



# BABAR

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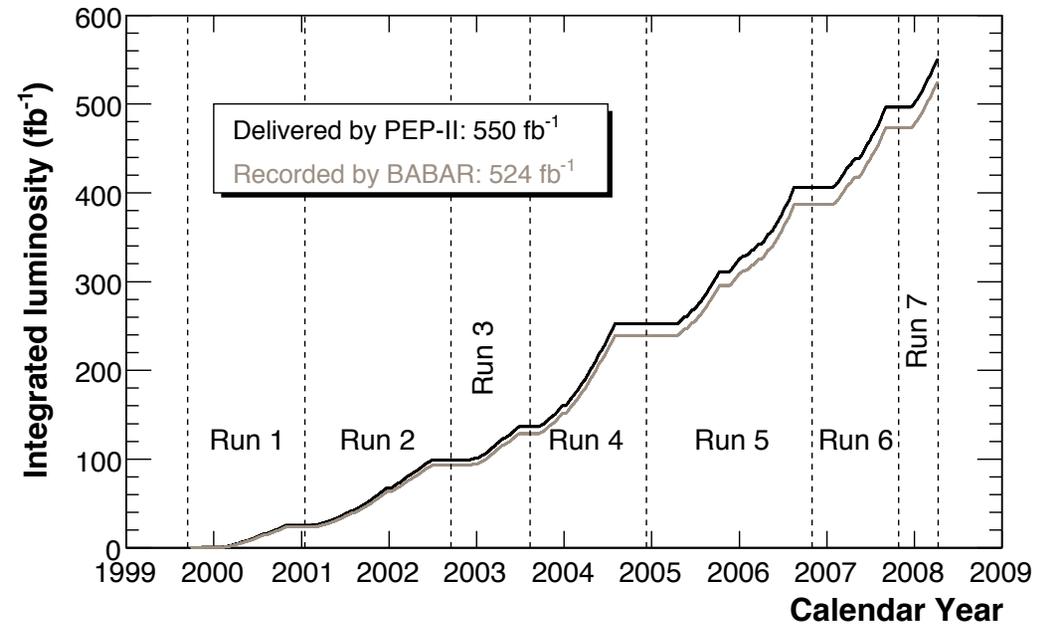
Christopher Hearty  
U. British Columbia / IPP  
June 15, 2014

# Overview

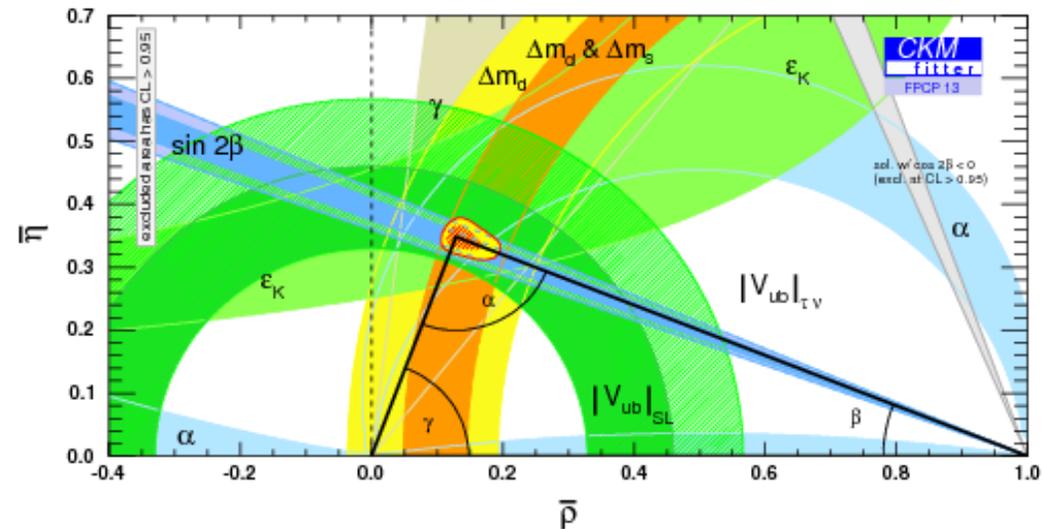
- Collected data at SLAC from 1999–2008 at the PEP-II collider, 9 GeV  $e^-$  on 3.1 GeV  $e^+$ .

$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$$

- Primary motivation: CP violation, weak force (Unitarity Triangle)
- Rare decays, tau and charm, spectroscopy, direct searches for new physics.



471M  $\Upsilon(4S)$ , 121M  $\Upsilon(3S)$ , 98M  $\Upsilon(2S)$   
10% off resonance



# 2008 Nobel prize in physics



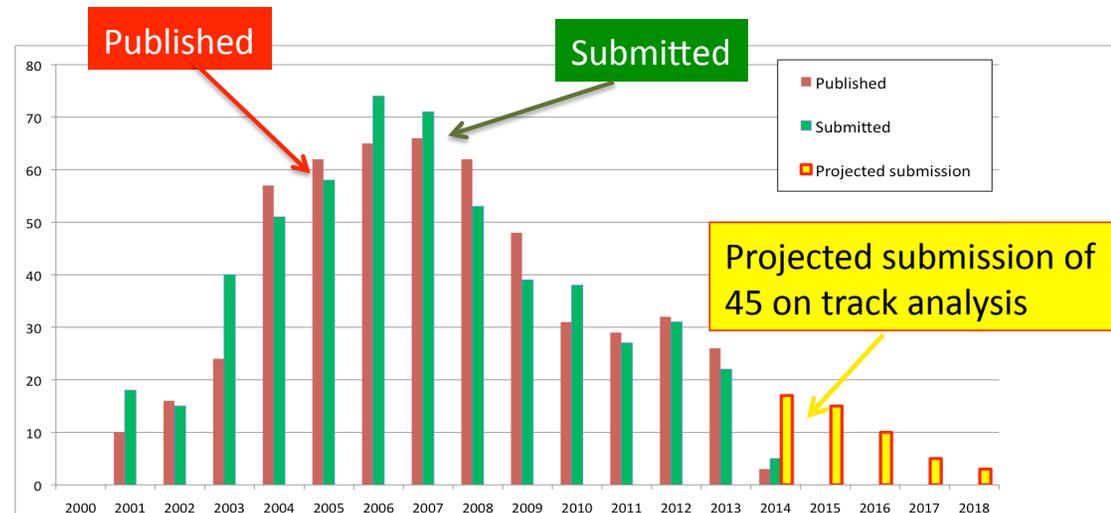
Kobayashi and Maskawa  
awarded 1/2 of the prize

“for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature”

“As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier.”

# Status

- Focus since 2008 has been on analysis. Support from SLAC through 2018.
- recent highlights on following slides
- BaBar continues to be well represented at conferences. 130 talks in 2013; 9 at ICHEP.
- New BaBar detector paper.
- Physics of the B-Factories book, in collaboration with Belle, about to be submitted to publisher.



532 papers published; 22 submitted in 2013



## The *BABAR* detector: Upgrades, operation and performance

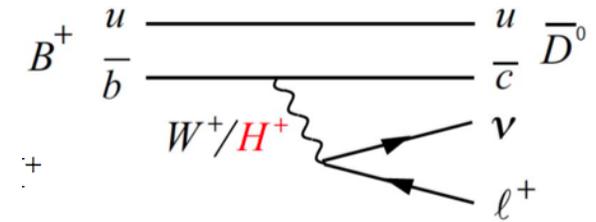
B. Aubert<sup>a</sup>, R. Barate<sup>a</sup>, D. Boutigny<sup>a</sup>, F. Couderc<sup>a</sup>, P. del Amo Sanchez<sup>a</sup>, J.-M. Gaillard<sup>a</sup>, A. Hicheur<sup>a</sup>, Y. Karyotakis<sup>a</sup>, J.P. Lees<sup>a</sup>, V. Poireau<sup>a</sup>, X. Prudent<sup>a</sup>, P. Robbe<sup>a</sup>, V. Tisserand<sup>a</sup>, A. Zghiche<sup>a</sup>, E. Grauges<sup>b</sup>, J. Garra Tico<sup>b</sup>, L. Lopez<sup>c,d</sup>, M. Martinelli<sup>c,d</sup>, A. Palano<sup>c,d</sup>, M. Pappagallo<sup>c,d</sup>, A. Pompili<sup>c,d</sup>, G.P. Chen<sup>e</sup>, J.C. Chen<sup>e</sup>, N.D. Qi<sup>e</sup>, G. Rong<sup>e</sup>, P. Wang<sup>e</sup>, Y.S. Zhu<sup>e</sup>, G. Eigen<sup>f</sup>, B. Stugu<sup>f</sup>, L. Sun<sup>f</sup>, G.S. Abrams<sup>g</sup>, M. Battaglia<sup>g</sup>, A.W. Borgland<sup>g</sup>,



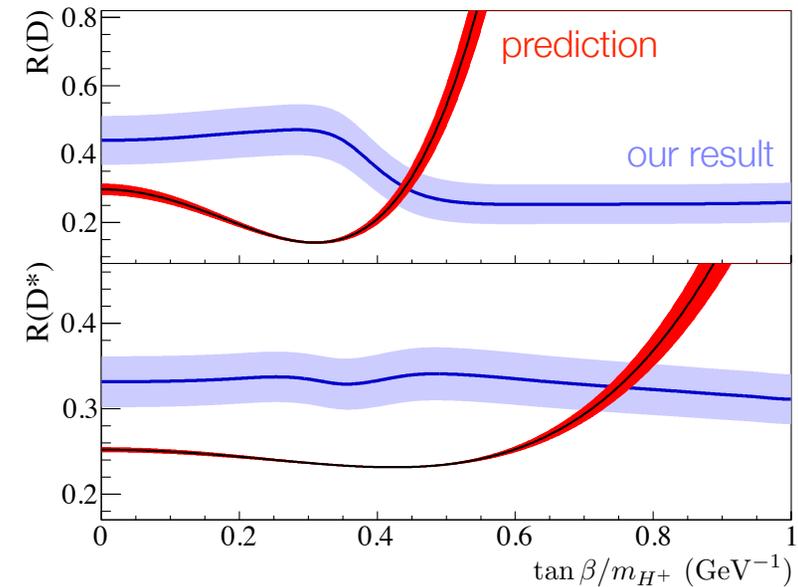
# $B \rightarrow D^{(*)} \tau \nu_\tau$ branching fraction

Phys. Rev. Lett 109, 101802 (2012)

- $B \rightarrow D^{(*)} \tau \nu_\tau$  is sensitive to a charged Higgs. Ratio to  $e/\mu$  final state reduces uncertainties.
- Result is inconsistent with the SM at  $3.4\sigma$ . Belle is similar.
- Also inconsistent with popular type-II 2HD model.



$H^+$  has negligible impact on  $e$  or  $\mu$  final states

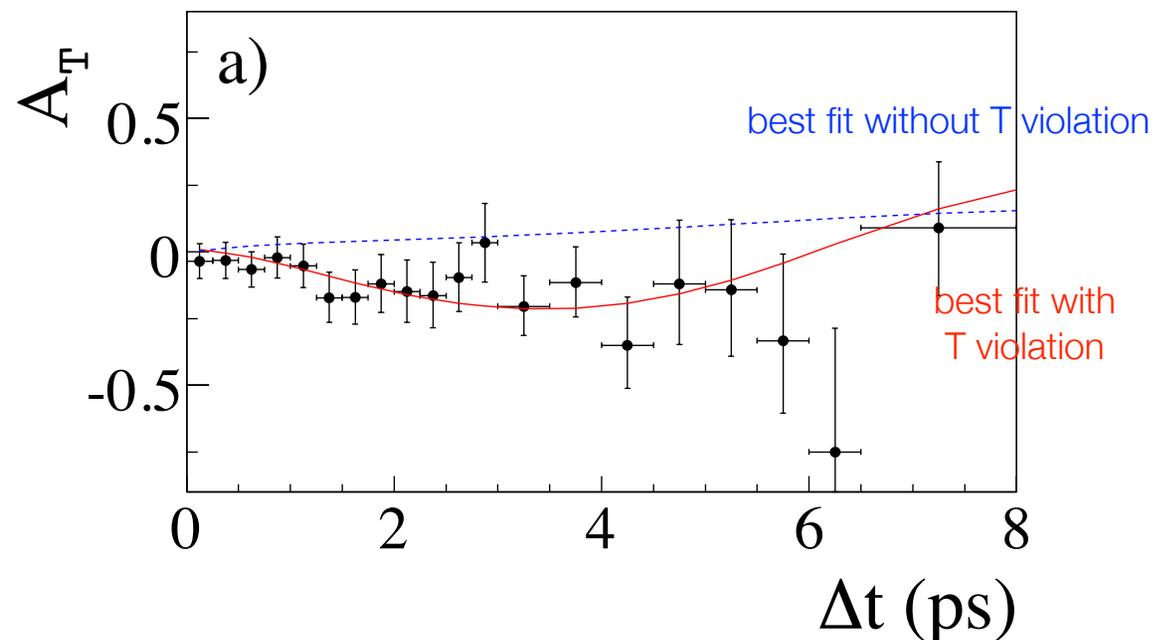


# Observation of Time-Reversal Violation in the $B^0$ Meson System

Phys. Rev. Lett. 109, 211801 (2012)

- Same event sample as CP violation (one B is tagged as  $B^0$  or  $\bar{B}^0$ ; other is CP even or CP odd), but include time-ordering of the two B decays to directly demonstrate T violation independent of CP violation for the first time.

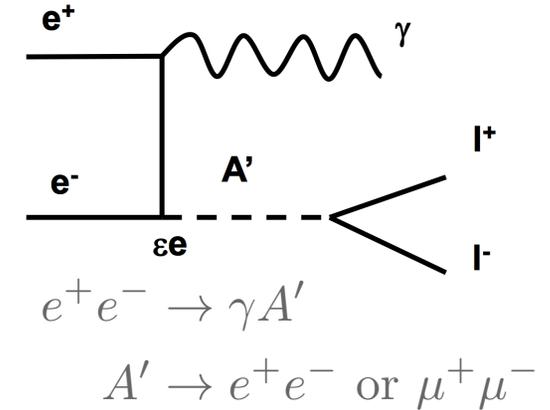
Asymmetry between  
 $\bar{B}^0 \rightarrow \text{CP-odd}$  and  
 $\text{CP-odd} \rightarrow \bar{B}^0$



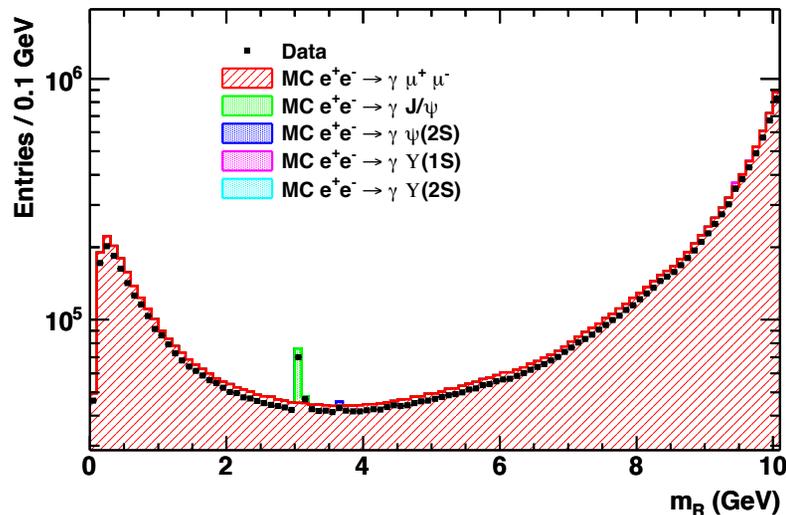
# Search for a dark photon

arXiv:1406.2980 [hep-ex]

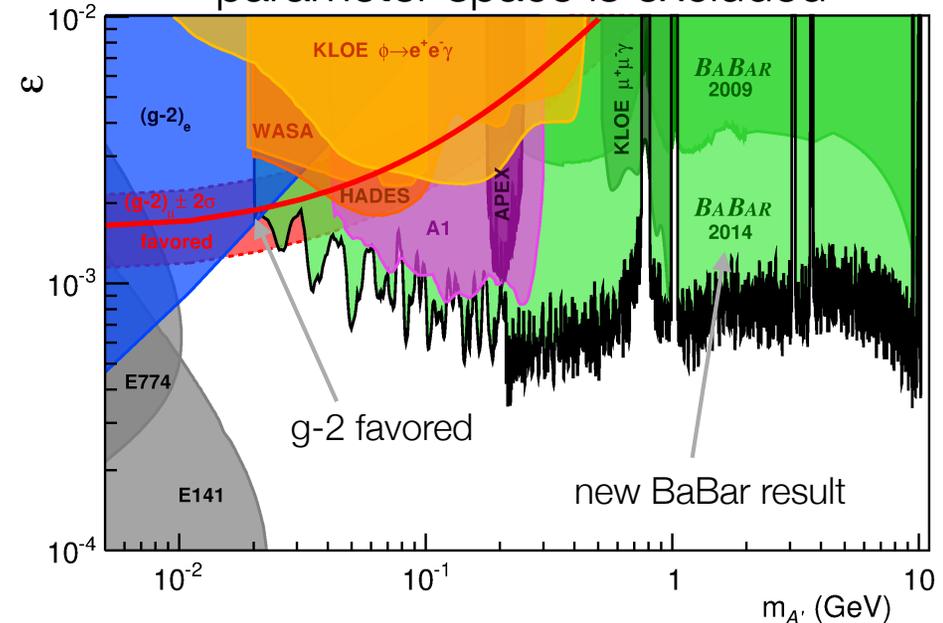
- Dark sector contains TeV-scale WIMPs, which can annihilate into SM fermions via dark photon  $A'$ .
- $A'$  couples to SM with strength  $\varepsilon$ .



Invariant mass distribution of  $\mu^+\mu^-$  final state



Most of the  $g-2$  favored parameter space is excluded



# Canadian grant holders

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- UBC: Chris Hearty, Janis McKenna, Tom Mattison
- Victoria: Justin Albert, Bob Kowalewski, Mike Roney
- McGill: Steve Robertson
- Total of 2 FTE. Peak was 10 faculty and 7 FTE.
- Montreal is no longer on the grant as of March 2013.

# Graduate students, postdoc

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Rocky So	PhD	UBC	Search for light Higgs
Greg King	PhD	Victoria	Lepton universality
Nafisa Tasneem	PhD	Victoria	Muon pair FB asymmetry
Alex Beaulieu	PhD	Victoria	Search for $\pi$
Thomas Lueck	RA	Victoria	$ V_{cb} , B \rightarrow D^{**} \ell \nu$
Robert Seddon	MSc	McGill	$B^- \rightarrow \Lambda \bar{p} \nu \bar{\nu}$
Racha Cheaib	PhD	McGill	$B \rightarrow K \tau^+ \tau^-$

- only Nafisa and Greg are on the BaBar project grant.
- 14 PhD and 25 MSc graduated.

# Canadian leadership

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- Canadians have had a big role in the leadership of the experiment:
  - Mike Roney is spokesperson
  - Hearty, Roney, and Robertson were the physics analysis coordinator
  - Kowalewski, Robertson, Hearty, Roney, and Sobie were analysis working group conveners.
  - Hearty, McKenna, and Roney were run coordinators.

# Canadian analysis

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- 35 papers have had primary Canadian analysts/authors
- Includes flagship measurements such as  $|V_{ub}|$ ,  $\tau^+ \rightarrow \mu^+ \gamma$ , and  $B \rightarrow K \nu \bar{\nu}$ .
- Also rare and forbidden decays, tau physics, charmonium, light Higgs searches

# Outlook

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- Project grant funding will end March 2015.
- Remaining students will be supported by the Belle II grant or possibly a discovery grant.
- Anticipate 7 more Canadian papers. Additional topics remain, but probably no analysts.