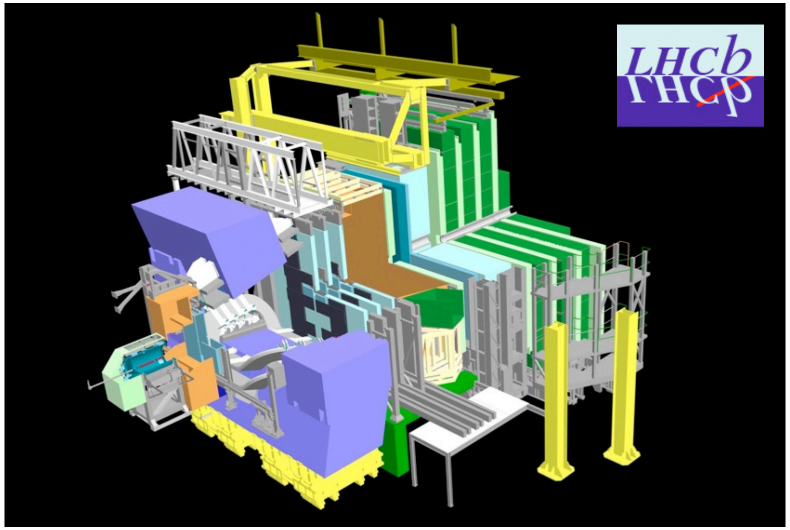
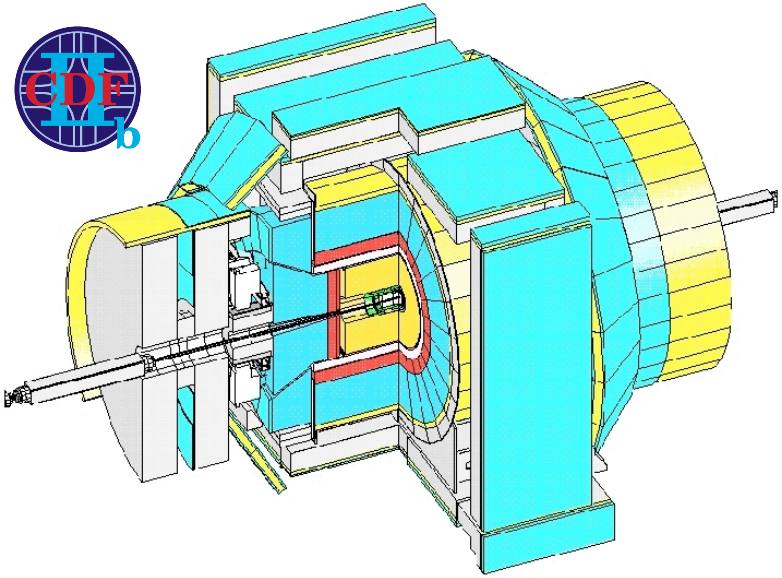
Thanks to D. Tonelli and M. Rescigno for their help in preparing this contribution!



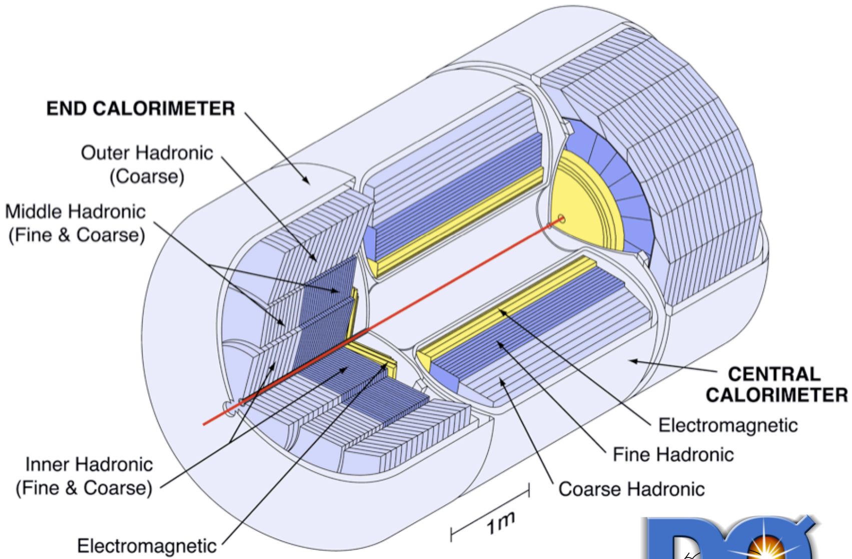
For LHCb [commissioning, det. status]:
See talks from
A. Carbone, U. Marconi

Tevatron & LHCb



Alessio Sarti

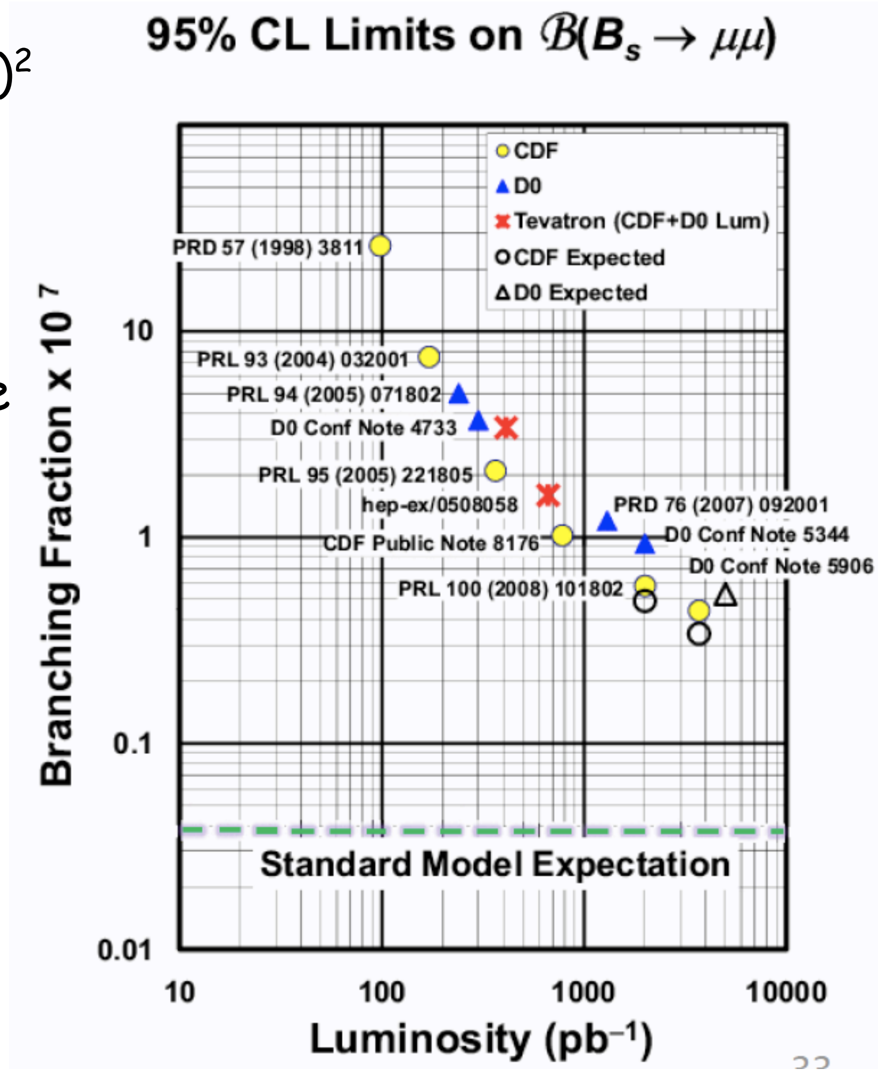
LNF - INFN - Italy

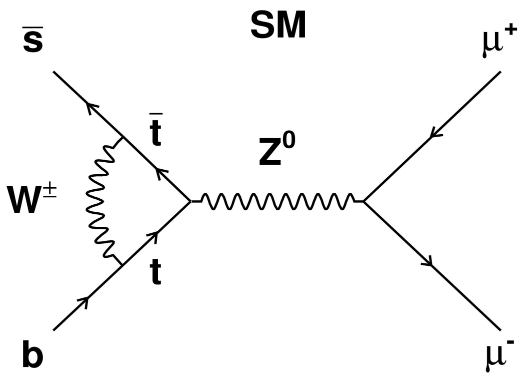


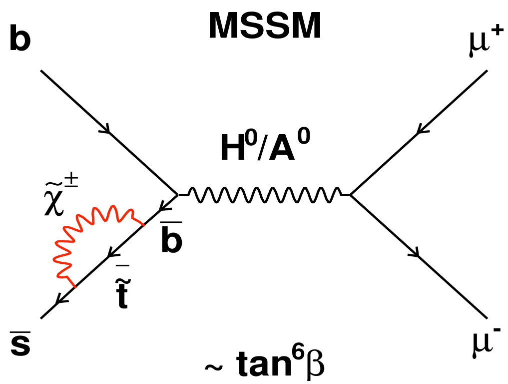
$B_s \to \mu\mu$

CDF note 9892, D0 note 5906, LHCb roadmap
arXiv0912.4179

- $B_s \to \mu\mu$ very rare
  - Effective FCNC +Helicity suppression $\sim(m_\mu/m_b)^2$
- Standard Model (SM) predictions
  - $B(B_s \to \mu\mu) = (3.6\pm0.3) \times 10^{-9}$; $B(B_d \to \mu\mu) = (1.1\pm0.1)\times10^{-10}$ [Buras, arXiv 0904.4917v1]
- Very sensitive to New Physics (NP) with large $\tan\beta$ [but not only: R-parity violation, etc etc]
  - MSSM $\sim \tan^6\beta/M^4_A$ (assuming SM<<MSSM) with large $\tan\beta$ favored by $b \to s\gamma$, $(g-2)_\mu$, $B \to \tau\nu$, etc.
  - **Upper limit on $BR(B_s \to \mu\mu)$ plays crucial role**

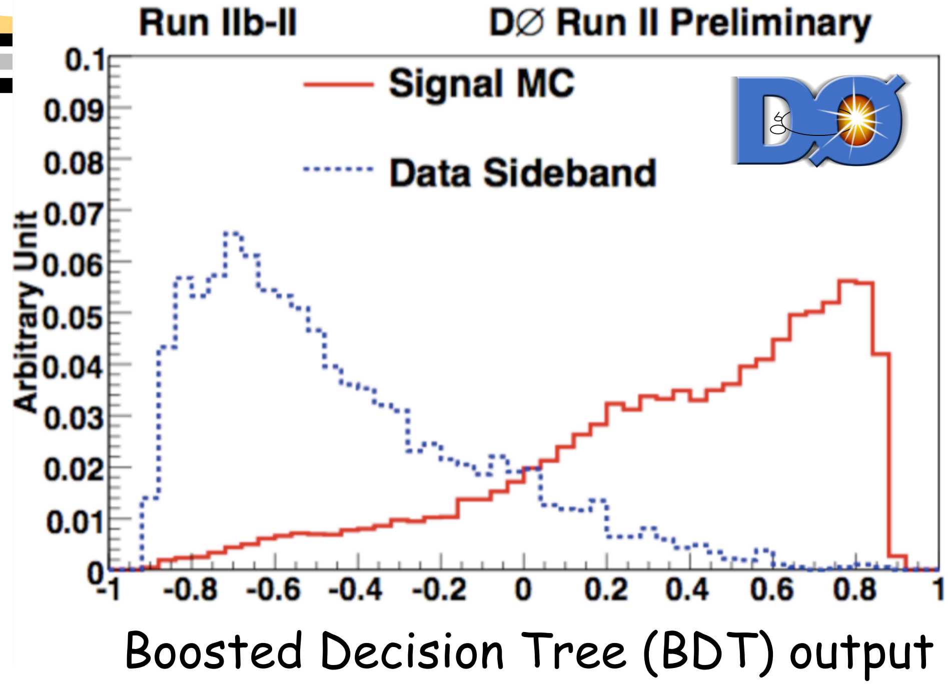


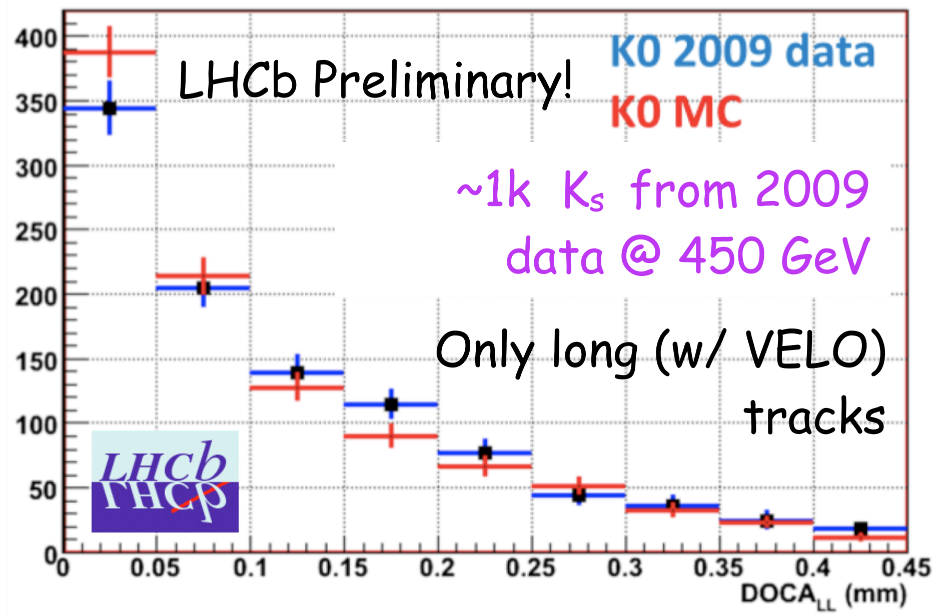




$B_s \to \mu\mu$ analysis

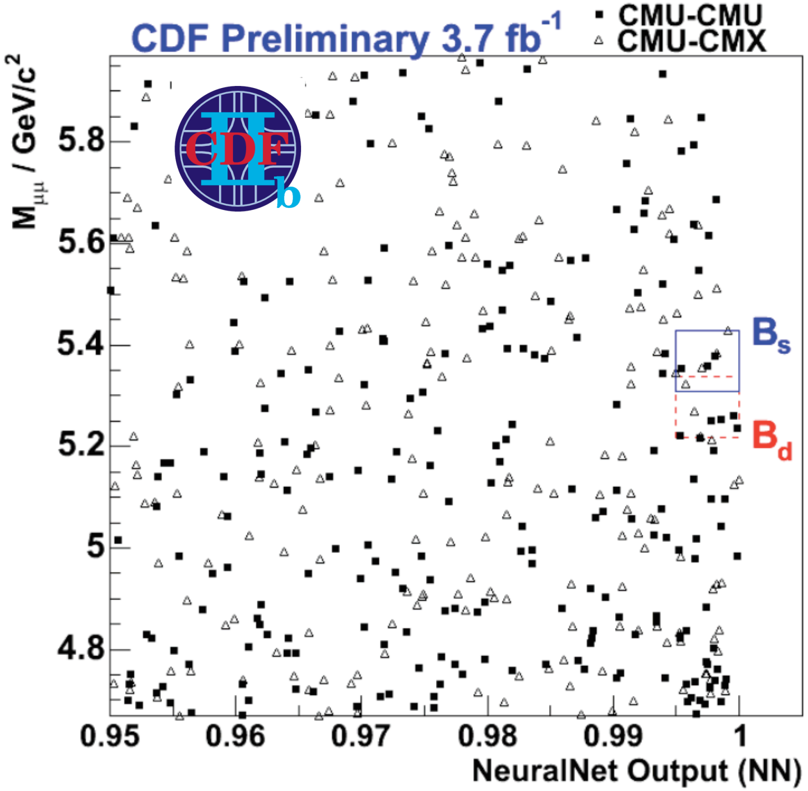
- Event preselection
  - Geometrical + kinematic cut
  - Control/norm. channels ($J/\psi K^+$, $J/\psi K^*$, h^+h^-): selected with same set of cuts → reduced systematics
- Analysis Strategies
  - Combine geometrical information into a Geometrical Likelihood (GL) [LHCb]; Use NNet algorithms [CDF] or Boosted Decision Trees [D0]
  - Apply μ-ID and use IM to evaluate CLs
- GL, pdf calibrations / Performances assessed on control samples
  - Ex, LHCb: Di-μ mass resolution (~25 MeV/c^2) from $B \to h^+h^-$ control sample, GL variables also from 2body channels





Results

- Event yields:
  - LHCb @ 7TeV: S ~5, B ~ 45 @ 1fb^{-1} in the most sensitive regions (Δm<60MeV/c^2, GL>0.5)
  - CDF,DØ: already expect ~2 SM $B_s \to \mu\mu$ events in their sample at this time ⇢ background reduction plays a central role in future analysis developments
- Control channels: $B^+ \to J/\psi K^+$ / $B \to hh$
  - LHCb: 1M / 200k events @ 1fb^{-1}
  - D0: 1.7k / 1.6fb^{-1}; CDF: 20k / 3.7fb^{-1}

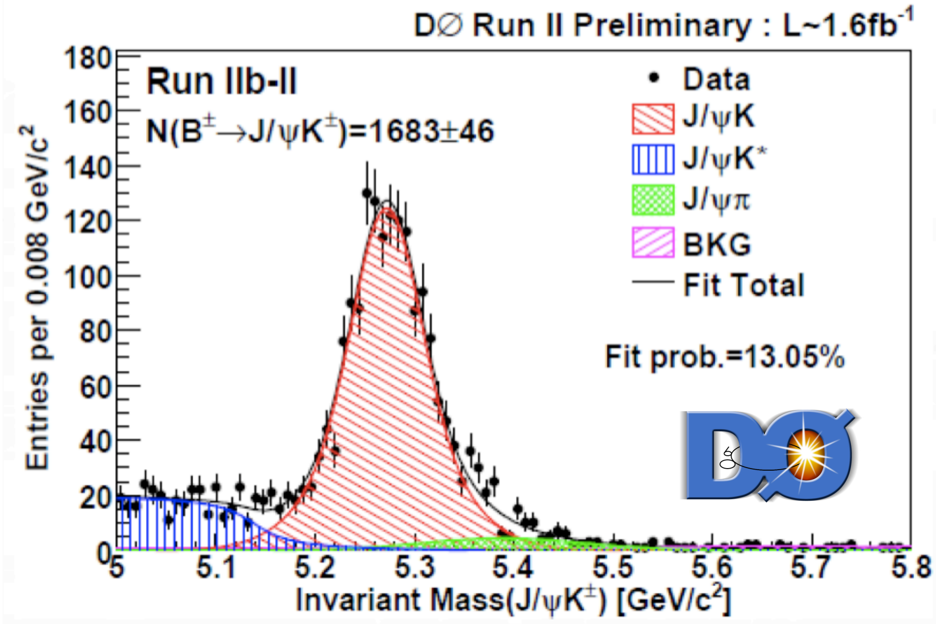


Current CDF result @95% CL!

$B(B_s \to \mu\mu) < 4.3 \times 10^{-8}$; $B(B_d \to \mu\mu) < 7.6 \times 10^{-9}$

Expected DØ limit @5fb^{-1} (Conf. Note 5906)

$B(B_s \to \mu\mu) < 4.3(5.3) \times 10^{-8}$ 90%(95%)C.L.

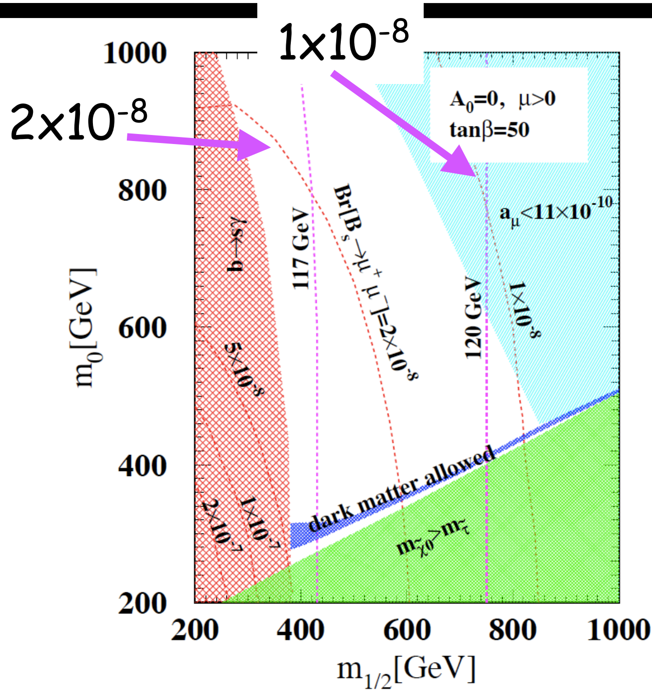


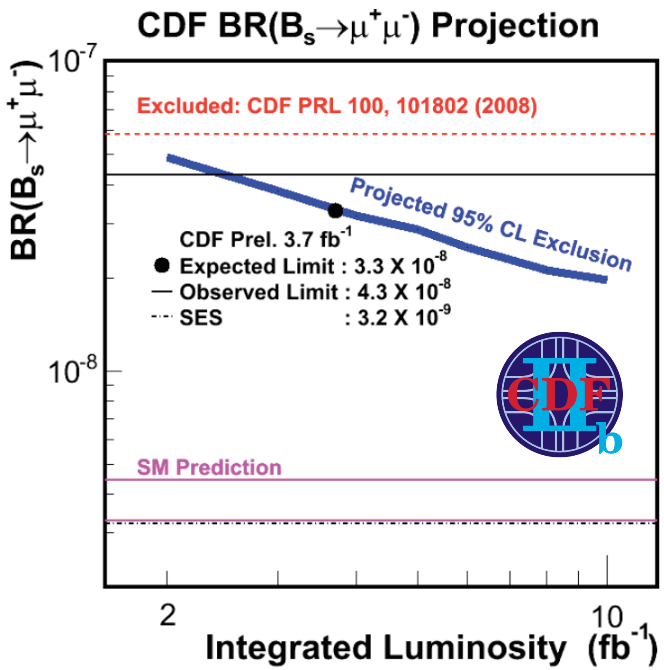
Main syst. : f_d/f_s needed to rescale normalization channel(s)

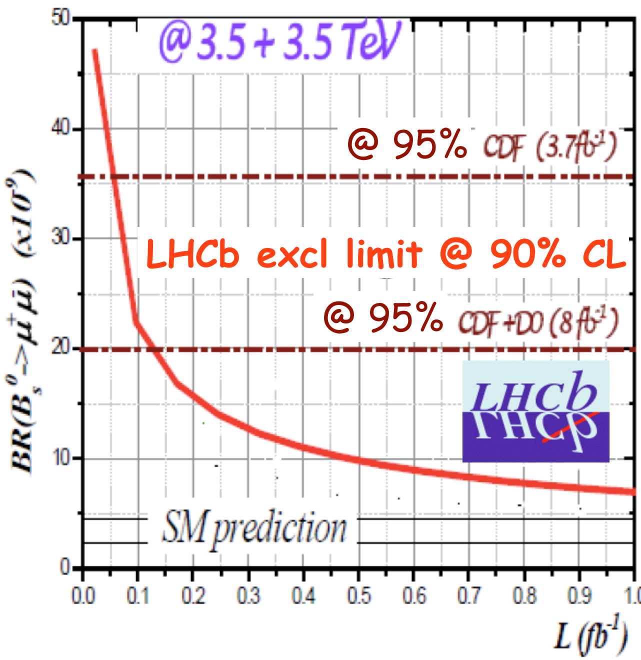
Projections for $B_s \to \mu\mu$ excl/observation

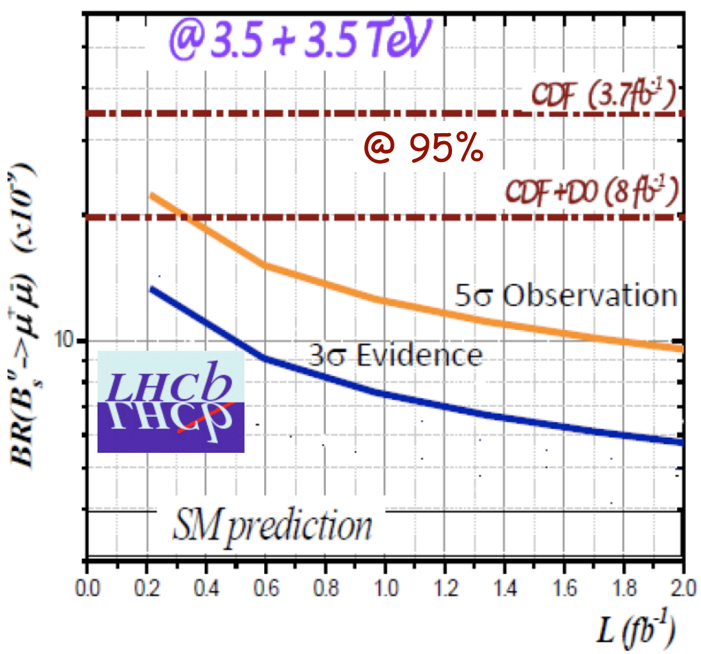
- Expect soon news from Tevatron:
  - Larger datasets (CDF,D0): analysis on 8fb[-1] ongoing... Expected to reach the 6xSM limit [each, 10 fb[-1]]
  - Single muon triggers (D0)
  - Particle ID dE/dx in silicon (D0)
- LHCb potential
  - Competitive with Tevatron already with ~0.1-0.2 fb[-1]
  - With 1 fb[-1] → 5σ evidence ~1.2 10[-8]

Channels into ee or eμ are ~ x10 worse
CDF, world best results
Phys.Rev.Lett.102:201801,2009







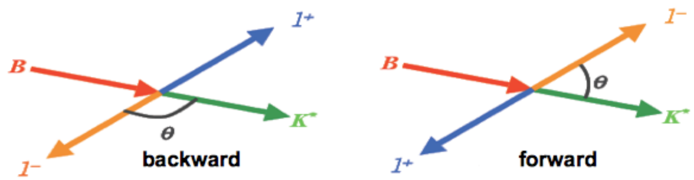


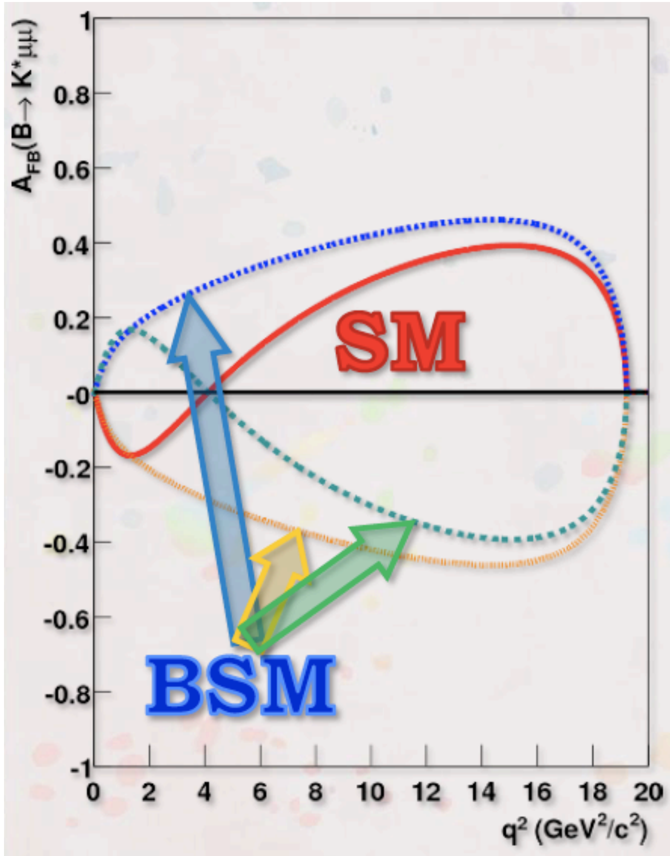
$b \to sll$ decays

- Inclusive decay difficult at an hadron collider.
  - Good prospects for excl decays: $B \to \ell\ell[K,K^*,\phi]$.
- Hadronic uncertainty reduced in:
  - Forward-backward asymmetry A_{FB} and s_0
- SM predictions of BR vs q^2 can be checked
  - Ex. from SM $BR(B^0_s \to \varphi\mu\mu) = 1.6\times10^{-6(*)}$ $BR(B_d \to K^*\mu\mu) = (1.22^{+0.38}_{-0.32})\times10^{-6(**)}$ and $s_0 = 4.39^{+0.38}_{-0.35}$ GeV$^{2(**)}$
- NP could contribute @ SM levels
  - modify BR and angular distributions: sensitivity to SUSY, gravitation exchange, extra-dimensions

(**) Beneke et al hep-ph/0412400

(*) JPHYS G 29, 1103 (2003)





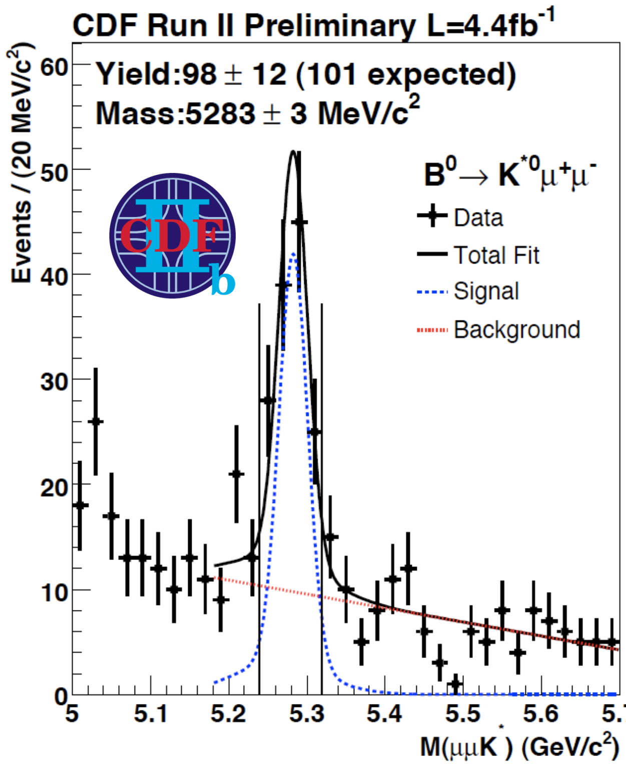
$B^{(+)}_d \to \phi/K^{(+)*}\mu\mu$

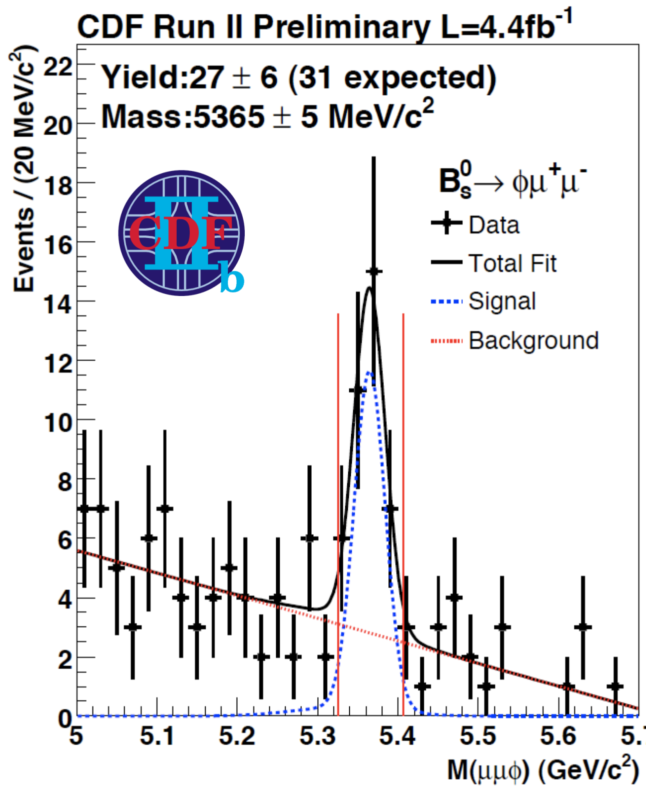
CDF note 10047, LHCb roadmap arXiv0912.4179

- B factories [~400 evts total] measured a BR = $(1.22^{+0.38}_{-0.32})10^{-6}$ that agrees to within ~30% with SM
  - Attempt also to measure A_{FB} as a function of the μμ invariant mass and determine s_0.
- CDF yields in $4.4fb^{-1}$ (prelim)
  - 120/100/30 in K,K*,ϕ modes
- LHCb expects ~150 evts with O(100) pb^{-1}

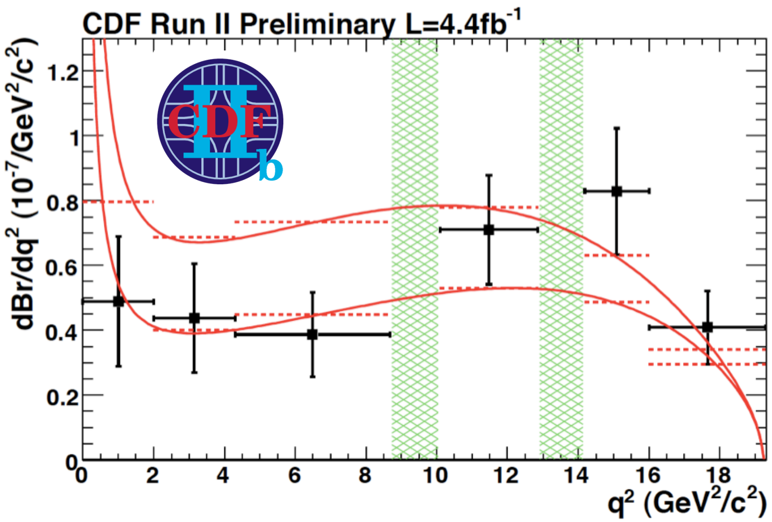
First attempt ever @ hadron machine: competitive with B fact!

First observation of ϕμμ!

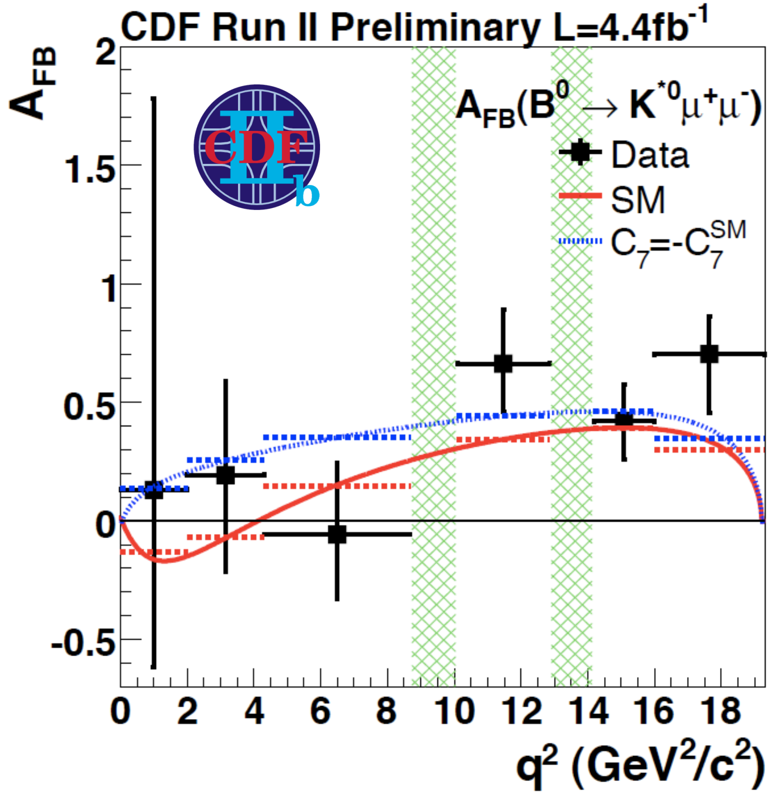




Measuring A_{FB}, s_0

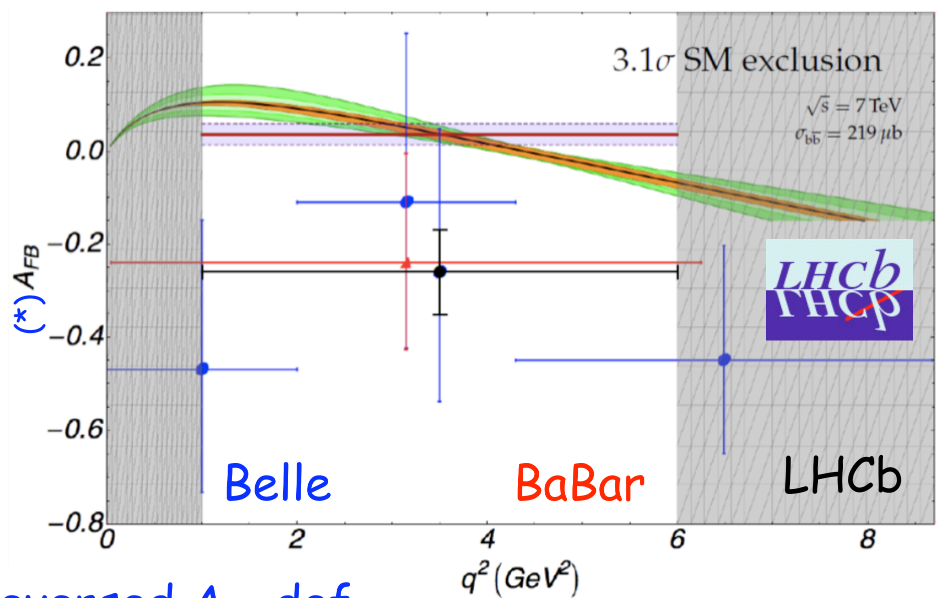


Tevatron: performances comparable with B factories, already performing an angular anlysis



- LHCb: with $L = 0.5\ fb^{-1}$@ 7TeV→700 evts: SM excluded @ 3.1σ
- Other handles come into play with higher statistics (better understood detector)
  - Including other modes: $B_s \to \Phi\mu^+\mu^-$, $\Lambda_b \to \Lambda^0\mu^+\mu^-$
  - Go for a full angular analysis
- Main syst. error from angular efficiency and bkg. angular distributions knowledge

SM average SM prediction



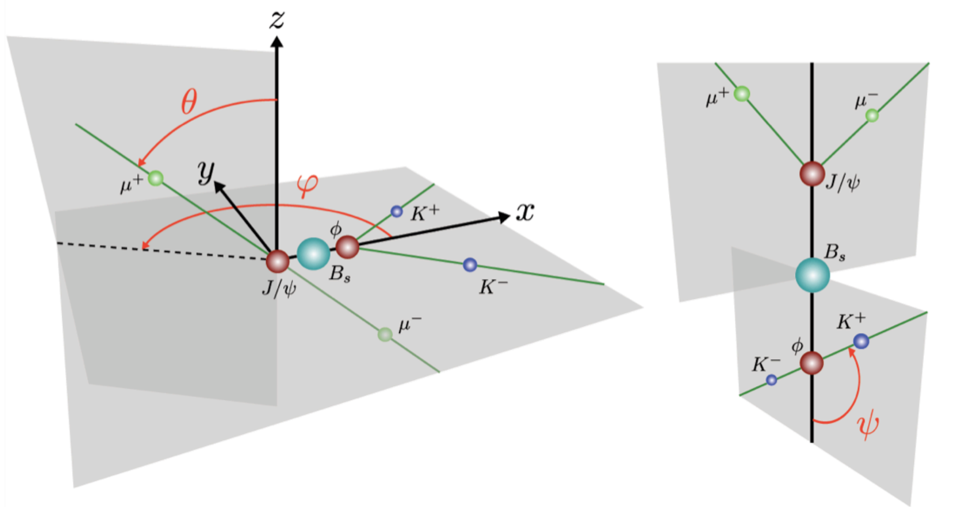
(*) Reversed A_{FB} def

$B_s \to J/\psi\varphi$

PRL 100, 161802 (2008) CDF; PRL 101, 241801 (2008) D0; LHCb roadmap arXiv0912.4179

- Measure $\varphi_s=-2\beta_s$ counterpart of $\varphi_d=2\beta_d$ [sin $2\beta_d$ = 0.671±0.023, PDG 09]
- φ_s [SM] = $-\arg(V_{ts}^2) = -2\lambda^2\eta = -0.0368 \pm 0.0018$ [CKMfitter, sum. 07]: small and hence sensitive probe of NP
- High BR ~$3\cdot10^{-5}$ and good exp. signature (μ trigger effective!)
- Time dependent CP asym. used to measure φ_s

$$A_{CP}(t) = \frac{-\eta_f \sin\beta_s \sin(\Delta m_s t)}{\cosh(\Delta\Gamma_s t/2) - \eta_f \cos\beta_s \sinh(\Delta\Gamma_s t/2)}$$



J/ψφ is not a pure CP eigenstate: angular analysis is needed to determine even (η_f = -1) and odd (η_f =1) states

$$\frac{d^4\Gamma(B_s^0 \to J/\psi\phi)}{dt\, d\cos\theta\, d\varphi\, d\cos\psi} \equiv \frac{d^4\Gamma}{dt\, d\Omega} \propto \sum_{k=1}^{6} h_k(t) f_k(\Omega)$$

k	$h_k(t)$	$\bar{h}_k(t)$	$f_k(\theta,\psi,\varphi)$
1	$\lvert A_0(t)\rvert^2$	$\lvert \bar{A}_0(t)\rvert^2$	$2\cos^2\psi(1-\sin^2\theta\cos^2\varphi)$
2	$\lvert A_\parallel(t)\rvert^2$	$\lvert \bar{A}_\parallel(t)\rvert^2$	$\sin^2\psi(1-\sin^2\theta\sin^2\varphi)$
3	$\lvert A_\perp(t)\rvert^2$	$\lvert \bar{A}_\perp(t)\rvert^2$	$\sin^2\psi\sin^2\theta$
4	$\Im\{A_\parallel^*(t)A_\perp(t)\}$	$\Im\{\bar{A}_\parallel^*(t)\bar{A}_\perp(t)\}$	$-\sin^2\psi\sin 2\theta\sin\varphi$
5	$\Re\{A_0^*(t)A_\parallel(t)\}$	$\Re\{\bar{A}_0^*(t)\bar{A}_\parallel(t)\}$	$\frac{1}{\sqrt{2}}\sin 2\psi\sin^2\theta\sin 2\varphi$
6	$\Im\{A_0^*(t)A_\perp(t)\}$	$\Im\{\bar{A}_0^*(t)\bar{A}_\perp(t)\}$	$\frac{1}{\sqrt{2}}\sin 2\psi\sin 2\theta\cos\varphi$

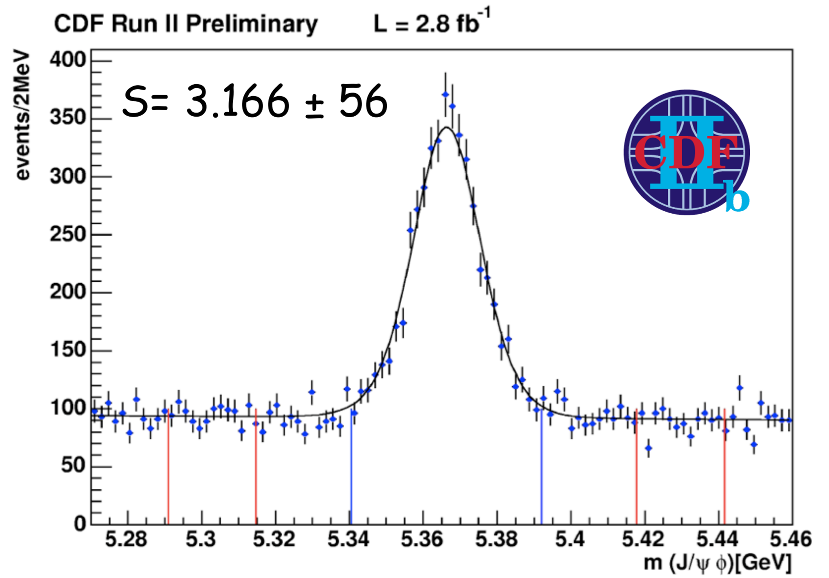
Results

- Yields [from IM fit]
  - $N(B_s^0)$ @ $2.8fb^{-1}$: DØ~2000, CDF~3200;
    $N(B_s^0)$ @ $0.5fb^{-1}$: LHCb ~ 13k
- Tagging, measured on control channels [$J/\psi K^+$, $J/\psi K^*$, $D_s\pi$]
  - CDF: εD^2 = 1.8% (OST); 4.8% (total)
    D0: = 2.5% (OST); 4.7% (total)

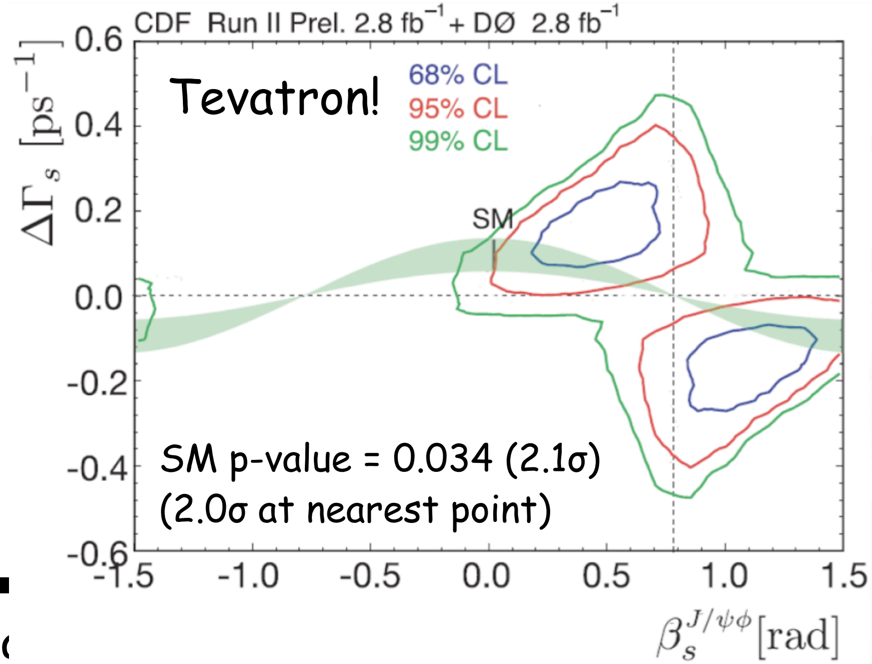
LHCb

Tagger	Tag eff.	mistag	$\varepsilon(1-2\omega)^2$
Opposite side	45%	36.5%	3.3%
+ same side	56%	33.3%	6.2%

  - Proper Time: $\sigma(t)$ ~38 fs (LHCb), 90fs (CDF)

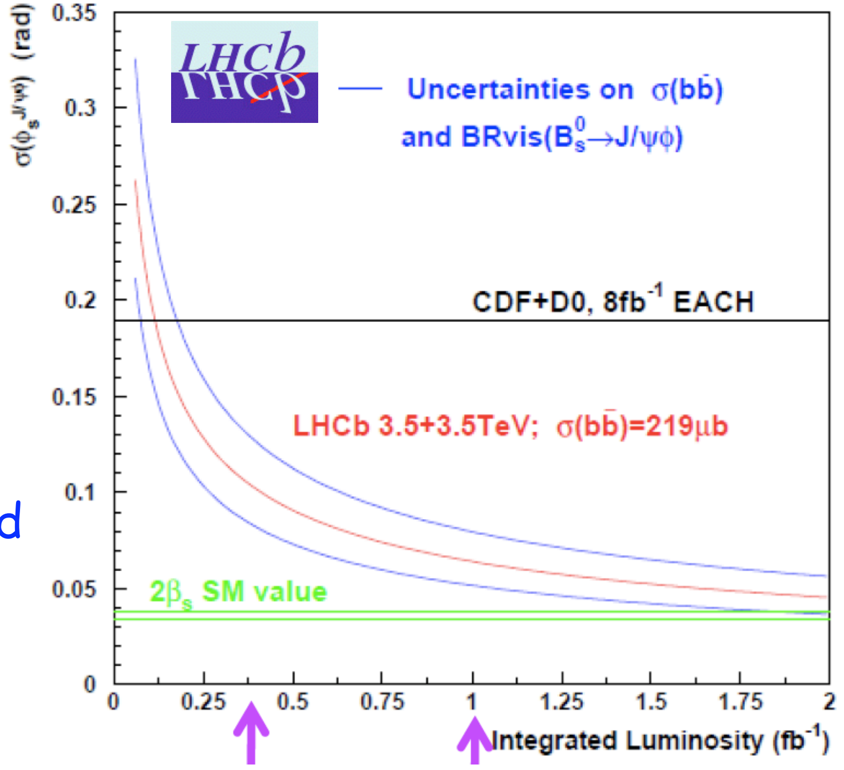


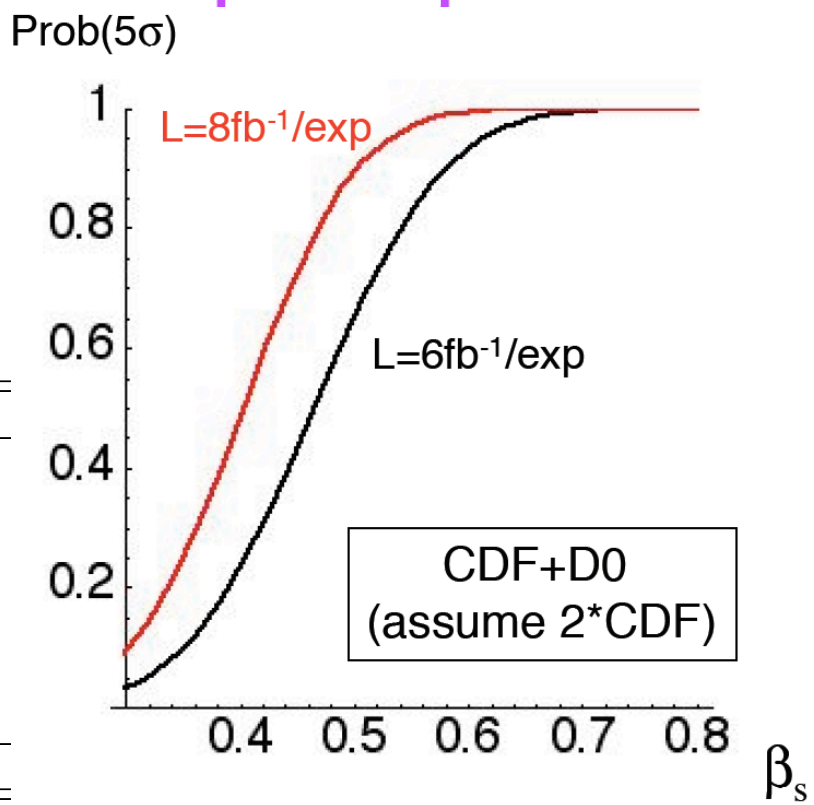
- Tevatron combined D0/CDF result in $\Delta\Gamma_s,\phi_s$ plane: probability of obs. deviation from SM = 3.4% (2.12 σ)
  - β_s ($J/\psi\varphi$) range: [0.27,0.59] U [0.97,1.30] @68%; [0.10,1.42] @95%



φs outlook

- LHCb potential:
  - If the central value is Tevatron (NP-like): 5σ measurement ⇢ ~400pb^{-1} needed
  - σ(stat) ~0.07 rad with 1 fb^{-1}. More than 2fb^{-1} needed to reach the SM value
- Tevatron "Coming soon":
  - D0: 2*stat + BDT to improve S/B
  - CDF: Same Side Kaon Tagger (SSKT) and PID for all stat [εD^2~3.2%], 2*stat, J/ψKK model will be included
  - **High P of 5σ discovery in interesting β_s range**





~6-7% in LHCb

Smaller impact on LHCb

Systematics	$\Delta\Gamma$ [ps^{-1}]	$c\tau_s$ [μm]	$\lvert A_\parallel(0)\rvert^2$	$\lvert A_0(0)\rvert^2$
Signal efficiency	0.003	0.8	0.007	0.007
Mass model	0.003	0.8	0.002	0.002
Resolution model	0.006	1.4	0.001	0.001
Background lifetime model	0.006	0.2	0.001	0.001
Background angular distribution	0.004	0.9	0.001	0.001
$B^0 \to J/\psi K^{*0}$ cross-feed	0.002	0.2	0.002	0.002
SVX alignment	0.003	2.0	0.000	0.002
Total	**0.011**	**3**	**0.007**	**0.008**

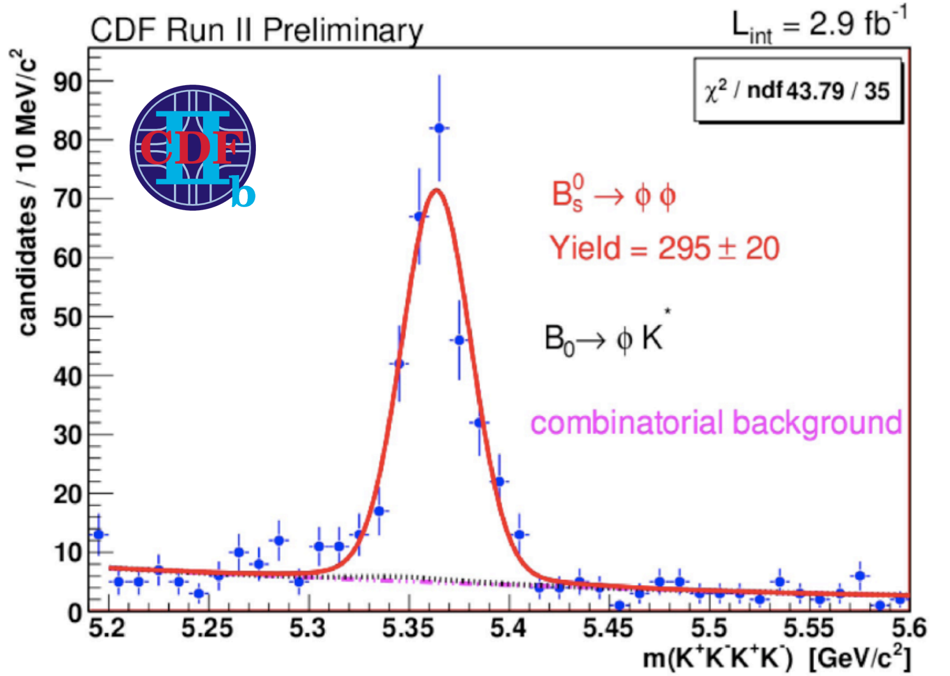
$B_s \to \phi\phi$

CDF Public Note 10064
CDF Public Note 10120 (polar.)

- $B_s \to \phi\phi$ with $\phi \to KK$
  - An independent $P \to VV$ decay: can extract $\Delta\Gamma_s$, φ_s etc;
  - Dominant SM process is the $b \to s$ penguin: look for deviations in BR, polarization, CPV
- Excellent probe of polarization amplitudes
  - SM exp. $|A_0|^2 \gg |A_{||}|^2 \sim |A_\perp|^2$
- CDF on 2.9 fb^{-1}: first results with ~10% precision
  - Expected amplitudes hierarchy disfavored
- LHCb ~ 450 evts in 0.5fb^{-1} B/S<2.4
  - $\sigma(\Phi_s(\varphi\varphi))$~0.06 with 10$fb^{-1}$ [@14 TeV]

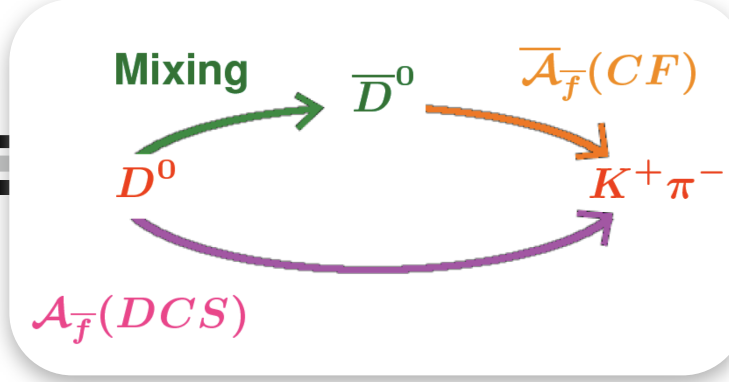
2009, CDFII BR update (2.9 fb^{-1})

$B(B_s \to \phi\phi) = 2.40 \pm 0.21\,(stat) \pm 0.27\,(syst) \pm 0.82\,(BR_{J/\phi})$



$$
\begin{aligned}
|A_0|^2 &= 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})\\
|A_{||}|^2 &= 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst})\\
|A_\perp|^2 &= 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst})\\
\cos\delta_{||} &= -0.91^{+0.15}_{-0.13}(\text{stat}) \pm 0.09(\text{syst})
\end{aligned}
$$

Charm Program

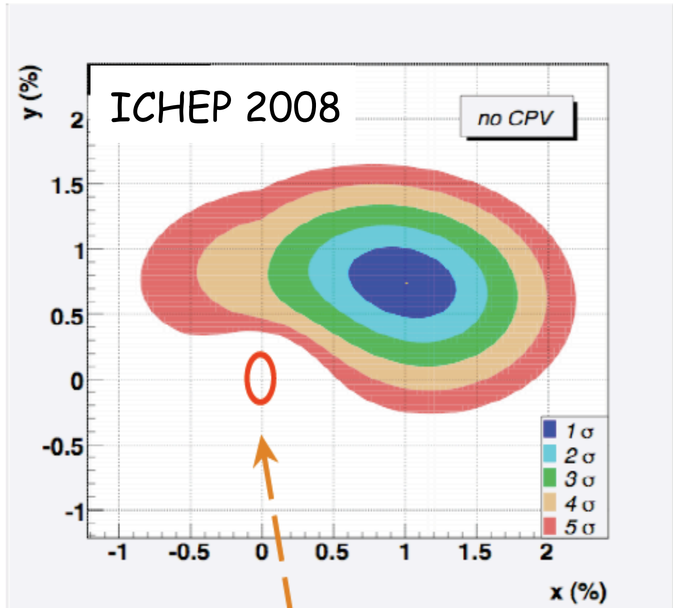


- Charm Mixing observed since 2007
  - Boosted interest in charm physics @ hadron machine: developing trigger algos + analysis strategies

$$x = \frac{\Delta M}{\Gamma} = \frac{M_H - M_L}{(\Gamma_H + \Gamma_L)/2}$$

$$y = \frac{\Delta\Gamma}{2\Gamma} = \frac{\Gamma_H - \Gamma_L}{(\Gamma_H + \Gamma_L)}$$

- Tevatron already collected a large c hadron data sample [$\sigma(c\bar{c})$~ 6-10 x $\sigma(b\bar{b})$]: even better now that LHCb comes into play
  - $A_{CP}(t)$ studies [ππ,KK modes] + mixing (Kπ)
  - Not only CP but also rare decays: $D^0 \rightarrow \mu\mu$
- Triggering is challenging
  - in CDF made possible, from RunII, by the Hadronic Trigger [online, cutting on IP and decay lenght] Optimized for B decays, large room to improve c-acceptance.
  - Dedicated (leptonic / hadronic) trigger in LHCb. With low L can be tuned to have high ε also on prompt charm: Ex. ε(L0xHLT1)~70% for $D^* \rightarrow D^0(hh)\pi$



$(x_D, y_D) = (0,0)$

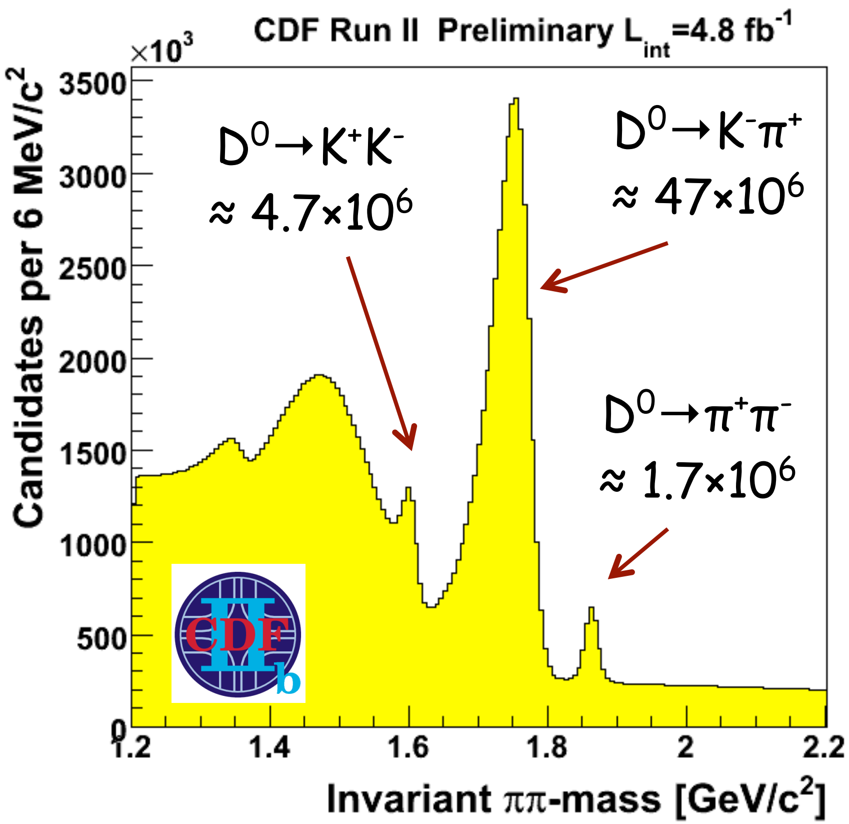
Channels, yields, crucial points

- LHCb: Expected tagged events in 100 pb^{-1}: ~40×10^6 $D^0 \to K\pi$ right sign and ~ 4×10^6 $D^0 \to KK$

	BaBar 390fb^{-1}		Belle 540fb^{-1}		CDF(*) 5fb^{-1}	
	evts	$\sigma(A_{CP})$	evts	$\sigma(A_{CP})$	evts	$\sigma(A_{CP})$
$D^0 \to \pi\pi$	64k	0.5	51k	0.5	270k	0.19
$D^0 \to KK$	129k	0.34	120k	0.30	780k	0.11

- Rare decays: SM BR($D^0 \to \mu\mu$) <10^{-12}
  - Actual best limit: BR($D_0 \to \mu\mu$)<1.4 x 10^{-7}@ 90%CL by Belle 660 fb^{-1}
  - LHCb expected limit (100 pb^{-1}): BR($D^0 \to \mu\mu$)< 2.6 10^{-8}@ 90% CL
  - Preliminary CDF results on 0.36/fb^{-1} [CDF note 9226] BR($D^0 \to \mu^+\mu^-$) < 3.0×10^{-7} @ 95%CL

Offline trigger confirmation, untagged



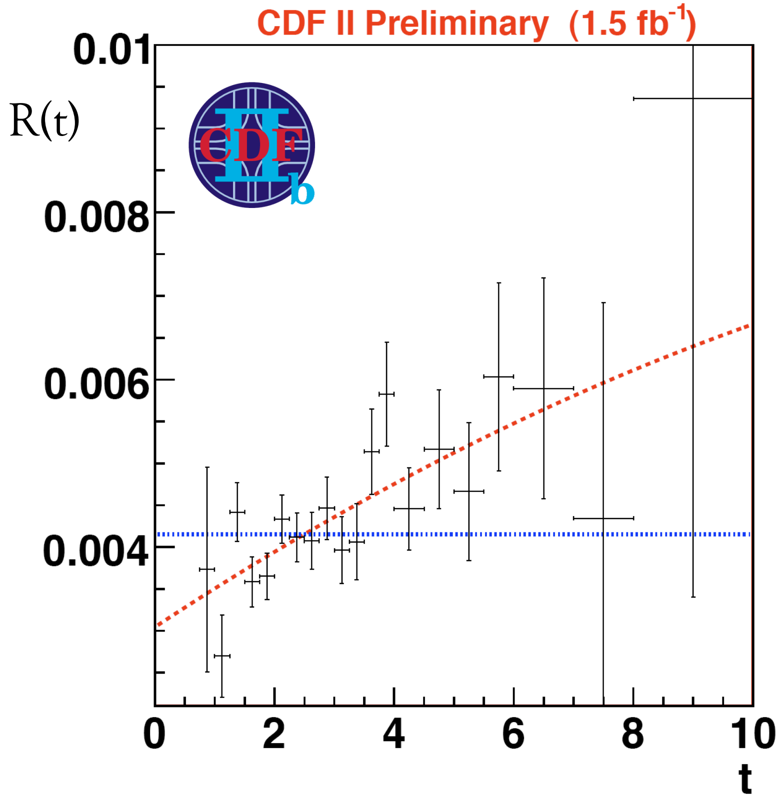
Without hadronic trigger in 5fb^{-1} just 50 $D^0 \to K^-\pi^+$

(*) CDF 2005 (120 pb^{-1}): PRL94,122001(2005) and D0 2004 http://www-cdf.fnal.gov/physics/new/bottom/031211.blessed-d0/ with update in preparation

Mixing

CDF PRL 100,121802(2008)

- Looking at R(t) vs t
  - Measure time-dependent of R(t)=WS/RS where:
    - wrong sign (WS) $D^{*+} \to D^0\pi^+ \to [K^+\pi^-]\pi^+$
    - right sign (RS) $D^{*+} \to D^0\pi^+ \to [K^-\pi^+]\pi^+$
  - Assuming |x|,|y|<<1 and no CPV:
    - $R(t) = R_D + \sqrt{R_D}\, y' \,(\Gamma_D t) + \frac{x'^2 + y'^2}{4} (\Gamma_D t)^2$



Using just a "first part of data" available [1.5 fb^{-1}], CDF **confirms evidence of mixing hypothesis at 3.8σ**. Next step: observation and precise measurement.

- Mixing can be tested also by looking at the lifetime ratios:
  - Current exp.: y_{CP}=1.11±0.22% A_Γ=0.12±0.25%
  - LHCb: expects $\sigma_{stat}(y_{CP})\sim 10^{-3}$ with 100 pb^{-1}
  - Tevatron: aiming @ precise measurement → work ongoing trying to keep under control all the systematics in the ε

$$y_{CP} = \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to K^-K^+)} - 1$$

$$A_\Gamma = \frac{\tau(\bar{D}^0 \to K^+K^-) - \tau(D^0 \to K^+K^-)}{\tau(\bar{D}^0 \to K^+K^-) + \tau(D^0 \to K^+K^-)}$$

$B \rightarrow h'h$ decays

CDF PRL 97, 211802 2006; Public Note 07-10-18 ; LHCb roadmap arXiv0912.4179

- ✓ All species of B hadrons produced in pp collisions: great opportunity to study B_d, B_s and Λ_b decays together!
  - ✓ PID and hadron trigger line are playing a central role

A rich shopping list:

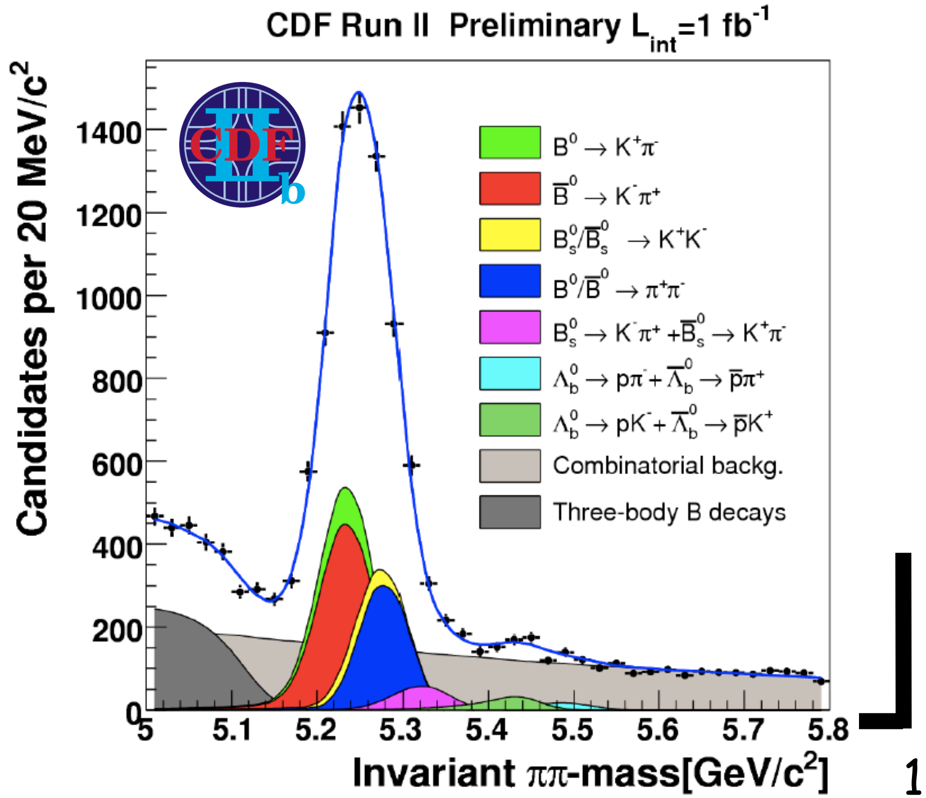
a. $B_d \rightarrow \pi^+\pi^-$ and $B_s \rightarrow K^+K^-$ time $A_{CP}(t)$

b. CP charge asymmetries for $B_d \rightarrow K^+\pi^-$, $B_s \rightarrow \pi^+K^-$, $\Lambda_b \rightarrow p\pi$, $\Lambda_b \rightarrow pK$

c. Checks of U-spin symmetry + γ studies

d. Branching fractions of all modes (In particular rare decays): $B_d \rightarrow K^+K^-$ and $B_s \rightarrow \pi^+\pi^-$, $B_d \rightarrow pp$ and $B_s \rightarrow pp$

LHCb expects 200k evts/fb^{-1} and will match the statistics of CDF (3fb^{-1}) with an integrated luminosity of ~100 pb^{-1}



CDF last IFAE

$$B\left(B_s^0 \rightarrow K^-\pi^+\right) = \left(5.3 \pm 0.7 \pm 0.9\right) \times 10^{-6}$$

$$A_{CP}\left(B^0 \rightarrow K^+\pi^-\right) = -0.086 \pm 0.023 \pm 0.009$$

$$A_{CP}\left(B_s^0 \rightarrow K^-\pi^+\right) = 0.39 \pm 0.15 \pm 0.08$$

Direct CP and BR sensitivities

(*) CDF note 8579, 9092 on 1fb^{-1} data

- Tevatron update on 2.7fb^{-1} in preparation
- LHCb potential (0.5fb^{-1})
  - Direct CP asymmetries sensitivies in πK, pK and pπ modes are competitive with current (2009) measurements **already with L=0.5 fb^{-1}**
  - Experimental knowledge of B_s and Λ_b BRs can be improved **already with L=0.5 fb^{-1}**

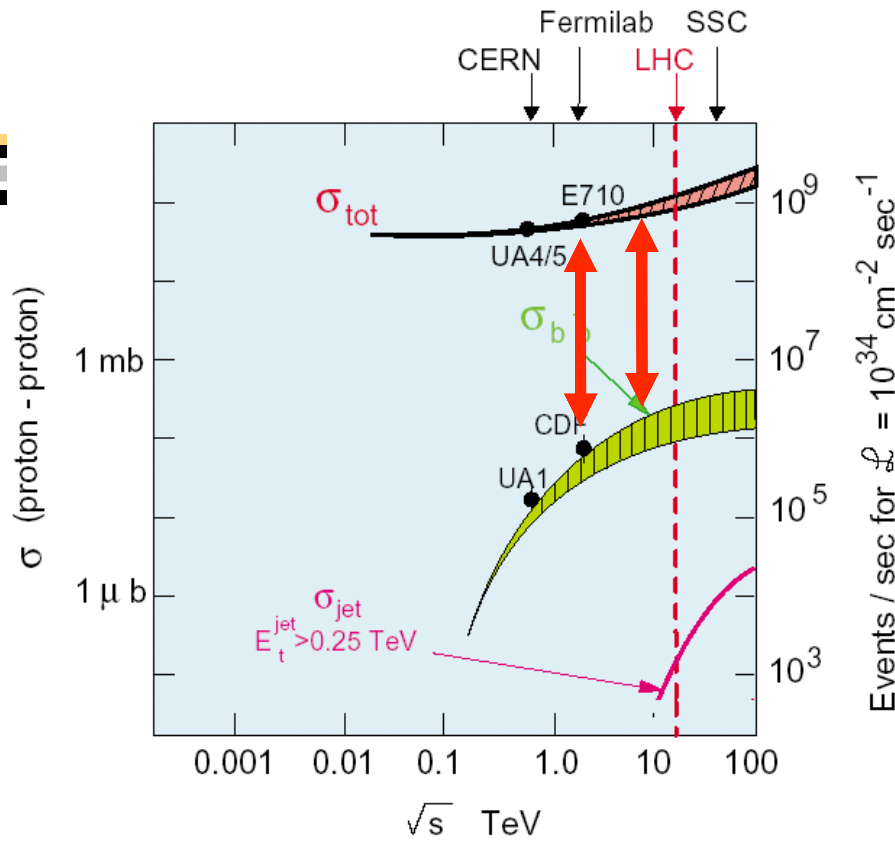
	Experimental status	LHCb 0.5fb^{-1}
$\mathcal{A}^{CP}_{K^+\pi^-}$	$-0.098^{+0.012}_{-0.011}$	0.008
$\mathcal{A}^{CP}_{\pi^+K^-}$	(*) $0.39 \pm 0.15 \pm 0.08$	0.05
$\mathcal{A}^{CP}_{p\pi^-}$	(*) $0.03 \pm 0.17 \pm 0.05$	0.05
$\mathcal{A}^{CP}_{pK^-}$	(*) $0.37 \pm 0.17 \pm 0.03$	0.03
$\mathcal{A}^{dir}_{\pi^+\pi^-}$	0.38 ± 0.06	0.13
$\mathcal{A}^{mix}_{\pi^+\pi^-}$	-0.65 ± 0.07	0.13
$\mathrm{Corr}(\mathcal{A}^{dir}_{\pi^+\pi^-}, \mathcal{A}^{mix}_{\pi^+\pi^-})$	0.08	-0.03
$\mathcal{A}^{dir}_{K^+K^-}$	To be measured	0.15
$\mathcal{A}^{mix}_{K^+K^-}$		0.11
$\mathrm{Corr}(\mathcal{A}^{dir}_{K^+K^-}, \mathcal{A}^{mix}_{K^+K^-})$		0.02
$\frac{\mathcal{BR}(B^0\to\pi^+\pi^-)}{\mathcal{BR}(B^0\to K^+\pi^-)}$	0.264 ± 0.011	0.006
$\frac{\mathcal{BR}(B^0\to K^+K^-)}{\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.020 \pm 0.008 \pm 0.006$	0.005
$\frac{f_s\,\mathcal{BR}(B^0_s\to K^+K^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	(*) $0.347 \pm 0.020 \pm 0.021$	0.006
$\frac{f_s\,\mathcal{BR}(B^0_s\to \pi^+K^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	(*) $0.071 \pm 0.010 \pm 0.007$	0.004
$\frac{f_s\,\mathcal{BR}(B^0_s\to \pi^+\pi^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	(*) $0.007 \pm 0.004 \pm 0.005$	0.002
$\frac{f_{\Lambda_b}\,\mathcal{BR}(\Lambda_b\to p\pi^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	(*) $0.0415 \pm 0.0074 \pm 0.0058$	0.0016
$\frac{f_{\Lambda_b}\,\mathcal{BR}(\Lambda_b\to pK^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	(*) $0.0663 \pm 0.0089 \pm 0.0084$	0.0018

Conclusions

- Tevatron beautifully demonstrated the power of hadronic collider experiments in the flavour physics field:
  - CPV studies using b and c hadrons, B,D rare decays, etc etc
- Largest b,c hadron sample ever collected is already available, thanks to Tevatron. With LHC up and running and we will have even much more...
  - LHCb Expect ~1 fb^{-1} by the end of 2011, with excellent detector performances [being validated on first data, see A. Carbone talk]
  - Tevatron expected final Lint ~10fb^{-1}
- Lot of new/improved results in the near (1y?) future
  - LHCb can make significant contributions to the experimental knowledge of B_s and D mesons rare decays + CP(t) already with the data collected in the first run [<2011]!
  - Tevatron is doubling the statistics + improving the analysis in many interesting channels...
- Great time ahead for flavour-addicted physicists... Hadron colliders experiments ready to make one more step towards the 'precision' era...

Spare slides

B physics @ LHC



- B phys @ pp machine @ 14 TeV:
  - $\sigma(b\bar{b})$ ~ 500μb : 5·104 $b\bar{b}$/s @ L = 1032
    In LHCb 230 μb visible σ with very low pT coverage
  - Large (x100) background from pp to be suppressed

B physics become difficult when pp interaction #/ crossing increases (>1, dirtier environment): care needed @ high lumi (>2•10^{32}) or bunch conditions != nominal (first year)

- LHC (+LHCb) ⇒ largest B factory (+ dedicated B det.) ever built:
  - Every kind of 'b-hadrons' are produced: B_d, B_s, B_u, B_c, Λ_b, ...
  - The statistics collected will permit to measure BRs in the 10^{-3} to 10^{-9} range!

bbar xsection from pythia