European Organization for Nuclear Research
Über 50 Jahre Grundlagenforschung

CERN

… das Labor … die Beschleuniger … die Experimente … die Physik …

Dr. Sascha Marc Schmeling
CERN PH

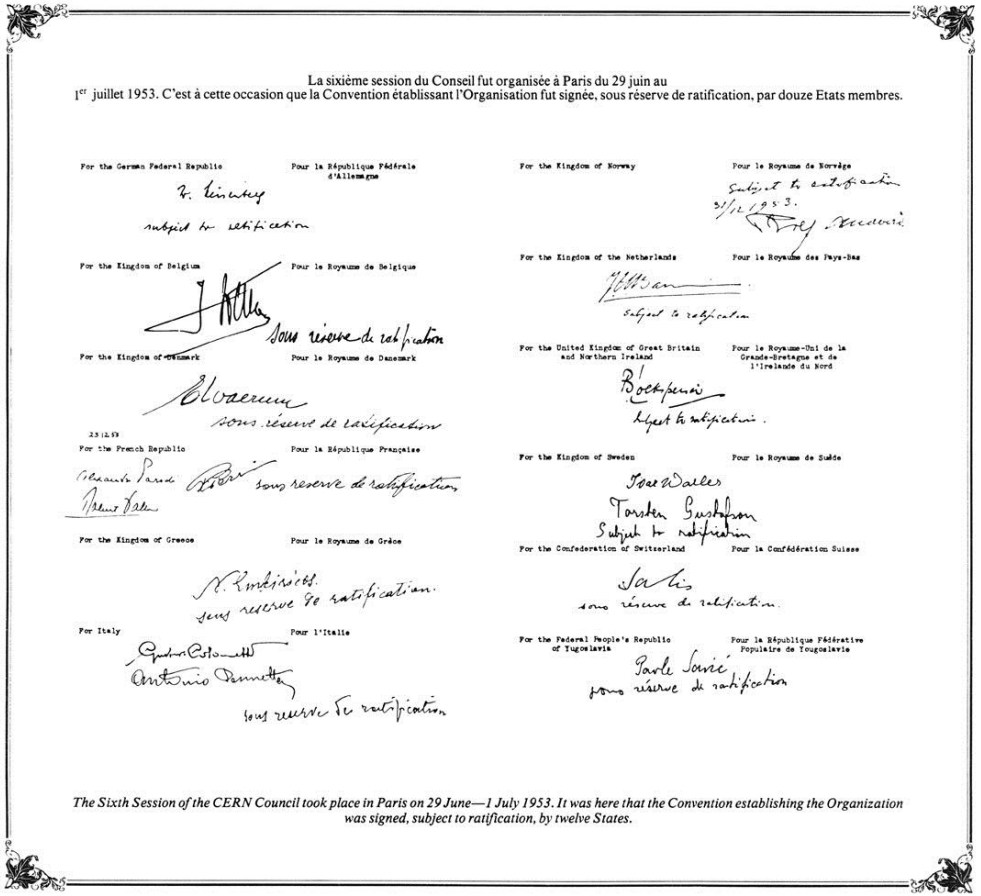
Photo © Thomas Jantscher

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



La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

For the German Federal Republic — Pour la République Fédérale d'Allemagne
subject to ratification

For the Kingdom of Belgium — Pour le Royaume de Belgique
sous réserve de ratification

For the Kingdom of Denmark — Pour le Royaume de Danemark
sous réserve de ratification

For the French Republic — Pour la République Française
sous réserve de ratification

For the Kingdom of Greece — Pour le Royaume de Grèce
sous réserve de ratification

For Italy — Pour l'Italie
sous réserve de ratification

For the Kingdom of Norway — Pour le Royaume de Norvège
Subject to ratification

For the Kingdom of the Netherlands — Pour le Royaume des Pays-Bas
Subject to ratification

For the United Kingdom of Great Britain and Northern Ireland — Pour le Royaume-Uni de la Grande-Bretagne et de l'Irlande du Nord
Subject to ratification

For the Kingdom of Sweden — Pour le Royaume de Suède
Subject to ratification

For the Confederation of Switzerland — Pour la Confédération Suisse
sous réserve de ratification

For the Federal People's Republic of Yugoslavia — Pour la République Fédérative Populaire de Yougoslavie
sous réserve de ratification

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.

The Twenty Member States of CERN

Member States (Dates of Accession)

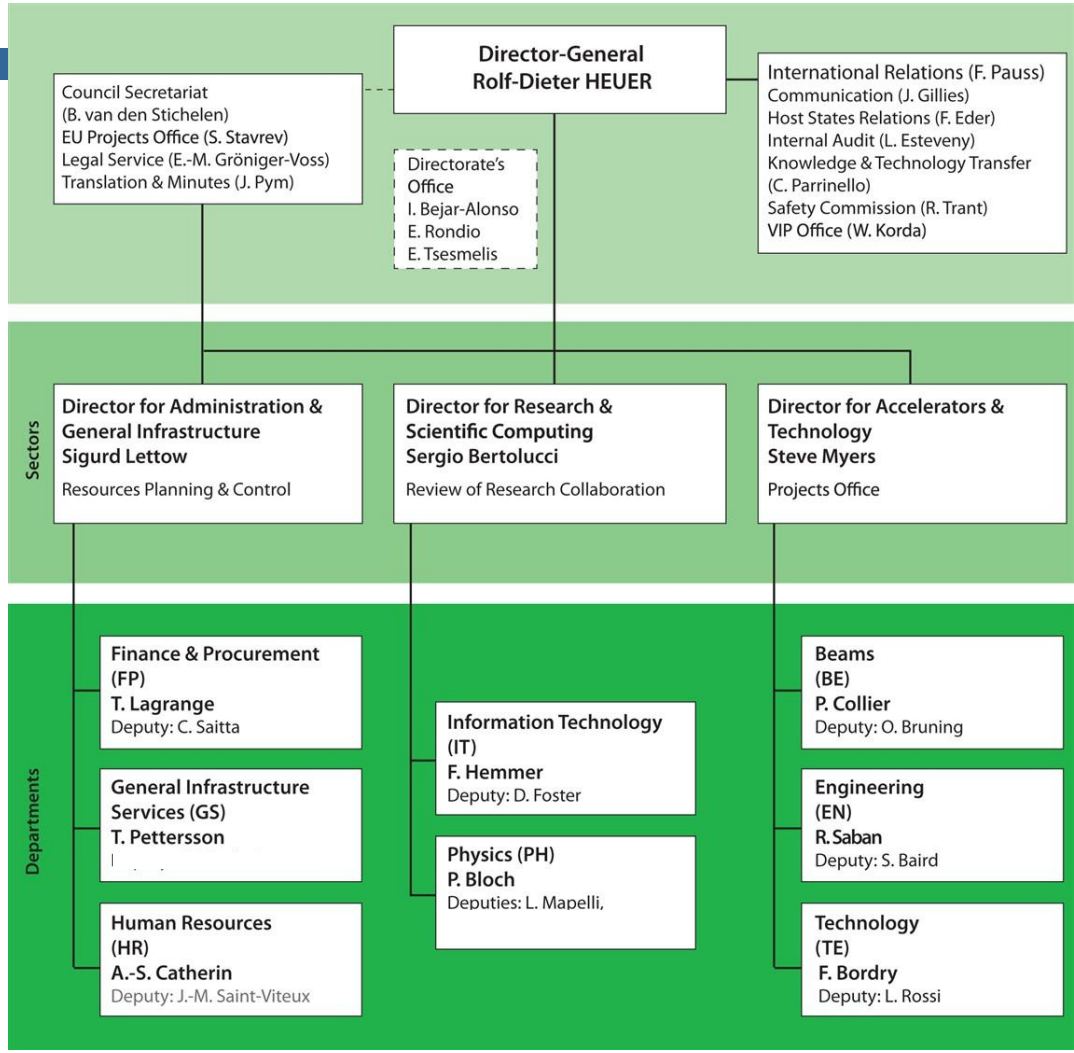
- AUSTRIA (1959)
- BELGIUM (1953)
- BULGARIA (1999)
- CZECH FR (1993)
- DENMARK (1953)
- FINLAND (1991)
- FRANCE (1953)
- GERMANY (1953)
- GREECE (1953)
- HUNGARY (1992)
- ITALY (1953)
- NETHERLANDS (1953)
- NORWAY (1953)
- POLAND (1991)
- PORTUGAL (1986)
- SLOVAK FR (1993)
- SPAIN (1/1961-12/1968-1/1983)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

CERN AC/DI/MM - ES36B 1999 - 15/6/99

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



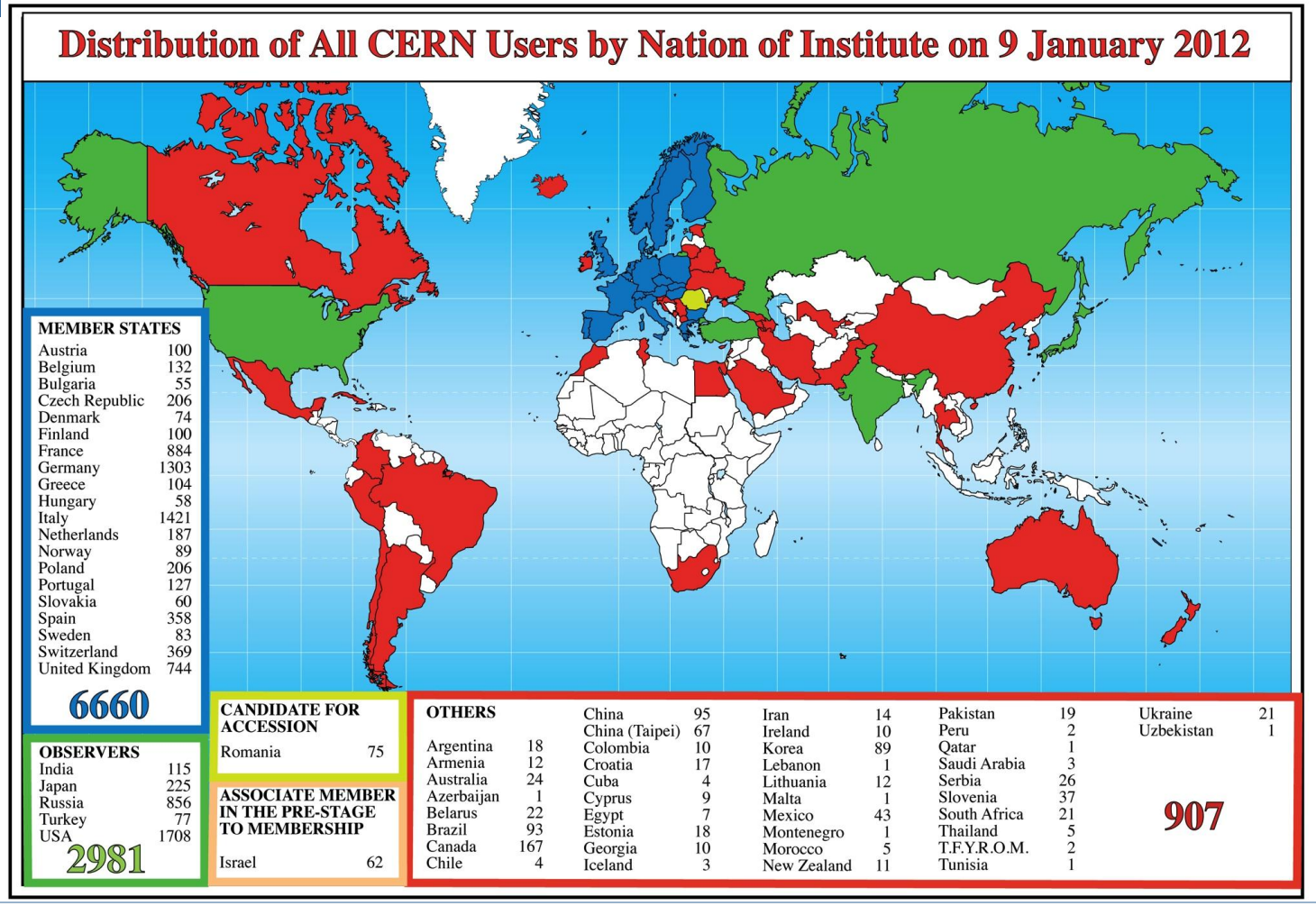
Menschen bei CERN – Januar 2012

Angestellte
- Staff
  - 2420
- Fellows
  - 487

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

Firmen
- 3818

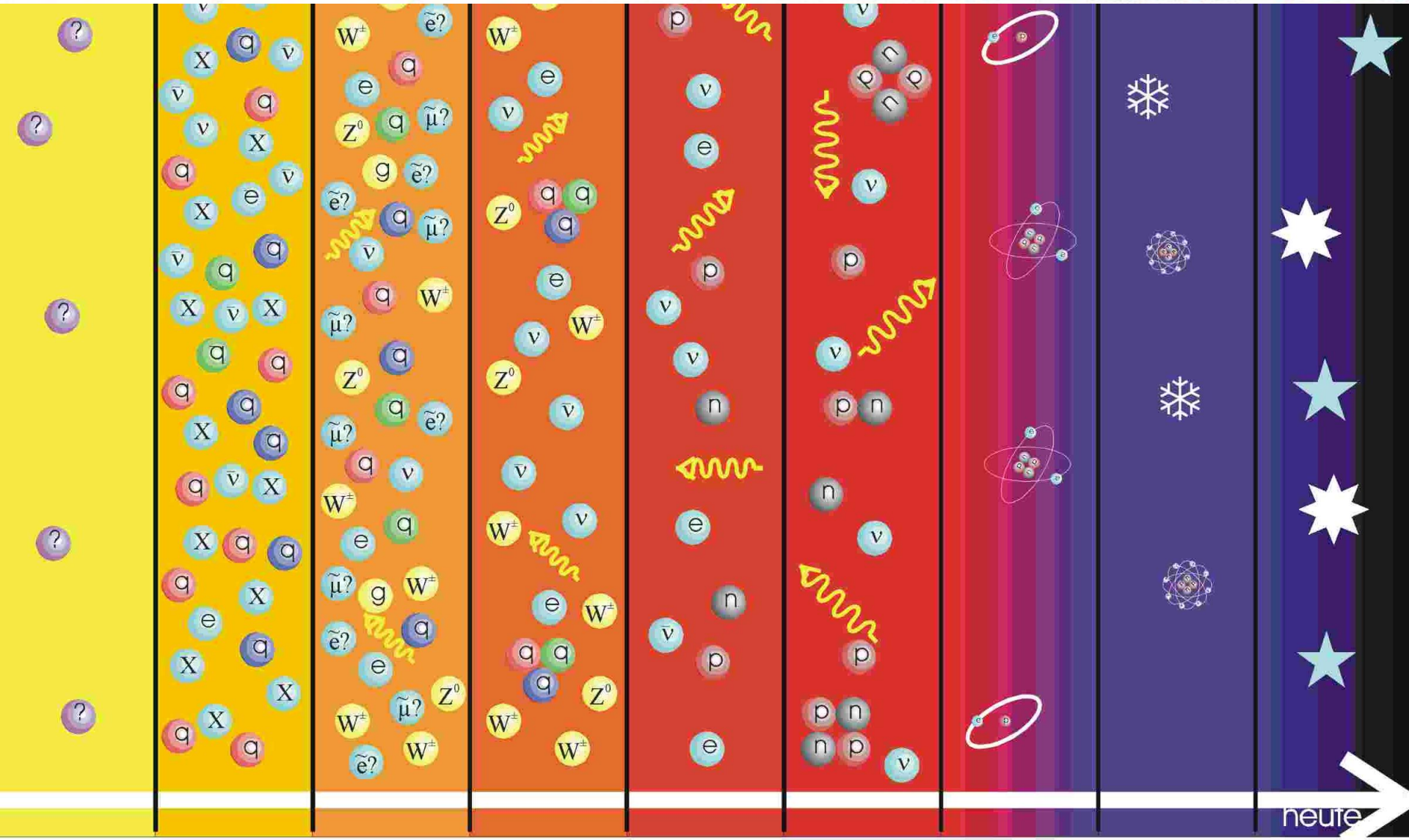
User
- 10685



HochEnergiePhysik

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

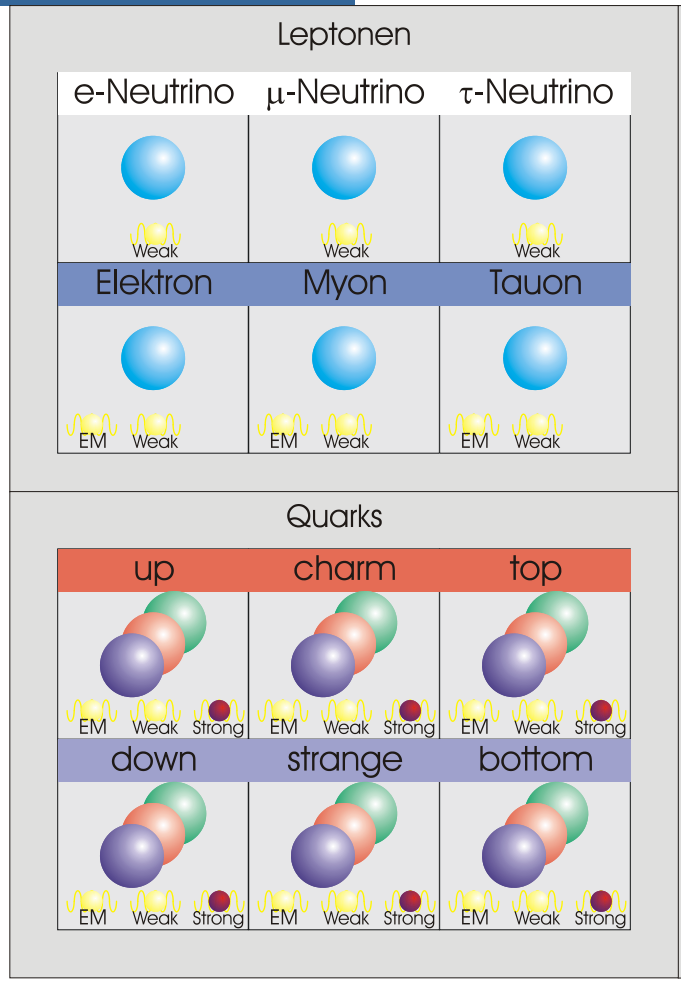
- Suche nach
  - elementaren Teilchen
  - Kräften
  - Symmetrien


heute
10^-43 s
10^32 K
10^19 GeV
10^-35 s
10^29 K
10^15 GeV
10^-10 s
10^15 K
10^2 GeV
1 s
10^10 K
1 MeV
3 min
10^9 K
0,1 MeV
10^5 y
4000 K
10^9 y
10 K
10^10 y
2,7 K

Das Standardmodell

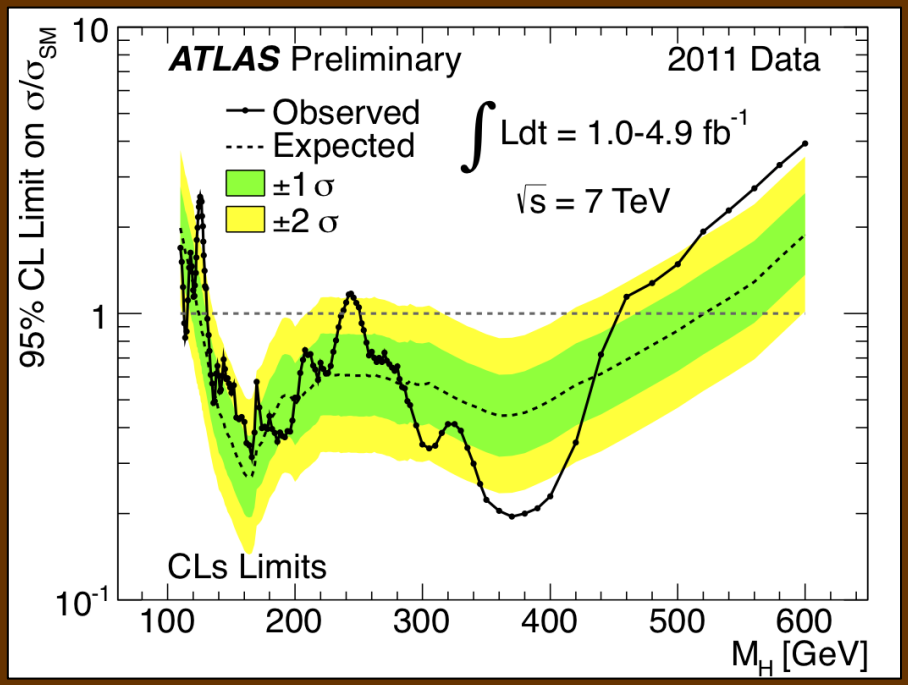
… ist …

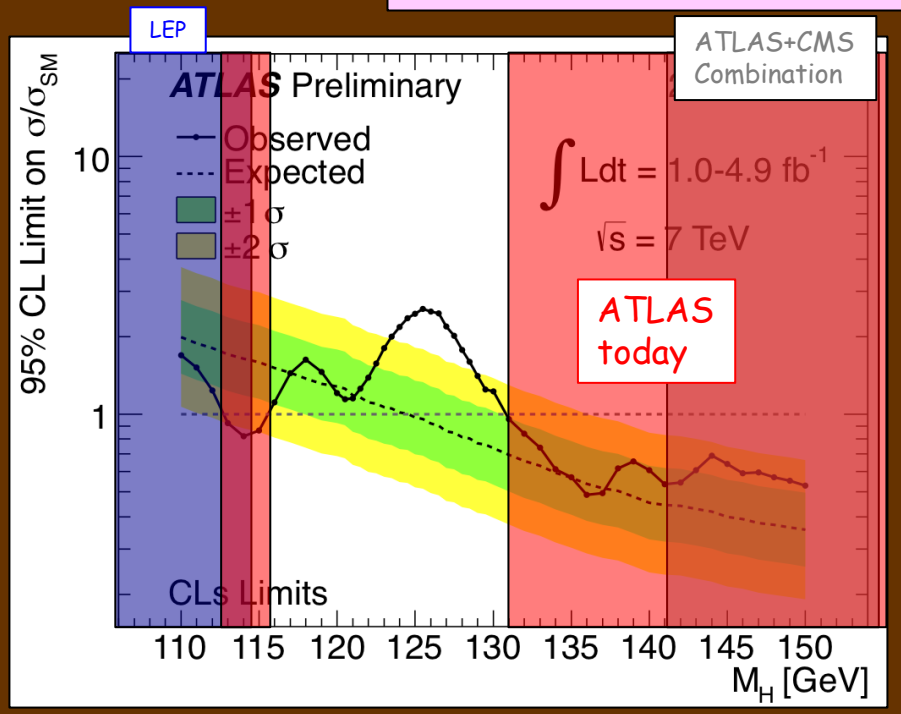
- … eine experimentell gut bestätigte Beschreibung unserer Welt auf der Ebene der Elementarteilchen
- … eine Zusammenfassung Alles Wissens um die Natur der kleinsten Teilchen
- … sehr präzise, sogar so weit, daß zukünftige Entdeckungen recht präzise vorhergesagt werden können



Putting all channels together → combined constraints

H→γγ, H→ ττ
H→ WW(*)→ lνlν
H→ ZZ(*) → 4l, H→ ZZ → llνν
H→ ZZ → llqq, H→ WW→lνqq
W/ZH→ lbb+X not included





Excluded at 95% CL

112.7 < m_H < 115.5 GeV
131 <m_H < 453 GeV, except 237-251 GeV

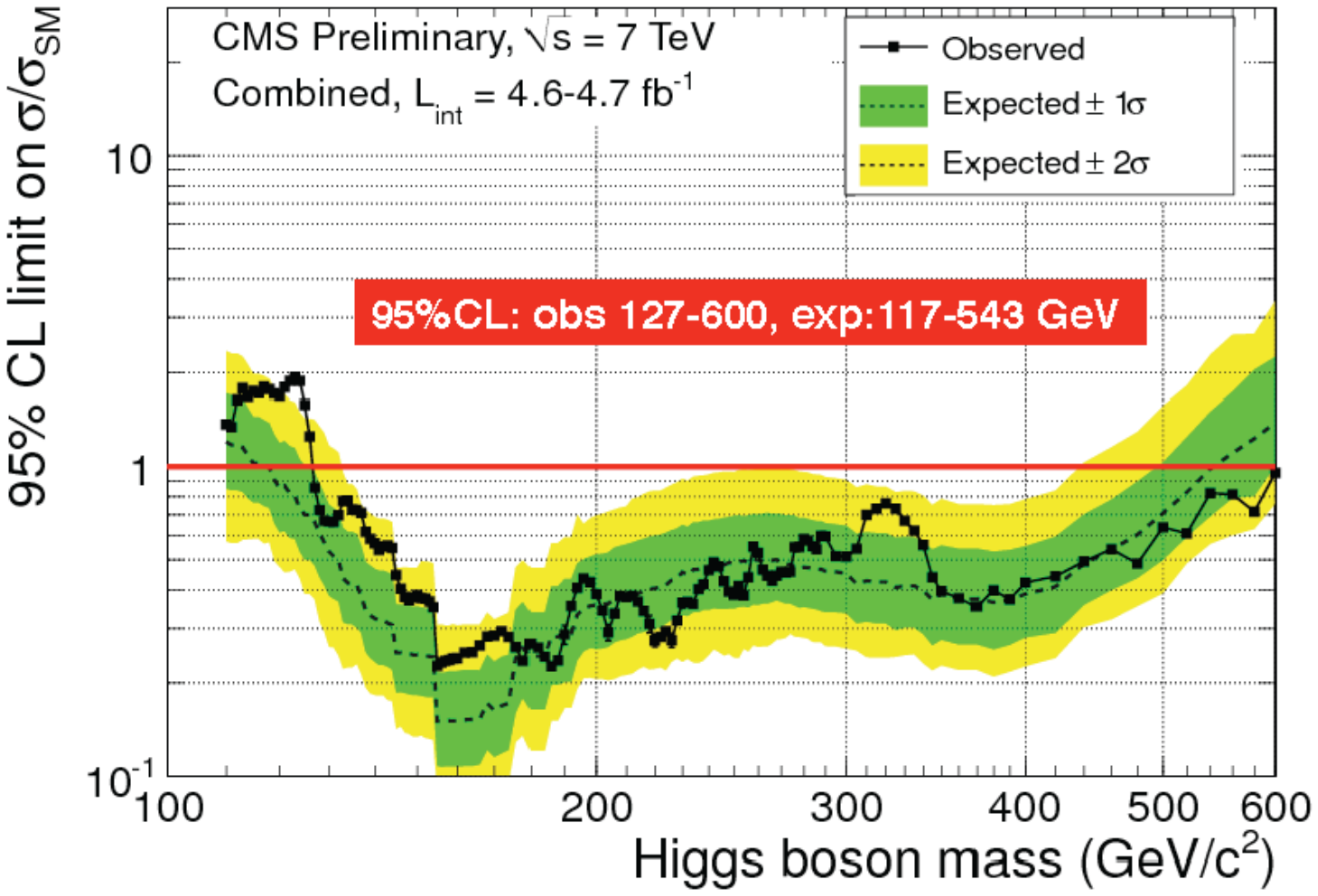
Expected if no signal

124.6-520 GeV

Excluded at 99% CL

133 <m_H < 230 GeV, 260 < m_H < 437 GeV

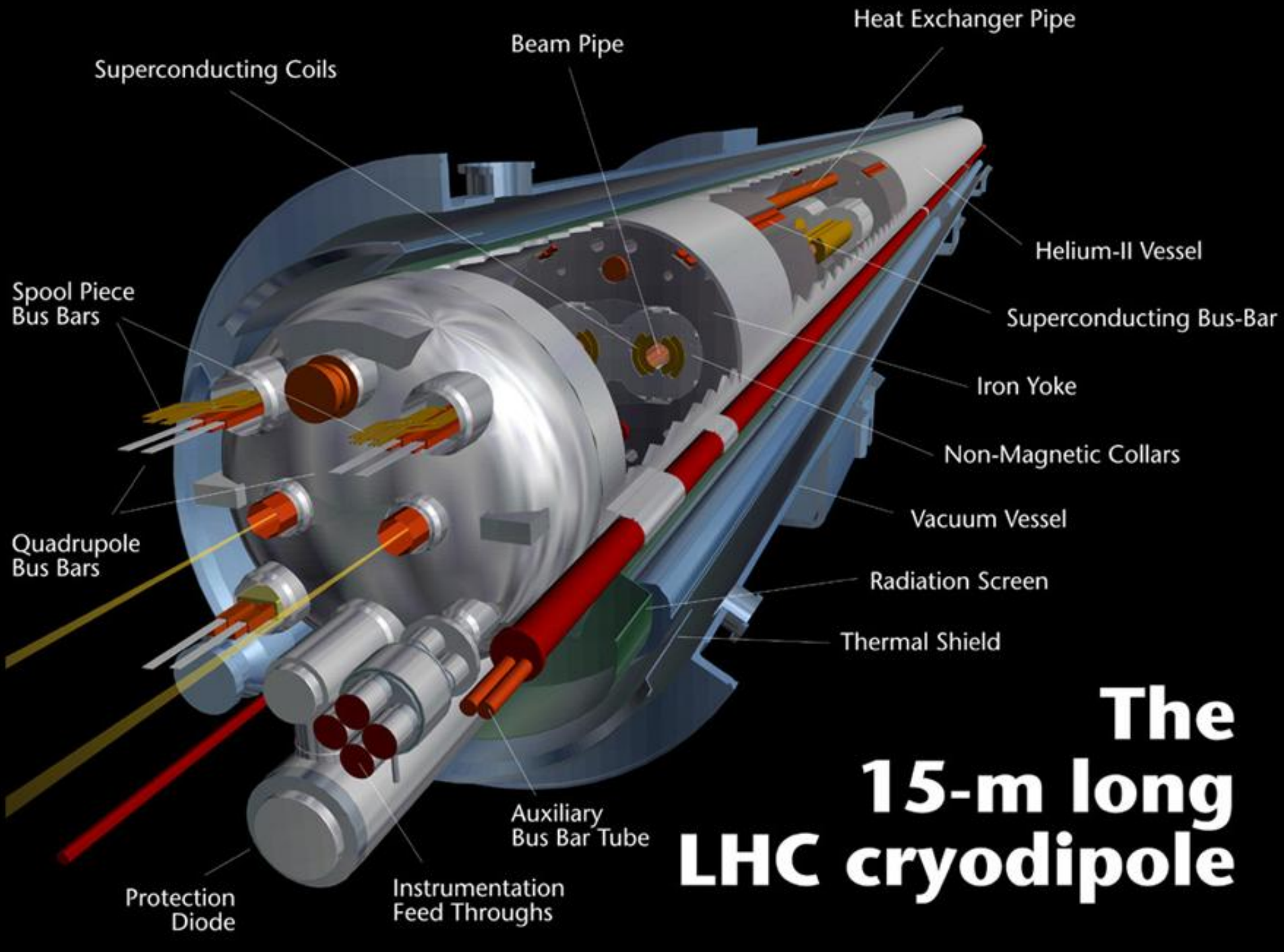
Limits on σ/σ_{sm} (CLs method)



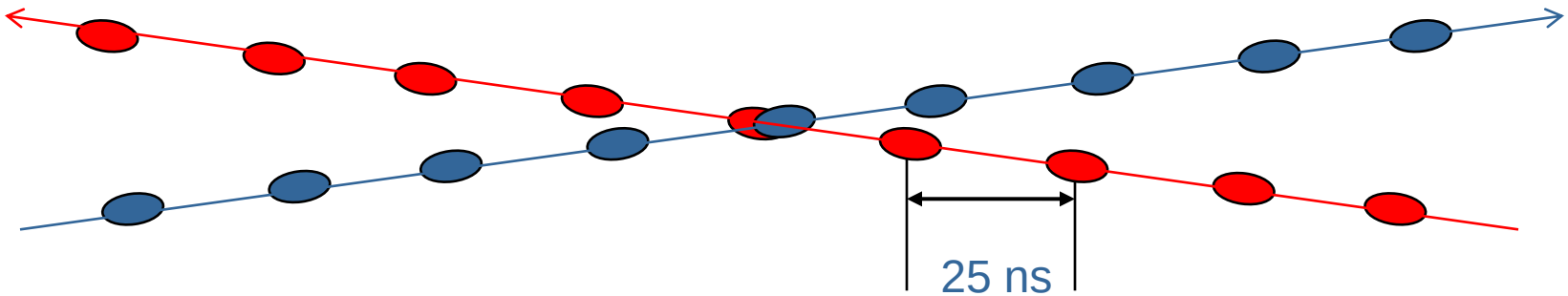
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

LHC – Von der Idee zum Beschleuniger

- 1982 : Erste Projektstudien
- 1983 : Z^0-Ereignis am S_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!*


Heat Exchanger Pipe
Beam Pipe
Superconducting Coils
Helium-II Vessel
Spool Piece
Bus Bars
Superconducting Bus-Bar
Iron Yoke
Non-Magnetic Collars
Quadrupole
Bus Bars
Vacuum Vessel
Radiation Screen
Thermal Shield
Auxiliary
Bus Bar Tube
Protection
Diode
Instrumentation
Feed Throughs
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: $1.05 \bullet 10^{11}$

Strahlenergie (pro Richtung): 346 MJoule

Gespeicherte Energie in den Magneten

$$E_{Dipol} = 0.5 \bullet L_{Dipol} \bullet I^2_{Dipol}$$

gespeicherte Energie in einem Dipol: 7.6 MJ

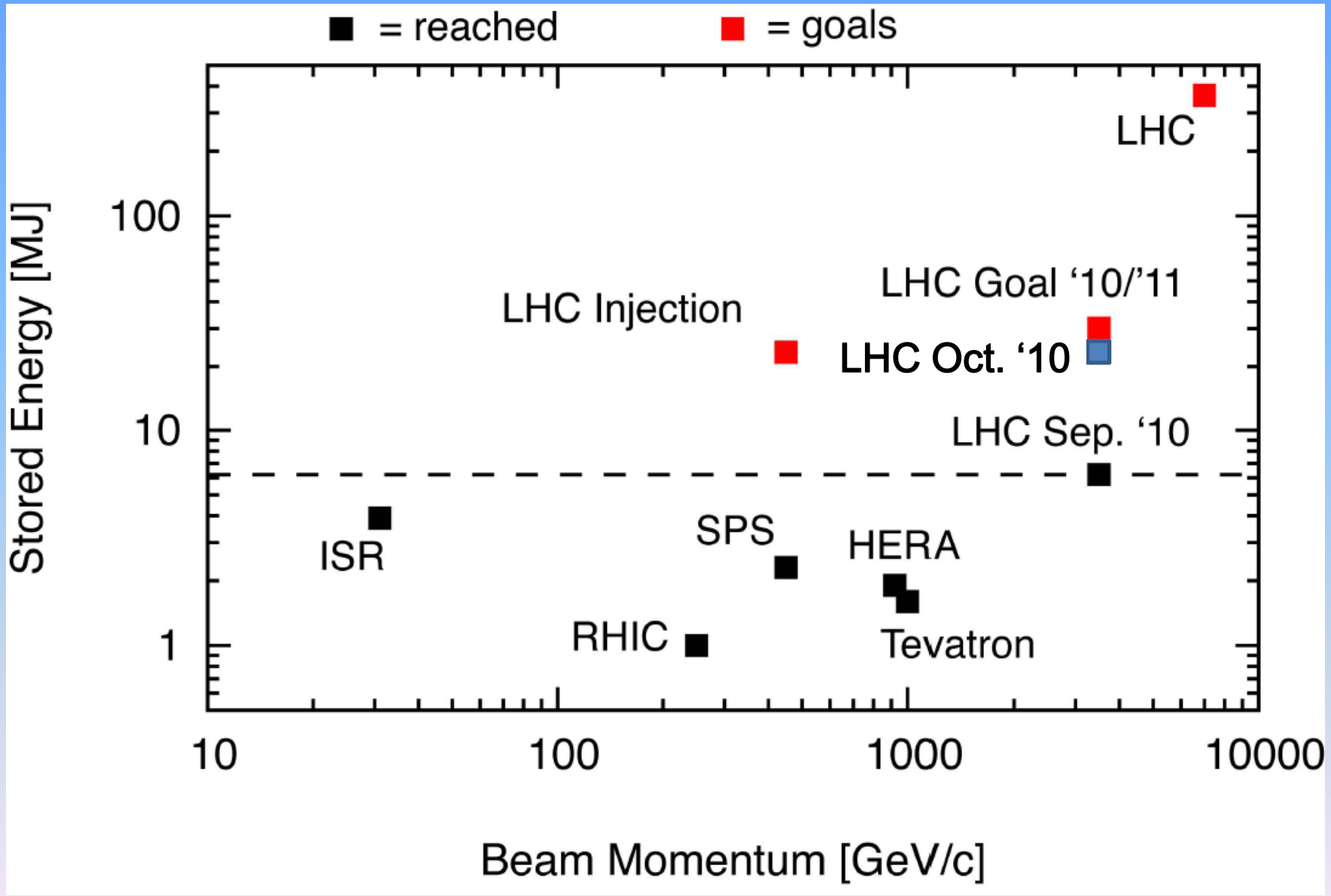
Gesamt für alle 1232 Dipole im LHC: 9.4 GJ

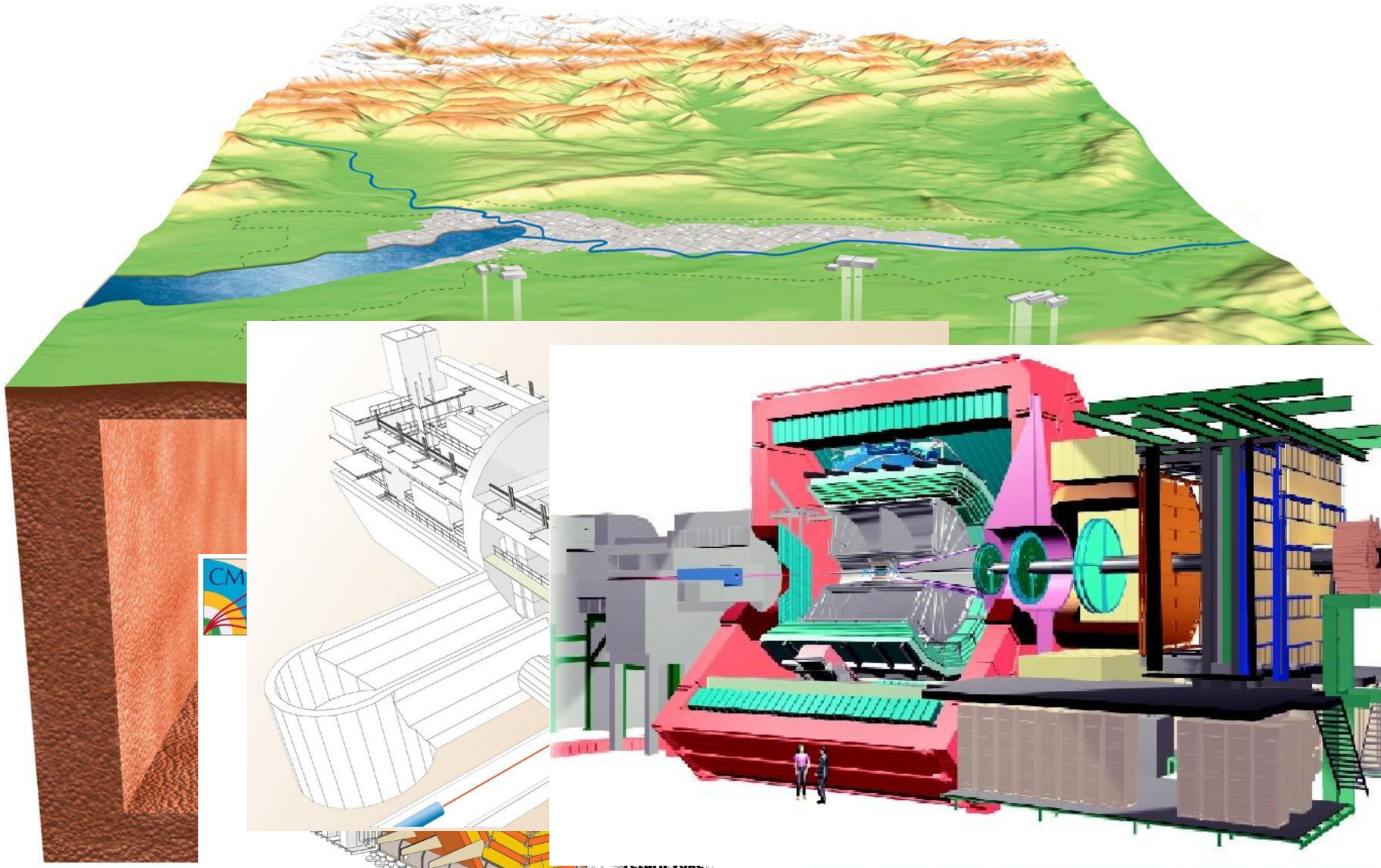
Nimitz Klasse Flugzeugträger (90000 t)
bei Reisegeschwindigkeit von 20 kn
Energie = ½ mv^2 ~ 10GJ

September 10th - control (show) room

For 3 days all went perfectly well with beam…

LHC now on its own in terms of stored energy

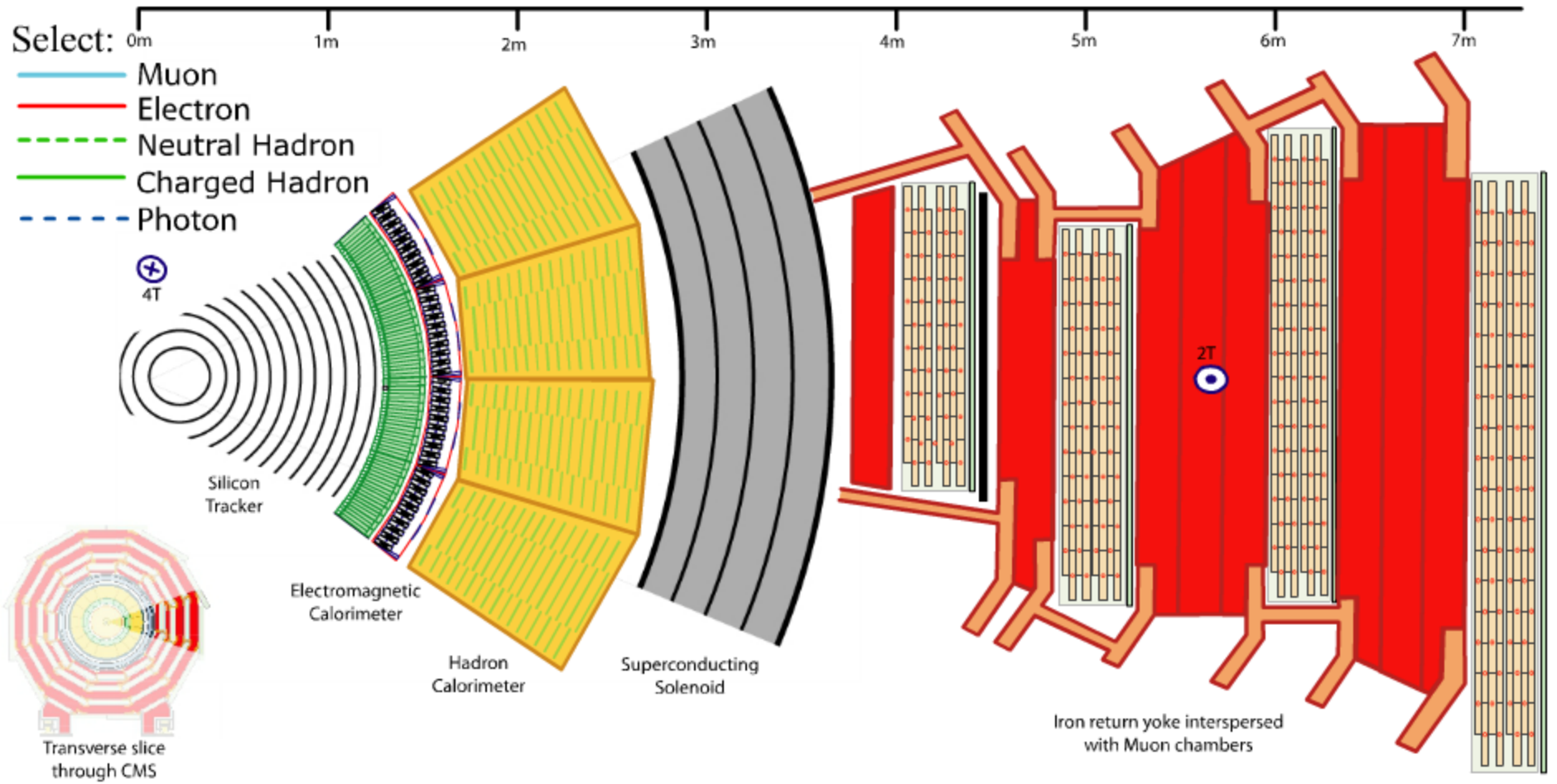




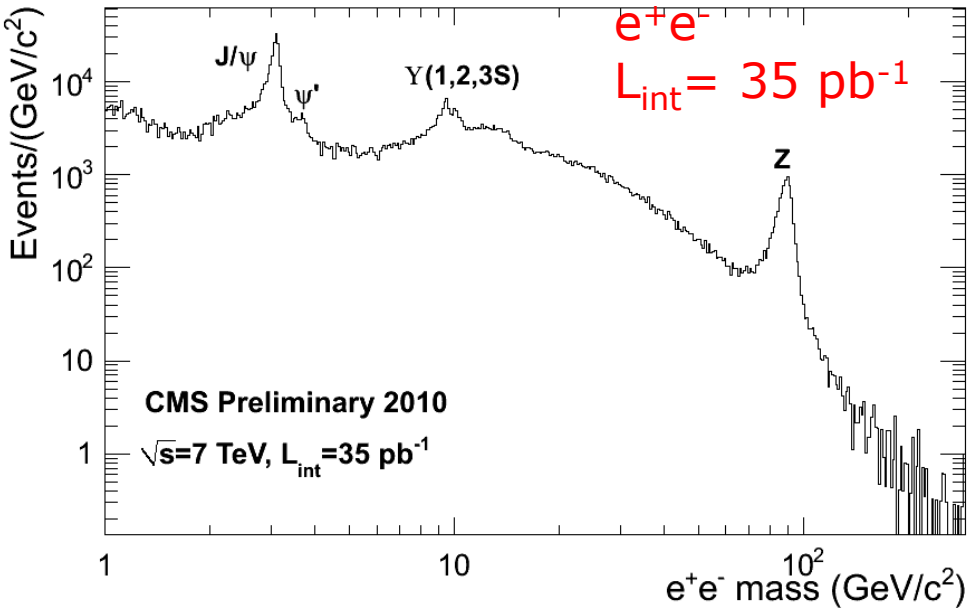
Detector characteristics

Width: 22m
Diameter: 15m
Weight: 14'500t

CMS Ereignis



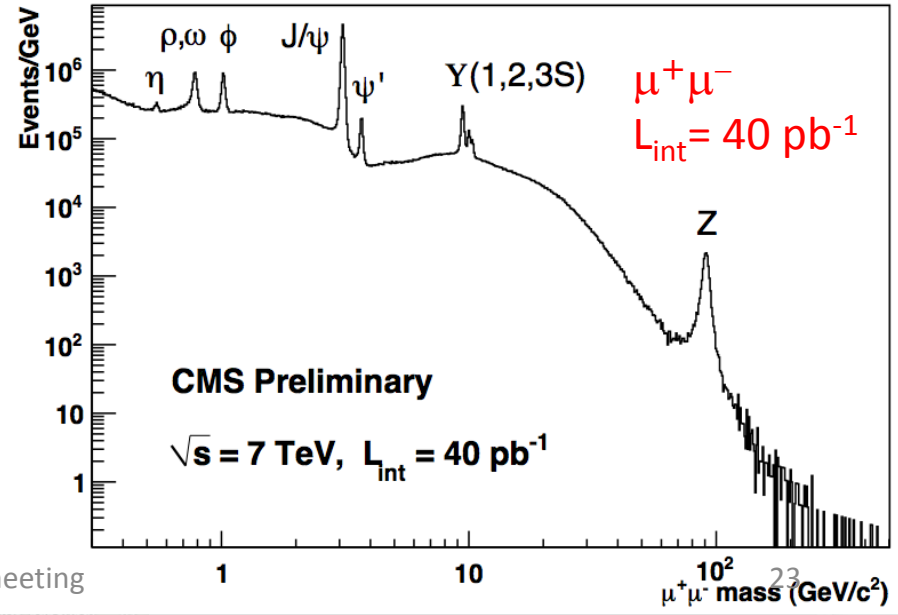
Invariant mass distributions



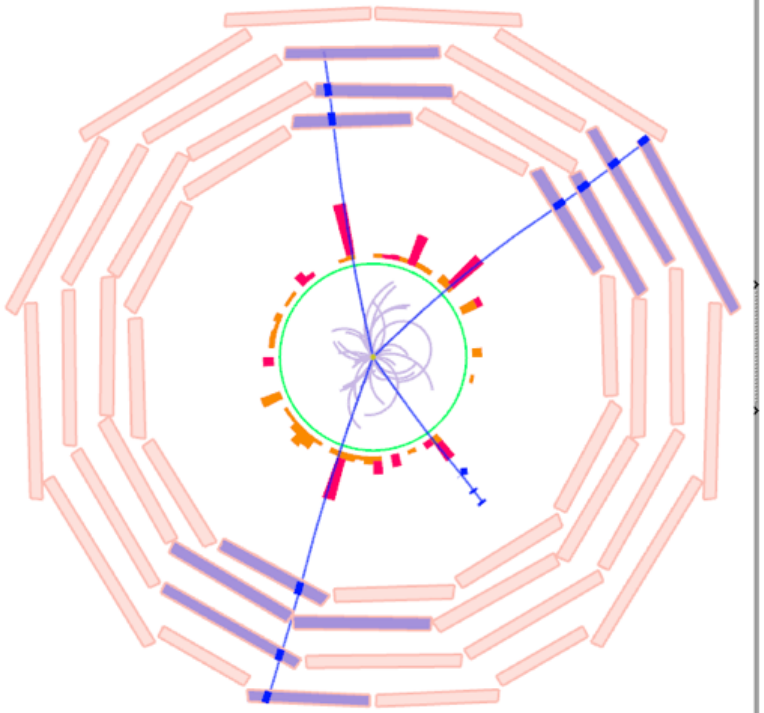
A tribute to Level1 and HLT trigger capability and flexibility

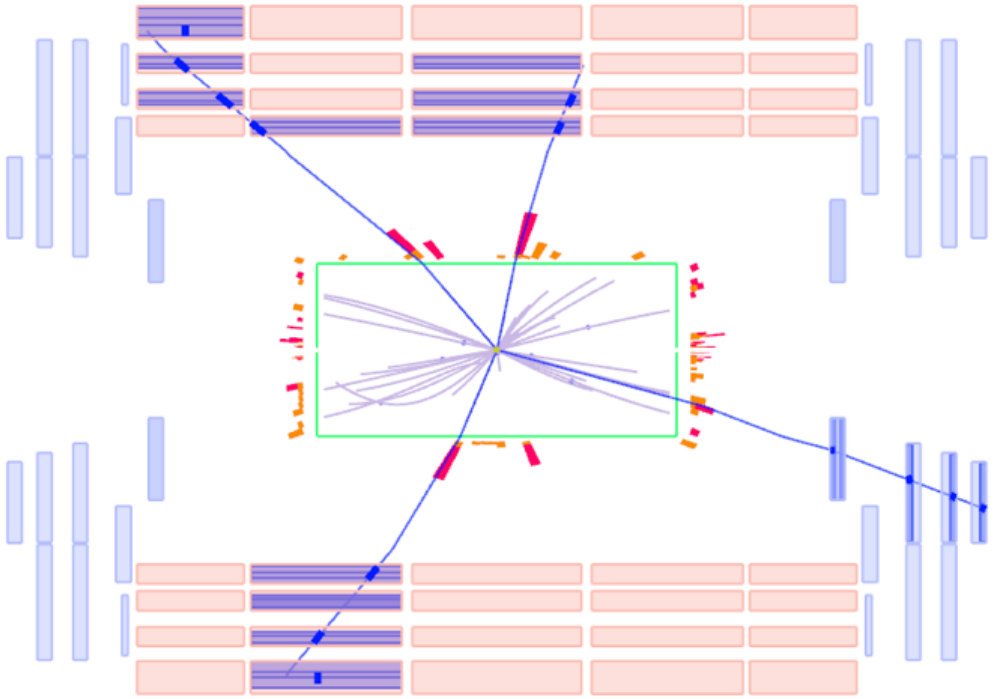
e^+e^- widths:
J/Ψ 52 MeV
Υ 149 MeV

$\mu^+\mu^-$ widths:
J/Ψ 30 MeV
Υ 67 MeV



A beautiful ZZ event

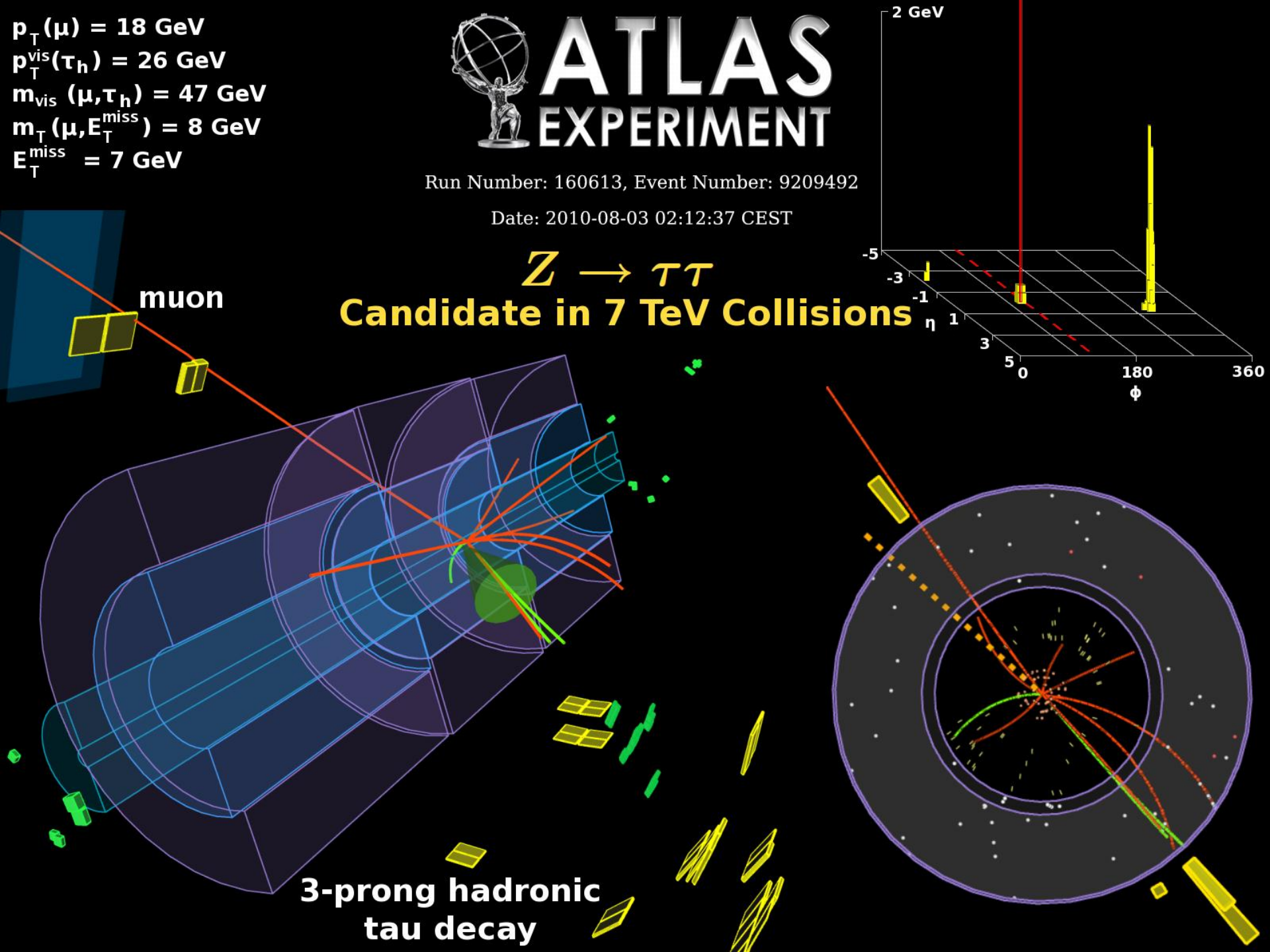




Invariant Masses

$\mu_0 + \mu_1$: 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).

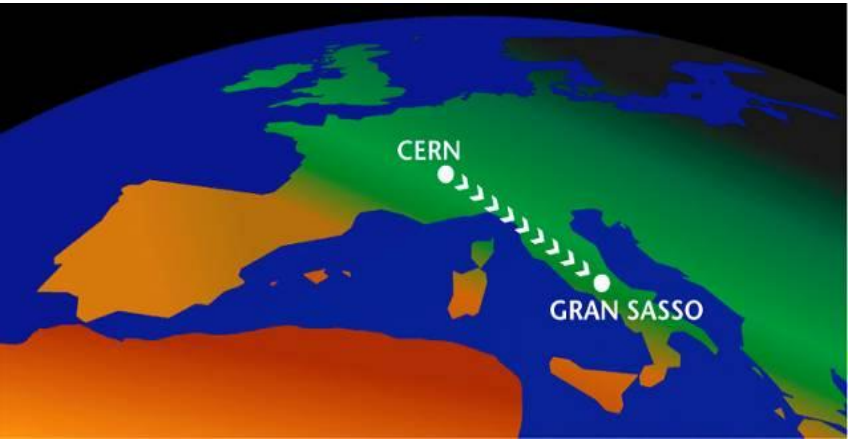
Invariant Mass of 4μ: 201 GeV

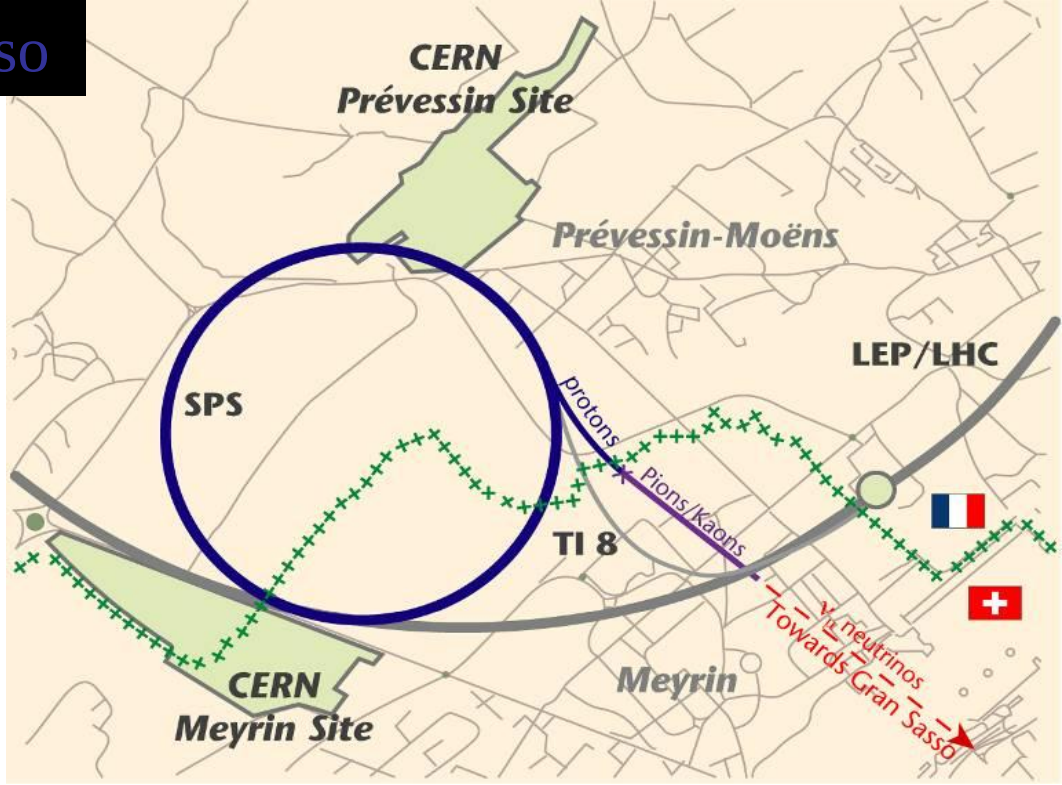

$p_T(\mu)$ = 18 GeV
$p_T^{vis}(\tau_h)$ = 26 GeV
m_{vis} (μ,τ_h) = 47 GeV
$m_T(\mu,E_T^{miss})$ = 8 GeV
E_T^{miss} = 7 GeV
ATLAS EXPERIMENT
Run Number: 160613, Event Number: 9209492
Date: 2010-08-03 02:12:37 CEST
$Z \rightarrow \tau\tau$
Candidate in 7 TeV Collisions
2 GeV
-5
-3
-1
1
3
5
η
0
180
360
φ
muon
3-prong hadronic
tau decay

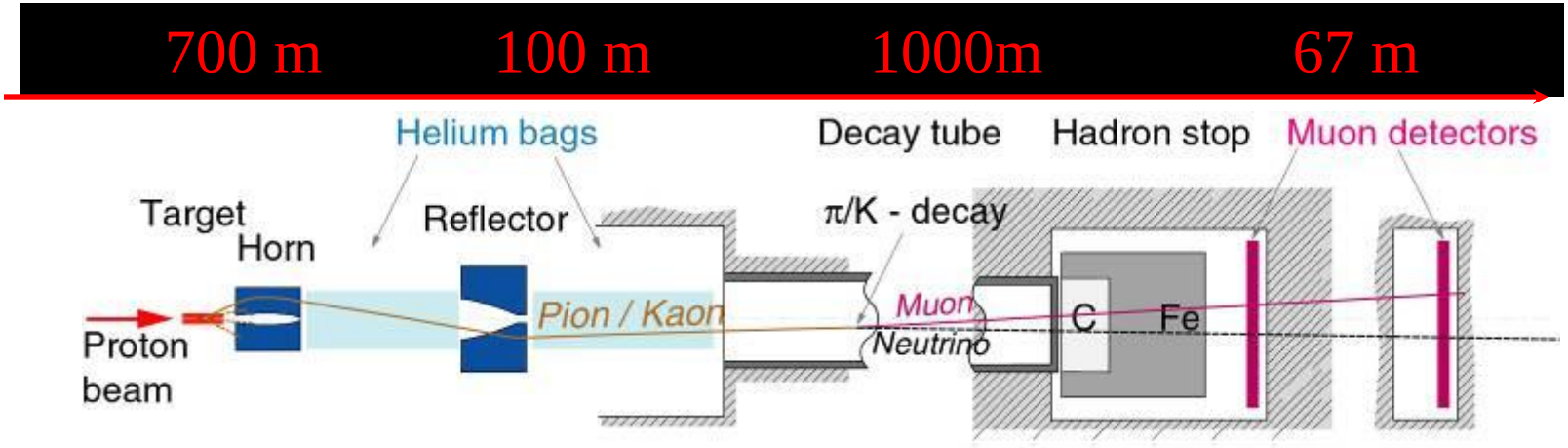
Weitere Aktivitäten am CERN

… eine kleine Auswahl …

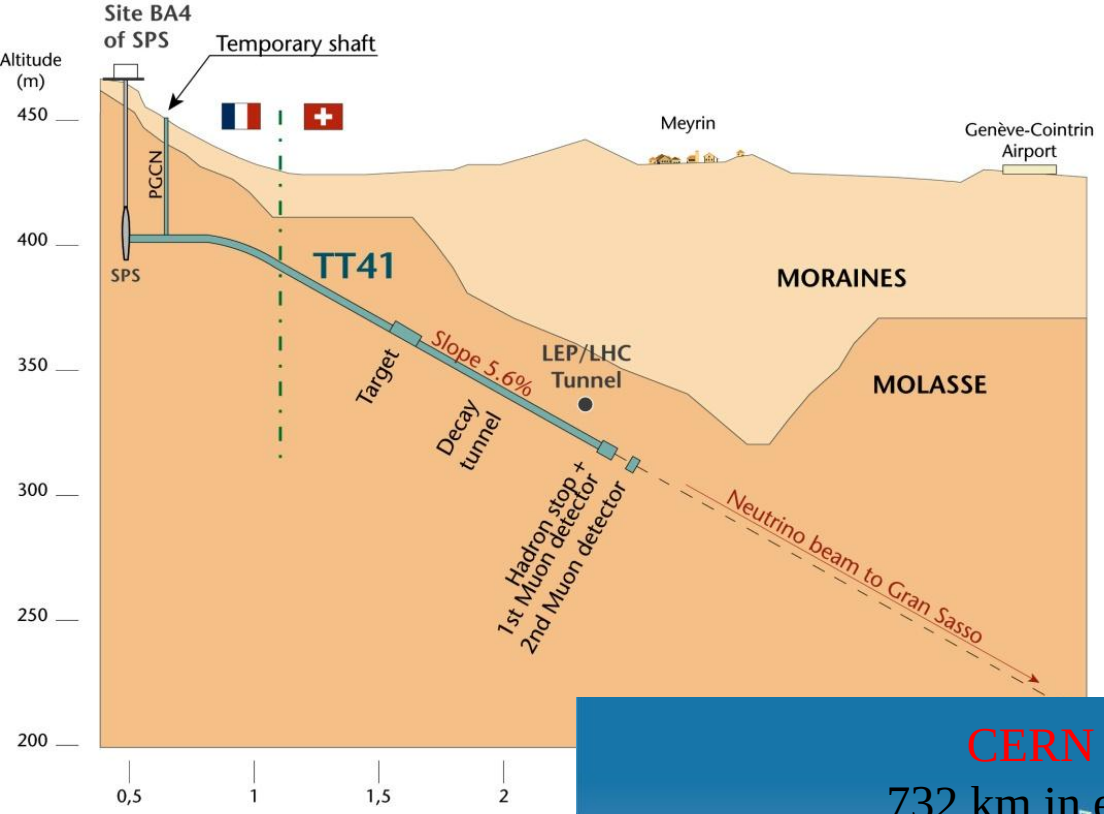
CERN Neutrinos zum Gran Sasso





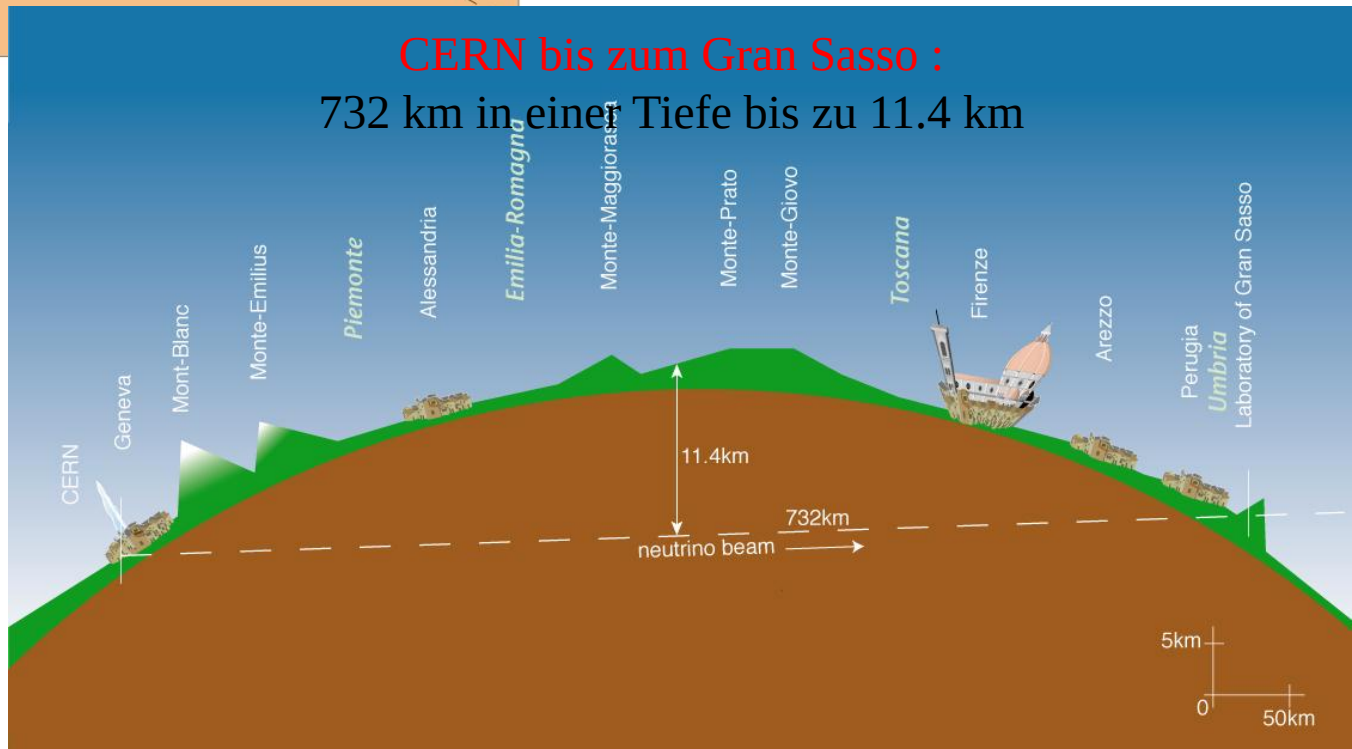


$p + C \rightarrow$ (Wechselwirkungen) $\rightarrow \pi^+, K^+ \rightarrow$ (Zerfall) $\rightarrow \mu^+ + \nu_\mu$

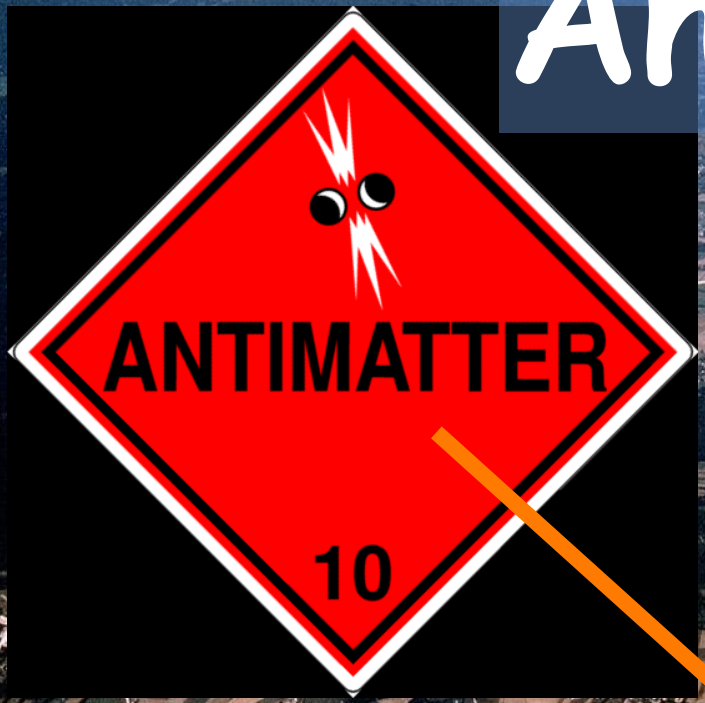


CERN bis zum Gran Sasso :

732 km in einer Tiefe bis zu 11.4 km



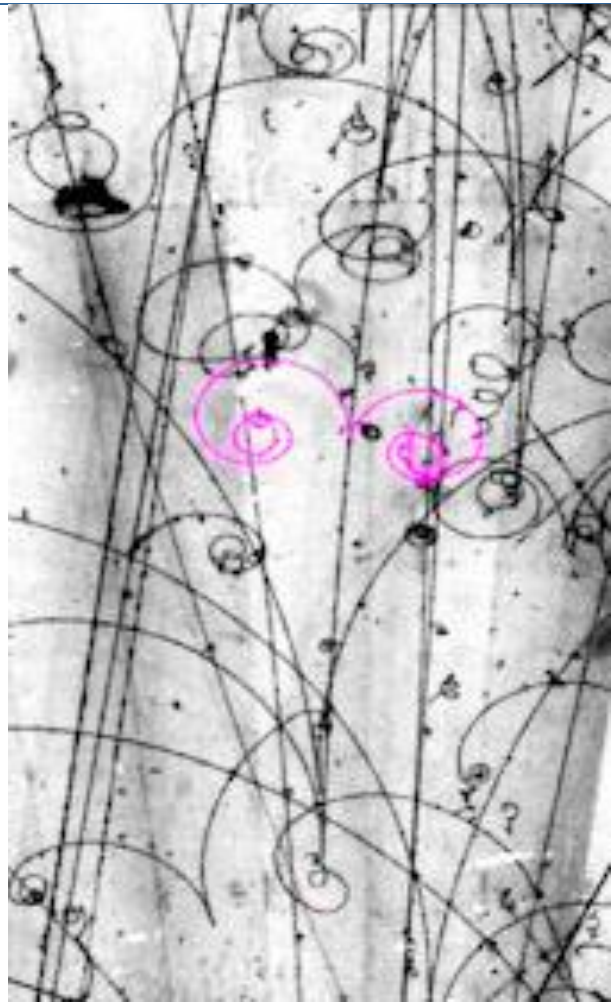
Antimaterie



Was ist Antimaterie?

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

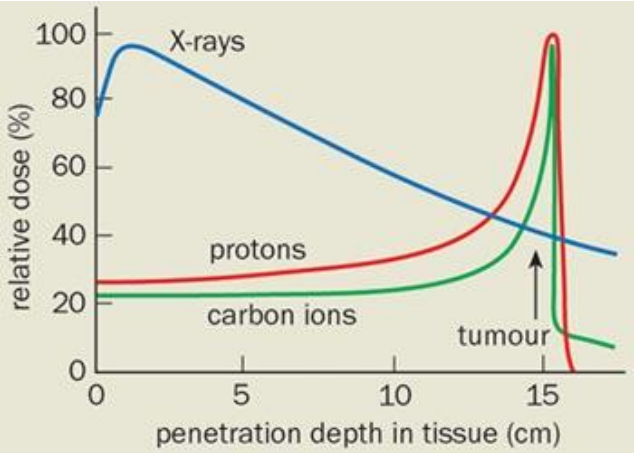
Elektron Positron

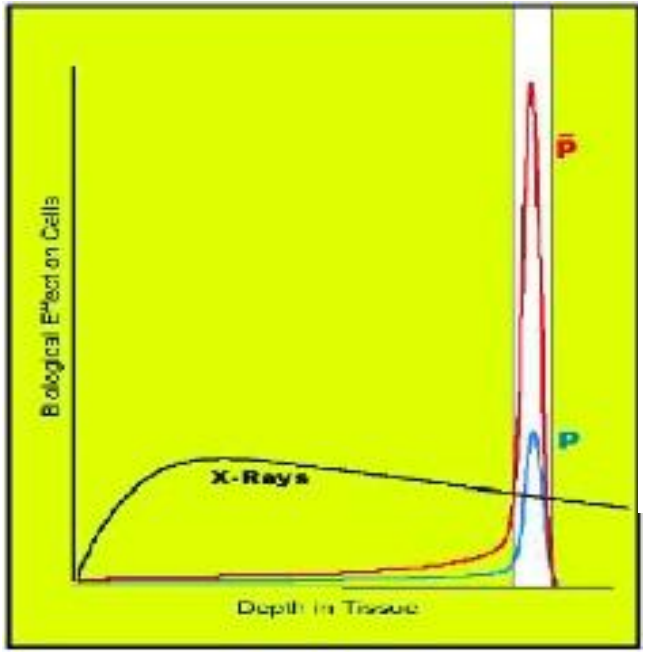


Dan Brown's

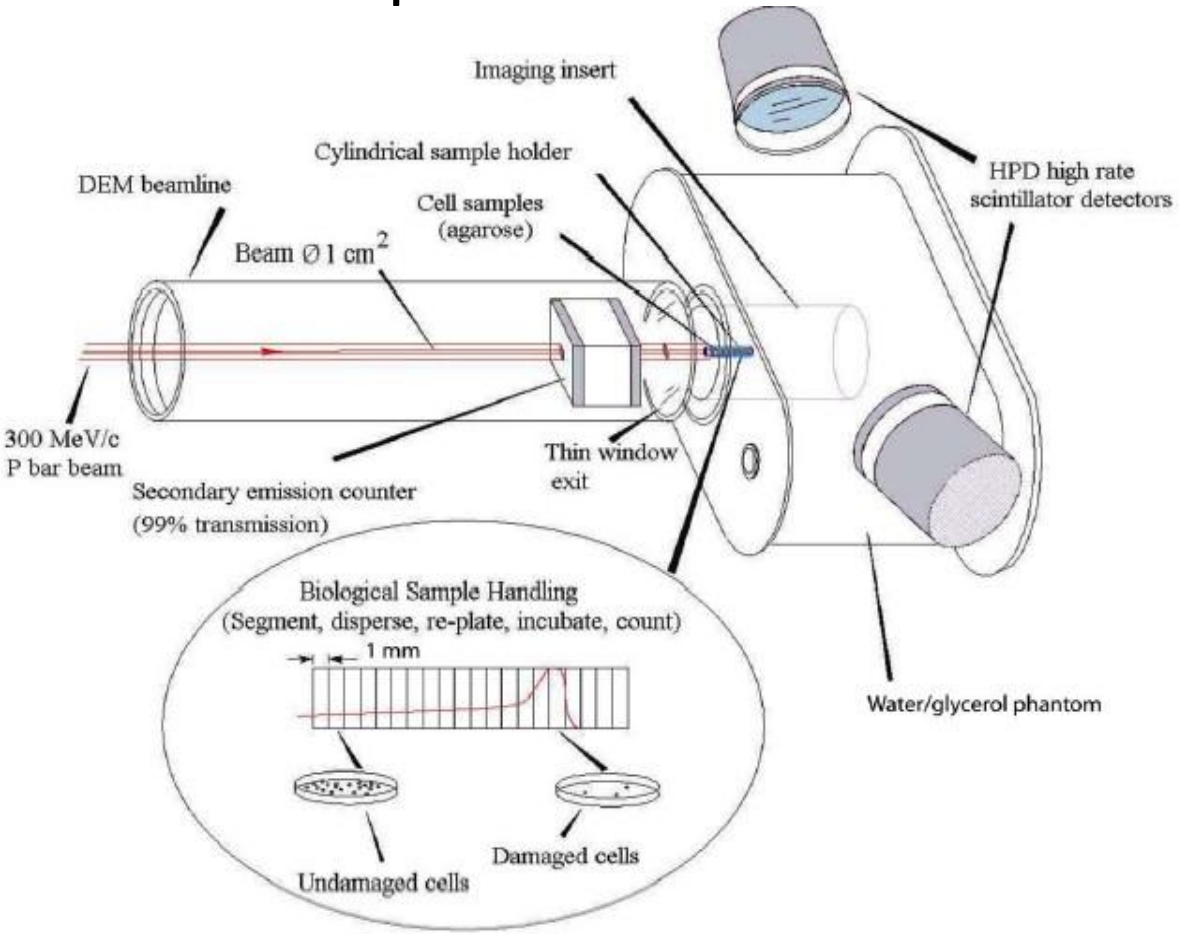
Tom's Angels and demons

Anwendung von Antimaterie - Tumorbekämpfung





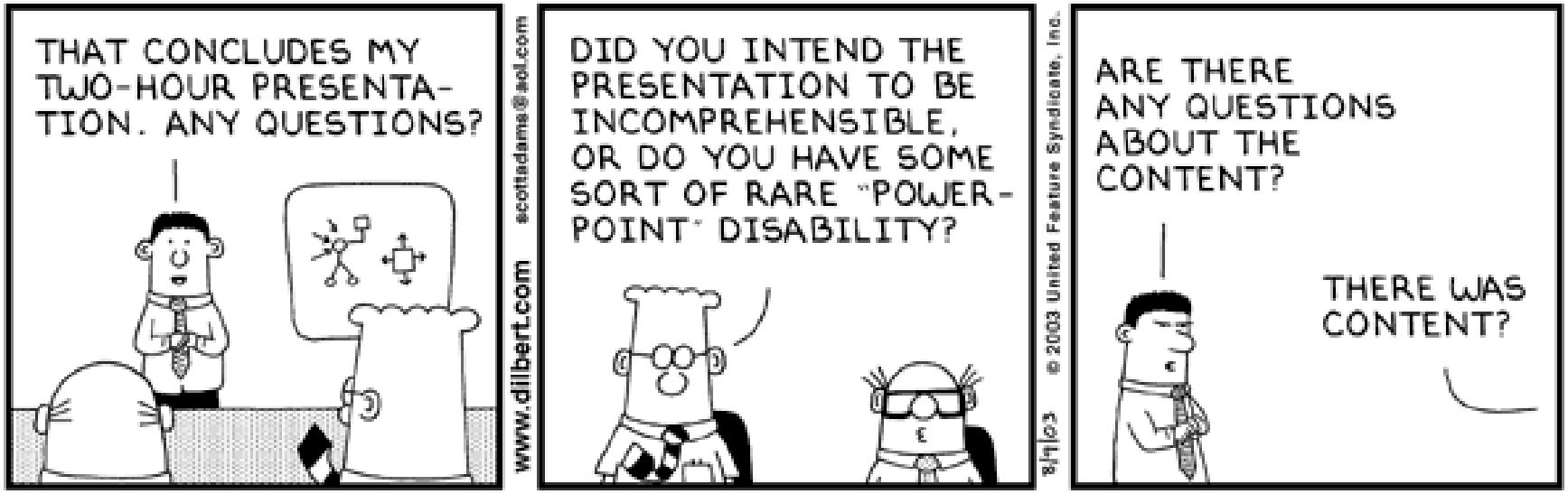
ACE Experiment bei CERN



*) Antiproton Cell Experiment

Physics Department

Fragen ?



© 2003 United Feature Syndicate, Inc.

Physique des Particules

Physique Nucléaire

Physique du Solide

Chimie - Biologie

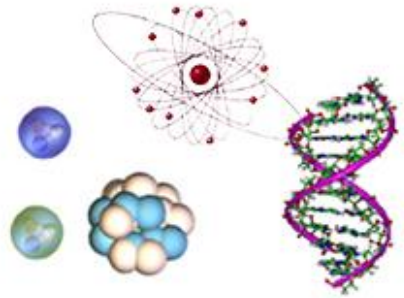
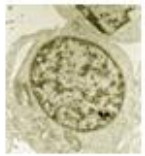
Mécanique

Cosmologie

Astrophysique

Astronomie

Géophysique

10^{-15} 10^{-12} 10^{-9} 10^{-6} 10^{-3} 10^{1} 10^{3} 10^{6} 10^{9} 10^{12} 10^{15} 10^{18} 10^{21} 10^{24}

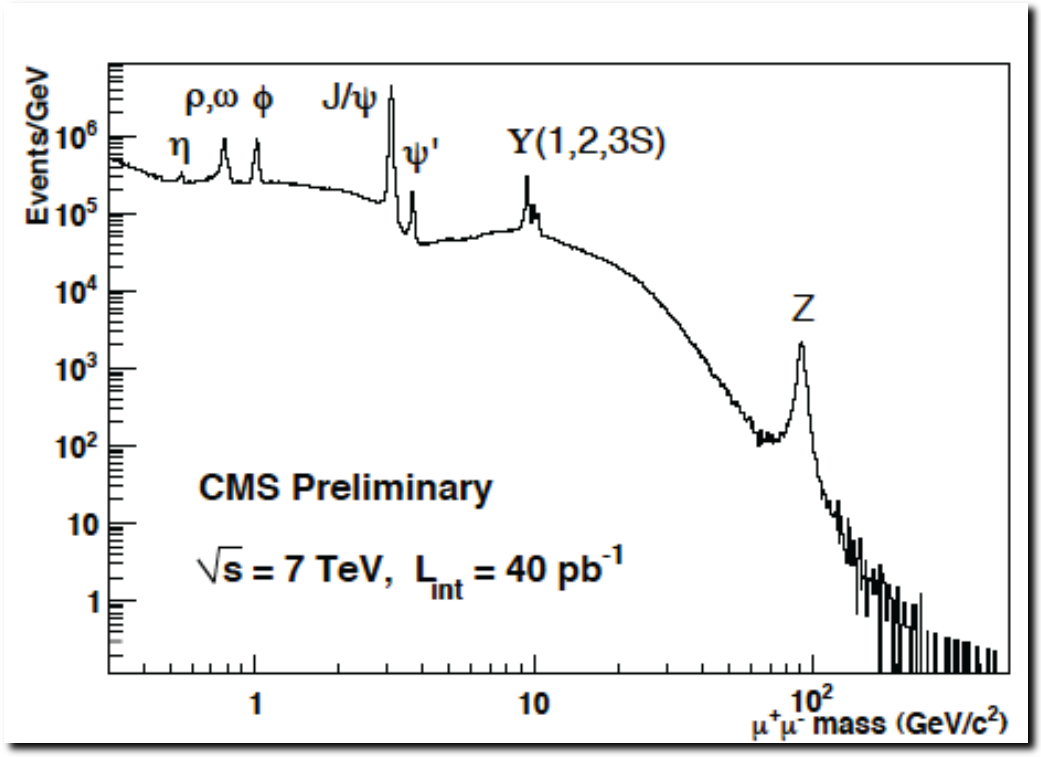
fm pm nm μm mm m km Mm Gm Tm Pm Em

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

D.Bertola/CERN

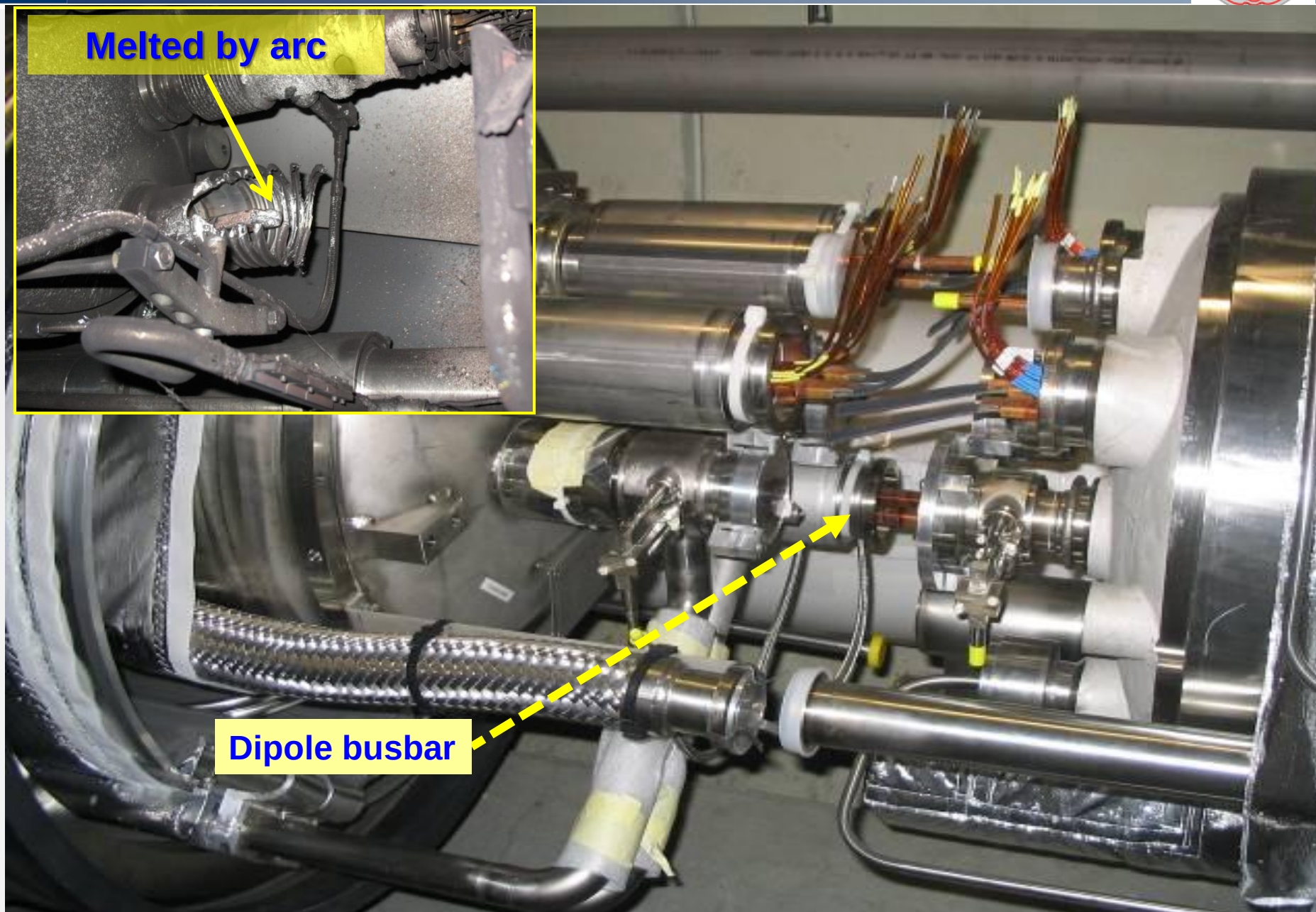
Excellent performances 2010

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

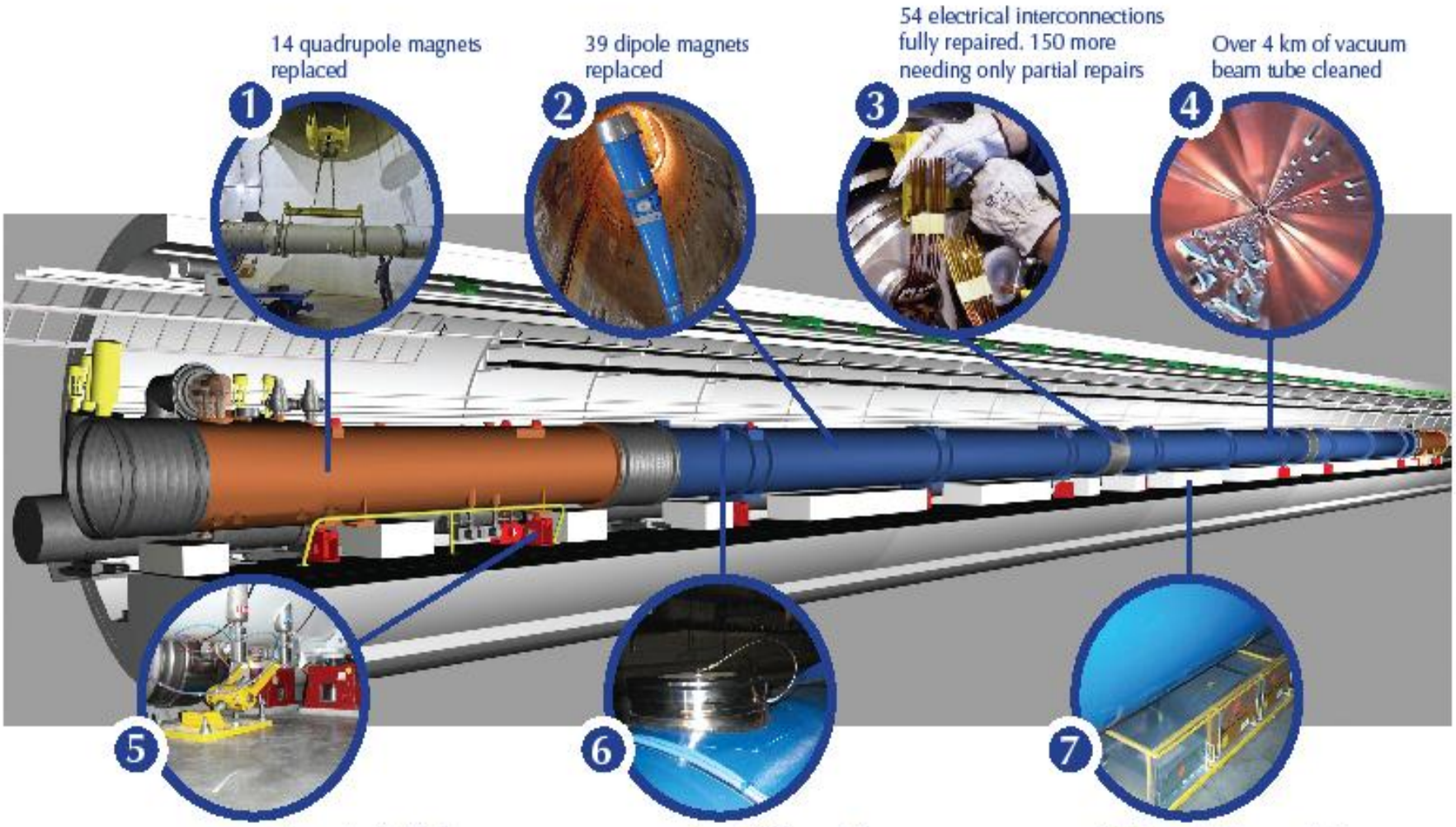


- Experiments demonstrated readiness in the exploitation of the 7 TeV p-p and 2.76 TeV Pb-Pb data;
- analyses proceeded very rapidly;
- Experiments have about completed their journey through the Standard Model … and have started to take us into uncharted territories …

Magnet Interconnection



The LHC repairs in detail



CERN

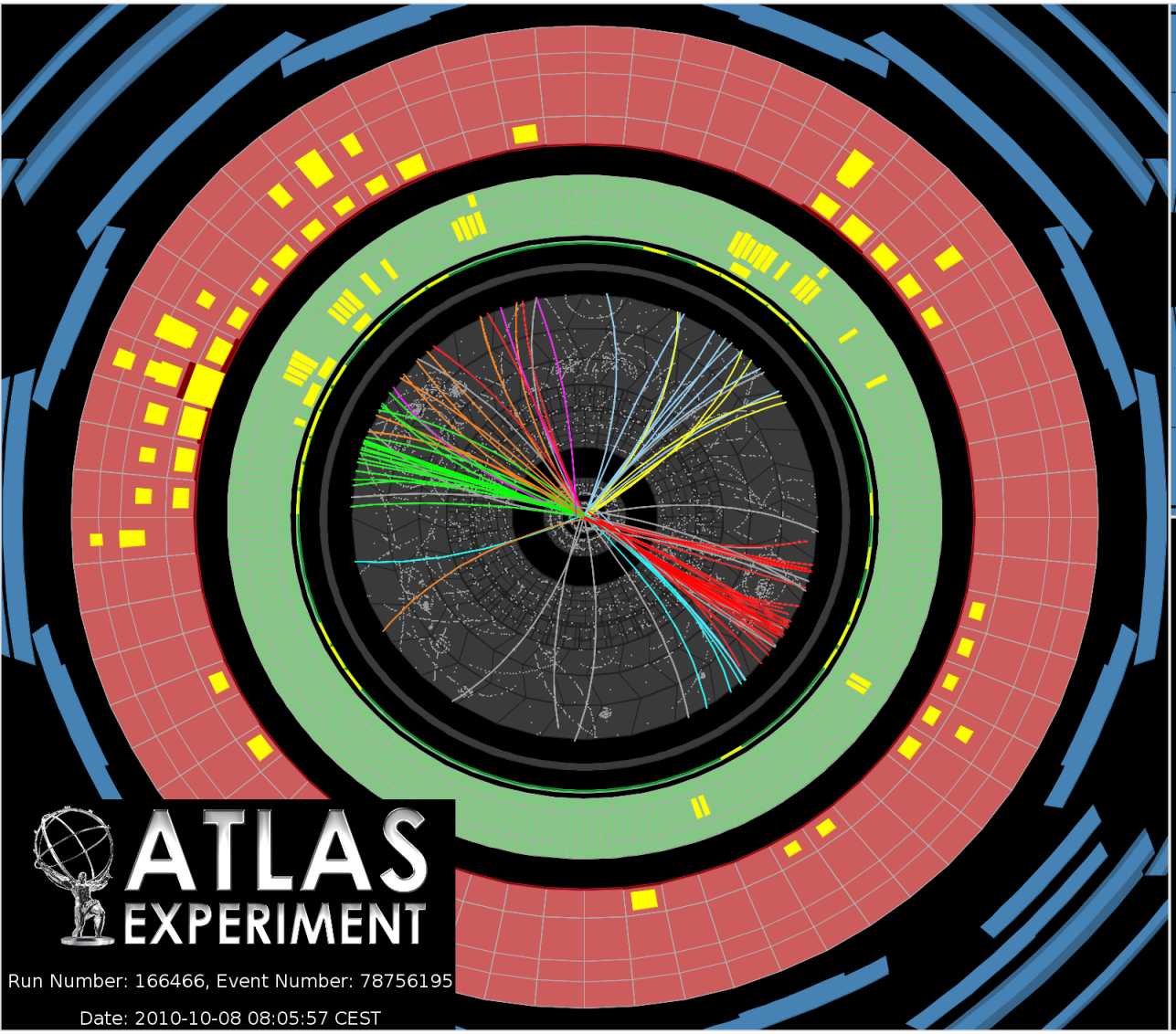
+ Kältetechnik

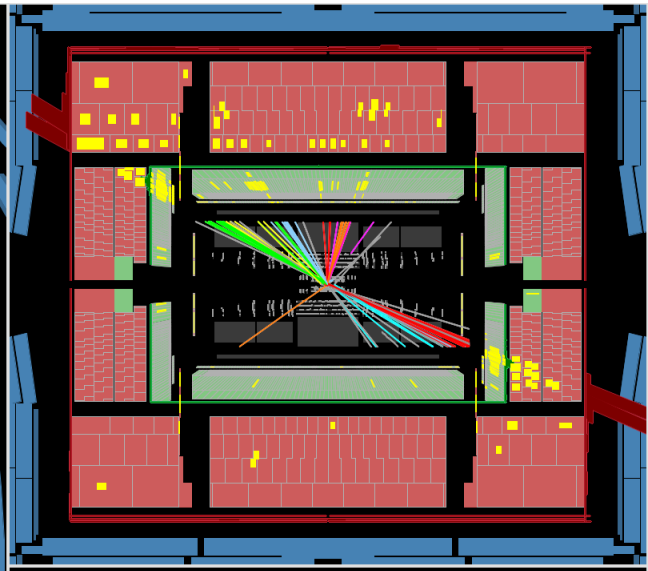
20th November 2009

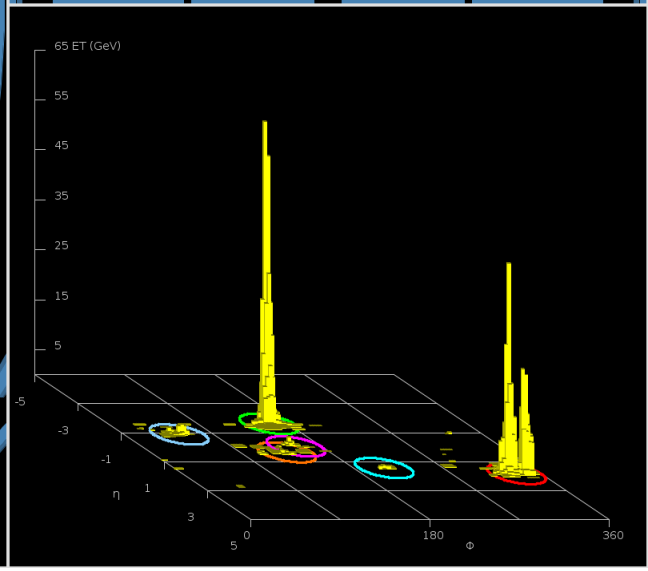
- 14 months to repair, consolidate and re-commissioning all elements.
- Great relief on November 20th when both beams circulated again !!!

Highest mass di-jet

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

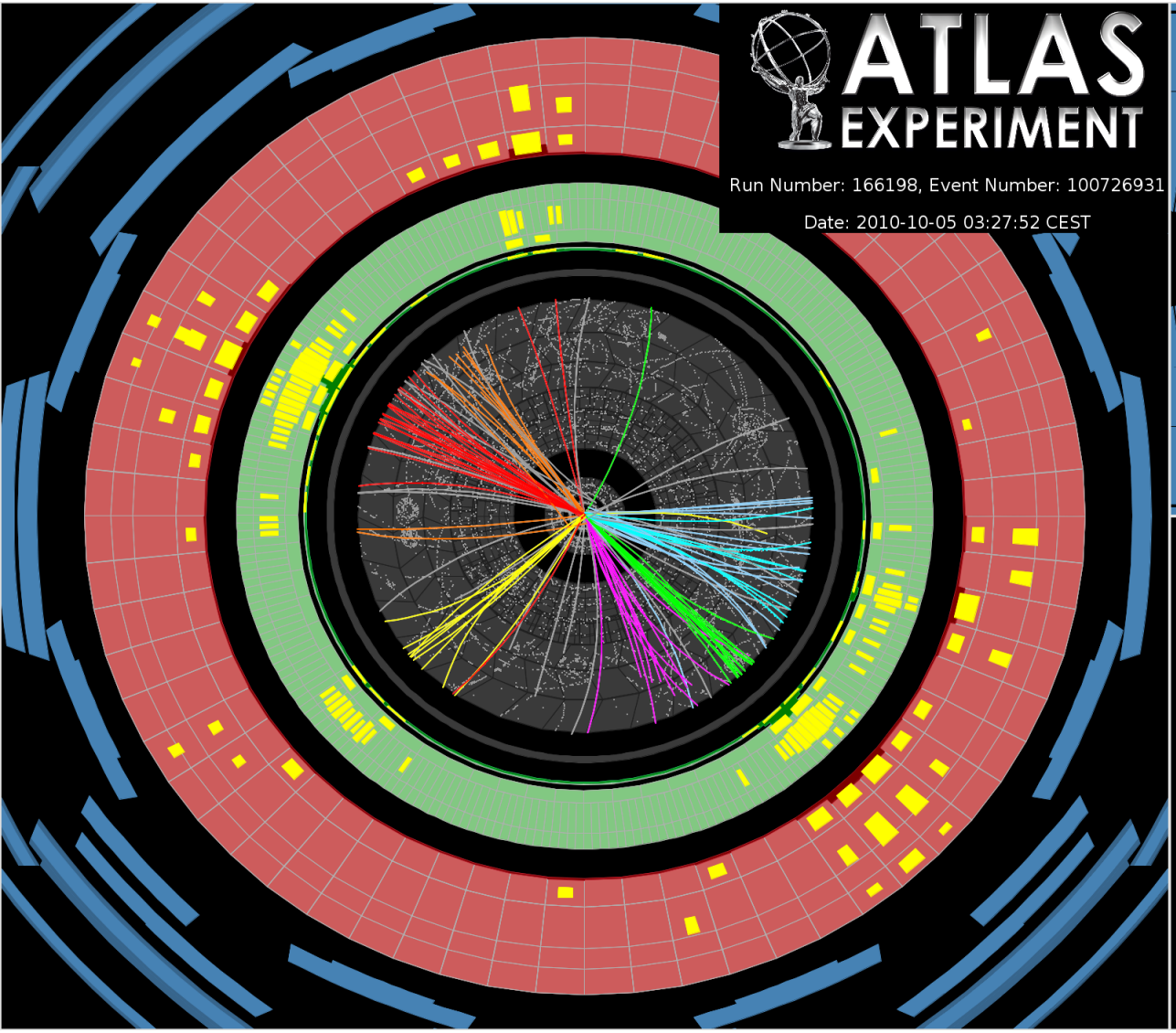


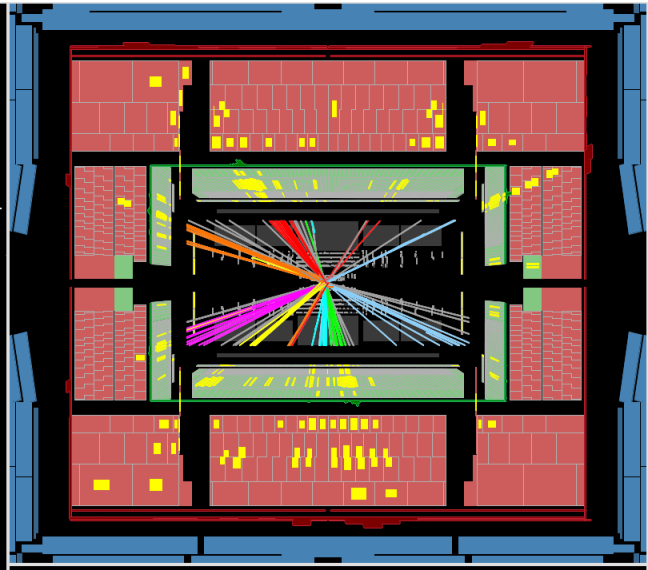


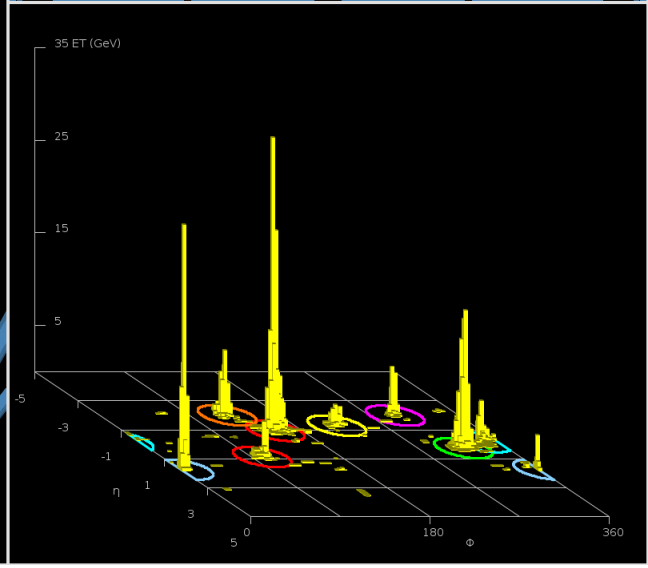


8-jet event

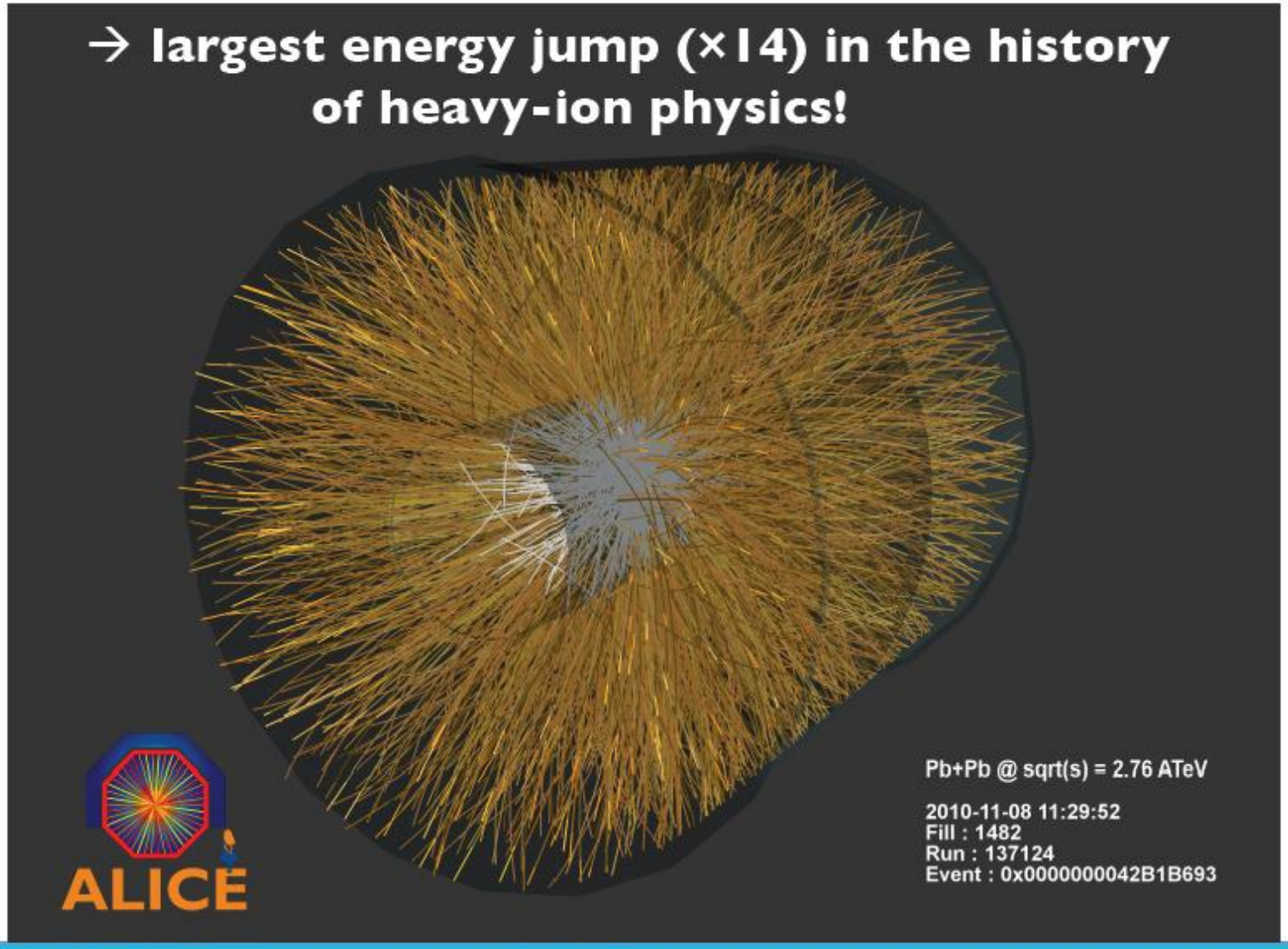
8 jets with p_T>60 GeV



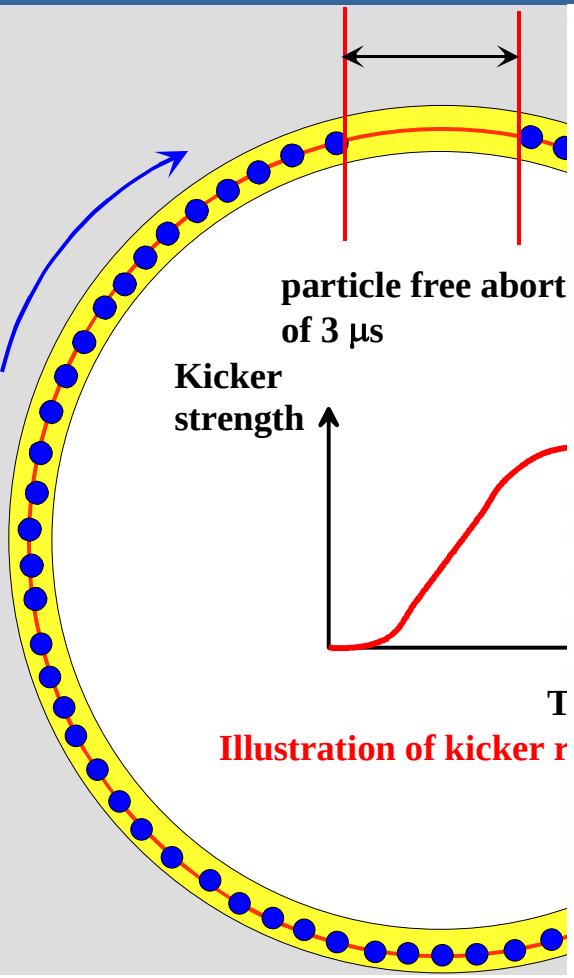


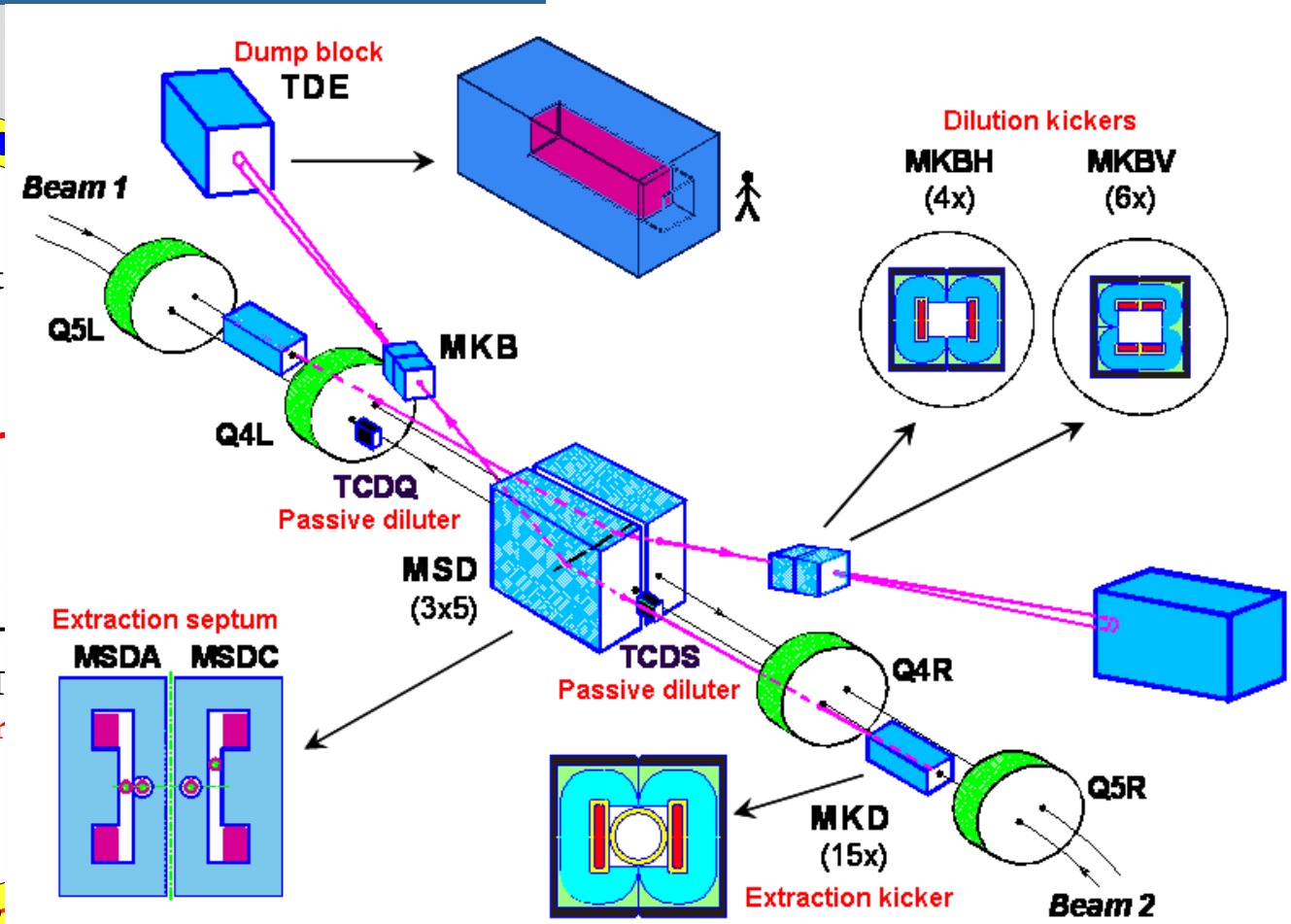
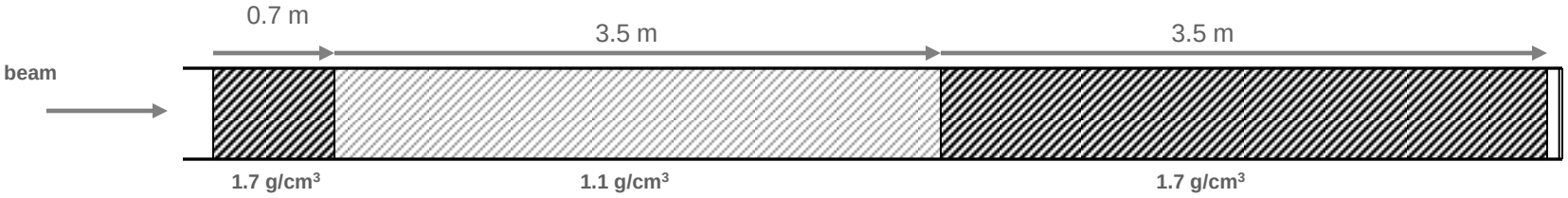
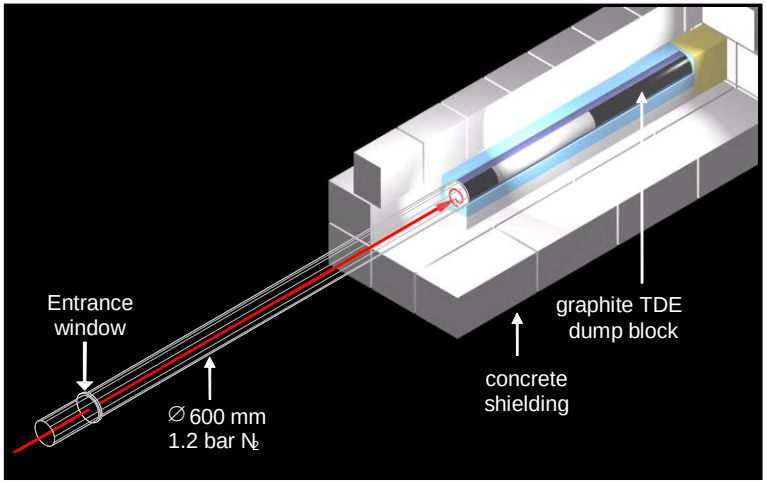


Pb-Pb collisions $\sqrt{s_{NN}}$=2.76 TeV !



Beam Dump System





Der Beam Dump