Risultati recenti a BaBar

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Outline

- BaBar dataset
- Charm physics
  - search for $D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$ branching fraction measurement
  - search for CP violation (CPv) in $D^+ \to K_s\pi^+$
  - measurement of D_s decay constant
- Bottomonium spettroscopy
  - evidence for $h_B(1P)$
- Above-Y(4S) scan
  - measurements of $B_s \to Xl\nu$ branching fraction and B_s fraction f_s

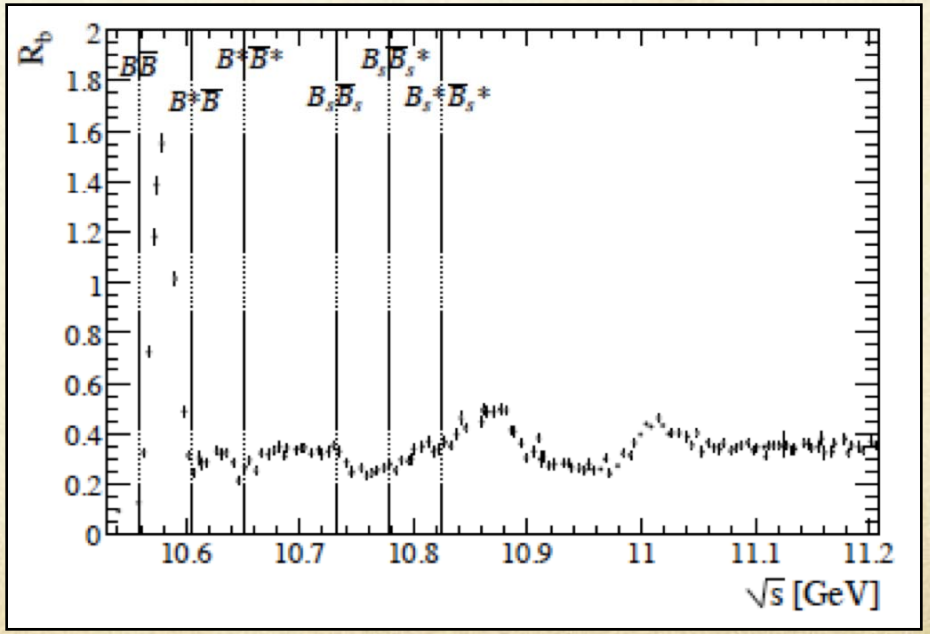
BaBar dataset

- 530 fb^{-1} collected by BaBar @ PeP-II during 9 years of data taking (1999-2008)
- Much more then Y(4S):
  - Y(3S) sample ≈ 7 x (Belle + Cleo) samples
  - Y(2S) sample ≈ 0.5 x (Belle + Cleo) samples
  - Scan above Y(4S)

    ~ 4 fb^{-1} collected in the $\sqrt{s}$ range [10.54,11.20] GeV

sample	fb^{-1}
$\Upsilon(4S)$	430
$\Upsilon(3S)$	30.2
$\Upsilon(2S)$	14.5
Off Υ -resonance	54

- ...and much more than B$\underline{\text{B}}$:
  - 690M $e^+e^- \to c\underline{c}$
  - 500M $e^+e^- \to \tau^+\tau^-$



Charm physics

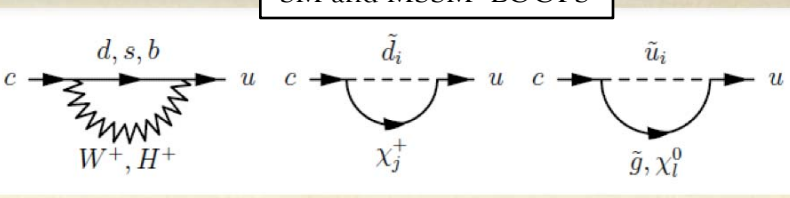
$D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$: motivations and analysis strategy

- FCNC, GIM-suppressed charm loop diagrams
  - SM dominated by LONG DISTANCE contributions (PRD 66,014009,2002)
  - looking for New Physics (NP) entering the loop

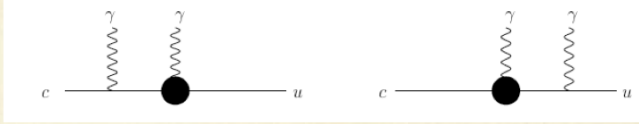
Mode	Value
$D^0 \to \gamma\gamma$ (SM,VMD)	$\approx (3.5\ ^{+4.0}_{-2.6}) \times 10^{-8}$
$D^0 \to \gamma\gamma$ (SM,HQχPT)	$(1.0 \pm 0.5) \times 10^{-8}$
$D^0 \to \gamma\gamma$ (MSSM)	6×10^{-6}
Experimental results	
Mode	Value
$D^0 \to \gamma\gamma$	$< 2.7 \times 10^{-5}$
$D^0 \to \pi^0\pi^0$	$(8.0 \pm 0.8) \times 10^{-4}$
$D^0 \to K^0_s\pi^0$	$(1.22 \pm 0.05) \times 10^{-2}$

(Exp. + theo. references in back-up)

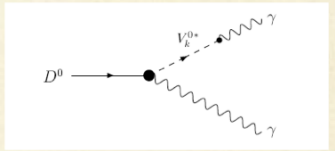
SM and MSSM LOOPS



SHORT DISTANCE CONTRIBS



LONG DISTANCE CONTRIBS



- Reconstruction strategy:
  - D^{*+} tag: D from $D^{*+} \to D^0\pi^+$
  - normalization channel $D^0 \to K_S\pi^0$

	$D^0 \to \gamma\gamma$	$D^0 \to \pi^0\pi^0$
selection efficiency		
signal	15.2 %	6.1%
normalization	12.0%	7.6%

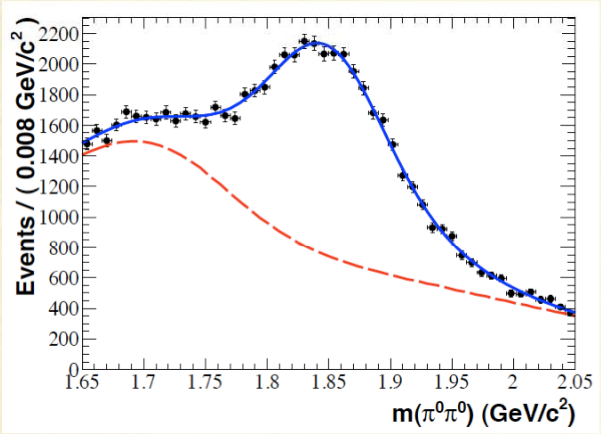
$D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$: results

Preliminary, 407.5 fb^{-1}

- m_{D0} fits:

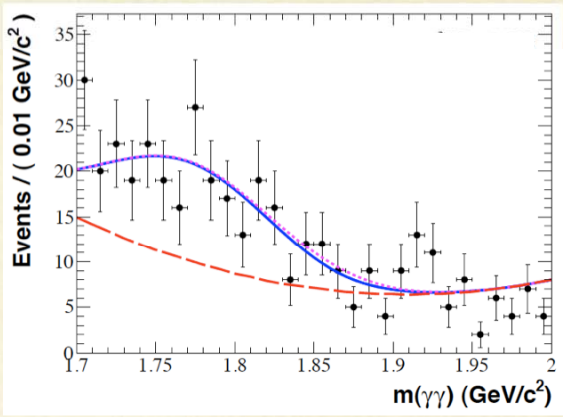
Comb bkg
Comb bkg + $D^0 \to \pi^0\pi^0$
Comb bkg + $D^0 \to \pi^0\pi^0$ + signal
data

$D^0 \to \pi^0\pi^0$



N_{sig} = 206010 ±304

$D^0 \to \gamma\gamma$



N_{sig} = -6 ±15

Systematic	$\sigma(D^0 \to \gamma\gamma)$ (%)	$\sigma(D^0 \to \pi^0\pi^0)$ (%)
Tracking (K^0_S) and Vertexing	0.96	0.96
Photon Reconstruction	0.60	3.00
π^0 Veto	1.80	-
D^{*+} Fragmentation	0.02	0.03
Signal Shape	*	0.20
Background Shape	*	0.80
Cut selection	*	2.50
$D^0 \to K^0_s\pi^0$ Signal Shape	0.53	0.17
$D^0 \to K^0_s\pi^0$ Background Shape	0.01	0.63
$D^0 \to K^0_s\pi^0$ Cut selection	0.76	0.76
Total Systematic Uncertainty	*	4.23

Results:

$\mathcal{B}(D^0 \to \pi^0\pi^0) = (8.4 \pm 0.1_{stat} \pm 0.4_{syst} \pm 0.3_{norm}) \times 10^{-4}$

40% improvement wrt PDG

$\mathcal{B}(D^0 \to \gamma\gamma) < 2.4 \times 10^{-6}$

x 10 improvement wrt PDG

CPv in $D^+ \to K_S\pi^+$: motivations and analysis strategy

- Look for deviation from SM prediction for CPv in charm sector
  - i.e. W replaced by charged Higgs in CS-like diagram, different strong and weak phases wrt CA diagram (PLB450,405,1999)

- CP Asymmetry: $\mathcal{A}_{CP} = \frac{\Gamma(D^+ \to K_S\pi^+) - \Gamma(D^- \to K_S\pi^-)}{\Gamma(D^+ \to K_S\pi^+) + \Gamma(D^- \to K_S\pi^-)}$

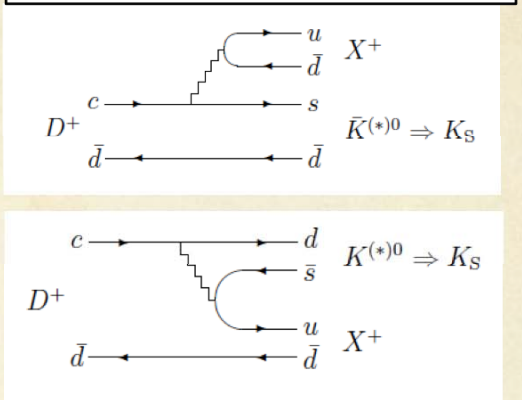
SM prediction : (-0.332 ± 0.006)% (mainly K^0-$\underline{K^0}$ mixing)

- Experimental challenges:
  - need high statistics and systematics effects well under control
  - detector-induced asymmetry: treated as correction factor determined from control sample
  - particle identification not applied: avoid bias due to different id efficiency for π^+/π^-

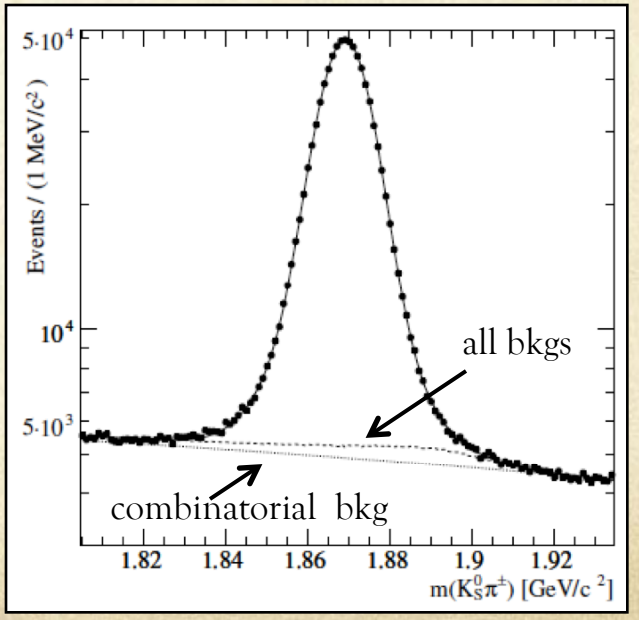
- yield extraction from ML fit to $K_S\pi$ invariant mass:

$N_{sig} = (807 \pm 1) \times 10^3$

Cabibbo Allowed (CA) diagram



Cabibbo Suppressed (CS) diagram



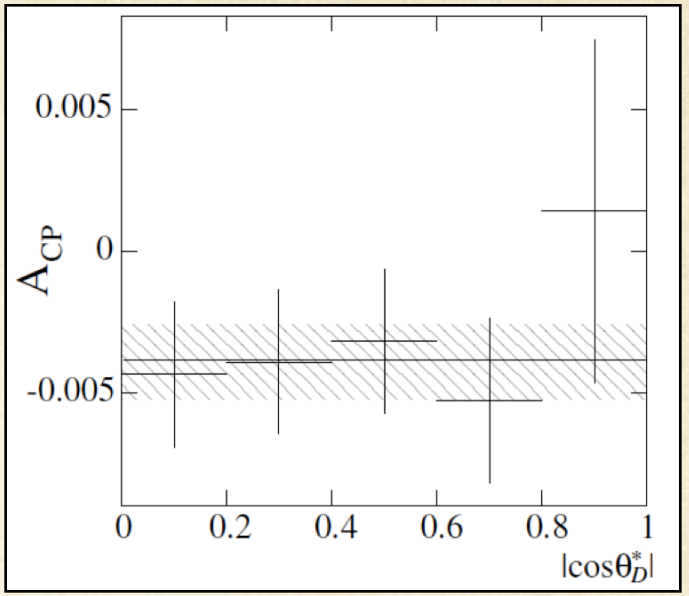
CPv in $D^+ \to K_s\pi^+$: result

hep-ex:10115477
Accepted by PRD, 469 fb^{-1}

- extract $\mathcal{A}_{CP}$ from yield asymmetry:

$$\mathcal{A} = \frac{N_{D^+} - N_{D^-}}{N_{D^+} + N_{D^-}} = \mathcal{F}(\mathcal{A}_{CP}, \mathcal{A}_{FB}, \mathcal{A}_{det})$$

forward-backward asymmetry measured together with $\mathcal{A}_{CP}$



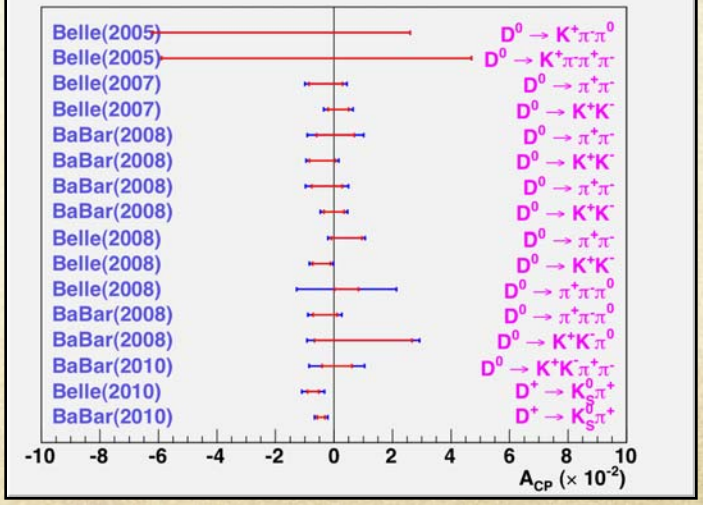
- Dominant systematic uncertainties:
  - bias due to π/K/lepton contamination, detector induced effects in π^+-π^- control sample and statistical error in $\mathcal{A}_{det}$ efficiency map and (±0.08%)
  - K^0-$\underline{K^0}$ rigeneration (±0.06%)

Result:

$\mathcal{A}_{CP} = (-0.44 \pm 0.13_{stat} \pm 0.10_{syst})\%$

most precise CPv measurement on charm sector reported to date

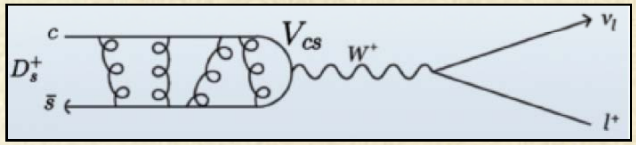
Chen @ Charm2010



Leptonic D_s decays : motivations and analysis strategy

- Semileptonic Ds decays:

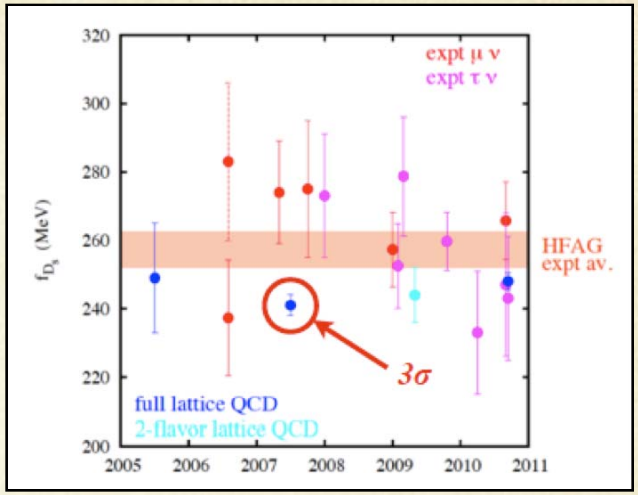
$$\Gamma(D_s \to \ell^- \nu_\ell) = \frac{G_F^2 |V_{cs}|^2 m_{D_s}}{8\pi} \left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2 m_\ell^2 f_{D_s}^2$$



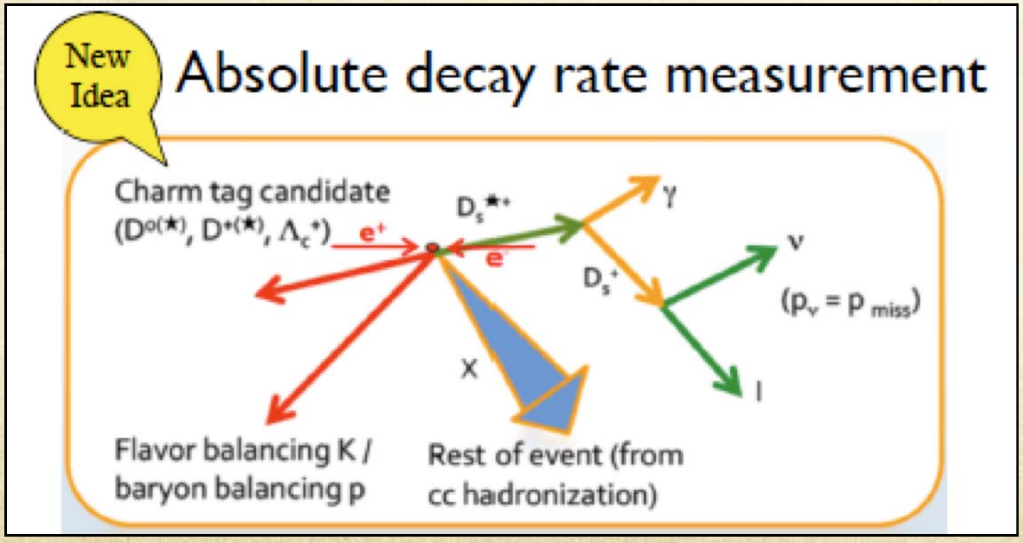
- Measure f_{Ds} and test SM predictions:
  - before this measurement

experiment : f_{Ds} = 256.9 ± 6.8 (HFAG 2009)

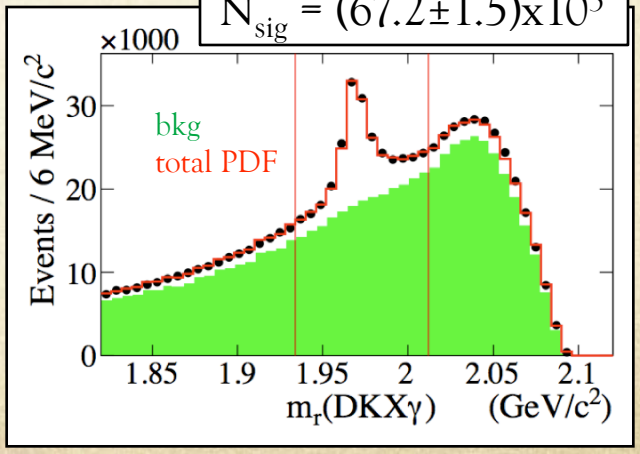
theory : f_{Ds} = 248.0 ± 2.5 (HPQCD PRD,82,114504 2008)



- Reconstruction techinque: inclusive D_s sample



$N_{sig} = (67.2 \pm 1.5) \times 10^3$



Leptonic D_s decays : $D_s \to l\nu$ yields

PRD82,091103 (R),2010
469 fb^{-1}

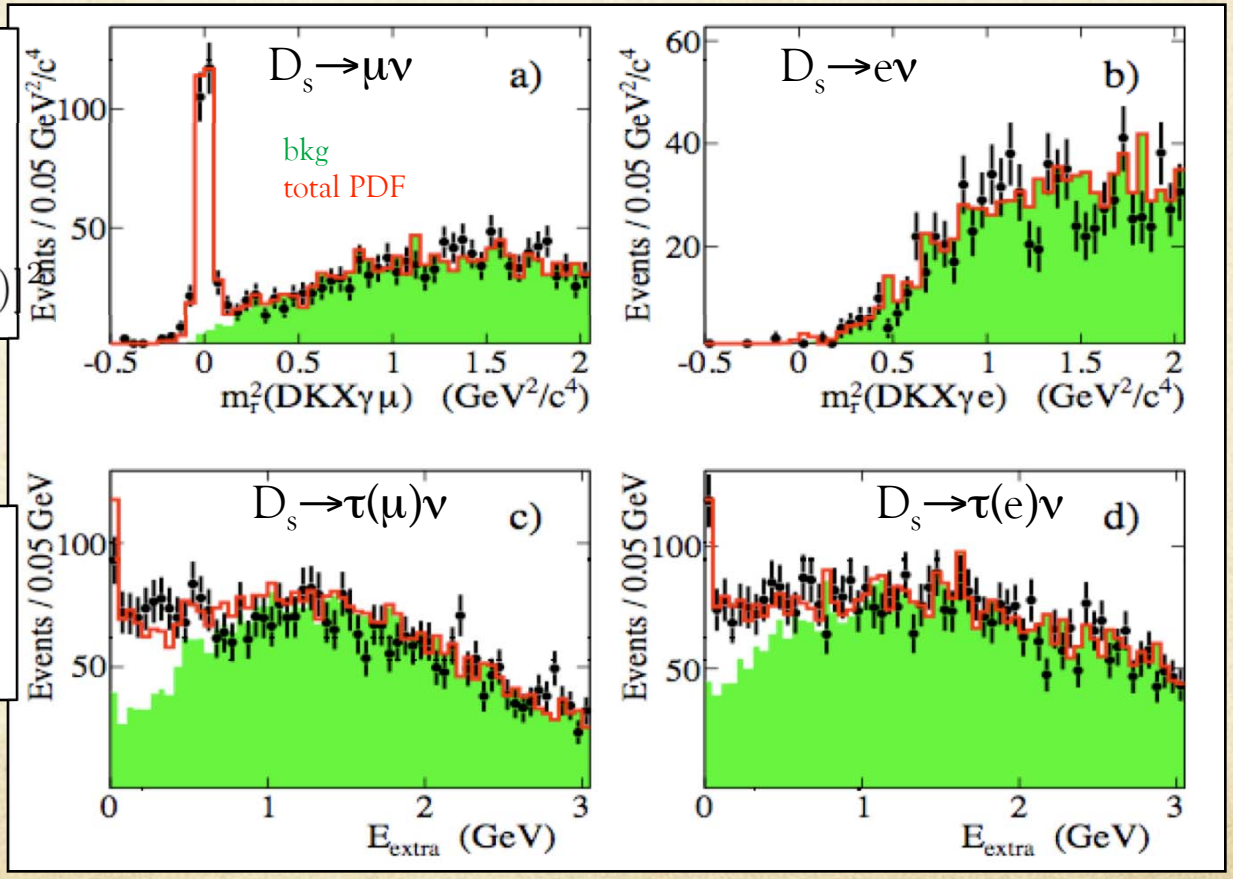
- $D_s \to l\nu$ yields
  - require ONE additional track identified as muon (electron)
  - in $D_s \to \tau\nu$ search remove $D_s \to e/\mu\nu$ events
  - yield extraction by fitting m_{miss} or E_{extra} distributions

$l = e/\mu$

$$m^2_{miss}(DKX\gamma\ell) = [p_{e^+} + p_{e^-} - (p_D + p_K + p_X + p_\gamma + p_\ell)]$$

$l = \tau$

Extra energy deposited in calorimeter (Eextra)



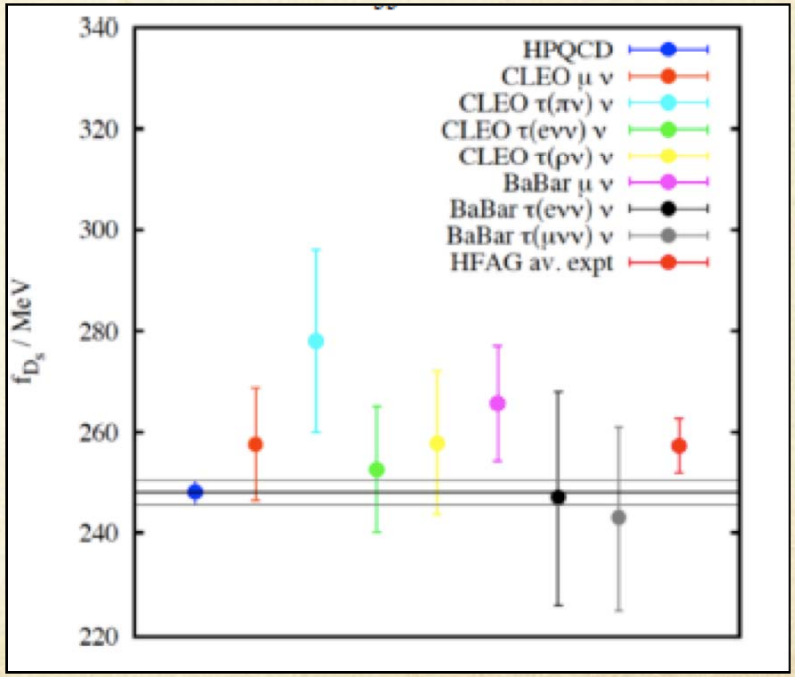
Leptonic D_s decays : results

- Semileptonic branching fraction

Decay	$\bar{\varepsilon}$	Signal Yield	$\mathcal{B}(D_s^- \to \ell^- \bar{\nu}_\ell)$
$D_s^- \to e^- \bar{\nu}_e$	70.5%	$6.1 \pm 2.2 \pm 5.2$	$< 2.3 \times 10^{-4}$ at 90% C.L.
$D_s^- \to \mu^- \bar{\nu}_\mu$	67.7%	275 ± 17	$(6.02 \pm 0.38 \pm 0.34) \times 10^{-3}$
$D_s^- \to \tau^- \bar{\nu}_\tau$ $(\tau^- \to e^- \bar{\nu}_e \nu_\tau)$	61.6%	408 ± 42	$(5.07 \pm 0.52 \pm 0.68) \times 10^{-2}$
$D_s^- \to \tau^- \bar{\nu}_\tau$ $(\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau)$	59.5%	340 ± 32	$(4.91 \pm 0.47 \pm 0.54) \times 10^{-2}$

- f_{Ds} measurement

Channel	$f_{D_s}(MeV)$
$D_s^- \to \mu^- \nu_\mu$	$265.7 \pm 8.4 \pm 7.8$
$D_s^- \to \tau^- (e^- \nu \bar{\nu}) \nu_\tau$	$247 \pm 13 \pm 17$
$D_s^- \to \tau^- (\mu^- \nu \bar{\nu}) \nu_\tau$	$243 \pm 12 \pm 14$
Combined	$258.6 \pm 6.4 \pm 7.5$



1.6 σ exp-theory difference

Below Y(4S): first evidence for $h_b(1P)$

h_b search (I) : motivations and experimental technique

- $^1P_1$ bottomonium state, axial vector partner of P-wave $\chi_{bJ}(1P)$, expected mass :

  m_{hb} = 9899.87 ± 0.27 MeV/c2

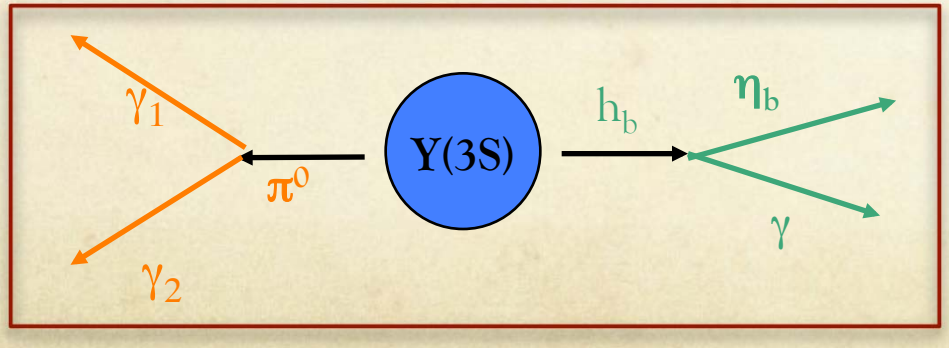
- study mass hyperfine splitting between

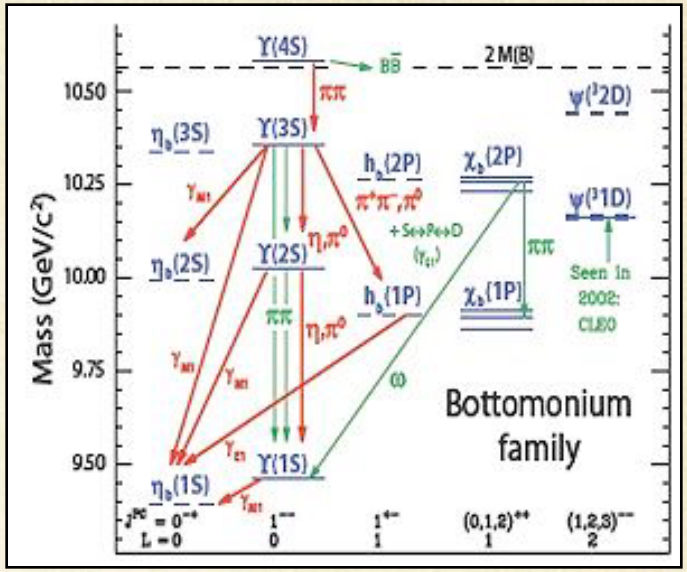
  $^1P_1$ and ($<^3P_j>$) to test spin dependence of $q\bar{q}$

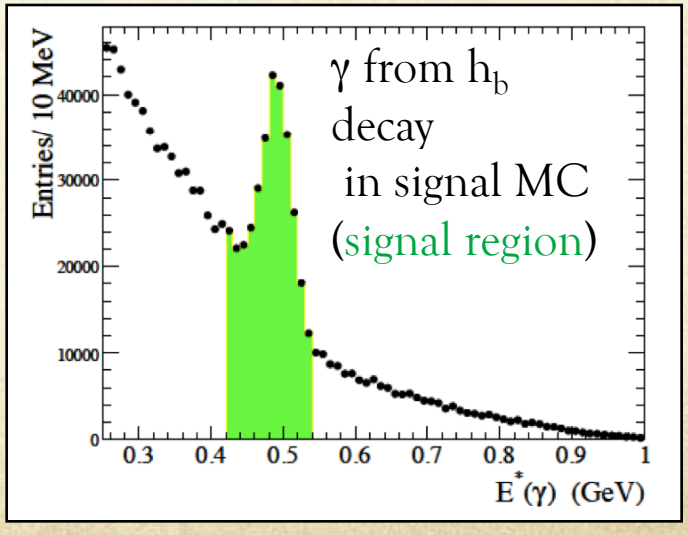
  potential : $\Delta M_{HF} = M(^3P_1)-M(^1P_1)\approx 0$

- dominant decay mode: $\mathcal{B}(h_b \rightarrow \eta_b\gamma) \approx (40\text{-}50)\%$

- experimental technique for $\Upsilon(3S)\rightarrow h_b\pi^0$ search:





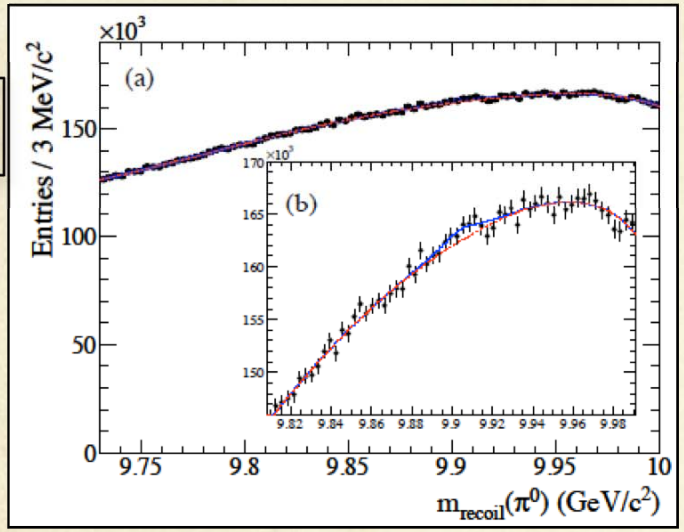


h_B search : FIRST EVIDENCE!

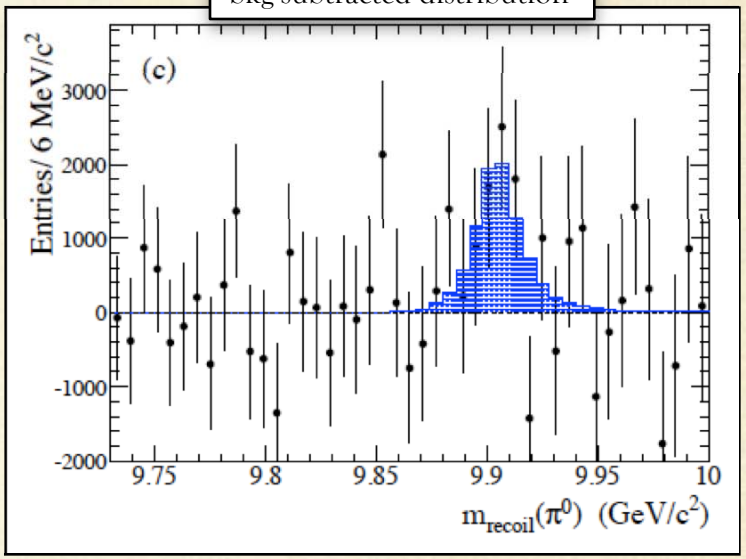
hep-ex:11024565
Submitted to PRD, 28 fb^{-1} @Y(3S)

- Signal yield from χ^2 fit to $m_{recoil}(\pi^0) = \sqrt{(E^*_{\Upsilon(3S)} - E^*_{\pi^0})^2 - (p^*_{\pi^0})^2}$

bkg
bkg+signal



bkg-subtracted distribution



- Results:

N_s = (9145 ± 2804 ±1082) events → 3.0σ significance (3.2σ without syst)

m_{hb} = (9902 ± 4 ± 1) MeV/c^2

ΔM_{HF} = (+2 ± 4 ± 1) MeV/c^2

$\mathcal{B}(\Upsilon(3S) \to \pi^0 h_b) \times \mathcal{B}(h_b \to \gamma\eta_b)$ = (3.7 ± 1.1 ±0.7) x 10^{-4} (< 5.4 x 10^{-4} @ 90% CL)

Scanning above Y(4S): $B_s \rightarrow X l \nu$

$B_s \to X l \nu$ and f_s : motivations

- Semileptonic Bs decays:
  - measurement from Belle (unpublished results) :

    $\mathcal{B}(B_s \to X l \nu) = (10.2 \pm 0.8 \pm 0.9)\%$ (hep-ex:07102548, 2007)
  - LHCb measure ratios of semi-exclusive decays to total inclusive:

    $\mathcal{B}(B_s \to (D_{s2}^*/D_{s1}) X l \nu) / \mathcal{B}(B_s \to X l \nu)$ (Phys.Lett.B 698,14,2011)

- Exploit BaBar above-Y(4S) data: $(25.5 \pm 6.2) \times 10^3$ $B_s^{(*)}\underline{B}_s^{(*)}$ decays

- abundance of ϕ meson in B_s final states (wrt to B) allow to measure size of B_s component
  - $\mathcal{B}(B_s \to D_s X) \times \mathcal{B}(D_s \to \phi X) \approx 15\%$
  - $\mathcal{B}(B_d \to \phi X) \approx 3.43\%$

→ measure f_s = # B_s produce above threshold / # $b\underline{b}$ events

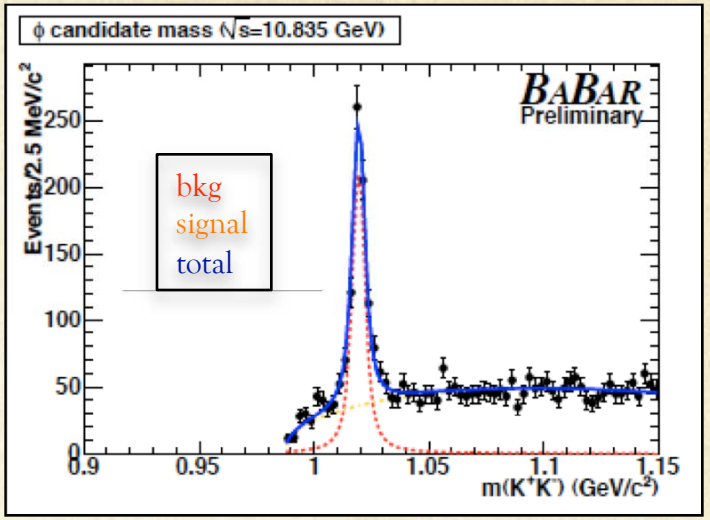
- measure $B_s \to X l \nu$ adding a high momentum lepton

$B_s \to X l \nu$ and f_s: strategy

- measure number of $b\bar{b}$, ϕ, and ϕ-l events

in bins of $\sqrt{s}$

fit KK invariant mass (with 1 high momentum e/μ candidate)



- Relations among yields

(after light qq-pairs event subtraction):

$$N_{b\bar{b}} = R_b[f_s \varepsilon_{B_s} - (1 - f_s)\varepsilon_B] \quad (1)$$

$$N_\phi = R_b[f_s P(B_s\bar{B}_s \to \phi X)\varepsilon_{B_s,\phi} - (1 - f_s)P(B\bar{B} \to \phi X)\varepsilon_{B,\phi}] \quad (2)$$

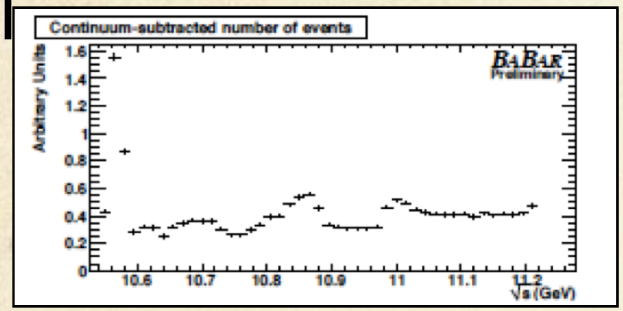
$$N_{\phi,\ell} = R_b[f_s P(B_s\bar{B}_s \to \phi \ell\nu X)\varepsilon_{B_s,\phi\ell} - (1 - f_s)P(B\bar{B} \to \phi \ell\nu X)\varepsilon_{B,\phi\ell}] \quad (3)$$

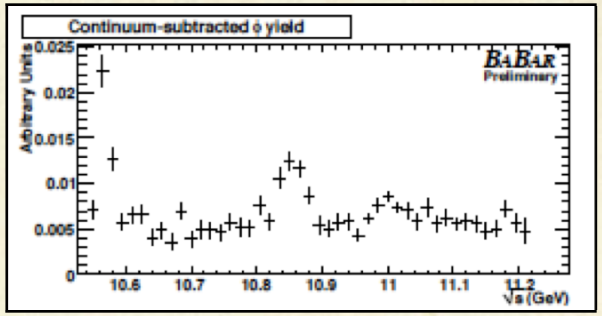
- B contribution measured from Y(4S) data
- $f_s(\sqrt{s})$ extracted from (1) + (2)
- B_s contributions in (3) depend on many BF taken from PDG and on $B(B_s \to X l \nu)$

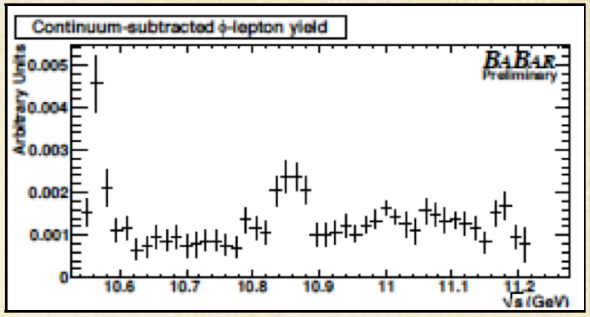
$B_s \to X l \nu$ and f_s : results

Preliminary

- Continuum subtracted yields:







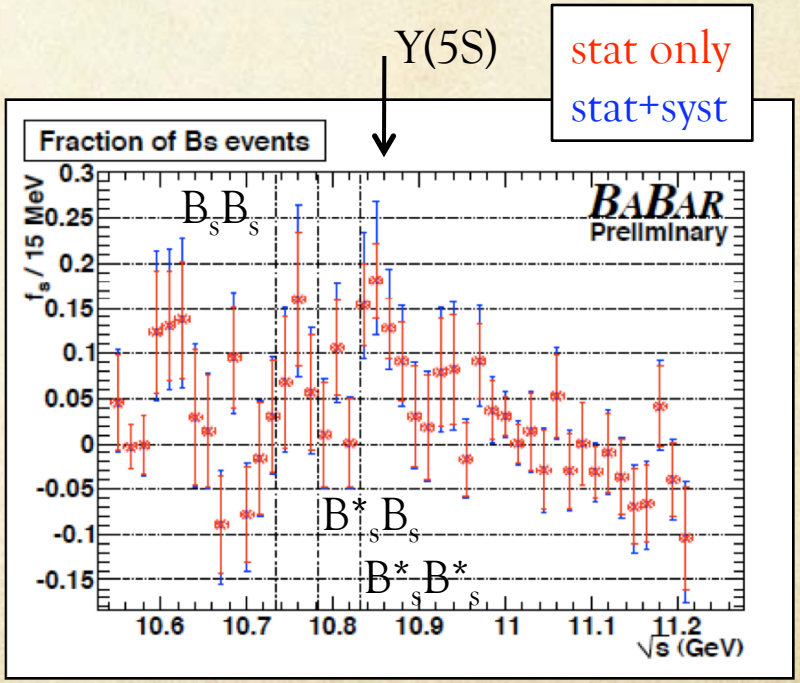
- Results:
  - Semileptonic BF:

$$\mathcal{B}(B_s \to \ell\nu X) = (9.9^{+2.6}_{-2.1}(\text{stat})^{+1.3}_{-2.0}(\text{syst}))\%$$

  - fs : near Y(5S) peak consistency with on-peak results from

Belle : f_s = (19.3 ± 2.9) % (PRD76, 012002, 2007)

Cleo : f_s = (16.8 ± 2.6) % (PRD75, 012002, 2007)



Conclusions

- BaBar data taking ended in 2008
- Data analysis still very active: > 455 published/submitted paper
  - final results on full datatset and latest reconstruction code
- Presented here some of the most recent results:
  - Charm physics
    - $B(D^0 \to \gamma\gamma)$: factor 10 improvement wrt PDG
    - CPV in $D^+ \to K_S\pi^+$: most precise CPV measurement in charm sector reported to date
    - Leptonic Ds decays: exp-theory discrepancy on f_{DS} reduced
  - First evidence for $h_b(^1P_1)$ in $\Upsilon(3S) \to h_b\pi^0$ @ 3σ level
  - Bs semileptonic branching fraction and fs measurement with above-Y(4S)-scan : data consistent with previous results and theoretical prediction

Back-up slides

$D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$: references

Theoretical predictions		
Mode	Value	Reference
$D^0 \to \gamma\gamma$ (SM,VMD)	$\approx (3.5\ ^{+4.0}_{-2.6}) \times 10^{-8}$	Burdman [11]
$D^0 \to \gamma\gamma$ (SM,HQχPT)	$(1.0 \pm 0.5) \times 10^{-8}$	Fajfer [12]
$D^0 \to \gamma\gamma$ (MSSM)	6×10^{-6}	Prelovsek [9]

Experimental results		
Mode	Value	Reference
$D^0 \to \gamma\gamma$	$< 2.7 \times 10^{-5}$	Nakamura [13]
		Coan [10]
$D^0 \to \pi^0\pi^0$	$(8.0 \pm 0.8) \times 10^{-4}$	Nakamura [13]
$D^0 \to K^0_s\pi^0$	$(1.22 \pm 0.05) \times 10^{-2}$	Nakamura [13]

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10] T. E. Coan *et al.* (CLEO), Phys. Rev. Lett. **90**, 101801 (2003), hep-ex/0212045.

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Semileptonic D_s decays : inclusive yield determination and syst

Inclusive D_s yield (normalization in the Ds→lν branching fraction measurement) :

- Split reconstructed sample in

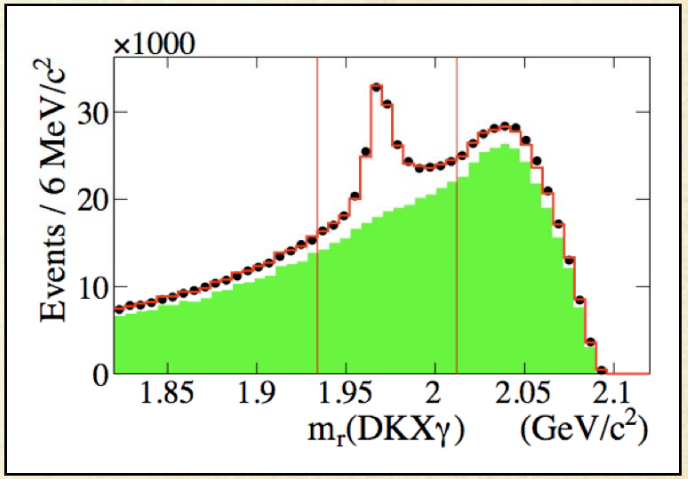
Right Sign : DKX charge= +1, (c,s) content consistent with being produced with D_s^-

Wrong Sing : DKX charge= +1, (c,s) content NOT consistent with being produced with D_s^-

- yiled depends on # of π enetring X reconstruction (n_X)
- fit 2D histogram of nX- m(DKXγ) simultaneously on WS and RS samples

(WS shares same bkg composition as RS)

N_{Ds} = (67.2 ± 1.5) x 10^3 events



Systematic	Difference in the B.F. ($\times 10^{-3}$)	Difference/Nominal
WS n_X^T weights	(-0.07,+0.00)	(-1.08,+0.00)%
RS n_X^T weights	(-0.00,+0.00)	(-0.04,+0.00)%
D_s Signal Shape	(-0.09,+0.09)	(-1.45,+1.45)%
Peaking Backgrounds	(-0.10,+0.10)	(-1.64,+1.67)%
Background Model	(-0.02,+0.01)	(-0.34,+0.23)%
n_X Resolution	(-0.03,+0.03)	(-0.51,+0.48)%
Signal Photon Backgrounds	(-0.14,+0.14)	(-2.24,+2.32)%
Numerator background model	(0.14)	(2.21)%
Numerator Signal model	(0.16)	(2.56)%
Tracking E ciency	(0.05)	(0.83)%
PID E ciency	(0.12)	(1.88)%
Numerator selection criteria	(0.11)	(1.73)%
Total	(0.34)	(5.44)%

h_B search : signal yield extraction

- event selection
  - expect multi-hadronic hb final state : ntrks ≥ 4, event shape cuts
  - π^0 veto to reduce mis-reconstructed π^0 and γ from π^0 in the $h_b \rightarrow h_b\gamma$ sample
  - cut on π^0 helicity angle to further reduce bkg from mis-reconstructed π^0
  - vertex constraints: all trks from same vertex, all nautrals from IP
- recoil mass: $m_{recoil}(\pi^0) = \sqrt{(E^*_{\Upsilon(3S)} - E^*_{\pi^0})^2 - (p^*_{\pi^0})^2}$
- divide $9.73 < m_{recoil}(\pi^0) < 10.0$ GeV/c^2 signal region in 90 intervals of 3MeV/c^2
- extract h_b yield by fitting $m_{\gamma\gamma}$
- distribution in each bin

obtain $m_{recoil}(\pi^0)$ distribution in full

$m\gamma\gamma$ range

- perform χ^2 fit to extract h_b yield