PREAMBLE

FONDAZIONE ETTORE MAJORANA E CENTRO DI CULTURA SCIENTIFICA
III Conferenza dei Progetti del Centro Fermi
A 450 anni dalla nascita di Galileo Galilei, padre della Scienza moderna
PROGETTO EEE — LA SCIENZA NEL CUORE DEI GIOVANI
Erice, 14-17 Dicembre 2014

IL TRIONFO DELLA TEORIA DI MAJORANA ELABORATA NEL 1937, UN ANNO PRIMA DELLA SUA MISTERIOSA SCOMPARSA

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INFN and University of Bologna, Italy
CERN, Geneva, Switzerland
Presidente Centro di Cultura Scientifica Ettore Majorana, Erice–Geneva
World Federation of Scientists, Beijing, Geneva, Moscow, New York

Paul A.M. Dirac Lecture Hall – Patrick M.S. Blackett Institute
Erice, 15 Dicembre 2014

La scoperta
della particella di Majorana
nella Superconduttività
ha richiamato l'attenzione
sulla esistenza
dei fermioni di Majorana.

Sono fermioni
tutte le particelle elementari
dotate di “moto a trottola”
(spin) dato da un multiplo
dispari (3, 5, 7, 9, 11, ...)
della quantità minima che è
(½) nelle unità dette di Planck.

La particella di Majorana
ha il valore minimo di spin.
È questa particella
che è entrata nella
fisica della
Superconduttività.

Quando il valore dello spin
è più grande del minimo il termine
è fermione di Majorana,
se la particella
è identica all'antiparticella.
Esistono infatti fermioni
che non hanno le proprietà
ipotizzate da Majorana.

Il primo fermione di Majorana
con spin eguale a (3/2)
è il “gravitino”.
Questa particella
è necessaria per spiegare
come mai il Sole
può brillare per miliardi di anni
senza saltare in aria.

Infatti nella
teoria gravitazionale di Einstein
(senza gravitini)
l'interazione tra luce e gravità
diverge matematicamente.
Il che corrisponde a dire che,
se fosse realmente così,
il Sole avrebbe dovuto esplodere
quando si è formato e noi non
potremmo essere qui a parlarne.

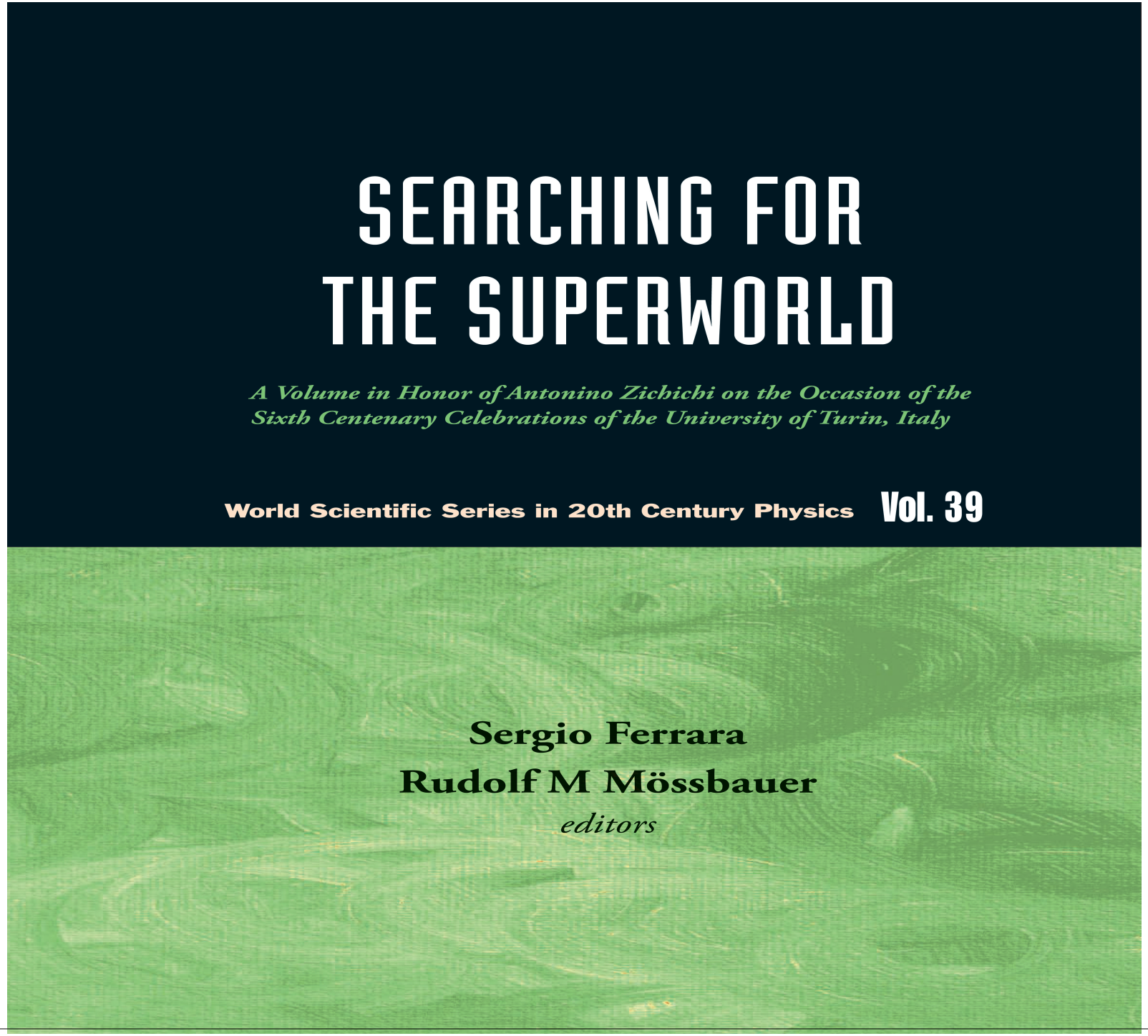
Lo spin del gravitino
è tre volte superiore al minimo.
L'esistenza teorica del gravitino
è stata scoperta nello studio delle
interazioni tra forze gravitazionali
(quelle che fanno cadere le pietre e ci
tengono legati al suolo)
e forze elettromagnetiche
(quelle che producono la luce e le altre
onde elettromagnetiche tra cui, radio,
TV, forni a microonde, raggi X ecc…).

La necessità di introdurre il gravitino è stata teoricamente scoperta da cinque famosi fisici teorici, grandi estimatori di **Ettore Majorana** [1].

[1] D.Z. Freedman, P. van Nieuwenhuizen and S. Ferrara, "*Progress Toward a Theory of Supergravity*", Phys. Rev. D13, 3214 (1976); S. Deser and B. Zumino, "*Consistent Supergravity*", Phys. Lett. B62, 335 (1976).

PER CAPIRE COME MAI
IL SOLE BRILLA SENZA
ESPLODERE
È NECESSARIA L'ESISTENZA
DEL GRAVITINO
CHE È UN
FERMIONE DI MAJORANA

Le gardien de la Supergravité


SEARCHING FOR
THE SUPERWORLD
A Volume in Honor of Antonino Zichichi on the Occasion of the
Sixth Centenary Celebrations of the University of Turin, Italy
World Scientific Series in 20th Century Physics
Vol. 39
Sergio Ferrara
Rudolf M Mössbauer
editors

«ETTORE MAJORANA» FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE
TO PAY A PERMANENT TRIBUTE TO ARCHIMEDES AND GALILEO GALILEI, FOUNDERS OF MODERN SCIENCE AND TO ENRICO FERMI, THE "ITALIAN NAVIGATOR", FATHER OF THE WEAK FORCES
INTERNATIONAL SCHOOL OF SUBNUCLEAR PHYSICS
THE FUTURE OF OUR PHYSICS INCLUDING NEW FRONTIERS
53rd Course – ERICE-SICILY: 24 JUNE – 3 JULY 2015

OPENING SESSION

THE FUTURE OF OUR PHYSICS

ANTONINO ZICHICHI
University of Bologna and INFN, Italy
CERN, Geneva, Switzerland
Enrico Fermi Centre, Rome, Italy
Pontifical Academy of Sciences, Vatican City
World Federation of Scientists, Beijing, Geneva, Moscow, New York
Ettore Majorana Foundation and Centre for Scientific Culture, Erice, Italy

Thursday, 25 June 2015
Paul A.M. Dirac Lecture Hall – Patrick M.S. Blackett Institute

THE FUTURE OF OUR PHYSICS

I Physics Problems

II The Whole of our Knowledge

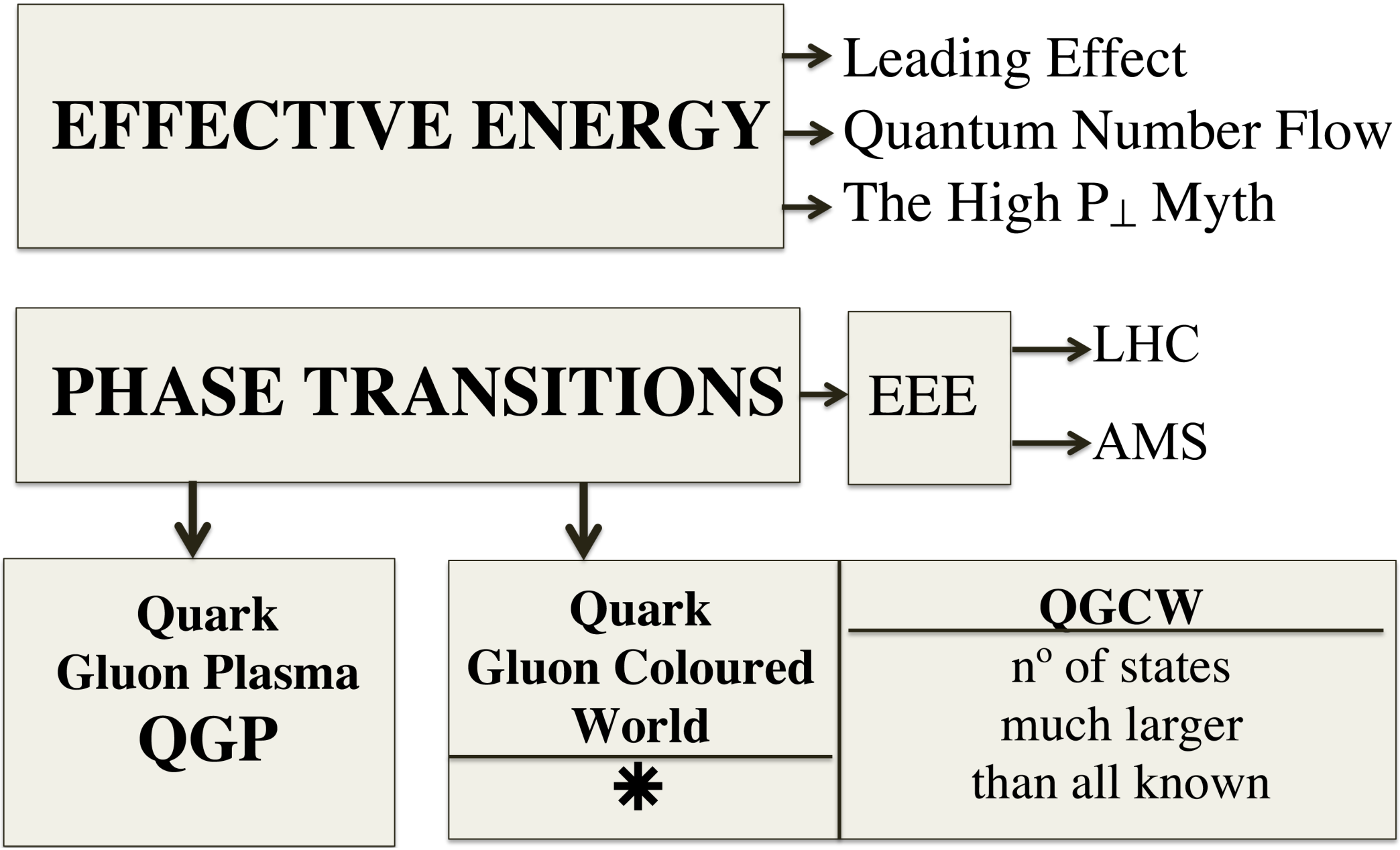
III The Future

Appendices

- **A** Dirac – Antiparticles & Antimatter
- **B** Blackett – The discovery of the "Vacuum Polarization" (1932) [the 1st example of radiative effect: pre-the Lamb-shift (1947)]
- **C** The New Manhattan Project

I

PHYSICS PROBLEMS


EFFECTIVE ENERGY
Leading Effect
Quantum Number Flow
The High P⊥ Myth
PHASE TRANSITIONS
EEE
LHC
AMS
Quark
Gluon Plasma
QGP
Quark
Gluon Coloured
World
*
QGCW
n° of states
much larger
than all known

EFFECTIVE ENERGY

- Leading Effect
- Quantum Number Flow
- The High $P_{\perp}$ Myth

The **"Effective Energy"**

EVIDENCE OF THE SAME MULTIPARTICLE PRODUCTION MECHANISM IN p-p COLLISIONS AS IN e^+e^- ANNIHILATION

M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Alì, P. Di Cesare, B. Esposito, P. Giusti, T. Massam, F. Palmonari, G. Sartorelli, G. Valenti and A. Zichichi

Physics Letters 92B, 367 (1980).

"*The agreement between the momentum distributions obtained in e^+e^- annihilation and in pp collisions suggests that the mechanism for transforming energy into particles in these two processes, so far considered very different, must be the same*".

The physics of strong interactions was characterized by two classes of phenomena, one of "**static**" nature, the other of "**dynamic**" nature.

Both were affected by proliferation in the most fundamental component of this physics: its elementary particles.

The proliferation in the "**static**" **sector** of the strong interaction was the huge number of mesons and baryons [1].

This multitude of states was reduced by an order of magnitude through the octets and decuplets of Gell-Mann and Ne'eman $SU(3)_f$ [2].

The proliferation in the "dynamic" sector was the multitude of final states produced by pairs of interacting particles, in strong, electromagnetic and weak processes:

Strong	EM	Weak
$\pi\ p$	$\gamma\ p$	$\nu\ p$
$K\ p$	$e\ p$	
$p\ p$	$\mu\ p$	
$p\ n$	e^+e^-	
$\bar{p}\ p$		

It is the introduction of the Effective Energy which allowed one to put all the different final states on the same basis.

This basis is the quantities measured in the multihadronic final states:

i) the average charged multiplicity; $< n_{ch} >$;

ii) the fractional energy distribution; ds / dx_i ;

iii) the transverse momentum distribution ds / dp_{t_i} ; etc. .... .

The results are the universality features measured in all multihadronic final states, no matter what is the pair of interacting particles in the initial state.

The universality features are a QCD **non-perturbative effect**.

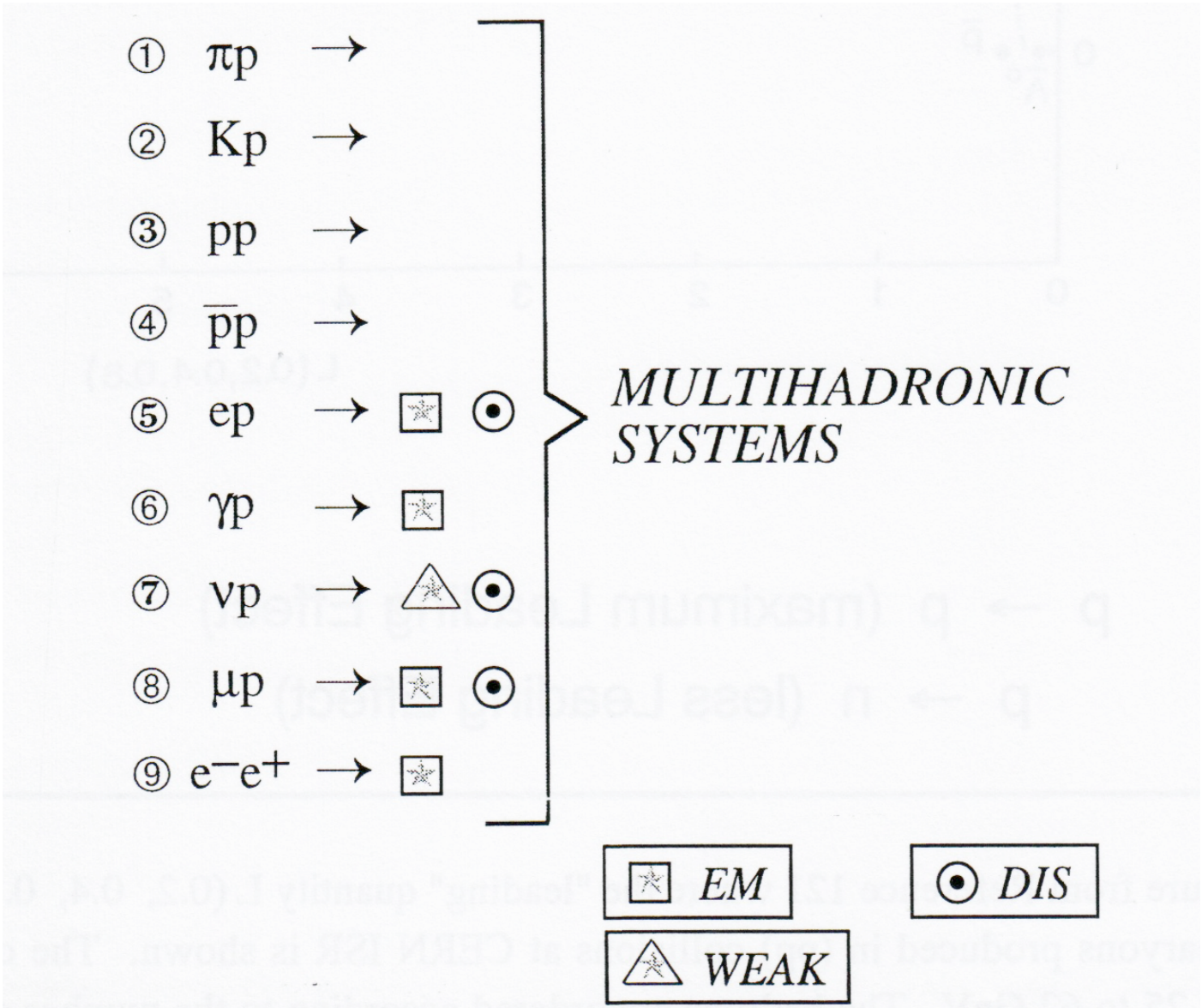
Systematic study of the Leading Effect in
***Strong EM Weak* INTERACTIONS**

THE "LEADING"-BARYON EFFECT IN STRONG, WEAK, AND ELECTROMAGNETIC INTERACTIONS

M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Alì, P. Di Cesare, B. Esposito, P. Giusti, T. Massam, R. Nania, F. Palmonari, V. Rossi, G. Sartorelli, M. Spinetti, G. Susinno, G. Valenti, L. Votano and A. Zichichi.

Lettere al Nuovo Cimento 32, 321 (1981).

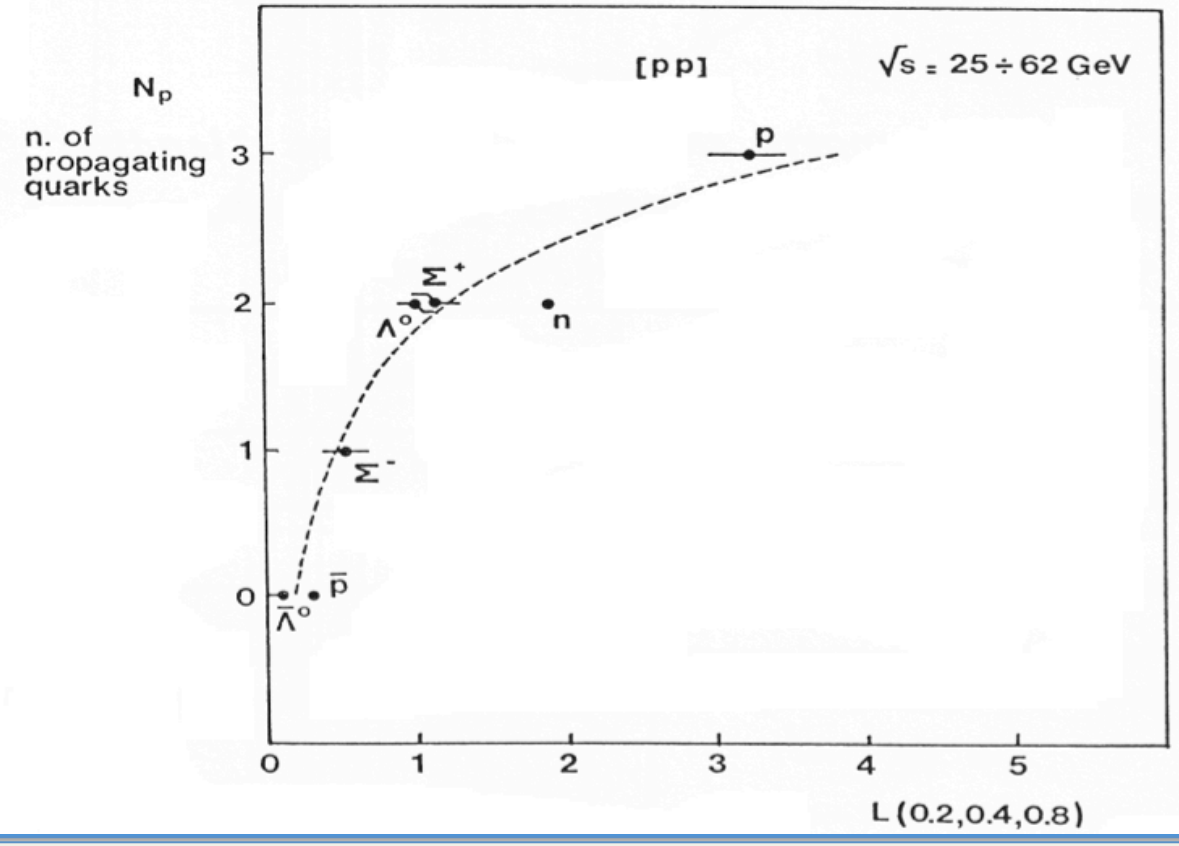
*"This supports the idea that the "leading" phenomenon is generated by the quantum number «**flow**» from the initial to the final state".*


① πp →
② Kp →
③ pp →
④ p̄p →
⑤ ep →
⑥ γp →
⑦ νp →
⑧ μp →
⑨ e⁻e⁺ →
MULTIHADRONIC SYSTEMS
EM
DIS
WEAK

Flow of Quantum Numbers in (pp) **Strong Interactions**

In fig. 1 we have plotted the values of L derived from the experimental x distributions of the different hadrons in the reactions (4*a*) to (4*g*). The final states are ordered according to the number of quarks propagating from the initial state (the proton) to the final state.

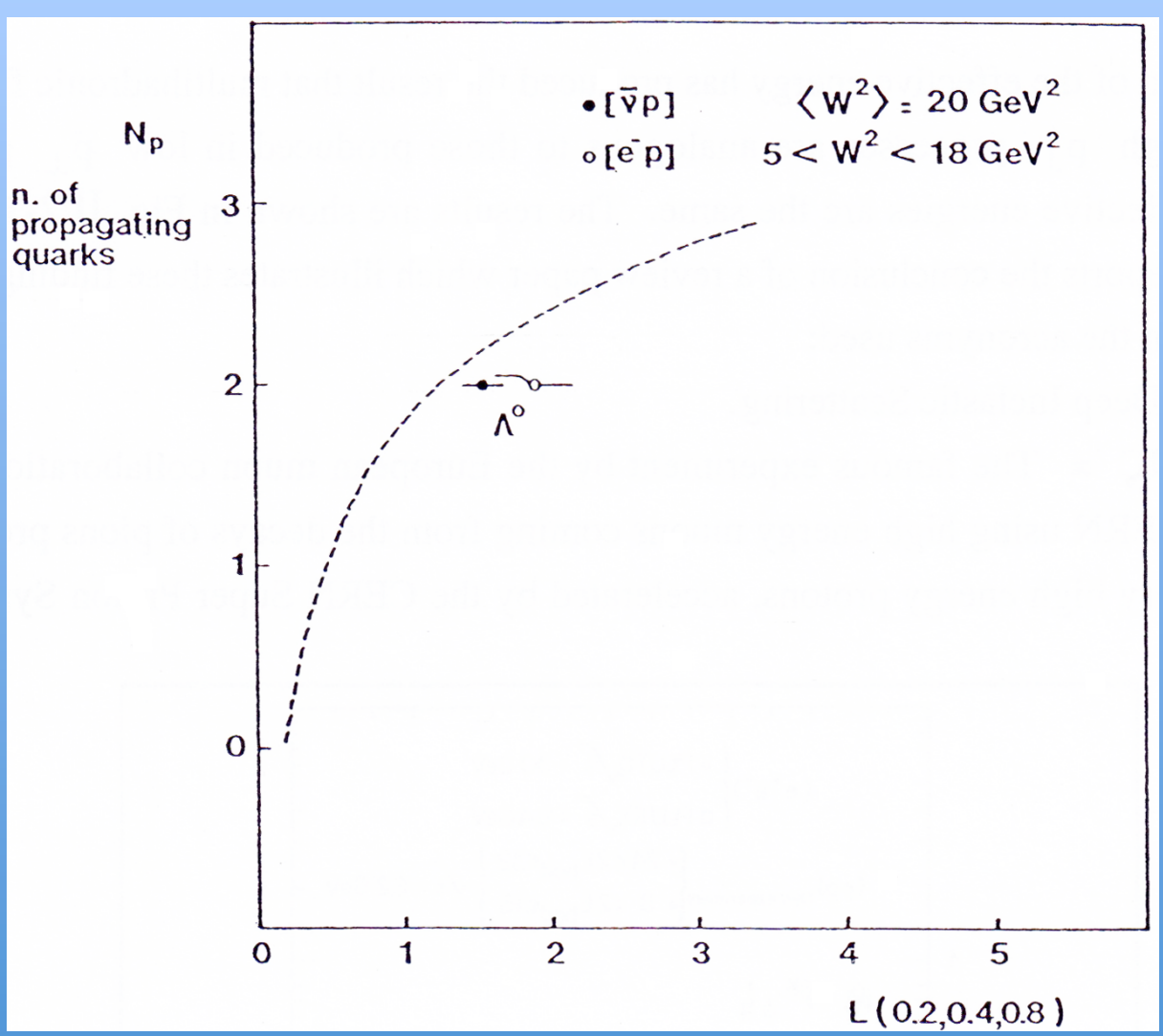
The results of fig. 1 show that for different hadrons the value of L is the same, provided the number of propagating quarks is the same



p → p (maximum Leading Effect)
p → n (less Leading Effect)

Figure 1: Figure from Reference 3 where the "leading" quantity L (0.2, 0.4, 0.8) derived for different types of baryons produced in (pp) collisions at CERN ISR is shown. The centre-of-mass energy ranges from 25 to 62 GeV. The hadrons are ordered according to the number of propagating quarks. The dotted curve superimposed is obtained by using a parametrization of the single-particle inclusive cross-section, $F(x) = (1 - x)^{\alpha}$, as described in section 3.

Flow of Quantum Numbers in **Electromagnetic** and **Weak Interactions**



– The «leading» quantity $L(0.2, 0.4, 0.8)$ of the Λ^0 produced in ($\bar{\nu}$p) interactions at $\langle W^2 \rangle = 20$ (GeV)² and in (e⁻p) interactions with $5 < W^2 < 18$ (GeV)². In this case the number of propagating quarks is two. The dashed curve of fig. 1 is also shown to guide the eye.

Figure 2: Reproduction of a Figure from Reference 3 where the "quantum number flow" from the initial to the final state is observed in an electromagnetic process ($e^- p \rightarrow \Lambda^0 x$) and in a weak process ($\bar{\nu} p \rightarrow \Lambda^0 x$).

It should be noticed, as discussed in ref. (1), that for Λ^0 production the energy dependence of L shows the same features as those observed for proton production. In fact, the three values of L obtained for the Λ^0 at ISR, at Fermilab, and at Cornell energies, suggest the following trend: the higher is the available energy, the lower is the value of L.

All the above results thus point out that it does not matter whether the hadron interacts strongly, weakly, or electromagnetically: its «leading» effect is always present.

5. *Conclusions.* – In baryon-baryon interactions, the «leading»-baryon effect shows up very clearly in the x range $(0.2 \div 0.8)$. This «leading» effect is maximum when the final-state hadron is the same as the initial-state hadron. However, the «leading» effect is present even when the initial-state quantum numbers differ from those of the final state (for instance, when a proton becomes a Λ^0). As the difference between the initial- and the final-state quark composition increases, the «leading» effect decreases. This supports the idea that the «leading» phenomenon is generated by the quantum number «flow» from the initial to the final state.

The «leading» baryon effect appears both in baryon-baryon and in lepton-baryon interactions. This means that a definite similarity must exist between processes in which a hadron is present in the initial state, no matter if the interaction is strong, weak or electromagnetic.

M. BASILE, *et al.*
14 Novembre 1981
Lettere al Nuovo Cimento
Serie 2, Vol. 32, pag. 321-326

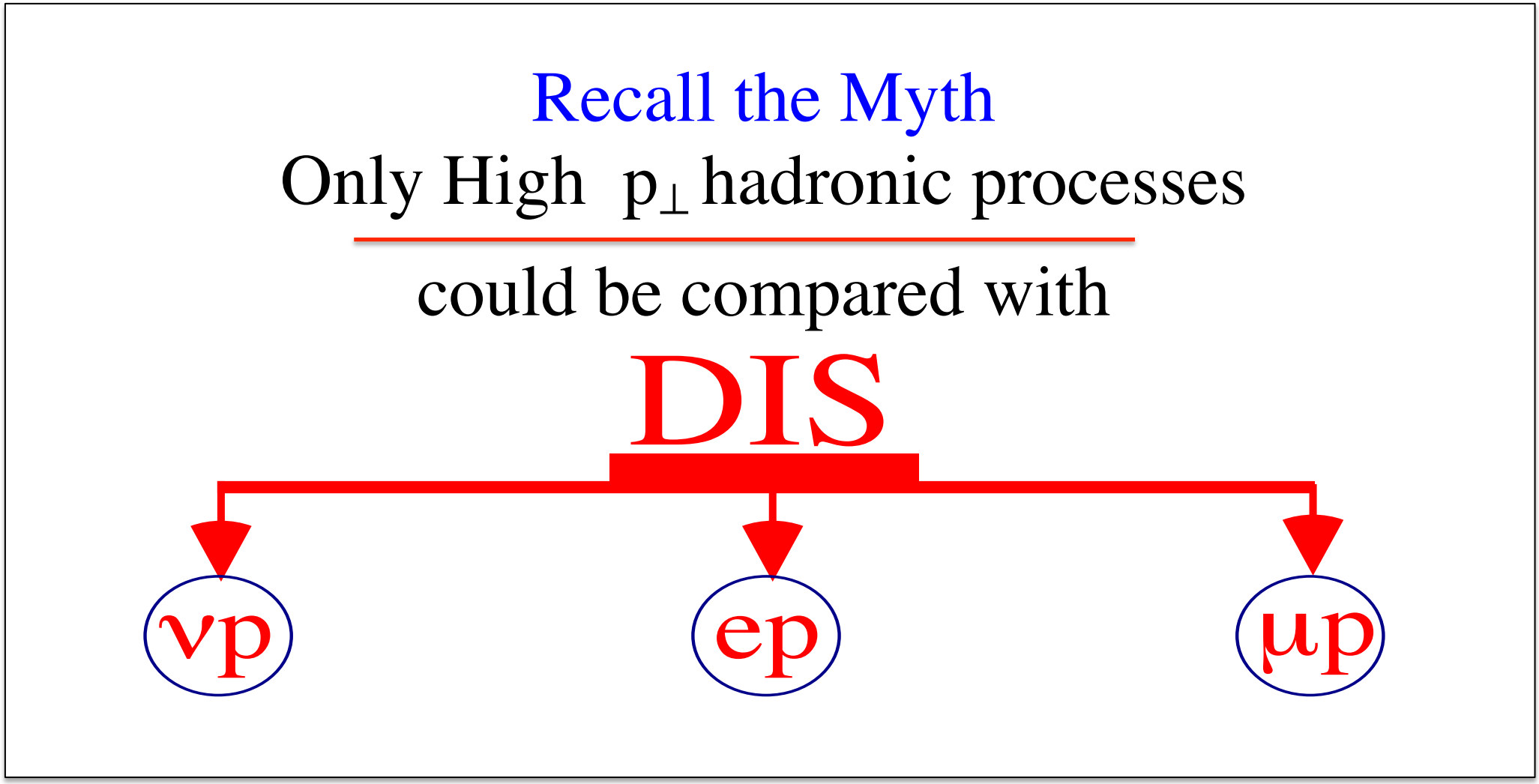


Figure 3: A synthesis of the high transverse momentum myth.

The introduction of the Effective Energy has produced the result that multihadronic final states produced in high $p_\perp$ processes are analogous to those produced in low $p_\perp$ processes, provided the Effective Energies are the same.

THE END OF A MYTH: HIGH-P_T PHYSICS

"So far, the main picture of hadronic physics has been based on a distinction between high$-p_T$ and low$-p_T$ phenomena.

In the framework of parton model, high$-p_T$ processes were the only candidates to establish a link between

- *purely hadronic processes*
- *(e^+e^-) annihilations*
- *(DIS) processes.*

The advent of QCD has emphasized in a dramatic way the privileged role of high$-p_T$ physics due to the fact that, thanks to asymptotic freedom, QCD calculations via perturbative methods can be attempted at high$-p_T$ and results successfully compared with experimental data [1]. The conclusion was: we can forget about everything else and limit ourselves to high$-p_T$ physics.

Being theoretically off limits, low$-p_T$ phenomena, which represent the overwhelming majority of hadronic processes (more than 99% of physics is here), have been up to now neglected. By subtracting the leading proton effects in order to derive the effective energy available for particle production and by using the correct variables, the BCF collaboration has performed a systematic study of the final states produced in low$-p_T$ (pp) interactions at the ISR and has compared the results with those obtained in the processes listed below:

Process		Data Sources
(e^+e^-)		SLAC, DORIS, PETRA
(DIS)		SPS/EMC
(pp)	Transverse physics	ISR (AFS)
$(\bar{p}p)$		SPS Collider (UA1)
(e^+e^-)		PETRA/TASSO (leading subtraction)

The results of this study [2-18] show that, once a common basis for comparison is found by the use of the correct variables, remarkable analogies are observed in processes so far considered basically different like

- *low$-p_T$ (pp) interactions*
- *(e^+e^-) annihilations*
- *(DIS) processes*
- *high$-p_T$ (pp) and $(\bar{p}p)$ interactions*

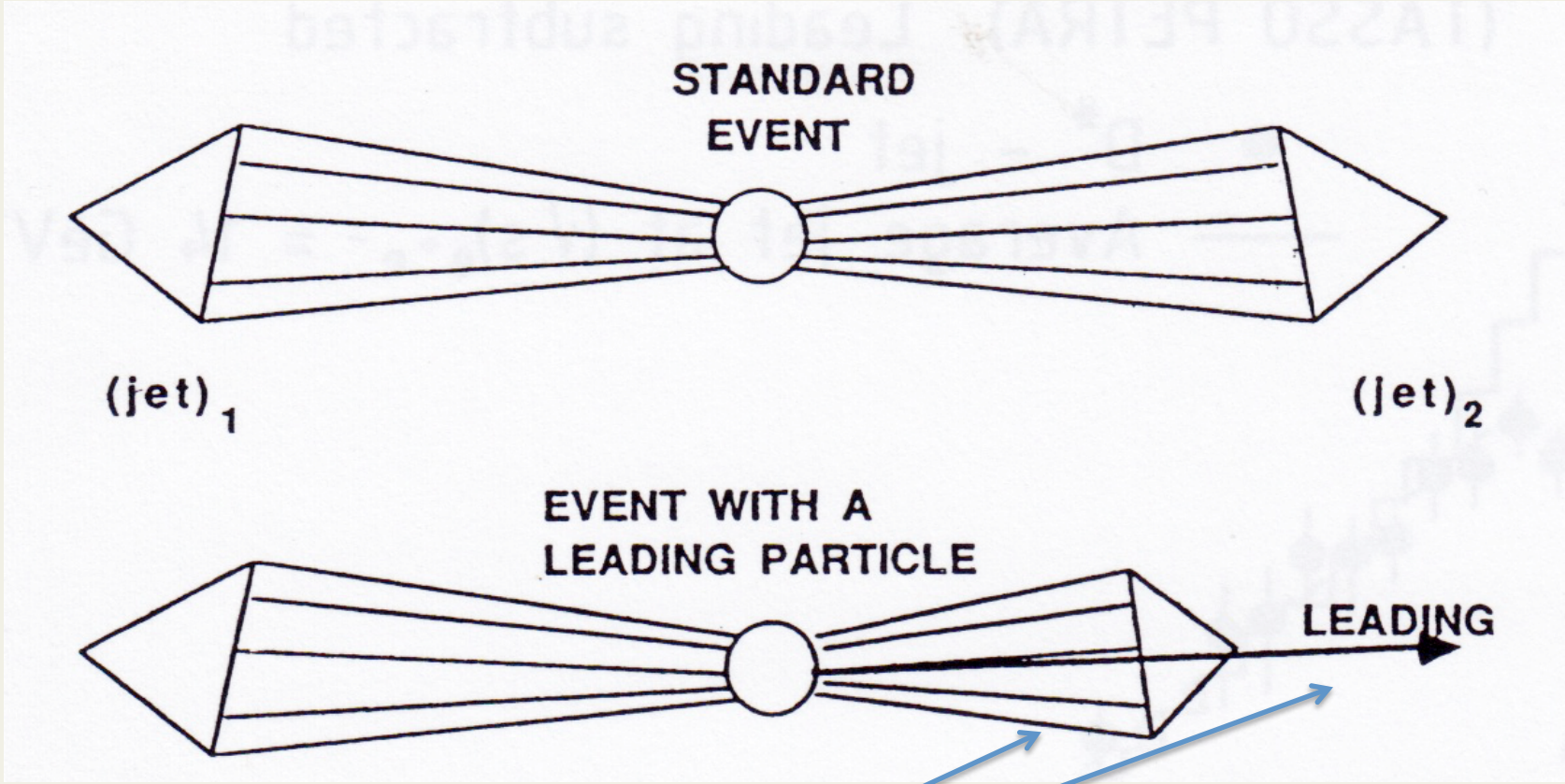
This is how universality features emerge, and this is the basis to proceed for a meaningful comparison, i.e.:

first identify the correct variables to establish a common basis,

then proceed to a detailed comparison."*

* *The root of this new approach to the study of hadronic interactions goes back a long time to a proposal by the CERN-Bologna group: "Study of deep inelastic high momentum transfer hadronic collisions" PMI/com-69/35, 8 July 1969."*

Figure 3: Reproduction of the conclusions of a review paper [4].



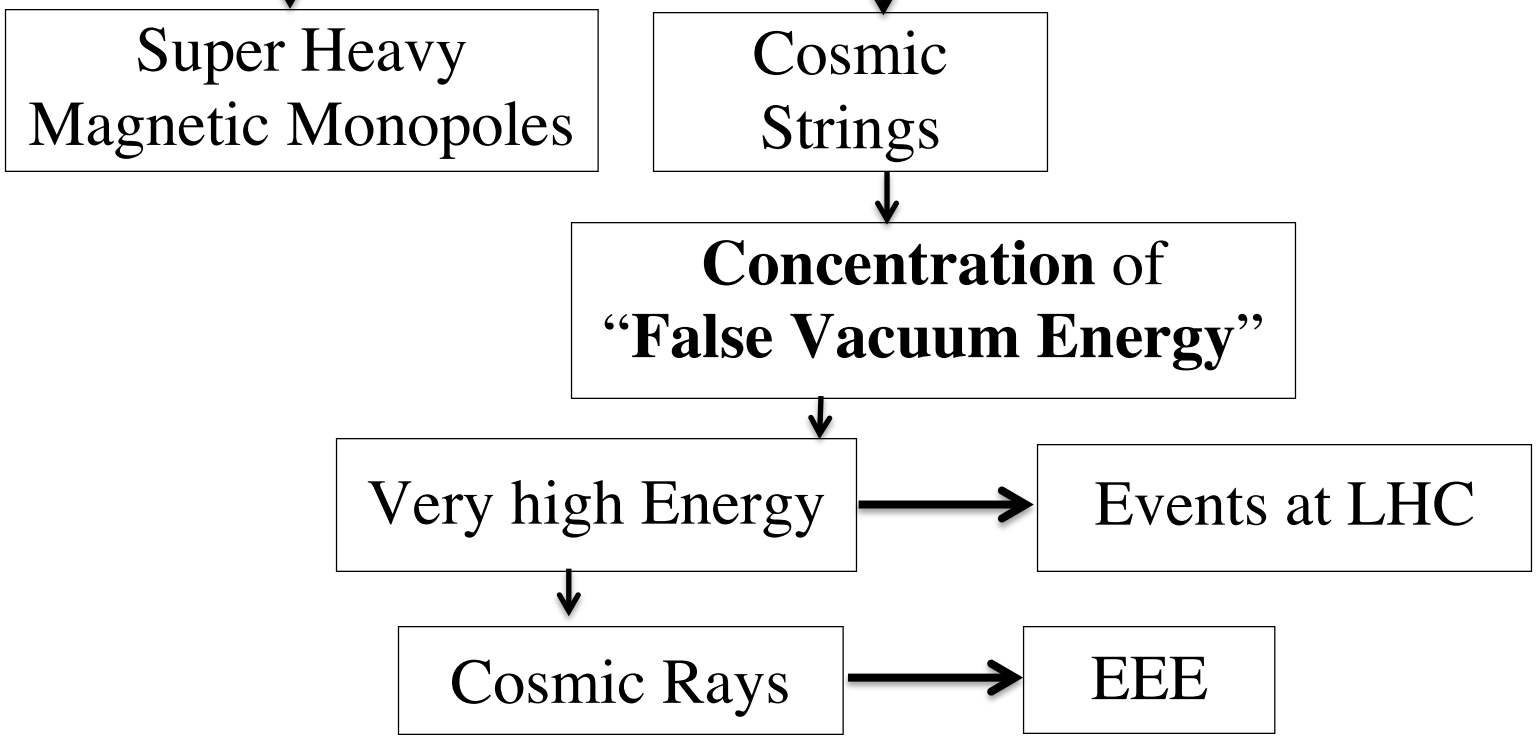
If the leading particle is not detected the Effective Energy can be deduced from all other particles detected.

PHASE TRANSITION

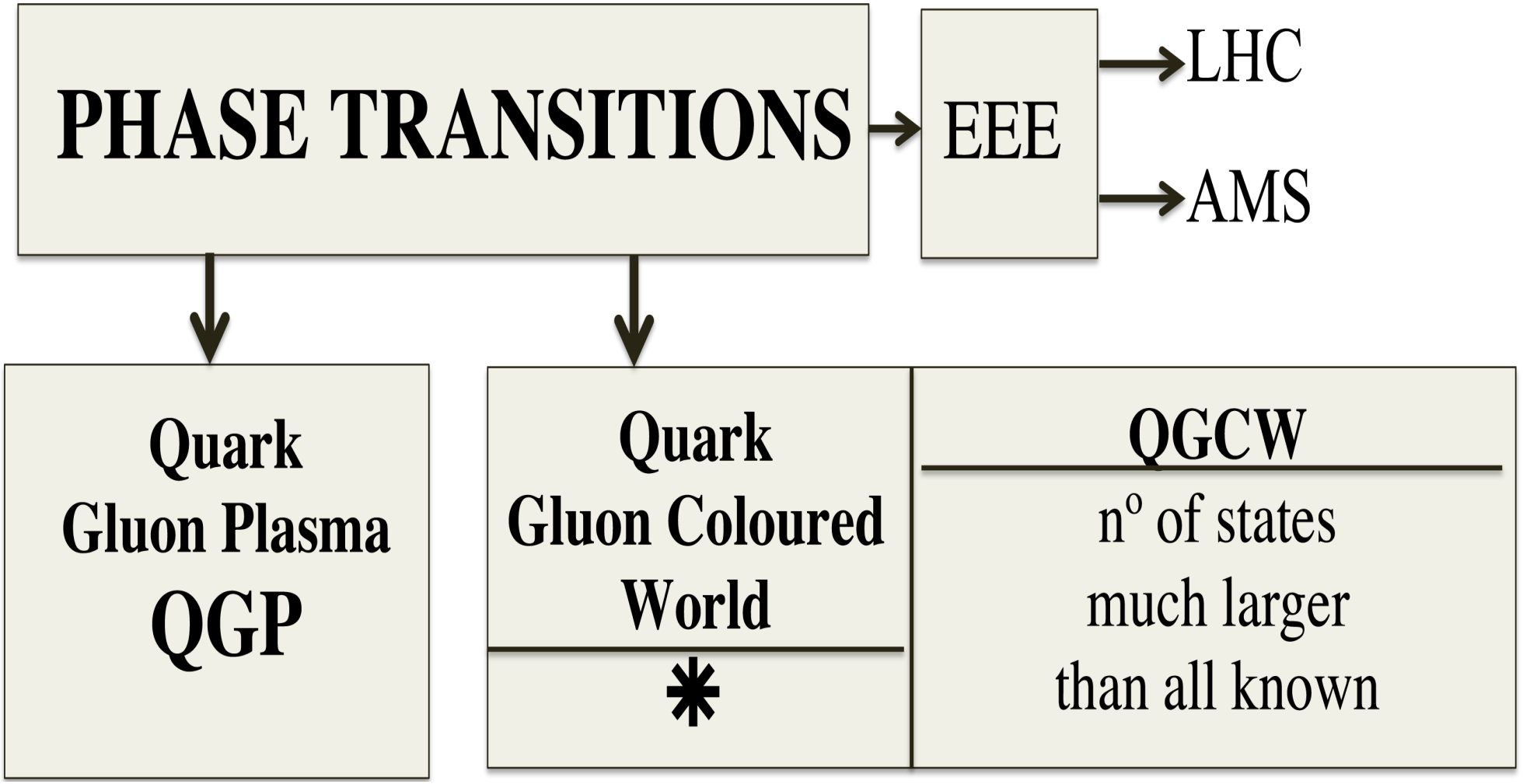
- If **smooth** and **uniform** nothing happens

PHASE TRANSITIONS

• If not then • "**Topological defects**" may have been formed



Time, t(sec)	**Energy** E(GeV)	**and Phase Transition** Phase Transition
10^{-44}	10^{18}	Planck epoch ≡ Quantum Gravity ≡ Supergravity Superstring
10^{-35}	10^{16}	GUT
10^{-10}	10^{2}	Weak Symmetry Breaking ≡ Fermi epoch
10^{-5}	10^{-1}	Confinement Transition
$1\text{-}10^{2}$	$10^{-3}\text{-}10^{-2}$	Nucleo-Synthesis
10^{12}	10^{-9}	Recombination/Galaxy Formation
10^{17}	10^{-13}	Today


PHASE TRANSITIONS
EEE
LHC
AMS
Quark
Gluon Plasma
QGP
Quark
Gluon Coloured
World
*
QGCW
nº of states
much larger
than all known

1st problem – In the QGCW there are all states allowed by the $SU(3)_c$ colour group. The number of possible states is by far more numerous than the number of colourless baryons and mesons, which have so far been built in all Labs, since the colourless condition is not needed. What are the consequences on the properties of the QGCW?

2nd problem – Light quarks versus heavy quarks. Are the **coloured quark masses the same** as the values we derive from the fact that baryons and mesons need to be in a **colourless state**? It could be that all six quark flavours are associated with nearly 'mass-less' states like those of the 1st family (u, d). In other words the reason why the 'top' quark appears to be so heavy ($\simeq 10^2$ GeV) could be due to the fact that it must satisfy some, **so far unknown**, condition related to the fact that the final state **must be QCD-'colourless'**. We know that confinement produces masses of the order of a GeV.

Therefore, according to our present understanding, **the QCD 'colourless' condition could not explain the heavy quark mass**, **but** since the origin of the quark masses is still not known, it cannot be excluded that in a QCD coloured world, the six quarks are **all nearly mass-less**. If this was the case, the masses we measure are heavier than the effective coloured quark masses. In this case all possible states generated by 'heavy' quarks would be produced in the **QGCW at much less temperature than** the one needed in our world made with baryons and mesons, **i.e. QCD colourless states**.

Here again we should try to see if with masses totally different from those expected, on the basis of what we know about colourless baryons and mesons, new **effects** could be detected due to the existence of all six flavours at relatively low temperature in the QGCW world.

3rd problem – We need to search for effects on the thermodynamic properties of the QGCW. Are these properties going to be along the 'extensivity' and / or 'non-extensivity' conditions?

(Murray Gell-Mann and Constantino Tsallis)

4th problem – We need to d**erive the equivalent** Stefan-Boltzmann Radiation Law for the QGCW. The relation between **energy density** at emission **U** and **Temperature T** of the source is

$$U = c \cdot T^4$$

in classical Thermodynamics.

In the QGCW the correspondence should be

$U \equiv p_\perp$ (transverse momentum)

$T \equiv$ average energy $\langle E \rangle$ in the CM system.

In the QGCW the production of 'heavy' flavours should be studied versus $\langle p_\perp \rangle$ and versus $\langle E \rangle$. The expectation is

$$\langle p_\perp \rangle \equiv C \cdot \langle E \rangle^4$$

and any deviation would be extremely important.

At extreme energies we do not know how many phase transitions can be involved. The higher the energy, the more complex is the interacting system of particles and more phase transitions can be involved.

There are **two sources** of unknown "phase transitions":

1) Those taking place at **CERN** (at LHC energy and its upgrading stages);
2) Those taking place in the **Universe**.

Both sources have in common a possible “signature”:

Extreme Energy Events (EEE).

In fact the evolution of the Universe has gone through a series of phase transitions whose last step was at the Fermi Energy when

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

generated QED and QFD.

This is
the low energy level.

At the other extreme,
there is E_{GUT} $(\simeq 10^{16}\ \mathrm{GeV})$
where the three gauge couplings
$(\alpha_1\ \alpha_2\ \alpha_3)$ converge,
and E_{SU} $(\simeq 10^{18}\ \mathrm{GeV})$
the energy level where RQST
(Relativistic Quantum String Theory)
puts the origin of
the gravitational force.

The **GAP** between

E_{GUT} and E_{SU}

could indeed be another source of phase transitions.

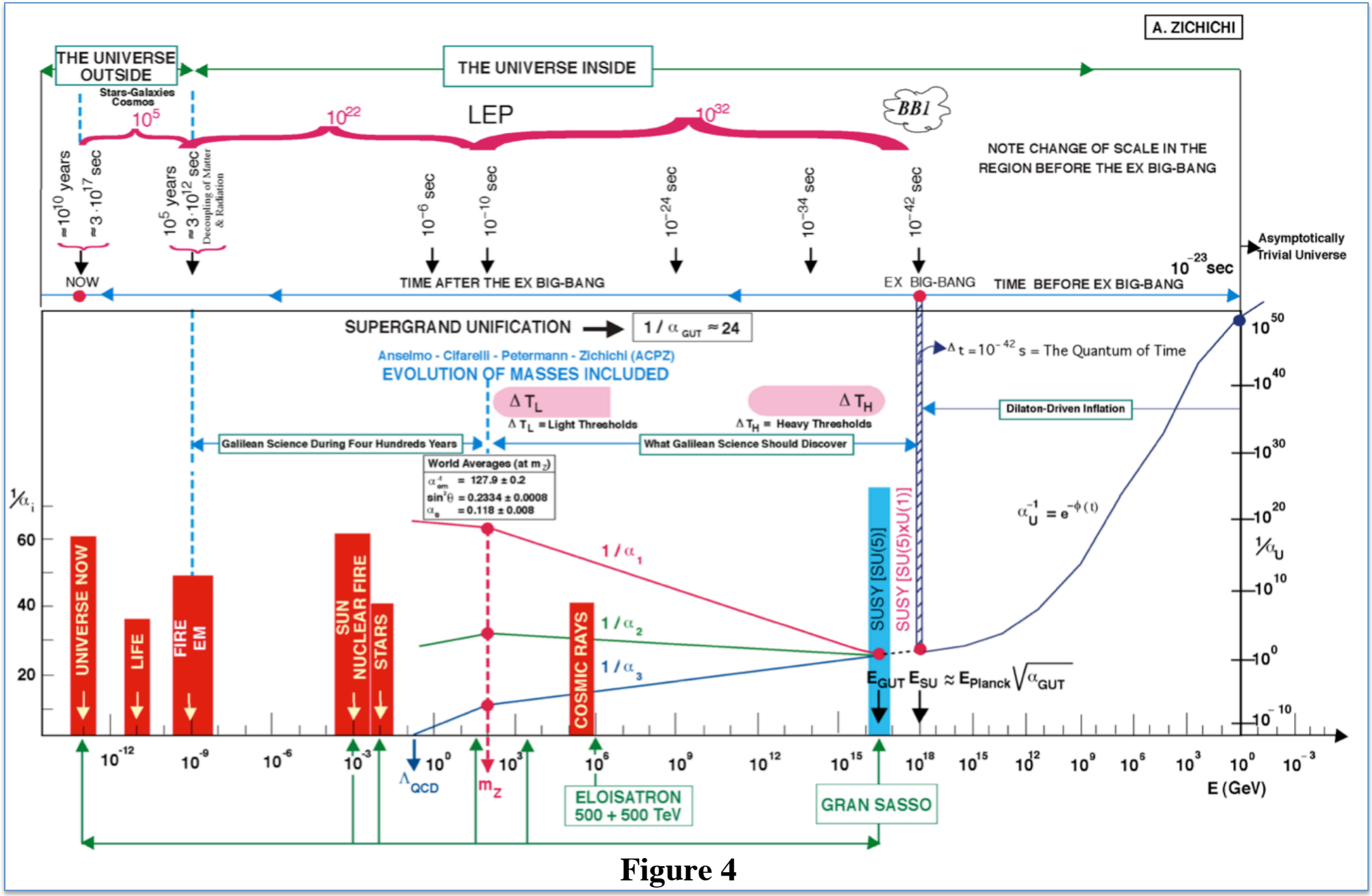

A. ZICHICHI
THE UNIVERSE OUTSIDE
THE UNIVERSE INSIDE
Stars-Galaxies Cosmos
LEP
BB1
NOTE CHANGE OF SCALE IN THE REGION BEFORE THE EX BIG-BANG
NOW
TIME AFTER THE EX BIG-BANG
EX BIG-BANG
TIME BEFORE EX BIG-BANG
Asymptotically Trivial Universe
SUPERGRAND UNIFICATION
Anselmo - Cifarelli - Petermann - Zichichi (ACPZ)
EVOLUTION OF MASSES INCLUDED
Galilean Science During Four Hundreds Years
What Galilean Science Should Discover
World Averages (at m_Z)
Dilaton-Driven Inflation
UNIVERSE NOW
LIFE
FIRE EM
SUN NUCLEAR FIRE
STARS
COSMIC RAYS
SUSY [SU(5)]
SUSY [SU(5)xU(1)]
ELOISATRON 500 + 500 TeV
GRAN SASSO
E (GeV)

Figure 4

THE UNIFICATION OF ALL FUNDAMENTAL FORCES

The lines in Figure 4 result from calculations executed with a supercomputer using the following system of equations:

$$\mu \frac{d\alpha_i}{d\mu} = \frac{b_i}{2\pi} \alpha_i^2 + \sum_j \frac{b_{ij}}{8\pi^2} \alpha_i \alpha_j$$

This is a system of coupled non-linear differential equations where the existence of the Superworld is included. This system describes how the gauge couplings (α_1, α_2, α_3) vary with "μ", the basic parameter which depends on the energy of the elementary process, from the maximum level of Energy (Planck Scale) to the energy level of our world. **During more than ten years (from 1979 to 1991), no one had realized that the energy threshold for the existence of the Superworld was strongly dependent on the "running" of the masses**.

This is now called: **the EGM effect** (from the initials of Evolution of Gaugino Masses).

Figure 5

WHY WE NEED THE SUPERWORLD

There are fundamental reasons making the superworld a need.

1) The two energy scales, 10^{19} GeV (Planck) and 10^{2} GeV (Fermi), must be kept separate.
2) The gravitational attraction of light must be prevented from being infinite. Otherwise we could see neither the light from Stars nor our light. The "gravitino" (supergravity) allows the gravitational attraction of light to be finite.
3) Gravitational attraction is powerful but it cannot be infinite. We would be stuck to the Sun. Space would not exist between Stars and Galaxies. Cosmic expansion would not exist. In order to have a finite gravitational attraction, theories are needed in which the Euclidean concept of point is abandoned. The point is replaced by a string. No more Point-like Theories but String Theories. These theories must be supersymmetric: the already quoted supersymmetry law (F ≡ B) must be valid in their mathematical structure. Otherwise "tachions" would appear. This is the origin of Relativistic Quantum String Theory (RQST).

4) If we want the unification of all fundamental phenomena – the synthesis of which is provided by three "gauge couplings", α_1 α_2 α_3 – running with the energy is needed. This "**running**" needs Supersymmetry.
5) An interesting detail: "no scale-supergravity" is an infrared solution of RQST. This might allow to understand the extremely small value of the Cosmological Constant.
6) Finally: why Three Columns and Three Forces? The answer to this question should come once we will be able to go from the compactification of the 43-dimensional superspace to our present world with (3+1) Space-Time dimensions.
7) **Note**: **A big problem**. Supersymmetry does not show up at our energy scale. Hence the problem arises to compute the energy above which the (F ≡ B) Law starts to act. Thanks to the **EGM effect**, this energy level is 700 times more accessible than thought so far.

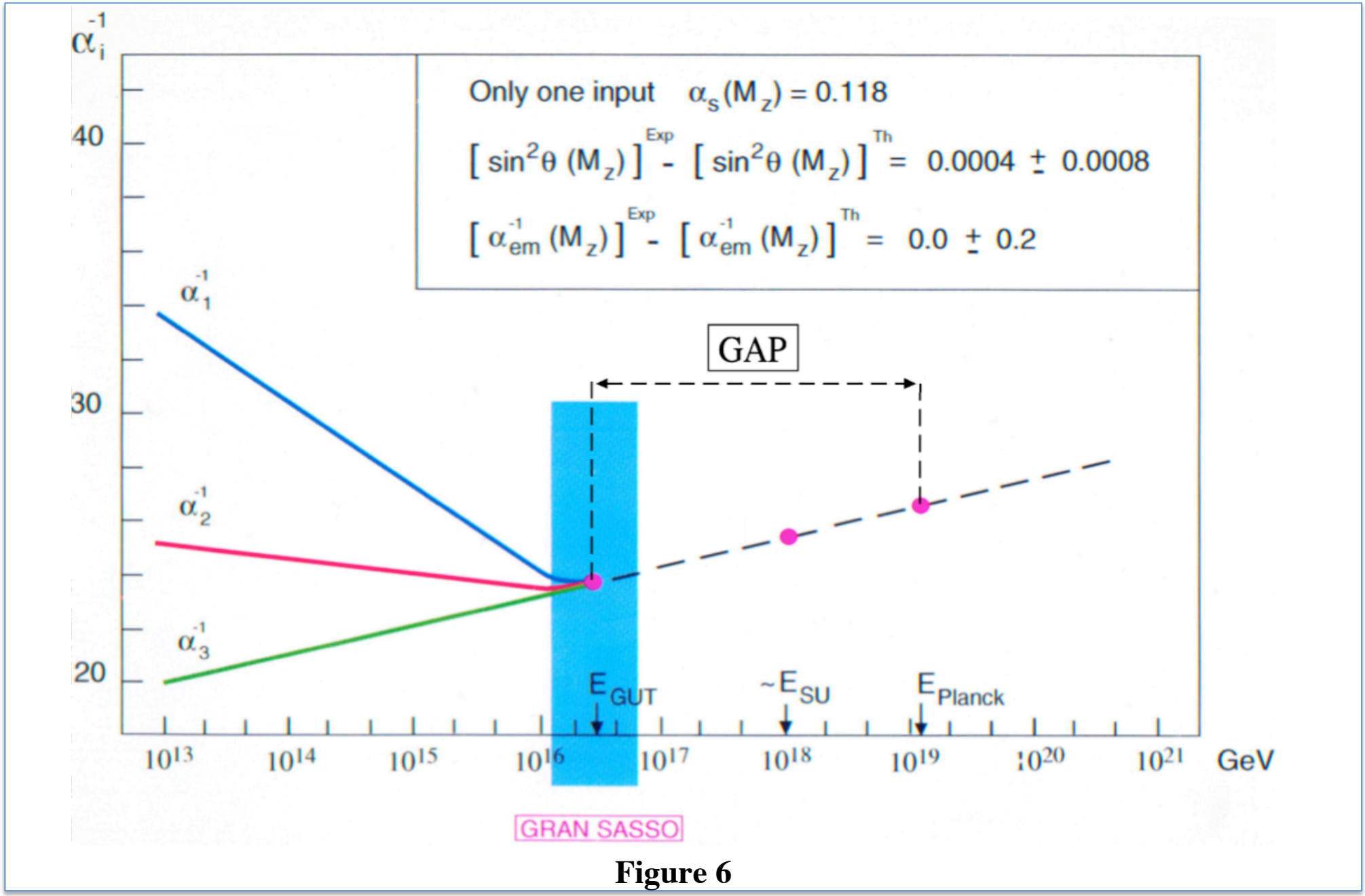

α_i^{-1}
Only one input $\alpha_s(M_z) = 0.118$
$[\sin^2\theta(M_z)]^{Exp} - [\sin^2\theta(M_z)]^{Th} = 0.0004 \pm 0.0008$
$[\alpha_{em}^{-1}(M_z)]^{Exp} - [\alpha_{em}^{-1}(M_z)]^{Th} = 0.0 \pm 0.2$
40
30
20
α_1^{-1}
α_2^{-1}
α_3^{-1}
GAP
E_{GUT}
$\sim E_{SU}$
E_{Planck}
10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} GeV
GRAN SASSO

Figure 6

If we could see the inner structure of the Black–Holes we would find that there are two types of Black–Holes. The primordial Black–Holes are made with matter whose charge is only the gravitational charge. The Black–Holes familiar to us are made with (p, n, e).

Conclusion.

All we could at present say on the correlation between the Subnuclear Universe and the one with Stars and Galaxies is to explain why: $N_{(p\,n\,e)} \simeq 10^{80}$ and $V(U) \simeq 98\%$; and to predict the existence of **two** types of Black–Holes: **Primordial Black–Holes** where matter has only the gravitational charge and **Standard Black–Holes** where matter is made with p, n, e.

On many occasions, during the activities of the International School of Cosmology and Gravitation, I have been discussing with friends and colleagues (including John Wheeler [5], Nathan Rosen [6] and Peter Bergmann [7]) how it happens that no one has been able so far to derive two basic values of our Universe:

① the number of protons, neutrons and electrons, $N_{(p\,n\,e)}$, which our Universe is made of, i.e.

① $N_{(p\,n\,e)} \simeq 10^{80}$;

and

② the volume of our Universe, V(U), which is empty, i.e.

② $V(U) \simeq 98\%$.

THE EVOLUTON OF THE UNIVERSE FOLLOWING THE SCHWARZSCHILD EQUATION

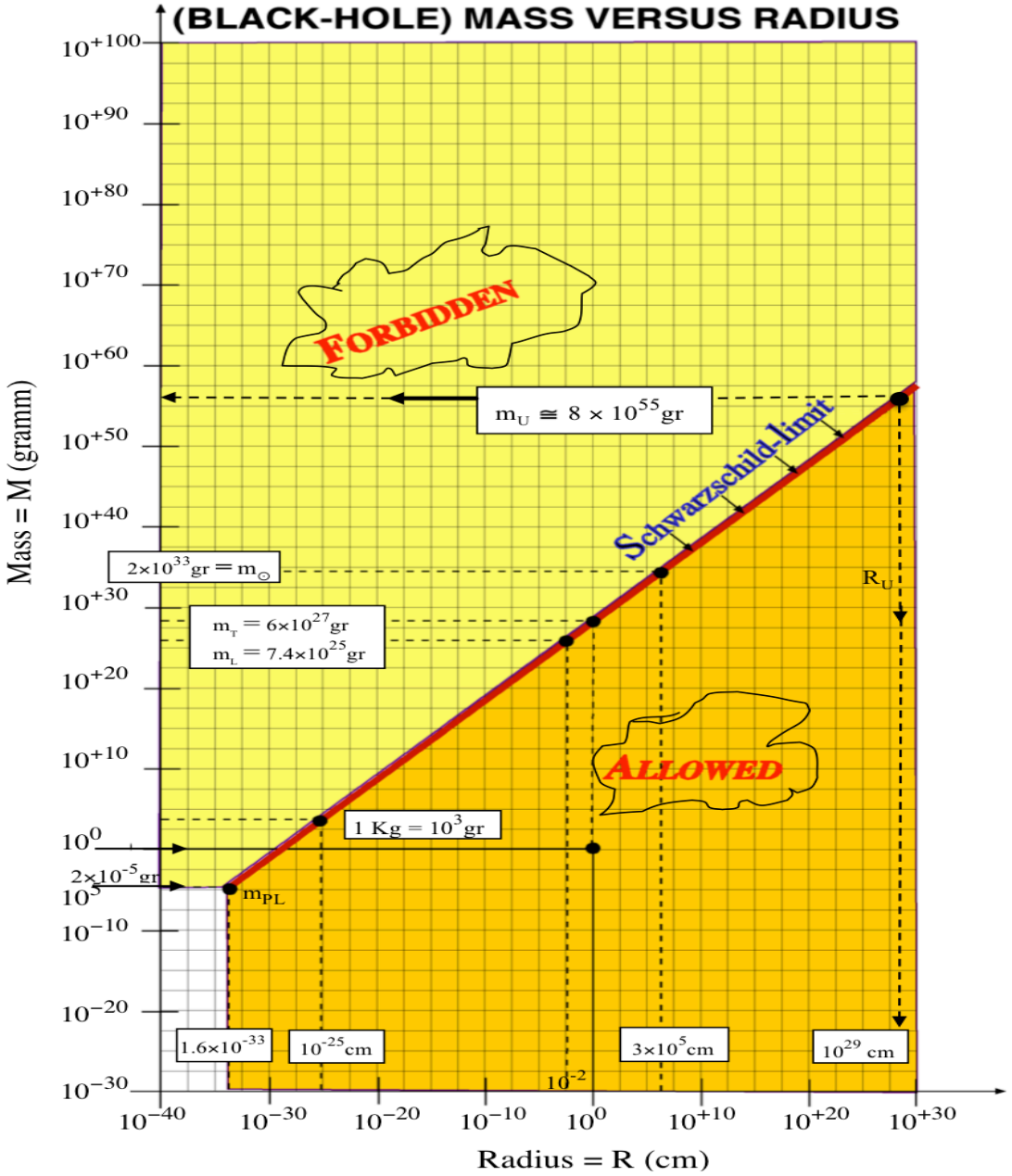


Figure 7

CONCLUSION:

all effects discovered

at $\simeq 10^2$ GeV $\Rightarrow$ need to be checked

at $\mathbf{13 \times 10^3 \times GeV}$.

From 10^2 GeV $\Rrightarrow$ $(13 \times 10^3 \times \text{GeV})$

SEARCH FOR

EEE AT LHC

II

THE WHOLE OF OUR KNOWLEDGE

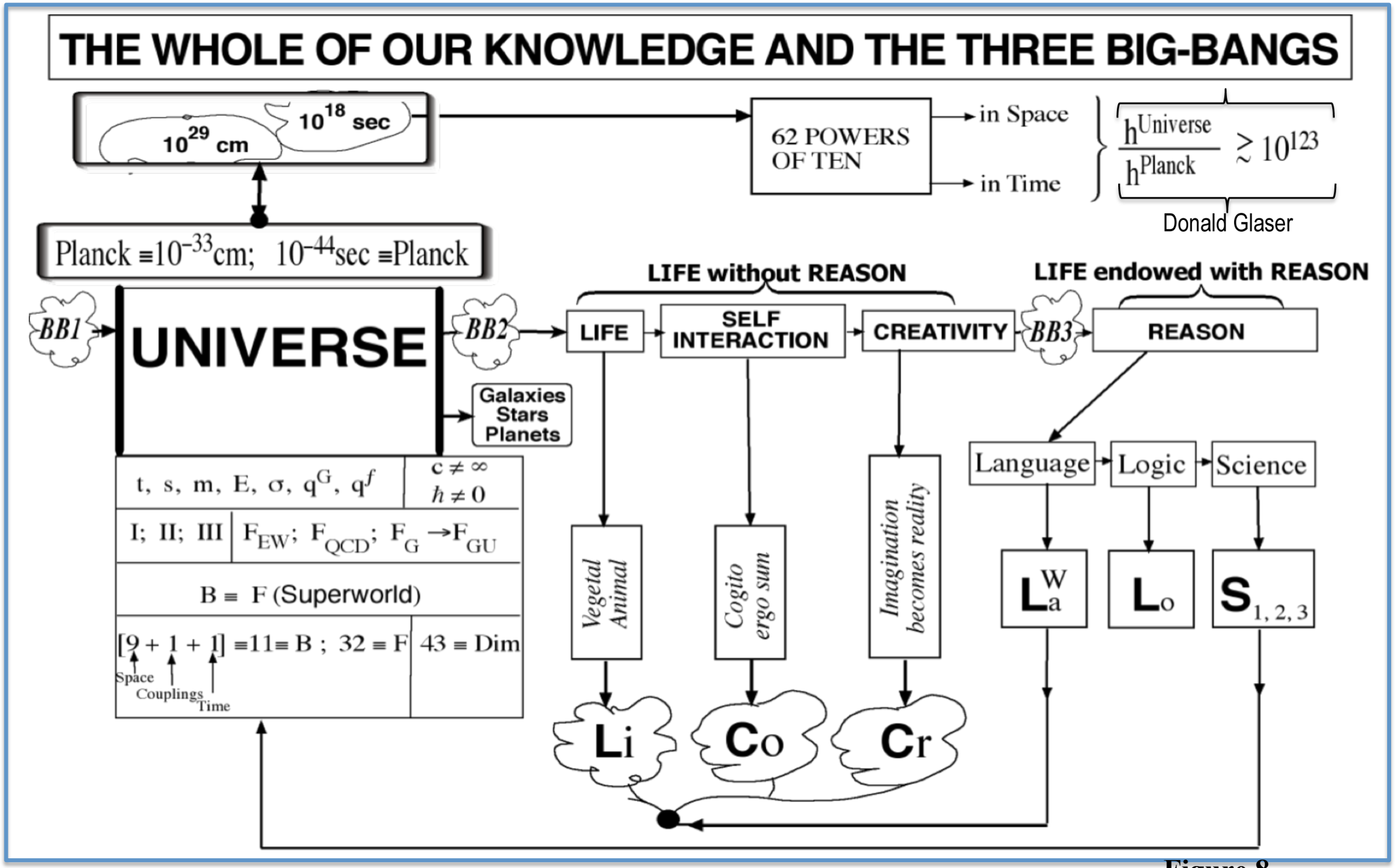

THE WHOLE OF OUR KNOWLEDGE AND THE THREE BIG-BANGS
10^{29} cm
10^{18} sec
62 POWERS OF TEN
in Space
in Time
$\frac{h^{Universe}}{h^{Planck}} \gtrsim 10^{123}$
Donald Glaser
Planck $\equiv 10^{-33}$cm; 10^{-44}sec $\equiv$Planck
LIFE without REASON
LIFE endowed with REASON
BB1
UNIVERSE
BB2
Galaxies
Stars
Planets
LIFE
SELF INTERACTION
CREATIVITY
BB3
REASON
Language
Logic
Science
t, s, m, E, σ, q^G, q^f
$c \neq \infty$
$h \neq 0$
I; II; III
F_{EW}; F_{QCD}; $F_G \rightarrow F_{GU}$
B ≡ F (Superworld)
[9 + 1 + 1] ≡11≡ B ; 32 ≡ F
43 ≡ Dim
Space
Couplings
Time
Vegetal Animal
Cogito ergo sum
Imagination becomes reality
Li
Co
Cr
L_a^W
L_o
$S_{1,2,3}$

Figure 8

We physicists **cannot remain silent** when the great public shows a vivid interest for topics such as:

- Global warming
- The energy crisis
- The information security
- The environment
- The Intelligent Design
- The Evolution
- and other Problem coming from the "Whole of our Knowledge".

We have to convince the great public that the solution to all these **problems** requires **clarity** and **rigour** and that the best way to study these problems is through Science. Since Physics is the "Queen of all Sciences", (**Enrico Fermi**), the solution of these problems needs physicists. But the present trend is to study the topics mentioned above through the "new Science", the so called "Science of Complexity".

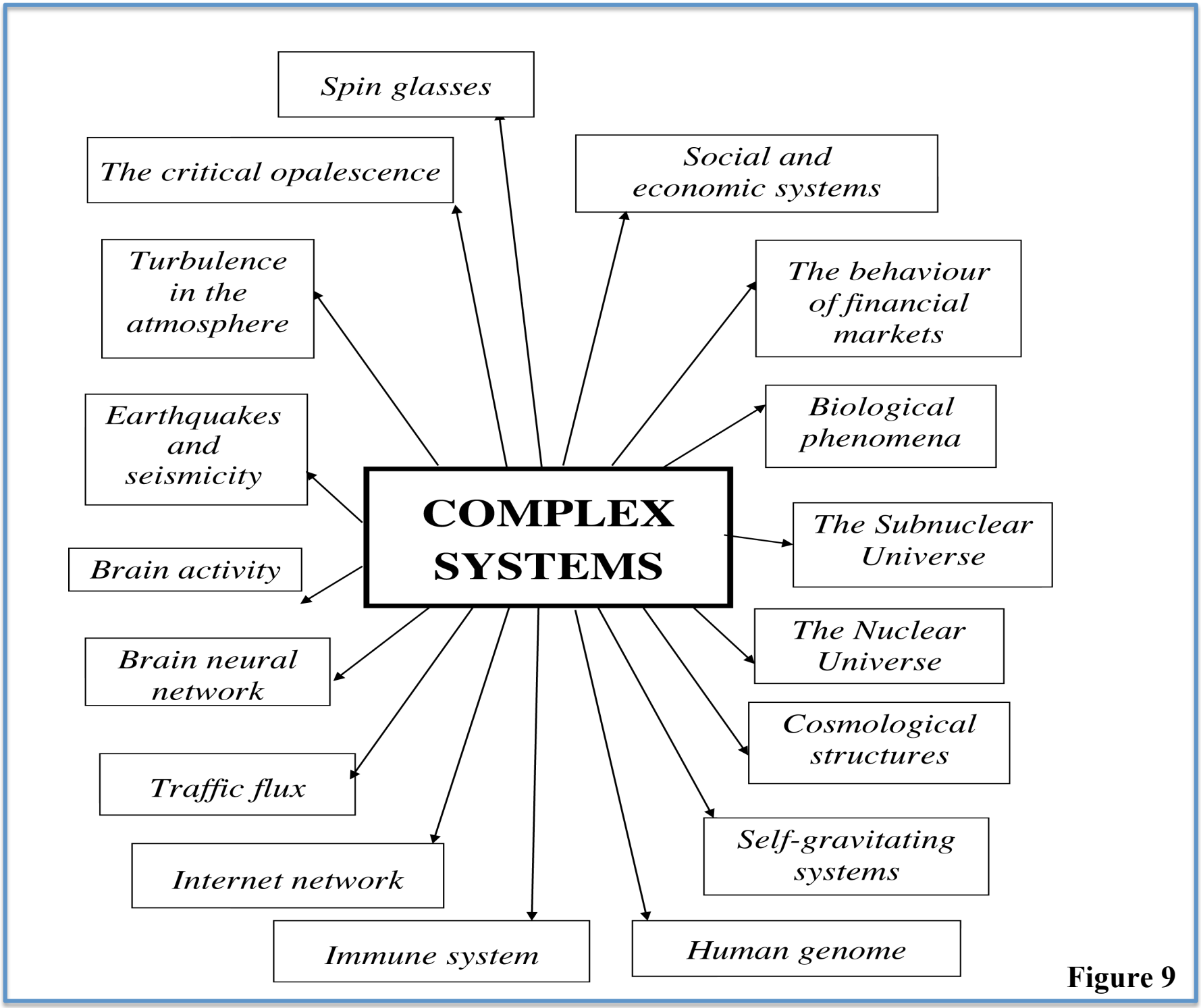

Spin glasses
The critical opalescence
Social and economic systems
Turbulence in the atmosphere
The behaviour of financial markets
Earthquakes and seismicity
Biological phenomena
COMPLEX SYSTEMS
The Subnuclear Universe
Brain activity
The Nuclear Universe
Brain neural network
Cosmological structures
Traffic flux
Self-gravitating systems
Internet network
Immune system
Human genome

Figure 9

In fact the "Modern Culture" considers "Complexity" a source of new insights in **physics**, **biology**, **geology**, **cosmology**, **social sciences** and in **all intellectual activities** which look at the world through the lens of a standard analysis in terms of either "**Platonic Simplicity**" or "**Complexity**".

The reason why we have to care about “Platonic Simplicity” is due to the emergence of this “new Science”, which condemns “Reductionism” and promote “Holism”.

But “Complexity” is ill-defined, as shown by the existence of very many definitions (at least seventy) of Complexity.

We will see that we have nothing to learn from this “new Science”. in fact it is thanks to “Reductionism” that we are able to reach the following conclusion: despite the **seventy** definitions of “Complexity” there are **only two** experimentally observable effects which exist when “Complexity” is at work. These two effects are the **UEEC** events and the **AFB** phenomena. Both are present in Physics.

Despite the seventy definitions of Complexity, the experimentally observable effects for the **existence** of **Complexity are only two**:

1) The Anderson-Feynman-Beethoven-type phenomena (**AFB**) i.e. phenomena whose laws and regularities ignore the existence of the Fundamental Laws of Nature from which they originate, and
2) The Sarajevo-type effects, i.e. Unexpected Events of quasi irrelevant magnitude which produce Enormous Consequences (**UEEC**).

The **SM&B** is the greatest synthesis of all times in the study of the fundamental phenomena governing the Universe in all its structures.

DETAILED INFORMATION ON THE STANDARD MODEL AND BEYOND

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

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

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 higher Symmetry Group (not containing U(1)) ⟹ 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.

The basic achievements of the **SM&B** have been obtained via an impressive series of UEEC events; moreover the **SM&B** could not care less about the existence of **Platonic Simplicity**. **Let me repeat** the reason why we have to care about "Platonic Simplicity": the emergence of the "new science": the so called "Science of Complexity", to which "modern Culture" attributes an enormous importance: **new insights** in physics, biology, geology, cosmology, social sciences should come from Complexity.

EXAMPLES OF PLATONIC SIMPLICITY

PLATONIC SIMPLICITY

THE PLATONIC GRAND UNIFICATION

Let us now move towards the problem of Platonic Simplicity, taking as example the structure of a Grand Unification. The simplest way is to have one and only one basic fundamental particle, B.

This particle must obey the very simple symmetry law which puts fermions and bosons on the same basis (Figure 10).

This basic fundamental particle can therefore exist either as being a boson B_B or as being a fermion B_F.

Let us consider first

B_B

The Fundamental Forces

exist

because a

Basic Fundamental Boson

B_B

EXISTS

Figure 10

Figure 11 illustrates the simple sequence which generates all known forces of Nature.

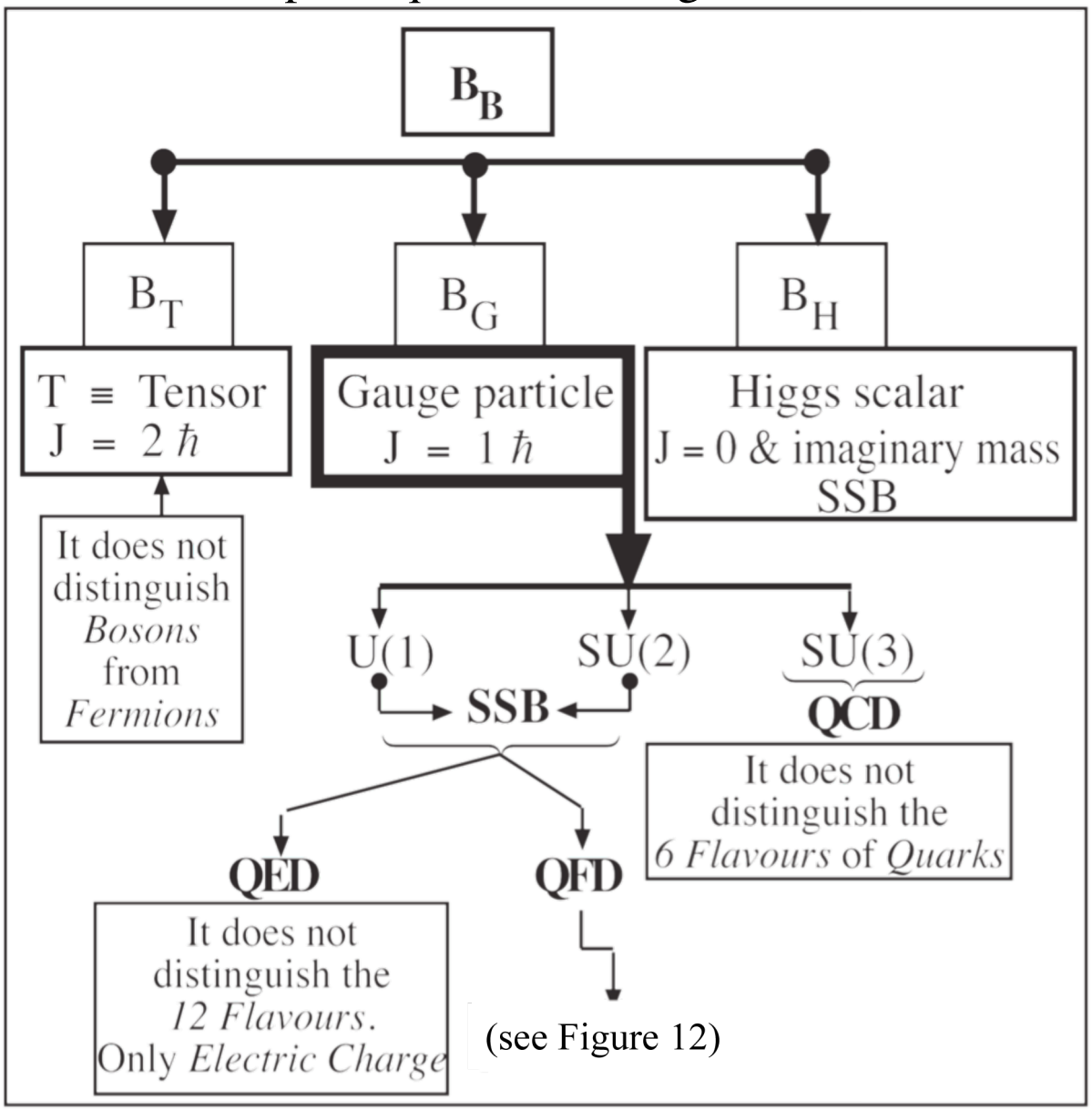


Figure 11

At the bottom of Figure 11 there is the force QFD, illustrated in Figure 12. The "Platonic" Simplicity suffers a further deviation.

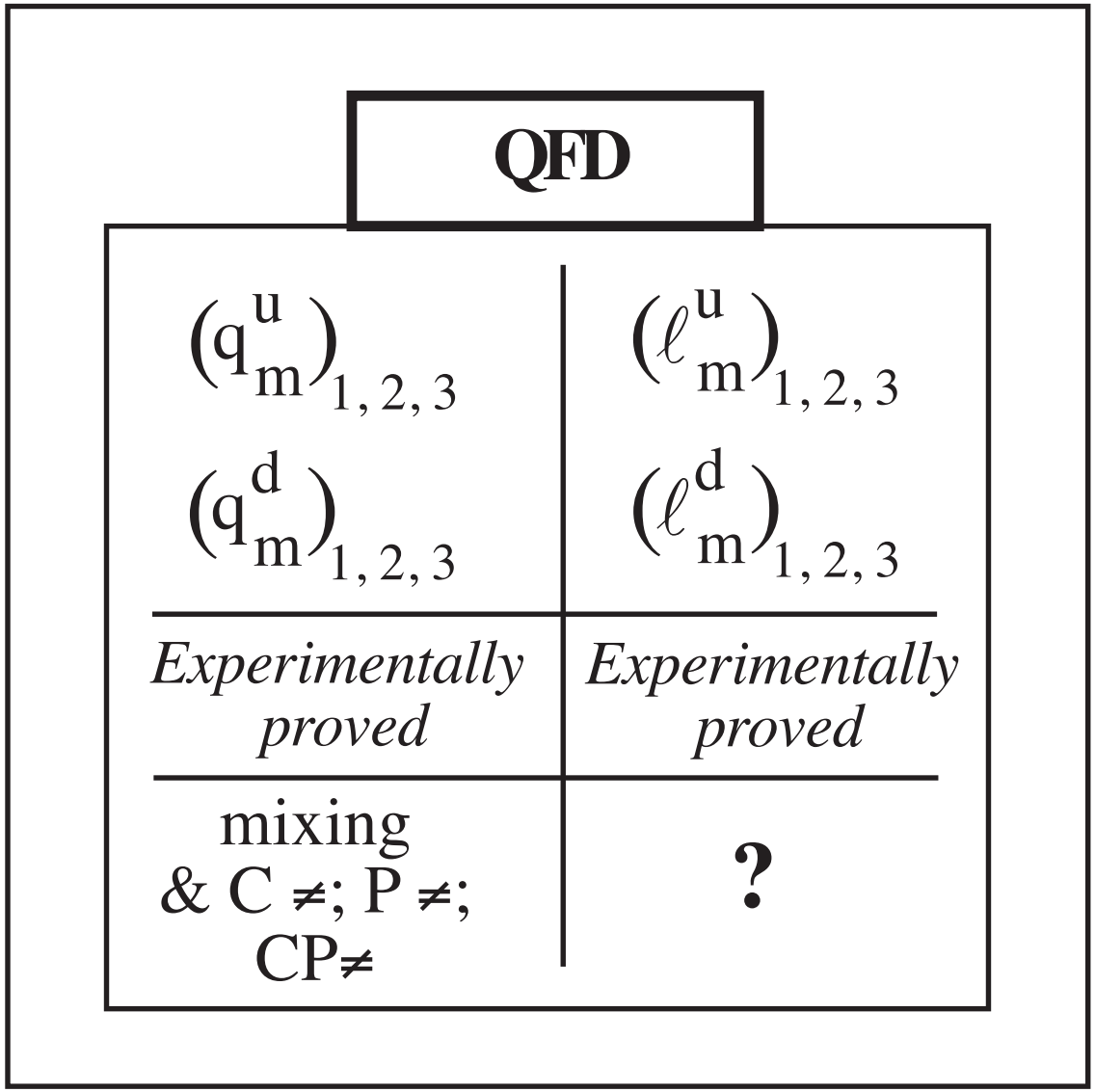


Figure 12

In fact, we need to introduce many complications. The three quarks and the three leptons are “mixed” among them, not among “quarks” and “leptons. This mixing is indicated by the index m, while the indices “u” and “d” refer to the two types of flavours

(up-type) and

(down-type)

which are present in each of the three families:

$$1, 2, 3.$$

There is a further complication.

The two mixings for the “up” and the “down” flavours **must be different**.

In the case of the quark, this mixing is experimentally measured.

In the case of the leptons, the experimental results are with nearly half a century of delay, compared with the quark case.

Mixing and violation of Symmetry Laws for charge conjugation (C), parity (P), and the product of the two (CP) are well established in the quark case.

In the leptonic sector, only future experiments will tell us if the same Symmetry Laws are violated.

There is no known reason why all these details, **mixing of states** and **Symmetry Law violations**, are needed.

They have been experimentally discovered and show how many deviations from the **simple “Platonic” structure** are needed.

So far we have developed the sequence of **Platonic deviations from Simplicity**, starting from the basic fundamental boson B_B .

We now show in Figure 24 the **deviations needed** from the **Platonic Simplicity**, when we start from the basic fundamental fermion B_F .

It has to be with "**quark**" and "**lepton**" **flavours** and have two flavours in each class (called Family).

Total number of flavours 12: **6** for quarks
6 for leptons

Why so many? The answer will probably come from the Super Space with 43 Dimensions compactified into (3+1).

The quark sector interacts with two forces, QCD and QED, while the lepton sector interacts using only QED. The QFD force comes into play only after all the mixings come in.

No one knows why all these **Deviations** from the **Platonic Simplicity** are needed.

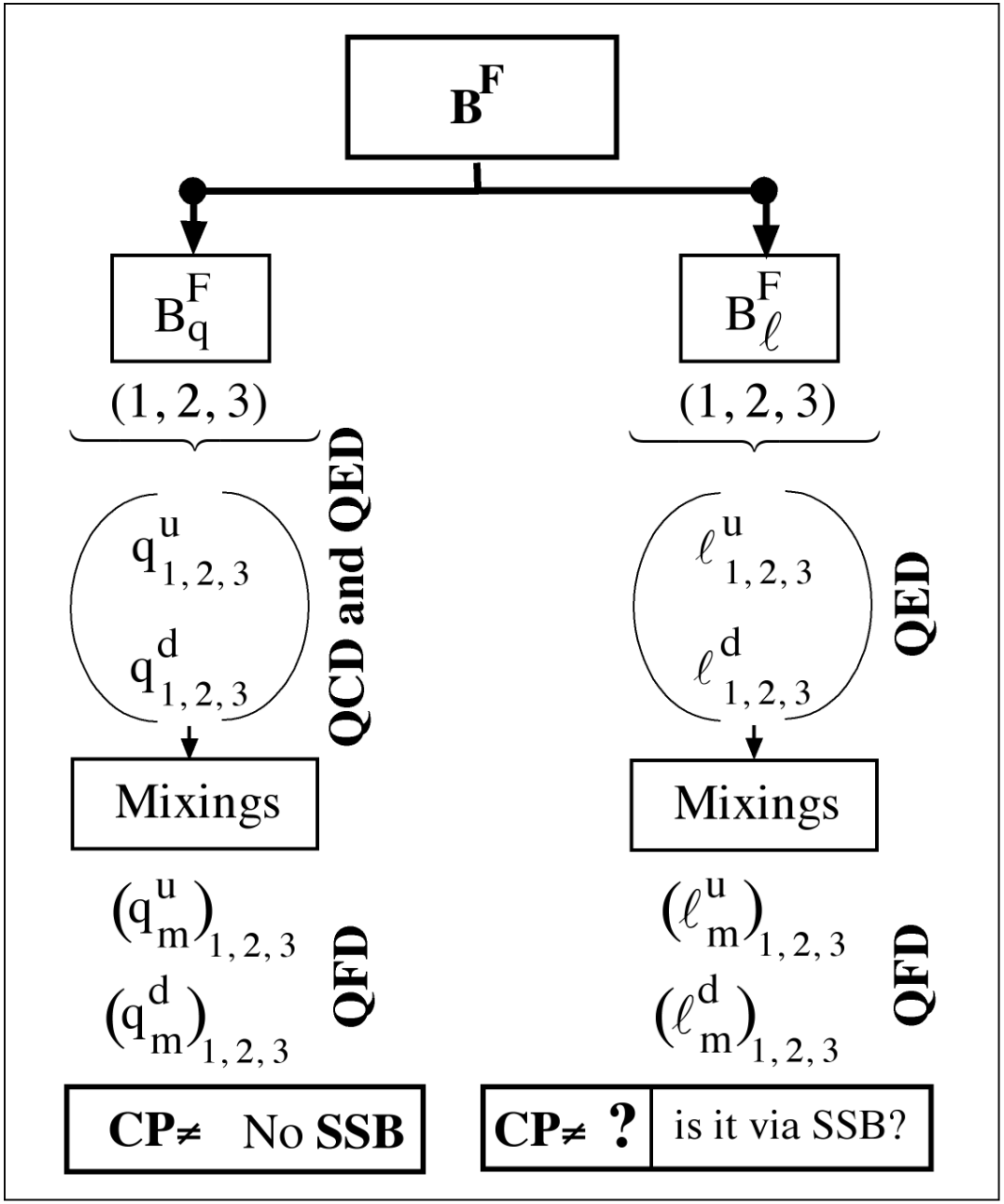

B^F
B^F_q
B^F_ℓ
(1, 2, 3)
(1, 2, 3)
$q^u_{1,2,3}$
$q^d_{1,2,3}$
QCD and QED
$\ell^u_{1,2,3}$
$\ell^d_{1,2,3}$
QED
Mixings
Mixings
$(q^u_m)_{1,2,3}$
$(q^d_m)_{1,2,3}$
QFD
$(\ell^u_m)_{1,2,3}$
$(\ell^d_m)_{1,2,3}$
QFD
CP≠ No SSB
CP≠ ?
is it via SSB?

Figure 13

The bold symbols, QCD, QED in the column

$$B_q^F$$

indicate that the 6 quarks flavours interact via these two forces. In the lower part of the same column, the "mixing" indicates that the quark states are no longer "pure" states. They are "mixed"; only these mixed states

$$\left(q_m^u\right)_{1,\,2,\,3} \quad \text{and} \quad \left(q_m^d\right)_{1,\,2,\,3}$$

interact via the QFD forces.

The column below

$$B_\ell^F$$

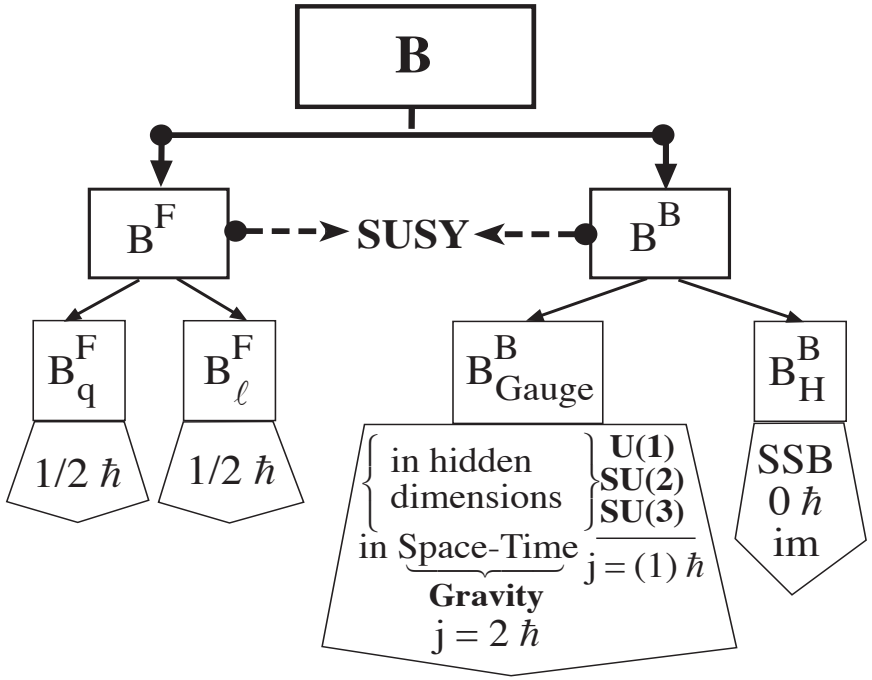
has the same structure, but the "mixings" are not the same as in the "quark" column. Furthermore, no one knows at present if the Symmetry CP is violated as it is in the quark case. This is why in the box CP $\neq$ there is a question mark. Another detail needs to be specified. In the quark case, the CP Symmetry breaking, CP $\neq$, has been experimentally established not to be via the basic Standard Model mechanism SSB.

A further Deviation from Simplicity

In the leptonic case, we do not know if the CP Symmetry is violated. It could be it is. In this case it will be interesting to know if it follows the SSB mechanism. All these question marks are evidence of **further deviations** from the **simple Platonic descriptions** of natural phenomena.

In Figure 14 a synthesis of all deviations needed is illustrated.

THE PLATONIC GRAND UNIFICATION AND THE DEVIATIONS NEEDED



- The fundamental **forces** exist because a Basic Fundamental Boson **exists** ≡ B^B
- The fundamental **fermions** exist because a Basic Fundamental Fermion **exists** ≡ B^F
- The SSBs originate from the existence of a scalar with imaginary mass (im).

Figure 14

THE PLATONIC CONCEPT OF SUPERSYMMETRY

The Platonic Concept of Supersymmetry is schematically reported in the upper part of Figure 15, where the basic point for a Platonic Concept of Supersymmetry is given; i.e. the only fermions allowed to exist, would be the "gauginos" (with spin 1/2 $\hbar$). To go from gauginos to fermions we need the 1st deviation from Platonic Supersymmetry. The 2nd deviation is needed in order to allow fermions to be quarks and leptons. The 3rd deviation is needed in order to have not one Family but three Families. The 4th deviation is needed in order to produce mixing. The 5th deviation is needed because we need at least two mixings, one for "up" and another one for "down" type quarks. All this is illustrated in Figure 15.

THE PLATONIC CONCEPT OF SUPERSYMMETRY

The **Gauge Principle** should generate a
Gauge Force ⟶ **Gauge Bosons**
If *NATURE* was platonically *SUPERSYMMETRIC*
Supersymmetry Transformation should generate **Gauginos**

1st **DEVIATION FROM PLATONIC SIMPLICITY**
OUR FERMIONS ARE NOT THE GAUGINOS

2nd **DEVIATION FROM PLATONIC SIMPLICITY**
THE FUNDAMENTAL FERMIONS ARE OF TWO DIFFERENT CLASSES: LEPTONS AND QUARKS

3rd **DEVIATION FROM PLATONIC SIMPLICITY**
THERE IS NOT ONLY ONE BUT THREE FAMILIES OF FUNDAMENTAL FERMIONS

4th **DEVIATION FROM PLATONIC SIMPLICITY**
THE FUNDAMENTAL FERMIONS BECOME MIXED WHEN THE WEAK FORCES ARE SWITCHED ON: MIXINGS EXIST

5th **DEVIATION FROM PLATONIC SIMPLICITY**
THERE ARE DIFFERENT MIXINGS

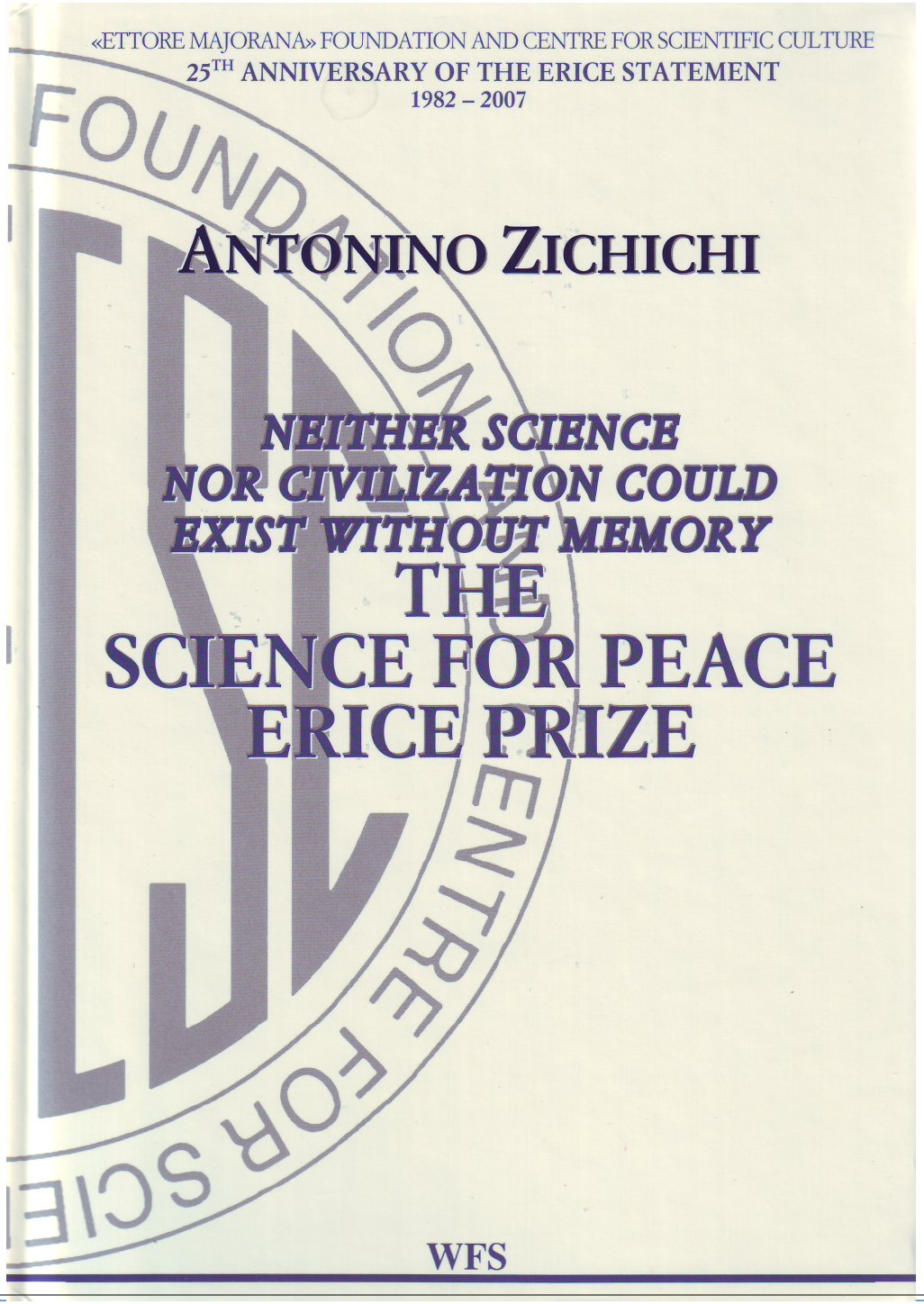
Figure 15

III

THE FUTURE

THE FUTURE

MEMORY


«ETTORE MAJORANA» FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE
25TH ANNIVERSARY OF THE ERICE STATEMENT
1982 – 2007
ANTONINO ZICHICHI
NEITHER SCIENCE
NOR CIVILIZATION COULD
EXIST WITHOUT MEMORY
THE
SCIENCE FOR PEACE
ERICE PRIZE
WFS

On the occasion of the twenty-fifth anniversary of the Ettore Majorana Foundation and Centre for Scientific Culture (EMFCSC), in order to promote the values of scientific culture worldwide and following a proposal by the World Federation of Scientists (WFS), a special law was voted unanimously by the Sicilian Parliament to establish the

"Ettore Majorana Prize – Erice – Science for Peace".

The Prize has been awarded to fellows who played a leading role in promoting and implementing the goals outlined in the "Erice Statement" for a Science without secrets and without borders.

P.A.M. Dirac, P.L. Kapitza, A.D. Sakharov, E. Teller, V.F. Weisskopf, J.B.G. Dausset, S.D. Drell, M. Gell-Mann, H.W. Kendall, L.C. Pauling, A. Salam, C. Villi, R. Doll, J.C. Eccles, T.D. Lee, L. Montagnier, Qian Jaidong, J.S. Schwinger, U. Veronesi, G.M.C. Duby, R.L. Garwin, S.L. Glashow, D.C. Hodgkin, R.Z. Sagdeev, K.M.B. Siegbahn, Y.P. Velikhov, J. Karle, J.M.P. Lehn, A. Magnéli, N.F. Ramsey, H. Rieben, J.J. van Rood, C.S. Wu, R.L. Mössbauer, A. Müller, H. Kohl, M.S. Gorbachev, H.H. John Paul II, R. Clark, M. Cosandey, A. Peterman, R. Wilson, J. Alderdice, J.J. Friedman, M. Koshiba, S. Coleman, A.N. Chilingarov, P.C.W. Chu, L. Esaki, W.N. Lipscomb Jr., J. Szysko, M.-K. Wu, H.A. Hauptman, D.H. Hubel, R. Huber, B.I. Samuelsson, H. Sun, A.E. Yonath, G. 't Hooft, Y.T. Lee, W. Arber, S.C.C. Ting.

Last December 2013 there was a Ceremony illustrated in the following **Figure 16**.

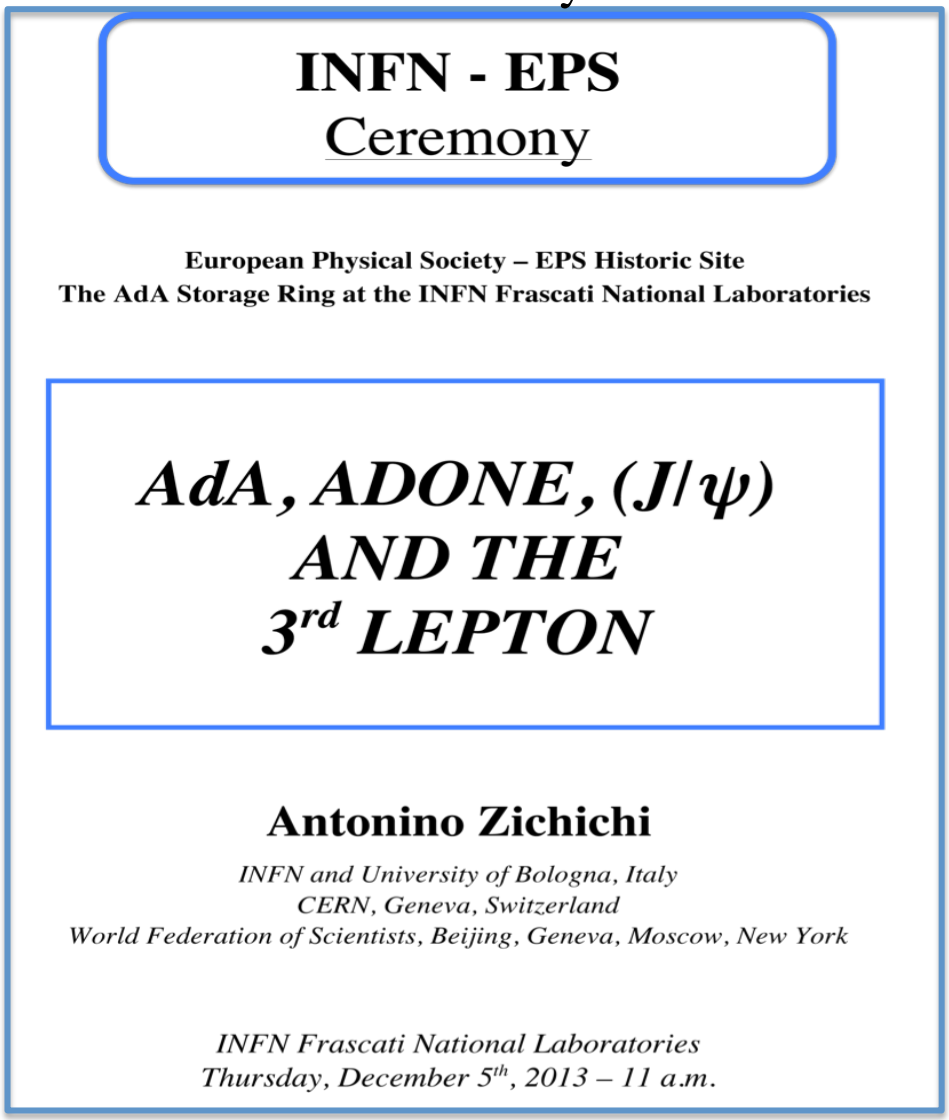
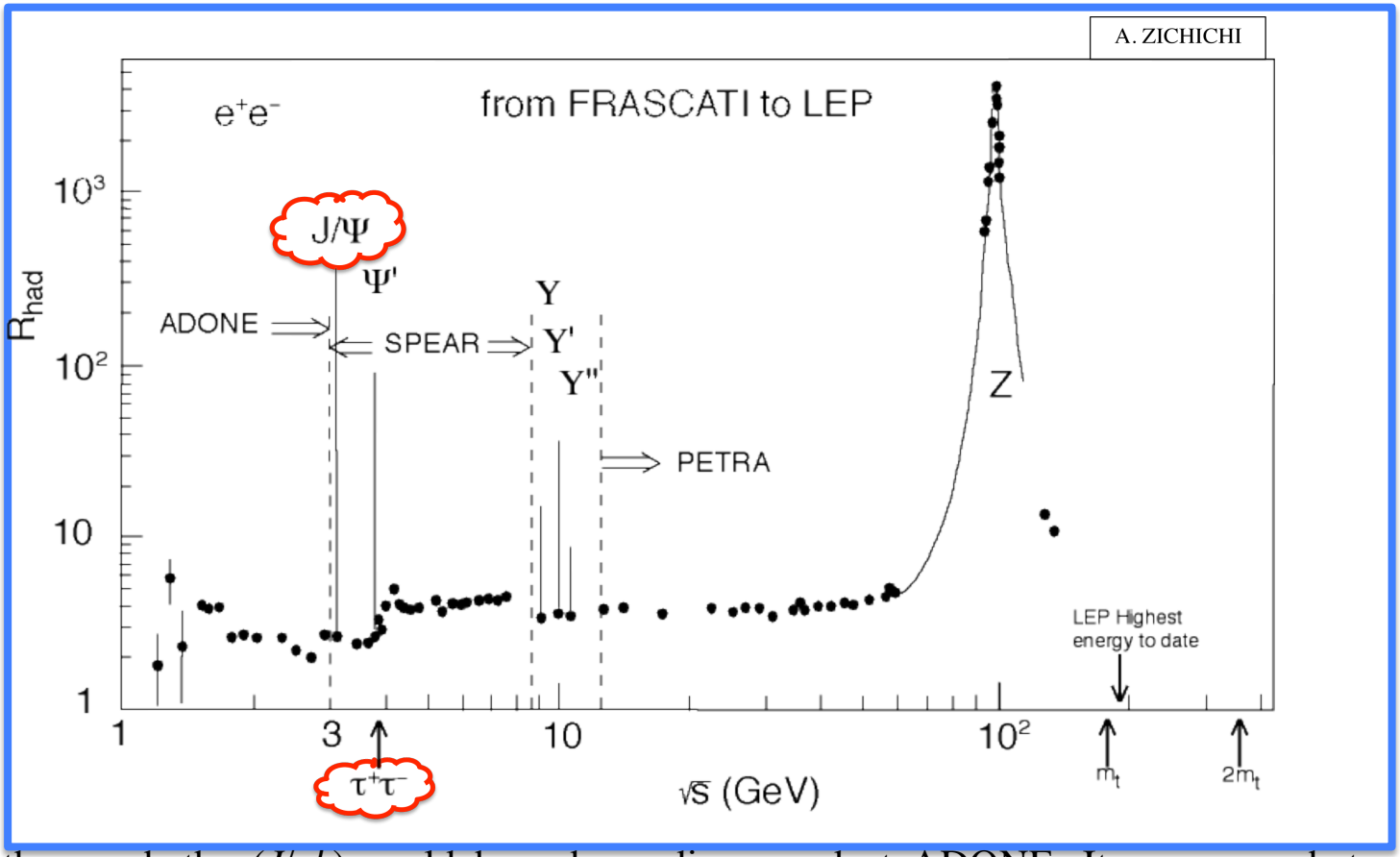


Figure 16

Let me show (**Figure 17**) one page of my Opening Lecture at the AdA-INFN-EPS unveiling Ceremony where it is proved the great value of Blackett teaching about Nature being smarter than all of us and about memory needed in order to never forget the consequences of neglecting this thanks to memory. But memory is needed not only in Physics but in our activities called Civilization.



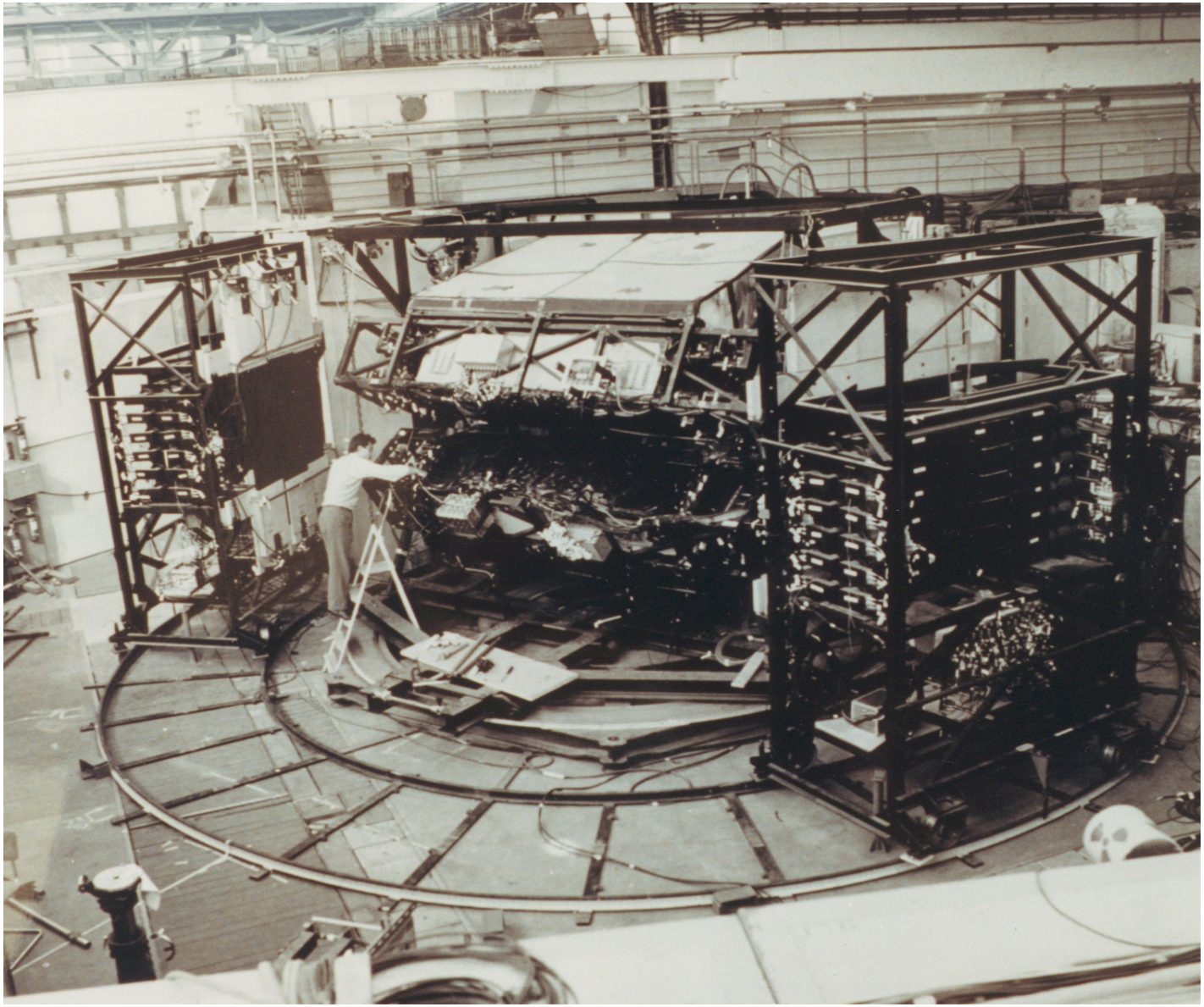
As show in the graph the (J/ψ) could have been discovered at ADONE. It was enough to increase the machine energy by 0.1 GeV as suggested by the CERN-Bologna group, but rejected by the responsible people.

Something similar did happen with PETRA whose lowest energy was not immediately after SPEAR but with the incredible gap where the Lederman's (Y, Y', Y") could have been discovered.

Let me go back to the origin of this new venture in elementary particle Physics based on the search for new Physics using non Bubble Chamber detectors. Needless to say that, in addition to the search for "narrow resonances", the search for the 3rd lepton (HL) was the reason for a stronger energy increase in ADONE, where the HL (now called τ) would have been discovered.

3

Figure 17



– 1963 –

PAPLEP
Proton **A**nti**P**roton
into **L**epton **P**airs
first search for
the 3rd lepton
and
$\theta_{PS} \neq \theta_V$.

The "pre-shower" technology implemented in the CERN experimental set-up for the study of the rare decay modes of the pseudoscalar and vector mesons.

THIS IS THE FIRST EXAMPLE of what is now "standard"
in experimental subnuclear physics: VERY LARGE ACCEPTANCE DETECTORS.
On the rails the "neutron missing mass spectrometer".

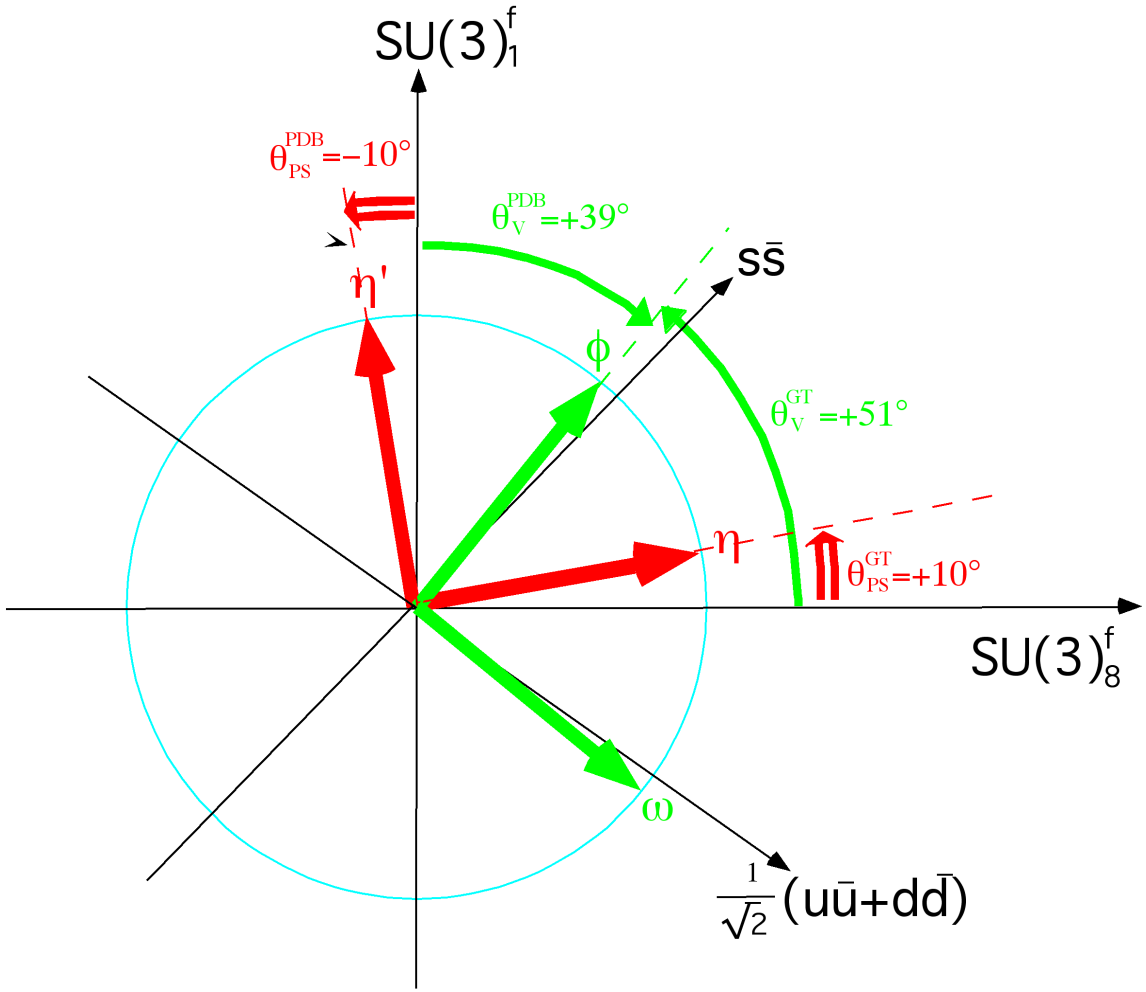
$$\theta_{PS} \neq \theta_{V}$$

INSTANTONS

In the Physics of Mesons the totally unexpected result was the difference existing between the two mesonic mixing angles, pseudoscalar θ_{PS} and vector θ_V. They should both be zero if $SU(3)_{uds}$ was a good Symmetry.

The experimental results gave $\theta_V = 51^o$ and $\theta_{PS} = 10^o$ **despite** $SU(3)_{uds}$. This is illustrated in Figure 18.

The Physics of Instantons in QCD is needed to explain θ_V and θ_{PS}, i.e. the mixing in the pseudoscalar and in the vector mesons. The existence of Instantons was not known. The Instantons came after the unexpected discovery that $\theta_{PS} \neq \theta_V \neq 0$.



PDB ≡ Particle Data Book
GT ≡ Gerardus 't Hooft

$\theta_{PS} \neq \theta_V$

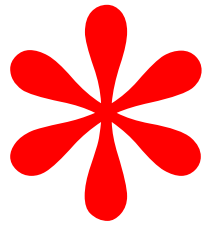
Direct: Not Using Mass Formulae

Figure 18

$$\theta_{PS} \neq \theta_{V}$$

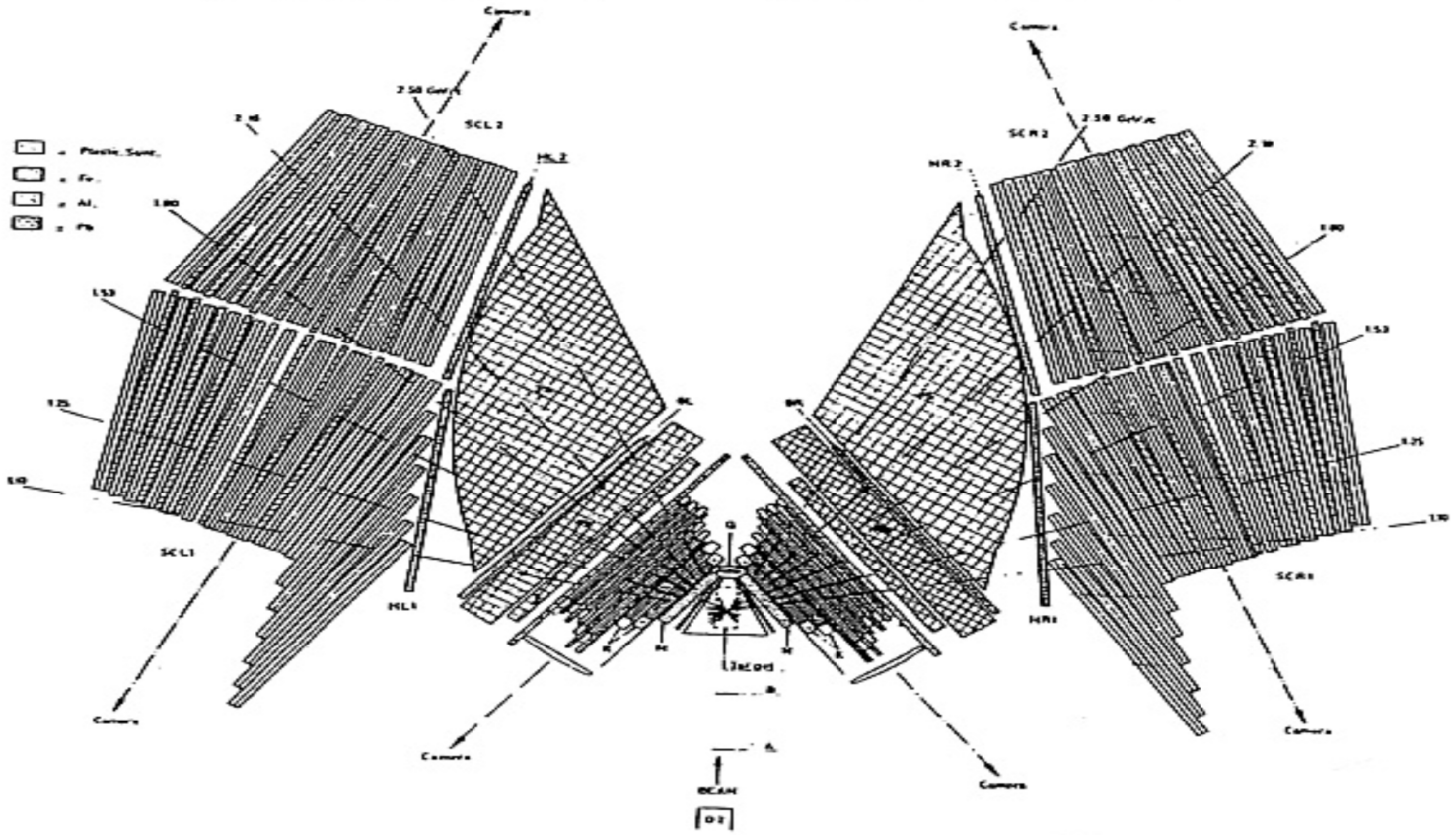
PRESHOWER $\pi/e = 5 \times 10^{-4}$

MUON PUNCH-THROUGH



To simultaneously detect $\mu^{\pm}e^{\mp}$ final states in $\bar{p}p$ annihilation.
The first experimental search for the **THIRD LEPTON** (HL ≡ τ)
and the discovery of the Time-Like Structure of the Proton

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



The Future

what about

Predictions

?

Recall

UEEC

TOTALLY UNEXPECTED DISCOVERIES: A PERSONAL EXPERIENCE

SUPERSYNTHESIS

1 *Lorentz Invariance (Lorentz).*
2 *The quantum nature of the World (Planck).*
3 *Two worlds: "Time-like" and "Space-like" (Einstein).*
4 *The photon (Einstein).*
5 *Gauge Invariance (Weyl).*
6 *The Space-Time curvature (Einstein).*
7 *Bose-Einstein statistics (Bose-Einstein).*
8 *The structure of the atom (Bohr).*
9 *The wave nature of particles (de Broglie).*
10 *The wave function (Schrödinger) and its probabilistic interpretation (Born).*
11 *Nuclear Forces (Rutherford) and their "glue" (Yukawa).*

12 The proof that Quantum Mechanics is self consistent (no contradictions) (Von Neumann).
13 The Weak Forces (Fermi).
14 The Exclusion Principle (Pauli).
15 The Uncertainty Principle (Heisenberg).
16 Fermi statistics (Fermi).
17 The antiparticles (Dirac).
18 The neutron (Chadwick).
19 Time Reversal Invariance (Wigner).
20 Other Invariance Laws (Wigner-Parity; Dirac, Weyl-charge conjugation; Pauli CPT).
21 The neutrino (Pauli-Fermi).
22 The Stars are "nuclear-fusion" candles (Fermi-Bethe).
23 Electronic computing (Von Neumann).
24 ***The sequence of unexpected Fermi discoveries****: Fermi-coupling, Fermi-gas, Fermi-momentum, Fermi-temperature, Fermi-surface, Fermi-statistics, Fermi-transition, Fermi-length (plus the other two quoted above).*

A FEW EXAMPLES
WHERE I HAVE BEEN INVOLVED

① **The 3rd lepton**
despite *the abundance of neutrinos:* ν_e (ν_μ) *another* ***one*** (ν_{HL}).

② **Antimatter**
despite *S-matrix and C, P, CP breaking.*

③ **Nucleon Time-like** EM structure
despite *S-matrix.* **inst**

④ **No quarks** in violent (pp) collisions
despite *scaling.*

⑤ **Meson mixings**
$\theta_V \neq \theta_{PS}$ **:** $(51^o) \neq (10^o) \neq 0$ ***despite*** $SU(3)_{uds}$. **inst**

⑥ **Effective energy:** *the QCD-light*
despite *QCD.*

⑦ **The running** of α_1 α_2 α_3 versus **energy** at ***a point*** E_{GU}.
(1979) (1991) ***despite*** *straight line convergence.*

EGM

Figura 19

1 Therefore **Totally Unexpected Effects** should **show up**.

2 **Effects**, which are impossible to be predicted on the basis of **present knowledge**.

3 Where these effects are most likely to be, no one knows.

4 **But**, with the advent of the Energy Level

of **13 TeV**

never reached so far with the LHC

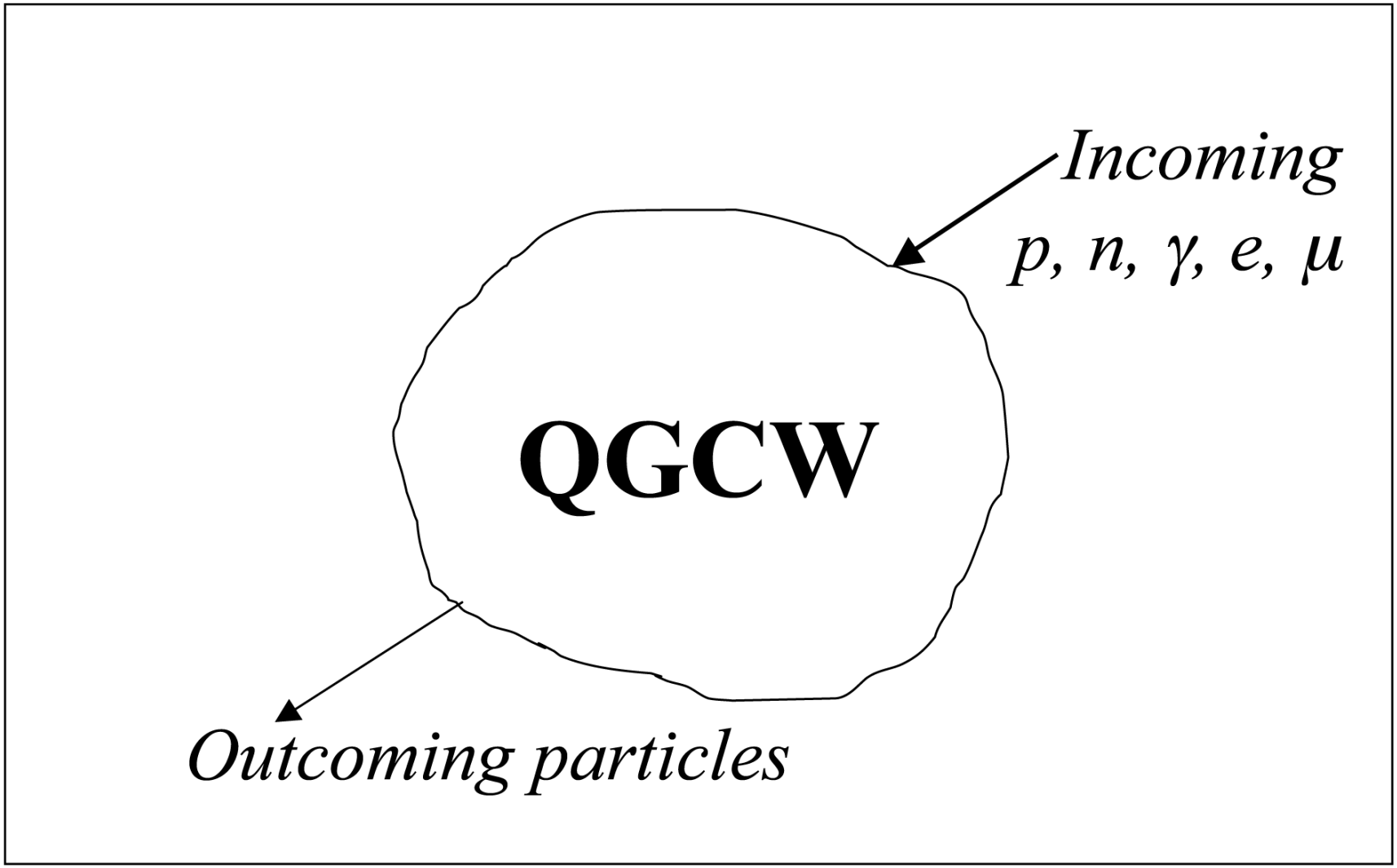
the ALICE experiment will study the properties of the **Quark-Gluon-Coloured-World**

(QGCW).

At this point Gerardus would ask me the question:

"***How do we detect the totally unexpected effects?***"

An example is illustrated in the Figure below where beams of known particles (p, n, γ, e, μ) bombard the QGCW and a special set of detectors measures the properties of the outcoming particles.


Incoming
p, n, γ, e, μ
QGCW
Outcoming particles

In the following years, much before the second 60th Gerardus Anniversary, we could celebrate another Gerardus Anniversary with the discovery of a totally unexpected effect.

It would be great if this happened using the ALICE apparatus at LHC.

This should indeed be the case if Nature follows the Logic of Complexity at the Fundamental level.

UEEC

'WHAT IF ?'

	In History ≡ EWRL		In Science ≡ EBUS
I	What if Julius Caesar had been assassinated many years before?	I	What if Galileo Galilei had not discovered that F = mg ?
II	What if Charles VII had not been able to win the 100 years war?	II	What if Newton had not discovered that $F = G\frac{m_1 \cdot m_2}{R_{12}^2}$?
III	What if America had been discovered a few centuries later?	III	What if Maxwell had not discovered the unification of electricity, magnetism and optical phenomena, which allowed him to conclude that light is a vibration of the EM field?
IV	What if Napoleon had not been born?	IV	What if Becquerell had not discovered radioactivity?
V	What if Louis XVI had been able to win against the 'Storming of the Bastille'?	V	What if Planck had not discovered that $h \neq 0$?
VI	What if the 1908 Tunguska Comet had fallen somewhere in Europe instead of Tunguska in Siberia?	VI	What if Lorentz had not discovered that space and time cannot both be real?
VII	What if the killer of the Austrian Archduke Francisco Ferdinand had been arrested the day before the Sarajevo event?	VII	What if Einstein had not discovered the existence of time-like and space-like real worlds? Only in the time-like world, simultaneity does not change, with changing observer.
VIII	What if Lenin had been killed during his travelling through Germany?	VIII	What if Rutherford had not discovered the nucleus?
IX	What if Hitler had not been appointed Chancellor by the President of the Republic of Weimar Paul von Hindenburg?	IX	What if Hess had not discovered cosmic rays?
X	What if the first nuclear weapon had been built either by Japan before Pearl Harbour (1941) or by Hitler in 1942 or by Stalin in 1943?	X	What if Dirac had not discovered his equation, which opens new horizons, including the existence of the antiworld?
XI	What if Nazi Germany had defeated the Soviet Union?	XI	What if Fermi had not discovered weak forces?
XII	What if Karol Wojtyla had not been elected Pope, thus becoming John Paul II?	XII	What if Fermi and Dirac had not discovered the Fermi–Dirac statistics?
XIII	What if Gorbachev had not been defeated by Yeltsin?	XIII	What if Yukawa had not proposed the existence of a "meson" in order to have the nuclear glue?
XIV	What if the USSR had not collapsed?	XIV	What if the 'strange particles' had not been discovered in the Blackett Lab?

History is

"**E**volution of the **W**orld in its **R**eal **L**ife" ≡ (**EWRL**)

Science is

"**E**volution of our **B**asic **U**nderstanding of the laws governing the world in its **S**tructure" ≡ (**EBUS**).

DARK MATTER

Figura 20

Question: What about UEEC in other fields? For example: condensed matter.

Tony Leggett, University of Illinois, Urbana - Champaign, USA, Nobel 2003 for "Superfluidity": "*It is relatively rare in Condensed-Matter Physics to predict discoveries, it is a field where you fall over them by accident*".

Our Community of

the Erice Subnuclear Physics School

has

Super Students Super

Fellows

in their fields

SSS

Recall: the 1st best Student

EUGENE WIGNER

This year
we have
FRANCIS HALZEN

APPENDIX A

DIRAC

Antiparticles & Antimatter

"Those who say that antihydrogen is antimatter should realize that we are not made of hydrogen and we drink water, not liquid hydrogen." These are words spoken by Paul Dirac to physicists gathered around him after his lecture "My life as a Physicist" at the Ettore Majorana Foundation and Centre for Scientific Culture in Erice in 1981 – 53 years after he had, with a single equation, opened new horizons to human knowledge.

CERN COURIER

Apr 29, 2009

Why antihydrogen and antimatter are different

As Paul Dirac realized, the existence of antihydrogen does not in itself prove the existence of antimatter. A look through the history of the subject, and in particular the role played by the CPT theorem, shows that ultimately it came down to experiment to prove the existence of antimatter through the discovery of the antideuteron at CERN in 1965.

Dirac - 1930

The existence of a single antiparticle,
the antielectron, guaranties the existence of

all antiparticles

antimatter

antistars

antigalaxies

because Nature obeys

C-INVARIANCE

1957: *discovery* of C ≠ and P ≠
by C.S. Wu et al. (Lee and Yang)
but CP ok

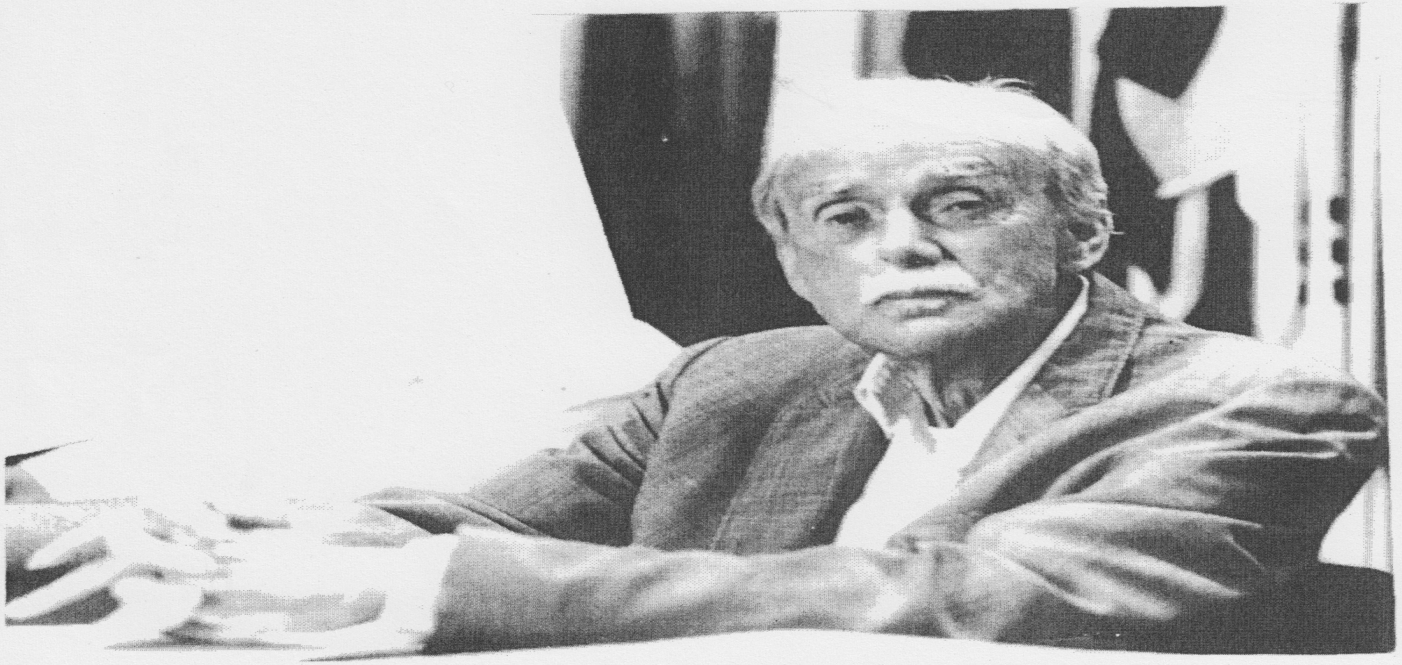
1964: *discovery* of CP ≠
by CCFT (Christenson, Cronin, Fitch and Turlay)

During the same Time

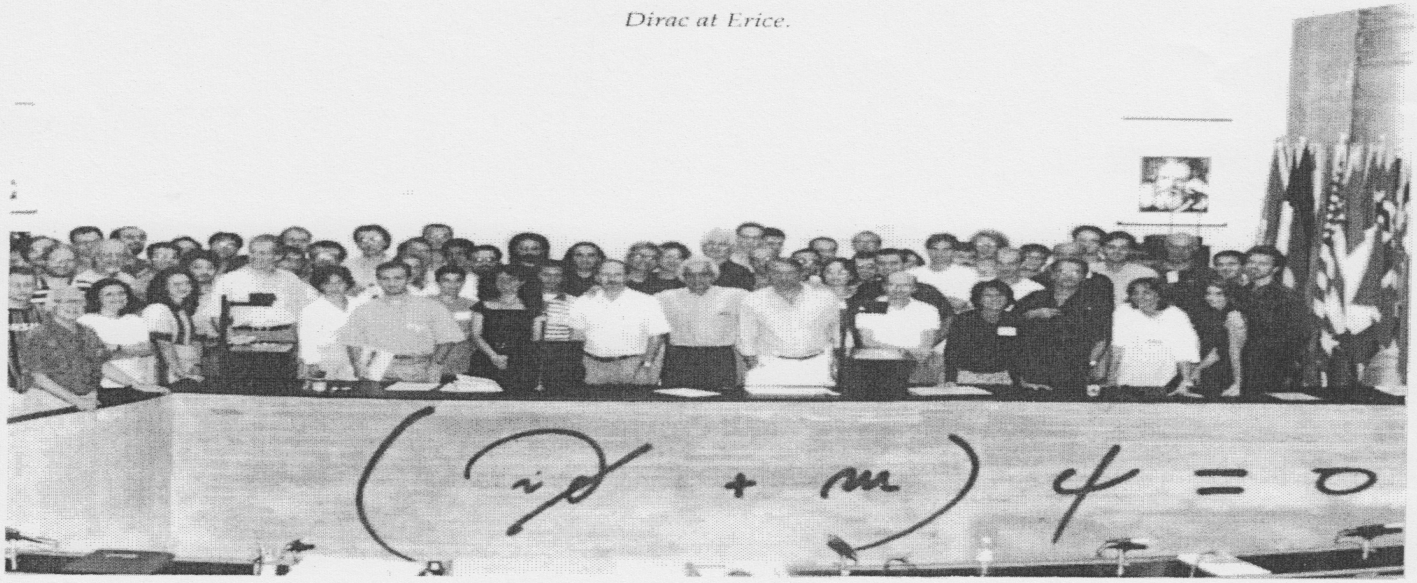
Triumph of the **S-Matrix**
(G. Chew) and *crisis* of the
RQFT

The existence of
ANTIPARTICLES DOES
NOT IMPLY
the existence of
ANTIMATTER.

Dirac - 1965



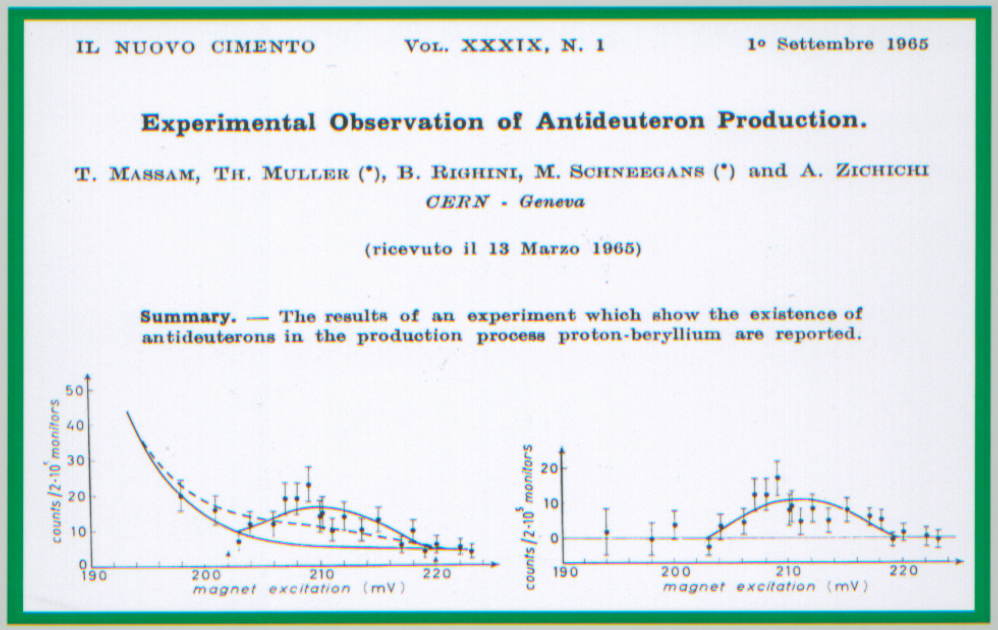
Dirac at Erice.



Symposium in honour of Antonino Zichichi to celebrate the 30th anniversary of

THE DISCOVERY OF NUCLEAR ANTIMATTER

Edited by L. Maiani and R. A. Ricci



IL NUOVO CIMENTO Vol. XXXIX, N. 1 1° Settembre 1965

Experimental Observation of Antideuteron Production.

T. Massam, Th. Muller (*), B. Righini, M. Schneegans (*) and A. Zichichi

CERN - Geneva

(ricevuto il 13 Marzo 1965)

Summary. — The results of an experiment which show the existence of antideuterons in the production process proton-beryllium are reported.

«I think that this discovery of antimatter was perhaps the biggest jump of all the big jumps in physics in our century»

Werner Heisenberg

T.D. Lee - 1995

The CPT theorem rests on a foundation which has to be unsound, at least at the Planck length, and maybe at a much larger distance.

The symmetry of matter and antimatter must rest on experimental evidence.

Mass ≠ Matter

$$|\, m_i \rangle \equiv \text{Mass} \equiv \text{Antimass} \equiv |\, \overline{m}_i \,\rangle$$

$i \equiv 1$ (Intrinsic); $i \equiv 2$ (Confinement); $i \equiv 3$ (Binding)

$$C\,|\, m_i \rangle = |\, m_i \,\rangle \qquad (***)$$

$$i \equiv 1, 2, 3$$

$$|\, m_i\, Q_j \,\rangle \equiv \text{Matter} \neq \text{Antimatter} \equiv |\, m_i\, \overline{Q}_j \,\rangle$$

$Q_j \equiv$ Flavour Charges

$j \equiv (\, u \quad d \quad c \quad s \quad t \quad b \,) \equiv (1, 2, 3, 4, 5, 6)$

$(\, \nu_e \quad e^- \quad \nu_\mu \quad \mu^- \quad \nu_{HL} \quad HL^- \,) \equiv (7, 8, 9, 10, 11, 12)$

$HL^- \downarrow \tau^-$

$$C\,|\, m_i\, Q_j \,\rangle = |\, m_i\, \overline{Q}_j \,\rangle \qquad (***)$$

$i \equiv 1, 2, 3$; $J \equiv 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12.$

Figure 21

Many deviations from **simplicity are needed** to corroborate the **stability of matter: one charge** (the electric one) is not enough. Another unexpected discovery was the distinguish "colour" charge from "flavour" charge, with six colour charges and twelve flavour charges.

Six "Colour" charges (1 + 2 + 3) → 1 for QED, 2 for QFD, 3 for QCD.

Twelve "Flavour" charges (6 + 6) → 6 for quarks + 6 for leptons.

We can see in Figure 22 that there are **seven decades of developments**, started **from** the **antielectron** and **C-invariance**, **to** arrive at the experimental discovery of **Matter Antimatter Symmetry**. The detailed series of all these totally unexpected events are reported in the volume published on the occasion of the 30th anniversary of the discovery of antimatter [8].

THE INCREDIBLE STORY TO DISENTANGLE THE ORIGIN OF THE STABILITY OF MATTER
FROM THE ANTIELECTRON TO ANTIMATTER
AND THE UNIFICATION OF ALL GAUGE FORCES

The validity of C invariance from 1927 to 1957.

After the discovery by Thomson in 1897 of the first example of an elementary particle, the Electron, it took the genius of Dirac to theoretically discover the Antielectron thirty years after Thomson.

1927 → Dirac equation [9]; the existence of the antielectron is, soon after, theoretically predicted. Only a few years were needed, after Dirac's theoretical discovery, to experimentally confirm (Anderson, Blackett and Occhialini [10]) the existence of the Dirac antielectron.

1930-1957 → **Discovery of the C operator** [(charge conjugation) H. Weyl and P.A.M. Dirac [11]]; discovery of the P Symmetry Operator [E.P. Wigner, G.C. Wick and A.S. Wightman [12, 13]]; discovery of the T operator (time reversal) [E.P. Wigner, J. Schwinger and J.S. Bell [14, 15, 16, 17]]; discovery of the CPT Symmetry Operator from RQFT (1955-57) [18].

1927-1957 → Validity of C invariance: e^+ [10]; $\bar{p}$ [19]; $\bar{n}$ [20]; $K_2^0 \to 3\pi$ [22] but see LOY [22].

The new era starts: C ≠ ; P ≠ ; CP ≠ (*) .

1956 → Lee & Yang P ≠ ; C ≠ [23].

1957 → Before the experimental discovery of P ≠ & C ≠, Lee, Oehme, Yang (LOY) [22] point out that the existence of the second neutral K-meson, $K_2^0 \to 3\pi$, is proof neither of C invariance nor of CP invariance. Flavour antiflavour mixing does not imply CP invariance.

1957 → C.S. Wu et al. P ≠ ; C ≠ [24]; CP ok [25].

1964 → $K_2^0 \to 2\pi \equiv K_L$: CP ≠ [26].

1947-1967 → QED divergences & Landau poles.

1950-1970 → The crisis of RQFT & the triumph of S-matrix theory (i.e. the negation of RQFT).

1965 → Nuclear antimatter is (experimentally) discovered [27]. See also [8].

1968 → The discovery [28] at SLAC of Scaling (free quarks inside a nucleon at very high q^2) but in violent (pp) collisions no free quarks at the ISR are experimentally found [29]. Theorists consider Scaling as being evidence for RQFT not to be able to describe the Physics of Strong Interactions. The only exception is G. 't Hooft who discovers in 1971 that the β-function has negative sign for non-Abelian theories [30].

1971-1973 → $\beta = -$; 't Hooft, Gross & Wilczek. The discovery of **non-Abelian** gauge theories. Asymptotic freedom in the interaction between quarks and gluons [30].

1974 → All gauge couplings $\alpha_1\ \alpha_2\ \alpha_3$ run with q^2 but they do not converge towards a unique point.

1979 → A.P. & A.Z. point out that the new degree of freedom due to SUSY allows the three couplings $\alpha_1\ \alpha_2\ \alpha_3$, **to converge towards a unique point** [31].

1980 → QCD has a "hidden" side: the multitude of final states for each pair of interacting particles: (e^+e^- ; $p\bar{p}$; πp; Kp; νp; pp; etc.) The introduction of the Effective Energy allows to discover the Universality properties [32] in the multihadronic final states.

1992 → All gauge couplings converge towards a unique point at the gauge unification energy: $E_{GU} \cong 10^{16}$ GeV with $\alpha_{GU} \cong 1/24$ [33, 34] .

1994 → The Gap [35] between E_{GU} & the String Unification Energy: $E_{SU} \cong E_{Planck}$.

1995 → **CPT loses its foundations at the Planck scale (T.D. Lee)** [36].

1995-1999 → **No CPT theorem from M-theory (B. Greene)** [37].

1995-2000 → A.Z. points out the need for new experiments to establish if matter-antimatter symmetry or asymmetry are at work.

(*) The symbol ≠ stands for "Symmetry Breakdown".

Figure 22

APPENDIX B

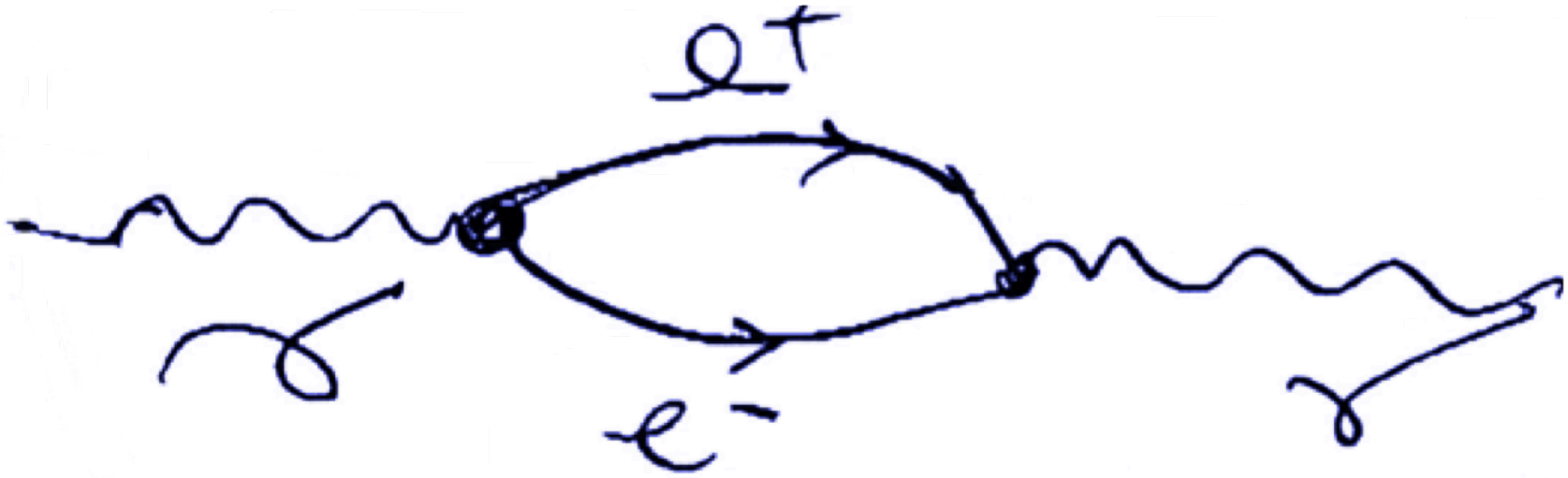
BLACKETT

The discovery of the "Vacuum Polarization" (1932) [the 1st example of radiative effect: pre-the Lamb-shift (1947)]

Before the Lamb-shift

Blackett ≡ experimental discovery of the "Vacuum Polarization"

The 1st Virtual Physics effect



ANTONINO ZICHICHI

MY TESTIMONY ON LORD PATRICK M. S. BLACKETT

A LESSON FOR THE FUTURE OF OUR SCIENCE

The content of this book
has its basis in two lectures and two books.

The two lectures are:

"MY TESTIMONY ON LORD PATRICK M.S. BLACKETT"
delivered at the Clore Lecture Theatre – Imperial College,
London, 30th April 2014 and the

"OPENING LECTURE"
at International School of Subnuclear Physics,
Erice, 25 June 2014.

The two books:

"CREATIVITY IN SCIENCE"
[first edition (1996), World Scientific (1999), translated into
Russian and published by YPCC, Moscow (2001)] and

"SUBNUCLEAR PHYSICS - THE FIRST FIFTY YEARS"
[a joint publication by the University and the Academy of
Sciences of Bologna, Italy (1998),
World Scientific, two editions (2000–2001)].

My Testimony on Lord Patrick M. S. Blackett

A Lesson for the Future of Our Science

Antonino Zichichi

University of Bologna and INFN, Italy
CERN, Geneva, Switzerland
Enrico Fermi Centre, Rome, Italy
Pontifical Academy of Sciences, Vatican City
World Federation of Scientists, Beijing, Geneva, Moscow, New York
Ettore Majorana Foundation and Centre for Scientific Culture, Erice, Italy

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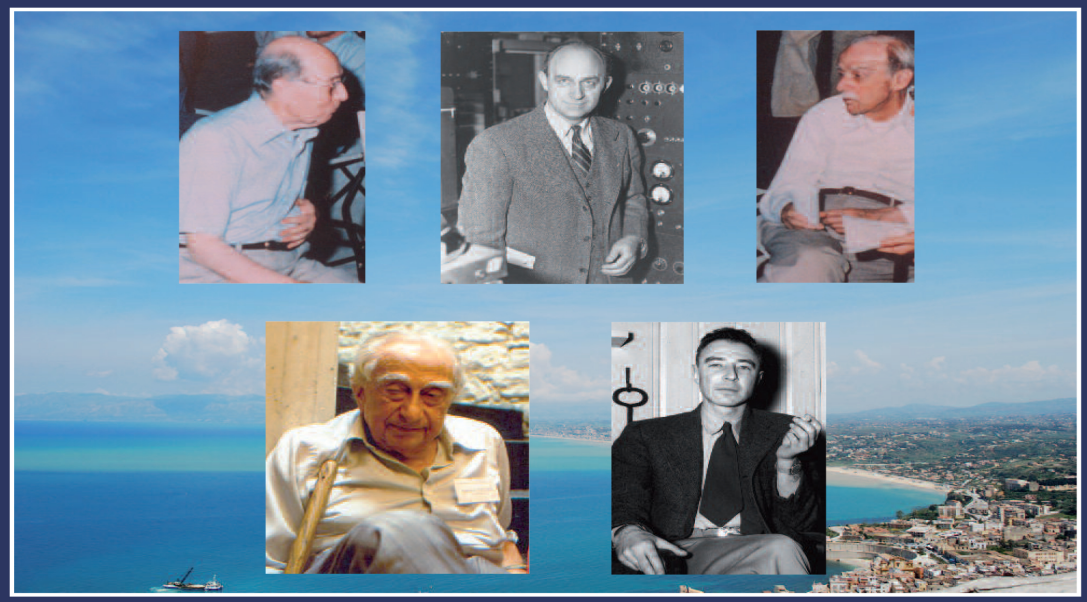
THE NEW MANHATTAN PROJECT CULTURAL HIROSHIMA 72 PLANETARY EMERGENCIES

THE NEW MANHATTAN PROJECT Science for Peace the World Over
ANTONINO ZICHICHI

THE NEW MANHATTAN PROJECT

Science for Peace the World Over



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Ettore Majorana Foundation and Centre for Scientific Culture, Erice, Italy

INTRODUCTORY SUMMARY

This book is a contribution to the THREE DAYS that the University of Bologna has dedicated to Science, Technology and Culture, so that they enter into the Heart of Everybody.

We are in the **Cultural Hiroshima**, as Fermi feared in the middle of the last Century, when (1945) we were in full Political Hiroshima.

The *Three Days* of Bologna has two objectives: to defeat the Cultural Hiroshima and to solve the problems of Planetary Emergencies, proposing the implementation of a project so that the great achievements of Science come soon in every day life.

The book has some parts in Italian and others in English, which is the universal language of Science.

The parts in Italian will be translated into all the other languages by our colleagues of WFS.

Figure 1 describes the Political Hiroshima (1945) and the Cultural Hiroshima (today).

Figure 2 illustrates the logic of the Project (The New Manhattan Project).

Figure 1

⊙ **POLITICAL HIROSHIMA (1945)**

The existence of Science is totally forgotten (for decisions at very high political level) as if it were not **thanks** to Science that the **new** war **Technologies**, million times more powerful, had been implemented.

⊙ **CULTURAL HIROSHIMA (NOW)**

The existence of Science is totally forgotten for political decisions (at any level) and in every day life as if it is not **thanks** to Science that the **new Technologies** have been invented: technologies which allow to win life-threatening illness, technologies that liberate from rough work and that allow humanity to have a standard of living never before achieved.

Figura 1

⊙ **HIROSHIMA POLITICA (1945)**

Ignorare la Scienza (nelle decisioni politiche di altissimo livello) e andare avanti come se non fosse **grazie** alla Scienza che sono state prodotte le **nuove Tecnologie** belliche, milioni di volte più potenti.

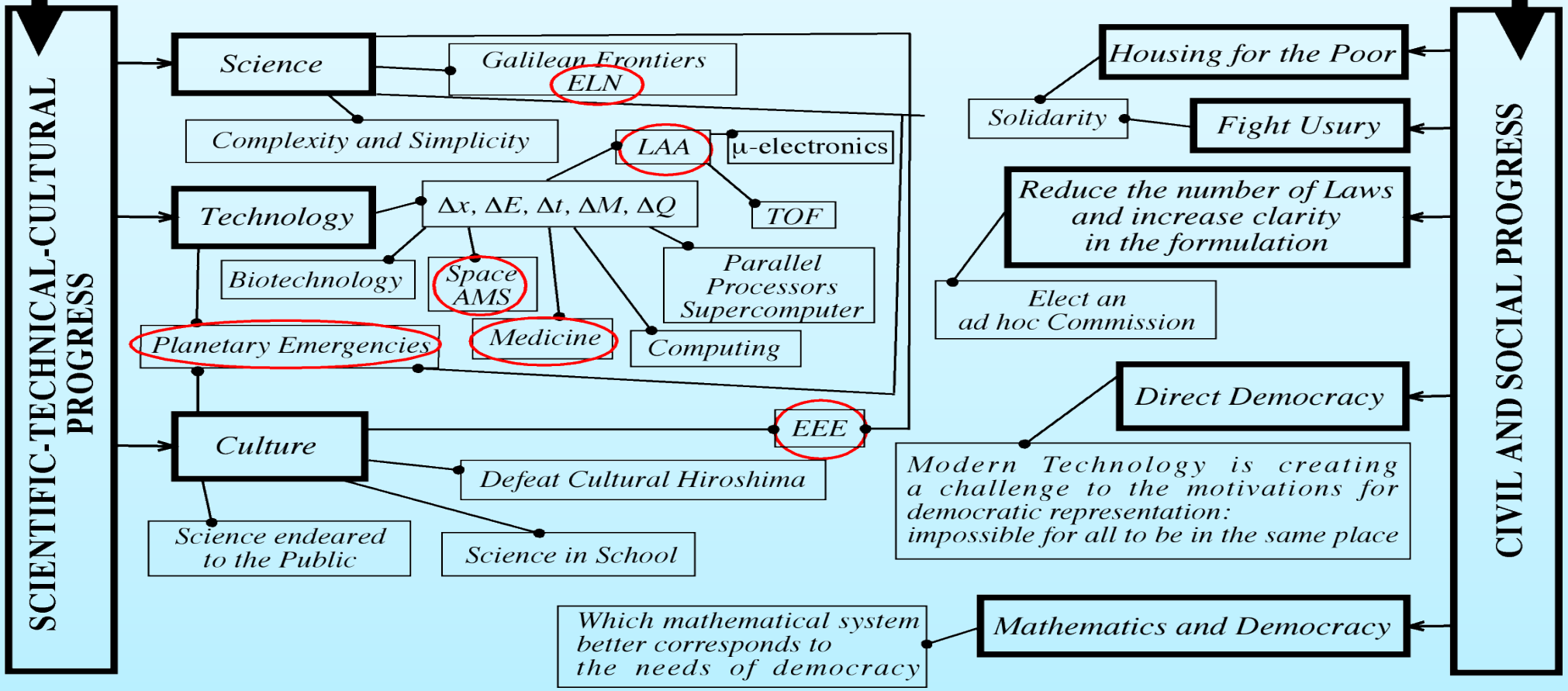
⊙ **HIROSHIMA CULTURALE (OGGI)**

Ignorare la Scienza nelle decisioni politiche (di qualsiasi livello) e nella vita di tutti i giorni come se non fosse **grazie** alla Scienza che sono state prodotte le **nuove Tecniche** che fanno superare malattie altrimenti letali, che liberano la forma di materia vivente cui apparteniamo da lavori spiacevoli e che permettono una qualità di vita mai prima raggiunta.

A PROJECT FOR MANKIND

SCIENCE FOR PEACE THE WORLD OVER: THE NEW MANHATTAN PROJECT

THE LOGICAL STRUCTURE OF THE PROJECT



ENCLOSURES:
1 ELN (300 KM: 10^6 GEV = 10^3 TEV = 1 PEV)
2 LAA (NEW TECHNOLOGIES FOR SPACE, TIME, ENERGY AND MASS)
3 EEE (EXTREME ENERGY EVENTS – SCIENCE IN SCHOOLS)
4 PLANETARY EMERGENCIES (PILOT-PROJECTS)
5 THE LOGICAL ROOTS OF COMPLEXITY

Figure 2

THE NEW MANHATTAN PROJECT

Science for Peace the World Over

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I L'Hiroshima Culturale potrebbe portarci a ripetere l'errore fatto con le due invenzioni mai capite dall'alba della Civiltà a Galilei

I-1 L'obiettivo della *Tre Giorni* di Bologna

La *Tre Giorni* che il Rettore Ivano Dionigi ha voluto dedicare alla Scienza alla Tecnica e alla Cultura, affinché entrino nel cuore del grande pubblico, ha come obbiettivo la lotta all'Hiroshima Culturale e la realizzazione del **Nuovo Progetto Manhattan** affinché le 72 Emergenze Planetarie possano essere affrontate e risolte.

La *Tre Giorni* di Bologna vuole portare al centro dell'attenzione mondiale l'Hiroshima Culturale proponendo la realizzazione di un "**Nuovo Progetto Manhattan**" affinché le grandi conquiste della Scienza producano invenzioni tecnologiche da usare nella vita di tutti i giorni. Non aspettando decine di migliaia di anni come avvenne con la **ruota** e il **fuoco**, né cento anni come avvenne con l'elettrone, ma facendo tesoro subito delle grandi scoperte scientifiche. Ecco perché è necessario che nessuno dimentichi la lezione che ci dà la Storia della nostra Civiltà. E cioè che se non fosse stato per Galilei avremmo potuto continuare a essere ancora oggi come i nostri antenati che, nel corso di decine di migliaia di anni, vissero con tecnologie totalmente equivalenti in quanto tutte erano basate sull'uso della **ruota** e del **fuoco** per un motivo molto semplice: nessuno era mai riuscito a capire **l'attrito** e la trasformazione della **massa in energia**.

Il **Nuovo Progetto Manhattan** ha le sue basi nei risultati ottenuti con 100 progetti-pilota realizzati da una comunità scientifica che coinvolge 150 Nazioni. I risultati ottenuti dimostrano che è possibile affrontare le Emergenze Planetarie e – se c'è volontà politica – superarle.

L'Università di Bologna ha il privilegio di essere, non solo la **più antica Università** del mondo occidentale, ma oggi il **fulcro** di un Progetto dalla cui realizzazione dipende il futuro che noi vogliamo assicurare ai nostri posteri, liberandoli dalle 72 Emergenze Planetarie.

Affinché il **Nuovo Progetto Manhattan**, possa diventare realtà è di vitale importanza che le grandi conquiste della Scienza e della Tecnica entrino nella vita di tutti i giorni, quindi nella Cultura del nostro tempo. Solo così può nascere la volontà politica in grado di liberare il futuro dell'Umanità dall'incubo dalle 72 Emergenze Planetarie. Una sintesi di queste Emergenze è riportata in questo volume. Per superarle è necessario capire le basi della posta in gioco.

Se **non c'è volontà politica** una scoperta scientifica impiega decine e decine di anni prima di entrare nella vita di tutti i giorni. La prova viene dalla scoperta del più piccolo "pezzettino di elettricità" cui venne dato il nome di "elettrone".

Viviamo l'era della tecnologia elettronica che – solo adesso – è entrata nella vita di tutti i giorni: telefonini, TV, radio, TAC, internet, e innumerevoli tecnologie mediche, non potrebbero esistere senza la scoperta dell'elettrone, fatta da J.J. Thomson oltre cent'anni fa (nel 1897).

Se ci fosse stato a quei tempi un Governo in grado di varare un **Progetto-tipo-Manhattan** per lo studio delle tecnologie che dovevano scaturire dalla scoperta dell'elettrone, oggi avremmo le invenzioni tecnologiche che i nostri posteri avranno fra cent'anni.

I-2 Cosa insegna il Progetto Manhattan

Il famoso **Progetto Manhattan** riuscì – in appena tre anni (1942-1945) – a trasformare una scoperta scientifica (la fissione nucleare) in "fuoco nucleare di pace" (reattori a fissione) e "fuoco nucleare di guerra" (Hiroshima e Nagasaki).

Il Progetto Manhattan insegna che – **se c'è volontà politica** – una scoperta scientifica può diventare tecnologia "pro" e "contro" la vita e la dignità umana nel giro di pochi anni. Attenzione però. È necessario impedire le invenzioni tecnologiche "contro".

Il motore del progresso è infatti la scoperta scientifica, che genera invenzioni tecnologiche: sta qui il problema.

Le invenzioni possono essere a scopi di pace ma anche a scopi di guerra. Sono infatti le invenzioni tecnologiche "pro" e mai "contro" che hanno portato all'attuale livello di vita: il più alto nella storia dell'Umanità.

Nel famoso incontro di Ginevra (1985), i due più potenti Capi di Stato (Ovest ed Est), Reagan e Gorbachev, dissero che il nemico n. 1 della pace nel mondo erano (e sono) i Laboratori segreti.

THE 72 PLANETARY EMERGENCIES IDENTIFIED BY THE ERICE SCIENTISTS AND CLASSIFIED INTO 15 BASIC SOURCES		NUMBER OF SOURCES
I	*WATER*	4
II	*SOIL*	3
III	*FOOD*	5
IV	*ENERGY*	5
V	*POLLUTION*	7
VI	*LIMITS OF DEVELOPMENT*	4
VII	*CLIMATIC CHANGES*	5
VIII	*GLOBAL MONITORING OF THE PLANET*	6
IX	*NEW MILITARY THREATS IN THE MULTIPOLAR WORLD*	3
X	*SCIENCE AND TECHNOLOGY FOR DEVELOPING COUNTRIES TO AVOID A NORTH-SOUTH ENVIRONMENTAL HOLOCAUST*	3
XI	*THE PROBLEM OF ORGAN SUBSTITUTION*	5
XII	*MEDICINE, INFECTIOUS AND OTHER DISEASES*	7
XIII	*CULTURAL POLLUTION*	8
XIV	*INFORMATION SECURITY AND COMMON DEFENSE AGAINST COSMIC OBJECTS*	2
XV	*THE HUGE MILITARY INVESTMENTS*	5
	Total	**72**

(From left) Luigi Dadda, Pierre A. Piroué, Enrico Bignami, Yuval Ne'eman, Richard L. Garwin, John C. Eccles, Eugene P. Wigner, A.Z., Edward Teller, Paul A.M. Dirac, George Charpak. This is one of the first sessions devoted to the Erice Statement and to the future of our planet.

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UNIVERSITÀ
DI BOLOGNA
19-21 GIUGNO 2015
Partiti insieme per un lungo viaggio,
torniamo a casa per diverse vie.
Catullo
PROGRAMMA

11.00 **Palazzo Re Enzo | Sala di Re Enzo**

SCONFIGGERE L'HIROSHIMA CULTURALE: UN PO' DI SCIENZA NELLA VITA DI TUTTI I GIORNI

Perché le scoperte scientifiche impiegano decine di anni per diventare tecnologia? Un programma di informazione scientifica per convincere le organizzazioni mondiali a sostenere politicamente ed economicamente la ricerca scientifica e risolvere le emergenze planetarie.

- **Antonino Zichichi**, Fisico, intervistato da **Fabrizio Binacchi**, Direttore Rai Emilia Romagna

REFERENCES

[1] A record of the annual evolution in the multitude of baryonic and mesonic states can be found in the proceedings of the Erice Schools [1bis]. An example of the proliferation in the meson resonances is "*Meson Resonances and Related Electromagnetic Phenomena*", R.H. Dalitz and A. Zichichi (eds), Editrice Compositori, Proceedings of the EPS Conference, Bologna (1971).

[1bis] The progress of Subnuclear Physics as reported in the Erice School books whose titles follow.
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