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Particle physics: Time's arrow in B mesons

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NATURE | RESEARCH HIGHLIGHTS

PARTICLE PHYSICS Time's arrow in B mesons

BOTANY Plant fertilization protein found

CLIMATE CHANGE Carbon drop in snail shell shock

ZOOLOGY Blue whales...

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The arrow of time: Backward ran sentences...

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The Economist

The arrow of time
Backward ran sentences...

To the relief of physicists, time really does have a preferred direction

Sep 1st 2012 | from the print edition

TIME seems to flow inexorably in one direction. Superficially, that is because things deteriorate with

...behaviour in isolation the past and the future are hard to

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Physics World reveals its top 10 breakthroughs for 2012

physicsworld.com

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Physics World reveals breakthroughs for 2012

Dec 14, 2012 9:18 comments

The Physics World award for the

PARTICLE PHYSICS

Time's arrow in B mesons

Nature 491, 640 (2012)

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Subject terms: Particle physics

A cornerstone of the way forwards in time

Members of the BABAR collaboration at the SLAC National Accelerator Laboratory researchers identified a direct comparison of the

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Physics - Particle Decays Point to an Arrow of Time

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Viewpoint: Particle Decays Point to an Arrow of Time

Michael Zetler, Department of Physics, Yale University, New Haven, CT 06520, USA

Published November 19, 2012 | Physics 5, 129 (2012) | DOI: 10.1103/Physics.5.129

An experiment studying B meson decays makes a direct observation of time-reversal violation without relying on assumed relationships with other fundamental symmetries.

Time moves irrevocably in one direction. Things get old, decay, and fall apart, but they rarely ever reassemble and grow young. But at the particle level, time's arrow is not so clearly defined. Most collisions and other particle interactions look the same whether run forwards or backwards. Physicists have, however, identified a few reactions that appear to change when time is reversed, but the reasoning has assumed certain relations between fundamental symmetries of particle physics. The BABAR collaboration has now observed time-reversal violation directly and unambiguously in decays of B mesons. The measured asymmetry, reported in *Physical Review Letters* [1], is statistically significant and consistent with indirect observations.

In trying to understand the nature of particle interactions, observing the behavior of those interactions under different symmetry transformations has proven invaluable in formulating and verifying the fundamental theory. It is well known, and has been experimentally shown, that the strong and electromagnetic interactions are unchanged when viewed in a mirror world in which particle positions are reflected (\vec{r} to $-\vec{r}$). In contrast, experiments in 1964 [2] demonstrated that the weak interaction is not invariant under such mirror inversions. In a similar

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

J. P. Lees et al. (The BABAR Collaboration)

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

Published November 19, 2012 | PRL (free)

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Time-reversal asymmetry in particle physics

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Time-reversal asymmetry in particle physics has finally been clearly seen

Bertram M. Schwarzschild

November 2012, page 16

DIGITAL OBJECT IDENTIFIER

http://dx.doi.org/10.1063/PT-3.1774

Bedrock theory has insisted since 1964 that the weak interactions should look slightly different when the movie is run backwards.

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Bottom mesons (|B|>0)

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When it was discovered in 1957 that the weak interactions of elementary particles are not symmetric under the parity operation P , theorists retreated to the seemingly safe presumption that the combined operation CP remained an inviolate symmetry. (The charge-conjugation operation C replaces all particles by their antiparticles.) But seven years later came a second rude awakening: The decay of neutral K mesons revealed a minuscule but undeniable violation of CP symmetry. So particles viewed in a mirror don't behave exactly like their antiparticles.



a_μ^{HAD} CONTRIBUTION TO $g-2$

$$a_\mu^{SM} = \left(\frac{g-2}{2} \right)_\mu = a_\mu^{QED} + a_\mu^{had} + a_\mu^{weak}$$

a_μ precisely measured at BNL E821:
 $a_\mu^{exp} - a_\mu^{SM} = (28.7 \pm 8.0) \times 10^{-10} \quad (\sim 3.4\sigma)$

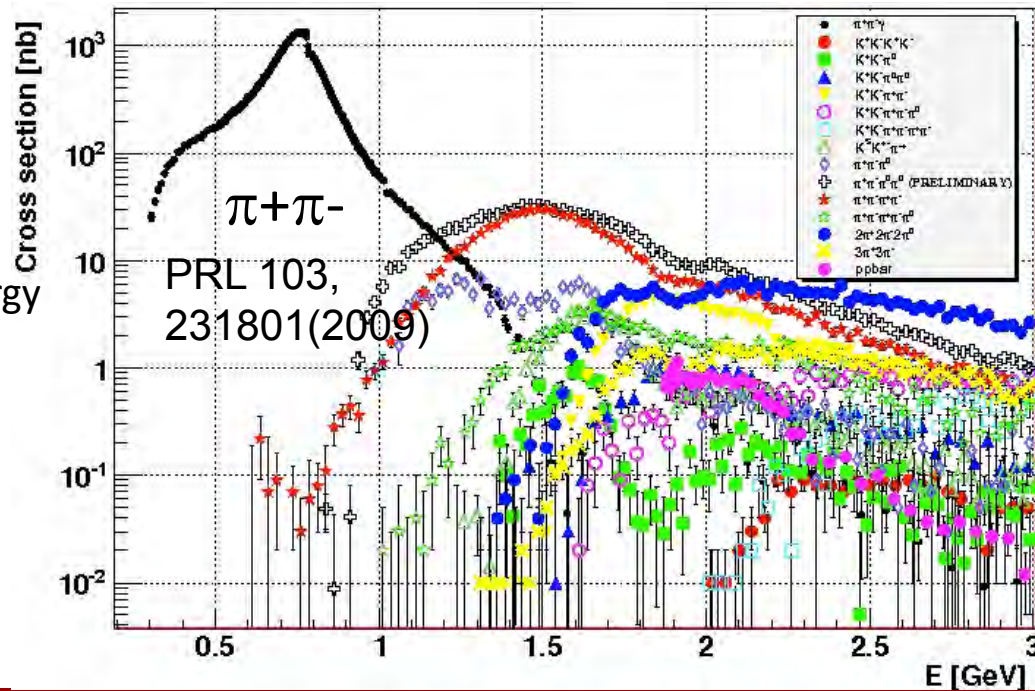
Dominant uncertainty from hadronic vacuum polarization. Cannot be calculated by QCD “first principles” so determine it via dispersion relations, by measuring the total hadronic cross section

$$a_\mu^{had} = \frac{\alpha^2}{3\pi^2} \int_{4m_\pi^2}^{\infty} \frac{K(s)}{s} R(s) ds$$

BaBar is the only experiment to measure low energy cross section from threshold up to ~4-5 GeV.

- In all cases most precise measurements

More results to be added from $\sigma(e+e- \rightarrow \pi+\pi-\pi+\pi-)$, $\sigma(e+e- \rightarrow K+K-)$ and other channels





SLAC AND DATA PRESERVATION

- Excluding BaBar no other current project at SLAC seems to be concerned with preservation
- Fermi/GLAST relies on NASA support
 - High level data is preserved in FITS and simulations and performance measures are all parameterized. There is no plan (yet) for the low level ROOT data.
 - High level simulation and analysis, and the lower level reconstruction/simulation. The NASA science support center is committed to supporting the high level code and data products for a long time (20 yrs)
 - No real plan for low level code life past the mission end
- LCLS has a 10 years policy
 - User home (up to 20GB) stored on disk + tape for indefinite amount of time
 - Tape archive (unlimited size) has two copies for 10 years
 - Committed to have the XTC file parser compatible with all data ever taken at LCLS
 - After end of LCLS program they will maintain the code for more than 2 years but less than 10
- New experiments and projects are too young to be worried about preservation but DOE will require soon a Data Management plan
- Older experiments like SLD and LASS have data saved on tape and code partly migrated to newer platform while documentation is on paper only (when still existent) but their survival is endangered (see DPHEP2)



CONCLUSION

- Long Term may not be as long as you think...
- Ramp down planning, freezing, validation,..., yes to all you want, but external factors could make the choice for you
 - Economic crisis, sequestration,...
- We need a robust foundation for data preservation that is really able to help on many levels, from technology to \$ if needed
 - Can DPHEP / DASPOS become such an entity ?



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