- ν OSCILLATIONS,
- NEW VECTOR BOSON G,
- POSSIBLE DARK MATTER,
- AND ATOMKI.
- AMONG OTHER FRAMED STANDARD MODEL (FSM) RESULTS.

CHAN HONG-MO (陳康武)

WITH [JOSE BORDES (VALENCIA)
TSOU SHEUNG TSUN (OXFORD)

THE GENERATION PUZZLE.

- 1 QUARKS AND LEPTONS IN 3 GENERATIONS.
- 2 MASS HIERARCHICAL:

e.g. $m_t >> m_c >> m_u$

175 GeV 1.27 GeV 2 MEV

- 3 UP-DOWN STATE VECTORS NOT ALIGNED.

e.g. $V_{CKM} \sim \begin{pmatrix} u\cdot d & u\cdot s & u\cdot b \\ c\cdot d & c\cdot s & c\cdot b \\ t\cdot d & t\cdot s & t\cdot b \end{pmatrix} \sim \begin{pmatrix} .97 & .22 & .0035 \\ .22 & .97 & .041 \\ .009 & .040 & .999 \end{pmatrix}$

$\neq I$

? WHY ?

SM TAKES ALL ABOVE FOR GRANTED!

1ST STEP IN ANSWER: [R2 M2]

ROTATING RANK-ONE MASS MATRIX

● 1

$$M = m_T \, \underline{\alpha} \, \underline{\alpha}^\dagger$$

$\underline{\alpha}$: { COLUMN VECTOR IN 3-D GENERATION SPACE
{ UNIVERSAL ~ SAME FOR ALL q AND ℓ.

● 2

$\underline{\alpha}$ ROTATES WITH CHANGING SCALE: μ

● 2 ⟹ MASS EIGENSTATES SCALE-DEPENDENT.

$m_t \neq m_b$ ⟹ $\underline{t} \neq \underline{b}$, $\underline{t} \cdot \underline{b} \neq 1$, MIXING.

● 1 ⟹ $\mu = m_t$, c HAS 0 EIGENVALUE, BUT AT

$\mu = m_c$, c ACQUIRES SMALL MASS.

- [R2M2] CAN EXPLAIN OBSERVED MASS AND MIXING PATTERN OF QUARKS AND LEPTONS.

BUT: WHY [R2M2] ??

- CONSTRUCT MODEL THEORY FSM TO GIVE [R2M2]

(FRAMED STANDARD MODEL)

- REMINDER:

  STANDARD MODEL IS GAUGE THEORY WITH GAUGE SYMMETRY $G = U(1) \times SU(2) \times SU(3)$

  DYNAMICAL VARIABLES (FIELDS)

  GAUGE BOSONS: A_μ, B_μ, C_μ

  MATTER FERMIONS: ψ_q, ψ_ℓ

  + HIGGS ??

  (TO BREAK FLAVOUR)

FSM IS AN EXTENSION OF SM

[NOT BY EXTENDING G AS IN SUSY, GUT]

BUT ADD DYNAMIC VARIABLES:

A_μ, B_μ, C_μ, ψ_q, ψ_ℓ, FRAMONS

WHILE KEEPING G THE SAME.

? WHAT ARE FRAMONS?

- THEORY INVARIANT UNDER LOCAL TRANSFORMATNS IN G.
- TRANSFORMATIONS IN G REPRESENTABLE AS NATRICES RELATING LOCAL FRAME TO FIXED REFERENCE FRAME
- COLUMNS OF MATRIX CALLED FRAME VECTORS

- TAKE THE ELEMENTS OF THE MATRIX, OR THE COMPONENTS OF THE FRAME VECTORS AS DYNAMICAL VARIABLES $\Rightarrow$ FRAMONS.

! FRAMING NOT NEW IDEA !

- REMINDER: GRAVITY, $g_{\mu\nu}$ DYNAMICAL VARIABLE. (EINSTEIN-CARTAN) USED INSTEAD VIERBEINS

e^a_μ (μ LOCAL, a GLOBAL, i.e. X-INDEPENDENT.)

$$g_{\mu\nu} = \sum_a e^a_\mu e^a_\nu$$

e^a_μ ARE FRAMONS IN PRESENT LANGUAGE.

- FRAMONS BY NATURE DEPEND ON BOTH LOCAL AND GLOBAL REFERENCE FRAMES.

  [CF: e^{a}_{μ} VIERBEIN WITH 2 INDICES;
  μ LOCAL, a GLOBAL]

  [CF: GAUGE FIELDS AND MATTER FERMION FIELDS
  DEPEND ONLY ON LOCAL FRAME]

- SINCE PHYSICS SHOULD NOT DEPEND ON FRAMES WHETHER LOCAL OR GLOBAL (REFERENCE)

- (*) ACTIONS WITH FRAMONS SHOULD BE INVARIANT UNDER DOUBLED SYMMETRY:

$$G \times \tilde{G} = \underbrace{U(1) \times SU(2) \times SU(3)}_{\text{LOCAL}} \times \underbrace{\tilde{U}(1) \times \tilde{SU}(2) \times \tilde{SU}(3)}_{\text{GLOBAL}}$$

- 1 (*) DOES NOT AFFECT ORIGINAL SM ACTION SINCE GAUGE AND MATTER FIELDS ARE INVARIANT UNDER $\widetilde{G}$.
- 2 (*) STRONGLY CONSTRAINS WHAT FORMS THE FRAMON ACTION WILL TAKE. ✓

- SINCE G IS PRODUCT SYMMETRY, SEVERAL REPRESENTATIONS POSSIBLE FOR FRAMON.

FSM CHOOSES: $\underline{1} \times (\underline{2} + \underline{3})$ { 'MINIMAL', WORKS.

⟹ { 'FLAVOUR FRAMON': $\underline{\alpha}_{\mu}\,\Phi$ [FF]

'COLOUR FRAMON': $\underline{\beta}_{\mu}\,\Phi$ [CF]

- IMMEDIATE ADVANTAGES:
  - 1 • Φ, COLUMNS ARE $SU(2)$ DOUBLETS.
    - ONE COLUMN REDUNDANT BY PROPERTY OF $SU(2)$
    - REMAINING COLUMN IDENTIFIED WITH THE ORDINARY HIGGS FIELD.

      → GEOM. MEANING TO HIGGS ✓
  - 2 • $\tilde{SO}(3)$ CAN PLAY THE ROLE OF GENERATIONS

    → GEOM. MEANING TO GENERATIONS ✓
  - 3 • GIVE FERMION MASS MATRIX OF FORM:

    $$m = M_T \, \underset{m}{\alpha} \, \underset{m}{\alpha}^{\dagger}$$

    WHERE $\underset{m}{\alpha}$ COMING FROM [FF] IS THE SAME FOR ALL q AND ℓ. [R2M2] • 1 ✓

- 4 • Φ CARRIES BOTH LOCAL AND GLOBAL INDICES.

  → RENORM^{N} WITH Φ LOOPS MAKES α ROTATE:

  $[R2\,M2] \bullet 2$ ✓

? DOES IT WORK?

CAN IMMEDIATELY BE PUT TO TEST.

- 1-LOOP CALCULATION GIVES RGE (RENORMALIZATION GROUP EQUATION)

  + INTEGRATION CONSTS ~ 7 PARAMETERS IN ALL

- REQUIRED TO FIT ALL MASSES AND MIXING PARAMETERS OF q AND ℓ.

- RESULT SHOWN IN TABLE I.

TFSM arXiv:1410.8022

	Expt (June 2014)	FSM Calc	Agree to	Control Calc
INPUT				
m_c	1.275 ± 0.025 GeV	1.275 GeV	$< 1\sigma$	1.2755 GeV
m_μ	0.10566 GeV	0.1054 GeV	0.2%	0.1056 GeV
m_e	0.511 MeV	0.513 MeV	0.4%	0.518 MeV
$\|V_{us}\|$	0.22534 ± 0.00065	0.22493	$< 1\sigma$	0.22468
$\|V_{ub}\|$	$0.00351^{+0.00015}_{-0.00014}$	0.00346	$< 1\sigma$	0.00346
$\sin^2 2\theta_{13}$	0.095 ± 0.010	0.101	$< 1\sigma$	0.102
OUTPUT				
m_s	0.095 ± 0.005 GeV (at 2 GeV)	0.169 GeV (at m_s)	QCD running	0.170 GeV
m_u/m_d	0.38—0.58	0.56	$< 1\sigma$	0.56
$\|V_{ud}\|$	0.97427 ± 0.00015	0.97437	$< 1\sigma$	0.97443
$\|V_{cs}\|$	0.97344 ± 0.00016	0.97350	$< 1\sigma$	0.97356
$\|V_{tb}\|$	$0.999146^{+0.000021}_{-0.000046}$	0.99907	1.65σ	0.999075
$\|V_{cd}\|$	0.22520 ± 0.00065	0.22462	$< 1\sigma$	0.22437
$\|V_{cb}\|$	$0.0412^{+0.0011}_{-0.0005}$	0.0429	1.55σ	0.0429
$\|V_{ts}\|$	$0.0404^{+0.0011}_{-0.0004}$	0.0413	$< 1\sigma$	0.0412
$\|V_{td}\|$	$0.00867^{+0.00029}_{-0.00031}$	0.01223	41 %	0.01221
$\|J\|$	$\left(2.96^{+0,20}_{-0.16}\right) \times 10^{-5}$	2.35×10^{-5}	20 %	2.34×10^{-5}
$\sin^2 2\theta_{12}$	0.857 ± 0.024	0.841	$< 1\sigma$	0.840
$\sin^2 2\theta_{23}$	> 0.95	0.89	$> 6\%$	0.89

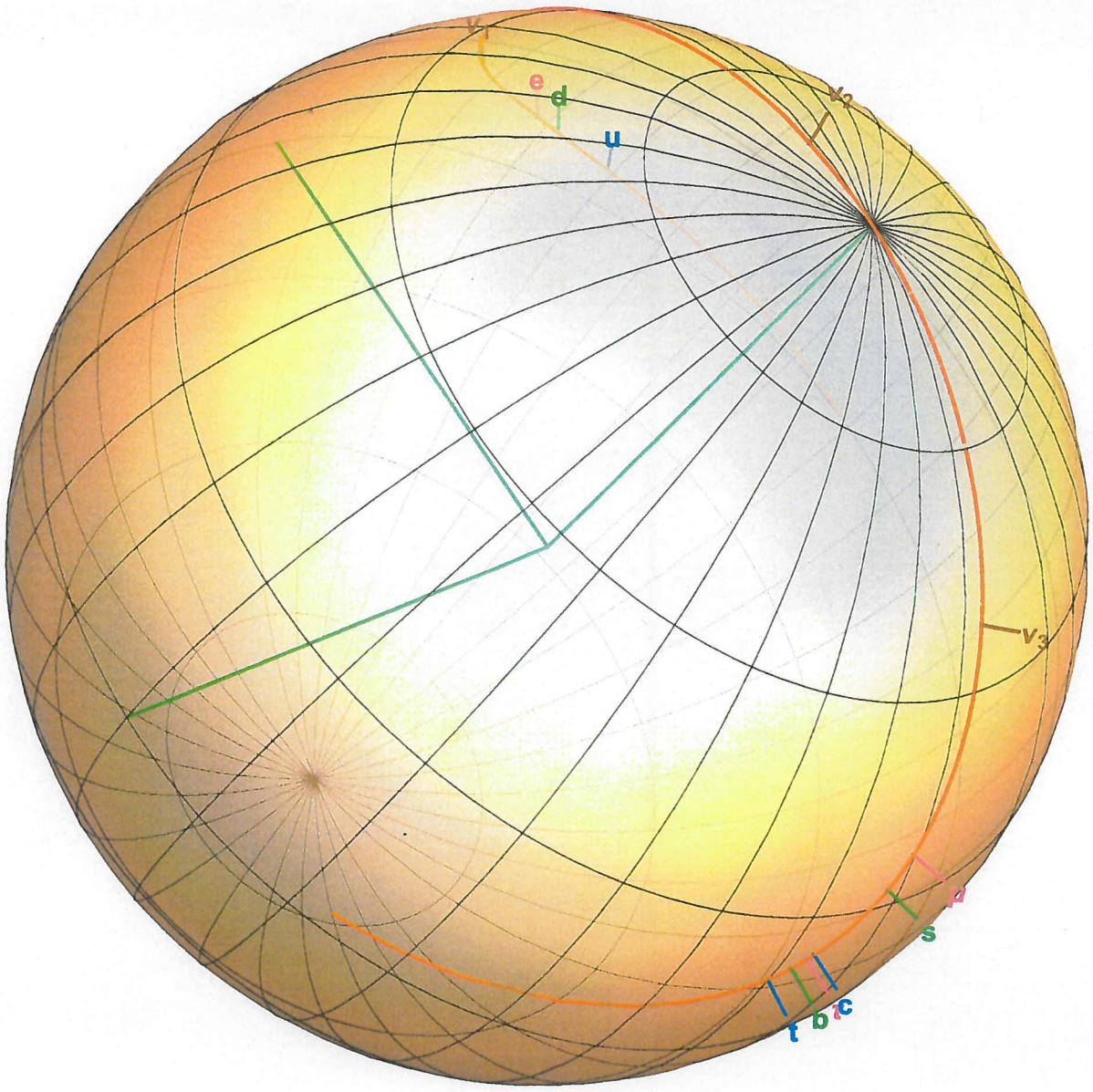
Table 1: Calculated fermion masses and mixing parameters compared with experiment

- 1 MOST ENTRIES FITTED TO WITHIN 1.5σ, NONE WILD.
- 2 TO THIS ACCURACY, REPLACES 17 OF SM PARAMETERS BY 7 FSM PARAMETERS.
- 3 GIVES ~~CP~~ PHASE (JARLSKOG INV. J) CORRECTLY, WHILE SOLVING STRONG CP PROBLEM WITHOUT AXIONS.
- 4 GIVES $m_\mu < m_d$ CORRECTLY (CRUCIAL FACT)

  DESPITE $m_c > m_s$, $m_t >> m_b$.

  (SHOW FIG. II)

- ! EVEN AS SHEER PARAMETRISATION OF DATA FSM FIT IS COMPETATIVE AGAINST ANY.
- ! CAN CLAIM FSM HAS DONE WHAT IT WAS INTENDED TO DO.



arXiv: 1410.8022

BUT THIS IS NOT ENOUGH!

- FSM MADE NEW ASSUMPTIONS.
- NEW ASSUMPTIONS IMPLY NEW PHYSICS.

?1 IS THIS NEW PHYSICS CONSISTENT WITH EXISTING DATA?

[arXiv:1806.08268
arXiv:1806.08271

AND IF SO,

?2 CAN IT BE TESTED BY FUTURE EXPERIMENT?

THE NEW ASSUMPTIONS OF FSM ARE THE FRAMONS

Φ [FF] [IDENTIFIED WITH HIGGS] ✓

Φ [CF] [9 NEW COMPLEX DEGREES OF FREEDOM] ?

[Q 1] ? WHY HAVE WE NOT BEEN AWARE OF THEM ?

- THE 9 COMPONENTS OF Φ ARE COLOURED (& COLOUR IS CONFINED) $\therefore$ CANNOT APPEAR AS PARTICLES IN FREE SPACE.

BUT THEY CAN FORM COLOUR NEUTRAL BOUND STATES TO APPEAR AS PARTICLES.

THUS:

$\Phi^\dagger \Phi$ SCALAR BD STATES: H

$\Phi^\dagger D_\mu \Phi$ VECTOR BD STATES: G

$\Phi^\dagger \Psi$ FERMION BD STATES: F

[Q 1'] ? WHY HAVE WE NOT SEEN THESE H, G, F ?

[Q2] MOST OF YOU WOULD ASK, GIVEN TIME TO THINK.

? IN FLAVOUR THEORY, SCALAR Φ BREAKS $SU(2)$ GIVES MASSES TO (h), (W, Z), (q, l).

WHY IN COLOUR THEORY, SCALAR Φ LEAVES $SU(3)$ CONFINING AND EXACT?

WHERE ARE THE COLOUR ANALOGUES OF (h), (W, Z), (q, l)?

't HOOFT'S CONFINEMENT PICTURE OF THE ELECTROWEAK THEORY. { G. 't HOOFT Acta. Phys. Aust Suppl. 22, 531 (19

THE E.W. TH. (USUALLY PERCEIVED AS HAVING $SU(2)$)

HAS A 'MATHEMATICALLY EQUIVALENT' INTERP^{N}

AS HAVING $SU(2)$ EXACT AND CONFINING.

WHAT IS BROKEN BEING ONLY GLOBAL $\widetilde{SU}(2)$. !

- SU(2) CONFINED ➡ ONLY FLAVOUR NEUTRAL BD STATES EXIST AS PARTICES.

$\Phi^+\Phi \sim h$, $\Phi^+ D_\mu \Phi \sim (W, Z)$, $\Phi^+ \psi \sim (q, l)$

[EXACT ANALOGUES OF:

$\Phi^+\Phi \sim H$, $\Phi^+ D_\mu \Phi \sim G$, $\Phi\psi \sim F$]

FRAMING NO CONFLICT WITH CONFᴵ. $[Q2] \equiv [Q1']$!

! 't HOOFT CONF. PICTURE AN OBSERVATION OF GREAT PERSPICACITY. !

- GIVES ALTERNATIVE INTERPᴺ. TO SYM. BREAKING IN E.W. THEORY WHICH SOME MAY FIND MORE APPEALING.
- GRAFTED ON TO FSM ➡ FAR-REACHING EFFECTS.

- REVEALS CLOSE PARALLEL BETWEEN THE FLAVOUR AND COLOUR THEORIES IN FSM.

	FLAVOUR THEORY	COLOUR THEORY
LOCAL GAUGE SYMM.	$SU(2)$	$SU(3)$
CONFINEMENT ?	CONFINED, EXACT. ('t HOOFT CONF. PICT.)	CONFINED, EXACT. (GENERAL CONSENSUS)
FRAMON SCALAR	Φ (~ STANDARD HIGGS)	Φ (NEW, FROM FSM)
↓ SYMMETRY DOUBLED	$SU(2) \times \widetilde{SU}(2)$	$SU(3) \times \widetilde{SU}(3)$
FRAMON VEV $\neq 0$	ζ_W (246 GeV)	ζ_S (~ TeV)
↓ GLOBAL SYM. BROKEN	$\widetilde{SU}(2)$ BROKEN → 2 (UP-DOWN) FLAVOUR	$\widetilde{SU}(3)$ BROKEN → 3 GENERATIONS
FRAMON BOUND STATES	BY $SU(2)$ FLAVOUR CONF. ('t HOOF) (h), (W, Z), (q, ℓ)	BY $SU(3)$ COLOUR CONF. H, G, F — Q (FLAVOUR), $\perp$ (NO FLAV)
HIGHER LEVEL CONSTRUCTS	$(Q\bar{Q})$ $[QQ]$ (CO-HADRONS) BD. BY FLAVOUR CONF.	$(q\bar{q})$ $[qqq]$ (HADRONS) BD. BY COLOUR CONF.

PARALLEL BETWEEN FLAVOUR AND COLOUR IN FSM

? PARALLEL DISTURBING ?

FLAVOUR INT. WEAK, COLOUR INT. STRONG. ✗

ν, W, Z, q, ℓ " " , HADRONS " " . ✓

(NOT COMPARING LIKES WITH LIKES)!

ν, W, Z, q, ℓ SHOULD COMPARE WITH H, G, F.

THEN PARALLEL HOLDS. REAL QUEST^N. [Q1']

✸ FLAVOUR - COLOUR PARALLEL ➡ 2 IMPORTANT RESULTS

● 1 [DoM] DICHOTOMY OF MATTER.

MATERIAL WORLD DIVIDES INTO 2 SECTORS

WITH ROLES OF FLAVOUR AND COLOUR INTERCHANGED.

● [PREDICTION OF HIDDEN SECTOR SURPRISING FROM FSM CONSTRUCTED TO EXPLAIN FERMION GENERATION]!

BUT HIDDEN SECTOR MOST WELCOME GIVEN THAT

WORLD IS MOSTLY DARK MATTER HIDDEN FROM US.

	STANDARD SECTOR	"HIDDEN" SECTOR
BUILDING BLOCKS	(h), (W,Z), (q,l) PT.-LIKE, PERTURB. INT.	H, G, F $\begin{matrix}Q\\L\end{matrix}$ PT.-LIKE, PERTURB. INT.
BOUND STATES OF ABOVE BY COLOUR CONF.	$(q\bar{q})$ MESON $[qqq]$ BARYON BULKY, SOFT INTER^{N}	
BOUND STATES OF ABOVE BY FLAVOUR CONF.		$(Q\bar{Q})$ CO-MESON $[QQ]$ CO-BARYON BOSONIC! BULKY, SOFT INTER.^{N}
BD. STATES BY SOFT INTER.^{N}	NUCLEI	CO-NUCLEI ?
BD. STATES BY e.m. INTER.^{N}	ATOMS, MOLECULES, US.	CO-ATOMS, CO-MOLECULES ? ?

THE FLAVOUR - COLOUR DICHOTOMY OF MATTER

2 [ToT] TRANSFER OF TECHNOLOGY

BETWEEN THE 2 SECTORS, IN PARTICULAR

PERTURBATIVE METHOD USED IN FLAVOUR TH. FOR (h), (W, Z), (q, l) APPLICABLE ALSO TO H, G, F !!!

FSM NOT ONLY SUGGESTS A HIDDEN SECTOR BUT EVEN SUPPLIES THE MEANS TO US FOR EXPLORING IT.

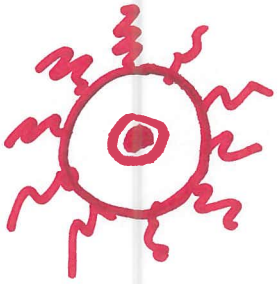
AS IN FLAVOUR TH, MASSES AND COUPLINGS GIVEN BY EXPANSION OF ACTION IN FRAMON FIELDS ABOUT THEIR VEV's [FRAMON ACTION LARGELY KNOWN ⁉ SYMMETRY UNDER $G \times \tilde{G}$]

- START WITH THE VECTOR BOSON MASS MATRIX.
- STANDARD PROCEDURE IN FLAVOUR TH. GIVES FOR W_i (LABELLED BY PAULI MATRICES τ_i):

  W_1, W_2 DIAGONAL, W_3 MIXES WITH A_μ ➡ γ, Z

- SAME PROCEDURE APPLIED TO COLOUR TH. GIVES G_k (LABELLED BY GELL-MANN MATRICES λ_k)

  $G_1, \ldots, G_7$ DIAGONAL, G_8 MIXES WITH A_μ ➡ γ, G.



MERE MENTION OF MIXING RINGS AN ALARM WHICH HAS TO BE ANSWERED AT ONCE.

?1: WILL THE MIXING WITH G_8 GIVE γ A MASS ???

[A PARALLEL PROBLEM AROSE IN THE E.W. THEORY FOR MIXING WITH W_3 BUT WEINBERG-SALAM JUDICIOUS CHOSE A CHARGE FOR THE HIGGS (FRAMON) SCALAR TO KEEP γ MASSLESS.]

A1: THE NEW MIXED γ CAN BE KEPT MASSLESS BY GIVING ONE COLOUR FRAMON CHARGE $+\frac{1}{3}$ AND THE OTHER 2 FRAMONS CHARGE, $-\frac{1}{3}$. CHOICE SIMILAR TO WEINBERG-SALAM FOR THE FLAVOUR CASE. ✓

?2: THE NEW G - MODIFIED MIXING DEVIATES FROM THE STANDARD WEINBERG MIXING, WHICH HAS BEEN CHECKED BY EXPT. TO GREAT ACCURACY. WILL THE DEVIATIONS REMAIN WITHIN PRESENT EXPTAL BOUNDS ?

A2: DEVIATIONS DEPEND ON ONLY 1 UNKNOWN PARAMETER Λ_s OF ORDER TeV.

IT HAS BEEN SHOWN THAT FOR:

$\Lambda_s > 2$ TeV ($m_G > 1$ TeV)

(a) $M_Z - M_W$, (b) $\Gamma(Z \to \ell^+\ell^-)$, (c) $\Gamma(Z \to q\bar{q})$

ALL REMAIN WITHIN PRESENT EXPTAL BOUNDS.

(ENCOURAGING, THOUGH INCOMPLETE, AND ONLY AT TREE-LEVEL).

✓

arXiv: 1806.08271

E.g. FOR $\sqrt{s}$ = 2 TeV, THE DEVIATION $\Delta(m_Z - m_W)$

FROM STANDARD = 10.4 MeV

cf. EXPTAL ERROR ~ 15 MeV.

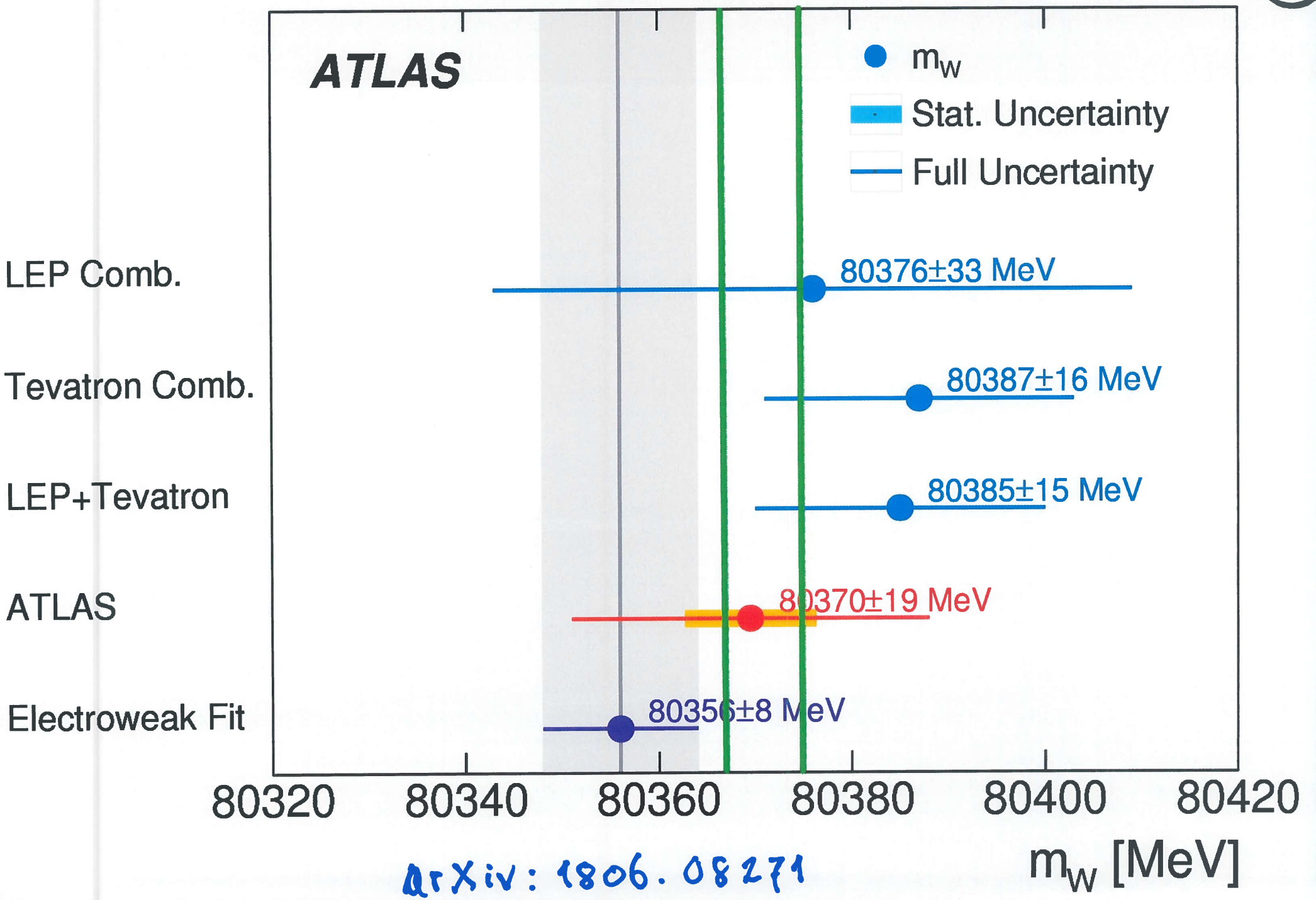
[N.B. THE DEVIATIONS CAN BE 2 ORDERS BIGGER IF IT WERE NOT FOR SUBTLE CANCELLATIONS IN ALL THREE CASES: (a), (b), (c).]

✸ REGARDED AS NEW PHYSICS, THESE DEVIATIONS SHOULD SOON BE TESTABLE WITH IMPROVED EXPTAL ACCURACY.

SHOW FIG WMASS: FSM ACTUALLY FITS BETTER THOUGH AS YET STAT. INSIGNIFICANT

● MORE WORK NEEDED ON TESTING G-MODIFIED MIXING

BUT GIVE IT TENTATIVE PASS TO PUSH ON.



ArXiv: 1806.08271

BACK TO EXPLORATION OF HIDDEN SECTOR

CONTINUING WITH MASS MATRIX OF G

- THE DIAGONAL ELEMENTS ARE:

$$\frac{1}{6} g_3^2 \zeta_s^2 (1-R) \qquad K = 1, 2, 3$$

$$\frac{1}{12} g_3^2 \zeta_s^2 (2+R) \qquad K = 4, 5, 6, 7$$

$$\frac{1}{6} g_3^2 \zeta_s^2 (1+R) \qquad K = 8.$$

ONLY THING NEW cf. FLAVOUR CASE IS DEPENDENCE ON PARAMETER R (NO EQUIVALENT IN FLAVOUR TH.)

- MATRIX ELEMENTS DEPEND ON SCALE μ.

PHYSICAL MASS OF STATE x GIVEN AS SOLUTION TO:

$$M_x(\mu) = \mu \qquad (*)$$

[cf. IN E.W. THEORY, M_Z MEASURED AT $\mu = M_Z$]

- TO SOLVE EQ. (*), NEED TO KNOW R AS FUNCTION OF μ.

FORTUNATELY, R KNOWN FROM FIT OF TABLE I.

SHOW FIG. OF p. (28)

- FOR $\mu \sim m_Z$, $\left.\begin{array}{l} \ell_s > 2\ \text{TeV} \\ R < 0.02 \end{array}\right\} \Rightarrow$ SOLUTIONS OF (*) DEGENERATE $\gtrsim$ TeV.
- EXCEPT FOR $k = 1, 2, 3$, $\because$ $R \to 1 \sim 17$ MeV

  $\exists$ A LOWER SOLUTION FOR (*) $\sim$ 17 MeV.

  [PREFERRED SOLUTION BEING STABLE.]

- SUGGESTED SPECTRUM FOR G SHOWN IN TABLE GM
- SIMILAR ANALYSIS GIVES SPECTRUM FOR H, [TABLE HM

  AND ALSO SPECTRUM FOR F. [NOT SHOWN, DEPENDS ON MORE ASSUMPTIONS]

Particle	State	Mass
H^0	mixture of $H_{\langle\bar{3}\vert\bar{3}\rangle}$, H_{even} and h_{W}	$\gtrsim$ multi-TeV
$H^+_{\bar{1}}$	$H_{\langle\bar{1}\vert\bar{3}\rangle}$	$\gtrsim$ TeV
$H^+_{\bar{2}}$	$H_{\langle\bar{2}\vert\bar{3}\rangle}$	
$H^-_{\bar{1}}$	$H_{\langle\bar{3}\vert\bar{1}\rangle}$	
$H^-_{\bar{2}}$	$H_{\langle\bar{3}\vert\bar{2}\rangle}$	
H^0_{low}	mixture of H_{even}, $H_{\langle\bar{3}\vert\bar{3}\rangle}$	
H^0	$H_{\langle\bar{1}\vert\bar{2}\rangle}$	$\sim$ 17 MeV
$\bar{H}^0$	$H_{\langle\bar{2}\vert\bar{1}\rangle}$	
H^0_{odd}	$\frac{1}{\sqrt{2}}(H_{\langle\bar{1}\vert\bar{1}\rangle} - H_{\langle\bar{2}\vert\bar{2}\rangle})$	

Table 2: Suggested spectrum of the H states

Particle	State	Mass
G^0	mixture of G_8, Z and γ	$\geq$ 1.1 TeV
G^+	$\frac{1}{\sqrt{2}}[G_4 + iG_5]$	$\geq$ 1.0 TeV
G^-	$\frac{1}{\sqrt{2}}[G_4 - iG_5]$	
G'^+	$\frac{1}{\sqrt{2}}[G_6 + iG_7]$	
G'^-	$\frac{1}{\sqrt{2}}[G_6 - iG_7]$	
G^0_1		$\sim$ 17 MeV
G^0_2		
G^0_3		

Table 3: Suggested spectrum of the G states

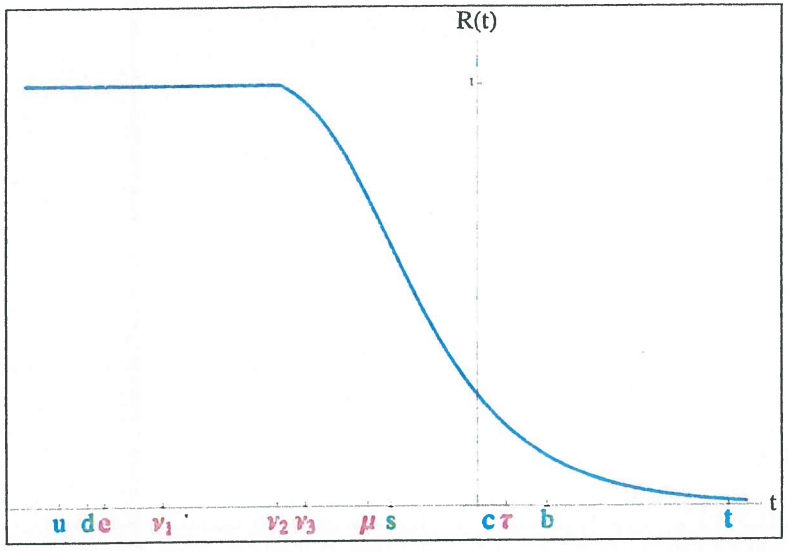


Figure 2: Dependence of R on scale obtained from the fit in [?]

EXPANSION TO HIGHER ORDERS GIVES INTERACTION VERTICES. [DONE, GIVING ~ 10 PAGES OF THEM (arXiv:1806.08268)]

→ CALCULATION OF FEYNMAN DIAGRAMS IN FUTURE

NB PLENTY OF INTERACTIONS AMONG H, G, F

BUT VERY FEW LINKING H, G, F TO h, W, Z, q, l.

[ONLY EXCEPTIONS VIA MIXING OF G WITH γ, Z AND MIXING OF SOME H's WITH h]

? → ANSWER TO [Q1'] OR "WHY HIDDEN SECTOR IS HIDDEN?"

A? AT DAWN OF CREATION (~ SOON AFTER BIG BANG) ALL PARTICLES H, G, F h, W, Z, q, l PRESENT

BUT BY OUR EPOCH ONLY LOW STABLE ONES REMAIN.

- IN OUR STANDARD SECTOR, WE KNOW WHAT REMAIN.

? WHAT REMAIN IN THE HIDDEN SECTOR?

- SUGGEST THOSE H's, G's, F's OF MASS ~ TeV DECAY, LEAVING ONLY THOSE OF MASS ~ 17 MeV
  - THESE ARE ELECTRICALLY NEUTRAL AND HAVE LITTLE INTERAC^{N} WITH US. THEY WILL APPEAR TO US AS <u>DARK MATTER</u>.
  - THOSE WITH MASSES ~ TeV NEED TO BE PRODUCED, <u>BUT</u> THIS IS HARD, GIVEN THE LITTLE COUPLING WITH OUR SECTOR.

<u>HENCE</u> TENTATIVE ANSWER TO OUR QUES. [Q1].

- ? HOW TO PROBE THE HIDDEN SECTOR?

CHINKS IN THE INVISIBILITY CLOAK? (HARRY POTTER)

- 1: G MIXING WITH γ AND Z ALLOWS DECAY INTO $\bar{\ell}\ell$. CAN APPEAR AS $\bar{\ell}\ell$ BUMP AT LHC.

  [PRODUCTION XSECTION AND WIDTH CALCULABLE (WE THINK). UNDER INVESTIGATION.]

- GATEWAY INTO HIDDEN SECTOR, DECAYING MOSTLY INTO DM.

- 2: ONE OF THE LOW MASS STATES G_3 AT 17 MeV CAN DECAY INTO e^+e^- VIA LOOP:

  HAS IT ANYTHING TO DO WITH THE ATOMKI ANOMALY AT 17 MeV IN Be^8 DECAY?

  (NEITHER EXPT. NOR THEORY YET VERY STRONG.)!

- 3: SEARCH FOR G_1, G_2, H_3, H_2 ETC. AS DARK MATTER (MASS TOO LOW FOR LUX, PERHAPS ALSO FOR LZ?)

  (SENSEI? ASK FERGUS WILSON)

! COMPLAINT OF SERGEI BALASHOV RE DM EXPT.:
"NOT ENOUGH KNOWN OF DM DYNAMICS."
IN FSM A LOT IS KNOWN! ONLY ? TRUE OR NOT?

● 4: CHARGED PARTICLES IN H, G, F ALL COUPLE AS USUAL TO γ. CAN EASILY BE PAIR-PRODUCED IN e^+e^- COLLIDERS.

[$p\bar{p}$ COLLIDERS BEING PLANNED MAY GO THROUGH e^+e^- STAGE, CEPC IN CHINA. ONE IN EUROPE)
BUT, TIME SCALE ~ 20 YRS. I SHALL BE 105]

✸ IN ANY CASE, IF THERE IS TRUTH IN WHAT WE SAY, OUR EXPTAL FRIENDS WILL BE KEPT BUSY FOR SOME TIME.