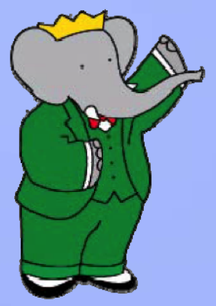
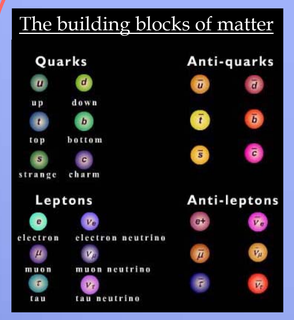


The BaBar experiment: A Beautiful Legacy to Particle Physics

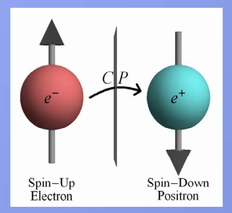
by Eugenia Maria Teresa Irene Puccio (University of Warwick)

Matter vs. anti-matter

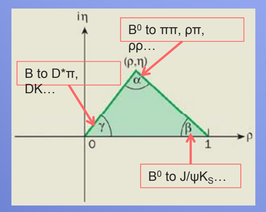


• *The unsolved physics problem:* Why does the universe have more matter than anti-matter, rather than equal amounts?
• The existence of CP violation is one of the Sakharov conditions that is key to explaining the matter and anti-matter asymmetry in the universe.
• CP is the combination of two fundamental symmetries:

- Charge conjugation(**C**): transforming a particle into its anti-particle.
- Parity(**P**): creating the mirror image in space of a physics system.



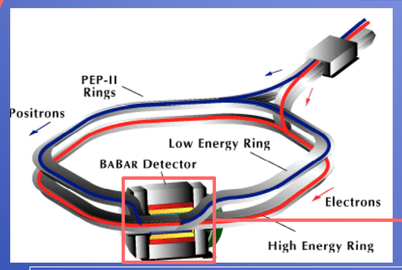
• Quark mixing, originally proposed by Cabibbo in 1963, was extended in 1972 by Kobayashi and Maskawa to explain CP violation, a hypothesis introducing for the first time the third quark generation.



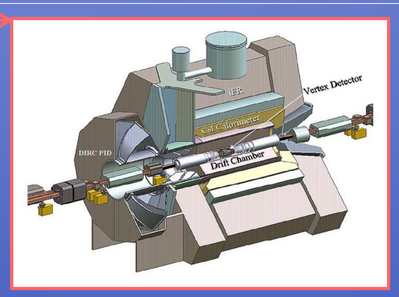
• The probability for each quark to mix is described by a 3x3 matrix called the Cabibbo-Kobayashi-Maskawa (CKM) matrix, the imaginary elements of which lead to CP violation.
• The CKM matrix is schematically represented as a triangle where, by measuring angles and sides, can determine two of the parameters.
• The area of the triangle gives the amount of CP violation.

The BaBar collaboration devoted many years to the measurement of CP violation in the B meson system and the parameters of the CKM matrix.

The BaBar detector



• *Vertex detector:* Provide precise position and momentum information on charged particle tracks.
• *Drift Chamber:* Main momentum measurement for charged particles and helps particle identification through energy loss measurements.

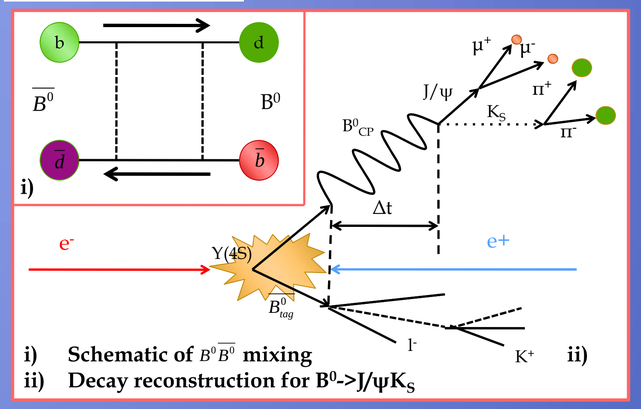


• *Cherenkov light detector:* Used to identify different type of particles.
• *Electromagnetic Calorimeter:* Identifies electrons and neutral particle by measuring energy deposition.
• *Instrumented Flux Return:* provides muon and neutral particles identification.

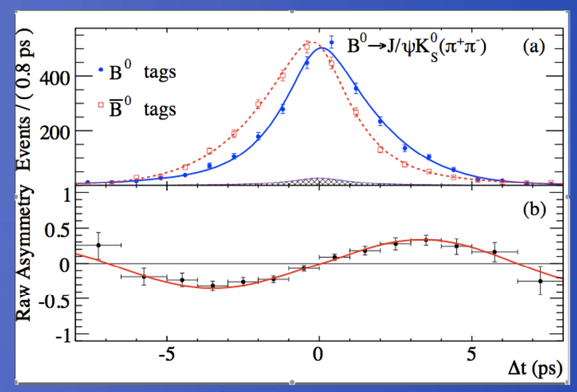
BaBar and the Golden Mode for sin(2β)

• The centrepiece of these studies is to look for an asymmetry between the decays of two neutral B mesons into a final state such as J/ψ ($c\bar{c}$ quark pair) and a short-lived K meson ($d\bar{s}$ quark pair).
• This mode is considered the "golden" mode to measure the angle β because the resulting state has well defined CP properties and the decay is experimentally easy to identify.

The measurement:



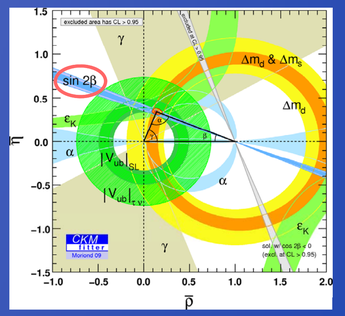
i) **Schematic of $B^0\overline{B^0}$ mixing**
ii) **Decay reconstruction for B^0->J/ψK_S**



Results extracted from Physical Review D 79: 072009

a) Flavour of B^0_{tag} particle is determined from reconstruction and the number of candidates in signal region is plotted for B^0_{tag} and $\overline{B^0_{tag}}$.
b) A clear asymmetry is observed between the number of events with B^0 and opposite $\overline{B^0}$ tag as a function of Δt. The amplitude of the oscillation curve is proportional to sin(2β).

$$\sin(2\beta) = 0.687 \pm 0.030$$



• All angles and sides measurements are combined within their respective error bands in the adjacent plot.
• All measurements intersect at a common apex point showing excellent consistency with the theoretical particle physics model.

The BaBar experiment made numerous measurements of the parameters of the CKM matrix and confirmed symmetry violation in the B system, exactly as was predicted by Kobayashi and Maskawa in 1972. The Nobel Prize for Physics was finally awarded to them in 2008.