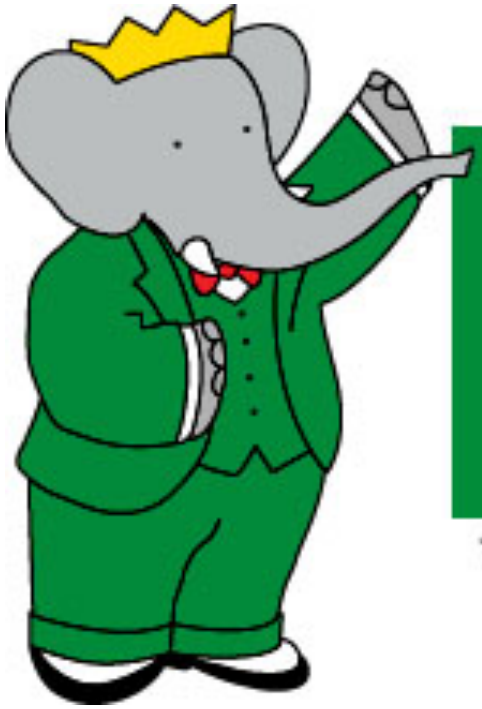
Search for a light Higgs Boson and dark bosons at *BABAR*



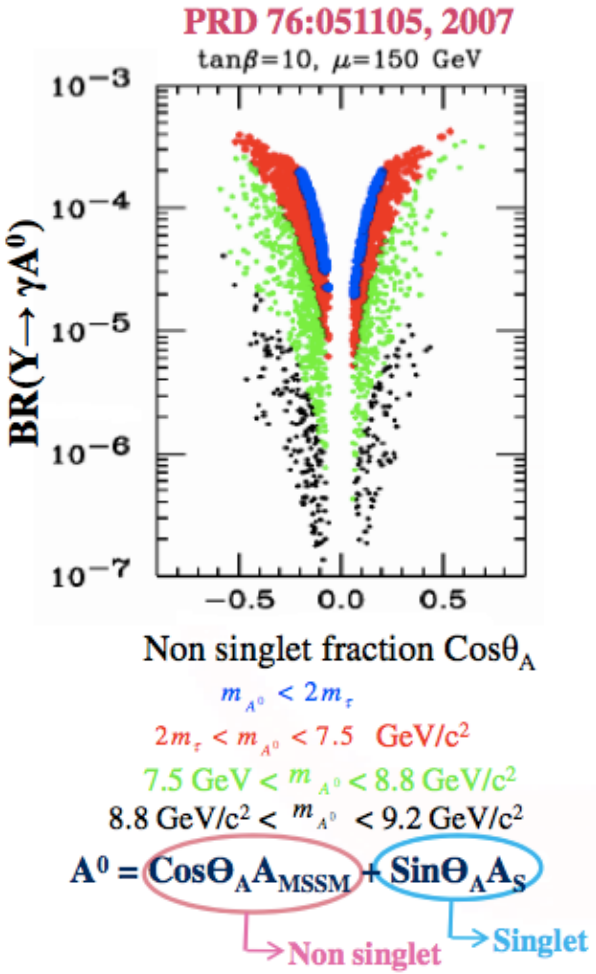
Rocky So, University of British Columbia, Canada

Dec 3rd, 2012, Kruger

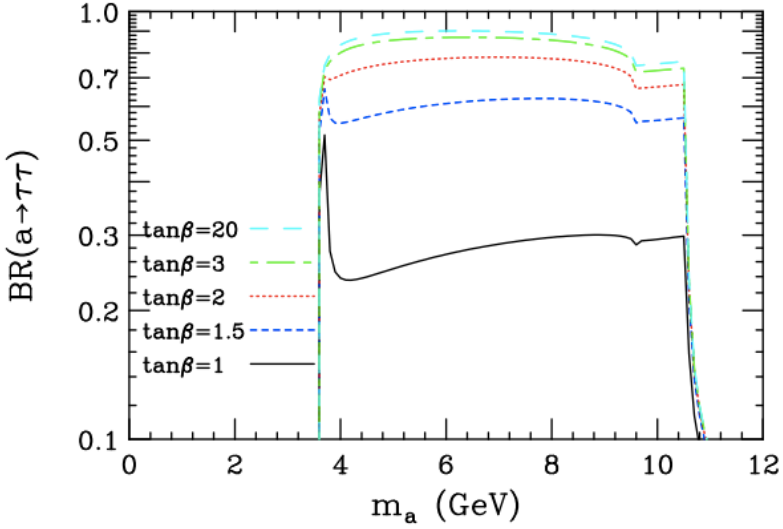
Possibility of a light Higgs

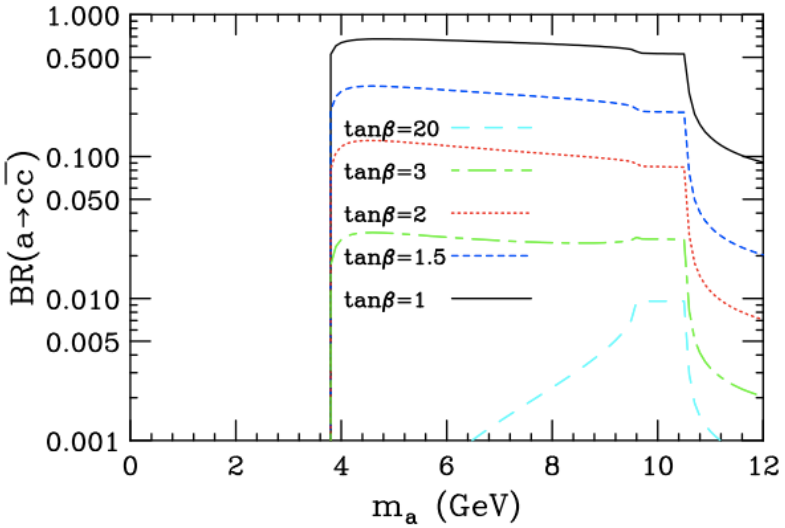
- a light Higgs boson is predicted in extensions of the Standard Model, such as the Next-to-Minimal Supersymmetric Standard Model (NMSSM)
  - R. Dermisek and J. F. Gunion, "New constraints on a light CP−odd Higgs boson and related NMSSM ideal Higgs scenarios", Phys. Rev. D 81, 075003 (2010).

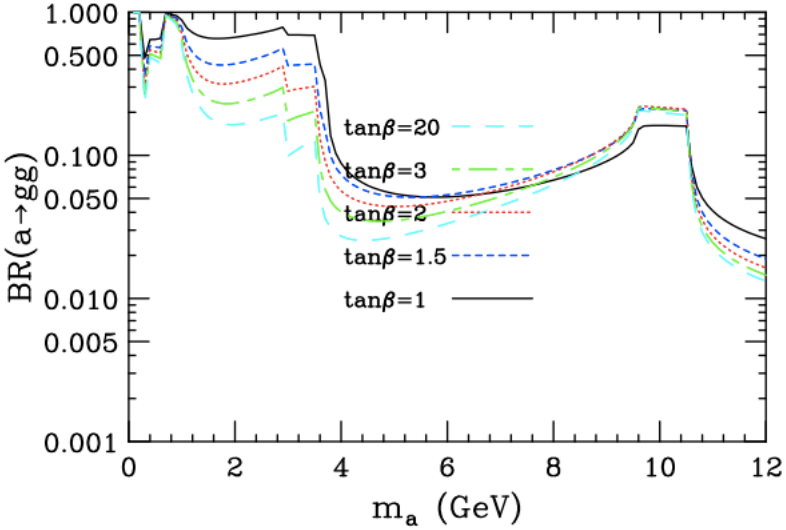
- Such Higgs with a mass < $2m_b$ is not excluded by LEP constraints, and should be observable in Υ(nS) decays

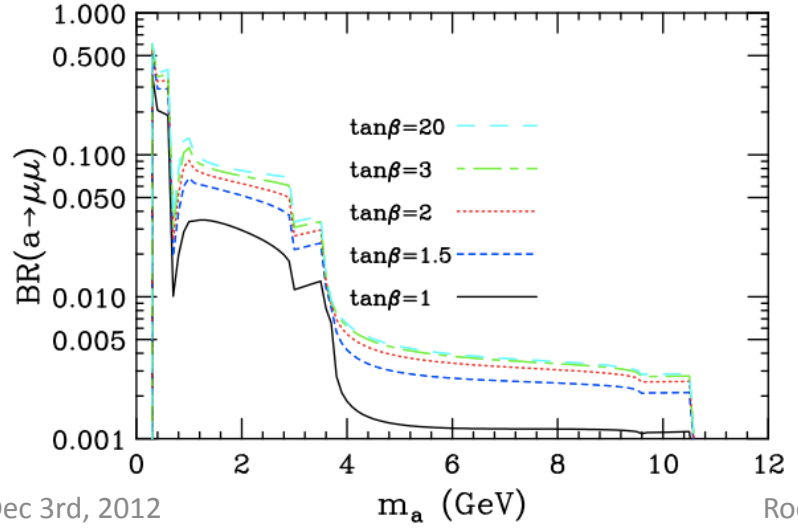


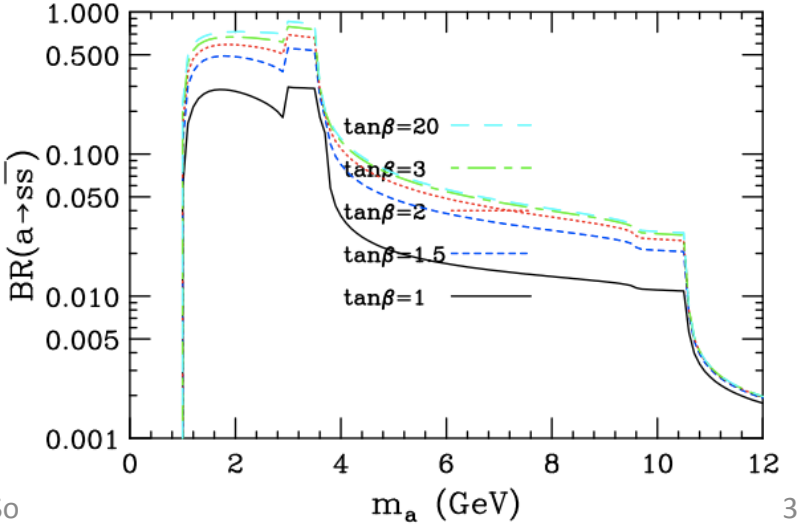
Higgs Branching Fractions



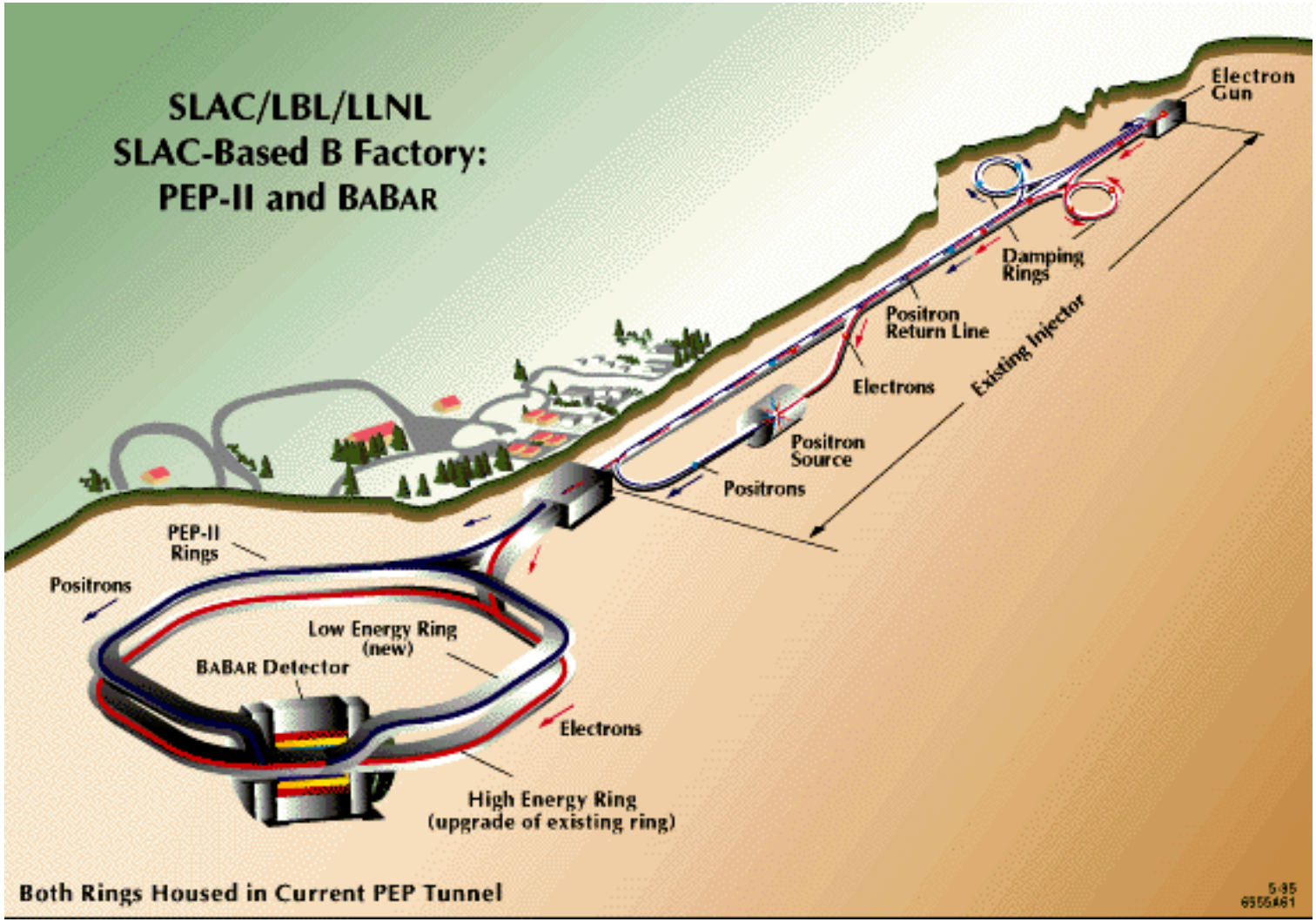




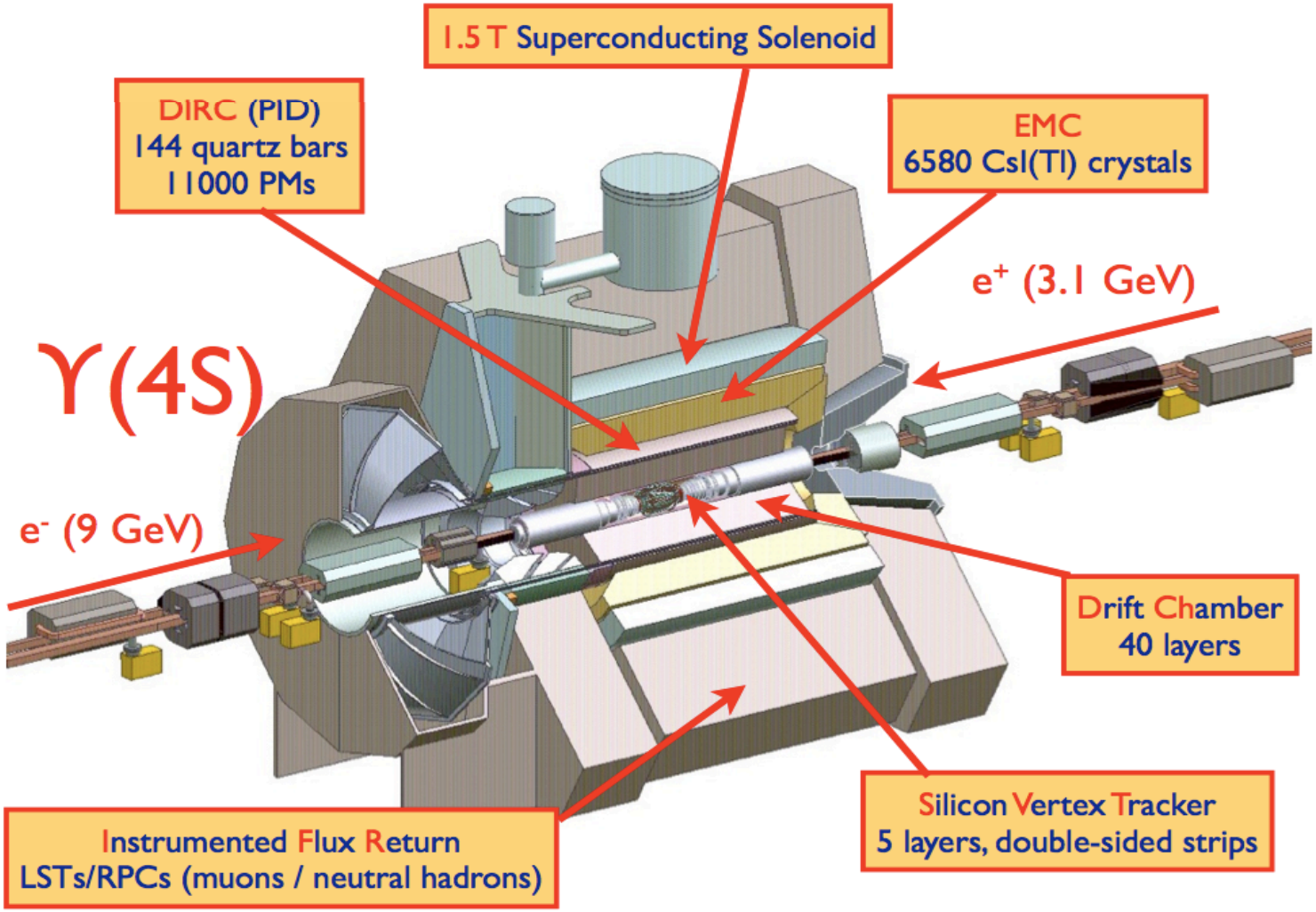




The *BABAR* Experiment

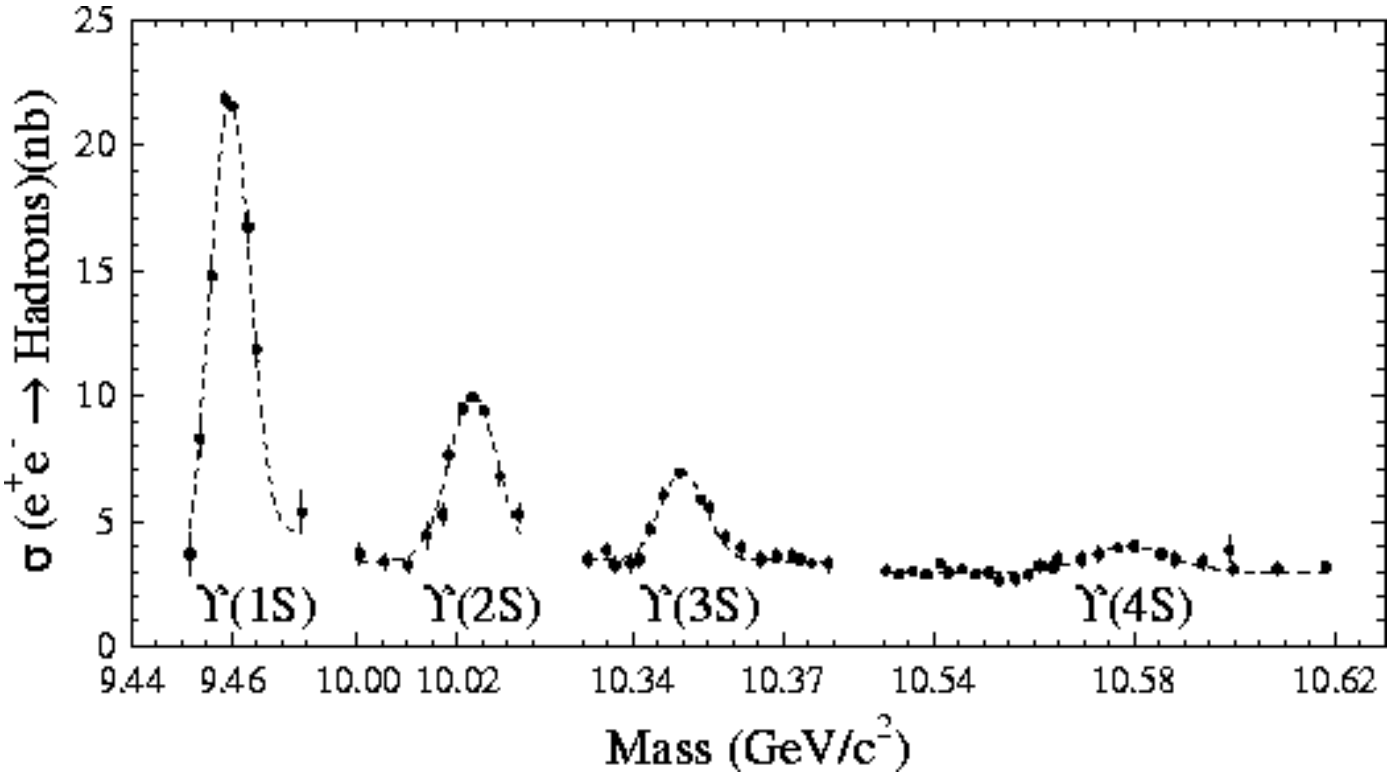


The *BABAR* Experiment

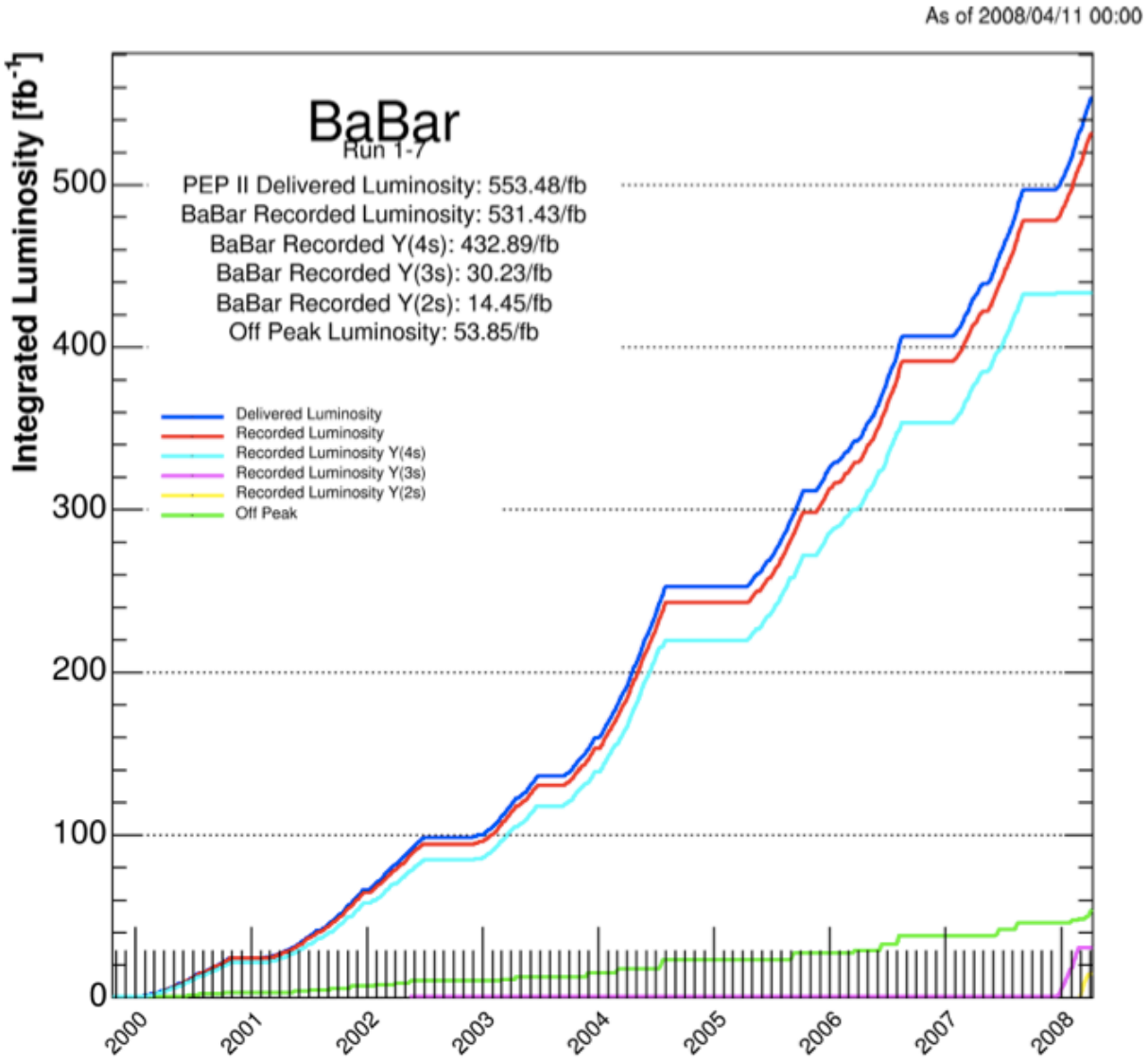


Υ(nS) Resonances

- 465M B meson pairs from Υ(4S) decays (2000-2007)
- 122M Υ(3S) and 99M Υ(2S) (2008)
- 23M Υ(1S) by tagging dipions Υ(2,3S) → $\pi^+\pi^-$Υ(1S)



Collected 531 fb^{-1} of data



Today's talk: 4 recent papers

- arXiv:1210.5669 $\Upsilon(1S) \rightarrow \gamma A^0$; $A^0 \rightarrow \tau^+\tau^-$
  - submitted to PRD-RC
- arXiv:1210.0287 $\Upsilon(1S) \rightarrow \gamma A^0$; $A^0 \rightarrow \mu^+\mu^-$
  - submitted to PRD-RC
- arXiv:1108.3549 $\Upsilon(2,3S) \rightarrow \gamma A^0$; $A^0 \rightarrow$ hadrons
  - PRL107, 221803(2011)
- arXiv:1202.1313 Dark bosons search
  - PRL108, 211801(2012)

$\Upsilon(1S) \rightarrow \gamma A^0$; $A^0 \rightarrow \tau^+\tau^-$

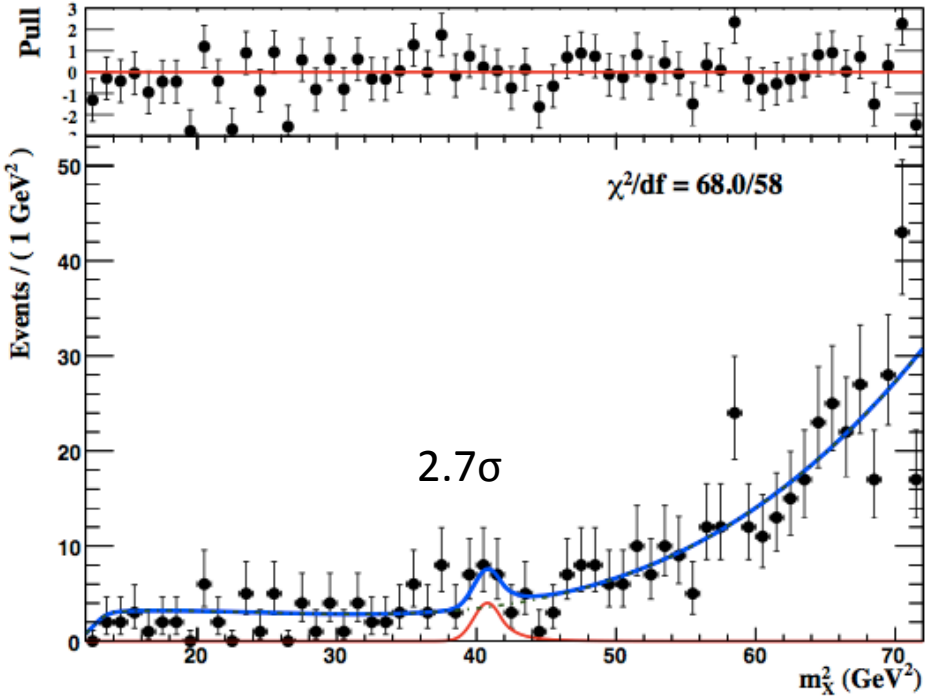
- Select tau pair events by using:
  ee, eμ, eπ, μμ, μπ
- Search for Higgs in the m_X^2 spectrum

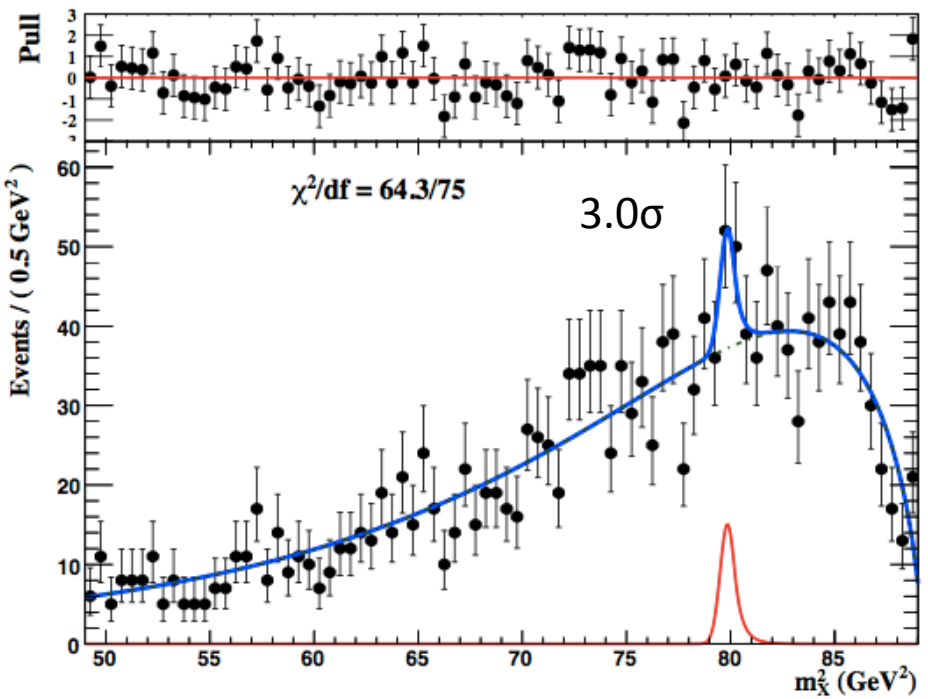
$$m_X^2 = (P_{e^+e^-} - P_{\pi\pi} - P_\gamma)^2$$

- By using dipion tagging to get an $\Upsilon(1S)$ sample, we reject a lot of non Υ background

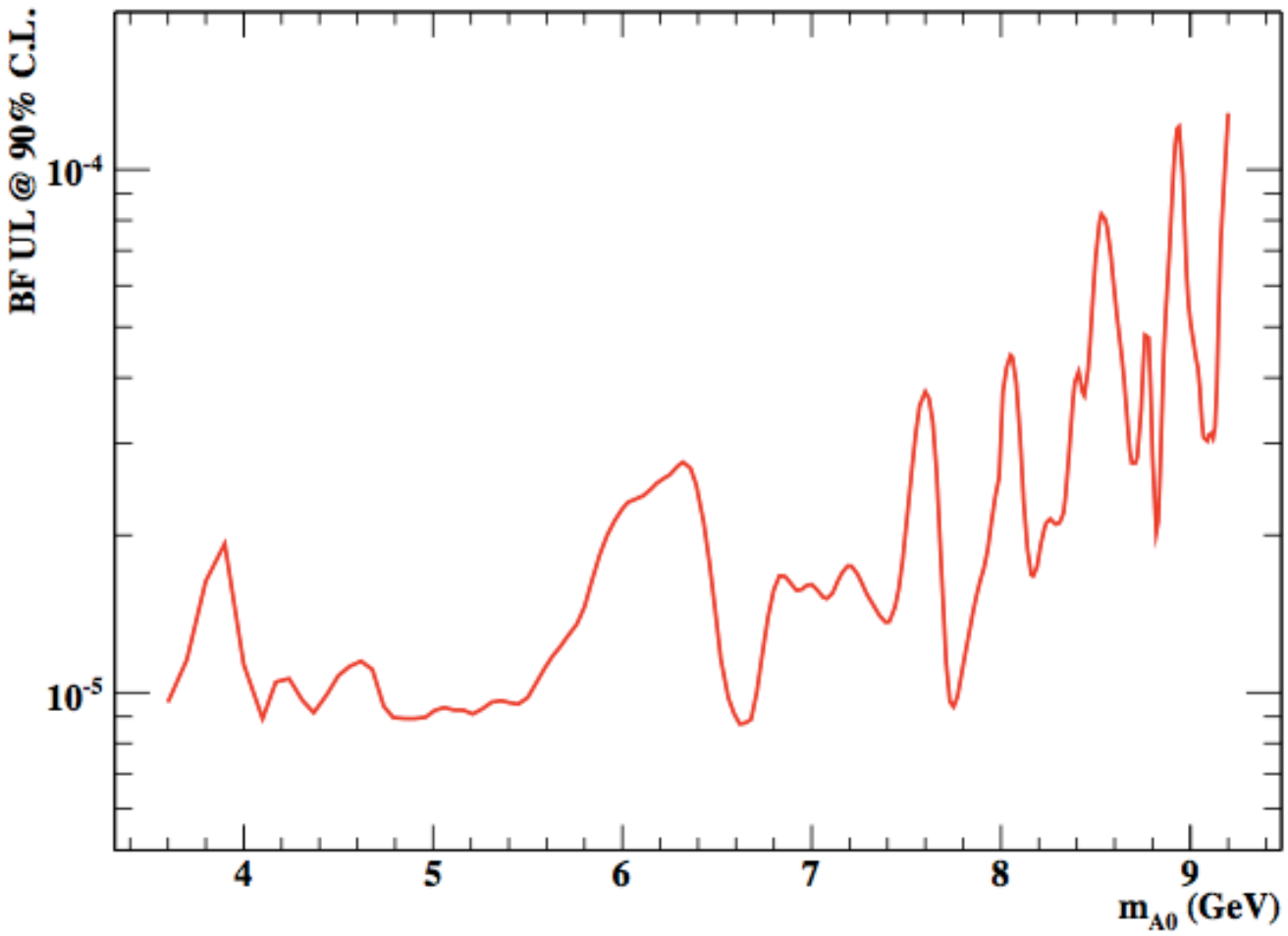
$\Upsilon(1S) \rightarrow \gamma A^0$; $A^0 \rightarrow \tau^+\tau^-$

- Used two mass regions
- Fit the largest upward fluctuation
- 7.5% of pseudo-experiments have a 3.0σ+ fluctuation



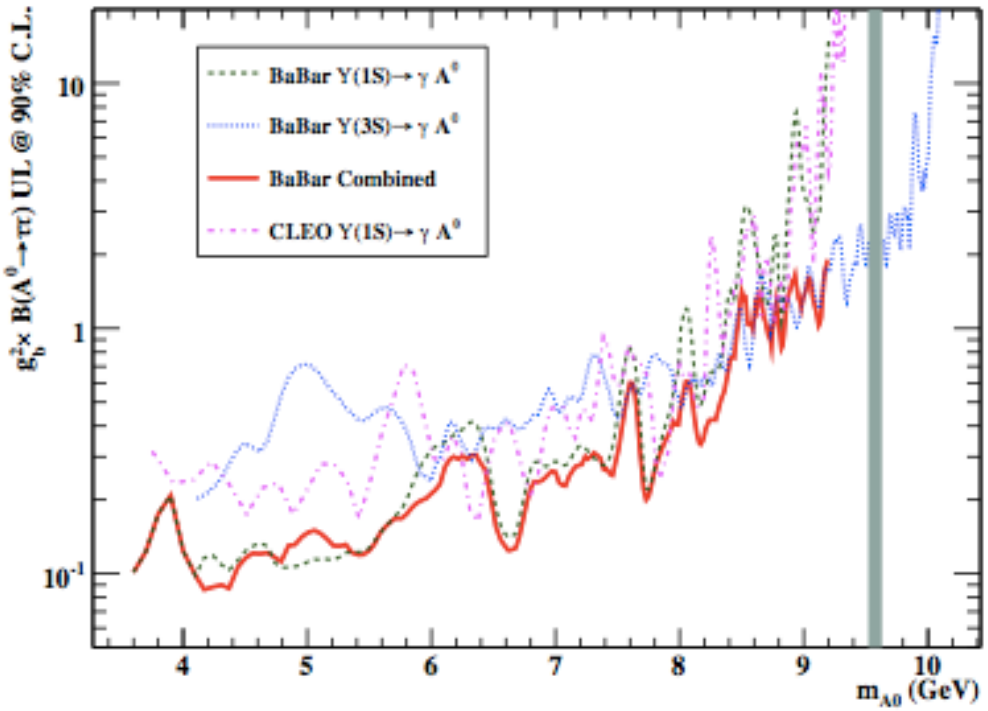


90% CL Upper limits



Combine with previous results in $\Upsilon(2,3S) \rightarrow \gamma A^0$; $A^0 \rightarrow \tau^+\tau^-$

$$\frac{\mathcal{B}(\Upsilon(nS) \rightarrow \gamma A^0)}{\mathcal{B}(\Upsilon(nS) \rightarrow l^+l^-)} = \frac{g_b^2 G_F m_b^2}{\sqrt{2}\pi\alpha} \mathcal{F}_{QCD} \left(1 - \frac{m_{A^0}^2}{m_{\Upsilon(nS)}^2}\right)$$



g_b = Yukawa coupling

The $\Upsilon(1S)$ analysis has better limits because the $\Upsilon(1S)$ sample has less background

$\Upsilon(1S) \rightarrow \gamma A^0$; $A^0 \rightarrow \mu^+\mu^-$

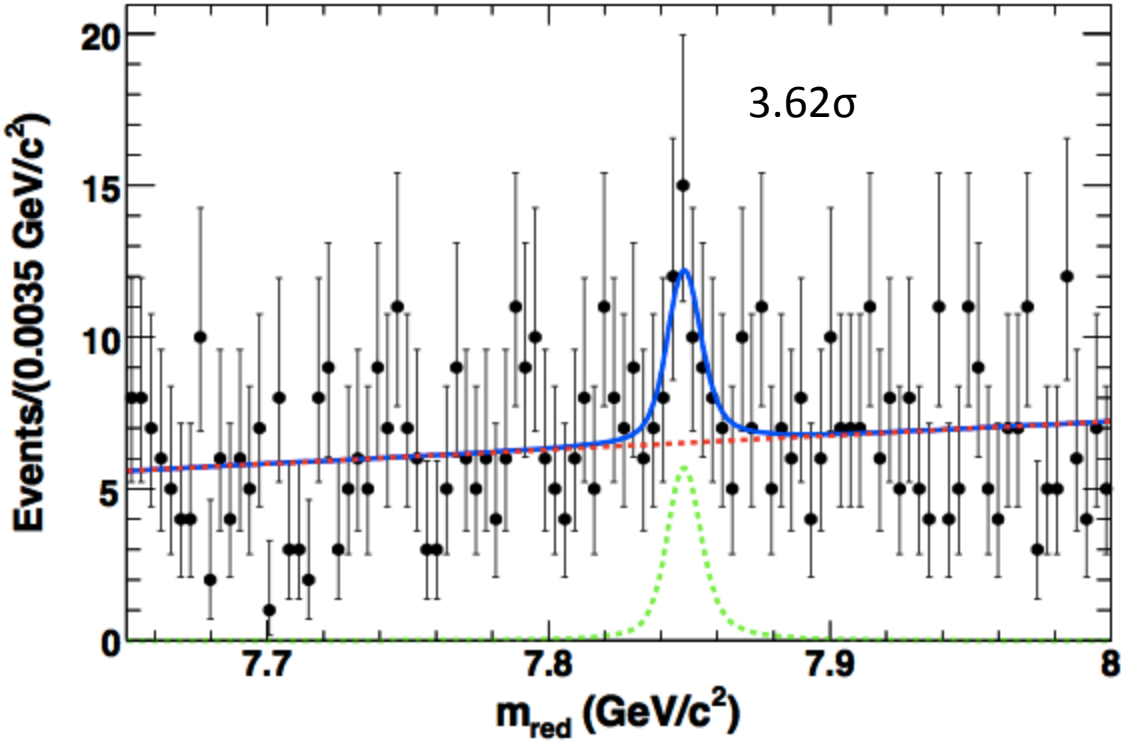
- Search for the Higgs in m_{red} spectrum

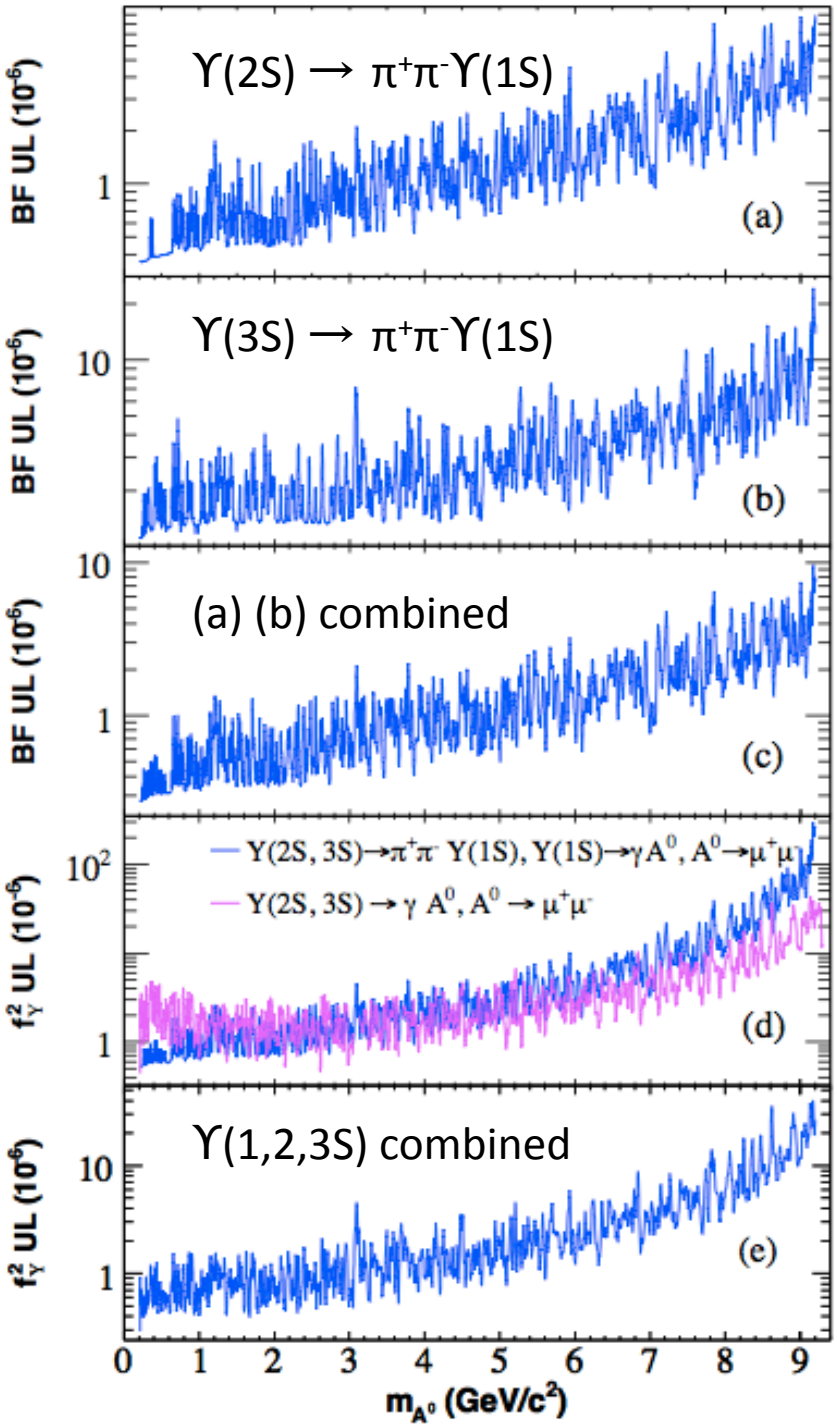
$$m_{\mathrm{red}} = \sqrt{m^2_{\mu^+\mu^-} - 4m^2_{\mu}}$$

- Simplifies the fitting procedure for Higgs mass close to $\mu^+\mu^-$

$\Upsilon(1S) \rightarrow \gamma A^0$; $A^0 \rightarrow \mu^+\mu^-$

- Unbinned max likelihood fit to highest upward fluctuation
- Using pseudo experiments, 18.1% probability of observing a 3.62σ+ fluctuation





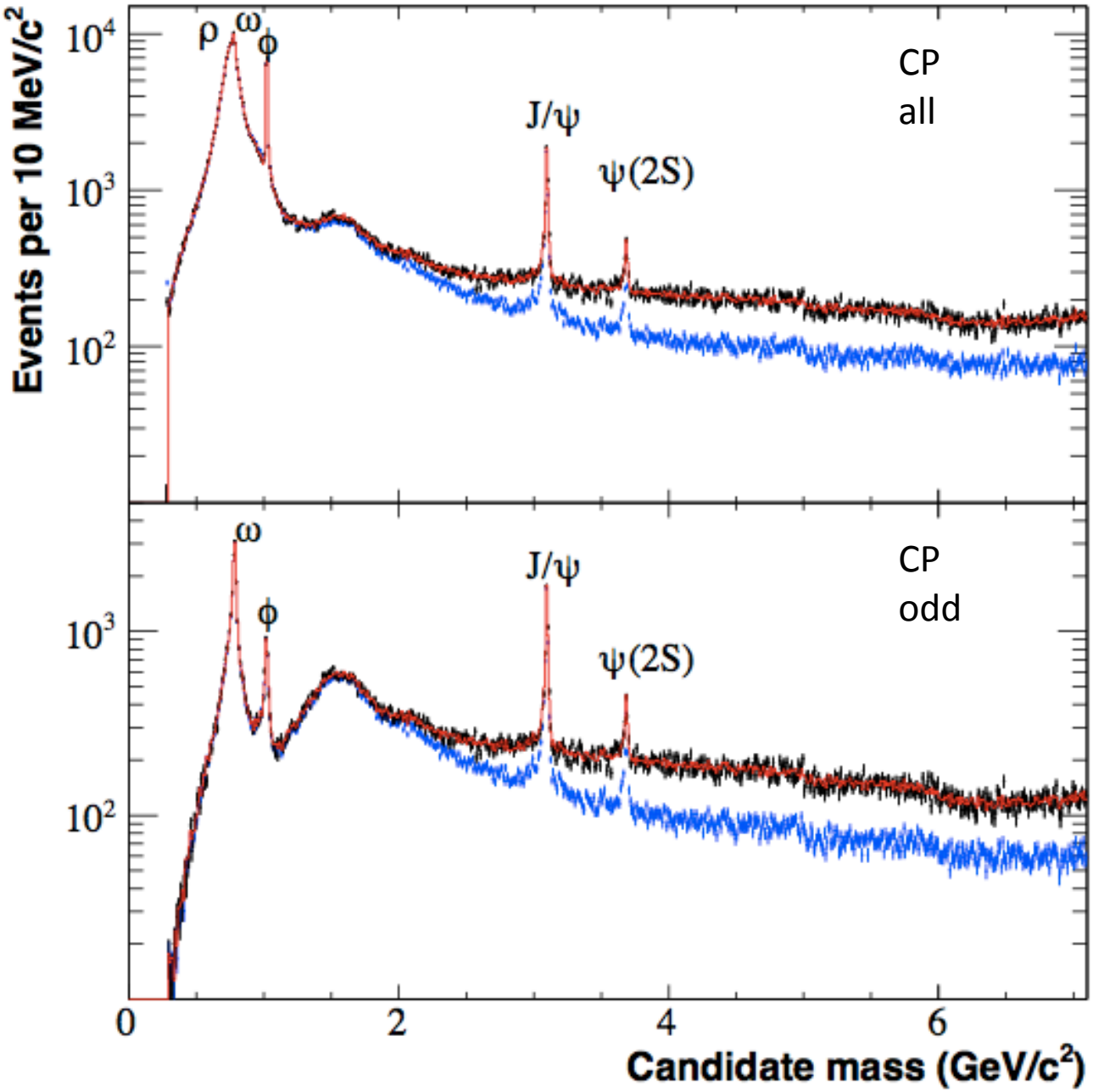
Upper limits

- Similar to $\tau^+\tau^-$ analysis, we combine with previous results and set limits on the effective Yukawa coupling

$$\frac{\mathcal{B}(\Upsilon(nS) \to \gamma A^0)}{\mathcal{B}(\Upsilon(nS) \to l^+l^-)} = \frac{f_\Upsilon^2}{2\pi\alpha}\left(1 - \frac{m_{A^0}^2}{m_{\Upsilon(nS)}^2}\right)$$

$\Upsilon(2,3S) \rightarrow \gamma A^0$; $A^0 \rightarrow$ hadrons

- Require a high energy photon
- Add up the 4-momenta of remaining hadrons and photons in the event
- Search from 0.23 to 7GeV/c^2
- Search for CP-odd Higgs final states as well as CP not specified
  - No 2 body Higgs final states for CP-odd



black = data

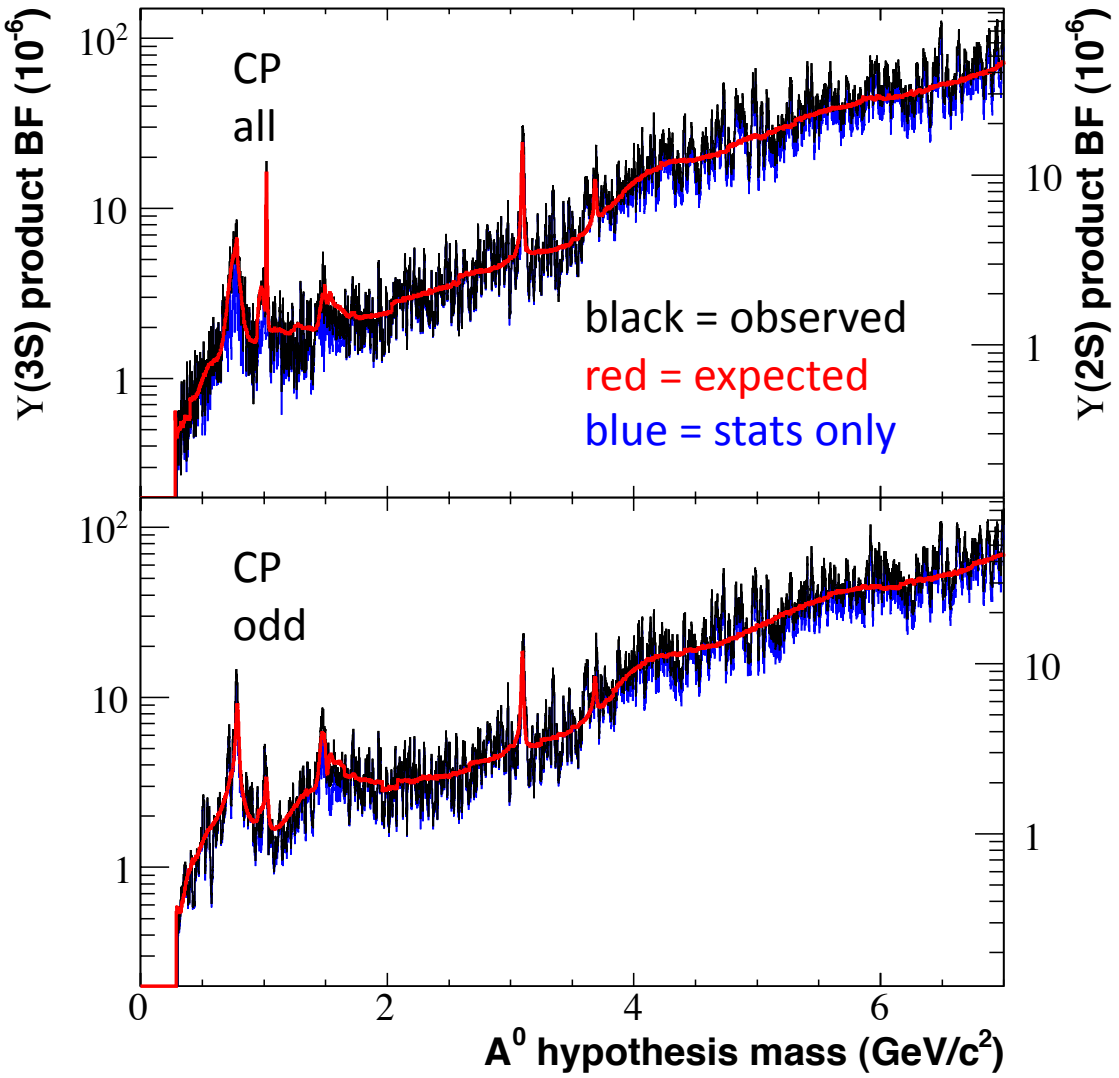
red = expected

blue = non-ϒ background

Resonances labeled are $e^+e^- \rightarrow \gamma_{ISR}X$

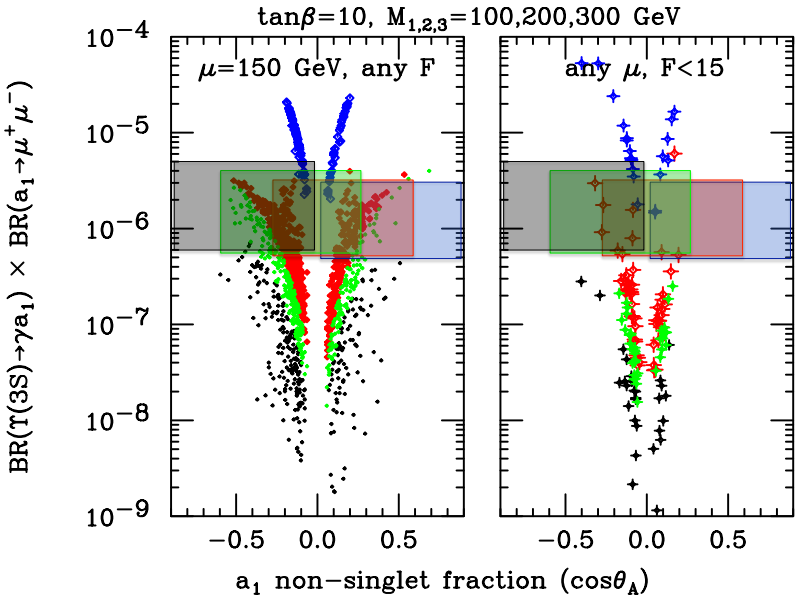
ISR = initial state radiation

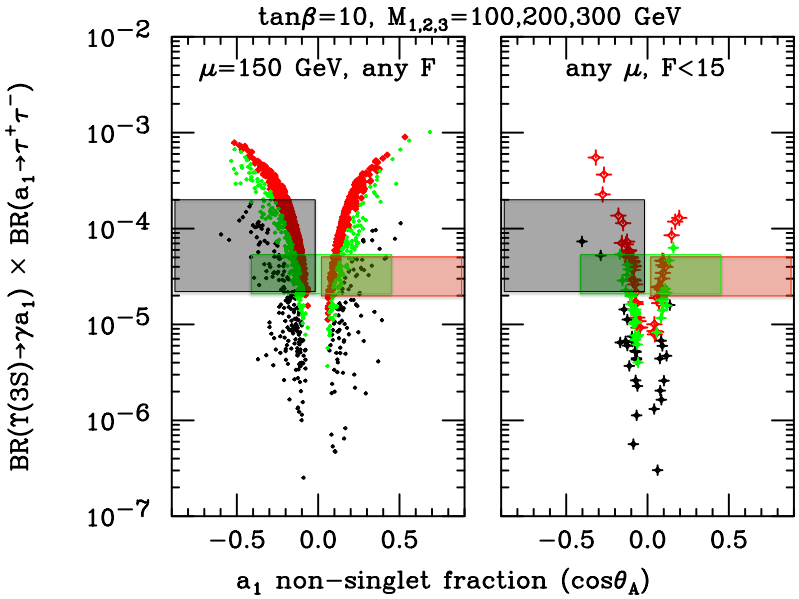
Branching Fraction Upper Limits



BF upper limits are worse at higher Higgs masses because the reconstruction efficiencies fall off at higher Higgs mass (some daughters escape)

Parameters space excluded by data





$$A^0 = \cos\theta_A A_{MSSM} + \sin\theta_A A_S$$

non singlet singlet

Dots = prediction at different masses
Box = range of exclusion by data at different masses

We reject the space above the boxes
(horizontal location of boxes separated for visual purposes)

For masses less than two τ, we reject most of the points, but not for higher masses

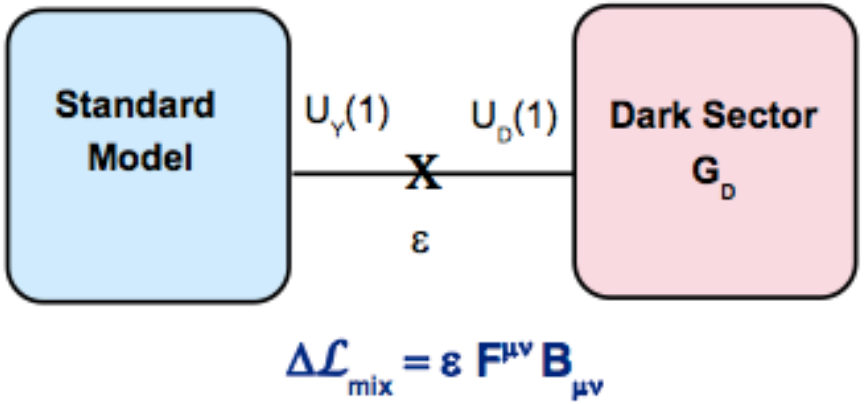
$0 < m_A < 2m_\tau$
$2m_\tau < m_A < 7.5\text{GeV}$
$7.5 < m_A < 8.8\text{GeV}$
$8.8 < m_A < 9.2\text{GeV}$

Dark bosons search

- Astrophysical and terrestrial experiments suggests a dark sector with GeV-scale gauge boson force carriers and new Higgs bosons
- We search for such dark boson via the "Higgs-strahlung" process

$$e^+e^- \rightarrow A'h', h' \rightarrow A'A'$$

ε is the mixing strength between the SM and the dark sector



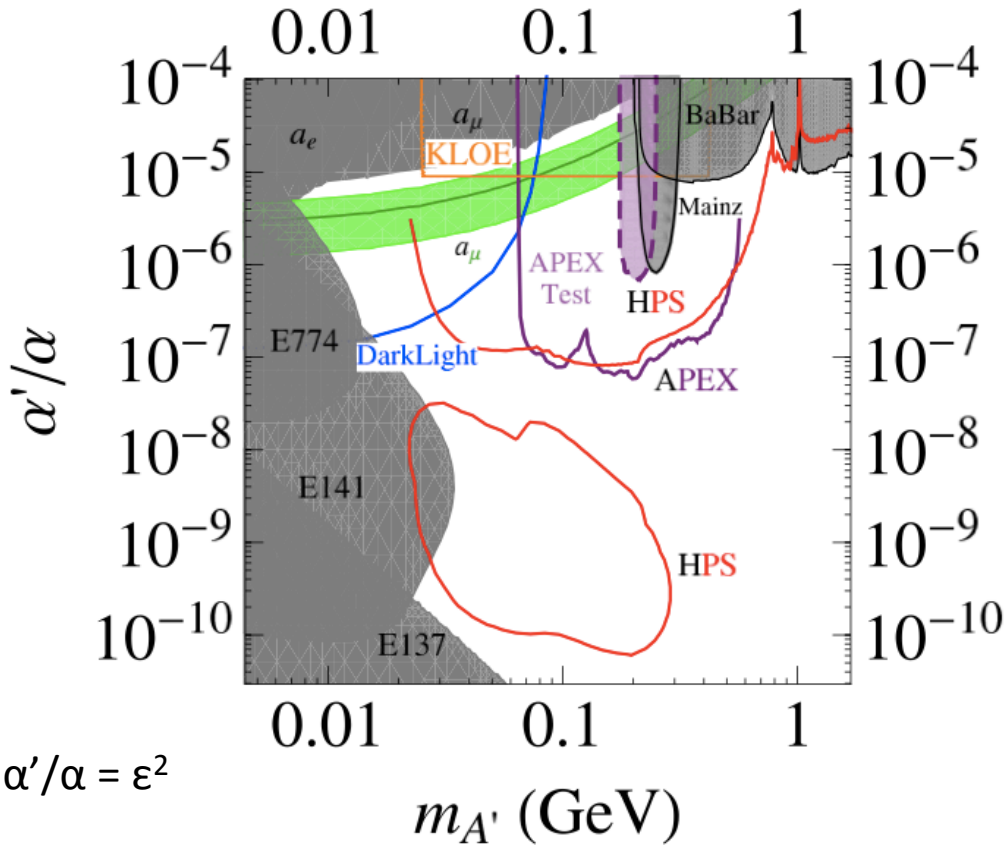
Dark bosons search

- Such A' couples to SM particles
- We reconstruct the A' with two leptons or two charged pions
- Practically no background

Grey = excluded by experiments

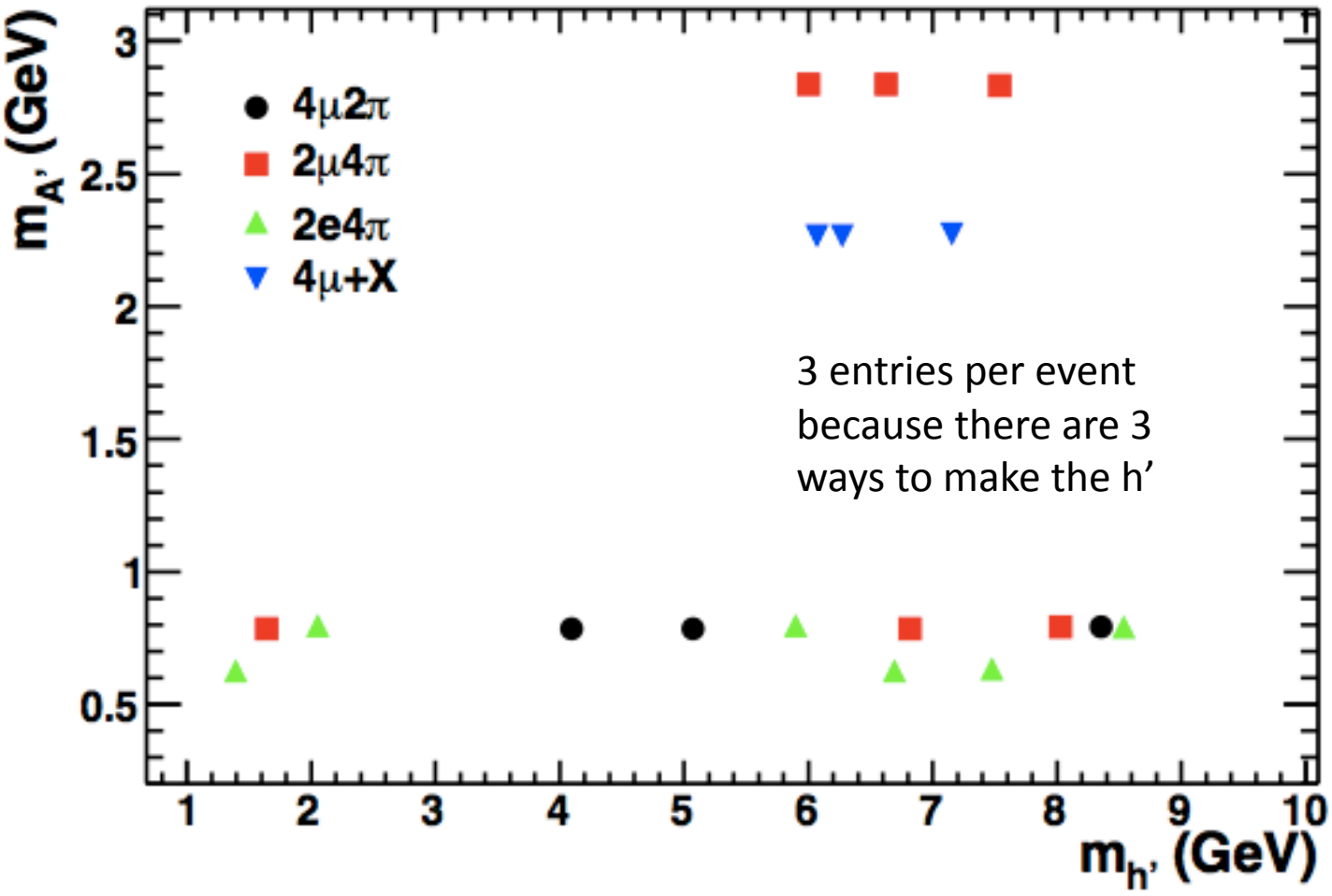
Red, blue, purple = expected sensitivity by experiments

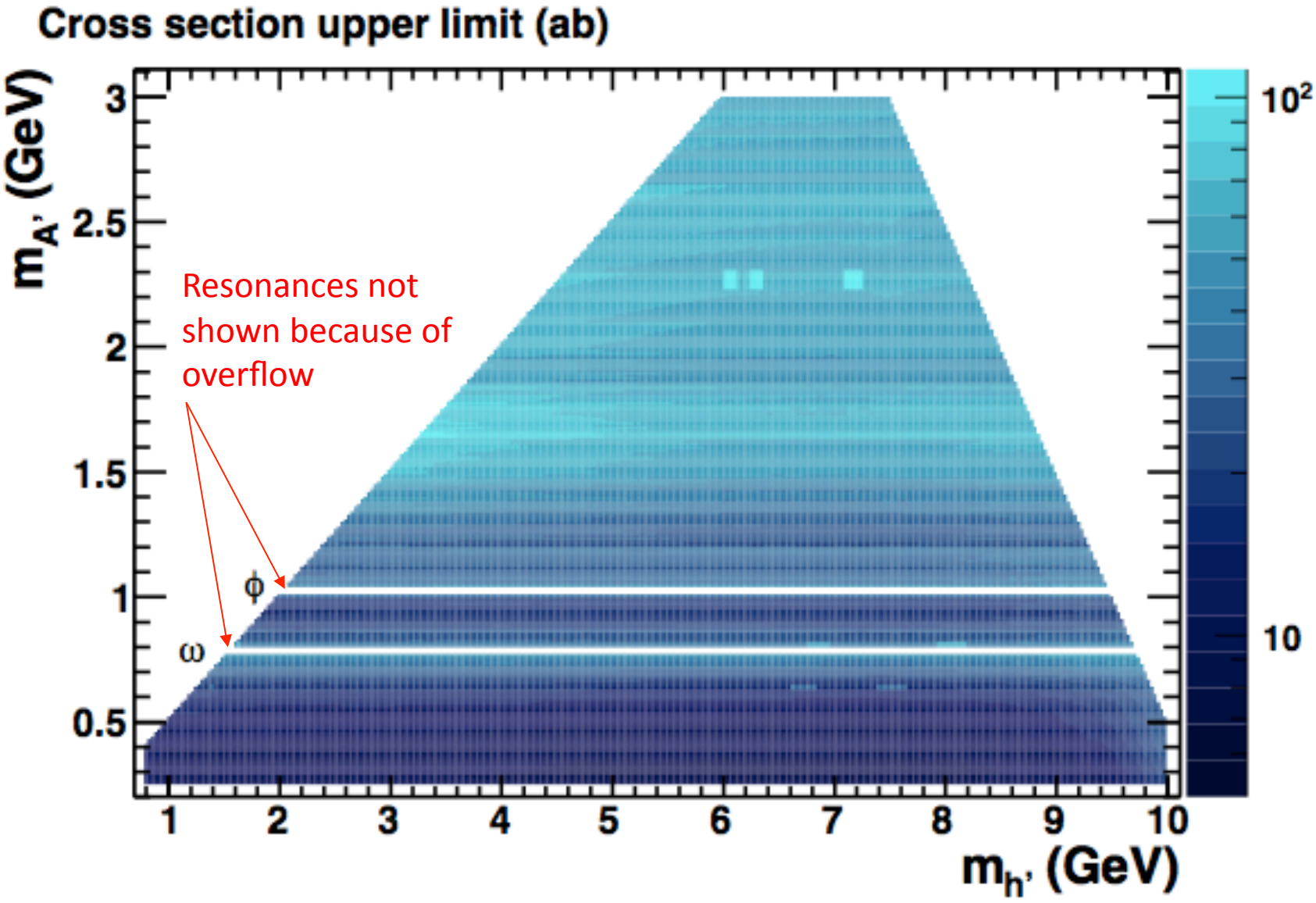
Green = the coupling needed to solve the g−2 discrepancy using the dark photon hypothesis



$\alpha'/\alpha = \varepsilon^2$

Dark bosons search

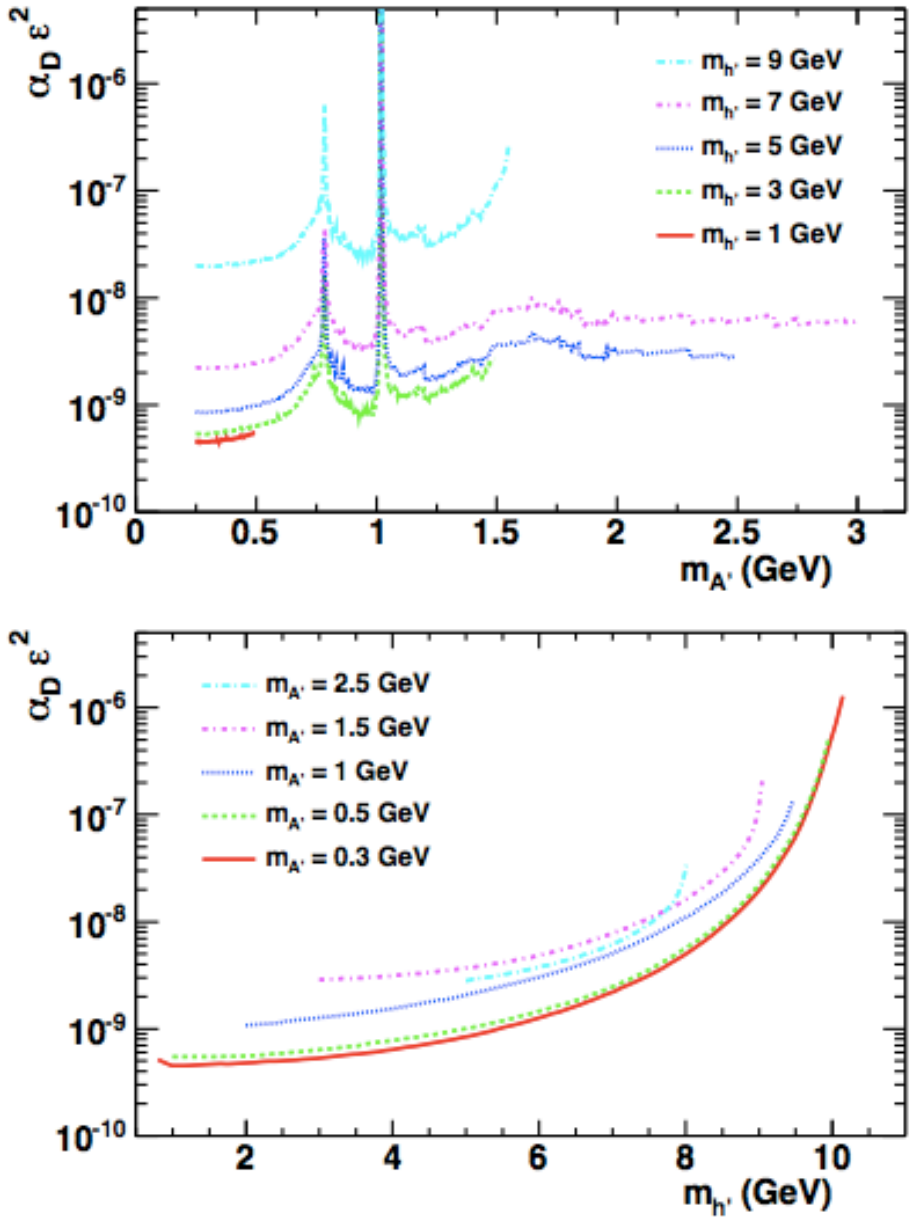



Cross section upper limit (ab)
$m_{A'}$ (GeV)
3
2.5
2
1.5
1
0.5
Resonances not shown because of overflow
ϕ
ω
1
2
3
4
5
6
7
8
9
10
$m_{h'}$ (GeV)
10^2
10

Upper limits on $\alpha_D \varepsilon^2$

$\alpha_D = g_D^2 / 4\pi$

g_D = dark sector gauge coupling



Summary and Outlook

- BaBar hasn't seen evidence for a Higgs or dark photons
- We exclude some NMSSM parameter space
- More analyses in progress
- Next generation B factories can improve searches