



European Organization for Nuclear Research Über 50 Jahre Grundlagenforschung

CERN

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

Dr. Sascha Marc Schmeling
CERN PH



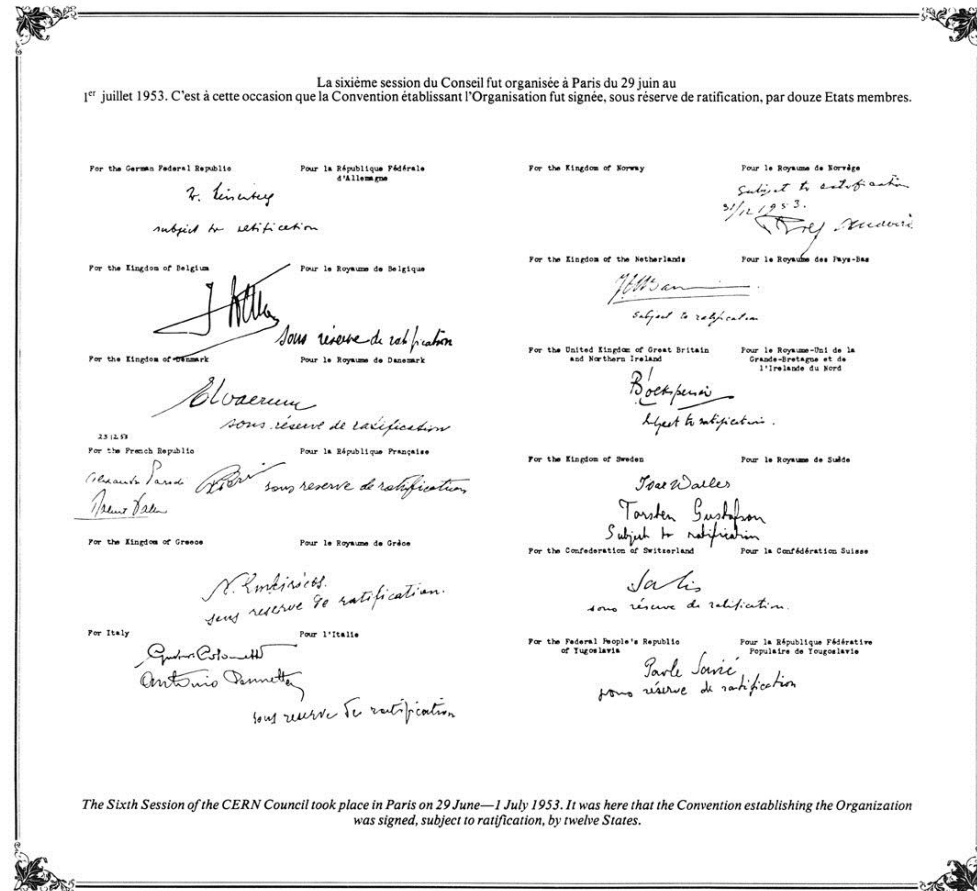
CERN – Eine Einführung

- 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



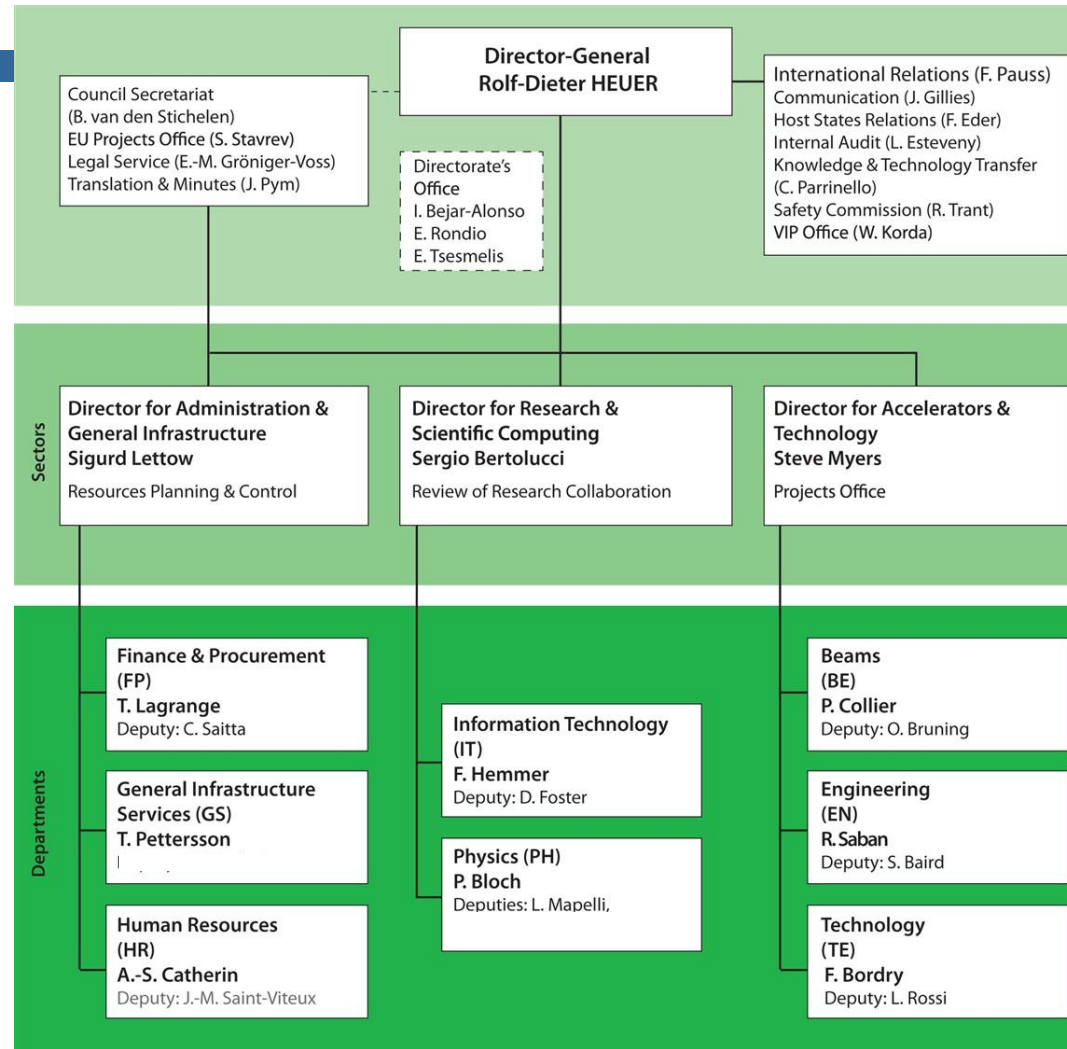


CERN Organisation

- **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 – Januar 2012

Angestellte

- Staff 2420
- Fellows 487

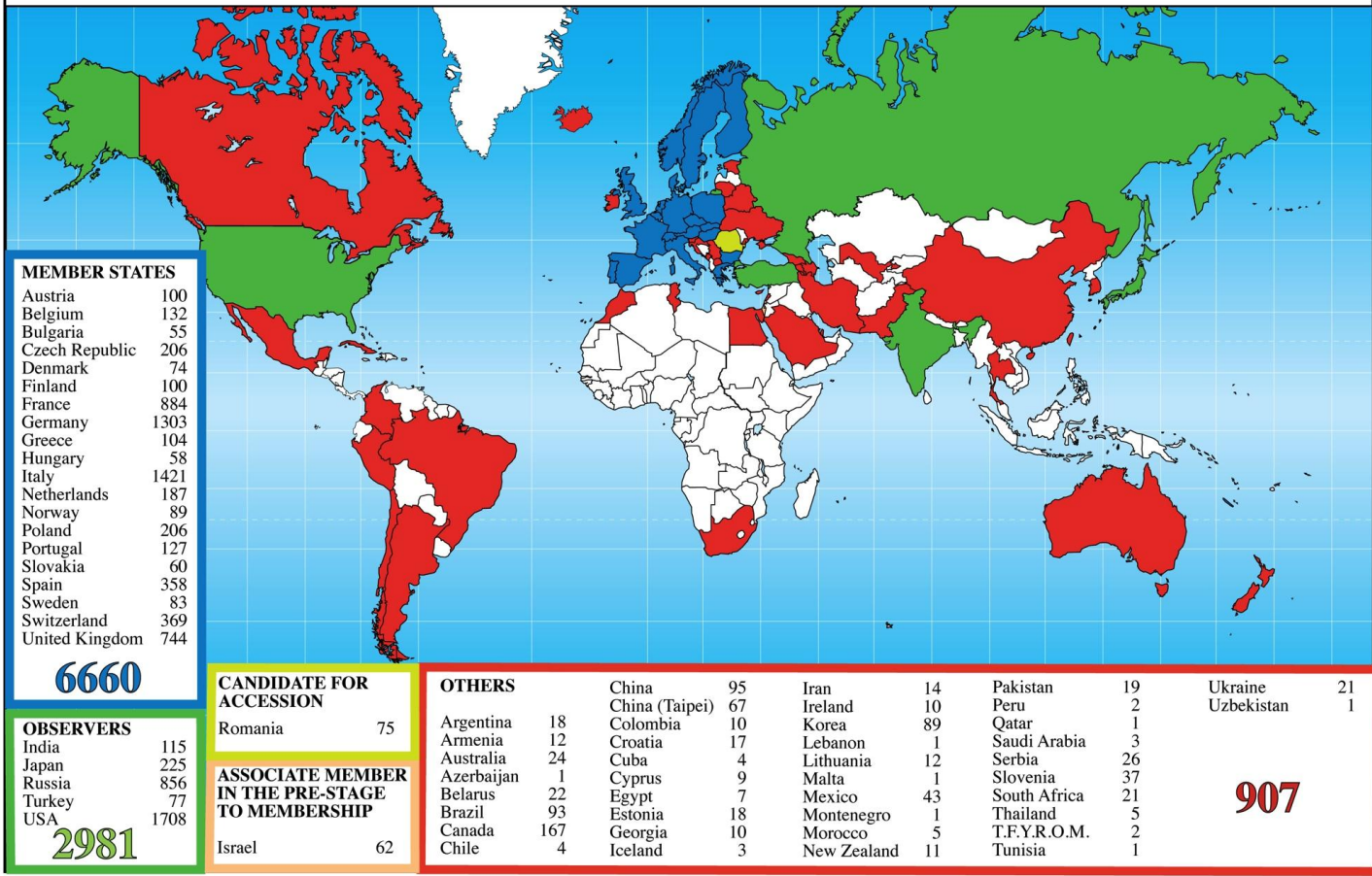
Abgeordnete

- Wissenschaftler 61
- Projektpersonal 161
- Studenten 134
- Doktoranden 148
- Sonstige 805

Firmen 3818

User 10685

Distribution of All CERN Users by Nation of Institute on 9 January 2012





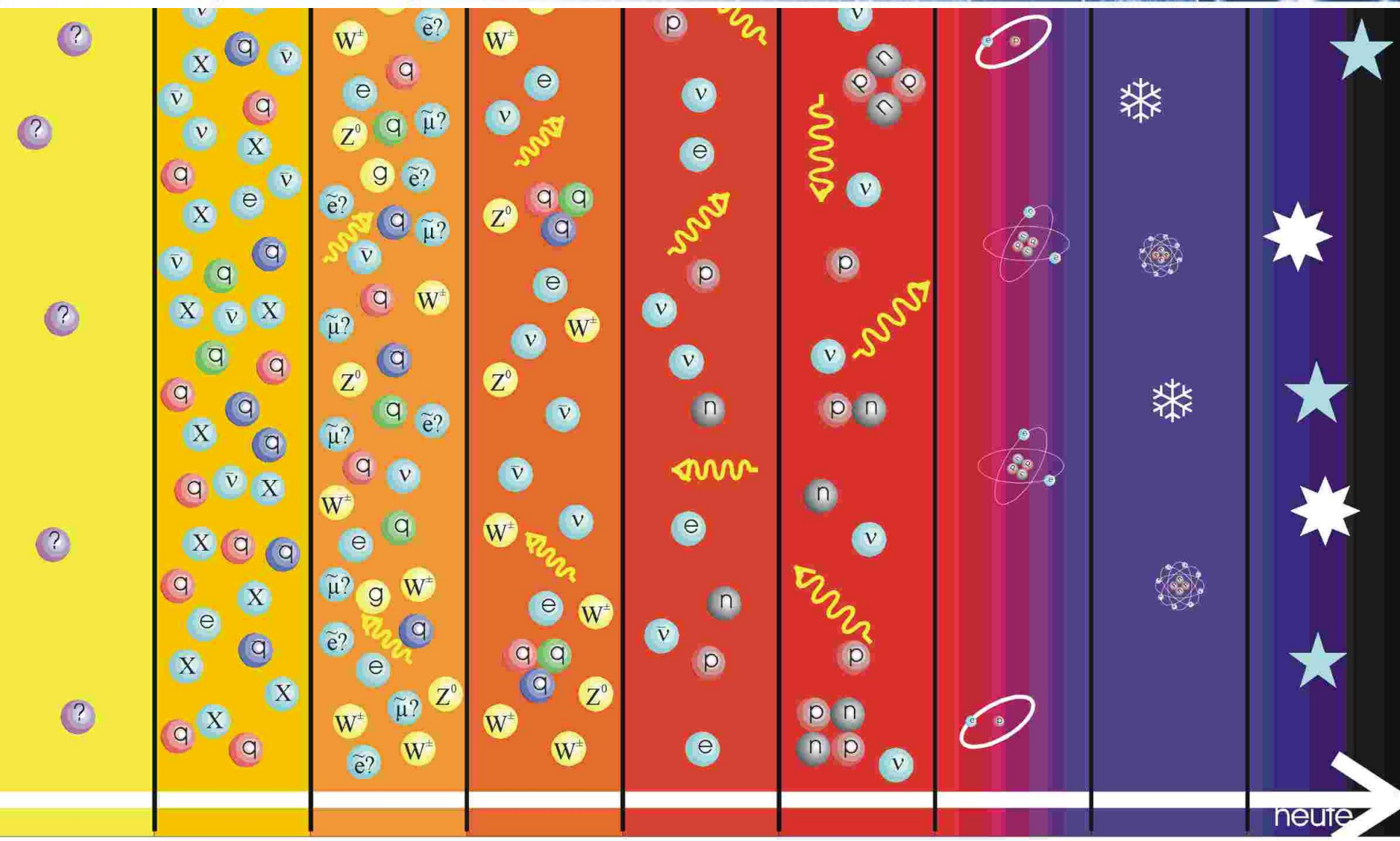
HochEnergiePhysik

- Auf der Suche nach dem,
"Was die Welt im Innersten zusammenhält"

- Suche nach
 - elementaren Teilchen
 - Kräften
 - Symmetrien



Physics Department



10^{43} s	10^{36} s	10^{-10} s	1 s	3 min	10^6 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			

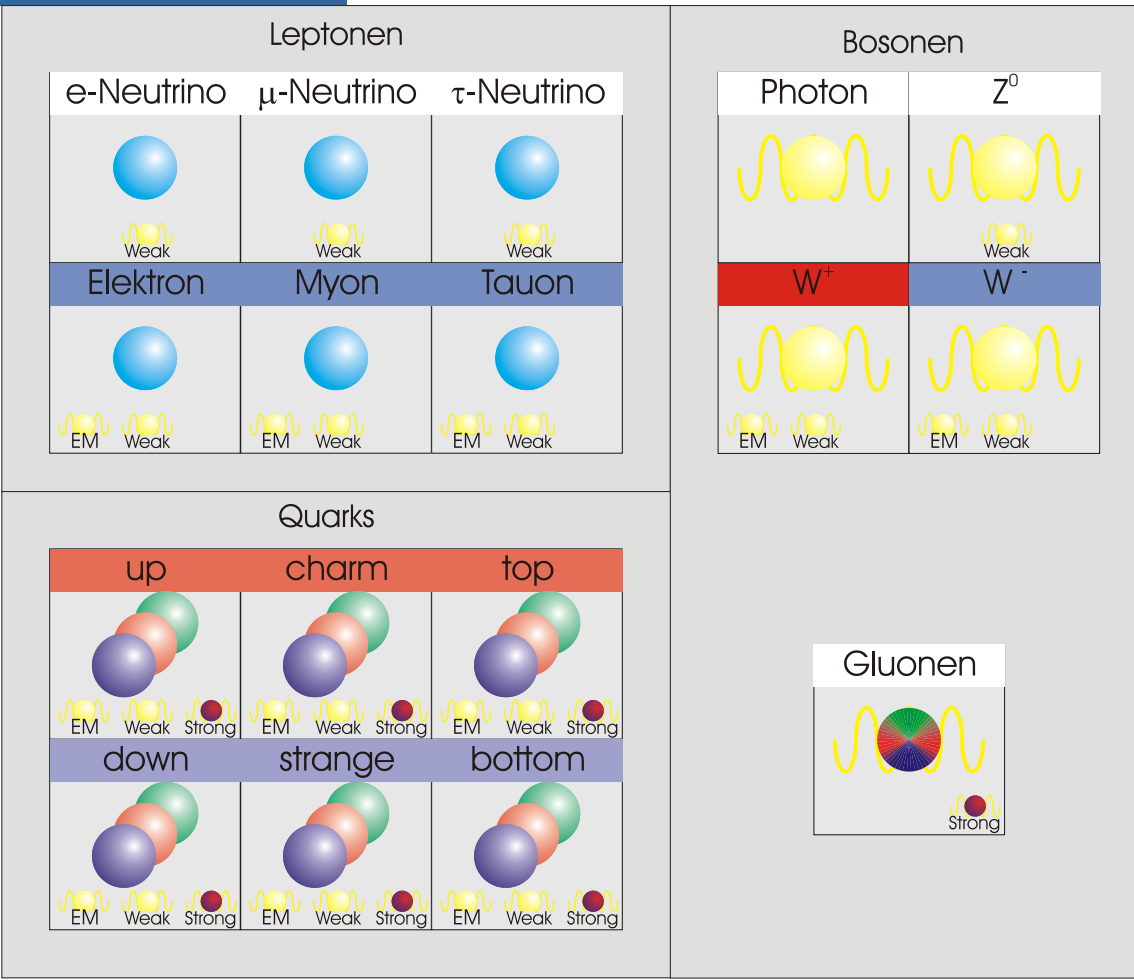
heute



Das Standardmodell

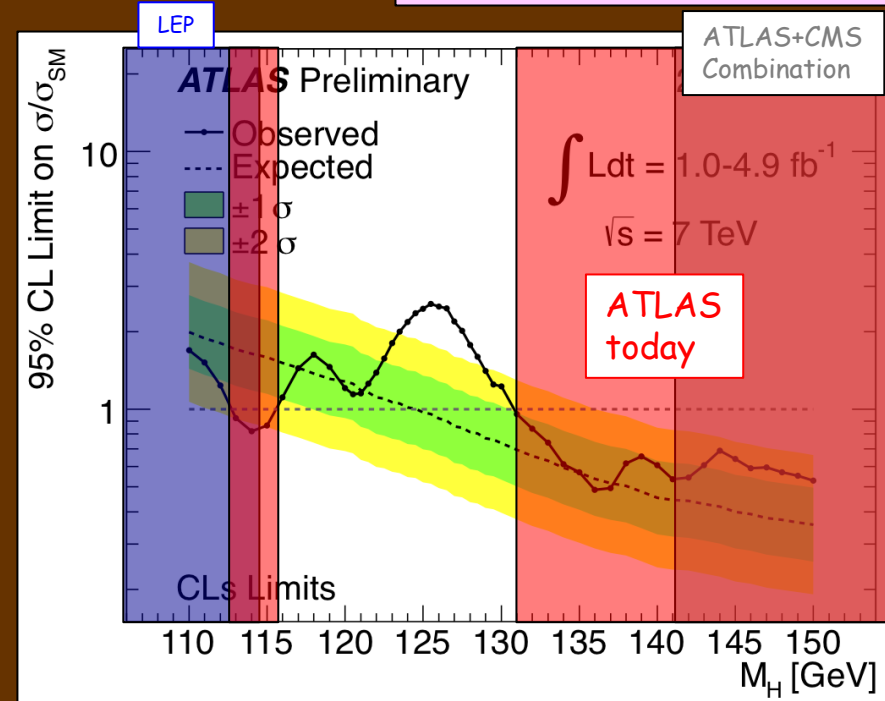
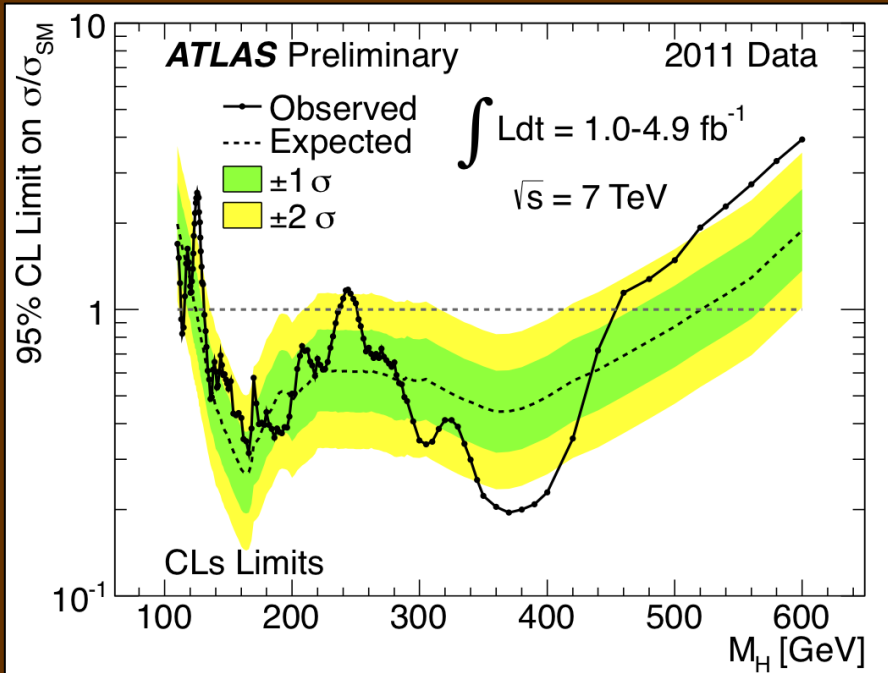
... ist ...

- ... 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



Putting all channels together → combined constraints

$H \rightarrow \gamma\gamma, H \rightarrow \tau\tau$
 $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$
 $H \rightarrow ZZ^{(*)} \rightarrow 4l, H \rightarrow ZZ \rightarrow ll\nu\nu$
 $H \rightarrow ZZ \rightarrow llqq, H \rightarrow WW \rightarrow lvqq$
 $W/ZH \rightarrow lbb+X$ not included



Excluded at 95% CL

$112.7 < m_H < 115.5 \text{ GeV}$
 $131 < m_H < 453 \text{ GeV, except } 237-251 \text{ GeV}$

Expected if no signal

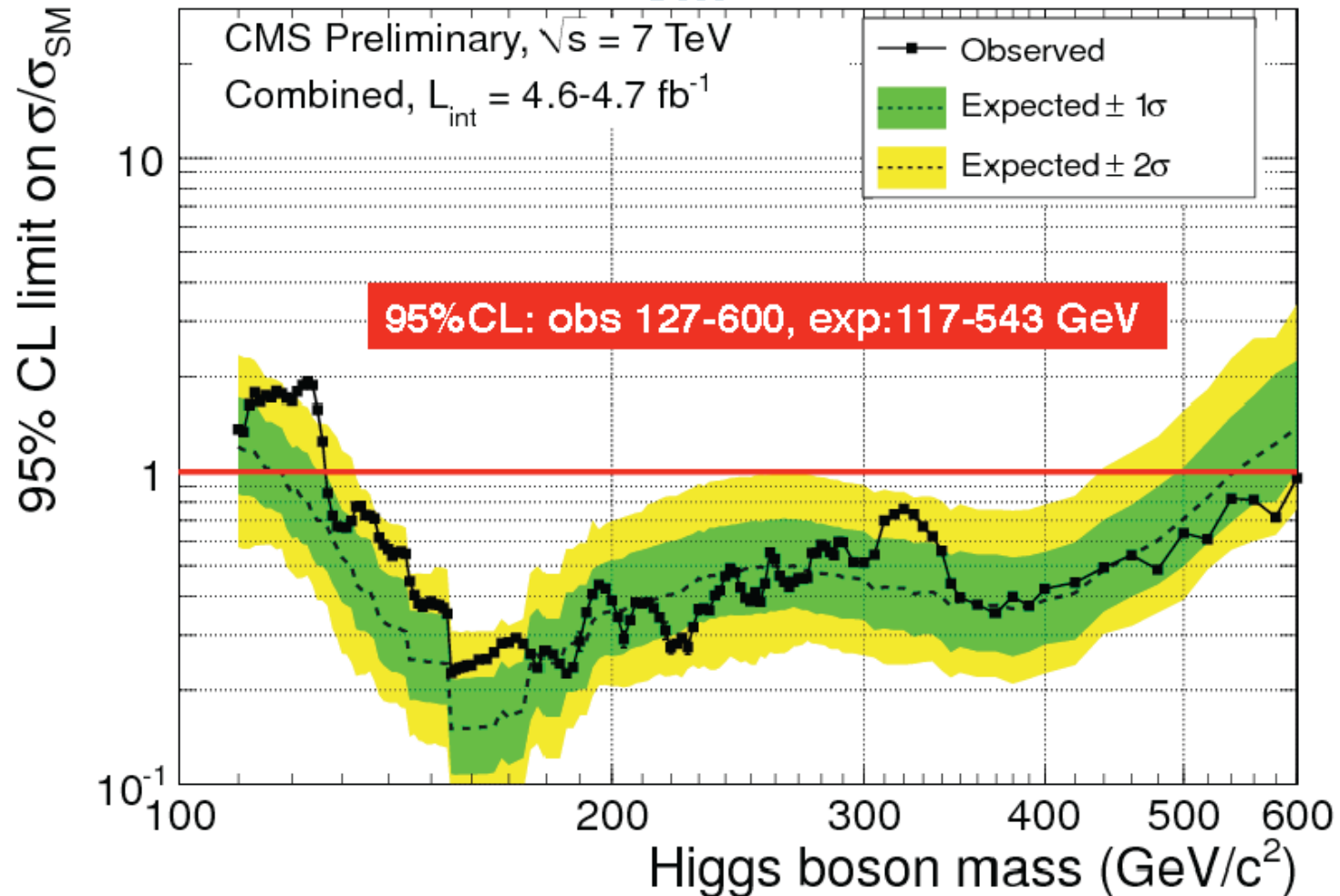
124.6-520 GeV

Excluded at 99% CL

$133 < m_H < 230 \text{ GeV, } 260 < m_H < 437 \text{ GeV}$



Limits on σ/σ_{SM} (CLs method)





SUISSE
FRANCE

CMS

LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

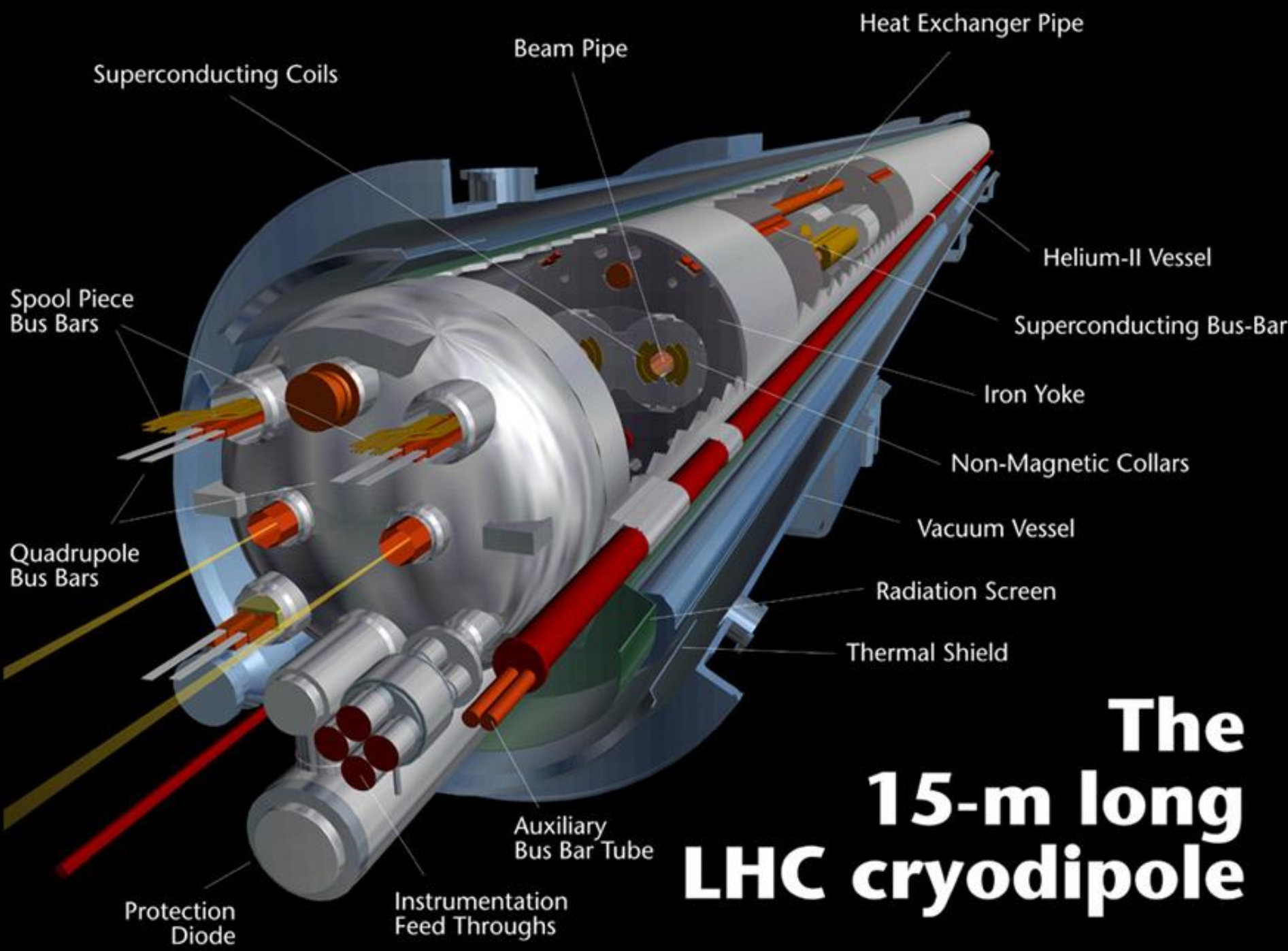
ALICE

LHC 27 km



LHC – Von der Idee zum Beschleuniger

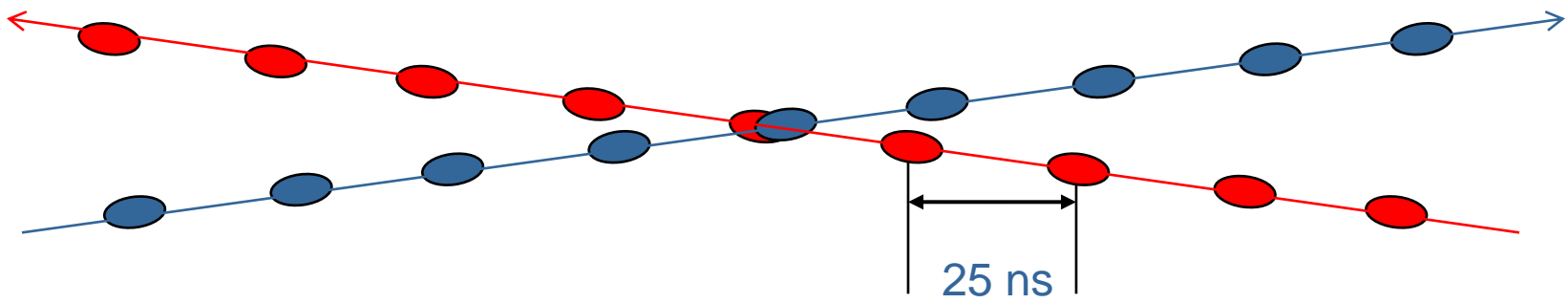
- 1982 : Erste Projektstudien
- 1983 : Z^0 -Ereignis am Sp^pS
- 1985 : Nobelpreis für S. van der Meer und C. Rubbia
- 1989 : Beginn des LEP-Betriebs (Z Factory)
- 1994 : Zustimmung zum LHC durch das Council
- 1996 : Endgültige Entscheidung zum Baubeginn
- 1996 : LEP Betrieb bei 100 GeV (W Factory)
- 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

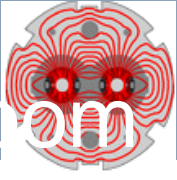
$$E_{\text{Dipol}} = 0.5 \cdot L_{\text{Dipol}} \cdot I_{\text{Dipol}}^2$$

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 = $\frac{1}{2} mv^2 \sim 10\text{GJ}$





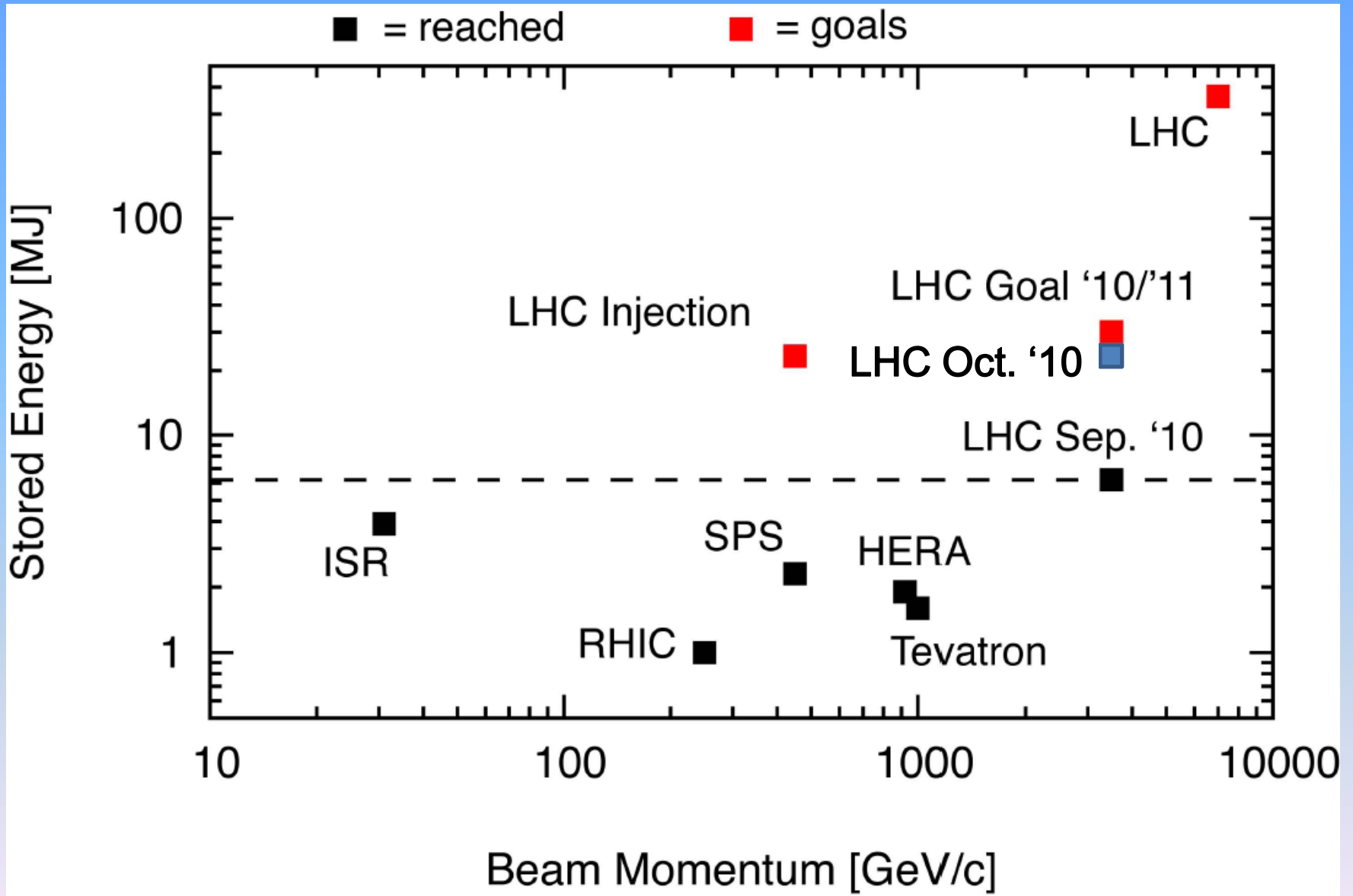
September 10th - control (show) room

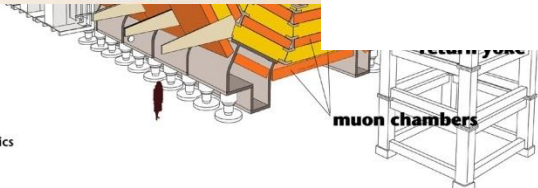
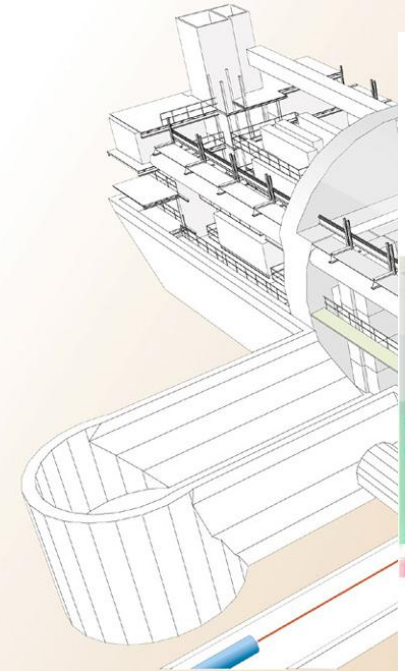
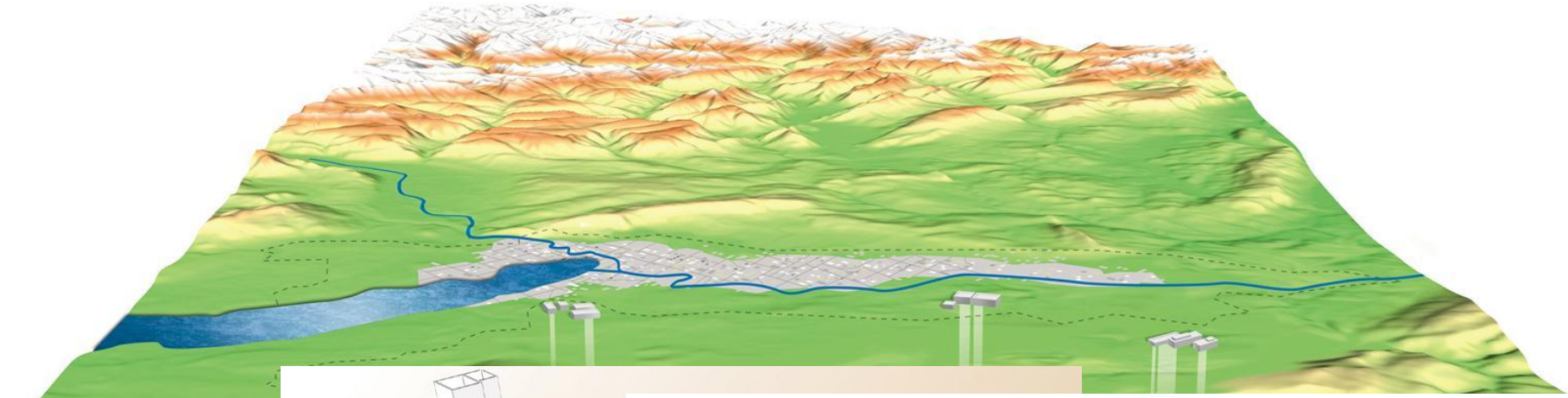


For 3 days all went perfectly well with beam...



LHC now on its own in terms of stored energy

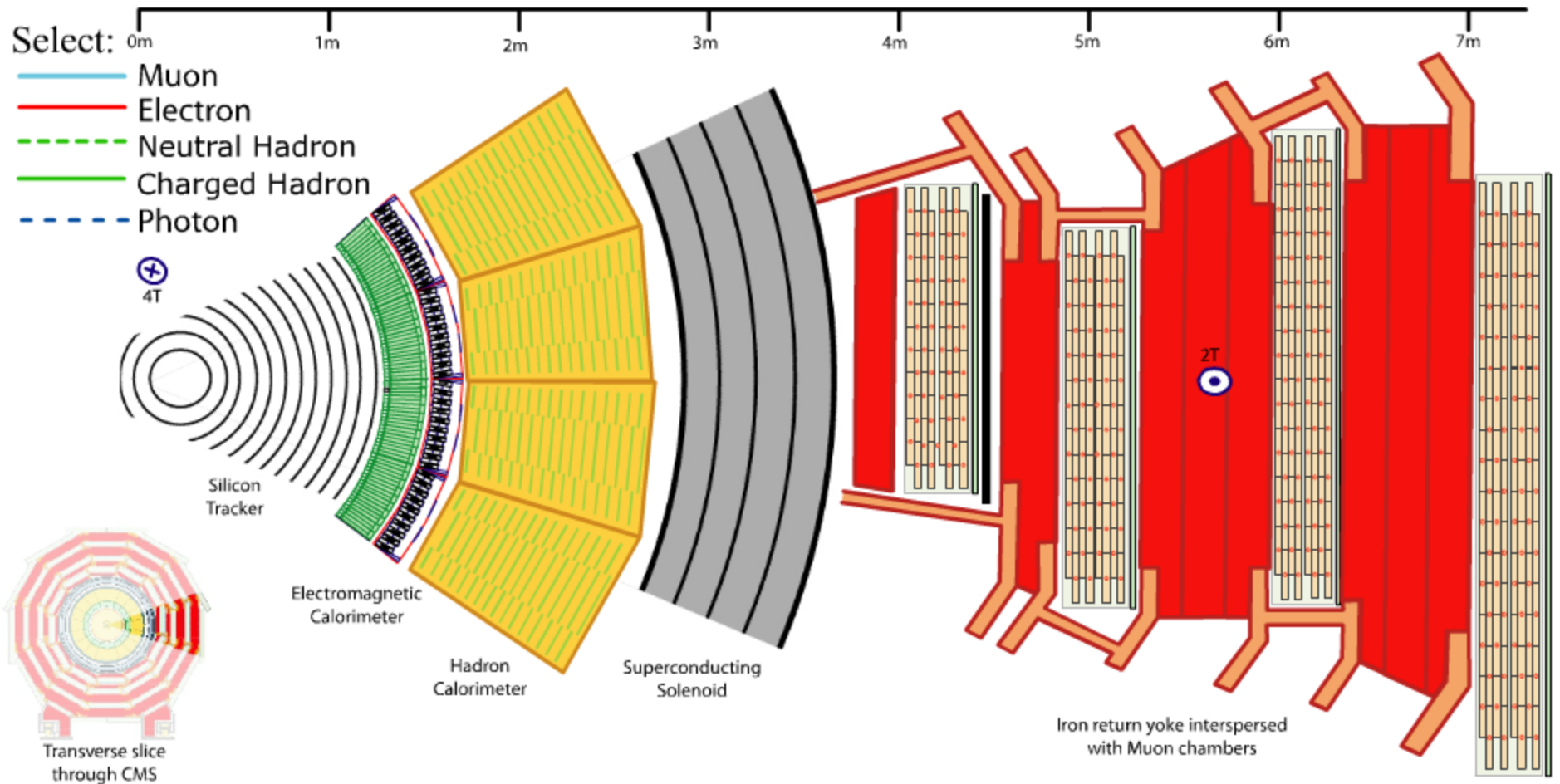




Detector characteristics

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

CMS Ereignis





Invariant mass distributions

A tribute to Level1 and HLT trigger capability and flexibility

e^+e^- widths:

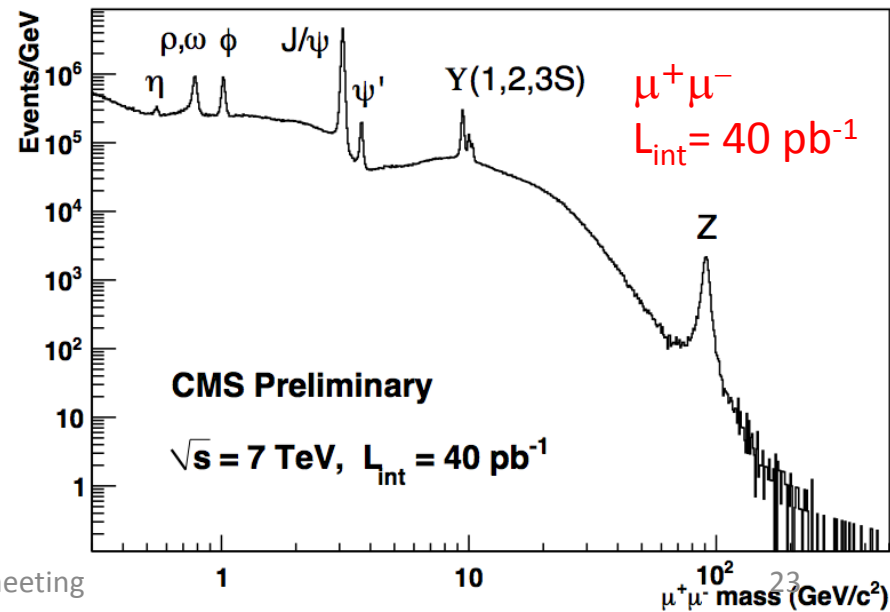
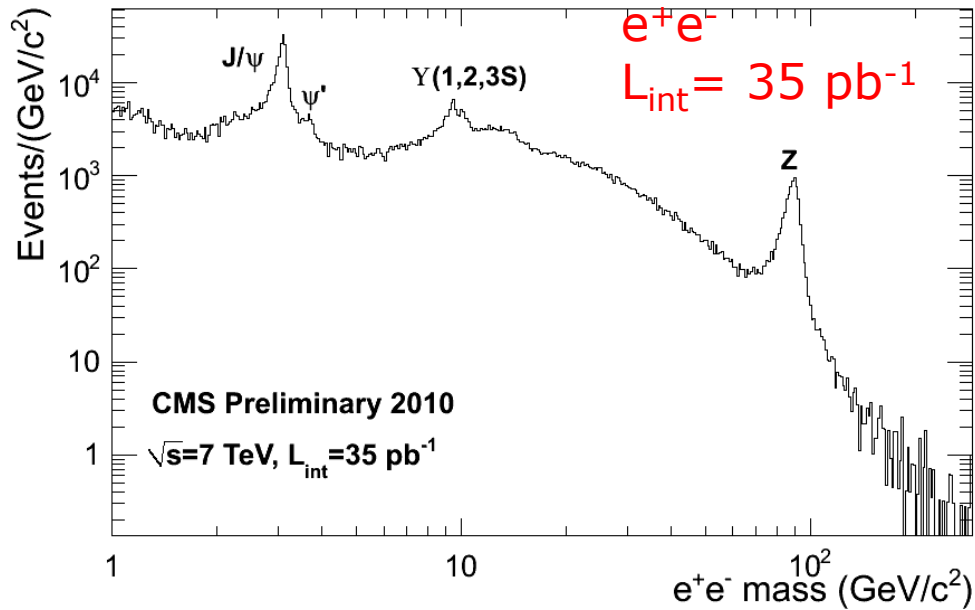
J/ Ψ 52 MeV

Y 149 MeV

$\mu^+\mu^-$ widths:

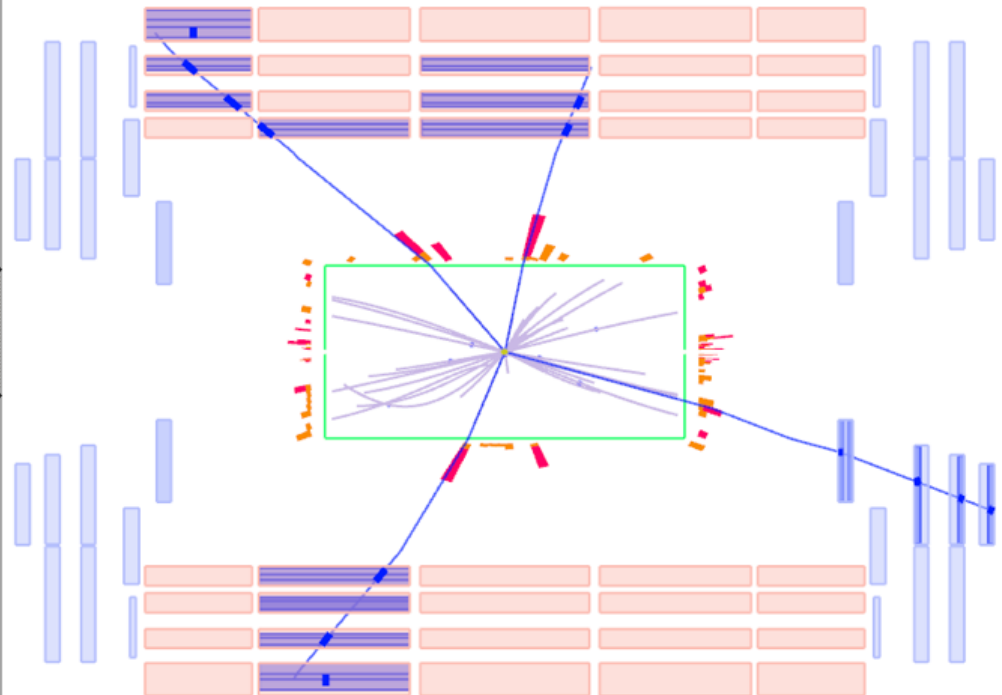
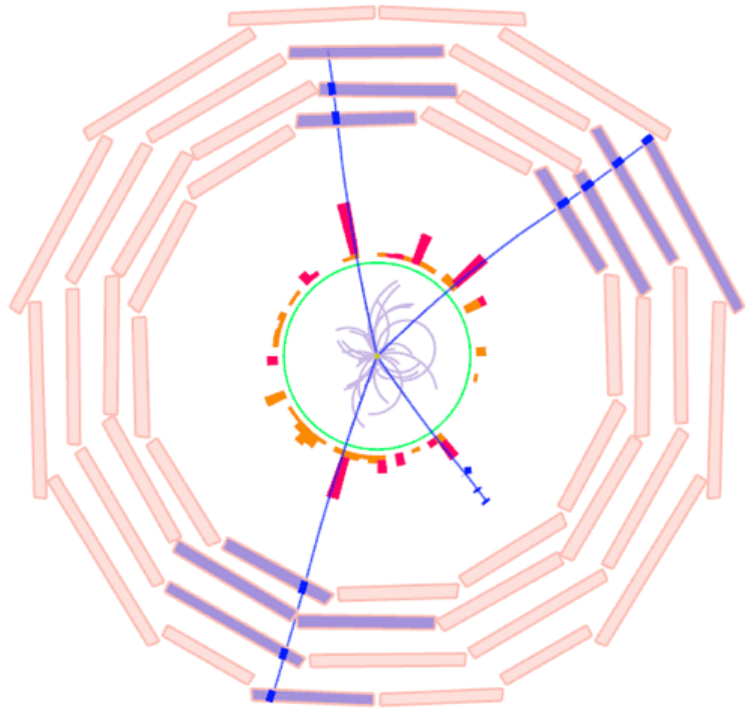
J/ Ψ 30 MeV

Y 67 MeV





A beautiful ZZ event



Invariant Masses

$\mu_0 + \mu_1$: 92.15 GeV (total(Z) p_T 26.5 GeV, ϕ -3.03),
 $\mu_2 + \mu_3$: 92.24 GeV (total(Z) p_T 29.4 GeV, ϕ +.06),
 $\mu_0 + \mu_2$: 70.12 GeV (total p_T 27 GeV),
 $\mu_3 + \mu_1$: 83.1 GeV (total p_T 26.1 GeV).

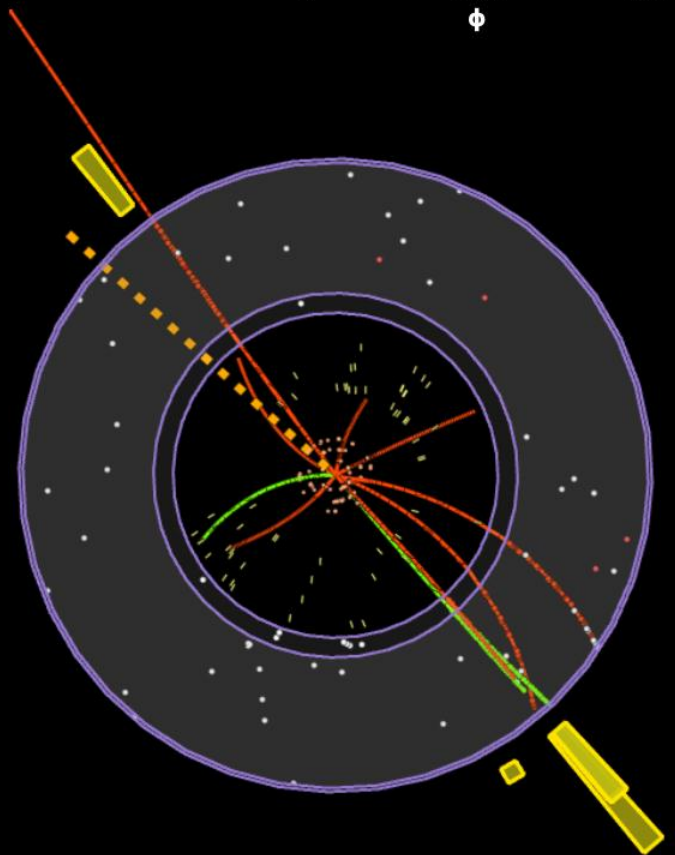
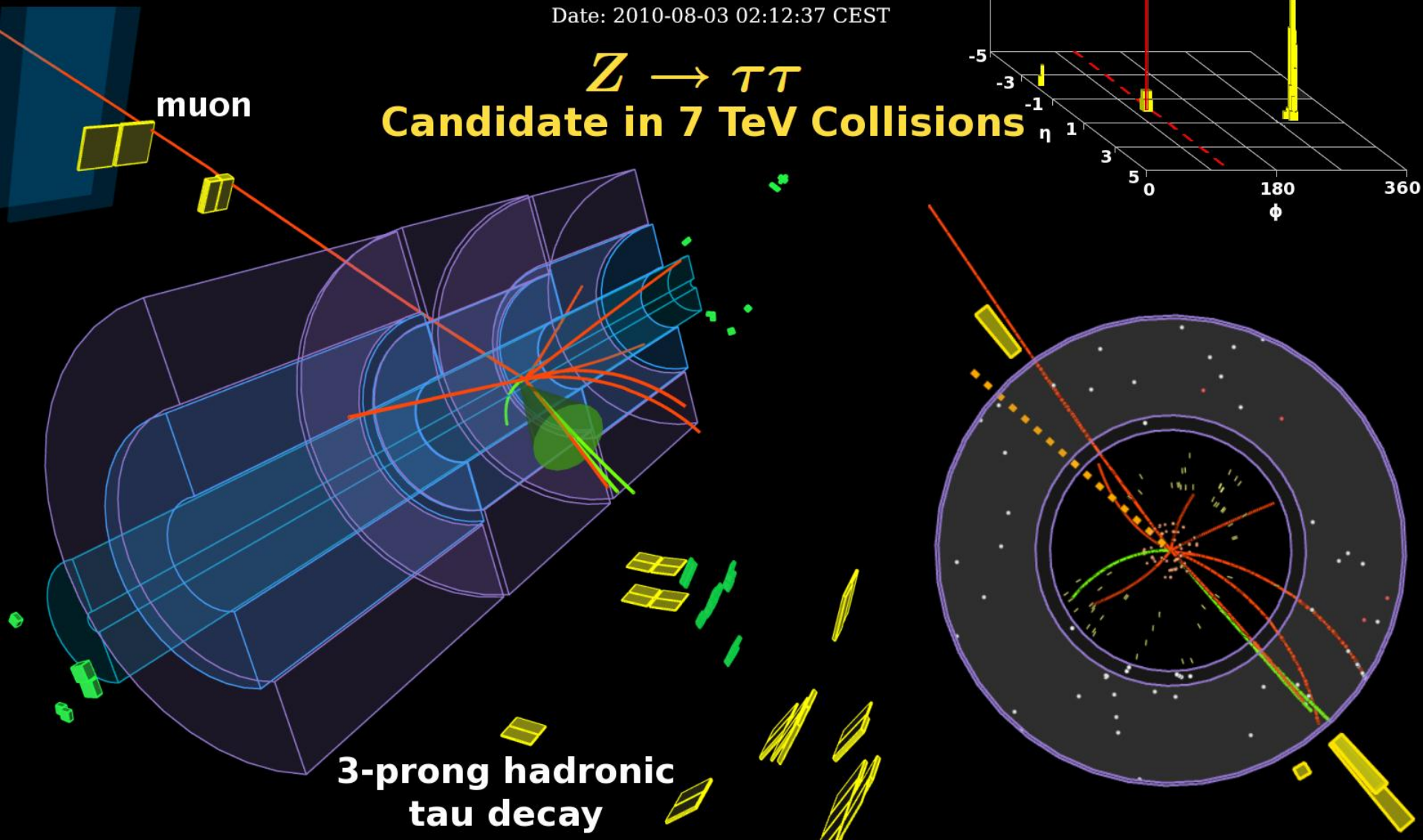
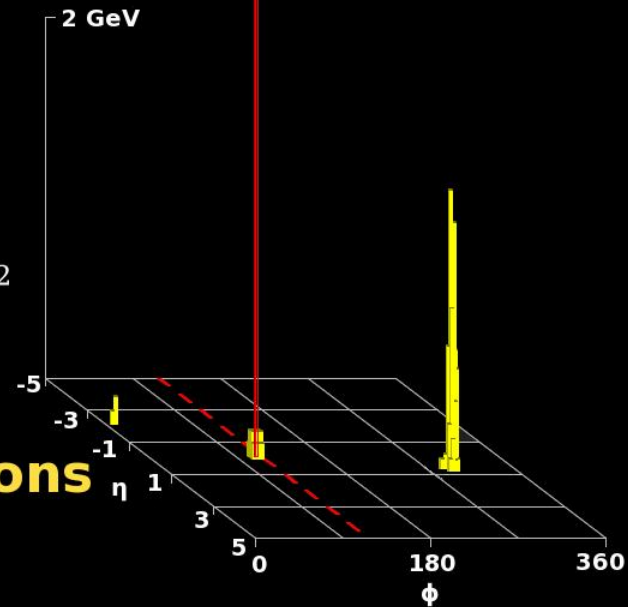
$p_T(\mu) = 18 \text{ GeV}$
 $p_T^{\text{vis}}(\tau_h) = 26 \text{ GeV}$
 $m_{\text{vis}}(\mu, \tau_h) = 47 \text{ GeV}$
 $m_T(\mu, E_T^{\text{miss}}) = 8 \text{ GeV}$
 $E_T^{\text{miss}} = 7 \text{ GeV}$

ATLAS EXPERIMENT

Run Number: 160613, Event Number: 9209492

Date: 2010-08-03 02:12:37 CEST

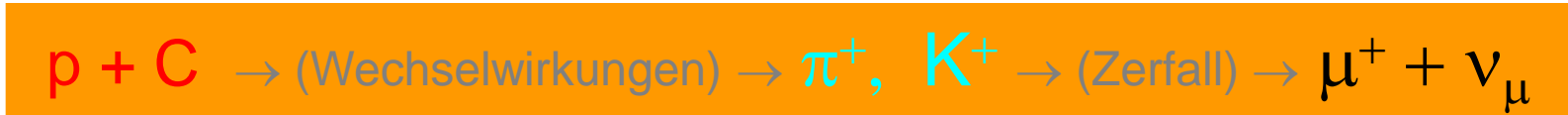
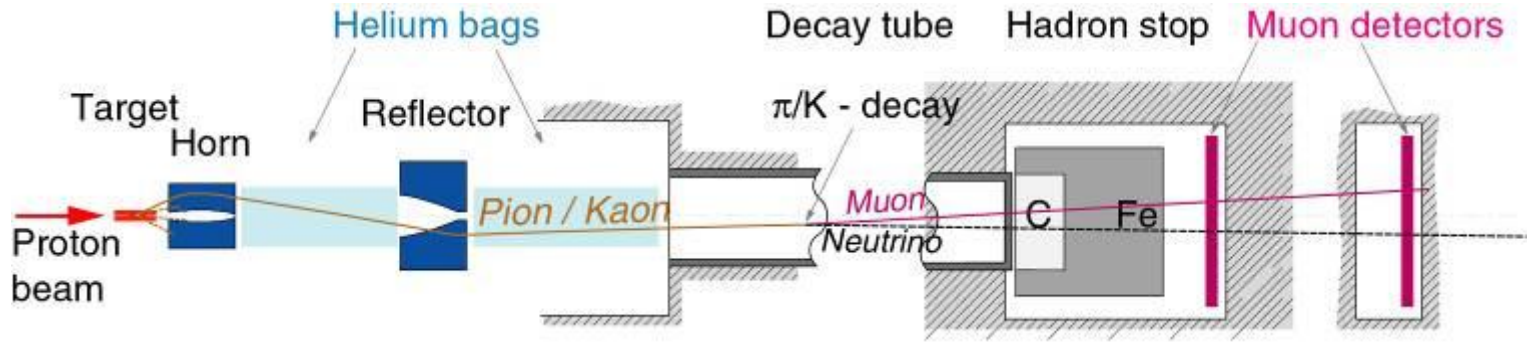
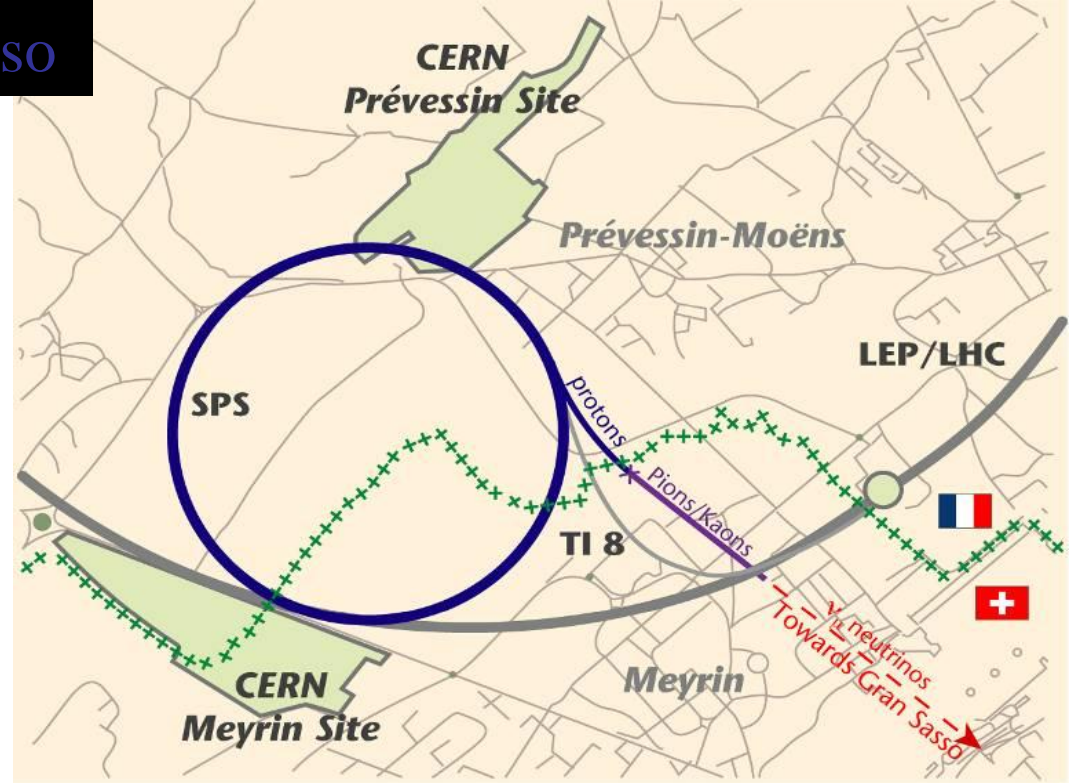
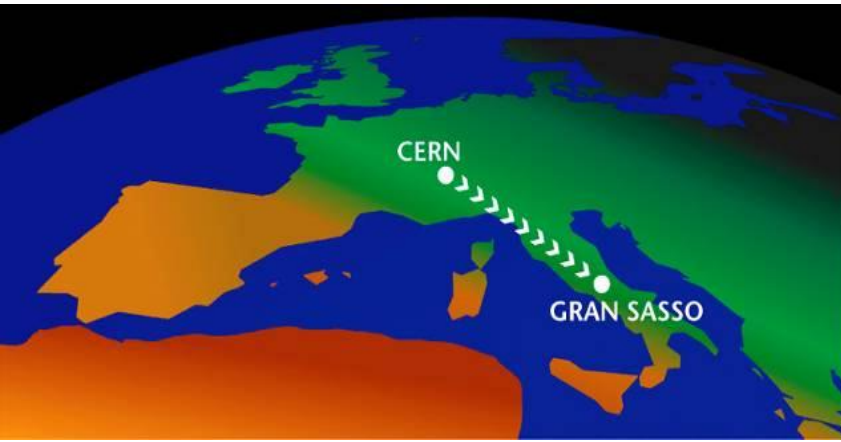
$Z \rightarrow \tau\tau$
Candidate in 7 TeV Collisions

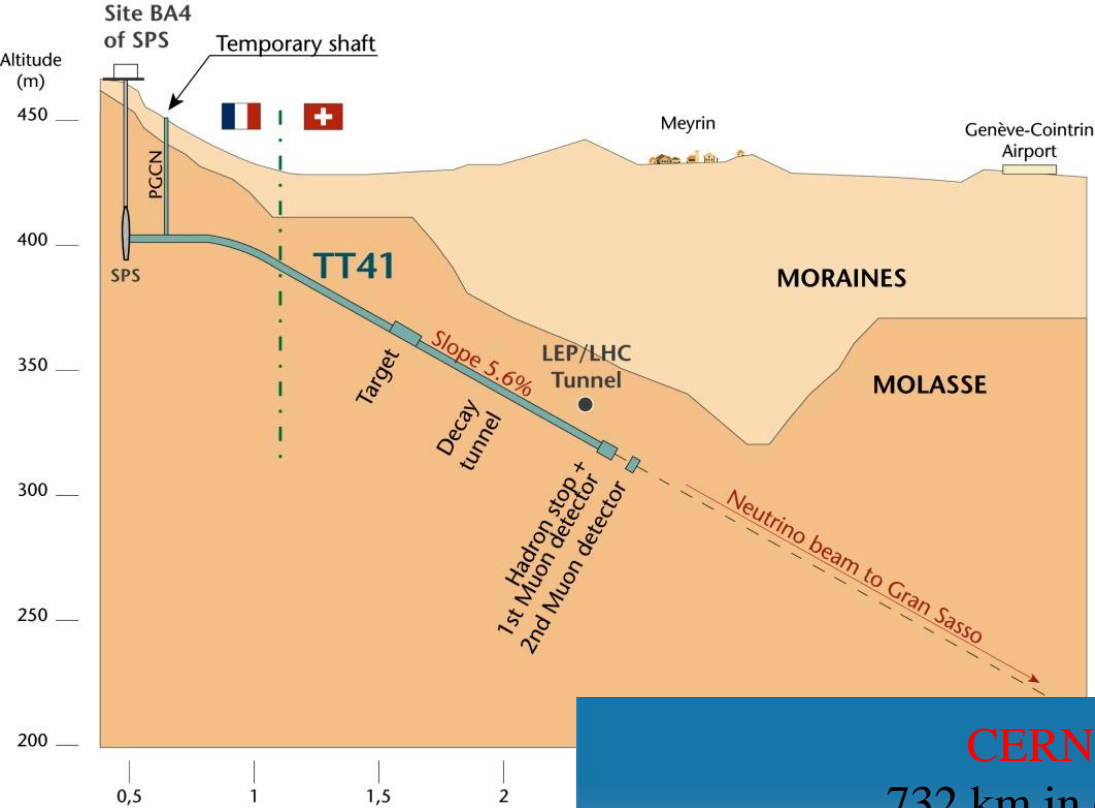


Weitere Aktivitäten am CERN

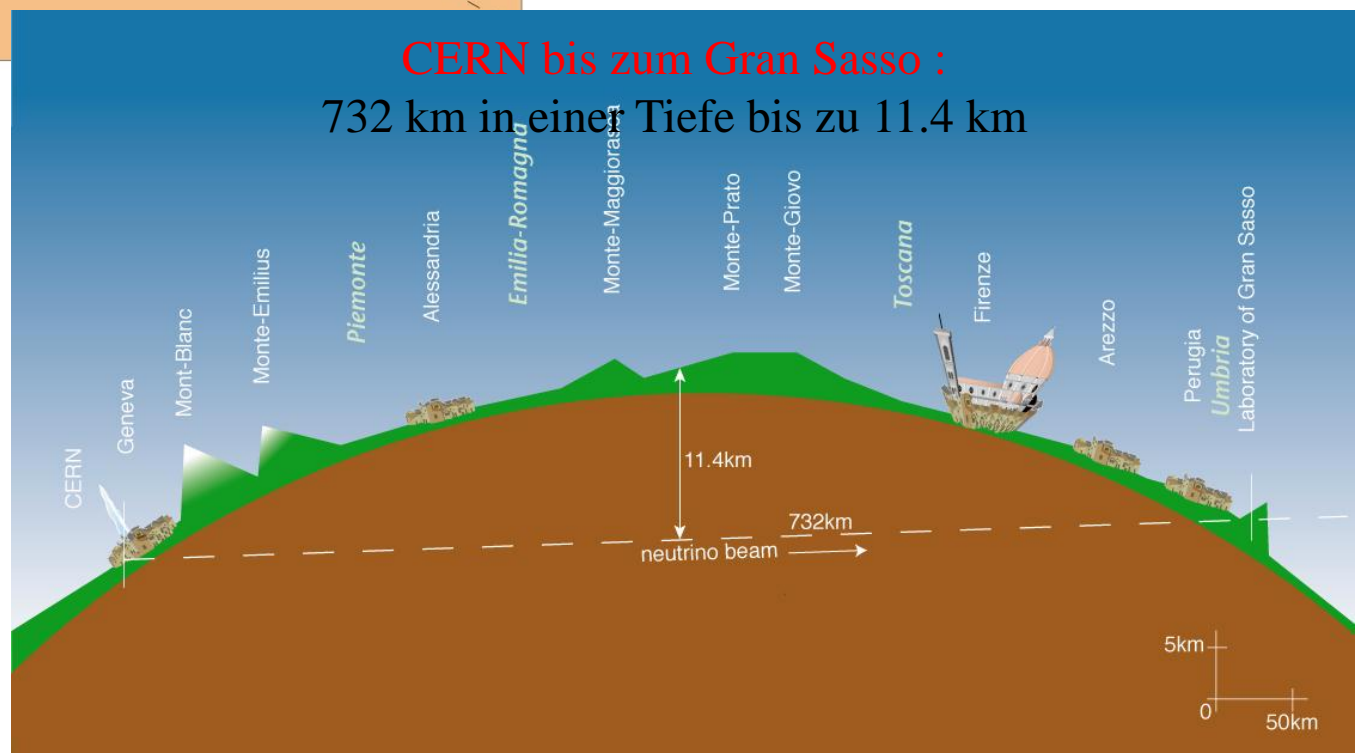
... eine kleine Auswahl ...

CERN Neutrinos zum Gran Sasso

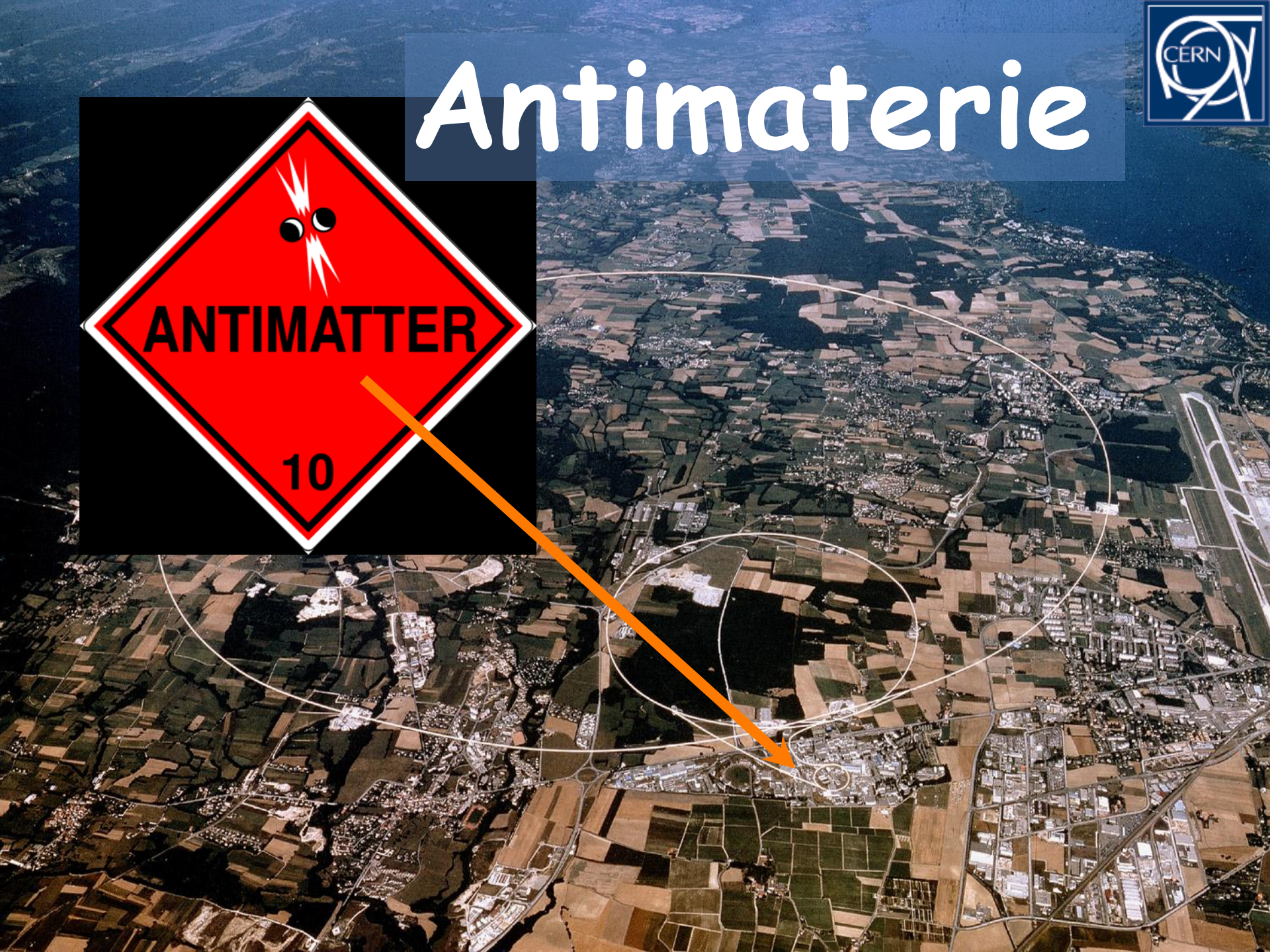
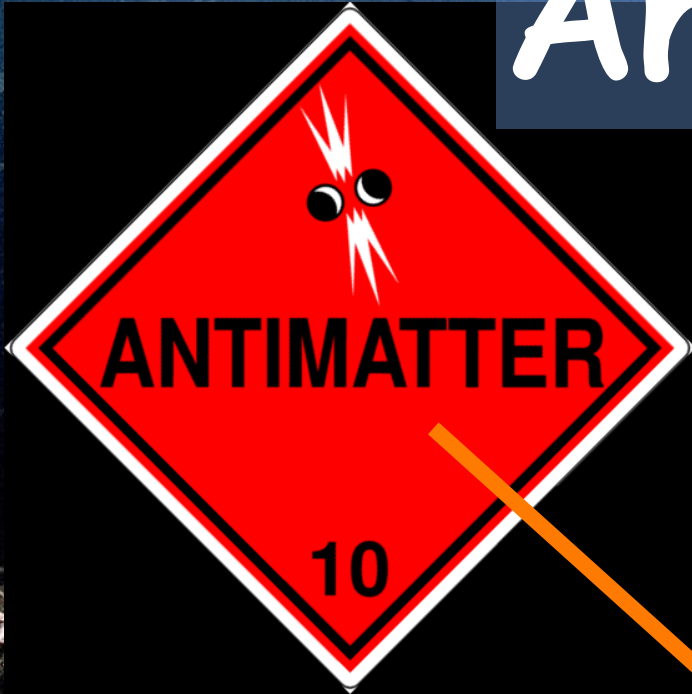




CERN bis zum Gran Sasso :
732 km in einer Tiefe bis zu 11.4 km



Antimaterie





Was ist Antimaterie?

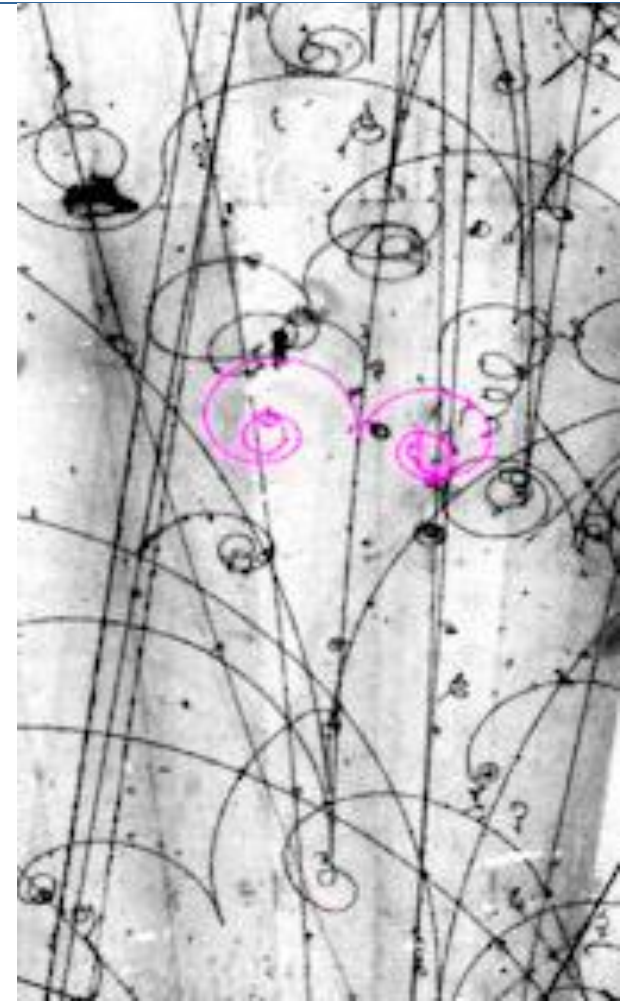
- Einstein
 - "Materie ist kondensierte Energie!"

- Dirac
 - "Teilchen entstehen immer in Paaren, Teilchen und Anti-Teilchen!"



Elektron

Positron

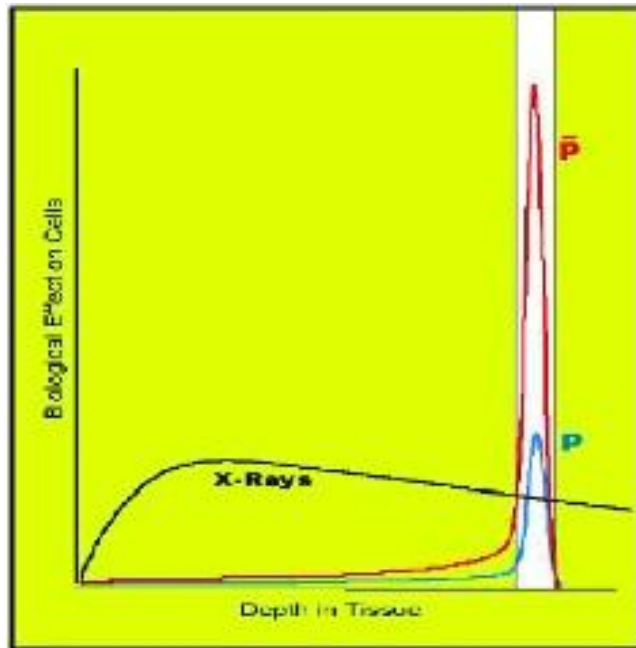
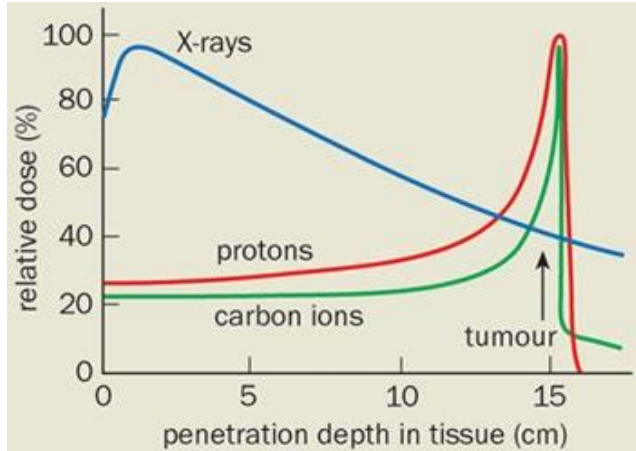


Novels of Dan Brown

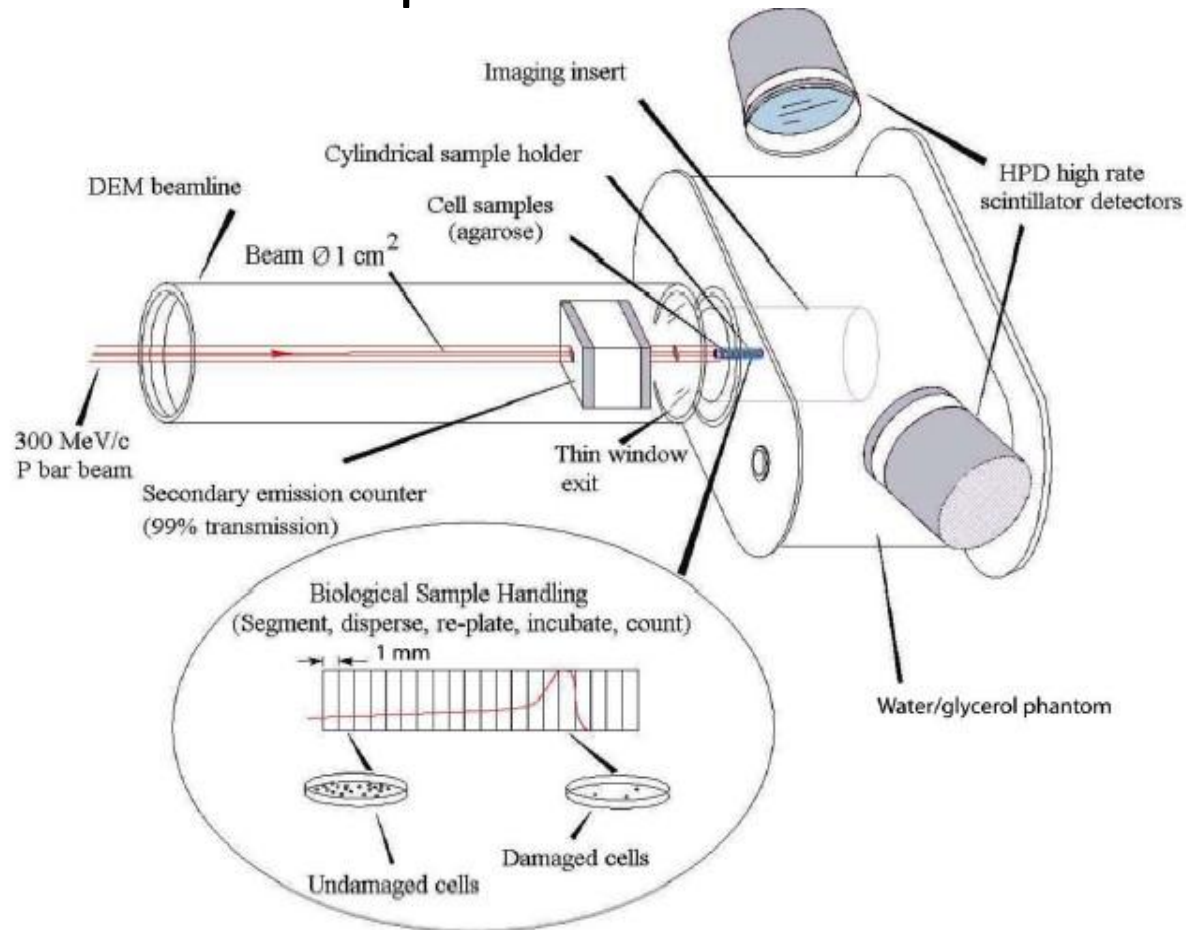


Tom's Angels and demons

Anwendung von Antimaterie - Tumorbekämpfung



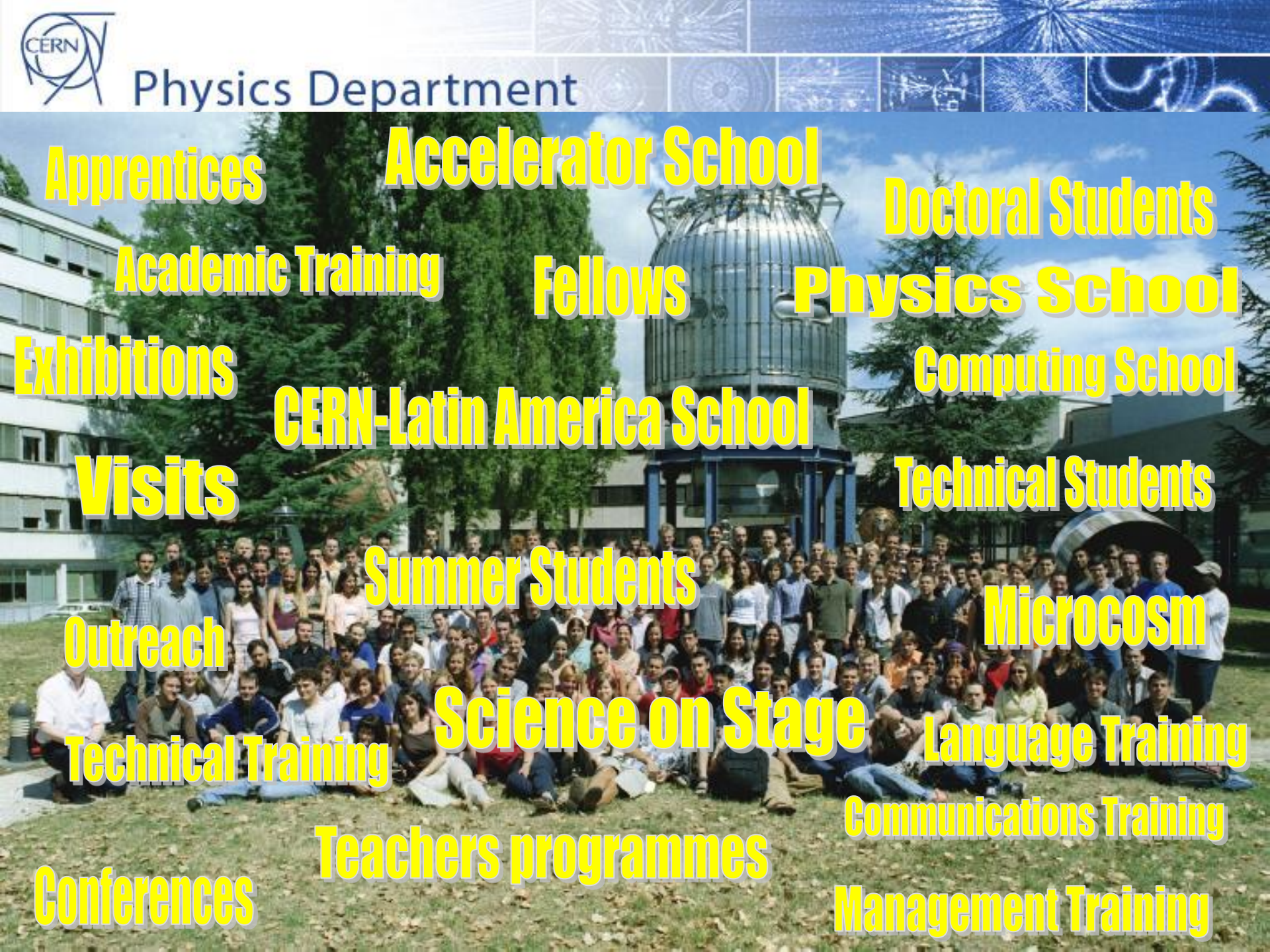
ACE Experiment bei CERN



*) 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

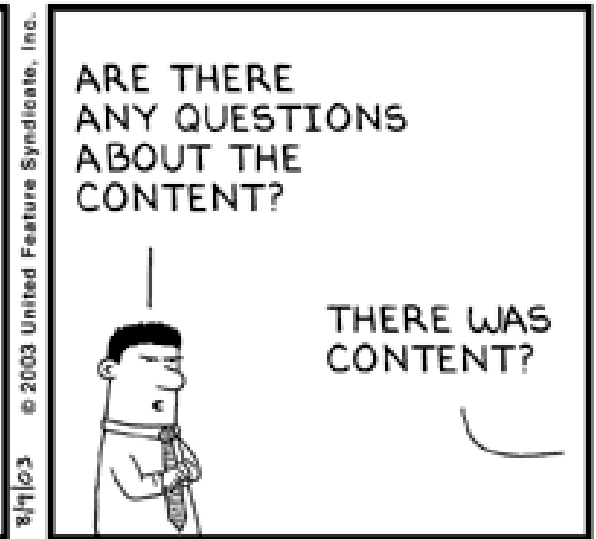
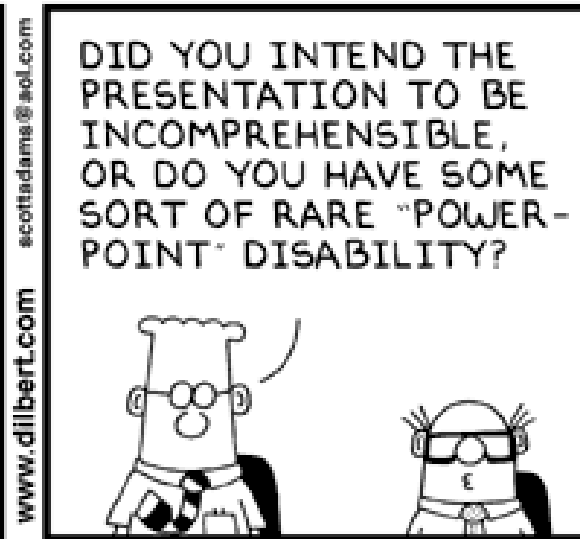
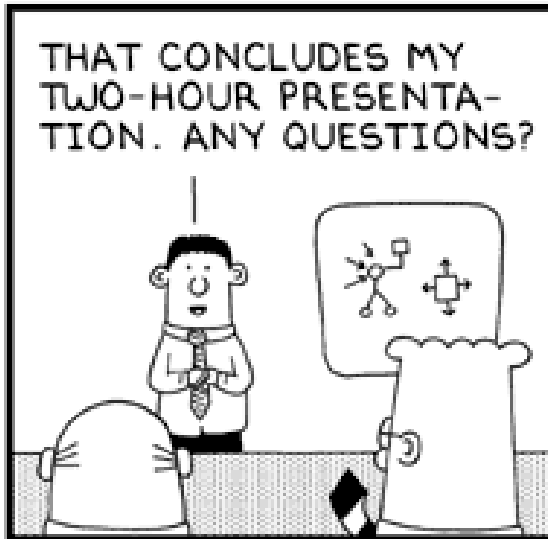
Communications Training

Teachers programmes

Conferences

Management Training

Fragen ?



www.dilbert.com scottadams@aol.com

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Physique des Particules

Cosmologie

Physique Nucléaire

Astrophysique

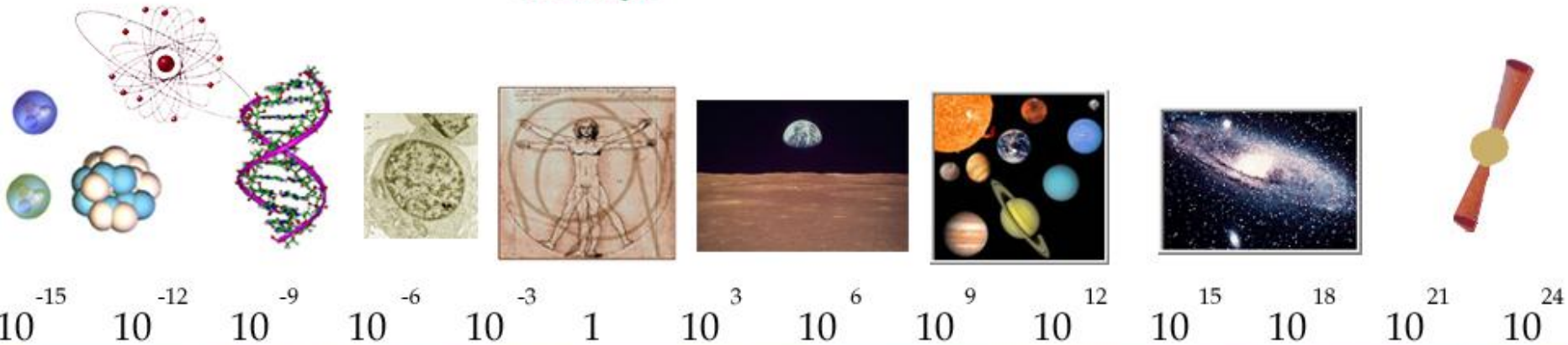
Physique du Solide

Astronomie

Chimie - Biologie

Géophysique

Mécanique



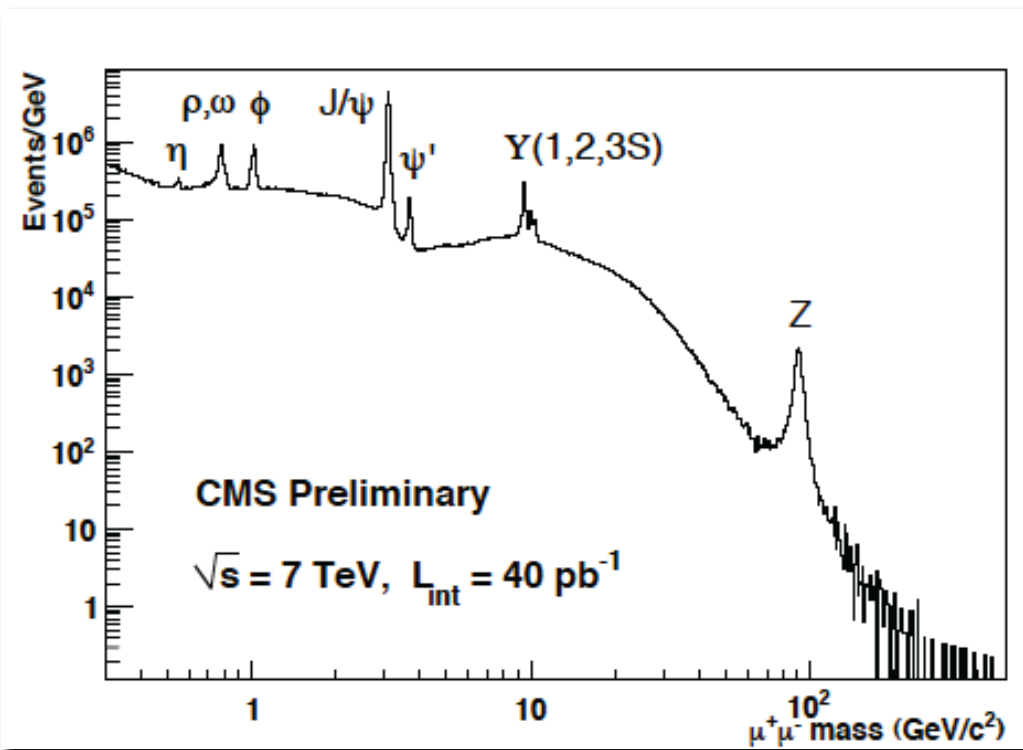
fm pm nm μm mm m km Mm Gm Tm Pm Em



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

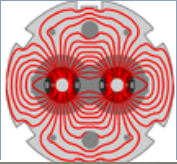
Excellent performances 2010

**Excellent start-up in 2011:
already some 27/pb delivered**

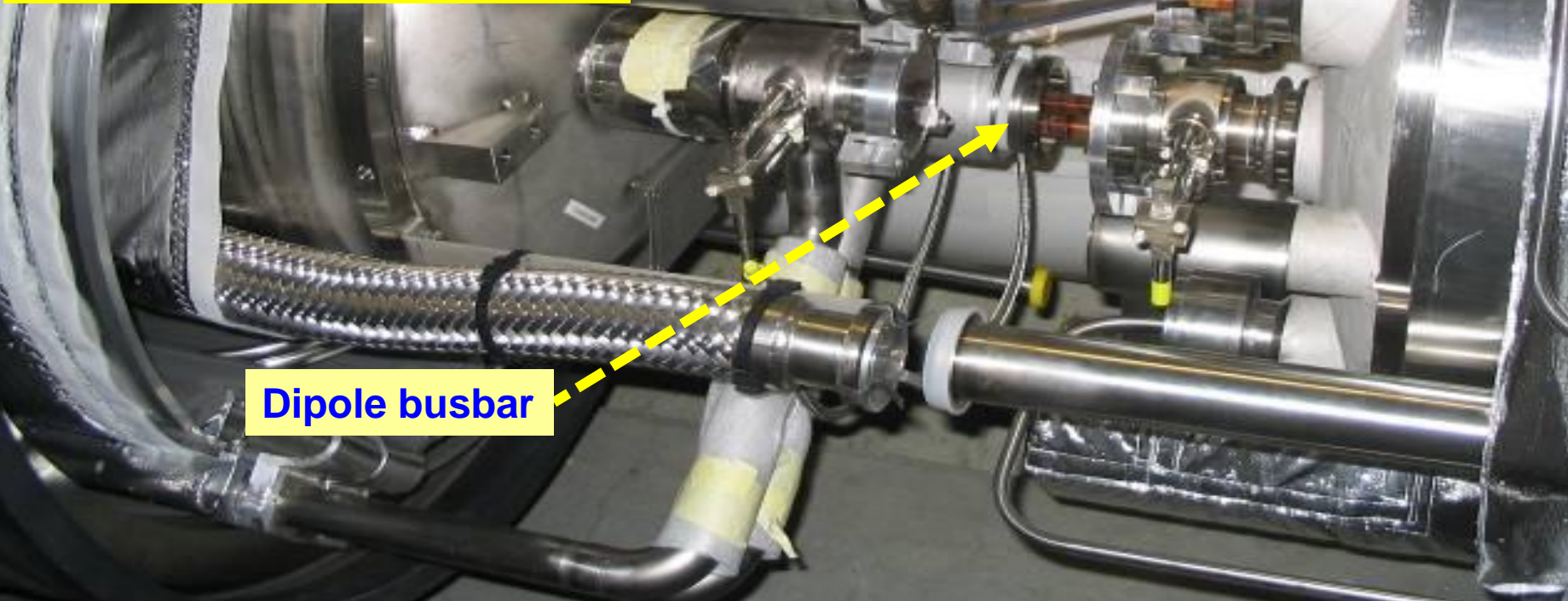
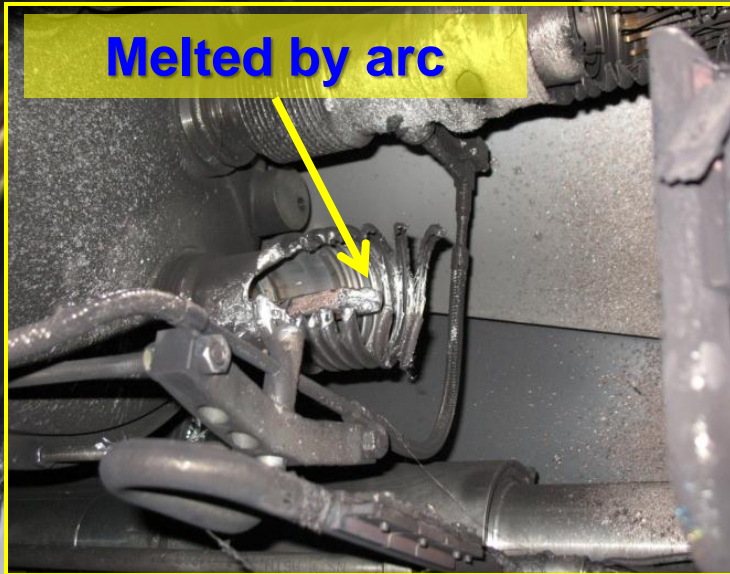


- Experiments demonstrated readiness in the exploitation of the 7 TeV p-p and 2.76 TeV Pb-Pb data;
- analyses proceeded very rapidly;
- Experiments have about completed their journey through the Standard Model ... and have started to take us into uncharted territories

...



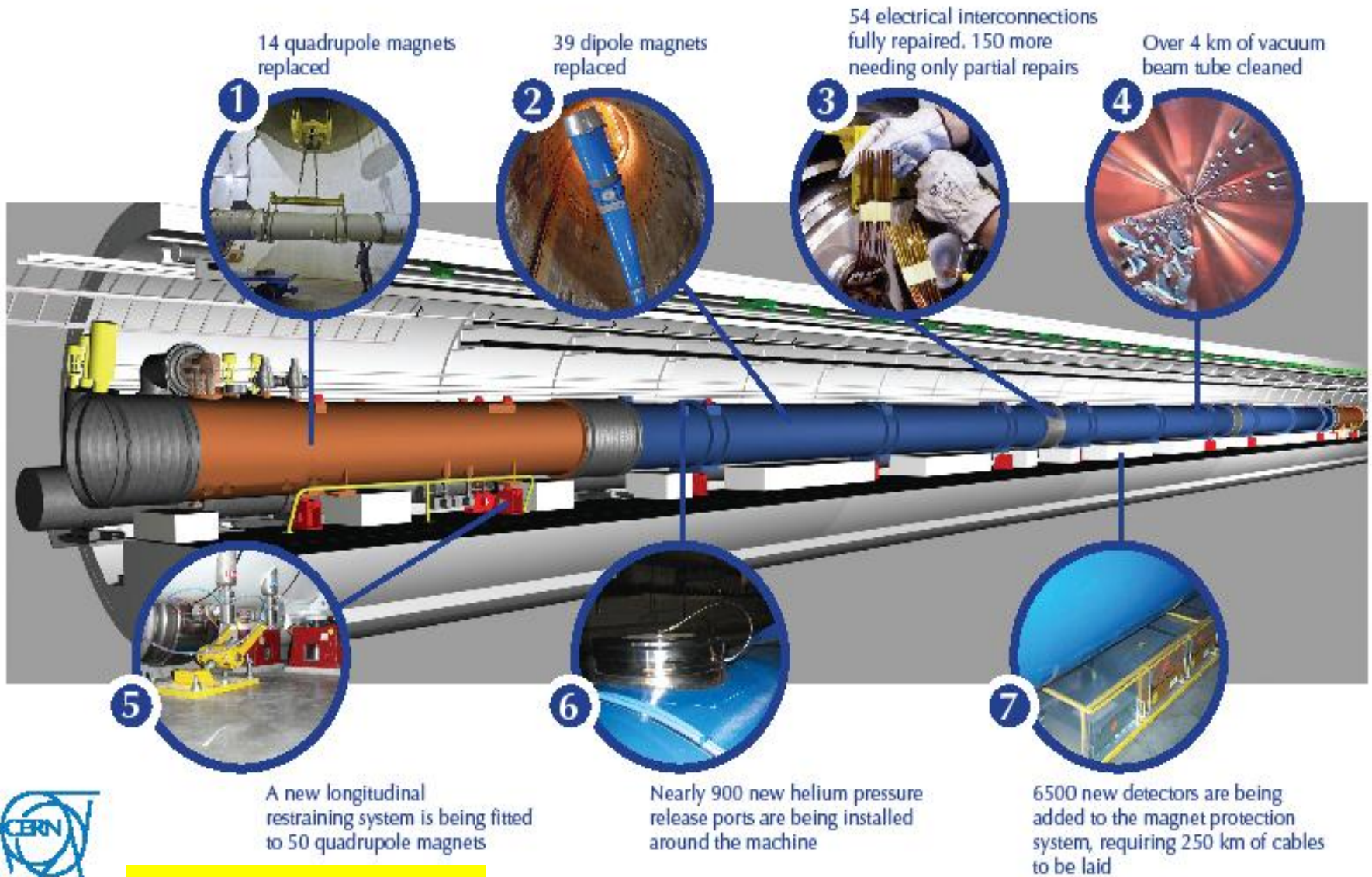
Magnet Interconnection



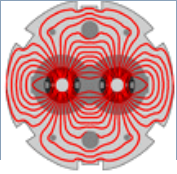
Melted by arc

Dipole busbar

The LHC repairs in detail



+ Kältetechnik

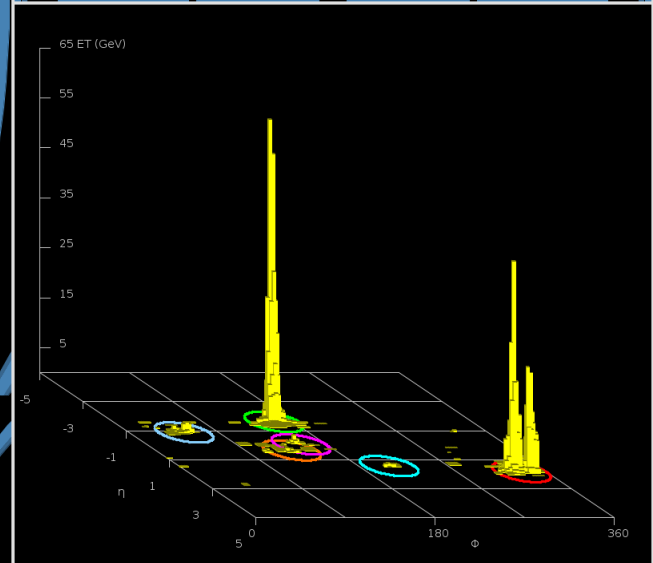
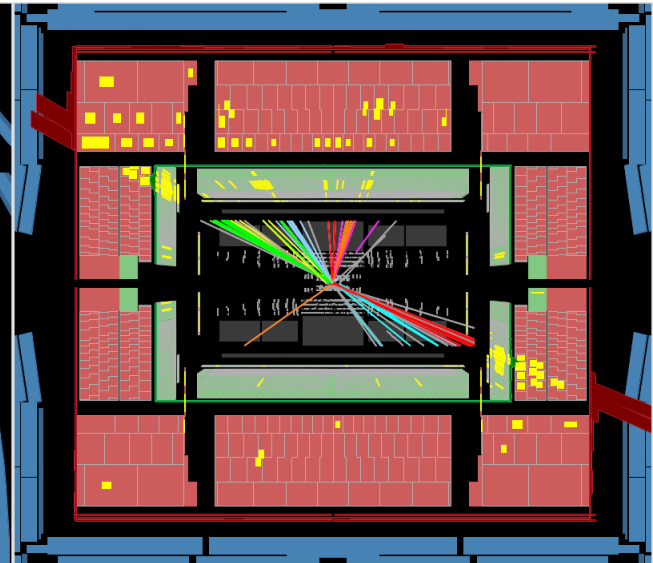
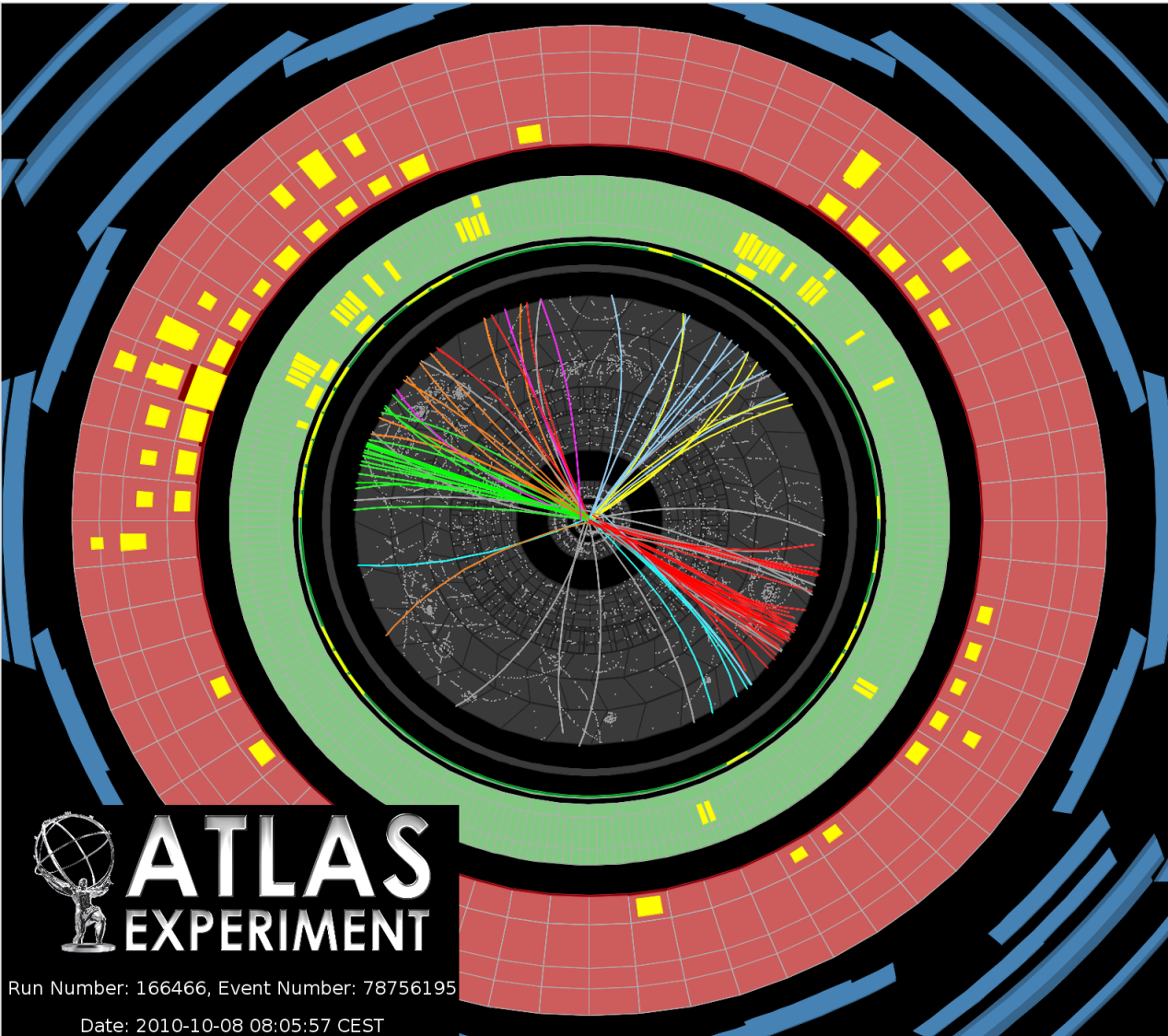


- ❑ 14 months to repair, consolidate and re-commissioning all elements.
- ❑ Great relief on November 20th when both beams circulated again !!!



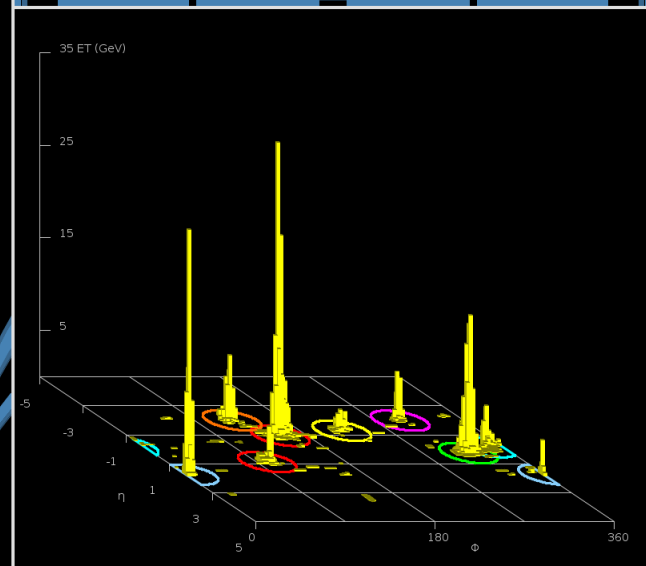
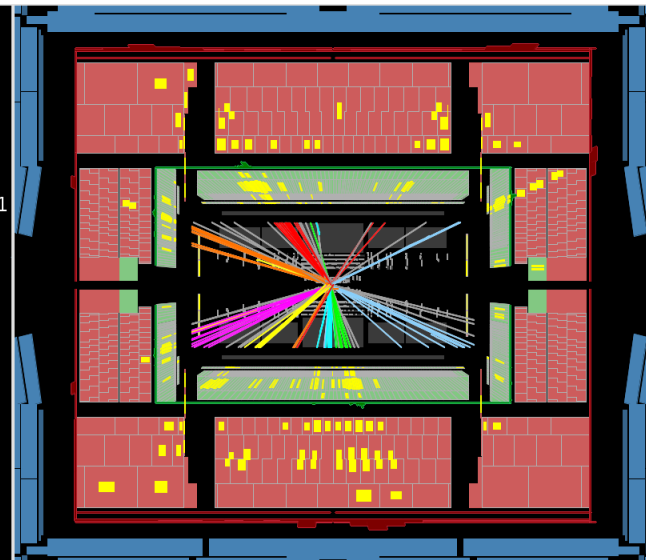
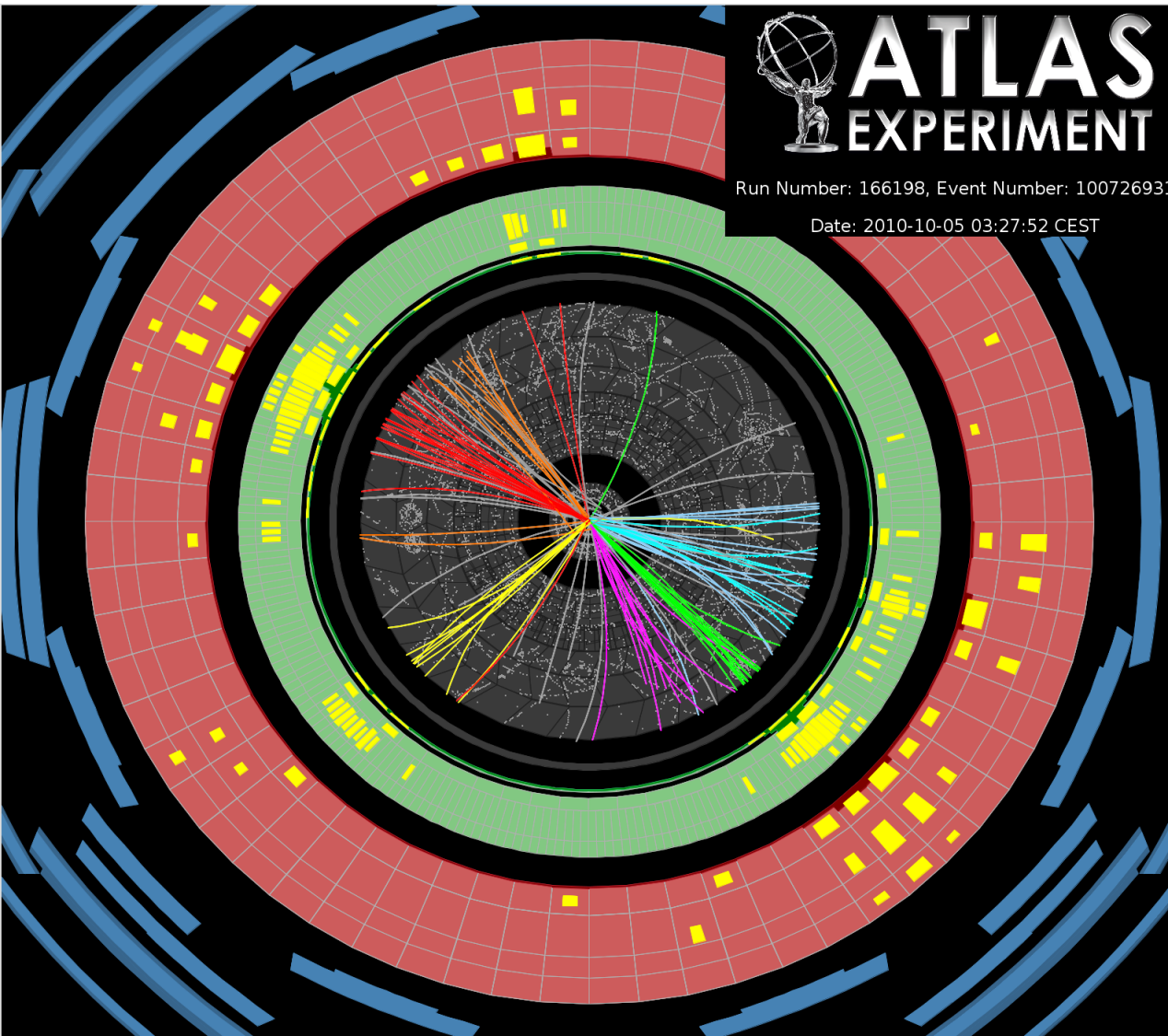
Highest mass di-jet

$p_T \text{ jet1} = 670 \text{ GeV}$,
 $p_T \text{ jet2} = 610 \text{ GeV}$, $m_{jj} = 3.7 \text{ TeV}$



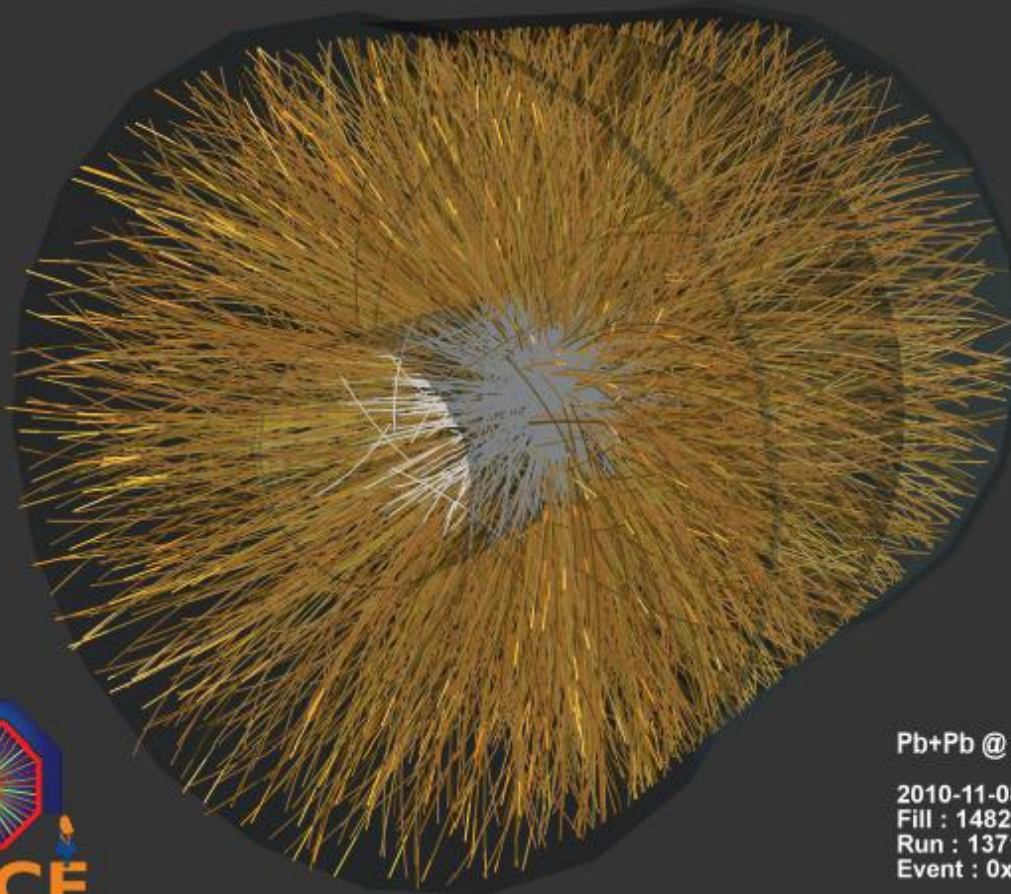
8-jet event

8 jets with $p_T > 60$ GeV



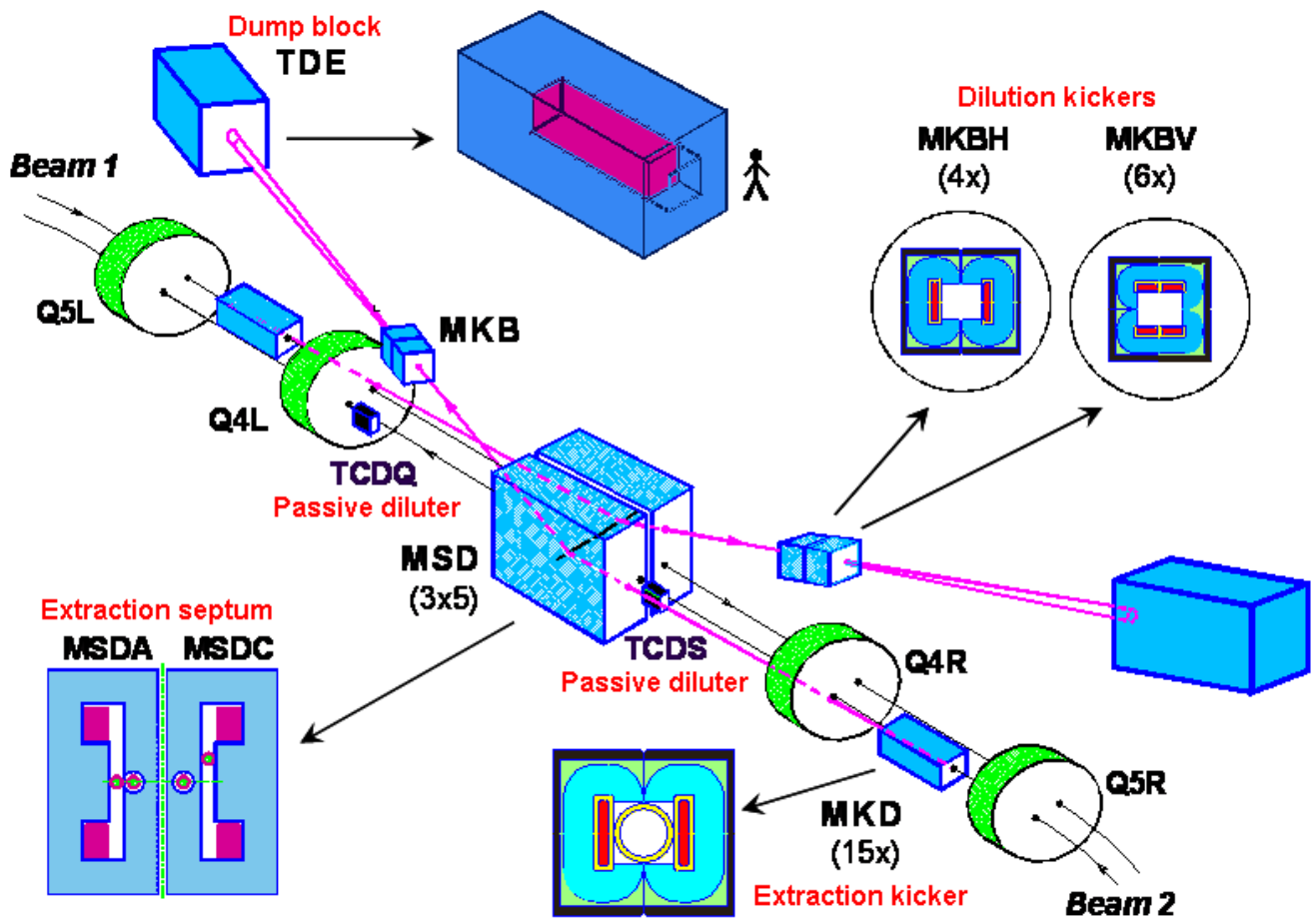
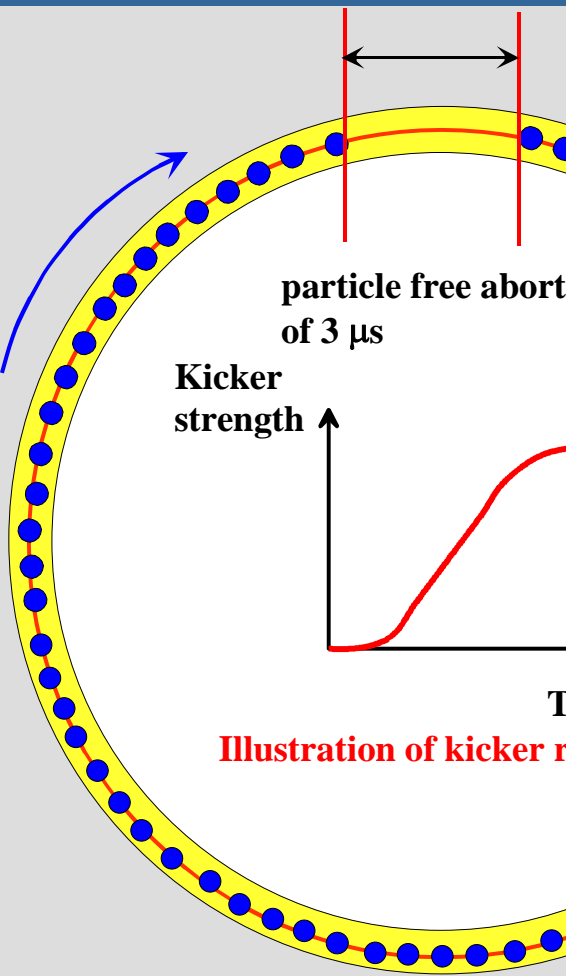
Pb-Pb collisions $\sqrt{s_{NN}} = 2.76 \text{ TeV} !$

→ **largest energy jump ($\times 14$) in the history of heavy-ion physics!**





Beam Dump System



Der Beam Dump

