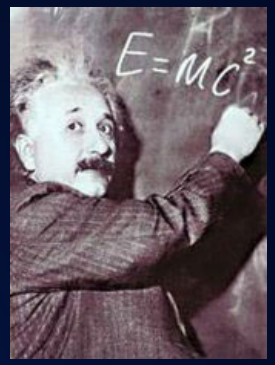
Big Questions, Small Particles and the Optimism of Curiosity

Click to edit Master subtitle style

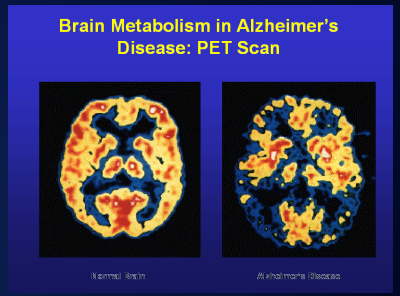
Bergen, September 7, 2012
Sergio Bertolucci
CERN

The Mission of CERN



- **Push forward** the frontiers of knowledge

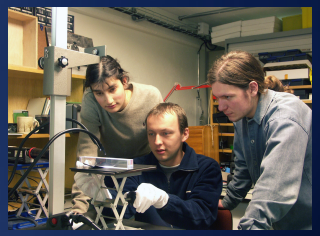
  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe's existence?



- **Develop** new technologies for accelerators and detectors

  Information technology - the Web and the GRID

  Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow

- **Unite** people from different countries and cultures

Refining candles would not have led candle into electric bulbs …

CERN was founded 1954: 12 European States

"Science for Peace"

Today: 20 Member States

~ 2300 staff
~ 1050 other paid personnel
> 11000 users
Budget (2012) ~830 MEuro

Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom

Candidate for Accession: Romania

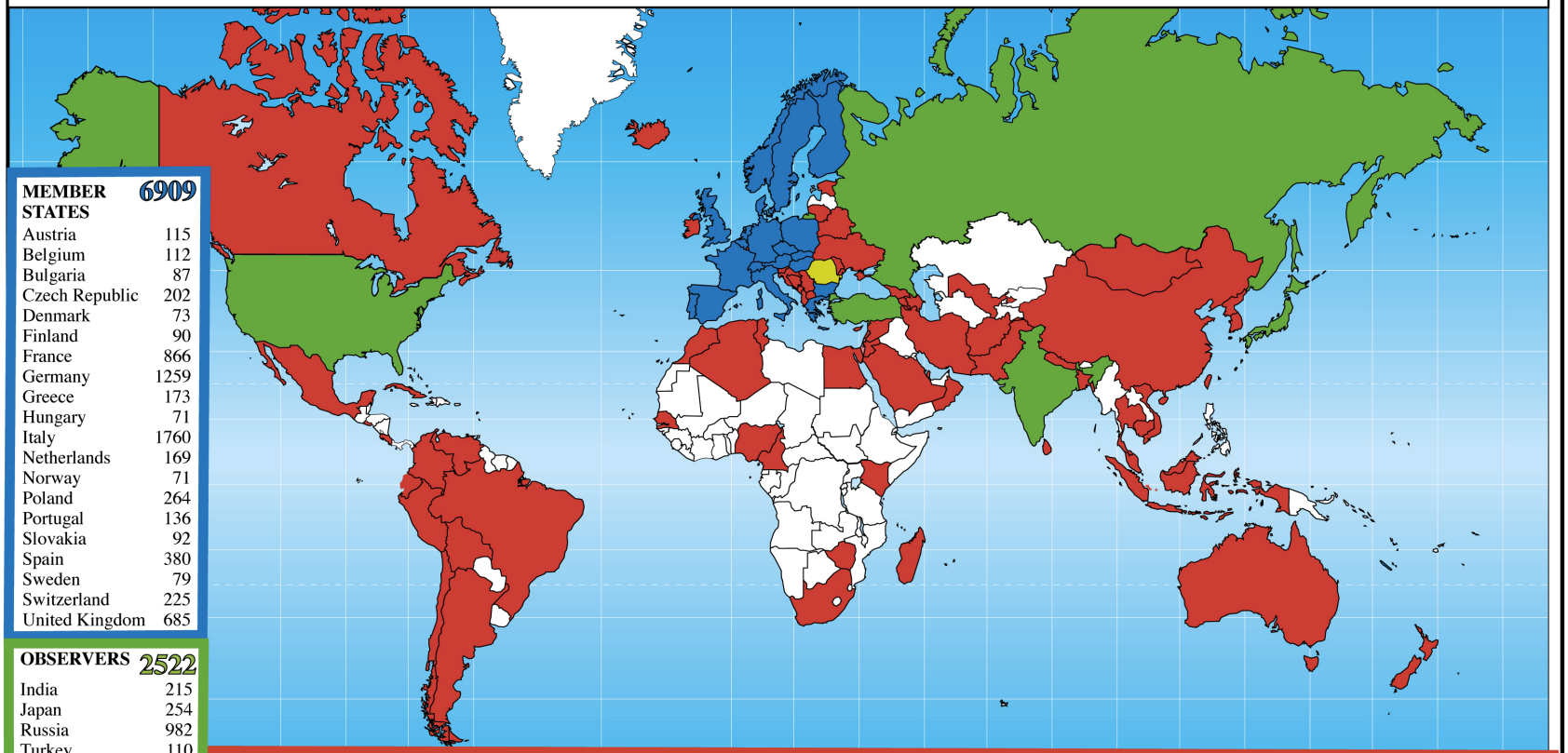
Associate Members in the Pre-Stage to Membership: Israel, Serbia

Applicant States: Cyprus, Slovenia, Turkey

Observers to Council: India, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO

CERN in Numbers

Distribution of All CERN Users by Nationality on 4 April 2012



MEMBER STATES	6909
Austria	115
Belgium	112
Bulgaria	87
Czech Republic	202
Denmark	73
Finland	90
France	866
Germany	1259
Greece	173
Hungary	71
Italy	1760
Netherlands	169
Norway	71
Poland	264
Portugal	136
Slovakia	92
Spain	380
Sweden	79
Switzerland	225
United Kingdom	685

OBSERVERS	2522
India	215
Japan	254
Russia	982
Turkey	110
USA	961

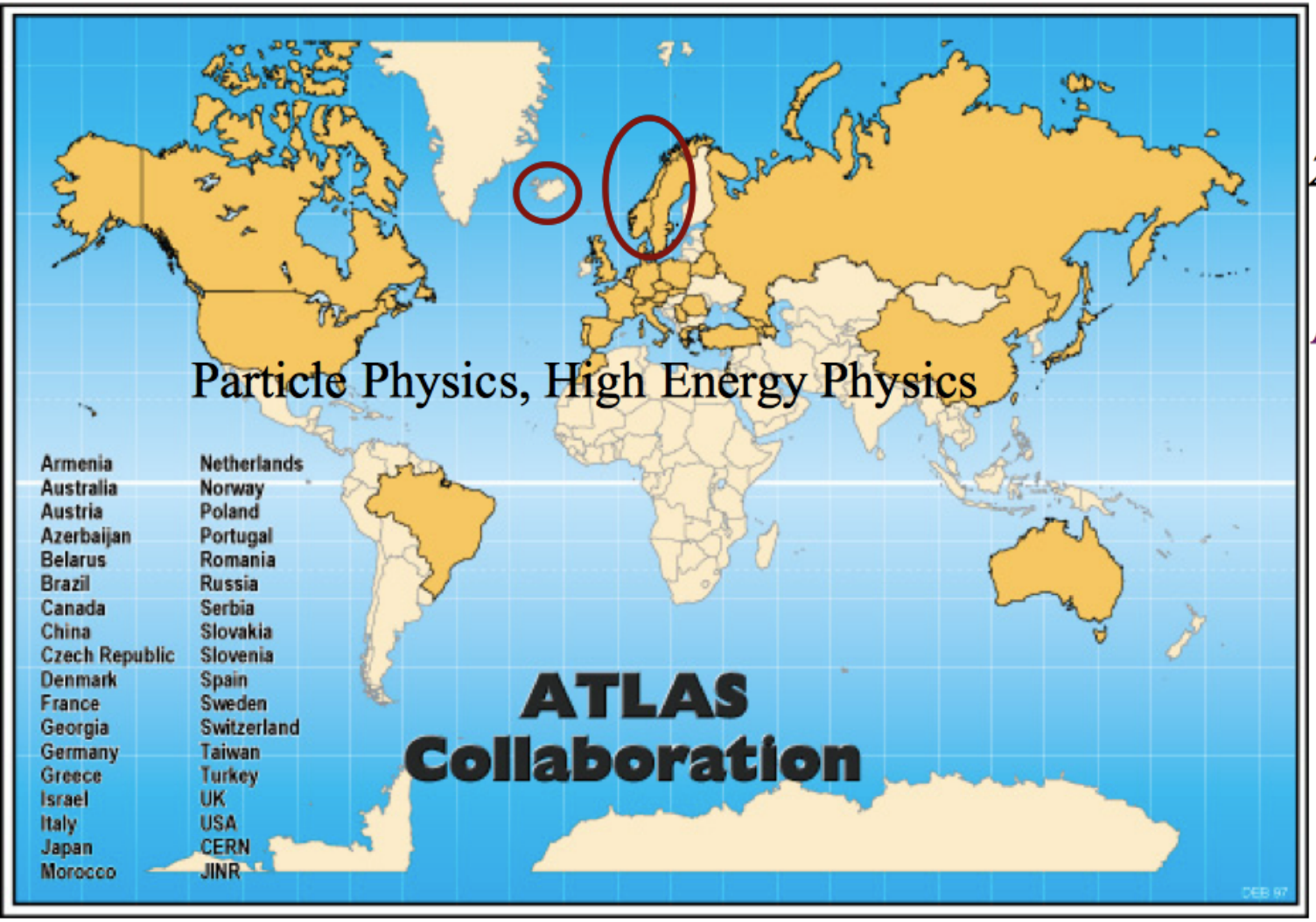
CANDIDATE FOR ACCESSION	
Romania	117

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP	
Israel	67
Serbia	39

OTHERS													
Afghanistan	1	Bosnia & Herzegovina	2	Cuba	6	Ireland	23	Mexico	63	Peru	5	Tunisia	6
Albania	3	Brazil	98	Cyprus	14	Jordan	2	Moldova	1	Qatar	1	Ukraine	46
Algeria	11	Cambodia	1	Ecuador	2	Kenya	1	Mongolia	1	San Marino	1	Uzbekistan	2
Argentina	16	Cameroon	2	Egypt	9	Korea, D.P.R.	1	Montenegro	2	Saudi Arabia	3	Venezuela	10
Armenia	21	Canada	141	El Salvador	1	Korea Rep.	119	Morocco	13	Senegal	1	Viet Nam	10
Australia	23	Chile	6	Estonia	15	Lebanon	11	Nepal	3	Slovenia	43	Zimbabwe	2
Azerbaijan	6	China	270	Georgia	31	Lithuania	17	New Zealand	8	South Africa	16		
Bangladesh	2	China (Tapei)	48	Hong Kong	1	Luxembourg	3	Nigeria	1	Sri Lanka	6		
Belarus	41	Colombia	29	Iceland	4	Madagascar	3	Oman	1	Syria	1		
Bolivia	2	Costa Rica	2	Indonesia	2	Malaysia	7	Pakistan	44	Thailand	7	1353	
		Croatia	30	Iran	21	Malta	2	Palestine (O.T.).	3	T.F.Y.R.O.M.	3		

LHC and ATLAS Collaboration

www.atlas.ch



ATLAS in the World

2300 participants

~130 institutions

ATLAS i Norden

main activity in

Denmark

Norway

Sweden

ATLAS i Norge

~60 participants

Bergen&Oslo

A Toroidal LHC AparatuS

Large Hadron Collider and large experiments ATLAS, situated in the largest man-made cavern.

Summer 2003

***ATLAS (experiment&theory) in Bergen (Department of Physics and Technology)*:**

4 faculty, 2 postdocs, 12 Master & PhD students.
Activities in silicon detectors,
computer reconstruction of detector information,
numerical simulation physics
studies, theory&phenomenology, outreach

Gerald Eigen, Anna Lipniacka, Per Osland, Bjarne Stugu

Researchers, BSF, Heidi Sandaker

Postdocs: Wolfgang Liebig ,*Thomas Burgess*

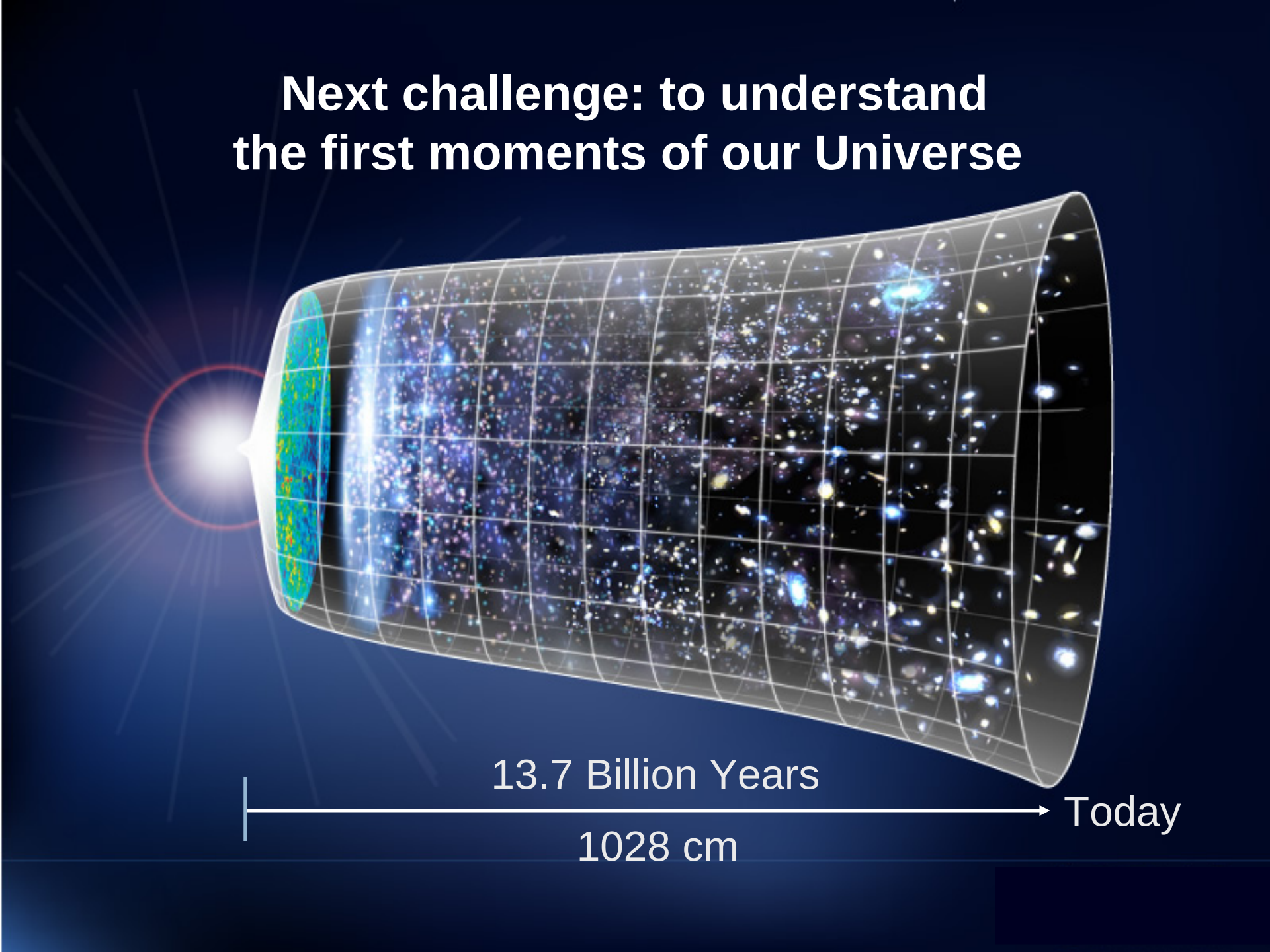
PhD: Alex Kastanas, Maren Ugland, Orjan Dale, Jan Lindroos, Justas Zalieckas

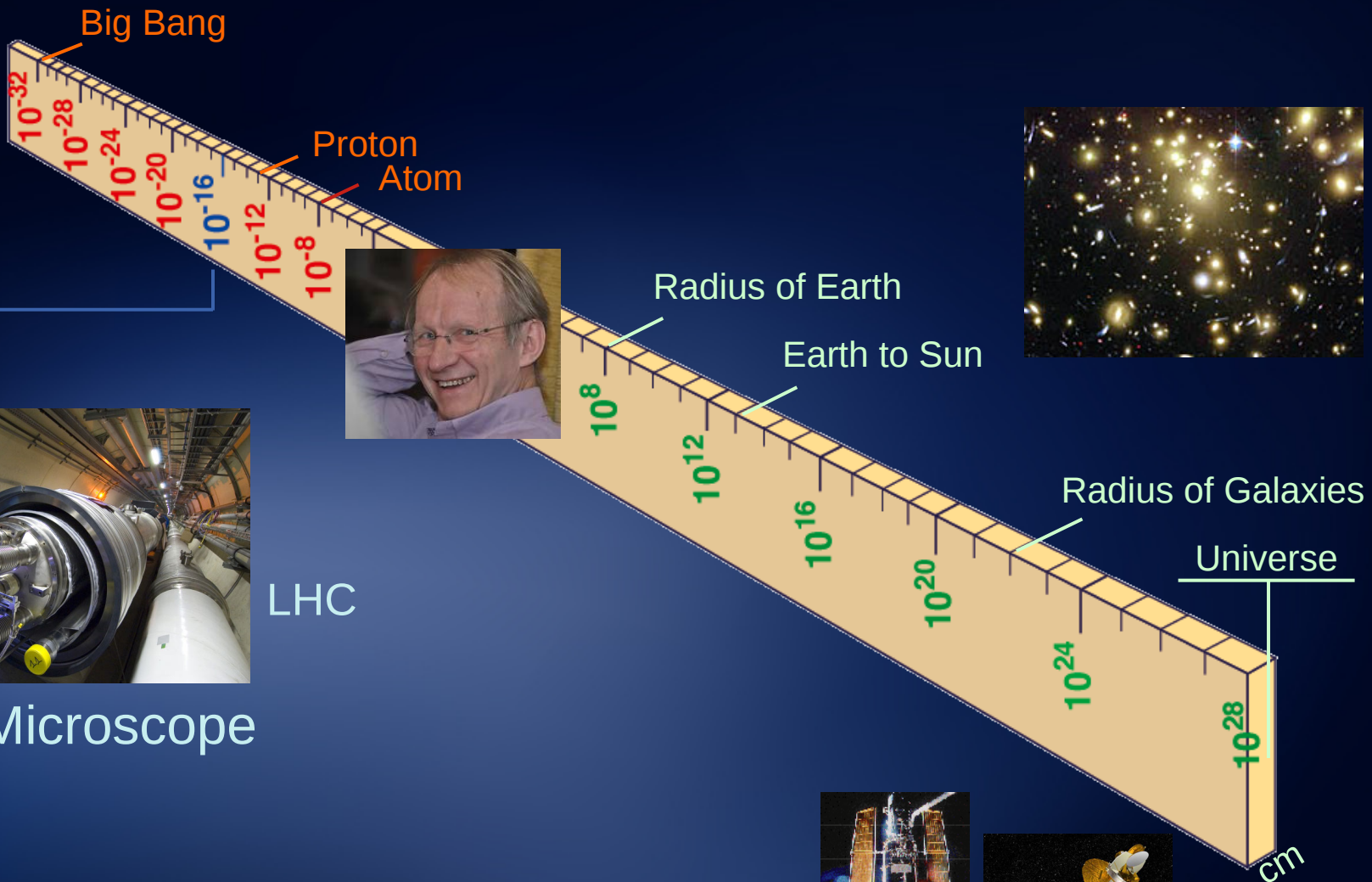
Arshak Tonoyan, Therese Sjursen, Peter Rosendahl

+Theory PhDs (*Niels Bomark*, Mahdi Purmohammadi)


NRK
Bjarne Stugu
Nyheter
professor UiB

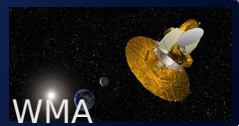
Next challenge: to understand the first moments of our Universe





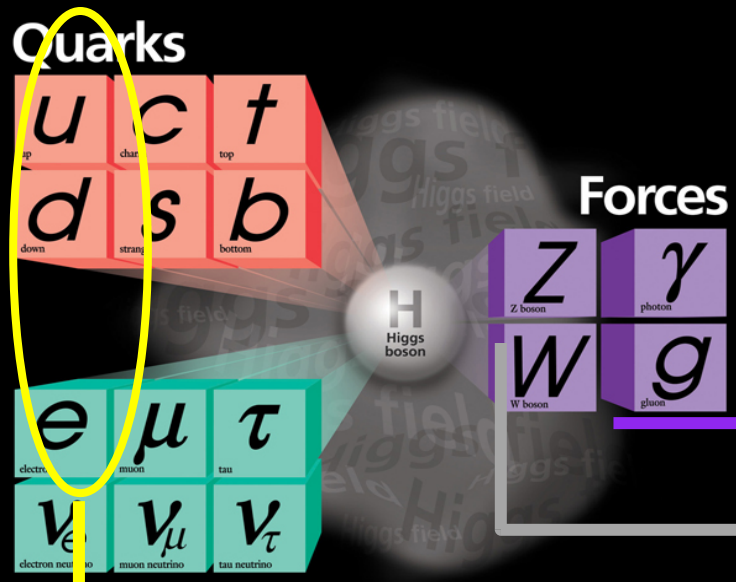
LHC

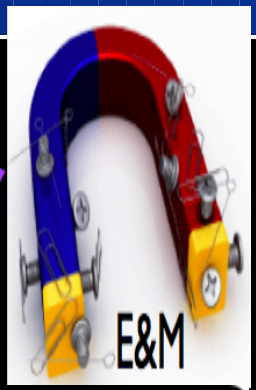
Super-Microscope

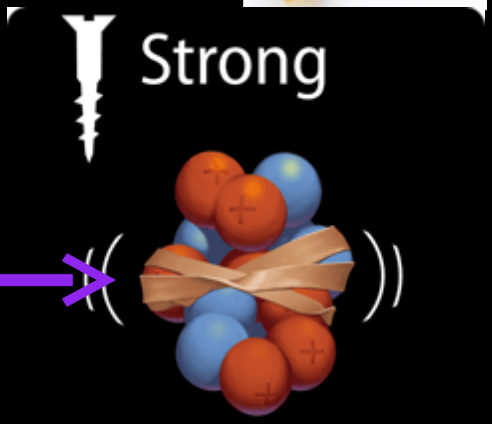


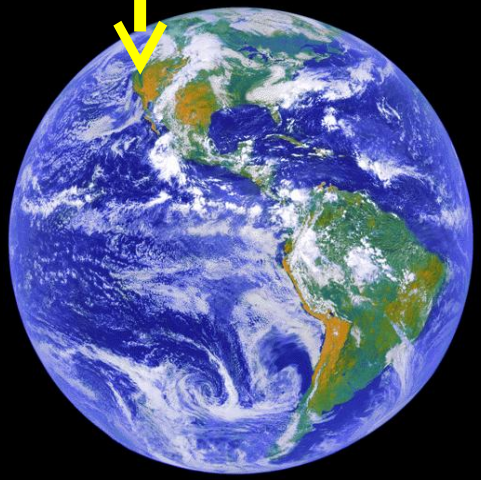
Study physics laws of first moments after Big Bang increasing Symbiosis between Particle Physics, Astrophysics and Cosmology

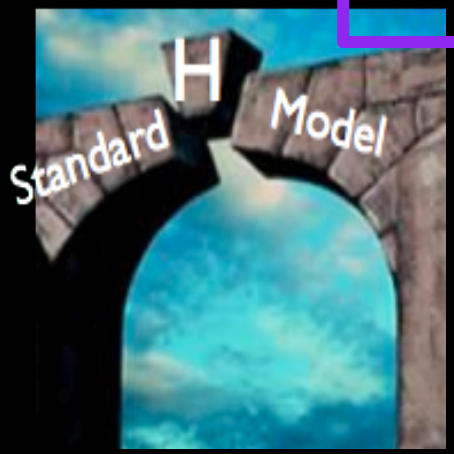
The Standard Model

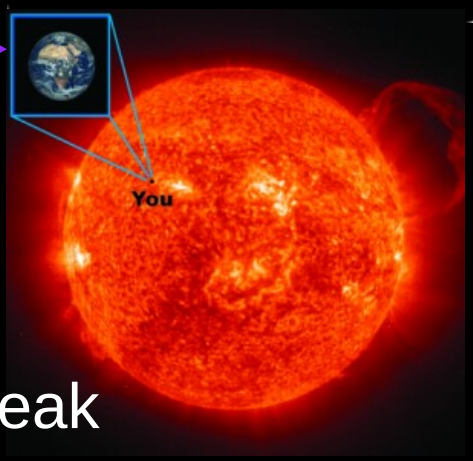






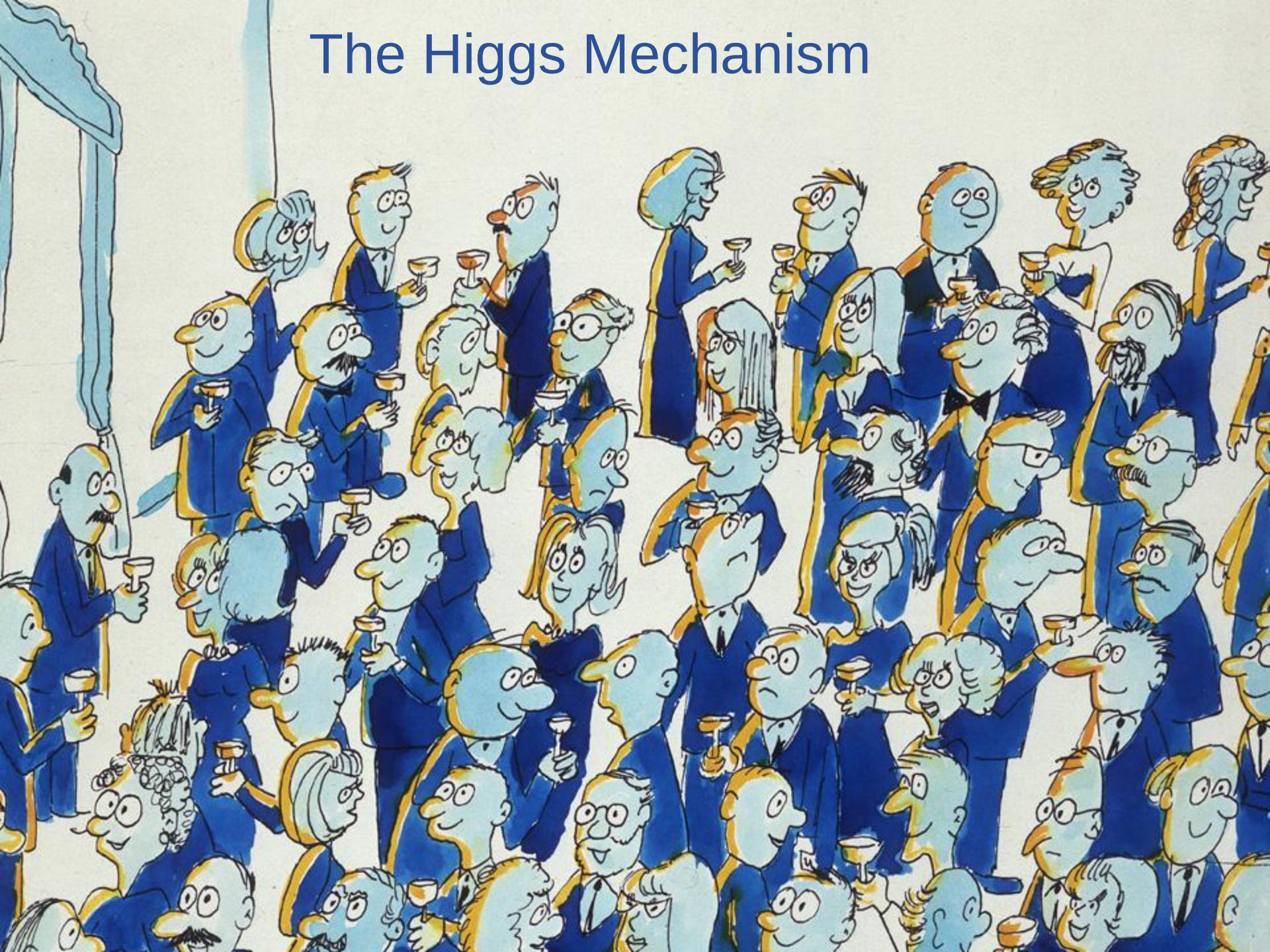






Weak

The Higgs Mechanism

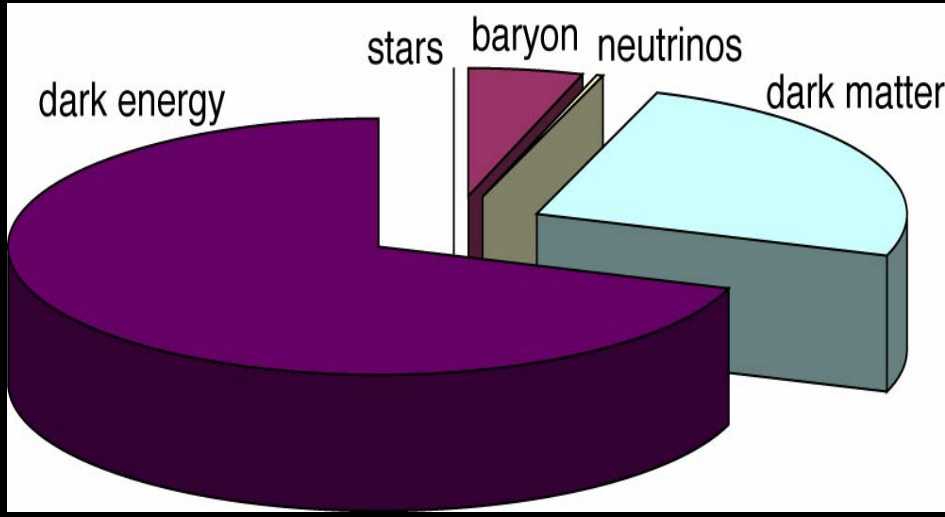



But What is Wrong with this Picture?

Cosmic problems.....

THE ENERGY DENSITY BUDGET

Standard



BARYONS

COLD DARK MATTER

NEUTRINOS

DARK ENERGY

A considerable number of key questions…

origin of mass/matter or
origin of electroweak symmetry breaking

unification of forces

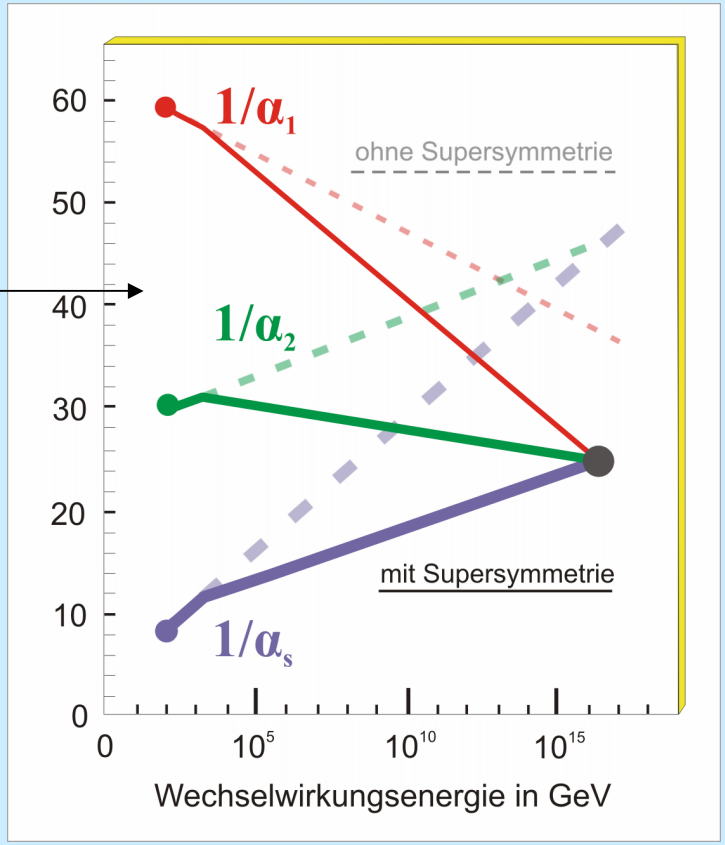
fundamental symmetry of forces and matter

unification of quantum physics and general relativity

number of space/time dimensions

what is dark matter?

what is dark energy?



Solutions?

Technicolor

New (strong) interactions produce EWSB

Extensions of the SM gauge group : Little Higgs / GUTs / …

Selected NP since 1957 Except P. Higgs

successful for ever ??

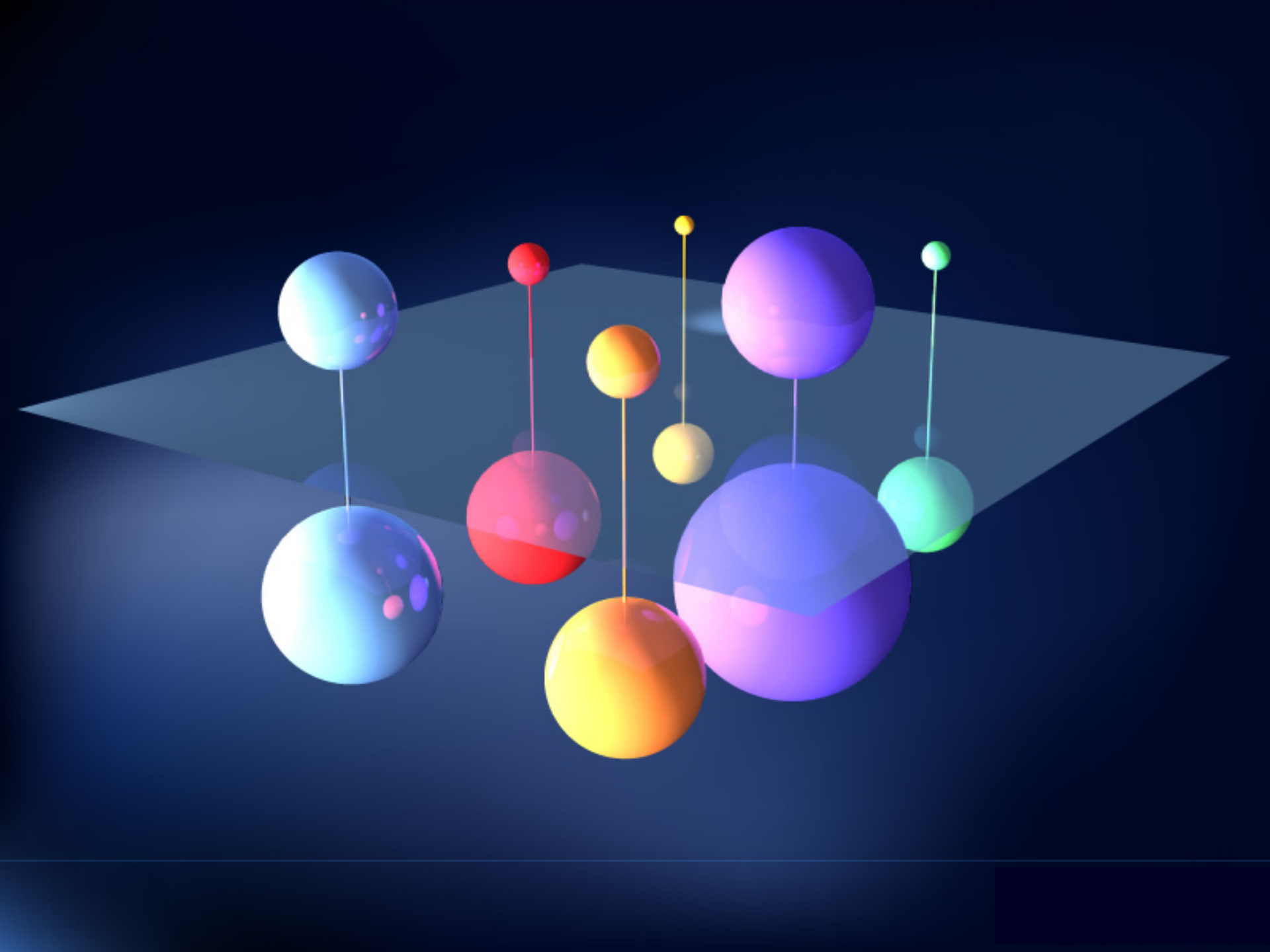
Supersymmetry

New particles at ≈ TeV scale, light Higgs
Unification of forces
Higgs mass stabilized
No new interactions

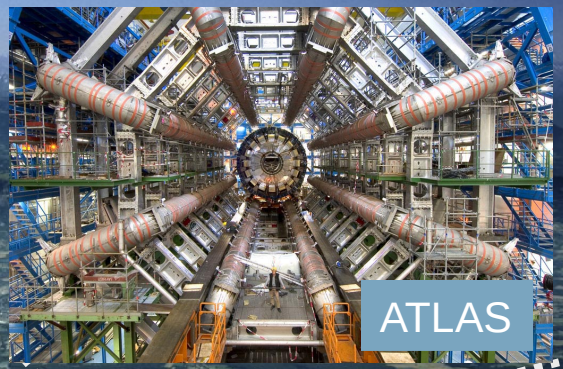
Extra Dimensions

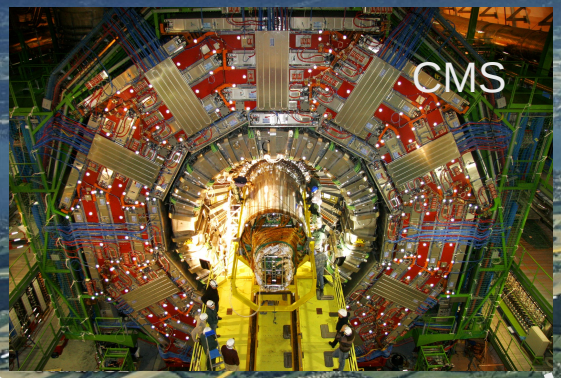
New dimensions introduced
mGravity ≈ melw Hierarchy problem solved

New particles at ≈ TeV scale



Enter a New Era in Fundamental Science

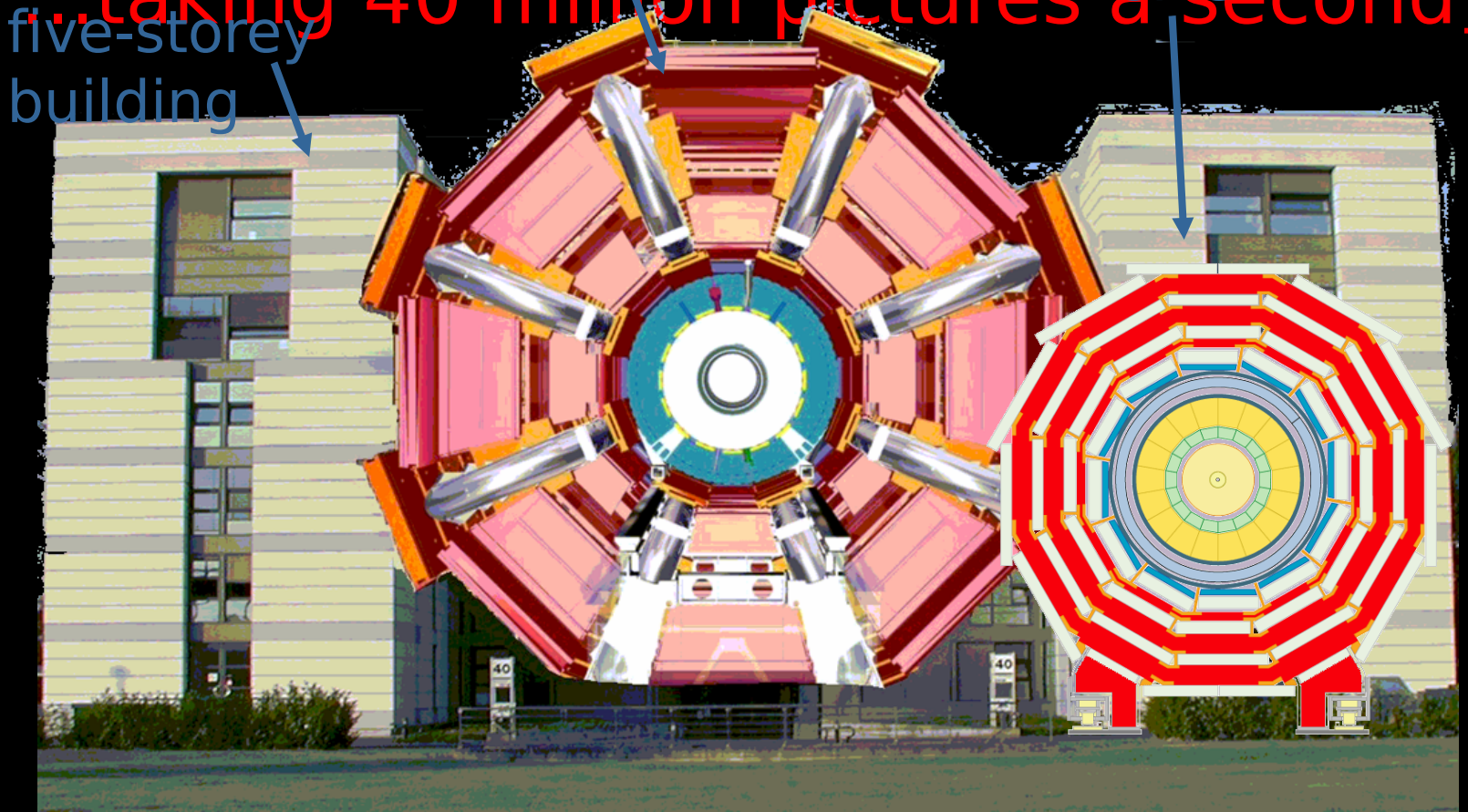




Since March 2010 exploration of a new energy frontier in p-p and Pb-Pb collisions

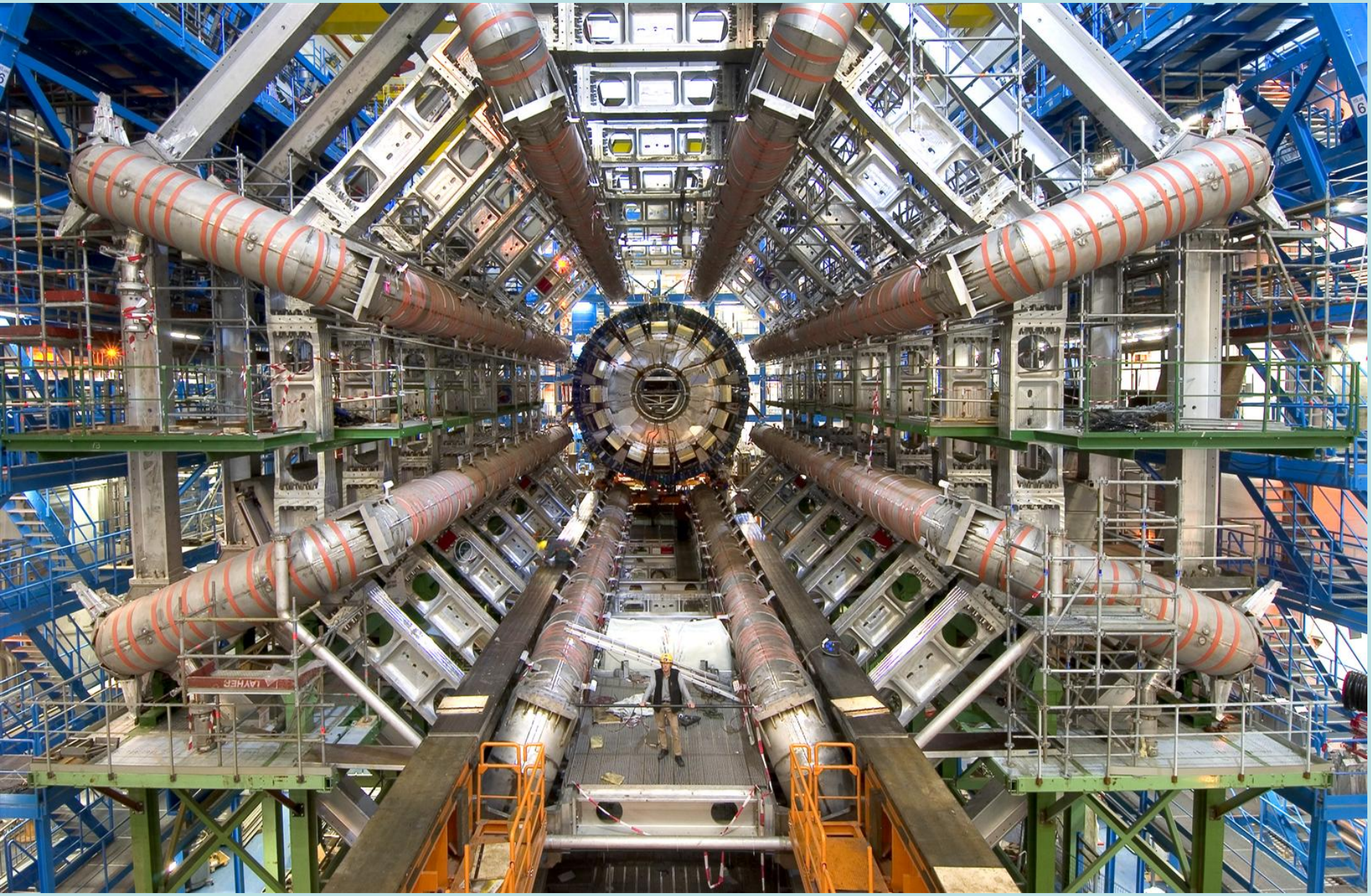
The Large Hadron Collider (LHC) tunnel

The LHC experiments: about 100 million “sensors” each [think your 6MP digital camera... ...taking 40 million pictures a second]

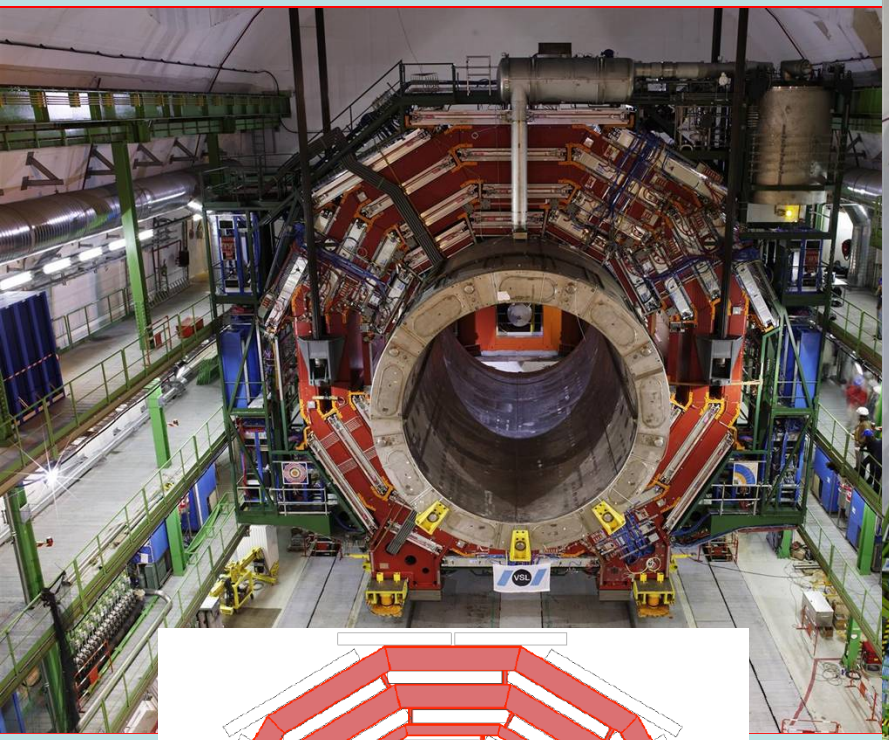


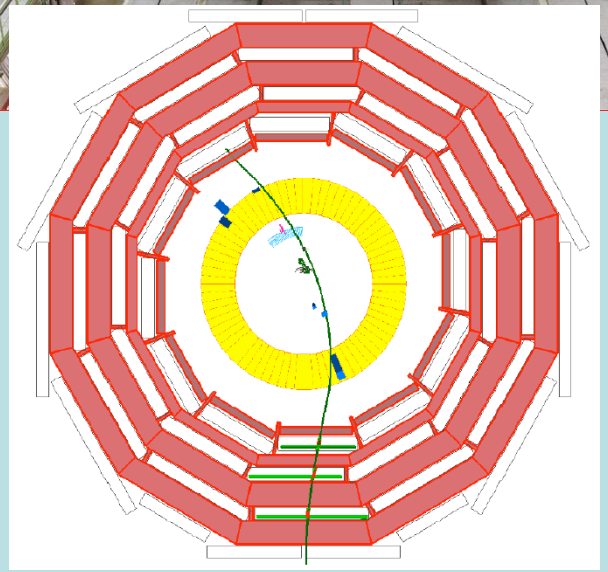

ATLAS cavern (-100 m) in June

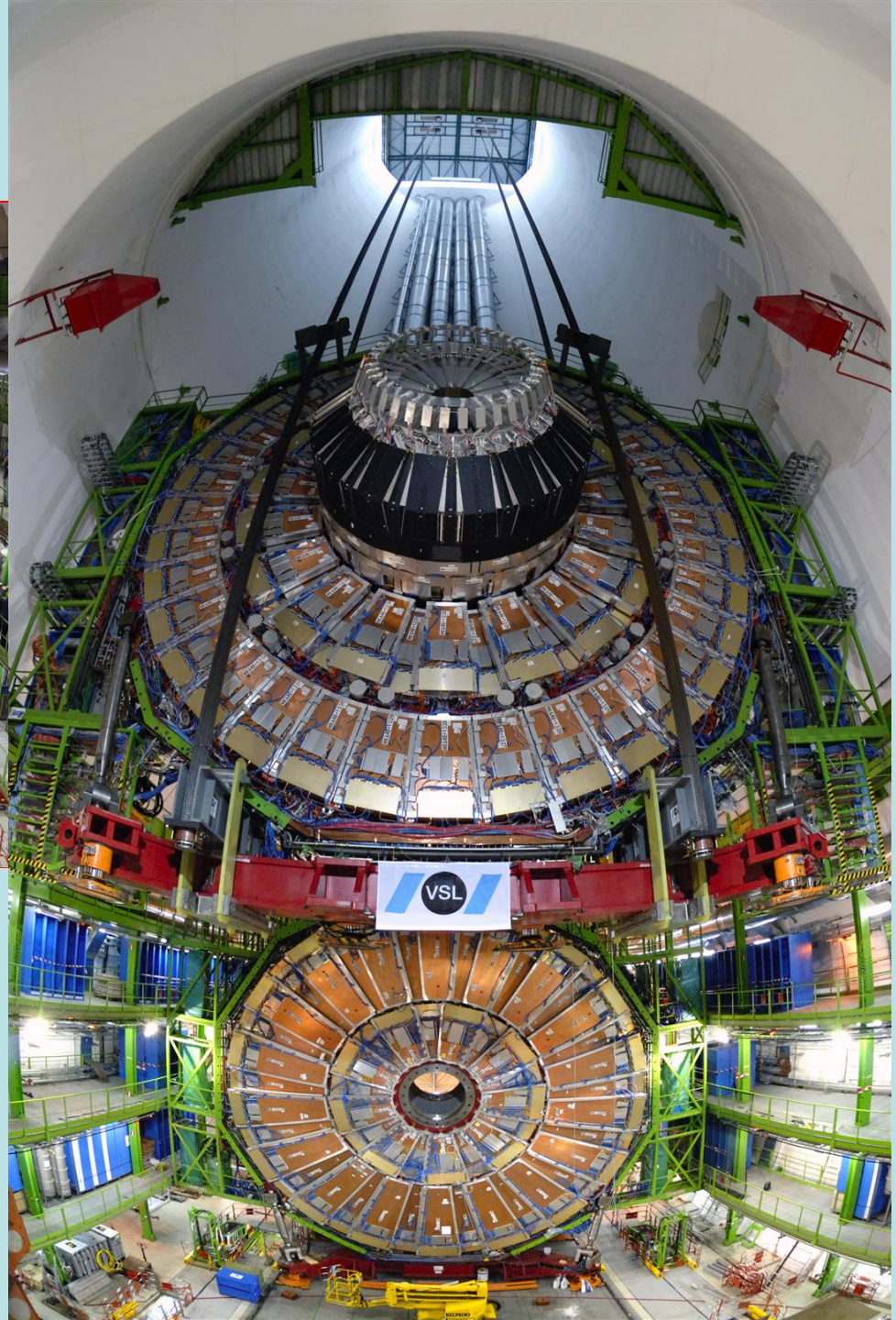
October 2005: Barrel toroid magnet system in place



The CMS experiment



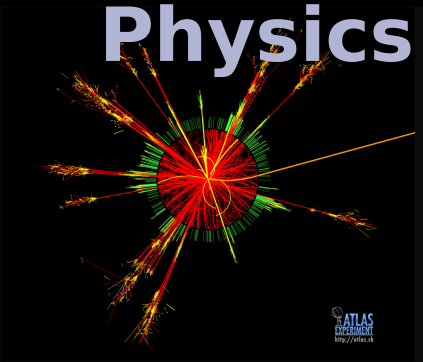


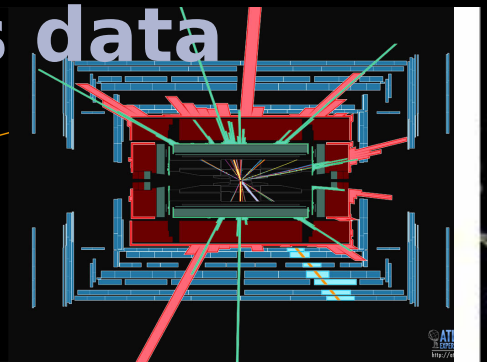


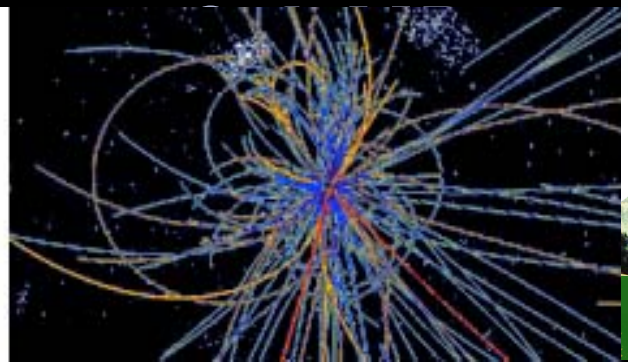
The LHC data

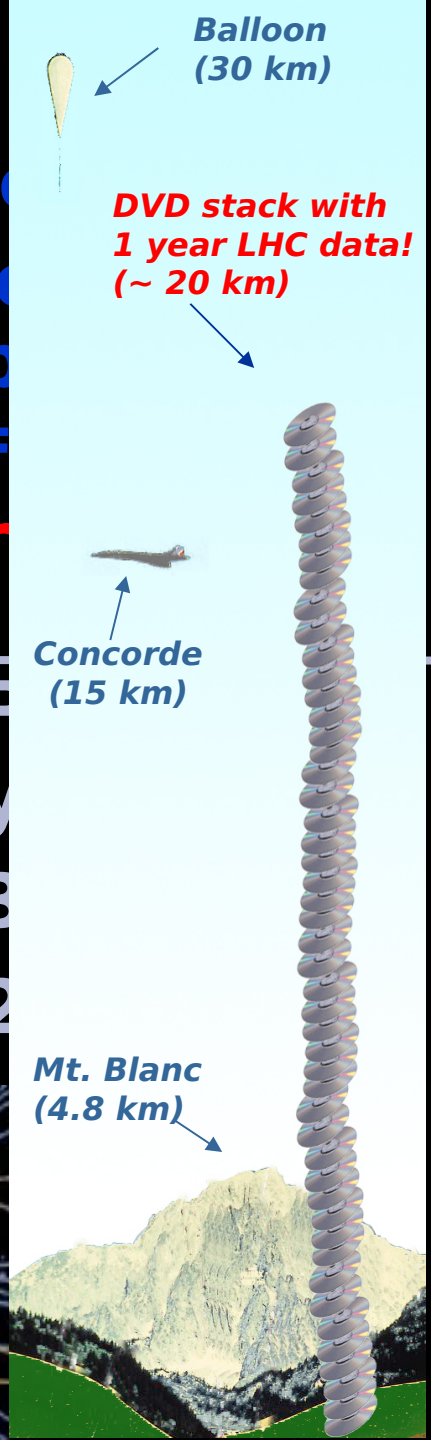
- **40 million events (pictures) per s**
- **Select (on the fly) the ~500 intere events per second to write on tap**
- **“Reconstruct” data and convert f analysis: “physics data” [the gr**

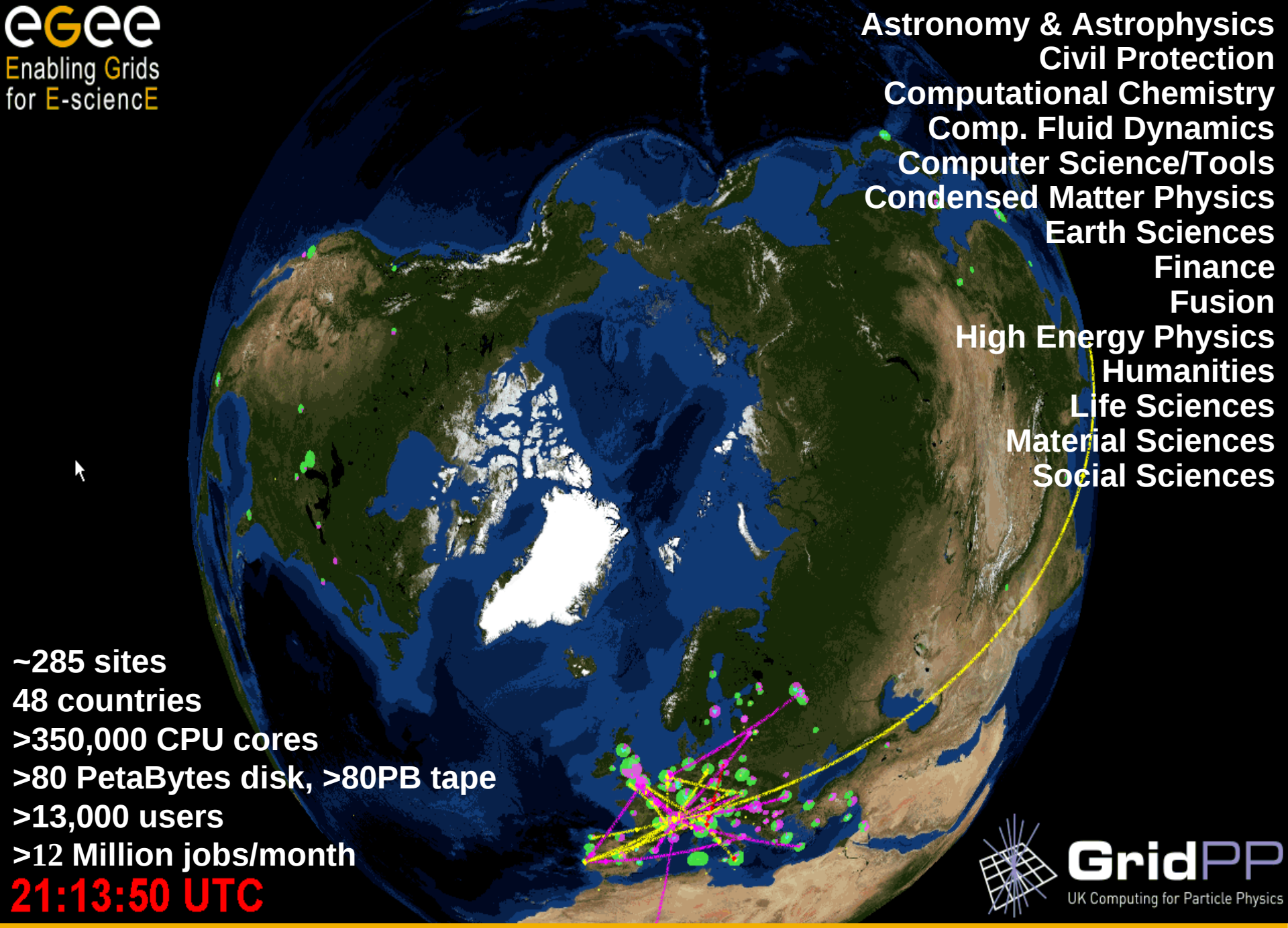
(x4 experiments x15 years)	Per event	P y
Raw data	1.6 MB	3
Reconstructed data	1.0 MB	2
Physics data		










Enabling Grids for E-sciencE
Astronomy & Astrophysics
Civil Protection
Computational Chemistry
Comp. Fluid Dynamics
Computer Science/Tools
Condensed Matter Physics
Earth Sciences
Finance
Fusion
High Energy Physics
Humanities
Life Sciences
Material Sciences
Social Sciences
~285 sites
48 countries
>350,000 CPU cores
>80 PetaBytes disk, >80PB tape
>13,000 users
>12 Million jobs/month
21:13:50 UTC
GridPP
UK Computing for Particle Physics

Stepping stones toward a discovery

Superb performance of the LHC

Excellent detectors performance in terms of data-taking efficiency and data quality

Experience gained with the 2011 data propagated to reconstruction and simulation (improved detector understanding, alignment and calibration, pile-up, …)

Huge amount of work to understand and mitigate the impact of pile-up on the reconstruction and identification of physics objects sizeable gain in efficiency for e/γ/μ, pile-up dependence minimized, smaller systematic uncertainties

Detailed studies of Standard Model processes and control of the (numerous) backgrounds

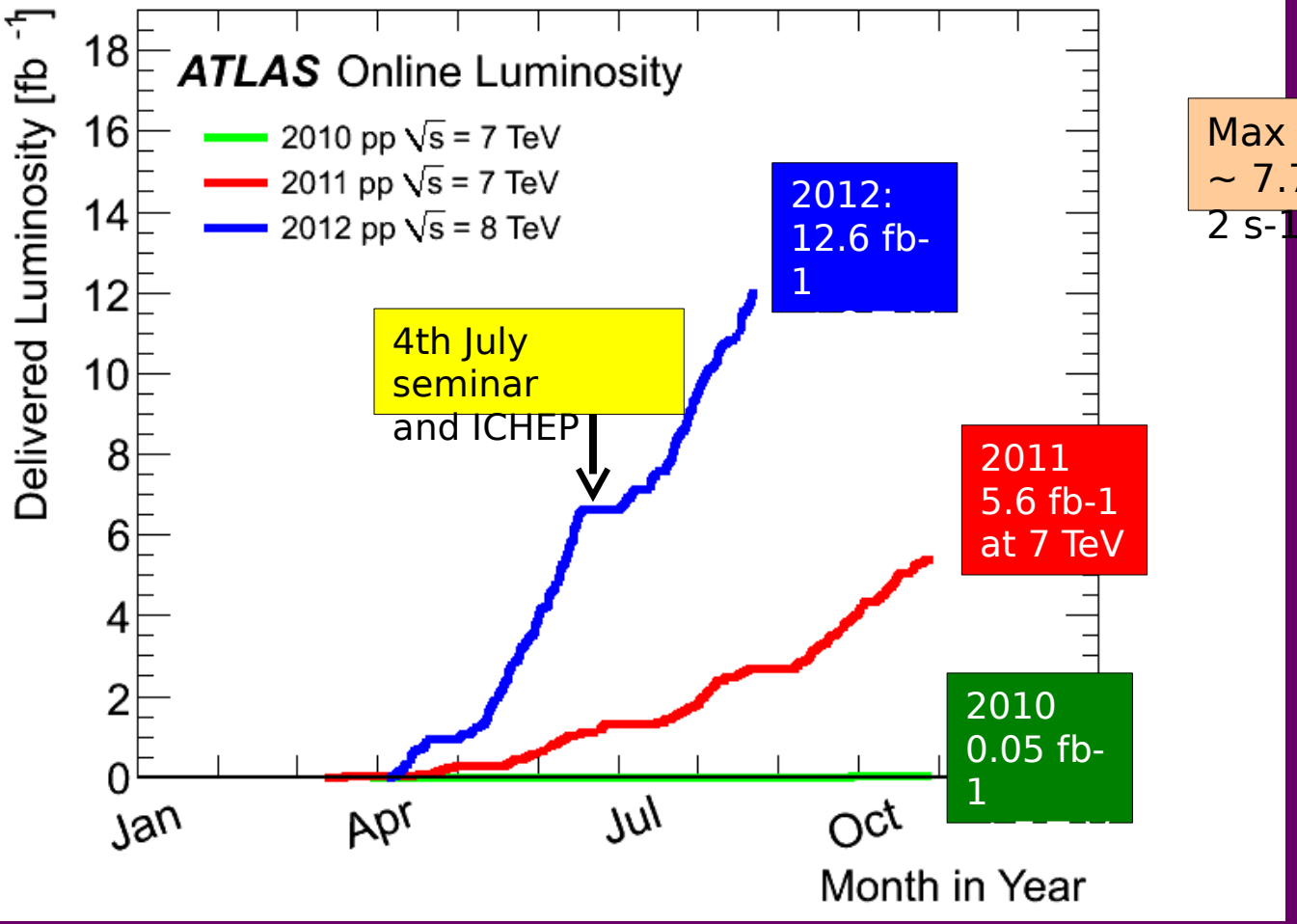
Sensitivity of H γγ, H 4l, H lνlν analyses improved using the following procedure:

- optimization only done on MC simulation
- then looked at 2012 data in signal sidebands and background control regions (note: large and sometimes not well-known backgrounds estimated mostly with data-driven techniques using background-enriched-signal-depleted control regions)
  validate MC simulation
- signal region inspected only after above steps satisfactory

Improved analyses applied also to 2011 data updated H γγ, 4l, lνlν results at 7 TeV

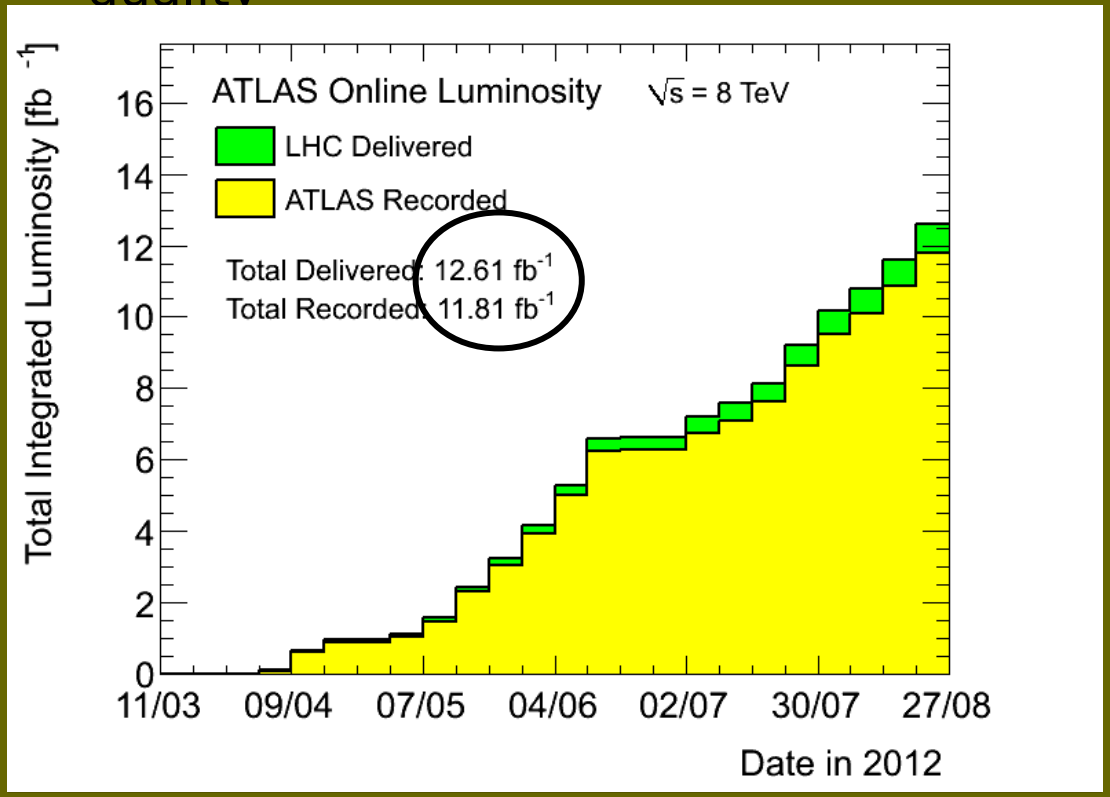
 Huge amount of painstaking foundation work !

Luminosity delivered to ATLAS since the



Max luminosity: ~ 7.7 x1033 cm-2 s-1

Detector operation, data-taking efficiency, data quality



Fraction of non-operational detector channels:
(depends on the sub-detector)

few permil (most cases) to 4%

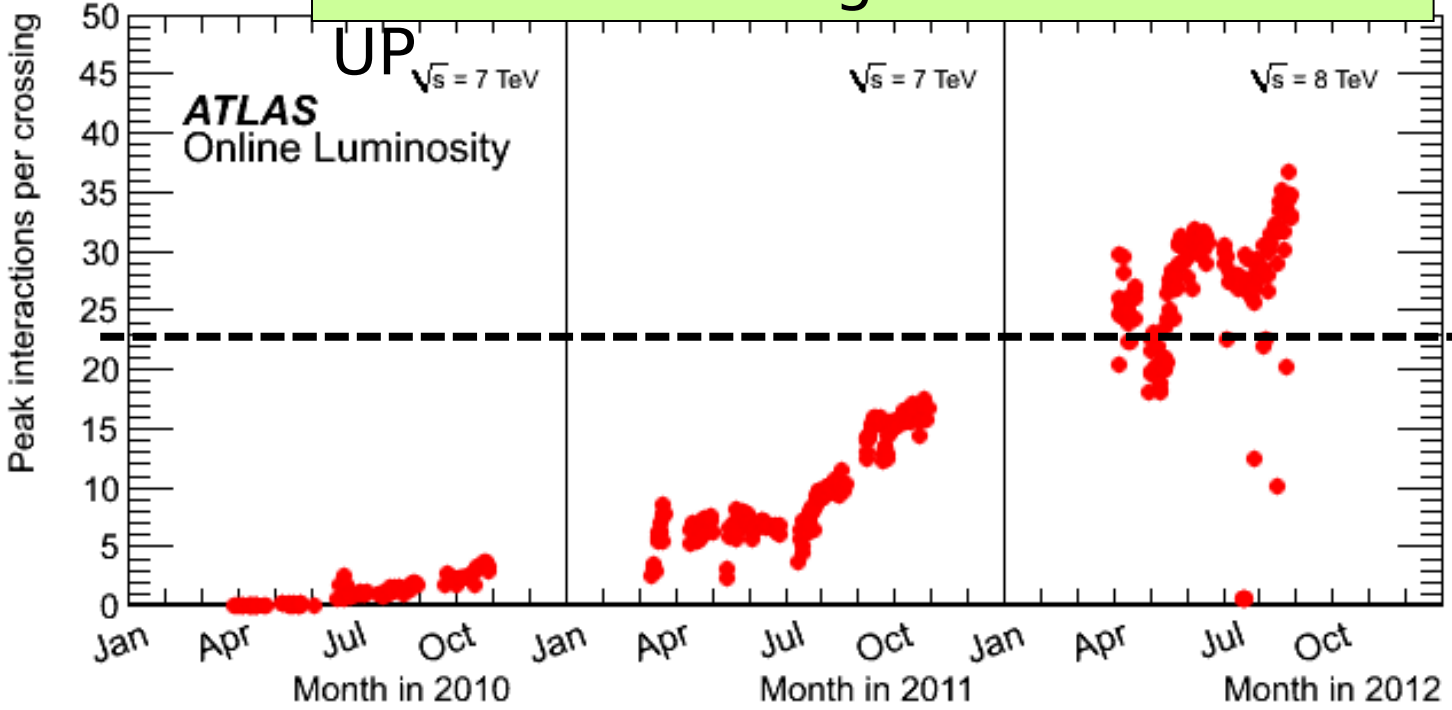
Data-taking efficiency = (recorded lumi)/(delivered lumi):

~ 93.7%

Good-quality data fraction, used for analysis :
(will increase further with data reprocessing)

~ 93 %

The BIG challenge in 2012: PILE-UP

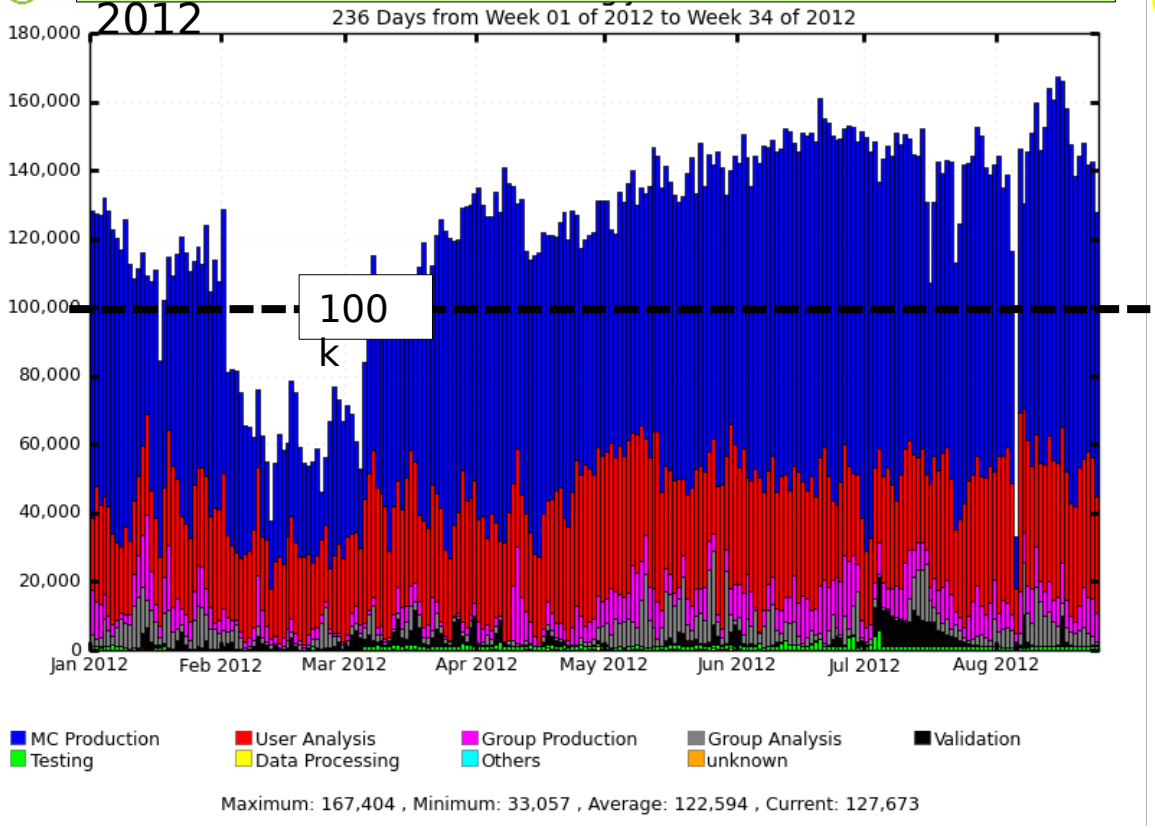


Experiment's design value (expected to be reached at L=1034 !)

The LHC performance and high pile-up conditions also stressed the Computing
It would have been impossible to release physics results so quickly without

ding the CERN Tier-0)

Number of concurrent ATLAS jobs Jan-Aug 2012

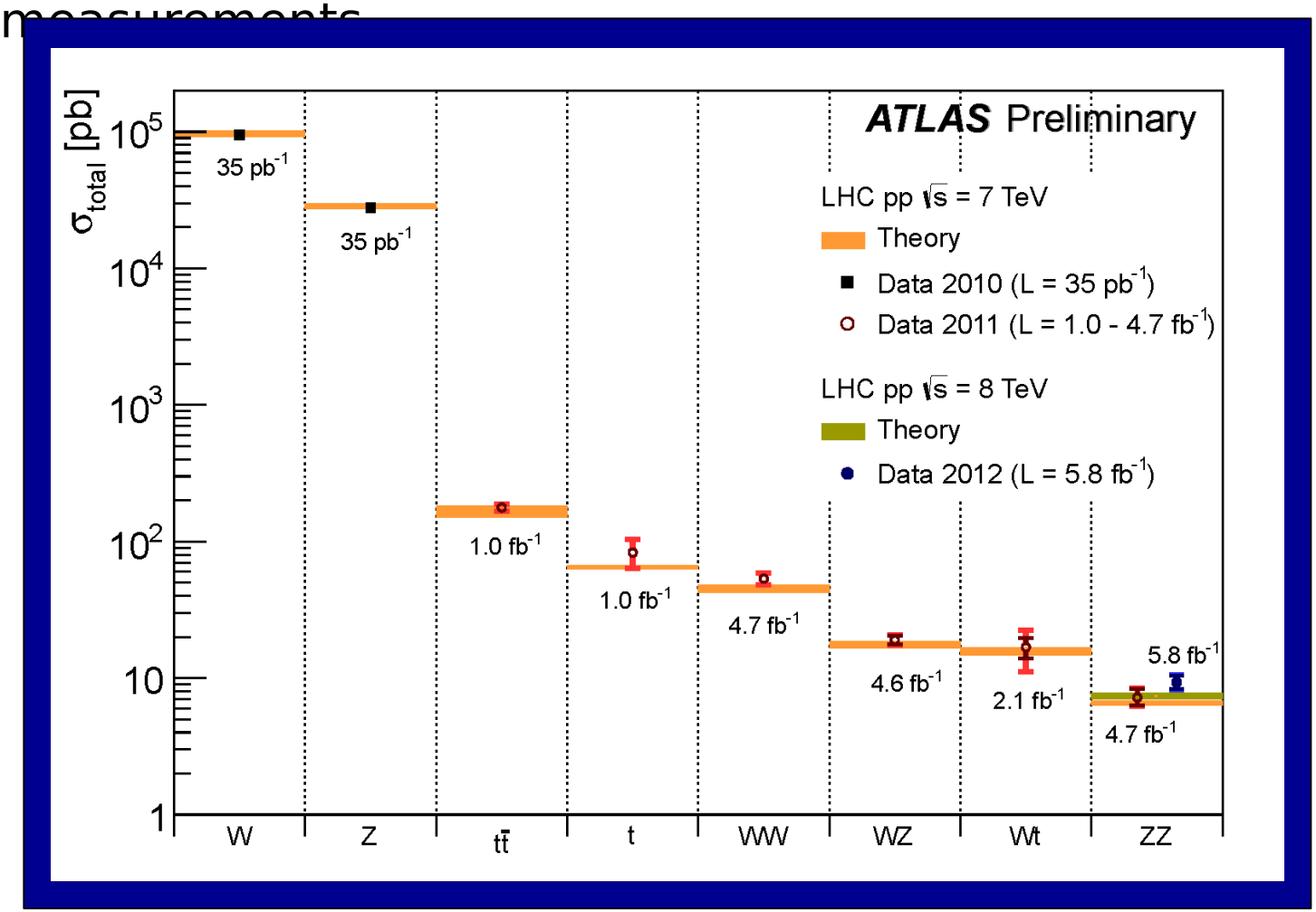


Includes MC production, user and group analysis at CERN, 10 Tier1-s,
~ 70 Tier-2 federations
> 80 sites

> 1500 distinct ATLAS users do analysis on the GRID

- Massive production of 8 TeV Monte Carlo samples
- Available resources fully used (beyond pledges in some cases)
- Very effective and flexible Computing Model and Operation team accommodate high trigger rates and pile-up, intense MC simulation, analysis demands from

Most recent electroweak and top cross-section measurements

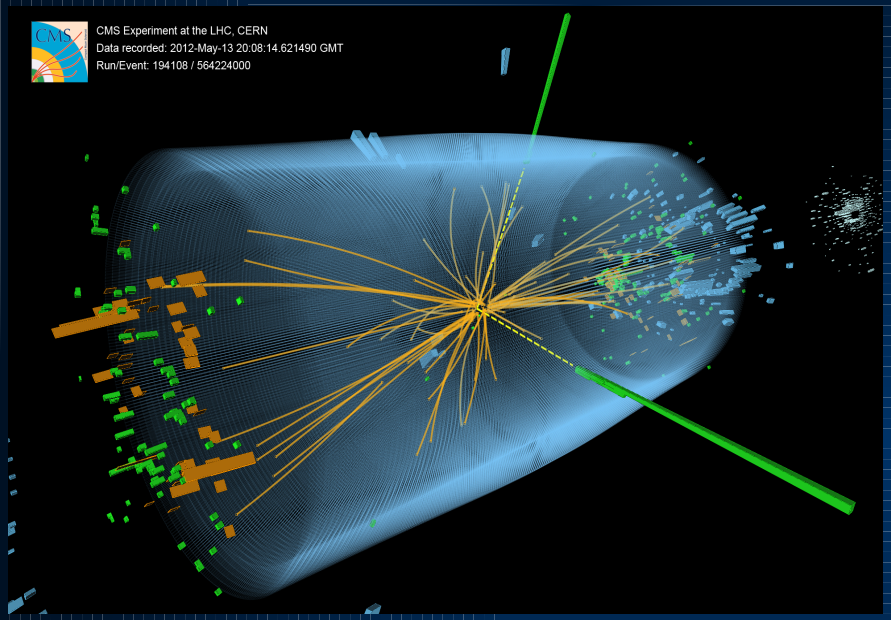


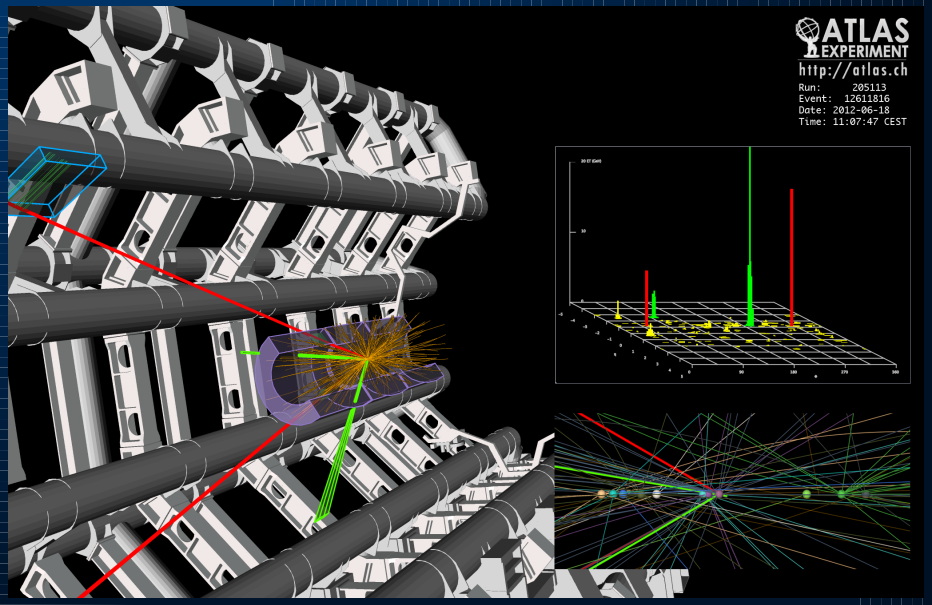
Inner error: statistical
Outer error: total

- Important on their own and as foundation for Higgs searches
- Most of these processes are reducible or irreducible backgrounds to Higgs
- Reconstruction and measurement of challenging processes (e.g. fully hadronic tt,

4 July 2012: CERN press conference

“CERN experiments observe particle consistent with long-sought Higgs boson”

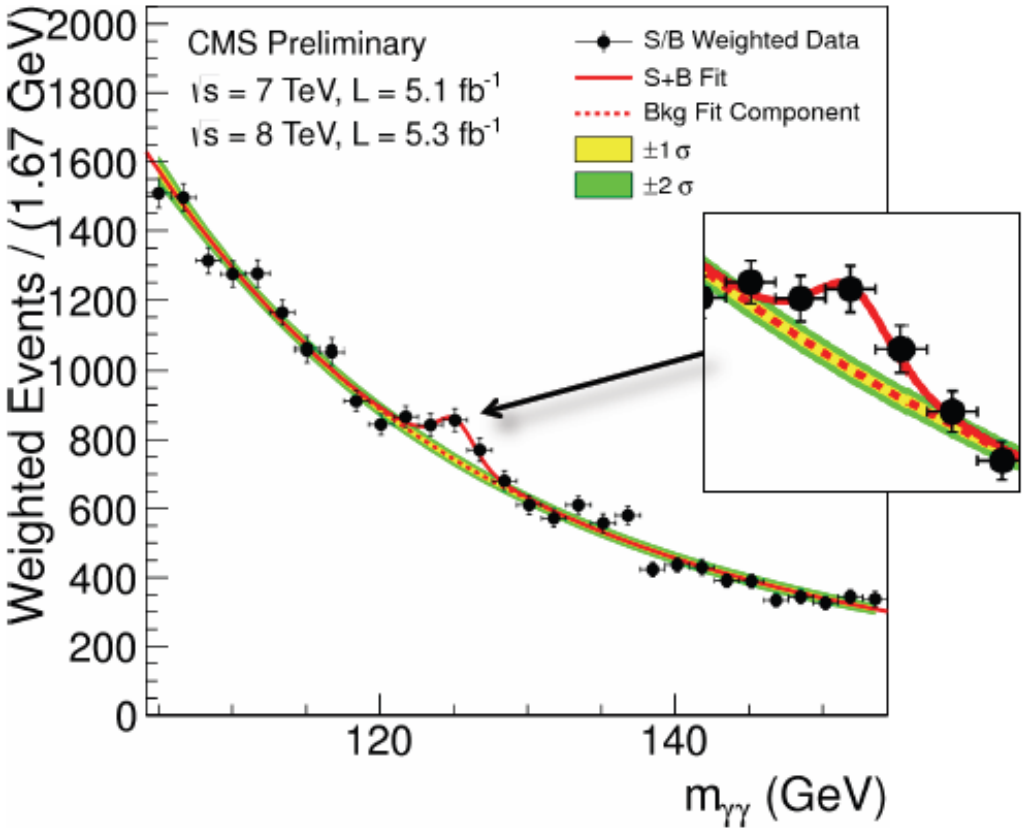




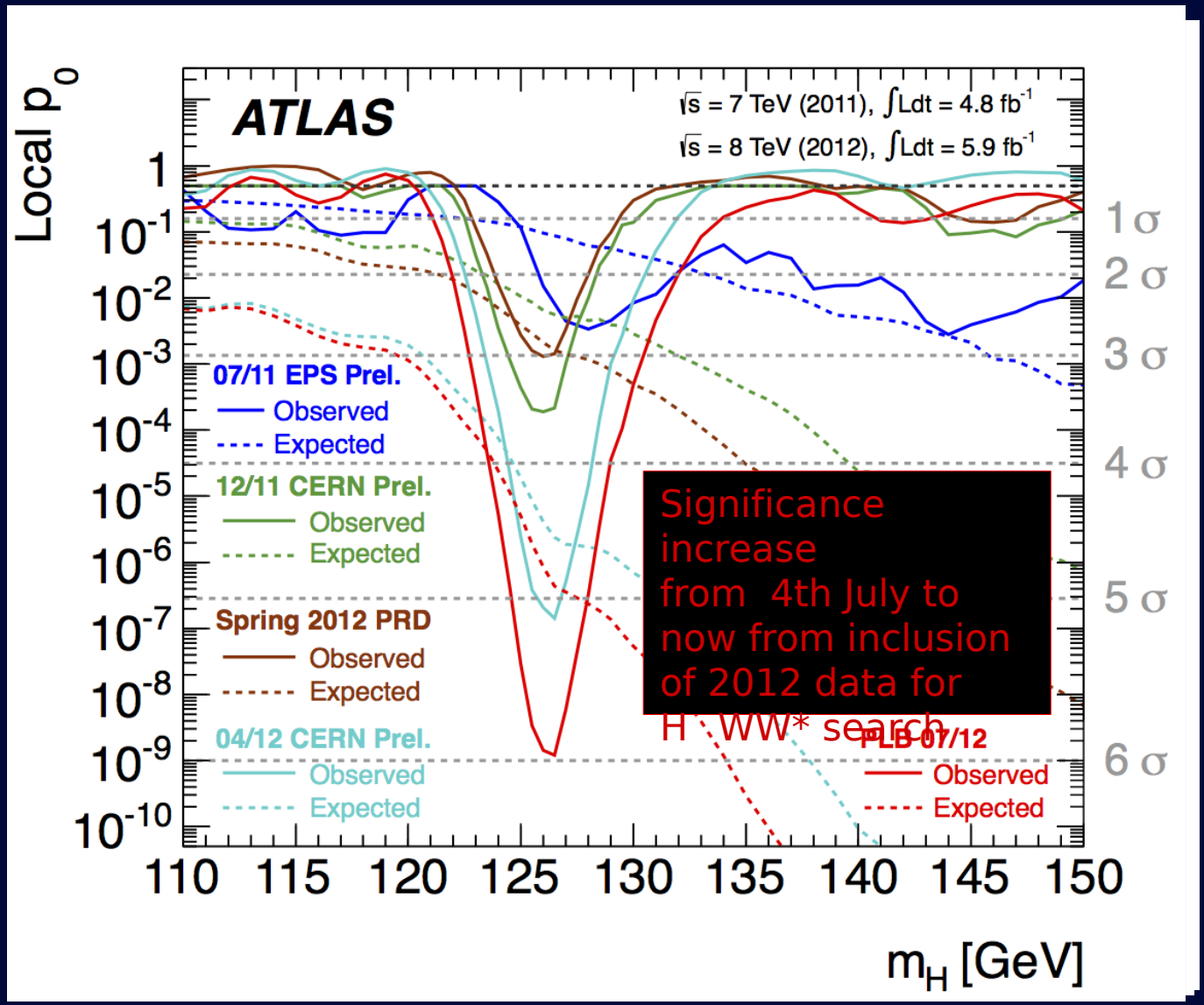
4 JULY 2012
CERN Press conference

S/B Weighted Mass Distribution

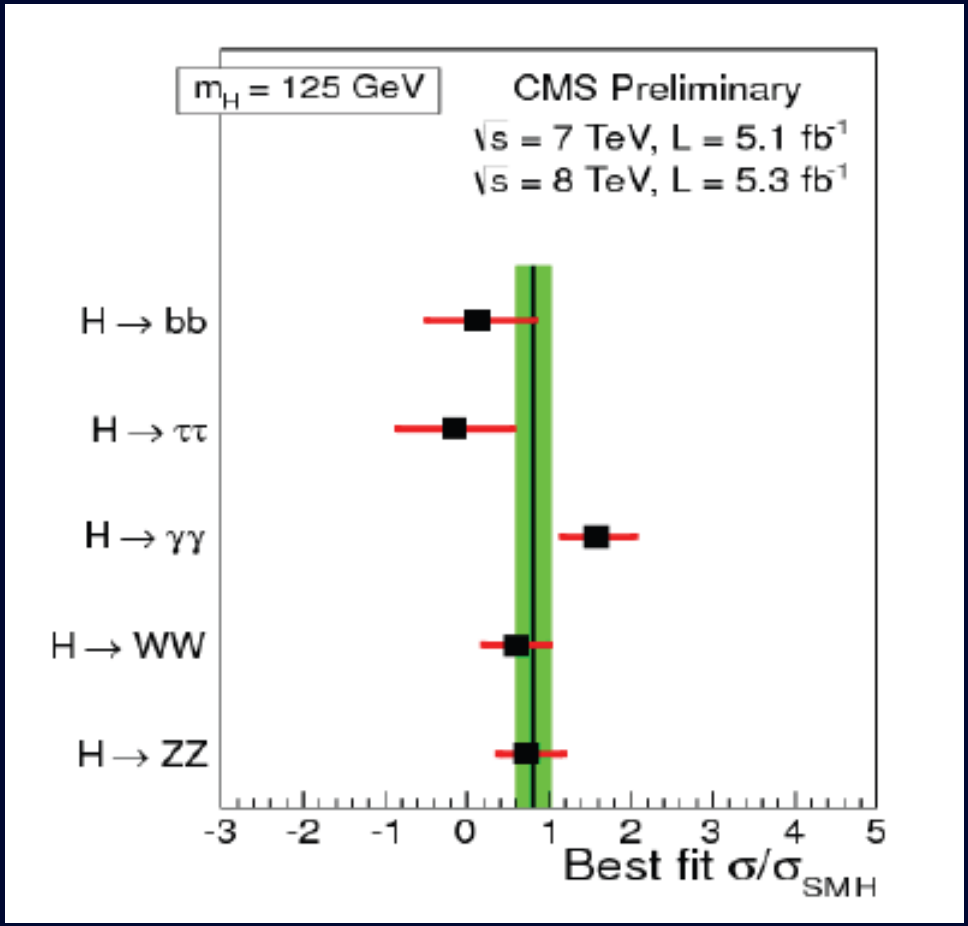
- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval



Evolution of the excess with time



… but that's only the beginning !
What's next ?

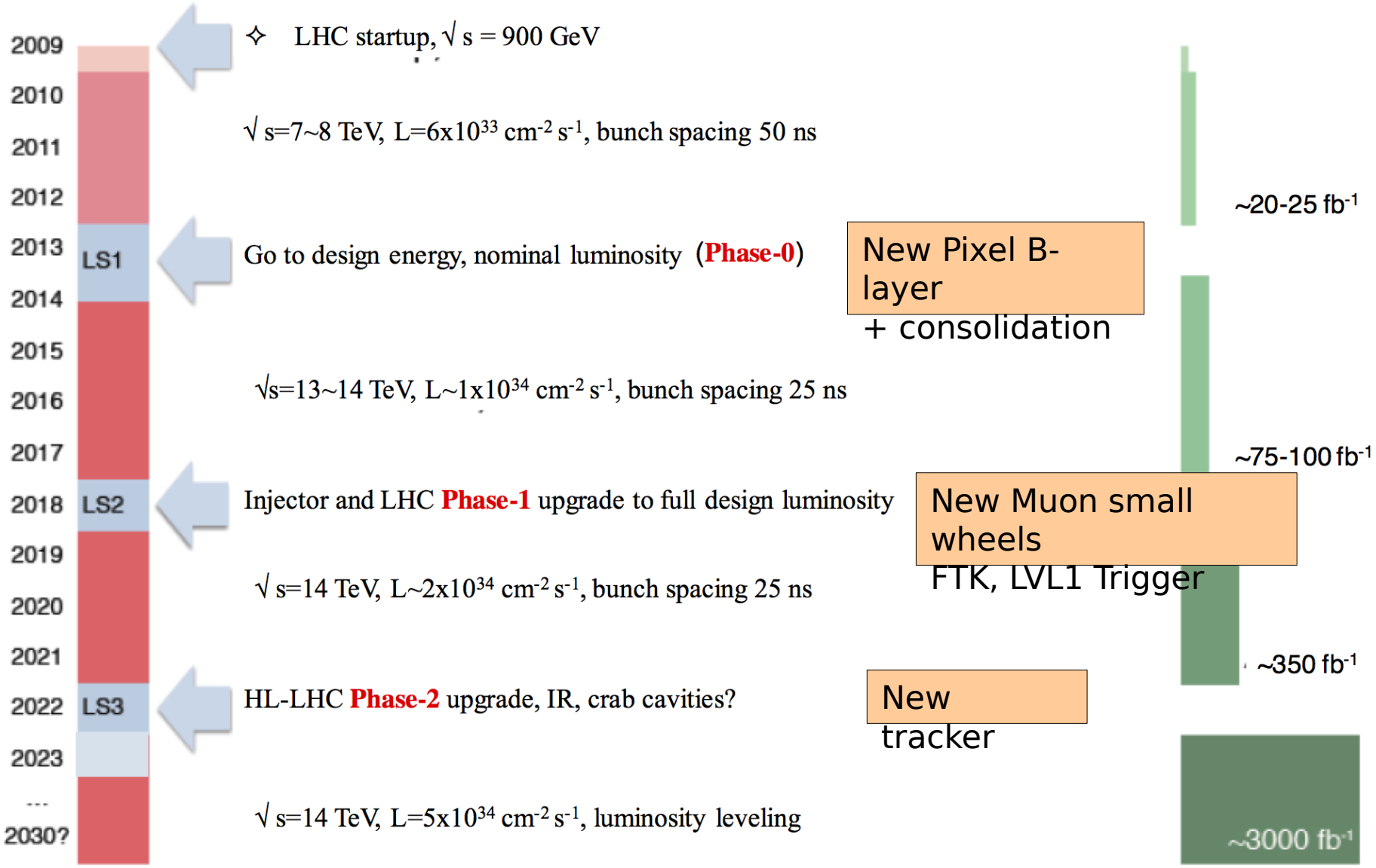


Measure the properties of the new particle with high precision!

….and keep looking for new phenomena!

Further ahead: present LHC upgrade plans

ATLAS



Is this new particle the Higgs boson ?

It looks like it, but it’s too early to tell … We will need to measure its properties in detail in the months to come.

Even if it is the Higgs boson, this is just the beginning, as this particle raises many other questions !

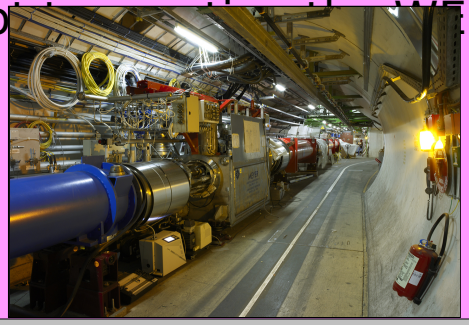
Will it change our day-by-day life ?

YES AND NO !

From fundamental science to everyone's life

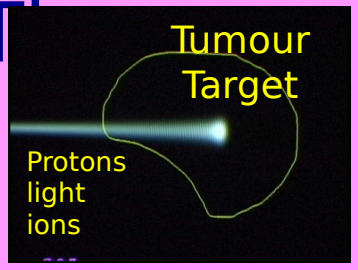
Extreme performance required in particle physics cutting-edge technologies

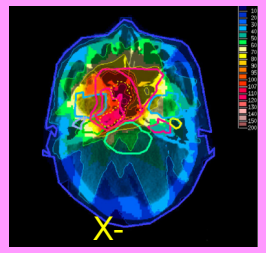
Applications: medical imaging (e.g. PET), cancer therapy, materials science, airport
scanners, cargo screening, food sterilization, nuclear waste transmutation, etc. ...
No[illegible] the WEB and the GRID ...

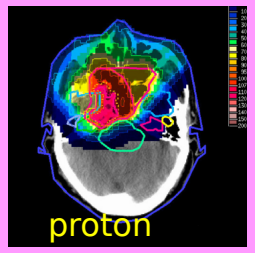


Accelerating particle beams
~30'000 accelerators worldwide
~17'000 used for medicine

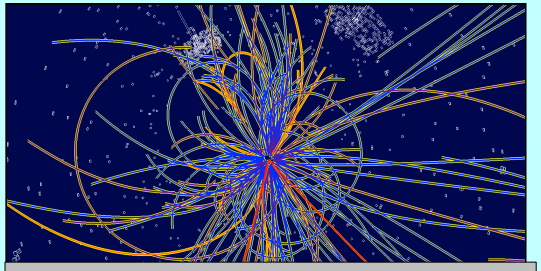
Hadron T[illegible]







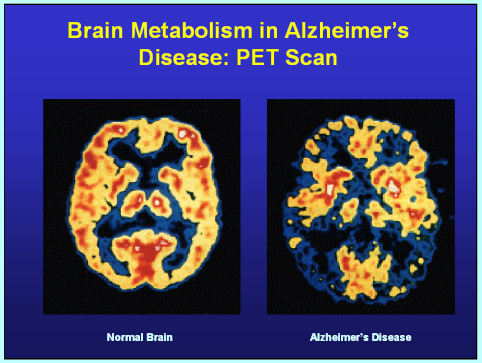
70000 patients treated worldwide (30 facilities)



Detecting particles

Imagin[illegible]

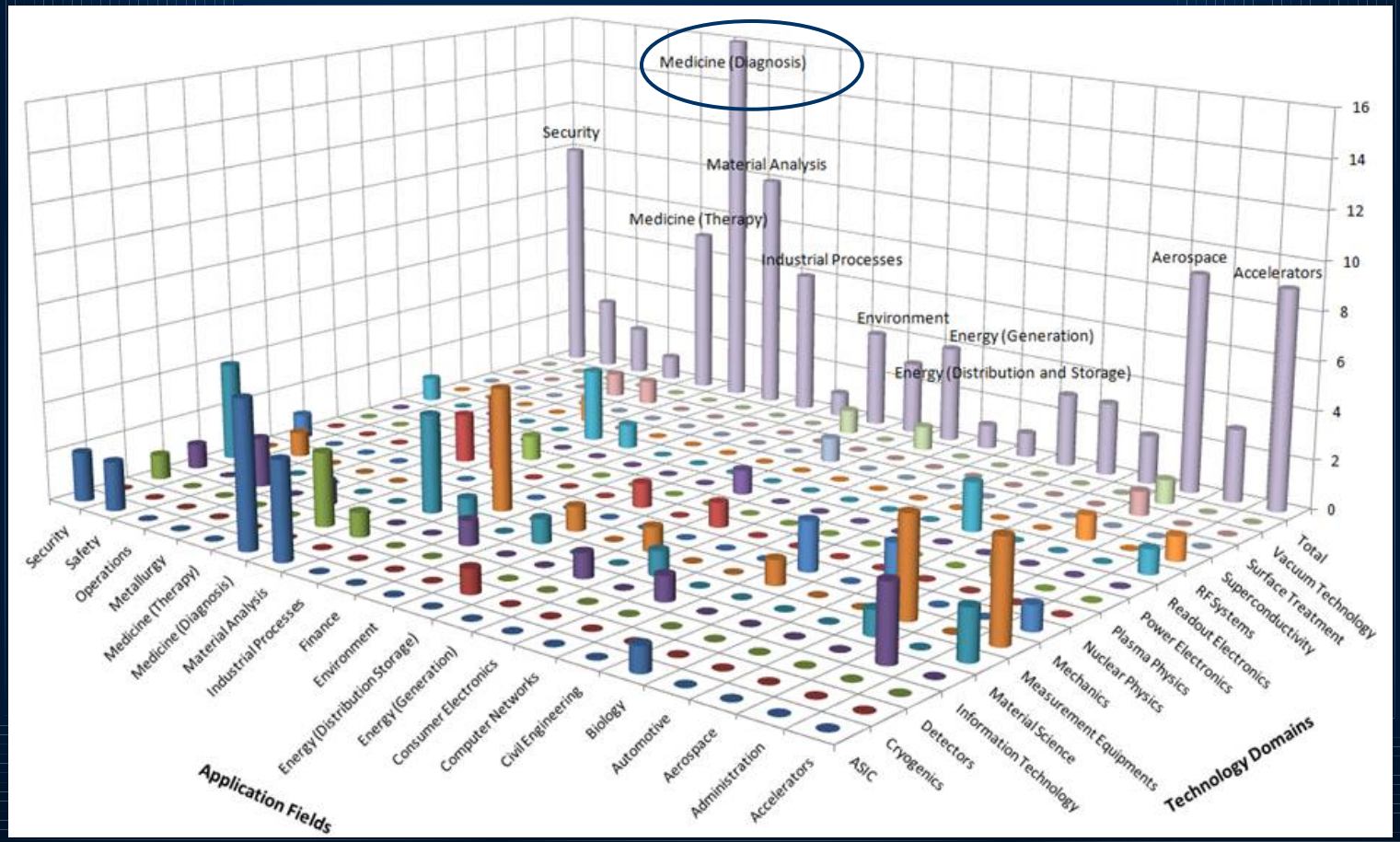
e.g. PET scanner



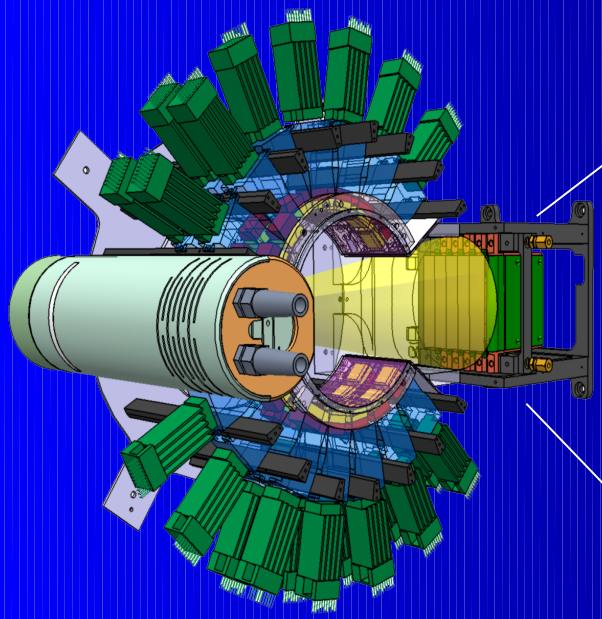
Innovation
Education
CERN
uniting people
Research

CERN Technologies and Innovation

Cutting edge Research Infrastructures play a key role in a knowledge driven society



ClearPET-XPAD



ClearPET/XPAD

- Simultaneous hybrid PET/CT imaging system

Courtesy of C. Morel CPPM/CERIMED

- RTW X-ray tube
  - Mo target, 50 µm spot size, 50 W
  - Nb/Mo additional filter
  - Threshold 3-35 keV

XPAD3/Si Hybrid pixel camera

- X-ray photon counting mode
- 500 µm silicon sensor thickness
- 78 x 75 mm² detector
- 130 x 130 µm² pixel size

PET FOV

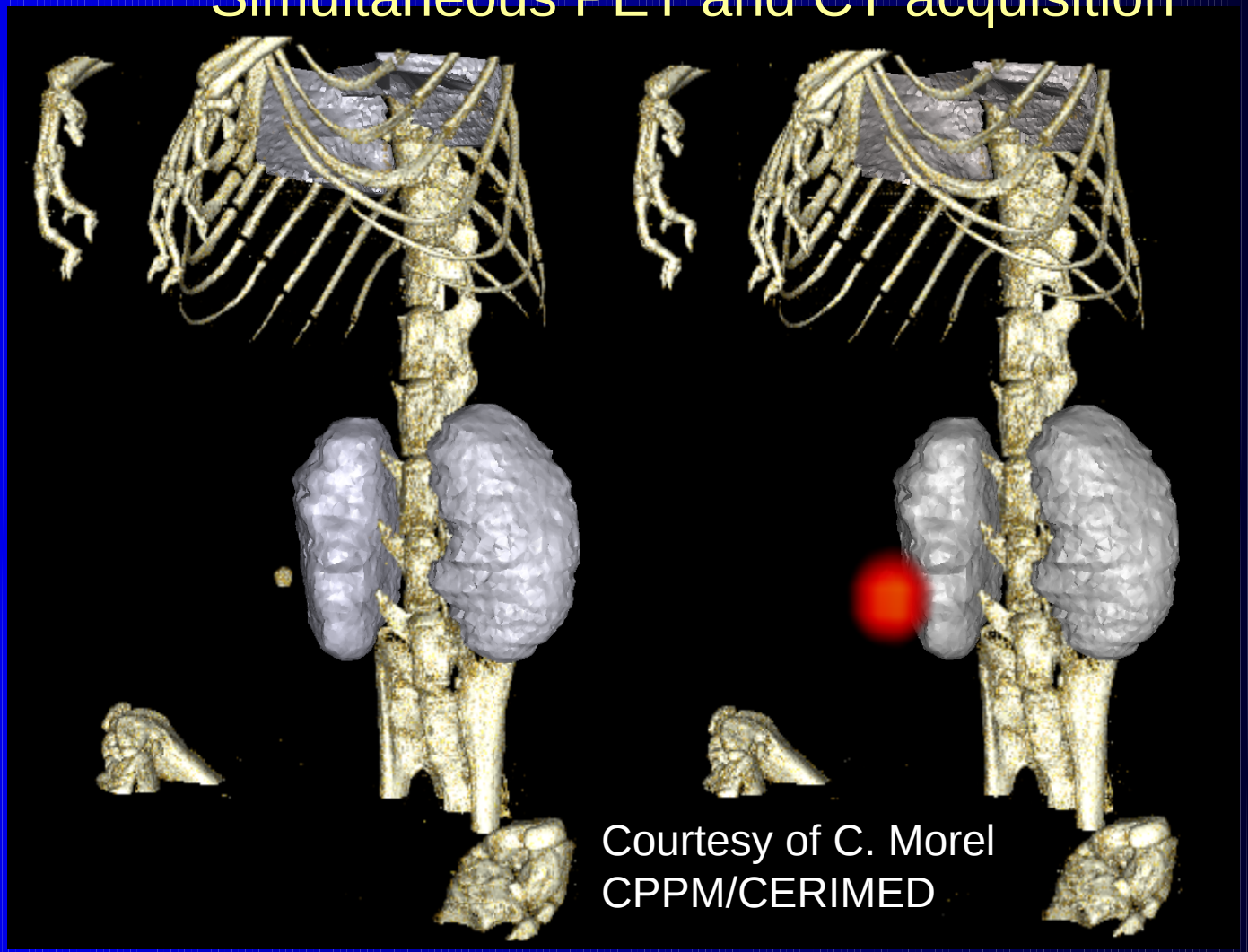
- 55mm axial
- 111mm transverse

35 mm transverse FOV

- 59mm axial
- 38mm transverse

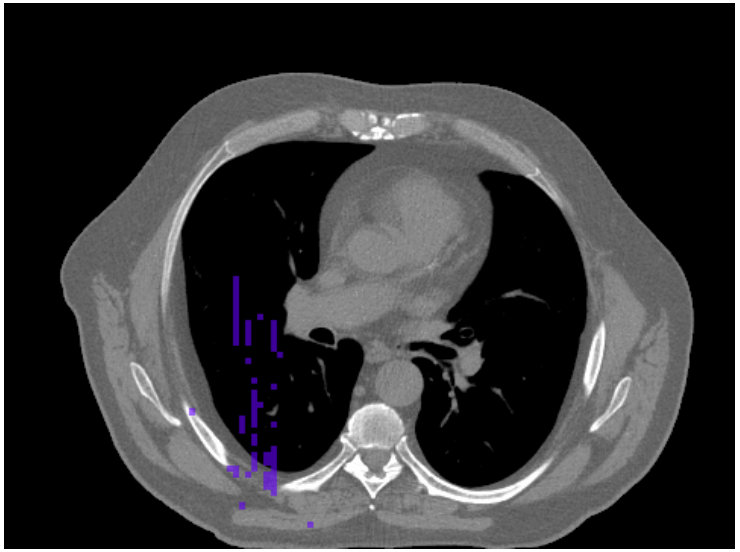
ClearPET-XPAD

Simultaneous PET and CT acquisition



22Na source surgically inserted in the belly of a dead mouse

ThIS: Therapeutic Irradiation Simulator



- Cancer treatment by irradiation of patient with beams of photons, protons or carbons
- CT image (482x360x141)
- 3D dose distribution, 700h CPU

- Offer an open platform to researchers for Monte Carlo simulations optimisation
- Offer a fast and reliable simulation tool for researchers in medical physics and medical imaging for treatment control
- Produce a reference dataset for non-conventional therapies (hadrontherapy).

To conclude….

- The relationship between basic research and sustainable progress is fundamental (contrary to common belief, technology does not sustain itself on the long term)
- In a globalized world, **knowledge** is becoming the most important asset.
- Developed countries are about to make a major strategic error by cutting funding for fundamental research (whereas emerging countries are doing the opposite and catching up fast)

Trading Future against “futures” doesn’t seem the right way to go

THANK YOU!