CHARGE TO PATICIPANTS

LCWS2000
FERMILAB

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MINIMUM

CHARGE

TO PARTICIPANTS

x 175

OR

x 200

REAL CHARGE TO PATICIPANTS

① POSITIVE DISCUSSIONS

② CONVINCE OURSELVES ABOUT THE CRUCIAL IMPORTANCE OF e^+e^- LINEAR COLLIDERS

THEN, TAKE A WIDE VIEW TO CONVINCE OTHERS.

⇒ THIS TALK NEEDS TO BE PROVOCATIVE.

PLAN OF THIS TALK

① CURRENT SITUATION OF ELEMENTARY PARTICLE PHYSICS

② ADVANTAGES OF e^+e^- COLLISIONS

③ POSSIBLE SCENARIOS

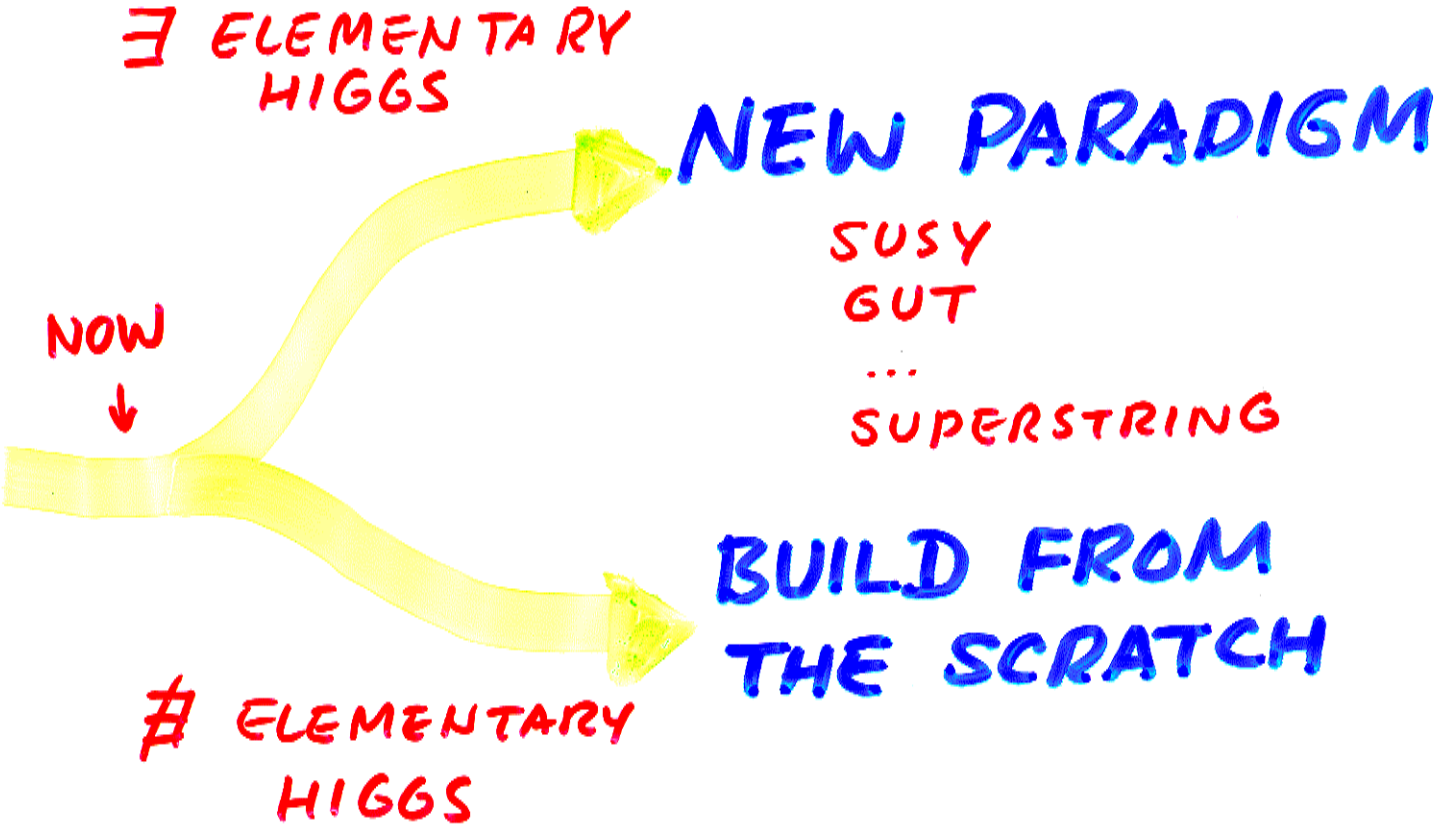
④ KEYWORDS TO FOCUS IN EACH WORKING GROUP

⑤ RELATED PHYSICS ⟷ LC
APPLICATION OF LC TECHNOLOGY

CURRENT SITUATION OF ELEMENTARY PARTICLE PHYSICS

ON THE EVE OF THE REVOLUTION

EVEN IF THE HIGGS BOSON WILL NOT BE DISCOVERED TOMORROW AT LEP2, THERE WILL BE A REVOLUTION.



LEARN FROM THE PAST REVOLUTION

NOVEMBER REVOLUTION 1974
(DISCOVERY OF J/ψ)

BEFORE

CHARM QUARK WAS PREDICTED

LEPTON-QUARK SYMMETRY

GIM MECHANISM 1970

(EVEN 3RD GENERATION WAS CONSIDERD BY KOBAYASH-MASKAWA 1973)

BUT PHYSICISTS ARE BUSY WITH HADRON SPECTROSCOPY / PHENOMENOLOGY

DISPERSION RELATION

REGGE POLE

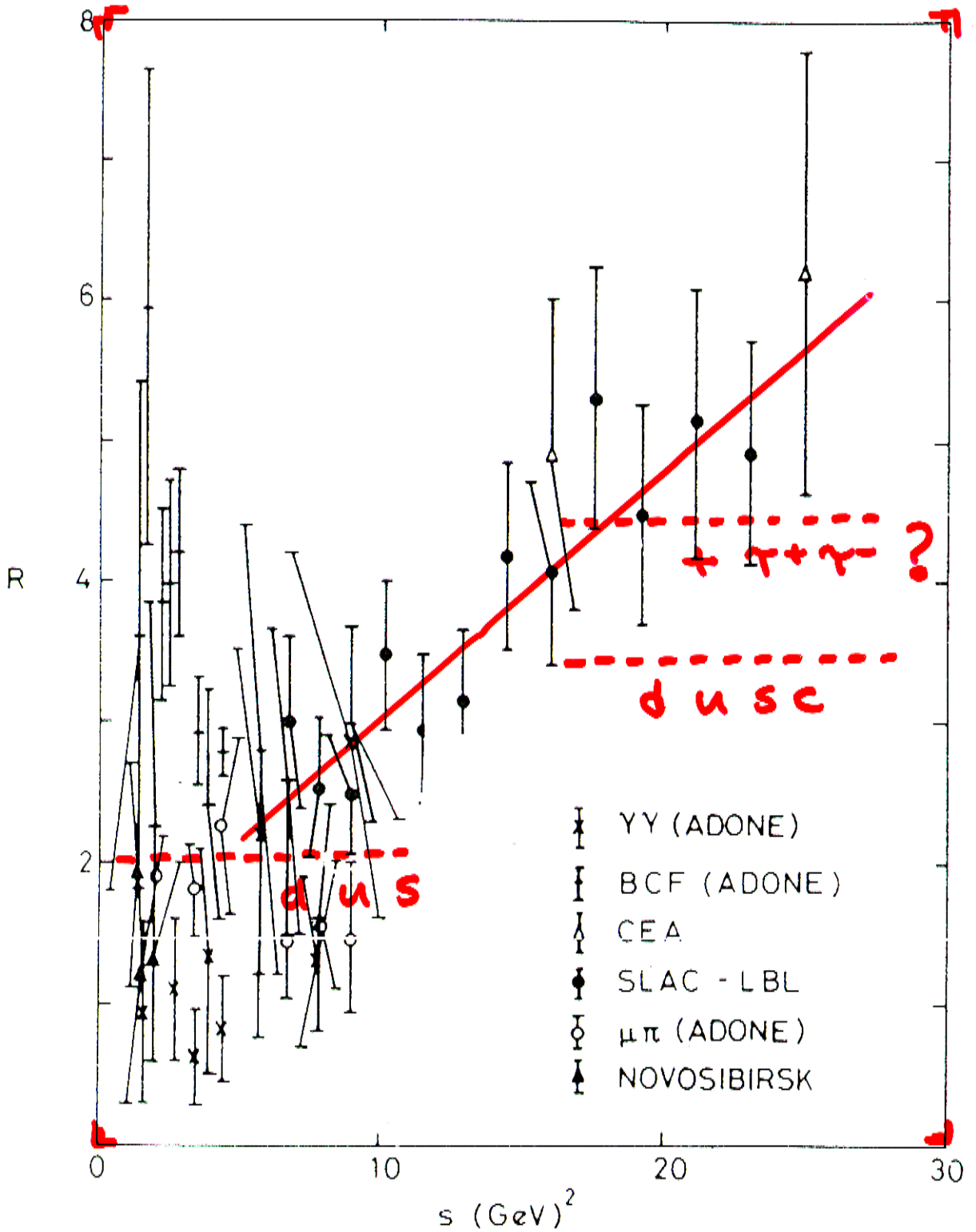
VECTOR MESON DOMINANCE

⋮

MANY PHYSICISTS THOUGHT THAT e^+e^- COLLISION IS JUST FOR QED STUDIES (OR AT MOST VMD).

SUMMER 1974 B. Richter @ LONDON CONF.

$$R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)} = 3\sum_q Q_q^2$$



SUMMER 1974

J Ellis

J. Ellis.

PRE DAWN OF NOVEMBER REVOLUTION

London CONF.

Table of Values of R

Value	Model	Source
0.36	Bethe-Salpeter bound quarks	Bohm et al, ref 42
2/3	Gell-Mann-Zweig quarks	
0.69	Generalized vector meson dominance	Renard, ref 49
~1	Composite quarks	Raitio, ref 43
10/9	Gell-Mann-Zweig with charm	Glashow et al, ref 31
2	Coloured quarks	
2.5 to 3	Generalized vector meson dominance	Greco, ref 30
2 to 5	" " " "	Sakurai, Gounaris, ref 47
$3^{1}/_{3}$	Coloured charmed quarks	Glashow et al, ref 31
4	Han-Nambu quarks	Han and Nambu, ref 32
5.7 ± 0.9	Trace anomaly and ρ dominance	Terazawa, ref 27
$5.8 \begin{smallmatrix} +3.2 \\ -3.5 \end{smallmatrix}$	Trace anomaly and ε dominance	Orito et al, ref 25
6	Han-Nambu with charm	Han and Nambu, ref 32
6.69 to 7.77	Broken scale invariance	Choudhury, ref 18
8	Tati quarks	Han and Nambu, ref 32
8 ± 2	Trace anomaly and ε dominance	Eliezer, ref 26
9	Gravitational cut-off, universality	Parisi, ref 40
9	Broken scale invariance	Nachtmann, ref 39
16	$SU_{12} \times SU_{12}$) gauge models	Fritzsch & Minkowski , ref 34
$35^{1}/_{3}$	$SU_{16} \times SU_{16}$) gauge models	Fritzsch & Minkowski , ref 34
~5000	High Z quarks)	Yock, ref 73
70,383	Schwinger's quarks)	Yock, ref 73
∞	∞ of partons	Cabibbo and Karl, ref 9
		Matveev and Tolkachev, ref 35
		Rozenblit, ref 36

AFTER THE REVOLUTION

$J/\psi = (c\bar{c})\ 1S^3$

EVEN EXPERIMENTALISTS RECOGNIZED THAT

LEPTONS AND QUARKS ARE ELEMENTARY PARTICLES OF THE SAME LAYER.

THE STANDARD MODEL AQUIRED A CITIZENSHIP.

IMPORTANCE OF e^+e^- COLLISION WAS STRONGLY RECOGNIZED.

SPEAR ADONE DORIS, ...

$\psi'(2S^3)$, P-STATE, ...

$\tau^+\tau^-$

DORIS II

PETRA / PEP CESR

TRISTAN BEPC

LEP I, II KEKB, PEP II

NOW

- PRECISE EW MEASUREMENTS WITH HEAVY TOP QUARK

- $112\ \mathrm{GeV} < m_{H^0_{SM}} < 210\ \mathrm{GeV}$ (95% CL)

  ($h^0 \approx H^0_{SM}$ in MSSM)

- UNIFICATION OF $\alpha_1, \alpha_2, \alpha_3$ AT $O(10^{16})$ GeV (SU(5) SUSY-GUT)

- NO REALISTIC MODELS WITHOUT ELEMENTARY HIGGS

- $\exists$ DARK MATTER

- $\tilde{\chi}^0_1$ IS AN IMPORTANT CANDIDATE OF COLD DM.

ALTHOGH EACH ARGUMENT IS WEAK, ALL SUGGEST THE DIRECTION OF ELEMENTARY HIGGS WITH SUSY.

SINCE INFORMATION FLOW IS MUCH FASTER THAN IN 1970TH, WE MUST BE ON THE RIGHT TRACK.

$\exists h$ OR $\exists$ SUSY

$\Rightarrow$ REVOLUTION

$\Rightarrow$ PARADIGM OF ELEMENTARY HIGGS WITH SUPERSYMMETRY

NUMBER OF ELEMENTARY PARTICLES INCREASES BY

$\times 2 + \alpha$

α ← MORE HIGGS

(C.f. DIRAC'S ANTIPARTICLES

$\Rightarrow \times 2 - \beta$

β ← SELF CONJUGATES)

$\Rightarrow$ NEEDS "CONTINUOUS REVOLUTION" TOWARS THE SUPER-UNIFICATION.

{ SUSY BREAKING
GENERATIONS OF Q & L
GRAVITY ...

$\nexists h$ AND $\nexists$ SUSY

$\Rightarrow$ REVOLUTION !

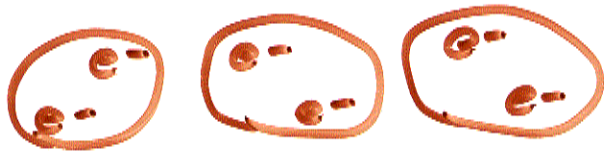
FREE FROM THE "MIND CONTROLE" BY SUSY THEORISTS.

BUILDING A MODEL $\nexists h$ $\nexists$SUSY FROM SCRATCH

HINTS

FERMION MONOISM
FERMION MONOTHEISM
} ⇒ HIGGS-LIKE OBJECT

ANALOGY OF THE MEISNER EFFECT



← COOPER PAIRS

NAMBU - GOLDSTONE

⇓

TECHNICOLOR

THIS IDEA ITSELF IS VERY ATTRACTIVE

→ ∅ S-, t - MEASUREMENTS

→ ∅ EXTENDED TECHNICOLOR

ALMOST EXTINCT

STUDY

- $t\bar{t}$ SYSTEM — $t\bar{t}$ CONDENSATION ∅
- W^+W^- SYSTEM

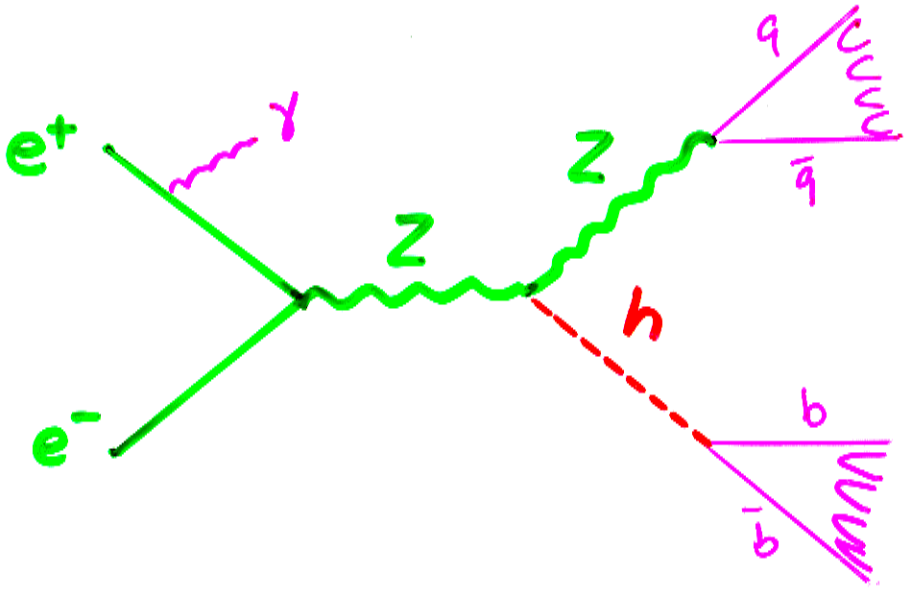
SOME VERY IMPORTANT CONCEPT MUST BE MISSING.

ADVANTAGES OF e^+e^- COLLISIONS

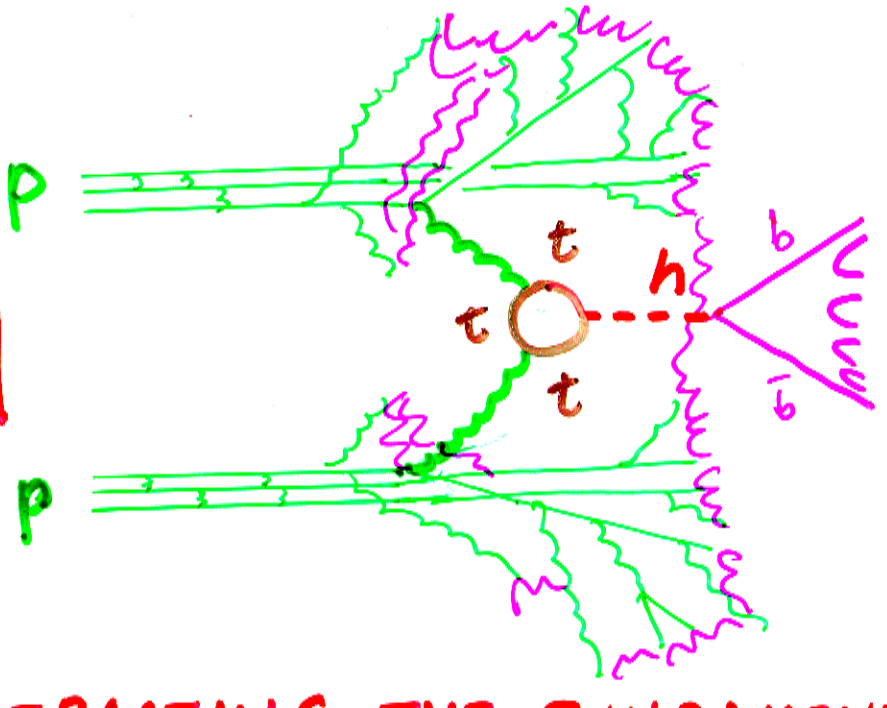
① PROCESSES

DIRECT OBSERVATION OF FUNDAMENTAL PROCESSES IS POSSIBLE IN e^+e^- COLL.

LC



LHC



EXTRACTING THE FUNDAMENTAL PROCESS IS DIFFICULT IN PP COLL.

② KINEMATICS

LC $\sqrt{s'} \approx \sqrt{s_{e^+e^-}}$

{ INITIAL STARE RAD.
BEAMSTRAHLUNG } ⇒ MINOR EFFECTS

- 3D KINEMATICAL FIT

LHC $\sqrt{s'} \ll \sqrt{s_{pp}}$

EVENTS ARE BOOSTED ALONG Z AXIS

- P_T BALANCE

③ BACKGROUND (PHYSICS)

LC

$$\frac{\sigma_{HZ}}{\sigma_{ZZ}} \sim \frac{0.2\ pb}{0.6\ pb}$$

$\sqrt{s} = 250$ GeV
$m_H = 120$ GeV

LHC

$$\frac{\sigma_{WH,\,W\to\ell\nu}}{\sigma_{Wjj,\,W\to\ell\nu}} \sim \frac{0.4\ pb}{5000\ pb}$$

$\sqrt{s} = 14$ TeV
$m_H = 120$ GeV

MANY BACKGROUND PROCESSES ARE DUE TO STRONG INTERACTION

4 THEORETICAL PREDICTIONS

LC 0.1% ~ 10%

LUMINOSITY
INITIAL STATE RAD.
EW THEORY

LHC 10% ~ 300%

K-FACTOR
STRUCTURE FUNCTIONS

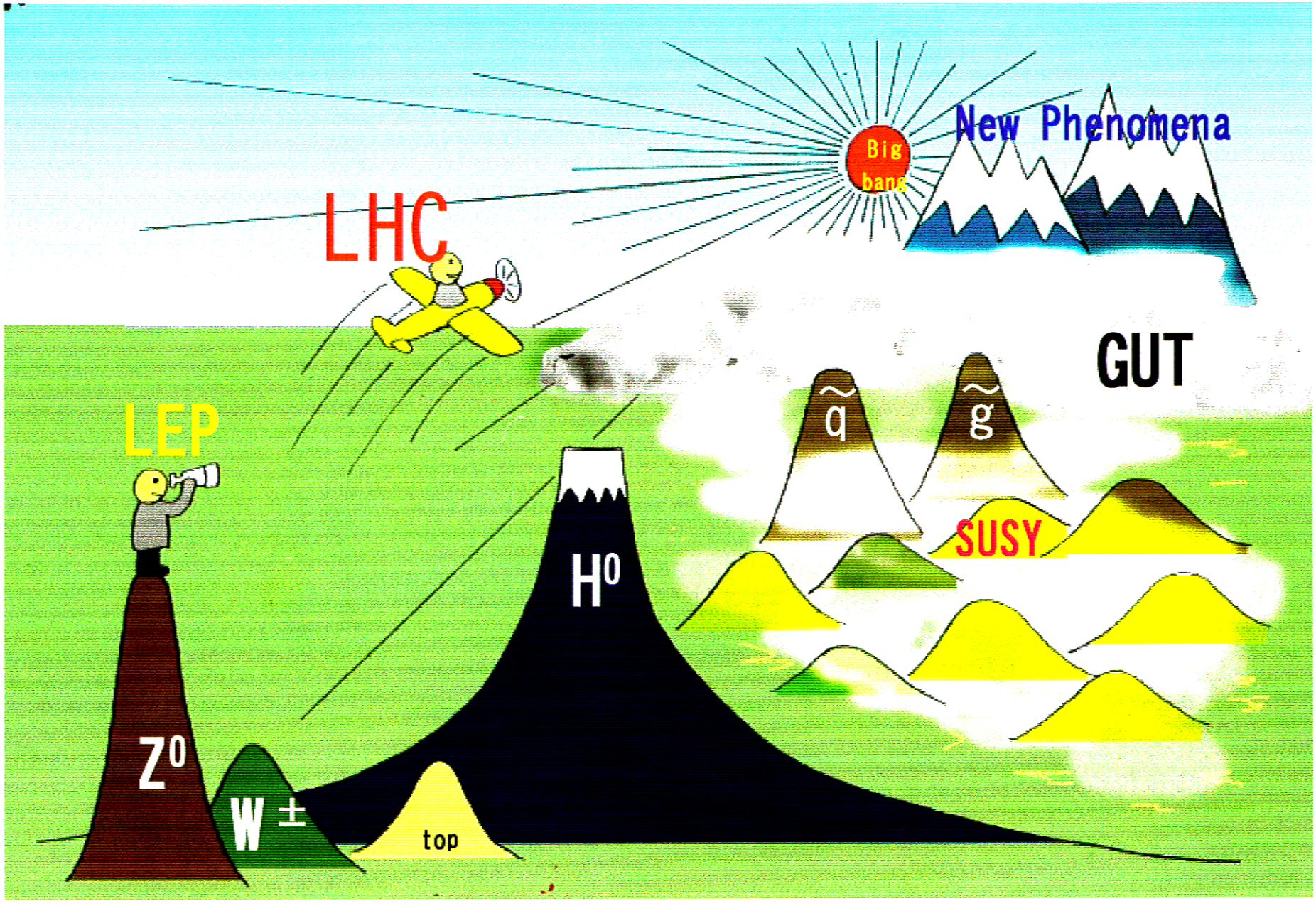
5 DETECTOR ISSUE

LC NO PROBLEMS EXCEPT FOR IR

CCD, DRIFT CHAMBER, TPC, COMPENSATING CAL, ... CAN BE USED

LHC

- RADIATION HARD CHIPS FOR FRONT-END ELECTR.
- PILE UP OF EVENTS IN CAL.
- SOFISTICATED TRIGGER.
- DETECTOR CANNOT BE ACCESSIBLE WITHOUT A LONG SHUT DOWN


New Phenomena
Big bang
LHC
GUT
LEP
$\tilde{q}$
$\tilde{g}$
SUSY
H^0
Z^0
$W^\pm$
top

SCENARIOS FOR e^+e^- LC's

CONDITIONS

① IN ANY CASE LHC EXPERIMENTS WILL TAKE DATA FROM 2005 OR 2006.

② O(TeV) LC TECHNOLOGY IS NOT SO EASY.

⇒ START FROM $\sqrt{s} < 500$ GeV

ACCORDING TO THE "WHITE PAPER" (AMERICAN LC WG), THERE ARE 4 CASES DEPENDING ON DISCOVERIES BY LHC EXPERIMENTS.

THE SCENARIOS ARE MODIFIED AIMING TO BE MORE REALISTIC.

ENERGY THRESHOLDS

- m_h $\lesssim 130$ GeV $\sqrt{s} \lesssim 250$ GeV
  $\lesssim 210$ GeV $\sqrt{s} \lesssim 350$ GeV

- $m_t = 175$ GeV $\sqrt{s} \approx 2m_t$
  ≈ 350 GeV

- M_{SUSY} ? $\lesssim O(\text{TeV})$
  WAIT FOR LHC

- $M_{STRONG\ EW}$?? $O(\text{TeV})$
  IF NO h, NO SUSY

- AVAILABLE TECHNOLOGY OF LC AT THE START
  $\sqrt{s} \lesssim 500$ GeV

UPGRADE STRATEGY

DEPENDS ON THE AVAILABLE TECHNOLOGY AFTER X YEARS.

PAST EXPERIENCES

PHASE 1		PHASE 2
LEP I		LEP II
1989 - 1995		1996 - 2000 ?
20M Z^0's	$\xrightarrow{7\ yrs}$	h ????????
$Sp\bar{p}S$		TEVATRON
1981 - 1990		1987 -
$W^\pm$, Z^0	$\xrightarrow{6\ yrs}$	t

LIGHT HIGGS AND/OR TOP RUN

+ $\sqrt{S_{max}} \simeq 500$ GeV RUN

WILL TAKE AT LEAST 6-7 years.

1) h IS DISCOVERED ($m_h \lesssim 150$ GeV)
AND EVIDENCE OF SUSY IS
FOUND @ LHC

$\boxed{\text{OPTIMIZE } \sqrt{s}_{LC} \text{ TO } \sigma_{hZ}^{max} \Rightarrow \text{HIGGS FACTORY}}$ h

.OR. m_{SUSY}* CAN BE REACHED AT LC
$\Rightarrow$ GO TO $\sqrt{s}_{max} \sim 500$ GeV χ's $\tilde{\ell}$'s
m_{SUSY} CANNOT BE REACHED
$\Rightarrow$ UPGRADE PLAN**

2) h IS SEEN, NO EVIDENCE FOR
SUSY @ LHC

$\boxed{\text{OPTIMIZE } \sqrt{s}_{LC} \text{ TO } \sigma_{hZ}^{max} \Rightarrow \text{HIGGS FACTORY}}$ h

THEN GO TO $\sqrt{s}_{max} \sim 500$ GeV
SEARCH FOR h, χ's, $\tilde{\ell}$s

* ROUGH ESTIMATE OF $m_{\tilde{\chi}, \tilde{\ell}}$
$\tilde{m}_g \Rightarrow m_{\tilde{\chi}_1^+} \lesssim m_{\tilde{g}}/3.5$

** DEPENDING ON THE TECHNOLOGY
AVAILABLE AT THAT TIME.

3) NO NEW PARTICLES ARE FOUND @ LHC

GRADUALLY INCEASE $\sqrt{s}$ FROM ~ 250 GeV TO $\sqrt{s}_{max} \sim 500$ GeV.

CHECK IF THERE IS h, $\tilde{\chi}$, ...

IF YES $\Rightarrow$ STAY THERE

IF NO $\Rightarrow$ GO TO $\sqrt{s} \sim 2m_t$ STUDY $t\bar{t}$.

DECIDE UPGRADE OR NOT DURING $2m_t$ RUN.

4) A WEALTH OF NEW PHENOMENA ARE SIGHTED AT LEP, TEVATRON, LHC.

(MULTIPLE SOURCES OF NEW PHYSICS)

THINK THE MOST COST EFFECTIVE WAY TO STUDY THESE PYSICS.

KEYWORDS / KEY POINTS TO BE FOCUSED IN THIS WS.

PHYSICS WG'S

HIGGS BOSONS

HIGGS BOSON IS HIDING AROUND THE CORNER.

- PRECISION MEASUREMENTS OF h PROPERTIES VS $\int \mathcal{L}\, dt$
- $\gamma\gamma \to h$

SUSY

- LHC INFO. $\longleftrightarrow$ LC INFO.

  $\tilde{g}, \tilde{q}$ $\qquad$ $\tilde{\chi}_1^+, \tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{l}$

  PRECISE MEASUM.

- SUSY BREAKING MECHANISM

  $\left.\begin{array}{l}\text{SUGRA}\\ \text{GMSB}\\ \text{AMSB}\\ \vdots\end{array}\right\} \leftarrow$ MASSES, MIXINGS

TOP QCD $\gamma\gamma$

- CONSIDER WHAT KIND OF FUNDAMENTAL PHYSICS BEYOND THE SM CAN BE EXTRACTED FROM THE STUDIES AT $t\bar{t}$ THRESHOLD. ← IF NO LIGHT $\tilde{t}$ NO SUSY
- PRECISION MEASUREMENTS AT $\sim 2m_t$ (m_t, α_s, Y_t, ...)

EW

- W^+W^- STUDIES (TGC, LET)
  COMPARE LC($\sqrt{s}$) ↔ LHC
  SYSTEMATIC
- GIGAZ
  - PHYSICS B, A_{LR}
  - SYSTEMATICS E_b, $\mathcal{L}$, Pol, ...
  - ACCELERATOR ISSUES

ALTERNATIVE NEW PHYSICS

- NEW/CRAZY IDEAS
- EXTRA-DIMENSIONS
  AIM OF LC / OTHER EXP'TS
  COSMOLOGY

DETECTOR WG'S

- THINK ABOUT THE DETECTOR AS A SYSTEM ..... DETECTOR CONCEPT.

  DETECTOR CONCEPT IS DRIVEN BY

  1. IMPORTANT PHYSICS
  2. POSSIBLE TECHNOLOGY
  3. COLLIDER DESIGN
     BUNCH STRUCTURE, IR DESIGN, BACKGROUND
  4. COST

- TAKE FULL ADVANTAGES OF e^+e^- COLLISIONS
  CLEAN ENVIRONMENT
  EVENT RATE, BUNCH STRUCTURE
  LHC EXP'TS GAVE UP MANY NICE DEVICES

- USE TECHNOLOGIES DEVELOPED FOR LHC DETECTORS, IF NEEDED
  → RAD. HARD
  USE COMMERCIALLY AVAILABLE DEVICES → LOW COST

DETECTOR MACHINE INTERFACE

- DESIGN OF SHORT LENGTH BEAM DELIVERY SYSTEM
- IR DESIGN (STABILITY OF FINAL Q)
- BACKGROUND (e^+e^- PAIR, n) VS DETECTOR CONCEPT (SIZE, $\vec{B}$)
- MEASUREMENTS AT IR / DAMP (E_b, Pol, BEAM PROFILE)

VERTEX + TRACKING

- VERTEX CCD VS APD (HYBRID, MONOLISIC)

  T_{min}, THICKNESS

- CENTRAL TRACKERS TPC VS JET

  BUNCH ID

  $\sigma\left(\frac{1}{p_T}\right) \sim \frac{\delta}{\sqrt{N}} \frac{1}{BL^2}$: OPTIMIZATION

- INTERMEDIATE TRACKER DEVICES

CALORIMETERS

- ENERGY FLOW
  - TRACKER + CAL INFOS
- DEVICES TILE+FIBER, WSi, SHASHLIC
  - COST, POSITION OF SOLENOID
  - ENERGY RESOLUTION
    - (COMPENSATION $e/\pi \sim 1$?)
  - GRANULARITY
  - LONG. SEGMENTATION
  - HERMETICITY (BARREL / EC / FWD)
    - OVERLAP, GAPS

MUON, PID, SPECIAL DETECTORS

- μ DEVICES ← LHC / LEP
  - COST
- PID ← LC PHYSICS

SIMULATION TOOLS

- GENERATOR ← LEP GEN. WG.
- FAST / FULL SIMULATION
  - PERFORMANCE
    - LOW ENERGY HADRON INT. in GEANT

FASHIONABLE PARTICLE / ASTRO-PHYSICS

1) NEUTRINO PHYSICS

$$\Delta m^2_{ij} \longrightarrow m_{\nu_L} \sim \frac{m_\ell^2}{M_R}$$

COMPARING THE MIXING MATRICES OF QUARKS / LEPTONS

$$\left[\ \text{CKM}\ \right] \longleftrightarrow \left[\ \text{MNT}\ \right]$$

$\Rightarrow$ PHYSICS @ $O(10^{11})$ GeV - GUT SCALE

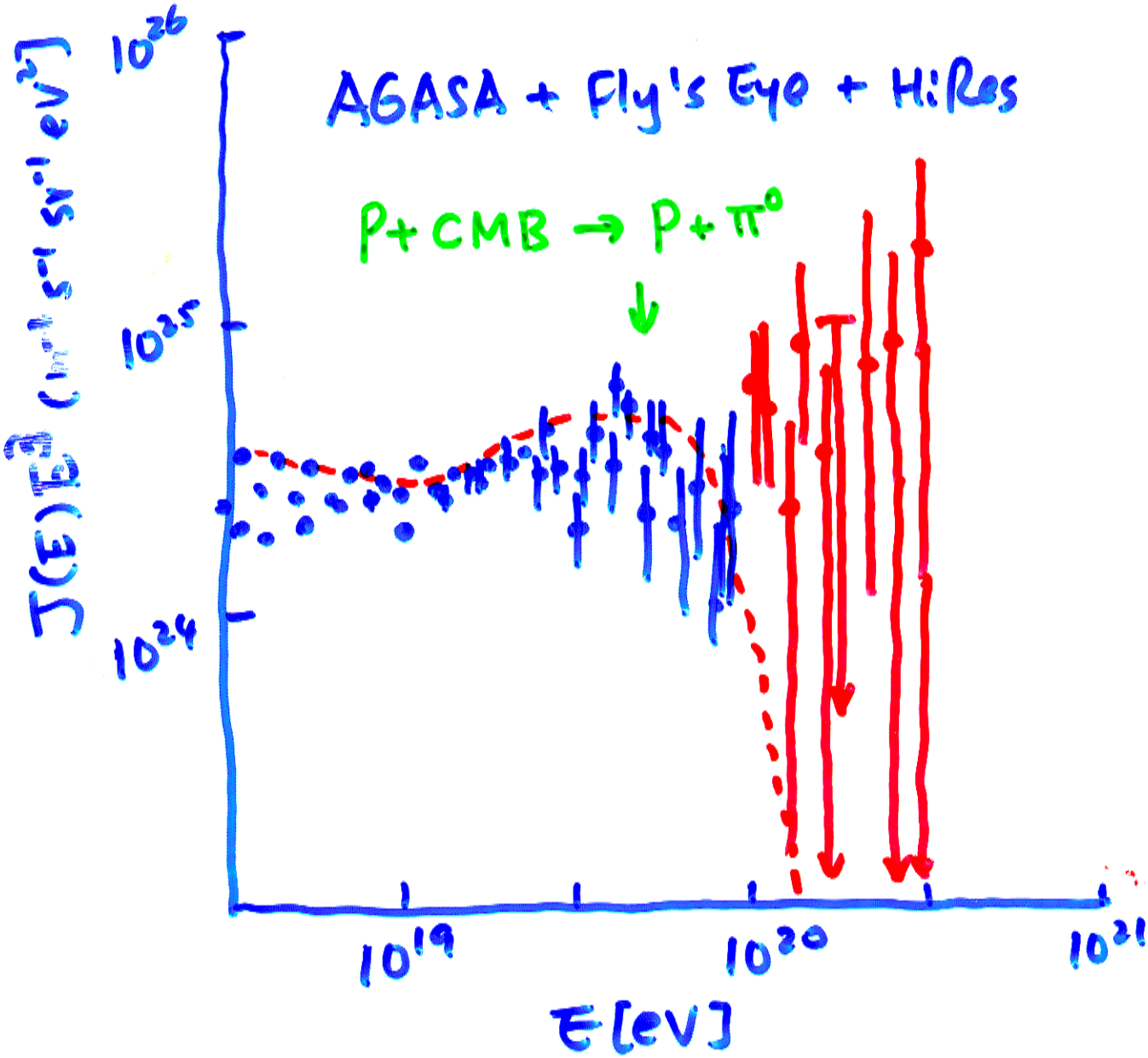
BUT THESE MASS MATRICES SHOULD COME FROM "HIGGS YUKAWA INT".

2) DARK MATTER

$$\begin{cases} \text{HOT} \\ \text{COLD} \end{cases} \ldots \quad \tilde{\chi}_1^0 \qquad \tilde{G}\ ???$$

$\Rightarrow$ SUSY

3) ASTROPARTICLE PHYSICS

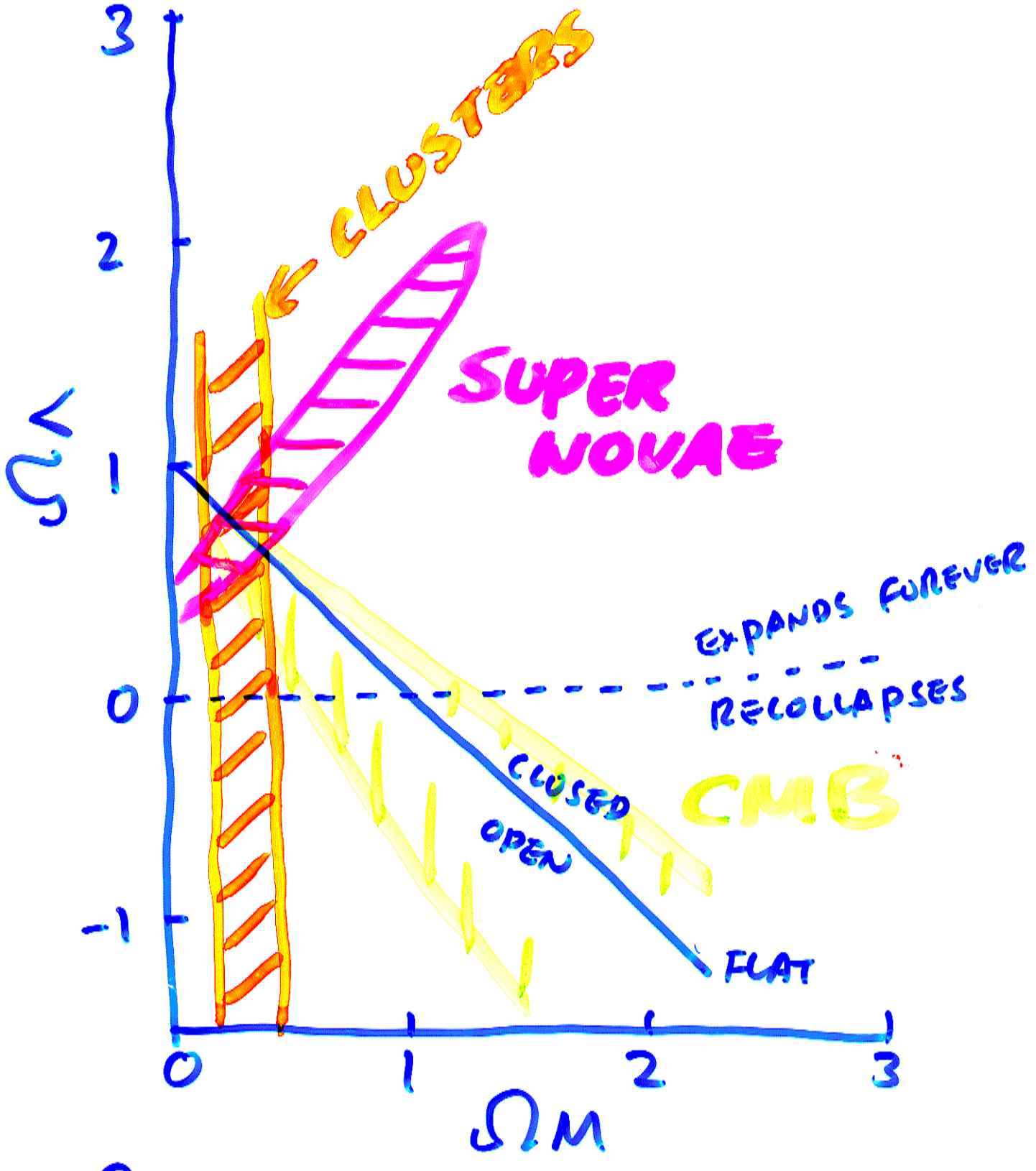


$$\sqrt{s'} \lesssim \sqrt{s_{pp}} \sim \sqrt{2 \times 10^{11}\,\mathrm{GeV} \times 1\,\mathrm{GeV}}$$
$$\sim 5 \times 10^{5}\,\mathrm{GeV}$$

THEY MAY SEE "SOMETHING" BUT CANNOT TELL WHAT IT IS.

⇒ PRECISE MEASUREMENTS @ COLLIDER ENERGIES MAY FIND "SOMETHING"

4) COSMOLOGICAL CONSTANT



Ω_Λ MAY COME FROM

SOME HIGGS

AFTER THE INFLATION.

APPLICATIONS OF LC TECHNOLOGIES

- MEDICAL APPLICATIONS

  SINCE C-BAND, X-BAND LINACS ARE MUCH SHORTER THAN CURRENTLY USED S-BAND LINACS, IF THEY ARE MUCH CHEAPER THAN S-BAND, THERE WILL BE MANY APPLICATIONS.

  ex. e^- LINAC FOR MEDICAL WASTES

- FEL AS 4TH GENERATION COHERENT X-RAY SOURCE

  MATERIAL SCIENCE
  BIOLOGY
  SUPER LSI
  ... ...

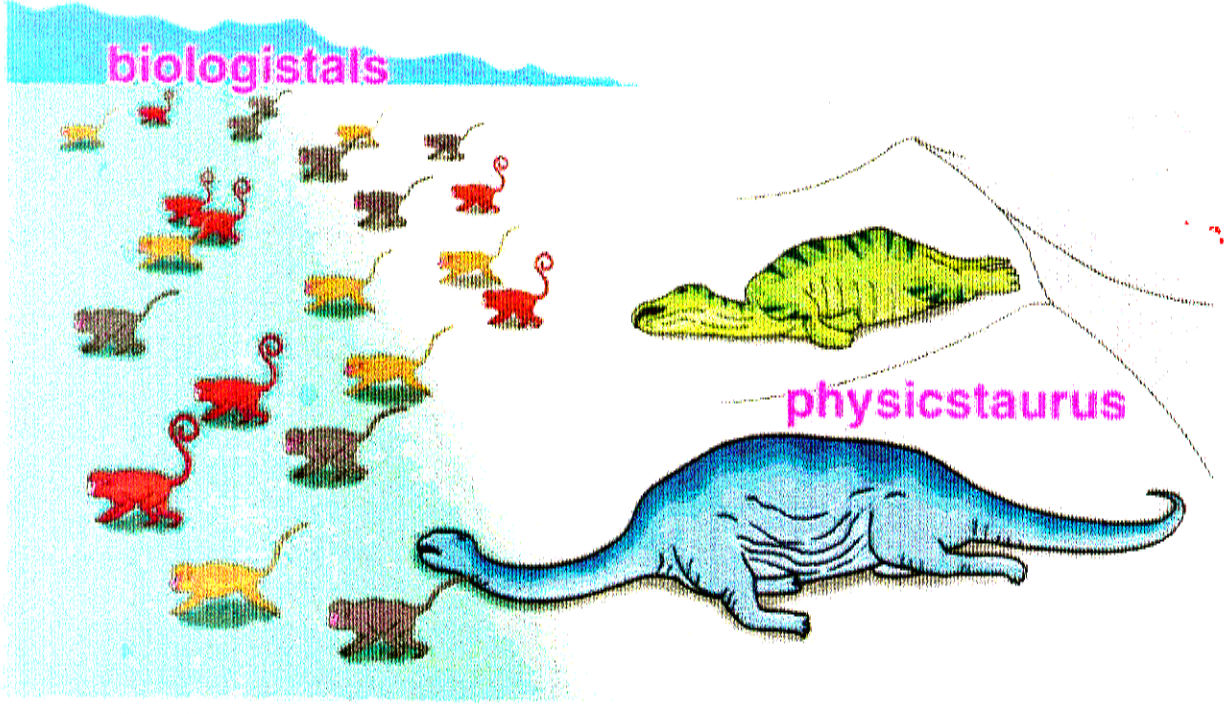
  ALL LC COMMUNITIES (EXCEPT FOR CLIC) CONSIDER FEL

  JLC-I REPORT 1992
  CDR DESY/ECFA STUDIES 1997
  ZDR NLC STUDIES 1997

PHYSICISTS CAN ONLY OBSERVED IN AN IVORY TOWER OF UNIVERSITY OF "GALAPAGOS ISLAND".

THIS SITUATION SHOULD ALSO BE AVOIDED

HEPOPTERICS HEPOTERANODON



21th century 20th century

ICEP2000
SUMMARY TALK
PROF. SUGAWARA

GOALS

1. DEVELOP CASE FOR $\sqrt{s} \approx 500$ GeV PROGRAM

2. BRING TOGETHER THE WORLDWIDE COMMUNITY WHICH WANT TO DO THIS PROGRAM

3. BUILD UP COOPERATION WITH THE COMMUNITY

4. REVIEW PRIORITIES FOR NEXT STEPS

   HIGHER ENERGY

   $\gamma\gamma$ $e\gamma$

   GIGAZ