Outlook For New Physics at B Factories

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Introduction

- **There are several processes at B-factories which suggest a deviation from the standard model and could indicate the presence of new physics.**

- **$B \to K\pi$**
  - Differing asymmetries: $A(K^+\pi^-) \neq A(K^+\pi^0)$ at 5σ level.
  - One possible explanation: new physics at the 1-Loop level.

- **$B^+ \to \tau^+\nu_\tau$**
  - $B_{SM} \neq B_{Measured}$ at 2σ level.
  - Potential interference with $H^\pm$.
  - Restrictions on m_H vs. $\tan(\beta)$.

- **$\Upsilon(1S) \to \gamma a^0$, $\Upsilon(3S) \to \gamma A^0$**
  - Direct searches for the light Higgs (a^0, A^0).

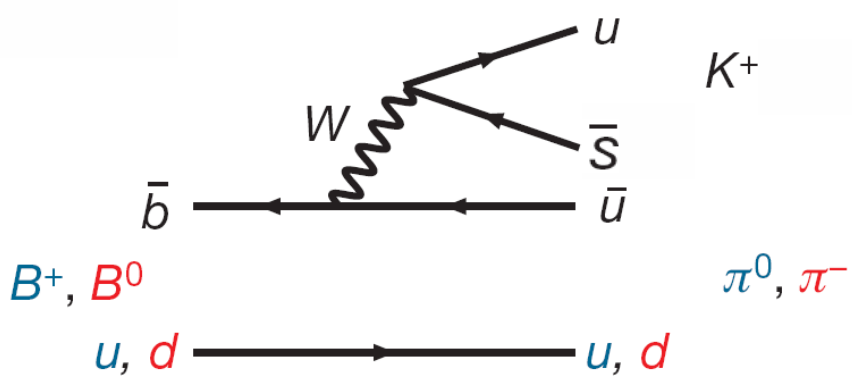
B→Kπ

❖ **The Standard Model to lowest order predicts ΔA=0.**

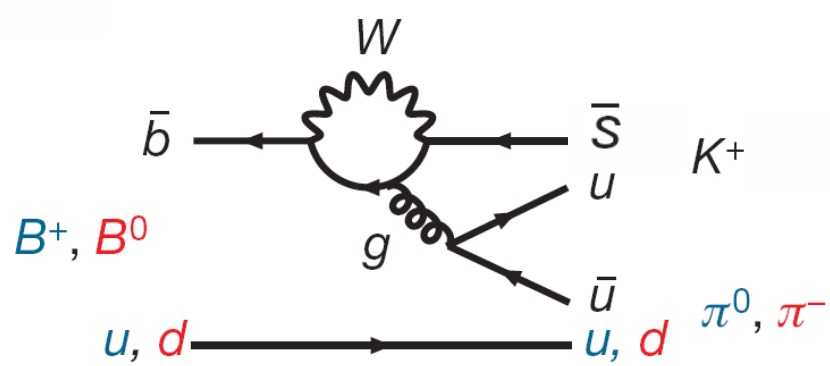
$$\Delta\mathcal{A} \equiv \mathcal{A}_{K^\pm\pi^0} - \mathcal{A}_{K^\pm\pi^\mp}$$

$$\mathcal{A}_{K^\pm\pi^\mp} \equiv \frac{N(\bar{B}^0 \to K^-\pi^+) - N(B^0 \to K^+\pi^-)}{N(\bar{B}^0 \to K^-\pi^+) + N(B^0 \to K^+\pi^-)}$$

❖ **Dominant Feynman Diagrams:**



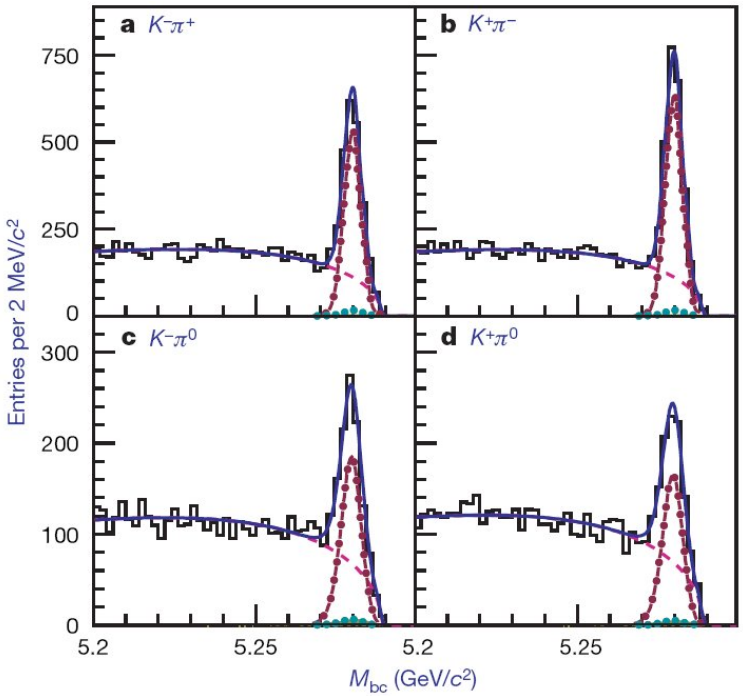
Tree Level



Strong Penguin Loops

$B \to K\pi$ Measurement & Puzzle

- **Candidate B mesons are reconstructed by pairing $K^{\pm}$ with the π and are identified by using the beam-energy constrained mass and the energy difference.**



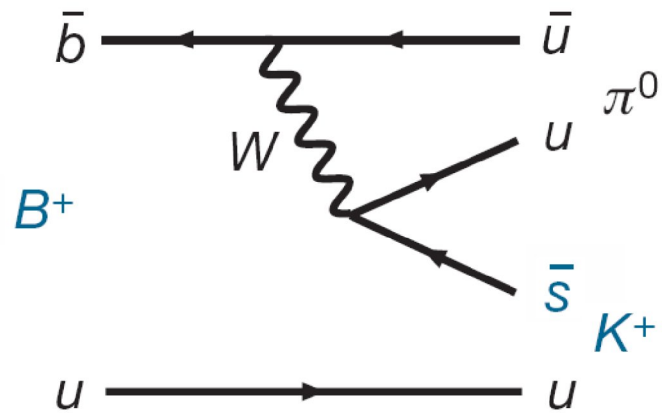
M_{bc} Projections for 535×10^6 BB pairs (*Belle: Nature 452, 332 (2008)*).

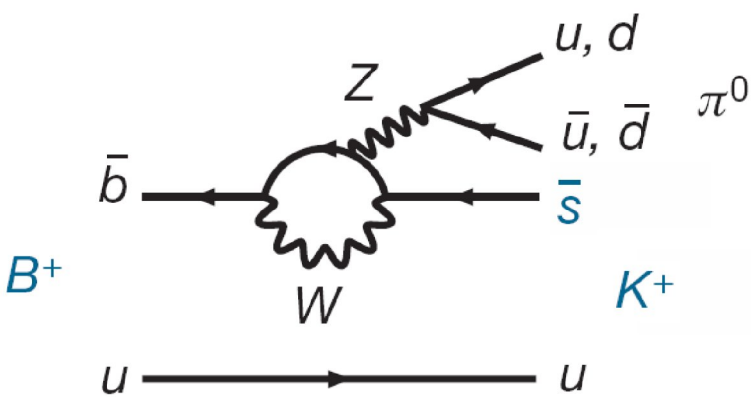
$A(B \to K^+\pi^-)$	
-0.107 ± 0.016 ± 0.006	▪BaBar
-0.094 ± 0.018 ± 0.008	▪Belle
-0.086 ± 0.023 ± 0.009	▪CDF
-0.04 ± 0.16 ± 0.02	▪CLEO
☞ **-0.098 ± 0.012 at 8.1σ**	▪**AVG**
$A(B \to K^+\pi^0)$	
+0.030 ± 0.039 ± 0.010	▪BaBar
+0.07 ± 0.03 ± 0.01	▪Belle
-0.29 ± 0.23 ± 0.02	▪CLEO
☞ **0.050 ± 0.025 at 2.0σ**	▪**AVG**

☞ $\Delta A = -0.147 \pm 0.028$ at 5.3σ

B→Kπ: Possible Resolutions

- **The color suppressed Tree-Level Contributions:**
- **Somewhat enhanced** (*Li, H.-n., Mishima, S. & Sanda, A. I. Phys. Rev. D 72, 114005 (2005).*)
- **Not yet sufficient to account for ΔA≠0.**

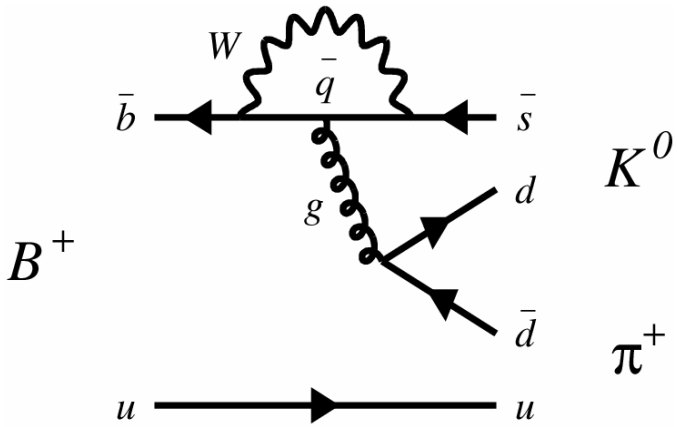




- **The 'Electroweak' Penguins:**
- **Violate Isospin, but are highly suppressed in the Standard Model.**
- **Sensitive to new physics.**

B→Kπ: Predictions

- **Decays to neutral Kaons:**
- **$A(B\to K^0\pi^+)=0.009 \pm 0.025$ (expected ~0 in SM).**
- **Model independent (Isospin) relation:**



$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

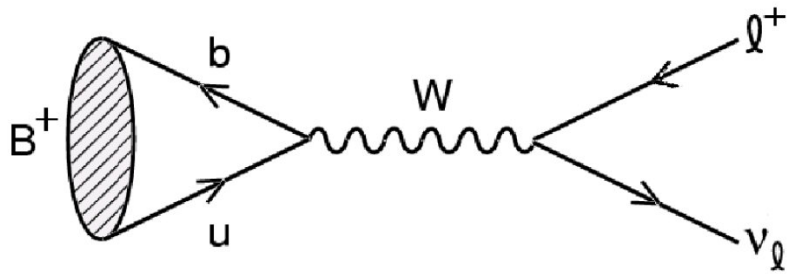
M. Gronau, PLB 627, 82 (2005); D. Atwood & A. Soni, Phys. Rev. D 58, 036005(1998).

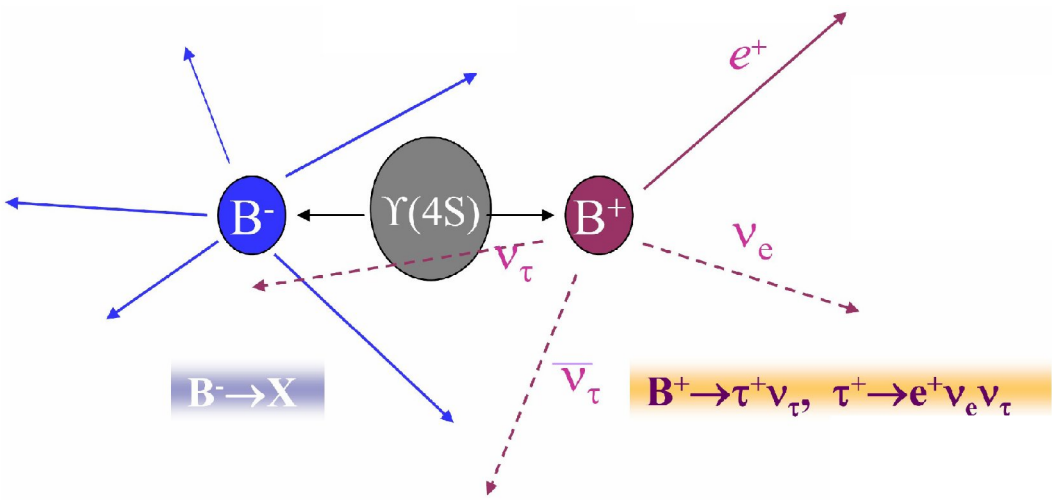
- **Predicts $A(B\to K^0\pi^0)=-0.151 \pm 0.043$**

Measure $A(B\to K^0\pi^0)=-0.01 \pm 0.10$ (HFAG avg.)

$B \to l\nu_l$

- Decays occur through annihilation (via W^+ in the SM).





- Reconstruct either *hadronic* ($B^- \to D^{*0}X^-$) or *semileptonic* ($B^- \to D^0 l\nu X$) decays on the tagged side.
- Search for recoil signal $B^+ \to l^+\nu_l$ (only *leptonic* decays of τ).

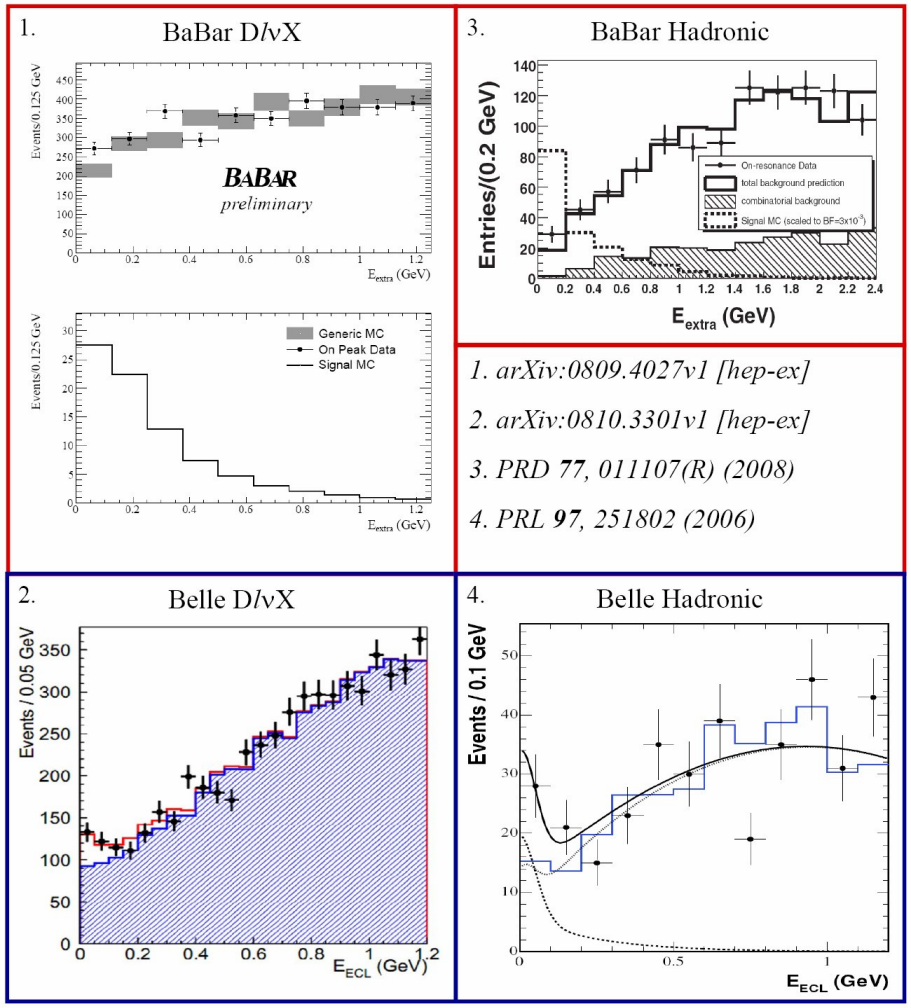
$B^+ \to \tau^+ \nu_\tau$ Measurements

- **Fit for the Extra Calorimeter Energy**
- **Most powerful discriminating variable when eliminating backgrounds**

$\mathcal{B}(B\to\tau\nu)\times10^4$	
$1.8 \pm 0.8 \pm 0.1$	▪Semileptonic BaBar
$1.8 \pm 0.9 \pm 0.4$	▪ Hadronic BaBar
$1.6 \pm 0.4 \pm 0.4$	▪Semileptonic Belle
$1.8 \pm 0.6 \pm 0.5$	▪ Hadronic Belle

☞ **HFAG Sept 08:**
$\mathcal{B}(B\to\tau\nu)=(1.5 \pm 0.3)\times10^{-4}$

☞ **CKM 2008 predicts:**
$\mathcal{B}(B\to\tau\nu)=(0.7 \pm 0.1)\times10^{-4}$



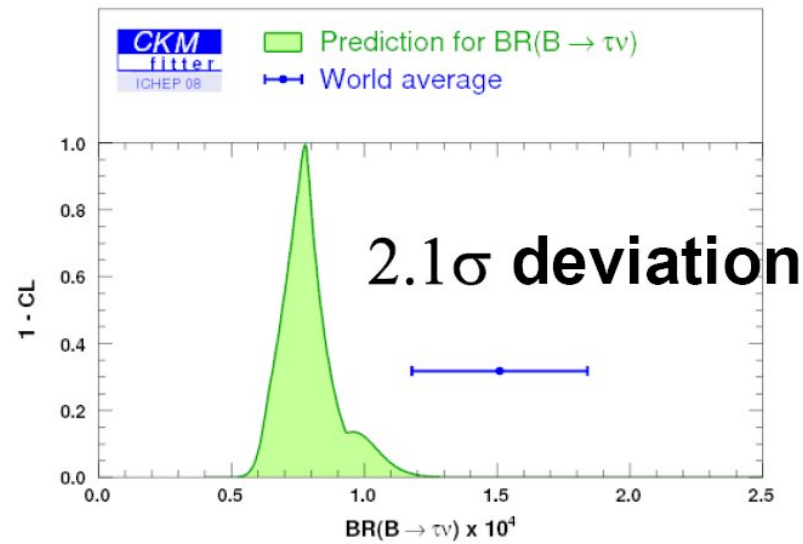
1. arXiv:0809.4027v1 [hep-ex]
2. arXiv:0810.3301v1 [hep-ex]
3. PRD **77**, 011107(R) (2008)
4. PRL **97**, 251802 (2006)

$B^+ \rightarrow \tau^+ \nu_\tau$ Decay

- **SM Branching Fraction:**

$$\mathcal{B}(B^+ \to \ell^+ \nu_\ell) = \frac{G_F^2 m_B m_\ell^2}{8\pi} \left[1 - \frac{m_\ell^2}{m_B^2}\right]^2 \tau_{B^+} f_B^2 |V_{ub}|^2$$

- **If the decay occurs via a charged Higgs, then B is modified:**



$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\mathrm{SM}} \times r_H$$

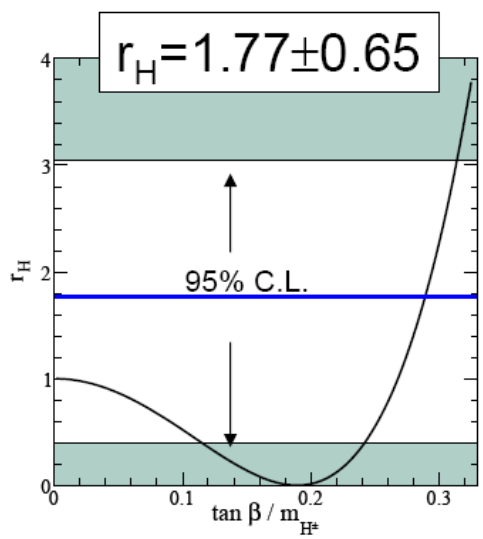
$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2\beta)^2$$

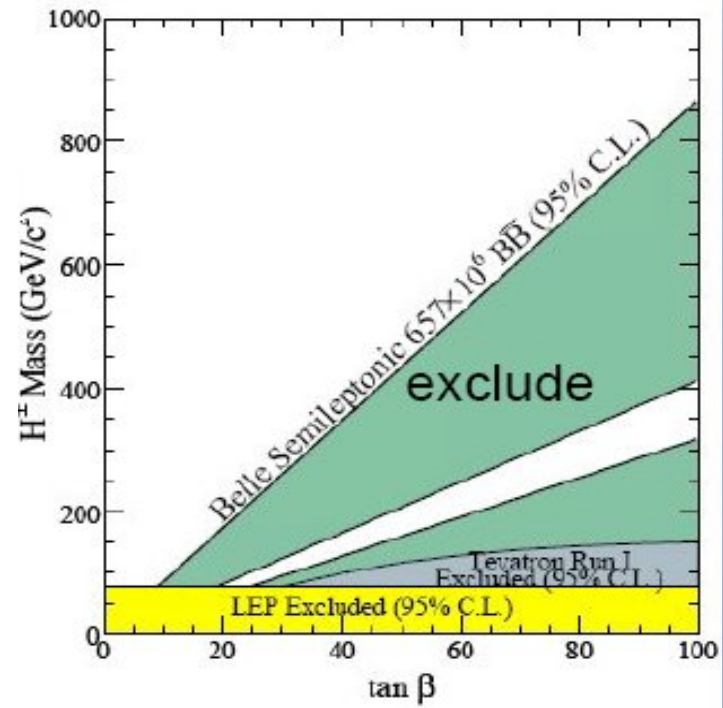
$\tan(\beta) \equiv V_2/V_1$, the ratio of the higgs vacuum expectation values.

☞ **r_H=1.77 ± 0.65**

$B \to l\nu_l$ Results

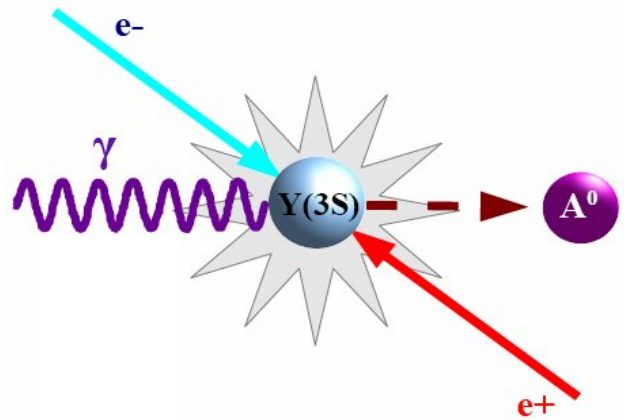
- $\mathcal{B}(B \to \tau\nu) = (1.5 \pm 0.3) \times 10^{-4}$, which deviates by 2.1σ from the SM predictions.
- $\mathcal{B}(B \to e\nu) < 1.0 \times 10^{-4}$, $\mathcal{B}(B \to \mu\nu) < 1.3 \times 10^{-4}$ (consistent with predictions).
- The decay constant f_B is computed on a lattice.
- $B_{measured} > B_{SM}$ suggests that the H^+ dominates.
- Significant constraints are placed on m_H vs. $\tan(\beta)$:



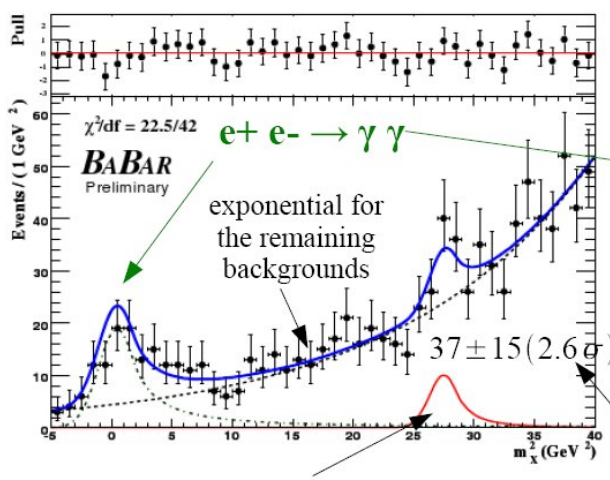


$\Upsilon \rightarrow \gamma A^0$

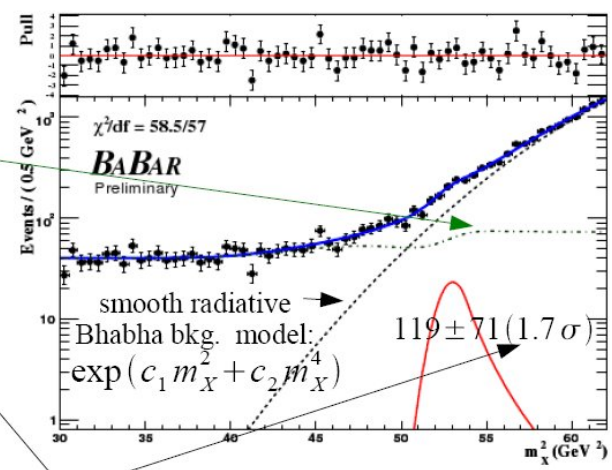
- Search for the higgs candidate: the 'invisible' A^0 recoiling against γ.
- Select γ based on the EMC shower shape, acceptance, vetoes, etc.
- Fit the missing mass squared:



LOW-MASS REGION



HIGH-MASS REGION



Signal model from Monte Carlo simulation

Statistical errors only

$\Upsilon \to \gamma A^0$ and the NMSSM

- **The Next To Minimal Super Symmetric Model predicts an extra Higgs singlet, which can be light (*PRL 95:041801,2005. PRD 76:051105,2007*).**

- **Parameter scans over the range of m_A:**

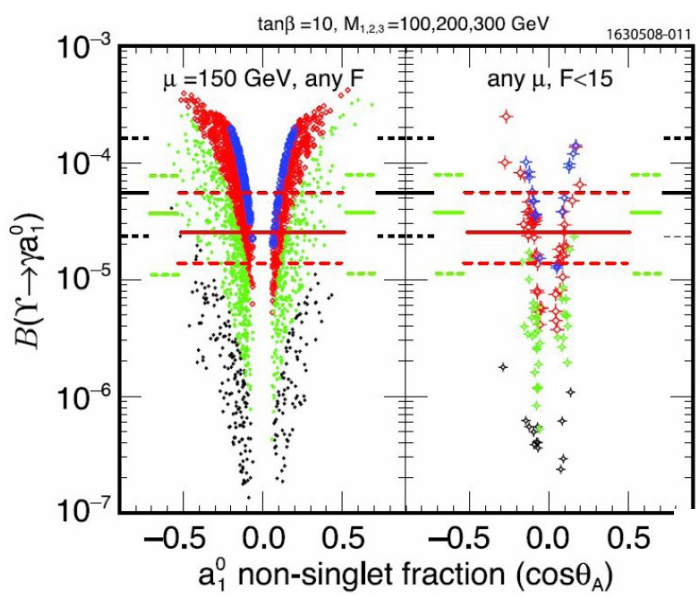
$m_A < 2m_\tau$

$2m_\tau < m_A < 7.5$GeV

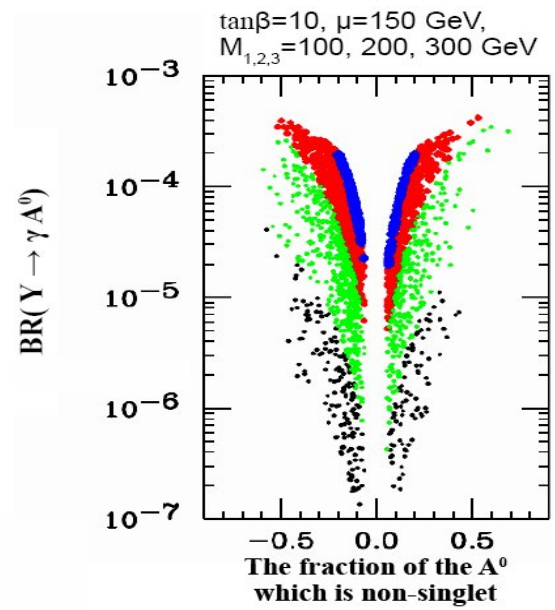
7.5GeV$< m_A < 8.8$GeV

8.8GeV$< m_A < 9.2$GeV

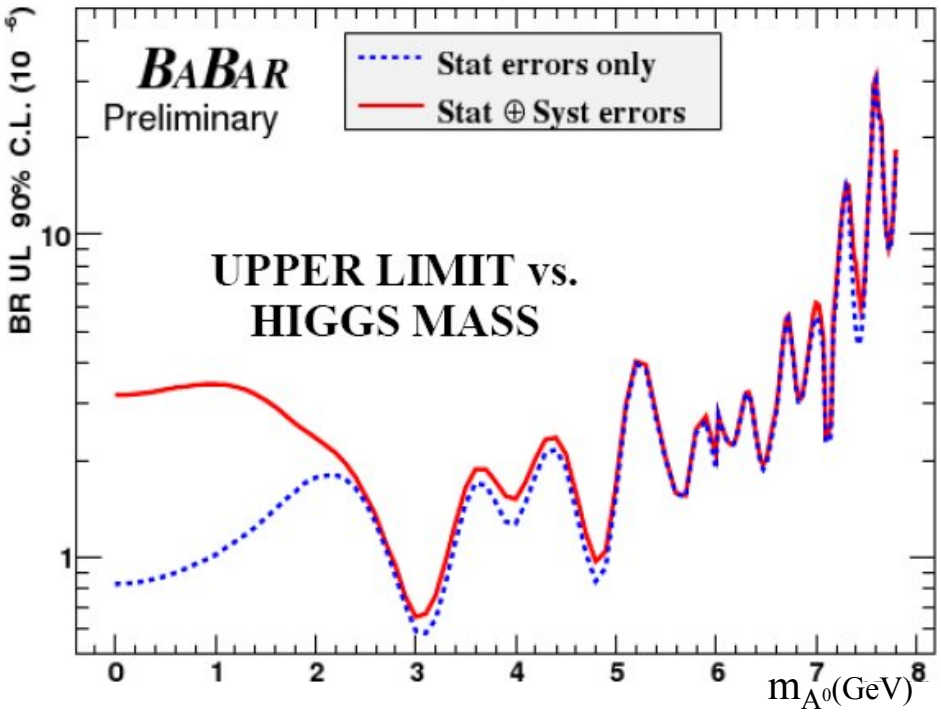
CLEO: $\Upsilon(1S) \to \gamma a^0$



BaBar: $\Upsilon(3S) \to \gamma A^0$

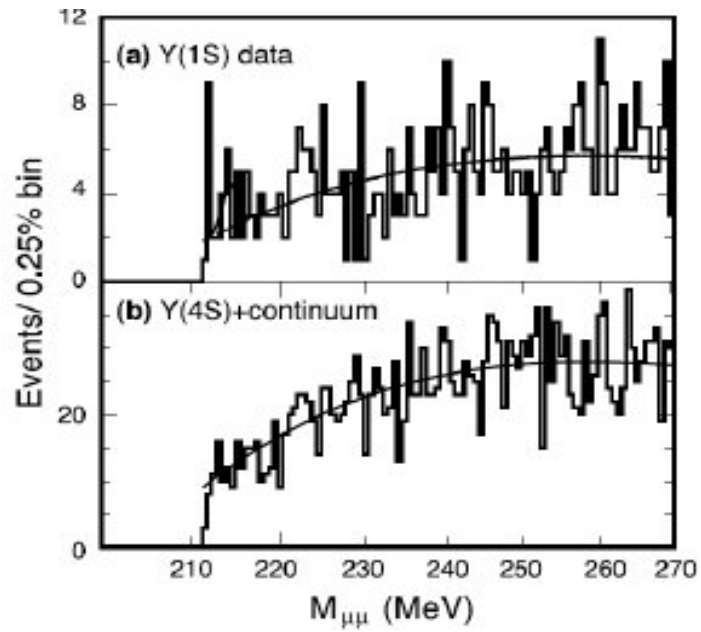


$\Upsilon \to \gamma A^0$ Search Results



arXiv:0808.0017 [hep-ex]

CLEO with $a^0 \to \mu\mu$:



arXiv:0807.1472 [hep-ex]

☞ $B(\Upsilon(3S) \to \gamma A^0) \sim 10^{-5}\text{-}10^{-6}$

☞ $B(\Upsilon(1S) \to \gamma a^0) < 2.3 \times 10^{-6}$

Conclusions

- **There are several possible indications of new physics.**
- **We need additional statistics or alternate (e.g. LHC) searches.**

- **$B \to K\pi$**
  - $\Delta A \neq 0$ at 5.3σ.
  - Various forms of new physics might enhance the 'Electroweak' Penguin.
- **$B^+ \to \tau^+ \nu_\tau$**
  - B_{SM}-$B_{Measured} \neq 0$ at 2.1σ.
  - Hints at the presence of charged Higgs.
  - Complementarity with LHC: Data from B-factories can be used to restrict m_H vs. $\tan(\beta)$.
- **$\Upsilon \to \gamma A^0$**
  - Limits on B.
  - The search is currently in progress.