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SCHOOL ON
NON-ACCELERATOR PHYSICS
25 April - 6 May 1988

SUPERSTRINGS IMPLICATIONS TO PARTICLE PHYSICS & COSMOLOGY (2)

by

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SUPERSTRING IMPLICATIONS TO PARTICLE PHYSICS/COSMOLOGY

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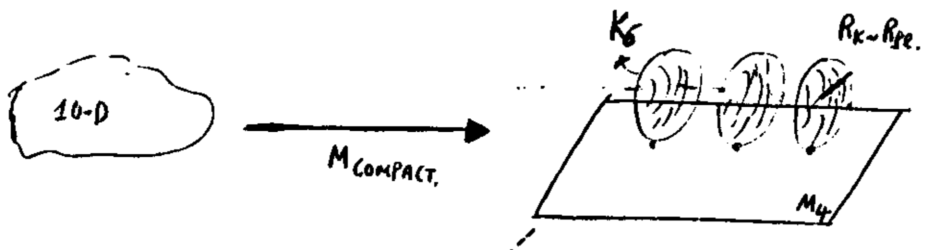
ICTP

3-5/5/88

SCHOOL ON NON-ACCEL. PHYSICS.

PHYSICS:



(C-H-S-W)

outside information: 1) M_4: cosmological constant; 2) $N=1$ SUSY $\rightarrow \Lambda_c = 0$

$M_4 \times K_6$ → Calabi-Yau manifold! ↳ ∃ large class of them

1) ∄ Extra gauge interactions !

2) ∄ Anomalies after compactification: $(F \wedge F)_6 \propto (R \wedge R)_6$

$E_8 \times E_8' \xrightarrow{M_c} E_6 \times E_8'$ → communicate only gravitationally !

$(F_{\mu\nu})_{E_6} = (F_{\mu\nu})_{E_8'} = 0$! (WATCH IT !)[1]

3) Particle content :

$E_8 \rightarrow E_6 \times SU(3)$

$248 = (78,1) + (27,3) + (\overline{27},\overline{3}) + (1,8)$ — Sub-... $\overline{\overline{27}}$

"gauge bosons" : $\supset 24_{SU5} \supset 8_g + 3_W + 1_\gamma$

"matter" : $\supset (10+\overline{5})_{SU(5)} \equiv \binom{u}{d}_L + \binom{\nu_e}{e}_L + u_R, d_R, e_R$

$N_g \equiv$ # generations ?

5)

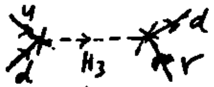
∴ 1) E_6 - breaking
2) N_g
3) Embarass. Yukawa relations. (wrong masses, fast proton decay, ⋮)

⟶ "HOLY" C-Y manifolds

• N_g can be 3 ✓ (χ/2)

•• Easily avoid (dud) GUT relations: $m_d = m_e$ ✓

$$\begin{pmatrix} \begin{pmatrix} H \\ H \\ H \end{pmatrix}_3 \\ H^+ \\ H^0 \end{pmatrix}$$ ⟶ W-S Higgs



✓

⟶ Can now be light!
NO HIERARCHY PROBLEM!

••• E_6- breaking : (Solenoid / B-A) HOSOTANI MECHANISM

$$A_M^{(78)} = \left(A_\mu^{(78)}, \text{"}A_{m}^{(78)}\text{"} \right)$$

($A_\mu^{(78)}$ ↓ gauge bosons; "$A_m^{(78)}$" ↓ "scalars")

VERY SPECIFIC BREAKING PATTERNS!

E_6 ⟶ $SU(3) \times SU(2) \times SU(2) \times U(1) \times U(1)$
$SU(3) \times SU(2) \times U(1) \times U(1) \times U(1)$

(CERN / CERN2) ⟵ $SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_E$ * (?)

$$\text{"}27\text{"} = {}_{1/3}\begin{pmatrix} u \\ d \end{pmatrix}_L + {}_{1/3}u_R + {}_{-1/6}d_R + {}_{-1/6}\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L + {}_{1/3}e_R + {}_{5/6}\nu_R +$$

$$+ {}_{-1/6}\begin{pmatrix} \bar{H}^- \\ \bar{H}^0 \end{pmatrix}_L + {}_{2/3}\begin{pmatrix} H^+ \\ H^0 \end{pmatrix}_R +$$

$$+ {}_{-1/6}D_R + {}_{-1/3}D_L \quad \{\text{heavy "d-type quark"}: Q = -1/3\}$$

$$+ {}_{5/6}N \quad \{Q = 0\}$$

($u \equiv G$, $\nu_e, e \equiv L$)

• Allowable v.e.v.s: UNIQUE

$\langle \bar{H} \rangle \equiv \bar{v}$; $\langle H \rangle \equiv v$; $\langle N \rangle \equiv X$

•• Superpotential: UNIQUE

$$f = \lambda_{\alpha\beta c} H_\beta \bar{H}_c N_\alpha + k_{\alpha\beta c} D^c_\alpha D_b N_c + \cdots +$$

$$+ h_{\alpha\beta c} H_\alpha q_b u^c_c + h'_{\alpha\beta c} \bar{H}_\alpha q_b d^c_c + \tilde{h}_{\alpha\beta c} L_\alpha \bar{H}_b e^c_c$$

$(\alpha, \beta, c = 1, 2, 3)$

∴ No problems with:
B ✓
L ✓ ⟶ m_{ν_h}
FCNC ✓
Weak universality ✓

(C-E-E-N)

"δf" = ① $\lambda' D^c L Q + \lambda'' D e^c u^c + \lambda_D D d^c \nu^c$ — $B_D = 1/3$ $L_D = 1$

(OR) (OR)

② $\lambda''' D Q Q + \lambda^{iv} D^c u^c d^c$ — $B_D = -2/3$ $L_D = 0$

- (OR) → Consew. of B-number
  Existence of one set of couplings → D-decay!
  *** No mixing between D-d ! Weak univers. ✓
  → B.conserv. guaranteed!

.. All above couplings + $\lambda_L H L \nu^c$
  i) large m_ν
  ii) large L-H mixing

Are the ONLY ones allowed by primordial E_6 !

→ WE NEED DISCRETE SYMMETRY ("R-PARITY") TO FORBID ONLY THE EXISTENCE OF $HL\nu^c$ ⊕ $\delta f_{①}$ or $\delta f_{②}$

NOT SO PECULIAR!!!

e.g.: ($Z_2 \times Z_2'$)

$\nexists$ $HL\nu^c + \delta f_{②}$ ⟶ { Z_2 : [SU(3), 3, $\bar{3}$] → (-1) [ ] ; Z_2' : ν^c → (-1) [ ] }

$\nexists$ $HL\nu^c + \delta f_{①}$ ⟶ { Z_2 : (L, e^c, ν^c) → (-1) [ ] ; Z_2' : ν^c → (-1) [ ] }

... ∃ $\lambda H\bar{H}N$ coupling FUNDAMENTAL
→ 1) $m_{1/2} \neq 0$
  2) $\tilde{H}, \tilde{\bar{H}}, \tilde{N}$ massive
  3) $\nexists$ "wrong" axions!

(E-E-N-Z)

∴ 1) Uniqueness of low energy gauge group G_0:

$G_0 \equiv SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_E$

with only 3-generations allowed! ⊕
(27)

2) Generically at low energies only 3 (27) allowed.

No $\overline{27}$ or parts of it ! at low energies!

3) Allowed v.e.v's: Unique. !

4) Allowed λ's: Unique !

VERY RESTRICTIVE.

⊕ $M_X \simeq 4.4 \cdot 10^{17}$ GeV

$\sin^2\theta_W(M_W) \simeq 0.21$

(CEEGN)

Bounds on Yukawa couplings from flavour-changing neutral currents and other rare processes. The generation structure of the couplings has not been taken explicitly into account, but it is clear, for each process studied, which fermion generations are involved.

		Rare process	1	2	3	4	5	6	7	8	9	10
			$\lambda_1 HQu^c$	$\lambda_2 \bar{H}Le^c$	$\lambda_3 \bar{H}Qd^c$	$\lambda_6 DQQ$	$\lambda_7 D^c u^c d^c$	$\lambda_8 De^c u^c$	$\lambda_9 D^c LQ$	$\lambda_{10} Dd^c \nu^c$ $\langle 0\|\tilde{\nu}\|0\rangle = 0$	ϵ_L $\langle 0\|\tilde{\nu}\|0\rangle \neq 0$	ϵ_R
K physics	1	$K^0 \leftrightarrow \bar{K}^0$	-	-	3×10^{-5}	0.1	0.1	-	0.1	0.1	1×10^{-3}	3×10^{-3}
	2	$K_L \to \mu^+\mu^-$	-	$\sqrt{\lambda_3\lambda_2} < 8 \times 10^{-4}$		0.4	0.4	-	0.6	0.2	6×10^{-3}	3×10^{-2}
	3	$K \to \pi\nu\bar{\nu}$	-	-		-	-	-	0.2	0.2	2×10^{-7}	0.1
	4	$K \to \pi e^+e^-$	-	$\sqrt{\lambda_3\lambda_2} < 8 \times 10^{-3}$		0.9	0.9	-	-	-	-	-
	5	$K_L \to \mu^\pm e^\mp$	-	$\sqrt{\lambda_3\lambda_2} < 6 \times 10^{-4}$		-	-	-	-	-	-	-
	6	$K^+ \to \pi^+\mu^\pm e^\mp$	-	$\sqrt{\lambda_3\lambda_2} < 2 \times 10^{-3}$		-	-	-	-	-	-	-
D physics	7	$D^0 \leftrightarrow \bar{D}^0$	2×10^{-4}	-	-	0.1	0.1	0.1	0.1	-	-	-
	8	$D^0 \to \mu^+\mu^-$	$\sqrt{\lambda_1\lambda_2} < 6 \times 10^{-2}$		-	-	-	-	-	-	-	-
	9	$D^0 \to \mu^\pm e^\mp$	$\sqrt{\lambda_1\lambda_2} < 6 \times 10^{-2}$		-	-	-	2	2	-	-	-
	10	$D \to \mu^\pm e^\mp X$	$\sqrt{\lambda_1\lambda_2} < 0.27$		-	-	-	1.7	1.7	-	-	-
B physics	11	$B^0 \leftrightarrow \bar{B}^0$	-	-	1×10^{-4}	0.1	0.1	-	0.1	0.1	1×10^{-3}	3×10^{-3}
μ physics	12	$\mu N \to eN$	-	$\sqrt{\lambda_3\lambda_2} < 8 \times 10^{-4}$		-	-	4×10^{-3}	4×10^{-3}	-	-	-
	13	$\mu \to \bar{e}ee$	-	2×10^{-3}	-	-	-	0.02	0.02	-	-	-
	14	$\mu \to e\gamma$	-	8×10^{-4}	-	-	-	0.1	0.1	-	-	-
	15	$(g-2)_\mu$	-	-	-	-	-	-	-	-	-	-

		Rare process	1	2	3	4	5	6	7	8	9	10
			$\lambda_1 HQu^c$	$\lambda_2 \bar{H}Le^c$	$\lambda_3 \bar{H}Qd^c$	$\lambda_6 DQQ$	$\lambda_7 D^c u^c d^c$	$\lambda_8 De^c u^c$	$\lambda_9 D^c LQ$	$\lambda_{10} Dd^c \nu^c$ $\langle 0\|\tilde{\nu}\|0\rangle = 0$	ϵ_L $\langle 0\|\tilde{\nu}\|0\rangle \neq 0$	ϵ_R
CP violation (Im λ)	16	$\mathrm{Im}(K^0 \leftrightarrow \bar{K}^0)$	-	-	1×10^{-6}	2×10^{-2}	2×10^{-2}	-	2×10^{-2}	2×10^{-2}	2×10^{-3}	5×10^{-3}
	17	ϵ'/ϵ	-	-	-	-	-	-	-	-	-	-
	18	$P(K \to \pi\mu\nu)$	-	$\sqrt{\lambda_2\lambda_3} < 6 \times 10^{-3}$		-	-	-	-	-	-	-
	19	d_n	$\sqrt{\mathrm{Im}\,\lambda_1\lambda_3} < 6 \times 10^{-3}$	-	$\sqrt{\mathrm{Im}\,\lambda_1\lambda_3} < 6 \times 10^{-3}$	$\sqrt{\mathrm{Im}\,\lambda_6\lambda_7} < 2 \times 10^{-2}$		$\sqrt{\mathrm{Im}\,\lambda_8\lambda_9} < 6 \times 10^{-2}$		2×10^{-2}	-	-
Weak universality	20	$\pi \to e\nu$	-	$\sqrt{\lambda_1\lambda_2} < 1 \times 10^{-3}$		-	-	-	-	-	-	-
	21	$\pi^0 \to ee$	$\sqrt{\lambda_{1,3}\lambda_2} < 0.2$			-	-	-	-	-	-	-
	22	U_{KM}	-	-	-	-	-	-	-	-	-	-
ν mass	23	m_ν	-	-	-	-	-	-	$\sqrt{\lambda_9\lambda_{10}} < 1 \times 10^{-3}$			
Best limit (process)		Re λ	2×10^{-4} $D^0 \leftrightarrow \bar{D}^0$	8×10^{-4} $\mu \to e\gamma$	3×10^{-2} $\mathrm{Re}(K^0 \leftrightarrow \bar{K}^0)$	0.1 $\mathrm{Re}(K^0\text{-}\bar{K}^0)$ $\mathrm{Re}(D^0\text{-}\bar{D}^0)$ $\mathrm{Re}(B^0\text{-}\bar{B}^0)$	0.1 $\mathrm{Re}(K^0\text{-}\bar{K}^0)$ $\mathrm{Re}(D^0\text{-}\bar{D}^0)$ $\mathrm{Re}(B^0\text{-}\bar{B}^0)$	4×10^{-3} $\mu N \to eN$	4×10^{-3} $\mu N \to eN$	0.1 $K^0 \leftrightarrow \bar{K}^0$ $B^0 \leftrightarrow \bar{B}^0$	2×10^{-3} $\mathrm{Im}(K^0\text{-}\bar{K}^0)$	5×10^{-3} $\mathrm{Im}(K^0\text{-}\bar{K}^0)$
		Im λ	2×10^{-4} $D^0 \leftrightarrow \bar{D}^0$	8×10^{-4} $\mu \to e\gamma$	1×10^{-6} $\mathrm{Im}(K^0 \leftrightarrow \bar{K}^0)$	2×10^{-2} $\mathrm{Im}(K^0\text{-}\bar{K}^0)$	2×10^{-2} $\mathrm{Im}(K^0\text{-}\bar{K}^0)$	4×10^{-3} $\mu N \to eN$	4×10^{-3} $\mu N \to eN$	2×10^{-2} $\mathrm{Im}(K^0\text{-}\bar{K}^0)$ d_n		

L- physics

(MNS, CEEGN, E.M, N=0.)

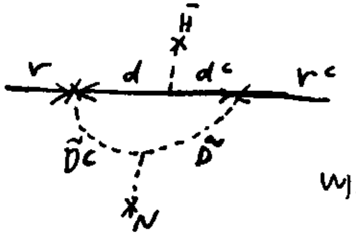
$$f_L = \lambda_L H L \nu^c + [\lambda' D^c L Q + \lambda'' D e^c u^c] + \lambda_D D d^c \nu^c$$

1) $\nexists$ Majorana mass $\rightsquigarrow$ no "see-saw" mechanism

$\lambda_L < 10^{-9}$!!! $\rightsquigarrow$ CUT

2) $\exists$ Possibil. for Radiat. induced small Dirac m_ν

e.g.: ...



$$m_\nu \simeq \frac{1}{4\pi^2} \cdot \lambda' \cdot \lambda_D m_d$$

(e.g): $\lambda' \sim \lambda_D \sim 10^{-3}$ $\rightsquigarrow$ $m_{\nu_\tau} \sim 50$ eV, $m_{\nu_\mu} \sim 1$ eV, $m_{\nu_e} \sim 10^{-2}$ eV } Dirac !

Consequences

1) No- ν-less 2-β decay / No- ν-ν̄ oscill.

2) ITEP ... (?)

3) Solar neutrino problem ✓ [M-S solution]

4) $\exists$ 3-Dirac-ν $\simeq$ 6 - 2 comp ν

→ PRIMORD. NUCLEOSYNT.

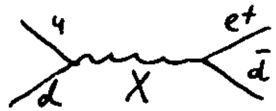
ORDINARY GUTs

Grand Unification : $SU(3) \times SU(2) \times U(1) \subset G \left(\equiv SU(5), SO(10), E_6, \vdots\right)$

new interactions → gauge : X, Y... ; → matter : H_3, ...

e.g.: $\begin{pmatrix} d \\ d \\ d \\ e \\ \nu \end{pmatrix}$ ($\bar{5}$) $\left(\begin{pmatrix} u \\ d \end{pmatrix}, u^c, e^c\right)$ (10)

"gauge decay"

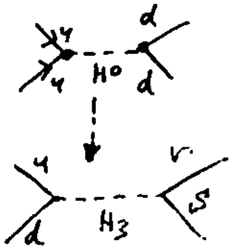


$p \to e^+ \pi^0$

$M_X \gtrsim 10^{15}$ GeV

"matter decay"

$\begin{pmatrix} H \\ H \\ H \\ \hline H^+ \\ H^0 \end{pmatrix}$ ($\bar{5}$) → $\exists$



$\propto m_u, m_d$

$p \to \nu K$, μK ...

WATCH IT

$M_{H_3} \gtrsim 10^{11-12}$ GeV

SUSY GUTS

All the above ⊕ "NEW STUFF"

α) $M_X \to 10^{16}$ GeV ---> gauge decay ?

β) "Matter decay" ---> H_3 ---> interesting in certain scenarios

{ inflation → phase transition } ⇝ $m_{H_3} \sim 10^{11}-10^{12}$ GeV !

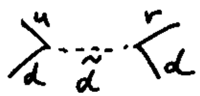
→ $p \to \begin{cases} \nu K \\ \mu K \end{cases}$

γ) NEW

γ1) $\bar{5}_F \cdot 10_F \cdot \bar{5}_H$ $\quad 10_F \cdot 10_F \, 5_H$

$\Downarrow$ $\bar{5}_F \cdot 10_F \cdot 5_{\tilde{F}}$ $\quad 10_F \cdot 10_F \, 5_{\tilde{F}}$

DIM 4 $\quad$ ↓ BAD

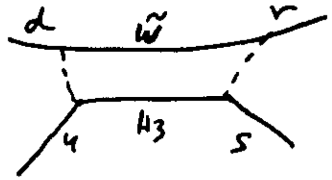


but $m_{\tilde{d}} \lesssim 1$ TeV ← gauge hierarchy

FORBID THEM $\quad$ e.g. R-parity: $f \to +1$, $\tilde{f} \to -1$ ...

γ2) $\bar{5}_F \cdot 10_F \cdot \bar{5}_{\tilde{F}} \cdot \begin{cases} 5_{\tilde{F}} \\ 10_{\tilde{F}} \end{cases}$ $\quad 10_F \cdot 10_F \cdot 5_{\tilde{F}} \begin{cases} 5_{\tilde{F}} \\ 10_{\tilde{F}} \end{cases}$ ...

DIM 5 $\quad$ R-parity ✓



$p \to \nu K$ ... (μK)

$$\tau \sim \alpha^2 \cdot \left(\frac{m_u \cdot m_s}{M_W^2}\right)^2 \cdot \left(\frac{1}{M_X \cdot M_W}\right)^2 \quad ✓$$

★ DIM 5 forbidden if ∃ extra U(1)'s !

★★ Supergravity / non-renormalizable interact.

↳ similar results:

$p \to K +$ lepton

AND THAT THE WAY IT WAS

UNTIL ...

(CEENG
NG.)

SUPERSTRINGS

all the above ⊕ NEW'

α) $M_X \sim M_{compact.}$ (~ 10^{18} GeV ?) → gauge decay ?

β) "Matter decay"

β1) ∄ ordin. dim 4 bad couplings → extra U(1)

β2) ∃ new dim 4 bad couplings

↳ banish them: Discrete symm. à la R-parity and/or topology

↳ CERN model example

β3) dim 5 → are out.
⇝ ∃ extra gauge symmetry
↳ Good !

β4) extra terms from ∫ out heavy degrees of freedom { field theory / Superstring modes

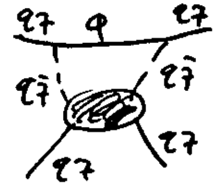
↳ respect symmetries

↳ e.g.: $h \frac{(27\,\overline{27})(27\,\overline{27})}{M}$ ⇢ need incomplete multiplets

$\tau_p \sim \frac{M^4}{m_{prot}^5}$!

↓ can be "dressed up" to provide ffff BX interact.

EVEN if $h' \varphi (27 \cdot \overline{27})$
↳ $(1,8) \in (248)_{E_8}$



⇝ B-violating !!!!

$\tau_p \sim \left(\frac{h h'}{M \cdot M_\varphi}\right)^{-2} \cdot m_{pr.}^{-5}$: All modes: incl. $\underline{\underline{M'}}$s

∴ ∃ extra gauge interact. at low energies
↳ Proton Stable !!!!!

You find proton decay: ∄ extra gauge symm. at low energy

α) E_6 → badly broken to (3,2,1)
β) SO(10), SU(5) ...
γ) ∃ φ

→ p → K + lepton

DARK MATTER (?)

Why (?)

- solar neighbourhood
  - galactic disc / halo
    - small groups and clusters of galaxies

Rotation curves.
[virial theorem]

- INFLATION: $\Omega_0 = 1$ (large scales)
  - Help Galaxy formation

⇝

i) $\frac{\delta\rho}{\rho}$ ⇝ enters the Horizon ⇝ no growth until matter/rad. separat.

ii) $\frac{\delta\rho}{\rho} \sim R(t) \sim \frac{1}{T}$ but.

$\frac{\delta\rho}{\rho} \sim 1$ at least before $T \sim 4T_0 \sim 10^0 K$ (galaxies; quasars....)

iii) $\left.\frac{\delta\rho}{\rho}\right|_{\lambda = ct} \simeq 1 \cdot \frac{(4T_0)}{1\,eV} \simeq 10^{-3}$ ≁ $\frac{\Delta T}{T} < 10^{-4}$

BAD !!!

BUT if ∃ Dark matter ⇝ matter domination earlier ($T > 1\,eV$) ⇝ avoid the clash !!!

... Dark matter: non-baryonic cause $\Omega_B < 0.2$ (Primor. Nuclear Synthesis)

⇝ (?) — ν, axions

COSMIC RELICS

LIGHTEST S(usy) PARTICLE (LSP)

(EHNOS, EHN, [redacted], CEEHNO)

R-parity (usually) ⇝ ∃ Stable S-particle → neutral / weakly interacting

Possibilities:

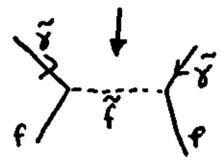
Spin 0	Spin 1/2	Spin 3/2
$\tilde{\nu}$	"$\tilde{\gamma}$"	$\tilde{G}_{3/2}$
Unlikely:	**YES**	unlikely: especially if $m_{3/2} \gtrsim 10^{12}$ GeV !!!

Unlikely ($\tilde{\nu}$):

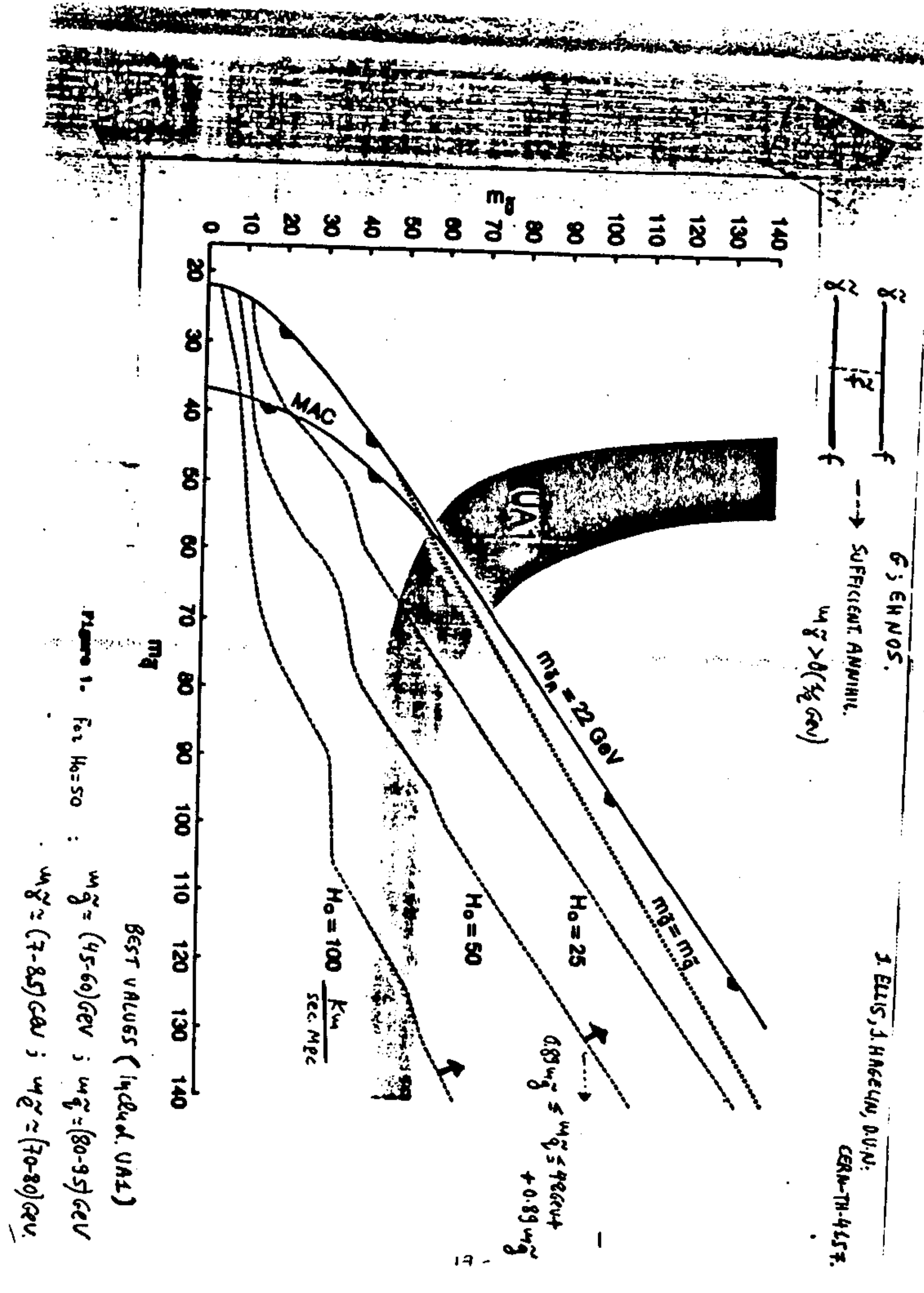
α) $m_{\tilde{\ell}}^2 \sim m_{\tilde{\nu}}^2 \sim m_e^2$

β) trapped in earth → too many neutrinos "not seen" in Proton decay detectors

NEW γ) Dark Matter Detectors exclude $\tilde{\nu}$ in the range $(16 \sim 10^3)$ GeV !



$m_{\tilde{\gamma}} \gg T_d$: "COLD" DARK MATTER (CDM)



Example: A S_{10} inspired model (EENZ)

gauge sector: $E_6 \supset SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_E$

Spin 1 : W_3 B B_E

SUSY :

Spin 1/2 : $\tilde{W}_3$ $\tilde{B}$ $\tilde{B}_E$

Matter sector: $27 = \underbrace{(10+\bar{5}+1)}_{\text{generation}} + 10 + \overline{10} + 1$

$\langle H^0 \rangle = v$
$\langle \bar{H}^0 \rangle = \bar{v}$
$\langle N \rangle = x$
⊕
∃ $\lambda H \bar{H} N$ coupling

Spin 0 : H^0 $\bar{H}^0$ N

SUSY :

Spin 1/2 $\tilde{H}^0$ $\tilde{\bar{H}}^0$ $\tilde{N}$

MIX

$$\chi_i = \alpha_i \tilde{W}_3 + \beta_i \tilde{B} + \gamma_i \tilde{H}^0 + \delta_i \tilde{\bar{H}}^0 + \varepsilon_i \tilde{B}_E + J_i \tilde{N}$$

1) relic Cosmol. mass density : ρ_χ

2) neutrino fluxes from LSP annih. in the sun.

3) Rates in DMD.

(CEEHNO)

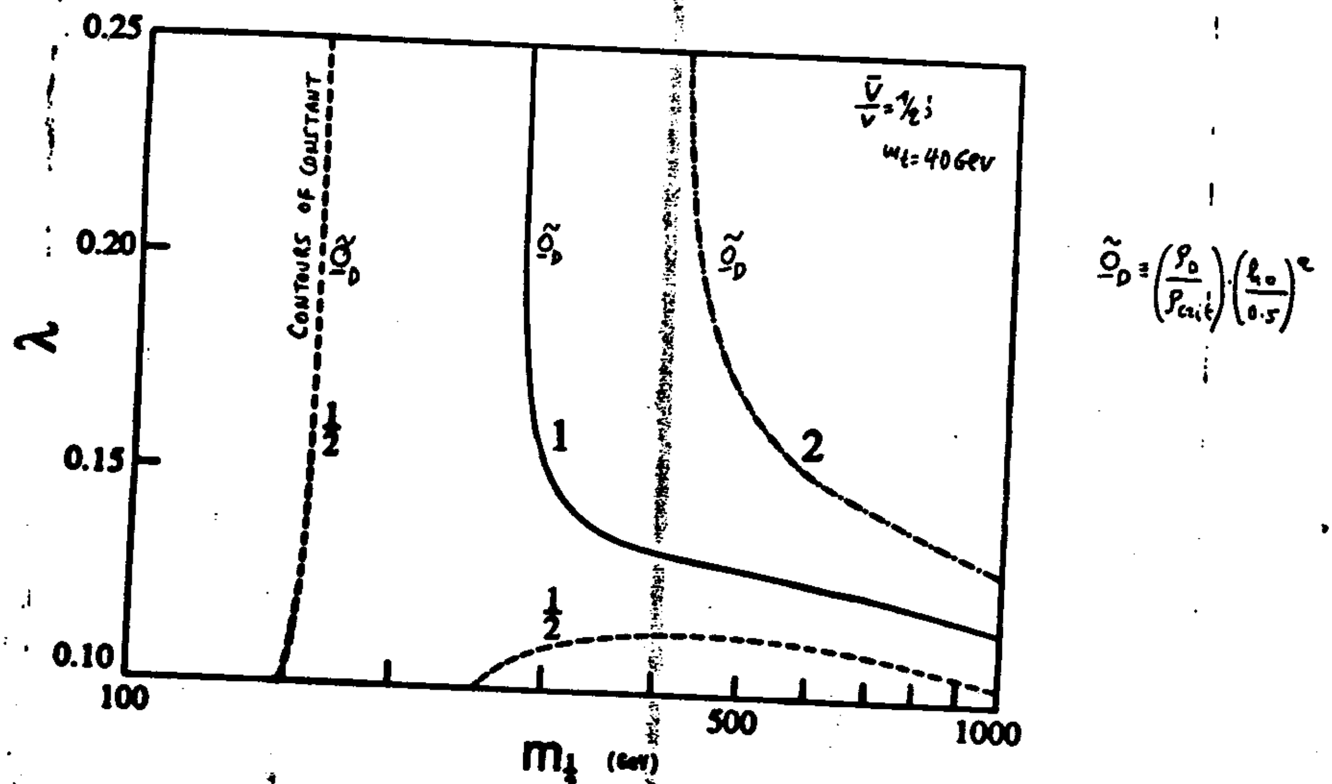
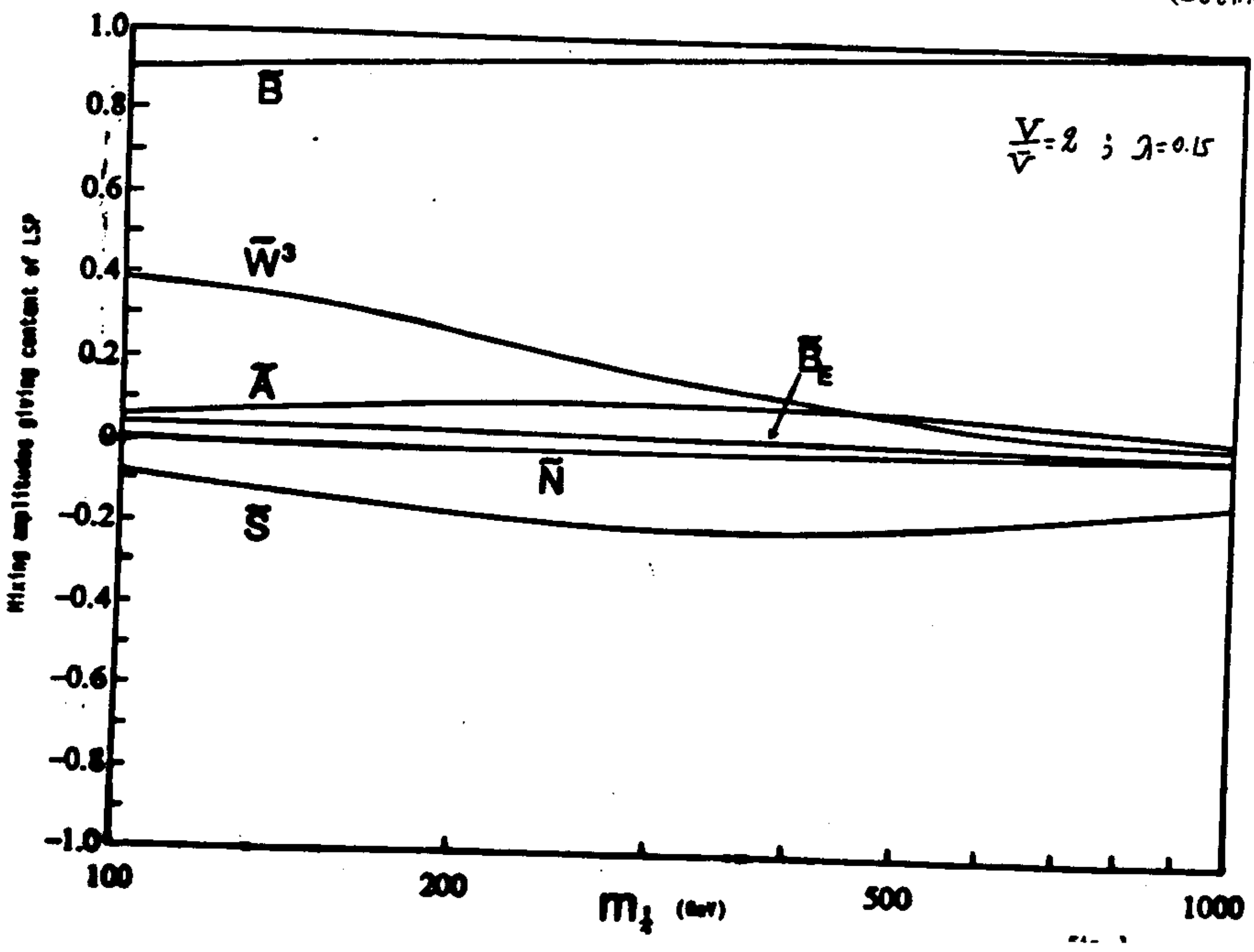


Fig. 3

(CEEHNO)



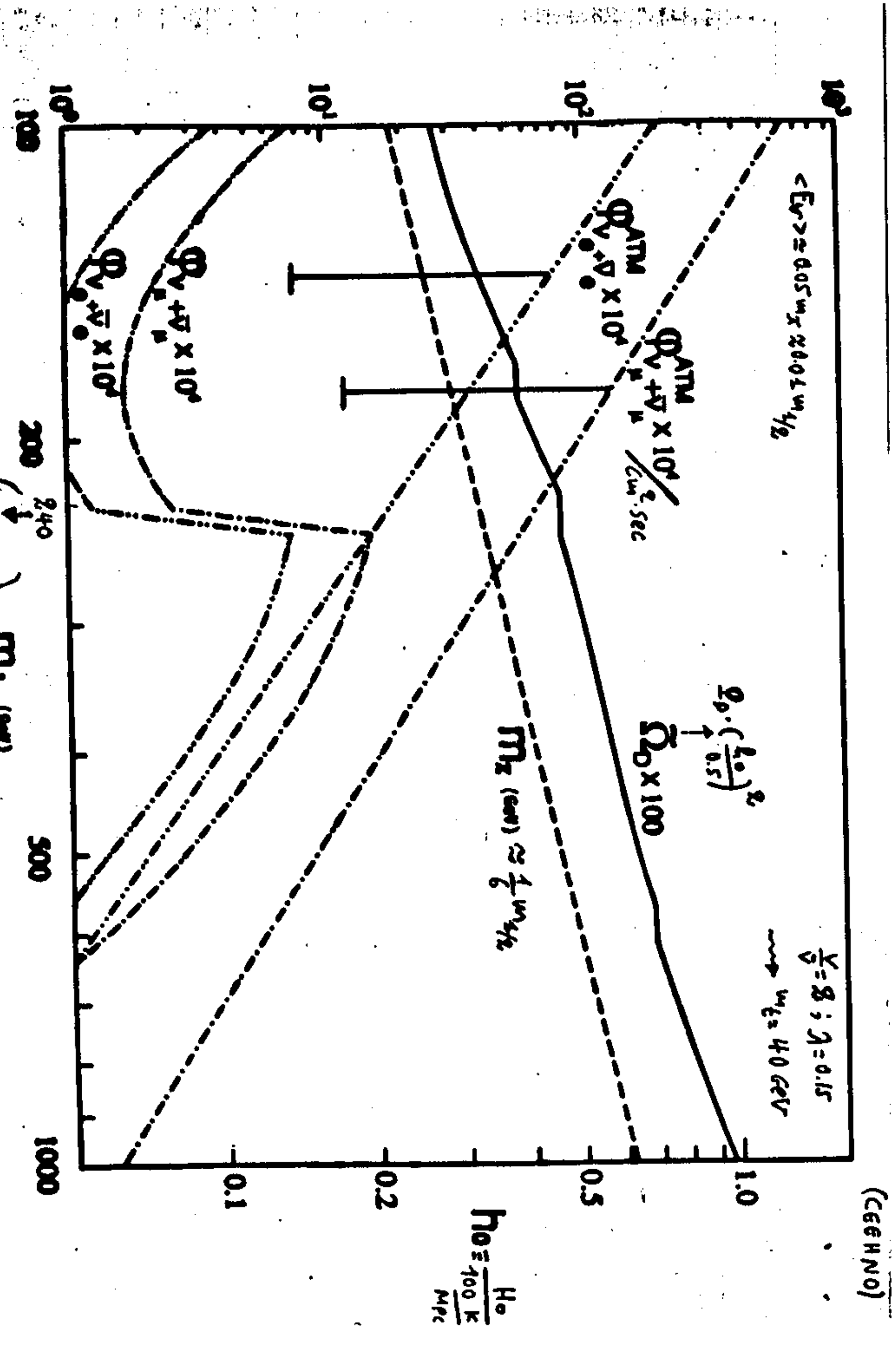


Fig. 2

RESULTS

1) $\Omega_D \equiv \frac{\rho_D}{\rho_{cr}} = 2^{0\pm1}\left(\frac{0.5}{h_0}\right)^2$!

2) Solar neutrino fluxes. $\{ \langle\sigma v\rangle \simeq 0.05\, m_\chi \}$

⇝ acceptable / observable   IFF: ⋆ $m_\chi \leq m_t$ ⋆ ⇝ $\{ m_{1/2} \leq 6\, m_t \}$ ⋆

Assuming $\Omega_D = 1$ [INFLATION] ⇝ (for $h_0 = 1/2$) ⇝ $m_t \gtrsim 40$ GeV !!!

∴ $\Omega_D = 1$ / heavy top FIT WELL

3) Rates in DMD:

$m_\chi = (20, 30, 40)$ GeV

$\# \frac{\text{events}}{\text{kg}\cdot\text{day}} = (23, 8, 6)\times 10^{-3}$ ↳ ~ BG. (^{27}Al ; $^{69,72}Ga$)

⋆ $\langle E\rangle \simeq \frac{m^2_{\tilde\gamma}\cdot m_{Z,A}}{(m_{\tilde\gamma} + m_{Z,A})^2} v^2$ /collision   e.g.: $\langle E\rangle \simeq 1$ keV for $m_{\tilde\gamma} \simeq 4$ GeV