WHAT'S NEXT IN ACCELERATOR PARTICLE PHYSICS?

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ABSTRACT

With LHC in full construction and proposals on the floor for linear electron–positron colliders in the sub-TeV region, it may be the right time to look forward to the long-term future of Accelerator Particle Physics. A synthetic view of the physical problems and of the accelerators currently being considered for their study is presented. Special attention is given to the multi- TeV energy region which, according to recent studies, is crucial for a full understanding of the physics beyond the Standard Model. Present attempts to devise second-generation, long-baseline neutrino beams are also reviewed. The need for a vigorous R&D on accelerator physics is clearly borne out by the arguments presented in this talk.

1. Introduction

The story has it, as is well known in all Physics Departments in Italy, that Fermi had considered a maximal proton accelerator with a ring going around the Earth. This story emerged again at a CERN seminar, when Fabiola Gianotti showed the logo of the Very Large Hadron Collider project, Fig. 1.

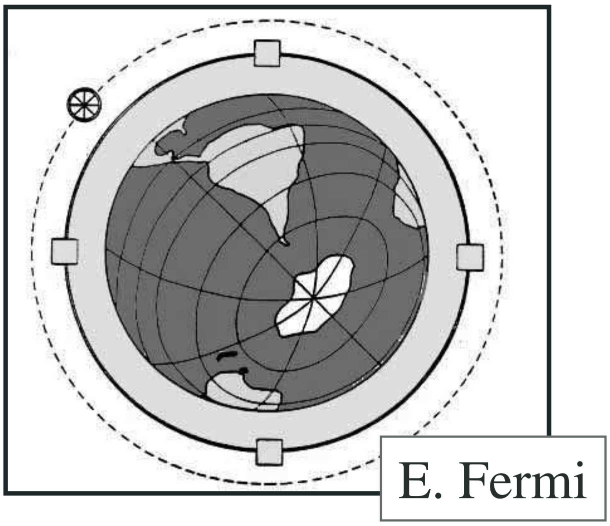

Figure 1: The logo of the Very Large Hadron Collider project at FermiLab.

A brief search carried out at the University of Chicago Library (thanks to Adrienne Kolb, Mark Oreglia and James Pilcher) produced a much more articulated picture.

The figure is in fact Fig. 1 of the talk 'What Can We Learn With High Energy Accelerators?' that Enrico Fermi presented at the American Physical Society, on 29 January 1954. Fermi was then leaving the APS Chair which he had taken during 1953. The University of Chicago Library has short personal notes that Fermi wrote for the talk as well as the slides of the figures. With typical insight, Fermi went directly to considering a proton accelerator with the Earth's radius as the maximum reachable. Assuming a magnetic field of 2 T, this gives an energy: $E_{\mathrm{Max}} \approx 5 \times 10^{15}$ eV. It is the energy of the cosmic rays around the 'knee', the most energetic cosmic rays that can be accelerated by the galactic magnetic clouds, according to Fermi's ideas developed in the very same years[1)]. By extrapolating with the available Livingstone plots of energy or money vs time, Fermi concluded that this energy could be reached in the year 1994, at a cost of about $170 billion.

It must be said that Fermi's successors did not fare badly at all. Transforming back to fixed-target energy, the Tevatron (2 TeV in the c.o.m.) reached 2×10^{15} eV in 1987. LEP and HERA have explored about the same energy range with the electron–positron probe (something unthinkable at Fermi's time) and the electron–proton probe. The LHC (14 TeV in the c.o.m.) will reach 1×10^{17} eV in 2006, 20 times E_{Max}, at an all-out cost of about $5 billion. If the VLHC which is being considered today at FermiLab or the Eloisatron proposed by INFN will materialise, with a c.o.m. energy of 200 TeV and a corresponding fixed-target energy around 2×10^{19} eV, mankind will have been able to produce collisions at an energy equivalent to that of the highest-energy cosmic rays that can originate from nearby galaxies, that is those below the GZK cut-off due to the onset of hadron photoproduction in the scattering of cosmic ray protons off the microwave cosmic background photons.

The key to high energy and relatively low cost (very low indeed, compared to Fermi's extrapolation) is of course technological innovation, above all the invention of the colliders: electron–positron (AdA, Frascati, 1962), proton–proton (ISR, CERN, 1971), proton–antiproton (Sp$\overline{\mathrm{p}}$S, CERN, 1981). We must do all we can to keep innovation going in the particle accelerator world.

What to do with the high energy? Fermi underlines the difficulty of looking into a "very, very cloudy crystal ball". He mentions the observation of antinucleons, the puzzle of the long lifetime of strange particles (high angular momentum barrier? associated production "at present more probable"?), the need for precision measurements. But also the possibility of "a lucky break, or theoretical leap, or more probably a combination of hard work, ingenuity and a little bit of good luck".

All that and much more did in fact happen from the 1950s until now in High-Energy Particle Physics. Progress is exemplified in Fig. 2, by the chart of what are now considered the elementary constituents of matter, the three generations of quarks and leptons.

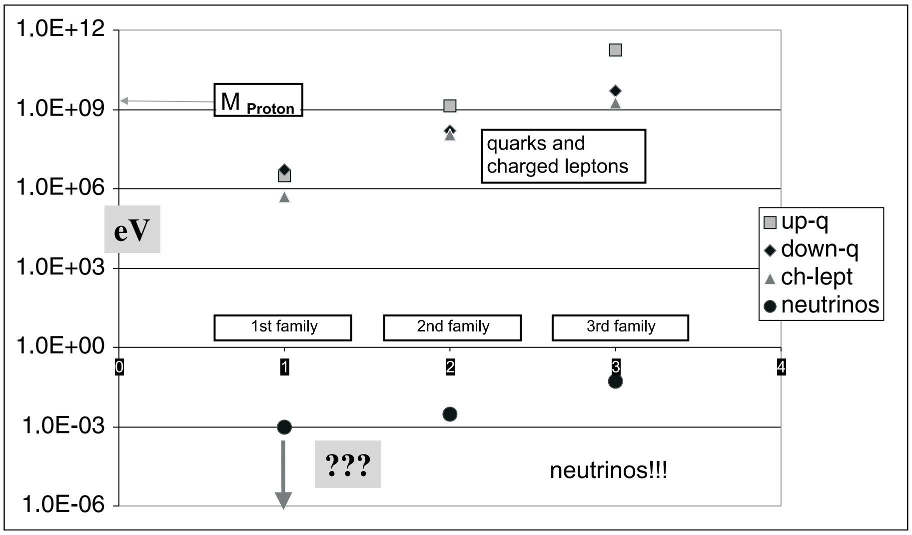

Figure 2: Mass spectrum of quarks and leptons. Upper bounds to neutrino masses are taken from beta decay spectra; estimates of ν_μ and ν_τ masses are from solar and atmospheric neutrino oscillations.

2. What's Next in Particle Physics?

The Standard Theory gives an accurate picture of the elementary particle interactions, but it leaves several open questions. The Higgs boson has not yet been observed. The naturalness of Standard Theory parameters requires a change at a critical energy around 1 TeV. Neutrino masses are exceptionally small, on the scale of other constituents' masses, and may indicate new interactions at very high energy. The first two issues call for accelerator searches, at the Tevatron, the LHC and beyond. Neutrino masses are investigated via the phenomenon of neutrino oscillations, probably seen in solar and atmospheric neutrinos but to be confirmed with long-baseline neutrino beams and dedicated neutrino factories, as well as more advanced non-accelerator facilities (SNO, Borexino, Kamland).

In addition, merging the Standard Theory with gravity requires additional (curved) space-dimensions. Recent speculations raise the possibility that indications of the new dimensions may be found already in the TeV region, again an objective for high-energy accelerators.

I shall review these issues in turn. Of course, some of these ideas may evaporate when confronted with real data (many suspect that this will be the case of supersymmetry) and there is always the possibility of a "lucky break". Nonetheless, for the planned facilities these ideas provide useful benchmarks, which are needed for decision making.

2.1. The Higgs Boson

Direct searches at LEP have excluded a mass below 113 GeV. A positive signal with a significance of 2.9σ has been reported by the LEP Collaborations in the year 2000 run[2], at a mass $M_{\rm H} = 115 \pm 1$ GeV.

This value is fully consistent with the fact that the overall fit to the electroweak observables, Fig. 3, gives tantalizingly small values of $M_{\rm H}$, namely[3]:

$$M_{\rm H} = 60^{+52}_{-29}\ \text{GeV}$$
$$(95\%\ \text{c.l.} : M_{\rm H} < 165\ \text{GeV})$$

(higher-order corrections as in the solid line of Fig. 3) or, more conservatively:

$$M_{\rm H} = 88^{+60}_{-17}\ \text{GeV}$$
$$(95\%\ \text{c.l.} : M_{\rm H} < 206\ \text{GeV})$$

(higher-order corrections as in the dotted line).

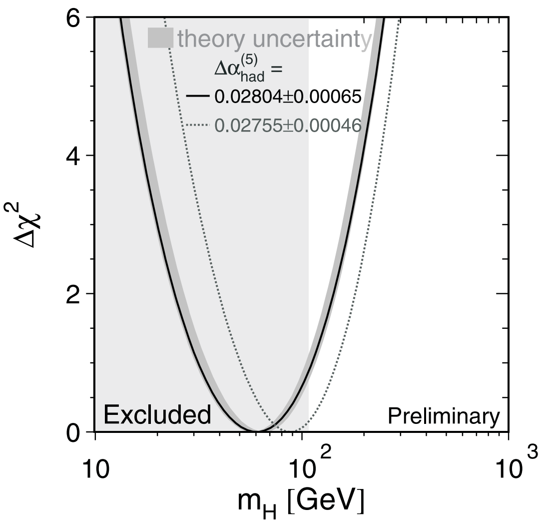

Figure 3: χ^2 vs. $M_{\rm H}$ curve in the overall fit to the electroweak observables[3]. The shaded band is the region excluded by direct searches at LEP.

After LEP, Higgs boson hunting will be taken over by the Tevatron, the LHC and possibly by a sub-TeV electron–positron linear collider. The branching ratios of the Higgs boson in a few crucial channels ($\rm WW^*$, $\rm ZZ^*$, gg) can be determined to 10% accuracy with the LHC, and even better with TESLA/NLC/JLC colliders[4], with few to several per cent accuracy and including the additional channels: bb, cc, $\tau\tau$.

The Higgs trilinear coupling is crucial for the final test of spontaneous symmetry-breaking in the electroweak interactions. The trilinear coupling can be determined by the double Higgs boson production $\left(e^+e^- \to \nu\bar{\nu}HH\right)$ at a sub-TeV linear collider or, with a much more favourable cross-section, at a multiTeV collider[5)] (Fig. 4).

- Extract λ_{HHH} from $\sigma\left(e^+e^- \to \nu\nu HH\right)$ for $M_H = 120$ GeV/ c^2
- $\sigma\left(e^+e^- \to \nu\nu HH\right) \simeq \sigma\left(e^+e^- \to \nu\nu ZZ \to b\bar{b}\right)$

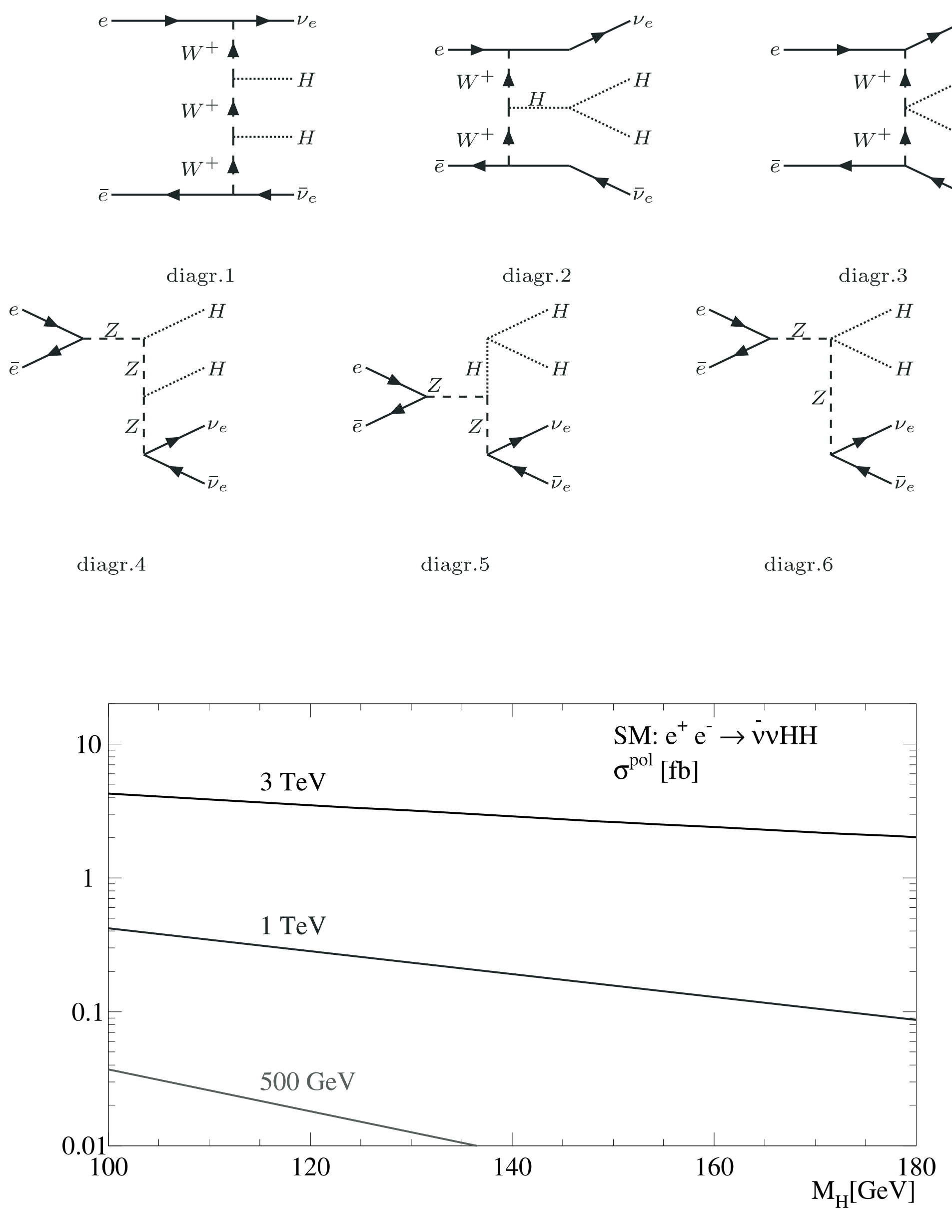

Figure 4: Feynman diagrams and cross section vs M_{H} for the double Higgs boson at an electron–positron collider (total energy 0.5, 1 and 3 TeV)[5)].

2.2. Supersymmetry

The spectrum of supersymmetric partners of quarks and leptons is widely different in the different models of supersymmetry breaking. In a recent study[6)], a number of representative models were chosen and the discovery potential of different accelerators was evaluated for each model. The results, Fig. 5, show clearly that the LHC and a sub-TeV e^+e^- collider are complementary, but indicate in addition that a further step into the multi-TeV region is needed for full understanding of the spectrum and therefore of the supersymmetry breaking mechanism, for instance by a multi-TeV, linear e^+e^- or muon collider.

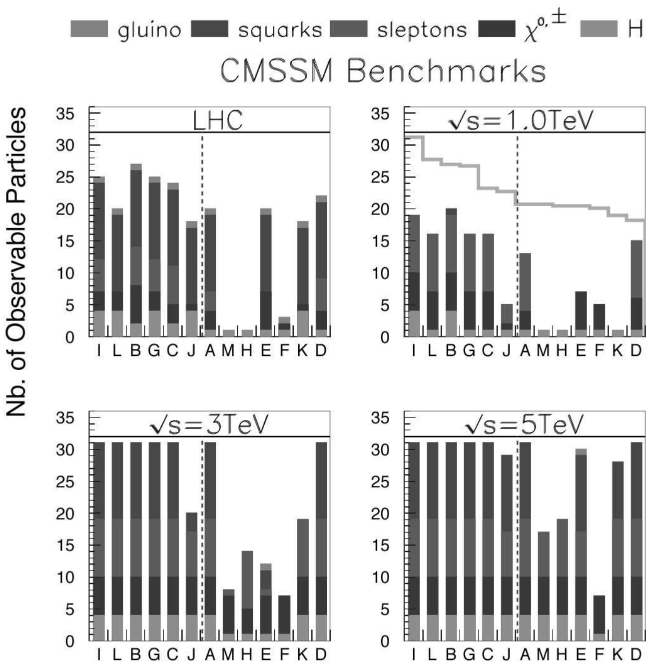

Figure 5: Number of SUSY particles observed in different models at the LHC and at e^+e^- linear colliders of 1.0, 3 and 5 TeV total energy[6)].

2.3. Neutrino Oscillations

After the very important SuperKamiokande result[7)], attention is being concentrated on the oscillations of muonic neutrinos in the region $\Delta m^2 \approx 10^{-2}$ to 10^{-3} eV^2. Remarkably, this mass range is the natural one if neutrino masses arise from non-renormalizable couplings[8)], indicative of new interactions at a high energy scale, Λ.

Assuming a term of the form (l denotes the left-handed lepton doublet, Majorana representation assumed):

$$L_{\mathrm{mass}} = \frac{g}{\Lambda}\left(\phi\tau_2\vec{\tau}\phi\right)\left(l_{\mathrm{L}}\tau_2\vec{\tau}l_{\mathrm{L}}\right).$$

One finds, for $\Lambda \approx 10^{15}$ GeV, a mass of the order of the tau neutrino mass indicated by the SuperKamiokande effect:

$$m^2 = \left[\frac{g\langle\phi\rangle^2}{\Lambda}\right]^2 = 1.6\cdot 10^{-2}\ \mathrm{eV}^2\left[g\left(\frac{\langle\phi\rangle}{200\ \mathrm{GeV}}\right)^2\left(\frac{10^{15}\ \mathrm{GeV}}{\Lambda}\right)\right]^2.$$

Long-baseline neutrino beams offer the opportunity to study in detail neutrino oscillations in the mass range indicated by the atmospheric neutrinos. The K2K (KEK to Kamioka, 250 km) beam is already operating in Japan[9)]. NuMi (Neutrinos to Minos, from FermiLab to the Soudan mine, 730 km) and CNGS (CERN Neutrinos to Gran Sasso, 730 km) are under construction.

2.4. Extra Dimensions?

String and superstring theories are consistent only in high-dimensional spaces. The success of these concepts in providing a consistent scheme of quantum gravity speaks by itself in favour of the existence of hidden, curved, additional dimensions. The idea was first advanced in the 1930s by P. Kaluza and by O. Klein. However, nothing is known about the radius associated with the extra dimensions, and therefore about the energies needed to probe the new space domains. Recently, it was observed that superstring theories give the possibility that the particles associated with the electroweak and strong forces live in lower-dimensional manifolds, D-branes, only gravitons being able to propagate in the full multidimensional space. The idea offers another intriguing possibility, namely that the largeness of the Planck mass (or the smallness of the Newton constant) can be explained by geometrical factors which relate the 4-dimensional world explored by the 'normal' particles to the full n-dimensional space, probed by gravity. In this case, there could be only one fundamental mass scale, namely the 1 TeV scale associated until now to the electroweak interactions only[10)]. There are several variants of this idea, which all lead to a new phenomenology of particles in the TeV scale.

In the extreme case, where the n-dimensional Planck mass (the constant determining the strenght of n-dimensional gravity) is itself of the order of 1 TeV, the radius of the additional dimensions would be in the millimetre range[11)], for $n = 4+2$. The collisions of quarks or leptons could produce[12)], in this case, the full tower of Kaluza–Klein excited states of the graviton, leading to an observable cross-section for:

$$\mathrm{f} + \bar{\mathrm{f}} \to \mathrm{b} + \text{invisible particles}$$

(f stands for any quark or lepton, b for gluon or photon). Lower bounds to the n-dimensional Planck mass of the order of TeV have been derived already from LEP data, which show no deviation[13)], within errors, of the one-photon spectrum in the process:

$$e^+ + e^- \to \gamma + \text{undetected particles}$$

from the prediction of the Standard Theory. The presence of additional dimensions at higher energy scales would show up with non-renormalizable interactions of the known particles. If detected at the LHC, the opening up of the new dimensions could be observed with a Very Large Hadron Collider up to energy scales of the order of 100 TeV, the highest energies that we can realistically consider today.

3. The Optimist's Scenario

The strategy to address the issues raised in the previous section may go as follows. First the LHC, as soon as possible, to get access to the crucial TeV region. The LHC was designed not to miss the Higgs boson, over a wide range of masses. If Supersymmetry is there it should see at least precursor signals of it and give us precious indications about any further step. One must not underestimate the importance of building the LHC within schedule and within budget. After the SSC débâcle, we have to show that particle physicists can indeed manage projects of this dimension successfully.

An electron–positron Linear Collider (LC) in the sub-TeV region is also justified. It would give complementary information on the Higgs boson and, in case they exist, on Supersymmetry particles' spectrum. TESLA or NLC/JLC have reached a status of maturity which should allow one to go on to the execution phase. It is unclear if we can, or who can, afford it.

In a recent seminar, H. Sugawara[14)] has called the LHC and the e^+e^-, sub-TeV, LC 'precursor' machines. According to all indications, while we can indicate the TeV region as the crucial energy range to understand what is beyond the Standard Theory, it is difficult to believe that everything will be settled within exactly 1 TeV. If there is indeed any new physics, access to the multiTeV region will be crucial to explore it in depth, as the considerations previously illustrated make abundantly clear.

Thus, we need to envisage a further step, or steps, in the High-Energy Frontier.

Realistic possibilities are, today, a multiTeV e^+e^- LC, such as CLIC being studied at CERN, and a VLHC of the kind studied in FermiLab. Muon colliders could bring us to even higher energies and exceptional precisions but, according to all estimates, they are in the future.

With CLIC and the VLHC we could probe space–time, searching for extra dimensions up to 40–50 TeV... and try for a "lucky break".

Flavour physics should not be underestimated. Neutrino superbeams (i.e. ν_μ beams made from low-energy protons, so as to have a very low background in ν_e) will be a helpful stage towards a fully-fledged neutrino factory. The neutrino programme can be very useful to help differentiate the tasks of different regions, in an era which has to avoid duplication, yet must keep alive competition.

CP violation in hadronic systems, e.g. kaons and B mesons, makes an integral part of our attempt to understand flavour. The present B-factories and the foreseen B-physics at LHC seem to make quite a complete programme, however, at least for the moment.

4. Accelerators for the Future

I would like to describe here the efforts being made in several Laboratories to develop more advanced facilities. No claim of completeness, but I hope to give at least an idea of the vast amount of work which is being undertaken around the world, to get the instruments which will allow us to explore beyond the Standard Theory.

4.1. Towards a ν-factory

Figure 6 shows the CERN conceptual design of an advanced neutrino factory[15].

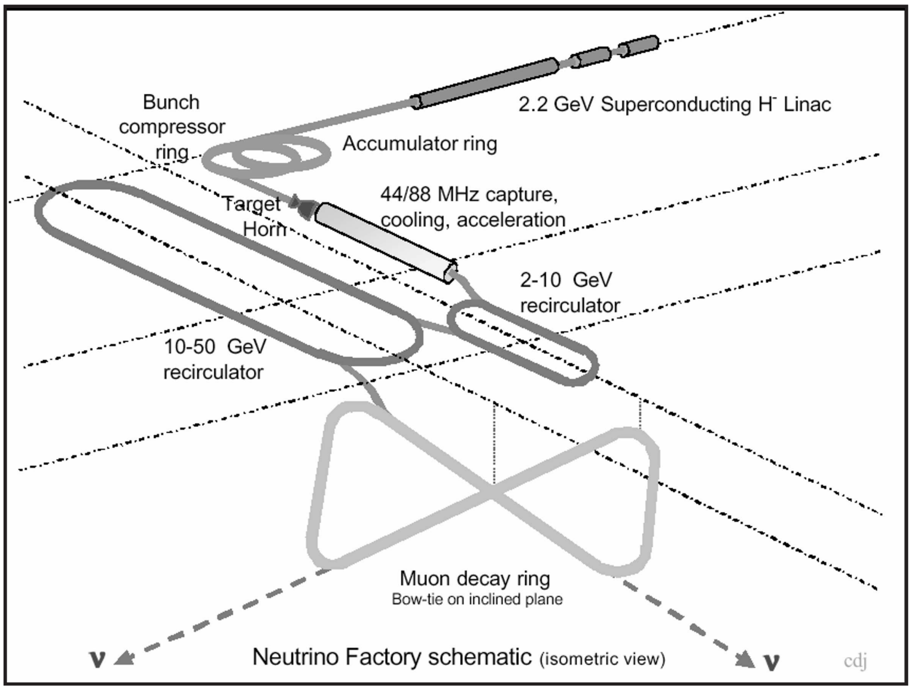

Figure 6: Isometric schematic of the CERN reference scenario for a neutrino factory.

Analogous studies have been made in FermiLab and Brookhaven. The first stage of a neutrino factory is the proton driver and the high-power target, where pions are produced from proton collisions. Muons from π decay are collected, cooled in transverse phase space (a reduction in transverse momentum by a factor of about 20), accelerated, and finally circulated in a decay ring. Muons decaying in the straight sections produce a very intense beam of muonic and electronic neutrinos. Owing to the V–A interaction, polarized μ^-'s of helicity -1 or $+1$, at $x = 1$ and in the very forward direction produce a pure ν_μ, or a three-to-one mixture of $\overline{\nu}_e$ and ν_μ, respectively[16)] (for μ^+'s, flip polarization and exchange neutrinos with antineutrinos). Thus, oscillations starting from well-determined flavour states can be observed and CP-violating asymmetries can be investigated[17)]. The range 10^{20}–$10^{21}\mu$ decays/year (roughly 10^{22}–10^{23} protons on target per year!) is considered necessary to observe CP violation, with an optimal baseline of 2000–3000 km, to limit matter effects in the neutrino propagation through the Earth.

In CERN's design, H^- ions are accelerated by a Superconducting Proton Linac (SPL) to 2.2 GeV. The conceptual design of the SPL has been completed[18)]. The front-end is very similar to the one under construction by CEA/CNRS and to which CERN could contribute the rf source in the form of two LEP klystrons. In the lower energy part, protons are accelerated by special cavities, designed to accelerate particles with $\beta < 1$. Superconducting cavities for $\beta = 0.8$ and 0.7 are under development (Fig. 7). The higher energy part is based on LEP rf modules containing four superconducting cavities.

Figure 7: The $\beta = 0.7$, 4-cell prototype for the SPL at CERN.

The H^- ions are stripped to become protons and are accumulated in a storage ring to get highest intensities. Proton bunches are compressed in length in another ring, before being ejected to the target.

R&D on a high-power target (4 MW) is in progress. The experimental determination of pion production at low energy, not so well known, and the study of the behaviour of highly irradiated rf cavities are also being made at CERN. The study of the second stage, mainly cooling, is a much more difficult story and has not found space, till now, in CERN's very compressed R&D programme. An international collaboration is being set up with the main European and US laboratories, to focus the available resources[19)].

An interesting intermediate step towards the neutrino factory is the SPL itself. Because of the low energy, kaons are not produced at the target. Pion decays would make a high-intensity, very pure ν_μ or $\overline{\nu}_\mu$ beam, thus allowing a precision study of $\nu_\mu \to \nu_e$ or $\overline{\nu}_\mu \to \overline{\nu}_e$ oscillations[20)] (contamination of ν_e's in a ν_μ beam would arise only from μ decays in the chain $\pi^+ \to \mu^+\nu_\mu \to e^+\nu_e\overline{\nu}_\mu\nu_\mu$). For the values of Δm^2 suggested by SuperKamiokande, a distance of the order of 60 to 100 km is required. Detectors at the bottom of Lake Geneva or in an underground laboratory along the new tunnel considered in Fréjus for the high-speed Lyon–Torino railway line, are being studied. Such a neutrino 'superbeam' would contribute to the determination of the third angle, θ_{13} (θ_{12} and θ_{23} being determined by solar and atmospheric or conventional long-baseline neutrinos, respectively), to an accuracy which is intermediate, on a logarithmic scale, between present studies (e.g. CHOOZ or K2K/MINOS/OPERA) and neutrino factories[21)]). The possibility to observe CP violation with a superbeam are limited. However, cost and difficulty are also roughly intermediate on a log-scale (about 0.5 GCHF vs. an order of magnitude of 2 GCHF) which makes superbeams quite an attractive possibility.

The SPL could be easily accommodated on the CERN site, Fig. 8, and it would be beneficial to ISOLDE, CNGS, LHC etc.

4.2. The MultiTeV Frontier: 1. The VLHC

A Very Large Hadron Collider is being studied at FermiLab[22)], to orient the relevant R&D. The idea is to consider a two-stage machine, in the same tunnel of 240 km. The first, low-field stage, VLHC1 ($B = 2$ T) envisages to reach 15 to 20 TeV per beam. The second high-field stage ($B = 10$ T) would reach 87.5 TeV per beam. The VLHC parameters are reported in Table 1. The similarity with the earlier Eloisatron project by INFN (Italy) is striking.

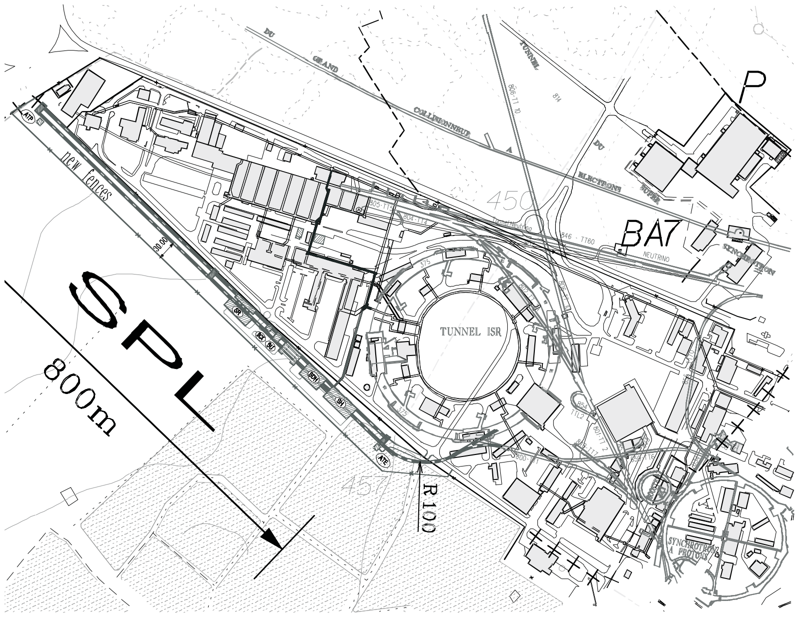

Figure 8: Layout of the SPL on the CERN site.

Table 1: Preliminary parameter list of the VLHC. FermiLab study (convenor J. Strait).

	Phase 1	Phase 2
E_{beam} [TeV]	20	87.5
B_{dip} [T]	2.0	10.0
R_{bend} [km]	33.3	29.1
Arc packing factor	95.0%	83.0%
C_{arc} [km]	220	220
$L_{\mathrm{straights}}$ [km]	20	20
C_{total} [km]	240	240
Luminosity [$\mathrm{cm}^{-2}\mathrm{s}^{-1}$]	10^{34}	10^{35}

Both VLHC phases envisage magnetic fields generated by superconducting systems. In the low-field case a superconducting conductor generates a cylindric field, with the two beam pipes running parallel to the superconductor, on opposite sides, so as to see opposite magnetic fields. High-field VLHC would borrow from LHC dipole technology, currently reaching 9 T with two-beams-in-one dipole design.

While the LHC could most likely be done with present technologies, the main problem of the VLHC is cost. R&D is directed towards improving cost efficiency, including tunnel boring technologies.

One major problem of the high-field machine will be synchrotron radiation. Increasing with the fourth power of energy, synchrotron radiation would deposit about 2 W/m on the beam pipe, compared to the 0.2 W/m of the LHC. In cryogenic machines, this power is expensive to carry away, due to the low temperature of the walls, where it is dissipated (thermal capacity vanishes like the fourth power of the absolute temperature). For this reason, in the LHC, there is an inner beam screen kept at about 19 K (gaseous helium cooling), considerably higher than the temperature of the cold mass of the dipoles (1.8 K, superfluid helium cooling).

On a different front, intensive R&D will be needed to develop detectors able to stand a luminosity of 10^{35} cm^{-2}s^{-1}. On the other hand, such an increase in luminosity with respect to the LHC (10^{34} cm^{-2}s^{-1}) is absolutely needed to make the energy discovery range to follow the increase in the beam energy (point-like cross-sections decrease with the square of beam energy).

VLHC does not seem to be the solution of choice for CERN, owing to the difficulty of excavating such a large tunnel. A preliminary study has considered an 80 km tunnel. It would have to go under Lake Geneva and through geologically difficult regions. Cost would be, most likely, forbidding.

4.3. The MultiTeV Frontier: 2. CLIC

Two-beam acceleration has been under development at CERN for over ten years and has been demonstrated in a test facility[23)]. The method could lead to high-gradient, multiTeV electron–positron linear colliders of reasonable length (whence the acronym, for Compact Linear Collider). The tentative design is optimized for a 3 TeV centre-of-mass collider but parameter sets for higher (5 TeV) and lower energy have also been examined. The design luminosity is 10^{35} cm^{-2}s^{-1} at 3 TeV with 154 bunches in a 102 ns long pulse and an overall wall plug power of 300 MW for the repetition frequency of 100 Hz.

The main linear accelerator is powered by an intense drive beam. This bunched beam which runs parallel to the main beam is decelerated in special structures where the beam energy is converted into pulsed 30 GHz microwave power (400 MW/m) which in turn is fed by short wave guides to the main linac, designed to operate at 150 MeV/m. The drive beam and main beam can be housed in a single tunnel as no second tunnel for modulators and klystrons is required.

Collaborations with INFN, IN2P3, and SLAC are active. Closer collaboration with European laboratories is being discussed (Orsay, RAL, Frascati). Physics studies have started.

CERN is now building a new test facility, CTF3, to further the study of the acceleration system. CTF3 will be built in collaboration with several groups at Orsay (France), Frascati (Italy) and SLAC. CTF3 will be housed in the LEP pre-injector building and should operate by 2003. CLIC will use the knowledge accumulated by the first generation of linear colliders, for what concerns the final focus and collision region. Intense, polarized photon beams can be produced by shooting a high-intensity laser against the electron or positron beams, so that a photon–photon collision facility could be added. If successful, CTF3 would be an important step towards the technical design of a 3–5 TeV collider. CLIC construction could start in the first part of the next decade, to begin physics before 2020, at the end of LHC exploitation. No significant problems are anticipated for the realization of the 40 km tunnel to house the collider, see Fig. 9, which would run parallel to Lake Geneva, in a geologically unproblematic region.

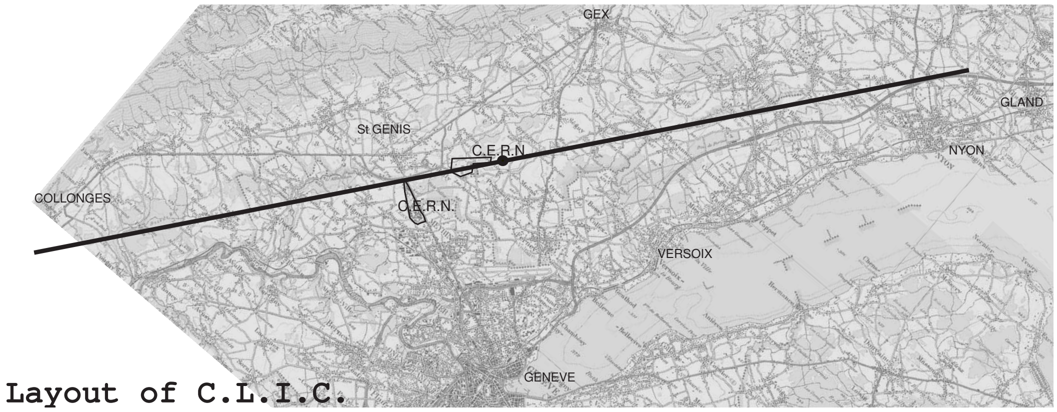

Figure 9: CLIC in the CERN region.

5. Conclusions

There are, indeed, many fascinating problems waiting for us in the 1–10 TeV region. They range from what we could call 'normal business', like finding the Higgs boson thereby confirming the present paradigm of gauge symmetry breaking, to 'new world' discoveries, like finding SUSY particles or extra dimensions, to the unknown.

The discovery of the W boson with fixed-target experiments would have required an antiproton beam of about the energy of the second phase of the VLHC! The key to the High Energy Frontier is, no doubt, technological innovation. Supporting research in accelerator physics is a must, more than ever, in order to reduce present estimates of cost and time-scale of future facilities.

A consensus seems to be forming, to complement the LHC with a sub-TeV, e^+e^- linear collider and to consider as further steps a multiTeV linear collider, such as CLIC, and a VLHC. A neutrino factory is also in the picture, which will enable us to progress on muon cooling technologies, in view of a muon collider further along in time.

Infrastructures like free electron lasers, high-intensity proton beams for neutron spallation sources, and extended data grids should complement the high-energy facilities, as gateways towards the application of particle physics technologies in other scientific and industrial communities.

The above programme is, of course, an optimal one. Compromises and reductions may be necessary. The problem, in fact, is: Can we make it in a reasonable time?

Can we afford it?

In the context of future facilities, the concept of a Global Accelerator Network, GAN, has been considered by ICFA (the International Committee for Future Accelerators). There is no consensus yet on what the GAN may be and what it could do for us.

I propose to see the GAN as a network of Laboratories which make R&D, plan and construct facilities (note the plural!) much like, today, business companies merge or airline companies operate flights together. Multinationals are supposed to do what national companies cannot do. Similarly, a GAN makes sense if we can realise, with it, something that will make real progress possible, such as the programme outlined above, which each individual region cannot do by itself.

The GAN should lead to a better efficiency in the decision making process. It should respect the geographical distribution of the users, which is essential to keep young generations, diffused in the Universities, in the game and to make more efficient use of the available resources.

A transition to the new global organization may be similar to the transition made in Europe from National Laboratories to CERN. It can be difficult, but the result may be worth trying.

6. Acknowledgements

It is a pleasure to acknowledge many enlightening discussions at CERN and elsewhere. In particular, I would like to thank R. Cashmore, J. Ellis, L. Evans, B. Gavela, F. Gianotti, G. Giudice, K. Hübner, K. Niwa and P. Strolin. I am grateful to Milla Baldo Ceolin for organizing this wonderful and ever exciting Conference.

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10) N. Arkani-Hamed and S. Dimopoulos, SLAC-PUB-8008, SU-ITP-98/62, hep-ph/9811353. See also M. E. Peskin in EPS HEP99, SLAC-PUB-8351 February, 2000, hep-ph/0002041; L. Hall *in* Int. Conf. on High Energy Physics, Osaka, July 2000.
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17) See e.g. P. Hernandez, this Conference.
18) M. Vretenar, Ed., Report of the Study Group on a Superconducting Proton Linac as a PS Injector, CERN/PS 98–063 (RF-HP), (1998); R. Garoby, M. Vretenar, CERN/PS/99–064 (RF), (1999).
19) An account of R&D at CERN in this area is found in: H. Haseroth CERN/PS 2000–064; see also http://molat.home.cern.ch/molat/neutrino/nfnotes.html
20) A low-energy beam from the PS to study oscillations was proposed some time ago, by M. Baldo Ceolin.
21) See J. J. Gomez Cadenas, this Conference. High-energy superbeams have been considered by B. Richter, hep-ph/0008222.
22) Information on the VLHC studies is found in: http://www-theory.fnal.gov/vlhc/vlhc.html
23) Information on CLIC studies is found in: http://cern.web.cern.ch/CERN/Divisions/PS/CLIC/General.html