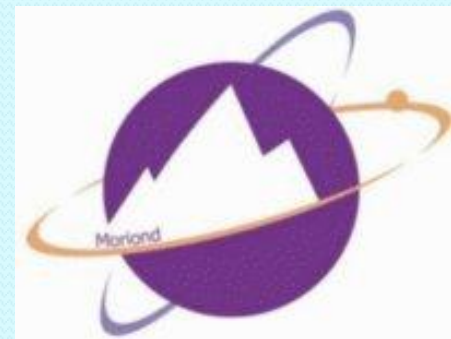


A SELECTION OF RECENT RESULTS FROM



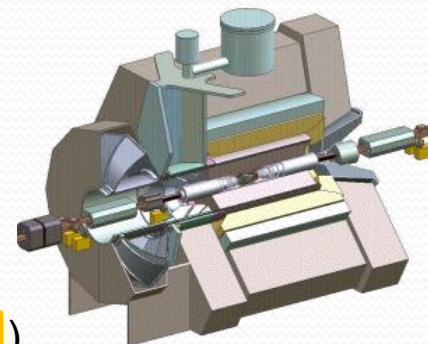
Vincent Poireau
CNRS-IN2P3, LAPP Annecy, Université de Savoie, France
On behalf of the BaBar collaboration





Recent results from *BABAR*

- The *BABAR* experiment switched off in 2008, but still produces a lot of results!
 - 471 papers in total
 - ~30 papers in 2011
- *BABAR* still competitive in many analyses with respect to LHCb
 - Many measurements can be performed **only** at **B-factories** (□)
- Results presented today:



NEW!

Exclusive measurements of $b \rightarrow s\gamma$ transition rate and photon energy spectrum

NEW!

Angular distributions in $B \rightarrow K^* l^+ l^-$

NEW!

Search for lepton-number violating processes in $B^+ \rightarrow h^+ l^+ l^-$

NEW!

Search for $B^\pm \rightarrow h^\pm \tau l$

Search for CP violation in $\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$



Exclusive measurements of $b \rightarrow s\gamma$ transition rate and photon energy spectrum

Preliminary result



$b \rightarrow s\gamma$: introduction

$471.10^6 \bar{B}\bar{B}$

- **FCNC** (flavor changing neutral current) **forbidden at tree level in SM**

- Occurs at **loop level**, precision test of the SM

$$\text{SM: } \text{BF}(\bar{B} \rightarrow X_s \gamma) = (3.15 \pm 0.23) \times 10^{-4}$$

M. Misiak and M. Steinhauser, Nucl. Phys. B764, 62 (2007)

($E_\gamma > 1.6 \text{ GeV}$)

- **New physics** may affect the transition rate
- **World average experimental value**

$$\text{Exp: } \text{BF}(\bar{B} \rightarrow X_s \gamma) = (3.55 \pm 0.24 \pm 0.09) \times 10^{-4}$$

HFAG

($E_\gamma > 1.6 \text{ GeV}$)

- **Photon energy spectrum**

- Gives insight into the **momentum distribution** function of the b quark inside the B meson
- Constrains the uncertainty on V_{ub}

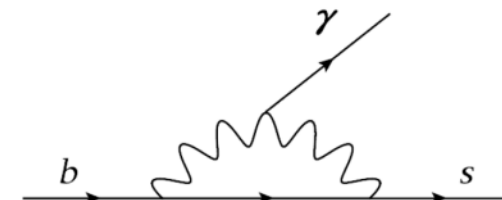
- Using « **sum of exclusive** » approach

- **38** different fully **reconstructed** X_s final states

- **Photon energy**

- **Range:** $1.9 < E_\gamma < 2.61 \text{ GeV}$
 $0.6 < m_{X_s} < 2.8 \text{ GeV}$

$$E_\gamma^B = \frac{m_B^2 - m_{X_s}^2}{2m_B}$$



X_s final states

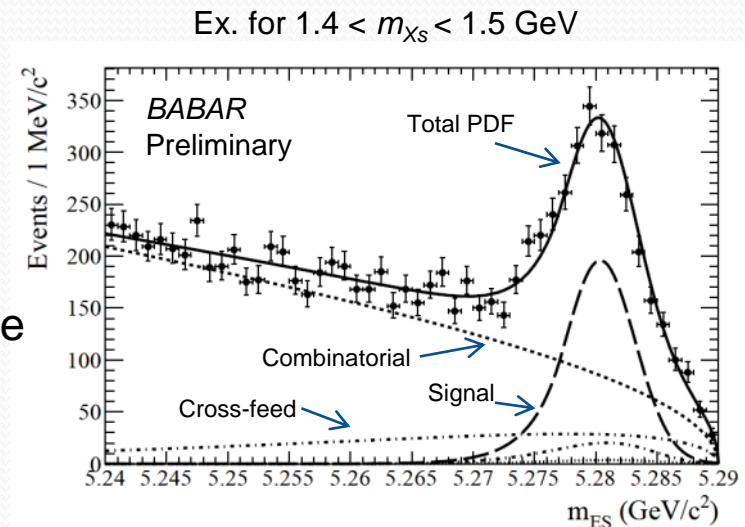
X_s = final state of the s quark hadronic system

| Mode Num. | Final State | Mode Num. | Final State |
|-----------|-------------------------------|-----------|-------------------------------|
| 1 | $K_S \pi^+$ | 20 | $K_S \pi^+ \pi^- \pi^+ \pi^-$ |
| 2 | $K^+ \pi^0$ | 21 | $K^+ \pi^+ \pi^- \pi^- \pi^0$ |
| 3 | $K^+ \pi^-$ | 22 | $K_S \pi^+ \pi^- \pi^0 \pi^0$ |
| 4 | $K_S \pi^0$ | 23 | $K^+ \eta$ |
| 5 | $K^+ \pi^+ \pi^-$ | 24 | $K_S \eta$ |
| 6 | $K_S \pi^+ \pi^0$ | 25 | $K_S \eta \pi^+$ |
| 7 | $K^+ \pi^0 \pi^0$ | 26 | $K^+ \eta \pi^0$ |
| 8 | $K_S \pi^+ \pi^-$ | 27 | $K^+ \eta \pi^-$ |
| 9 | $K^+ \pi^- \pi^0$ | 28 | $K_S \eta \pi^0$ |
| 10 | $K_S \pi^0 \pi^0$ | 29 | $K^+ \eta \pi^+ \pi^-$ |
| 11 | $K_S \pi^+ \pi^- \pi^+$ | 30 | $K_S \eta \pi^+ \pi^0$ |
| 12 | $K^+ \pi^+ \pi^- \pi^0$ | 31 | $K_S \eta \pi^+ \pi^-$ |
| 13 | $K_S \pi^+ \pi^0 \pi^0$ | 32 | $K^+ \eta \pi^- \pi^0$ |
| 14 | $K^+ \pi^+ \pi^- \pi^-$ | 33 | $K^+ K^- K^+$ |
| 15 | $K_S \pi^0 \pi^+ \pi^-$ | 34 | $K^+ K^- K_S$ |
| 16 | $K^+ \pi^- \pi^0 \pi^0$ | 35 | $K^+ K^- K_S \pi^+$ |
| 17 | $K^+ \pi^+ \pi^- \pi^+ \pi^-$ | 36 | $K^+ K^- K^+ \pi^0$ |
| 18 | $K_S \pi^+ \pi^- \pi^+ \pi^0$ | 37 | $K^+ K^- K^+ \pi^-$ |
| 19 | $K^+ \pi^+ \pi^- \pi^0 \pi^0$ | 38 | $K^+ K^- K_S \pi^0$ |



$b \rightarrow s\gamma$: analysis

- Two types of **signal MC** events are generated
 - **$K^*(892)$** region ($m_{Xs} < 1.1$ GeV)
 - **Inclusive** region ($1.1 < m_{Xs} < 2.8$ GeV)
- **Flat photon spectrum** in the inclusive region at the generation level
 - Allows us to reweight for **whichever model we like**
- Using 3 **classifiers** (random forest classifiers) to reject the **background**, optimized in 4 m_{Xs} regions
 - Choice of **best B candidate**
 - **Veto** to avoid selecting a photon coming from a π^0
 - **Continuum** background
- **Signal yield** extracted from m_{ES} fit in each m_{Xs} bin
- **Fragmentation study and models**
 - Grouping the final states by **topology** and correct signal + cross-feed so that they agree with data
 - Included in the **systematics** using several models for quark hadronization

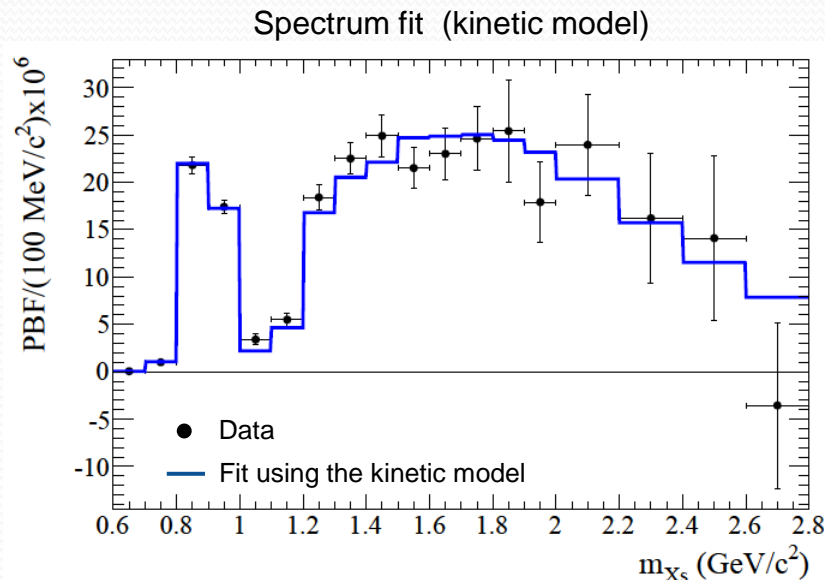




$b \rightarrow s\gamma$: results

- Result on **partial BF** in each m_{Xs} bin:
- Fit of the spectrum and extraction of the **moments** (HQET parameters)
 - Using « **kinetic** » and « **shape function** » models

| | Kinetic model | Shape function |
|-------------------------|---------------------------|---------------------------|
| m_b (GeV/ c^2) | $4.568^{+0.038}_{-0.036}$ | $4.579^{+0.032}_{-0.029}$ |
| μ_π^2 (GeV 2) | 0.450 ± 0.054 | $0.257^{+0.034}_{-0.039}$ |



- Can be compared with the **world average**

| | Kinetic model | Shape function | HFAG |
|-------------------------|-------------------|---------------------------|------|
| m_b (GeV/ c^2) | 4.591 ± 0.031 | $4.620^{+0.039}_{-0.032}$ | |
| μ_π^2 (GeV 2) | 0.454 ± 0.038 | $0.288^{+0.054}_{-0.074}$ | |

Kinetic model: Nucl. Phys. B**710**, 371 (2005)
 Shape function: Phys. Rev. D**72**, 073006 (2005)

- Result on **total BF**
 - Sum the **partial BF** in each m_{Xs} bin

$$\text{BF}(\bar{B} \rightarrow X_s \gamma) = (3.29 \pm 0.19 \pm 0.48) \times 10^{-4} \quad (E_\gamma > 1.9 \text{ GeV})$$



Angular distributions in $B \rightarrow K^* l^+ l^-$

Preliminary result

For BF and rate asymmetry, see Liang Sun's talk



$B \rightarrow K^* l^+ l^-$: introduction

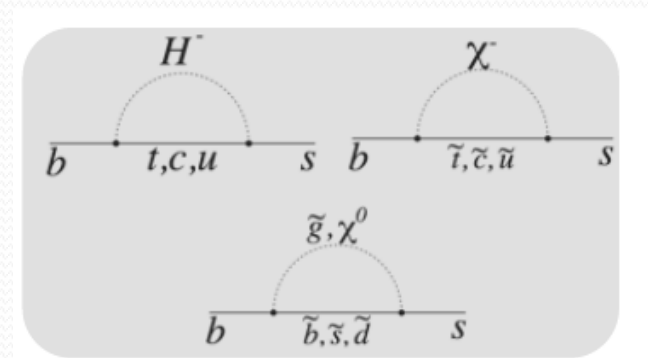
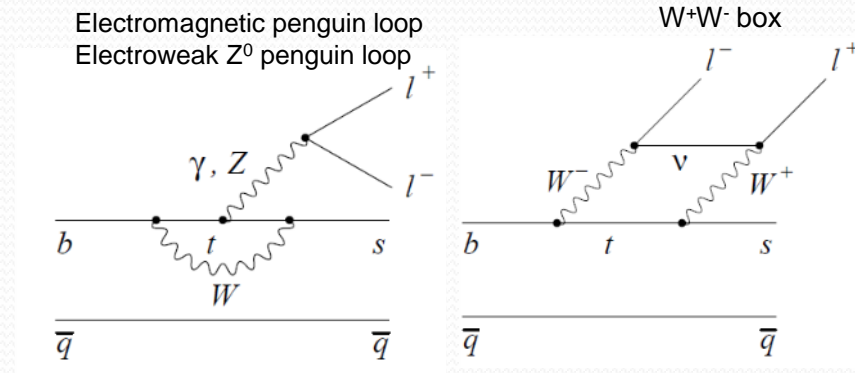
$465.10^6 B\bar{B}$

- $B \rightarrow K^* l^+ l^-$ in the SM via penguin and box diagrams

- Effective Hamiltonian given by

$$\mathcal{H} = \sum_{i=1,10} C_i \mathcal{O}_i$$

- \mathcal{O}_i local operators
- C_i Wilson coefficients
 - C_7^{eff} from photon penguin
 - $C_9^{\text{eff}}/C_{10}^{\text{eff}}$ from vector/axial-vector parts of the Z penguin and W box
- $B \rightarrow K^* l^+ l^-$ affected by new physics
 - Could lead to sizeable deviations from SM
- In the following, $s = m^2(l^+ l^-)$

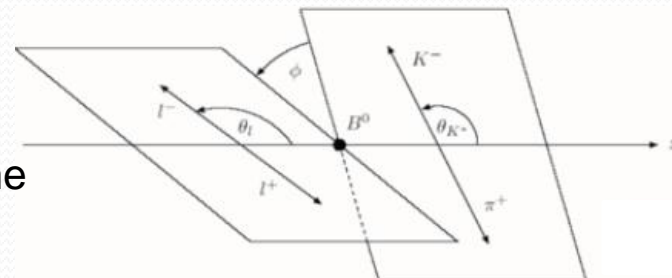




$B \rightarrow K^* l^+ l^-$: observables

- Angular distribution

- θ_K : angle between the K and the B in the K^* frame
- θ_l : angle between l^+ (l^-) and the B (\bar{B}) in the $l^+ l^-$ frame

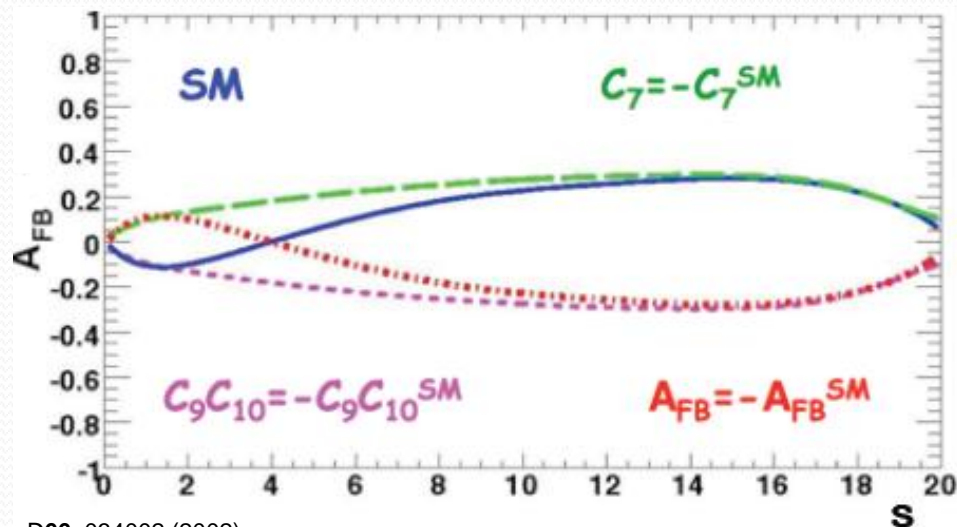
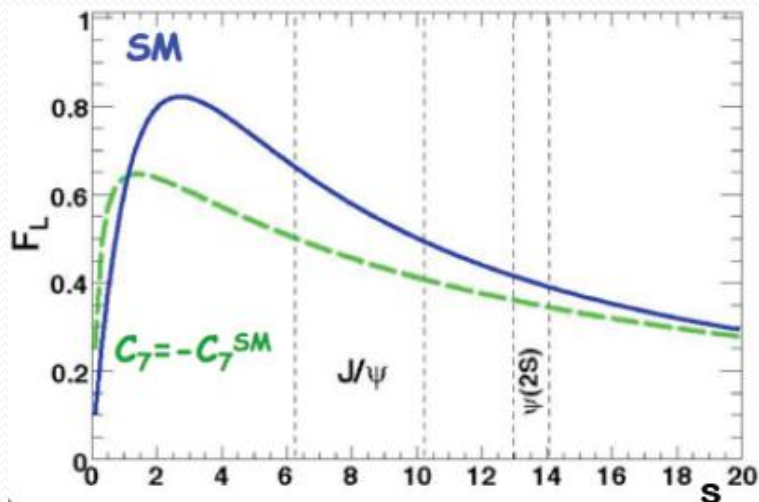


- Fraction of the longitudinal polarization of the K^* : F_L

$$\frac{1}{\Gamma(s)} \frac{d\Gamma}{d \cos \theta_K} = \frac{3}{2} F_L(s) \cos^2 \theta_K + \frac{3}{4} (1 - F_L(s)) (1 - \cos^2 \theta_K)$$

- Lepton forward-backward asymmetry: A_{FB}

$$\frac{1}{\Gamma} \frac{d\Gamma}{d \cos \theta_\ell} = \frac{3}{4} F_L (1 - \cos^2 \theta_\ell) + \frac{3}{8} (1 - F_L) (1 + \cos^2 \theta_\ell) + \mathcal{A}_{FB} \cos \theta_\ell$$



Phys. Rev. D**61**, 074024 (2000), Phys. Rev. D**63**, 014015 (2001), Phys. Rev. D**66**, 034002 (2002),
Phys. Rev. D**61**, 114028 (2002), Phys. Rev. D**71**, 094009 (2005)



$B \rightarrow K^* l^+ l^-$: analysis

- 7 bins in the s variable
 - Same binning as **CDF**, **Belle**, and **LHCb** to ease the comparison and average
 - Two **vetoed** regions dominated by **J/ψ** and **$\psi(2S)$** (control samples)
- 5 final states
 - $B^+ \rightarrow K^{*+} l^+ l^-$, $K^{*+} \rightarrow K^+ \pi^0, K^0_s \pi^+$ $l = e, \mu$
 - $B^0 \rightarrow K^{*0} l^+ l^-$, $K^{*0} \rightarrow K^+ \pi^-$
 - $B^+ \rightarrow K^{*+} \mu^+ \mu^-$, $K^{*+} \rightarrow K^+ \pi^0$ **not used** (no improvement + shows bias in control sample)
- **Bagged decision trees (BDT)** to suppress continuum and $B\bar{B}$ background
 - Based on ΔE , event shape and vertexing variables
 - **Likelihood ratio R** constructed from $B\bar{B}$ BDT
- **Angular observables** extracted from simultaneous fits over the combinations of final states
- **Strategy in each bin in s**
 - For each of the 5 modes, fit of m_{ES} , $M(K\pi)$ and R , fix parameters for next stage
 - **Fit $\cos\theta_K$** to extract F_L
 - Fix F_L , **fit $\cos\theta_l$** to extract A_{FB}

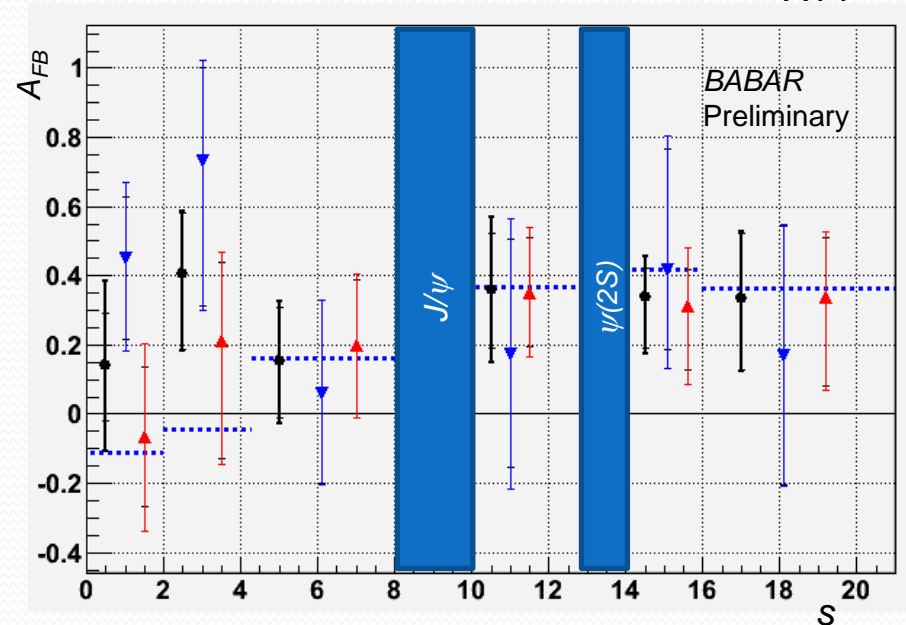
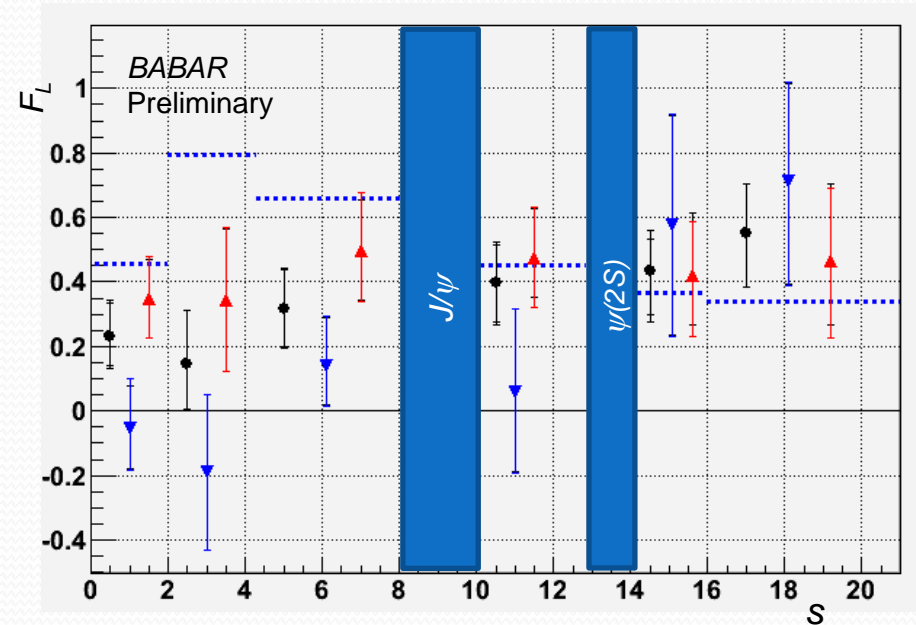


$B \rightarrow K^* l^+ l^-$: results

- SM
- ▼ $K^{*+} l^+ l^-$
- ▲ $K^{*0} l^+ l^-$
- $K^{*+} l^+ l^-$

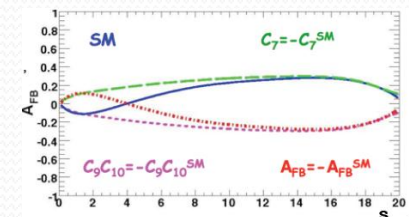
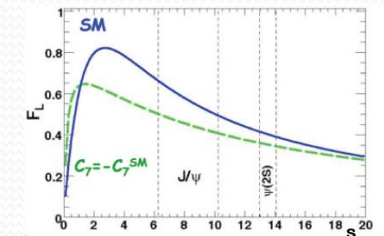
F_L

A_{FB}



Theoretical uncertainties of 5-10% in low s region and 10-15% in high s region

- Our values have **similar precision** compared to LHCb
 - Significantly **more precise** than either Belle or CDF
- $K^{*0} l^+ l^-$ values compares well with other experiments
 - Other experiments **predominantly** $K^{*0} l^+ l^-$
- Some **tension** in low s region for $K^{*+} l^+ l^-$



Belle: Phys. Rev. Lett. **103**, 171801 (2009) ; LHCb: arXiv:1112.3515 (2011) ; CDF: Phys. Rev. Lett. **108**, 081807 (2012)



Search for lepton-number violating processes in $B^+ \rightarrow h^- l^+ l^+$

Submitted to Phys. Rev. D
arXiv:1202.3650

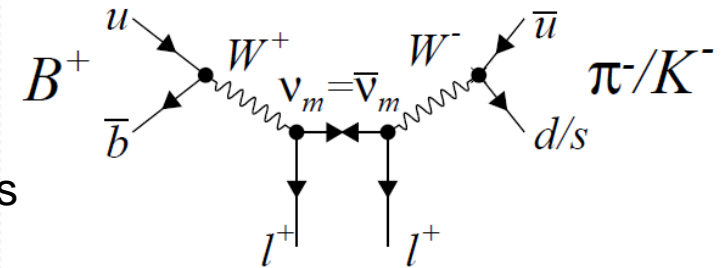


$B^+ \rightarrow h^- l^+ l^+$: introduction

$471.10^6 B\bar{B}$

- In **SM**, lepton number L conserved in low-energy collisions and decays
- Neutrino **oscillation** \Rightarrow neutrinos have **mass**
 - If neutrinos are of **Majorana** type, L violation becomes possible
 - Processes involving **meson decays** alternative to neutrinoless double beta decays

Eur. Phys. Jour. C71, 1715 (2011)

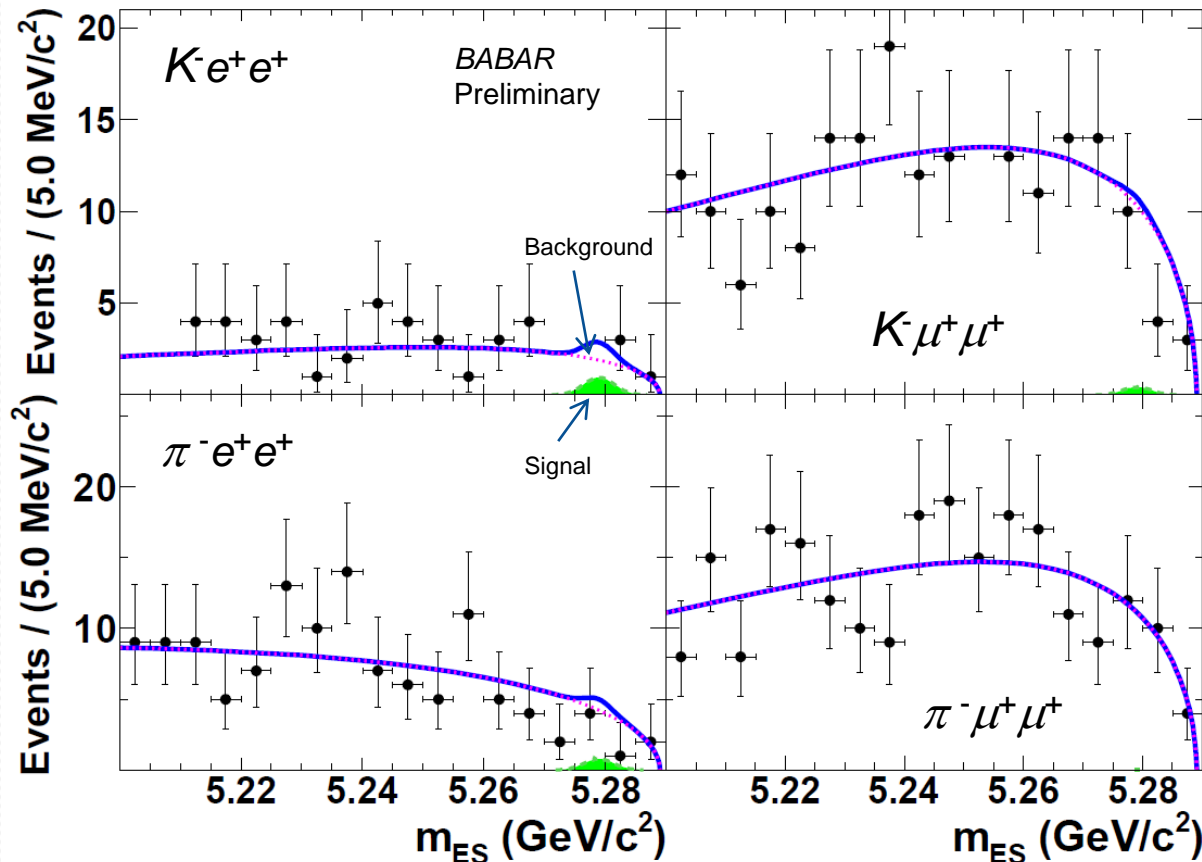


- **Beyond the SM**
 - L can be **violated** in left-right symmetric gauge theories, SO(10) SUSY, R -parity violating models, extra-dimensions
- **4 final states**
 - $h = K, \pi \quad l = e, \mu$
- Same selection as $K^* l^+ l^-$ analysis



$B^+ \rightarrow h^- l^+ l^+$: results

- Unbinned maximum likelihood fits of m_{ES} and R for each of the 4 modes
 - Use of $B^+ \rightarrow J/\psi h^+$ data for m_{ES} PDF parameters
- No signal is observed





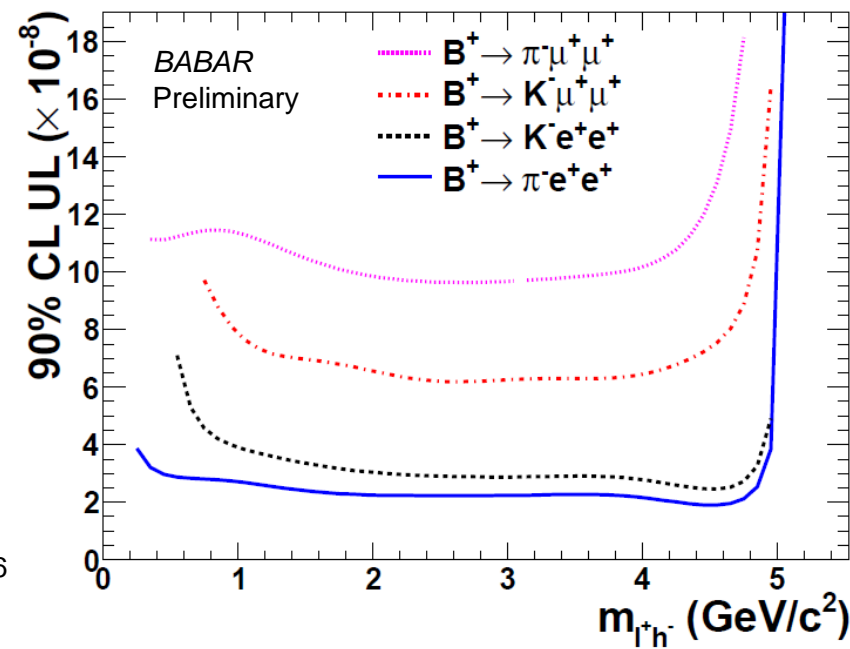
$B^+ \rightarrow h^- l^+ l^+$: upper limits

• Upper limits (90% CL)

- $\text{BF}(B^+ \rightarrow \pi^- e^+ e^+) < 2.3 \times 10^{-8}$
- $\text{BF}(B^+ \rightarrow K^- e^+ e^+) < 3.0 \times 10^{-8}$
- $\text{BF}(B^+ \rightarrow \pi^- \mu^+ \mu^+) < 10.7 \times 10^{-8}$
- $\text{BF}(B^+ \rightarrow K^- \mu^+ \mu^+) < 6.7 \times 10^{-8}$

• Other experiments

- **CLEO**: $\text{BF}(B^+ \rightarrow h^- l^+ l^+) < (1.0 - 8.3) \times 10^{-6}$
 $h = \pi, K^{(*)}, \rho$
- **Belle**: $\text{BF}(B^+ \rightarrow D^- l^+ l^+) < (1.1 - 2.6) \times 10^{-6}$
- **LHCb**: $\text{BF}(B^+ \rightarrow X^- \mu^+ \mu^+) < 1.3 \times 10^{-8} - 2.6 \times 10^{-6}$
 $X^- = D^{(*)-}, D_s^-, \pi^-, D^0 \pi^-$ (with 41 pb⁻¹)



• Electron results 40-70 times more stringent than before



Search for $B^{\pm} \rightarrow h^{\pm} \tau l$

Preliminary result



$B^\pm \rightarrow h^\pm \tau l$: introduction

472.10⁶ $B\bar{B}$

- **FCNC** and **charged lepton flavor violation (LFV)** forbidden in SM at tree level

- In many **extensions of the SM**, **FCNC** and/or **LFV** enhanced

- Especially for **second** and **third** generations

Phys. Rev. D44, 1461 (1991)

- **8 final states**

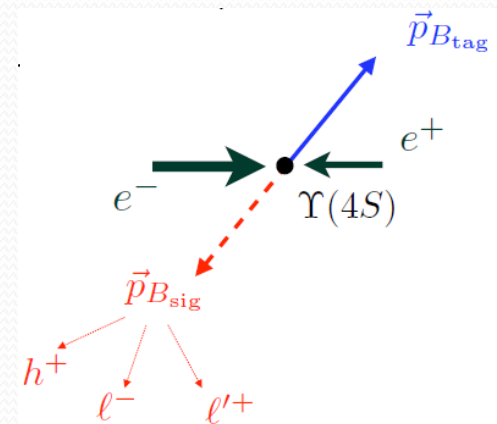
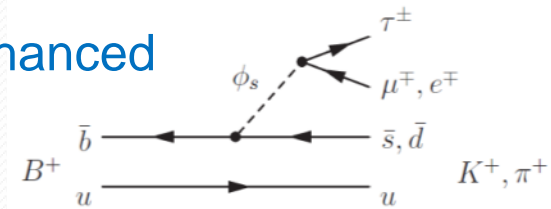
- $h = K, \pi$ $l = e, \mu$
- $B^+ \rightarrow K^+ \tau e, B^+ \rightarrow \pi^+ \tau \mu, B^+ \rightarrow \pi^+ \tau e$ **never done** before

- **Indirect reconstruction of the tau**

- **Fully reconstructed** hadronic B on one side (**tag B**)
 - $B \rightarrow D^{(*)0} X$, X composed of $\pi^\pm, K^\pm, K_S^0, \pi^0$
- This determines the three-momentum of the other B (**signal B**) and thus the **tau**
 - $\vec{p}_\tau = \vec{p}_B - \vec{p}_h - \vec{p}_l$
 - $E_\tau = E_{beam} - p_h - p_l$

- **Single-prong tau decays**

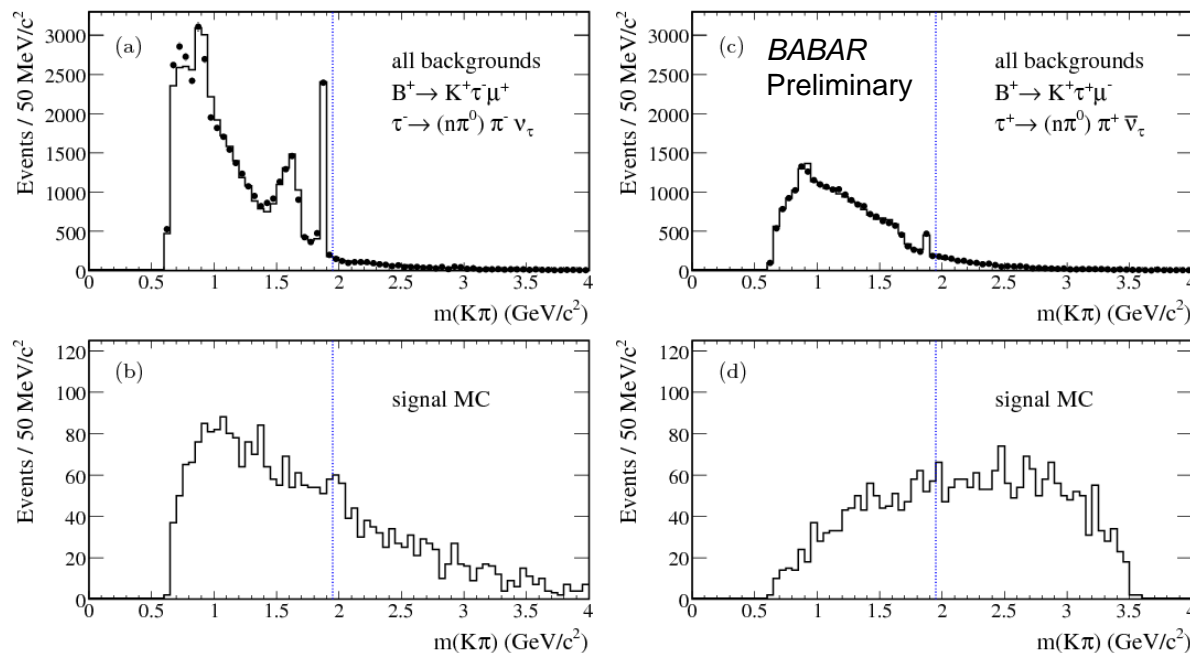
- $\tau \rightarrow e \nu \bar{\nu}$
- $\tau \rightarrow \mu \nu \bar{\nu}$
- $\tau \rightarrow \pi^+ (\geq 0\pi^0) \nu$





$B^\pm \rightarrow h^\pm \tau l$: analysis

- Selection based on **PID** and **event shape**
- **Veto** on m_{ll} when consistent with J/ψ and $\psi(2S)$
- **Background** coming from
 - **Semileptonic B** decays when $Q(B_{\text{sig}}) = Q(l)$
 - **Semileptonic D** decays when $Q(B_{\text{sig}}) = -Q(l)$
 - Remove these background with " $m(K\pi) > 1.95 \text{ GeV}$ "

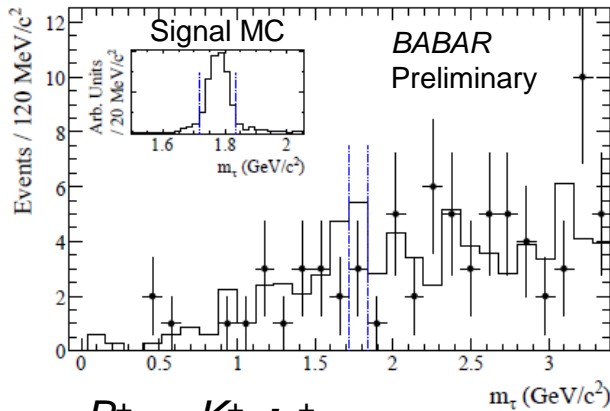


- Cut on likelihood ratio R to suppress the **continuum**

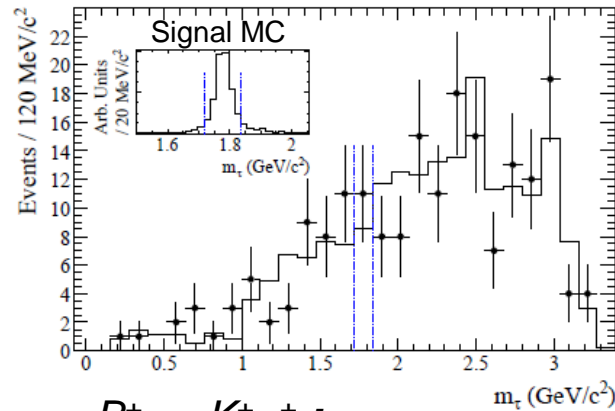


$B^\pm \rightarrow h^\pm \tau l$: Kaon modes

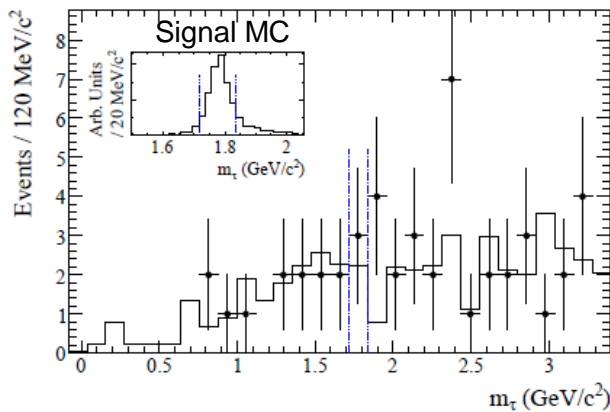
$B^+ \rightarrow K^+ \tau^- \mu^+$



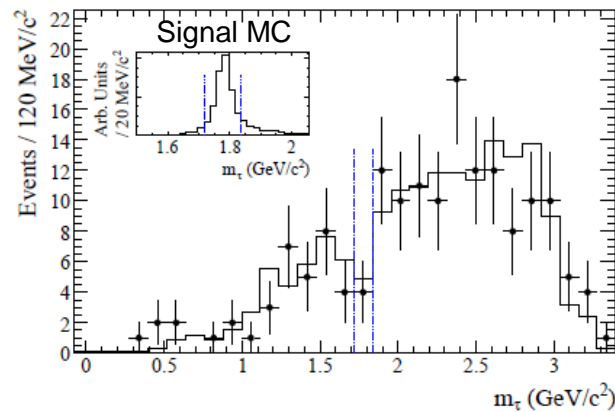
$B^+ \rightarrow K^+ \tau^+ \mu^-$



$B^+ \rightarrow K^+ \tau^- e^+$



$B^+ \rightarrow K^+ \tau^+ e^-$



Dots are data
Histogram are MC

m_τ

- Signal region
 - $m_\tau \pm 60$ MeV
- No evidence for signal
- Combined limits

| Mode | 90% CL Upper Limit (10^{-5}) |
|--------------------------------|-------------------------------------|
| $B^+ \rightarrow K^+ \tau \mu$ | 4.8 |
| $B^+ \rightarrow K^+ \tau e$ | 3.0 |

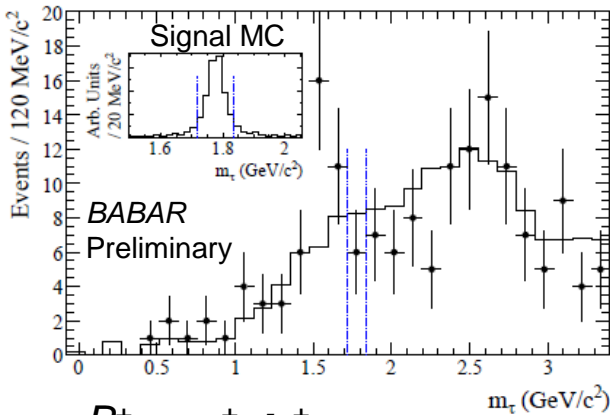
- Model-independent bounds on the energy scale of new physics in flavor-changing operators
 - $\Lambda_{\bar{b}s} > 15$ TeV (90% CL)
 - (was 2.6 TeV)

Phys. Rev. D**66**, 053002 (2002)

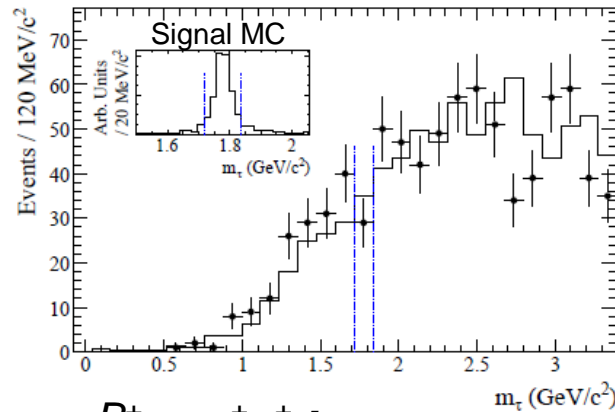


$B^\pm \rightarrow h^\pm \tau l$: Pion modes

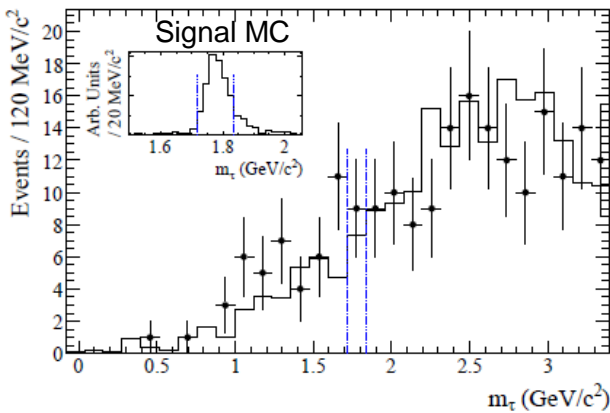
$$B^+ \rightarrow \pi^+ \tau^- \mu^+$$



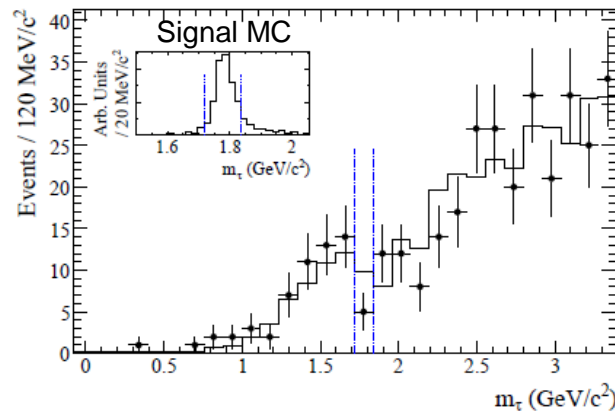
$$B^+ \rightarrow \pi^+ \tau^+ \mu^-$$



$$B^+ \rightarrow \pi^+ \tau^- e^+$$



$$B^+ \rightarrow \pi^+ \tau^+ e^-$$



Dots are data
Histogram are MC

m_τ

- No evidence for signal

- Combined limits

| Mode | 90% CL Upper Limit (10^{-5}) |
|----------------------------------|-------------------------------------|
| $B^+ \rightarrow \pi^+ \tau \mu$ | 7.2 |
| $B^+ \rightarrow \pi^+ \tau e$ | 7.5 |

- Model-independent bounds on the energy scale of new physics in flavor-changing operators

- $\Lambda_{\bar{b}d} > 11 \text{ TeV}$ (90% CL)
 - (was 2.2 TeV)

Phys. Rev. D66, 053002 (2002)



Search for *CP* violation in $\tau^- \rightarrow \pi^- K_S^0 (\geq 0 \pi^0) \nu_\tau$

Phys. Rev. D85, 031102 (2012)



$\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$: introduction

437.10⁶ $\tau\bar{\tau}$

- **CP violation** only observed in **hadronic decays** (K , B , D systems)
- Decay rate asymmetry in **tau decays**

$$A_Q = \frac{\Gamma(\tau^+ \rightarrow \pi^+ K_S^0 \bar{\nu}_\tau) - \Gamma(\tau^- \rightarrow \pi^- K_S^0 \nu_\tau)}{\Gamma(\tau^+ \rightarrow \pi^+ K_S^0 \bar{\nu}_\tau) + \Gamma(\tau^- \rightarrow \pi^- K_S^0 \nu_\tau)}$$

- Bigi and Sanda predict **$A_Q = (0.33 \pm 0.01)\%$**

Phys. Lett. B**625**, 47 (2005)

- Due to **CP violation** in K^0 in SM
- A_Q **independent** of the number of π^0

- Grossman and Nir (2011)

arXiv:1110.3790 (2011)

- Must take into account **interferences** between the amplitudes of intermediate K_S^0 and K_L^0 (as important as the pure K_S^0 amplitude)
- A_Q **depends on the reconstruction efficiency** as a function of $K_S^0 \rightarrow \pi^+ \pi^-$ decay time

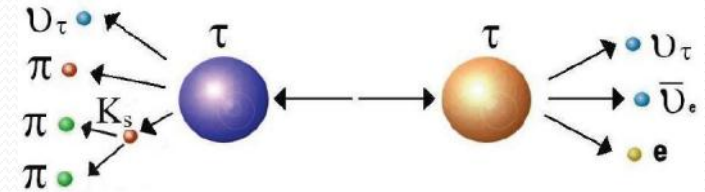
- **Deviation from SM** can be a sign of new physics



$\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$: analysis

- Two hemispheres: **signal** and **tag** side

- signal side:** 1 pion, 1 K_S^0
- tag side:** $\tau^- \rightarrow l^- \bar{\nu}_l \nu_\tau$ $l = e, \mu$

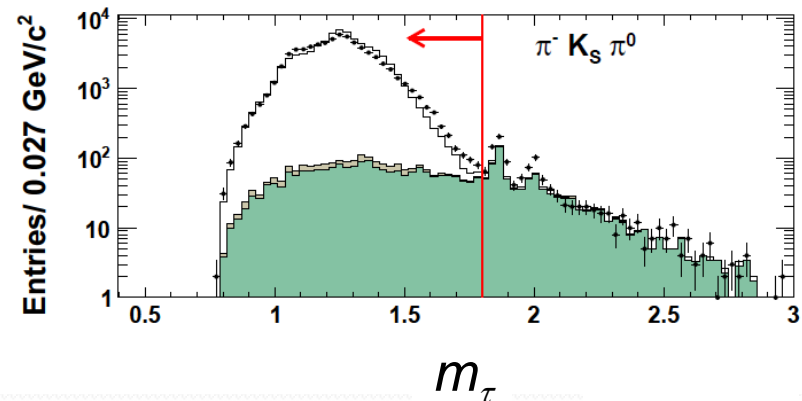
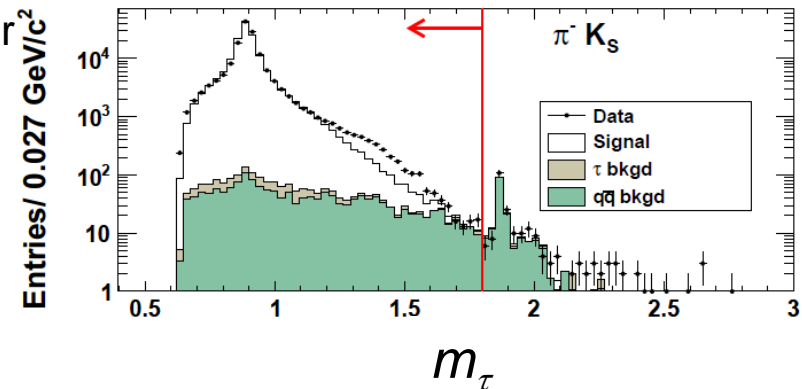


- Selection based on**

- Invariant mass of **reconstructed tau** smaller than **1.8 GeV**
- Likelihood ratio** based on energy, calorimeter clusters, thrust and momentum ($q\bar{q}$ bkg) and on K_S^0 reconstruction parameters (K_S^0 bkg)

- 199 064** candidates for the **e-tag**
- 140 602** for the **μ -tag**, with:

| Source | Fractions (%) | |
|---|-----------------|-----------------|
| | e-tag | μ -tag |
| $\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$ | 78.7 ± 4.0 | 78.4 ± 4.0 |
| $\tau^- \rightarrow K^- K_S^0 (\geq 0\pi^0) \nu_\tau$ | 4.2 ± 0.3 | 4.1 ± 0.3 |
| $\tau^- \rightarrow \pi^- K^0 \bar{K}^0 \nu_\tau$ | 15.7 ± 3.7 | 15.9 ± 3.7 |
| Other background | 1.40 ± 0.06 | 1.55 ± 0.07 |





$\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$: results

- Correct the raw asymmetry

- $\tau^- \rightarrow K^- K_S^0 (\geq 0\pi^0) \nu_\tau$: exp. asymmetry **opposite** of signal
- $\tau^- \rightarrow \pi^- K^0 \bar{K}^0 \nu_\tau$: exp. asymmetry = 0

- Ko *et al* (2011)

Phys. Rev. D **84**, 111501 (2011)

- need to take into account a **correction** on A_Q due to the different **nuclear-interaction cross-section** of the K^0 and \bar{K}^0 mesons with the material in the detector
- correction is **$-(0.07 \pm 0.01)\%$**

- Result (combined)

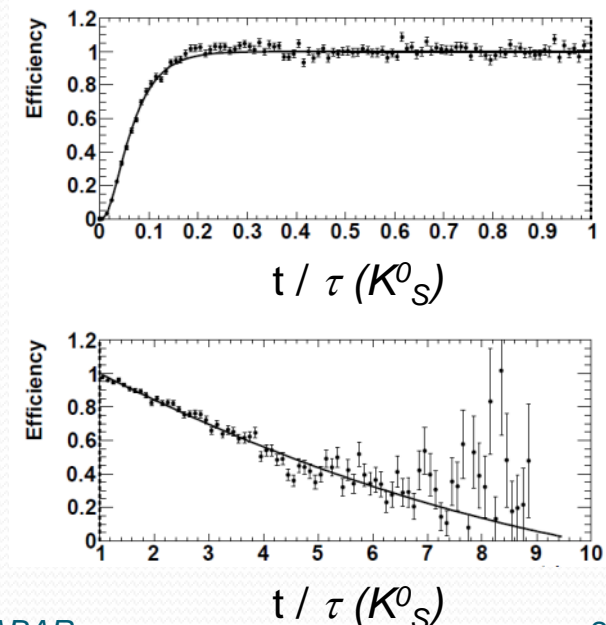
$$A_Q = -(0.36 \pm 0.23 \pm 0.11)\%$$

- Correction for the $K_S^0 \rightarrow \pi^+ \pi^-$ decay time dependence (Grossman and Nir)

arXiv:1110.3790 (2011)

- Multiplicative factor of **1.08 ± 0.01**
- $A_Q^{\text{SM}} = (0.36 \pm 0.01)\%$

- 2.8σ** away from the SM





Summary

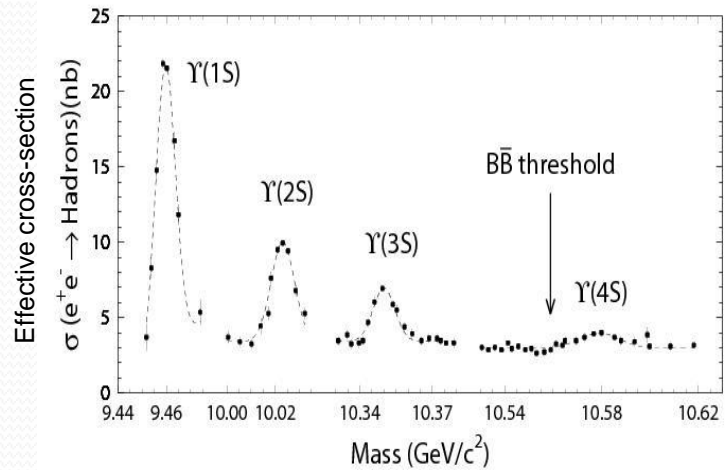
- 5 new results from *BABAR* have been presented
- In general, good agreement with the SM, except
 - $B \rightarrow K^* l^+ l^-$: some **tension** at low $m^2(l^+ l^-)$ for F_L and A_{FB}
 - $\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$: CP violation parameter **2.8σ away** from SM
- The actual statistics is not sufficient to tell whether or not these could be indication for new physics



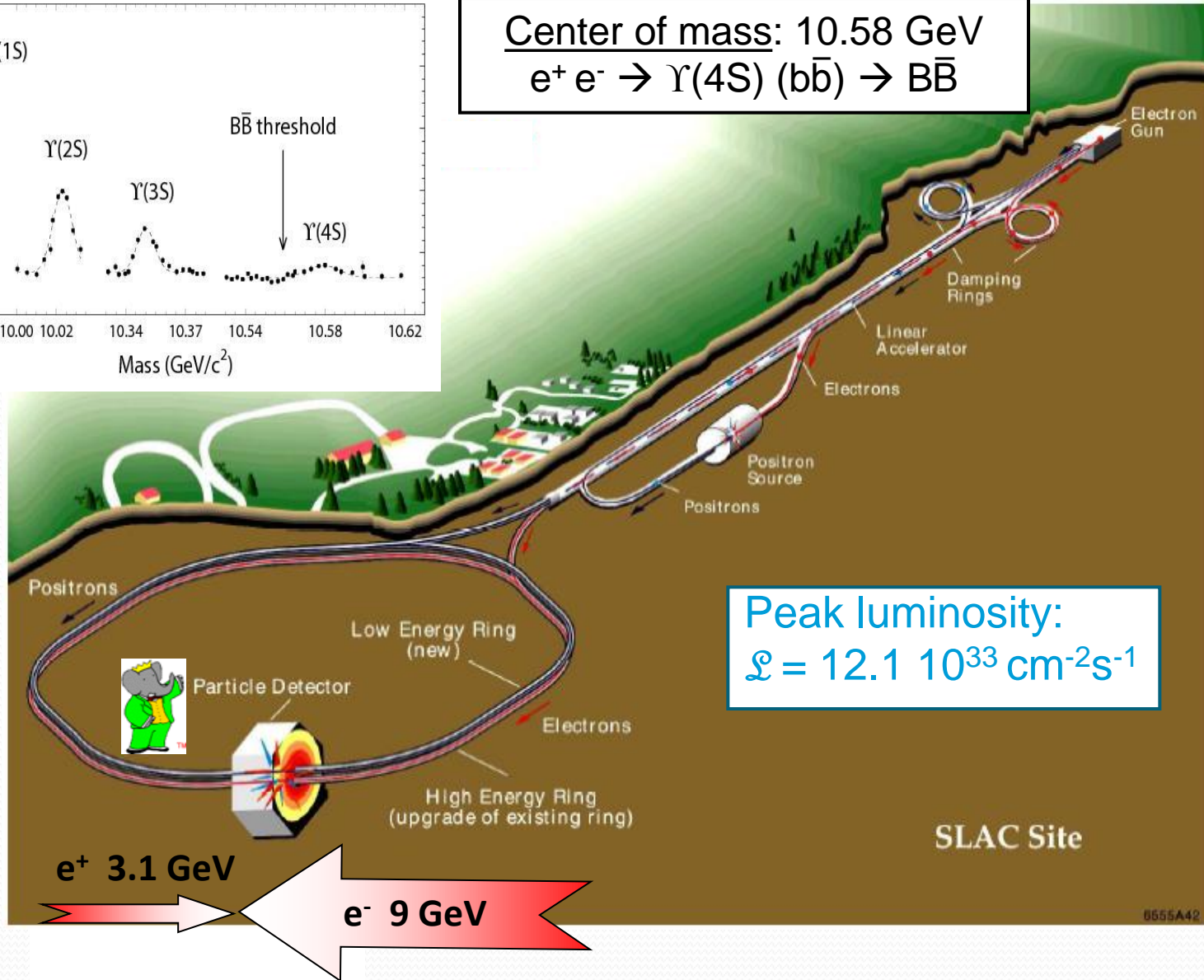
ADDITIONAL SLIDES



PEP-II AND BABAR



Center of mass: 10.58 GeV
 $e^+e^- \rightarrow \Upsilon(4S) (b\bar{b}) \rightarrow B\bar{B}$



Peak luminosity:
 $\mathcal{L} = 12.1 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

8655A42



THE BABAR EXPERIMENT

Silicon Vertex Tracker

Precision vertex reconstruction, dE/dx

1.5 T Solenoid

Drift Chamber

Momentum, dE/dx

3.1 GeV e^+

9 GeV e^-

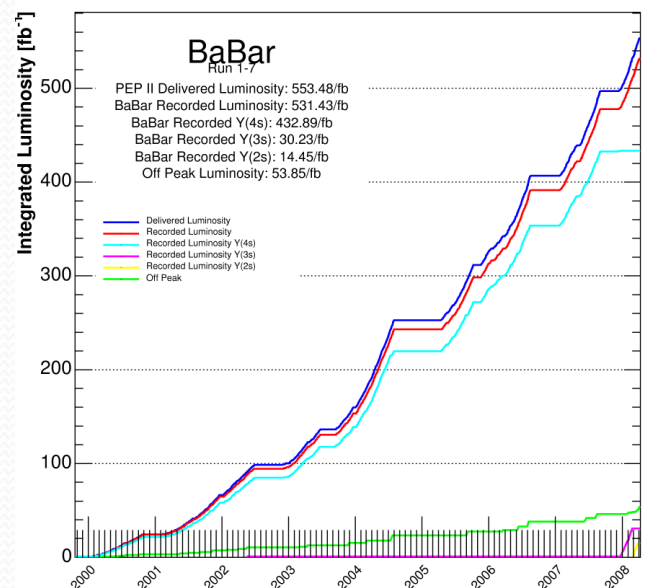
DIRC

PID, K/π

EM Calorimeter

low energy reach for π^0 , γ
 e^- ID, neutral hadron detection

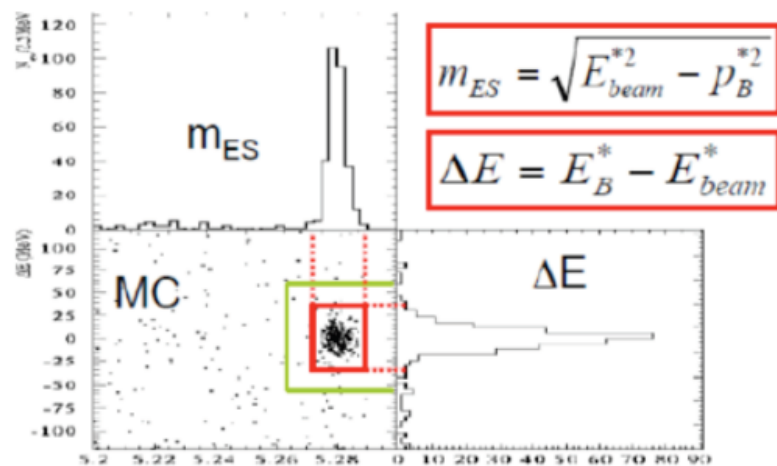
Instrumented Flux Return
 μ ID, neutral hadron detection





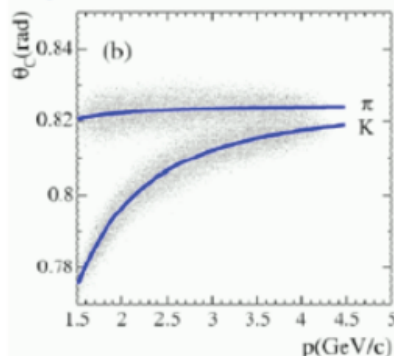
Common analysis techniques

Kinematics of fully reconstructed B



K/ π separation

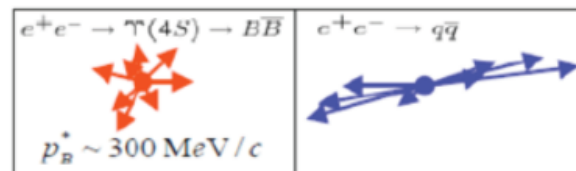
Very good
particle ID
between 1.5
and 4 GeV/c



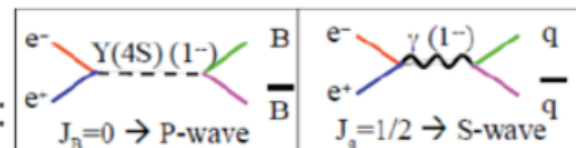
Background discrimination

Suppression by **multi-variable classifiers** based on **event-shape variables**:
Fisher discriminant, Boosted Decision Trees (BDT)...

Topology:



Angular distribution:



- Strongly discriminate continuum events ($e^+e^- \rightarrow q\bar{q}$ ($q = u, d, s, c$))
- Background from B decays

Variables are often combined to a **likelihood function**, used in a **maximum likelihood fit** for signal/background separation and to measure parameters of interest



$$b \rightarrow s\gamma$$

TABLE VI: Signal yields from fits to the on-peak data and corresponding χ^2/dof from the fits (the uncertainties are statistical only).

| m_{X_s} (GeV/c ²) | N_{yield} (events) | Data Fit χ^2/dof |
|------------------------------------|--------------------------------|---------------------------------|
| 0.6-0.7 | 5.9 ± 12.2 | 0.8 |
| 0.7-0.8 | 114.7 ± 24.0 | 0.9 |
| 0.8-0.9 | 2627.4 ± 50.2 | 1.0 |
| 0.9-1.0 | 2249.5 ± 53.1 | 0.9 |
| 1.0-1.1 | 380.4 ± 36.1 | 0.9 |
| 1.1-1.2 | 393.7 ± 37.1 | 0.8 |
| 1.2-1.3 | 1330.5 ± 47.1 | 0.6 |
| 1.3-1.4 | 1501.0 ± 54.7 | 1.0 |
| 1.4-1.5 | 1479.6 ± 58.3 | 1.0 |
| 1.5-1.6 | 1039.6 ± 55.7 | 0.9 |
| 1.6-1.7 | 929.1 ± 56.7 | 0.9 |
| 1.7-1.8 | 736.5 ± 48.6 | 1.2 |
| 1.8-1.9 | 585.8 ± 50.8 | 1.0 |
| 1.9-2.0 | 272.0 ± 37.4 | 1.0 |
| 2.0-2.2 | 684.4 ± 68.2 | 1.1 |
| 2.2-2.4 | 277.5 ± 64.6 | 1.0 |
| 2.4-2.6 | 159.7 ± 54.4 | 0.8 |
| 2.6-2.8 | -34.4 ± 62.0 | 1.1 |

TABLE VII: The PBFs in each mass bin reflecting branching fractions per 100 MeV/c², and the total branching fraction for $b \rightarrow s\gamma$ with $E_\gamma > 1.9$ GeV. The uncertainties quoted are statistical and systematic.

| m_{X_s} (GeV/c ²) | Branching Fraction per 100 MeV/c ² ($\times 10^{-6}$) | | |
|------------------------------------|--|-----------|--|
| 0.6-0.7 | 0.1 ± 0.1 | ± 0.0 | |
| 0.7-0.8 | 1.0 ± 0.2 | ± 0.1 | |
| 0.8-0.9 | 21.8 ± 0.4 | ± 0.8 | |
| 0.9-1.0 | 17.4 ± 0.4 | ± 0.6 | |
| 1.0-1.1 | 3.4 ± 0.3 | ± 0.5 | |
| 1.1-1.2 | 5.5 ± 0.5 | ± 0.4 | |
| 1.2-1.3 | 18.4 ± 0.7 | ± 1.2 | |
| 1.3-1.4 | 22.5 ± 0.8 | ± 1.5 | |
| 1.4-1.5 | 24.9 ± 1.0 | ± 2.0 | |
| 1.5-1.6 | 21.5 ± 1.2 | ± 1.8 | |
| 1.6-1.7 | 23.0 ± 1.4 | ± 2.3 | |
| 1.7-1.8 | 24.6 ± 1.6 | ± 3.0 | |
| 1.8-1.9 | 25.4 ± 2.2 | ± 5.0 | |
| 1.9-2.0 | 17.9 ± 2.5 | ± 3.4 | |
| 2.0-2.2 | 24.0 ± 2.4 | ± 4.7 | |
| 2.2-2.4 | 16.2 ± 3.8 | ± 5.7 | |
| 2.4-2.6 | 14.1 ± 4.8 | ± 7.3 | |
| 2.6-2.8 | -3.5 ± 6.4 | ± 6.1 | |
| 0.6-2.8 | 329 ± 19 | ± 48 | |

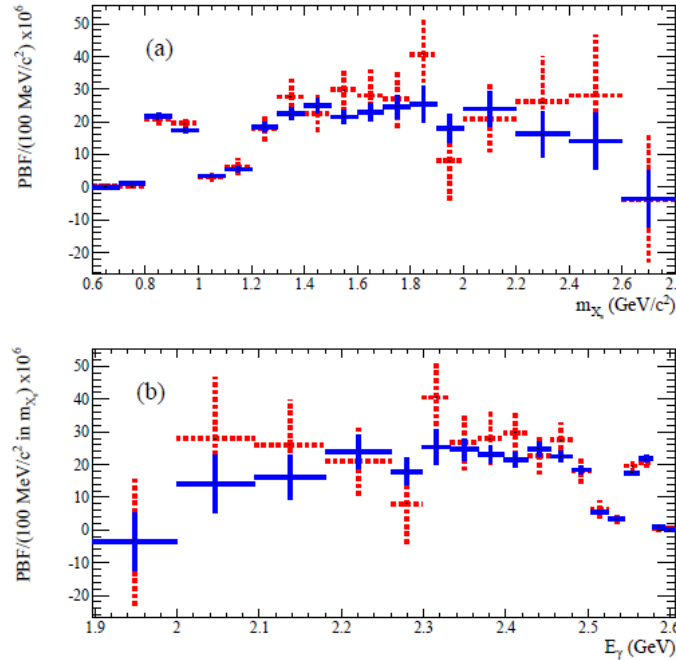


FIG. 2: The PBFs binned in both (a) X_s mass and (b) the corresponding E_γ bins with the statistical and systematic uncertainties added in quadrature. The current results (solid lines) and former *BABAR* results [15] (dashed lines) are shown.



$$b \rightarrow s\gamma$$

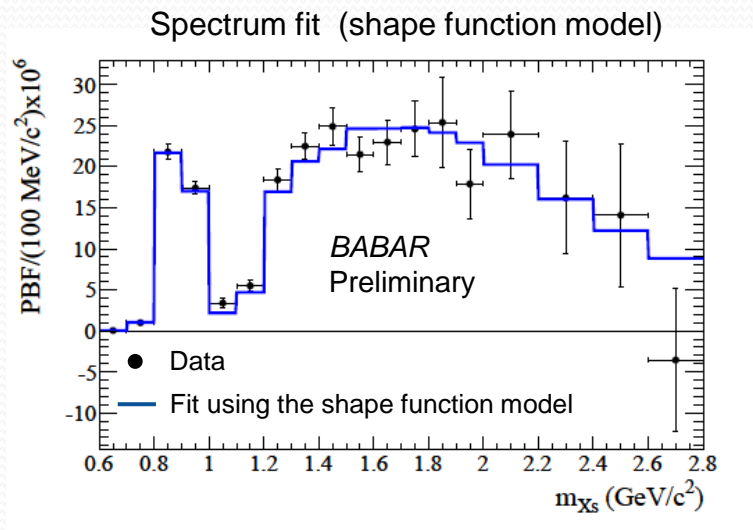


TABLE IX: The mean and variance of the photon energy spectrum, calculated at multiple photon energy cutoffs. The errors are statistical and systematic.

| $E_{\gamma min}$ (GeV) | $\langle E \rangle$ (GeV) | $\langle E^2 \rangle - \langle E \rangle^2$ (GeV ²) |
|---------------------------|-------------------------------------|--|
| 1.897 | $2.346 \pm 0.018^{+0.027}_{-0.022}$ | $0.0211 \pm 0.0057^{+0.0055}_{-0.0069}$ |
| 1.999 | $2.338 \pm 0.010^{+0.020}_{-0.017}$ | $0.0239 \pm 0.0018^{+0.0023}_{-0.0030}$ |
| 2.094 | $2.365 \pm 0.006^{+0.016}_{-0.010}$ | $0.0176 \pm 0.0009^{+0.0009}_{-0.0016}$ |
| 2.181 | $2.391 \pm 0.003^{+0.008}_{-0.007}$ | $0.0129 \pm 0.0003^{+0.0005}_{-0.0005}$ |
| 2.261 | $2.427 \pm 0.002^{+0.006}_{-0.006}$ | $0.0082 \pm 0.0002^{+0.0002}_{-0.0002}$ |

We have also measured the mean and variance of the photon spectrum. At the lowest photon energy cutoff ($E_{\gamma} > 1.897$ GeV), these values are

$$\langle E \rangle = 2.346 \pm 0.018^{+0.027}_{-0.022} \text{ GeV}, \quad (10)$$

$$\langle E^2 \rangle - \langle E \rangle^2 = 0.0211 \pm 0.0057^{+0.0055}_{-0.0069} \text{ GeV}^2 \quad (11)$$

(compared with the previous *BABAR* analysis results of $\langle E \rangle = 2.321 \pm 0.038^{+0.017}_{-0.038}$ GeV, and $\langle E^2 \rangle - \langle E \rangle^2 = 0.0253 \pm 0.0101^{+0.0041}_{-0.0028}$ GeV² [15]).



$$B \rightarrow K^* l^+ l^-$$

Table 8: Data fit combined mode signal yields. Using the most recent HFAG results, the expected yield from MC is given parenthetically after each fit yield.

| | Modes | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|----------------------------------|--------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| $B \rightarrow K^* l^+ l^-$ | 7,8,10,11,12 | 40.7 ± 8.4 (43.0) | 31.9 ± 7.1 (25.0) | 11.8 ± 5.5 (19.0) | 21.5 ± 8.6 (36.7) | 31.8 ± 8.2 (31.8) | 19.5 ± 5.5 (16.5) | 15.3 ± 5.6 (13.5) |
| $B^0 \rightarrow K^{*0} l^+ l^-$ | 8,12 | 23.0 ± 6.6 (27.8) | 23.1 ± 5.8 (15.8) | 8.0 ± 3.8 (12.2) | 13.9 ± 6.4 (24.1) | 22.9 ± 6.6 (21.1) | 13.1 ± 4.6 (11.2) | 9.1 ± 4.7 (9.1) |
| $B^+ \rightarrow K^{*+} l^+ l^-$ | 7,10,11 | 17.7 ± 5.2 (15.2) | 8.9 ± 4.1 (9.2) | 3.8 ± 3.9 (6.8) | 7.7 ± 5.7 (12.7) | 8.9 ± 4.8 (10.7) | 6.4 ± 3.0 (5.3) | 6.2 ± 3.0 (4.4) |

We consider several sources of systematic uncertainty for the F_L and \mathcal{A}_{FB} fits in each of s bin:

- the fit uncertainty on the signal yield from the m_{ES} , $M(K\pi)$ fit;
- the fit uncertainty on F_L , which is propagated into the \mathcal{A}_{FB} fit.
- the random combinatorial background fit shape and normalization;
- crossfeed modeling;
- the signal gaussian m_{ES} and resonant $M(K\pi)$ shapes;
- signal angular efficiencies as a function of generator-level variations in the Wilson coefficients;
- fit bias;
- characterization of peaking backgrounds from muon mis-identification and charmonium leakage;
- variations in event selection.



$$B \rightarrow K^* \ell^+ \ell^-$$

Table 11: Preliminary F_L results with systematics.

| $s(\text{GeV}^2/c^4)$ | $B \rightarrow K^* \ell^+ \ell^-$ | $B^0 \rightarrow K^{*0} \ell^+ \ell^-$ | $B^+ \rightarrow K^{*+} \ell^+ \ell^-$ |
|-----------------------|-----------------------------------|--|--|
| 0.1 – 2.00 | $0.23^{+0.10}_{-0.09} \pm 0.04$ | $0.35^{+0.13}_{-0.12} \pm 0.04$ | $-0.06^{+0.14}_{-0.12} \pm 0.06$ |
| 2.00 – 4.30 | $0.15^{+0.17}_{-0.14} \pm 0.04$ | $0.34^{+0.22}_{-0.22} \pm 0.08$ | $-0.19^{+0.24}_{-0.24} \pm 0.04$ |
| 4.30 – 8.68 | $0.32^{+0.12}_{-0.12} \pm 0.06$ | $0.50^{+0.18}_{-0.15} \pm 0.05$ | $0.14^{+0.15}_{-0.12} \pm 0.05$ |
| 10.09 – 12.86 | $0.40^{+0.12}_{-0.12} \pm 0.06$ | $0.48^{+0.13}_{-0.12} \pm 0.10$ | $0.06^{+0.26}_{-0.25} \pm 0.05$ |
| 14.18 – 16.00 | $0.43^{+0.10}_{-0.13} \pm 0.09$ | $0.42^{+0.12}_{-0.16} \pm 0.11$ | $0.58^{+0.34}_{-0.35} \pm 0.06$ |
| > 16.00 | $0.55^{+0.15}_{-0.17} \pm 0.03$ | $0.47^{+0.18}_{-0.20} \pm 0.13$ | $0.71^{+0.30}_{-0.32} \pm 0.03$ |
| 1.00 – 6.00 | $0.25^{+0.09}_{-0.08} \pm 0.03$ | $0.47^{+0.13}_{-0.13} \pm 0.04$ | $0.03^{+0.11}_{-0.10} \pm 0.03$ |

Table 13: Current F_L experimental results.

| $s(\text{GeV}^2/c^4)$ | Belle | CDF | LHCb | $B \rightarrow K^* \ell^+ \ell^-$ | $B^0 \rightarrow K^{*0} \ell^+ \ell^-$ | $B^+ \rightarrow K^{*+} \ell^+ \ell^-$ |
|-----------------------|----------------------------------|---------------------------------|---------------------------------|-----------------------------------|--|--|
| 0.1 – 2.00 | $0.29^{+0.21}_{-0.18} \pm 0.02$ | $0.30^{+0.16}_{-0.16} \pm 0.02$ | $0.00^{+0.13}_{-0.00} \pm 0.02$ | $0.23^{+0.10}_{-0.09} \pm 0.04$ | $0.35^{+0.13}_{-0.12} \pm 0.03$ | $-0.06^{+0.14}_{-0.12} \pm 0.06$ |
| 2.00 – 4.30 | $0.71^{+0.24}_{-0.24} \pm 0.05$ | $0.37^{+0.25}_{-0.24} \pm 0.10$ | $0.77^{+0.15}_{-0.15} \pm 0.03$ | $0.15^{+0.17}_{-0.14} \pm 0.03$ | $0.34^{+0.22}_{-0.22} \pm 0.03$ | $-0.19^{+0.24}_{-0.24} \pm 0.03$ |
| 4.30 – 8.68 | $0.64^{+0.23}_{-0.24} \pm 0.07$ | $0.68^{+0.15}_{-0.17} \pm 0.09$ | $0.60^{+0.06}_{-0.07} \pm 0.01$ | $0.32^{+0.12}_{-0.12} \pm 0.03$ | $0.50^{+0.18}_{-0.15} \pm 0.03$ | $0.14^{+0.15}_{-0.12} \pm 0.03$ |
| 10.09 – 12.86 | $0.17^{+0.17}_{-0.15} \pm 0.03$ | $0.47^{+0.14}_{-0.14} \pm 0.03$ | $0.41^{+0.11}_{-0.11} \pm 0.03$ | $0.40^{+0.12}_{-0.12} \pm 0.05$ | $0.48^{+0.13}_{-0.12} \pm 0.09$ | $0.06^{+0.26}_{-0.25} \pm 0.04$ |
| 14.18 – 16.00 | $-0.15^{+0.27}_{-0.23} \pm 0.07$ | $0.29^{+0.14}_{-0.13} \pm 0.05$ | $0.37^{+0.09}_{-0.09} \pm 0.05$ | $0.43^{+0.10}_{-0.13} \pm 0.08$ | $0.42^{+0.12}_{-0.16} \pm 0.11$ | $0.58^{+0.34}_{-0.35} \pm 0.06$ |
| > 16.00 | $0.12^{+0.15}_{-0.13} \pm 0.02$ | $0.20^{+0.19}_{-0.17} \pm 0.05$ | $0.26^{+0.10}_{-0.08} \pm 0.03$ | $0.55^{+0.15}_{-0.17} \pm 0.03$ | $0.47^{+0.18}_{-0.20} \pm 0.13$ | $0.71^{+0.30}_{-0.32} \pm 0.03$ |
| 1.00 – 6.00 | $0.67^{+0.23}_{-0.23} \pm 0.05$ | $0.69^{+0.19}_{-0.21} \pm 0.08$ | $0.55^{+0.10}_{-0.10} \pm 0.03$ | $0.25^{+0.09}_{-0.08} \pm 0.03$ | $0.47^{+0.13}_{-0.13} \pm 0.03$ | $0.03^{+0.11}_{-0.10} \pm 0.03$ |



$$B \rightarrow K^* \ell^+ \ell^-$$

Table 12: Preliminary \mathcal{A}_{FB} results with systematics.

| $s(\text{GeV}^2/c^4)$ | $B \rightarrow K^* \ell^+ \ell^-$ | $B^0 \rightarrow K^{*0} \ell^+ \ell^-$ | $B^+ \rightarrow K^{*+} \ell^+ \ell^-$ |
|-----------------------|-----------------------------------|--|--|
| 0.1 – 2.00 | $0.14^{+0.15}_{-0.16} \pm 0.20$ | $-0.07^{+0.20}_{-0.20} \pm 0.19$ | $0.45^{+0.18}_{-0.24} \pm 0.15$ |
| 2.00 – 4.30 | $0.40^{+0.18}_{-0.22} \pm 0.07$ | $0.21^{+0.23}_{-0.34} \pm 0.11$ | $0.73^{+0.27}_{-0.42} \pm 0.07$ |
| 4.30 – 8.68 | $0.15^{+0.16}_{-0.16} \pm 0.08$ | $0.20^{+0.19}_{-0.20} \pm 0.08$ | $0.06^{+0.27}_{-0.26} \pm 0.07$ |
| 10.09 – 12.86 | $0.36^{+0.16}_{-0.17} \pm 0.10$ | $0.35^{+0.16}_{-0.16} \pm 0.11$ | $0.17^{+0.33}_{-0.33} \pm 0.16$ |
| 14.18 – 16.00 | $0.34^{+0.08}_{-0.15} \pm 0.07$ | $0.31^{+0.11}_{-0.19} \pm 0.13$ | $0.42^{+0.35}_{-0.23} \pm 0.09$ |
| > 16.00 | $0.34^{+0.19}_{-0.21} \pm 0.07$ | $0.34^{+0.17}_{-0.26} \pm 0.08$ | $0.17^{+0.38}_{-0.38} \pm 0.11$ |
| 1.00 – 6.00 | $0.17^{+0.12}_{-0.14} \pm 0.07$ | $0.02^{+0.16}_{-0.18} \pm 0.07$ | $0.31^{+0.12}_{-0.14} \pm 0.07$ |

Table 14: Current \mathcal{A}_{FB} experimental results.

| $s(\text{GeV}^2/c^4)$ | Belle | CDF | LHCb | $B \rightarrow K^* \ell^+ \ell^-$ | $B^0 \rightarrow K^{*0} \ell^+ \ell^-$ | $B^+ \rightarrow K^{*+} \ell^+ \ell^-$ |
|-----------------------|---------------------------------|----------------------------------|----------------------------------|-----------------------------------|--|--|
| 0.1 – 2.00 | $0.47^{+0.26}_{-0.32} \pm 0.03$ | $-0.35^{+0.26}_{-0.23} \pm 0.10$ | $-0.15^{+0.20}_{-0.20} \pm 0.06$ | $0.14^{+0.15}_{-0.16} \pm 0.20$ | $-0.07^{+0.20}_{-0.20} \pm 0.19$ | $0.45^{+0.18}_{-0.24} \pm 0.15$ |
| 2.00 – 4.30 | $0.11^{+0.31}_{-0.36} \pm 0.07$ | $0.29^{+0.32}_{-0.35} \pm 0.15$ | $0.05^{+0.16}_{-0.20} \pm 0.04$ | $0.40^{+0.18}_{-0.22} \pm 0.07$ | $0.21^{+0.23}_{-0.34} \pm 0.11$ | $0.73^{+0.27}_{-0.42} \pm 0.07$ |
| 4.30 – 8.68 | $0.45^{+0.15}_{-0.21} \pm 0.15$ | $0.01^{+0.20}_{-0.20} \pm 0.09$ | $0.27^{+0.06}_{-0.08} \pm 0.02$ | $0.15^{+0.16}_{-0.16} \pm 0.08$ | $0.20^{+0.19}_{-0.20} \pm 0.08$ | $0.06^{+0.27}_{-0.26} \pm 0.07$ |
| 10.09 – 12.86 | $0.43^{+0.18}_{-0.20} \pm 0.03$ | $0.38^{+0.16}_{-0.19} \pm 0.09$ | $0.27^{+0.11}_{-0.13} \pm 0.02$ | $0.36^{+0.16}_{-0.17} \pm 0.10$ | $0.35^{+0.16}_{-0.16} \pm 0.11$ | $0.17^{+0.33}_{-0.33} \pm 0.16$ |
| 14.18 – 16.00 | $0.70^{+0.16}_{-0.22} \pm 0.10$ | $0.44^{+0.18}_{-0.21} \pm 0.10$ | $0.47^{+0.06}_{-0.08} \pm 0.03$ | $0.34^{+0.08}_{-0.15} \pm 0.07$ | $0.31^{+0.11}_{-0.19} \pm 0.13$ | $0.42^{+0.35}_{-0.23} \pm 0.09$ |
| > 16.00 | $0.66^{+0.11}_{-0.16} \pm 0.04$ | $0.65^{+0.17}_{-0.18} \pm 0.16$ | $0.16^{+0.11}_{-0.13} \pm 0.06$ | $0.34^{+0.19}_{-0.21} \pm 0.07$ | $0.34^{+0.17}_{-0.26} \pm 0.08$ | $0.17^{+0.38}_{-0.38} \pm 0.11$ |
| 1.00 – 6.00 | $0.26^{+0.27}_{-0.30} \pm 0.07$ | $0.29^{+0.20}_{-0.23} \pm 0.07$ | $-0.06^{+0.13}_{-0.14} \pm 0.04$ | $0.17^{+0.12}_{-0.14} \pm 0.07$ | $0.02^{+0.16}_{-0.18} \pm 0.07$ | $0.31^{+0.12}_{-0.14} \pm 0.07$ |



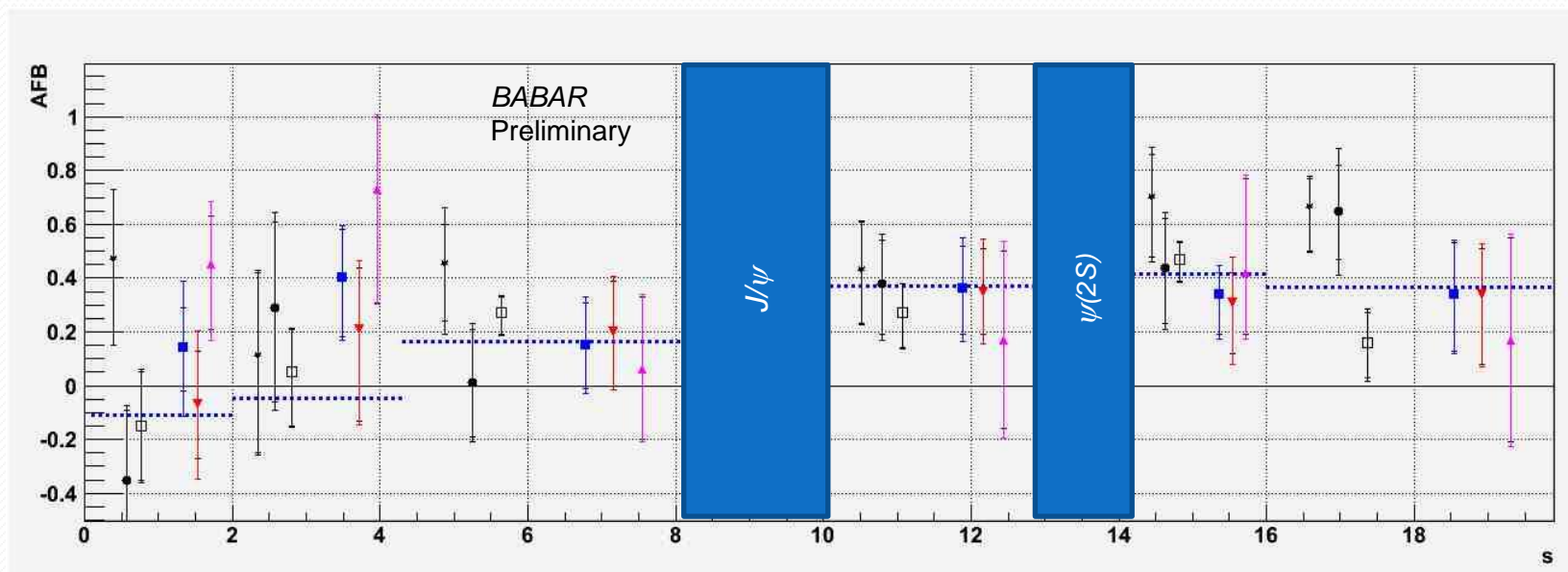
$$B \rightarrow K^* l^+ l^-$$

- In each s bin, from left to right

- Belle
- CDF
- LHCb
- $BABAR K^*$
- $BABAR K^{*0}$
- $BABAR K^{*+}$

..... SM

A_{FB}





$$\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$$

- Correction to the raw asymmetry

$$\begin{aligned} \mathcal{A} &= \frac{f_1 A_1 + f_2 A_2 + f_3 A_3}{f_1 + f_2 + f_3} \\ &= \left(\frac{f_1 - f_2}{f_1 + f_2 + f_3} \right) A_Q \\ &\quad \parallel \\ &0.75 \pm 0.04 \end{aligned}$$

| Source | Fractions (%) | |
|---|-----------------|-----------------|
| | e-tag | μ -tag |
| $\tau^- \rightarrow \pi^- K_S^0 (\geq 0\pi^0) \nu_\tau$ | 78.7 ± 4.0 | 78.4 ± 4.0 |
| $\tau^- \rightarrow K^- K_S^0 (\geq 0\pi^0) \nu_\tau$ | 4.2 ± 0.3 | 4.1 ± 0.3 |
| $\tau^- \rightarrow \pi^- K^0 \bar{K}^0 \nu_\tau$ | 15.7 ± 3.7 | 15.9 ± 3.7 |
| Other background | 1.40 ± 0.06 | 1.55 ± 0.07 |

- Ko *et al* (2011)

- need to take into account a **correction** on A_Q due to the different **nuclear-interaction cross-section** of the K^0 and \bar{K}^0 mesons with the material in the detector
- correction is $-(0.07 \pm 0.01)\%$

