BNM2006, September 14, 2006

$\Upsilon(5S)$: present and future

- $\Upsilon(5S)$ event scenario
- SM and New Physics with $\Upsilon(5S)$
  - present
  - near future
  - far future

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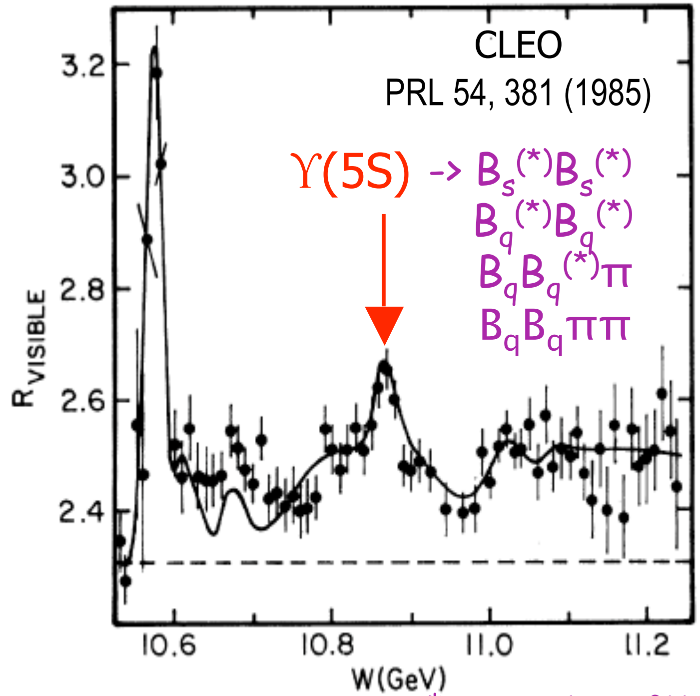
$\Upsilon(5S)$ physics outline

B_s meson: familiar but different

- Similarity (hadronic) w $B_{u/d}$:
  Spectator dominates, incl. some CP modes
  -> well-defined expectation on overall
  properties (lifetime, semileptonic)
  -> test quark-hadron duality,
  -> fine-tune HQ hadronic models
  -> spectroscopy (masses, event fractions)
- Difference (CKM):
  high mixing rate
  low CP-asymmetry
  $\Delta\Gamma_{CP}/\Gamma = O(10\%)$ -> differences in
  CP, flavor eigenstates

-> windows to New Physics in suppressed modes, CP asym

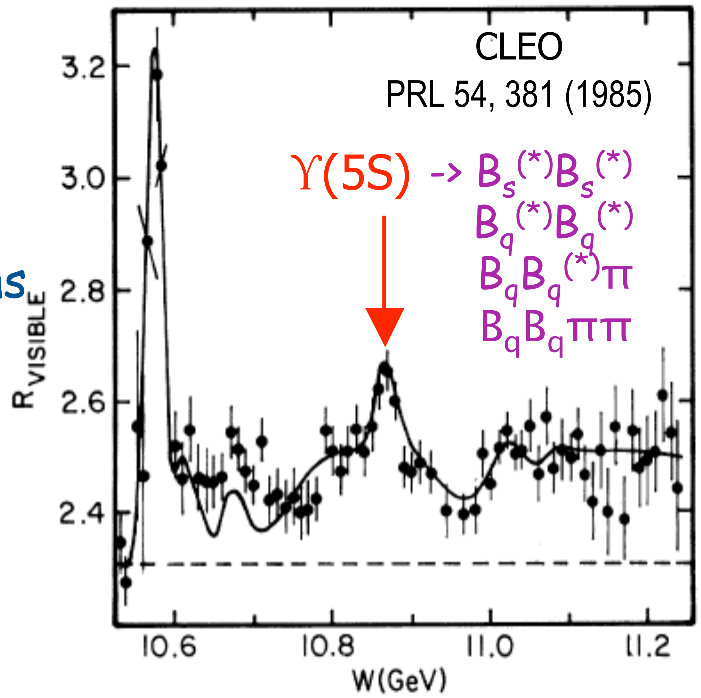


$B_s^* \to B_s\gamma$ (100%)

K. Kinoshita

Why study B_s in e^+e^- -> Υ(5S) vs hadron collider?

- Pro
  ~zero uncertainty on production model
  trigger efficiency -> 100%
  high efficiencies: high multiplicities, gamma
  direct bb count -> absolute branching fractions
  exclusive pair events -> inclusive rates
  near-threshold -> partial reconstruction
  well-understood detector, Υ(4S) data ->
  low systematic uncertainty
- Con
  beam priority
  low rate compared to hadron machine
  insufficient boost vis-à-vis B_s mixing
- PRO - opportunity exists!
  existing experiment, high luminosity, ability to run at Υ(5S)
  current data (1.86 fb^{-1}, June 2005): learn about Υ(5S), $B_s^{(*)}$ mass
  near future (+21.7 fb^{-1}, June 2006): branching fractions, lifetime
  far future (100-500 fb^{-1}): rare decays, CP studies, seeking more ideas!



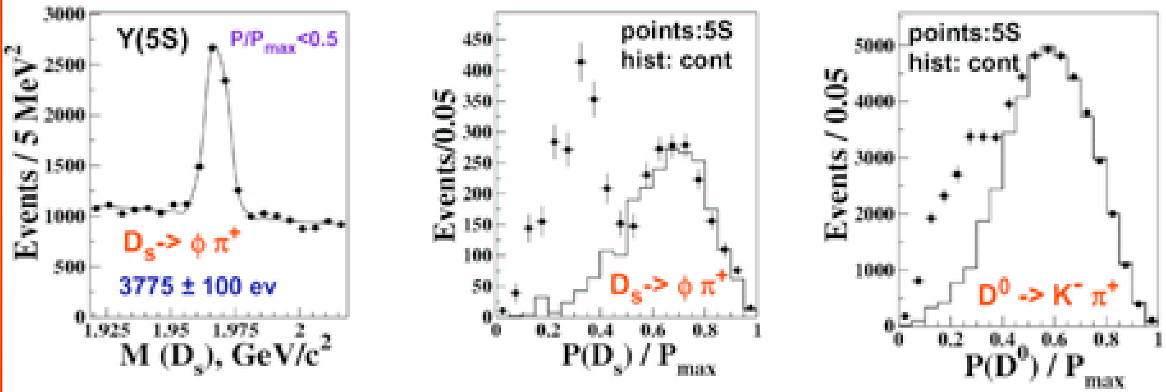
Present: $\Upsilon(5S)$ "engineering run"

KEKB operation:

- peak scan (5 pts, 30 pb^{-1} ea) 30 pb^{-1} pts, -> 10869 MeV (consistent w CESR)
- @peak: smooth operation, L_{max} ~ 1.39 x 10^{34} $cm^{-2}s^{-1}$

$\Upsilon(5S)$ properties:

Inclusive analyses : Y(5S) -> D_s X , Y(5S) -> D^0X



After continuum subtraction and efficiency correction:

Bf (Y(5S) -> D_s X) / 2 = (23.6 ± 1.2 ± 3.6) %

Bf (Y(5S) -> D^0 X) /2 = (53.8 ± 2.0 ± 3.4) %

L = 1.86 fb^{-1}

N_{bb}(5S) = 561,000 ± 3,000 ± 29,000 events

=> $f_s = N(B_s^{(*)} B_s^{(*)}) / N(bb)$ = (18.0 ± 1.3 ± 3.2)%

$N(B_s)$ / fb^{-1} = 108,000 ± 21,000 events in good agreement with CLEO

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$$\frac{\sigma(e^+e^- \to B_s^* \bar{B}_s^*)}{\sigma(e^+e^- \to B_s^{(*)} \bar{B}_s^{(*)})} = (94^{+6}_{-9})\%$$

Present:

B_s properties:

$M(B_s^*) = 5418 \pm 1 \pm 3$ MeV/c^2

$M(B_s) = 5370 \pm 1 \pm 3$ MeV/c^2

(K. Sudoh)

TABLE IV: B_s meson mass spectra (first order). Units are in MeV.

State ($^{2s+1}L_J$)	k	J^P	M_0	c_1/M_0	M_{calc}	M_{obs}
$^1S_0$	−1	0^-	5375	0.287×10^{-2}	5391	5369
$^3S_1$	−1	1^-		0.898×10^{-2}	5424	–

Decays Search

	Decay mode	Yield events	Backg. events	Eff. (%)	Up. limit (10^{-4})	PDG UL (10^{-4})	Theory
b->s penguin/b->u spectator	$B_s \to K^+K^-$	2 (< 5.61)	0.14	9.5	3.4	0.59	0.2
b->s penguin	$B_s \to \phi\gamma$	1 (< 4.16)	0.15	5.9	4.1	1.2	0.4
intrinsic penguin	$B_s \to \gamma\gamma$	0 (< 1.94)	0.5	20.0	0.56 Best	1.48	0.01
spectator	$B_s \to D_s^+D_s^-$	0 (< 2.44)	0.02	0.020	710.	-	100
	$B_s \to D_s^{*+}D_s^-$	1 (< 4.36) hint?	0.01	0.0099	1270.	-	200
	$B_s \to D_s^{*+}D_s^{*-}$	0 (< 2.44)	<0.01	0.0052	2730.	-	200

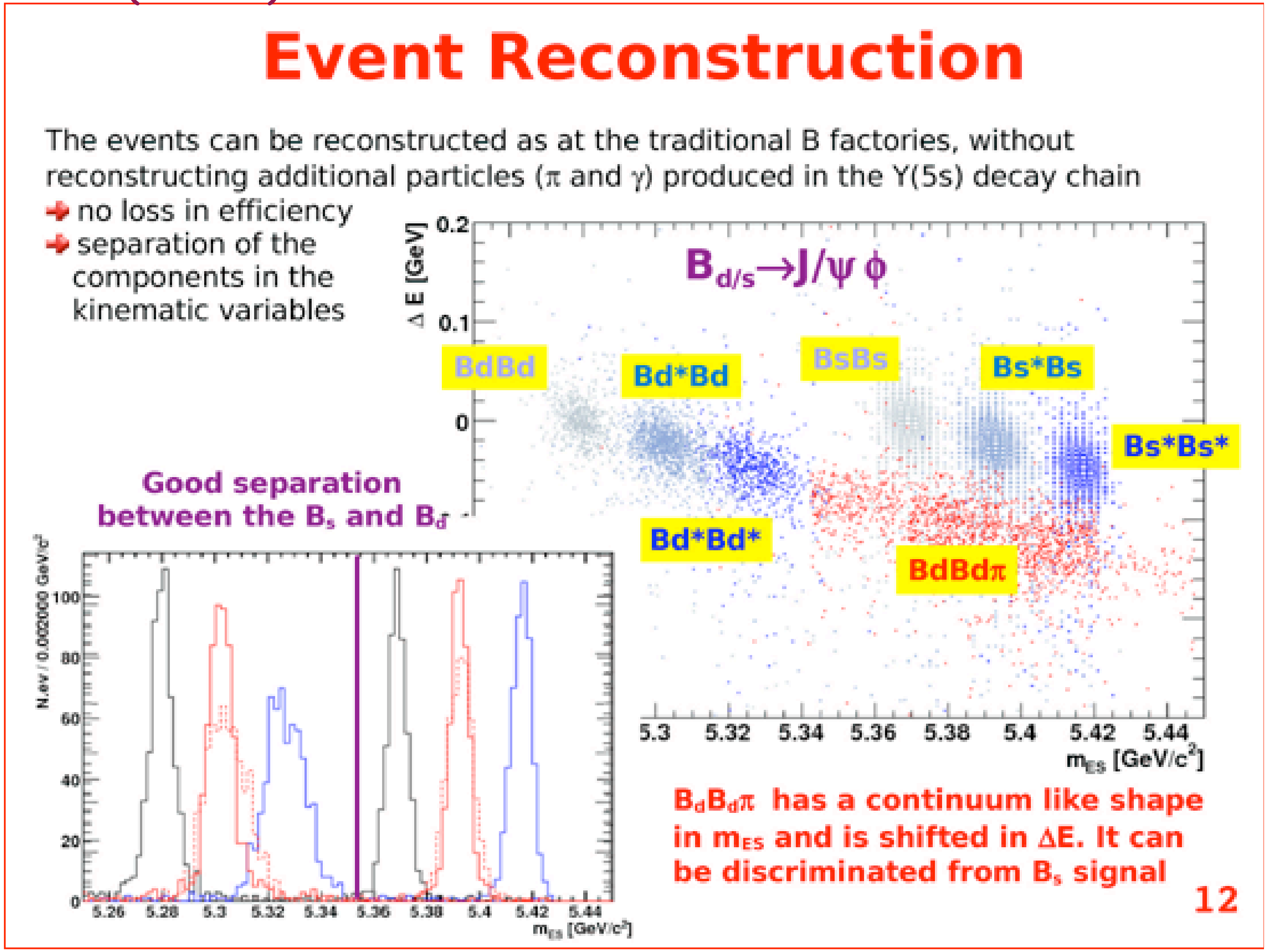
K. Kinoshita

Near future: 23.6 fb^{-1} L_{max} ~ 1.65 x 10^{34} $cm^{-2}s^{-1}$

more Υ(5S):

sort out events (needed to understand backgrounds for B_s studies)

(Pierini)



Near future: B_s decay rates

$\Delta\Gamma_s/\Gamma_s$ measurement from *Bf* ($B_s \to D_s^{+(*)} D_s^{-(*)}$)

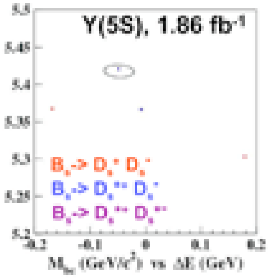
Expected with 25 fb^{-1} at Y(5S):

Eff($B_s \to D_s^+ D_s^-$) ~ 2×10^{-4} N ~ $2.5\times10^6 \times 2\times10^{-4} \times 10^{-2}$ ~ 5 ev

Eff($B_s \to D_s^{*+} D_s^-$) ~1×10^{-4} N ~ $2.5\times10^7 \times 10^{-4} \times 2\times10^{-2}$ ~ 5+5 ev

Eff($B_s \to D_s^{*+} D_s^{*-}$) ~$5\times10^{-5}$ N ~ $2.5\times10^7 \times 5\times10^{-5} \times 3\times10^{-2}$ ~ 4 ev

=>Accuracy of *Bf* ($B_s \to D_s^{(*)+} D_s^{(*)-}$) has to be ~30%.



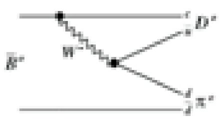
$D_s^+ \to \phi\pi^+$, $K^{*0} K^+$, $K_s K^+$

$$\frac{\Delta\Gamma_{CP}^{s}}{\Gamma_s} \approx \frac{Bf(B_s \to D_s^{(*)+} D_s^{(*)-})}{1 - Bf(B_s \to D_s^{(*)+} D_s^{(*)-})/2}$$

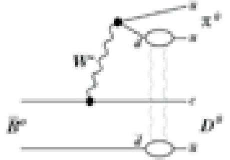
<= should be compared with direct $\Delta\Gamma_s/\Gamma_s$ measurement to test SM.

$\Delta\Gamma_s/\Gamma_s$ lifetime difference can be measured directly with high accuracy at Y(5S) and also at Tevatron and LHC experiments.

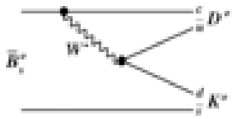
Color-suppressed $B_s \to D^0 K^0$ decay



Color-suppressed



FSI



Color-suppressed

$$\frac{Bf(B^0 \to D^0\pi^0)}{Bf(B^0 \to D^+\pi^-)} = \frac{(2.91 \pm 0.28)\times10^{-4}}{(3.4 \pm 0.9)\times10^{-3}} \approx 0.1$$

Which diagram, color-suppressed or FSI, is dominant in $B^0 \to D^0\pi^0$ decay ? Decay mode $B_s \to D^0K^{(*)0}$ has no FSI diagram. If the ratio Bf($B_s \to D^0K^0$)/Bf($B_s \to D_s^+\pi^-$) ~0.1, then color-suppressed diagram dominates. If the ratio is significantly smaller, then FSI diagram dominates.

If Bf($B_s \to D^0K^0$) is ~3×10^{-4}, then ~8 events are expected with 25fb^{-1} at Y(5S).

Semileptonic B_s decays

At the Y(5S) we can measure precisely semileptonic decays:

Bf ($B_s \to X^+ \ell^- \nu$)

Bf ($B_s \to D_s^+ \ell^- \nu$)

Bf ($B_s \to D_s^{*+} \ell^- \nu$)

Accuracy is expected to be ~(5-10)% with 25 fb^{-1} at Y(5S)

Difficult to measure in hadron-hadron colliders.

These *Bf*'s have to be compared with corresponding B meson *Bf*'s. Within SM : *Bf* ($B_s \to X^+ \ell^- \nu$) = *Bf* ($B \to X^+ \ell^- \nu$)
If not, nonstandard contributions should be considered.

How to explain:
$\tau(B^0) > \tau(B_s)$ - 2.9σ difference (in contrast with theory).

(Drutskoy)

Plus, time-dependent:
- lifetime
- studies toward $\Delta\Gamma/\Gamma$

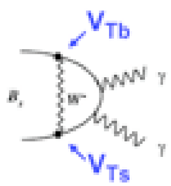
Near/far future: search/reconstruct

Final state	Process	$\mathcal{B}_{est}$	$\epsilon_{recon}(\%)$	Events/100 fb^{-1}
$D_s^-\pi^+$	spectator	2.9×10^{-3}	0.81	220
$D_s^{*-}\pi^+$	spectator	2.8×10^{-3}	0.45	120
$D_s^-\rho^+$	spectator	7.7×10^{-3}	0.15	110
$D_s^{*-}\rho^+$	spectator	6.8×10^{-3}	0.081	52
$D_{sJ}^-(2317)\pi^+$	spectator	7.3×10^{-4}	0.28	19
$J/\psi\phi$	color-suppressed spectator	1.3×10^{-3}	1.3	180
$J/\psi\eta$	color-suppressed spectator	8.5×10^{-4}	0.56	45
$D_s^+D_s^-$	spectator	8.0×10^{-3}	0.020	19
$D_s^{*+}D_s^-$	spectator	2.0×10^{-2}	0.0099	19
$D_s^{*+}D_s^{*-}$	spectator	1.9×10^{-2}	0.0052	15
$\phi\gamma$	$b \to s$ penguin	4.0×10^{-5}	5.9	22
$\bar{D}^0K_S$	color-suppressed spectator	3.0×10^{-4}	1.2	34
$D_s^-K^+$	spectator; ϕ_3	2.0×10^{-4}	0.64	12
K^-K^+	$b \to s$ penguin, $b \to u$ spectator	4.0×10^{-5}	9.5	36
$K^+\pi^-$	$b \to s$ penguin, $b \to d$ penguin	5.0×10^{-6}	8.7	4.1
$\gamma\gamma$	intrinsic penguin	1.0×10^{-6}	20.0	1.9

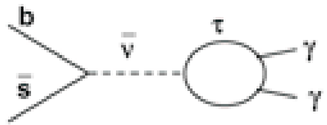
(Drutskoy)

Exclusive $B_s \to \gamma\gamma$ decay

Many "conventional" BSM models can be better constrained by $B \to K^* \gamma$ and $B \to s\gamma\gamma$ processes, however not all. In some BSM models $B_s \to \gamma\gamma$ provides the best limit, in particular in 4-generation model (V_{Ts}) and R- parity violating SUSY (x $M(\gamma\gamma)$).



hep-ph/0302177 (Huang et al) : limits on four-generation matrix elements V_{Tb} and V_{Ts} were obtained from B decays. $Bf(B_s \to \gamma\gamma)$ can increase up to one order of magnitude under specific conditions. Decay $B \to \gamma\gamma$ is not affected.



hep-ph/0404152 (Gernintern et al): within R-parity violation SUSY, diagram with sneutrino will increase $Bf(B_s \to \gamma\gamma)$ up to one order of magnitude.

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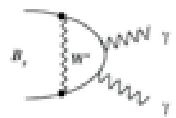
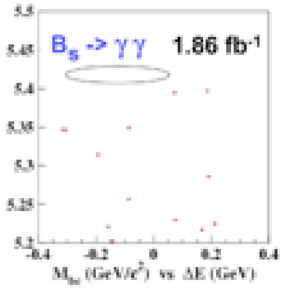
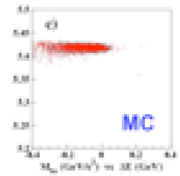
Exclusive $B_s \to \gamma\gamma$ decay



Natural mode to search for BSM effects, many theoretical papers devoted to this decay.





PDG limit : $Bf(B_s \to \gamma\gamma) < 1.48 \times 10^{-4}$

90% *CL* UL with 1.86 fb^{-1} : $Bf(B_s \to \gamma\gamma) < 0.53 \times 10^{-4}$.

Expected UL with 100 fb^{-1} : $Bf(B_s \to \gamma\gamma) < 1. \times 10^{-6}$.

SM : $Bf(B_s \to \gamma\gamma) = (0.5\text{-}1.0) \times 10^{-6}$.

BSM can increase *Bf* up to two orders of magnitude.

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window on some New Physics models: not accessible at hadron colliders

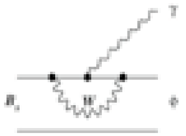
Exclusive $B_s \to K^- \pi^+$ and $B_s \to \phi\gamma$ decays (Drutskoy)

Direct CP-violation => non-zero charge asymmetry parameter
A = (*Bf* (+) – *Bf* (-)) / (*Bf* (+) – *Bf* (-)).

Expected number of events with 5 ab^{-1}:
$B_s \to K^- \pi+$: ~300 events.

Large statistics is required to observe direct CP-violation on the level of 10%.

$B_s \to \phi\gamma$



New Physics can contribute in penguin decay loops.

Estimated number of events with 100 fb^{-1} : ~20 ev.

Partner of $B \to K^* \gamma$ penguin decay .
Bf's have to be compared.

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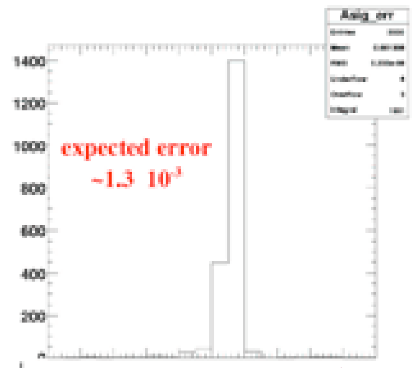
(Pierini)

Semileptonic Asymmetry

Several experimental strategies:

- Counting $D_s^{(*)+} l^- \nu$ and $D_s^{(*)-} l^+ \nu$ events against a hadronic or semileptonic tag
  - $\bar{q}q$ Background killed by the full reconstruction of the other B
  - $B_d B_d \pi$ background killed by CKM suppression on reco and tag sides
  - ~2.5% background from other B_s decays

  From a toy Monte Carlo study, we expect $\sigma(A_{SL}^s)$~1.3•10^{-3}



30 ab^{-1}

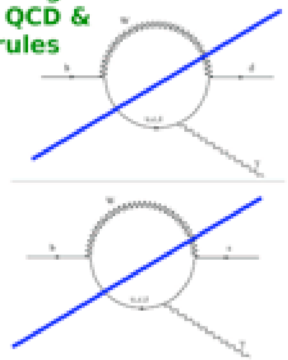
- Using the dileptonic events
  - Events are selected looking for two same-sign leptons
  - Background is rejected using the time evolution
  - Time evolution allows to separate B_d from B_s events (A_{SL}^s and A_{SL}^d can be measured simultaneously)

  Scaling present B-factory errors to the superB luminosity we expect
  - $\sigma(A_{SL}^d)$~0.8•10^{-3}
  - $\sigma(A_{SL}^s)$~1.5•10^{-3}

Measuring (NP sensitive) V_{td}/V_{ts}

SU(3) breaking from Lattice QCD & QCD sum rules

$$\frac{BR(B_s \to K^* \gamma)}{BR(B_s \to \phi\gamma)} = \frac{V_{td}}{V_{ts}} \; \frac{1}{\xi^2}$$



Advantages:
- no theoretical error from additional contributions
- ϕ is a narrow resonance (less background and better theory estimation of ξ)

NP can affect the loops in a different way than the box diagrams of Δm_s
Different sensitivity to NP, stronger constraint from the combination

Experimental challenge:
$B_s \to K^* \gamma$ might suffer from large background from $B_d \to K^* \gamma$ in $BB\pi$ decays.
These events are
- distributed as an Argus function under the signal in m_{Miss}
- shifted in ΔE

They can be separated from signal using a ML fit

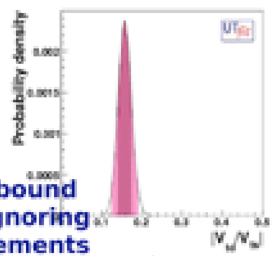
(Pierini)

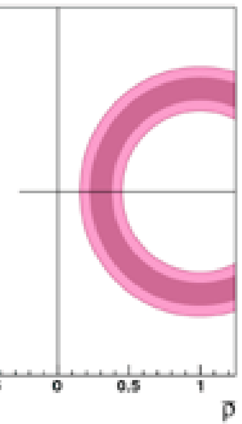
Plus, A. Soni:
Radiative B_s decays

V_{td}/V_{ts} with B_s decays

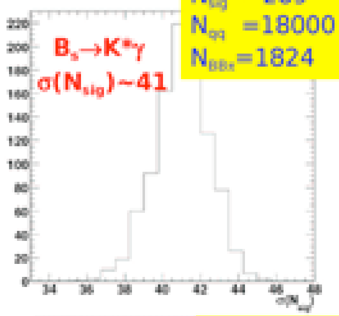
We assumed
- 30 ab^{-1} of data collected at $\Upsilon(5s)$
- same detector performances than BaBar
- SU(3) symmetry to estimate the BR
- same $\bar{q}q$ background shapes than for $\Upsilon(4s)$ events

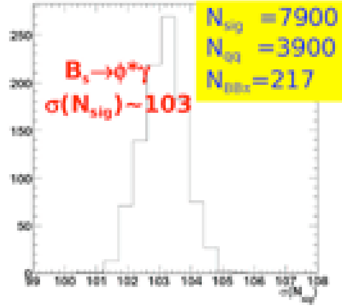
And we used a full detector simulation to estimate likelihood shape. From a set of Toy Monte Carlo, we estimate the average error on the two BR's and the error on $|V_{td}/V_{ts}|$





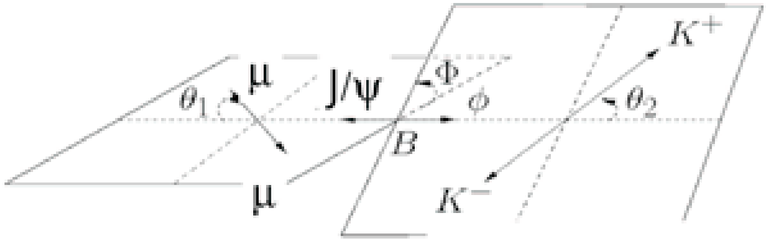
good bound even ignoring improvements in lattice and/or in data analysis





17

$\Delta\Gamma/\Gamma$ in $B_s \to J/\psi\phi$ (II)

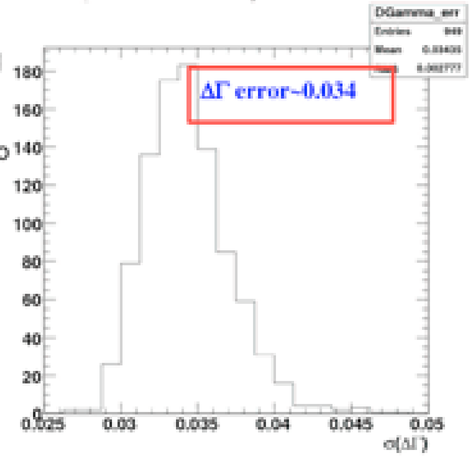


- In SM odd and even CP component associated respectively to heavy (long) and light (short) B_s angular analysis
- The distribution in cosθ, cosψ,φ, and t allows to separate the two components

$$\frac{d^4\mathcal{P}(\phi,\cos\theta,\cos\psi,t)}{d\phi\, d\cos\theta\, d\cos\psi\, dt} \propto$$

$$|A_0|^2 e^{-\Gamma_L t}\cdot f_1(\vec{\rho}) + |A_\parallel|^2 e^{-\Gamma_L t}\cdot f_2(\vec{\rho})$$

$$+ \quad |A_\perp|^2 e^{-\Gamma_H t}\cdot f_3(\vec{\rho}) + \mathrm{Re}(A_0^* A_\parallel) e^{-\Gamma_L t}\cdot f_5(\vec{\rho})$$



Time-dependent measurement (used@Tevatron)

Outlook

$\Upsilon(5S)$: opportunity at B-factory
Current data (24 fb^{-1} =5x10^6 B_s's):
- properties of $\Upsilon(5S)$, $B_s^{(*)}$ mass
- reconstruct favored B_s decays (exclusive & inclusive)
- tests of flavor SU(3)
- $\Delta\Gamma_{CP}/\Gamma$ via $D_s^{(*)}D_s^{(*)}$ branching fraction
- find/limit NP for rare modes, esp. $\gamma\gamma$, $\varphi\gamma$
- time-dependent measurements:
  - lifetime, CP asymmetries, $\Delta\Gamma_{CP}/\Gamma$, $\Delta\Gamma/\Gamma$

Future (100-500+ fb^{-1}):
- rare hadronic (NP, φ_3)
- radiative decays (NP, $|V_{td}/V_{ts}|$)
- CP asymmetries
- prospect: experimentally feasible but need strong theoretical motivation

Please think about the possibilities!