

From LEP to LHC

Carlo Rubbia 75th birthday

Happy Birthday

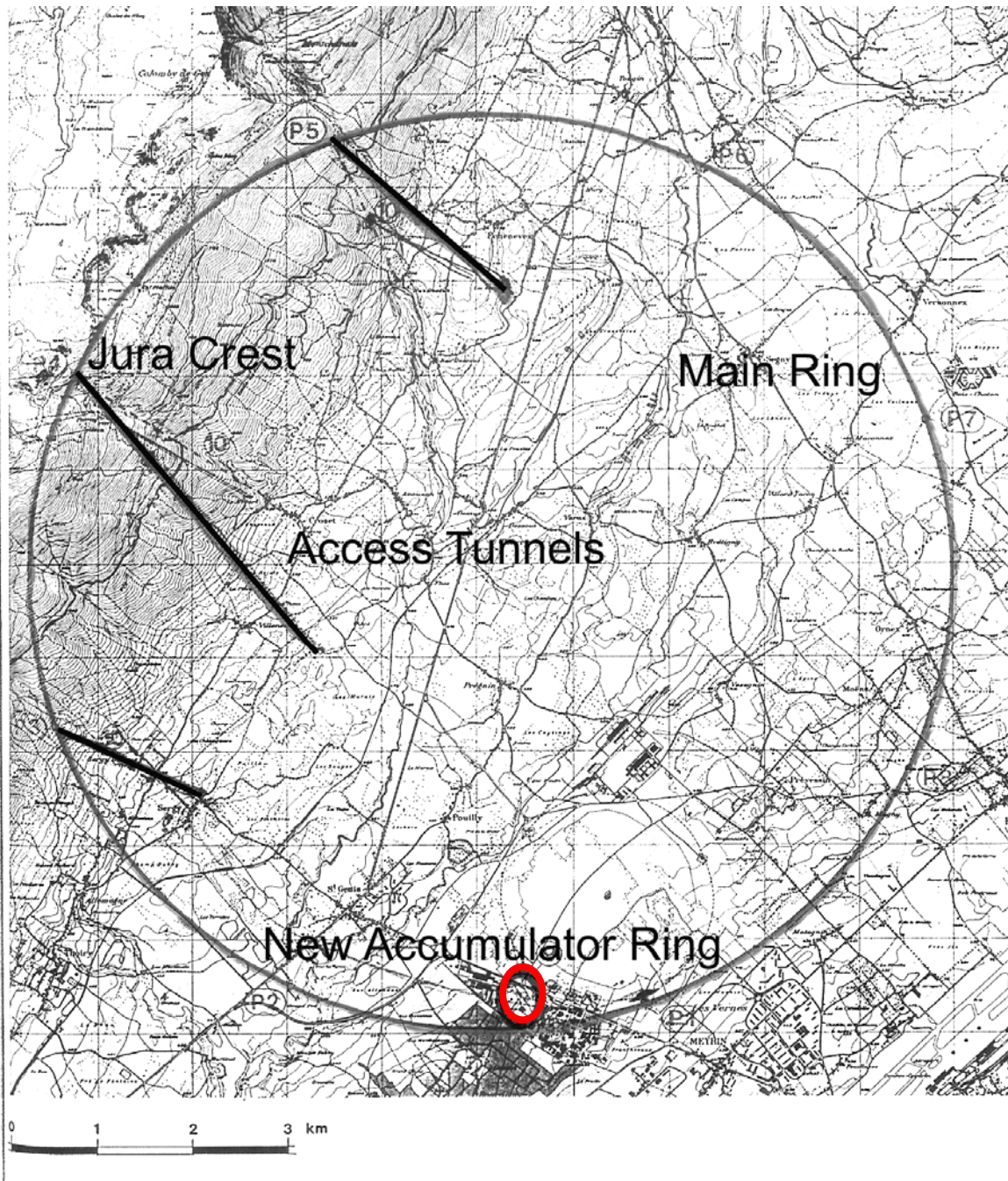
Herwig Schopper

The Very Big Accelerator

- International meeting 3/7 March 1975 at New Orleans
Next large facility has to be a world project VBA, regions too weak
preference for e+e- collider
International study groups established
Headquarter at CERN (Gregory DG)
Which project for CERN? VBA?
p-p collider (successor of ISR), e-p collider CHEEP, e+e collider
CERN hesitated to leave proton machines
- 1977 ECFA recommends for Europe
e+e- collider with ~100 GeV/beam for CERN
- **CERN took brave decision to go ahead not waiting for worldwide agreement**
- **Same for LHC**
(disaster of ITER avoided)

Physics Questions

- How many quarks and leptons?
- Do the W and Z exist and correspond to SM prediction?
At approval of LEP not yet discovered
- Properties of electroweak and strong interactions? Standard Model
- **Where is the top quark?**
- Is there as Higgs particle?
- **Any results beyond the SM? SUSY?**



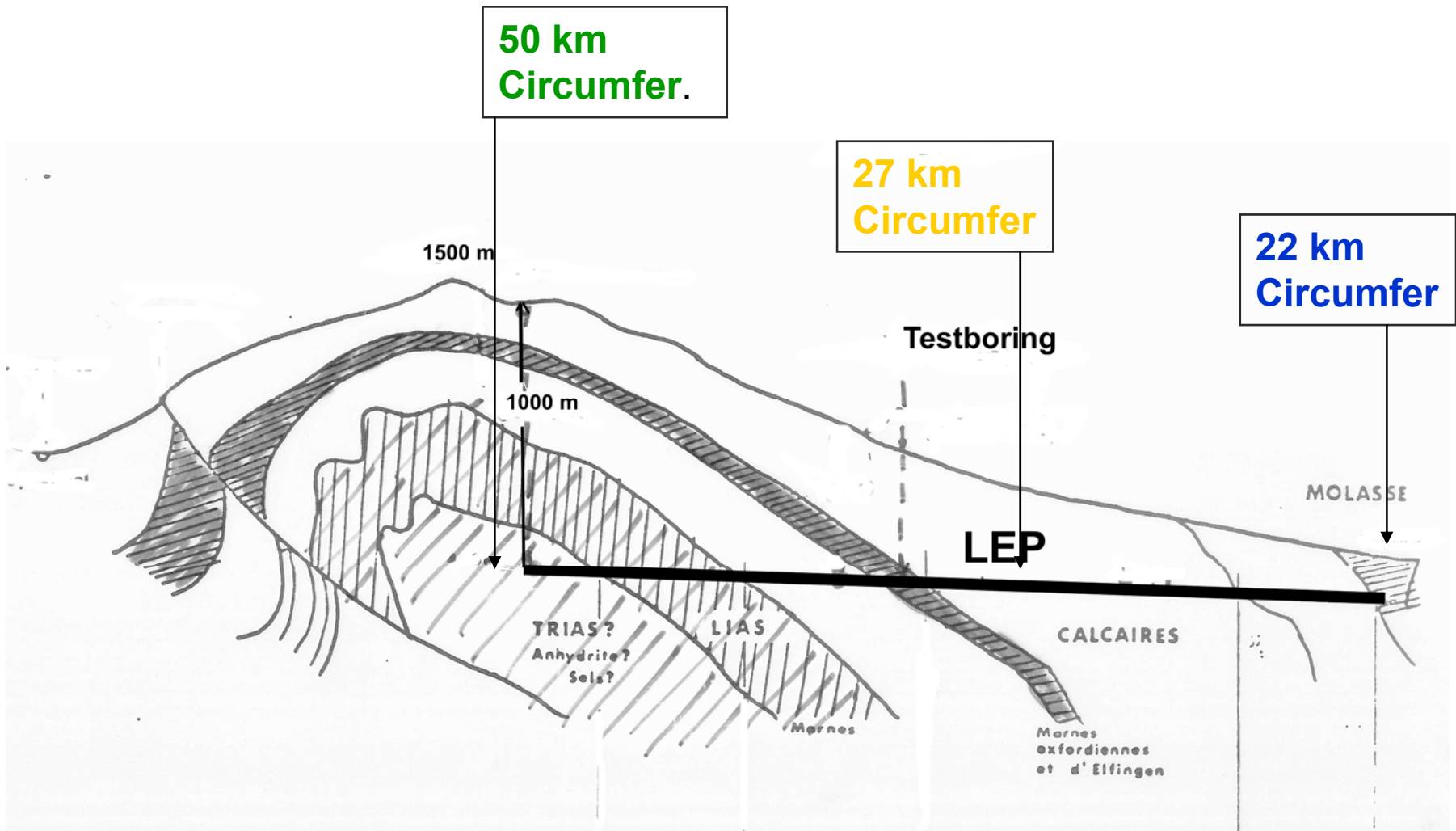
LEP100

50 km
circumference
with new
accumulator ring

- too expensive**
- too risky**
- too difficult to operate**

CERN LEP -Studies

Study	Energy/ beam GeV	Circum- ference km	Year	Cost Estimate MCHF
LEP 100	100	50	1976	Too high
Blue Book	70	22	1978	??
Pink Book	86 Cu rf (120) SC rf	30.6	1979	1300 New injector
Green Book	50 Cu rf (100) SC rf	26.7	1981	910 Use existing injector, no contingency



Geological risks

LEP Positions

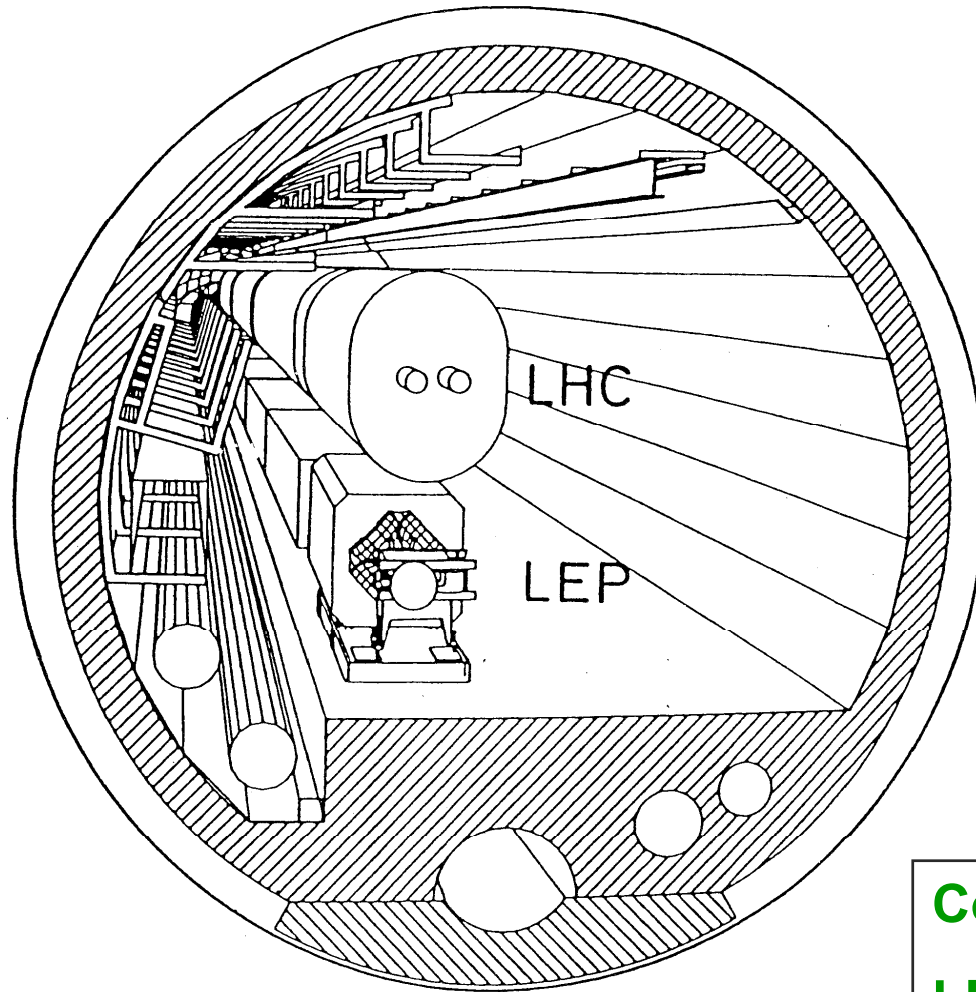


Top secret

ECFA 84/85
CERN 84-10
5 September 1984

ECFA - CERN Workshop

Lausanne,
5 September 1984



LARGE HADRON COLLIDER
IN THE LEP TUNNEL

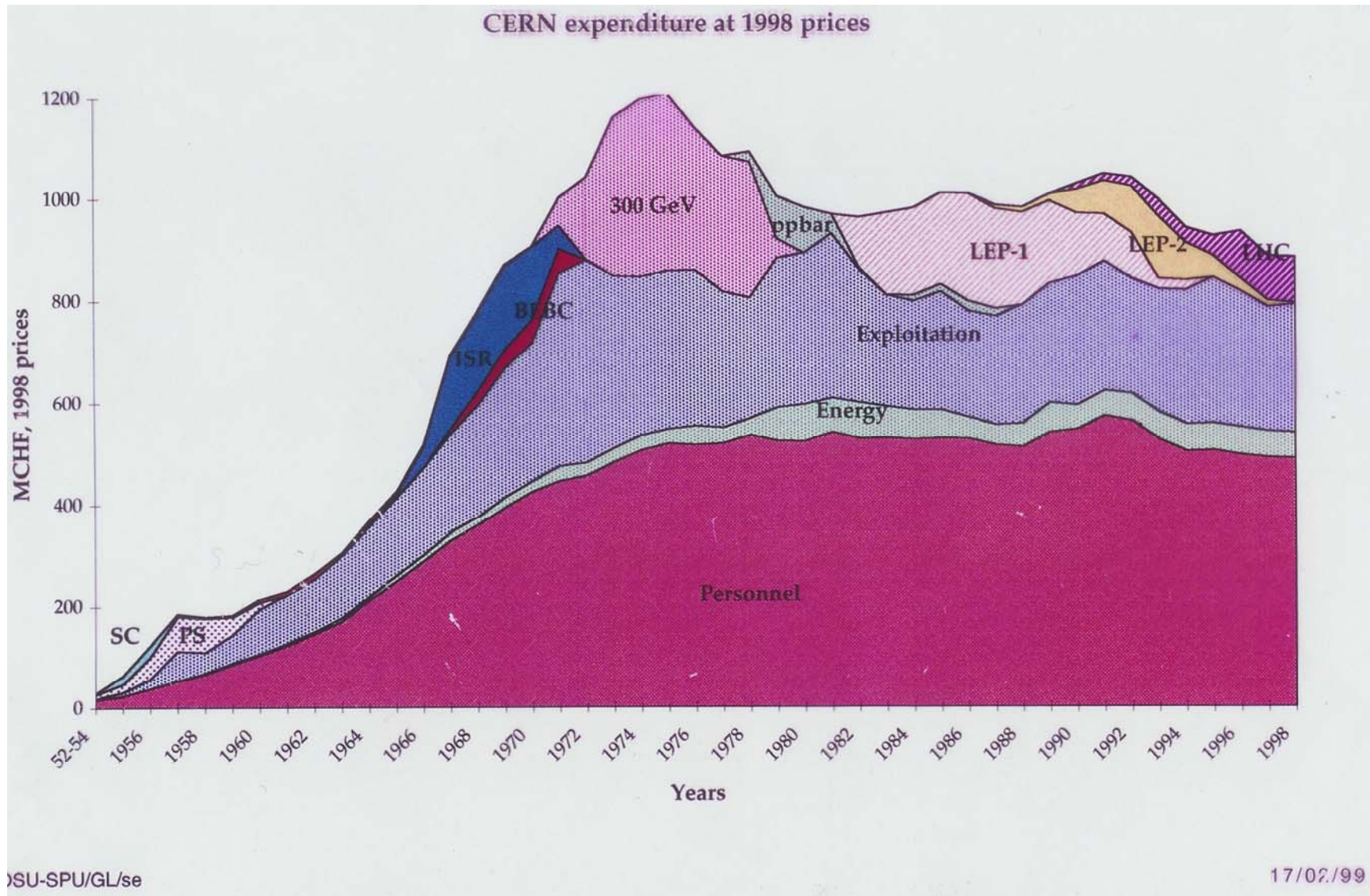
**Main reason for taking
the risk of 27 km
circumference was
LHC**

**Coexistence of LEP and LHC
LEP magnets installed low**

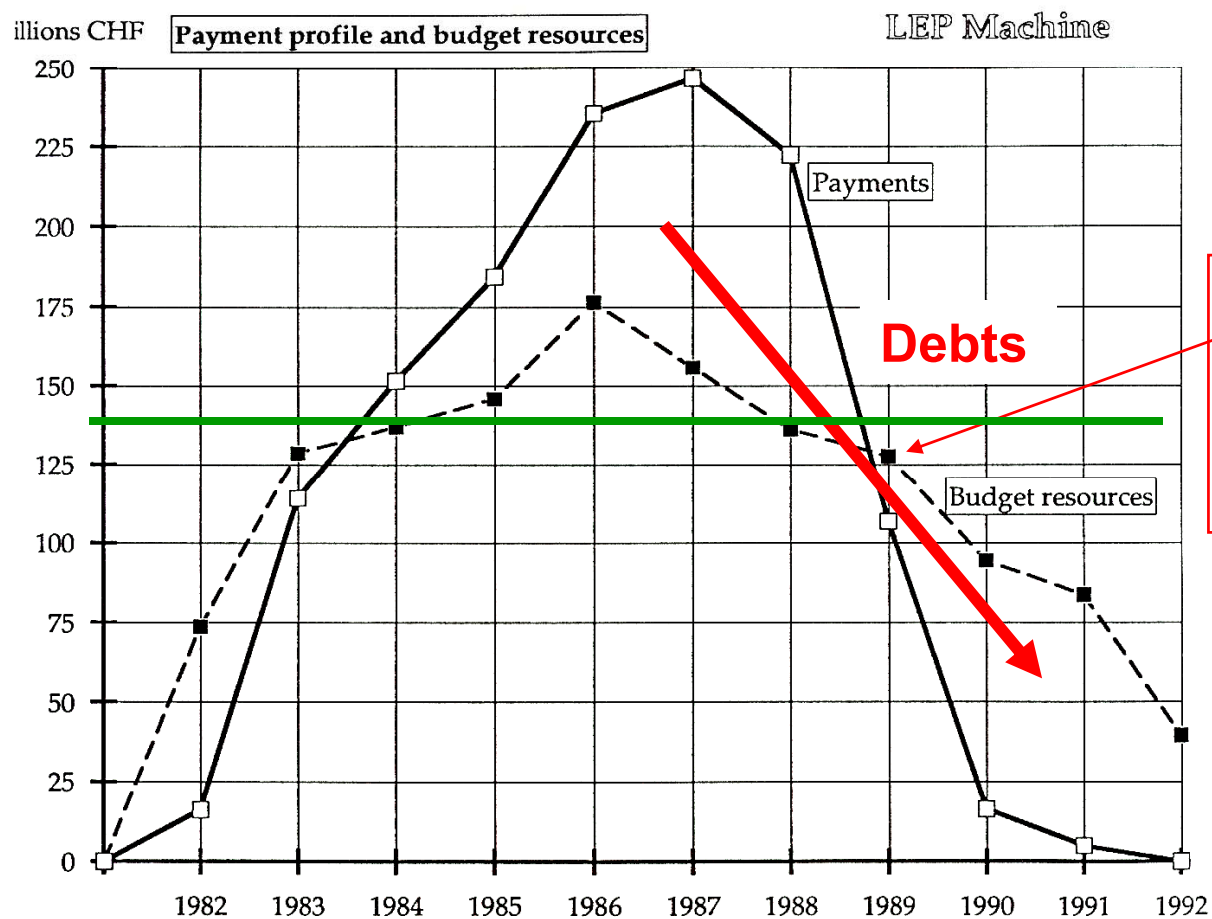
Approval of LEP

- **Very difficult**
- **Fear that national programmes would suffer**
- **Constant budget** (stop ISR and other activities)
no compensation for inflation (material)
- **No contingency - 'Contingency is time'**
- **Construction time extended by 1 year**
- **Several rounds of vote in Council**
- **Finally**
Unanimous Approval 30 October 1981

CERN Budget



Spending profile

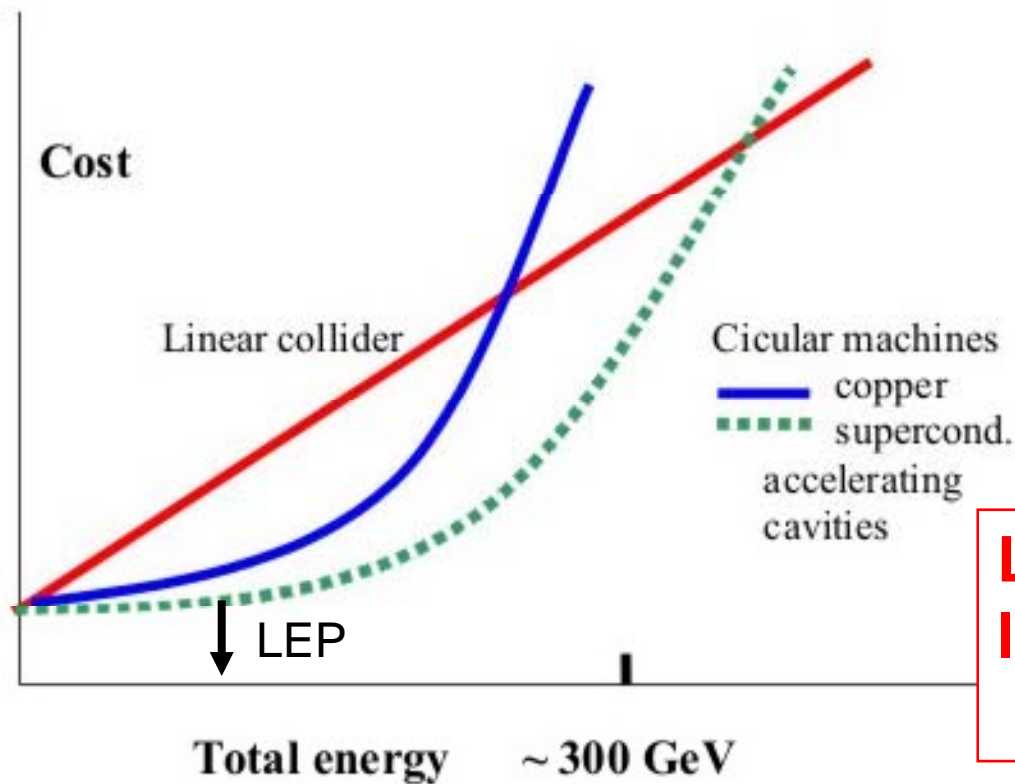


**Carlo takes over,
did not like
debts!**

Mrs. Thatcher at CERN in fall 1982



Round or linear ?



Synchrotronradiation Loss
 $\sim E^4/R$

Cost Optimisation gives
 $R \sim E^2$

LEP will remain the largest circular e+e- machine

Great event: Discovery of W and Z in 1983



**Letter to M. Thatcher
in November 1982!**

**Discovery announced in
January 1983**

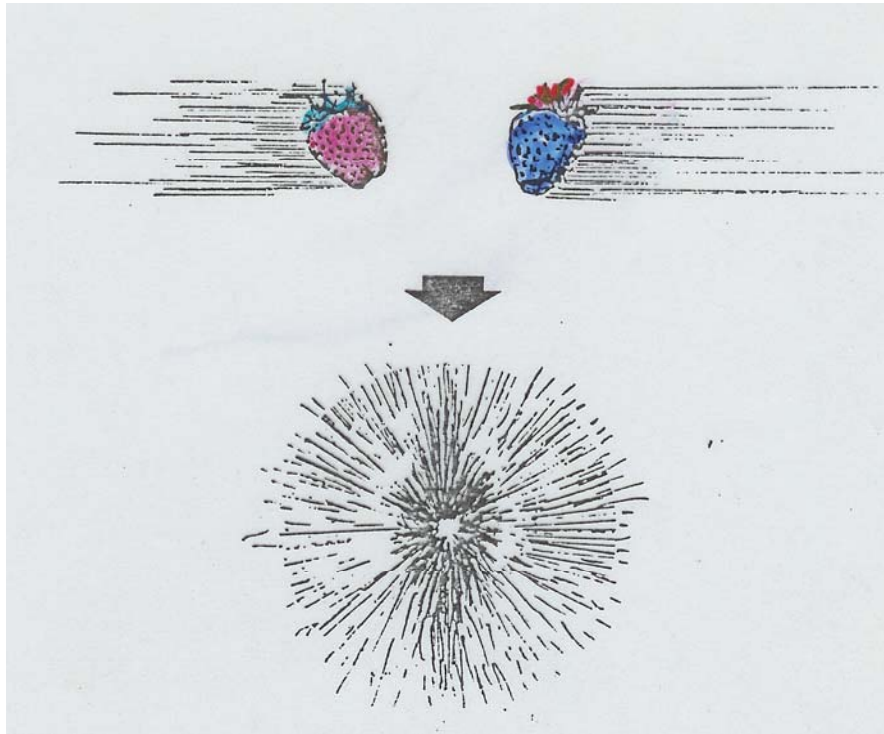


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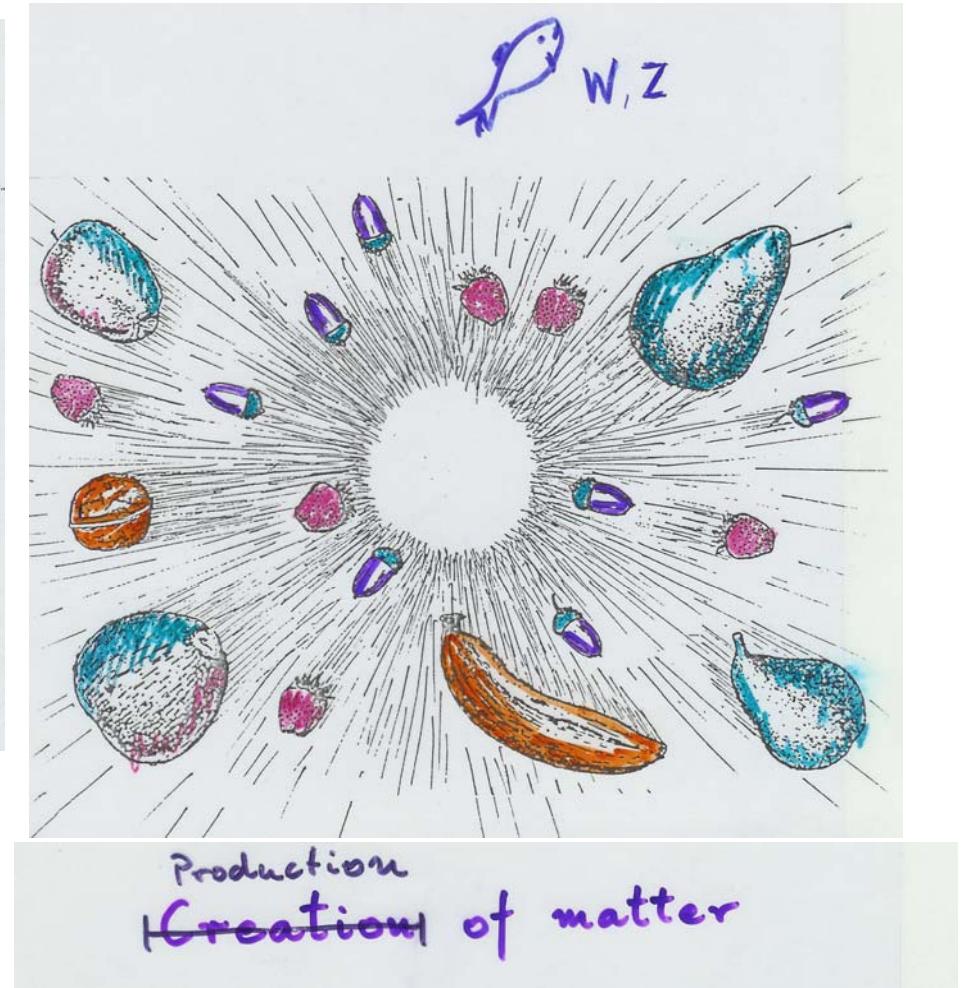
Paul John II at CERN



15 June 1982



1. Annihilation of strawberry and anti-strawberry
High concentration of 'pure' energy
2. From energy matter is created





**Dalai Lama
at CERN 1982**

Groundbreaking of LEP



13 September 1983



**Water under
high pressure,
flowing**

Disaster under Jura!! Delay about 1 year

LEP Tunnel



First beam in LEP



14 July 1989
200 anniversary of
French Revolution

Length of beam orbit
right within 1 cm !!
Out of 27 km

Carlo Rubbia DG from 1. January 1989

LEP Operation

LEP 1: beam energy around 50 GeV for 7 years
„Z- Factory“ millions of Z- particles produced
(UA1 und UA2 had only handful events for discovery)

LEP 2: from 1996 energy increase in steps
with **288** SC cavities (Nb massiv and coated)
one of largest SC linacs, not properly recognised!

During 11 years LEP worked extremely well

LEP Experiments

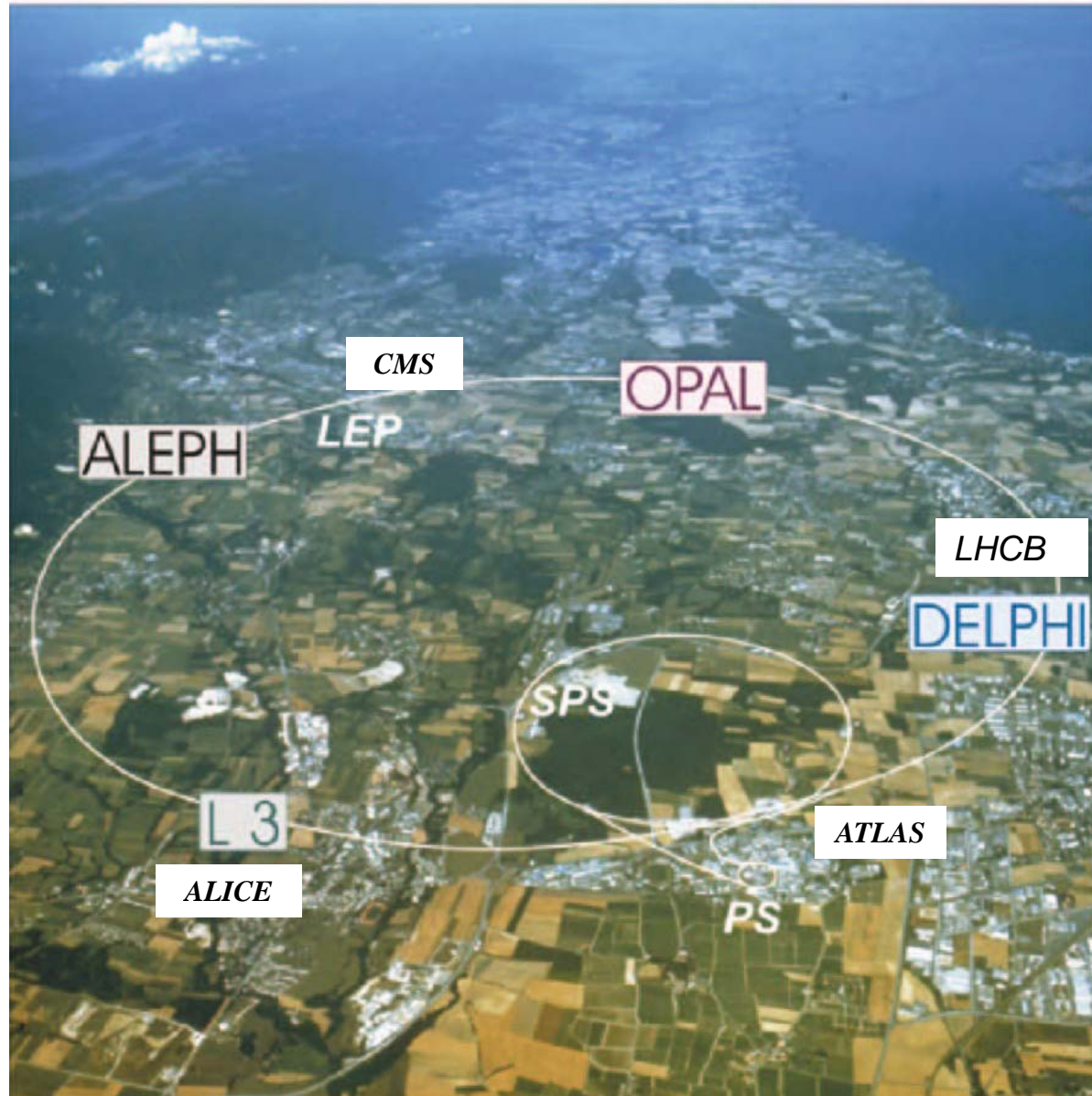
ALEPH, DELPHI, L3 und OPAL

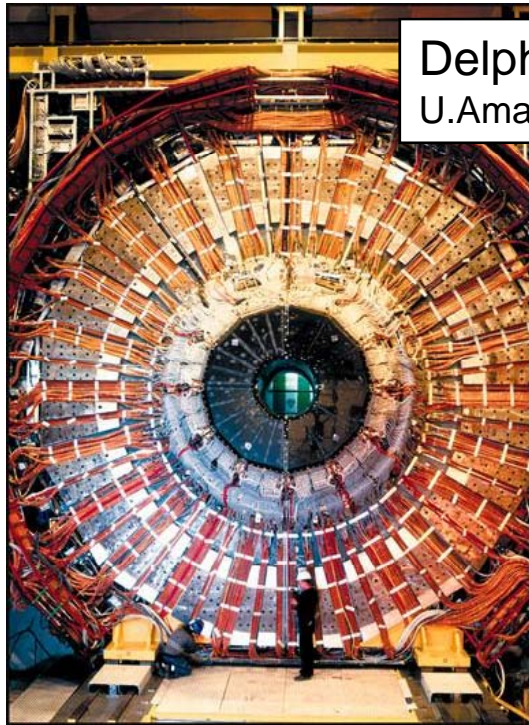
**introduced new style of experiments
(based on UA 1 experience)**

Outstanding example of International collaborations

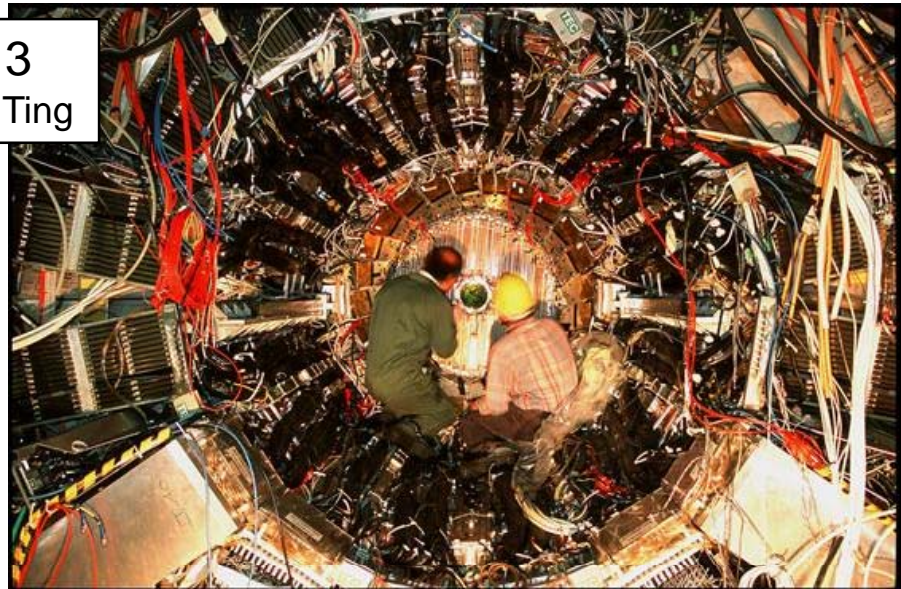
- **up to several hundreded scientists
from countries with different political systems, various
traditions, mentalities and religions**
- **Experiments essentially financed by users
Contributions in kind (components) from non-Member States**
- **‘Finance committee’ for each experiment**

**„LEP Model“ expanded for LHC experiments
1000 to 2000 scientists**



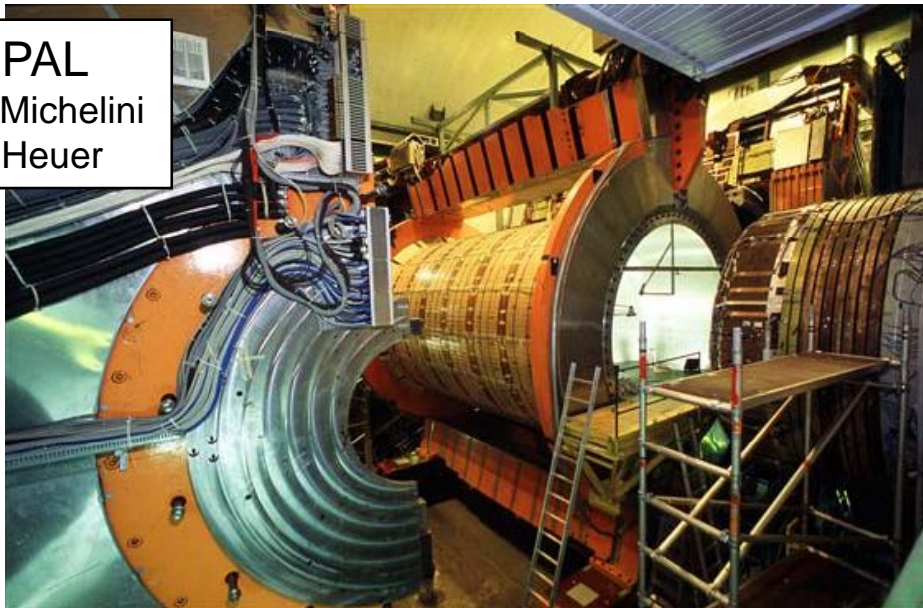


Delphi
U.Amaldi

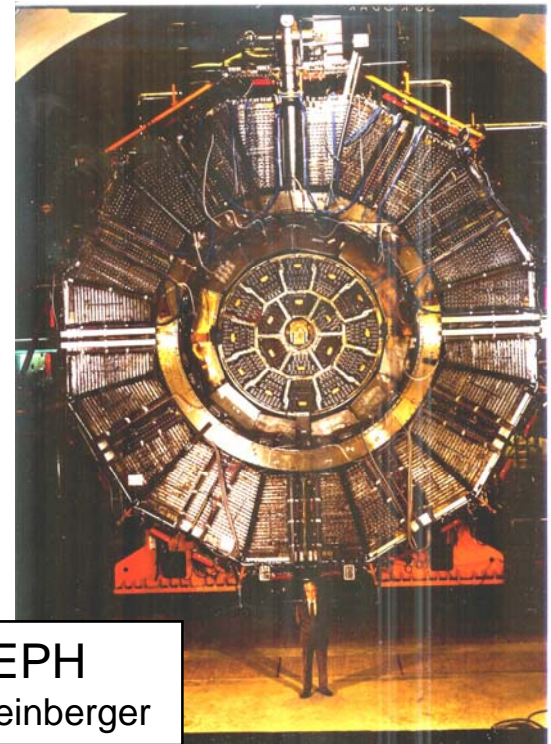


L 3
S.Ting

LEP Experiments

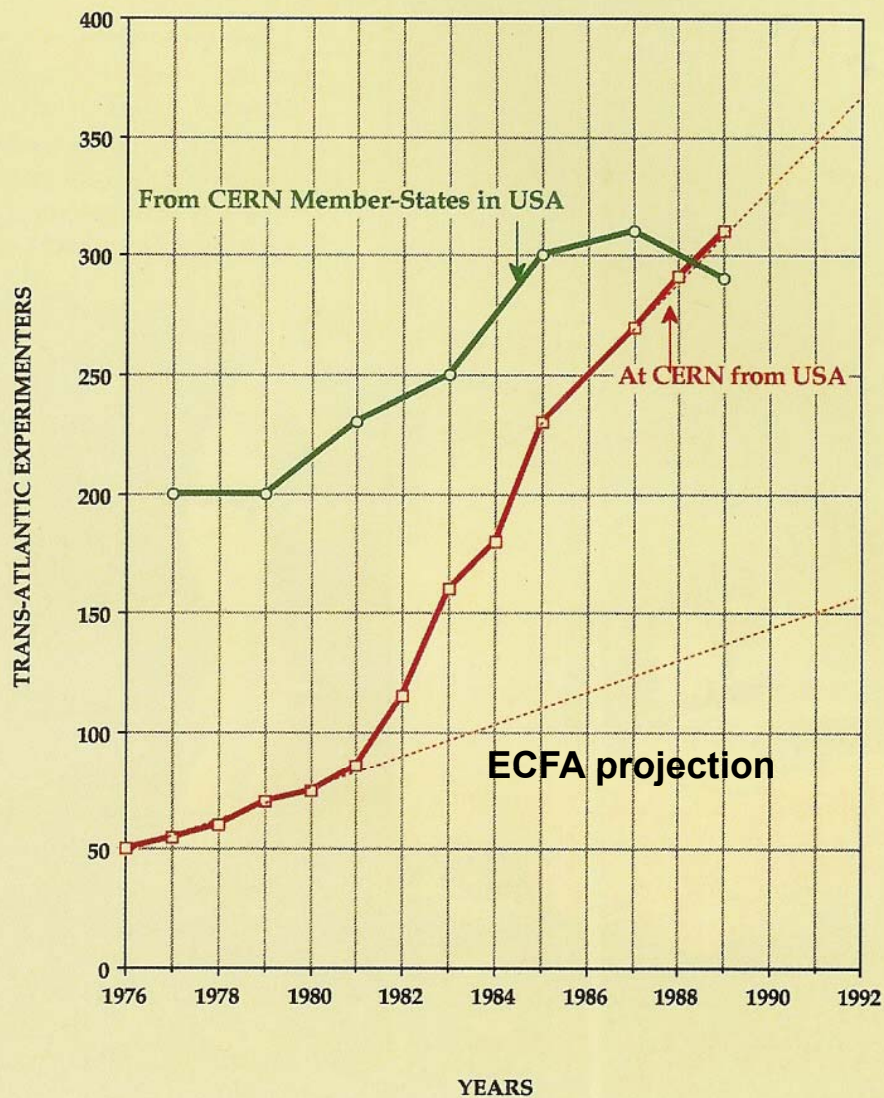


OPAL
A.Michelini
R.Heuer



ALEPH
J.Steinberger

CERN towards a world laboratory



**LEP turned CERN
into world laboratory
regarding users**

LEP Results

No Sensations (TOP, SUSY, Higgs)

**But great progress in science also
from detailed hard work**

- **Precision measurements**

LEP turned HEP into Precision Physics ($< 0.5\%$)

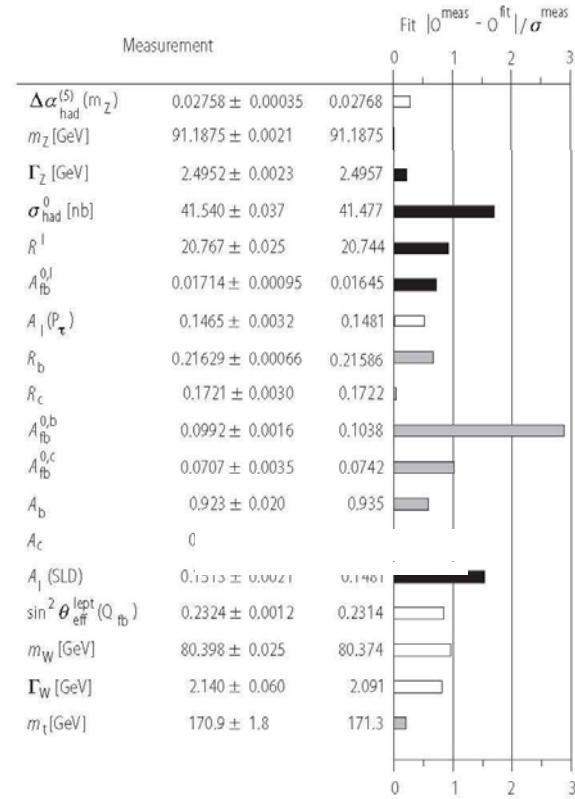
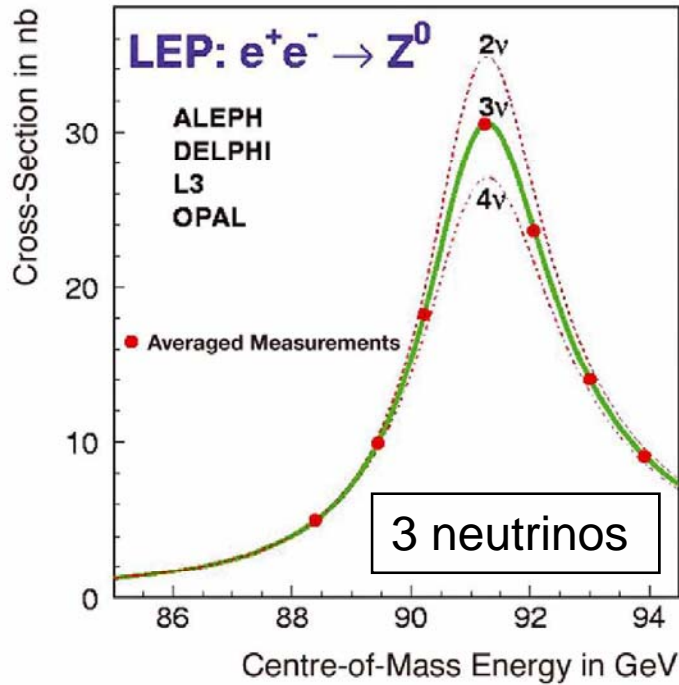
- **Standard-Model**

is renormalisable Field theory

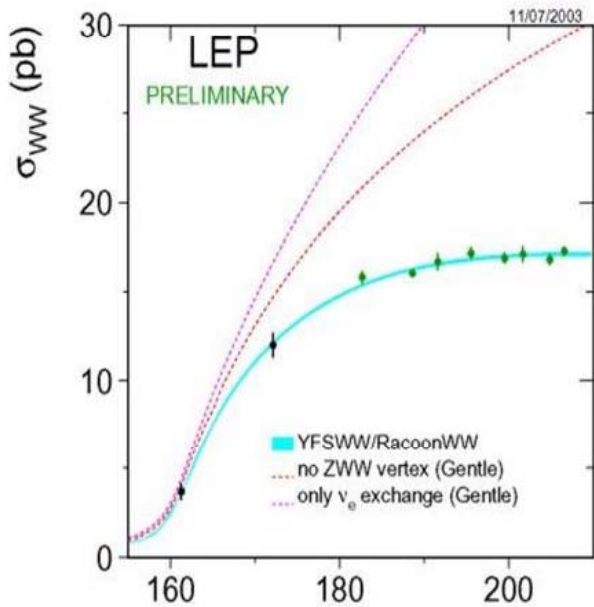
Radiative corrections

Nobel Prize to G.Veltman and G.t'Hooft, not to experiments

For QED also for Experiment (Lambshift)



SM confirmed with <1%



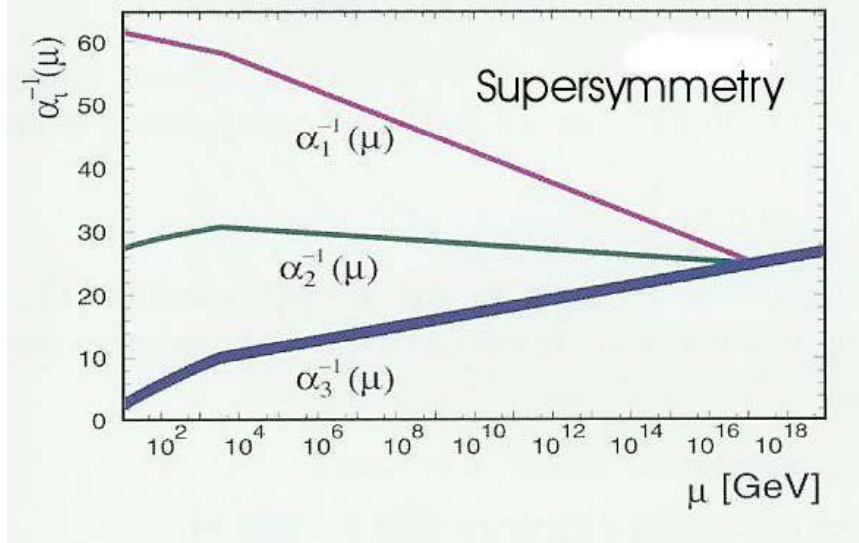
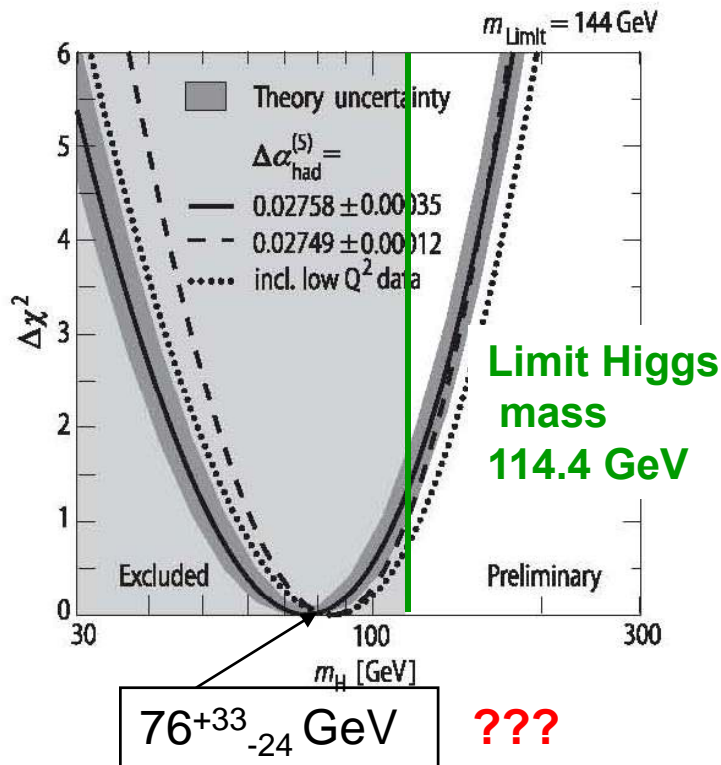
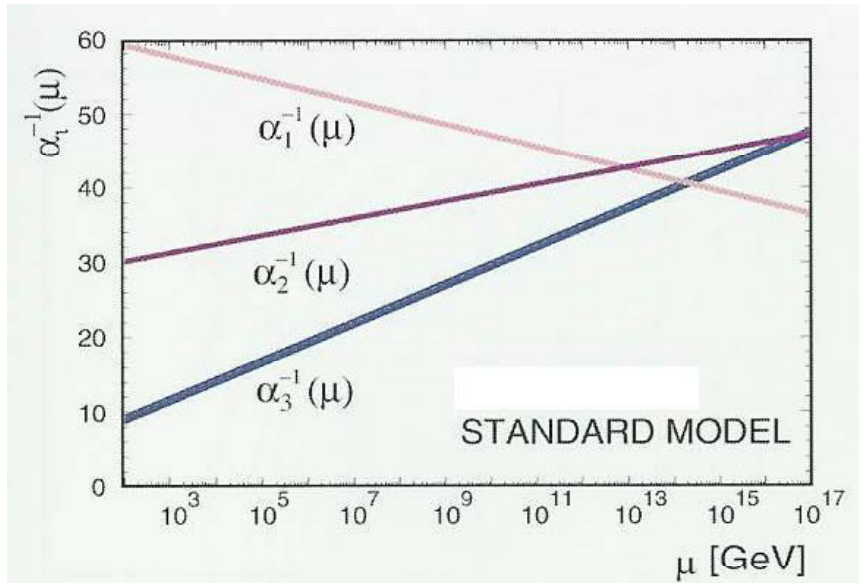
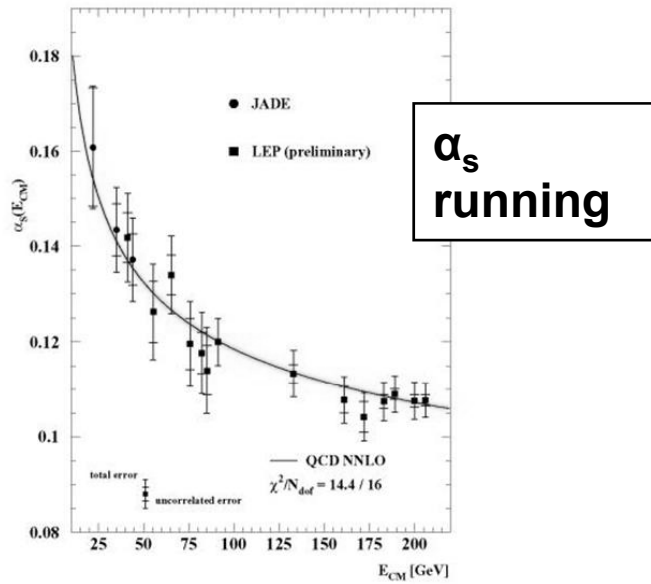
Direct Z-W-coupling

Top mass from radiative corrections

LEP $172.6^{+13.2}_{-10.2}$

TEVATRON

170.9 ± 1.8 GeV



Running coupling constants
Only indication beyond SM

Long-Range Planning Committee

- **February 1985 Council established LRPC**
Chair Carlo Rubbia
- **Members** (agreed by Rubbia and DG)
 - G.Brianti (CERN)
 - P.Darriulat (CERN)
 - G.Ekspong (Sweden)
 - A.Salam (UK)
 - S.C.C.Ting (USA)
 - S. van der Meer (CERN)
 - G.A.Voss (D)
 - invited chair ECFA (J.Sacton), A.Abragam (F)

Subpanels:

1. **Hadron Collider in LEP Tunnel,** chair **G.Brianti**
2. **e+e- Collider in 1 TeV Energy Range,** chair **K.Johnson**

Recommendations June 1987

1. LHC

8+8 TeV p + p with 10 Tesla Magnets (two in one)

$1.4 \times 10^{23} \text{ cm}^{-2} \text{ s}^{-1}$ (not proton + antiproton)

- would offer the fastest and most economic way to achieve 1 TeV range (still in competition with SSC)
- infrastructure at CERN (LEP tunnel, injectors, experience)
- Lower energy than SSC partly compensated by higher luminosity
- Coexistence with LEP (e-p possible) (*revival??? LHeC*)
- Start vigorous programme in cooperation with interested national institutions

2. **e+ e- linear collider for 1 TeV** regime, CLIC seems attractive

But many technical questions open

Too early for decision, **vigorous R&D**

SSC

- January 1987 President Reagan approves SSC (20 + 20 TeV) in Texas
- US Congress asks for international participation
because of high cost (\$4.4billion)
Hearings in Congress
- Negotiations at Washington with DOE



Negotiations at Washington for international participation in SSC in 1987

G.Montanet, D.Colley, D.Stairs
J.Horowitz, V.Sbergel, N.Cabibbo, P.Fasella, H.Schopper;
J.Rembser, A.Trievelpiece, H.Atkinson, Nishikawa;

Negotiations with DOE failed!

Question by Europeans and Japanese:

‘Can we influence parameters?’

- Trievelpiece: “the president has decided to build SSC, you join or leave it”
- **End of negotiations**
- **October 1993 SSC stopped by Congress
cost risen to \$ 11 billion**

Carlo pushes LHC

- SSC – LHC competition disappeared, US, Japanese, physicists joined LHC
- **LEP – LHC coexistence, transition ??**
- C.Rubbia
presents long term strategy paper in 1990
LEP and LHC still co-existing
- Council: “LHC is right machine for .. the future of CERN” asks Rubbia to make complete proposal before end of 1993

Final design LHC and approval

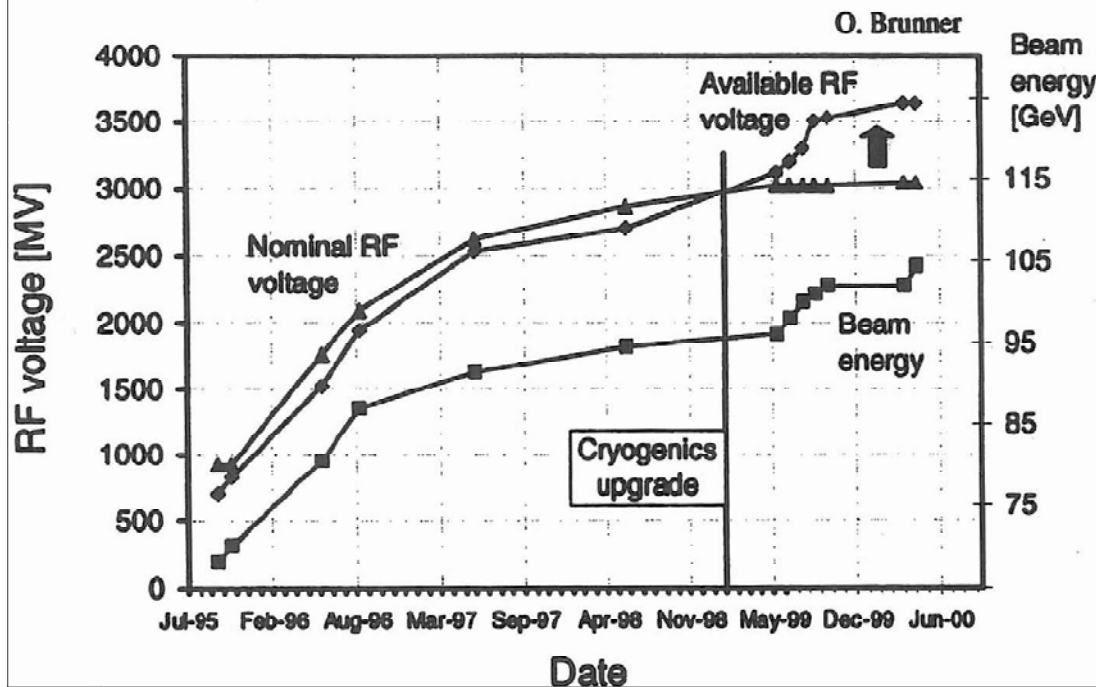
- **Lyn Evans and machine experts worked out new design (Summer 1993)**
Lq He channel outside magnets
LEP magnets removed from tunnel
- **Ch.Llewellyn-Smith presents new design to Council with 'bumped budget'**
- **Long fights over budget, D and UK ask for 'constant budget' (reminder of LEP)**
- **LHC approved December 1997**
no budget increase, debts, *bank loans allowed*,
find contributions from non-Members,
extend construction to 2005

Any similarities with 'LEP' purely accidental!

Dramatic last period of LEP

RF voltage (design and actual):

Higgs mass low



May 1998 94.5 GeV

November 1998 101 GeV

Indications for Higgs!!?

Heroic attempt

Activate all available cavities
(Cu and Nb)

May 2000 104.5 GeV

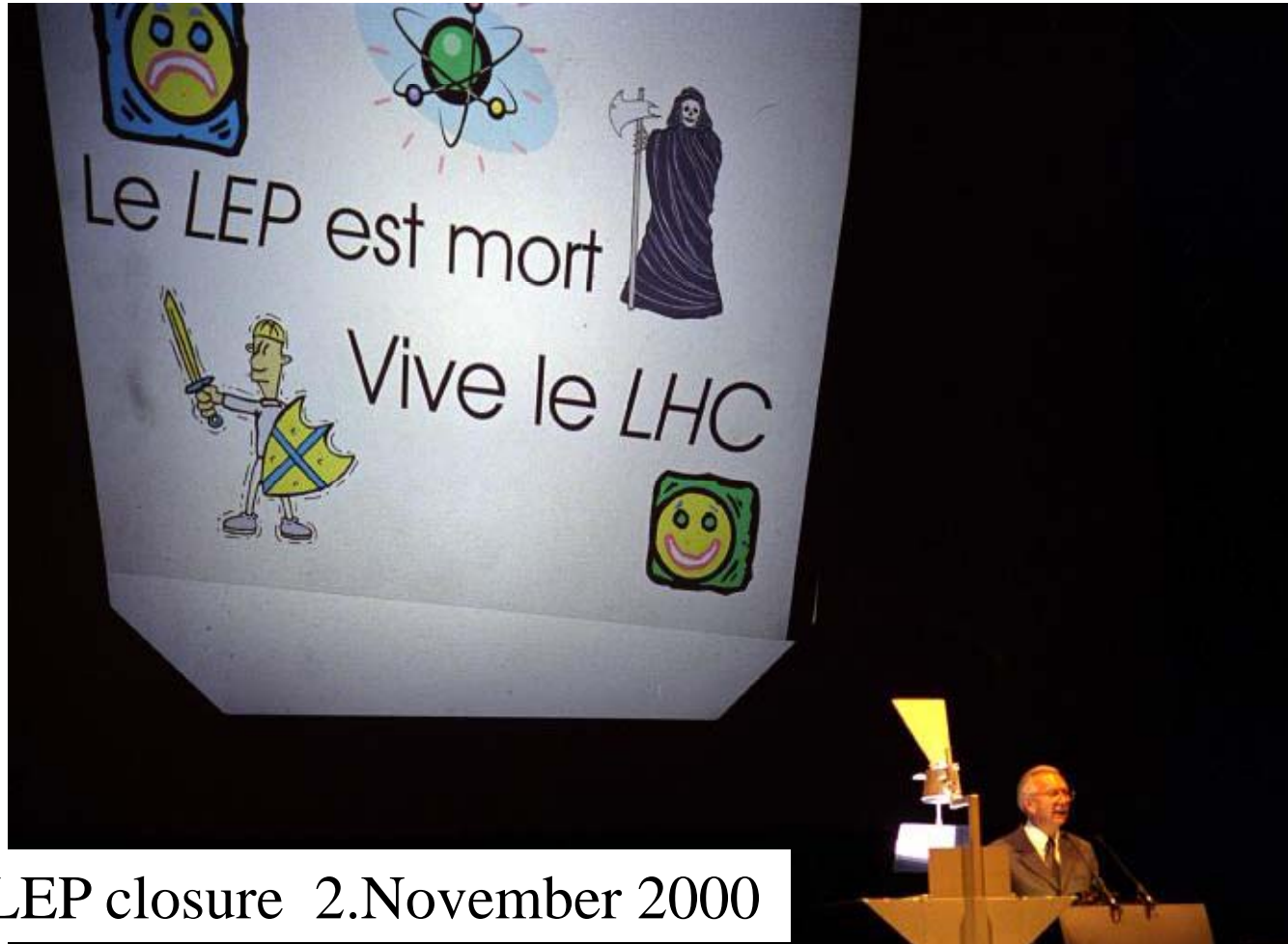
Heated discussion when LEP should stop

Operation extended from May to 2. November 2000

L.Maiani decided to stop, not to delay LHC

No Higgs, but
Limit Higgs mass
114.4 GeV

Higgs in reach of LEP? LEP magnets for 125 GeV! But no RF cavities!
Tevatron? **Wait for LHC!!**



LEP closure 2.November 2000

**Lyn Evans
and his staff**

**First beam in LHC
15 September 2008
Congratulations**



**New management has taken
right decision to compensate
for time lost due to accident**

**LHC will answer many questions
left open by LEP and TEVATRON**

Six Stages of a Project

1. Wild enthusiasm
2. Total confusion
3. Complete disillusion
4. Search for the guilty
5. Punishment of the innocent
6. Promotion of the non-participants

With the complement of the Lp Project Leader
Imilia



Thank you Carlo
Many happy returns