

LHC a detektor ATLAS



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1973: The discovery of **neutral currents** in the **Gargamelle** bubble chamber.

1983: The discovery of **W and Z bosons** in the **UA1** and **UA2** experiments.

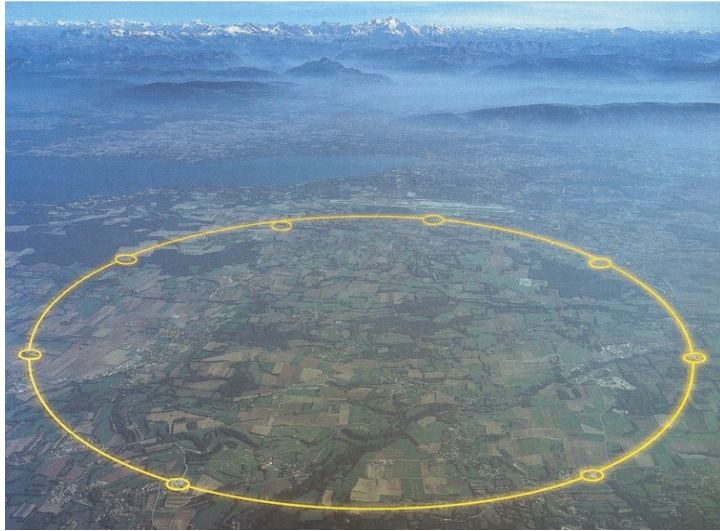
1989: The determination of the number of neutrino families at the **Large Electron Positron Collider (LEP)** operating on the Z boson peak.

1995: The first creation of **antihydrogen** atoms in the **PS210 experiment**.

2001: The discovery of direct **CP-violation** in the **NA48** experiments.

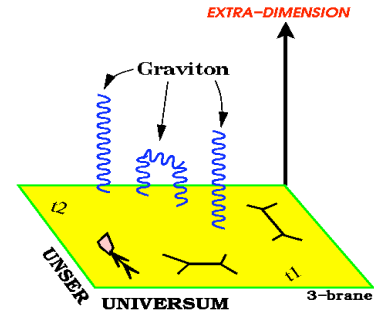
+ ISOLDE
+ CNGS
+ R&D
+

High energy physics today



Large Hadron Collider

- Length of 27 km.
- Has 4 large detectors.
- Unprecedented energy scales.
- It is most complex human-built machine.



Fundamental questions:

What is the origin of mass?

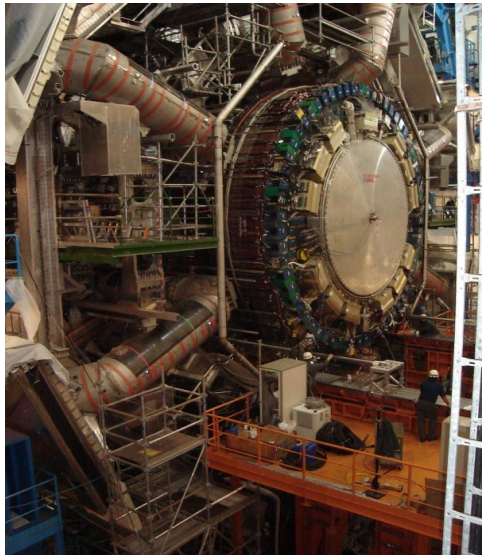
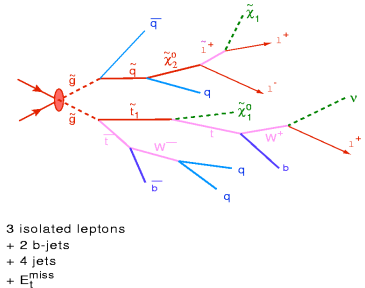
Why there was less antimatter than matter?

What is dark matter and dark energy?

Are there extra dimensions?

Also, new technologies emerge:

- The WWW
- The GRID
- Medical applications
- Storage challenge
- Data processing
- Superconductors, electronics, etc.



Obvod: 26658,883 m

Celkový počet magnetů: 9 593 (z toho 1232 hlavních dipólů)

Rychlost částic: 99,9999991 %c (odpovídá energii protonu 7 TeV)

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

Počet kolizí za vteřinu: ~ 600 milionů

Počet interakčních bodů: 4

Částice: protony nebo ionty Pb82+

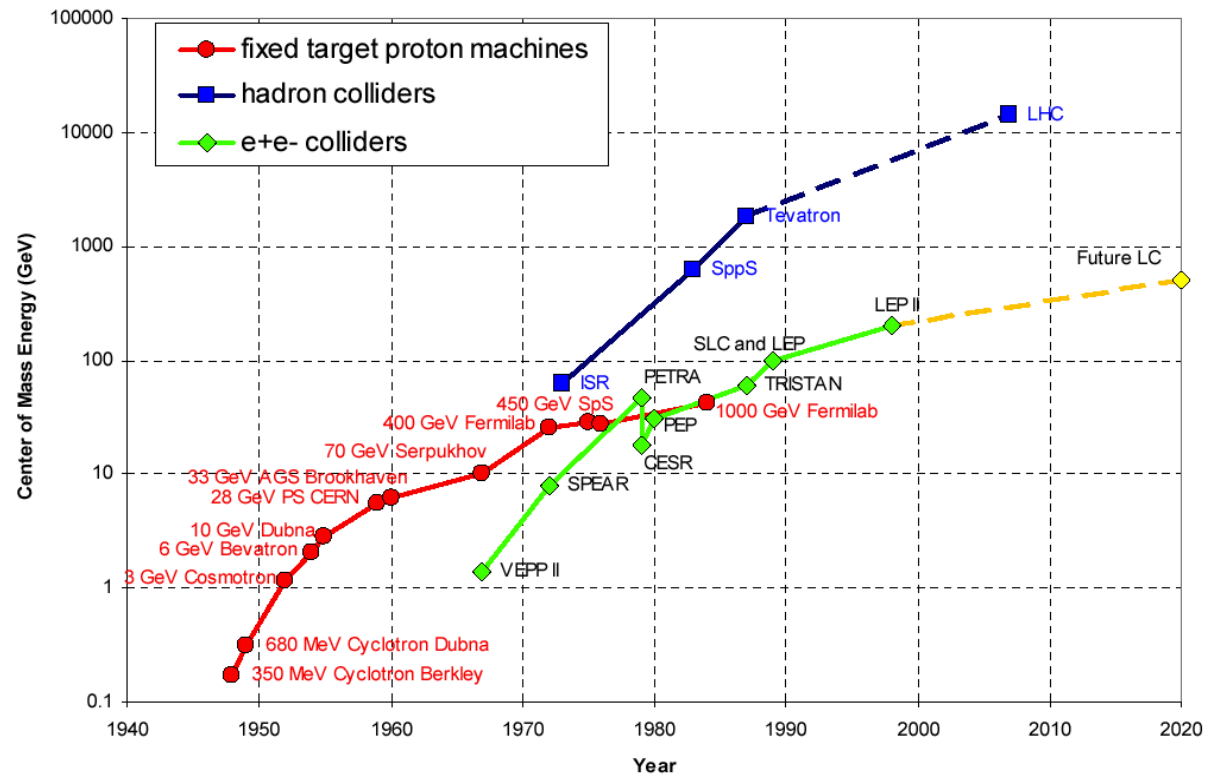
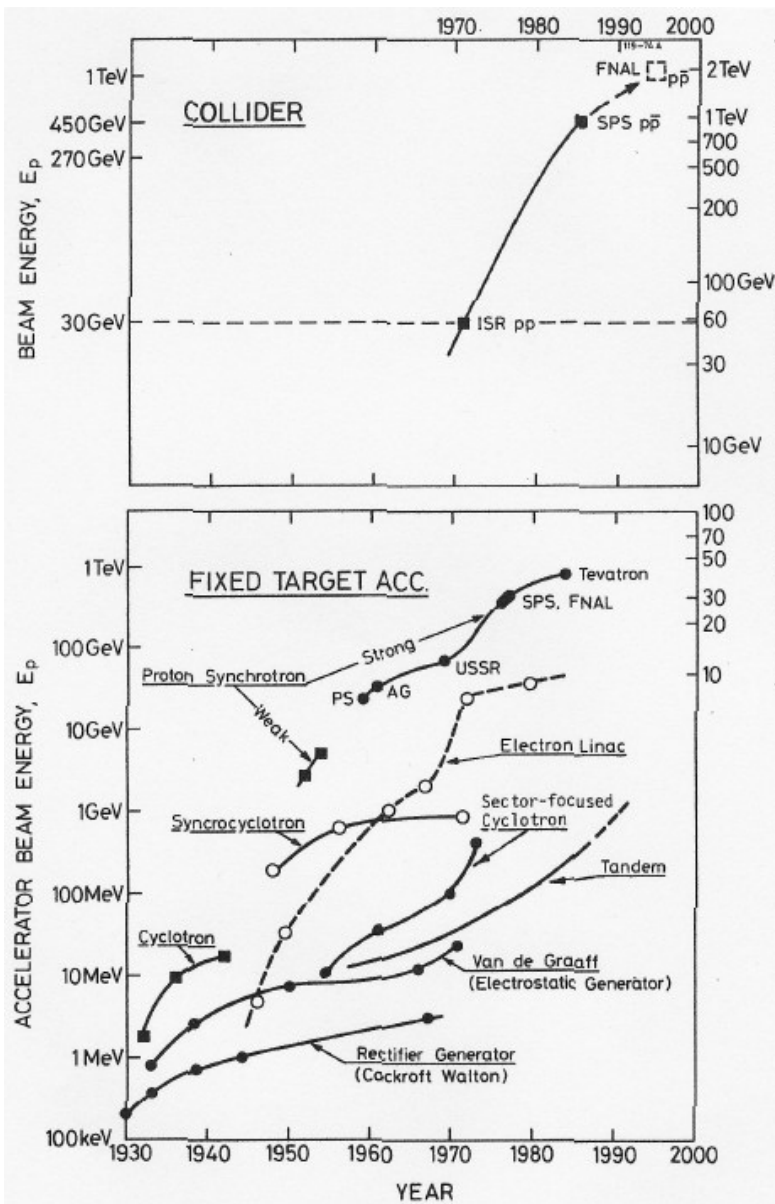
Cena: 4,98 miliardy CHF



LHC has a total stored beam energy:
 10^{14} protons of $14 \cdot 10^{12} \text{ eV} \sim 10^8 \text{ J}$
...or, if you like one 100 T truck
at 100 km/h



Worldwide colliders



	SPPS	Tevatron	LHC
Physics start	1981	1987	2007
Particles	Pbar-p	Pbar-p	p-p
cm energy (TeV)	0.62	1.96	14
Lumi ($10^{30} \text{ cm}^{-2} \text{ s}^{-1}$)	6	50-100	$0.1 - 1.0 \times 10^4$
Lumi ($\text{fb}^{-1} \text{ year}^{-1}$)	0.05	0.5	100
Bunch spacing (ns)	3800	396	25
Particles per bunch (10^{10})	P: 15, Pbar: 8	P: 24, Pbar: 3	P: 11.5
Max.no Pbar in accumulator	1.2×10^{12}	2.6×10^{12}	-
Bunches	6 + 6	36 + 36	2835 + 2835
Circumference (km)	6.9	6.28	26.7
Nr. dipoles	232	774	1232 (main dipoles)
Magnet type	warm	cold, warm iron	cold, cold iron
Peak magnetic field (T)	1.4	4.4	8.3

SSC – Superconducting SuperCollider



- 20 TeV / Beam
- 87Km tunnel



Towards LHC

CERN: 50 YEARS AND COUNTING

The life of an experiment

- 1984** Workshop in Lausanne on installing a Large Hadron Collider (LHC) in the LEP tunnel
- 1987** CERN's long-range planning committee chaired by Carlo Rubbia recommends LHC as the right choice for lab's future
- 1989** ECFA Study Week on instrumentation technology for a high-luminosity hadron collider; Barcelona; LEP collider starts operation
- 1990** ECFA LHC workshop, Aachen
- 1992** General meeting on LHC physics and detectors, Evian-les-Bains
- 1993** Letters of intent for LHC detectors submitted
- 1994** Technical proposals for ATLAS and CMS approved
- 1998** Construction begins
- 2000** CMS assembly begins above ground; LEP collider closes
- 2003** ATLAS underground cavern completed and assembly started
- 2004** CMS cavern completed
- 2007** Experiments ready for beam
- 2007** First proton-proton collisions
- 2008** First results
- 2010** Reach design luminosity
- >2014** Upgrade LHC luminosity by factor of 10

ECFA

European Committee for Future Accelerators

CERN

European Organization for Nuclear Research

Towards the LHC Experimental Programme

5-8 March 1992
Evian-les-Bains, France



CS 92/338



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GEN

Proceedings
of the General Meeting
on LHC Physics & Detectors

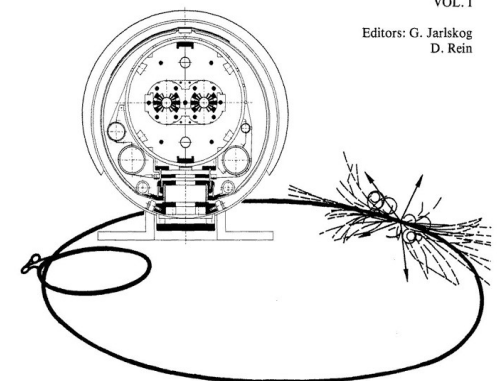
CERN 90-10
ECFA 90-133
Volume I
3 December 1990

EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS

Large Hadron Collider Workshop

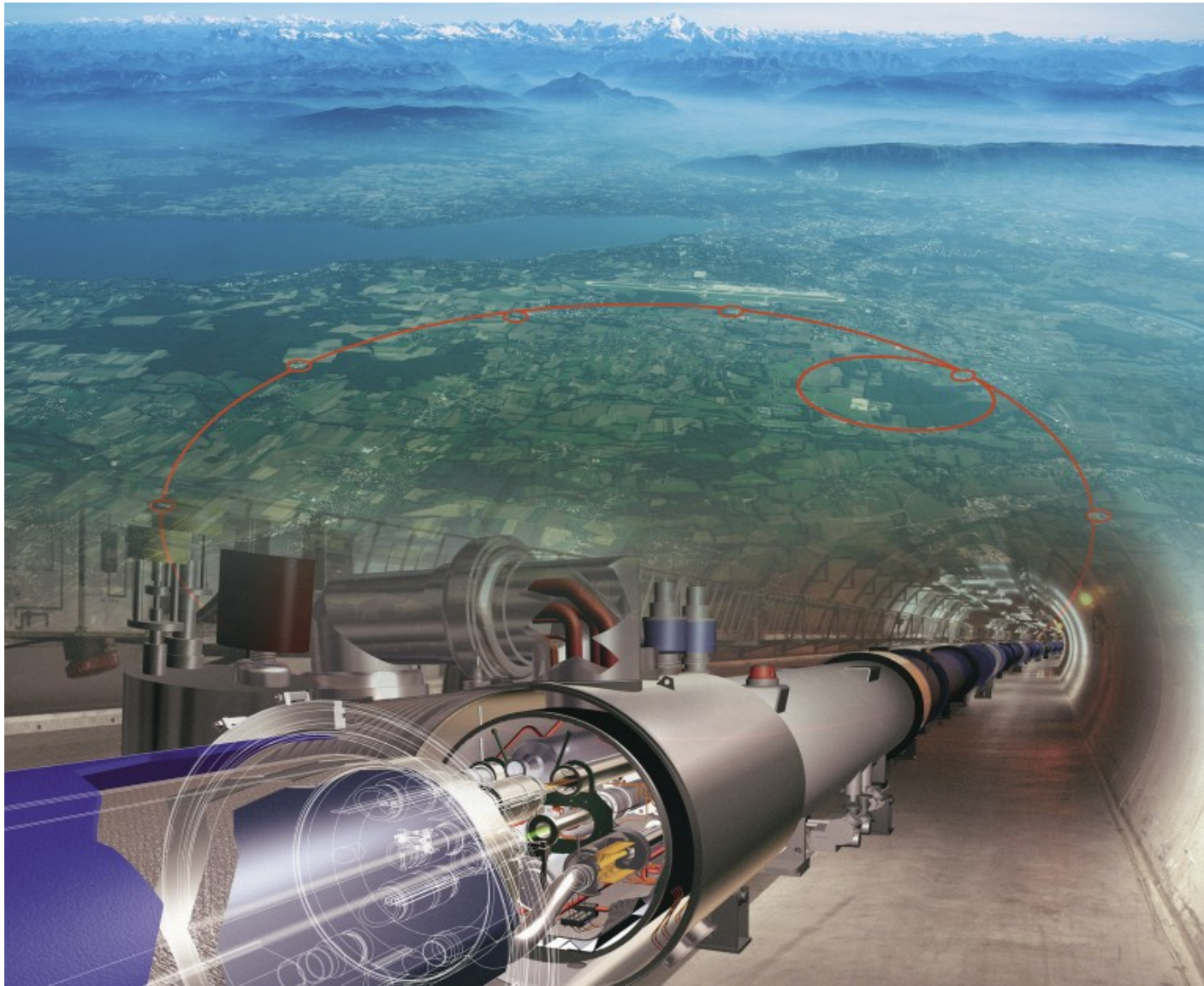
PROCEEDINGS
VOL. I

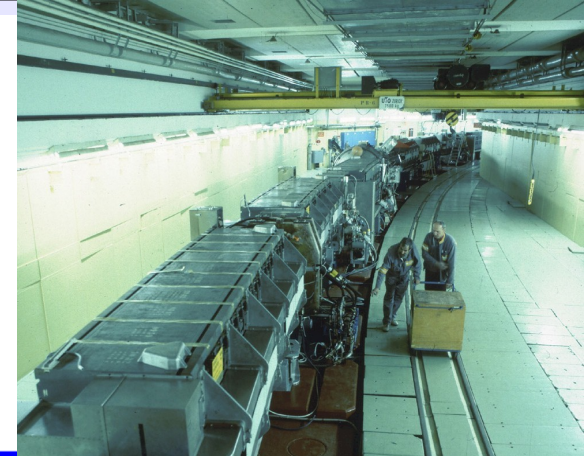
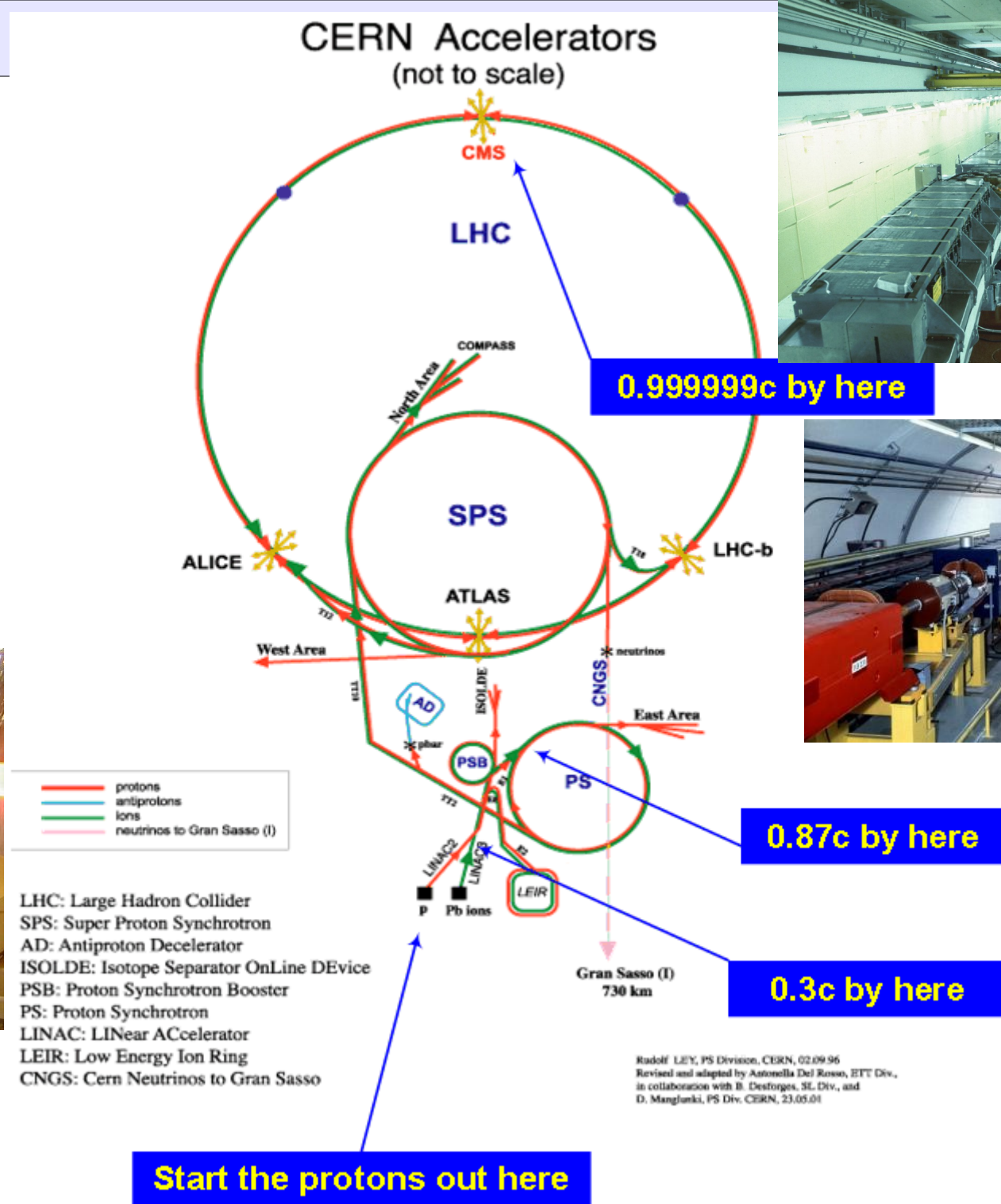
Editors: G. Jarlskog
D. Rein



Aachen, 4-9 October 1990



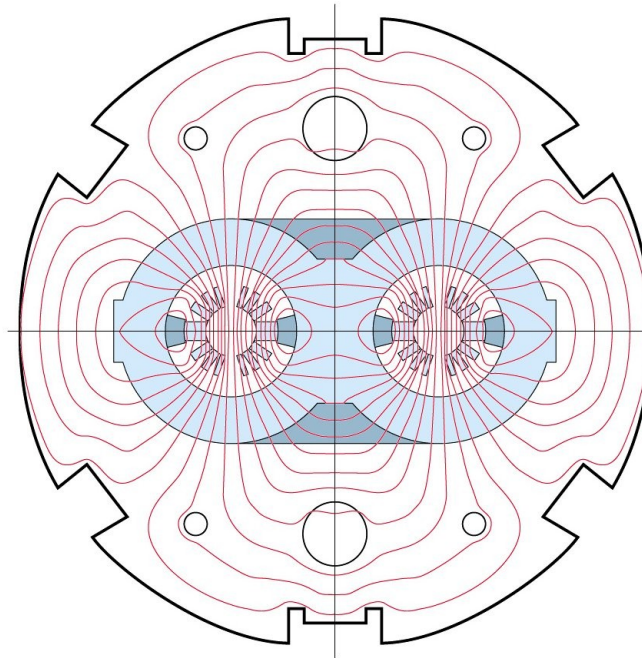
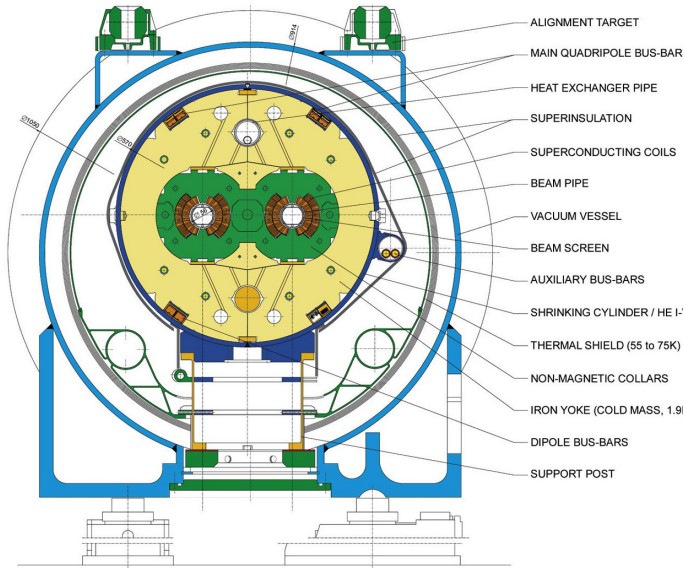




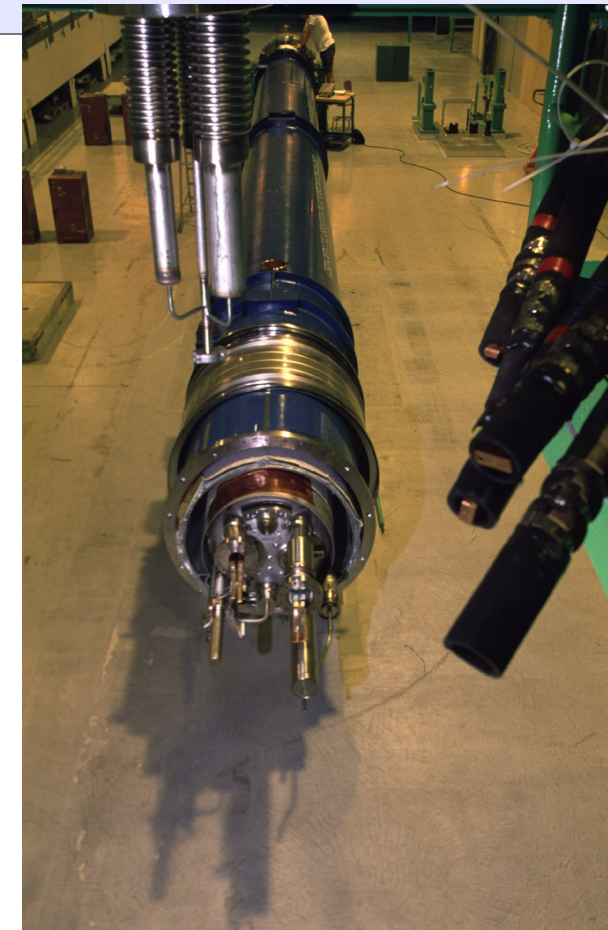
Magnety

LHC DIPOLE : STANDARD CROSS-SECTION

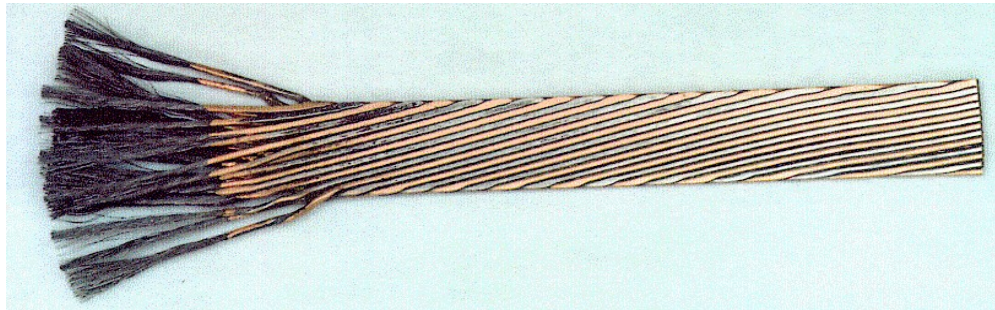
CERN AC/DB/1994 - 10.107 - 30.04.1999

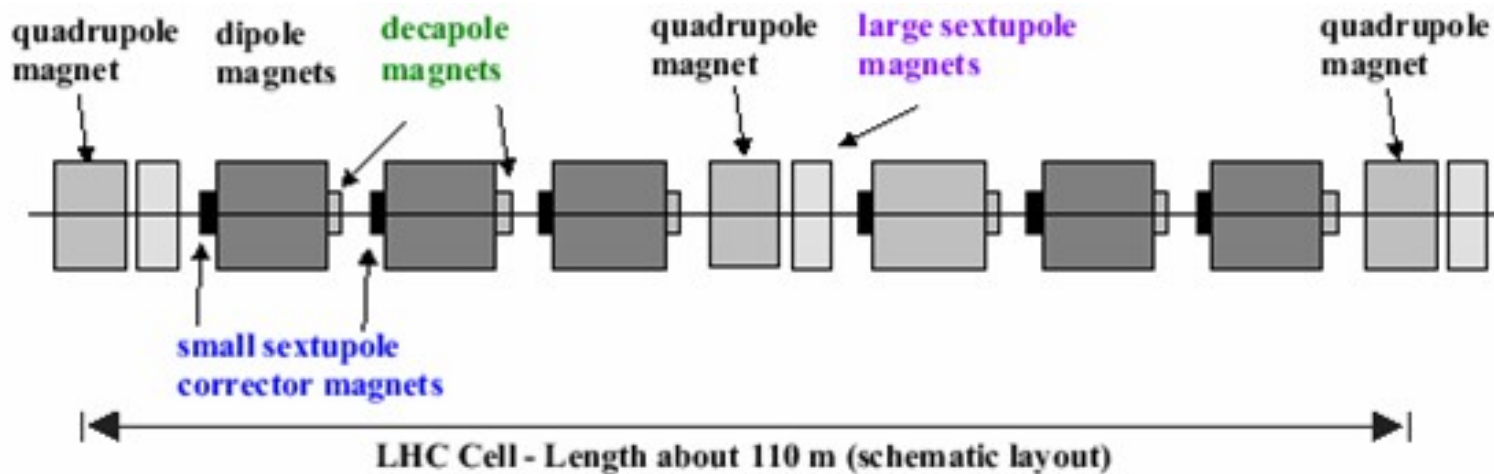
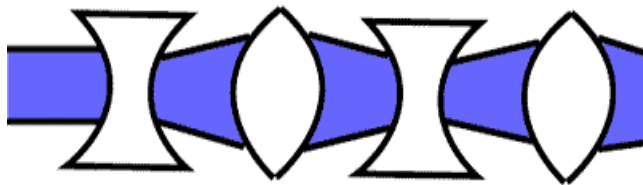
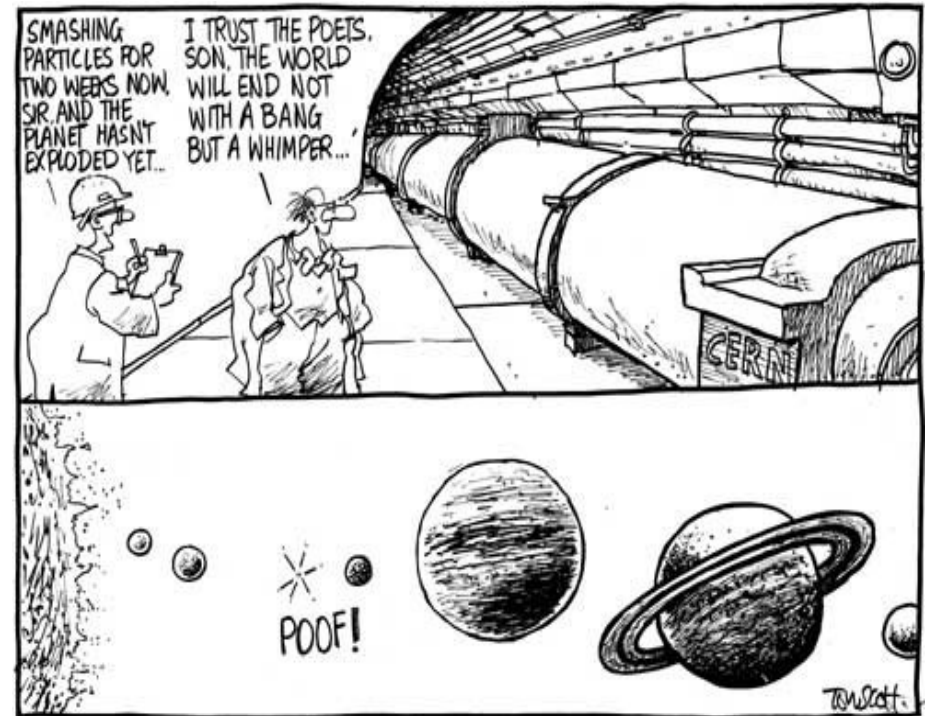
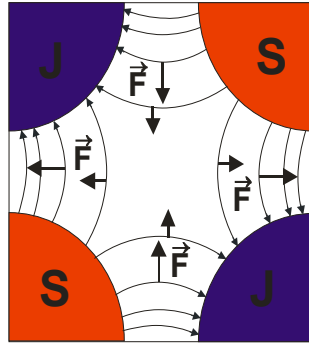


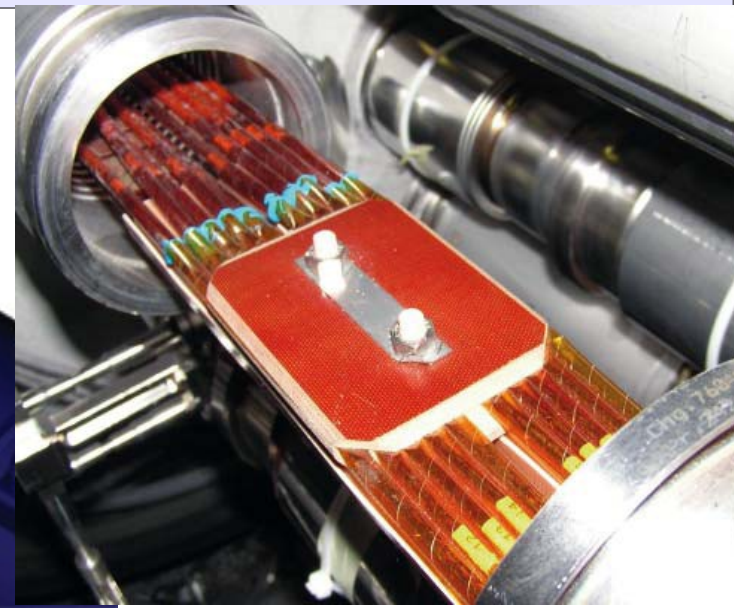
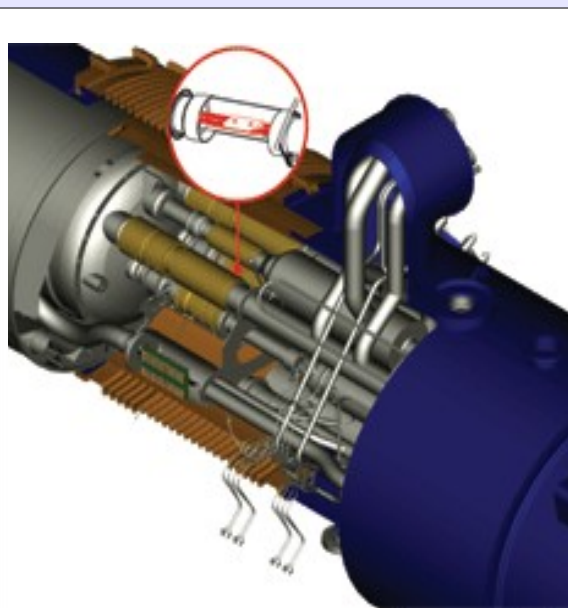
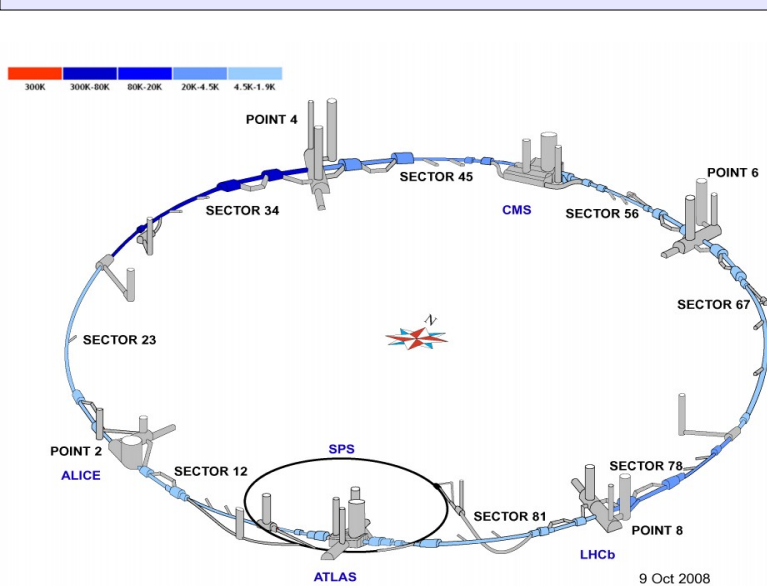
Computed magnetic flux map at $B_0=10$ Tesla



1232 Dipole magnets
Length about 15 m
Magnetic Field 8.3 T
Two beam-tubes with an opening of 56 mm

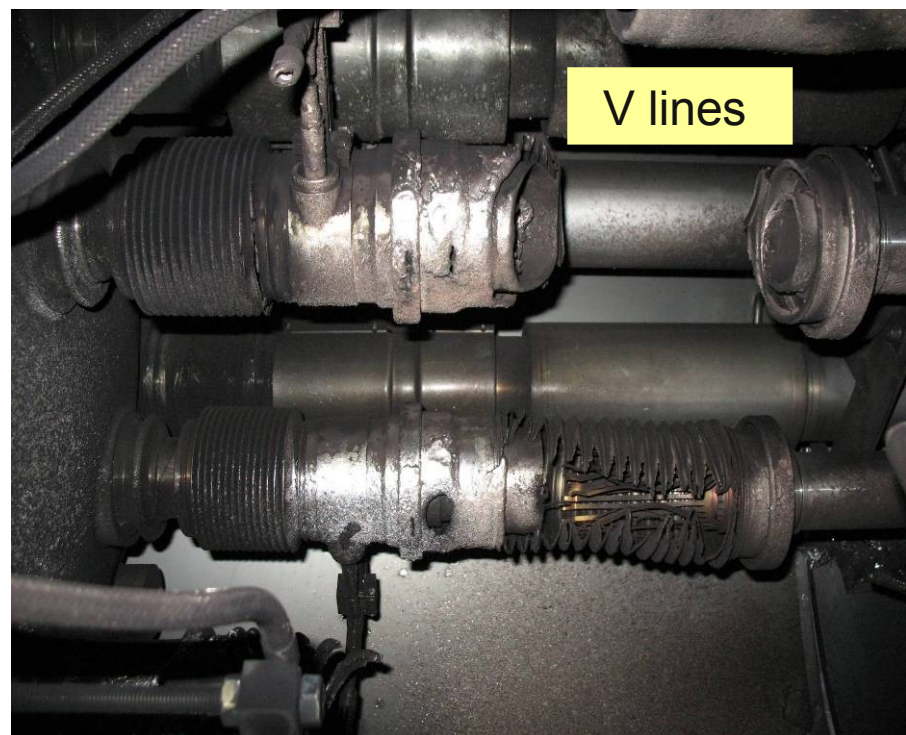
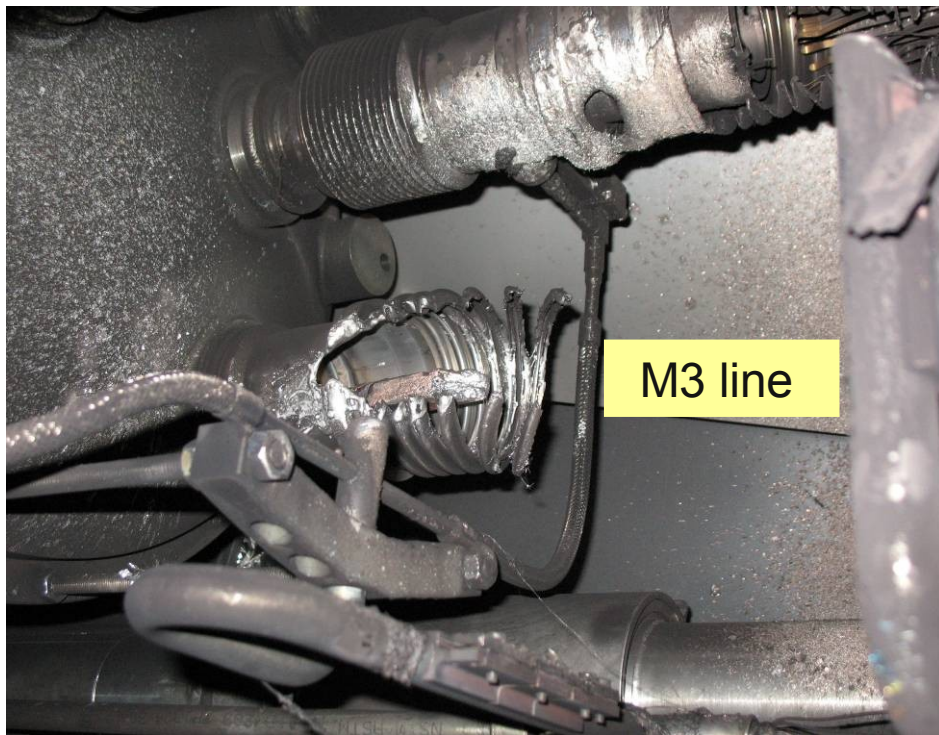




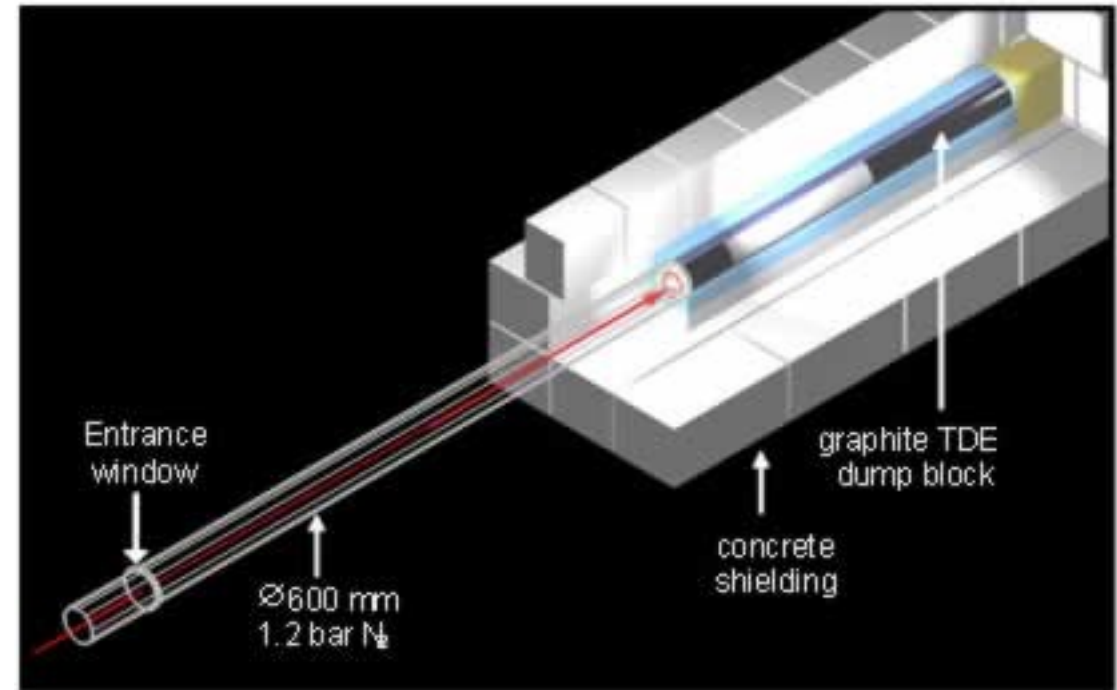
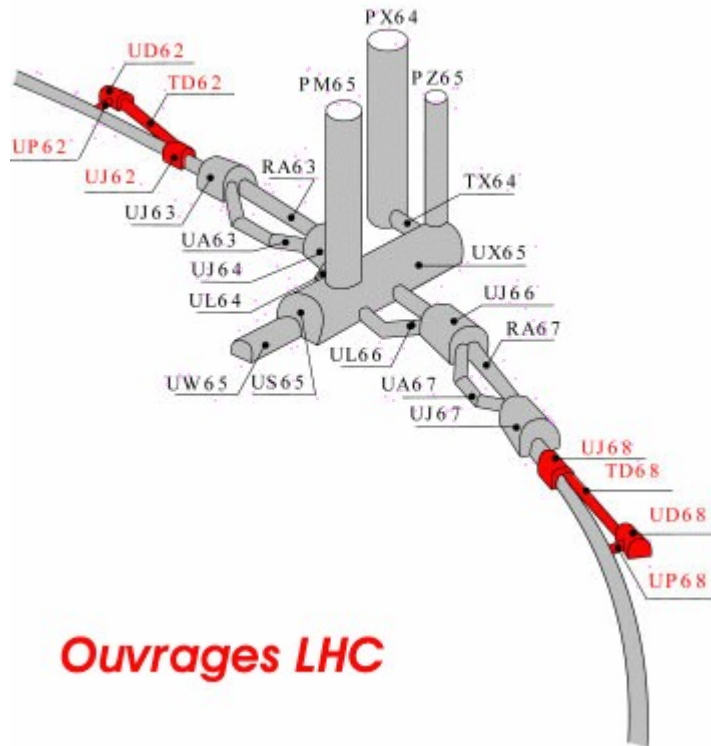


On 19 September 2008, during powering tests of the main dipole circuit in sector 3-4 of the LHC, an electrical fault occurred resulting in mechanical damage and release of helium from the magnet cold mass. Proper safety procedures were in force, safety systems performed as expected, and no one was put at risk. An ad hoc task force was set up on 22 September 2008 to investigate the incident, establish the sequence of events, analyse and explain their development in relation with design assumptions and manufacturing and test data, and recommend preventive and corrective actions for further powering of the machine. Today a number of findings have been established, but inspections are not completed and investigations are continuing. Consequently this is an interim summary report of this task force as of 15 October 2008.

Electrical arc between C24 and Q24

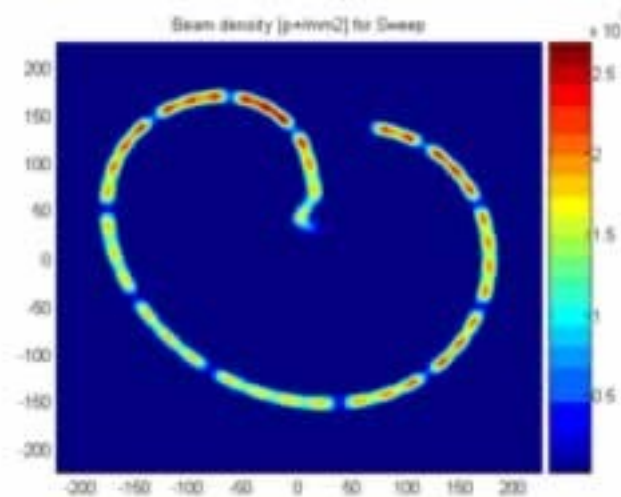


Point 6

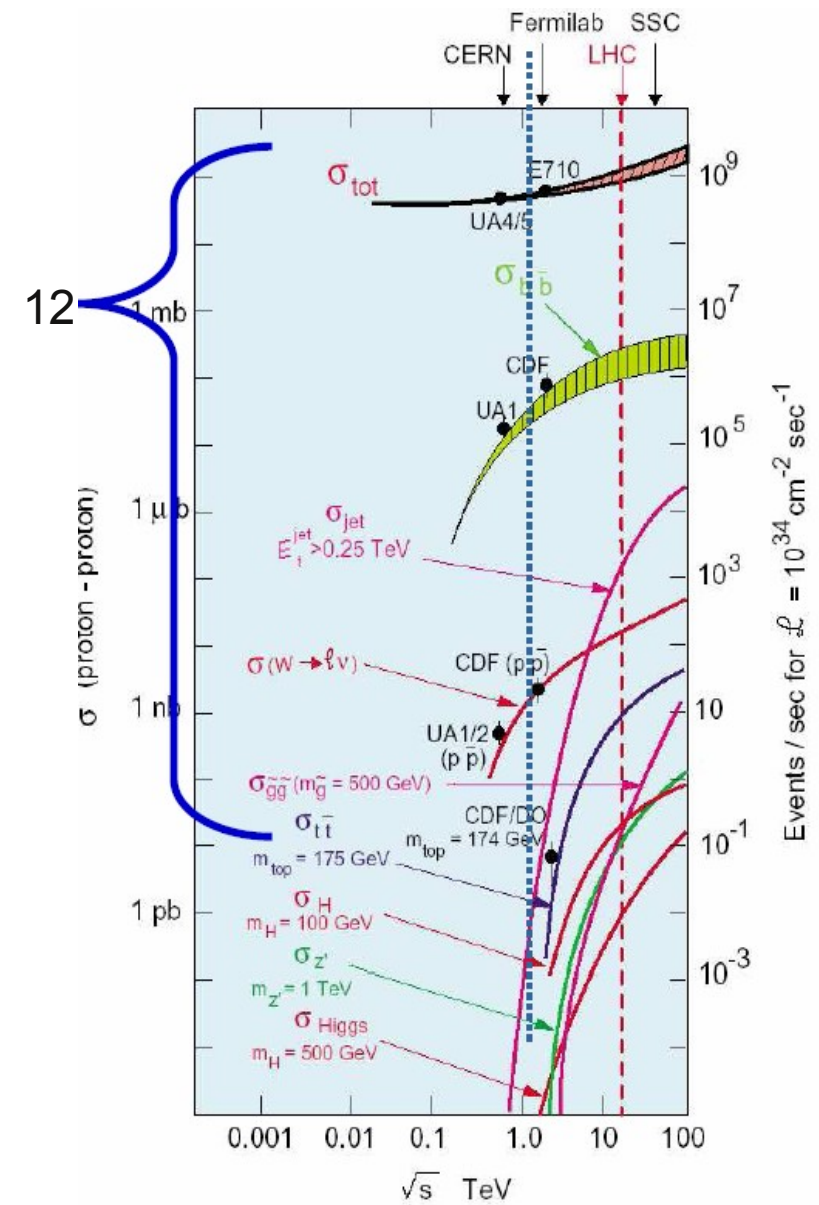
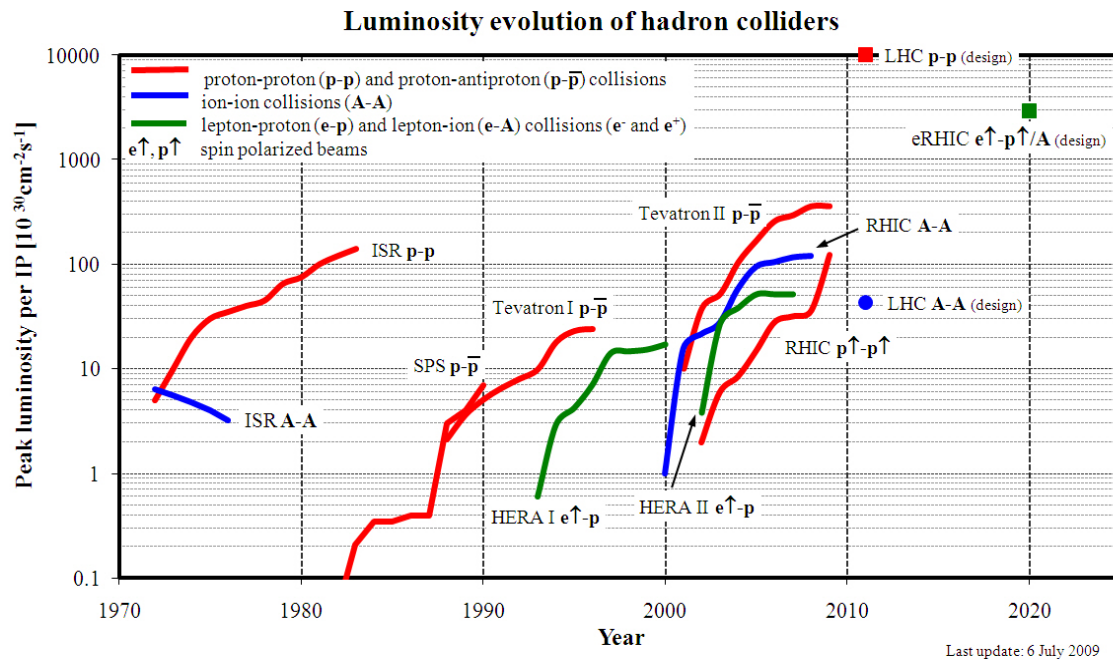


Ouvrages LHC

The nominal LHC beam contains an unprecedented stored energy of 360 MJ, contained in 2808 bunches with a beam sigma of the order of 0.3 mm.

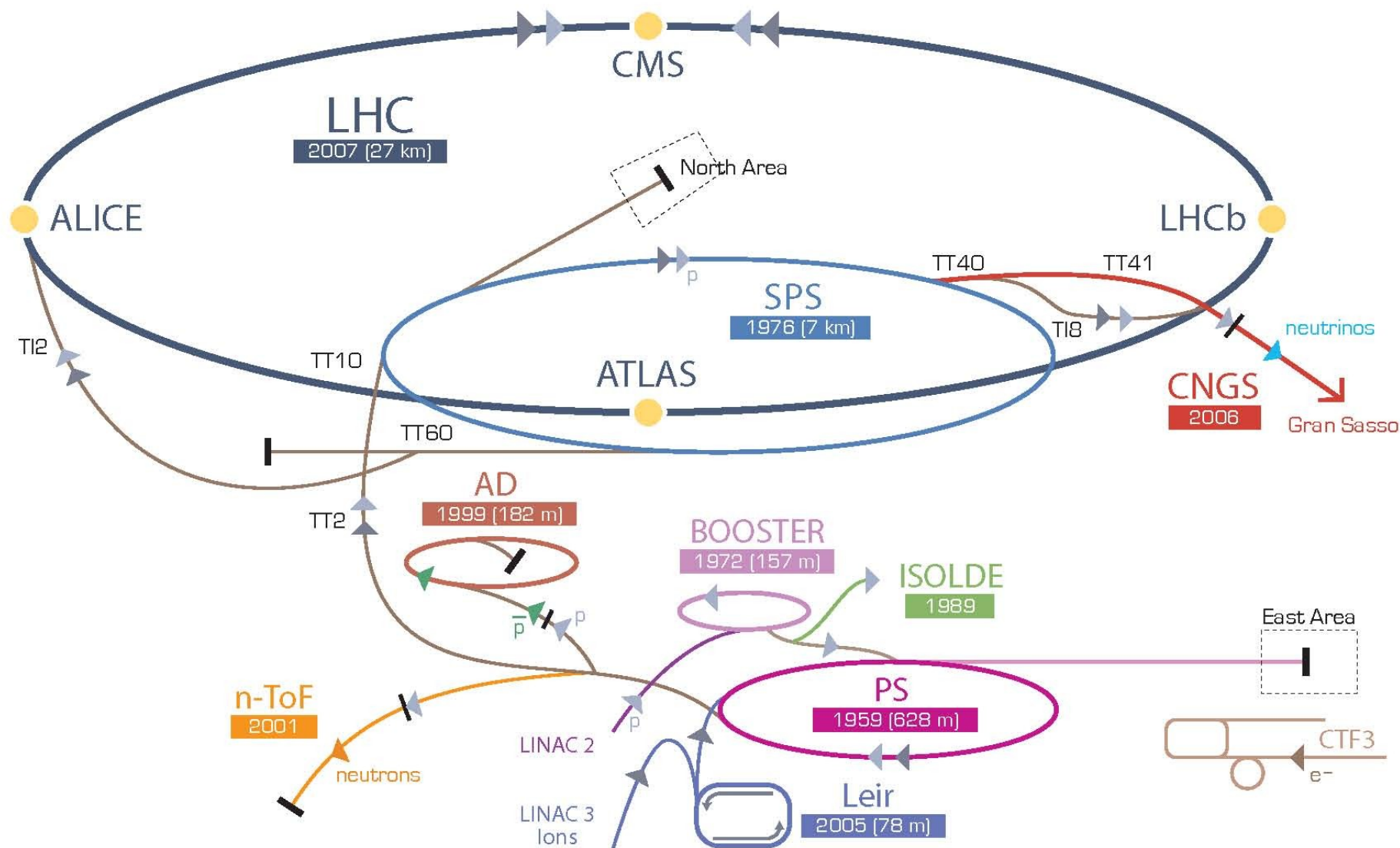


Luminosita, etc



$$N = L \cdot \sigma$$

$$1 \text{b} = 10^{-28} \text{m}^2$$

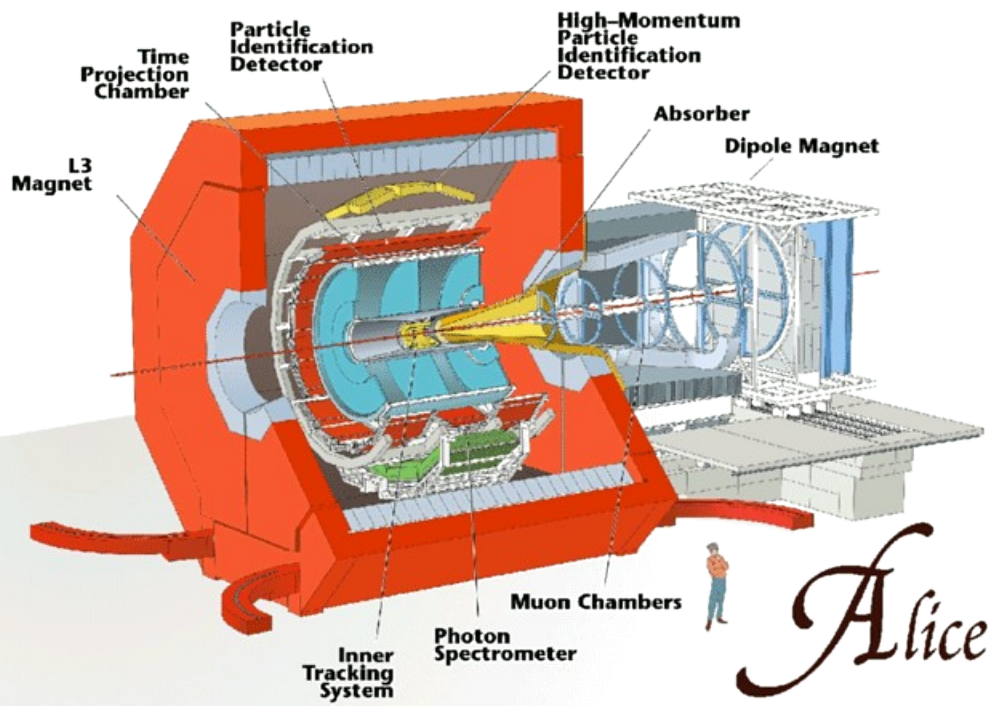


▶ p [proton] ▶ ion ▶ neutrons ▶ \bar{p} [antiproton] $\rightarrow + -$ proton/antiproton conversion ▶ neutrinos ▶ electron

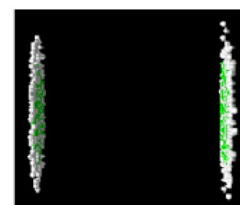
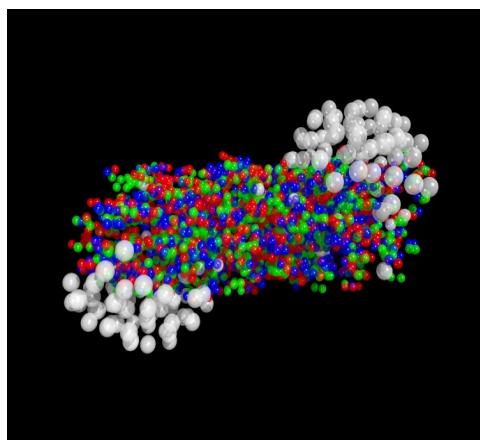
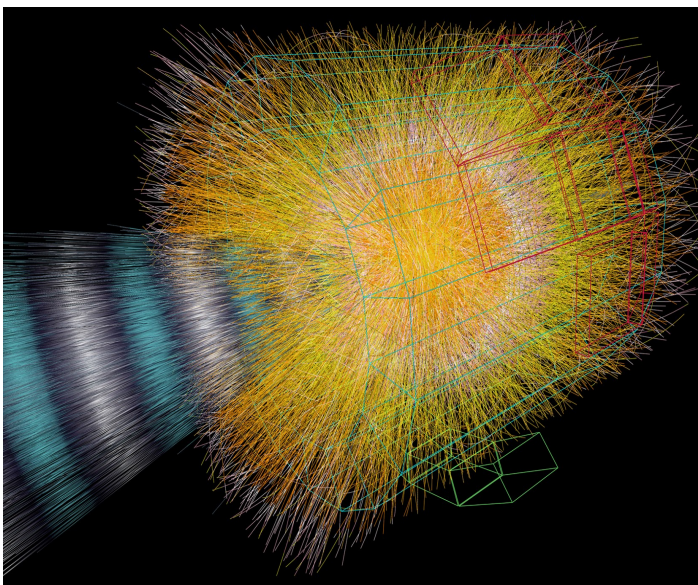
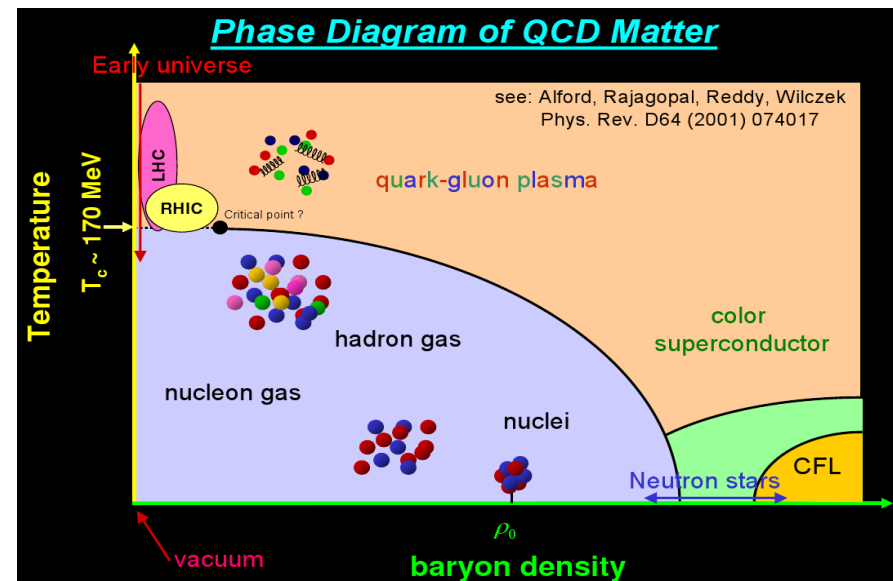
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

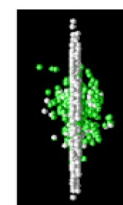
LEIR Low Energy Ion Ring LINAC LINEar ACcelerator n-ToF Neutrons Time Of Flight



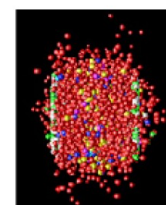
A Large Ion Collider Experiment



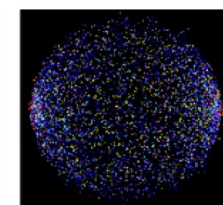
Two nuclei approach each other, relativistically contracted to thin pancakes



Hard collisions dominate first instants of collision



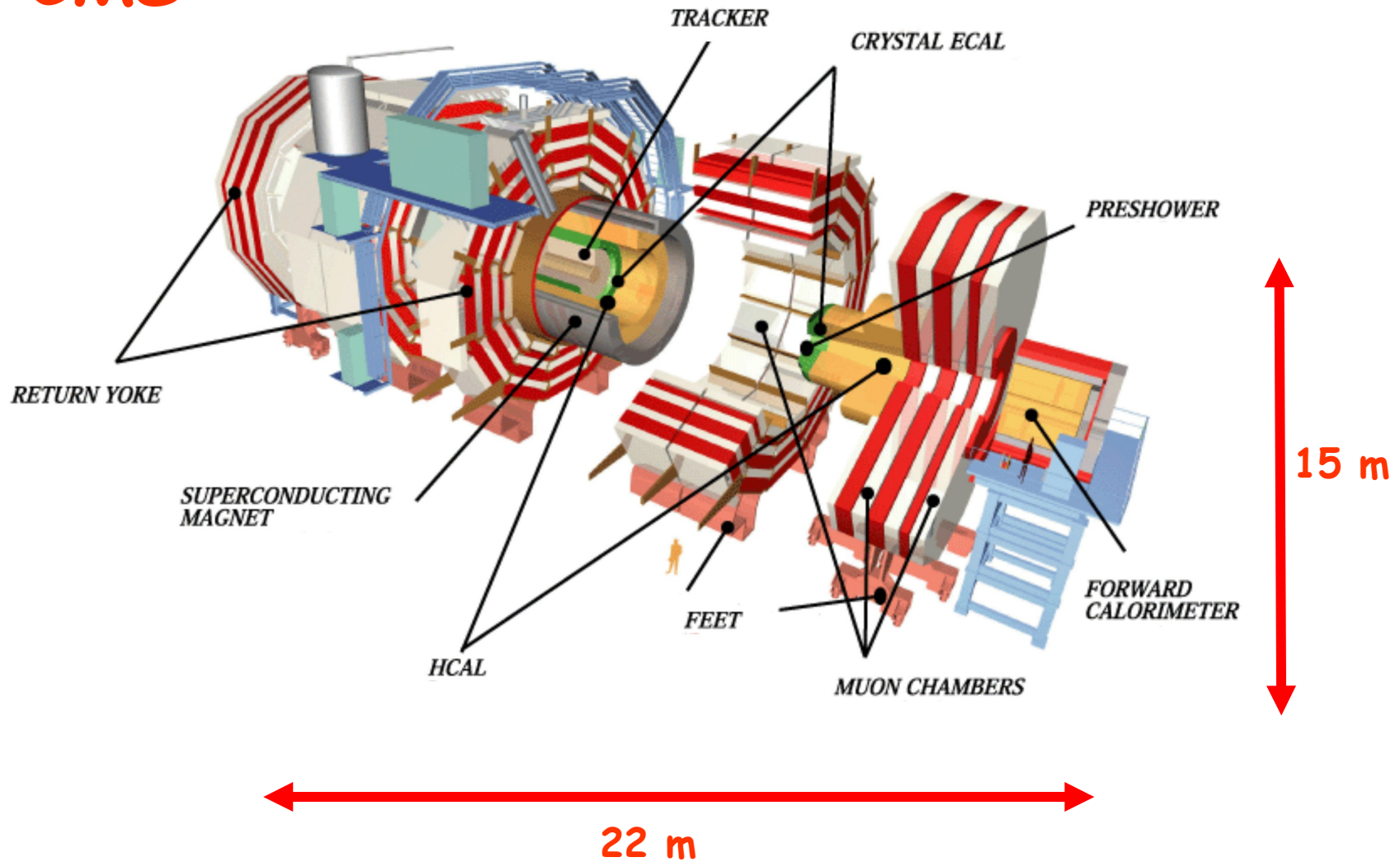
Produced particles reinteract at hard and soft scales



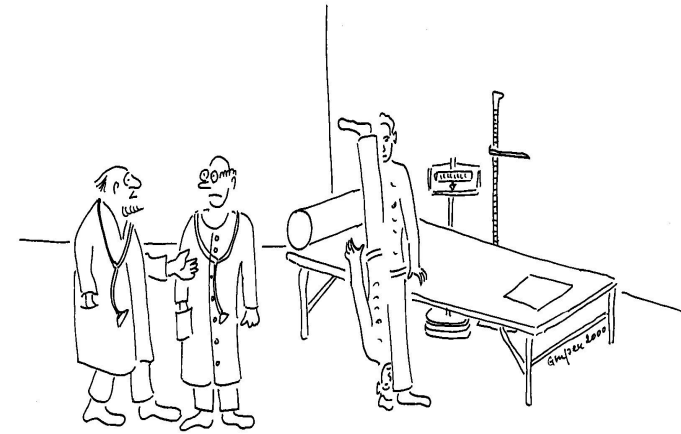
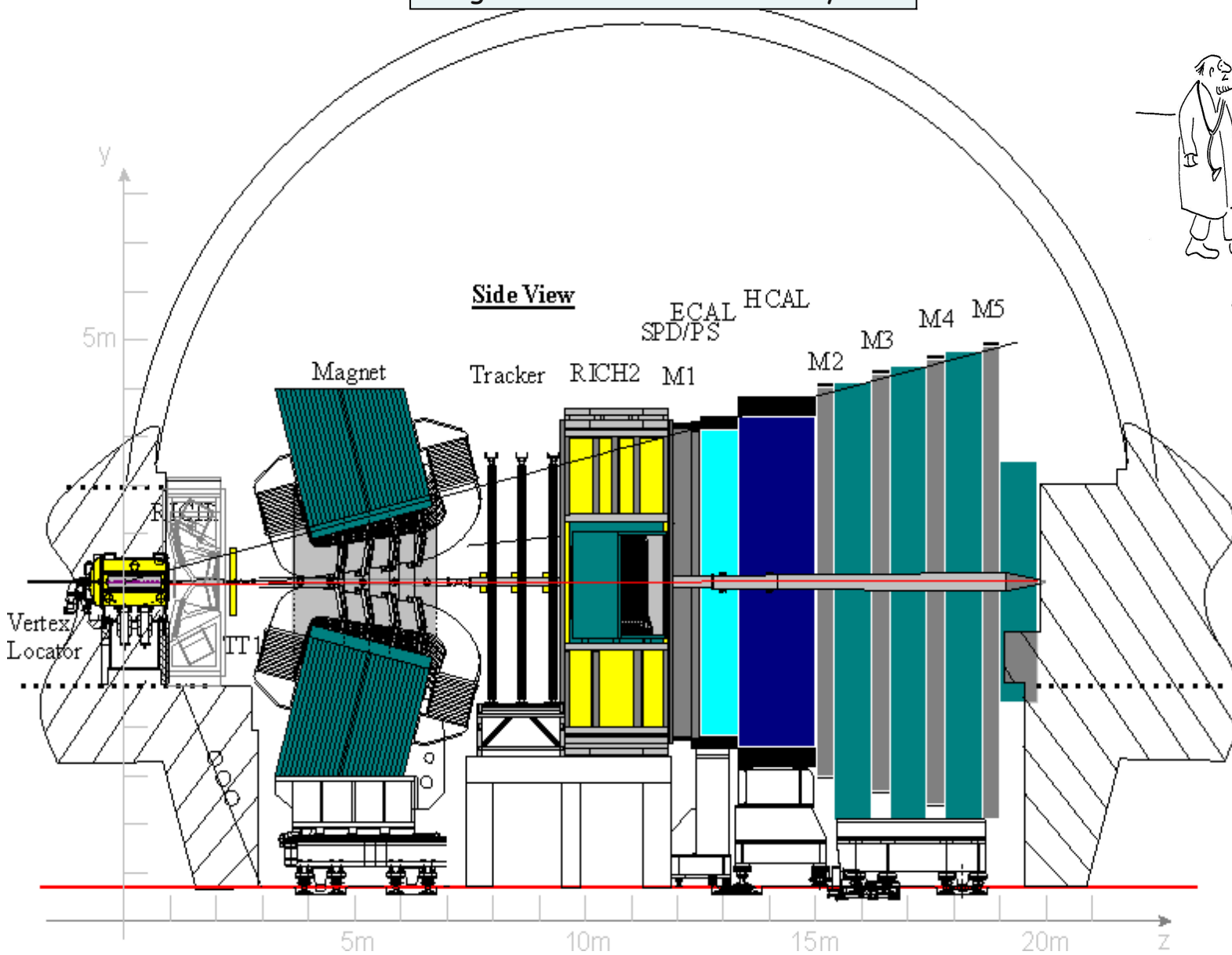
Final state particles freeze-out and stream towards the detectors...

Compact Muon Spectrometer

CMS

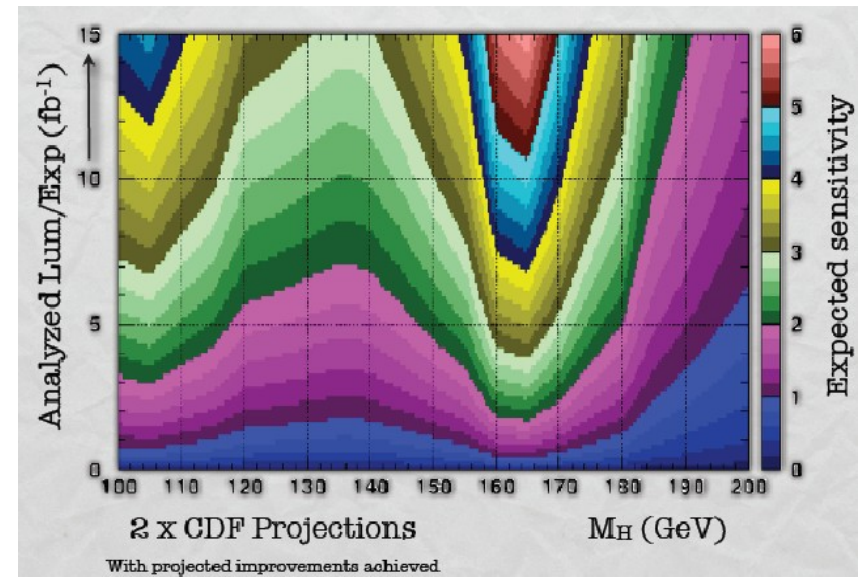
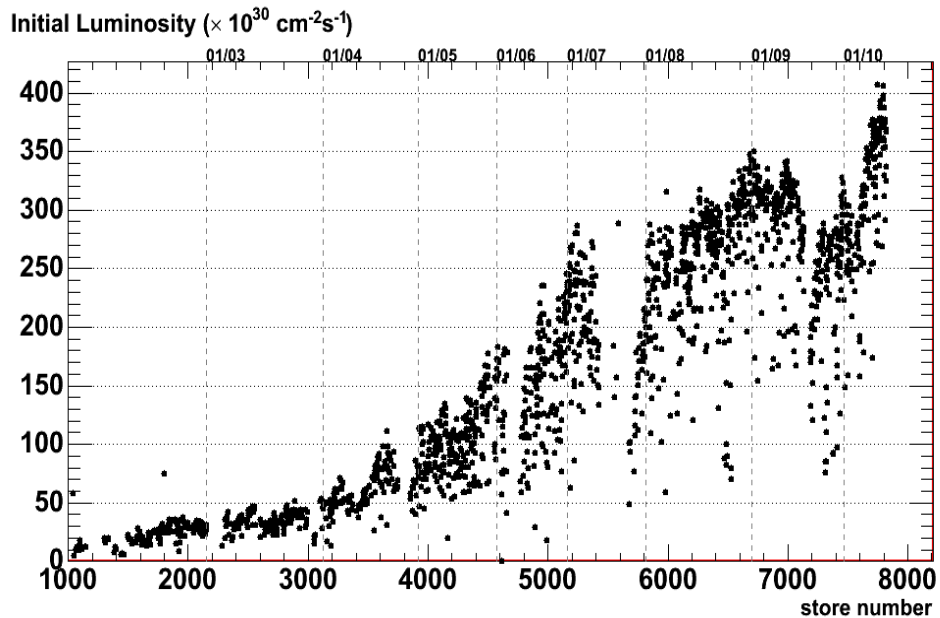
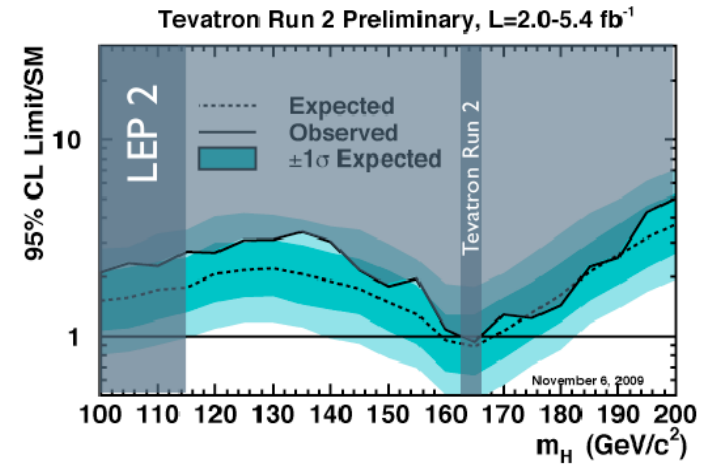
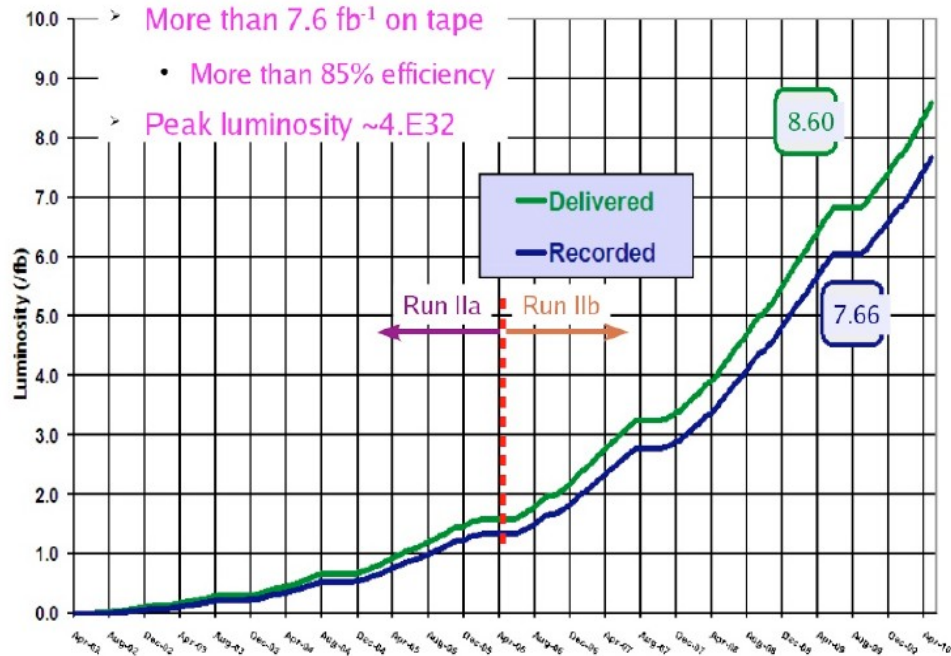


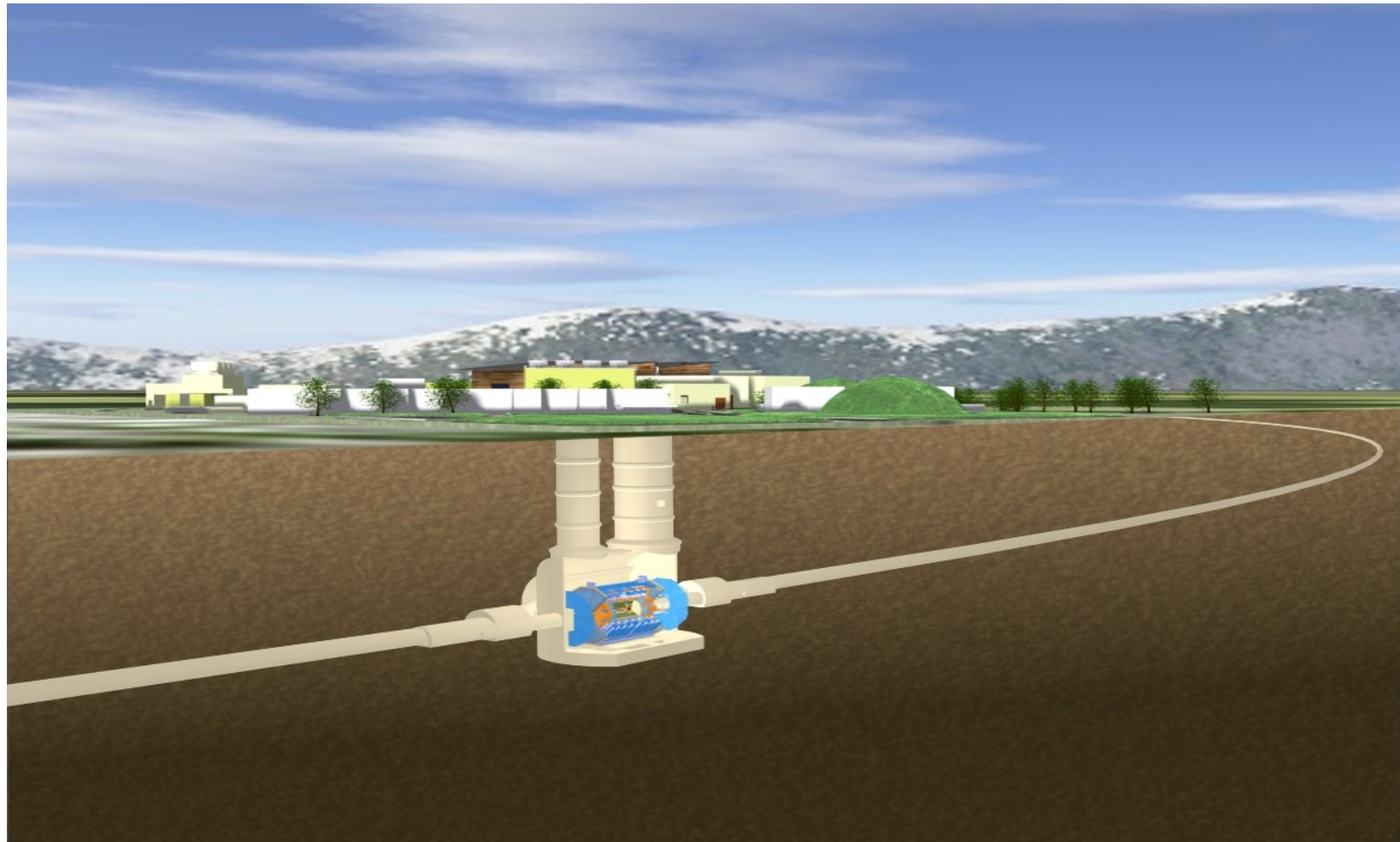
Large Hadron Collider Beauty



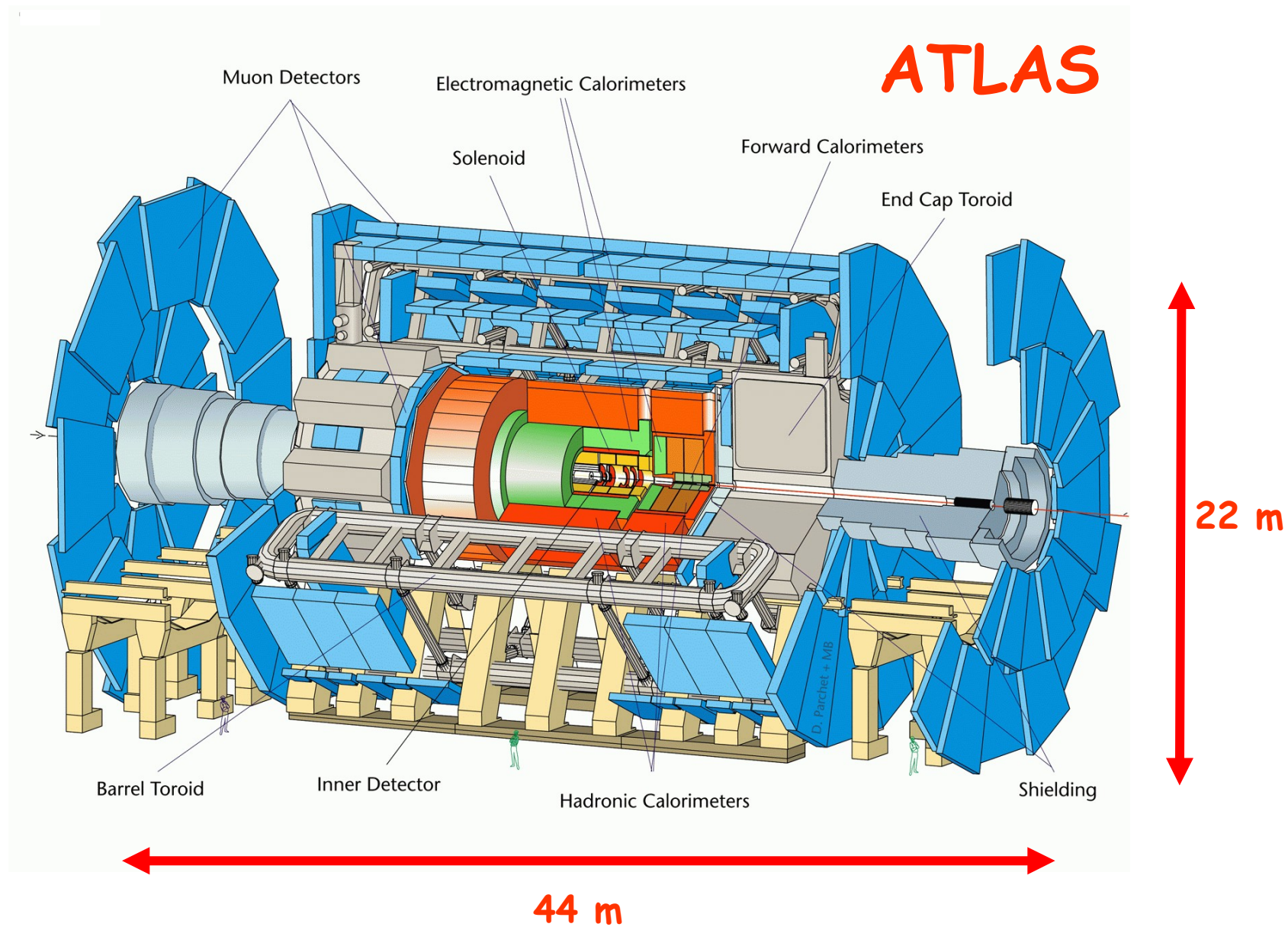
“A severe case of symmetry breaking!”

Meanwhile @ TeVatron

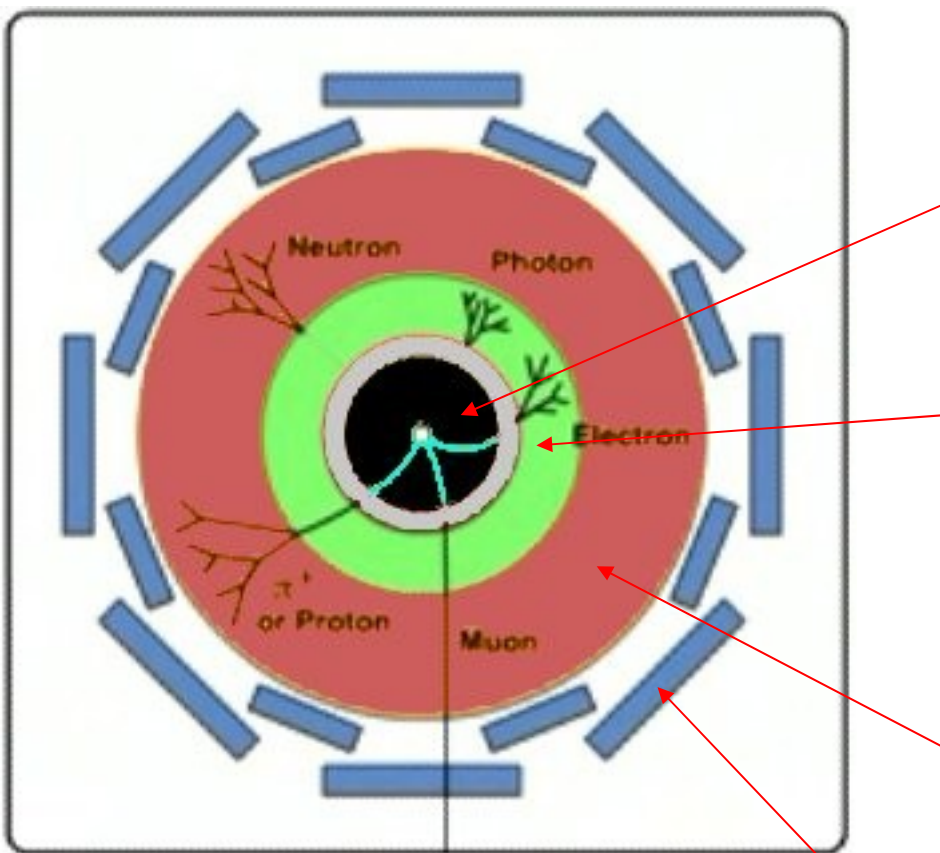




A Toroidal LHC Apparatus



A Typical Detector



Inner detector (Tracker)

Measures charge and momentum of charged particles in magnetic field

Electro-magnetic calorimeter

Measures energy of electrons, positrons and photons

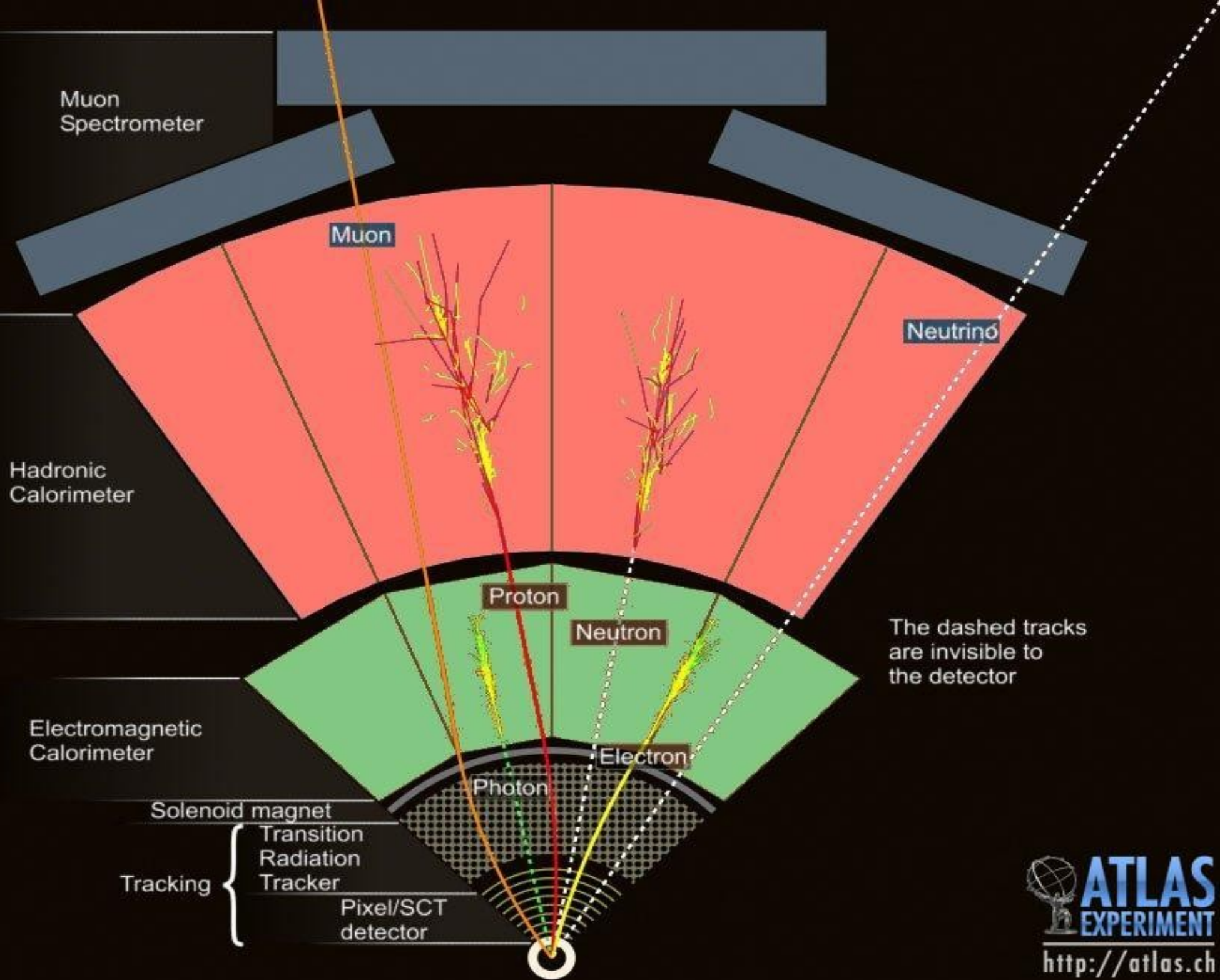
Hadronic calorimeter

Measures energy of hadrons (particles containing quarks), such as protons, neutrons, pions, etc.

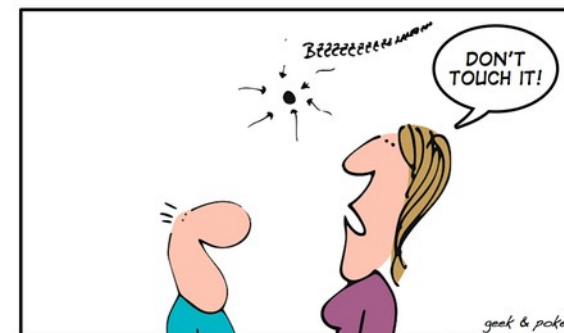
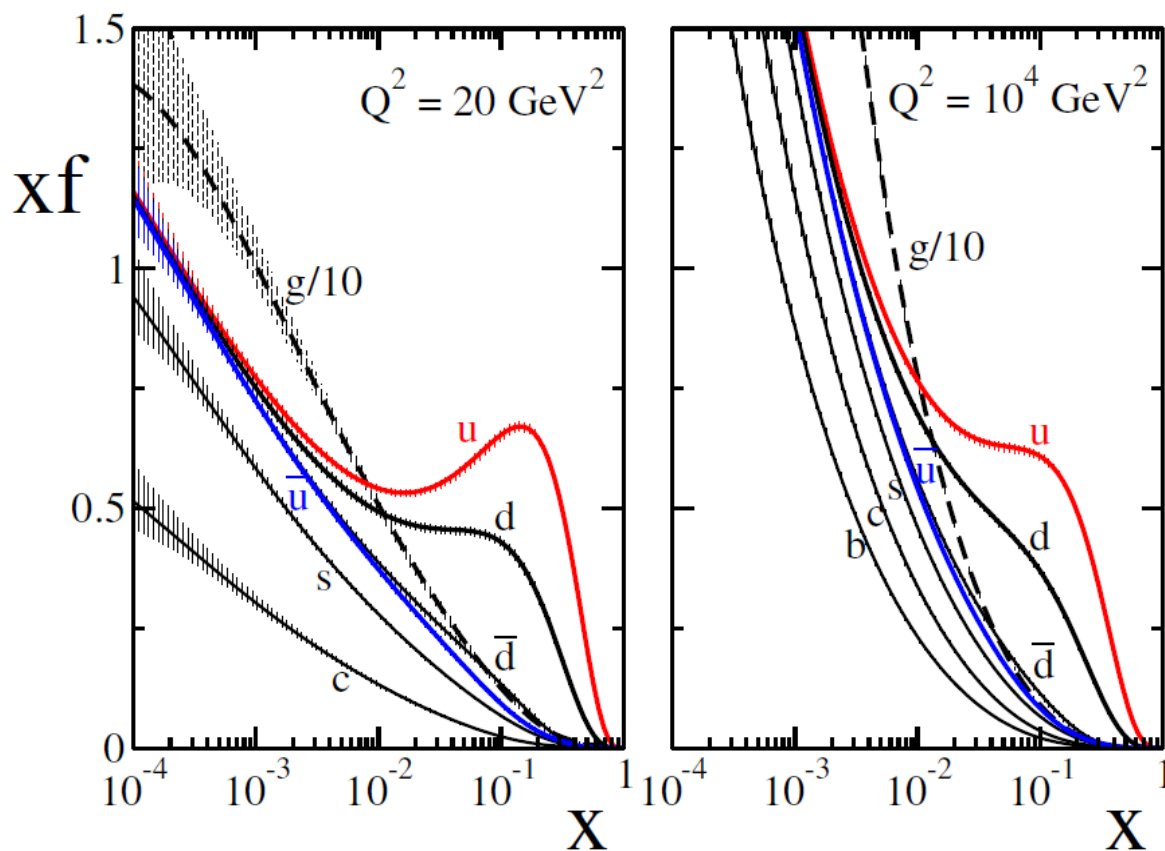
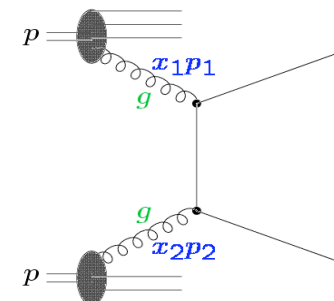
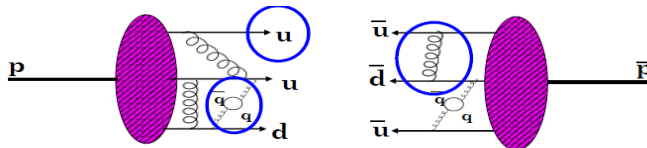
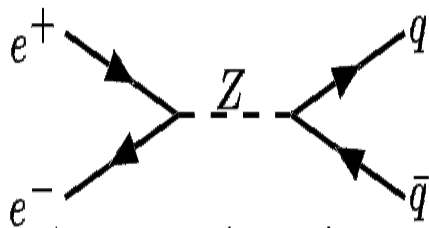
Muon detector

Measures charge and momentum of muons

Neutrinos are only detected indirectly via 'missing energy' not recorded in the calorimeters

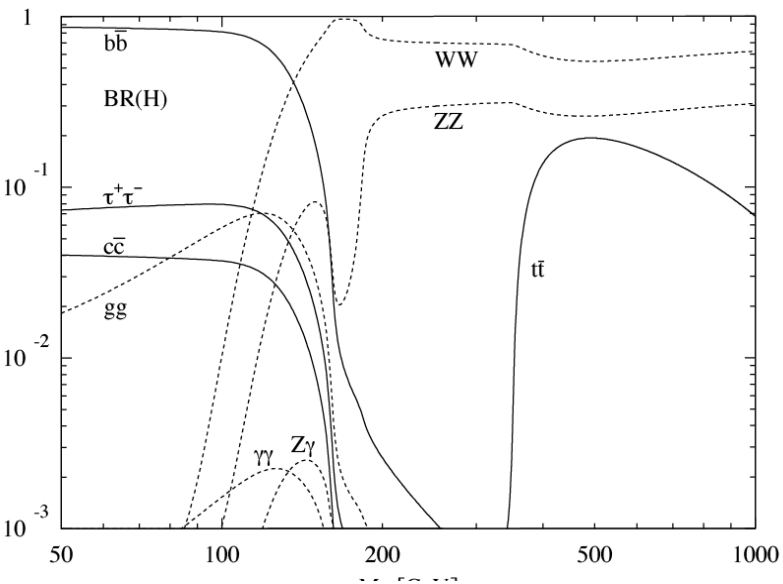
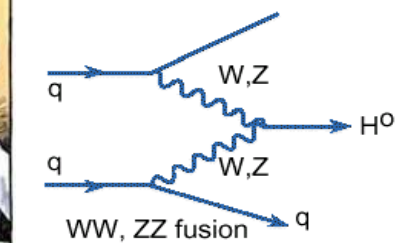
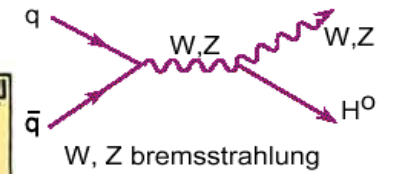
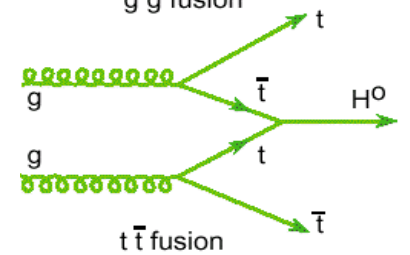
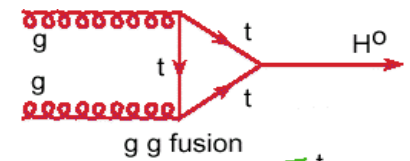
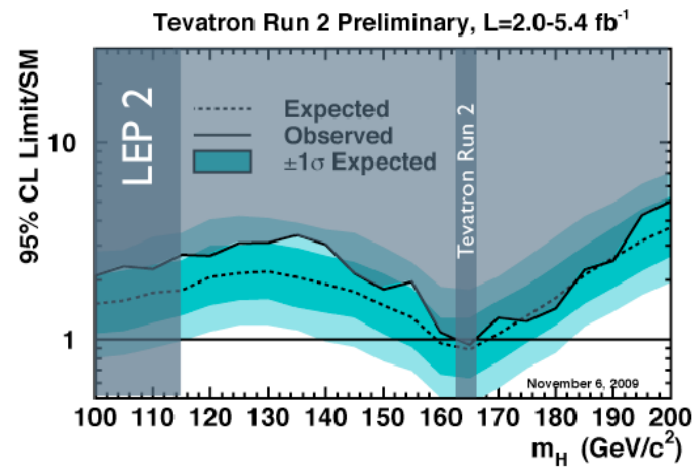
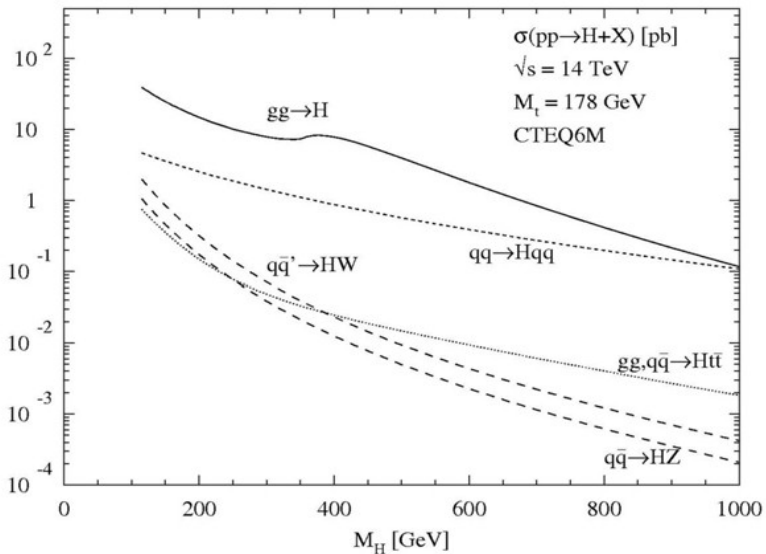


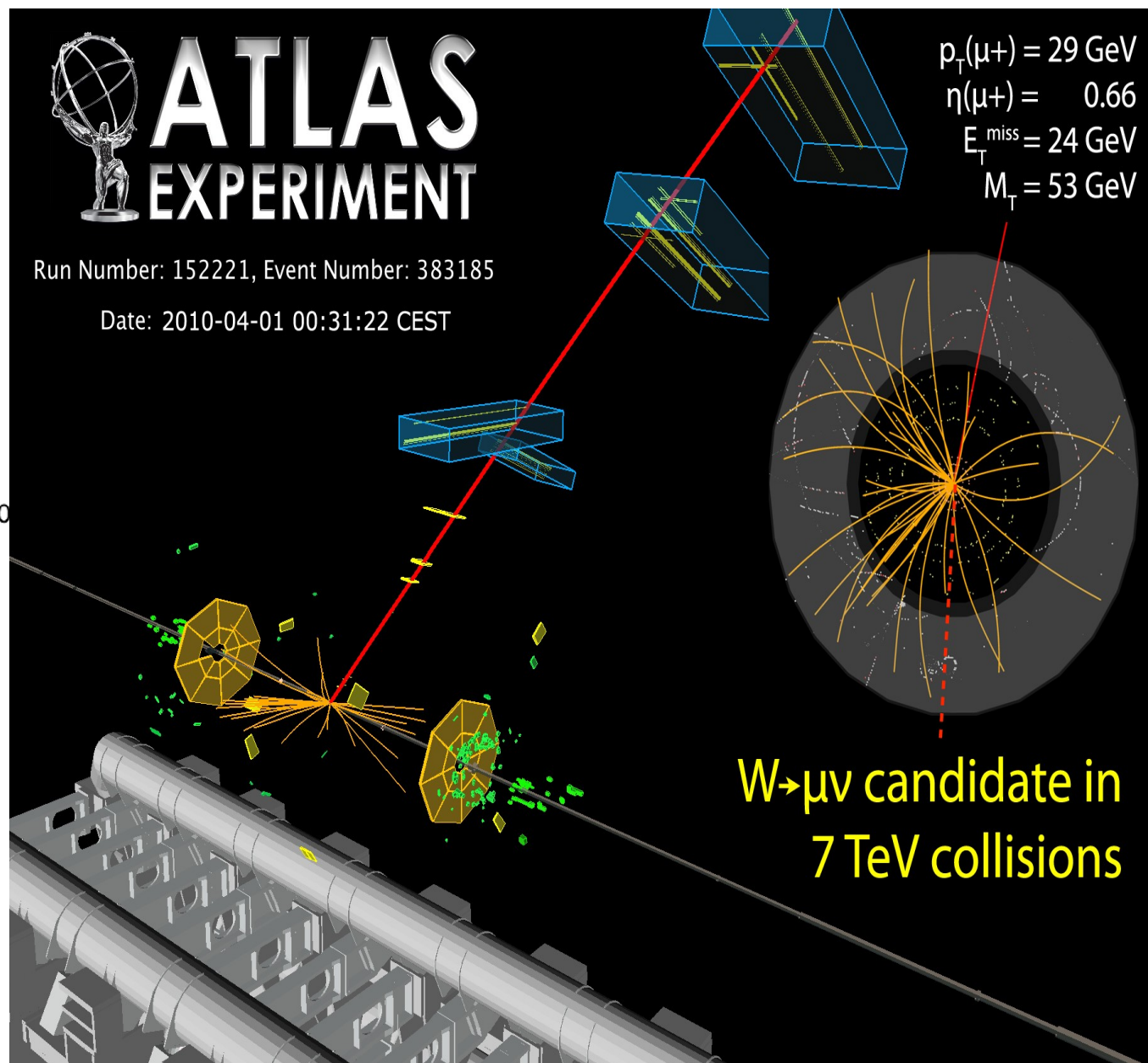
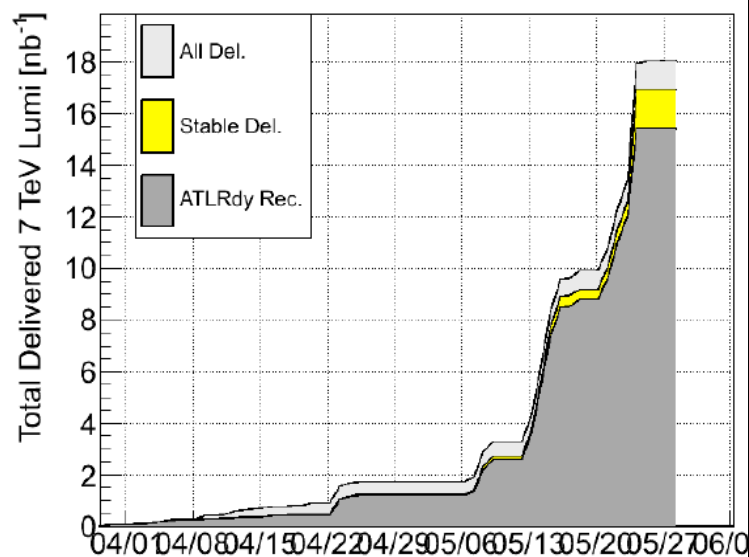
Hadron vs lepton colliders



NOW THAT THE LARGE HADRON COLLIDER HAS STARTED WE CAN WATCH THE FIRST BLACK HOLES HANGING AROUND IN THE WILD

Higgs

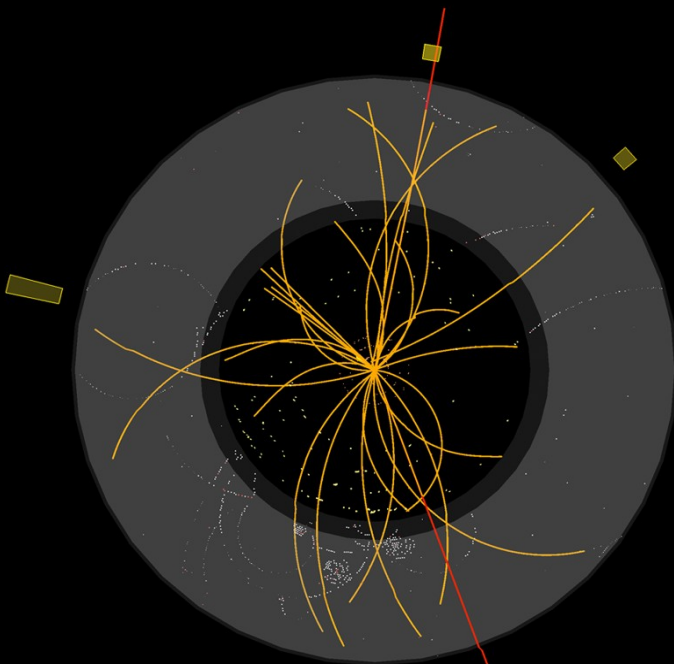






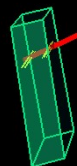
ATLAS EXPERIMENT

Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST

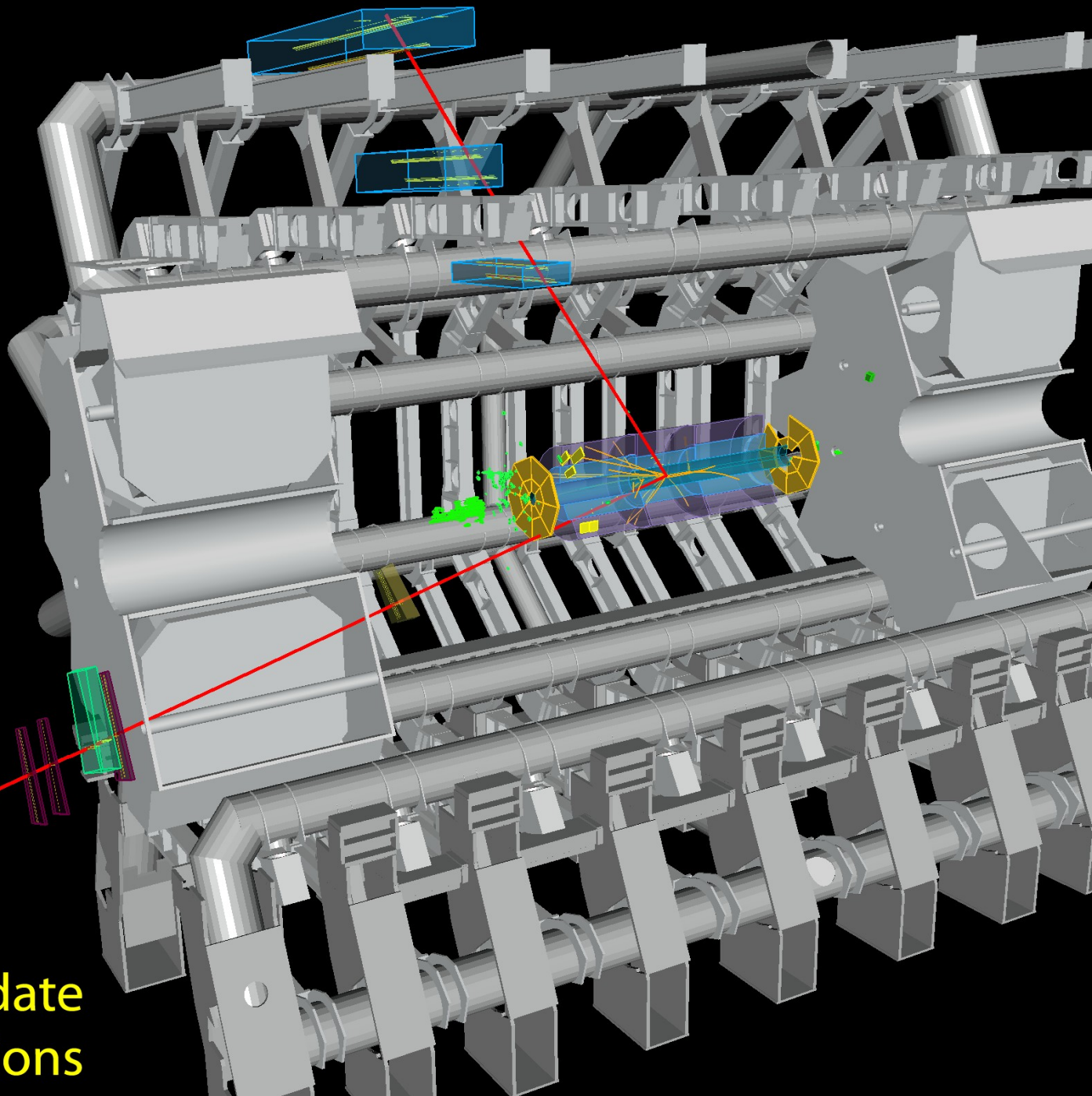


$p_T(\mu^-) = 27 \text{ GeV}$ $\eta(\mu^-) = 0.7$
 $p_T(\mu^+) = 45 \text{ GeV}$ $\eta(\mu^+) = 2.2$

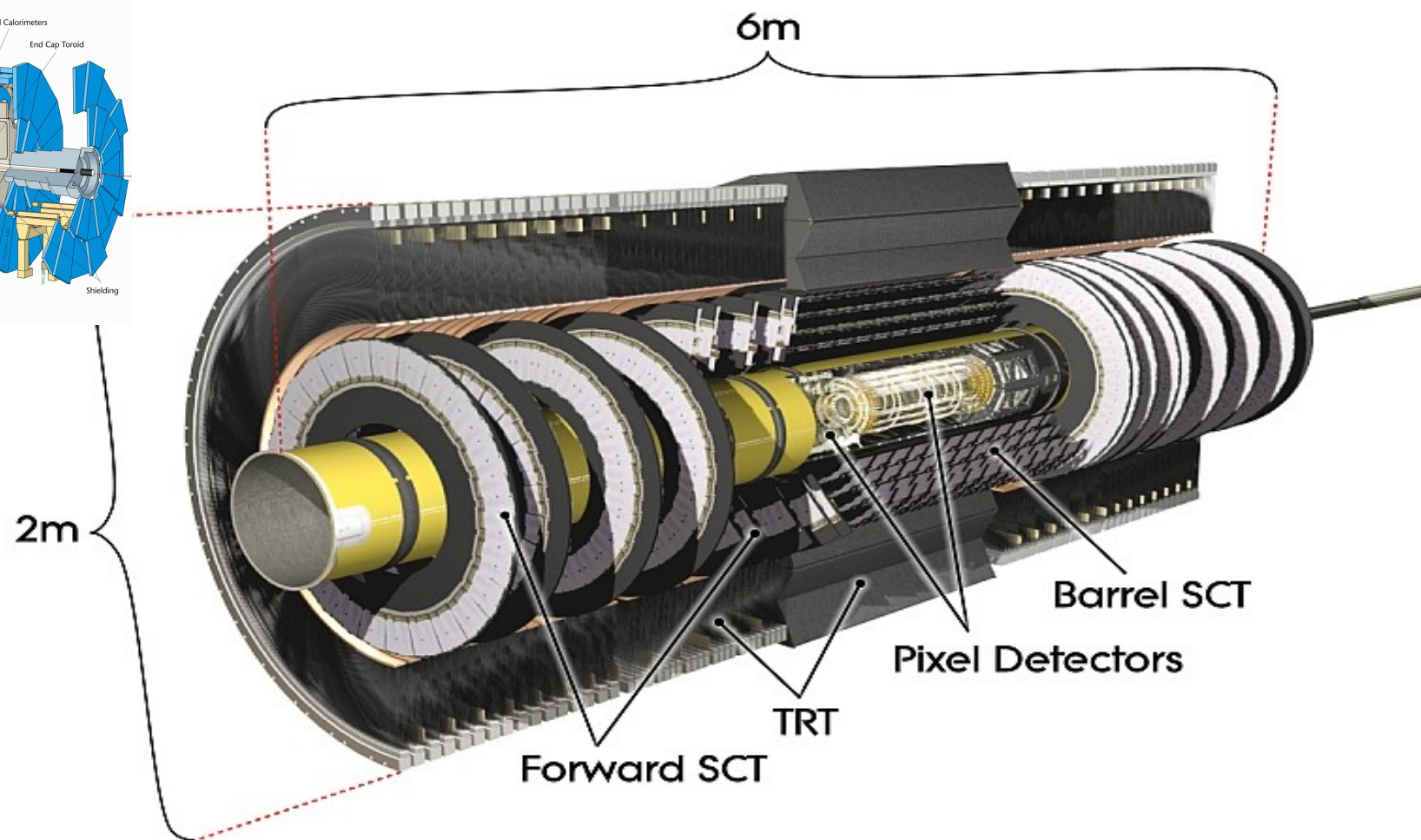
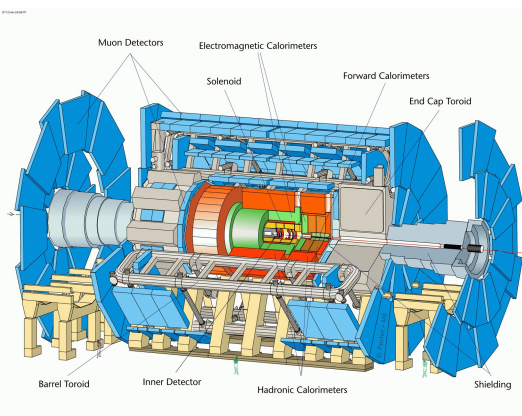
$M_{\mu\mu} = 87 \text{ GeV}$



**$Z \rightarrow \mu\mu$ candidate
in 7 TeV collisions**



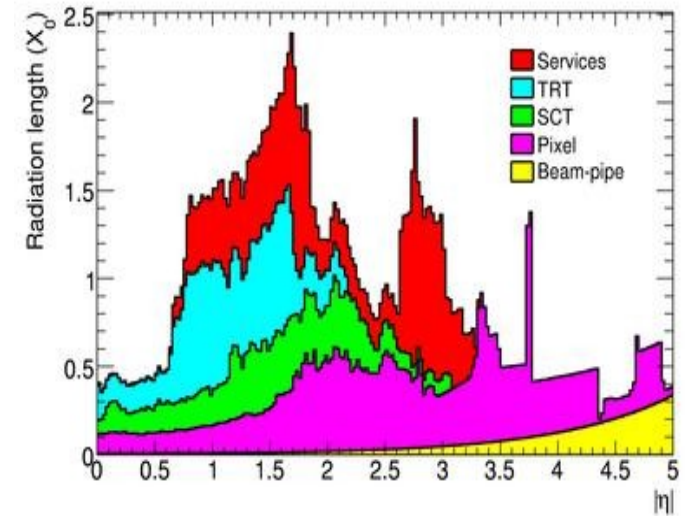
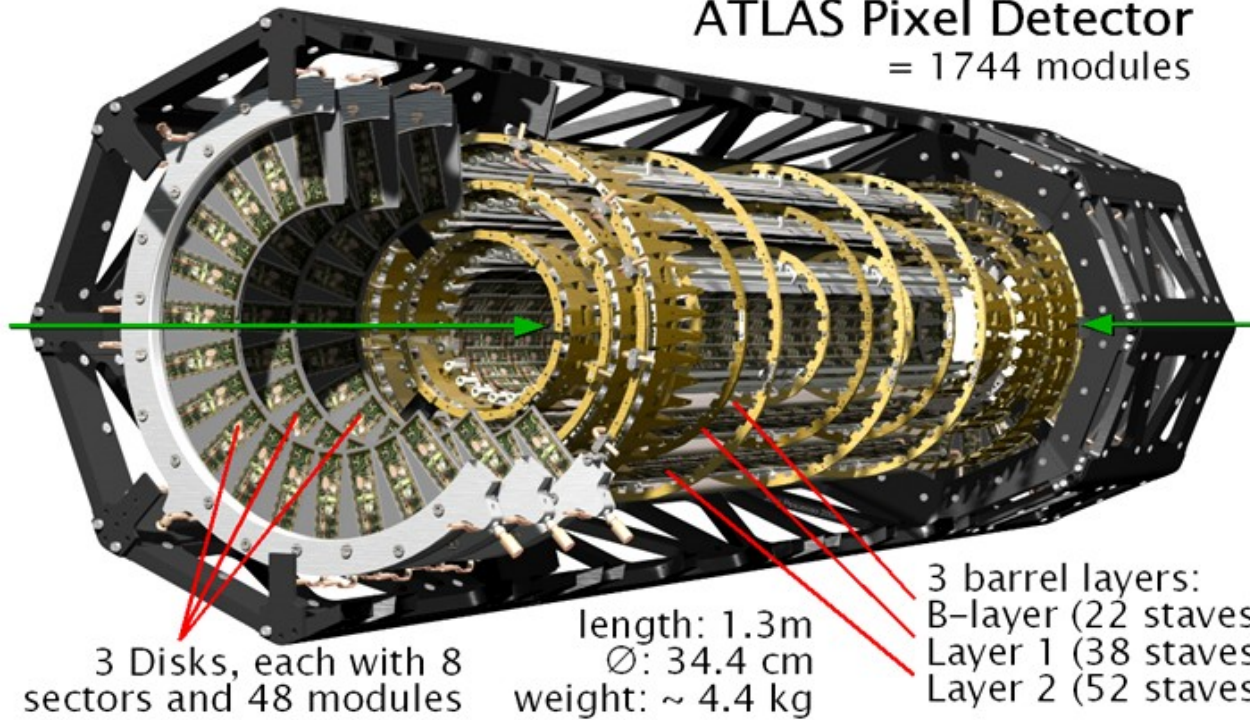
ATLAS Inner Detector



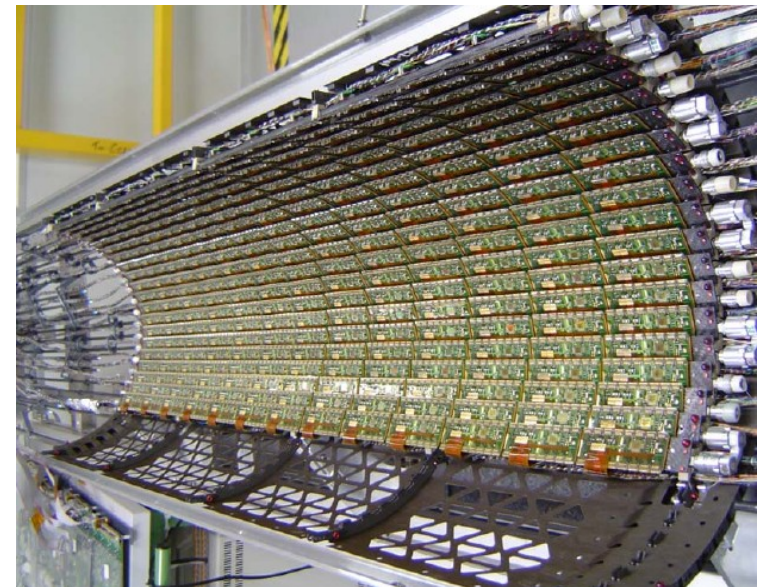
ID je umiestnený v solenoide s homogénnym poľom 2T.

Pixel

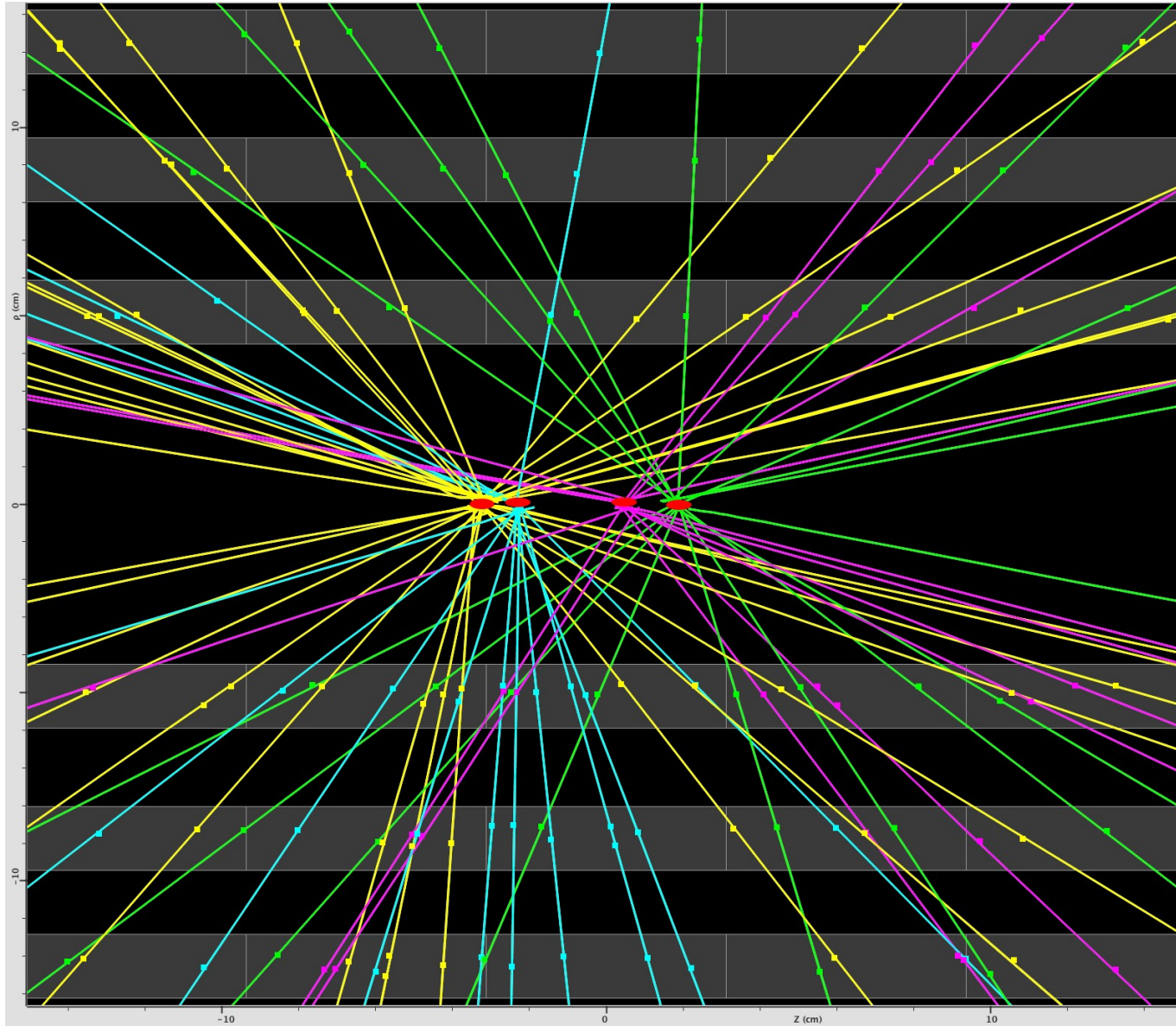
ATLAS Pixel Detector = 1744 modules



- 3 hity pre $|\eta| < 2.5$
- časové rozlíšenie < 25 ns
- ~ 80 M kanálov
- 1.8 m^2 aktívna plocha
- IP rozlíšenie $115 \mu\text{m}$ v Z, v R- $\phi < 15 \mu\text{m}$
- Odparovacie C_3F_8 chladenie



Vertexing

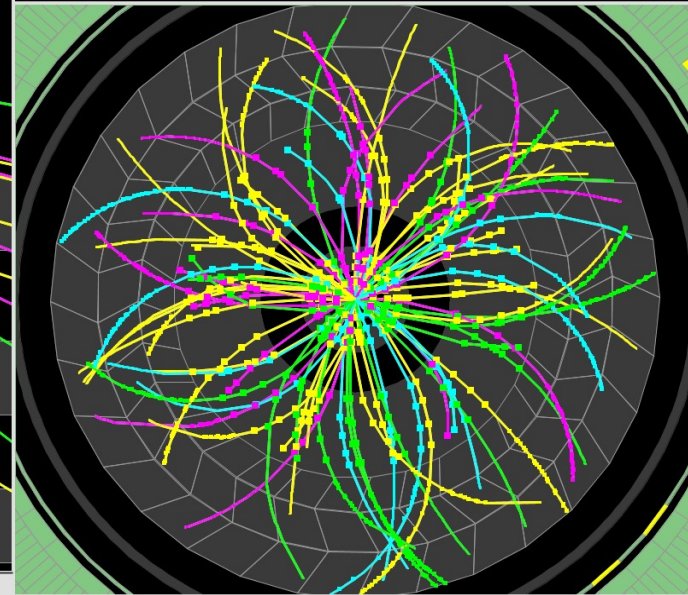


ATLAS EXPERIMENT

Run Number: 153565, Event Number: 4487360

Date: 2010-04-24 04:18:53 CEST

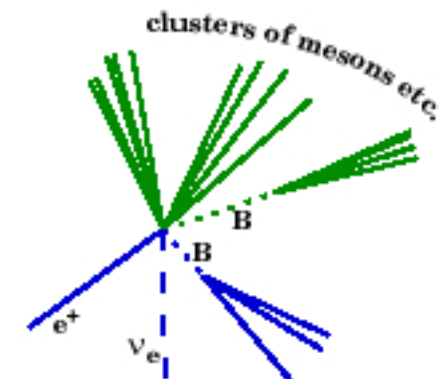
**Event with 4 Pileup Vertices
in 7 TeV Collisions**



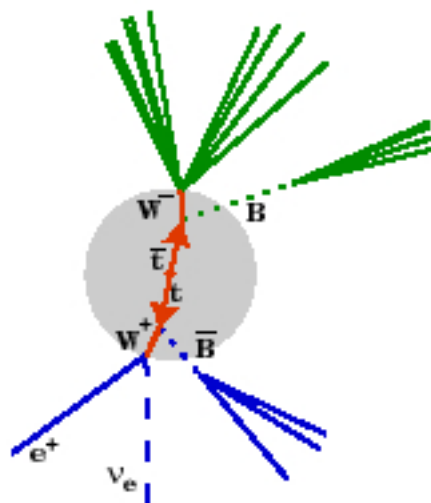
$T\bar{T}$



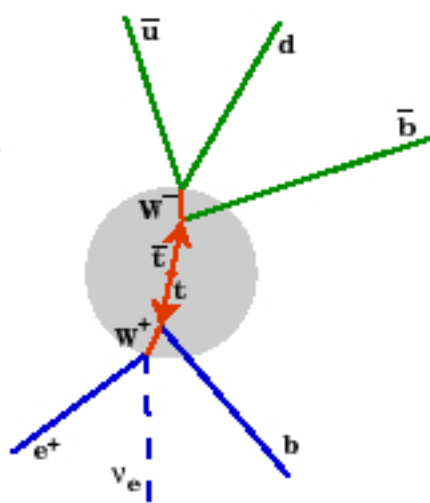
Detector View



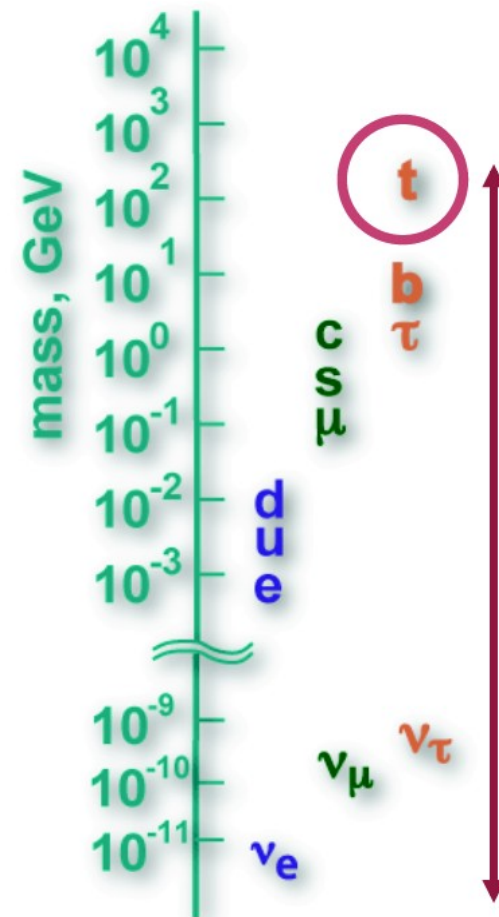
Computer Reconstruction



Physicist Interpretation

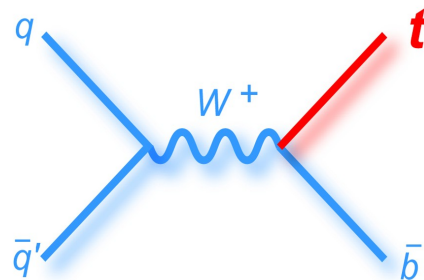
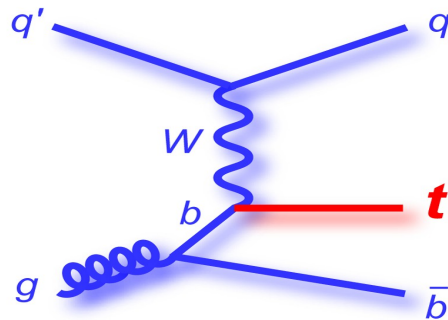
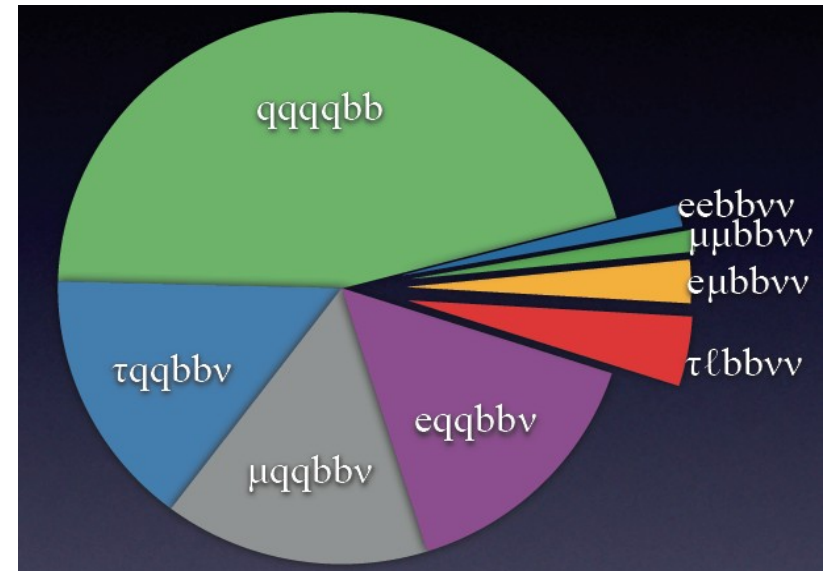
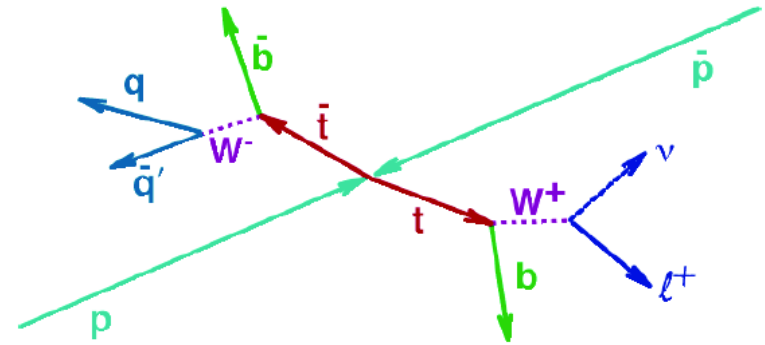
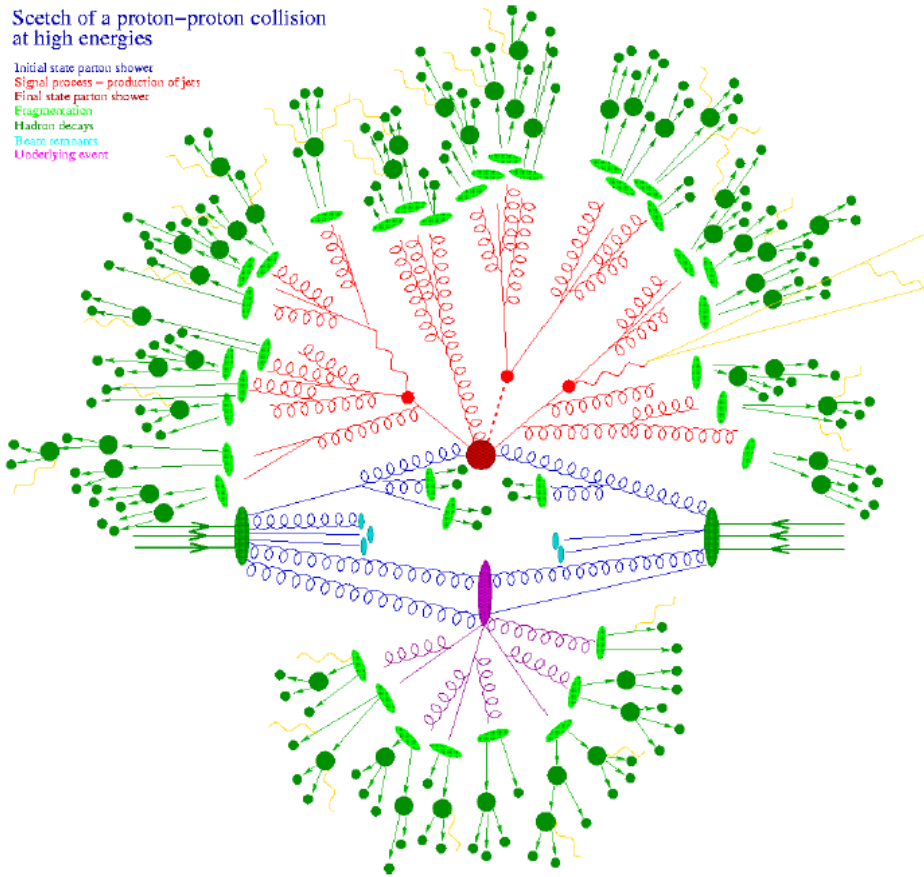


Quark View

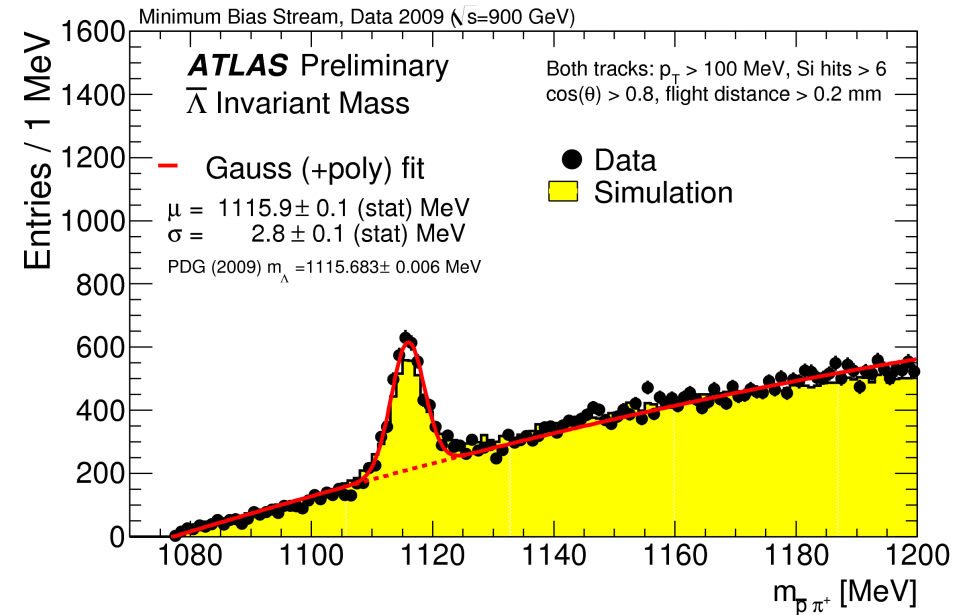
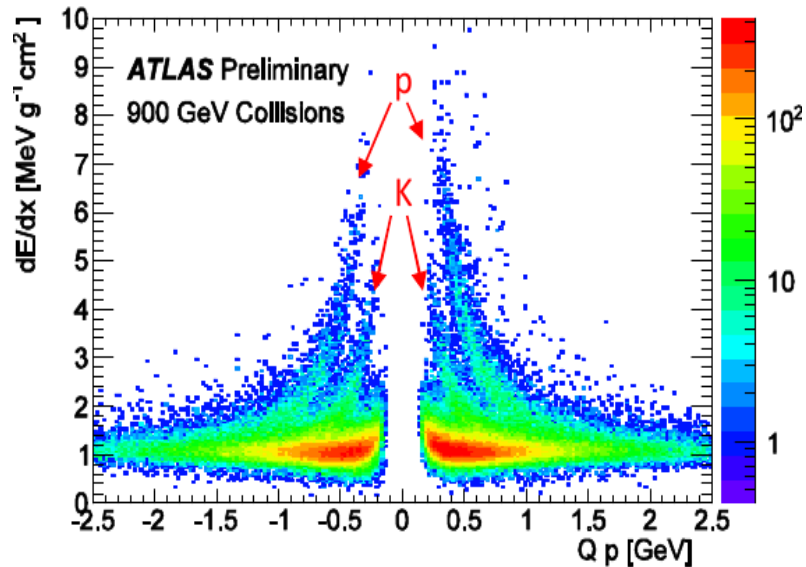
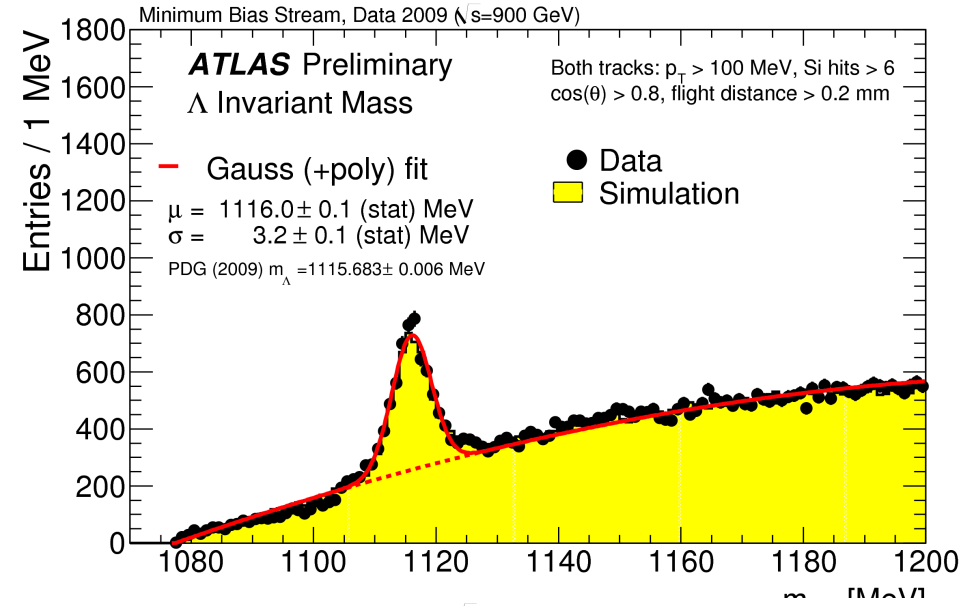
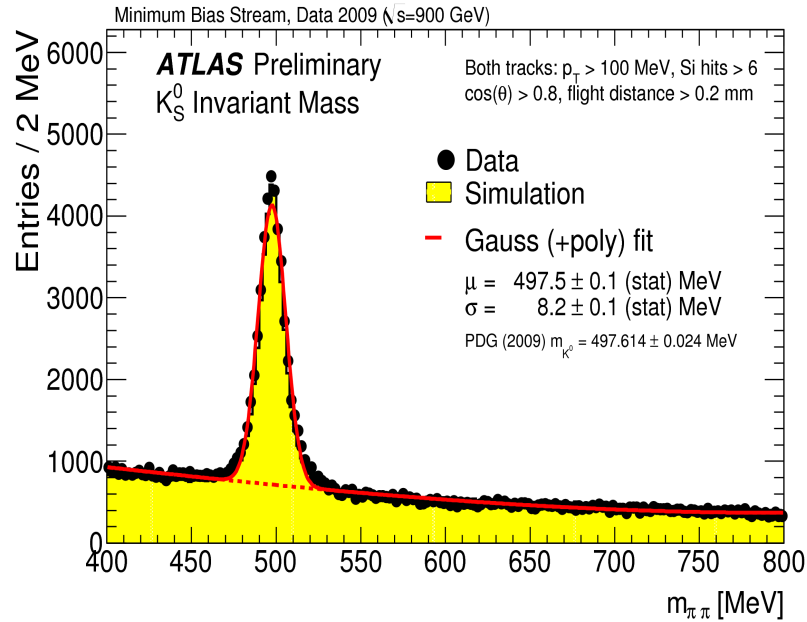


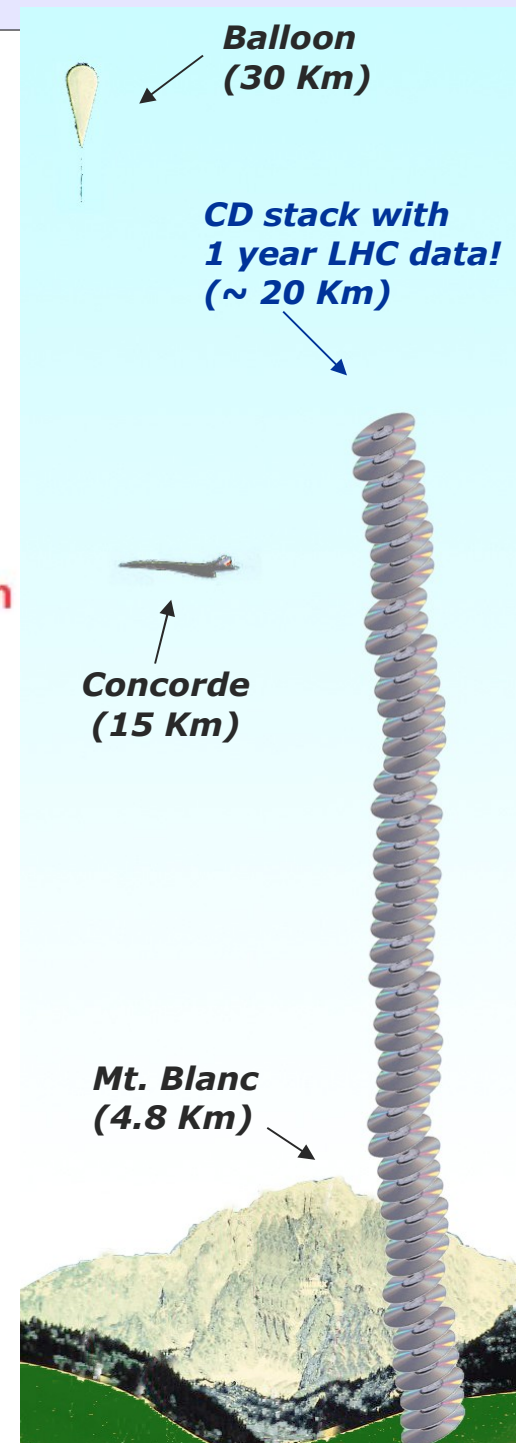
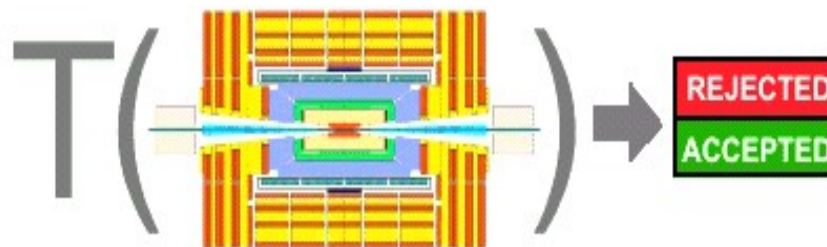
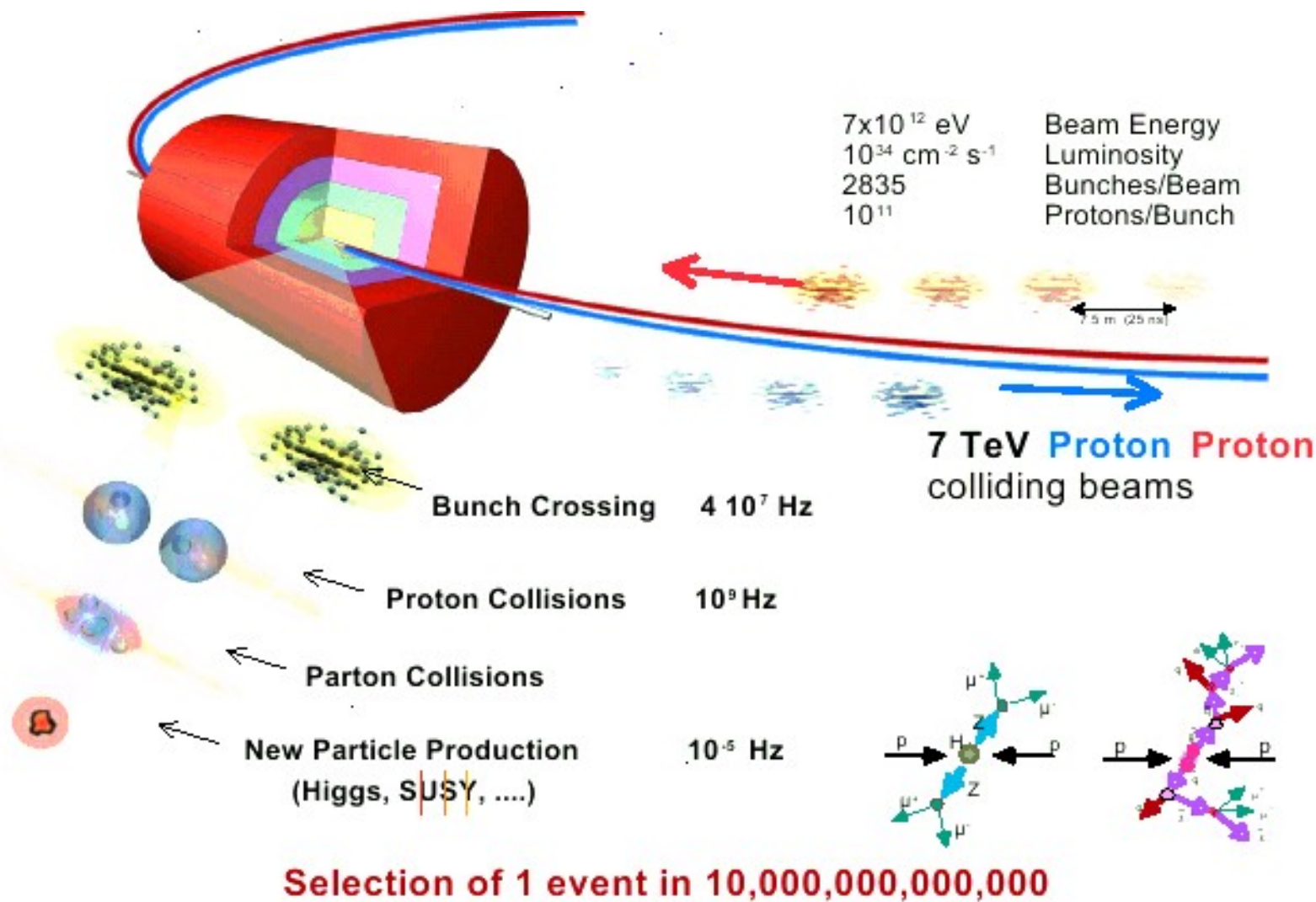
Sketch of a proton-proton collision at high energies

Initial state parton shower
Signal process – production of jets
Final state parton shower
Fragmentation
Hadron decays
Beam remnants
Underlying event

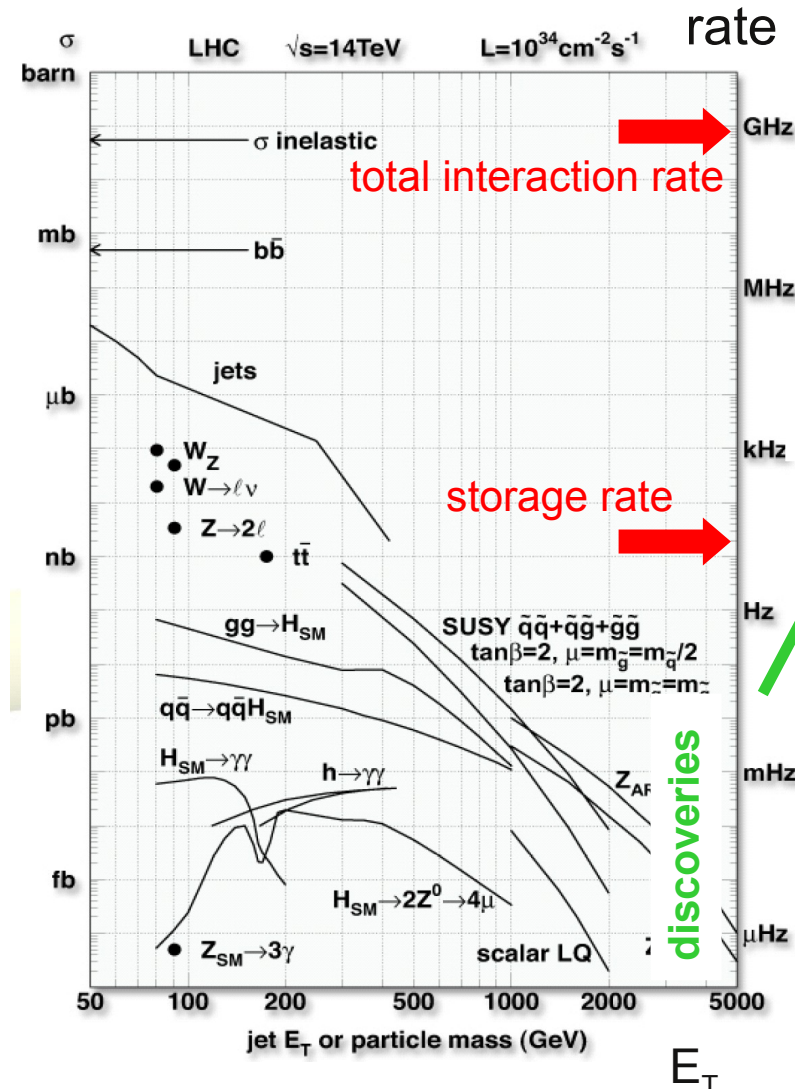


Collisions - ATLAS





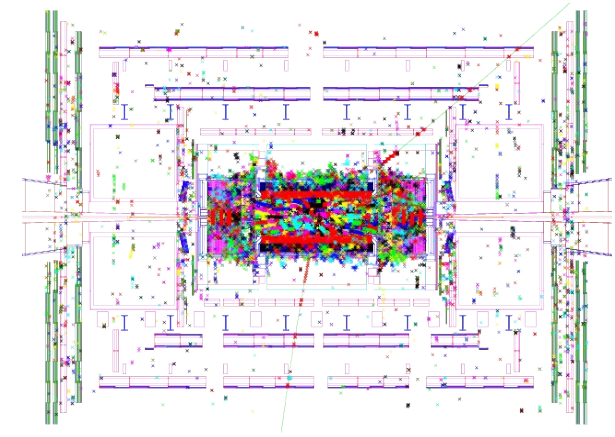
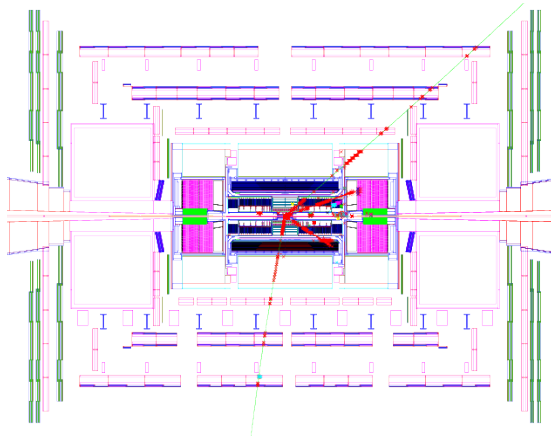
Trigger motivation



bunch crossing rate: 40 MHz
 total interaction rate: ~ 1 GHz
 event size: ~ 1.5 MB

affordable: ~ 300 MB/s
 storage rate: ~ 200 Hz
 \rightarrow online rejection: 99.9995%

e.g.: Higgs $\rightarrow ZZ \rightarrow 2e+2\mu$

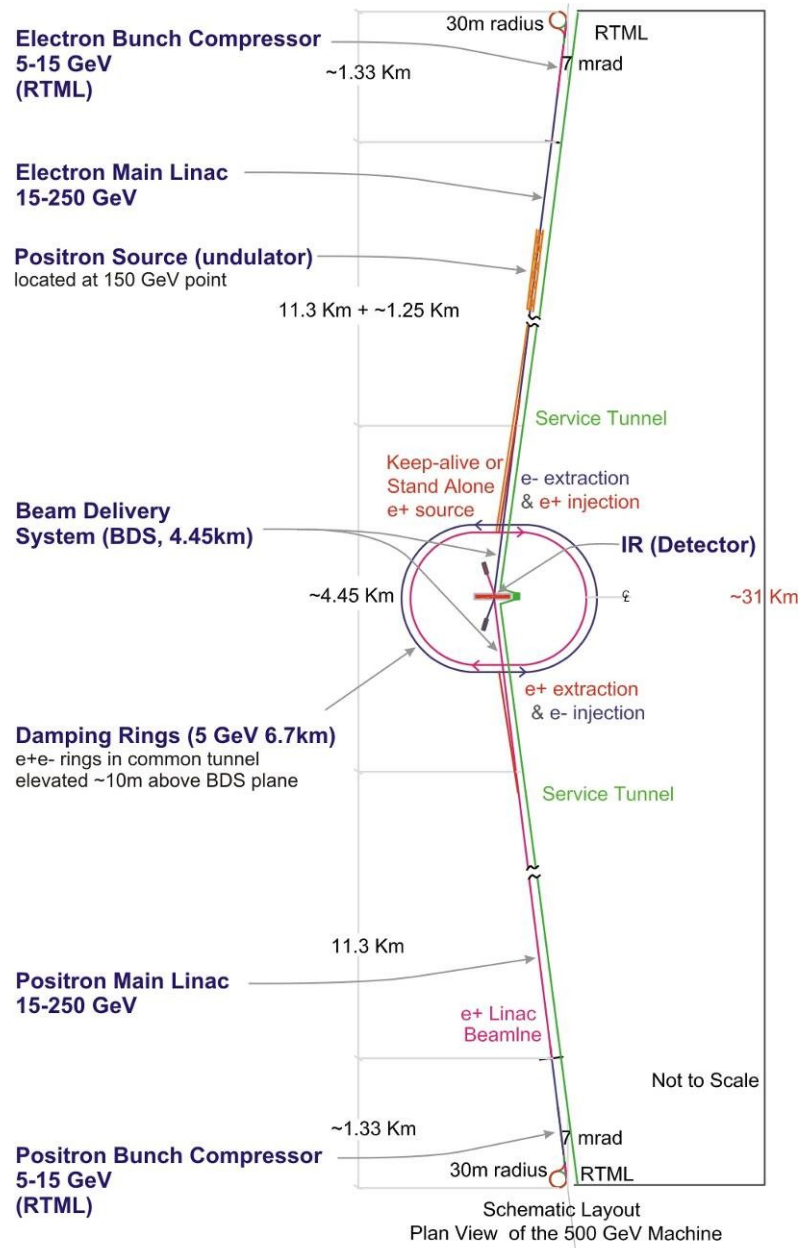


23 min. bias events:
 ~ 1725 particles/BC

powerful trigger needed

- Enormous rate reduction
- Retaining the rare events in the very tough LHC environment
- Sharing in between physics and technical triggers

The ILC – International Linear Collider



- e⁺ e⁻ collider
 - Possibility of e⁻e⁻, e⁻γ or γγ
- 500 to 1000 (upgrade) GeV
- Luminosity of $2 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- Polarized beams
- Ability to scan in 200-500 GeV & 91 GeV
- Energy stability and precision of 0.1%

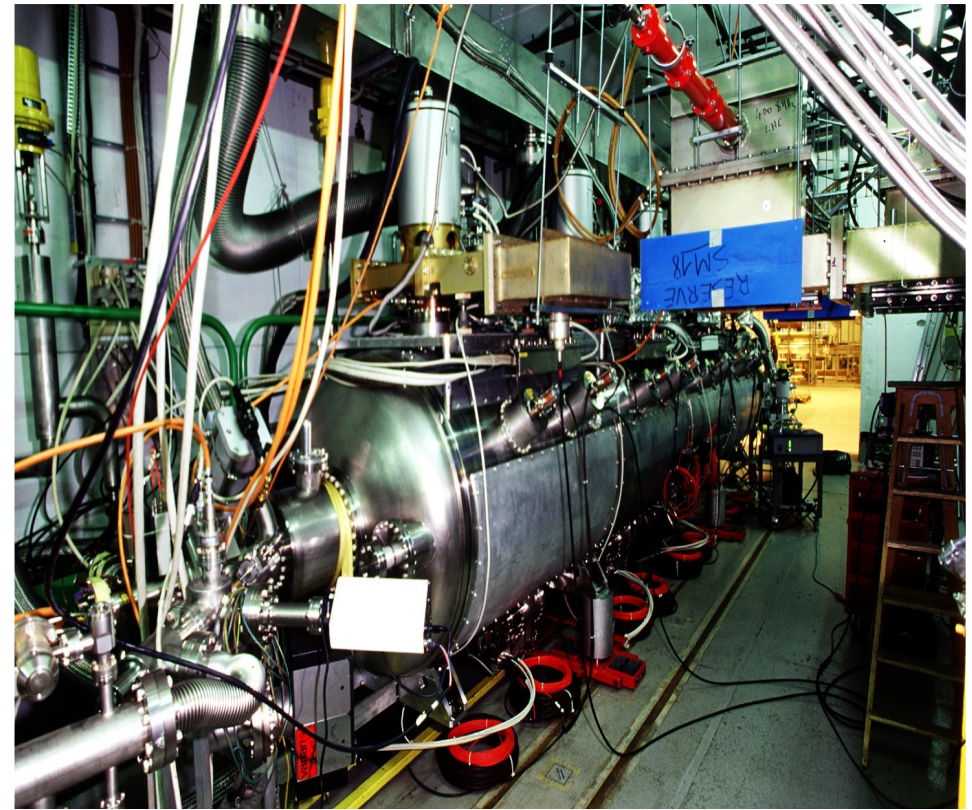
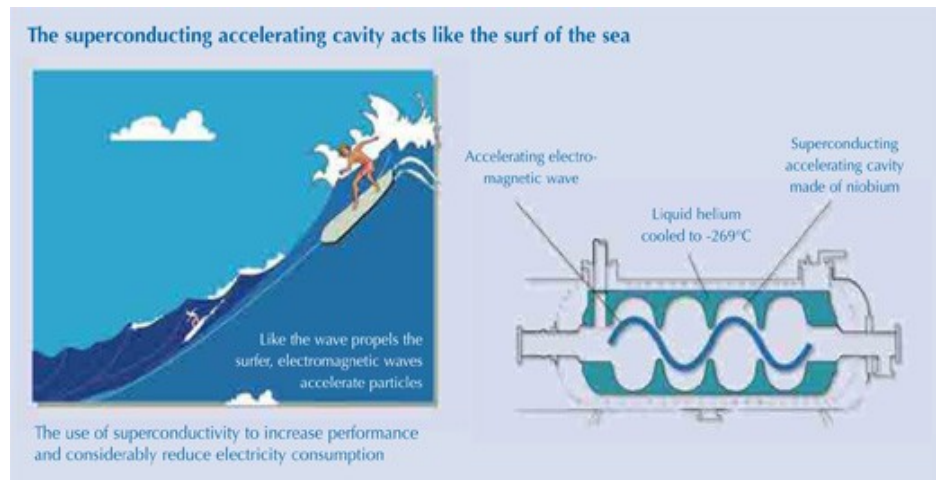


The 1.3 GHz TESLA cavity

BACKUP SLIDES

RF System

- 400 MHz
- 16 super-conducting cavities for 16 MV/beam
- 4 Modules



Supercyklus

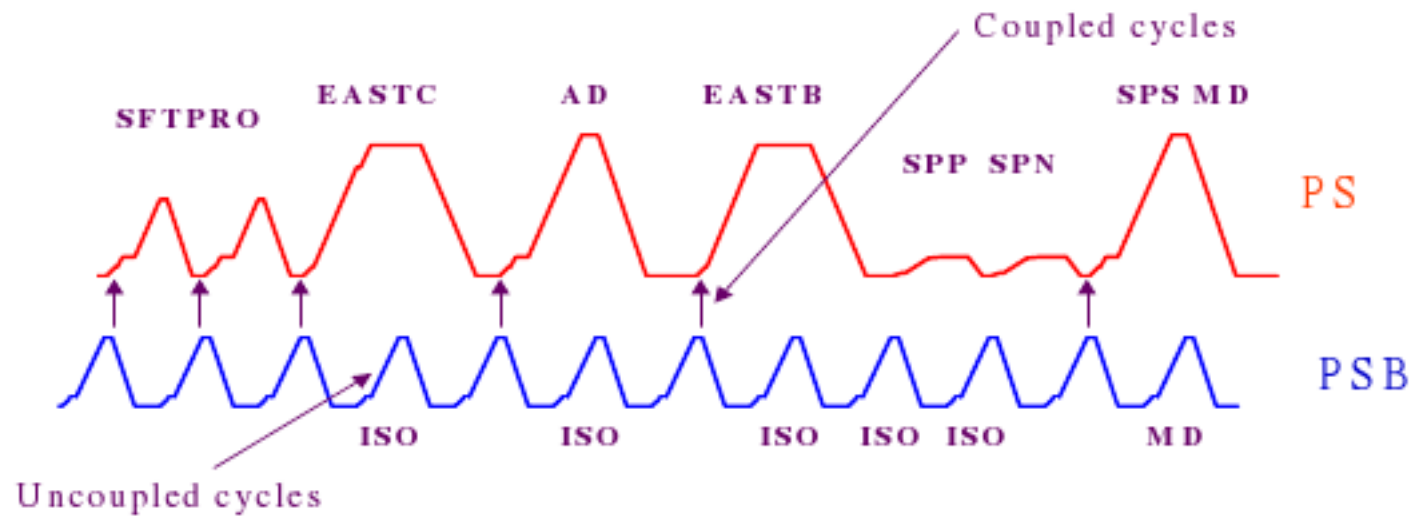


Figure 1: A typical PS Complex super-cycle

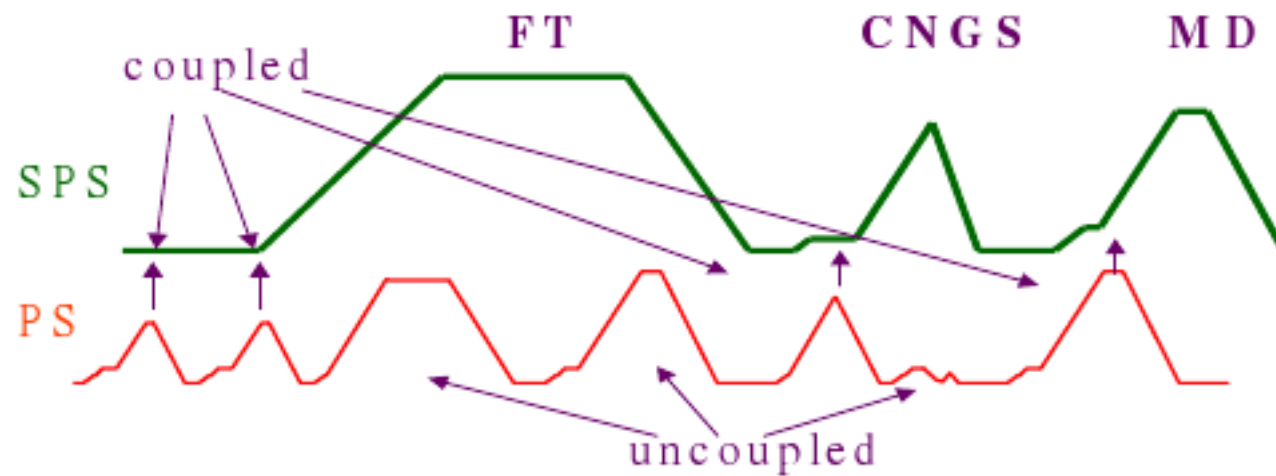
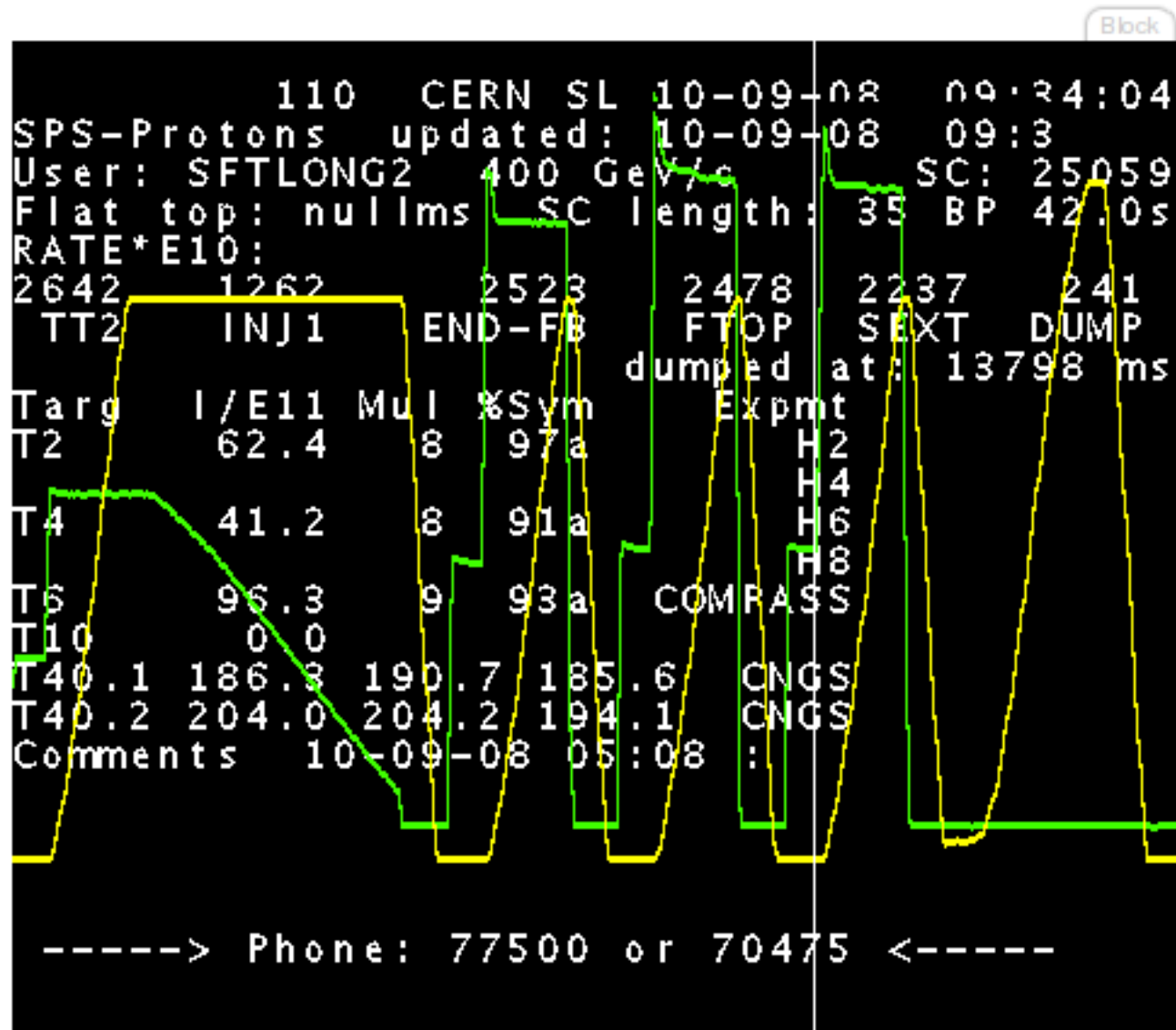


Figure 2: A possible PS/SPS super-cycle for CNGS and FT operation

SPS Page 1



- Fixed target
- Fast/Slow extraction
- LHC