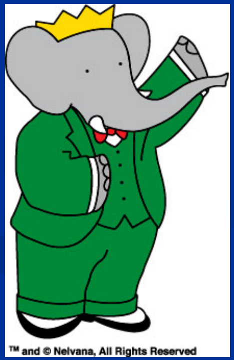
Recent results on Leptonic and Radiative B decays at BaBar

[$B \to \tau\nu$, $b \to (s,d)\gamma$]



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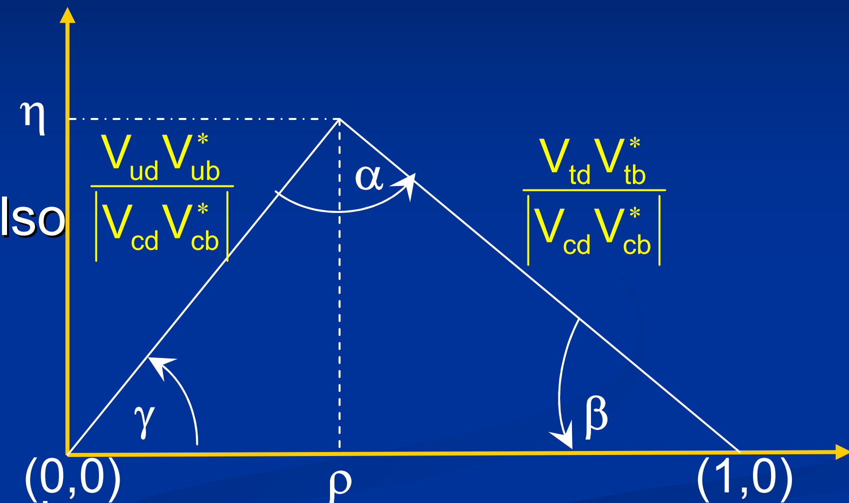
On Behalf of the BaBar Collaboration

XIIIth Lomonosov Conference on Elementary Particle Physics
August 23-29, 2007
Moscow State University, Moscow, Russia

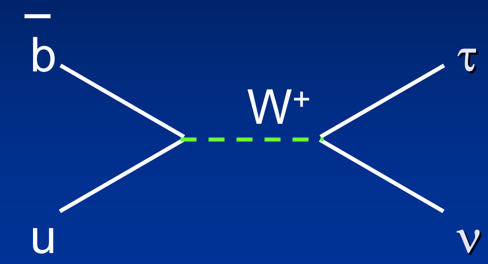
Rare Decays: Physics Motivation

- The constrain on Unitarity Triangle due to tree level or $\Delta F=2$ processes
- Processes other than tree level can also be used for constraining the UT



- Flavour-Changing neutral current (FCNC) [$b \to (s,d)\gamma$, $b \to sll$, etc]
  - Forbidden at tree level, proceed at one loop
  - Suppressed (rare decays) due to the CKM matrix elements
  - Good place to search for non-SM
    - New particles in the loop can enhance the observables (Branching Fraction, Asymmetries, etc) predicted by the SM
- Pure leptonic decays suppressed (CKM parameters - $|v_{ub}|$ and helicity - lepton mass squared)

Leptonic Decays: $B^+ \to \tau^+ \nu$



- Helicity suppressed pure leptonic B decay
  - Measure $|V_{ub}|$, f_B
- $\tau : \mu : e = 1 : 5\times10^{-3} : 1\times10^{-7}$
- SM prediction :

  $Br(B^+ \to \tau^+ \nu) = (1.6 \pm 0.4)\times10^{-4}$

  $f_B = 0.216 \pm 0.022$ GeV, $|V_{ub}| = (4.31 \pm 0.30)\times10^{-3}$

$$Br(B^+ \to l^+ \nu_l)_{SM} = \frac{G_F^2}{8\pi} m_B m_l^2 \tau_B \left(1 - \frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2$$

- First evidence by Belle (PRL 97, 251802 (2006))

$$Br(B^+ \to \tau^+ \upsilon) = (1.79^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(sys))\times10^{-4}$$

(3.5σ, 414 fb^{-1})

- Possibility to constrain physics beyond SM
  - 2HDM model can enhance Branching fraction

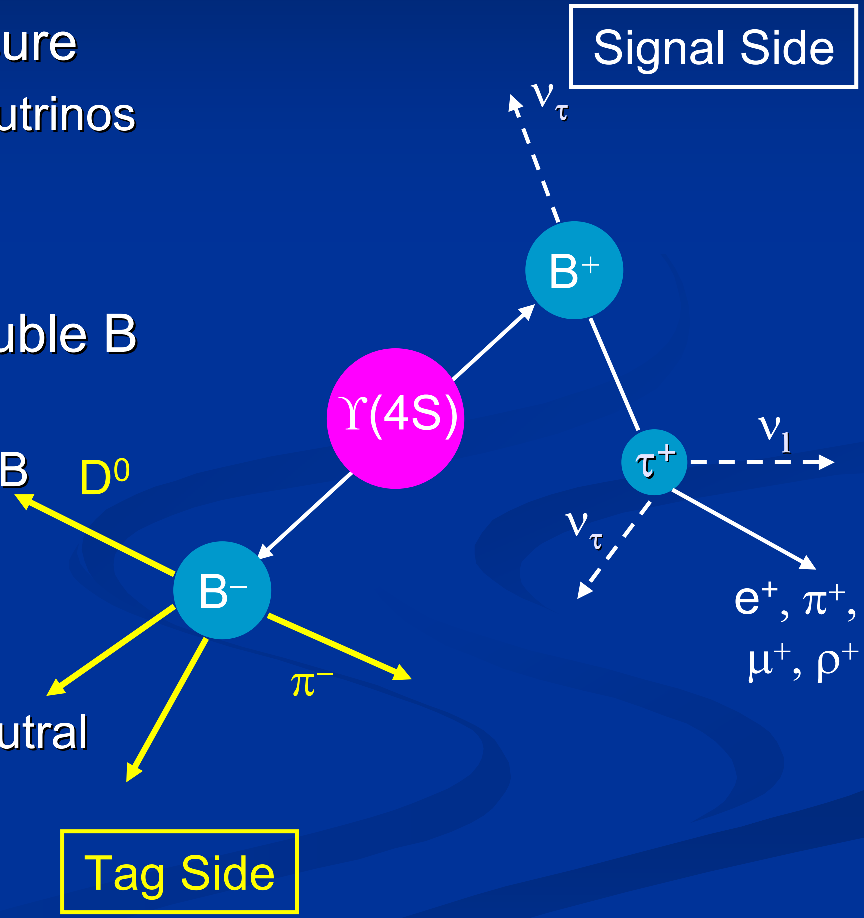
$$Br(B \to \tau\nu) = Br(B \to \tau\nu)_{SM} \times \left(1 - \tan^2\beta \frac{m_{B^\pm}^2}{m_{H^\pm}^2}\right)^2$$

Hou, PRD 48, 2342 (1993)

$B^+ \to \tau^+ \nu$: Analysis Overview

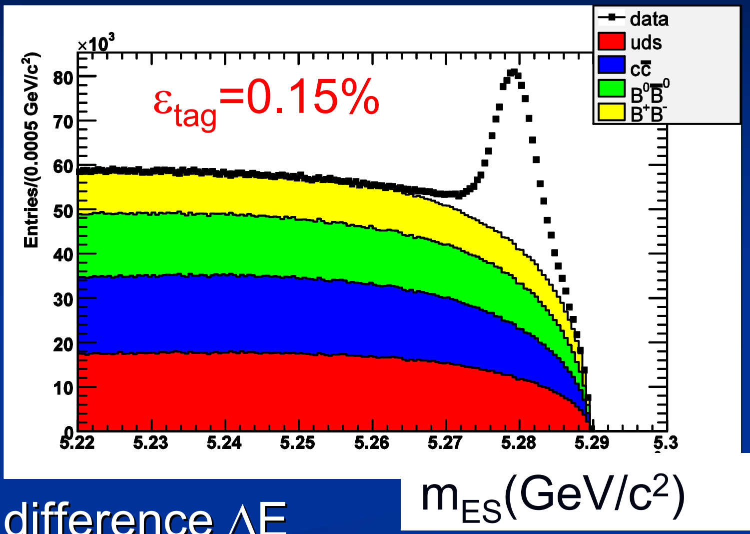
- Experimentally challenging to measure
  - Final state contains two or more neutrinos
  - Less kinematic constraints

- Method : Take the advantage of double B production in $\Upsilon(4S)$
  - Full or partial reconstruction of one B ("Tag B")
    - $B^- \to D^0 l^- \nu X^0$ (Semileptonic Tag)
    - **$B^- \to D^{0(*)} X^-$ (Hadronic Tag)**
  - Attribute remaining charged and neutral particles to the other B ("signal B")



$B^+ \to \tau^+ \nu$: Tag Side

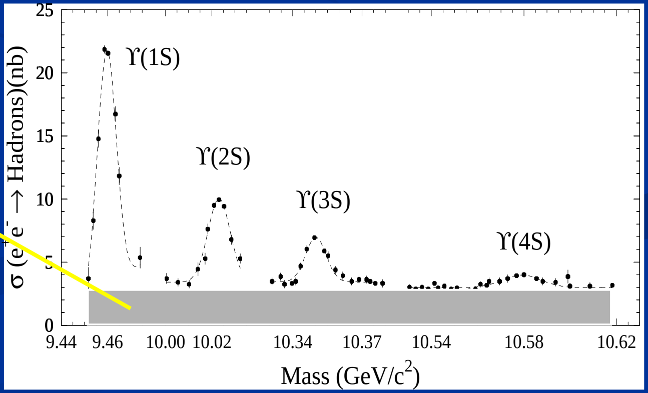
- Hadronic: $B^- \to D^{(*)0} X^-$ (~2700/ fb^{-1})
  - $D^{*0} \to D^0 (\pi^0/\gamma)$
    $D^0 \to K^+\pi^-, K^+\pi^-\pi^0, K^+\pi^-\pi^-\pi^+, K_S\pi^+\pi^-$
  - $X^+ = n_1 K^\pm + n_2 \pi^\pm + n_3 K_S + n_4 \pi^0$
    $(n_1+n_2 \le 5,\ n_3 \le 2,\ n4 \le 2)$



- Full reconstruction of an event
  - Beam energy-substituted mass m_{ES}; Energy difference ΔE

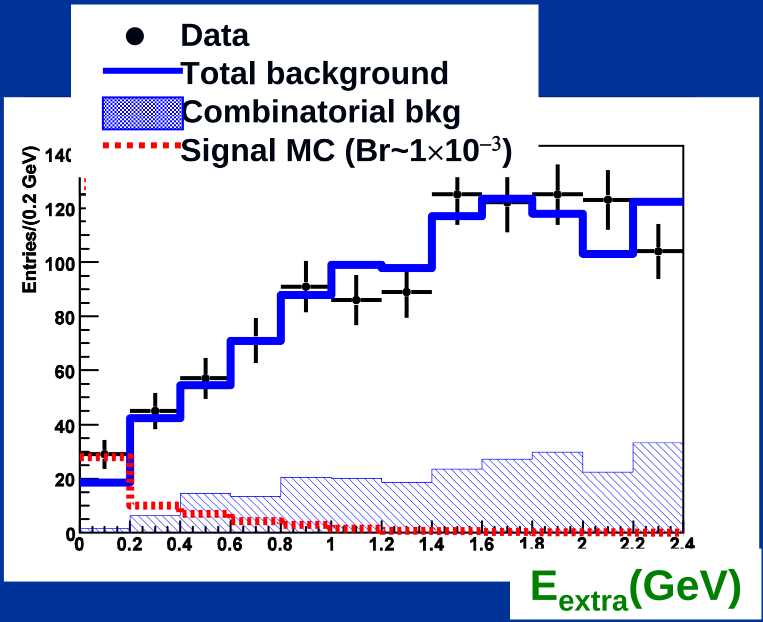
$$m_{ES} \equiv \sqrt{E_{beam}^{*2} - p_B^{*2}} \sim m_B \qquad \Delta E \equiv E_B^* - E_{beam}^* \sim 0$$

- Backgrounds
  - Events not from $B\bar{B}$, $e^+e^- \to \bar{q}q$ ($q=u,d,s,c,\tau$) "continuum"
  - Mis-reconstructed B candidates "combinatorial"



$B^+ \rightarrow \tau^+ \nu$: Signal Side

- Signal events $B^+ \rightarrow \tau^+ \nu$
  - $\tau^+ \rightarrow e^+\nu\nu$, $\mu^+\nu\nu$, $\pi^+\nu$, $\pi^+\pi^0\nu$ (71%)
- Signal optimization for each mode separately
  - Particle ID, Charged track momentum, ρ quality ($\pi^+\pi^0$ mode),..
  - E_{extra} sum of neutral energy not associated with Tag B or Signal B (π^0 in $\tau + \rightarrow \pi^+\pi^0\nu$)
    - E_{extra} <-160, 100, 230 and 290 MeV (use $s/(s+b)^{1/2}$ for optimization)
- Background is estimated from side band region ($0.4 < E_{extra} < 2.4$ GeV)



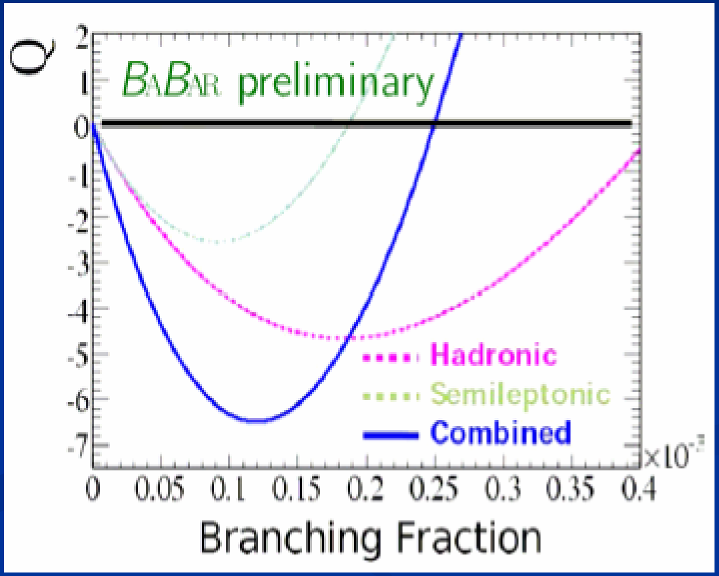
Mode	Expected background	Observed
$\tau \rightarrow e\nu\nu$	1.5 ± 1.4	4
$\tau \rightarrow \mu\nu\nu$	1.8 ± 1.0	5
$\tau \rightarrow \pi\nu\nu$	6.8 ± 2.1	10
$\tau \rightarrow \pi\pi^0\nu$	4.2 ± 1.4	5
All	14.3 ± 3.0	24

$B^+ \to \tau^+ \nu$: Branching Fraction Results

Signal yield is extracted from minimizing the likelihood-based estimator

$$-2\ln Q = -2\ln(L(s+b)/L(b))$$

$$L(s+b) \equiv \prod_{i=1}^{4} \frac{e^{-(s_i+b_i)}(s_i+b_i)^{n_i}}{n_i!}$$



arXiv:0705.1820
Submitted to PRD

L = 346 fb^{-1}

	$Br(B^+ \to \tau^+ \nu_\tau) \times 10^4$	Significance	$(f_B \cdot \lvert V_{ub} \rvert) \times 10^4$
Semileptonic	$0.9 \pm 0.6(\text{stat}) \pm 0.1(\text{sys})$	1.3σ	$7.2^{+2.0}_{-2.8} \pm 0.2$
Hadronic	$1.8^{+1.0}_{-0.9}(\text{stat} + \text{bkg sys}) \pm 0.3(\text{other sys})$	2.2σ	$10.1^{+2.8}_{-2.5} \pm 0.8$
Combined	$1.2 \pm 0.4(\text{stat}) \pm 0.3(\text{bkg sys}) \pm 0.2(\text{sys})$	2.6σ	$--$

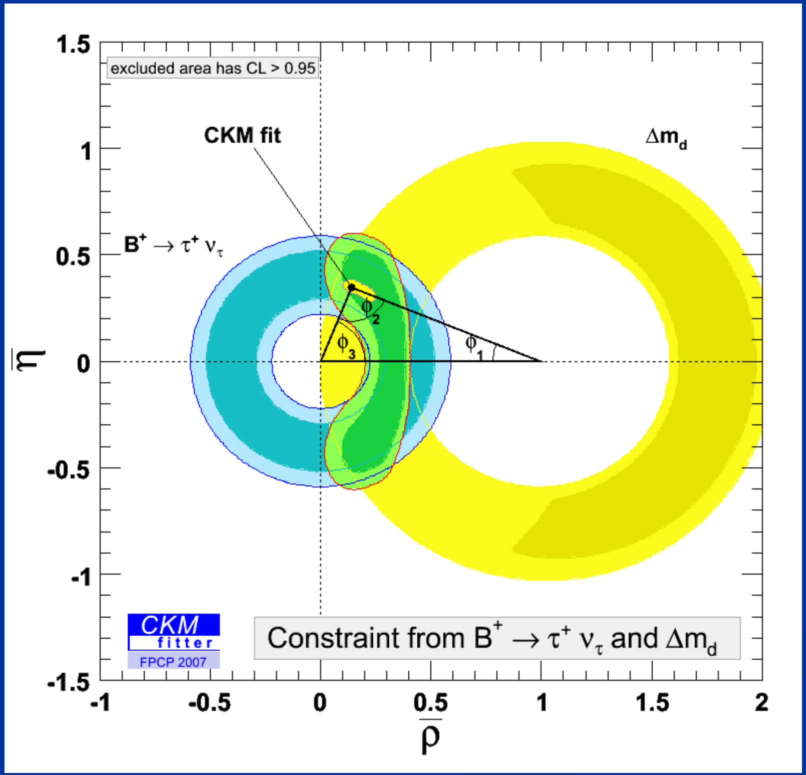
arXiv:0708.2260, Submitted to PRD

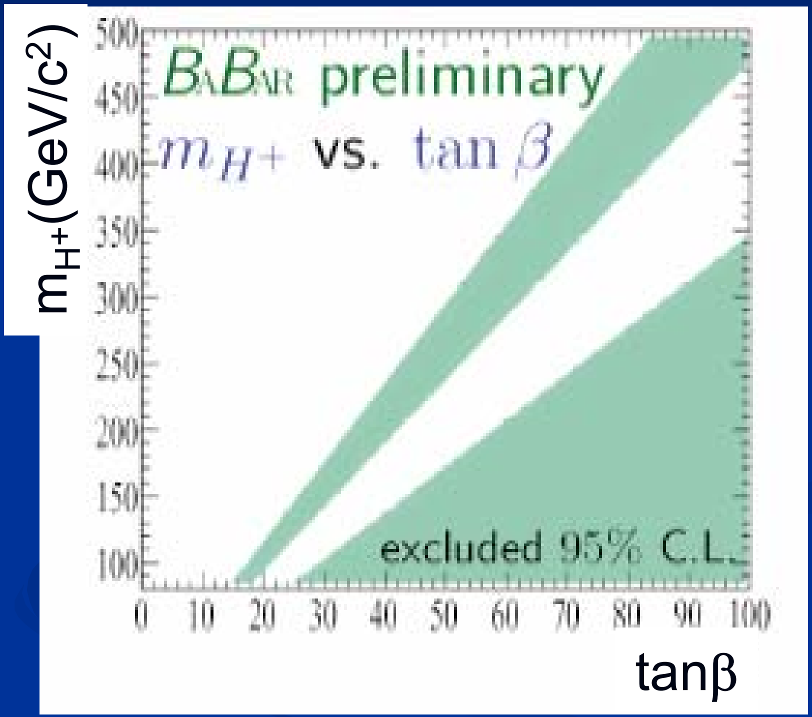
Constraints from $B^+ \to \tau^+ \nu$

CKMfitter, http://ckmfitter.in2p3.fr

Exclusion plot in (ρ, η) plane

Inputs
- f_B = (223±15±26) MeV
- $B \to \tau\nu$ (Belle and BaBar)
- Δm_d = (0.507 ±0.005) ps^{-1} (PDG'07)

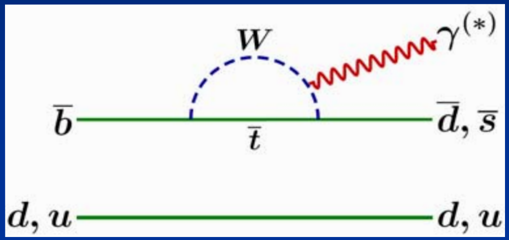




Exclusion plot in (tanβ, m_{H+}) plane

Inputs
- Babar combined result
- $m_{H+} > 79.3$ GeV/c^2 (LEP limit)

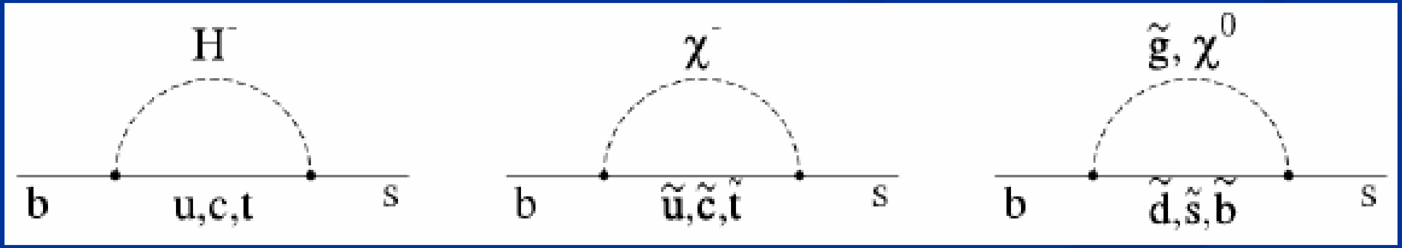
Inclusive $b\to s\gamma$ decays



- FCNC decay dominated by W-loop
- Not so rare decay , SM $Br(b\to s\gamma) \sim O(10^{-4})$
- Recent NNLO calculations (E_γ > 1.6 GeV)

  $Br(b\to s\gamma) = (3.0\text{-}3.5)\times 10^{-4}$ (7-14)% uncertainties

  HFAG 2006 average $Br(b\to s\gamma) = (3.55\pm 0.26)\times 10^{-4}$ (7%)
- Inclusive $b\to(s,d)\gamma$ is one of the cleanest decays for searching for NP
  - Look for any deviation in observables (branching fraction, CP asymmetry etc)

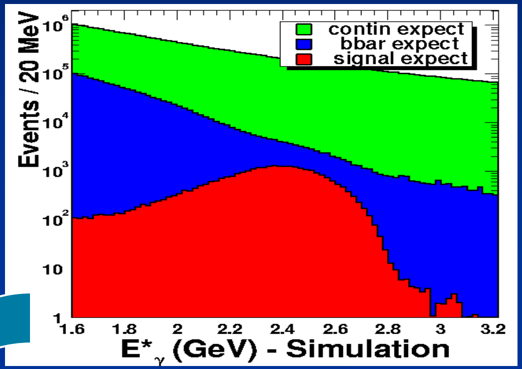


- γ spectrum is sensitive to mass and momentum of b quark inside B meson

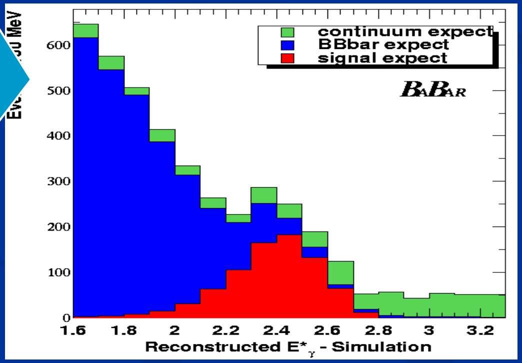
$$\text{First Moment} = \langle E_\gamma^B \rangle \approx \frac{m_b}{2} \qquad \text{Second Moment} = \langle (E_\gamma^B)^2 \rangle - \langle E_\gamma^B \rangle^2 \approx \mu_\pi^2$$

$b \to s\gamma$: Previous Measurements

- Inclusive methods
  - Request high energetic γ
  - No X_s sensitivity to fragmentation
  - Huge background from continuum events
    ($e^+e^- \to q\bar{q}$, q = u,d,s,c) with γ from ISR, π^0 or η
    - A lepton tag on the other B
  - Need to translate to B rest frame



Lepton tag



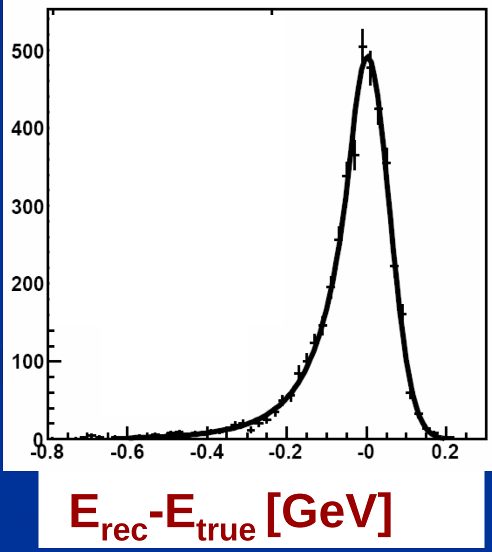
- Semi-Inclusive methods
  - Sum of 38 exclusive decays ($K\pi\pi$, $K_S\pi$, etc)
  - Experimentally easier
  - B is fully reconstructed (m_{ES} and ΔE)
  - Photon in the B rest frame
  - Large error due to form factors

$$E_\gamma = \frac{M_B^2 - M(X_S)^2}{2M_B}$$

$b \to s\gamma$: New technique

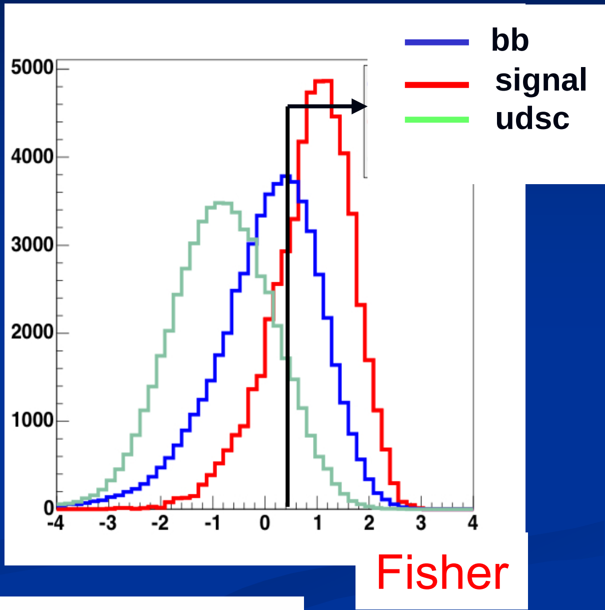
- Hadronic Tag method
- Fully reconstruct one B with hadronic decays:
  $B \to D^{(*)}X$ (X: combination of π, and K with $|\Sigma q|=1$)
  - Flavour, charge and four momentum of signal B known
- Photon energy can be measured in B rest frame
  - Require a high energy photon (E_γ > 1.3 GeV in B frame) in other B (signal B)
- Small Tag efficiency (~0.3%)
- Photon energy spectrum and partial branching fractions in bins of photon energy
  - Number of events determined from fit to m_{ES} in E_γ bins

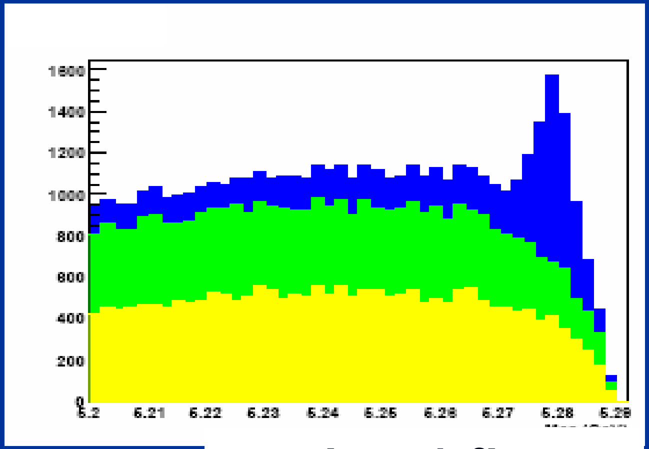
γ Energy resolution



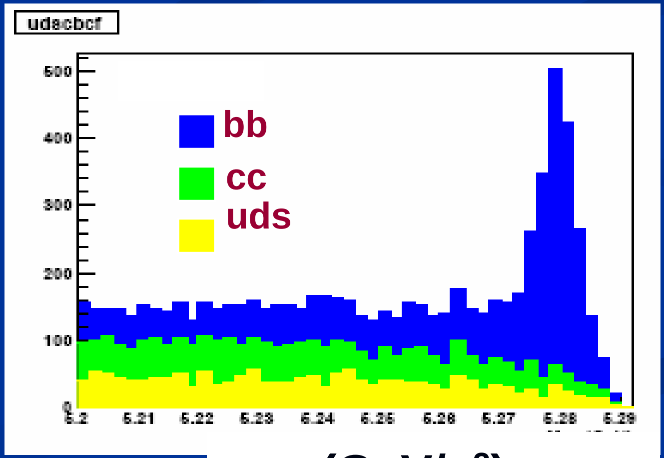
b→sγ: Background Rejection

- Main backgrounds
  - Photons originating from π^0, η, ρ
  - Continuum background: suppress using Fisher discriminants
    - 12 inputs based on event shapes variables
- Selection optimized by maximizing $s/(s+b)^{1/2}$





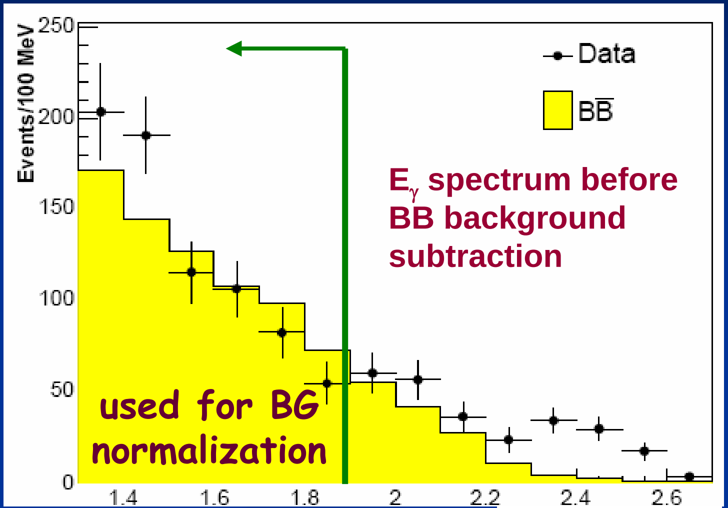
m_{ES} (GeV/c²)



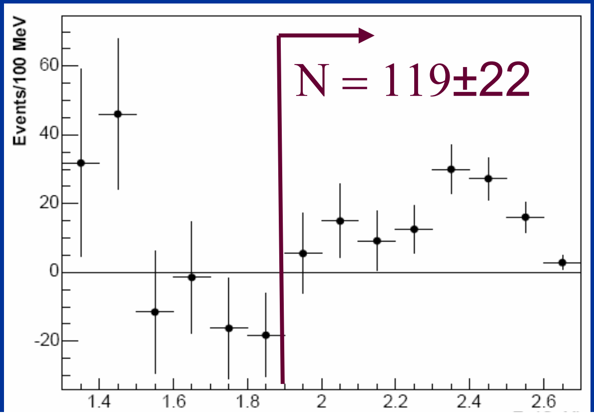
m_{ES} (GeV/c²)

$b \to s\gamma$: Photon Energy Spectrum

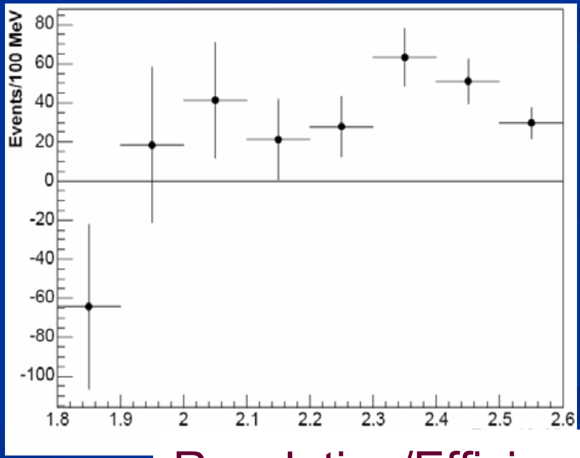
- Photon energy spectrum
  - b quark mass (m_b) and momentum inside the B meson (μ_π^2)
  - Input for $|V_{u(c)b}|$ extraction from semileptonic B decays
- In two body decays, γ is monochromatic energy at b quark rest frame, due to "Fermi motion" the energy spectrum is smeared



E_γ (GeV)

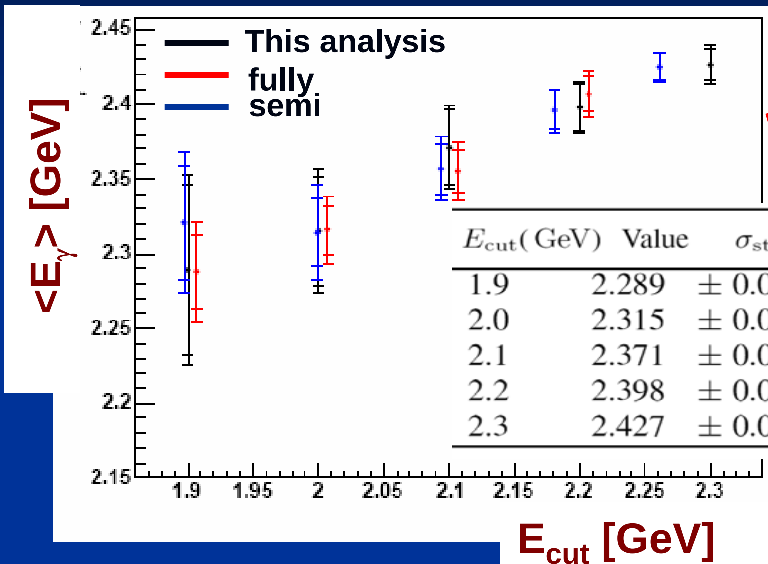


Background subtracted E_γ (GeV)

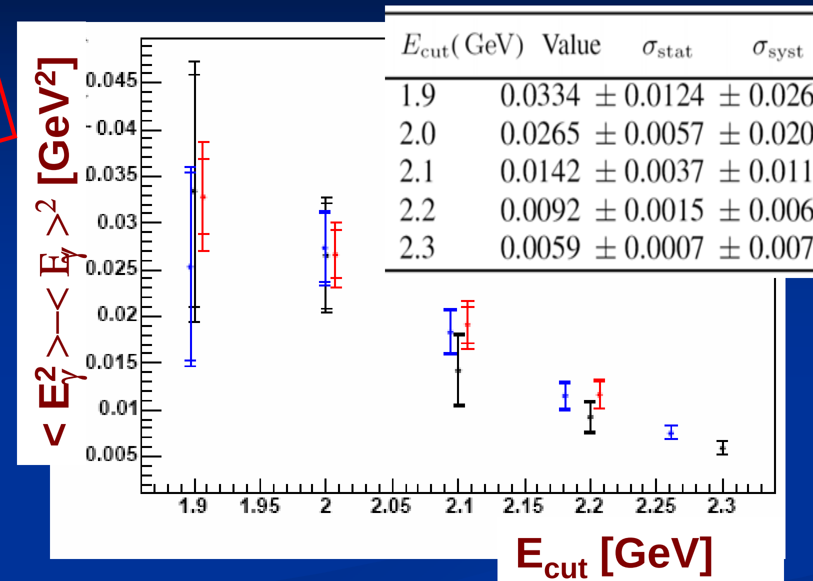


Resolution/Efficiency corrected E_γ (GeV)

b→sγ: Moments & Partial Branching Fraction



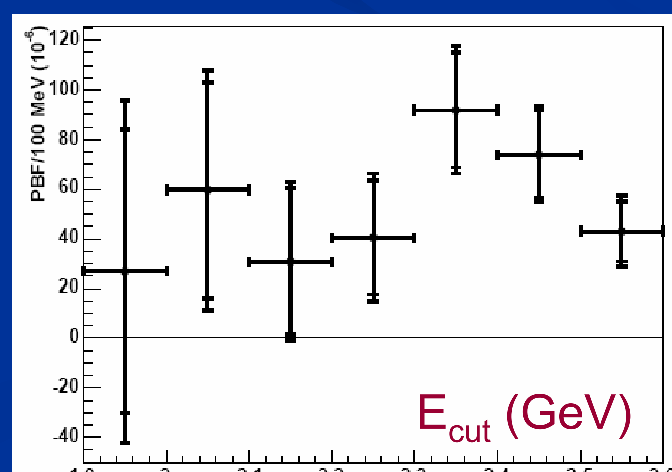
E_{cut}(GeV)	Value	σ_{stat}	σ_{syst}
1.9	2.289	± 0.058	± 0.026
2.0	2.315	± 0.036	± 0.020
2.1	2.371	± 0.025	± 0.011
2.2	2.398	± 0.016	± 0.006
2.3	2.427	± 0.010	± 0.007



E_{cut}(GeV)	Value	σ_{stat}	σ_{syst}
1.9	0.0334	± 0.0124	± 0.0263
2.0	0.0265	± 0.0057	± 0.0203
2.1	0.0142	± 0.0037	± 0.0111
2.2	0.0092	± 0.0015	± 0.0061
2.3	0.0059	± 0.0007	± 0.0073

- Photon energy moments from different methods agree well
- Next Step: Extract HQE parameters, combine the results and measure Asymmetries

	$BF[E_\gamma > E_{cut}]/10^{-6}$		
E_{cut}(GeV)	Value	σ_{stat}	σ_{syst}
1.9	366	± 85	± 59
2.0	339	± 64	± 47
2.1	278	± 48	± 34
2.2	248	± 38	± 26
2.3	207	± 30	± 19



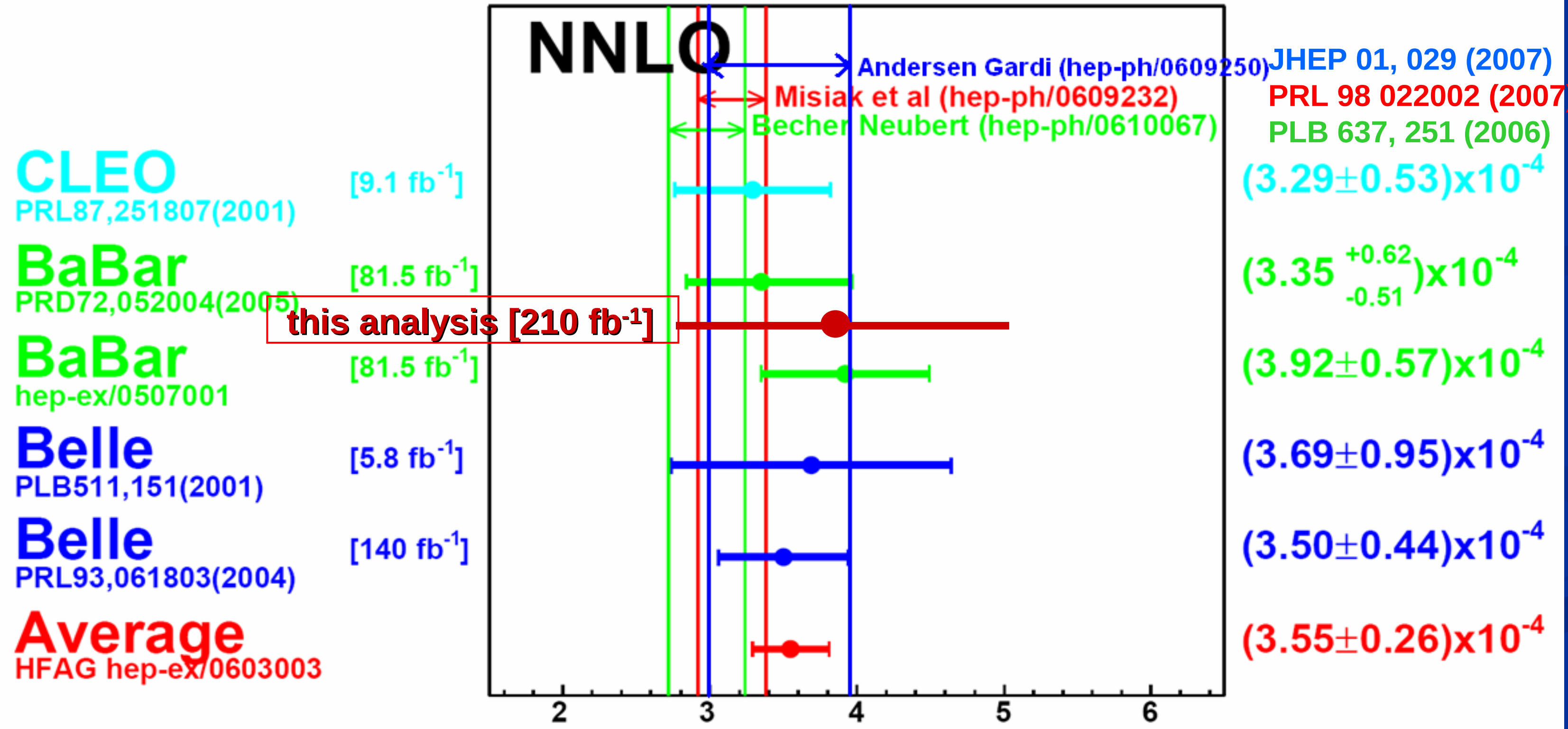
- Statistical error dominant
- Systematic error will be reduced with more data as well

$b\to s\gamma$: Branching Fraction

$E_\gamma > 1.9$ GeV $Br(B\to X_s\gamma) = (3.66 \pm 0.85 \pm 0.59) \times 10^{-4}$

$E_\gamma > 1.6$ GeV $Br(B\to X_s\gamma) = (3.91 \pm 0.91 \pm 0.63) \times 10^{-4}$

Extrapolation down to 1.6 GeV
Buchmuller and Flacher
PRD 73, 073008 (2006)



$B^0 \to K^{*0}\gamma$: Time dependent CP Asymmetry

- Interference between $B^0 \to K^{*0}(K_s\pi^0)\gamma$ (decay) and $B^0 \to \overline{B}^0 \to K^{*0}(K_s\pi^0)\gamma$ (mixing) is suppressed due to photon polarization
  - Left-handed γ (B^0) and right handed γ ($\overline{B}^0$)
- CP asymmetry measures the interference
  - SM : $A_{CP} \sim -0.02$

    (Ball and Zwicky, PLB 642, 478 (2006))

$$A_{CP}(t) = \frac{\Gamma(\overline{B}^0 \to K_S\pi^0\gamma) - \Gamma(B^0 \to K_S\pi^0\gamma)}{\Gamma(\overline{B}^0 \to K_S\pi^0\gamma) + \Gamma(B^0 \to K_S\pi^0\gamma)}$$

$$= S\sin(\Delta m t) - C\cos(\Delta m t)$$

- Time evolution of the $B^0 \to K^{*0}\gamma$

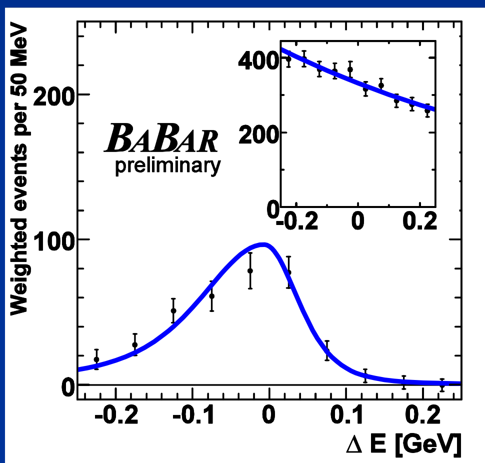
$$P_\pm(\Delta t) = \frac{e^{-|\Delta t|/\tau_B}}{4\tau_B} \times \left[1 \pm S\sin(\Delta m_d \Delta t) \mp C\cos(\Delta m_d \Delta t)\right]$$

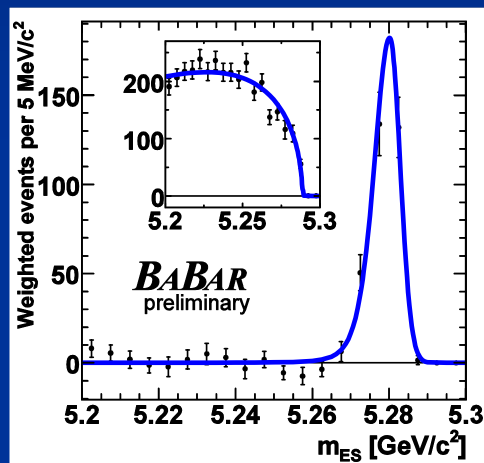
S: CP violation in interference between decay and mixing
C: Direct CPV

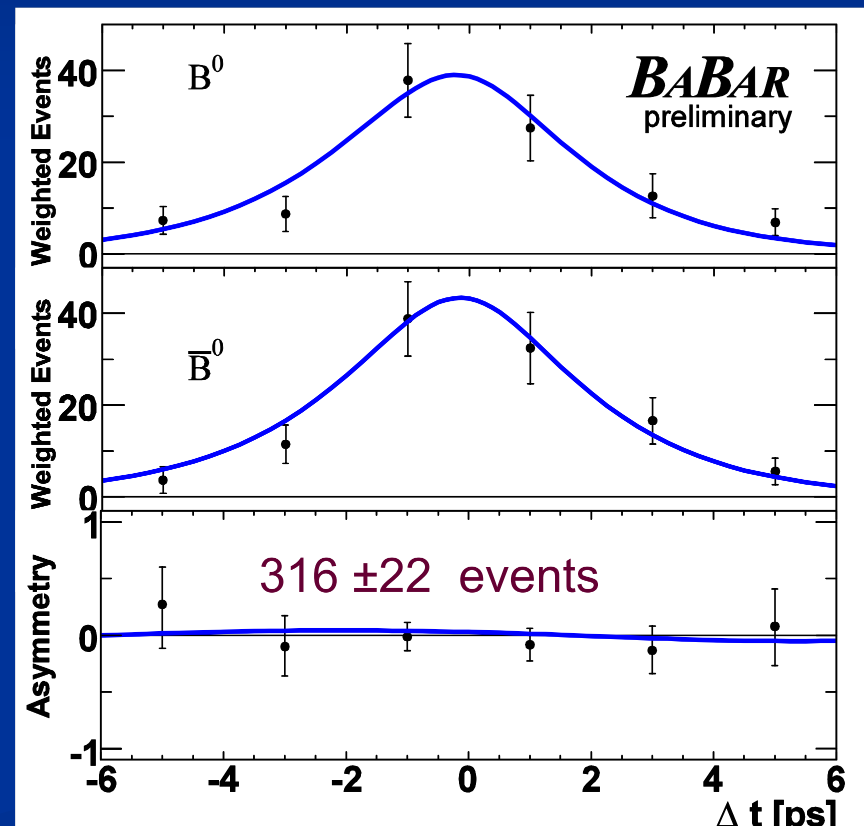
(Details on the method: Talk presented this morning by Jacques Chauveau - Measurements of CP violation in B decays and CKM parameters)

$B^0 \to K^{*0}\gamma$: Time dependent CP Asymmetry

- $\Delta t = t_{sig} - t_{tag}$ t_{sig} : decay time $B^0 \to K_S\pi^0\gamma$ ($K_S \to \pi^+\pi^-$)
  t_{tag}: B_{tag} (reconstructed from the rest of the tracks and clusters)





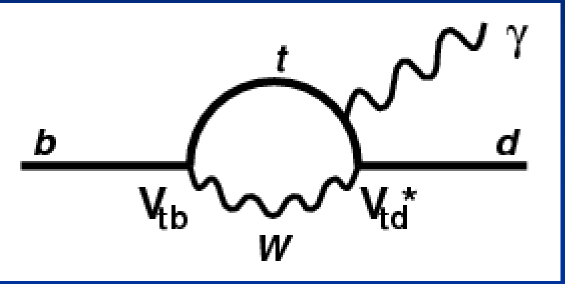


L = 391 fb^{-1}

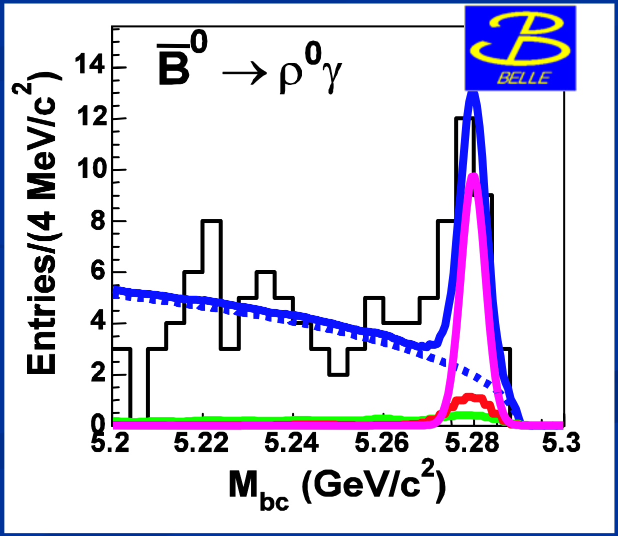
$$S_{K^*\gamma} = -0.08 \pm 0.31 \pm 0.05$$
$$C_{K^*\gamma} = -0.15 \pm 0.17 \pm 0.03$$

Exclusive $b \to d\gamma$ Decays

- $B^{\pm} \to \rho^{\pm}\gamma$, $B^0 \to (\rho^0, \omega)\gamma$
- Suppressed by $|V_{td}/V_{ts}|^2 \sim 0.04$ compared to $b \to s\gamma$
  - SM: $Br(B \to (\rho, \omega)\gamma) \sim (0.9\text{-}1.8)\times 10^{-6}$

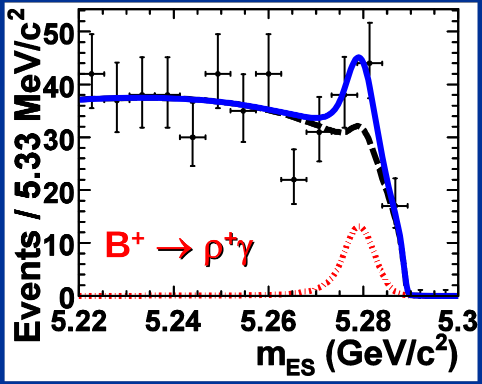


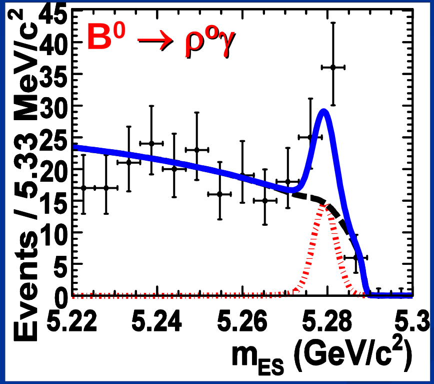
- Difference between $|V_{td}/V_{ts}|$ from this decays and B_s mixing can indicate NP
- First observation by Belle on $B^0 \to \rho^0\gamma$ decay with 5.2σ significance **(PRL 96, 221601 2006)**
- BaBar measurements
  - Results at 316 fb^{-1} presented here **(PRL 98 151802 (2007))**

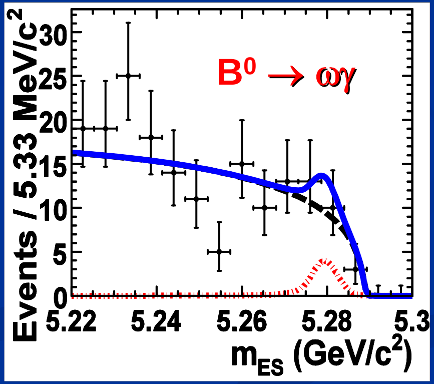


Exclusive $b \to d\gamma$: Analysis & Results

- Reconstruct $\rho^{+(0)} \to \pi^+\pi^{0(-)}$ $\omega \to \pi^+\pi^-\pi^0$
- Backgrounds (continuum, $B \to K^* \gamma$ and γ from π^0, η) rejection
- Signal extraction from maximum 4D (5D) likelihood fit for ρ (ω)







Mode	N_{sig}	Significance	$Br(10^{-6})$
$B^+ \to \rho^+\gamma$	$42.0^{+14.0}_{-12.7}$	3.8σ	$1.10^{+0.37}_{-0.33} \pm 0.09$
$B^0 \to \rho^0\gamma$	$38.7^{+10.6}_{-9.8}$	4.9σ	$0.79^{+0.22}_{-0.20} \pm 0.06$
$B^0 \to \omega\gamma$	$11.0^{+6.7}_{-5.6}$	2.2σ	$0.40^{+0.24}_{-0.20} \pm 0.05$
$B \to (\rho,\omega)\gamma$		6.4σ	$1.25^{+0.25}_{-0.24} \pm 0.09$

Isospin-averaged $Br(B \to (\rho,\omega)\gamma)$

$$Br(B \to (\rho,\omega)\gamma) = B(B^- \to \rho^-\gamma)$$
$$= 2\frac{\tau_{B^+}}{\tau_{B^0}} B(B^0 \to \rho^0\gamma)$$
$$= 2\frac{\tau_{B^+}}{\tau_{B^0}} (B^0 \to \omega\gamma)$$

First evidence for charged mode

First BaBar observation of $B \to (\rho,\omega)\gamma$

Exclusive $b \to d\gamma$: $|V_{td}/V_{ts}|$

Branching fraction results from BaBar and Belle agree well

	$Br(B \to (\rho,\omega)\gamma)(10^{-6})$
BaBar	$1.25^{+0.25}_{-0.24} \pm 0.09$
Belle	$1.13 \pm 0.20 \pm 0.11$

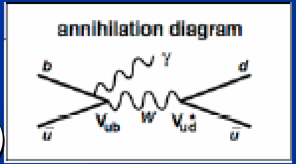
(Belle preliminary result presented at LP07 by M. Nakao, KEK)

Ratio of branching fraction can be used for the extraction of $|V_{td}/V_{ts}|$

$$\frac{Br(B \to (\rho,\omega)\gamma)}{Br(B \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1 - m_{\rho,\omega}^2 / m_B^2}{1 - m_{K^*}^2 / m_B^2}\right)^3 \varsigma^2 [1 + \Delta R]$$

$\zeta = f_{K^*} / f_\rho$ f = form factor

ΔR accounts for the annihilation diagram (not exist K*)



Inputs

- $\zeta = 1.17 \pm 0.09$ **(Ball and Zwicky, JHEP 0604, 046 (2006))**
- $\Delta R = 0.1 \pm 0.1$ **(Ali et al, PLB 595, 323 (2004))**
- BaBar isospin-averaged Br

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.200^{+0.021}_{-0.020}(\exp) \pm 0.015(th)$$

Exclusive $b \to d\gamma$: Constraints on UT

BaBar result:

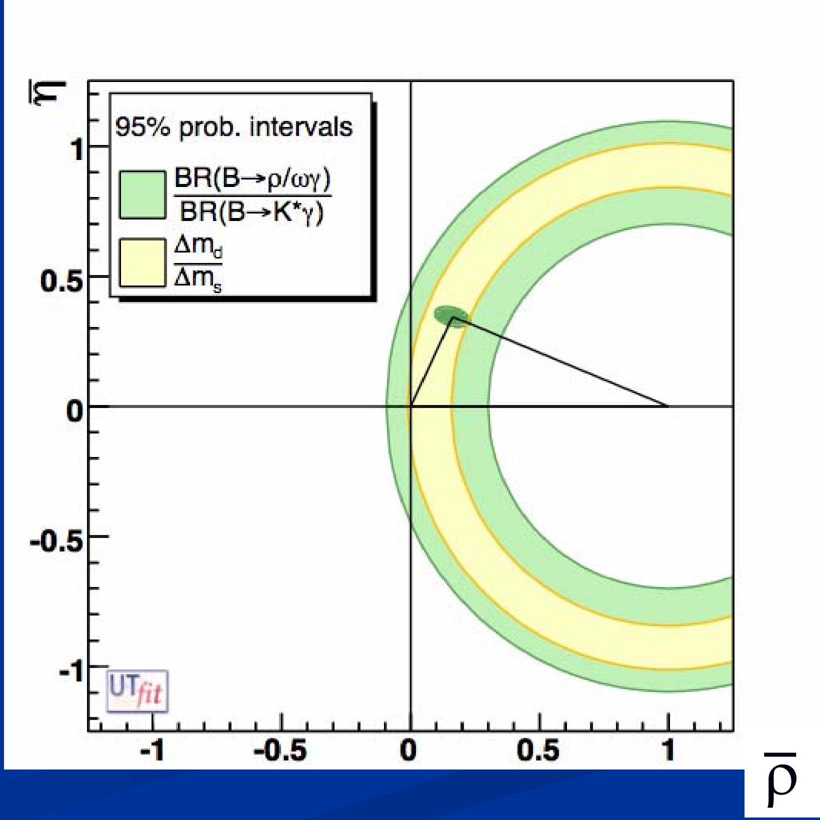
$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.200^{+0.021}_{-0.020}(\text{exp}) \pm 0.015(th)$$

CDF **(PRL 97, 242003 (2006))**

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.2060 \pm 0.0007^{+0.0081}_{-0.0060}$$

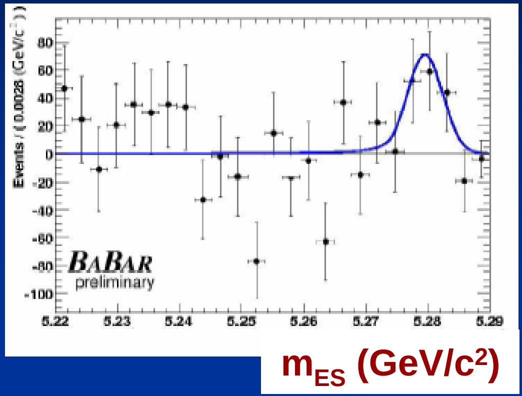
- Excellent agreement between two results
- The constraints on UT coming from two different physics is the same

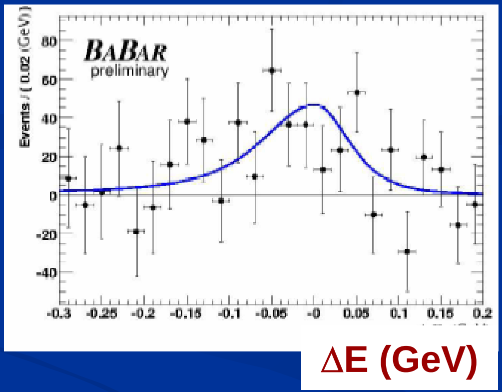
http://utfit.roma1.infn.it/



Inclusive $b \to d\gamma$

- First inclusive search on $b \to d\gamma$
  - Sum of 7 exclusive decay modes
  - $B^0 \to \pi^+\pi^-\gamma$, $B^+ \to \pi^+\pi^0\gamma$, $B^+ \to \pi^+\pi^-\pi^+\gamma$, $B^0 \to \pi^+\pi^-\pi^0\gamma$, $B^0 \to \pi^+\pi^-\pi^+\pi^-\gamma$, $B^+ \to \pi^+\pi^-\pi^+\pi^0\gamma$, $B^+ \to \pi^+\eta\gamma$
- Hadronic mass system
  - $1.0 < M(X_d) < 1.8$ GeV/c^2
  - Seven final states corresponds to ~50% of the total X_d fragmentation in this mass range
- $0.6 < M(X_{s(d)}) < 1.8$ GeV/c^2 region used as control sample for Br of $B \to K^*\gamma$ ($B \to \pi^+\pi^-\gamma$, $B^+ \to \pi^+\pi^0\gamma$, $B^0 \to \pi^+\pi^-\pi^0\gamma$)
- 2D (m_{ES}, ΔE) Unbinned-likelihood fit used for signal and background yields extraction
  - 348 fb^{-1}, 178±53 signal events found





$$\sum_{X_d=1}^{7} Br(B \to X_d\gamma)\Big|_{1.0<X_d<1.8\,\text{GeV/c}^2} = \left(3.1 \pm 0.9(stat)^{+0.6}_{-0.5}(sys) \pm 0.5(th)\right) \times 10^{-6}$$

3.1σ significance
First evidence for $b \to d\gamma$ outside $B \to (\rho,\omega)\gamma$ resonance

Next step: Extrapolate hadronic mass region, $|V_{td}/V_{ts}|$ extraction using **$b \to s\gamma$**

Summary

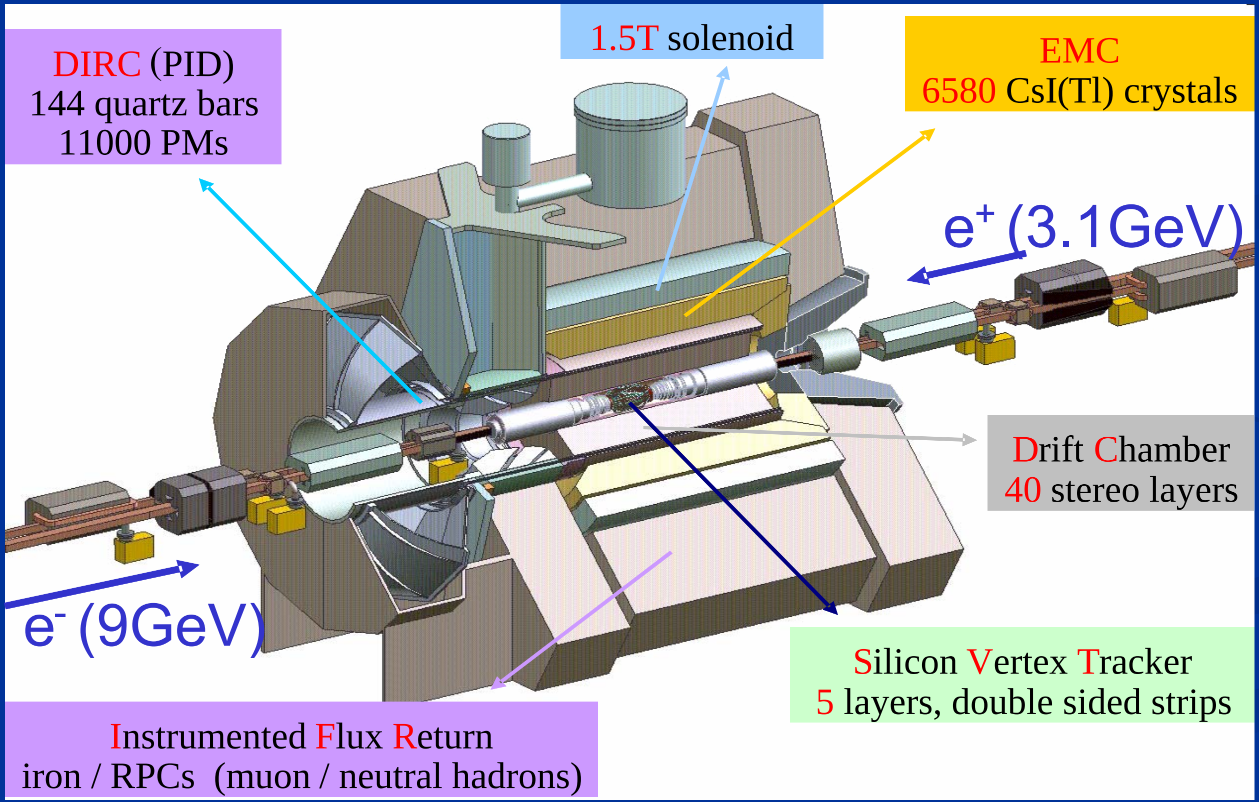
- Rare decays are very interesting place to study new physics and test the constraints on Unitarity Triangle
- $B^+ \to \tau^+ \nu$ signal seen and the sensitivity is approaching to SM rates
- Recent progress in $b \to s\gamma$ decays both
  - Theory: NNLO

  and
  - Experimental (new approach)
    - Complementary to previous measurements (advantages direct information on photon B rest frame and better systematic control)
    - Different methods agree well
- No TDCP asymmetry is observed in $B \to K^{*0}\gamma$
- Exclusive $b \to d\gamma$ decays through $B \to (\rho,\omega)\gamma$
  - First evidence of $B^+ \to \rho^+\gamma$ and first BaBar observation of isospin-averaged branching fraction
  - Excellent agreement on $|V_{td|}/V_{ts}|$ from decay and B_s mixing (Tevatron)
- First evidence on inclusive $b \to d\gamma$ transition in a $M(X_d)$ outside ρ/ω resonances

Backup Slides

The BaBar Detector

- B factory experiment operated at SLAC since 1999
- Two asymmetric (electron & positron) beams at the center-of-mass energy of 10.58 GeV
- B mesons are produced in pairs: $e^+e^- \rightarrow \Upsilon(4S) \rightarrow BB$

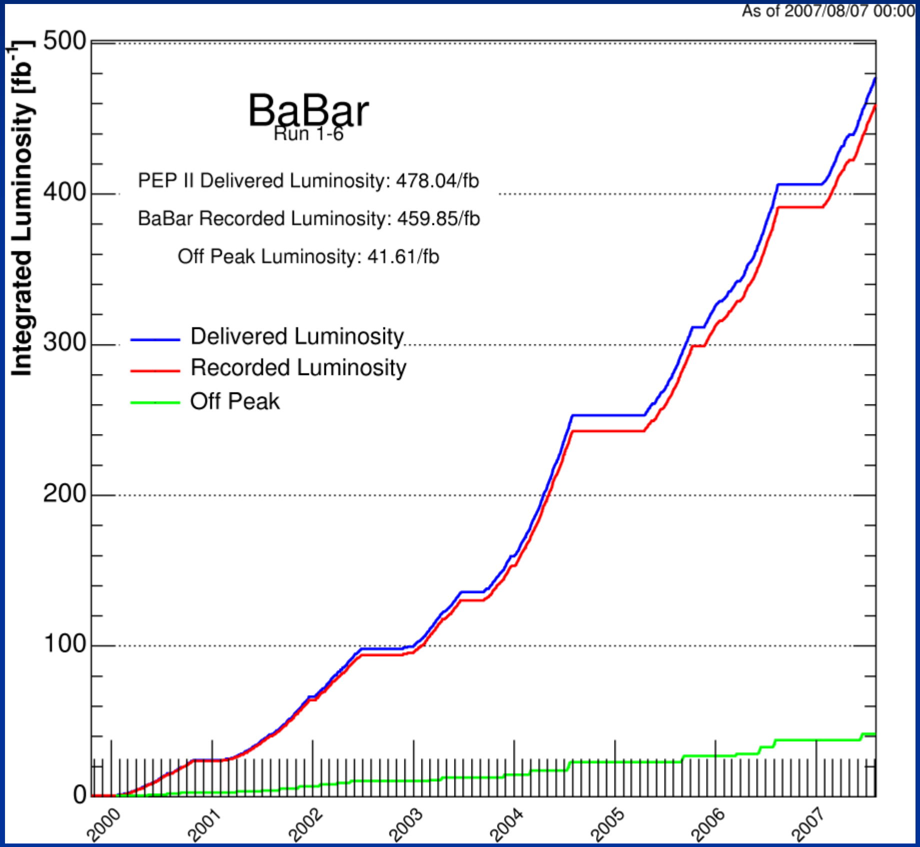


$\sigma_E/E = 2.3\%E^{-1/4} \oplus 1.9\%$ (E in GeV)

$\sigma_{pt}/p_t = 0.13 p_t + 0.45\%$

15µm single hit resolution
Resolution of σ_z = 65 µm (at 1GeV)

The B Factory

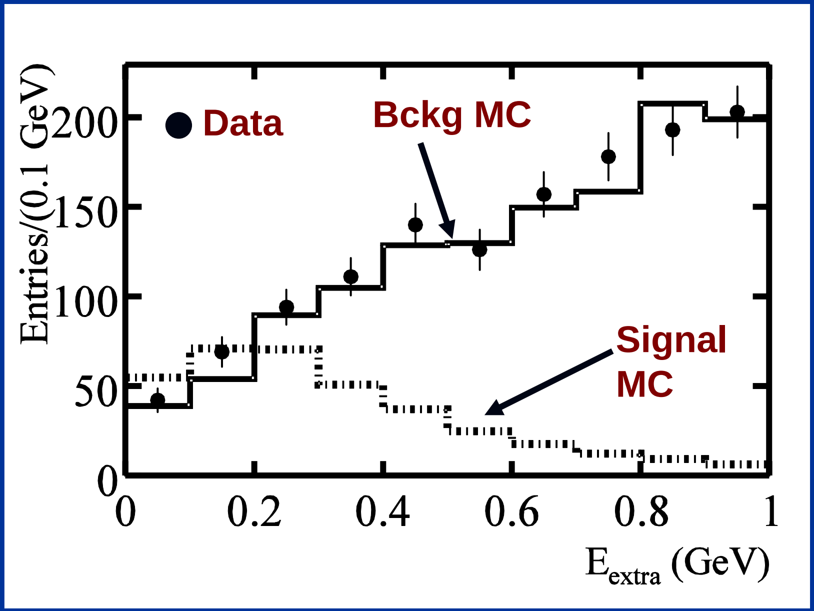


- Total ~500 fb^{-1} data recorded until now at the $\Upsilon(4S)$ cm energy
- In addition, ~10% of total data with an energy that is 40 MeV less than the nominal c.m. energy
  - Background from continuum event
- BaBar/PEPII programme to run until end of summer 2008

$B^+ \to \tau^+ \nu$: Signal Side

Semileptonic Tag

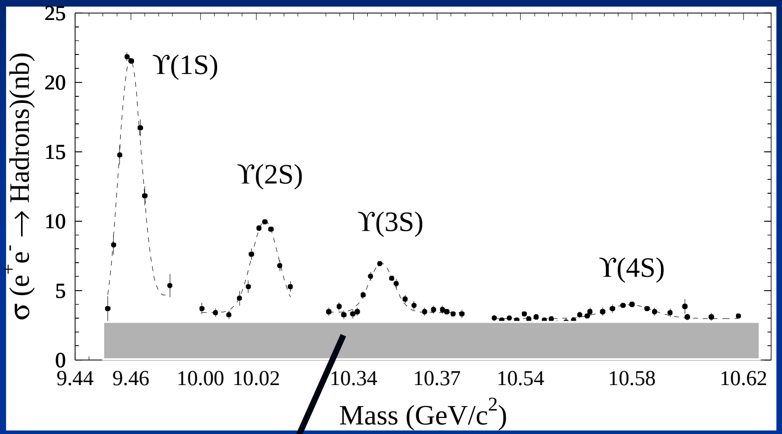
- Same τ decay modes as in hadronic tag analysis
- E_{extra} sum of charged tracks and neutral clusters which are not associated signal B or Tag B
  - E_{extra} < 310 (e), 260 (μ), 480 (π), 250 ($\pi\pi^0$) MeV
- Background estimated E_{extra} sideband (E_{extra} > 500 MeV) and verified with D^0 mass sideband (4σ and 9σ) above and below D^0 mass



Mode	Expected background	Observed
$\tau \to e \nu\nu$	44.3 ± 5.2	59
$\tau \to \mu\nu\nu$	39.8 ± 4.4	43
$\tau \to \pi\nu\nu$	120.3 ± 10.2	125
$\tau \to \pi\pi^0\nu$	17.3 ± 3.3	18
All	221.7 ± 12.7	245

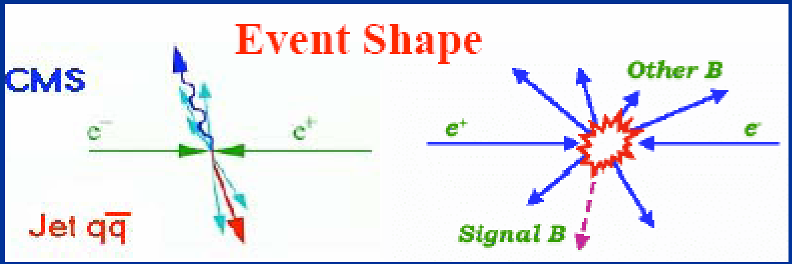
Continuum Background

$\sigma(e^+e^- \to \Upsilon(4S) \to B\bar{B})$=1.05 nb



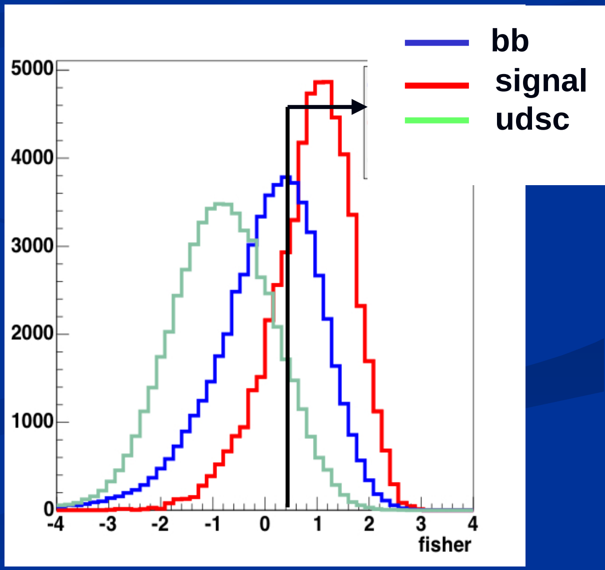
Non-resonant background "continuum"
$e^+e^- \to q\bar{q}$ (q=u,d,s,c,τ)

Events from continuum are jet-like while signal events are spherical



- Event shape variables
  - $R_2 = H_2/H_0$; $H_l = \sum_{i,j} |p_i||p_j| P_l(\cos(p_i, p_j))$

    H_l= Fox-Wolfram moments, P_l= Legendre Polynomials
    R_2 ~ 1 (continuum), R_2~0 ($B\bar{B}$ events)
    Thrust , Sphericity, etc
  - Combine the variables in Fisher discriminants, Neural network



Example for Fischer Discriminants

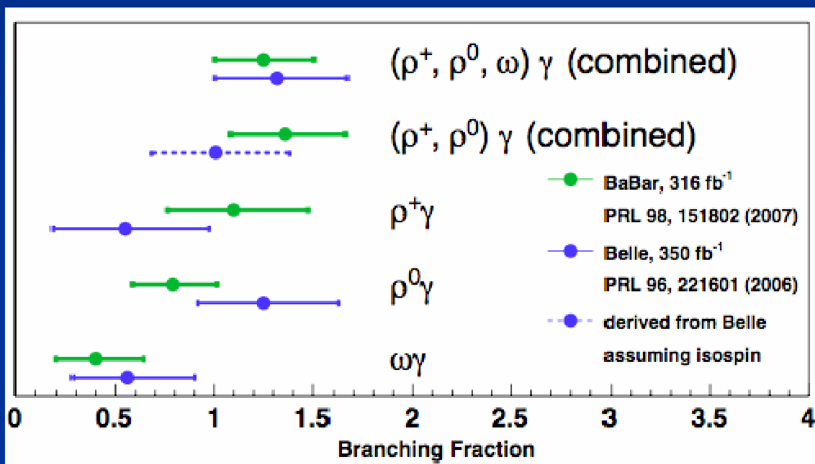
Inclusive b→sγ Decays

Systematic Uncertainties:

$E_{\rm cut}$ (GeV)	Value	$\sigma_{\rm stat}$	$\sigma_{\rm syst}$	$\mathcal{B}(B \to X_s\gamma)$ (10^{-6}) Background Modelling	M_{ES} fit Parameterisation	Detector Response	$B \to X_s\gamma$ Model	$b \to d\gamma$ Subtraction
1.9	366	± 85	± 59	35	44	16	8	2
2.0	339	± 64	± 47	31	34	4	6	1
2.1	278	± 48	± 34	22	24	6	5	1
2.2	248	± 38	± 26	14	18	8	5	1
2.3	207	± 30	± 19	10	14	1	5	1

Exclusive b→dγ Decays

Comaprison between BaBar and Belle results

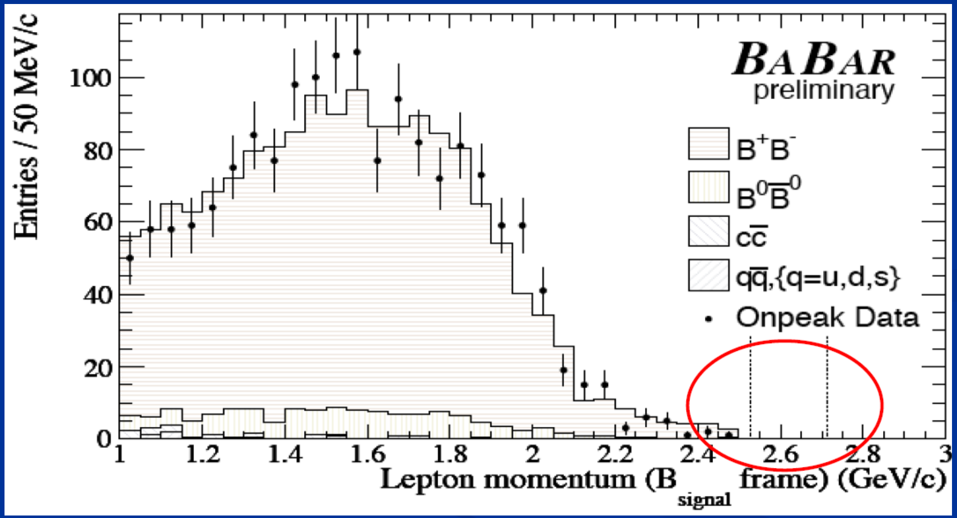


	$Br(B \to (\rho,\omega)\gamma)(10^{-6})$
BaBar	$1.25^{+0.25}_{-0.24} \pm 0.09$
Belle	$1.32^{+0.34+0.10}_{-0.31-0.09}$
Average	$1.28^{+0.20}_{-0.19} \pm 0.06$

$B^+ \to (e^+, \mu^+)\nu$

- SM prediction
  - $B(B^+ \to e^+\nu) \sim 10^{-12}$
  - $B(B^+ \to \mu^+\nu) \sim 4\times10^{-7}$
- Search done using 209 fb^{-1}
- No events observed in either mode
- Expected background events
  e: 0.23 μ: 0.12
- @90% CL
  $B(B^+ \to e^+\nu) < 7.9\times10^{-6}$
  $B(B^+ \to \mu^+\nu) < 6.2\times10^{-6}$

arXiv:hep-ex/0607110v1



$B^+ \to l^+ \nu\gamma$

- Due to photon in the final state, no helicity suppression
  - Branching fraction is enhanced
  - SM prediction: $(1\text{-}5)\times 10^{-6}$ (Korchemsky, Pirjol, and Yan, PRD 61, 114510 2000)

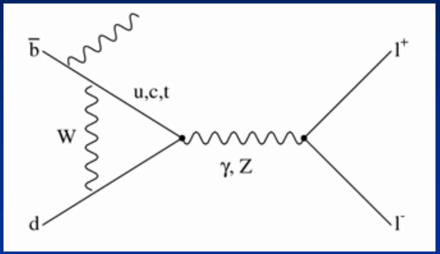
$$\Gamma(B^+ \to l^+ \nu\gamma) = \alpha \frac{G_F^2 |V_{ub}|^2 m_B^5}{288\pi^2} f_B^2 \left(\frac{Q_u}{\lambda_B} - \frac{Q_b}{m_b} \right)$$

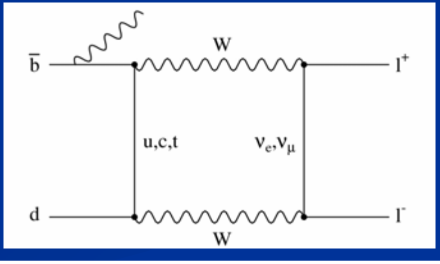
$\Lambda \sim$ B light cone distribution amplitude

- 90% CL (210.5 fb^{-1} 0704.1478 [hep-ex])
  - $B(B \to \mu\nu\gamma) < 2.1 \times 10^{-6}$
  - $B(B \to e\nu\gamma) < 2.8 \times 10^{-6}$
  - $B(B \to l\nu\gamma) < 2.3 \times 10^{-6}$
- Experimental sensitivity reaching to theoretical prediction

$B^0 \to l^+l^-\gamma$

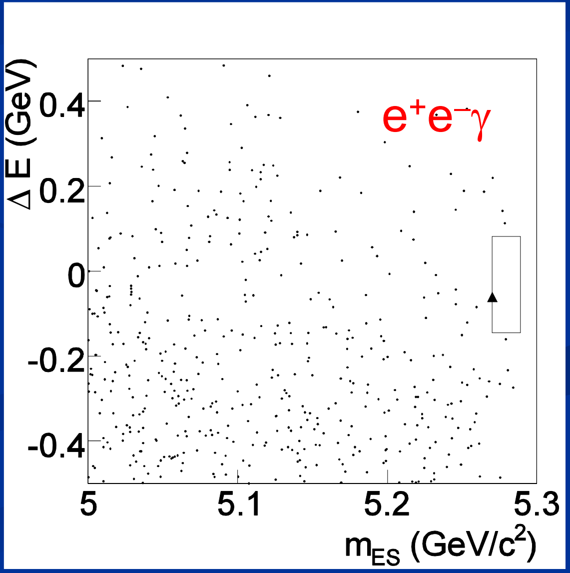
- First search on $B^0 \to l^+l^-\gamma$ (l=e, μ) FCNC process
  - Main contributions: photon emission from one of the initial quark
  - Not helicity supressed, still Br is small
    - SM prediction: Br ~ $O(10^{-10})$
- m_{ES} and ΔE for two leptons and a photon
- Backgrounds: QED process, J/Ψ, $\Psi(2S)$, π^0, continuum.
- 292 fb^{-1}, limits are set at 90% CL



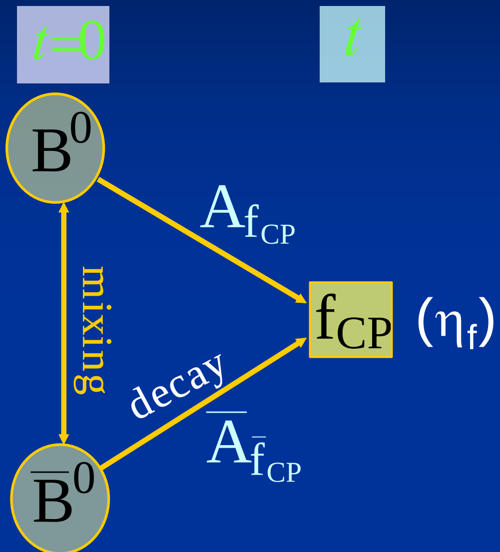


arXiv:0706.2870 [hep-ex], submitted to PRL

	N_{obs}	N_{bkg}	$\varepsilon(\%)$	$Br(B^0 \to l^+l^-\gamma)$
e	1	$1.75 \pm 1.38 \pm 0.36$	7.4 ± 0.3	1.2×10^{-7}
μ	1	$2.66 \pm 1.40 \pm 1.58$	5.2 ± 0.2	1.5×10^{-7}



Time Dependent Asymmetry



$$A_{CP}(t) = \frac{N(\bar{B}^0(t) \to f_{CP}) - N(B^0(t) \to f_{CP})}{N(\bar{B}^0(t) \to f_{CP}) + N(B^0(t) \to f_{CP})}$$

$$= S_f \sin(\Delta m t) - C_f \cos(\Delta m t)$$

$$C_f = \frac{1-|\lambda_f|^2}{1+|\lambda_f|^2} \qquad S_f = \frac{2\,\mathrm{Im}\,\lambda_f}{1+|\lambda_f|^2} \qquad \lambda_f = \frac{q}{p}\cdot\frac{\bar{A}_f}{A_f}$$