Brief PReview on a Possible Fourth Generation World to Come

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3G to 4G


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Календарь
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Taipei 101

0. Intro/Outline

- Nondecoupling of t′/b′ in Z-penguin/Box — Inami & Lim, 1981; WSH, Willey, Soni, PRL1987
- CPV Phase in $V_{t's}^* V_{t'b}$: b → s transistion — WSH & Arhrib, EPJC 2003
- N_ν = 3/EWPrT? See "Four Statements" — Kribs et al., PRD 2007; Holdom et al., PMCPA 2009

I. Twilight: B → Kπ DCPV Difference

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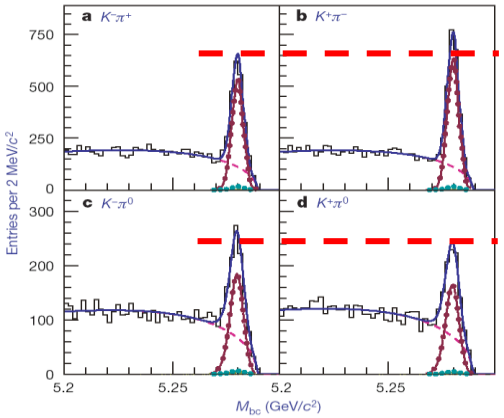
VI. 4G Preview
- * CPV-4-U?
- * 4-EWSB?

I. Twilight: $B \to K\pi$ DCPV Difference

- $A_{K^+\pi^-} \cong -10\%$ observed 2004; $A_{K^+\pi^0}$ not significant, but deviate by $+3.8\sigma$
- Belle Nature 2008:

4.4σ
by single experiment



Not anticipated!

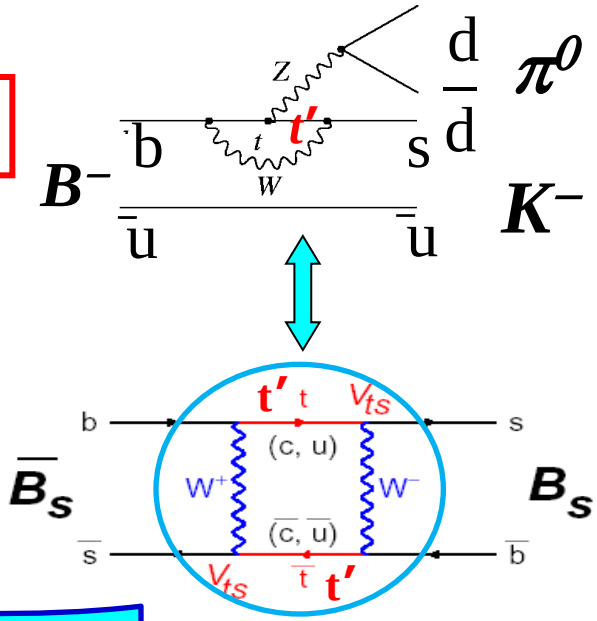
Difference Is Large !

$\Delta A_{k\pi} \cong +16\%$

- b → s Z-penguin: Nondecoupled t' w/ $V_{t's}^* V_{t'b}$
  - PQCD at LO WSH, Nagashima, Soddu, PRL, 2005
  - PQCD at NLO WSH, Li, Mishima, Nagashima, PRL, 2007

⇨ Can in principle generate $\Delta A_{k\pi}$

Predict $\sin 2\Phi_{B_s} = -0.2$ to -0.7 ⇦



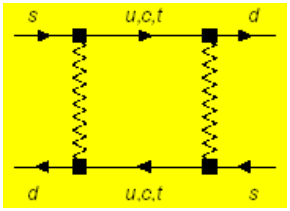
Can determine full 4×4 by facing all flavor constraints

WSH, Nagashima, Soddu, PRD, 2005

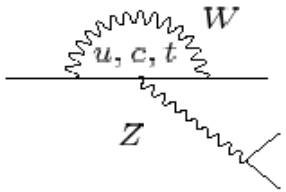
Agenda for All Aspects of Flavor/CPV

Nondecoupling

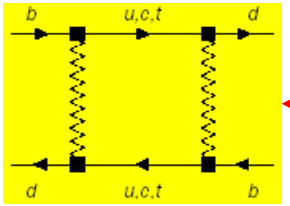
∵ Large Yukawa!



GIM, charm, ε_K

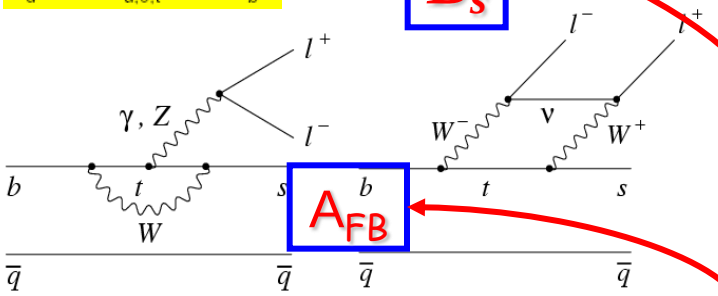


small ε'/ε, $K \to \pi\nu\nu$ (still waiting)



heavy top, $\sin 2\phi_1/\beta$

B_s



A_{FB}

$Z \to bb$

Z dominance for heavy top

1986 → 2002

All w/ 3-generations,
Just wait if there's a 4th

D !

b', t' @ (Tevatron/)LHC

PAMELA !

- PAMELA e^+ could be due to (near by) Pulsars (so, Astrophysics);
  see e.g. Hooper, Blasi and Serpico, JCAP01(2009)025

  BUT THAT DIDN'T STOP DM PARTICLE SPECULATOR/THEORISTS

- $B \to K\pi$ DCPV Difference could be due to "Enhanced Color-suppressed *C*"

  AND THIS SEEMS TO STOP FURTHER THOUGHTS ACROSS ATLANTIC !?

N.B. QCDF did not predict $A_{K^+\pi^-}$;

SCET got wrong sign for $\Delta A_{k\pi}$

but PQCD did predict (ca. 2001) sign and strength of $A_{K^+\pi^-}$;

What Theorists Should Do ! (like "Blind Analysis")

II. Moonshine: Prediction/Quest for TCPV in $B_s \to J/\psi\phi$

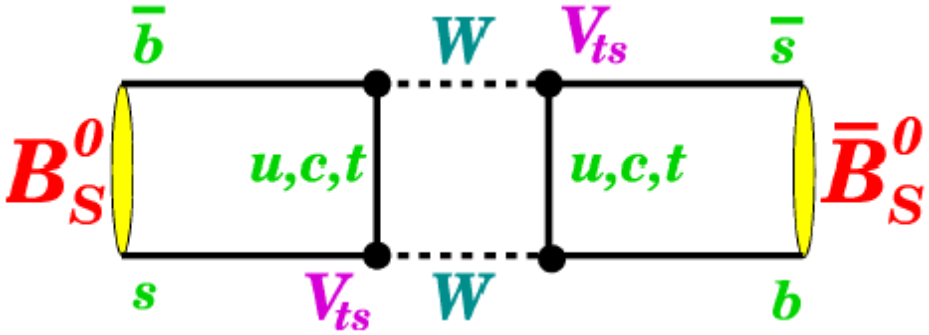
Tevatron 2008; Tevatron 2010; LHCb?

An Updated Measurement of the *CP* Violating Phase $\beta_s^{J/\psi\phi}$

The CDF Collaboration[1]

CDF/ANAL/BOTTOM/PUBLIC/9458
Version 1.0
August 7, 2008

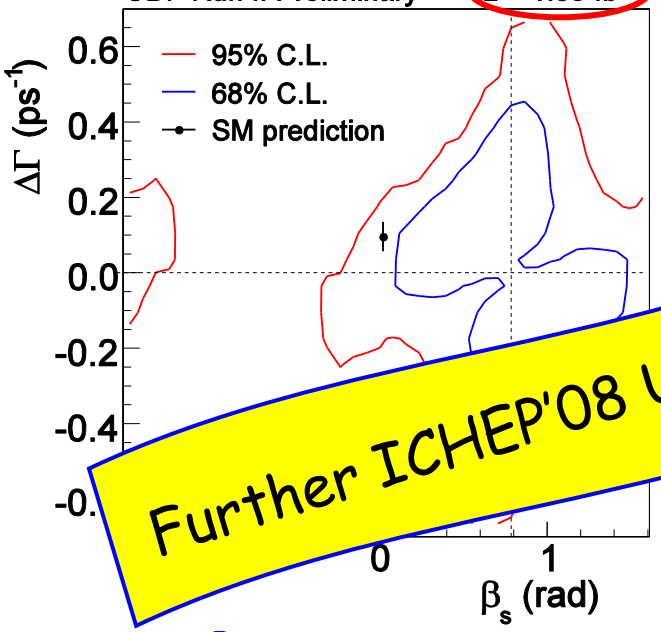
It is interesting to note that the Belle and *BABAR* collaborations have observed an asymmetry between direct *CP* asymmetries of charged and neutral $B \to K\pi$ decays with 5σ significance [5, 6]. In the absence of an under-estimation of the contribution from color-suppressed tree decays, it is difficult to explain this discrepancy without some source of new physics contributing to the electroweak penguin which governs the $b \to s$ transition.In the standard model, this isospin-violating diagram should be highly suppressed, but if a new source of physics is indeed present in these transitions it may be enough to cause the different *CP* asymmetries that have been observed.. In the $B_s^0 \to J/\psi\,\phi$ decay, the $b \to s$ transition occurs through the mixing box diagram shown in Fig. 1. It is possible that new particles could enter this transition through the $b \to s$ quark transition. While there are surely a number of possible sources of new physics that might give rise to such discrepancies, George Hou predicted the presence of a t' quark with mass between ~ 300 and 1,000 GeV/c^2 in order to explain the Belle result and predicted *a priori* the observation of a large *CP*-violating phase in $B_s^0 \to J/\psi\,\phi$ decays [7, 8]. Another result of interest in the context of these measurements is the excess observed at ~ 350 GeV/c^2 in the recent t' search at CDF using 2.3 fb^{-1} of data [9]. In this direct search for a fourth generation up-type quark, a significance of less than 2σ is obtained for the discrepancy between the data and the predicted backgrounds, so that the effect, while intriguing, is presently consistent with a statistical fluctuation. A updated search with more data would also clearly be of interest, particularly if a large value of $\beta_s^{J/\psi\phi}$ persists with the addition of more data.



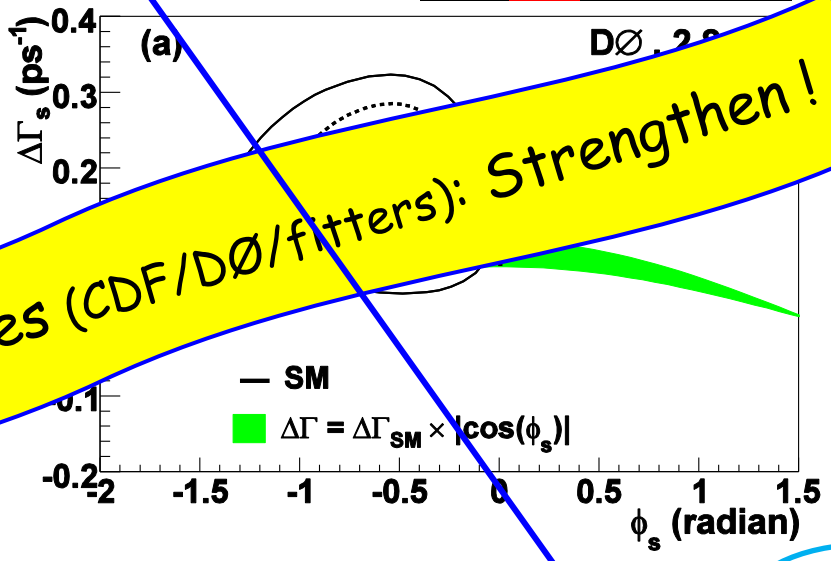
$\sin 2\Phi_{B_s} \sim -0.5 - -0.7$

WSH, Nagashima, Soddu, PRD'07 (– 0.2 to –0.7 already in 05)

PRL'08
arXiv:0712.2397 [hep.ex]
CDF Run II Preliminary L = 1.35 fb^{-1}



PRL'08
arXiv:0802.2255 [hep.ex]



Further ICHEP'08 Updates (CDF/DØ/fitters): Strengthen !

Observable	68% Prob.	95% Prob.
ϕ_{B_s} [°]	-19.9 ± 5.6	[-30.45, -9.20]
	-68.2 ± 4.9	[-78.45,-58.2]

UTfit

arXiv:0803.0659 [hep.ph]
[PMC Phys.A3:6,2009]

Summer '09
2.1
~2.8σ

$\sin 2\Phi_{B_s} = -0.64$ ± ?

Incredible !!!

$\sin 2\Phi_{B_s} \sim -0.5 - -0.7$

$m_{t'} = 300$ GeV

WSH, Nagashima, Soddu, PRD'07 (already in 05)

$\sin 2\Phi_{B_s} \equiv -\sin 2\beta_s \equiv \sin\phi_s$

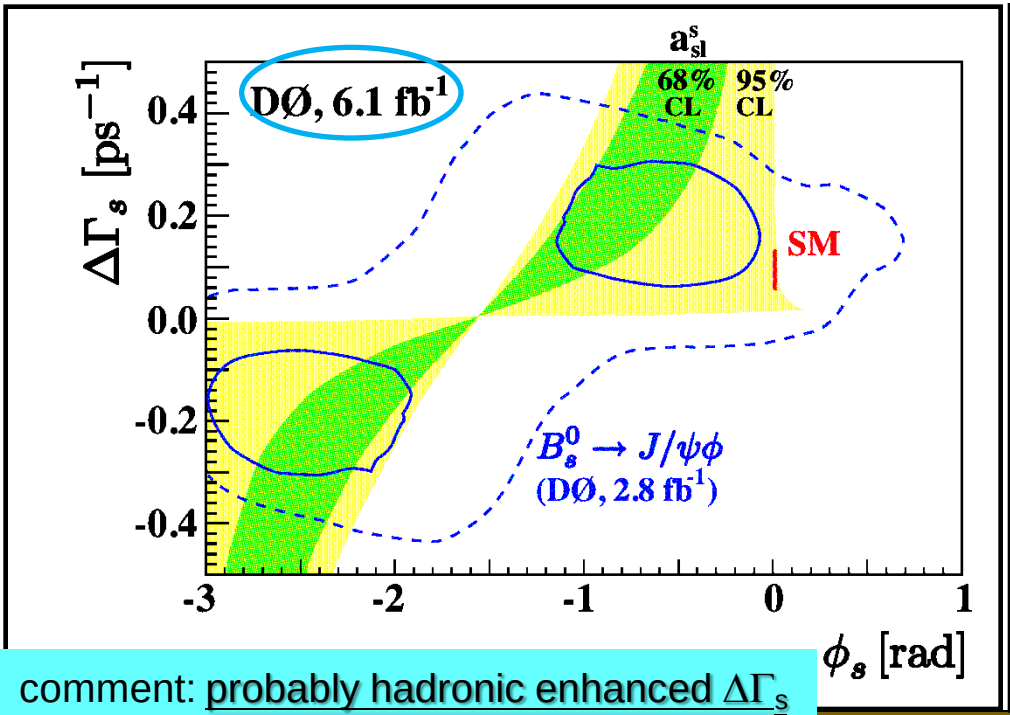
$\sin 2\Phi_{B_s} \sim -0.33$

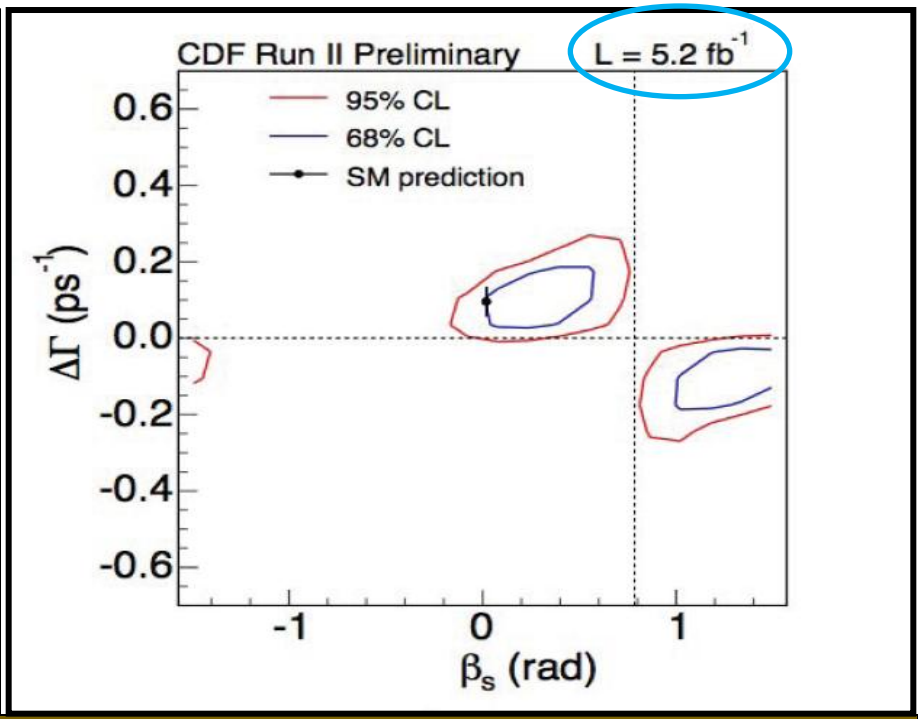
$m_{t'} = 500$ GeV

WSH, Ma, arXiv:1004.2186 [hep-ph]

Also, Soni et al., arXiv:1002.0595 [hep-ph]
Buras et al. arXiv:1002.2126 [hep-ph]
Lenz et al., arXiv:1005.3505 [hep-ph]

4th generation "prediction" still robust, but needs LHCb to verify





comment: probably hadronic enhanced $\Delta\Gamma_s$

III. Starry Heavens: CPV 4 Universe?

- Sakharov Conditions for Baryon Asymmetry of Universe (BAU)

  Baryon Number Violation; CP Violation; Out of Equilibrium

> Matter dominance of the Universe seems requiring new source of CP violation

Kobayashi, Nobel Lecture

- Jarlskog Invariant for CP Violation

$$\mathrm{Im}\,\det\left[m_u m_u^\dagger,\ m_d m_d^\dagger\right]$$

$$J = (m_t^2 - m_u^2)(m_t^2 - m_c^2)(m_c^2 - m_u^2)(m_b^2 - m_d^2)(m_b^2 - m_s^2)(m_s^2 - m_d^2)A$$

3G

CPV *iff* $J \neq 0$ ⇒ J seem short by 10^{-10}

- If shift by One Generation in 4G

by-product of Nature writing

$$J^{sb}_{(2,3,4)} \simeq (m_{t'}^2 - m_c^2)(m_{t'}^2 - m_t^2)(m_t^2 - m_c^2)(m_{b'}^2 - m_s^2)(m_{b'}^2 - m_b^2)(m_b^2 - m_s^2)\,A^{sb}_{234}$$

$$\sim \frac{m_{t'}^2}{m_c^2}\left(\frac{m_{t'}^2}{m_t^2} - 1\right)\frac{m_{b'}^4}{m_b^2 m_s^2}\frac{A^{sb}_{234}}{A}\,J$$

~ 10^{+15} Gain

Large Yukawa!

WSH, **arXiv:0803.1234 [CJP, 2009]**

- detailed algebraic check: WSH, Mao and Shen, **arXiv:1003.4361** [hep-ph]

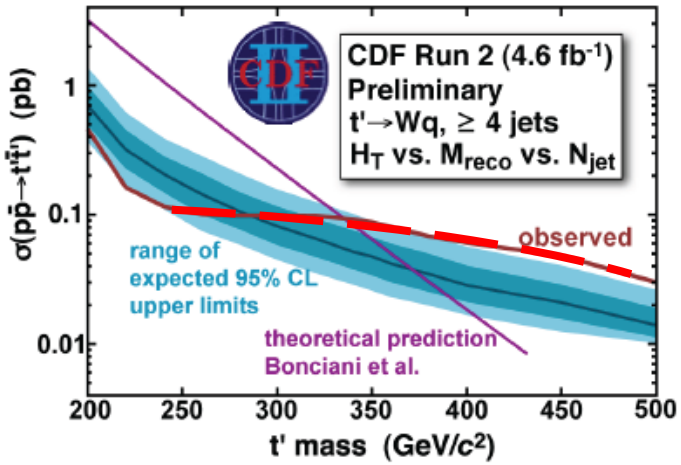
  ⇨ indeed Leading Effect; due to mass hierarchy mostly; subleading at ~ 1/10

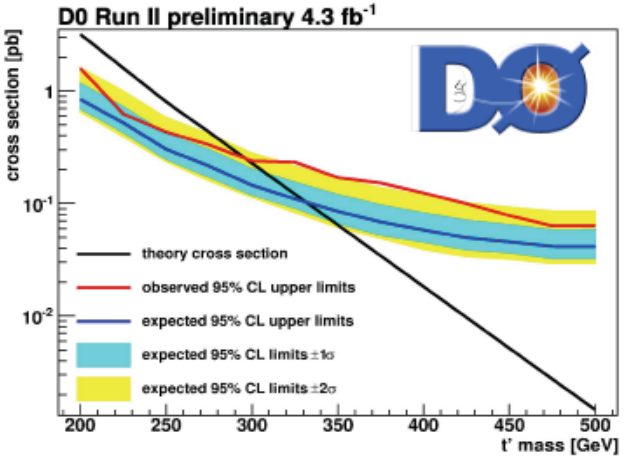
IV. Cauldron: Large Yukawa & EWSB?

- t′/b′ Mass Bounds: Getting heavier

Same Sign Dilepton

t′ → Wq Search



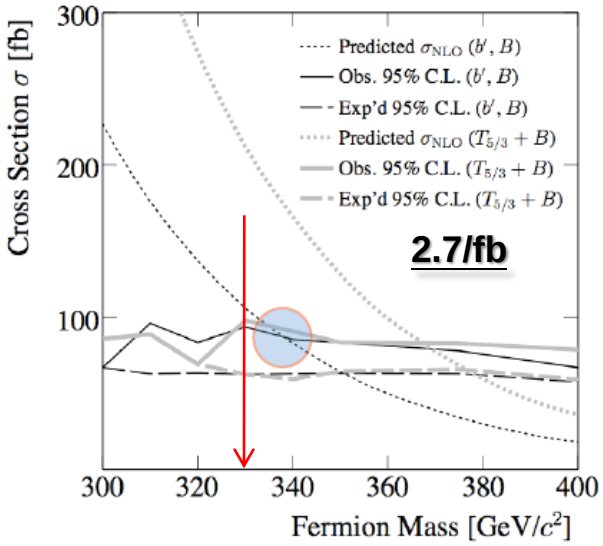


Exclude M(t′) < 335 (296) GeV @ 95% CL at CDF (D0)

Excess at high M_{reco} and H_T

Alison Lister, yesterday

b′ → Wt Search



Comparable bound, clean

- Unitarity Bound: Partial Wave Unitarity breaksdown starting 500-600 GeV!

Chanowitz, Furman and Hinchliffe, 1979

- Could EWSB be due to b′ and t′ above unitarity bound?

~ Nambu

$\langle \bar{Q}Q \rangle$ can Condense by Large Yukawa !

Need Study Platform Higgs-Yuk. on Lattice

EW "Theory" on a Lattice ?

No Higgs !

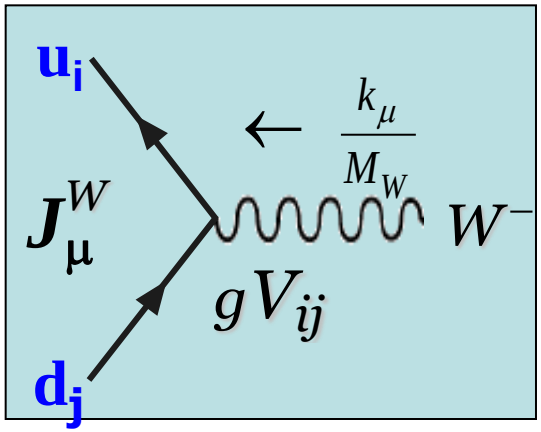
- $SU(2)_L \times U(1)$: (chiral) gauge symmetry experimentally established
- SSB also experimentally established: Massive W and Z (Massive Fermions, Too)
- Renormalizability depend only on Ward Identities (unaffected by SSB)
- In Physical Gauge: No would-be-Goldstone, or unphysical, scalars
  - But **Longitudinal W** ($\mathbf{k_\mu} k_\nu$ part of propagator) "couple" to Fermion Mass

⇒ Effective Yukawa Coupling ➡ Generate $\langle \bar{Q} Q \rangle \neq 0$ also ?

How to Formulate ?

On a Lattice ?

Intriguing



$$g\gamma_\mu L \Rightarrow g\not{k} L \Rightarrow g(\not{p}_i - \not{p}_j)L$$

$$\Rightarrow g(m_i L - m_j R)$$

$$g\frac{m_i}{M_W} = g\frac{m_i}{gv} = \frac{m_i}{v}$$

M_W

$$\lambda_Q \equiv \frac{m_Q}{v}$$

V. Prognosis — 2011; 2012; beyond

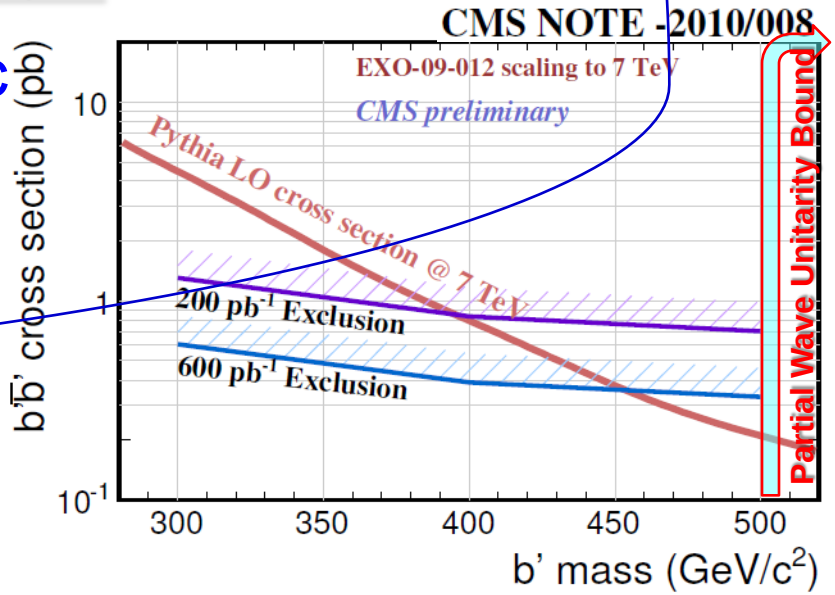
2011 2012 beyond

- $\sin 2\Phi_{B_s} \equiv -\sin 2\beta_s \equiv \sin\phi_s$ **Tevatron** ⟨ **-----⟩ LHC(b)**

  Tug-of-war depending on value, and LHCb "throughput"

- t′/b′ Direct Search **Tevatron ----⟩ LHC**
  - Surpass Tevatron w/ ~100 pb^{-1}
  - Start Reach ~ Unitarity Bound w/ ~1 fb^{-1}

  can in principle extract CPV phase via b′ → sγ, ca. 2020
  WSH and Arhrib, PRD 2009



Beyond

- $K_L \to \pi^0\nu\nu$ KOTO @ J-PARC

- Super B Factories

Are there any definitive measurements? ⟸ Not quite know yet.

Second Workshop on Beyond 3 Generation Standard Model --- New Fermions at the Crossroads of Tevatron and LHC

January 2010, Taipei

http://indico.cern.ch/conferenceDisplay.py?confId=68036

Forum: How can Super B factory pin down 4th generation parameters

Eugenio PAOLONI, Paoti CHANG, Heiko LACKER, Mikihiko NAKAO, Marcus MUSY, GiovanniPUNZI,

4G Preview

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   - * CPV-4-U? — raison d'être for U
   - * 4-EWSB? — raison d'être for LHC

Comment: will put 4G on backburner if $\sin 2\Phi_{B_s}$ SM3-like