CP Violation and Hot Topics From BABAR Experiment

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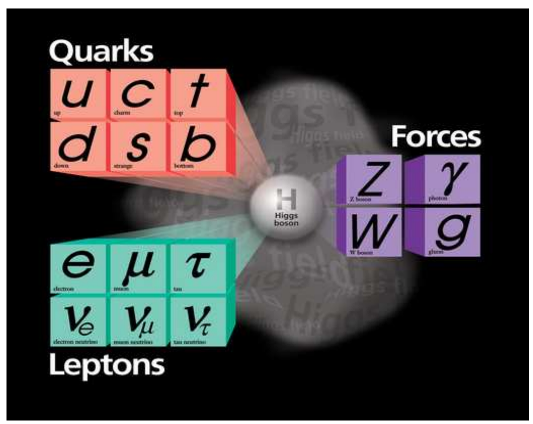
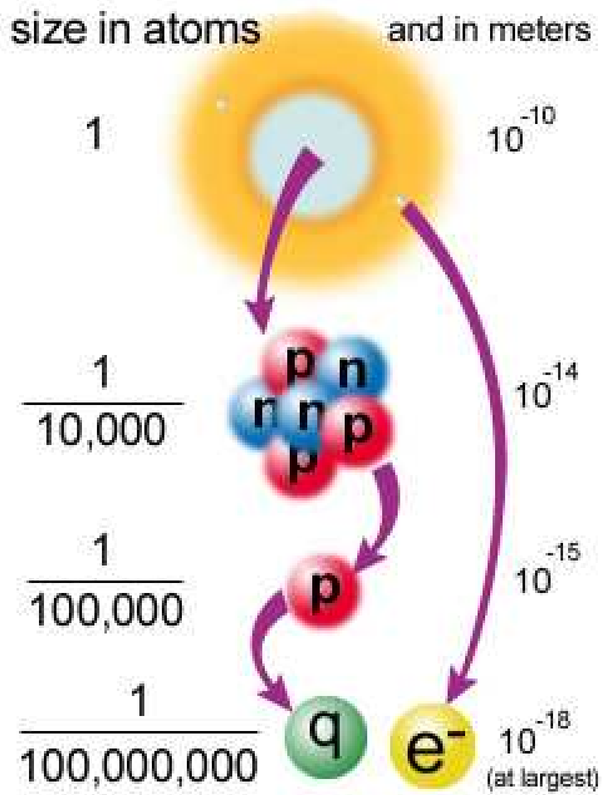
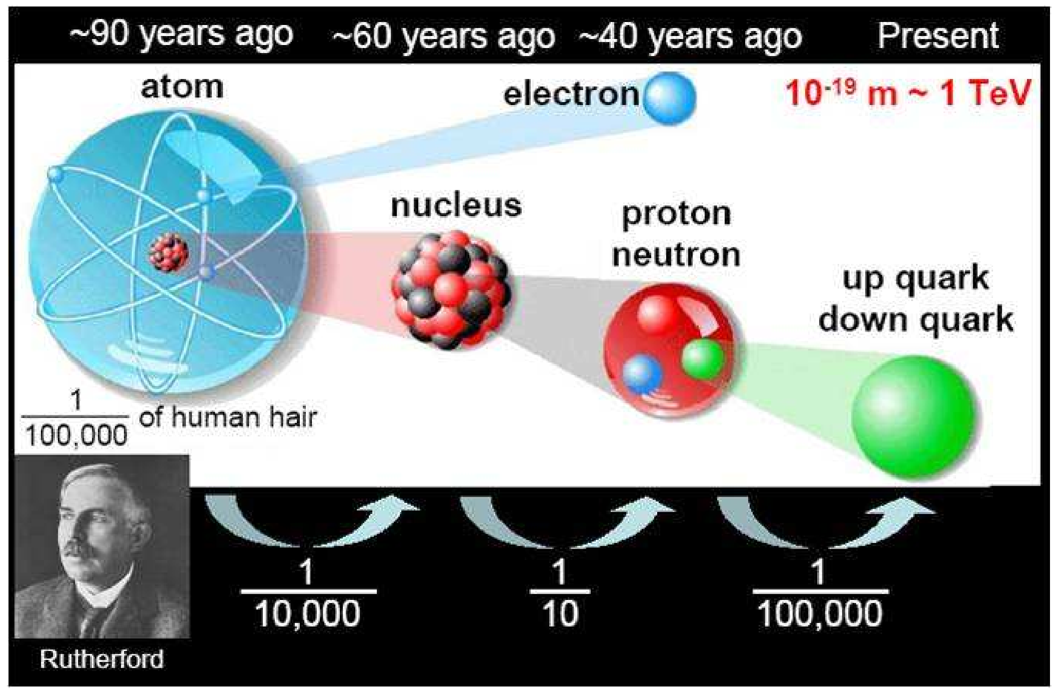
Wednesday, March 14, 2012
Department of Physics



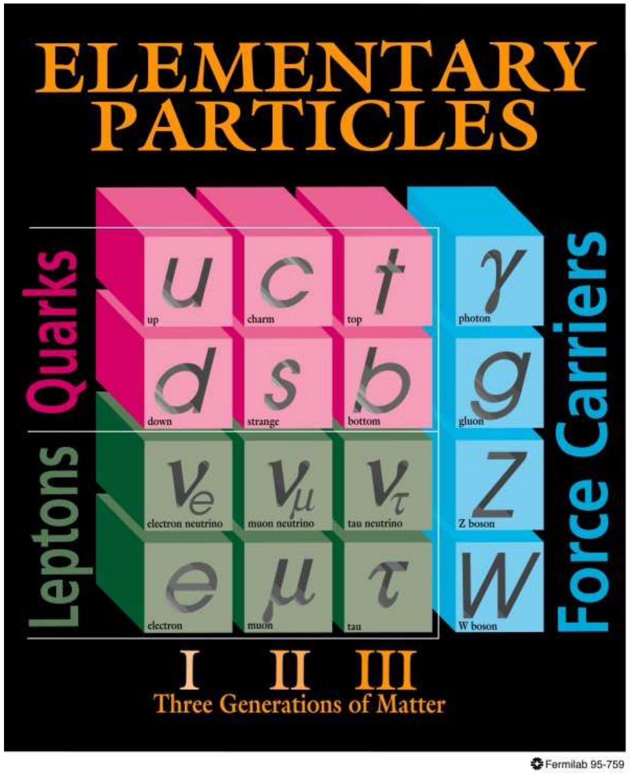
What is the World Made of ?

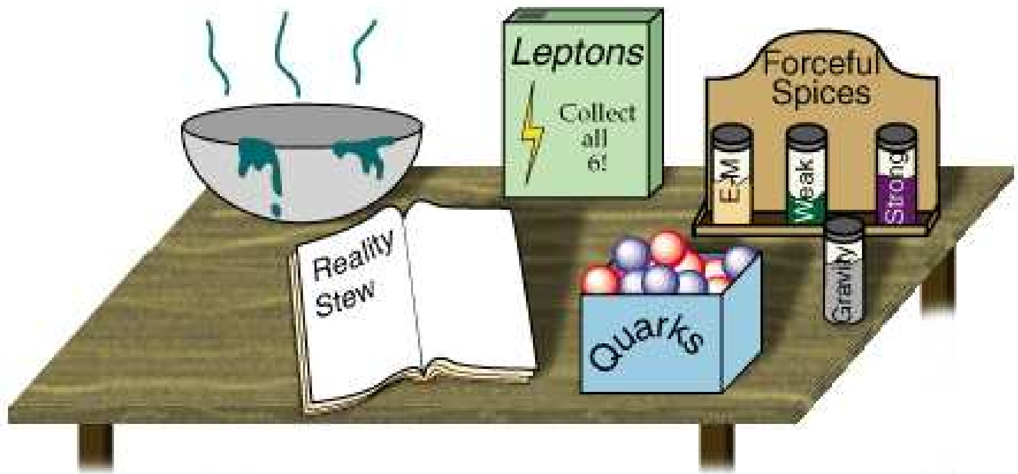
- Scientists originally thought the nucleus was a fundamental particle but
  - $\longrightarrow$ nucleus is made of protons and neutrons
  - $\longrightarrow$ protons and neutrons are made of quarks





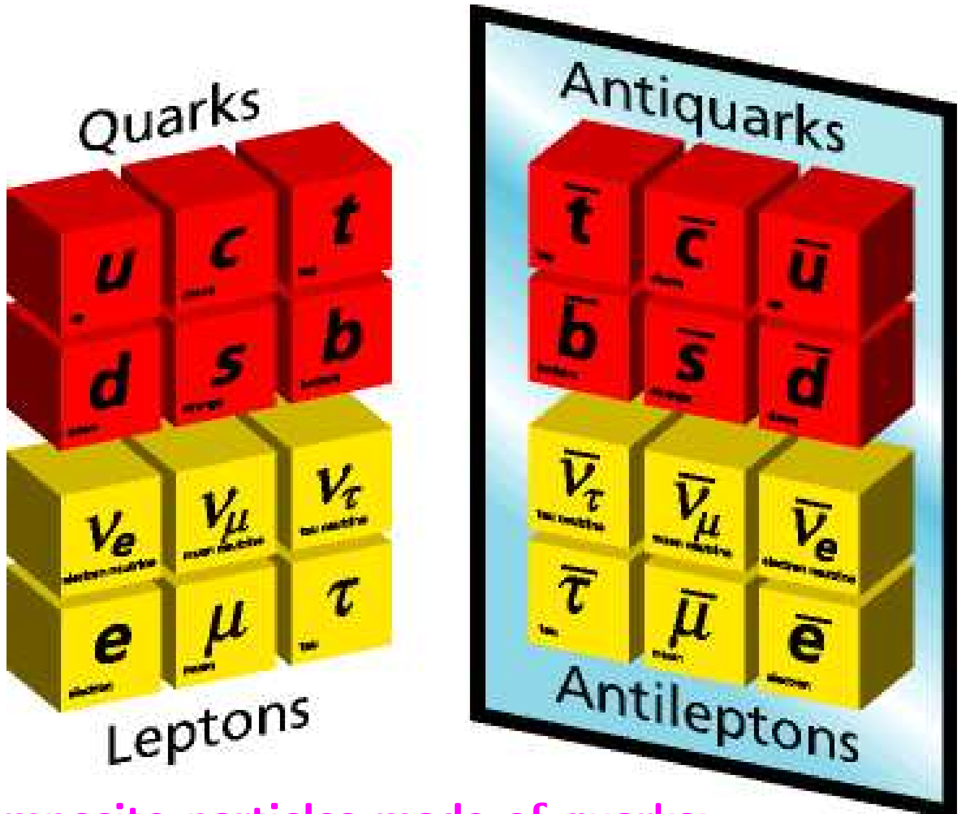
Standard Model





- All the known matter particles are composites of 6 quarks and 6 leptons and they interact by exchanging force carrier particles:
  - ↪ Electromagnetic (γ), Weak (Z^0, $W^{\pm}$), and Strong (gluons)
  - ↪ Gravity (Graviton is not in SM)

Standard Model



□ Hadrons are composite particles made of quarks:

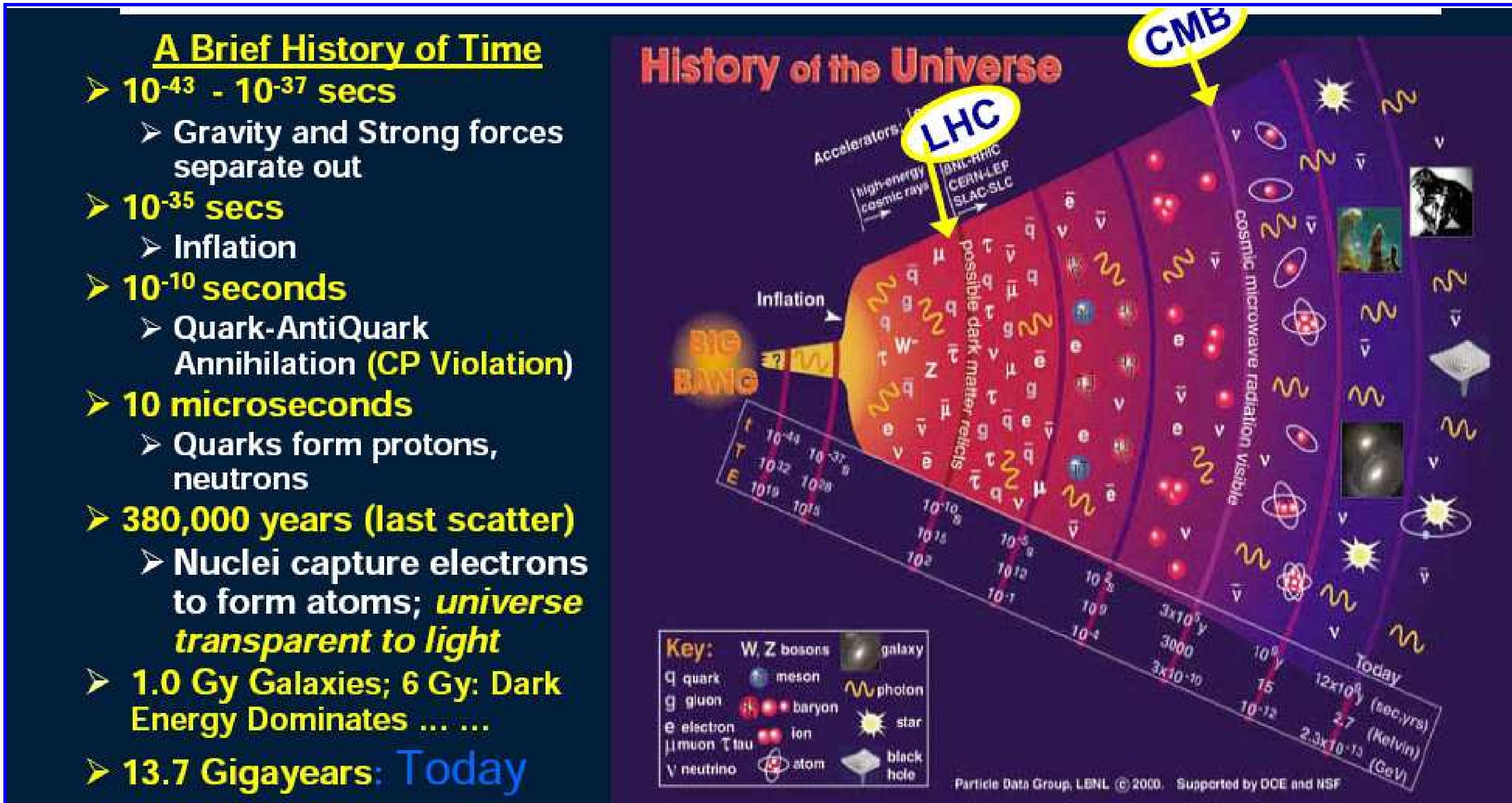
- Baryons are any hadron which is made of three quarks (qqq)

  ↪ proton (uud) and antiproton $(\bar{u}\bar{u}\bar{d})$

- Mesons contain one quark (q) and one antiquark $(\bar{q})$

  ↪ B^0 $(d\bar{b})$ and $\overline{B}^0$ $(\bar{d}b)$

The Birth of the Universe (13.7 Billion Years Ago)

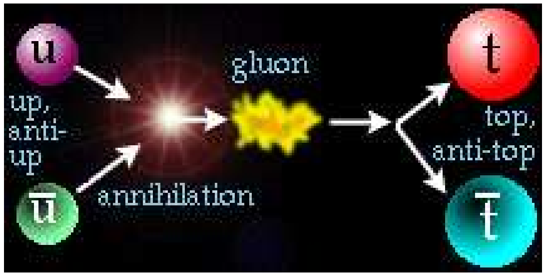


- After the Big Bang exploded with enormous energy, the universe began to cool-down that has lasted until our own time
- CP Violation process occurred 10^{-10} seconds after the explosion.

What Was Happened to the Antimatter

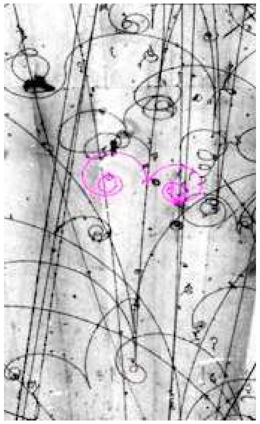
What Was Happened to the Antimatter ?

- How do we know there is almost no antimatter around ?
  - When a matter and antimatter meet, they annihilate into pure energy
    $\longrightarrow$ leaving only photons and neutrinos



  - The fact: we don't see this kind of energy in our daily life

- Can we see the evidence of antimatter ?



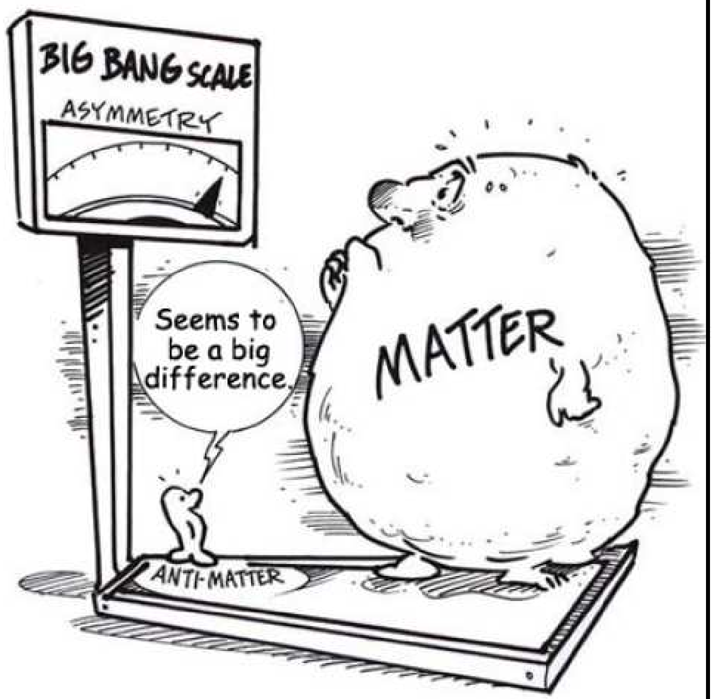
- The magnetic field makes negative particles curl left, positive particles curl right

Why is the Universe Exclusively Made of Matter ?

☐ Andrei Sakharov (JETP, 5, No 1, 1967)

1. Baryon violating interactions
2. Thermal non-equilibrium situation
3. CP Violation

Nobel Peace Prize in 1975 →

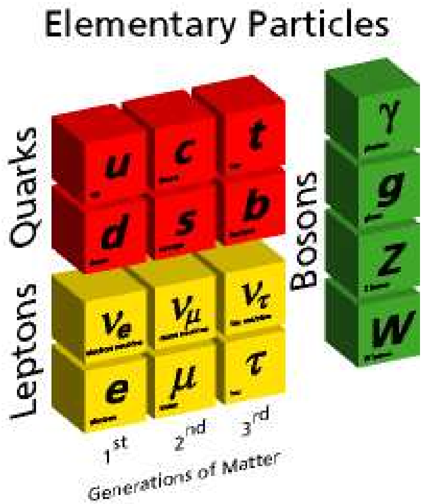


☐ Testing the Sakharov's criteria:

1. No evidence that baryon number is violated
2. In thermal equilibrium particles are identical → No asymmetry

CP violation is necessary to understand matter-antimatter imbalance

CP Violation in B Mesons



- In 1962: Nicola Cabibbo introduced 2 generation quarks

- In 1972: Kobayashi and Maskawa introduced 3 generation quarks with

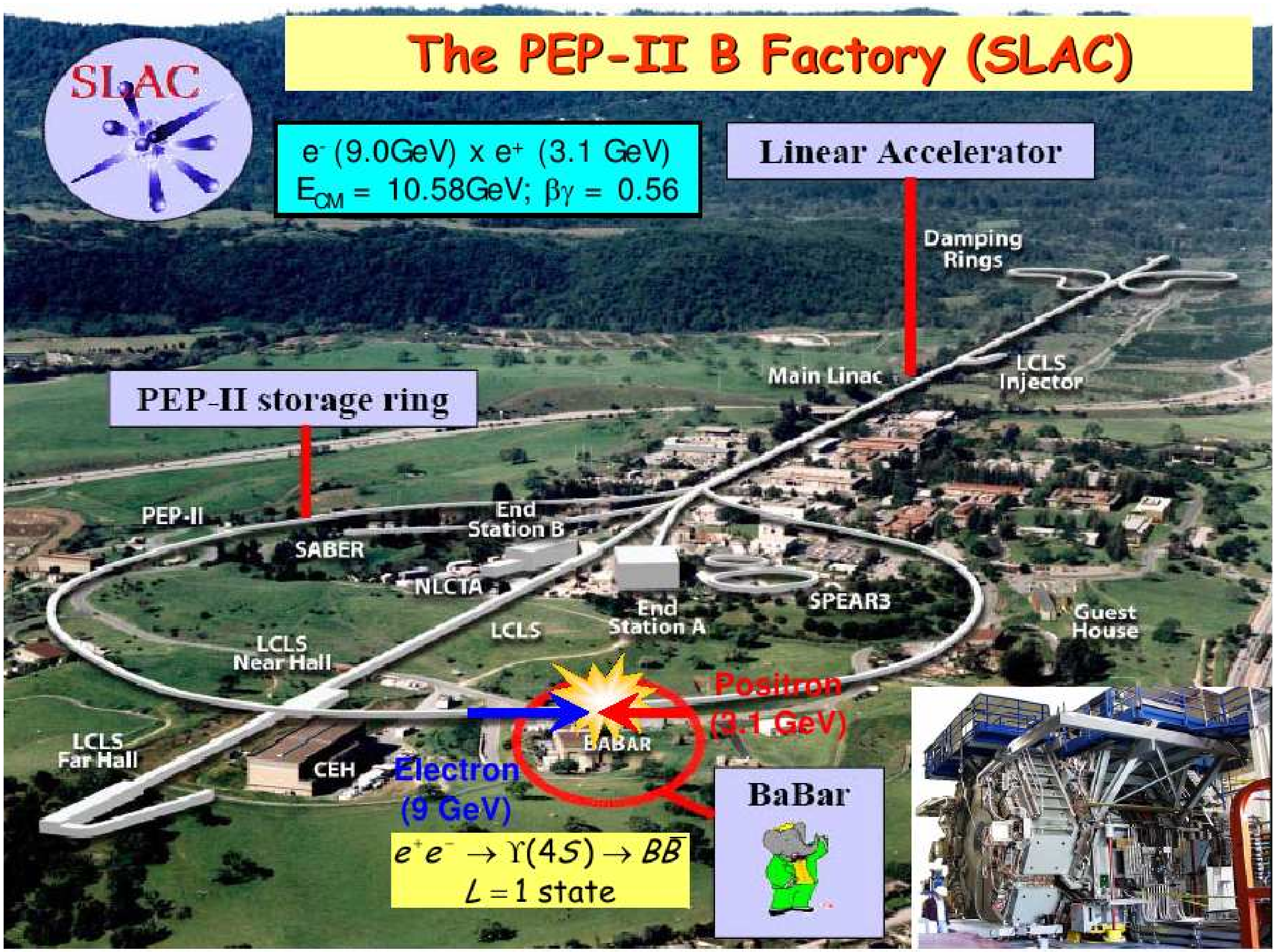
  CP violation in B Meson $\rightarrow$ A Brilliant Idea

- All Fundamental Particles in Standard Model

  (12 + 36 + 12 + Higgs) = 61 particles (excluding Graviton)

BABAR Experiment in USA

- BABAR at Stanford Linear Accelerator Center (SLAC), California

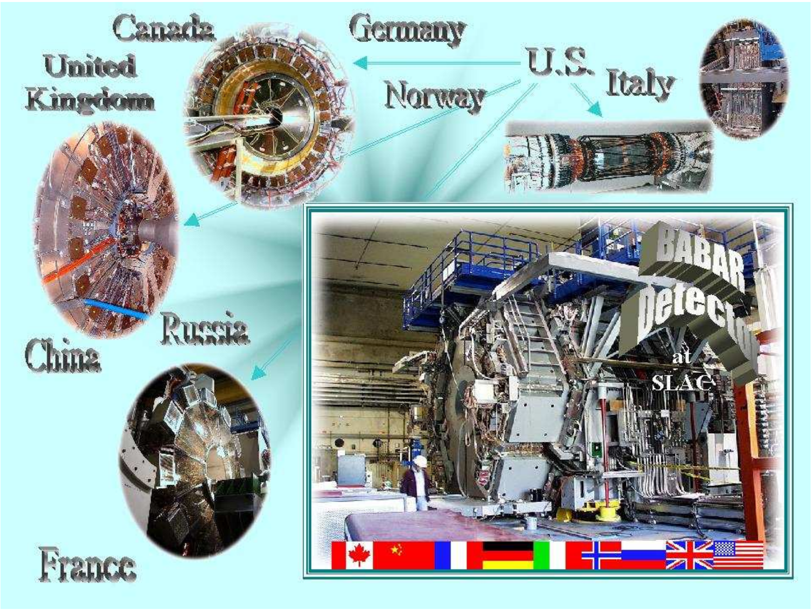


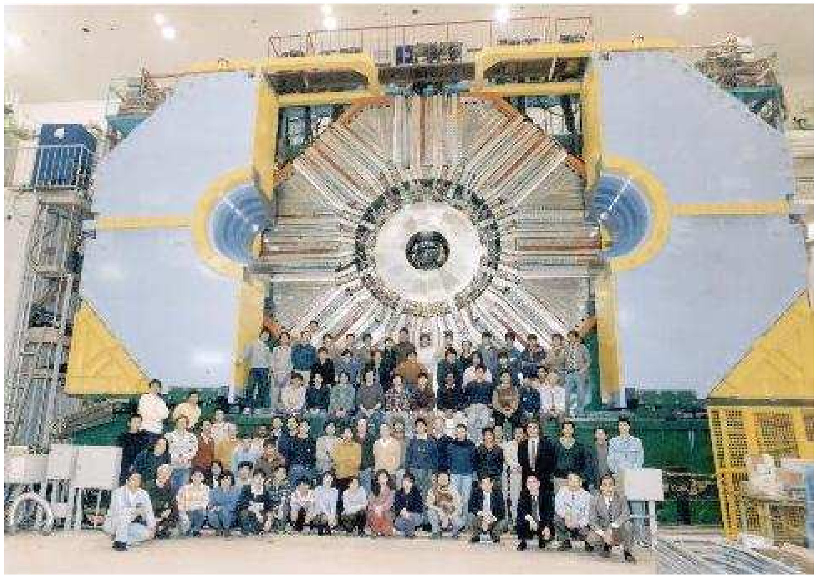
- Sister B-factory machine is at KEKB (Tsukuba) in Japan

BELLE Experiment in Japan

CP Violation in B Meson

☐ BABAR and Belle directly measured CP violation in B system





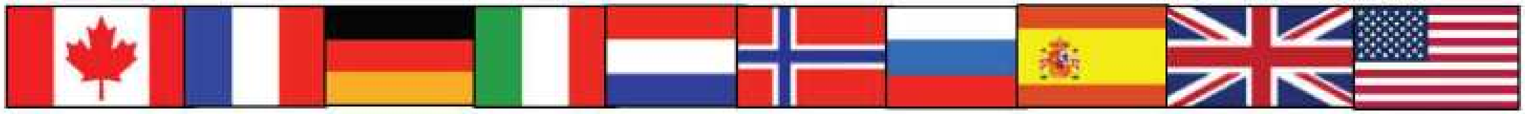
BABAR : e^+ (3.1 GeV) - e^- (9 GeV)   Belle : e^+ (3.5 GeV) - e^- (8 GeV)

In 1999 BABAR and Belle had first colliding beam

In 2001 BABAR and Belle reported the first measurement of direct

CP violation in B meson $\hookrightarrow$ fundamental matter-antimatter asymmetry

BABAR Collaboration



The BABAR Collaboration
10 Countries
77 Institutions
522 Physicists

USA [34/256]
California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, Riverside
UC, San Diego
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
Yale

Canada [4/23]
University of British Columbia
McGill University
University de Montréal
University of Victoria

France [5/40]
LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris VI et VII
Ecole Polytechnique, Laboratoire Leprince-Ringuet
CEA, DAPNIA, CE-Saclay

Germany [6/31]
Ruhr Universitaet Bochum
Universitaet Dortmund
Technische Univeritaet Dresden
Universitaet Heidelberg
Universitaet Rostock
Universitaet Karlsruhe

Italy [12/90]
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

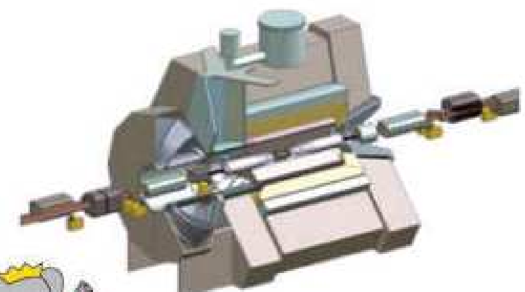
The Netherlands [1/3]
NIKHEF, Amsterdam

Norway [1/4]
U of Bergen

Russia [1/10]
Budker Institute, Novosibirsk

Spain [2/7]
IFAE-Barcelona
IFIC-Valencia

United Kingdom [11/58]
U of Birmingham
U of Bristol
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



October 17, 2006

BABAR Collaboration

University of South Alabama: R. Godang

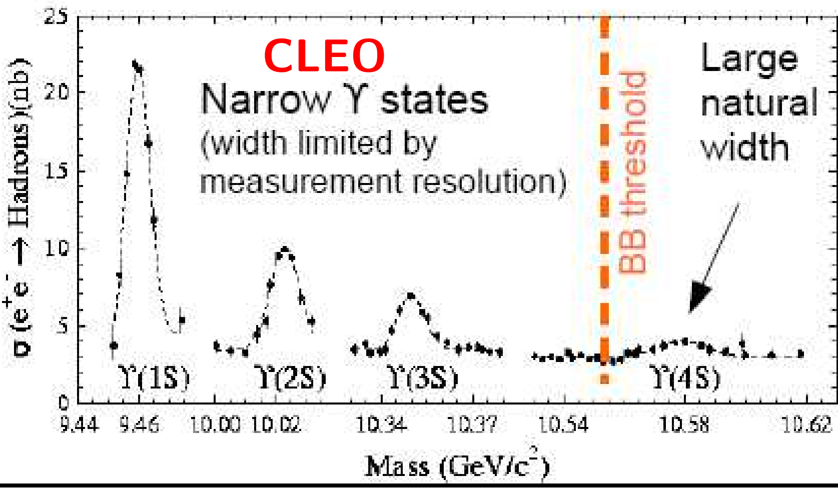
SLAC Control Room

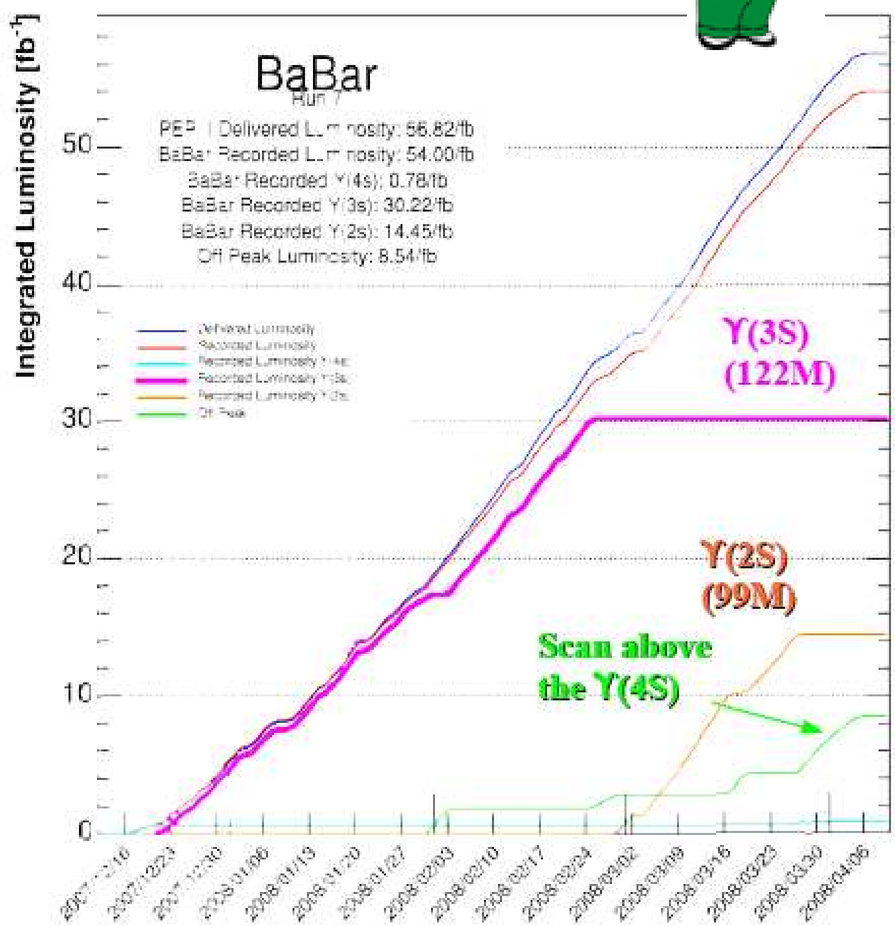
SLAC Main Control Room

BABAR Data: $\Upsilon(nS)$

Final BABAR Data

- BaBar data sets:
  - 122×10^6 $\Upsilon(3S)$ decays
  - 99×10^6 $\Upsilon(2S)$ decays
  - "offpeak" samples of 1.4fb^{-1} and 2.4fb^{-1} collected ~30 MeV below the $\Upsilon(2S)$ and $\Upsilon(3S)$
  - 79 fb^{-1} "continuum background" samples of $\Upsilon(4S)$ with similar detector conditions





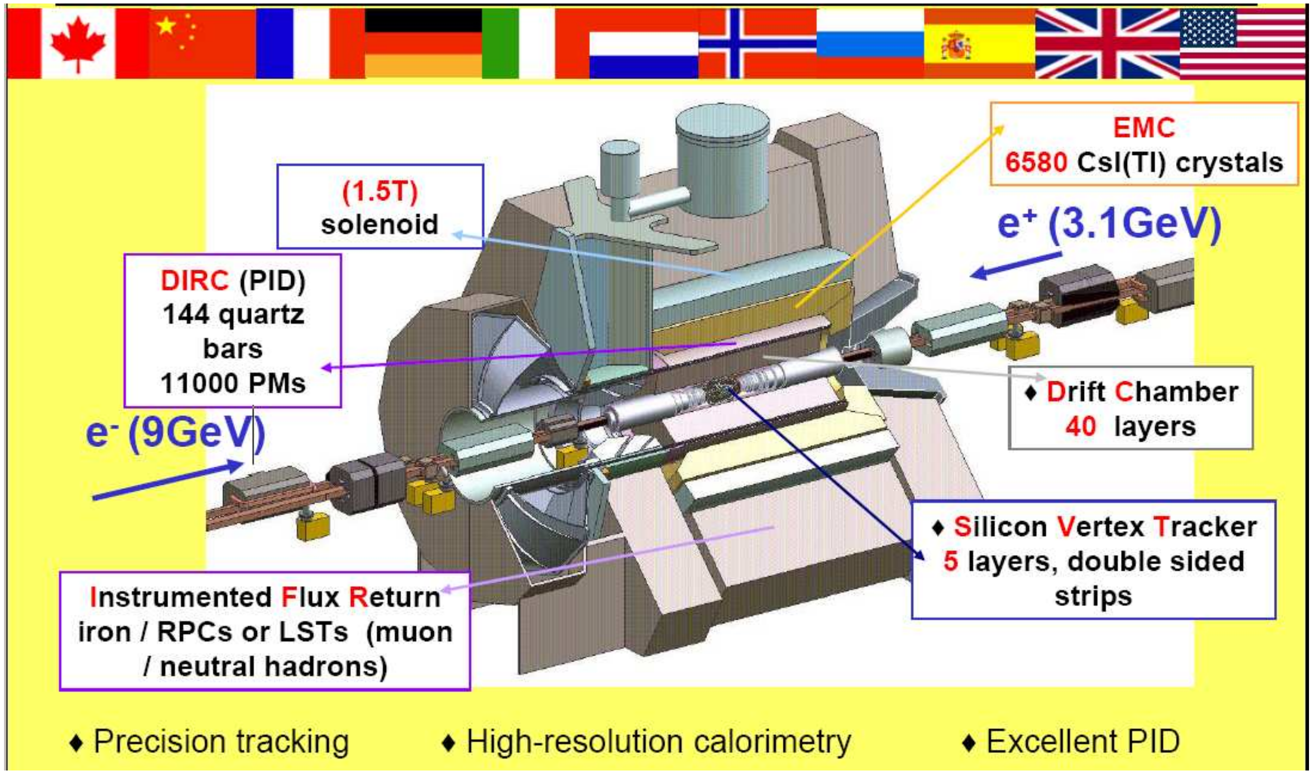
- Trigger requirements modified for narrow Υ data taking

BELLE II Machine

University of South Alabama: R. Godang

BELLE II - TSUKUBA, Japan

CP Violation in B Meson



BABAR : (3.1 GeV) $e^+ \Longrightarrow\Longleftarrow e^-$ (9 GeV)

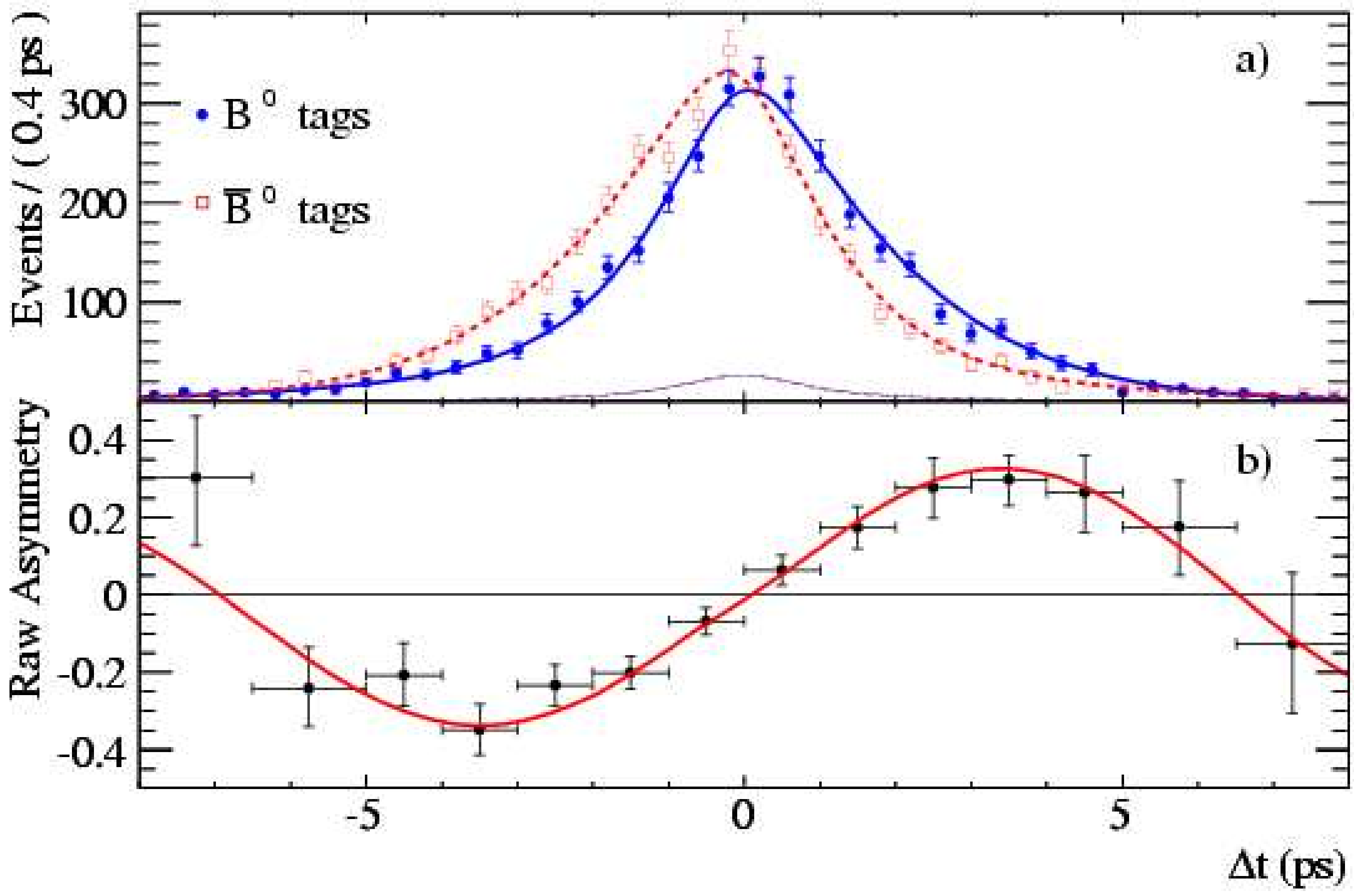
$\longrightarrow$ **In 2001 BABAR and Belle discovered direct CP violation in B mesons**

$\hookrightarrow$ **A source of matter-anti-matter asymmetry**

$\longrightarrow$ YET a lot more physics to come...

CP Violation Discovery

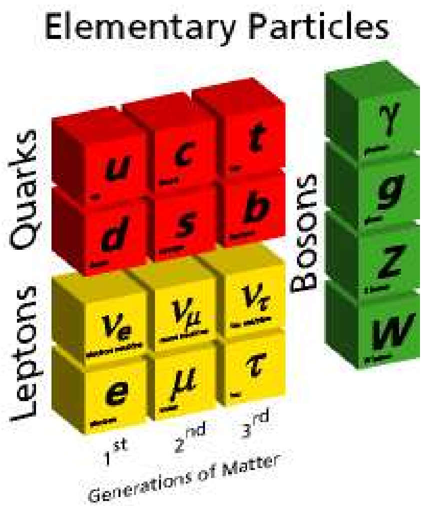
- CP violation was discovered by BABAR and Belle in 2001

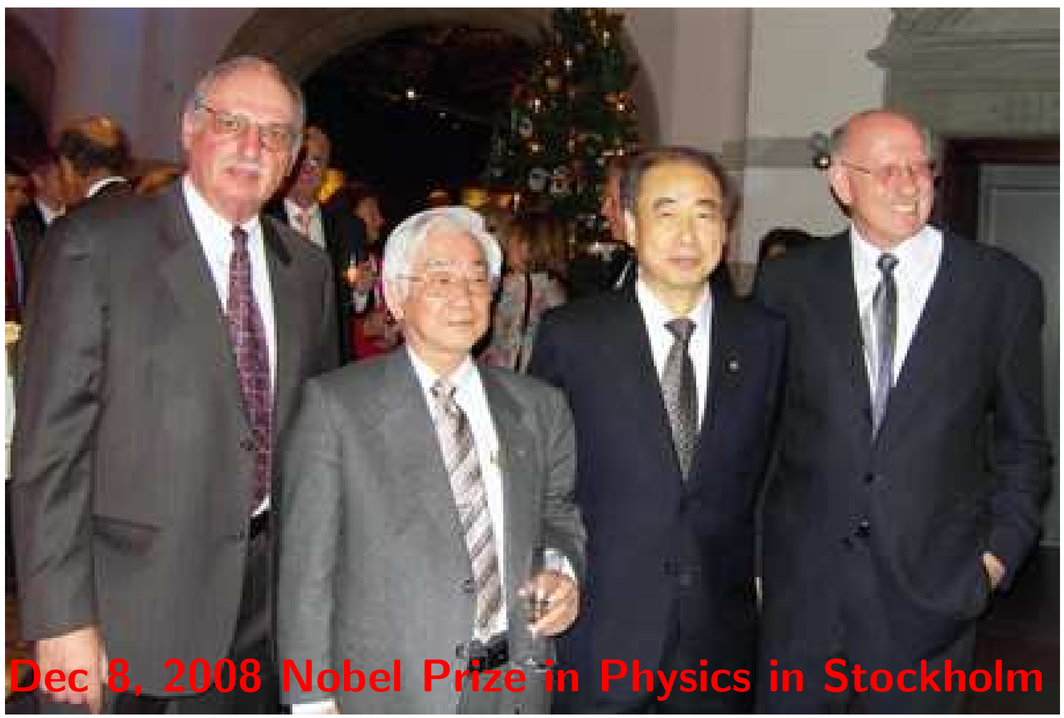


- This plot shows CP violation (3.2% asymmetry precision)

  Matter and anti-matter is behaving differently (CP violation)

Nobel Price in Physics 2008





Dec 8, 2008 Nobel Prize in Physics in Stockholm

Mobile, Alabama USA

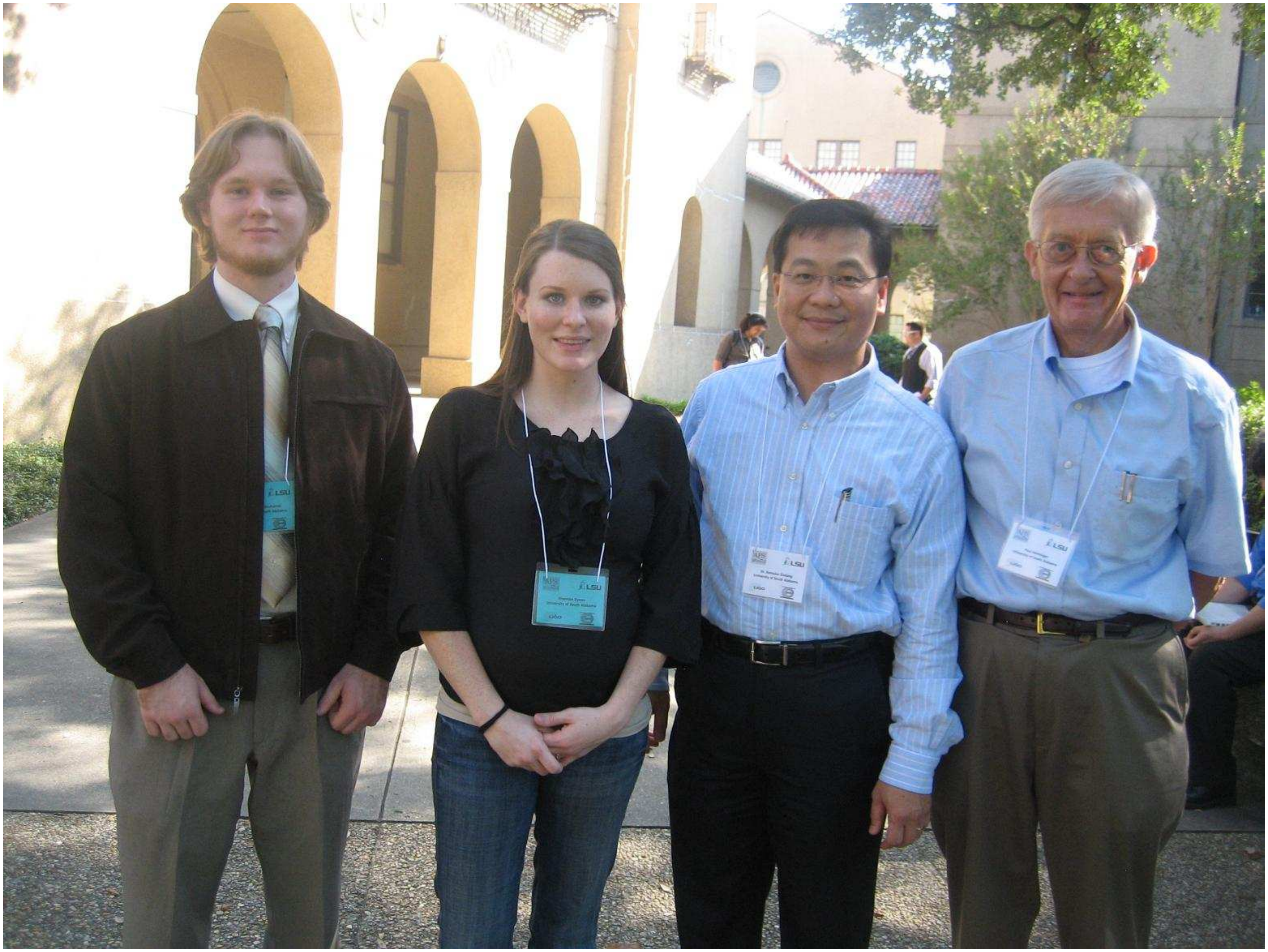
University of South Alabama

USA Main Campus

Students Enrolled: 15,000

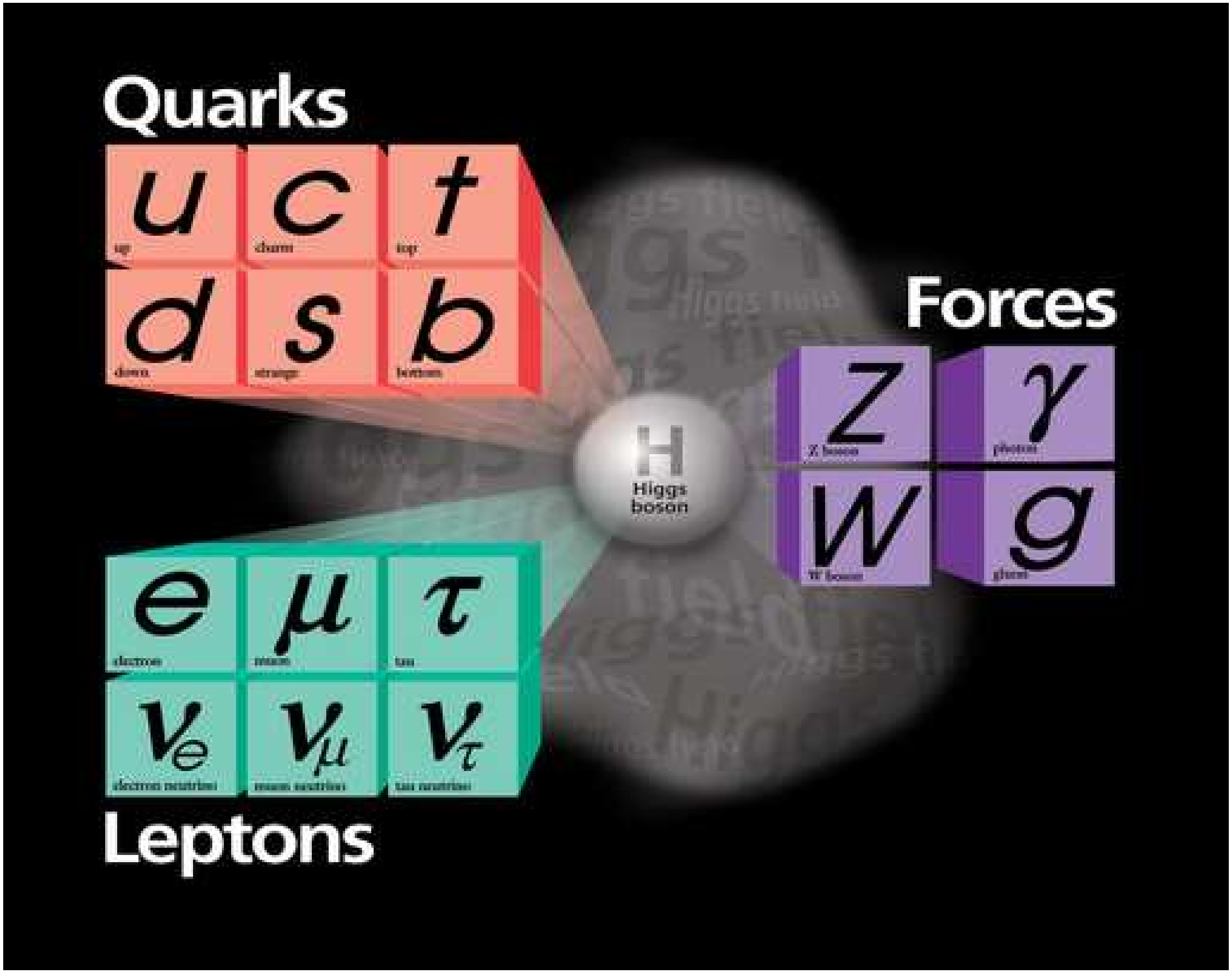
http://www.southalabama.edu **Established in 1964**

USA Undergraduate Students



SESAPS Conference at LSU, 2010

Search for New Physics

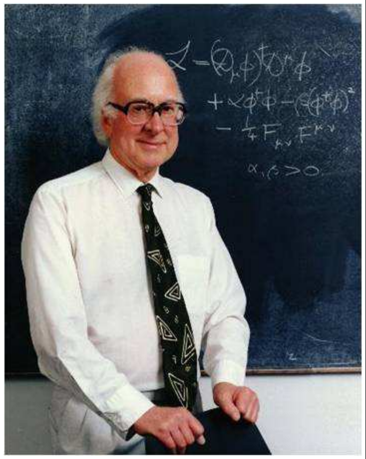


Search for Higgs Bosons

How the elementary particles get their mass ?

- Spontaneous symmetry-breaking: the Higgs generates mass by self-interaction

  ★ It implies the existence new particle so called "Higgs boson"



- Higgs particle is named after Peter Higgs

- Leon Lederman (Nobel 1988) called it "God Particle"

- Challenge: The Higgs mass is a free parameter in the SM

  ↪ What is the Higgs mass?

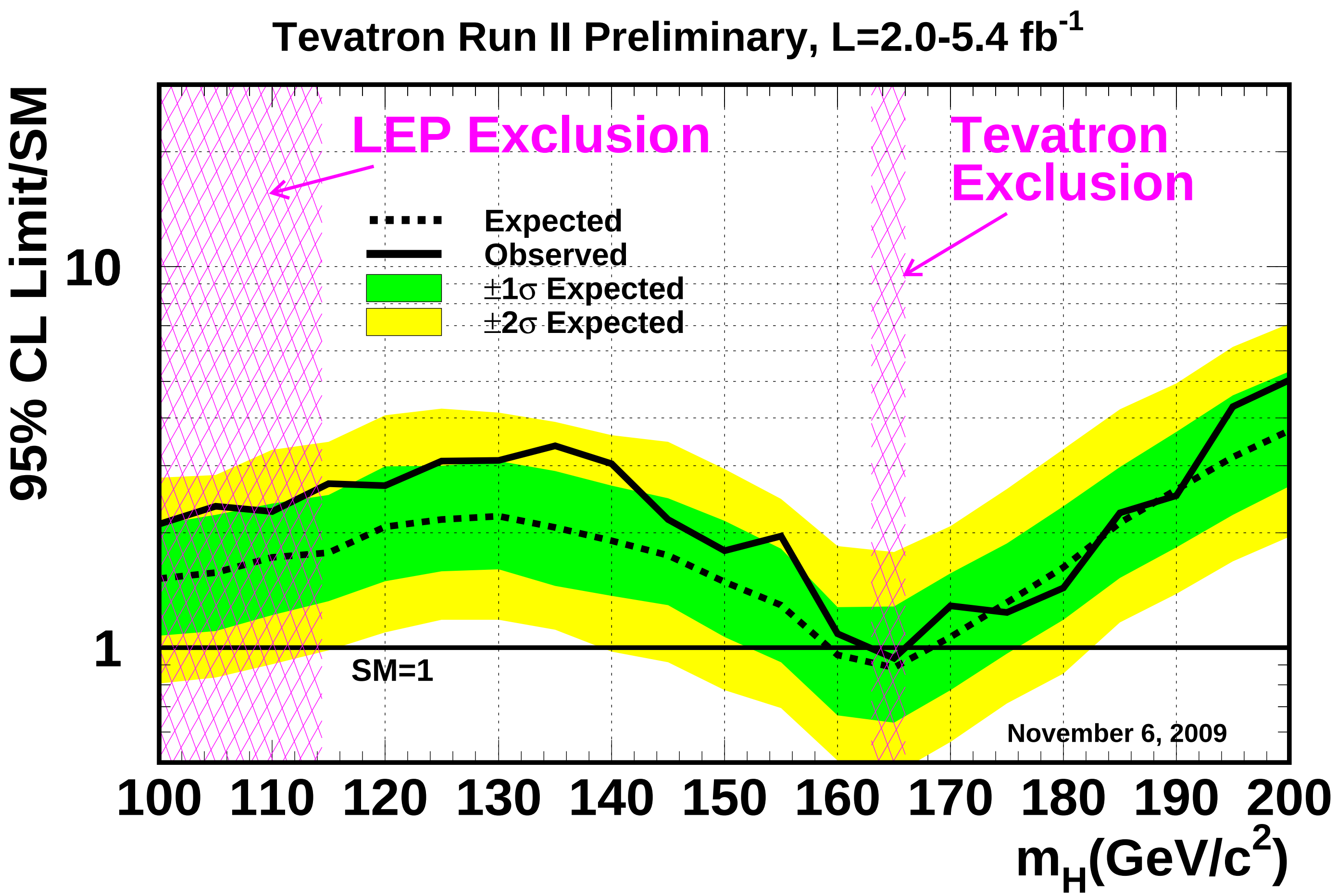
- LEP ($e^+ - e^-$) at CERN (2002) searched for the SM Higgs

  ↪ **Yield a lower limit: $M_H > 114.4$ GeV (C.L. only)**

Search for SM Higgs (CP-Even Scalar)

☐ November, 2009 : Update from CDF and D0 arXiv:0911.3930

Excluded $163 < M_H < 166$ GeV/c^2 (95% C.L. Limit)



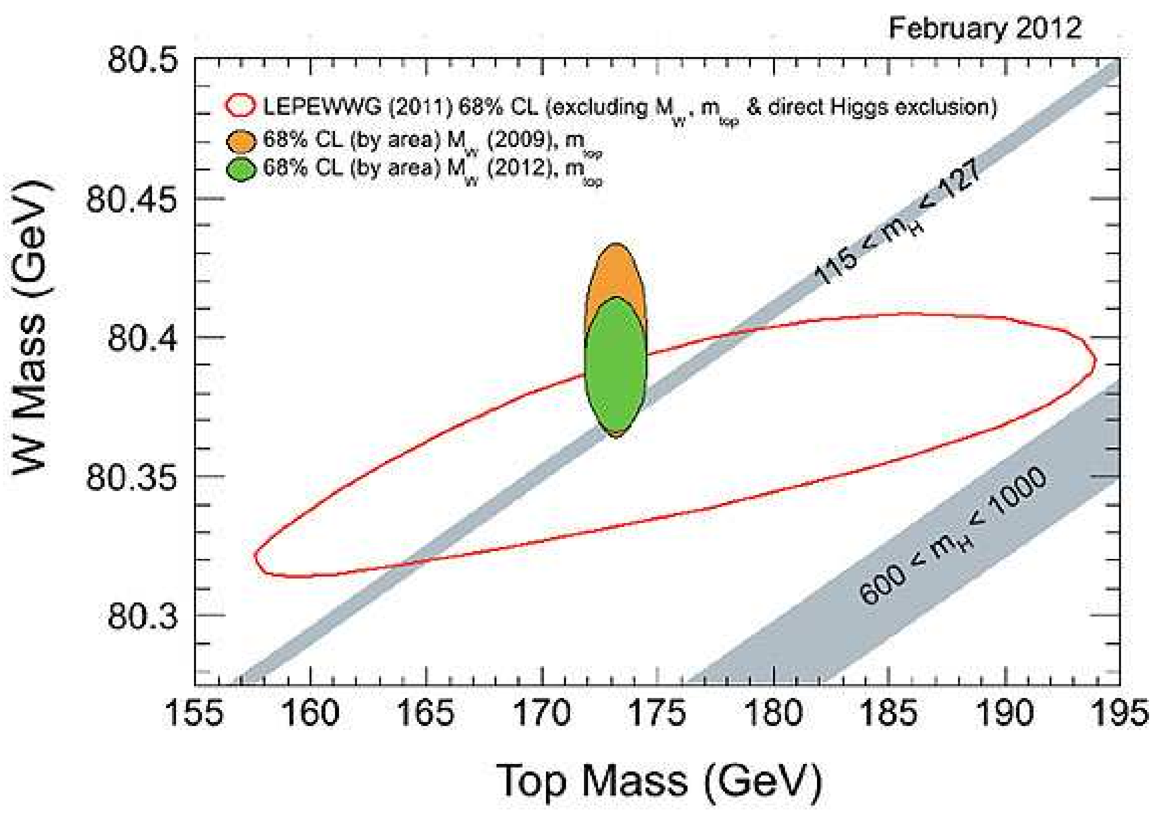
Search for SM Higgs at Tevatron

- February, 2012 : CDF measured the mass of W

$$M_W = 80.347 \pm 0.019 \text{ GeV}/c^2 \text{ (a precision of 0.02\%)}$$

- CDF and LHC results:

$$\text{Allowed } 115 < M_H < 127 \text{ GeV}/c^2$$



NMSSM Higgs PRD 76, 051105, 2007: Dermisek, Gunion, McElrath

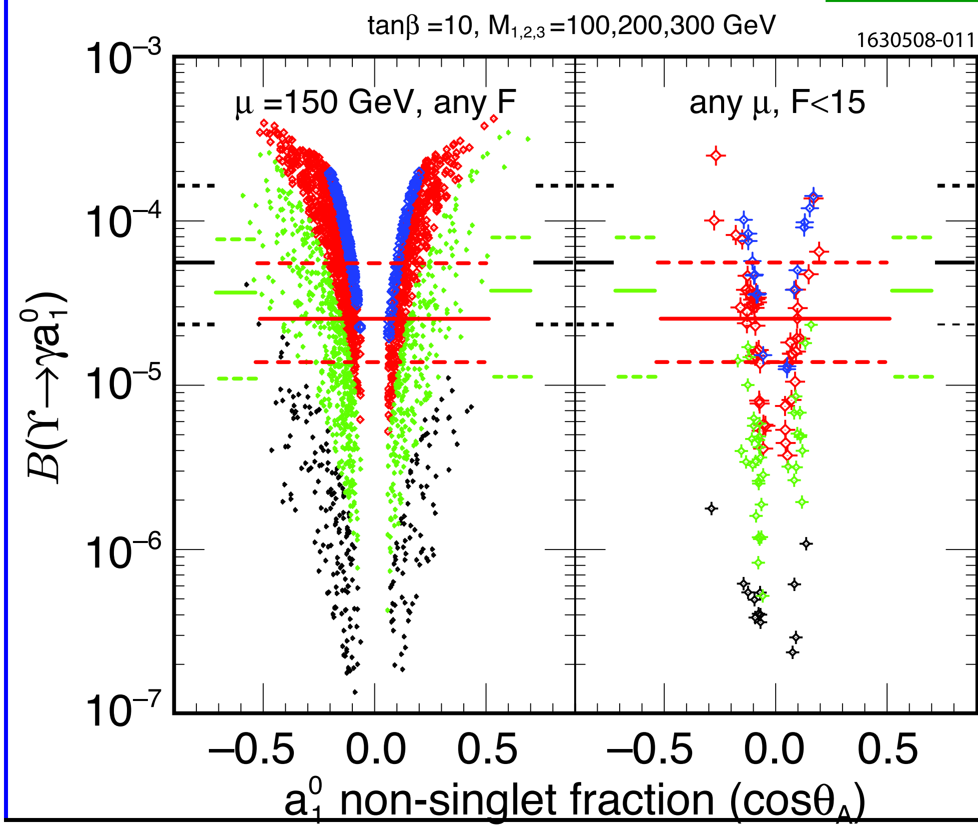
- Next-to-Minimal Supersymmetric Standard Model (NMSSM)

  → Light CP-Odd Pseudoscalar:

$$A^0 \equiv a_1^0 \equiv a_1 = cos\ \theta_A\ a_{MSSM} + sin\ \theta\ a_S$$

- For $m_{a_1} < 2m_b$, the lightest CP-even Higgs (h^0)

$h^0 \rightarrow a_1 a_1$ can avoid LEP limits



F = Electroweak Symmetry Breaking (EWSB) fine tuning

$tan\ \beta$ = ratio of the vacuum expectation values

$m_{a_1} < 2m_\tau$

$2m_\tau < m_{a_1} < 7.5$ GeV

7.5 GeV $< m_{a_1} <$ 8.8 GeV

8.8 GeV $< m_{a_1} <$ 9.2 GeV

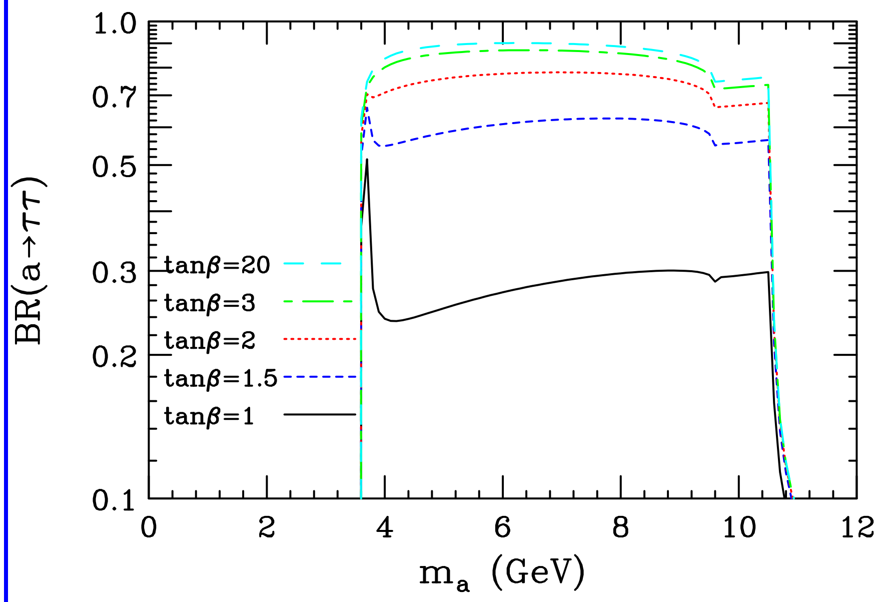
Prediction Higgs A^0: PRD 81, 075003 (2010): Dermisek, Gunion

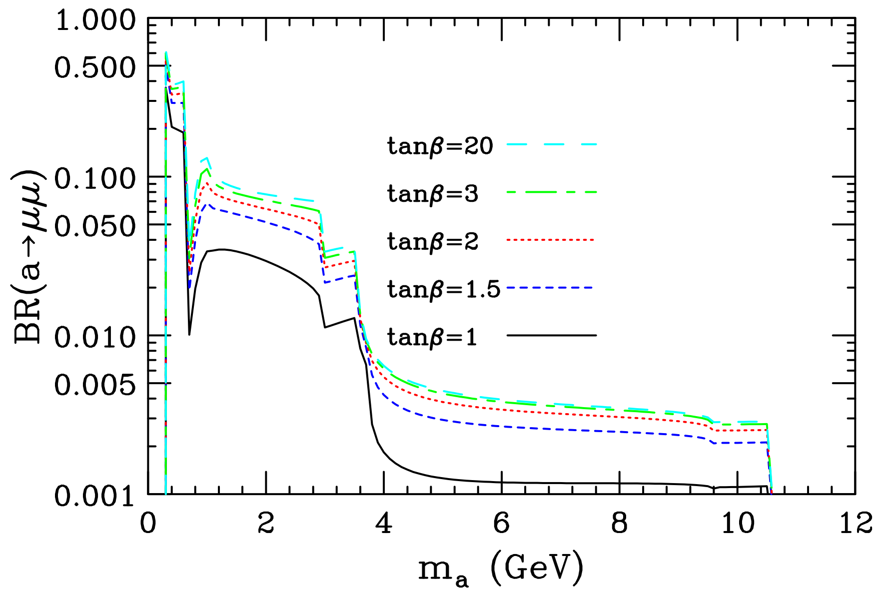
- **At tree-level, $\mathcal{B}(a)$ apply equally to $\mathcal{B}(A^0)$**

  independent of $cos\ \theta_A$ due to the absence of tree-level a

- **$\mathcal{B}(a \to \tau^+\tau^-)$ and $\mathcal{B}(a \to \mu^+\mu^-)$ as a function of $tan\ \beta$**

  $tan\ \beta = h_u/h_d$ = ratio of the vacuum expectation value





- **At $tan\ \beta > 2$, $\mathcal{B}(a \to \tau^+\tau^-)$ and $\mathcal{B}(a \to \mu^+\mu^-)$**

  change very little with increasing $tan\ \beta$ at any given m_a

BABAR Data: $\Upsilon(nS)$

Final BABAR Data

- BaBar data sets:
  - 122 x 10^6 $\Upsilon(3S)$ decays
  - 99 x 10^6 $\Upsilon(2S)$ decays
  - "offpeak" samples of 1.4fb^{-1} and 2.4fb^{-1} collected ~30 MeV below the $\Upsilon(2S)$ and $\Upsilon(3S)$
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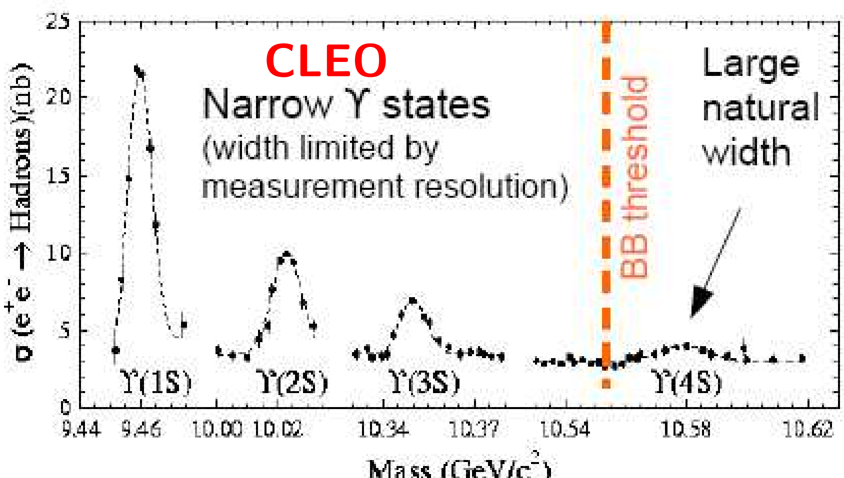
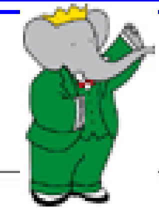
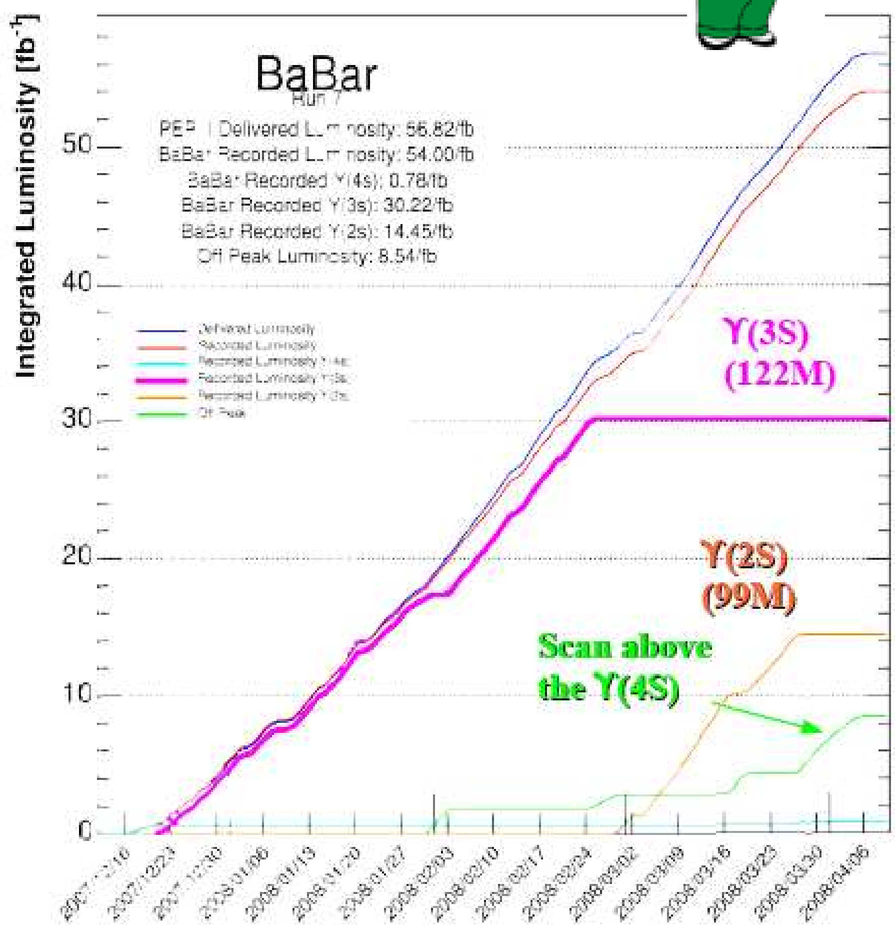






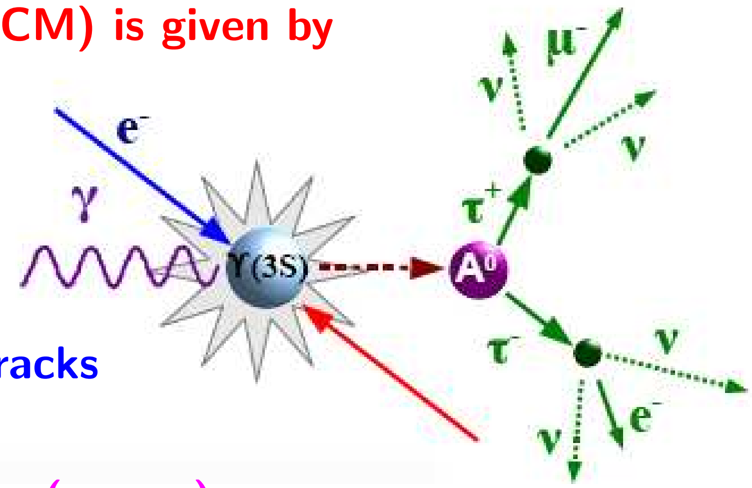
- Trigger requirements modified for narrow Υ data taking

$\Upsilon(3S) \rightarrow \gamma A^0$, $A^0 \rightarrow \tau^+\tau^-$ BABAR

◇ Search for $\Upsilon(3S) \rightarrow \gamma A^0$, $A^0 \rightarrow \tau^+\tau^-$, PRL 103, 181801 (2009)

- The photon energy in the Center-of-Mass (CM) is given by

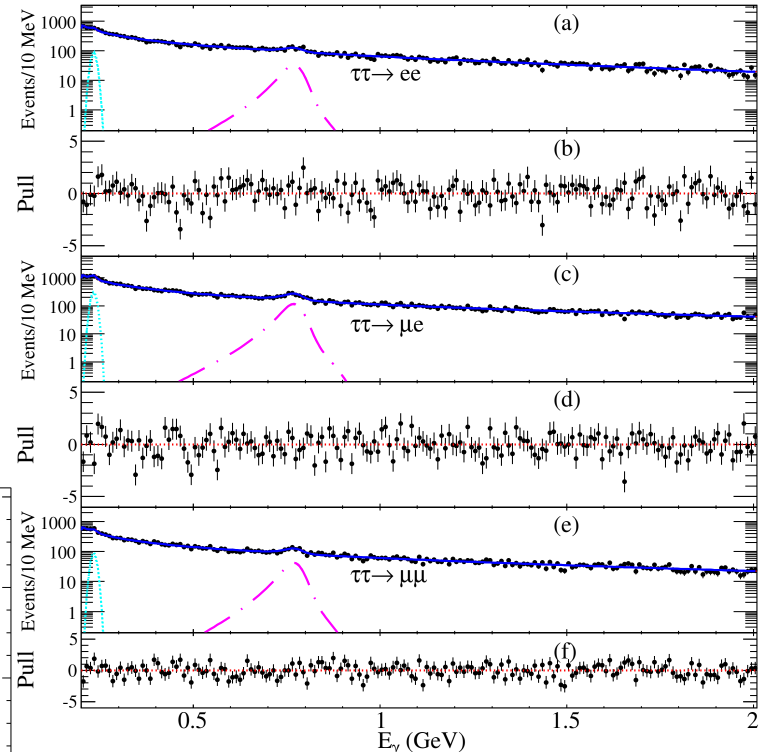
$$E^*_\gamma = \frac{m^2_\Upsilon - m^2_{A^0}}{2m_\Upsilon}$$



- $E_\gamma > 100$ MeV, and exactly two charged tracks
- Both charged tracks are identified as leptons (e or μ)
- Backgrounds
  - $e^+e^- \rightarrow \gamma\tau^+\tau^-$ (mostly)
  - QED process including two photons i.e:
    - ▷ $e^+e^- \rightarrow e^+e^-e^+e^-$
    - ▷ $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$
  - $e^+e^- \rightarrow q\bar{q}$ $(q = u, d, s, c) \rightarrow$ small

$\Upsilon(3S) \to \gamma A^0$, $A^0 \to \tau^+\tau^-$ PRL 103, 181801 (2009) BABAR

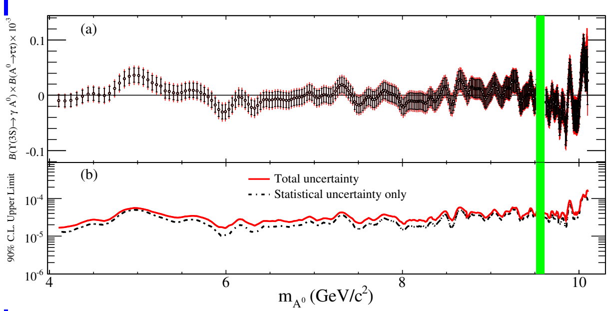
- The residual background is exploited by 8 kinematic and angular variables

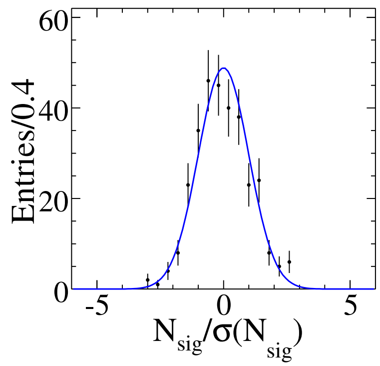


- Peaking contributions
  - $\Upsilon(3S) \to \gamma\ \chi_{bJ}(2P)(J = 0, 1, 2)$

    $\hookrightarrow \chi_{bJ}(2P) \to \gamma\Upsilon(nS)(n = 1, 2)$

    $\hookrightarrow \Upsilon(nS) \to \tau^+\tau^-$





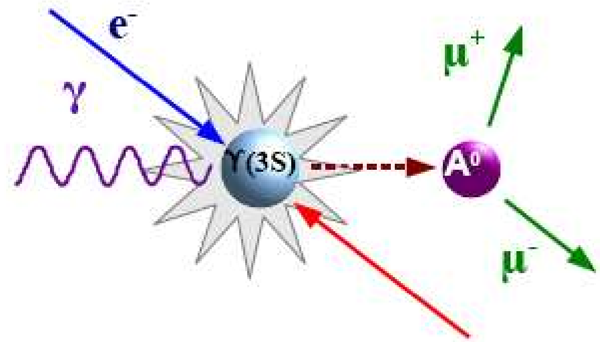
- Search A^0 in E_γ spectrum at $4.03 < m_{A^0} < 10.10$ GeV$/c^2$

$\mathcal{B}(\Upsilon(3S) \to \gamma A^0) \times \mathcal{B}(A^0 \to \tau^+\tau^-) < (1.5 - 16) \times 10^{-5}$ 90% C.L.

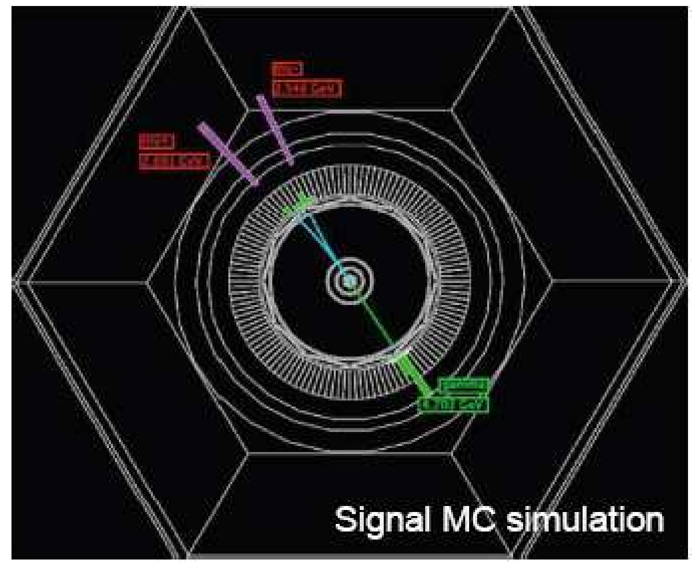
$\mathcal{B}(\eta_b \to \tau^+\tau^-) < 9\%$ at 90% C.L.

$\Upsilon(2S, 3S) \to \gamma A^0$, $A^0 \to \mu^+\mu^-$ BABAR

- Search for A^0 scalar boson in the radiative decays of $\Upsilon(2S)$ and $\Upsilon(3S)$



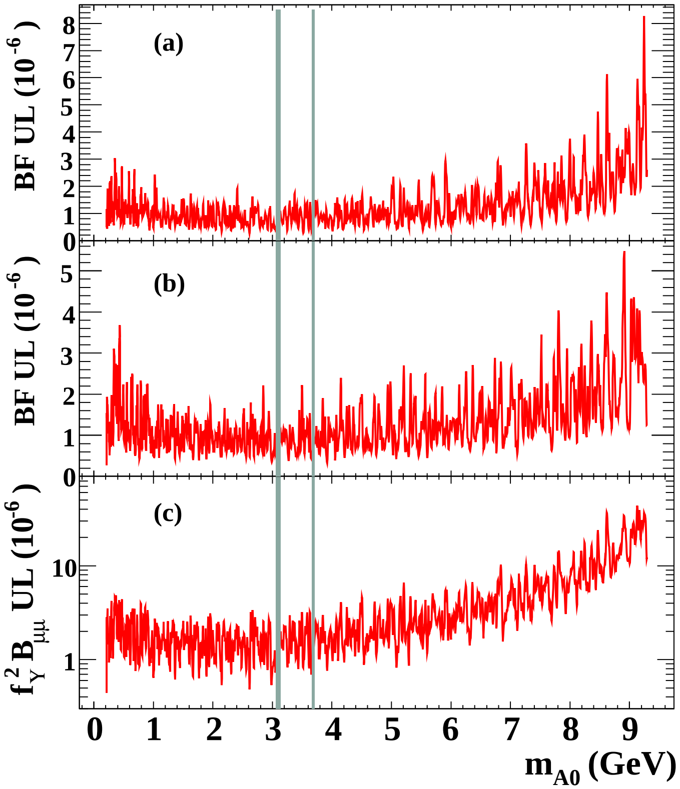
- If A^0 exists its decays depends on its mass
- Assuming no invisible (neutralino) decays $\mathcal{B}(A^0 \to \mu^+\mu^-) \approx$ sizable at low $m_{A^0} < 2m_\tau$



- Require 2 oppositely charged tracks and one γ at least one of which is identified as a muon
- $E_\gamma > 200$ MeV (COM), while allowing additional γ with energy lower than 200 MeV
- Use kinematic fit of $\gamma\mu^+\mu^-$ system, including the beam energy and decay vertex constraints

$\Upsilon(2S,3S) \to \gamma A^0$, $A^0 \to \mu^+\mu^-$, PRL 103, 081803 (2009) BABAR

- Search for A^0 as a function of mass m_{A^0}



Scan range $0.212 < m_{A^0} < 9.3$ GeV

(a) $\mathcal{B}(\Upsilon(2S) \to \gamma A^0) \times \mathcal{B}_{\mu\mu}$

(b) $\mathcal{B}(\Upsilon(3S) \to \gamma A^0) \times \mathcal{B}_{\mu\mu}$

(c) $f_\Upsilon^2 \times \mathcal{B}_{\mu\mu}$

$\mathcal{B}(\Upsilon(nS) \to \gamma A^0)$ are related to the effective

Yukawa coupling f_Υ of bound b quark to A^0

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

- Shaded area is excluded from the search around the J/ψ and $\psi(2S)$ resonances
- No signal observed at $m_{A^0} \sim 214$ MeV

Significant positive fluctuation of $\Upsilon(3S) \sim 2.8\sigma$ and $\Upsilon(2S) \sim 3.1\sigma$

$\mathcal{B}(\eta_b \to \mu^+\mu^-) < 0.9\%$ at 90% C.L.

CKM Matrix

- In SM, quark can change flavor by weak interactions:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Cabibbo-Kobayashi-Maskawa (CKM) matrix

[Weak eigenstates] = [V_{CKM}] [quark mass eigenstates]

The CKM matrix contains complex numbers

- **Wolfenstein's CKM matrix form:**

$$V_{CKM} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

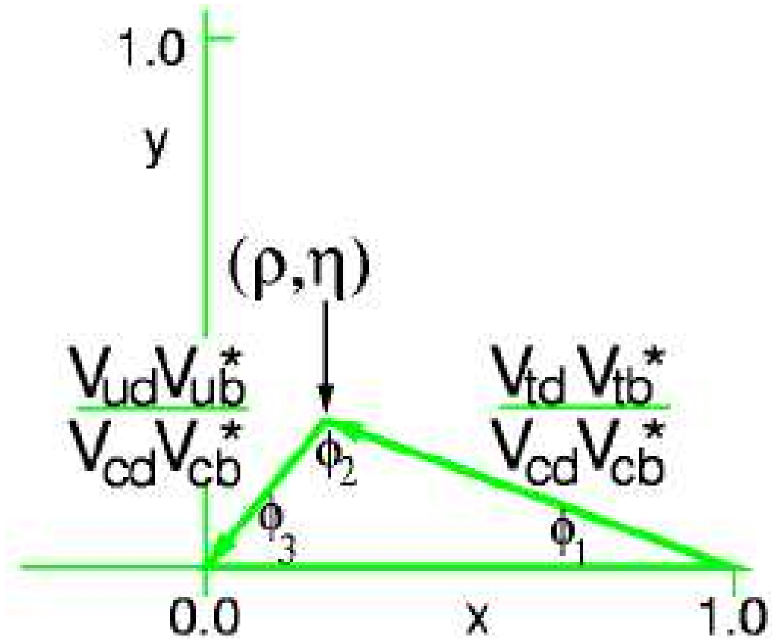
- $\lambda \sim$ 0.22 (expansion parameter)
- A, ρ, and η can be measured in B decays

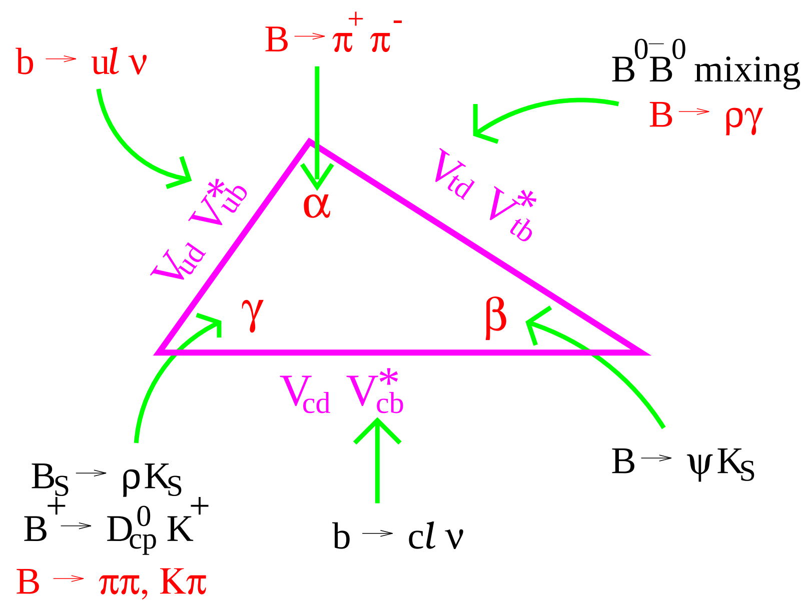
Unitarity Triangle (UT)

- By applying the Unitarity condition (scalar product of any two rows or columns):

$$V_{ub}^{*}V_{ud} + V_{cb}^{*}V_{cd} + V_{tb}^{*}V_{td} = 0$$

- CKM matrix can be presented in the complex plane → Unitarity Triangle (UT)

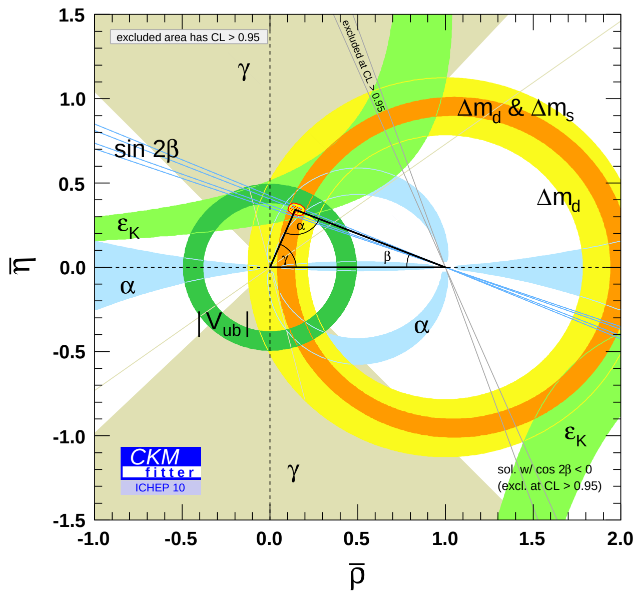


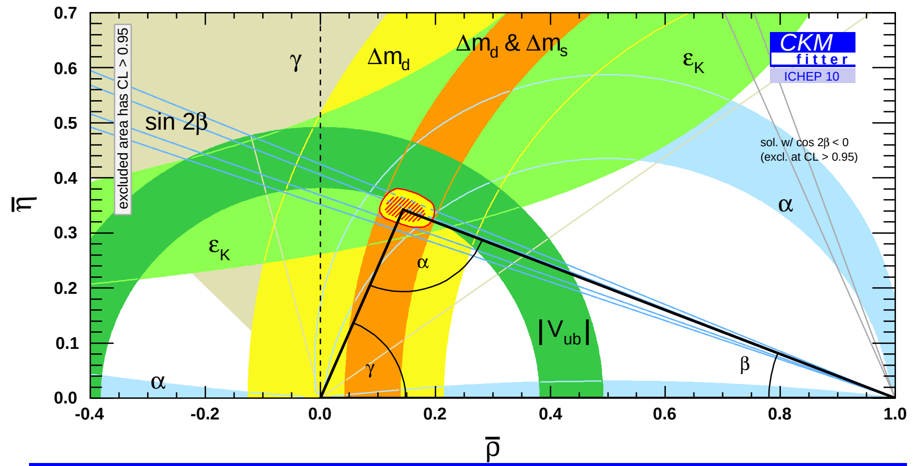


- It is very important to measure the CKM angles and its sides!
- We need to measure them precisely in order to search for New Physics

→ Deviation from the Standard Model will signal New Physics!

Status of UT Triangle





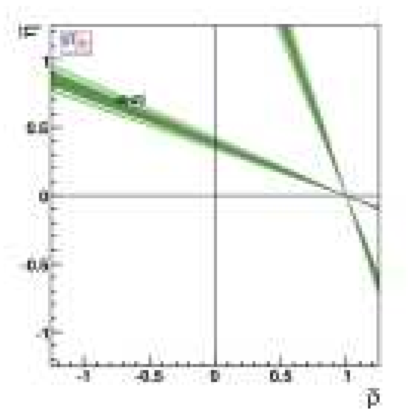
Constraints in the $\bar{\rho} - \bar{\eta}$ plane

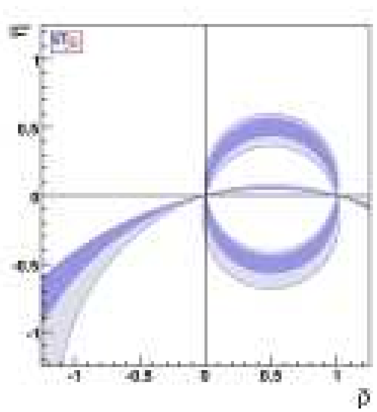
Zoomed constraints in the $\bar{\rho} - \bar{\eta}$ plane

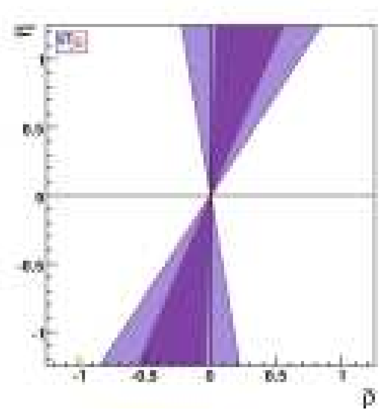
Precision $\beta \approx 1^o$

Precision $\alpha \approx 4^o$

Precision $\gamma \approx 14^o$

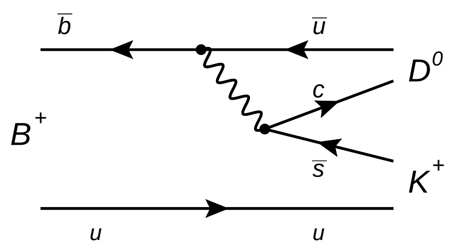


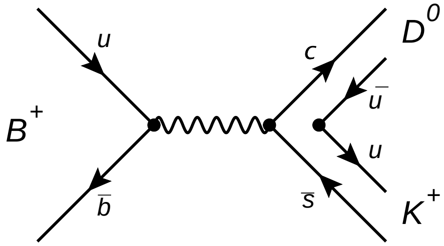




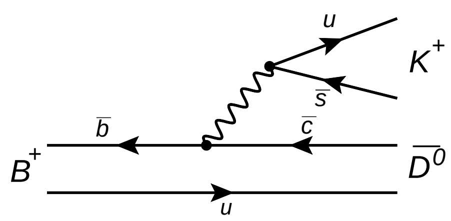
Measuring Angle γ

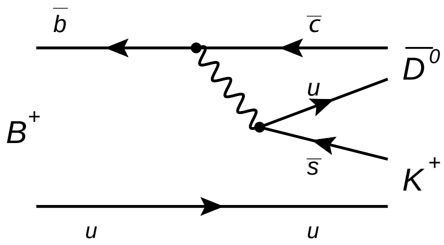
- **Interference between $b \to c\bar{u}s$ and $b \to u\bar{c}s$ tree amplitudes**





$b \to c\bar{u}s$ transition: $B^+ \to D^0 K^+$





$b \to u\bar{c}s$ transition: $B^+ \to \bar{D}^0 K^+$

- **GLW: Cabibbo-suppressed $D \to$ CP-eigenstates $(K^+K^-, \pi^+\pi^-)$**
  Gronau, London, Wyler: PLB 253, 1991 & PLB 265, 1991

- **ADS: $D \to$ Cabibbo-favored and doubly-Cabibbo-suppressed $(K^\pm\pi^\mp)$**
  Atwood, Dunietz, Soni: PRL 78, 3257, 1997

- **GGSZ: Cabibbo-favored $D \to$ self-conjugate $(K_s^0\pi^+\pi^-, K_s^0K^+K^-)$**
  Giri, Grossman, Soffer, Zupan: PRD 68 054018, 2003 $\to$ time limited

GLW on $B^{\pm} \to DK^{\pm}$ PLB 253, 1991 & PLB 265, 1991

- In GLW method the D^0 mesons are reconstructed:
  - $CP+: D^0 \to K^+K^-, \pi^+\pi^-$
  - $CP-: D^0 \to K^0_s\pi^0, K^0_s\omega, K^0_s\phi$

  $\to D_{CP\pm}$ = CP eigenstates of D system

- Two direct CP-violating partial decay rate asymmetries:

$$A_{CP\pm} \equiv \frac{\Gamma(B^- \to D_{CP\pm}K^-) - \Gamma(B^+ \to D_{CP\pm}K^+)}{\Gamma(B^- \to D_{CP\pm}K^-) + \Gamma(B^+ \to D_{CP\pm}K^+)}$$

$\to \Gamma$ = partial decay width

- Two ratios of charged averaged partial rates:

$$R_{CP\pm} \equiv 2\frac{\Gamma(B^- \to D_{CP\pm}K^-) + \Gamma(B^+ \to D_{CP\pm}K^+)}{\Gamma(B^- \to D^0K^-) + \Gamma(B^+ \to \bar{D}^0K^+)}$$

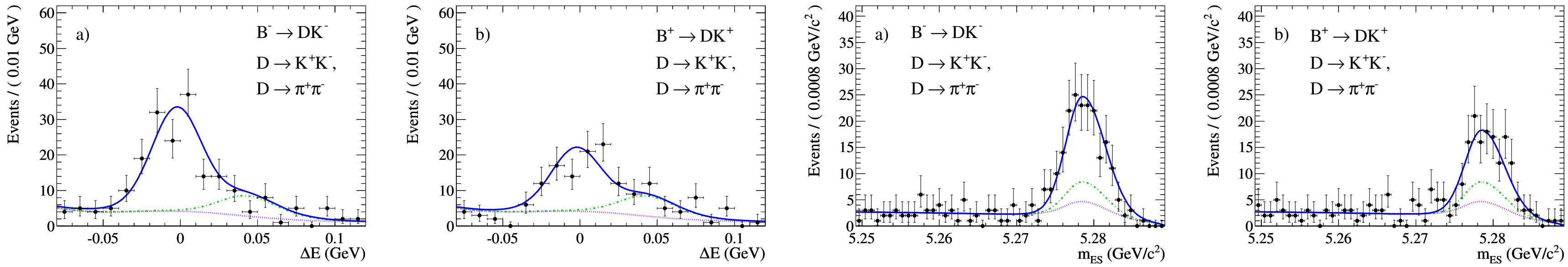
- Then γ can be extracted from the other two unknowns variables δ_B and r_B:

$$R_{CP\pm} = 1 + r_B^2 \pm 2r_B cos\delta_B cos\gamma \qquad A_{CP\pm} = \frac{\pm 2r_B sin\delta_B sin\gamma}{1 + r_B^2 \pm 2r_B cos\delta_B cos\gamma}$$

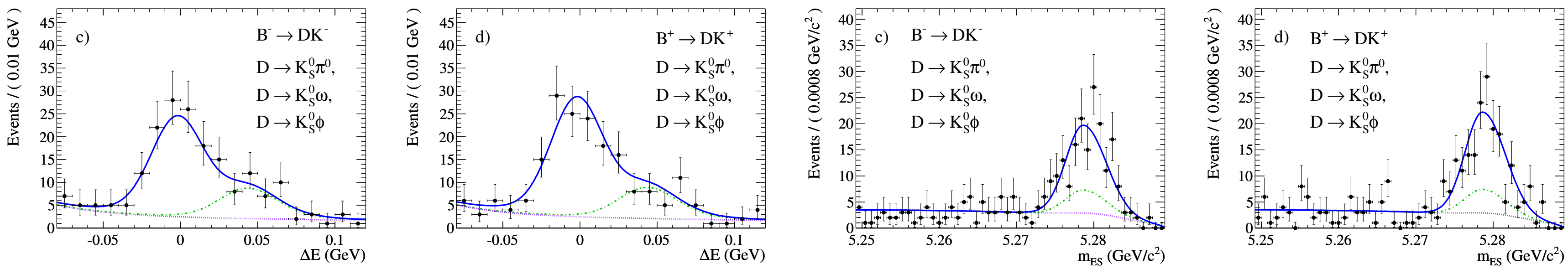
- δ_B = the difference of their strong phases
- r_B = the magnitude of the ratio of the amplitudes for each decay

$$r_B \equiv \frac{|A(B^- \to \bar{D}^0K^-)|}{|A(B^- \to D^0K^-)|}$$

- ML fit to $\Delta E, m_{ES}$, and Fisher (event shape variable)



$CP+$: ΔE $CP+$: m_{ES}



$CP-$: ΔE $CP-$: m_{ES}

- GLW: Cabibbo-suppressed $D \to$ CP-eigenstates $(K^+K^-, \pi^+\pi^-)$

  Gronau, London, Wyler: PLB 253, 1991 & PLB 265, 1991

- Blue line: full PDF, Green: $B \to D\pi$, Purple: remaining backgrounds

- $B \to DK$ contribution: the region between blue and green

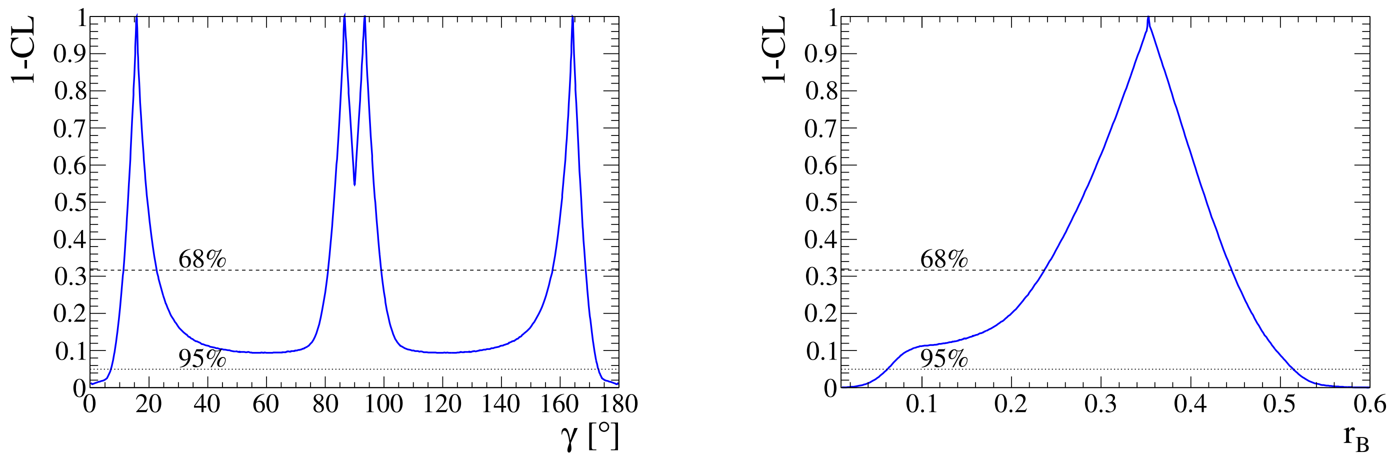
GLW BABAR Continue... PRD 82 072004, 2010

- Using BABAR Data: 425 fb^{-1} (467 M $B\overline{B}$)

$$A_{CP+} = 0.25 \pm 0.06 \pm 0.02 \qquad A_{CP-} = -0.09 \pm 0.07 \pm 0.02$$

$$R_{CP+} = 1.18 \pm 0.09 \pm 0.05 \qquad R_{CP-} = 1.07 \pm 0.08 \pm 0.04$$

- Direct CP-Violation on $B^{\pm} \to DK^{\pm}$: $A_{CP}+$ at 3.6σ from zero



- At 68% CL: angle γ mod 180^o belongs to one of the three intervals:

  $(11.3,\ 22.7^o)$, $(80.8^o,\ 99.2^o)$, $(157^o,\ 168.7^o)$

- At 68% CL: $0.24 < r_B < 0.45$

ADS on $B^{\pm} \to DK^{\pm}$ Theory: PRL 78, 3257, 1997

☐ In ADS method (D. Atwood, I Dunietz, A Soni)

- $B^+ \to \bar{D}^0 K^+ \to \bar{D}^0 \to K^- \pi^+$ [doubly-Cabbibo-suppressed]

  (interferes with $\Leftrightarrow$)

- $B^+ \to D^0 K^+ \to D^0 \to K^- \pi^+$ [Cabbibo-favored]

  $\Longrightarrow$ Opposite-sign (OS) because two kaons have opposite charges

☐ Define same-sign (SS) events:

- $B^+ \to \bar{D}^0 K^+ \to \bar{D}^0 \to K^+ \pi^-$ [Cabbibo-favored]

☐ BABAR published 2 results where D^0 are reconstructed:

- $D^0 \to K^+ \pi^-$; Data: 467×10^6 $B\overline{B}$ $\to$ PRD 82 072006, 2010
- $D^0 \to K^+ \pi^- \pi^0$; Data: 474×10^6 $B\overline{B}$ $\to$ PRD 84 012002, 2011

ADS on $B^{\pm} \rightarrow DK^{\pm}$ Continue...

- Extract new set of variables:
  - $R^{+} = \frac{\Gamma(B^{+}\rightarrow[K^{-}\pi^{+}]K^{+})}{\Gamma(B^{+}\rightarrow[K^{+}\pi^{-}]K^{+})} \equiv \frac{opposite\ sign\ yield}{same\ sign\ yield}$ from B^{+}
  - $R^{-} = \frac{\Gamma(B^{-}\rightarrow[K^{+}\pi^{-}]K^{-})}{\Gamma(B^{-}\rightarrow[K^{-}\pi^{+}]K^{-})} \equiv \frac{opposite\ sign\ yield}{same\ sign\ yield}$ from B^{-}
- Neglecting D-mixing effects the ratios R^{+} and R^{-} can be written as

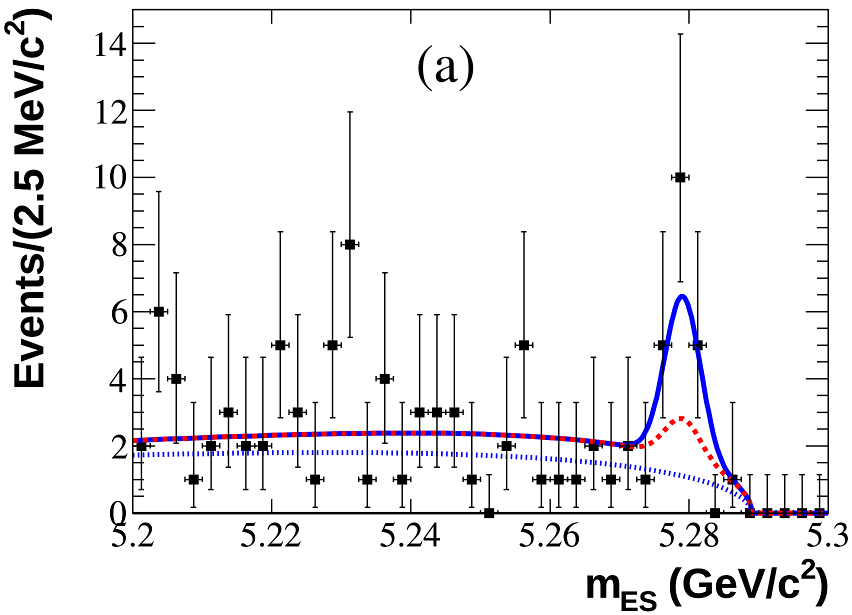
$$R^{+} = r_B^2 + r_D^2 + 2 r_B r_D k_D\ cos(\gamma + \delta_B + \delta_D)$$

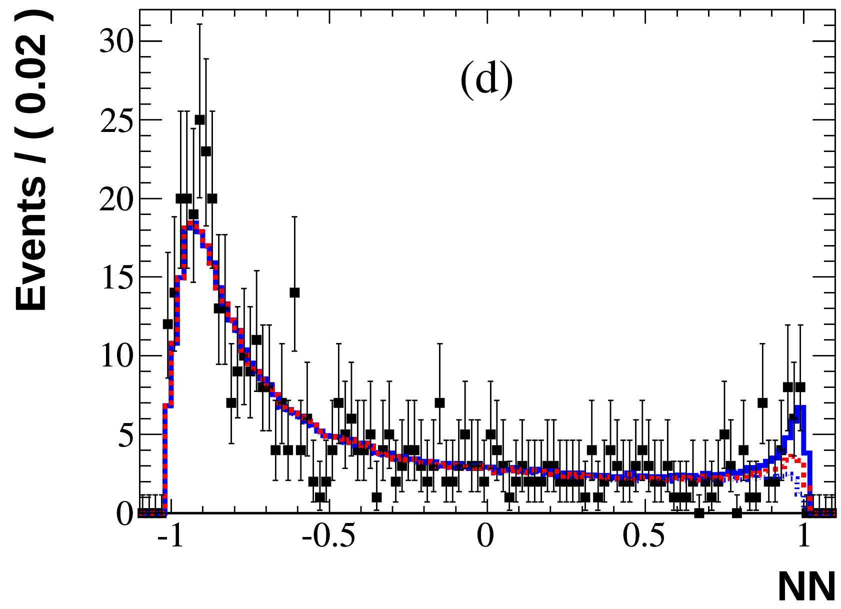
$$R^{-} = r_B^2 + r_D^2 + 2 r_B r_D k_D\ cos(\gamma - \delta_B + \delta_D)$$

- where
  - $r_B \equiv \frac{|A(B^{+}\rightarrow D^{0}K^{+})|}{|A(B^{+}\rightarrow \bar{D}^{0}K^{+}))|} = 0.106 \pm 0.016$ $\quad r_D^2 = \frac{\Gamma(D^{0}\rightarrow K^{+}\pi-)}{\Gamma(D^{0}\rightarrow K^{-}\pi^{+})} = (2.2 \pm 0.1) \times 10^{-3}$
  - δ_B and $\delta_D = (47^{+14}_{-17})^{o}$ are CP conserving strong phase
  - γ is CP violating weak phase
  - k_D is the coherence factor between 0 to 1: $k_D = 0.84 \pm 0.07$
  - k_D and δ_D were measured from CLEOc

ADS Results on $D^0 \to K^+\pi^-$ PRD 82 072006, 2010

- Simultaneous fit to m_{ES} and NN (event shape and tagging variables)





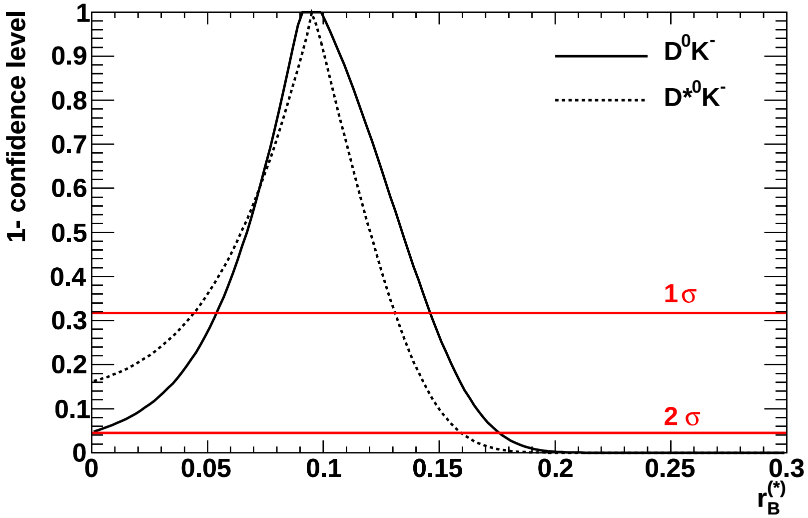
m_{ES}: opposite-sign $B^+ \to D^0K^+$ | NN: opposite-sign $B^+ \to D^0K^+$

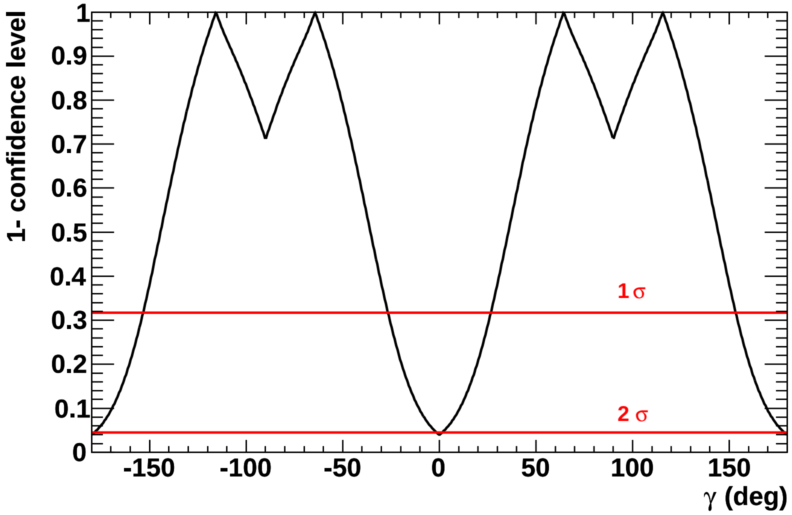
- Solid-blue: Full PDF, Red: sum of all bkgs, Dotted-blue: $q\bar{q}$ background
- ADS $B^\pm \to DK^\pm$ results:

$$R^+ = (2.2 \pm 0.9 \pm 0.3) \times 10^{-2} \qquad R^- = (0.2 \pm 0.6 \pm 0.2) \times 10^{-2}$$

ADS BABAR Results Continue...

- This measurement allowed us to extract variables: r_B and γ





Constraints on $r_B^{(*)}$: $B^- \to D^{(*)}K^-$

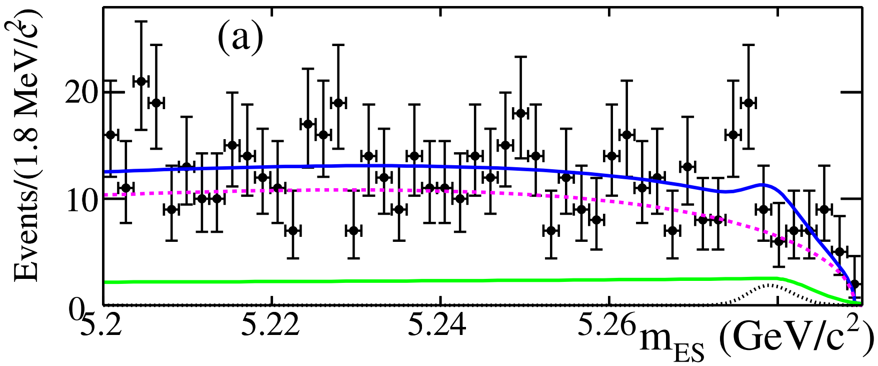
C.L. curve as a function of γ

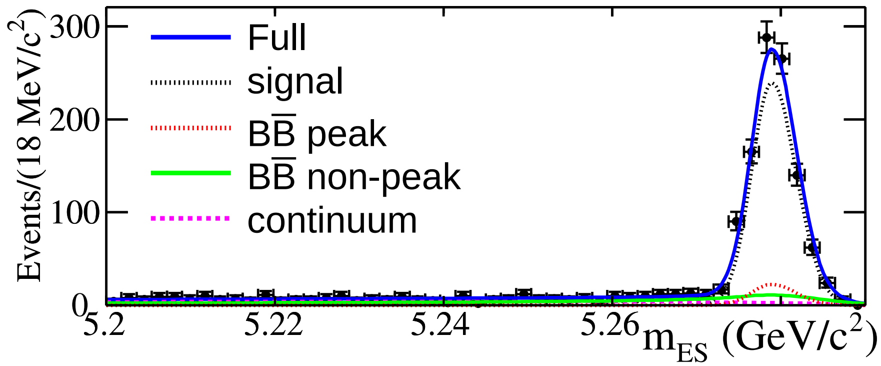
- For γ result: combining $B \to DK$ and D^*K
- The variables $r_B^{(*)}$ can be extracted:

$$r_B = (9.5^{+5.1}_{-4.1})\% \qquad r_B^* = (9.6^{+3.5}_{-5.1})\%$$

ADS Results on $D^0 \to K^+\pi^-\pi^0$ PRD 84 012002, 2011 (NEW)

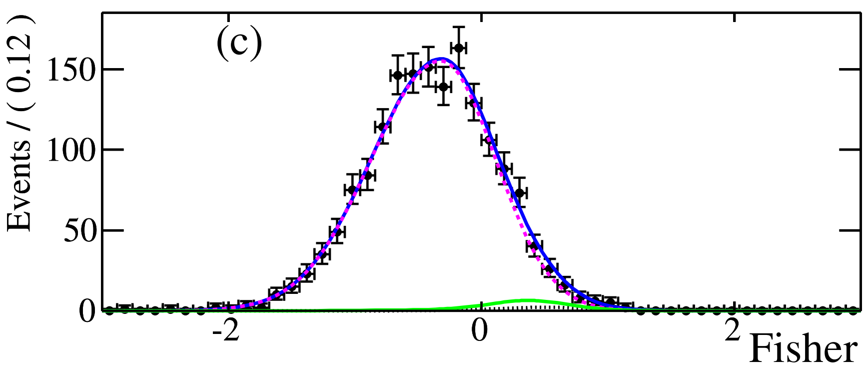
☐ **Simultaneous fit to m_{ES} and Fisher: OS ≈ 20 events; SS ≈ 2000 events**

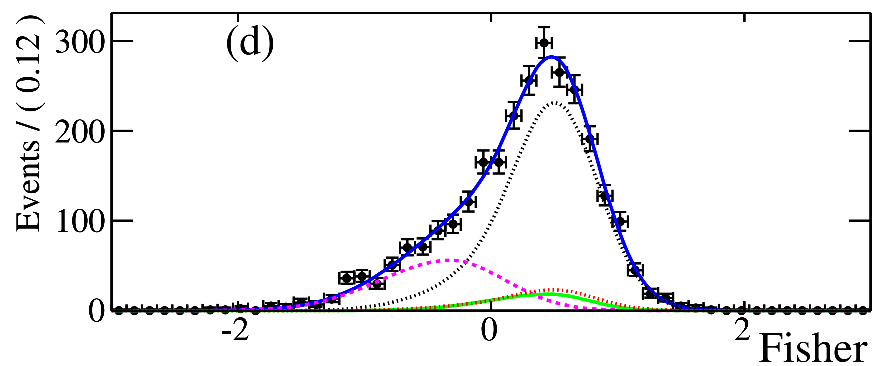




m_{ES}: opposite-sign with F > 0.5

m_{ES}: same-sign with F > 0.5



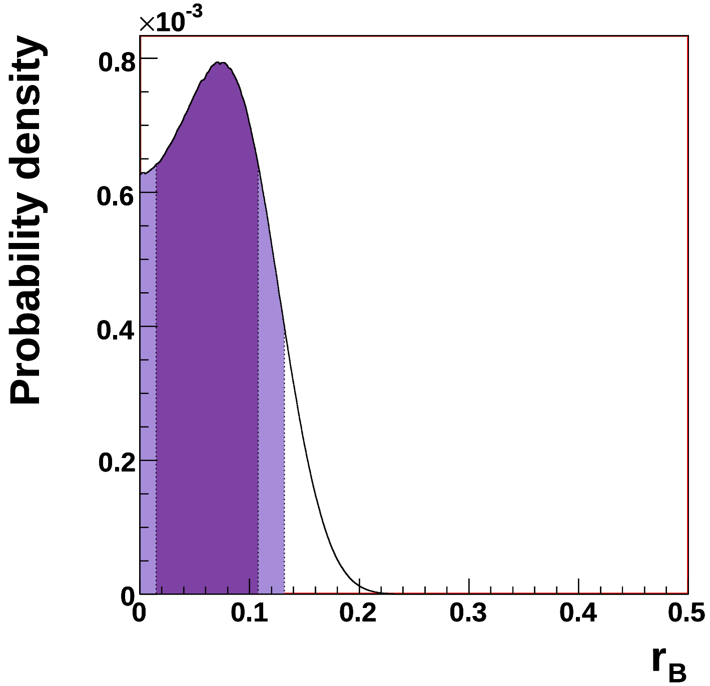


Fisher: OS $m_{ES} > 2.27$ GeV$/c^2$

Fisher: SS $m_{ES} > 2.27$ GeV$/c^2$

ADS Results on $D^0 \to K^+\pi^-\pi^0$ PRD 84 012002, 2011 (NEW)

- ADS results on r_B:



Bayesian probability density function for r_B

Dark: $0.01 < r_B < 0.11$ at 68% probability

Light: $r_B < 0.13$ at 90% probability

$\to$ Subject to small r_B, this measurement has less precision for γ result

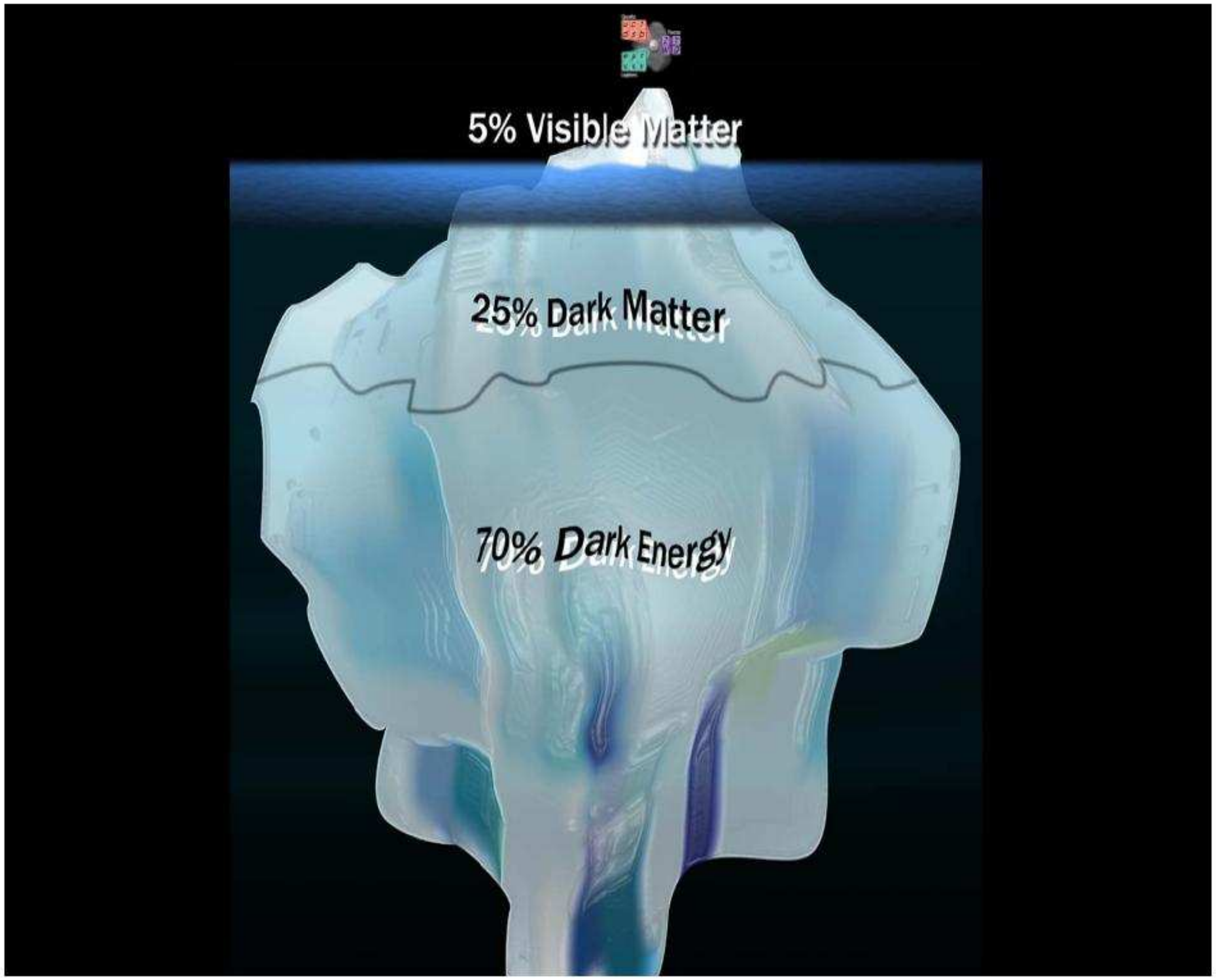
- New results on R^+ and R^- (statistical limited):

$$R^+ = (5^{+12+1}_{-10-4}) \times 10^{-3} \qquad R^- = (12^{+12+2}_{-10-4}) \times 10^{-3}$$

- At 90% probability limit:

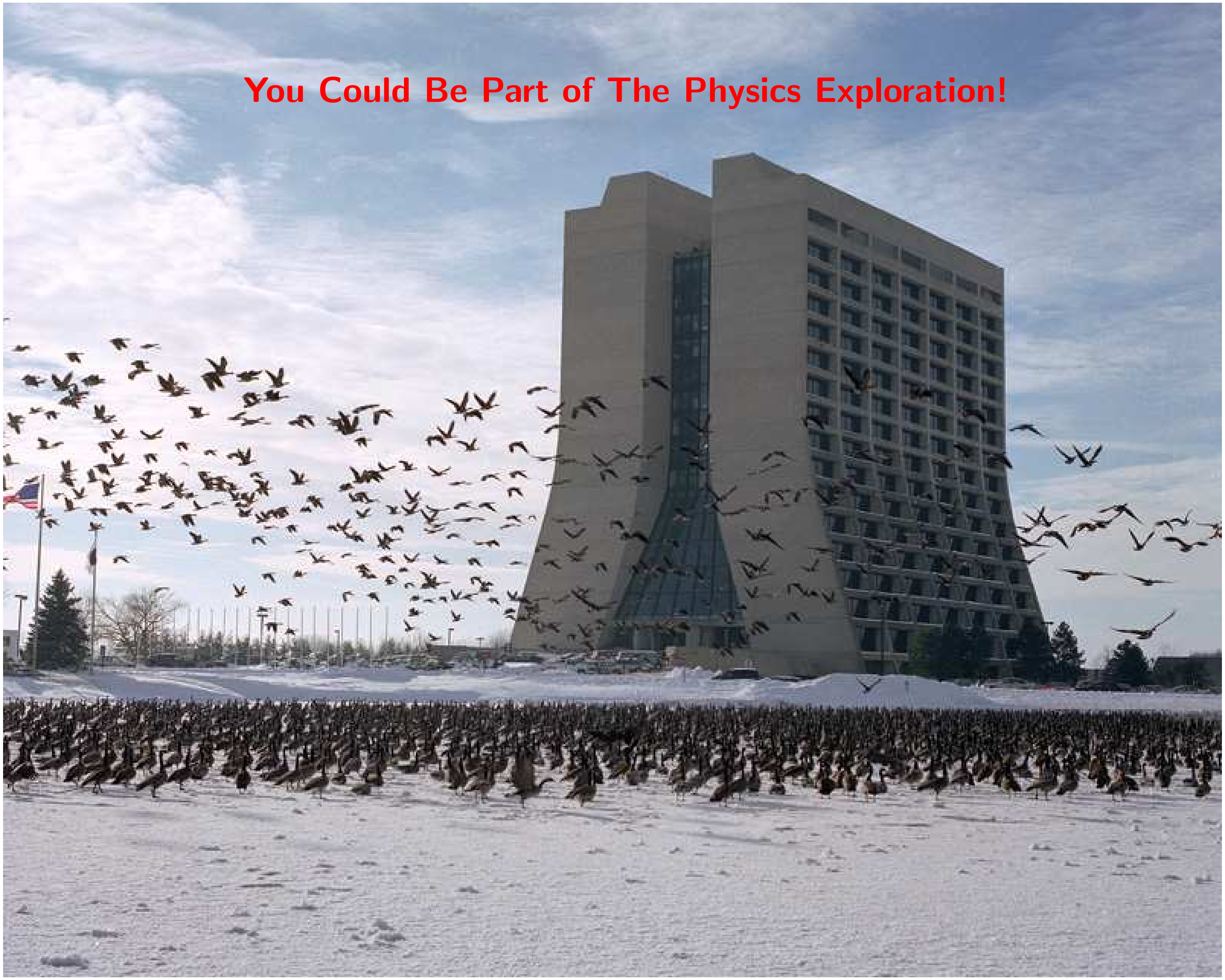
$$R^+ < 23 \times 10^{-3} \qquad R^- < 29 \times 10^{-3}$$

SUMMARY: Where Are We Now?



★ **A lot of things need to be discovered**

We Are Not Alone



T H A N K   Y O U!