B Lifetimes and Lifetime Differences

- Lifetimes and Lifetime Ratios
  - Results from the B factories
  - Results from the Tevatron
  - Predictions & Projections.
- Lifetime Differences
  - Current Status
  - Methods
  - Projections

Jonas Rademacker,
CDF.

Lifetime (ratios) and Heavy Quark Expansion

- HQE fequently used to relate measurements to CKM parameters e.g. Γ_d to $|V_{cb}|$ or $\Delta m_s/\Delta m_d$ to $|V_{ts}/V_{td}|$.
- Need to be sure this tool works!
- HQE gives precise predictions for B-hadron lifetime ratios - good testing ground.

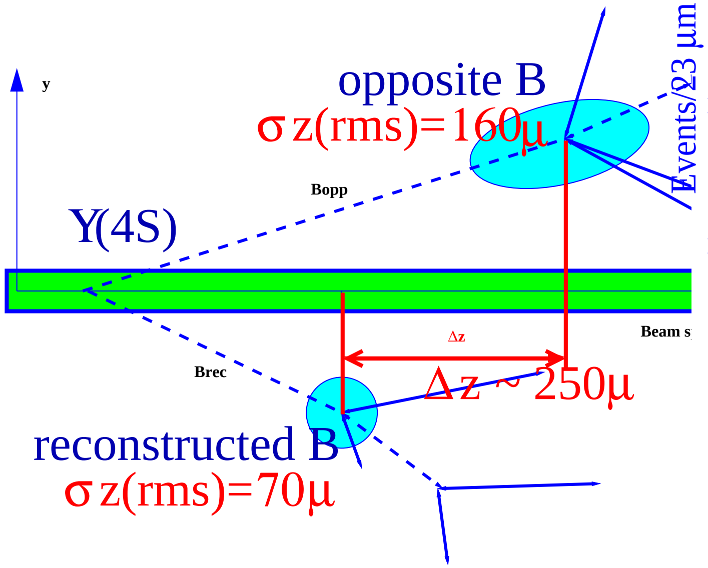
HQE predictions for B lifetimes

$$\tau(\mathrm{B_c}) \ll \tau(\Xi_b^0)$$
$$\sim \tau(\Lambda_\mathrm{b}) < \tau(\mathrm{B_d^0}) \sim \tau(\mathrm{B_s^0}) < \tau(\mathrm{B^-})$$
$$< \tau(\Xi_\mathrm{b}^-) < \tau(\Omega_\mathrm{b})$$

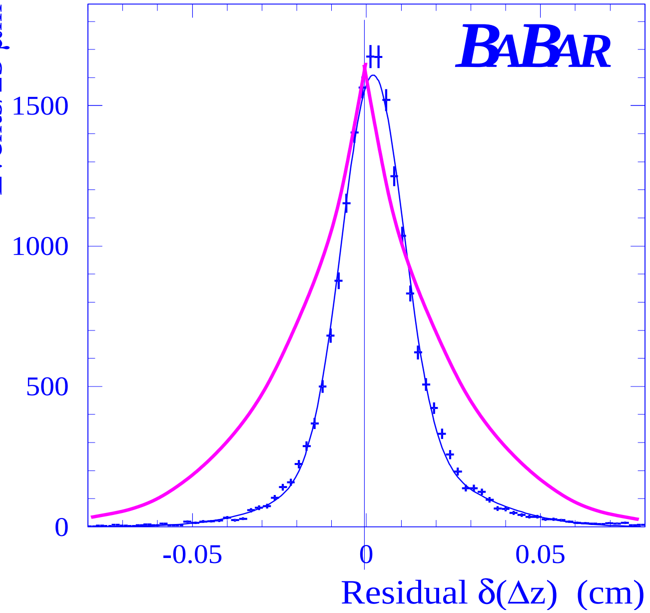
- $\tau(\mathrm{B^-})/\tau(\mathrm{B_d^0}) = 1.067 \pm 0.027$
- $\tau(\mathrm{B_s})/\tau(\mathrm{B_d^0}) = 0.998 \pm 0.015$
- $\tau(\Lambda_\mathrm{b})/\tau(\mathrm{B_d^0}) \approx 0.9$

Lifetimes from B-factories

Principle (numbers from BaBar)



Reconstructed B fully (hadronic) or partially (semileptonic) reconstructed. Opposite B z-pos from one or more tracks.

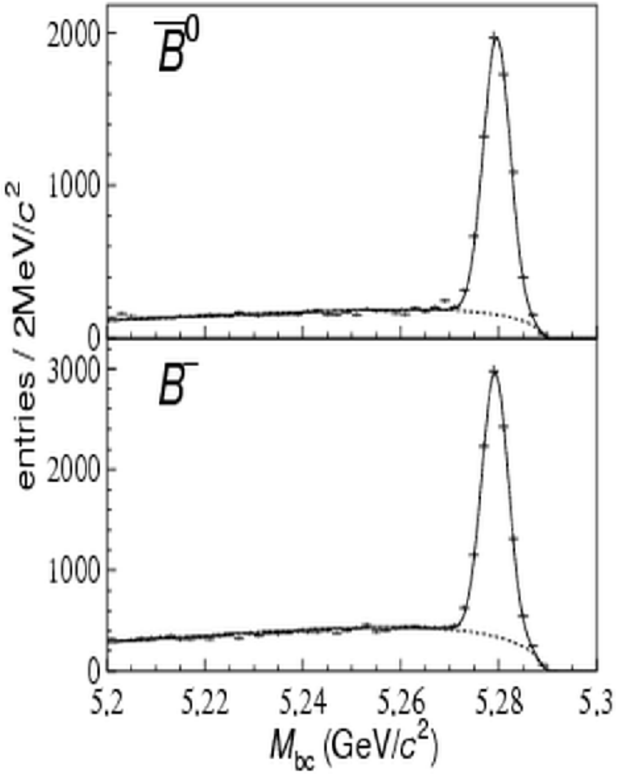


Resolution fct from MC (blue), fully rec. hadronic. For illustration: $\exp(\Delta z/250\,\mu)$

- Boosted ($\beta\gamma = 0.55$) $\Upsilon(4S)$ decays to pair of B's that travel (nearly) along z-axis.
- $\Delta\tau$ from $\Delta z = z_{\text{rec}} - z_{\text{opp}}$ of two B vertices.
- Main challenge: Resolution fct & bckg. model.

Lifetimes from BELLE

Fit Method - fully reconstructed hadronic decays.



use mass for evt-by-evt signal probability

- Fit 3 Components: Sg + Bckg + Outliers (Outliers = Sg or Bg evts with very large $\Delta\tau$)
- Complex model for Resolution and Background.
- Beam-constrained mass for evt-by-evt signal prob.(see Fig)
- Simultaneous unbinned likelihood fit to B^+ and B^0 $\Delta\tau$.

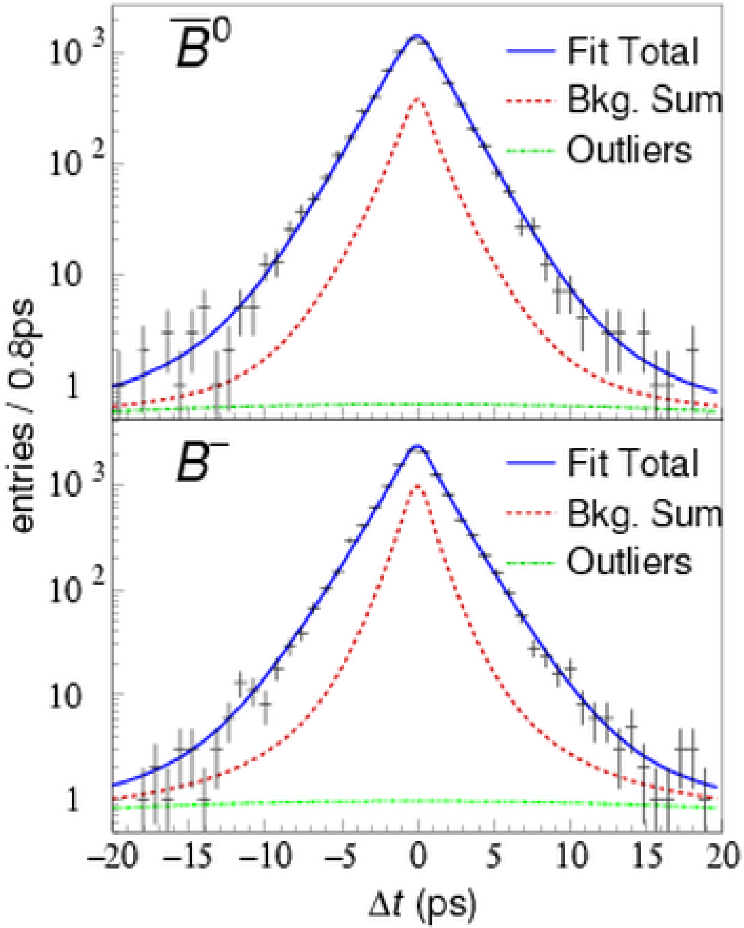
Results from BELLE

From $B^0 \to D^{(*)-}(\pi^+, \rho^+), J/\psi K^0_S, J/\psi K^{*0}$ and $B^+ \to \overline{D}^0 \pi^+, J/\psi K^+$.

$$\tau_{B^0_d} = 1.554 \pm 0.030 \pm 0.019\,\text{ps}$$
$$\tau_{B+} = 1.695 \pm 0.026 \pm 0.015\,\text{ps}$$
$$\tau_{B+}/\tau_{B^0_d} = 1.091 \pm 0.023 \pm 0.014$$

(PRL 88, 171801 (2002))

Dominant sytematics: Time-resolution function and background parametrisation.



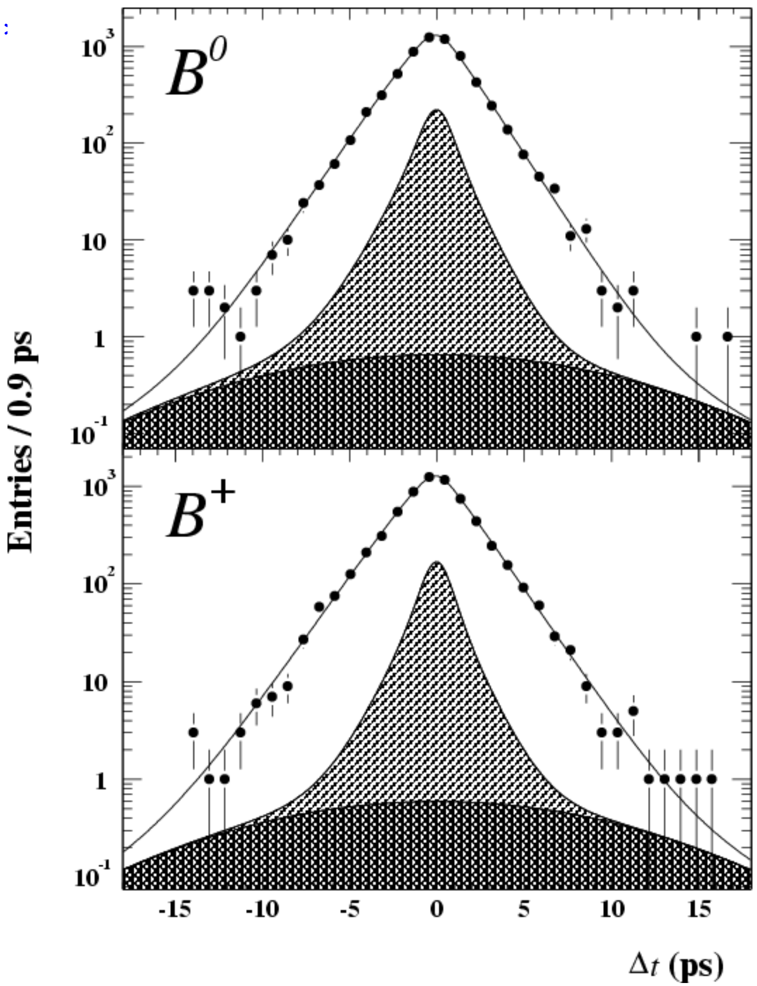
Results from BaBar

From $B^0 \to D^{(*)-}(\pi^+, \rho^+, a_1^+), J/\psi K_S^0, J/\psi K$
and $B^+ \to \overline{D}^0\pi^+, J/\psi K^+, \psi(2S)K^+$.

$$\begin{aligned} \tau_{B_d^0} &= 1.546 \pm 0.032 \pm 0.022\,\text{ps} \\ \tau_{B^+} &= 1.673 \pm 0.032 \pm 0.023\,\text{ps} \\ \tau_{B^+}/\tau_{B_d^0} &= 1.082 \pm 0.026 \pm 0.012 \end{aligned}$$

Sytematics in ratio: Time-resolution function, outliers, MC stats, bg model.

Also many new results from partially re-constructed channels.

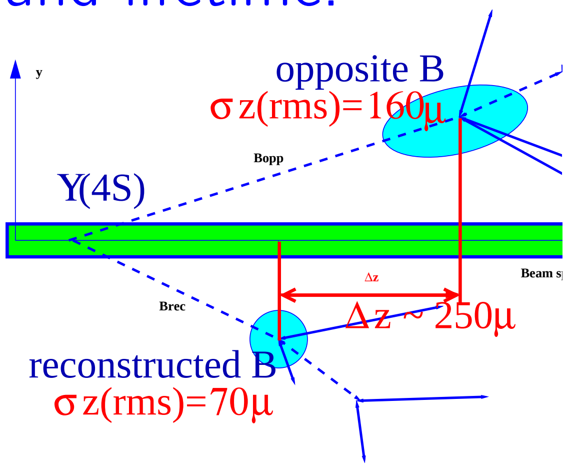


More from BaBar *Decays with missing $\vec{p}$*

	$B^0 \to D^{*-}(\text{partial})\ell^+\nu$
$\tau_{B_d^0}$	$1.529 \pm 0.012 \pm 0.029$ ps
	$B^0 \to D^{*-}(\text{partial})(\pi^+, \rho^+)$
$\tau_{B_d^0}$	$1.510 \pm 0.040 \pm 0.038$ ps
	$B^0 \to D^{*-}\ell^+\nu$
$\tau_{B_d^0}$	$1.523^{+0.024}_{-0.023} \pm 0.022$ ps
	Di-lepton (prelim)
$\tau_{B_d^0}$	$1.557 \pm 0.028 \pm 0.027$ ps
τ_{B+}	$1.655 \pm 0.026 \pm 0.027$ ps
$\tau_{B+}/\tau_{B_d^0}$	$1.064 \pm 0.031 \pm 0.026$ ps

"D^{*-}(partial)" is a D^* reco'ed from the slow π in $D^{*-} \to D^0\pi$, without the D^0.

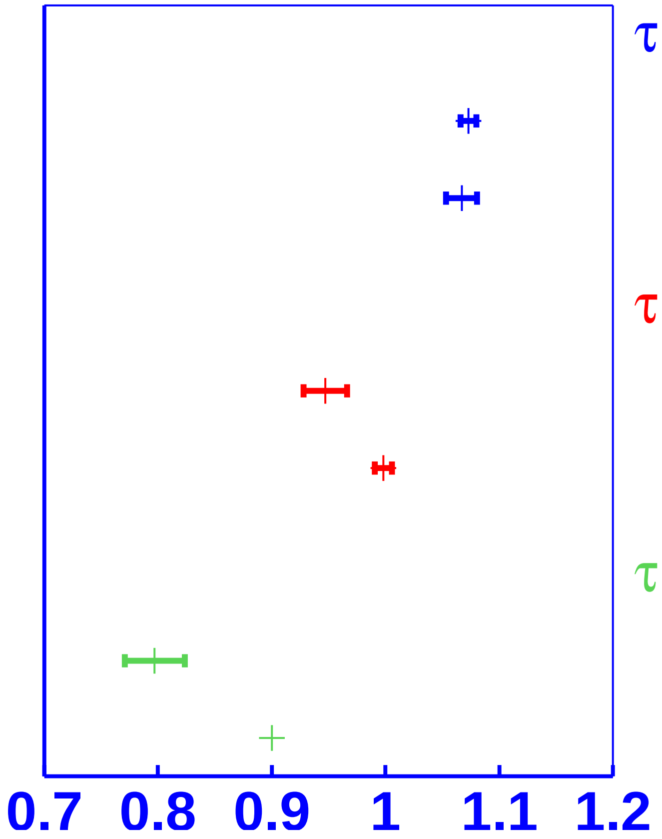
In principle, because each B's $\vec{p}$ is known from beam constraint, need only one decay product from each B to reconstruct B vertices and lifetime.



B-factory Summary and Outlook

- Decreased error on $\tau_{B+}/\tau_{B_d^0}$ by half since data taking started.
- Increase statistics by factor of 10 by 2008.
- Systematics will improve because
  - Large statistics allow more robust analyis techniques (can afford to require more tracks for both B vertices).
  - Detector upgrades promise better vertex resolution
- Expect measurement of $\tau_{B+}/\tau_{B_d^0}$ far beyond current theoretical precison.

Status - Lifetime Ratios Experiment, HQE



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

EXP: 1.073 $\pm$ 0.014

HQE: 1.067 $\pm$ 0.027

$\tau(B_s)/\tau(B_d^0)$:

EXP: 0.949 $\pm$ 0.038

HQE: 0.998 $\pm$ 0.015

$\tau(\Lambda_b^0)/\tau(B_d^0)$:

EXP: 0.797 $\pm$ 0.053

HQE: $\approx$ 0.9

- $\tau_{B+}/\tau_{B_d^0}$ experimental accuracy better than HQE.
- Not the case for $\tau_{B_s}/\tau_{B_d^0}$.
- $\tau_{\Lambda_b}/\tau_{B_d^0}$: largest experimental error of the three. Theoretical error unclear.

Exp from LEP-B averaging group, with results from LEP, CDF Run I, and, for $\tau_{B+}/\tau_{B_d^0}$, BaBar & BELLE (fully rec, hadronic).

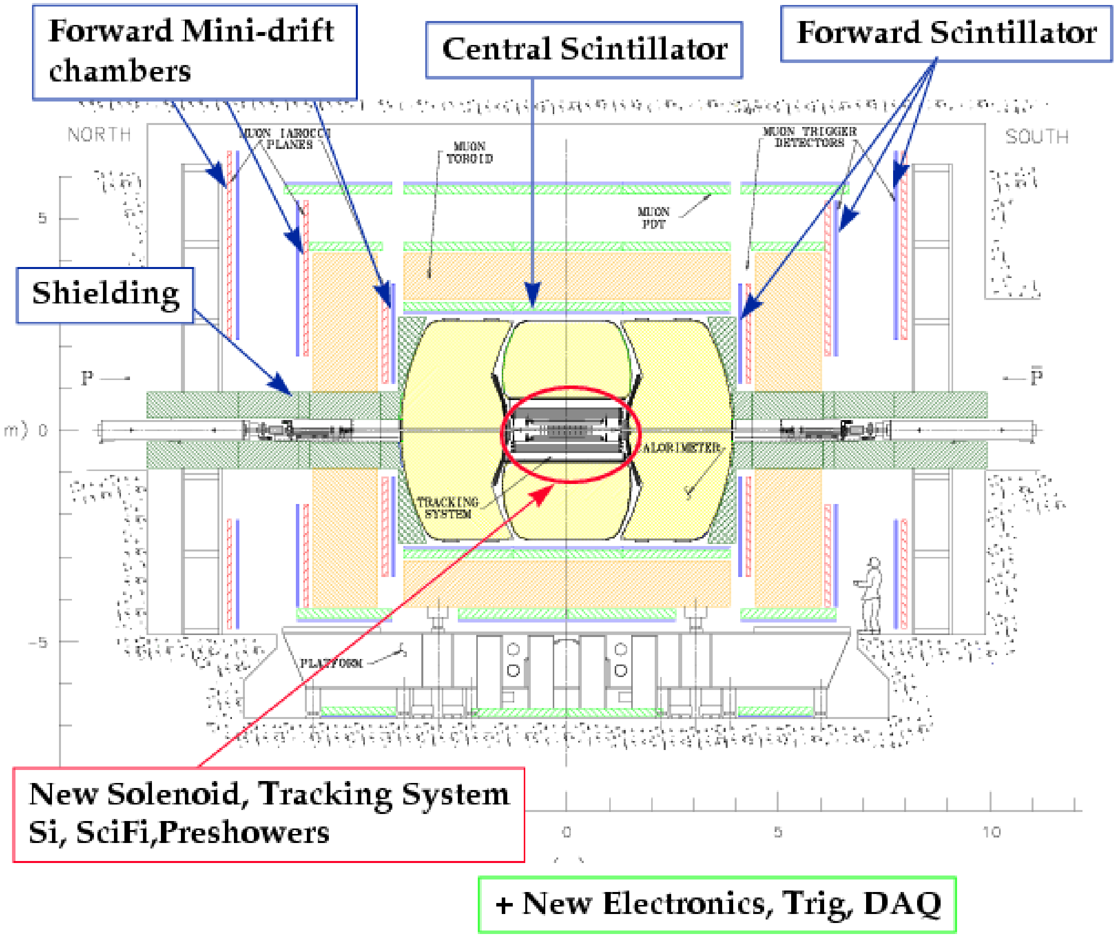
Tevatron Run II

- $p\bar{p}$ collisions @ 1.96 TeV, $\sigma_{b\bar{b}} \sim 0.1$ mb
- $\mathcal{L} \sim 10^{32}$
- Produce many $B^0, B_s, \Lambda_b, ...$
- Find them with newly upgraded CDF & DØ, both with many new features optimising the detectors for B physics..

Projected $\int \mathcal{L}$ [fb^{-1}]

Year	*Baseline*	*Stretch*
2002	0.08	0.08
2003	0.2	0.32
2004	0.4	0.6
2005	1.0	1.5
2006	1.5	2.5
2007	1.5	3.0
2008	1.8	3.0
Total	6.5	11.

DØ

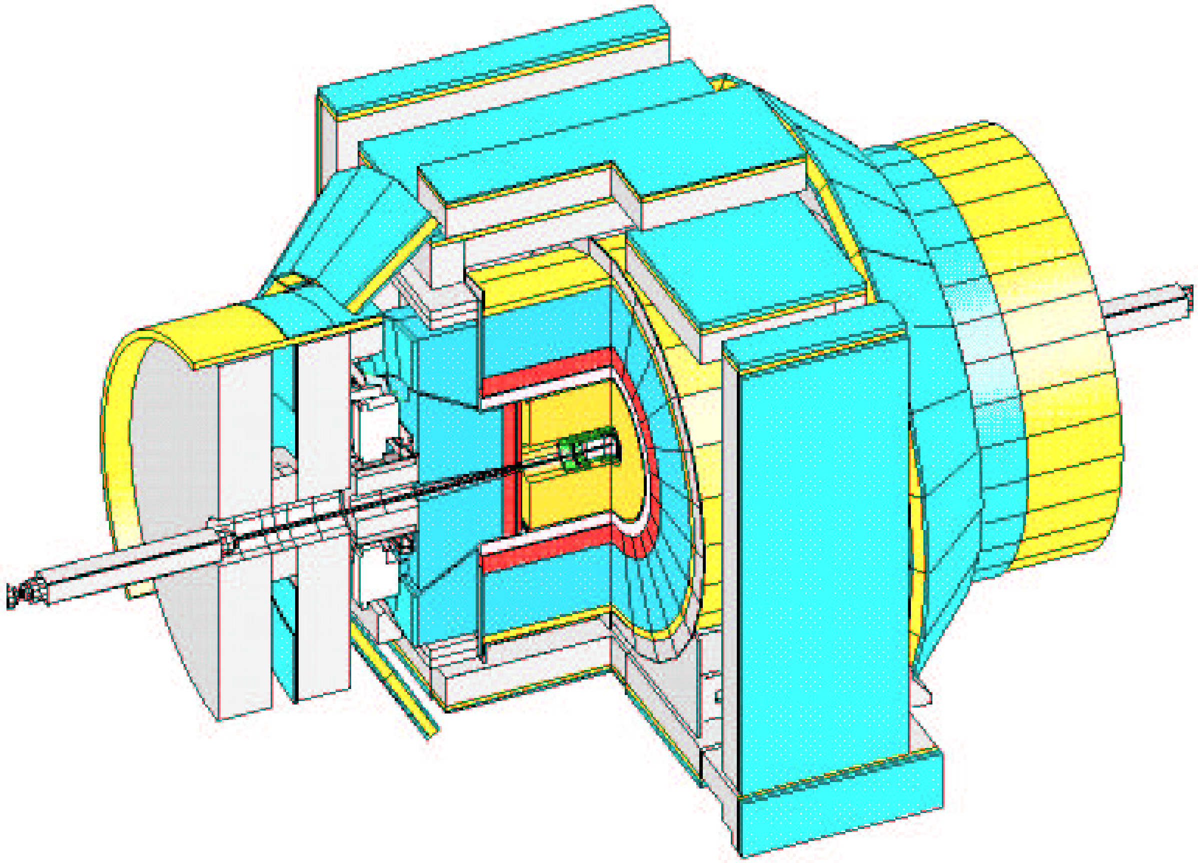


D0 Upgrade

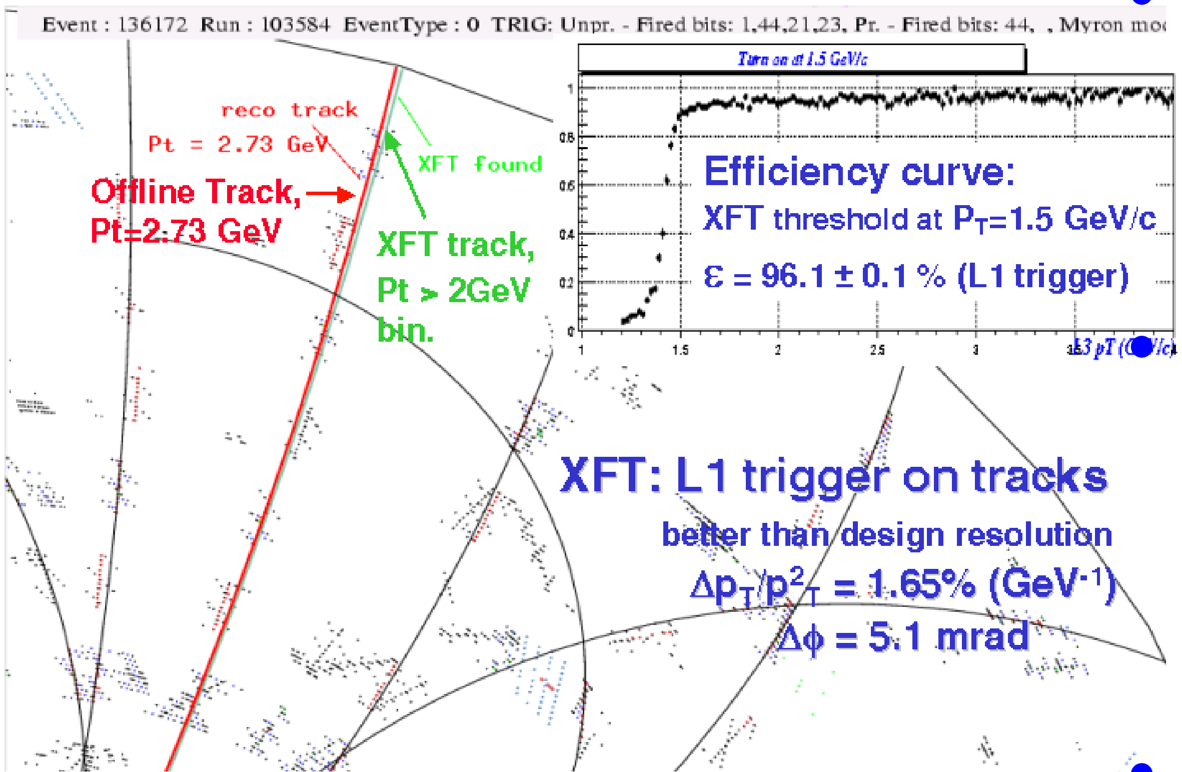
- New 2T Magnet
- New Fiber Tracker
- New Si Tracker
- New Forward Cal
- New Trigger, New DAQ System
- Muon Trigger up to $|\eta| = 2$ finds lots of $B \rightarrow J/\psi X$

CDF

- New Si Tracker
- Faster Drift Chamber
- Extended μ coverage
- New Plug Cal.
- Time of Flight
- IP-trigger to find long-lived B/Charm, J/ψ Trigger for B $\rightarrow$ J/ψX.



Triggering on Impact Parameter - XFT and SVT



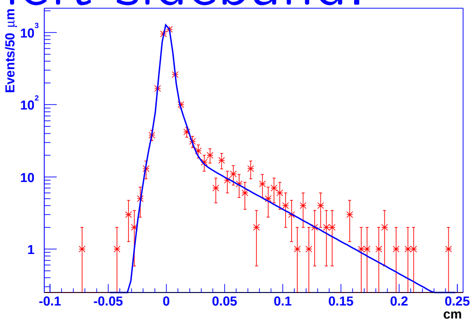
More on the SVT from Ivan Vila, Mo 17:00.

- eXtremely Fast Tracker uses pattern-matching to track within 5.5 μs, in time for L1.
- Silicon Vertex Tracker combines XFT-tracks with Si information. Used by L2 to trigger on displaced tracks.
- Finds loads of B's. Problematic: Lifetime bias.

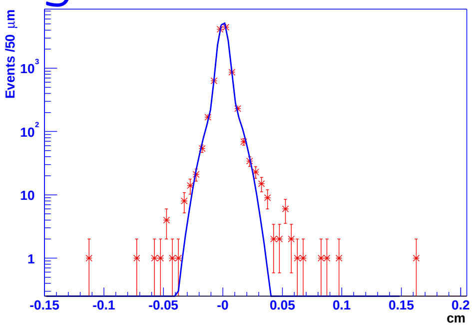
Lifetimes w/o IP trigger $B_u^+ \to J/\psi(\mu^+\mu^-)K^+$ *at DØ*

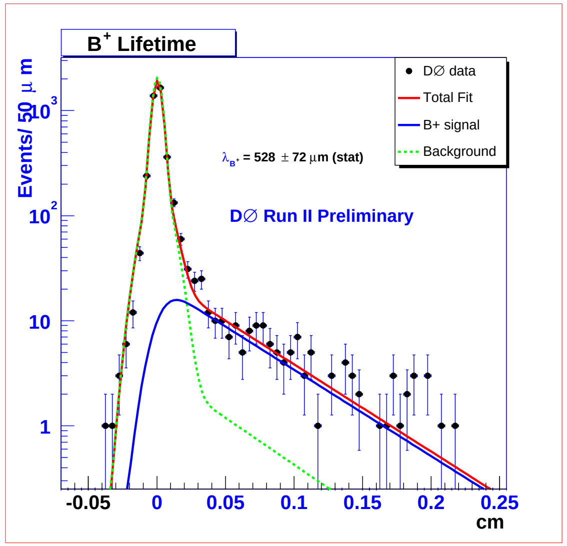
Sidebands · *Signal-region* · *Mass* $(L_{xy} > 400\,\mu m)$

left sideband:



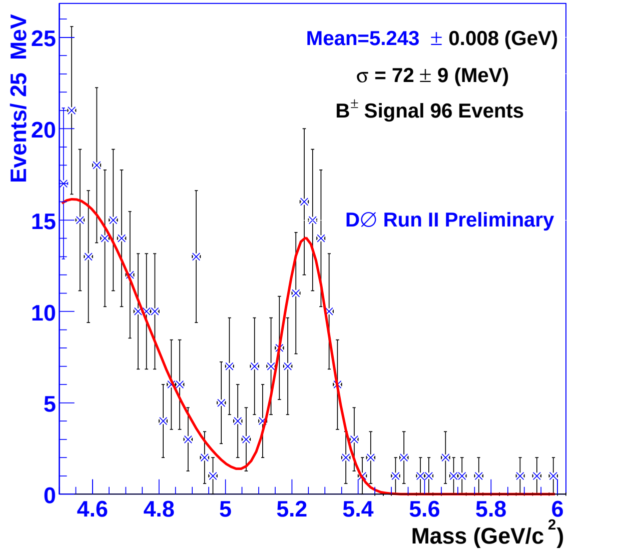
right sideband





Fit result:

$1.761 \pm 0.24(\text{stat})$ ps

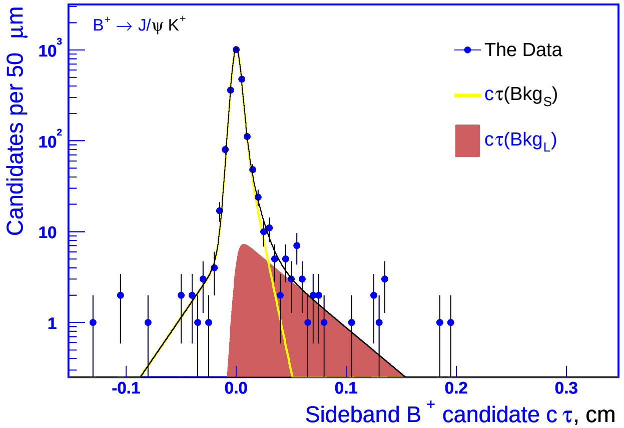


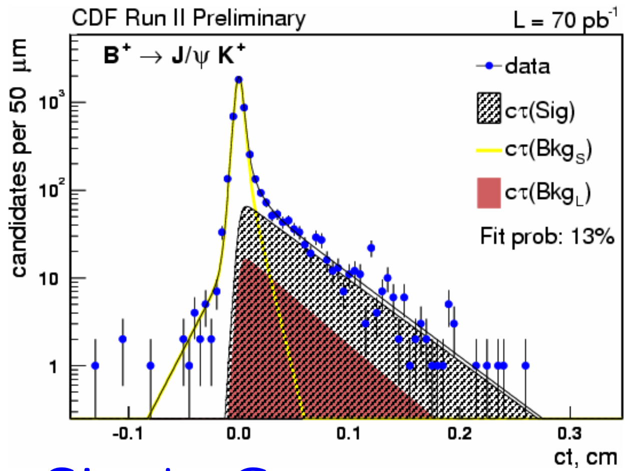
(Mass resolution has improved by factor ~ 2 since this plot was produced)

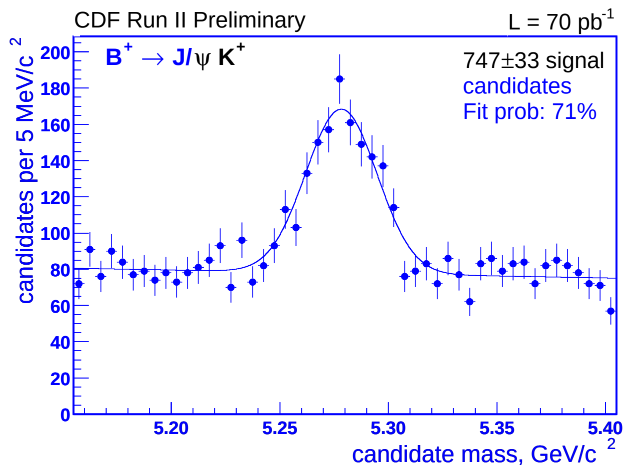
Right sideband to model non-B BG. Long lifetime component in left s.b. from other B decays. 12% B contamination in sg region (MC).

Lifetimes w/o IP trigger $B \to J/\psi(\mu\mu)X$ *fully reco'ed (CDF)*

Background *Signal+Bg* *Mass*







- Resolution function: Single Gauss.
- Signal: exp $\otimes$ Gauss.
- Bckg model: (prompt + 1 negative and 2 positive exp) $\otimes$ Gauss.

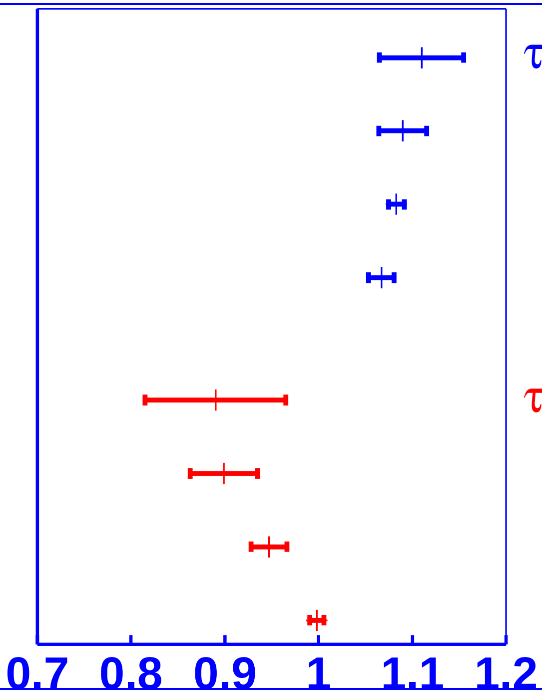
(due to smaller stats, only one pos. exp for B_s)

Mass (gauss + linear) for evt-by-evt signal purity.

Unbinned likelihood fit with $\mathcal{L} = \mathcal{L}(\tau, \text{mass})$

CDF Run II Results: Lifetime Ratios (prelim)

$B_u^+ \to J/\psi(\mu^+\mu^-)K^+$, $B_d^0 \to J/\psi(\mu^+\mu^-)K^{*0}$, $B_s^0 \to J/\psi(\mu^+\mu^-)\phi$



$\tau(B^+)/\tau(B_d^0)$=1.11 $\pm$ 0.09

Run I: 1.091 $\pm$ 0.050

Ave: 1.073 $\pm$ 0.014

HQE: 1.067 $\pm$ 0.027

$\tau(B_s)/\tau(B_d^0)$=0.89 $\pm$ 0.15

Run I: 0.899 $\pm$ 0.072

Ave: 0.997 $\pm$ 0.038

HQE: 0.998 $\pm$ 0.015

Run II results from 70 pb^{-1}

By the end of this year, expect $\sim 280\,pb^{-1}$.

Reach Run I precision (all channels combined) this year, from $B \to J/\psi(\mu\mu)X$ fully reconstructed decays alone.

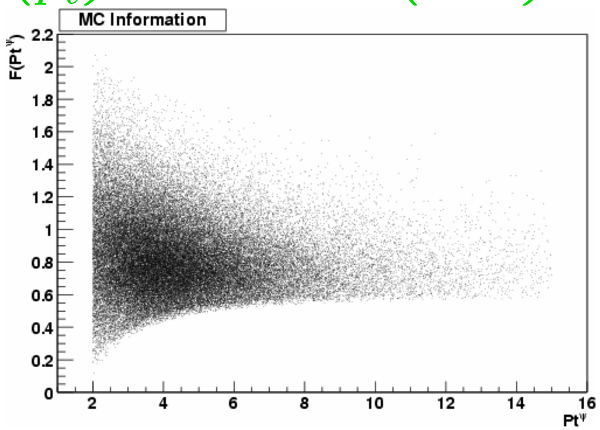
$$\tau_{B^+} = 1.57 \pm 0.07 \pm 0.02\,ps,\ \tau_{B_d^0} = 1.42 \pm 0.09 \pm 0.02\,ps,$$
$$\tau_{B_s^0} = 1.26 \pm 0.20 \pm 0.02\,ps$$

Run II Results: Inclusive $\tau(B)$

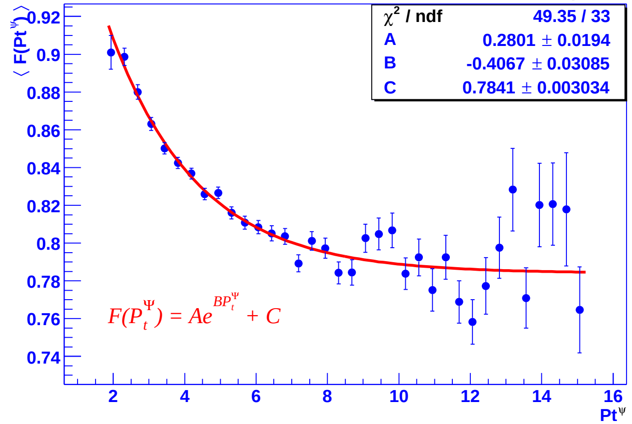
- Reconstruct τ(B) from J/ψ only.
- Missing info: p_t(B) in
  $\tau = L_{xy}M(B)/(cp_t(B))$
  On average:
  $p_t(\mathrm{B}) = F(p_t) \cdot p_t(\mathrm{J}/\psi)$.
- Prelim Results
  - DØ (March 03)
    $1.561 \pm 0.024 \pm 0.074$ ps
  - CDF (July 02)
    $1.526 \pm 0.034 \pm 0.035$ ps

$F(p_t)$ from MC (DØ)

$\frac{p_t(B)}{p_t(\mathrm{J}/\psi)}$



$F = \left\langle \frac{p_t(B)}{p_t(\mathrm{J}/\psi)} \right\rangle$



$p_t(\mathrm{J}/\psi)$

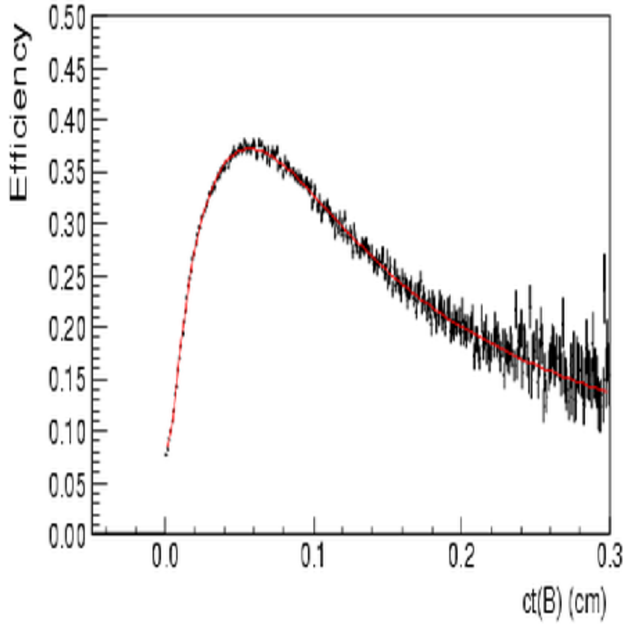
CDF Run II: Semileptonic with ℓ+IP trigger

$B \rightarrow D\ell\nu X$ *and* $\Lambda_b \rightarrow \Lambda_c \ell\nu$

Challenges:

- *Lifetime Bias* Use lepton + SVT trigger. 0.12 mm< IP <1 mm cut biases lifetime distribution. Get SVT ϵ from detailed MC.
- *Missing* p_t from missing ν and possibly other particles (depending on analysis). Similar as for inclusive - get K in $p_t(B) = K(p_t) \cdot p_t(D+\ell)$ from MC.

Trigger acceptance vs $c\tau$ for $B \rightarrow D\ell\nu$ (MC)

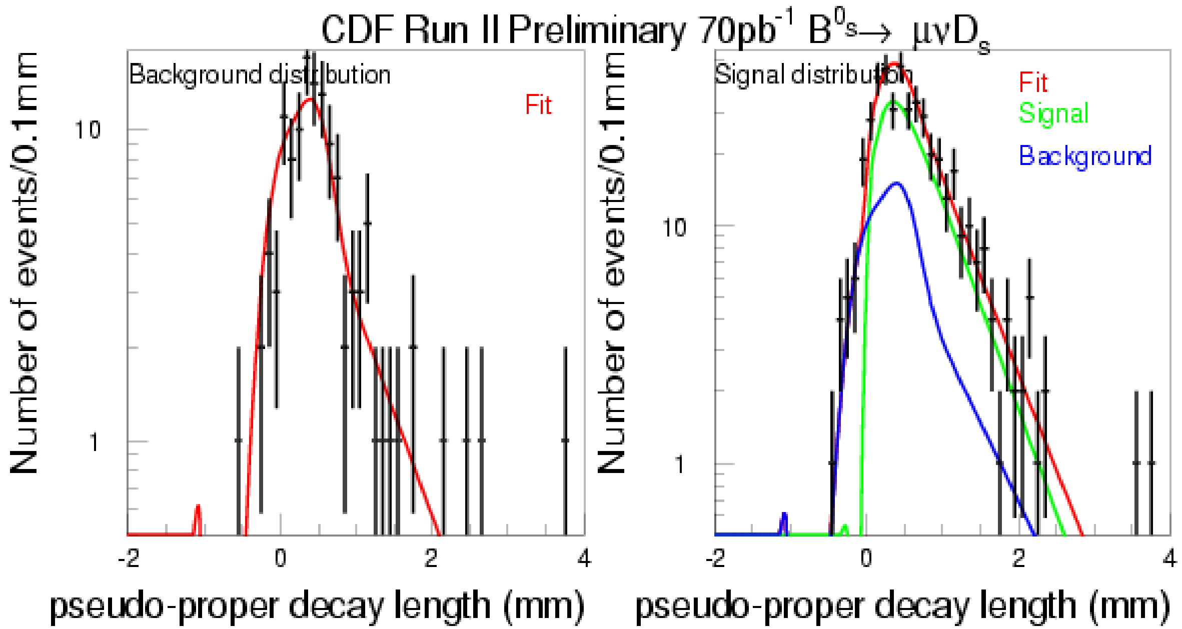


Statistical precision (Sytematics not yet fully understood.)

$\sigma_{\tau_{B+}} = \sim 0.05$ ps, $\sigma_{\tau_{B_d^0}} = \sim 0.06$ ps, $\sigma_{\tau_{B_s}} = \sim 0.10$ ps, $\sigma_{\tau_{\Lambda_b}} = \sim 0.13$ ps

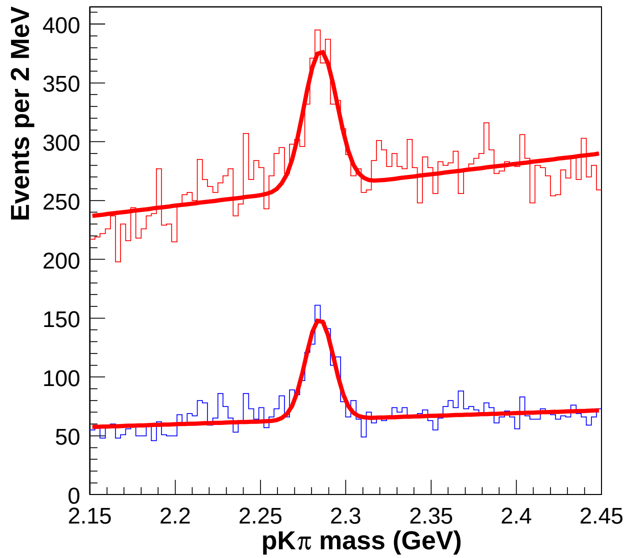
CDF Run II Semileptonic: a few plots

$B_S \to D_S \mu\nu$ life time



Fit to lifetime distribution from $B_S \to D_S \mu\nu$. Left: Sideband. Right: Signal region

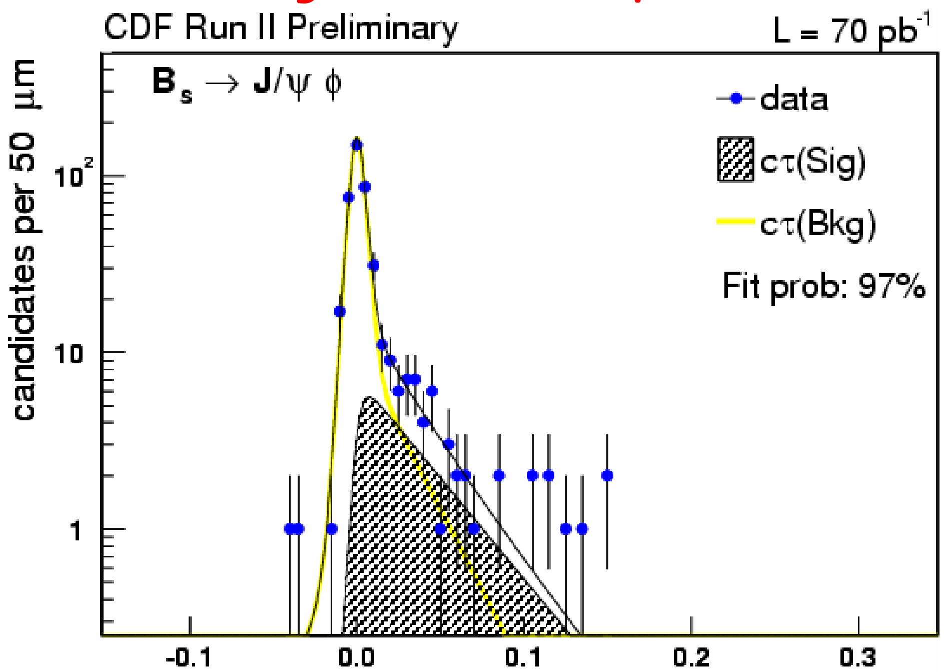
Λ_C mass



Λ_c mass with and without proton ID from TOF and $\frac{dE}{dx}$.

Lifetime Ratios at TEV - Summary & Prospects.

- Get high stats on all B-hadrons, including B_s, Λ_b.
- First Run II results from fully reconstructed hadronic already close to total Run I accuracy.
- Results from lepton + displaced track trigger very soon.



Fit to B_s lifetime.

- TEV Run IIa projections (Dec-01): $\sigma(\tau_{B_s}/\tau_{B_d^0})$, $\sigma(\tau_{\Lambda_b}/\tau_{B_d^0}) < 1\%$.

Real test of theory for B_s. Need better calculation for Λ_b •

Lifetime Differences

- $\Delta\Gamma$ = width difference between long and short lived CP eigen-states in $B^0_{s,d} - \bar{B}^0_{s,d}$ system.
- Theory: $\frac{\Delta\Gamma_s}{\Gamma_s}$ $\mathcal{O}(10)\%$; $\frac{\Delta\Gamma_d}{\Gamma_d}$ $\mathcal{O}(1\%)$
- $\frac{\Delta\Gamma_s}{\Gamma_s}$ large enough to be experimentally accessible, soon.
- $\frac{\Delta\Gamma_s}{\Gamma_s} = A \cdot \Delta m_s/\Gamma_s$, with A calculable (with some uncertainty):
  - Larger Δm_s (harder to measure) suggests larger $\Delta\Gamma_s$ (easier to measure).
  - Given limits on Δm_s, very small $\Delta\Gamma_s$ would hint at new physics.

Strategies for Extracting $\Delta\Gamma_s$

Since $\frac{\Delta\Gamma_s}{\Gamma_s}$ $\mathcal{O}(10\%)$ only, need very high stats to fit 2 lifetimes to mixed-CP decays. Better: use extra information to seperate the CP eigenstates. Possible strategies include:

- Fit lifetime to (nearly) purely CP-even $B_s^0 \to D_s^{(*)} D_s^{(*)}$. Compare result to mean lifetime from CP-mixed channels.
- Fit 2 lifetimes to $B_s^0 \to J/\psi\phi$. Can have 3 ang. mom. states, 2 CP even, 1 CP odd. Can be disantangled by an angular analysis.
- The B.R. Method: Assume width difference is entirely due to CP-even $B_s^0 \to D_s^{(*)} D_s^{(*)}$. In small velocity (Shifman-Voloshin) limit:

$$BR(B_s^0 \to D_s^{(*)} D_s^{(*)}) = \frac{\Delta\Gamma_s/\Gamma_s}{1 + \frac{1}{2}\Delta\Gamma_s/\Gamma_s}$$

$\Delta\Gamma_s$, $\Delta\Gamma_d$ - status and prospects

Status:

- $\frac{\Delta\Gamma_d}{\Gamma_d} < 0.20$ (90% CL) (DELPHI, EPS HEP 2001)
- $\frac{\Delta\Gamma_s}{\Gamma_s} < 0.31$ (95% CL) (combined LEP, CDF, for $1/\Gamma_s = \tau(B^0_d)$, using lifetime method)
- $\frac{\Delta\Gamma_s}{\Gamma_s} = 0.26^{+0.30}_{-0.15}$ (ALEPH, from B.R. method)

Prospects (TEV Run IIa, status: Dec-01)

- CDF Run IIa ($2\,\text{fb}^{-1}$) projections, assuming $\frac{\Delta\Gamma_s}{\Gamma_s} = 15\%$ (stat only):
  - $B_s \to J/\psi\phi$: $\sigma(\frac{\Delta\Gamma_s}{\Gamma_s}) \sim 5\%$
  - $B_s \to D_s^{(*)}D_s^{(*)}$: $\sigma(\frac{\Delta\Gamma_s}{\Gamma_s}) \sim 3\%$ (assume decay 100% CP even)
  - B.R. method: $\sigma(\frac{\Delta\Gamma_s}{\Gamma_s}) \sim 1\%$ (model dependent)
- Assuming similar performance of DØ in $B_s \to J/\psi\phi$, total Run IIa prospect (excluding B.R. method): $\sigma(\frac{\Delta\Gamma_s}{\Gamma_s}) \sim 2\%$

Summary

lifetime ratios

- B-factories halved $\sigma(\tau_{\mathrm{B+}}/\tau_{\mathrm{B_d^0}})$ to 1.7% - better than HQE.
- Further improvements on $\sigma(\tau_{\mathrm{B+}}/\tau_{\mathrm{B_d^0}})$ from B-factories and Tevatron, soon.
- TEV Run IIa: $\sigma(\tau_{\mathrm{B_s}}/\tau_{\mathrm{B_d^0}})$, $\sigma(\tau_{\Lambda_\mathrm{b}}/\tau_{\mathrm{B_d^0}}) < 1\%$. Real test of theory for $\mathrm{B_s}$. Need better calculation for Λ_b.

lifetime differences

- No strong constraints on $\frac{\Delta\Gamma_s}{\Gamma_s}$, yet.
- $\Delta\Gamma_s$ and Δm_s complementary (see Donatella's talk for Δm_s (Mo 11:20)).
- CDF: First steps taken - $\mathrm{B_s} \to J/\psi\phi$ evts reconstructed, and average $\mathrm{B_s}$ lifetime extracted.
- TEV: Expect $\sigma(\frac{\Delta\Gamma_s}{\Gamma_s}) \sim 2\%$ by end of Run IIa.

BACKUP SLIDES

CDF Run II Results: Lifetimes (prelim)

$B \to J/\psi(\mu\mu)X$ *fully reconstructed*, $70\,\text{pb}^{-1}$.

750 ± 30 $B_u^+ \to J/\psi(\mu^+\mu^-)K^+$ evts: $\tau_{B+} = 1.57 \pm 0.07 \pm 0.02\,\text{ps}$

Compare Run I (all channels): $1.66 \pm 0.05\,\text{ps}$, PDG: $1.674 \pm 0.018\,\text{ps}$

380 ± 30 $B_d^0 \to J/\psi(\mu^+\mu^-)K^{*0}(K^+\pi^-)$ evts: $\tau_{B_d^0} = 1.42 \pm 0.09 \pm 0.02\,\text{ps}$

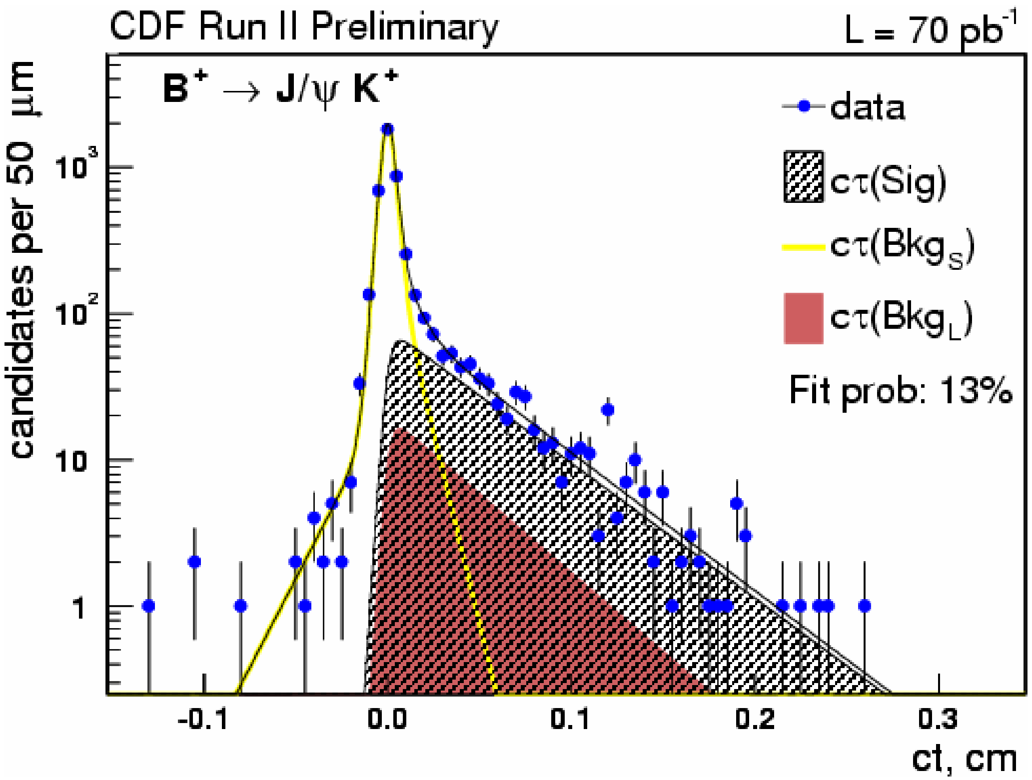
Compare Run I (all channels): $1.51 \pm 0.05\,\text{ps}$, PDG: $1.542 \pm 0.016\,\text{ps}$

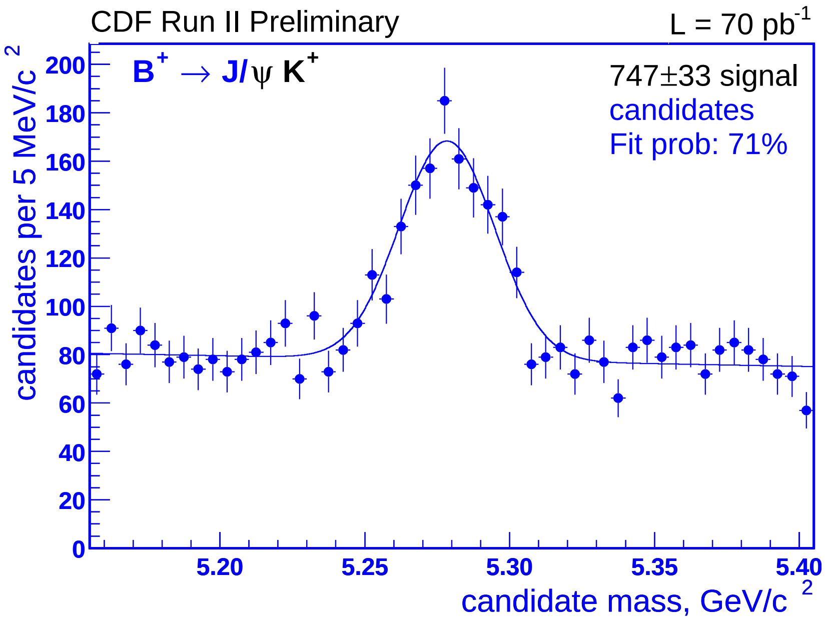
55 ± 9 $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$ evts: $\tau_{B_s^0} = 1.26 \pm 0.20 \pm 0.02\,\text{ps}$

Compare Run I (all channels): $1.36 \pm 0.10\,\text{ps}$, PDG: $1.461 \pm 0.057\,\text{ps}$

RunII: $\tau(B_u^+)$ from $B_u^+ \to J/\psi(\mu^+\mu^-)K^+$

Lifetime *Mass*





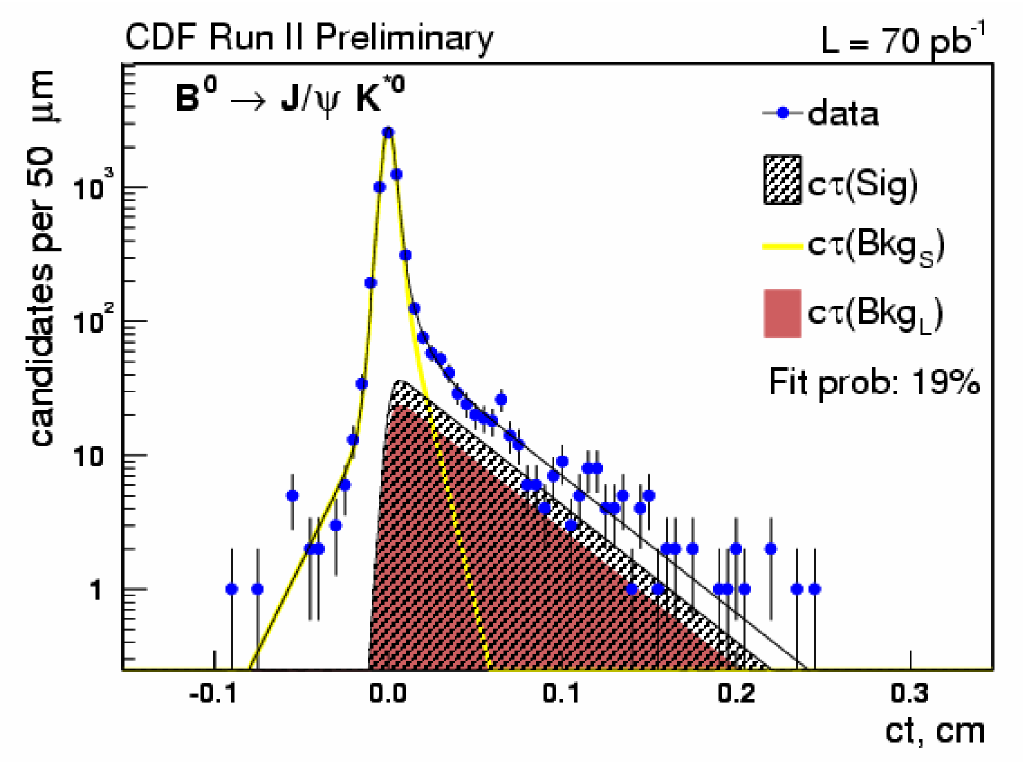
For 750 ± 30 signal events:

$\tau_{B+} = 1.57 \pm 0.07 \pm 0.02\,\text{ps}$

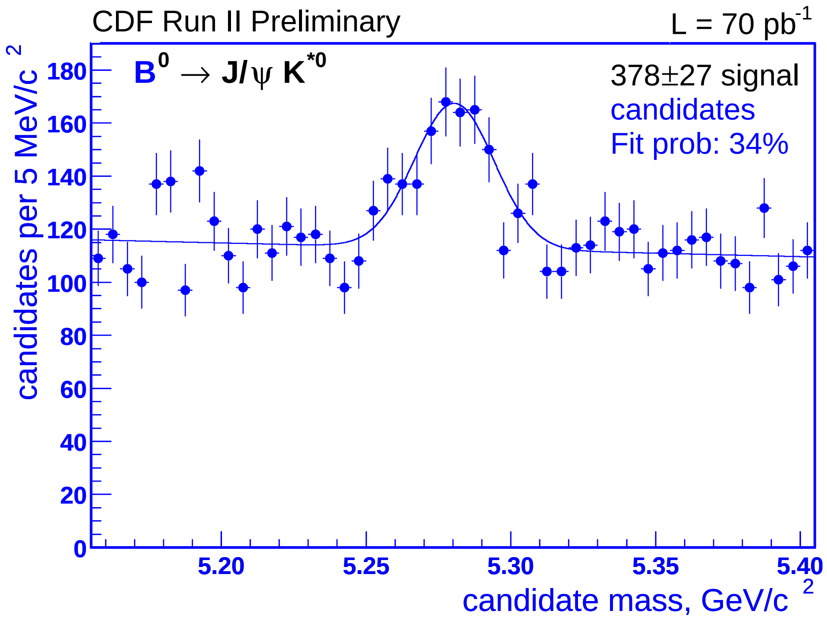
Compare Run I: $1.66 \pm 0.05\,\text{ps}$, PDG: $1.674 \pm 0.018\,\text{ps}$

RunII: $\tau(B_d^0)$ from $B_d^0 \to J/\psi(\mu^+\mu^-)K^{*0}(K^+\pi^-)$

Lifetime



Mass



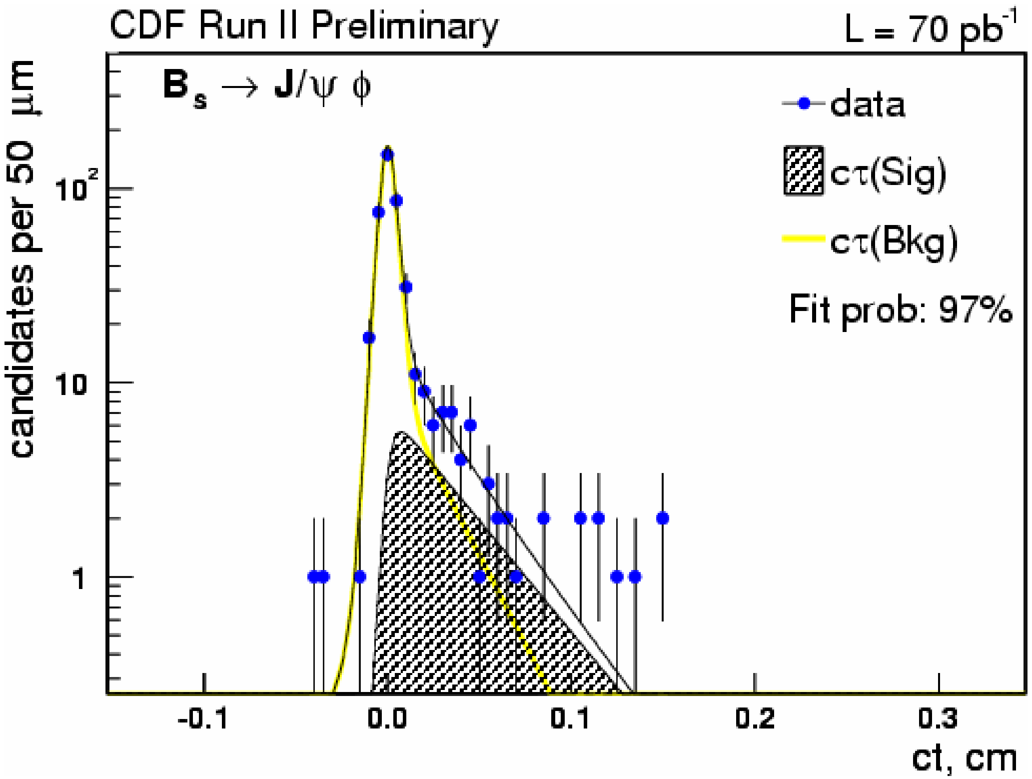
For 380 ± 30 signal events:

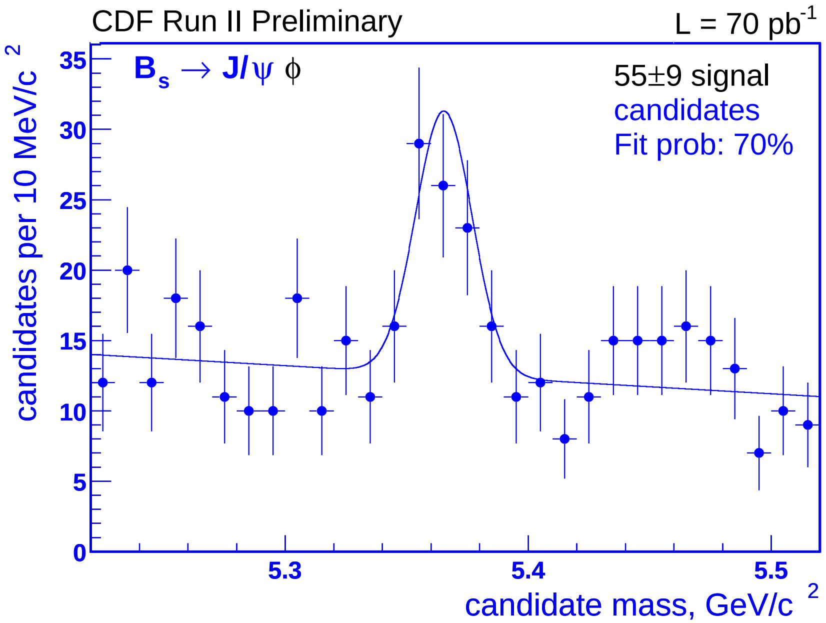
$\tau_{B_d^0} = 1.42 \pm 0.09 \pm 0.02\,\text{ps}$

Compare Run I: $1.51 \pm 0.05\,\text{ps}$, PDG: $1.542 \pm 0.016\,\text{ps}$

RunII: $\tau(B_s^0)$ from $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

Lifetime *Mass*





For 55 ± 9 signal events:

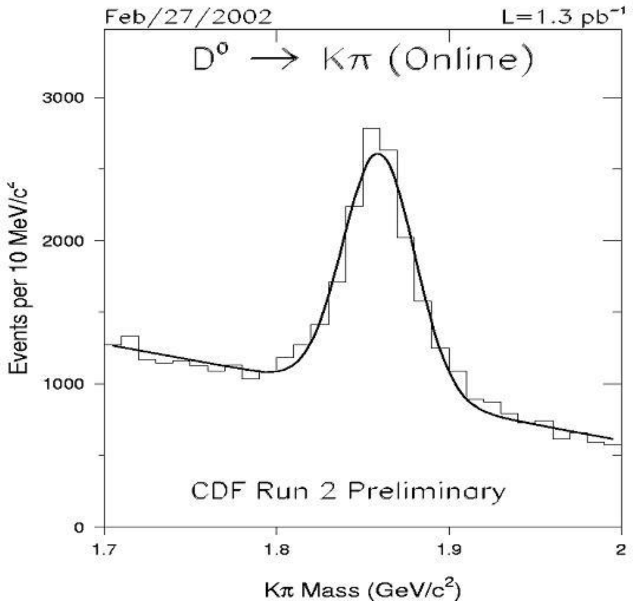
$\tau_{B_s^0} = 1.26 \pm 0.20 \pm 0.02$ ps

Compare Run I: 1.36 ± 0.10 ps, PDG: 1.461 ± 0.057 ps

Silicon Vertex Trigger *Impact Parameter trigger at L2*

Combines L1-tracks with Si-info to calculate IP.

$\sigma_{IP} = 48\,\mu\text{m} = 0.35\,\mu\text{m(intrinsic)} \oplus 0.33\,\mu\text{m(beam-size)}$



Finds lots of charm. Use $D^0 \to K\pi$ as online monitor for SVT.

2-Track Hadron Trigger

L1: 2 XFT tracks, $p_t > 2\,\text{GeV}$, $\Delta\phi < 135^\circ$, $p_{t1} + p_{t2} > 5.5\,\text{GeV}$.

L2:

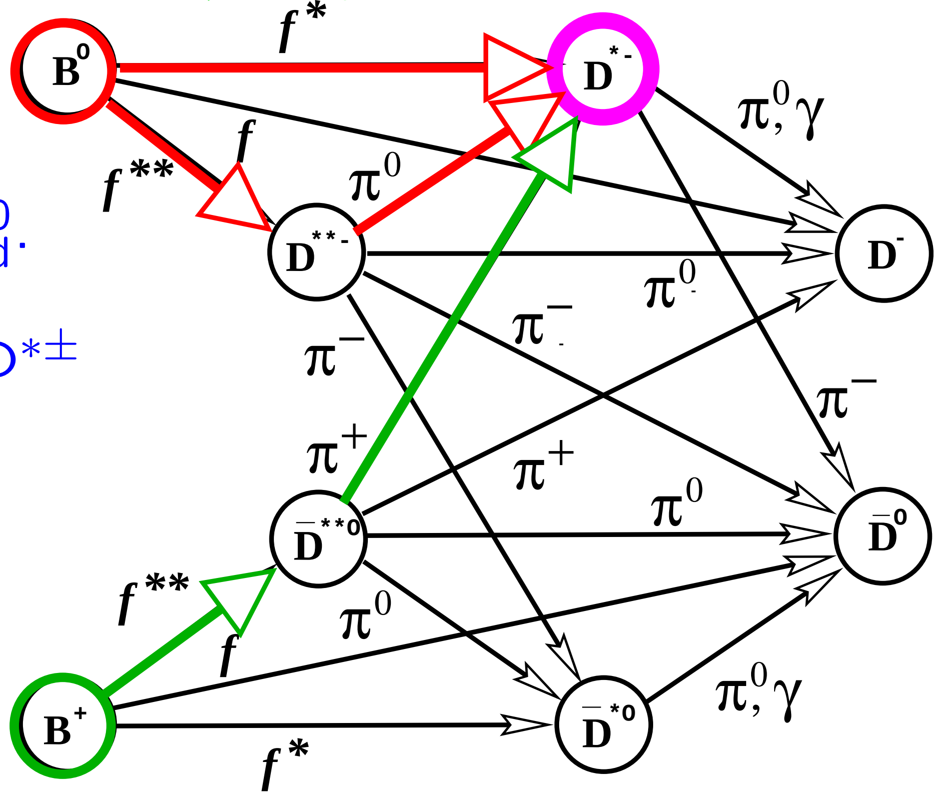
2-body: e.g. $B^0_d \to \pi\pi$	Multi-body: e.g. $B^0_s \to D_s\pi$
IP$> 100\,\mu$m	IP$> 120\,\mu$m
$20^\circ < \Delta\phi < 135^\circ$	$2^\circ < \Delta\phi < 90^\circ$
$L_{xy} > 200\,\mu$m	$L_{xy} > 200\,\mu$m
IP of B $< 140\,\mu$m	–

L3: Same with refined tracks & mass cuts.

CDF Run II Semileptonic:

$\tau(B^+)/\tau(B_d)$ *from* $B \rightarrow D\ell\nu X$

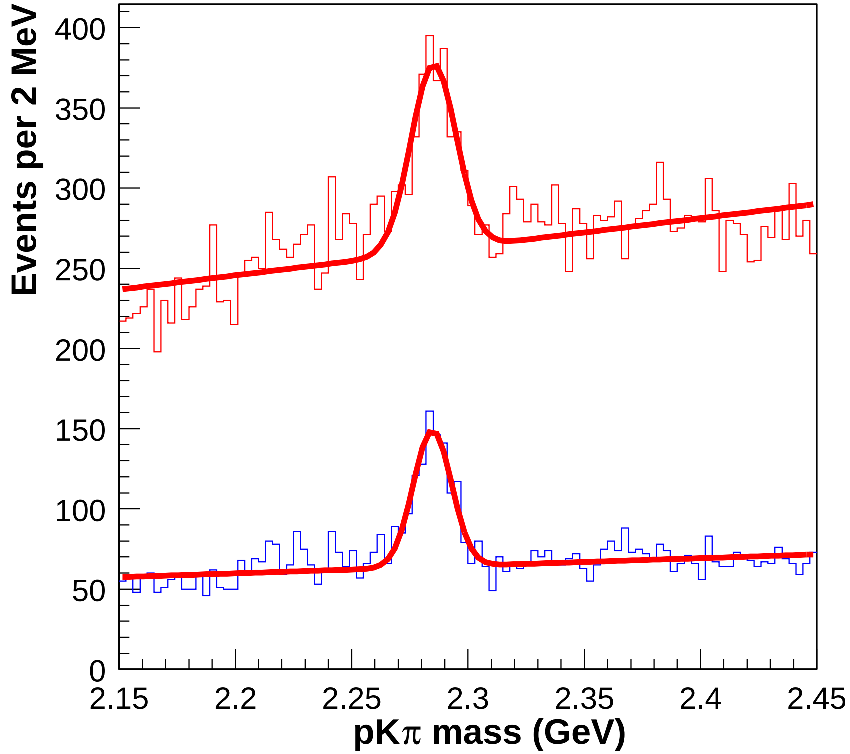
- Reconstruct $D + \mu$.
- Use $D^{*\pm}$ to seperate B^+ from B^0_d.
- $D^{*\pm} - D^0$ Δm cleanly identifies $D^{*\pm}$
- With $D^{*\pm}$: B^0_d enriched sample.
  No $D^{*\pm}$: B^+ enriched sample.
  Crucial: what is f^{**}
- Fit both samples simultaneously.



Statistical precision from current sample: $\sigma(\tau_{B+}/\tau_{B^0_d}) = 0.066$

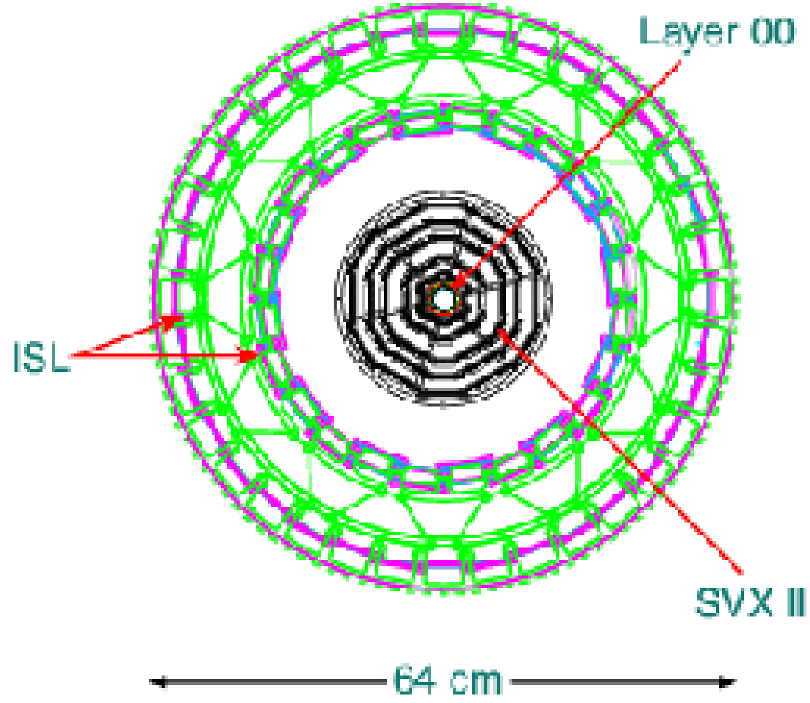
CDF Run II Semileptonic: $\tau(\Lambda_b)$ *from* $\Lambda_b \to \Lambda_c^+(pK^+\pi^-)\ell^-\nu$

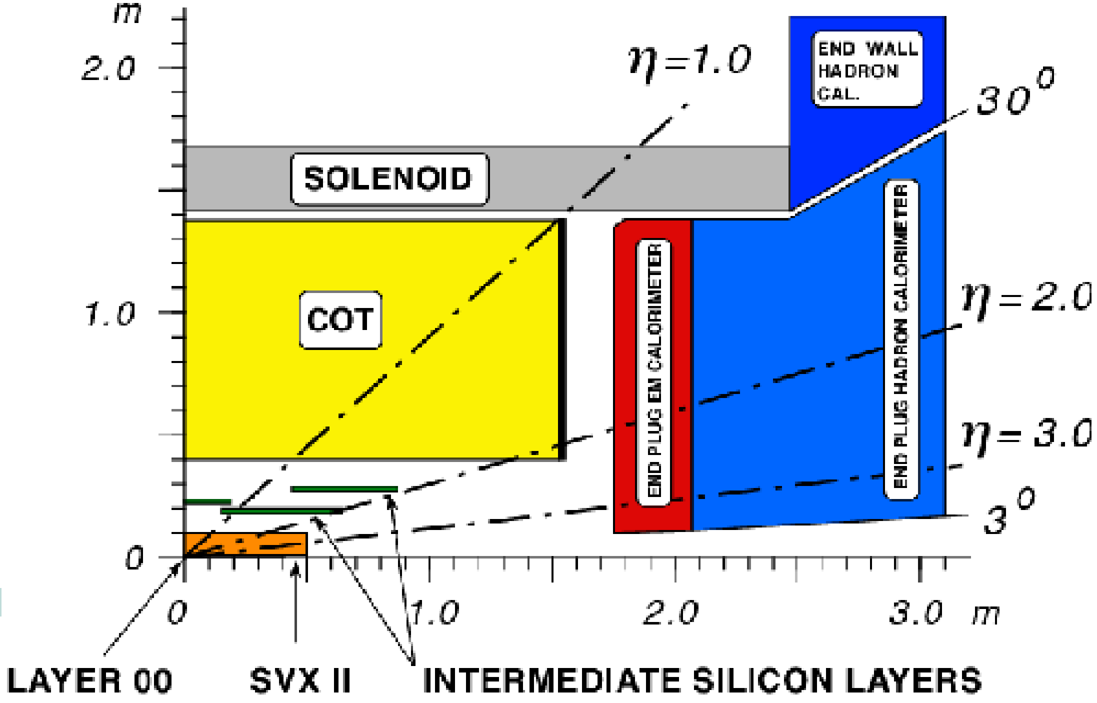
- Use combined particle ID from time of flight and $\frac{dE}{dx}$ to identify protons and reduce background (see Figure).
- Find 590 ± 50 Λ_c.
- Combine Λ_c with ℓ, accept masses between $M(\Lambda_c)$ and $M(\Lambda_b)$
- Statistical precision of current sample: $\sigma(\tau_{\Lambda_b}) = 0.13\,\text{ps}$



Λ_c mass with and without proton ID from TOF and $\frac{dE}{dx}$.

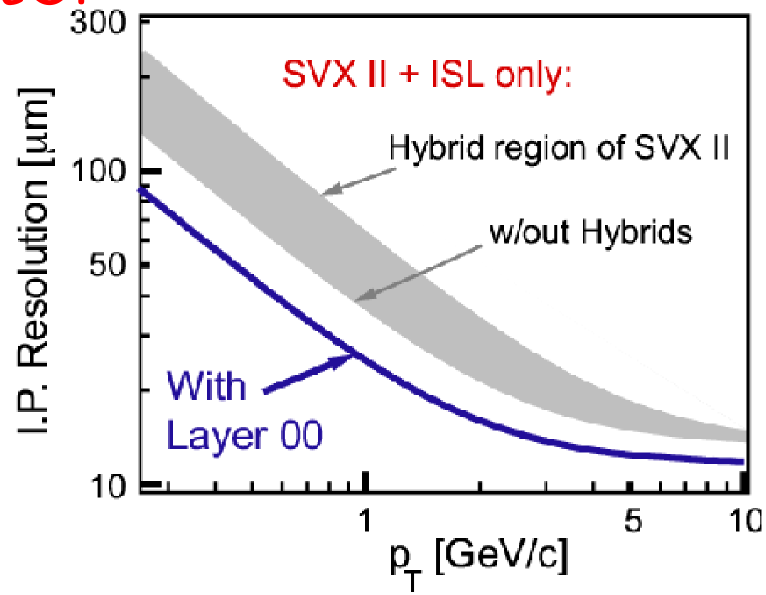
Silicon Vertex Detector





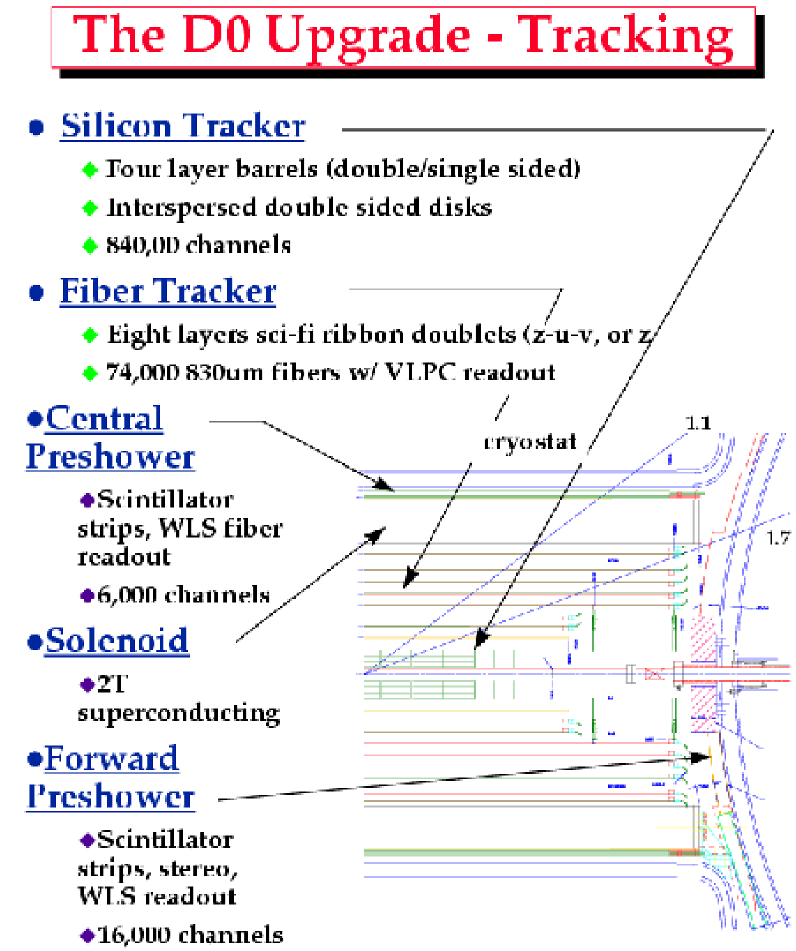
Silicon Vertex Detector

- Layer 00 fully functional
- Cooling problem solved.
- Chip-failures in z-layers understood, can be prevented in future (no problems since Nov).
- Need to finalise Alignment: For now, ISL, Layer 00 and z-information not used (coming soon).

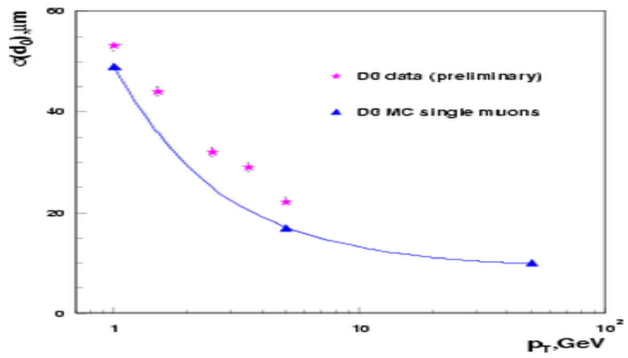


For "simple" τ measurements, SVX II in 2-D fully adequate. Improvement from L00, ISL, and z available soon, esp. for Δm_s, and to improve acceptance.

DØ tracking system

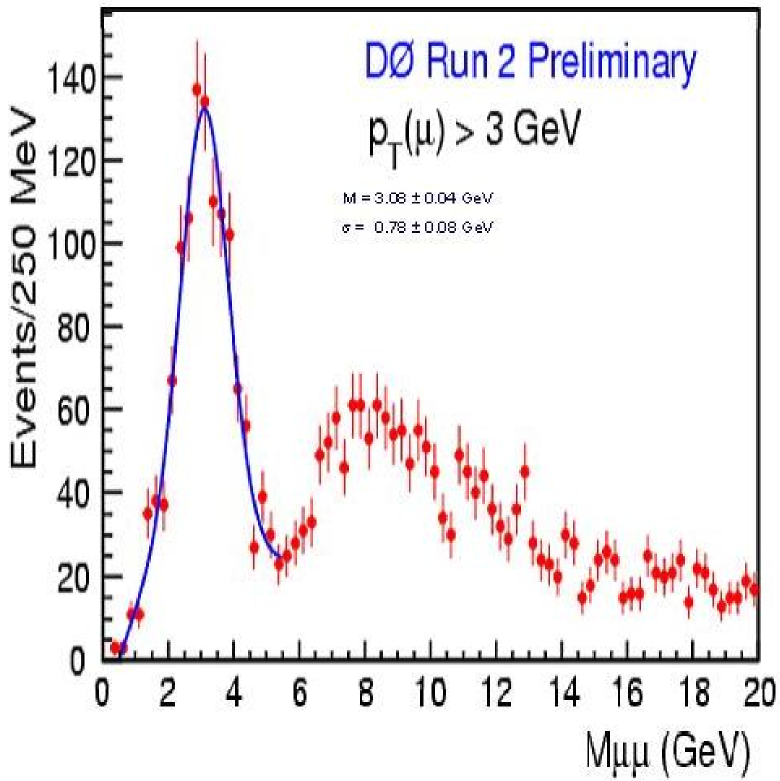


- Momentum information from magnetic tracking
- Si Microstrip Tracker
  - $0.8M$ channels
  - hit resolution: $10\,\mu$m
  - 2^{nd}ary vertex resolution $40\,\mu$m $(r-\phi)$, $80\,\mu$m $(r-z)$.

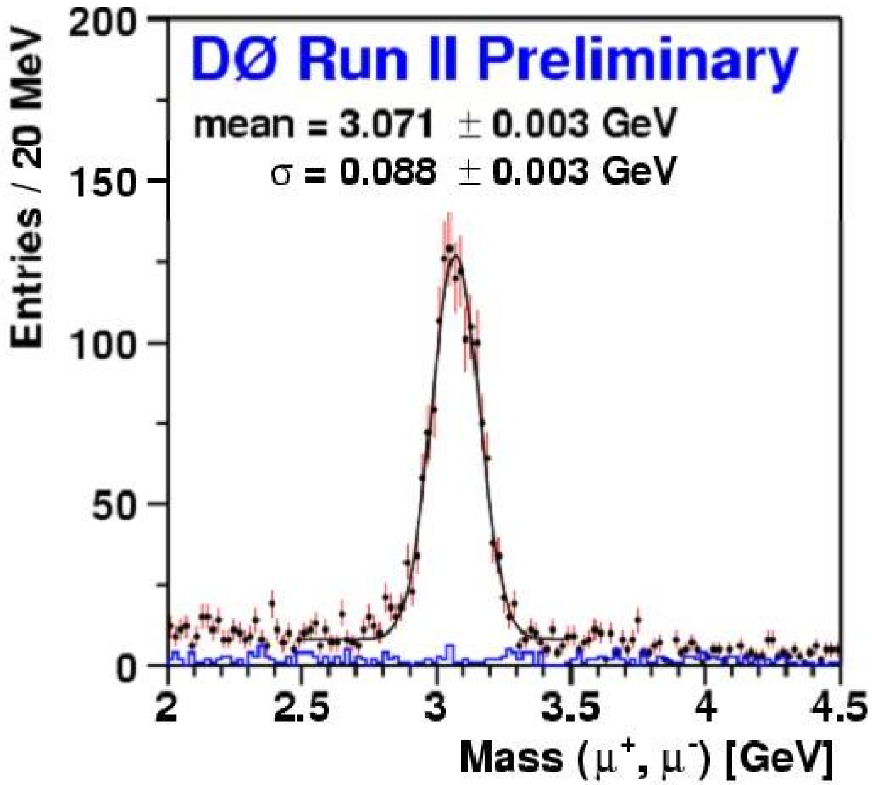


Magnetic Tracking at DØ

J/psi mass from Muon-Chambers only ... *from Muon+Tracking*



$\sigma = (0.78 \pm 0.08)$ GeV



$\sigma = (0.088 \pm 0.003)$ GeV

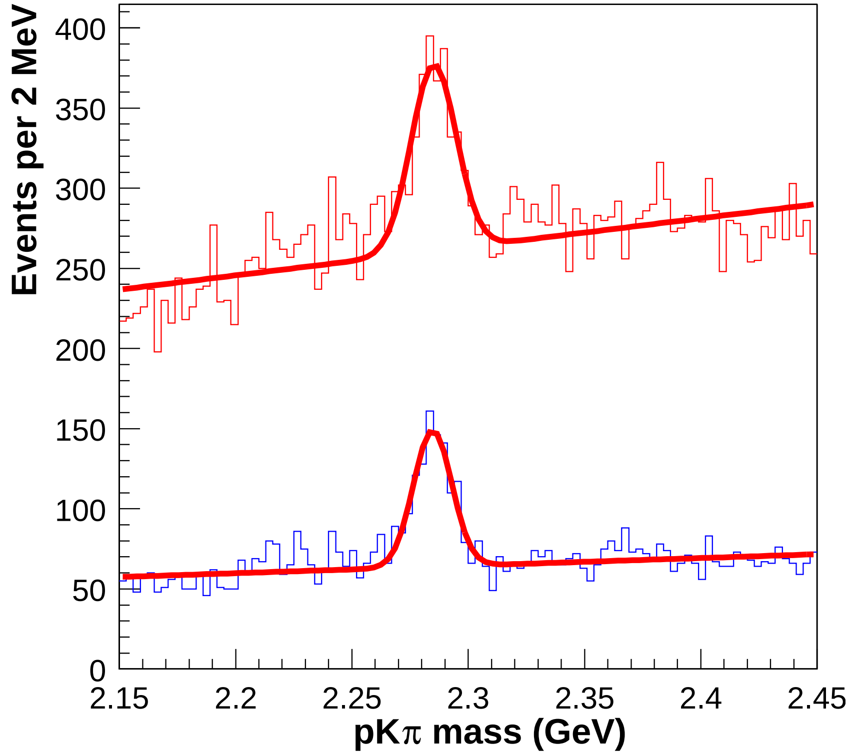
CDF Run II Semileptonic: $\tau(\Lambda_b)$ *from* $\Lambda_b \to \Lambda_c^+(pK^+\pi^-)\ell^-\nu$

- Use combined particle ID from time of flight and $\frac{dE}{dx}$ to identify protons and reduce background (see Figure).

- Find 590 ± 50 Λ_c.

- Combine Λ_c with ℓ, accept masses between $M(\Lambda_c)$ and $M(\Lambda_b)$

- Statistical precision of current sample: $\sigma(\tau_{\Lambda_b}) = 0.13\,\text{ps}$



Λ_c mass with and without proton ID from TOF and $\frac{dE}{dx}$.