The DELPHI experiment

at

the LEP accelerator

at

the CERN laboratory

The LEP accelerator

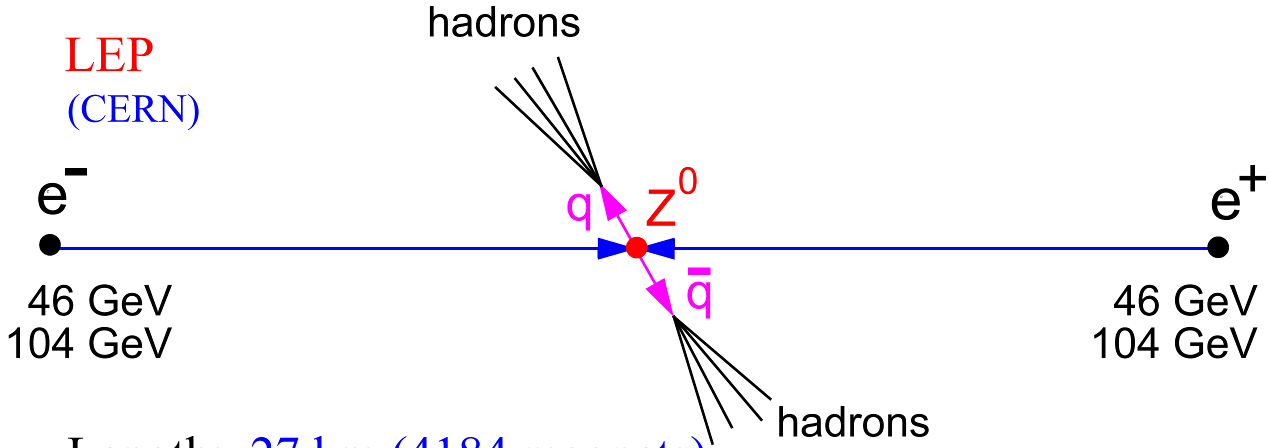
The study of collisions between
electrons and positrons.

LEP 1 : The collision energy = 91 GeV = Z

LEP 2: The collision energy = 209 GeV > 2W

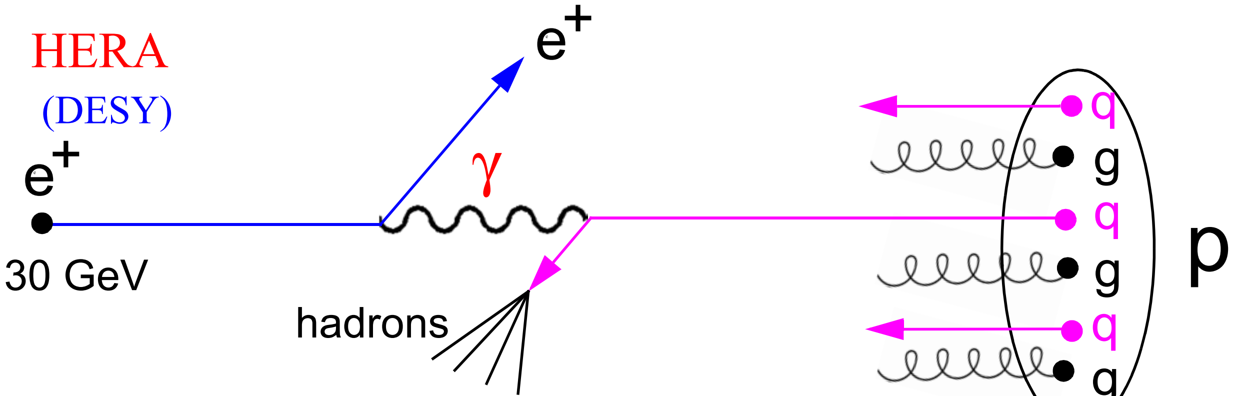
The largest accelerators in the world

LEP
(CERN)



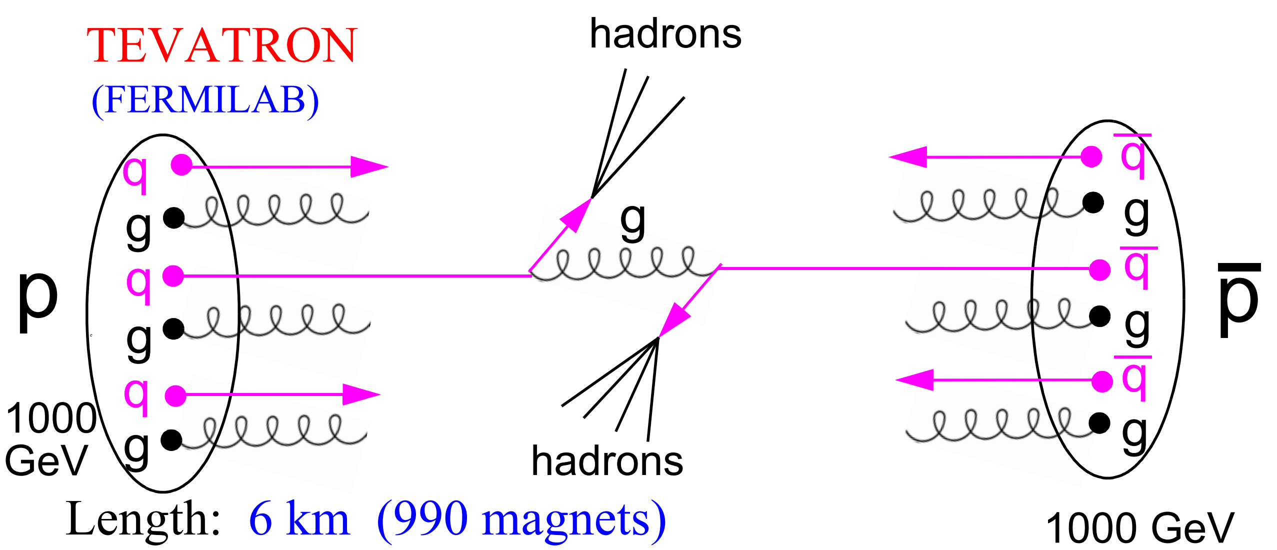
Length: 27 km (4184 magnets)
Experiments: DELPHI, OPAL, ALEPH, L3

HERA
(DESY)



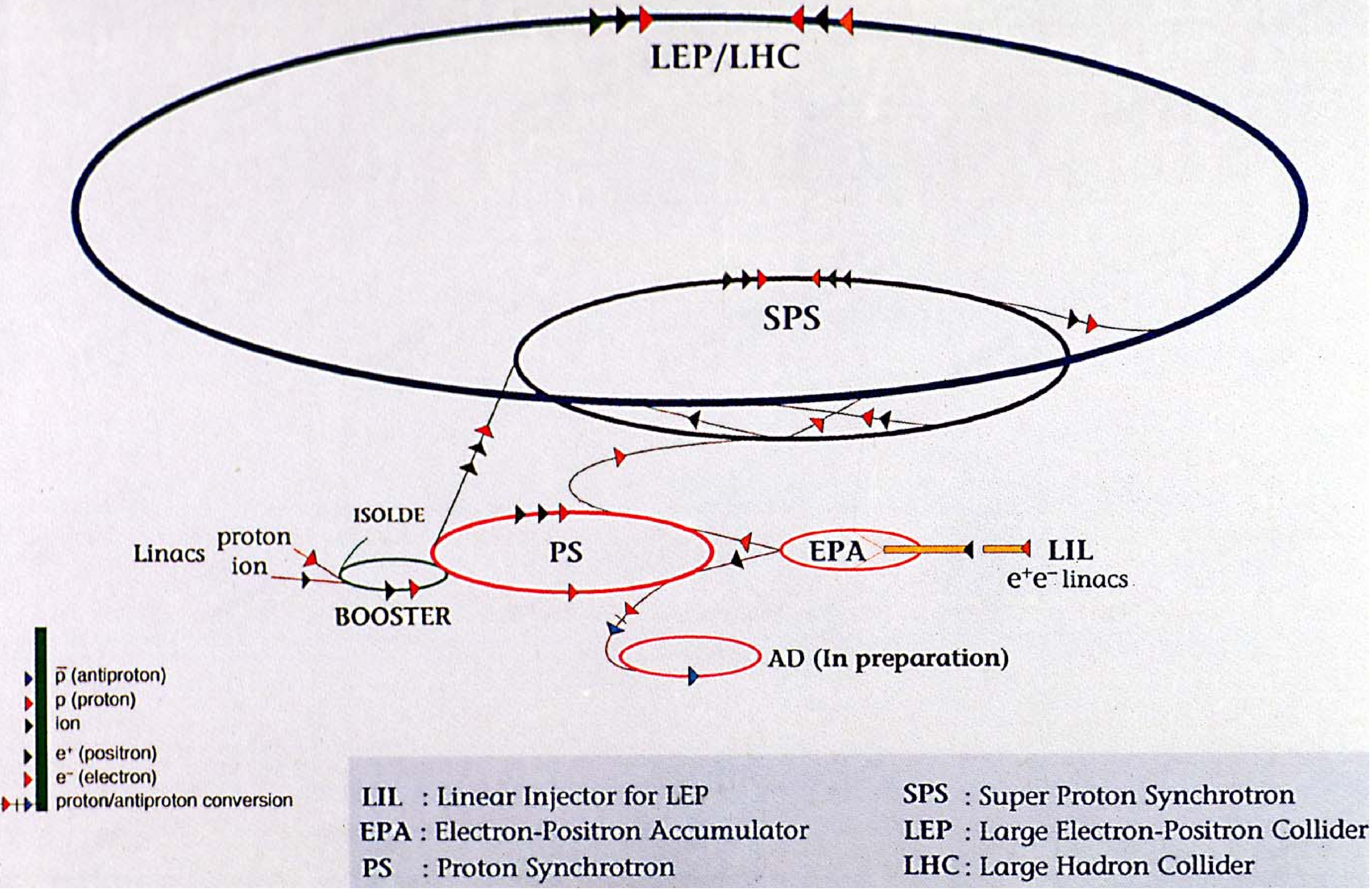
Length: 6 km (1650 magnets)
Experiments: H1, ZEUS

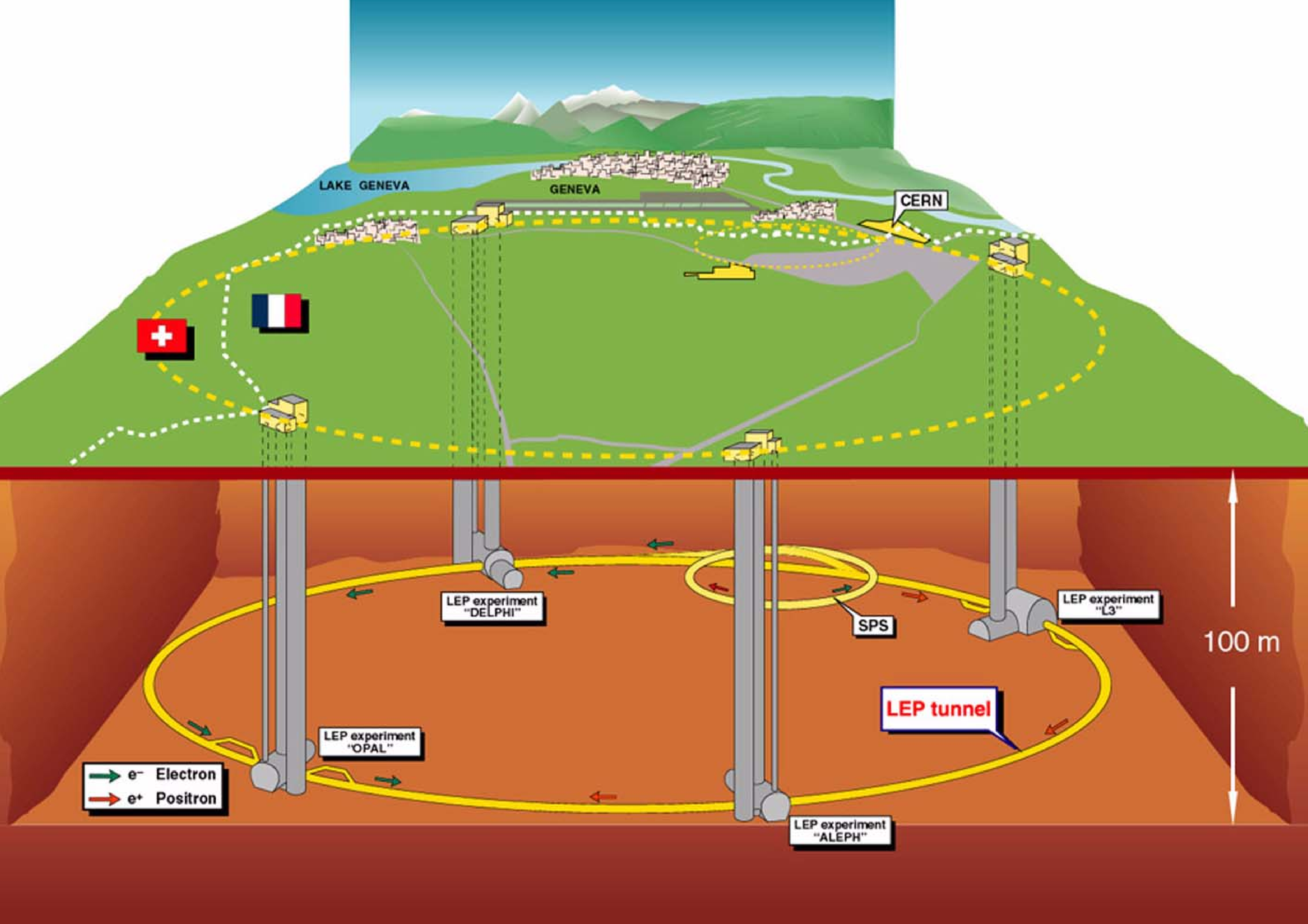
TEVATRON
(FERMILAB)

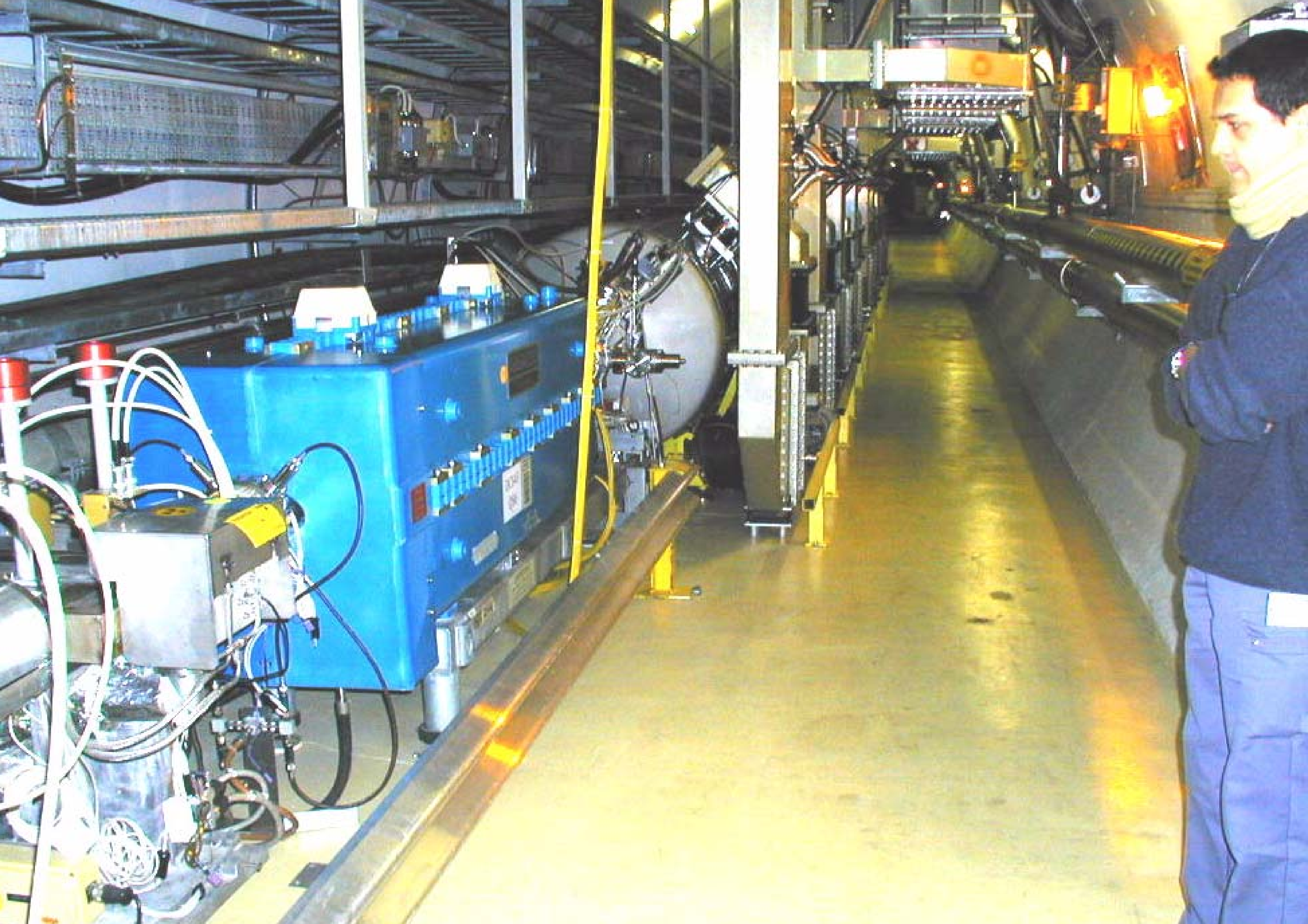


Length: 6 km (990 magnets)
Experiments: CDF, D0

CERN's Chain of Accelerators



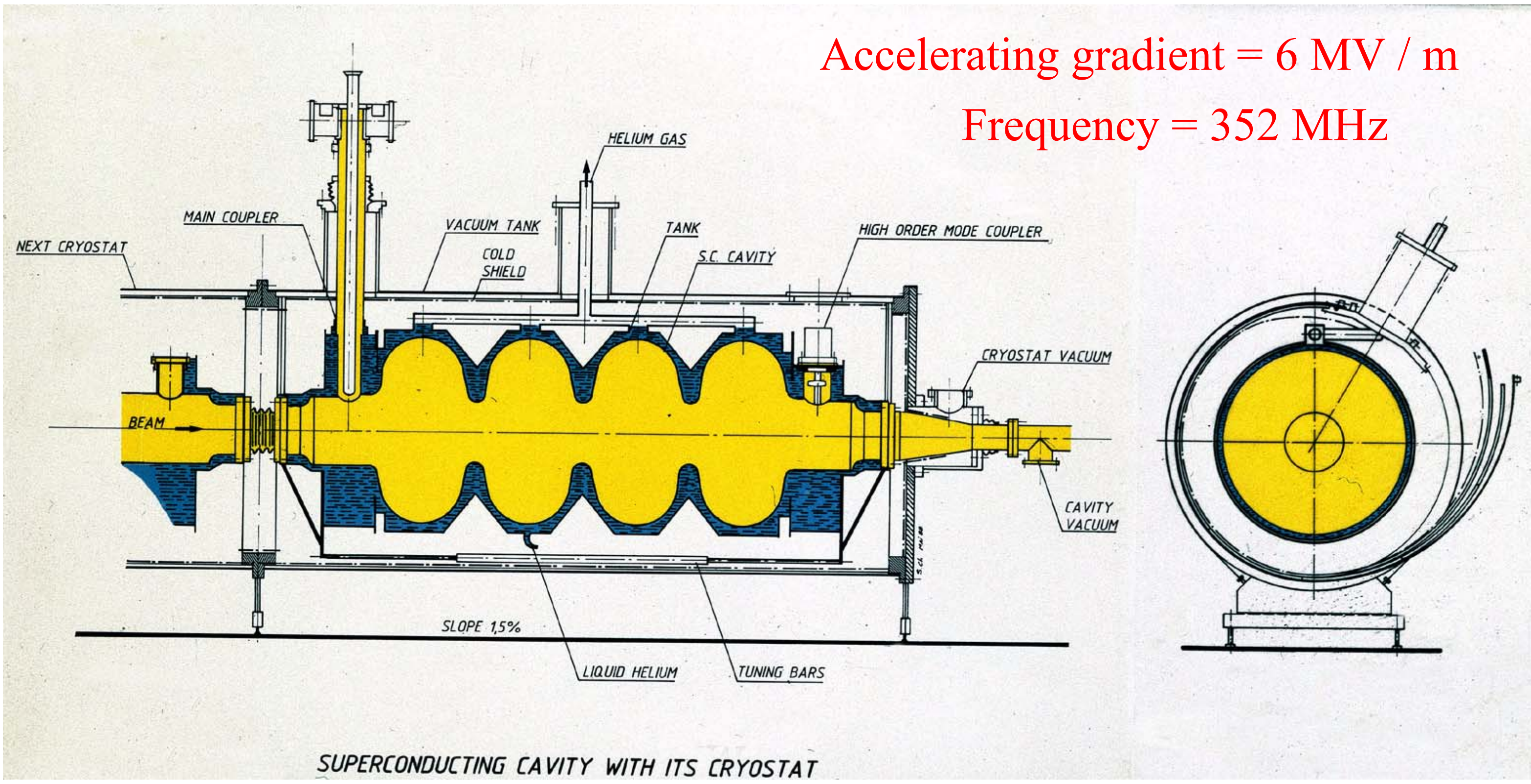

LAKE GENEVA
GENEVA
CERN
LEP experiment "DELPHI"
SPS
LEP experiment "L3"
100 m
LEP tunnel
LEP experiment "OPAL"
e⁻ Electron
e⁺ Positron
LEP experiment "ALEPH"




ORNEX

LEP 1 → LEP 2

In order to increase the collision energy one had to build 240 superconducting radio-frequency cavities.



Accelerating gradient = 6 MV / m

Frequency = 352 MHz

The energy lost due to synchrotron radiation is 2.3 GeV / turn

→

Radio-frequency accelerating voltage has to be 2.3 GV / turn

Year:	1989-94	1995	1996	1997	1998	1999	2000
Collision energy: (GeV)	91	136	174	184	189	204	209

The collision energy

At LEP the collision energy could be determined

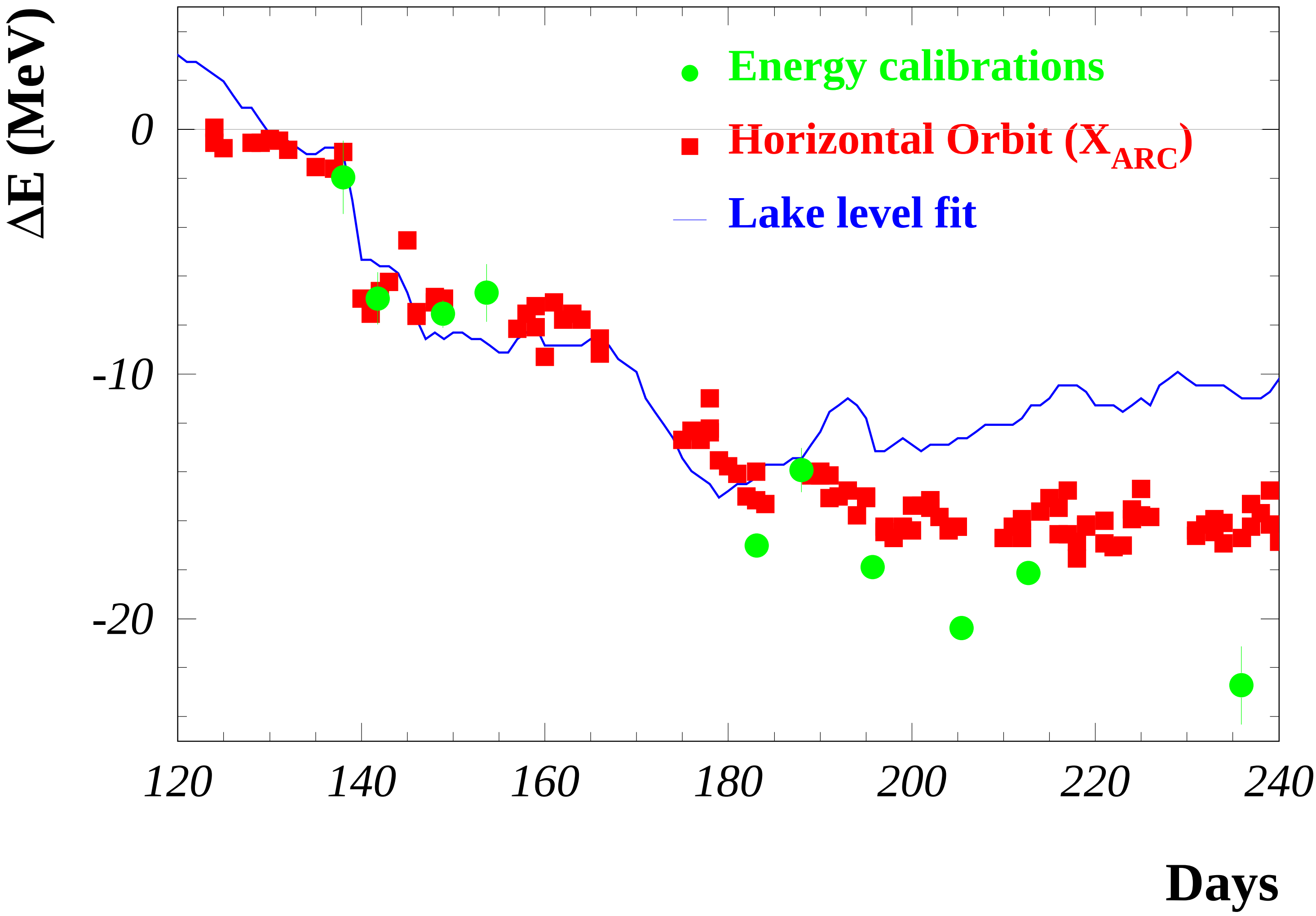
with a very high accuracy:

91.187 GeV with an error of 0.002 GeV

Things which affected the energy of LEP:

1. The level of the water in the lake !
2. The moon !
3. The trains to Paris !

Geological shifts

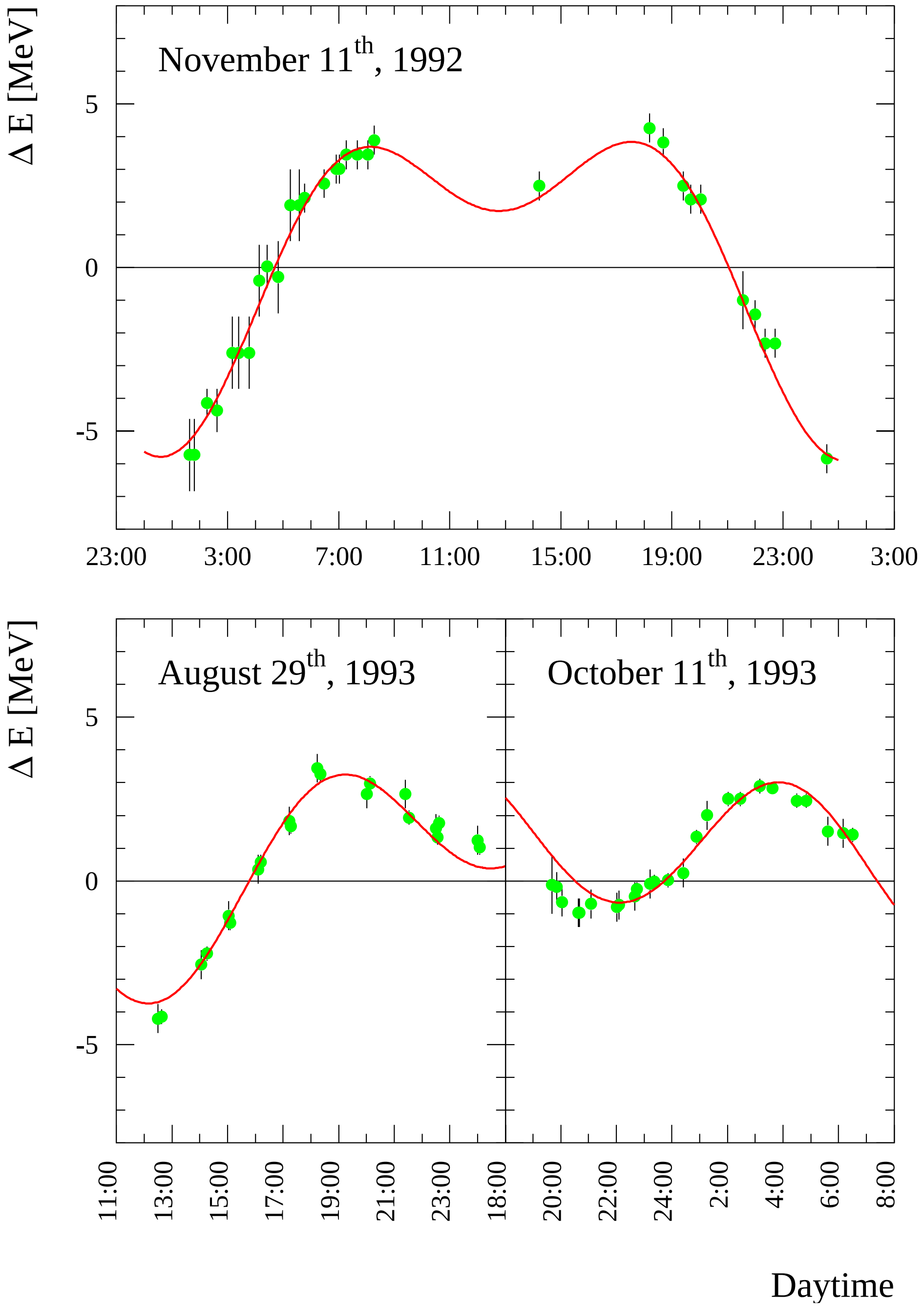


During 1993 the LEP energy was observed to change with time.

Part of the change was due to the water level in lake Geneva which caused small geological shifts of the accelerator.

Rainfalls and the water table in the Jura mountains also affected the LEP energy.

Tides



Earth tides caused by the moon will produce small distortions of the earth´s crust.

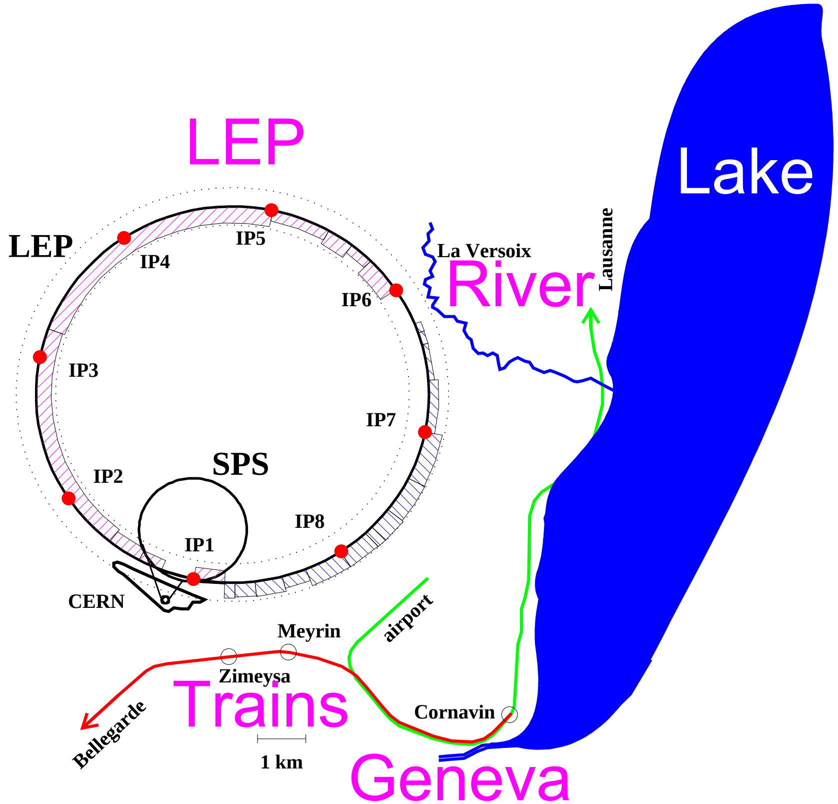
This can affect the accelerator so that the electrons orbit change.

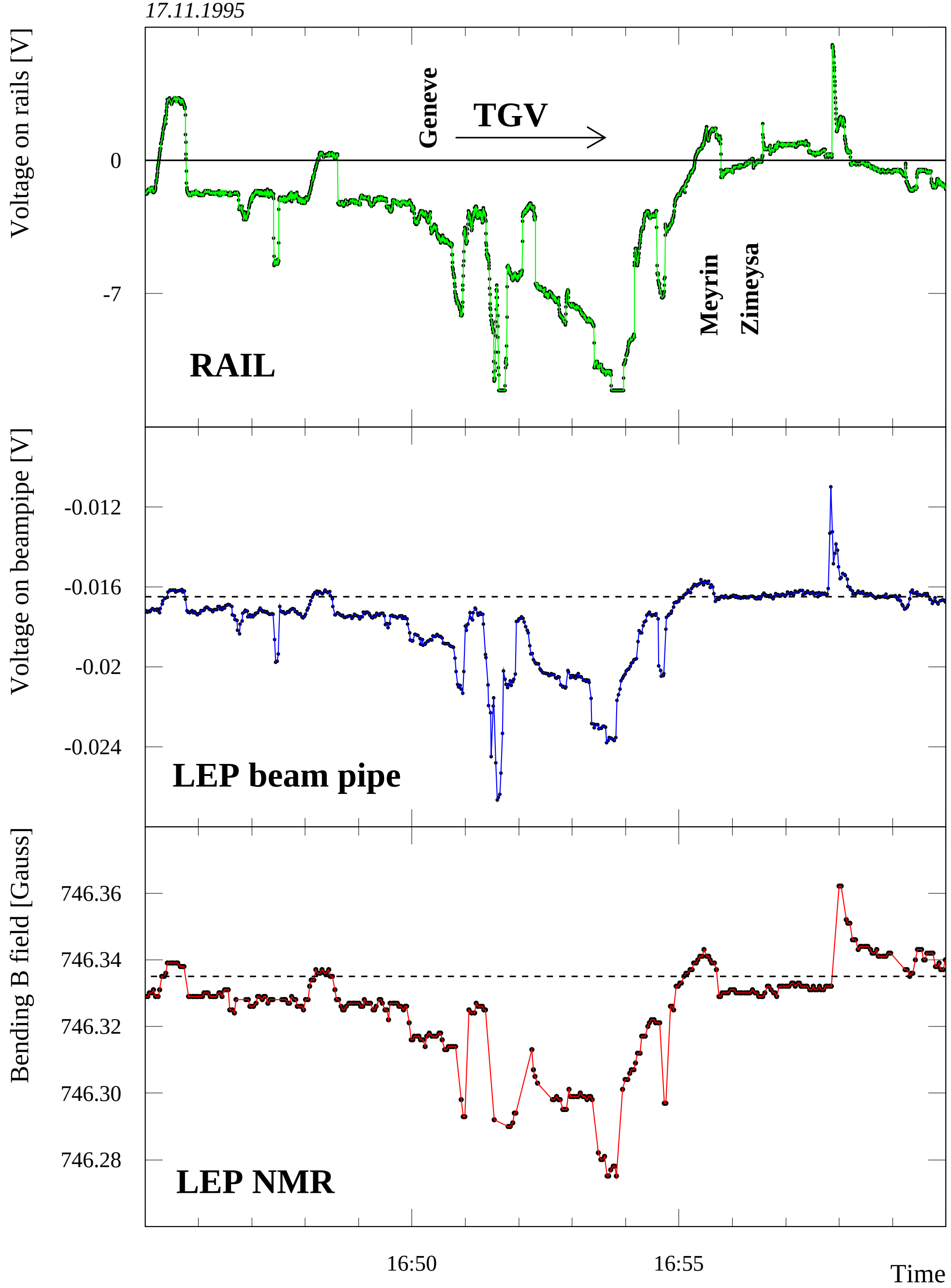
An orbit change of 1 mm will change the energy with about 10 MeV.

Beampipe current

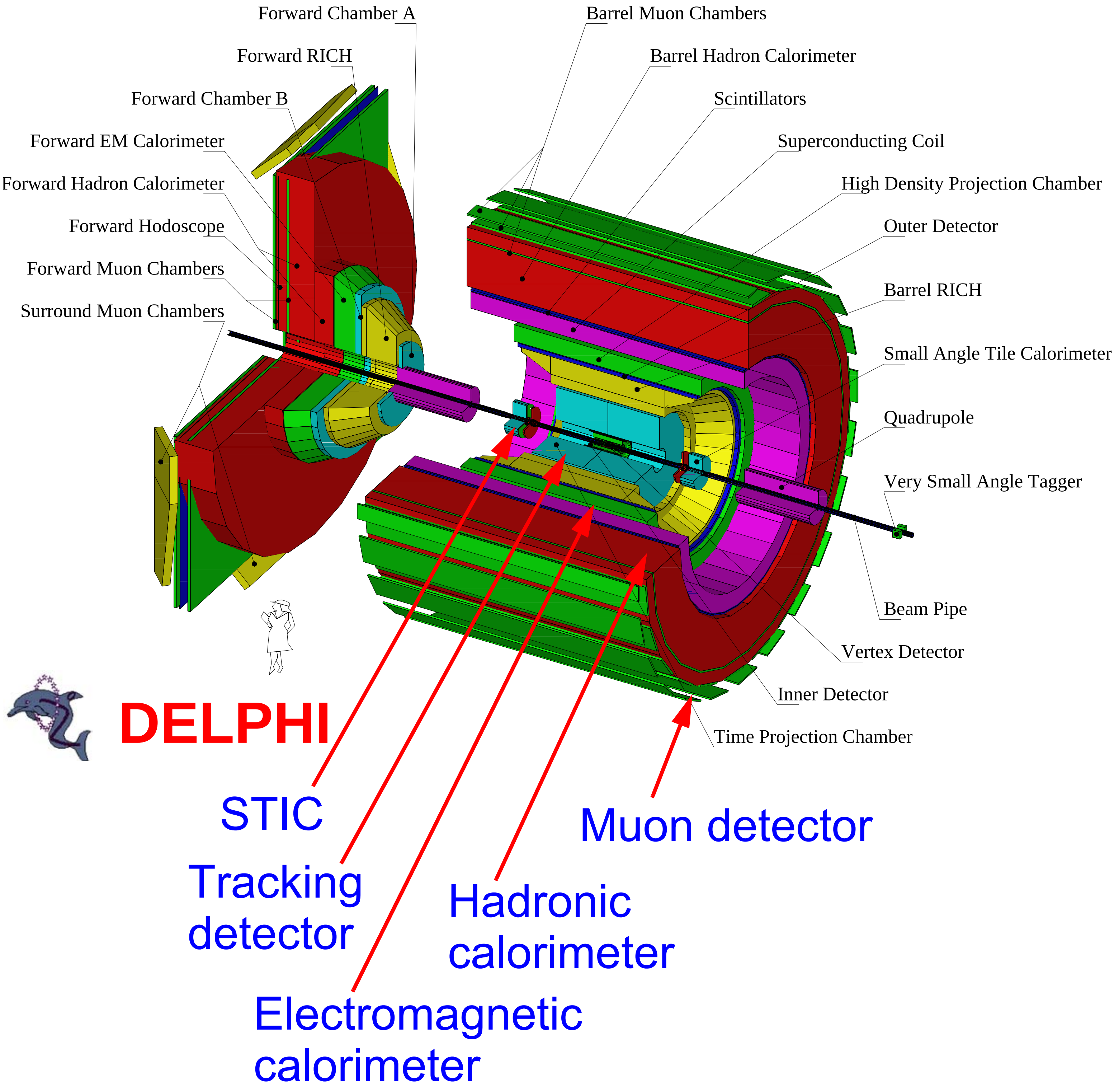
The trains from Geneva to France caused parasitic currents on the LEP beampipe.

These currents (1 A) affected the magnetic field in the LEP magnets and this changed the energy.



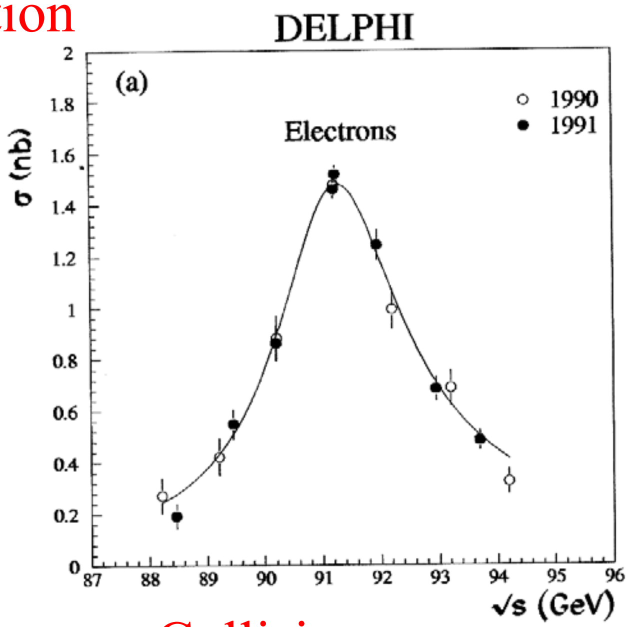


The DELPHI experiment

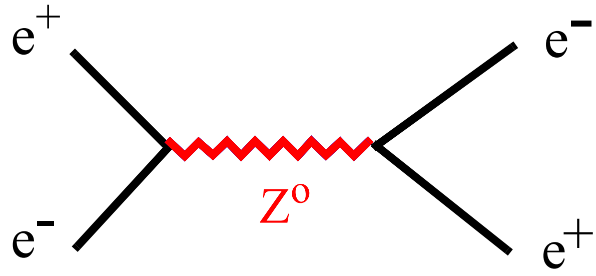


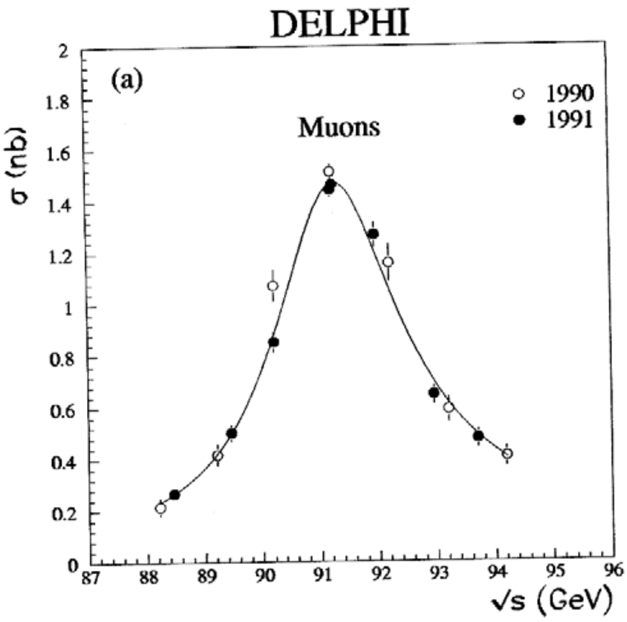

DELPHI
A
B
C

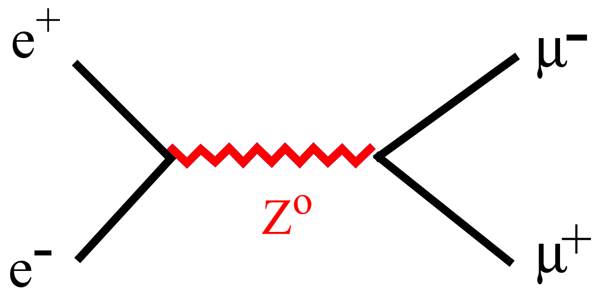
Cross-section

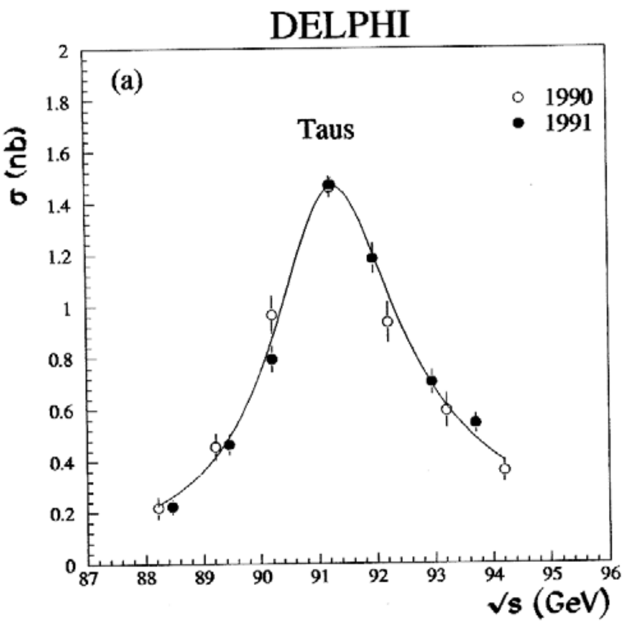


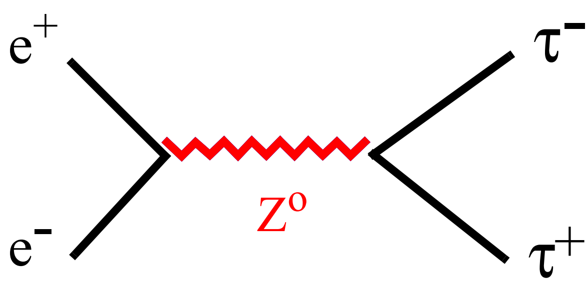
Collision energy

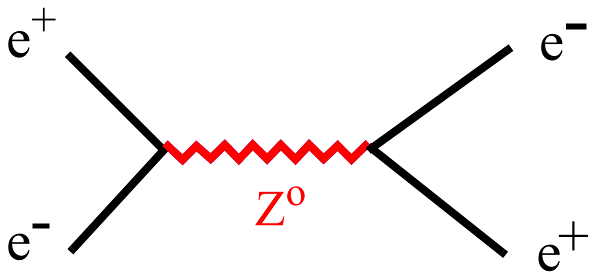


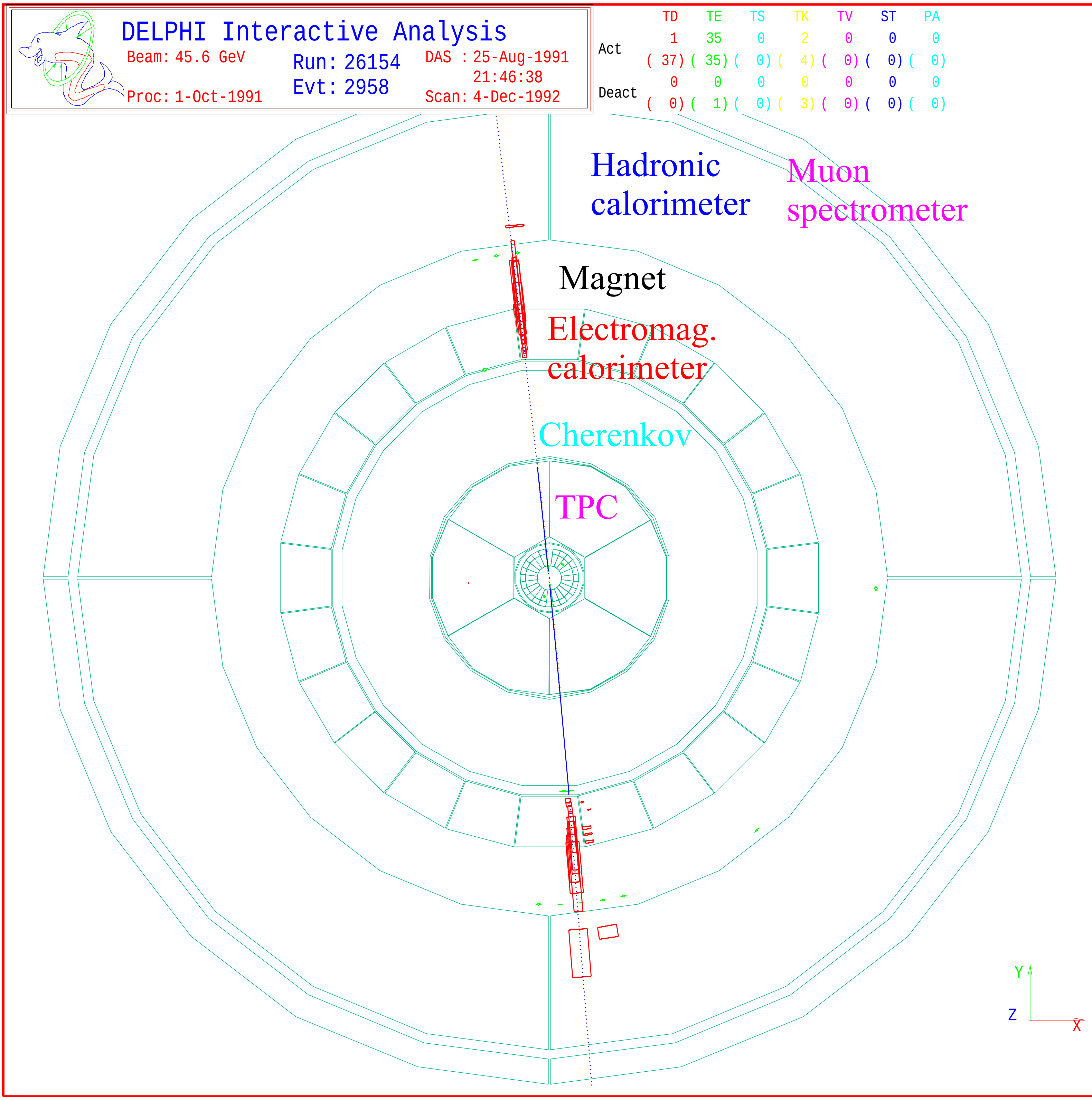


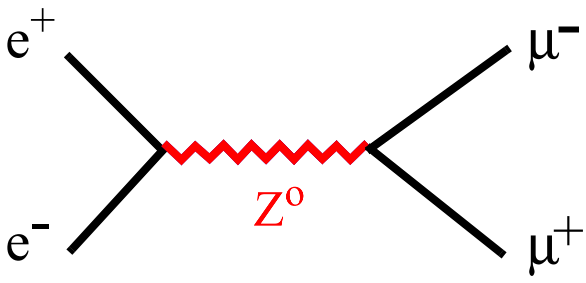


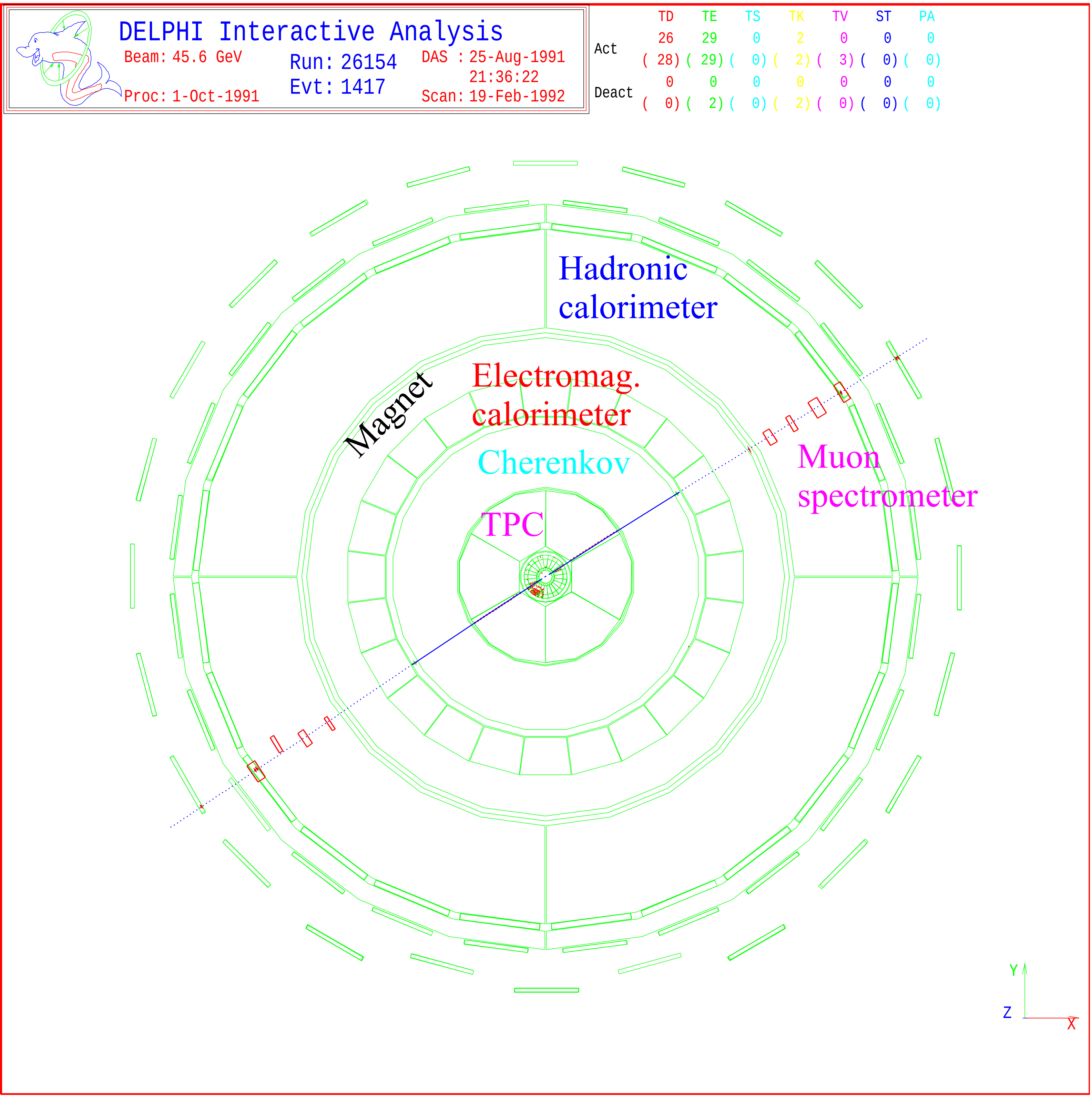


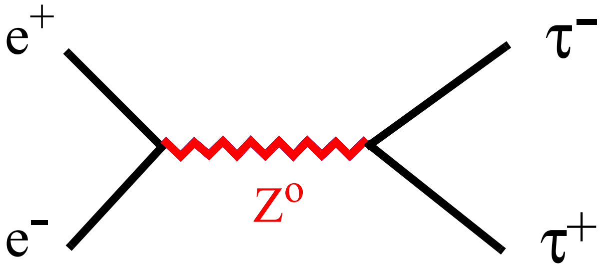


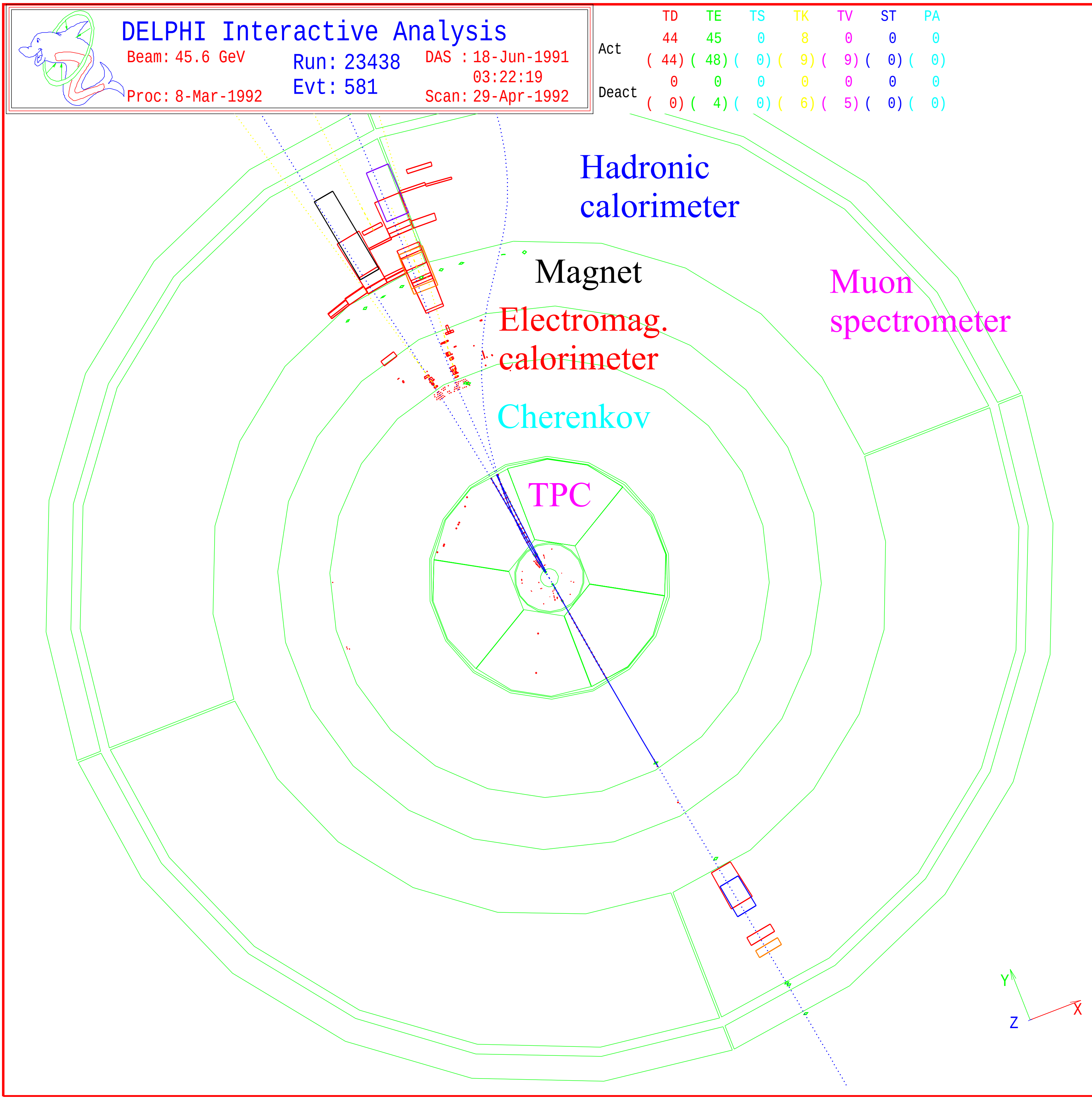

e+
e-
e-
e+
Zo

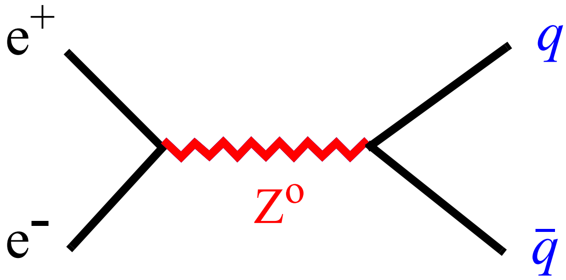

DELPHI Interactive Analysis
Beam: 45.6 GeV
Run: 26154
Evt: 2958
DAS : 25-Aug-1991
21:46:38
Proc: 1-Oct-1991
Scan: 4-Dec-1992
TD TE TS TK TV ST PA
Act
1 35 0 2 0 0 0
(37) (35) (0) (4) (0) (0) (0)
Deact
0 0 0 0 0 0 0
(0) (1) (0) (3) (0) (0) (0)
Hadronic calorimeter
Muon spectrometer
Magnet
Electromag. calorimeter
Cherenkov
TPC
Y
Z
X


e+
e-
Zo
μ-
μ+

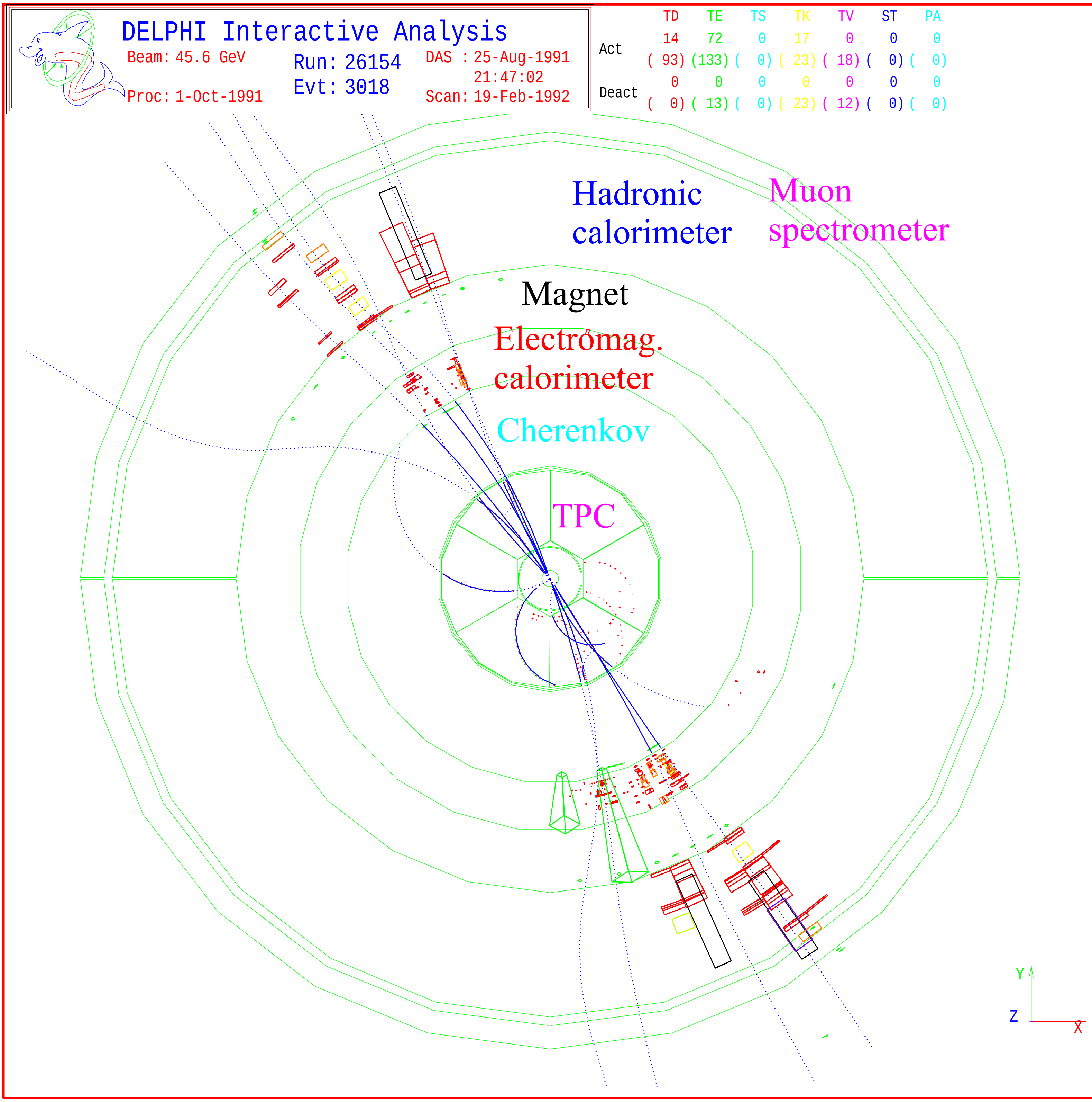

DELPHI Interactive Analysis
Beam: 45.6 GeV
Proc: 1-Oct-1991
Run: 26154
Evt: 1417
DAS : 25-Aug-1991
21:36:22
Scan: 19-Feb-1992
TD TE TS TK TV ST PA
Act
26 29 0 2 0 0 0
(28) (29) (0) (2) (3) (0) (0)
Deact
0 0 0 0 0 0 0
(0) (2) (0) (2) (0) (0) (0)
Hadronic
calorimeter
Electromag.
calorimeter
Magnet
Cherenkov
TPC
Muon
spectrometer
Y
Z
X


e+
e-
Zo
τ-
τ+


DELPHI Interactive Analysis
Beam: 45.6 GeV
Run: 23438
Evt: 581
DAS : 18-Jun-1991
03:22:19
Proc: 8-Mar-1992
Scan: 29-Apr-1992
TD TE TS TK TV ST PA
Act
44 45 0 8 0 0 0
(44) (48) (0) (9) (9) (0) (0)
Deact
0 0 0 0 0 0 0
(0) (4) (0) (6) (5) (0) (0)
Hadronic calorimeter
Magnet
Muon spectrometer
Electromag. calorimeter
Cherenkov
TPC
Y
Z
X



e+
e-
Zo
q
q̄



DELPHI Interactive Analysis
Beam: 45.6 GeV
Proc: 1-Oct-1991
Run: 26154
Evt: 3018
DAS : 25-Aug-1991
21:47:02
Scan: 19-Feb-1992
TD TE TS TK TV ST PA
Act
14 72 0 17 0 0 0
(93) (133) (0) (23) (18) (0) (0)
Deact
0 0 0 0 0 0 0
(0) (13) (0) (23) (12) (0) (0)
Hadronic
calorimeter
Muon
spectrometer
Magnet
Electromag.
calorimeter
Cherenkov
TPC
Y
Z
X

What does a particle physicist do ?

- The building of detectors

Examples:

- The TPC (Time Projection Chamber)
- The STIC (Electromagnetic calorimeter)

- Analysis of the data from the experiment

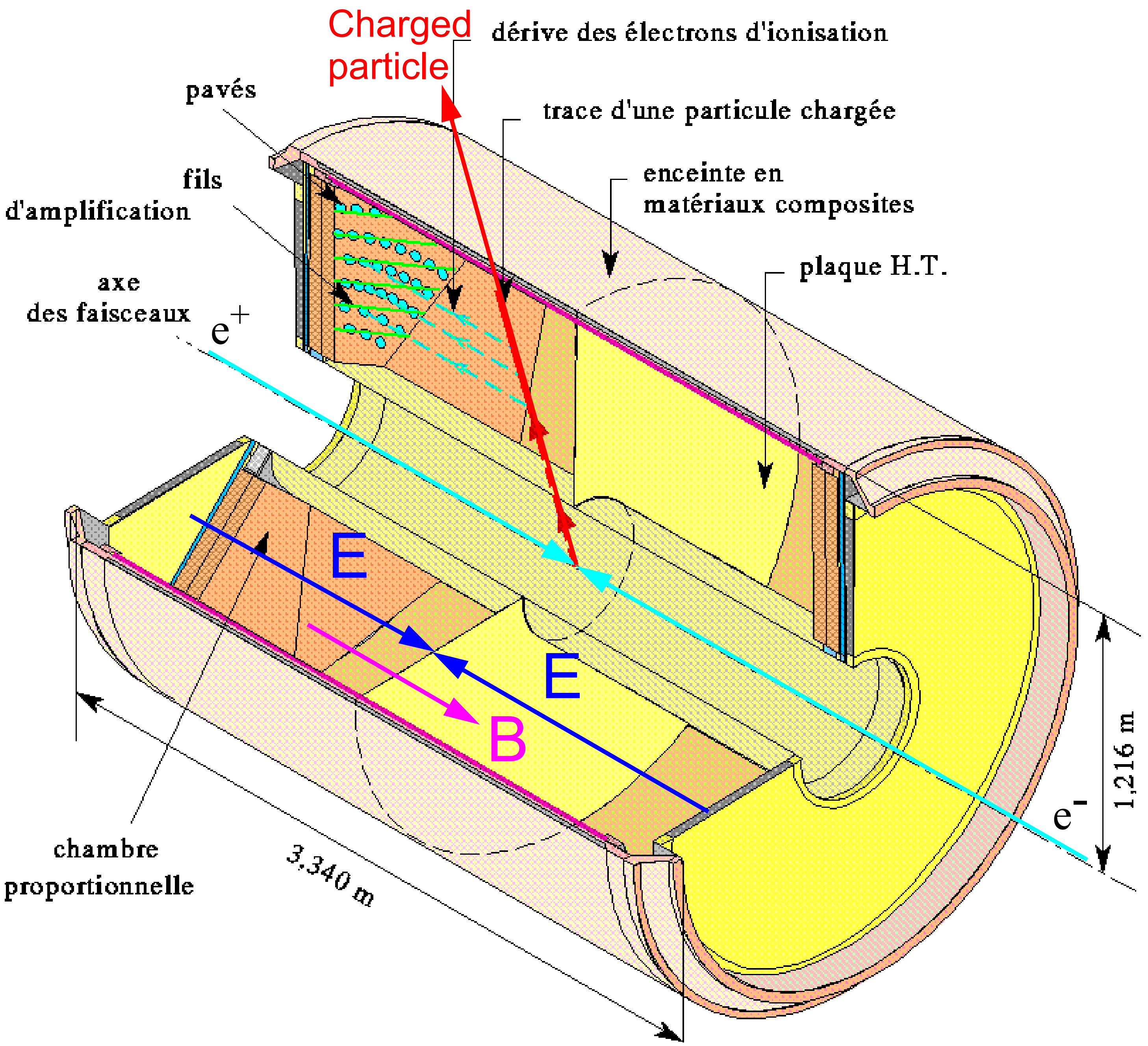
Examples at LEP 1:

- Luminosity
- Studies of the Z-boson

Examples at LEP 2:

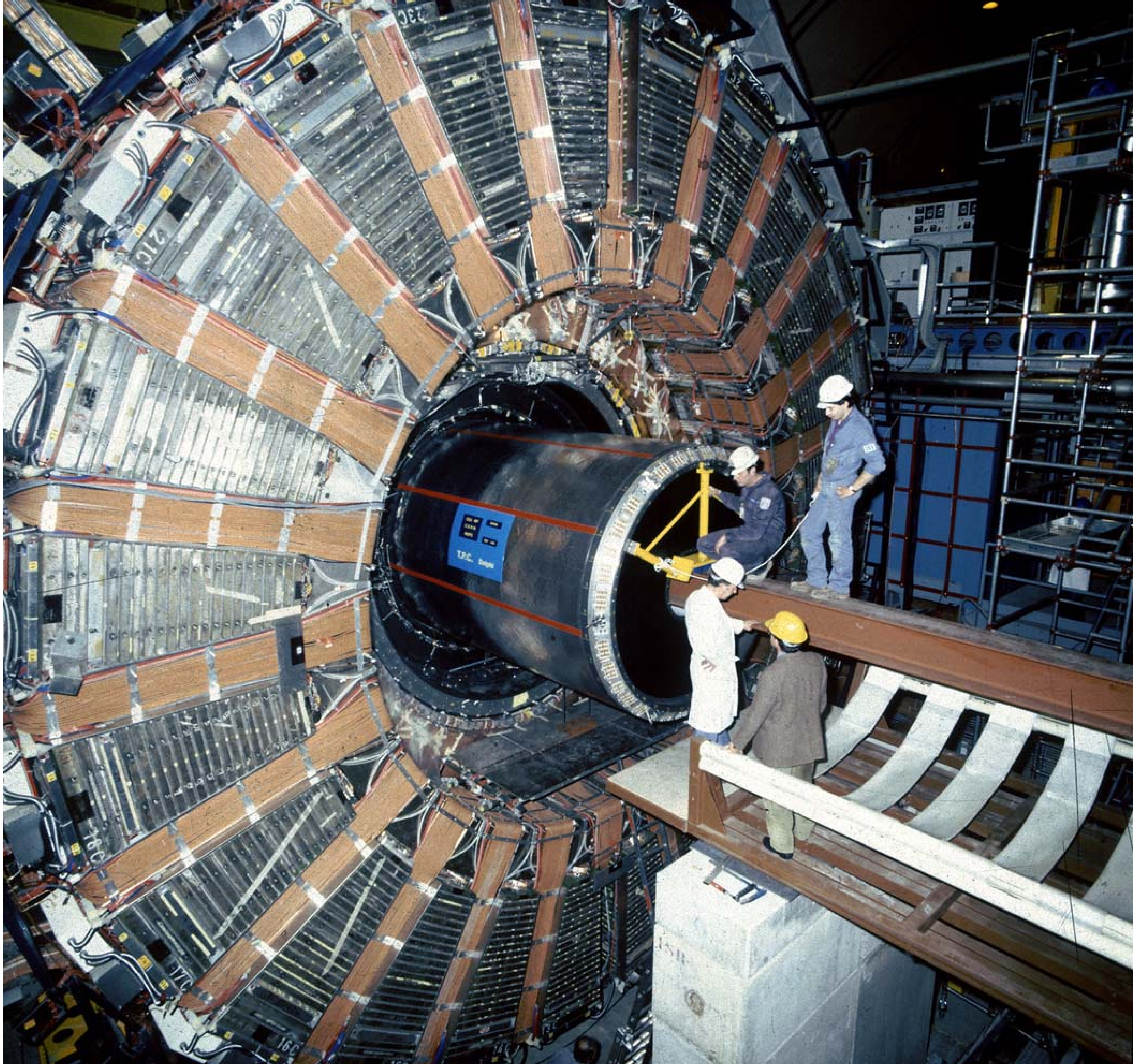
- Studies of the W-boson
- Search for new particles

The Time Projection Chamber



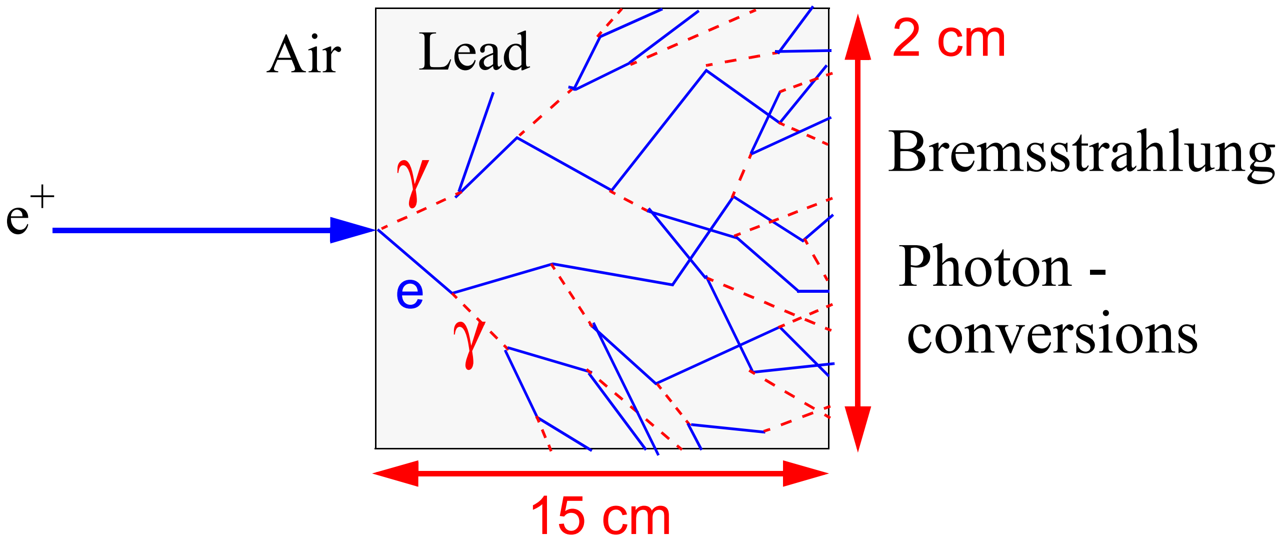
A charged particle ionize the gas in the cylinder and the electrons drift in an electrical field to the detectors at the ends of the cylinder.

Three-dimensional tracks can be reconstructed from the signals from the detectors.

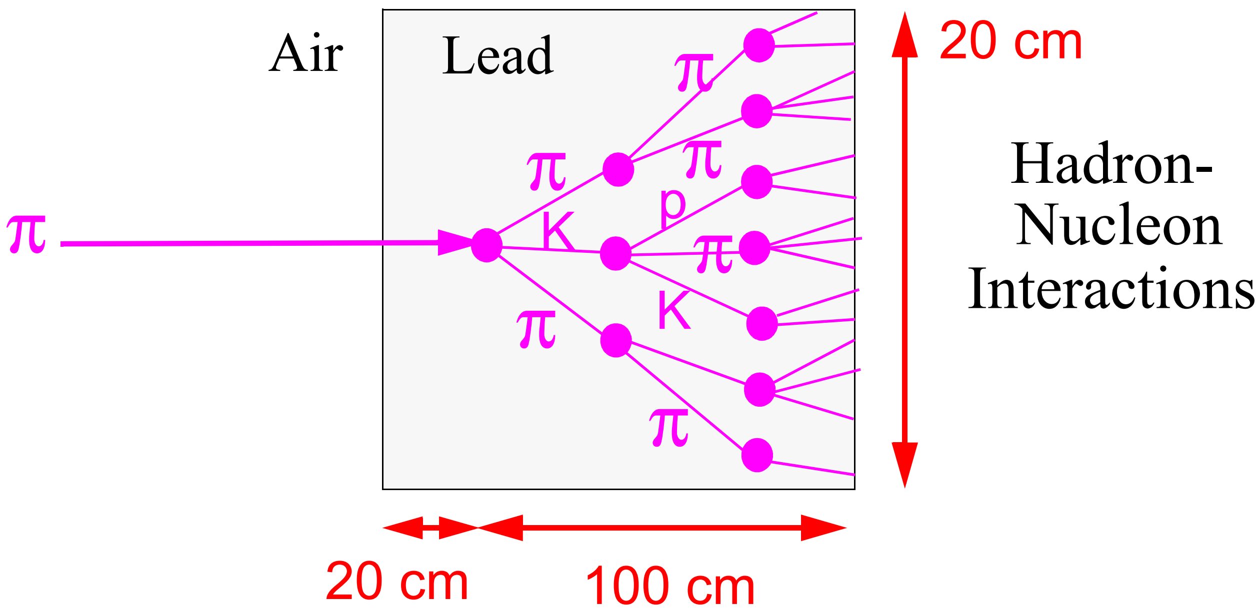

T.P.C. Delphi

The calorimetric processes

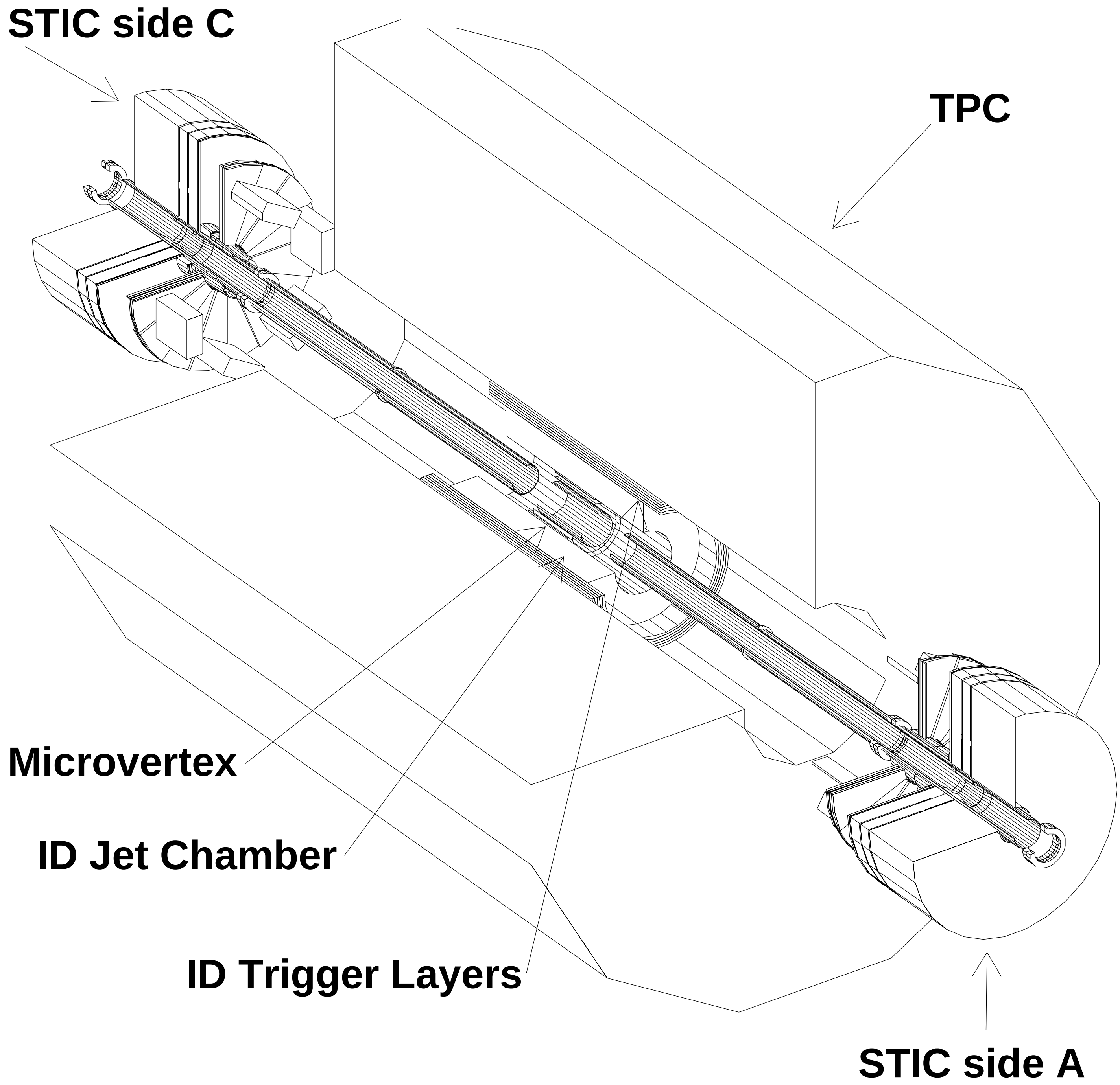
An electromagnetic shower



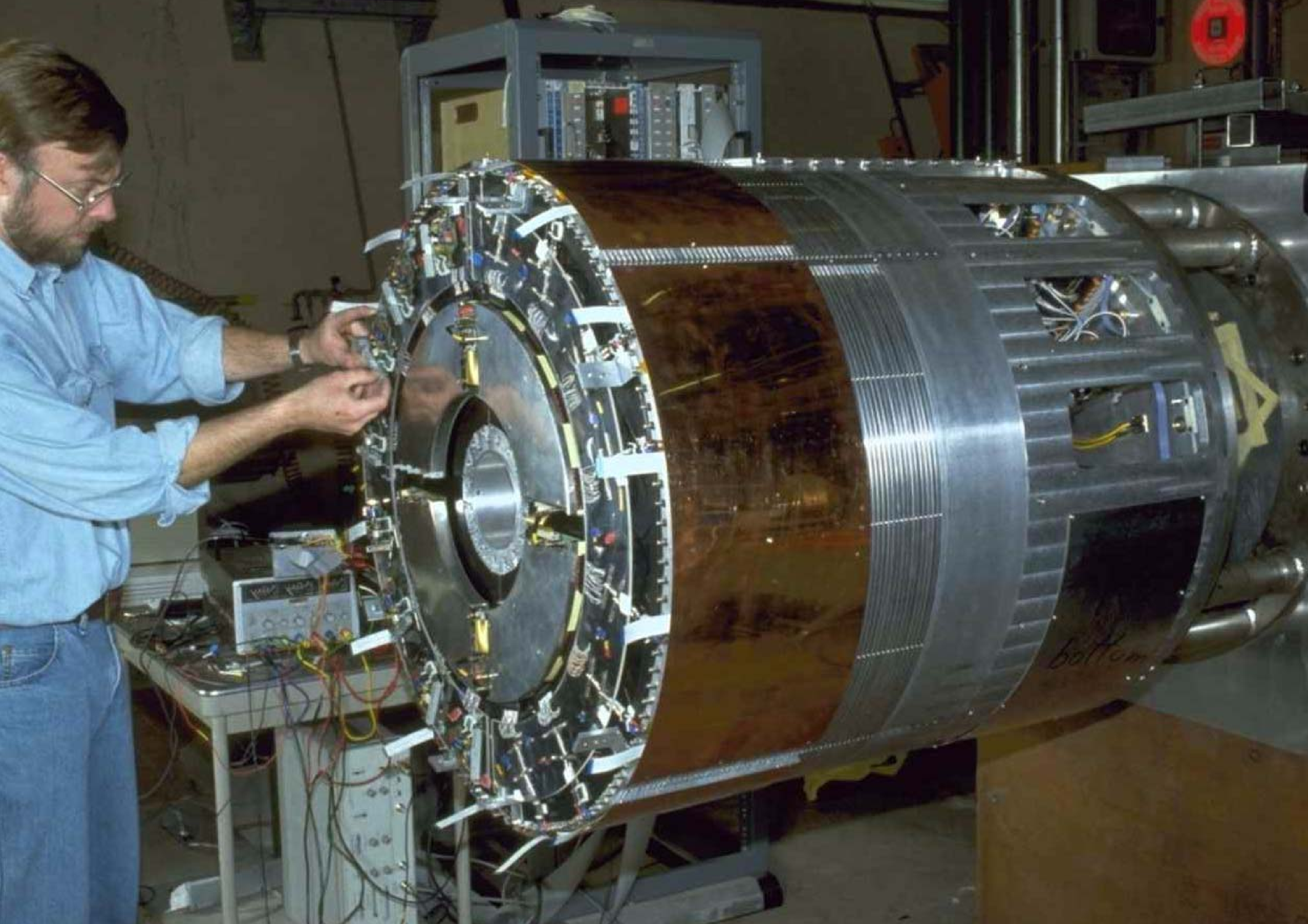
A hadronic shower

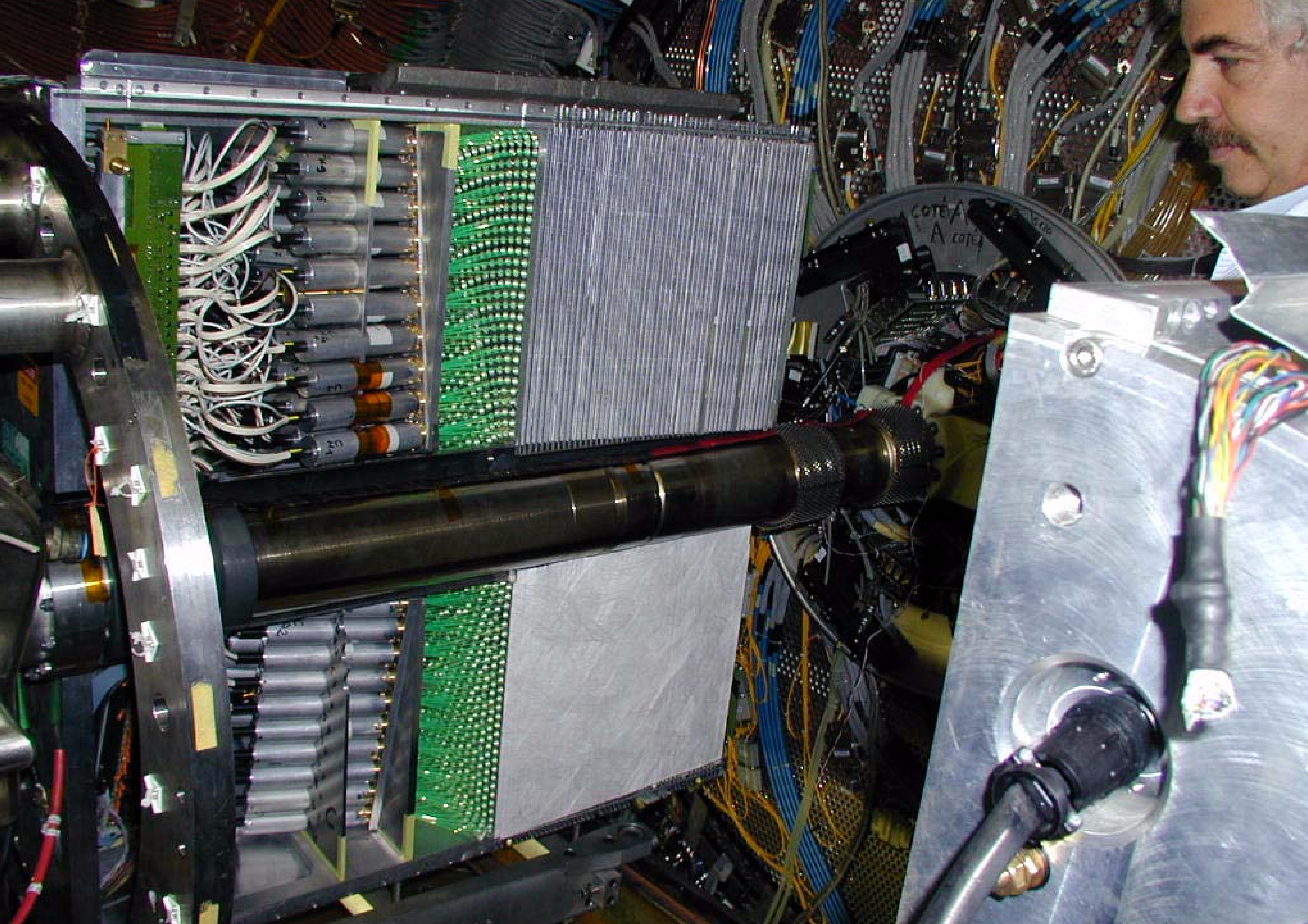


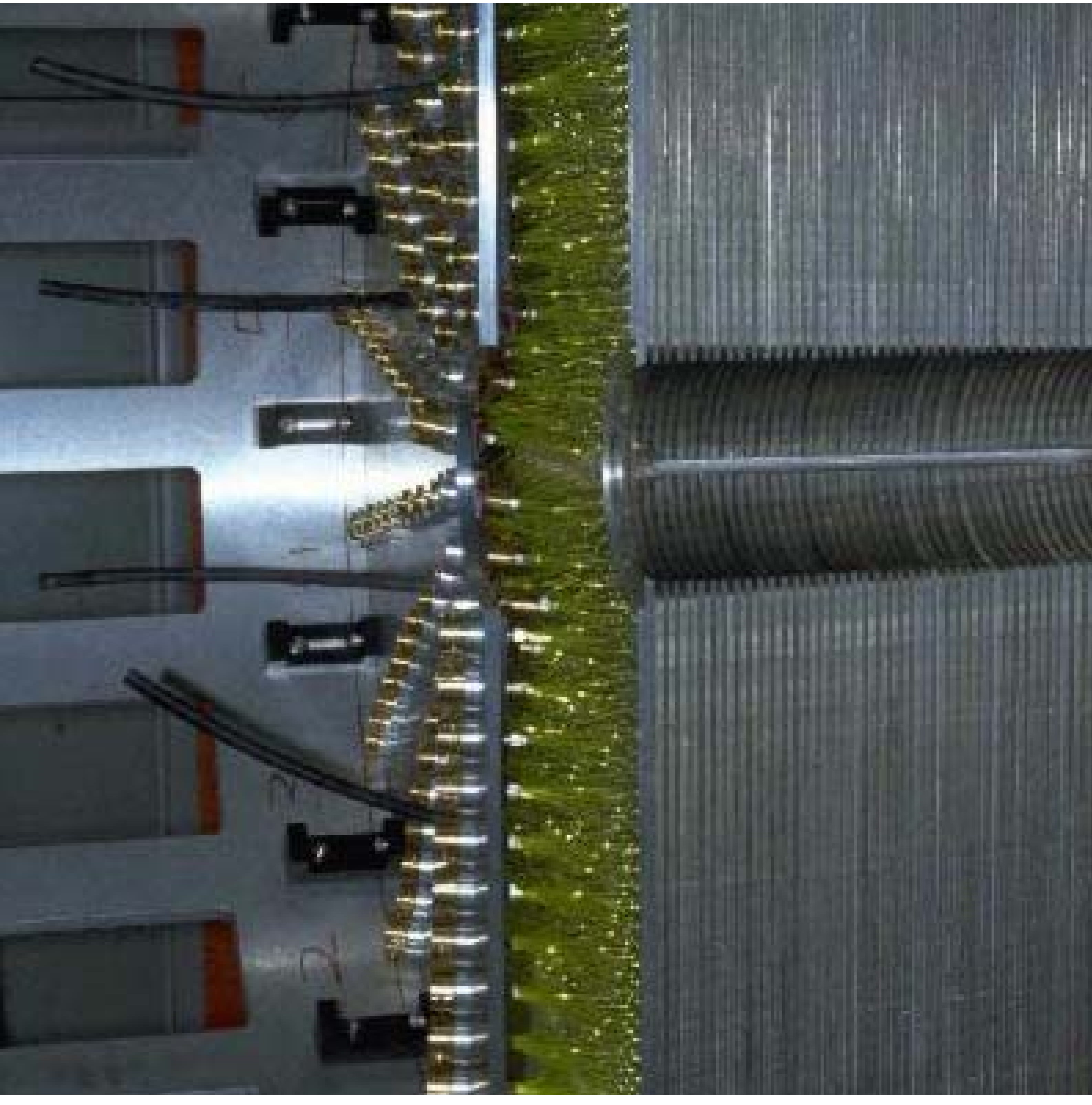
STIC

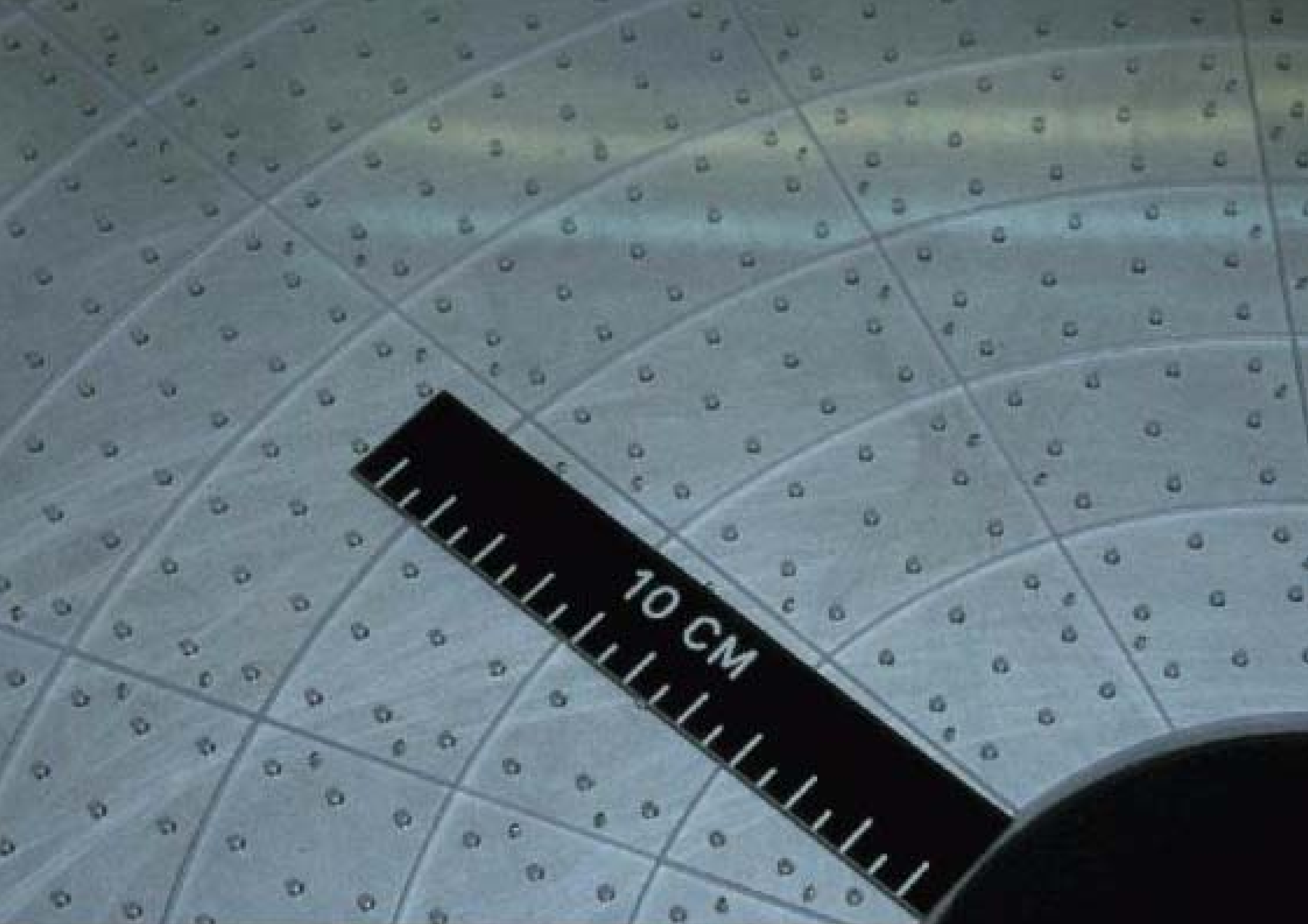


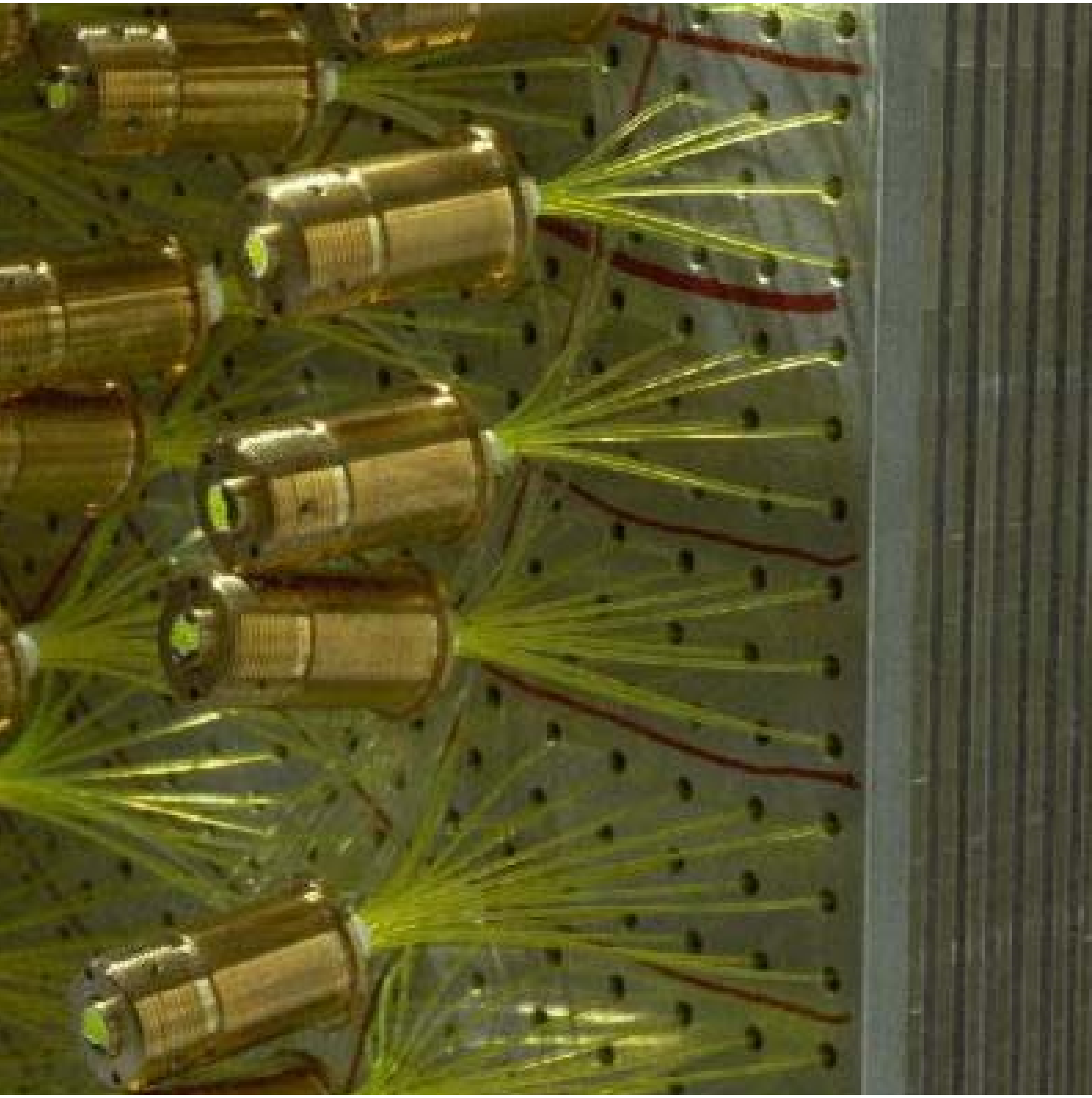
STIC was two electromagnetic calorimeters built by Lund in collaboration with physicists from 12 other institutes in 6 countries.

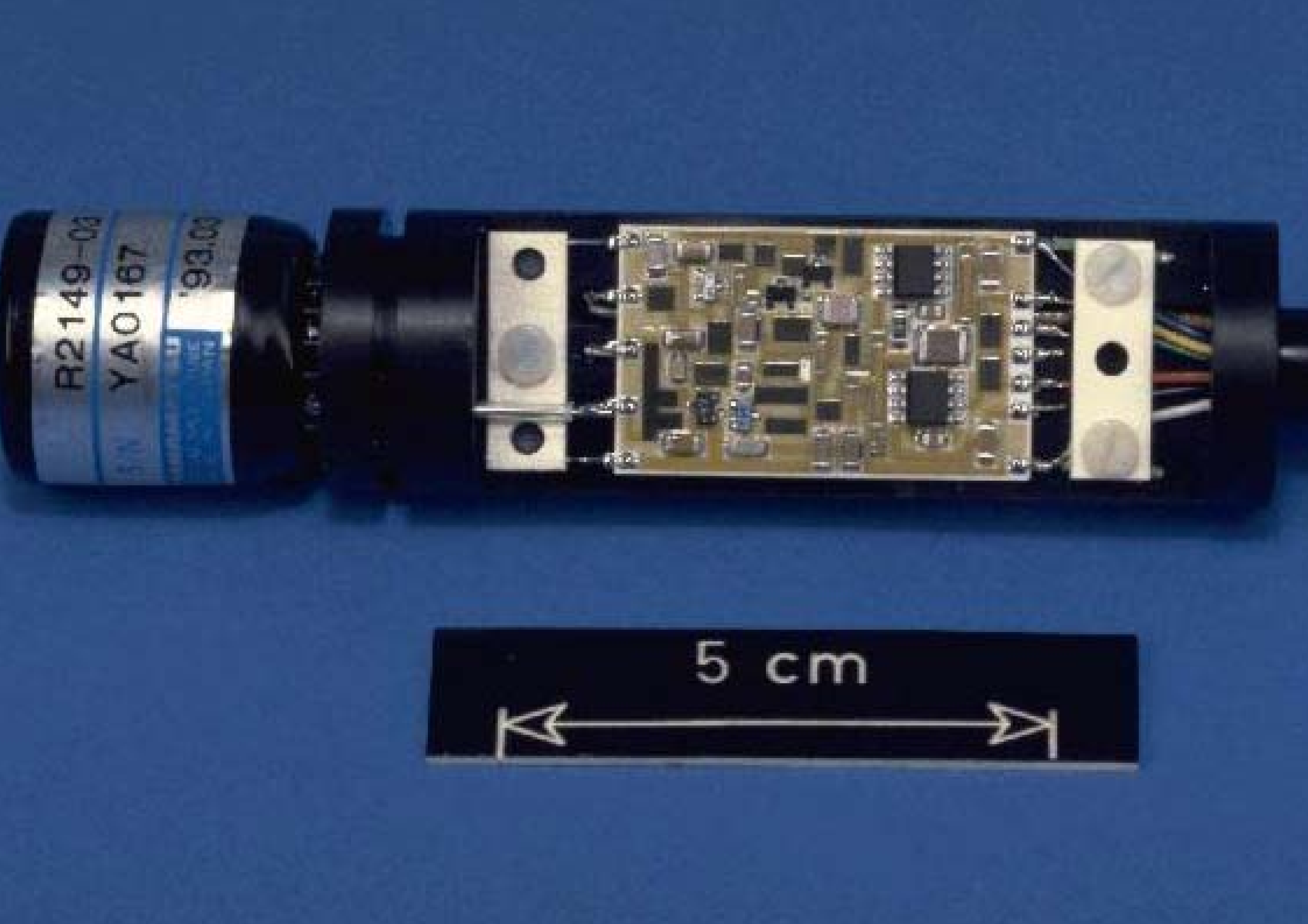

bottom



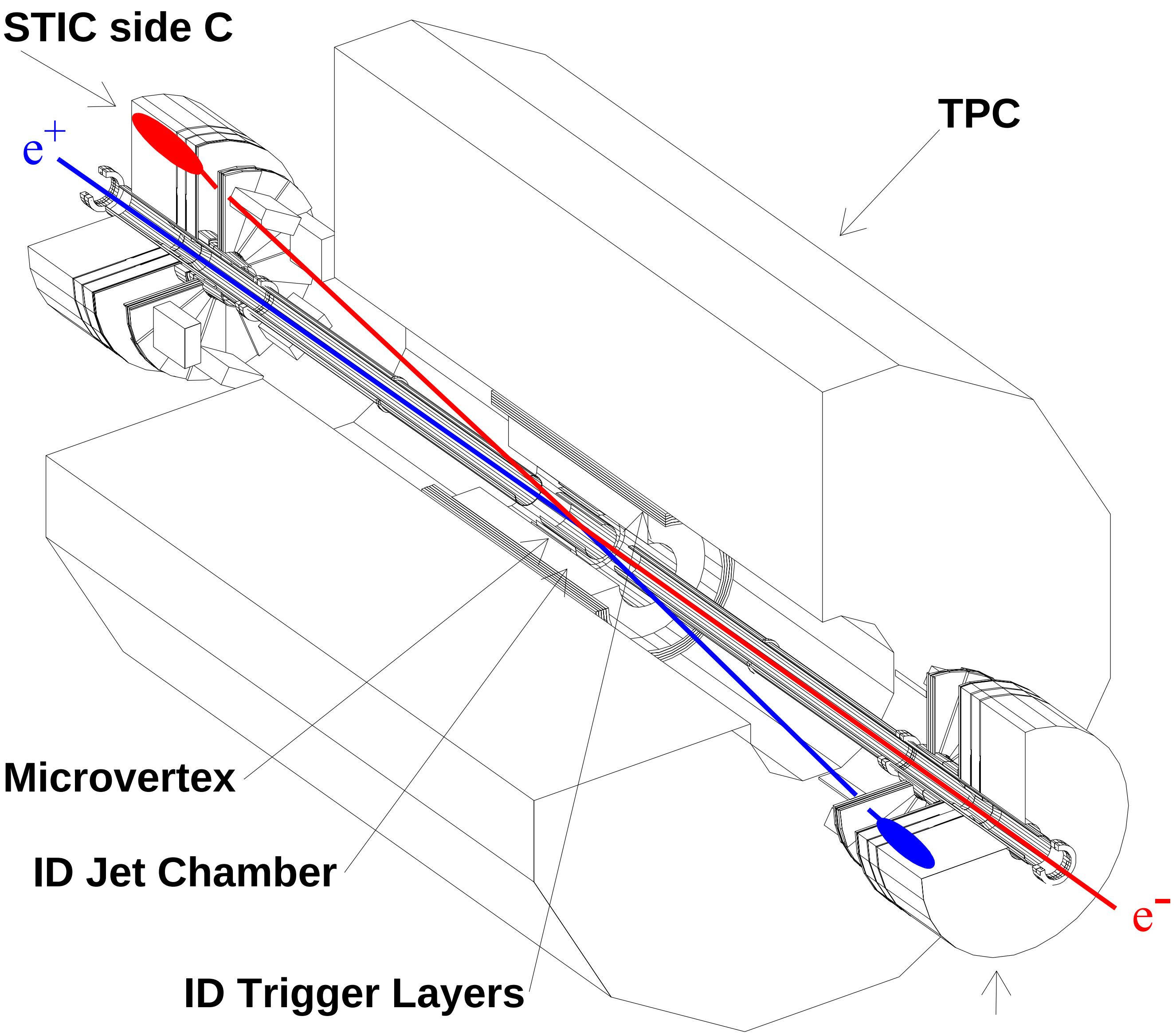



10 CM




YA0167
5 cm

Luminosity



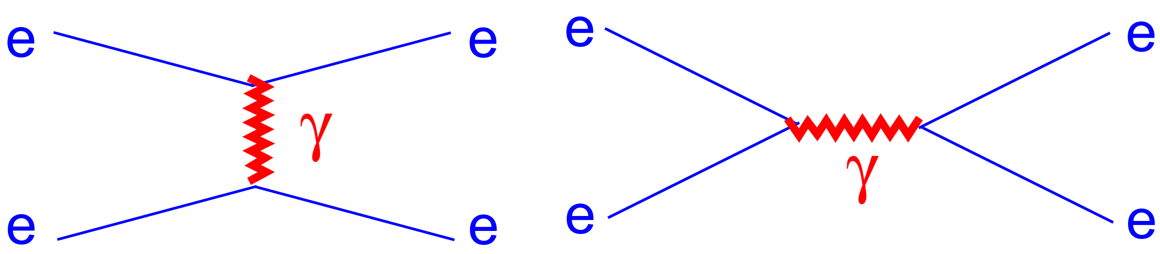
What is luminosity ?

The number of events per s = cross section x Luminosity

How is the luminosity measured ?

By counting the number of events from a process for which the cross section can be calculated.

Which process was used at LEP ?

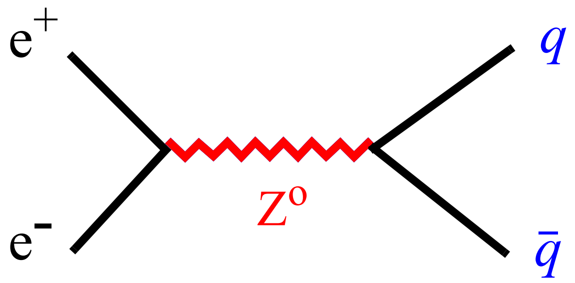


Bhabha Scattering

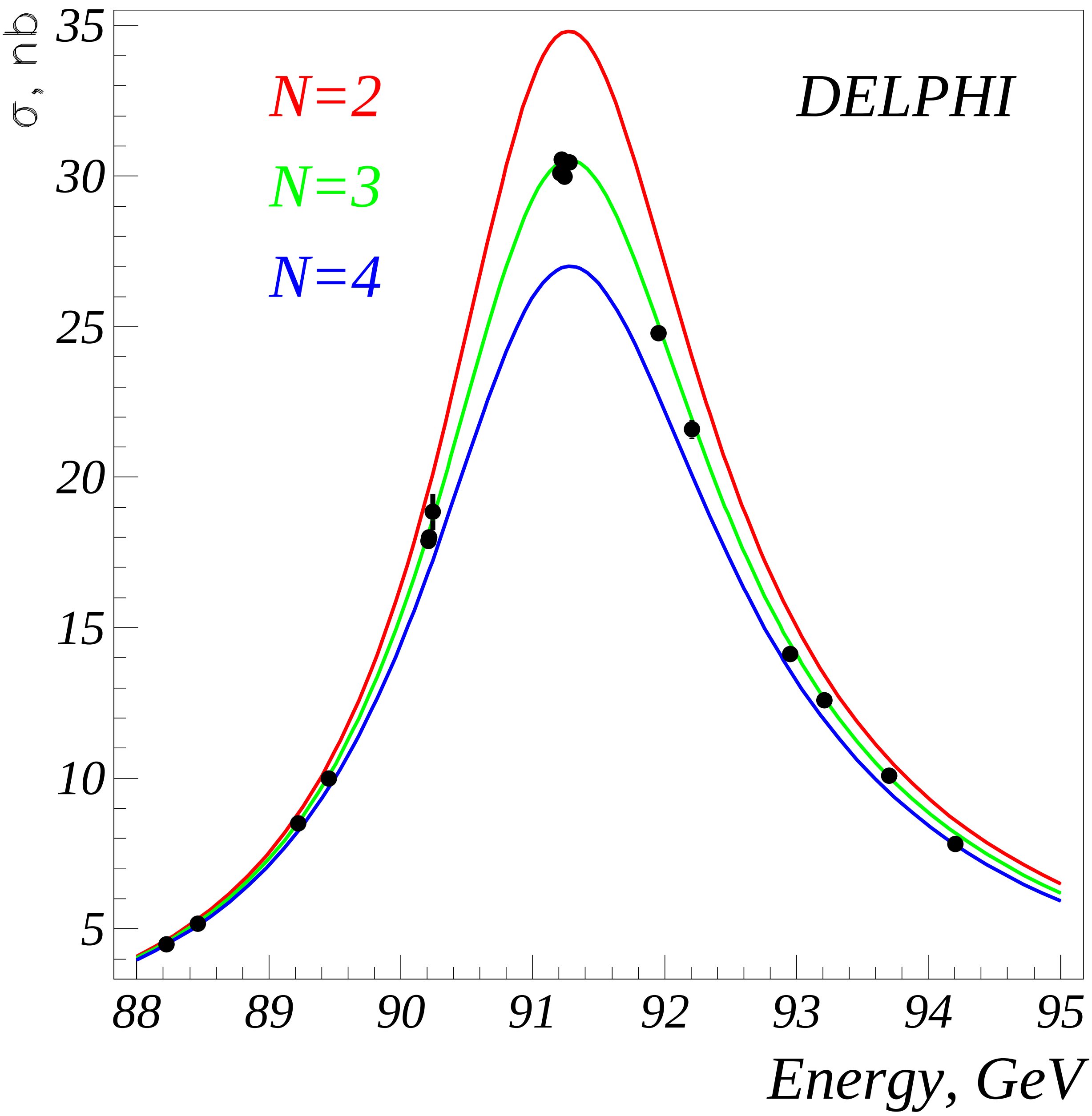
The hadronic lineshape of the Z-boson

The width of the Z-boson peak depends on the number of light neutrino species (N).

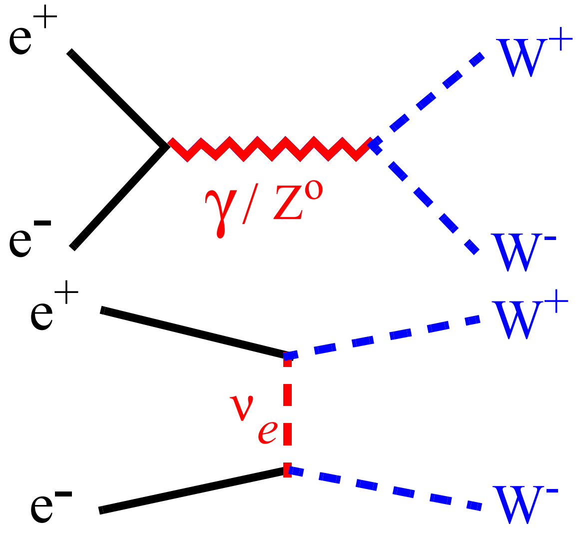
$\sigma_Z =$

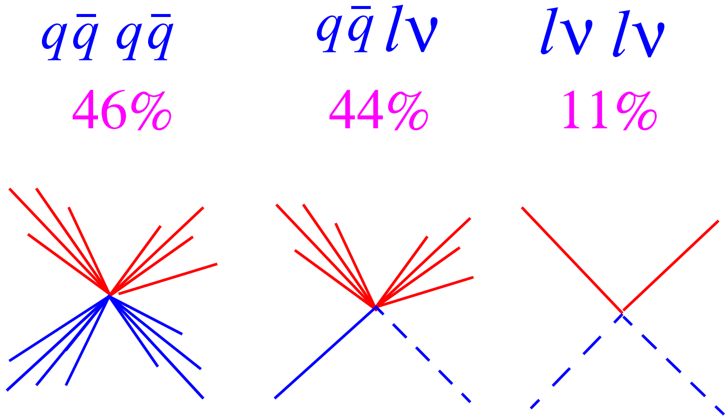


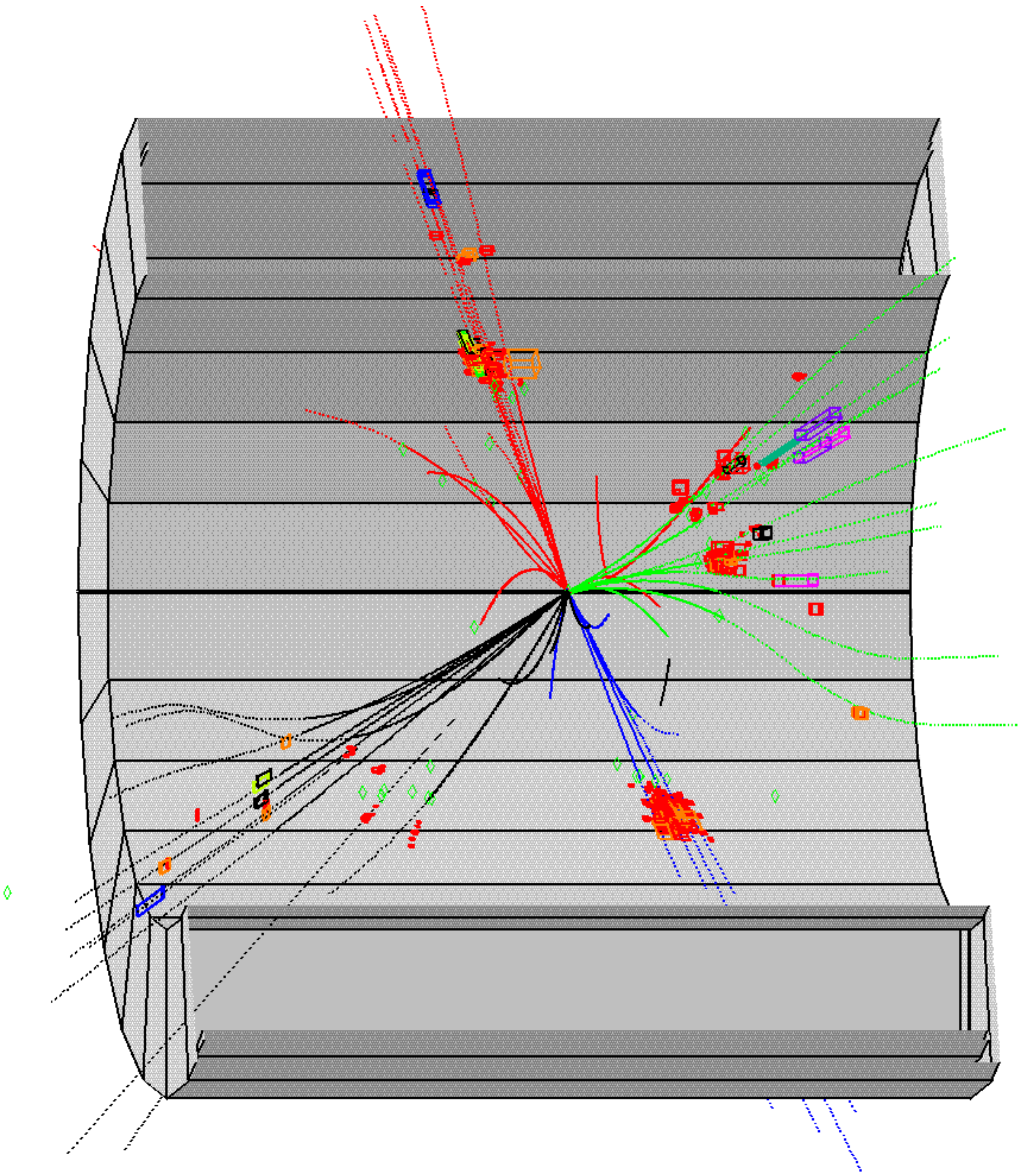
/ Luminosity



WW-events



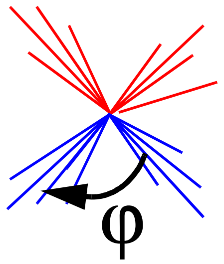




The mass of the W-boson

$q\bar{q}\ q\bar{q}$

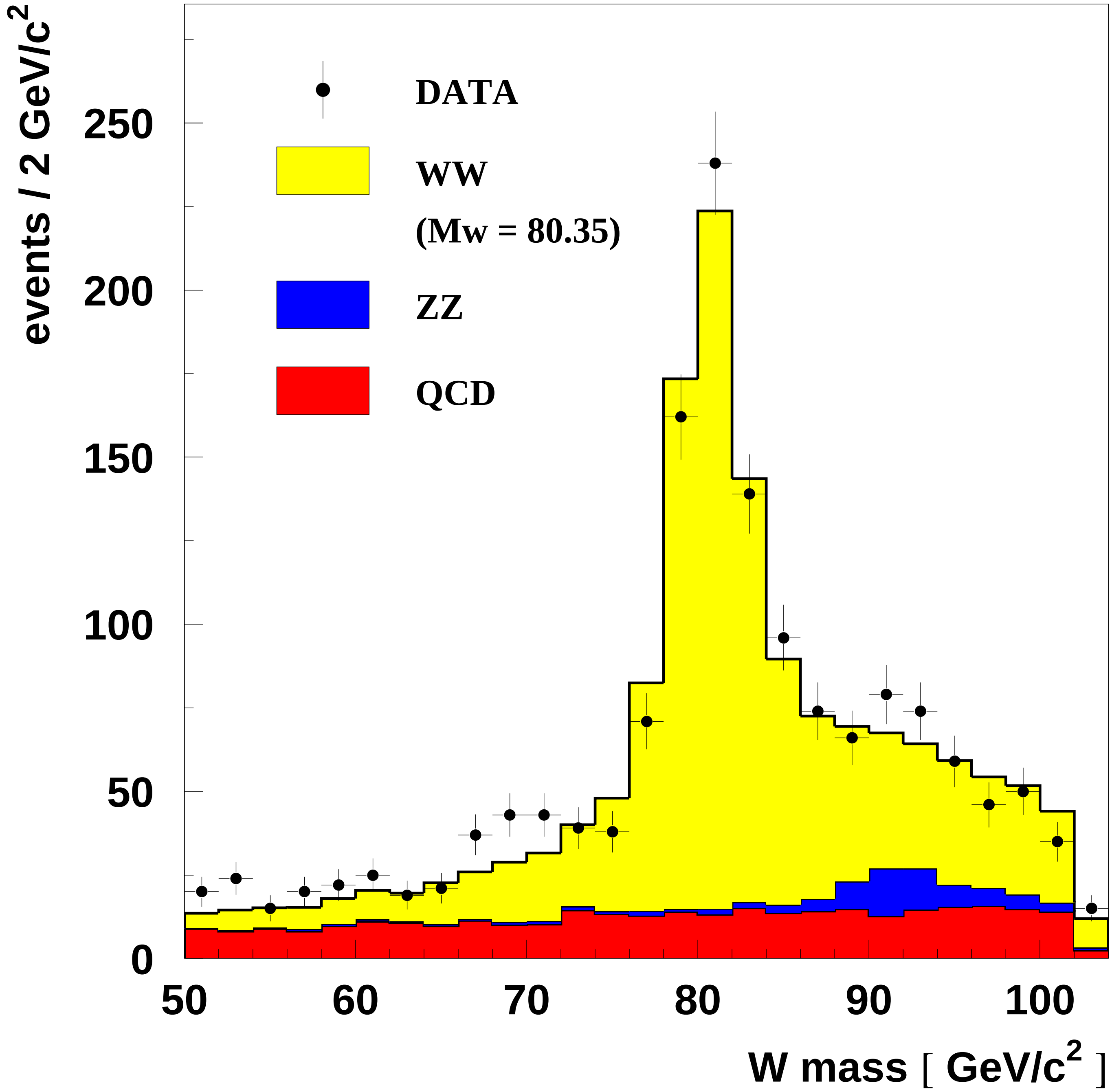
46%



$$M_W^2 = (\bar{P}_q + \bar{P}_{\bar{q}})^2 \quad \text{(4-vectors)}$$

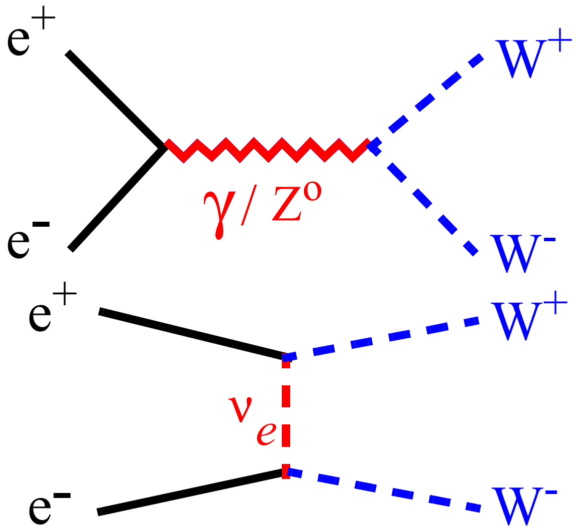
$$M_W^2 = 2\, E_q E_{\bar{q}}\, (1 - \cos\varphi)$$

if $m_q = 0$



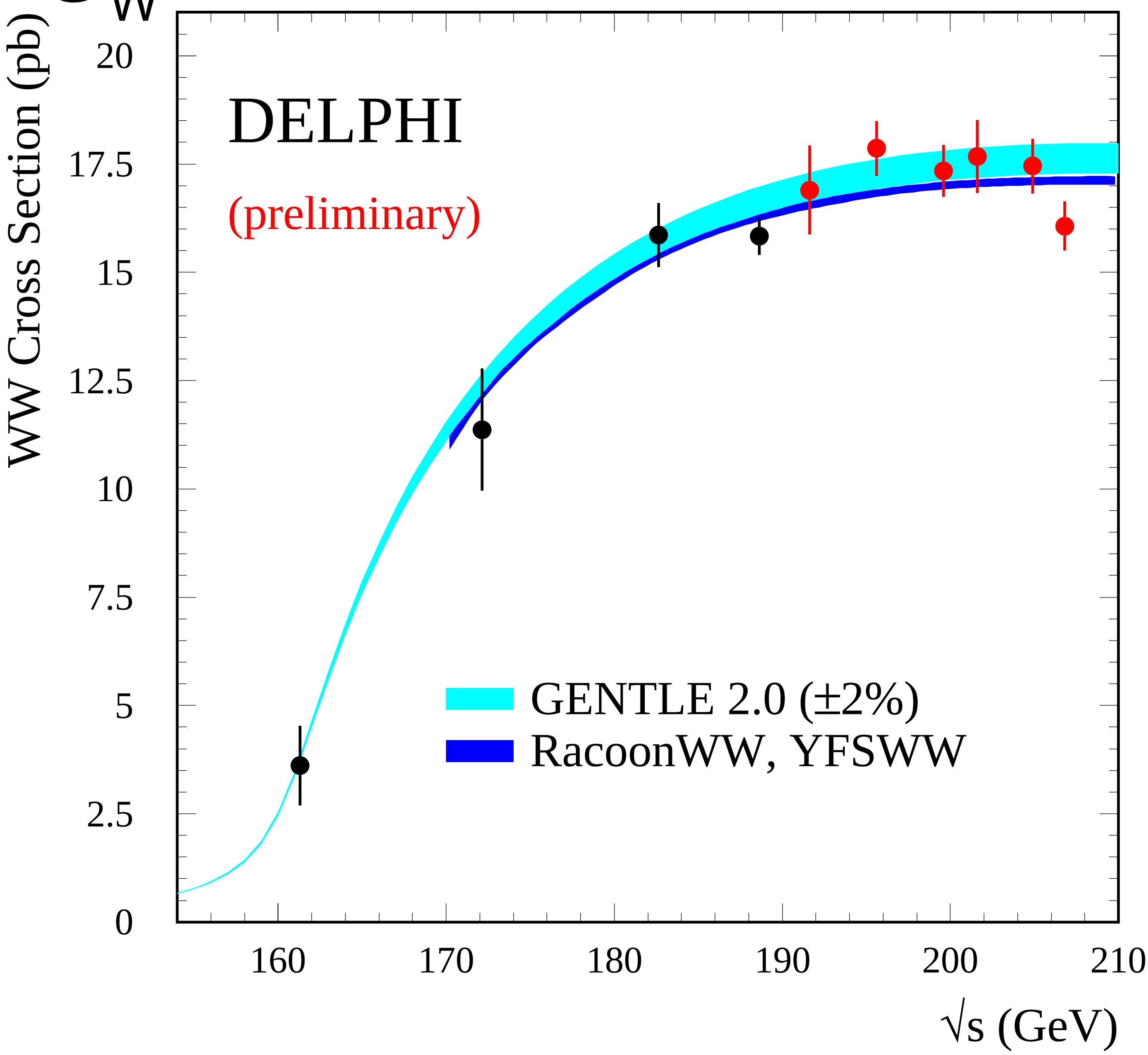
The W-cross section

σ_W =



/ Luminosity

σ_W



The search for new particles

Extra dimensions

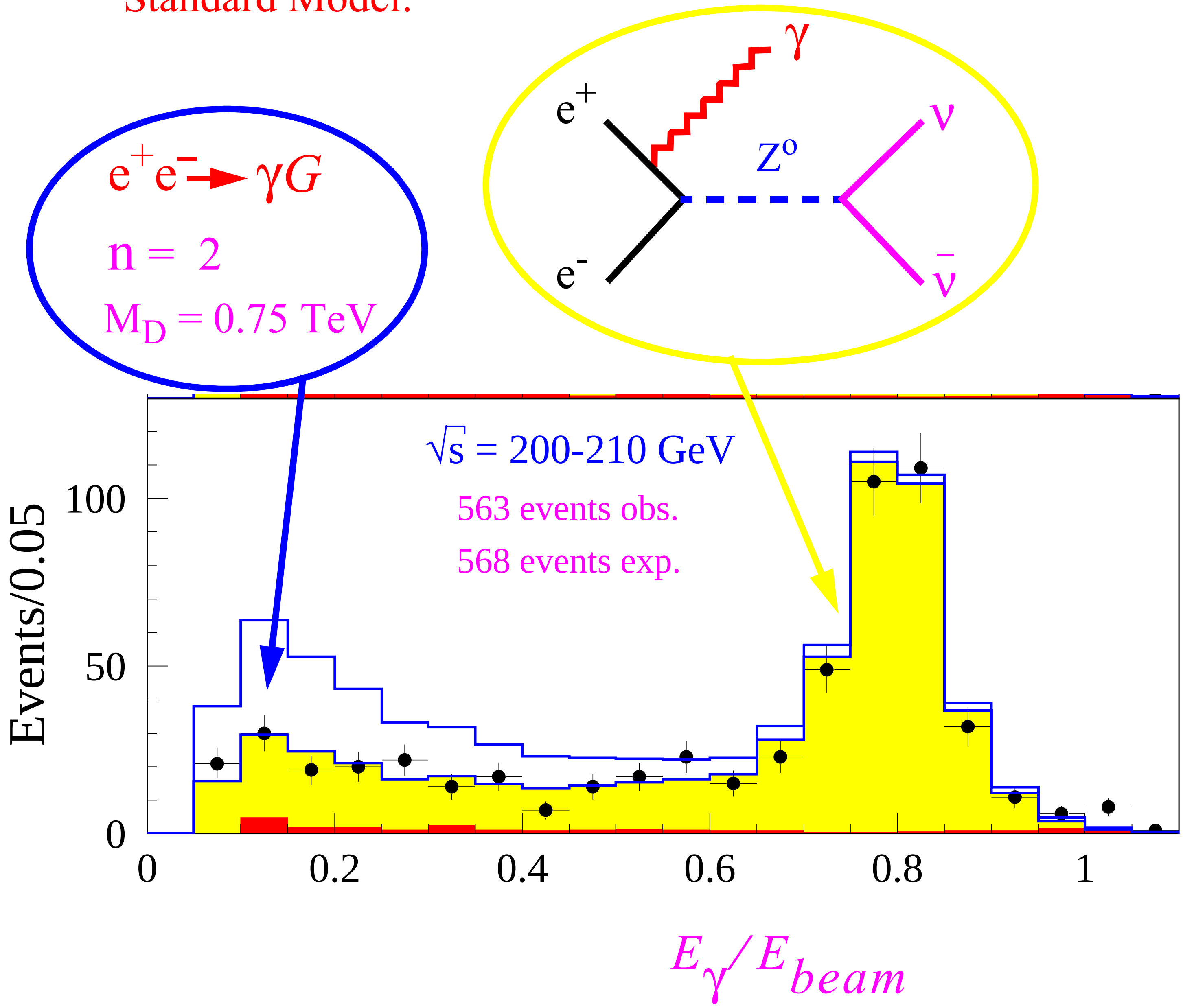
Basic idea: Unification of gravity with other interactions by introducing new compact dimensions of space in which only gravity propagates.

Cross sec.: $\sigma(e^+e^- \rightarrow \text{Grav.} + \gamma)$ depends on :

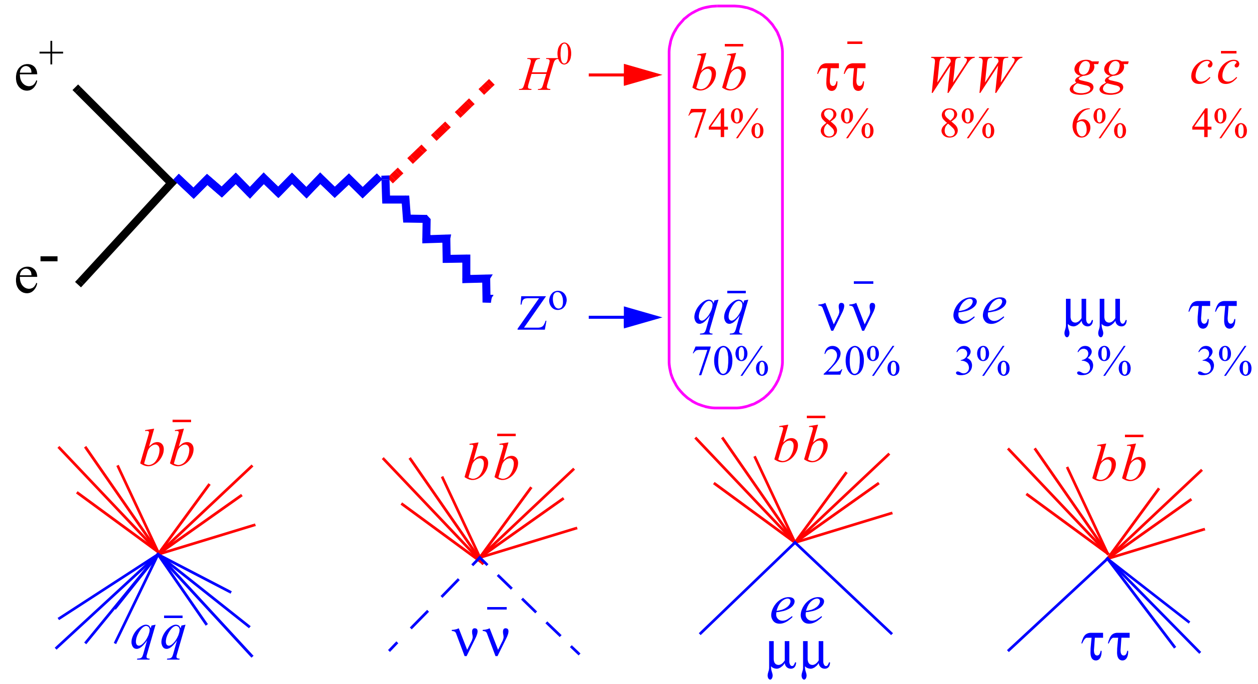
n - the number of extra dimensions

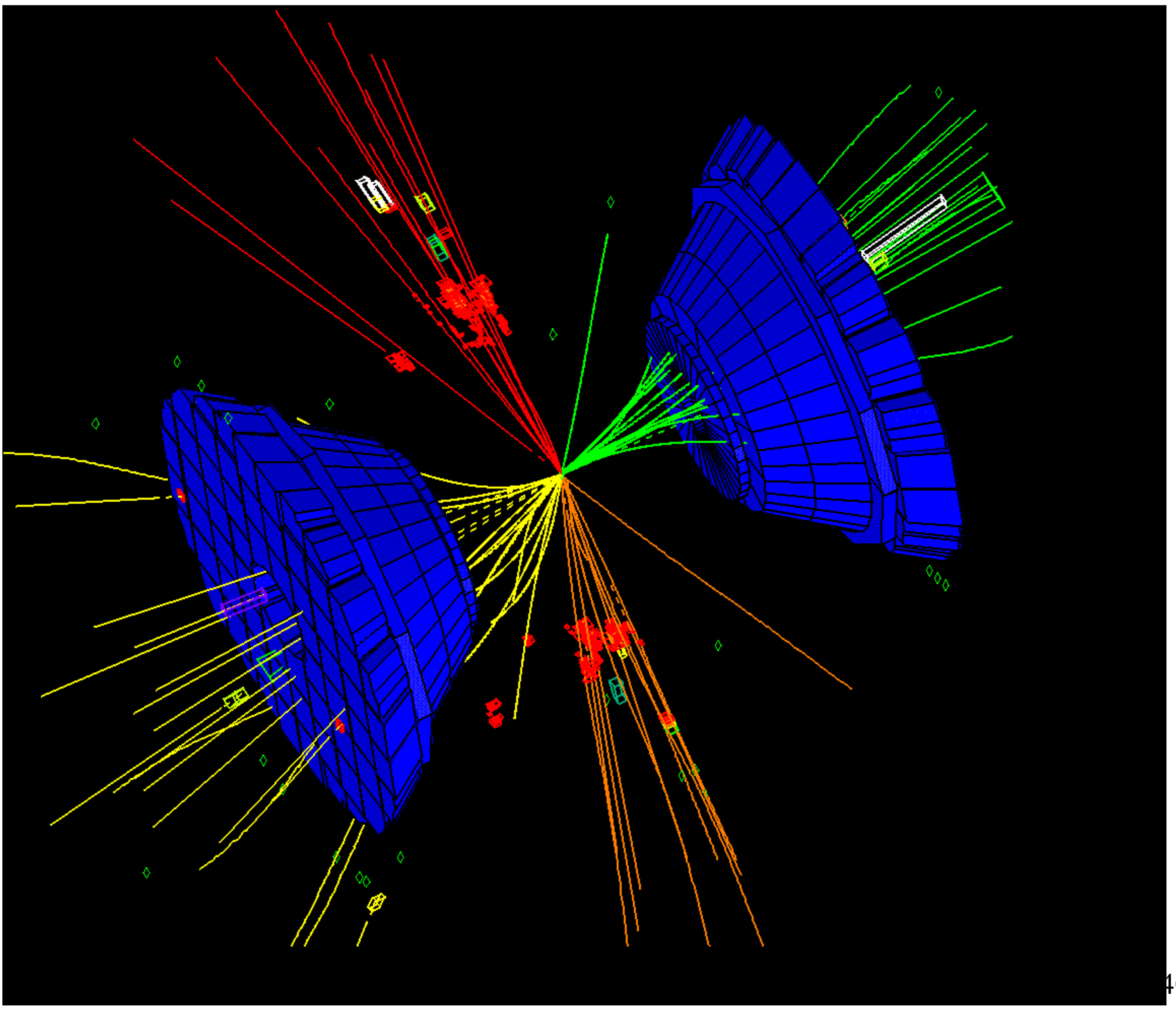
M_D - the fundamental mass scale in the theory

Standard Model:

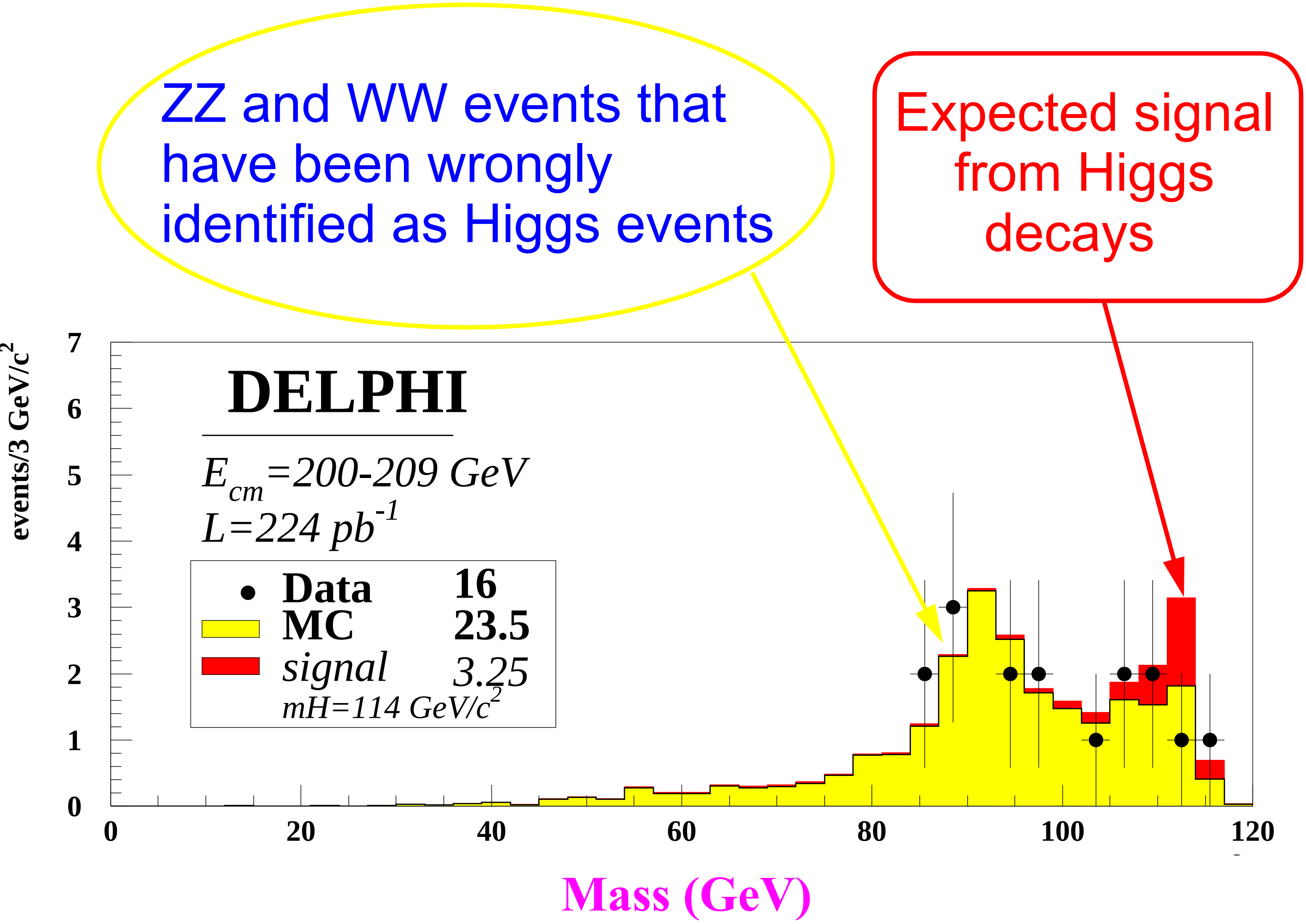


The search for Higgs events





The mass spectrum of Higgs candidates



Summary

The LEP accelerator was the largest accelerator the world has ever seen.

DELPHI was one of the huge experiments that studied the collisions between electrons and positrons.

DELPHI has contributed much to our present understanding of the standard model.

The accelerator and the experiments have been dismantled but the physicists continue to analyze the data that was collected.