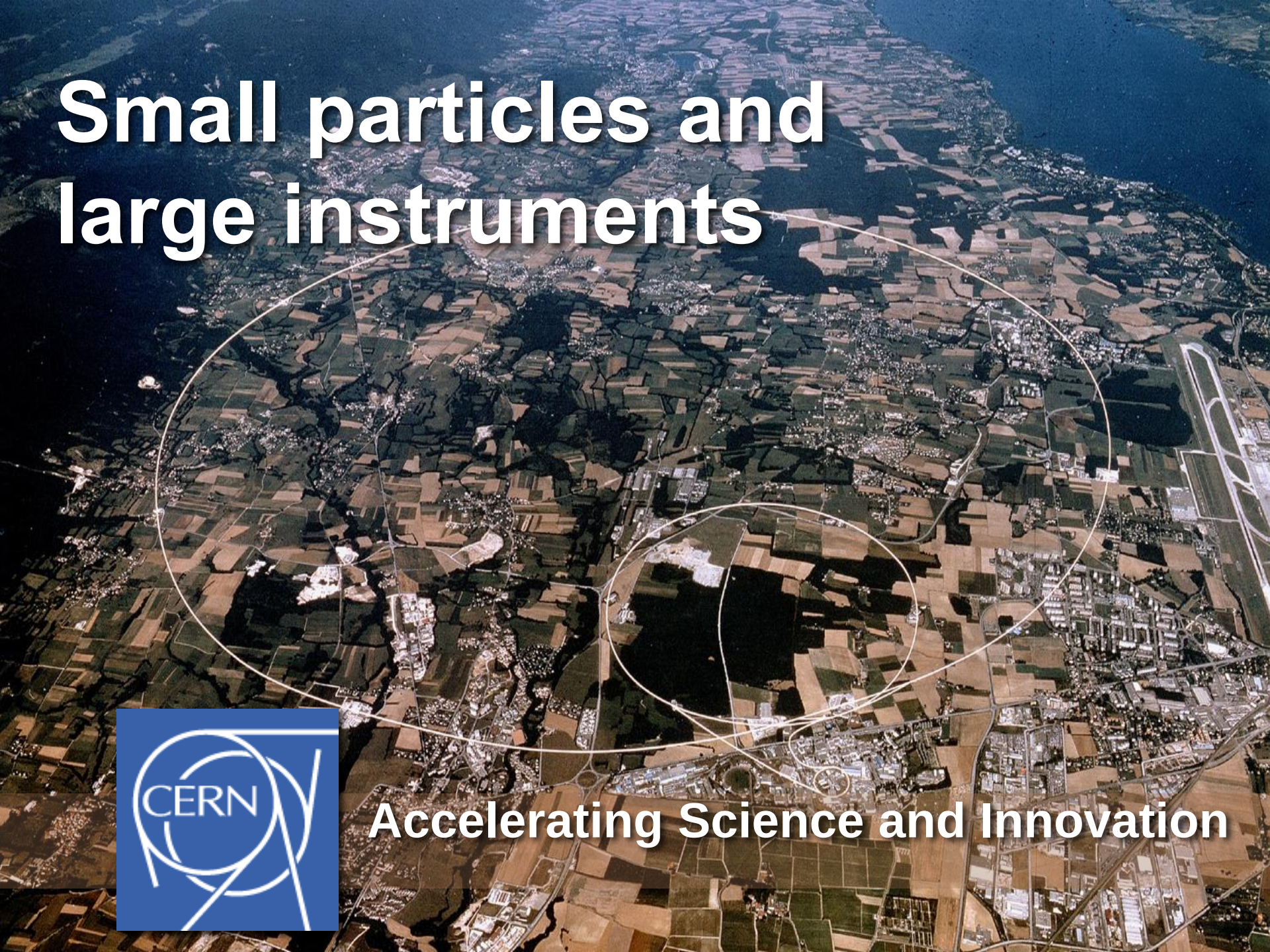
Small particles and large instruments



Accelerating Science and Innovation

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

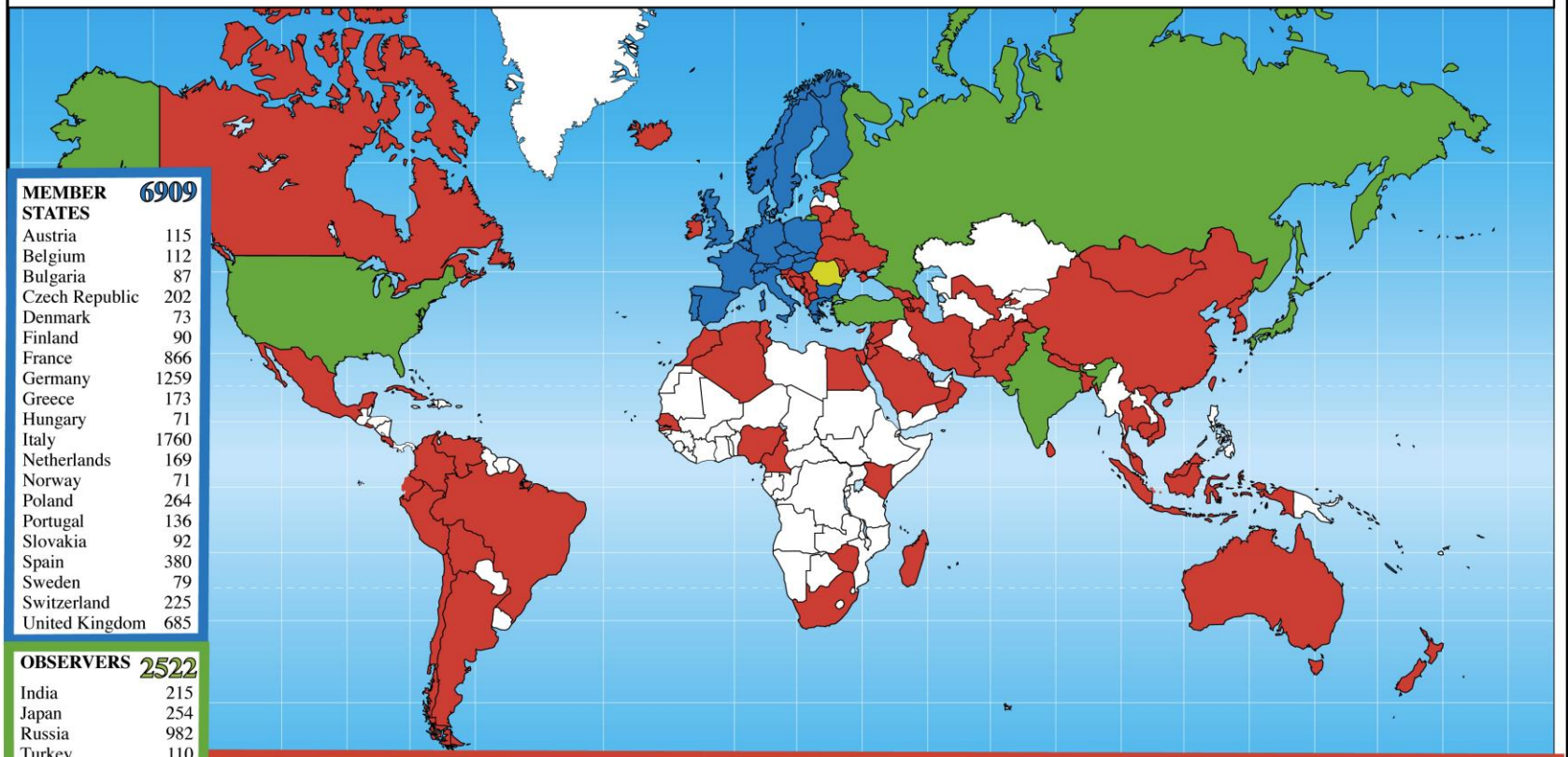
Associate Members in the Pre-Stage to Membership: Israel, Serbia

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

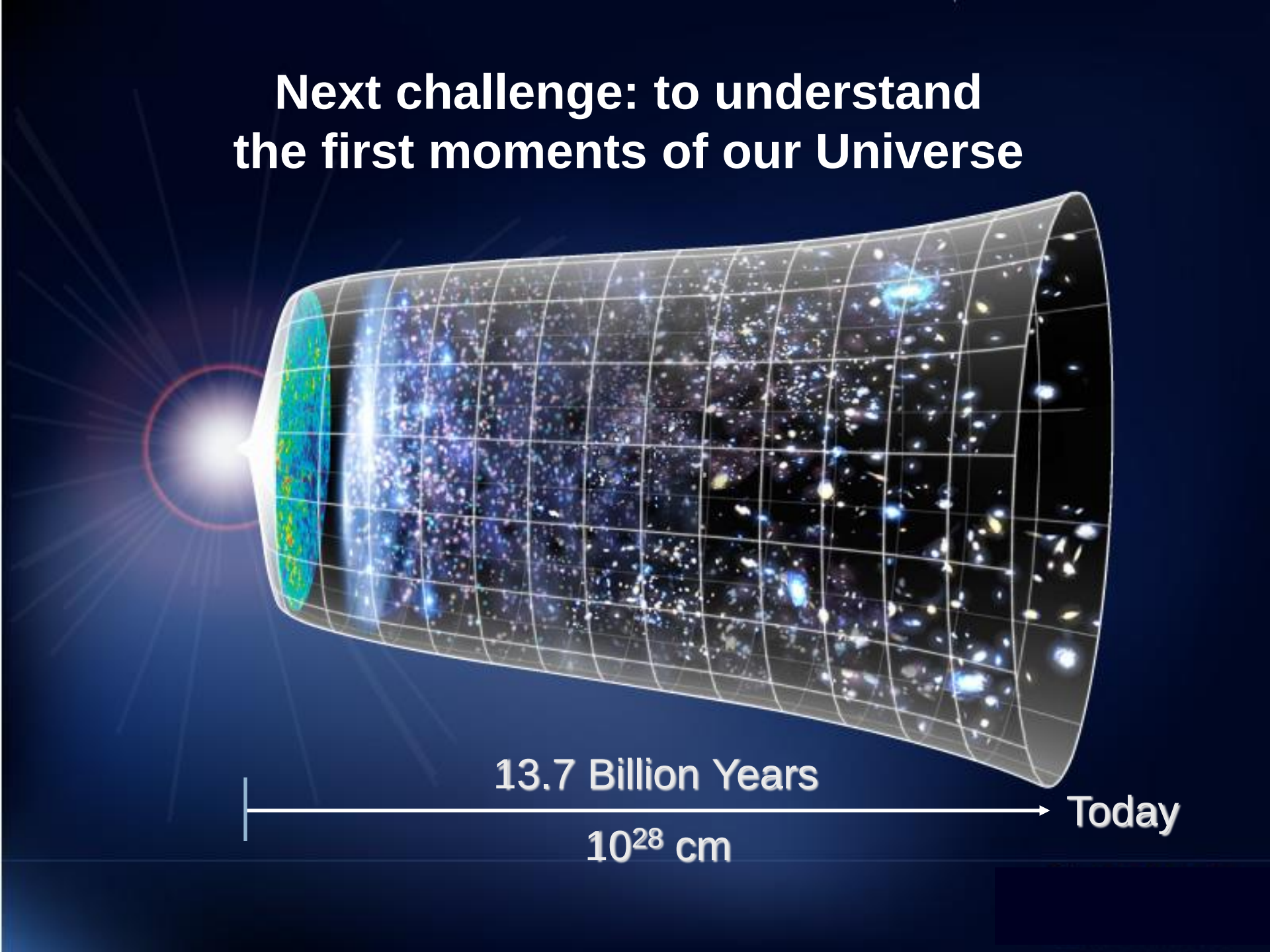
CANDIDATE FOR ACCESSION	
Romania	117

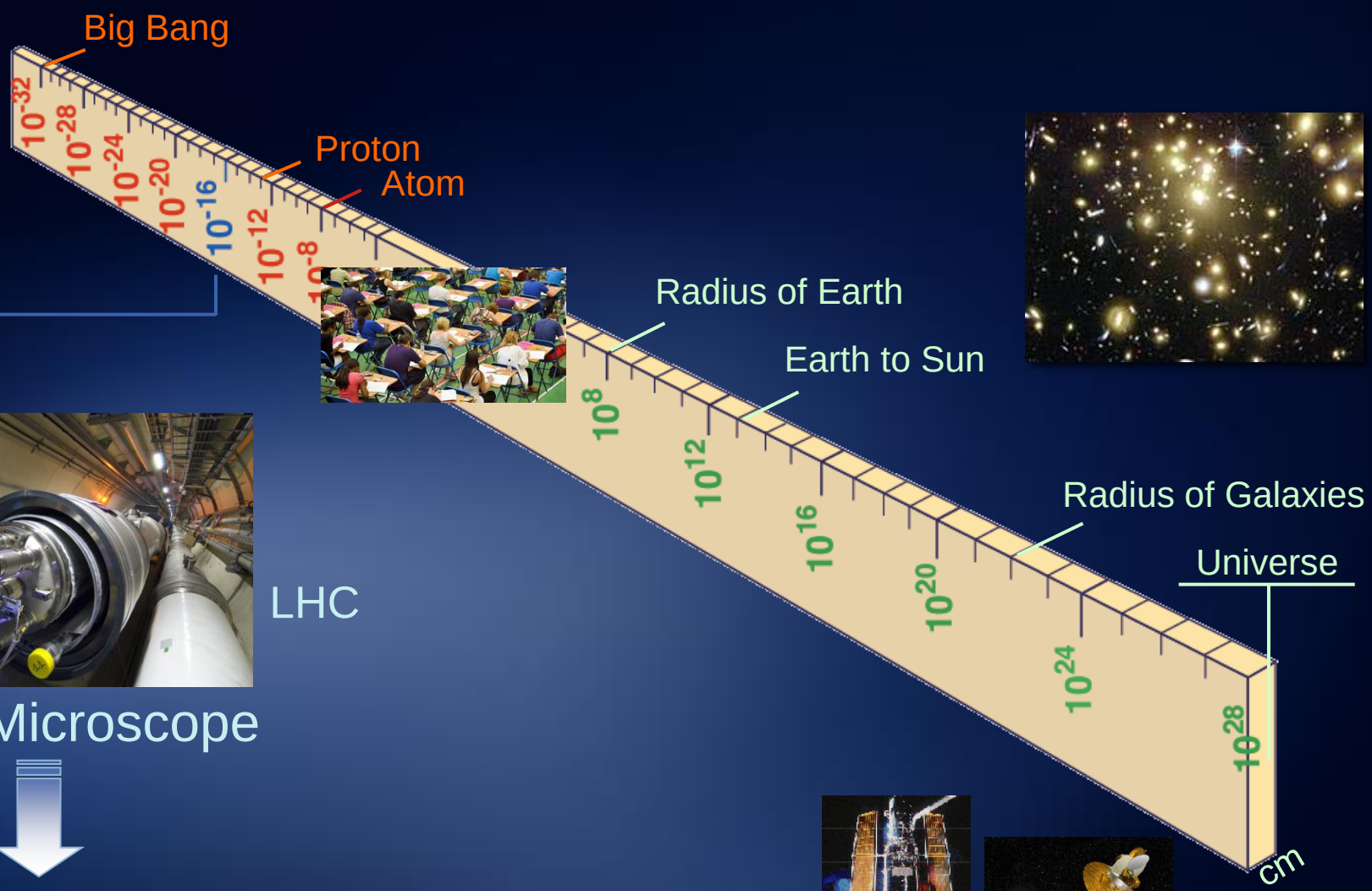
ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP	
Israel	67
Serbia	39

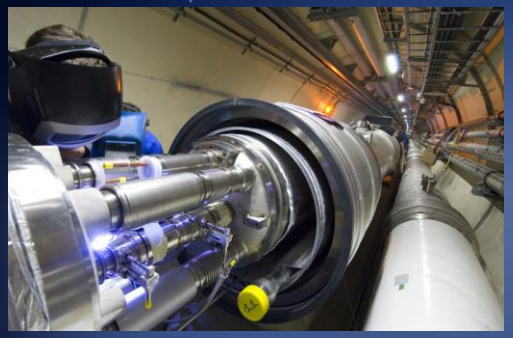
OTHERS													
Afghanistan	1	Bosnia & Herzegovina	2	Cuba	6	Ireland	23	Mexico	63	Peru	5	Tunisia	6
Albania	3	Brazil	98	Cyprus	14	Jordan	2	Moldova	1	Qatar	1	Ukraine	46
Algeria	11	Cambodia	1	Ecuador	2	Kenya	1	Mongolia	1	San Marino	1	Uzbekistan	2
Argentina	16	Cameroon	2	Egypt	9	Korea, D.P.R.	1	Montenegro	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		
		Croatia	30	Iran	21	Malta	2	Palestine (O.T.).	3	T.F.Y.R.O.M.	3		

1353

Next challenge: to understand the first moments of our Universe



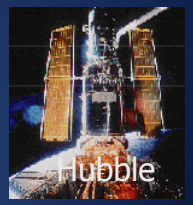




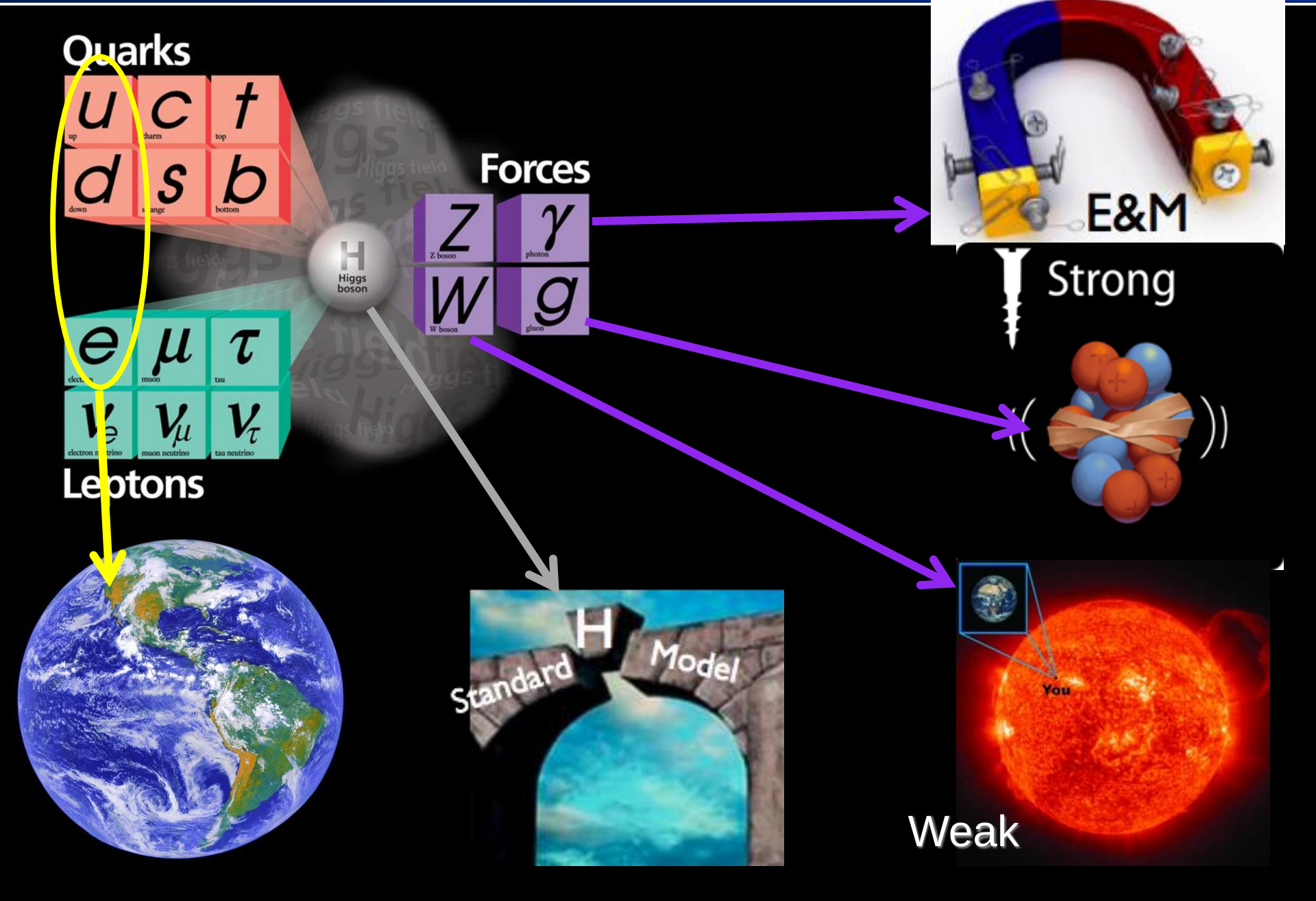
LHC

Super-Microscope

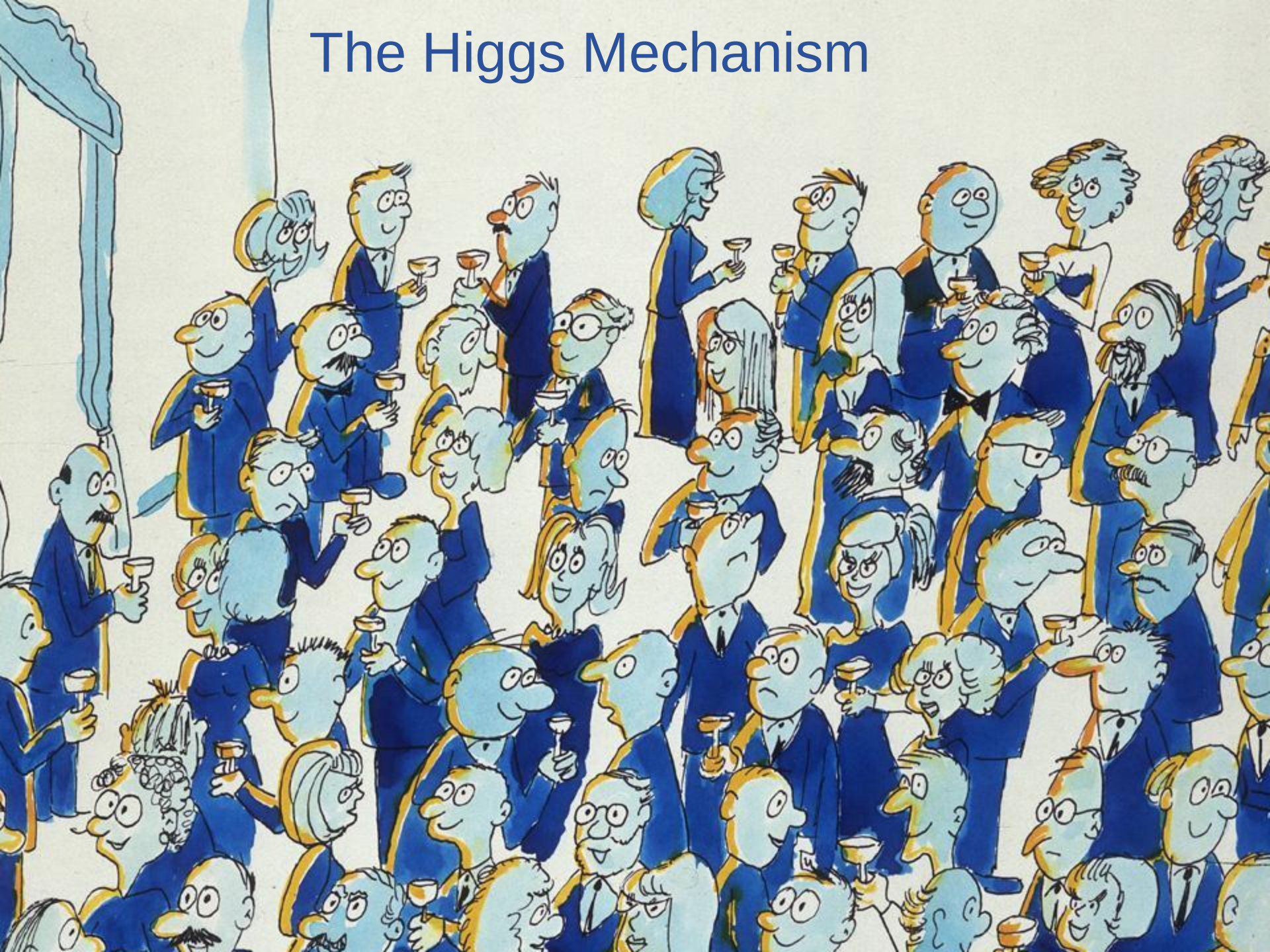
Study physics laws of first moments after Big Bang increasing Symbiosis between Particle Physics, Astrophysics and Cosmology



The Standard Model

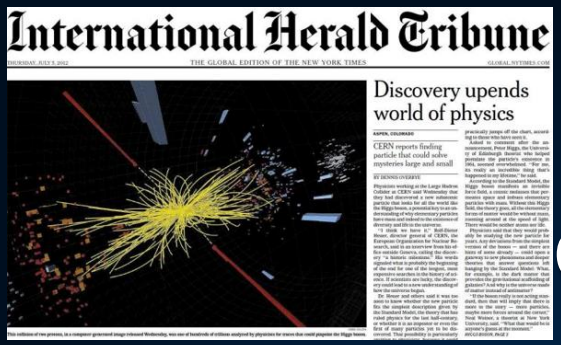


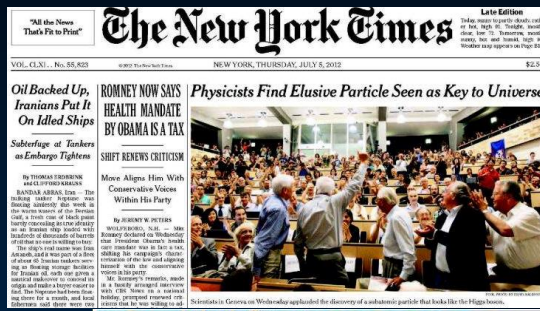
The Higgs Mechanism

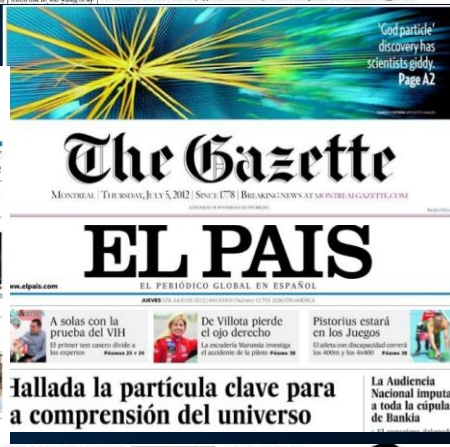


4 JULY 2012

CERN Press conference

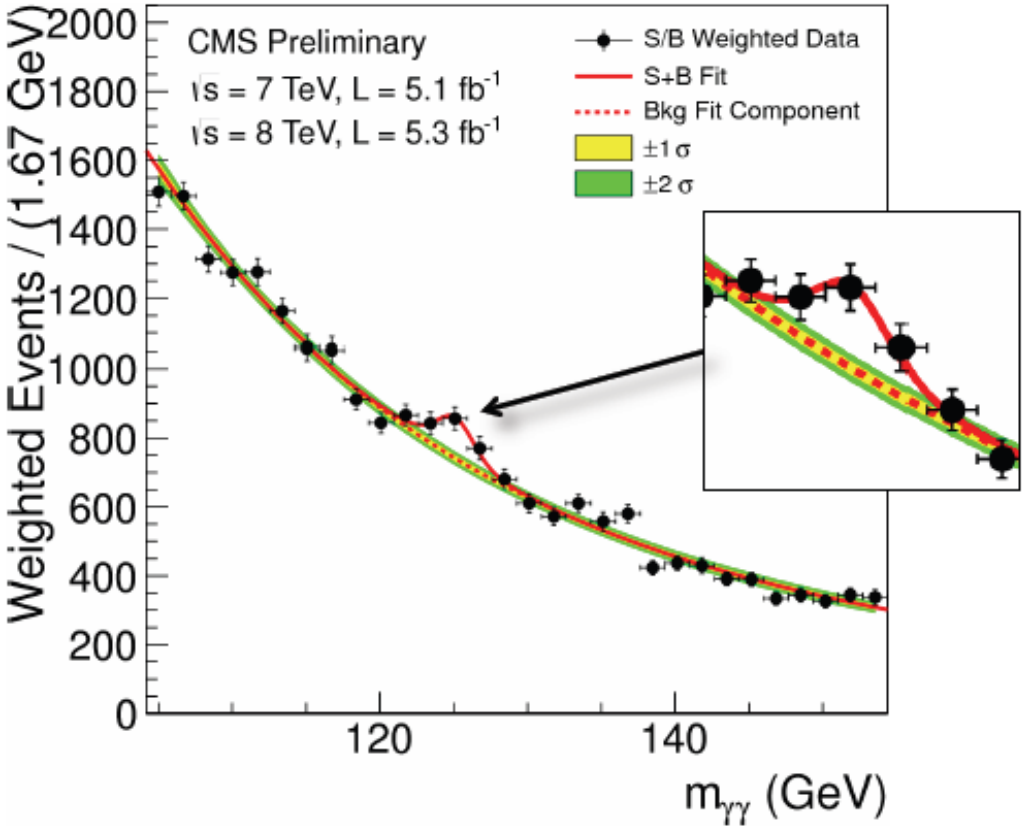




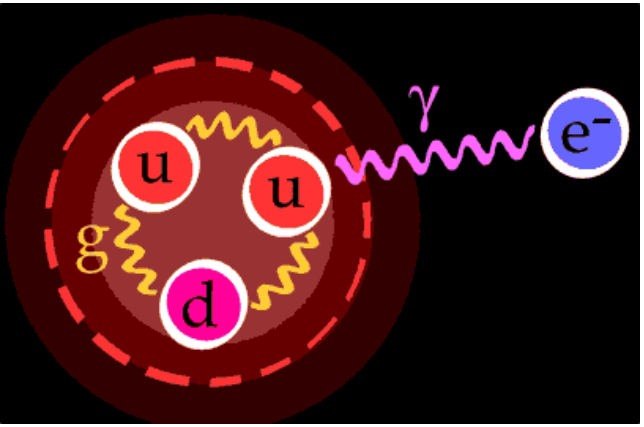


S/B Weighted Mass Distribution

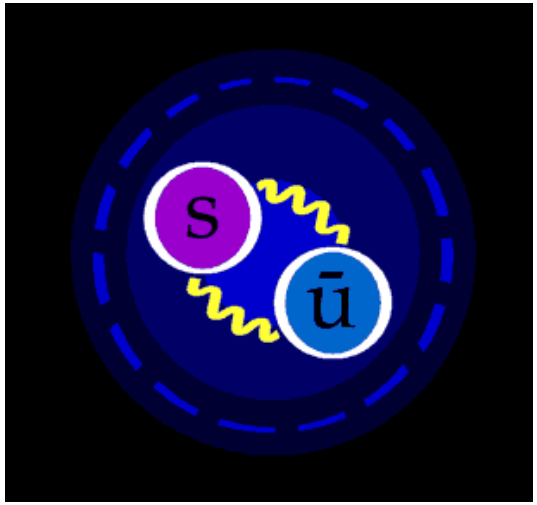
- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval



Some particles and processes

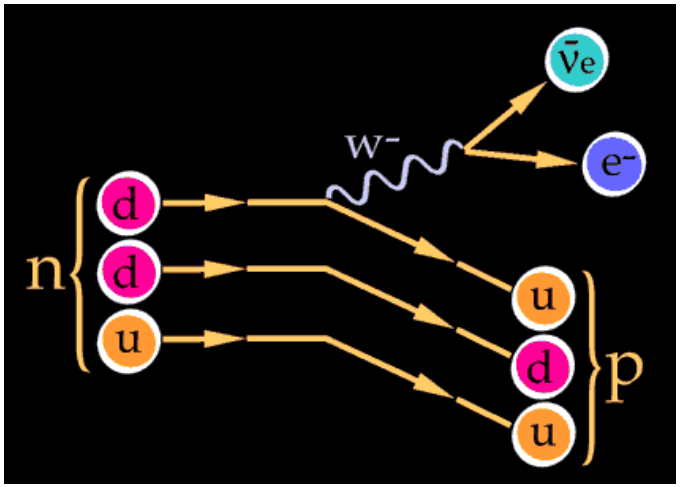


Hydrogen Atom



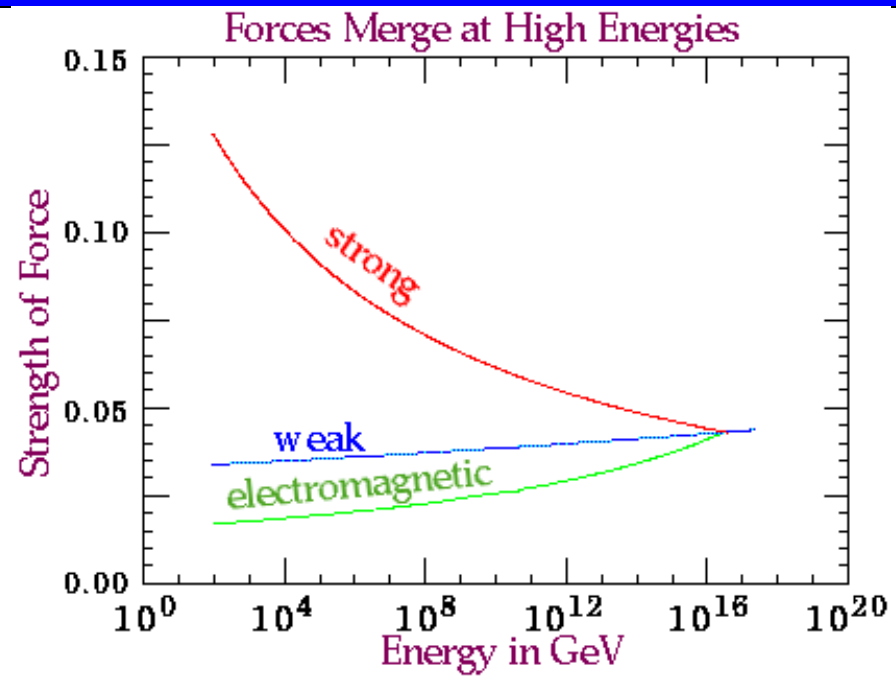
More exotic particle observes in accelerators

K- (kaon)

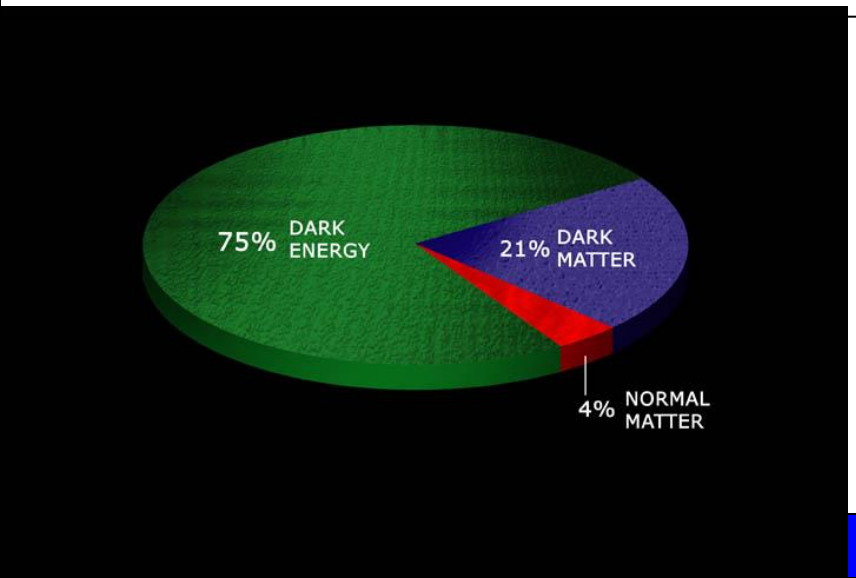


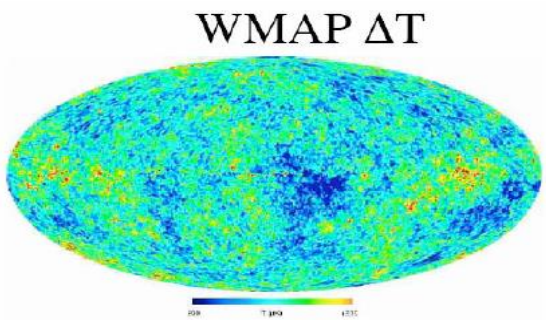
Beta decay

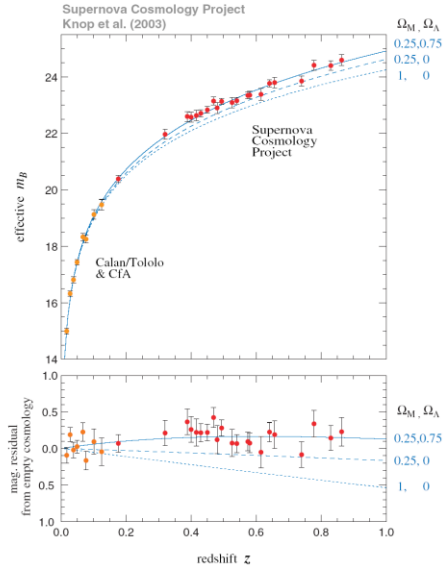
Unification of forces, dark matter



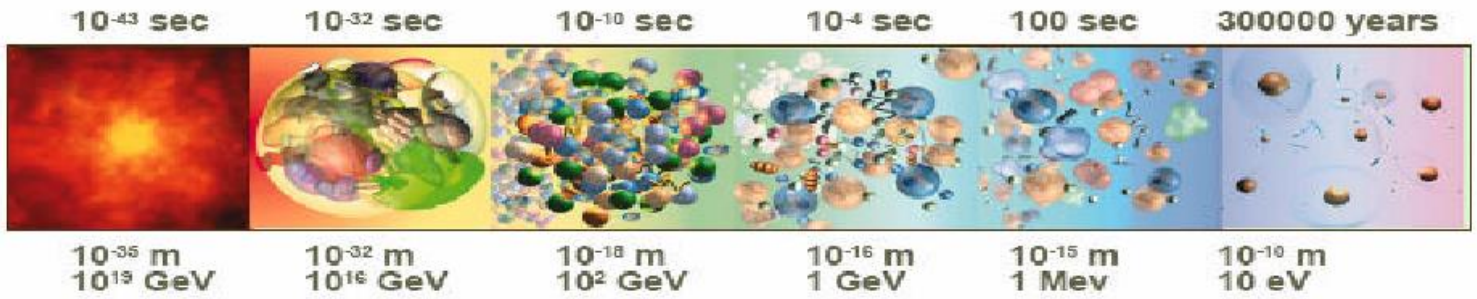
Supersymmetric particles = dark matter ?

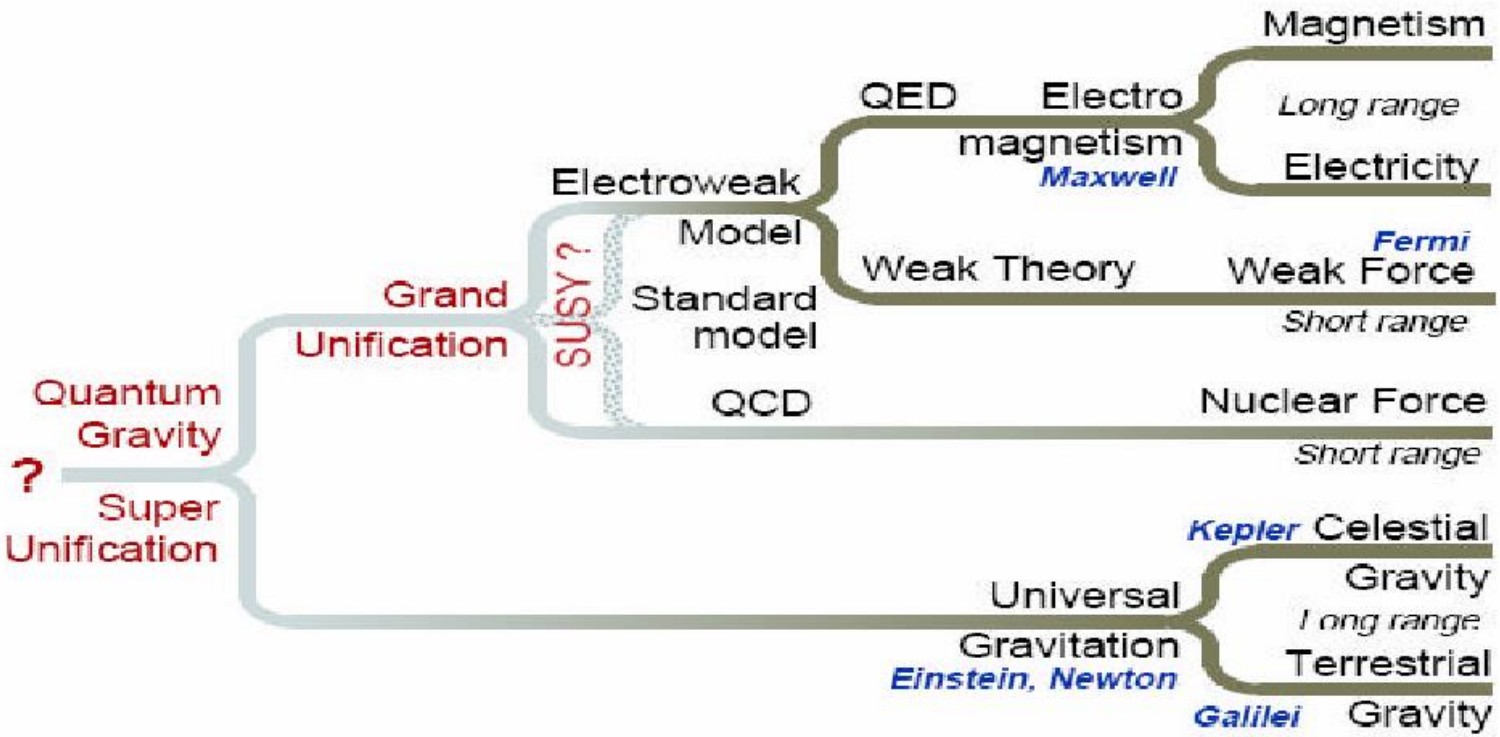




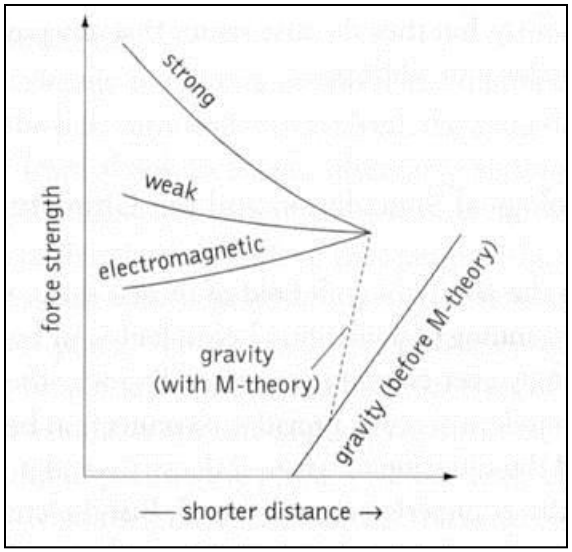


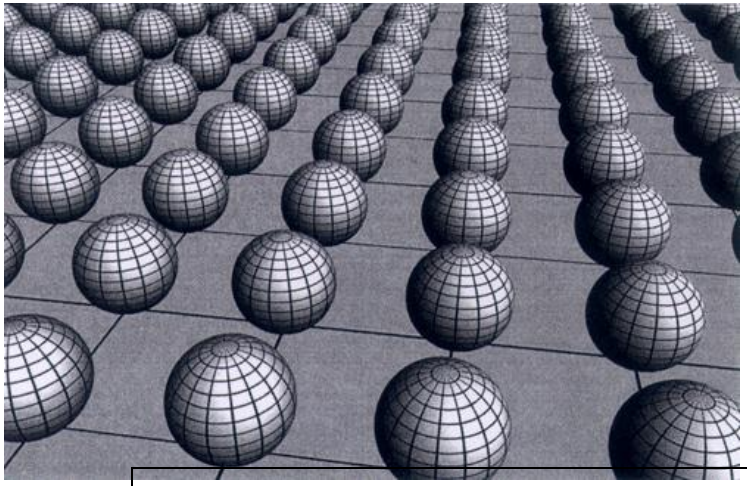
Unification of forces



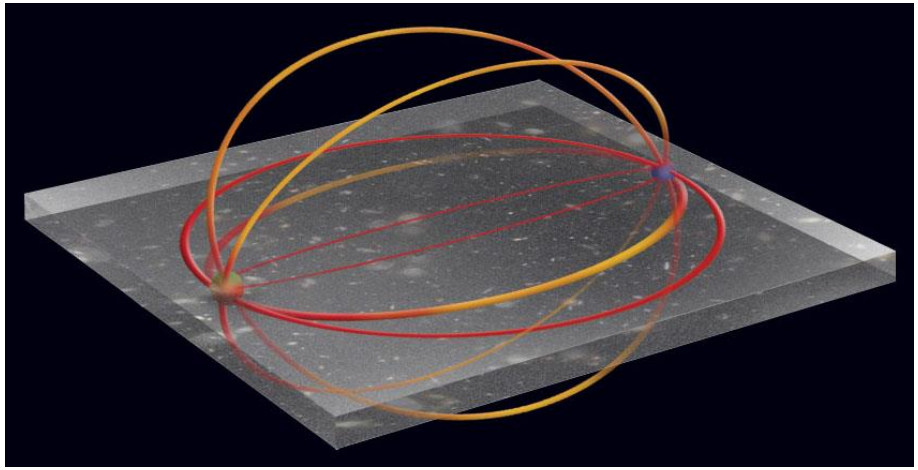


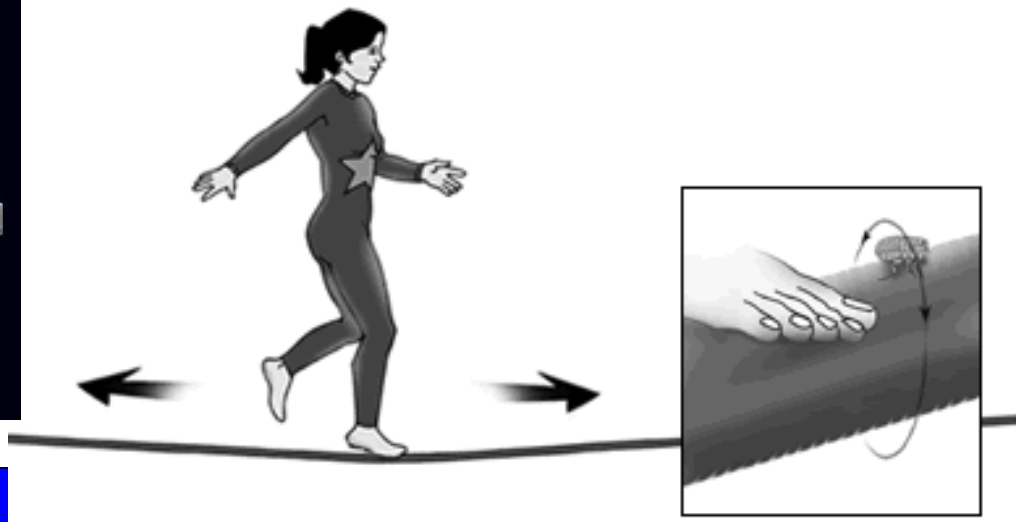
Extra dimensions



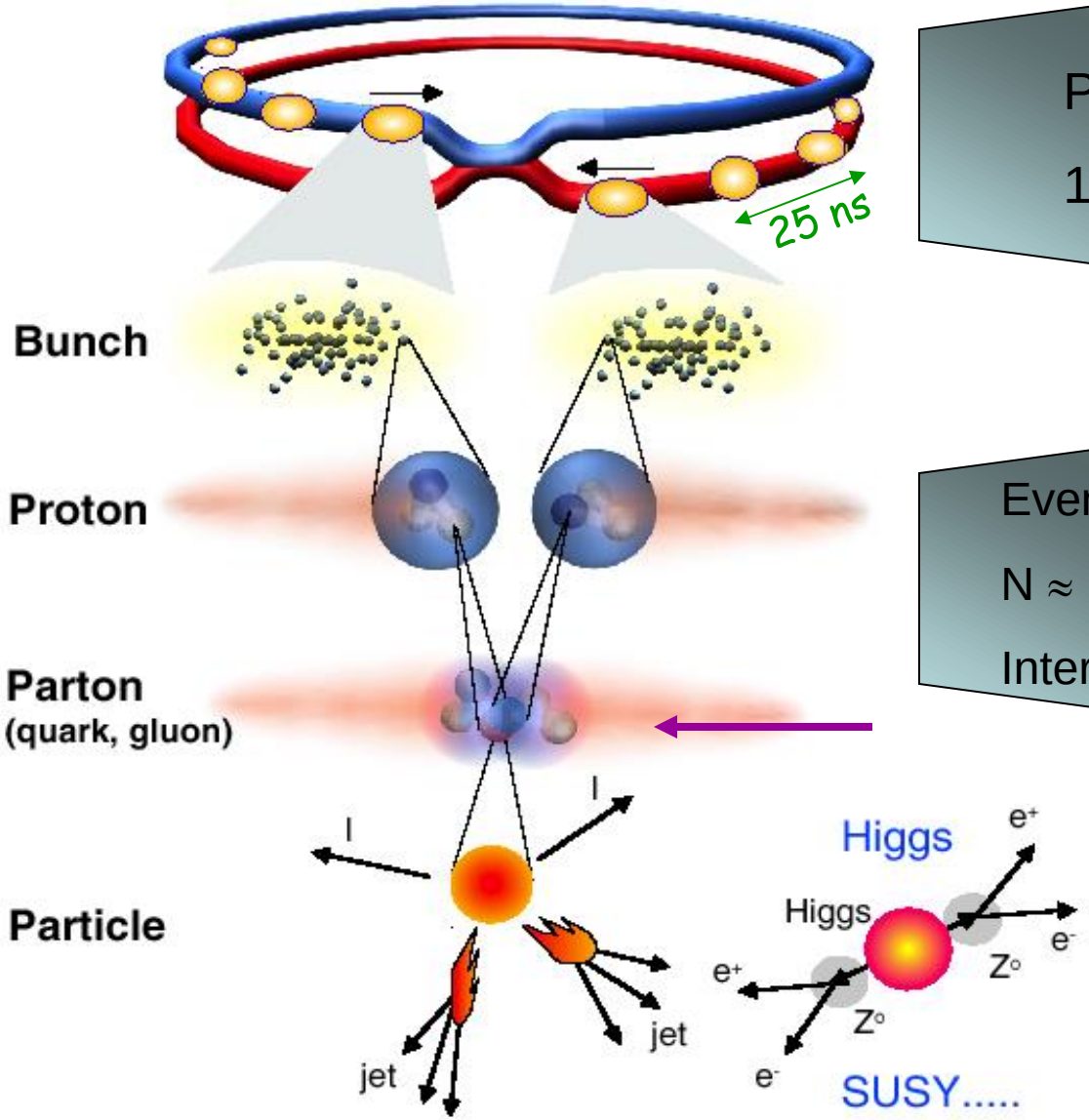


Gravitation and Quantum Mechanics





Collisions at LHC



Proton/Proton collisions

10^{11} protons per bunch

Event rate in detectors :

N ≈ 1,000,000,000 interactions/s

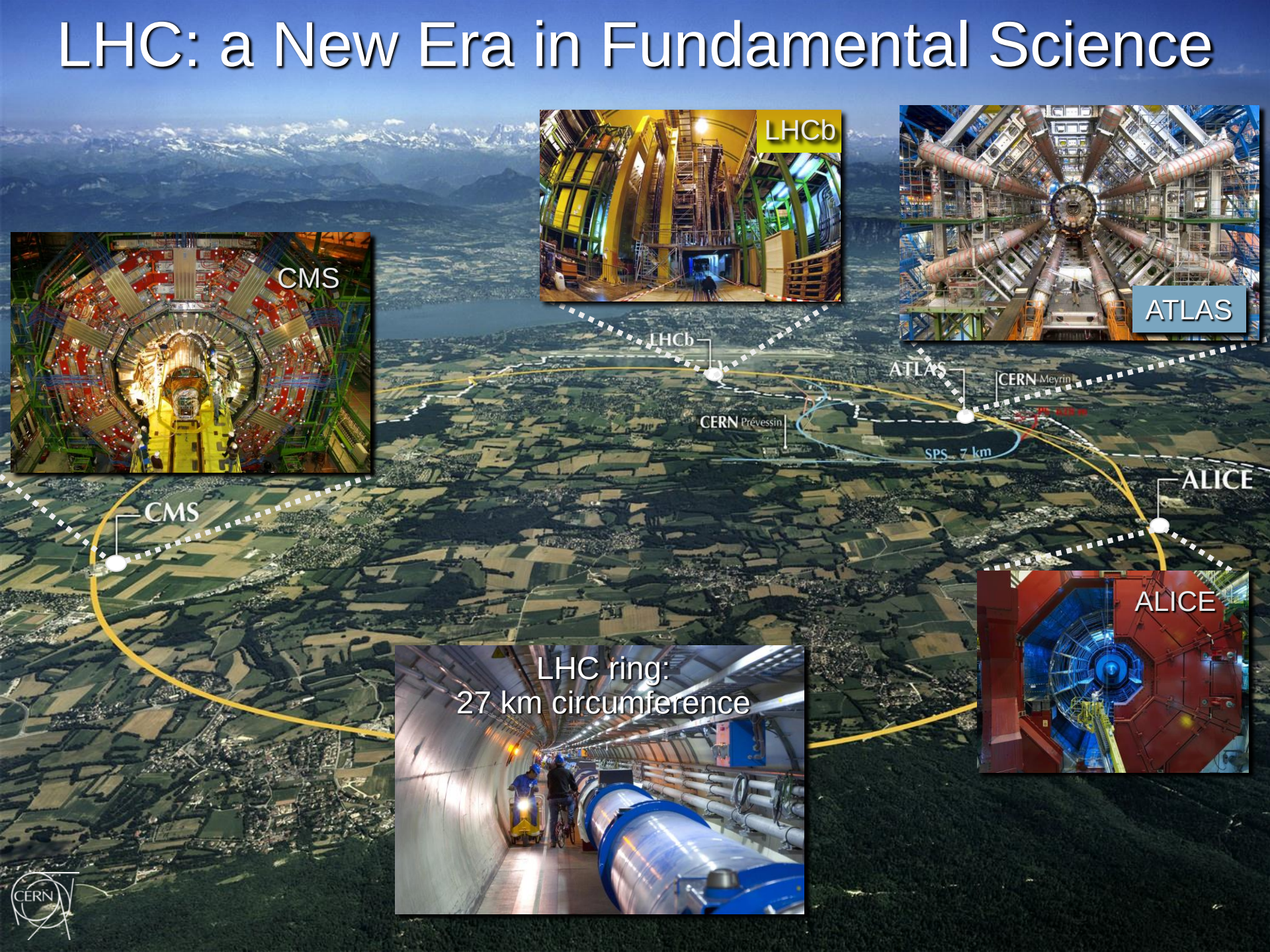
Interesting hard events are rare

Selection of 1 in

10,000,000,000,000

→ very powerful detectors needed → → → → →

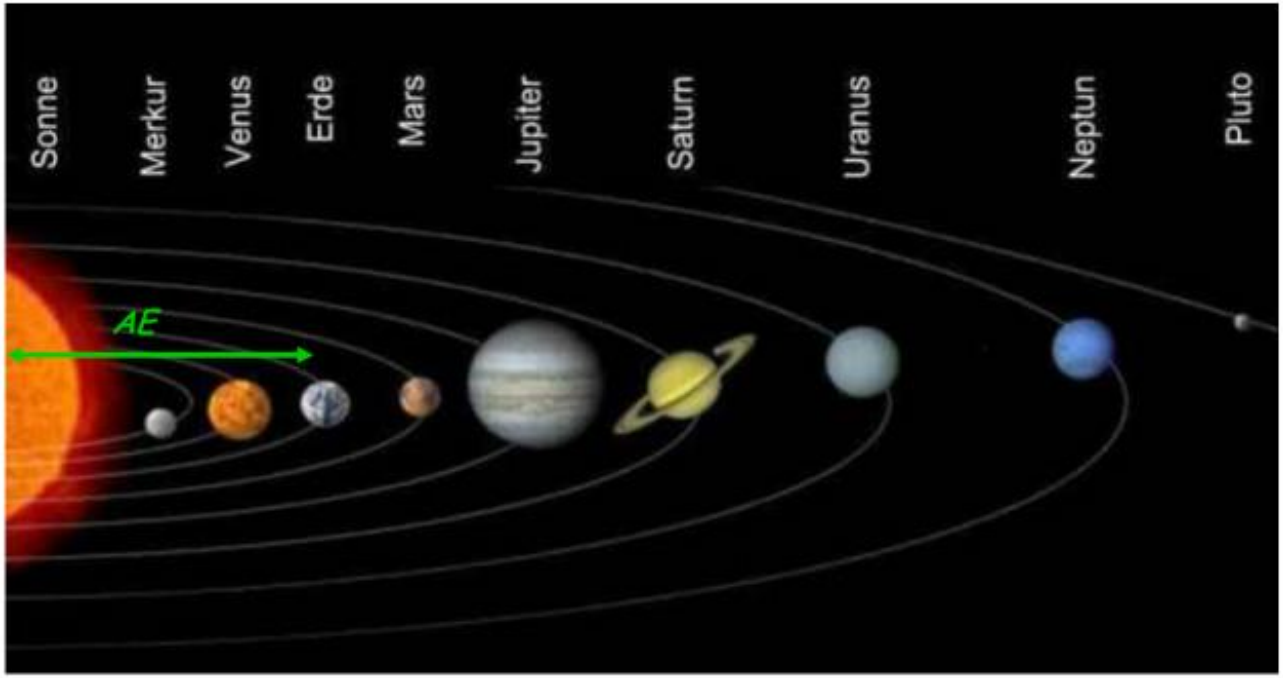
LHC: a New Era in Fundamental Science



The Large Hadron Collider (LHC) tunnel

Capabilities of particle accelerators

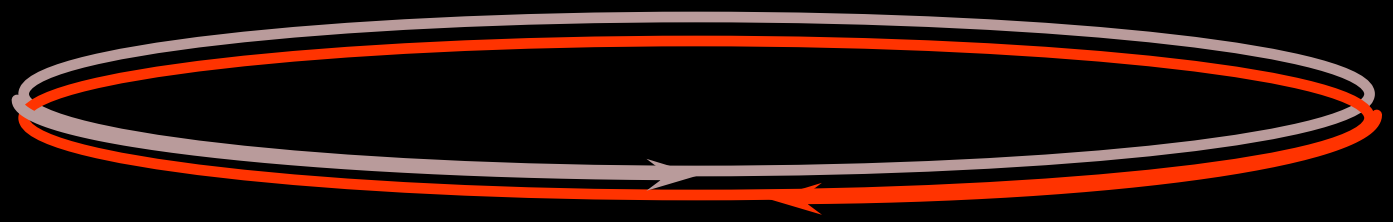
- A modern HEP particle accelerator can accelerate particles, keeping them within millimeters of a defined reference trajectory, and transport them over a distance of several times the size of the solar system



HOW ?

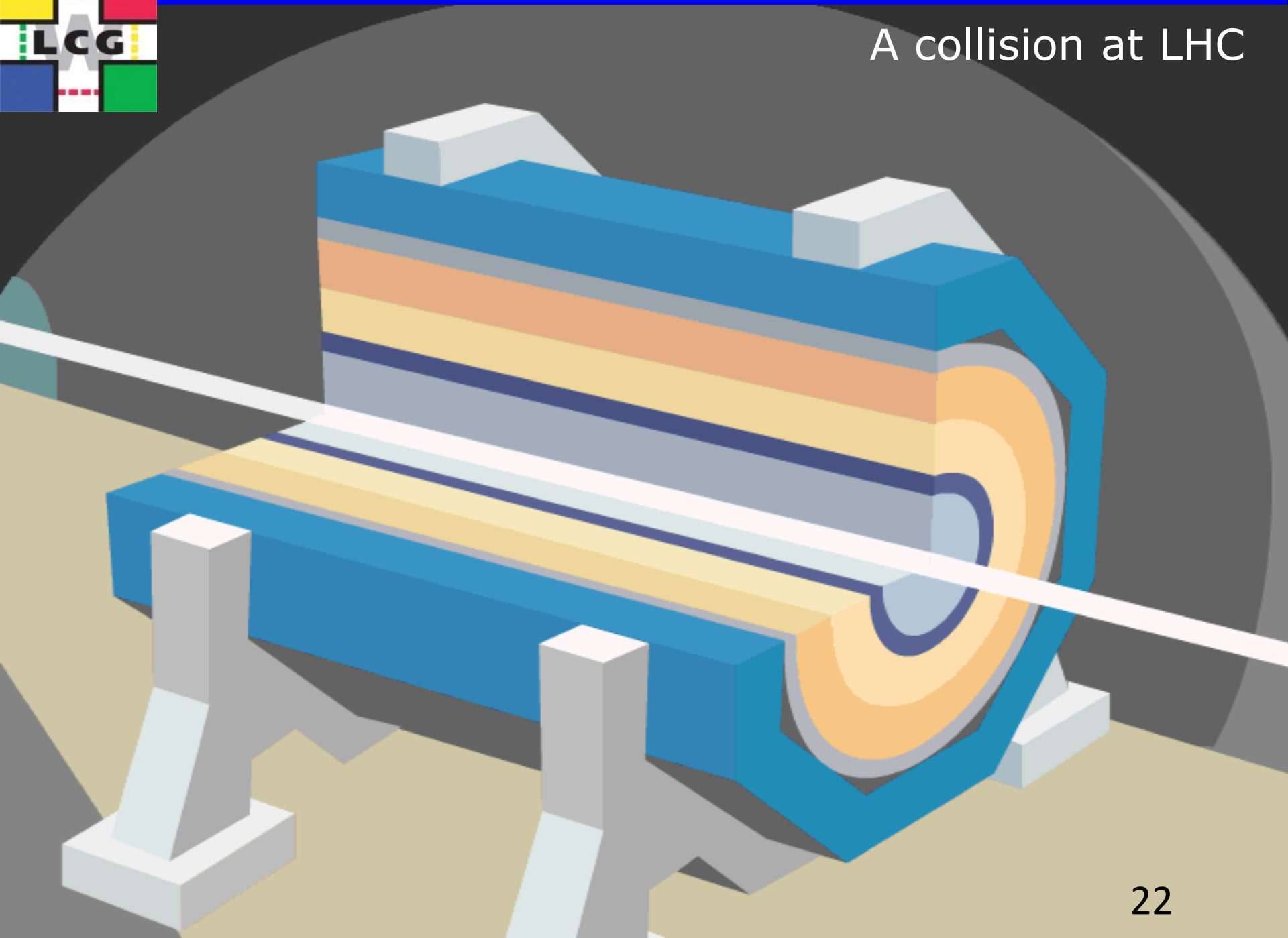
A proton-proton collider

- Electric fields accelerate while magnetic fields are used to focus and bend the particle trajectories

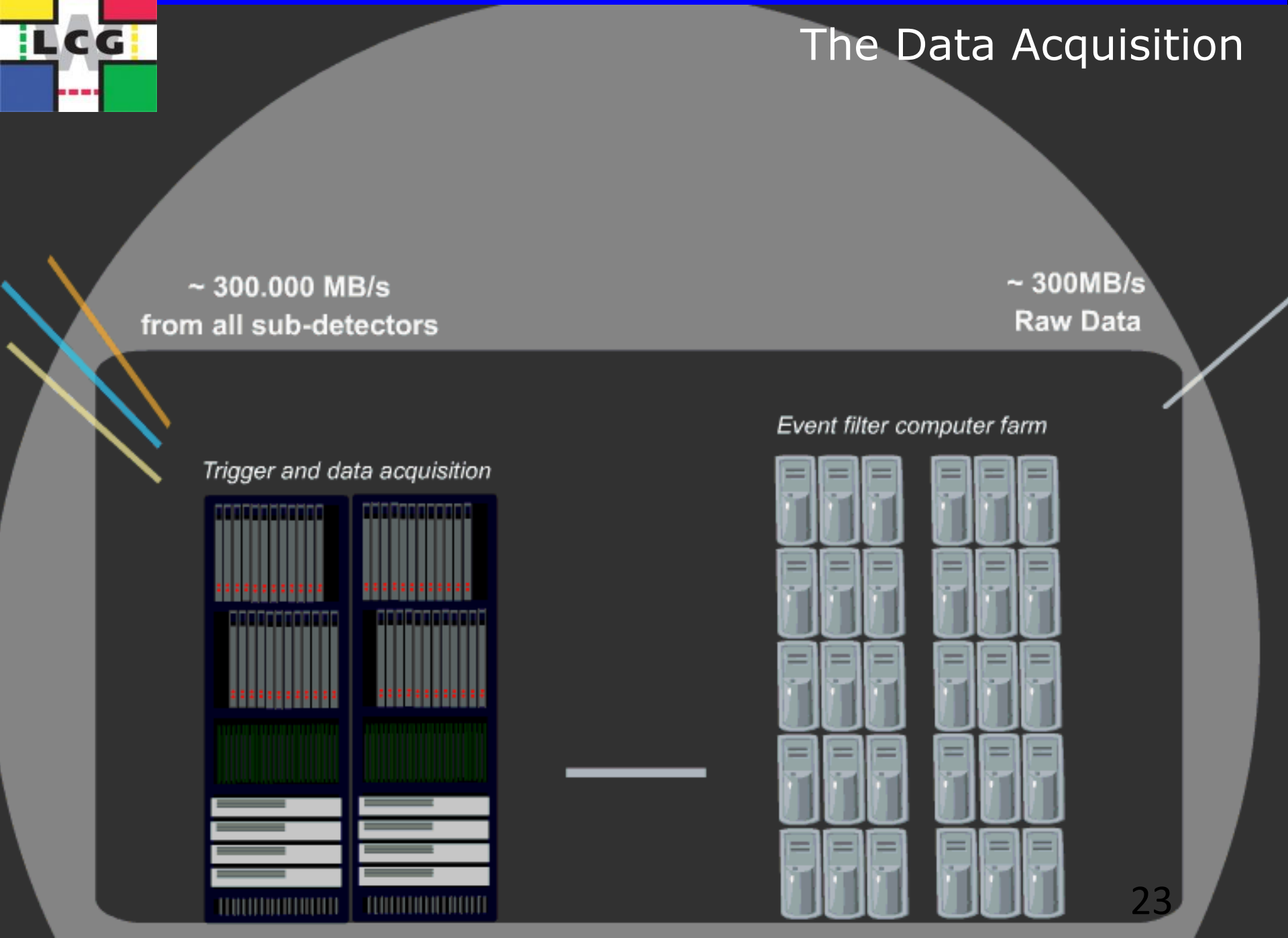


Energy is limited by magnet strength and ring size.
$\Rightarrow$We use really strong magnets and really big rings.

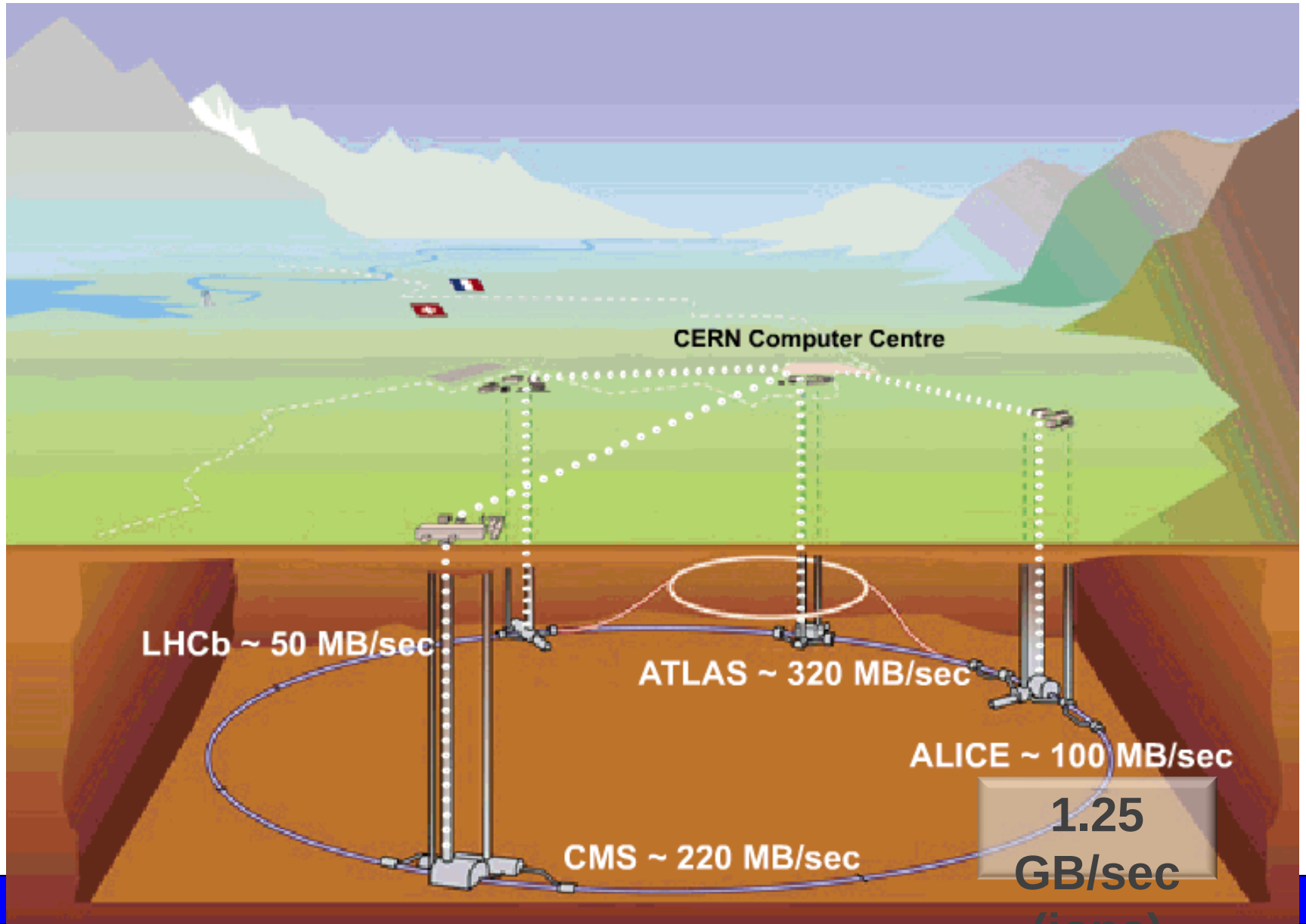
A collision at LHC



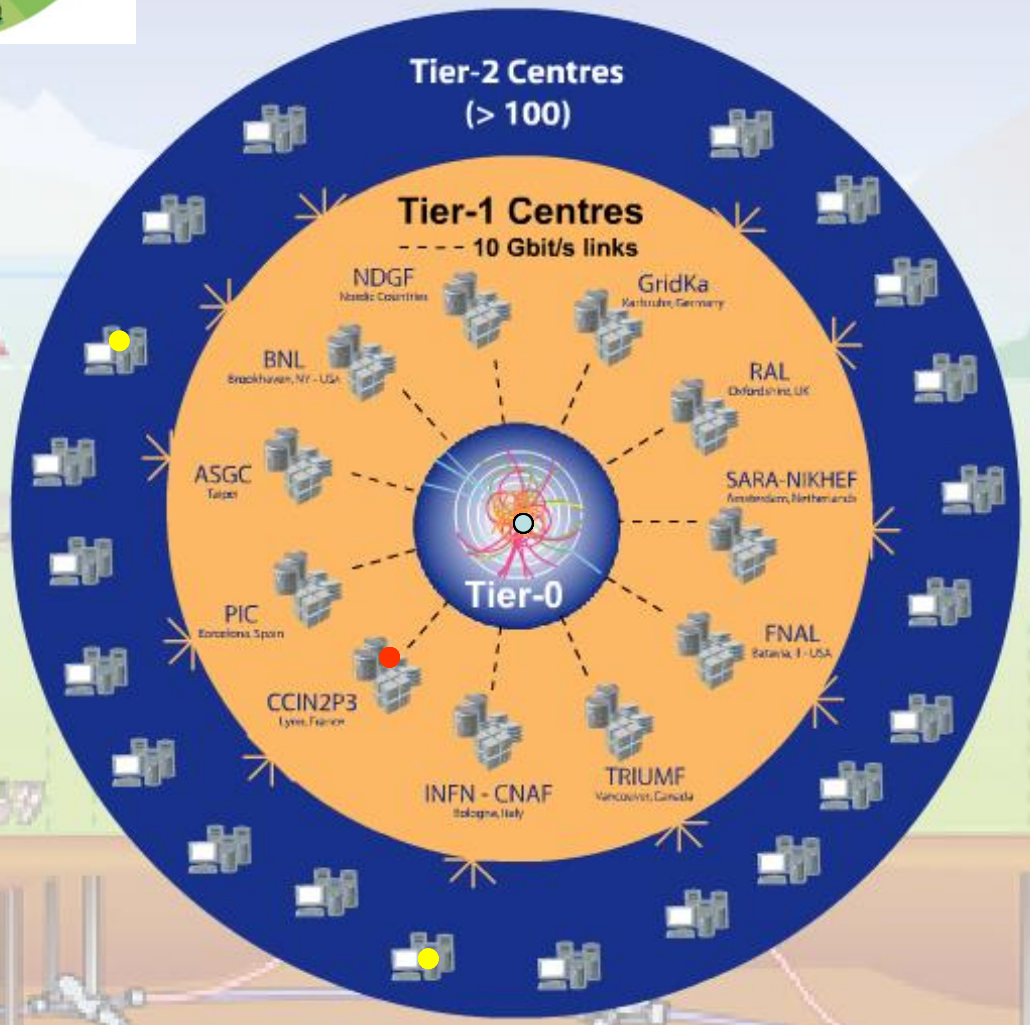
The Data Acquisition



Tier 0 at CERN: Acquisition, First pass processing Storage & Distribution



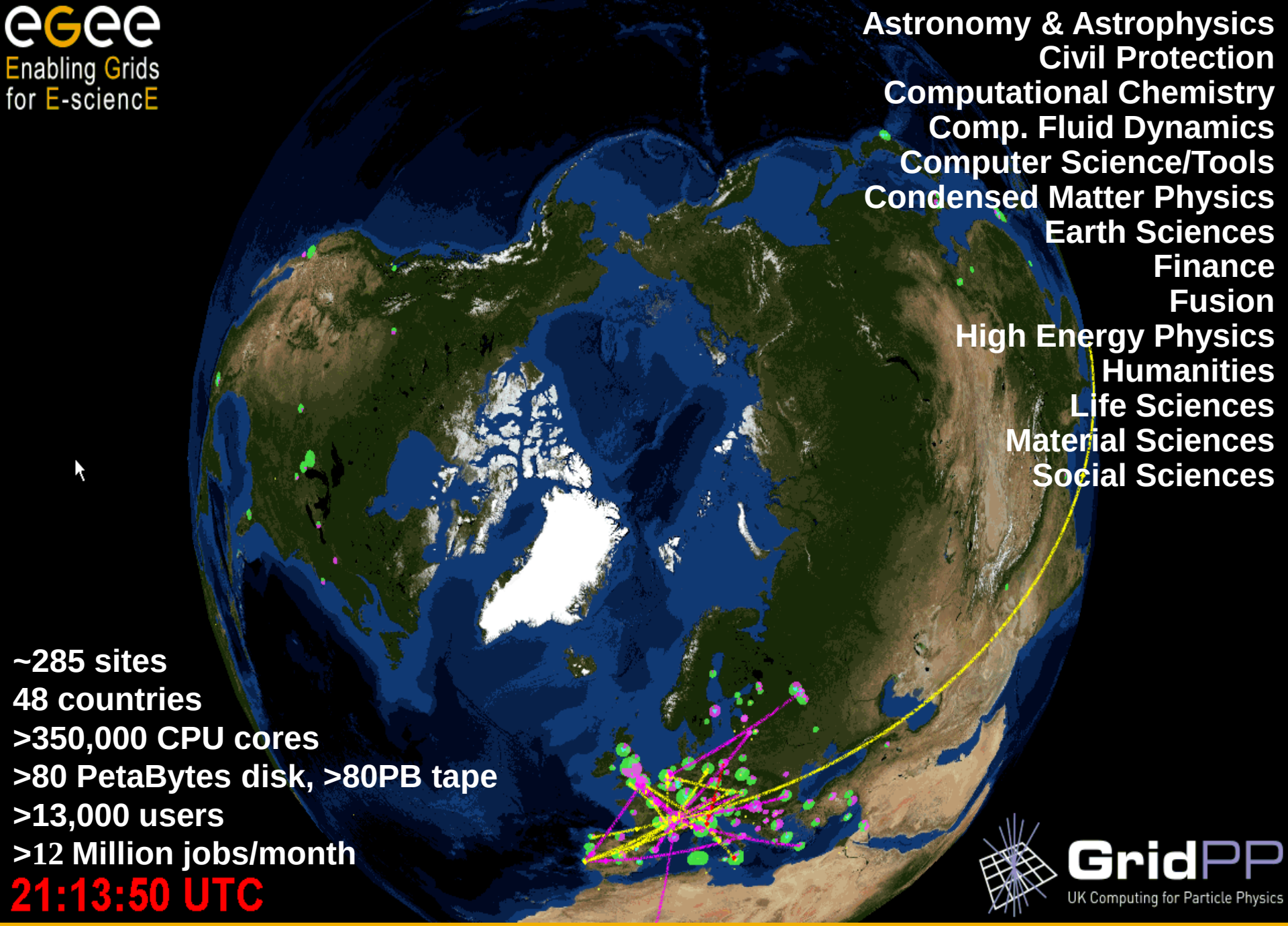
Tier 0 – Tier 1 – Tier 2

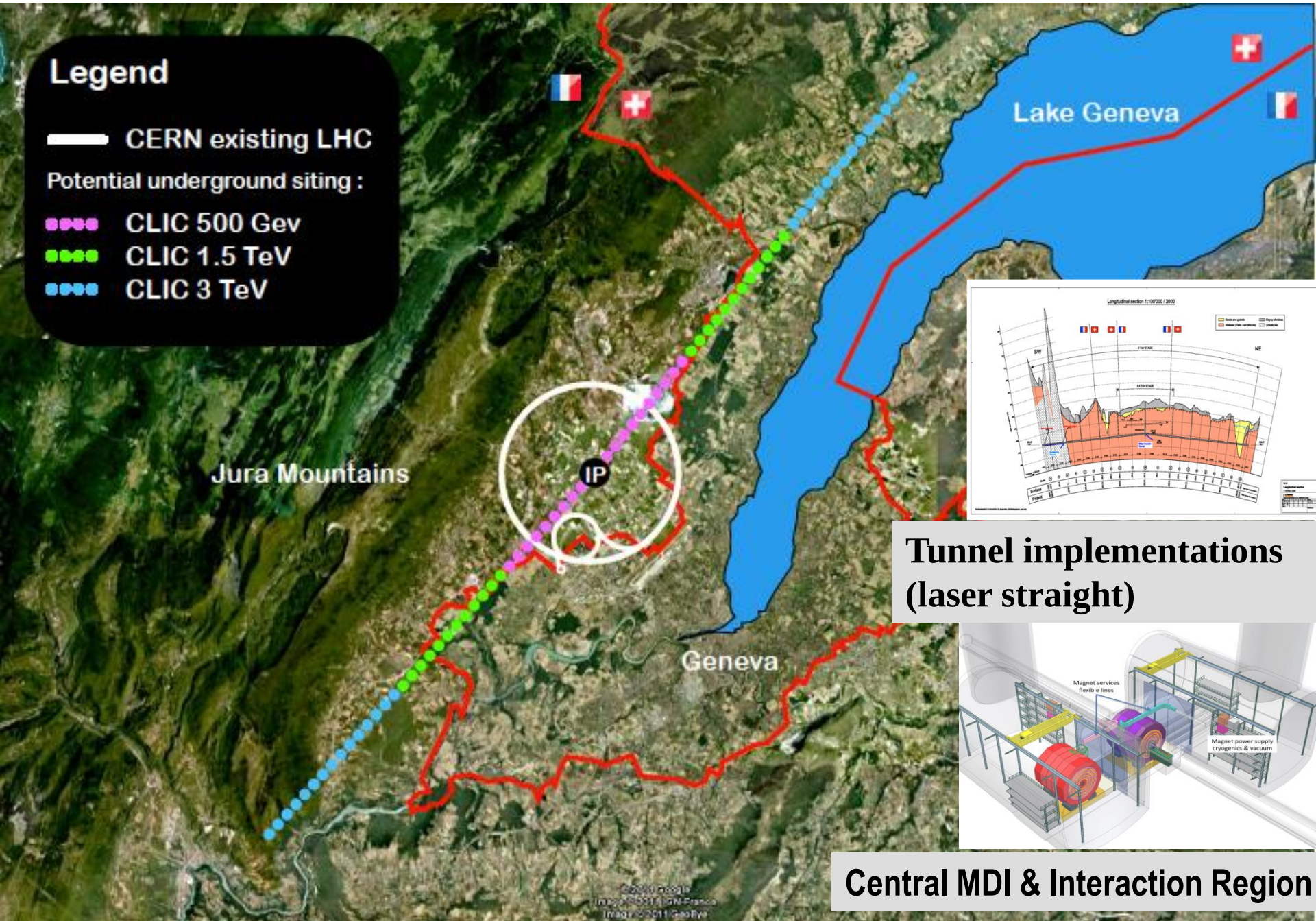


Tier-0 (CERN):
- Data recording
- Initial data reconstruction
- Data distribution

Tier-1 (11 centres):
- Permanent storage
- Re-processing
- Analysis

Tier-2 (~130 centres):
- Simulation
- End-user analysis


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

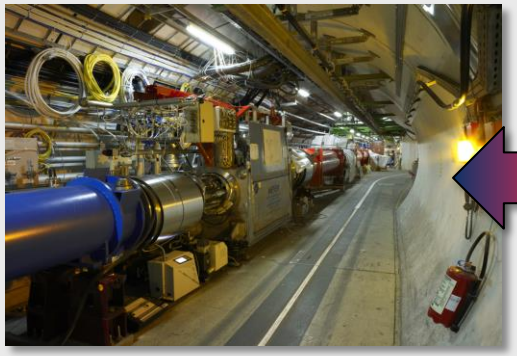

Legend
CERN existing LHC
Potential underground siting :
CLIC 500 Gev
CLIC 1.5 TeV
CLIC 3 TeV
Lake Geneva
Jura Mountains
IP
Geneva
Tunnel implementations (laser straight)
Central MDI & Interaction Region

CERN Technologies - Innovation

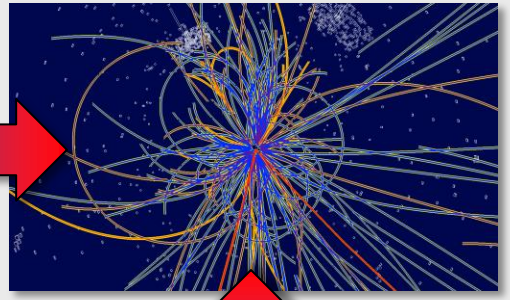
Medical imaging

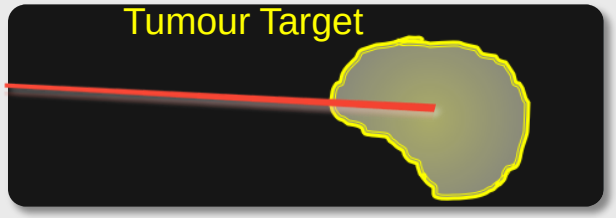
Example: medical application

Accelerating particle beams



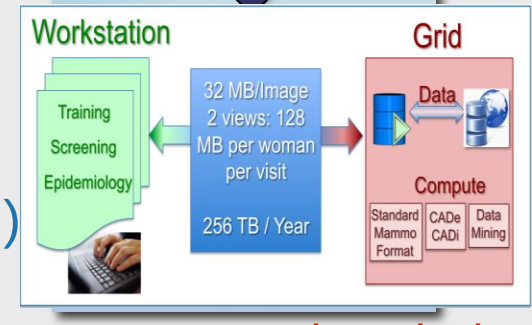
Detecting particles





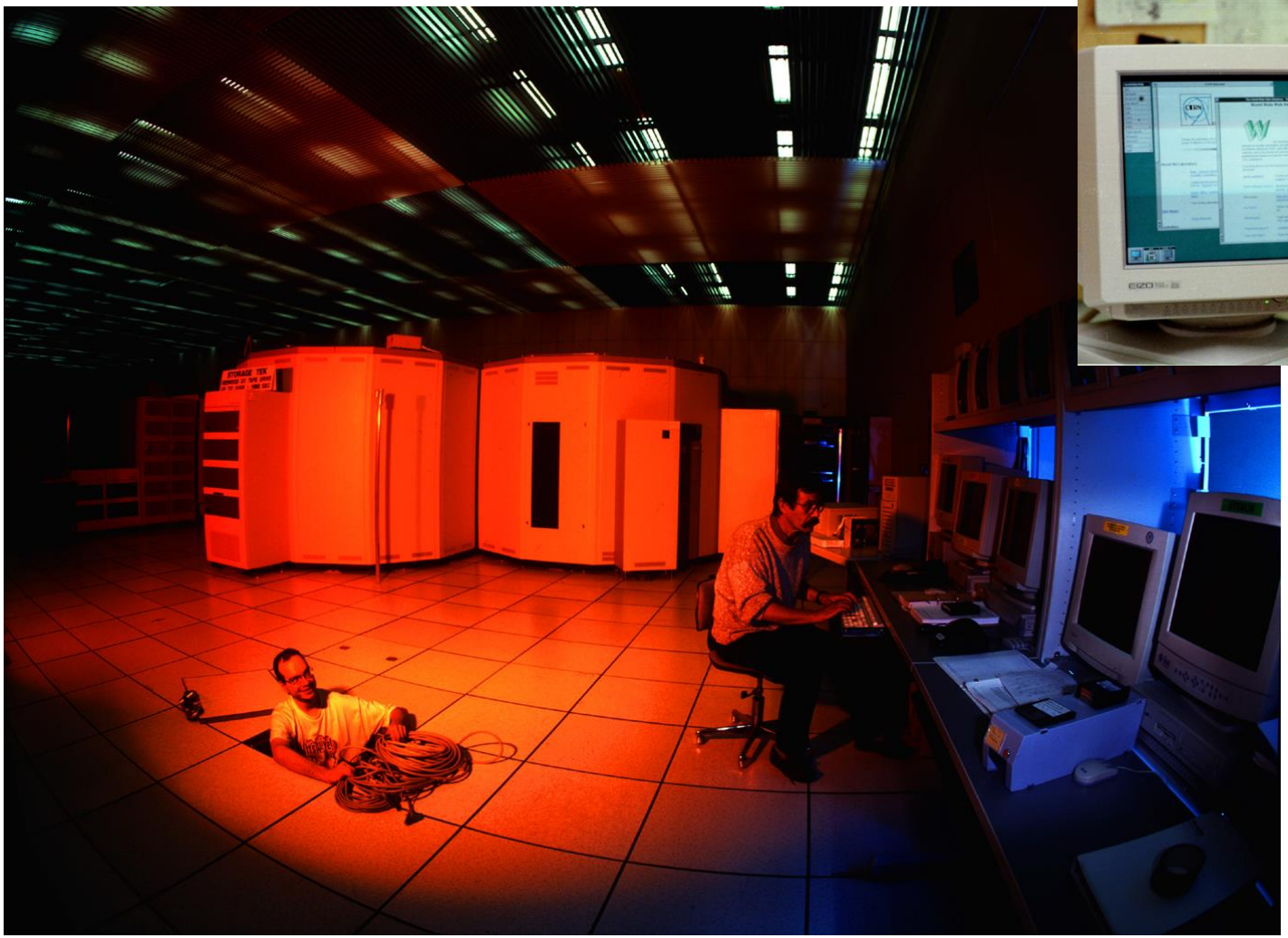
Charged hadron beam that loses energy in matter

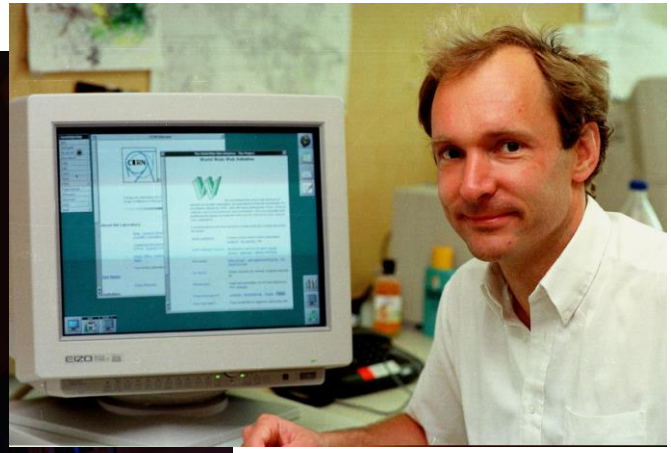
Large-scale **computing** (Grid)

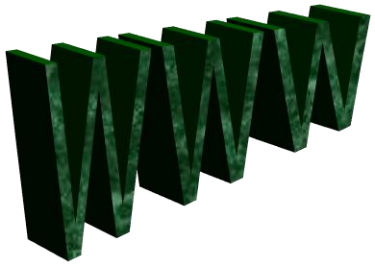


Grid computing for medical data management and analysis

CERN, Internet and the WWW







Norway and CERN

Strong involvement in the ATLAS and ALICE experiments

ALICE:

- University of Bergen
- Bergen University College
- University of Oslo

ATLAS:

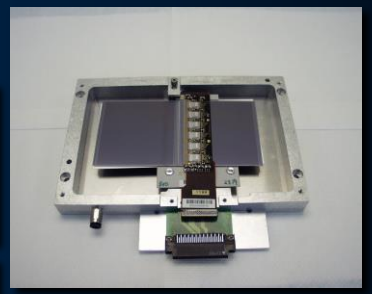
- University of Bergen
- University of Oslo

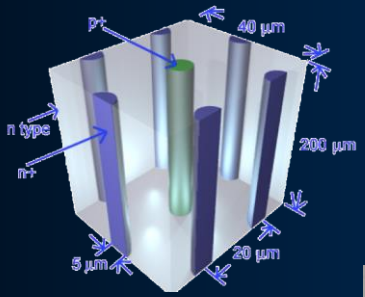
+ participation in smaller projects (CLIC, ISOLDE, AEGIS, NA61)

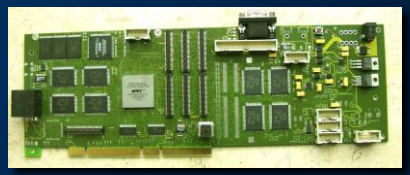
Norway and CERN

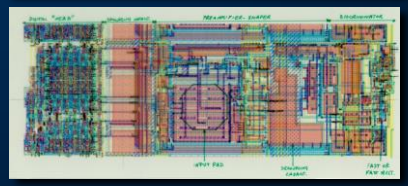
The major technology activities at CERN last 15 years:

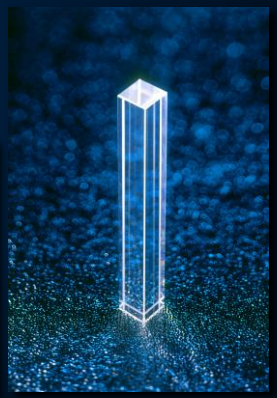
- Construction of silicon modules for ATLAS (UiB, UiO)
- PHOS detector readout for ALICE (UiB, UiO)
- High Level Trigger development for ALICE (UiB, HiB, UiO)
- Construction of cryogenics tanks for ATLAS (NTNU, UiO, Industry)
- R&D work for future detector systems (UiO, UiB, SINTEF)
- GRID development and deployment (UiO, HiB, UiB, computer centres)
- CLIC accelerator studies (UiO)



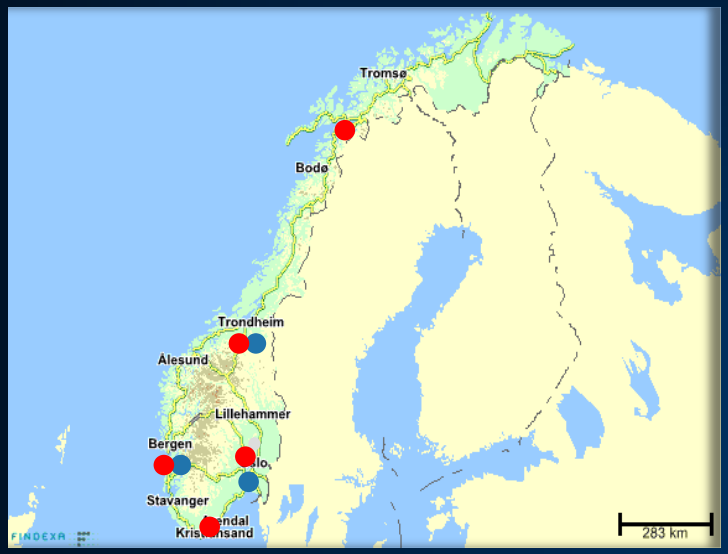








High Energy Physics in Norway



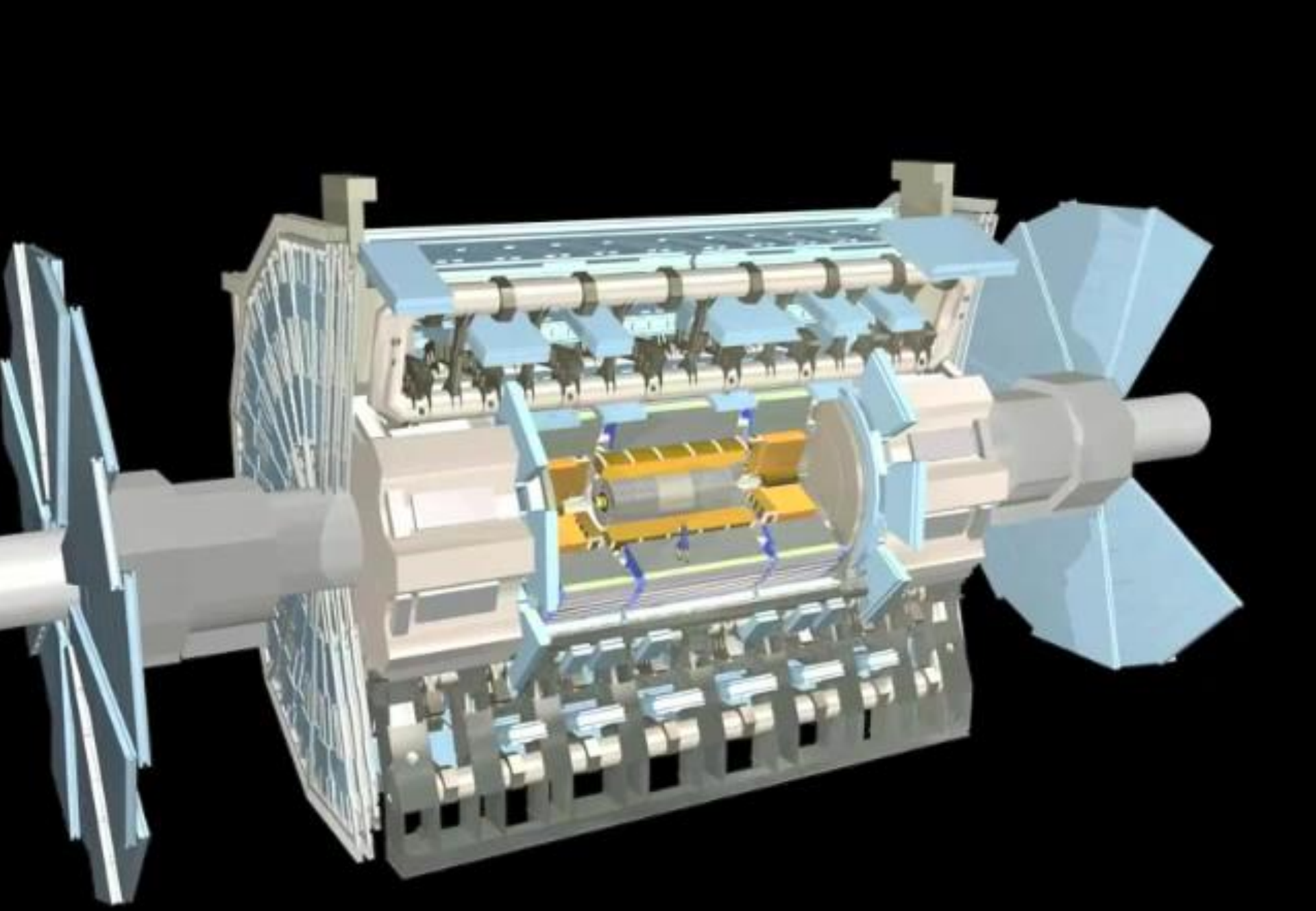
Blue: Oslo, Bergen, Trondheim: Universities (offering everything up through PhD)

Red: University Colleges currently involved at CERN (offering up through master level) – some becoming Universities (soon). Some also involved in the ATLAS/ALICE experiments. Supply, with NTNU, all technical students at master level (10-15 yearly)

Today around 140 Norwegian researchers, engineers, postdocs (15-20), PhD students (20-25) and master students (20-25) are involved in the CERN activities:

- At CERN: Around 15-20 technical students at CERN in addition to the Norwegian staff (10-15 at master and ~5 ph.d level)
- Around 90 Norwegian researchers (of all categories above) are registered as users travelling frequently to CERN
- The rest travelling are less frequently or working in Norway within the CERN related research programmes

THANK YOU!



Lorentz equation

- The two main tasks of an accelerator
  - Increase the particle energy
  - Change the particle direction (follow a given trajectory, focusing)

- Lorentz equation:

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) = q\vec{E} + q\vec{v} \times \vec{B} = \vec{F}_E + \vec{F}_B$$

- $F_B \perp v \Rightarrow F_B$ does no work on the particle
  - ***Only F_E can increase the particle energy***

- F_E or F_B for deflection? $v \approx c \Rightarrow$ Magnetic field of 1 T (feasible) same bending power as en electric field of $3 \cdot 10^8$ V/m (NOT feasible)
  - ***F_B is by far the most effective in order to change the particle direction***