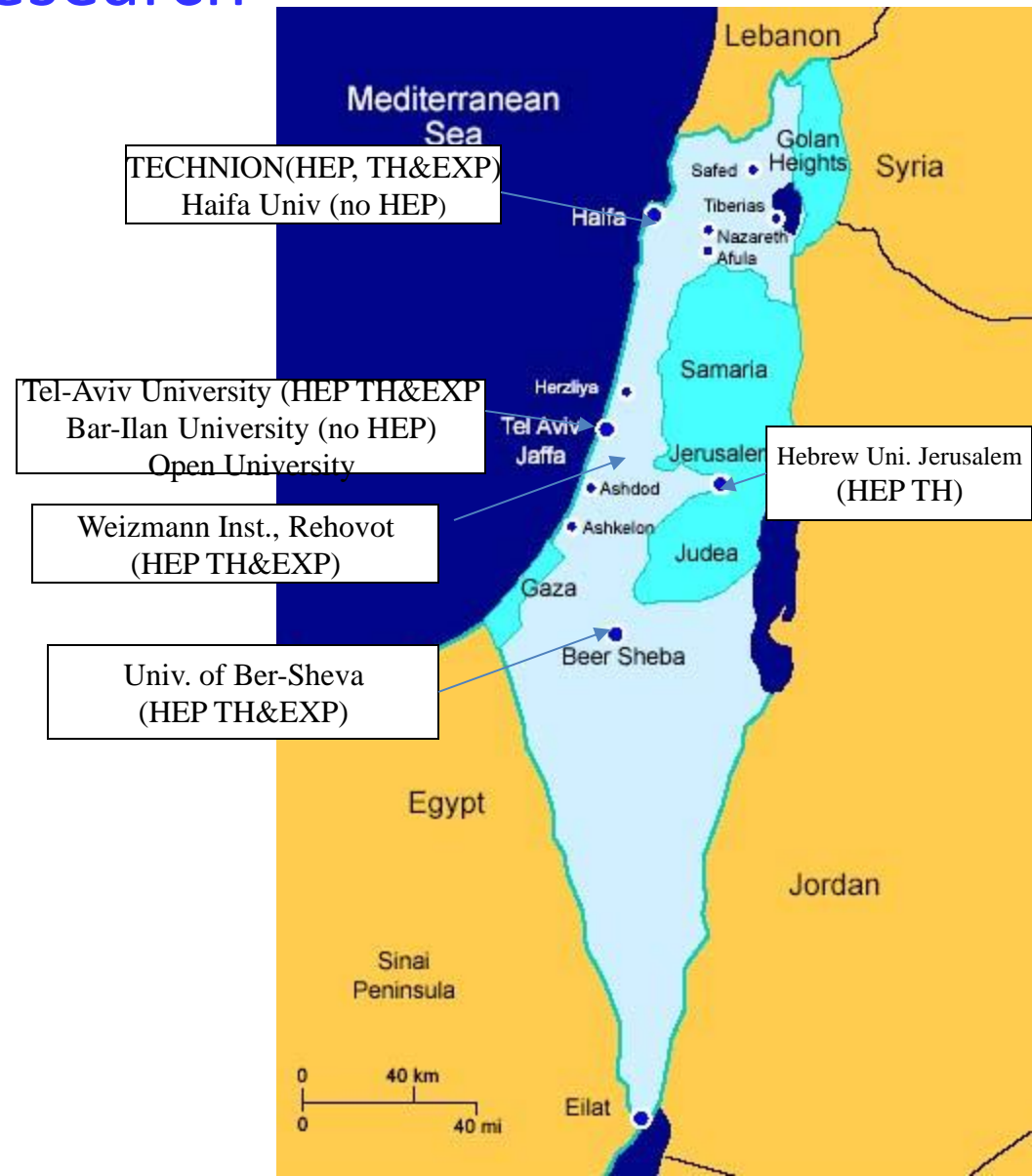


Israeli Participation in the construction of the largest Microscope in the world, the LHC

- Introduction to the Israeli educational system and its influence in the High-Tech revolution
- Israeli relations with CERN
- The Physics of the LHC
- The largest High Energy Physics Experiment in the world, ATLAS and the Israeli participation.
- First results and expectations
- Conclusions.

General Comments on Israeli Education and Research

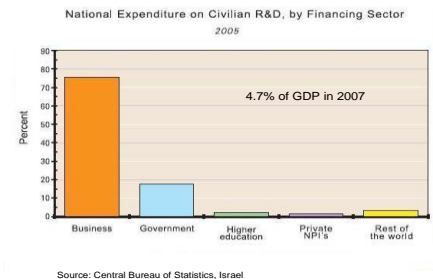
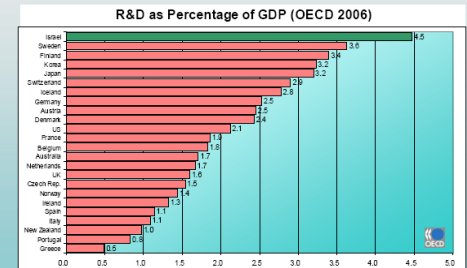
- Israeli Population 8 Millions habitants (=CH)
- GDP (PPP)/capita=33.9K\$ (>IT, GR, <CH=44.9, CL=18.2K\$)
- Unemployment ~6% (not very high taking into account 1M immigration wave, and in particular the present economic crisis) (IT=12%, CH=4%)
- 8 Universities (7 with large Research Programs) & 60 Academies/Colleges.
- % of GDP for Civilian R&D: 4.3% (2011)
- Average monthly wage:2.7K\$ (IT=3.1K\$, GR2.1K\$, CH=7.5K\$)
- TECHNION created in 1924 & HU Jerusalem in 1925, Weizmann in 1935 (in 1948: 1,600 students, in 2008: 260,000)



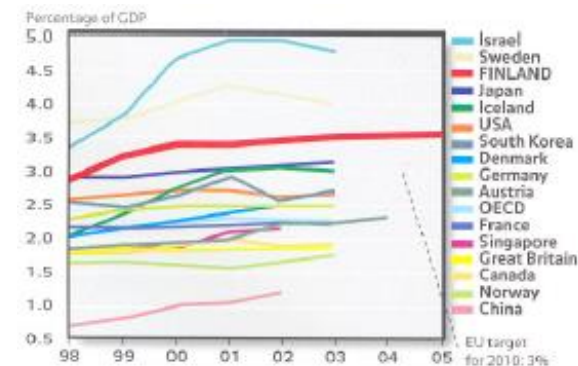
General Comments on Israeli Education and Research

- Education has always been a priority in Israel and the first two Universities were established 24 years before the existence of the State of Israel.
- 47% of the age group 25-64 years old have 16+ years of education (just behind Canada and Russia)
- In the early period, research was mainly driven by Agricultural Research, out of the need of transforming the desert and swamps.
- Serious Industrial Research only started in the late 70's early 80's (mainly electronics and communication).
- In 85 Law to Encourage Industrial R&D was approved. Fund was established, that reached 400M\$ in 2000-1
- Physics Research started in Jerusalem, following the Racah School, and at the Technion, following the Rosen School. This, together with some new immigrants formed most of the Theorists, while Experimentalists were formed by sending them abroad in the 50's and 60's, where they participated in some important discoveries.
 - Funding for Basic Science is mainly done through the National Science Foundation (depending on the Academy of Science and Humanities)

R&D intensity: National Expenditure on R&D



Civilian R&D as % of GDP



Higher Education in Israel

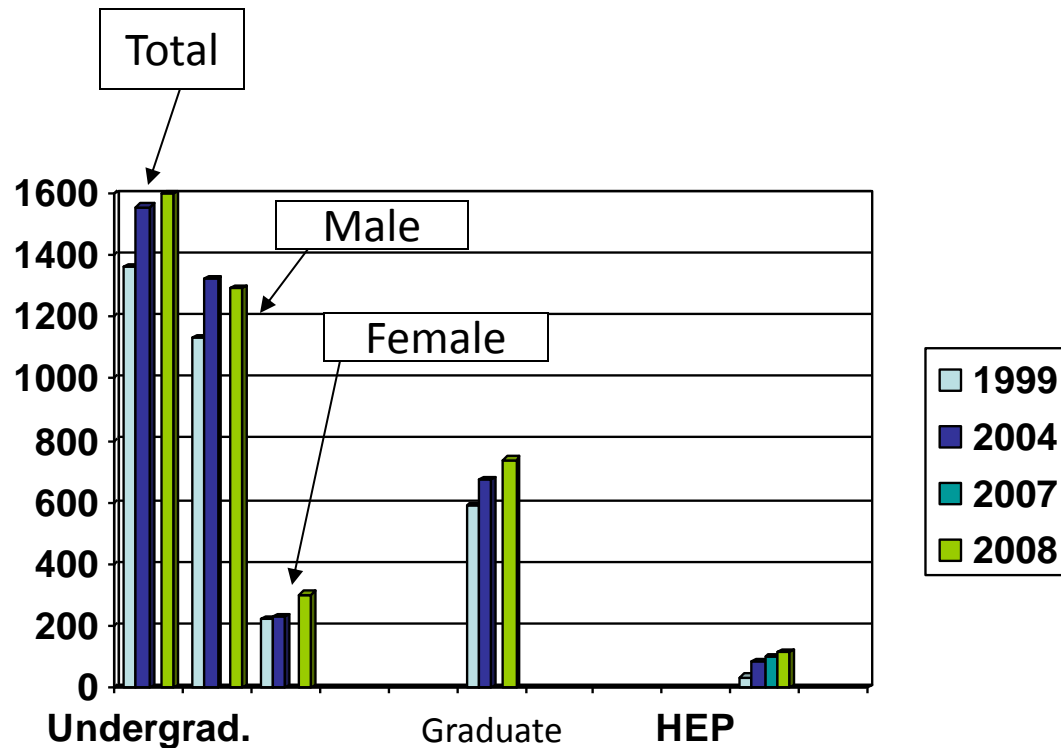
Higher Education in Israel

A Quick Glance: Facts & Figures

	1990	2007
INSTITUTIONS	21	62
• Universities	7	7
• Open University	1	1
• Art Academies	2	2
• Comprehensive Colleges	0	9
• Engineering Colleges	2	7
• Teacher Training Colleges	7	27
• Non-Budgeted Comprehensive Colleges	2	9
 STUDENTS	 89,000	 256,438

- Growth of number of academic institutions in Israel in the last 17 years.

Physics Students in Israel

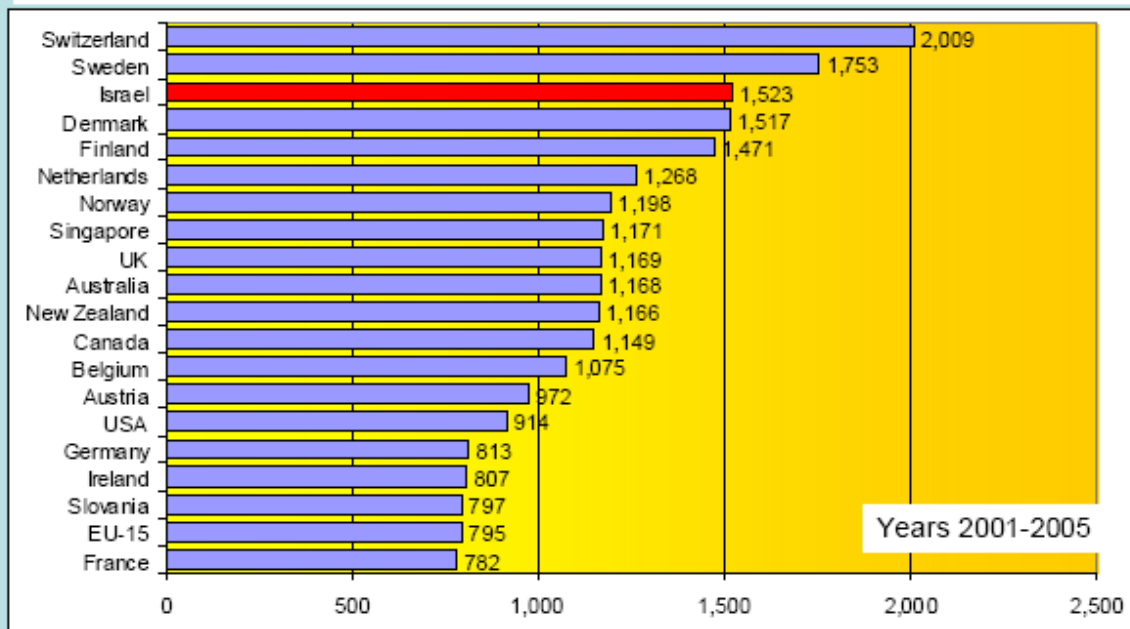


- Although there was a general drop of Physics Students in the late 90's, this trend has changed considerably, mainly due to the immigration from Science minded Students from Russia as well as the High-Tech boom.

Good Scientific Education leads also to a high level of publications

Scientific Output

Papers per 1 million population **World Top 20**



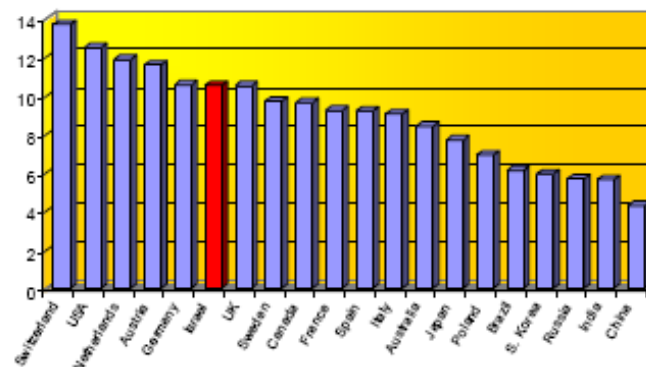
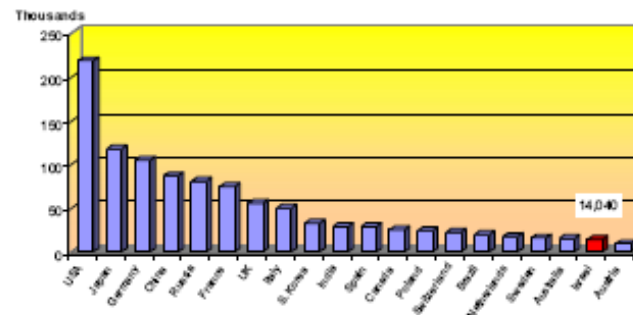
Including in Physics

Top Countries in Physics (1997-2007)

Israel ranked
19th by total
N° of Papers

But...

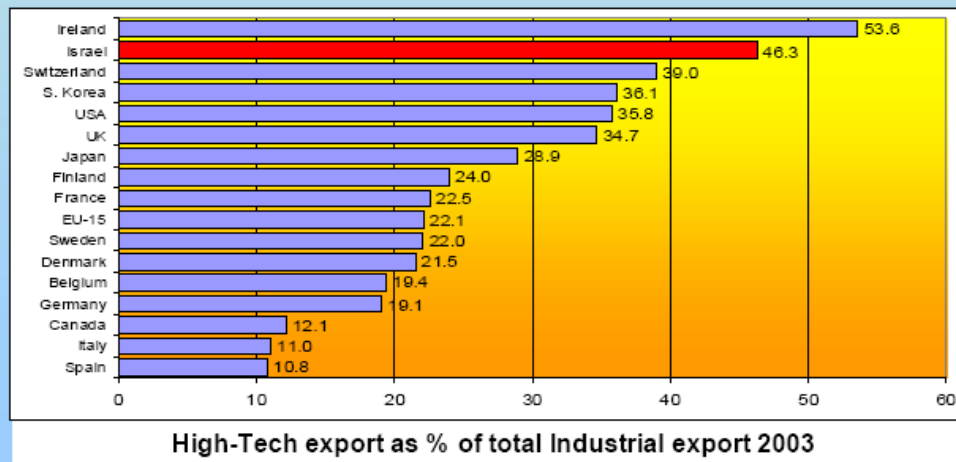
Ranked 6th by
importance
(Citations per Paper)



As well as in the importance of High-Tech in the Industrial Production

High-Tech Economic Engine

Over last decade High-Tech contributed 40% to GDP growth in Israel, and 15% to increase in employment



- Sales of High-Tech products have reached 21B\$ in 2008, with a yearly growth of 10%.

Relations with CERN

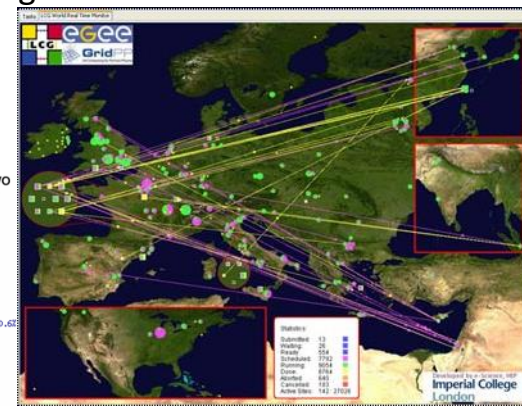
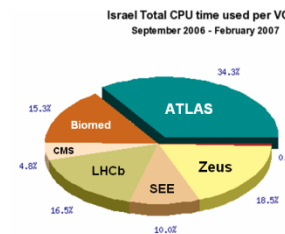
- Israel has been the first paying Observer State of CERN. This Status includes now India, Japan, Russia, Turkey and the USA.
- In August 1991 a Protocol to the Agreement was signed and renewed several times since then (last time in December 2006). The agreement is financed by the Ministries of Science and Technology (13%) and of Industry Trade and Labour (87%).
- The last version of the agreement includes an overall contribution corresponding of 25% of what would be the total contribution of Israel as a CERN Member State. The framework of this agreement provides 27% in cash and 73% in-kind, by Israeli firms participating in CERN tenders.
- In October 2004 an additional Protocol to the Agreement was signed, by which Israel increases its contribution by 50% for a period of 2 years. The additional contribution was intended to help the LHC Experiments and the GRID Project, by covering 50% of the cost of products purchased in Israeli Industry.
- Typically during these years (2004-2005), the Israeli returns was 130%, while for the normal contribution varies between 90-110%.
- Since December 2013, Israel is a full Member of CERN. This is an important step in the recognition of Israeli Contribution to CERN, both Technologically and Scientifically.

Relations with CERN before applying for membership

Cash contribution support a number of programs:

- 1) Fellows and Associates Program:
 - The regular fellowship program was expanded to include Israeli Fellows, competing on equal footing as their European colleagues, as well as CASS.
- 2) Industrial Associates program:
 - engineers from Israeli Industries have spent various periods at CERN working in the large LHC Experiments and in IT. Over 10 such posts have been funded in the last 5 years (from firms like CHIARO, BATM, INTEL, NICE, MEKOROT, etc.) working for long periods at CERN.
- 3) Doctoral Technical and Summer Students programs:
 - 32 Summer Students in the last 10 years (7 Palestinians)
 - 2 PhD students worked on CLIC and on Signal Processing.
- 4) Israeli Technical Associates:
 - The program supports Engineers and Physicists from European Countries working for the TC of the large LHC Experiments (12 until 2011).
- 5) GRID project (mainly Israeli software engineers working on the central GRID development, spending part of the time in Israel).

4 Have become Associate Professors at Technion and Weizmann
2 Have positions of responsibility in Industry
1 is the director of the largest Educational Scientific Exhibit in Israel.
1 is working as Assistant Professor in the USA

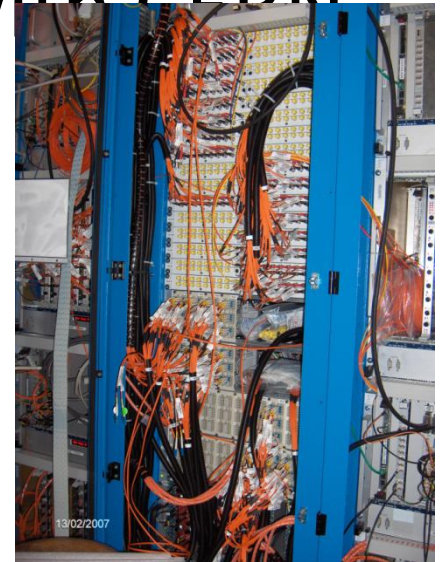


Relations with CERN

- In-kind Contributions:
 - Although at the start of the program there was good contact and interest from the Machine side, later on most of the purchasing was done by the experiments, including network equipment. Examples of such contracts are:
 - Optical transmission equipment for the synchronization of the LEP-200 RF signal (This tender allowed the firm Phasecom to get involved in very high frequency transmission equipment)
 - Construction of an aqueous cleaning system not involving Freon
 - Heat Shields for the ATLAS End-Cap Toroid (HATEHOF). This has allowed the firm to develop new Al welding techniques and get involved in the field of Cryogenics.
 - Optical Fibers and optical splitters. The firm (FIBERNET) has become one of the main Optical Fibers supplier of the two Large LHC Experiments.
 - Control and Supervision software from the firm AXEDA (this is being used for the LHC cooling control).
 - All high precision resistors used in the machine (VISHAY).
 - Network Switches from BATM, that are widely used by the two Large LHC Experiments.
 - Network equipment from Silicom
 - A large number of high precision detector-support structures for the LHC Experiments TAL, Maresco).
 - Various CAD Systems and System Interfaces (SmarTeam)
 - High precision Al profiles for various support structures (EXTAL, Mishor Haadumim)

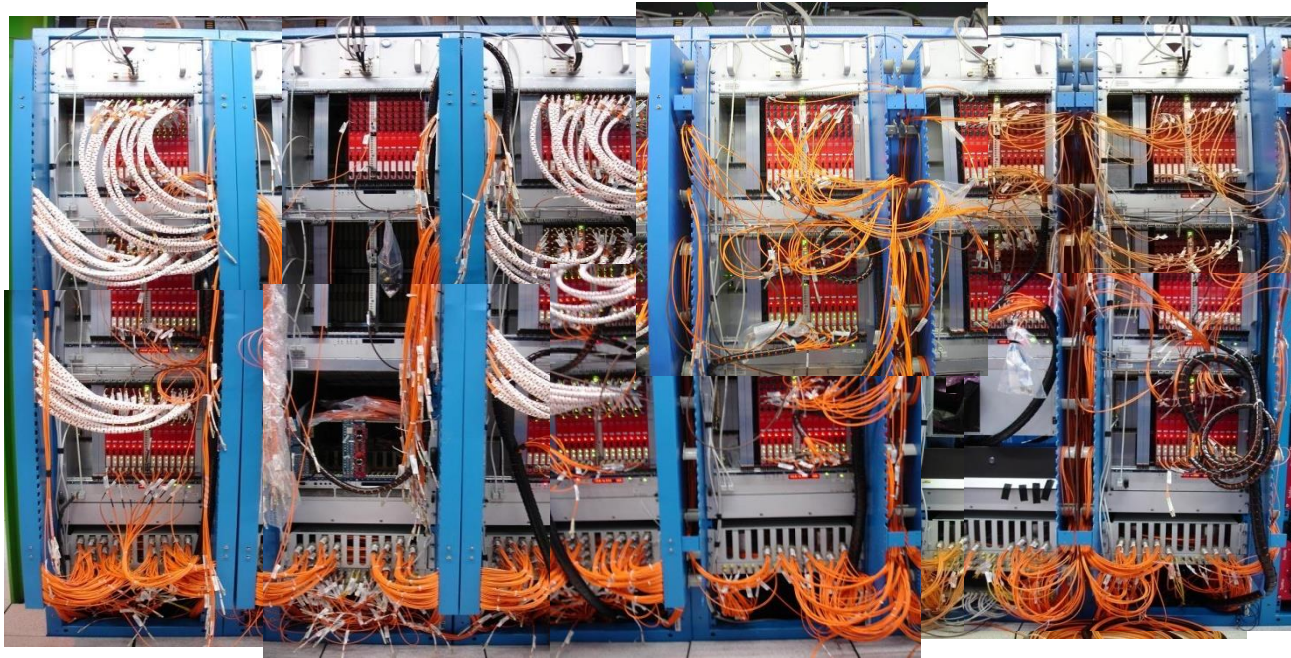
R&D and Industrial Contracts with CERN

- Transmission elements: Fiber optics and converters.
- Very strong contacts with FIBERNET (small firm (150 employees) with a lot of flexibility and network connections to other firms. This allowed to produce various custom products for 3 experiments, for a total of 3.6 MCHF:
 - Large number of halogen-free multi-fiber bundles and patch-cords
 - Development of custom made patch-panels and fiber supports.
 - Development of single to multimode optical panels, using connections to another R&D firm (COLORCHIP)
 - Development of special high density connectors for Si detectors (ALICE)
 - Development with a cable firm (Superior) of special LV cables.
- The firm got an special recognition (prize) from 3 of the LHC experiments for their excellent work. They are, however, not included in most of the general CERN contracts for infrastructure.
- Typically, only 5% of the firms involved with CERN get such a recognition.



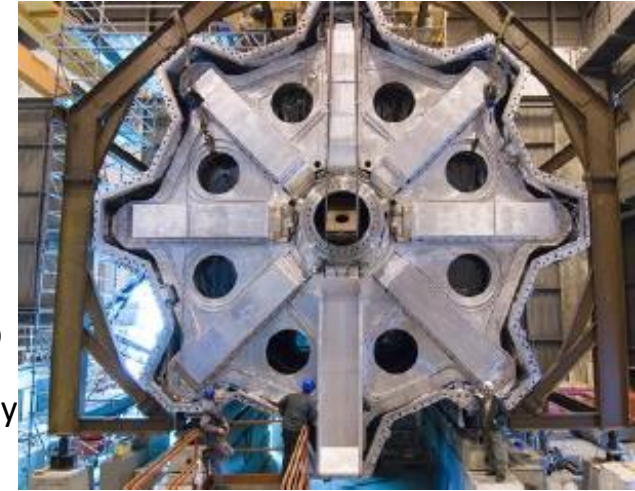
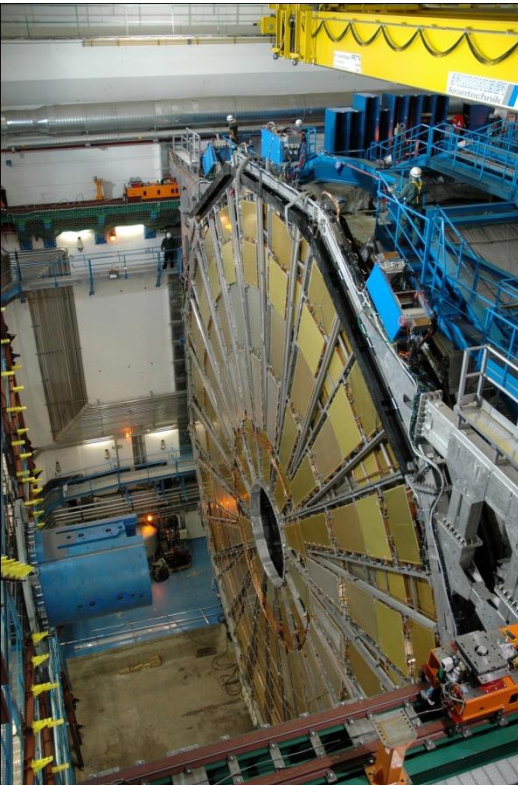
R&D and Industrial Contracts with CERN

- Production of custom electronics boards:
 - Various small to mid-size industries have a lot of experience in small production series.
 - They are not afraid of jumping into new projects that constitute a challenge.
 - 80% of the world market in PCB optical inspection machines is shared by 2 Israeli firms.
 - Major experience in flexible PCB's.
 - Major contractor has been PCB Technologies in Migdal Haemek.
- Orders of over 15MCHF during the last 7 years before application for membership, partly paid by Israel (84%), partly paid by the experiments:
 - 6.5MCHF (ATLAS), 1.5MCHF (CMS), 0.3 MCHF(ALICE), 6.7MCHF (various CERN divisions).



R&D and Industrial Contracts with CERN

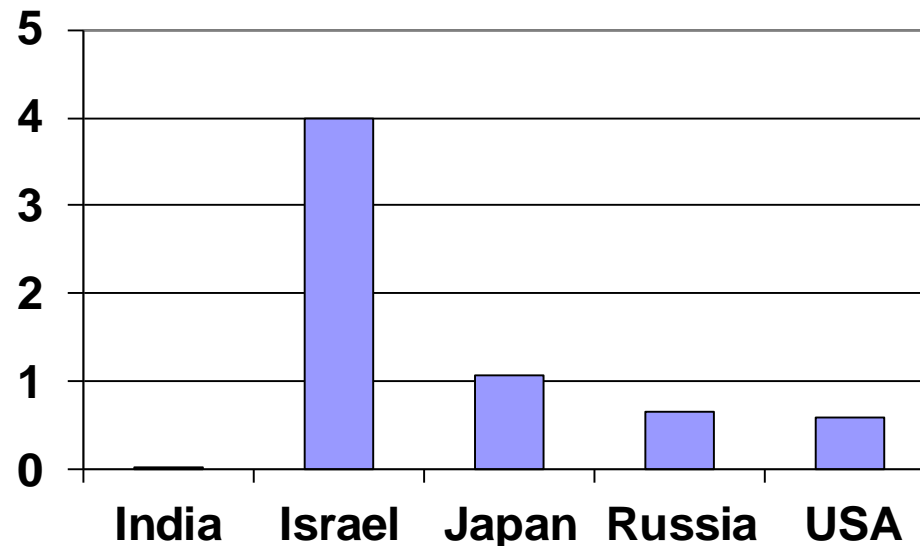
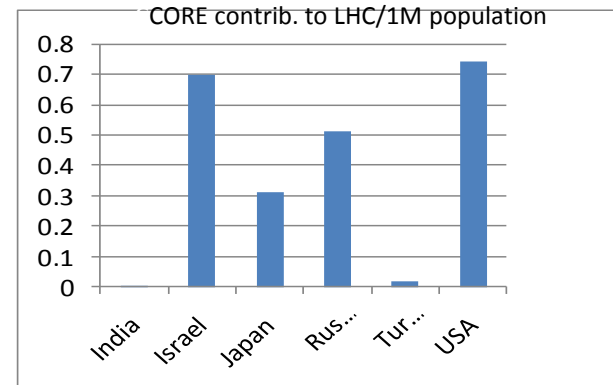
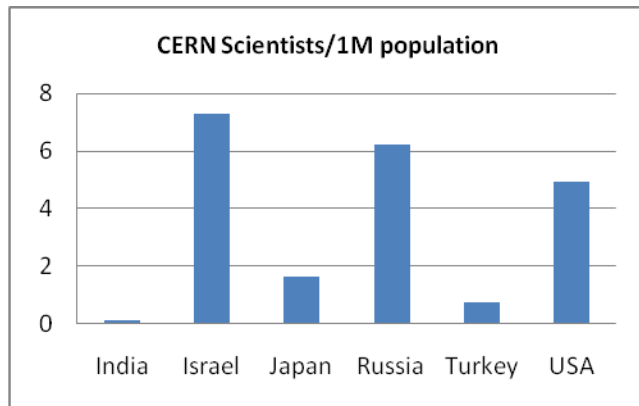
- Al welding and precision mechanics:
 - Due to the work with the Military and Aircraft Industry, firms are used to high quality requirements; this includes their sub-contractors (this is important, since the large firms have very high overheads).
 - Experience, combined with NETWORKING have been a critical element in obtaining excellent results in Orbital Welding (UNIWELD Ltd) for the Heat Shields of the EC Toroids. According to the firm, the experience that they have gained with the CERN project has been important for jumping into other contracts.
 - High quality welding (usually complemented by penetration tests), combined with precision machining (2 of the firms: MARESCO and TAL Technologies got also a CERN award), as well as measurement equipment, have been crucial to the success of the various projects.
 - Very high quality extrusion facilities, mainly motivated by the fabrication of complicated Al profiles for antennas have been important in the production of various profiles used in the ATLAS experiment (EXTAL)



Israeli contributions to general CERN Infrastructure from 1992 to 2011

[illegible]

While Israel makes good use of the CERN facilities, its contribution/habitant to the Infrastructure is the largest among the Observer Countries



- Contribution in CHF per habitant to the CERN Infrastructure for each of the CERN Observer States.

Present situation (purchasing)

- The total value of purchasing's of Israeli products since October 17, 2011 has been 1,6MCHF during the last 24 months (**compare to previous 1.5MCHF/year**)
- **October Finance Committee of CERN approved a 4MCHF contract with Tower-Jazz.**

Years	LHC	IT	Tech. Services	Admin.	Experim Infrastr.	ATLAS	CMS	ALICE	Others	Total
10/11 07/13	231,260	24,088	202,296		340,204	217,558	129,049	355,566	102821	1,602,842
	231,260	24,088	202,296	0	340,204	217,558	129,049	355,566	102,821	

It is crucial to increase the manpower involved in this activity to be able to achieve the relevant level of industrial orders.

Educational aspects

Israeli High School and University Students

- Israeli teachers:
 - 1 in 2011
 - 2 in 2012
 - 3 in 2013
 - 35 expected next year
- High School groups from Israel:
 - 20 High School Students 2012
 - 110 High School students 2013
- Israeli BSc Physics & Engineering Students
 - 32 Summer Students (+7 Palestinians) since 2003.
- Israeli MSc & PhD students involved in ATLAS: 25



What is matter made off?



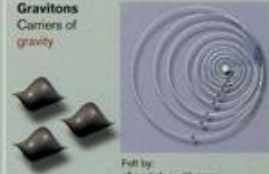
Matter → **Atom** → **Electron** → **Proton** → **Quarks**

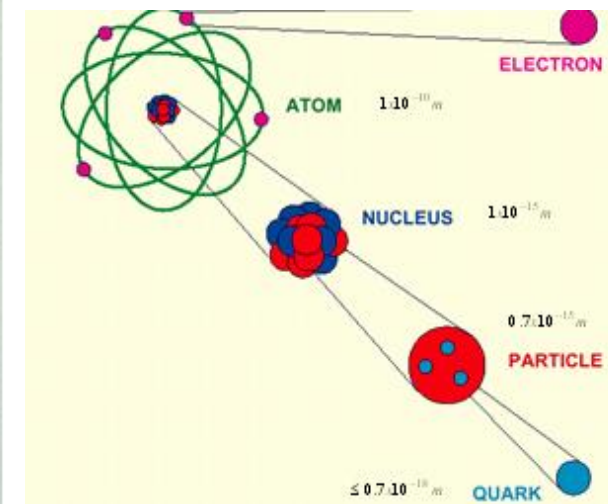
Nucleus → **Neutron**

Matter particles
All ordinary particles belong to this group

	LEPTONS		QUARKS	
FIRST FAMILY	Electron Responsible for electricity and chemical reactions; it has a charge of -1	Electron neutrino Particle with no electric charge, and possibly no mass; billions fly through your body every second	Up Has an electric charge of plus two-thirds; protons contain two, neutrons contain one	Down Has an electric charge of minus one-third; protons contain one, neutrons contain two
SECOND FAMILY	Muon A heavier relative of the electron; it lives for two-millionths of a second	Muon neutrino Created along with muons when some particles decay	Charm A heavier relative of the up; found in 1974	Strange A heavier relative of the down; found in 1964
THIRD FAMILY	Tau Heavier still, it is extremely unstable. It was discovered in 1975	Tau neutrino Not yet discovered but believed to exist	Top Heavier still	Bottom Heavier still; measuring bottom quarks is an important test of electroweak theory

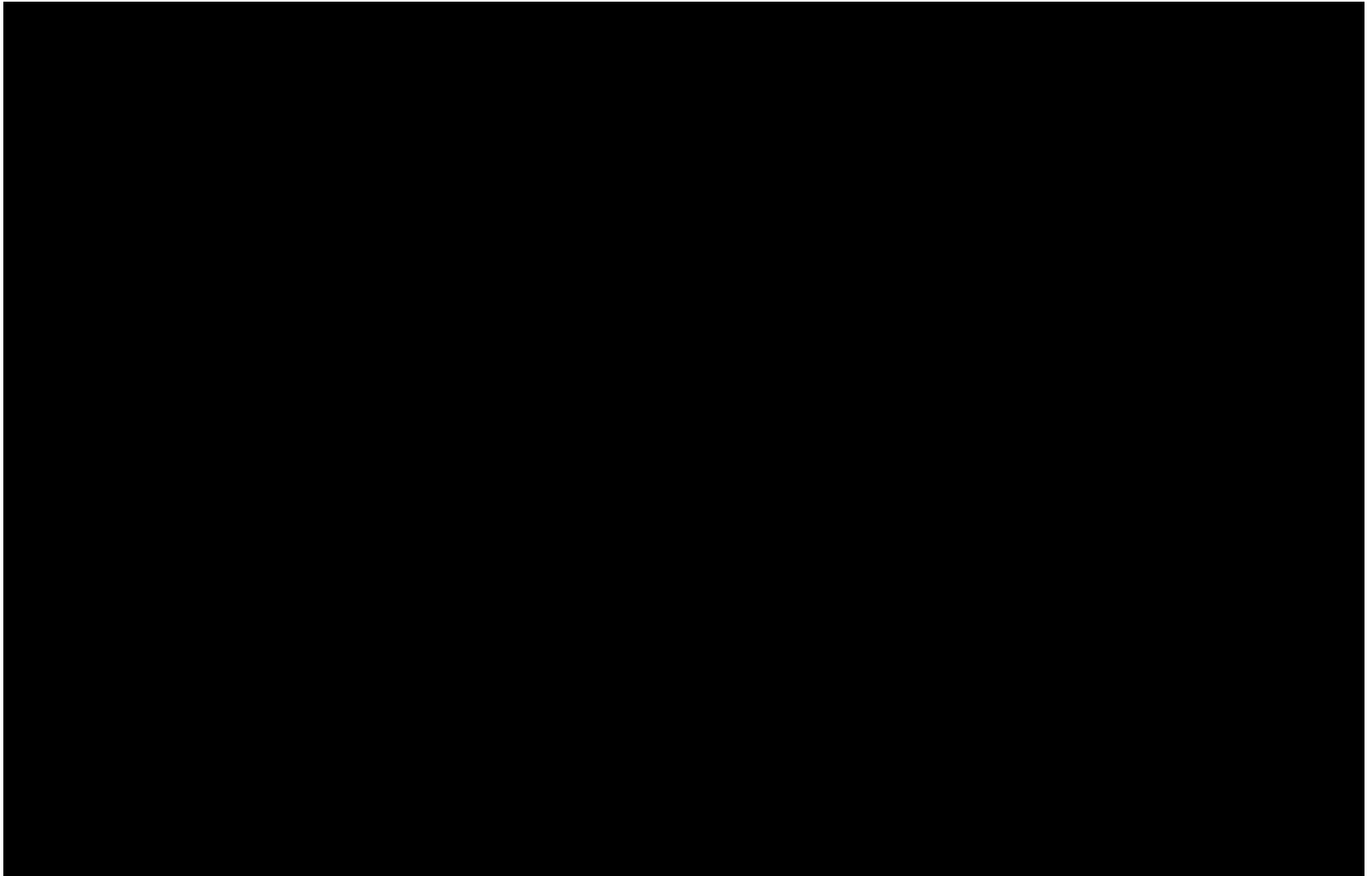
Force particles
These particles transmit the four fundamental forces of nature although gravitons have so far not been discovered

Gluons Carriers of the strong force between quarks  Felt by: quarks The explosive release of nuclear energy is the result of the strong force	Photons Particles that make up light; they carry the electromagnetic force  Felt by: quarks and charged leptons Electricity, magnetism and chemistry are all the results of electro-magnetic force	Intermediate vector bosons Carriers of the weak force  Felt by: quarks and leptons Some forms of radio-activity are the result of the weak force	Gravitons Carriers of gravity  Felt by: all particles with mass All the weight we experience is the result of the gravitational force
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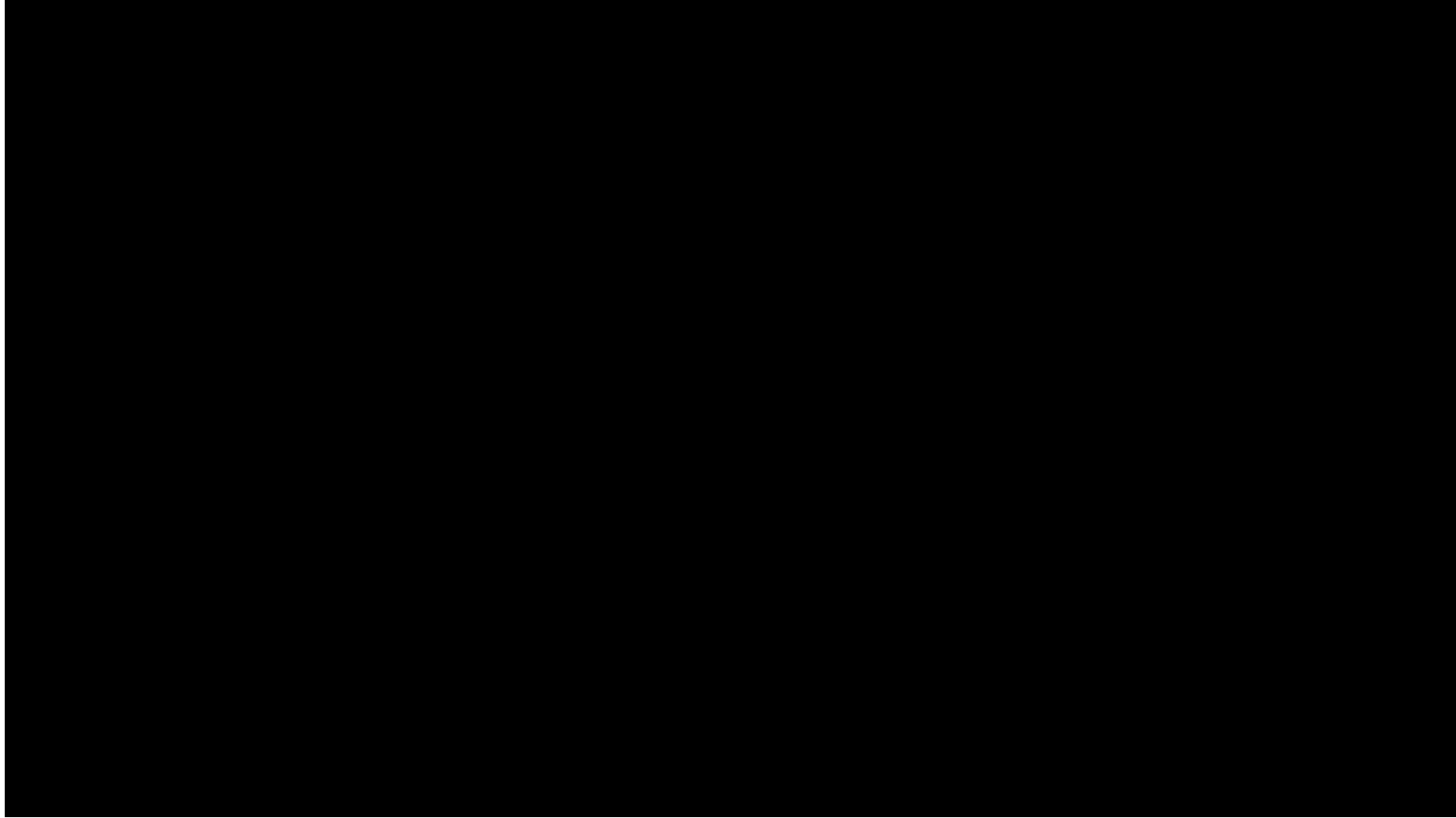


- But if particles have no dimensions, how can they have mass?
- If energy can become pairs of matter and anti-matter, where is the anti-matter?
- Are there other basic particles besides those that we know?

Our understanding of the Big-Bang

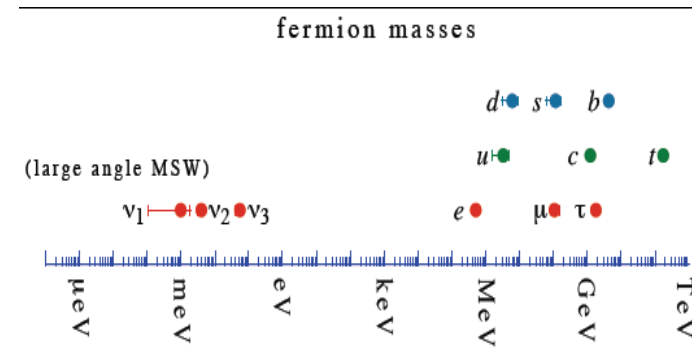
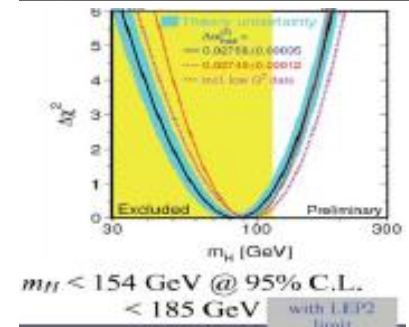
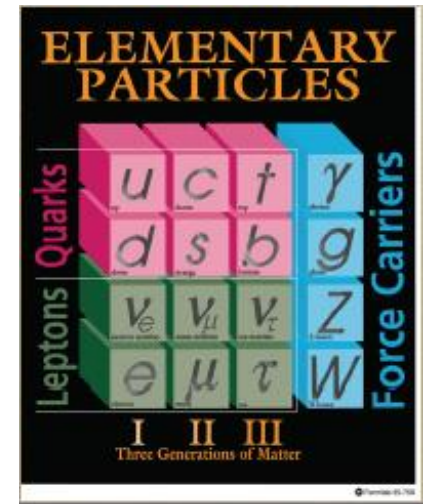


How can we observe this?



The Standard Model and its problems

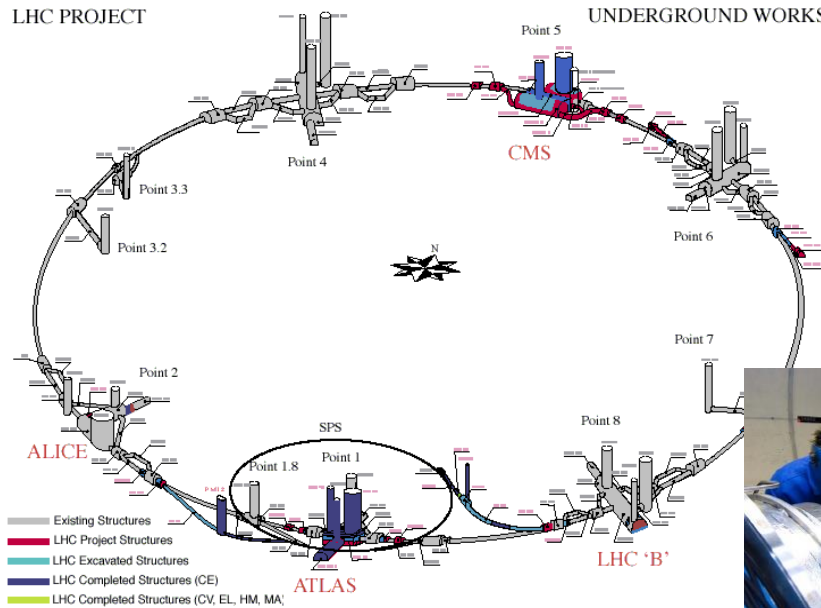
- The SM provides us an excellent description of the basic interactions between quarks and leptons, with tests of Electro-weak radiative corrections at the level of 10^{-3} .
- There are, however, number of open questions:
 - The Higgs boson(s), responsible for the mechanism of providing mass to all particles, has finally been found.
 - We have no understanding of the large mass differences between the basic components of matter.
 - The SM has no explanation for the non-zero neutrino masses.



LHC and its Experiments

LHC PROJECT

UNDERGROUND WORKS

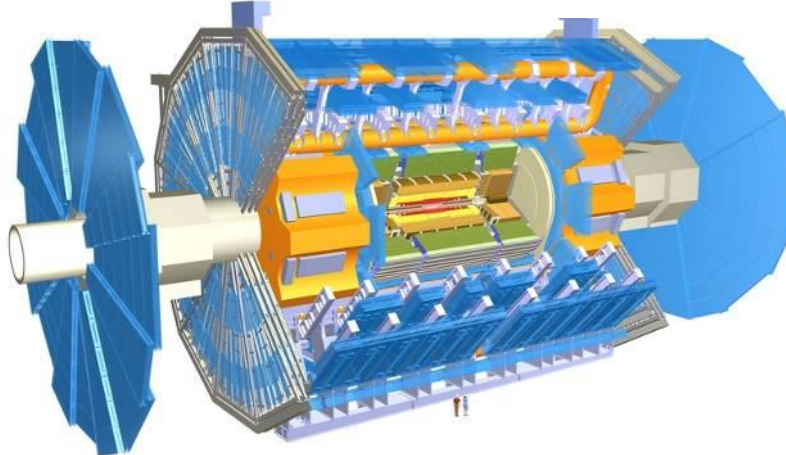
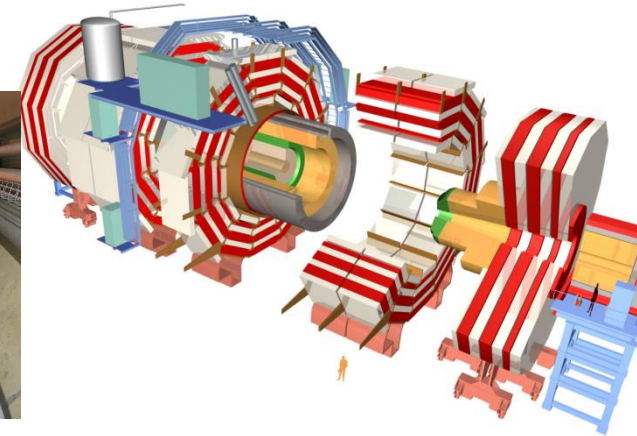


LHC machine

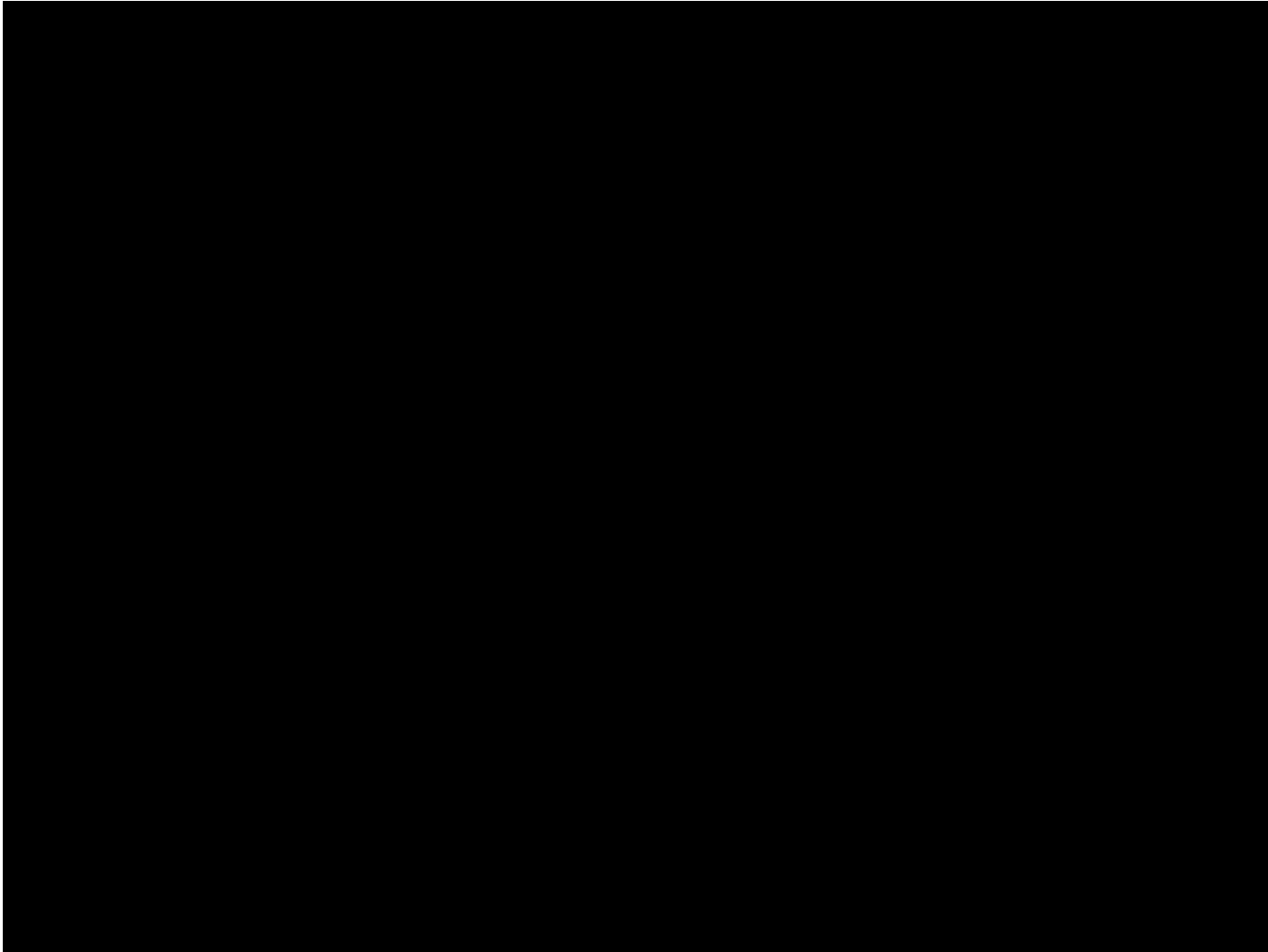
P-P collisions at 3.5+3.5TeV

Start : Spring 2010

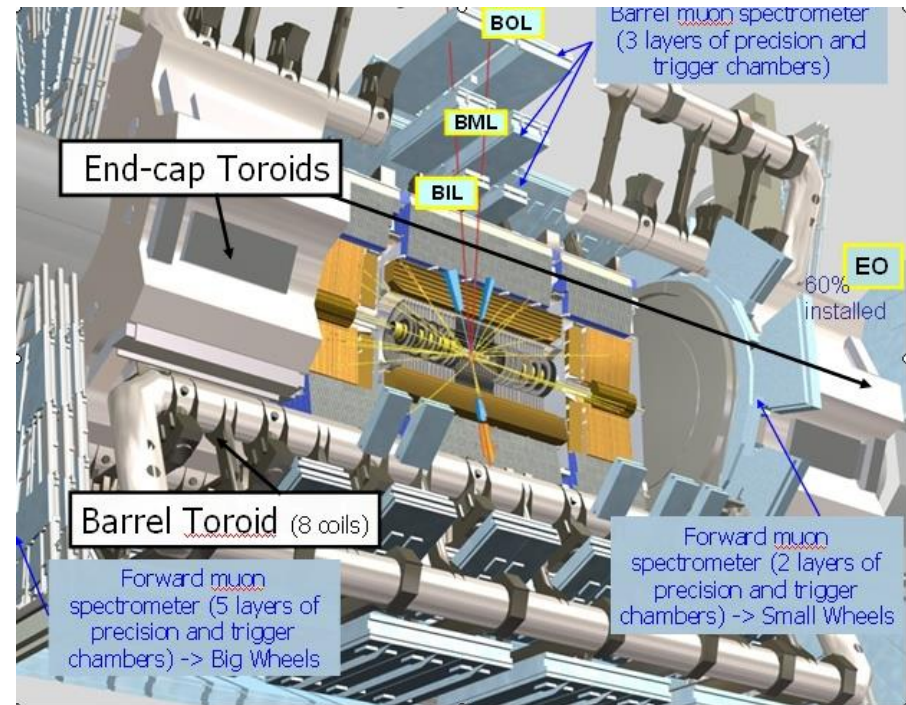
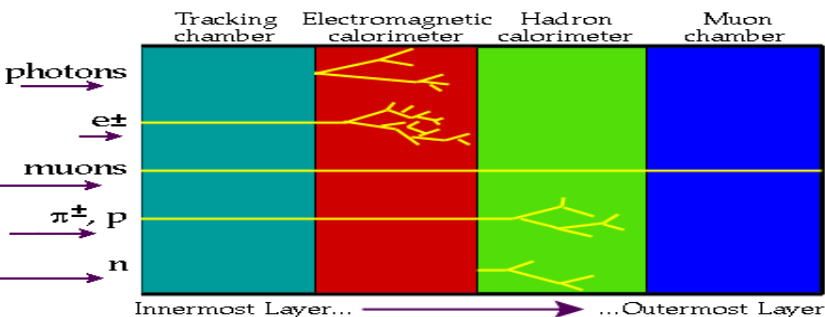
7+7 TeV in 2014



How do we measure the particles?



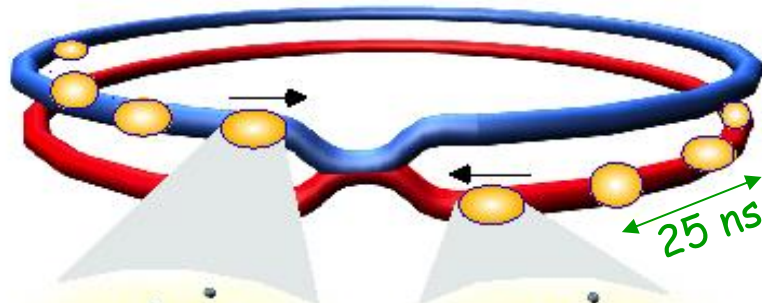
The ATLAS Experiment



- **Tracking ($|\eta| < 2.5$, $B=2T$) :**
 - Si pixels and strips (3 layers of pixel to optimize b tagging)
 - Transition Radiation Detector (e/π separation)
- **Calorimetry ($|\eta| < 5$) :**
 - EM : Pb-LAr (to obtain high granularity, with a pre-sampler to achieve a vector measurement for lower background in $H \rightarrow \gamma\gamma$)
 - HAD: Fe/scintillator (central), Cu/W-LAr (fwd)(to achieve full hermeticity up to rapidity of 5)
- **Muon Spectrometer ($|\eta| < 2.7$) :**
 - air-core toroids with muon chambers (to achieve a uniform $\Delta(p)/p$ response throughout the full rapidity range).



Collisions at LHC



Proton-Proton

Protons/bunch

10^{11}

Beam energy

7 TeV (7×10^{12} eV)

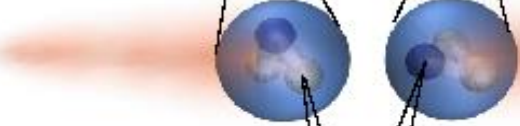
Luminosity

$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

Bunch



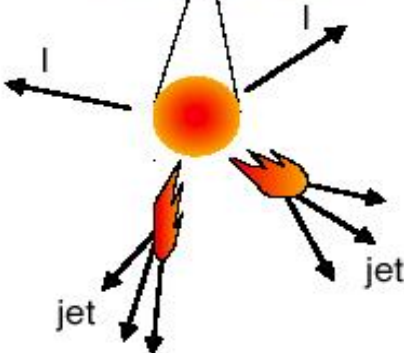
Proton



Parton
(quark, gluon)



Particle

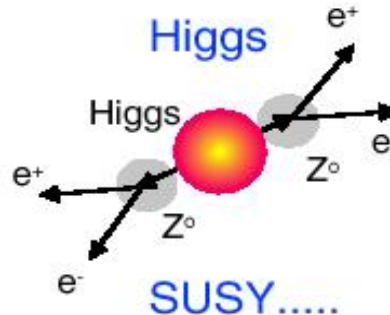


Event rate in ATLAS :

$N = L \times \sigma \text{ (pp)} \approx 10^9 \text{ interactions/s}$

Mostly soft (low p_T) events

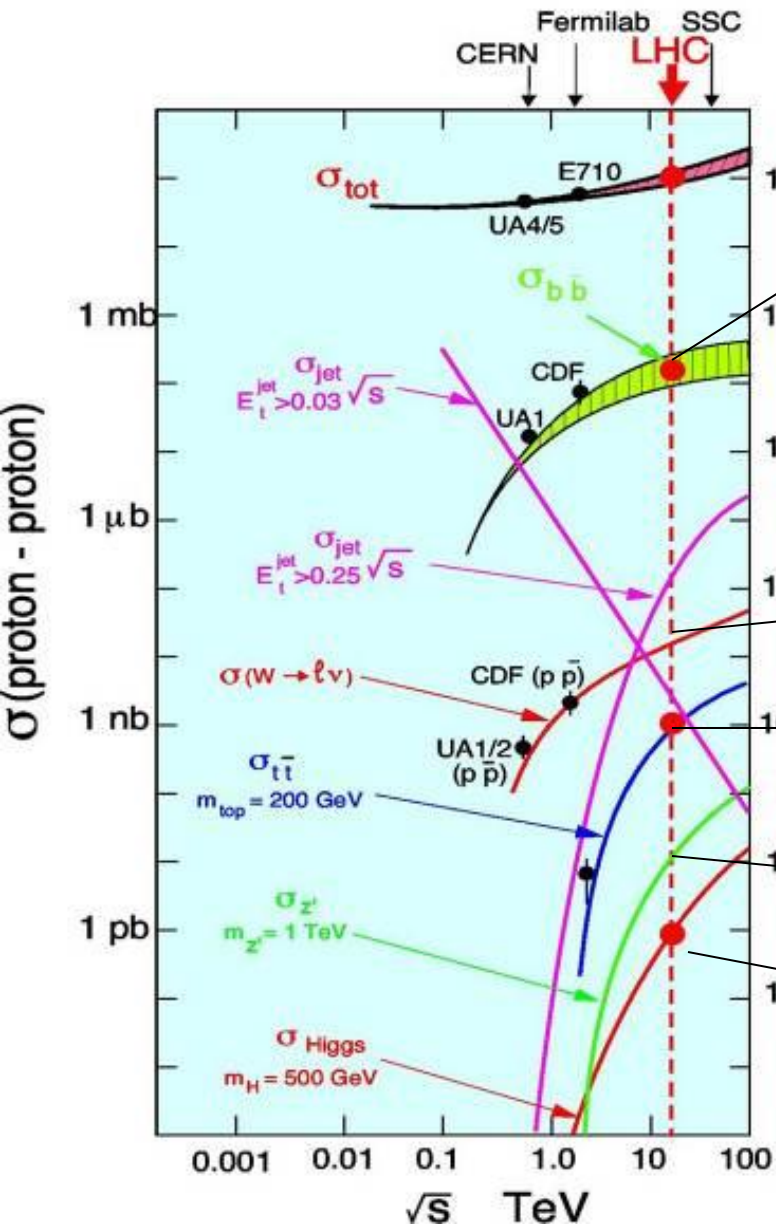
Interesting hard (high- p_T) events are rare



**Selection of 1 in
10,000,000,000,000**

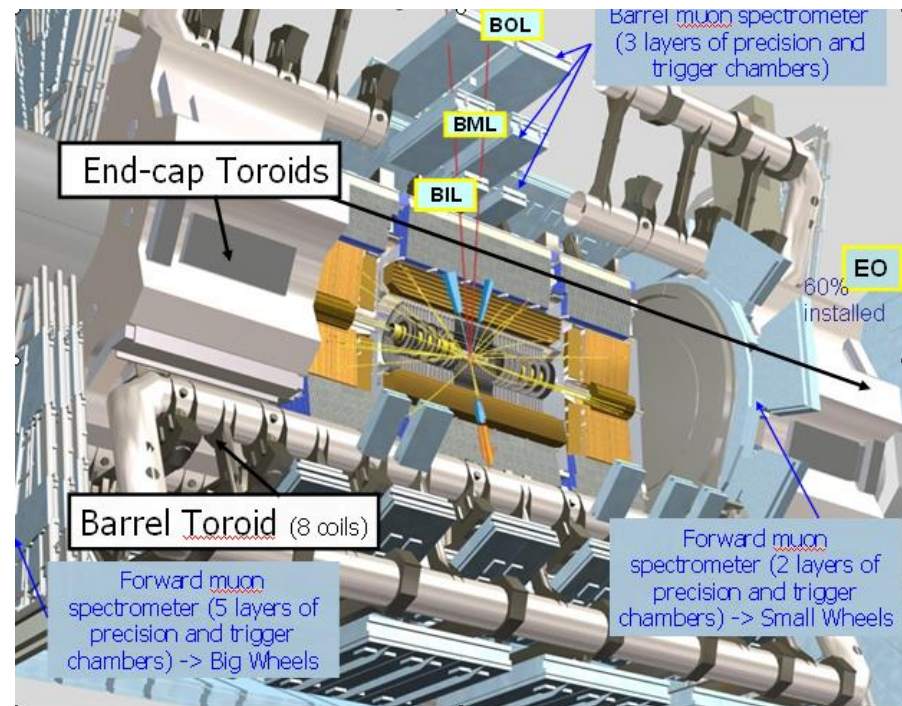
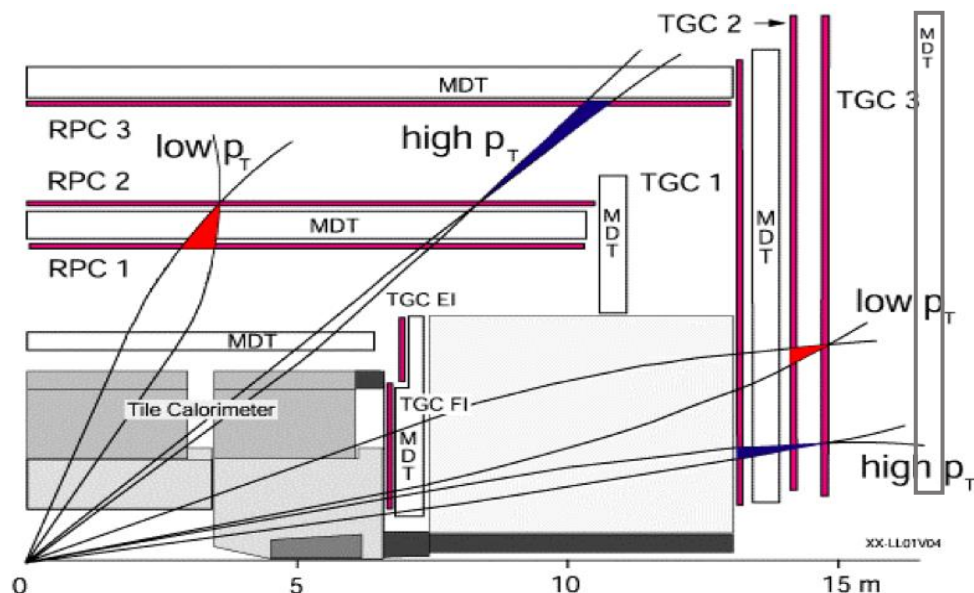
→ Main Problem is to select right collisions

Main Physics Goals at LHC

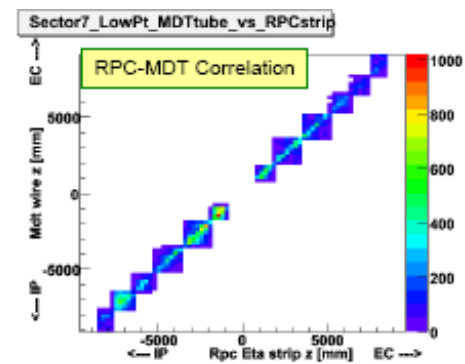


- **B-physics:** CP violation, rare decays, B^0 oscillations.
- **QCD** jet cross-section and α_s .
- Precise measurement of W mass.
- Precise measurement of Top mass, couplings and decay properties.
- Z' and W' discoveries?
- Measurement of Higgs properties

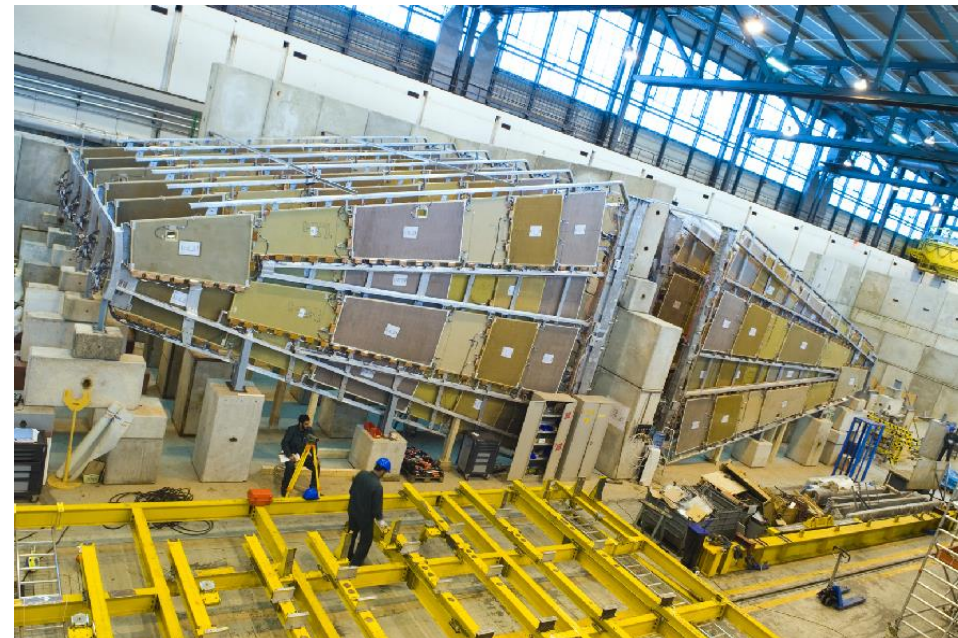
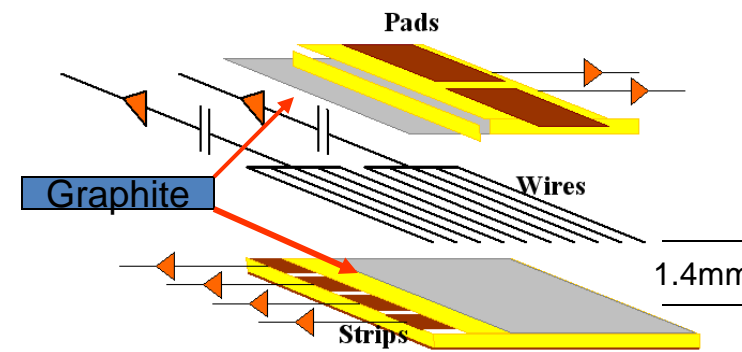
Trigger is a crucial element in LHC Physics



- The MUON trigger philosophy is based on opening a cone (which defines a given $p(t)$ threshold) around a point in a pivot plane (that contains non-overlapping geometry).
- The barrel includes a 3-out-of-4 trigger logic for low $p(t)$, combined with a 1-out-of-2 confirmation logic for high $p(t)$
- The end-cap requires a 3-out-of-4 logic combined with a 2-out-of-3 logic in the inner layer. The low $p(t)$ is obtained by a non-linear combination in the inner layer, while linear for the high $p(t)$
- The end-cap has a more robust logic, due to the higher background conditions, combined with the fact that the stations are located in a non-magnetic region.



•End-Cap MUON TRIGGER SECTORS

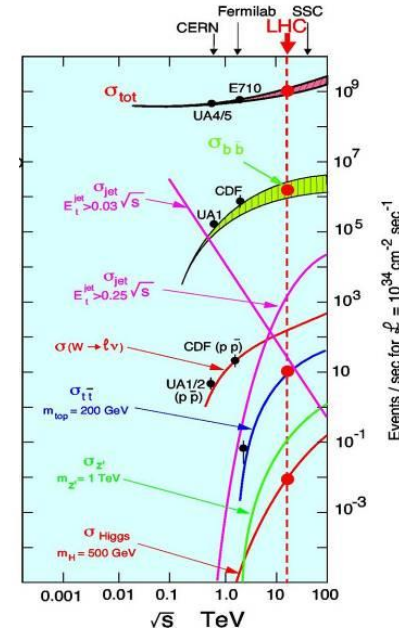
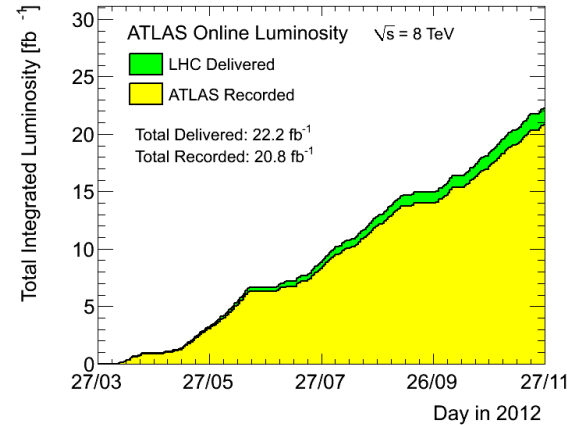
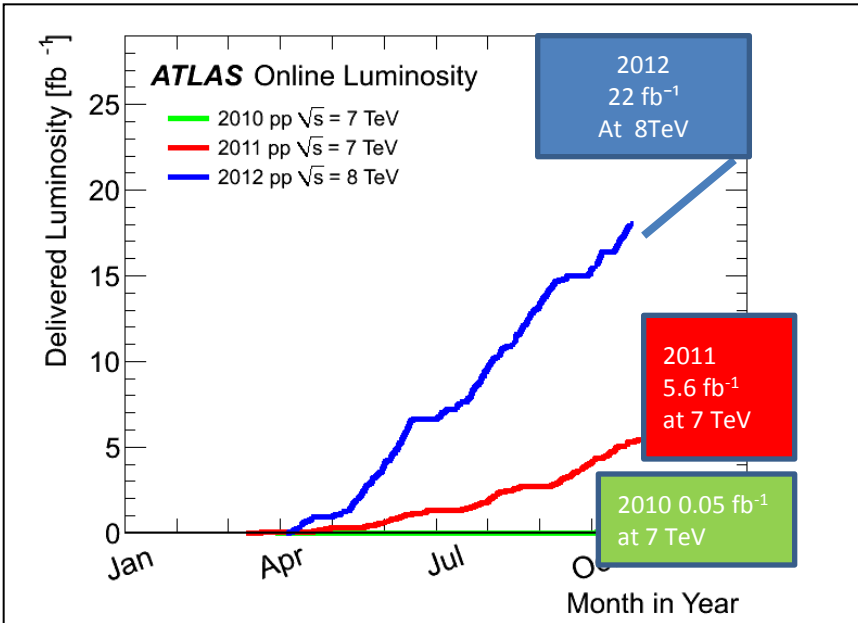


All 6 Big-Wheels that constitute the MUON Trigger System in the End-Cap (4000 detectors based on a technology developed in Israel) have been assembled and commissioned.

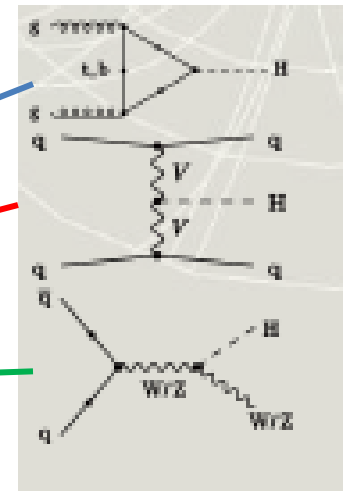
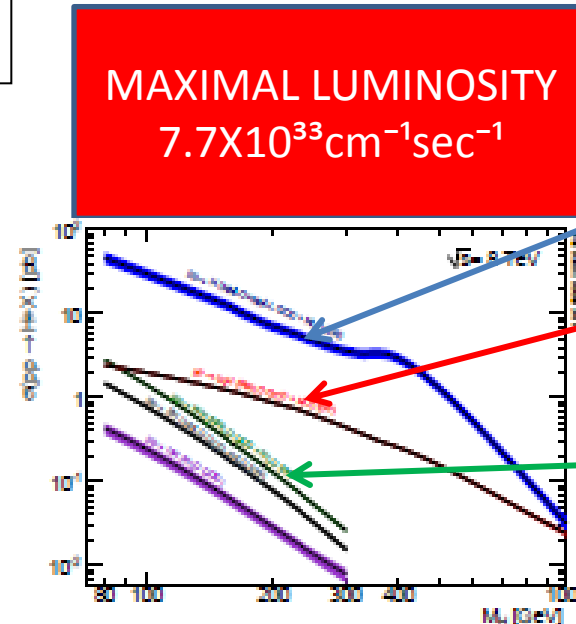
All mechanical components have been manufactured by Israeli Industry.

All support assembly elements have been fabricated by Pakistani Industry

How did we find the Higgs Boson ?

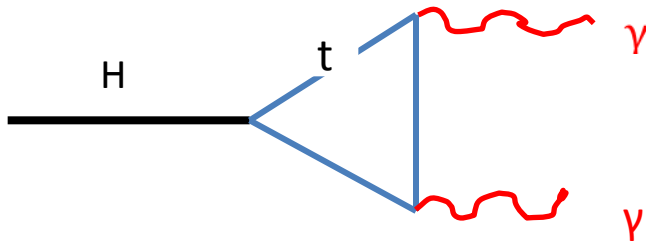
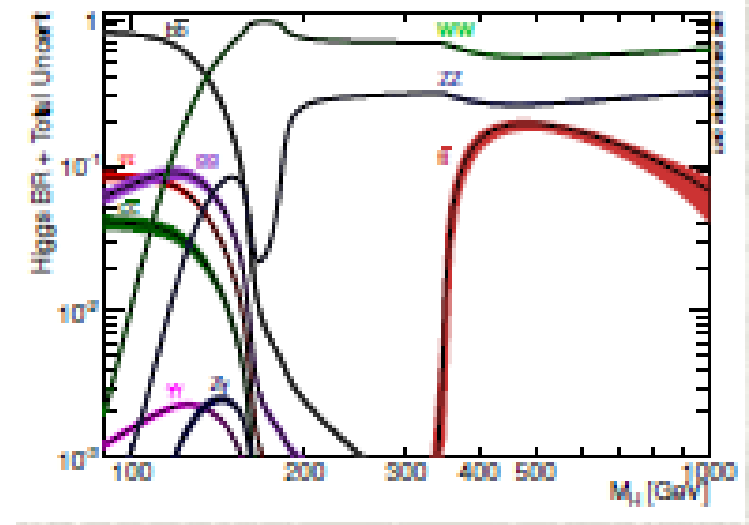


- The probability to find it is very low.
- The probability to recognize it, is lower than to find a needle in a haystack.



The Higgs couples to mass

- The heaviest point-like particles that we know are:
 - The W and Z Bosons, then $h \rightarrow WW, ZZ$, but to reduce the backgrounds, it should be observed in final states not containing quarks, i.e. $W \rightarrow e, \mu + \nu$; $Z \rightarrow e^+e^-, \mu^+\mu^-$.
 - The Top Quark ($M \sim 175 \text{ GeV}$) but if $M(H) \sim 125 \text{ GeV} < 2 \times 175 \text{ GeV}$, the coupling can only be virtual, while isolated high energy photons are rare:

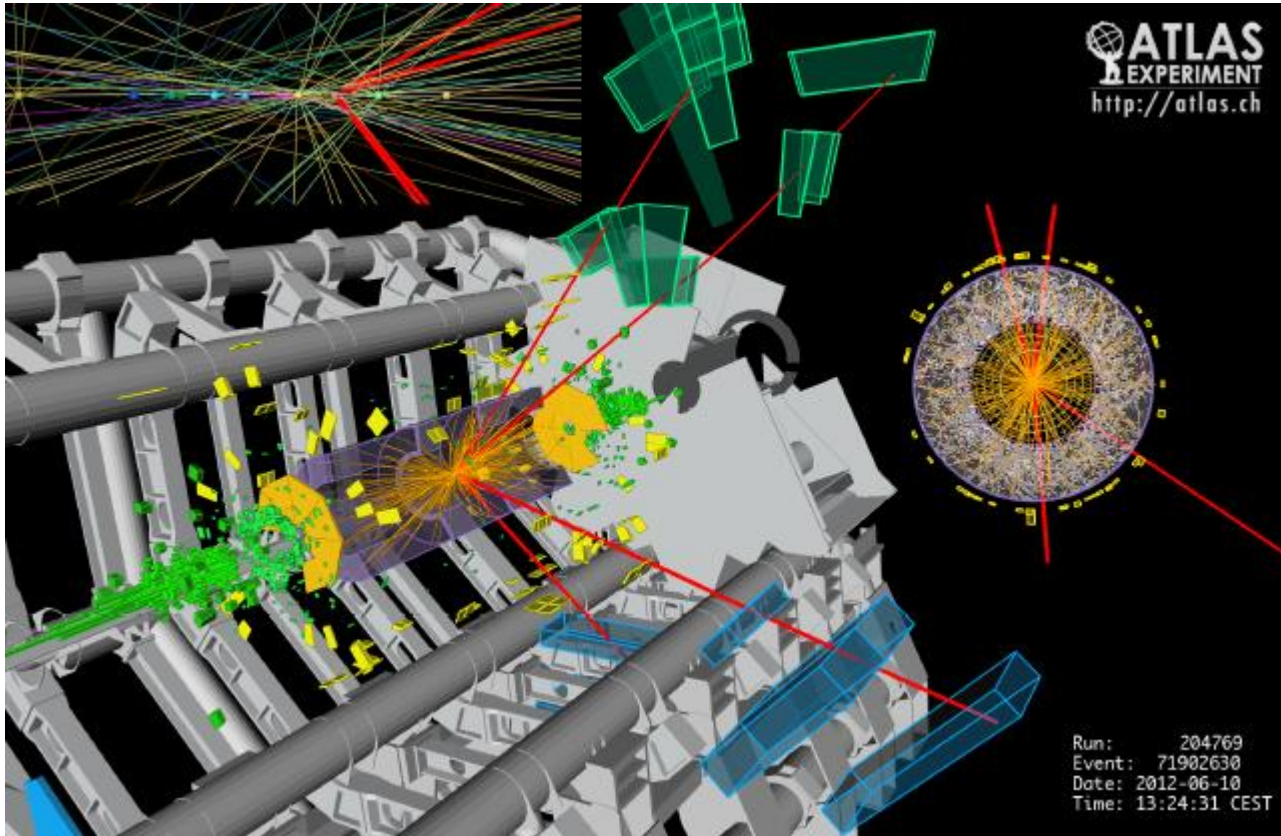


Look for Final States containing:

- 4 energetic, isolated leptons ($2e+2\mu, 4\mu, 4e$)
- 2 energetic, isolated leptons + missing ν
- 2 high energy isolated photons

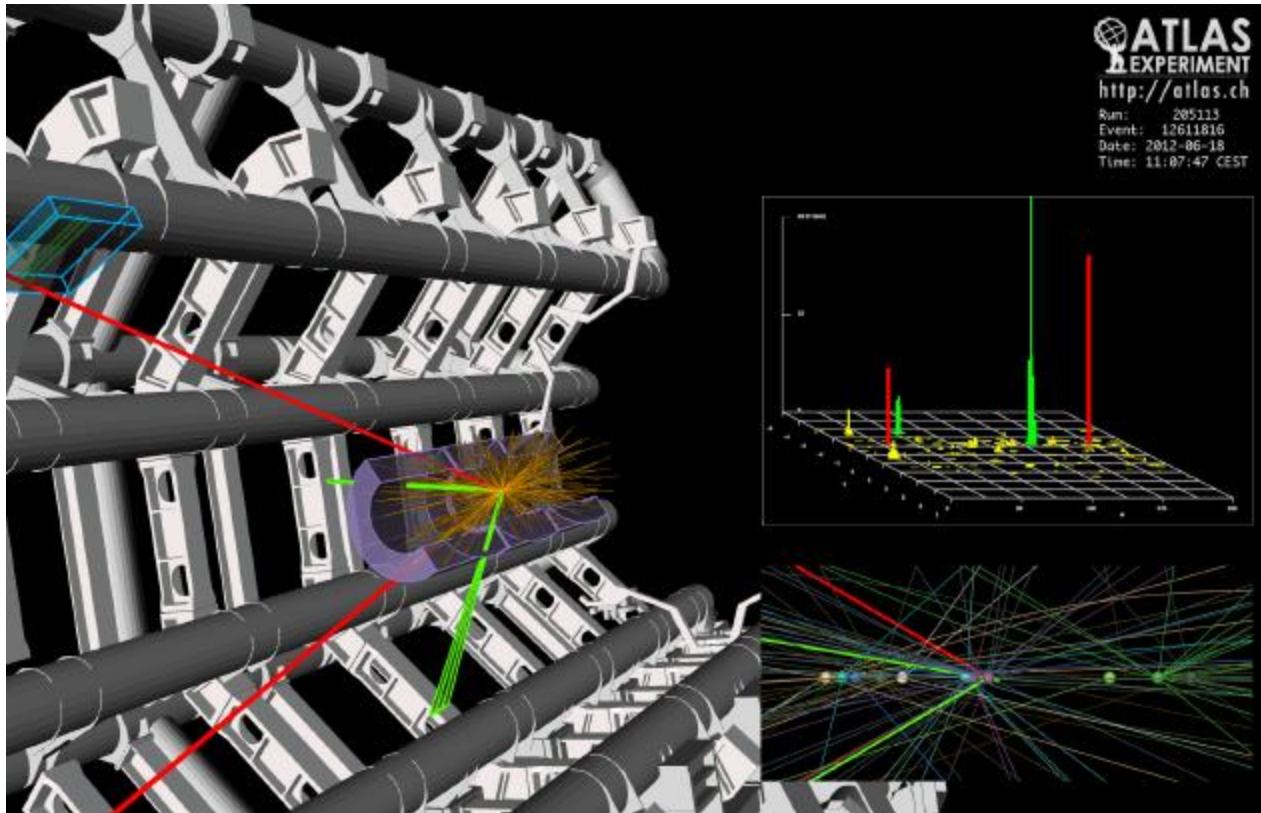
Reconstruct their effective mass
(transverse mass in the case of missing energy)

4μ



- Typical 4μ candidate, 80% of which were triggered by the system constructed mainly in Israel.

$$2e+2\mu$$



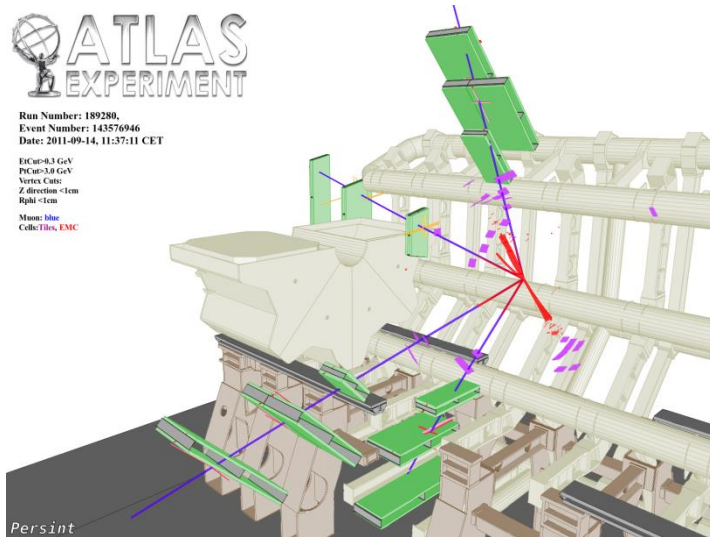
- $2e+2\mu$; 80% where also triggered by the detectors constructed mainly in Israel.

Adding up the 3 ($2e+2\mu$, 4μ , $4e$) final states

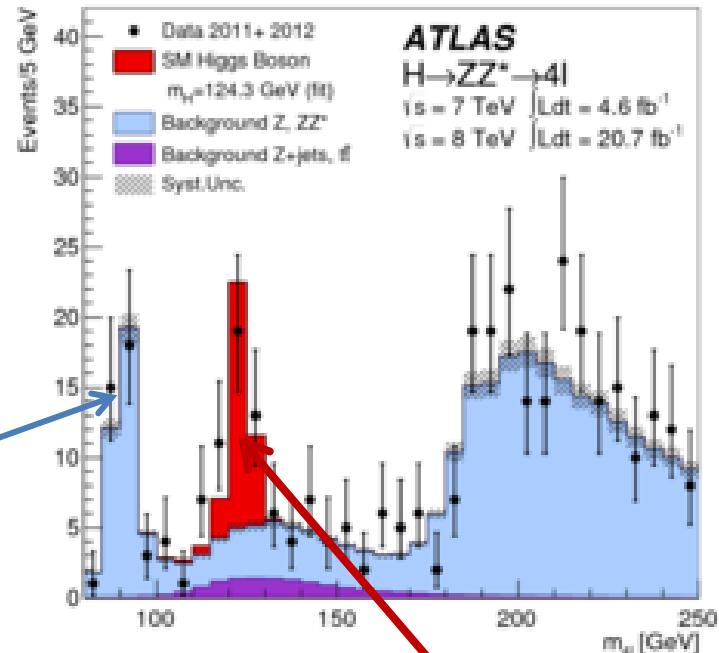
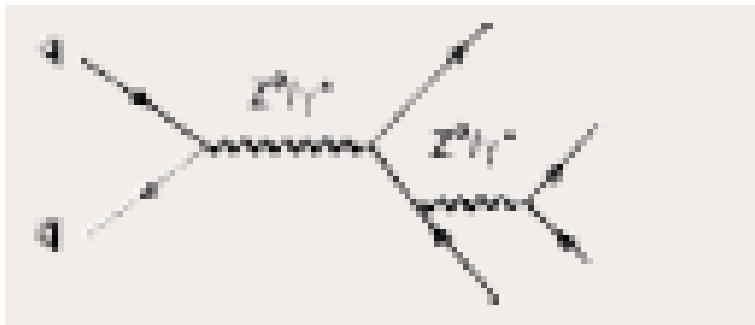


Run Number: 189280,
Event Number: 143576946
Date: 2011-09-14, 11:37:11 CET

ECut=0.3 GeV
PCut=3.0 GeV
Vertex Cuts:
Z direction <1cm
Rphi <1cm
Masses: blue
Color: blue, EMC



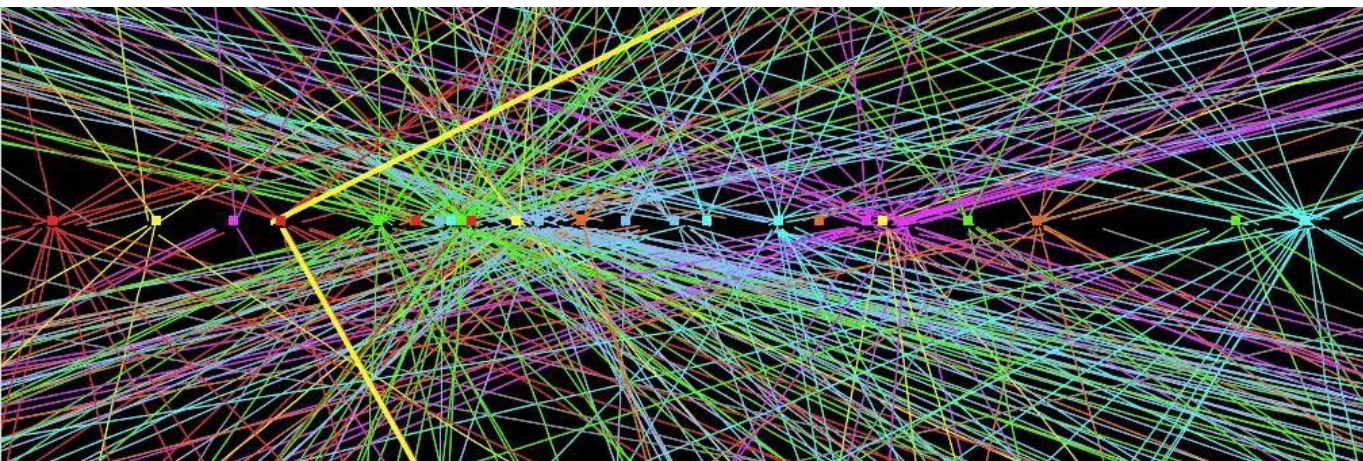
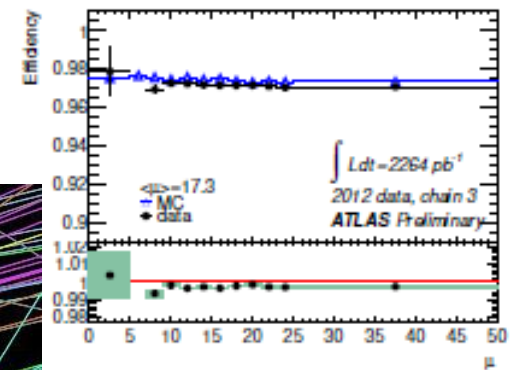
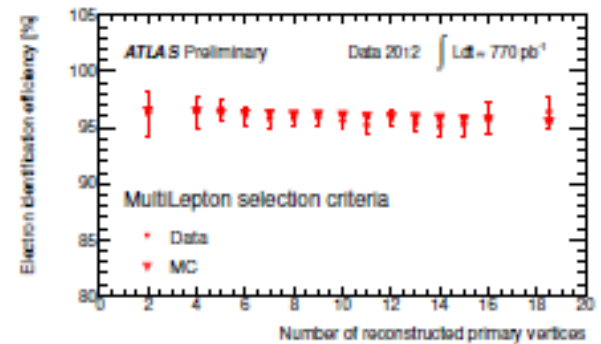
- Also a clear Z peak is seen, from the radiative decay $Z \rightarrow 4\text{leptons}$.



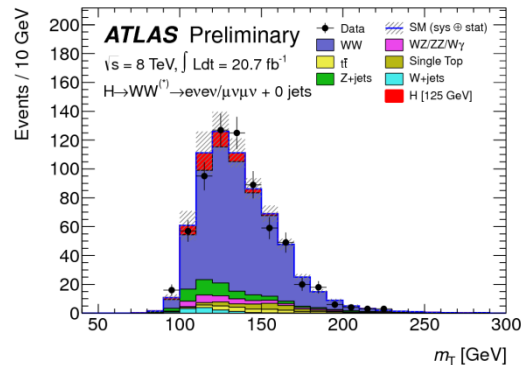
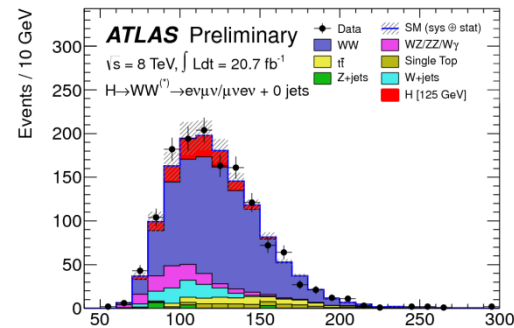
Excess of events at
125GeV

Is this credible with up to 40 interactions occurring at once?

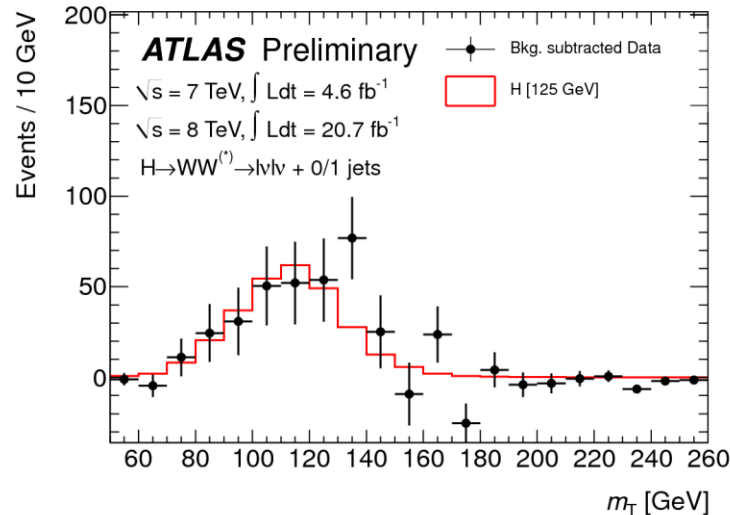
- The lepton reconstruction efficiency is constant with the number of simultaneous interactions, both for e and μ .



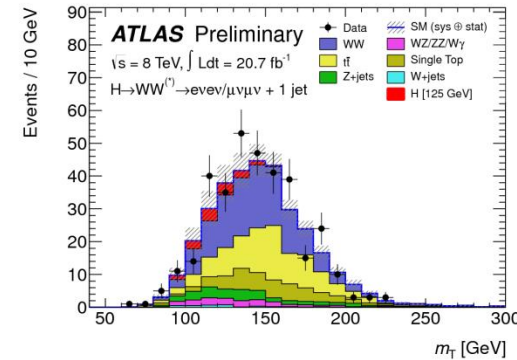
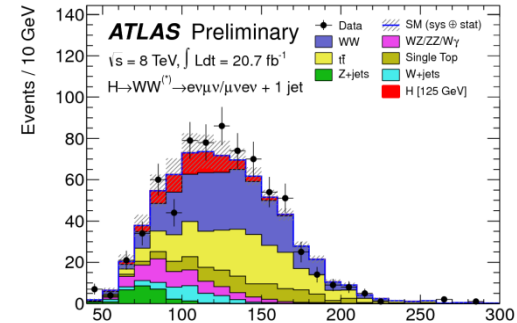
WW→eμ, ee, μμ (+2ν unseen neutrinos)



0 jets



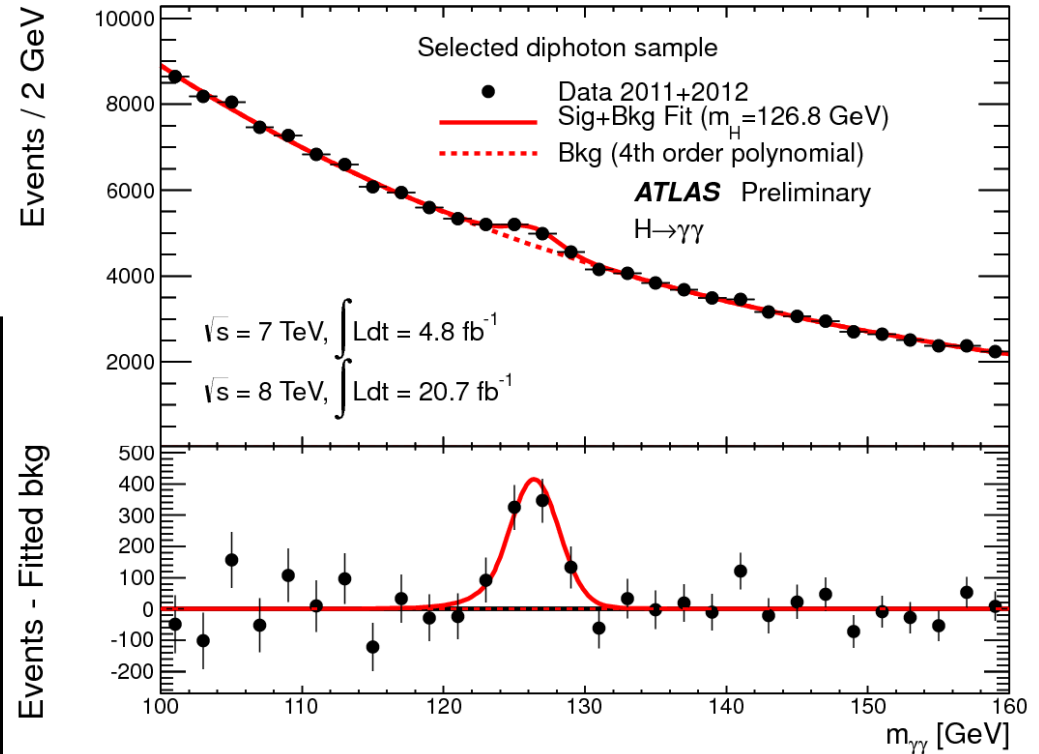
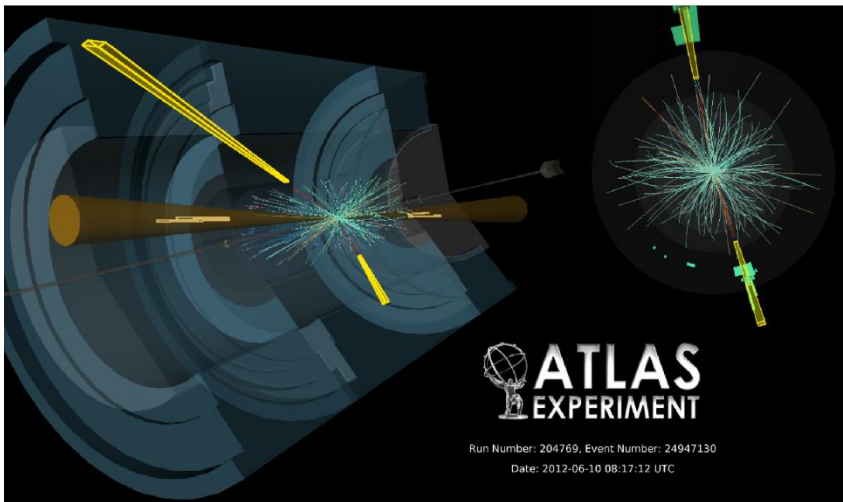
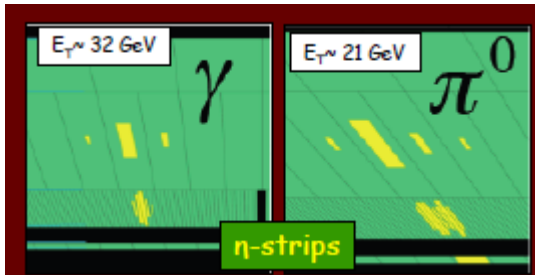
Total after background subtraction



1 jet

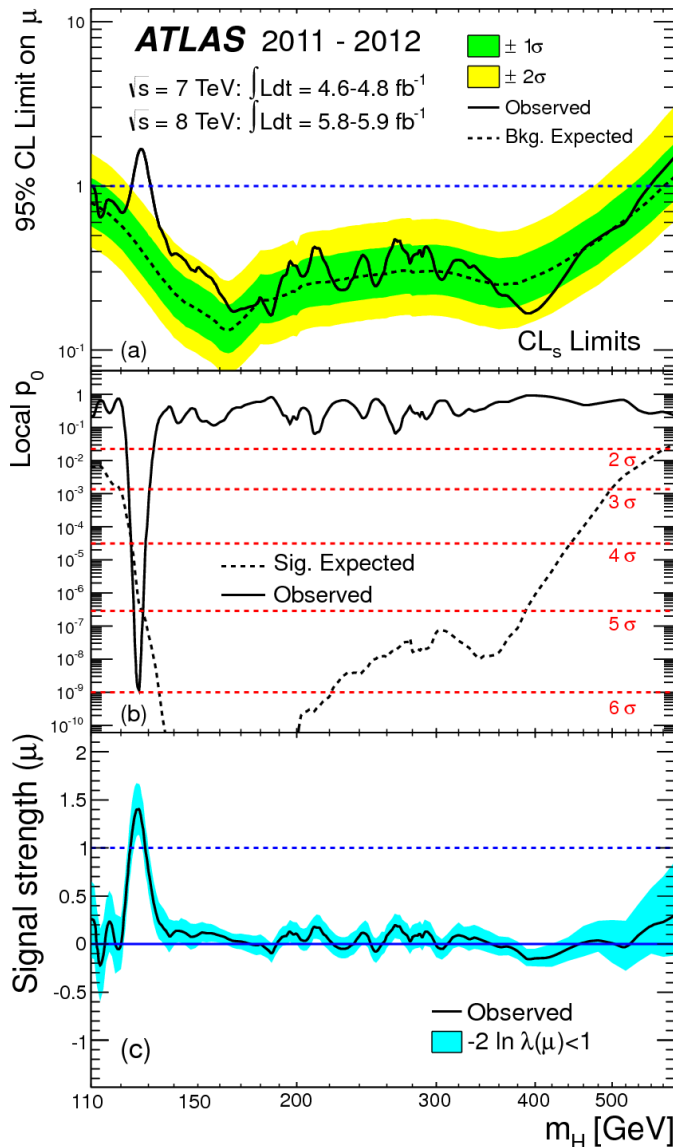
- There is an excess of events corresponding to the mass of a Higgs Boson Higgs of $\sim 125 \text{ GeV}$.

Two isolated photons final states



- Due to the excellent energy resolution for each of the photons, combined with the possibility of eliminating 2 nearby photons from π^0 decay, a clear signal is obtained when combining the various cases.

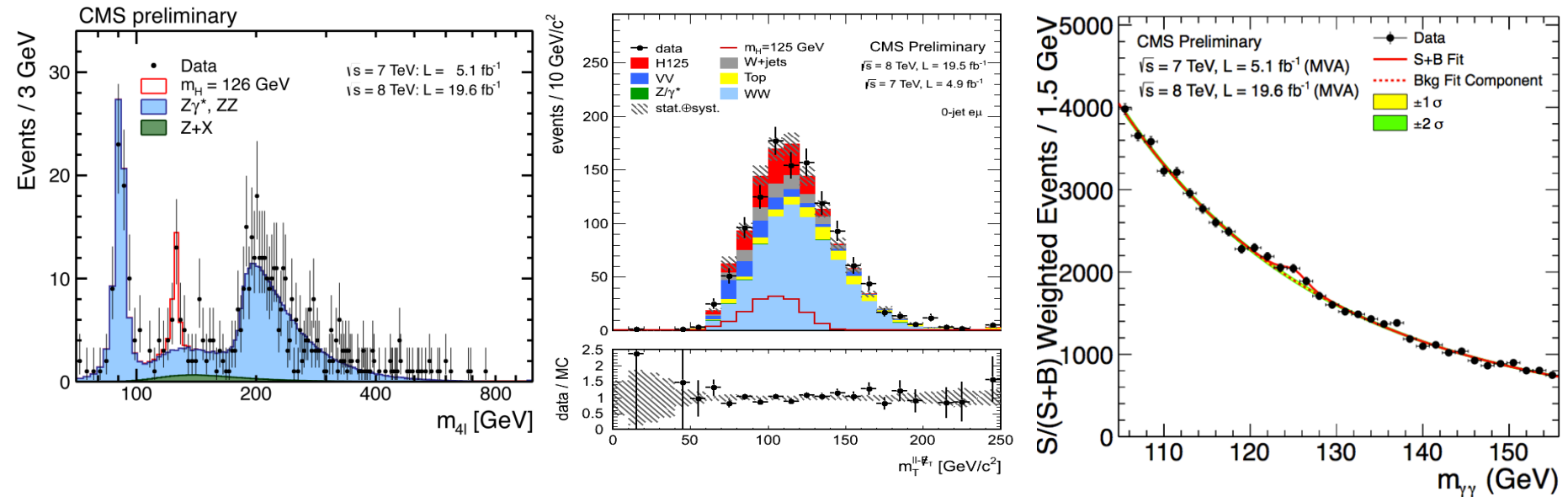
Combining all the channels



- Probability to exclude the existence of a Higgs Boson.
- Probability of having found a false signal as a function of the mass.
- Comparing the probability of finding the right signal with the expected one.

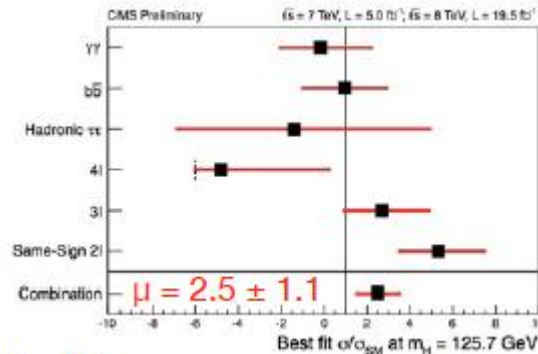
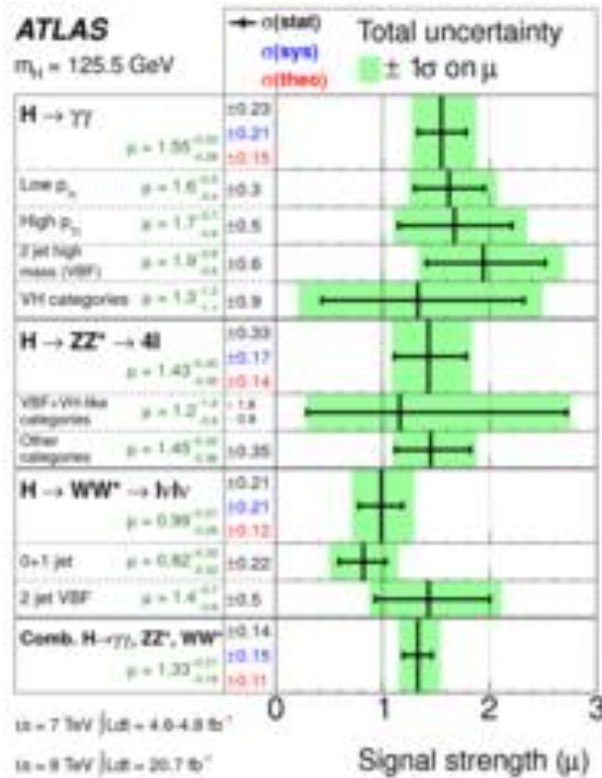
An object consistent with the Higgs Boson has been discovered

and the other LHC Experiment (CMS) observed a similar effect



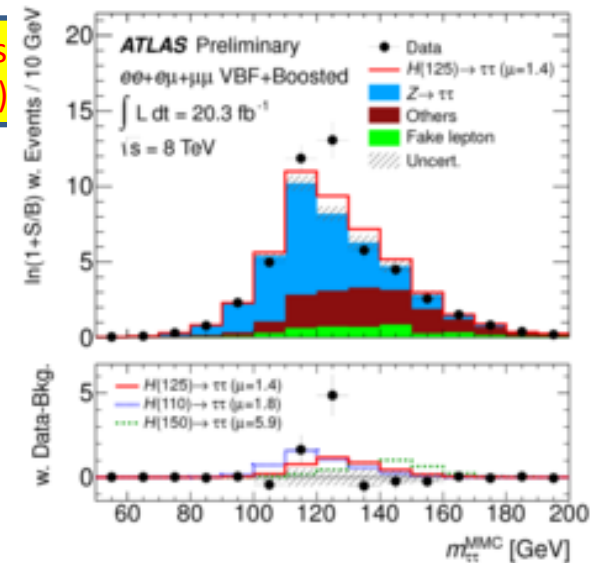
- Is it a Higgs Boson ?

But it also allows to measure the various Higgs couplings to bosons and fermions



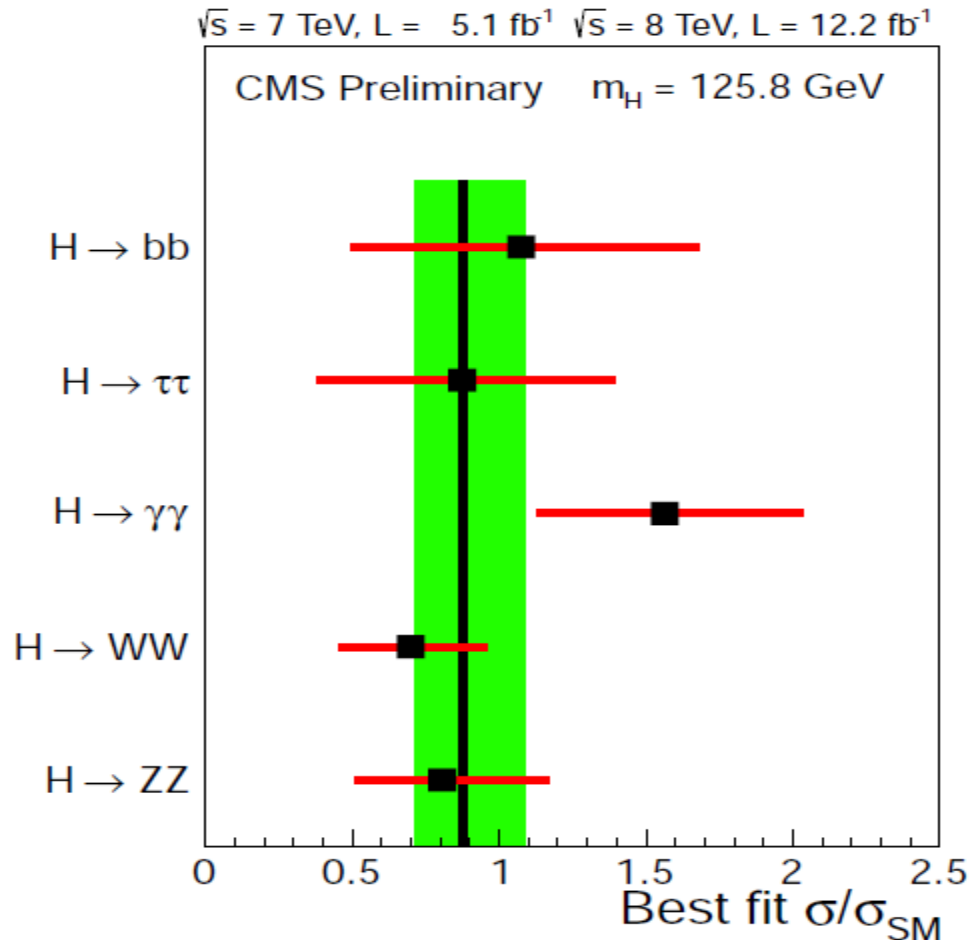
CMS coupling from $t\bar{t}H$ for various H final states (consistent with SM)

- ATLAS coupling measurements to bosons, consistent with the SM



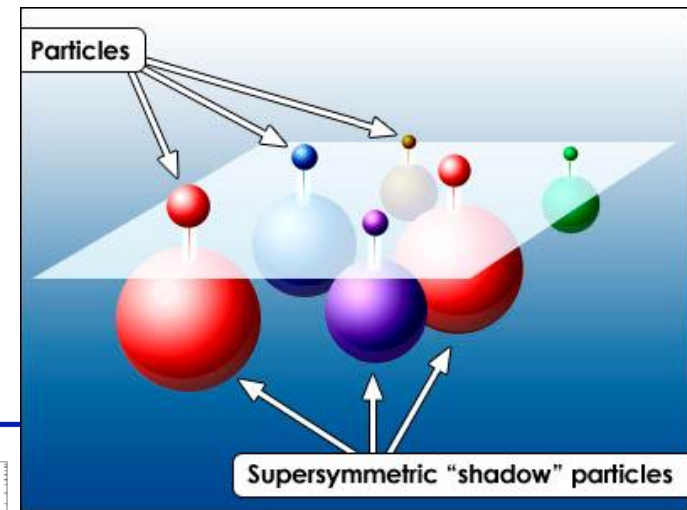
- $H \rightarrow \tau\tau$ from ATLAS obtained by weighting the events $\ln(1+S/B)$.

And also CMS is consistent with the SM

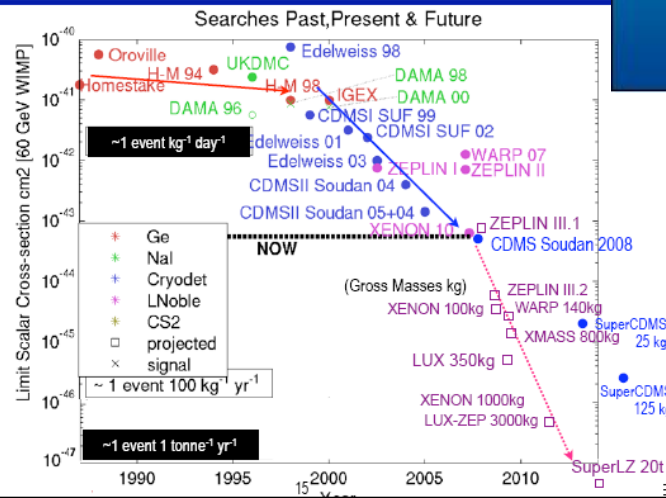


Other mysteries to be solved

- We do not understand our Universe.
- We know that our Universe is made of only 4% of regular matter, but another 30% is made of a different kind of matter (maybe Super-symmetric particles). The LHC will open a large window (up to 3TeV in mass) to find this kind of matter.
- This search is complementary to the future, more sensitive, series of underground experiments looking for dark matter interactions.

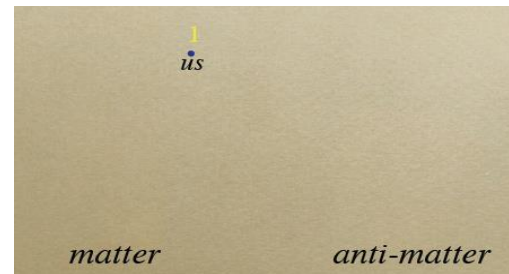
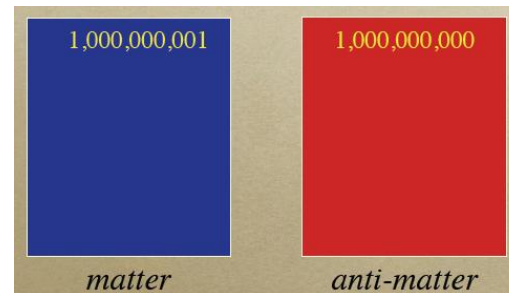
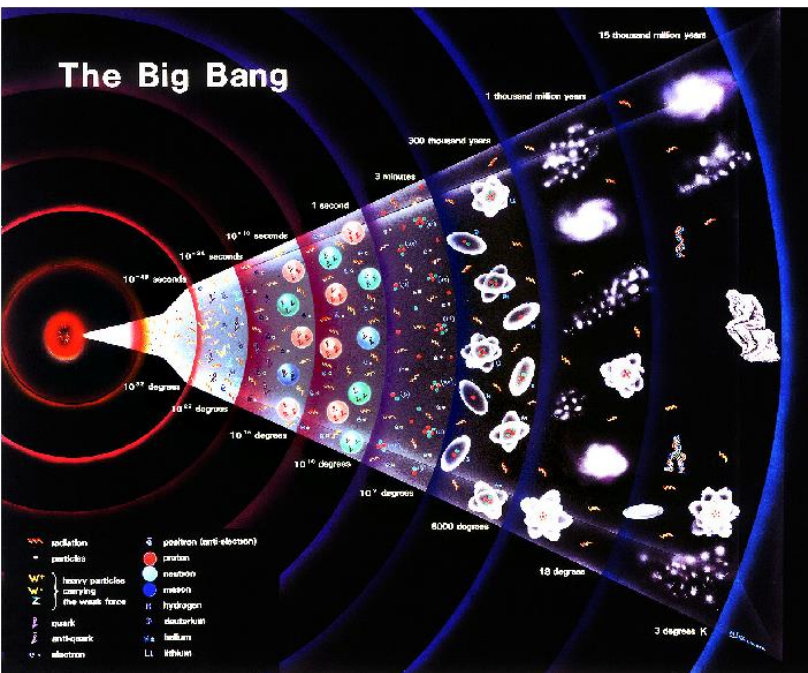


DM Direct Search Progress Over Time (2008)



Slide from Hanchao Wana Oct 2008

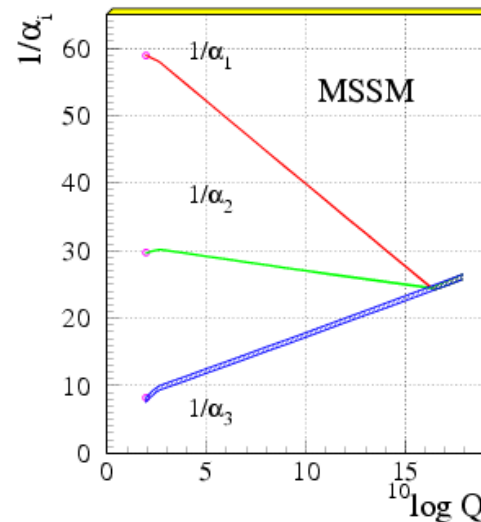
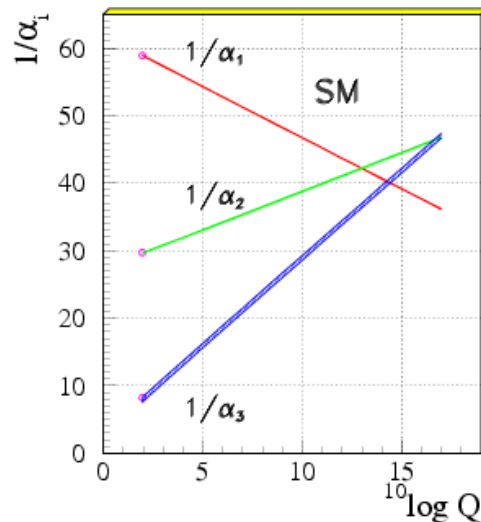
Looking at the basic interactions gives us information about the earliest moments of the beginning of the Universe



- The Weak force (responsible for radioactivity, i.e. $n \rightarrow p + e + \bar{\nu}$) gives a mechanism to produce more matter than anti-matter.
- Similarly to the beginning of the Universe, at the LHC energies, the weak interactions play a major role.
- Heavy quarks ($b \rightarrow c + \mu + \bar{\nu}$) through non-time-reversal, can give us a hint in to this mechanism to produce a small excess of matter.

Why are our expectations so high at the LHC collision energies

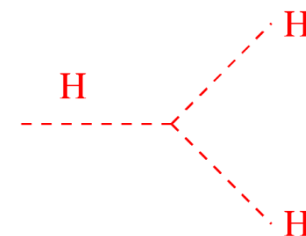
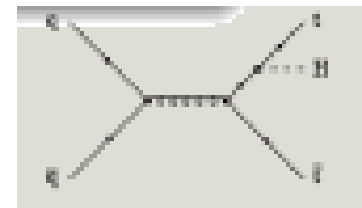
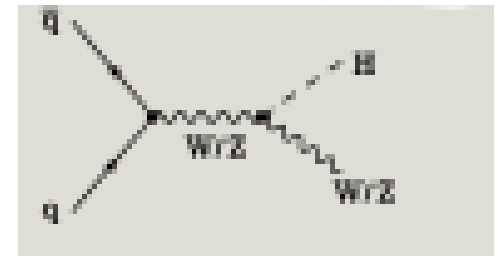
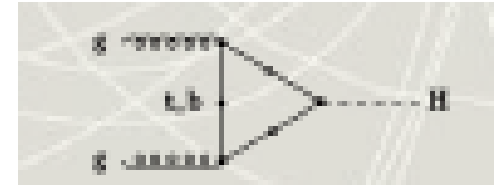
- *~1900 reached atomic scale $10^{-8}\text{cm} \approx \alpha/m_e$*
- *~1970 reached strong scale $10^{-13}\text{cm} \approx Me^{-2\pi/\alpha_s b_0}$*
- *~2010 will reach weak scale $10^{-17}\text{cm} = \text{TeV}^{-1}$*



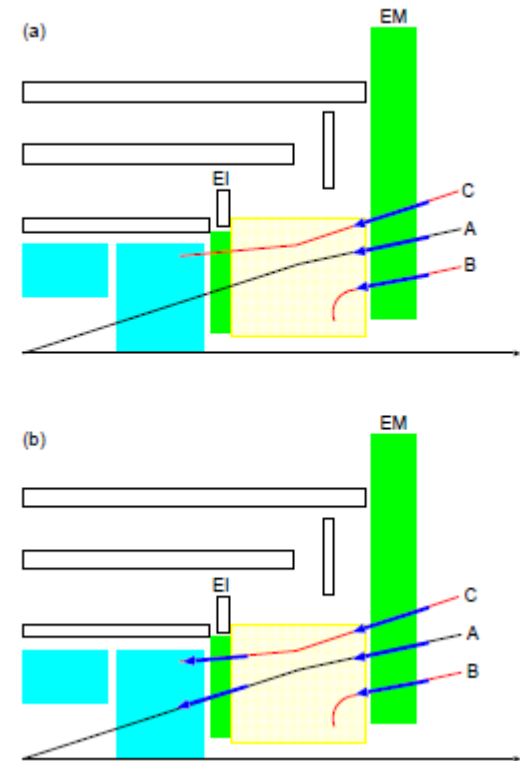
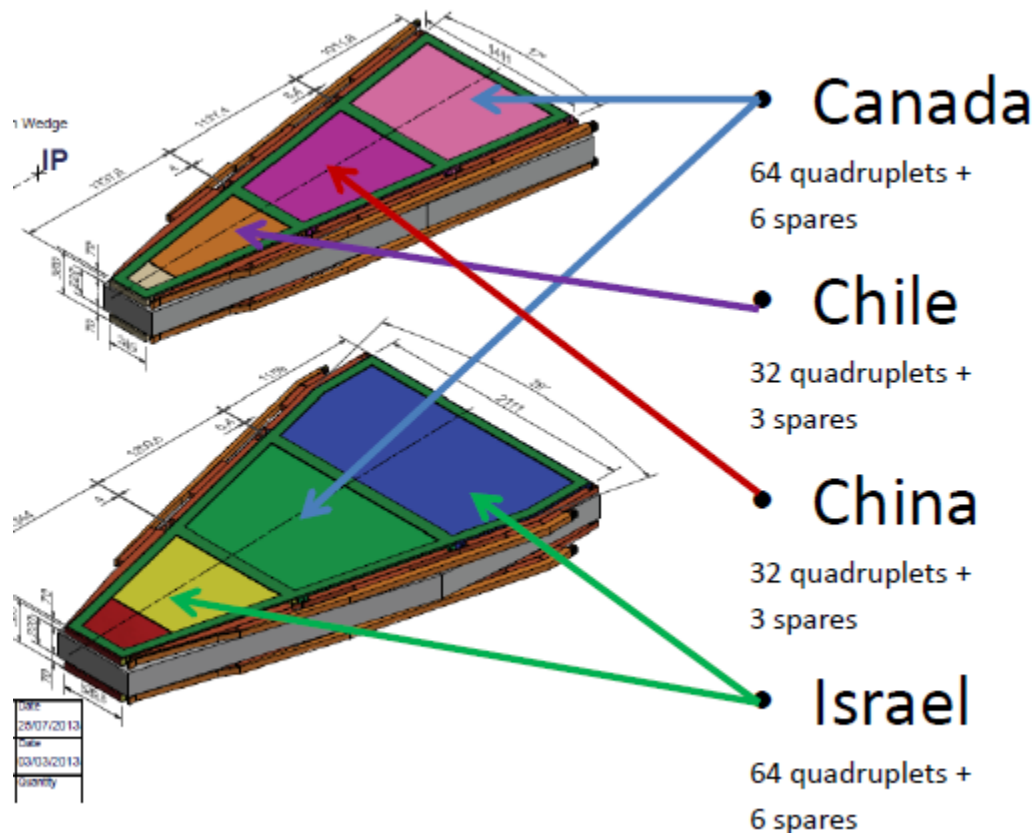
- Having a new phenomena at the TeV scale, would allow for a unification of the various forces at higher energy.
- If new phenomena at 1TeV=>2 LHC years; if 3 TeV=> 10LHC years

This is just the start, we need to do much more to get hints of what is behind...

- Most of the present H observations are based on production by Gluons (+/-14% systematic errors).
- Need to look at real Yukawa couplings, on a well defined production mode. This is the base of the future upgrades (with a strong Israeli participation to ensure single lepton trigger) of the LHC experiments for the High Luminosity program.
- Need to look at the coupling to UP-like quarks, which is possible at the LHC with the increase energy and Luminosity.
- Need to look at the Higgs self coupling, which will only be possible (within 30%) with very high Luminosity (3Abarns^{-1}) with the LHC upgrade.



And again here, the Israeli contribution in close collaboration with Chile will play a major role



Primera vez que detectores criticos para un gran experimento van a ser construidos en Sud America

Conclusions

- Israel has shown that good education and high level scientific research are crucial inputs to develop High-Tech.
- The Israeli contribution to the CERN experiments, although small, plays a very important role.
- The LHC and its experiments will allow to clarify very important questions on our Universe:
 - The origin of mass , via the discovery of the Higgs Boson **has just been found. This is the most important discovery in Particle Physics in the last 30 years.**
 - The possibility of finding dark matter, that makes most of the **Universe (still no signs of it , but we have only explored 1/3 of the range)**
 - The possibility of understanding the asymmetry between matter and anti-matter in the Universe **(making progress, but I did not show results)**
 - Finding new phenomena (higher dimensions, mini- black holes, etc.
- The next 10 years promise to be very interesting to our understanding of the Universe.