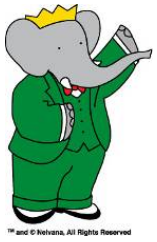
BaBar Status & Plans

Hassan Jawahery, spokesperson
University of Maryland

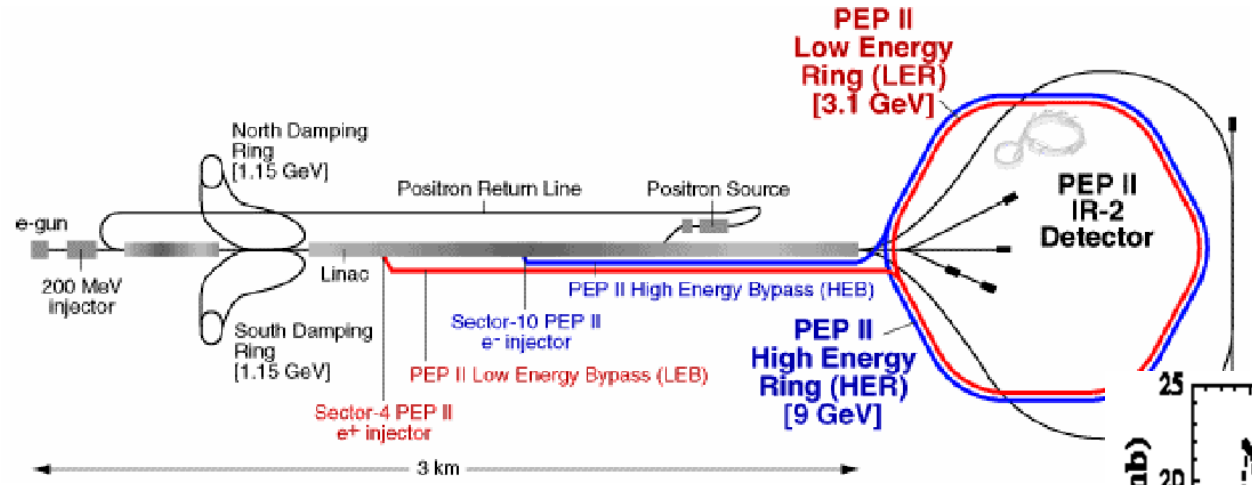
HEPAP meeting
February 15, 2008

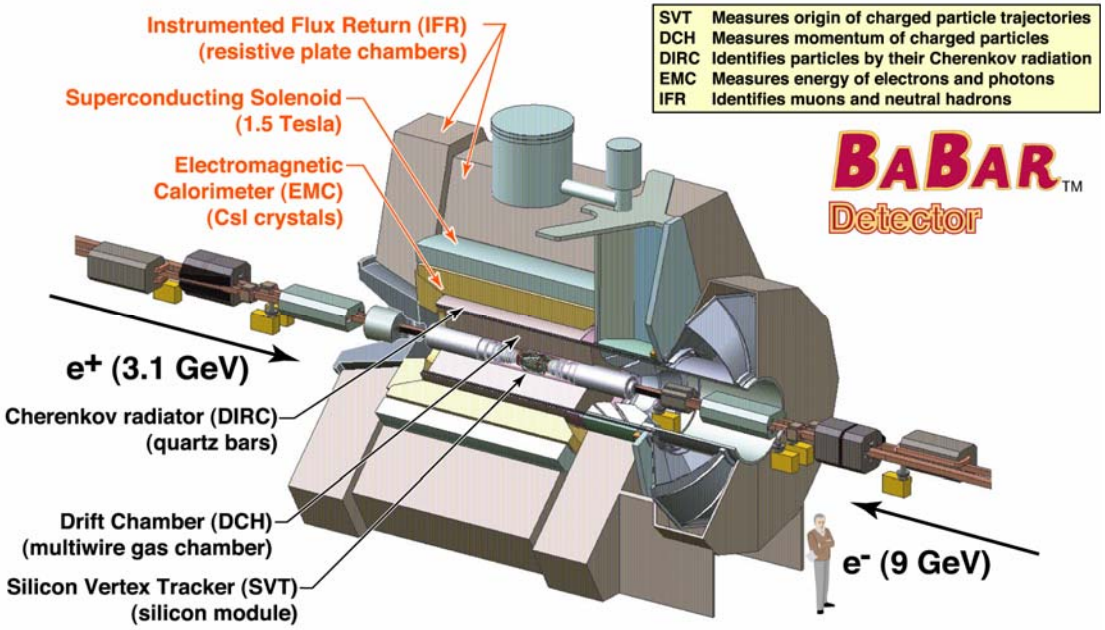


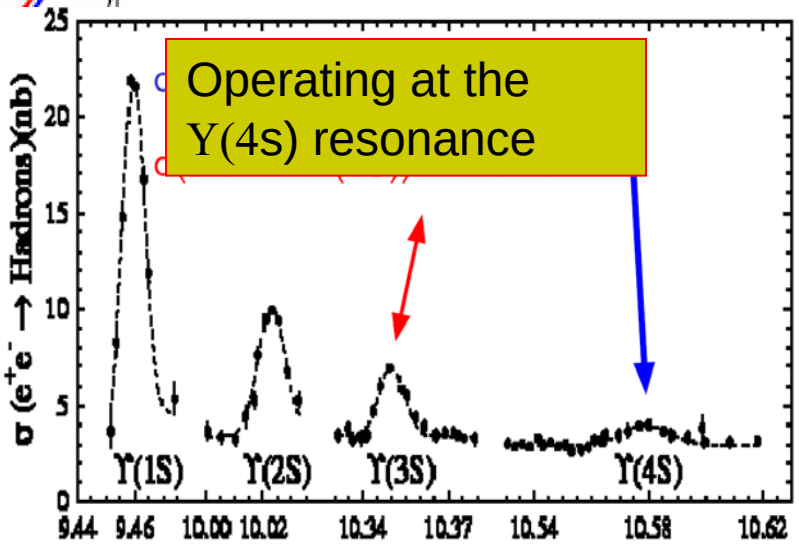
Outline

- Status of the experiment
  - PEPII & BaBar
  - The collaboration status
  - **Status & Evolution of BaBar's final Run**
- BaBar Data & its Physics Impact
- The plan for the physics analysis phase of the experiment

The setup of the experiment:







Operating at the Υ(4s) resonance

$$\Upsilon(4S) \rightarrow B\overline{B}$$

Principal Science Mission of the B factory

- Investigation of CP violation in B meson Decays & tests of the CKM paradigm
  - ✓**Is the CP symmetry broken in B decays?**
  - ✓**Can we fit the CPV effects in the CKM picture?**
  - ❑Is there room for New Physics?

- Search for New Physics in rare (SM suppressed-FCNC) decays ?

- B Decay dynamics: Tests of QCD predictions

November 2007: PEP-II Parameter Goals

From John Seeman

Parameter	Units	Design	Present best	2008 goal
I+	mA	2140	3026	4000
I-	mA	750	1977	2200
Number bunches		1658	1732	1740
β_y*	mm	15-20	10	8-8.5
Bunch length	mm	15	11-12	8.5-9
ξ_y		0.03	0.05-0.07	0.054-0.075
Luminosity	$x10^{33}$	3	12	20
Int lumi / day	pb^{-1}	130	911	1300

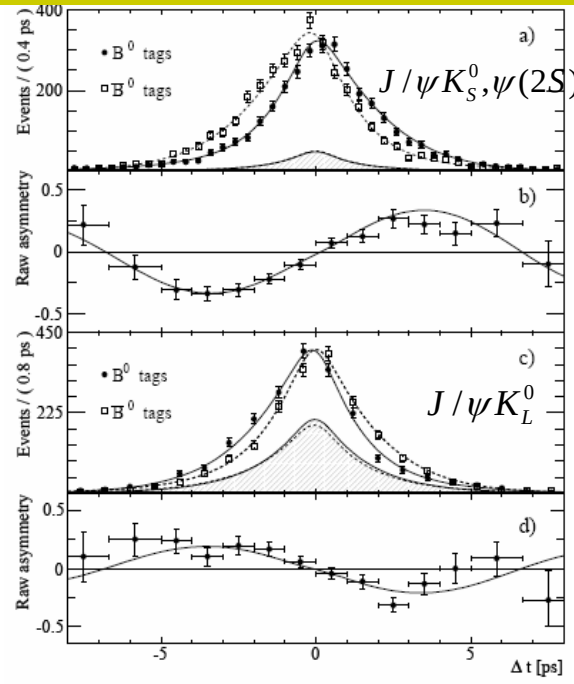
Total: 523/fb

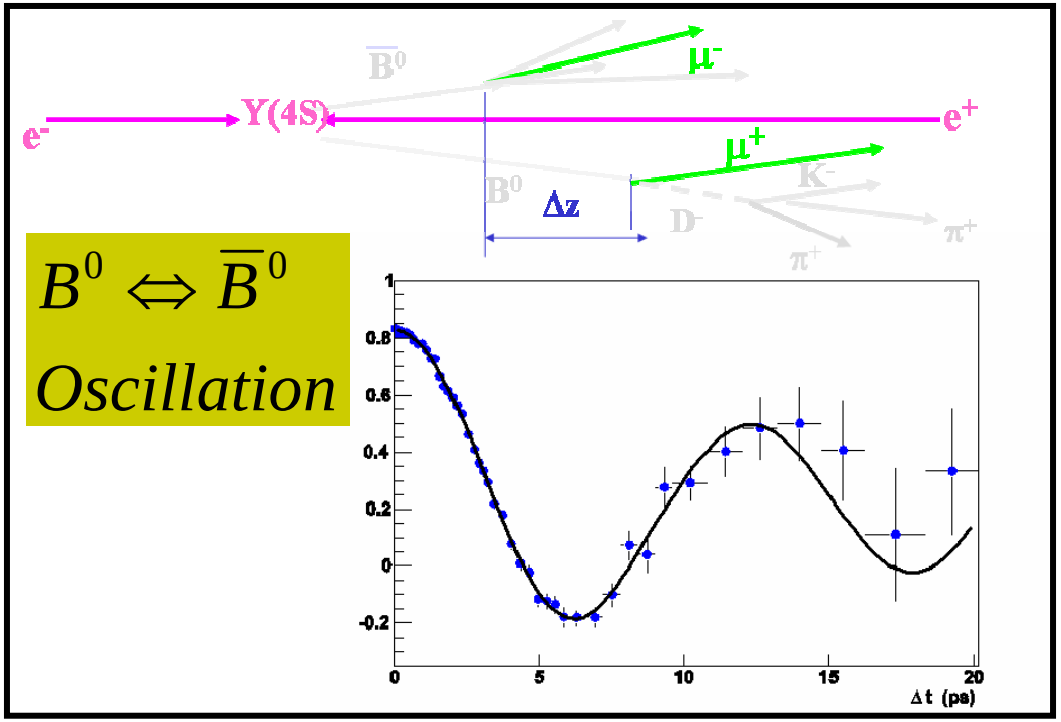
4 times design

7 times design

A few indicators of BaBar's performance & precision

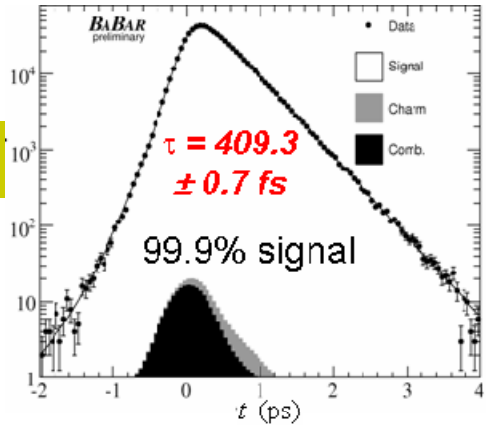
CP Asymmetry (sin2β)





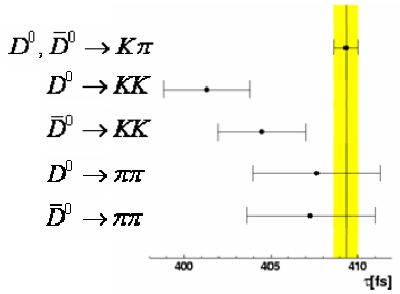
D⁰ mixing

$D^0 \to K^-\pi^+$ + c.c.



D⁰ lifetimes

$K\pi$ and KK lifetimes differ at ~1%



$$a_{CP}^{KK} = (\ 0.00 \pm 0.34\ (\text{stat.}) \pm 0.13\ (\text{syst.}))\%$$
$$a_{CP}^{\pi\pi} = (-0.24 \pm 0.52\ (\text{stat.}) \pm 0.22\ (\text{syst.}))\%$$

The *BABAR* Collaboration

10 Countries
74 Institutions
459 Physicists

USA [32/223]

California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, Riverside
UC, Santa Barbara
UC, Santa Cruz
U of Cincinnati
U of Colorado
Colorado State
Harvard U
U of Iowa
Iowa State U
Johns Hopkins U
LBNL
LLNL
U of Louisville
U of Maryland
U of Massachusetts, Amherst
MIT
U of Mississippi
SUNY, Albany
U of Notre Dame
Ohio State U
U of Oregon
Princeton U
SLAC
U of South Carolina
Stanford U
U of Tennessee
U of Texas at Austin
U of Texas at Dallas
U of Wisconsin

Canada [4/19]

University of British Columbia
McGill University
University de Montréal
University of Victoria

France [5/41]

LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris VI et VII
Ecole Polytechnique, Laboratoire Leprince-Ringuet
CEA, DAPNIA, CE-Saclay

Germany [6/28]

Ruhr Universitaet Bochum
Universitaet Dortmund
Technische Univeritaet Dresden
Universitaet Heidelberg
Universitaet Rostock
Universitaet Karlsruhe

Italy [12/83]

INFN, Bari
INFN, Ferrara
Lab. Nazionali di Frascati dell' INFN
INFN, Genova & Univ
INFN, Milano & Univ
INFN, Napoli & Univ
INFN, Padova & Univ
INFN, Pisa & Univ & Scuola Normale Superiore
INFN, Perugia & Univ
INFN, Roma & Univ "La Sapienza"
INFN, Torino & Univ
INFN, Trieste & Univ

The Netherlands [1/2]

NIKHEF, Amsterdam

Norway [1/3]

U of Bergen

Russia [1/11]

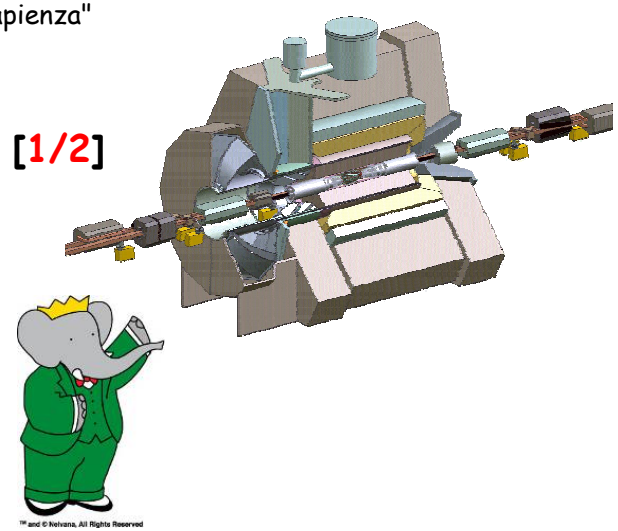
Budker Institute, Novosibirsk

Spain [2/7]

IFAE-Barcelona
IFIC-Valencia

United Kingdom [10/43]

U of Birmingham
Brunel U
U of Edinburgh
U of Liverpool
Imperial College
Queen Mary , U of London
U of London, Royal Holloway
U of Manchester
Rutherford Appleton Laboratory
U of Warwick

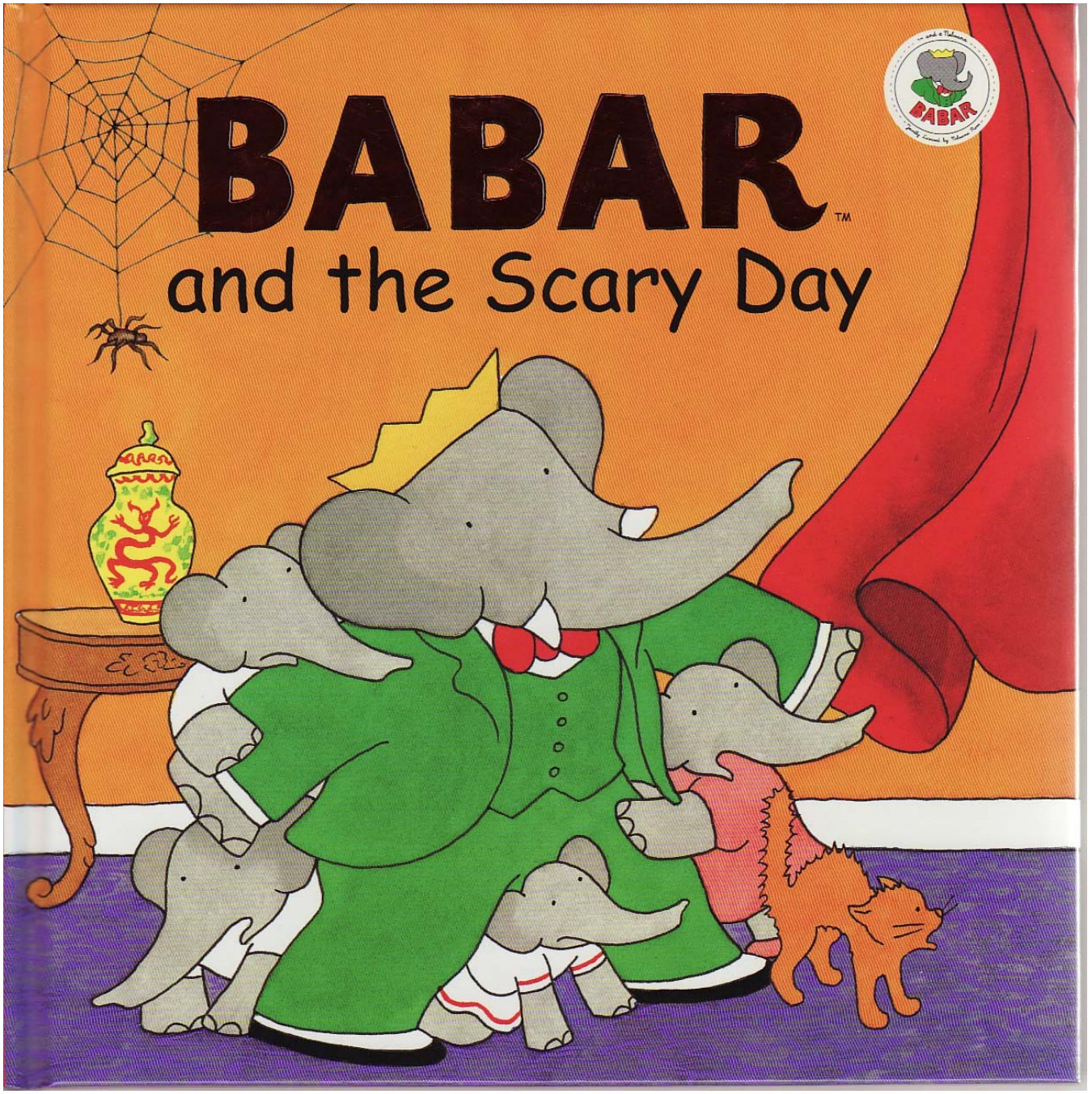


The BaBar Collaboration

74 Institutions in 10 countries

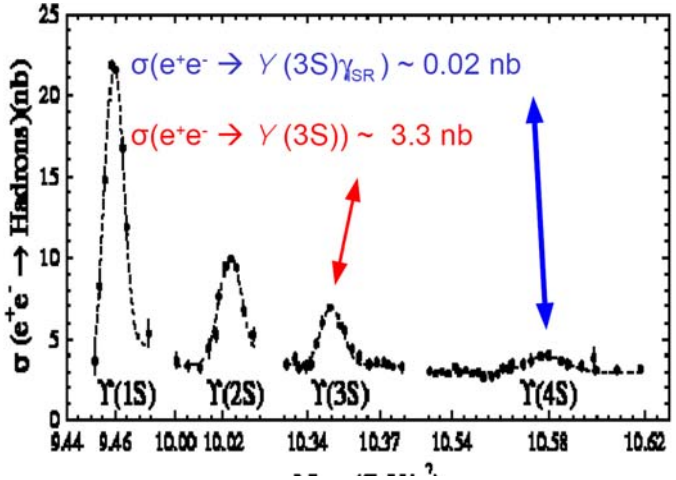
	Faculty	PhD Staff	Postdoc	Grad	Non-PhD	Totals
Canada	10		2	7		19
France	14	12	3	12	4	45
Germany	7	4	1	15		27
Italy	27	28	15	14		84
Netherlands	1			1		2
Norway	2			1		3
Russia	2	6		2	1	11
Spain		3	2	3		8
United Kingdom	18	1	12	12	1	44
United States	72	47	40	64	19	242
Totals	**153**	**101**	**75**	**131**	**25**	**485**

With more than 200 students and postdocs the collaboration continues to be on a very strong foundation.


BABAR™
and the Scary Day
BABAR

Status & Evolution of BaBar's Final Run

- Run 6 concluded on September 3rd, 2007, followed by a 3-month downtime: Sept. 3- Dec 4th, 2007
  - Significant work on PEPII to prepare for higher beam currents & the luminosity regime of 2×10^{34} /cm2/s.
  - Expectation for this run: 250/fb (50% increase in total data) - nearly a 3-fold increase in the data with fully upgraded muon ID.
- Start of Run 7:
  - stored beams in PEPII Dec. 9th
  - Budget news on Dec. 17 - Switched to $\Upsilon(3S)$ running on Dec. 21.
  - Received a 2-month extension of the run- in response to the physics case of the run- & another month on 2S- till April 6, 2008



Aiming for: ~30/fb on $\Upsilon(3S)$

~20/fb on $\Upsilon(2S)$

➔10^8 3S & 1.4×10^8 2S

Current data:

CLEO: 9M 2S & 6 M 3S : Belle: 11 M 3S

The Physics Reach of the data at Upsilon Resonances

•Sensitivity to New Physics effects:

➢ **Invisible width of Υ(1S):**

Standard Model: $Br(\Upsilon(1S) \to \nu\bar{\nu}) \approx 10^{-5}$

$$\Upsilon(3S) \to \pi\pi\Upsilon(1S)$$
$$\Upsilon(1S) \to x\bar{x}$$

Significant enhancement possible due to coupling to:

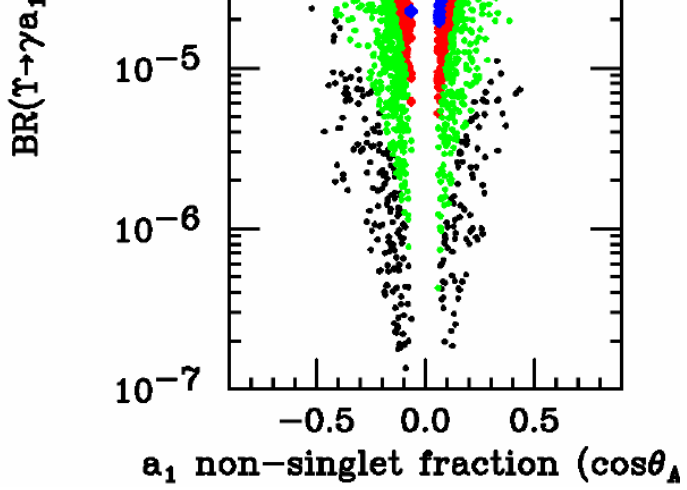
➢ light dark matter (such as motivated by the INTEGRAL anomaly)

➢ exotic light higgs(e.g. CP-odd higgs in NMSSM)

Related channels

$$\Upsilon(nS) \to \gamma a_1 (a_1 \to x\bar{x})$$

$$\Upsilon(nS) \to \gamma a_1 (a_1 \to \tau^+\tau^-)$$



•Lepton Universality:

$$\Upsilon(nS) \to \tau^+\tau^- / \Upsilon(nS) \to \mu^+\mu^- / \Upsilon(nS) \to e^+e^-$$

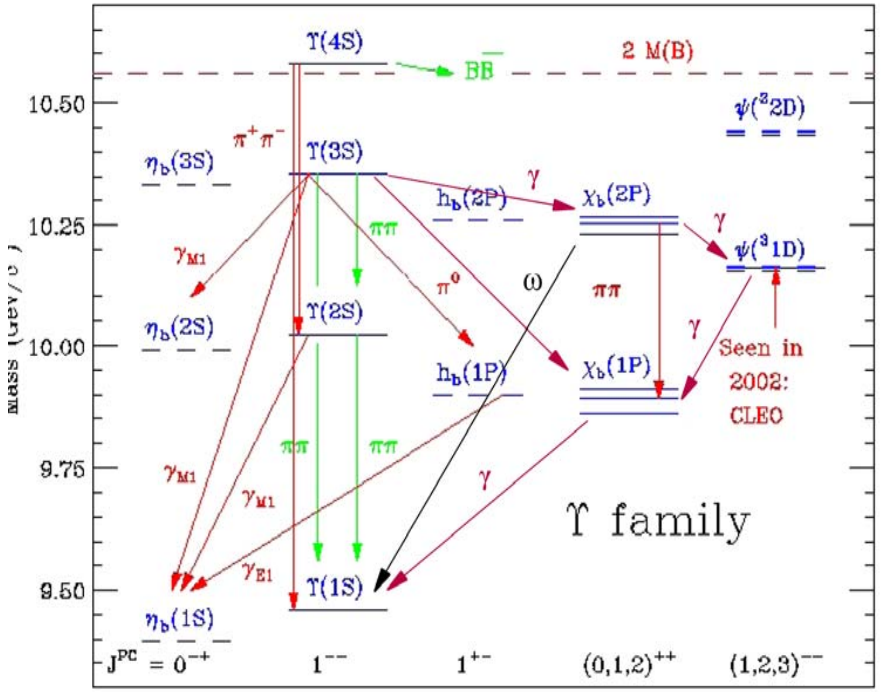
Search Channel	Theoretical Range	Existing Result *Experiment (Sample)*	*BABAR* Sensitivity ($30\,\text{fb}^{-1}$)
Low-mass Higgs boson			
$\Upsilon(nS) \to \gamma a_1$ $a_1 \to \tau^+\tau^-$	Up to 5×10^{-4} (NMSSM)		$(3\text{–}5) \times 10^{-5}$
$\Upsilon(nS) \to \gamma a_1$ $a_1 \to \mu^+\mu^-$			$< 10^{-5}$ or better
$\Upsilon(nS) \to \gamma a_1$ $a_1 \to invisible$		$< 3 \times 10^{-5}$ ($m_\chi < 7.2\,\text{GeV}/c^2$) CLEO (960k $\Upsilon(1S)$)	$(6\text{–}8) \times 10^{-6}$ ($m_\chi < 8.1\,\text{GeV}/c^2$)
Low-mass dark matter			
$\Upsilon(1S) \to \chi\overline{\chi}$	Up to $(4\text{–}18) \times 10^{-4}$	$< 25 \times 10^{-4}$ Belle (11M $\Upsilon(3S)$)	6×10^{-4}
Lepton Universality Tests			
$R(nS)_{\tau\mu} = \frac{\mathcal{B}(\Upsilon(nS)\to\tau^+\tau^-)}{\mathcal{B}(\Upsilon(nS)\to\mu^+\mu^-)}$	1.0 (SM) (1.1–1.10) (NMSSM)	$R(3S)_{\tau\mu} = 1.07 \pm 0.08 \pm 0.05$ CLEO (5M $\Upsilon(3S)$) $R(2S)_{\tau\mu} = 1.04 \pm 0.04 \pm 0.05$ CLEO (10M $\Upsilon(2S)$) $R(1S)_{\tau\mu} = 1.02 \pm 0.02 \pm 0.05$ CLEO (20M $\Upsilon(1S)$)	$(1\text{–}2)\%$ precision - -
Lepton Flavor Violation Tests			
$\frac{\mathcal{B}(\Upsilon(3S)\to\mu\tau)}{\mathcal{B}(\Upsilon(3S)\to\tau\tau)}$	0.0 (SM)	$< 0.13\%$	$< 0.03\%$

The Physics Reach of the data at Upsilon Resonances (cont.)

•Bottomonium spectroscopy: an unfinished program

The data set is comparable to the largest set on charmonium decays- 58 Million at BES

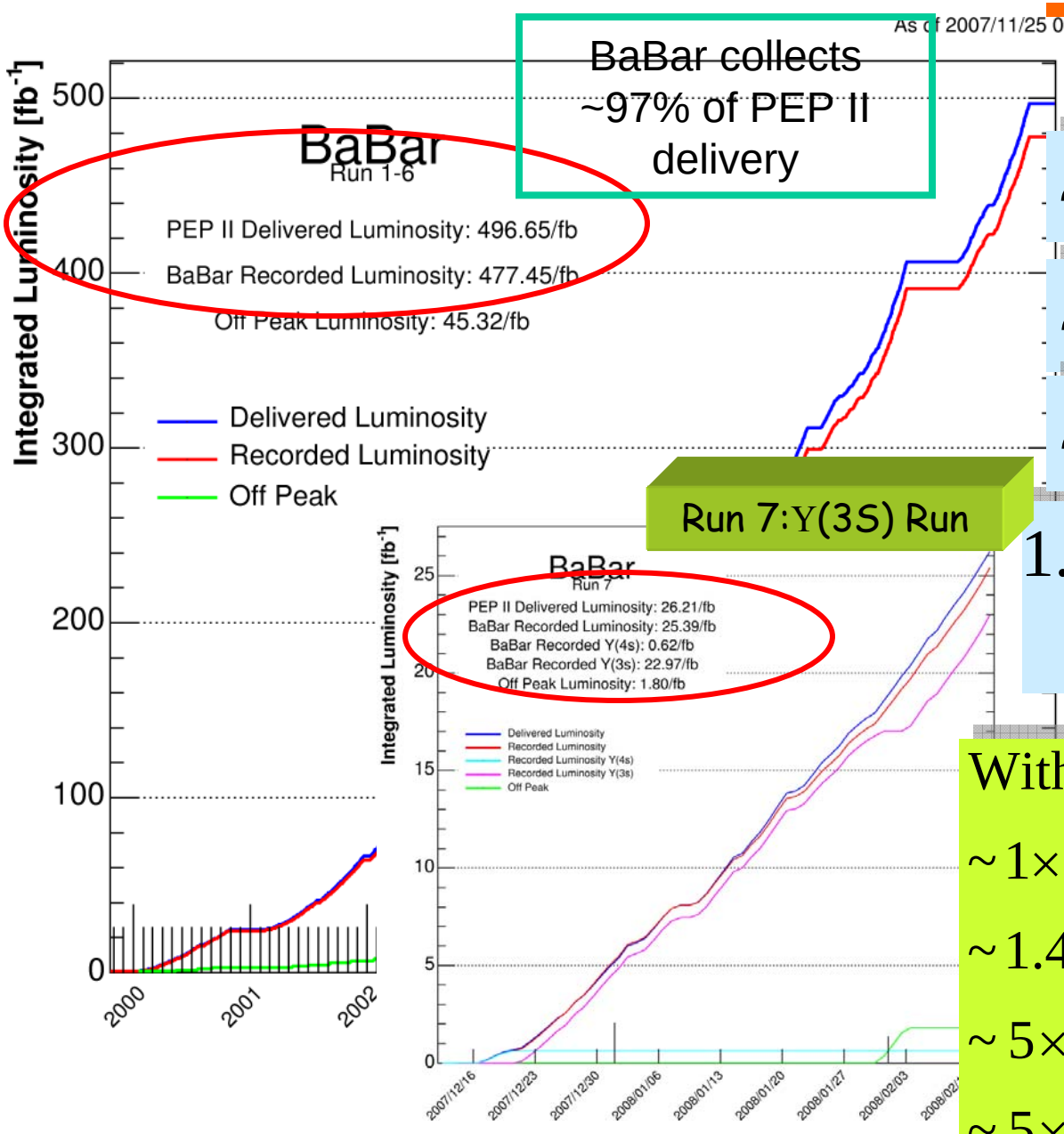
- The measurements are of significant interest to tests of LQCD and potential models-
- Observe as-yet unseen new states and transitions including: singles states- e.g. η_b & h_b & suppressed M1 transitions



Search Channel	Theoretical Range	Existing Result *Experiment (Sample)*	*BABAR* Sensitivity ($30\,\text{fb}^{-1}$)
M1-Suppressed Transitions			
$\Upsilon(3S) \to \eta_b(1S)\gamma$	$(3.4 - 22) \times 10^{-4}$	$< 5.2 \times 10^{-4}$ (90% CL) CLEO (6M $\Upsilon(3S)$)	$< 1.3 \times 10^{-4}$
$\Upsilon(3S) \to \eta_b(2S)\gamma$	$(1.4 - 7.0) \times 10^{-4}$	$< 6.4 \times 10^{-4}$ (90% CL) CLEO (6M $\Upsilon(3S)$)	$< 1.6 \times 10^{-4}$
Hadronic Transitions			
$\chi_{b0}(2P) \to \eta\eta_b(1S)$	$\approx 10^{-3}$	NONE	$\approx 10^{-4}$

The whole of BaBar Data

BaBar collects ~97% of PEP II delivery



Run 7: Υ(3S) Run

Partial composition of the data

$\sim 0.5 \times 10^9 \; B\bar{B}$

$\sim 0.5 \times 10^9 \; c\bar{c}$

$\sim 0.5 \times 10^9 \; \tau\bar{\tau}$

$1.5 \times 10^9 \; e^+ + e^- \Rightarrow q\bar{q}$

ISR

With 30/fb on 3S & 20/fb on 2S

$\sim 1 \times 10^8$ Υ(3S)

$\sim 1.4 \times 10^8$ Υ(2S)

$\sim 5 \times 10^6$ $\Upsilon(3S) \rightarrow \pi\pi\Upsilon(1S)$

$\sim 5 \times 10^7$ $\Upsilon(2S) \rightarrow \pi\pi\Upsilon(1S)$

The physics reach of the BaBar Data

Just about any physics that is accessible at

$\sqrt{s} \approx 10 \quad GeV$

CP Studies with B & B Physics

The Principal Mission

- CP breaking in B decays
- Test the CKM paradigm
- Search for New Physics in SM suppressed decays

New unexplained States: X,Y,Z's

Charm Physics D^0 Mixing, New States, F_{Ds}

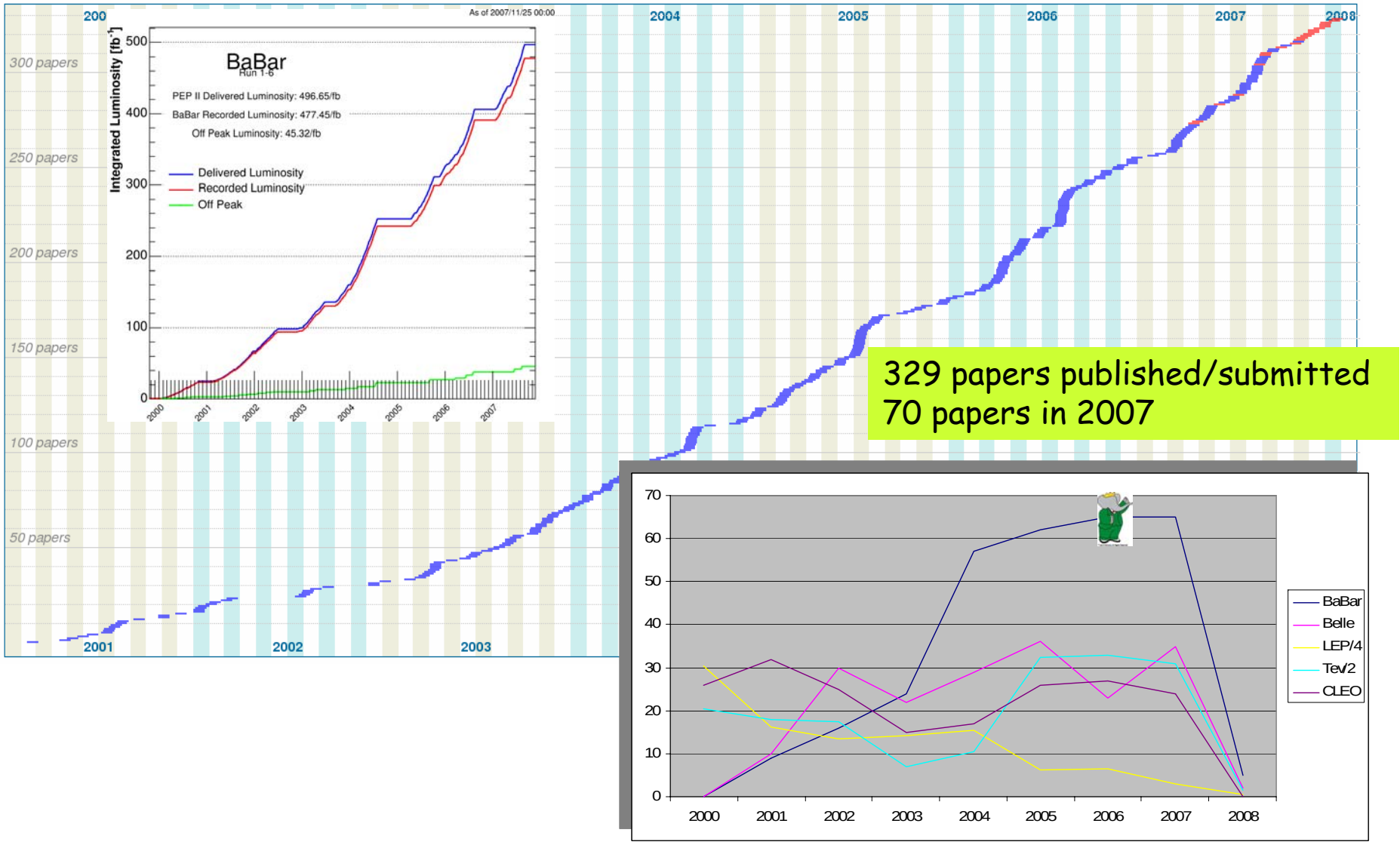
Lepton Flavor Violation **Tau physics**

Continuum $e^+e^- \rightarrow$ hadrons

ISR: R($e^+e^- \rightarrow$ hadrons) from threshold to ~5 GeV

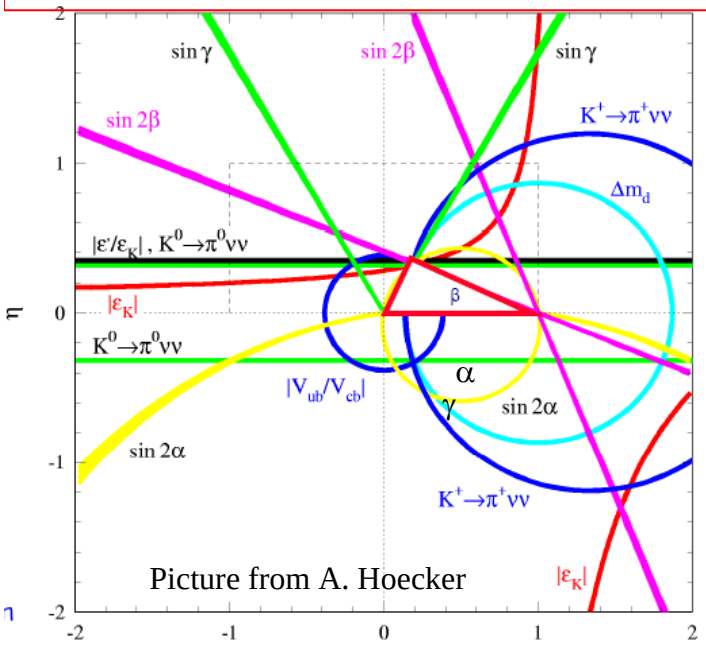
Measuring the hadronic part of photon vacuum polarization

A look at the timeline of BaBar's physics publications

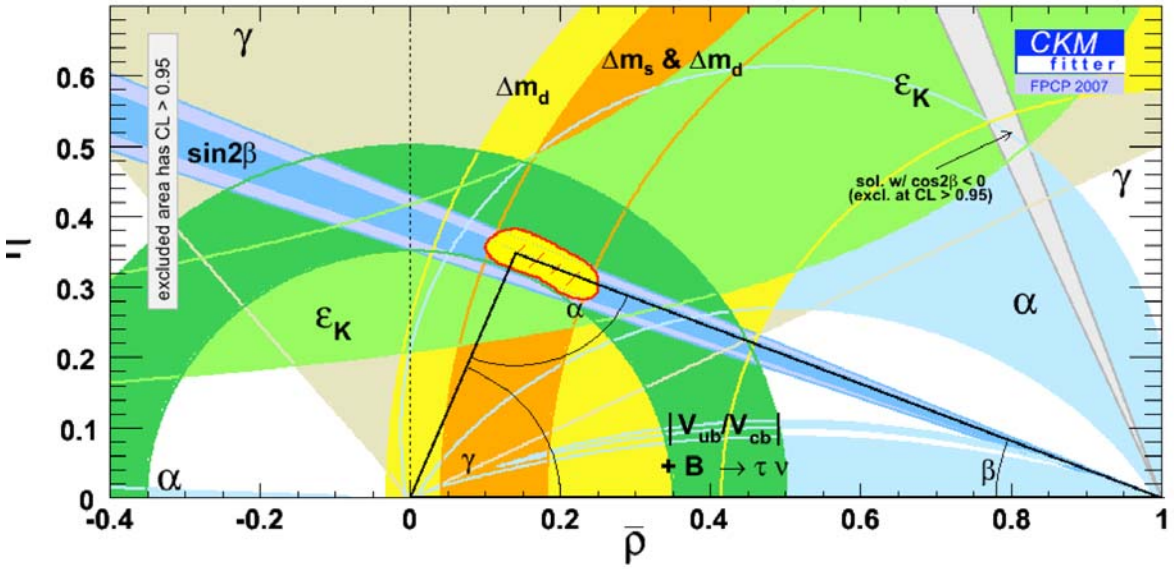


Tests of the CKM Paradigm

Theorist view of CKM Observables



The view from the experiments



B factories aiming for:

$$\sigma(|V_{ub}|) \approx 5\%$$

$$\sigma(\gamma) \approx 5-10^{o}$$

$$\sigma(\alpha) \approx 8^{o}$$

$$\sigma(\sin 2\beta) = 0.02$$

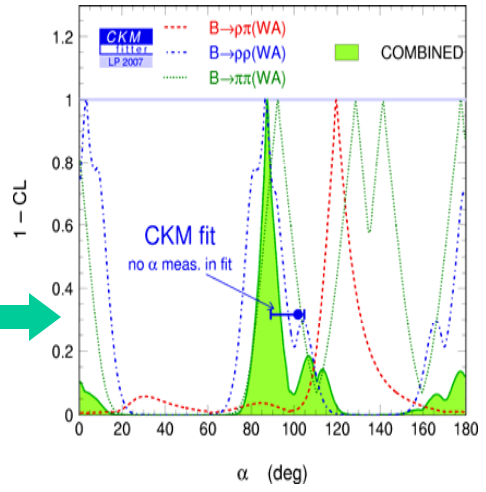
Now

~7-10%

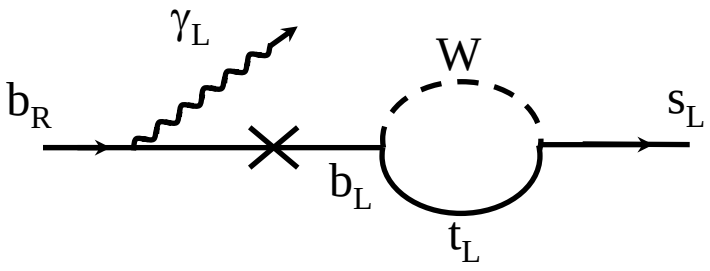
~20º

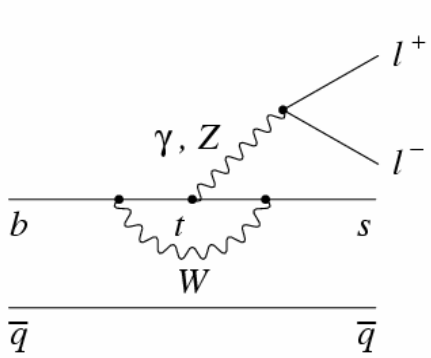
~10-15º

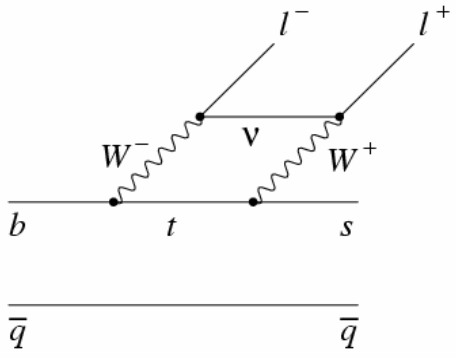
~0.04 (~1º)



- **A major focus of the experiment is now on searches for New Physics via FCNC decays of B- Deviation from SM searched for:**



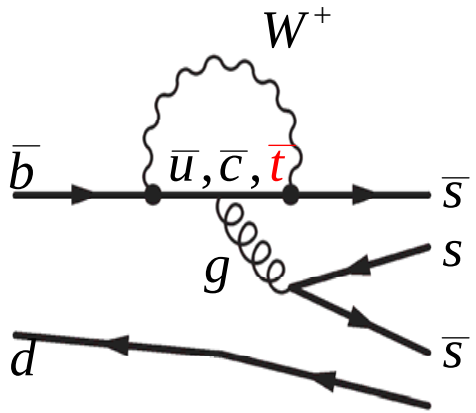




There is more than just rate in these channels now:

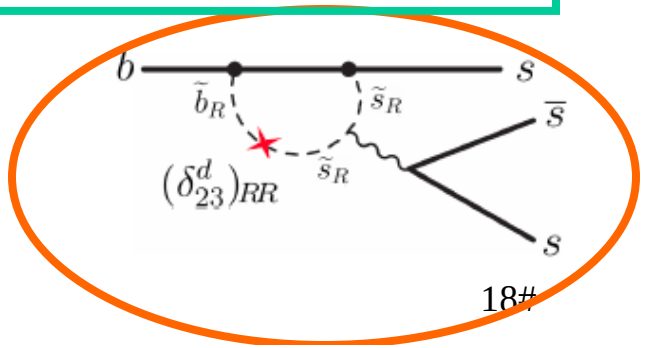
- Photon polarization in b→γs_L (γ left-handed in SM)
- Direct CP violation – nearly zero in SM
- In B→Kll- q^2 dependence of the rate; FB asymmetry, polariztion

Search for NP modification of Wilson coefficients C7, C9, C10



Possible New Physics presence can alter the observables from SM expecations

Sin2β test in Penguin dominated modes



A list of topics on BaBar's "core" physics program

The ultimate job on CKM – until the SuperB era

The no-stone-unturned search for New Physics

A major effort underway to perform these measurements

~ 2/3 of the core measurements performed with <1/2 of the full dataset

Core physics areas	Analysis Channels
CKM: Angle β Measurements of Time-Dependent CP Asymmetries and direct CP asymmetries	sin2β from $B \to c\bar{c}K^0$
	cos2β from $B \to J/\psi K^{*0}$
	β from $B \to Dh$
	β from $B \to D^{(*)+}D^{(*)-}$
CKM : Angle α Measurements of decay rates, TDCP asymmetries and direct CP asymmetries	$B \to \pi\pi$ $[\pi^+\pi^-, \pi^+\pi^0, \pi^0\pi^0], K\pi, KK$
	$B \to 3\pi$ Dalitz analysis
	$B \to \rho\rho$ $[\rho^+\rho^-, \rho^+\rho^0, \rho^0\rho^0]$
	$B \to A_1\pi$
CKM: Angle γ Measurements of Rates, Direct CP asymmetry and Dalitz Analysis	$B \to D^{(*)+}K^{(*)-}$ [Dalitz analysis, GLW, ADS]
	$B \to D^{(*)0}K^{(*)0}$
	$B \to D^{(*)}\pi$
	$B \to D^{(*)}\rho$
CKM: V_{ub}	Inclusive $B \to X_u l\nu$
	Exclusive $B \to X_u l\nu$ $[B \to \pi\ l\nu, B \to \rho\ l\nu, \ldots]$
Loop Dominated Processes As probes of New Physics	**Radiative B decays**: Inclusive and exclusive $B \to s\gamma$ [Rate, A_{ch},..] • TDCP in $B \to K^{*0}\gamma$ [Probe of helicity of γ] Inclusive and exclusive $B \to d\gamma$ [Rate, A_{ch},..] Inclusive and exclusive $B \to sl^+l^-$ [Rate, A_{ch},A_{FB}, ..] Search for $B \to s\nu\bar{\nu}$
	TDCP in Gluonic Penguin Dominated Channels: $B \to K^0\phi,\ K^0\eta',\ K^0K^+K^-,\ K^0\pi^0,\ K^0K_s^0K_s^0,$ $K^0\rho,\ K^0\omega,\ K^0\pi^0\pi^0$
	Charmless Decay Properties: Decay Rate, Direct CP, Polarization $B \to VV$ *Decays* $(\rho\rho, \phi K^*, \rho K^*, \omega\rho, \omega K^*, ..)$ $B \to \eta'\pi^0, \eta\pi^0, \eta'\eta, \eta'\eta', \eta\eta$ *(for SU(3) analysis)* $B \to \rho K, \eta K, K\pi\pi, 3K, 3\pi$
Leptonic B and Charm decays: B and D decay Constant (LQCD) Probe of New Physics	$B^+ \to \tau^+\nu$, $B^+ \to l\nu(\gamma)$, $B \to ll$, $D_s^+ \to l^+\nu$
Charm Physics	D^0 mixing and CPV Rare Charm Decays ($D \to ll$, FCNC in charm decays)
Tau Physics	**Lepton Flavor Violation:** $\tau \to \mu\gamma,\ e\gamma,\ \tau \to lll,\ l\pi^0,\ l\eta,\ l\eta',\ lK_s^0,$

Table 2: Some of the key measurements on the "core" physics program of BaBar.

The Analysis-Computing strategy

The task at hand

More than 100 core physics measurements

currently ~250 ongoing analyses

Analysis-Computing program: current realities

- 2/3 of BaBar's core physics measurements have been performed with less than ½ of the full data set. Nearly all core physics channels are covered with active analysts and will be updated with full data.

- We have developed the final BaBar reconstruction code- after extensive studies over the past year- and plan to reprocess the full 4S data by Fall 2008.

- We have been planning for the post-data taking phase in the past few years- defining the "core" physics and planning for the resources needed to complete it:

  - We expect and plan for a period of ~2 (perhaps 3) years of intense analysis activity following the end of the data taking.

Analysis-Computing program: Post-data taking phase

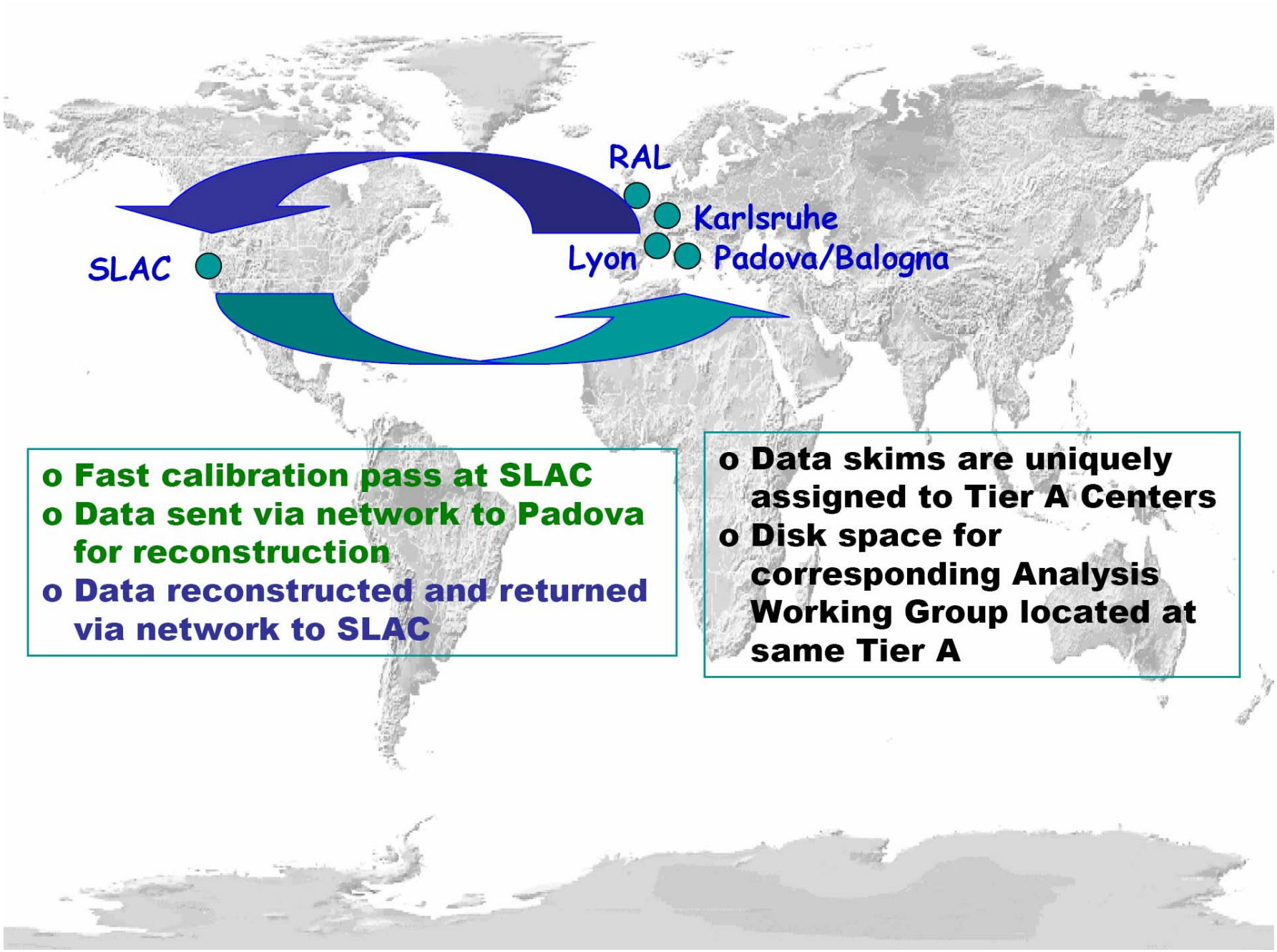
- ✓ The intense-Analysis Activity has already begun

- The key element of the program is the continuing availability of the computing resources (hardware and manpower) at SLAC & the 5-Tier-A centers.

- This strategy is consistent with BaBar physics goals and the manpower realities of the experiment:
  - The key players in the analyses effort are the current postdocs and graduate students, whose life span in the experiment is the next 2-3 year.
  - The success of this program depends on keeping a coherent and well coordinated effort- as it has been throughout the life of the experiment. A strong SLAC centered analysis effort is crucial.

- We expect the analysis life of the experiment to go on for another 2 to 3 years beyond this period- the plan assumes SLAC centered computing resources beyond 2010.

BaBar Computing Tier-A centers



- o Fast calibration pass at SLAC
- o Data sent via network to Padova for reconstruction
- o Data reconstructed and returned via network to SLAC

- o Data skims are uniquely assigned to Tier A Centers
- o Disk space for corresponding Analysis Working Group located at same Tier A

Summary remarks

- Tremendous disappoint in the collaboration at the early termination of run 7 at the 4S:
  - Even so, an enormous amount of physics still to come from the analysis of the 4S data- the principal physics program of the experiment: Majority of our core physics measurements will be updated with the full data set in the next 2 (or 3) years.
  - The current data on narrow Upsilon resonances expands the physics reach of the program with unique opportunities in the quarkonium spectroscopy and searches for the effects of New Physics.
- The collaboration is healthy(although angry & puzzled) with a strong base of students and postdocs- more than 130 Ph.D. thesis in the pipeline.
- Full exploitation of BaBar physics needs continued support of the community and the funding agencies of the experiment and BaBarians through the intense-analysis period & beyond.
  - We have received strong support from the DOE HEP and BaBar's International Finance Committee for the completion of the run and the intense analysis phase of the program.