Discrete Symmetries: the Standard Model and Beyond

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A Decade of Discovery Ahead

- Higgs search and study
- Elucidate EWSB / 1-TeV scale
- B $\not{C}\!\not{P}$
- Rare decays (K, D, ...)
- ν oscillations
- Top as a tool
- New phases of matter
- Exploration!
  - Extra dimensions
  - New dynamics / SUSY
  - New forces + constituents
- Proton decay
- What kinds of matter + energy make up the Universe?


Penumbra
Synthetic Spring
Neptune
Big Technology
I'm With You
Cooled
Faith (Yourself)
Travel
Perpetual Symmetry
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Snowmass Village
at Aspen

TWO VIEWS OF SYMMETRY

1• Indistinguishability

One object in a representation can be transformed into another.

Familiar (and useful!) from

GLOBAL SYMMETRIES: isospin, $SU(3)_f$, ...
SPACETIME SYMMETRIES
GAUGE SYMMETRIES

"EQUIVALENCE"

IDEALIZE MORE PERFECT WORLDS, THE BETTER TO UNDERSTAND OUR WORLD OF DIVERSITY + CHANGE.

UNBROKEN UNIFIED THEORY
Perfect world of equivalent forces, interchangeable massless particles.
(Perfectly boring?)

SYMMETRY ⟷ DISORDER

2. UNobservable

Goodness of a symmetry means something cannot be measured

e.g. vanishing asymmetry

UNOBSERVABLE	Transform.	Conserved
ABSOLUTE POSITION	$\vec{r} \to \vec{r} + \vec{\Delta}$	$\vec{P}$
" TIME	$t \to t + \delta$	E
" ORIENTATION	$\hat{r} \to \hat{r}'$	$\vec{L}$
" VELOCITY	$\vec{v} \to \vec{v}'$	
" RIGHT	$\vec{r} \to -\vec{r}$	$\mathbb{P}$
" FUTURE	$t \to -t$	$\mathbb{T}$
" CHARGE	$e \to -e$	$\mathbb{C}$
" PHASE		
⋮		

VIOLATION OF A SYMMETRY

→ OBSERVATION OF AN UNOBSERVABLE

... MEASURING A QUANTITY THAT WOULD VANISH IF THE SYMMETRY HELD ...

VARIETIES OF SYMMETRIES

- CONTINUOUS SPACETIME SYMMETRIES

  Poincaré invariance:

  translations +

  Lorentz transforms

  STARTING POINT FOR THEORIES

- PERMUTATION (IDENTICAL -PARTICLE) SYMMETRIES

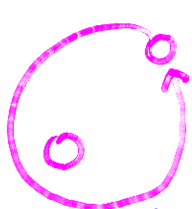
  Spin + statistics:

  Bose-Einstein &

  Fermi-Dirac

  (DERIVED ... IN ≥ 3 SPACE DIM)

Recent development: ANYONS in 2+1 D



ACQUIRES PHASE $\begin{cases} 0 \text{ mod } 2\pi & \text{BOSON} \\ \pi \text{ mod } 2\pi & \text{FERMION} \\ \theta & \text{ANYON} \end{cases}$

Statistics interpolate

- INTERNAL SYMMETRIES

Global symmetries:

isospin, $SU(3)_{flavor}$

chiral symmetry

Gauge symmetries:

$SU(3)_{color}$

$SU(2)_L \otimes U(1)_Y$

⋮

- DISCRETE SYMMETRIES

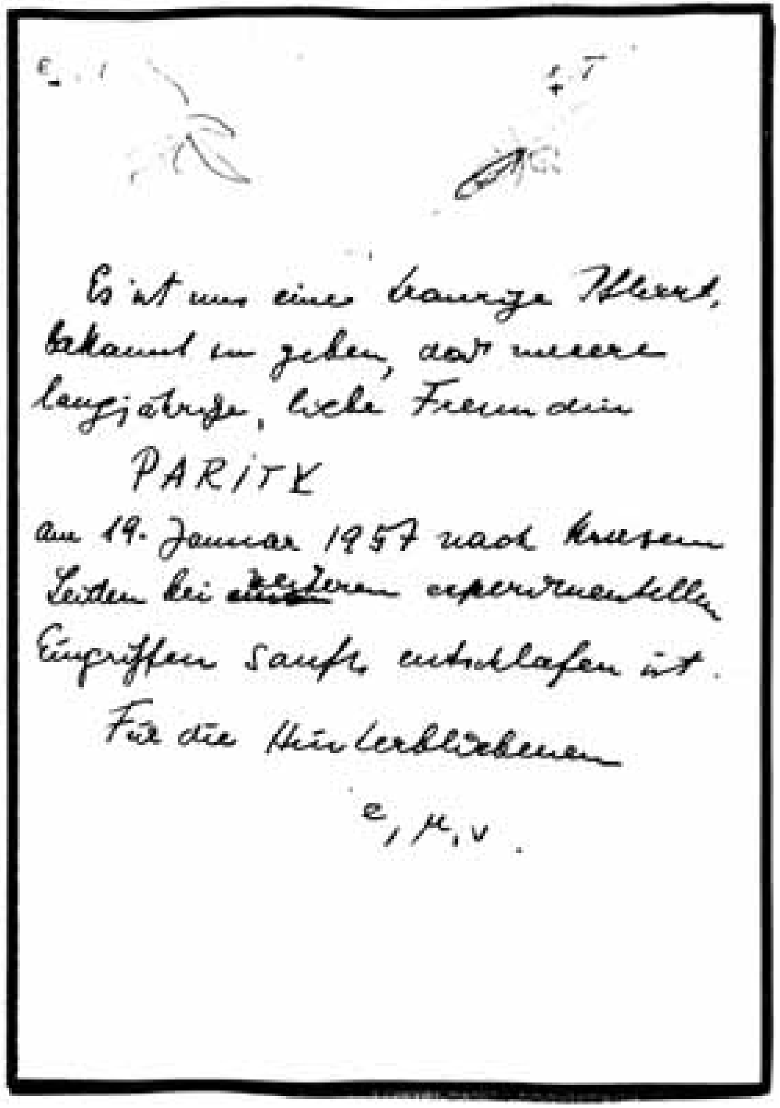
$\mathbb{P}$ - parity $\vec{x} \to -\vec{x}$

$\mathbb{C}$ - charge conjugation

$\mathbb{T}$ - time reversal $t \to -t$

L. Grillich WIEN & FRANZENSBAD

Pauli's Reaction to the Downfall of Parity



Es ist uns eine traurige Pflicht, bekannt zu geben, daß unsere langjährige, liebe Freundin

PARITY

am 19. Januar 1957 nach kurzem Leiden bei weiteren experimentellen Eingriffen sanft entschlafen ist.

Für die Hinterbliebenen

e, μ, ν.

Pauli's Reaction to the Downfall of Parity

Es ist uns eine traurige Pflicht, bekannt zu geben, daß unsere langjährige ewige Freundin

PARITY

den 19. Januar 1957 nach kurzen Leiden bei weiteren experimentellen Eingriffen sanfte entschlafen ist.

Für die hinterbliebenen

$e \quad \mu \quad \nu$

It is our sad duty to announce that our loyal friend of many years

PARITY

went peacefully to her eternal rest on the nineteenth of January 1957, after a short period of suffering in the face of further experimental interventions.

For those who survive her,

$e \quad \mu \quad \nu$

INSTEAD OF

{taking for granted the existence / mourning the loss} OF DISCRETE SYMMETRIES,

LET US ASK WHAT (INTACT or BROKEN) THEY ARE TRYING TO TELL US.

$\mathbb{CPT}$: Don't leave home without it!

WHAT WOULD BREAKDOWN MEAN?

ARE SMALL VIOLATIONS THINKABLE?

HOW PARAMETRIZE?

$\mathbb{P}$: Why violated in weak interactions?

LR SYMMETRIC THEORIES

& SCALES OF SSB

Why respected in EM + Strong?

HOW COULD IT BE VIOLATED?

WHAT WOULD WE LEARN?

$\mathbb{C}$: Why violated in weak interactions?

FERMION MASSES / ν SPECTRUM?

What about EM and strong?

We can prove the

CPT Theorem:

Lorentz Invariance
+
Local field theory
+
Spin / Statistics

⇒ under CPT

PARTICLE → ANTIPARTICLE

MOMENTUM FIXED

HELICITY REVERSED

all matrix elements
→ complex conjugates

PARTICLES VS ANTIPARTICLES, from 2000 Review of Particle Physics

CPT INVARIANCE

●	$(m_{W^+} - m_{W^-}) / m_{\text{average}}$		-0.002 ± 0.007
●	$(m_{e^+} - m_{e^-}) / m_{\text{average}}$		$<8 \times 10^{-9}$, CL = 90%
+	$\lvert q_{e^+} + q_{e^-} \rvert / e$		$<4 \times 10^{-8}$
+	$(g_{e^+} - g_{e^-}) / g_{\text{average}}$		$(-0.5 \pm 2.1) \times 10^{-12}$
Δ	$(\tau_{\mu^+} - \tau_{\mu^-}) / \tau_{\text{average}}$		$(2 \pm 8) \times 10^{-5}$
+	$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}}$		$(-2.6 \pm 1.6) \times 10^{-8}$
●	$(m_{\pi^+} - m_{\pi^-}) / m_{\text{average}}$		$(2 \pm 5) \times 10^{-4}$
Δ	$(\tau_{\pi^+} - \tau_{\pi^-}) / \tau_{\text{average}}$		$(6 \pm 7) \times 10^{-4}$
●	$(m_{K^+} - m_{K^-}) / m_{\text{average}}$		$(-0.6 \pm 1.8) \times 10^{-4}$
Δ	$(\tau_{K^+} - \tau_{K^-}) / \tau_{\text{average}}$		$(0.11 \pm 0.09)\%$ (S = 1.2)
Δ	$K^\pm \to \mu^\pm \nu_\mu$ rate difference/average		$(-0.5 \pm 0.4)\%$
Δ	$K^\pm \to \pi^\pm \pi^0$ rate difference/average	[f]	$(0.8 \pm 1.2)\%$
●	$\lvert m_{K^0} - m_{\overline{K}^0} \rvert / m_{\text{average}}$	[g]	$<10^{-18}$
	CPT-violation parameters in K^0-$\overline{K}^0$ mixing		
	real part of Δ		$(2.9 \pm 2.7) \times 10^{-4}$
	imaginary part of Δ		$(-0.8 \pm 3.1) \times 10^{-3}$
	phase difference $\phi_{00} - \phi_{+-}$		$(-0.1 \pm 0.8)^\circ$
●	$\lvert m_p - m_{\overline{p}} \rvert / m_p$	[h]	$<5 \times 10^{-7}$
+	$(\lvert \frac{q_{\overline{p}}}{m_{\overline{p}}} \rvert - \frac{q_p}{m_p}) / \frac{q_p}{m_p}$		$(-9 \pm 9) \times 10^{-11}$
+	$\lvert q_p + q_{\overline{p}} \rvert / e$	[h]	$<5 \times 10^{-7}$
+	$(\mu_p + \mu_{\overline{p}}) / \mu_p$		$(-2.6 \pm 2.9) \times 10^{-3}$
●	$(m_n - m_{\overline{n}}) / m_n$		$(9 \pm 5) \times 10^{-5}$
●	$(m_\Lambda - m_{\overline{\Lambda}}) / m_\Lambda$		$(-0.1 \pm 1.1) \times 10^{-5}$ (S = 1.6)
Δ	$(\tau_\Lambda - \tau_{\overline{\Lambda}}) / \tau_\Lambda$		0.04 ± 0.09
Δ	$(\tau_{\Sigma^+} - \tau_{\overline{\Sigma}^-}) / \tau_{\Sigma^+}$		$(-0.6 \pm 1.2) \times 10^{-3}$
+	$(\mu_{\Sigma^+} + \mu_{\overline{\Sigma}^-}) / \mu_{\Sigma^+}$		0.014 ± 0.015
●	$(m_{\Xi^-} - m_{\overline{\Xi}^+}) / m_{\Xi^-}$		$(1.1 \pm 2.7) \times 10^{-4}$
Δ	$(\tau_{\Xi^-} - \tau_{\overline{\Xi}^+}) / \tau_{\Xi^-}$		0.02 ± 0.18
+	$(\mu_{\Xi^-} + \mu_{\overline{\Xi}^+}) / \lvert \mu_{\Xi^-} \rvert$		$+0.01 \pm 0.05$
●	$(m_{\Omega^-} - m_{\overline{\Omega}^+}) / m_{\Omega^-}$		$(-1 \pm 8) \times 10^{-5}$
Δ	$(\tau_{\Omega^-} - \tau_{\overline{\Omega}^+}) / \tau_{\Omega^-}$		-0.002 ± 0.040

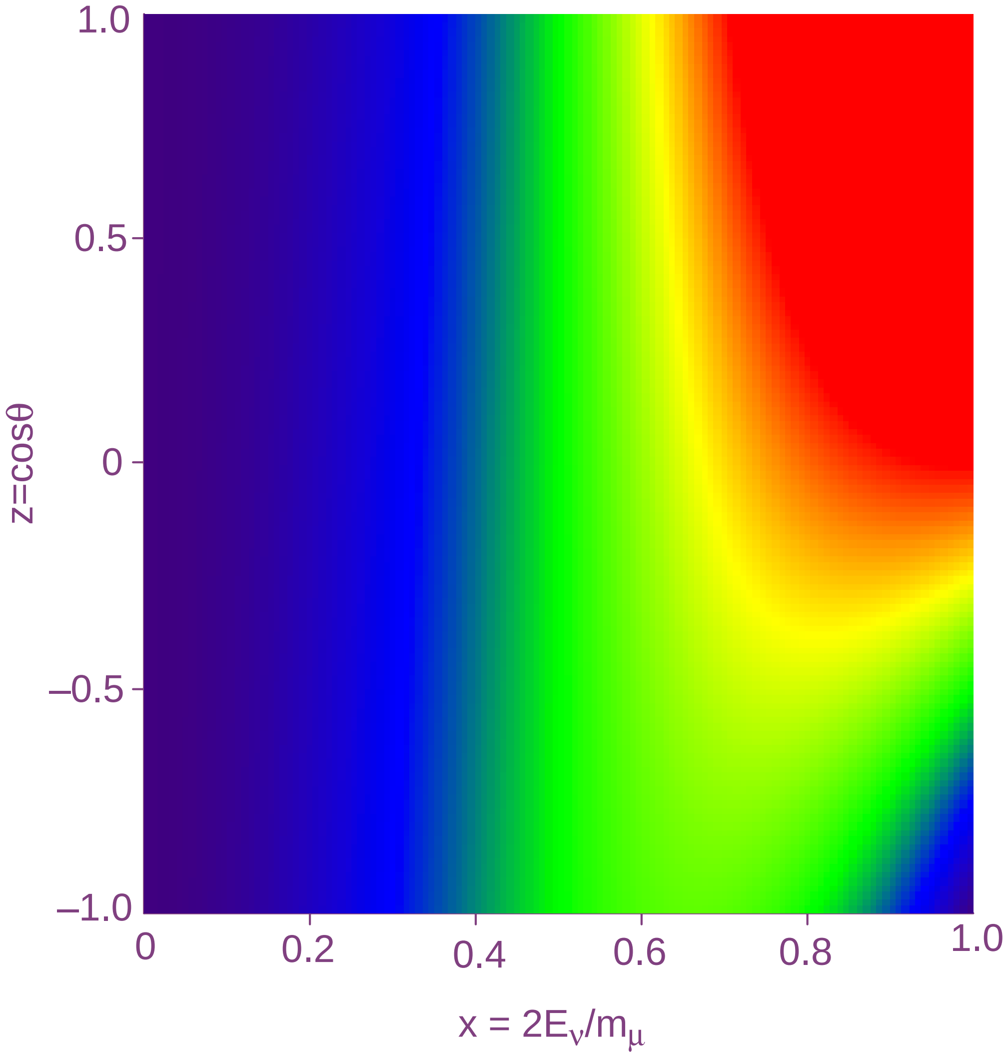
● EQUAL MASSES

\+ OPPOSITE CHARGES & FORM FACTORS

Δ EQUAL RATES

$$\mu^+ \to e^+ \bar{\nu}_\mu \nu_e$$

$$\frac{d^2 N_{\bar{\nu}_\mu}}{dx d\Omega} = \frac{x^2}{2\pi}[(3-2x) - (1-2x)\cos\theta]$$



$$\cos\theta = \hat{p}_\nu \cdot \hat{s}_\mu$$

$\mathbb{CP}$: Why violated in weak int.?

QUARK MIXING MATRIX?

WHAT SCALE?

WHAT ABOUT LEPTONS?

OTHER SOURCES?

Why not violated in strong?

θ-VACUUM (PECCEI-QUINN SYM.)

AXIONS

QUARK MASSES?

What accounts for Baryogenesis?

$\mathbb{T}$: Can we establish independent of $\mathbb{CPT}$?

WHY MIGHT WE SUSPECT $\not{CP}$?

(NON-HISTORICAL)

Can we understand why matter dominates over antimatter in the U?

DENSITY OF BARYONS IS SMALL $n_B/n_\gamma \approx 4\times10^{-10}$

BUT IMPORTANT,

WHILE DENSITY OF ANTIBARYONS IS NEGLIGIBLE

If the U began in a symmetric state of ZERO BARYON NUMBER, How did the present MATTER EXCESS evolve?

Sakharov's 3 conditions:

- Processes that violate BARYON #
- Departure from thermal eq$^{\underline{m}}$ while $\not{B}$
- $\not{CP}$

To illustrate, suppose that

X decays → B_1 with prob. f
→ B_2 " " $(1-f)$

and its antiparticle

$\bar{X}$ decays → $\bar{B}_1 = -B_1$ with $\bar{f}$
→ $\bar{B}_2 = -B_2$ " $(1-\bar{f})$

$\mathbb{CPT}$: $\Gamma(X \to \text{all}) = \Gamma(\bar{X} \to \text{all})$, so

STARTING FROM EQUAL POPULATIONS OF X AND $\bar{X}$, NET BARYON # IS

$$\Delta B = (f-\bar{f})B_1 + [(1-f)-(1-\bar{f})]B_2$$
$$= (f-\bar{f})(B_1 - B_2)$$

$\Delta B \neq 0$ REQUIRES $B_1 \neq B_2$ ($\not{B}$)

AND $f \neq \bar{f}$ ($\not{\mathbb{CP}}$)

Our Picture of Matter

Pointlike ($R \lesssim 10^{-18}$ m)

QUARKS: $\begin{pmatrix} u \\ d' \end{pmatrix}_L$ $\begin{pmatrix} c \\ s' \end{pmatrix}_L$ $\begin{pmatrix} t \\ b' \end{pmatrix}_L$

LEPTONS: $\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L$ $\begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L$ $\begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L$

WITH INTERACTIONS SPECIFIED BY

$$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$$

GAUGE INTERACTIONS

Quantum Nos. of each generation $(\underset{\sim}{SU(3)}_c, \underset{\sim}{SU(2)}_L)_Y$:

$(\underset{\sim}{3}, \underset{\sim}{2})_{1/3}$	L_q	$(\underset{\sim}{1}, \underset{\sim}{2})_{-1}$	L_ℓ
$(\underset{\sim}{3}, \underset{\sim}{1})_{4/3}$	R_u	$(\underset{\sim}{1}, \underset{\sim}{1})_{-2}$	R_e
$(\underset{\sim}{3}, \underset{\sim}{1})_{-2/3}$	R_d		

(not the whole story)

$$\mathcal{L} = \mathcal{L}_{gauge} + \mathcal{L}_{EWSB} + \mathcal{L}_{Yukawa}$$

$\mathcal{L}_{gauge}$: $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ + matter

$\mathcal{L}_{EWSB}$: $SU(2)_L \otimes U(1)_Y \to U(1)_{EM}$

$\Rightarrow \mathcal{L}_{Higgs}$

Complex φ : $(\underset{\sim}{1}, \underset{\sim}{2})_1$

$$\langle \varphi \rangle_0 = \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$$

$\mathcal{L}_{Yukawa}$: generates fermion mass

$$-\mathcal{L}_{Yukawa} = \left. \begin{array}{l} \varsigma_u^{ij} \bar{L}_{qi} \bar{\varphi} R_{uj} \\ + \varsigma_d^{ij} \bar{L}_{qi} \varphi R_{dj} \\ + \varsigma_\ell^{ij} \bar{L}_{\ell i} \varphi R_{ej} \end{array} \right\} + h.c.$$

NO MIXING: $\varsigma_t \approx 1$, $\varsigma_e \approx 3 \times 10^{-6}$, ...

ELEMENTARITY

- Are quarks and leptons composite?

SYMMETRY

- What are the gauge symmetries?
- EWSB and the 1-TeV scale?
- What are discrete symmetries telling us?

UNITY

- Gauge coupling unification
- Quarks + leptons
- Constituents + Force Particles
- Incorporation of Gravity

IDENTITY

- Fermion masses and mixings
- CP violation
- Neutrino oscillations
- What makes an electron an electron, a neutrino a neutrino, a top quark a top quark?

One aspect of the Problem of Identity:

THE ORIGIN OF MASS

$[\pi]$ p ρ ...	UNDERSTOOD QCD
$W^{\pm}$ Z^0	EWSB
q, ℓ^-	EWSB + Yukawa
ν	EWSB + Yukawa + new physics?

THE PROBLEMS OF MASS, AND OF MASS SCALES

- EWSB sets M_W, M_Z

$$M_W^2 = g^2 v^2/2 = \pi\alpha/G_F\sqrt{2}\sin^2\theta_W$$

$$M_Z^2 = M_W^2/\cos^2\theta_W$$

EW SCALE IS $v = (G_F\sqrt{2})^{-1/2} = 246$ GeV

NOT THE ONLY SCALE!

STRONG GRAVITY

$$M_{Planck} = (\hbar c/G_{Newton})^{1/2}$$

$$\approx 1.22 \times 10^{19} \text{ GeV}$$

$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ unification scale

$$\approx 10^{15} \text{ GeV}$$

FLAVOR SCALE ? SUSY? TC?

SOMEWHERE?

How to keep scales from mixing?

stabilize M_H?

PROBLEMS OF MASS ...

- EACH FERMION MASS ⇒

A NEW, UNKNOWN, YUKAWA COUPLING

$$\mathcal{L}^{(e)}_{Yukawa} = -\zeta_e \left[\bar{R}_e(\varphi^+ L_e) + (\bar{L}_e \varphi) R_e\right]$$

$$m_e = \zeta_e v/\sqrt{2}$$

ALL FERMION MASSES ~ PHYSICS BEYOND STD. MODEL

$\zeta_t \simeq 1, \quad \zeta_e \simeq 3 \times 10^{-6}, \quad \zeta_\nu \simeq 10^{-10}$??

What accounts for the range and values of the Yukawa couplings?

BEST HOPE UNTIL NOW:

Unified theories suggest pattern of fermion masses SIMPLIFIES on high scales

Yukawa couplings offer the possibility of CP violation ...

CONSIDER

$$-\mathcal{L}^{(d)}_{Yukawa} = \zeta^{d}_{ij}\, \underbrace{\bar{L}_{qi}\, \varphi\, R_{dj}} + \zeta^{d*}_{ij}\, \underbrace{\bar{R}_{dj}\, \varphi^{+} L_{di}}$$

CP INTERCHANGES

IF $\zeta^{d}_{ij} \neq \zeta^{d*}_{ij}$,

CP IS NOT A SYMMETRY OF $\mathcal{L}_{Yukawa}$

THE CP VIOLATION WITHIN THE SM (ARISING FROM THE QUARK MIXING MATRIX/YUKAWA COUPLINGS) IS ITSELF A WINDOW ON PHYSICS BEYOND THE STANDARD MODEL.

We know from EW theory alone that the 1-TeV scale is special:

$$M_H^2 < \frac{8\pi\sqrt{2}}{3G_F} = 1\ \mathrm{TeV}^2$$ (Higgs boson or new physics)

<u>CONVENTIONAL APPROACH</u> TO UNDERSTAND

WHY $(M_H, v) \ll M_{Pl}$

(resolve hierarchy problem):

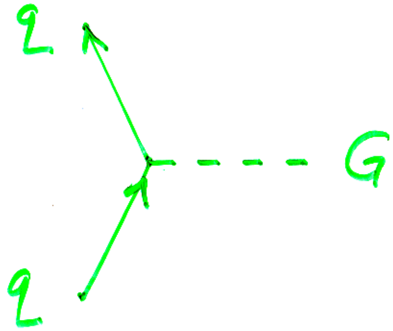
EXTEND THE STANDARD MODEL

$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$
- composite Higgs (technicolor / topcolor)
- supersymmetry
- . . .

(effects on discrete symmetries)

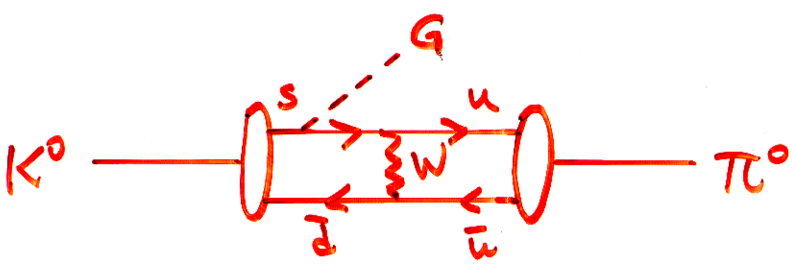
NATURAL TO NEGLECT GRAVITY IN PARTICLE PHYSICS:

G_N SMALL $\Leftrightarrow$ M_{Pl} LARGE



$G \sim \frac{E}{M_{Pl}}$

ESTIMATE $B(K \to \pi G) \sim \left(\frac{M_K}{M_{Pl}}\right)^2 \sim 10^{-38}$



Newton + 300 yrs: why is gravity weak?

NOVEL SPECULATION

Change Gravity to understand why $M_{Pl} \gg v$

STRING THEORY: EXTRA SPACE DIMENSIONS TRADITIONALLY ASSUMED $R_{ED} \lesssim 1/M_{Pl}$ (10^{-35} m)

EXPERIMENT: GRAVITY FOLLOWS NEWTONIAN FORCE LAW TO ~ 1 mm.

IF GRAVITY PROPAGATES IN EXTRA DIM,
dimensional analysis changes (Gauss)

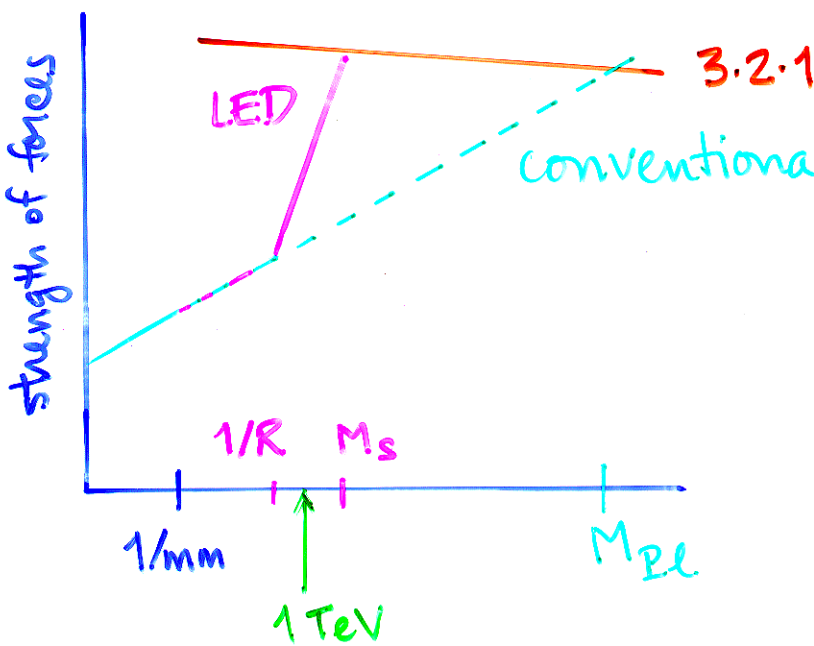
n extra dim., radius R ⇒

$$G_N \sim M_{Pl}^{-2} \sim M_s^{-n-2} R^{-n}$$

If $M_s \sim 1$ TeV, $R \lesssim 1$ mm for $n \geq 2$

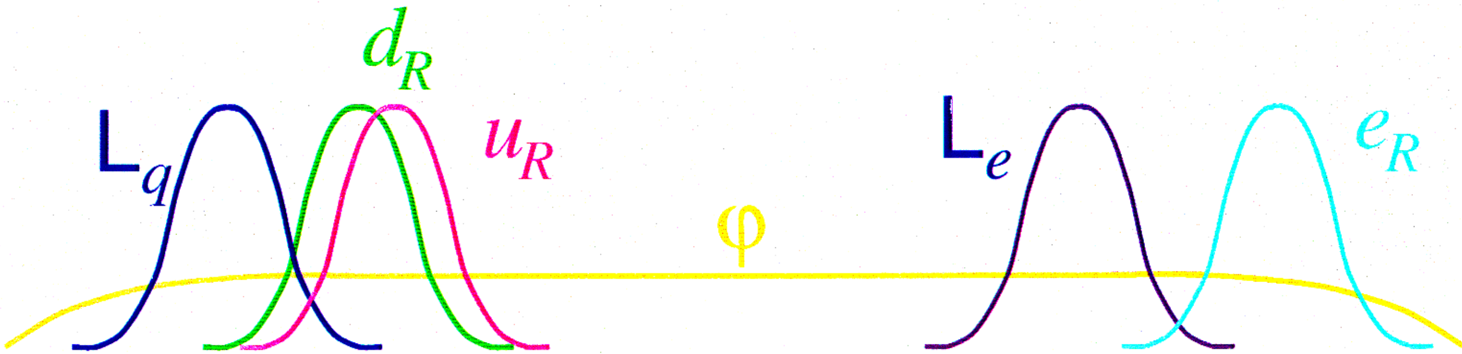
$$M_{Pl} = M_s (M_s R)^{n/2}$$

would mean that M_{Pl} results from a false extrapolation



Gravity's true scale could be near EW scale.. (Subversive idea)

Might Extra Dimensions Explain the Range of Fermion Masses?



$$\mathcal{L}^{(e)}_{\text{Yukawa}} = -\zeta_e[\bar{\mathsf{R}}_e(\varphi^\dagger \mathsf{L}_e) + (\bar{\mathsf{L}}_e\varphi)\mathsf{R}_e], \qquad \langle\varphi\rangle_0 = \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$$

$$m_e = \zeta_e v/\sqrt{2} \approx \zeta_e \times 176\ \text{GeV}/c^2$$

Arkani-Hamed, Schmaltz…

THE VACUUM ENERGY PROBLEM

Higgs potential

$$V(\varphi^\dagger\varphi) = \mu^2(\varphi^\dagger\varphi) + |\lambda|(\varphi^\dagger\varphi)^2$$

at minimum,

$$V(\langle\varphi^\dagger\varphi\rangle_0) = \frac{\mu^2 v^2}{4} = \frac{-|\lambda| v^4}{4} < 0$$

Identify $M_H^2 = -2\mu^2$

$$\rightarrow \varrho_H = M_H^2 v^2/8$$

vacuum energy density

Search for a cosmological constant tells us

$$\varrho_{vac} \lesssim 10^{-46}\ \mathrm{GeV}^4$$

BUT $\varrho_H \gtrsim 10^8\ \mathrm{GeV}^4$

MISMATCH BY 54 ORDERS OF MAGNITUDE

WITHIN EW THEORY, THE GAUGE AND EWSB (HIGGS) INTERACTIONS RESPECT CP.

CP VIOLATION ARISES ONLY IN MIXING OF QUARK MASS EIGENSTATES TO FORM INTERACTION EIGENSTATES

CHARGED CURRENT

$$(\bar{u}, \bar{c}, \bar{t}, \ldots) \, \mathbf{V} \begin{pmatrix} d \\ s \\ b \\ \vdots \end{pmatrix}$$

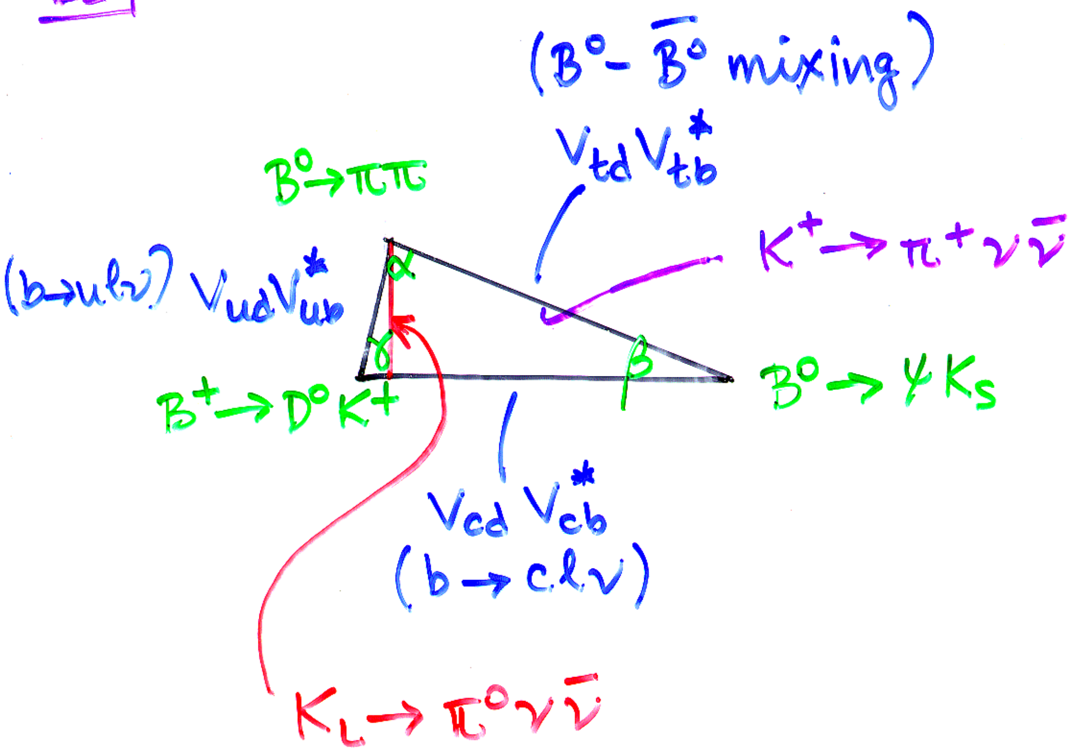
must contain complex elements
$\Rightarrow \geq 3$ families

QUARK MIXING MATRIX IS UNITARY

$$VV^{+} = I$$

↳ CLOSE UNITARY TRIANGLES

bd



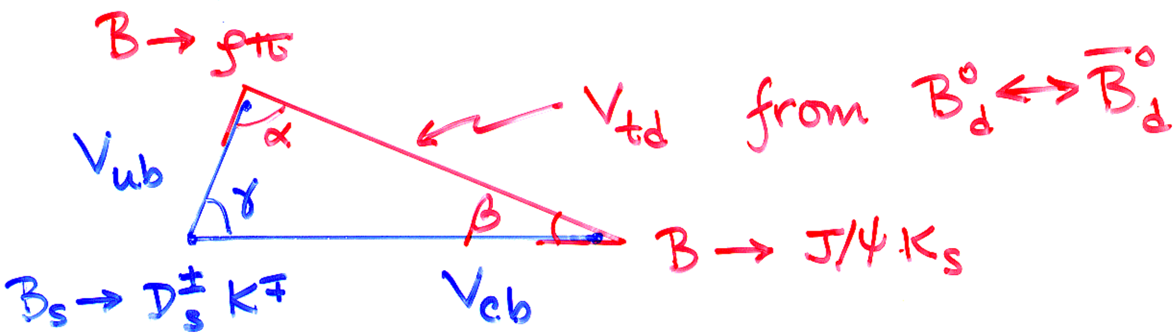
Some immediate goals:

- Establish CP̸ in B decays (measure sin 2β in $B^0 \to \psi K_S$)
- Measure B_s - $\bar{B}_s$ mixing
- Measure rates for $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$
- Improve theoretical interpretations (quarks ↔ hadrons)
- Overconstrain unitarity △

BTeV

Approved at Fermilab June 2000, to run in parallel with LHCb.

MANY MEASUREMENTS NEEDED TO TEST KM PHASE AS SOLE ORIGIN OF CP VIOLATION



Tree processes — Mixing processes

BTeV / LHCb needed for $B_s \to D_s^{\pm} K^{\mp}$

BTeV or B-factory $\mathcal{L}$ upgrade needed for $B \to \rho\pi$

Comparing tree Δ with mixing Δ tests for anomaly in $\mathcal{A}(B^0 \to \bar{B}^0)$.

Weirdness in magnitude corrupts V_{td}, phase corrupts α, β.

Similar test of $B_s \leftrightarrow \bar{B}_s$, $B_s \to D_s^{\pm} K^{\mp}$, and $B_s \to J/\psi\, \eta^{(\prime)}$ is sensitive to
$\eta^{(\prime)} \to \gamma\gamma$

new $B_s \leftrightarrow \bar{B}_s$ physics.

MEASURING SIDES $\longleftrightarrow$ HADRONIC M.E.
(LATTICE QCD)

How will BTeV do it?

★ $PbWO_4$ e-cal (π^0, γ)

$B \to \rho\pi$ (always a π^0)

$B_s \to J/\psi\, \eta^{(\prime)}$
$\eta^{(\prime)} \to \gamma\gamma$

★ Versatile (+ challenging) trigger

- driven by detached vertices in Si pixel detector

- accepts a wide range of decays (including charm), so sensitive to unanticipated effects in Λ_b, B_s; strong in rare decays
- compensates LHCb's better σ, σ/σ_{tot}

Unitarity Δ is not the beginning and end of our program.

~~CP~~ in the standard model is
explicit + very constrained
predictive (+ becomes more so)
highly testable.

- Arises from $\xi_{ij}^{q} \neq \xi_{ij}^{q\,*}$ (IMAG. PARTS)
- 3 generations ⇒ one complex phase δ_{KM} in quark mixing matrix.

NOT SMALL!

- Resides only in CC interactions of QUARKS ⇒ Δ Flavor
(Generalization to leptons, but may well entail other new physics)
- Is absent in NC interactions.
- Is predicted tiny in experimentally interesting cases (EDM)
- Appears only in weak interactions

Not shared in general by NEW PHYSICS

Why is CP so interesting?

- Even in SM, points us to physics we do not understand
  «problem of identity»
- Is highly sensitive to New Physics
- What we understand of Baryogenesis suggests that a new source of CP violation is required.
  Can we find it in the laboratory.
- Is accessible to a wide range of experiments NOW.

The importance of leaving the human scale.