物理･測定器専門委員会報告　　2004 年５月 18 日

1．LCWS2004 関係

(ア) 400 人以上の申し込みがあったが会場の制限のため参加者は 330 人｡アジアからは 40 名程度。内容、トピックスについては以下の関連資料を参考にしてください。

① 資料 1：LCWS２００４および WWS 会議の報告（By 山本氏）

② 資料２：4 月 23 日の WWS 委員会の議事録

③ 資料３：ITRP からの質問 30b,d に対する回答（4 月 23 日版ドラフト）
5/14 までコメントを受け付け修正する。最新版は
http://hep.uchicago.edu/~oreglia/Q30bd.pdf　にある。
内容は、500-1000GeV の LC は LHC の結果如何にかかわらず重要であることを ACFA、ECFA､US の Study Group の総意としてまとめたものとなっている｡CLIC を押す CERN の動きに対抗することを意識し、500-1000GeV 施設の重要性、LHC との比較・相補性・それを超える部分をまとめたもの（草稿にはアジアから宮本・岡田・山下が参加、他欧米各２名ずつ)。

④ 資料４：全世界で 2600 名以上が署名した LC の物理に関する”Consensus Report”のプレスリリース。http://www.interactions.org/　に掲載されている。

⑤ 資料５：測定器の CDR 作成、実験グループ結成に向けた進め方に関する、LCWS での全体議論の際の D.Miller 氏の報告。7 月末の Victoria （カナダ）での ALCWG の際の会合で WWS の提案をまとめ、8 月北京の ILCSC に報告する予定。

2．WWS の FALC に対する対応（この事情については資料 1 を参照のこと）

(ア) LCWS では､「ユーザーコミュニティーの意見を反映してもらいたい」との要望を FALC に伝えることになった。

(イ) 要望文書案に関して､WWS 委員内で E-mail discussion を進めている。ILCSC と協調して進めるべきである、との意見がある。

3．測定器に関する Warm/Cold 比較について

(ア) アジアの Contact Person は山下氏。

(イ) 検討項目と分担(Contact Person からの提案)：

① Energy, Luminosity, (+polarization 測定)：栗原、大森他

② IP 特に crossing-angle に起因する問題（上とも関連あり）: 田内他

③ タイミング（bunch ID issues）: 竹下、川越、藤井、宮本、松田、山下他

④ SiVTX 特に cold の場合の読み出しの問題 ：杉本、山本

(ウ) 6/28-29 Caltech の ITRP にて報告を行う。亜、欧、米から 1 名づつ Warm/Cold の話題を混ぜて発表する計画

資料１： LCWS2004（パリ、4/19〜23）の報告

（山本均氏 4/24 付けメールより）

パリ LCWS の報告を御送りします。

まず、M. Spiro の press release に対する要求について。 初日の午後だったと思いますが、M. Spiro が comment を 初め、UK での funding agency meeting において、2010 に sub-Tev LC と multi-TeV LC の選択をすることが 合意され、minutes にもあると言ったので、Wagner は すぐさまそのような合意は無かったと否定しました。 Consensus document の press release は in2p3 から なされる予定でしたが、M. Spiro（in2p3）が上の 「合意」を press release に入れようと提案したために 3 人の wws co-chair は協議の末、Consensus document は in2p3 を通さずに wws として出すことを決定しました。
Consensus document は press release の最終版が会議中に 書かれ、Rolf Heuer が concluding talk で発表しました。 press-release の text は添えつけてあります。

会議期間中に 3 回 WWS committee meeting が開かれました。 １回目と２回目は、extended members (asia からは、山下氏)を含まず、３回目は extended members も含めて 行われ、１回目は Jim Brau が、２回目は David Miller が、そして ３回目は山本が議長を務め、一応予定されていた課題をこなしました。 簡単にまとめてみます。

1. ITRP からの物理の質問に対する回答。
１回目の meeting で、wws として合同で回答を draft することが 決定され、すぐさま task force が形成されました。asia からは 山下、宮本、岡田（Y）に御願いしました。１日ほどで draft は かかれ、8 人の reviewers (asia からは駒宮、大森)によって review され、木曜午後の discussion session で Joanne Hewett によって発表され、３回目の wws meeting で承認されました。wws cochairs から lab directors と Barry Barish に送られる 予定です。

2. ILCSC からの detector に関する要請について。
その主旨は、どのようにして 2006 までにいくつかの CDR を出すように組織するかということです。
合意は、detector の段階は、加速器の段階に会わせること、現在存在し発展している global collaborations (CALICE for calorimeter, LC-TPC for TPC, Si-LC for Si tracker, etc.)を壊さないことです。具体的には、

- 2005 accelerator CDR - それに間に合うように detector cost estimate document をだす。複数の detector concepts に関する一つの document.
- 2007 accelerator TDR - いくつかの LOI を受け取る。ここで将来の collaboration の核が形成されます。Cost estimate に出てきた detector concepts と違っていても良い。
- 2008 site selection - detector TDR（書きはじめ）。TDR はおそらく ふたつ。LOI からの selection/merger を通しての形成。

回答は、Victoria (North America workshop) で最終版を確認するため WWS committee phone conference をする。今回はヨーロッパが 3AM 頃まで起きている番となる。 Beijing で ILCSC に渡す。（Cost estimation の段階で collaboration の核が形成してしまう 可能性は大きい。今、US は small detector の collaborator を 集めようと躍起になっている。ヨーロッパの Si-LC に主導権 をとられないようにと asia にも加わって欲しい様子。Asia 日本としては、GLC detector を押し進めるのか、Tesla detector に加わるのかを決めなければならない。）

3. ITRP Caltech Meeting (6/28,29)に technology の実験／物理 への影響を説明するグループを派遣する各地域から一人 organizer を選択、asia からは山下氏にお願いしました。

4. LC notes. World-wide な document system をつくる。 asian contact person: 宮本。

5. 次の LCWS は来年３月はじめ頃。北アメリカがホストする 番だが、VISA の問題が指摘された。

30b) How do you make the case for determining the final energy choice for the LC prior to the LHC results? What if LHC results indicate that a higher energy than design is required?

The physics case for the 200-500 GeV Linear Collider, upgradable to energies around 1 TeV, rests on arguments that are independent of the findings at the LHC. (We note that this design and upgrade energy are common to both the warm and superconducting technologies.) There are many reports that document this physics case. We cannot repeat all of these documented arguments, so will only recall the essential points here. The question of whether the top end energy should be 800 or 1000 GeV will be commented on at the end of this response.

1) Electroweak Symmetry Breaking: The LC will decipher the mechanism responsible for electroweak symmetry breaking, regardless of whatever it may be. If the standard model is a good low energy effective theory, the current precision electroweak data indicate that the Higgs boson is lighter than about 250 GeV. In addition, supersymmetric extensions to the SM also predict that a light Higgs boson exists. If the Higgs is similar in nature to that predicted by the Standard Model, it will be discovered at the LHC and a LC will be essential in order to study its properties in detail in a model independent way. The precision measurements of the Higgs couplings available at the LC will distinguish the Standard Model Higgs from those which can arise in many other scenarios. In particular, the 500 GeV LC can precisely measure the elementary couplings of the Higgs boson to quarks, leptons, and gauge bosons.
These measurements are essential for an experimental verification of the scalar dynamics underlying the electroweak symmetry breaking.

Some scenarios predict that a light Higgs may decay invisibly and thus escape detection at the LHC. By utilizing the recoil mass technique
in the reaction e+e- -> Z+Higgs will allow for a Higgs discovery at the LC in a model independent fashion.

If the Higgs boson is heavier than indicated by the precision electroweak data, its properties can be accurately determined at a 1 TeV LC. Furthermore, consistency with the precision electroweak data implies that other new particles whose masses lie below 1 TeV must also be present. As discussed below, the LC then plays a crucial role in identifying the nature of this new physics.

A last possibility is that a light Higgs boson is not realized in nature. In this case, WW scattering violates unitarity at around a TeV unless there is new physics. If the associated new states would be out of direct reach, precision measurements would enable the LC to explore these states through their virtual contributions to existing processes. This has been studied in great detail for many scenarios, such as strong electroweak symmetry breaking. In particular, the complete threshold region of the new strong interaction can be explored at a LC with energies around 1 TeV.

2) The Hierarchy Problem: A shortcoming of the Standard Model is its instability against the huge hierarchy of the vastly different scales relevant in fundamental physics. The Higgs and gauge boson masses are unstable to quantum fluctuations and would naturally rise to the Planck scale without the onset of new physics around a TeV. It is essential that this hypothesis be tested as precisely as possible. The leading candidates for resolution of this hierarchy problem are:

(i) Weak-scale Supersymmetry. The lightest superpartners are expected to be within reach of a 500-1000 GeV LC. A LC with its capabilities of polarized beams and threshold scans will precisely determine the properties of this spectrum. Only the combined information of the LHC and LC measurements can decipher the supersymmetry breaking mechanism and provide clues about the physics at the grand unified scale.

(ii) Extra Spatial Dimensions. In this case, a 1 TeV LC can observe both the direct production and virtual effects of Kaluza-Klein excitations of the graviton and Standard Model particles. The LC with its superb energy resolution does a particularly good job observing the narrow resonances characteristic of some models. Including virtual effects, the discovery reach of a 1 TeV LC for these excitations is 6-20 TeV and will cover the natural region of parameter space that is relevant for resolution of the hierarchy problem.

(iii) Little Higgs Models. These models predict a strongly interacting sector and predict the existence of new scalars, gauge bosons, and fermions at energies of order 10 TeV. In particular, the LC can determine the couplings of these new particles to the Higgs sector and verify the specific structures of such models. There is sensitivity to physics that lies beyond the direct energy reach of the LC which can provide important clues to the high energy behavior.

In any scenario addressing the hierarchy, precision measurements of Standard Model processes at the LC with polarized beams are sensitive to virtual effects at high energy scales and will be crucial to determine the nature of the new physics.

3) Dark Matter: One of the simplest explanations for cosmic dark matter, the invisible matter that constitutes 80% of the mass of large clusters of galaxies, is that it is composed of a new stable particle with weak interaction cross sections. Astrophysical observations are consistent with the mass for such a particle being of the order of 100 GeV and it would thus be copiously produced at the LC. In this case the LC would be ideally suited for establishing the quantum numbers of dark matter candidates; this is discussed more in the answer to 30d.

4) Precision measurements of the Standard Model: A 500 GeV LC will make important precision measurements within the Standard Model. (i) The mass of the top quark can be measured to an accuracy better than 100 MeV and the top quark couplings to the photon and the Z can be determined at the percent level. The uncertainty on the top quark mass is a limiting factor in the global fit to the electroweak data set. A measurement with 100 MeV precision, together with the improved measurement of the W mass at the LHC (or with even better accuracy by running the LC at the W pair threshold), thus allows for much better exploitation of the LHC results and a precise consistency check of the Standard Model with unique sensitivity to new physics beyond 1 TeV. (ii) The LC can measure the WWgamma and WWZ couplings to parts in 10^4. The radiative corrections to these couplings within the Standard Model are at the level of 10^-3. The LC thus has the sensitivity to probe new physics contributions at a high level of precision. In particular, these are key experiments that are sensitive to new strong interactions in the Higgs sector. (iii) The LC can determine alpha_s to better than 1%, and a precise evolution of alpha_s is an important ingredient for models of grand unification. (iv) The option exists to run the LC at the Z-boson pole, and at the W-boson pair production threshold. The high luminosity of the LC will allow for 10^9 Z-bosons to be produced. This Giga-Z option will allow for the measurement of the effective weak mixing angle at the 10^-5 level (an order of magnitude improvement) and of the W boson mass to 6-7 MeV. Together with the 100 MeV top mass determination, this will be an unprecendented precision test of the Standard Model, which would be all the more important in the unlikely event that the LHC discovers nothing.

The arguments stated above demonstrate the need for a 500-1000 GeV LC, regardless of LHC results. If the LHC experiments only discover a particle sector at mass scales beyond 1 TeV, it will be important to establish the effects on Standard Model processes via precision measurements, and to search for lower mass states which might have couplings or backgrounds which would prevent their observation by LHC experiments. In many cases, the sensitivity to new physics via virtual effects at the LC exceeds that of direct searches at the

LHC. Precision EW measurements by a LC are important for distinguishing among multiple interpretations of new physics which may be observed by the LHC.

It is difficult to make a strong case for whether the top energy of the LC should be 800 GeV or 1 TeV. Certainly, the higher energy provides a somewhat higher window to new physics and gives larger production rates for some Standard Model processes, such as those relevant for the Higgs self-coupling determination. Of course, there is an energy-luminosity tradeoff which also must be considered for the different processes.

30d) Considering the LC will start much later than LHC (although it can have a concurrent operation period), what physics capability does LC have which LHC does not share? Can this be realized at 500 GeV or does it require much higher energy?

The LHC and the LC have complementary and synergetic physics capabilities. This synergy can be best explored if both machines run concurrently. However, the LC has unique physics capabilities that are crucial to our understanding of nature and will be needed regardless of the LHC findings and the LC startup time. The LHC strength lies in its mass reach, while the LC is a precision machine with:
- better knowledge of the intial state;
- well defined energy and ability to perform energy scans;
- much lower backgrounds than LHC and therefore the ability to detect signals which have low cross sections (e.g. sleptons) or prohibitive backgrounds at LHC (e.g. Higgs bosons decaying hadronically into light quarks);
- better measurement of angular distributions and therefore particle helicities; and,
- polarized beams which allow measurement of quantum numbers, and the reduction of major backgrounds (e.g., WW).

The LC is uniquely capable of measuring the quantum numbers of new particles. In this way, the LC can determine the nature and underlying origin of new phenomena discovered at the LHC and also provides a unique discovery window on its own. The search reach for new physics via virtual effects at the LC exceeds that of the LHC in many scenarios. The LC is both sensitive to new physics that LHC cannot observe (or cannot observe well), and can aid LHC in distinguishing multiple interpretations of TeV-scale phenomena. These capabilities have been detailed in the answer to question 30b. To further illustrate this point, we expand on several of the items presented in the answer to 30b.

(1) Electroweak Symmetry Breaking: The LC will precisely measure, at the percent level, the properties of the Higgs boson in a model independent way and thus experimentally verify the scalar dynamics responsible for electroweak symmetry breaking; this is not possible at the LHC for a light Higgs boson. For example, for a 120 GeV Higgs boson, the bb-bar (tau, charm, gluon) branching fraction can be determined at the level of 1% (5%, 10%, 10%) at a 500 GeV machine. At a 1 TeV LC, the top-quark Yukawa coupling and Higgs self-coupling can be measured with an accuracy better than 10%.

For strong electroweak symmetry breaking, detailed measurements of cross sections and angular distributions at a LC will be essential for identifying the new states and disentangling the underlying physics. The 500 GeV LC can establish the existence of a new state with a significance better than 5 sigma for values of the model parameters in addordance with current constraints; the significance increases by more than a factor of two at a 1 TeV machine. In addition, the LC can separate the different isospin production channels such as nu nubar t tbar, which is not accessible at the LHC.

(2) Hierarchy Problem: The prospects that the color neutral part of the supersymmetric spectrum (sleptons, charginos, neutralinos) is accessible at 500-1000 GeV are very good. The LC can make precise (100 MeV or better) mass measurements, as well as coupling, spin, and mixing parameter determinations of the supersymmetric partners. In particular, the accurate mass determination of the lightest supersymmetric particle will sharpen all the mass determinations and understanding of superpartner decay chains at the LHC. These measurements can uniquely confirm the symmetries predicted by supersymmetry. A general exploration of the SUSY breaking mechanism and extrapolation to the GUT scale is only possible by combining the data from the LC and LHC (see LHC/LC report).

In the case of extra spatial dimensions, the polarized beams and accurate measurement of angular distributions at a LC allow for the simultaneous determination of the size, geometry, and number of the additional dimensions in a model independent fashion. This is achievable at a 500 GeV (1 TeV) LC for extra dimensions of size 3-5 (6-10) TeV^-1. In addition, the LC capability for the identification of spin-2 exchange in all scenarios can demonstrate the connection to gravity.

In any scenario addressing the hierarchy, precision measurements of Standard Model processes at the LC with polarized beams are sensitive to virtual effects at energy scales significantly beyond 1 TeV and will be crucial to determine the nature of the new physics. Important information will come from a 500 GeV LC; running at higher energies will, of course, improve the precision and sensitivity to new physics. For example, limits obtained from difermion production on compositeness and extra gauge bosons scale with the center-of-mass energy; spin-2 exchange scales somewhat less with energy.

(3) Dark Matter: Good candidates for the dark matter are neutralinos from supersymmetry and Kaluza-Klein excitations of the photon from extra dimension theories. A 500-1000 GeV machine is expected to cover the cosmologically favored parameter region within supersymmetry. This affords an intriguing opportunity to compare particle accelerator measurements to those from astrophysics experiments. In fact, the LC is unique in its capability to provide a measurement of supersymmetric dark matter to a precision of 3% which matches the level expected from future astrophysical observations of 2% (such as PLANCK). The LC is needed to identify the superpartners which can complicate the SUSY dark matter scheme. For instance, if the LSP has a slightly heavier partner with the same quantum numbers and a larger annihilation cross section, the effective LSP annihilation is significantly altered. Simply knowing the LSP mass and self annihilation cross section is not good enough to place this as the dark matter, and this stresses the need for precision measurements in this physics. If the dark matter consists of the KK excitations, the LC with its superb energy resolution will be essential in identifying the narrow states, and their spin can be determined from angular distributions.

4) Precision measurements: this has been described in the answer to 30b, but indeed this is also very important for this question. The LC capability for precision measurements of SM processes provides a unique window on new physics. The 500 GeV LC has a sensitivity to many processes of new physics with a mass reach well beyond that of the LHC in many cases.

In conclusion, the clean experimental environment of the LC and the unique ability to select helicity channels and measure quantum numbers open new avenues to discover and identify new physics. As for the energy question, we have shown that the baseline LC operating at 200-500 GeV (or as low as 90 GeV as an option) is an essential tool for understanding the physics of the TeV scale, independent of LHC. Upgrading to 1 TeV opens new potential for discovery.

資料4："Consensus Report"のプレスリリース

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HIGH-ENERGY PHYSICS NEWS AND RESOURCES

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Contact:
Judy Jackson (Fermilab) +630-461-8731 jjackson@fnal.gov
Neil Calder (SLAC) +650-926-8707 neil.calder@slac.stanford.edu
Petra Folkerts (DESY) +49-40-8998-3616 petra.folkerts@desy.de
Youhei Morita (KEK) +81-29-879-6046 youhei.morita@kek.jp

Date: 23 April 2004

World's Physicists Endorse Linear Collider

Paris--Over 2600 physicists from around the world have signed a document supporting a high-energy electron-positron linear collider as the next major experimental facility for frontier particle physics research, members of the World Wide Study of Physics and Detectors for a Linear Collider announced today.

"Such consensus on what the next research facility should be is unprecedented," said Prof. Jim Brau, University of Oregon, "It is a tremendous endorsement. Experimenters, theorists and accelerator scientists, graduate students and Nobel prizewinners have all signed up to support the linear collider." The announcement came today at an International Conference on Linear Colliders being held in Paris this week under the auspices of the World Wide Study.

In January 2004, a Ministerial Statement from the Organisation for Economic Co-operation and Development also endorsed the plan for global collaborative development of a linear collider and noted the consensus of the scientific community on the importance of a new-generation facility.

The linear collider will be one of the essential tools to answer new and emerging questions about matter, energy, space and time. In the last 30 years, physicists have achieved a profound understanding of the fundamental particles and the physical laws that govern matter, energy, space and time. Researchers have subjected this "Standard Model" to countless experimental tests; and, again and again, its predictions have held true. Now, in a development that some have compared to Copernicus's recognition that the earth is not the center of the solar system, startling new data have confirmed that only five percent of the universe is made of normal, visible matter described by the Standard Model. Ninety-five percent of the universe consists of dark matter and dark energy whose fundamental nature is a mystery. The Standard Model's orderly and elegant view of the universe must be incorporated into a deeper theory that can explain the new phenomena. The result will be a revolution in particle physics as dramatic as any that have come before.

"The linear collider will be a revolutionary research facility that will provide the sharpest, cleanest window to the world of elementary particles ever built, allowing scientists to probe with clarity the most fundamental mechanisms of matter and the universe," said Nobel laureate Masatoshi Koshiba of the University of Tokyo.

The 30-km-long accelerator will have two main linear accelerators oriented opposite one another, propelling head-to-head beams of electrons and their antimatter twins, positrons, to within nearly light speed before colliding them. Working in a real-time dialogue with the Large Hadron Collider (LHC), currently being installed in CERN in Geneva, will allow the discoveries from each accelerator to be used to make further discoveries at the other.

The strong support from the world physics community for the linear collider is another step forward in the build-up toward approval of the project.

"The linear collider will not only investigate new frontiers in physics and technology but also in international science collaboration. This project will go ahead as a closely coordinated international collaboration, with shared costs and shared benefits, on a scale and scope not seen before in science," said Maury Tigner, director of the Laboratory of Elementary Particle Physics at Cornell University and chair of the International Linear Collider Steering Group.

In 1999, scientific panels studying the future directions for particle physics in Europe, Asia and the United States concluded that a linear collider would be an essential complement to the LHC at CERN. As a consequence, the International Committee for Future Accelerators (ICFA) recommended pursuit of accelerator research and development for a linear collider in the TeV energy range. In 2001-2002, the three regional organizations of the high energy physics community--the Asian Committee for Future Accelerators (ACFA), the European Committee for Future Accelerators (ECFA) and the High Energy Physics Advisory Panel (HEPAP) from the U.S.--reached the common conclusion that the next accelerator should be an electron-positron linear collider with an initial energy of 500 GeV, running in parallel with LHC, and later upgradeable to higher energies.

"I am delighted by the response from physicists worldwide, particularly by the number of young researchers who have signed the document," said Prof. Francois Le Diberder, deputy director of IN2P3 in Paris. "Participation in the linear collider gives young scientists the challenge of taking part in the most exciting scientific quest of the 21st century."

Issued by Worldwide Study of Physics and Detectors for a Linear Collider.

Full information on the consensus paper 'Understanding Matter, Space and Time' is available at http://sbhep1.physics.sunysb.edu/~grannis/lc_consensus.html

資料5:　　LCWSでのD.Miller氏の報告

How do we propose to organise the Global LC Experimental Programme?

Preparation of a response to the ILCSC/ICFA request
(as reported in Jim Brau's charge on Monday)

At their February meetings, ILCSC and ICFA asked us to propose, in parallel with the Global Design Initiative for the LC machine, an *organisation* which will do three separate jobs:

1. **Ensure that at least two different detector concepts are developed; by worldwide teams which will:**
   - **prepare CDR(s) on concepts, by ~2006;**
   - ***be ready to form the cores of the collaborations** when funding is in place and bids are called for.**
2. **Encourage and coordinate inter-regional R&D on essential detector technologies, and give peer-reviewed recognition to nationally funded R&D programmes as part of the worldwide project.**
3. **Make sure that vital questions of machine-detector interface and beamline instrumentation are as fully supported as accelerator and detector R&D. This will involve close links with the GDI.**

• *slightly edited from Monday's ungrammatical version.

World Wide Study of
Physics and Detectors
for a future e^+e^-
Linear Collider

The WWS organising committee will reply to the ILCSC meeting at ICHEP Beijing in August.
Proposal to be finalised at ALCPG Victoria workshop, end July.

Points so far:

Detector and MDI R&D is underfunded; so many essential tests can not be done yet.

But we must give cost and performance input at each stage of the GDI accelerator roadmap to show that the experiments can do the physics.

The community will grow and R&D accelerate when more funding appears. We must encourage new ideas and new entrants.

>1 overall detector concept is needed.

World Wide Study of
Physics and Detectors
for a future e^+e^-
Linear Collider

We propose to tie detector milestones to the Global LC Design Initiative.

GDI Milestones

2004	Technology choice. Global Design Effort MOUs
2005	Accelerator CDR
2007	Accelerator TDR
2008	Site selection

Proposed Detector Milestones

A. Costing of >1 whole-detector concepts (single joint document with performance estimates for each concept, + reference to R&D done and still needed) [→ 2005 Accelerator CDR]

B. Receive Letters of Intent (or "CDRs"?) for experiments (maybe different set of concepts from A, above, as new ideas come with new people) [— 2007 Accelerator TDR]

C. Global Lab immediately invites ~2 TDRs on basis of Letters of Intent. TDRs to be presented within 1 year. [← 2008 Site selection]

~2009 Construction begins

What structures should we propose to meet these milestones?

1. Cost estimate in 2005. *Must get going soon!*
   Who triggers teams to work on detector concepts?
   Expect that Editorial Board would peer review or edit the contribution from each concept to make sure it is realistic.

2. How do we support new detector and MDI R&D, as requested?
   Some projects already recognised by regional peer review panels.
   Do we need a worldwide panel, with ILCSC/ICFA support,
   to advise national funding agencies which projects are worthwhile?
   Will ICFA find funding to pay its expenses?

3. Who will call for the Letters of Intent?

We need your suggestions now, or within the next few weeks.