)$$

  - x^M is integrated over full width of bin i
  - Σ is taken over all decay channels contributing to this type of B meson
  - Br is branching fraction of given channel

Fit procedure (cnt'd)

- Expected asymmetry (per VPDL bin)

$$A_i^e = \frac{(N_i^{non-osc} - N_i^{osc})}{(N_i^{non-osc} + N_i^{osc})}$$

- Δm and η are determined from χ^2 minimization – they are free parameters of the fit

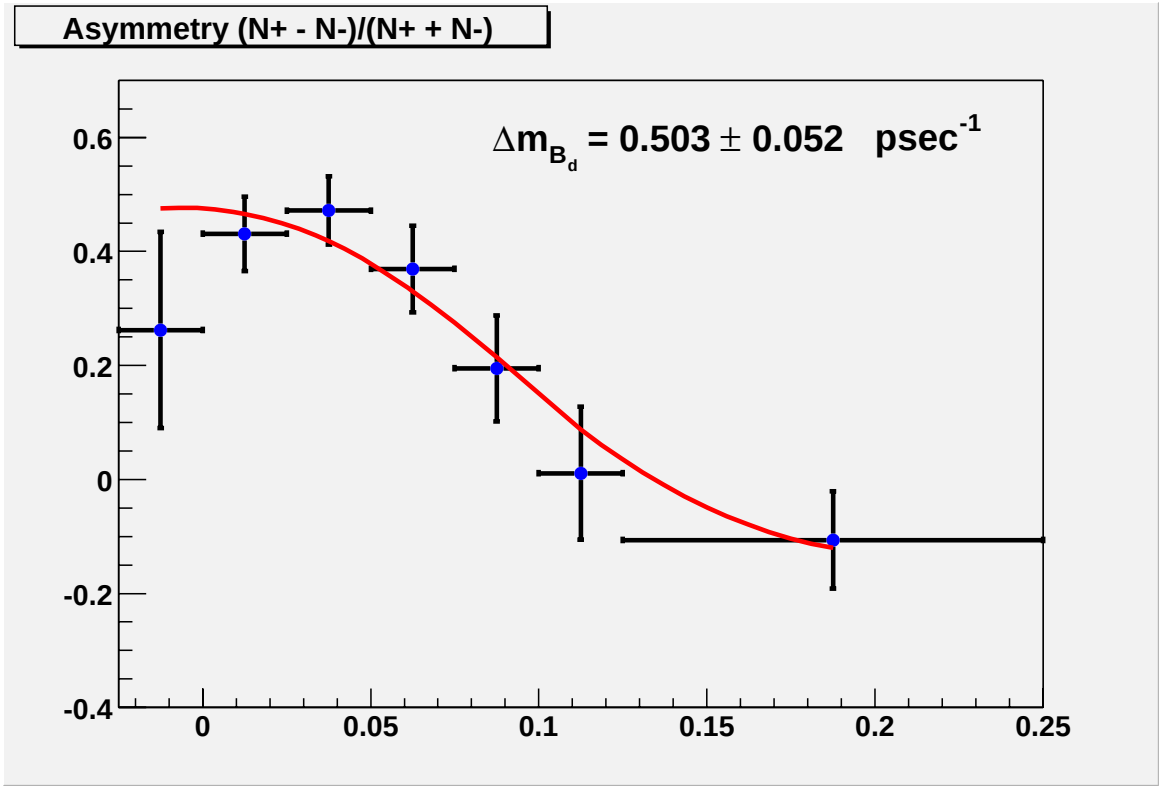
$$\chi^2(\Delta m, \eta) = \sum_i \frac{(A_i - A_i^e(\Delta m, \eta))^2}{\sigma^2(A_i)}$$

Inputs for the fit

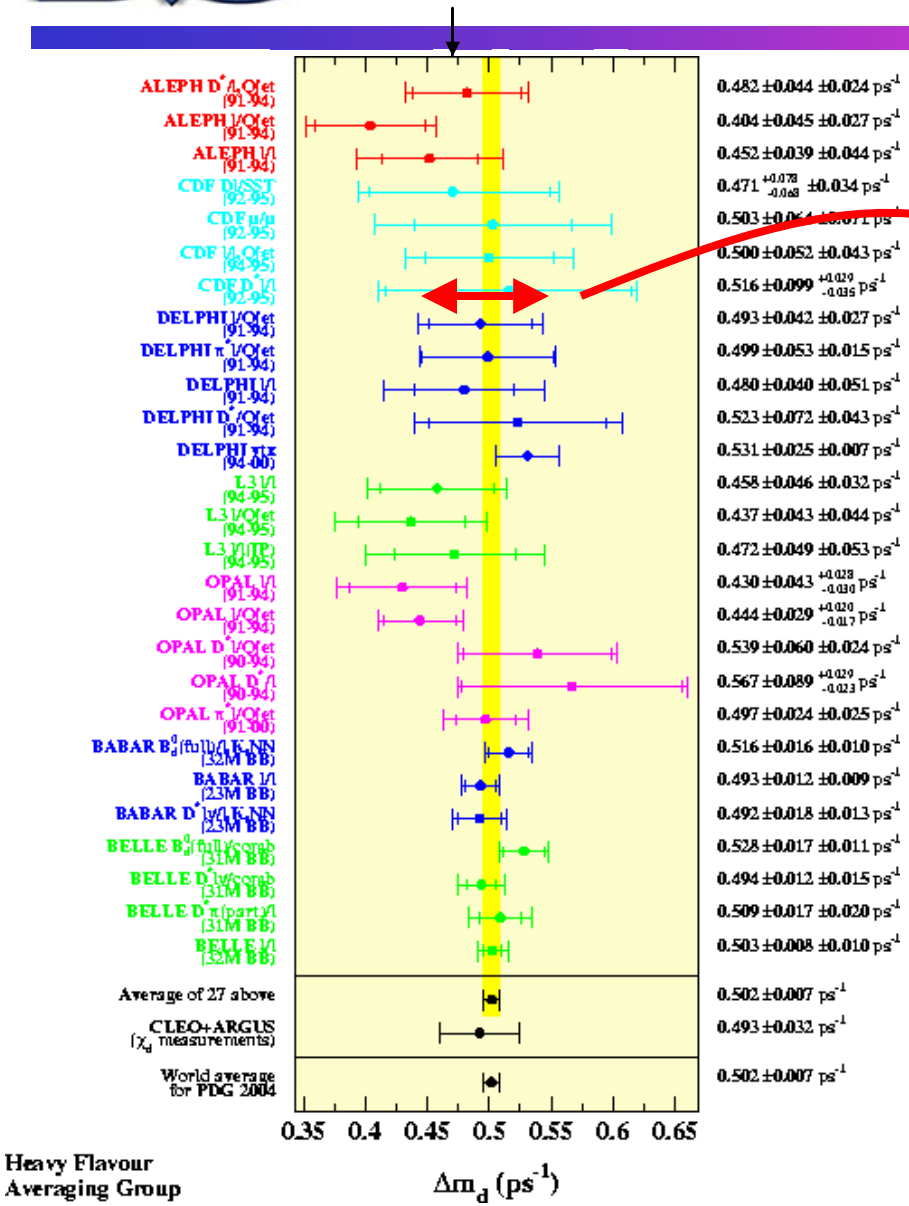
- Considered 11 decay channels of B mesons, see D0note 4280 for details
- All inputs for the fit are the same as in the lifetime ratio analysis – this is why we used the same sample
  - Lifetime, Br & sample composition from PDG
  - K-factors, Resolution, Efficiency from MC

Fit result

- Δm = 0.503 +/- 0.052 $psec^{-1}$
  - HFAG : 0.502 +/- 0.007
- Purity $\eta = 74.3 +/- 2.2\ \%$
- χ^2/NDF = 3.4/5



How are we doing?



- Our result has factor of 3 larger statistical error than the best single measurement
- Same statistical error as CDF RunI best single measurement

First look at systematics

- As in the lifetime ratio analysis we can hope on cancellation of some systematics in asymmetry
  - Situation is even better because we compare D*'s with other D*'s (i.e. same K-factors, Eff etc)

so far varied +/- 1σ:

- Br(B->D** $\mu\ \nu$) small
- Br(B->D*$\pi\ \mu\ \nu$ X) +0.012 ps-1
- Eff(slow pion) 88->80% small

- Drop the negative VPDL bin +0.005 ps-1

Plans

- By conferences
  - Finalize D0note 4330
  - Study systematics
  - Certify fitting procedure on MC
- Longer term
  - Add statistics
    - Looser cuts on D* (x 1.5-2)
    - More channels : $D^0 \to K\pi\pi^0$; $K3\pi$ (x 3-4)
    - More luminosity
  - Event by event fit
  - Combined tagging
  - Potentially will have best single measurement at hadron colliders
    - Has value because of possible contributions from higher mass exotics not produced at B-factories
      - Ex. 12-16 GeV gluino->sbottom/bottom, see hep/ex-0309030
- For more information about analysis, see http://d0server1.fnal.gov/users/nomerot/Run2A/Bd_osc/B_d_oscillations.html