Several Unfinished Thoughts
on
Strong Yukawa Coupling

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Outline

I. Breaching Unitarity Bounds

II. From Gauge to Yukawa Couplings

III. Yukawa Bound States: A Postulate

IV. Gap Equation without Higgs

V. Discussion and Conclusion

I. Breaching Unitarity Bounds

Celebration: 5 fb^{-1} @ LHC 7 TeV in 2011 !

Apprehension: No-New-Physics !!

Unfortunately, no hint of New Physics in the LHC data (yet)

1-2-3 of 2011

	Lower Limit (95% C.L.)
SUSY ($m_{\tilde{q}} = m_{\tilde{g}}$)	1 TeV
Gauge bosons (SSM)	2 TeV
Excited quark	3 TeV

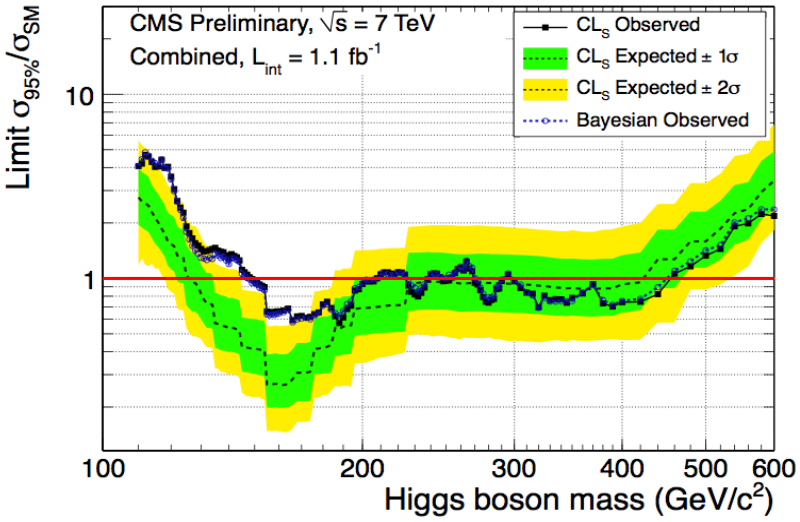
Michael Peskin at LP11

Our field seems to be approaching a definite point of reckoning. But will it lead us to *enlightenment*, or to disillusionment and chaos ?

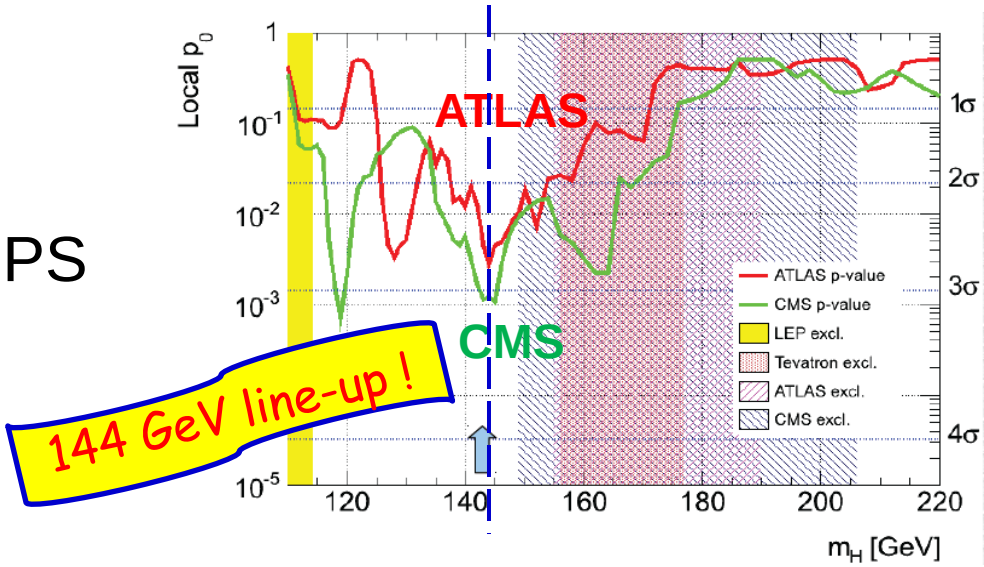
Confutatis maledictis,
flammis acribus addictis,
voca me cum benedictus.

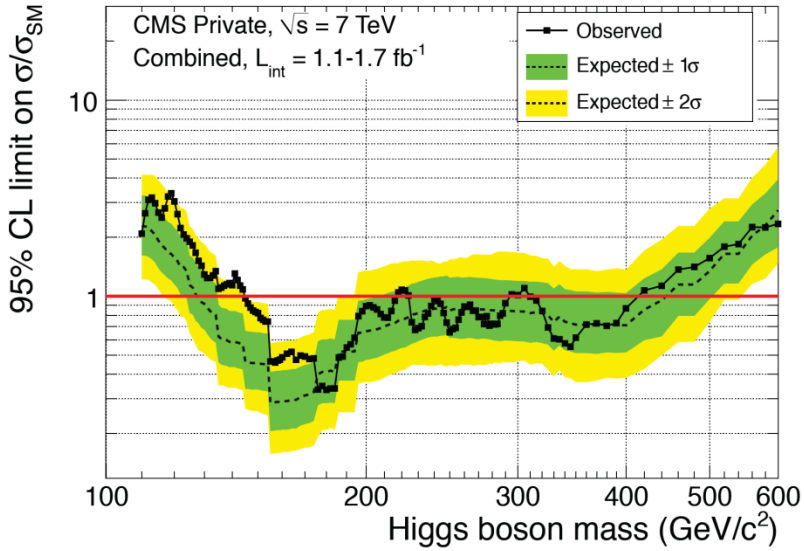
When ***the accursed are confounded,***
and ***doomed to flames of woe,***
Call me among the Blessed.

Higgs Saga: July => August

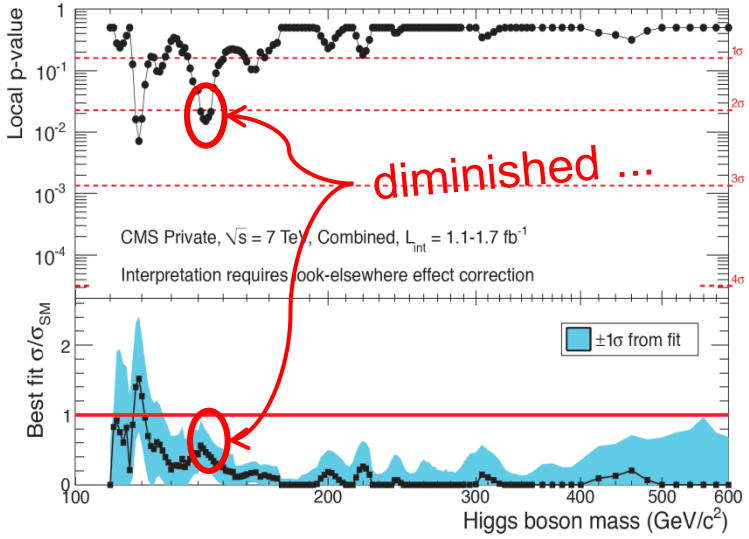


EPS

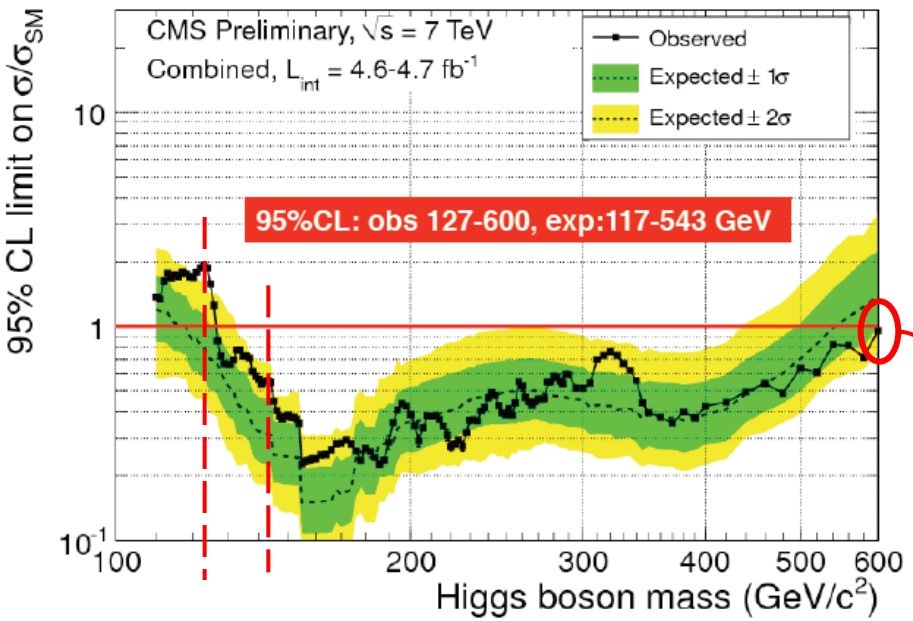


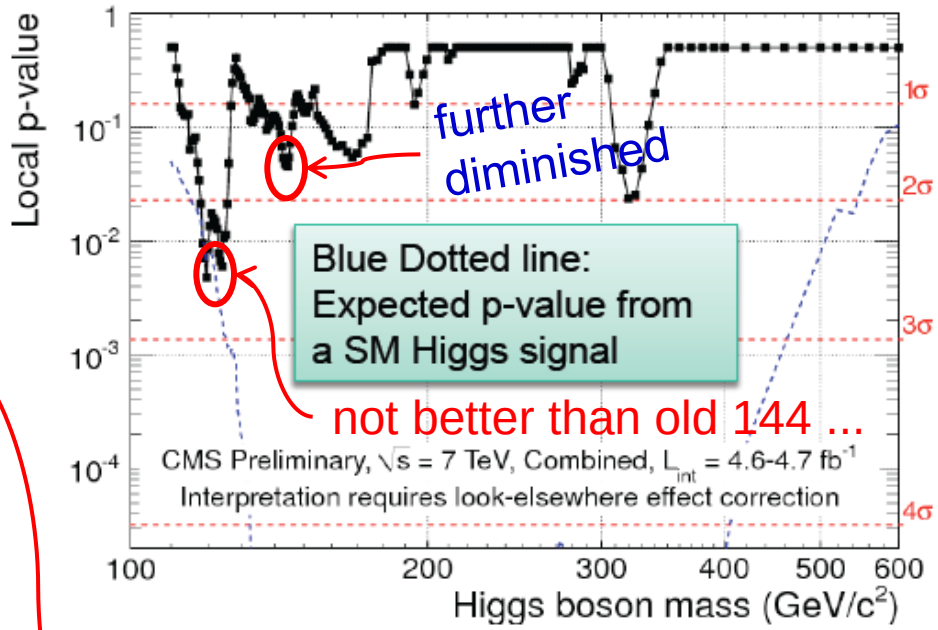


LP



Higgs Saga: December 13, 2011





We do not have any firm experimental knowledge that the Higgs boson even exists.

Will 125 GeV survive ?

$$m_{t'} \cong m_{b'} \equiv m_Q \gtrsim 500 \text{ GeV}$$

CMS '11 prelim.

Correlated ?

- strong $W_L W_L$ scattering
- strong $Q\bar{Q}$ scattering

Theme: Can *Strong Yukawa Coupling* generate EWSB itself ?

II. From Gauge to Yukawa Couplings

Experimental Facts:

- q & ℓ pointlike to 10^{-18} m
  Governed by $\boxed{\mathrm{SU(3)_C \otimes SU(2)_L \otimes U(1)_Y}}$
- $\boxed{M_W = \frac{1}{2} g v}$ ==> SSB
- All fermions Massive ==> EWSB as well

Elementary Higgs Not yet a Fact

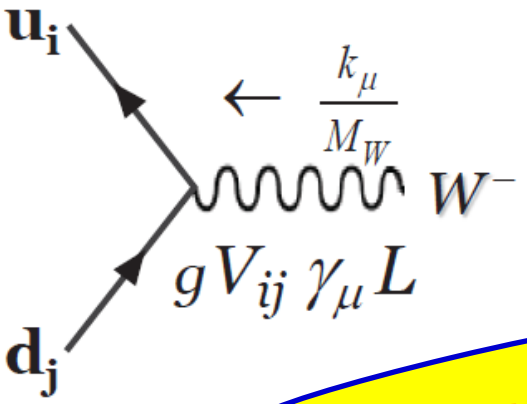
Theoretical Foundation: Renormalizability of Gauge Theories

Proof based on Ward Identities, unaffected by SSB.
't Hooft. 1972

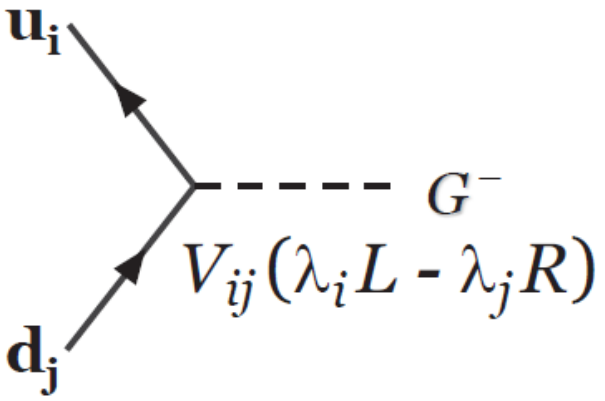
⇩

Existence of Yukawa Couplings an Experimental Fact !

Unitary Gauge (no scalar particles)



$\xrightarrow{1/\sqrt{2}}$



Higgs Not Mentioned !

Eq. of Motion (known massive)

$$\frac{g}{\sqrt{2}}\frac{\not{k}}{M_W}L = \frac{g}{\sqrt{2}}\frac{\not{p}_i - \not{p}_j}{M_W}L = \frac{g}{\sqrt{2}}\frac{m_i L - m_j R}{M_W}$$

$$= \sqrt{2}\left(\frac{m_i}{v}L - \frac{m_j R}{v}\right)$$

$$\equiv \lambda_i L - \lambda_j R,$$

$$\lambda_Q \equiv \frac{\sqrt{2}m_Q}{v}$$

W_L

Yukawa Coupling from Purely Left-handed Gauge: Goldstone Coupling

N.B. KM and Flavor/CPV Provide further evidence for Yukawa Dynamics, yet again No Higgs

III. Yukawa Bound States: A Postulate

Could there be more chiral generations ? — Already 3 !

PMC Physics A

(EW S, T variables)

"Heavy Isospin"

CMS

$$m_{t'} \cong m_{b'} \equiv m_Q \gtrsim 500 \text{ GeV}$$

Mini-review

Four statements about the fourth generation

Bob Holdom[1], WS Hou[2], Tobias Hurth[3], Michelangelo L Mangan
Saleh Sultansoy[4] and Gokhan Ünel[5]

Getting Nonperturbative !

Published: 28 September 2009
PMC Physics A 2009, 3:4 doi:10.1186/1754-0410-3-4
Received: 19 Augus
Accepted: 28 Septe

~ 148 citations today

Abstract

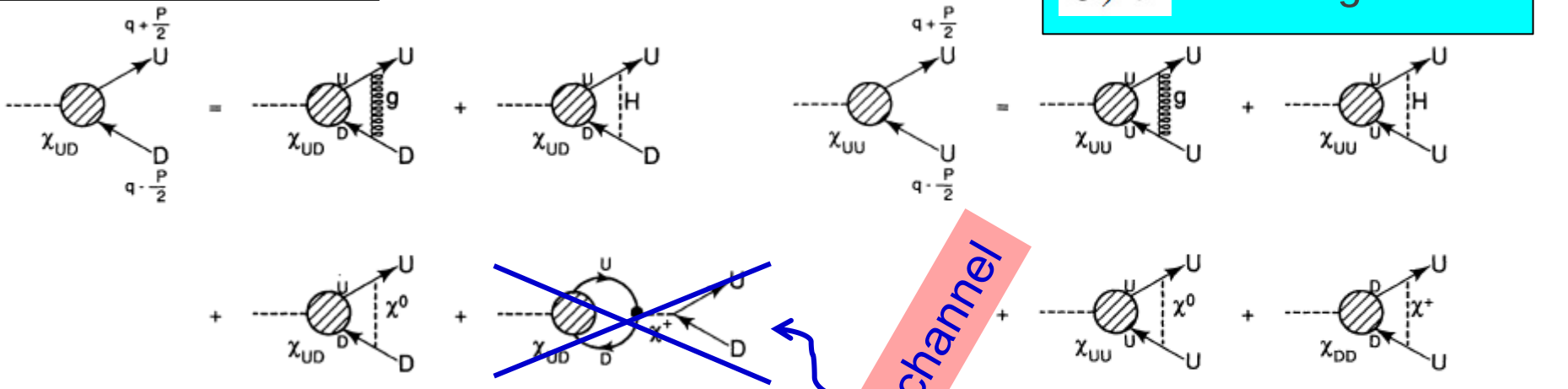
This summary of the Workshop "Beyond the 3-generation SM in the LHC era" presents a brief discussion of the following four statements about the fourth generation: 1) It is not excluded by EW precision data; 2) It addresses some of the currently open questions; 3) It can accommodate emerging possible hints of new physics; 4) LHC has the potential to discover or fully exclude it.

PACS codes: 12.60.-i; 14.60. Hi; 14.80.-j

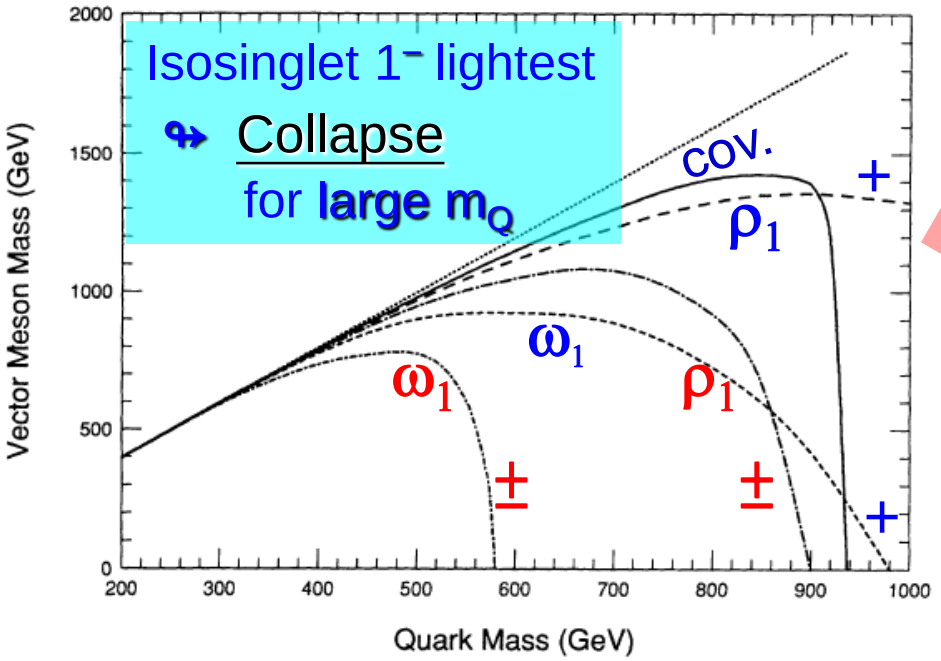
Bethe-Salpeter approach to new Heavy Isospin

b', t' semi-degenerate

Jain et al., PRD 92; 94



subtract s-channel



π_1 becomes most attractive!

but s-channel is repulsive !

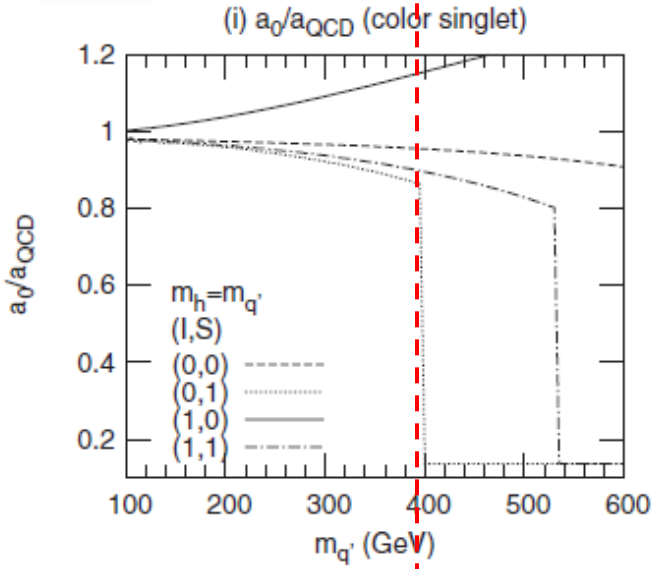
Ishiwata & Wise, PRD 11

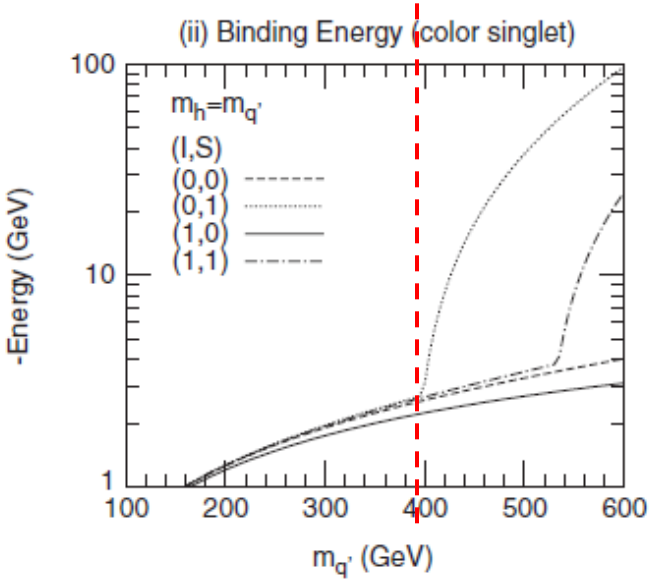
relativistic correction study

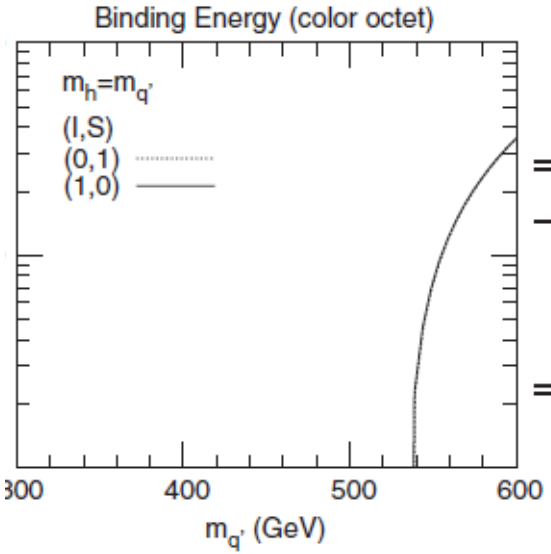
breaks down ?

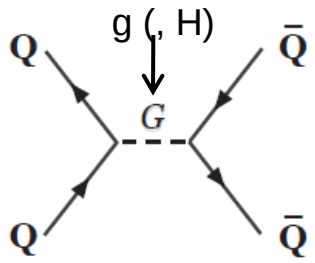
Fourth Generation Bound States

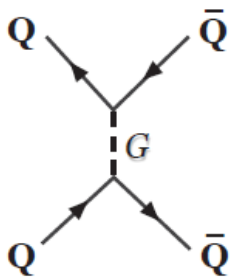
relativistic expansion study











breaks down ?

My interpretation:

- QCD-bound for GeV scale binding energy
- Sudden turn-on of Large Yukawa Coupling
  ⇒ Sudden drop in radius, jump in binding
- Rel. Expan. fails just when it turns interesting.

accidental degeneracy

	(C, I, S)		Lower limit of $m_{q'}$
	$(\mathbf{8}, 0, 0)$		No bound state
	$(\mathbf{8}, 0, 1)$	ω_8	534 GeV
	$(\mathbf{8}, 1, 0)$	π_8	534 GeV
ρ_8	$(\mathbf{8}, 1, 1)$		696 GeV

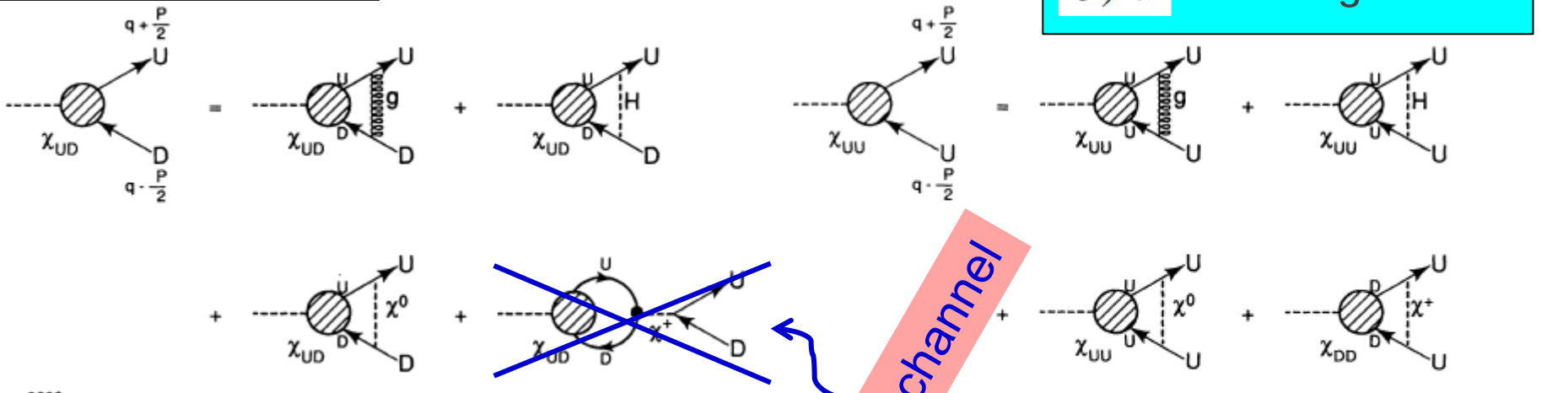
less bound

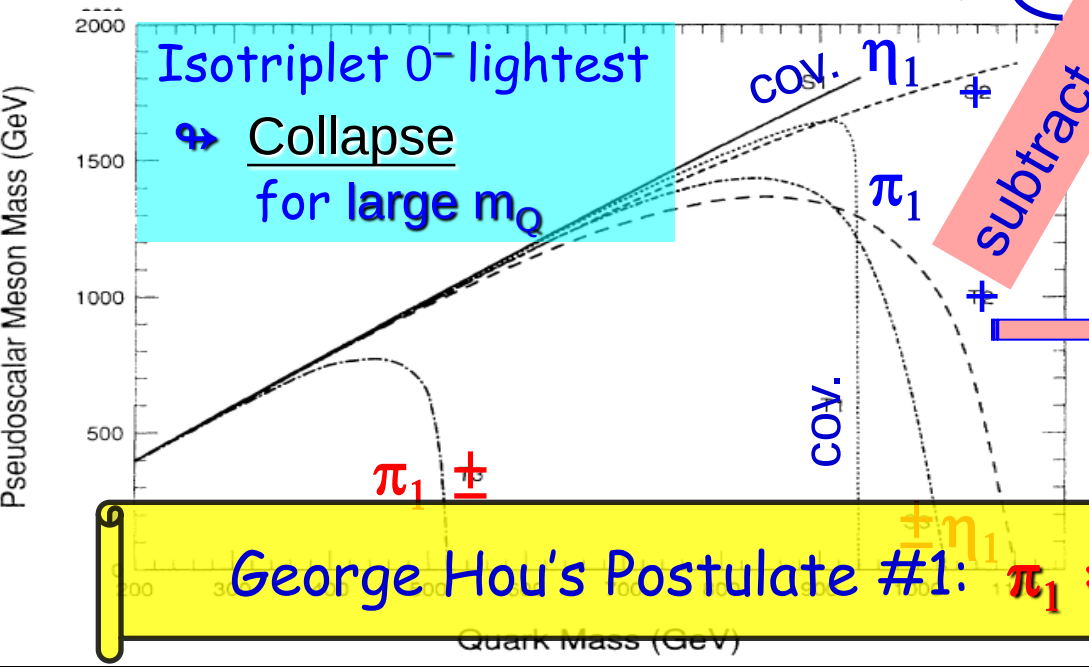
Ishiwata and Wise, PRD 11

Bethe-Salpeter approach to new Heavy Isospin

b', t' semi-degenerate

Jain et al., PRD 92; 94





π_1 becomes MAC !

but s-channel is repulsive !

Ishiwata & Wi… relativistic … breaks

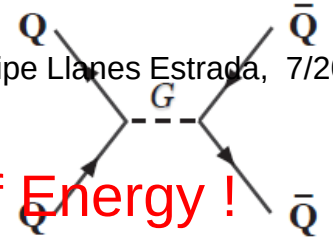
Goldstone as Collapsed $\bar{Q}Q$

George Hou's Postulate #1: $\pi_1 = G$

IV. Gap Equation without Higgs

Disc. w/ Enkhbat and Yokoya, 1/2011

Disc. w/ Felipe Llanes Estrada, 7/2010



Self Energy !

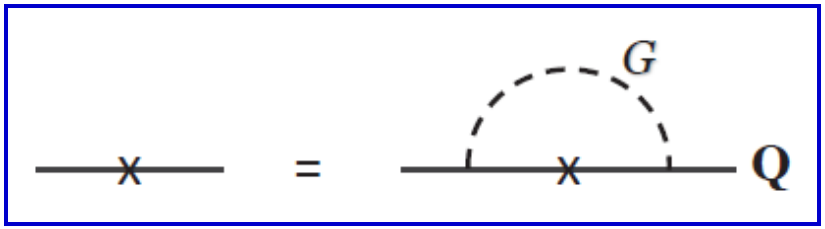
Can one form Gap Eq.?

Tight and Tiny

"Empirical"

- Got Mimura interested (since 4/2011)
- Asked Kohyama to check vs NJL (since 1/2011)
- Literature:
  - Maskawa et al. '70s
  - Higashijima '84
  - Fukuda & Kugo '76
- Bingo: finally read Hung & Xiong '11, recently
  - Almost same Eq., with G replaced by massless H-doublet
  - Follow Fukuda-Kugo/Leung-Love-Bardeen "Strongly-coupled Scale-Inv. QED" ==> Dynamical Chiral Symmetry Breaking
  - Idiosyncrasy on UV fixed-point
- Integral Eq. ==> DEq. + B.C.

ad hoc



$G = \pi_1$

up to almost $2m_Q$

Numerical Guess:

$\lambda_Q \sim \sqrt{2}\pi$

Goldstone

critical $m_Q \sim 800$ GeV

Collapsed QQ

Will study with Mimura and Kohyama (maybe Kohda?)

V. Discussion and Conclusion

- We adhered to Empirical/Heuristic Approach
- Yukawa-bound "mesons" might collapse
  ==> Postulate that Goldstone is MAC
- Simple Gap Eq. ~ Strong Scale-inv. QED
  - vs. NJL: No 4Q-operator assumed
    Instead, tightly bound Goldstone
  - vs. QCD/TC: Q is Not Confined !
    Pion of QCD a Stringy state;
    here, yet unknown — Theory of Yukawa —
- Experimental View:
  From 3-2-1/No-New-Physics, no objects @ v.e.v.
  - Gap Eq. seem to sum up all dominant effect
  - V_L = G may be the only "portal" to New Physics, other than direct production of heavy Q pair.

$\pi_1 = G$

Look mom, no ~~hands~~!
Higgs

Origin of EWSB: $\bar{Q}Q$ condensation

==> Strongly Coupled Higgs Sector
$\oplus$ spectrum of heavy $\bar{Q}Q$ states

In essence, we suggest a "bootstrap" picture where both the Goldstone boson, and the heavy quark mass, are generated by a strongly coupled gap equation.