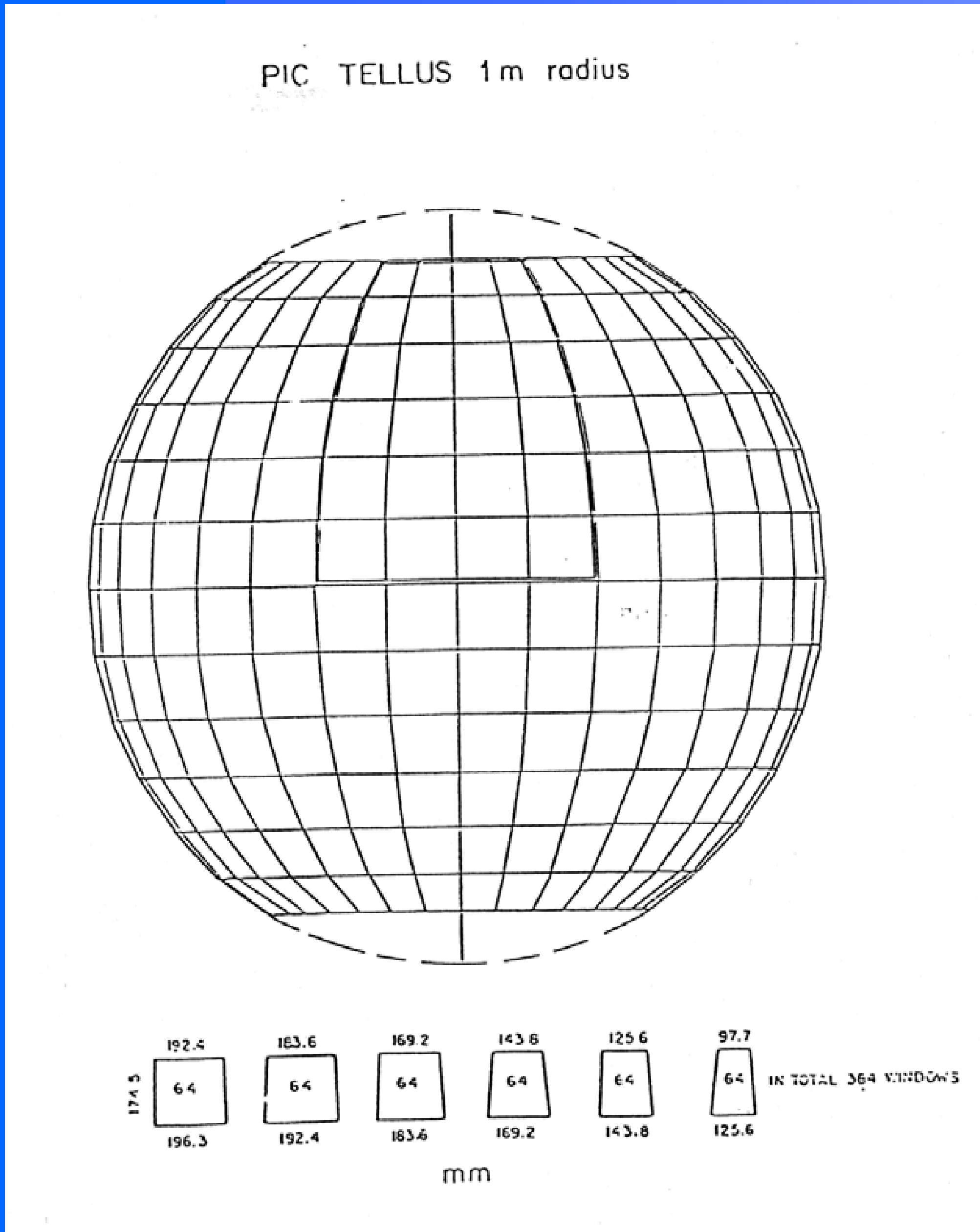
BIRTH AND TEETHING PROBLEMS

Ugo Amaldi

University Milano Bicocca and TERA Foundation

Pic Tellus – 1977
ECFA Hamburg Meeting



Jacques Seguinot and Tom Ypsilantis

The next steps:

June 1977
Les Houches
Daniel Treille
and U.A. work
on b-tagging

June 1980
Uppsala Conf.
organized by
Tord Ekelöf

TERA

Preparation of the design of a new detector

Summer 1980: Bernard Hyams to UA: "… a silicon microvertex is feasible"

Fall 1980: Guido Barbiellini to UA: "…let us organize a LEP collaboration"

Fall 1980: Hans J. Hilke to UA: "… the TPC is a wonderful instrument"

January 1981: COLlaboration for LEP Studies meeting

3 possible designs

3 possible TPCs

GROUPS

AMSTERDAM
BERGEN
BOLOGNA
CERN
EC.POLYTECHNIQUE
GENOVA
LUND
NIJMEGEN
ORSAY
OSLO
UPPSALA
ROME
SACLAY
STOCKHOLM
STRASBOURG

JVA/22/1/81

Jim Allaby

First Team Leader

LEP DISCUSSION MEETING 19-21 JANUARY

Notes on the Final Session

At the final session held on Wednesday 21 January, Ugo Amaldi tried to collect some general trends emerging from the meeting and to single out those areas where specific work was needed. The following general points emerged:

1. Preference for essentially a uniform magnetic field providing (if feasible) a $\Delta p/p^2 \sim 0.2\text{-}0.4\%$.

2. Preference for the use of Čerenkov imaging for particle identification.

3. Preference to study two solutions:

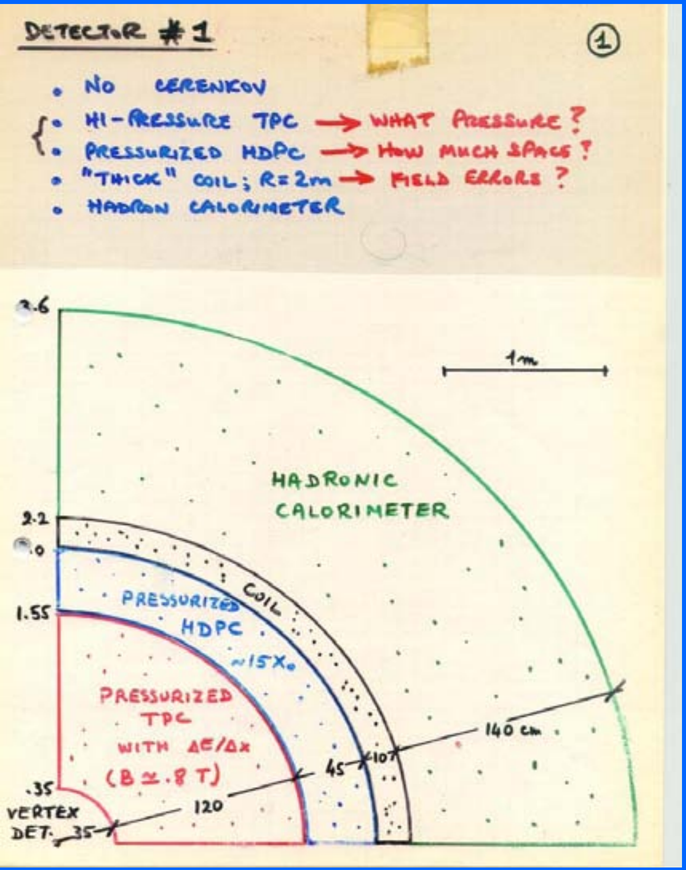
   a) an innovative Čerenkov counter detector or innovation in dE/dx such as may be provided by cluster counting.

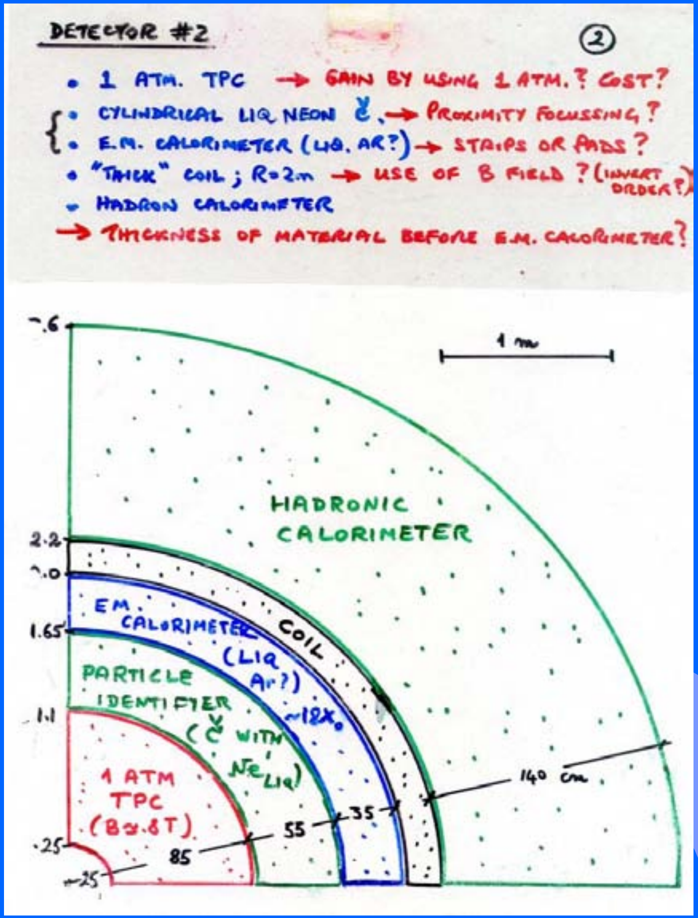
   b) A more conservative design using atmospheric TPC's or jet-chambers.

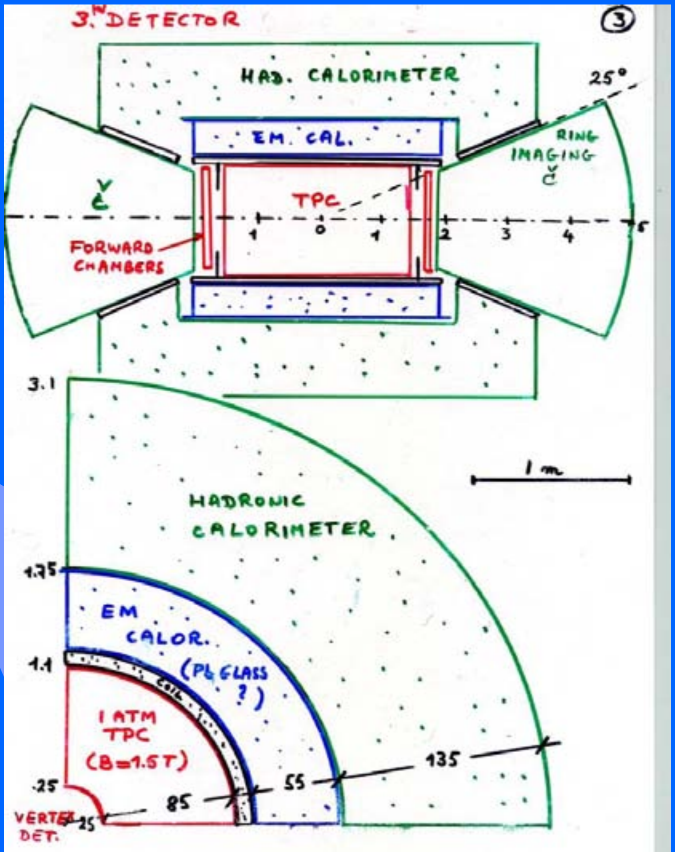
4. There was need for a vertex detector.

5. There was interest in the possibility of forward arms including Čerenkov counters.

My concluding transparencies with Jim Allaby's writing







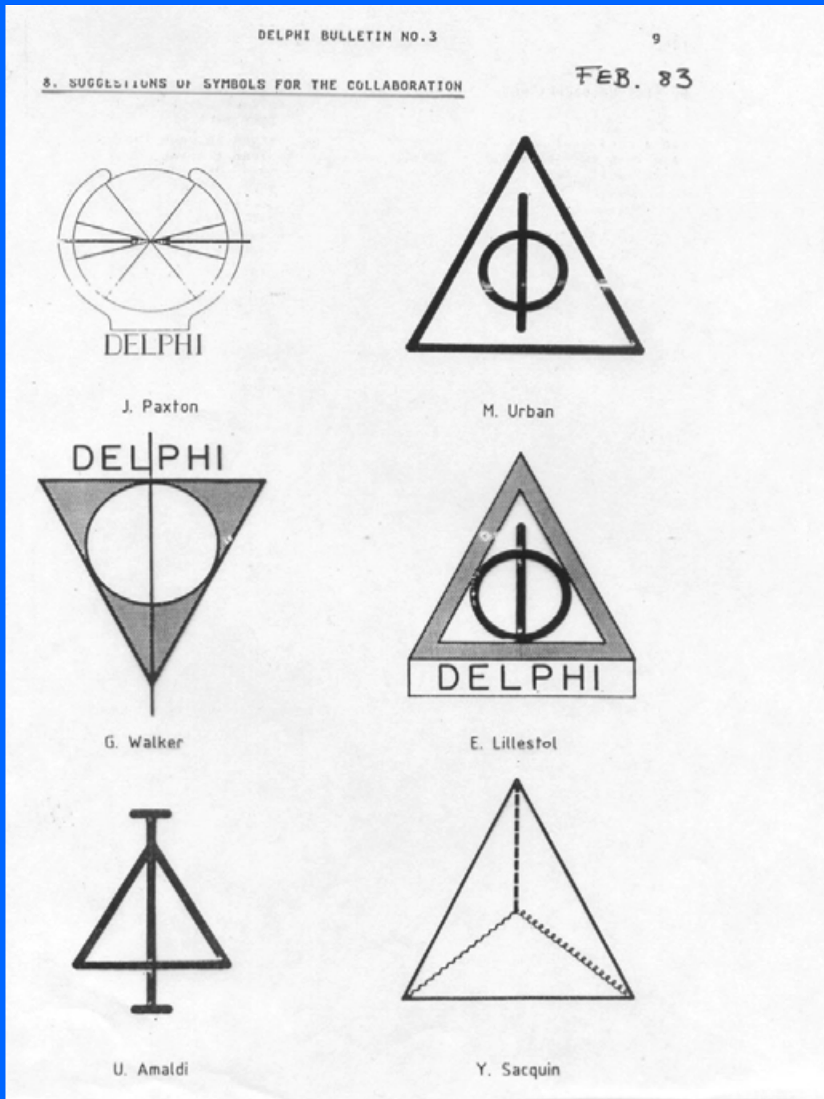
21st January 1981

Villars Meeting – Summer 1981

Herwig Schopper - CERN DG:

L of I of no more than 10 pages by January 1982

Two contests for the name and the logo



December 1981:

Choice of the name DELPHI

proposed by G. Myatt

1983:

Choice of the logo

proposed by the Padua Group

The legend of Apollo, two dolphins and the shore of Delphi

The Collaboration

DELPHI

A DETECTOR WITH LEPTON, PHOTON AND HADRON IDENTIFICATION

Letter of intent for an experimental program at LEP

DELPHI COLLABORATION

GROUP	CONTACTMAN
Collège de France	M. Crozon
Ecole Polytechnique	M. Urban
Orsay	F. Richard
Paris – LPNHE	M. Baubillier
Saclay	G. Smadja
Strasbourg	A. Degré
Karlsruhe	J. Engler
Wuppertal	J. Drees
Oxford	G. Myatt
Rutherford	W. Venus
Athens – Nat. Tech. Univ.	T. Filippas
Athens	L. Resvanis
NIKHEF – Amsterdam	F. Udo
INFN – Bologna	L. Monari
INFN – Genoa	M. Bozzo
INFN – Milan	A. Pullia
INFN – Padua	L. Ventura
INFN – Rome – Sanità	C. Bosio
Bergen	E. Lillestøl
Oslo	T. Buran
Cracow	K. Rybicki
Lund	G. Jarlskog
Stockholm	G. Ekspong
Uppsala	S. Kullander
CERN	J.V. Allaby

January 82: letter of intent

D E L P H I

Detector for Electron Photon and Hadron Identification

Country	Institute
Austria	Vienna
Belgium	Antwerp, IIHE, Mons
Denmark	Copenhagen
Finland	Helsinki
France	College de France, LAL Orsay Paris LPNHE, Saclay, CRN Strasbourg
Fed.Rep.Germany	Karlsruhe, Wuppertal
Great Britain	Liverpool, Oxford, RAL
Greece	Ath.Demokritos, Ath.NTU, Ath.Univ.
Italy	INFN: Bologna, Genoa, Milan, Padua, Turin, Trieste, Rome , Udine
Netherlands	NIKHEF
Norway	Bergen, Oslo
Poland	Cracow, Warsaw
Portugal	Lisboa
Spain	Santander, Valencia
Sweden	Lund, Stockholm, Uppsala
USA	Ames Iowa
USSR	IHEP Protvino (Serpukhov)
International Organisations	JINR (Dubna) CERN

YB 89

Fall 82: DELPHI after the "marriages"

The first bulletin

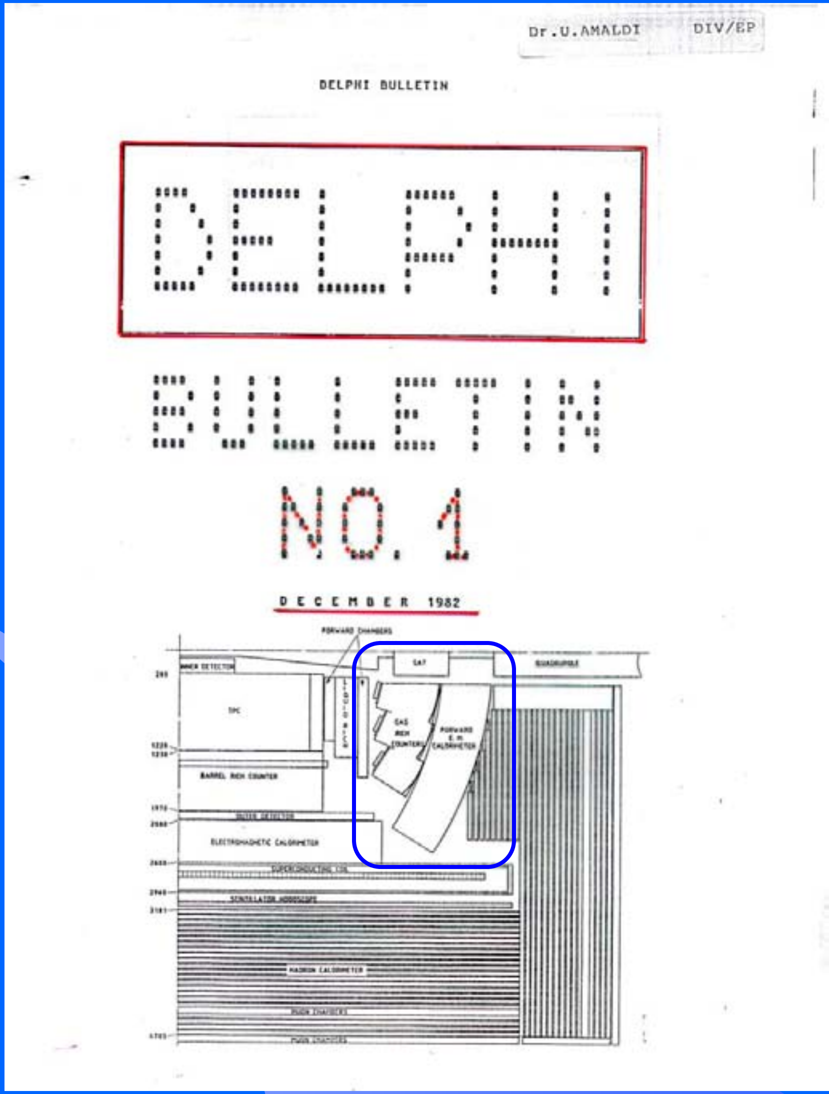
Provisional approval: May 82

Final approval: Dec. 82

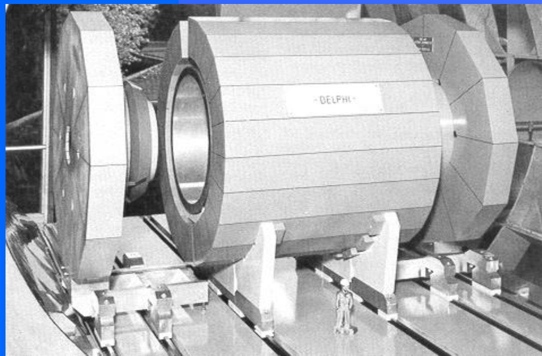
DELPHI specialties:

3-layer microvertex (B. Hyams, P. Weilhammer)

2 Riches (T. Ekelöf, J. Seguinot, T. Ypsilantis)



With Guido, Hans Jurgen and Gregoire



First DELHI model

LEP News

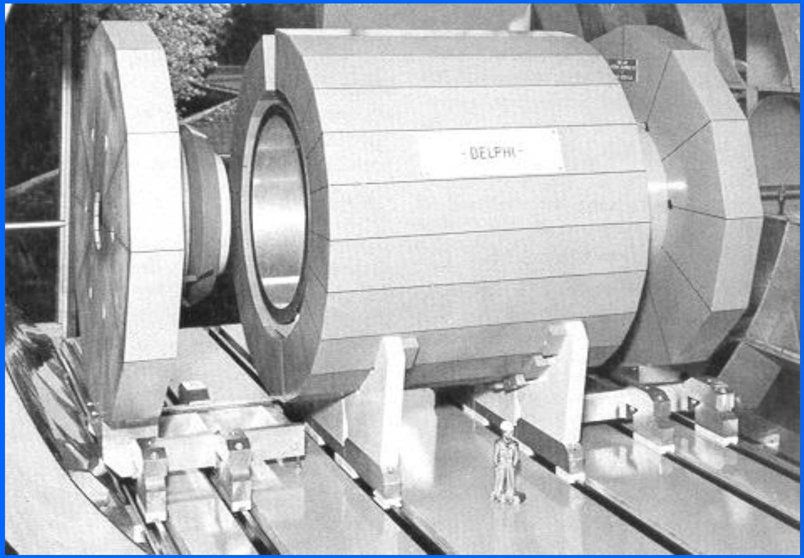
N. 6

December 1982

September 1983: visit of President Mitterand

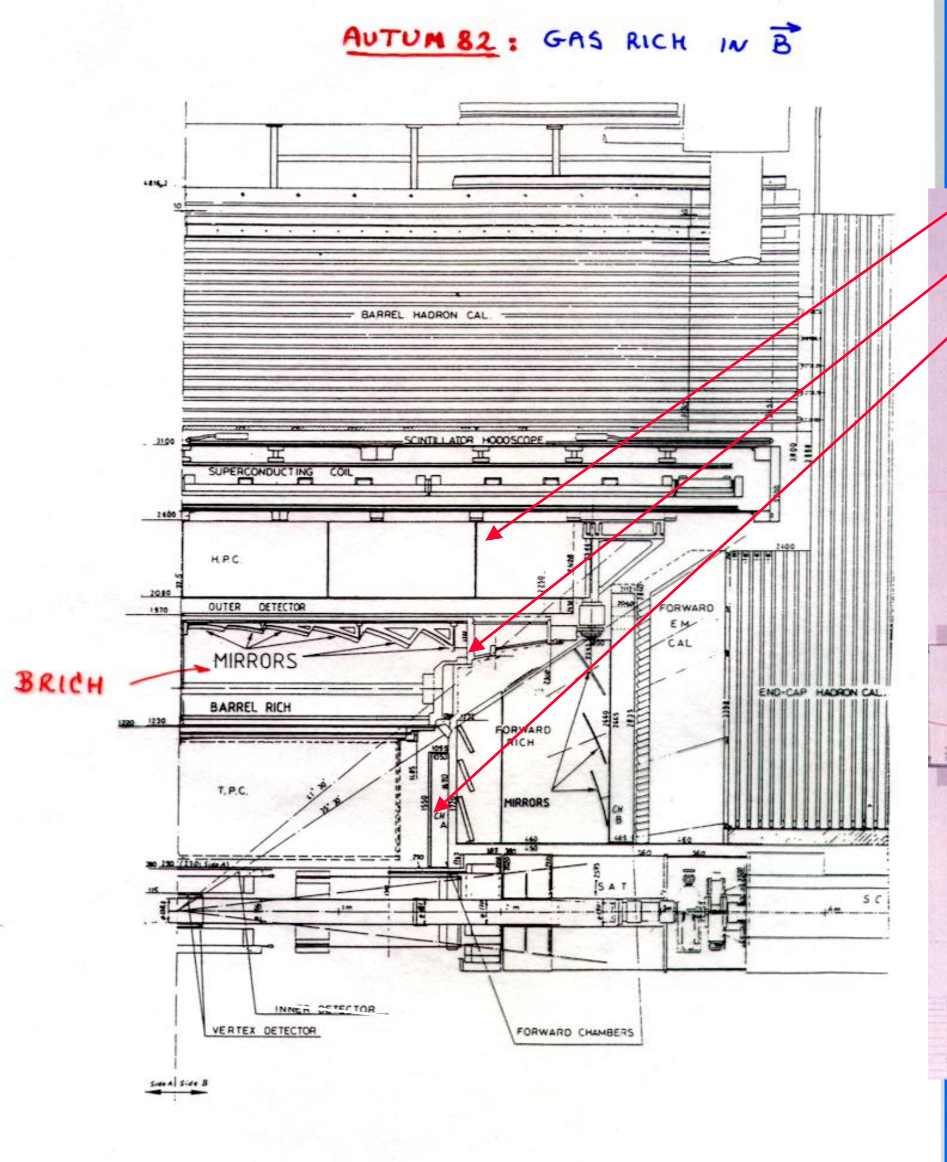
The only thing

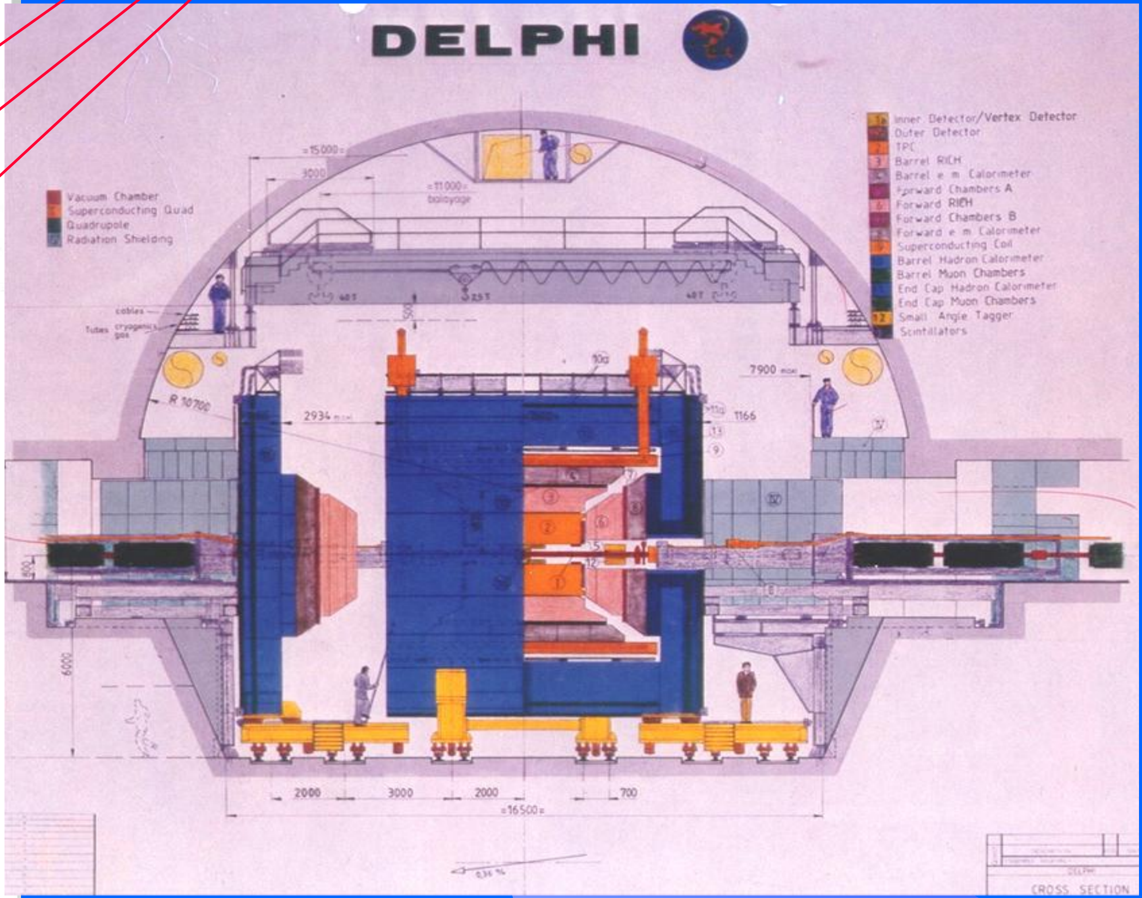
we could show …



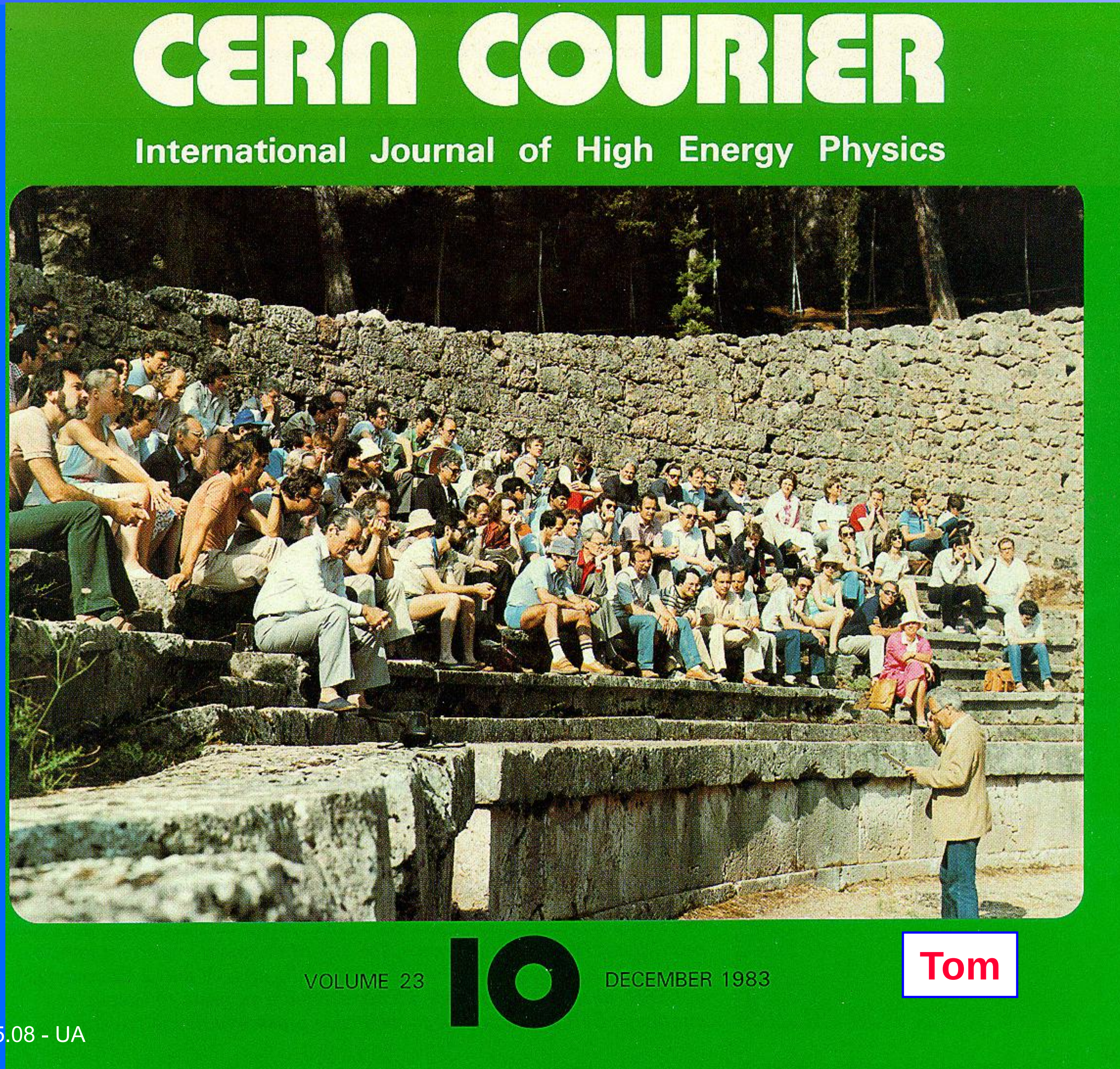
1983: Technical Proposal

DELPHI, the 'drifting' detector



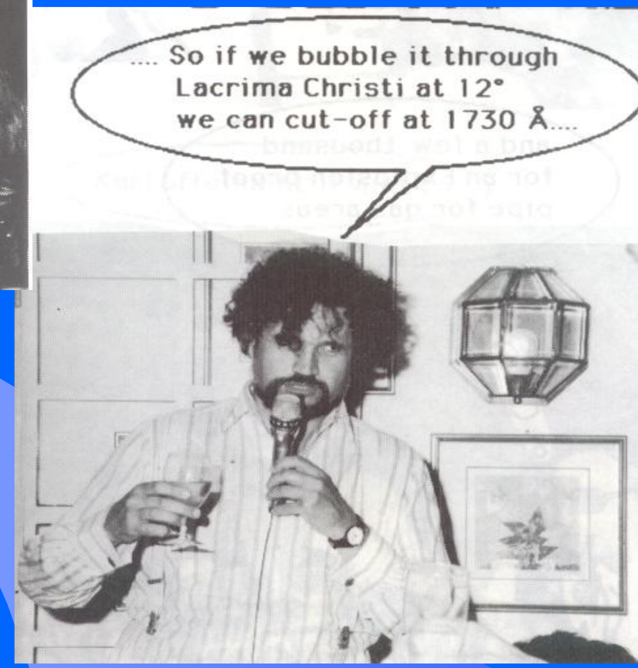


25 years ago: DELPHI meeting at Delphi



September 85: DELPHI week in Padova

From the DELPHI Bulletin N. 27



iMAGES

DELPHI à Padoue

Du 9 au 13 septembre, les membres de l'expérience DELPHI se sont retrouvés à Padoue. Ils y ont surtout fait le point sur l'état d'avancement de la construction de leur détecteur. Rappelons que le terme DELPHI (acronyme anglais de Détecteur pour l'identification des leptons, photons et hadrons) désigne l'énorme ensemble de détecteurs utilisé pour l'une des quatre expériences prévues au collisionneur LEP, expérience qui regroupe quelque trois cents collaborateurs fournis par une quarantaine de laboratoires de dix-sept pays.

L'étude et la mise au point des prototypes sont arrivées à leur terme et la production proprement dite des diverses pièces d'équipements a démarré. La construction de ces installations, qui représente un travail de plus de 1 000 années-homme, comporte plus de 100 000 voies électroniques réparties dans une quinzaine d'éléments principaux du détecteur.

Parmi ces installations, on peut citer l'aimant solénoïdal où le cryostat a 5,20 mètres de diamètre interne, ce qui en fait le plus grand les aimants supraconducteurs en

1. C'est dans l'Université de Padoue que les gens de DELPHI ont tenu leurs réunions et non pas dans cette ravissante chapelle de la petite île vénitienne de Torcello, où ils savourent ici un peu de détente. (Photo F. Danesin)

1. DELPHI's members held their meetings at the University of Padua and not in this delightful little chapel on the Venetian island of Torcello where they are pictured enjoying a moment's relaxation. (Photo F. Danesin)

From CERN Images

TERA

Other DELPHI weeks

Hiukkaskiihdytin on Cernissä rakenteilla

Hiukkassäteilyn erikoisasiantuntijat päättivät perjantaina kokouksensa Helsingissä. Viikon kestäneeseen kokoukseen osallistui 150 asiantuntijaa. He selvittivät rakenteilla olevan hiukkassäteilyilmaisimen eri osien rakennusvaiheiden nykytilaa. Kokousedustajat vierailivat myös suomalaisissa yrityksissä ja tutkimuslaitoksissa.

Euroopan hiukkastutkimuskeskus Cern rakentaa 27 kilometriä pitkää ympyränmuotoista hiukkaskiihdytintä. [illegible]Delphi eli hiukkassäteilyilmaisin on teknisesti vaativin sen neljästä törmäysasemasta.

Projektin johtaja Risto Orava arvioi törmäyttimen rekisteröintiin tarvittavien avaruusluotaimien rakentamisen olevan haastavan työn. Ne ovat mutkikkaimpia elektronisia järjestelmiä.

Risto Orava sanoo kokeiden ääriolosuhteiden edellyttävän uusia ratkaisuja niin tietotekniikassa kuin materiaalitekniikassakin. Aineen perustutkimuksen varaan rakentuu tuleva hyvinvointi.

Delphin rakentamiseen osallistuu 17 eri maata. Suomalaisten vastuulla on Delphin erään säteilyilmaisimenkokonaisuuden suunnittelu ja teollinen valmistus.

Suomalaisten valmistamat laitteet perustuvat 1970-luvun lopussa havaittuun ja vaikeasti hallittavaan fysiikan ilmiöön. Suomessa nähdään hiukkasfysiikan hallitseminen tärkeimmäksi edellytykseksi perustutkimukselle.

Projektin johtaja Risto Orava sanoo vuoden 1985 merkinneen suomalaisille läpimurtoa Cernissä. Suomen teollisuus toimittaa sekä huippuluokan elektroniikkaa että materiaalitekniikkaa koejärjestelmään.

LEP-Delphi säteilyilmaisinkokouksen yhteenvetoinfossa olivat mm. saksalainen Hans-Jürgen Hilke ja Suomen ryhmän johtaja Risto Orava.

H.J. Hilke R. Orava

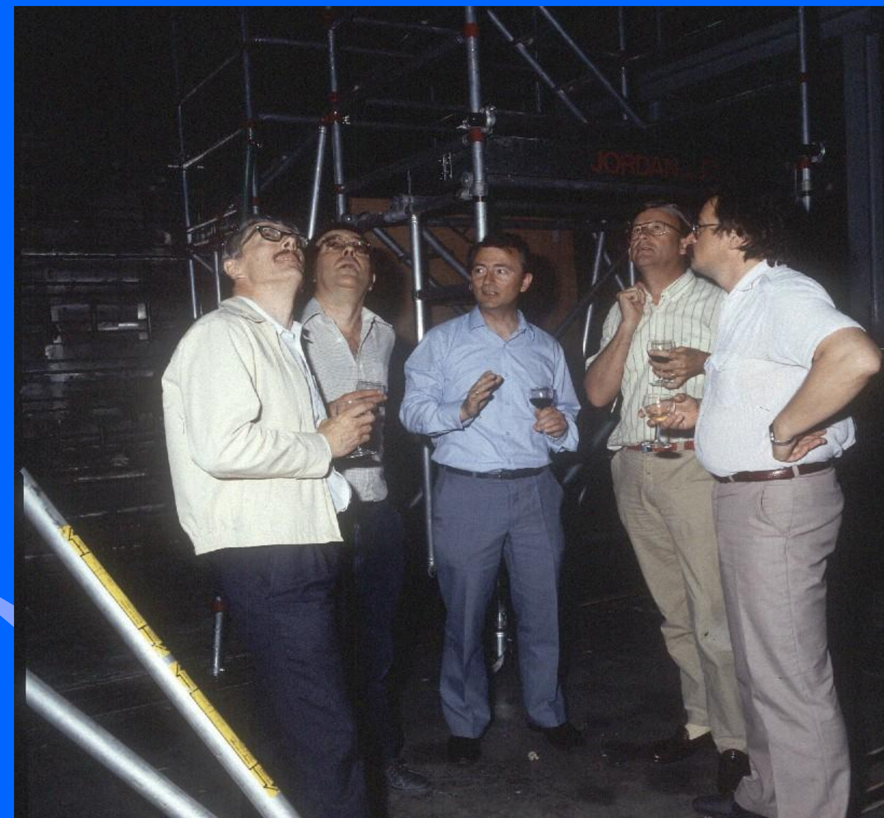
A clear description of DELPHI

on an Helsinki newspaper

1986

Lisboa 88

February 87: the yoke mounted in I4

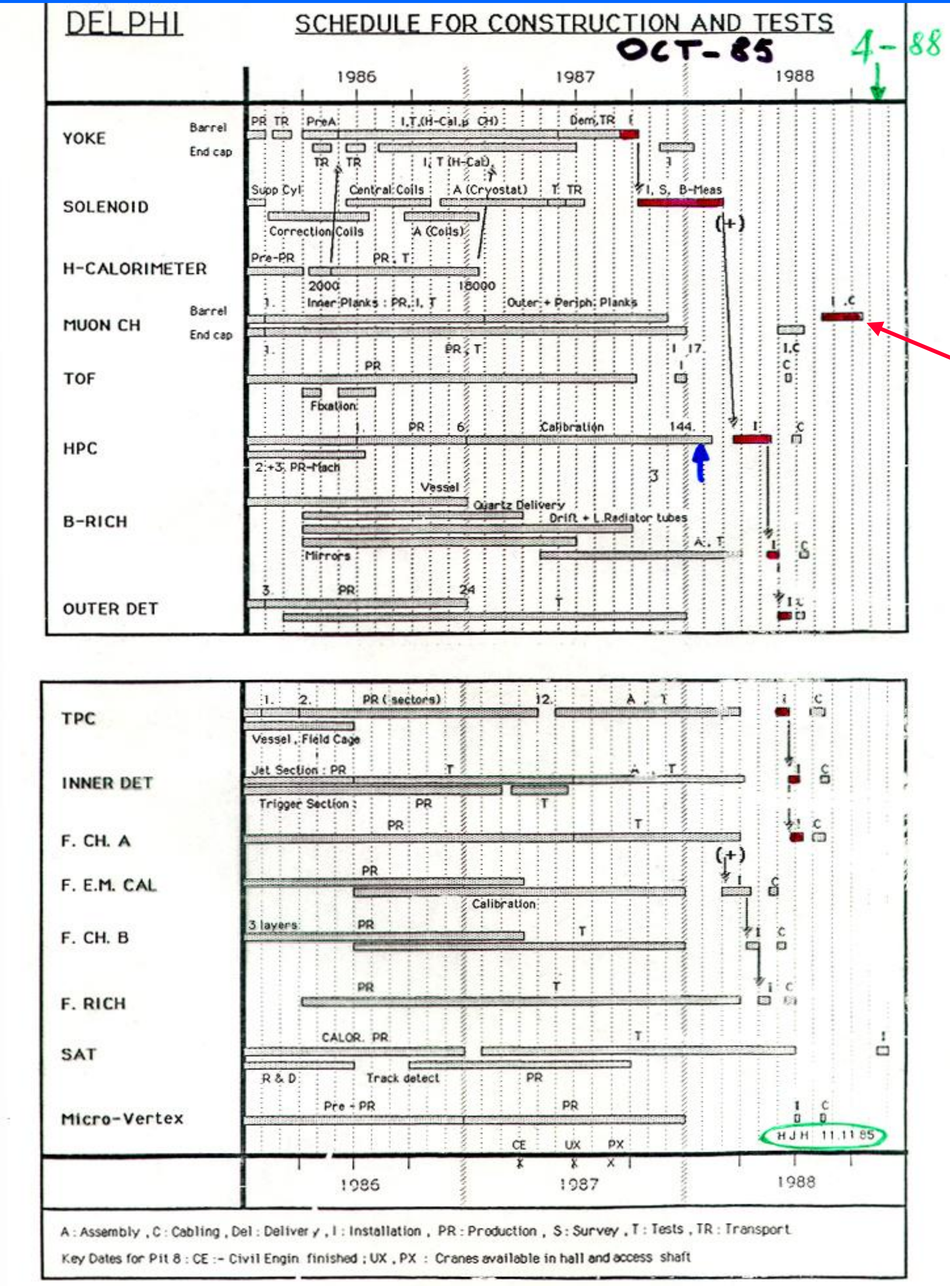


Hans Jürgen and George

The Rutherford solenoid – the world's largest

Joyeux Noël
et meilleurs vœux
pour la nouvelle année

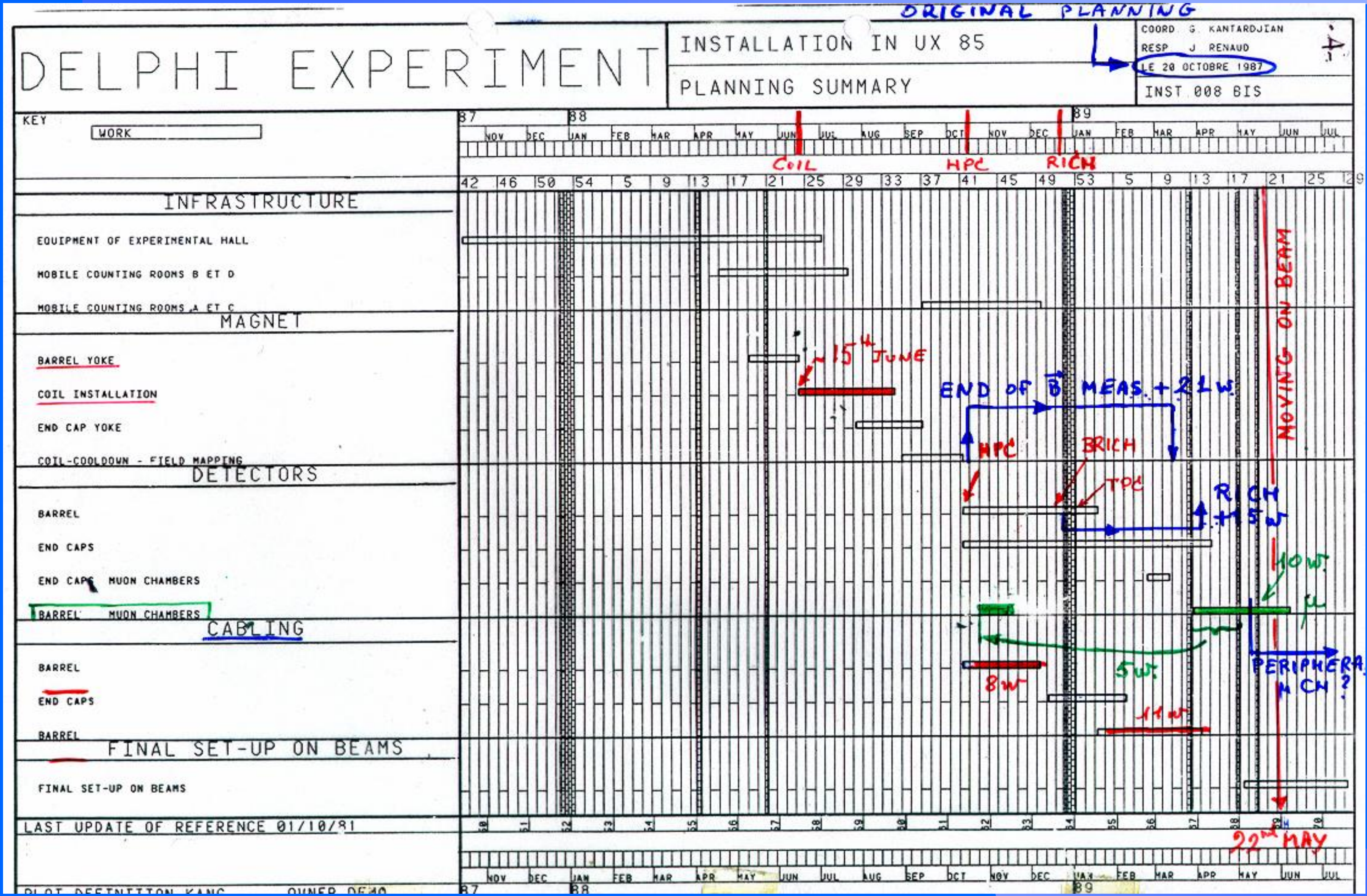
The planning of October 1985



The plan

ended in March 88

The planning of October 1987 and its updates



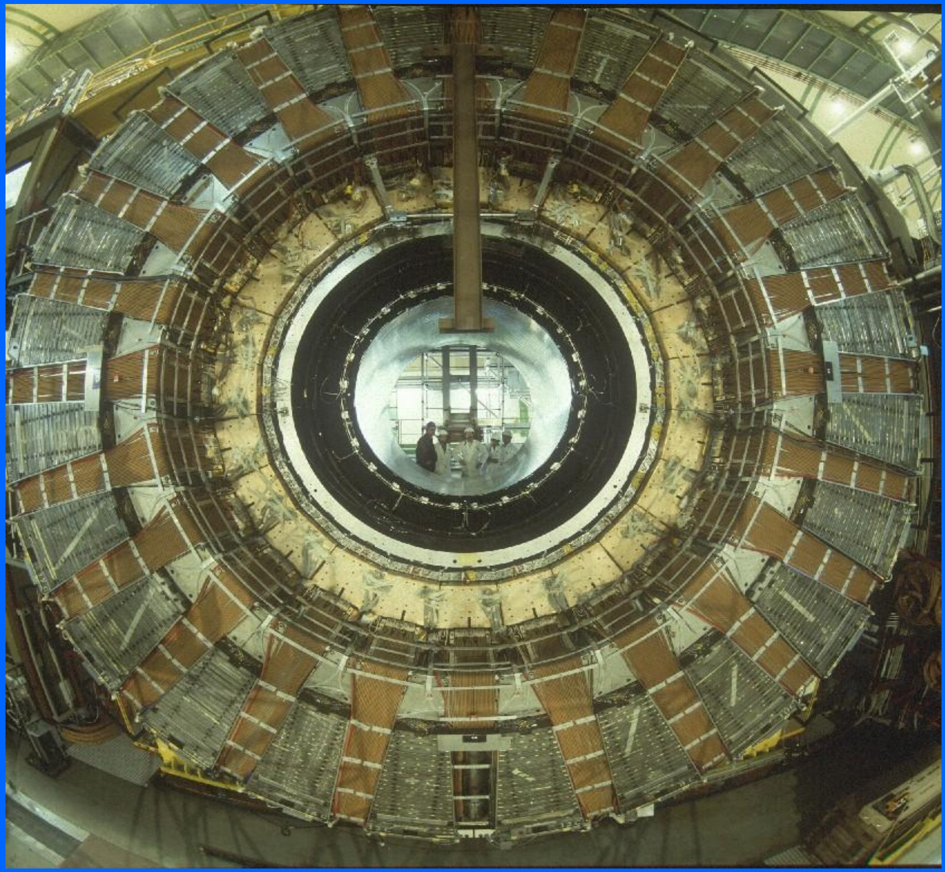
October 1988: the broken joint that almost killed DELPHI

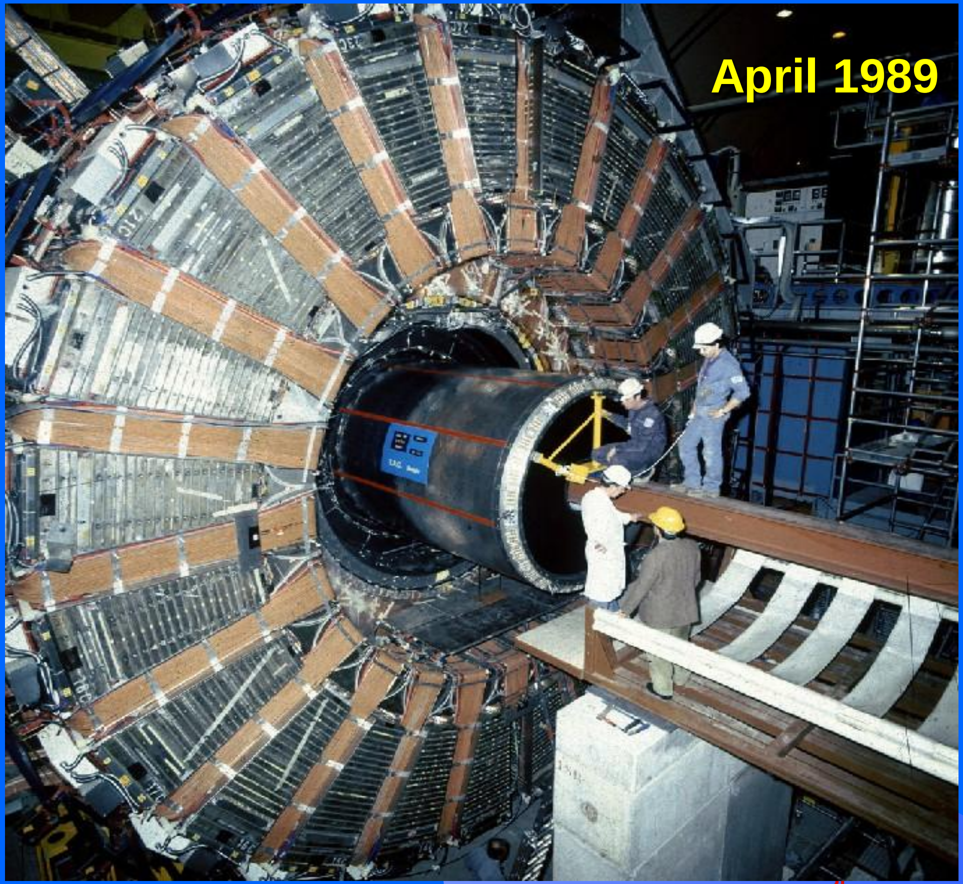
Three months

of passion

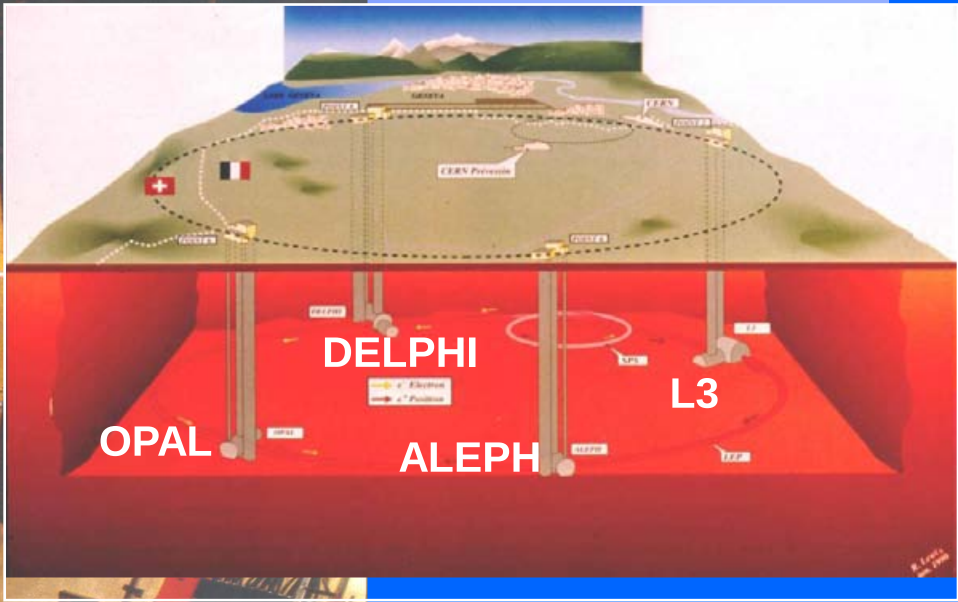
Before and after the insertion of the TPC

Be careful with MY TPC!

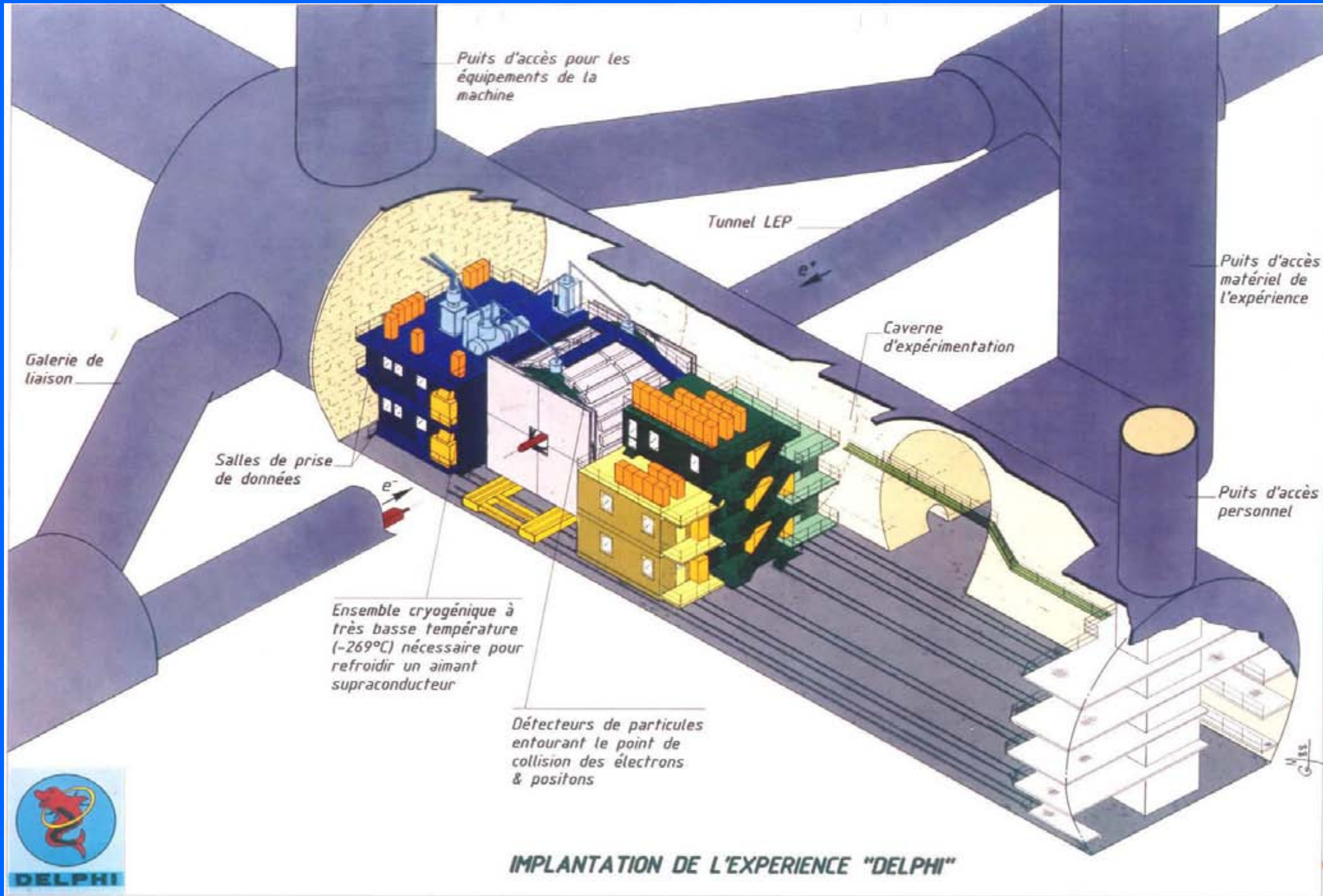


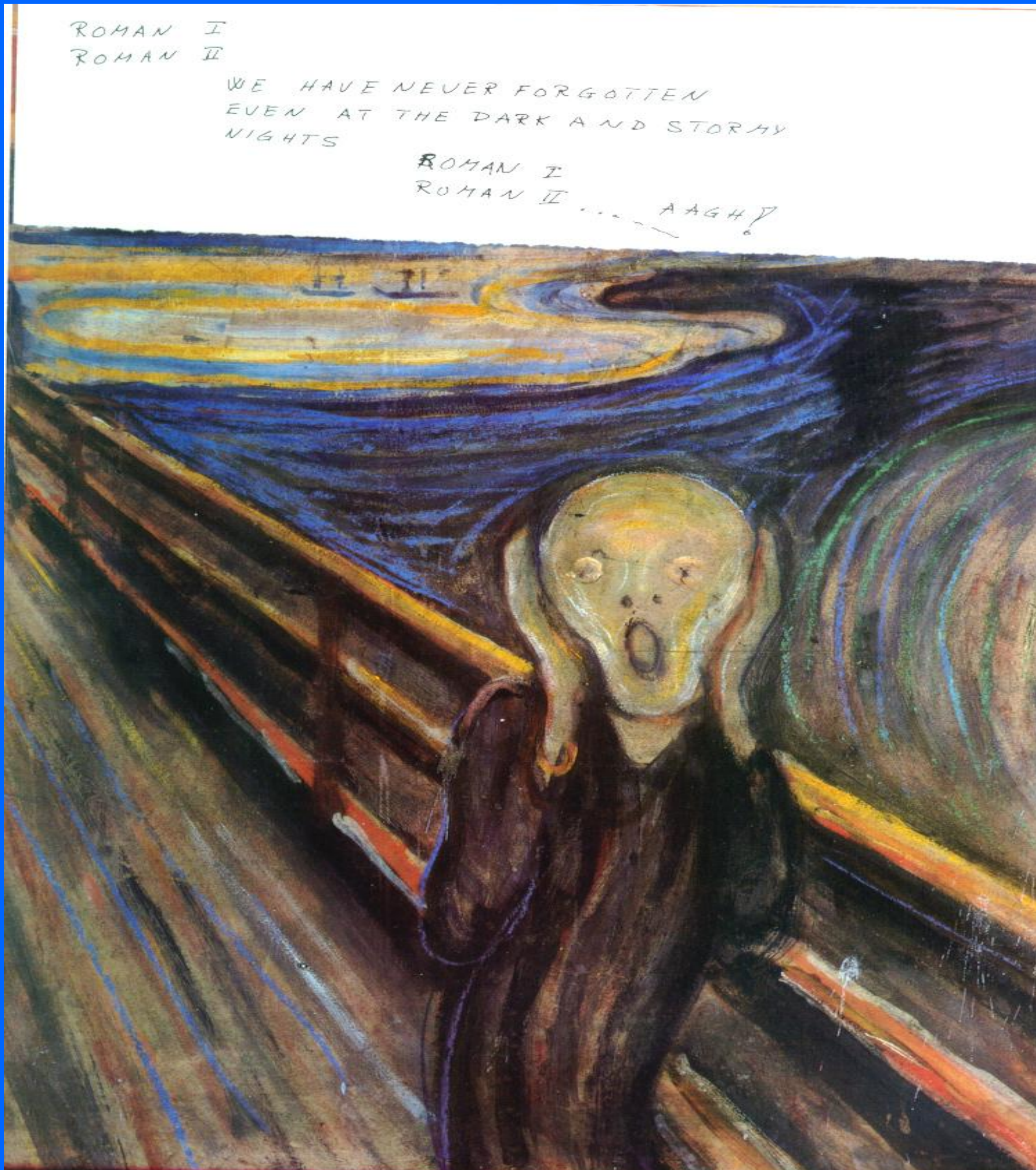


Family photo



DELPHI's is completed: June 1989

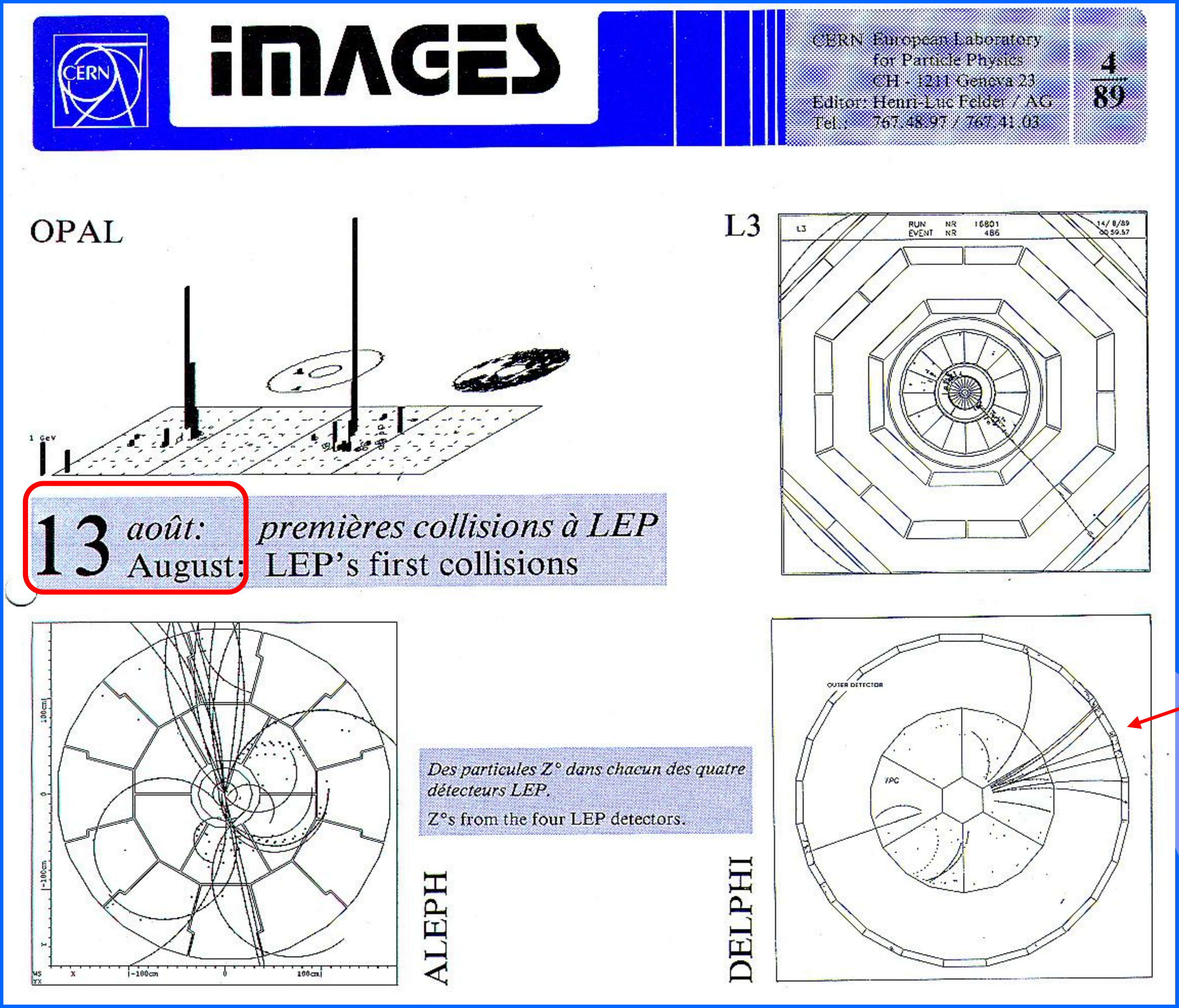




The pilot run as seen by Ariella and Olaf

From the book prepared in 1993 when UA left the spokesmanship

First events



iMAGES

CERN European Laboratory
for Particle Physics
CH - 1211 Geneva 23
Editor: Henri-Luc Felder / AG
Tel.: 767.48.97 / 767.41.03

4
89

OPAL

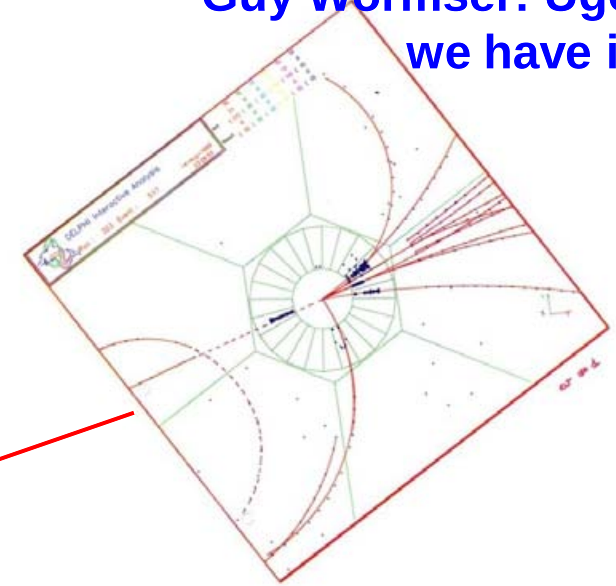
L3

13 août: *premières collisions à LEP*
August: LEP's first collisions

Des particules Z° dans chacun des quatre détecteurs LEP.
Z°s from the four LEP detectors.

ALEPH

DELPHI

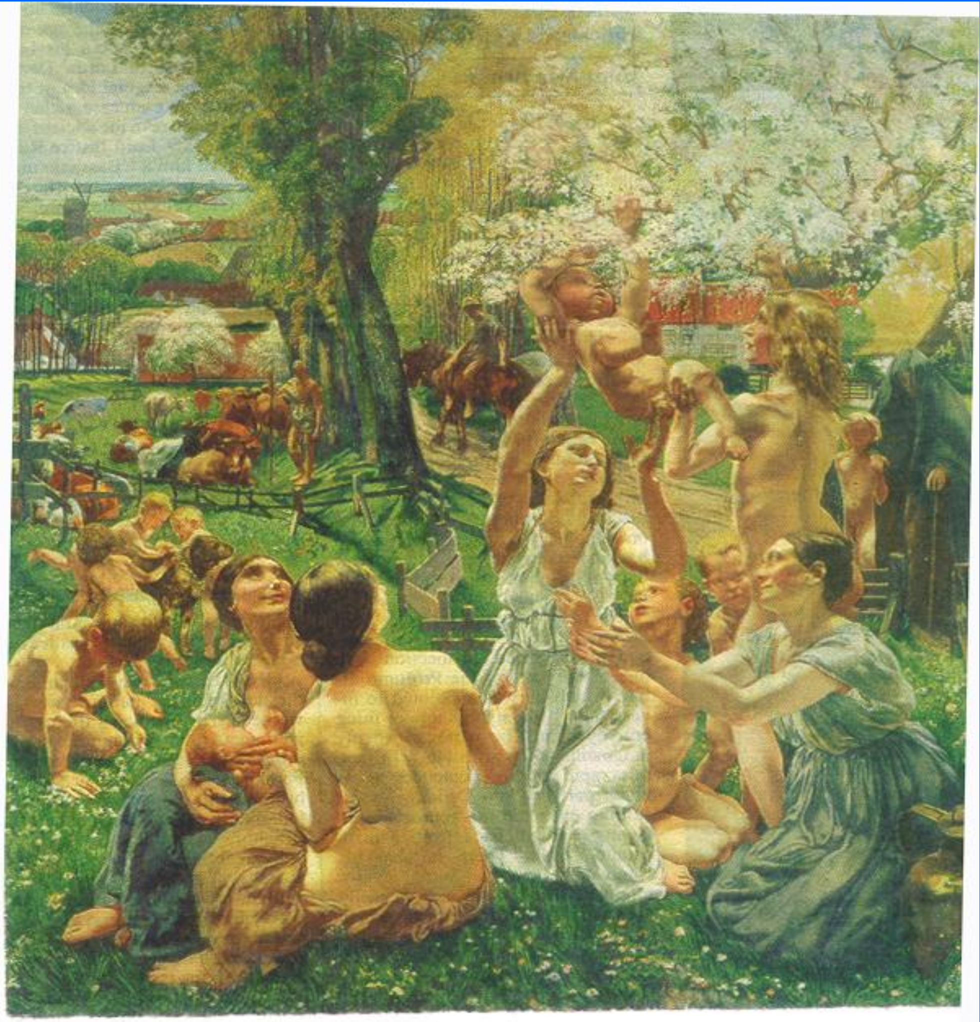


Guy Wormser: Ugo, we have it!

Sunday, October 14

Probability 10^{-3}

Ariella and Olaf views



LIFE AT THE DELPHI PIT AUGUST 1989

[AS SEEN BY THE OFF-LINE]

life in the pit as seen by the off-line people

AND THE SEARCH
COULD START.
EVERYWHERE
FOR
WHATEVER.

Our searches

Borer, K; Strangelet **search** in S-W collisions at 200 A GeV/c. - 1993. (Shelf no: CERN PRE 93-067)

Battaglia, M; A **search** for exclusive FCNC decays of the b quark with the DELPHI detector at LEP. - 1993. (Shelf no: HU SEFT R 93-14)

Abreu, P; **Search** for Z0 decays to two leptons and a charged particle- antiparticle pair. - 1993. (Shelf no: CERN PPE 93-77)

Crosetti, G; **Search** for Higgs bosons at LEP. - 1993. (Shelf no: INFN AE 93-03)

Abreu, P; A **search** for lepton flavour violation in Z0 decays. - 1992. Phys. lett., B : 298 (1992) - 247-256

De Angelis, A; **Search** for intrinsic anisotropies of time dilation. - 1992. (Shelf no: UDINE P 92-01 AA rev)

Goobar, A; **Search** for Higgs bosons in Z.sup(0) decays using the DELPHI detector. - 1991. (Shelf no: EX 10309)

Camporesi, T; **Search** for new particles with the DELPHI detector at LEP : standard Higgs boson and supersymmetric particles. - 1990. Proceedings. - Ed. Frontieres, Gif-sur-Yvette, 1990. - 191-203

Keranen, R; Energy measurement in collider experiments and the **search** for scalar quarks in Z0 decays at LEP I. - 1991. (Shelf no: EX HU SEFT 91-09)

Abreu, P; **Search** for scalar leptoquarks from Z0 decays. - 1992. Phys. lett., B : 275 (1992) - 222-230

Abreu, P; A **search** for neutral Higgs particles in Z0 decays. - 1991. (Shelf no: CERN PPE 91-132)

Abreu, P; **Search** for excited charged leptons in Z0 decays. - 1991. (Shelf no: CERN PPE 91-100)

Abreu, P; **Search** for low mass Higgs bosons produced in Z.sup(0) decays. - 1991. Z. Phys. C : 51 (1991) - 25-35

Renton, P B; **Search** for neutral Higgs bosons using the DELPHI detector. - 1991. Proceedings / Ed. by K K Phua and Y Yamaguchi. - World Sci., Singapore, 1991. - 1290-1293 (Shelf no: OUNP 90-18)

Abreu, P; **Search** for non-standard Z0 decays in two-particle final states. - 1990. (Shelf no: CERN PPE 90-167)

Eerola, P; A **search** for new heavy particles in Z0 decays at LEP. - 1990. (Shelf no: EX HU SEFT 90-01)

Abreu, P; **Search** for Higgs bosons using the Delphi detector. - 1990. (Shelf no: CERN PPE 90-163)

Wormser, G; **Search** for new particles with DELPHI. - 1990. Z0 physics : Proceedings / Ed. by J Tran Thanh Van. - Ed. Frontieres, Gif-sur-Yvette, 1990 - (M65). - 147-163 (Shelf no: LAL 90-28)

Abreu, P; A **search** for sleptons and gauginos in Z0 decays. - 1990. Phys. lett., B : 247 (1990) - 157-166

Abreu, P; **Search** for scalar quarks in Z0 decays. - 1990. Phys. lett., B : 247 (1990) - 148-156

Abreu, P; **Search** for pair production of neutral Higgs bosons in Z0 decays. - 1990. Phys. lett., B : 245 (1990) - 276-288

Abreu, P; **Search** for light neutral Higgs particles produced in Z0 decays. - 1990. Nucl. phys., B : 342 (1990) - 1-14

Abreu, P; **Search** for the t and b' quarks in hadronic decays of the Z0 boson. - 1990. Phys. lett., B : 242 (1990) - 536-546

Abreu, P; **Search** for heavy charged scalars in Z0 decays. - 1990. Phys. lett., B : 241 (1990) - 449-458

Grivaz, J; Supersymmetric particles **search** at LEP200. - 1987. Proceedings / Ed. by A Bohm and W Hoogland. - CERN, Geneva, 1987 - (ECFA 87-108). - 380-413 (Shelf no: CERN EP 87-24)

Boucrot, J; **Search** for neutral Higgs at LEP 200. - 1987. Proceedings / Ed. by A Bohm and W Hoogland. - CERN, Geneva, 1987 - (ECFA 87-108). - 312-379 (Shelf no: CERN EP 87-40)

Baillon, P; Cherenkov ring **search** using a maximum likelihood technique. - 1985. Publ. in Nucl. instrum. methods phys. res., A : 238 (1985) - 341-346

Borer, K; Strangelet **search** in S-W collisions at 200 A GeV/c. - 1993. (Shelf no: CERN PPE 93-067)

Buskulic, D; **Search** for a non-minimal Higgs boson produced in the reaction e+e- -¿ hZ. - 1993. Phys. lett., B : 313 (1993) - 312-325

Buskulic, D; **Search** for the standard model Higgs boson. - 1993. Phys. lett., B : 313 (1993) - 299-311

Crosetti, G; **Search** for Higgs bosons at LEP. - 1993. (Shelf no: INFN AE 93-03)

Buskulic, D; **Search** for high mass photon pairs in e+e- -¿ ff.bar.. gamma..gamma. (f = e, .mu., .tau., .nu., q) at LEP. - 1993. (Shelf no: CERN PPE 93-75)

Buskulic, D; **Search** for contact interactions in the reactions e+e- - ¿ l.sup(+)l.sup(-) and e+e- -¿ .gamma..gamma.. - 1993. (Shelf no: CERN PPE 93-52)

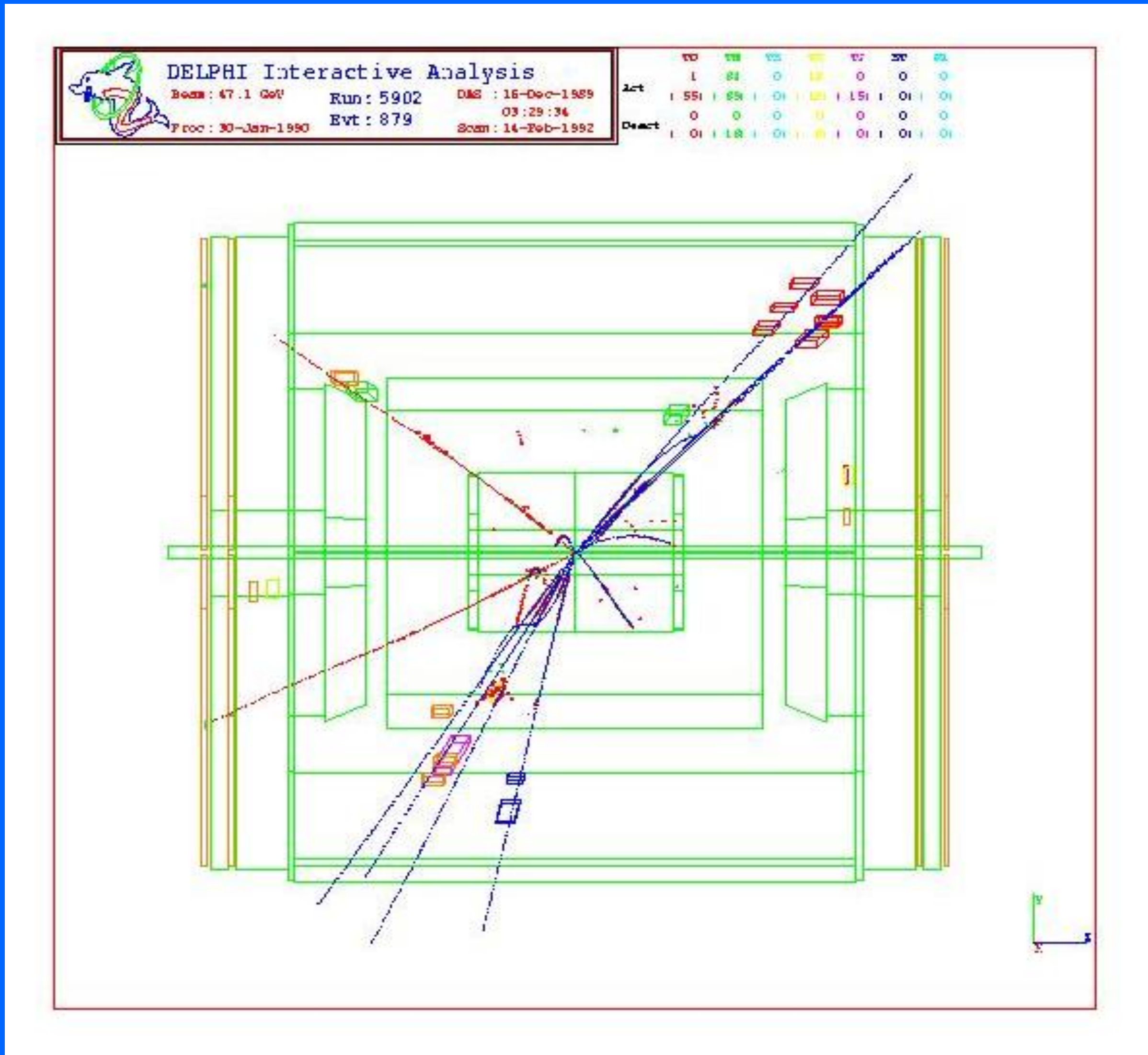
Buskulic, D; **Search** for particles with unexpected mass and charge in Z decays. - 1992. (Shelf no: CERN PPE 92-210)

Buskulic, D; **Search** for CP violation in Z -¿ .tau..tau.. - 1992. (Shelf no: CERN PPE 92-161)

Buskulic, D; **Search** for a very light CP-odd neutral Higgs boson of the MSSM. - 1992. Phys. lett., B : 285 (1992) - 309-318

Cattaneo, M; **Search** for new particles with ALEPH. - 1990. Proceedings. - Ed. Frontieres, Gif-sur-Yvette, 1990. - 165-182

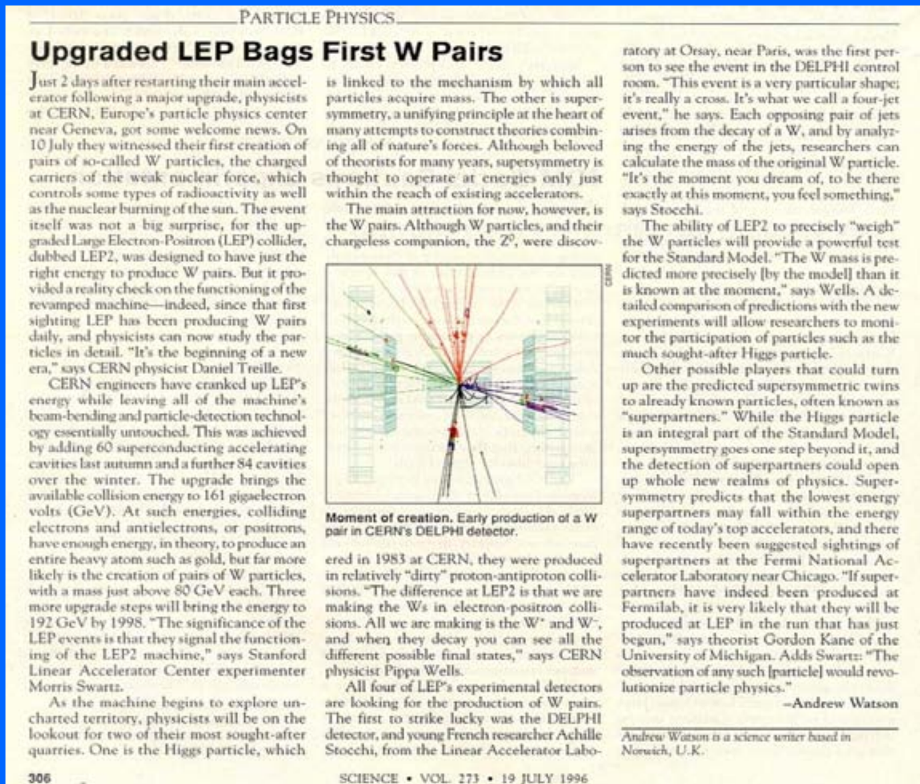
Sunday, December 15 -1989: two jets and two muons



a higsson!

the great delusion

July 1996 – Science publishes the first WW event



PARTICLE PHYSICS

Upgraded LEP Bags First W Pairs

Just 2 days after restarting their main accelerator following a major upgrade, physicists at CERN, Europe's particle physics center near Geneva, got some welcome news. On 10 July they witnessed their first creation of pairs of so-called W particles, the charged carriers of the weak nuclear force, which controls some types of radioactivity as well as the nuclear burning of the sun. The event itself was not a big surprise, for the upgraded Large Electron-Positron (LEP) collider, dubbed LEP2, was designed to have just the right energy to produce W pairs. But it provided a reality check on the functioning of the revamped machine—indeed, since that first sighting LEP has been producing W pairs daily, and physicists can now study the particles in detail. "It's the beginning of a new era," says CERN physicist Daniel Treille.

CERN engineers have cranked up LEP's energy while leaving all of the machine's beam-bending and particle-detection technology essentially untouched. This was achieved by adding 60 superconducting accelerating cavities last autumn and a further 84 cavities over the winter. The upgrade brings the available collision energy to 161 gigaelectron volts (GeV). At such energies, colliding electrons and antielectrons, or positrons, have enough energy, in theory, to produce an entire heavy atom such as gold, but far more likely is the creation of pairs of W particles, with a mass just above 80 GeV each. Three more upgrade steps will bring the energy to 192 GeV by 1998. "The significance of the LEP events is that they signal the functioning of the LEP2 machine," says Stanford Linear Accelerator Center experimenter Morris Swartz.

As the machine begins to explore uncharted territory, physicists will be on the lookout for two of their most sought-after quarries. One is the Higgs particle, which is linked to the mechanism by which all particles acquire mass. The other is supersymmetry, a unifying principle at the heart of many attempts to construct theories combining all of nature's forces. Although beloved of theorists for many years, supersymmetry is thought to operate at energies only just within the reach of existing accelerators.

The main attraction for now, however, is the W pairs. Although W particles, and their chargeless companion, the Z^0, were discovered in 1983 at CERN, they were produced in relatively "dirty" proton-antiproton collisions. "The difference at LEP2 is that we are making the Ws in electron-positron collisions. All we are making is the W^+ and W^-, and when they decay you can see all the different possible final states," says CERN physicist Pippa Wells.

Moment of creation. Early production of a W pair in CERN's DELPHI detector.

All four of LEP's experimental detectors are looking for the production of W pairs. The first to strike lucky was the DELPHI detector, and young French researcher Achille Stocchi, from the Linear Accelerator Laboratory at Orsay, near Paris, was the first person to see the event in the DELPHI control room. "This event is a very particular shape; it's really a cross. It's what we call a four-jet event," he says. Each opposing pair of jets arises from the decay of a W, and by analyzing the energy of the jets, researchers can calculate the mass of the original W particle. "It's the moment you dream of, to be there exactly at this moment, you feel something," says Stocchi.

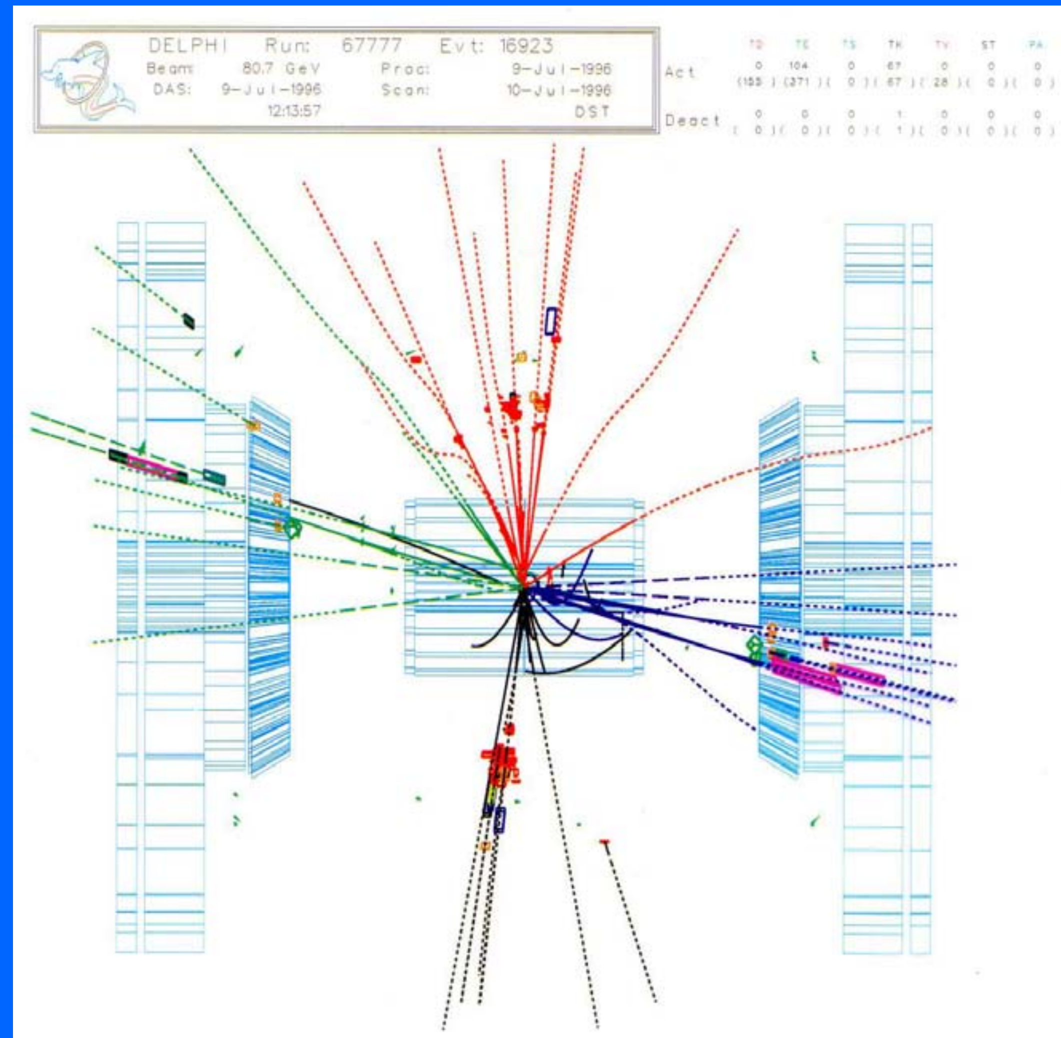
The ability of LEP2 to precisely "weigh" the W particles will provide a powerful test for the Standard Model. "The W mass is predicted more precisely [by the model] than it is known at the moment," says Wells. A detailed comparison of predictions with the new experiments will allow researchers to monitor the participation of particles such as the much sought-after Higgs particle.

Other possible players that could turn up are the predicted supersymmetric twins to already known particles, often known as "superpartners." While the Higgs particle is an integral part of the Standard Model, supersymmetry goes one step beyond it, and the detection of superpartners could open up whole new realms of physics. Supersymmetry predicts that the lowest energy superpartners may fall within the energy range of today's top accelerators, and there have recently been suggested sightings of superpartners at the Fermi National Accelerator Laboratory near Chicago. "If superpartners have indeed been produced at Fermilab, it is very likely that they will be produced at LEP in the run that has just begun," says theorist Gordon Kane of the University of Michigan. Adds Swartz: "The observation of any such [particle] would revolutionize particle physics."

–Andrew Watson

Andrew Watson is a science writer based in Norwich, U.K.

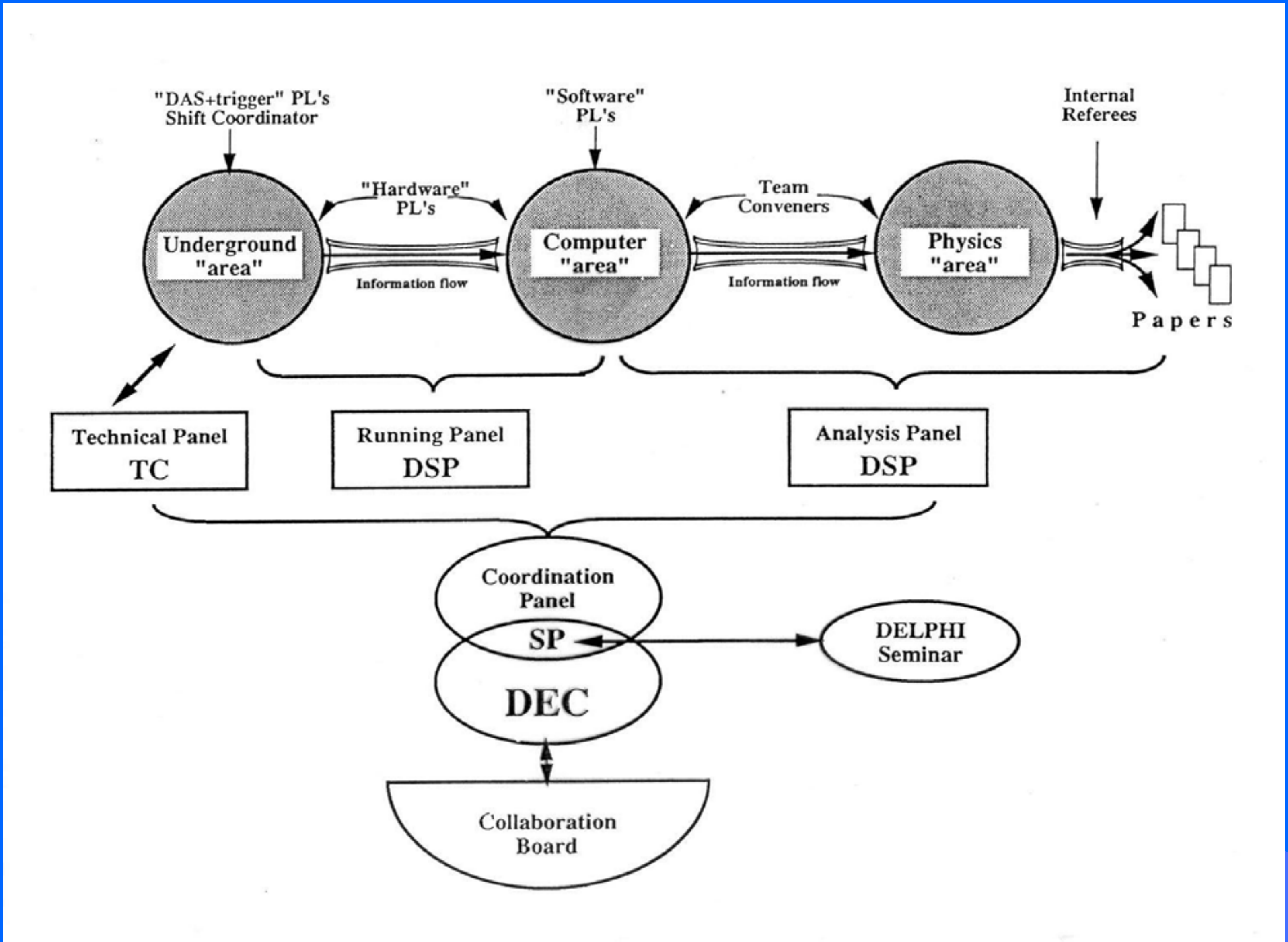
306 SCIENCE • VOL. 273 • 19 JULY 1996



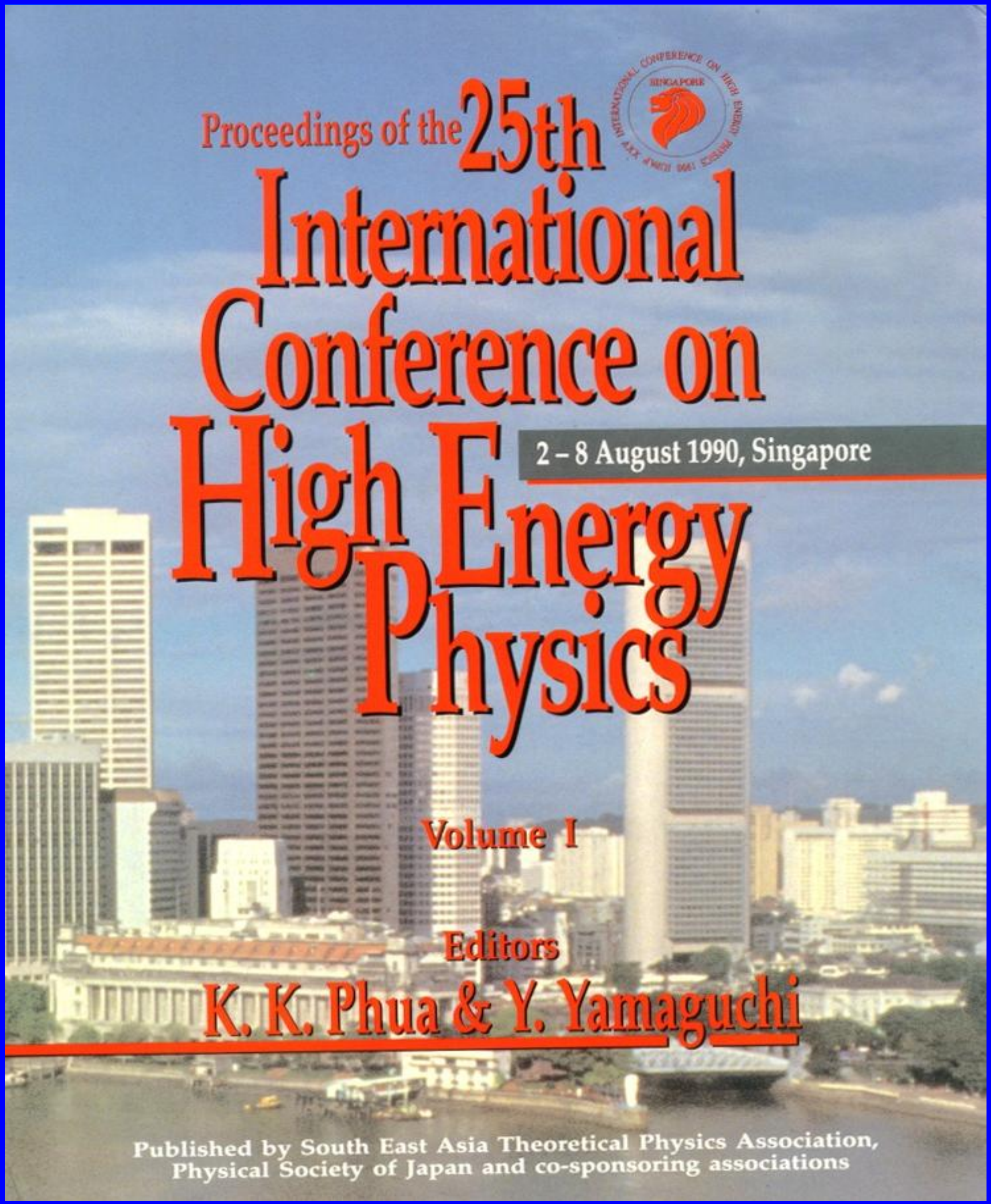
DELPHI was last in Z detection

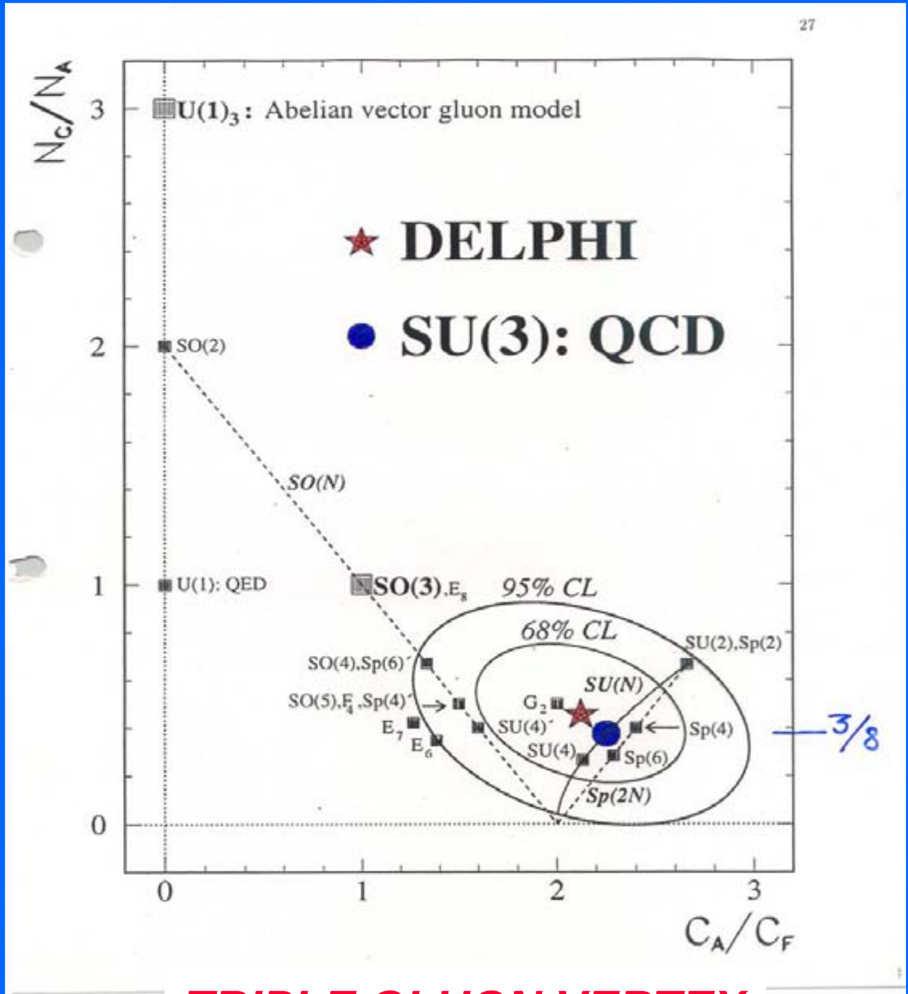
but first in WW production

My 'horizontal' view of DELPHI organization



A beautiful result ready in 1990

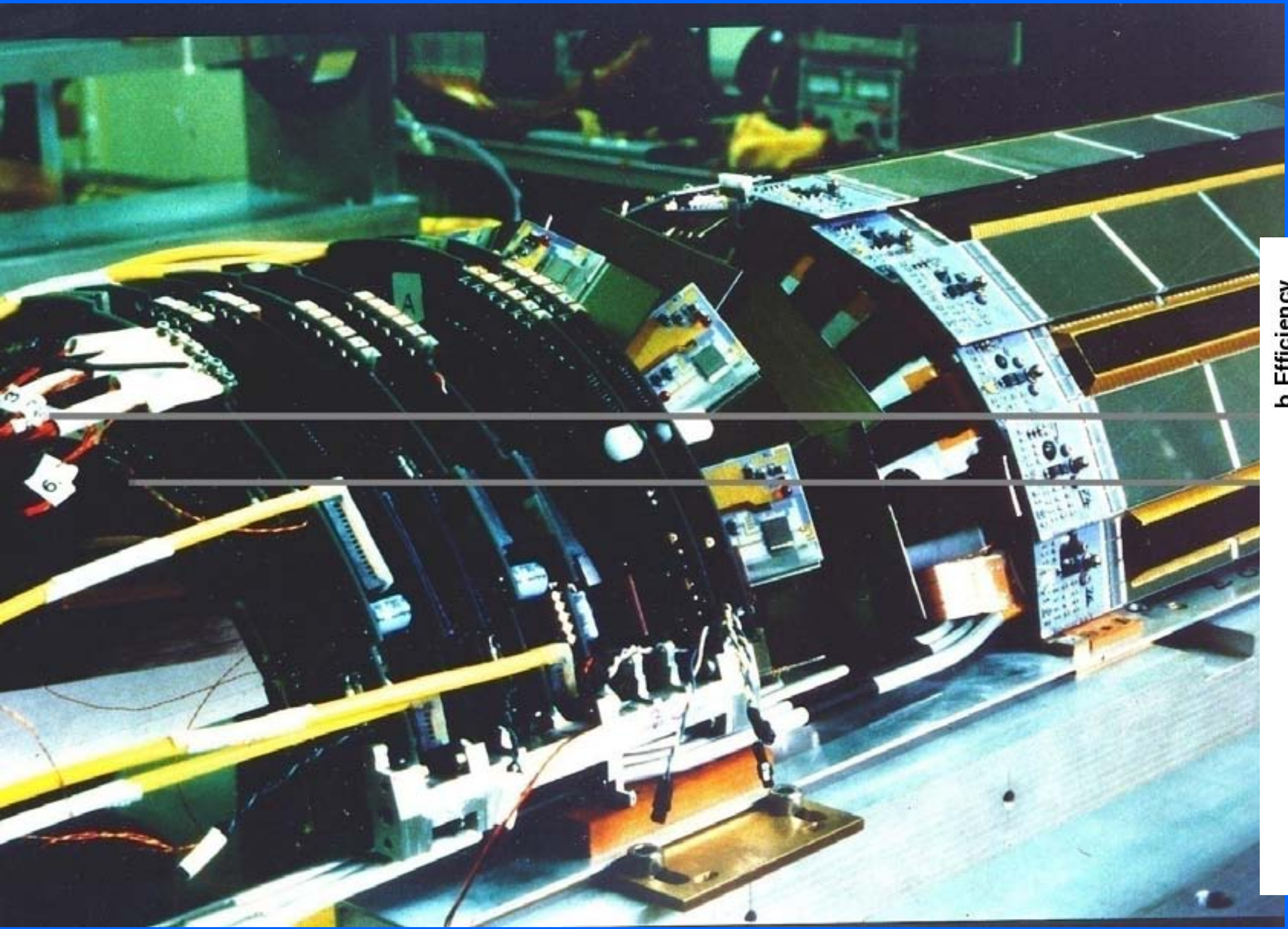


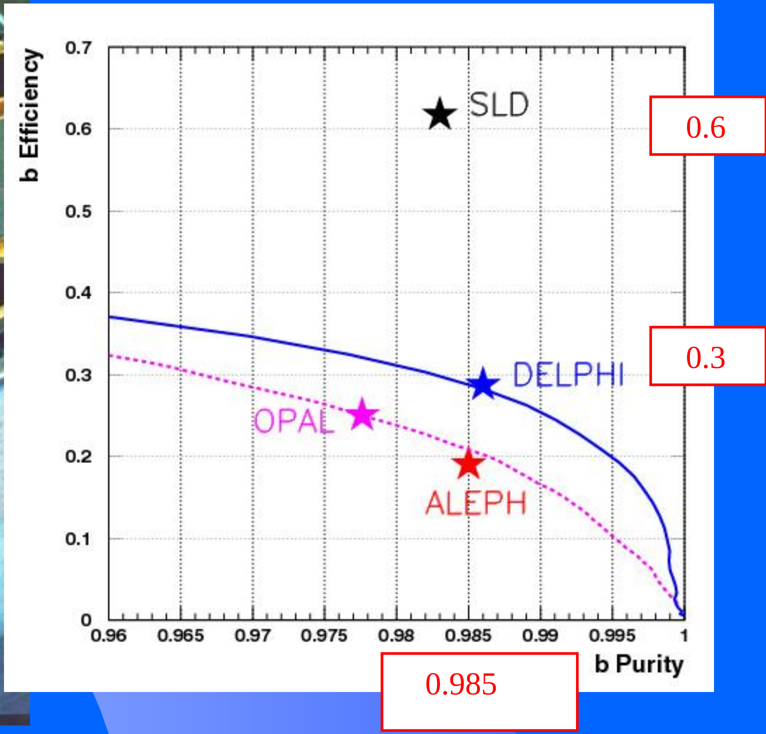


TRIPLE GLUON VERTEX

Karlsruhe et al

From the 1992 Workshop: the new microvertex detector





Daniel's long way to higher energies

D. Treille at Cargèse, August 1990:

Higgs mass limit $m_H \leq \sqrt{s} - 100$ GeV

~90

"SLEP"

LEP 230
instead of "LEP 176"

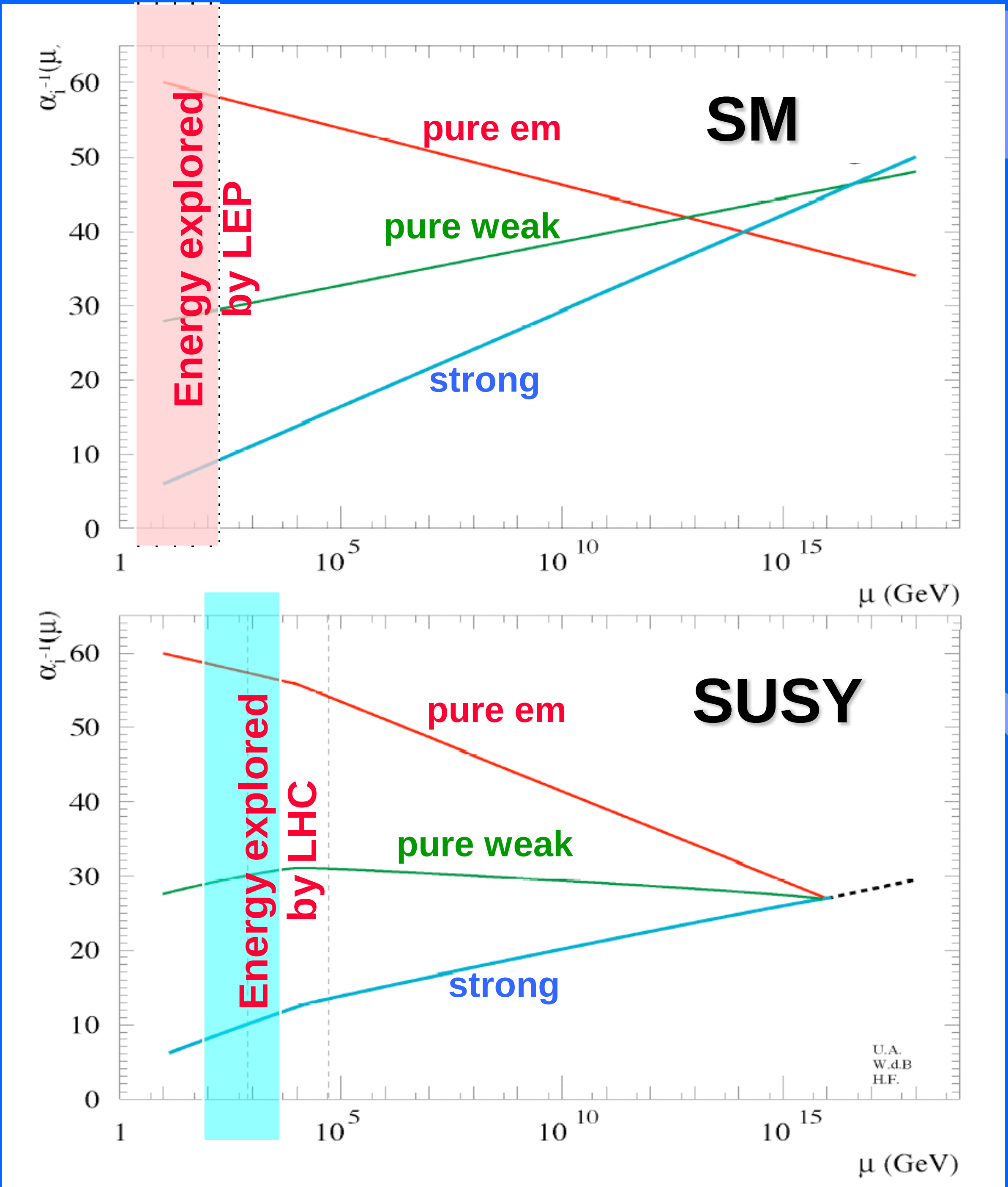
- $V_{RF} \sim E_b^4$
  ↓
  ×2 → $\times \sqrt[4]{2}\ E_b$
  ↳ dumb = twice more cavities
  clever = R/D on cavities, more MV/m

- 192 → 256 cav ⟶ 512 OK for room

MV/m				
6	88	94.5	- - - - - - -	112
7		⋮		117
8		⋮		121
10		⋮		
12	- - - - -	112		

extra Cost ~ 0.5 MSF/cav
~ 1 MSF/klystron
≤ 200 MSF

TERA



SUSY unification of the three couplings

U.A., W. De Boer, H. Furstenau

Comparison of grand unified theories with electroweak and strong coupling constants measured at LEP. Dec. 1990

Published in Phys.Lett.B260:447-455,1991.

On the Top Ten in Physics list

for many weeks

On the Top Ten in HEP list

for many years

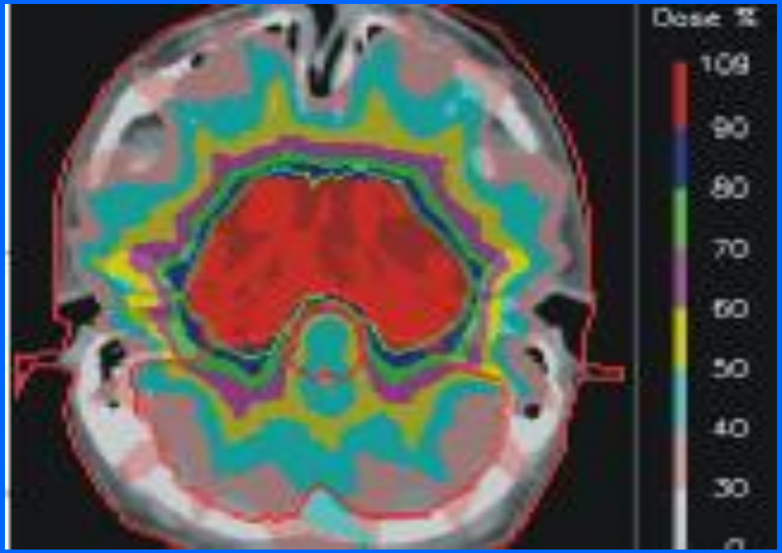
7th quoted paper on CERN 35 000 papers in 50 years 1954-2004

TERA

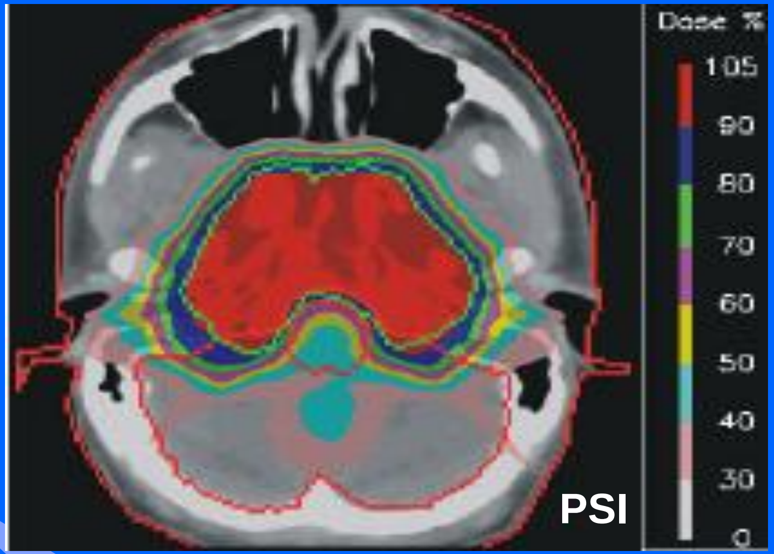
The next 15 years: accelerators against cancer

Protons are quantitatively different from X-rays

9 X-ray fields

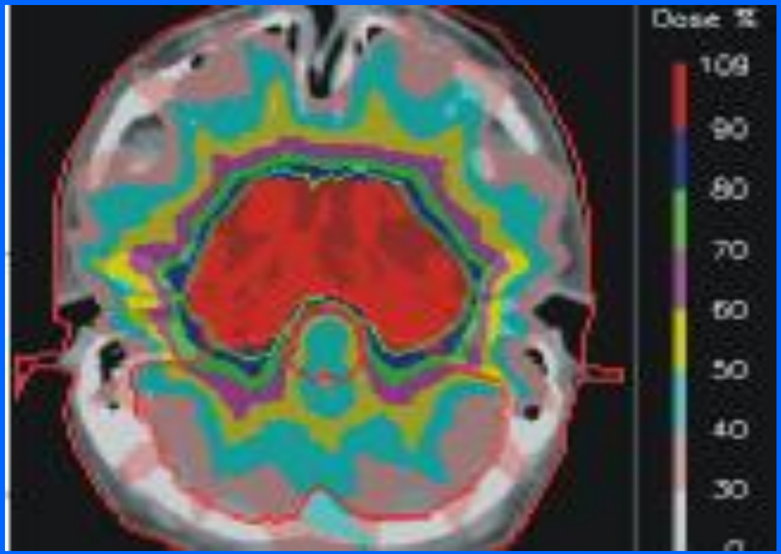


4 proton fields

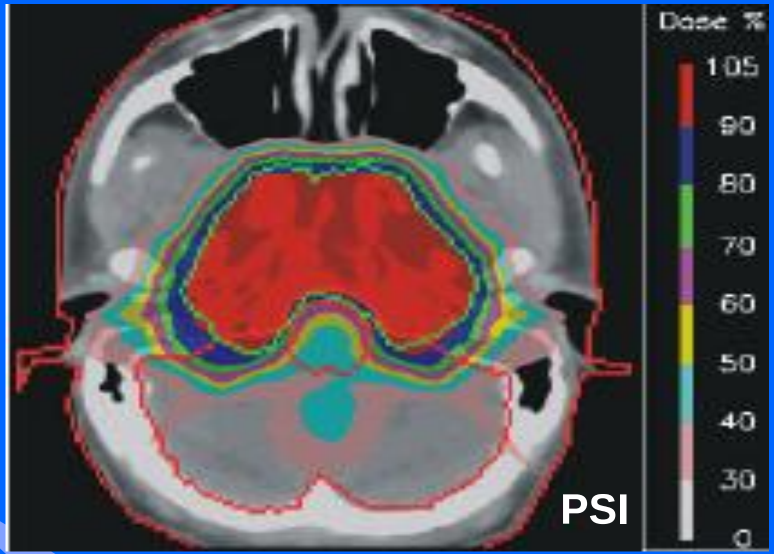


Protons are *quantitatively* different from X-rays

9 X-ray fields



4 proton fields



Carbon ions deposit in a cell 24 times more energy than a proton

producing not reparable multiple close-by double strand breaks

Carbon ions can control radio-resistant tumours

TERA has proposed and designed the 'dual' National Centre for carbon ions and protons

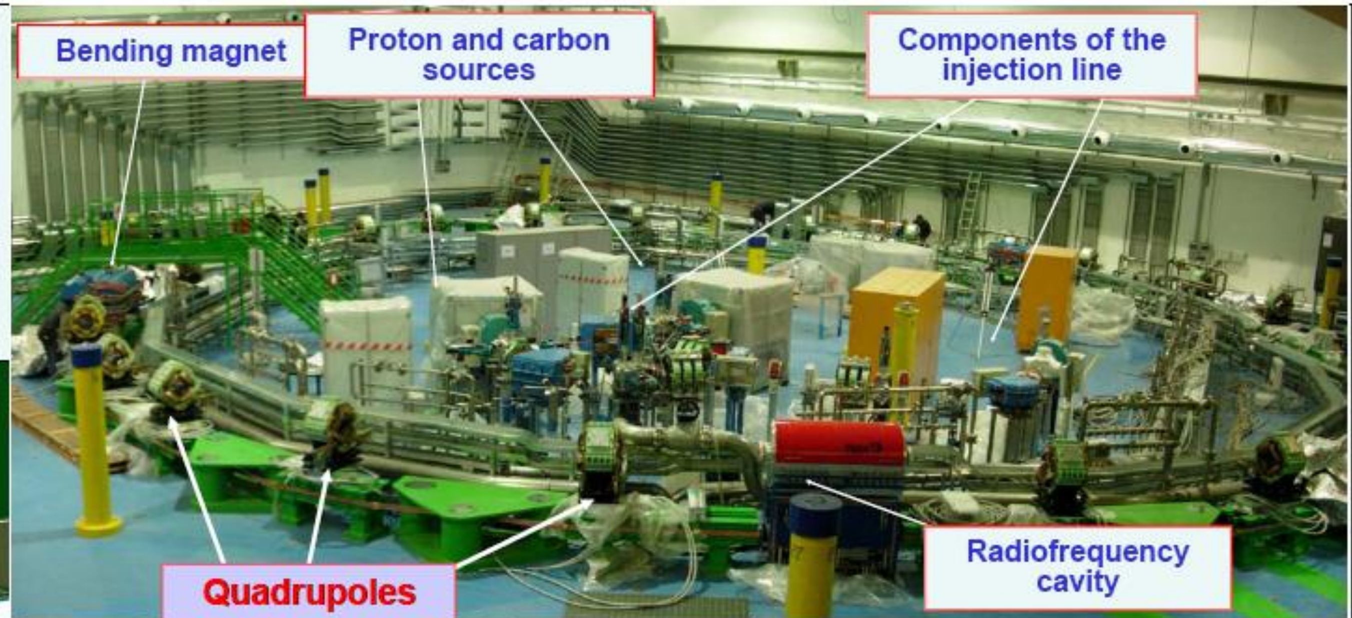
1. CNAO is being built in Pavia

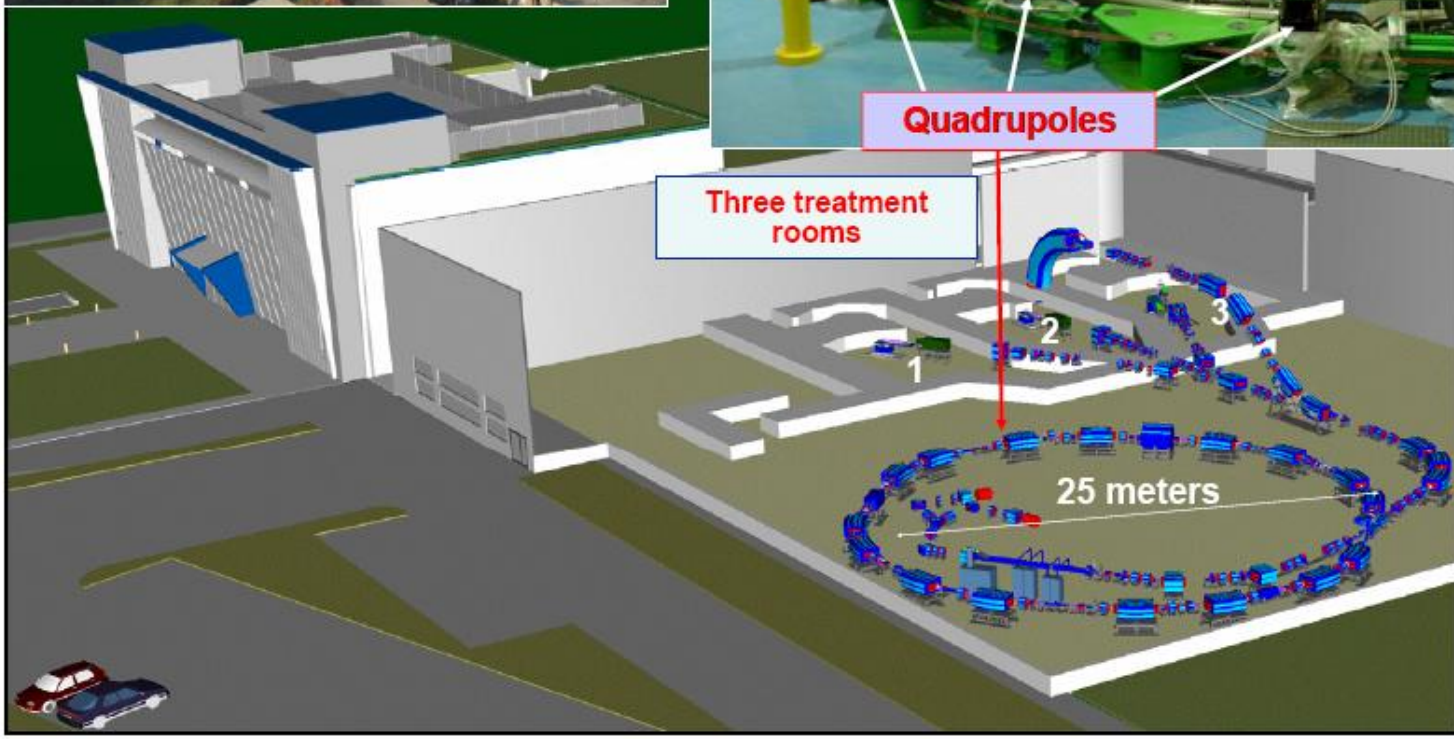
TERA has introduced and developed a novel type of accelerator:

the "cyclinac"

2. "cyclinacs" for protons and carbon ions

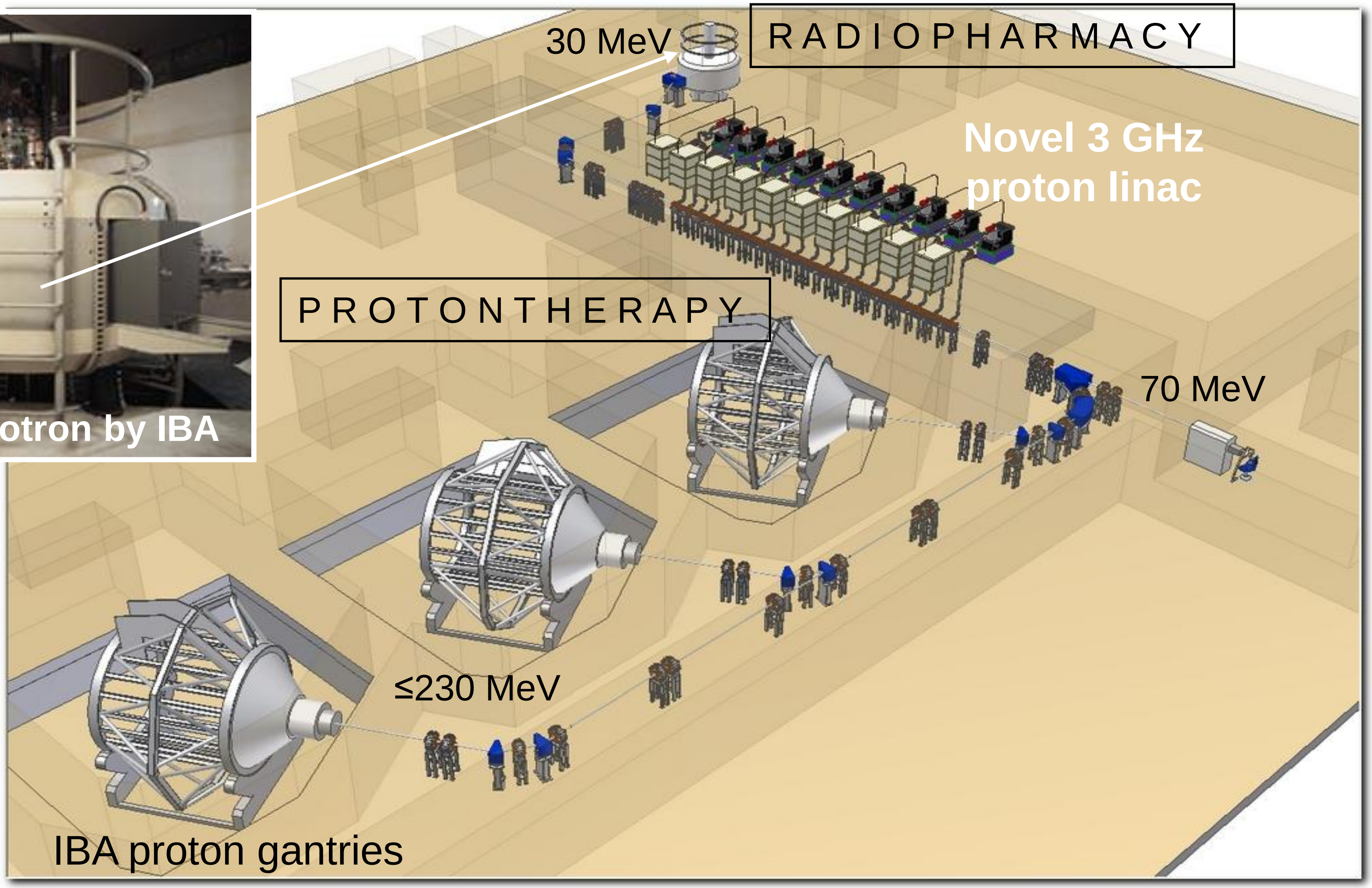
CNAO à Pavia



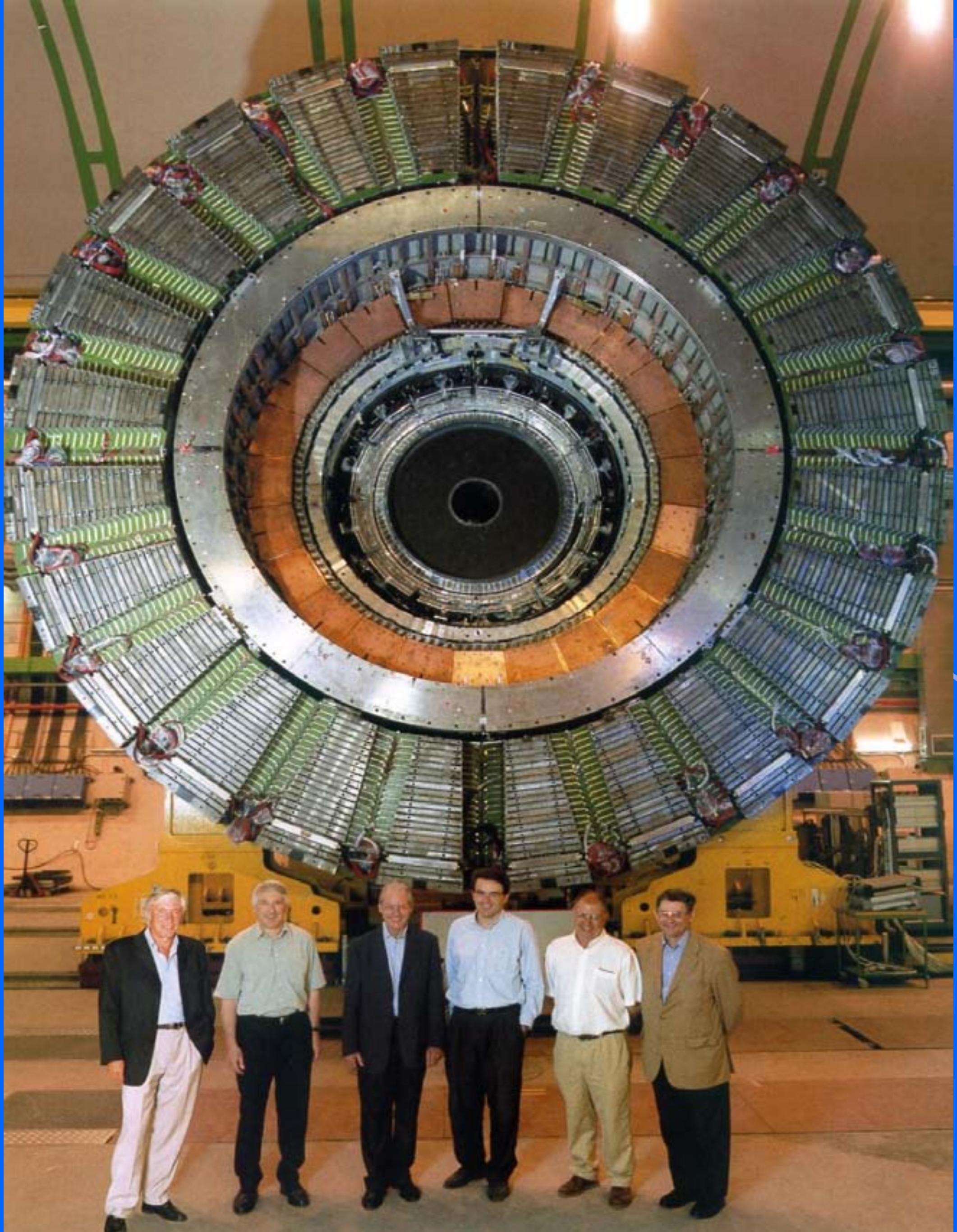


CNAO
Centro Nazionale di
Adroterapia Oncologica
Pavia

IDRA = Institute for Diagnostica and RAdiotherapy



Project passed in Decembre 2007 to A.D.A.M.
Applications of Detectors and Accelerators to Medicine

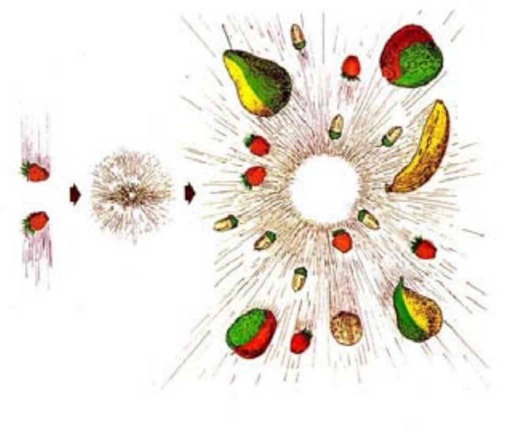


Conclusion: the last "spokesmen conference" in front of the DELPHI barrel

But what have we

REALLY done for 20 years?

No more than:



A short movie