CERN

European Organization for Nuclear Research

Introduction to LHCb

High School Teachers program
30th June 2009

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CERN’s objectives are to understand

•the structure of matter and particles

•the forces that hold them together

•the evolution of the early Universe

The Standard Model of particles and forces has been tested and proven very successful BUT…
it leaves many unsolved questions

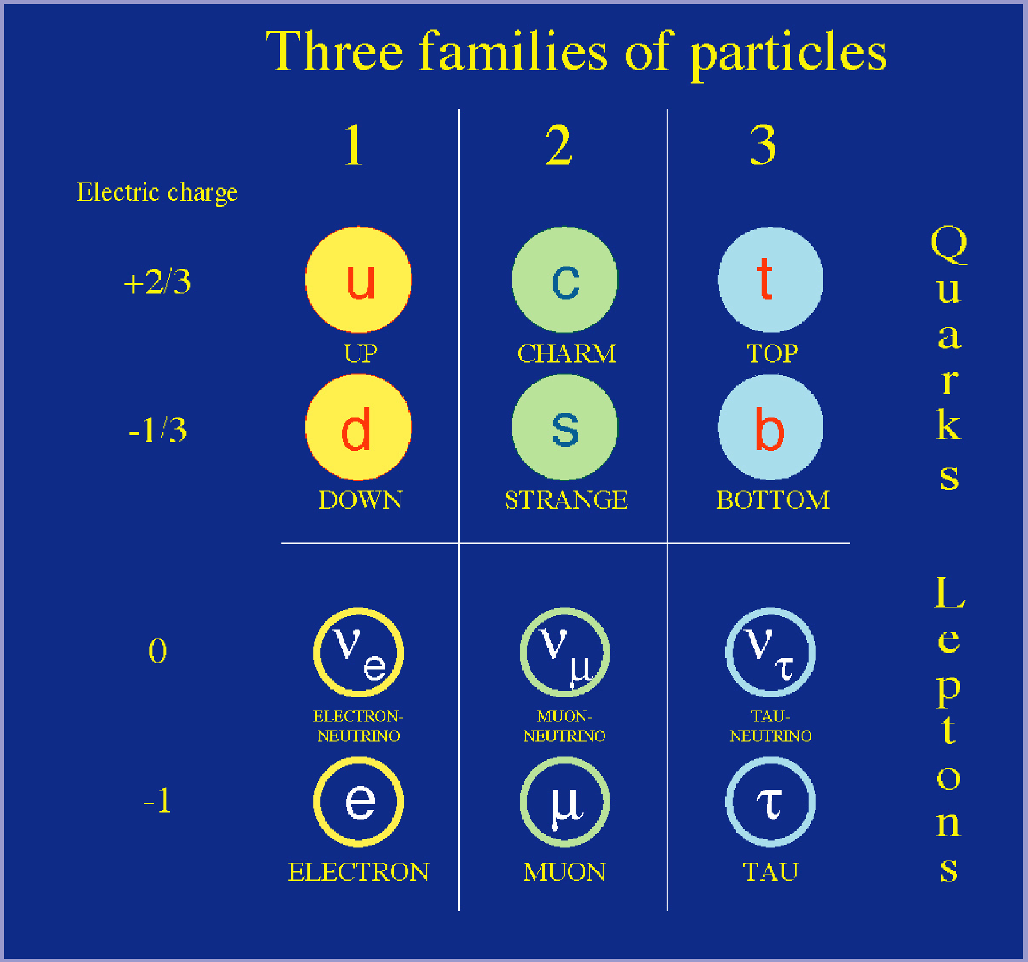
why?

The known constituents of the Universe :

Why 3 families?

How do particles get their mass?

Answer may be so-called 'Higgs mechanism'.
If Higgs particle exists, LHC will detect it.



Stable (very) short lived

why?

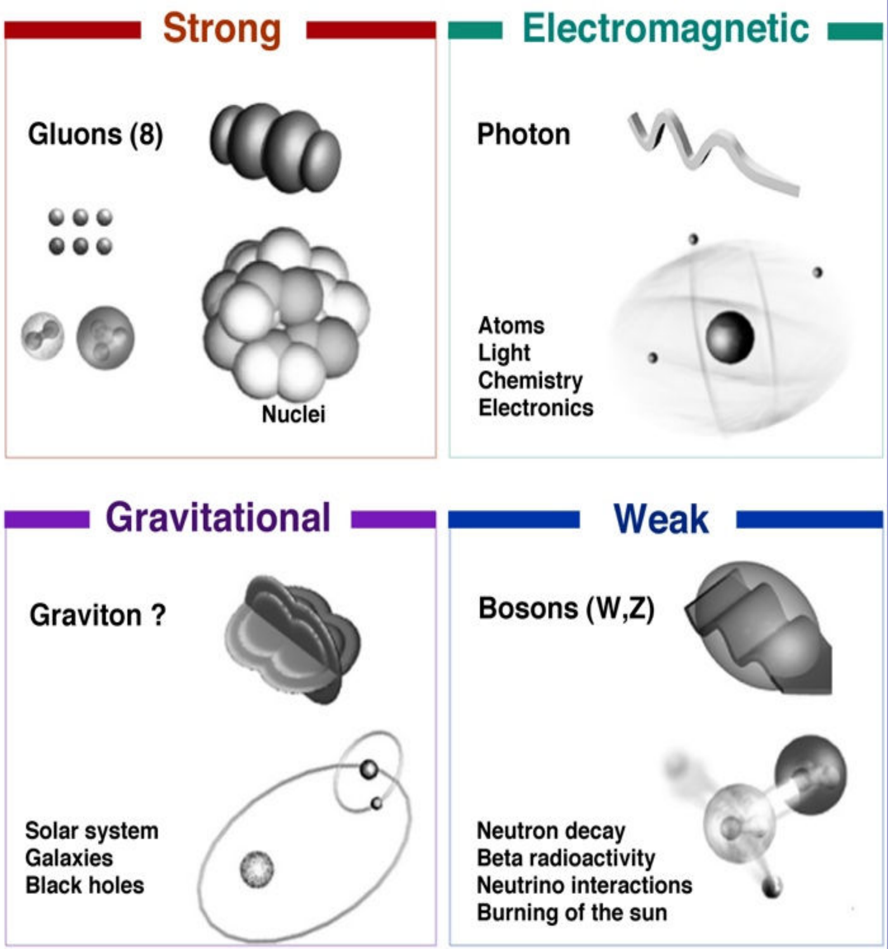
Relative strengths of the interactions?

The SM does not offer a unified description of all fundamental forces.

Supersymmetry could facilitate the unification of fundamental forces.

Lightest SUSY particles may be found at the LHC.

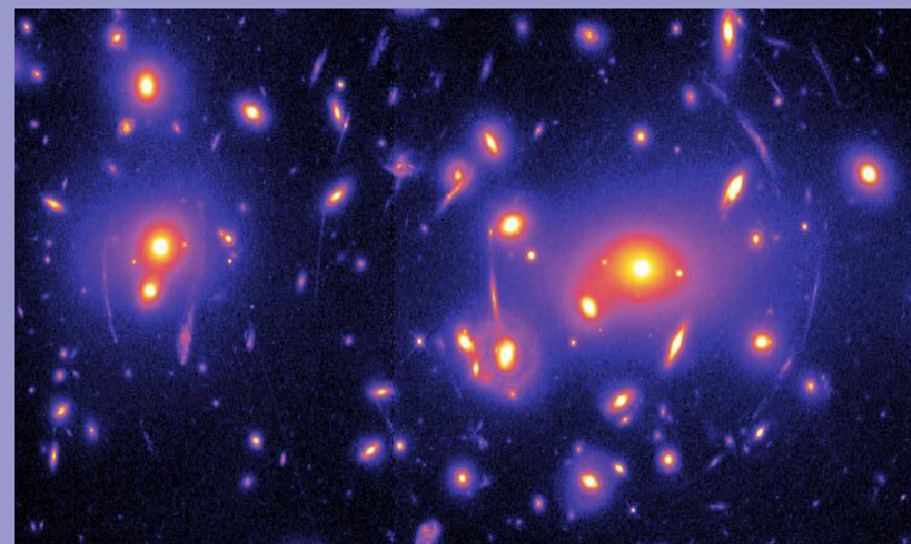
FORCES



why? to understand the evolution of the early Universe

Cosmological and astrophysical observations have shown that all visible matter accounts for only 4% of the Universe

1 - Galaxies rotate too fast



2 - Light is bent more than expected

Is there a new type of matter ? Dark matter could be made of neutral SUSY particles. We shall look for them with the LHC!

why

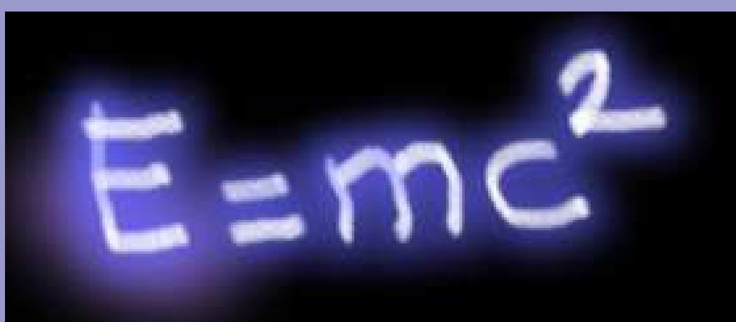
Dirac predicted the existence of **antimatter**:

same mass

opposite internal properties: electric charge, …

Discovered in cosmic rays

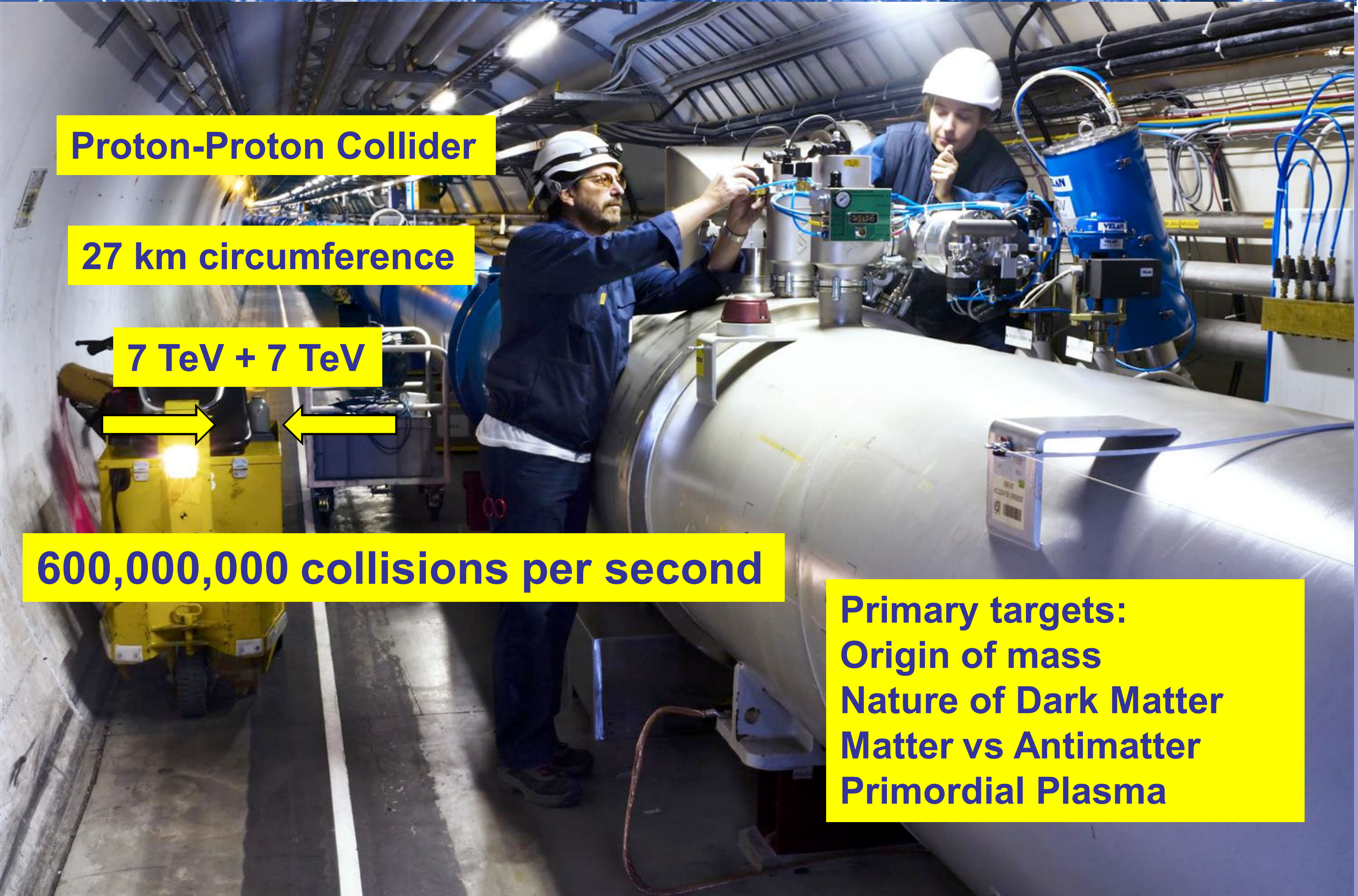
Studied using accelerators



If energy converts equally into MATTER and ANTIMATTER….
where has the antimatter gone?

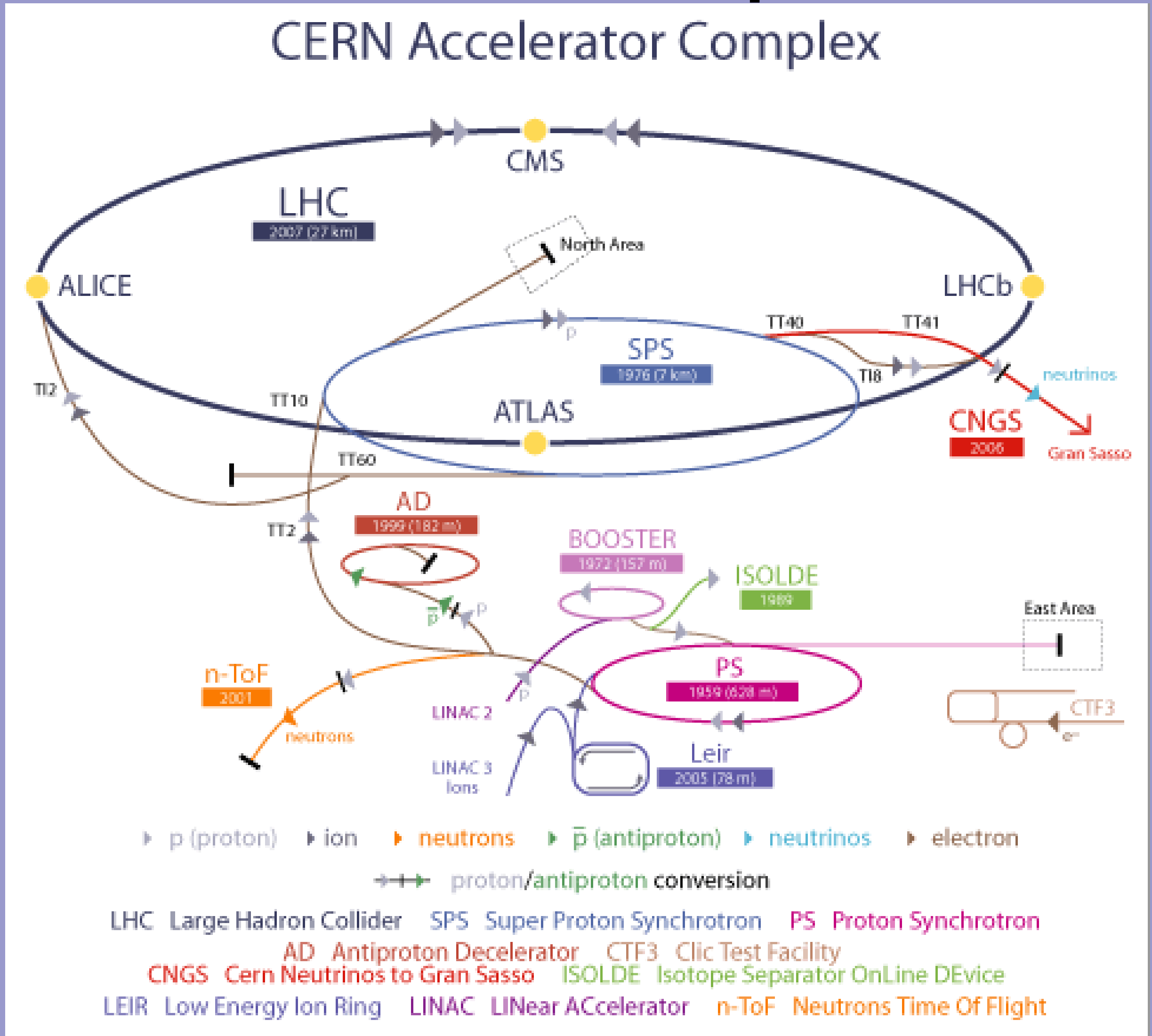
The theory of particle physics is not symmetric between matter and anti-matter.
The disappearance of anti-matter has been produced dynamically in the history of the universe (baryogenesis).
Experiments at the LHC (and elsewhere), LHCb in particular, looking for clues

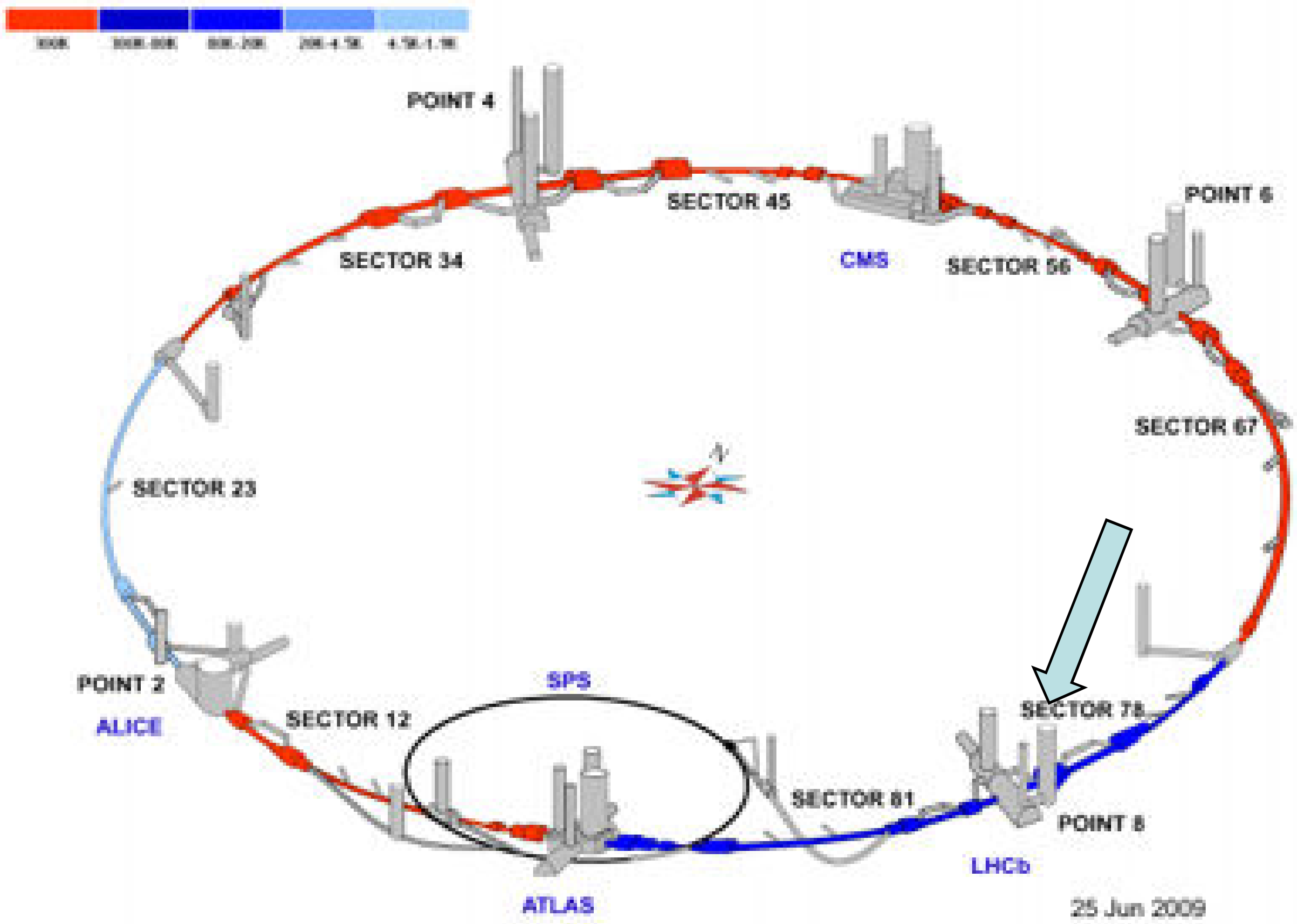
The Large Hadron Collider (LHC)



CERN Accelerator Complex

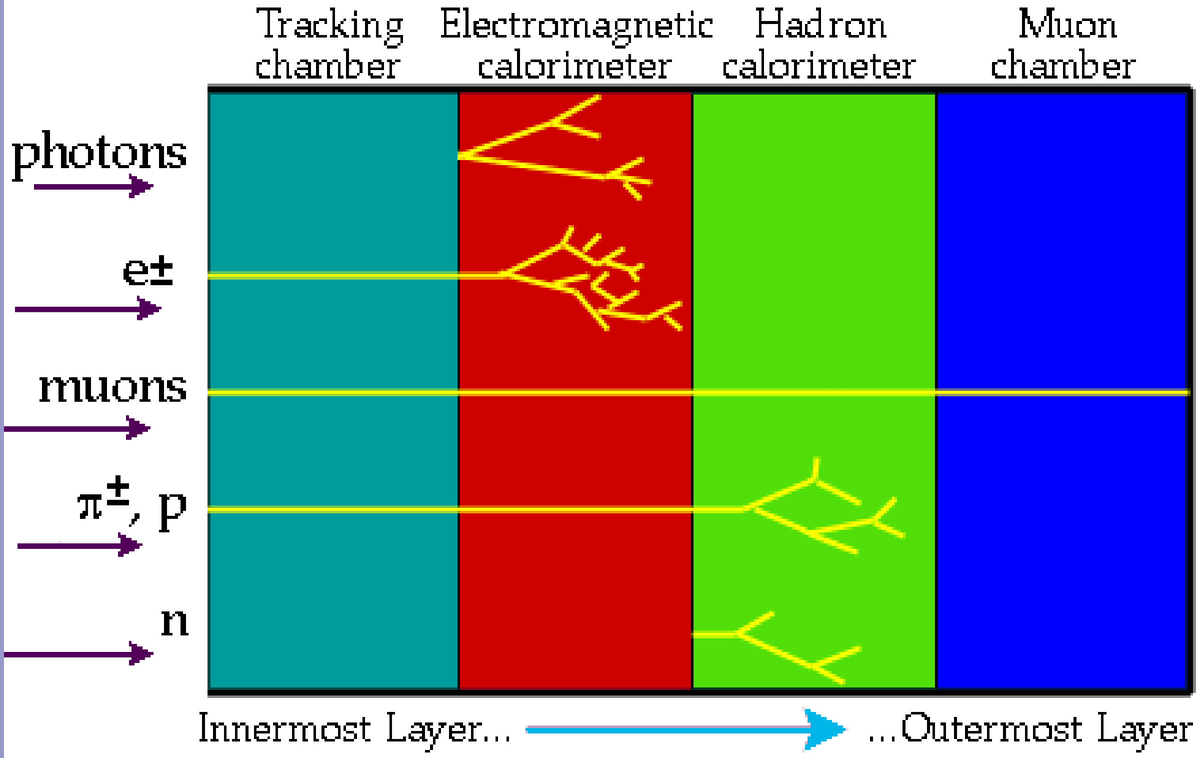
LINAC 2	50 MeV
PS Booster	1.4 GeV
PS	25 GeV
SPS	450 GeV
LHC	7 TeV



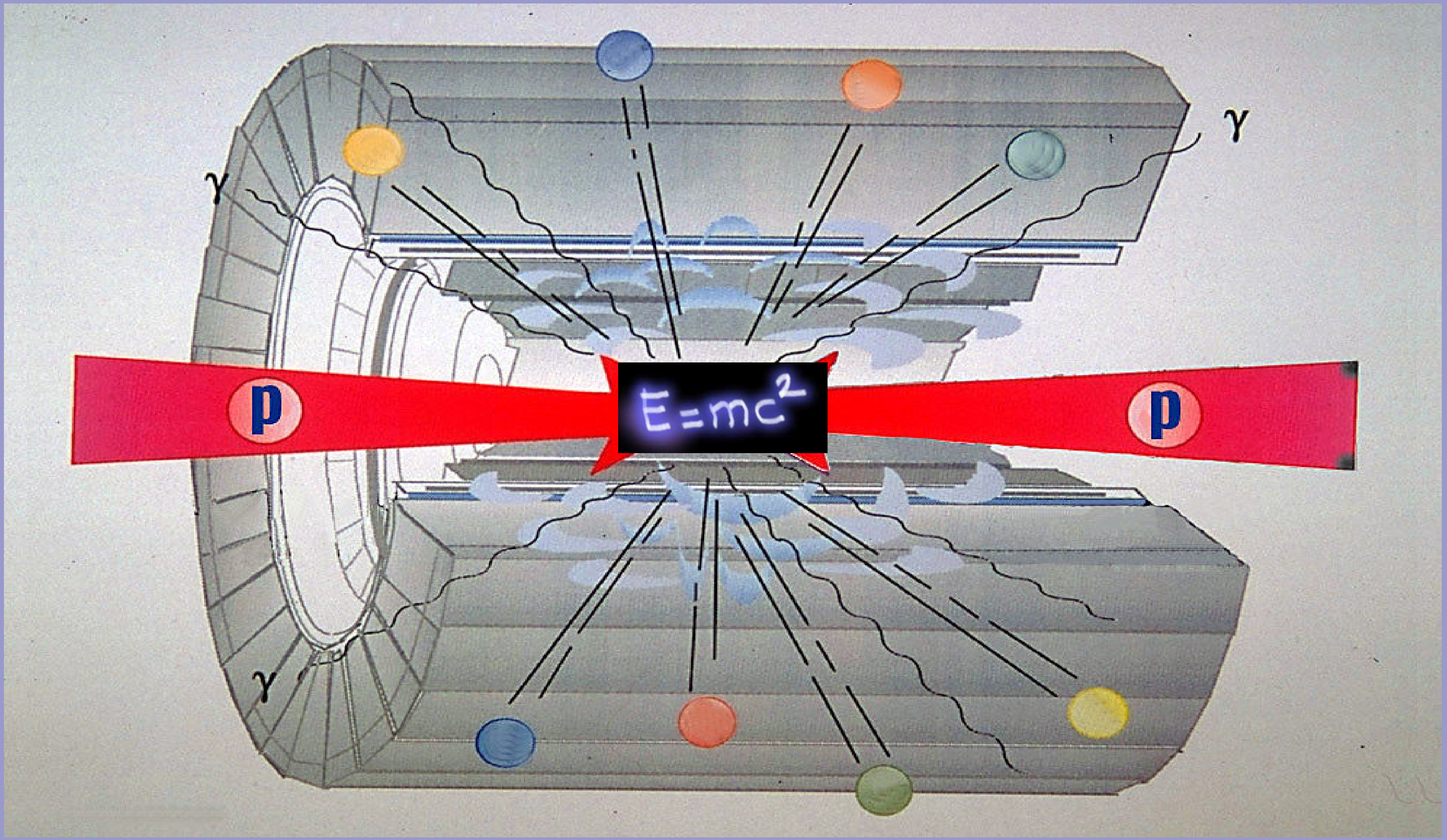


LHC Cooldown Status

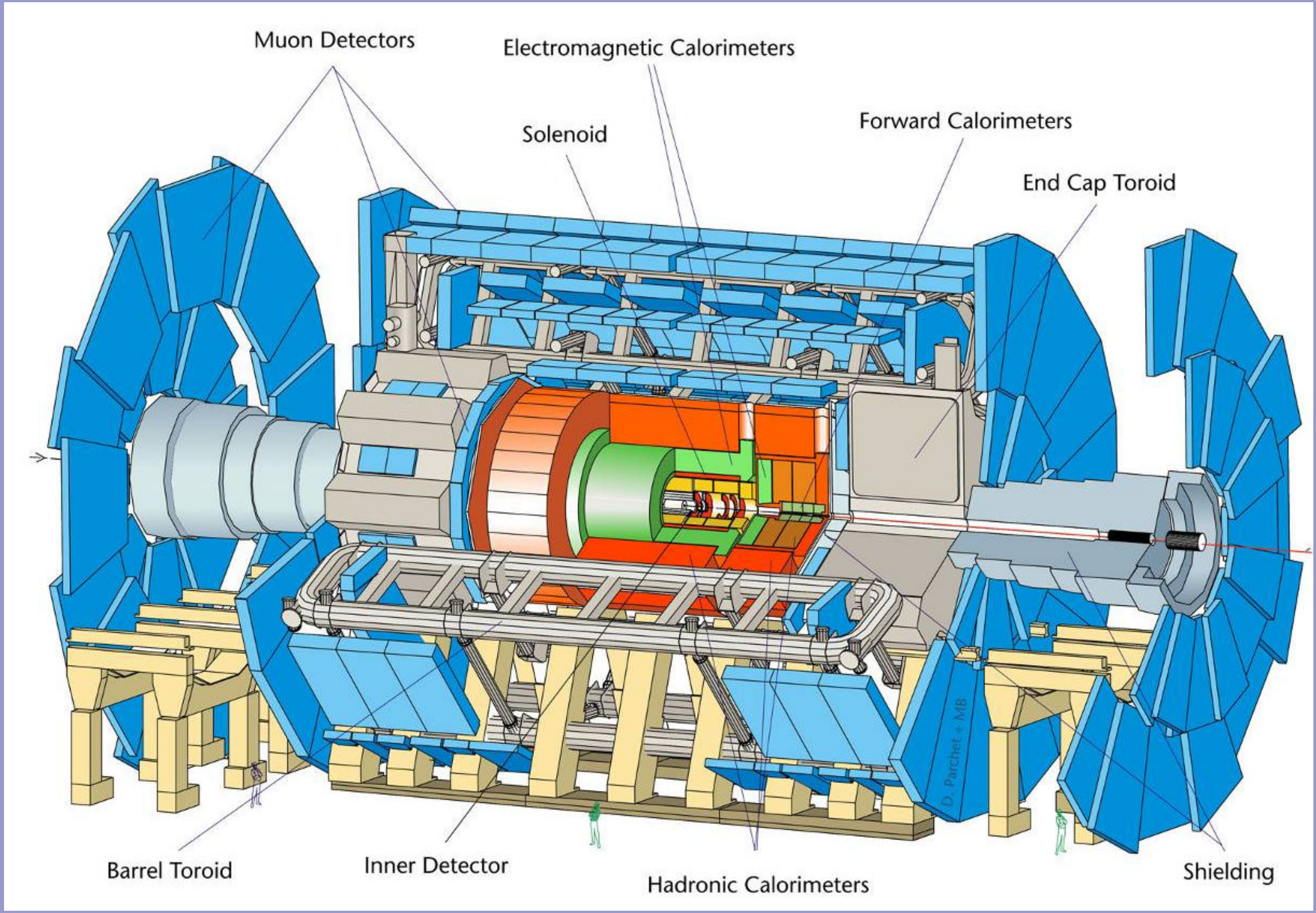
how? Each sub-detector specializes in measuring a different characteristic of the particles produced by colliding protons. Collectively the detector's components gather information about trajectory, momentum, energy, identity of each particle generated in the collision



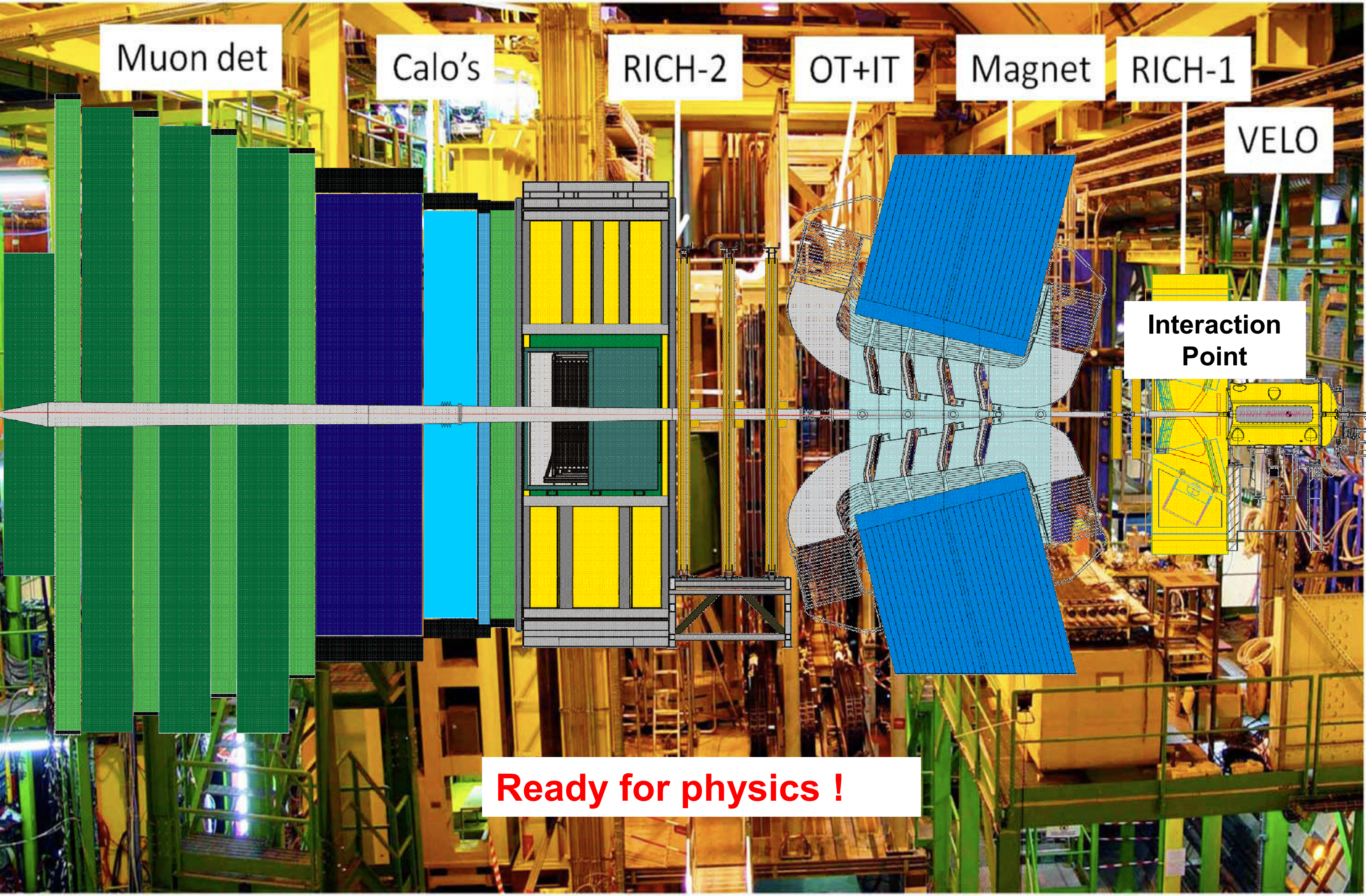
how?



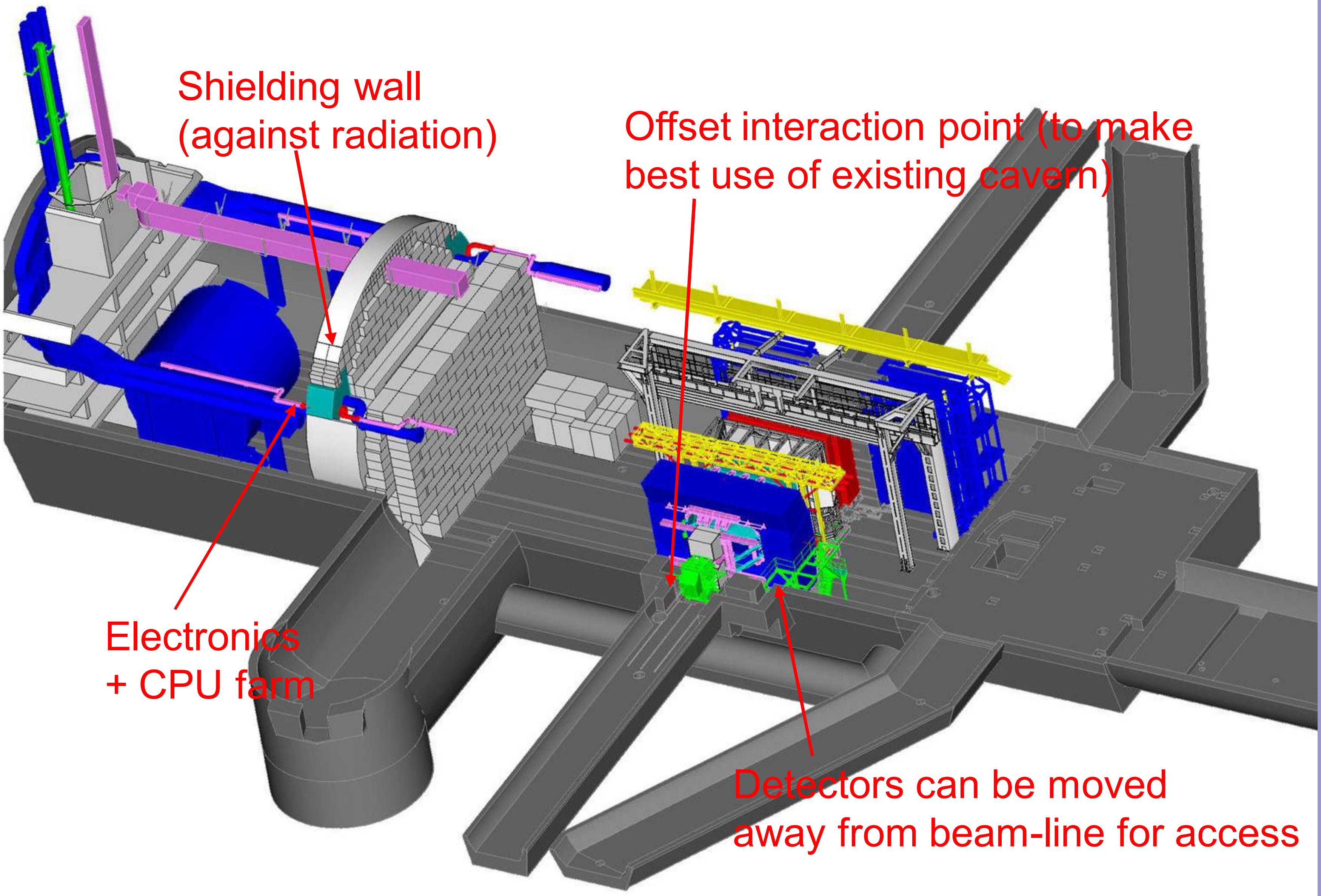
- **ATLAS**: It is the biggest HEP experiment ever – about the size of a five-story building 45 m long, 7000 tons



LHCb


Muon det
Calo's
RICH-2
OT+IT
Magnet
RICH-1
VELO
Interaction Point
Ready for physics !

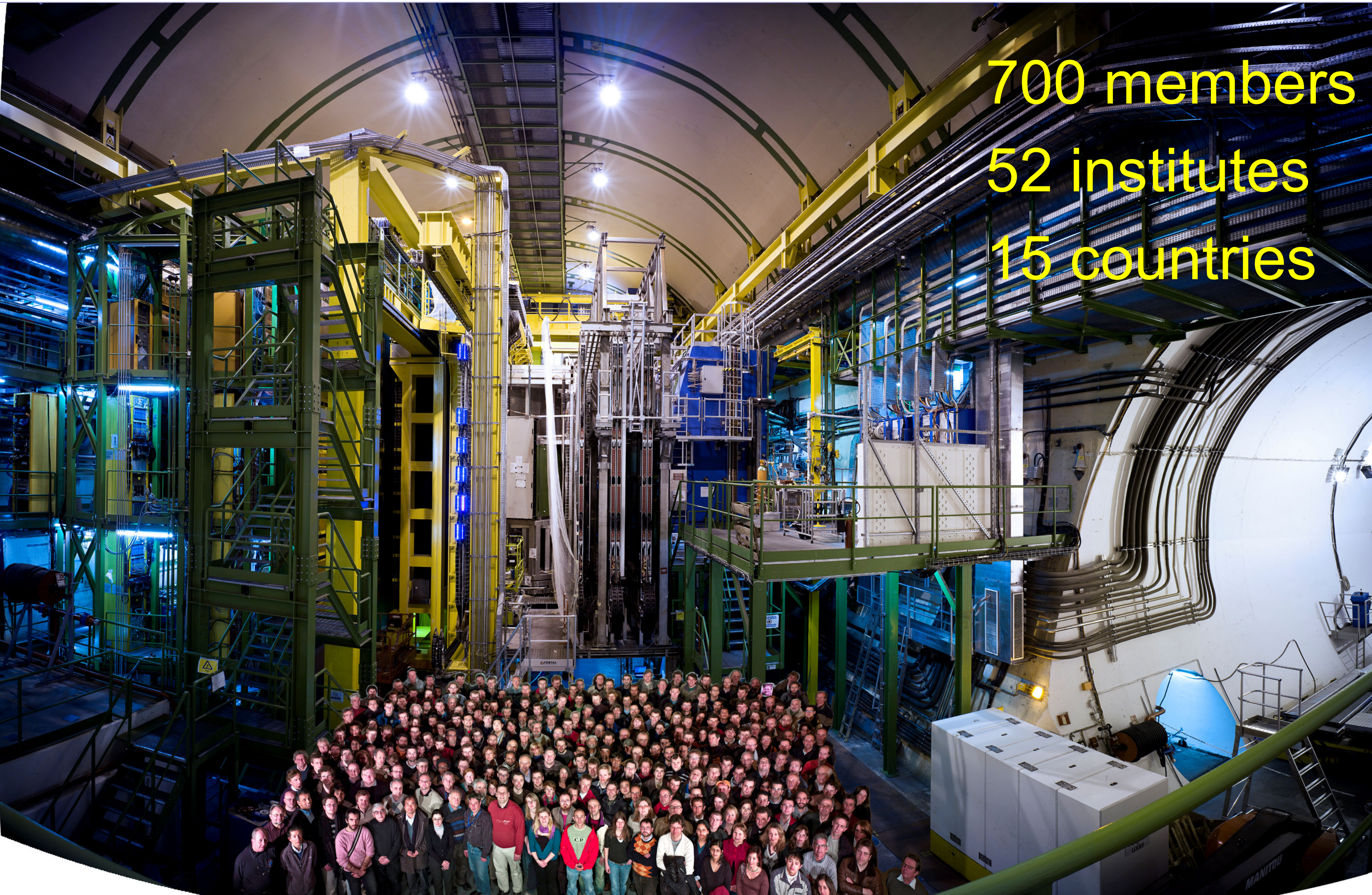
LHCb in its cavern



A lot of progress!

February 2002
Cavern ready for detector installation

LHCb



LHCb b stands for beauty!

Specializes in the study of the slight asymmetry between matter and anti-matter present in interactions of **B-particles** (particles containing the b(eauty) quark).

Imbalance between matter and anti-matter requires breaking the symmetry between them, known as **CP violation**:

Combined operation of

C =charge conjugation (swapping particles & antiparticles)

P =parity (spatial inversion, like reflection in a mirror)

B and anti-B particles are unstable and short-lived (~1 ps lifetime), decaying rapidly into many other particles. Physicists believe that by comparing their decays, they may be able to gain useful clues on CP violation.

General Purpose Detectors (ATLAS and CMS) will search for new physics by direct production of the new particles.

LHCb will study possible effects of the same new particles in B decays as they contribute as intermediate states in some decay amplitudes (Feynman diagrams with loops).

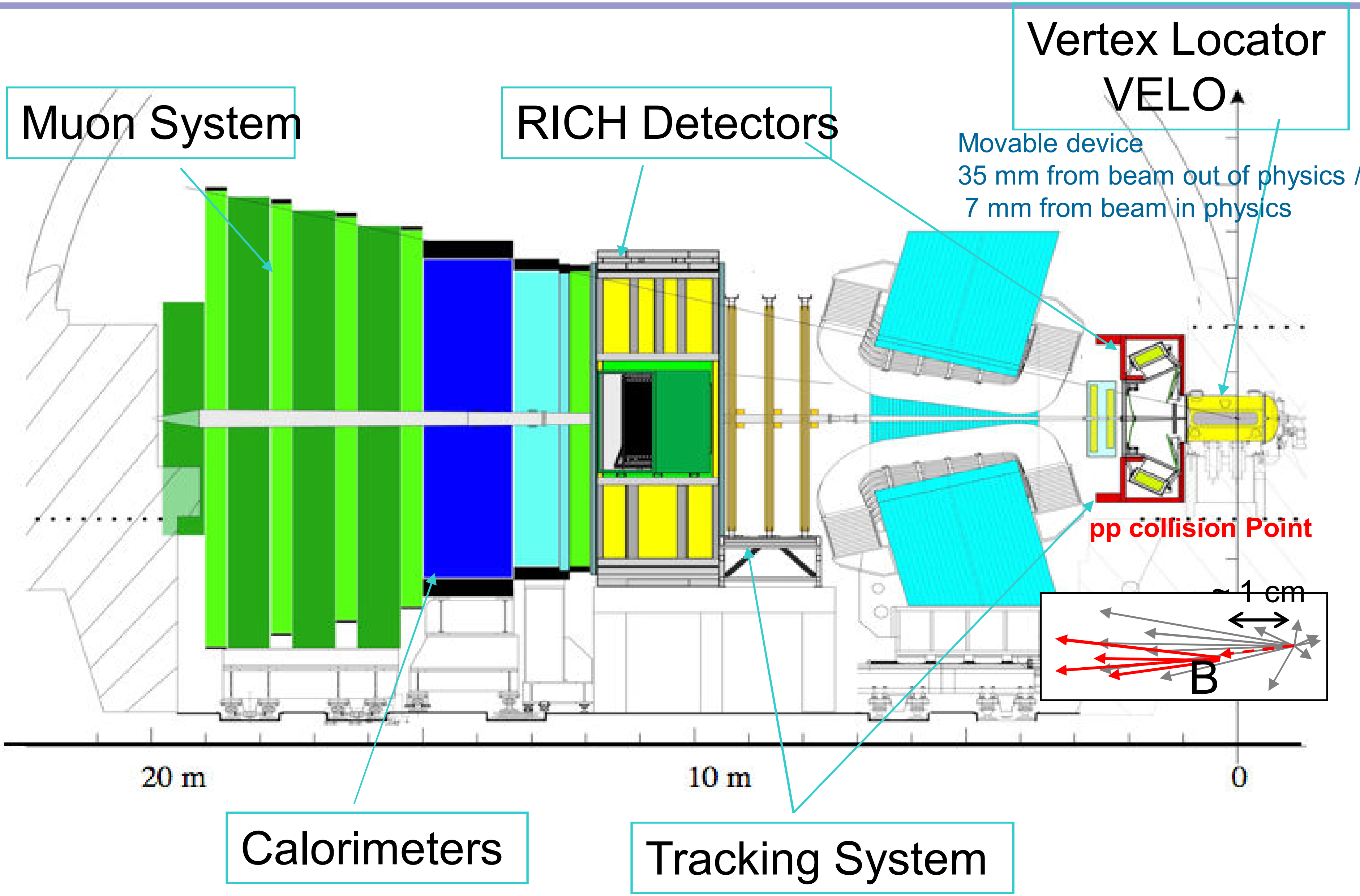
A complementary approach!

CP violation has also been studied in kaon decays.

B decays are simpler both experimentally and theoretically.

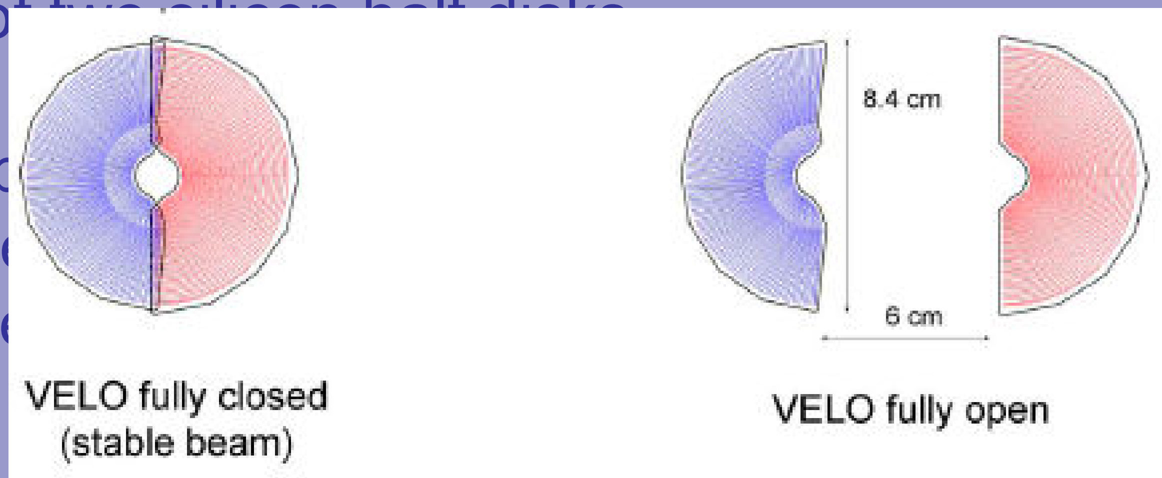
Why does LHCb look so different?

B mesons formed by the colliding proton beams (and the particles they decay into) stay close to the line of the beam pipe, and this is reflected in the design of the detector. Other LHC experiments surround the entire collision point with layers of sub-detectors, like an onion, but the LHCb detector stretches for 20 metres along the beam pipe, with its sub-detectors stacked behind each other like books on a shelf.


Vertex Locator
VELO
Muon System
RICH Detectors
Movable device
35 mm from beam out of physics /
7 mm from beam in physics
pp collision Point
~ 1 cm
B
20 m
10 m
0
Calorimeters
Tracking System

The VELO

The VELO is a precise particle tracking detector which surrounds the pp collision point inside LHCb. It is composed of 21 stations, each made o



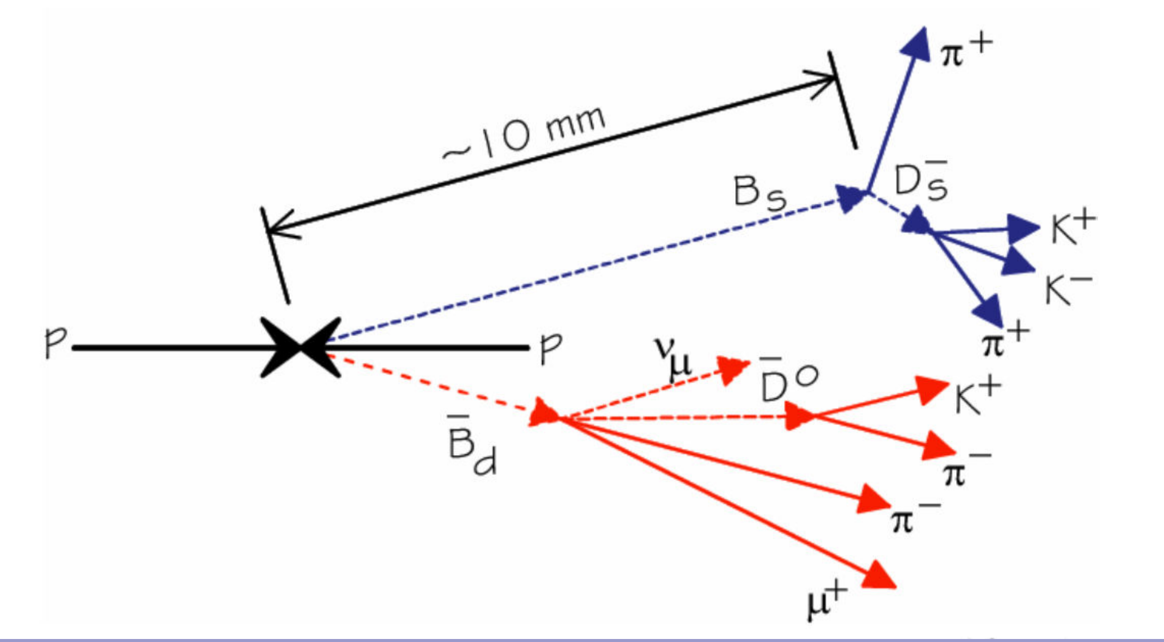
LHC proton b ... detector,
safely encase ... where the
beams collide ... d, is inside
the VELO.

The VELO’s job is to pick out B particles from the multitude of other particles produced. To find them, the detector elements must be positioned very close to the point where protons collide, at a distance of just few mm!

Solution is retractable geometry!

The VELO measures the distance between the point where protons collide (and where B particles are created) and the point where the B particles decay. The B particles are therefore never measured directly - their presence is inferred from the separation between these two positions

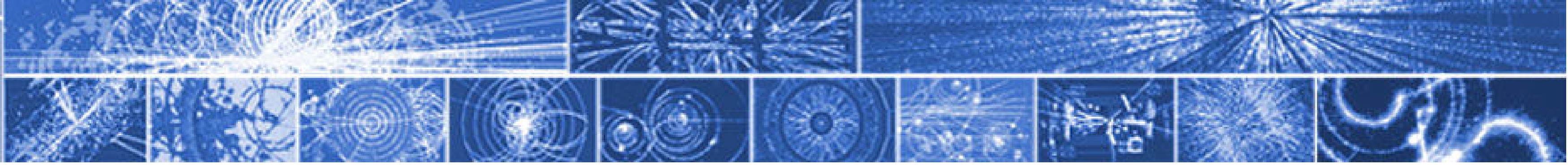
VELO can locate the position of B particles to ~10 µs

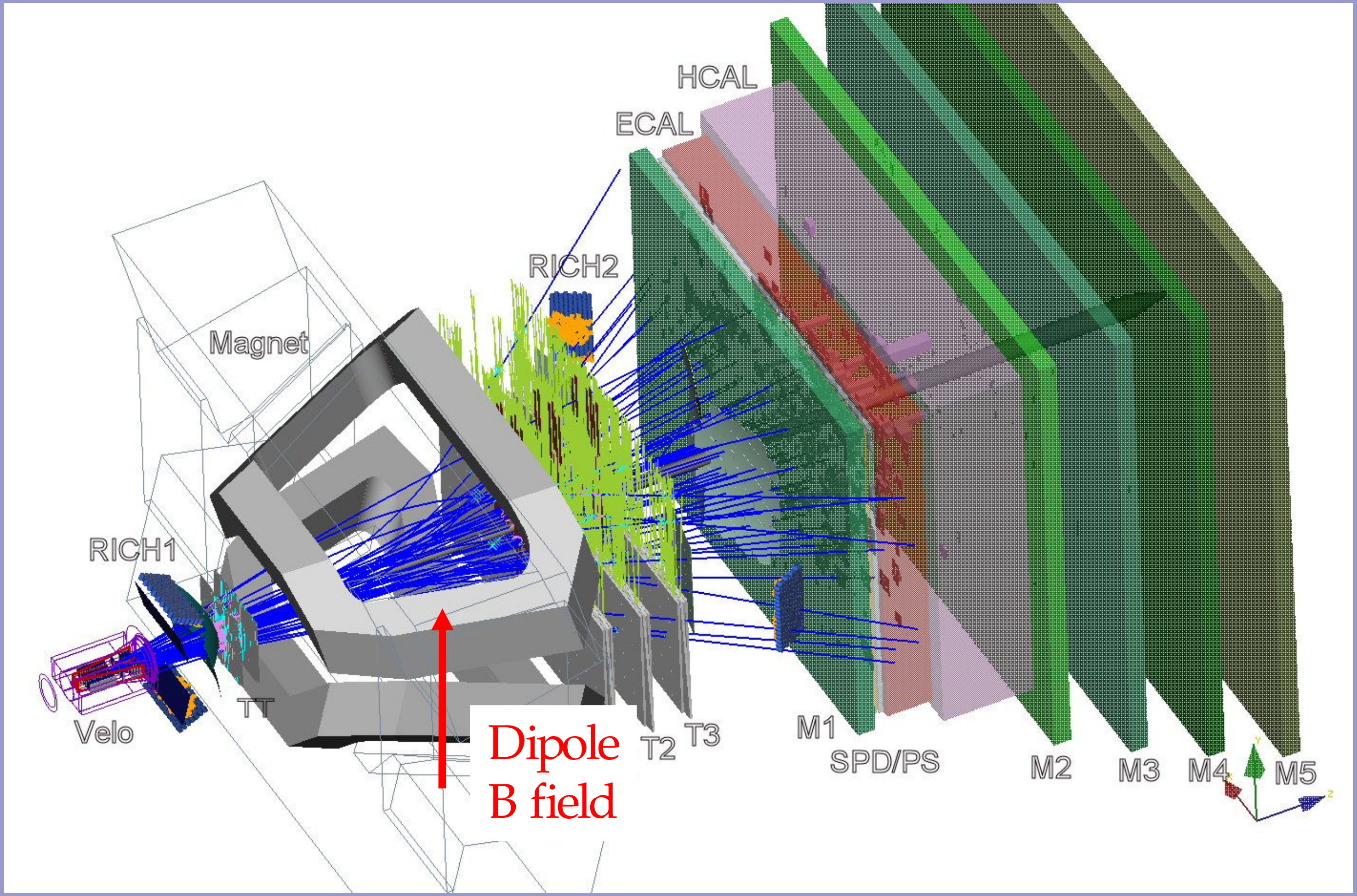


The magnet

To help identify particles produced when protons are smashed together, particle detectors typically include a powerful magnet. LHCb is no exception..

Particles normally travel in straight lines, but the presence of a magnetic field causes the paths of charged particles to curve, with positive and negative particles moving in opposite directions. By examining the curvature of the path, it is possible to calculate the momentum of a particle.

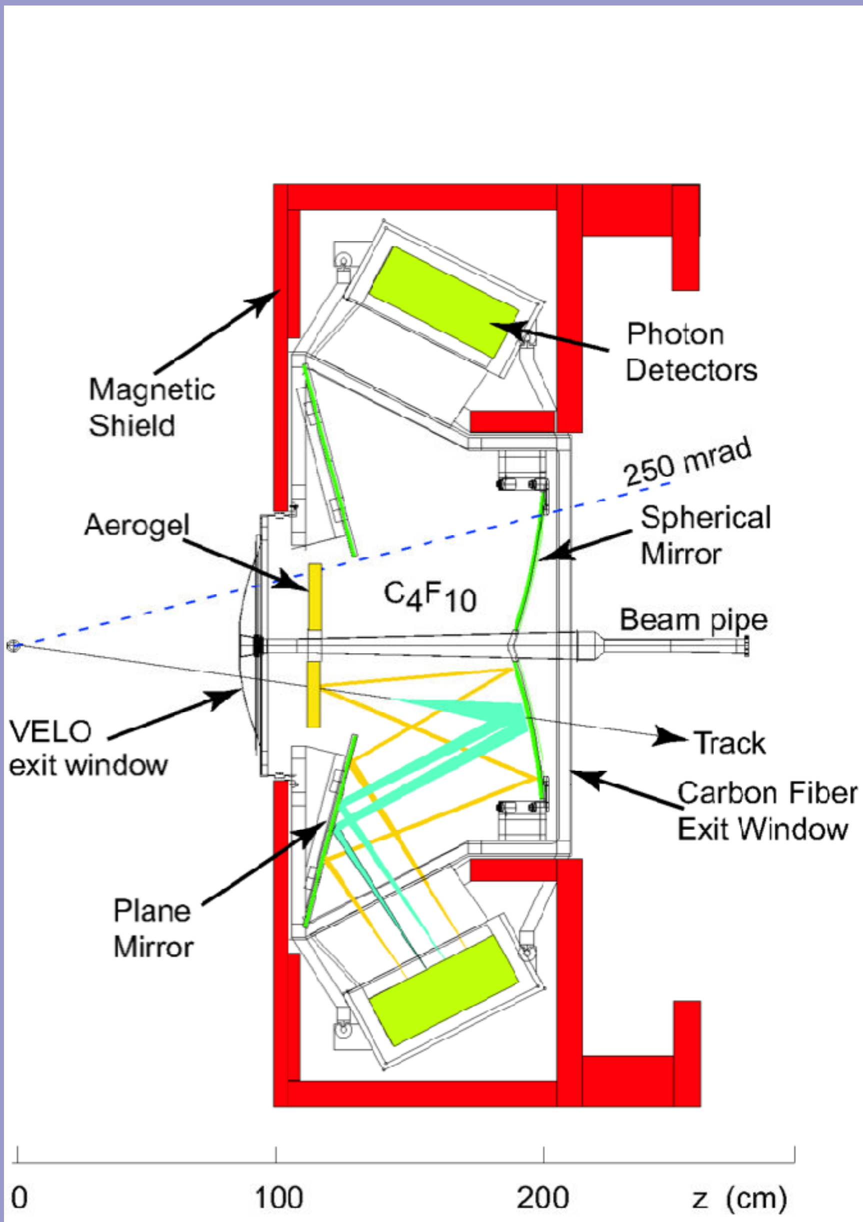



HCAL
ECAL
RICH2
Magnet
RICH1
TT
Velo
Dipole
B field
T2
T3
M1
SPD/PS
M2
M3
M4
M5

Ring Imaging Cherenkov (RICH) detectors

RICH detectors work by measuring emissions of Cherenkov radiation. This occurs when a charged particle passes through a certain medium faster than light does. As it travels, the particle emits a cone of light, which the RICH detectors reflect onto an array of sensors using mirrors.

The shape of the cone of light depends on the particle's velocity, enabling the detector to determine its speed. Knowing the momentum of the particle allows computing its mass which is unique for its identity.

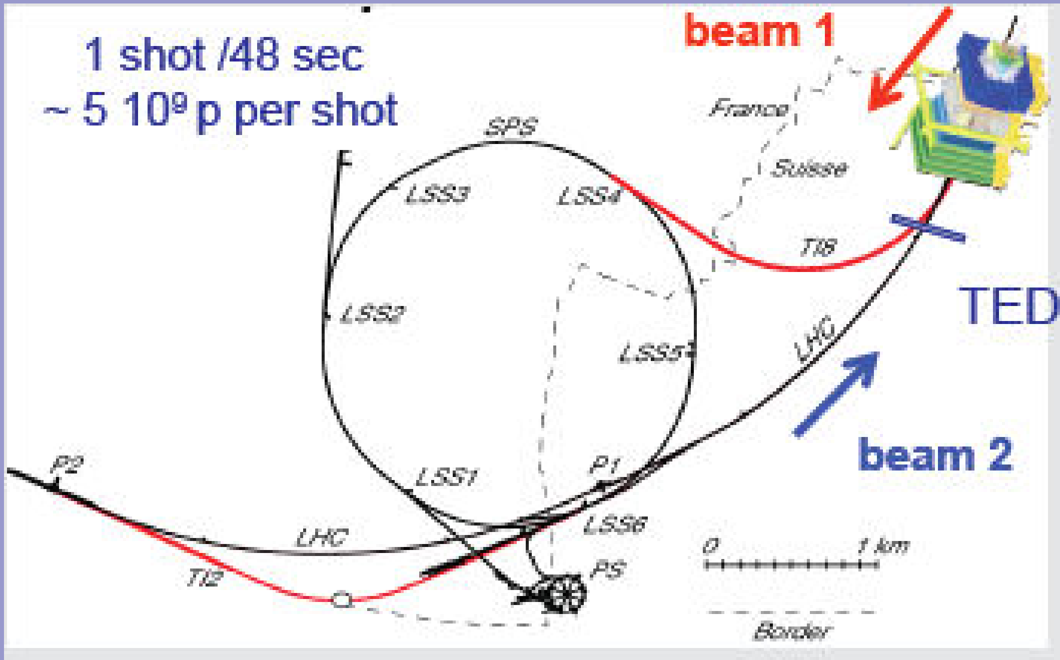

Magnetic Shield
Photon Detectors
250 mrad
Aerogel
Spherical Mirror
C_4F_{10}
Beam pipe
VELO exit window
Track
Carbon Fiber Exit Window
Plane Mirror
0
100
200
z (cm)

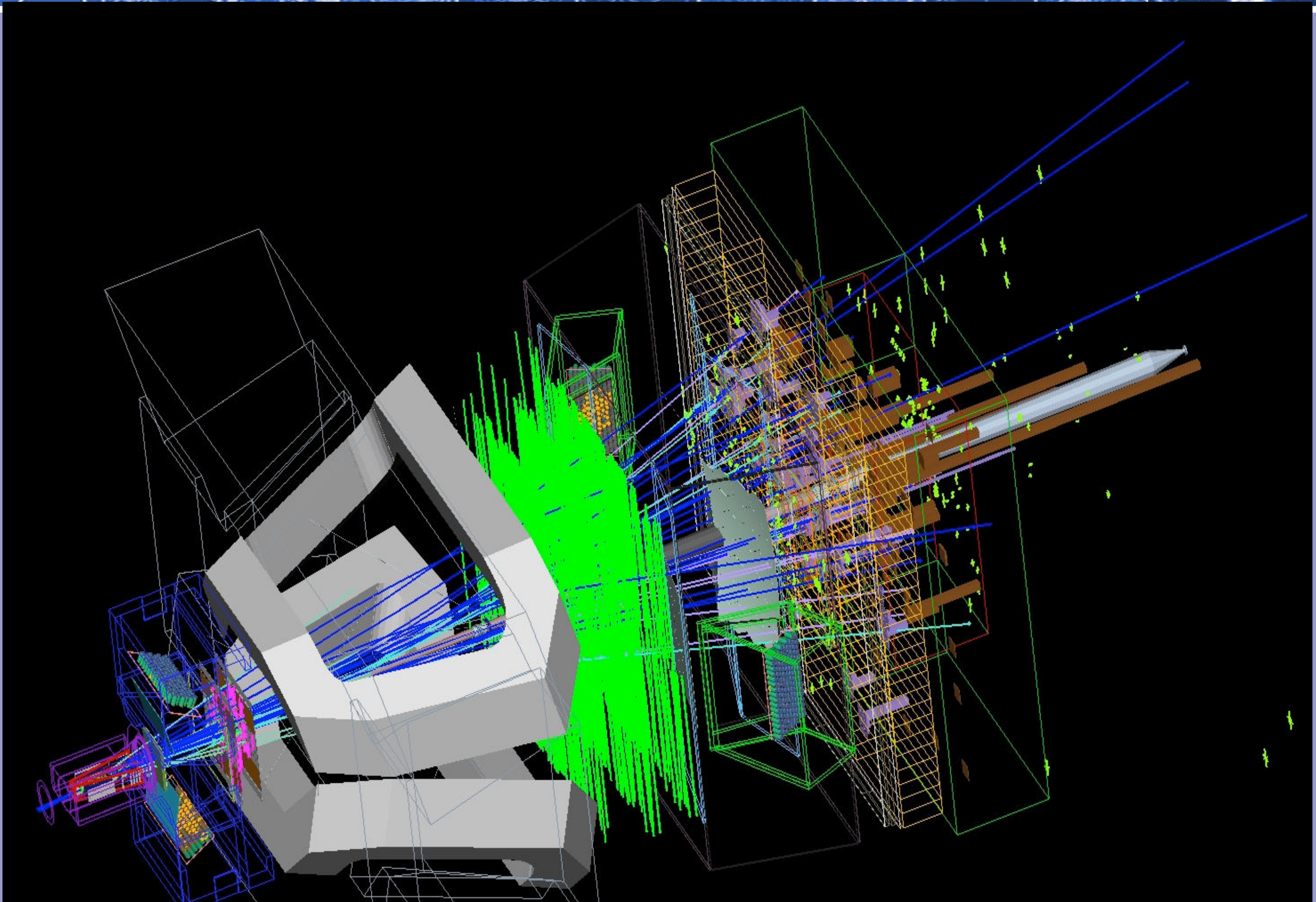
First Glimpse of LHC Protons

Beam 2 dumped on an injection line beam stopper located ~350 m before LHCb along beam 2

Wrong direction for LHCb !

High flux of particle hitting detector from the back





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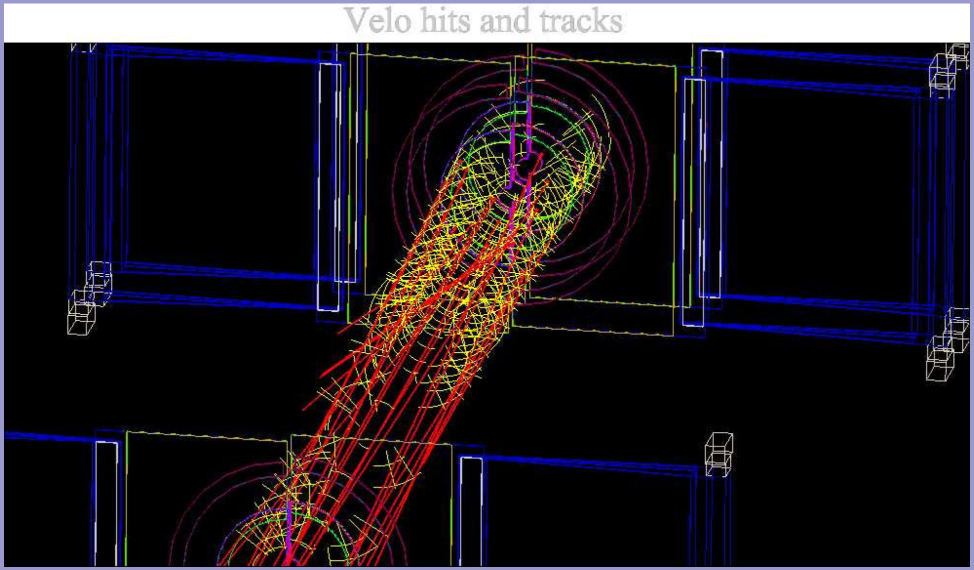
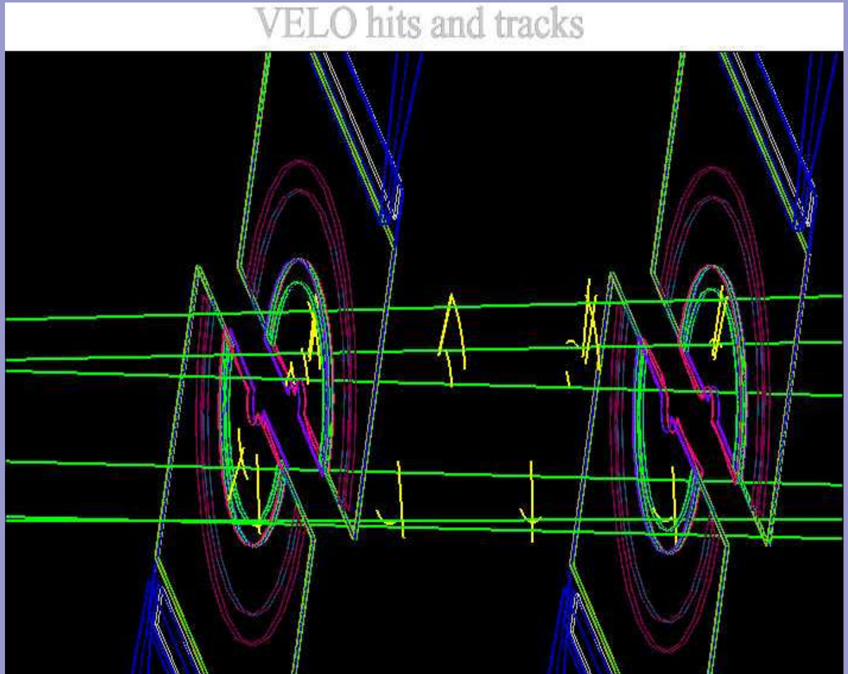
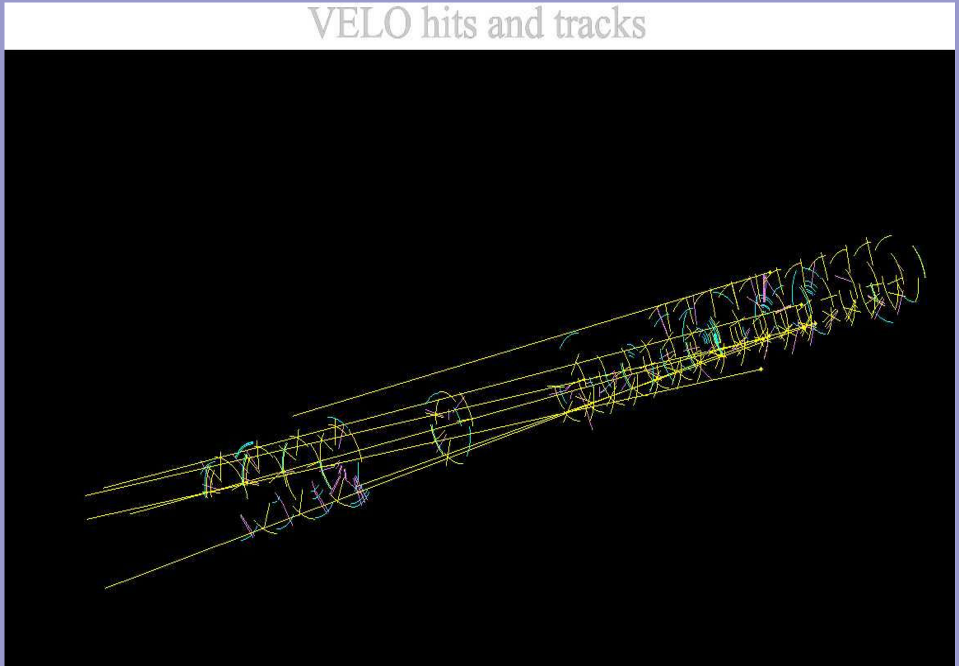
VELO hits and tracks







JUNE 2009
An event with many tracks