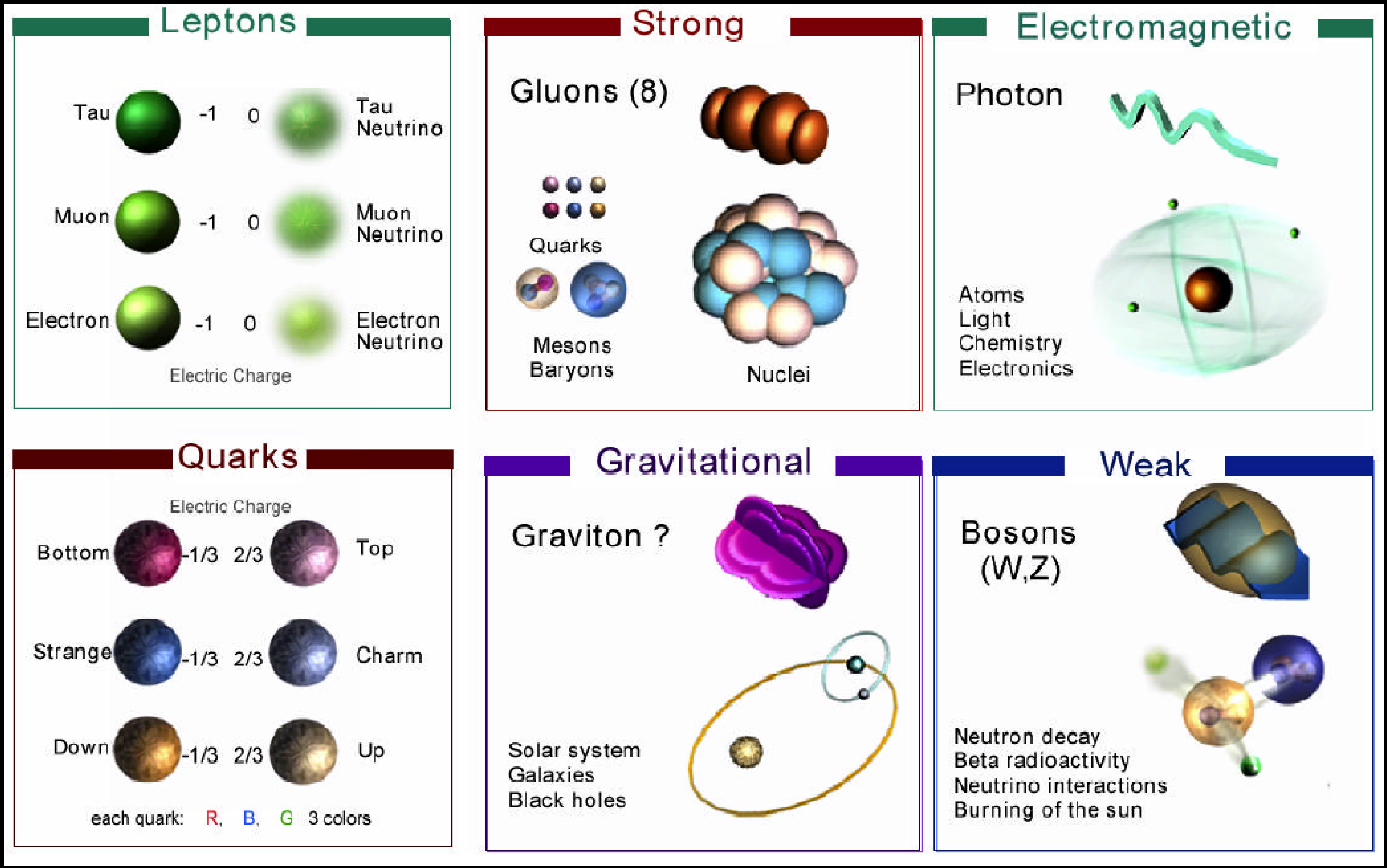
# Jakten på ny fysikk

*Heidi Sandaker*

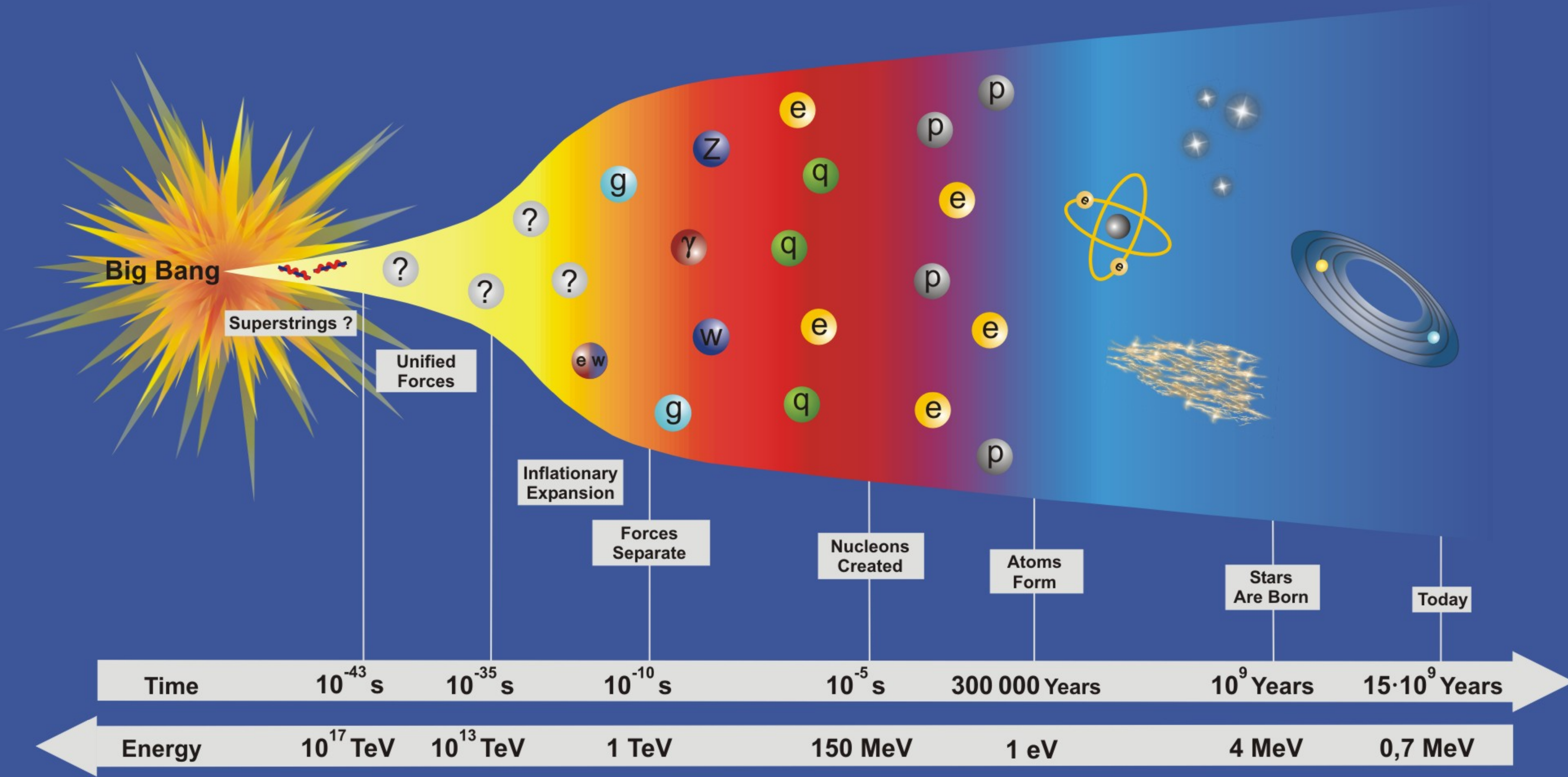
# Standard modellen for fundamentale partikler og vekselvirkninger




**En modell som er testet med veldig høy presisjon !**

# Men Standard Modellen har ikke svar på alt vi lurer på !

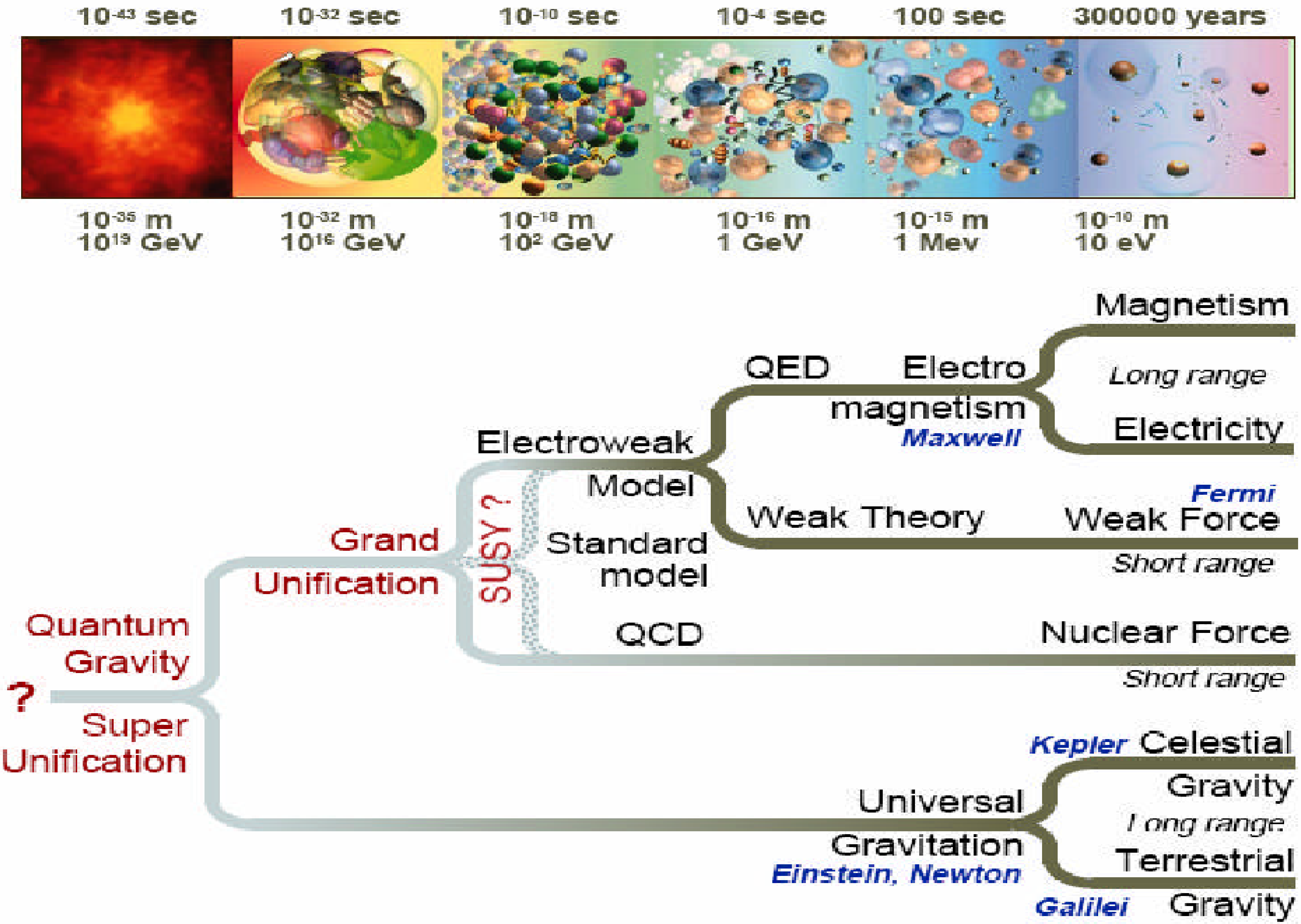
**The Big Bang - Hva skjedde egentlig like etterpå ?**




Ekstrapolering via presisjonsmålinger ← LHC

**Hvorfor ble det ikke laget like mye materie som antimaterie ?**

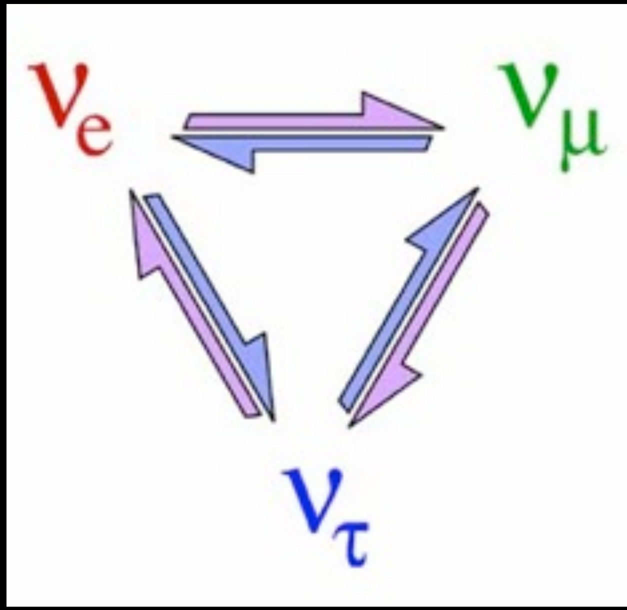
**Hvordan ble kvarkene dannet ? ...**




**Forening av noen krefter mangler i Standard Modellen !**

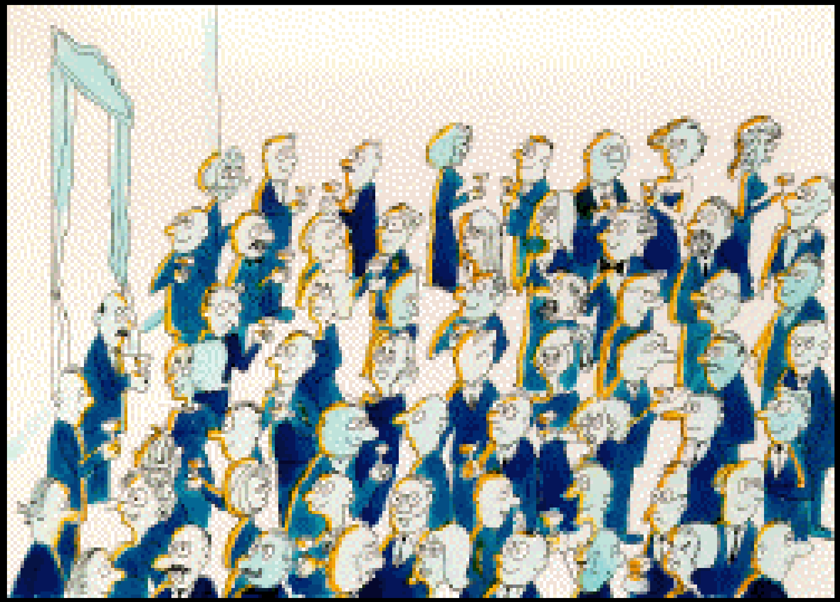
## ... Og Standard Modellen forklarer ikke hvorfor partikler har masse !

- Standard modellen forutsier at neutrinoer skal være masseløse - i virkeligheten har de masse !
- Faktisk kan ikke Standard modellen forutse noen av massene til de forskjellige partiklene !




### Higgs mekanismen :

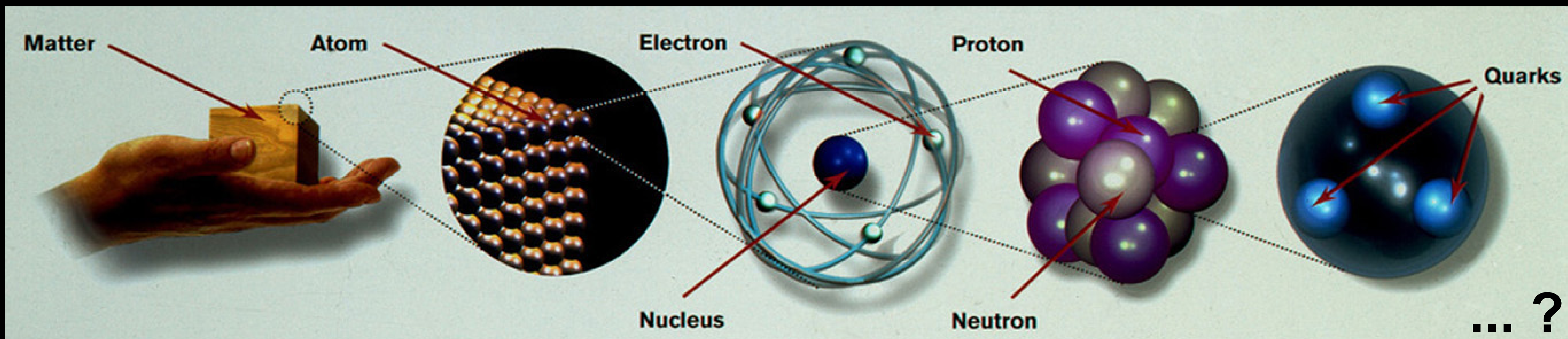
The result of Higgs field in the vacuum is that all particles get masses by gluing into it

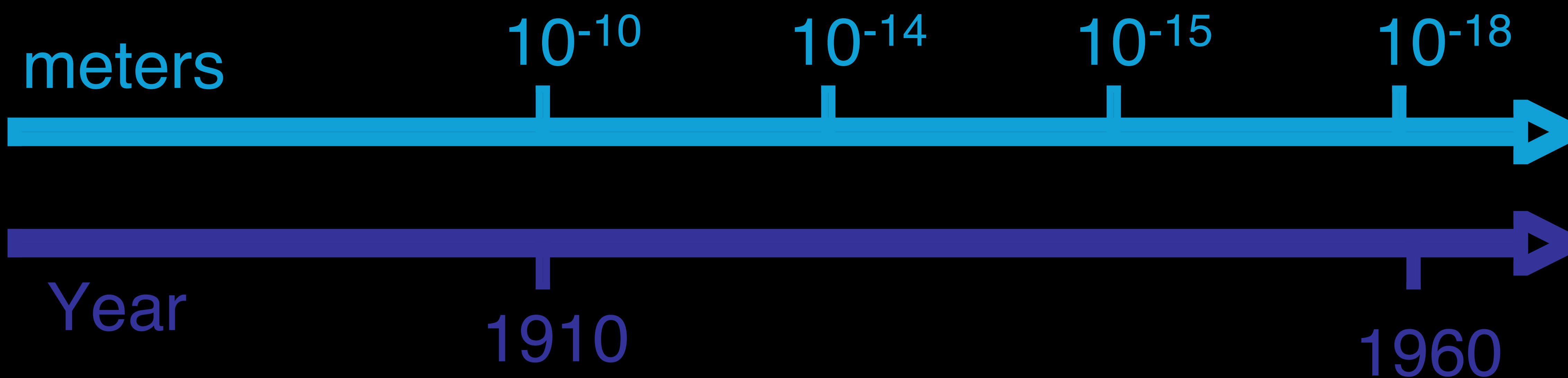


**Hvis modellen stemmer må det finnes en ny partikkel, Higgs partikkelen !**

## ... Og vi vet heller ikke om kvarker er fundamentale !

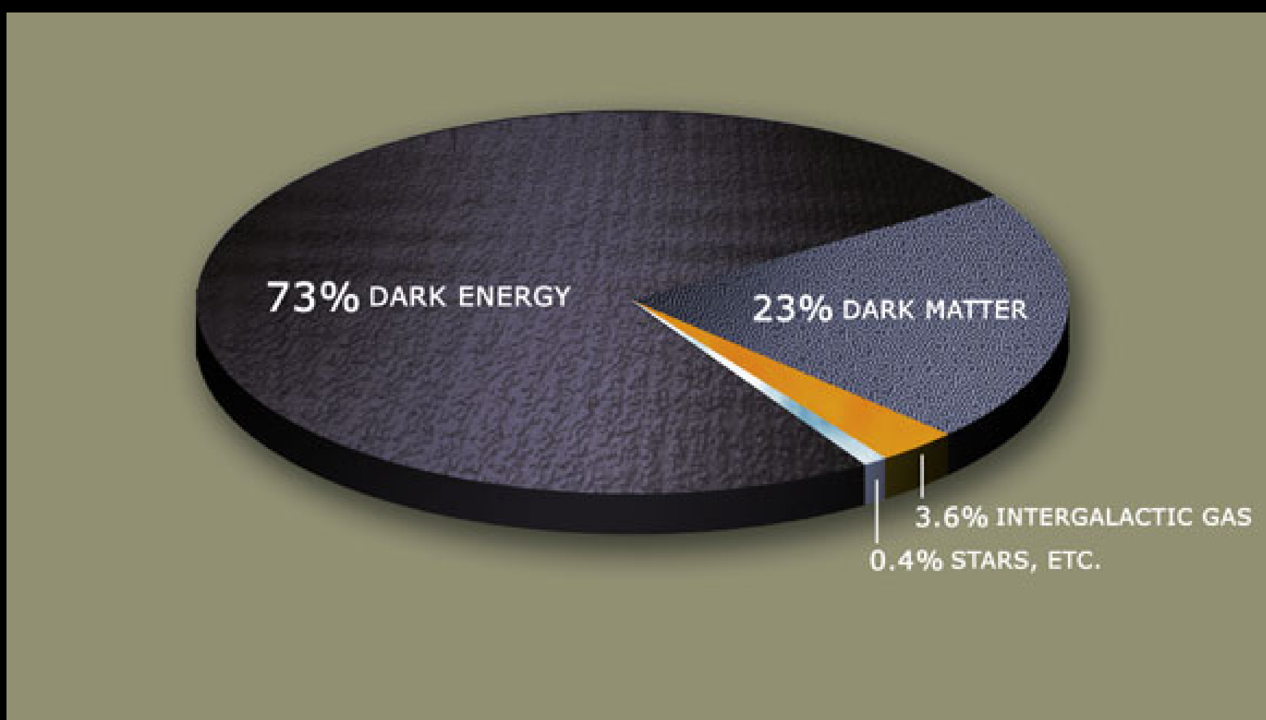
$10^{-18} = 0.000000000000000001$



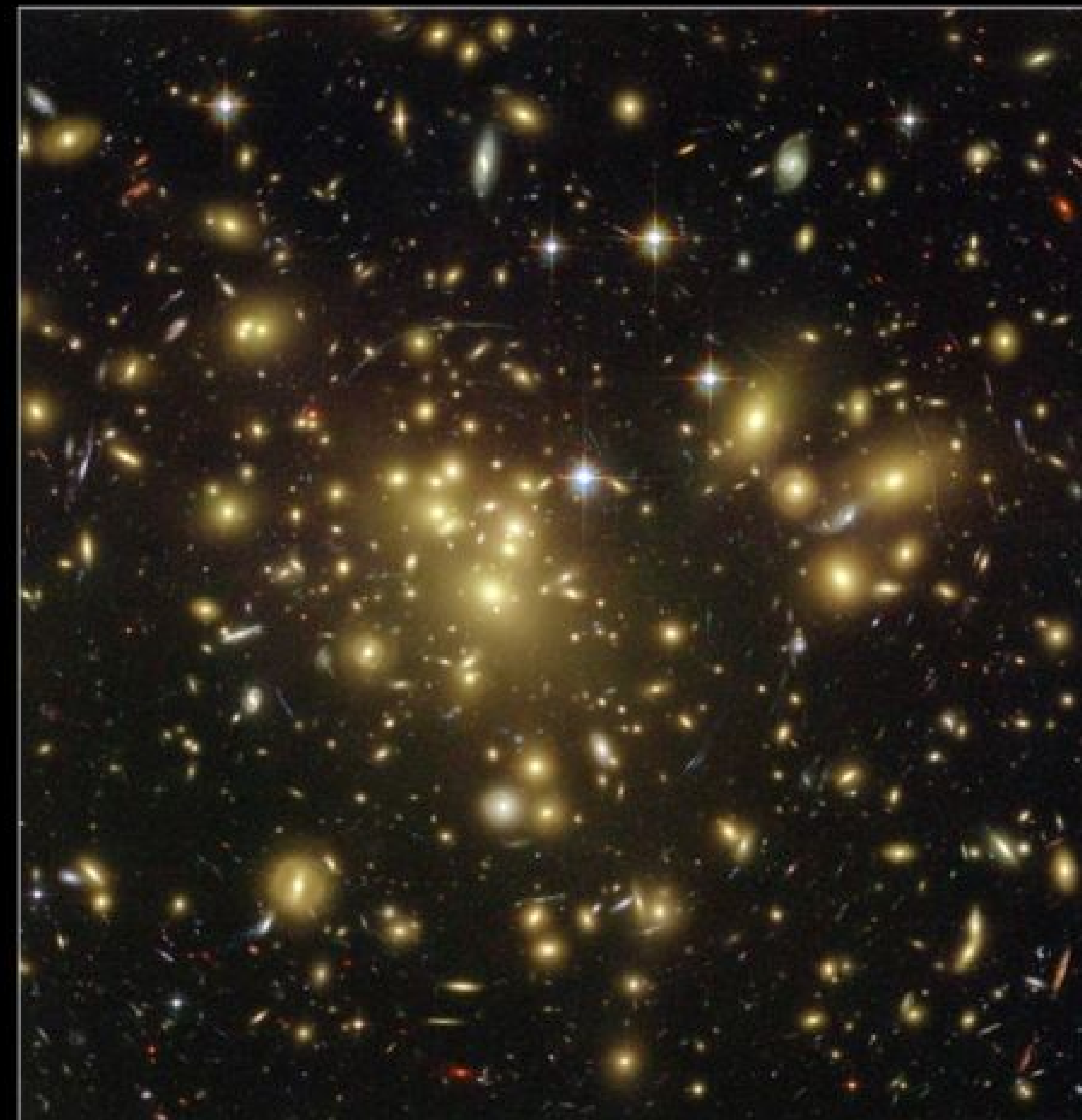



# ... Og heller ikke Mørk Materie !

➡ Bare 4 % av det universet består av vet vi hva er !




➡ Kanskje det finnes nye partikler som er opphavet til mørk materie ?



**Galaxy Cluster Abell 1689**
**Hubble Space Telescope** • Advanced Camera for Surveys

NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin(STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
STScI-PRC03-01a

# What is dark matter ?

**Definition:**

**Dark Matter is matter which one can only observe through gravitational effects on visible matter**

**- does not interact with electromagnetic radiation**

No doubt that dark matter exists - there is a multitude of direct observational evidence (since the 1930s):

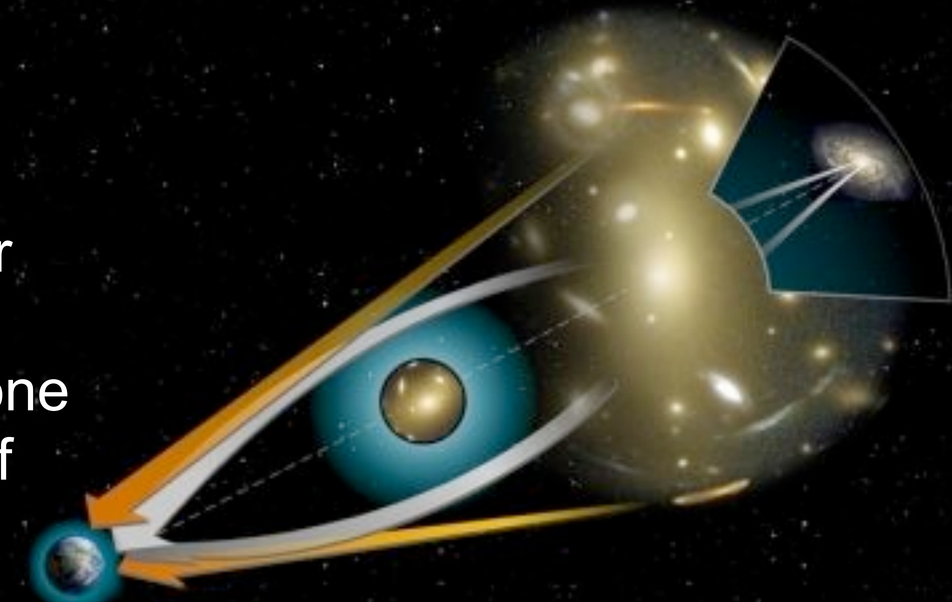
- Galactic rotational curves
- Velocity dispersion of galaxies
- Galaxy clusters and gravitational lensing
- Cosmic microwave background
- Sky surveys and baryon acoustic oscillations

*Fritz Zwicky*

*Vera Rubin*

**A couple of examples:**

# Observational evidence for dark matter



Picture of the galaxy cluster ZwCI0024+1652, 5 billion light years away, showing one of the strongest evidence of dark matter !

Pictures from the Hubble telescope

Gravitational lensing makes the galaxies appear as disks

# Observational evidence for dark matter

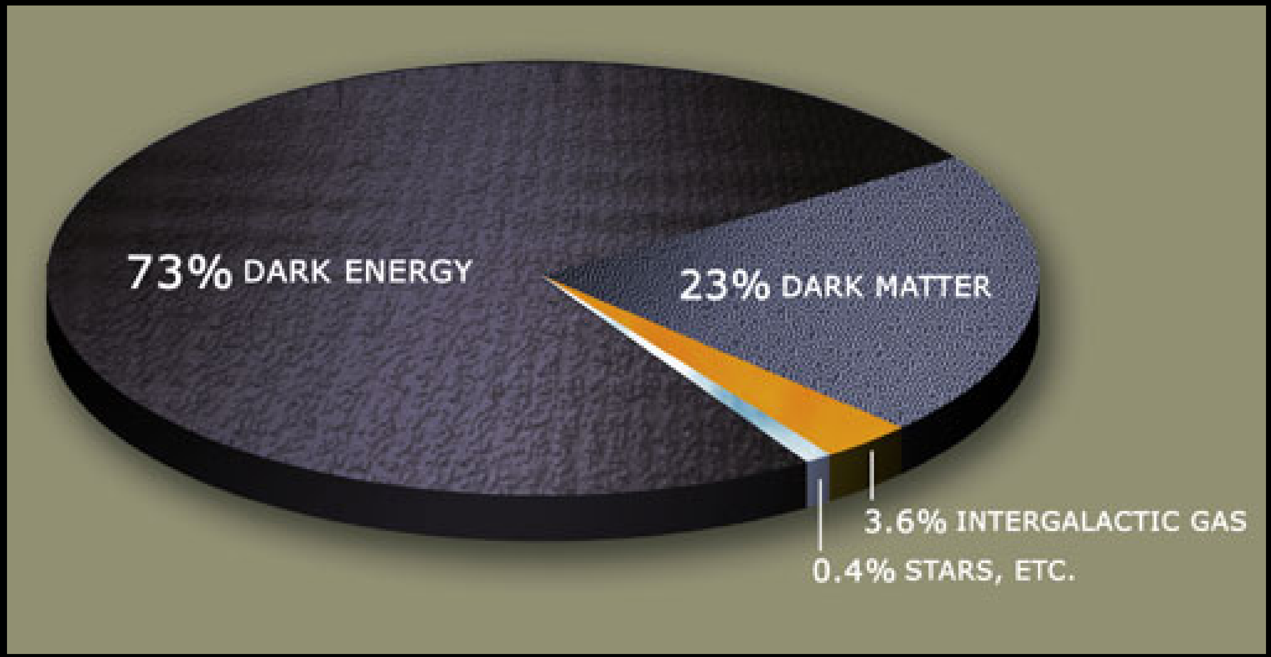
Hot gas (pink) detected in two galaxy clusters, one with a particular bullet shape. Other telescopes detected the bulk matter in the clusters which turns out to be dark matter (blue)

CREDIT: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

# What is dark matter ?

***These and similar studies of the universe show that the universe consists of :***

- *4 % matter*
- *23 % dark matter*
- *73 % dark energy*




DARK MATTER IS PROPOSED TO EXPLAIN THE EXTRA MASS SEEN IN THE UNIVERSE ASSUMING THAT OUR ASSUMPTIONS ABOUT GRAVITY ARE CORRECT

## WHAT DO WE KNOW ABOUT DARK MATTER ?

- It accounts for the additional gravitational effects observed in the universe
- It interacts only weakly with regular matter
- It also interact with other dark matter particles only through gravity

# Three detection methods

**THIS MAKES DARK MATTER VERY HARD TO DETECT AND STUDY !**

- Indirect searches for the products of dark matter particle annihilation (e.g. Amanda, IceCube, GLAST-FERMI, EGRET)

- Direct searches for the atom recoil energy when a WIMP is passing (e.g. DAMA, CDMS, Xenon-10)

- Direct production made in high energy laboratories on earth (e.g. CERN, LHC, Tevatron)

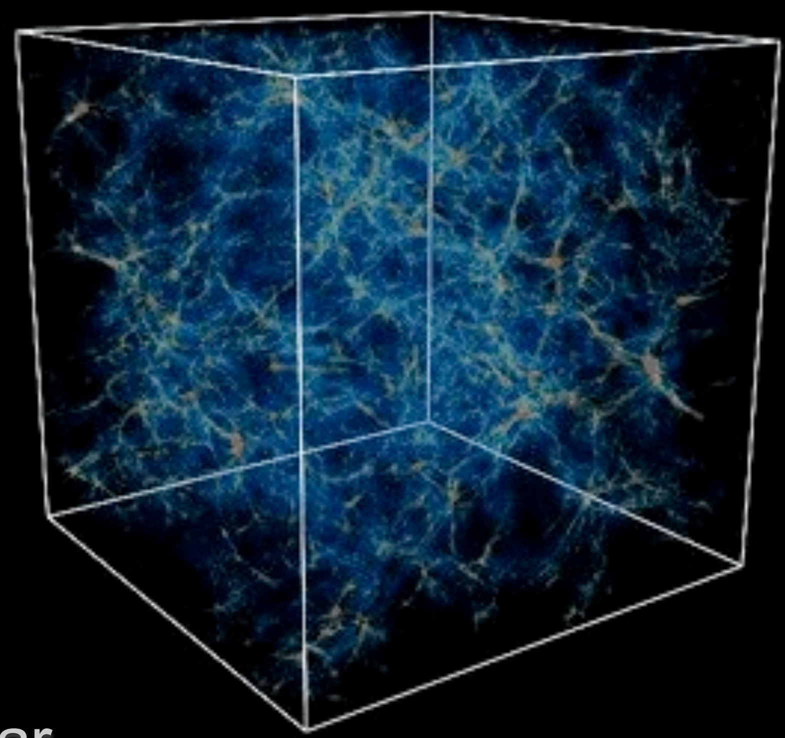
  Starting in 2009 LHC could be the first dark matter factory

# What is dark matter ?

## Different theories

- Multitude of models providing candidates as to what dark matter could be, from astrophysics, cosmology and particle physics

- **MACHOS** - *Massive, Compact Halo Objects*
    - Brown dwarfs, neutron stars or black holes, ...
      → not likely to account for more than a small fraction
- **WIMPS** - *Weakly Interactive Massive Particles*
    - ***Known particle***
        - Neutrino → not likely to clump as DM do
    - ***Unknown particle***
        - Supersymmetry → Massive neutralinos (superpartner of neutral SM bosons)
        - Other exotic particles, e.g. gravitinos, axions, scalar dark matter

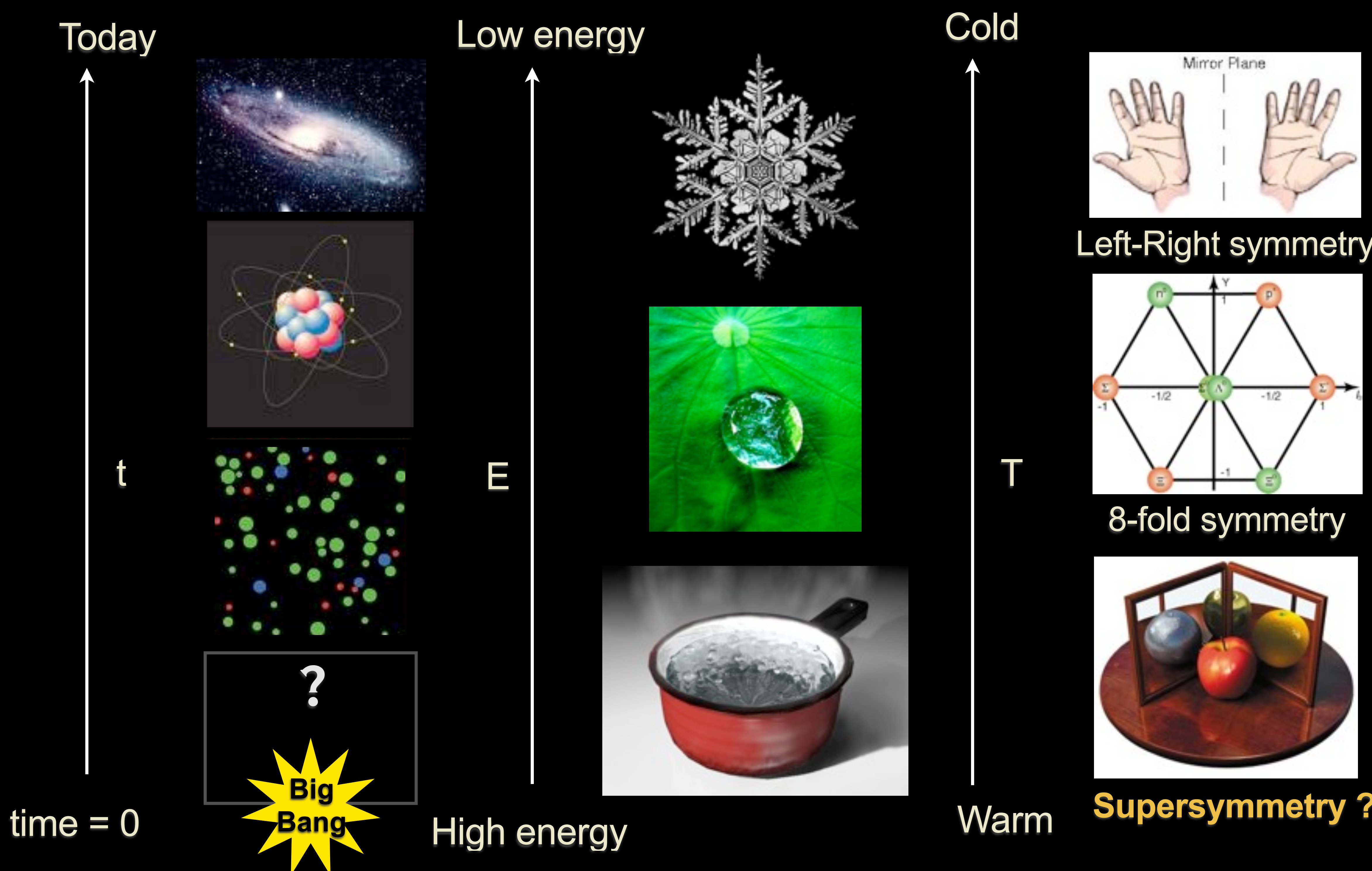


simulation represents the distribution of galaxy superclusters.

**We need to look for new physics beyond the standard model !**

# Possible new physics

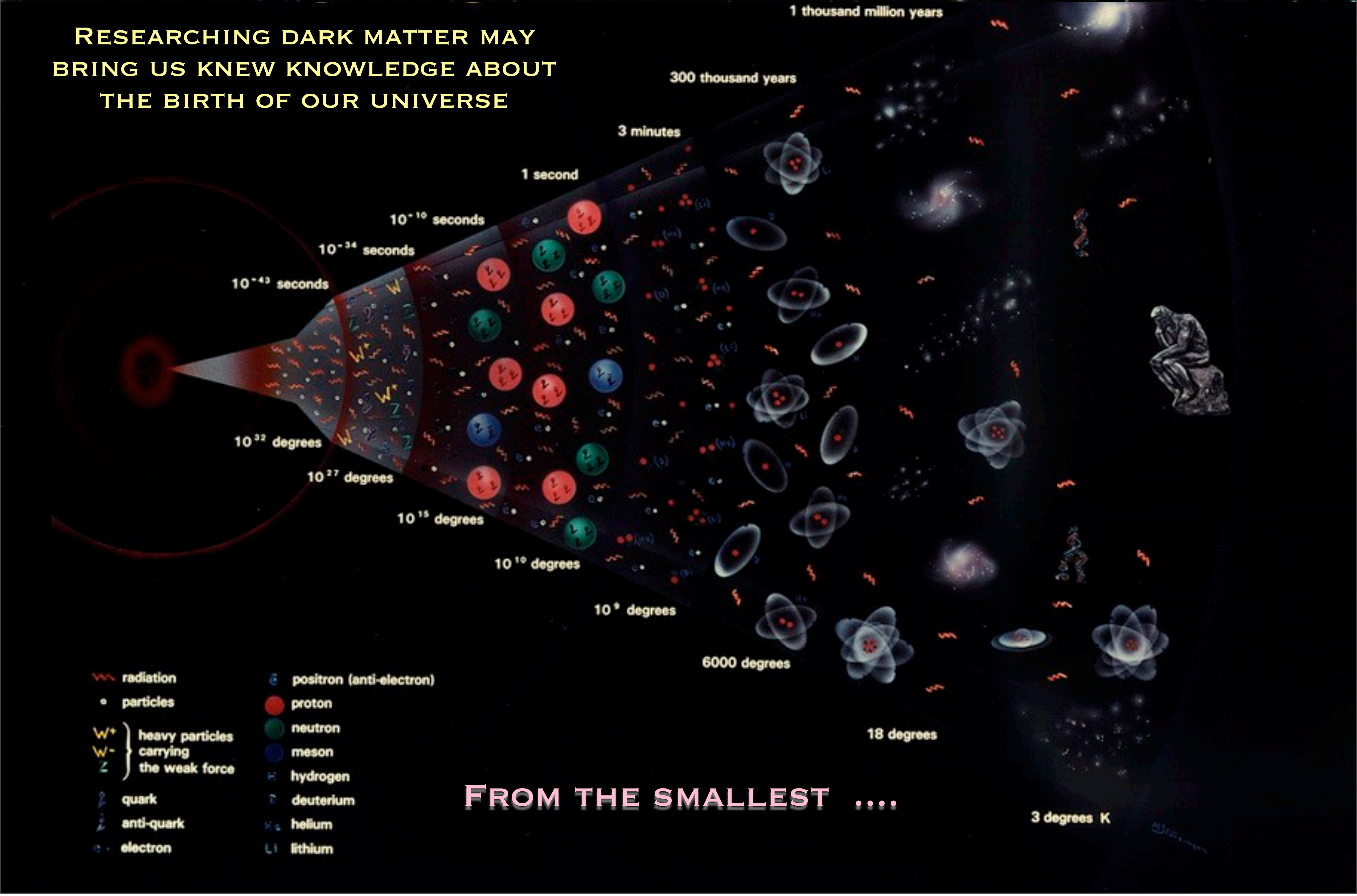
## New states and new symmetries could have existed just after the Big Bang




## Maybe supersymmetry ?

# Particle physicists view of the Big Bang

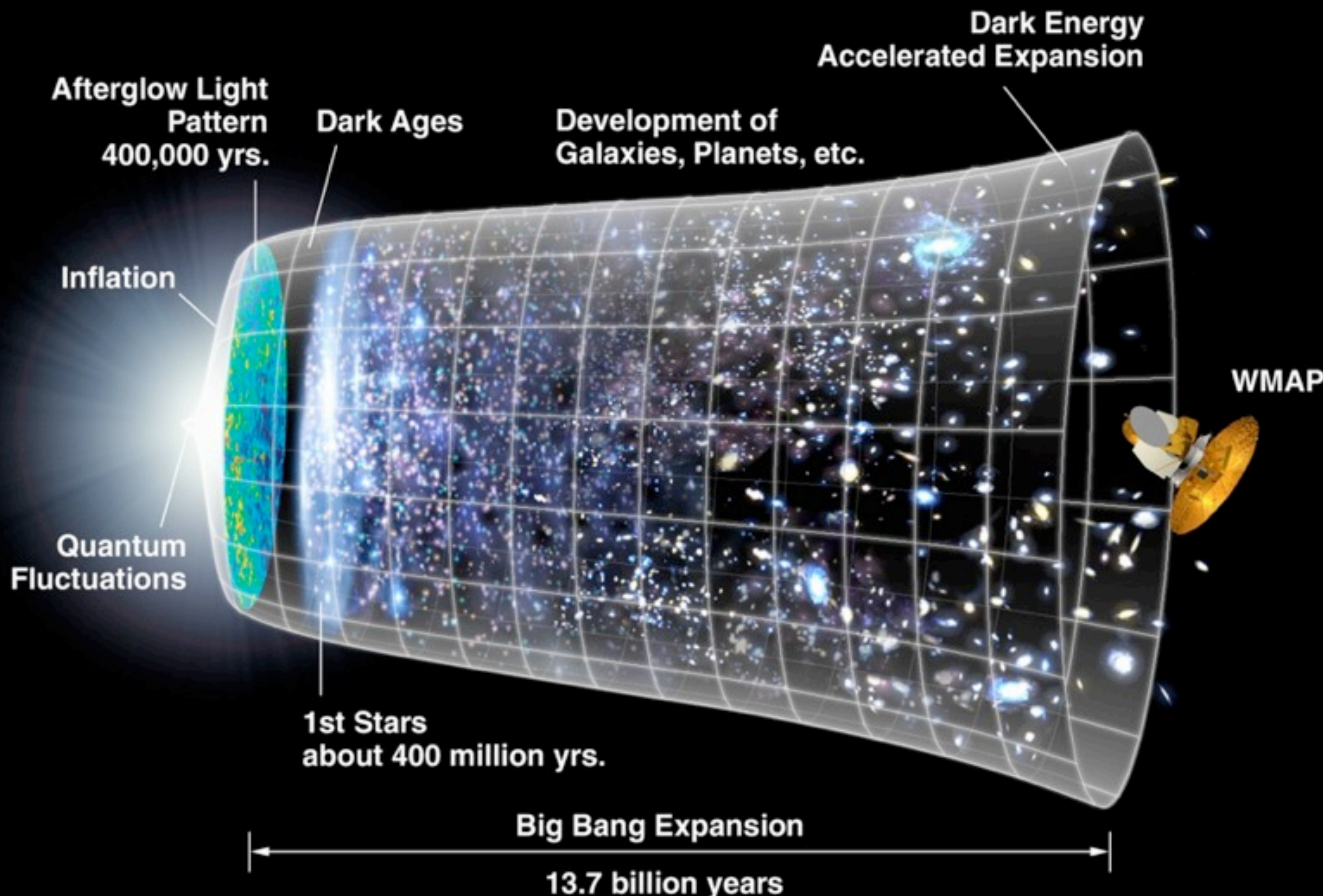
RESEARCHING DARK MATTER MAY BRING US KNEW KNOWLEDGE ABOUT THE BIRTH OF OUR UNIVERSE




FROM THE SMALLEST ....

# Astrophysicist view of the Big Bang

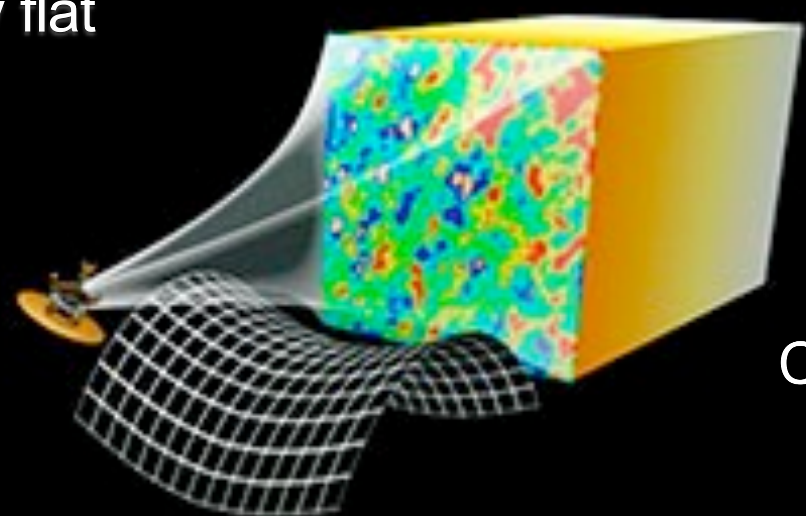
.... To the biggest !

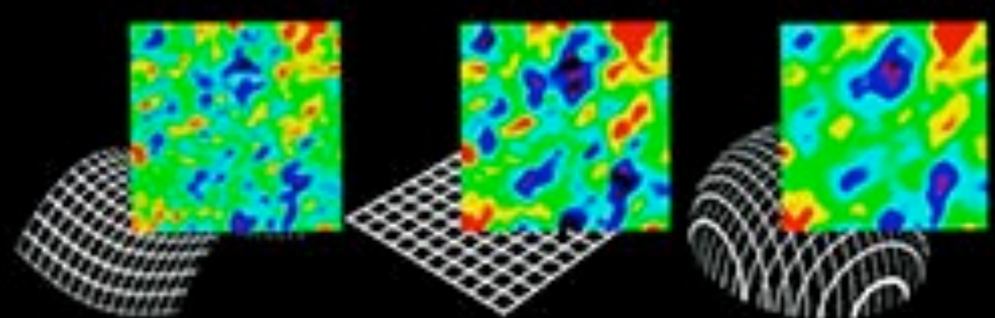



Dark matter plays a central role in the modeling of structure formation and the evolution of galaxies

# New information of the geometry of the universe

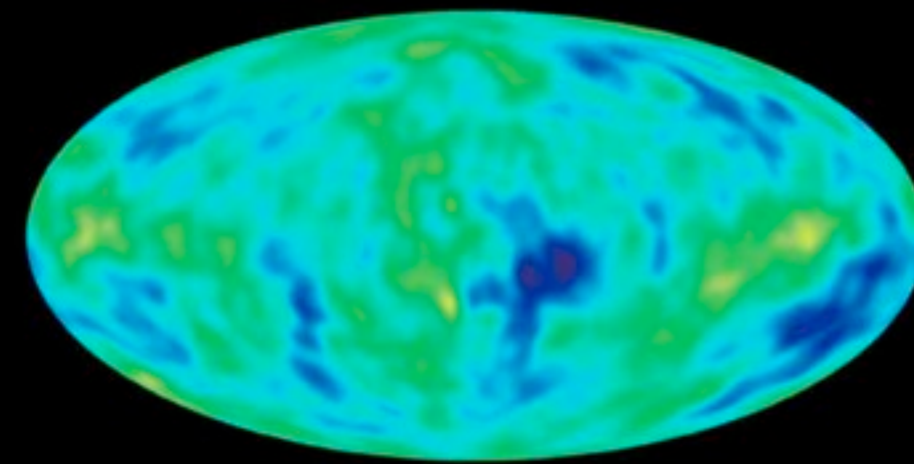
- The amount of dark matter and dark energy in the universe is crucial to determine the geometry of space
    - Open : density less than critical density
    - Flat : density equal to critical density
    - Closed: density more than the critical density
- Gives information on the evolution of the universe (eternal expansion, in equilibrium, or stop and collapse)
- The spacial geometry have been measured by WMAP to be nearly flat



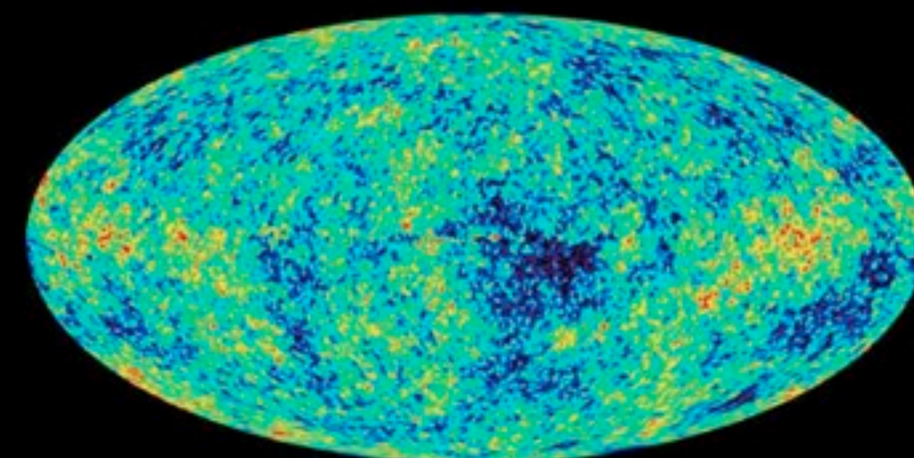


Open Flat Closed

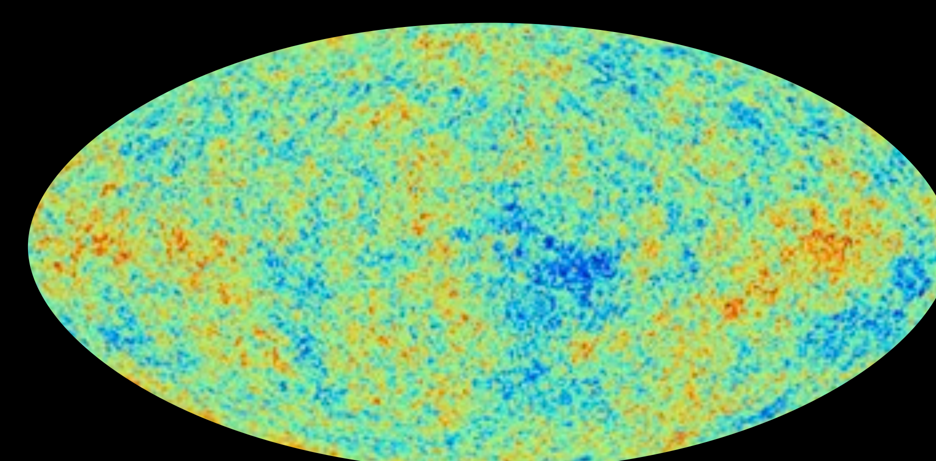
Cosmic microwave background



COBE



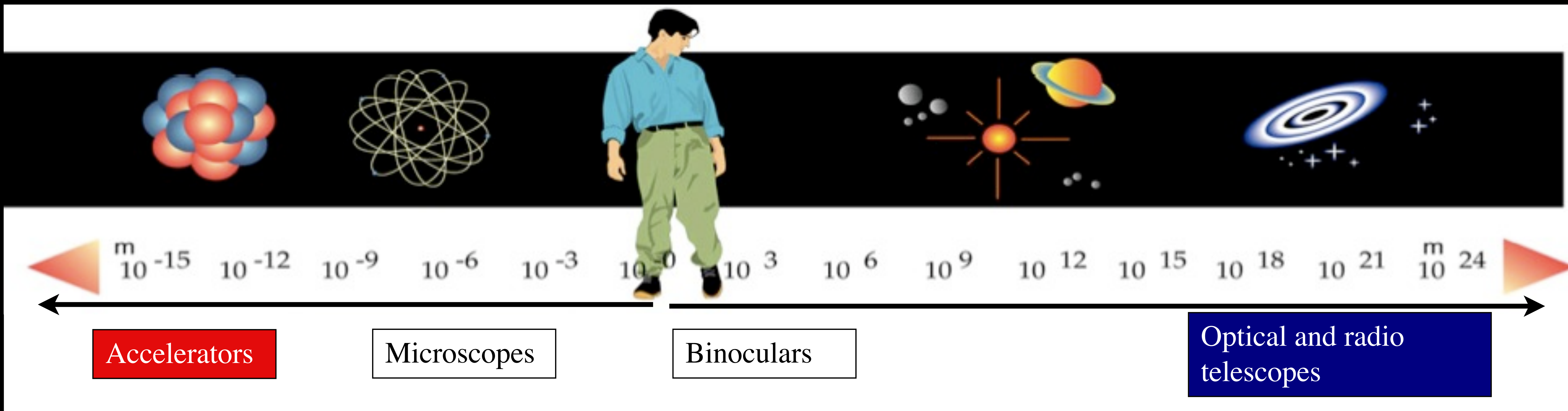
MAP



PLANCK (simulated)

ESA/NASA

## Hva trenger vi for å undersøke dette nærmere ?
## Eksempel: LHC




**Et sterkt mikroskop - Akselerator !**

**Som også er en tidsmaskin**

**- Vi kan studere tilstander like etter big bang**

# Hva trenger vi for å undersøke dette nærmere ?


**Et veldig god detektor ! - ATLAS -**

**Som fungerer som kamera som tar bilder av kollisjonene**

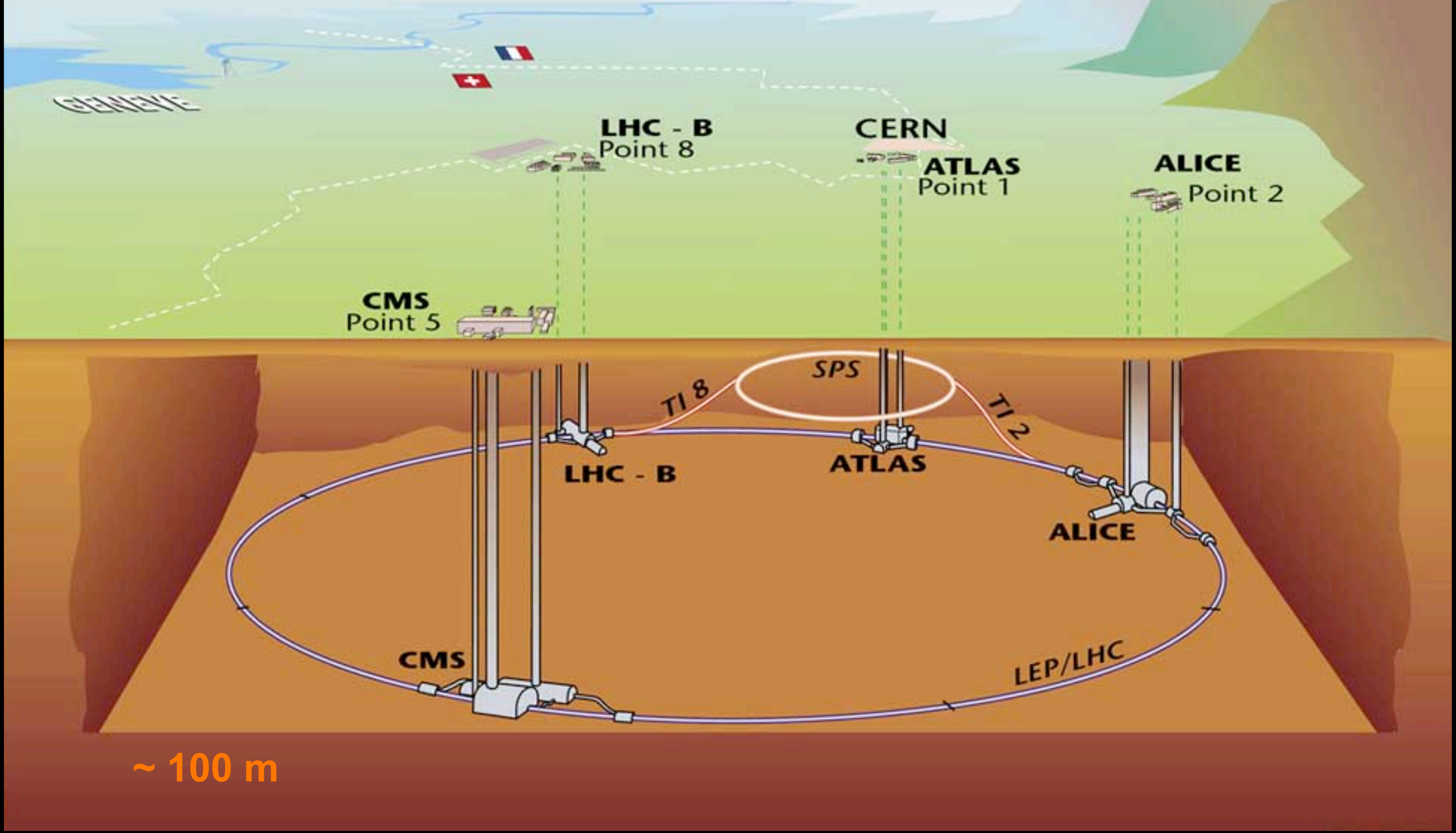
# 1. The challenge of LHC

Four gigantic underground caverns to host the huge detectors

The highest energy of any accelerator in the world

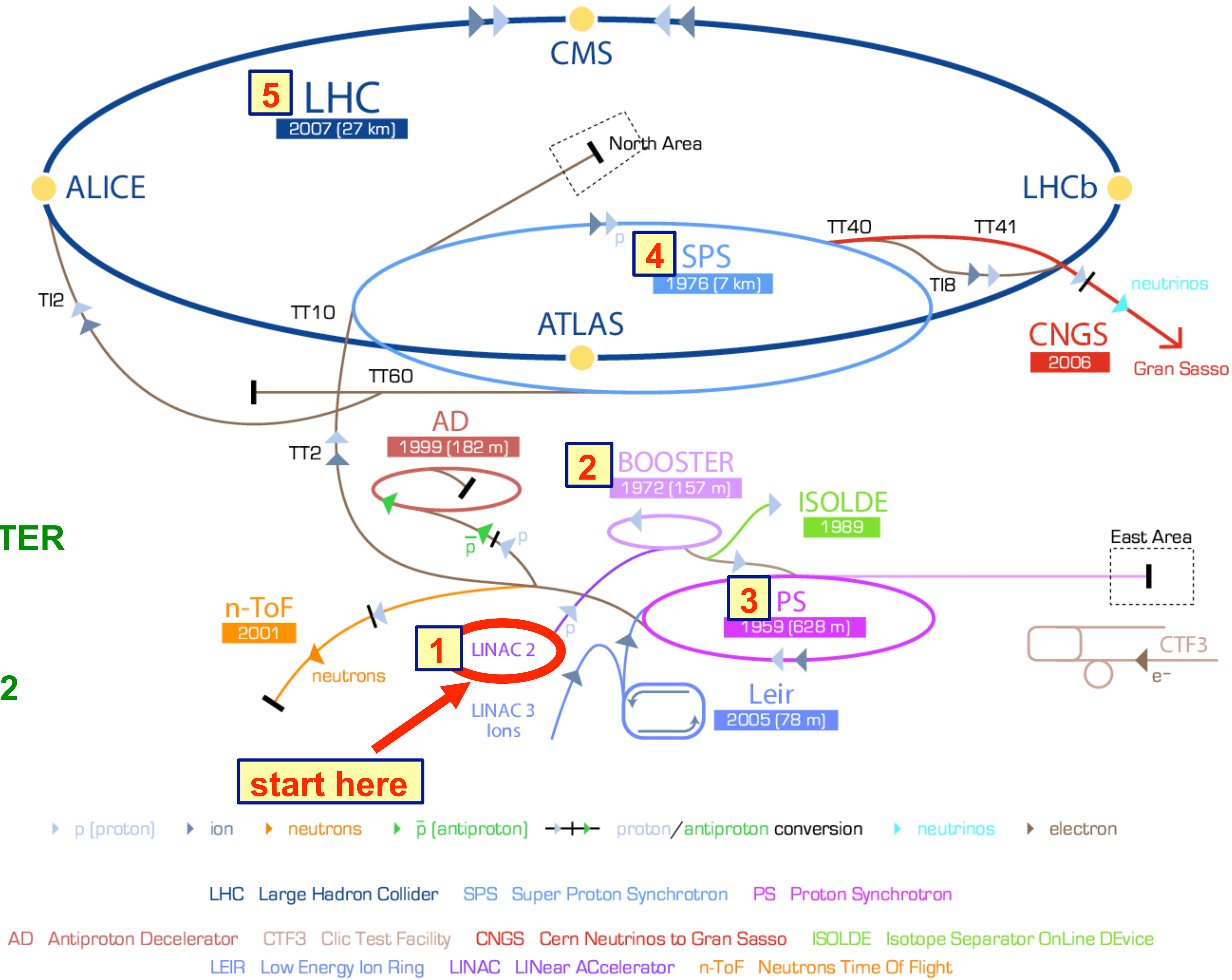
The most intense beams of colliding particles

It will operate at a temperature (1.9 K) colder than outer space



# 1. CERN accelerator complex

7 GeV
5 LHC
450 GeV
4 SPS
26 GeV
3 PS
1.4 GeV
2 BOOSTER
50 MeV
1 LINAC2

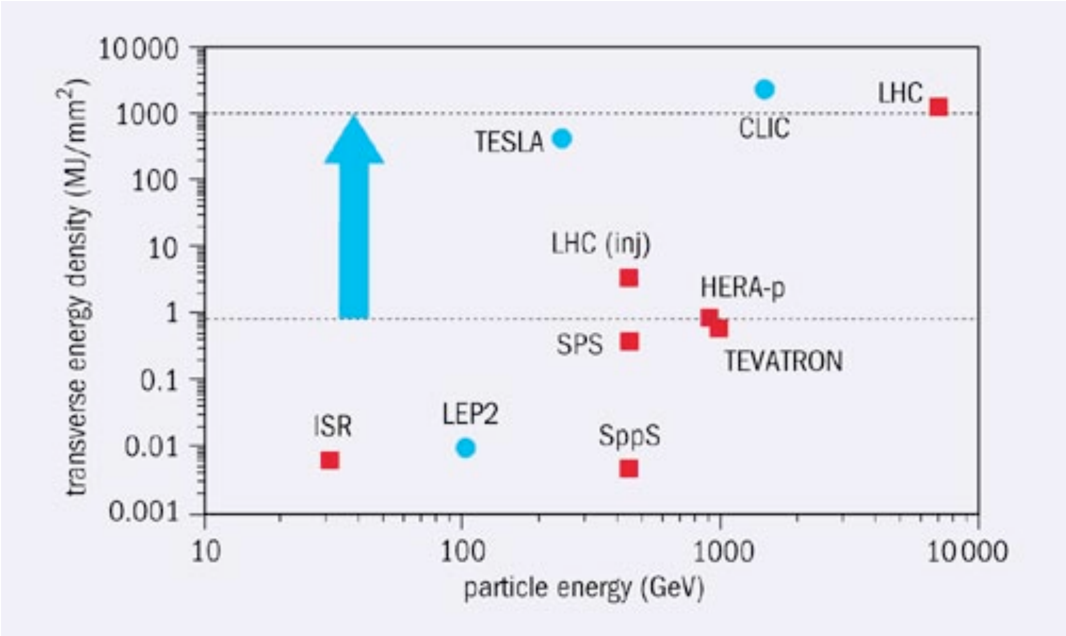
# 1. LHC parameters

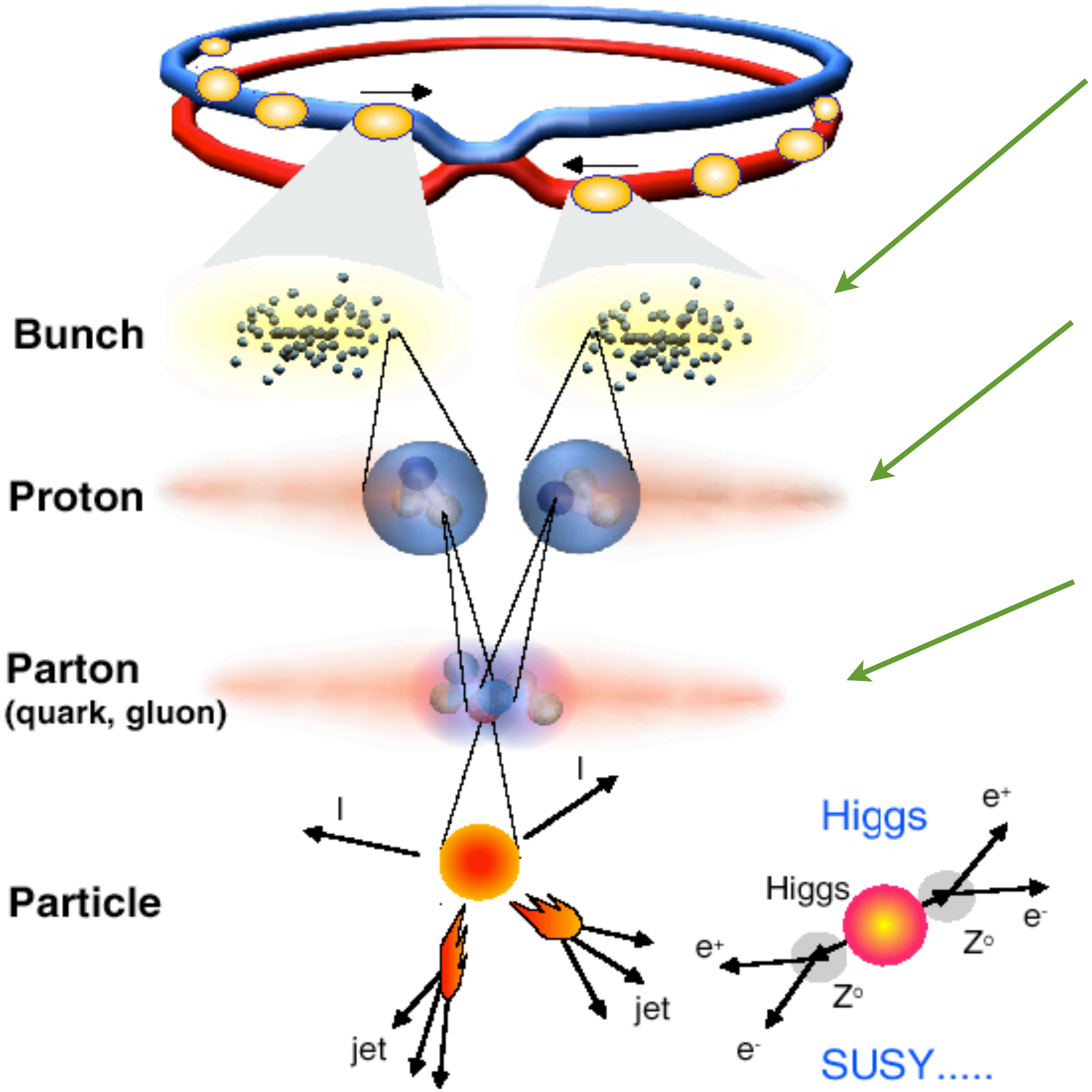
| | LHC (2009) | Tevatron (1987) | SppS (1981) |
|---|---|---|---|
| max. Energy (TeV) | 7 | 1 | 0.450 |
| circumference (km) | 26.7 | 6.3 | 6.9 |
| luminosity ($10^{30}cm^{-2}s^{-2}$) | 10000 | 210 | 6 |
| time between collisions (μs) | 0.0025 | 0.396 | 3.8 |
| crossing angle (μrad) | 300 | 0 | 0 |
| p/bunch ($10^{10}$) | 11 | 27/7.5 | 15/8 |
| number of bunches | 2808 | 36 | 6 |
| beam size (μm) | 16 | 34/29 | 36/27 |
| filling time (min) | 7.5 | 30 | 0.5 |
| acceleration (s) | 1200 | 86 | 10 |

**Compared with Tevatron:**

- 7 times more energy
- ~ 50-100 times more luminosity

**We need to build detectors for energies and luminosity not yet explored !**






**Proton/proton collisions**

- 7 TeV beam energy
- $10^{11}$ protons per bunch

**Event rate in detectors**

- N = L x σ (pp)
- N ~ 1 000 000 000 interactions/s

**Event Type**

- Mostly soft (low $p_T$) events
- Interesting hard (high $p_T$) events are rare

**Interesting events are very rare !**

- 1 in 10 000 000 000 000 collisions !

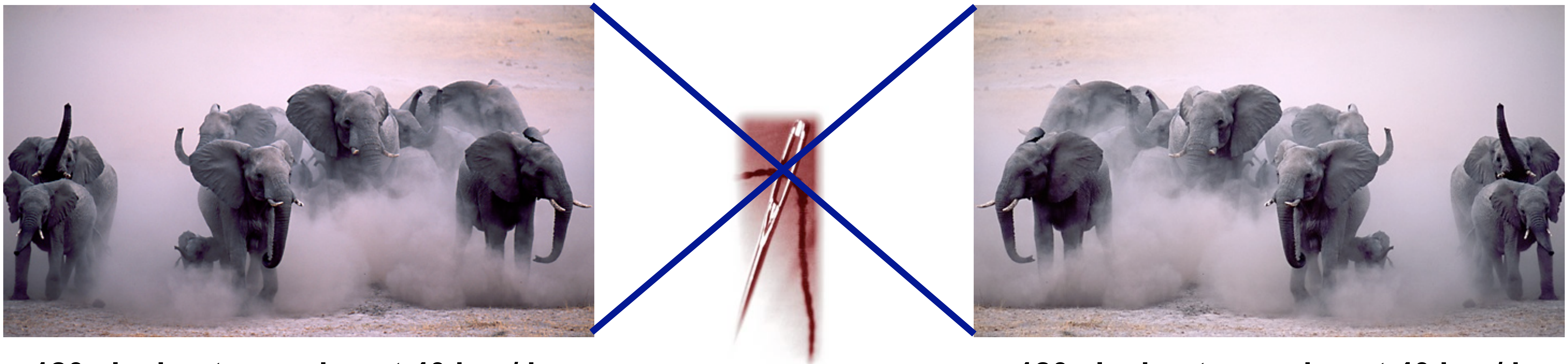
**We need detectors that can cope with high statistics !**

# 1. LHC Beam Energy and Density

- 2808 bunches in the ring
- 1.1 x $10^{11}$ protons per bunch
- 7 TeV

**= 350 MJ stored energy per proton beam**

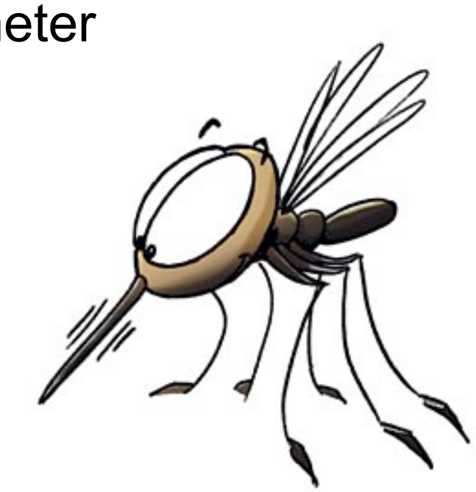
**Same as colliding 2 x 120 elephants !**



**120 elephants running at 40 km / h** **120 elephants running at 40 km / h**

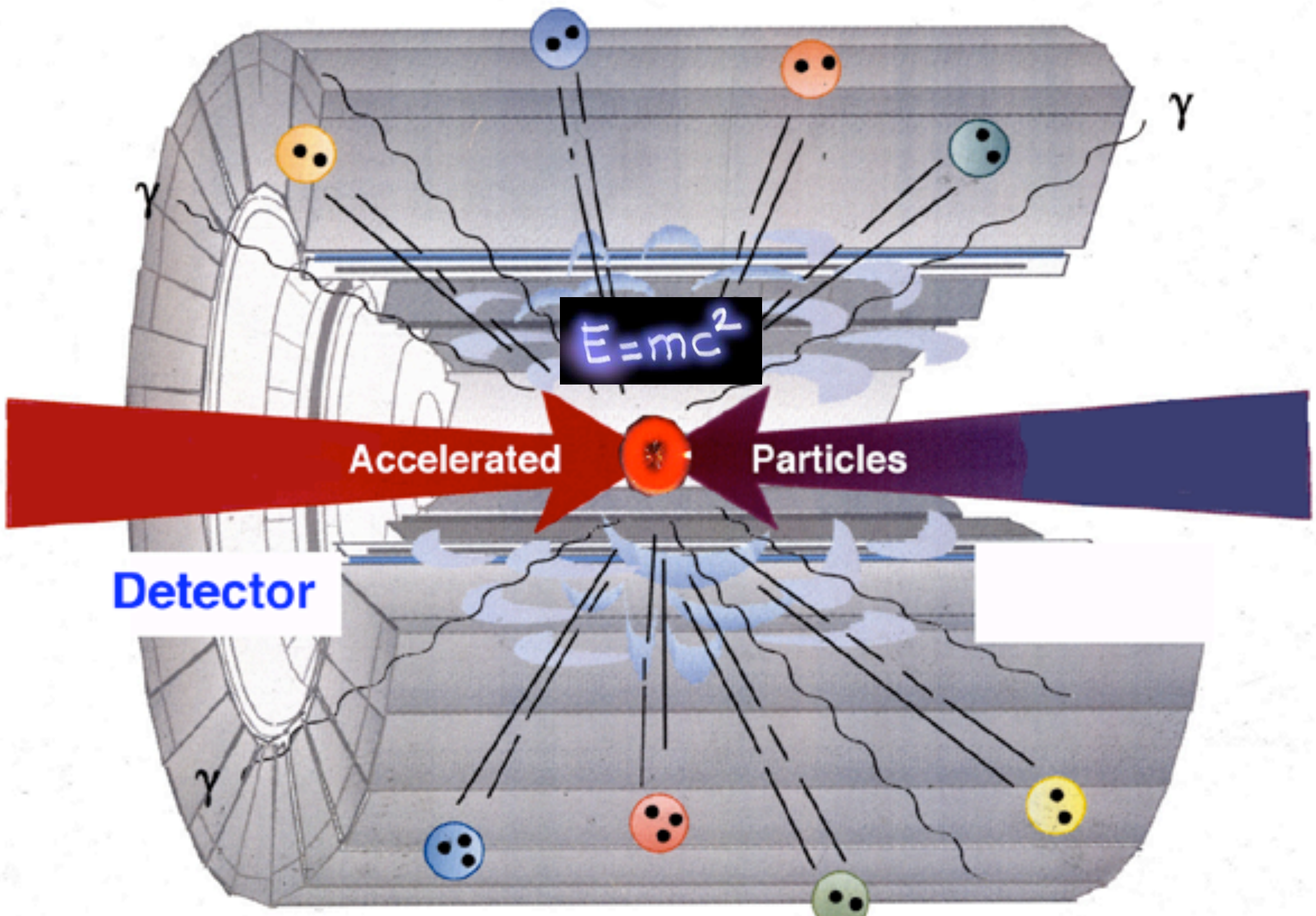
- The eye of a needle is 0.3 mm in diameter, the proton beams at the interaction point are 10 times smaller = 0.03 mm in diameter

- The energy of a single 7 TeV proton is equivalent to a flying mosquito 1 μJ

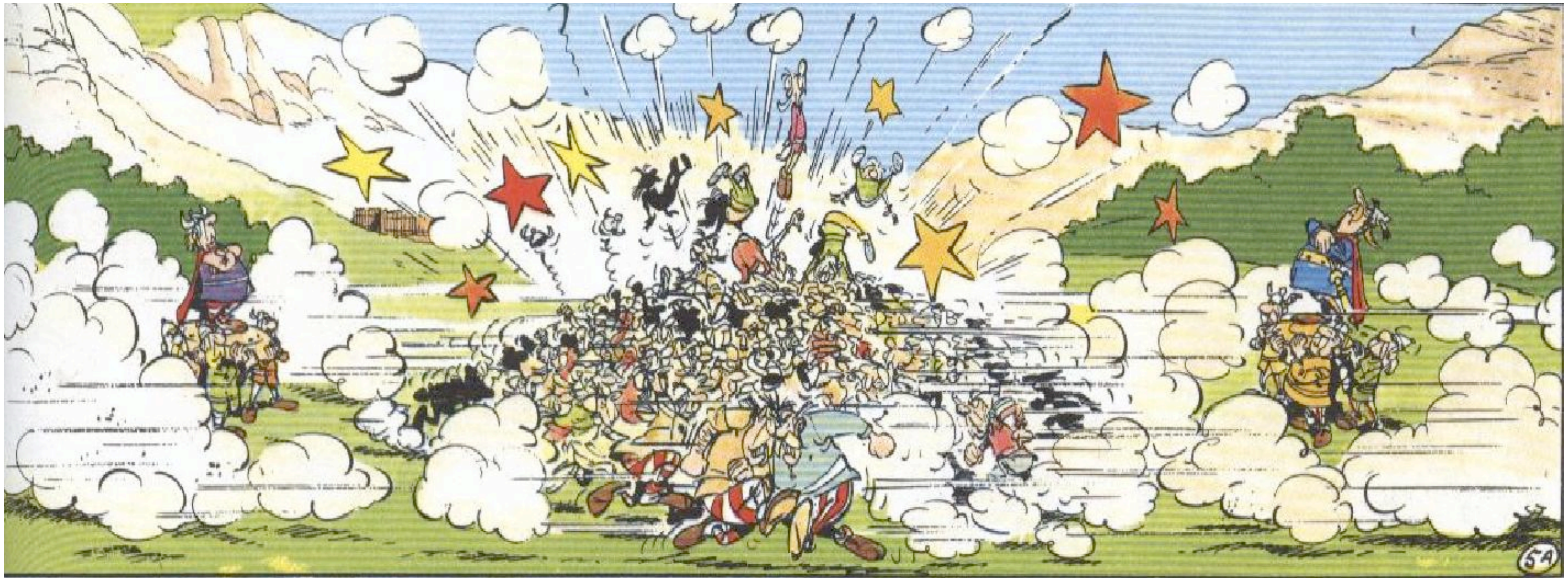


H. Pernegger

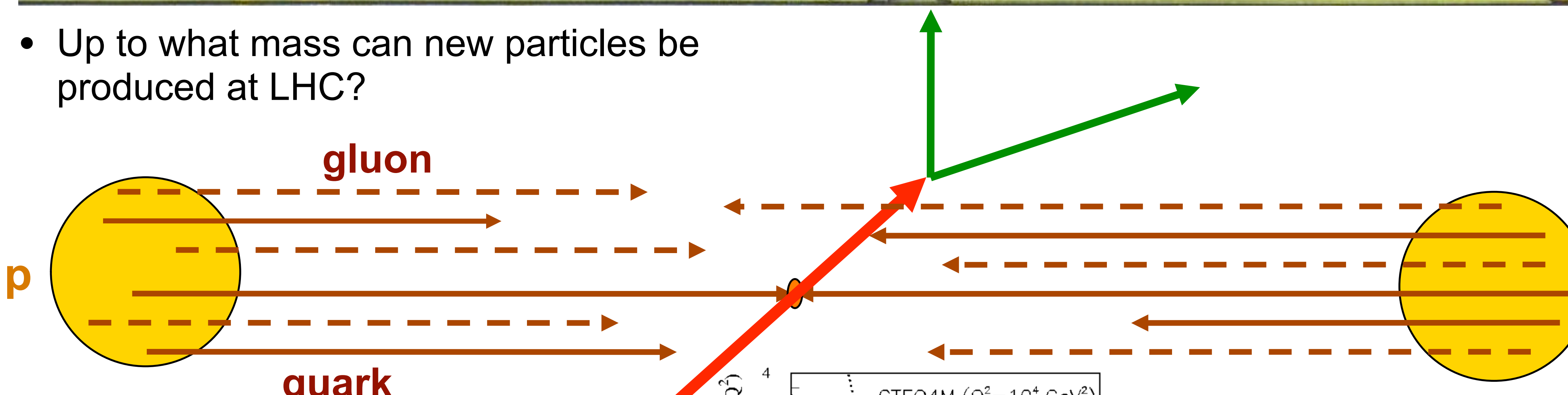
# 1. Particle Detection

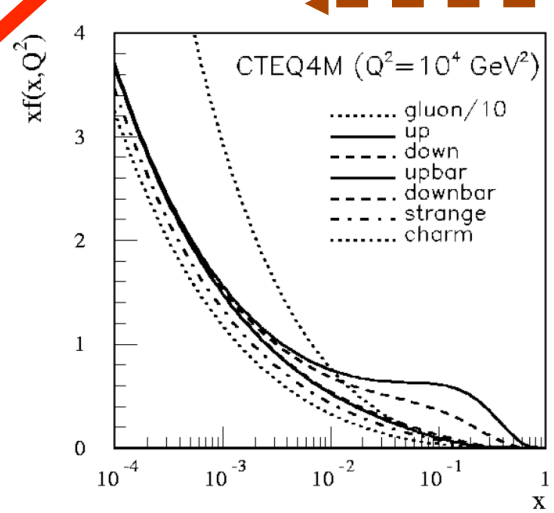


# 1. Particle Production



- Up to what mass can new particles be produced at LHC?




- spectrum ends at x ~ 0.35
- $m_{max}$ = 0.35 x 7 TeV (p) ~ 2.5 TeV

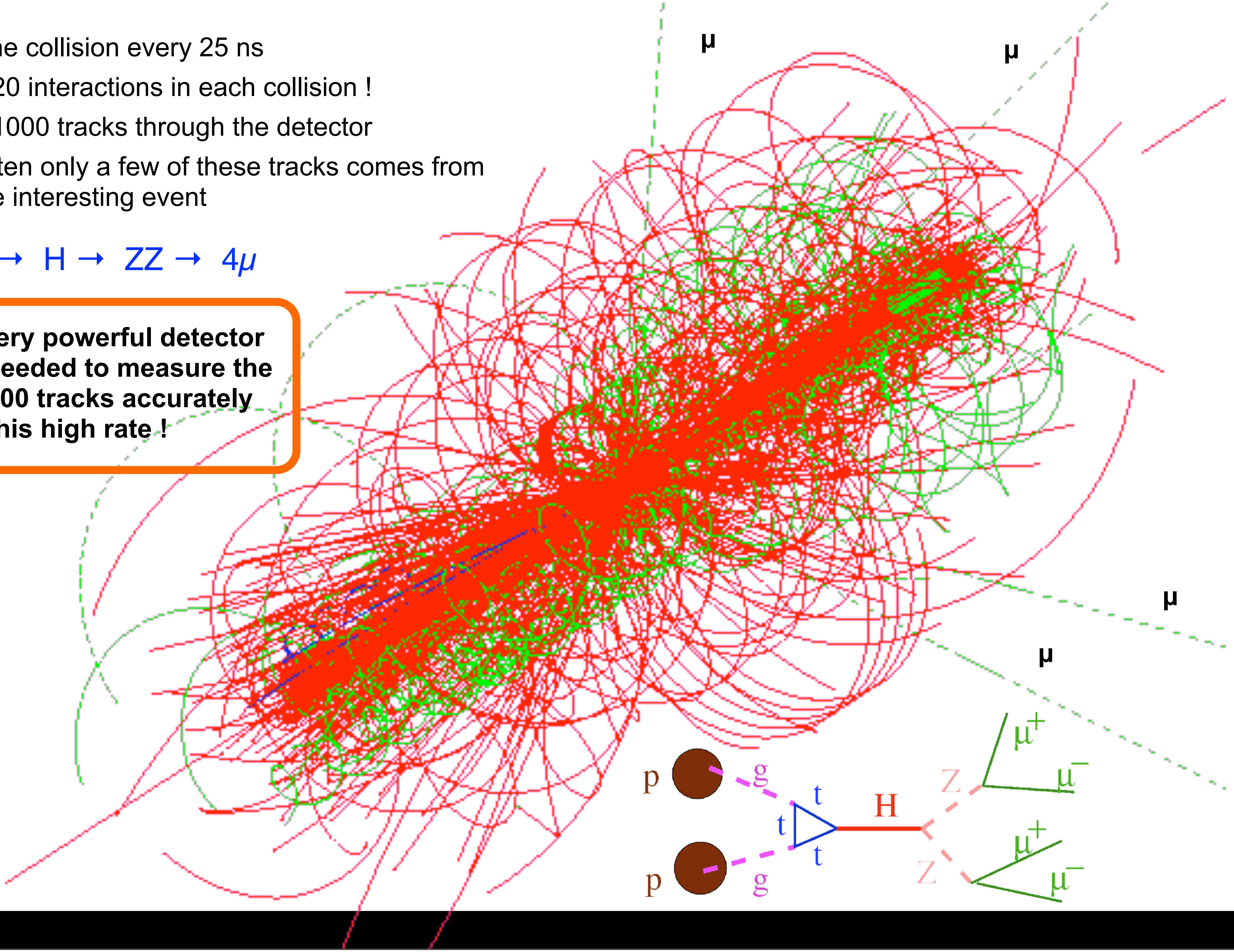
- Fraction x of proton momentum carried by partons

H. Pernegger

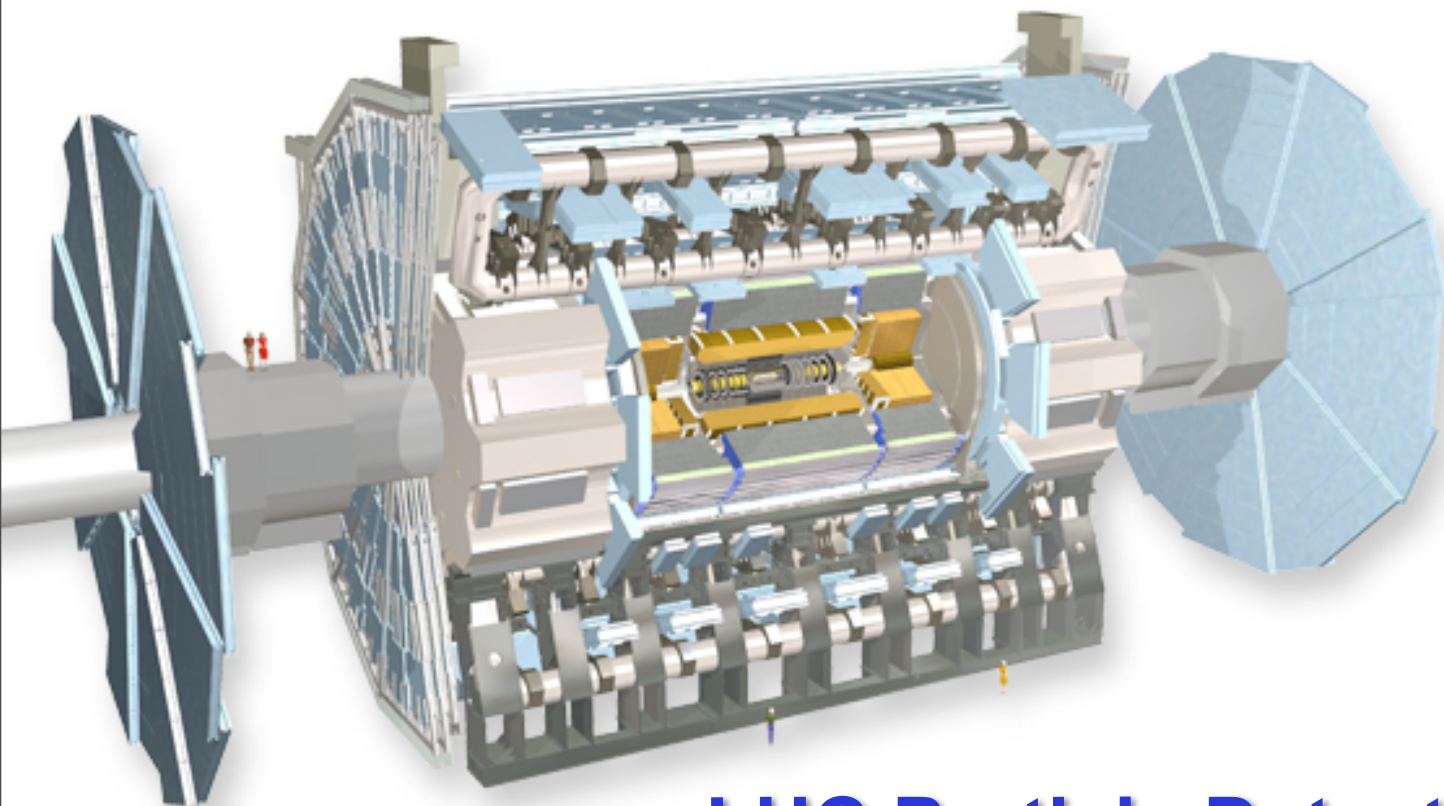
- One collision every 25 ns
- < 20 interactions in each collision !
- ~ 1000 tracks through the detector
- Often only a few of these tracks comes from the interesting event

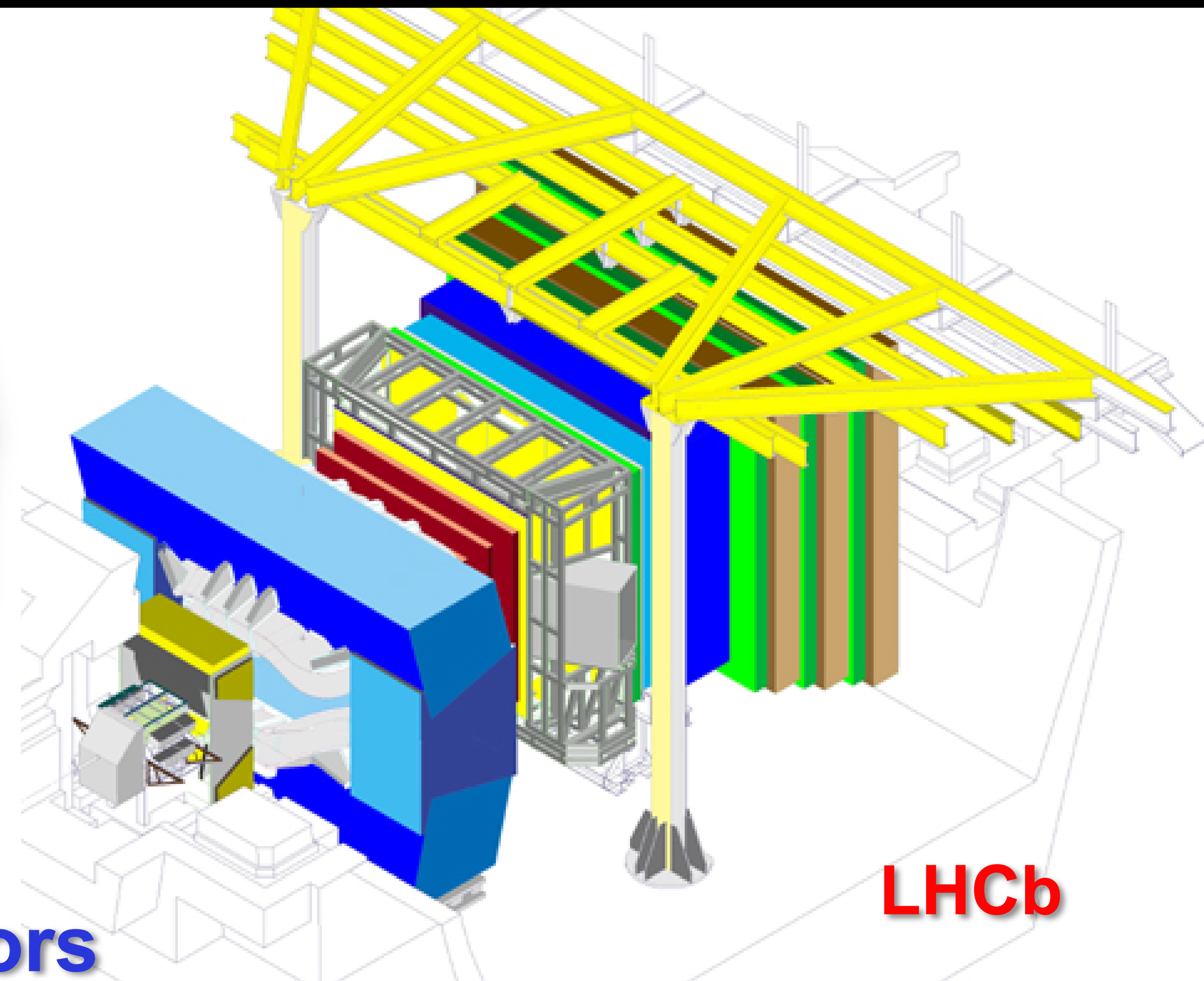
$pp \rightarrow H \rightarrow ZZ \rightarrow 4\mu$

**A very powerful detector is needed to measure the ~1000 tracks accurately at this high rate !**

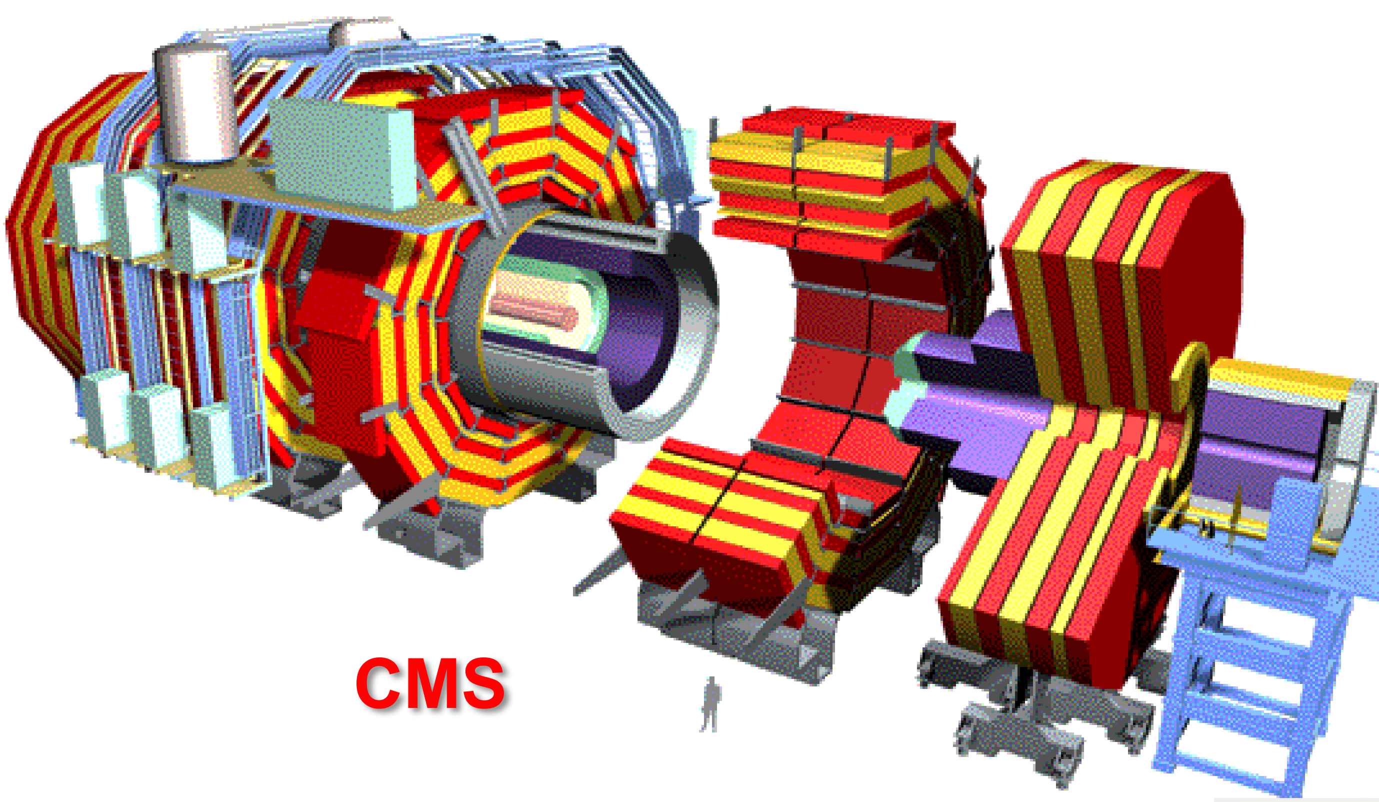


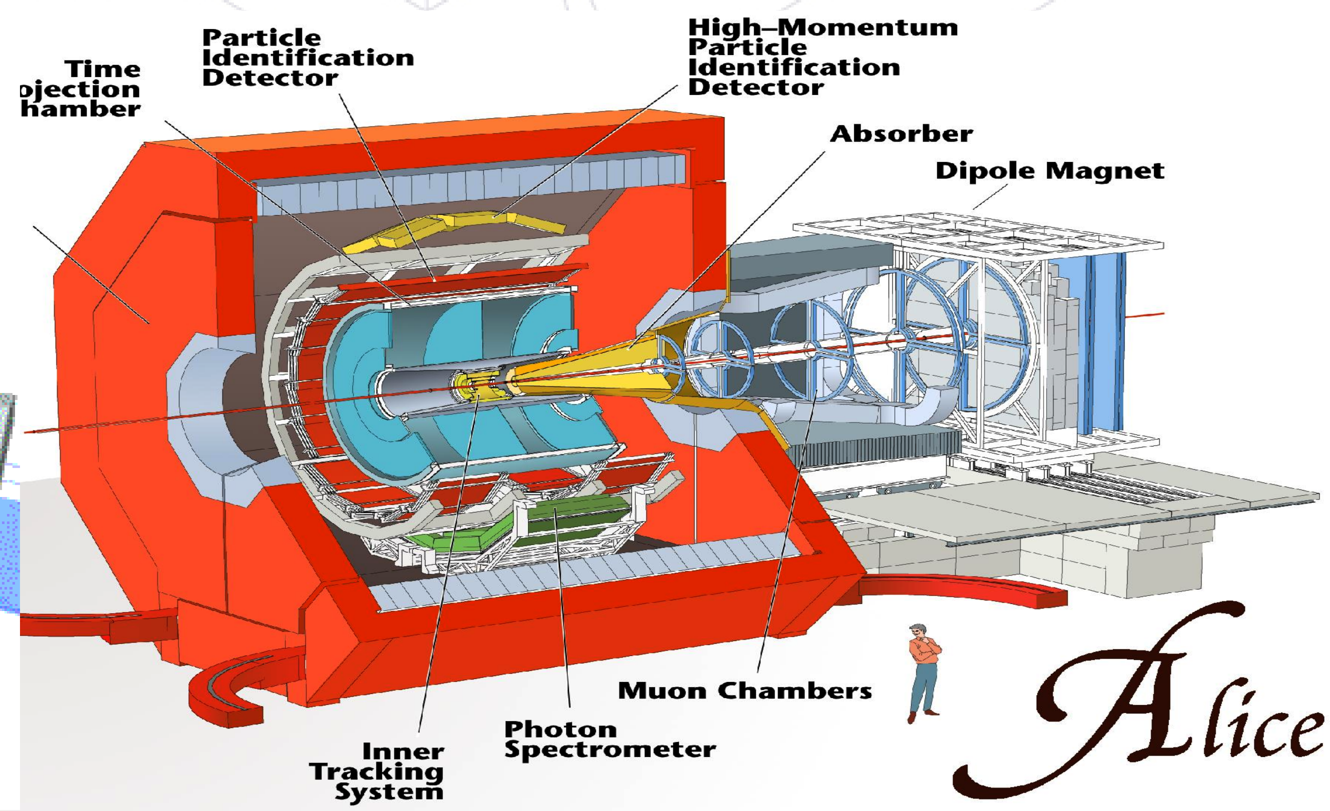
# 1. LHC detectors




## LHC Particle Detectors

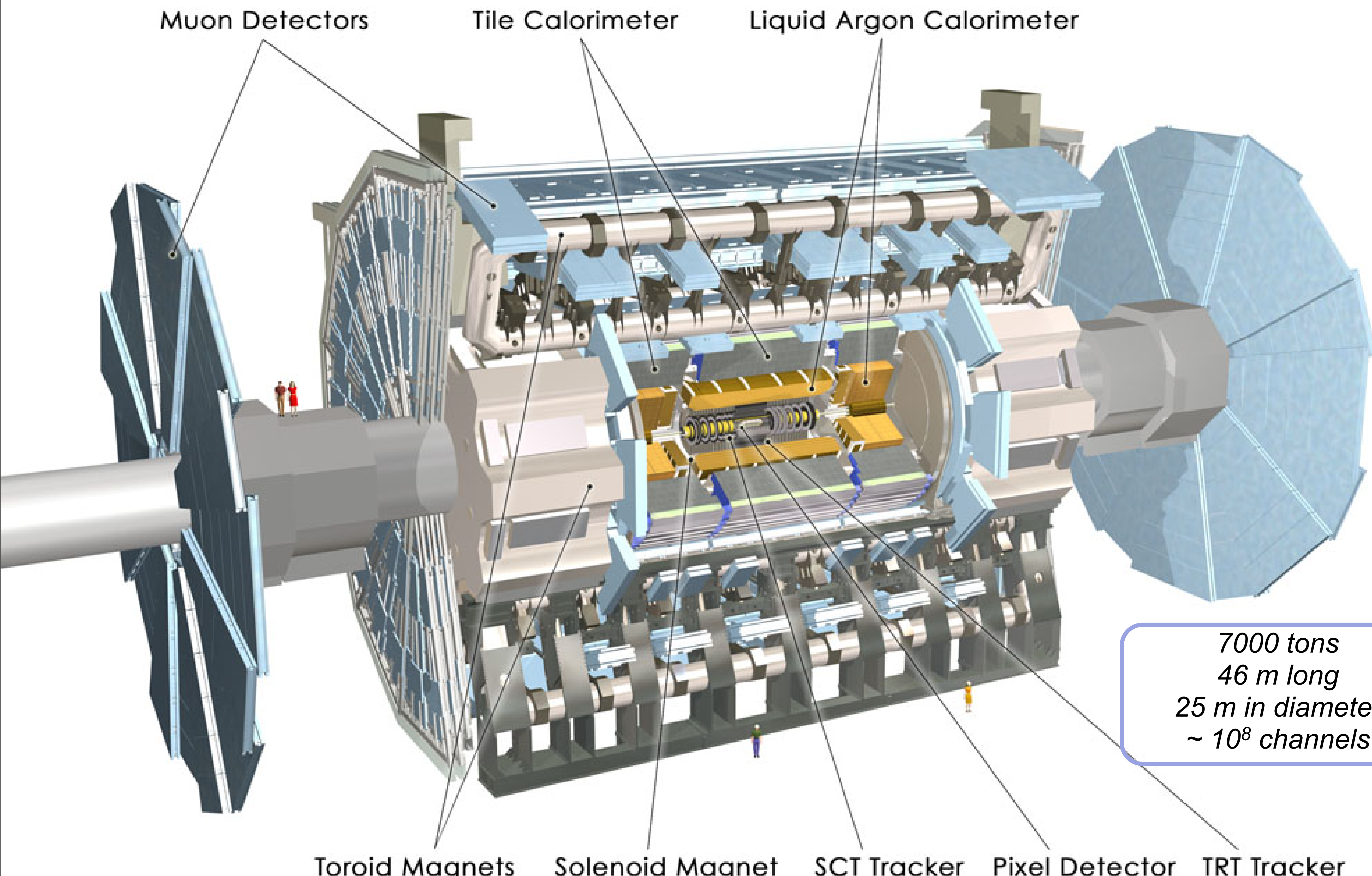


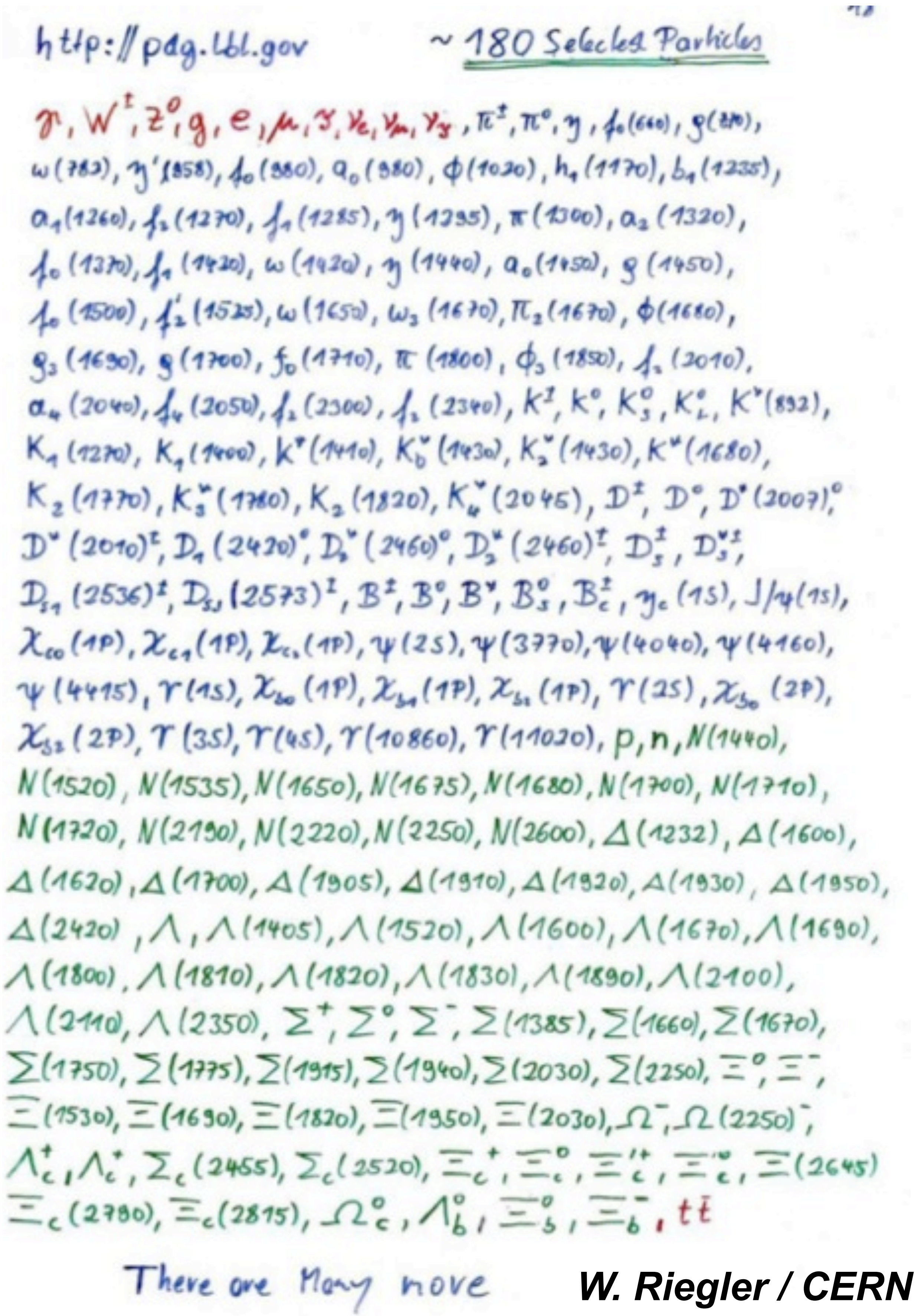
# 4. Constructing ATLAS


**35 countries**
**158 institutions**
**1770 scientific authors**
**100s of people at CERN for ~ 3 years**

# 3. Example: The ATLAS detector




*7000 tons*
*46 m long*
*25 m in diameter*
*~ $10^8$ channels*



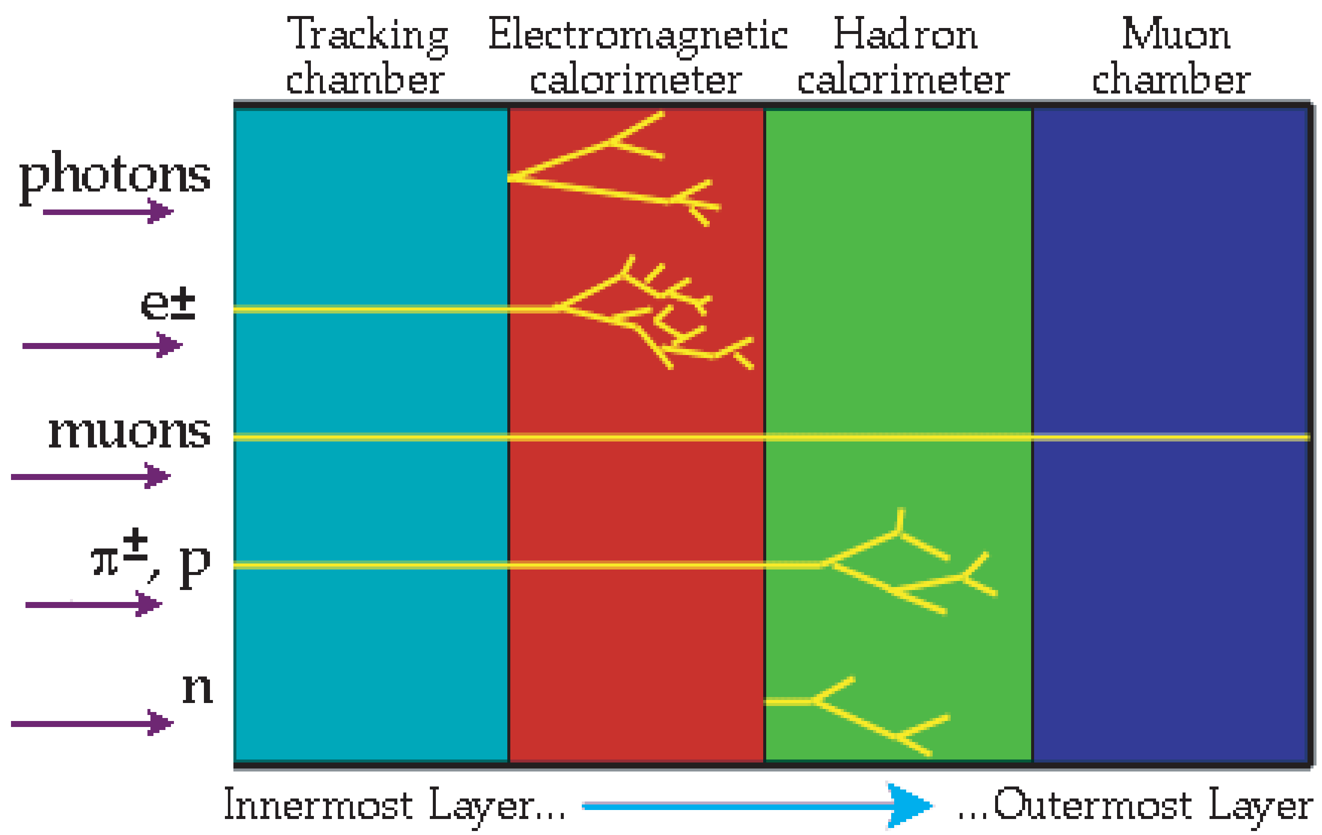

*W. Riegler / CERN*

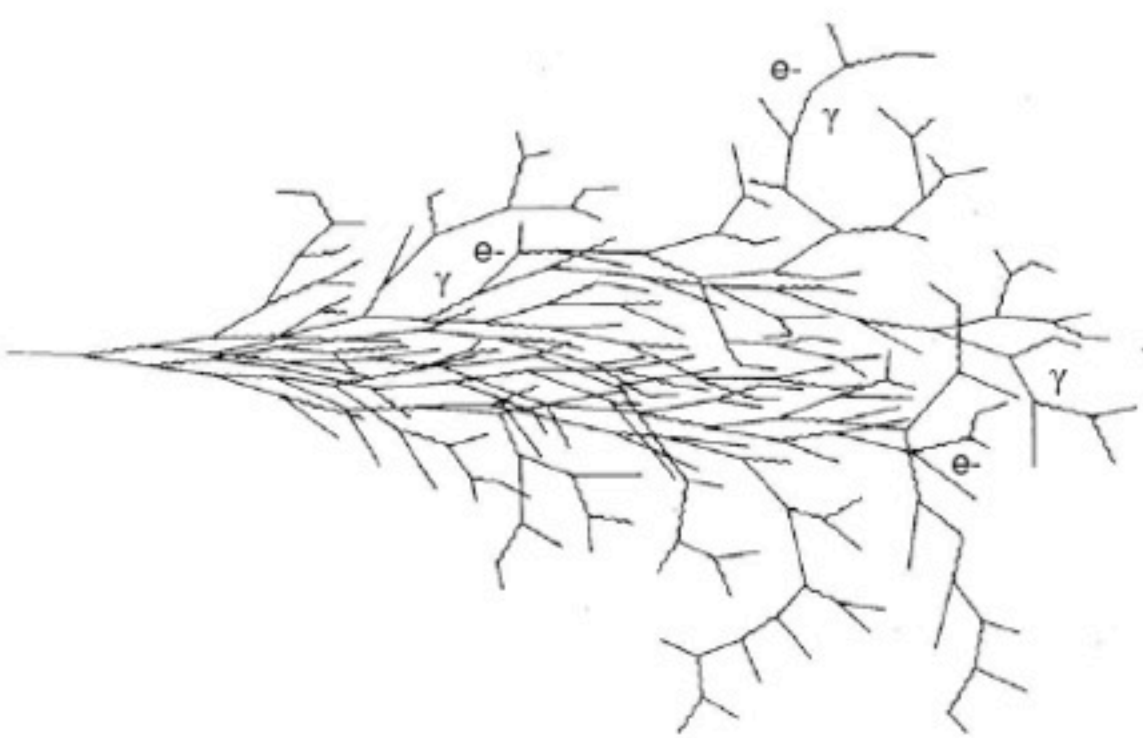
**Particle lifetimes:**

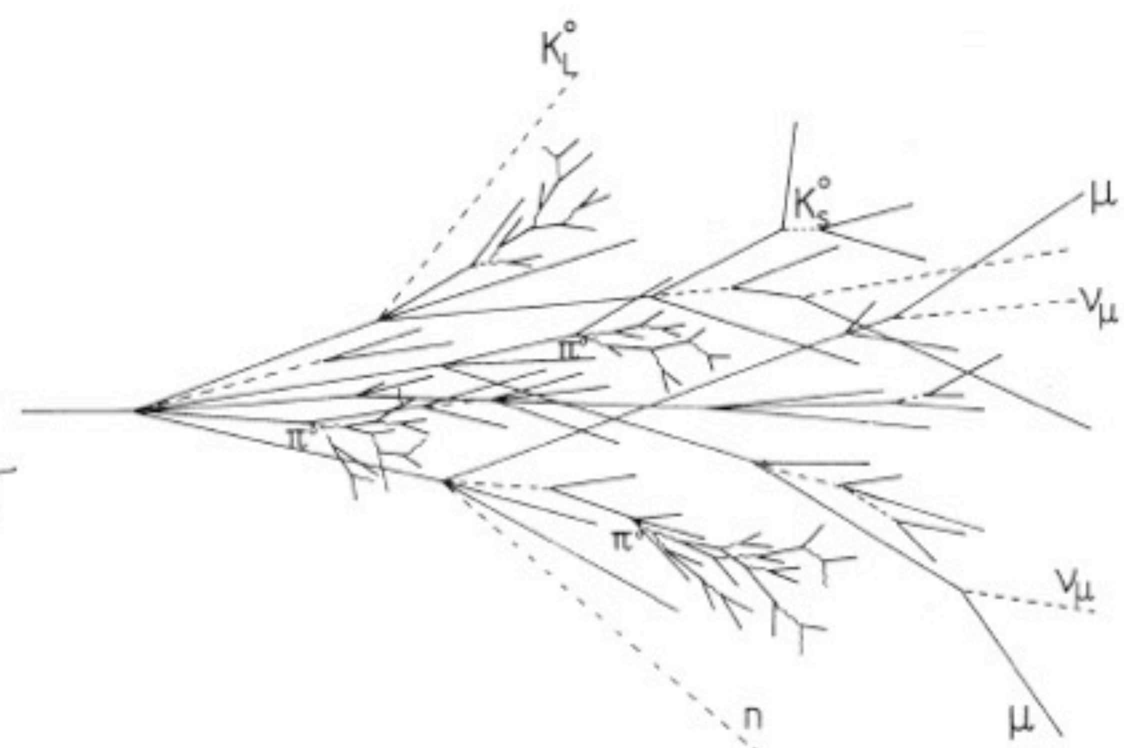
- Large number of particles !
- Only ~ 27 with a lifetime **$c\tau > 1\ \mu m$**, which we can see as tracks in the detector
- ~ 13 of these have **$c\tau < 500\ \mu m$**, very short tracks
- From the ~14 remaining particles only 8 are very frequent:
- $e^{+/-}$, $\mu^{+/-}$, $\gamma$, $\pi^{+/-}$, $K^{+/-}$, $K^0$, $p^{+/-}$, n
- A particle detector must be able to identify and measure energy and momentum of these 8 particles !

**Although many particles are produced in the collisions only a few live long enough to move through the detector !**

- Electrons ionise and show **bremsstrahlung** due to the small mass
- Photons don't ionise but show **pair production** in high Z material
- Charged hadrons ionise and produce a shower in dense materials
- Neutral hadrons don't ionise and produce a **shower** in dense material
- Muons ionise and **don't** produce a **shower**
- **Magnetic fields to bend the tracks !**



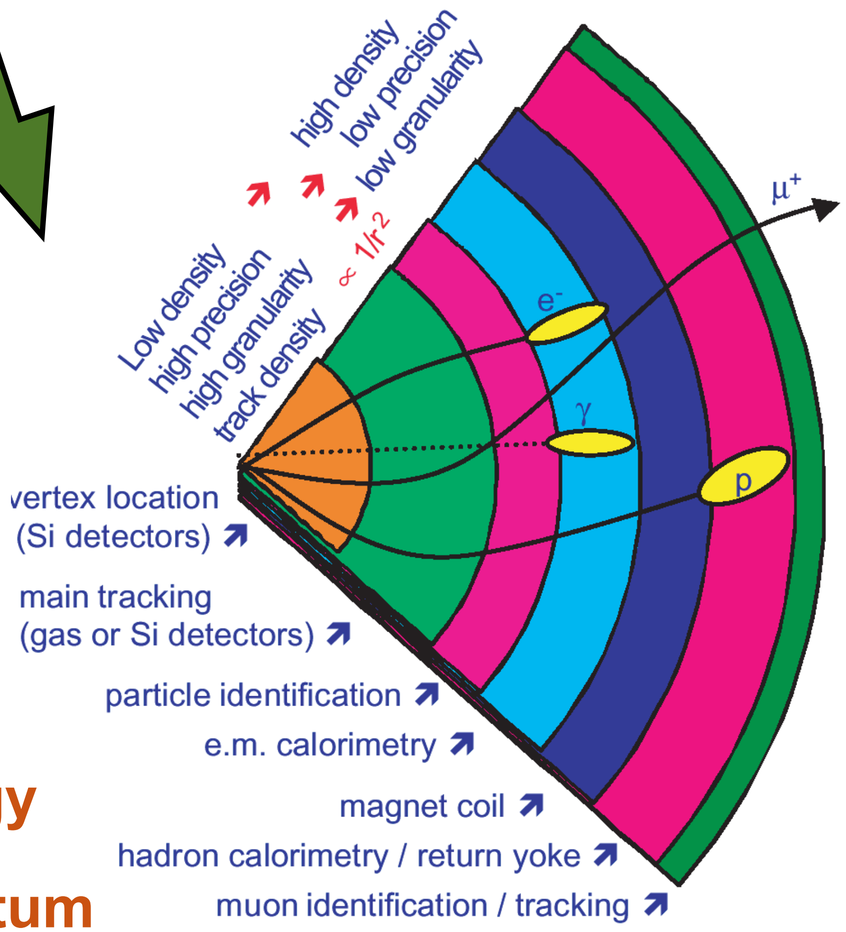



# 2. Detecting Particles

**To collect all information from all particles we build a 4 π multipurpose detector**

**... and use different layer to find different parameters**

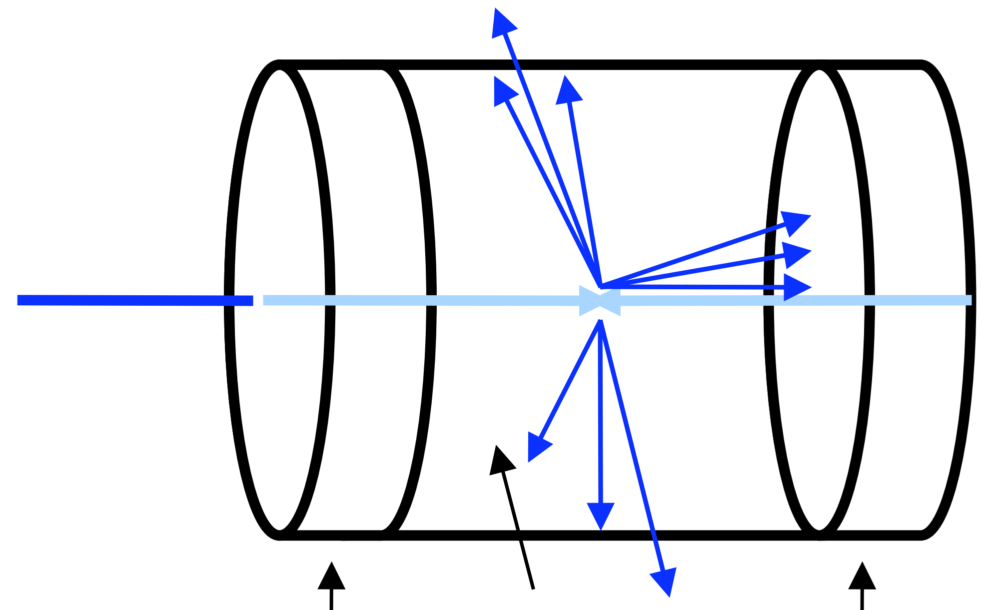



**Momentum**

**Identity**

**Energy**

**Momentum**



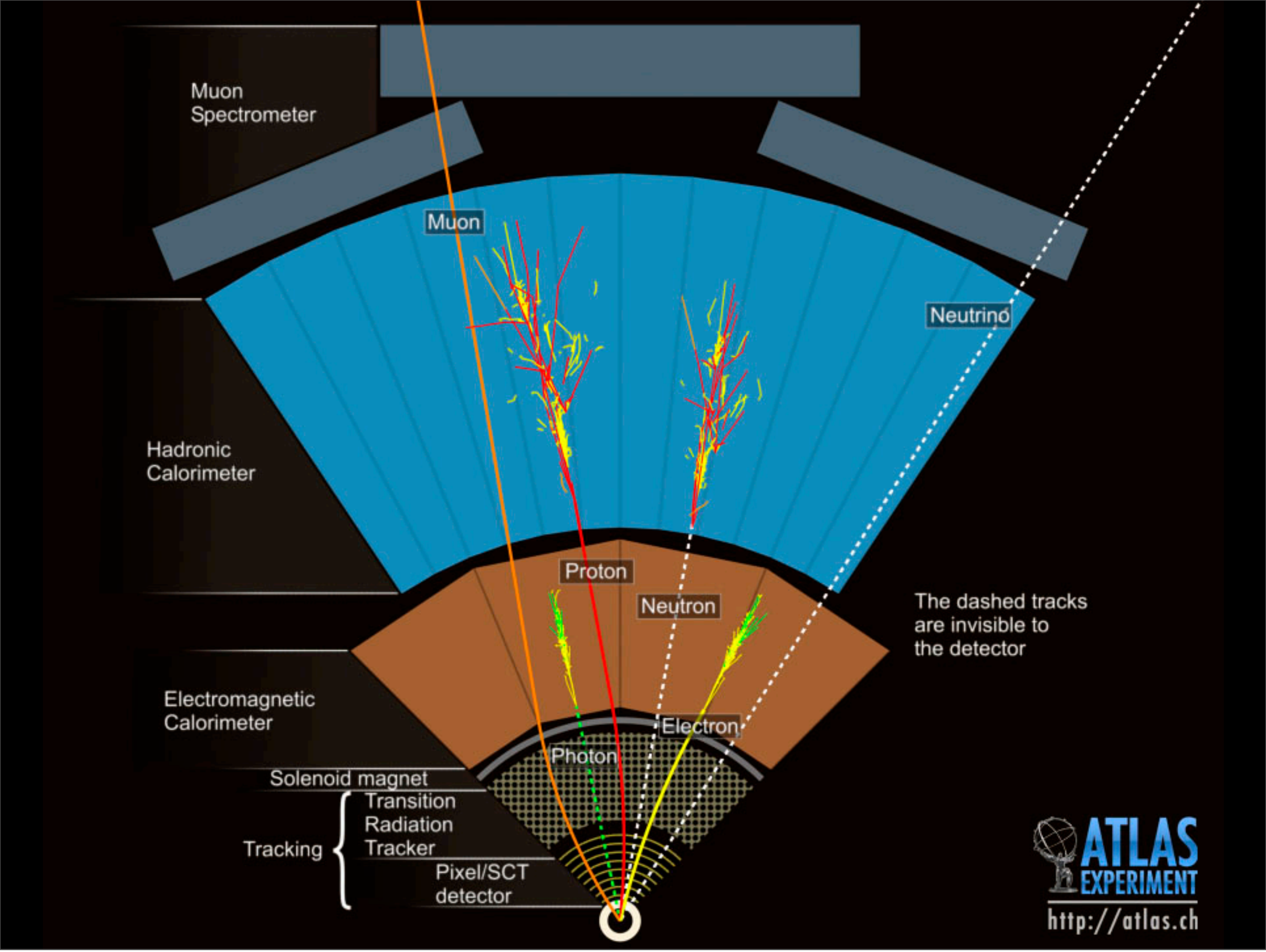
**barrel +**
**2 endcap**

**What do we need to know about each particle in a collision?**

- **Charge**
- **Mass**
- **Momentum-vector**

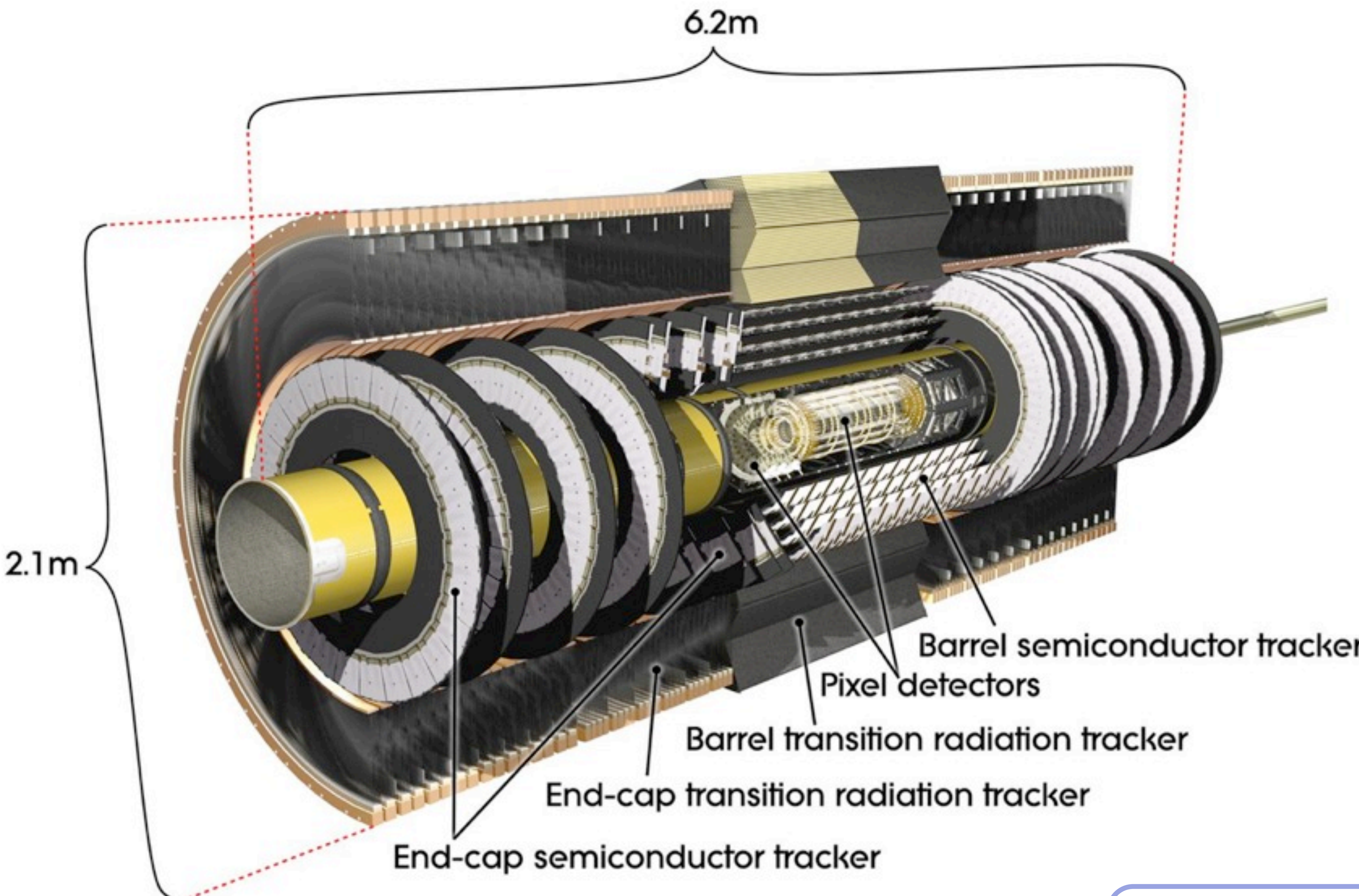
**A perfect detector would reconstruct any type of interaction with 100 % efficiency and unlimited resolution !**

- But not all particles are detected
  - Neutrinos escape (missing energy) !
  - Some particles goes through non sensitive detector areas (pipes, cables, electronics, cooling, mechanics)



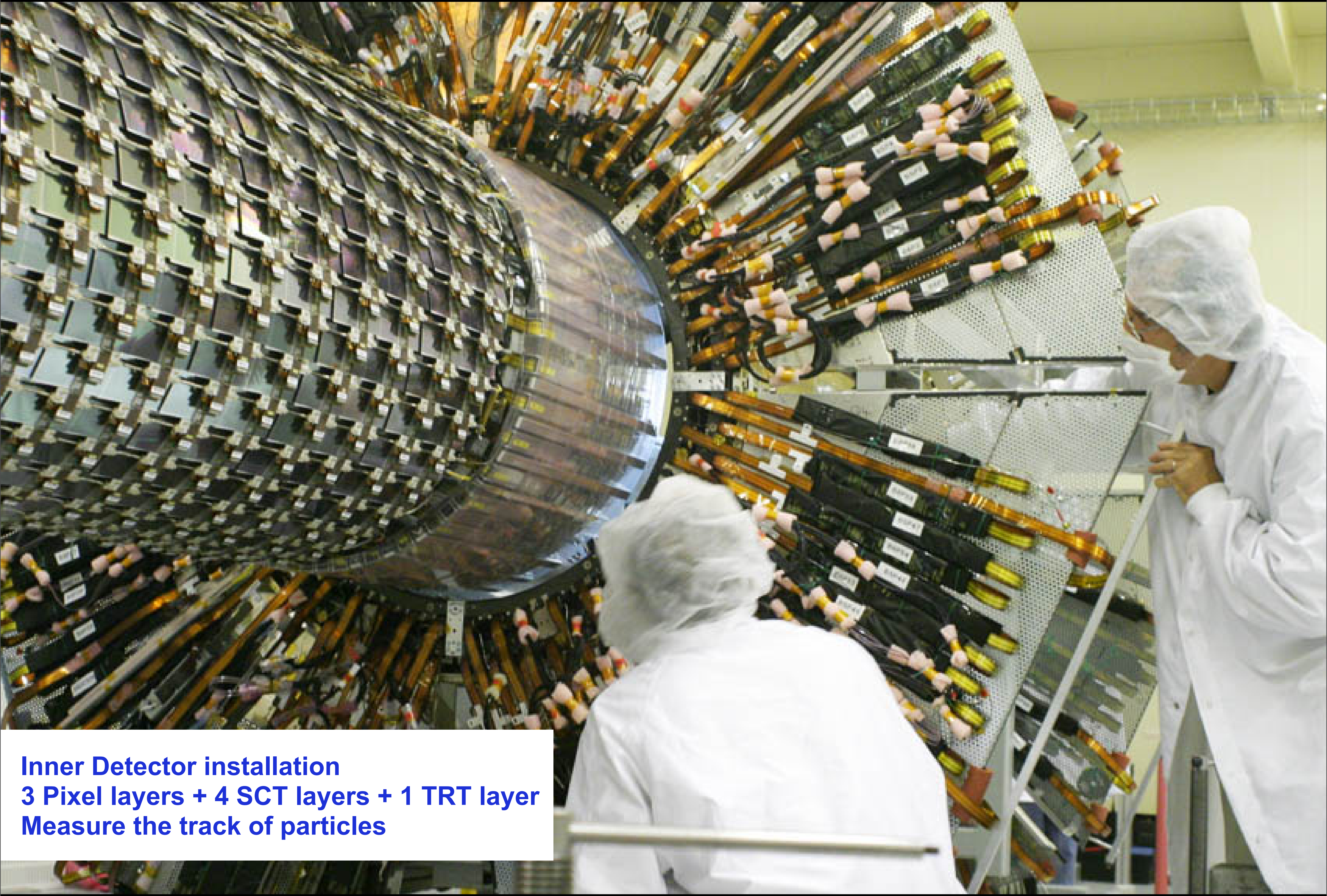
Muon Spectrometer
Hadronic Calorimeter
Electromagnetic Calorimeter
Solenoid magnet
Tracking
Transition Radiation Tracker
Pixel/SCT detector
Muon
Neutrino
Proton
Neutron
Electron
Photon
The dashed tracks are invisible to the detector
ATLAS EXPERIMENT
http://atlas.ch

# *Inner Detector*



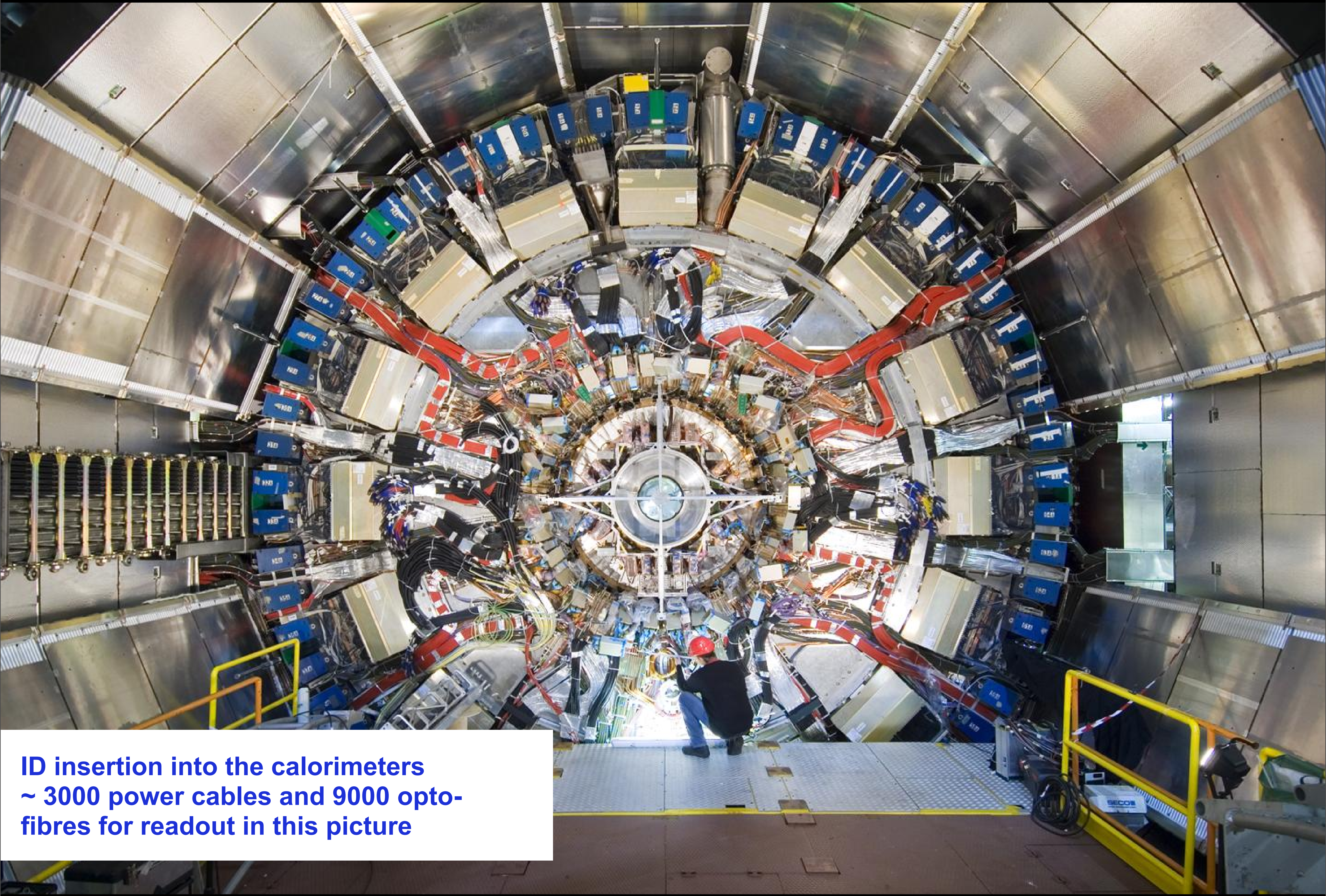

2T solenoid field

# 4. Constructing ATLAS



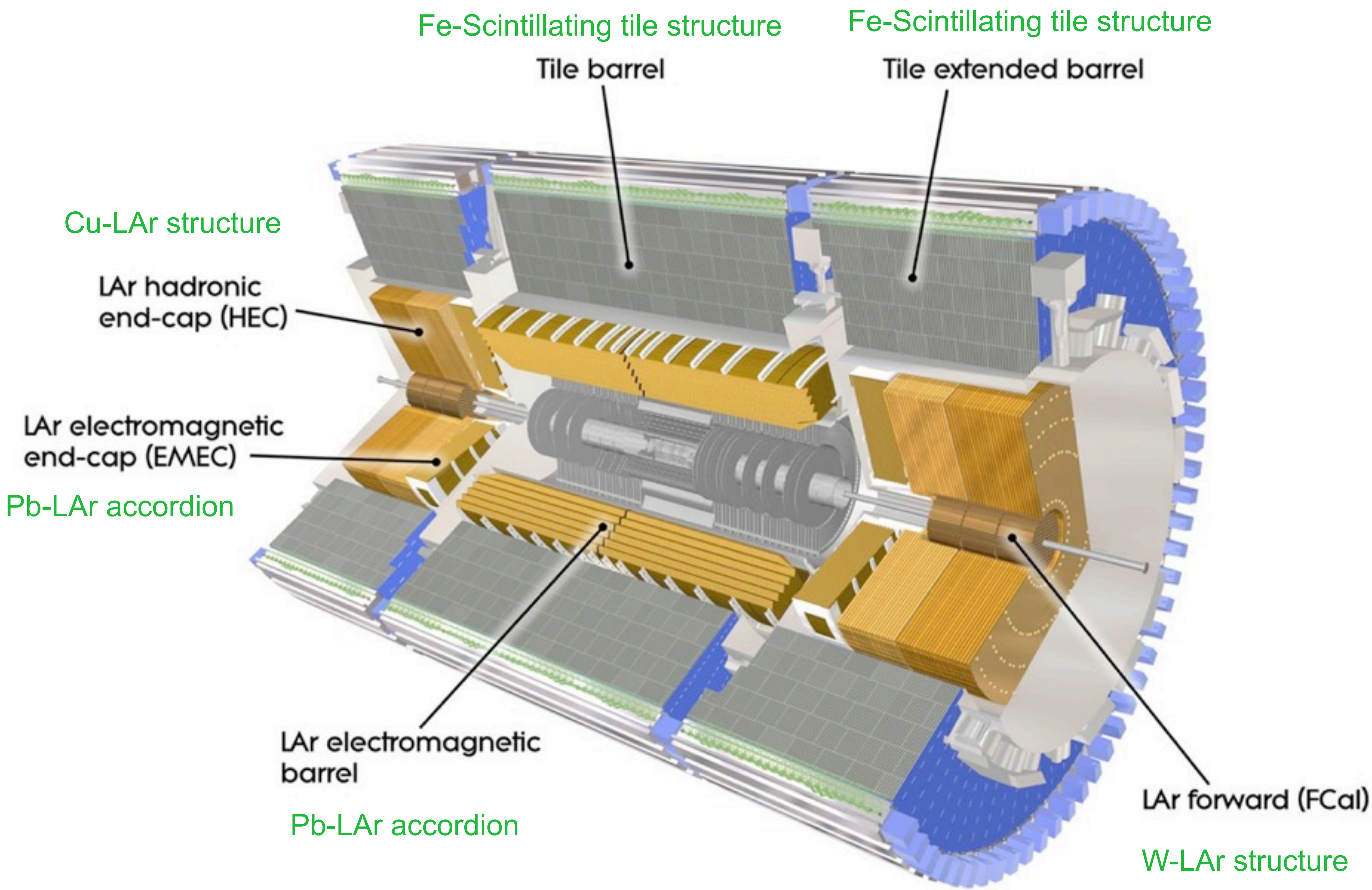
**Inner Detector installation**
**3 Pixel layers + 4 SCT layers + 1 TRT layer**
**Measure the track of particles**

# 4. Constructing ATLAS

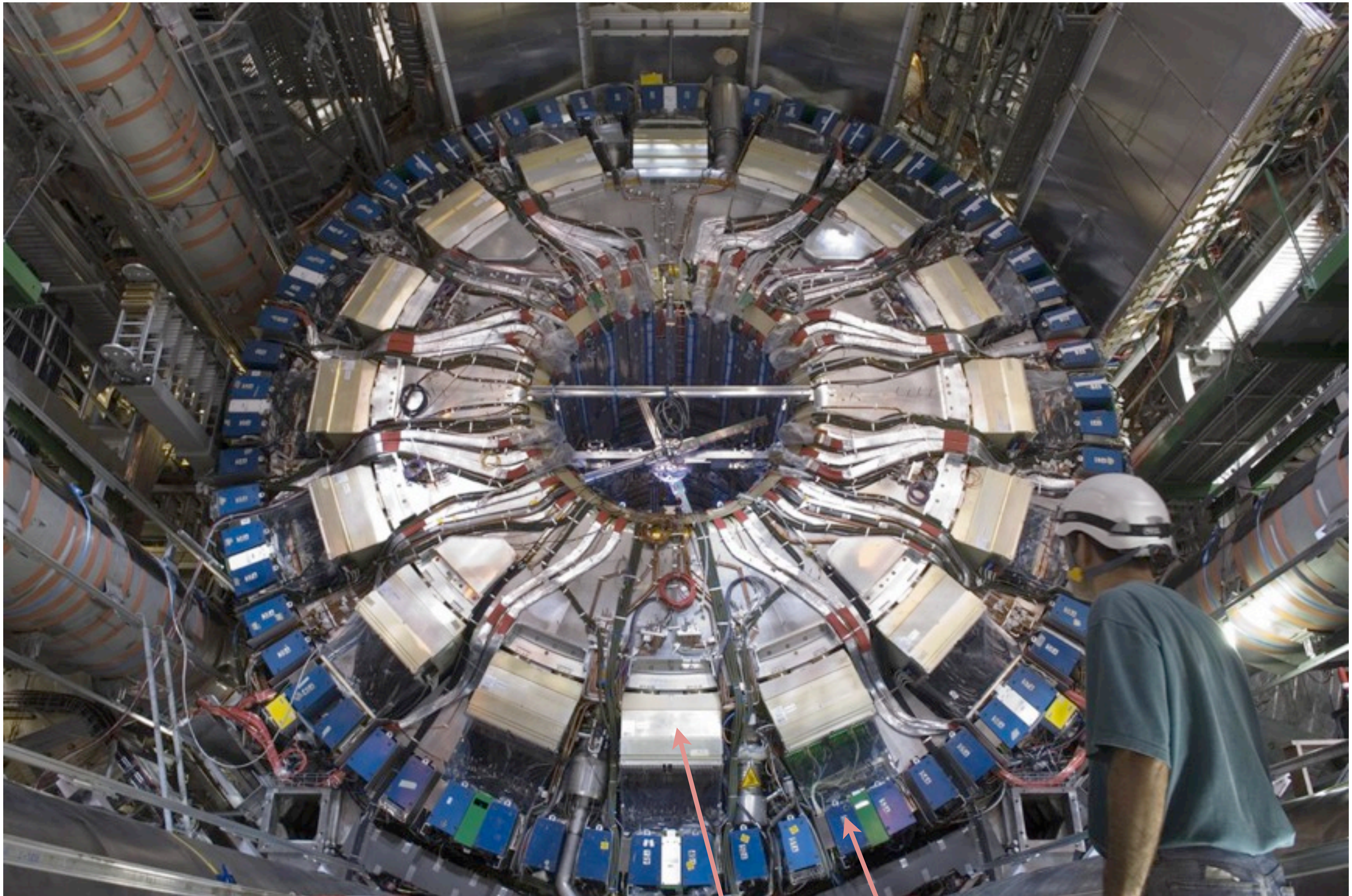


**ID insertion into the calorimeters**
**~ 3000 power cables and 9000 opto-fibres for readout in this picture**

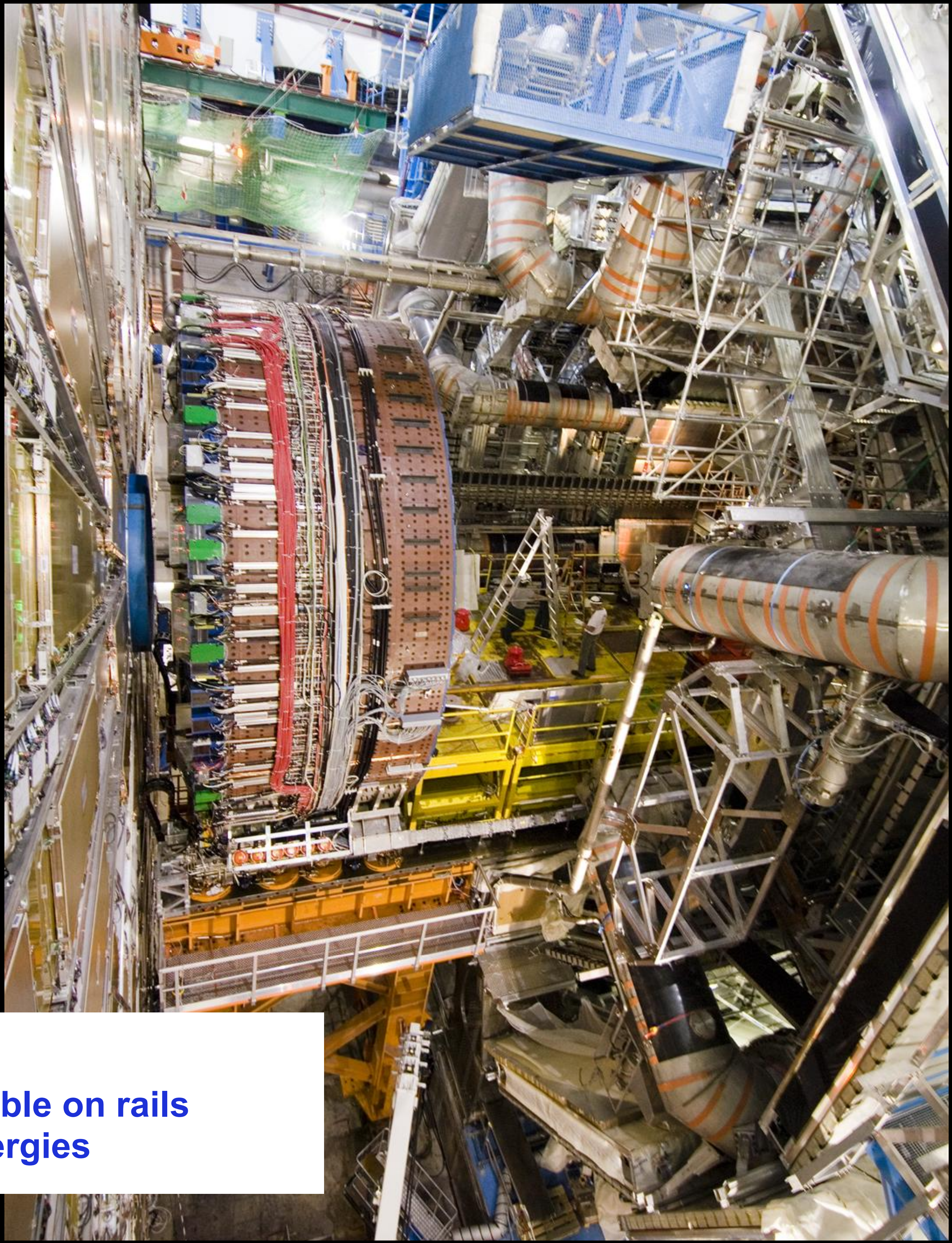
# *Calorimeters*



*Calorimeters*

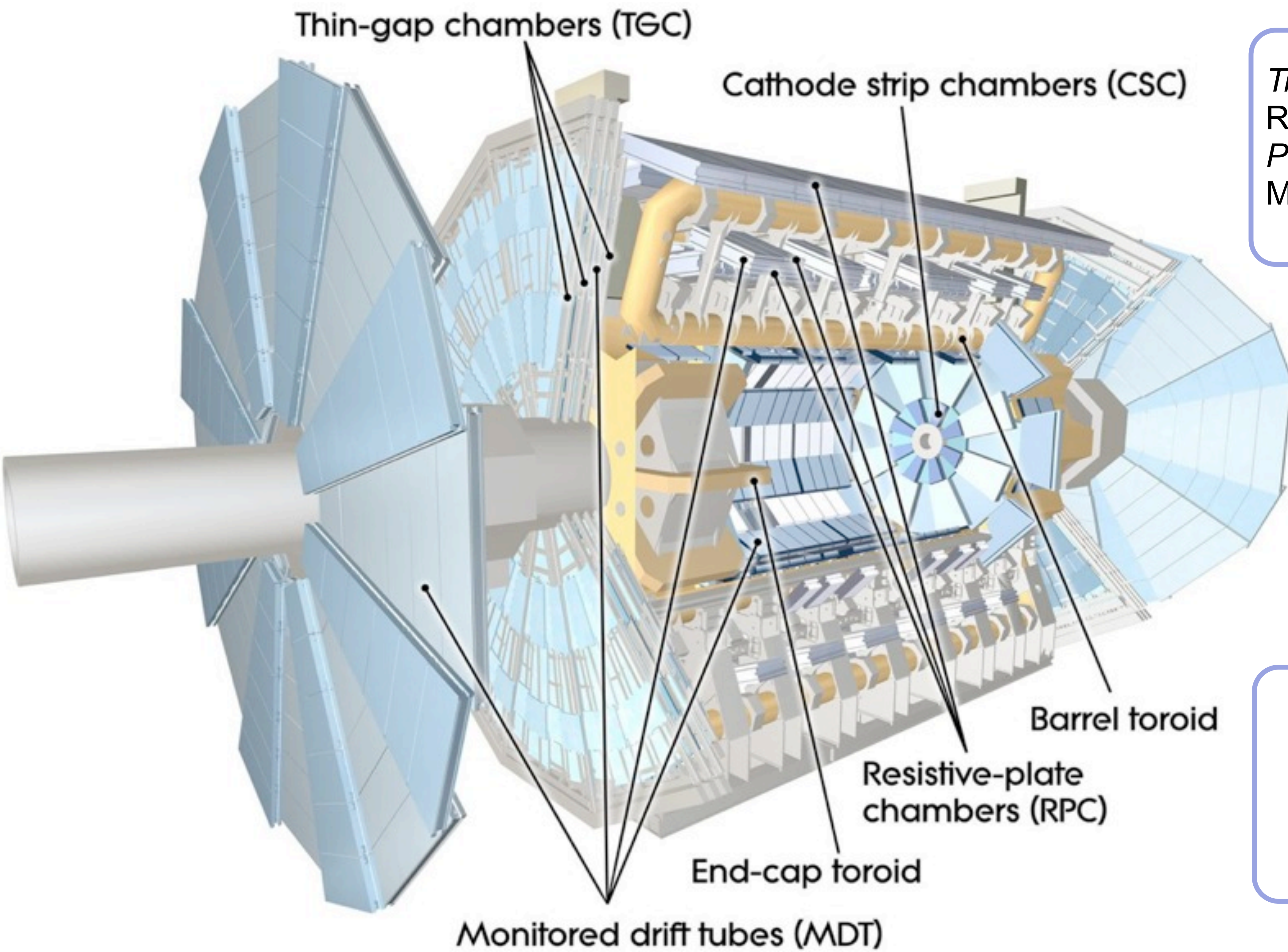


# 4. Constructing ATLAS



**Calorimeter installation**
**Barrel + 2 endaps, movable on rails**
**Measure the particle energies**

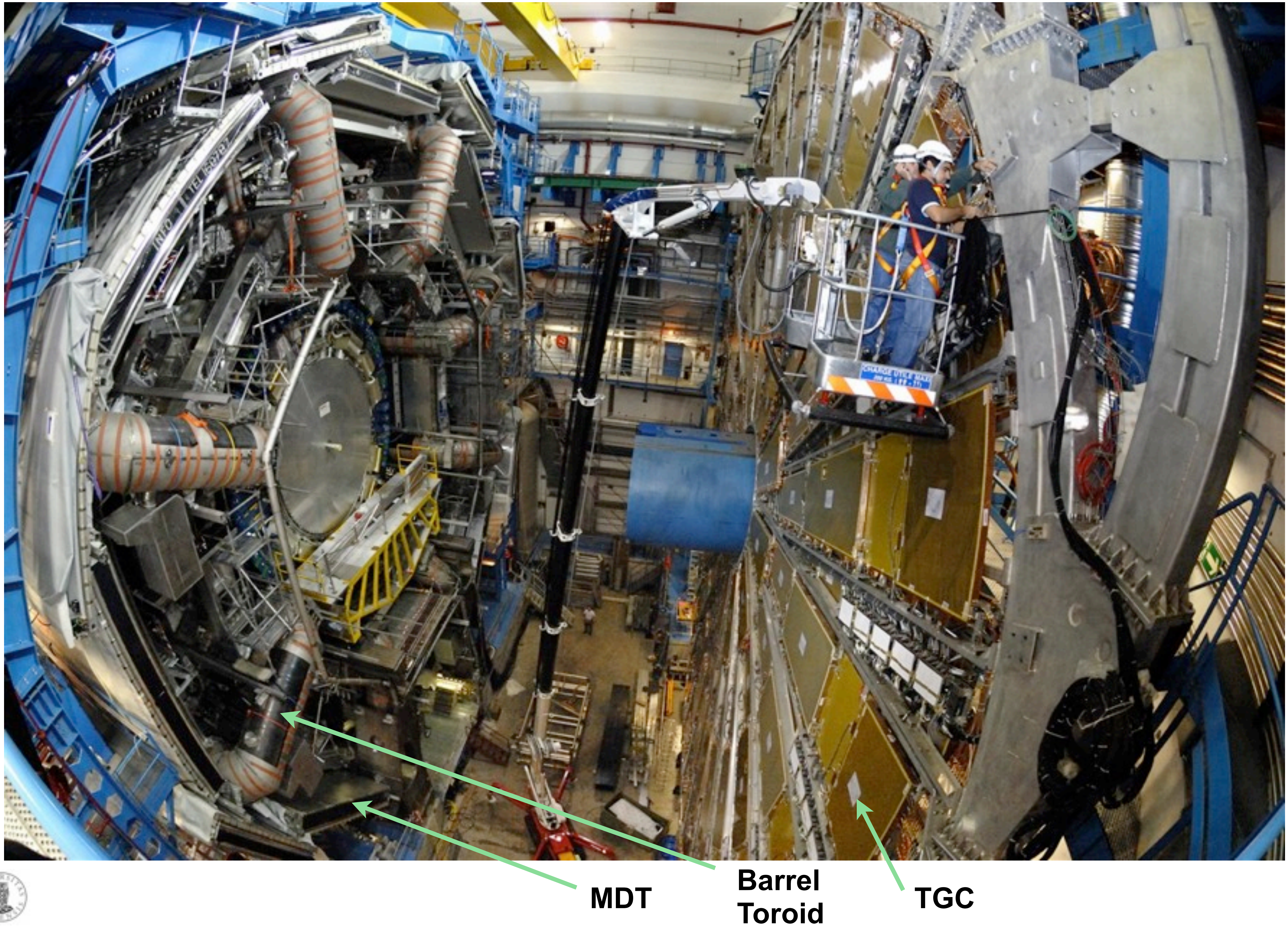
# *Muon Spectrometer*




*Triggers*:
RPC and TGC
*Precision*:
MDT and CSC

Toroid field:
Peak field 4 T
Bending power
~ 2-5 Tm

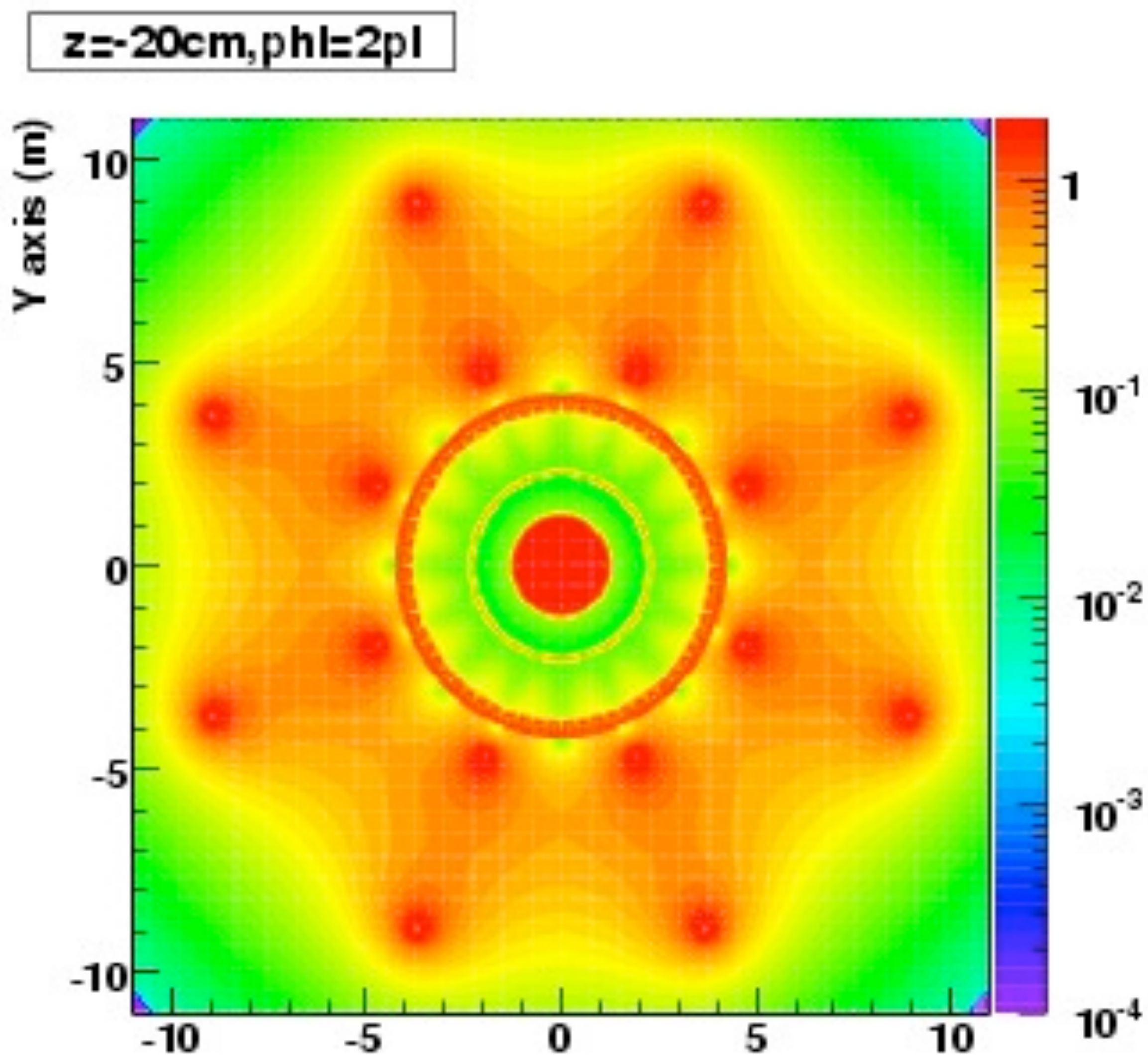
# *Muon Spectrometer*

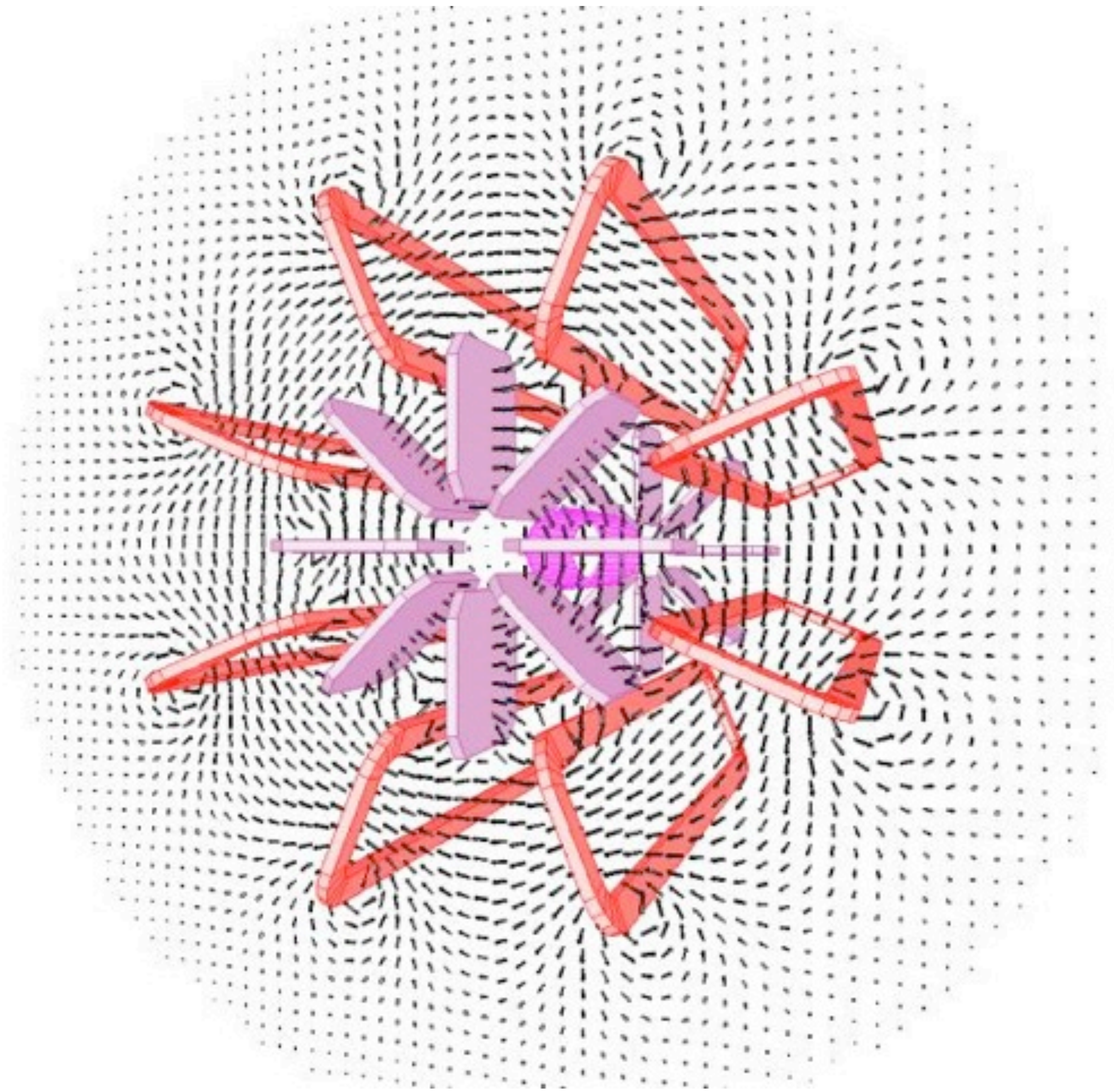


# 4. Constructing ATLAS

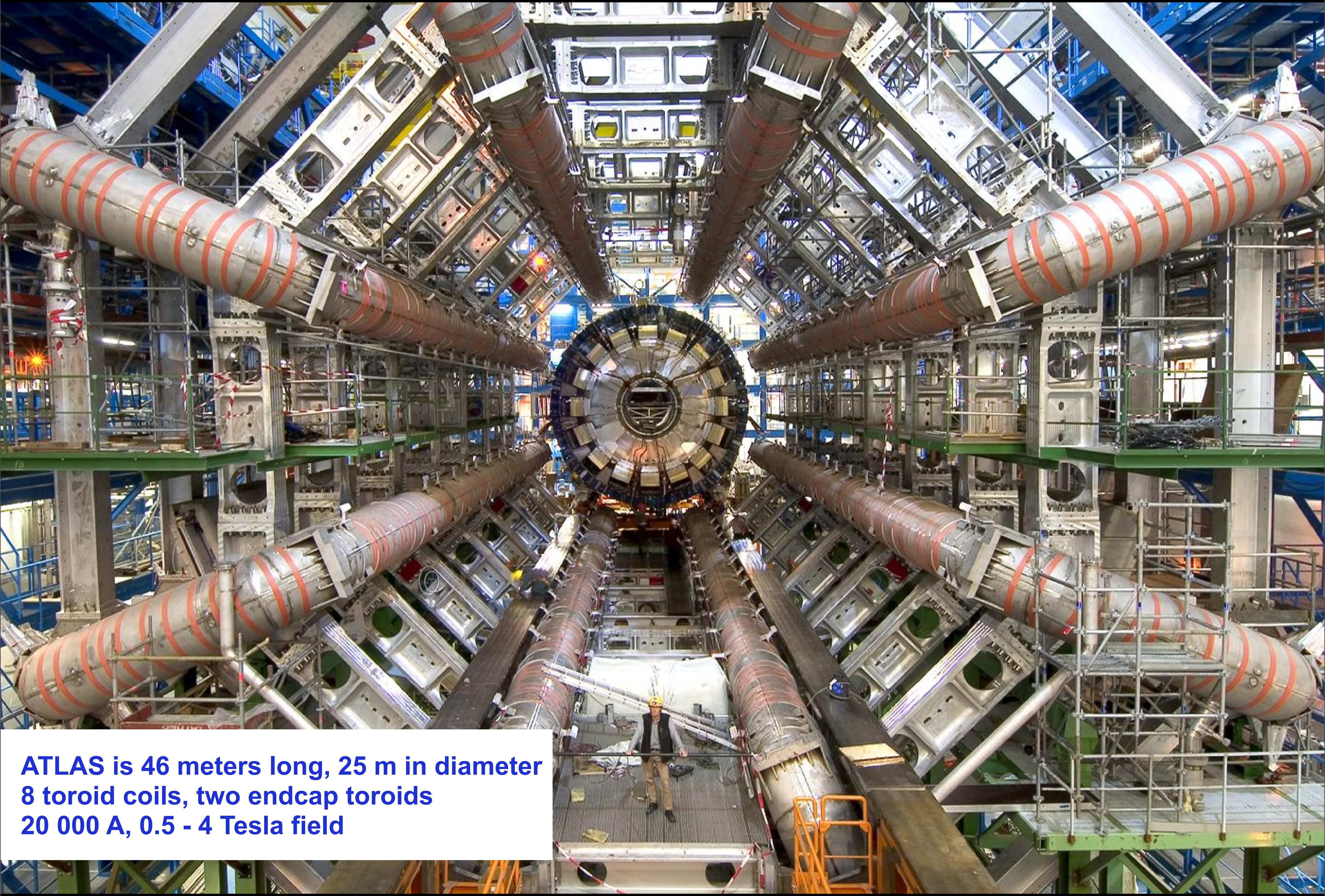
## *Magnet system*

Solenoid field: 2T
Toroid field: Peak field 4 T,  Bending power ~ 2-5 Tm



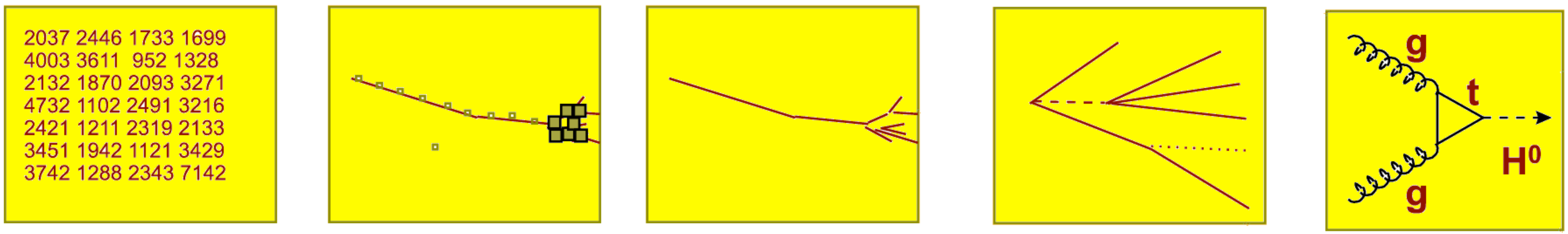



# 4. Constructing ATLAS



ATLAS is 46 meters long, 25 m in diameter
8 toroid coils, two endcap toroids
20 000 A, 0.5 - 4 Tesla field

# From raw data to physics




| Raw data | Detector response | Interaction with detector material | Fragmentation Decay | Basic physics |
|---|---|---|---|---|
| Convert to physics quantities | apply calibration, alignment | Pattern, recognition, Particle identification | Physics analysis | Results |

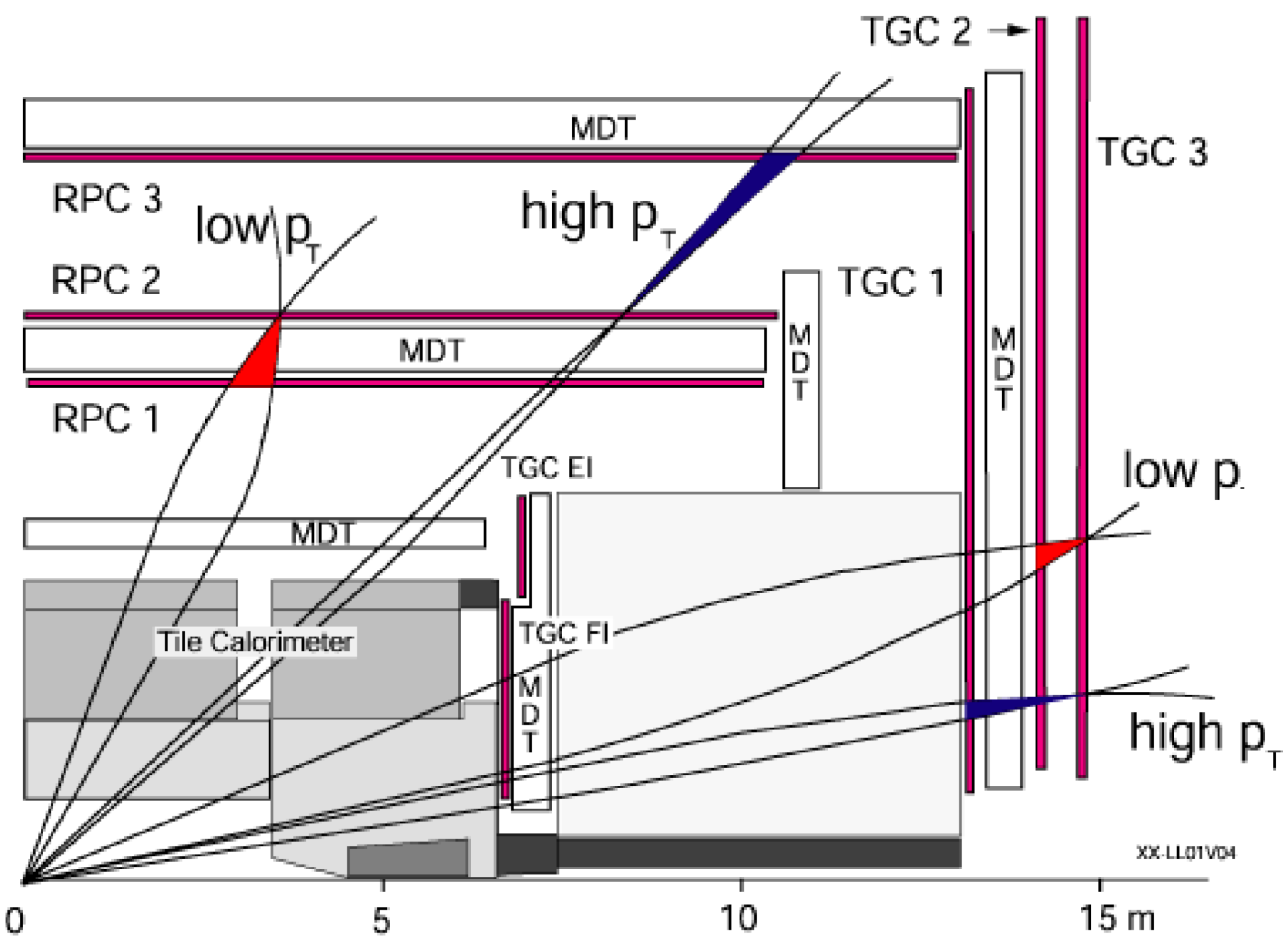
**Reconstruction** → **Analysis** →

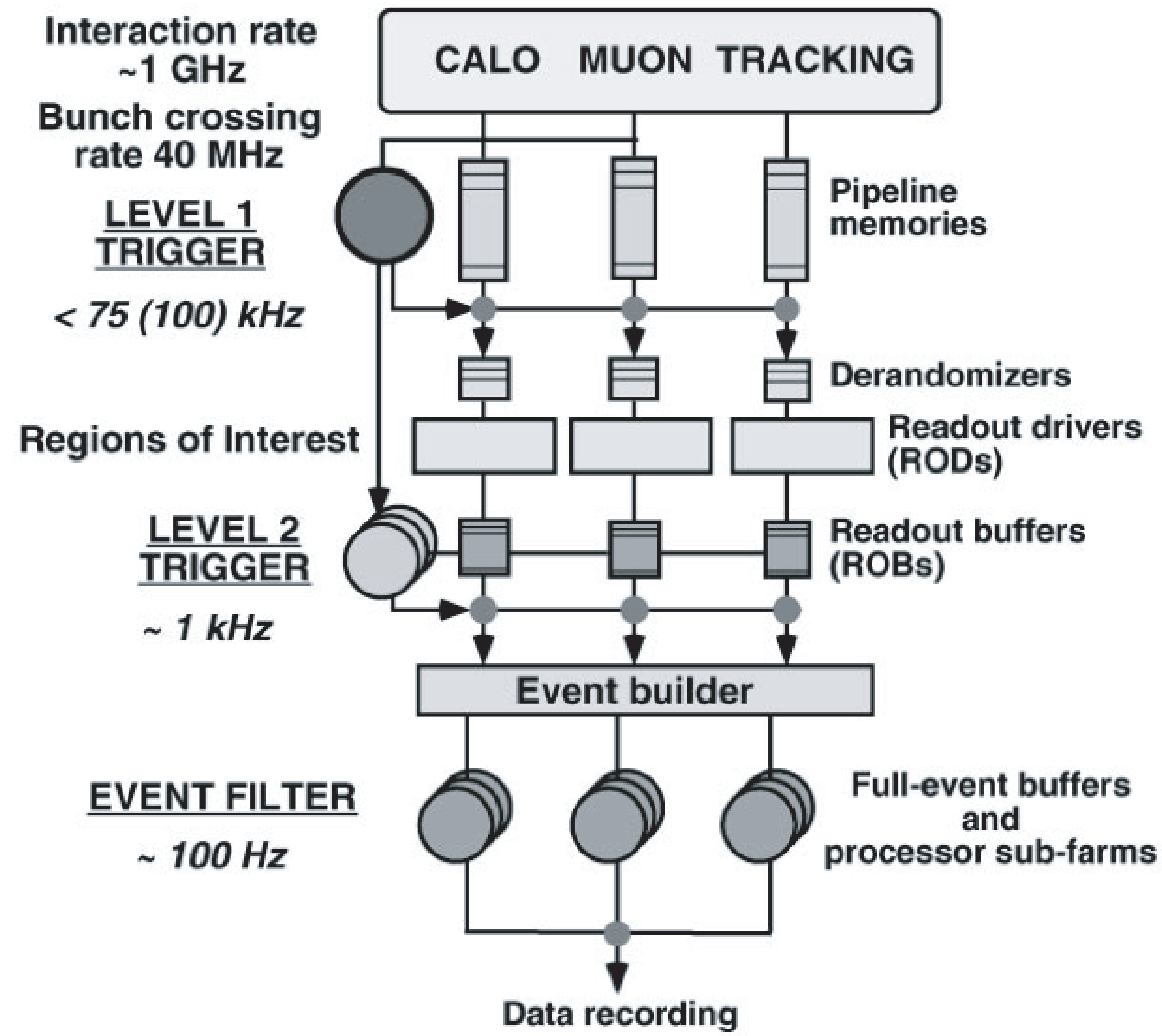
- Raw data strongly reduced by trigger and event selection (~40MHz to ~50kHz)
- Will record raw data at a rate of 400MB/s for Atlas &CMS
- Need a lot (!) of computing power to reconstruct and analyse data

# 5. Trigger system

**Dedicated fast detectors provides fast readout of the collisions !**

- Muon system and Calorimeter have fast detectors
- This information is fed back to the LVL1 trigger who removes all non-interesting events based on a set of trigger criterias




**The trigger system reduces the data from ~ 1 GHz to 100 Hz !**

# 5. Data readout


ATLAS - ~ 100 racks / 2500 highest performance mulit-core PCs in the final system

Computing centre

# 5. Data readout

**Simulations:**

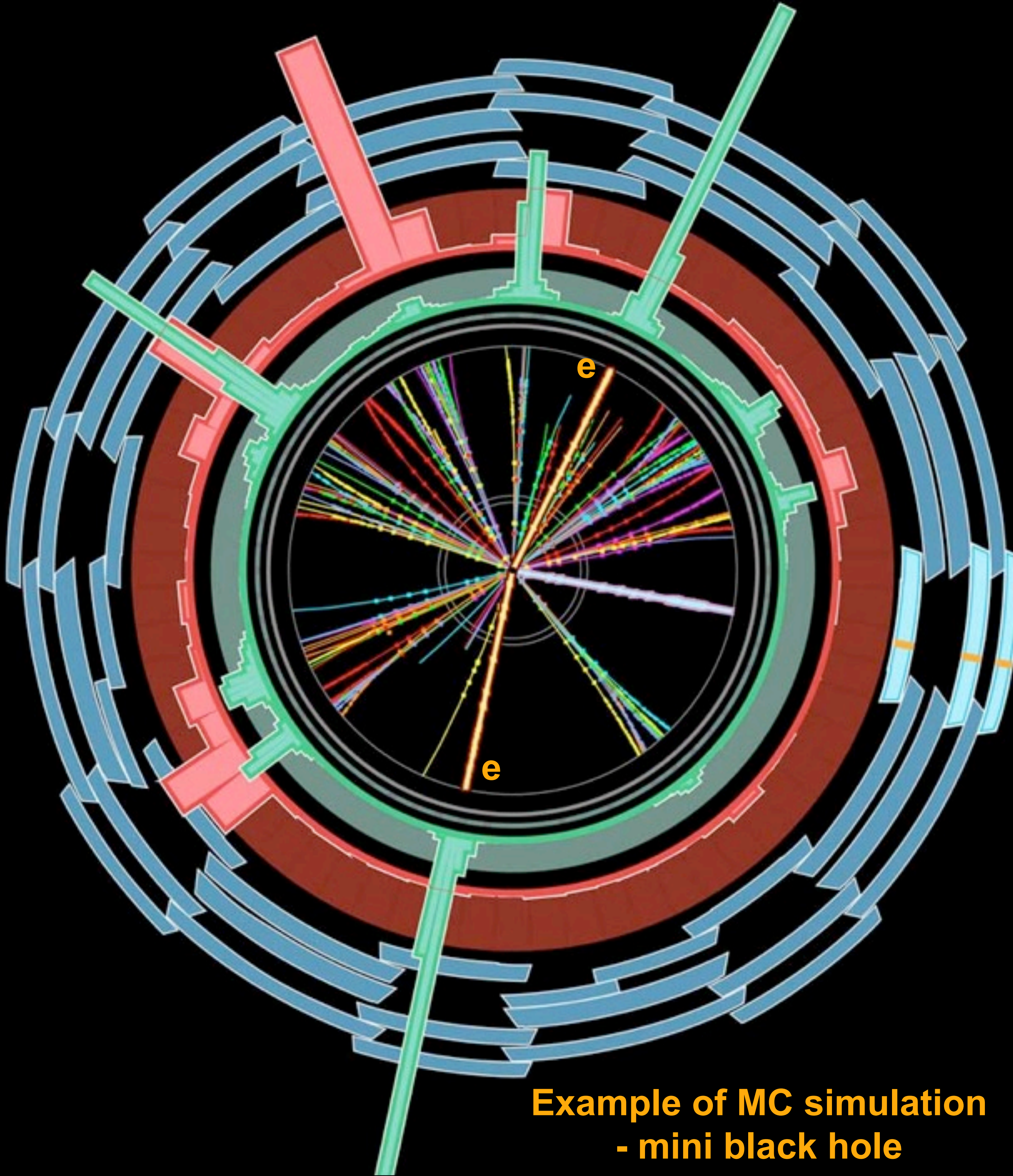
- We use Monte-Carlo simulations to study the behaviour of particles when they pass through ATLAS
- Signal + Background
- Standard Model signals & new physics

**Cosmic radiation:**

- To verify and improve the detector performance before LHC start

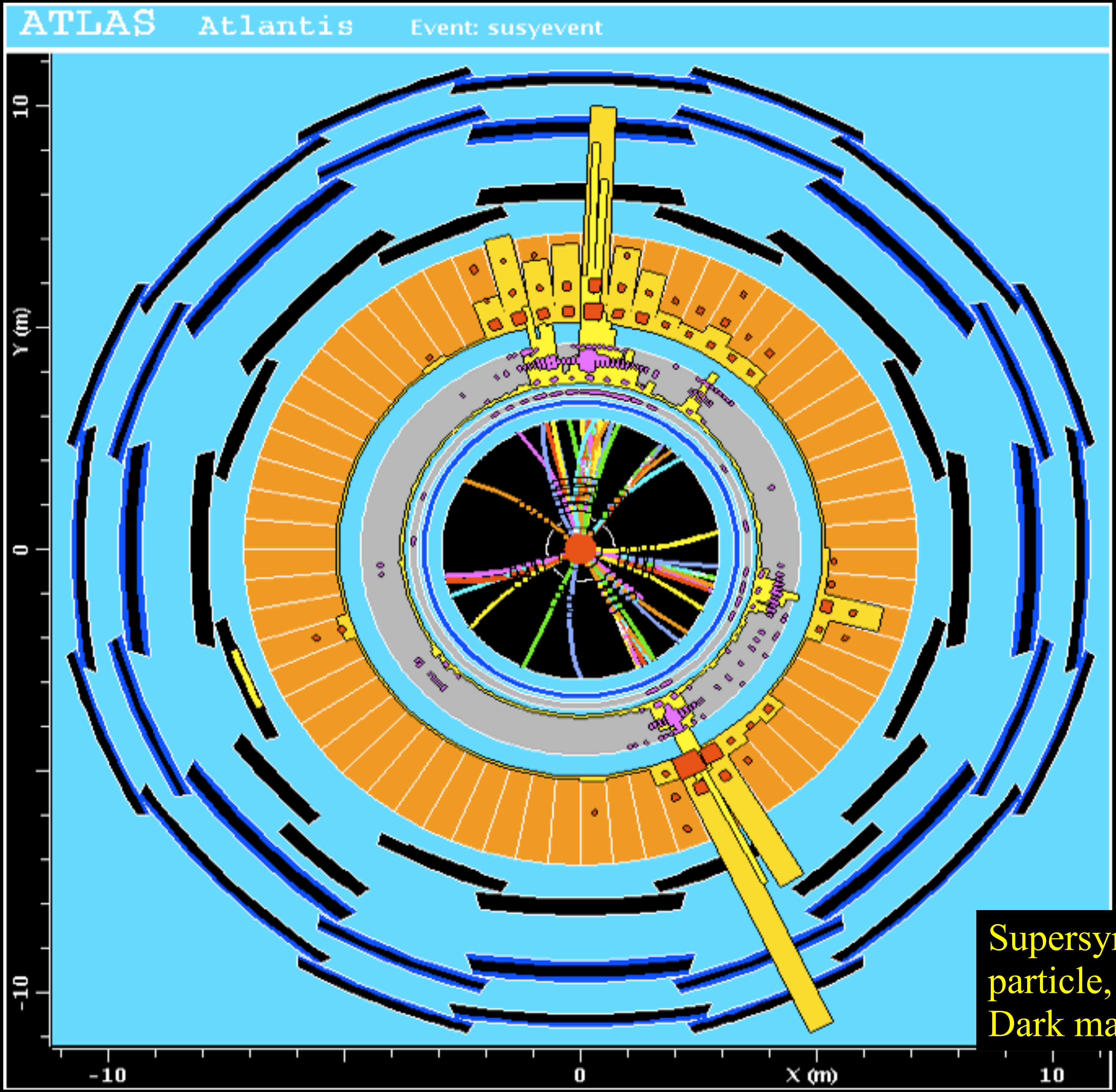
**Data from LHC:**

- Some data from LHC are being looked at to learn about the beam and the detector response to single beam operation




Example of MC simulation - mini black hole

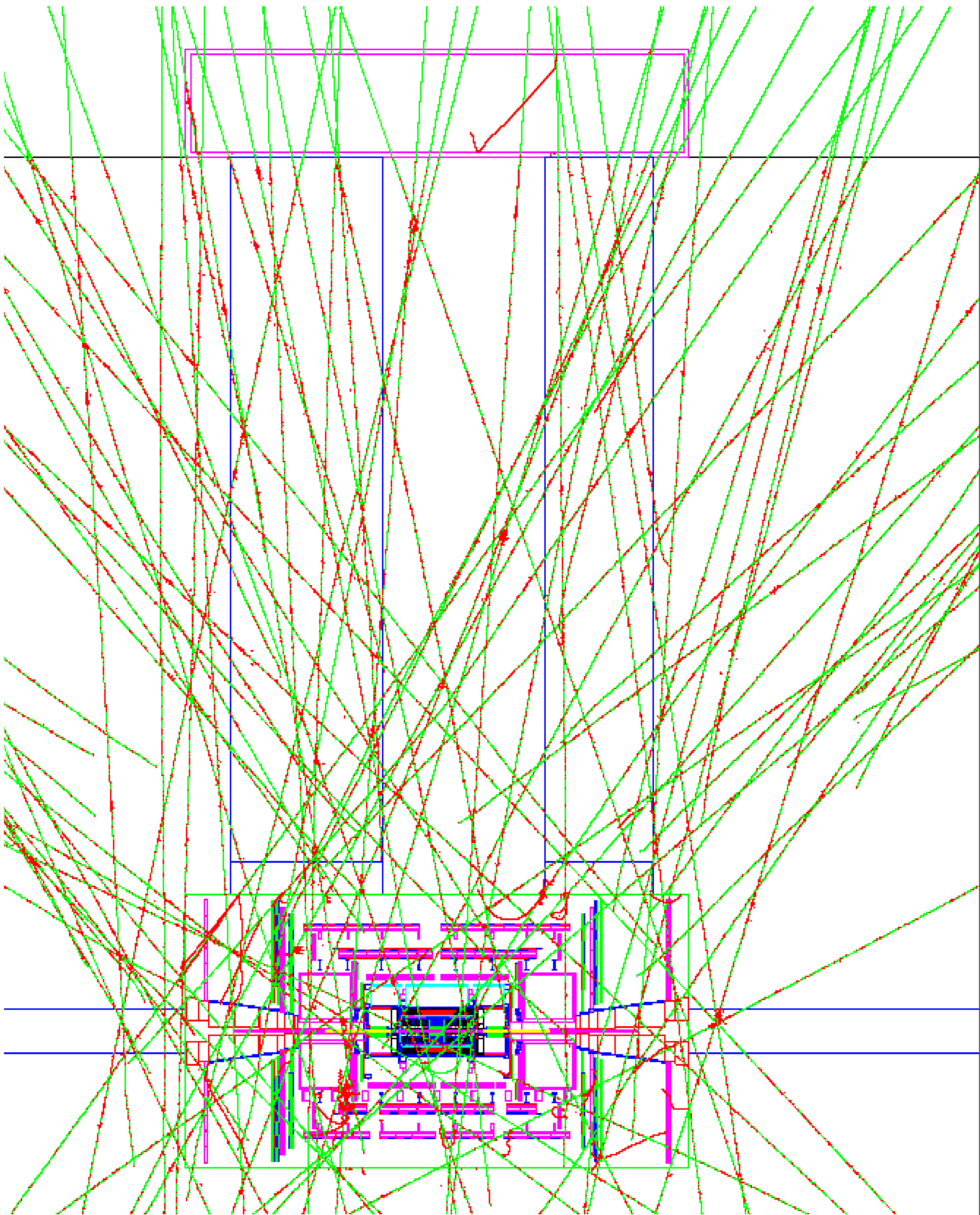
# 5. Simulated Data




Supersymmetric invisible particle,
Dark material candidate.

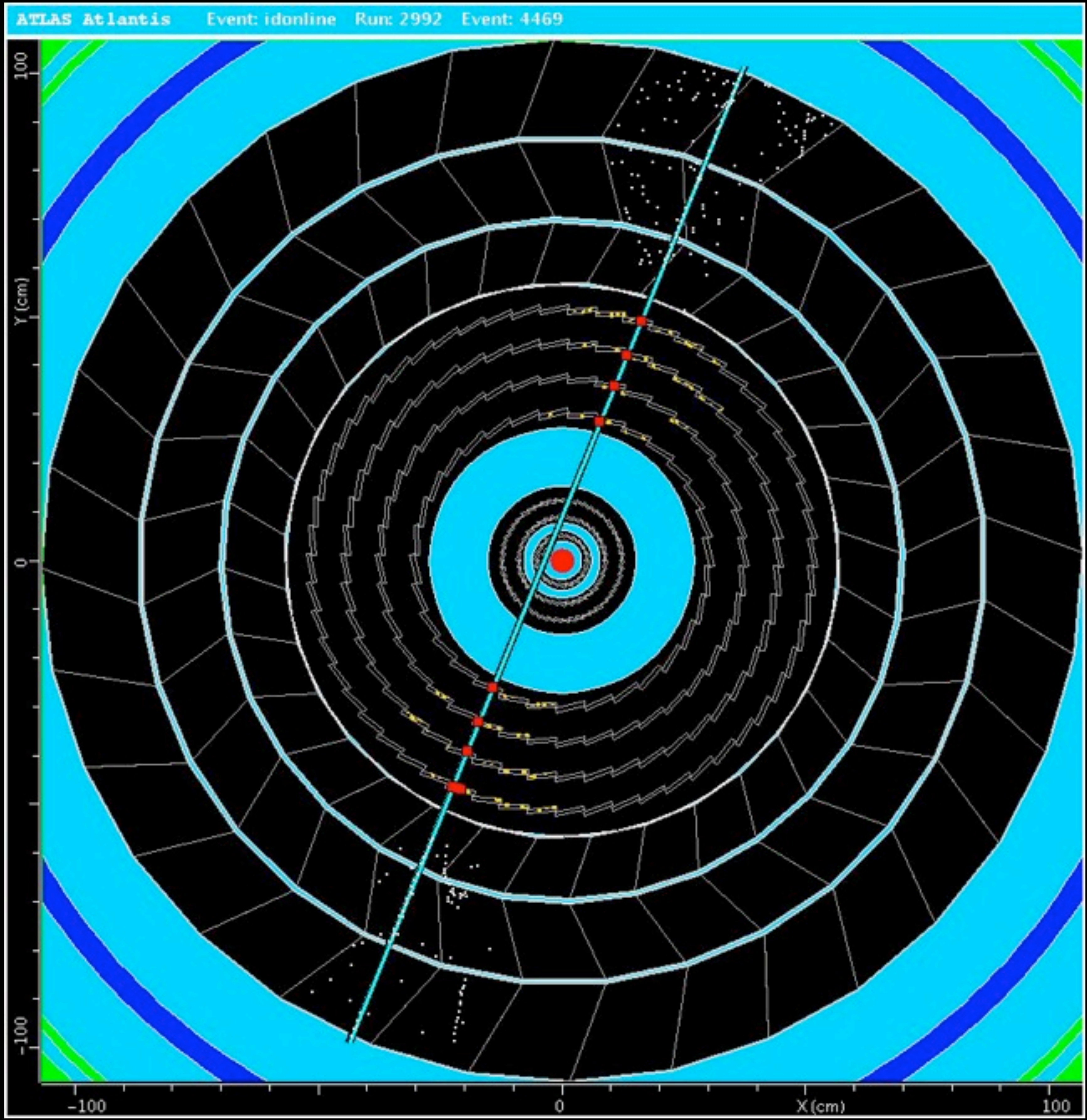
# 5. Cosmic radiation

- **Combined Inner Detector runs**
  - DAQ, Online, Offline software integration
  - Final tuning of readout parameters
  - Detector calibration, finding dead or noisy channels
  - Detector synchronisation
  - Track reconstruction and Alignment
  - Physics performance studies
- **Combined ATLAS runs**
  - Using the ATLAS trigger system
  - Integrated ATLAS software
  - Combined runs with the Calorimeter and the Muon systems
  - Building ATLAS events



**Cosmic muons in 0.01 seconds**

# 5. Cosmic Ray Data

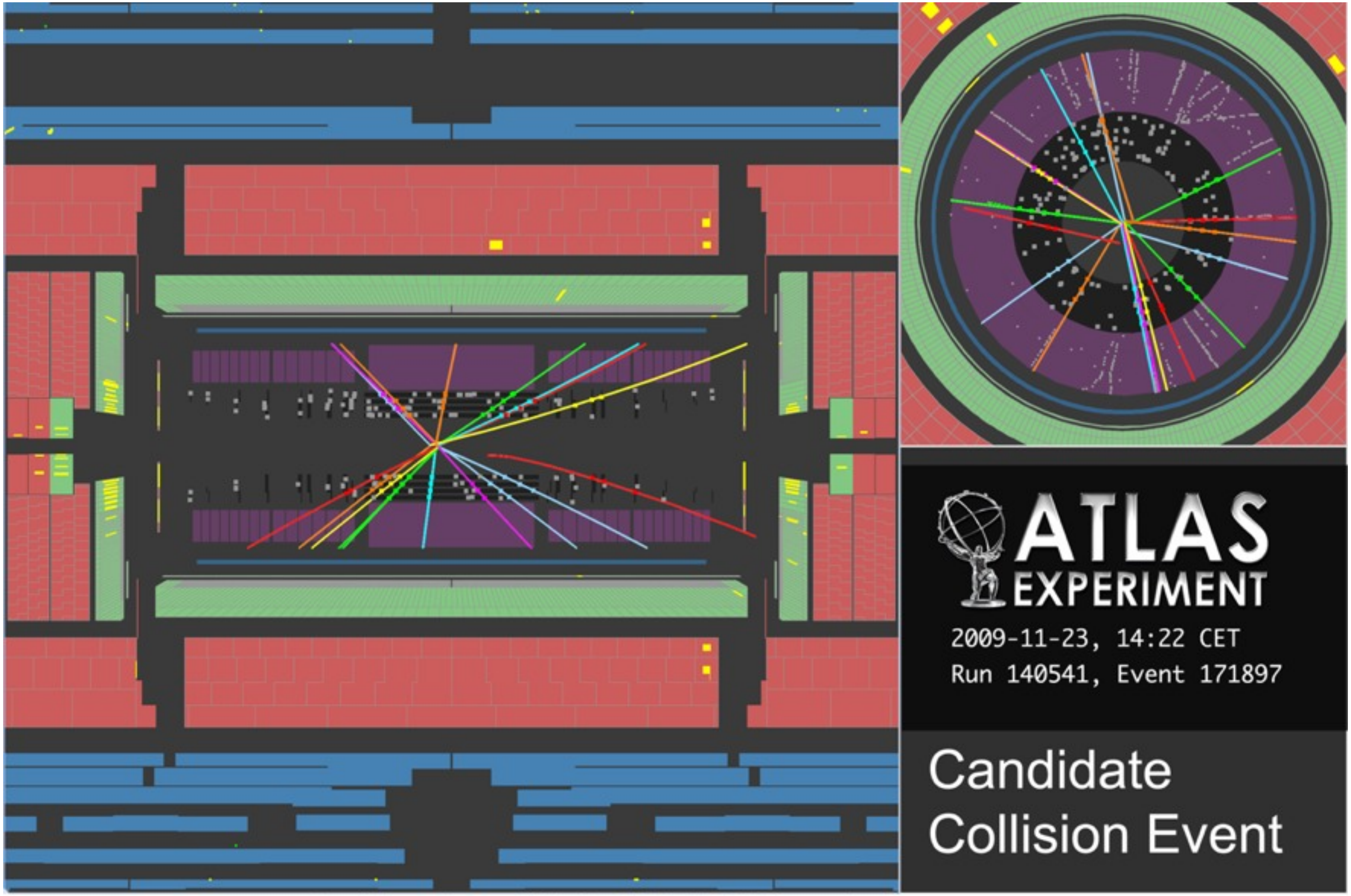



**Cosmic ray through the ID**

**Offline data**

*First LHC beam - 20.11.2009*

## *First beam, 900 GeV collisions - 20.11.2009*

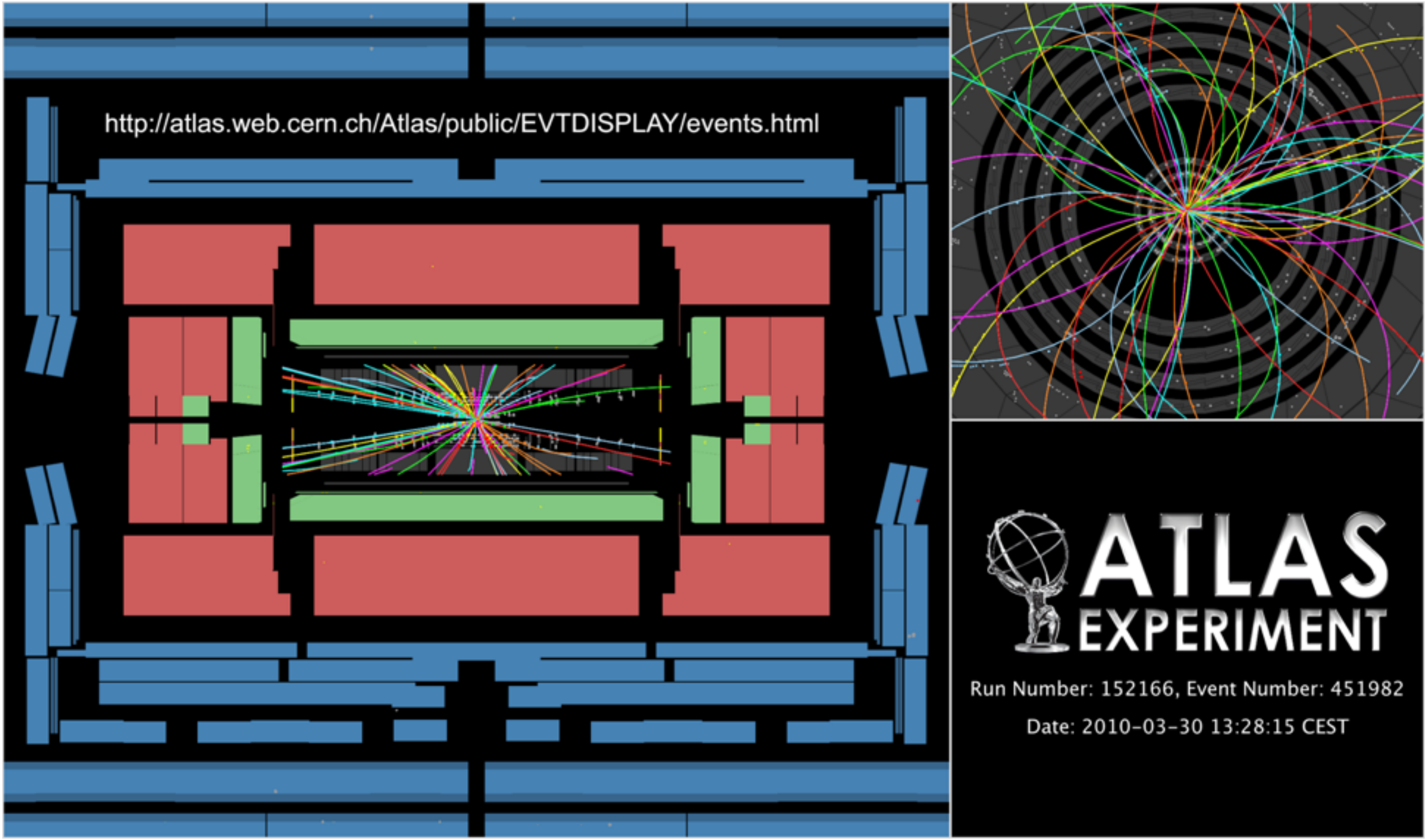



http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

*SCT in standby, Pixel off, no solenoid field*

# *First 7 TeV collisions - 30.03.2010*

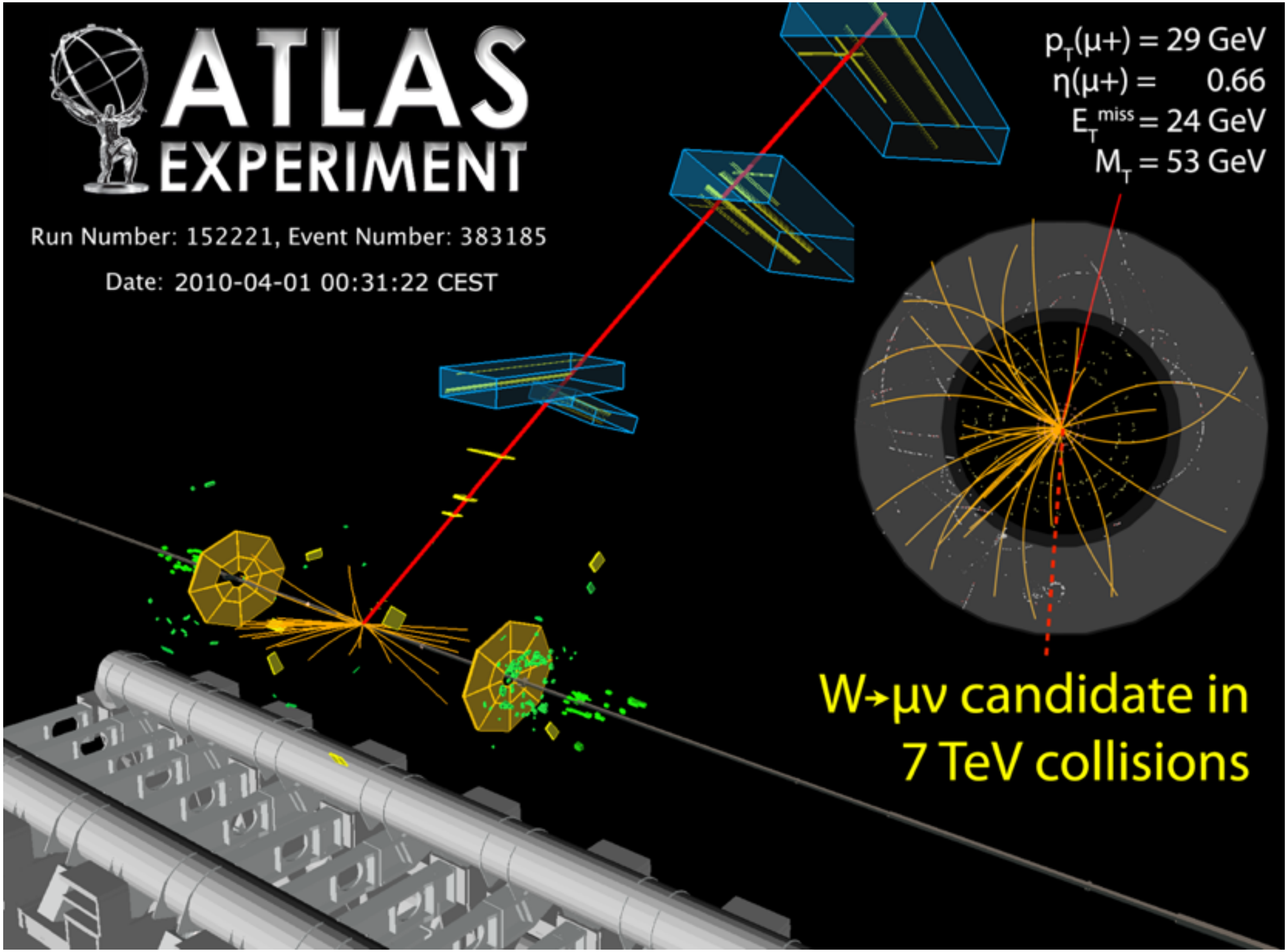
# First 7 TeV collisions - 30.03.2010



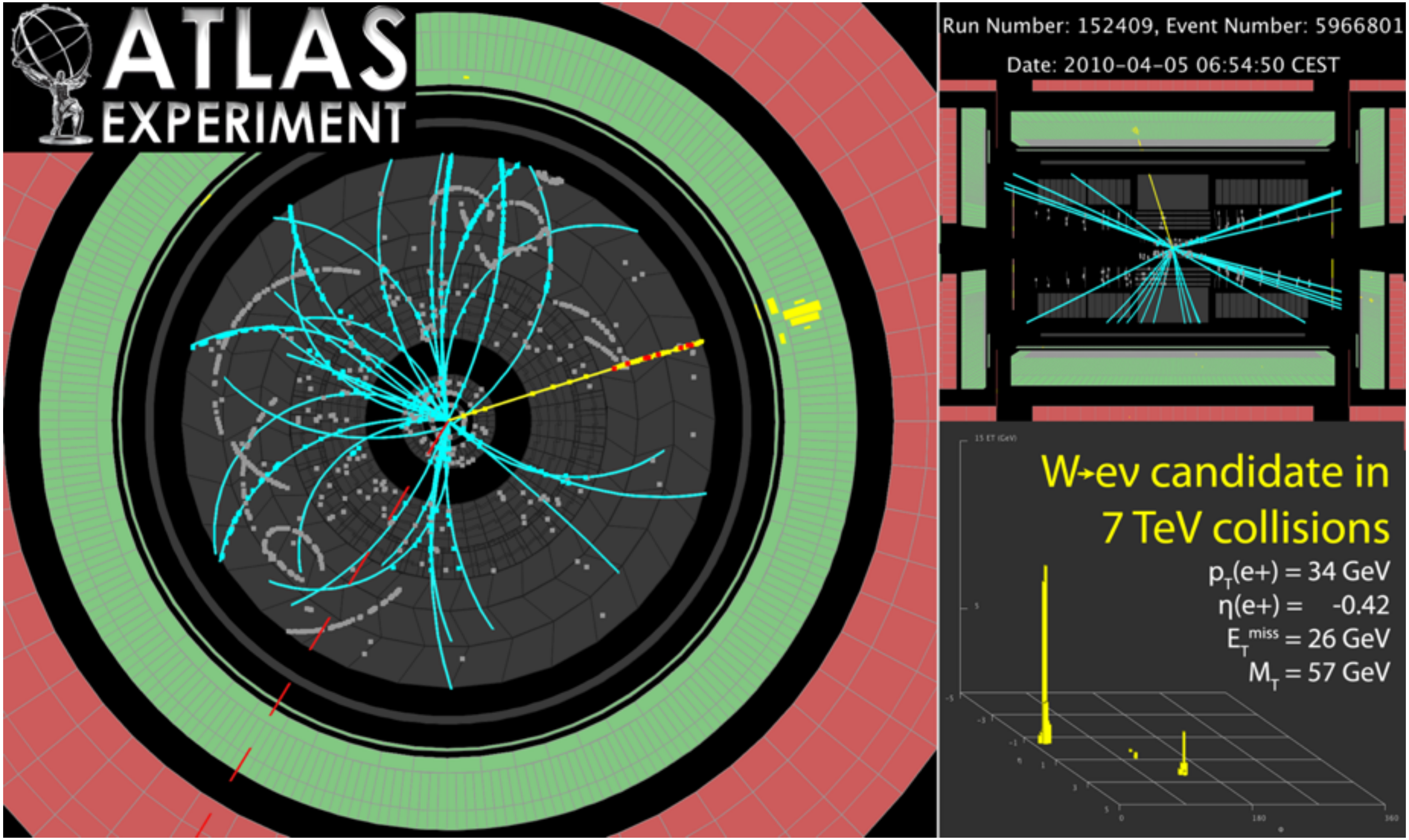

*All Inner Detectors and solenoid on !*

*Trigger System*

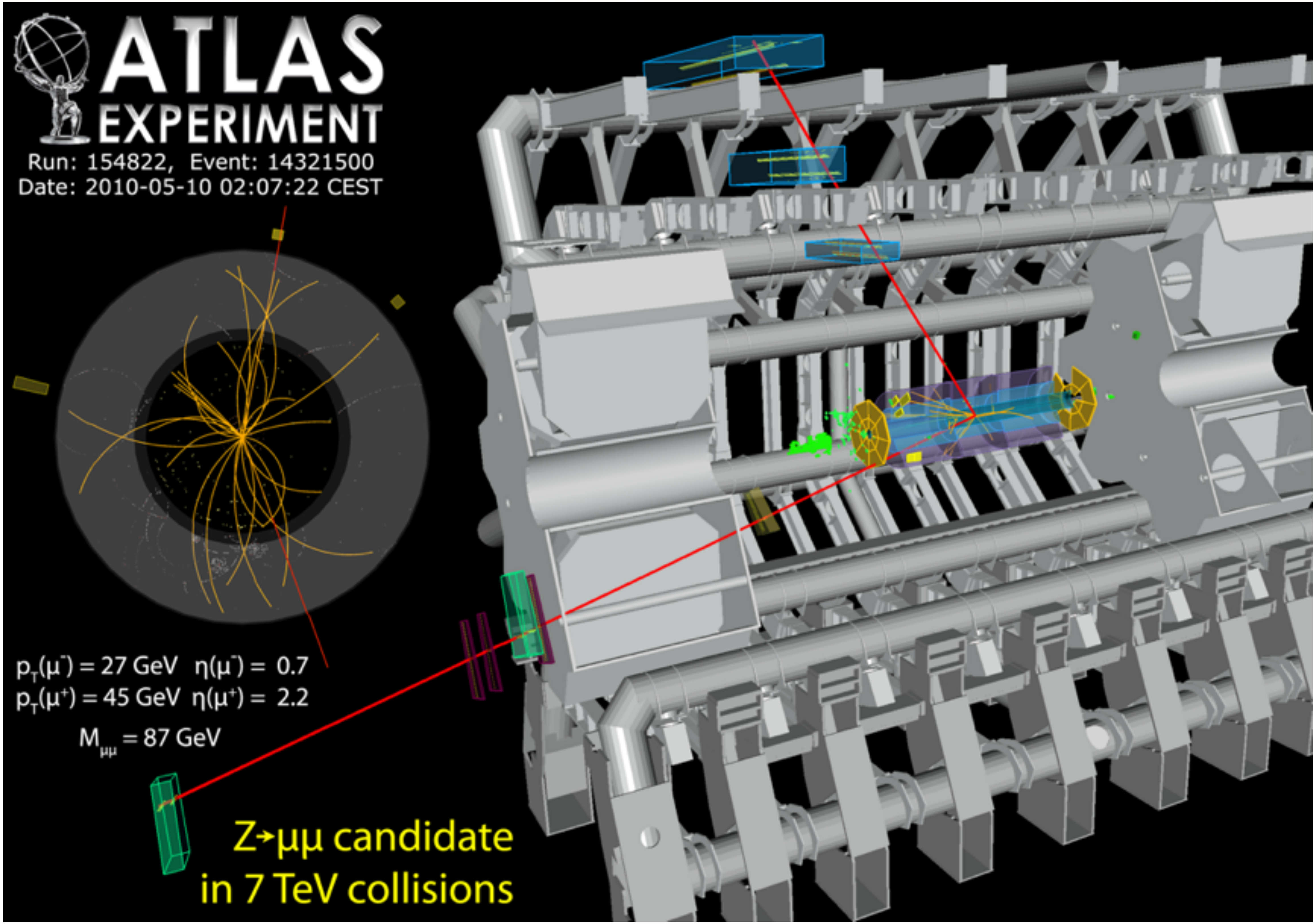
# *W → μν candidate in 7 TeV*



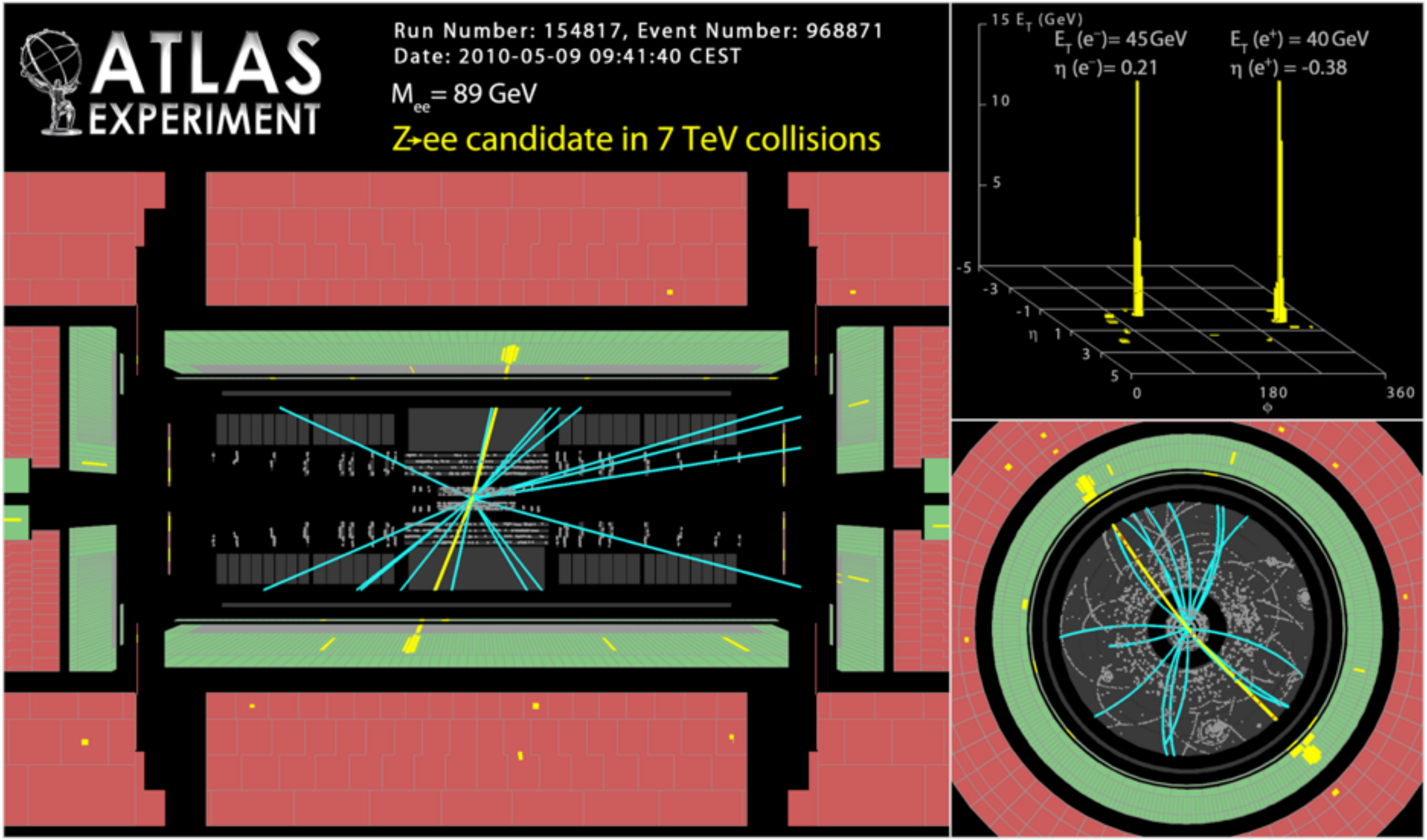
## *W → eν candidate in 7 TeV*



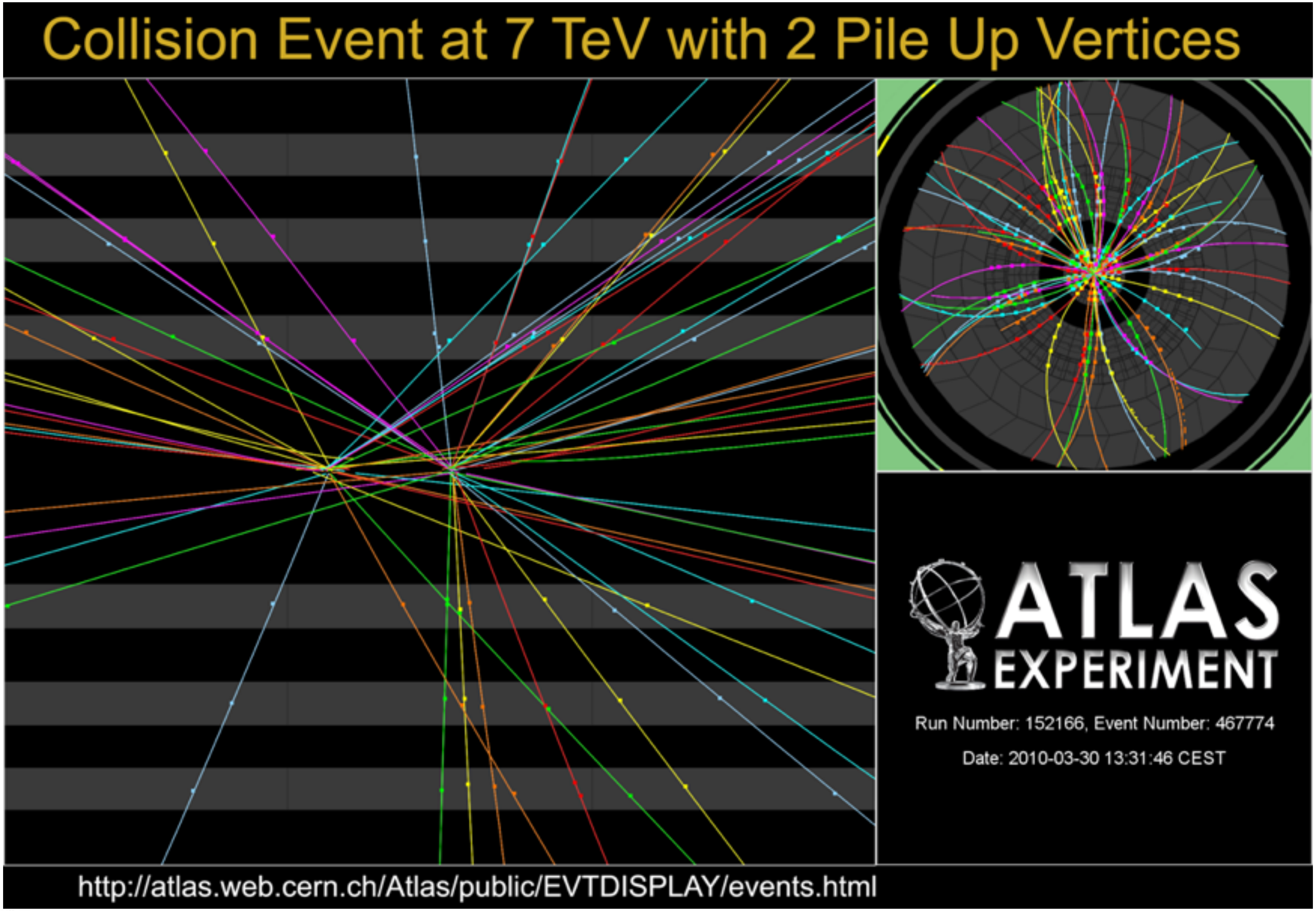
## $Z \rightarrow \mu^+\mu^-$ candidate 7 TeV



## *Z → e+e- candidate 7 TeV*

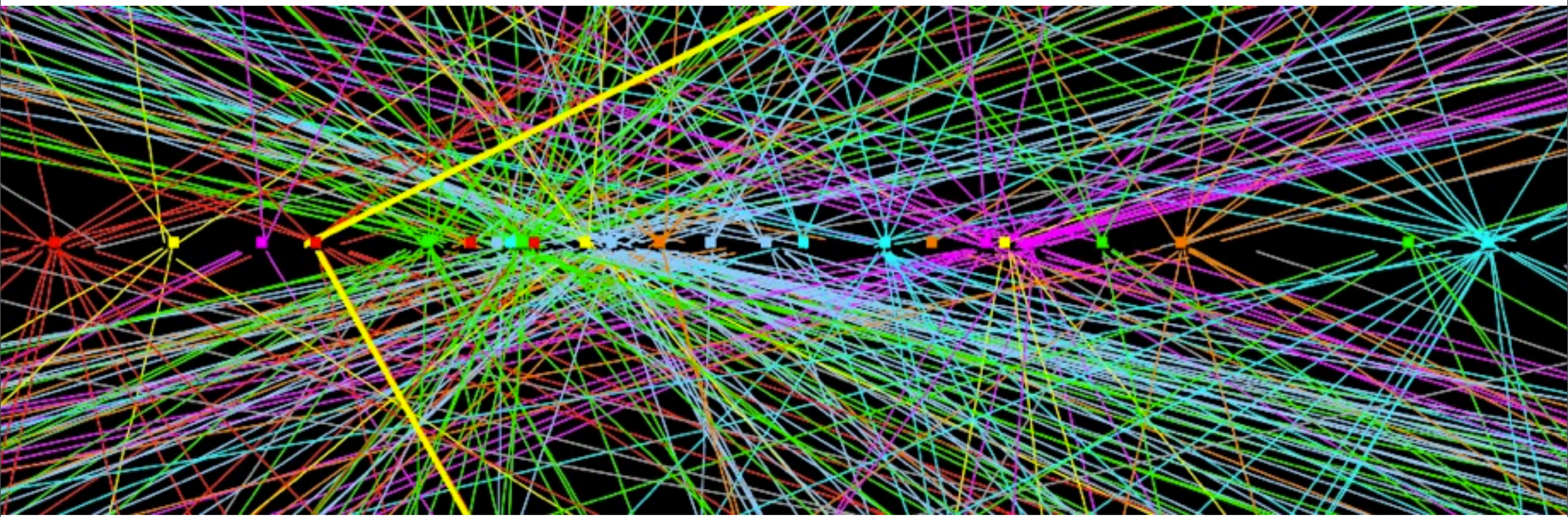


*Pile up 7 TeV*



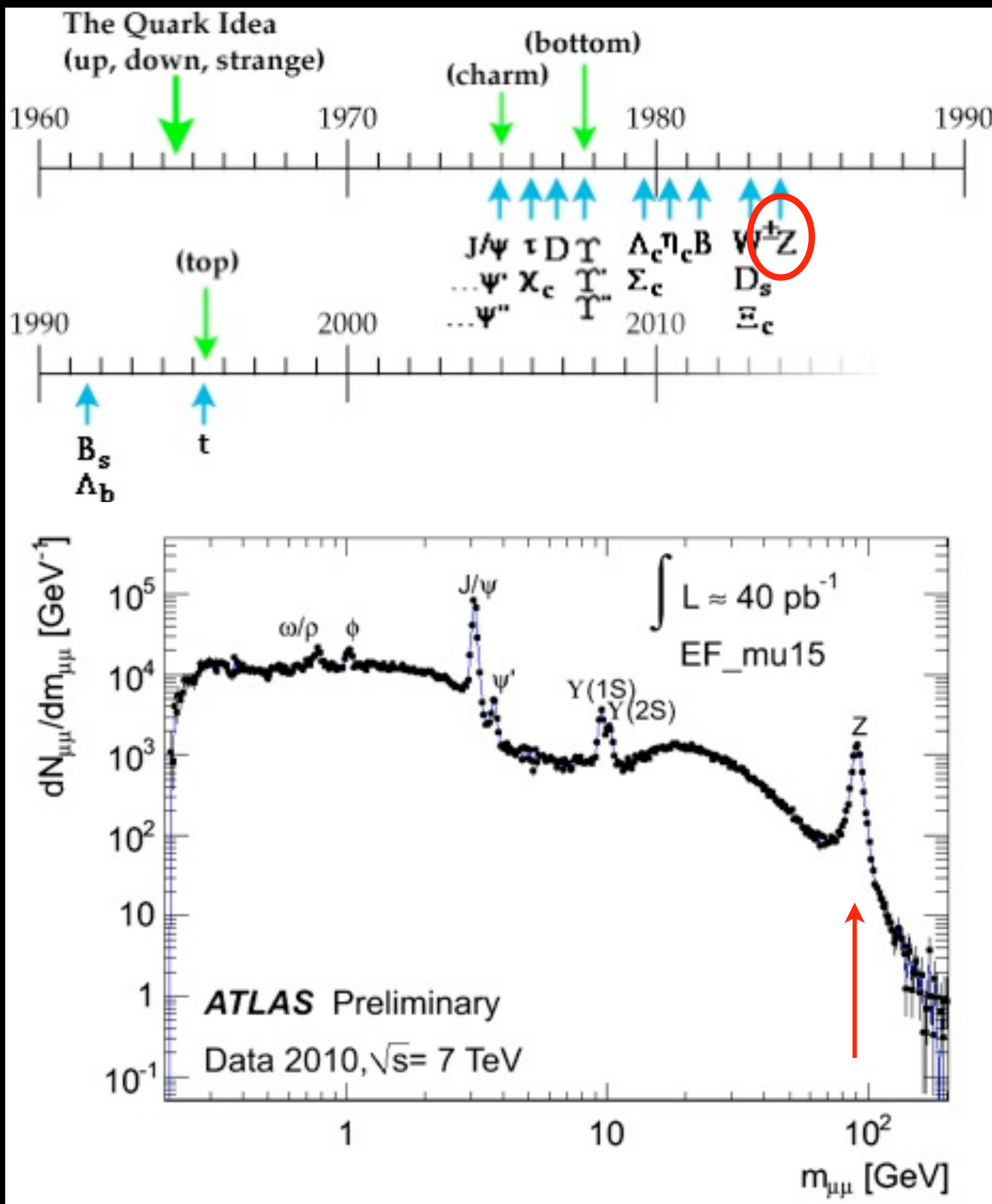

*Mulitvertex events have been reconstructed*

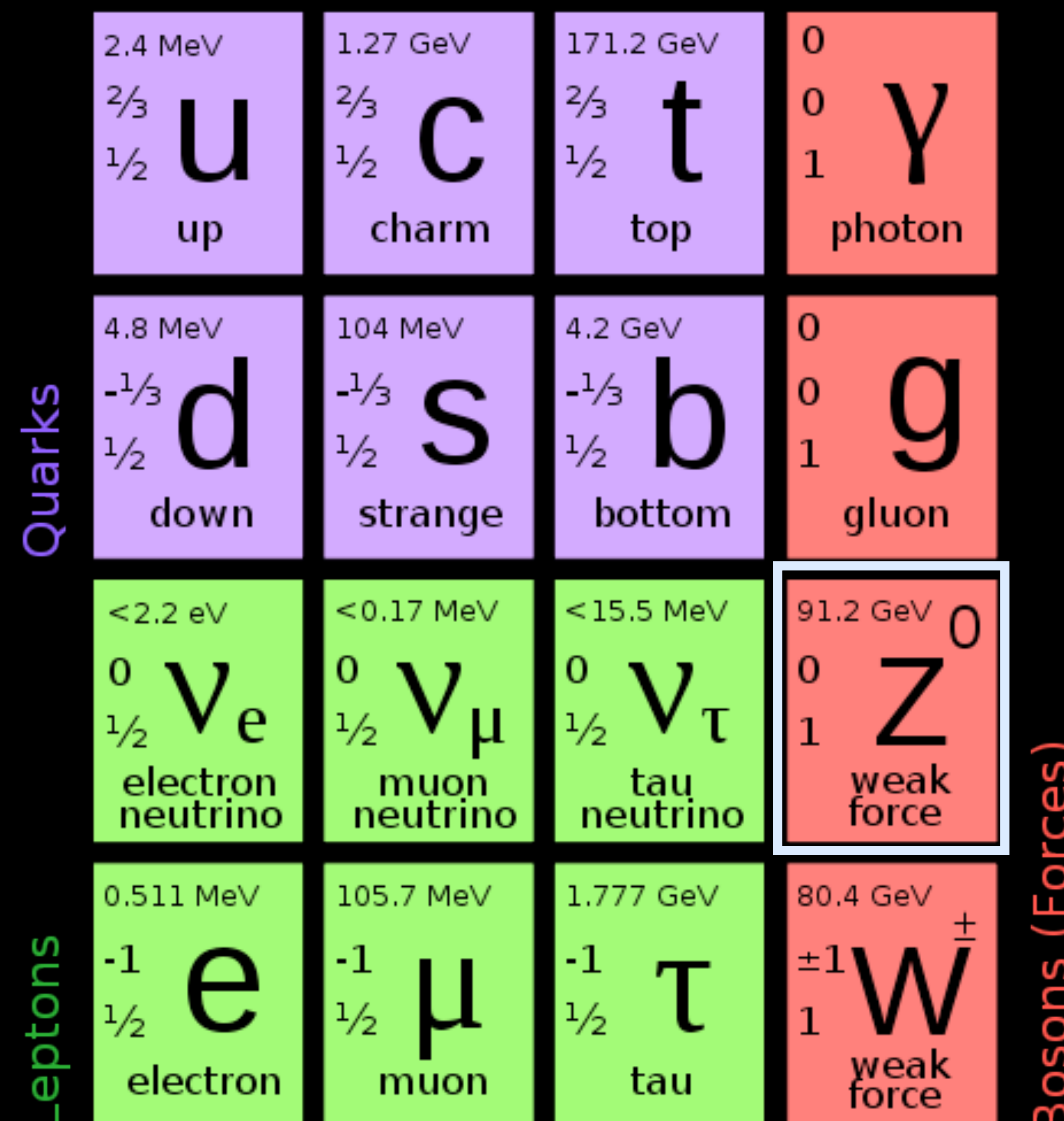
# Pile up 2012 - 8 TeV



Lykke til med å finne SUSY !

# Remeasuring the standard model




All ok ...

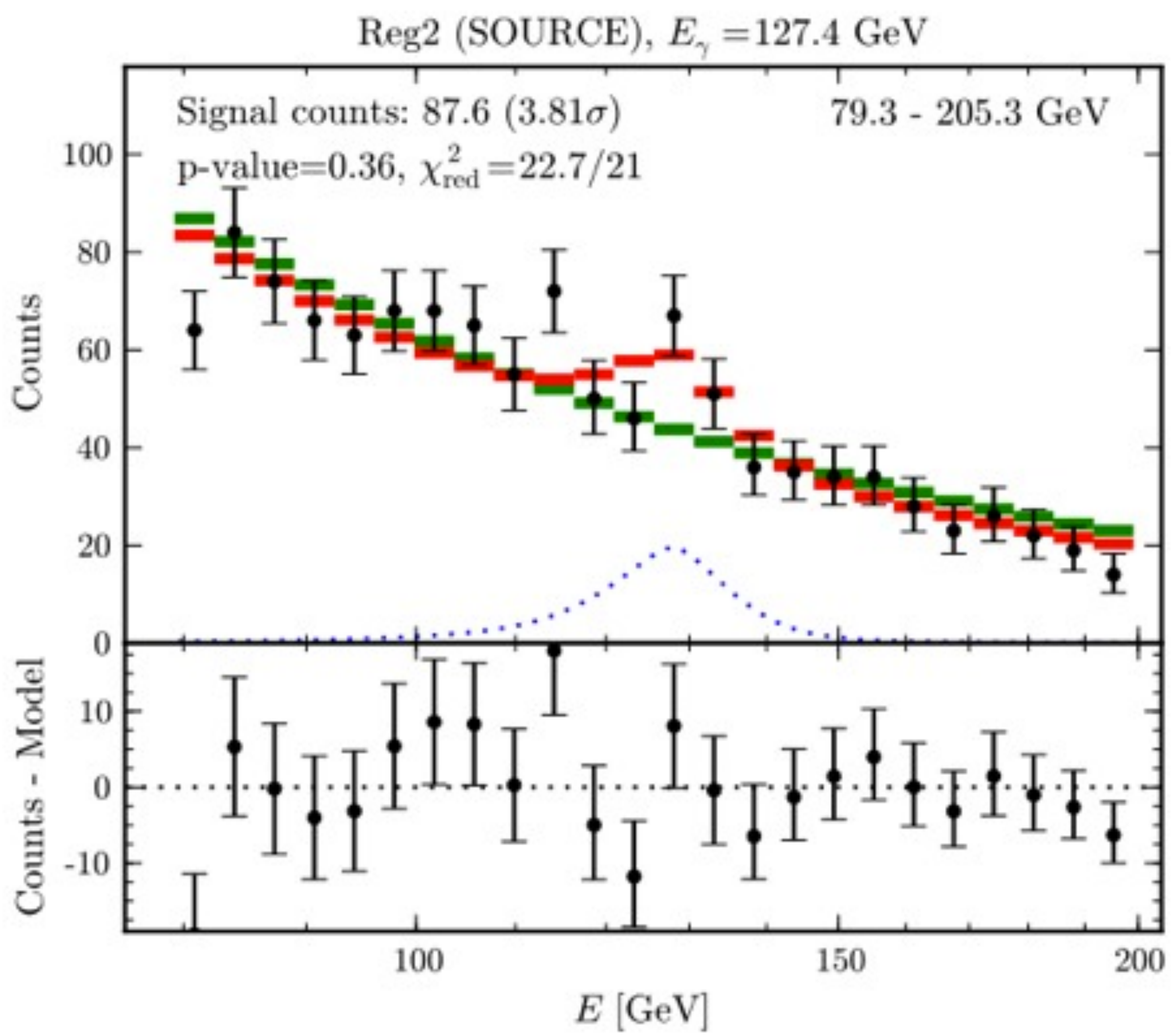
# 6. Results from summer 2012

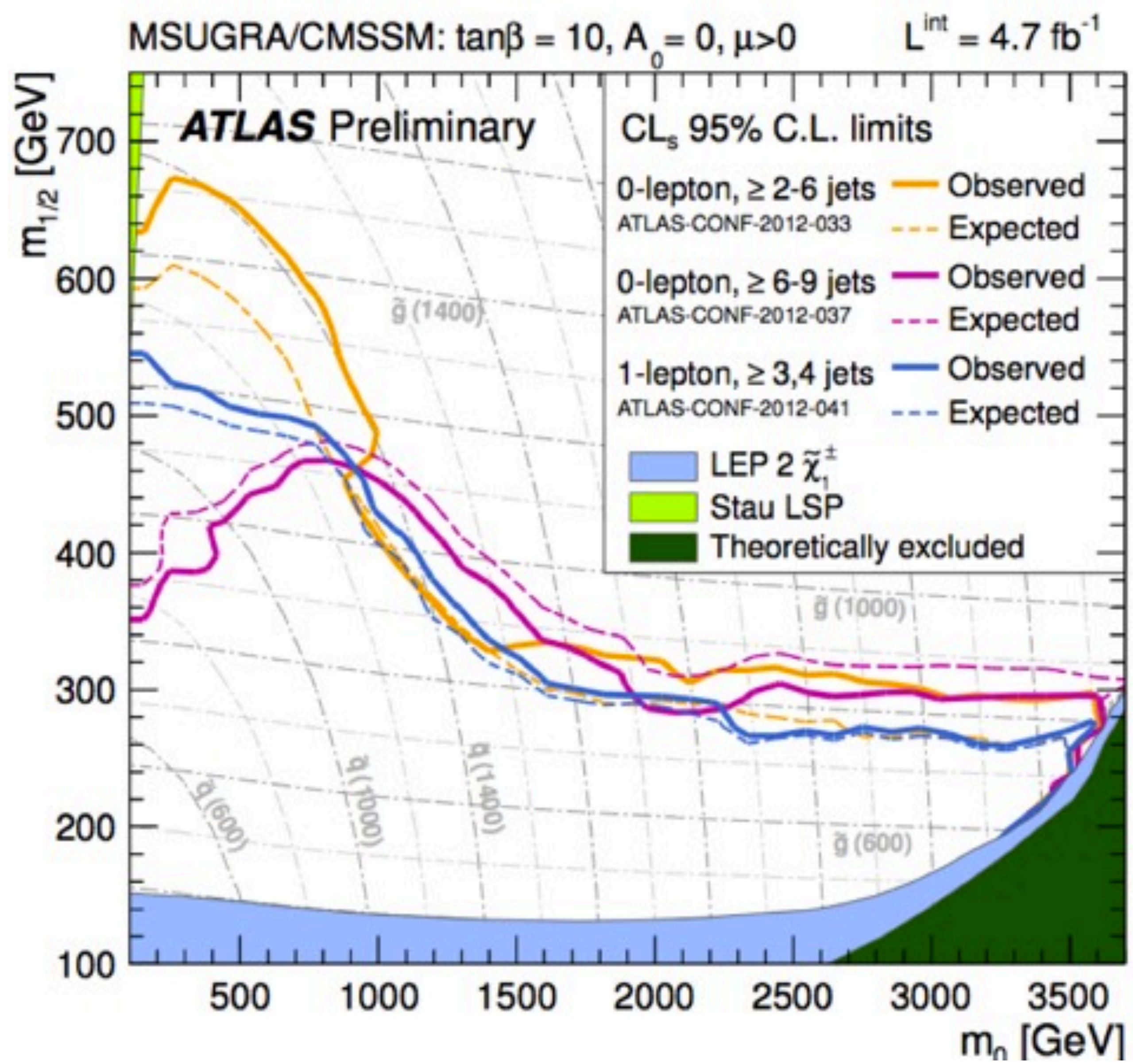
**News from LHC**

A new boson, probably Higgs is found

Supersymmetry is increasingly excluded in various limits in various models

No sign of Dark Matter signals in model "independent searches" like monojets and monophotons




**News from Fermi**

Intriguing signal at 130 GeV found by several teams, Fermi will recalibrate and perform a new search for this gamma emission line

## Noen store oppdagelser og oppfinnelser (CERN)

- ISR produserte i **1971** verdens første proton - proton kollisjoner !
- Oppdagelsen av Neutral Currents **1973** ved Gargamelle boble kammer
- I **1979** bestemte CERN å gjøre om SPS til verdens første proton-antiproton collider
- Oppdagelsen av W og Z bosonene i **1983** ved UA1 og UA2 eksperimentene. Dette resultatet bekreftet foreningen av svake og elektro-magnetiske krefter som beskrevet i standard modellen.
  - *Nobelprisen i fysikk i 1984 ble gitt til Carlo Rubbia og Simon van der Meer for oppdagelsen av W og Z*
  - *Nobelprisen i fysikk i 1992 gitt til Georges Charpak for utviklingen av MultiWire Proportional Chamber*
- Oppfinnelsen av World Wide Web av Tom Berners-Lee. Allerede i 1991 var et tidlig www-system tilgjengelig på CERN.

# Noen historiske Nordmenn på CERN

- **Normenn har vært involvert på CERN siden begynnelsen og er det fremdeles....**
- **Odd Dahl** ble med i en nimanns ekspertgruppe som ble dannet i 1951. Han ble snart leder for byggingen av CERNs første akselerator (en synkrosyklotron – SC) som sto ferdig i 1957.
  - Odd Dahl ble tilbudt stillingen som CERNs første generalsekretær men takket nei
- **Rolf Widerøe**, en annen norsk fysiker, var også veldig aktiv fra begynnelse. Han konstruerte blant annet den første **linear akseleratoren** for positive ioner. Han regnes også som en av oppfinnerene av **betatronen**
  - Widerøe overbeviste Dahl i 1952 om nødvendigheten av en protonsynkroton (PS) noe Widerøe hadde tatt patent på allerede i 1949, og Dahl var veldig aktiv med å fremme byggningen av en slik akselerator. Stod ferdig i 1959 som verdenes største akselerator
- **Kjell Johnsen**, som var sentral i byggingen av PS, ledet byggingen av ISR (Intersecting storage rings) for å bedre partiklenes kinetiske energi

# Hvordan delta i CERN's aktiviteter

- Mange relevante studier
  - ✓ Partikkel fysikk, material fysikk, detektor teknologi, elektronikk, mekanikk, informatikk, instrumentering ....
  - ✓ Universiter (UiB, UiO...), Siv-Ing. Studier (NTNU..), Ing. Studier, Høyskoler etc...
  - ✓ Utenlands studier (INSA, ...)

Summer Students enjoying a lecture on particle physics by Ronald Kleis

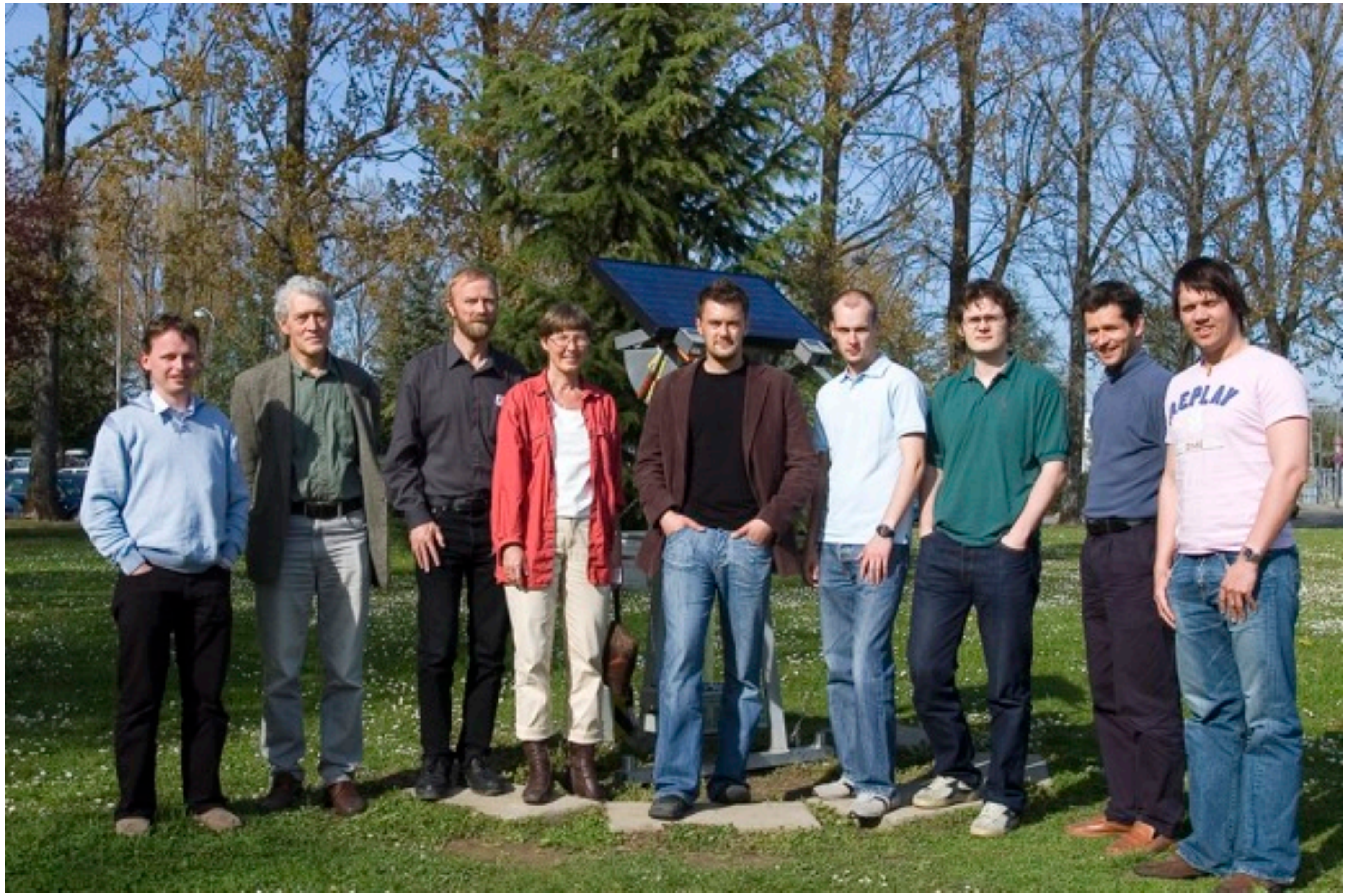
## Sommer skole

- ✓ Allerede under studiet er det mulig å delta på CERN !
- ✓ 2-3 måneder om sommeren
- ✓ Undervisning i akselerator fysikk, detektorer og partikkel fysikk
- ✓ Prosjekt oppgave
- ✓ Møt unge forskere fra hele verden !

Wolfgang Pauli at the Summer School for teoretical physics Les Houches

## ❖ Teknisk Student

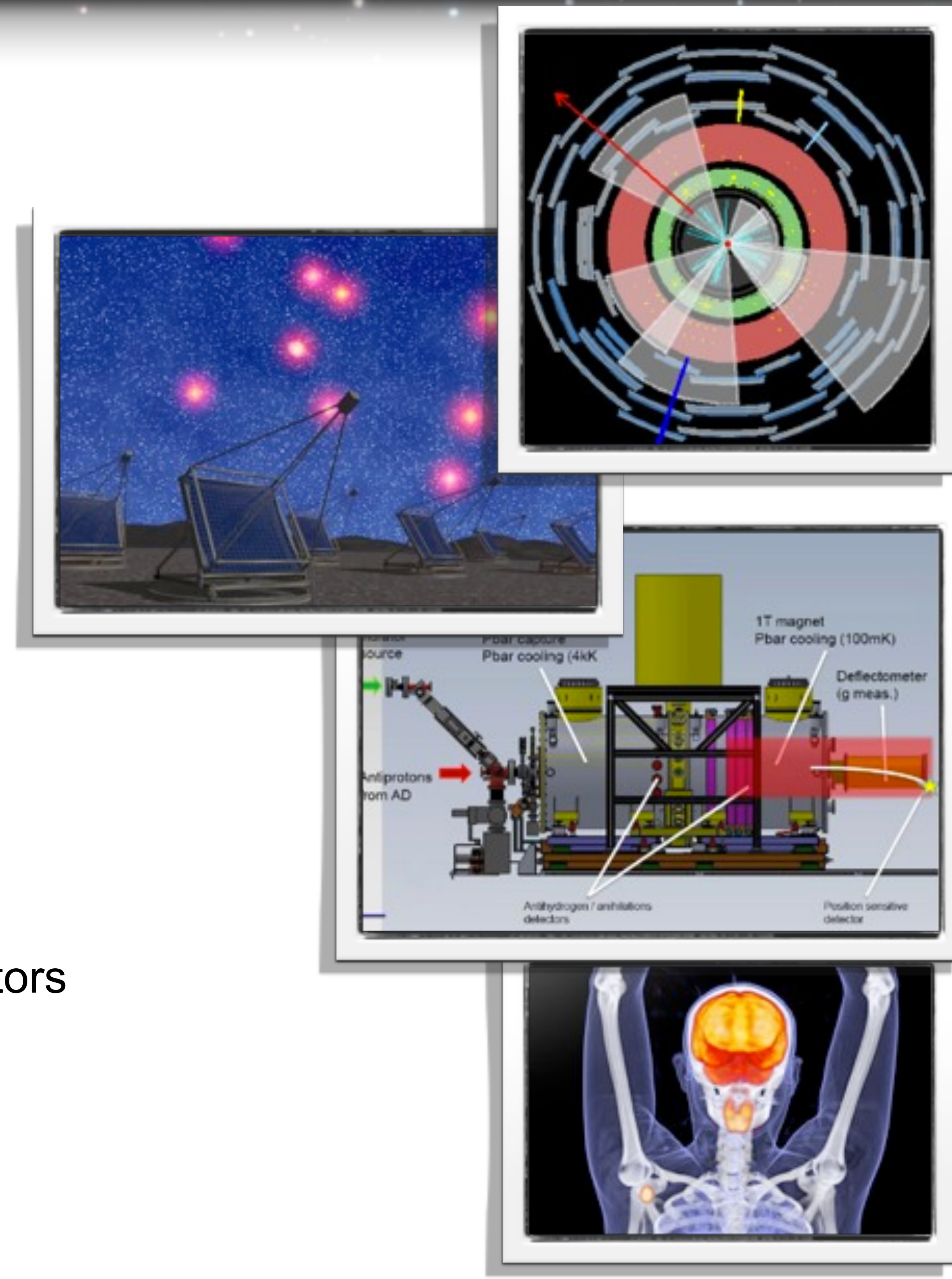
- ✓ Diplomarbeid eller Master
- ✓ ~ 6-12 måneder
- ✓ Prosjektarbeid
- ✓ Mulighet til å følge seminarer ved CERN
- ✓ Internasjonalt samarbeid !



**The Technical Student Programme draws Norwegians**

Erik Hejne, second from left, Chairman of the Technical Students Committee, and Jens Vigen, who is concerned spefically with Norwegian students at CERN, with some of the Norwegian technical students who arrived at CERN in spring 2005, together with their teachers.

# Typical Master project work




**Example 1:**

LHC study of Dark Matter candidates (ATLAS)

(1 PhD + 1/2 postdoctor)

**Example 2:**

Astroparticle study of Dark Matter candidates (CTA)

(1 PhD + 1/2 postdoctor)

**Example 3:**

Particle detector upgrade for dark matter detection (ATLAS upgrade, AEgIS and CTA)

(1 PhD + 1 postdoctor)

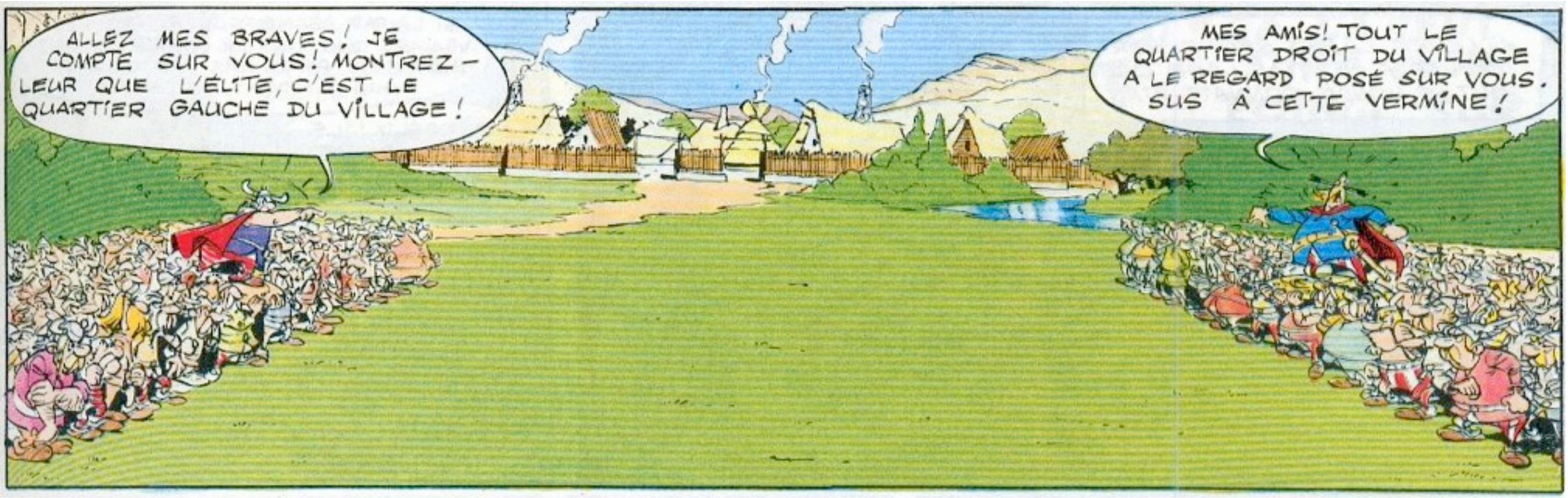
**Example 4:**

New applications for particle and astroparticle detectors (Masters)

- TAKK FOR BESØKET !

- VELKOMMEN TILBAKE !

En LHC kollisjon?

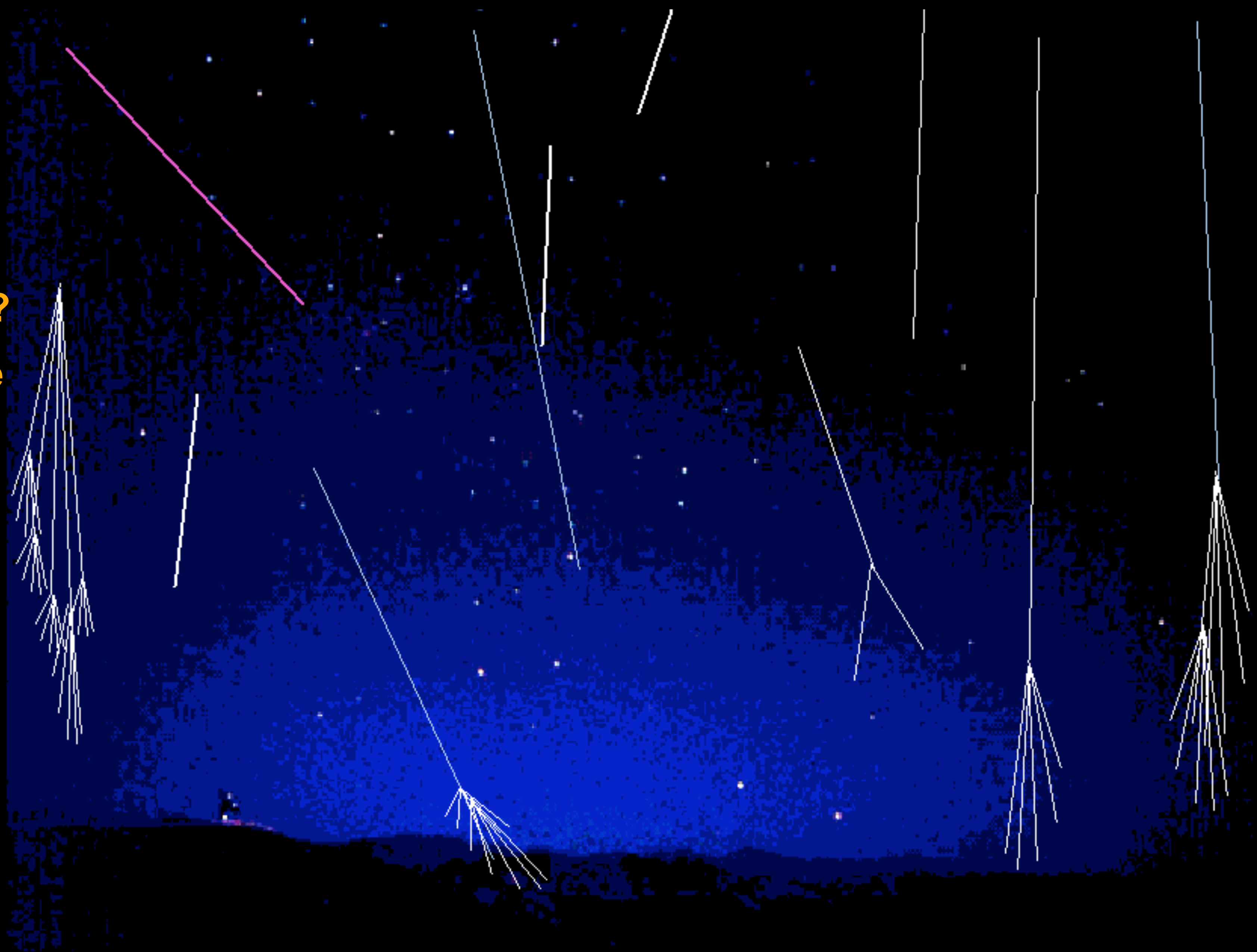


# En LHC kollisjon?

***Takk for oppmerksomheten***

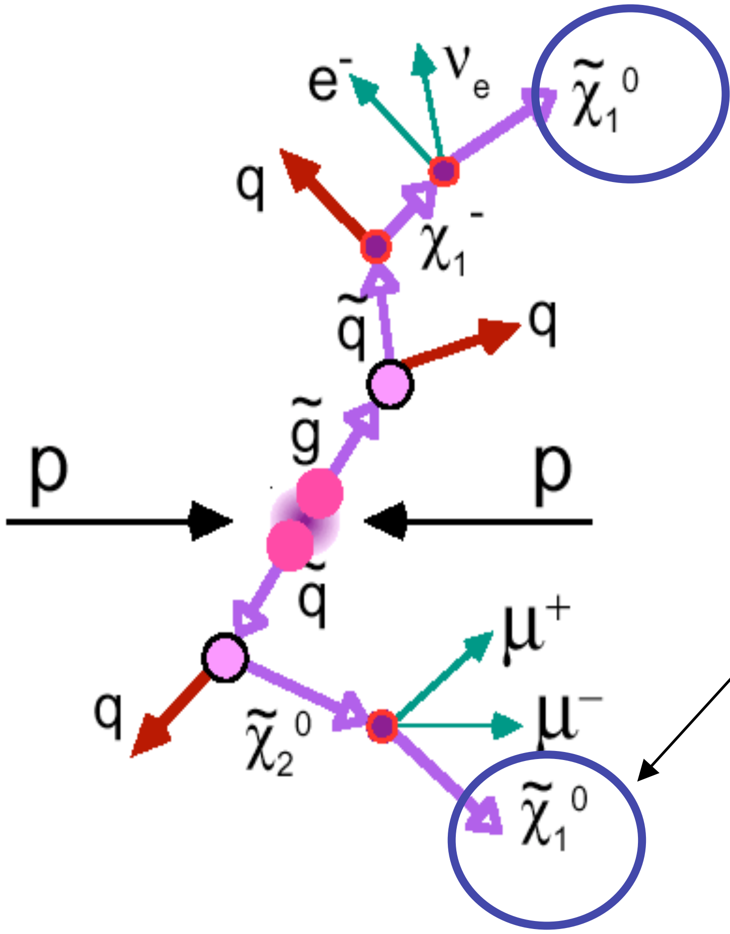
# *Ekstra*

1. Hva skal ATLAS forske på?
2. Hvordan skjer kollisjonene
3. Om ATLAS detektoren
4. Data fra ATLAS 2010
5. Planer for 2011



Partikkel kollisjoner i atmosfæren

# Supersymmetry & Dark Matter




This particle (neutralino) is a good candidate for the universe dark matter

ATLAS discovery reach

| Time | reach in squark/gluino mass |
|---|---|
| 1 month | ~ 1.3 TeV |
| 1 year | ~ 1.8 TeV |
| 3 years | ~ 2.5 TeV |
| ultimate | up to ~ 3 TeV |

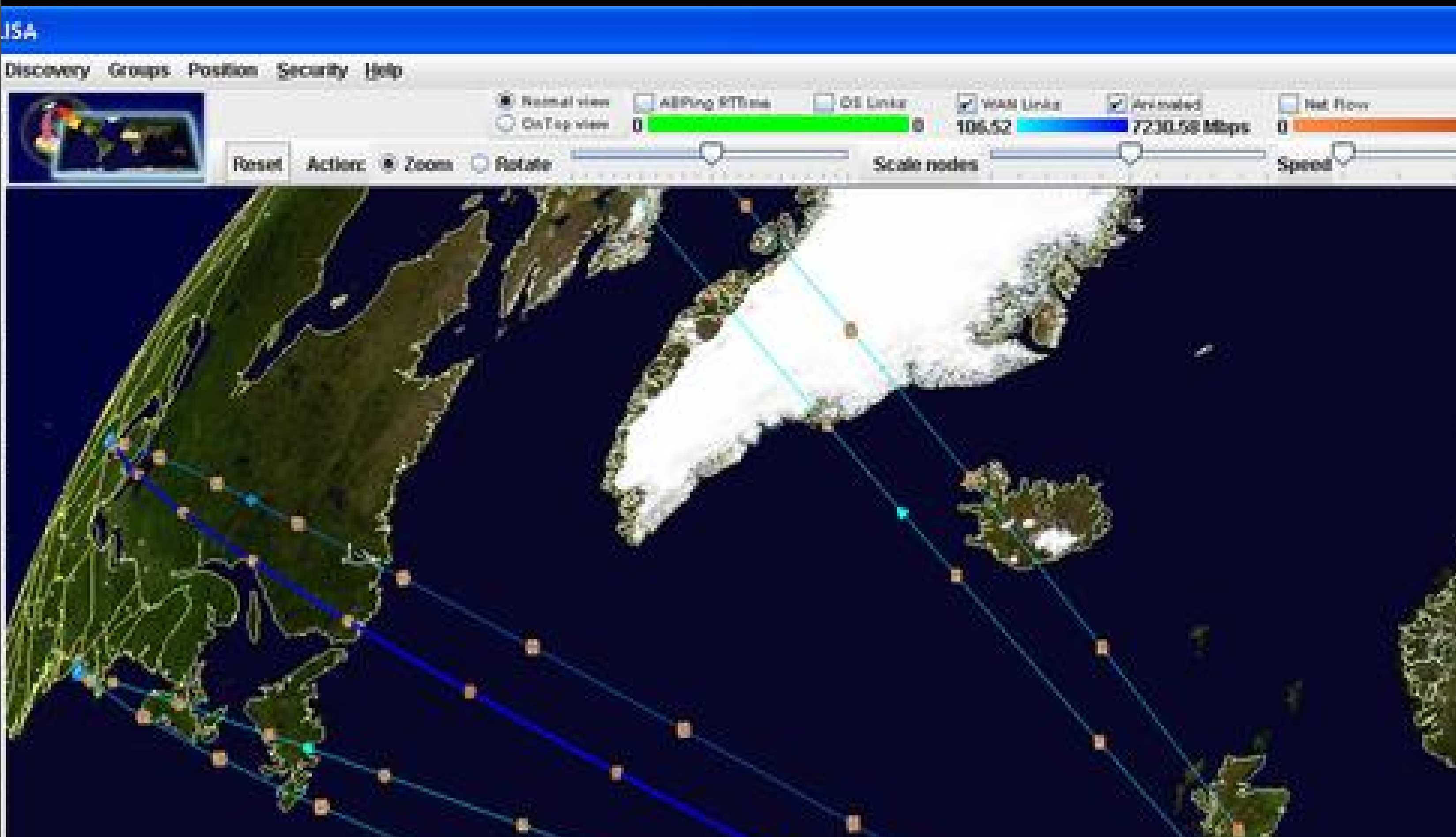
**New particle discoveries depends on mass of the particles !**

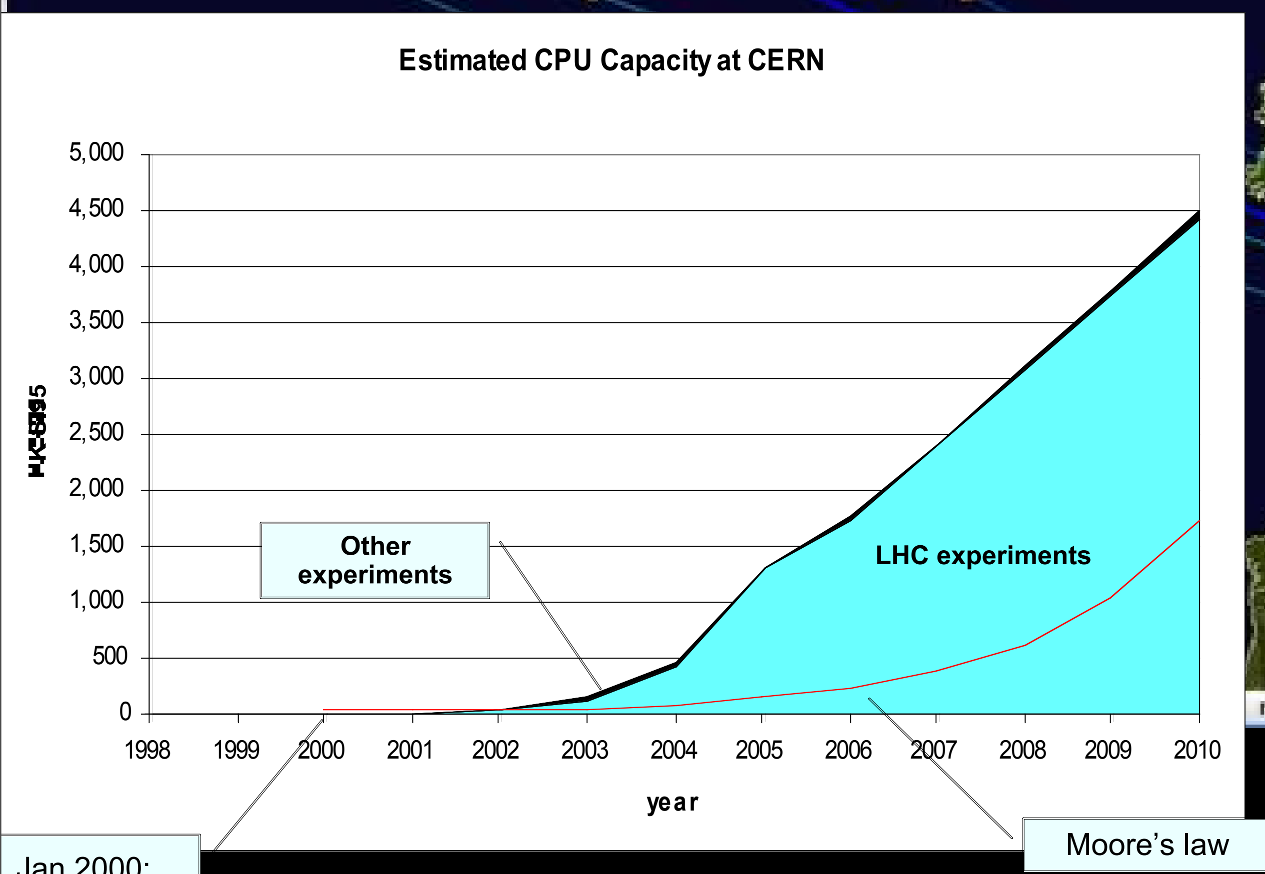
**.... may take some time ...**

**Neutralino mass can be measured to 10% -> SUSY discovery and neutralino mass measurement at LHC can solve problem of universe cold dark matter**

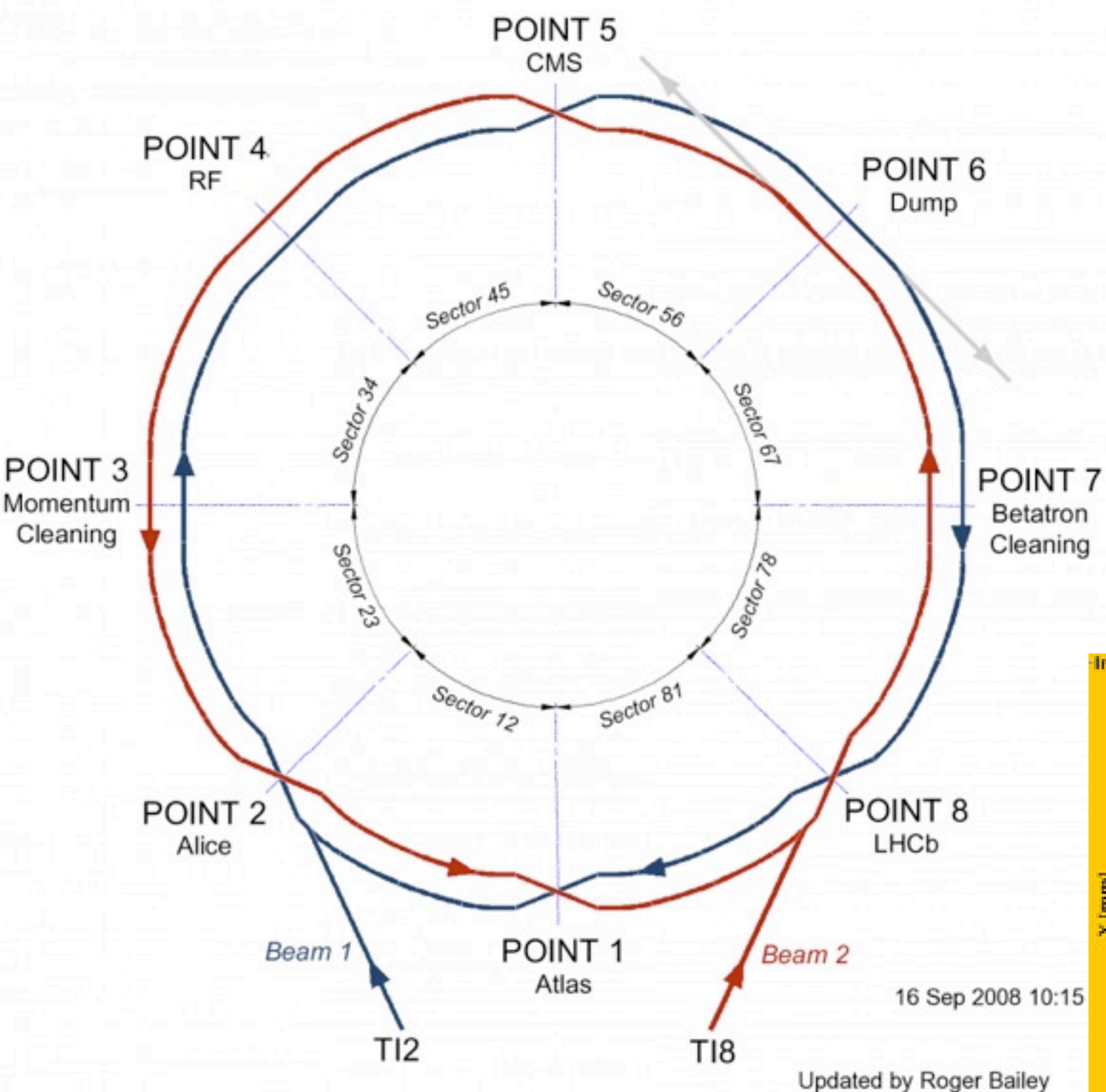
H. Pernegger

# 5. Grid - World wide analysis



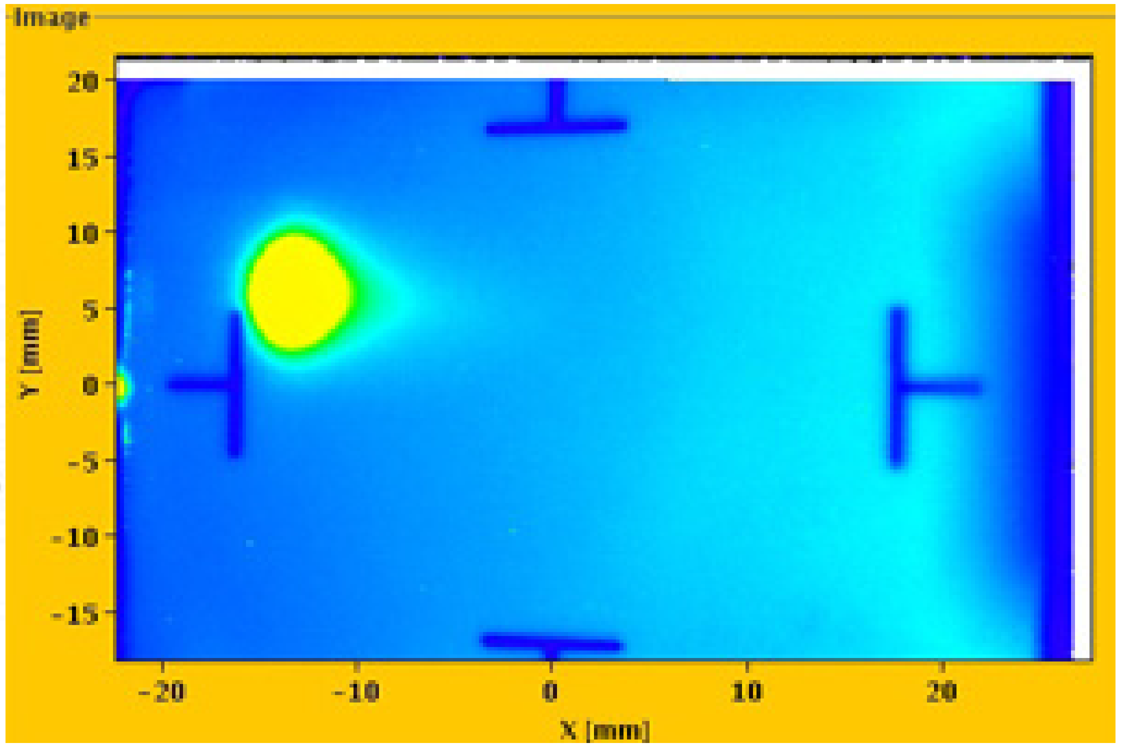



# 10. September - historical LHC start !

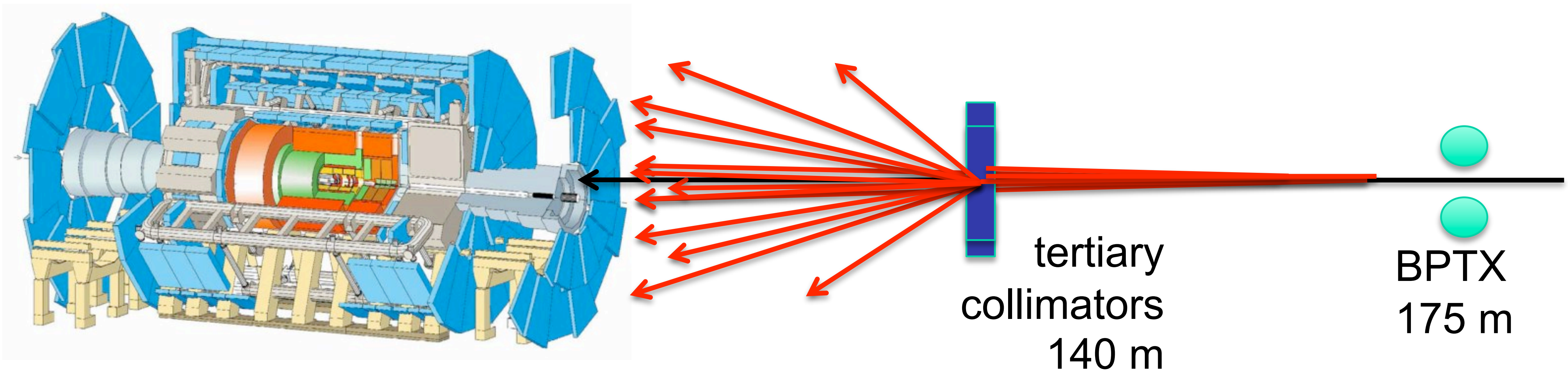



"Geneva, 10 September 2008. The first beam in the Large Hadron Collider at CERN was successfully steered around the full 27 kilometres of the world's most powerful particle accelerator at 10h28 this morning"

"On Thursday night, 11 September, beam two, the anti-clockwise beam, was captured and circulated for over half an hour before being safely extracted from the LHC... The LHC is on course for first collisions in a matter of weeks"



## What particles did we see in ATLAS ?




**ATLAS was ready for first beam:**

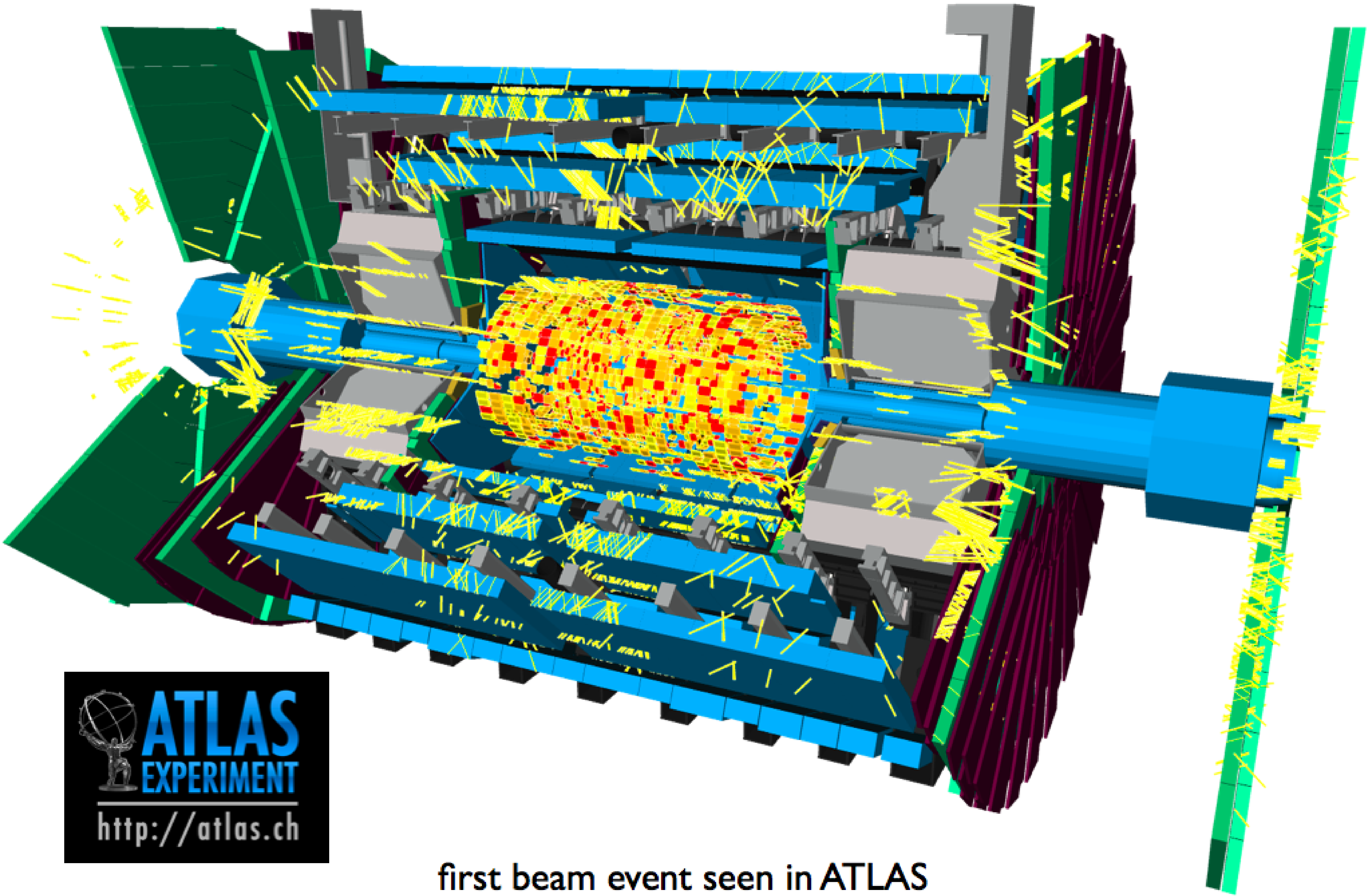
- Muon system (MDT, RPC, TGC) on at reduced HV
- LAr (-FCAL HV), Tile on
- TRT on, SCT reduced HV, Pixel off
- BCM, LUCID, MinBias Scint. (MBTS), Beam pickups (BPTX)
- L1 trigger processor, DAQ up and running, HLT available (but used for streaming only)

**Two LHC start-up scenarios:**

1. Open all collimators, go around as far as beam goes, correct as needed
   - Little activity expected except for accidents
2. Go step-by-step, stopping beam on collimators, re-align with centre, open collimator, keep going
   - Splash event from collimators for each beam shot

B. Stugu

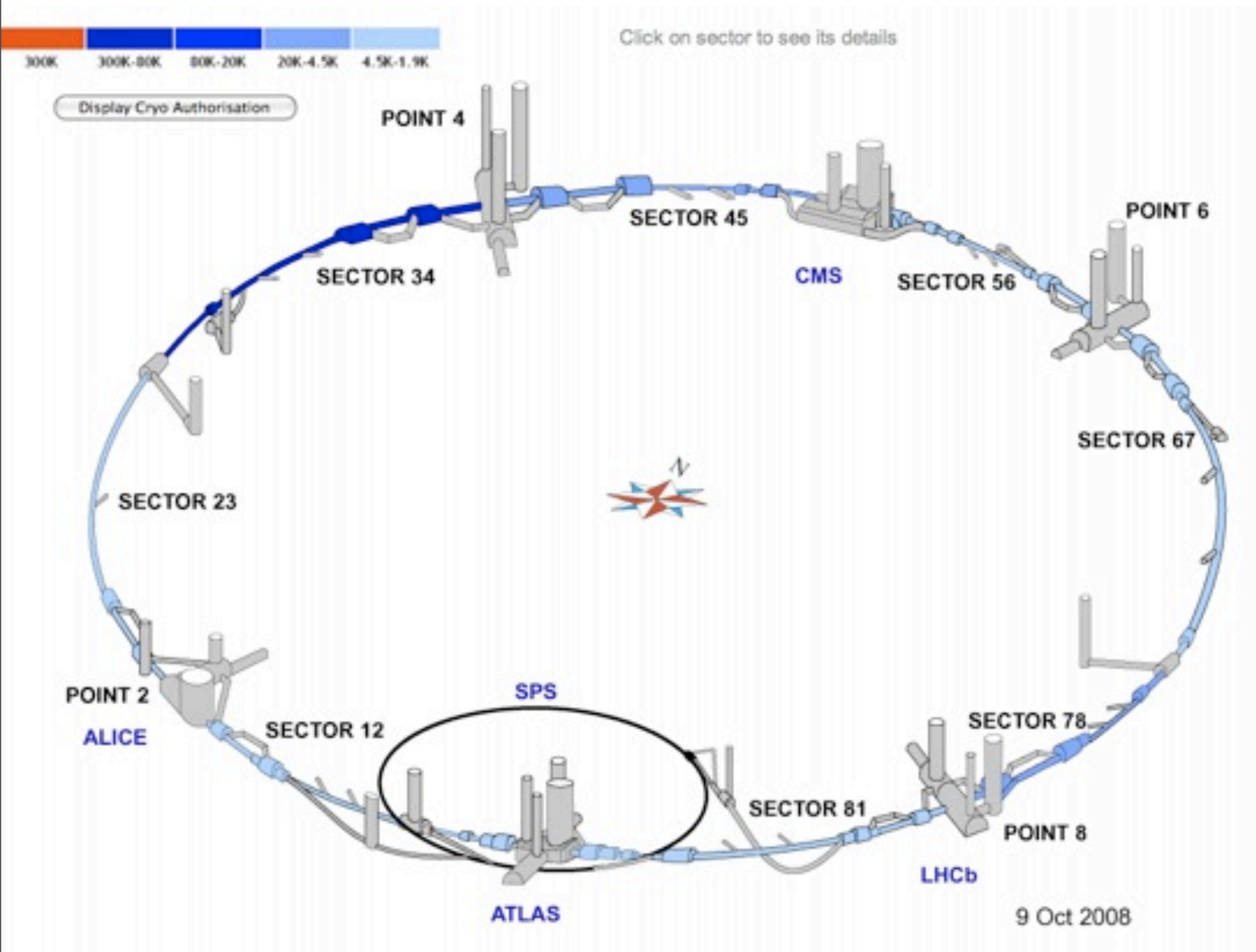
# 6. First results from LHC

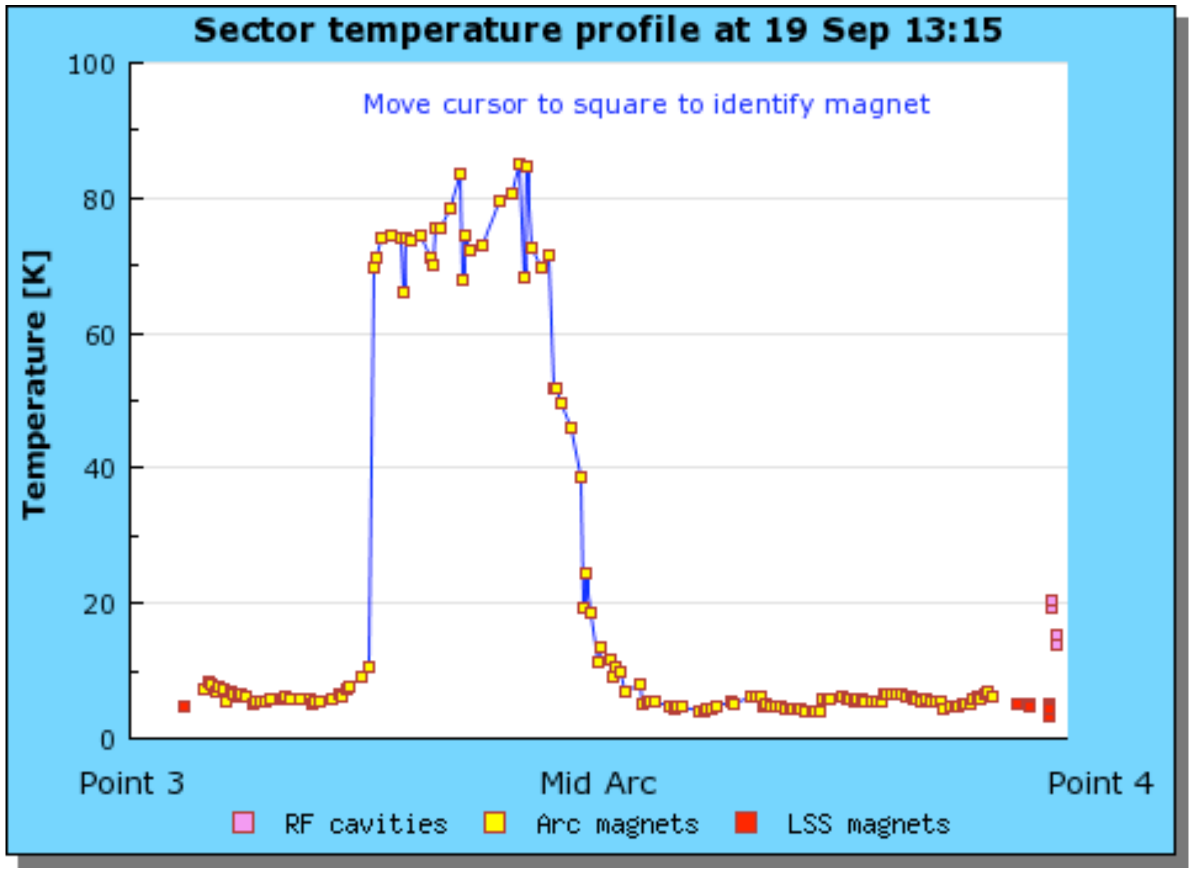



first beam event seen in ATLAS

# 19. September - historical LHC stop !

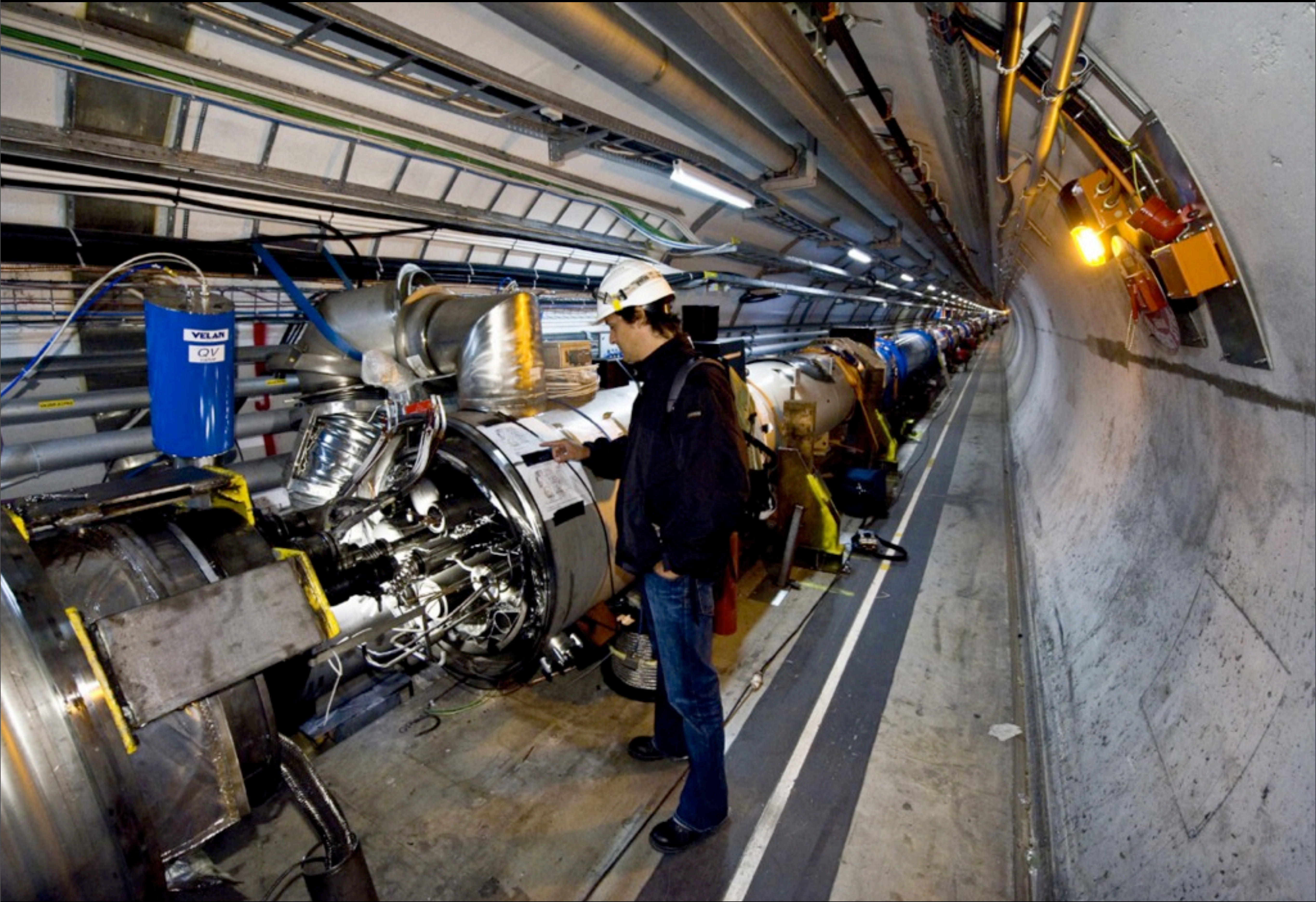
"During commissioning (without beam) of the final LHC sector (sector 3-4) at high current for operation at 5 TeV, an incident occurred at mid-day on Friday 19 September resulting in a large helium leak into the tunnel. ... the initial malfunction was caused by a faulty electrical connection between two magnets, which resulted in mechanical damage and release of helium from the cold mass into the tunnel"




**But the exitement is not over ... new startup in 2009 !**

# 6. First results from LHC



# Plan for 2009

**Reparasjon og installering**

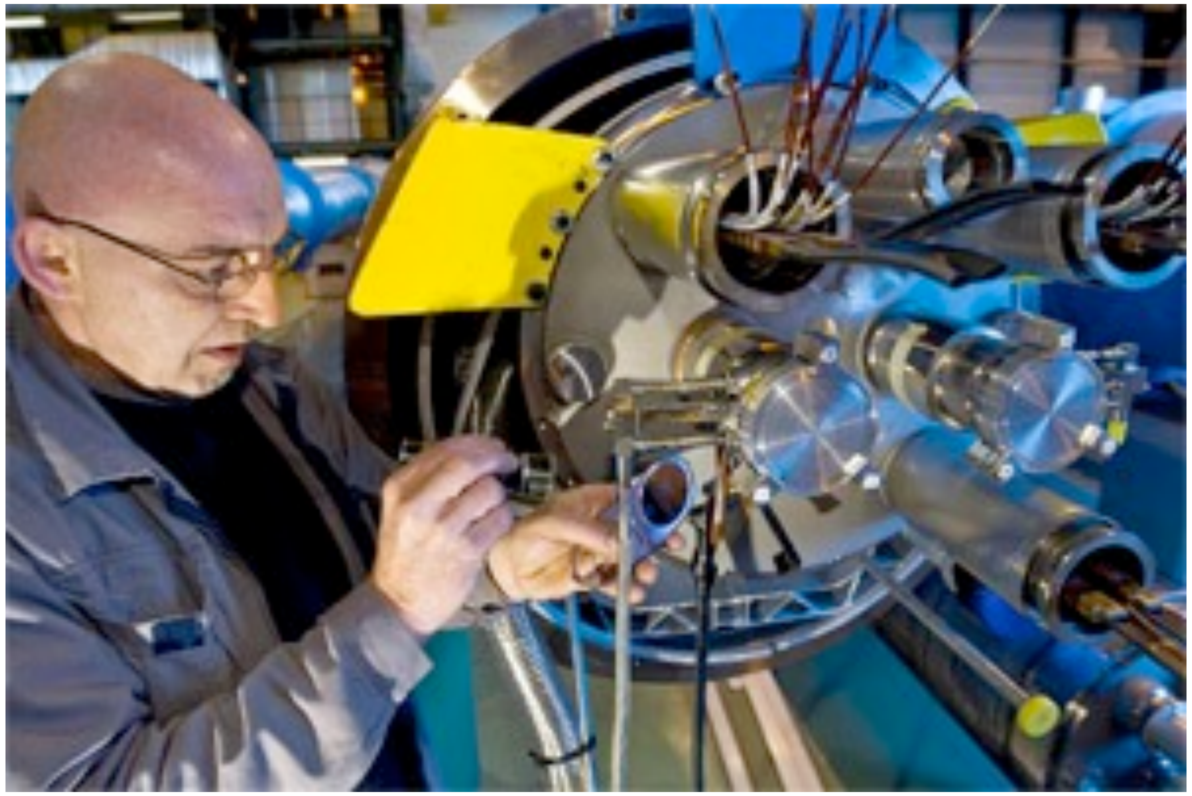
- 53 magneter måtte ut av tunnellen for rensing eller reparasjon
- Planen er at den siste magneten er tilbake i tunellen i slutten av mars

**Testing**

- Nedkjøling av magnetene tar flere måneder
- Planen er at det er klart for strømtester ved slutten av juni

**Kollisjoner**

- I løpet av høsten
- En konferanse i Chamonix akkurat nå hvor dette blir diskutert samt en plan for hvilke kollisjoner man skal ha til hvilken energi



*Final preparations on a replacement magnet ready to be lowered into sector 3-4*

***"The top priority for CERN today is to provide collision data for the experiments as soon as reasonably possible"***

# Mini svarte hull på CERN

## Universet har laget høy energetiske proton-proton kollisjoner i løpet av milliarder av år. Vi er fremdeles her ...

*"The world will not come to an end when the LHC turns on. The LHC is absolutely safe. ... Collisions releasing greater energy occur millions of times a day in the earth's atmosphere and nothing terrible happens."*

**Prof. Steven Hawking, Lucasian Professor of Mathematics, Cambridge University**

**Universet**

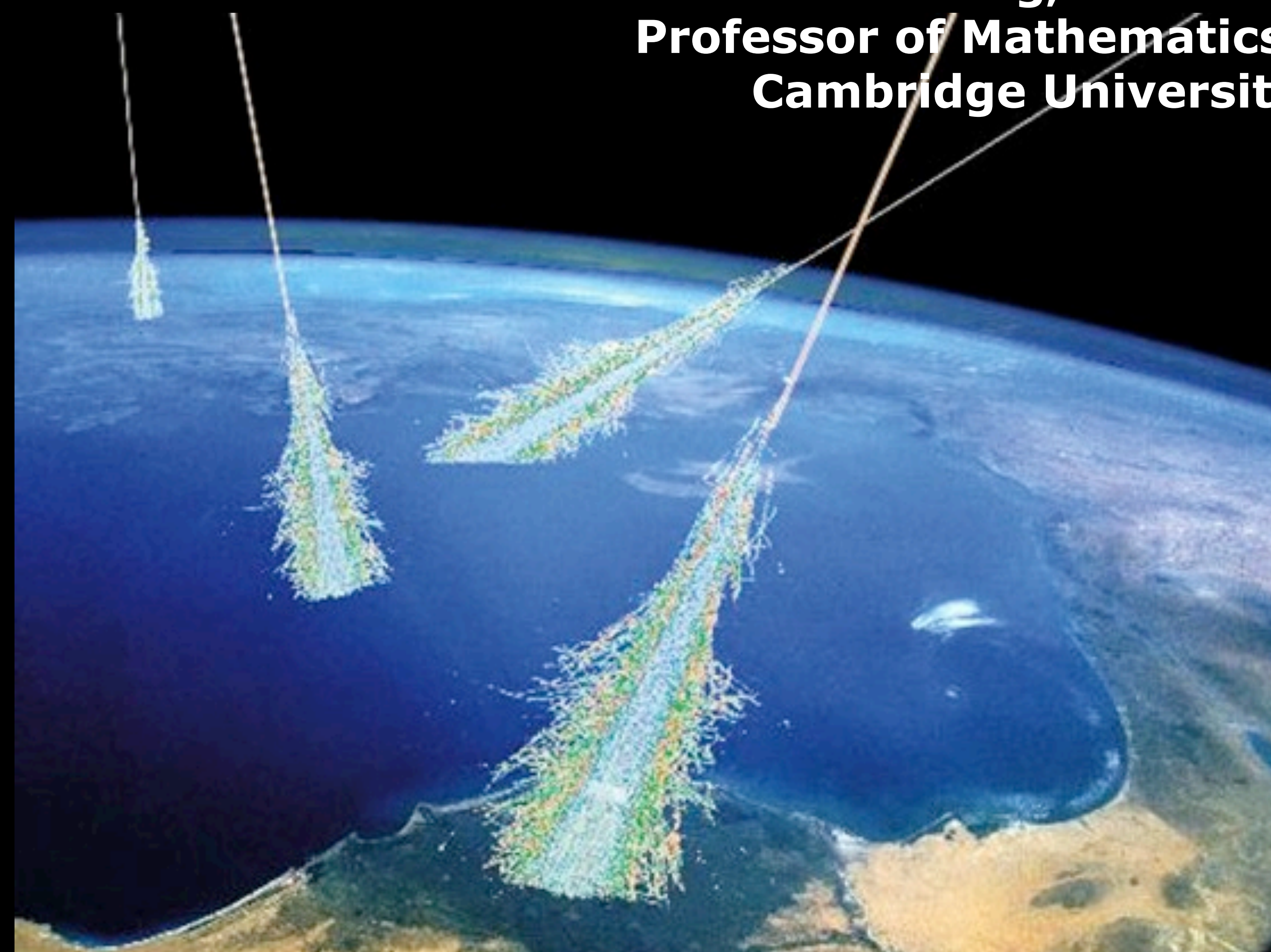
- Det skjer det mer en 10 millioner millioner LHC-lignende eksperiment hvert sekund !

**Cosmisk stråling**

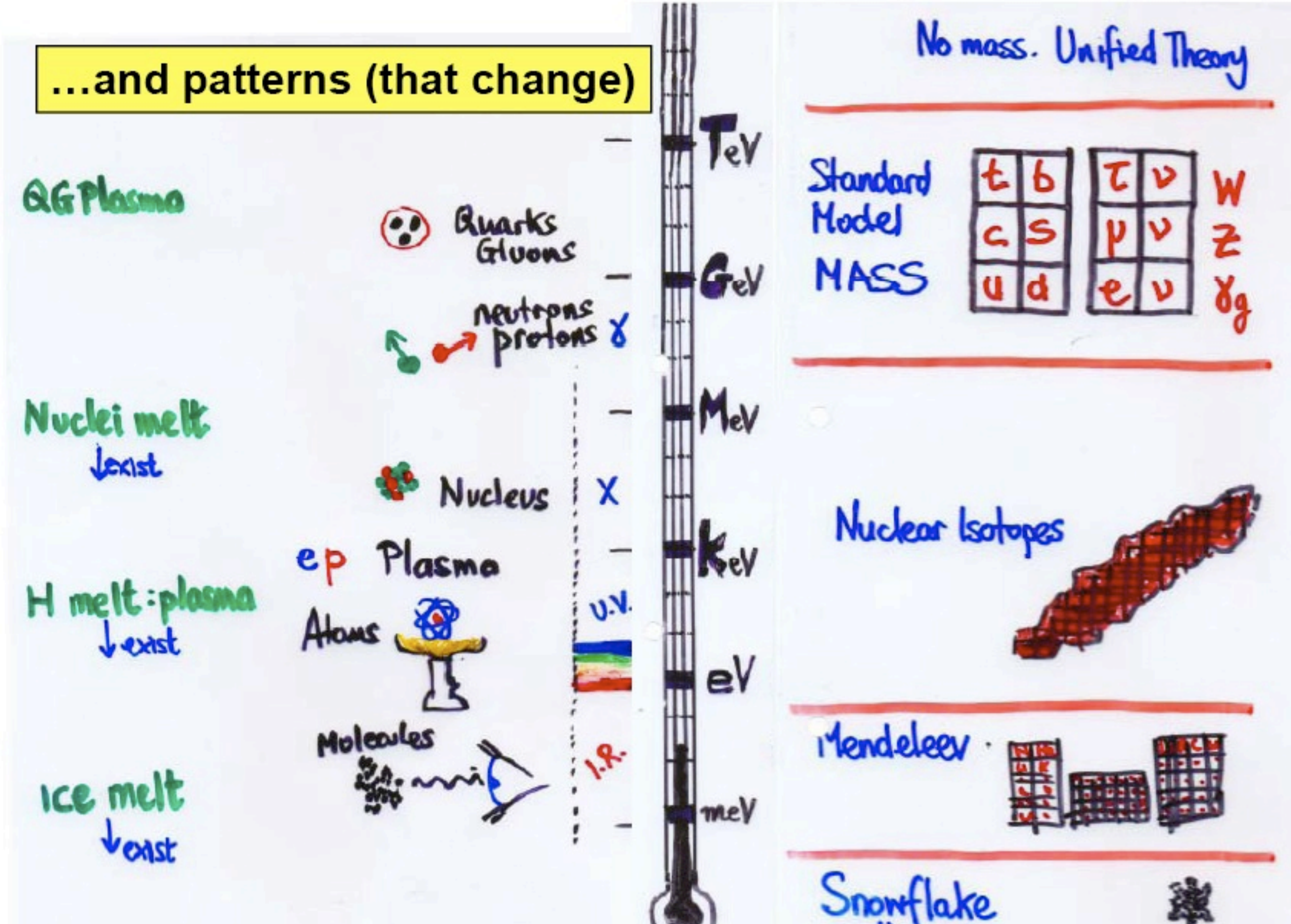
- Hele tiden skjer det at kosmiske stråler kolliderer med vår atmosfære, dette skjer ofte med mye høyere energi enn det vi kan lage ved LHC

**Svarte hull**

- En mulig teoretisk modell !
- Astronomiske svarte hull kan ikke lages på CERN, det som kanskje! kan lages er mikroskopiske hull når to protoner kolliderer
- Disse er ikke levedyktige og dør med en gang

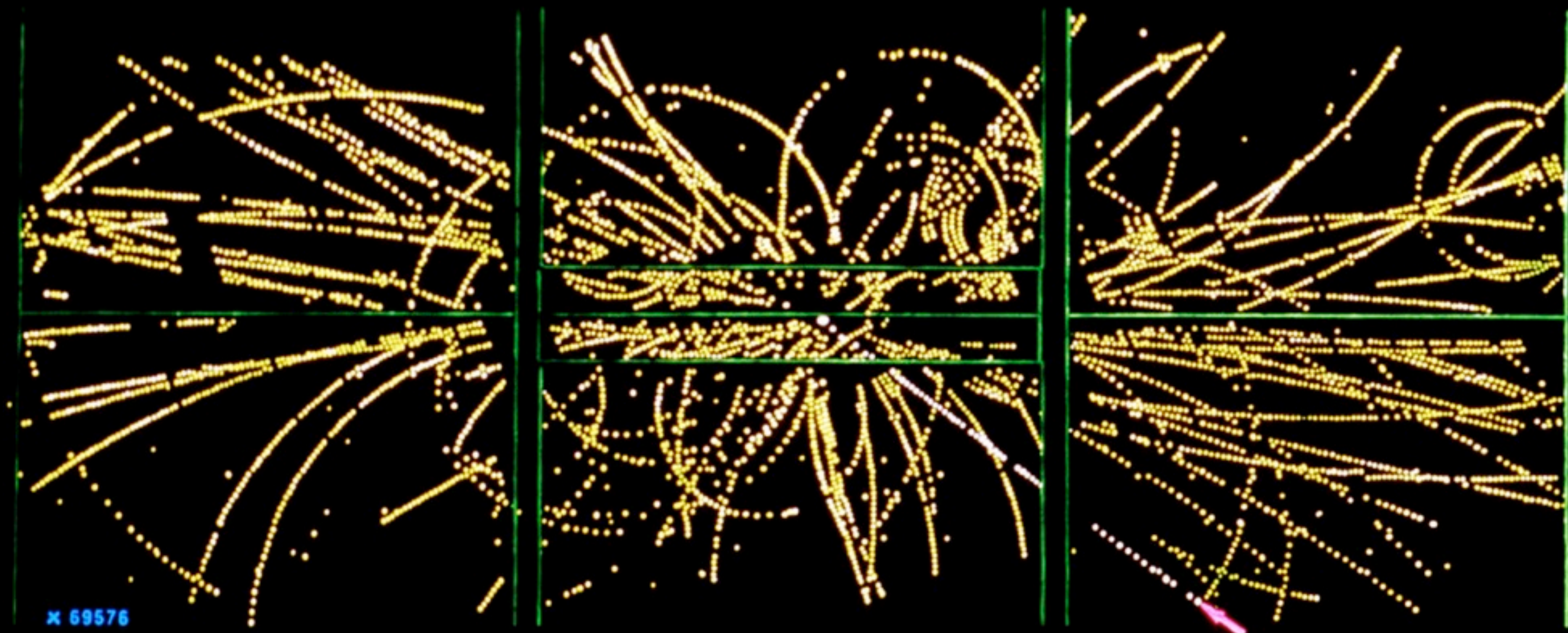


# …and patterns (that change)



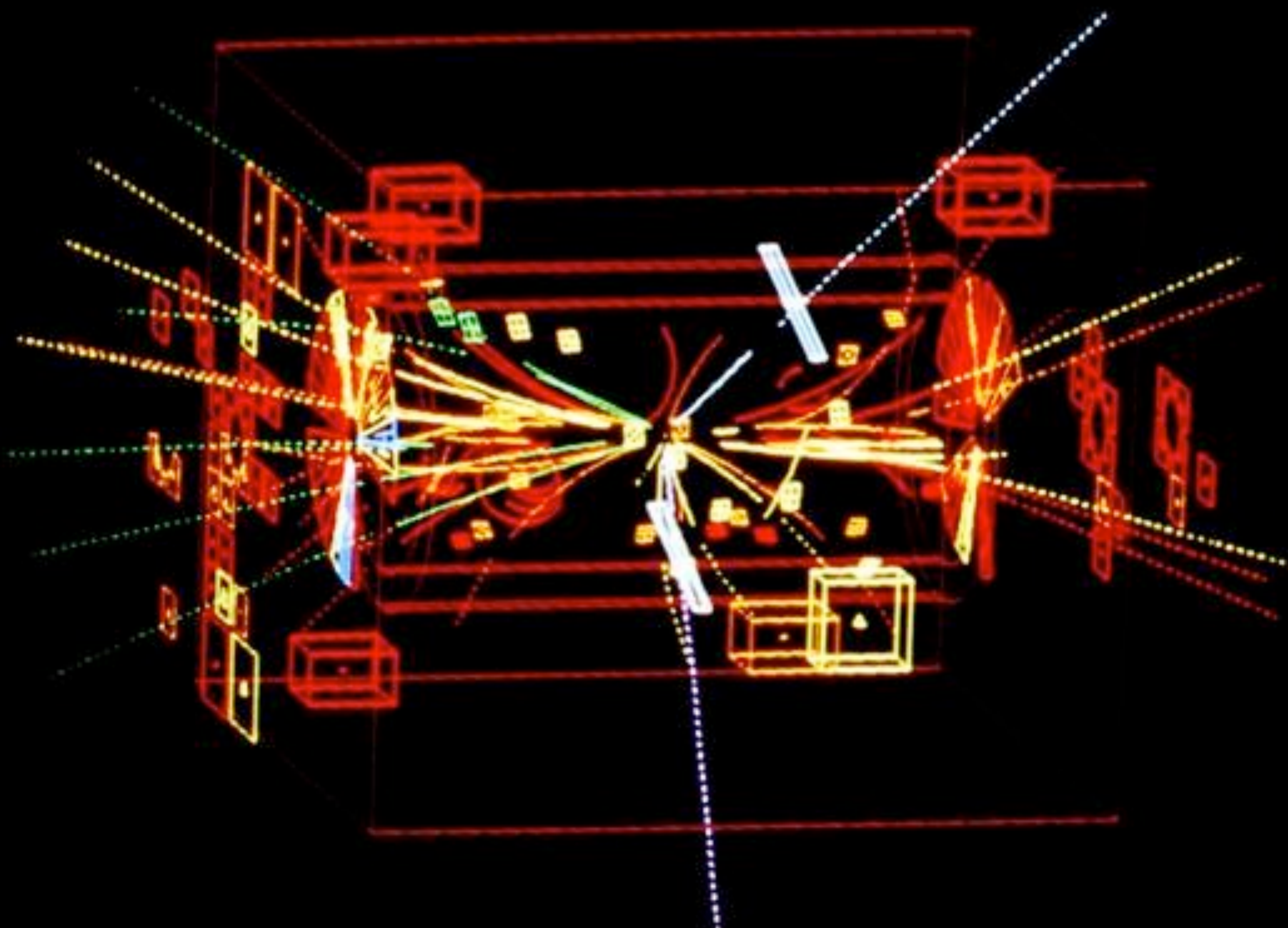

F. Close

## Oppdagelsen av W bosonet ved UA1 (SppS)



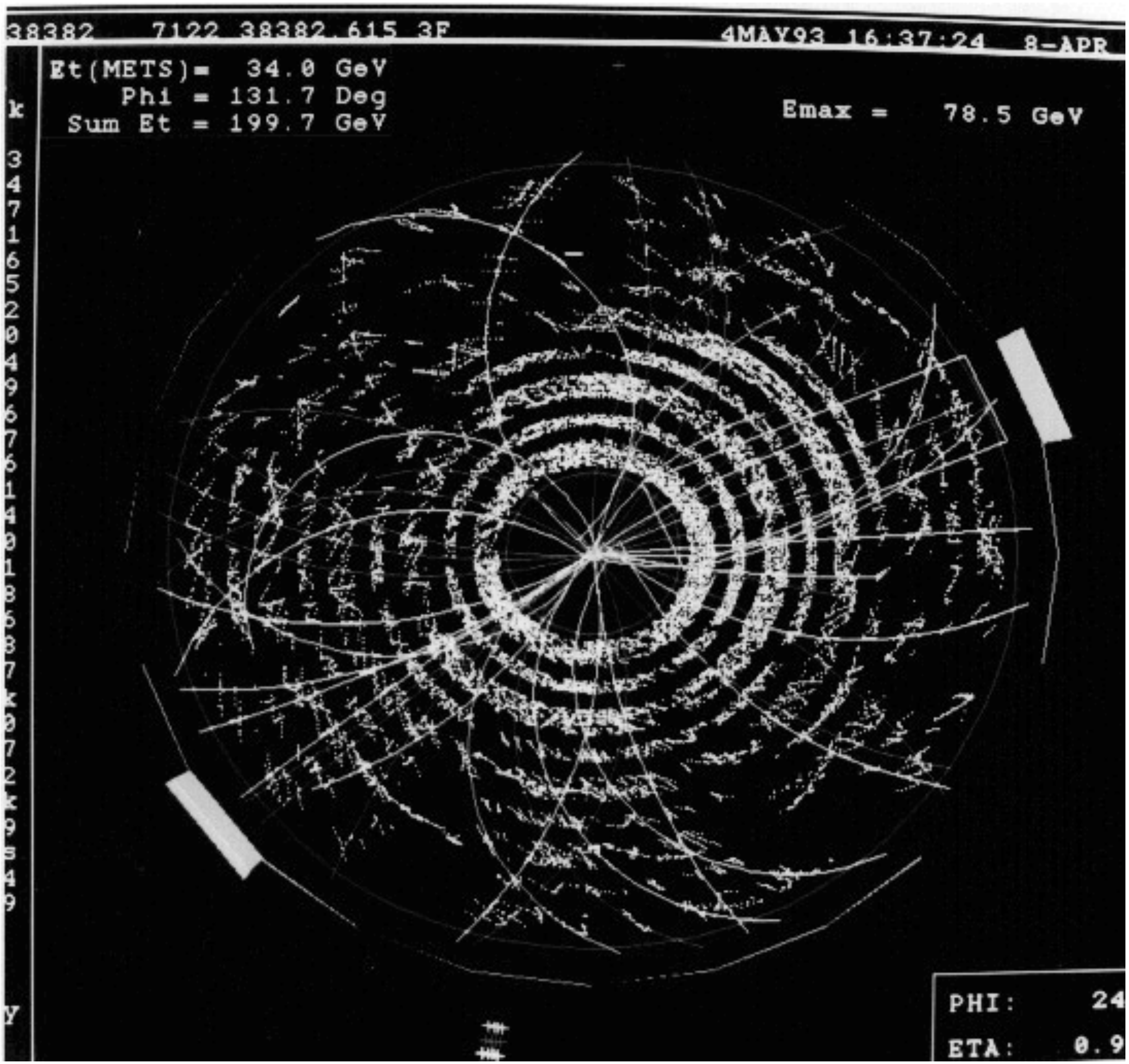

➡ Discovery of the W particle in 1982, producing a high transverse energy electron back to back with missing energy (neutrino)

# Oppdagelsen av Z bosonet ved UA1 (SppS)

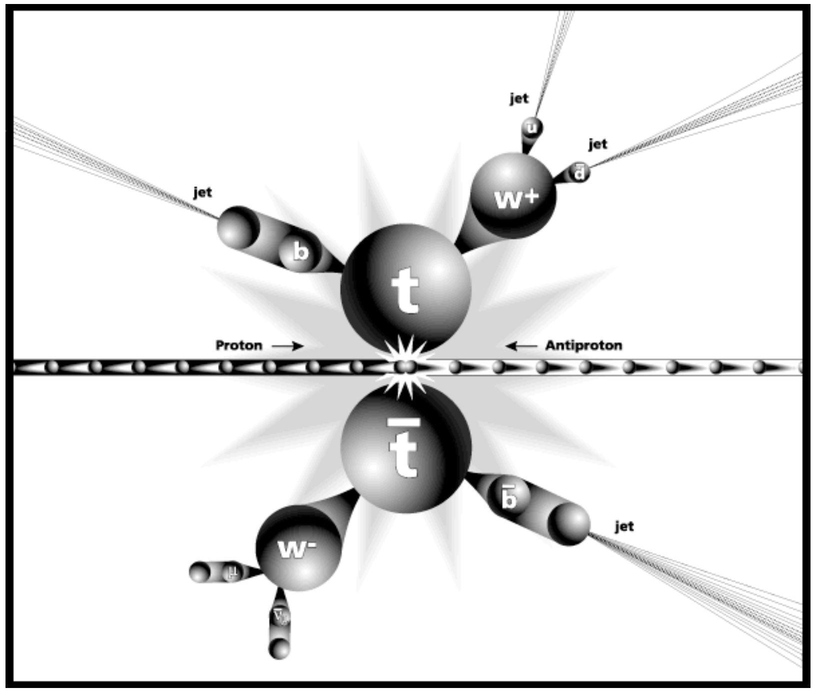


➡ Discovery of the Z particle in 1983. In this the neutral Z decays into a high-energy electron and a positron (antielectron) carrying the mass that once was the Z particle, converted accoring to E =mc2.

# 4. Standard Modellen - En familie til !

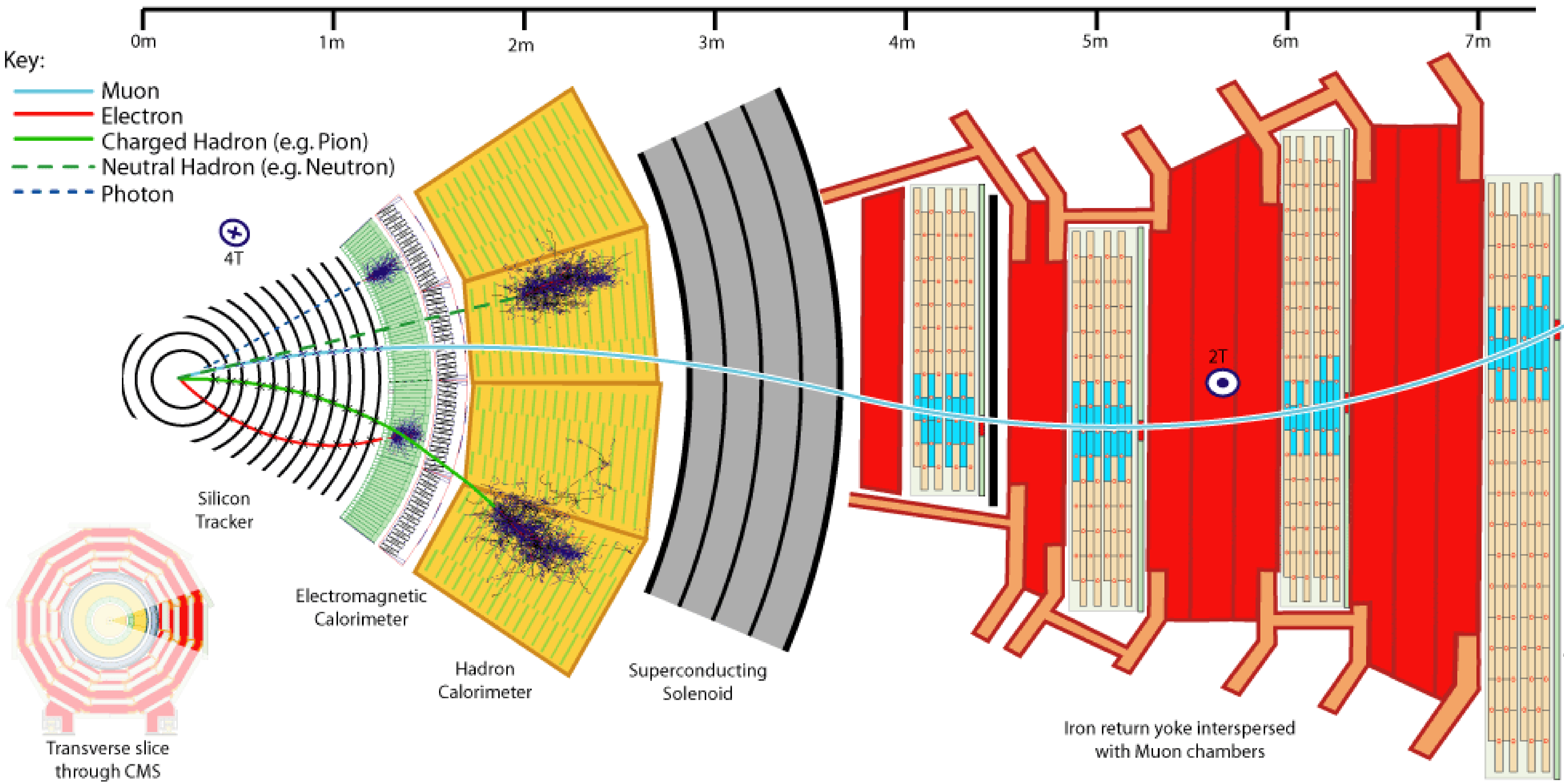



- ➡ **Top kvarken ble oppdaget i 1995 ved Fermilab, Chicago**
- ➡ **Masse 172 GeV (proton 0.94 GeV)**




*Physicists recognize particles produced in collisions by their electronic signatures, shown graphically by computers. The circle shows a computer-generated view of a potential top quark signature, with particle tracks emerging from the center of a collision.*

# Partiklenes bane gjennom en detektor

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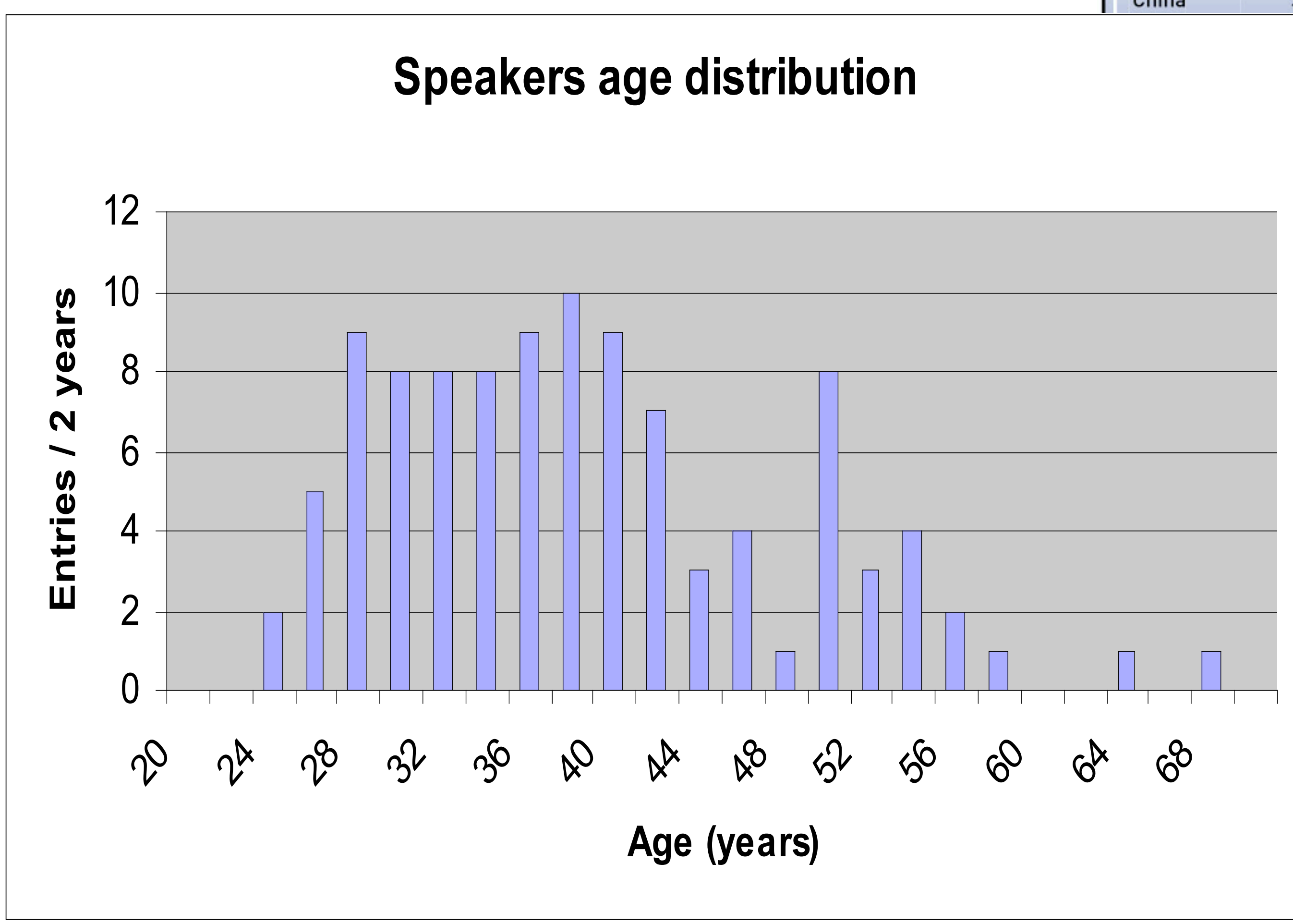
# The Atlas collaboration

**A truly worldwide collaboration:**

35 Countries

158 Institutions

1770 Scientific Authors


**e.g 4th ATLAS Physics Workshop Athens, May 2003**

**Speakers age distribution of 103 (of the 104) talks**

**28 female and 76 male speakers**

# Black holes in LHC?

- Black holes could, in principle, be arbitrarily small. However, according to standard General Relativity, there is no chance to prodce black holes at the LHC, since conventional gravitational forces between fundamental particles are too weak.
- There is no established quantum theory for gravitation (certainly needed for small ones).
- Some quantum gravity proposals (involving more than 3 spacial dimensions) make speculative predictions on production of black holes in proton.proton collisions at LHC
- *But in these models they are always unstable, both because of Hawking radiation, and because they always can decay back into the particles that produced them.*
- (I'm of course brainwashed by the Cern/LHC Safety Assesment Group, Ellis,Guidice,Mangano,Tkachev,Wiedemann, CERN-PH-TH/ 2008-136)