

The role of Theoretical Physics in a decade of discovery



Luis Alvarez-Gaume

An optimist view...

The 2010's is likely to be a golden decade where substantial progress will be made in our understanding of what lies beyond the SM

A collective consequence of many experimental results, and joint analysis of experimentalists and theorists may lead to a totally unexpected view of the Universe by 2020

Some of our paradigms are likely to be shifted. The very way we think about the UV completion of the SM. There may be more than symmetries, and there may be more than a Landscape of Anthropic explanations...

What should be the role of theorists in this quest?



Paraphrasing V.I. Arnold:

Theoretical Physics is the part of HEP where the experiments are cheap...



Questions circulated

- ❖ How do you see the role of theory for the field of particle physics?
- ❖ What are the areas of particle and related theory that may (or may not) require strategic coordination at the European level?
- ❖ How do you see the medium-term development of particle theory research (research directions, human resources, organisation)?
- ❖ How do you see the role of the different EU actions for theory, and, vice versa, the role of theory within the different EU actions?
- ❖ How do you see the role of CERN for European theory, and vice versa?
- ❖ What are the strong/weak points of European theory versus other regions, and what could be done to improve on possible weak points?



General contributions

General Comments

ID	Title	
10	Fundamental Science at the European Spallation Source	link
16	Synergy of Particle Physics with other disciplines; the CERN CLOUD experiment	link
18	High-energy physics in Finland Strategic outlook for Helsinki Institute of Physics	link
20	Statement of Interest and Support from the Brazilian HEP Community	link
22	Open Infrastructures for Scholarly Communication	link
25	Suggestion from a Taiwan physicist	link
27	Swiss contribution to the Update of the European Strategy for Particle Physics	link
32	Statement from NuPECC regarding the LHeC and ALICE	link
51	TIARA contribution to the European Strategy for Particle Physics	link
59	UK input to European Particle Physics Strategy Update	link
64	Imaging and Imagination, how to exploit semiconductor technology for particle physics	link
85	Input of Nikhef to the European Particle Physics Strategy Discussion 2012	link
92	Input for European Strategy for Particle Physics from IFIN-HH, Romania	link
96	The fourth generation, linac-ring type colliders, preons and so on	link
98	Input from CPAN on behalf of the Spanish community	link
113	Statement by the German Committee for Particle Physics (KET)	link
121	Future Strategy of Japanese High Energy Physics Community	link
124	Interfaces with Earth sciences. Input from the French community.	link
125	Towards a Global Effort for Sustainable Data Preservation in High Energy Physics [DPHEP Study Group]	link
133	Monte Carlo Simulation for Particle Detectors	link
136	A view from the INFN National Scientific Committee 1	link
166	National Research Centre 'Kurchatov Institute' input to the European Particle Physics Strategy Update	link



Specific Theory contributions

Particle Physics Theory

ID	Title	
5	"The QGSM Monitoring of Standard Model Baryon Spectra in High Energy Proton Collisions at LHC."	link
17	Search for GeV-scale sterile neutrinos responsible for active neutrino masses and baryon asymmetry of the Universe	link
18	High-energy physics in Finland Strategic outlook for Helsinki Institute of Physics	link
46	Particle and Astroparticle Physics in Poland	link
59	UK input to European Particle Physics Strategy Update	link
91	Particle Physics at High Energies but Low Luminosities	link
93	The CERN Theory Unit and the future of European High Energy Physics	link
99	CLIC e+e- Linear Collider Studies	link
106	The future of Monte Carlo Event Generators	link
109	Higgs/top factory and Planck physics	link
116	Theoretical physics in France (particle physics, nuclear physics, astroparticle physics and cosmology)	link
121	Future Strategy of Japanese High Energy Physics Community	link
127	Searching for Dark Matter	link
131	Implications of LHC results for TeV-scale physics: signals of electroweak symmetry breaking	link
137	Input for the European Strategy Update from the DESY theory groups	link



The future of HEP hinges on the LHC

1st mission: look for the Higgs

$$A(W_L^+W_L^- \rightarrow Z_LZ_L) = \frac{G_F E^2}{8\sqrt{2}\pi} \left(1 - \frac{E^2}{E^2 - m_H^2} \right)$$

Without Higgs $\Rightarrow E < 1.2$ TeV

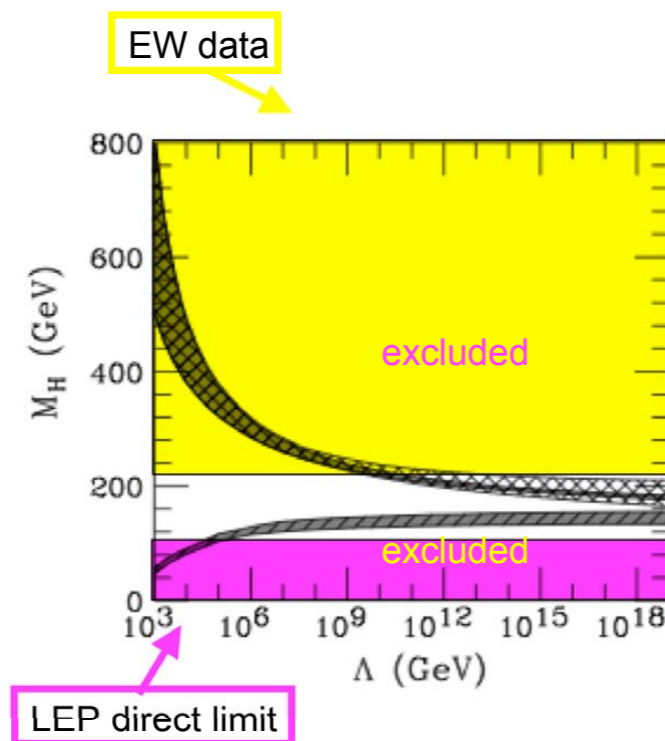
With Higgs $\Rightarrow m_H < 780$ GeV

LHC must discover Higgs or New Physics below TeV,
or else *unitarity* is violated

2

2nd mission: search for New Physics

Extrapolate to high energies: $V(H) = -\mu_H^2 |H|^2 + \lambda |H|^4$



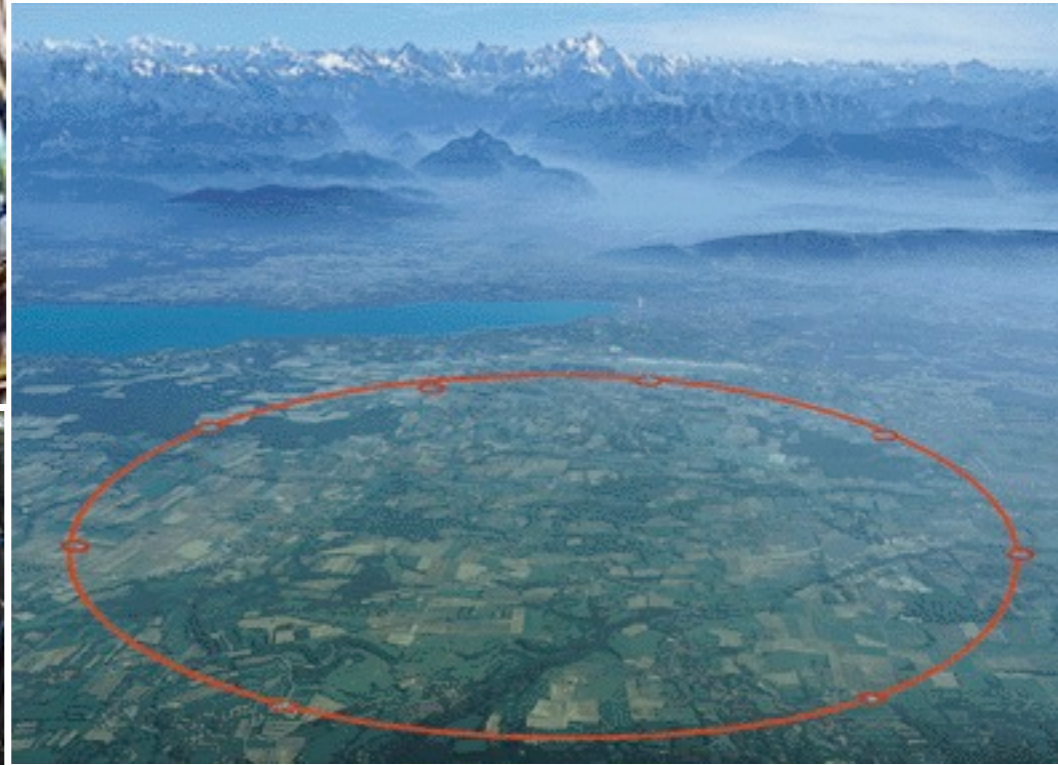
114 GeV < m_H < 130 GeV:
 $V(H)$ unstable for $\Lambda < 10^7$ GeV

130 GeV < m_H < 180 GeV:
 valid extrapolation to M_{GUT}

$m_H > 219$ GeV:
 conflict with EW data

3

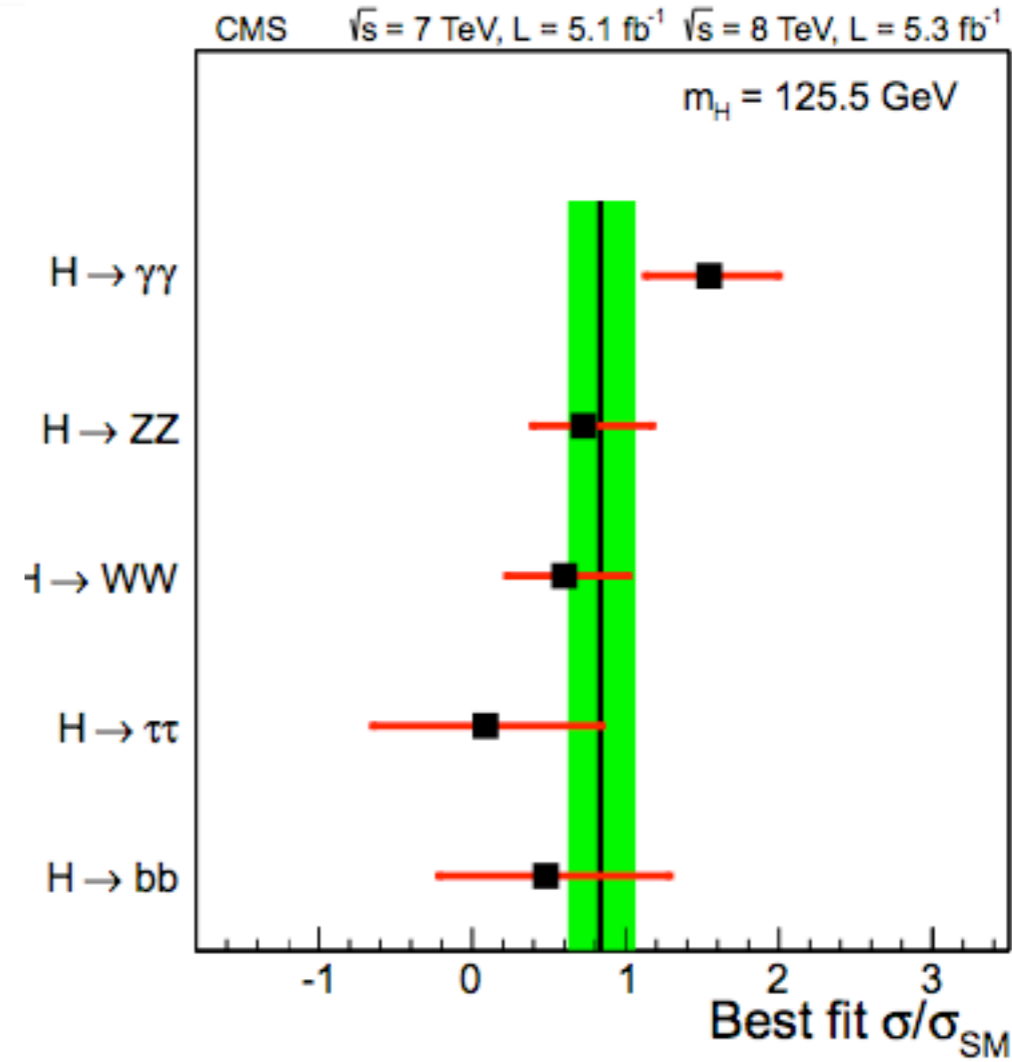
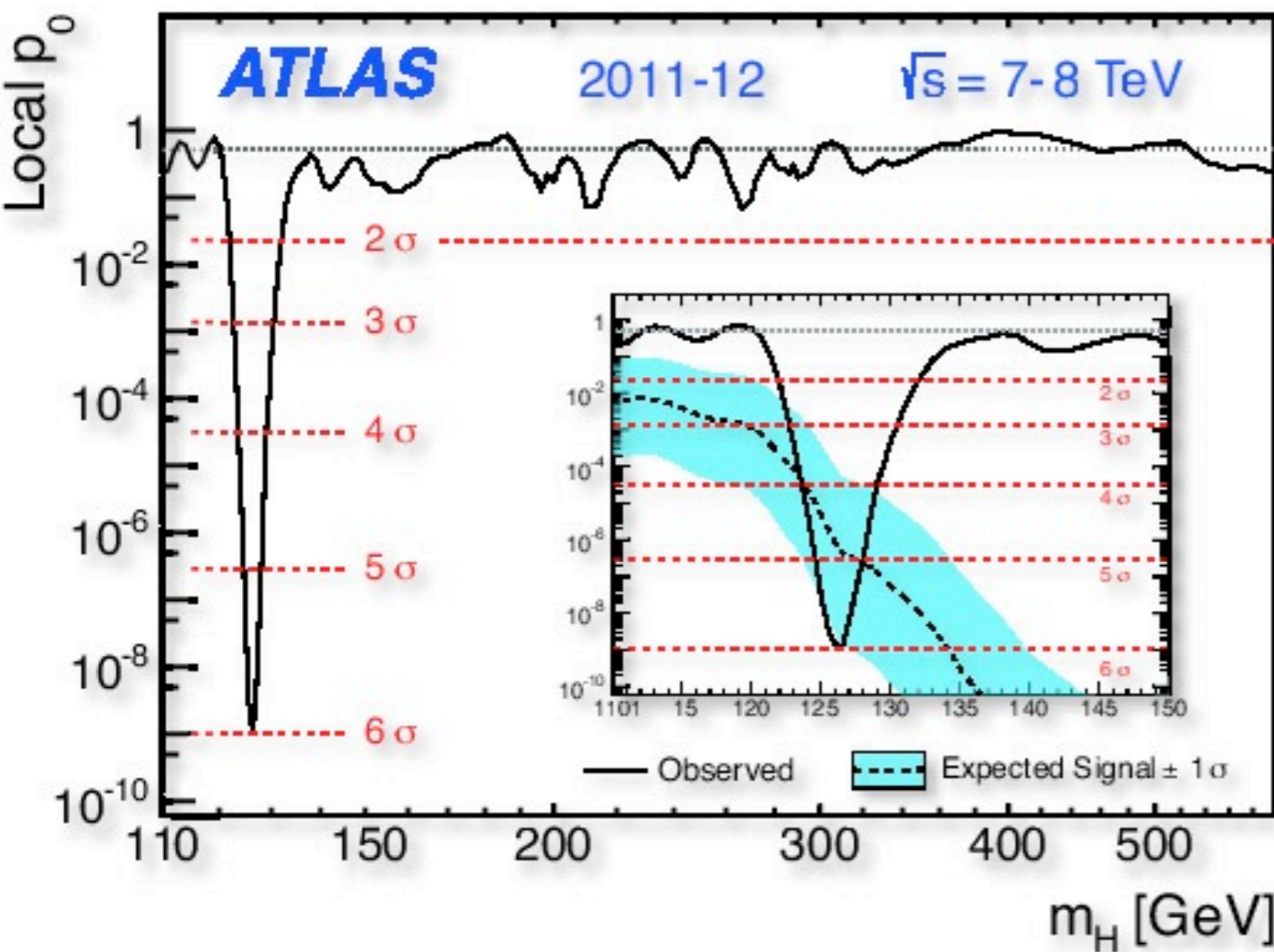
The LHC finally joined the search



- After initial difficulties the LHC has begun to produce results
- Scalar particle discovery
- Basic results in the BSM search
- Important understanding of QGP extending Brookhaven/RHIC results



It looks like the Higgs...



- ▶ Weakly coupled (thanks Nature?)
- ▶ No new state observed up to 1-1.5 TeV
- ▶ Naturalness in trouble?



The tip of the iceberg?



The burial of naturalness?



It deserves a nice mausoleum...

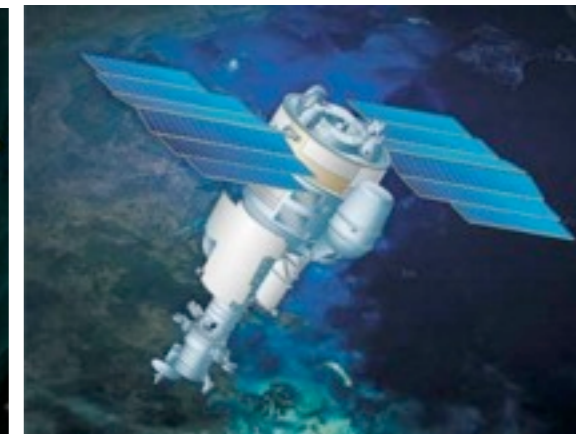
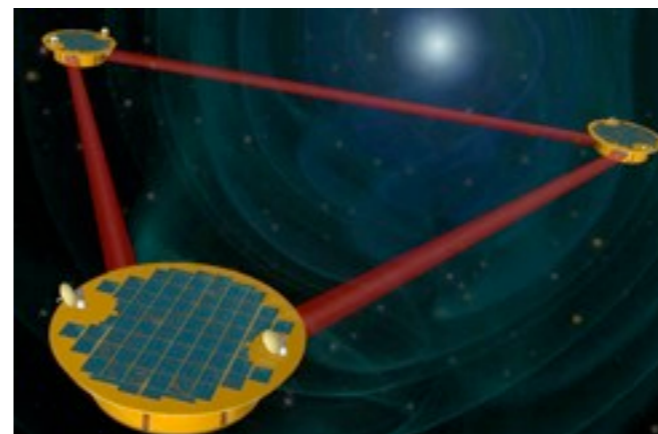
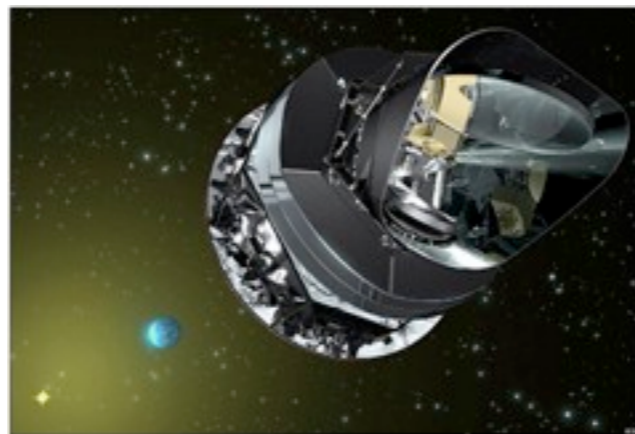
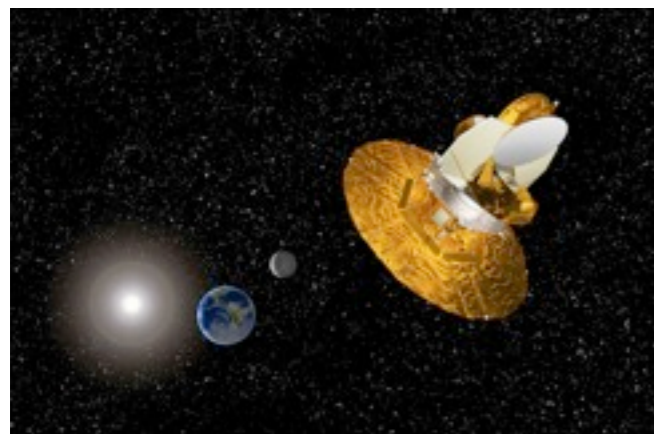


Cleaning the space of theories

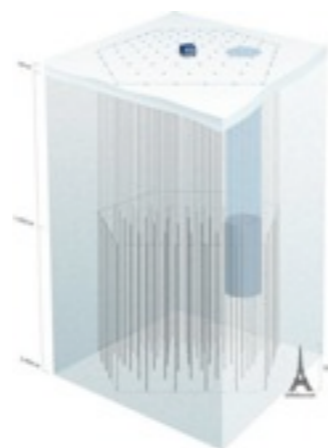


- The LHC is contributing to populate the graveyard of theories
- As more is learned about the Higgs, many theories get important constraints
- This is the beginning of our understanding of what underlies symmetry breaking, hopefully we will find clues to what lies beyond

News from the sky and the underground



PIERRE AUGER OBSERVATORY



...

A data rich decade, we are bound to find something new (optimist)...







Some aspects of TH community



Some aspects of TH community

The community does not really need a Global Strategy

It is a global and well connected community (remember the arXives)

Flexible, resilient, adaptive and highly motivated

Different parts of the community have different and/or complementary strengths,
healthy mutual competition

Variety, independence and complexity are virtues

Sometimes a little crazy (also a virtue)

So, why do we come to the ESPP meeting?



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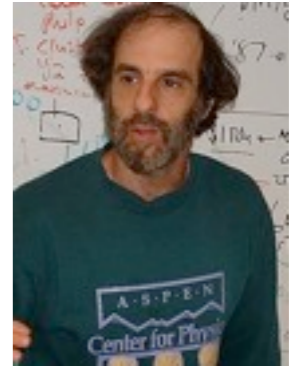
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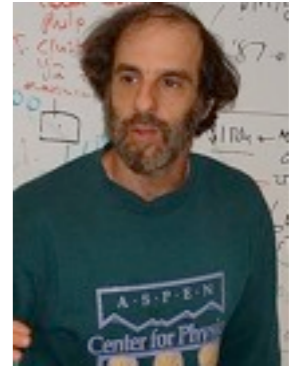
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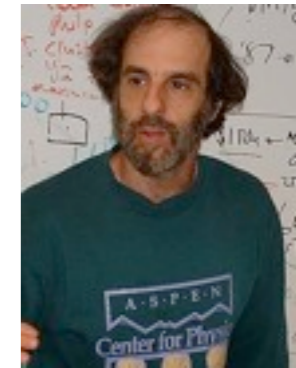
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To raise issues about the future of the young

To improve and optimise our relation with experimentalists

And of course to ask for money...

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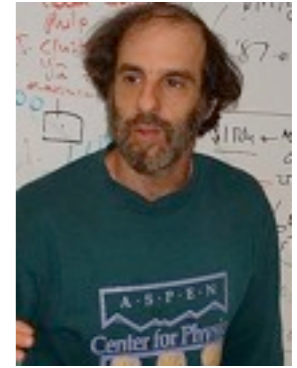


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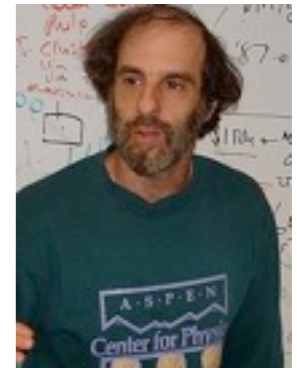


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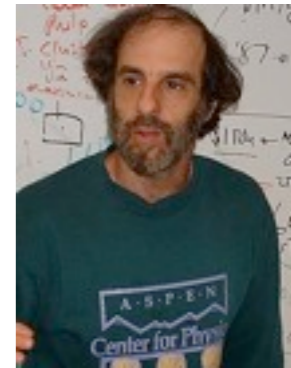


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“... on the shoulders of giants”

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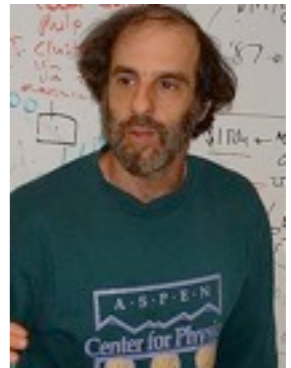


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“... on the shoulders of giants”

“... on the shoulders of experiment(alists)”

Luis Alvarez-Gaume



Roles of Theory



Without Theory there would have been no SM today

The Higgs search is to a large extent inspired by theoretical considerations

Pointing possibilities for extensions of the SM

Precision computations

Supersymmetry, Supergravity

Technicolour

LEDs RS...

Conformal symmetry beyond few TeV

Interface with Astrophysics and Cosmology

Dark matter, dark energy, modifications of gravity at long distances, gravity as an entropic force

Pleasant, unexpected surprises: QGP and AdS/CFT

We have plenty of crazy ideas, but are they crazy enough? (N. Bohr)

Help define the Physics case of new facilities or for the extension of existing one

Close(r) relation with experimentalists



Plenty of examples from the submissions to the Symposium

Interesting proposals for new accelerators, in particular ILC, CLIC... After the discovery of the scalar particle the full assessment of the Physics case for this facilities is crucial. Other proposals like LeHC, LEP3... involved the close collaboration of theorists and experimentalists. From Masiero's talk one can see that theorists do not stay idle:

The low-energy frontier (axion, CPT test, LIV etc)

The high energy/intensity frontiers

Missing energy analysis

Neutrino facilities

WIMP WISP searches

HI, QGP, CGC...

Exotica

Close connection with Astroparticle Physics and Cosmology (APC). HEP and APC complement each other in many ways. They have many common goals with complementary approaches. A well-structured relationship in the next decade is highly desirable. Have school with theory and experimental students from both communities. They will benefit from each other.

The flavour problem as a promising venue to obtain BSM information

...



Tools and Analysis



Create tools to understand and analyse data. The LHC is a QCD machine. A huge amount of theoretical work is and has been necessary to define and understand signal/background. This involves practical tools like PHYTHIA, HERWIG, ALPGEN... as well as the study of new theoretical tools to meet the challenges of complex final states and/or precision measurement. Many hundreds of human/years have been spent in these problems using biological and silicon brains

Help with data analysis and interpretation. Define signals, exclude models and scenarios, look for concomitant phenomena in other areas

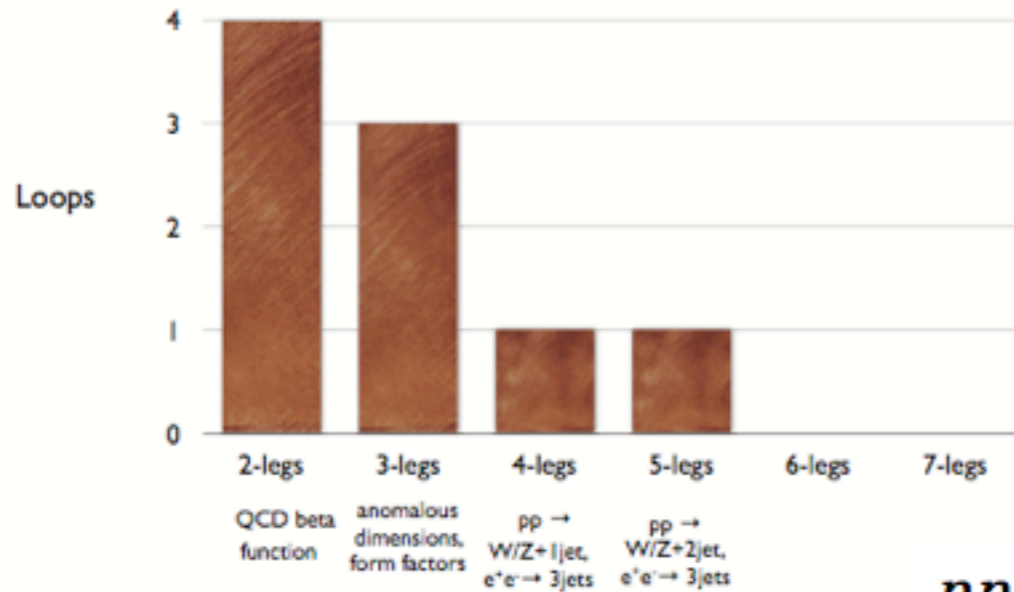
MCnet collaboration: “ We argue that continuing a strategy of European co-ordination and funding of general purpose Monte Carlo event generator development is vital to keeping pace with the increase precision and breadth needed to fully exploit the experimental data.

Matching parton showers with NLO matrix elements for multi-jet processes
User friendly interfaces to future automatic NLO matrix element generators
Testing and validation of the algorithms using existing data
Non-perturbative modelling...”

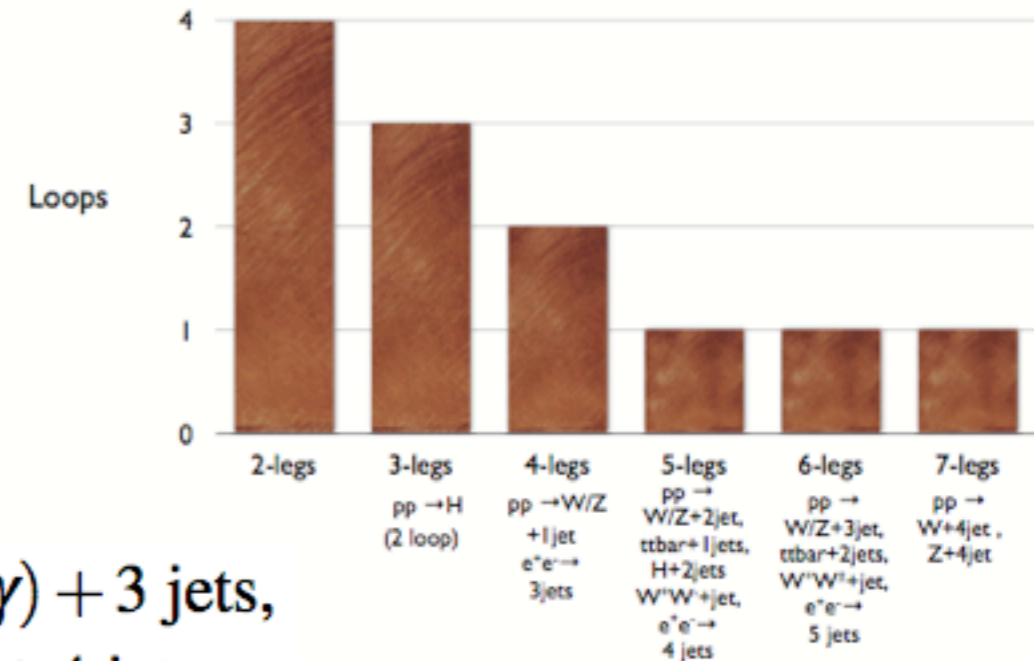


Steady progress in computations

Loops and legs (circa 2007)



Loops and legs - 2011



$$pp \rightarrow W^\pm(Z, \gamma) + 3 \text{ jets},$$

$$pp \rightarrow W^\pm(Z) + 4 \text{ jets},$$

$$pp \rightarrow 4 \text{ jets},$$

$$pp \rightarrow t\bar{t}b\bar{b},$$

$$pp \rightarrow t\bar{t} + 2 \text{ jets},$$

$$pp \rightarrow b\bar{b}b\bar{b},$$

$$pp \rightarrow t\bar{t} \rightarrow W^+W^-b\bar{b},$$

$$pp \rightarrow W^+W^+ + 2 \text{ jets},$$

$$pp \rightarrow W^+W^- + 2 \text{ jets},$$

$$pp \rightarrow W\gamma\gamma + \text{jet},$$

$$e^+e^- \rightarrow \geq 5 \text{ jets}$$

Courtesy of J. Blümlein and K. Ellis

Training

Training of students: common graduate workshops, summer institutes, etc for TH and EP students (i.e. European school in HEP, CERN-Latinamerican School, Academic Training programmes in different laboratories)



Maintaining Theory Groups

Quality training of students, and active and stimulating environments for them as well as postdocs are fundamental in maintaining a high quality research (and education) group, whether at a University or Research Lab. They are our future.

Critical size of groups difficult to define and implement. Better perhaps to focus on optimise use and sharing of resources.

Share programmes and resources:

GGI activities

Durham IPPP

DESY programmes

CERN-TH Institutes, LPCC

Without forgetting US initiative like TASI and programmes on other parts of the world

Run coordinated workshops, summer institutes, visitor programmes at major centres, with shared responsibility and resources

Share students and postdocs: increase mobility. Major labs and/or groups should engage in “prepostdoc” experience.

Shared graduate programmes through RTN-like networks

Improve work facilities

...continued

Prime flexibility. Avoid rigidity and full control of major laboratories. Avoid too much “legislation”. Often common sense and some experience are the best guide.

Provide realistic career opportunities. This is a major issue for many theorists, as well as for experimentalists. Otherwise, bright people are turned away from HEP activities

The issue is not just 2 vs 3 years postdocs, but also the fair assessment of work done in different activities.

For instance, those working on say NNLO or lattice computations, and those doing model building. The luminosity and visibility and accessibility to the job market should be equilibrated.



Changes in CERN-TH since ESPP 2006

CERN TH Institutes

It was decided to restructure the Visitors programme to increase its quality and impact. In the LHC era we focussed and restructured it. The ultimate aim is to make the best use of our resources and to share them with the community. We also strive to coordinate our activities with those of other Institutes, Universities and Research Centres

The LPCC

The LPCC collects a set of initiatives in support of the LHC physics programme. These range from the organization of Workshops, to the support of the development of event generators and other physics tools, to the development of this web page, which is intended as a portal into LHC physics resources for the whole HEP community. These initiatives include :

- LHC WGs: The LHC working groups provide a common forum for discussion among the LHC experiments and the theoretical physicists.
- LPCC events:
 - **Workshops**
 - **LHC Physics Day**
 - **EP/PP/LPCC seminar**
 - **LPCC students' lecture**
 - **LHC reports**
- Tools
- Theory contacts: the list of theorists at CERN that one can contact for physics questions, MC support, BSM ideas to be pursued, etc.etc.



General education and outreach

The fanciful way of saying today is “knowledge transfer”

High School Teacher’s Programmes. They are our colleagues dealing with the young. They have a fundamental impact in inspiring and encouraging them to choose Science as their major.

Different regions and countries have adapted programmes: Fermilab, Notre Dame, CERN-HST, Frascati, IN2P3,... But more importantly, keep in touch regularly. Provide support when needed. Help create networks

HST day in major HEP conferences

Would it help to coordinate activities, share online programmes?

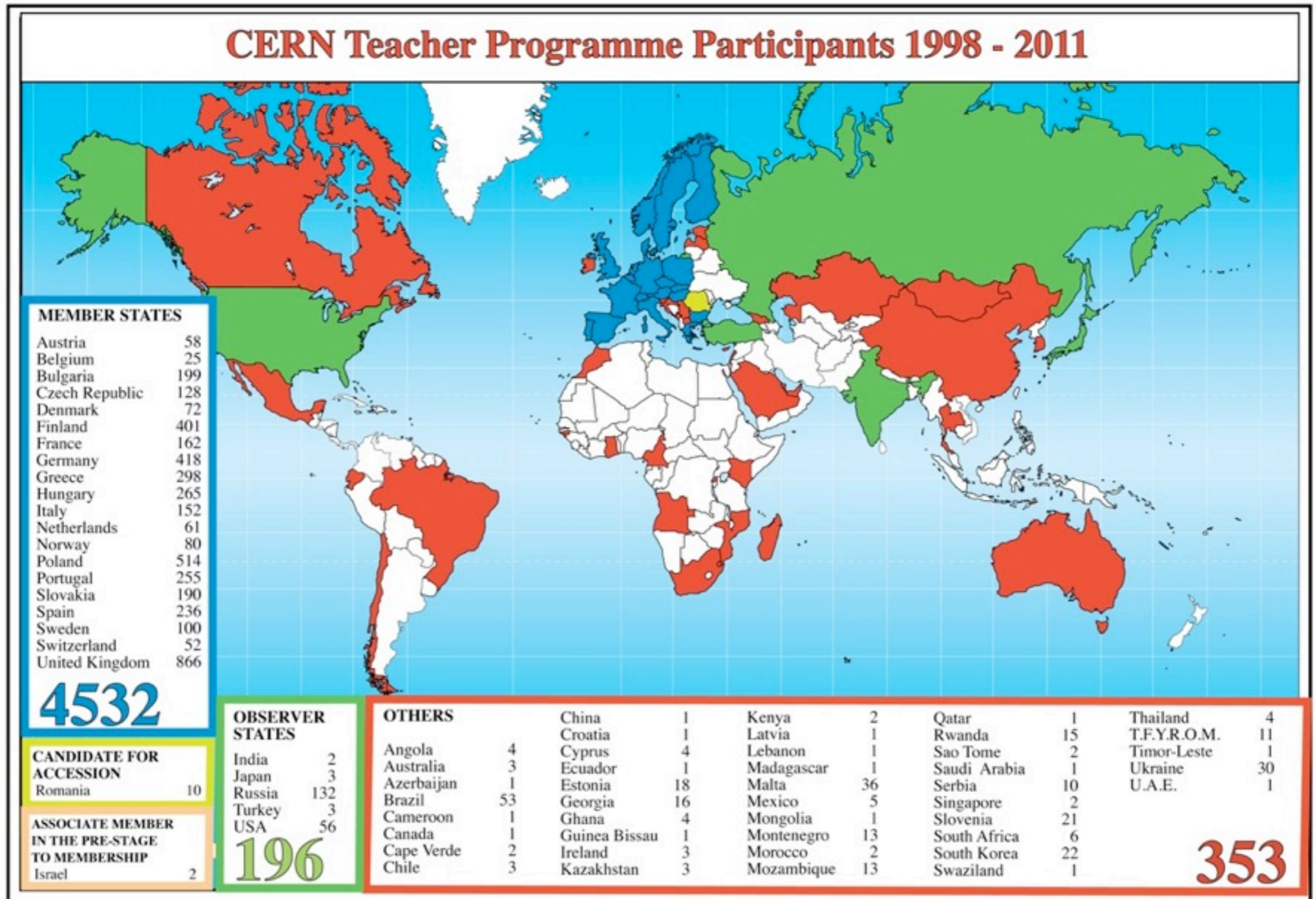
Take an active role in bringing our Science, its fascination and results to the general public.

The enthusiastic participation of the scientific community, among them the TH sub-community are instrumental to the success of this activity. We have everything to gain.

Thanks to Michelangelo Mangno and Mick Storr



General education and outreach



Coordination with EU

Many issues still standing from the 2006 meeting (see Mangano's summary)

Particle Physics recognised as a subfield in the call for proposals. It would be desirable to have some representation/coordination in/with the deciding bodies

Balance between training, postdocs, interface with industry. Different frameworks have stressed aspects of training and research that were not very consistent (as seen from our field). Emphasis on postdocs in one, but on students in the next, with little support for postdocs.

In some cases the interface with industry is natural (experimental proposals), in others it is unrealistic. More flexibility would be desirable. Less "strict project orientation" is beneficial. In fundamental research you cannot define "goals" so precisely.

Balance between TH and EXP EU support. In HEP we are far from a healthy equilibrium regarding TH vs EXP support, and also with the age distributions of PIs in senior ERC grants

It would be highly desirable to have close contacts between the CERN Council and the ERC



Conclusions

The TH community is useful and healthy, we should keep it that way

Improve coordination of activities. Avoid unnecessary duplication

Increase contact between Th and Exp students and communities

Increase mobility and sharing of resources

Address the problems associated with career structures

Become present in EU, ERC funding

Improve the outreach to young students and to the general public





Thank you