Global Research Strategies

(in particle physics & related subjects)

Symposium on
Physics of Elementary Particles in the LHC Era

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Warsaw, 22nd April 2008

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Particle physics

The particle physics "Mission Statement"

1) Identify the most fundamental constituents of the Universe
2) Describe how they interact and inter-relate

and if possible

3) Explain why 1) and 2) above are as they are, and cannot be otherwise

Then, we will have "understood" how the Universe works at its deepest (simplest?) level

in the first billionths of a second after the Big Bang

But we are left with the task of explaining how the rich complexity that developed in the ensuing ~14 billion years came about…

Which is a much more complex task!

European Strategy for Particle Physics

“Particle physics stands on the threshold of a new and exciting era of discovery. The next generation of experiments will explore new domains and probe the deep structure of space-time. They will measure the properties of the elementary constituents of matter and their interactions with unprecedented accuracy, and they will uncover new phenomena such as the Higgs boson or new forms of matter. Long-standing puzzles such as the origin of mass, the matter-antimatter asymmetry of the Universe and the mysterious dark matter and energy that permeate the cosmos will soon benefit from the insights that new measurements will bring. Together, the results will have a profound impact on the way we see our Universe.”

Key Questions in Particle Physics (**For The Uninitiated)**

- Can all of the forces between particles be understood in a unified framework?
- What do the properties of particles reveal about the nature and origin of matter and the properties of space and time?
- What are dark matter and dark energy, and how has quantum mechanics influenced the structure of the universe?
- **In the judgment of particle physicists** these questions, together with accumulating experimental evidence, emerging technologies and experimental facilities (***actual and planned***), point to a **potential** transformation of particle physics

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

9

Harold Shapiro

The Quantum Universe

EINSTEIN'S DREAM OF UNIFIED FORCES

1

ARE THERE UNDISCOVERED PRINCIPLES OF NATURE: NEW SYMMETRIES, NEW PHYSICAL LAWS?

The quantum ideas that so successfully describe familiar matter fail when applied to cosmic physics. Solving the problem requires the appearance of new forces and new particles signaling the discovery of new symmetries-undiscovered principles of nature's behavior.

2

HOW CAN WE SOLVE THE MYSTERY OF DARK ENERGY?

The dark energy that permeates empty space and accelerates the expansion of the universe must have a quantum explanation. Dark energy might be related to the Higgs field, a force that fills space and gives particles mass.

3

ARE THERE EXTRA DIMENSIONS OF SPACE?

String theory predicts seven undiscovered dimensions of space that give rise to much of the apparent complexity of particle physics. The discovery of extra dimensions would be an epochal event in human history; it would change our understanding of the birth and evolution of the universe. String theory could reshape our concept of gravity.

4

DO ALL THE FORCES BECOME ONE?

At the most fundamental level all forces and particles in the universe may be related, and all the forces might be manifestations of a single grand unified force, realizing Einstein's dream.

THE PARTICLE WORLD

5

WHY ARE THERE SO MANY KINDS OF PARTICLES?

Why do three families of particles exist, and why do their masses differ so dramatically? Patterns and variations in the families of elementary particles suggest undiscovered underlying principles that tie together the quarks and leptons of the Standard Model.

6

WHAT IS DARK MATTER?

HOW CAN WE MAKE IT IN THE LABORATORY?

Most of the matter in the universe is unknown dark matter, probably heavy particles produced in the big bang. While most of these particles annihilated into pure energy, some remained. These remaining particles should have a small enough mass to be produced and studied at accelerators.

7

WHAT ARE NEUTRINOS TELLING US?

Of all the known particles, neutrinos are the most mysterious. They played an essential role in the evolution of the universe, and their tiny nonzero mass may signal new physics at very high energies.

THE BIRTH OF THE UNIVERSE

8

HOW DID THE UNIVERSE COME TO BE?

According to cosmic theory, the universe began with a singular explosion followed by a burst of inflationary expansion. Following inflation, the universe cooled, passing through a series of phase transitions and allowing the formation of stars, galaxies and life on earth. Understanding inflation requires breakthroughs in quantum physics and quantum gravity.

9

WHAT HAPPENED TO THE ANTIMATTER?

The big bang almost certainly produced equal amounts of matter and antimatter, yet the universe seems to contain no antimatter. How did the asymmetry arise?

OPPORTUNITIES FOR DISCOVERY

We live in an age when the exploration of great questions is leading toward a revolutionary new understanding of the universe.

"Opportunities have emerged for discovery about the fundamental nature of the universe that we never expected," Presidential Science Advisor John Marburger said recently. "Technology places these discoveries within our reach, but we need to focus efforts across widely separated disciplines to realize the new opportunities."

Quantum Universe is a response to that challenge. It serves as a guide to where the search for understanding has taken us so far, and to where it is going. The chapters that follow articulate how existing and planned particle physics experiments at accelerators and underground laboratories, together with space probes and ground-based telescopes, bring within reach new opportunities for discovery about the fundamental nature of the universe.

Questions from the Quantum Universe

1. Are there undiscovered principles of nature?

   New symmetries, New Physical Laws

2. How can we solve the mystery of Dark Energy?
3. Are there extra dimensions of space?
4. Do all the forces become one?
5. Why are there so many kinds of particle?
6. What is Dark Matter?

   How can we make it in the laboratory?

7. What are neutrinos telling us?
8. How did the Universe come to be?
9. What happened to the antimatter?

Questions to be answered by the LHC

1. Is there a Higgs?
2. What is the Higgs mass?
3. Is the Higgs a SM-like weak doublet?
4. Is the Higgs elementary or composite?
5. Is the stability of M_W / M_P through symmetry or dynamical principle?
6. Is supersymmetry effective at the weak scale?
7. Will we discover DM at the LHC?
8. Are there extra dimensions? Are there new strong forces?
9. Are there totally unexpected phenomena?
10. What is the mechanism of EW breaking?

Gian Giudice

Also Flavour Physics @ LHC

Conclusions

- Consistency of flavor precision measurements at $E_{\rm exp} \sim GeV$ with SM poses a problem to NP at $\Lambda_{\rm NP} \sim TeV$
- If new particles are discovered – New flavor parameters will be measured
- The parameters of interest: M, BR($\rightarrow f_3, f_l$), $\sigma_{\rm prod}$
- Rare decays constrain $(\Delta m_{ij}/m) \times K_{ij}$; ATLAS/CMS can measure Δm_{ij} and K_{ij} separately
- The new physics flavor puzzle may be understood
- MFV can, in principle, be excluded
- With supersymmetry: The SM flavor puzzle may be solved

Yosef Nir

The European Strategy for Particle Physics

The European Strategy for Particle Physics

The European strategy for particle physics

Particle physics stands on the threshold of a new and exciting era of discovery. The next generation of experiments will explore new domains and probe the deep structure of space-time. They will measure the properties of the elementary constituents of matter and their interactions with unprecedented accuracy, and they will uncover new phenomena such as the Higgs boson or new forms of matter. Long-standing puzzles such as the origin of mass, the matter-antimatter asymmetry of the Universe and the mysterious dark matter and energy that permeate the cosmos will soon benefit from the insights that new measurements will bring. Together, the results will have a profound impact on the way we see our Universe; European particle physics should thoroughly exploit its current exciting and diverse research programme. It should position itself to stand ready to address the challenges that will emerge from exploration of the new frontier, and it should participate fully in an increasingly global adventure.

General issues

1. European particle physics is founded on strong national institutes, universities and laboratories and the CERN Organization; *Europe should maintain and strengthen its central position in particle physics.*

2. Increased globalization, concentration and scale of particle physics make a well coordinated strategy in Europe paramount; *this strategy will be defined and updated by CERN Council as outlined below.*

Scientific activities

3. The LHC will be the energy frontier machine for the foreseeable future, maintaining European leadership in the field; *the highest priority is to fully exploit the physics potential of the LHC, resources for completion of the initial programme have to be secured such that machine and experiments can operate optimally at their design performance.* A subsequent major luminosity upgrade (SLHC), motivated by physics results and operation experience, will be enabled by focussed R&D; *to this end, R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015.*

4. In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme; *a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.*

5. It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier; *there should be a strong well-coordinated European activity, including CERN, through the Global Design Effort, for its design and technical preparation towards the construction decision, to be ready for a new assessment by Council around 2010.*

6. Studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012; *Council will play an active role in promoting a coordinated European participation in a global neutrino programme.*

7. A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; *Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest.*

8. Flavour physics and precision measurements at the high-luminosity frontier at lower energies complement our understanding of particle physics and allow for a more accurate interpretation of the results at the high-energy frontier; *these should be led by national or regional collaborations, and the participation of European laboratories and institutes should be promoted.*

9. A variety of important research lines are at the interface between particle and nuclear physics requiring dedicated experiments; *Council will seek to work with NuPECC in areas of mutual interest, and maintain the capability to perform fixed target experiments at CERN.*

10. European theoretical physics has played a crucial role in shaping and consolidating the Standard Model and in formulating possible scenarios for future discoveries. Strong theoretical research and close collaboration with experimentalists are essential to the advancement of particle physics and to take full advantage of experimental progress. *The forthcoming LHC results will open new opportunities for theoretical developments, and create new needs for theoretical calculations, which should be widely supported.*

Organizational issues

11. There is a fundamental need for an ongoing process to define and update the European strategy for particle physics; *Council, under Article II-2(b) of the CERN Convention, shall assume this responsibility, acting as a council for European particle physics, holding a special session at least once each year for this purpose. Council will define and update the strategy based on proposals and observations from a dedicated scientific body that it shall establish for this purpose.*

12. Future major facilities in Europe and elsewhere require collaborations on a global scale; *Council, drawing on the European experience in the successful construction and operation of large-scale facilities, will prepare a framework for Europe to engage with the other regions of the world with the goal of optimizing the particle physics output through the best shared use of resources while maintaining European capabilities.*

13. Through its programmes, the European Union establishes in a broad sense the European Research Area with European particle physics having its own established structures and organizations; *there is a need to strengthen this relationship for communicating issues related to the strategy.*

14. Particle physicists in the non-Member States benefit from, and add to, the research programme funded by the CERN Member States; *Council will establish how the non-member States should be involved in defining the strategy.*

Complementary issues

15. Fundamental physics impacts both scientific and philosophical thinking, influencing the way we perceive the universe and our role in it. It is an integral part of particle physics research to share the wonders of our discoveries with the public and the youth in particular. Outreach should be implemented with adequate resources from the start of any major project; *Council will establish a network of closely cooperating professional communication officers from each Member state, which would incorporate existing activities, propose, implement and monitor a European particle physics communication and education strategy, and report on a regular basis to Council.*

16. Technology developed for nuclear and particle physics research has made and is making a lasting impact on society in areas such as material sciences and biology (e.g. synchrotron radiation facilities), communication and information technology (e.g. the web and grid computing), health (e.g. the PET scanner and hadron therapy facilities); *to further promote the impact of the spin-offs of particle physics research, the relevant technology transfer representatives at CERN and in Member states should create a technology transfer forum to analyse the keys to the success in technology transfer projects in general, make proposals for improving its effectiveness, promoting knowledge transfer through mobility of scientists and engineers between industry and research.*

17. The technical advances necessary for particle physics both benefit from, and stimulate, the technological competences available in European industry; *Council will consolidate and reinforce this connection, by ensuring that future engagement with industry takes account of current best practices, and continuously profits from the accumulated experience.*

Unanimously approved by the CERN Council at the special Session held in Lisbon on 14 July 2006

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- **Preparatory group**
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  - S. Bertolucci — ECFA
  - A. Blondel — SPC
  - M. Cavalli-Sforza — SPC
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  - J. Zinn-Justin — Dapnia
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THE EUROPEAN PHYSICAL JOURNAL C

Review

Towards the european strategy for particle physics: The briefing book

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Abstract. This document was prepared as part of the briefing material for the Workshop of the CERN Council Strategy Group, held in DESY Zeuthen from 2nd to 6th May 2006. It gives an overview of the physics issues and of the technological challenges that will shape the future of the field, and incorporates material presented and discussed during the Symposium on the European Strategy for Particle Physics, held in Orsay from 30th January to 2nd February 2006, reflecting the various opinions of the European community as recorded in written submissions to the Strategy Group and in the discussions at the Symposium.

Contents

} E Rondio

The Scientific Strategy

- The LHC and R&D for its upgrade
- R&D for future facilities
- The ILC (0.5-1TeV)
- R&D for future neutrino facilities
- Non-accelerator experiments
- Flavour physics and precision measurements
- Particle and nuclear physics

Ordered Priorities

1. Exploit the opportunities offered by the LHC
2. Plan and initiate a comprehensive program to participate in the global effort to complete the necessary R&D to design and plan an international linear collider
3. Do what is necessary to mount an internationally compelling bid to build the international linear collider on U.S. soil
4. Seize the opportunities at the intersection of particle physics, astrophysics, and cosmology by coordinating and expanding domestic efforts
5. Pursue an internationally coordinated, staged program in the physics of neutrinos and proton decay
6. Pursue precision probes of physics beyond the Standard Model using available resources as a guide to overall level of effort while maintaining diversity

Similar statements from Japan …

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- N. Augustine (Lockheed Martin)
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OECD Global Science Forum

Science, Technology and Innovation for the 21st Century.

Meeting of the OECD Committee for Scientific and Technological Policy at Ministerial Level, 29-30 January 2004 - Final Communiqué

High-energy physics

Ministers acknowledged the importance of ensuring access to large-scale research infrastructure and the importance of the long-term vitality of high-energy physics. They noted the worldwide consensus of the scientific community, which has chosen an electron-positron linear collider as the next accelerator-based facility to complement and expand on the discoveries that are likely to emerge from the Large Hadron Collider currently being built at CERN. They agreed that the planning and implementation of such a large, multi-year project should be carried out on a global basis, and should involve consultations among not just scientists, but also representatives of science funding agencies from interested countries. Accordingly, Ministers endorsed the statement prepared by the OECD Global Science Forum Consultative Group on High-Energy Physics (Annex 3).

Annex 3

International Co-operation on Large Accelerator-based Projects in High-energy Physics

Ministers expressed their appreciation for the work of the OECD Global Science Forum Consultative Group on High-Energy Physics. They welcomed the report from the Group and commended the clarity and worldwide consensus they found among the high-energy physics community in developing the roadmap for future large accelerator-based facilities.

In particular, the Ministers noted several important points that were articulated in the report:

- A roadmap that identifies four interdependent priorities for global high-energy physics (HEP) facilities: i) the exploitation of current frontier facilities until contribution of these machines is surpassed; ii) completion and full exploitation of the Large Hadron Collider at CERN; iii) preparing for the development of a next-generation electron-positron collider; and iv) the continued support for appropriate R&D into novel accelerator designs.

The 4 “interdependent priorities”

i) the exploitation of current frontier facilities until contribution of these machines is surpassed;

ii) completion and full exploitation of the Large Hadron Collider at CERN;

iii) preparing for the development of a next-generation electron-positron collider; and

iv) the continued support for appropriate R&D into novel accelerator designs.

… and the rest …

- The need to have large, next-generation facilities funded, designed, built, and operated as global-scale collaborations with contribution from all countries that wish to participate.
- The need for strong international R&D collaboration and studies of the organisational, legal, financial, and administrative issues required to realise the next major accelerator facility on the Consultative Group's roadmap, a next-generation electron-positron collider with a significant period of concurrent running with the LHC.
- The need to continue to educate, attract and train young people in the fields of high-energy physics, astrophysics and cosmology in the face of the increasingly competitive environment where all areas of science, industry and commerce are seeking to capture the imagination of the most creative minds.

Ministers agreed that, given the complexity and long lead times for decision making of major international projects, it is important that consultations continue within the scientific communities and, when it becomes appropriate, within interested governmental communities in order to maximise the advantages offered by global collaboration.

2004-2006

- **Global consensus**
  – With Ministerial endorsement
- **A global particle physics programme**
  – LHC
  – ILC
  – R&D
  – Neutrinos … ???
  … and as much particle astrophysics, flavour physics, precision physics & nuclear particle physics as can be fitted in to the programme …

Why do we have such a clear consensus?

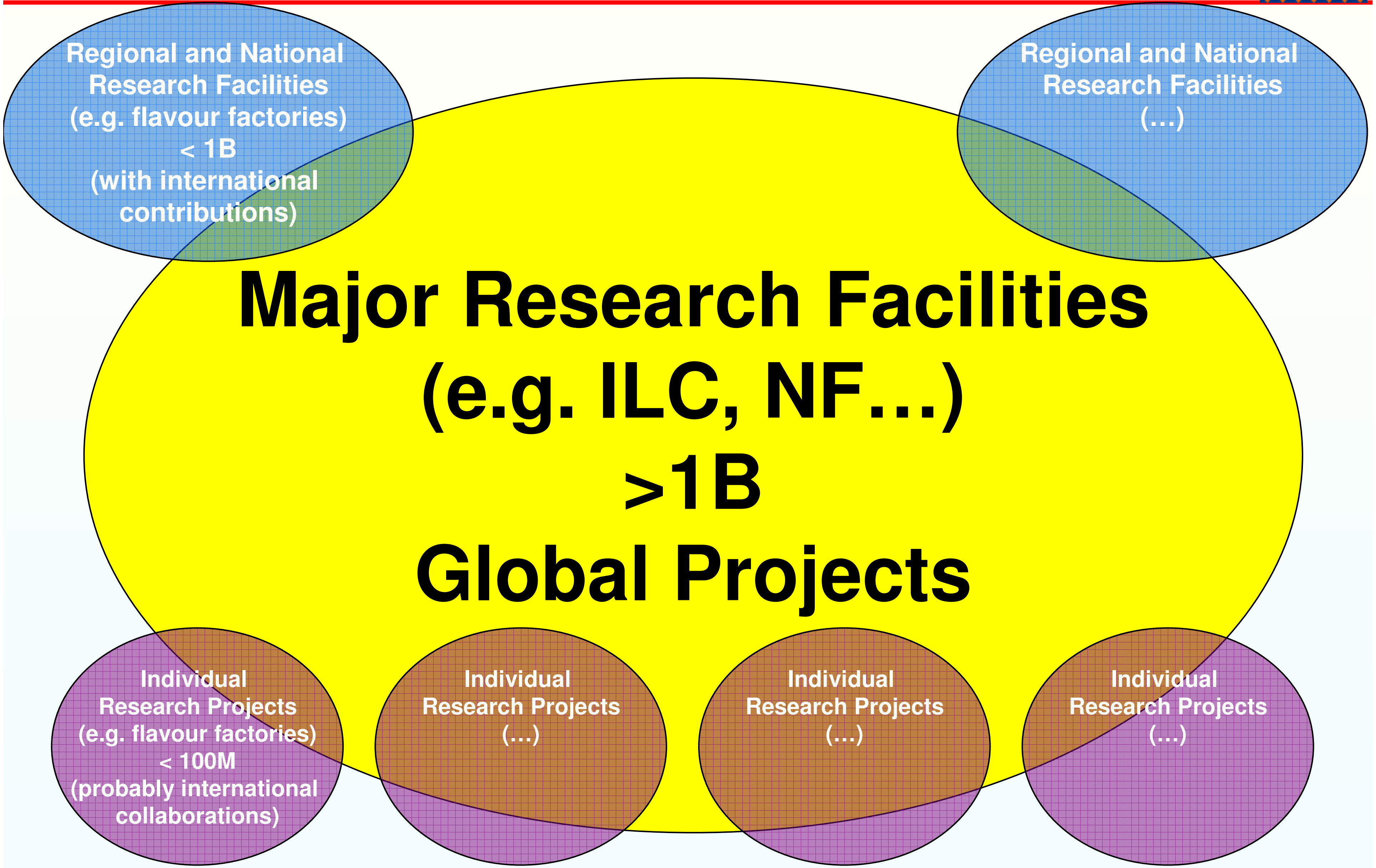
- ***Because*** **we have the *Standard Model***
  - This gives a unique framework within which to ask questions
  - Not surprisingly, smart people come up with the same set of questions
  - and the same ideas for answering them

The Standard Model Effective Lagrangean

$$
\begin{array}{rcl}
\mathcal{L}_{\text{(Standard Model)}} & = & \\
{[W^{\pm}]} & - & \frac{1}{2}(\partial_\mu W_\nu - \partial_\nu W_\mu)(\partial^\mu W^{\dagger\nu} - \partial^\nu W^{\dagger\mu}) + M_{\text{W}}^2 W_\mu W^{\dagger\mu} \\
{[\text{Photon}]} & - & \frac{1}{4} F^{\text{A}}_{\mu\nu} F^{\text{A}\mu\nu} \\
{[Z^o]} & - & F^{\text{Z}}_{\mu\nu} F^{\text{Z}\mu\nu} + \frac{1}{2} M_{\text{Z}}^2 Z_\mu Z^\mu \\
{[\ell, \nu_\ell]} & + & \imath \overline{L_\ell}\, \not{\partial} L_\ell + \imath \overline{R_\ell}\, \not{\partial} R_\ell - m_\ell \overline{\ell}\ell \\
{[W\ell\nu]} & - & \frac{g}{\sqrt{2}} \overline{L_\ell}(\tau_+ \not{W} + \tau_- \not{W}) L_\ell \\
{[\gamma\ell^+\ell^-]} & + & e_{e/m} \overline{\ell} \not{A} \ell \\
{[Z\ell^+\ell^-, Z\nu\overline{\nu}]} & - & \frac{g}{\cos\theta_{\text{W}}} \overline{L_\ell} \left(\frac{\tau_3}{2} \cos^2\theta_{\text{W}} + \frac{1}{2} \sin^2\theta_{\text{W}} \right) \not{Z} L_\ell - \frac{g \sin^2\theta_{\text{W}}}{\cos\theta_{\text{W}}} \overline{R_\ell} \not{Z} R_\ell \\
{[\text{H}]} & + & \frac{1}{2}\partial_\mu H \partial^\mu H - \frac{1}{2}\mu^2 H^2 - \frac{1}{2}\lambda\mu H^3 - \frac{1}{8}\lambda^2 H^4 \\
{[\text{HH\&H } W^+W^-]} & + & \frac{g^2}{8}\left(H^2 + \frac{2\mu}{\lambda} H\right)\left(2 W_\mu W^{\dagger\mu}\right) \\
{[\text{HH\&H } ZZ]} & + & \frac{g^2}{8}\left(H^2 + \frac{2\mu}{\lambda} H\right)\left(\frac{1}{\cos^2\theta_{\text{W}}} Z_\mu Z^\mu\right) \\
{[\text{H } \ell^+\ell^-]} & - & m_\ell \sqrt{\sqrt{2} G_{\text{F}}}\, \overline{\ell}\ell H \\
{[\text{quark } \gamma]} & + & Q \overline{q} \not{A} q \\
{[\text{quark Z}]} & - & \frac{g}{\cos\theta_{\text{W}}} \overline{L_q} \left(\frac{\tau_3}{2} \cos^2\theta_{\text{W}} + \frac{\sin^2\theta_{\text{W}}}{2} \right) \not{Z} L_q \\
{[\text{quark W}]} & - & \frac{g}{\sqrt{2}} \overline{\mathcal{U}} V_{\text{CKM}} \left(\tau_+ \not{W} + \tau_- \not{W}\right) \mathcal{D} \\
{[\text{quark H}]} & - & m_q \sqrt{\sqrt{2} G_{\text{F}}}\, \overline{q} q H \\
{[\text{gluons}]} & - & \frac{1}{4} F^a_{\mu\nu} F^{a\mu\nu} \\
{[\text{quarks}]} & + & \overline{\mathcal{U}}(\imath \not{\partial} - m_{\mathcal{U}})\mathcal{U} + \overline{\mathcal{D}}(\imath \not{\partial} - m_{\mathcal{D}})\mathcal{D} \\
{[\text{quark gluon}]} & + & \imath g T^a \left(\overline{\mathcal{U}} \not{A}^a \mathcal{U} + \overline{\mathcal{D}} \not{A}^a \mathcal{D} \right) \\
{[\text{ 3 gluons}]} & + & \frac{g}{2} \left(\partial_\mu A^a_\nu - \partial_\nu A^a_\mu \right) f^{abc} A^{b\mu} A^{c\nu} \\
{[\text{4 gluons}]} & - & \frac{g^2}{4} f^{abc} f^{axy} A^b_\mu A^c_\nu A^{x\mu} A^{y\nu}
\end{array}
$$

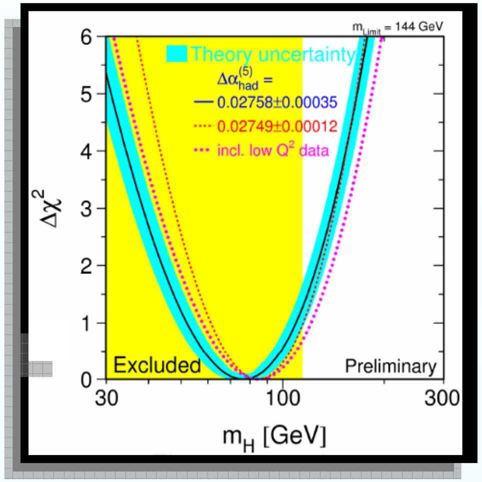
excluding **GRAVITY**

The Global Research Strategy



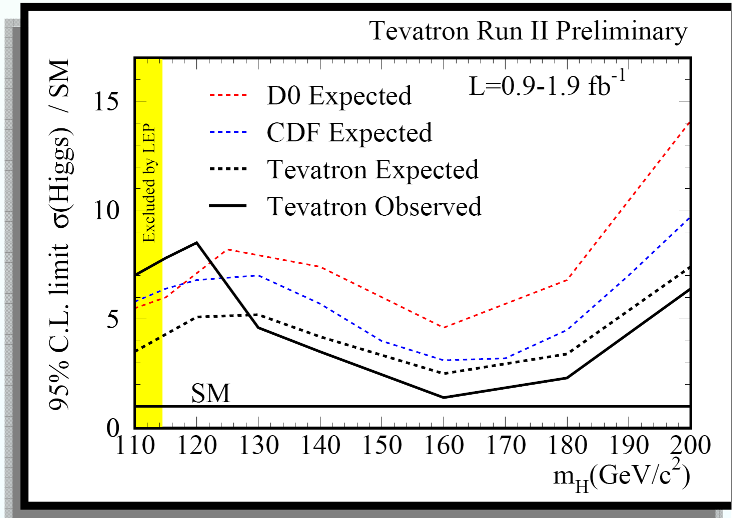
Where are we in 2008?

- ***Scientifically***
  - We are still waiting for the LHC results
    - Higgs?
    - SUSY?
    - Exotica of all kinds?
  - Nothing has changed!!!
  - Not even the Tevatron



Higgs Mass < 182 GeV/c²

(95% probability)



Where is the new Physics?

- Neutrinos
  - Origin of the (very small) masses?
  - Majorana and/or Dirac?
- g-2
  - SUSY?
- b-physics
  - b→s transitions – new physics?
- Dark stuff
  - Matter and Energy?
- Baryon Asymmetry of the Universe
  - Leptogenesis, SUSY, Sphalerons, …?
- Standard Model mysteries
  - Flavour structure, $SU(3)\otimes SU(2)\otimes U(1)$,

2007 – "annus horribilis"♠

- Two events in 2007, both related to the ILC, cast a cloud on the Global Strategy
- February 22nd
  - [US] Orbach statement to HEPAP
- December 11th
  - [UK] STFC Delivery Plan

♠"1992 is not a year on which I shall look back with undiluted pleasure. In the words of one of my more sympathetic correspondents, it has turned out to be an *Annus Horribilis*." Queen Elizabeth II, Guildahall, 24 November 1992.

J.A.I.

Orbach Statement to HEPAP

Royal Holloway University of London

Remarks Prepared for Delivery by
Under Secretary for Science Raymond L. Orbach
to the High Energy Physics Advisory Panel
February 22, 2007

- Over the next few years, the U.S. and the international high-energy physics communities will see great scientific opportunities and profound changes. These, in turn, will pose profound challenges. We must make the right choices on the right timescales to ensure the vitality and continuity of the field for the next several decades and to maximize the potential for major discovery throughout that period.
- Three events are notable:
  - The U.S. accelerator-based program will complete within the next several years two highly successful experimental campaigns – the Tevatron at Fermilab and the B Factory at SLAC. They are making very significant advances in the field, and I congratulate them for this and for succeeding to run far above their original design luminosities.
  - Second, within the next year, the LHC is scheduled to commence operations, opening wide the door to the Terascale, and ushering in a period of new and exciting scientific opportunity.
  - Finally, the Global Design Effort (GDE) just recently has released a reference design for the International Linear Collider (ILC) – a machine that though its power, precision, and clarity holds great promise for deepening our insight into the mysteries of the universe.

- In making our plans for the future, it is important to be conservative and to learn from our experiences. Even assuming a positive decision to build an ILC, the schedules will almost certainly be lengthier than the optimistic projections. Completing the R&D and engineering design, negotiating an international structure, selecting a site, obtaining firm financial commitments, and building the machine could take us well into the mid-2020s, if not later.
- Within this context, I would like to re-engage HEPAP in discussion of the future of particle physics. If the ILC were not to turn on until the middle or end of the 2020s, what are the right investment choices to ensure the vitality and continuity of the field during the next two to three decades and to maximize the potential for major discovery during that period?

STFC Delivery Plan

Delivery plan
2008/9-2011/12

11 December 2007

SECTION 2 DELIVERING WORLD CLASS SCIENCE

Our world class science and facilities programmes enable our research community to address a wide range of Big Science questions that are fundamental to the advance of knowledge and are of high societal and economic impact.

- *Why is there a Universe?*
- *How did galaxies form?*
- *Was there ever life on Mars?*
- *How do planetary systems evolve?*
- *How are the chemical elements created?*
- *How does our climate work?*
- *How can we create new materials to store energy?*
- *How can we meet mankind's need for abundant clean energy?*
- *How can we design smart materials?*
- *How do cells work?*
- *How do degenerative diseases develop?*
- *How can we design better treatments for cancer?*

The science programmes and facilities needed to answer these questions all build on, and are connected by, common technological foundations. World leading capabilities in particle accelerators, sensors and detectors, advanced engineering, space technology, and cutting edge computing, simulation and modelling underlie the whole range of the Council's capabilities, and are made possible by a strong collaborative skills base in universities, industry and our laboratories. These capabilities will also enable us to contribute to the planned cross-Council programmes, building naturally on our core competencies and to contribute a step-change in economic impact.

2.1 SCIENCE AND TECHNOLOGY STRATEGY

Particle physics

Particle physics aims to discover the fundamental building blocks of the Universe, how they interact, and how this has shaped the structure of the cosmos.

Our highest priority will be to exploit the Large Hadron Collider (LHC) at CERN, which starts operation in 2008; this is because discoveries are guaranteed. This accelerator is the first with sufficient energy to access the regime where our existing knowledge breaks down: at the very least, we hope to find the Higgs Boson, which is postulated to give particles their mass; theoretical models suggest we will likely observe new symmetries of nature, new particles and forces beyond those known.

With the commissioning of the LHC, CERN will be for at least the next decade the world's most advanced particle physics laboratory. Our membership of CERN gives us a strong and central role in this transformative project: one of the two major experiments at LHC is UK-led. If CERN Council agrees the proposed uplift in the CERN subscription to enable the LHC to be operated optimally. This uplift will be funded from the particle physics grants line.

The UK research community has been a major player in constructing the LHC and the highly advanced computing infrastructure to handle the data. The community is now prepared and ready to exploit the results from the machine and we will support the community to do so, within our financial constraints.

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strategy for further investment in this area. The level of future funding will be dependent on the success of our restructuring plans.

Comments

1. **Both of these comments were made for domestic political reasons**
   - Worry about RDR cost estimate (US)
   - Worry about timescale (UK)
2. **Neither comment followed from any review of the ILC project or scientific case**
   - Both views of (powerful) individuals
3. **Addressing the *domestic* political agenda, ignored *international* impact**

Comment - 2

- **What is particularly disappointing (!) is that both of these announcements *ignored* FALC (Funding Agencies for Large Colliders)**
  - **which was established by the US and the UK *expressly* to enable Funding Agencies to communicate and collaborate on such issues …**
- **In the light of this, the *need* for a truly Global Strategy is even greater**

The "annus horribilis" continues

December 18th, US Congress

House - MAJ

DIVISION C – ENERGY AND WATER DEVELOPMENT AND RELATED AGENCIES APPROPRIATIONS ACT, 2008

Following is an explanation of the effects of this division of the House amendment to the Senate amendment to H.R. 2764 (hereafter referred to as "the amended bill") relative to the versions of the Energy and Water Development Appropriations Act, 2008 (H.R. 2641 and S. 1751) passed by the House of Representatives and reported by the Senate Appropriations Committee.

SCIENCE

The amended bill provides $4,055,483,000 for Science instead of $4,514,082,000 as proposed by the House and $4,496,759,000 as proposed by the Senate. Funds previously provided for the Coralville, Iowa, project in the Consolidated Appropriations Act, 2004, are rescinded.

High Energy Physics.—Funding under this heading in the amended bill includes $694,638,000 for High Energy Physics. Within funding for Proton Accelerator-Based Physics, no funds are provided for the NOvA activity in Tevatron Complex Improvements. Within Advanced Technology R&D, in the current constrained environment and without a Critical Decision 0 by the Department, only $15,000,000 is provided for International Linear Collider R&D and $5,455,000 for Superconducting RF R&D.

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Comment - 3

- The UK and US funding decisions were taken independently
  - UK: some deep antipathy to particle physics in some sections of the Ministry and Funding Agency
  - US: Linear Collider supported by DoE, President's Budget and both Houses, but lost in the power struggle between President and Congress

Moving on …

- **Until we know**
  - **Whether the Higgs exists or not**
    - **If it does not exist below 180 GeV, the Standard Model is in crisis**
  - **SuperSymmetry exists or not**
    - **If it does not, we need some new ideas**
  - **Other exotica (ED, KK, BH, …)**
    - **If they do, a new era begins**
- **we cannot plan the next major facility**
  - **LHC upgrade, ILC, CLIC, MC**
- **but we *MUST* do more (not less) R&D**
  - **both accelerators and detectors**
- **fortunately, the EU is more scientifically forward thinking than the UK**
  - **through FP7**
- **and *CERN* can take the lead**
  - **through Council, MS, laboratory and collaboration**

The Role of CERN

- **CERN currently focussed on the LHC**
  - This ***is*** the highest priority
- **also true in 2009 (…?...)**
  - … but begin to explore the longer term
  - Options for CERN
    - Modest upgrade of the LHC
      - sLHC
    - Major upgrade of the LHC
      - DLHC
    - Linear Collider
      - CLIC@CERN or ILC@
        - » both with major European participation
    - Neutrino Facility
      - Not the high energy frontier!
      - Step on the way to a Muon Collider @ CERN
  - This should be a European decision

The Role of the CERN Member States

1. European particle physics is founded on strong national institutes, universities and laboratories and the CERN Organization; *Europe should maintain and strengthen its central position in particle physics.*

- The national, European and Global strategies for particle physics need to be aligned
- The CERN Council Strategy process *in principle* achieves this
- The European strategy should be interwoven with the national strategy
- Need to promote particle physics in the Member States
  - press, public, politicians, pedagogy
  - All reflected in this Symposium

Opportunities for CERN/Europe

- While CERN as a laboratory ***must*** concentrate on the LHC

  CERN as an organisation ***should*** lead the debate about the next major facility

  wherever it is built

  supported by Council

  and the member states

- If you do not lead, you either

  follow

  or

  do not participate at all

Is Physics Popular?

There is strong evidence that physics stories are popular with at least part of the general population.

- **Popular science magazines like New Scientist know that a good physics story on the front page increase sales by an impressive amount (several thousand copies), and (from the same magazine) of the 10 most popular cover stories last year, 6 were physics based… Other popular science series have similar results.**

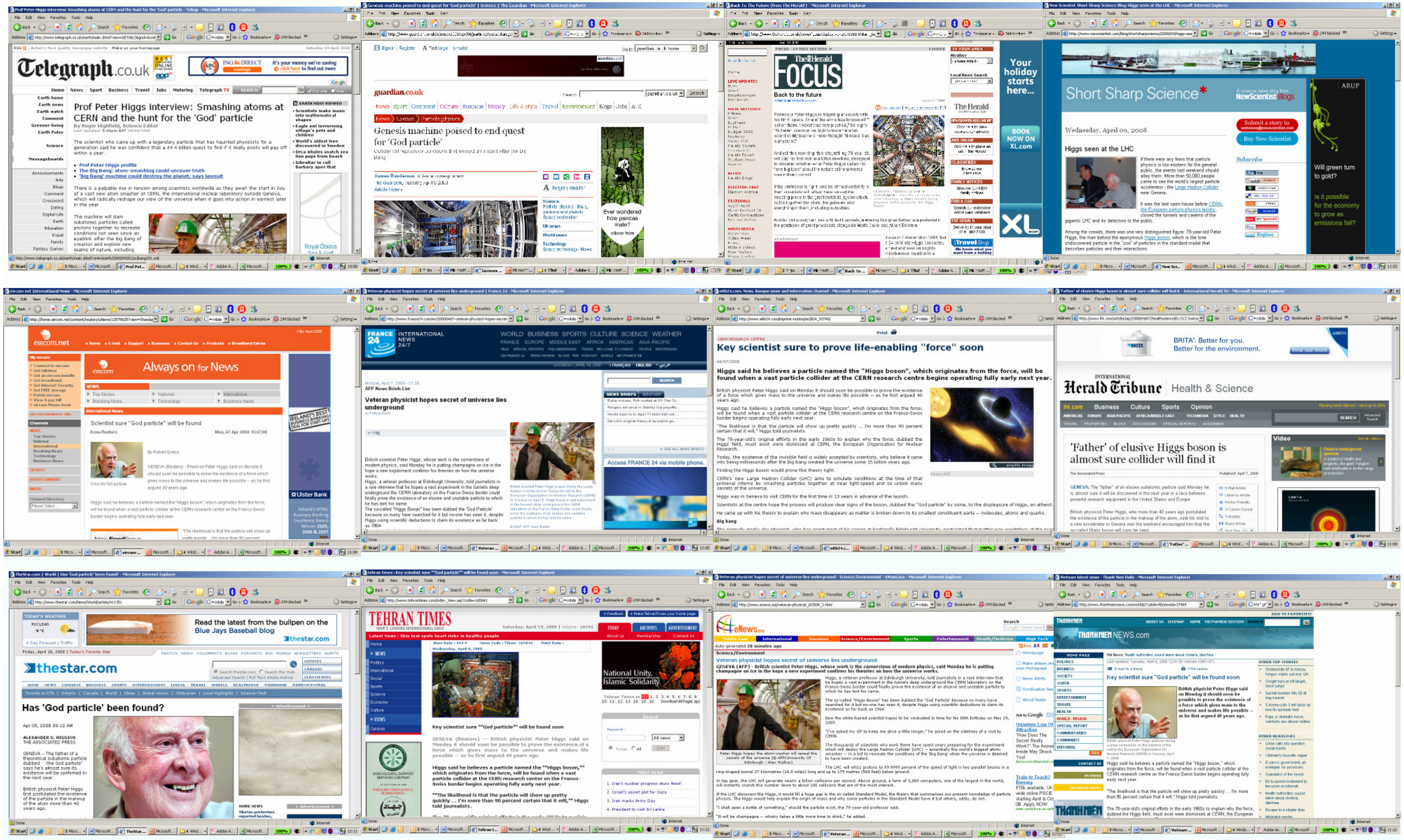
2. The recent BBC Horizon programme

What on Earth is wrong with gravity?

by Brian Cox attracted 2.1M viewers, compared with a typical Horizon audience of about 1.2M.

from a science journalist

Peter Higgs visit to CERN



... and many more ...

… and in Poland too

From the preamble …

"Particle physics stands on the threshold of a new and exciting era of discovery."

- **We must be ready to cross that threshold with a global strategy to address the new questions the discoveries will provoke…**

- **Europe should lead …**

Summary & Conclusions

- **At the scientific and technical level**
  - **Two major international programmes**
    - **Linear Colliders (ILC & CLIC)**
    - **Neutrinos (Factory, Super and Beta Beams)**
  - **Should have clear options 2010-2012**
    - **When early LHC results known**
- **At the political level**
  - **Still much to do**
    - **Statements made for domestic political reasons**
      - **Have international consequences in a global age**
- **We need to work harder on selling the science**
  - **We have the press and the public on our side!**

Thank you!

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