FERMILAB-CONF-05-388-E

Current Topics in DØ B-Physics

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Beauty 2005

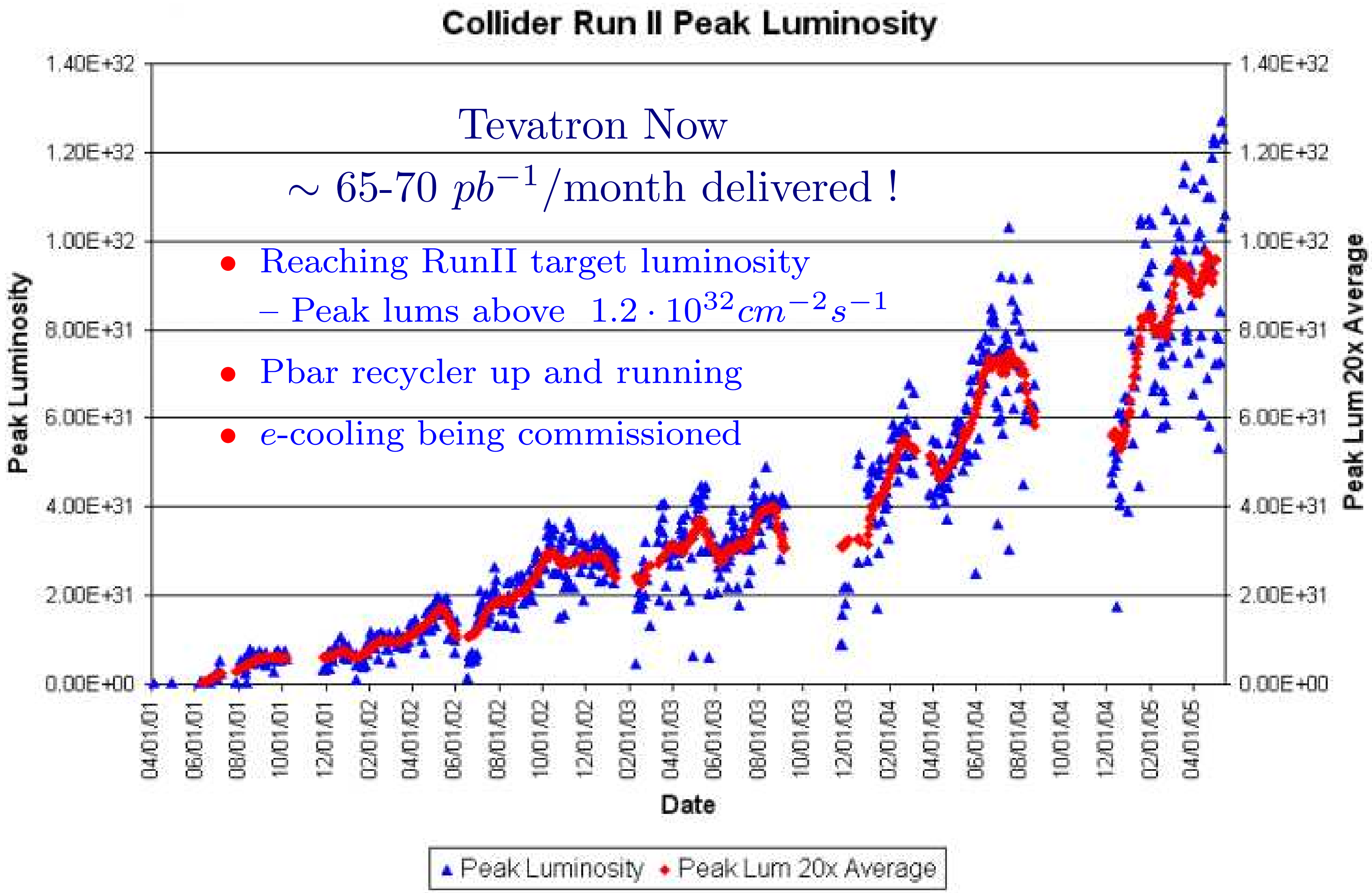
- DØ and the Tevatron
- Muon Triggers, Yields
- The DØ B_s Program
- FCNC, Rare Decays
- DØ RunIIb Upgrades

Tevatron RunII

Tevatron Now

$\sim$ 65-70 pb^{-1}/month delivered !

- Reaching RunII target luminosity
  - Peak lums above $1.2 \cdot 10^{32} cm^{-2} s^{-1}$
- Pbar recycler up and running
- *e*-cooling being commissioned

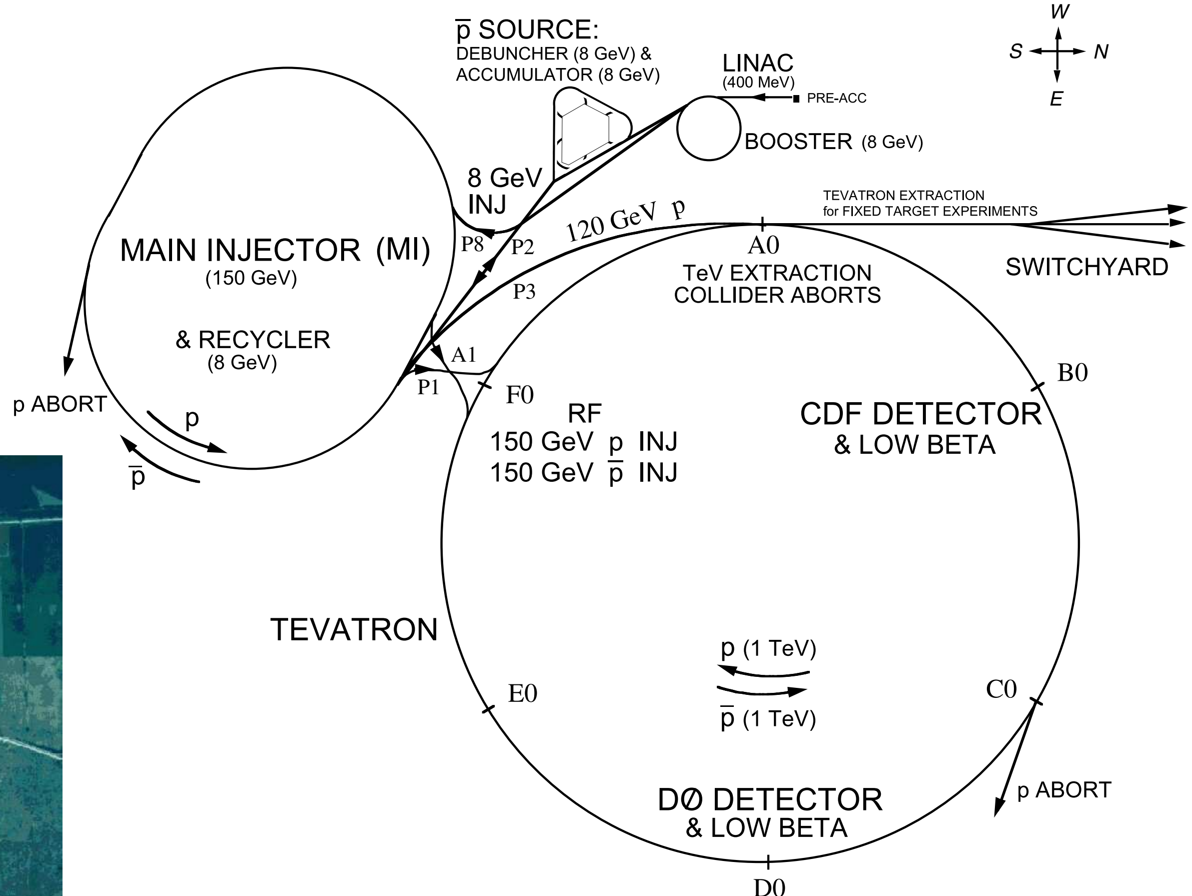


Tevatron

Delivered: 1 fb^{-1}

Recorded: 0.8 fb^{-1}

(each experiment)



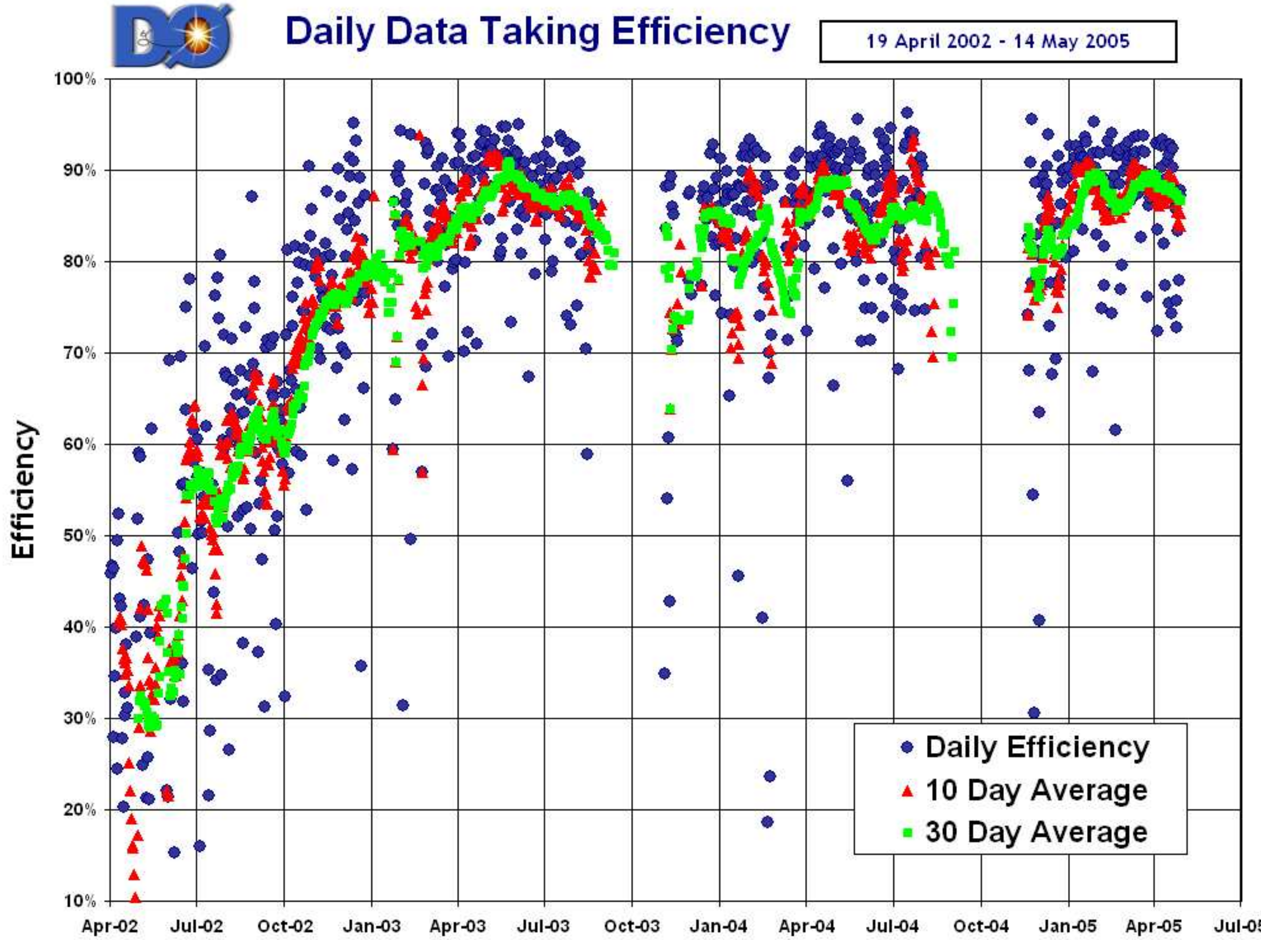
RunIIb expecting $> 1\ fb^{-1}$/yr.

(starts ∼Jan. 2006)

DØ RunII

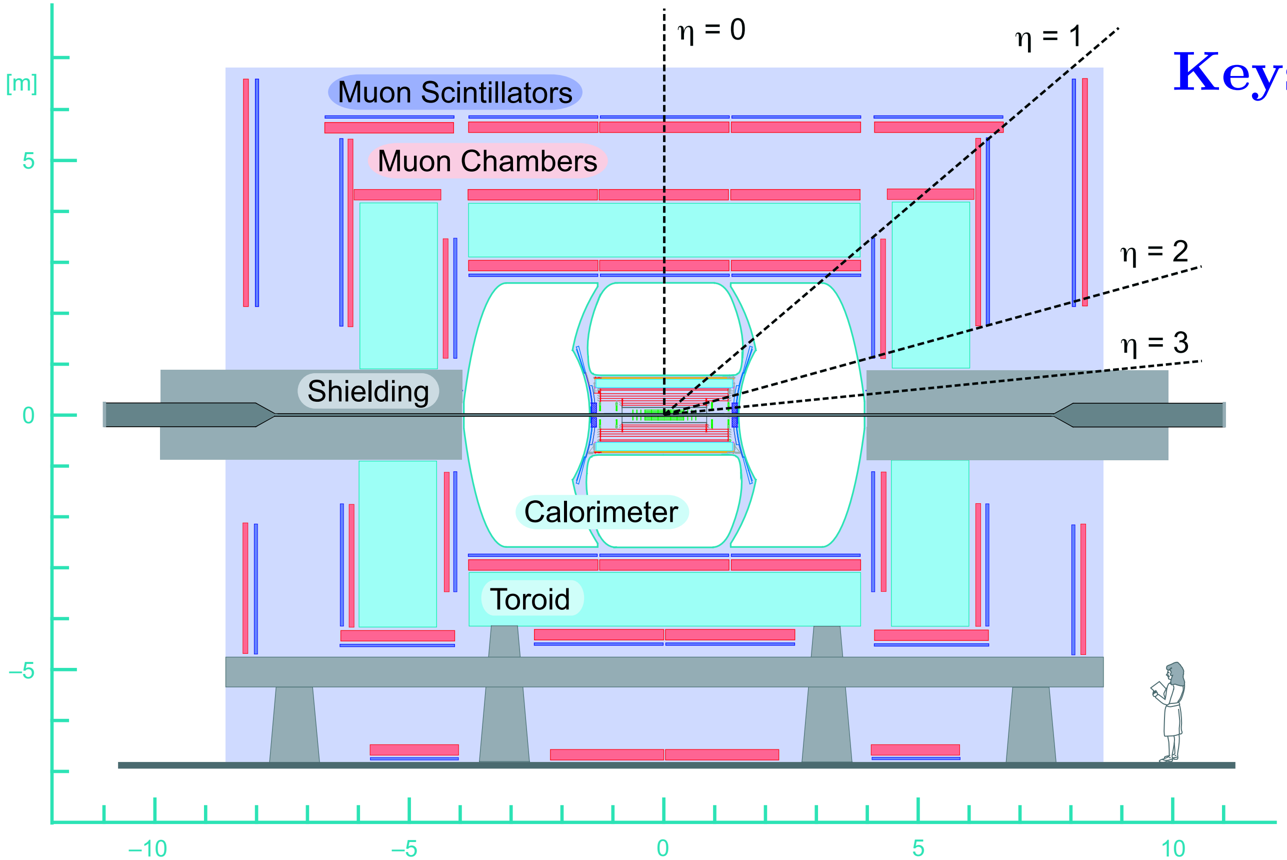
- Data taking efficiency in 2005 is ∼88%
  - currently translates to 55-60 pb^{-1}/month
- RunIIb upgrades
  - Trigger and DAQ
  - SMT Layer-0
- Tev B-program success largely dependent on trigger strategies

$\Longrightarrow$



- $\sigma(p\bar{p} \to b\bar{b}) \approx 150\mu$b at 2 TeV
- $\sigma(e^+e^- \to b\bar{b}) \approx 7$ nb at $M(Z)$
- $\sigma(e^+e^- \to b\bar{b}) \approx 1$ nb at Υ_{4s}
- but... $\sigma(b\bar{b})/\sigma^{inel} \approx 10^{-3}$

The DØ Detector – RunIIa



Keys to the B-program:

Central magnetic tracking volume:

- Is a RunII addition
- Compact ($r < 52cm$)
- Modest p resolution $\Gamma_{\mu\mu} = 60$ MeV at J/ψ

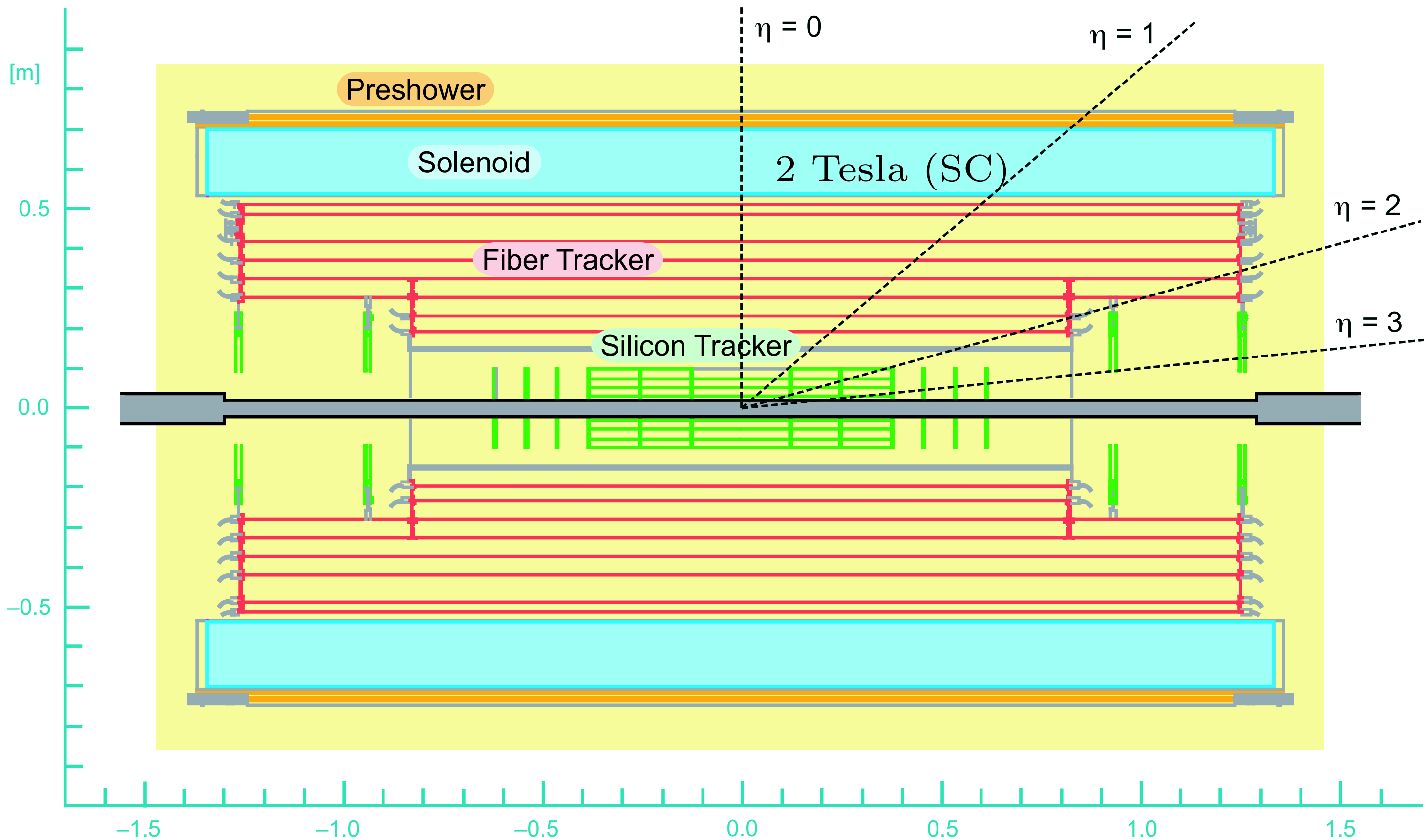
Wide angle coverage:

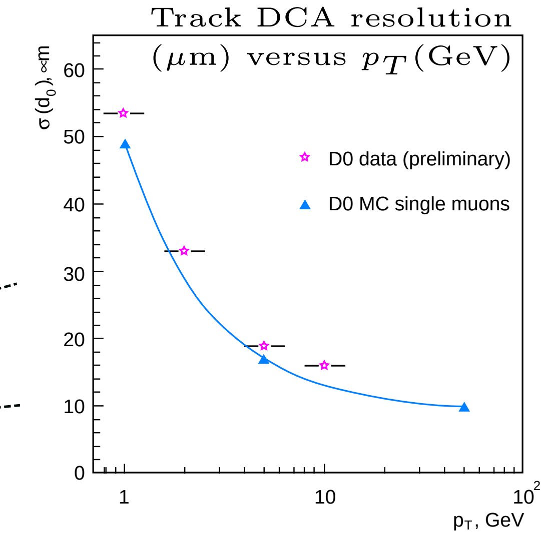
- Muon chambers; $|\eta| < 2.0$
- Tracking volume; $|\eta| < 3.0$

Clean muon-ID:

- Efficient muon triggers
- single-μ 60% pure at L1

The DØ Tracking Volume

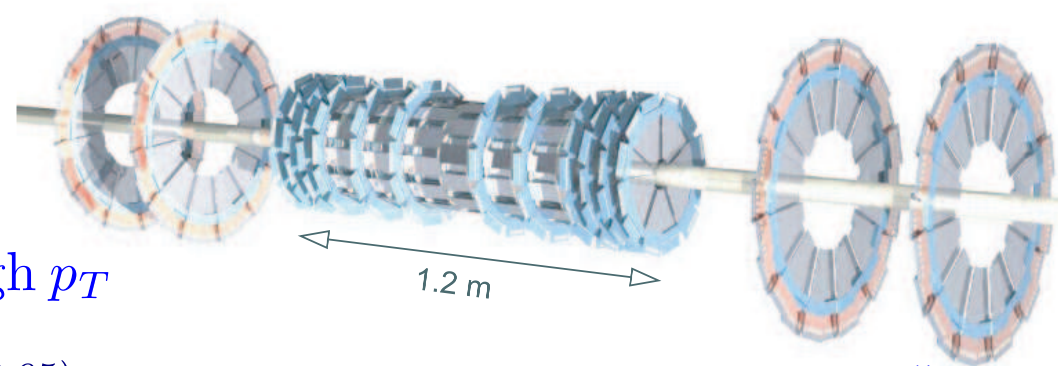




SMT 2nd^{ry} vtx resol^n:

- 40μm (r, ϕ)
- 80μm (r, z)

- Impact parameter resolution
  - of $\sim 50\mu$m at p_T of 1 GeV
  - improving to $\sim 10\mu$m at high p_T



Muon Triggers

- Keys to the DØ B-Program (and access to unbiased lifetimes)
- Levels 1 and 2 dominated by muon hits, aided by tracking
- Level 3 flexible and fast reconstruction of full event
- Typical rates (Hz):

	input	L1	L2	L3
DØ total	1 MHz	2000	800	50
dimuons		75	20	2

Level 1 (hardware)	Level 2 (hybrid)	Level 3 (software)
muon scint hits	muon tracking (indept.)	accurate tracking
muon wire hits	choice of time gates	and matching
central tracks	flexible track matching	prim. vertex z
prim. vertex z	**impact parameter**	impact parameter
	see talk Wed.11:20 by Sasha Caron	invariant mass

(In red, tools not yet in use, are "on call" for the higher lum.)

Examples of Reconstruction Yields

- From J/ψ triggers;
  (5K J/ψ's / pb^{-1})

decay		$\sim N/pb^{-1}$
$B_u^{\pm} \longrightarrow J/\psi + K^{\pm}$		21
$B_d^0 \longrightarrow J/\psi + K^*$	$(K\pi)$	8
$B_d^0 \longrightarrow J/\psi + K_s^0$	$(\pi\pi)$	2
$B_s^0 \longrightarrow J/\psi + \phi$	(KK)	2
$\Lambda_b^0 \longrightarrow J/\psi + \Lambda^0$	$(p\pi)$	0.3

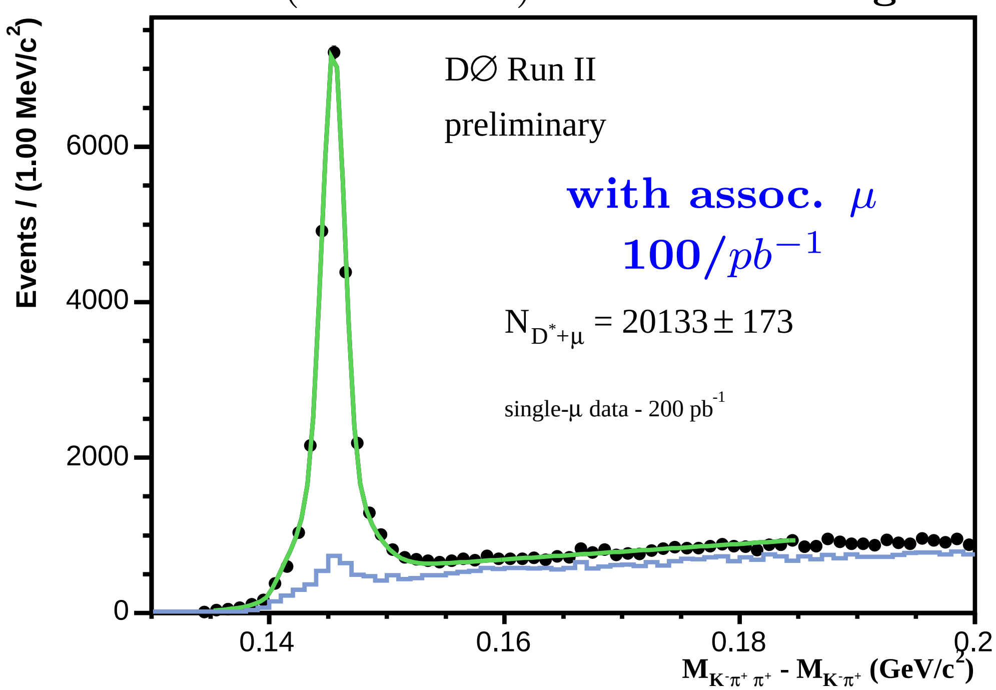
- From single muon triggers;
  (1M events / pb^{-1})

  $\bar{D}^0\mu^+\nu X$ ($500/pb^{-1}$)
  (semileptonic) containing;

  $B_u^+ \rightarrow \bar{D}^0\mu^+\nu$, and

  $B_d^0 \rightarrow D^{*-}(2010)\mu^+\nu \implies$

$\Delta m(K\pi\pi - K\pi)$ **The D^* signal**



The DØ B-Physics Roadmap

- Mixing, oscillations (Tania Moulik, today 14:30)
  - benchmark tests and measurements completed (Δm_d)
  - extraction of tagging efficiency and dilution from real data
  - a first shot at B_s mixing – tool development and a limit

- Hadron lifetimes (A. Sanchez ($\Delta\Gamma_s/\Gamma_s$), Tues. 12:00)
  - competitive measurements of lifetimes and their ratios

$$\left(\frac{\tau(\Lambda_b^0)}{\tau(B_d^0)} \; , \; \frac{\tau(B_s^0)}{\tau(B_d^0)} \right)_{\text{exclus}(J/\psi)} \qquad \left(\frac{\tau(B_u^+)}{\tau(B_d^0)} \; , \; \tau(B_s) \right)_{\text{semilept}}$$

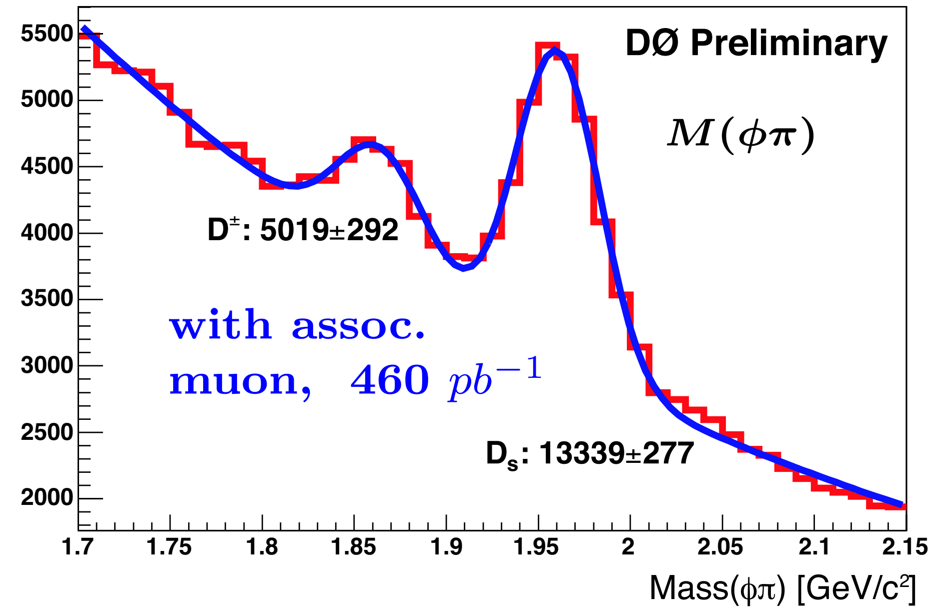
  - currently a world's most precise measurement of $\tau(B_s)$

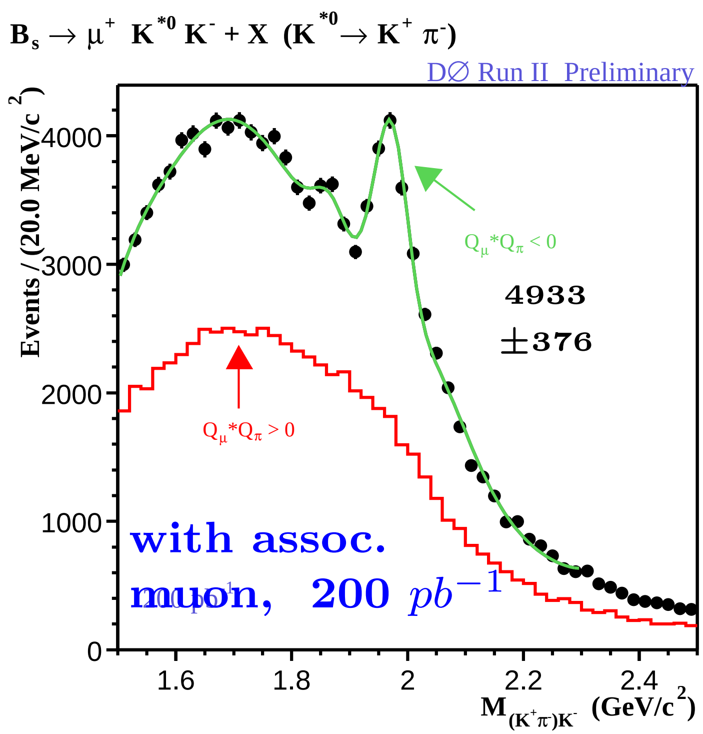
- Rare decays (S.F. and S.D. -CDF- Tues. morning)
  - searches for FCNC decays in both b and c sectors

- HF production and spectroscopy (DB,WW,ECB,UK - Fri. morning)
  - bottomonium, b-baryons, excited mesons, $X(3872)$, $B_c \cdots$

The DØ B_s Program

- Access to a large sample of semileptonic B_s decays
  - will strongly contribute to the extraction of $\Delta(\Gamma_s)/\Gamma_s$ when combined with $B_s \to J/\psi\phi$ measurements





- Reconstructed D_s mesons with a nearby muon

mode	yield/pb^{-1}
$D_s^- \to \phi\pi^-$	29 evts.
$D_s^- \to K^{*0}K^-$	25 evts.

The DØ B_s Program

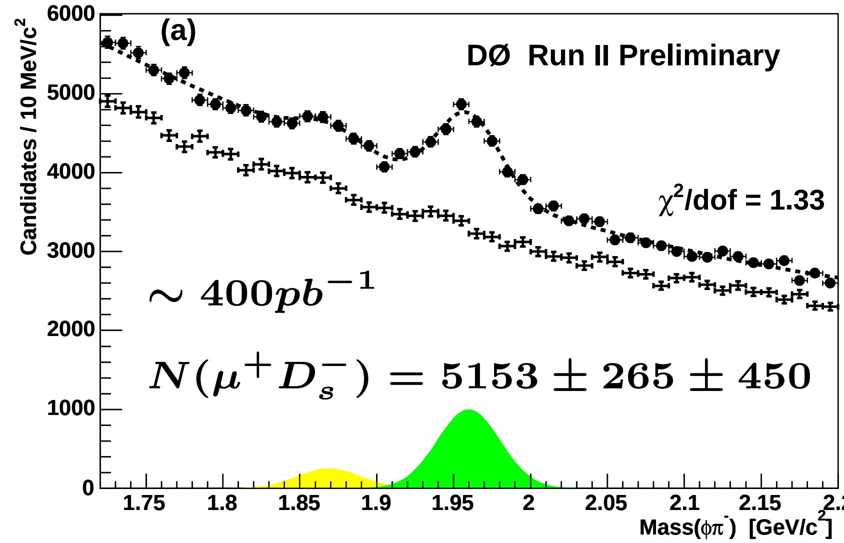
- B_s lifetimes: the single exponential description $\Longrightarrow$

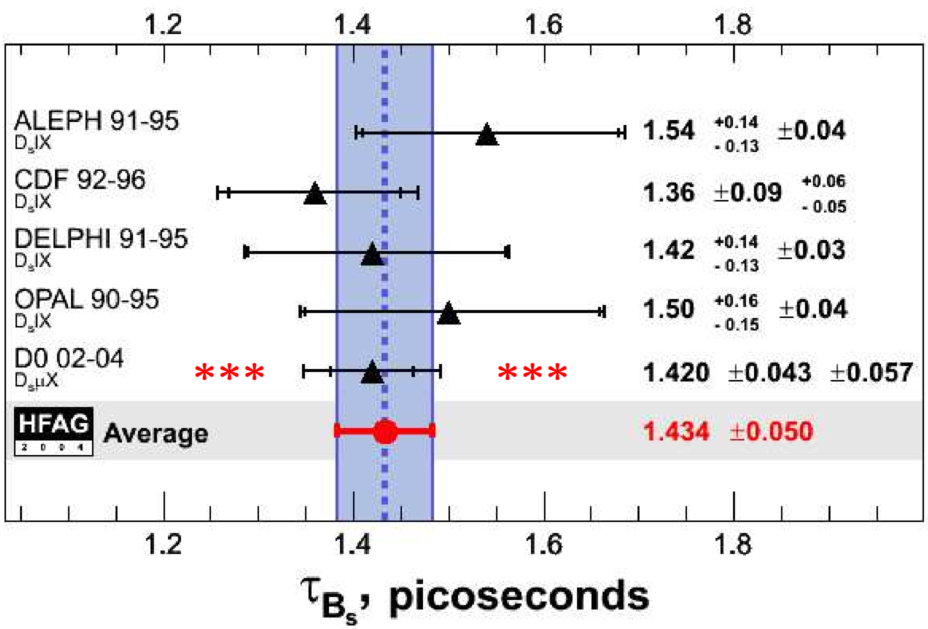
  (flavor specific)

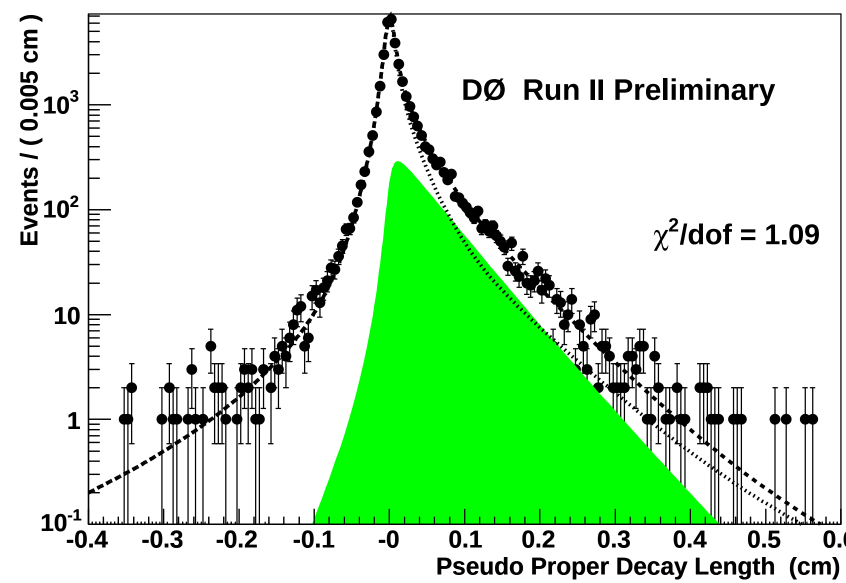
world's single most precise measurement of $\tau(B_s)$

$\boldsymbol{\tau(B_s^0) = 1.420 \pm 0.043 \pm 0.057}$ ps

$M(\phi\pi)$



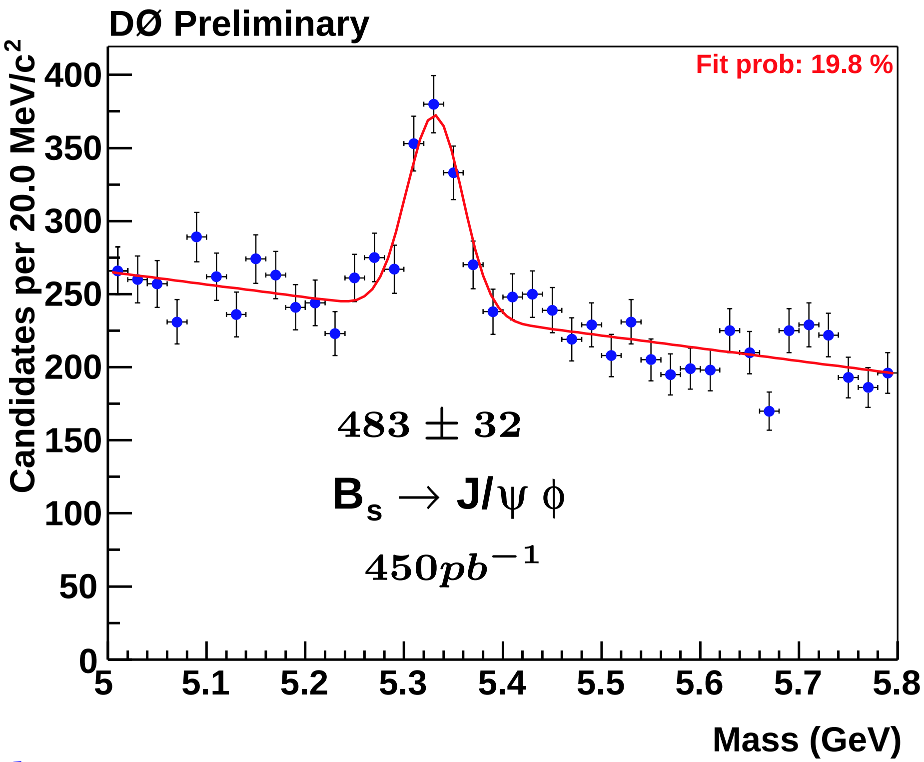




B_s Lifetimes – $\Delta\Gamma_s/\Gamma_s$

- B_s lifetimes: the double exponential description
  - uses $B_s \to J/\psi\phi$ $\Longrightarrow$
  - flavor non-specific final state
  - assuming no CP violation,
  - discriminate eigenstates

$$(CP\ even) \quad B_s^H \quad m^H$$
$$(CP\ odd) \quad B_s^L \quad m^L$$



- $\Delta m_s = m^H - m^L$ significantly larger than Δm_d

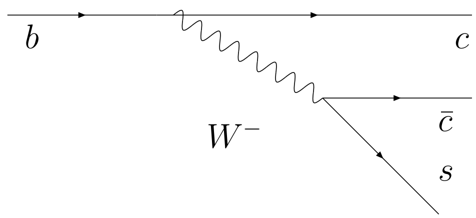
- Mass (CP) eigenstates may end up with a sizeable lifetime difference $\Delta\Gamma_s$

$$\Delta\Gamma_s = \Gamma(B_s^H) - \Gamma(B_s^L)$$
$$\bar{\Gamma} = (\Gamma^H + \Gamma^L)/2$$
$$\bar{\tau} = 1/\bar{\Gamma}$$

B_s ($\Delta\Gamma/\Gamma$) – cont.

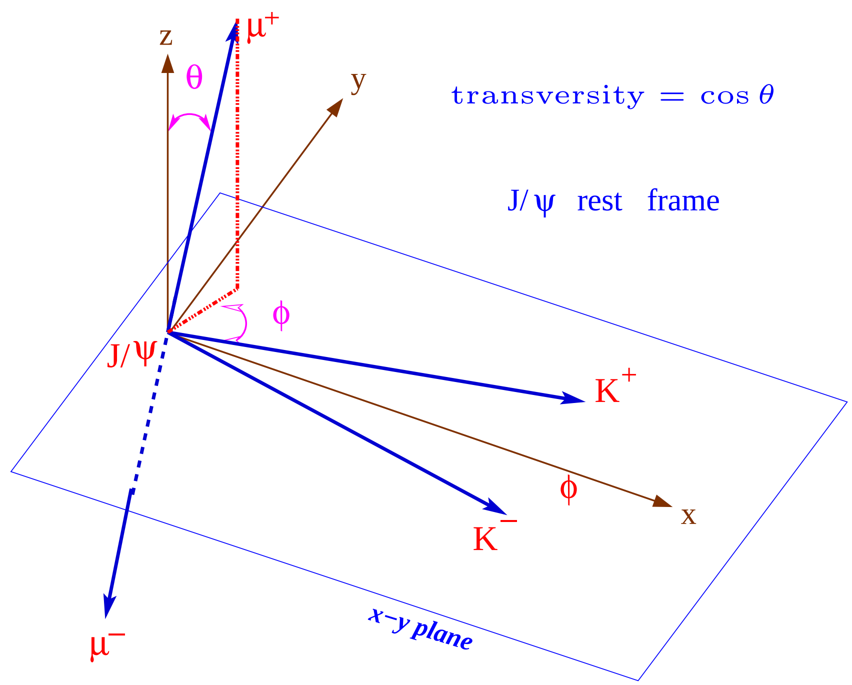
$$\begin{pmatrix} B_s \\ \bar{B}_s \end{pmatrix} \longrightarrow J/\psi\phi \quad \Longleftarrow \text{similar} \Longrightarrow \quad \begin{pmatrix} B_d \\ \bar{B}_d \end{pmatrix} \longrightarrow J/\psi K_s$$

untagged decays via



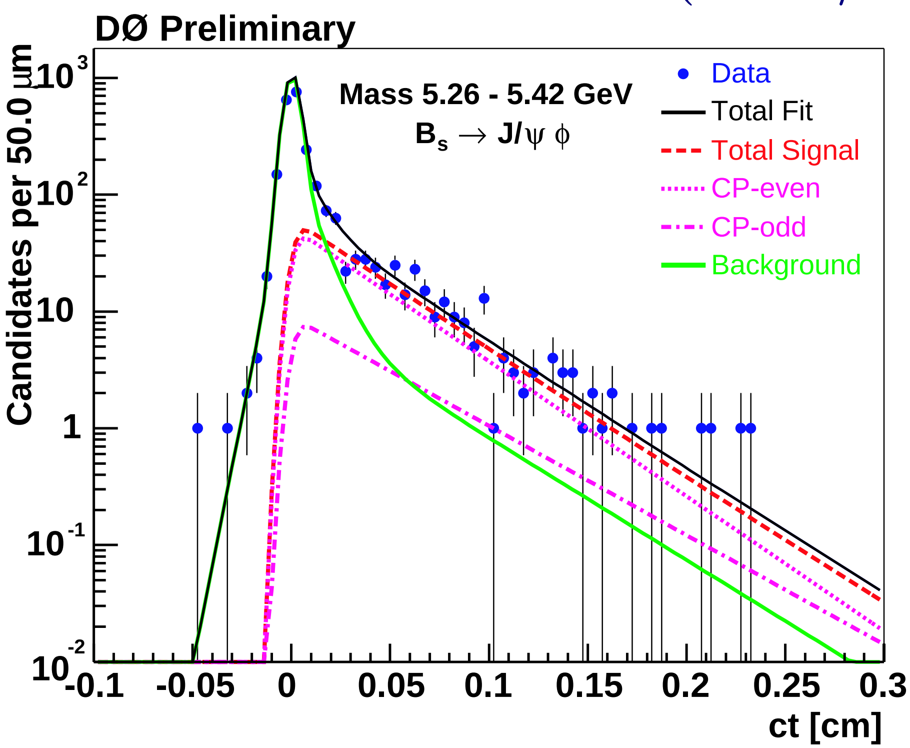
- Final states are common to (mixed) meson & anti-meson.

- Separate the two CP components of the decay by means of polarization properties ("transversity") of the final state.



P→VV; J=0 ⇒ L=0,1,2
S&D waves are CP-even for $\psi\phi$
P wave is CP-odd for $\psi\phi$

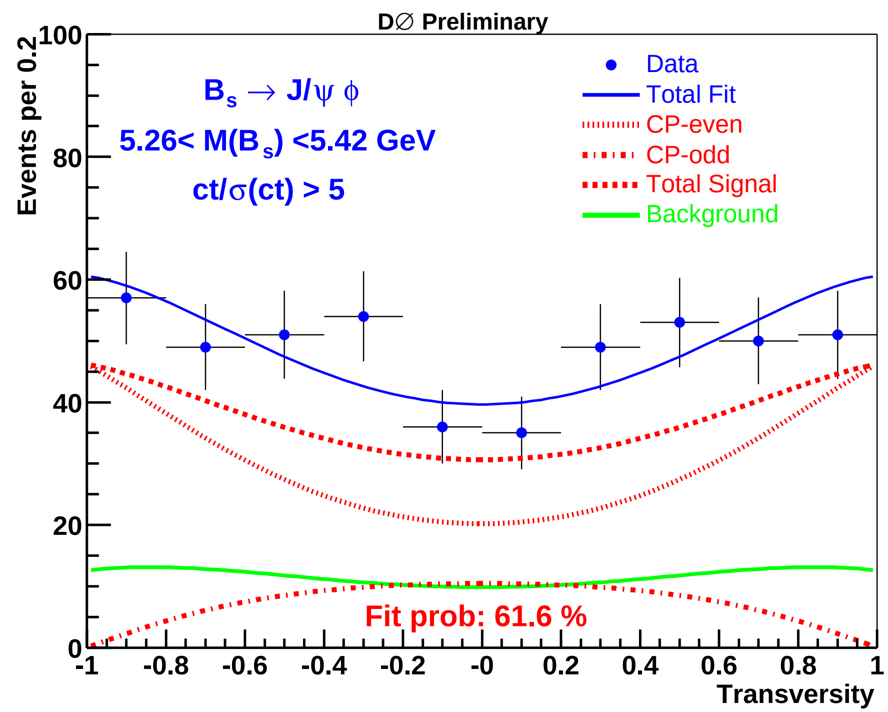
B_s ($\Delta\Gamma/\Gamma$) – Results



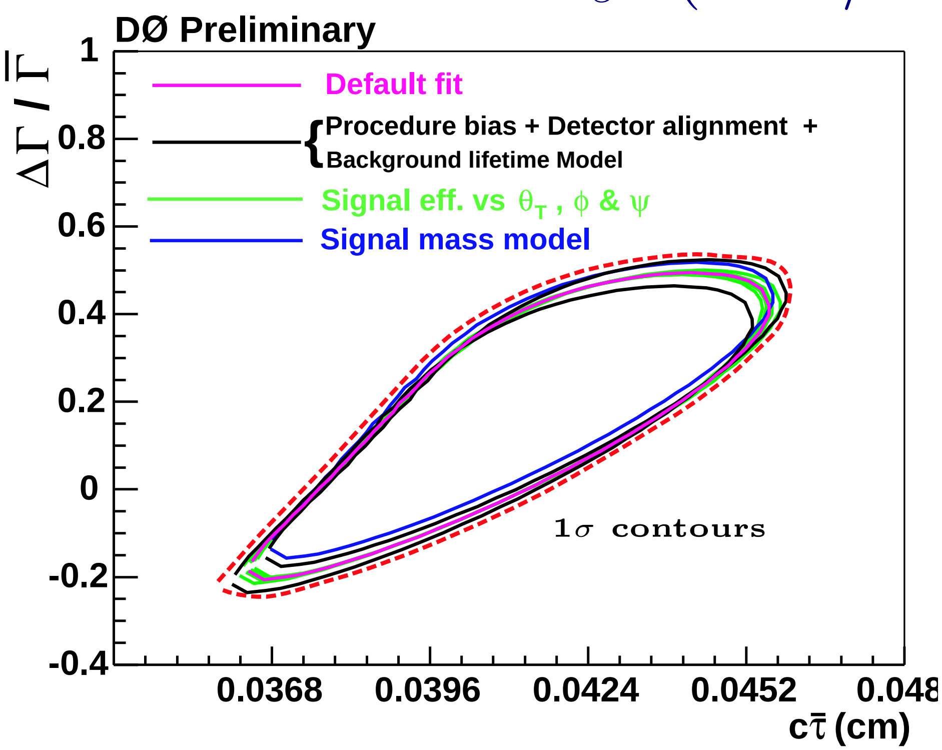
- A simultaneous fit (unbinned LL)
  - to mass,
  - proper time evolution,
  - transversity distribution,

  separates the two decay modes

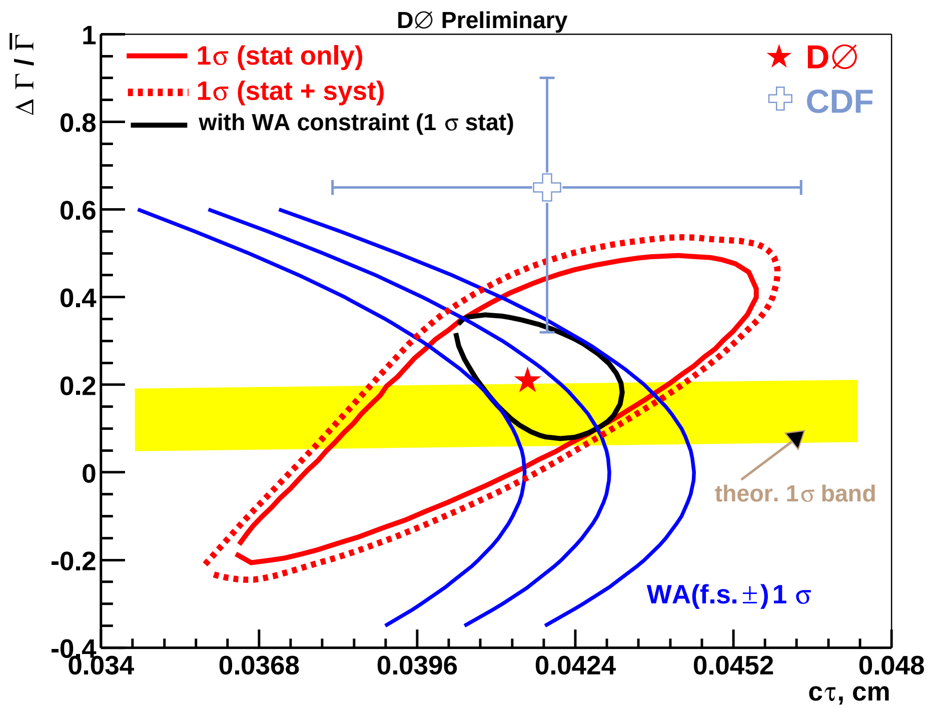
$\bar{\tau}$	$1.39\ ^{+0.13}_{-0.14} \pm 0.08\ ps$
τ_L	$1.23\ ^{+0.16}_{-0.13}\ (s+s)$
τ_H	$1.52\ ^{+0.39}_{-0.43}\ (s+s)$
$\Delta\Gamma/\bar{\Gamma}$	$0.21\ ^{+0.27}_{-0.40} \pm 0.20$
$f_{odd}^{(t=0)}$	$0.17 \pm 0.10 \pm 0.02$



B_s ($\Delta\Gamma/\Gamma$) – Results



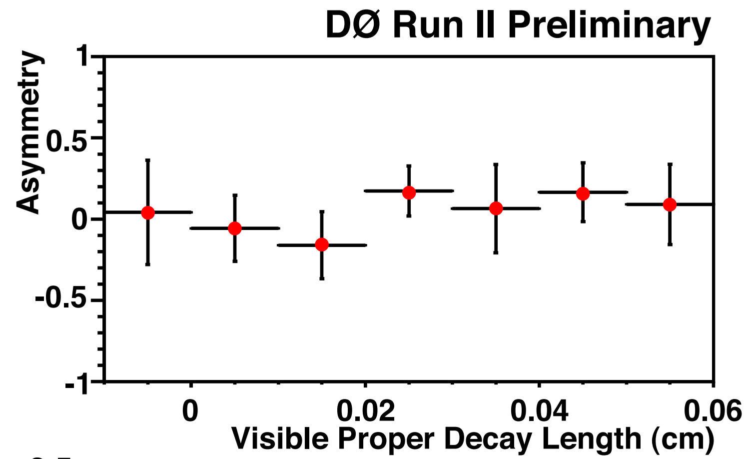
- The semileptonic (f.s.) τ_s measurements provide an independent relation (or constraint) between $c\bar{\tau}$ and $\Delta\Gamma/\bar{\Gamma}$ $\Downarrow$

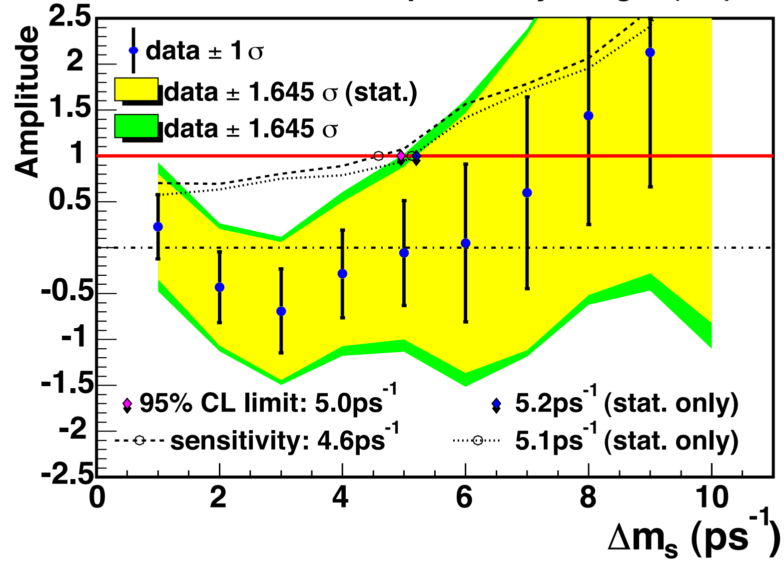


- See talk by A. Sanchez (Tues. 12:00) for details and a discussion on combined results and averages

B_s Mixing

- Developing tools to measure Δm_s — lots of room for improvement
- Currently using only one semilept. channel: $B_s \to D_s(\phi(KK)\ \pi)\ \mu\ X$ and binned likelihoods
- Flavor tagger builds a $(b, \bar{b})$ likelihood from a choice of OS(μ) discrim. vars; μ , p_T^{rel}, jetQ , svtQ ...
- ($460\ pb^{-1}$) 380 tagged events in VPDL range (-100,600) μm
- Fit inputs;
  - sample composition,
  - K-factors, VPDL resolution,
  - efficiencies, and tagger dilution

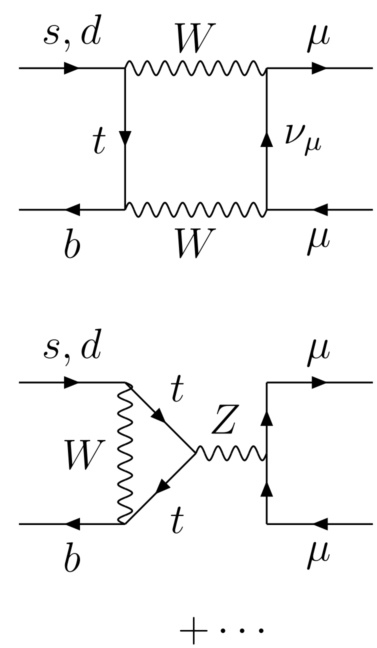




$\Delta m_s > 5.0\ ps^{-1}$
at 95% CL
using "amplitude" method

Searches for FCNC B-Decays

- Forbidden at tree-level in SM, must proceed via higher order WI processes $\Longrightarrow$



- Physics beyond SM becomes potentially dominant over (competitive with) SM itself
  - tree level contribs in R_p-viol. models
  - BR's increase like $(\tan\beta)^6$ in MSSM
- DØ studies two channels:

$B_s \longrightarrow \mu^+\mu^-$

- Cleaner theory predictions SM: $BR = (3.4 \pm 0.5) \cdot 10^{-9}$
- Blind analyses, normalized to well measured channels

$B_s \longrightarrow \mu^+\mu^-\phi$

- Add a spectator strangeness to LHS of diagrams above
- Larger hadronic uncertainties (∼30%) SM: $BR \approx 1.6 \cdot 10^{-6}$

Results for FCNC B-Decays

- $B_s \to \mu^+\mu^-$ summary table: $BR <$ (at 95% C.L.)

	published		
	CDF-I (100 pb^{-1})	$2.6 \cdot 10^{-6}$	(PRD57, 1998)
	CDF-II (170 pb^{-1})	$7.5 \cdot 10^{-7}$	(PRL93, 2004)
	DØ-II (240 pb^{-1})	$5.0 \cdot 10^{-7}$	(PRL94, 2005)
	updates – this conference		
combined results in progress	DØ-II (300 pb^{-1})	$3.7 \cdot 10^{-7}$	(preliminary)
	CDF-II (360 pb^{-1})	$2.0 \cdot 10^{-7}$	(preliminary)

- $B_s \to \mu^+\mu^-\phi$
  - Presently only one (95% C.L.) limit, CDF-I

$$BR < 6.7 \cdot 10^{-5}$$

  - DØ signal region still blinded; box to be opened soon. Sensitivity study shows expected (95% C.L.) limit

$$BR < 10^{-5}$$

Towards FCNC D-Decays

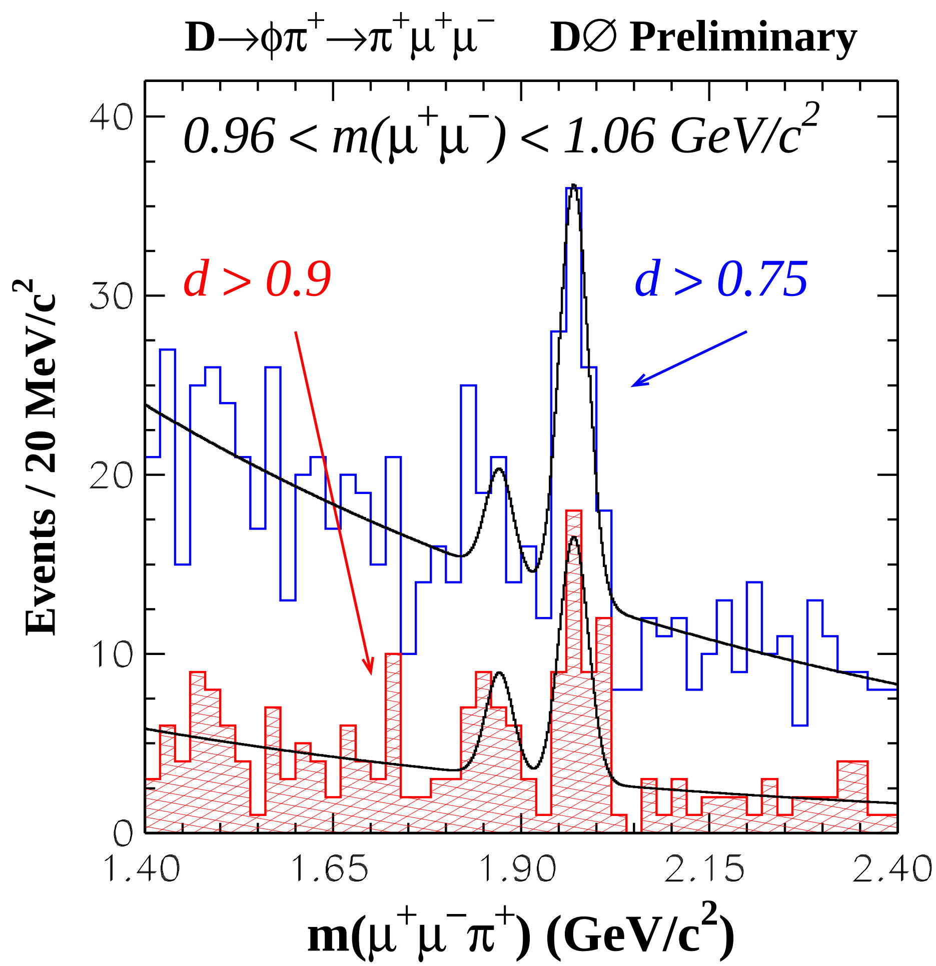
- Ideal (and largely untapped) testing ground for new phenomena.
- Attention to FCNC is mainly focused at the $I_3 = -1/2$ sector,
  - B-decays; $b \rightarrow s\,\ell^+\ell^-$, $(b \rightarrow s\gamma)$, K-decays; $s \rightarrow d\,\ell^+\ell^-$
  - SM: $(b \rightarrow s)$ transitions have top-assisted higher order loops
- ***In contrast***, the $I_3 = +1/2$ sector SM transitions involve loops with the "all-light" d-sector fermions ($\Rightarrow$ an efficient GIM cancellation).
- Consequence: SM expectations for $D - \bar{D}$ mixing and FCNC D-decays are very small. However... SM extensions may upset this cancellation,
  - $(c \rightarrow u)$ transitions induced by new phenomena may exceed SM expectations by many orders of magnitude.
  - see *hep-ph/0112235* for a discussion of different scenarios.

$\sim$anything non-resonant that is observed $\Rightarrow$ New Phen!!

- DØ plan: to set model indept. limits on diff. decay rate $\frac{d\Gamma(\mu^+\mu^-\pi)}{dm(\mu^+\mu^-)}$

Towards FCNC D-Decays

- General strategy:
  - Step-1; understand the resonant regions in $\mu^+\mu^-\pi$ spectrum (long-distance contributions, non-perturbative and therefore non-calculable).
  - Step-2; search for excesses in continuum regions of spectrum.



- Current status: $(\sim 500\ pb^{-1})$

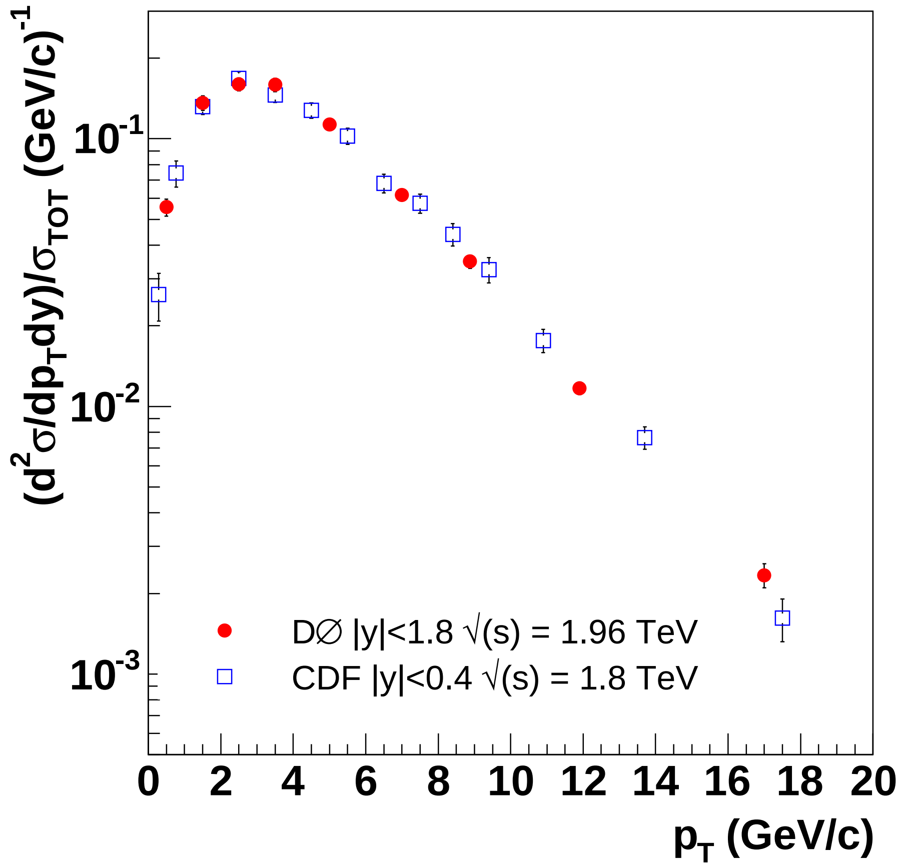
  First observation of the decay $D_s^\pm \to \phi\pi^\pm,\ \phi \to \mu^+\mu^- \quad \Rightarrow$ $(7\sigma:\ 33 \pm 7$ candidates)

- Spin-off; a (preliminary) best limit on the decay $D^\pm \to \phi(\mu^+\mu^-)\ \pi^\pm$

  $BR < 3.14 \cdot 10^{-6}$ (90% CL)

And we have not talked about...

- production
- baryons
- lifetimes and ratios
- spectroscopy
  B^{**} , D^{**} , B_c
- ...

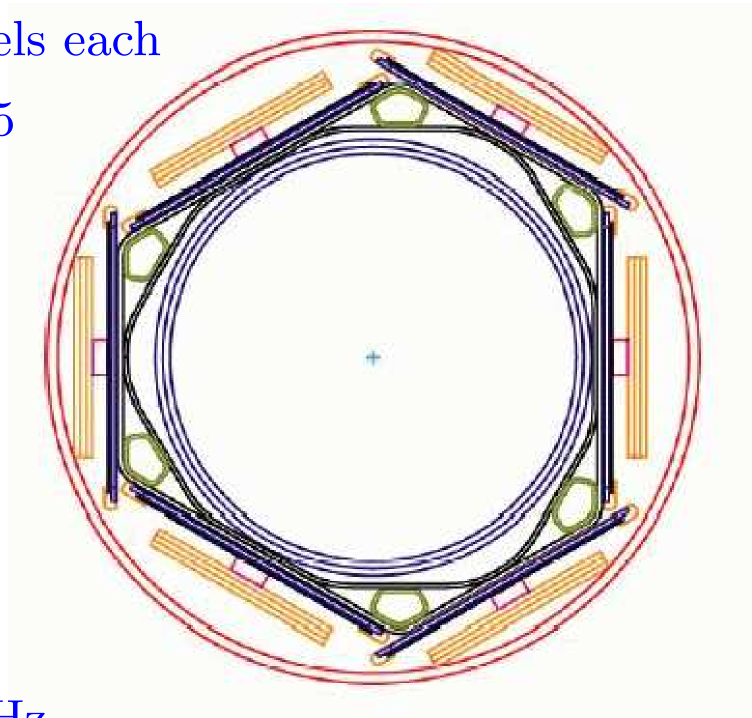


the Υ cross section

Phys. Rev.Lett. 94, 232001 (2005)

RunIIb Upgrades (B-specific)

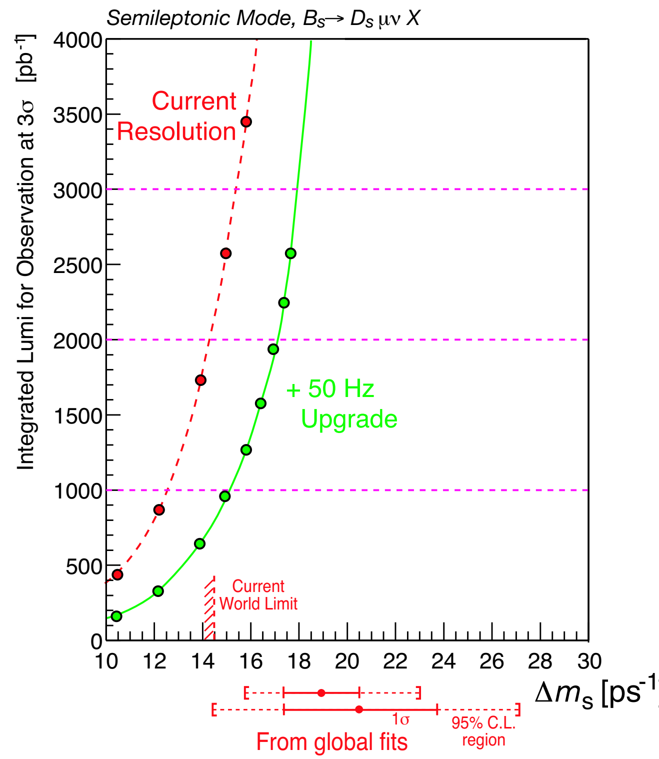
- **SMT Layer-0**
  - addition of an inner layer: $R_1 = 26mm \Rightarrow R_0 = 17mm$
  - offsets expected degradation of (non-upgraded) SMT
  - 48 modules: $6\phi + 8z$ segments, 256 channels each
  - installation during next shutdown, Fall'05
  - simulation ⇒ 25% improvement in decay length resolution (and proper time for hadronic modes)



- **Bandwidth increase**
  - unprescaled reach to lower p_T muons
  - DØ muons not rate-limited at L1 and L2
  - current limiting rate is L3-to-tape at 50 Hz
  - proposal: an extra 50 Hz dedicated to B-physics
  - basically just increased cpu resources – Fall'05

Impact on Δm_s Program

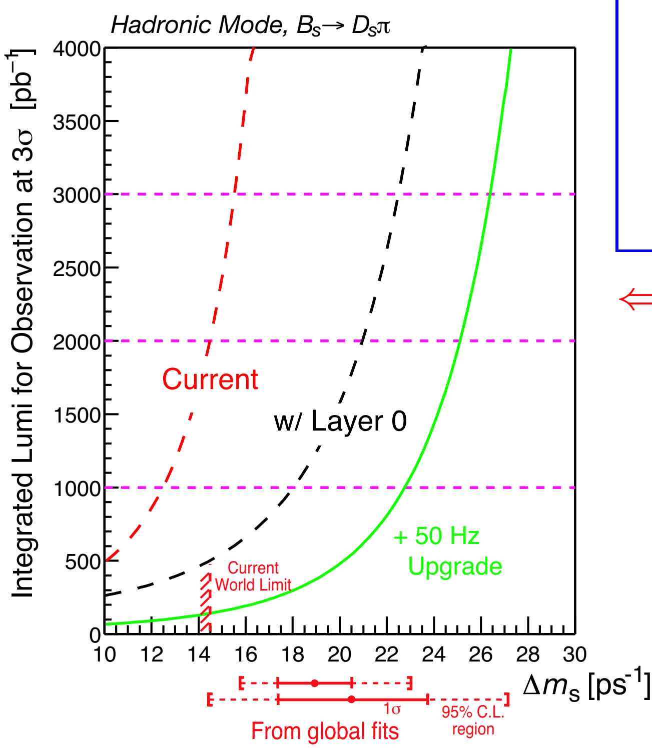
- Both cases using 1μ-inclusive triggers
- Impact of Layer-0 on semilept mode not as significant due to ν-smearing



semileptonic mode $\Rightarrow$

Int. Lum. needed to achieve a 3σ measurement as a function of Δm_s

$\Leftarrow$ **hadronic mode**



- Both cases assuming single-channel analyses
- Semileptonic mode hits a resolution wall
- Hadronic mode needed for extended reach

Conclusion

- DØ is producing a wealth of B-results.
- A competitive B program, with decisive impact on world's averages and limits.

- Key RunII measurements are on track, with uncertainties dominated by statistics, not systematics.
- B program to be further enhanced by RunIIb upgrades.

Backup Slides

Extra

Flavor Tagging

- Work in progress: tool development and calibration exercises with B_u and B_d semileptonic decays to $(\bar{D}^0\ \mu^+\ \nu\ X)$ final states.
- The $(\bar{D}^0\ \mu^+)$ sample is divided into two mutually exclusive components
  - The "neutral" sample (B_d enriched):
    $\bar{D}^0$ has an associated pion (opp. charge to muon)
    Dominated ($\sim 85\%$) by $B_d^0 \rightarrow D^{*-}(2010)\mu^+\nu$
  - The "charged" sample (B_u enriched): the remainder,
    Dominated ($\sim 85\%$) by $B_u^+ \rightarrow \bar{D}^0\mu^+\nu$
  - See plot and yields two pages back
- Flavor at decay time given by sign of $\bar{D}^0$-associated muon
- At production time, different tagging algorithms are under tests

OS: soft muon "SLT" jet charge "jetQ" sec.vtx charge "vtxQ"
SS: soft pion "SST" and their combinations

Combined Tagging Performance - I

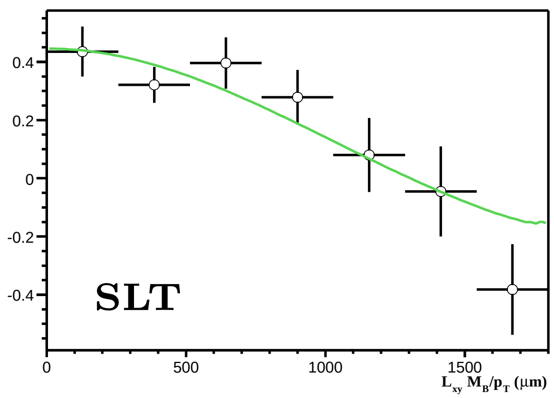
- Tagged sample divided into two uncorrelated components

SLT: events have OS muon tag. Other taggers not used.

jetQ⊕SST: remaining events. Use combined jetQ and SST;

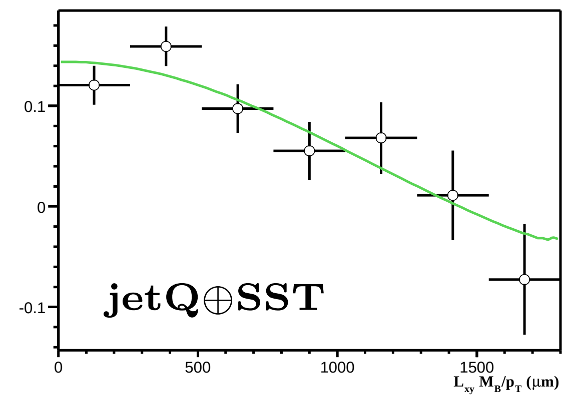
  - ∗ reject events with conflicting jetQ and SST results
  - ∗ accept events tagged by either jetQ or SST or both

200 pb^{-1}	Efficiency (%)	Dilution(%) charged		Dilution(%) neutral
SLT	5.0 ± 0.2	44.8 ± 5.1	↔	44.8 ± 5.1
jetQ⊕SST	68.3 ± 0.9	27.9 ± 1.2	→	14.9 ± 1.5



$\Delta m_d = 0.456$
± 0.034 (stat)
± 0.025 (sys)
ps^{-1}

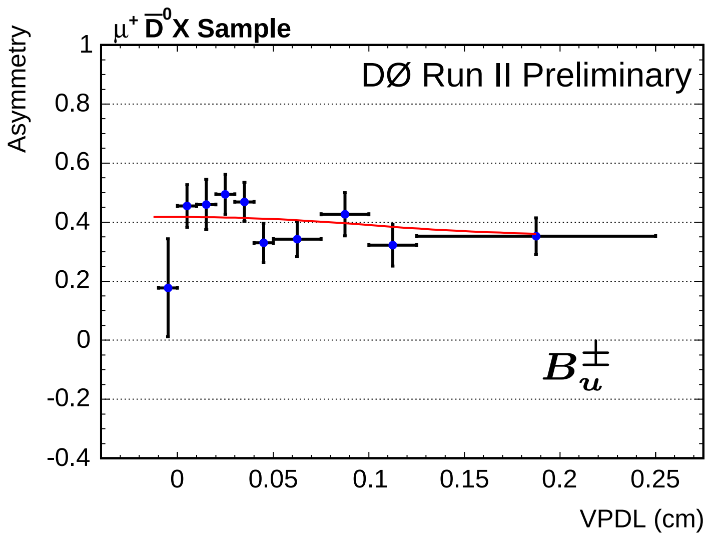
(consistent with WA)



Combined Tagging Performance - II

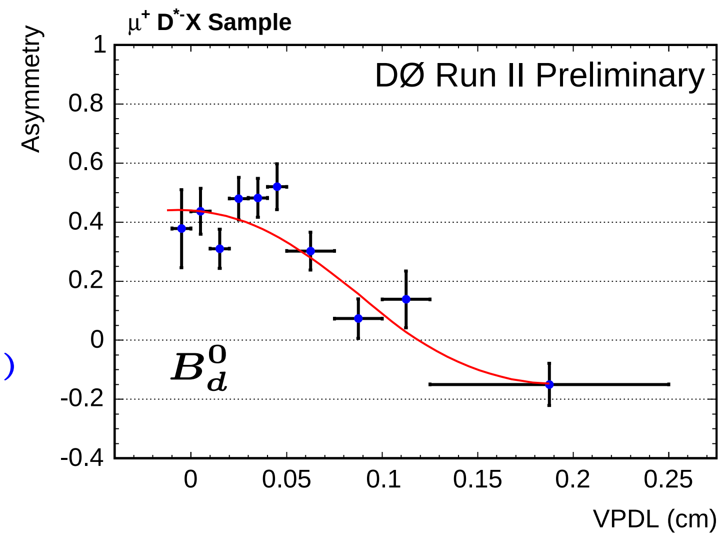
- A different (OS-only) tagger used in B_s mixing
- Here used on $B_u^{\pm}$ and B_d^0 samples as cross checks
- Flavor tagger builds a $(b, \bar{b})$ likelihood from a choice of OS(μ) discriminating variables; μ , p_T^{rel}, jetQ , svtQ . . .

460 pb^{-1}	**Efficiency (%)**	**Dilution(%)**	
		charged	**neutral**
OST	**5.0 ± 0.1**	**46.8 ± 3.0**	**44.8 ± 4.2**



$\Delta m_d = 0.558$
± 0.048 (stat)
ps^{-1}

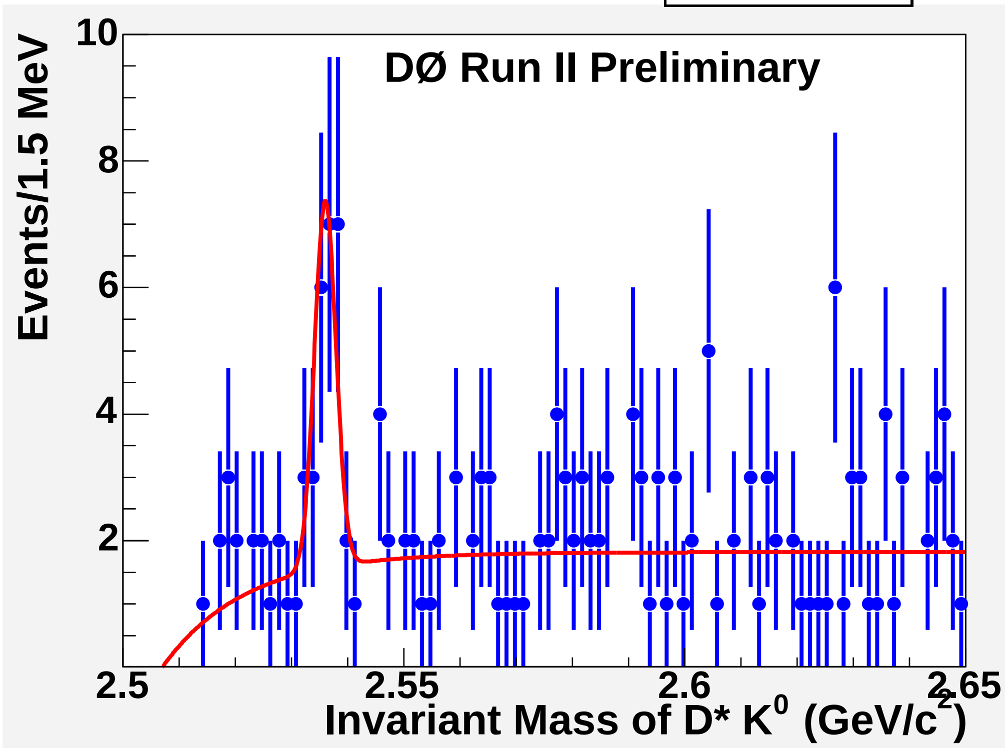
(consistent with WA)



$B_s \to D_{s1}^{\pm}(2536)\mu\nu X$

$485\ pb^{-1}$

$D_{s1}^{\pm}(2536)$ is an orbitally excited (c, s) pair in a $J^P = 1^+$ state



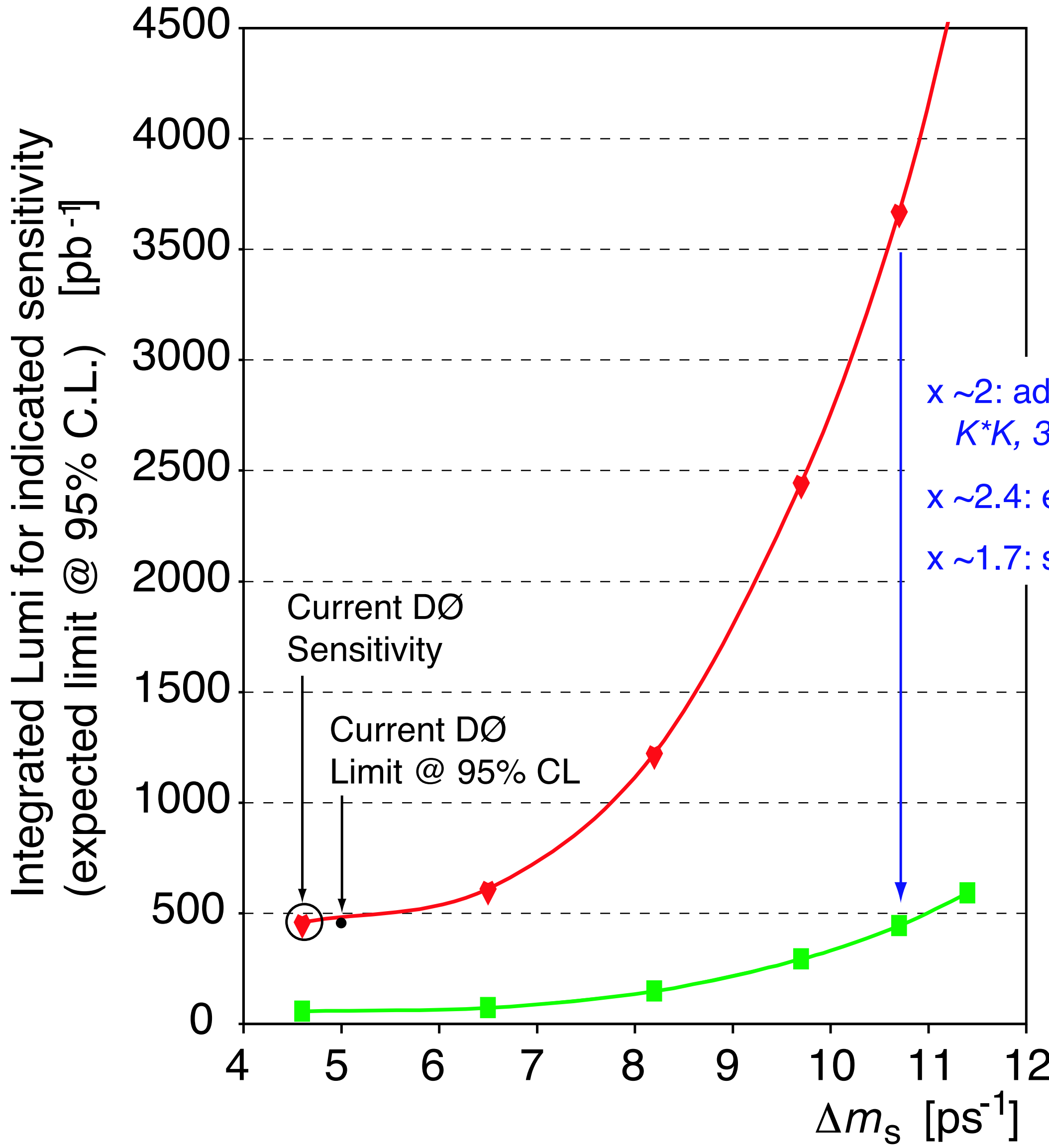
- Reconstruction
  - 18 ± 5 events
  - significance $> 3\sigma$
- Decay chain is

$$D_{s1}^{\pm}(2536) \to D^{*\pm}\ K_s^0$$
$$D^{*+} \to D^0\pi^+$$
$$D^0 \to K^-\pi^+$$

- **Muon plus 5-Track final state**
- Next step: investigate signal properties

Current Δm_s Reach

- **How current sensitivity will scale with luminosity if analysis remains unchanged.**



- **Expected improvements independently of upgrade.**

Further improvement, unbinned likelihood:

x ~2: flavor tag probability event-by-event

x ~1.3: resolution event-by-event