



# European Organization for Nuclear Research Über 50 Jahre Grundlagenforschung in Physik

## CERN

... das Labor ... die Beschleuniger ... die Experimente ... die Physik ...

Dr. Sascha Marc Schmeling  
CERN PH



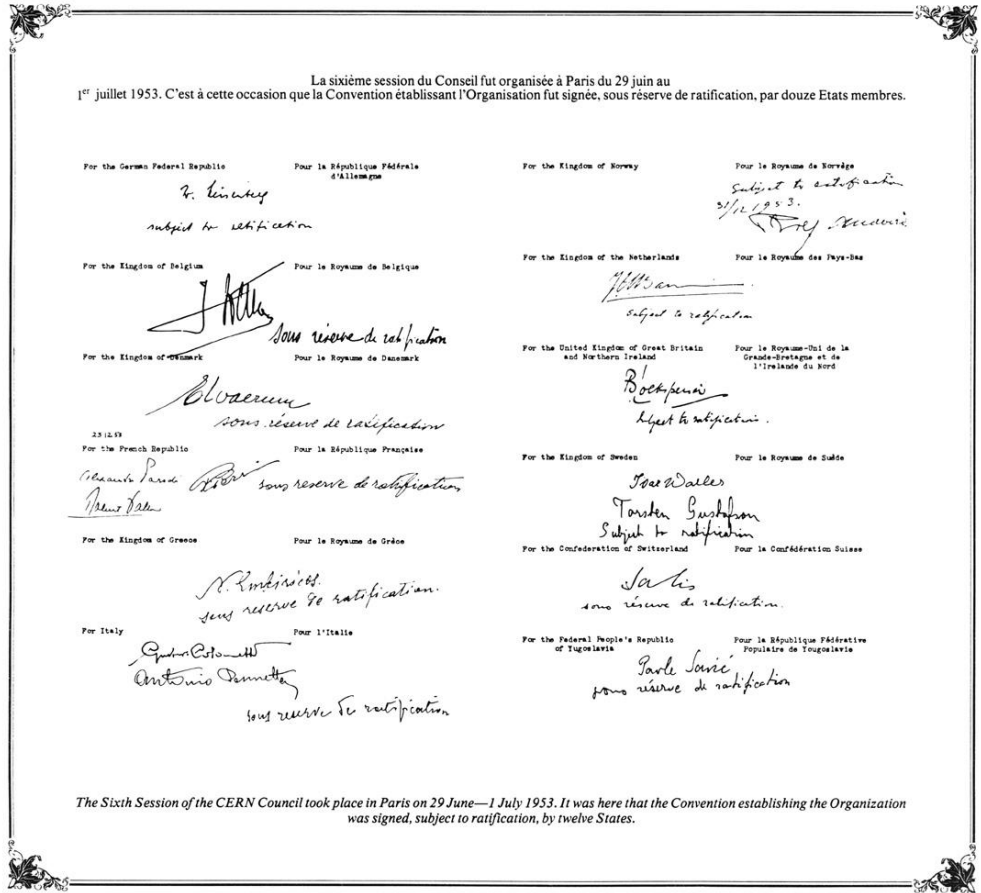
# CERN – Eine Einführung

- CERN – Organisation, Teilchenphysik, Forschung
- Beschleuniger und Experimente
  - vom Wasserstoff zum schnellen Proton
  - Experimente
- Der LHC – In Betrieb!



# Geschichte

- 1949  
Erste Ansätze ziviler Forschung im Bereich der Nukleartechnik
- 1952  
Gründung des **C**onseil **E**uropéen pour la **R**echerche **N**ucléaire unter der Obhut der UNESCO
- Oktober 1952  
Standortauswahl für Genf
- 1. Juli 1953  
Unterzeichnung der CERN Charta
- 29. September 1954  
Abschluß des Ratifikationsprozesses in den ursprünglichen zwölf Mitgliedsstaaten





# The Twenty Member States of CERN



## Member States (Dates of Accession)

 AUSTRIA (1959)	 DENMARK (1953)	 GREECE (1953)	 NORWAY (1953)	 SPAIN (1/1961-12/1968-1/1983)
 BELGIUM (1953)	 FINLAND (1991)	 HUNGARY (1992)	 POLAND (1991)	 SWEDEN (1953)
 BULGARIA (1999)	 FRANCE (1953)	 ITALY (1953)	 PORTUGAL (1986)	 SWITZERLAND (1953)
 CZECH FR (1993)	 GERMANY (1953)	 NETHERLANDS (1953)	 SLOVAK FR (1993)	 UNITED KINGDOM (1953)





Physics Department



# CERN – Das Laboratorium

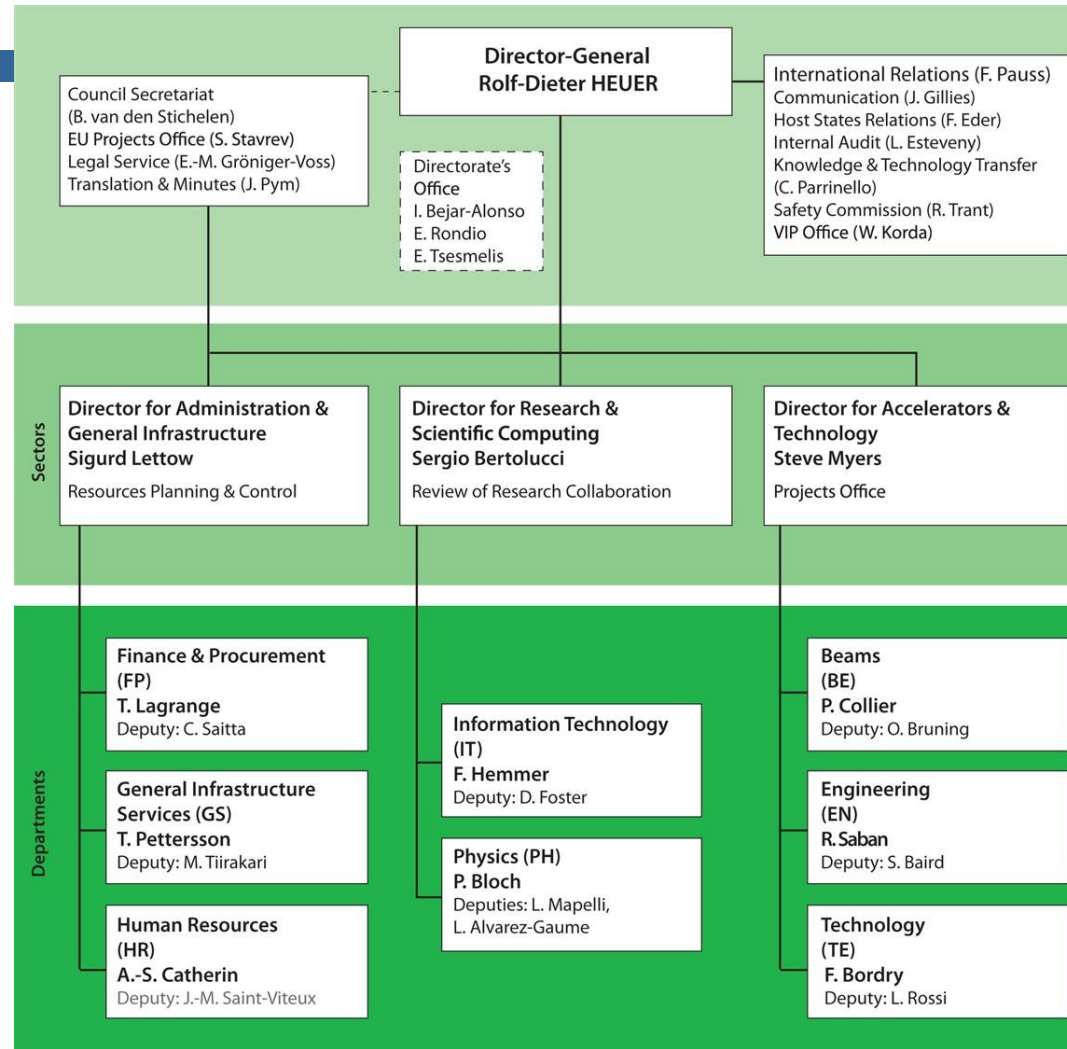






## CERN Organisation

- **CERN Council**  
Rat der Mitgliedsstaaten
  - 2 Sitze und Stimmen pro Mitgliedsstaat
  - Beobachter
    - z.B. UNESCO, EU
  - 4 Sessionen im Jahr
  
- **Scientific Policy Committee**
  - 16 Mitglieder
  - 5 Sitzungen im Jahr
  
- **Finance Committee**
  - alle Mitgliedsstaaten vertreten
  - Stimmenverteilung je nach Abstimmungsthema verschieden
  - 5 Sitzungen im Jahr





## Menschen bei CERN

### Angestellte

- Staff 2378
- Fellows 371

### Abgeordnete

- Wissenschaftler 67
- Projektpersonal 140
- Studenten 103
- Doktoranden 118
- Sonstige 652

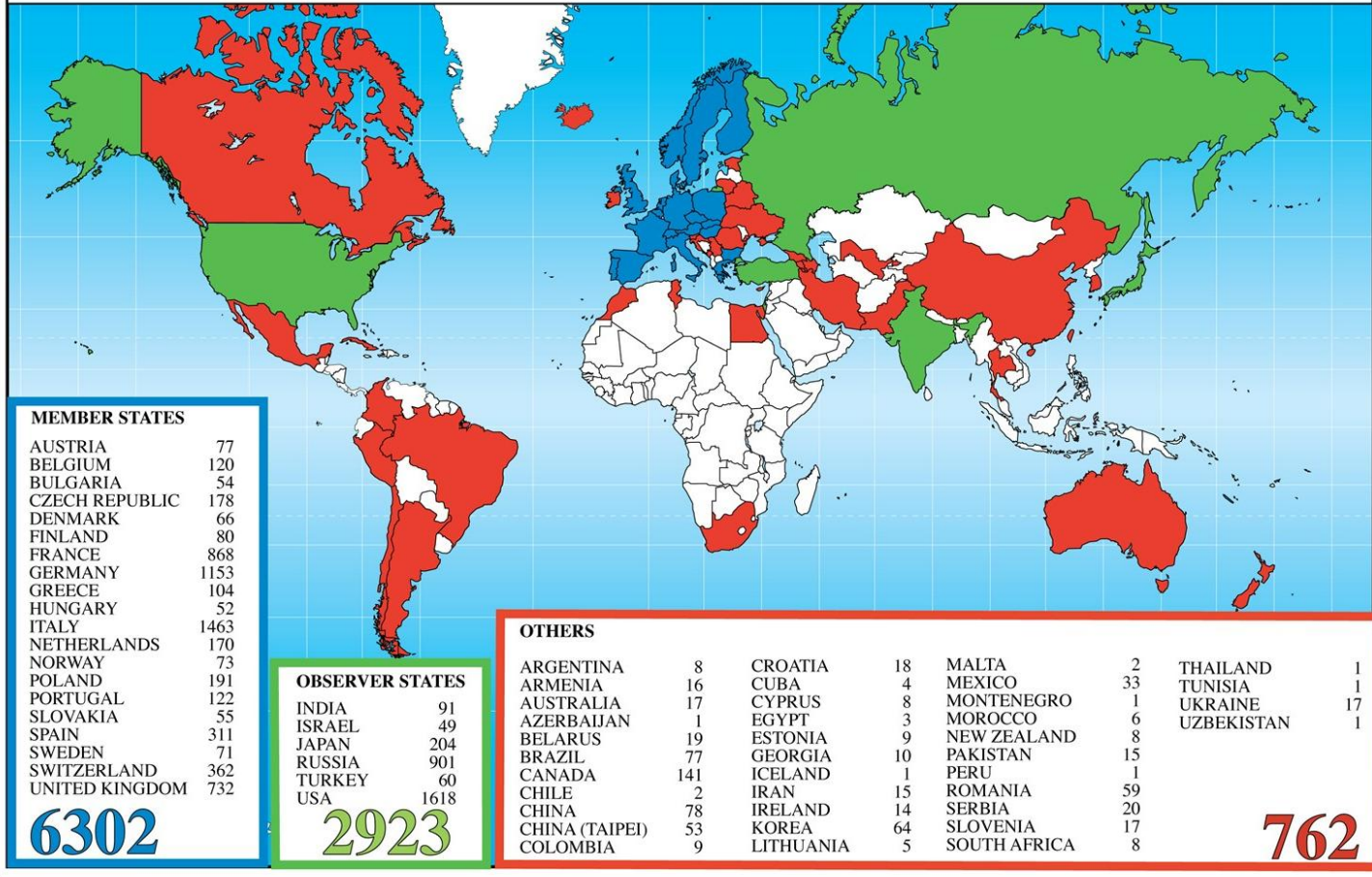
### Firmen

3071

### User

11044

### Distribution of All CERN Users by Nation of Institute on 20 January 2010







# HochEnergiePhysik

- Auf der Suche nach dem,  
"Was die Welt im Innersten zusammenhält"
  
- Suche nach
  - elementaren Teilchen
  - Kräften
  - Symmetrien

Physique des Particules

Cosmologie

Physique Nucléaire

Astrophysique

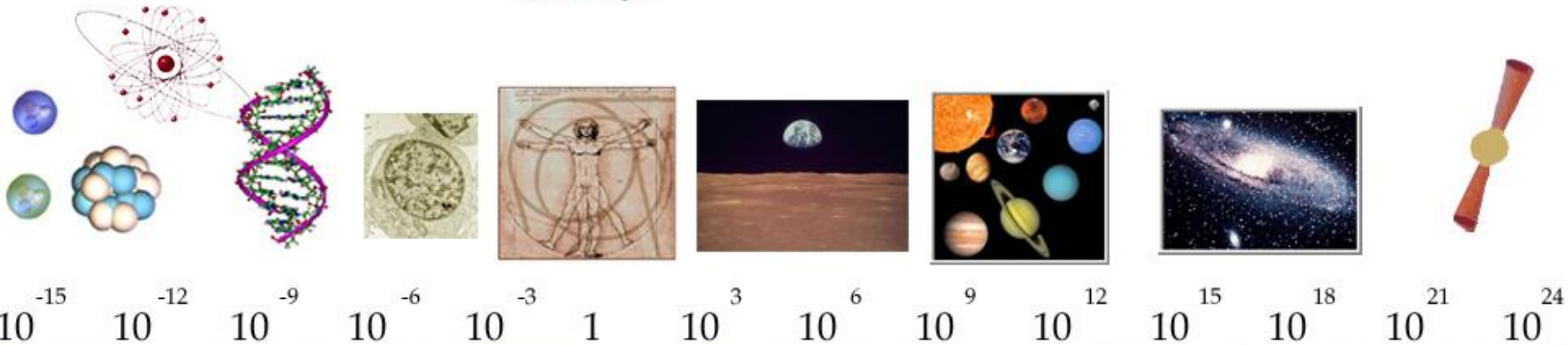
Physique du Solide

Astronomie

Chimie - Biologie

Géophysique

Mécanique



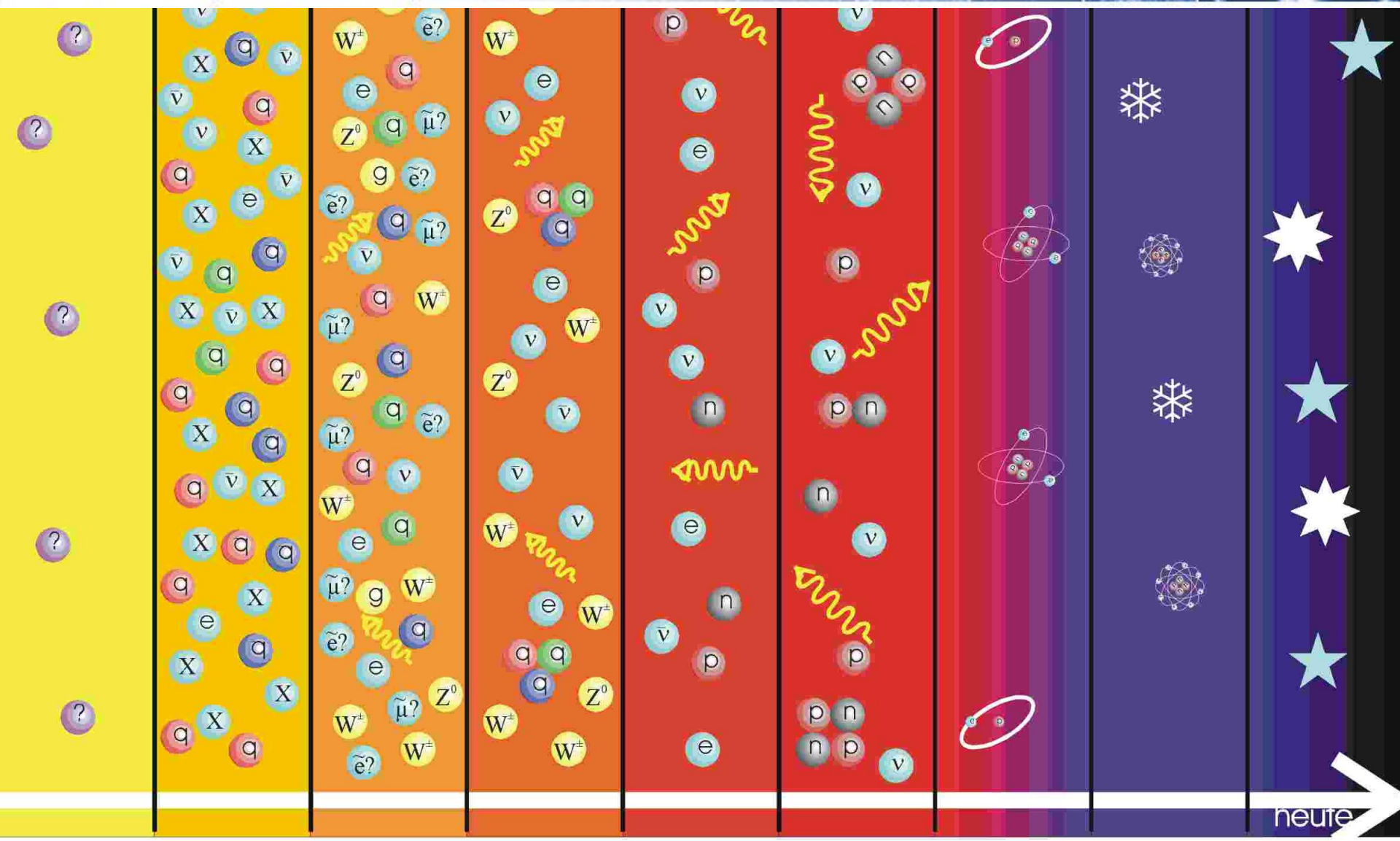
fm   pm   nm    $\mu$ m   mm   m   km   Mm   Gm   Tm   Pm   Em



$10^{-15}$  m = 0,000 000 000 000 001 m



# Physics Department



$10^{43}$ s	$10^{36}$ s	$10^{-10}$ s	1 s	3 min	$10^5$ y	$10^9$ y	$10^{10}$ y
$10^{32}$ K	$10^{28}$ K	$10^{15}$ K	$10^{10}$ K	$10^9$ K	4000 K	10 K	2,7 K
$10^{19}$ GeV	$10^{15}$ GeV	$10^2$ GeV	1 MeV	0,1 MeV			

heute





# Das Standardmodell

... ist ...

- ... eine experimentell gut bestätigte Beschreibung unserer Welt auf der Ebene der Elementarteilchen
- ... eine Zusammenfassung Alles Wissens um die Natur der kleinsten Teilchen
- ... sehr präzise, sogar so weit, daß zukünftige Entdeckungen recht präzise vorhergesagt werden können



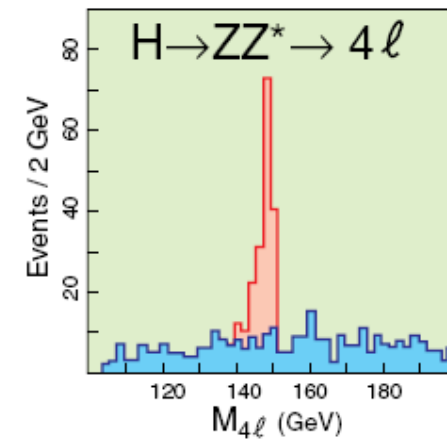
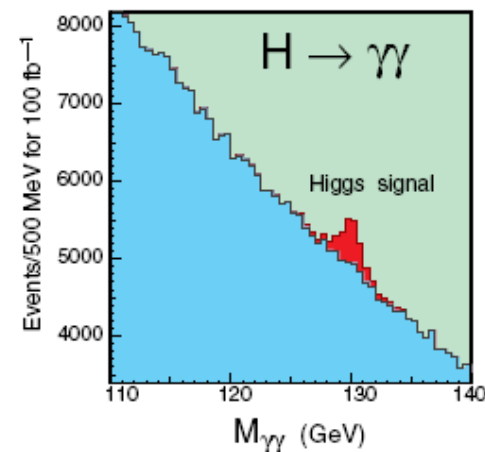
# Higgs

## the mystery of mass

What causes particles to have mass? Why do the masses of fundamental particles differ so enormously - the top quark is more than 200,000 times heavier than the electron?

A solution has been developed by several physicists and takes the name of Peter Higgs. According to this, the whole of space is permeated by a field, similar in some ways to the electromagnetic field. As particles move through space they travel through this field. The interaction between the particles and the field is similar to the action of a viscous force felt by a particle moving through a thick liquid. The stronger the interaction of the particles with the Higgs field, the more mass they appear to have.

We know from quantum theory that fields have particles associated with them, so if the Higgs idea is right, there must be a Higgs particle. Finding it is the key to verifying whether our best hypothesis for the origin of mass is indeed correct.







SUISSE  
FRANCE

CMS

LHCb

CERN Prévessin

ATLAS

CERN Meyrin

SPS 7 km

ALICE

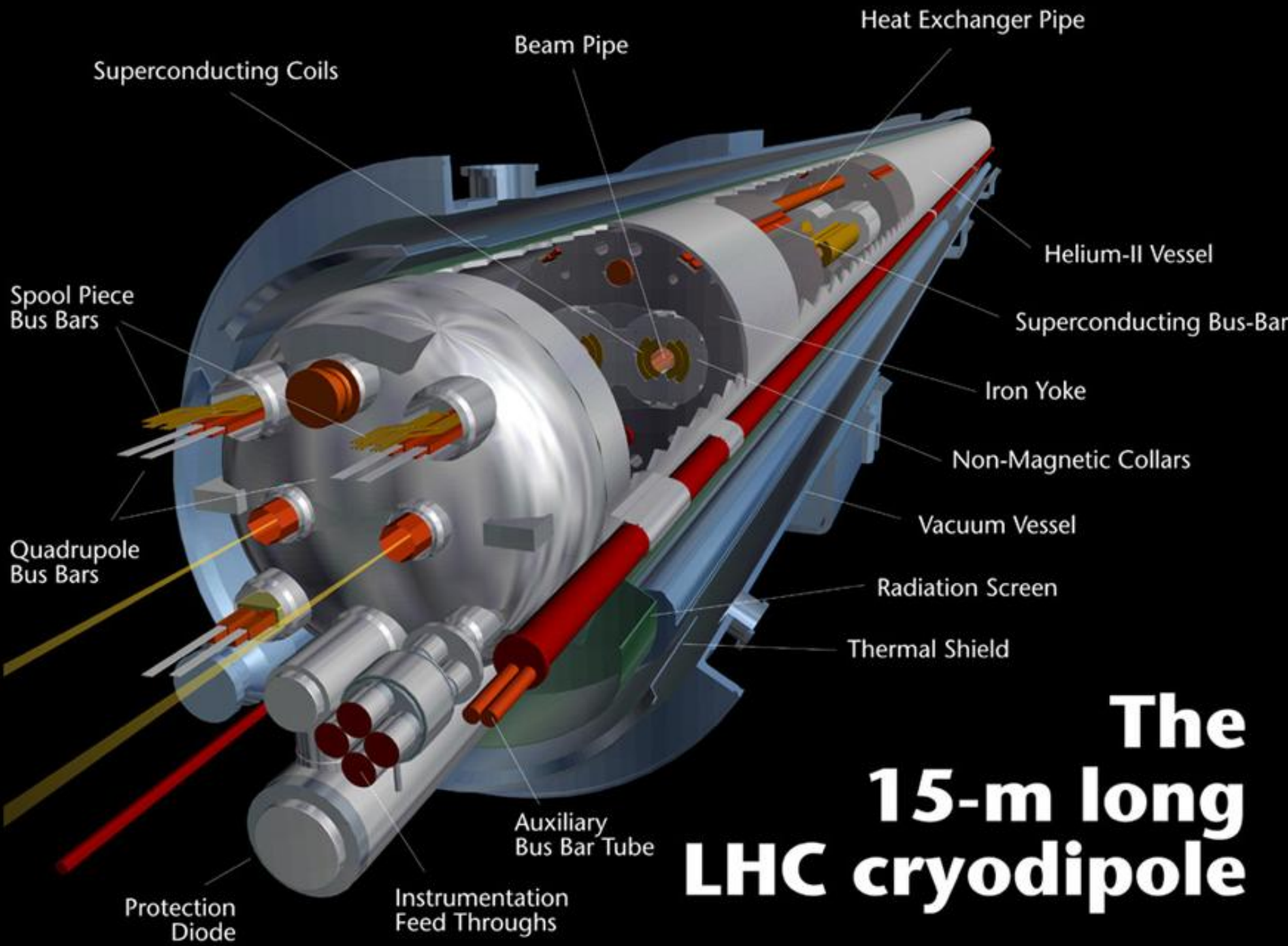
LHC 27 km





## LHC – Von der Idee zum Beschleuniger

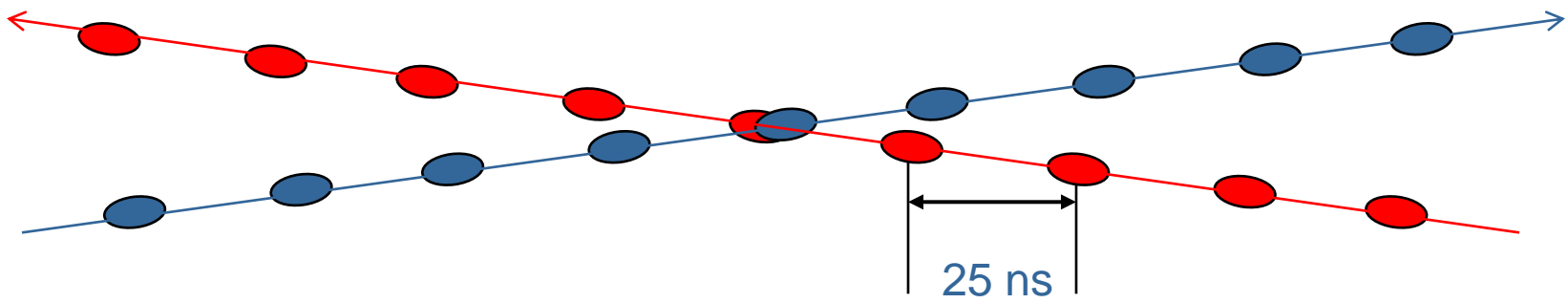
- 1982 : Erste Projektstudien
- 1983 :  $Z^0$ -Ereignis am  $S_p^pS$
- 1985 : Nobelpreis für S. van der Meer und C. Rubbia
- 1989 : Beginn des LEP-Betriebs (Z Factory)
- 1994 : Zustimmung zum LHC durch das Council
- 1996 : Endgültige Entscheidung zum Baubeginn
- 1996 : LEP Betrieb bei 100 GeV (W Factory)
- 2000 : Ende des LEP Betriebs
- 2002 : Abschluß des LEP Abbaus
- 2003 : Beginn der LHC Installation
- 2005 : Beginn der LHC Tests
- 2008 : Erste Betriebsaufnahme LHC
- 2009 : *Physik!*



# The 15-m long LHC cryodipole



# Strahlenergie



Strahlenergie = Protonenenergie • Anzahl der Wolken • Anzahl der Protonen pro Wolke

Protonenenergie: 7 TeV

**bei höchster Intensität:**

Anzahl der Wolken pro Richtung: 2808

Anzahl der Protonen je Wolke:  $1.05 \cdot 10^{11}$

**Strahlenergie (pro Richtung): 346 MJoule**





# Gespeicherte Energie in den Magneten

$$E_{\text{Dipol}} = 0.5 \cdot L_{\text{Dipol}} \cdot I_{\text{Dipol}}^2$$

gespeicherte Energie in einem Dipol: 7.6 MJ

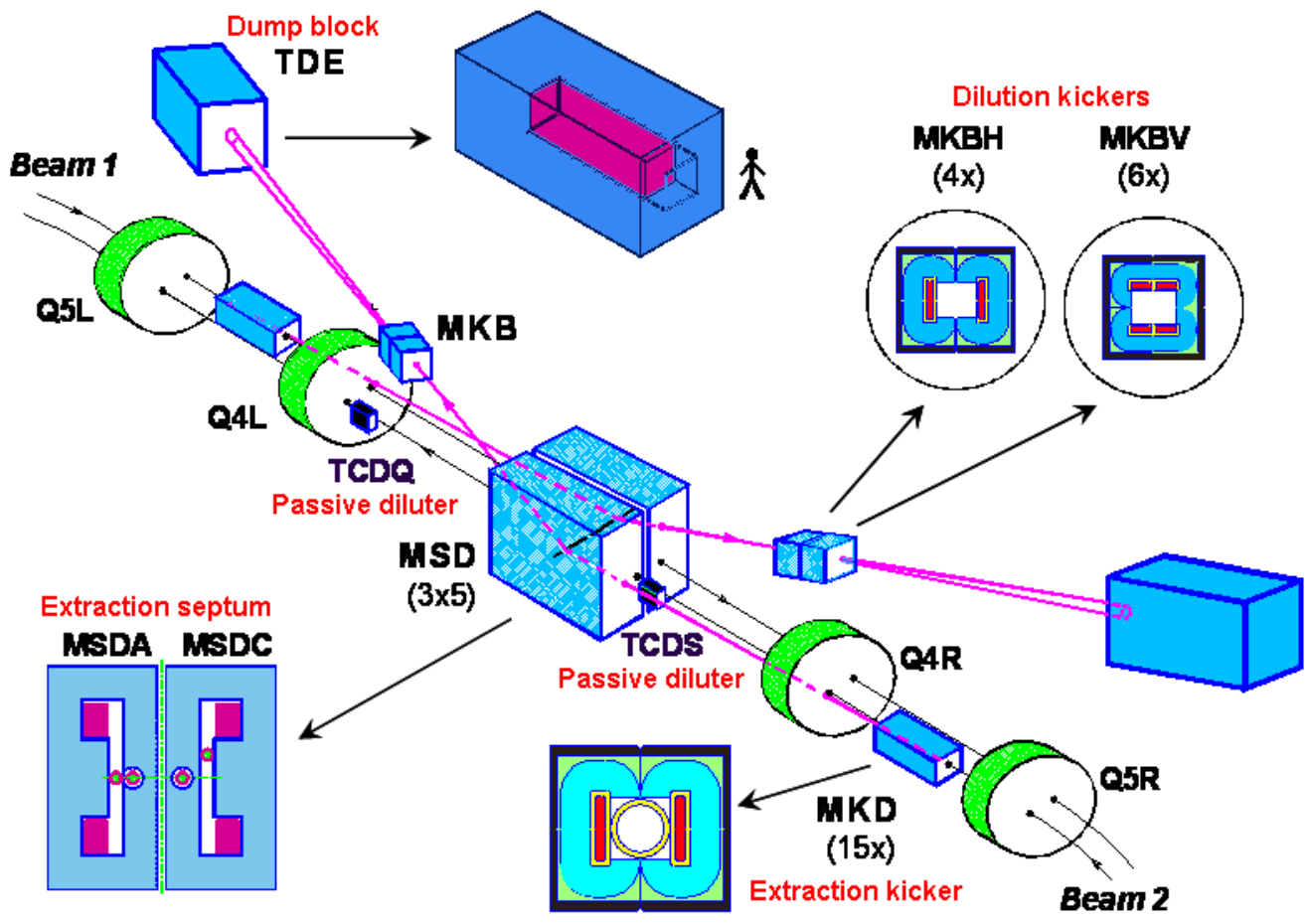
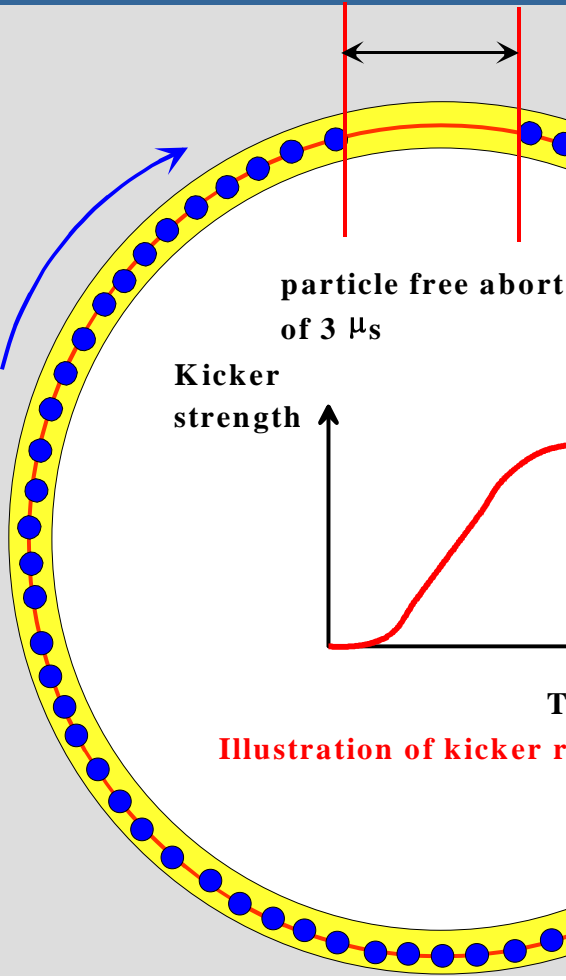
**Gesamt für alle 1232 Dipole im LHC: 9.4 GJ**

Nimitz Klasse Flugzeugträger (90000 t)  
bei Reisegeschwindigkeit von 20 kn  
Energie =  $\frac{1}{2} mv^2 \sim 10\text{GJ}$





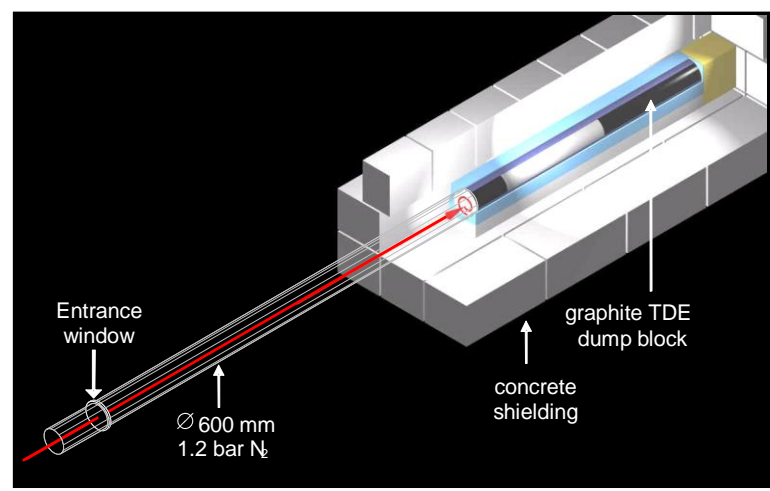
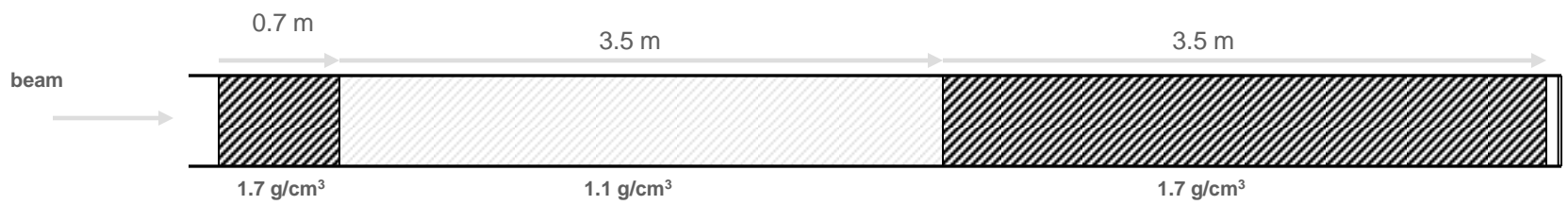
# Beam Dump System





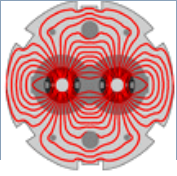


# Der Beam Dump





# September 10<sup>th</sup> - control (show) room

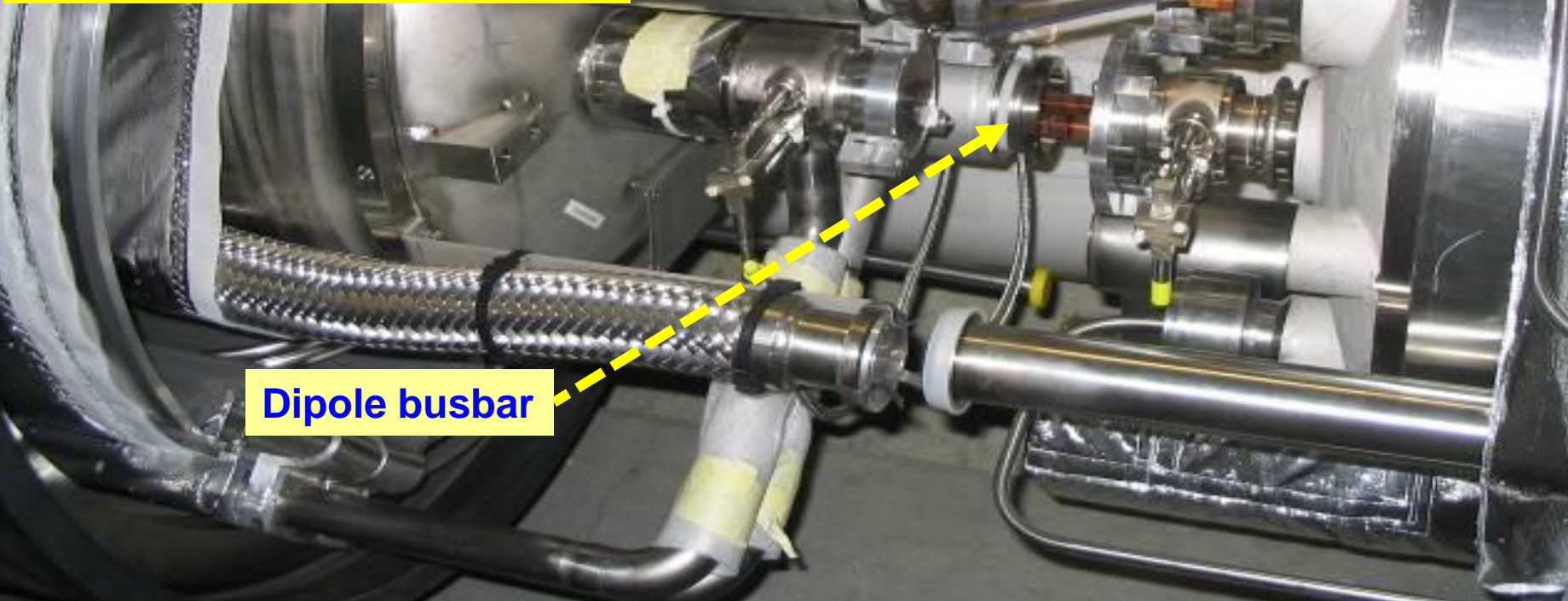
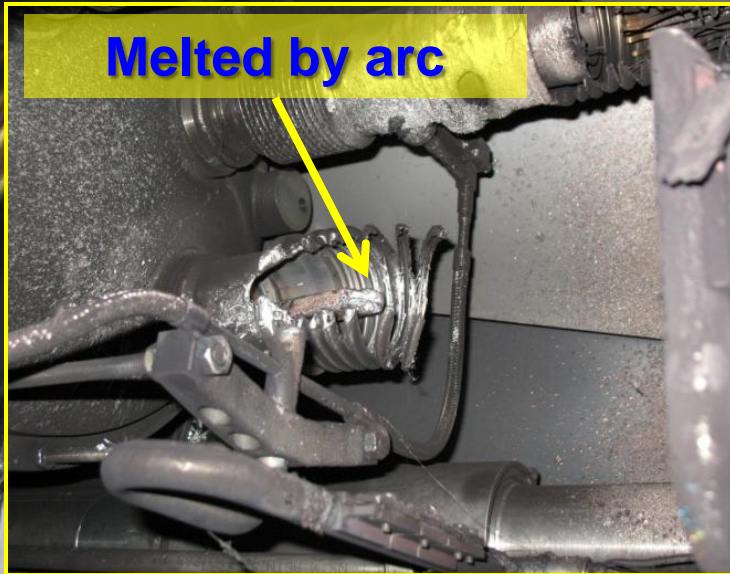
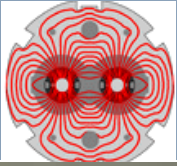


For 3 days all went perfectly well with beam...



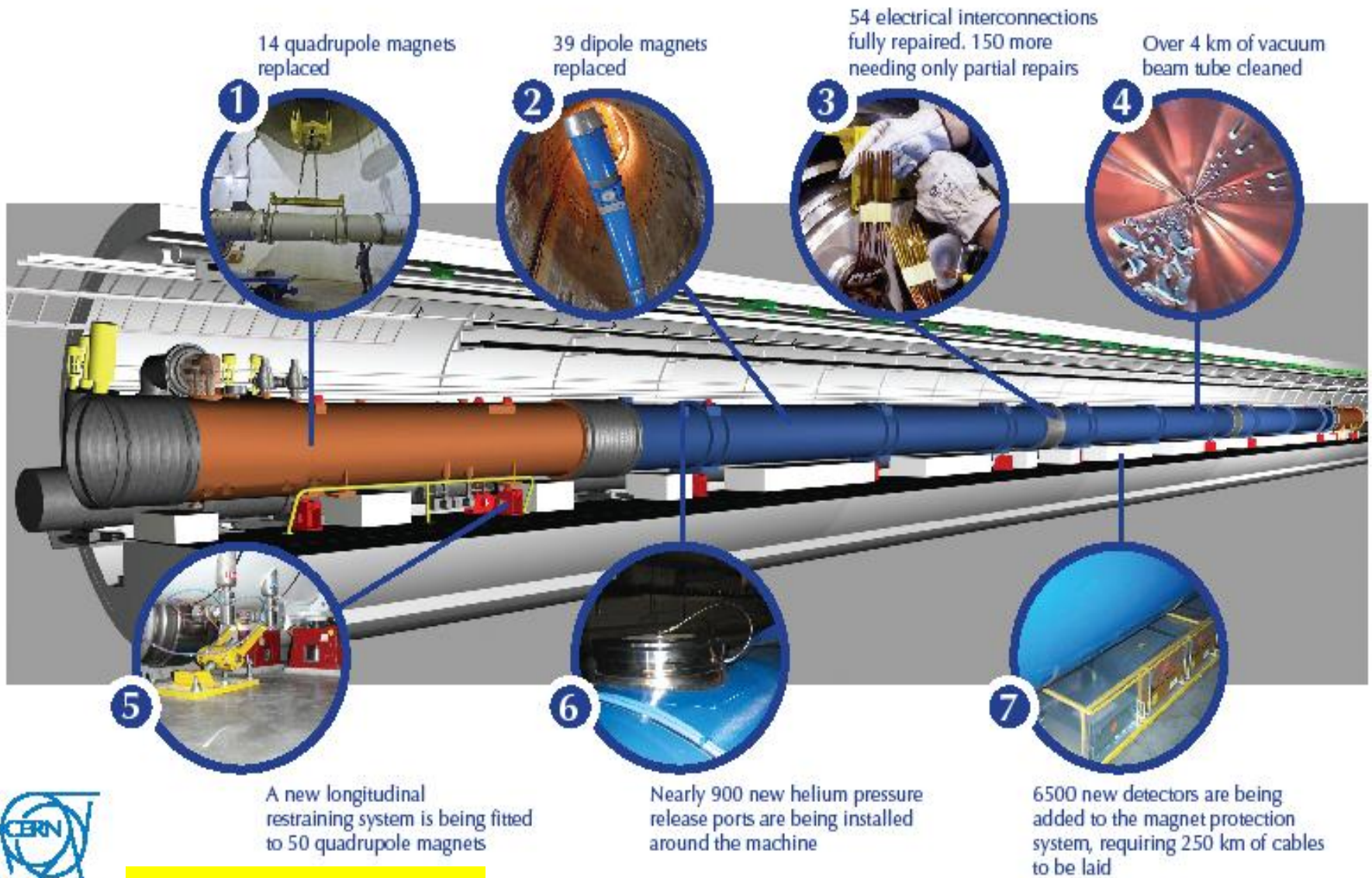


# Magnet Interconnection

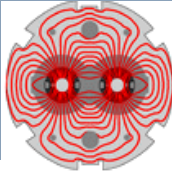




# The LHC repairs in detail



+ Kältetechnik

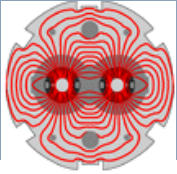


- ❑ 14 months to repair, consolidate and re-commissioning all elements.
- ❑ Great relief on November 20<sup>th</sup> when both beams circulated again !!!



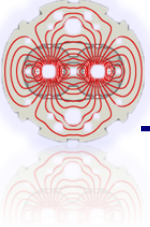


# 2009 beam operation milestones



20 <sup>th</sup> Nov	Day 0	Both beams circulating after 6 hours
23 <sup>rd</sup> Nov	Day 3	First pilot collisions at 450 GeV
29 <sup>th</sup> Nov	Day 9	Beams ramped to 1.18 TeV
6 <sup>th</sup> Dec	Day 16	Stable collisions @ 450 GeV for the experiments
8 <sup>th</sup> Dec	Day 18	Both beams ramped to 1.18 TeV – first collisions

- ❑ Many LHC systems were commissioned at forced pace – aim to check as much as possible.
- ❑ Overall uptime ~60% - very good at this stage.
- ❑ **Our most optimistic plan became true !!**
- ❑ A touch of modesty...
  - The stored energy did not exceed 30 kJ – 0.01% of nominal.

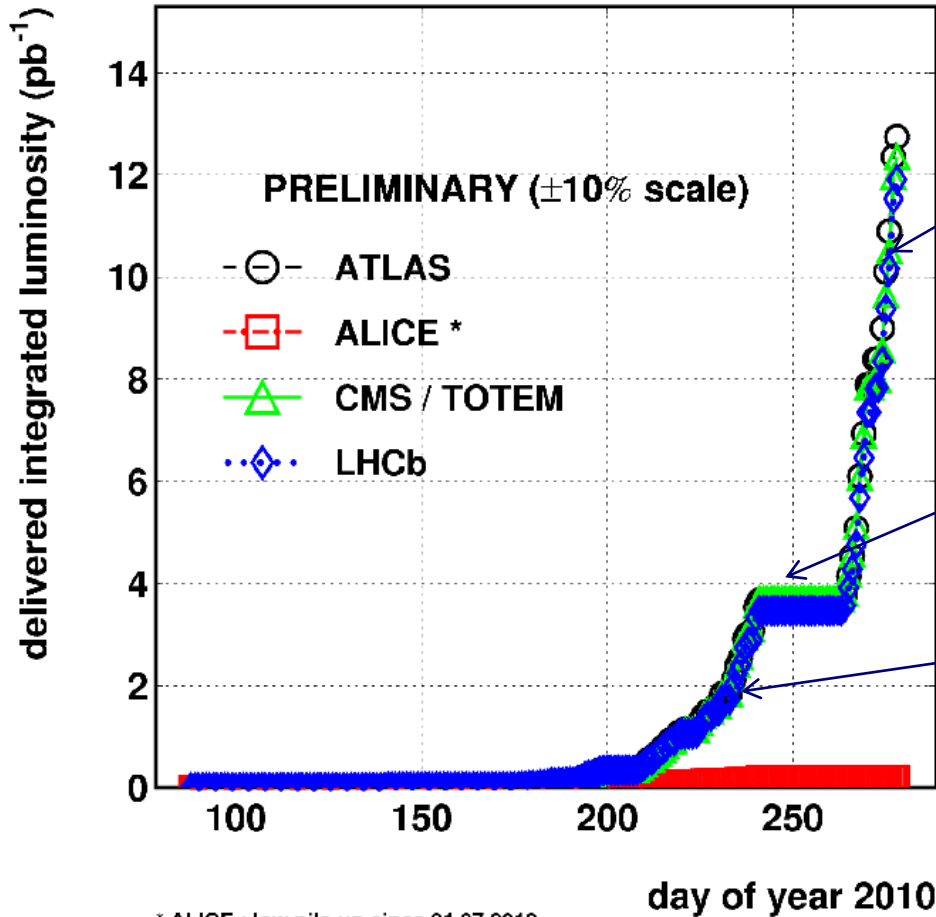


# The road to our targets



2010/10/07 10.36

## LHC 2010 RUN (3.5 TeV/beam)



\* ALICE : low pile-up since 01.07.2010

September:  
**2 Week s (!) of  
Bunch Trains**

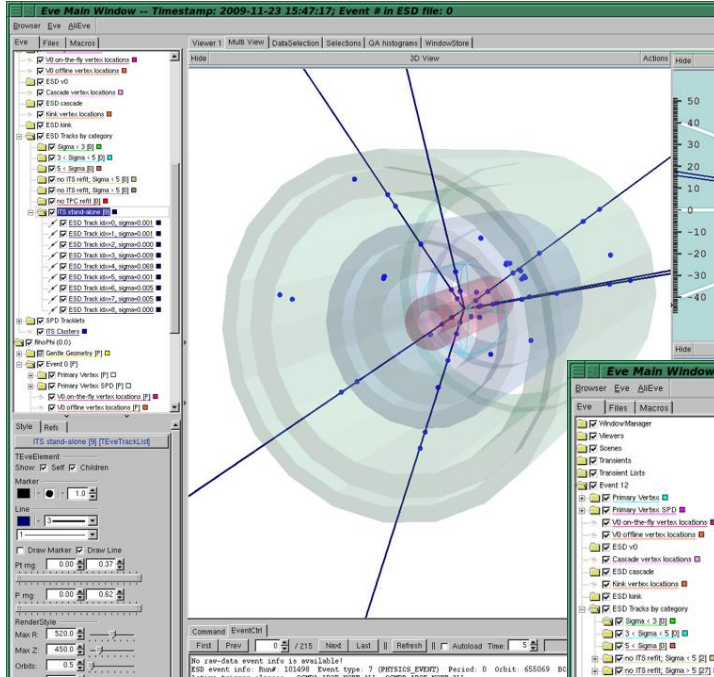
Development of  
**Bunch Trains**

August: Stable  
running with  
about  $1 \mu\text{s}$   
bunch spacing

*M. Ferro-Luzzi*

# Events...

ALICE first event at 0.9 TeV ...

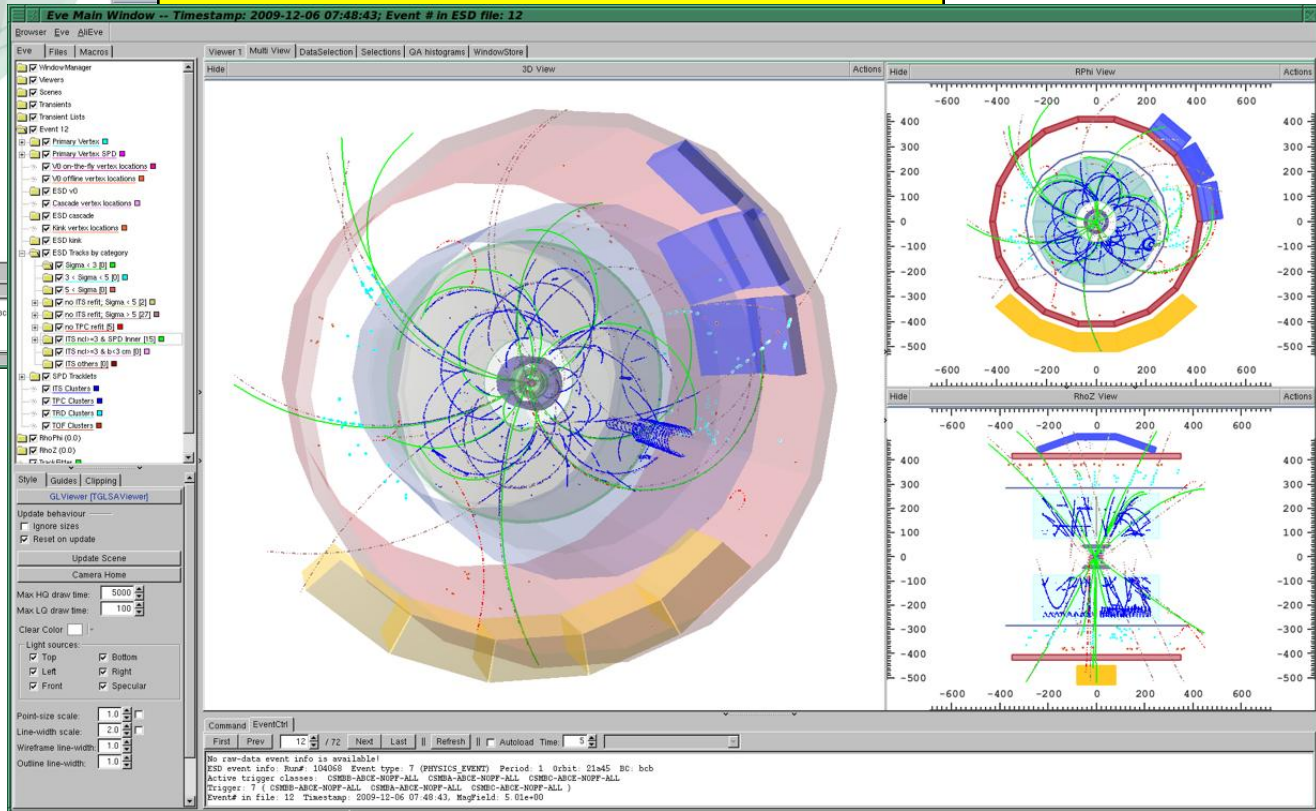


days after submitting our first paper  
(28 Nov, 2009; ~3 authors/event !)

National Geographic News (4 Dec.)

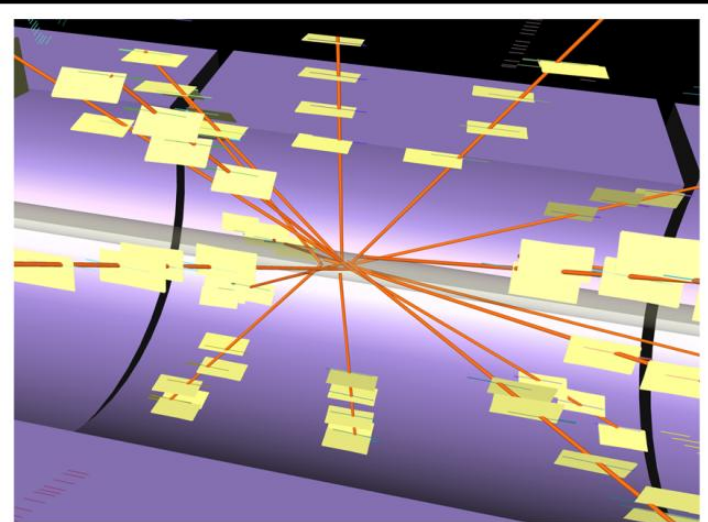
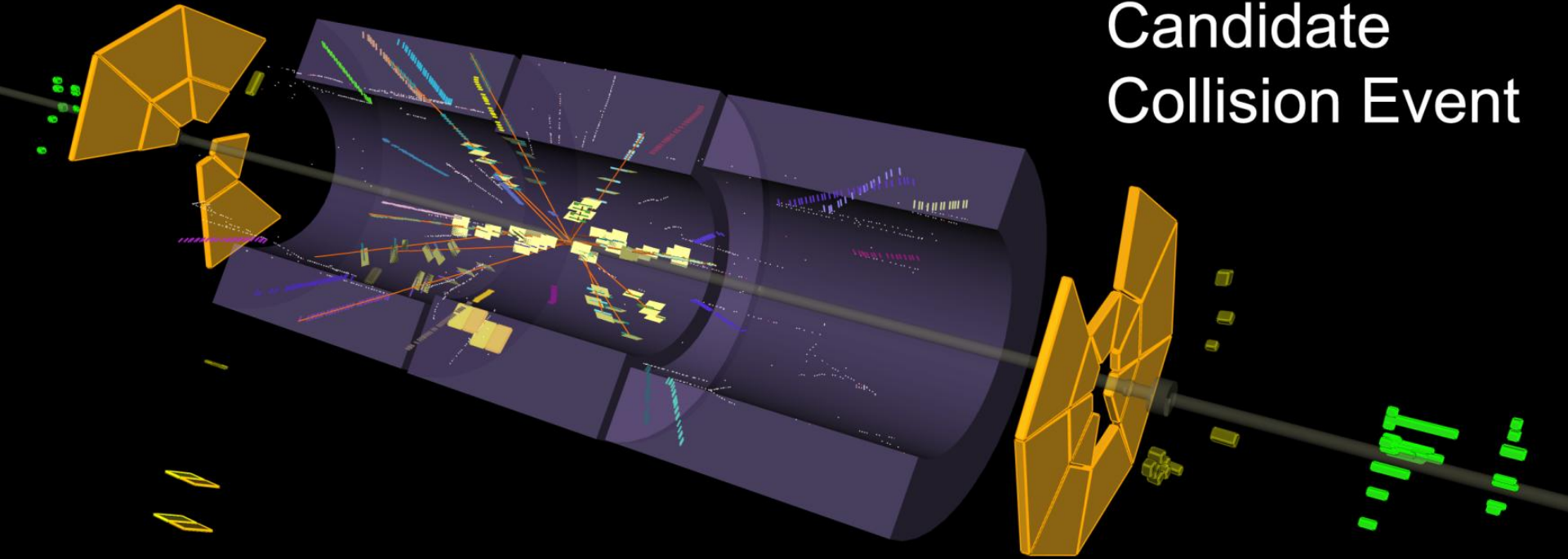
‘...a machine called ALICE...  
found that a (!) proton-proton collision  
recorded on November 23  
created the precise ratio  
of matter and antimatter particles

... and at 7 TeV





# Candidate Collision Event



**ATLAS**  
EXPERIMENT

2009-11-23, 14:22 CET  
Run 140541, Event 171897

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



Delay  
3.0s

Run  Event

Mon Nov 23 19:20:55 2009 CEST

Lumi block id: 25



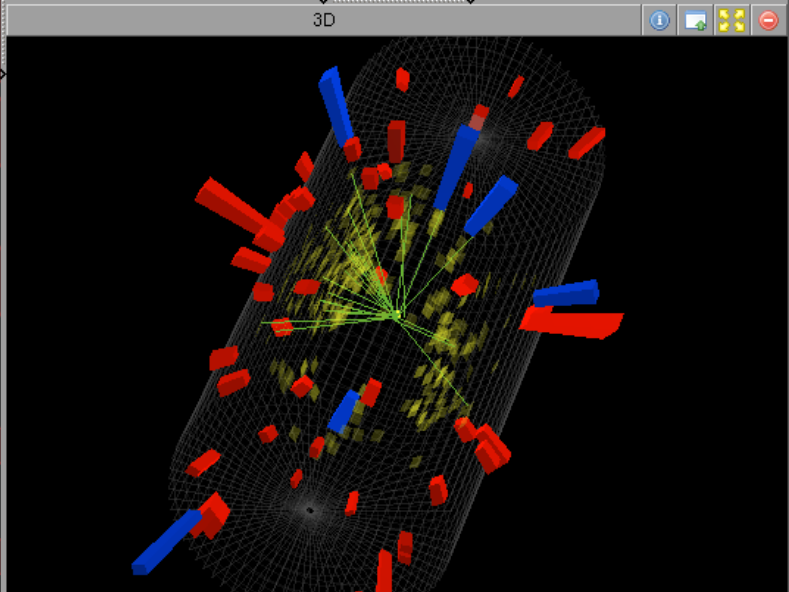
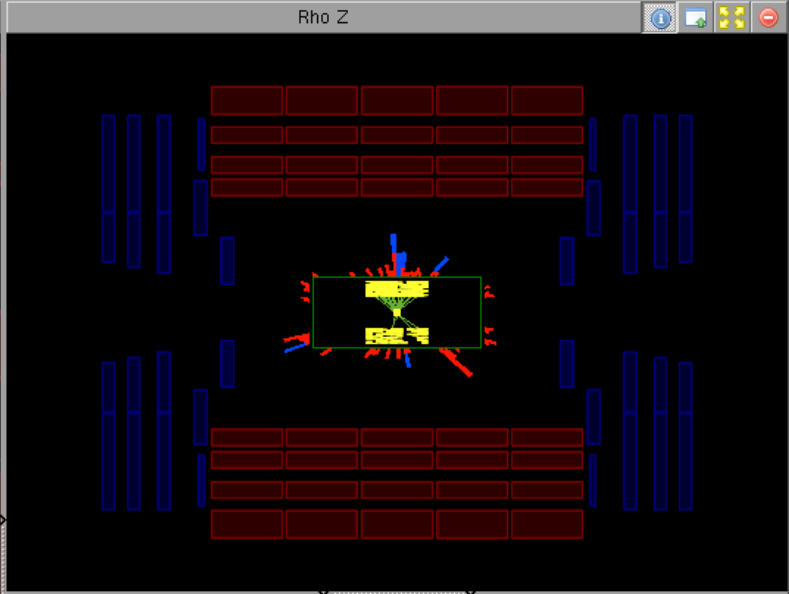
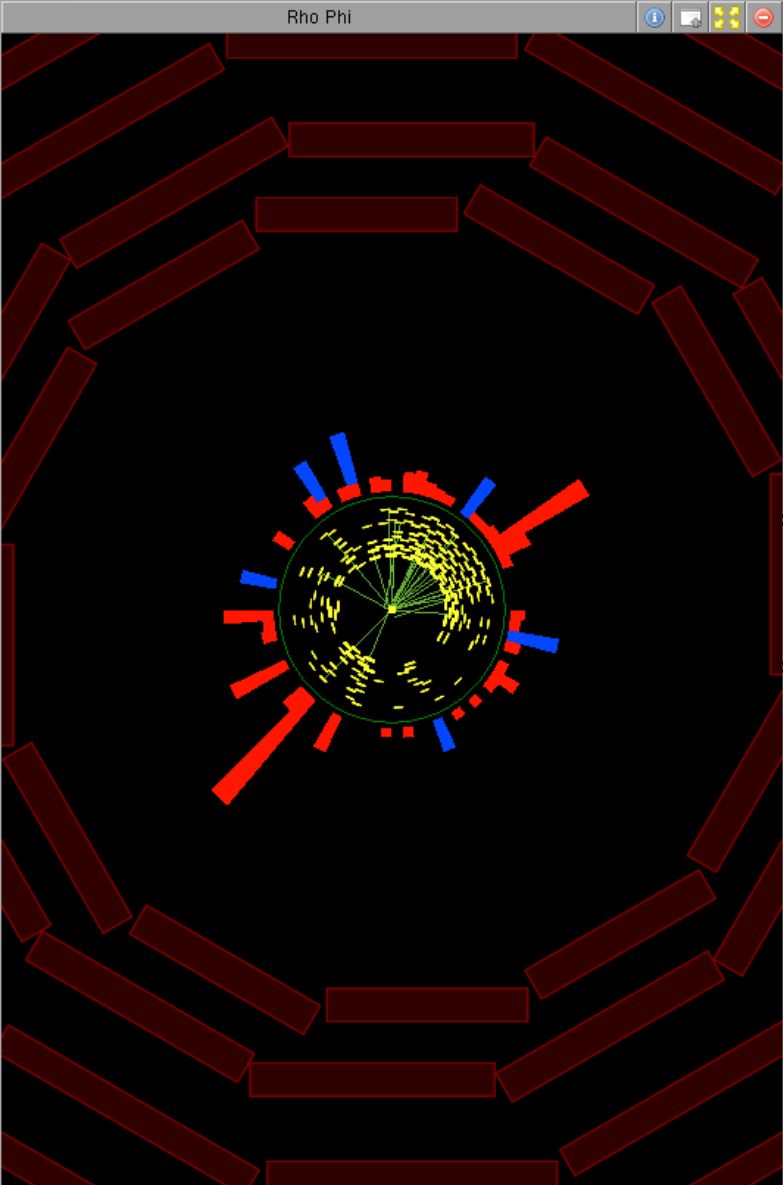
Summary View

Views

- Add Collection
- ECal
  - HCal
  - Jets
  - Tracks

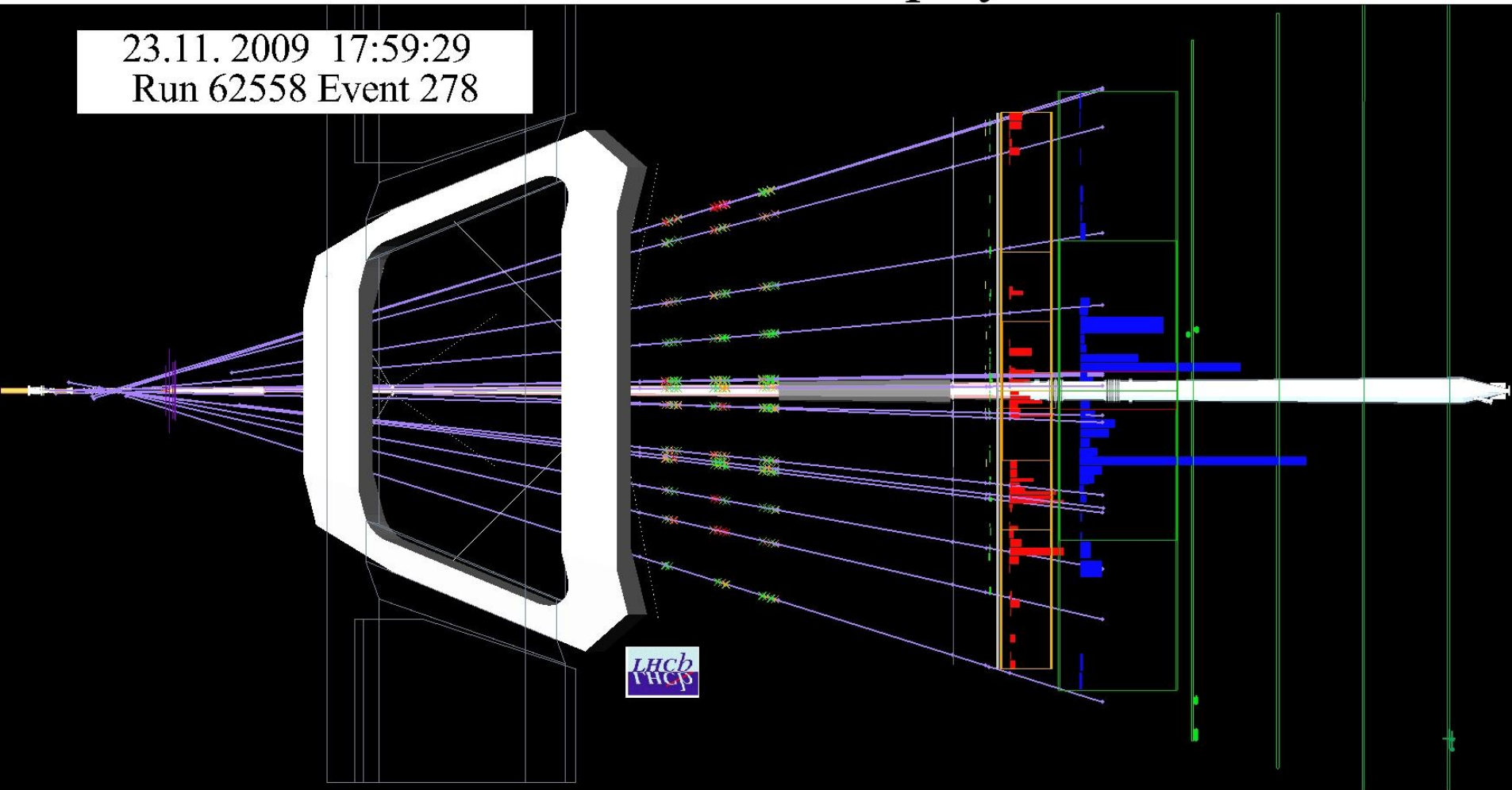
	pt	eta	phi
<input checked="" type="checkbox"/> Track 0	4.9	-0.2	0.3
<input checked="" type="checkbox"/> Track 1	5.0	-0.1	0.2
<input checked="" type="checkbox"/> Track 2	3.7	-0.8	0.3
<input checked="" type="checkbox"/> Track 3	4.0	-0.7	0.3
<input checked="" type="checkbox"/> Track 4	4.6	-0.4	0.6
<input checked="" type="checkbox"/> Track 5	4.8	-0.3	0.6
<input checked="" type="checkbox"/> Track 6	4.9	-0.2	1.0
<input checked="" type="checkbox"/> Track 7	5.0	-0.1	1.1
<input checked="" type="checkbox"/> Track 8	4.4	-0.5	1.1
<input checked="" type="checkbox"/> Track 9	3.0	-1.1	1.1
<input checked="" type="checkbox"/> Track 10	3.0	-1.1	1.0
<input checked="" type="checkbox"/> Track 11	5.0	-0.1	1.2
<input checked="" type="checkbox"/> Track 12	4.1	-0.7	1.5
<input checked="" type="checkbox"/> Track 13	3.6	-0.9	2.6
<input checked="" type="checkbox"/> Track 14	4.9	-0.2	-2.3
<input checked="" type="checkbox"/> Track 15	3.5	0.9	0.4
<input checked="" type="checkbox"/> Track 16	3.7	0.8	0.7
<input checked="" type="checkbox"/> Track 17	5.0	0.1	0.8
<input checked="" type="checkbox"/> Track 18	3.6	0.8	0.9
<input checked="" type="checkbox"/> Track 19	4.3	0.6	1.4
<input checked="" type="checkbox"/> Track 20	4.6	0.4	1.6
<input checked="" type="checkbox"/> Track 21	3.0	1.1	1.9
<input checked="" type="checkbox"/> Track 22	4.6	0.4	2.3
<input checked="" type="checkbox"/> Track 23	3.6	0.9	-2.0
<input checked="" type="checkbox"/> Track 24	2.8	1.2	-0.1

- Muons
- Electrons
- Vertices
- DT-segments
- CSC-segments
- Photons
- MET
- siStripClusters

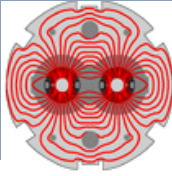


# LHCb Event Display

23.11. 2009 17:59:29  
Run 62558 Event 278

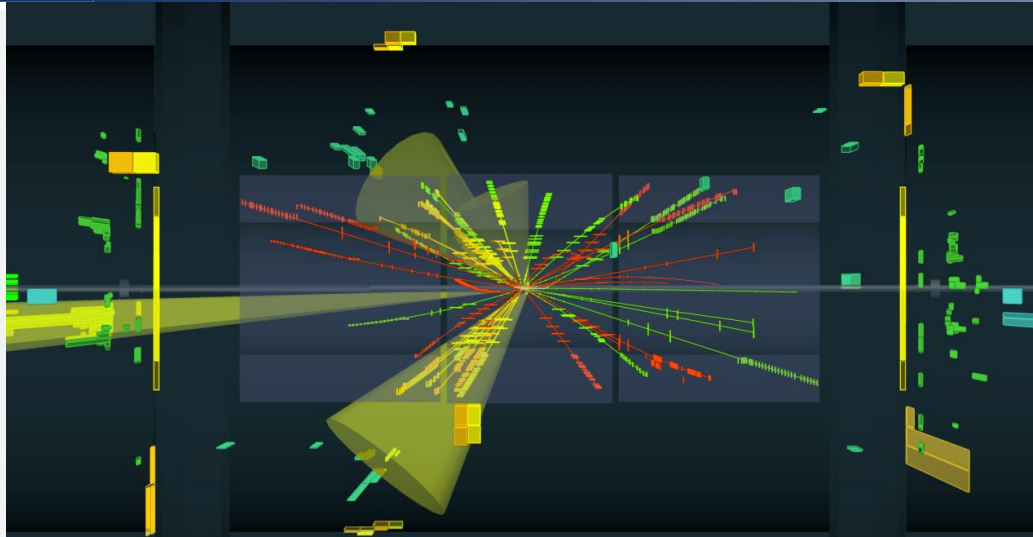






# 1.2 TeV Collisions

- With very clean beam conditions, the experiments could record first collisions at 1.2 TeV.



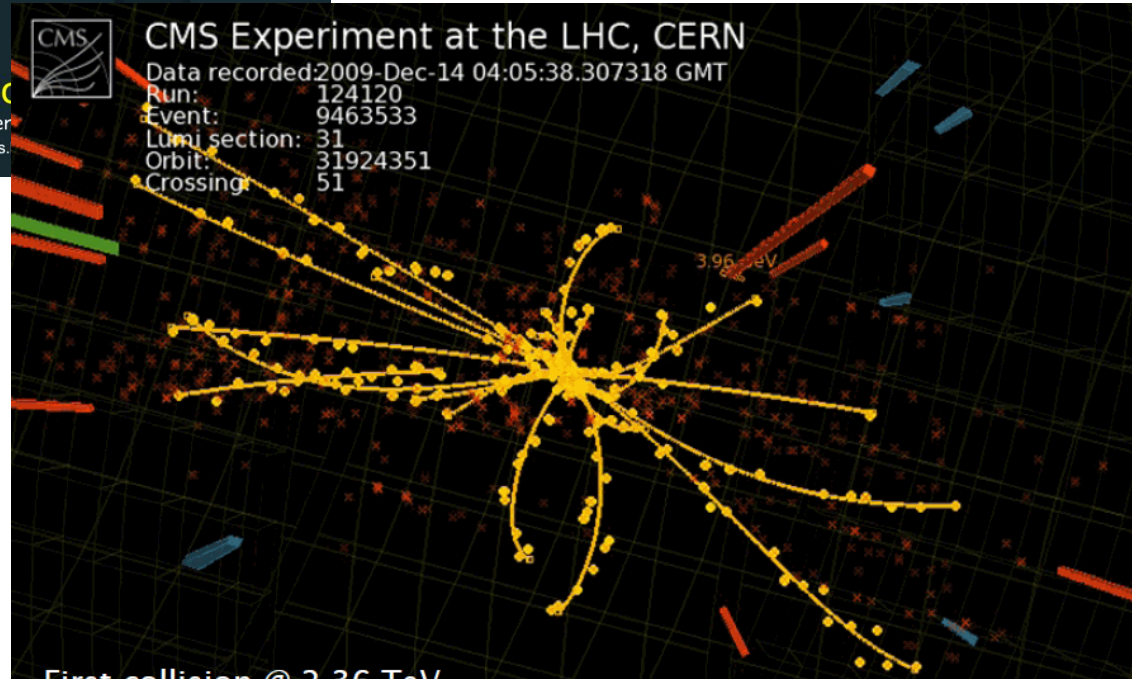
**ATLAS**  
EXPERIMENT

**Jet Event at 2.36 TeV**  
2009-12-14, 04:30 CET, Run 142308, Event  
<http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events>



**CMS Experiment at the LHC, CERN**

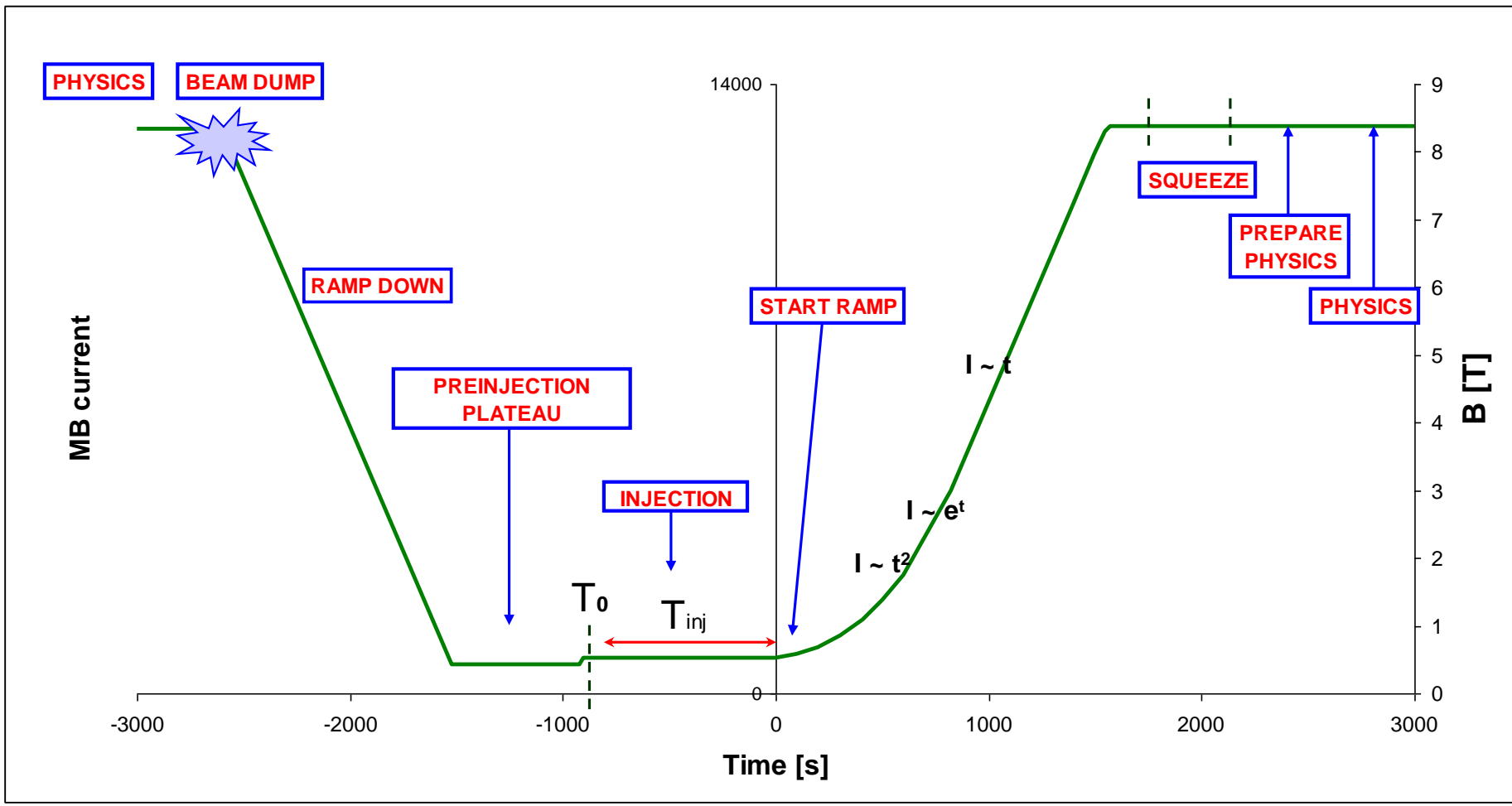
Data recorded: 2009-Dec-14 04:05:38.307318 GMT  
Run: 124120  
Event: 9463533  
Lumi section: 31  
Orbit: 31924351  
Crossing: 51



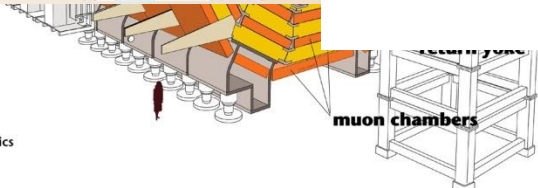
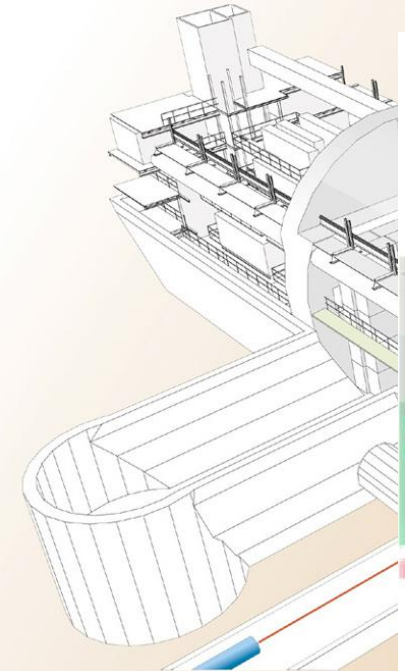
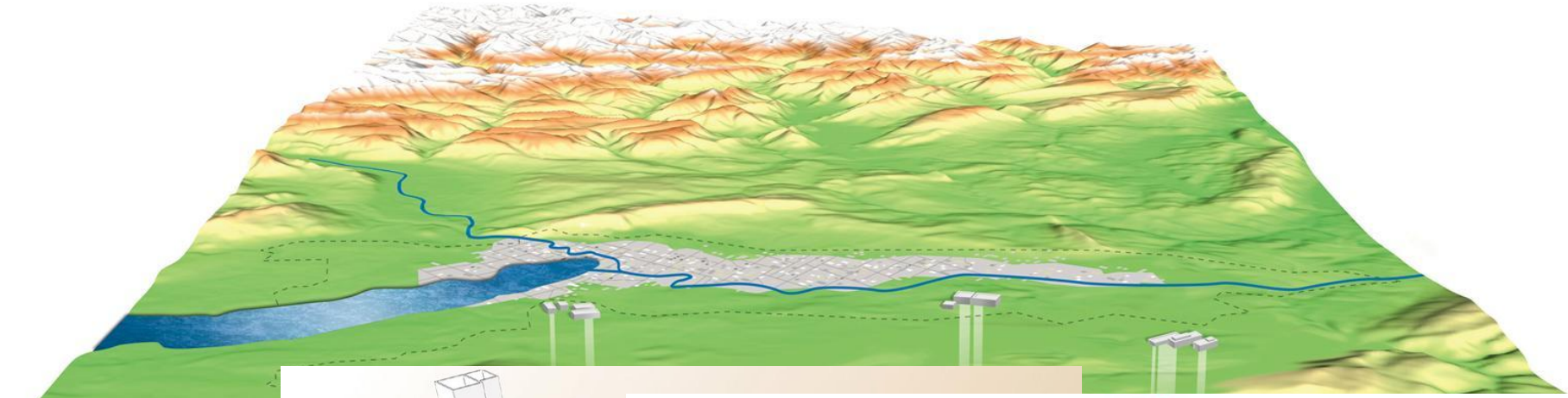
**First collision @ 2.36 TeV**



# Normale Operation





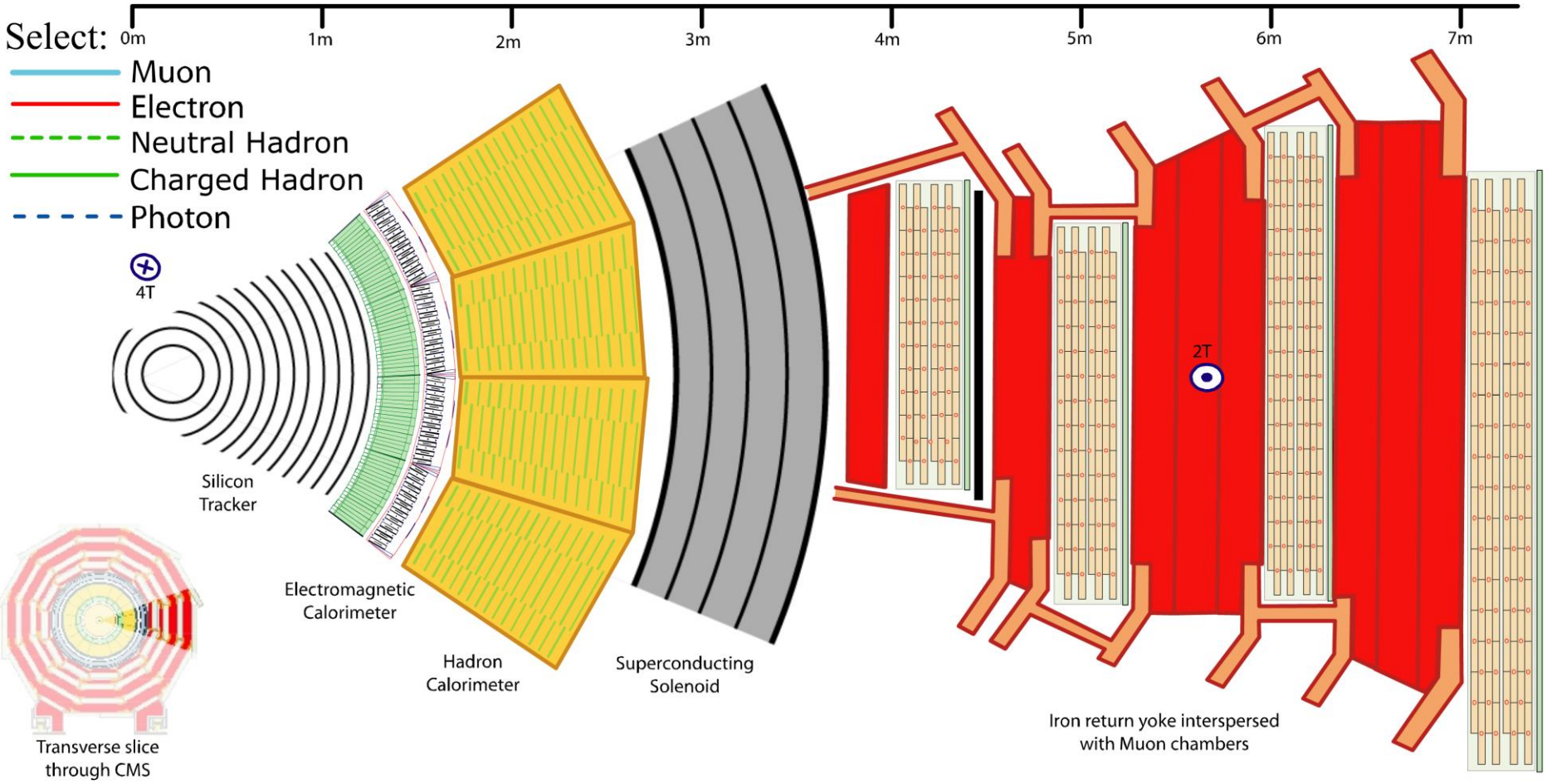


Detector characteristics

Width: 22m  
 Diameter: 15m  
 Weight: 14500t



# CMS Ereignis

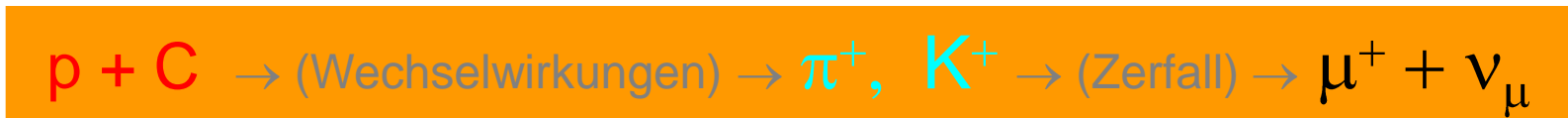
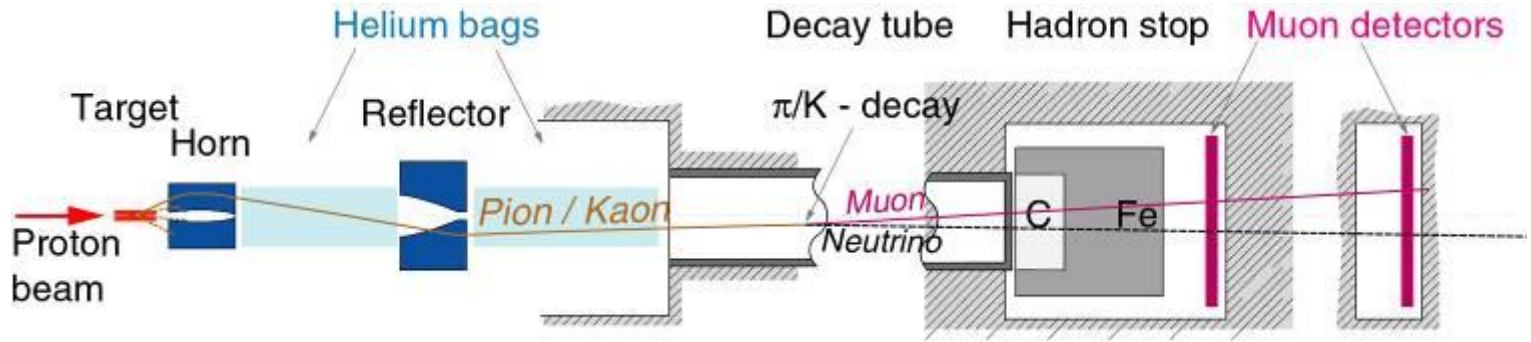
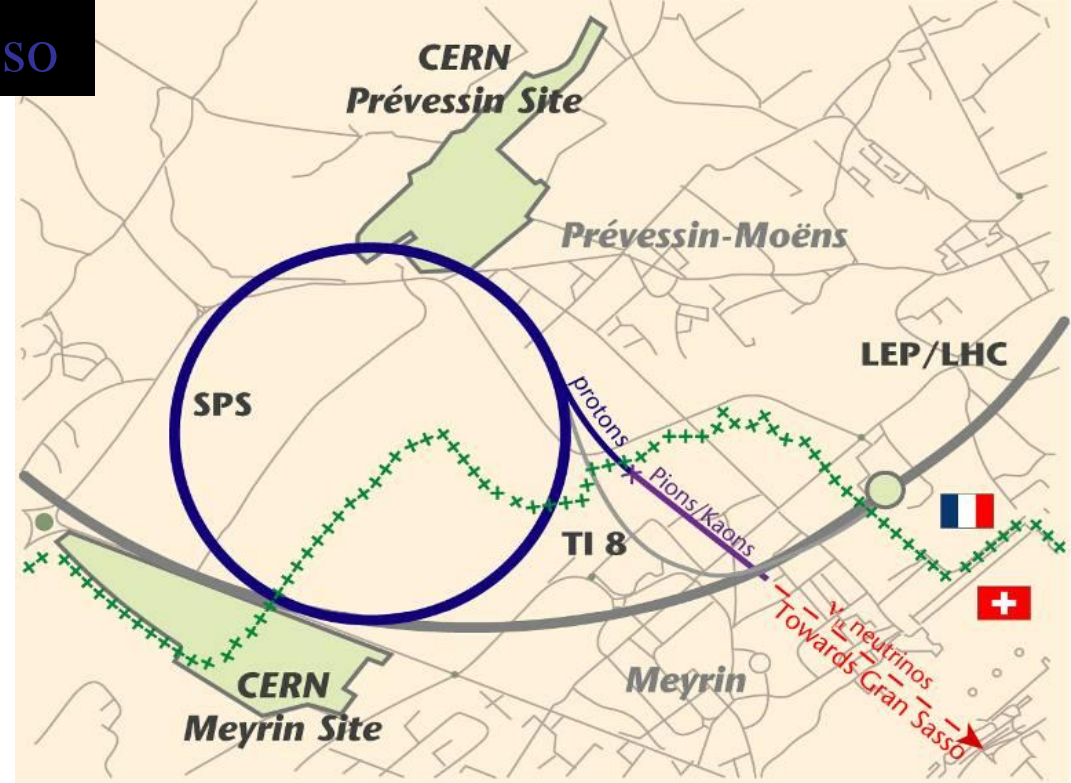
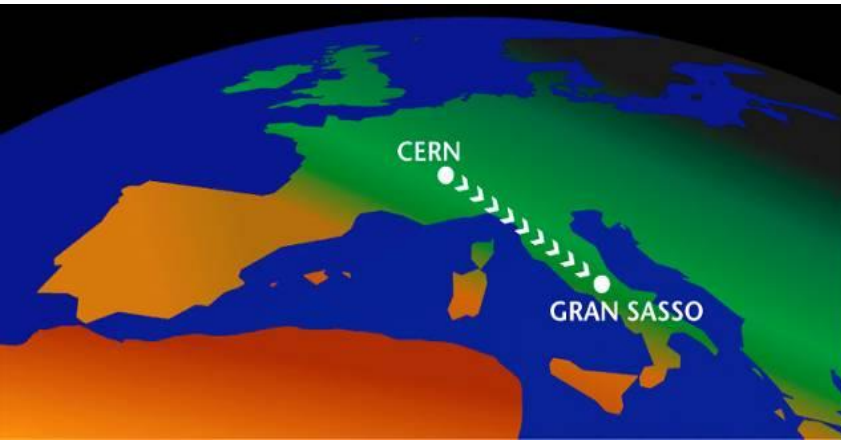


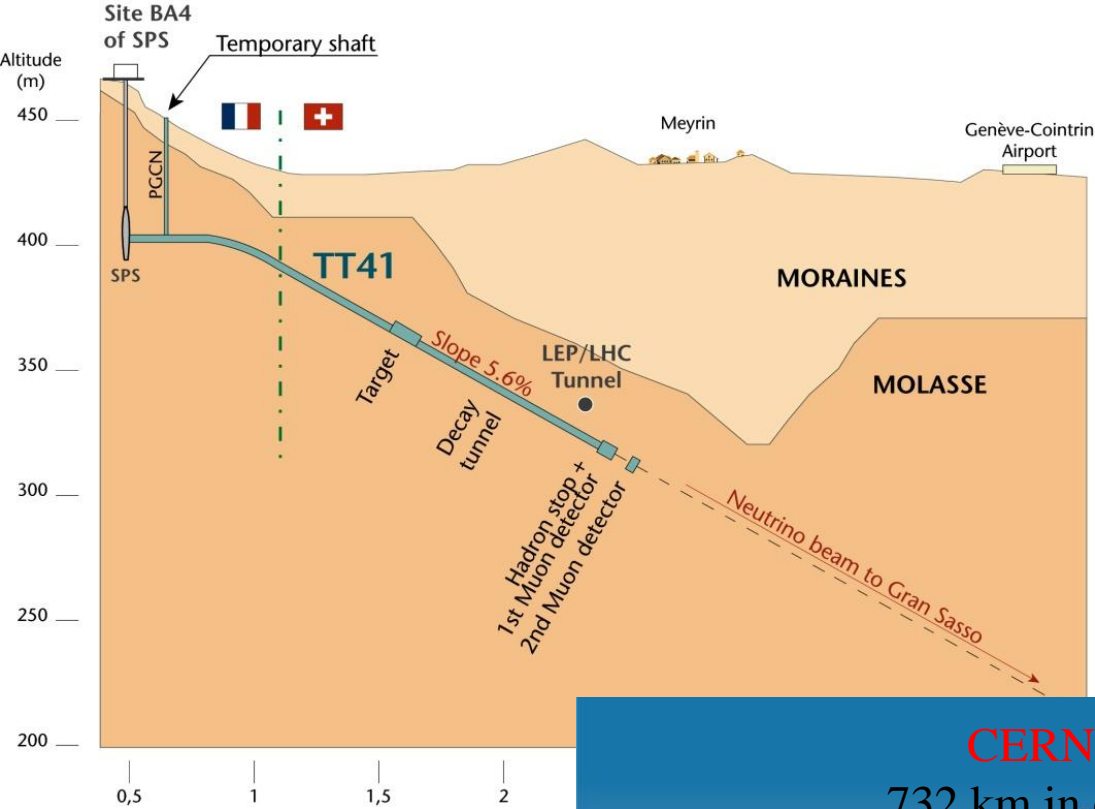
# Weitere Aktivitäten am CERN

... eine kleine Auswahl ...

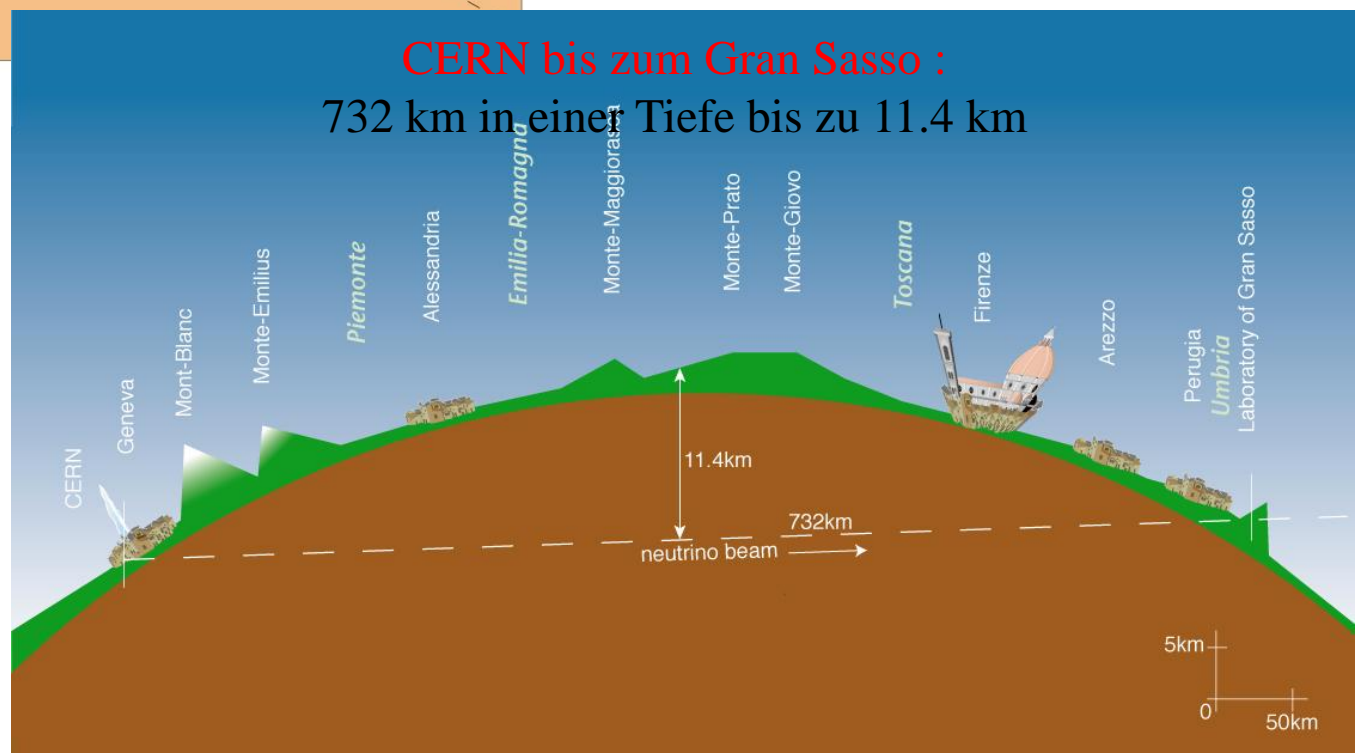


# CERN Neutrinos zum Gran Sasso



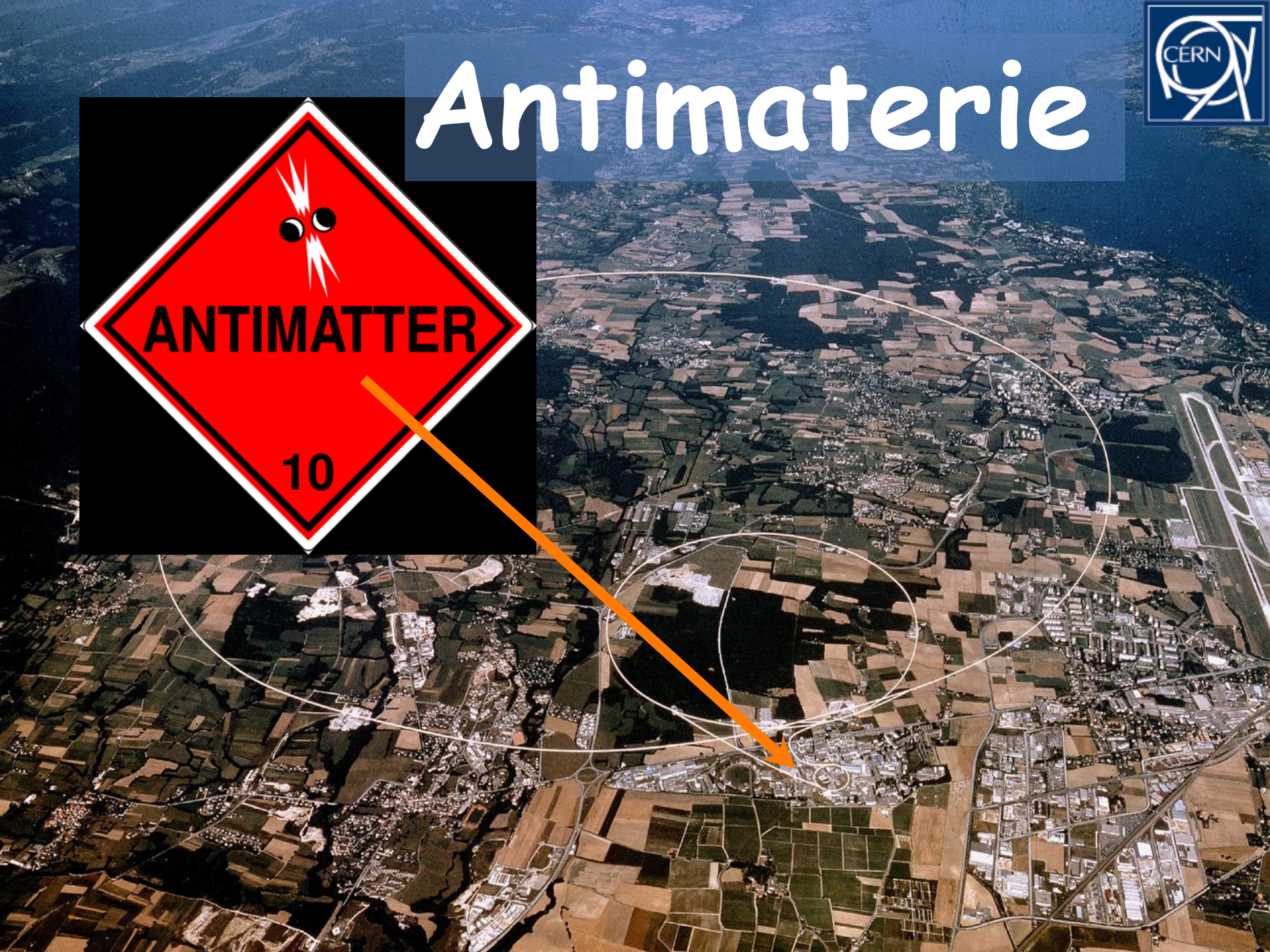
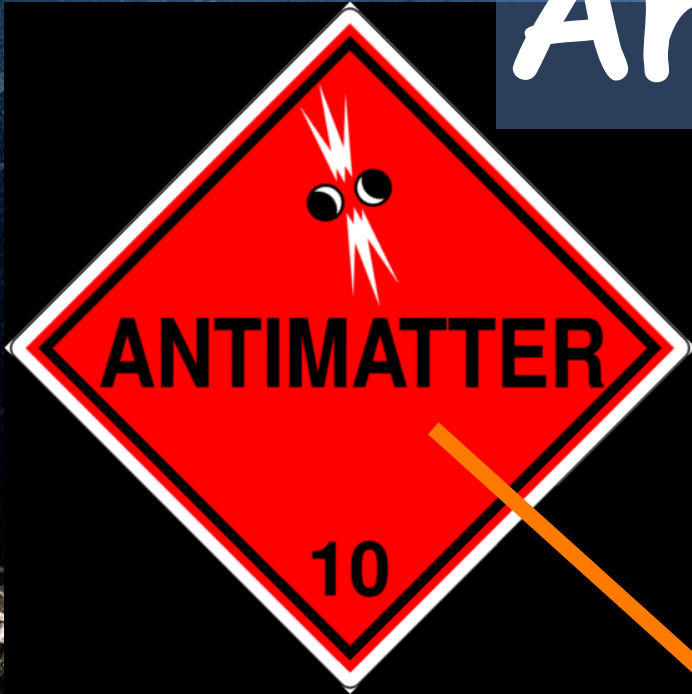


**CERN bis zum Gran Sasso :**  
**732 km in einer Tiefe bis zu 11.4 km**





# Antimaterie





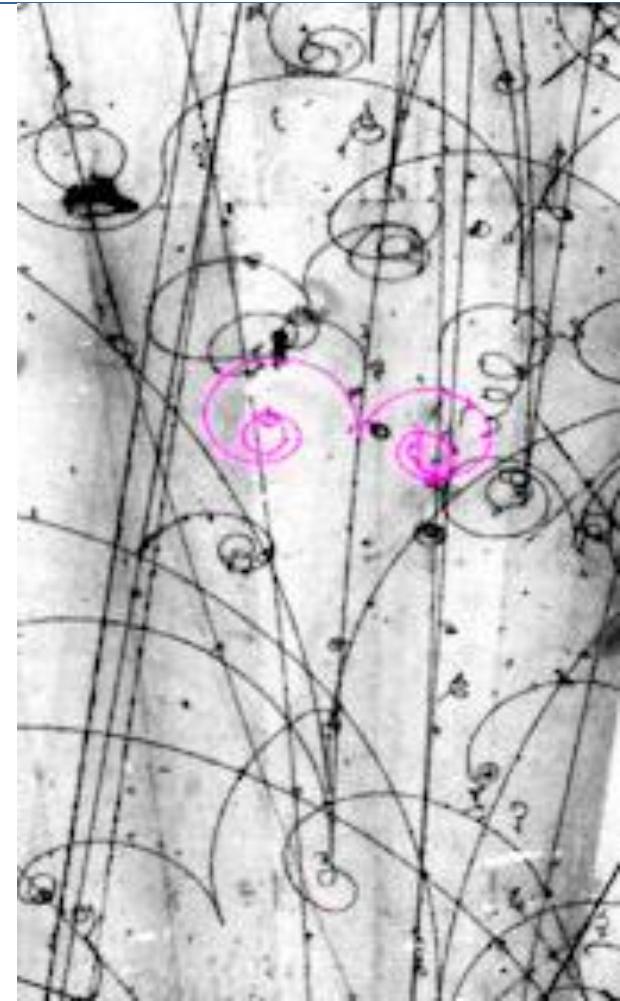
# Was ist Antimaterie?

- Einstein
  - "Materie ist kondensierte Energie!"
  
- Dirac
  - "Teilchen entstehen immer in Paaren, Teilchen und Anti-Teilchen!"



Elektron

Positron



# Snobs & Spoons

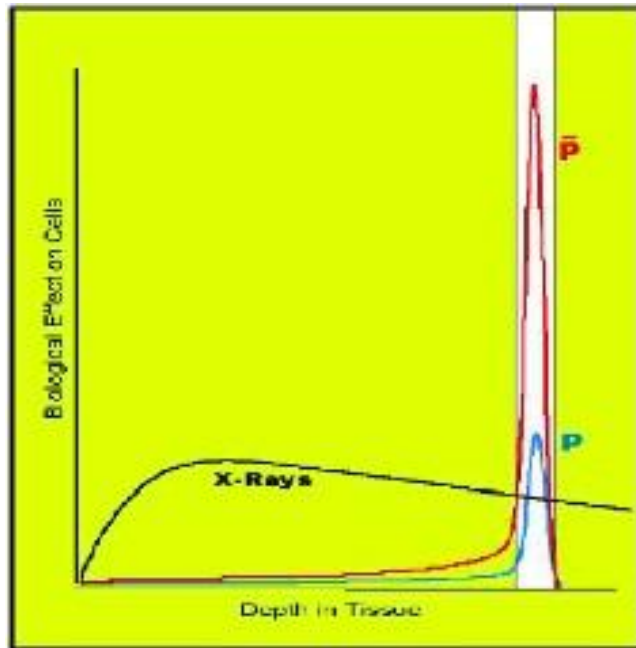
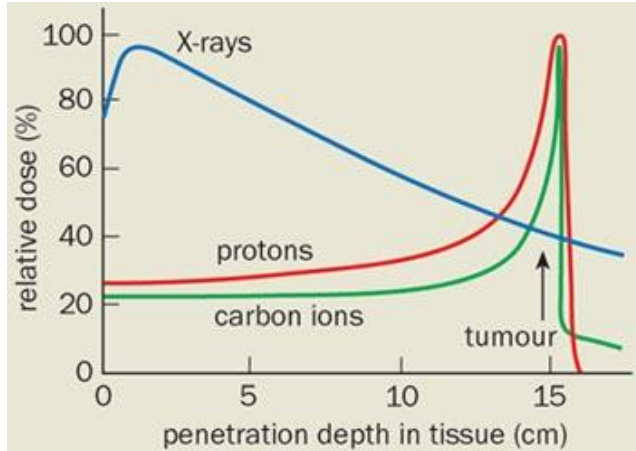




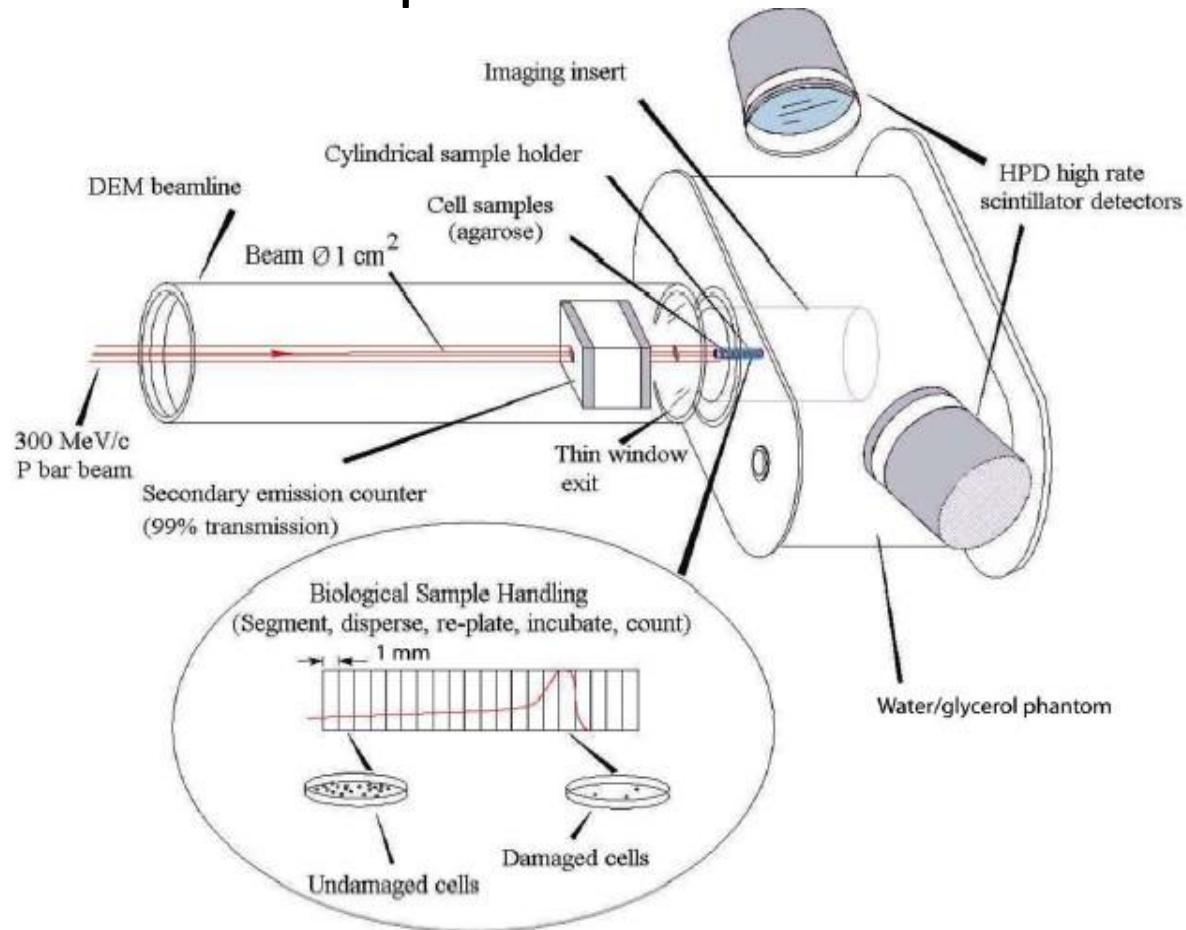
Tom's Angels and demons



# Anwendung von Antimaterie - Tumorbekämpfung



## ACE Experiment bei CERN



\*) Antiproton Cell Experiment





# Physics Department

Apprentices

Accelerator School

Doctoral Students

Academic Training

Fellows

Physics School

Exhibitions

CERN-Latin America School

Computing School

Visits

Technical Students

Summer Students

Microcosm

Outreach

Science on Stage

Language Training

Technical Training

Communications Training

Teachers programmes

Conferences

Management Training



# Fragen ?

