9th International Workshop on: "Neutrino Telescopes"

THE
TEN CHALLENGES OF SUBNUCLEAR PHYSICS

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"Istituto Veneto di Scienze, Lettere ed Arti" - Campo Santo Stefano 2945, Venice

THE
TEN CHALLENGES OF SUBNUCLEAR PHYSICS

SUMMARY

A — *Introduction*

B — *The 10 Challenges*

C — *The Future (on the basis of past achievements)*

D — *Conclusions*

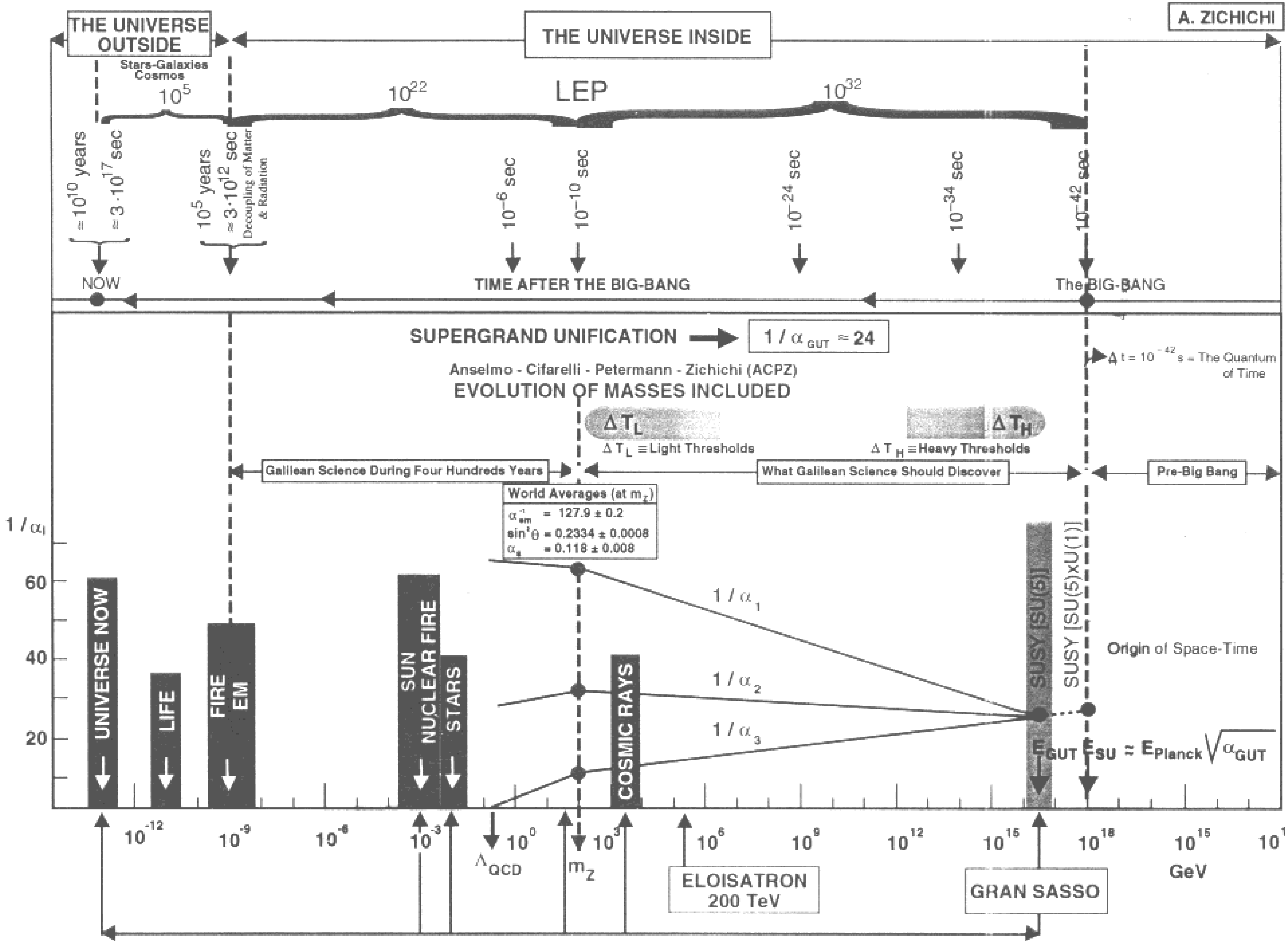
PRELIMINARY REMARKS

Does
SUBNUCLEAR PHYSICS
STILL EXISTS
?

How about the
other disciplines as

ASTROPHYSICS
INFORMATICS
GENETICS

?

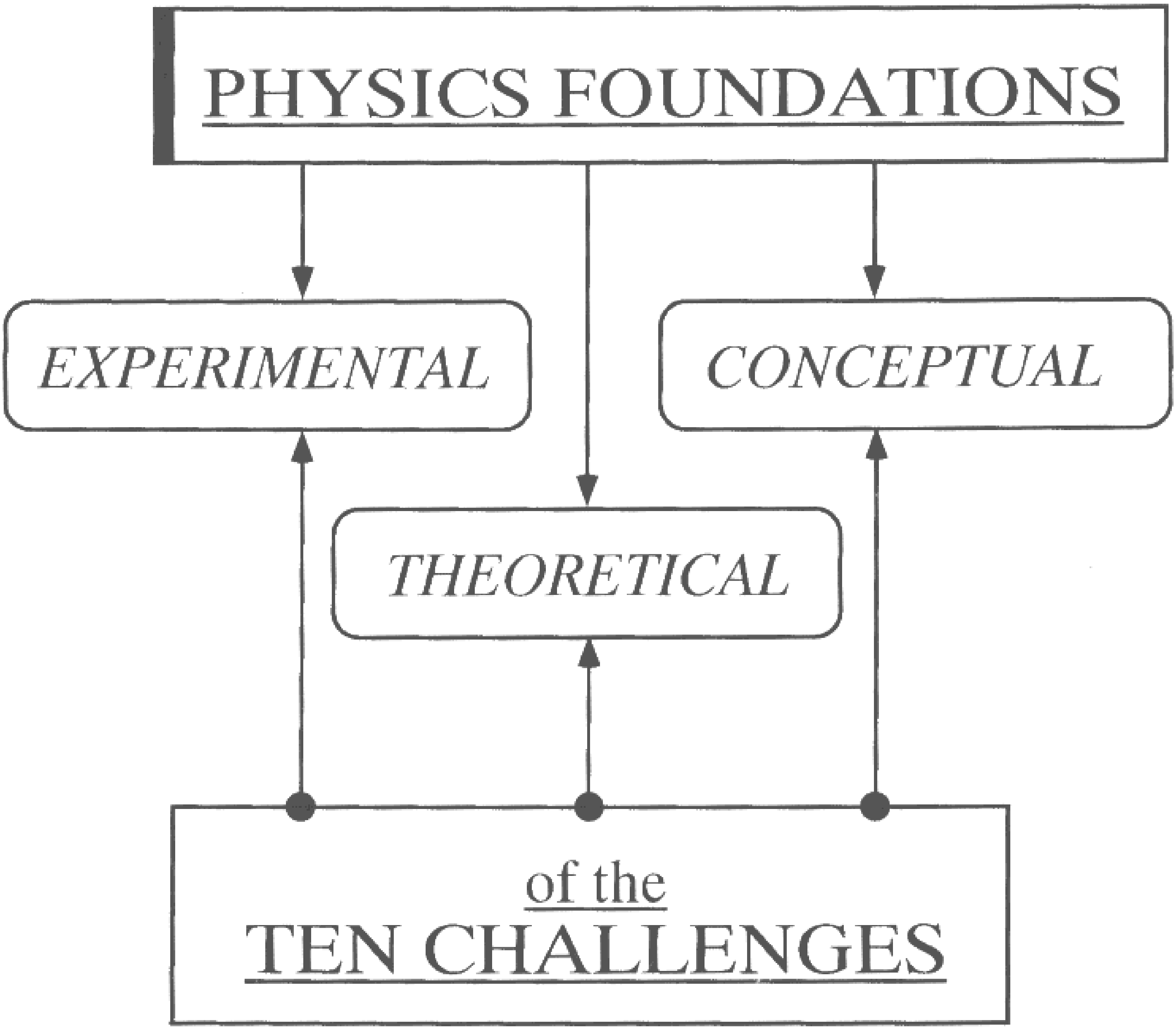

A. ZICHICHI
THE UNIVERSE OUTSIDE
THE UNIVERSE INSIDE
Stars-Galaxies Cosmos
10^5
10^{22}
LEP
10^{32}
$\simeq 10^{10}$ years
$\simeq 3 \cdot 10^{17}$ sec
10^5 years
$\simeq 3 \cdot 10^{12}$ sec
Decoupling of Matter & Radiation
10^{-6} sec
10^{-10} sec
10^{-24} sec
10^{-34} sec
10^{-42} sec
NOW
TIME AFTER THE BIG-BANG
The BIG-BANG
SUPERGRAND UNIFICATION
$1/\alpha_{GUT} \approx 24$
$\Delta t = 10^{-42}$ s = The Quantum of Time
Anselmo - Cifarelli - Petermann - Zichichi (ACPZ)
EVOLUTION OF MASSES INCLUDED
ΔT_L
$\Delta T_L \equiv$ Light Thresholds
ΔT_H
$\Delta T_H \equiv$ Heavy Thresholds
Galilean Science During Four Hundreds Years
What Galilean Science Should Discover
Pre-Big Bang
World Averages (at m_Z)
$\alpha_{em}^{-1} = 127.9 \pm 0.2$
$\sin^2\theta = 0.2334 \pm 0.0008$
$\alpha_s = 0.118 \pm 0.008$
$1/\alpha_i$
60
40
20
UNIVERSE NOW
LIFE
FIRE EM
SUN NUCLEAR FIRE
STARS
COSMIC RAYS
$1/\alpha_1$
$1/\alpha_2$
$1/\alpha_3$
SUSY [SU(5)]
SUSY [SU(5)xU(1)]
Origin of Space-Time
E_{GUT} $E_{SU} \approx E_{Planck}\sqrt{\alpha_{GUT}}$
10^{-12}
10^{-9}
10^{-6}
10^{-3}
10^0
10^3
10^6
10^9
10^{12}
10^{15}
10^{18}
10^{15}
10^{12}
GeV
Λ_{QCD}
m_Z
ELOISATRON 200 TeV
GRAN SASSO

A

Introduction

** INTRODUCTION

RABI



The next decade will be a decisive one for Subnuclear Physics. It is therefore necessary to consider, in a critical and constructive way, the challenges being faced.

The common picture is that we have spent the last decade trying to find two particles: the Higgs and the lightest Supersymmetric. None of these particles has been found. The search for these two particles must be put in the correct framework including the risk of not being there, not only because the threshold for their production cannot be computed and is therefore unknown, but also because of possible fundamental reasons still to be understood.

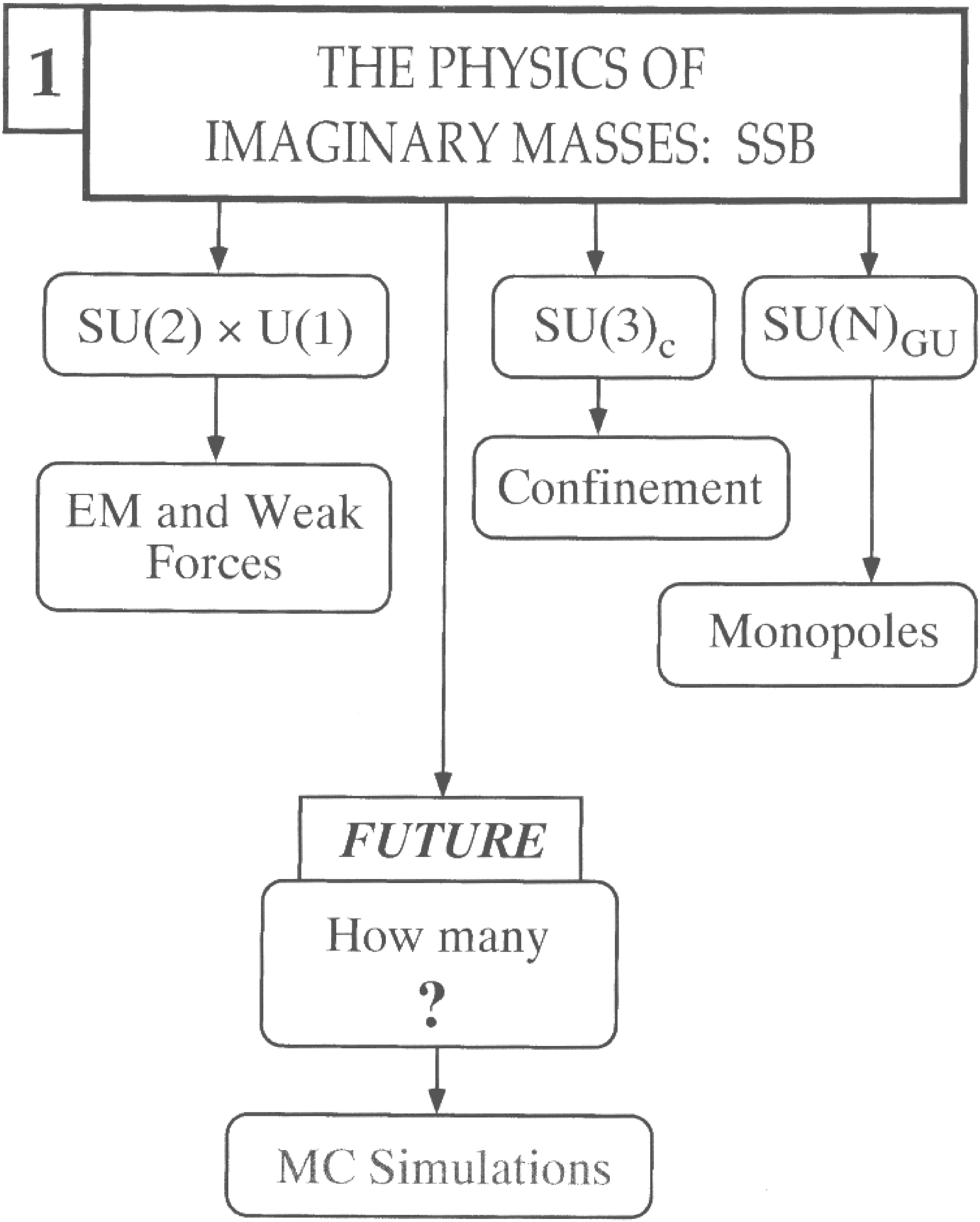
The existence of other problems whose solution could open new frontiers must be clearly spelt out. During the next decade, our projects must be presented in their full scientific potential as illustrated by the following ten challenges.

B

The 10 Challenges

THE TEN CHALLENGES

1) *The Physics of Imaginary Masses* ●
2) *CP ≠ T ≠ CPT ≠*
   Matter-Antimatter Symmetry
3) *Supersymmetry* ●
   SUSY
4) *Non perturbative QCD* ●
5) *Anomalies and Instantons*
6) *Flavour mixing in the quark sector*
7) *Flavour mixing in the leptonic sector*
8) *The problem of the missing mass in the Universe*
9) *The problem of the hierarchy*
10) *The Physics at the Planck Scale and the number of expanded Dimensions* ●



1 THE PHYSICS OF IMAGINARY MASSES: SSB

$SU(2) \times U(1)$

EM and Weak Forces

$SU(3)_c$

Confinement

$SU(N)_{GU}$

Monopoles

FUTURE

How many

?

MC Simulations

Higgs production cross-section (pb)
gg and W^+W^- fusion

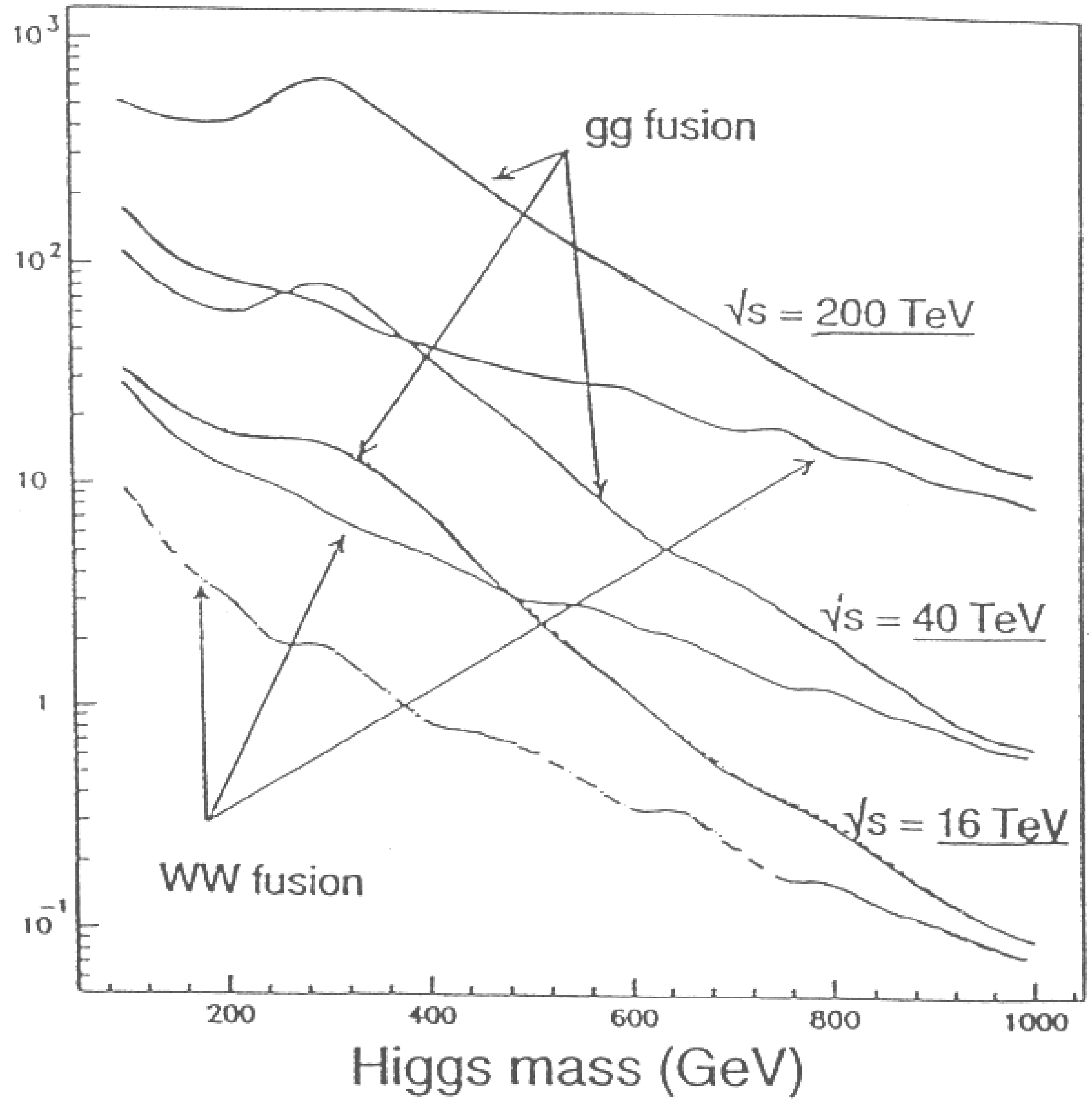


Fig. 8: Higgs production cross-section (pb) (versus Higgs mass) at $\sqrt{s} = (16, 40)$ TeV following two different production processes: (gg) and (WW) fusion.

7

16 TeV

40 TeV

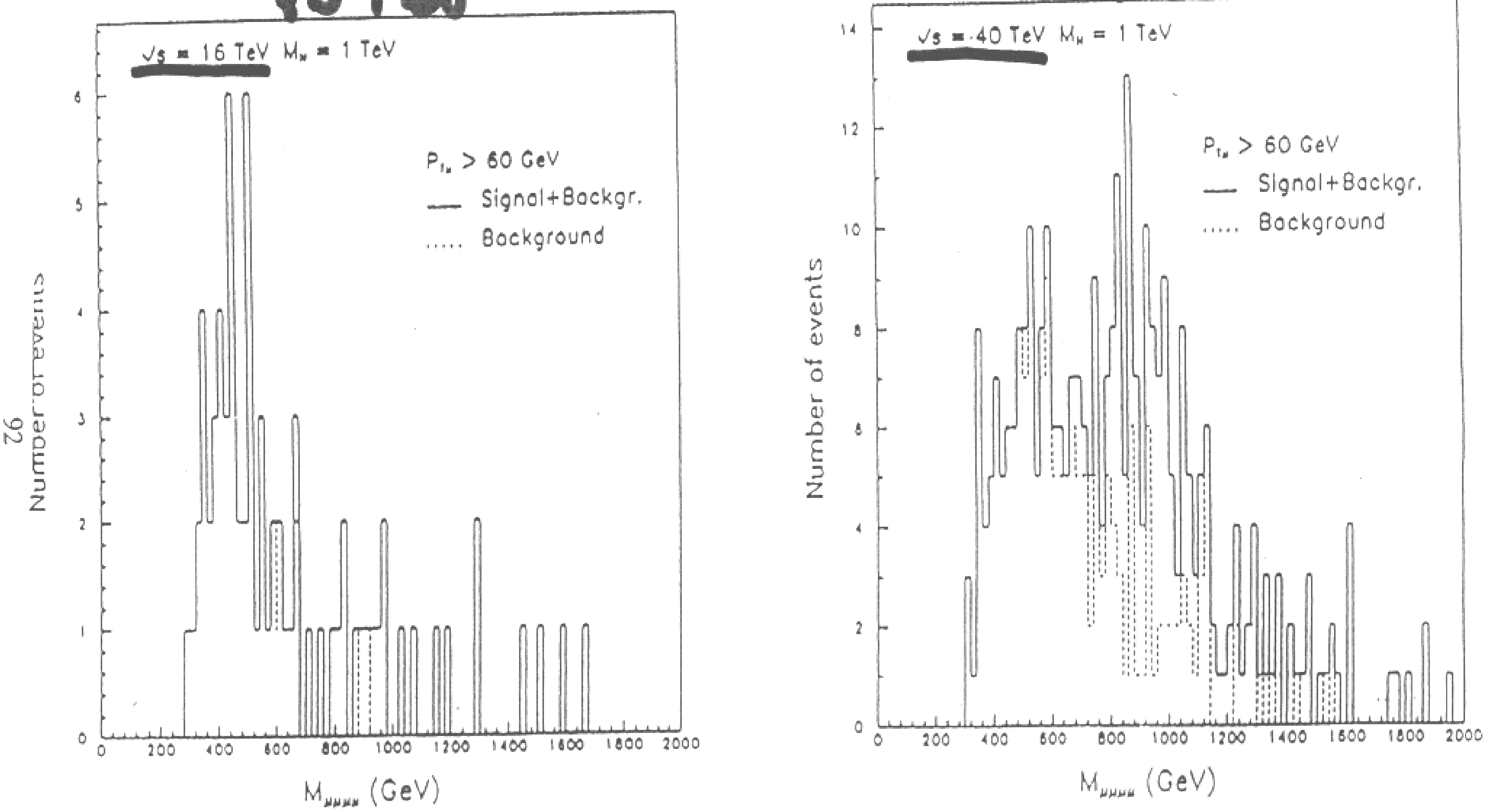
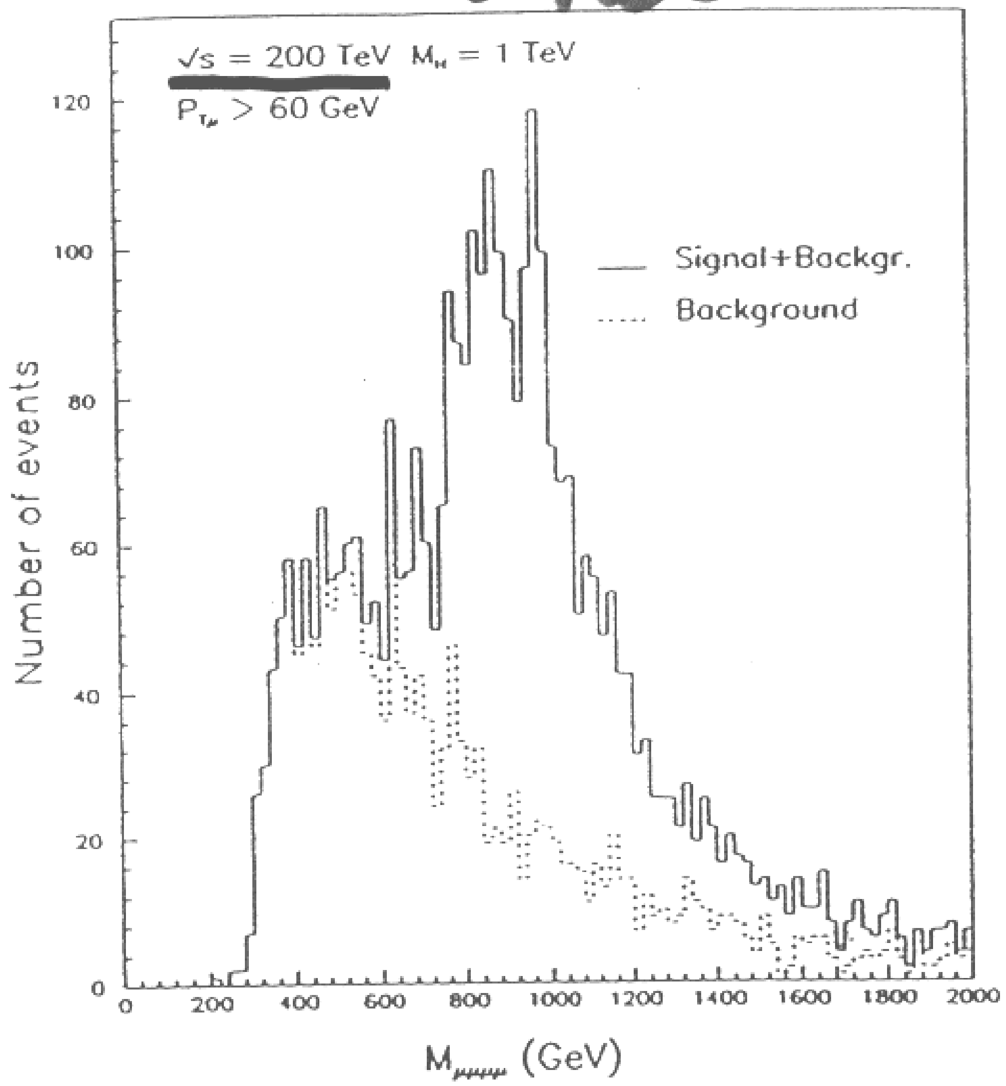


Fig. 9: Heavy Higgs: signal/background at $\sqrt{s}$ = (16, 40) TeV.

8

200 TeV



ELOISATRON

is definitely the best collider

where a heavy Higgs could be observed.

Fig. 10: Heavy Higgs: signal/background at $\sqrt{s}$ = 200 TeV.

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If a Heavy Higgs is there, there is no question that ELN is the best collider.

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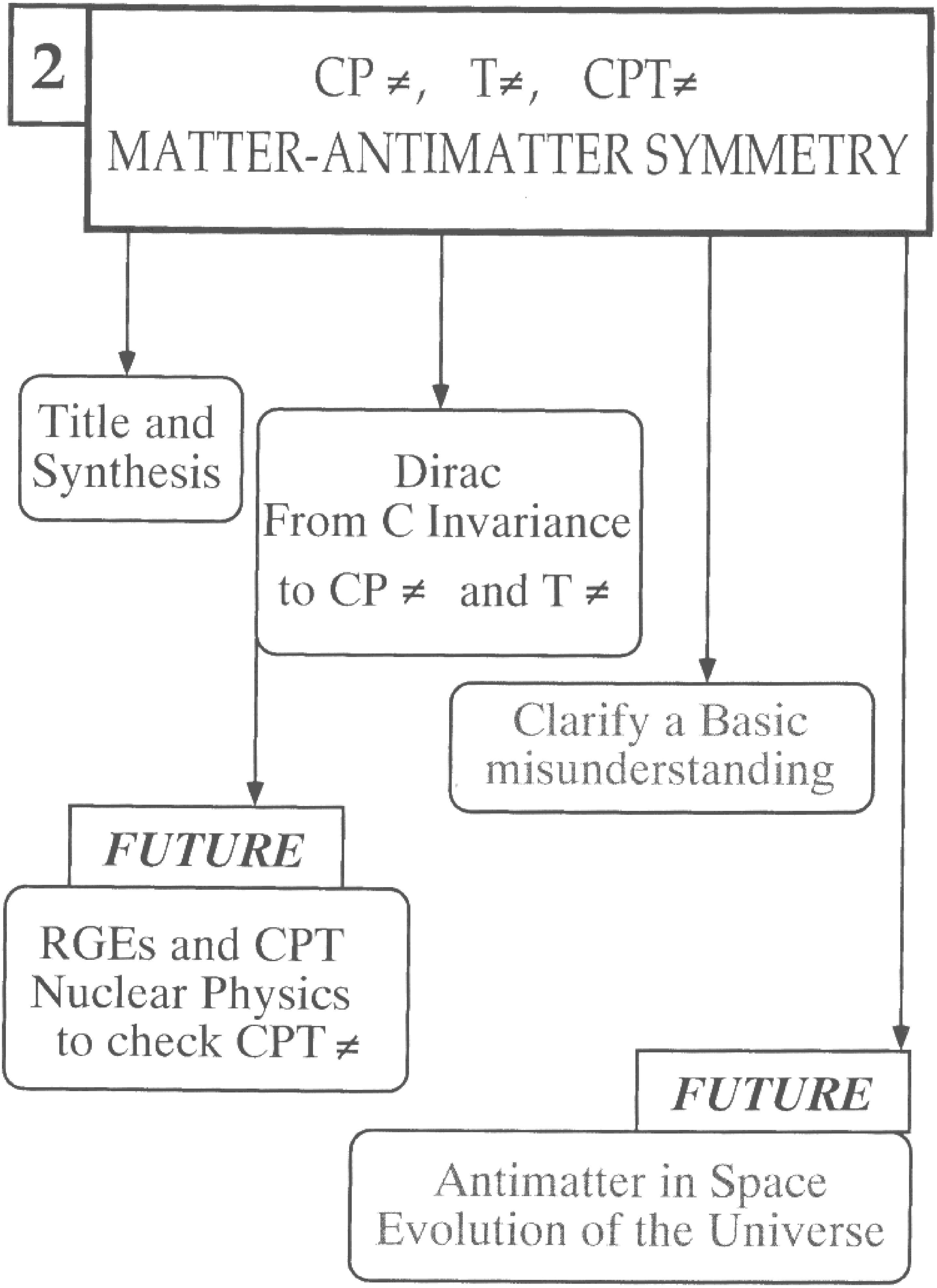


2

CP ≠, T≠, CPT≠
MATTER-ANTIMATTER SYMMETRY

Title and
Synthesis

Dirac
From C Invariance
to CP ≠ and T ≠

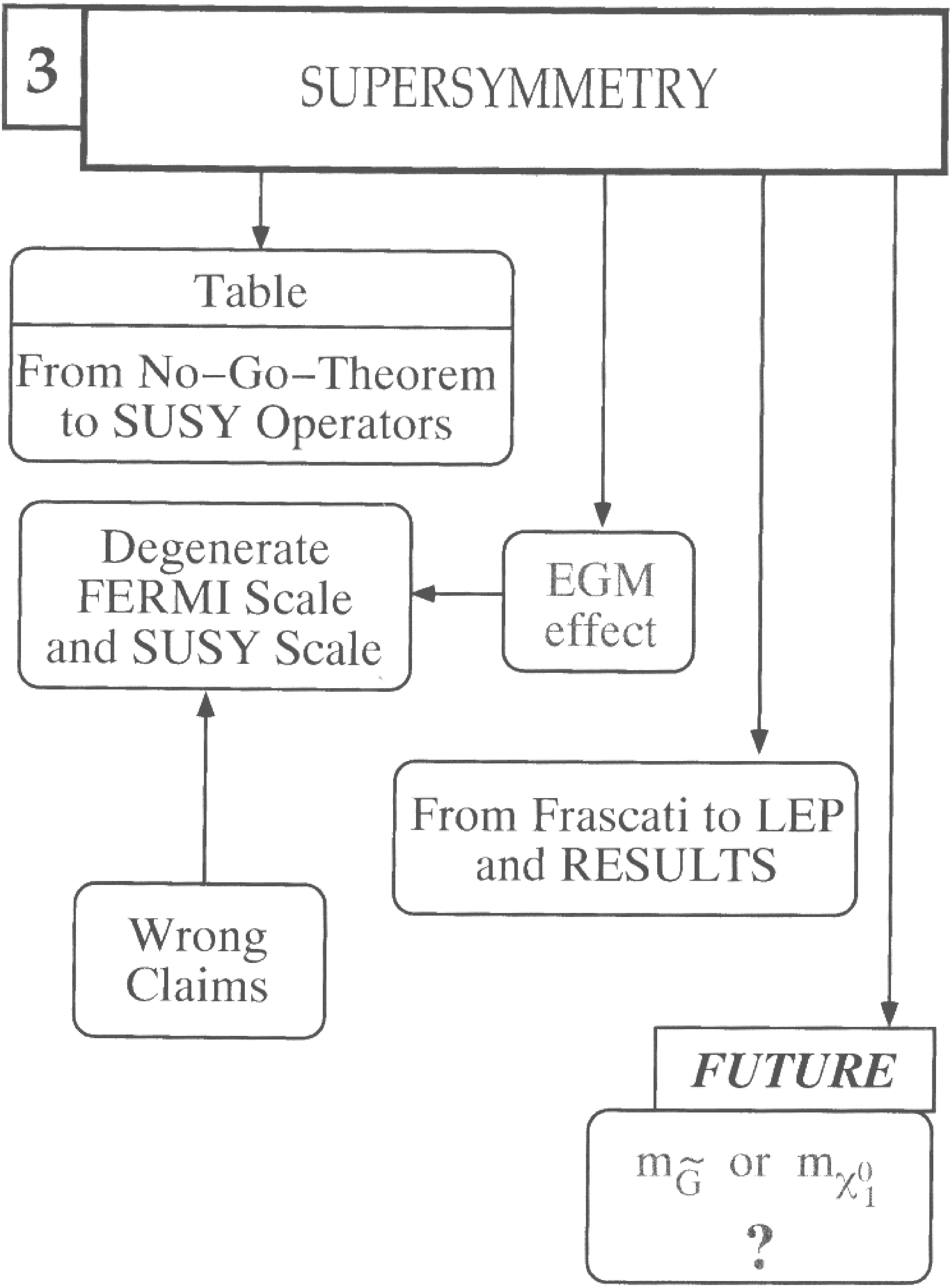
Clarify a Basic
misunderstanding

FUTURE

RGEs and CPT
Nuclear Physics
to check CPT ≠

FUTURE

Antimatter in Space
Evolution of the Universe



3

SUPERSYMMETRY

Table

From No–Go–Theorem to SUSY Operators

EGM effect

Degenerate FERMI Scale and SUSY Scale

Wrong Claims

From Frascati to LEP and RESULTS

FUTURE

$m_{\tilde{G}}$ or $m_{\chi_1^0}$

?

Thus
suggesting a new
Symmetry Law of Nature

SUSY

Why not the
Platonic one
?

4

QCD — NON PERTURBATIVE

The
Effective Energy

FUTURE

(ALICE)

The Physics of the coloured
QCD world (qg)

Free quarks and gluons in
a volume (light proton)
(heavy π)

No one is able

to make the

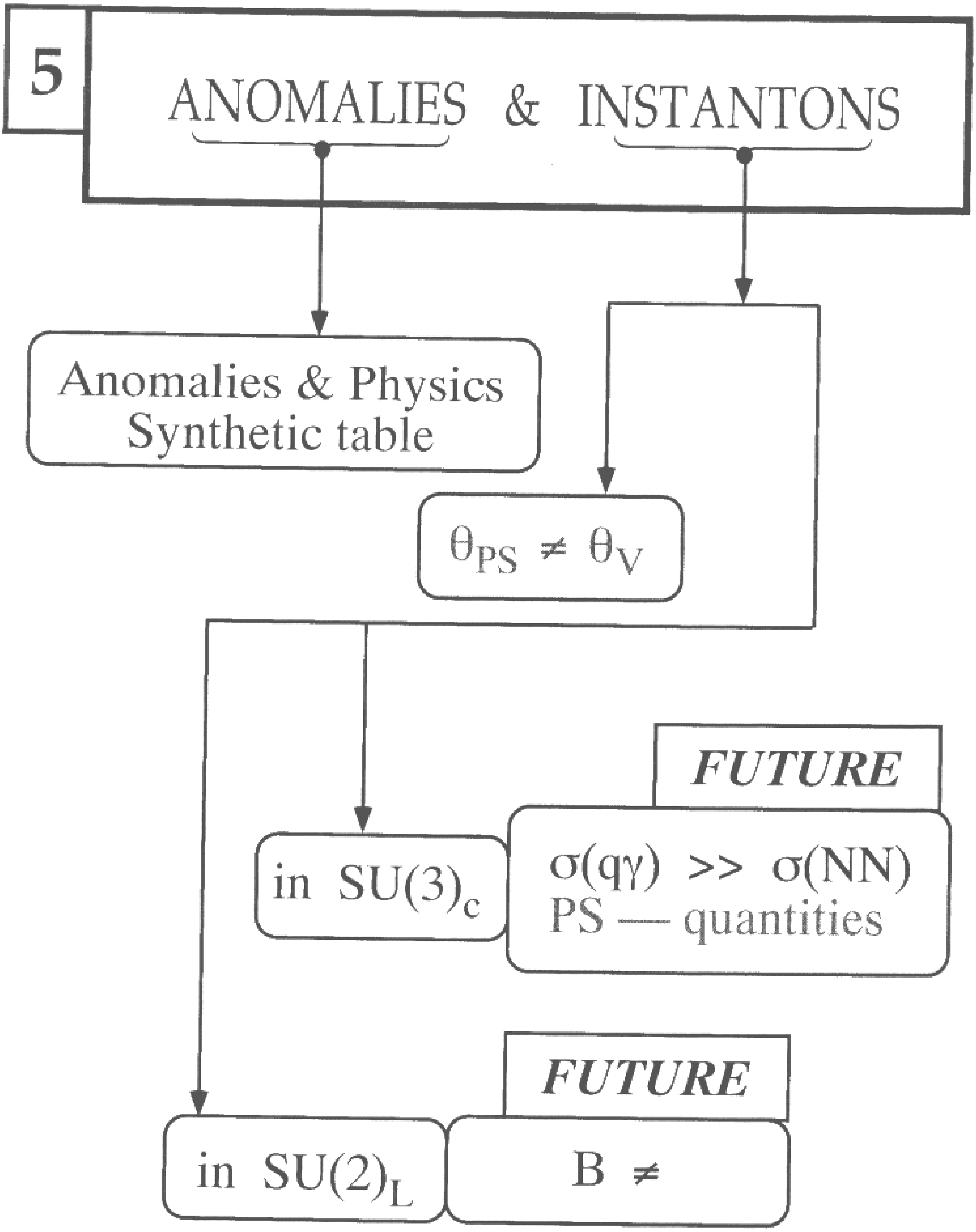
TRANSITION

from

- **QCD**: the colour-full world of quarks and gluons

to

- **Nuclear Physics**: the colour neutral world of mesons and baryons.



5 ANOMALIES & INSTANTONS

Anomalies & Physics
Synthetic table

$\theta_{PS} \neq \theta_V$

in $SU(3)_c$

FUTURE

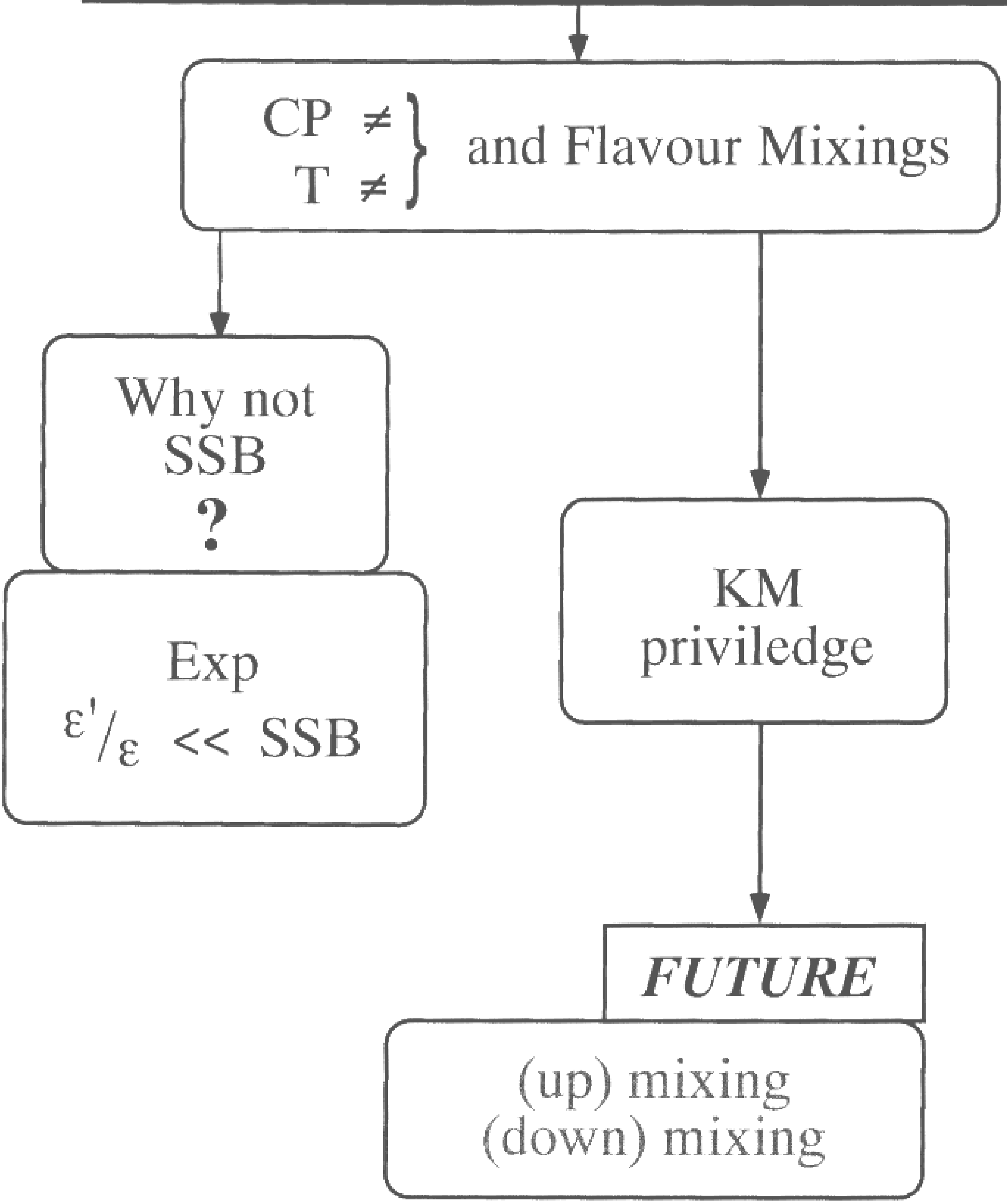
$\sigma(q\gamma) \gg \sigma(NN)$
PS — quantities

in $SU(2)_L$

FUTURE

B $\neq$

6 FLAVOUR MIXING IN THE QUARK SECTOR



$\left.\begin{array}{r} CP \neq \\ T \neq \end{array}\right\}$ and Flavour Mixings

Why not SSB ?

Exp

$\varepsilon'/\varepsilon \ll$ SSB

KM priviledge

FUTURE

(up) mixing
(down) mixing

The
mixing mechanism
for
quark flavours

NEEDS
to be understood

24

Conclusion:

Two mixtures:

- the **up-type** and
- the **down-type**.

The K.M. Matrix corresponds to the product of these two mixtures.

A. Zichichi, Lezioni di Fisica Superiore, Bologna University, (1977).

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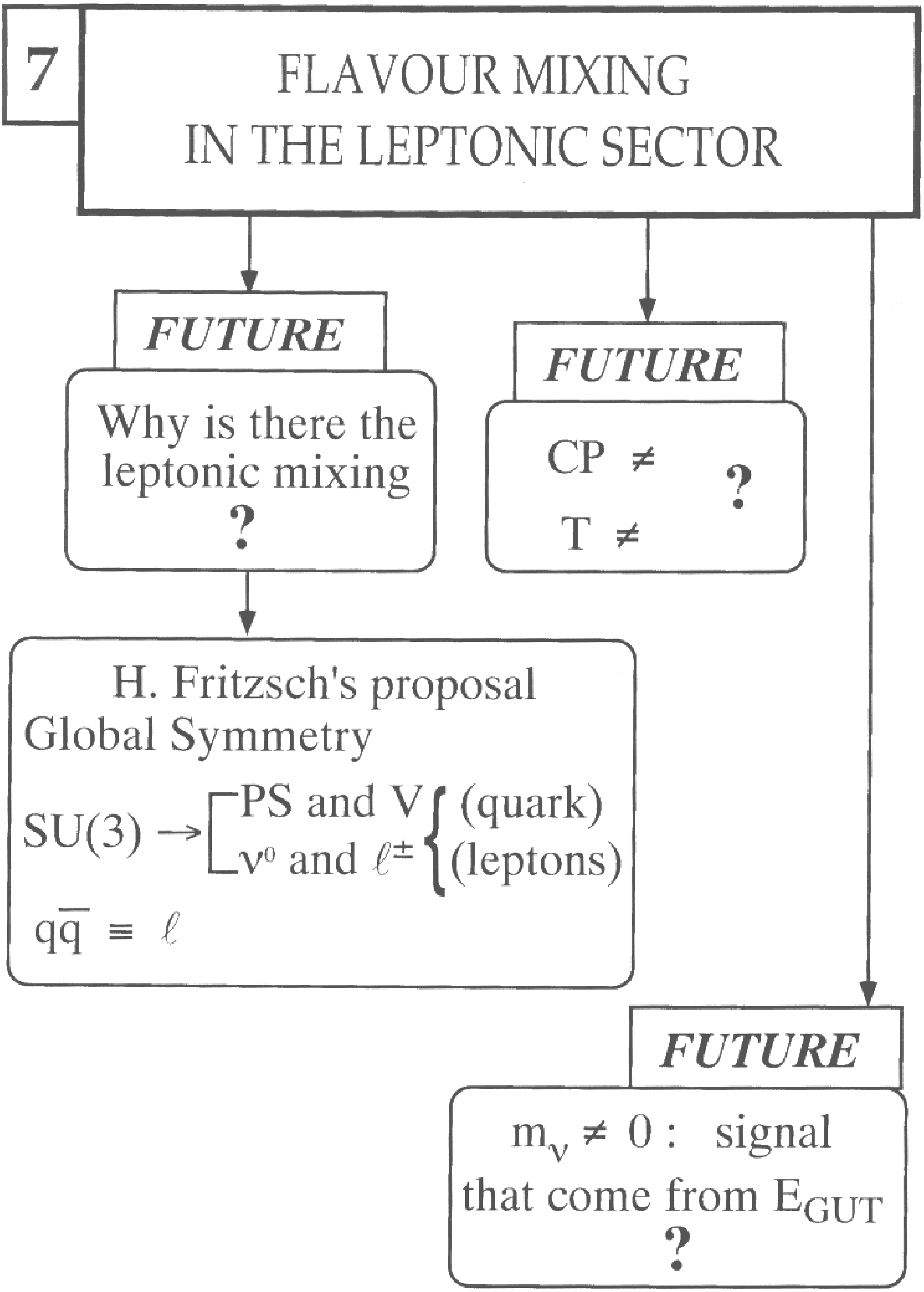


7 FLAVOUR MIXING IN THE LEPTONIC SECTOR

FUTURE

Why is there the leptonic mixing ?

FUTURE

CP ≠

T ≠ ?

H. Fritzsch's proposal

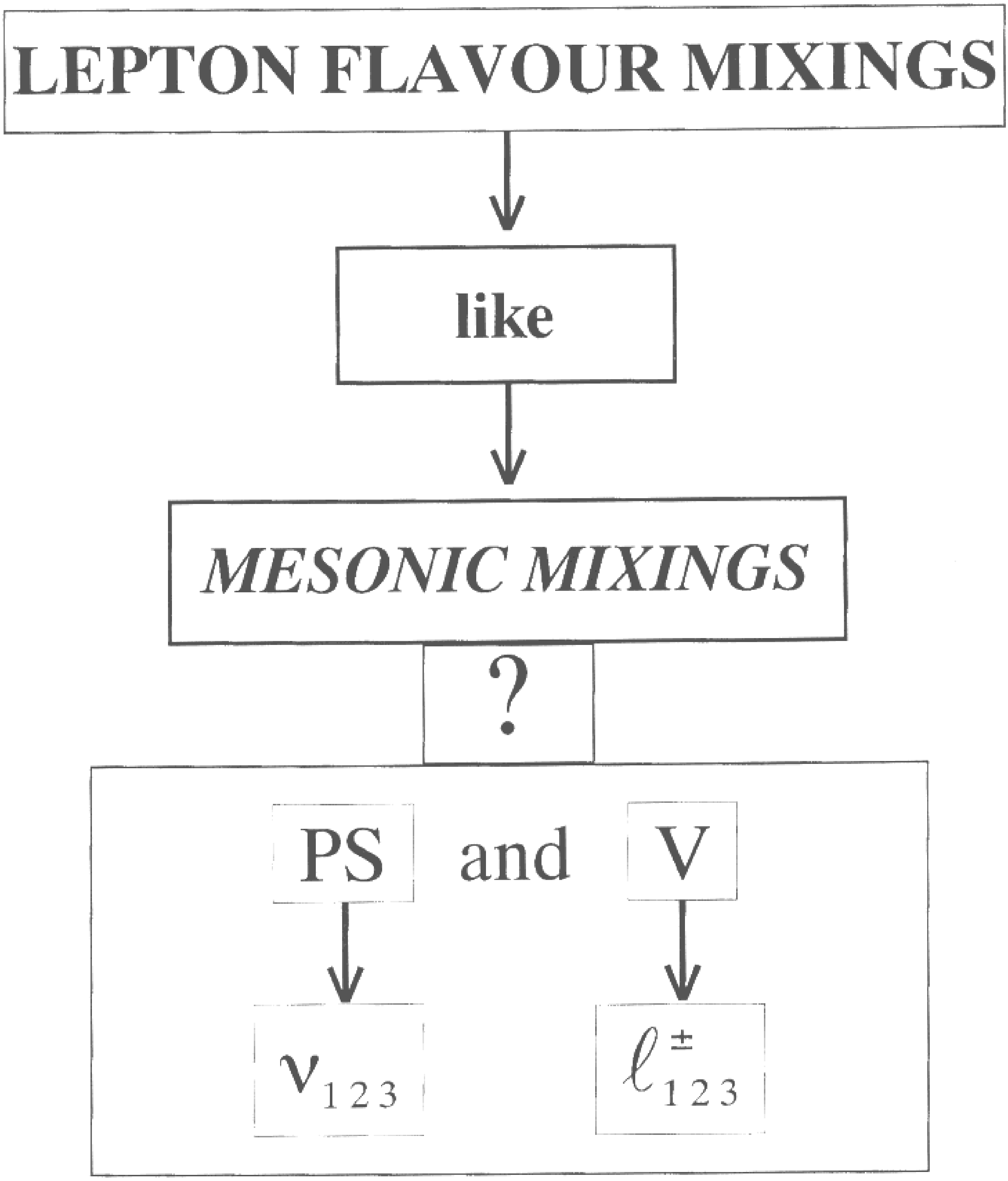
Global Symmetry

$$SU(3) \rightarrow \begin{cases} PS \text{ and } V & \text{(quark)} \\ \nu^0 \text{ and } \ell^{\pm} & \text{(leptons)} \end{cases}$$

$q\bar{q} \equiv \ell$

FUTURE

$m_\nu \neq 0$: signal that come from E_{GUT} ?



LEPTON FLAVOUR MIXINGS

like

MESONIC MIXINGS

?

PS and V

$\nu_{1\,2\,3}$

$\ell^{\pm}_{1\,2\,3}$

8 THE PROBLEM OF THE MISSING MASS IN THE UNIVERSE

Table

From 10^{-5} eV to 10^{6} $M_{\odot}$

& Modified Gravitational Law

9

THE PROBLEM OF THE HIERARCHY

A set of
BASIC ISSUES

$$\frac{\text{B-Asymmetric Universe}}{\text{B-Symmetric Universe}} \simeq 10^{16}$$

FUTURE

Do we understand these
16 orders of Magnitude
?

FUTURE

τ_p and decay channels

10

THE PHYSICS AT THE PLANCK SCALE AND THE NUMBER OF EXPANDED DIMENSIONS

FUTURE

The GAP problem between E_{GU} and E_{SU}

FUTURE

Are we missing a great opportunity

?

C

The Future (on the basis of past achievements)

E adesso
qual'è
il prossimo
TRAGUARDO

?

The proton collider
with the
highest energy and luminosity which could be built with simple extrapolations of the presently known technologies:

the ELN project.

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ELN

200 TeV

300 Km

20 G$

The ELN project is very ambitious but we should be encouraged by our previous experiences.

55

C

The Future (on the basis of past achievements)

In fact,
the path from 1979
to the ELN project now
has already gone through:

the Gran Sasso project

(now the largest and most powerful underground laboratory in the world)

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the LEP-white-book

which allowed this great European venture to overcome the many difficulties that had blocked its implementation during many years

27 Km (not 12 Km)

the roots of LHC,

the 5-metre diameter ***

for the LEP tunnel

not 3 metre diameter

as wanted by

the CERN Research Directors of the time

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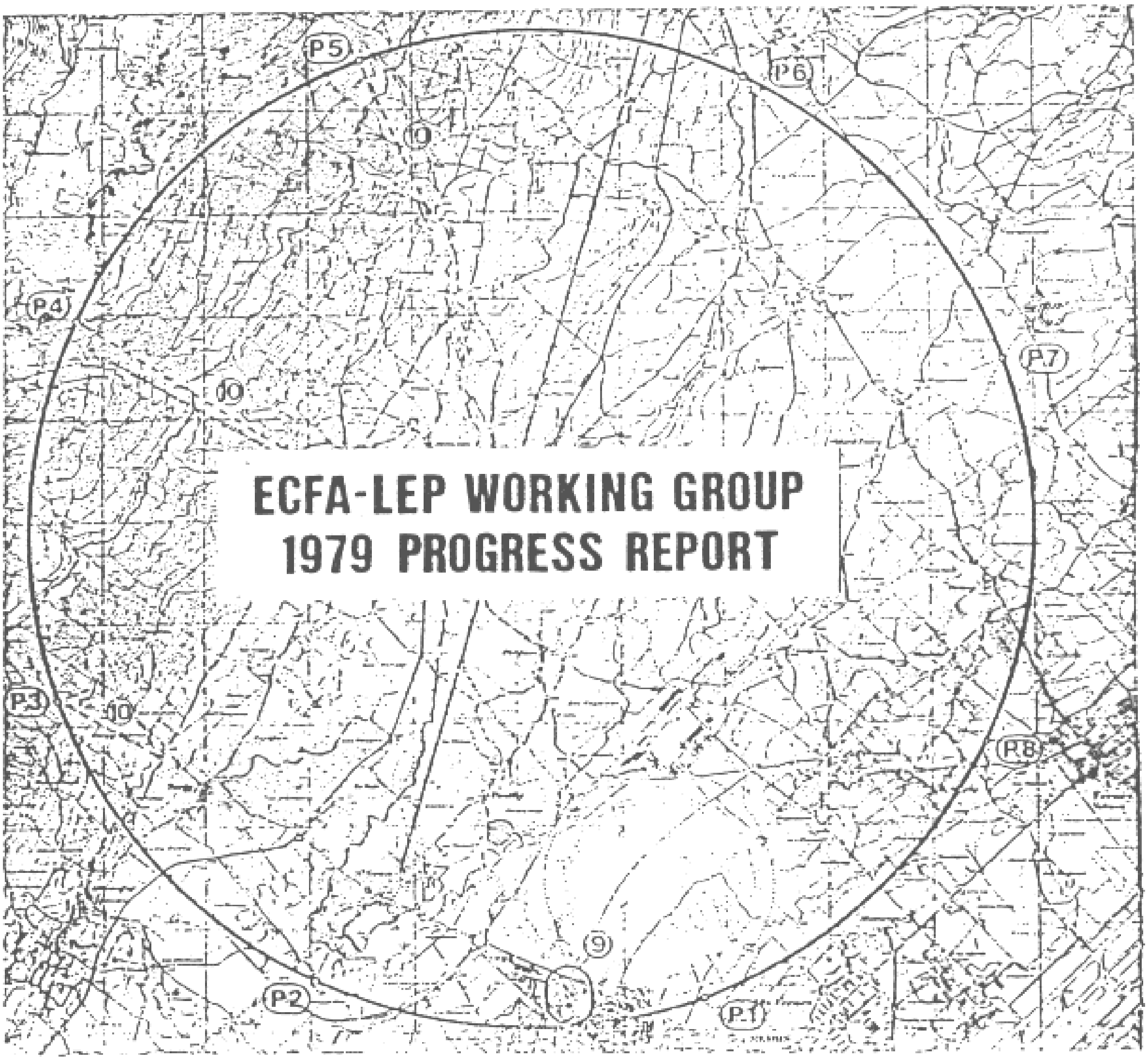
Conclusions
ECFA/79/39
15/4/1980

ECFA EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS



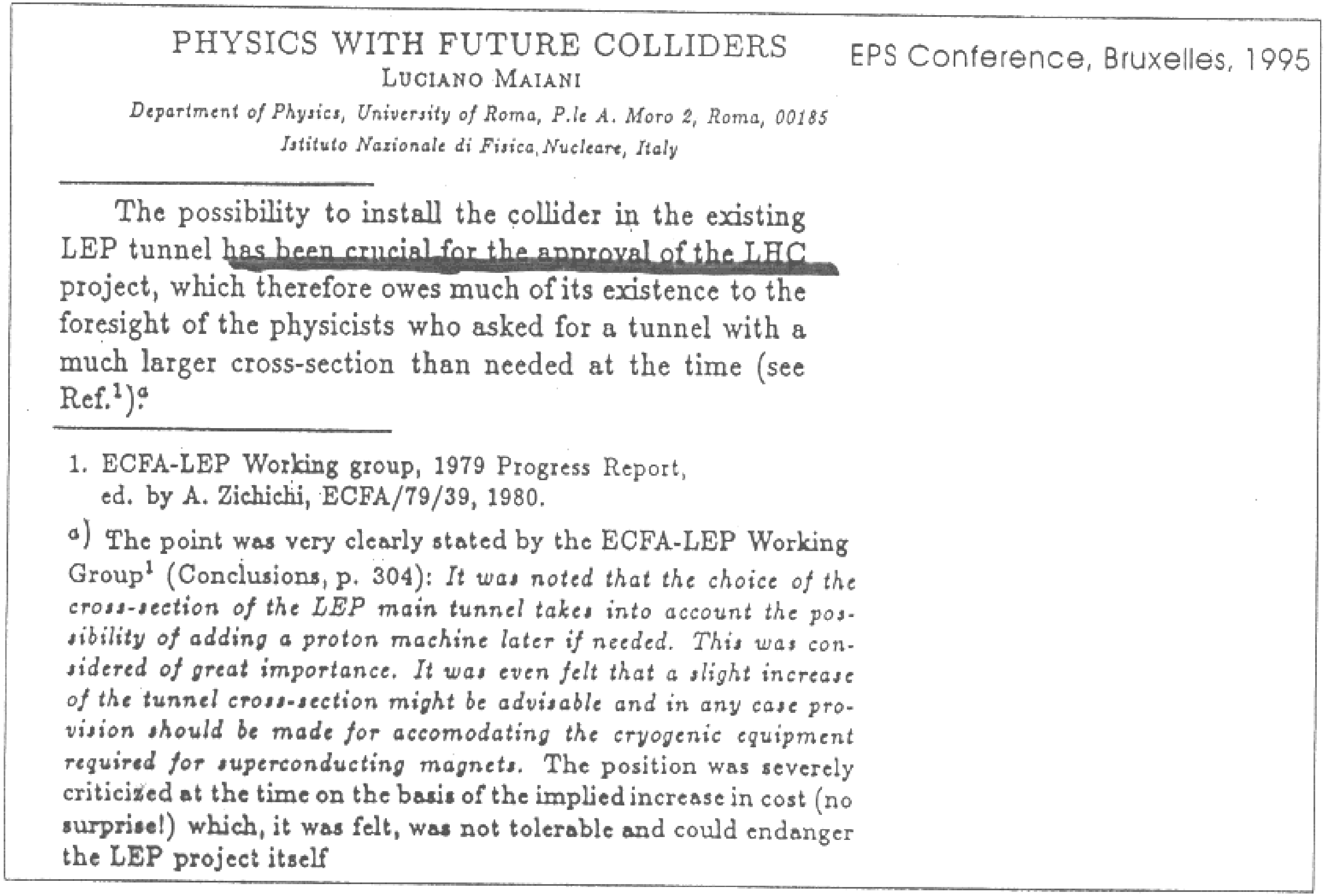
ECFA-LEP WORKING GROUP
1979 PROGRESS REPORT

Edited by

A. Zichichi, Chairman
ECFA-LEP Working Group

~~4~~60

This proposal was heavily criticised by the CERN Research Directors of the time, but has been essential for the realization of LHC, as mentioned by L. Maiani (paper reproduced below).



PHYSICS WITH FUTURE COLLIDERS

EPS Conference, Bruxelles, 1995

LUCIANO MAIANI

Department of Physics, University of Roma, P.le A. Moro 2, Roma, 00185
Istituto Nazionale di Fisica Nucleare, Italy

The possibility to install the collider in the existing LEP tunnel has been crucial for the approval of the LHC project, which therefore owes much of its existence to the foresight of the physicists who asked for a tunnel with a much larger cross-section than needed at the time (see Ref.[1])[a].

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1. ECFA-LEP Working group, 1979 Progress Report, ed. by A. Zichichi, ECFA/79/39, 1980.

[a] The point was very clearly stated by the ECFA-LEP Working Group[1] (Conclusions, p. 304): *It was noted that the choice of the cross-section of the LEP main tunnel takes into account the possibility of adding a proton machine later if needed. This was considered of great importance. It was even felt that a slight increase of the tunnel cross-section might be advisable and in any case provision should be made for accomodating the cryogenic equipment required for superconducting magnets.* The position was severely criticized at the time on the basis of the implied increase in cost (no surprise!) which, it was felt, was not tolerable and could endanger the LEP project itself

the HERA collider

(now successfully running)

and

the LAA-R&D project,

implented to find the original
detector technologies
needed for the new colliders.

An intensive **R&D project** to study new subnuclear technologies has been implemented at CERN.

LAA

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LAA BASIC POINTS:

1. RADIATION HARDNESS	• • •
2. HERMETICITY	• • •
3. RATE CAPABILITY	• • •
4. MOMENTUM RESOLUTION	•
5. ENERGY RESOLUTION	•
6. TRACK & SPACE RESOLUTION	•
7. TIME RESOLUTION	•
8. PARTICLE IDENTIFICATION	•

Note that hermeticity is an essential feature as the discovery potential of a detector lies essentially in its capability to see "missing" momenta. A (4 π) detector has never been built. The challenge to study how to build a detector without holes in the 4 π solid angle coverage, able to handle high rates and be radiation hard, has been the main (R&D) task of the LAA Project.

LAA

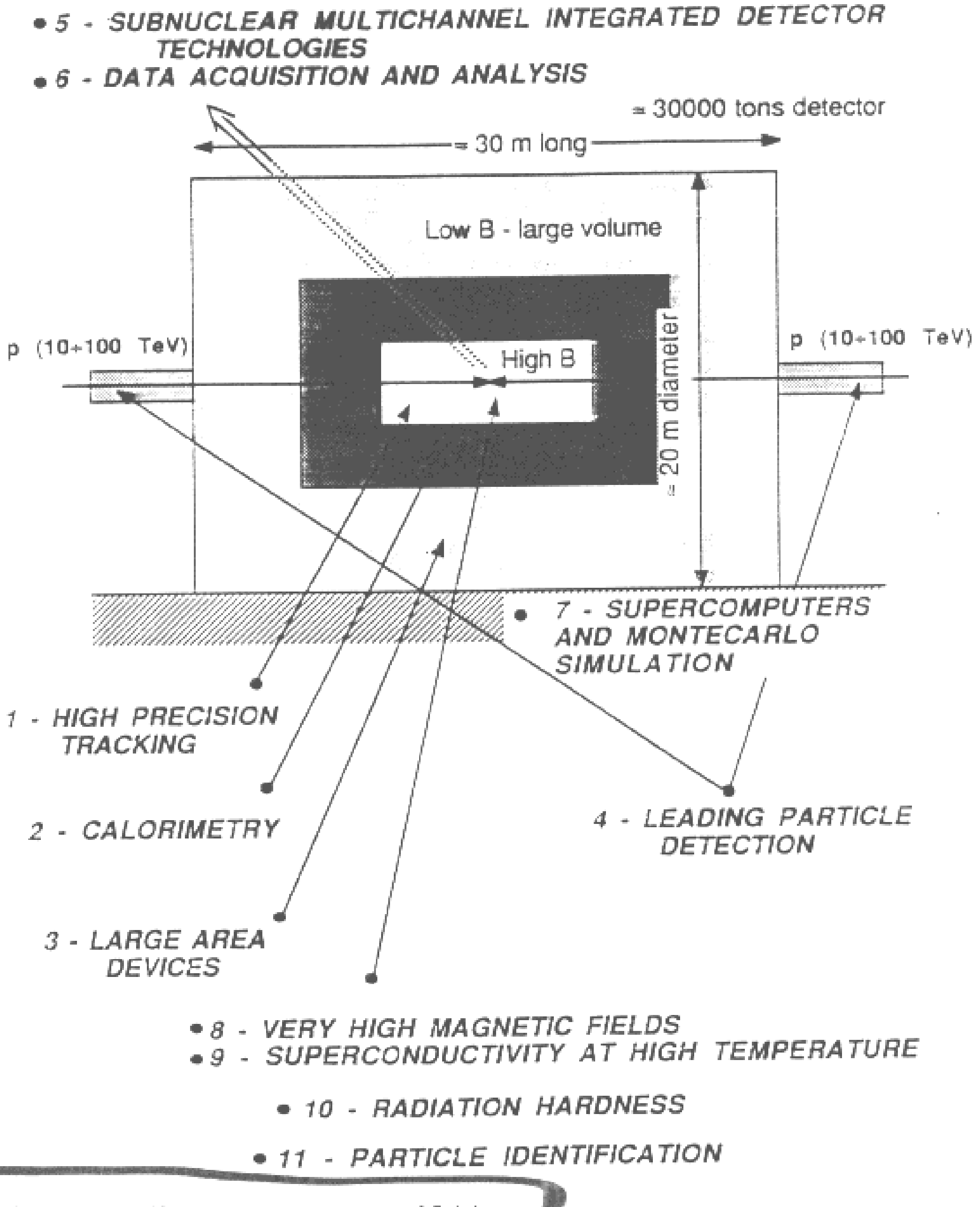
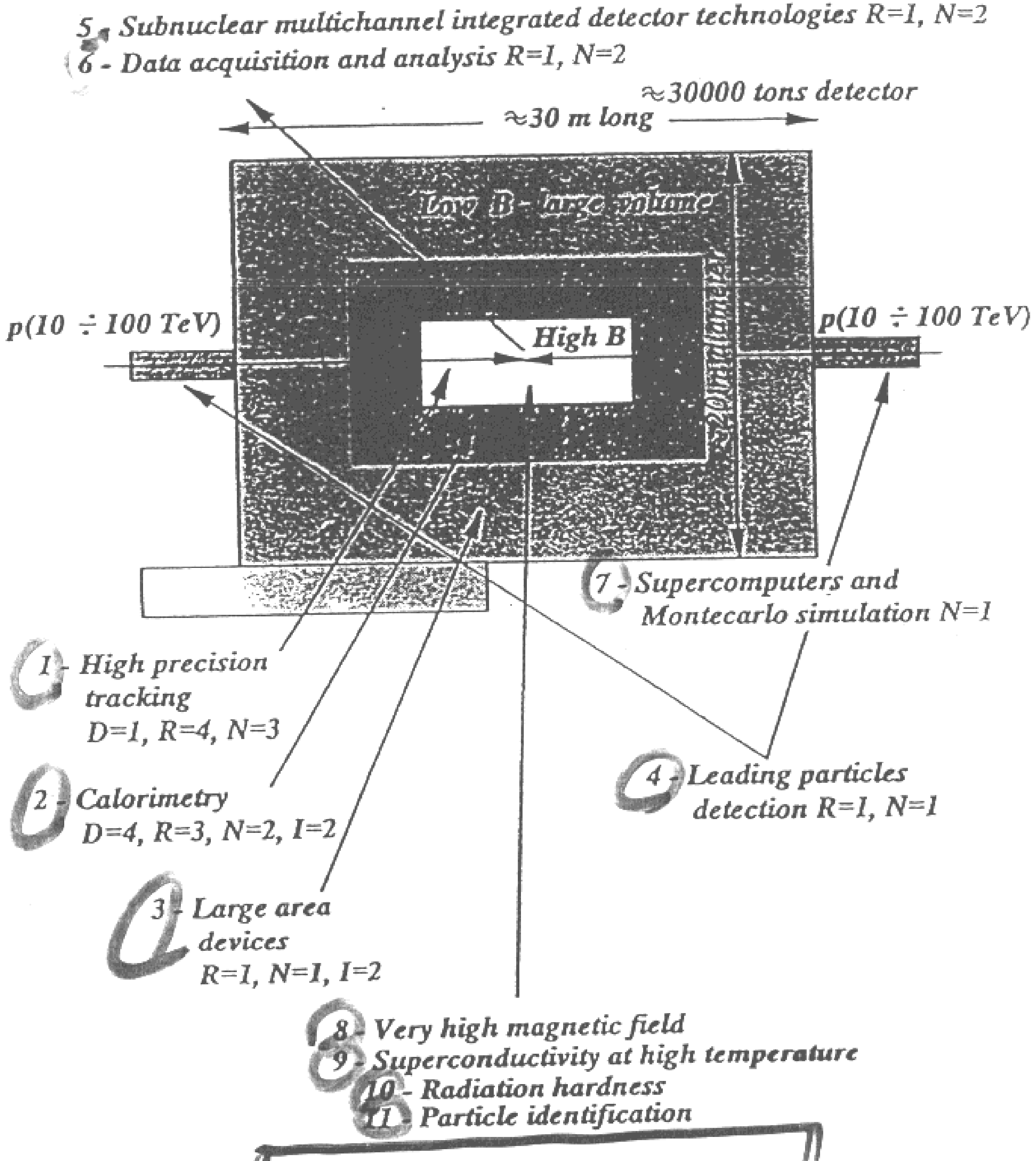


Fig. 1.2.1. – The eleven components of LAA.

A synthesis of the main results is shown in Fig. 7 where the crucial components needed for a (4 π) detector working in the (20 – 200) TeV energy range are indicated, together with the number of important results obtained in each component. It is impossible to report telegraphically and in a non-boring way the work of 200 specialists during ten years.

D ≡ Discoveries
R = Records
N = New Developmt
I = Inventions

THE LAA PROJECT



5 - Subnuclear multichannel integrated detector technologies R=1, N=2
6 - Data acquisition and analysis R=1, N=2

7 - Supercomputers and Montecarlo simulation N=1

1 - High precision tracking D=1, R=4, N=3

2 - Calorimetry D=4, R=3, N=2, I=2

3 - Large area devices R=1, N=1, I=2

4 - Leading particles detection R=1, N=1

8 - Very high magnetic field
9 - Superconductivity at high temperature
10 - Radiation hardness
11 - Particle identification

TOTAL: D=5, R=11, N=12, I=4

Fig. 7: R&D for new detector technologies (LAA). The numbers of main results (D, R, N, I) are shown for each component.

Table I.6.I. Main achievements of the LAA Project in terms of:
D=Discoveries, R=Records,
N=New developments, I=Inventions

	D	R	N	I
1. HIGH PRECISION TRACKING				
a) Gaseous detectors		2	1	
b) Scintillating fibres	1	2	1	
c) Microstrip GaAs			1	
2. CALORIMETRY				
a) High precision EM	2		1	
b) Compact EM+Hadronic	1	2		2
c) "Perfect" Calorimetry	1	1	1	
3. LARGE AREA DEVICES				
a) Construction				2
b) Alignment		1	1	
4. LEADING PARTICLE DETECTION		1	1	
5. SMIDT				
a) Microelectronics			2	
b) New, Radiation-resistant Technologies		1		
6. DATA ACQUISITION AND ANALYSIS				
a) Real Time Data Acquisition			1	
b) FASTBUS RISC computer		1		
c) Fine-grained Parallel Processor			1	
7. SUPERCOMPUTERS AND MONTECARLO SIMULATIONS			1	
TOTAL	5	11	12	4

I

D

R

N

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Let me just say that is thanks to this effort that many problems connected with the possibility of doing physics in the multi-TeV energy range, with high luminosity and rates have been solved. If it were not for this component of the ELN Project, i.e. LAA, we would not be in a position to compete — here in Europe — with our American colleagues. In fact we are — in many areas of technological detector developments — ahead of them.

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5^{a}

THE ROOTS OF LAA

5 – *LAA and its Roots (**Experimental** Tricks Versus **Theoretical** Tricks)*

* * *

«*There is no*
New Physics
without
New Projects»

John S. Bell, Erice 1963

For the new projects,
of vital importance **are**
what John
liked to call
«Experimental Tricks»

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~~5~~

*«**Experimental Tricks** are (at least) as important as **Theoretical Tricks**».*

«So in both theory and experiment, to improve the physics of the future, I would like to see a little more pride in the work».

Richard P. Feynman, Erice 1964

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«We experimentalists are not like theorists: the originality of an idea is not for being printed in a paper, but for being shown in the implementation of an original experiment.»

Lord Patrick Maynard Stuart Blackett, 1962

The **Experimental Tricks**
strongly supported by
John Stewart Bell
have contributed to the
following developments
in Subnuclear Technologies

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THE ROOTS OF LAA

SUMMARY

- High Precision Magnetic Fields $\frac{\Delta B}{B} = \pm 10^{-4}$.
- Preshower $= \pm 5 \times 10^{-4} \equiv \pi/e$.
- Muon Punch-Through.
- Calorimetry.
- TOF $= \pm$ 70 psec.
- Neutron Missing-Mass Spectrometer (± 100 psec).
- High Precision $\frac{dE}{dx}$ with $\lambda_{abs} = 30$ meters.

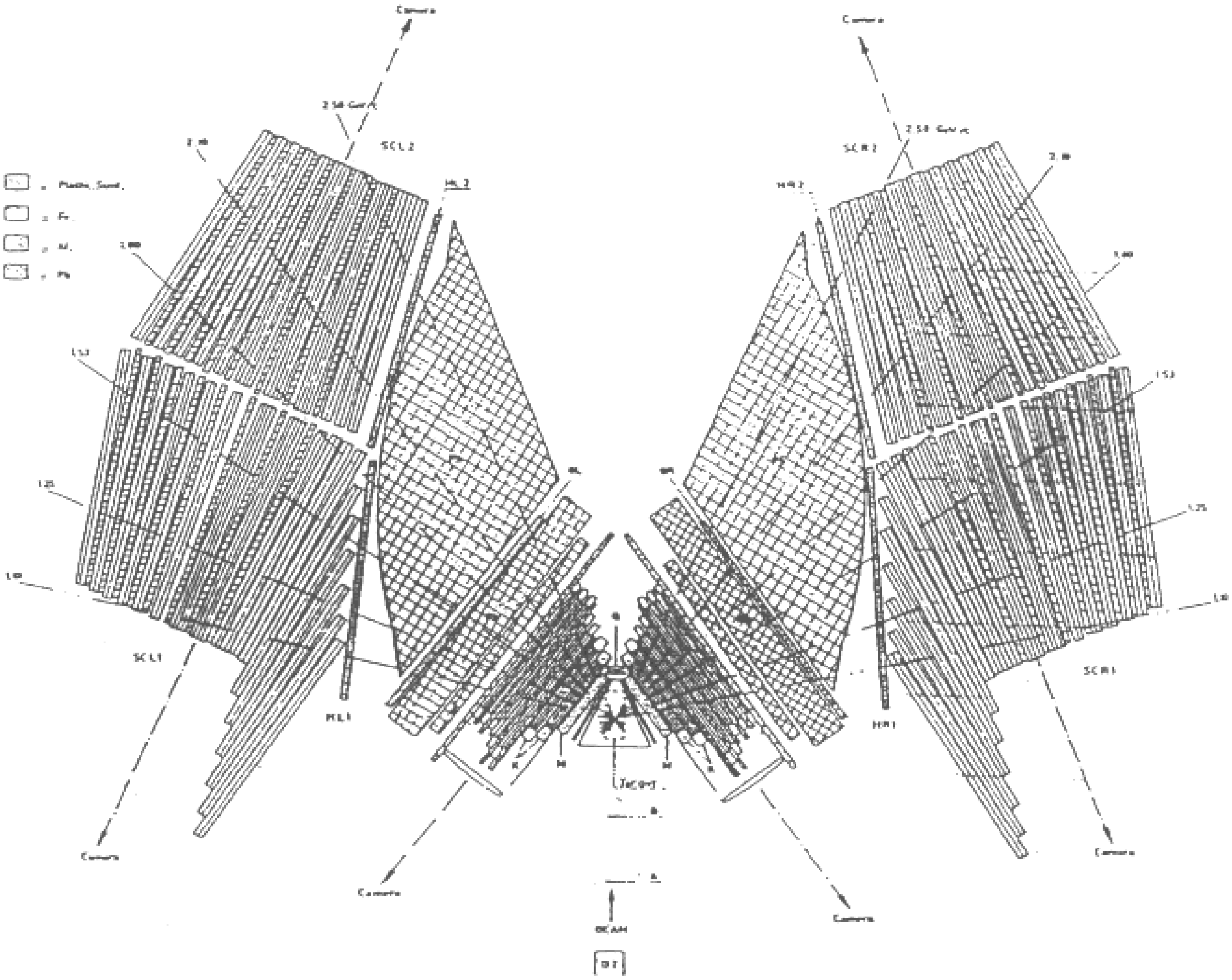
The problem of divergences in electro-weak interactions and the third lepton.

PRESHOWER $\pi/e = 5 \times 10^{-4}$

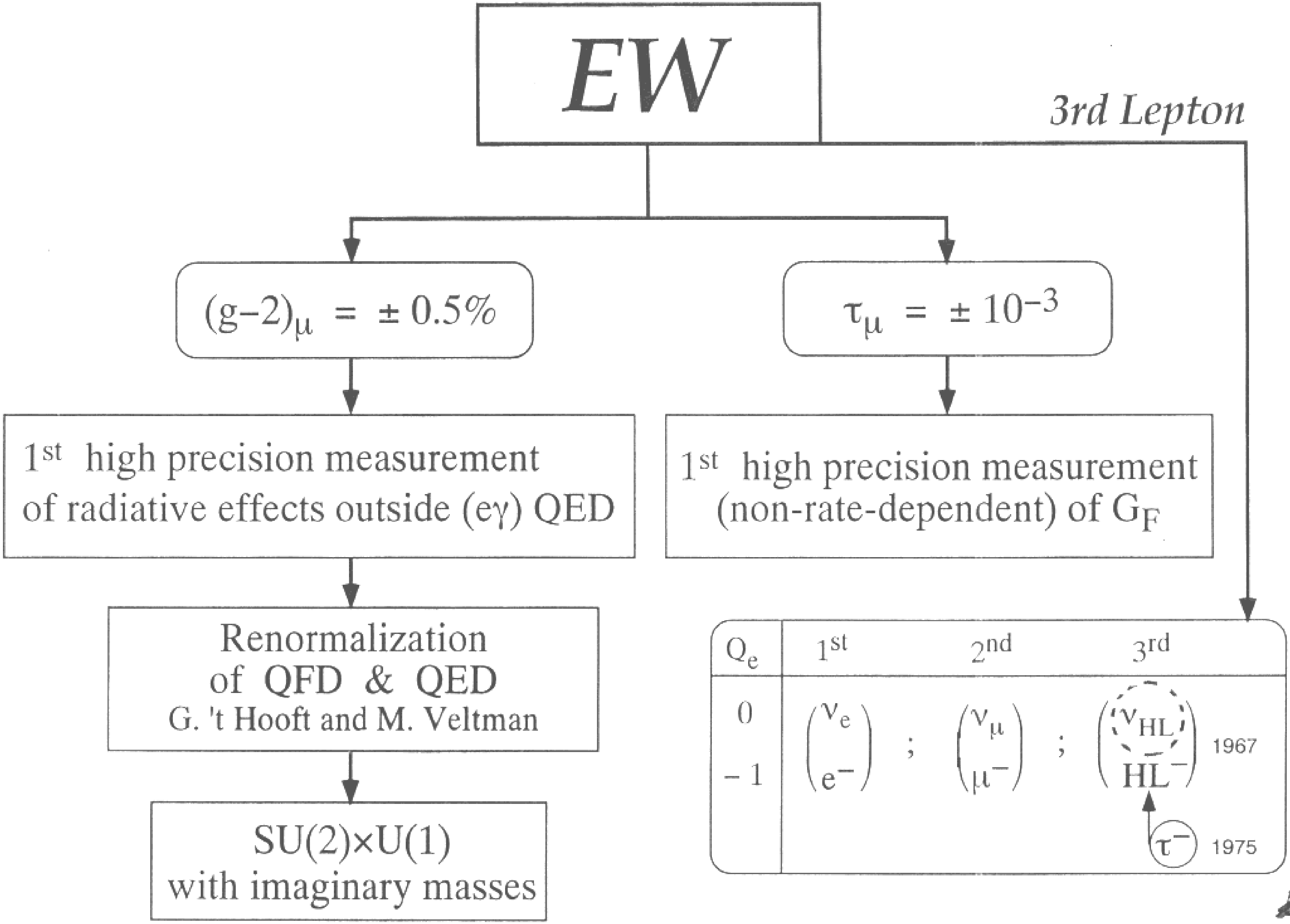
MUON PUNCH-THROUGH

To simultaneously detect $(e^{\pm}\mu^{\mp})$ final states in $(\bar{p}p)$ annihilation ≡ the 1st experiment to search for the THIRD LEPTON (HL ≡ τ).

$(HL^{\pm}) \equiv \tau^{\pm}$ & $F_p^{em}(q^2)_{\text{time-like}}$



The experimental set-up implemented to search for the Third Lepton (HL ≡ τ) and for a time-like electromagnetic structure of the proton ($F_p^{em}(q^2)_{\text{time-like}}$). The set-up was able to detect simultaneously the (e^+e^-), the $(\mu^+\mu^-)$ and the $(\mu^{\pm}e^{\mp})$ final states of the $(\bar{p}p)$ annihilation.



EW

3rd Lepton

$(g-2)_\mu = \pm 0.5\%$

1st high precision measurement of radiative effects outside ($e\gamma$) QED

Renormalization
of QFD & QED
G. 't Hooft and M. Veltman

SU(2)×U(1)
with imaginary masses

$\tau_\mu = \pm 10^{-3}$

1st high precision measurement (non-rate-dependent) of G_F

Q_e	1st		2nd		3rd	
0 – 1	$\begin{pmatrix}\nu_e \\ e^-\end{pmatrix}$	;	$\begin{pmatrix}\nu_\mu \\ \mu^-\end{pmatrix}$	;	$\begin{pmatrix}\nu_{HL} \\ HL^-\end{pmatrix}$	1967
					τ^-	1975

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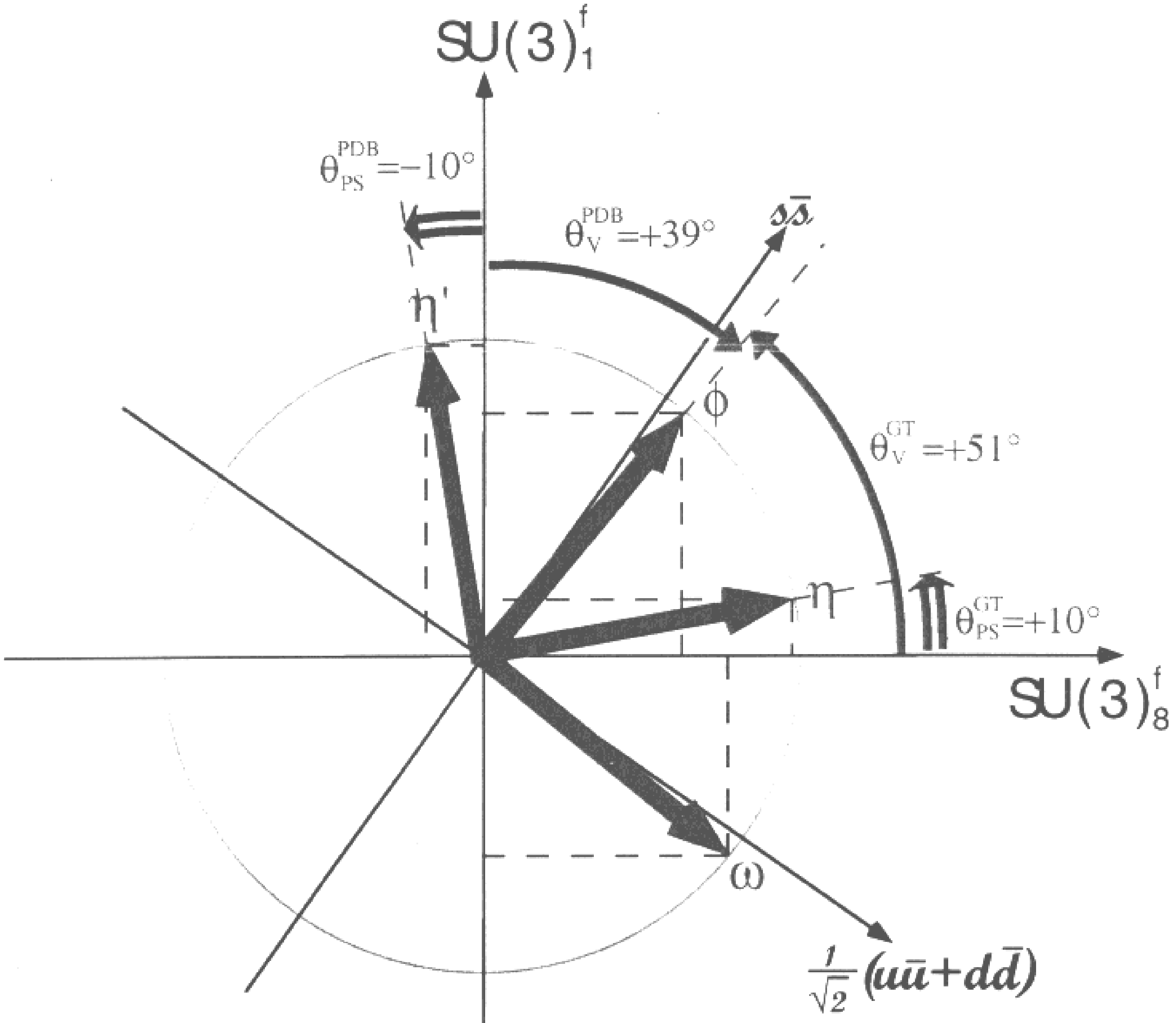

PDB ≡ Particle Data Book
GT ≡ Gerardus 't Hooft

$\Theta_{PS} \neq \Theta_V$

Direct us ?

using mass-formulae

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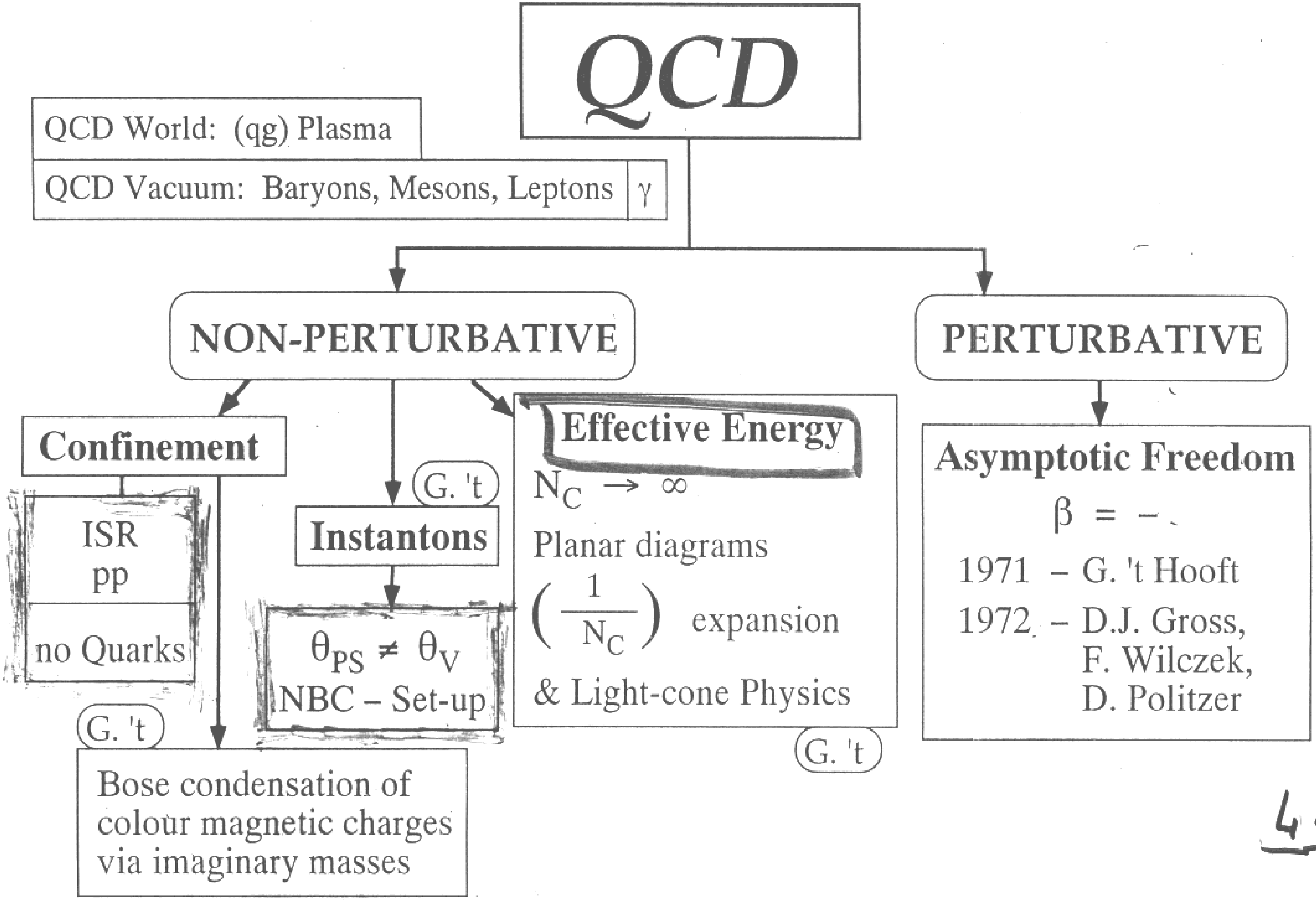

QCD

QCD World: (qg) Plasma

QCD Vacuum: Baryons, Mesons, Leptons | γ

NON-PERTURBATIVE

Confinement

ISR
pp

no Quarks

(G. 't)

Bose condensation of colour magnetic charges via imaginary masses

(G. 't)

Instantons

$\theta_{PS} \neq \theta_V$
NBC – Set-up

Effective Energy

$N_C \to \infty$

Planar diagrams

$\left(\frac{1}{N_C}\right)$ expansion

& Light-cone Physics

(G. 't)

PERTURBATIVE

Asymptotic Freedom

$\beta = -$

1971 – G. 't Hooft
1972 – D.J. Gross,
F. Wilczek,
D. Politzer

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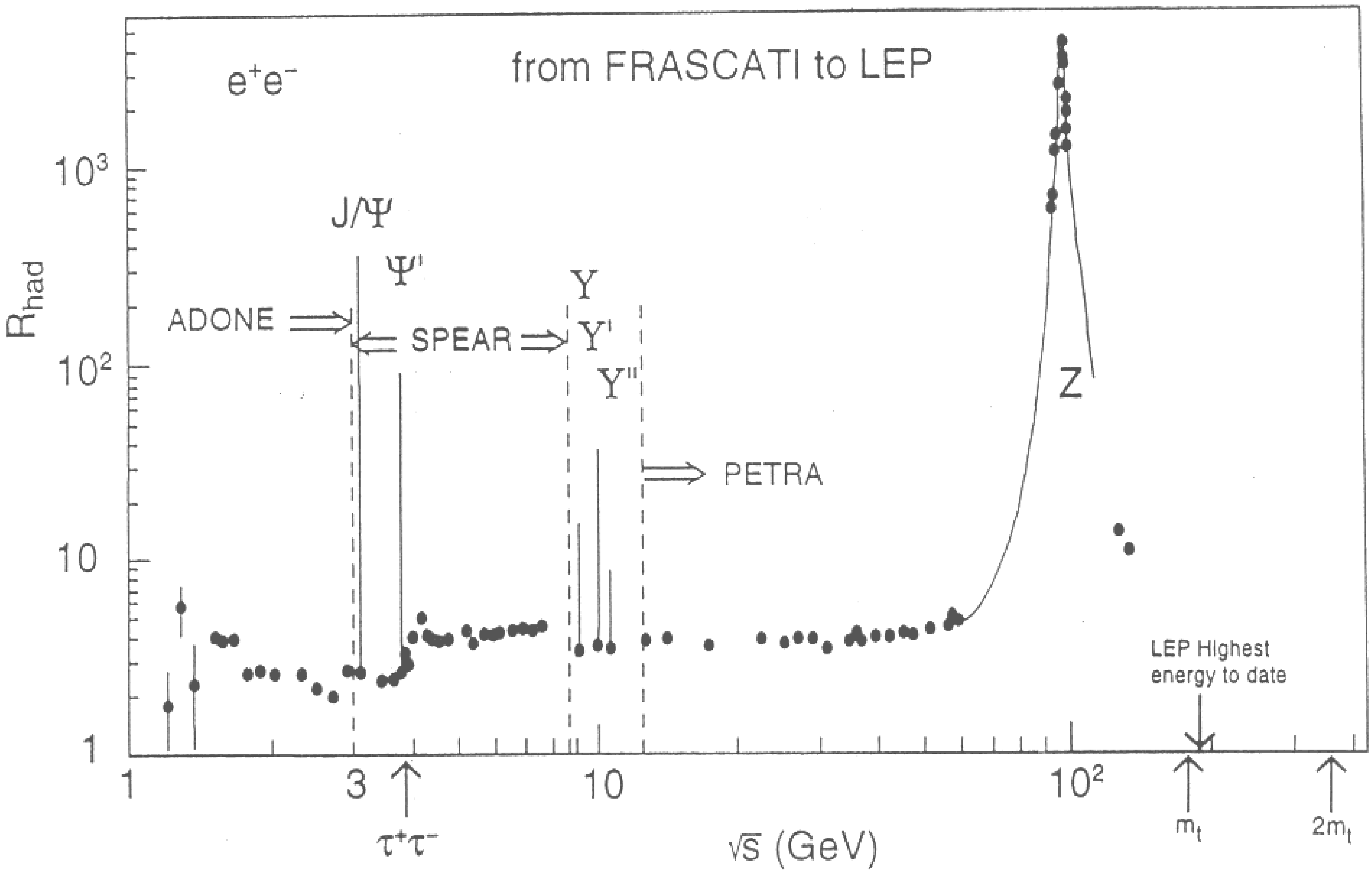
Recall
two famous
Statements
against AZ

Zichichi
cerca **farfalle:**
le farfalle erano

$$J/\Psi \qquad \text{e} \qquad \underbrace{\text{HL}}_{\tau \qquad\qquad \nu_{HL}}$$


e⁺e⁻
from FRASCATI to LEP
R_had
10³
10²
10
1
J/Ψ
Ψ'
ADONE ⟹
⟸ SPEAR ⟹
Υ
Υ'
Υ''
⟹ PETRA
Z
LEP Highest energy to date
1
3
10
10²
τ⁺τ⁻
√s (GeV)
m_t
2m_t

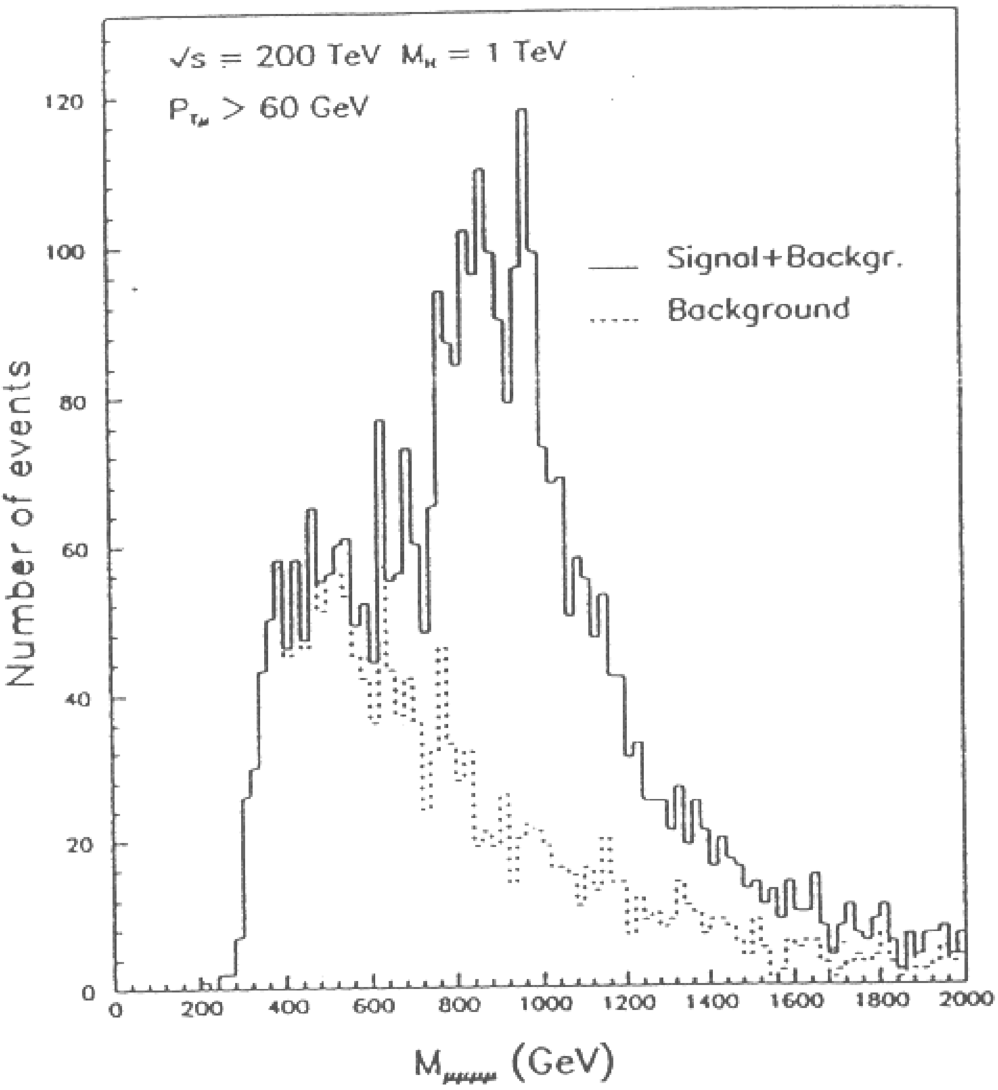
Zichichi sogna:

i sogni erano

- Gran Sasso
- HERA
- 27 Km (e^+e^-) tunnel ≡> LEP
- 5 meter ϕ tunnel ≡> LHC
- LAA ≡ New Technologies
  for Supercolliders

ELN

A. ZICHICHI



ELOISATRON

is definitely the best collider

where a heavy Higgs could be observed.

Fig. 10: Heavy Higgs: signal/background at $\sqrt{s} = 200$ TeV.


THE ELONGATION PROJECT

The conceptual design of ELN has been performed by **K. Johnsen** and collaborators. This study shows that there are no conceptual difficulties in the realisation of a (100 + 100) TeV collider able to work with a luminosity $L = (0.9 \div 1.8) \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$. The basic and lattice parameters of the collider are shown in Fig. 3, and the collider layout in Fig. 4.

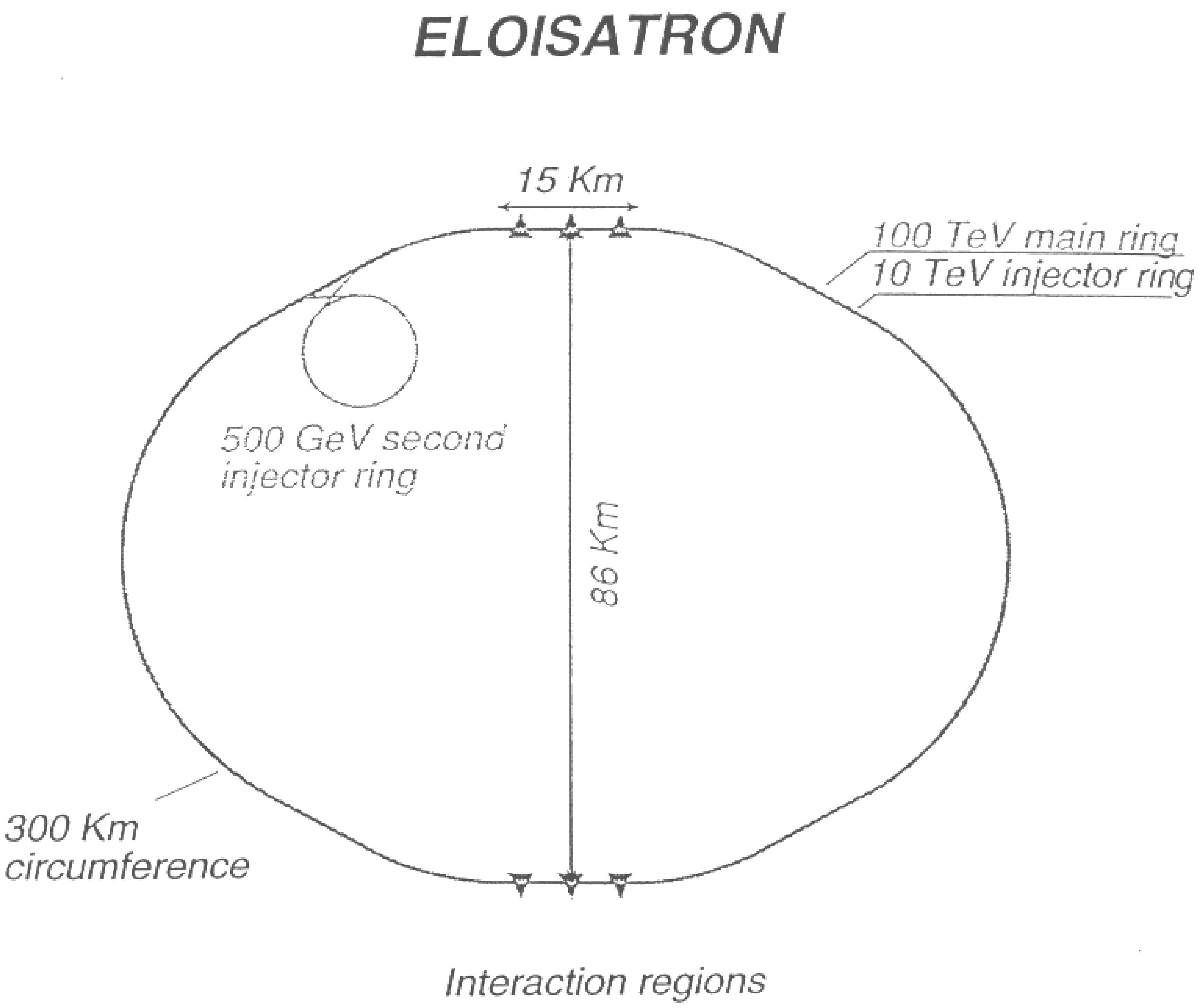


Fig. 4: ELN Collider layout.

The 100 TeV ring is working as a 10 TeV injector to the same ring. The circumference is 300 KM and the intersections are (3 + 3) on two opposite sides.

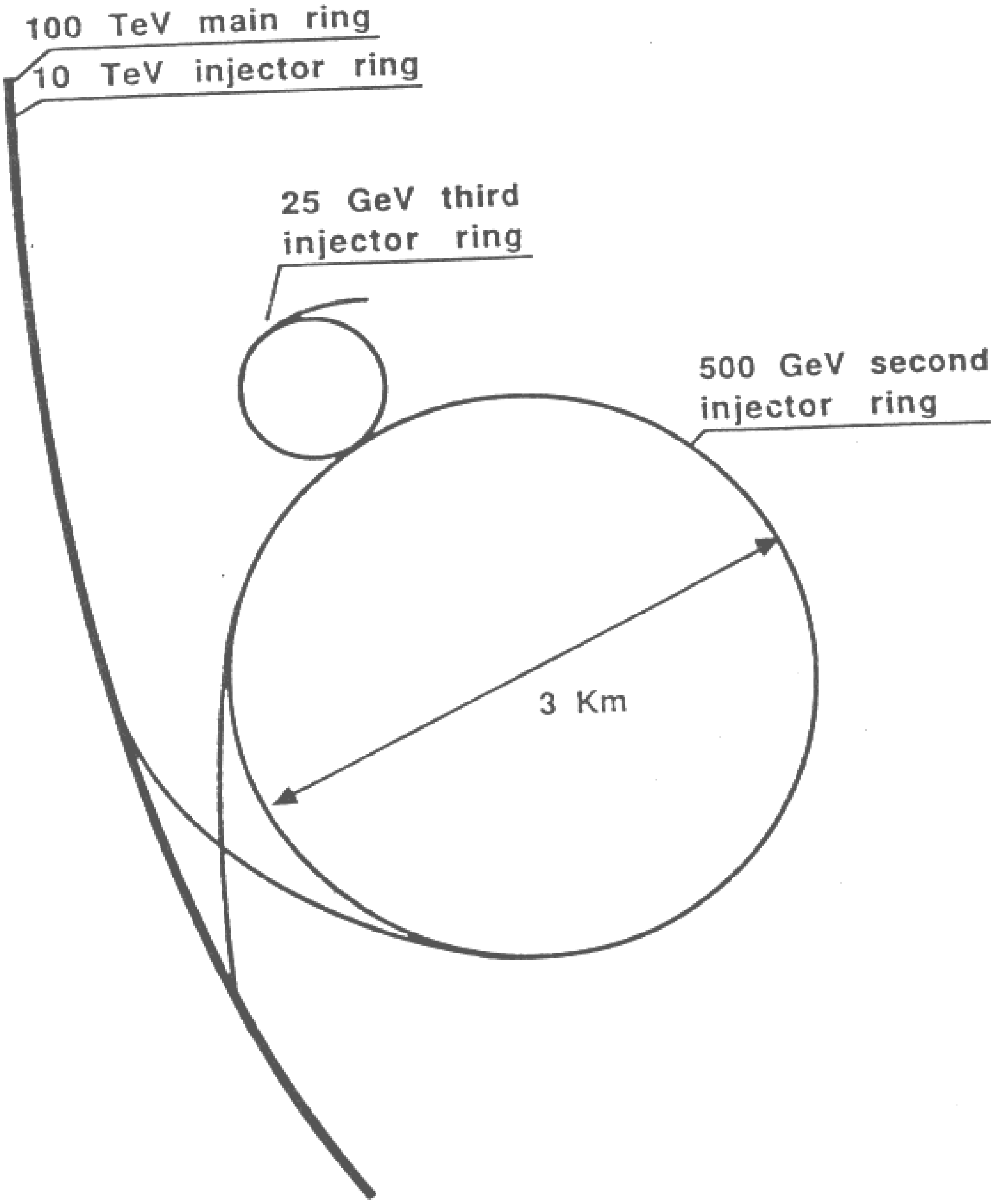


Fig. 5.6 - ELOISATRON Injection.

BASIC PARAMETERS

Energy per beam	100 TeV
Number of bunches	39600 per beam
β-value at interaction point	1.25 – 0.6 m
Normalized emittance	$0.75\pi \times 10^{-6}$ m
r.m.s. beam radius at interaction point	$1.25 - 0.9 \times 10^{-6}$ m
Circulating current	16.43 mA
Particles per bunch	2.56×10^{9}
Beam-beam tune shift per crossing (with 6 active crossings)	1.67×10^{-3}
Bunch spacing	25×10^{-9} s
Stored beam energy	1.623×10^{9} J
Luminosity ($cm^{-2}s^{-1}$)	$0.9 - 1.8 \times 10^{33}$
Energy loss per turn due to synchrotron radiation	23.34 MeV
Radiated power (per beam)	385 KW
Power per unit length of one beam	1.89 W/m
Transverse em. damping time	1.2 h

LATTICE PARAMETERS

Length of period	200 m
Phase advance per period	$\pi/3$
Betatron wavelength	1200 m
Bending angle per normal period	4.7 mrad
Number of quads per period	2
Effective length of each quad	13.6 m
Nº of quadrupoles (without insertion)	2664
Maximum dipole field	10 Tesla
Bending radius	33356 m
Number of dipoles per normal period	12
Effective dipole length	13.1 m
Nº of dipoles	15984

Fig. 3: Basic and lattice parameters of ELN.

Superconducting Dipole Magnet Studies

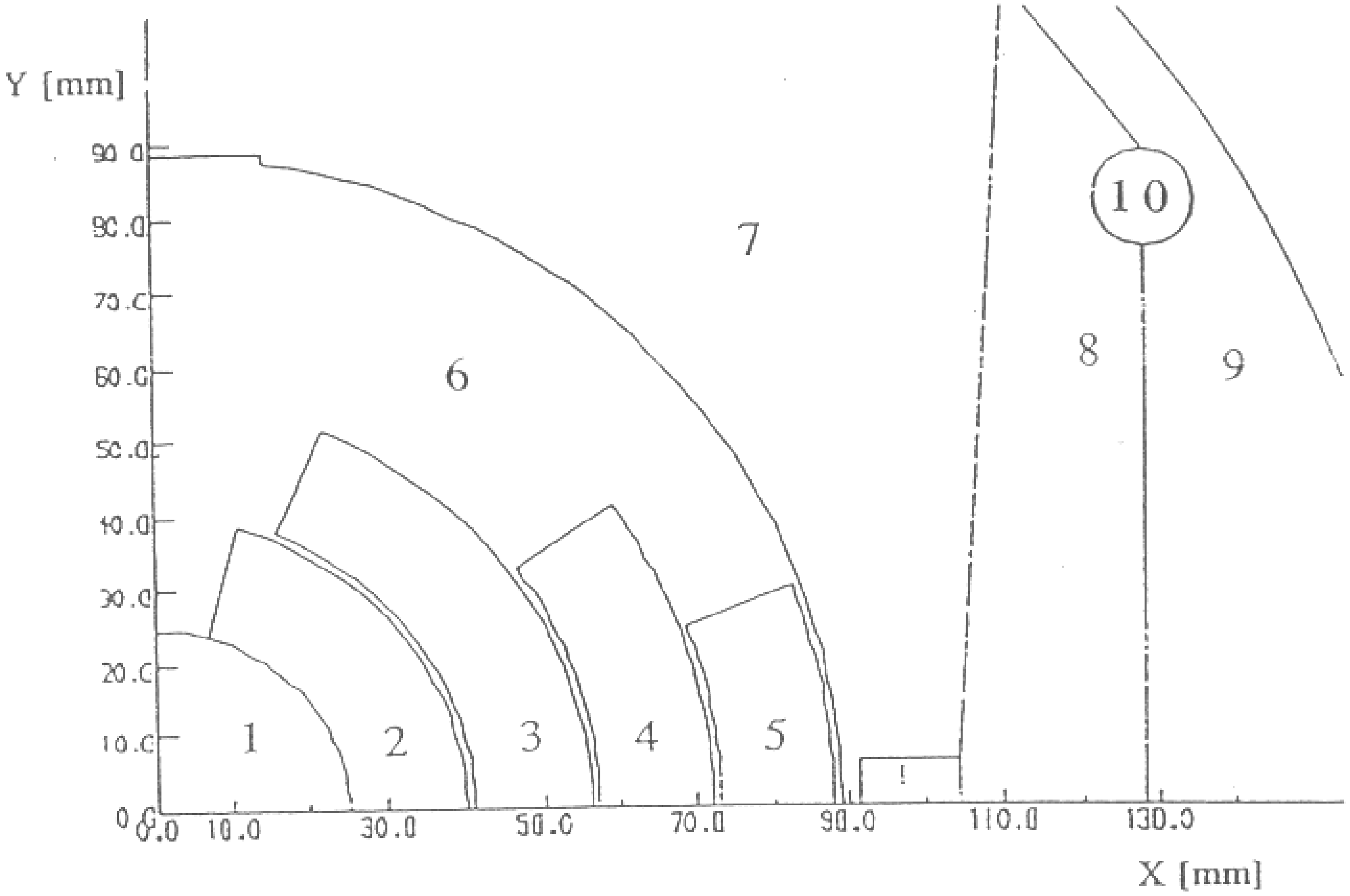
Using Nb_3Sn superconducting material and cables, it is possible to reach 13.5 T with a quite good field uniformity:

$$\boxed{(5.8 \div 13.5)\ \mathrm{T}, \quad \frac{\Delta B}{B_0} \leq 10^{-4}}$$

$$\boxed{(3 \div 5.8)\ \mathrm{T}, \quad \frac{\Delta B}{B_0} \leq (9 \div 1) \times 10^{-4}}$$

A dipole design is shown in Fig. 6 for Scheme 3 with

4–layer coils



One - quarter dipole cross - section.
Scheme (3) for field uniformity calculation.

1)	Beam Pipe
2, 3, 4, 5)	(Nb_3Sn)-Cu Superconducting Cable
6)	Aluminium Collar
7, 8, 9)	Iron Lamination
10)	Helium Channel

Fig. 6: An example of detailed dipole design.

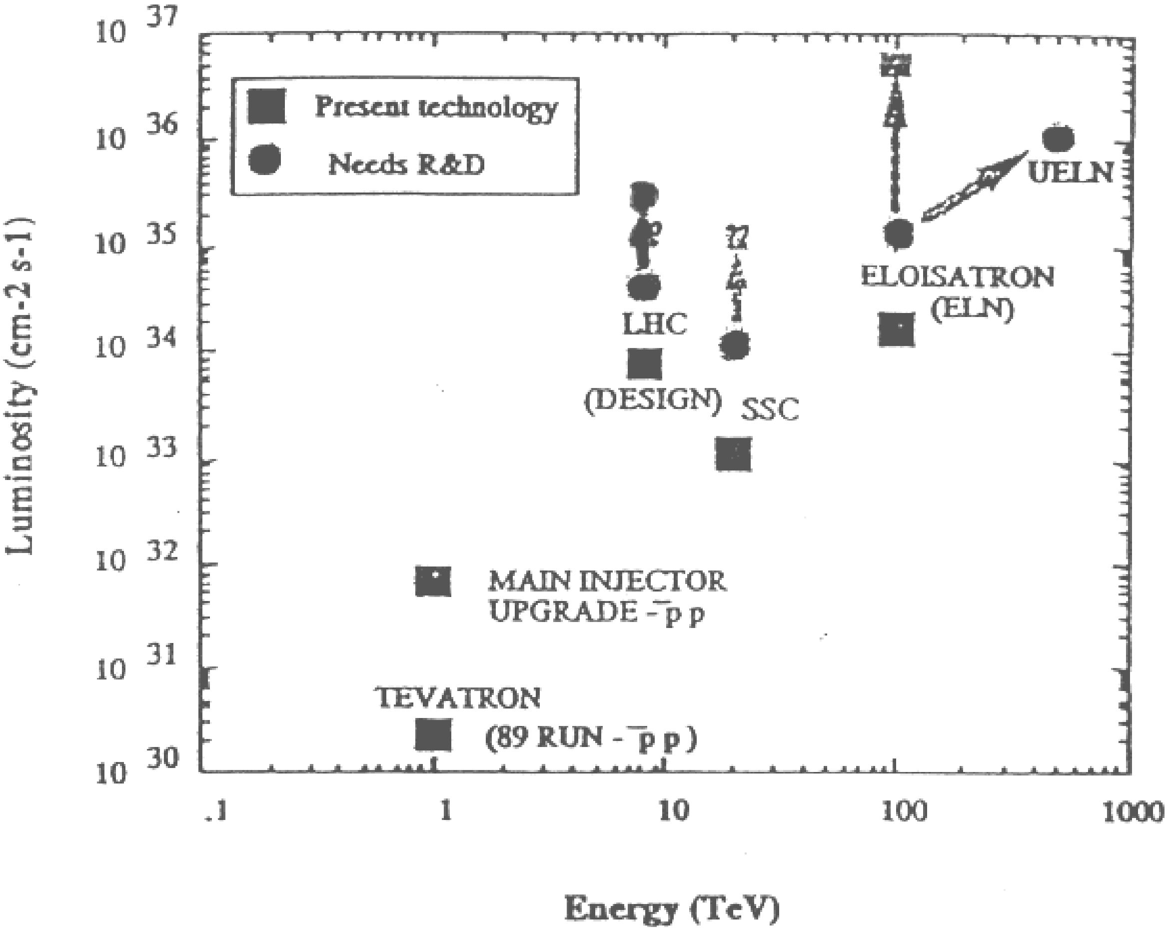


Fig. 5: The ultimate energy and luminosity of ELN, compared with all other colliders in the world.

FINAL CONCLUSION

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«*There is no*
New Physics
without
New Projects»

John S. Bell, Erice 1963

2

FACILITIES AND THE BASIC STEPS

FACILITIES

Present: GRAN SASSO - LEP - HERA - SLAC - TEVATRON - RHIC.
Future: (10%) ELN ≡ LHC → TESLA → ELN.

BASIC STEPS

Present: the Standard Model; **Future:** the open problems.

① RGEs $(\alpha_i \, (i \equiv 1, 2, 3); \; m_j \, (j \equiv q, \, l, \, G, \, H)) : \; f(k^2)$.
- GUT $\left(\alpha_{GUT} \simeq \frac{1}{24}\right)_m$ & GAP $(10^{16} - 10^{18})$ GeV.
- SUSY (to stabilize $\frac{m_F}{m_P} \simeq 10^{-17}$).
- RQST (to quantize Gravity).

② Gauge Principle (hidden dimensions).
— How a Fundamental Force is generated: SU(3); SU(2); U(1).

③ The Physics of Imaginary Masses: SSB.
— The Imaginary Mass in SU(2) × U(1) produces masses $(m_{W^\pm}; \; m_{Z^0}; \; m_q; \; m_l)$, including $m_\gamma = 0$.
— The Imaginary Mass in SU(5) ⇒ SU(3) × SU(2) × U(1) or in any – not containing U(1) – higher Symmetry Group ⇒ SU(3) × SU(2) × U(1) produces Monopoles.
— The Imaginary Mass in $SU(3)_c$ generates Confinement.

④ Flavour Mixings & CP ≠ , T ≠ .
— No need for it but it is there.

⑤ Anomalies & Instantons.
— Basic Features of all Non-Abelian Forces.

Note:
q ≡ quark and squark;
l ≡ lepton and slepton;
G ≡ Gauge boson and Gaugino;
H ≡ Higgs and Shiggs;
RGEs ≡ Renormalization Group Equations;
GUT ≡ Grand Unified Theory;
SUSY ≡ Supersymmetry;
RQST ≡ Relativistic Quantum String Theory;
SSB ≡ Spontaneous Symmetry Breaking.

m_F ≡ Fermi mass scale;
m_P ≡ Planck mass scale;
k ≡ quadrimomentum;
C ≡ Charge Conjugation;
P ≡ Parity;
T ≡ Time Reversal;
≠ ≡ Breakdown of Symmetry Operators.

The five basic steps in our understanding of nature. ① The renormalization group equations (RGEs) imply that the gauge couplings (α_i) and the masses (m_j) all run with k^2. It is this running which allows GUT, suggests SUSY and produces the need for a non point-like description (RQST) of physics processes, thus opening the way to quantize gravity. ② All forces originate in the same way: the gauge principle. ③ Imaginary masses play a central role in describing nature. ④ The mass-eigenstates are mixed when the Fermi forces come in. ⑤ The Abelian force QED has lost its role of being the guide for all fundamental forces. The non-Abelian gauge forces dominate and have features which are not present in QED.

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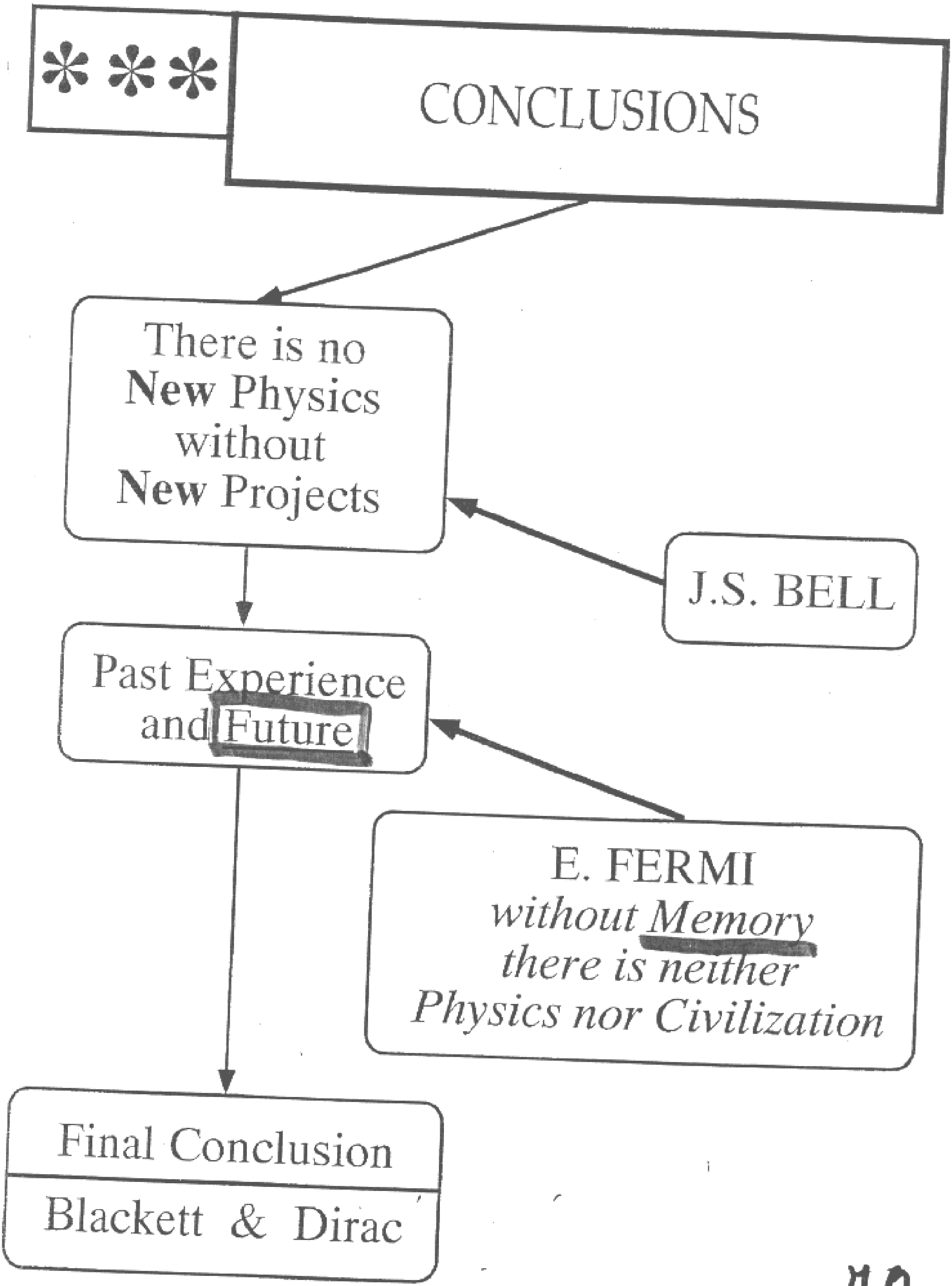
MEMORY

These past achievements in project realization are mentioned in order to corroborate my optimism and enthusiasm in encouraging new actions and new ideas for the future of Subnuclear Physics in Europe and in the world.



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CONCLUSIONS

There is no **New** Physics without **New** Projects

J.S. BELL

Past Experience and Future

E. FERMI
without Memory
there is neither
Physics nor Civilization

Final Conclusion

Blackett & Dirac

CONCLUSIONS

BLACKETT

«We experimentalists are not like theorists: the originality of an idea is not for being printed in a paper, but for being shown in the implementation of an original experiment.»

Lord Patrick Maynard Stuart Blackett, 1962

DIRAC

«To "understand" a physical problem means to be able to see the answer without solving equations».

Richard P. Feynman,
in "*The Pleasure of Finding Things out*" page 202.