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SMR.1508 - 26

SUMMER SCHOOL ON PARTICLE PHYSICS

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STRING PHENOMONOLOGY

Lecture I

H-P. NILLES
University of Bonn
Bonn
GERMANY

QUESTIONS:

* ORIGIN OF $SU(3) \times SU(2) \times U(1)$
* CHIRAL SPECTRUM
* $N \leq 1$ SUPERSYMMETRY
* QUARK - LEPTON FAMILIES
  $[(3,2), (\bar{3},1), (1,2), (1,1)]$
* HIGGS DOUBLETS
  (DOUBLET - TRIPLET SPLITTING)
* EXOTIC STATES ?
* ADDITIONAL GAUGE GROUPS ?
* WHY 3 FAMILIES OF QUARKS AND LEPTONS

* GRAND UNIFICATION ?
  (SU(5), SO(10) ....)

* $\sin^2\theta_W$ AND UNIFICATION WITH GRAVITY

* PROTON STABILITY

* FLAVOUR PROBLEM (FCNC..)

* STRONG CP PROBLEM

* LIGHT NEUTRINOS

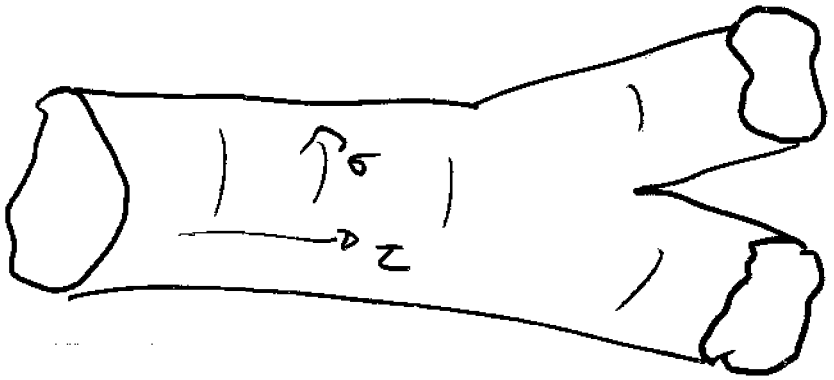
* YUKAWA COUPLINGS

* SU(2) x U(1) BREAKDOWN

* SUSY BREAKDOWN

STRING THEORY

EXTENDED OBJECTS



$$X^M(\sigma,\tau) \qquad M = 0, \ldots, d-1$$

REPARAMETRIZATION

INVARIANCE ON WORLD SHEET

$$S \approx \frac{1}{\alpha'} \int d\sigma d\tau \, \partial^\mu X^M \partial_\mu X_M$$

$$\mu = 0, 1 \longleftrightarrow \sigma, \tau$$

⟶ CONFORMAL SYMMETRY

$$X^M(\sigma,\tau) = X_R^M(\tau-\sigma) + X_L^M(\tau+\sigma)$$

MODE EXPANSION:

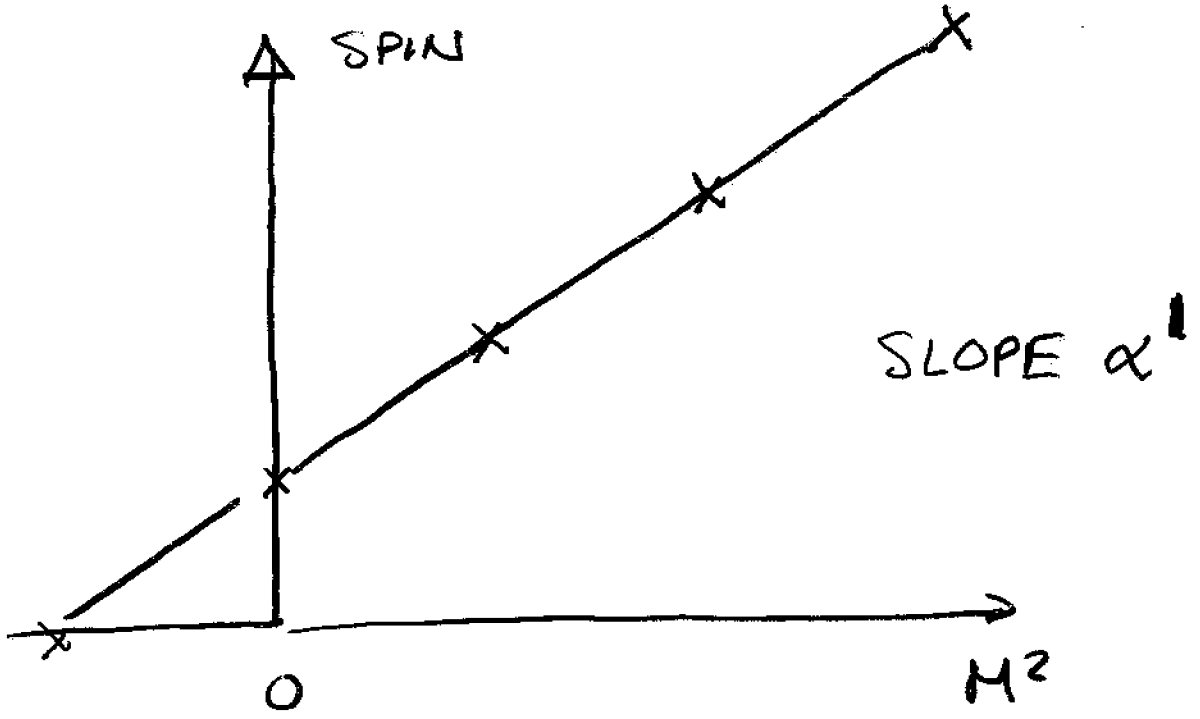
$$X_R^M(\tau-\sigma) = X_R^M + P_R^M(\tau-\sigma) + i\sum_{\substack{n\neq 0 \\ -\infty}}^{+\infty} \frac{1}{n}\alpha_n^M e^{-2in(\tau-\sigma)}$$

$\alpha_n^+ = \alpha_{-n}$ CREATION OPERATORS

$$H \sim \sum \alpha_n^+ \alpha_n$$

$\alpha' M^2 \sim N_R + N_L$ FOR CLOSED STRINGS

$\alpha' = \frac{1}{T}$: $T = M^2_{string}$ TENSION



CLOSED STRINGS

MASSLESS SPIN 2 ← GRAVITON

OPEN STRINGS

MASSLESS SPIN 1 ← GAUGE BOSONS

BUT:

TACHYONS !

SURPRISE:

CONSISTENCY REQUIRES

$d = 26$

SO FAR ONLY BOSONS

NEED FERMIONS AS WELL

NEVEU SCHWARZ STRING

RAMOND STRING

CRITICAL DIMENSION

NOW

$d = 10$

MOREOVER TACHYONS CAN BE AVOIDED IF THEORY IS

SUPERSYMMETRIC

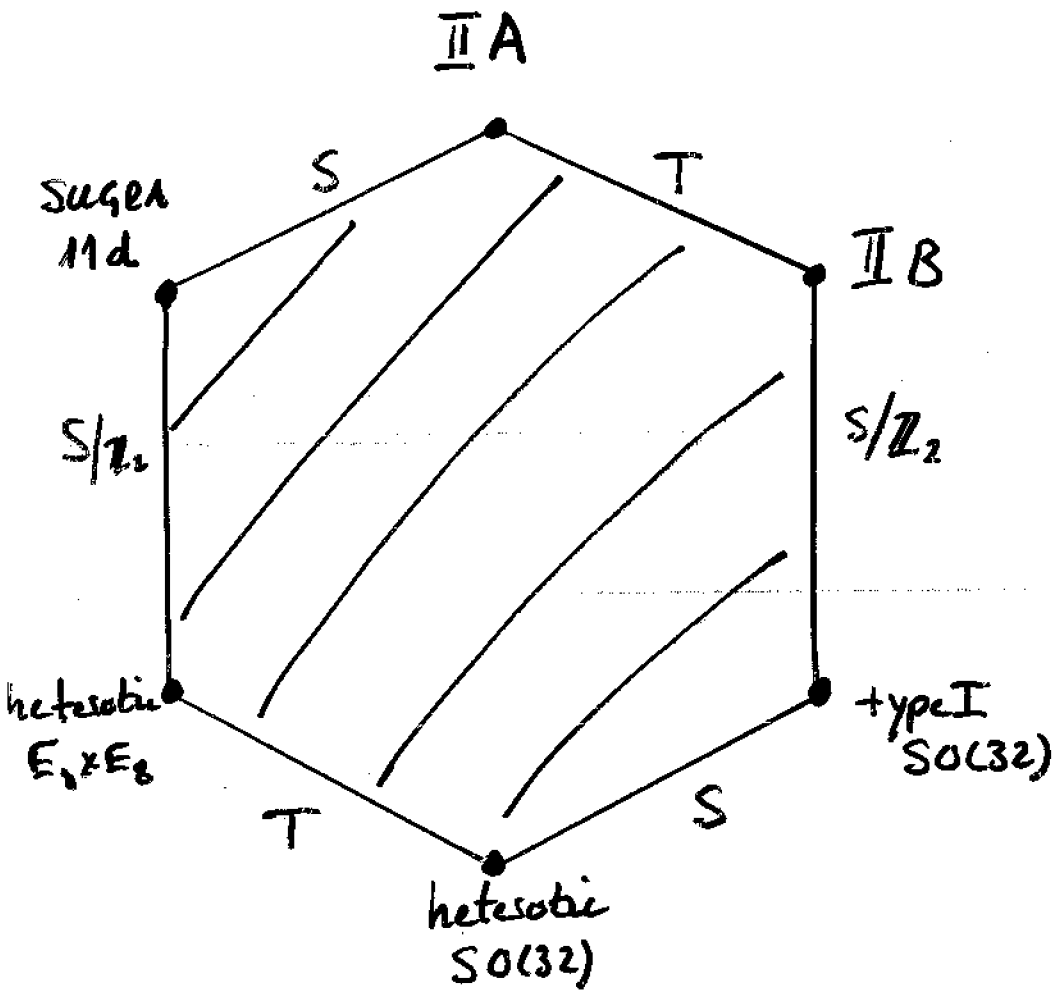
→ 5 DIFFERENT SUPERSTRING THEORIES IN $d=10$

TYPE I ($SO(32)$)

TYPE II A + II B

HETEROTIC ($E_8 \times E_8$ OR $SO(32)$)

M - THEORY



"connected via dualities"

LESSONS FROM STRING THEORY

* $d = 10$ OR 11

* SUSY

* GRAVITY + GAUGE THEORY
  (SOMETIMES CONNECTED
  TO CLOSED OR
  OPEN STRINGS)

* GRAVITY SCALE $\sim M_{STRING}$

* UNIQUE COUPLING —
  "CONSTANT"
  — FIELD DEPENDENT
  (DILATON)
  + OTHER MODULI

* SPECIFIC GAUGE GROUPS IN $d=10$

($E_8 \times E_8$, $SO(32)$)

* DEFECTS OF VARIOUS DIMENSIONALITIES

(D-BRANES, FIXED POINTS OF ORBIFOLDS)

* UNIFICATION OF ALL KNOWN INTERACTION

(THOUGH GRAVITY AND GAUGE BOSONS MIGHT LIVE IN DIFFERENT DIMENSIONS)

* PICK YOUR FAVOURITE STRING THEORY

* PICK YOUR FAVOURITE DIMENSION $d = 10, 11$?

* SO TO $d = 4$ COMPACTIFICATION OR SUITABLE p-BRANE

* WORK OUT SPECTRUM AND PROPERTIES OF LOW-ENERGY EFFECTIVE FIELD THEORY

* WORK OUT "PREDICTIONS"

OUTLINE

* SUSY IN $d = 4, 10, 11$

* HOW TO GET TO $d = 4$

* EXPLICIT STRING CONSTRUCTIONS
  (ORBIFOLDS, ORIENTIFOLDS ....)

* SPECIFIC QUESTIONS

  - SPECTRUM
  - COUPLINGS
  - AXIONS + GLOBAL SYMMETRIES
  - GUTS
  - UNIFICATION
  - LARGE(R) EXTRA DIMENSION

  etc.