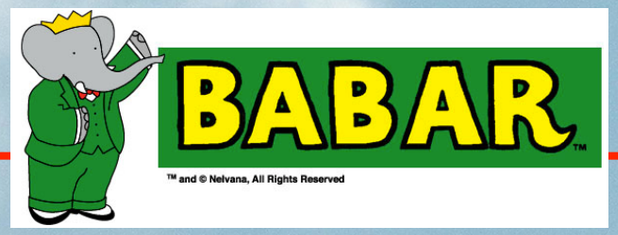

Low mass new physics search of the CP-odd Higgs A^0 to $s\bar{s}$ and gluon gluon

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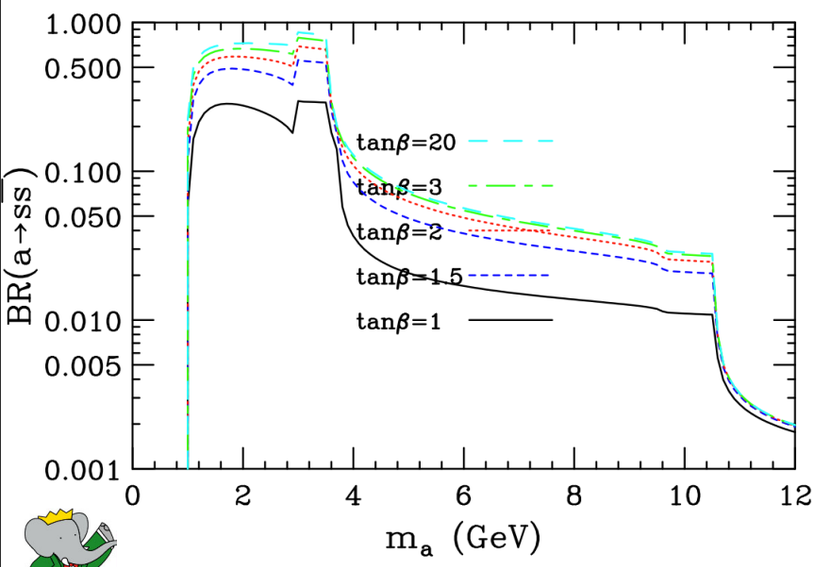
(on behalf of the BABAR Collaboration)

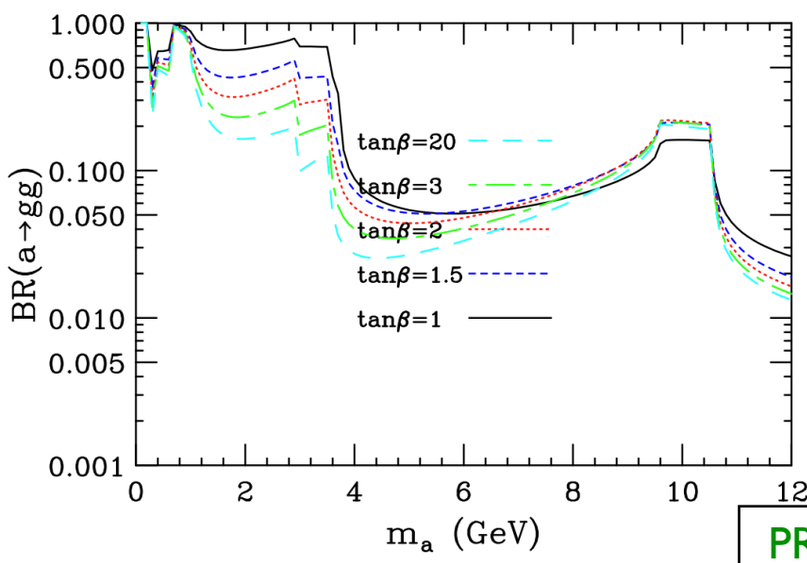
Rencontres de Moriond EW 2014 - La Thuile, 17th March 2014

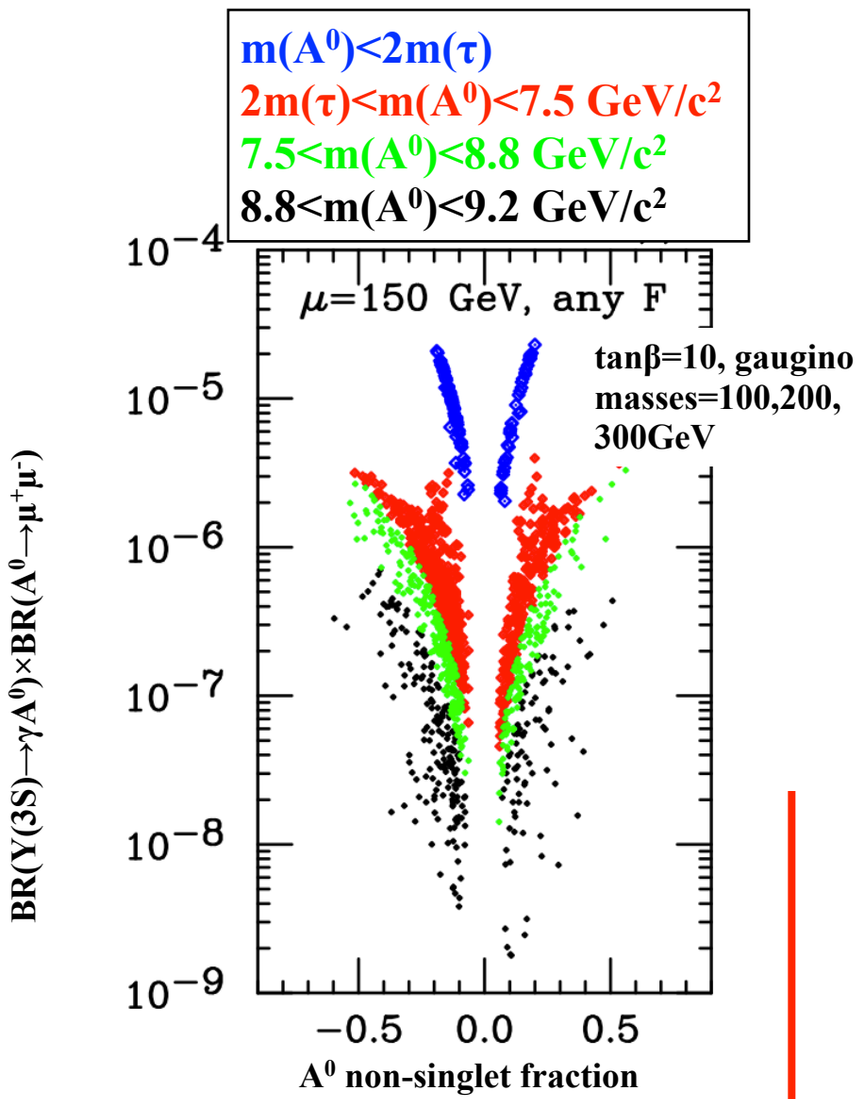
Theory

- ✓ Next to Minimal Super-symmetric SM (**NMSSM**) includes the possibility of a light pseudoscalar Higgs boson $A^0 = \cos(\theta_A)a_{MSSM} + \sin(\theta_A)a_{singlet}$
  - ✓ Not excluded by LEP limits
  - ✓ Light —> accessible to B-factories (and intensively searched for at BABAR since 2009)
- ✓ Radiative decays of narrow Υ resonances have predicted BRs up to ~O(10^{-5}):
  - ✓ $\Upsilon(nS) \to \gamma A^0$, with the different A^0 decays dominant for different mass regions

In this talk, A^0—>$s\bar{s}$ and A^0—>gg





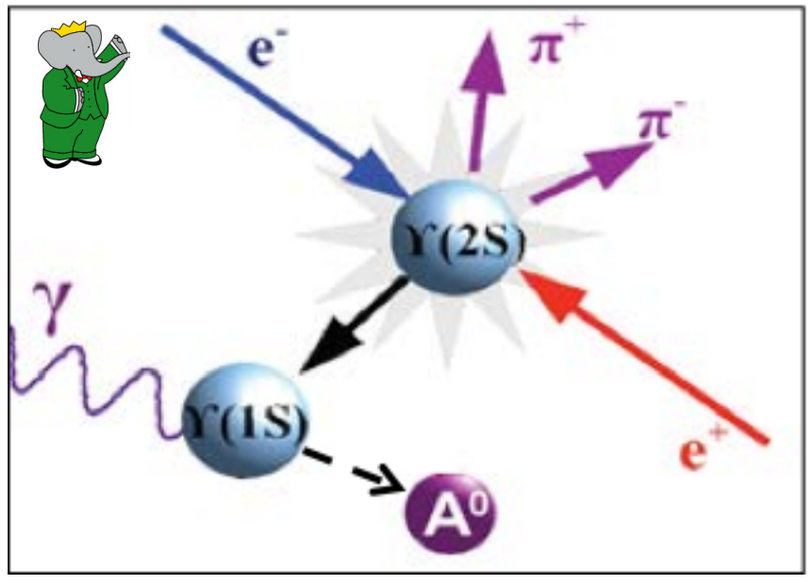


PRD 81, 075003 (2010)

Experimental technique

PRD 88, 031701 (2013)

- ✓ **Y(2S) data** sample: **~14 fb^{-1}** + off-resonance sample for continuum background studies
- ✓ Y(1S) is tagged from **dipion transitions of Y(2S) —> 2 charged tracks**
- ✓ **Y(1S)—>γA^0 —> a radiative photon (E*$_\gamma$>200MeV)**
- ✓ **A^0 fully reconstructed into a hadronic system** : exclusive reco in 26/14 final states for A^0—>gg/A^0—>s$\bar{s}$
  2-body decays excluded (A^0 is CP-odd and cannot decay into 2 pseudoscalar mesons)



#	Channel	#	Channel
1	$\pi^+\pi^-\pi^0$	14	$K^+K^-\pi^+\pi^-$
2	$\pi^+\pi^-2\pi^0$	15	$K^+K^-\pi^+\pi^-\pi^0$
3	$2\pi^+2\pi^-$	16	$K^\pm K^0_S\pi^\mp\pi^+\pi^-$
4	$2\pi^+2\pi^-\pi^0$	17	$K^+K^-\eta$
5	$\pi^+\pi^-\eta$	18	$K^+K^-2\pi^+2\pi^-$
6	$2\pi^+2\pi^-2\pi^0$	19	$K^\pm K^0_S\pi^\mp\pi^+\pi^-2\pi^0$
7	$3\pi^+3\pi^-$	20	$K^+K^-2\pi^+2\pi^-\pi^0$
8	$2\pi^+2\pi^-\eta$	21	$K^+K^-2\pi^+2\pi^-2\pi^0$
9	$3\pi^+3\pi^-2\pi^0$	22	$K^\pm K^0_S\pi^\mp2\pi^+2\pi^-\pi^0$
10	$4\pi^+4\pi^-$	23	$K^+K^-3\pi^+3\pi^-$
11	$K^+K^-\pi^0$	24	$2K^+2K^-$
12	$K^\pm K^0_S\pi^\mp$	25	$p\bar{p}\pi^0$
13	$K^+K^-2\pi^0$	26	$p\bar{p}\pi^+\pi^-$

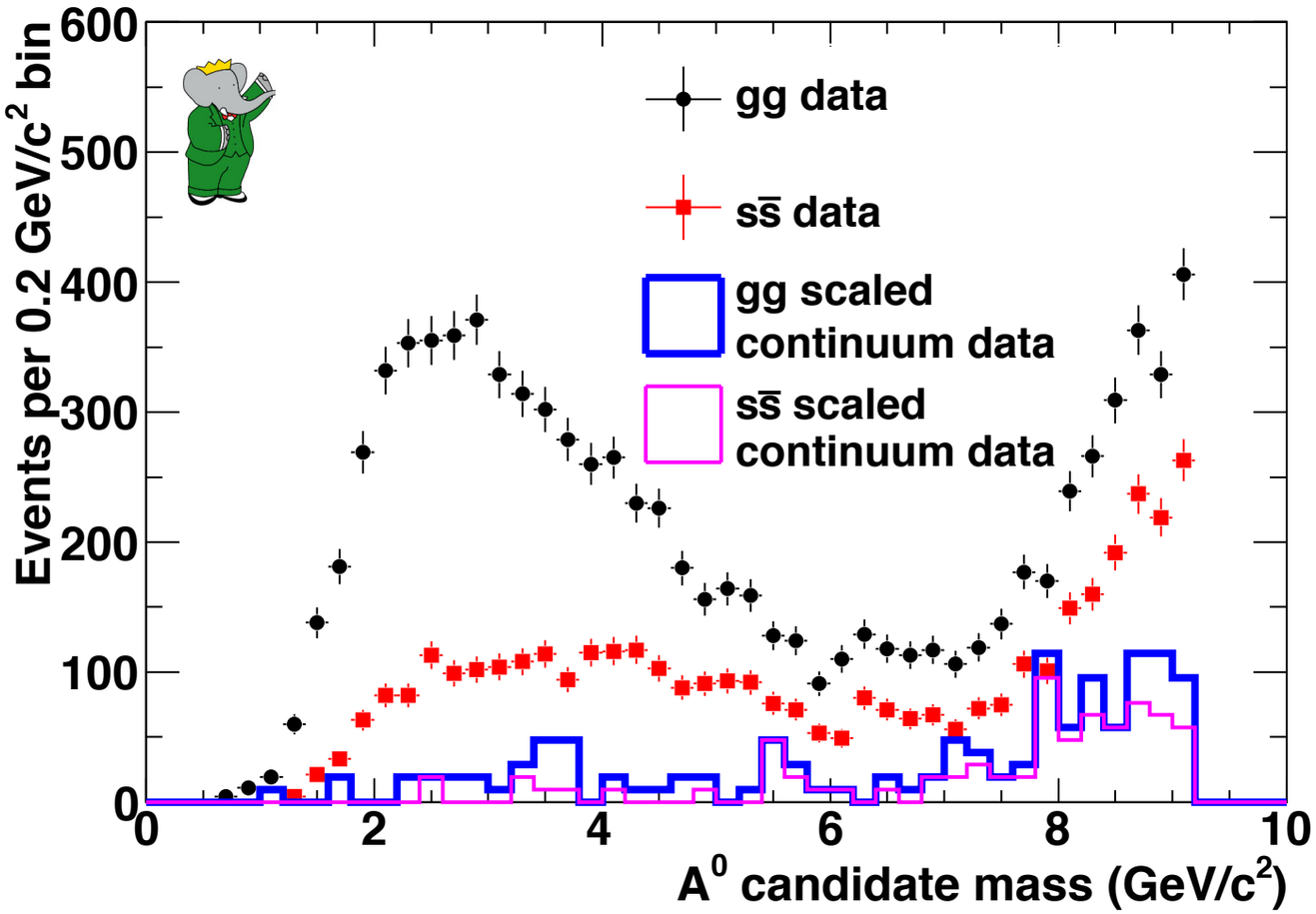
A^0—>gg

A^0—>gg and A^0—>s$\bar{s}$

- ✓ A^0 mass resolution improved (~100MeV/c^2) by constraining the A^0 candidate and γ to the Y(1S) mass
- ✓ Main backgrounds:
  - ✓ **Y(1S)—>γgg** with gluons hadronizing to more than one daughter (2-4 GeV/c^2 masses)
  - ✓ **Y(1S)—>ggg** with a π^0 mistaken as a γ (7-9 GeV/c^2 masses)
- ✓ Reliance on the **hadronization modeling** in simulations: the agreement data/MC is checked on Y(1S)—>γgg events
- ✓ scaling factors and a global **systematic uncertainty of 50%** are applied to the efficiencies

Results

- ✓ A^0 would appear as **a narrow peak in the candidate mass spectrum**
- ✓ Scan of the mass spectrum in 10 MeV/c^2 steps, **from 0.5 to 9.0 GeV/c^2**
- ✓ **No significant signal through the entire mass region analyzed**
- ✓ Minimum p-value 0.003 (@8.13GeV/c^2, ~2.7σ) for A^0—>gg, and 0.002 (@8.63GeV/c^2, ~2.9σ) for A^0—>s$\bar{s}$
- ✓ A significance as large as the observed one is obtained with a probability of 86% and 59%, assessed with toys MC
- ✓ Bayesian upper limits at 90% CL are set on the product of braching fractions



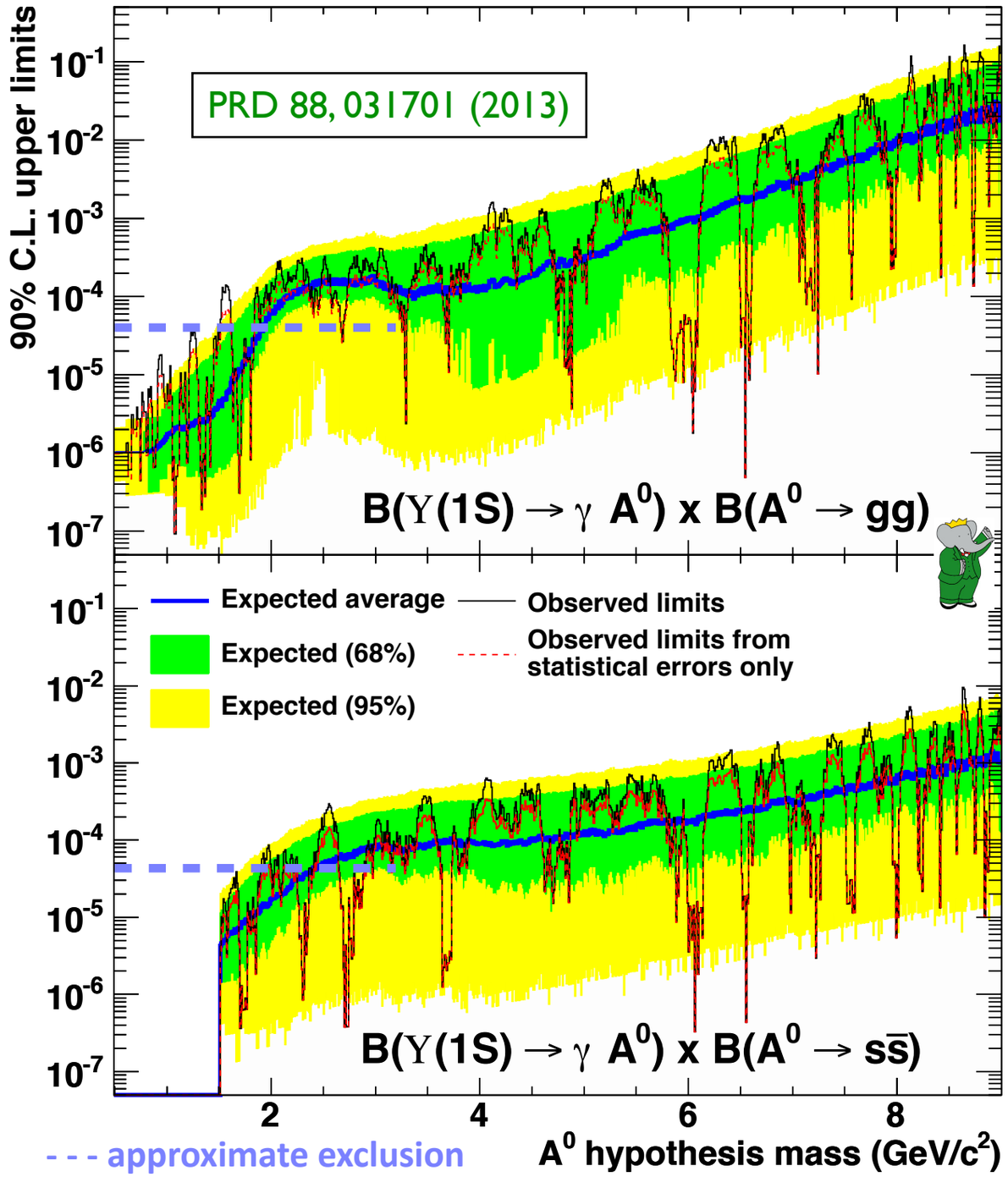
BR(Y(1S)—>γA^0)×BR(A^0—>gg) < 10^{-6} - 10^{-2} → **low-mass region excluded**

BR(Y(1S)—>γA^0)×BR(A^0—>s$\bar{s}$) < 10^{-5} - 10^{-3}

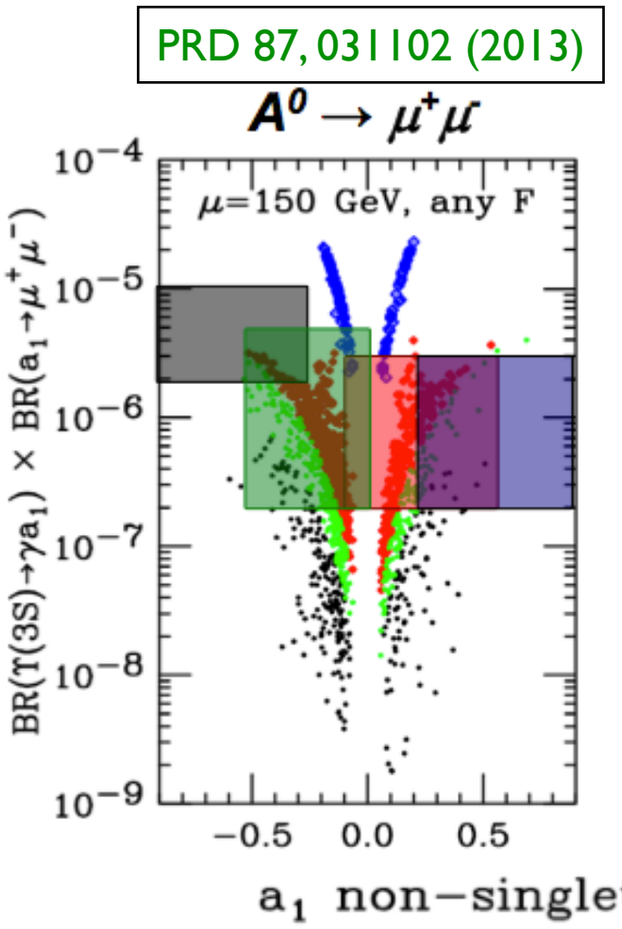
No evidence either for the A^0 signal or for any narrow hadronic resonance

Several searches at BABAR...

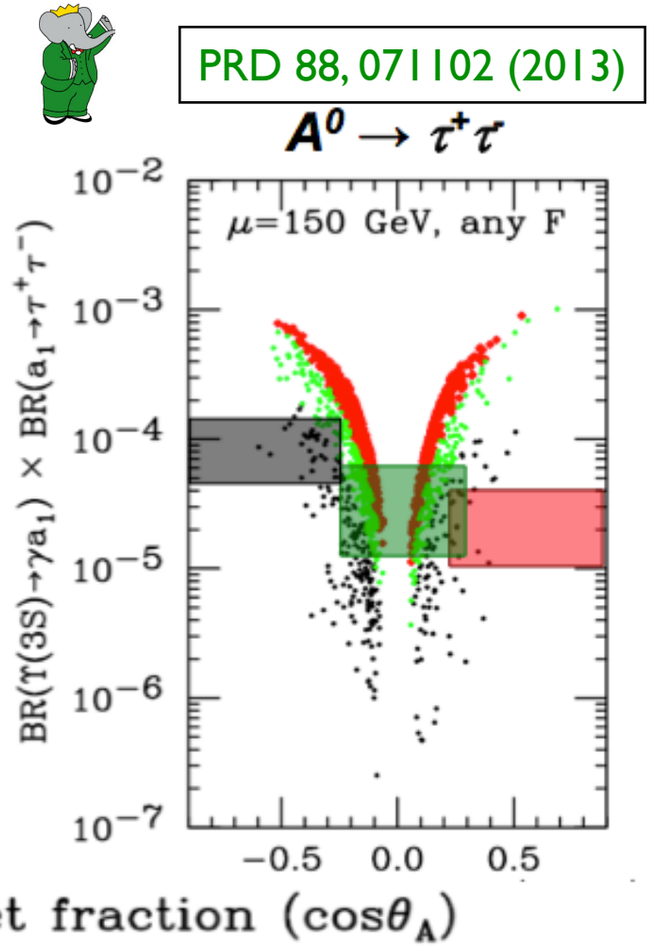
PRD 88, 031701 (2013)



PRD 87, 031102 (2013)



PRD 88, 071102 (2013)



Upper limits (90% CL)

$2m_\mu < m_{A0} < 2m_\tau$
$2m_\tau < m_{A0} < 7.5$ GeV
$7.5 < m_{A0} < 8.8$ GeV
$8.8 < m_{A0} < 9.2$ GeV

+ many others: see backup for a complete list of BaBar searches for A^0

Now in progress: $Y(2S) \to \pi^+\pi^- Y(1S)$, $Y(1S) \to \gamma A^0$, $A^0 \to \gamma\gamma$ and $A^0 \to c\bar{c}$

… no sign of A^0 found yet,

and the available parameter space is significantly reduced

Backup

The BABAR detector

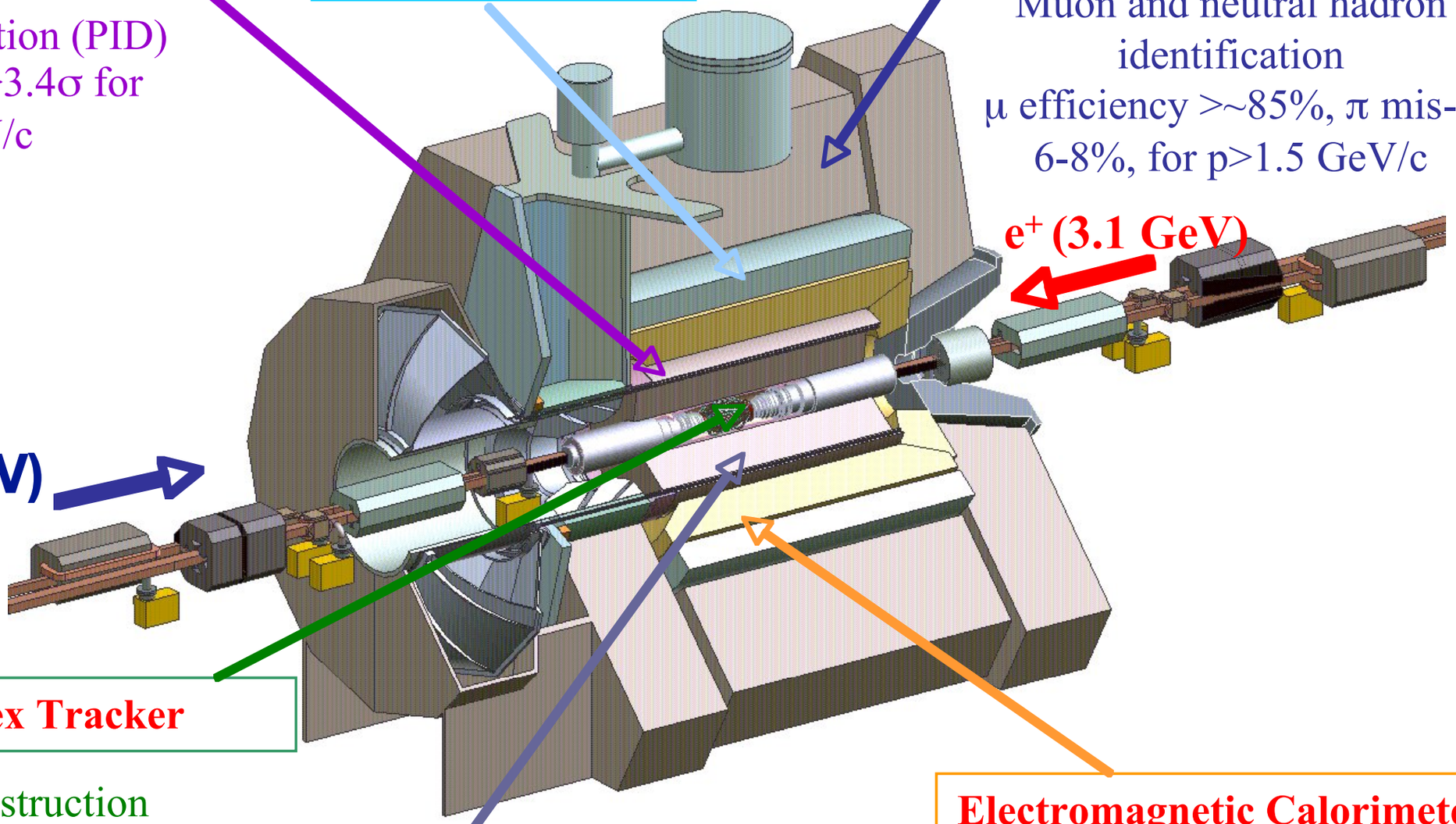
Cherenkov Detector

Particle identification (PID)
K-π separation >3.4σ for
p<3.5GeV/c

Solenoid 1.5T

Instrumented Flux Return

Muon and neutral hadron identification
μ efficiency >~85%, π mis-id 6-8%, for p>1.5 GeV/c



Silicon Vertex Tracker

Vertex reconstruction and tracking + dE/dx.
Efficiency ~ 97%

Drift Chamber

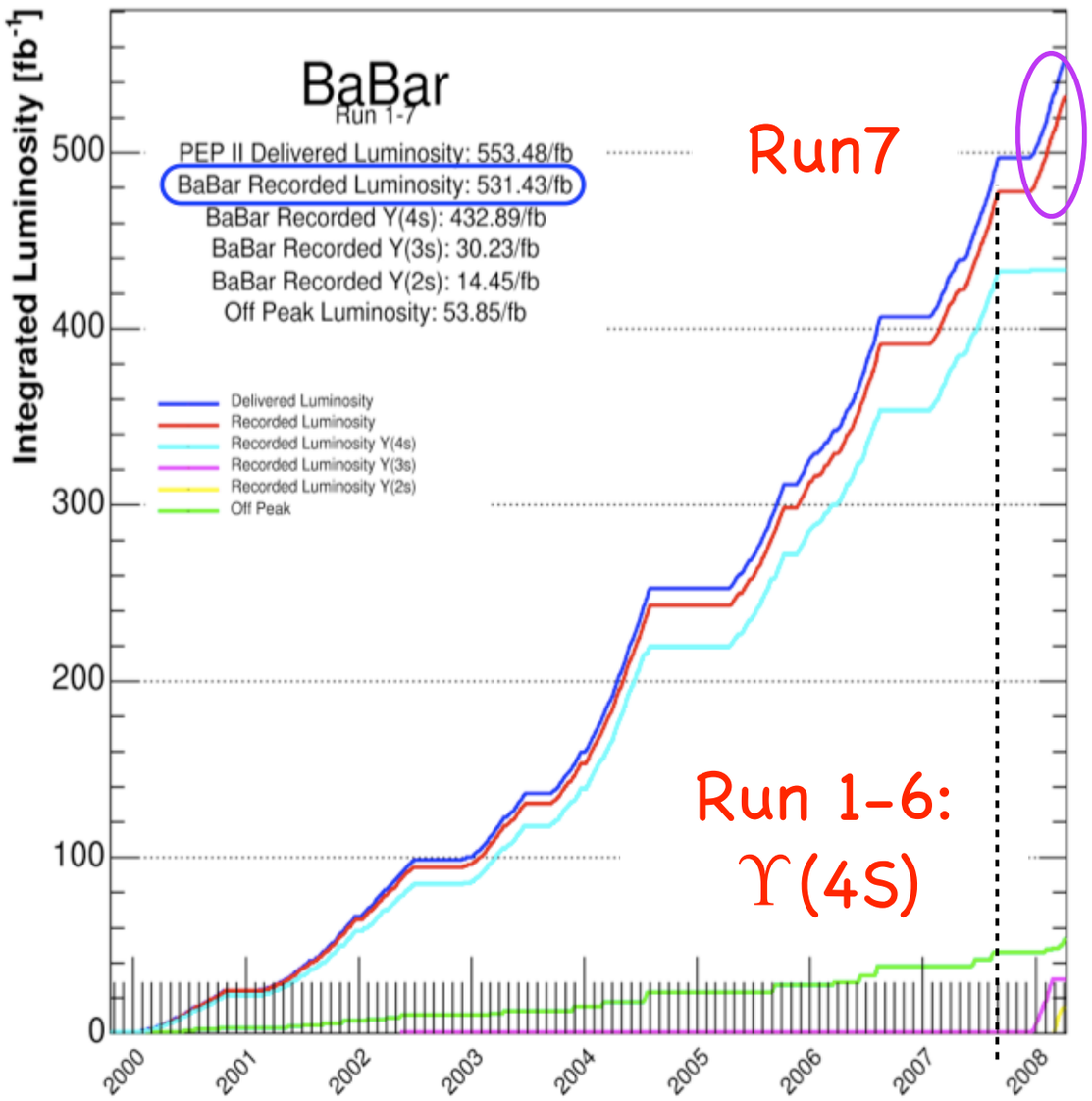
Momentum measurement for charged particles + dE/dx.
$\sigma(p_T)/p_T = 0.13\% p_T \oplus 0.45\%$

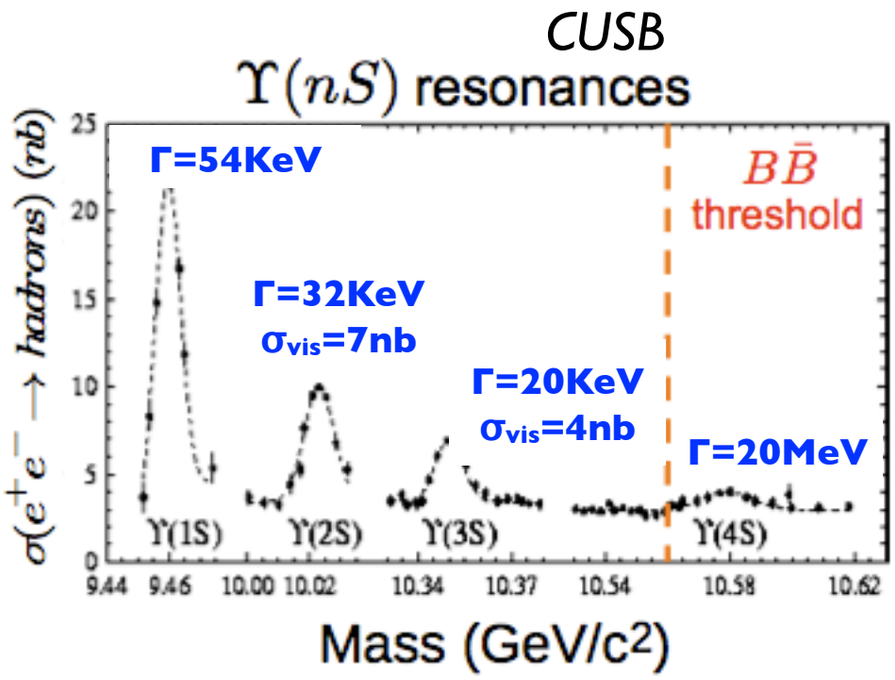
Electromagnetic Calorimeter

Electron and photon energy measurement. σ
$(E)/E = 1.33\% E^{-1/4} \oplus 2.1\%$

BaBar data samples

- ✓ PEP-II asymmetric energy e^+e^--collider operating at the Υ resonances
- ✓ BABAR recorded luminosity





- ✓ 28.5 fb^{-1} of data at $\Upsilon(3S)$

  → ~$122 \cdot 10^6$ $\Upsilon(3S)$

- ✓ 14.4 fb^{-1} of data at $\Upsilon(2S)$

  → ~$99 \cdot 10^6$ $\Upsilon(2S)$

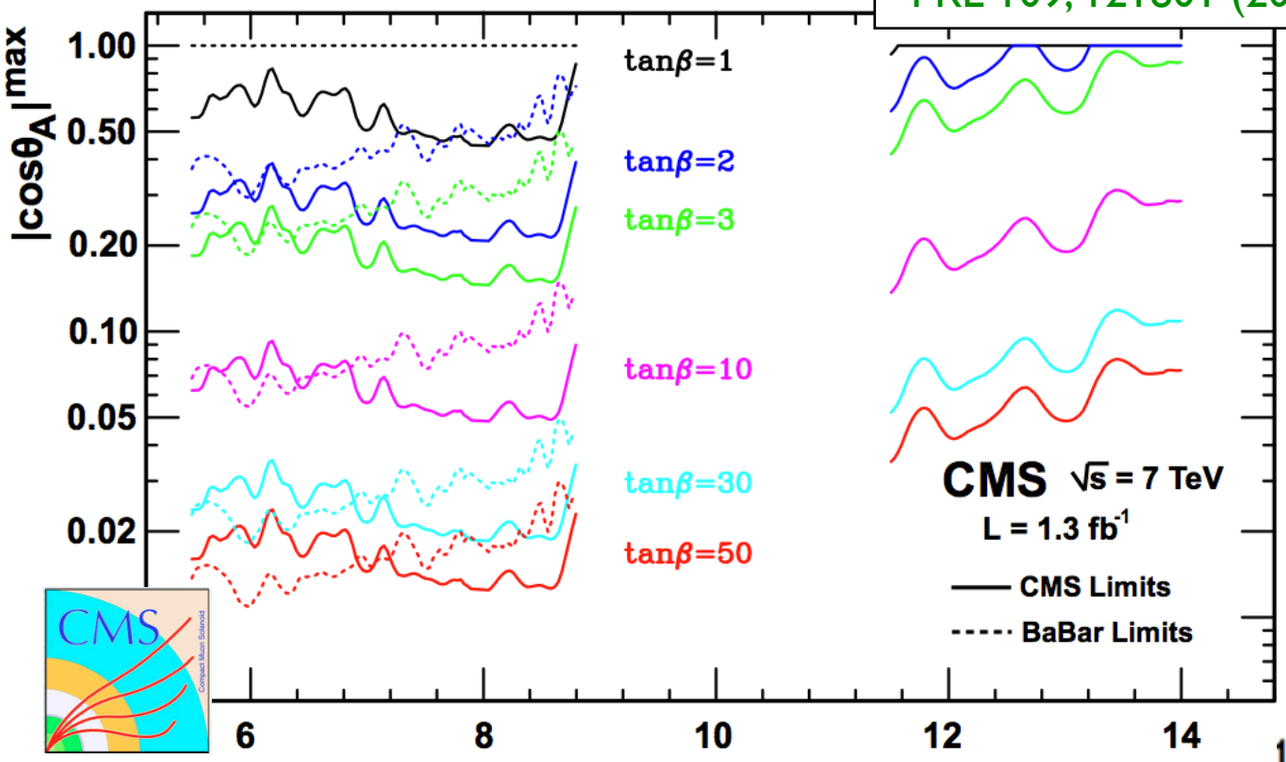
BaBar searches for A^0

- ✓ radiative Y(2S,3S) decays
- ✓ radiative Y(1S) decays tagged through Y(2S,3S) dipion transitions to Y(1S)

- ✓ $Y(2S,3S) \to \gamma A^0$, $A^0 \to \mu^+\mu^-$ Phys. Rev. Lett. 103 (2009) 081803
- ✓ $Y(2S,3S) \to \gamma A^0$, $A^0 \to \tau^+\tau^-$ Phys. Rev. Lett. 103 (2009) 181801
- ✓ Test of lepton universality in Y decays Phys. Rev. Lett. 104 (2010) 191801
- ✓ $Y(2S,3S) \to \gamma A^0$, $A^0 \to$ hadrons Phys. Rev. Lett. 107 (2011) 221803
- ✓ $Y(1S) \to \gamma A^0$, $A^0 \to$ invisible Phys. Rev. Lett. 107 (2011) 021804
- ✓ $Y(2S,3S) \to \gamma A^0$, $A^0 \to$ hadrons Phys. Rev. Lett. 107 (2011) 221803
- ✓ $Y(1S) \to \gamma A^0$, $A^0 \to \mu^+\mu^-$ Phys. Rev. D 87 (2013) 031102
- ✓ $Y(1S) \to \gamma A^0$, $A^0 \to \tau^+\tau^-$ Phys. Rev. D 88 (2013) 071102
- ✓ $Y(1S) \to \gamma A^0$, $A^0 \to gg, s\bar{s}$ Phys. Rev. D 88 (2013) 031701
- ✓ $Y(2S,3S) \to \gamma A^0$, $A^0 \to$ invisible arXiv:0808.0017 + new analysis in progress

Searches for A^0 at the LHC

PRL 109, 121801 (2012)



ATLAS-CONF-2011-020