Charmless and Penguin Decays at CDFII: $B_s^0 \to \phi\phi$, $B_{(s)}^0 \to h^+h'^-$

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(on behalf of the CDF Collaboration)

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Warwick, 6-10 Sept.

The charmless Beauty

"Charmless" is pleasant!

B non-leptonic 2-body charmless decays:

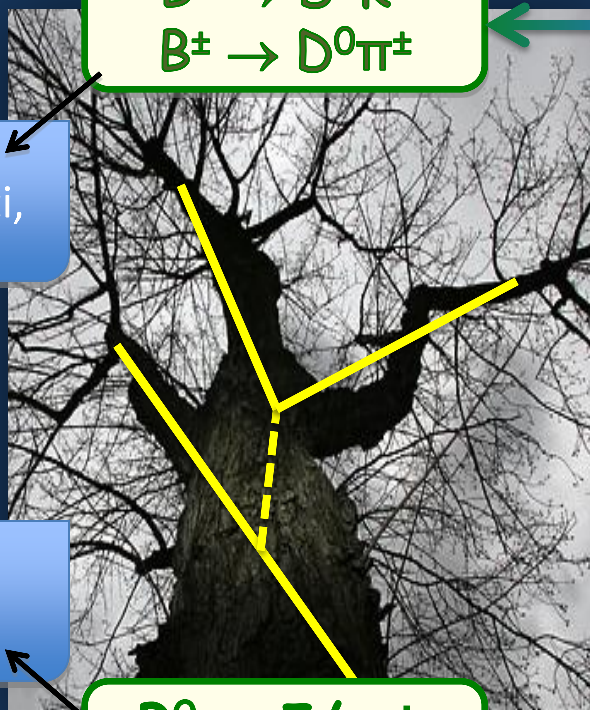
unique interplay of EW and low-energy strong interactions

why penguins 

The Penguin Beauty

A loop's treasure:

Another potential place for NP.

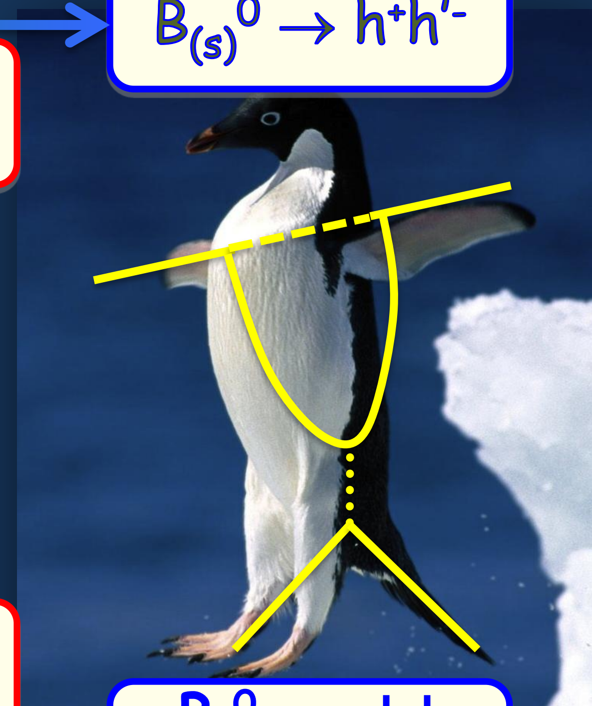


$B^{\pm} \to D^0 K^{\pm}$
$B^{\pm} \to D^0 \pi^{\pm}$

See
P. Squillaciotti,
WG V

γ

$B_{(s)}^0 \to h^+ h'^-$



See
M. Kreps,
WG IV

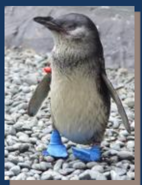
Φ_s

$B^0_s \to J/\psi\phi$
mixing

$B_s^0 \to \phi\phi$
mixing+decay

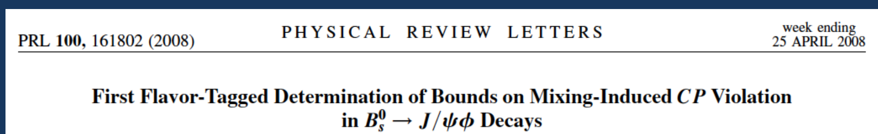
For neutral mesons, comparing to Tree transitions, allow to disentangle NP contribution in mixing and decay

The Penguin Beauty



Penguin: thought as opportunity rather than as limitation!

The best (hard) way: observables from full tagged and time-dependent analysis as for tree transitions.



PRL **100**, 161802 (2008) PHYSICAL REVIEW LETTERS week ending 25 APRIL 2008

First Flavor-Tagged Determination of Bounds on Mixing-Induced *CP* Violation in $B_s^0 \to J/\psi\phi$ Decays

…but: lot of statistics, disfavored by BR

statistics

Investigate step by step…

1. BR, time-integrated ACP - Polarization Amplitudes
2. $\Delta\Gamma_s$ from Penguins (time dependent)
3. Tagged: Φ_s

A CDF's Beauty$_{(s)}$

PRL **95,** 031801 (2005) PHYSICAL REVIEW LETTERS week ending 15 JULY 2005

Evidence for $B_s^0 \to \phi\phi$ Decay and Measurements of Branching Ratio and A_{CP} for $B^+ \to \phi K^+$

PRL **97,** 211802 (2006) PHYSICAL REVIEW LETTERS week ending 24 NOVEMBER 2006

Observation of $B_s^0 \to K^+K^-$ and Measurements of Branching Fractions of Charmless Two-Body Decays of B^0 and B_s^0 Mesons in $\bar{p}p$ Collisions at $\sqrt{s} = 1.96$ TeV

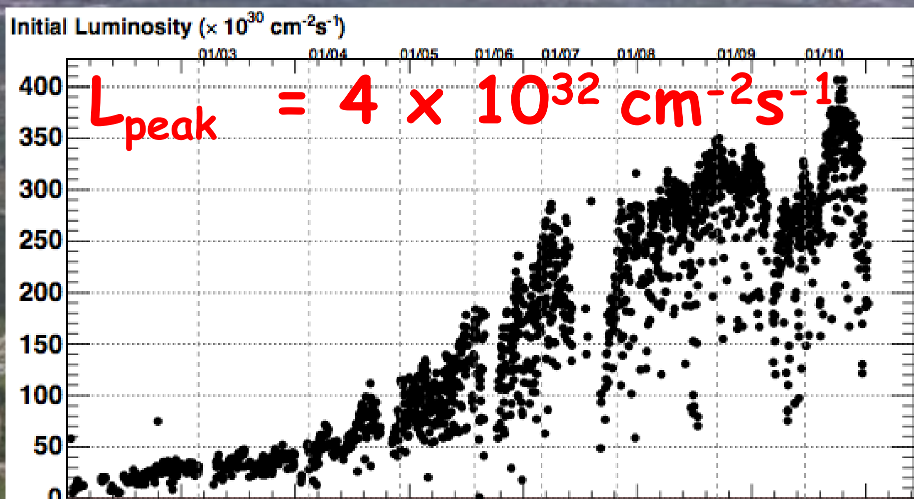
PRL **103,** 031801 (2009) PHYSICAL REVIEW LETTERS week ending 17 JULY 2009

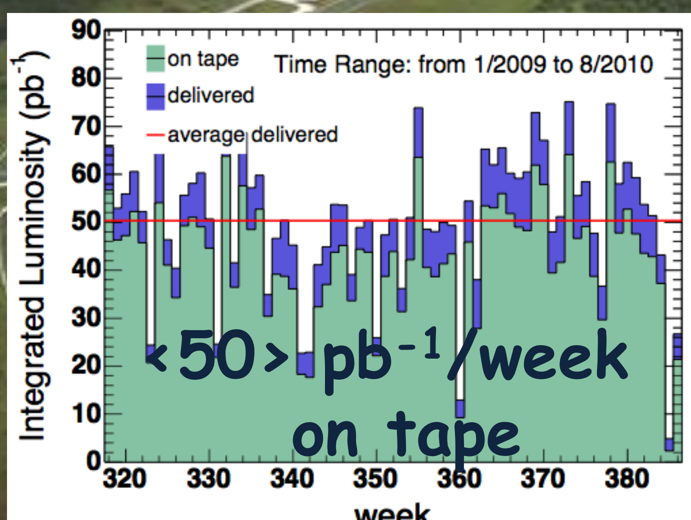
Observation of New Charmless Decays of Bottom Hadrons

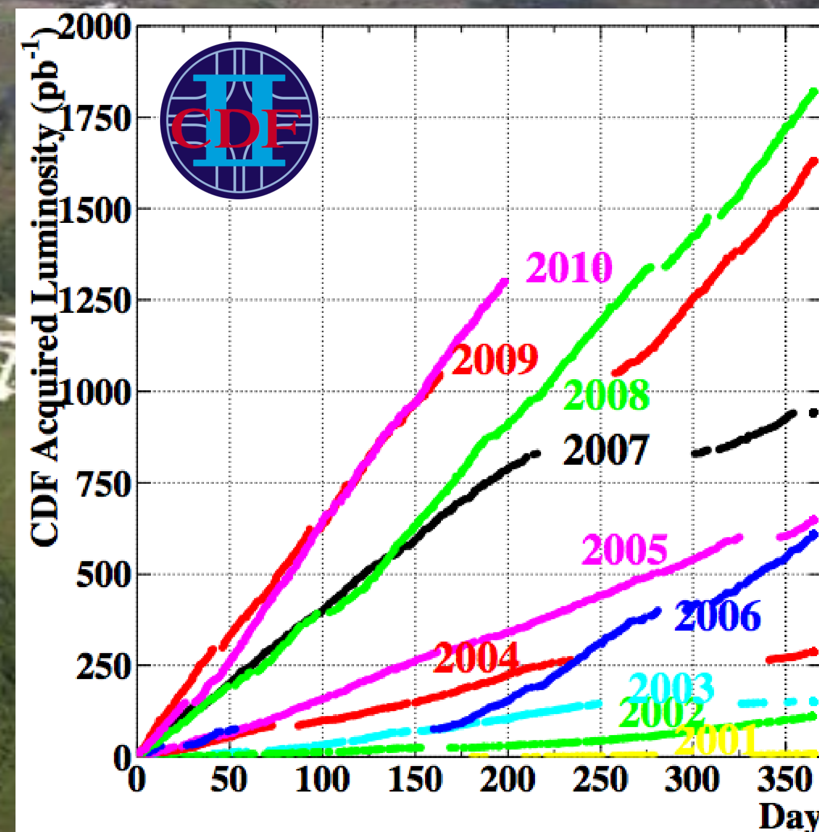
Today:
- News on $B_s^0 \to \phi\phi$
- Results on $B_{(s)}^0 \to h^+h^-$
- Prospects

“No Country for Old Colliders”

TeVatron: superconducting proton-synchrotron
36 (p) × 36 ($\bar{p}$) bunches collide every 396 ns at $\sqrt{s}$ = 1.96 TeV







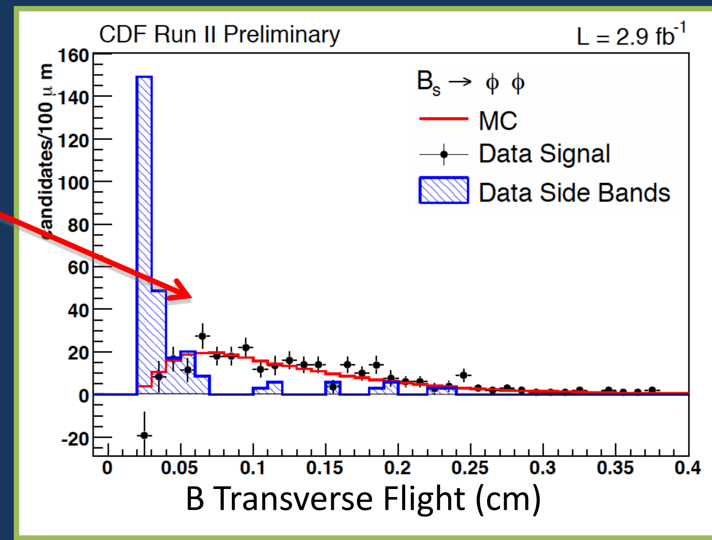
The CDF (hadronic) trigger…

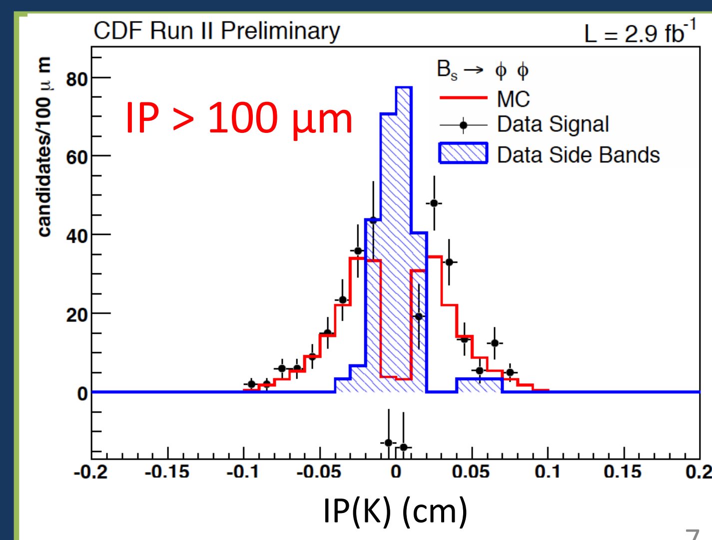
$\sigma_{p\bar{p}\to b\bar{b}X} \approx 50\ \mu b$ vs $\sigma_{p\bar{p}\to X} \approx 60\ mb$

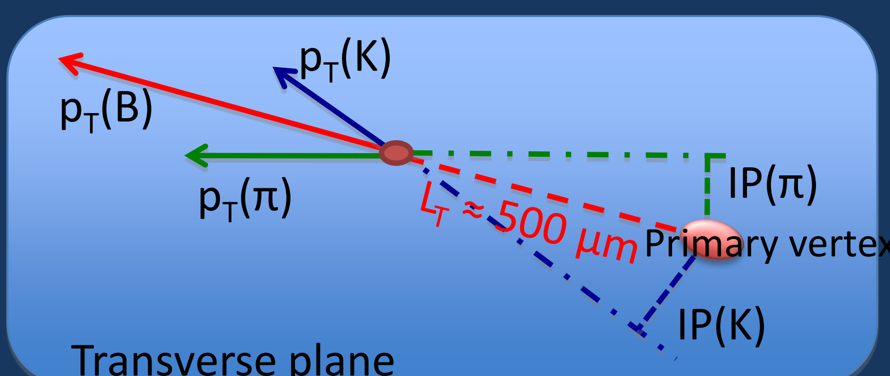
$\langle\tau(B)\rangle \approx 1.5$ ps: in the lab frame B flights ≥500 μm: a **powerful signature accesible at trigger level**, that requires:

- ✓ high resolution vertex detector
- ✓ read out silicon (212 K channels)
- ✓ do pattern recognition and track fitting

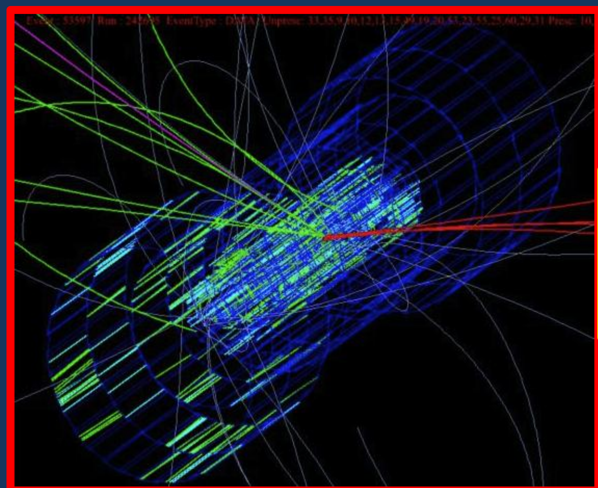
SVT: within 25 μs, IP resolution 48 μm!

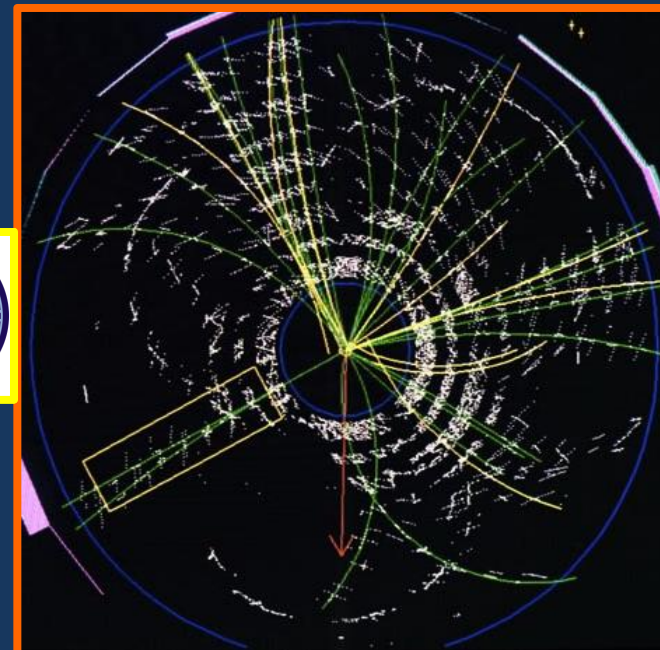






… and tracker



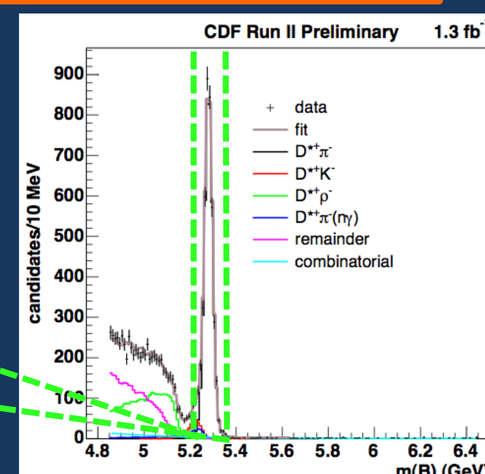


1.4T in 132 cm lever-arm.

6 silicon + **96 drift chamber** samplings.

1st layer 1.5 cm from beam

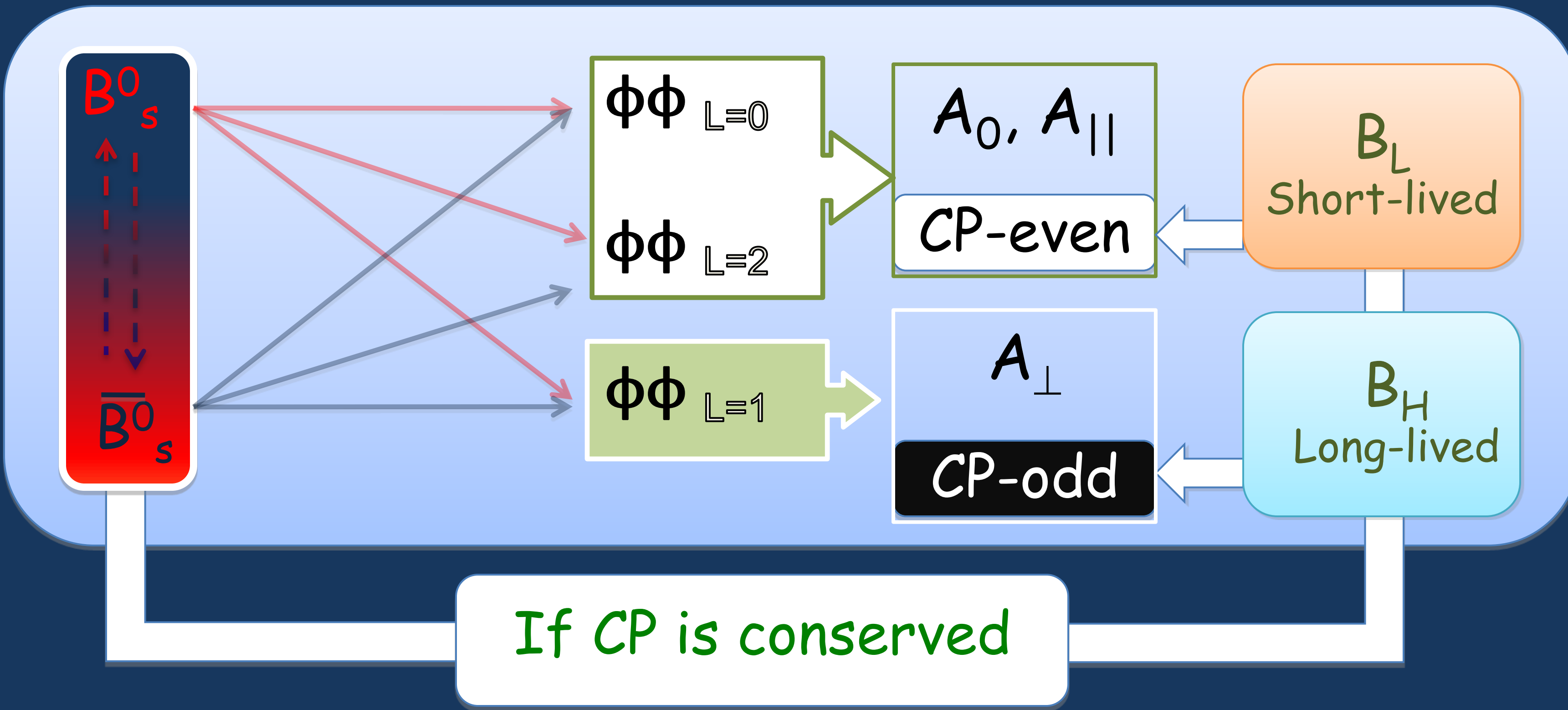
$$\delta p_t / p_t^2 = 10^{-3}\ [(GeV/c)^{-1}]$$



$$B_s{}^0 \rightarrow \phi\phi$$

The Vector-Vector Richness...

B^0_s (Pseudoscalar) → φ (Vector) φ (Vector)



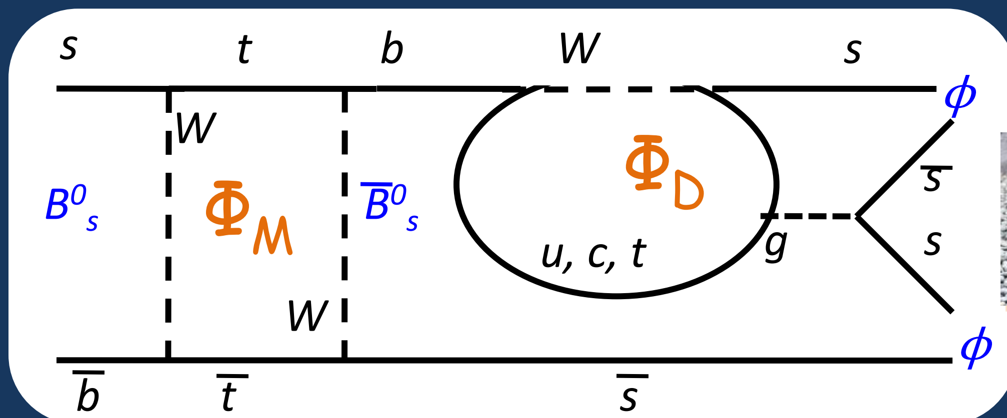
A_0: logitudinal polarization amplitude
$A_{||}$: parallel polarization amplitude
$A_\perp$: transverse polarization amplitude

$B_{L(H)}$: light (heavy) mass eigeinstate

…and (loop's) Potential

In principle, all may be mixed by a **CP-violating phase**:

$$\Phi_s = \Phi_M - \Phi_D$$



SM: dominated by top, $\Phi_M \cong \Phi_D \cong 2\arg(V_{tb}V_{ts}{}^*)$ and $\Phi_s \cong 0.0041 \pm 0.0008$

NP??? $\Phi_s \neq 0$

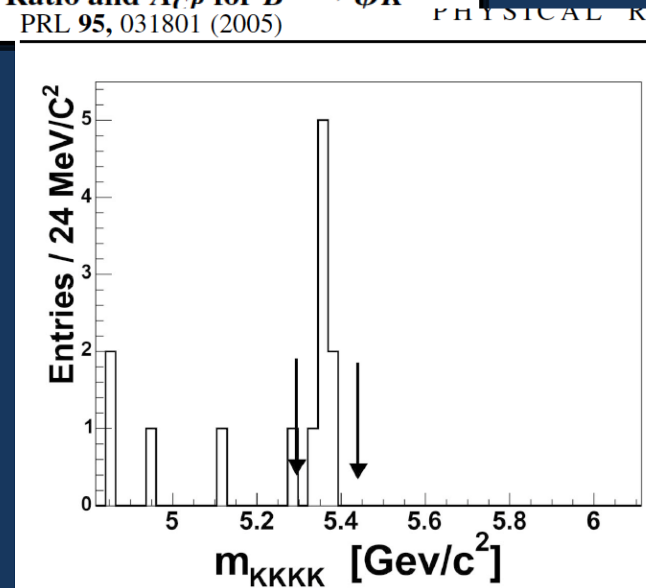
independent probe on **sin2βs** to be compared with tree-dominated $B^0{}_s \rightarrow J/\psi\phi$ determination (NP in Φ_M only)

$B_s^0 \to \phi\phi$: a CDF privilege

First (and only) evidence, CDF 2005 180 pb^{-1},
looking at $B_s^0 \to \phi\phi \to [K^+K^-]\,[K^+K^-]$

PRL **95,** 031801 (2005) PHYSICAL REVIEW LETTERS week ending 15 JULY 2005

Evidence for $B_s^0 \to \phi\phi$ Decay and Measurements of Branching Ratio and A_{CP} for $B^+ \to \phi K^+$



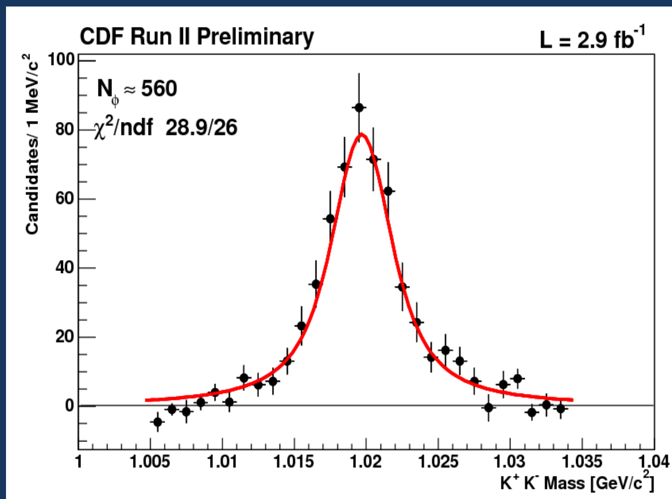
8 signal events

$$BR = [14^{+6}_{-5}(\text{stat}) \pm 6(\text{syst})] \times 10^{-6}$$

Theoretical prediction:
QCDf: $(19.5 \pm 1.0^{+13.1}_{-8.0}) \times 10^{-6}$ NPB 774, 64 (2007)
pQCD: $(35.3^{+8.3}_{-6.9}{}^{+16.7}_{-10.2}) \times 10^{-6}$ PRD 76, 074018 (2007)

2009: $B_s^0 \rightarrow \phi\phi$ in 2.9 fb^{-1}

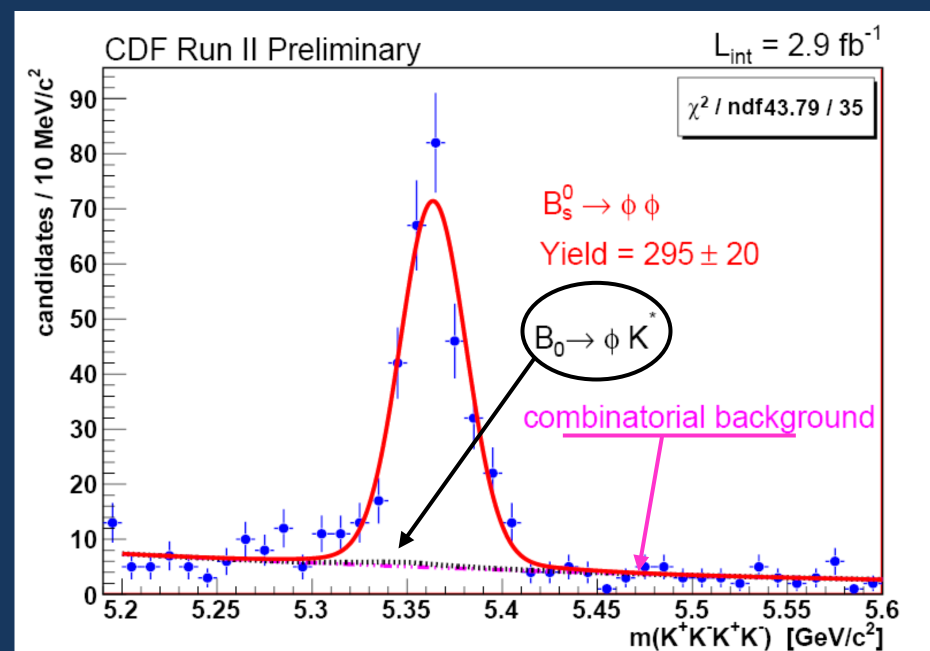
Take $|m_{[KK]}-m_{\phi(1020)}|<15$ MeV/c^2



Optimized selection

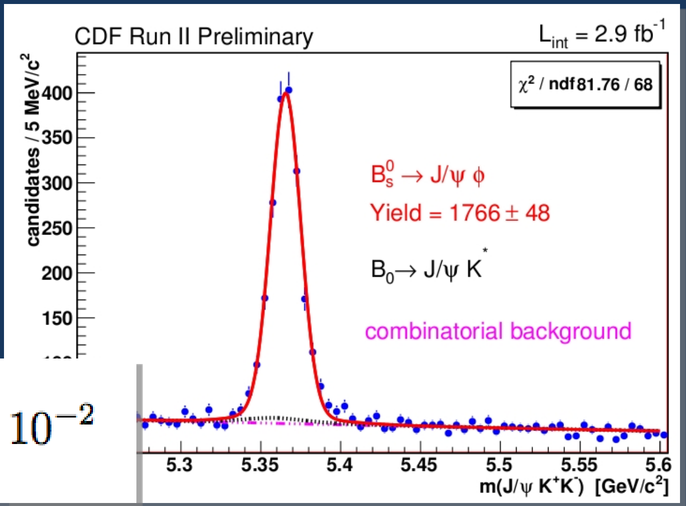
L_{xy}^B	[μm]	> 330
$p_{T\,min}^K$	[GeV/c]	> 0.7
p_T^ϕ	[GeV/c]	
χ^2_{xy}		< 17
d_0^B	[μm]	< 65
$d_0^{\phi max}$	[μm]	> 85
$p_T^{J/\psi}$	[GeV/c]	

$B_s^0 \rightarrow \phi K^*$ reflection ~3%, no other peaking bkg from simulation of B_s^0 or Λ_b decays



Branching Ratio update

Use $B^0_s \to J/\psi\phi$ with the same trigger selection for normalization, avoid dependence on fragmentation probabilities f_s/f_d



$$\frac{BR(B^0_s \to \phi\phi)}{BR(B^0_s \to J/\psi\phi)} = [1.78 \pm 0.14(stat) \pm 0.20(syst)] \cdot 10^{-2}$$

Using $BR(B^0_s \to J/\psi\phi)$ from PDG, updated to current values of f_s/f_d :

$$BR(B^0_s \to \phi\phi) = [2.40 \pm 0.21(stat) \pm 0.27(syst) \pm 0.82(BR)] \cdot 10^{-5}$$

CDF-PUB-10064 (2010)

Previous CDF result $(1.4^{+0.6}_{-0.5} \pm 0.6) \times 10^{-5}$

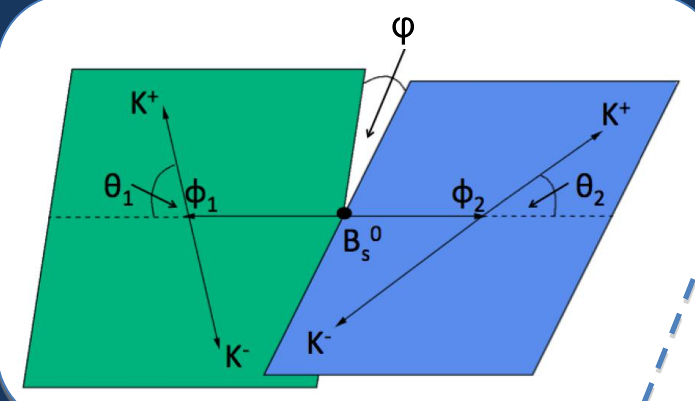
Theoretical prediction:

QCDf: $(1.95 \pm 1.0^{+1.31}_{-0.80}) \times 10^{-5}$ NPB 774, 64 (2007)

pQCD: $(3.53^{+0.83}_{-0.69}{}^{+1.67}_{-1.02}) \times 10^{-5}$ PRD 76, 074018 (2007)

World's 1° Polarization Measurement

Measure polarization amplitudes from untagged time-integrated differential decays rate as a function of kaon decay angles (θ_1,θ_2) and the angle between the two decay planes (φ)



Fix $\Phi_s = 0$

$$\frac{d^3\Lambda(\vec{\omega})}{d\vec{\omega}} = \frac{9}{32\pi}\frac{1}{\tilde{W}}\left[\tilde{\mathcal{F}}_{\rm e}(\vec{\omega}) + \tilde{\mathcal{F}}_{\rm o}(\vec{\omega})\right]$$

$$\tilde{\mathcal{F}}_{\rm e} = \frac{2}{\Gamma_{\rm L}}\left[|A_0|^2 f_1(\vec{\omega}) + |A_{\|}|^2 f_2(\vec{\omega}) + |A_0||A_{\|}|\cos\delta_{\|} f_5(\vec{\omega})\right],$$

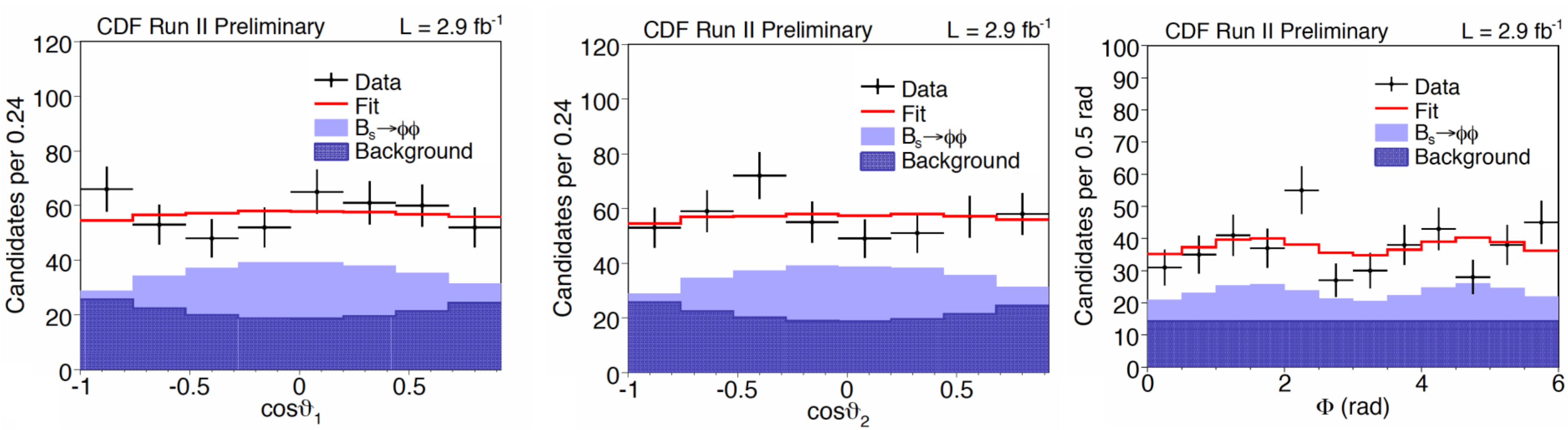
$$\tilde{\mathcal{F}}_{\rm o} = \frac{2}{\Gamma_{\rm H}}|A_{\perp}|^2 f_3(\vec{\omega}),$$

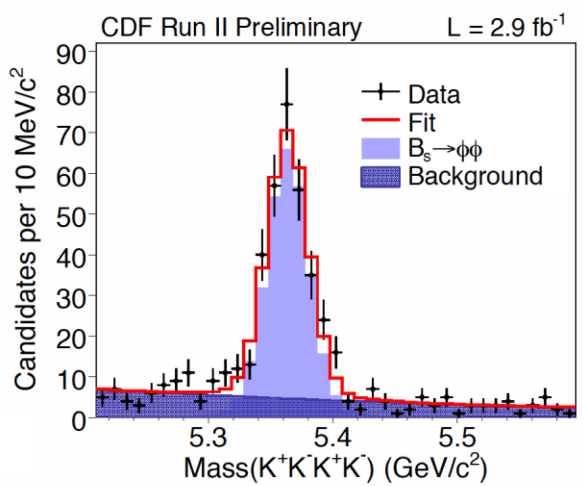
PDG

observables

1° Polarization Measurement

Unbinned Maximum Likelihood fit to Mass and Angles





- Acceptance correction from simulation
- background modeled on sideband (polynomials) and fitted in the whole mass range

Polarization Results

- Cross check with $B^0_s \to J/\psi\phi$ sample used in BR measurement (same trigger, ~1800 ev.) consistent with WA within stat. uncertainties

- Systematics dominated by:
  - Non-resonant contributions ($B^0_s \to \phi(KK)$ and $B^0_s \to \phi f_0$): ~1%
  - Dependence of acceptance on $\Delta\Gamma_s$: ~1%
  - Uncertainties of $\tau_{L(H)}$: ~1%

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

CDF-PUB-10120 (2010)

…a little insight the Puzzle

Naïve expectation: $|A_0|^2 >> |A_{||}|^2 \sim |A_\perp|^2$

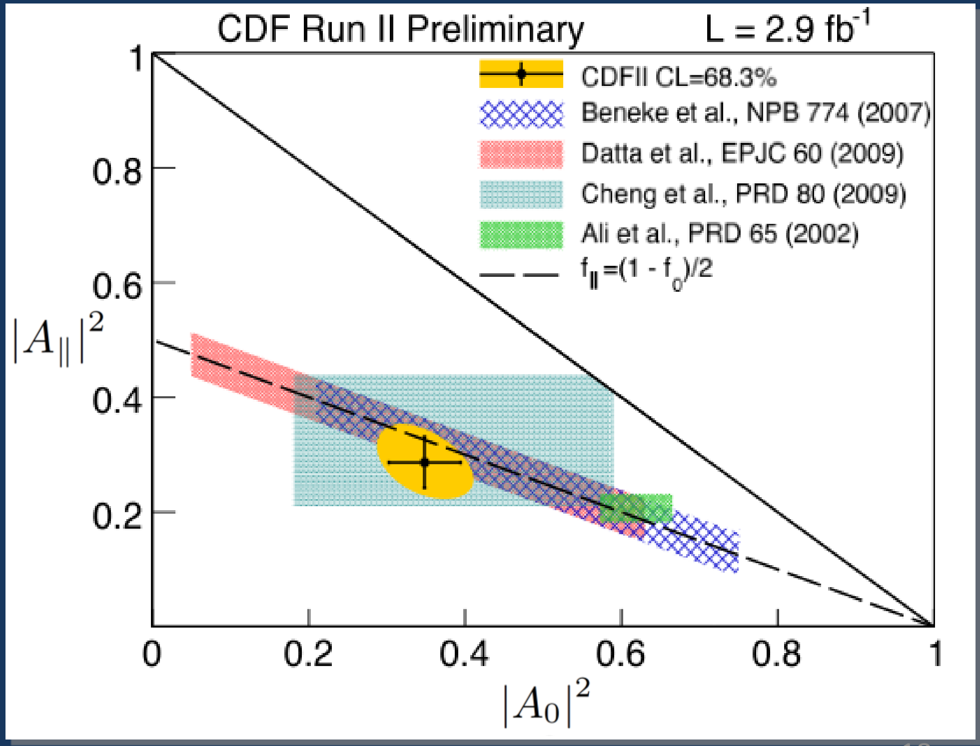
- V-A nature of weak interaction and conservation helicity in QCD

Experimentally violated in penguin decays (BaBar, Belle):

- PA [e.g. PL B601, 151 (2004); NP B774, 64 (2007)]
- FSI [PL B597, 291 (2004) + many others]
- NP? [PR D76, 075015 (2007)]

Agreement with QCDf prediction

	$\cos\delta_{\|\|}$	
CDF	$-0.91^{+0.15}_{-0.13}(stat)\pm 0.09(syst)$	
QCDf	$-0.80^{+0.31}_{-0.16}$	NP B774 (2007)
QCDp	$0.27^{+0.09}_{-0.27}$	PR D76 (2007)



A look at the future

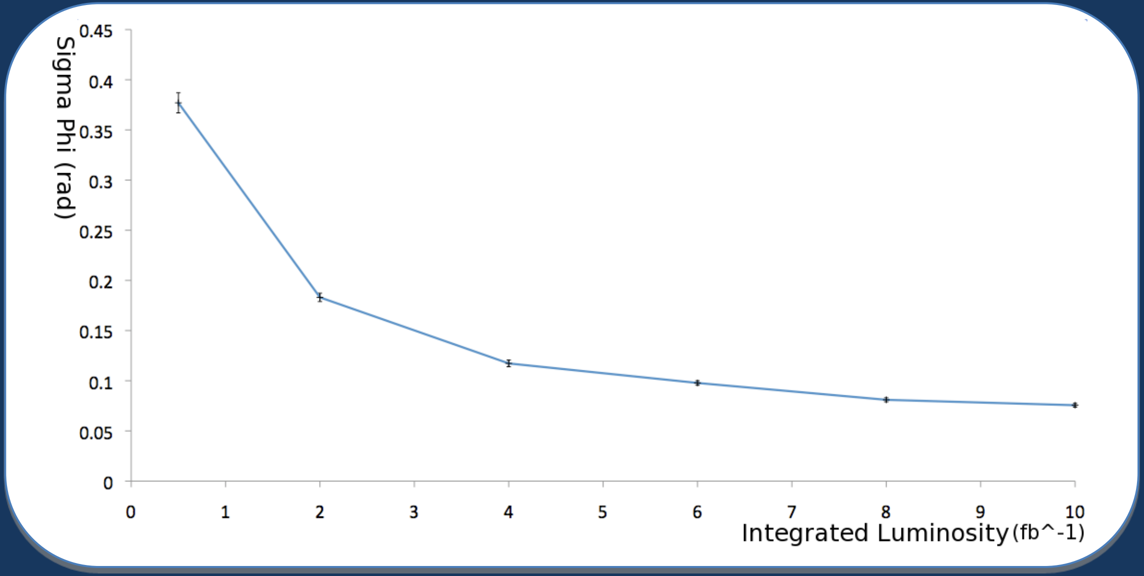
CDF: 10 fb^{-1} of data on tape expected in 2011

$\Delta\Gamma_s$ measurement from penguin, sensitivity O(10%)

to compare with (tree-level) $B^0_s \rightarrow J/\psi\phi$ determination

LHCb: with 2 fb^{-1}, 6.2K events expected (S/B≈0.8 @90% CL),

$\sigma(\Phi_s)$ = 0.14-0.18 rad [LHCB-PUB-2009-025]



$$B_{(s)}^{0} \rightarrow h^{+}h'^{-}$$

2-body charmless decays

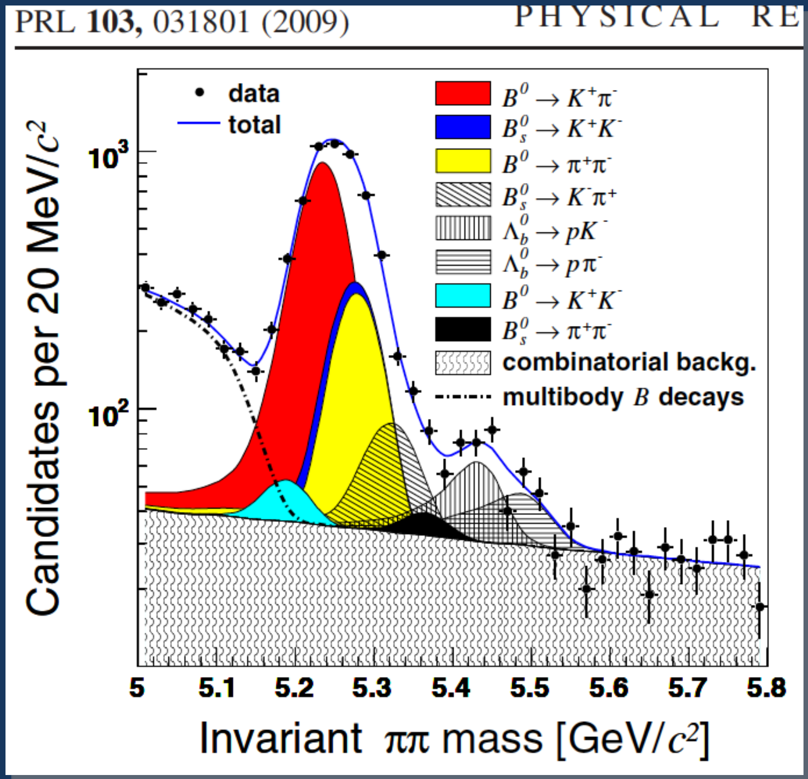
B^0 and $B^0_s \to K^+K^-$, $\pi^+\pi^-$ and $K\pi$ sensitive to γ (PL B459, 306 (1999)) and NP (PL B492, 297 (2000), PL B621,126, (2005)). Theory and exp. uncertainties largely cancel thanks to flavor symmetries and similar final states.

CDF has **world's largest sample**:
4K $B^0 \to K^+\pi^-$ and 1.3K $B^0_s \to K^+K^-$ per fb^{-1}.

Unique joint access to large samples of charmless B^0 and B^0_s

Challenging analysis but fruitful:

- ✓ observation of **4 new modes** (so far)
- ✓ unique access to **direct CPV in B^0_s**
- ✓ competitive in **direct CPV in B^0**



CDFII results (1 fb^{-1})

PRL **103,** 031801 (2009) PHYSICAL REVIEW LETTERS week ending 17 JULY 2009

Observation of New Charmless Decays of Bottom Hadrons

	Mode	Relative $\mathcal{B}$	Absolute $\mathcal{B}(10^{-6})$
✓	$B_s^0 \to K^- \pi^+$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0 \to K^-\pi^+)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.071 \pm 0.010 \pm 0.007$	$5.0 \pm 0.7 \pm 0.8$
✓	$B_s^0 \to \pi^+ \pi^-$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0 \to \pi^+\pi^-)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.007 \pm 0.004 \pm 0.005$	$0.49 \pm 0.28 \pm 0.36$ (<1.2 at 90% C.L.)
	$B^0 \to K^+ K^-$	$\frac{\mathcal{B}(B^0 \to K^+K^-)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.020 \pm 0.008 \pm 0.006$	$0.39 \pm 0.16 \pm 0.12$ (<0.7 at 90% C.L.)
✓	$\Lambda_b^0 \to p K^-$	$\frac{f_\Lambda}{f_d}\frac{\mathcal{B}(\Lambda_b^0 \to pK^-)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.066 \pm 0.009 \pm 0.008$	$5.6 \pm 0.8 \pm 1.5$
✓	$\Lambda_b^0 \to p \pi^-$	$\frac{f_\Lambda}{f_d}\frac{\mathcal{B}(\Lambda_b^0 \to p\pi^-)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.042 \pm 0.007 \pm 0.006$	$3.5 \pm 0.6 \pm 0.9$

- ▯ world's first
- ▯ world's best

submitted soon

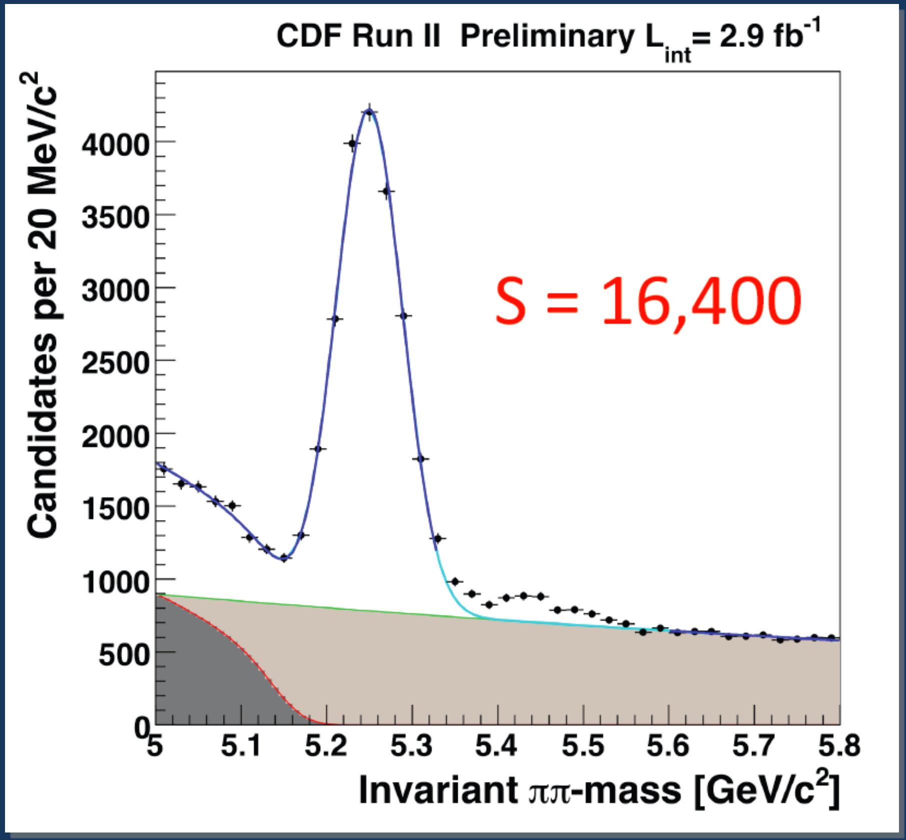
	Mode	Relative $\mathcal{B}$	Absolute $\mathcal{B}(10^{-6})$
	$B^0 \to \pi^+\pi^-$	$\frac{\mathcal{B}(B^0 \to \pi^+\pi^-)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.259 \pm 0.017 \pm 0.016$	$5.02 \pm 0.33 \pm 0.35$
✓	$B_s^0 \to K^+K^-$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0 \to K^+K^-)}{\mathcal{B}(B^0 \to K^+\pi^-)} = 0.347 \pm 0.020 \pm 0.021$	$24.4 \pm 1.4 \pm 3.5$

	Mode	CP–asymmetry
	$B^0 \to K^+\pi^-$	$\frac{\mathcal{B}(\overline{B}^0 \to K^-\pi^+) - \mathcal{B}(B^0 \to K^+\pi^-)}{\mathcal{B}(\overline{B}^0 \to K^-\pi^+) + \mathcal{B}(B^0 \to K^+\pi^-)} = -0.086 \pm 0.023 \pm 0.009$
✓	$B_s^0 \to K^-\pi^+$	$\frac{\mathcal{B}(\overline{B}_s^0 \to K^+\pi^-) - \mathcal{B}(B_s^0 \to K^-\pi^+)}{\mathcal{B}(\overline{B}_s^0 \to K^+\pi^-) + \mathcal{B}(B_s^0 \to K^-\pi^+)} = +0.39 \pm 0.15 \pm 0.08$
✓	$\Lambda_b^0 \to pK^-$	$\frac{\mathcal{B}(\Lambda_b^0 \to pK^-) - \mathcal{B}(\overline{\Lambda}_b^0 \to \overline{p}K^+)}{\mathcal{B}(\Lambda_b^0 \to pK^-) + \mathcal{B}(\overline{\Lambda}_b^0 \to \overline{p}K^+)} = +0.37 \pm 0.17 \pm 0.03$
✓	$\Lambda_b^0 \to p\pi^-$	$\frac{\mathcal{B}(\Lambda_b^0 \to p\pi^-) - \mathcal{B}(\overline{\Lambda}_b^0 \to \overline{p}\pi^+)}{\mathcal{B}(\Lambda_b^0 \to p\pi^-) + \mathcal{B}(\overline{\Lambda}_b^0 \to \overline{p}\pi^+)} = +0.03 \pm 0.17 \pm 0.05$

Next

5 fb^{-1} analysis in progress

- ✓ Expect observation of DCPV in B^0_s.
- ✓ DCPV in B^0 competitive with Belle.
- ✓ Precision measurement of rare modes' BR.
- ✓ Observe new modes? (aim at $B^0_s \rightarrow \pi^+\pi^-$)

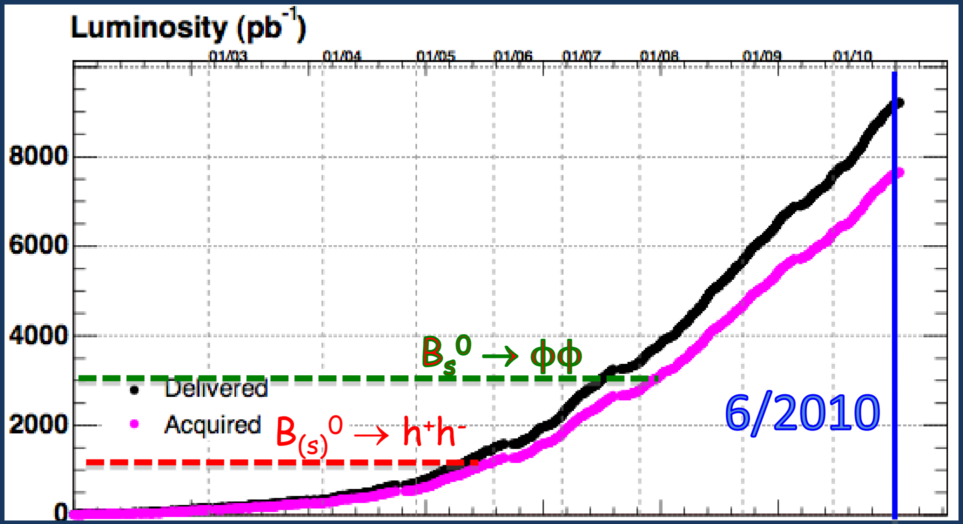


Conclusion

CDF keeps leading a rich and unique program in charmless B^0_s physics

Competitive results with B-factories in B^0 sector

- ✓ $B_s^0 \to \phi\phi$ – NP and Φ_s from $b \to s\bar{s}s$ penguin: ~halved BR uncertainty. 1st Polarization analysis.
- ✓ $B_{(s)}^0 \to h^+h^-$ - NP and constrain for γ from penguins: Many new decays observed - BR and DCPV measured. 5 fb^{-1} analysis in progress.



analyses steadily improving: exciting years of overlap with LHC exps. are coming

Backup

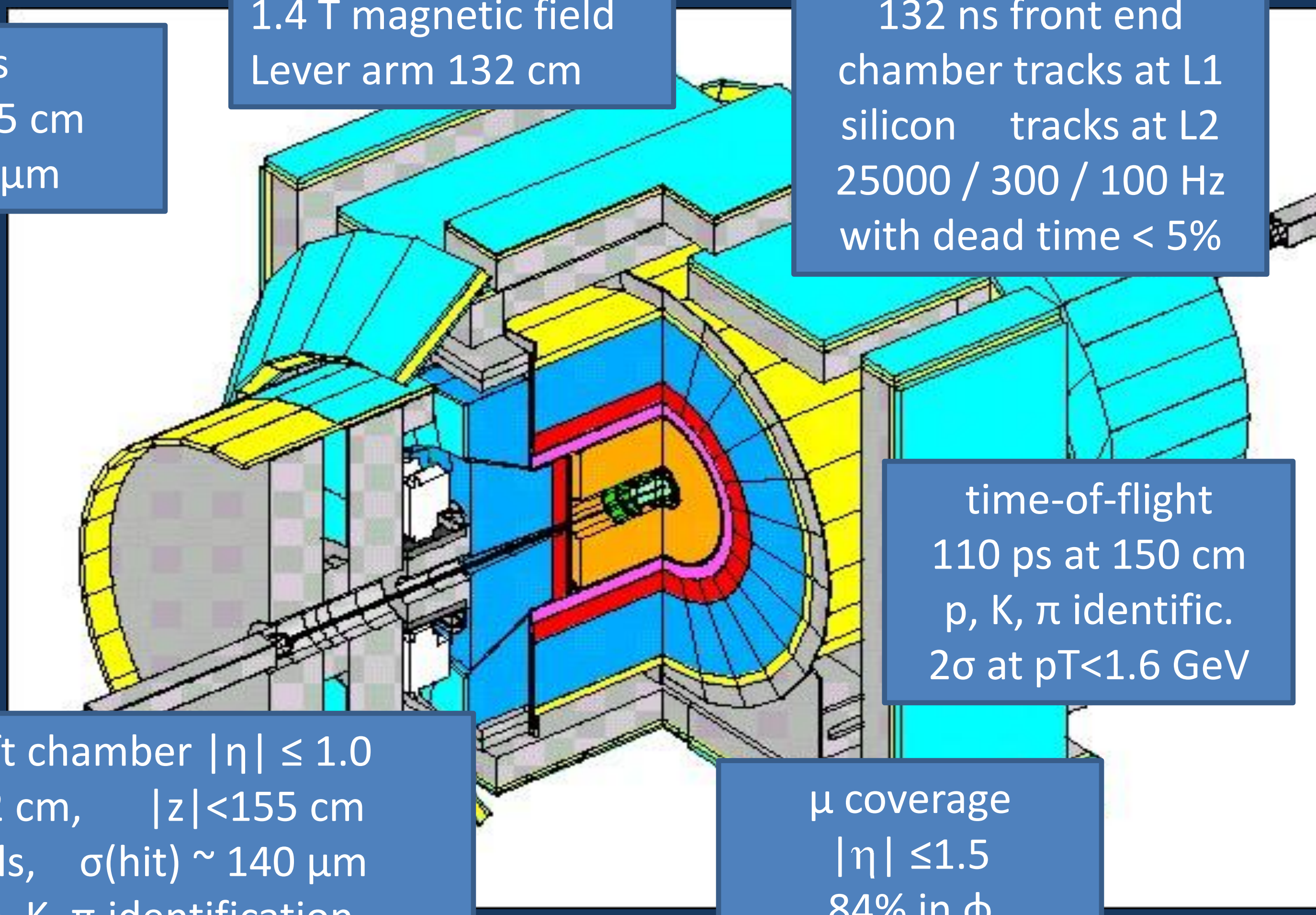
CDFII detector

7 to 8 silicon layers
$1.6 < r < 28$ cm, $|z|<45$ cm
$|\eta| \leq 2.0$ σ(hit) ~ 15 μm

1.4 T magnetic field
Lever arm 132 cm

132 ns front end
chamber tracks at L1
silicon tracks at L2
25000 / 300 / 100 Hz
with dead time < 5%

Some resolutions:
pT~0.15% pT (c/GeV)
J/Ψ mass ~14 MeV
IP~ 40 μm
(includes beam spot)



time-of-flight
110 ps at 150 cm
p, K, π identific.
2σ at pT<1.6 GeV

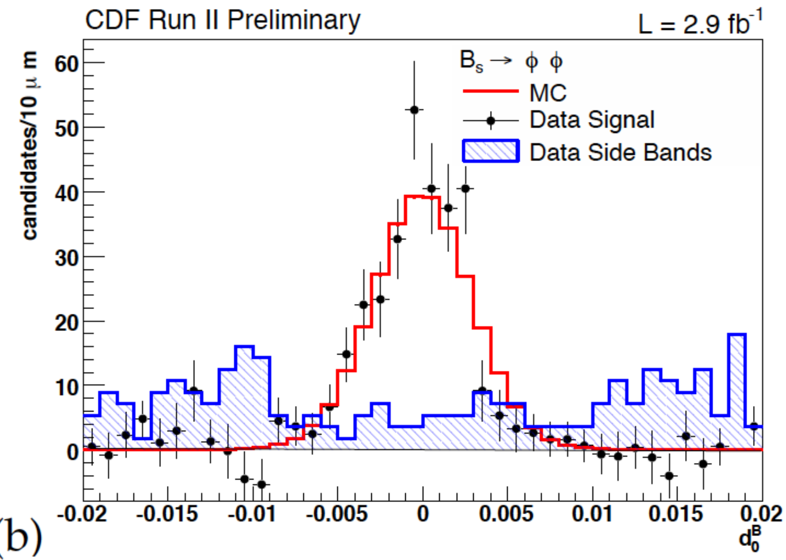
96 layer drift chamber $|\eta| \leq 1.0$
$44 < r < 132$ cm, $|z|<155$ cm
30k channels, σ(hit) ~ 140 μm
dE/dx for p, K, π identification

μ coverage
$|\eta| \leq 1.5$
84% in ϕ

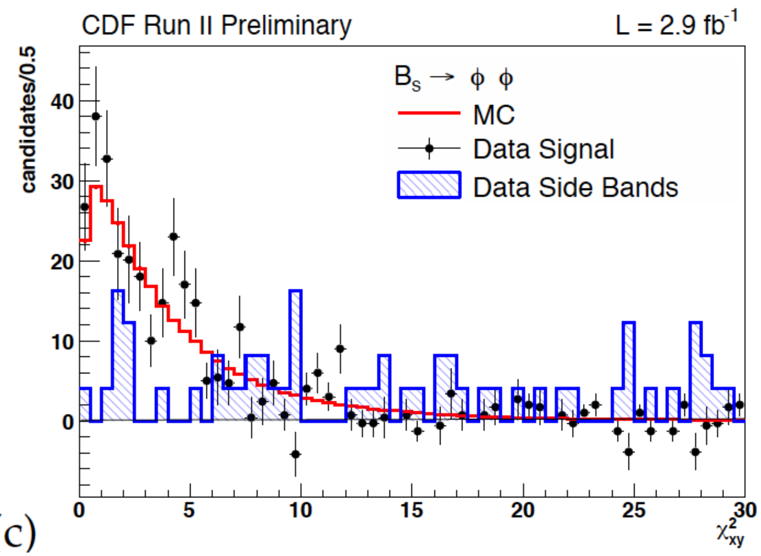
Hadronic Trigger details

	Level-1	Level-2	Level-3
	XFT tracks	SVT tracks	COT+SVXII tracks
B_CHARM_HIGHPT	opposite charge $p_T > 2.5\,\mathrm{GeV}/c$ $\Delta\varphi_6 < 135°$ $\sum p_T > 6.5\,\mathrm{GeV}/c$	opposite charge $p_T > 2.5\,\mathrm{GeV}/c$ $2° < \Delta\varphi_0 < 90°$ $\sum p_T > 6.5\,\mathrm{GeV}/c$ $120\,\mu\mathrm{m} < d_0 < 1000\,\mu\mathrm{m}$ $L_{xy} > 200\,\mu\mathrm{m}$	opposite charge $p_T > 2.5\,\mathrm{GeV}/c$ $2° < \Delta\varphi_0 < 90°$ $\sum p_T > 6.5\,\mathrm{GeV}/c$ $80\,\mu\mathrm{m} < d_0 < 1000\,\mu\mathrm{m}$ $L_{xy} > 200\,\mu\mathrm{m}$ $\lvert\Delta z_0\rvert < 5\,\mathrm{cm}$
B_CHARM_L1	opposite charge $p_T > 2.0\,\mathrm{GeV}/c$ $\Delta\varphi_6 < 135°$ $\sum p_T > 5.5\,\mathrm{GeV}/c$	opposite charge $p_T > 2.0\,\mathrm{GeV}/c$ $2° < \Delta\varphi_0 < 90°$ $\sum p_T > 5.5\,\mathrm{GeV}/c$ $120\,\mu\mathrm{m} < d_0 < 1000\,\mu\mathrm{m}$ $L_{xy} > 200\,\mu\mathrm{m}$	opposite charge $p_T > 2.0\,\mathrm{GeV}/c$ $2° < \Delta\varphi_0 < 90°$ $\sum p_T > 5.5\,\mathrm{GeV}/c$ $120\,\mu\mathrm{m} < d_0 < 1000\,\mu\mathrm{m}$ $L_{xy} > 200\,\mu\mathrm{m}$ $\lvert\Delta z_0\rvert < 5\,\mathrm{cm}$
B_CHARM_LOWPT	$p_T > 2.0\,\mathrm{GeV}/c$ $\Delta\varphi_6 < 90°$	$p_T > 2.0\,\mathrm{GeV}/c$ $\Delta\varphi_0 < 90°$ $120\,\mu\mathrm{m} < d_0 < 1000\,\mu\mathrm{m}$ $L_{xy} > 200\,\mu\mathrm{m}$	$p_T > 2.0\,\mathrm{GeV}/c$ $2° < \Delta\varphi_0 < 90°$ $120\,\mu\mathrm{m} < d_0 < 1000\,\mu\mathrm{m}$ $L_{xy} > 200\,\mu\mathrm{m}$ $\lvert\Delta z_0\rvert < 5\,\mathrm{cm}$

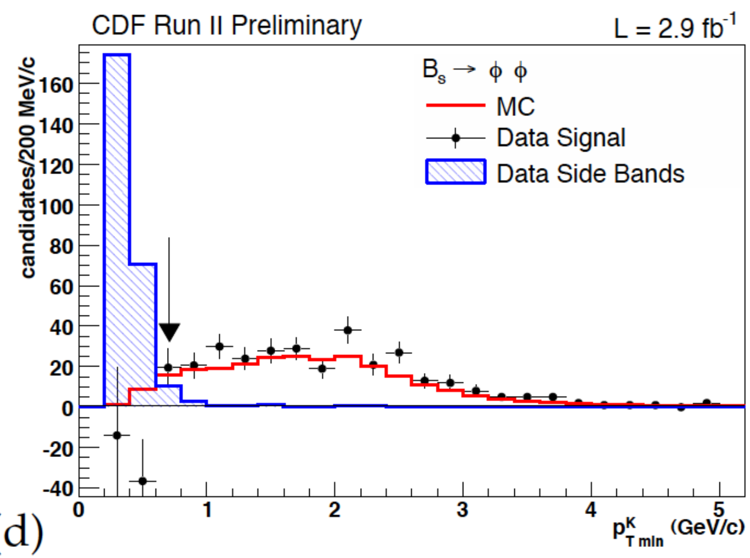
$B_s^0 \to \phi\phi$ optimization



(b)



(c)



(d)

Variables		Requirements $B_s \to \phi\phi$	Requirements $B_s \to J/\psi\phi$
L_{xy}^{B}	[μm]	> 330	> 290
$p_{T\,\mathrm{min}}^{K}$	[GeV/c]	> 0.7	
$p_{T\,\mathrm{min}}^{\phi}$	[GeV/c]		> 1.4
χ_{xy}^{2}		< 17	< 15
d_0^B	[μm]	< 65	< 80
$d_{0\,\mathrm{max}}^{\phi}$	[μm]	> 85	
$p_{T\ \mathrm{min}}^{J/\psi}$	[GeV/c]		> 2.0

Branching Ratio update: strategy

$$N_{\phi\phi} = 295 \pm 20(\text{stat}) \pm 12(\text{syst})$$
$$N_{J/\psi\phi} = 1766 \pm 48(\text{stat}) \pm 41(\text{syst})$$

Fit to mass in data

$$\frac{\mathrm{BR}(B_s^0 \to \phi\phi)}{\mathrm{BR}(B_s^0 \to J/\psi\phi)} = \frac{N_{\phi\phi}}{N_{\psi\phi}} \frac{\mathrm{BR}(J/\psi \to \mu\mu)}{\mathrm{BR}(\phi \to KK)} \frac{\epsilon_{\psi\phi}}{\epsilon_{\phi\phi}} \epsilon^{\mu}_{\psi\phi},$$

PDG

Trigger and selection acceptance/efficiency from simulation

Muon-ID efficiency from control samples of data

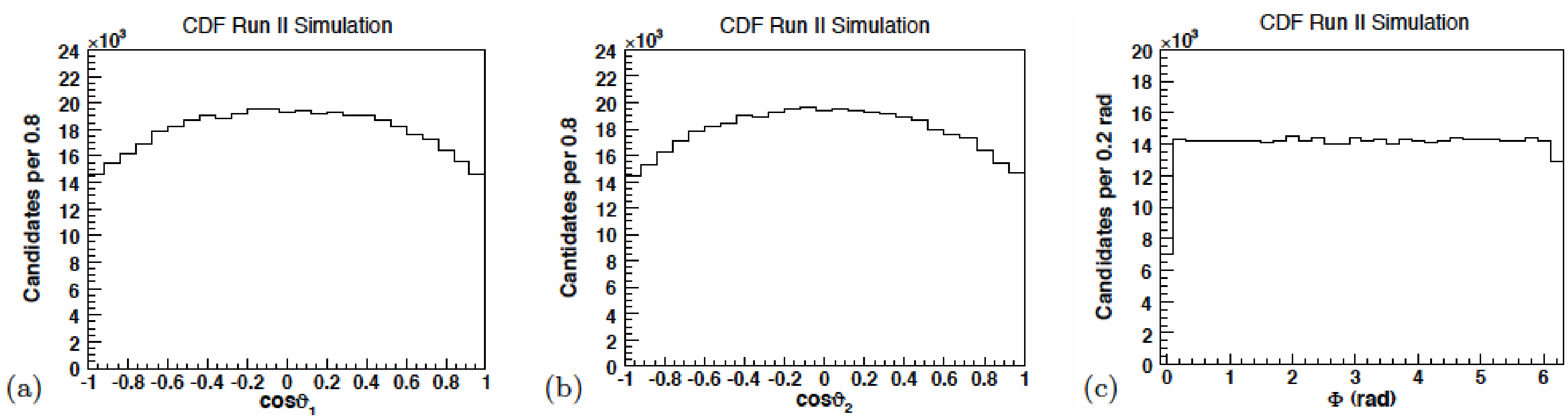
$$\frac{\epsilon_{\psi\phi}}{\epsilon_{\phi\phi}} = 0.939 \pm 0.030 \pm 0.009 \qquad \epsilon^{\mu}_{\psi\phi} = 0.8695 \pm 0.0044(\text{stat})$$

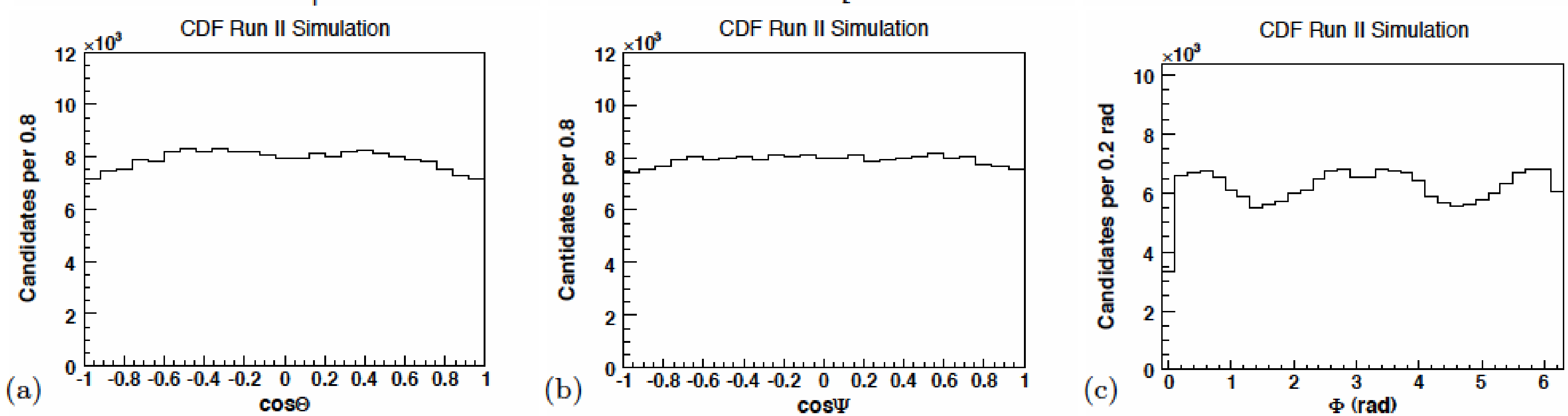
Acceptance

- model the **angular acceptance** for both $B_s^0 \to \phi\phi$ and $B_s^0 \to J/\psi\phi$

respectively 400K and 200K events of **PHSP** decay model:

§ it performs the decay using only phase space,
§ it averages all final state spin values without taking into account any spin correlations between the two vectors in the final state
§ it generates uniform angular distribution

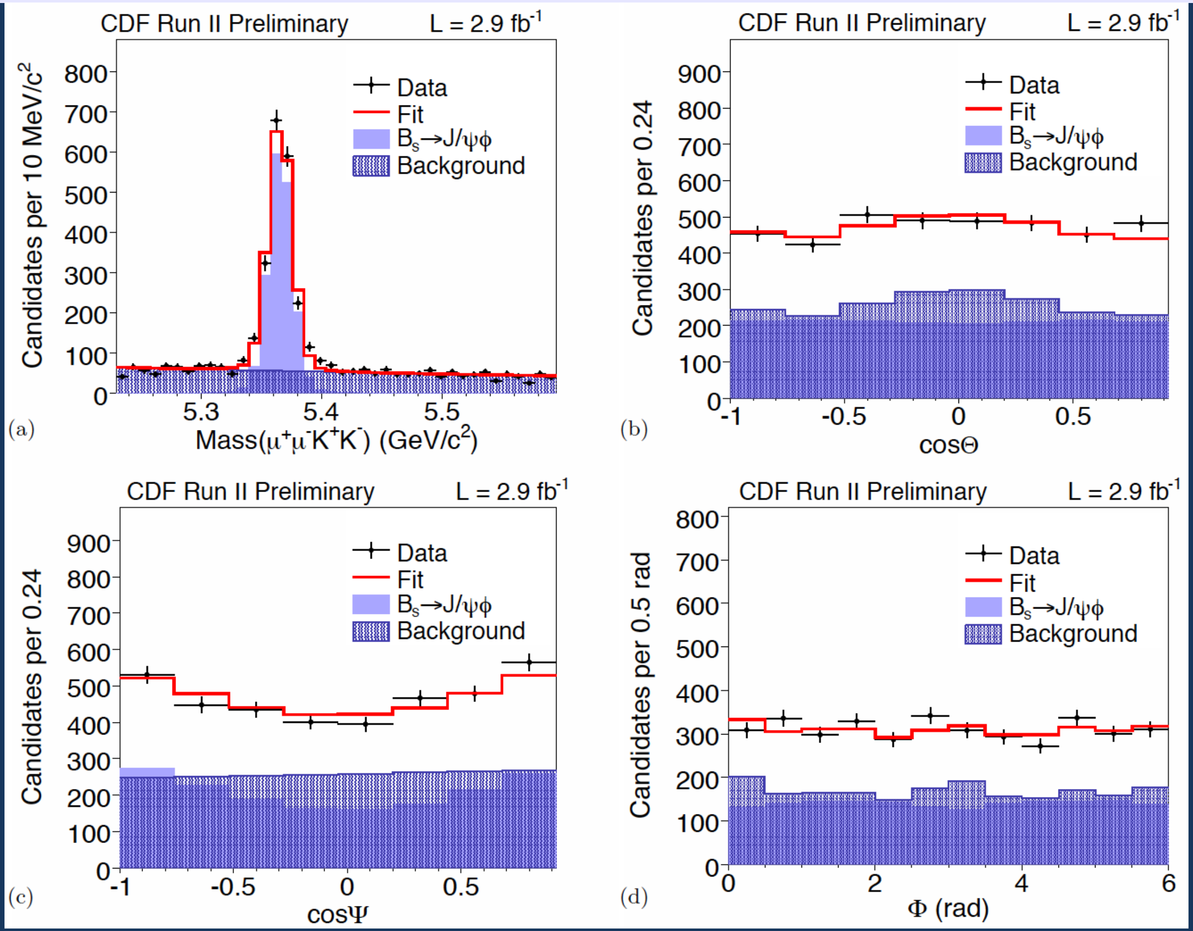




Control Sample

Control sample (same trigger selection): $B_s^0 \to J/\psi\phi \to [K^+K^-][\mu^+\mu^-]$

	$\lvert A_0\rvert^2$	$\lvert A_\parallel\rvert^2$
Main Analysis fitter	0.534 ± 0.019	0.220 ± 0.025
CDFII [PRL100, 121803 (2008)]	0.531 ± 0.020	0.239 ± 0.029
D0 [PRL102, 032001 (2009)]	0.555 ± 0.027	0.244 ± 0.032



Systematic Tables

	$B_s^0 \to \phi\phi$	$B_s^0 \to J/\psi\phi$
	$\Delta N_{\phi\phi}/N_{\phi\phi}$	$\Delta N_{J/\psi\phi}/N_{J/\psi\phi}$
fit range	3%	-
signal parametrization	3%	2%
background subtraction: error on BRs	1%	1%
	$\Delta\varepsilon_{\phi\phi}/\varepsilon_{\phi\phi}$	$\Delta\varepsilon_{J/\psi\phi}/\varepsilon_{J/\psi\phi}$
polarization in MC	7%	6%
	$\Delta\varepsilon_{\phi\phi}/\varepsilon_{J/\psi\phi}$	
XFT particle dep.	4%	
p_T reweight	0.9%	
	$\Delta\varepsilon_{\mu}/\varepsilon_{\mu}$	
η parametrization & correlation	0.9%	

Table 16: *Contributions to the total relative uncertainty from the systematic uncertainty sources considered.*

BR measurement

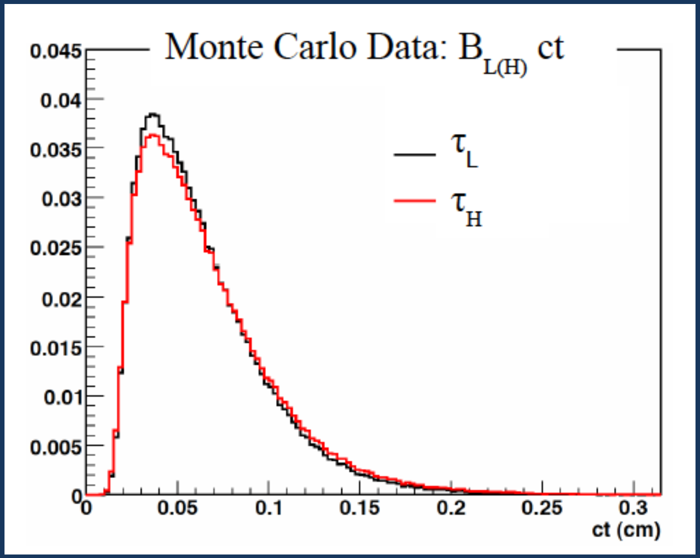
Polarization measurement

	$\lvert A_0\rvert^2$ syst	$\lvert A_\parallel\rvert^2$ syst	$\lvert A_\perp\rvert^2$ syst	$\cos\delta_\parallel$ syst
MC reweight	±0.003	±0.001	±0.002	±0.007
Acceptance binning	±0.001	±0.001	±0.000	±0.004
Acceptance Model	±0.005	±0.002	±0.003	±0.005
Background Model	±0.001	±0.001	±0.002	±0.009
Acceptance ct-dependence	±0.000	±0.001	±0.001	±0.004
Reflection component	±0.008	±0.002	±0.006	±0.019
Non-resonant contribution	±0.013	±0.003	±0.010	±0.084
Satellite peak	±0.004	±0.000	±0.004	±0.020
Acceptance $\Delta\Gamma$-dependence	±0.009	±0.009	±0.016	±0.011
$\tau_{\mathrm{L(H)}}$ uncertainties	±0.008	±0.006	±0.017	
CP-violation	±0.002	±0.001	±0.003	±0.009
total	±0.021	±0.011	±0.027	±0.090

$\Delta\Gamma_s$ effect on the Acceptance

2 effects:

1. Normalization of the decay rate
2. Non uniform acceptance with the B_s^0 ct introduced by the displaced tracks trigger



The MC reproduces the ct acceptance of the trigger and selection reasonably well.

Systematic: full shift expected in measured polarization assuming a value for $\Delta\Gamma_s$ equal to the world average $+1\sigma$