



European Organization for Nuclear Research Über 50 Jahre Grundlagenforschung

CERN

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

Dr. Sascha Marc Schmeling
CERN PH



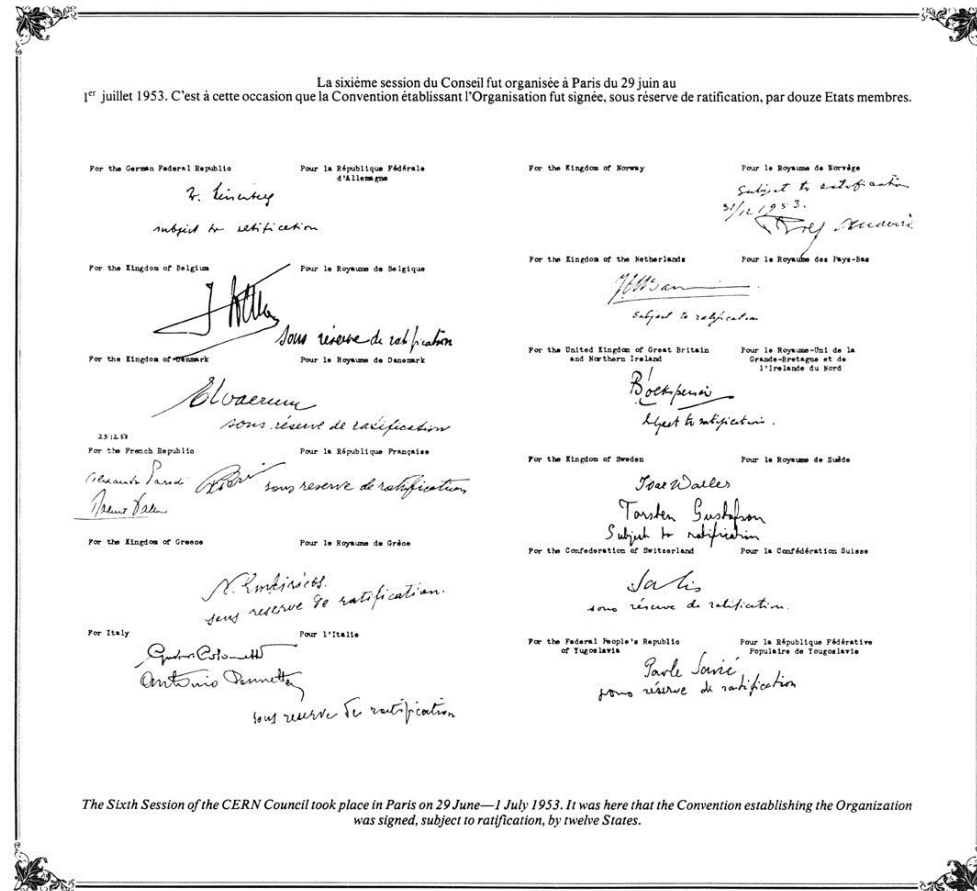
CERN – Eine Einführung

- 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



CERN was founded 1954: 12 European States

“Science for Peace”

Today: 20 Member States



~ 2300 staff

~ 980 other paid personnel

> 10000 users

Budget (2012) ~1000 MCHF

Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom

Candidate for Accession: Romania

Associate Member in the Pre-Stage to Membership: Israel

Applicant States: Cyprus, Serbia, Slovenia, Turkey

Observers to Council: India, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO



Physics Department



CERN – Das Laboratorium



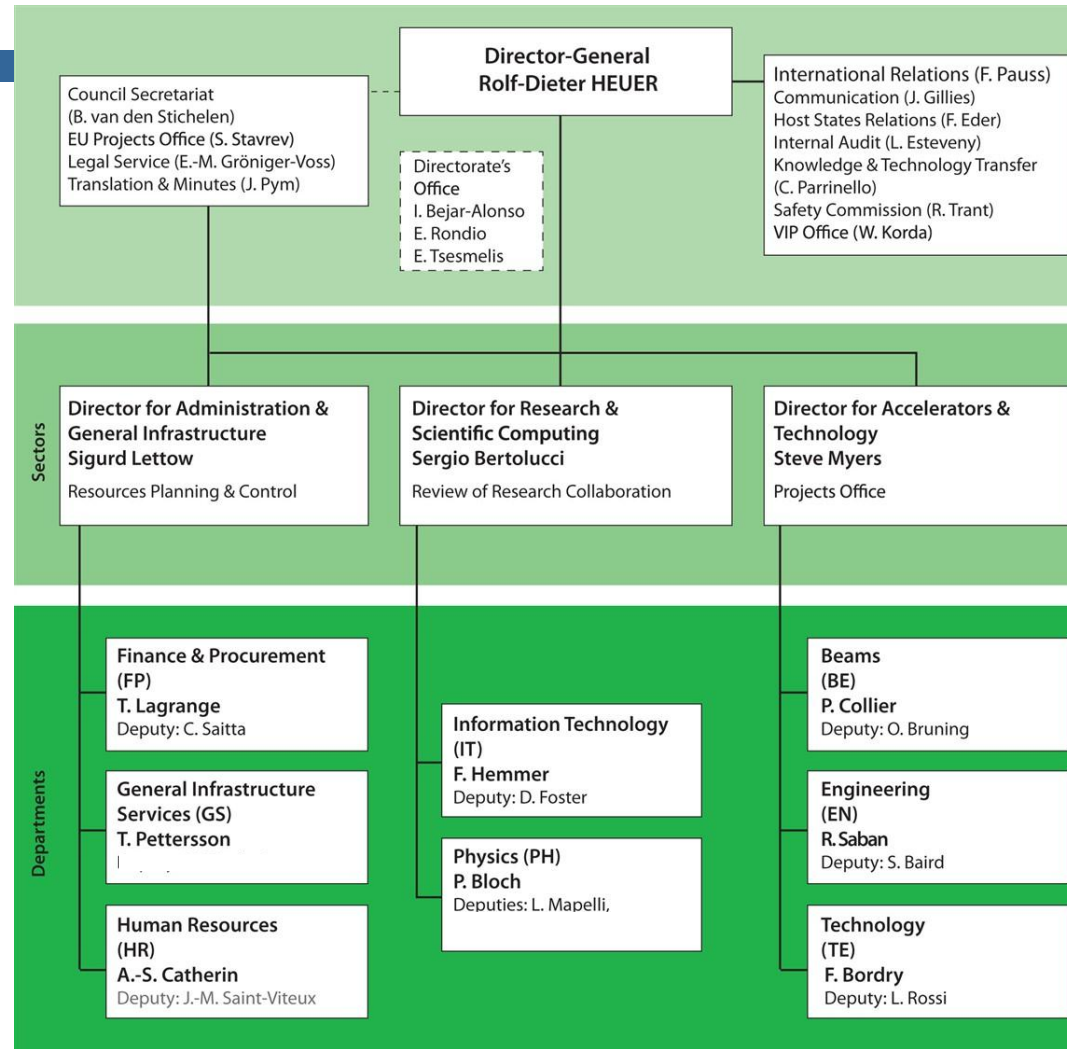


CERN Organisation

- **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

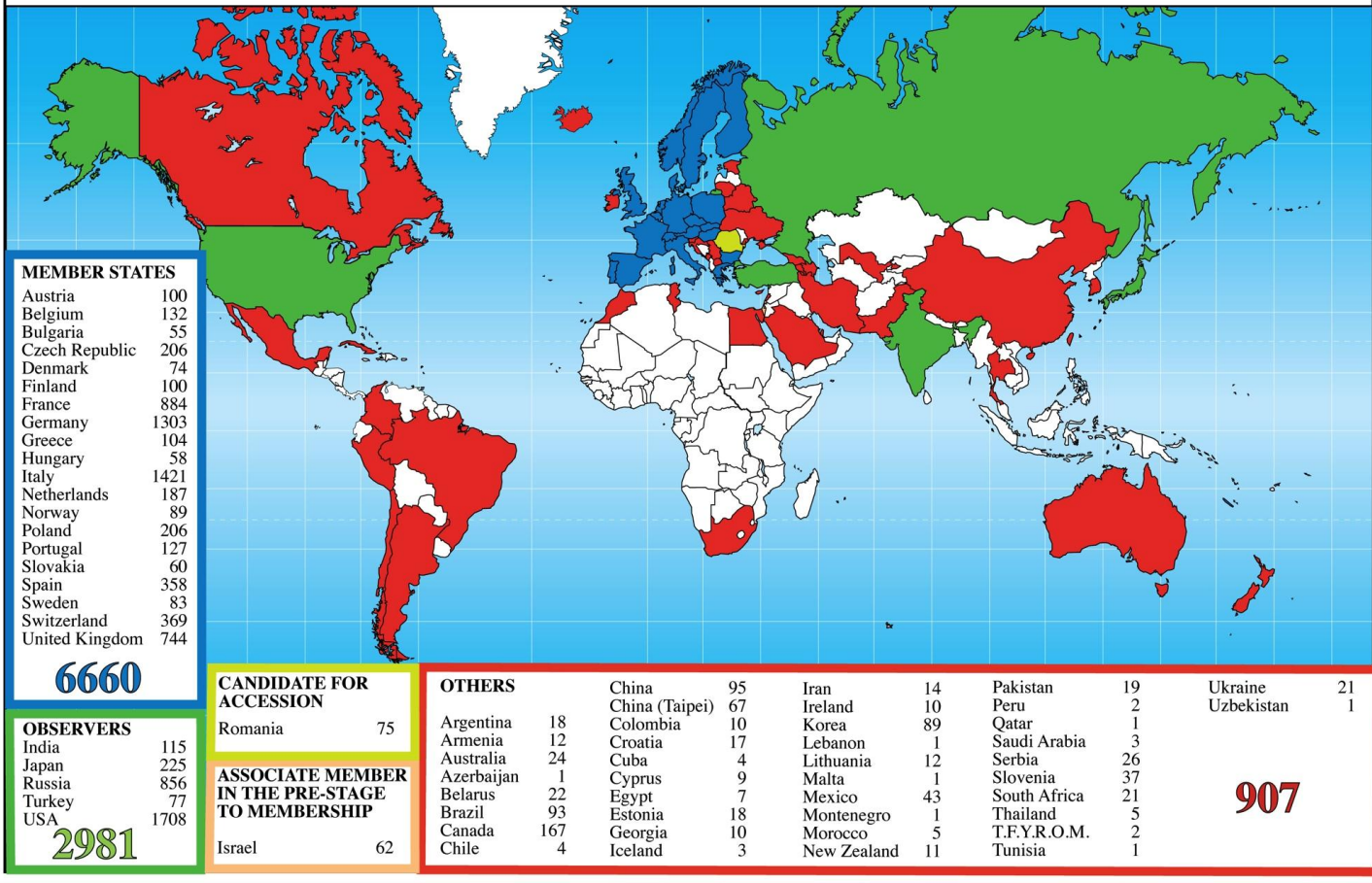
Firmen

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"

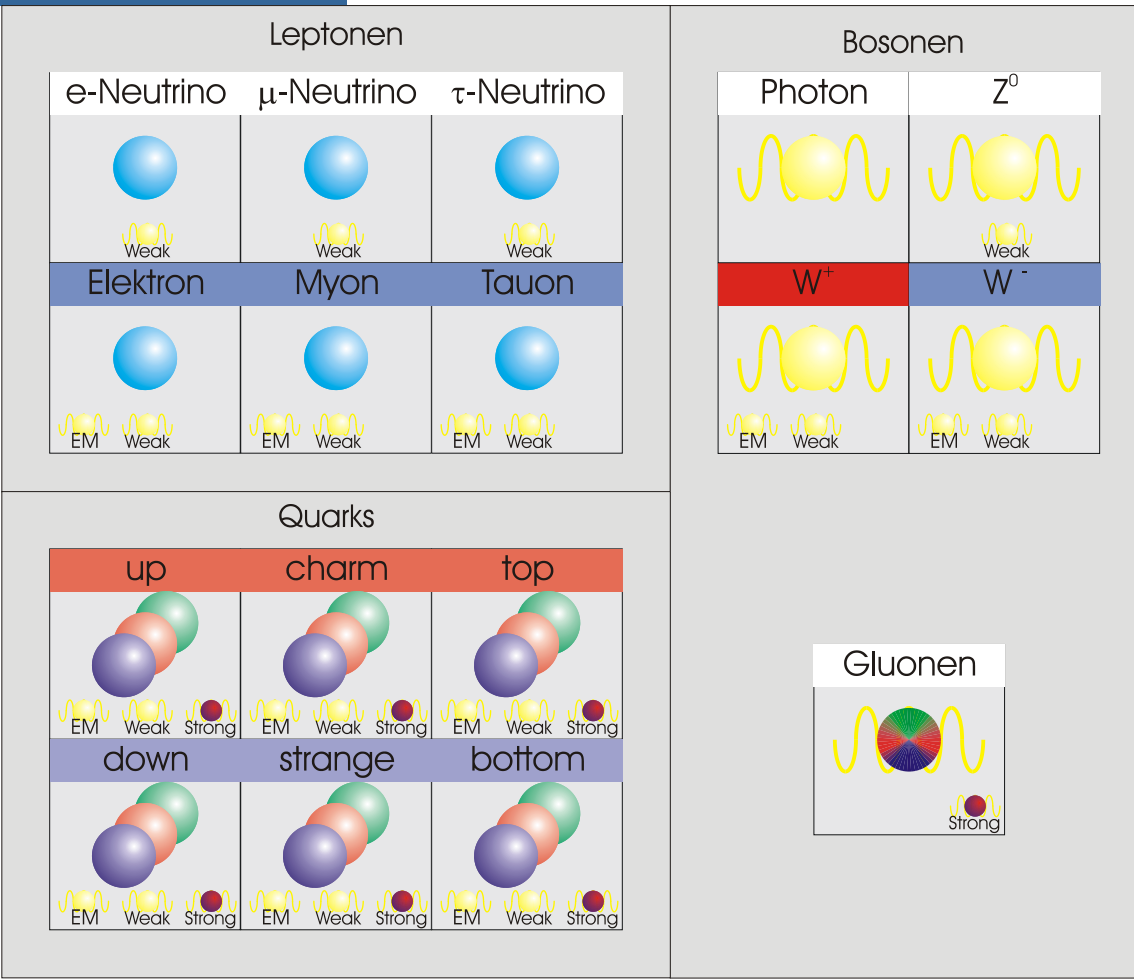
- Suche nach
 - elementaren Teilchen
 - Kräften
 - Symmetrien



Das Standardmodell

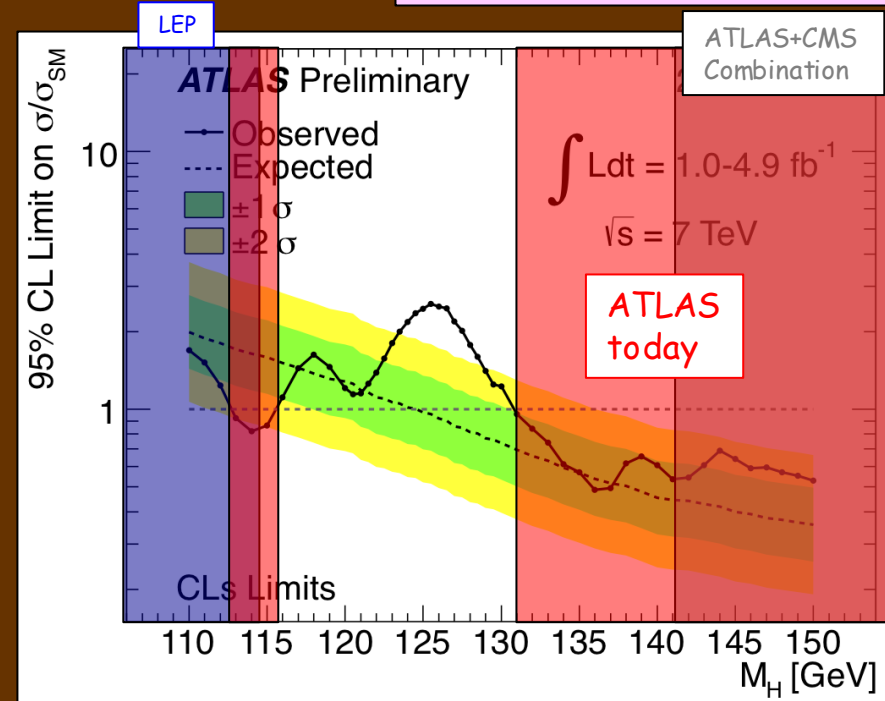
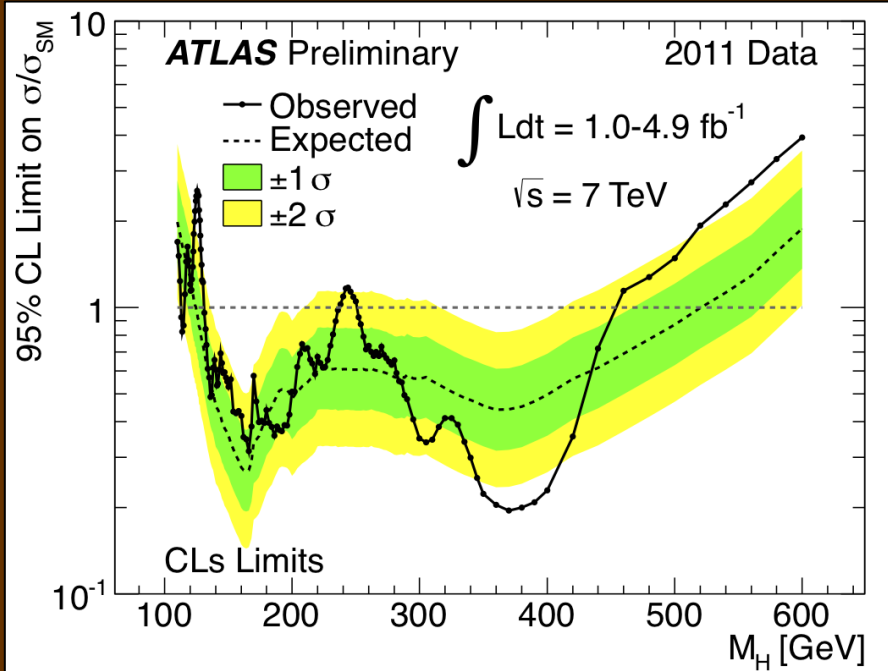
... ist ...

- ... 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

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



Excluded at 95% CL

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

Expected if no signal

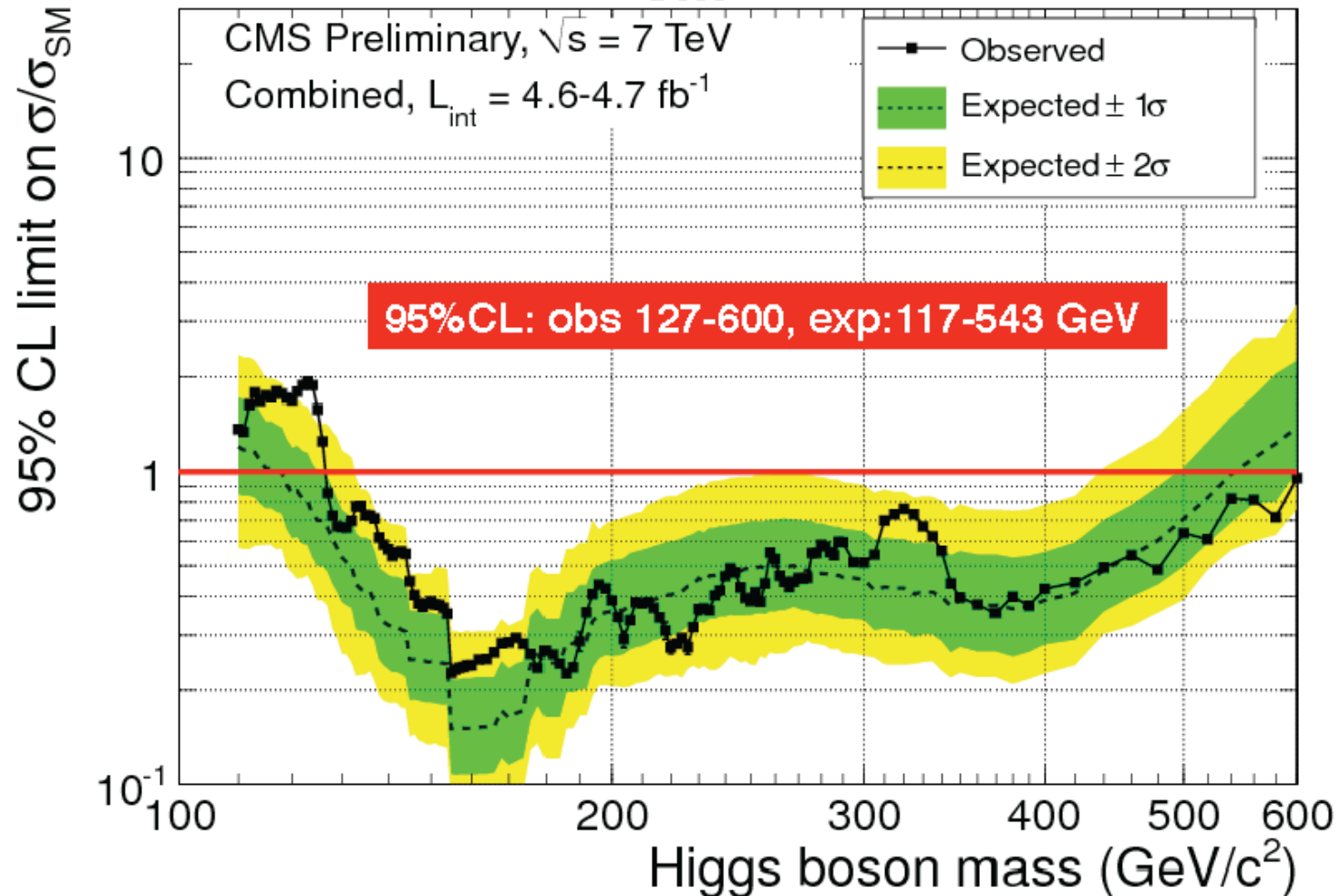
124.6-520 GeV

Excluded at 99% CL

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



Limits on σ/σ_{SM} (CLs method)





LHCb

ATLAS

CERN Meyrin

SPS 7 km

ALICE

CERN Prévessin

CMS

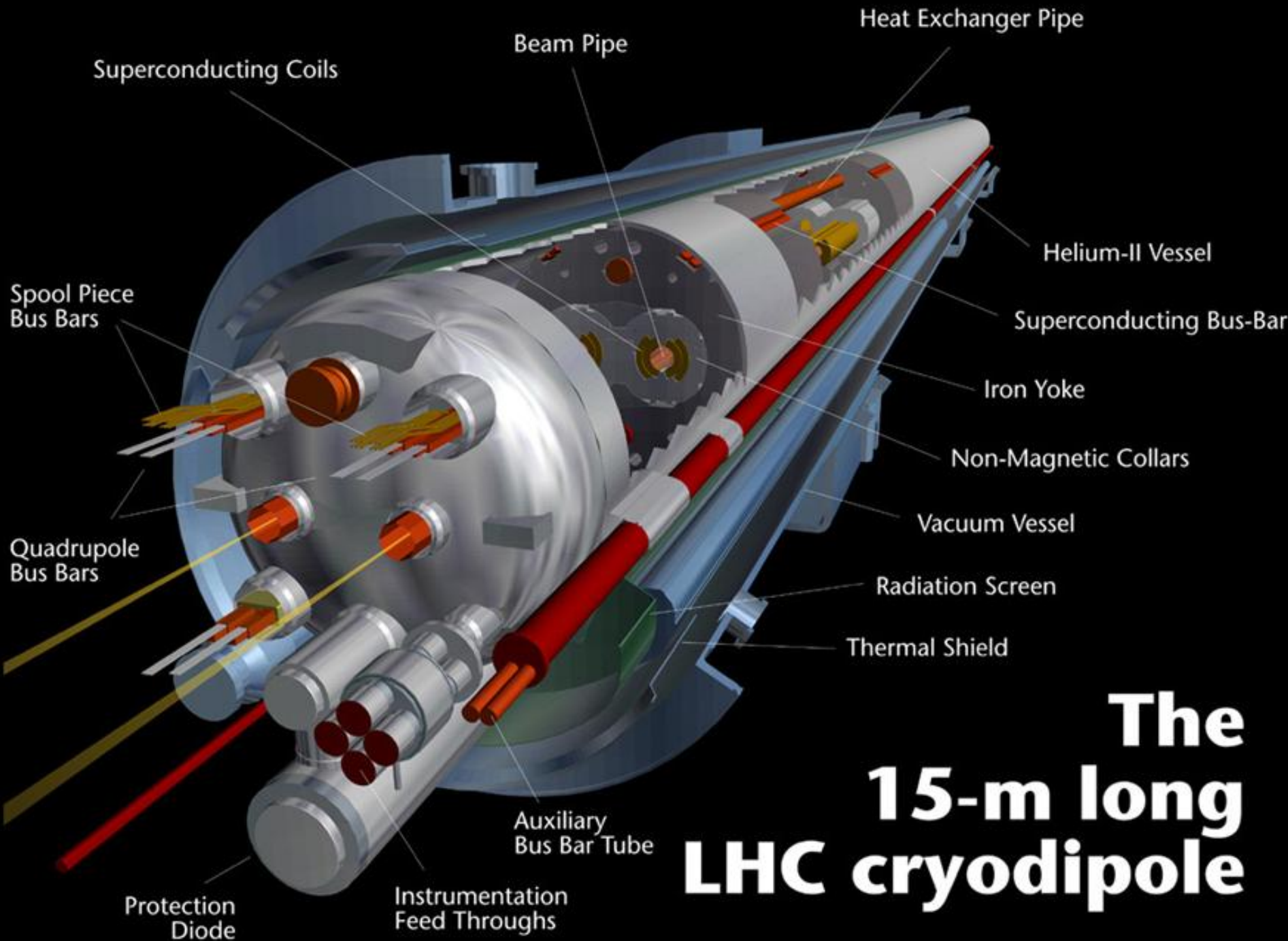
LHC 27 km

SUISSE
FRANCE



LHC – Von der Idee zum Beschleuniger

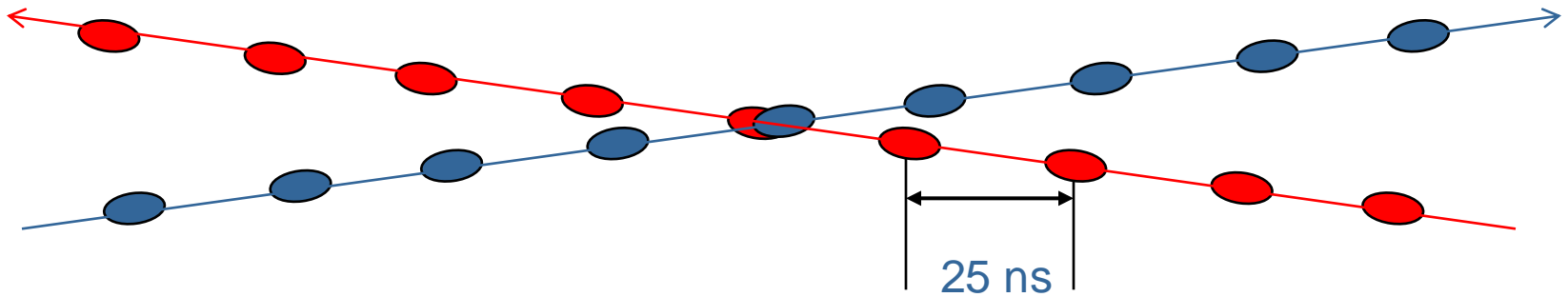
- 1982 : Erste Projektstudien
- 1983 : Z⁰-Ereignis am Sp^pS
- 1985 : Nobelpreis für S. van der Meer und C. Rubbia
- 1989 : Beginn des LEP-Betriebs (Z Factory)
- 1994 : Zustimmung zum LHC durch das Council
- 1996 : Endgültige Entscheidung zum Baubeginn
- 1996 : LEP Betrieb bei 100 GeV (W Factory)
- 2000 : 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

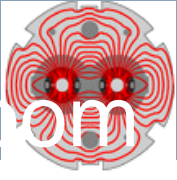
$$E_{\text{Dipol}} = 0.5 \cdot L_{\text{Dipol}} \cdot I_{\text{Dipol}}^2$$

gespeicherte Energie in einem Dipol: 7.6 MJ

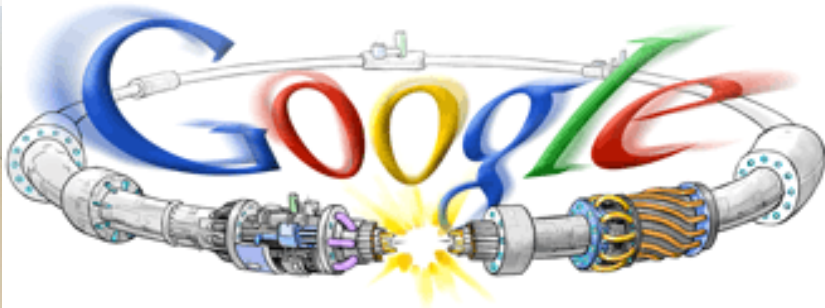
Gesamt für alle 1232 Dipole im LHC: 9.4 GJ

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





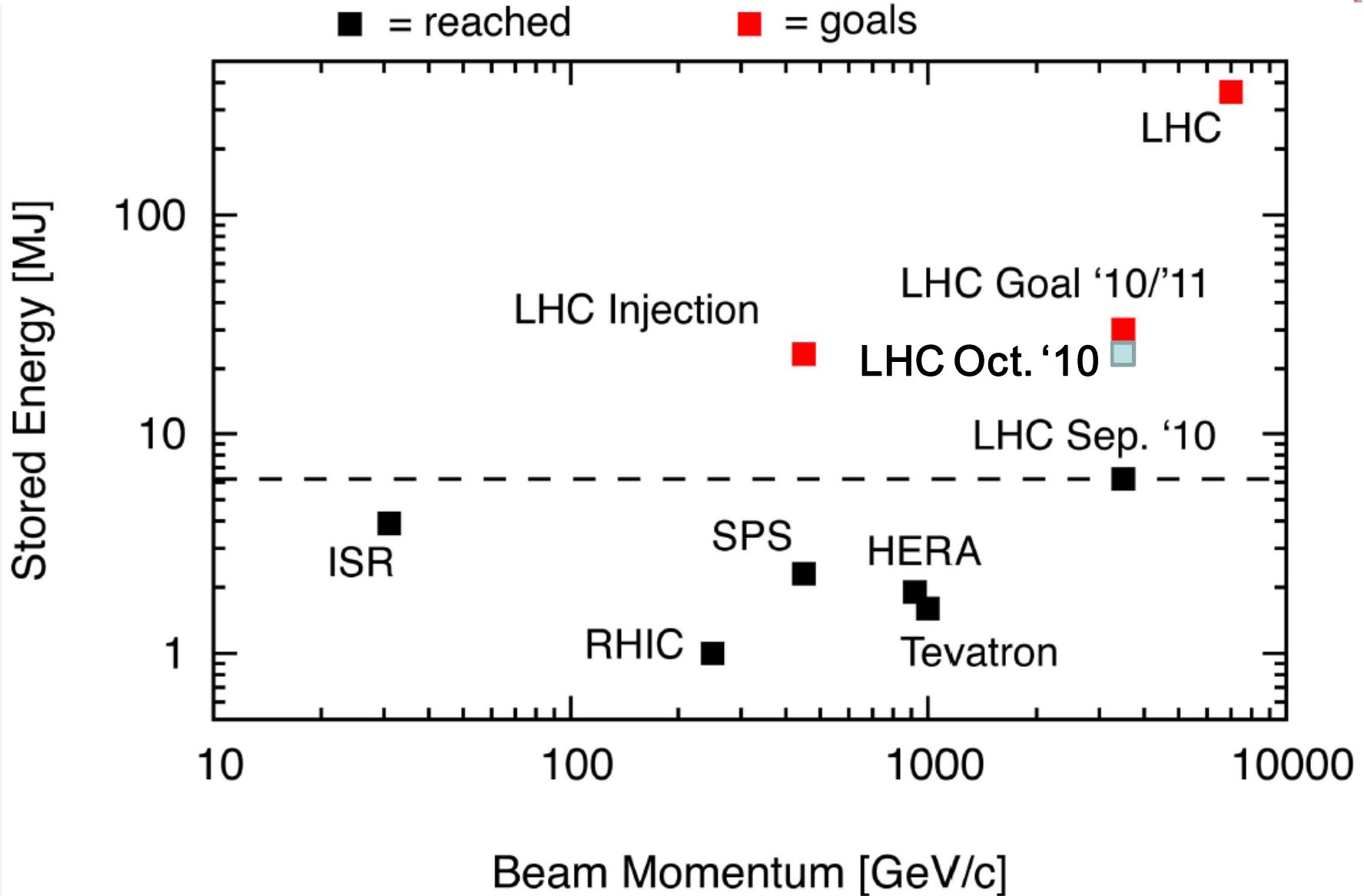
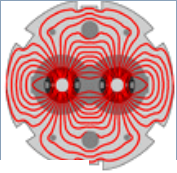
September 10th - control (show) room



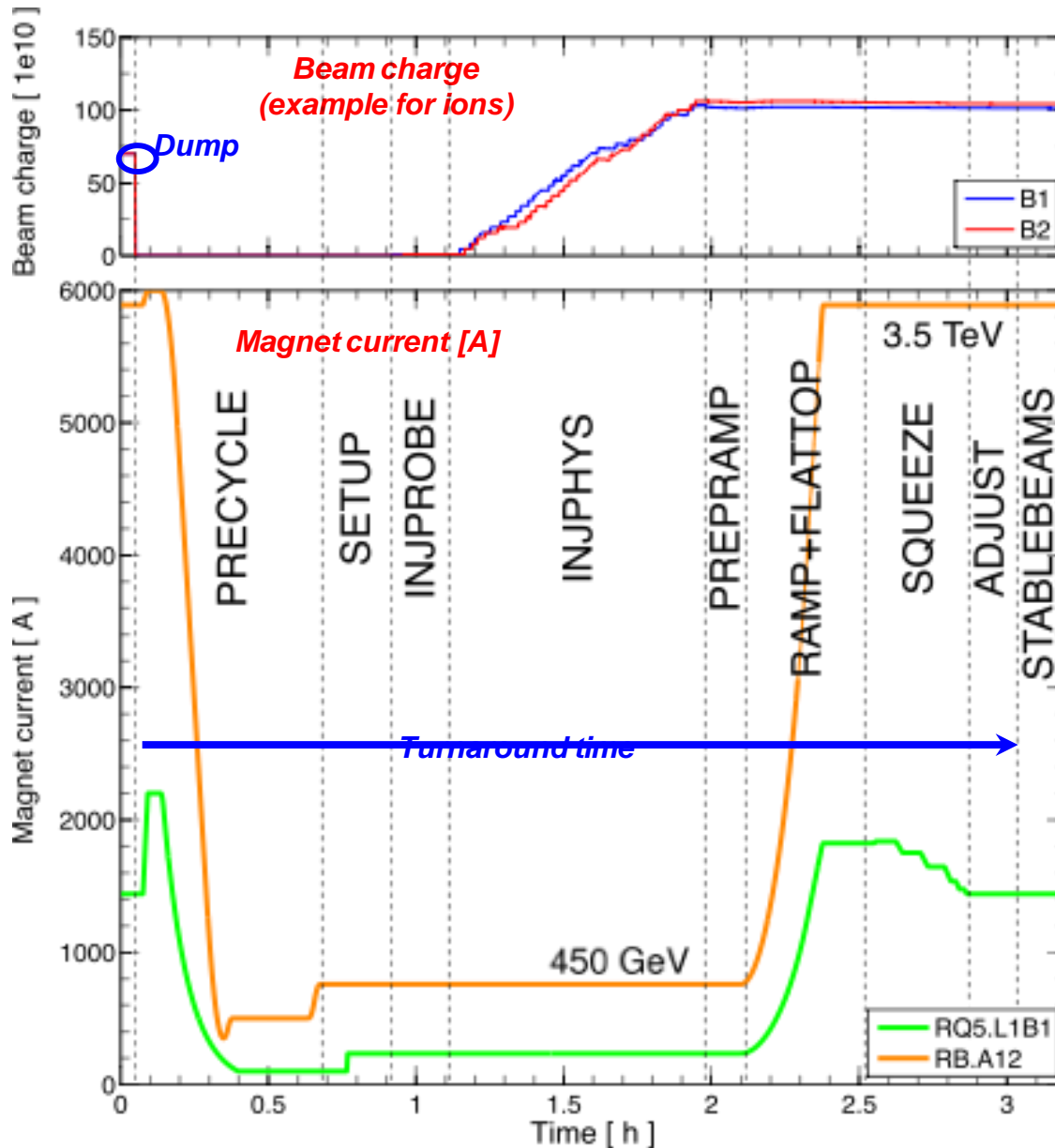
For 3 days all went perfectly well with beam...



LHC now on its own in terms of stored



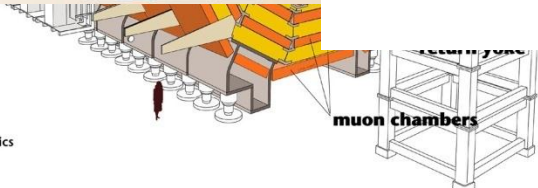
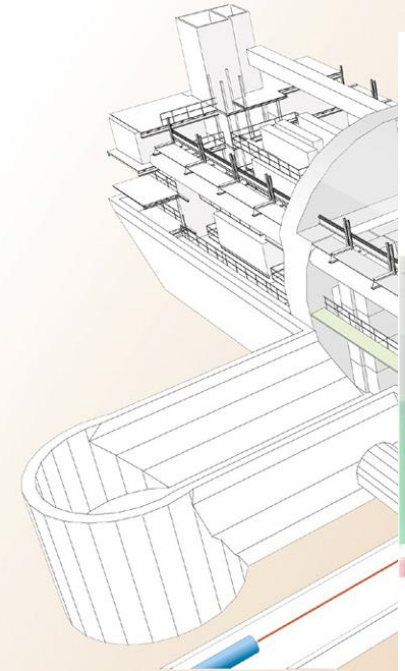
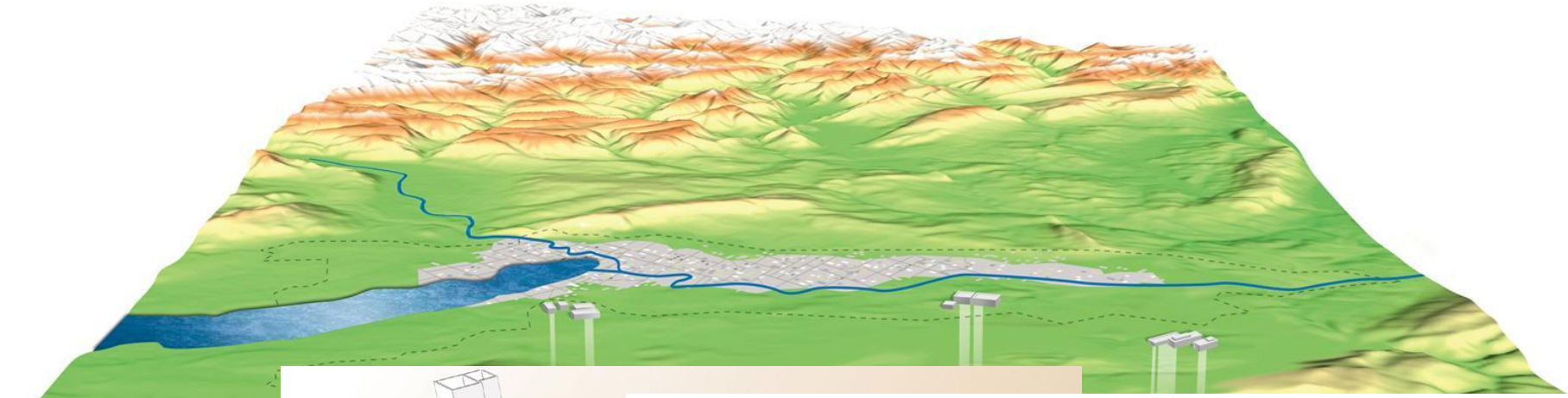
Recap.: operational cycle



Time-functions for settings of
 (1) ramp,
 (2) squeeze(s),
 (3) collisions,
 (4) pre-cycle (without beam).

Discrete (“actual”) settings for:
 (1) injection,
 (2) prepare ramp,
 (3) flat-top,
 (4) adjust (end of squeeze),
 (5) stable beams.

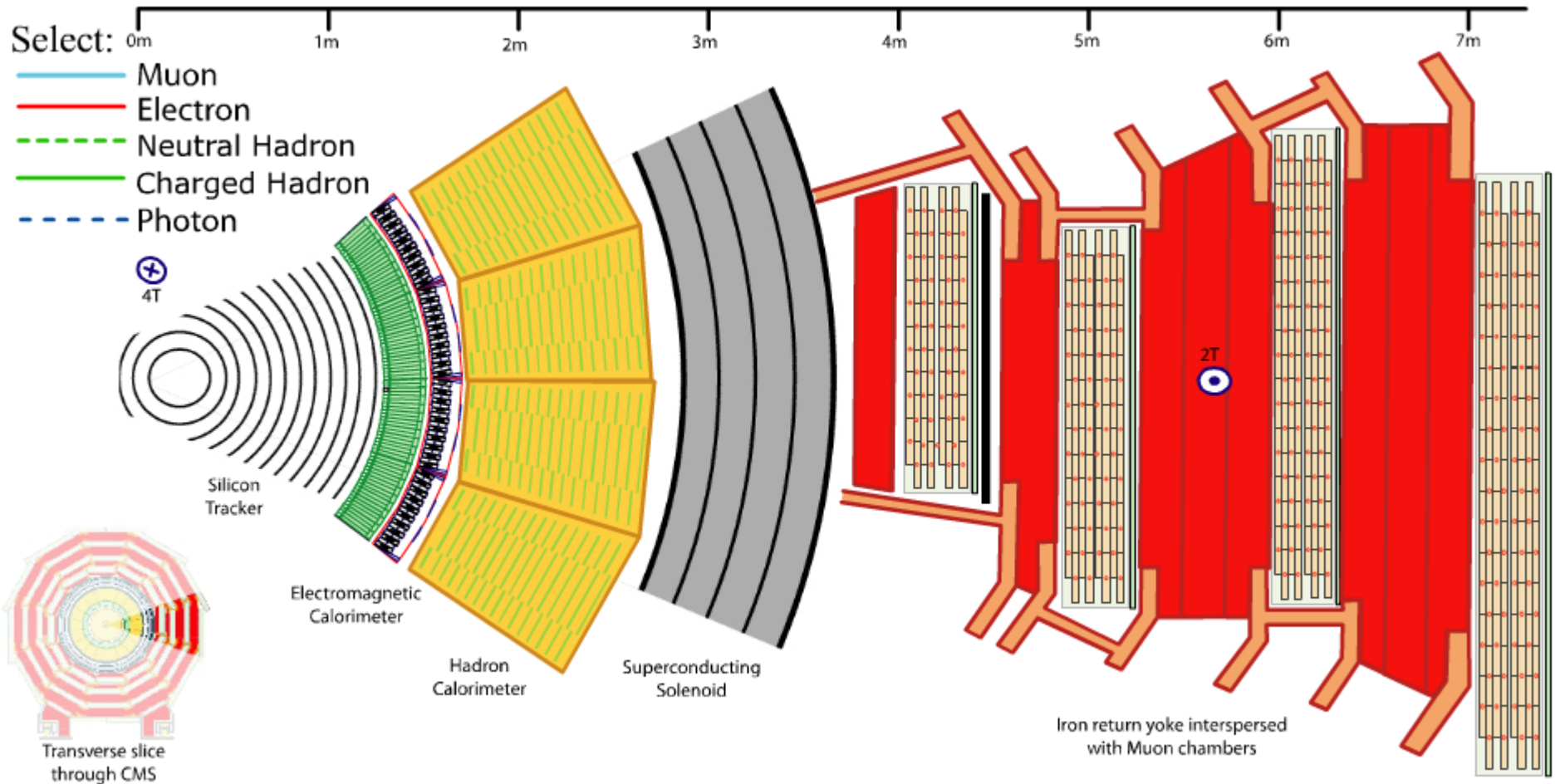
Remark:
 Machine recovery after dump
 at top energy full in the shade
 of the pre-cycle → analysis
 starts from injection



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:

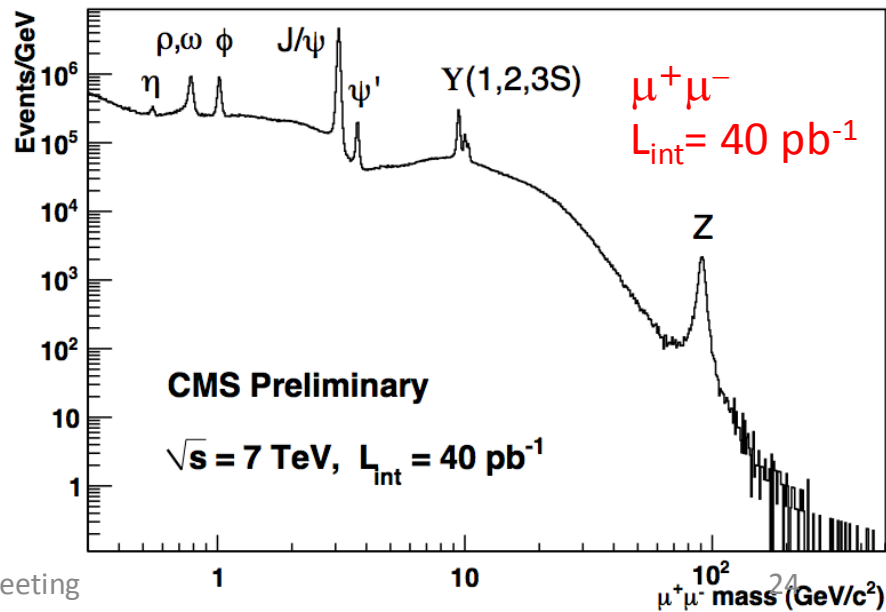
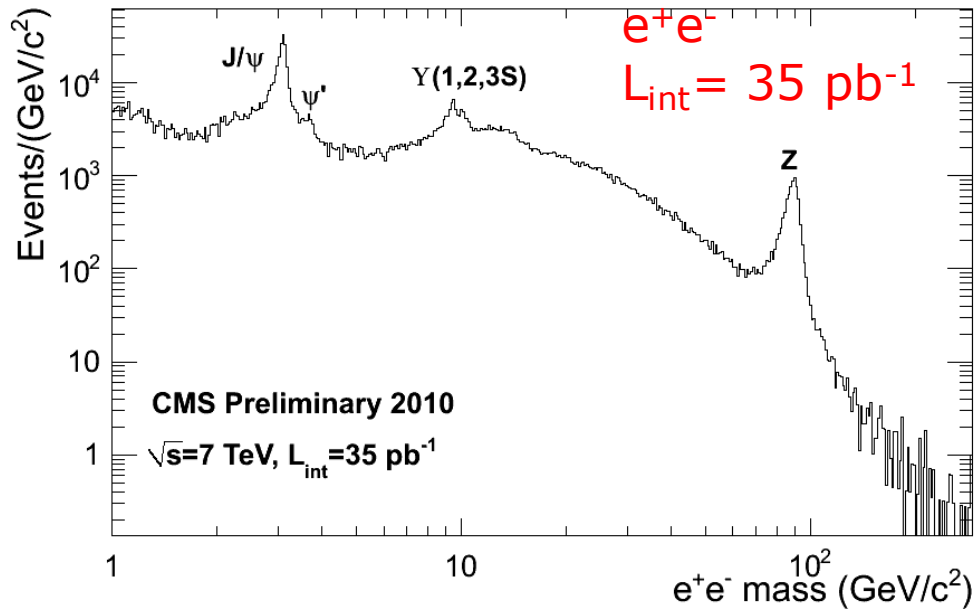
J/ Ψ 52 MeV

Y 149 MeV

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

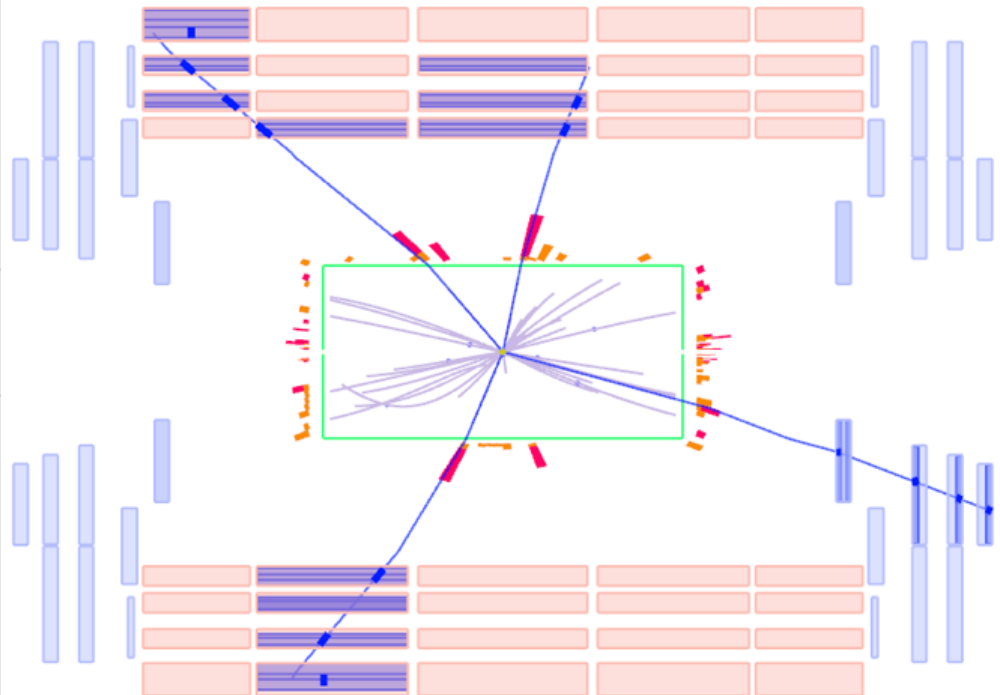
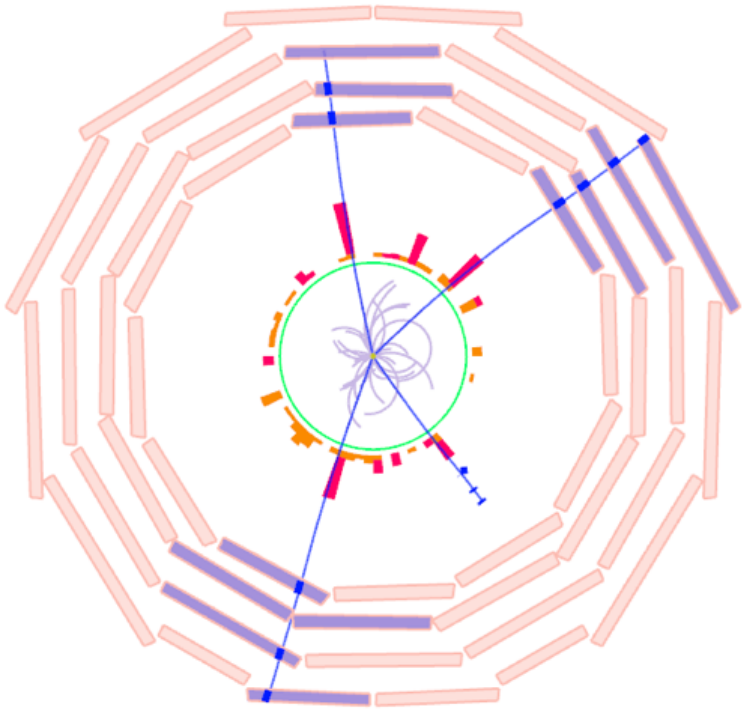
J/ Ψ 30 MeV

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).

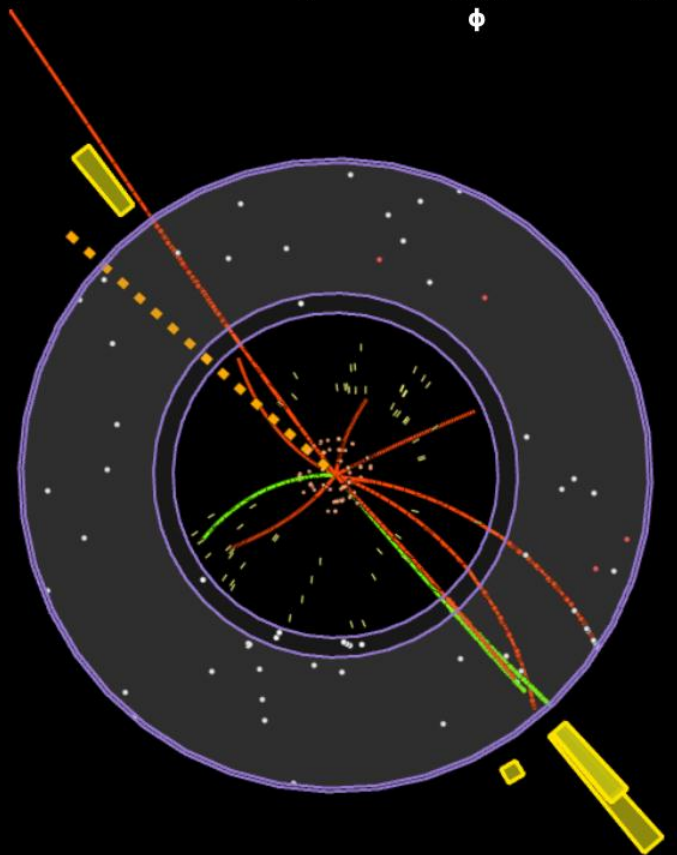
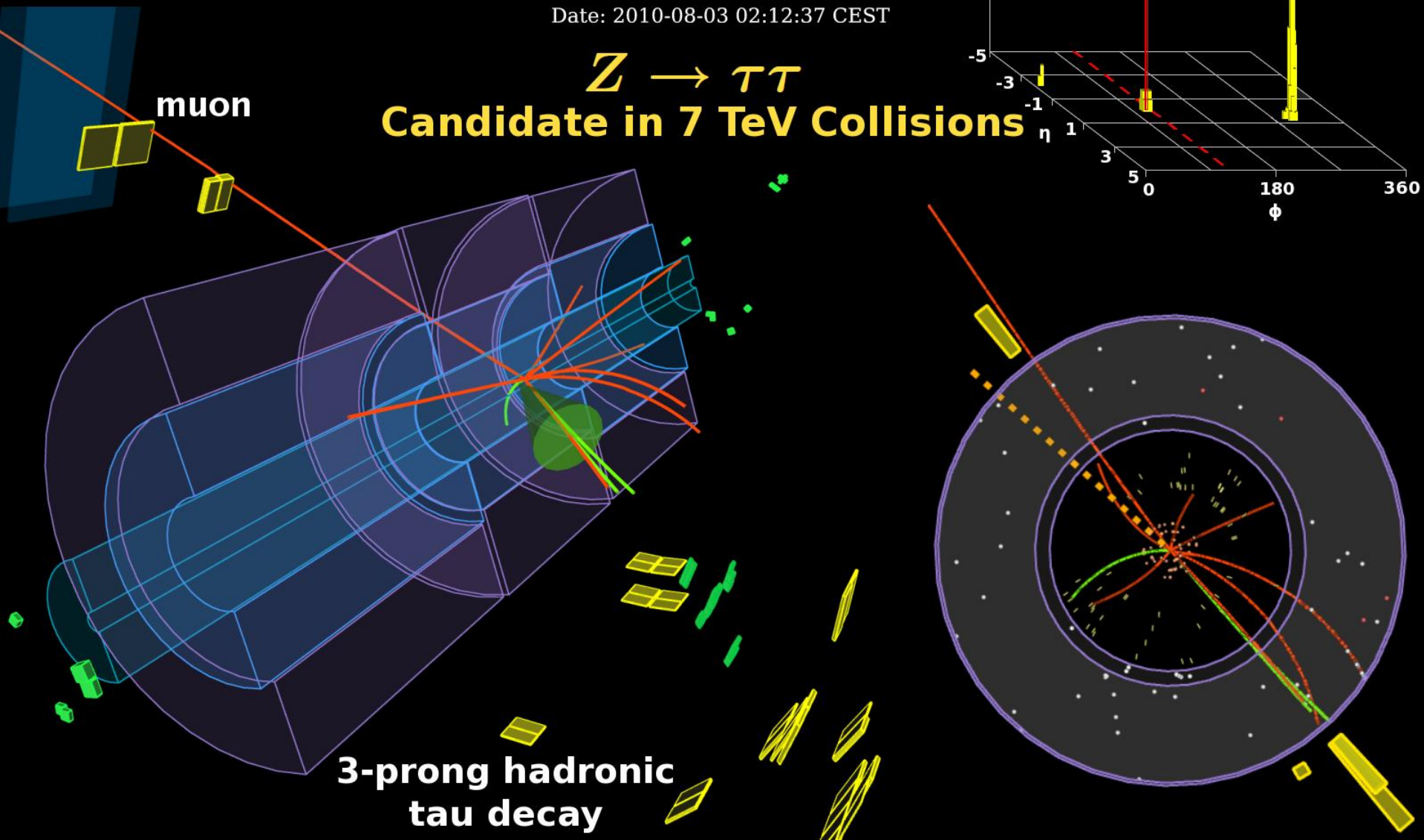
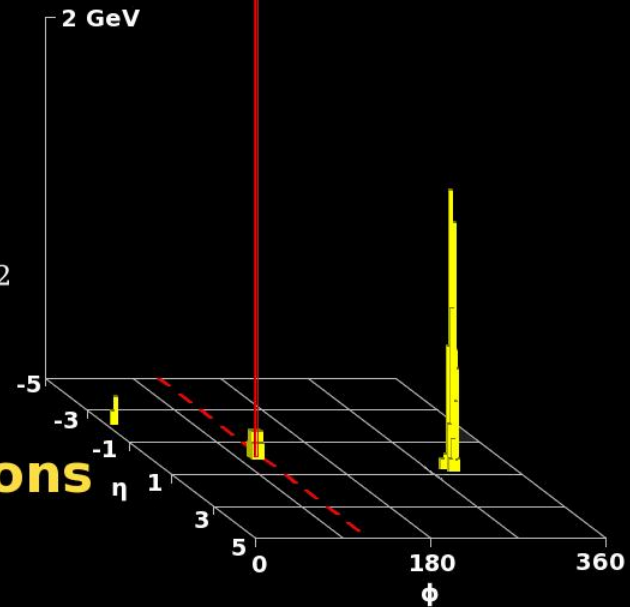
$p_T(\mu) = 18 \text{ GeV}$
 $p_T^{\text{vis}}(\tau_h) = 26 \text{ GeV}$
 $m_{\text{vis}}(\mu, \tau_h) = 47 \text{ GeV}$
 $m_T(\mu, E_T^{\text{miss}}) = 8 \text{ GeV}$
 $E_T^{\text{miss}} = 7 \text{ GeV}$

ATLAS EXPERIMENT

Run Number: 160613, Event Number: 9209492

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

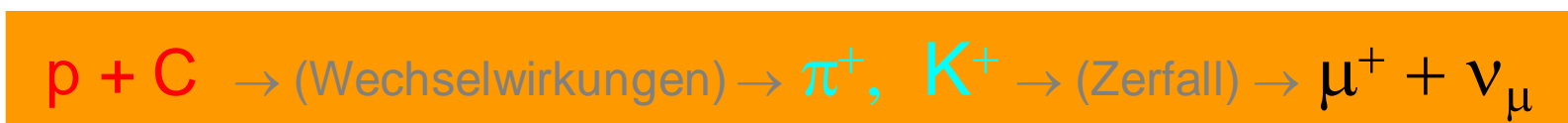
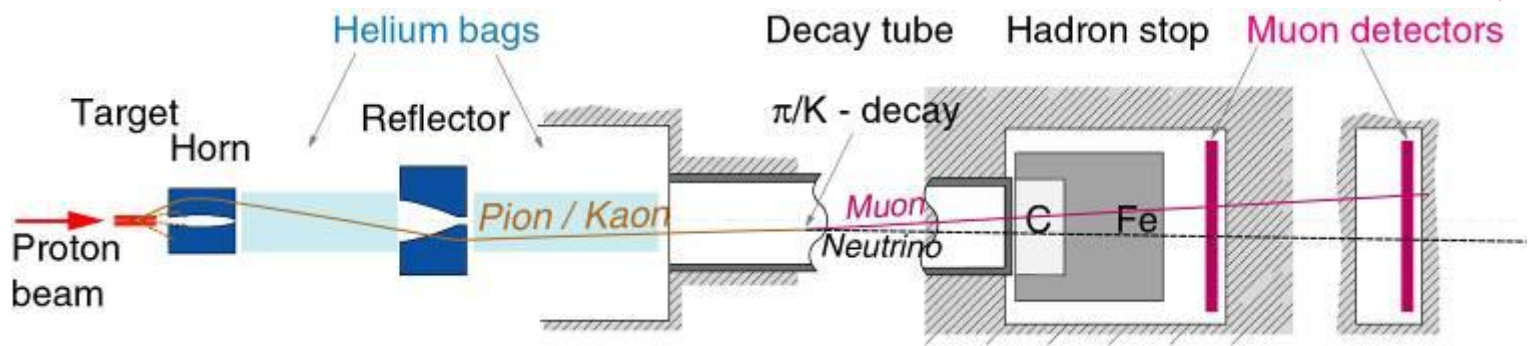
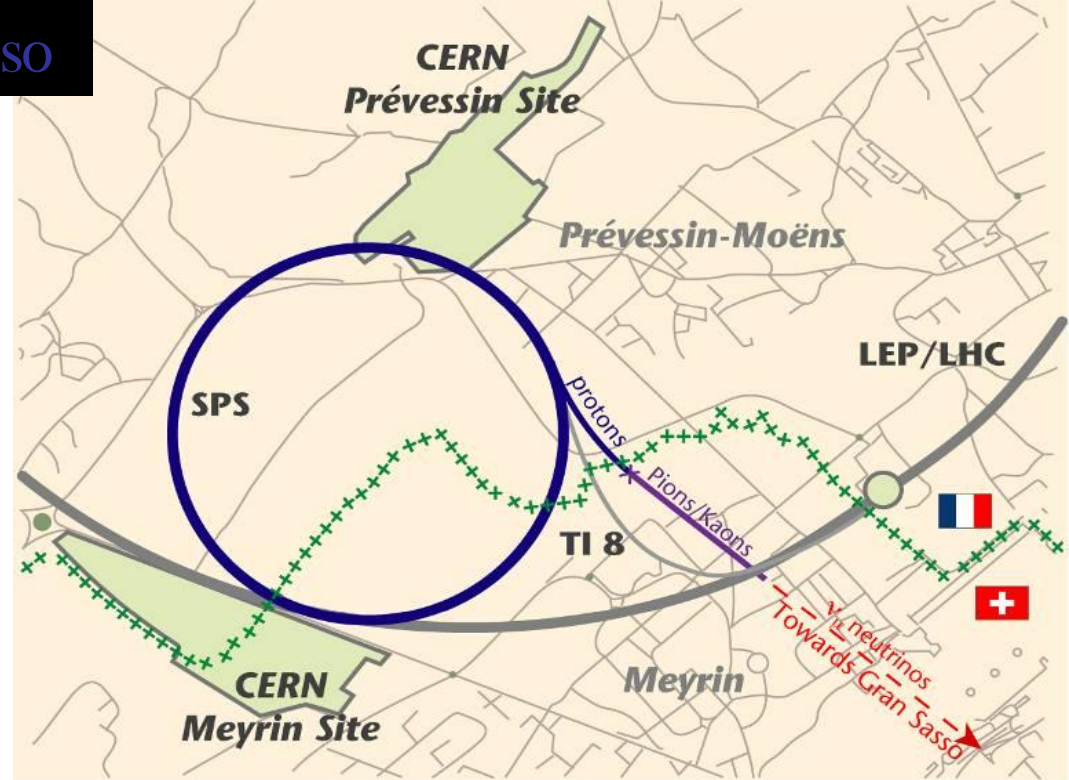
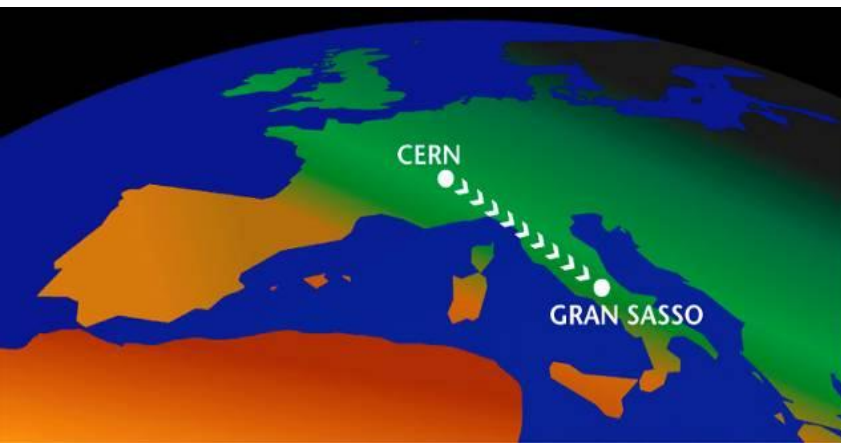
$Z \rightarrow \tau\tau$ Candidate in 7 TeV Collisions

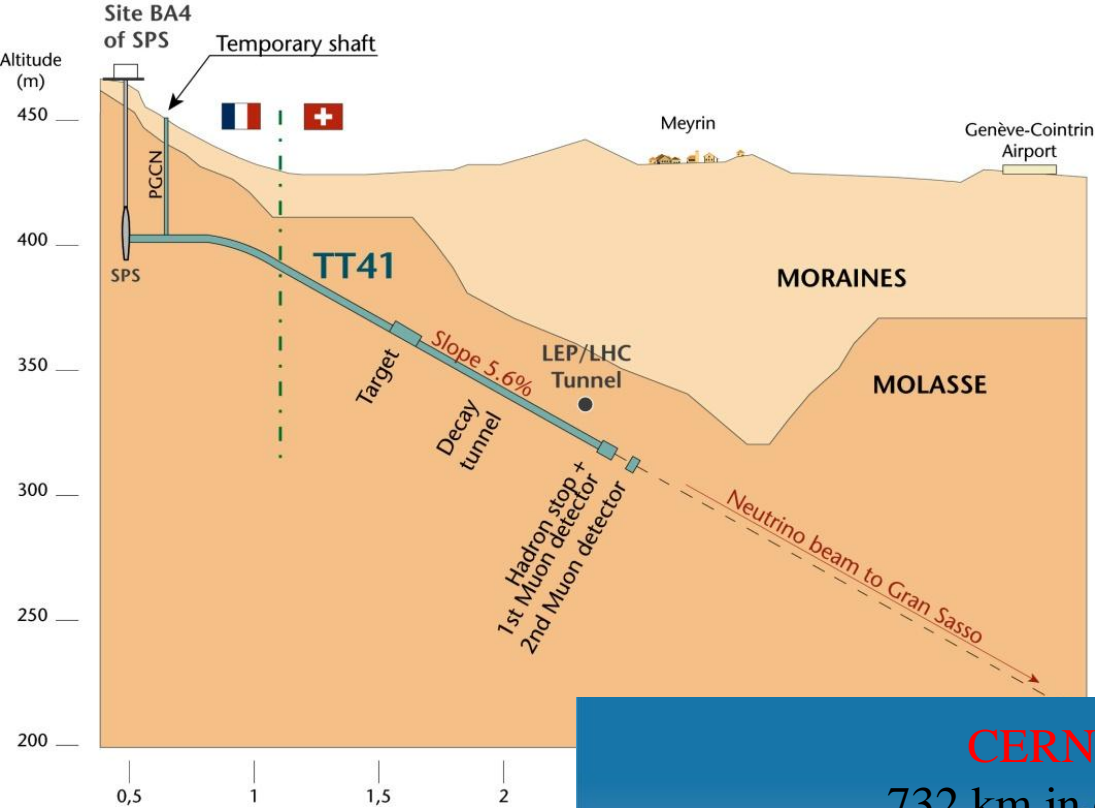


Weitere Aktivitäten am CERN

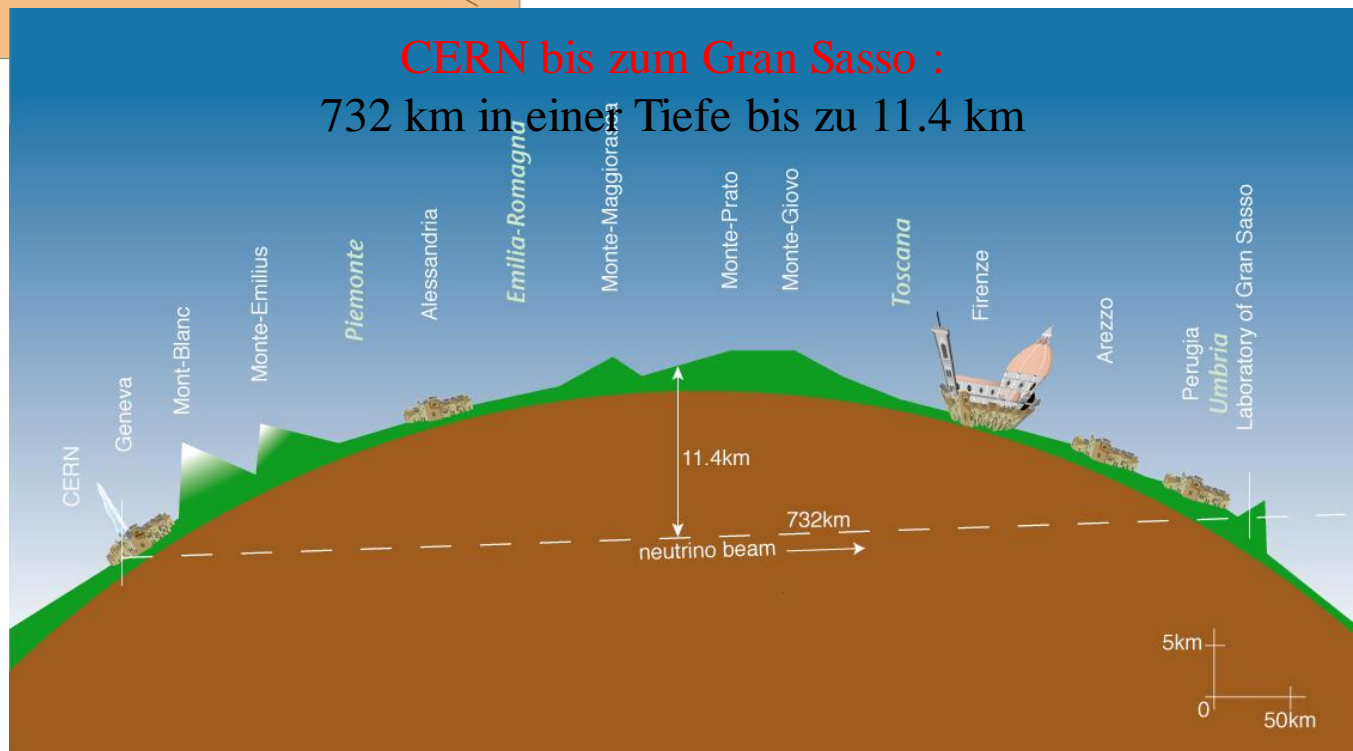
... eine kleine Auswahl ...

CERN Neutrinos zum Gran Sasso

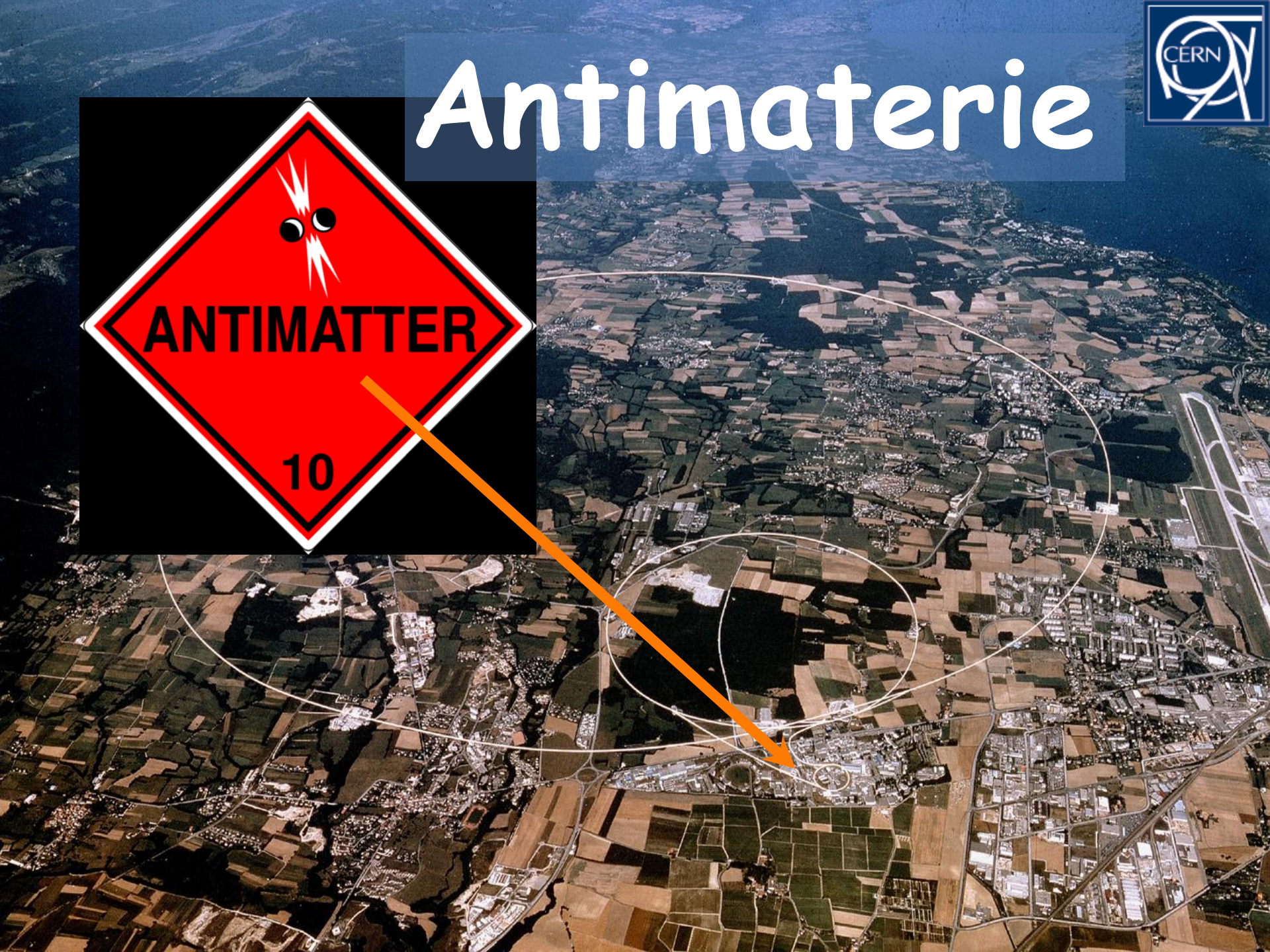
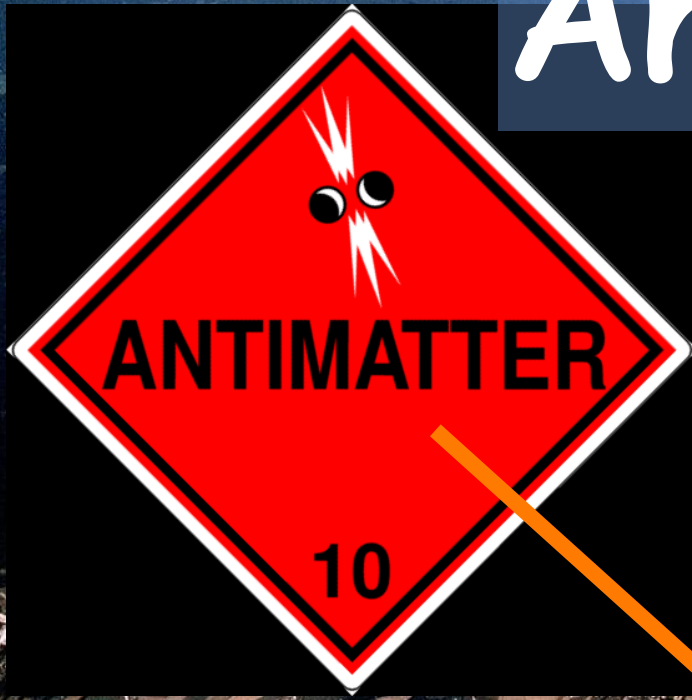




CERN bis zum Gran Sasso :
732 km in einer Tiefe bis zu 11.4 km



Antimaterie



Was ist Antimaterie?

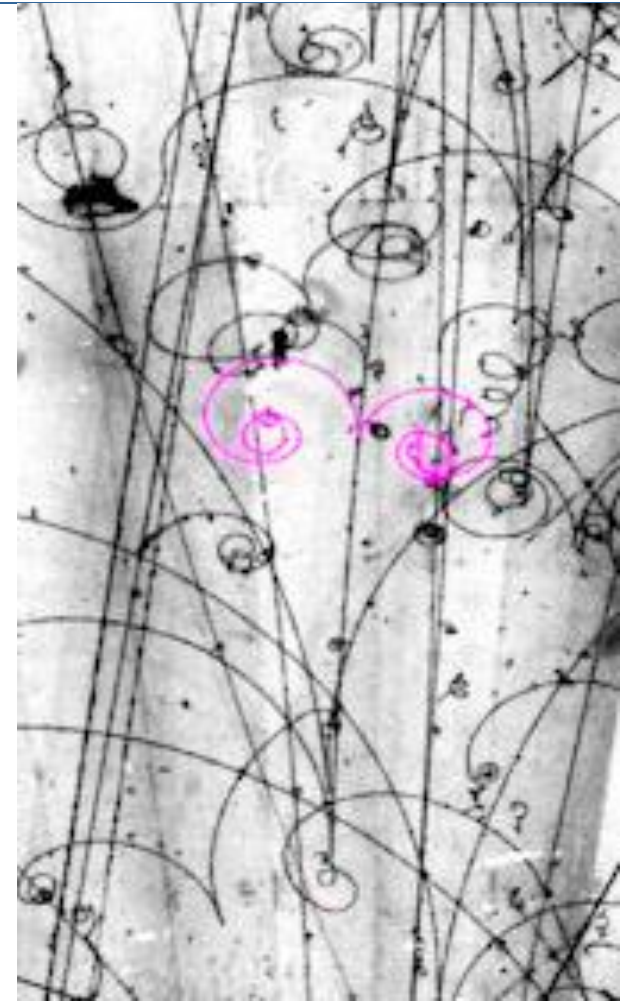
- Einstein
 - "Materie ist kondensierte Energie!"

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



Elektron

Positron

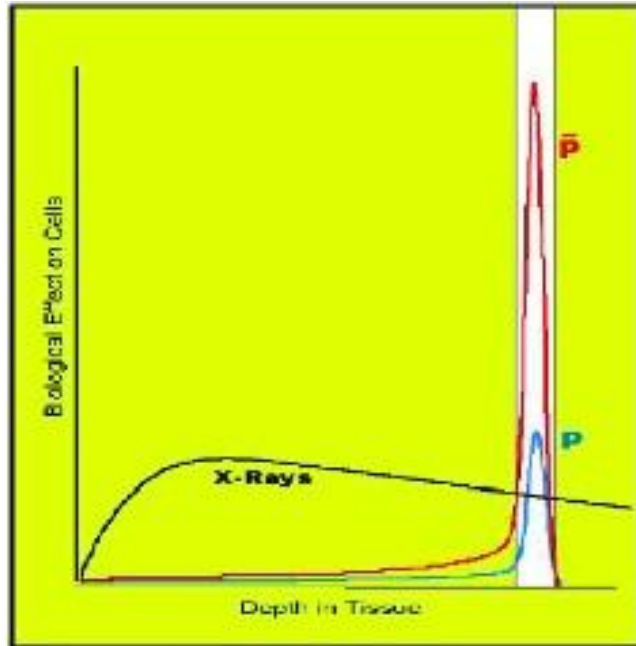
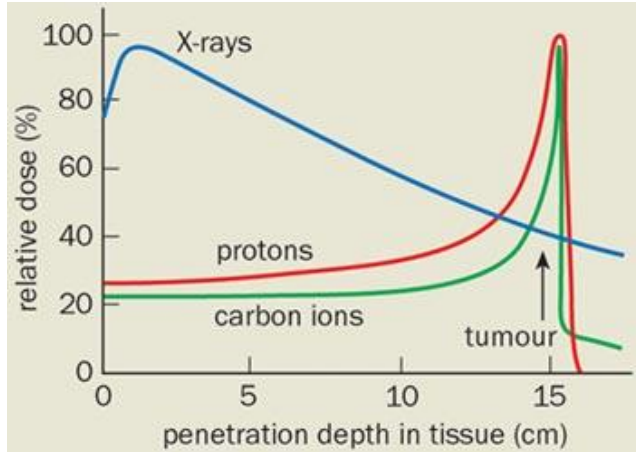


Snobs & Spoons

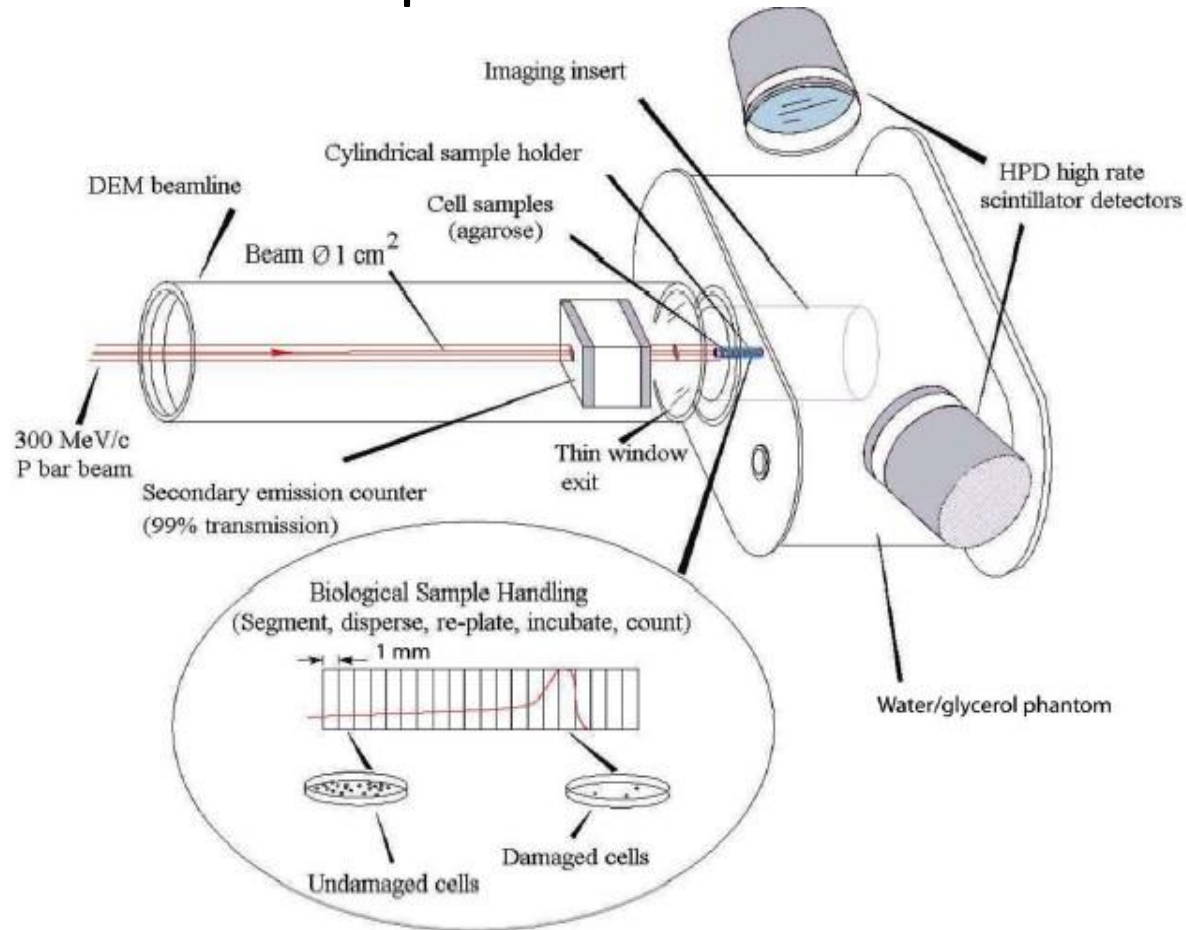


Tom's Angels and demons

Anwendung von Antimaterie - Tumorbekämpfung



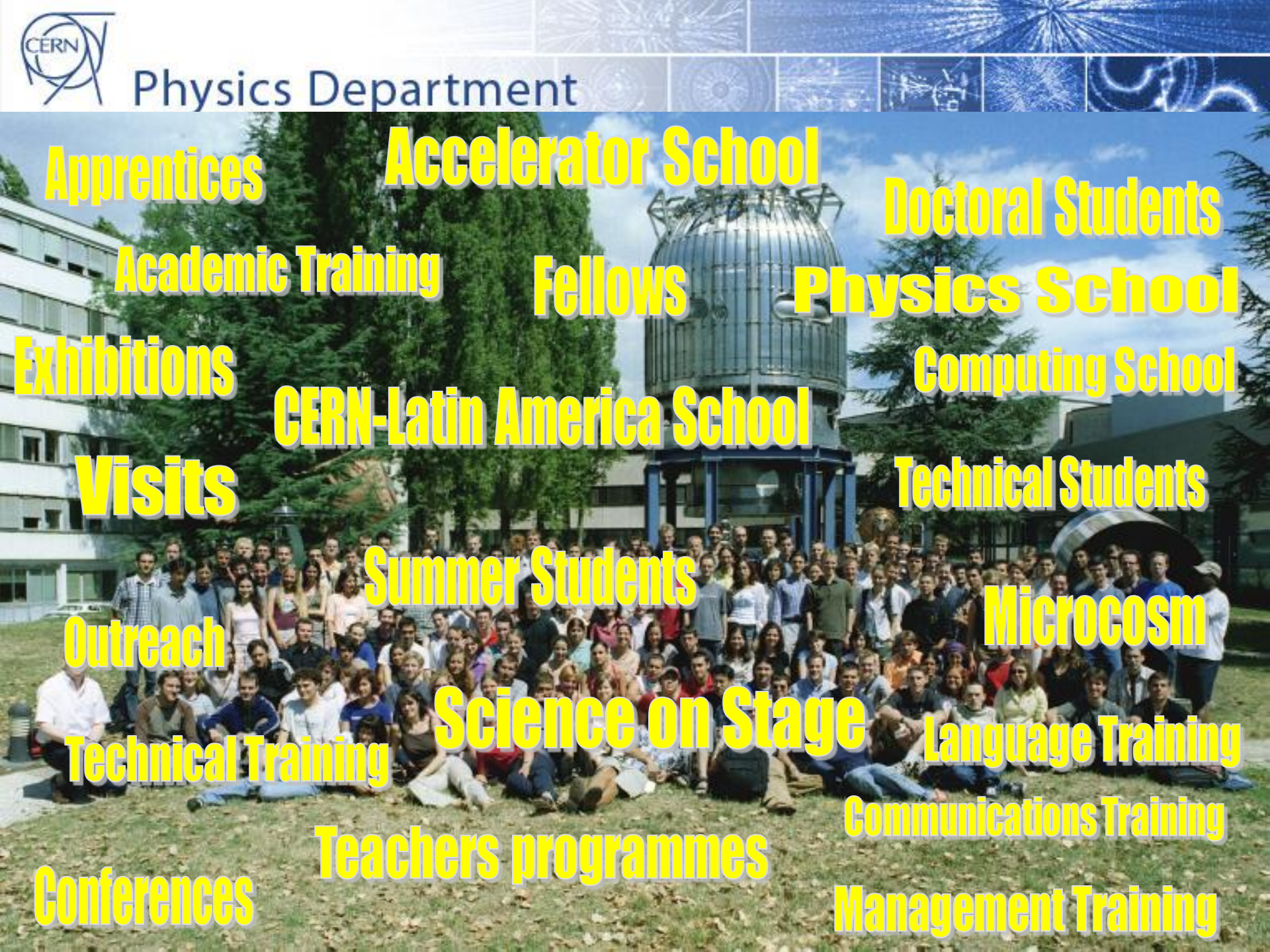
ACE Experiment bei CERN



*) 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

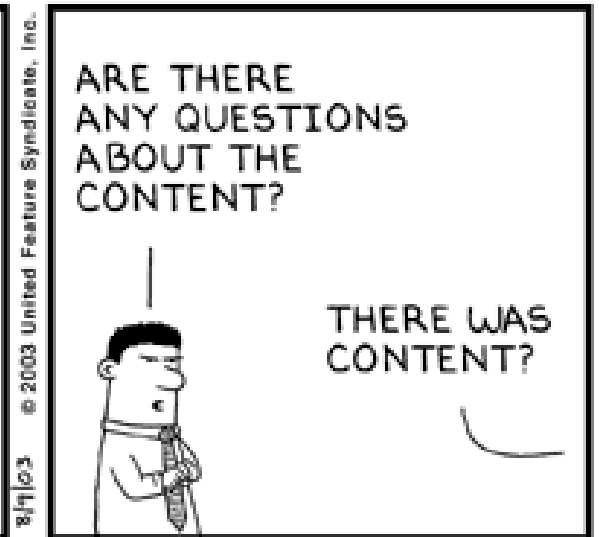
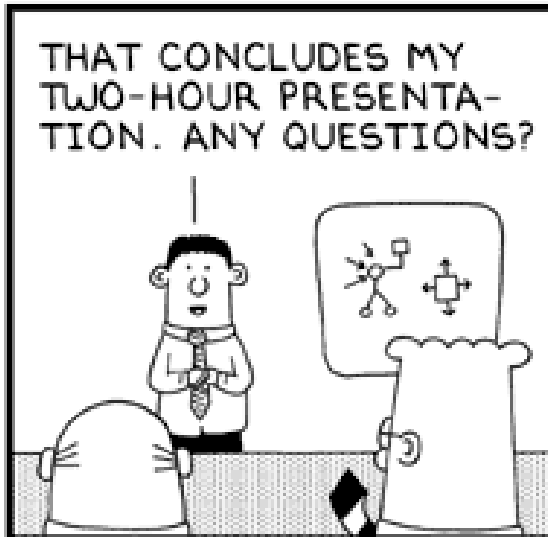
Communications Training

Teachers programmes

Conferences

Management Training

Fragen ?



www.dilbert.com scottadams@aol.com

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Physique des Particules

Cosmologie

Physique Nucléaire

Astrophysique

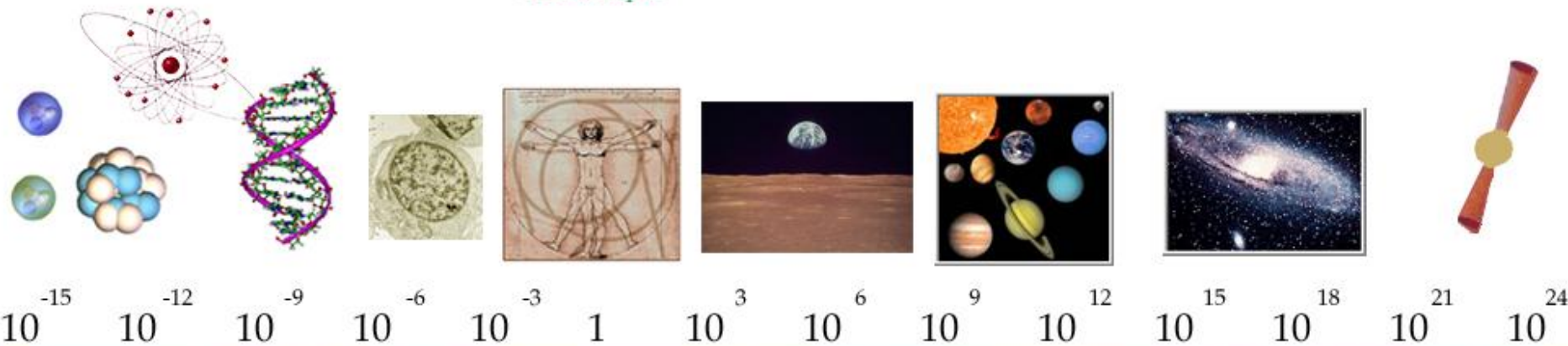
Physique du Solide

Astronomie

Chimie - Biologie

Géophysique

Mécanique



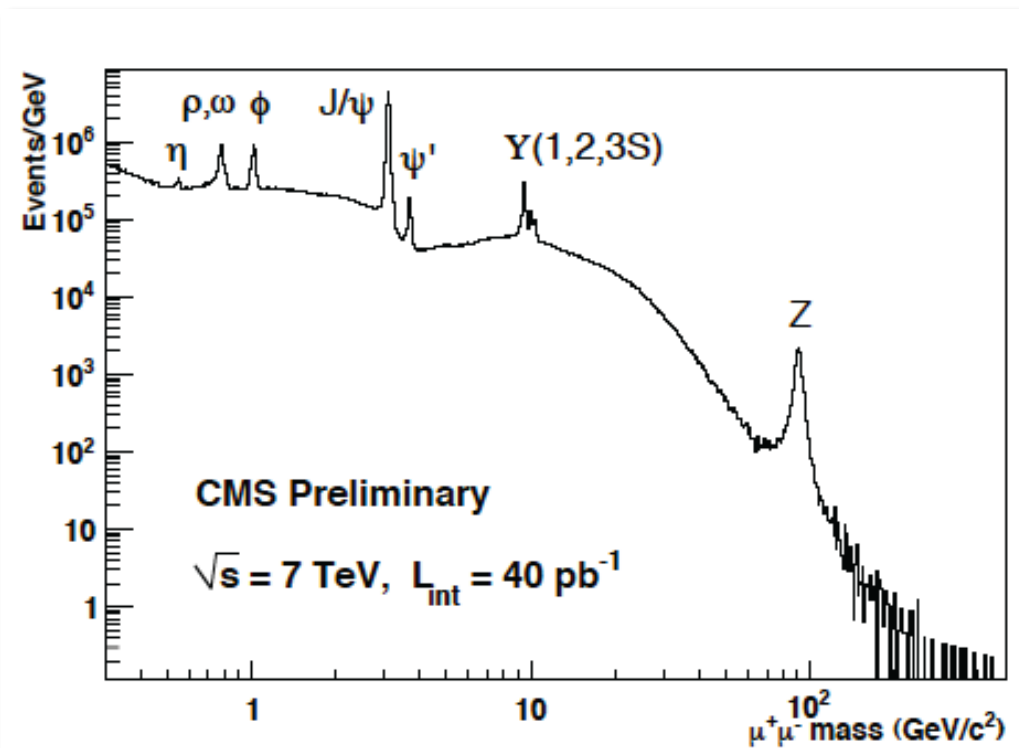
fm pm nm μm mm m km Mm Gm Tm Pm Em



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

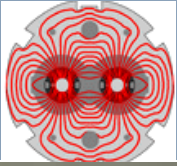
Excellent performances 2010

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

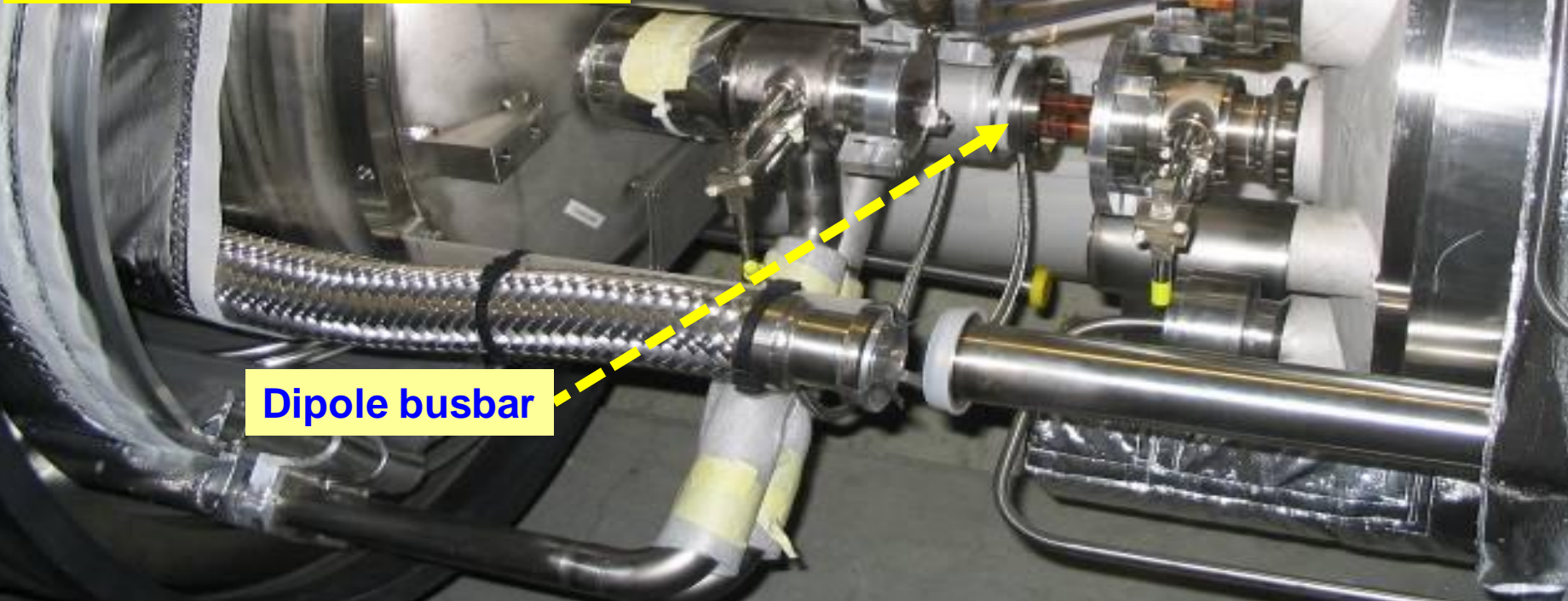
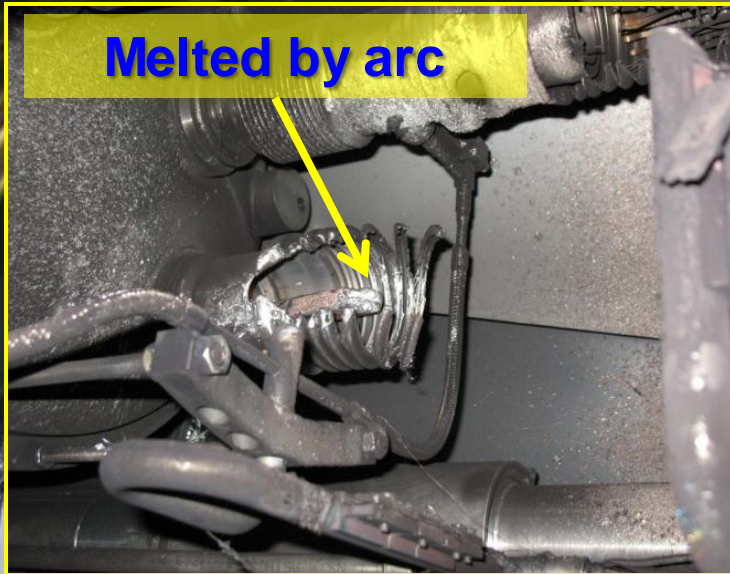


- Experiments demonstrated readiness in the exploitation of the 7 TeV p-p and 2.76 TeV Pb-Pb data;
- analyses proceeded very rapidly;
- Experiments have about completed their journey through the Standard Model ... and have started to take us into uncharted territories

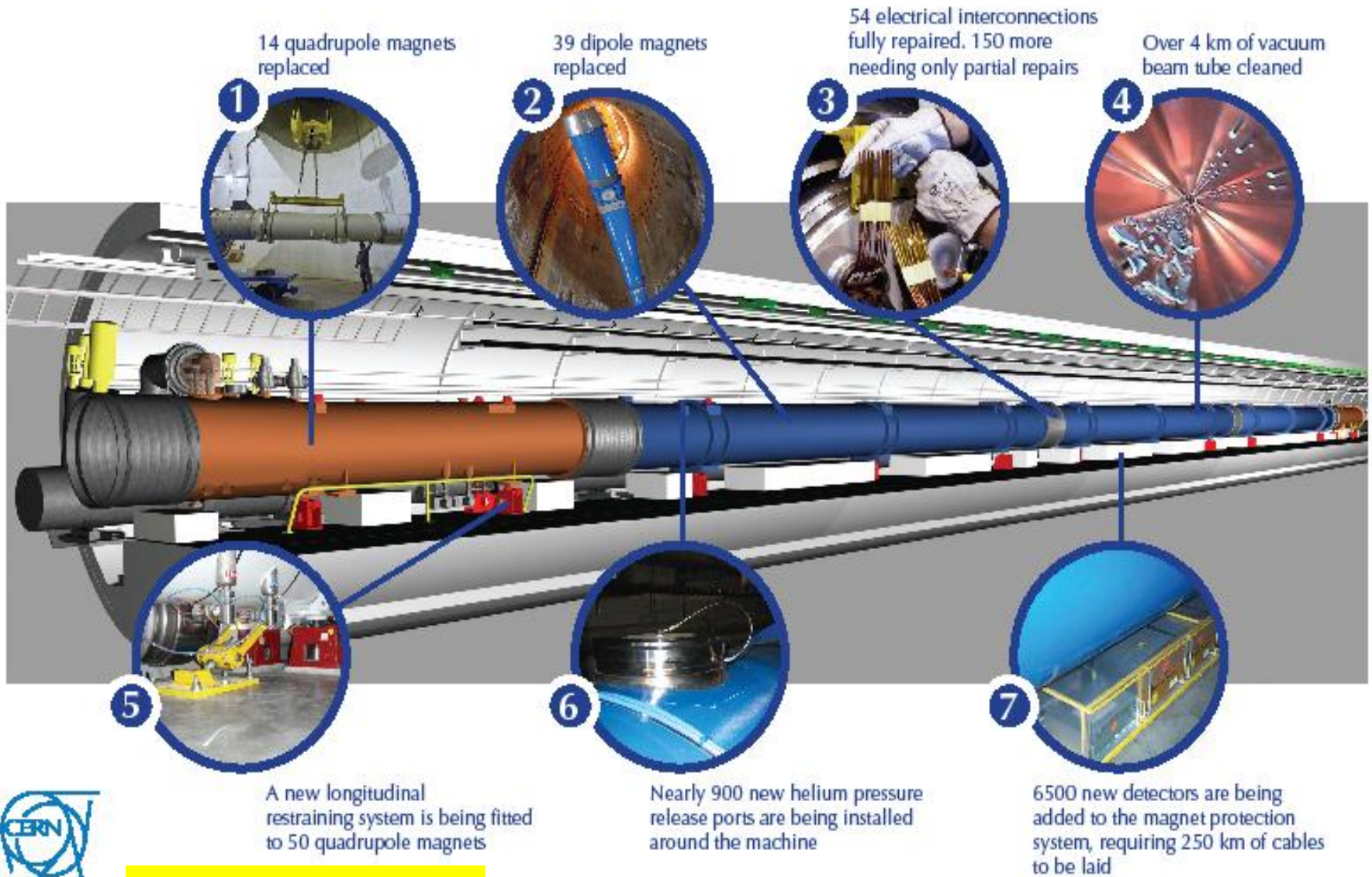
...



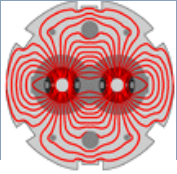
Magnet Interconnection



The LHC repairs in detail



+ Kältetechnik

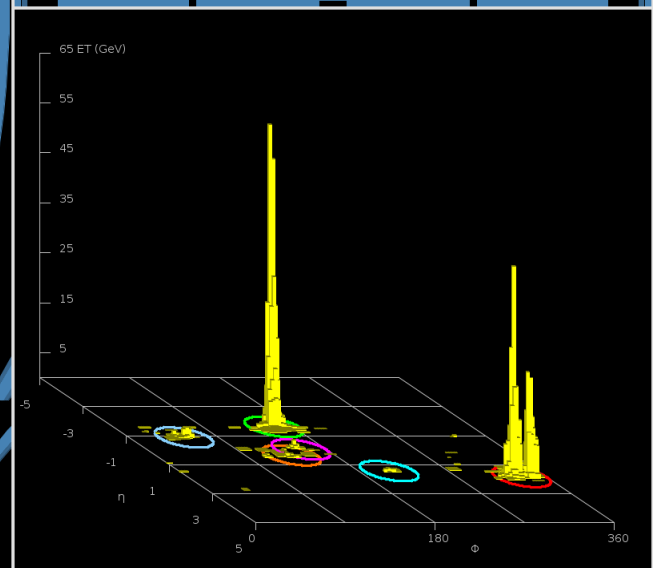
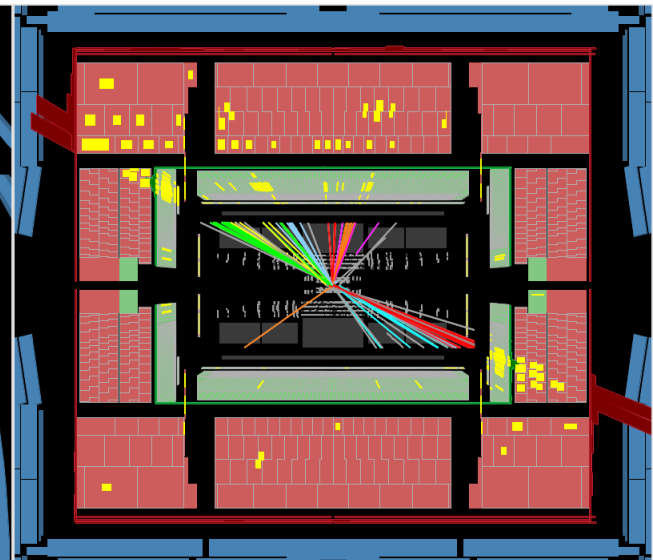
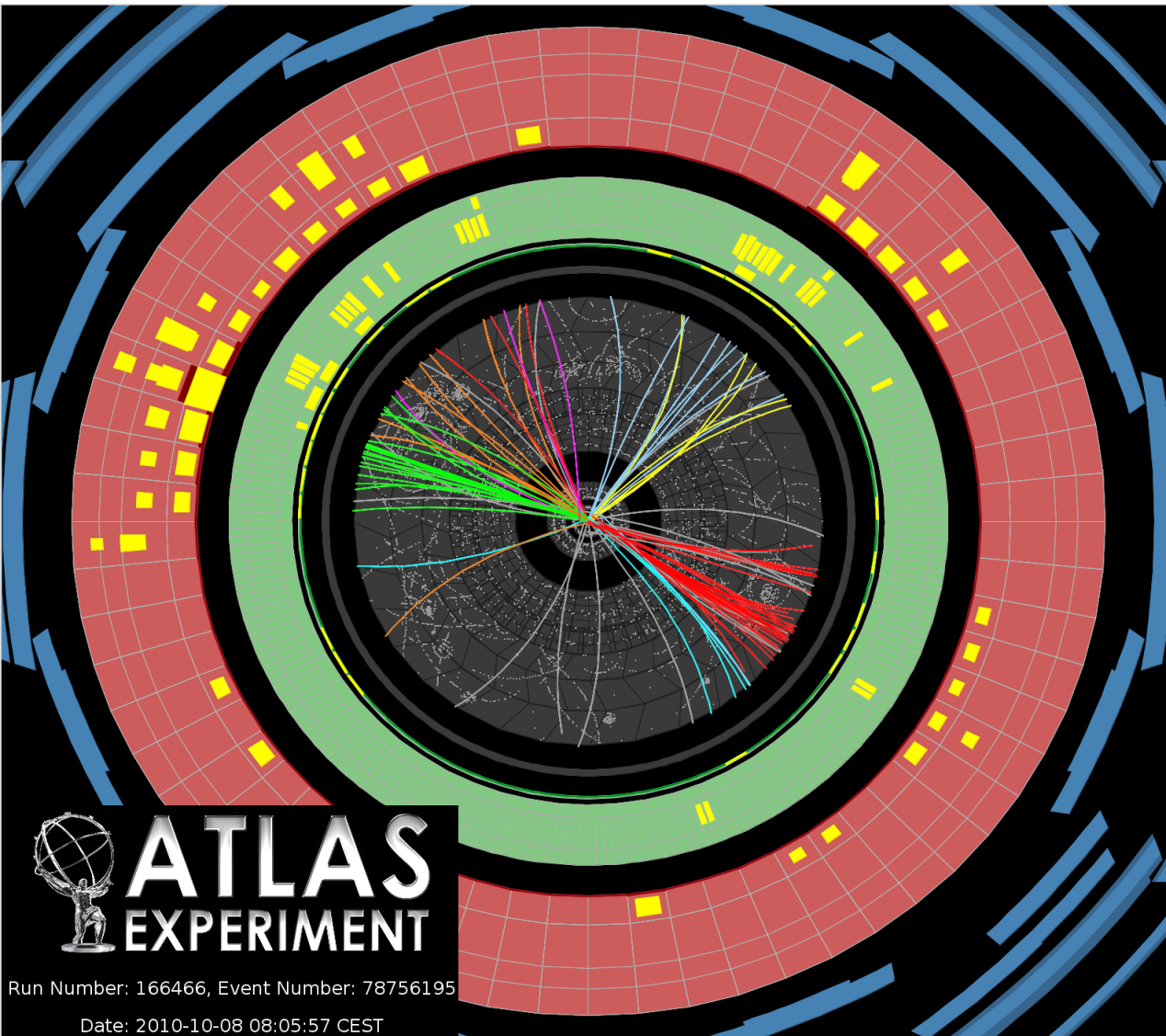


- ❑ 14 months to repair, consolidate and re-commissioning all elements.
- ❑ Great relief on November 20th when both beams circulated again !!!



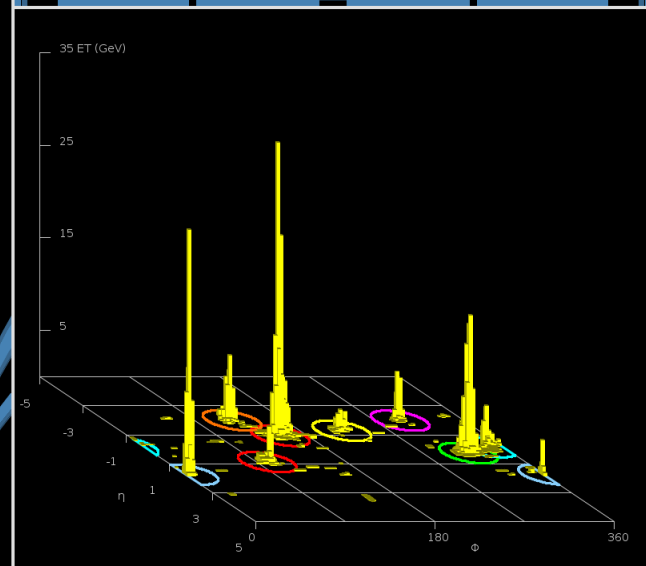
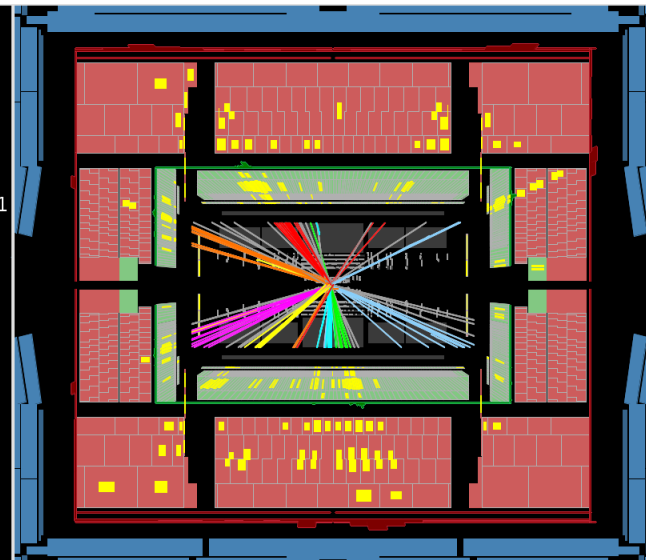
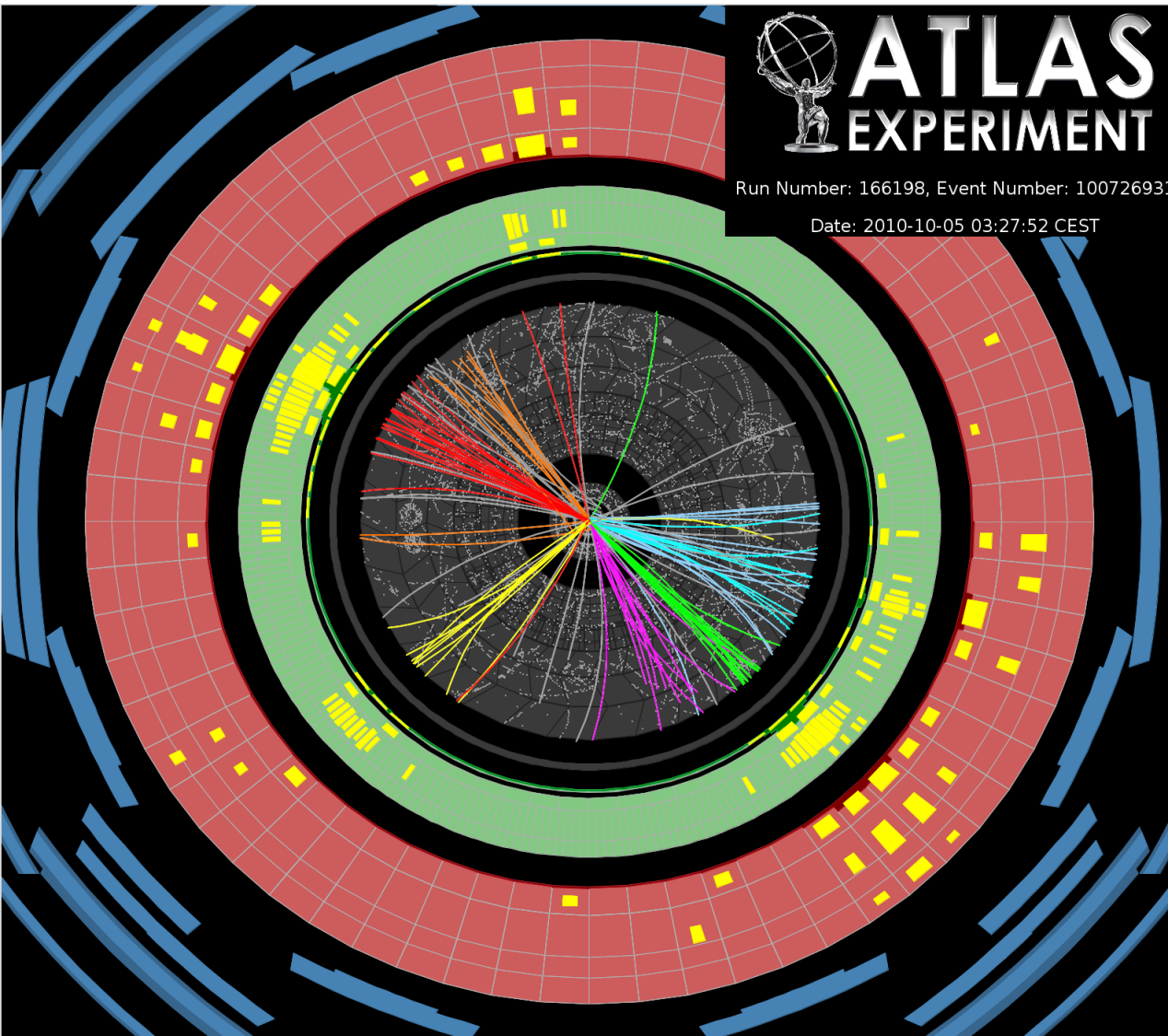
Highest mass di-jet

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



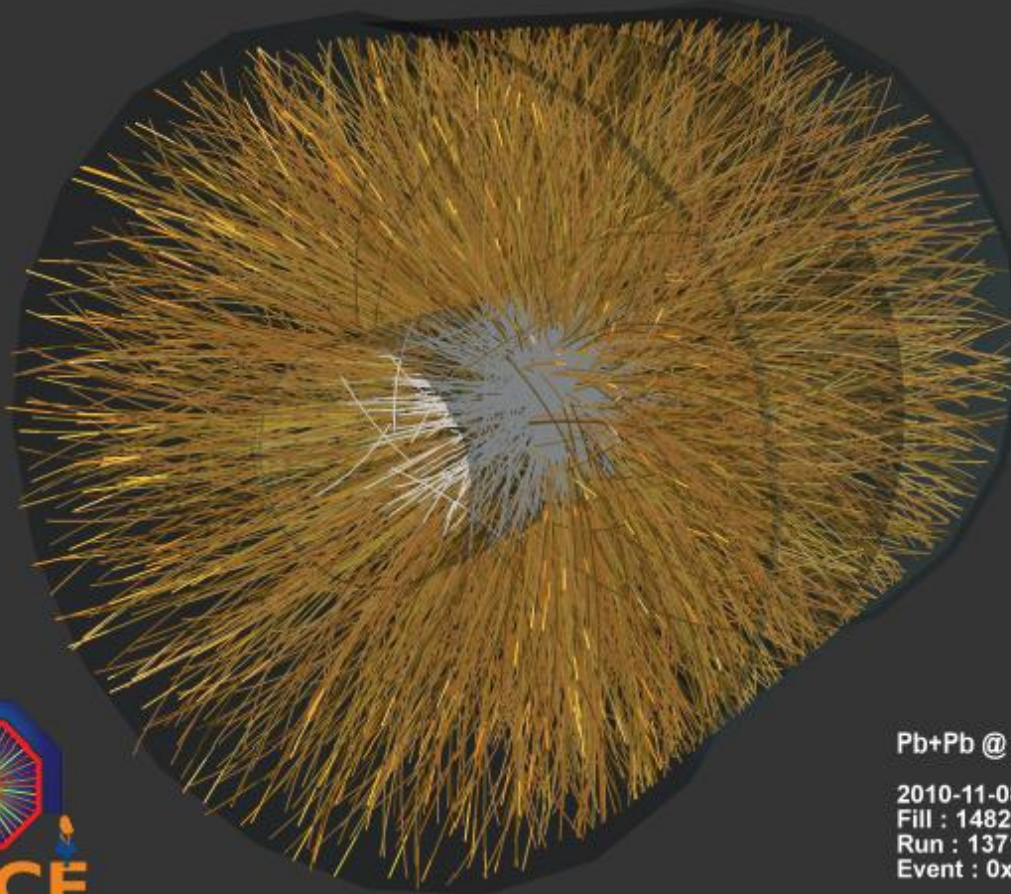
8-jet event

8 jets with $p_T > 60$ GeV



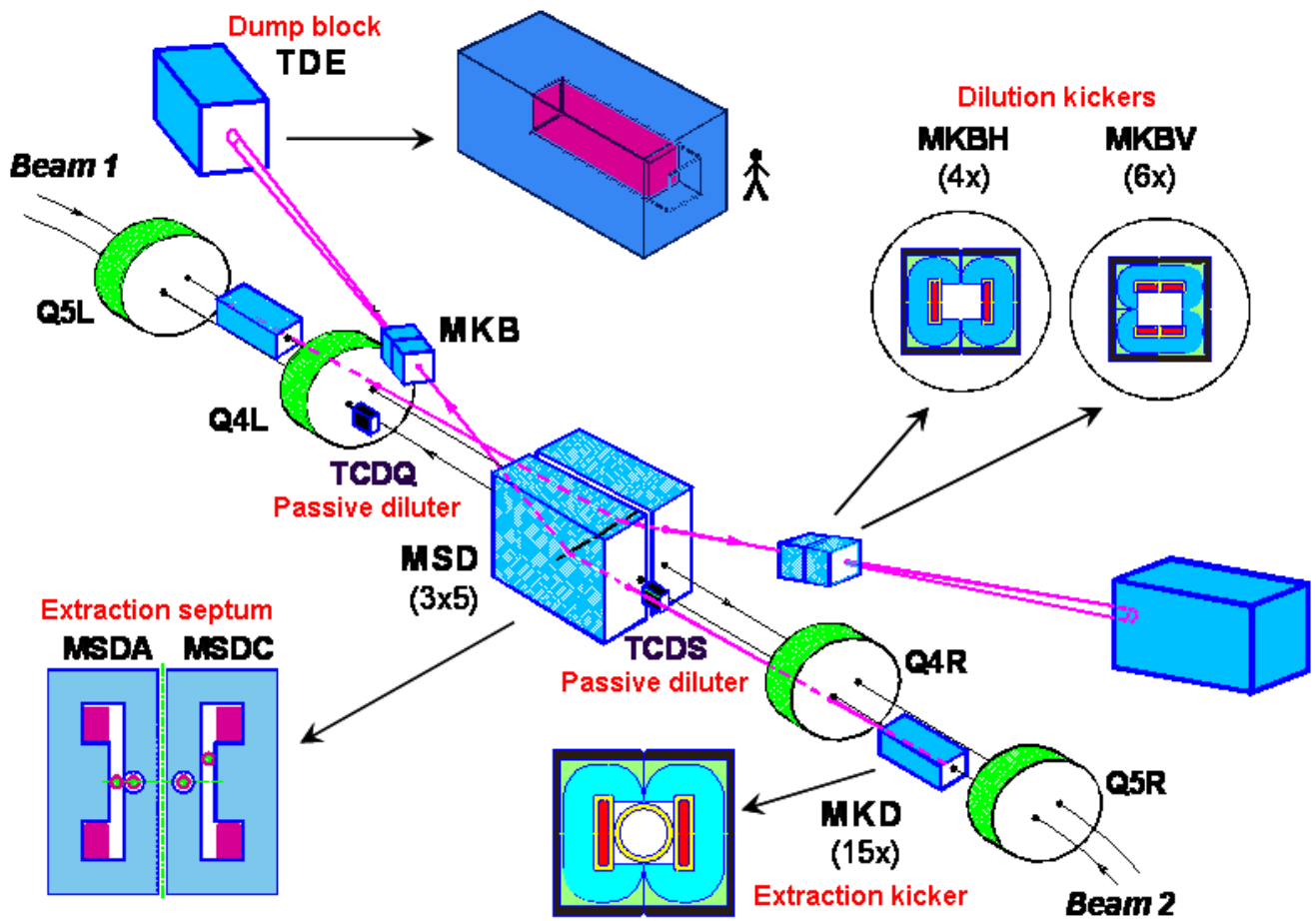
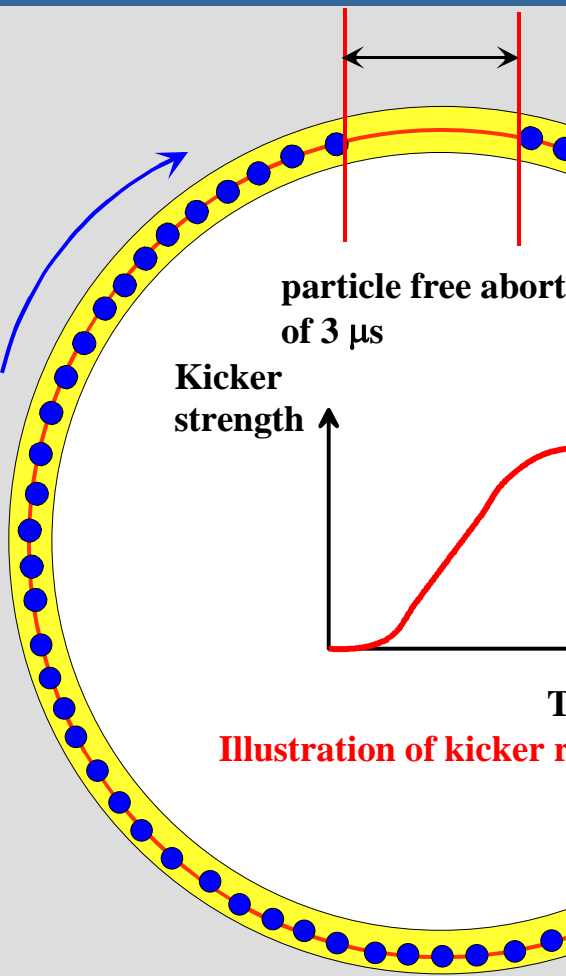
Pb-Pb collisions $\sqrt{s_{NN}} = 2.76 \text{ TeV} !$

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





Beam Dump System



Der Beam Dump

