Welcome – Murakaza neza - *to CERN*

CERN - History and achievements from 1954 to 2009: great successes - missed opportunities

The Organisation

>5 decades of accelerators and experiments

Networked, collaborative science and education, enabled by ICT

Origin

Official birthday of CERN 29. September 1954

(CERN: « Conseil Européen pour la Recherche Nucléaire »)

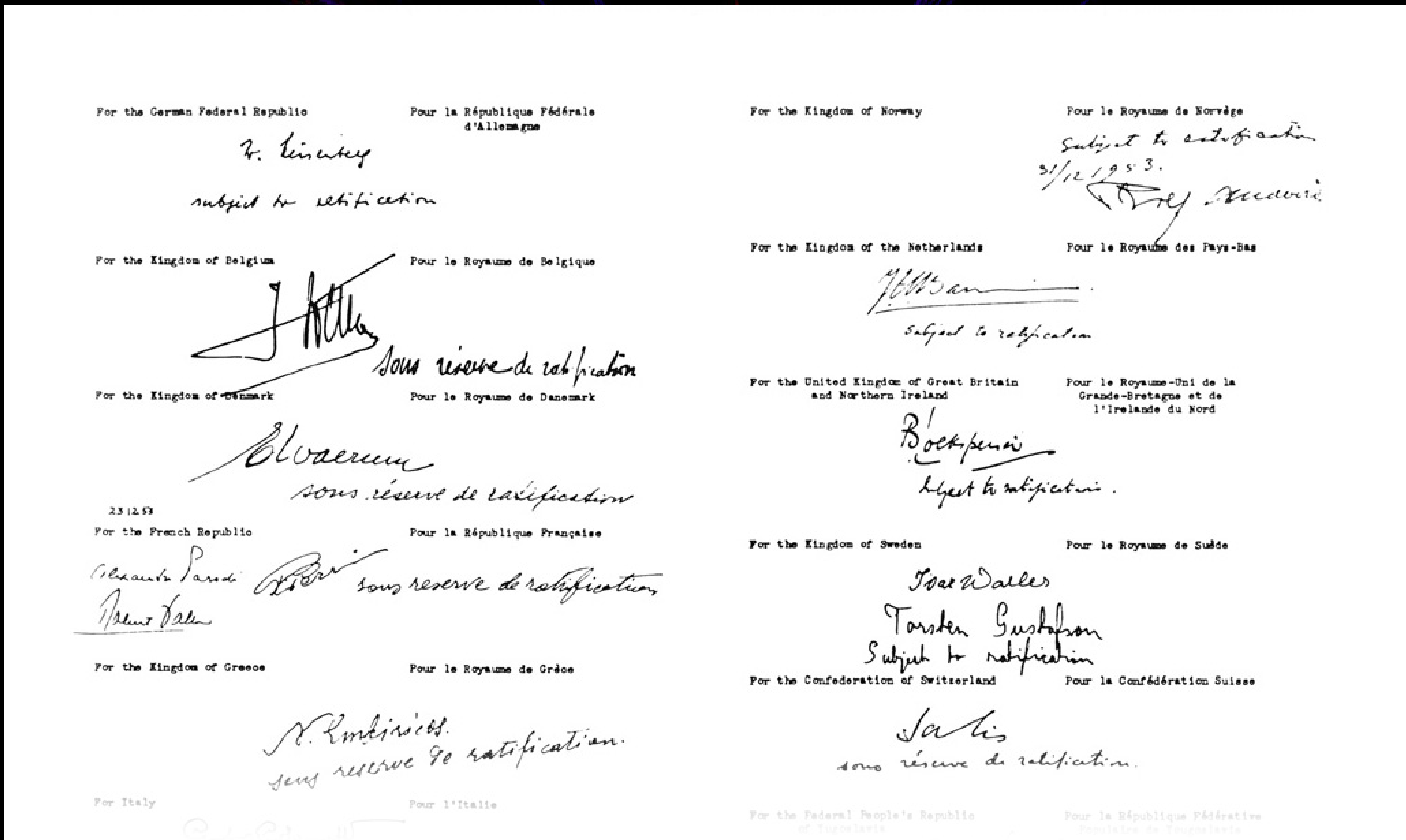
- Treaty ratified by 7 of 12 member states on 29-09-1954
- Treaty signed already 15 Februar 1952 → first employees
- Long discussion "where": Geneva (CH), Copenhague (DK), Arnhem (NL), Longjumeau (Paris) and financial basis stiff fight because of scientific prestige and financial gain

Two initiatives: (background: World War II, Manhattan project, nuclear energy)

- European Physicists (Edoardo Amaldi, Pierre Auger, Werner Heisenberg, Louis de Broglie, later Isidor Rabi, . .)
  - Physics in Europe only competitive with common efforts
- European Politicians (Denis de Rougemont), Institute for European culture (Lausanne 1946):
  - Opportunities for peaceful cohabitation in Europe and the world

Both initiatives combined by UNESCO → Starting one of the most striking successes of European Science Policy-added value

The CERN convention


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

23.12.53

For the French Republic — Pour la République Française

sous reserve de ratification

For the Kingdom of Greece — Pour le Royaume de Grèce

sous reserve de ratification.

For Italy — Pour l'Italie

For the Kingdom of Norway — Pour le Royaume de Norvège

Subject to ratification

31/12 1953.

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'Irelande du Nord

Subject to ratification.

For the Kingdom of Sweden — Pour le Royaume de Suède

Torsten Gustafson

Subject to ratification

For the Confederation of Switzerland — Pour la Confédération Suisse

sous réserve de ratification.

For the Federal People's Republic of Yougoslavia — Pour la République Fédérative Populaire de Yougoslavie

Purposes of the Organisation

The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto.

The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.

CERN is the oldest European Organisation

According to the CERN model were founded:

JINR Dubna 1956 (Warsaw pact states) collaborating since 1967 with CERN

ESO and EMBL (Europe)

SESAME international synchrotron-radiation laboratory in Jordan (Middle East (Jordan, Egypt, Bahrain, Iran, Israel, Palestin, Pakistan, Turkey, Emirates, ...) and as observers (USA, Germany, France, Japan,.....)

Who can participate: anybody from any country competent in CERN's science and pursuing the CERN's objectives in science

UNESCO: science brings nations together-for peace

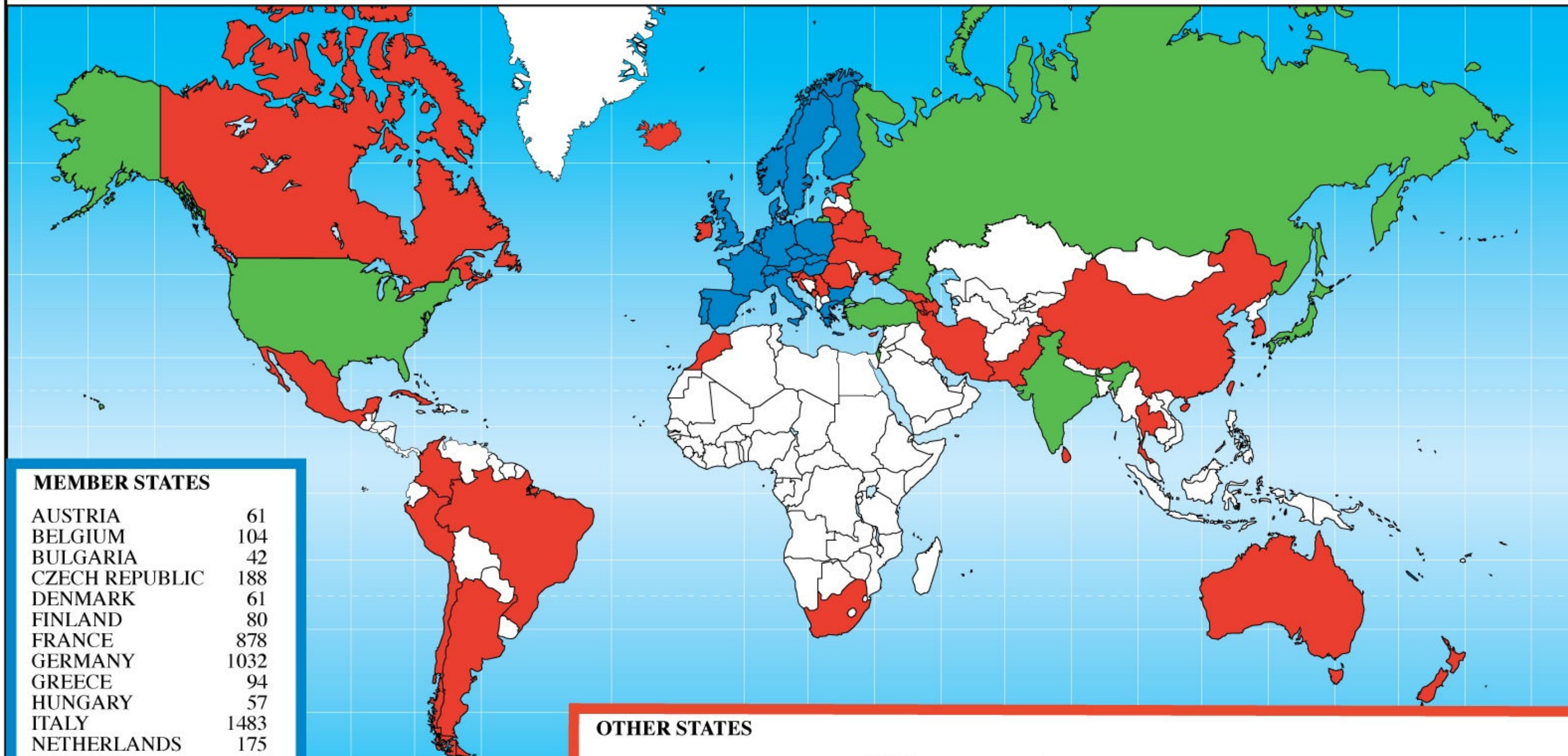
CERN in Numbers 2009

- 2256 staff
- ~700 other paid personnel
- ~9500 users
- Budget (2009) 1100 MCHF

- 20 Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- 1 Candidate for Accession to Membership of CERN: Romania
- 8 Observers to Council: India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and Unesco

CERN in Numbers 2009

Distribution of All CERN Users by Nation of Institute on 6 January 2009



MEMBER STATES

AUSTRIA	61
BELGIUM	104
BULGARIA	42
CZECH REPUBLIC	188
DENMARK	61
FINLAND	80
FRANCE	878
GERMANY	1032
GREECE	94
HUNGARY	57
ITALY	1483
NETHERLANDS	175
NORWAY	78
POLAND	174
PORTUGAL	111
SLOVAKIA	49
SPAIN	286
SWEDEN	73
SWITZERLAND	330
UNITED KINGDOM	715

6071

OBSERVER STATES

INDIA	89
ISRAEL	59
JAPAN	200
RUSSIA	883
TURKEY	52
USA	1485

2768

OTHER STATES

ARGENTINA	10
ARMENIA	15
AUSTRALIA	14
AZERBAIJAN	1
BELARUS	19
BRAZIL	73
CANADA	136
CHILE	4
CHINA	64
COLOMBIA	11
CROATIA	20
CUBA	3
CYPRUS	6
ESTONIA	11
GEORGIA	11
ICELAND	1
IRAN	12
IRELAND	12
KOREA	51
LITHUANIA	5
MEXICO	28
MONTENEGRO	1
MOROCCO	5
NEW ZEALAND	6
PAKISTAN	24
PERU	1
ROMANIA	49
SERBIA	17
SLOVENIA	16
SOUTH AFRICA	8
SRI LANKA	1
TAIWAN	42
THAILAND	1
UKRAINE	18

696

~70% of world particle physics population; change over~ 1500/year

Member States of CERN

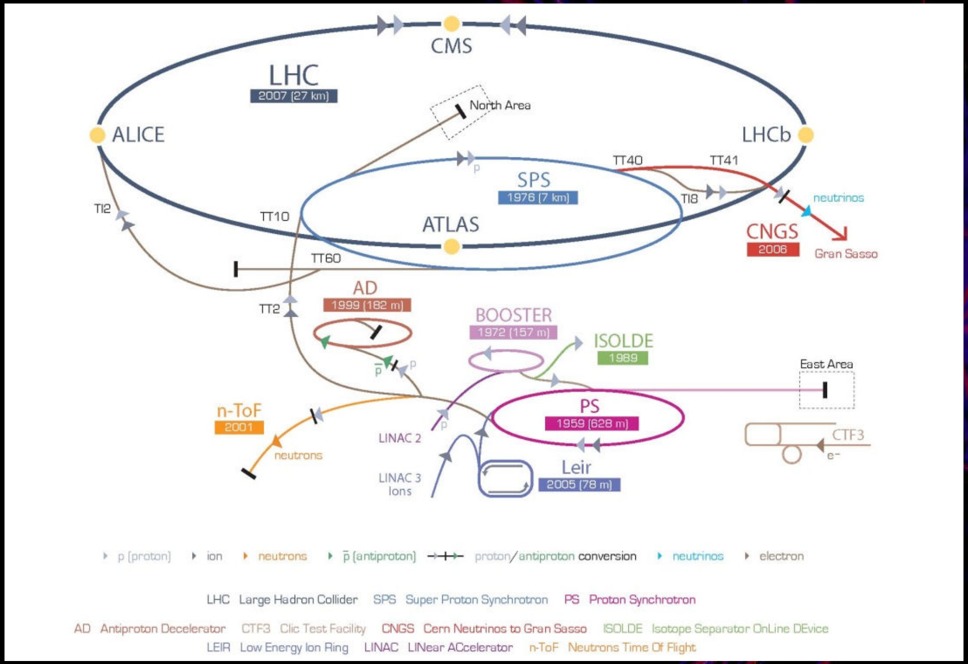
From 12 zu 20 Member States (and counting)

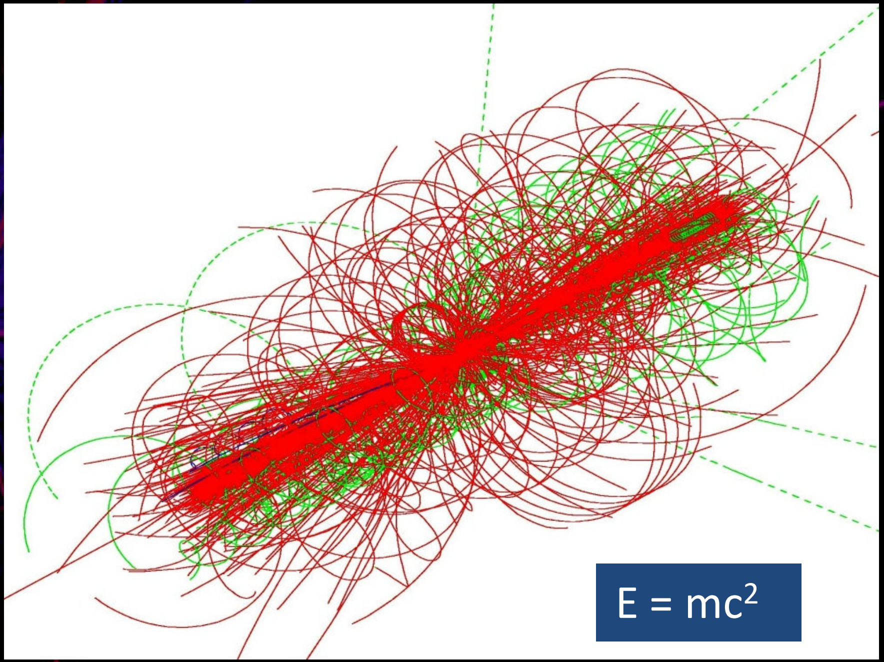
+ Associates USA, Russia, Japan, India, Israel,. . .

CERN across the Swiss-French Border

How is Particle Physics done at CERN

Accelerators heat up matter to ever extremer temperatures and experiments observe the resulting reactions





Motivation:

what are the elementary particles, their properties and the forces acting between them, what are the differences of matter and antimatter, what is the origin of mass, what is dark matter, . . . ?

Accelerators and colliders and corresponding experiments and results

4 periods in CERN's history:

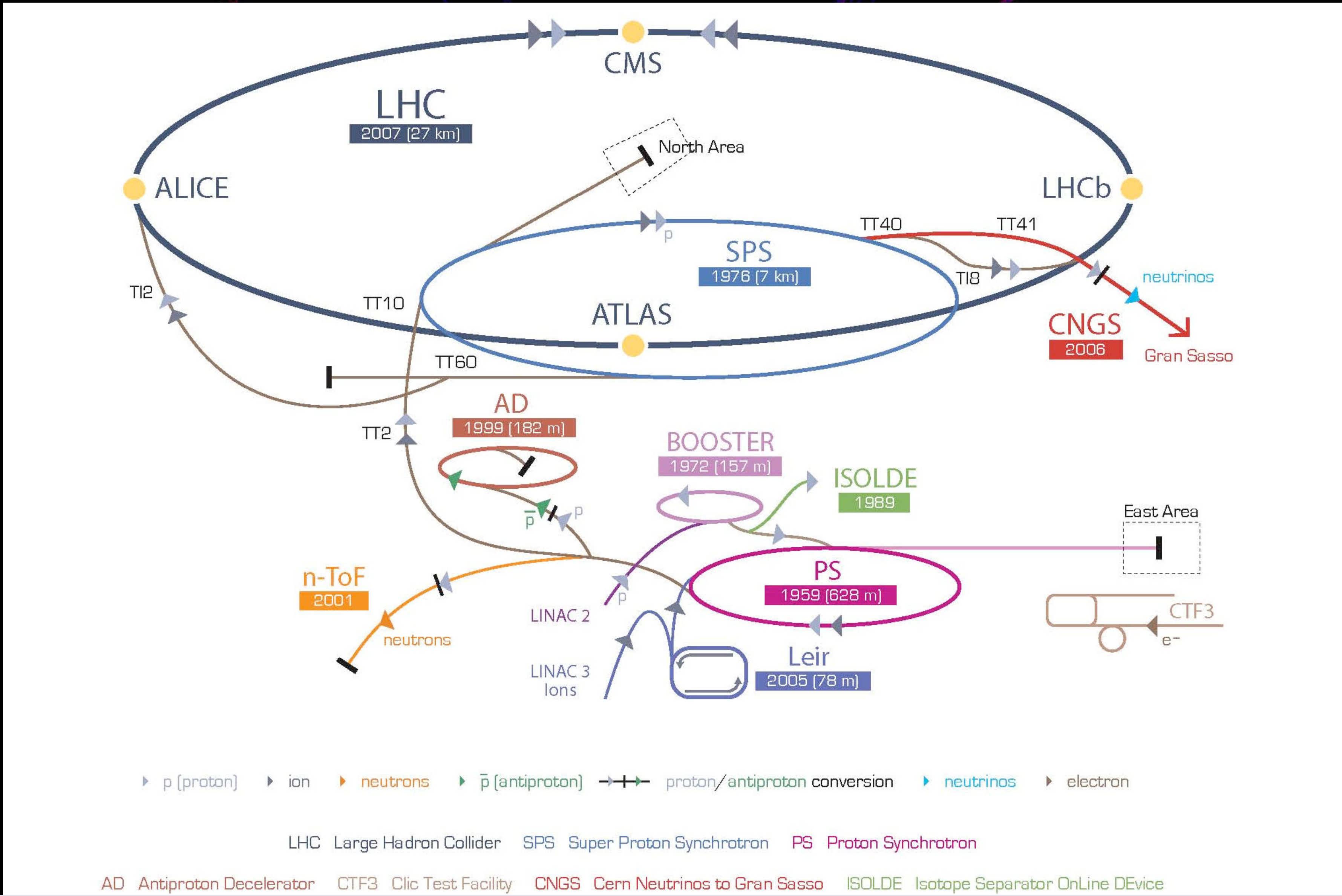
1 copying accelerators from the US with some improvements: SC, CPS (until ~1970);

2 new devices and competition with fixed target accelerators ISR, SPS (1970 - 1982)

3 matter-antimatter colliders Sp-pbarS, LEP

4 LHC (we are almost there, hopefully)

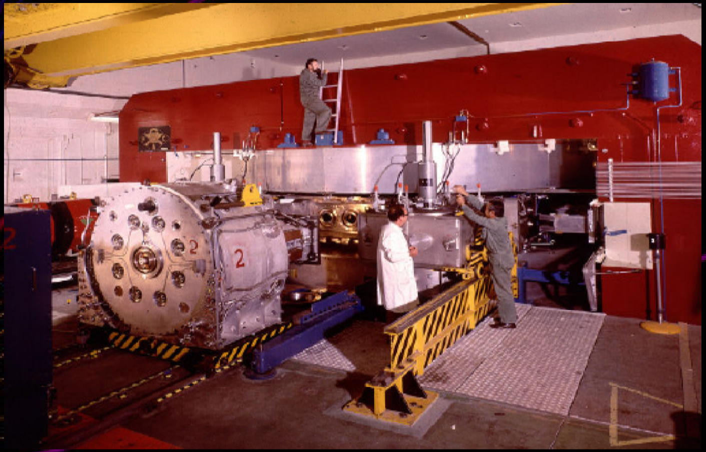
The CERN Accelerator Complex
(not to scale)



1st period "copying": SC and PS
no doubt, many of the discoveries were made elsewhere

SC synchrocyclotron:

- Protons 0.6 GeV; fairly high intensity beam
- Started 1955 to produce physics results soon; shut down after 34 very productive years in nuclear-, atomic- and particle physics-ISOLDE

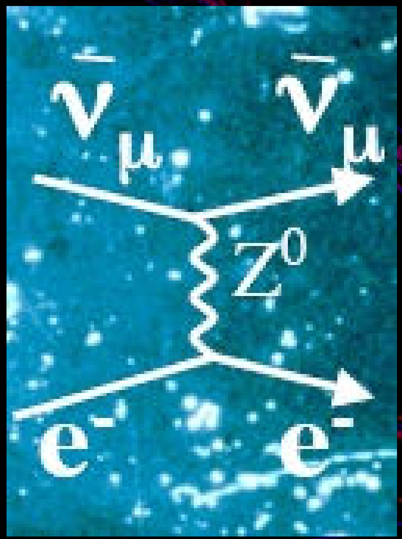


PS proton synchrotron (the "big machine" and reason to create CERN):

- Protons 28 GeV, alternating gradient - AG, 628 m circumference, a most versatile accelerator (p, pbar, e+,e-, ions), highest energy in Europe
- 1st beam 1959, work horse of CERN for many years; AGS at BNL operates in 1961
- Still operating as pre-accelerator today

"For awful gamble stands AG but if it works or not we'll see" R Peierls

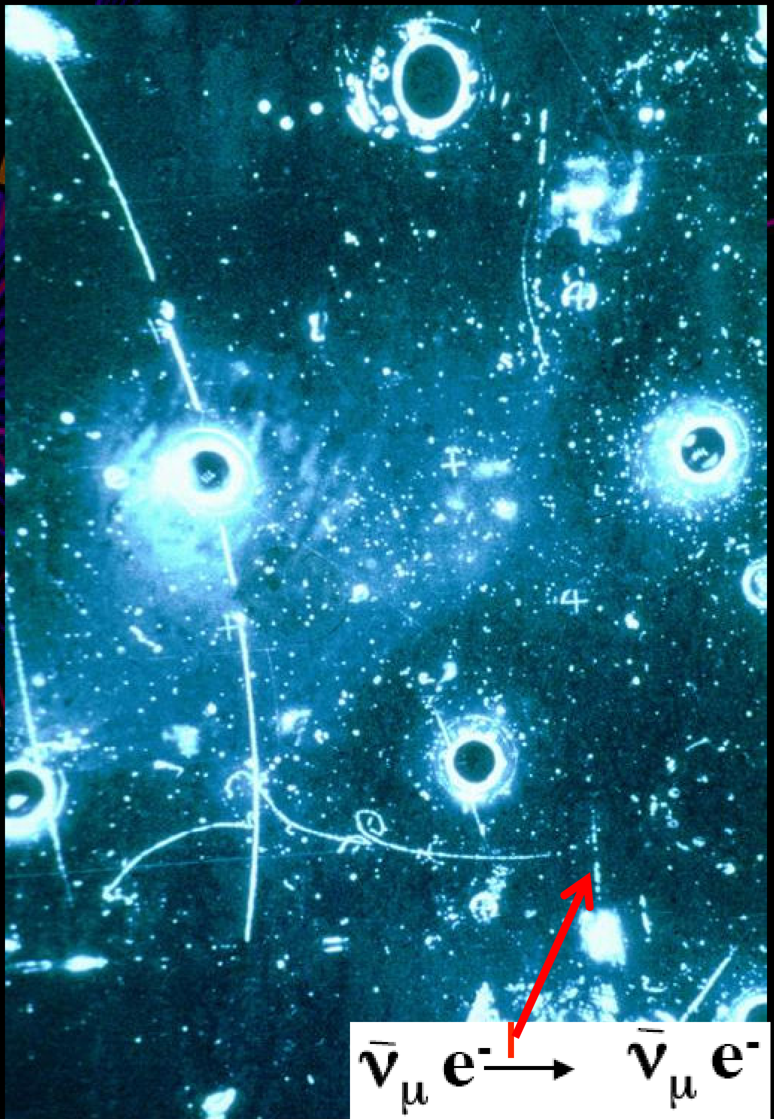
Neutral currents: Gargamelle 1973
weak interaction, no charge exchanged



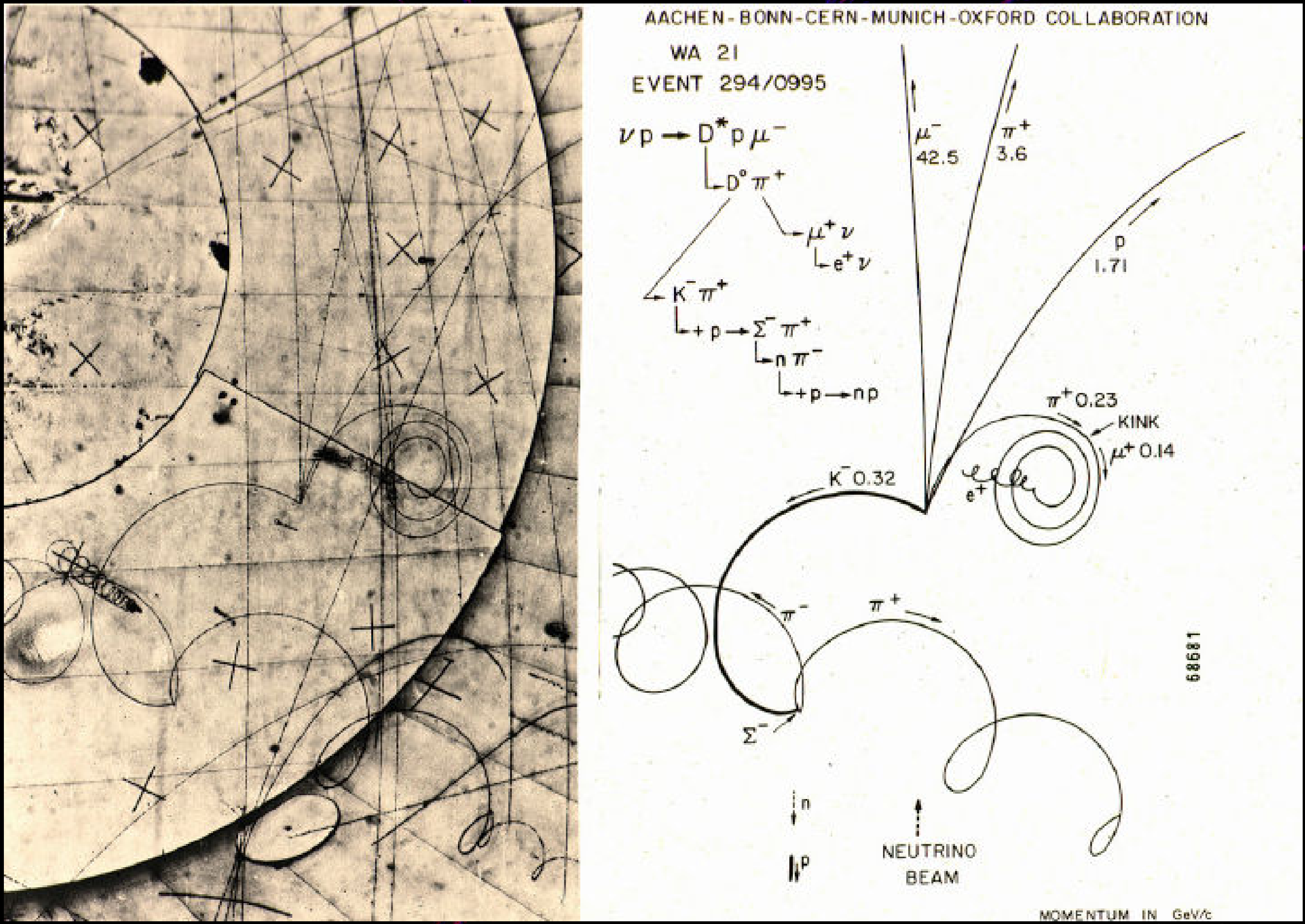
Elastic Scattering

$\nu + e \rightarrow \nu + e$

Electron $\rightarrow$
Bremsstrahlungcascade



Bubble chambers



2^{nd} period: "new devices" ISR

ISR, Intersecting Storage Rings
  Proton-Proton Collider
    Counter-rotating beams up to 60A, 10^{15} particles
    62 GeV cm collision energy

Collider: $E_{cm} = 2 \times E_{beam}$

No secondary beams!

CERN's accelerator training and technology development place

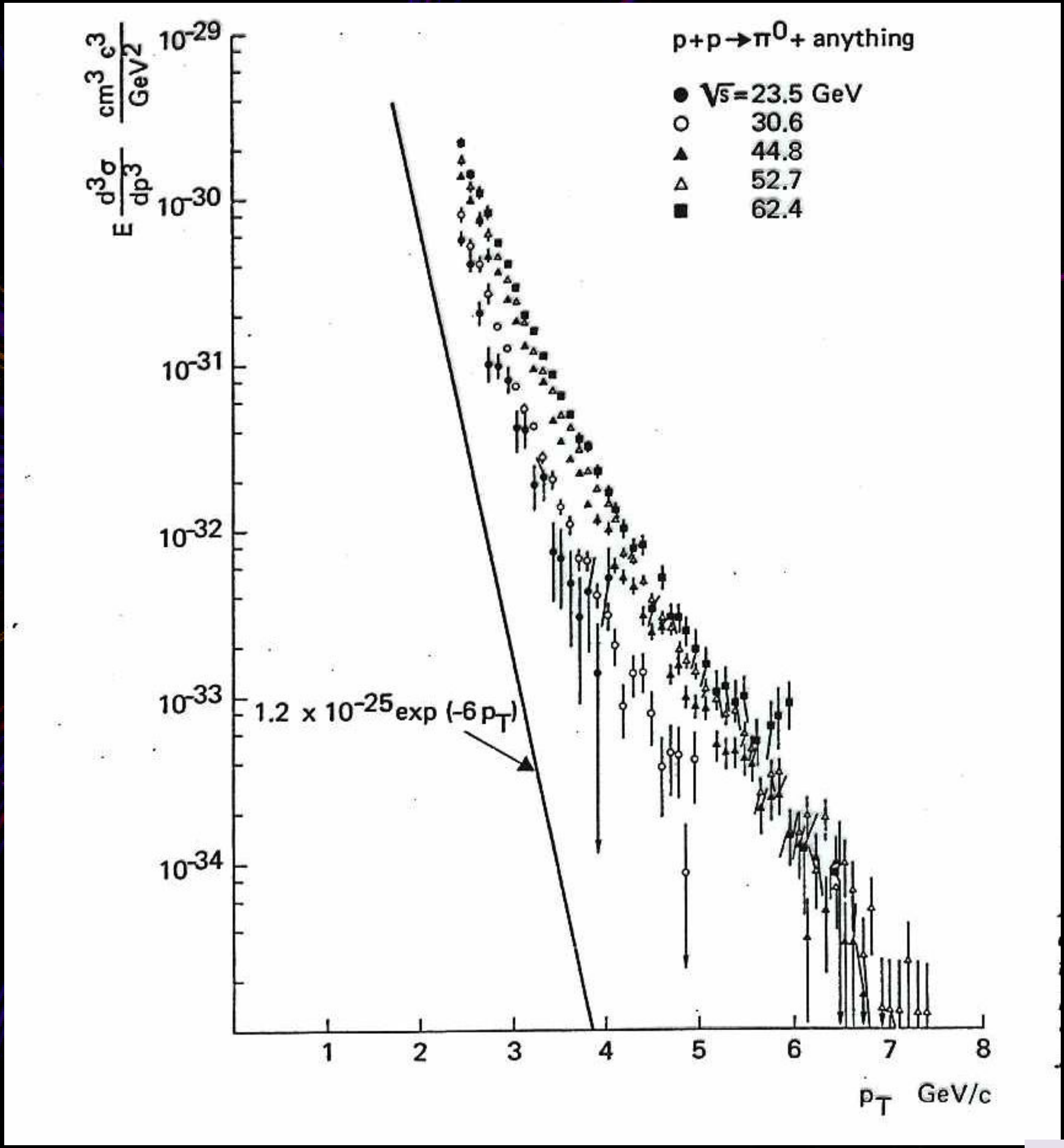
New physics domains

- rising σ_{tot}, large p_t events
  →pointlike partons, quarks;
- J/ψ; ϒ, . . were missed

Detectors: 4π proportional chambers, unprecedented rates; 1st liquid Argon calorimeter

Pions with large transverse momenta at ISR

Indication of pointlike partons inside proton



2nd period: "competition" SPS

- 400 GeV proton synchrotron
  - Almost a disaster for CERN because of site discussions: Lab I in Geneva and LabII in France, missing magnet scheme, 2 DGs, unification 1981
  - 1000 magnets in 6.9km circumference, <30GeV cm constituent energy,
  - fixed target
  - Start-up 1976
  - Great effort in intensity and quality of secondary beams
  - Compete successfully with FNAL in Chicago

John Adams and Willibald Jentschke 1973 in SPS tunnel

SPS super proton synchrotron

* Fixed target, secondary beams of high quality, two new experimental areas, West and Nord (both France)

Neutrino-, muon-, pion beams as well as polarized beams and targets

Nucleon structure, PC-violation, neutrino physics

* Ions (Au, Pb) accelerated

Study quark – gluon plasma (first identification?)

* Detectors: large scale drift chambers, calorimetry, μ spectrometers, silicon pixel and strip detectors

LEP and LHC detector technologies

SPS Tunnel

3rd period: matter-antimatter colliders Sp-pbarS ISR p-pbar, LEP

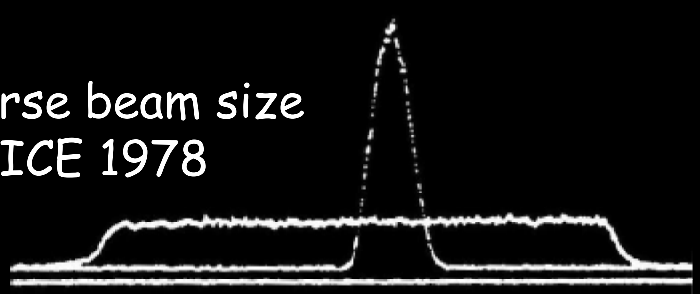
D.Cline, P. Macintyre, C. Rubbia 1976: accumulate pbar, inject into SPS counter-rotating to collide with protons in the same machine

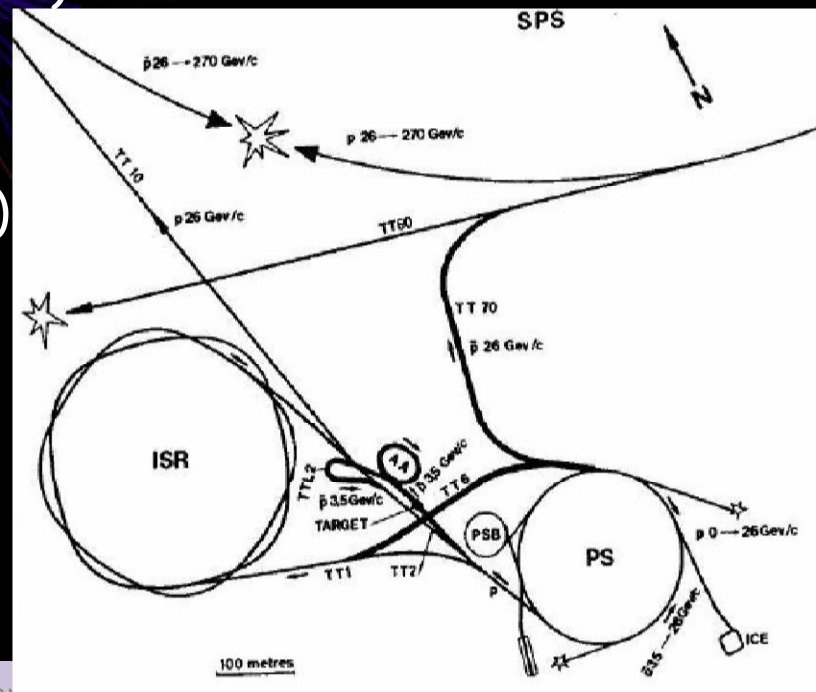
Construct pbar source AA based on stochastic cooling (Simon van der Meer Nobel Prize in 1984)

- Reduce emittance (transverse movements and momentum spread) of beams in accelerators (Maxwell's demon)
- accumulate up to 10^{12} pbars
- first collisions in summer 1981 at
- cm energy of 540 GeV (later 620 GeV)

FNAL's Tevatron p-pbar: 1988

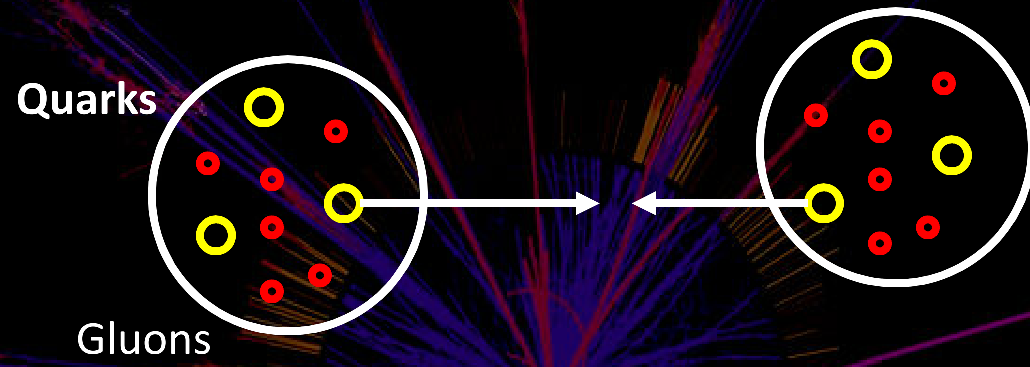
Transverse beam size cooling, ICE 1978



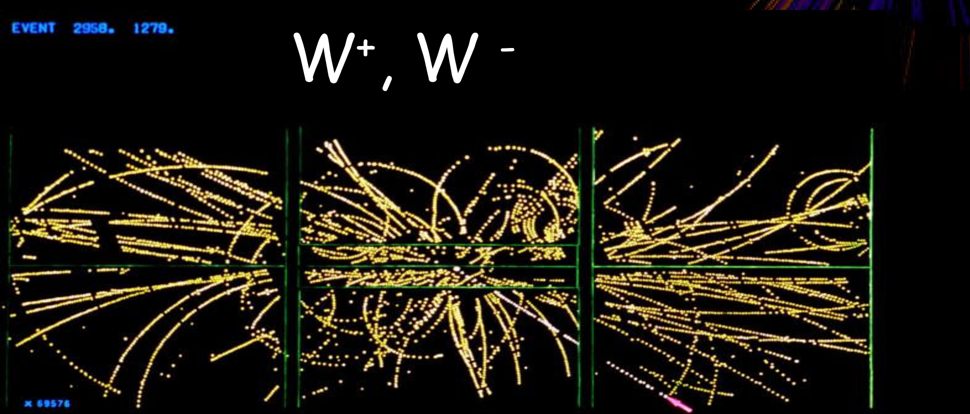


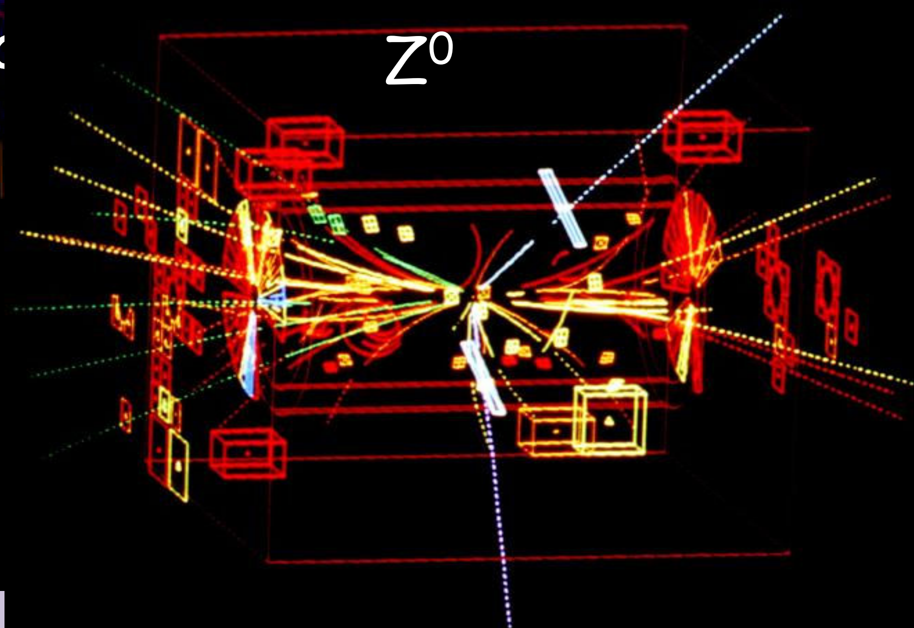
Experiments UA1 und UA2

Complex events, since protons and antiprotons are composite particles



Discovery or W and Z bosons, the carriers of weak interactions (Nobel Prize for Co

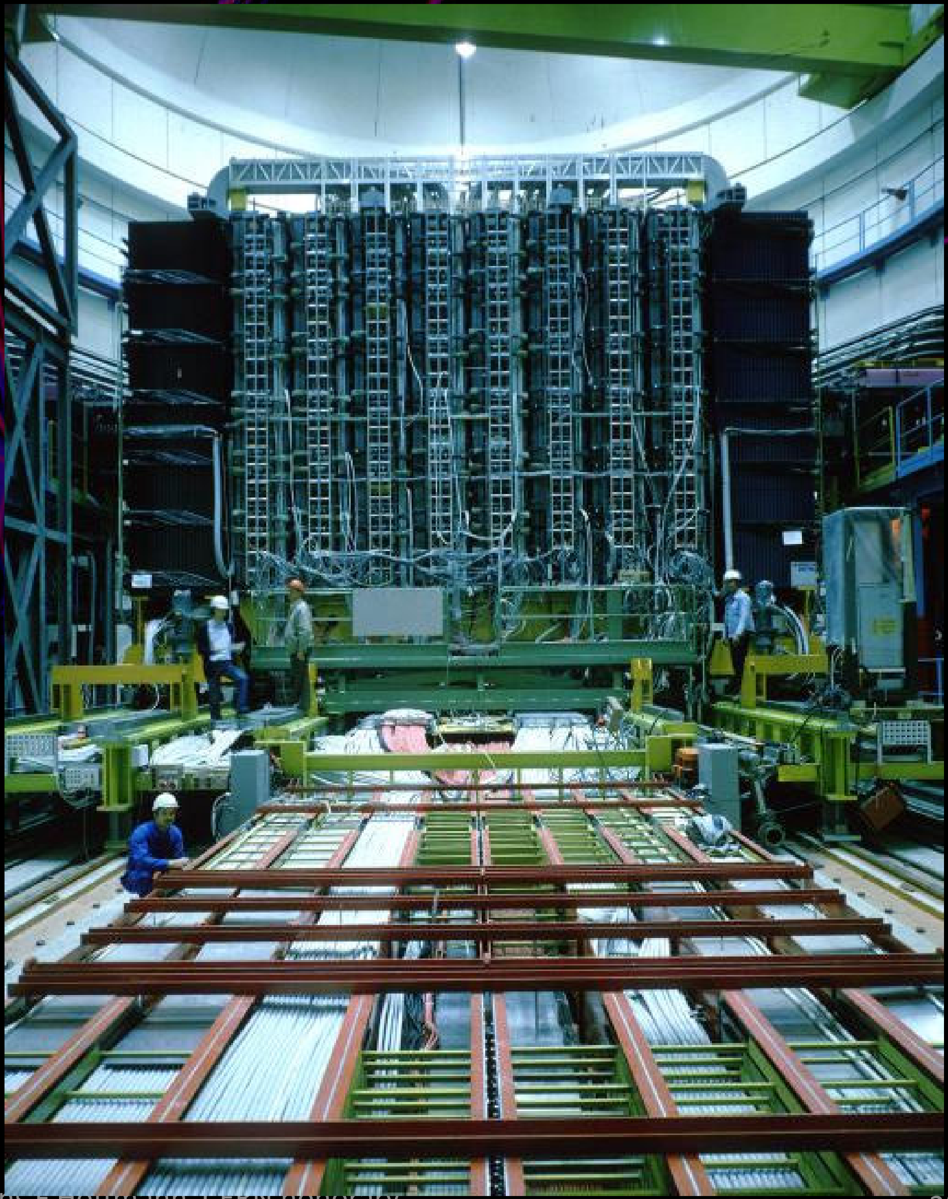




UA 1 Detector (without muon chambers)

"Hermetic" Detector

- Coverage with tracking, electromagnetic and hadronic calorimetry, down to mrad angles, large muon coverage
- High precision drift chamber- "visual " events
- Prototype of large, massively using electronics and complete multipurpose collider detectors (LEP, Tevatron, HERA)



Discovery of W and Z Press Conference 1983

3^{rd} period: matter-antimatter colliders LEP: large electron positron

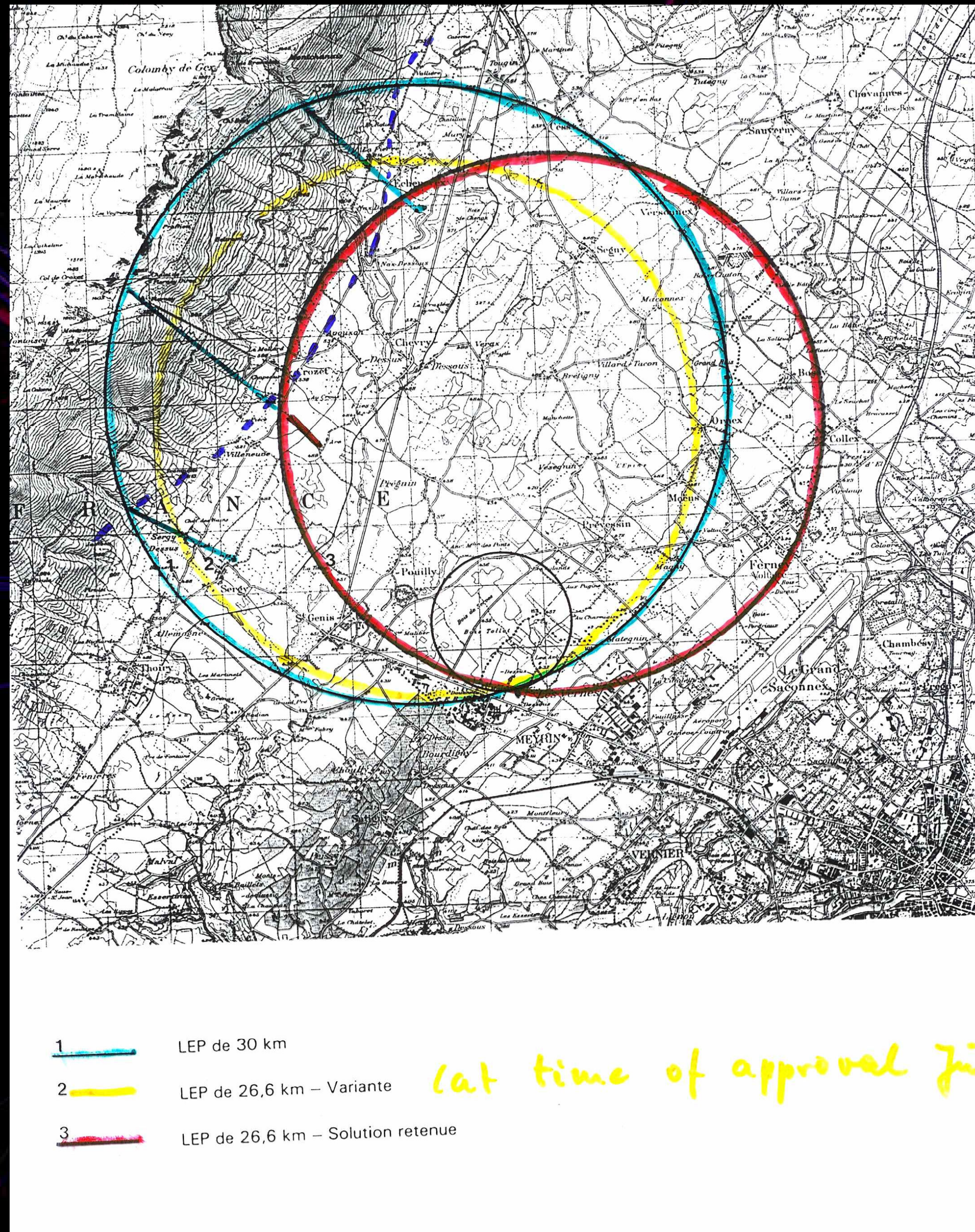
Mid-70 study by B. Richter, SLAC and CERN scientists on a 50-100 GeV/beam $e^+ e^-$ collider at CERN after the successes of Adone, Spear, Petra, PEP, Tristan

- Explore W, Z and the Standard Model in detail
- New phenomena

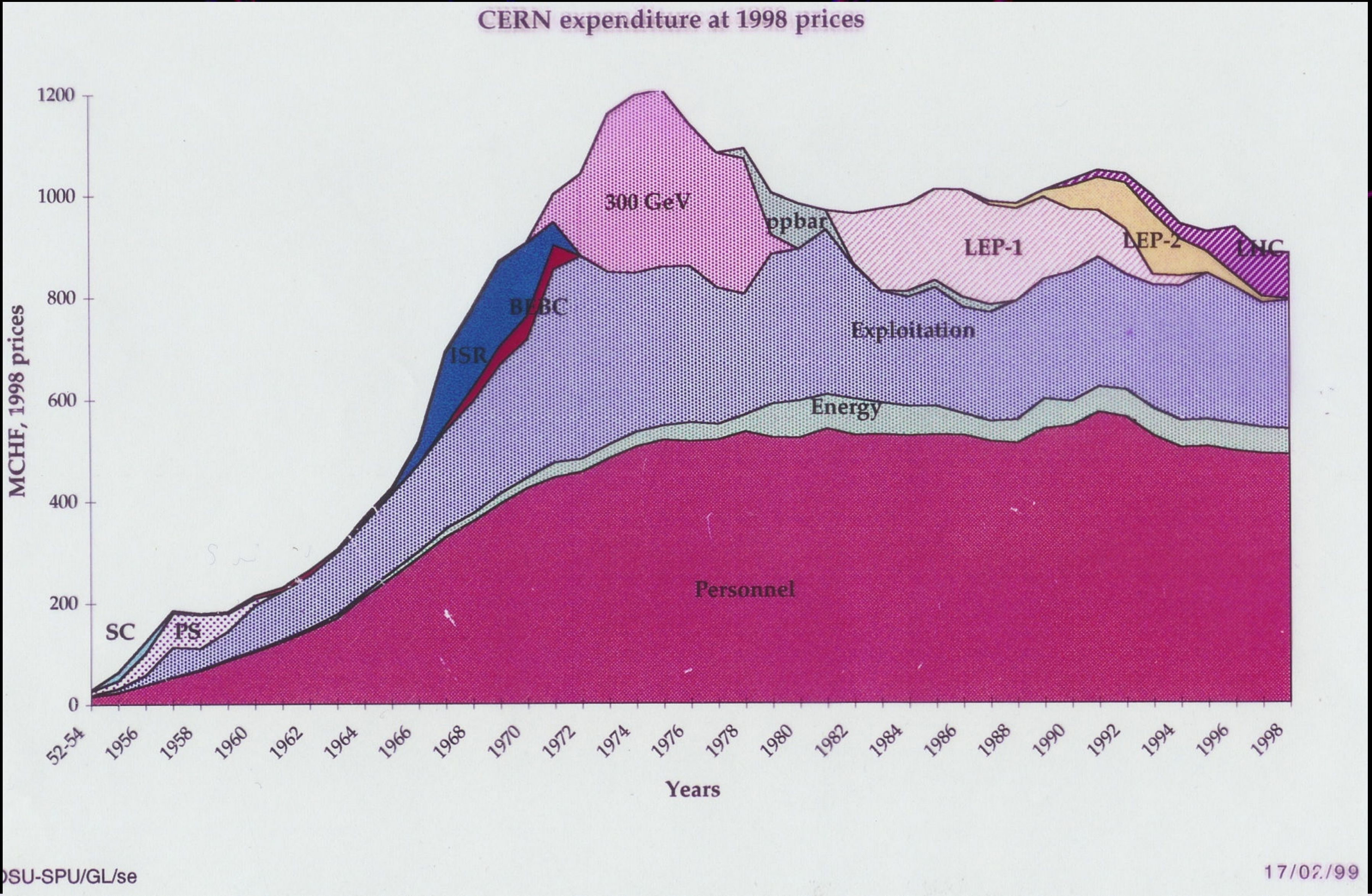
e^+ and e^- are point-like particle without inner structure resulting in very clean and significant events

Disadvantage of synchrotron radiation with energy losses of the circulating particles ~ E^4/R requiring a very large radius accelerator (LEP: 27km circumference)

LEP Positions



CERN Budget



CERN expenditure at 1998 prices
MCHF, 1998 prices
1200
1000
800
600
400
200
0
52-54
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Years
SC
PS
ISR
BEBC
300 GeV
pbar
LEP-1
LEP-2
LHC
Exploitation
Energy
Personnel
SU-SPU/GL/se
17/02/99

LEP Groundbreaking 1983

Presidents Aubert (CH) and Mitterand (F)

LEP experiments ALEPH, DELPHI, L3, OPAL

International collaborations of hundreds (300-500) of scientists from ~15-25 institutes and many countries, across religions, political systems, development

Novel management of large scientific projects

- Flat hierarchies
- Every institute autonomous
- High global communication needs
- Exemplary scientific, financial, technical coordination, QA

Institutes provide "deliverables"; cost 100-300 MCHF; CERN ~30% of total

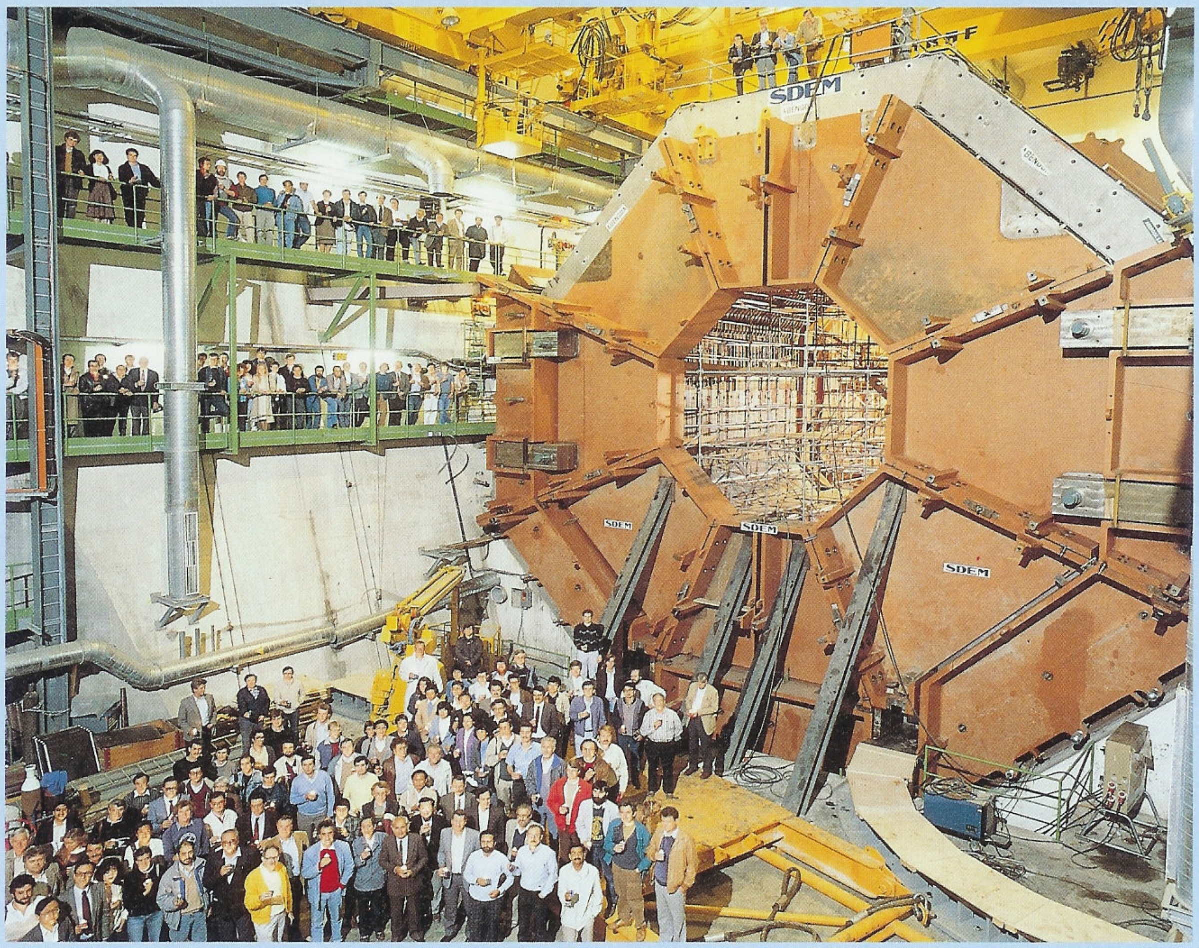
4 experiments

- to assure scientific quality of results
- to provide "discovery" competition

Positions of LEP- (and LHC-) experiments

L3

L3: An International Collaboration



A contingent of the L3 Collaboration in front of the L3 Magnet. The collaboration represents physicists, engineers, technicians, administrators and graduate students from thirty-six different institutes from thirteen nations all working towards a common goal.

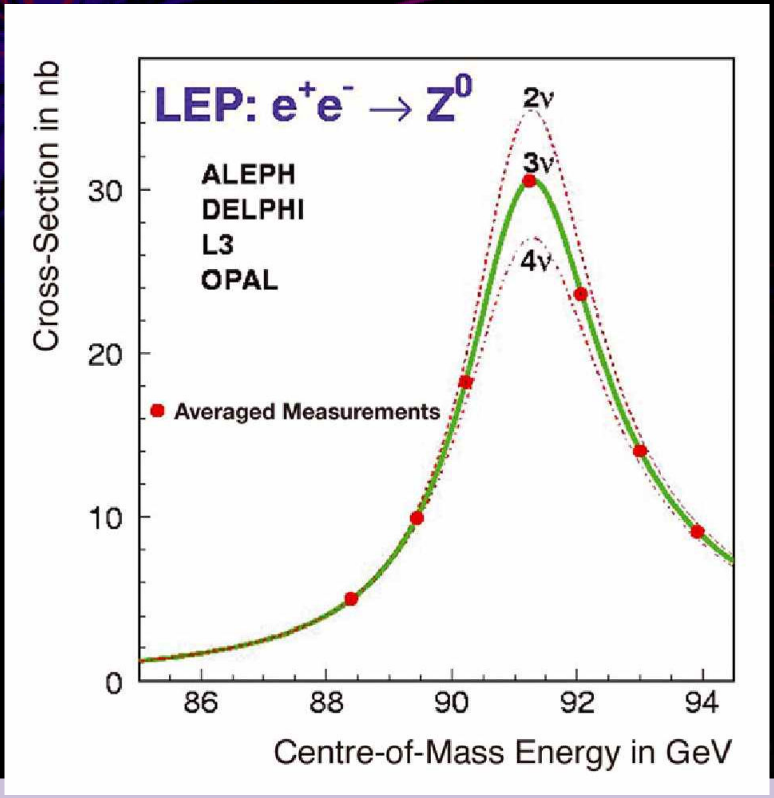
LEP results

No headlines (Top, SUSY, Higgs) but many important details establishing the standard model to < 1 % precision

Weak interactions are re-normalizable field theory (top mass indications)

3 neutrino species →

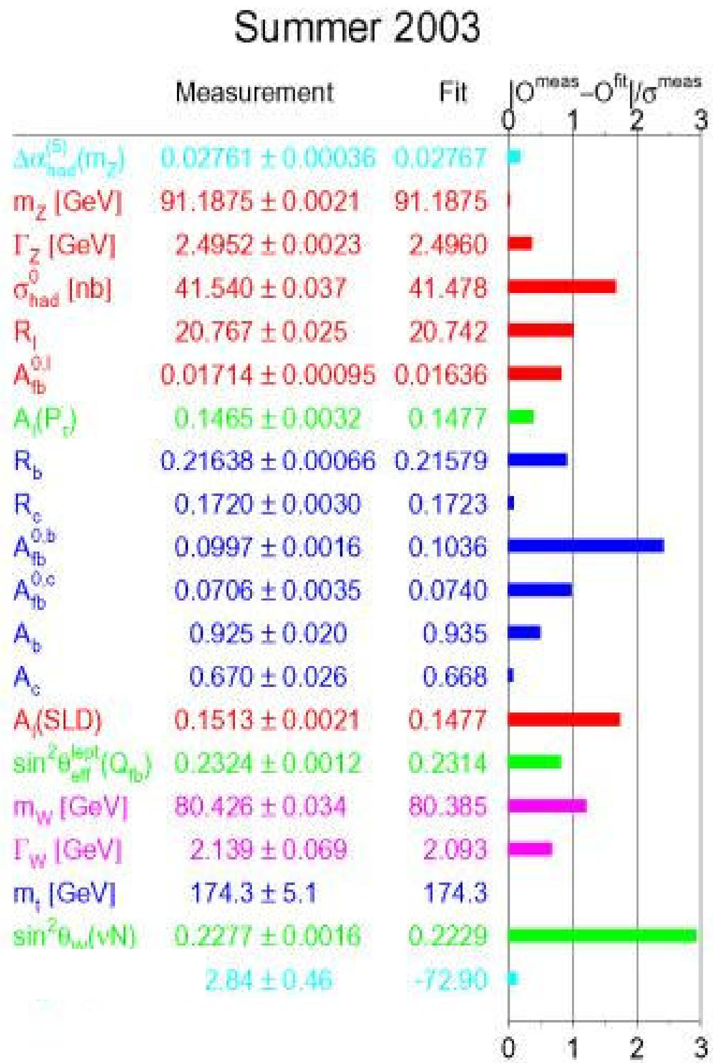
Coupling W-Z, Z-Z



$(N_\nu = 2.985 \pm 0.008)$

HEP is precision science

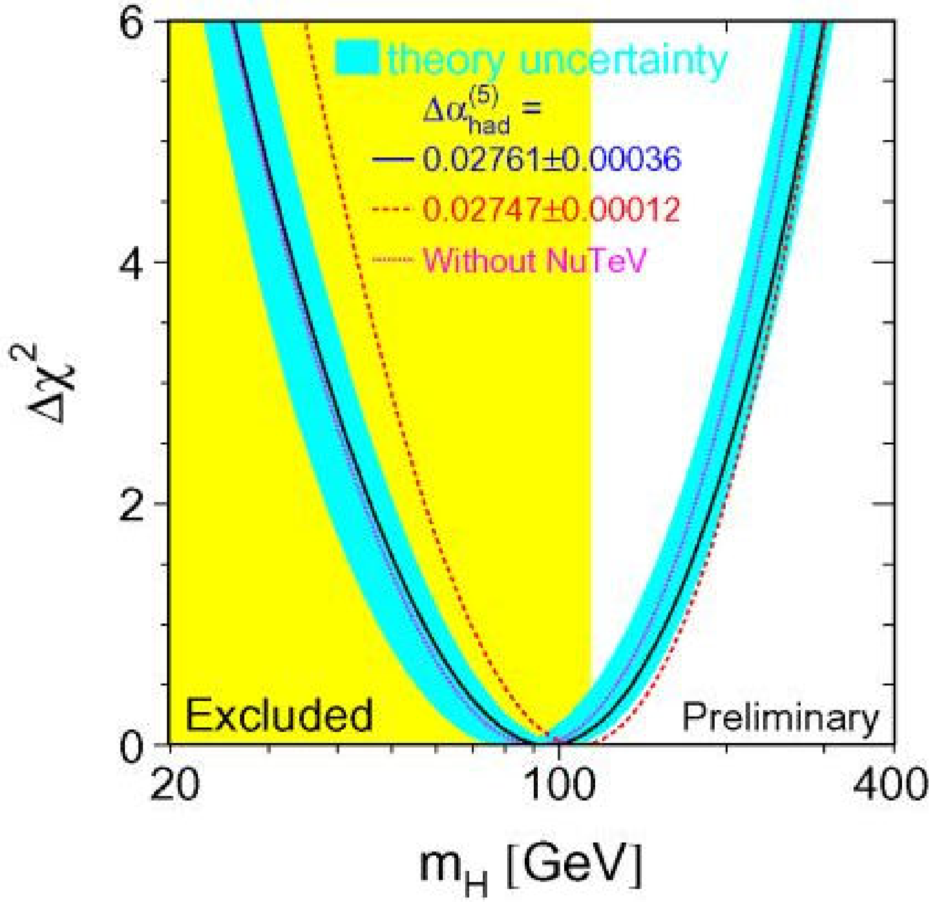
Parameters of Standard Model with <1% precision confirmed



	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02761 ± 0.00036	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1875
Γ_Z [GeV]	2.4952 ± 0.0023	2.4960
σ_{had}^{0} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01636
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1477
R_b	0.21638 ± 0.00066	0.21579
R_c	0.1720 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0997 ± 0.0016	0.1036
$A_{fb}^{0,c}$	0.0706 ± 0.0035	0.0740
A_b	0.925 ± 0.020	0.935
A_c	0.670 ± 0.026	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1477
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.426 ± 0.034	80.385
Γ_W [GeV]	2.139 ± 0.069	2.093
m_t [GeV]	174.3 ± 5.1	174.3
$\sin^2\theta_W(\nu N)$	0.2277 ± 0.0016	0.2229
	2.84 ± 0.46	-72.90

Kolloqium Erlangen 19 April 2004

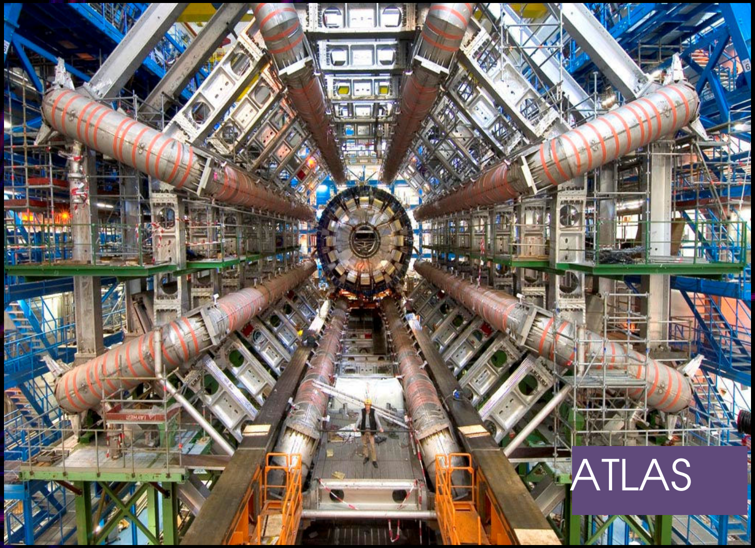
Higgs (?) excitement

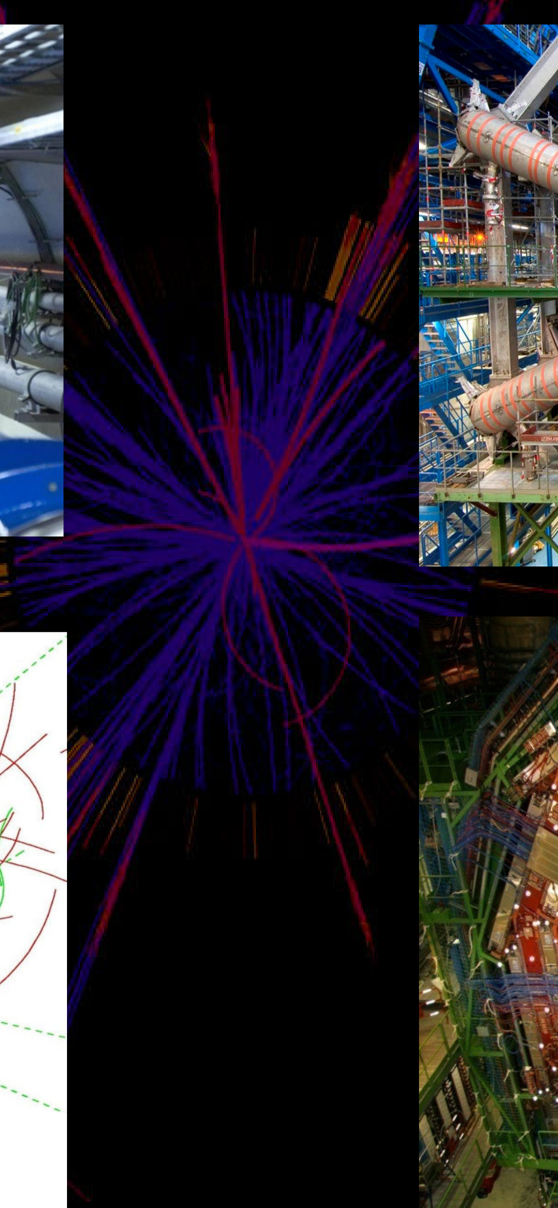


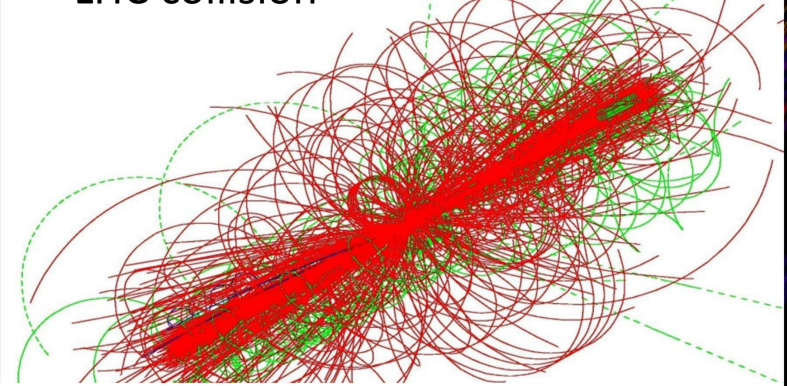
Kolloqium Erlangen 19 April 2004

Next step in Particle Physics: LHC

LHC ring:
27 km circumference

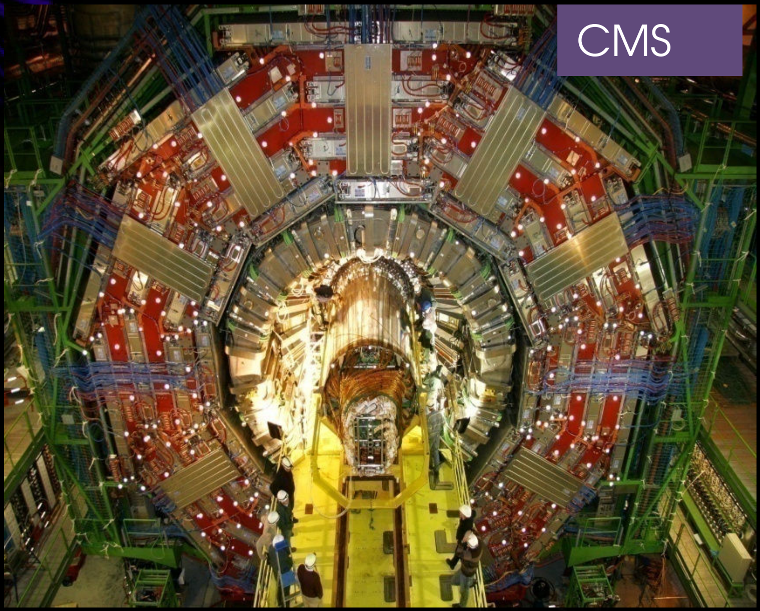




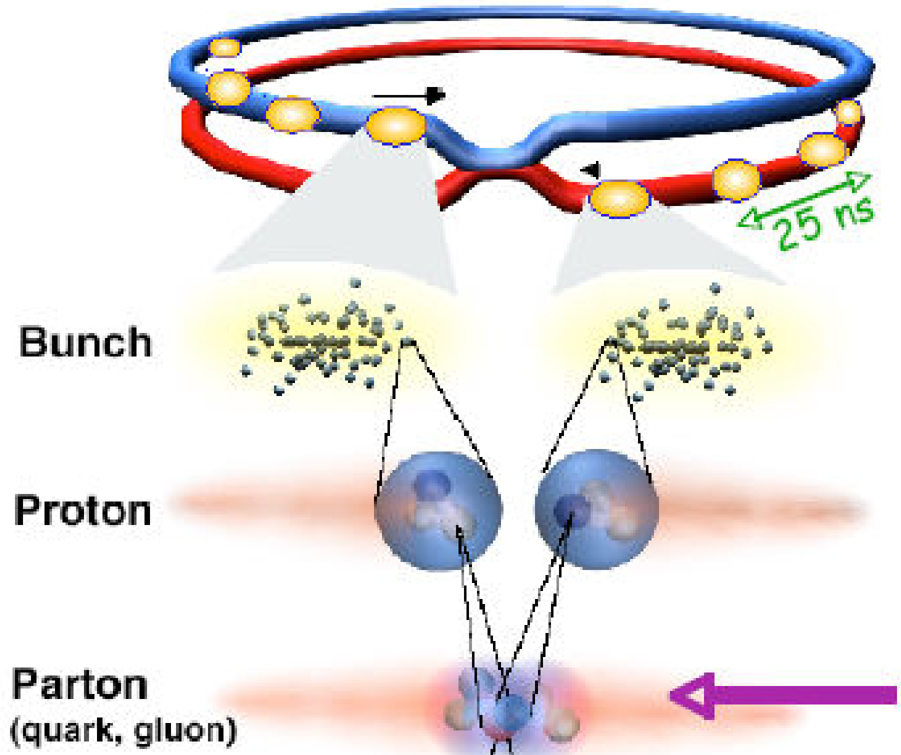


Simulation of
LHC collision

Equivalent temperature:1billion x temperature inside the sun



Collisions at LHC



Proton-Proton

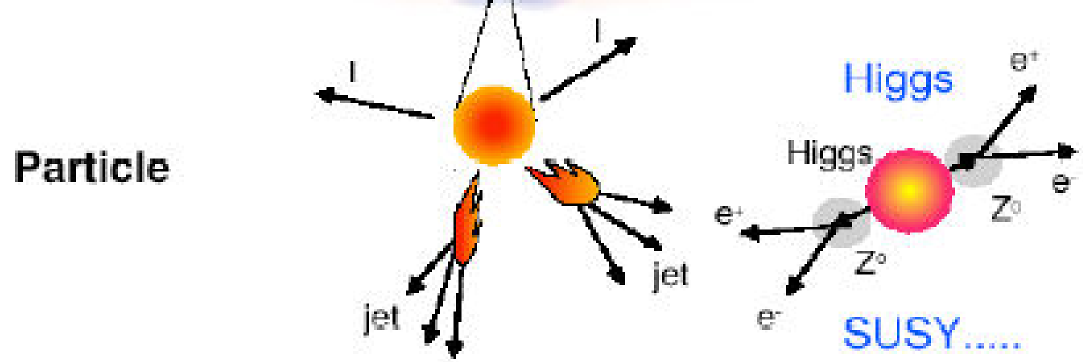
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}

Event rate in ATLAS :

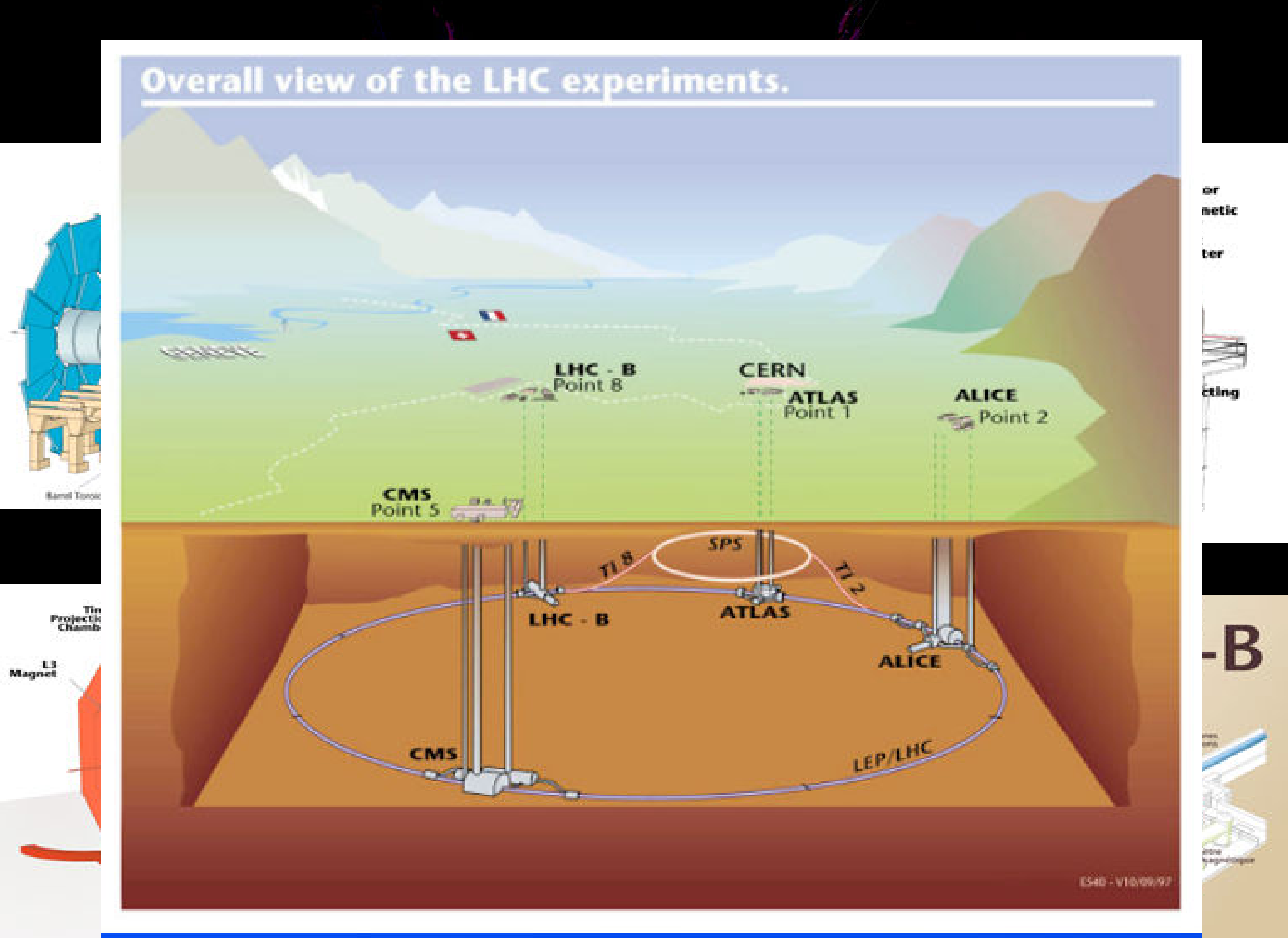
$N = L \times \sigma$ (pp) ≈ 10^9 interactions/s

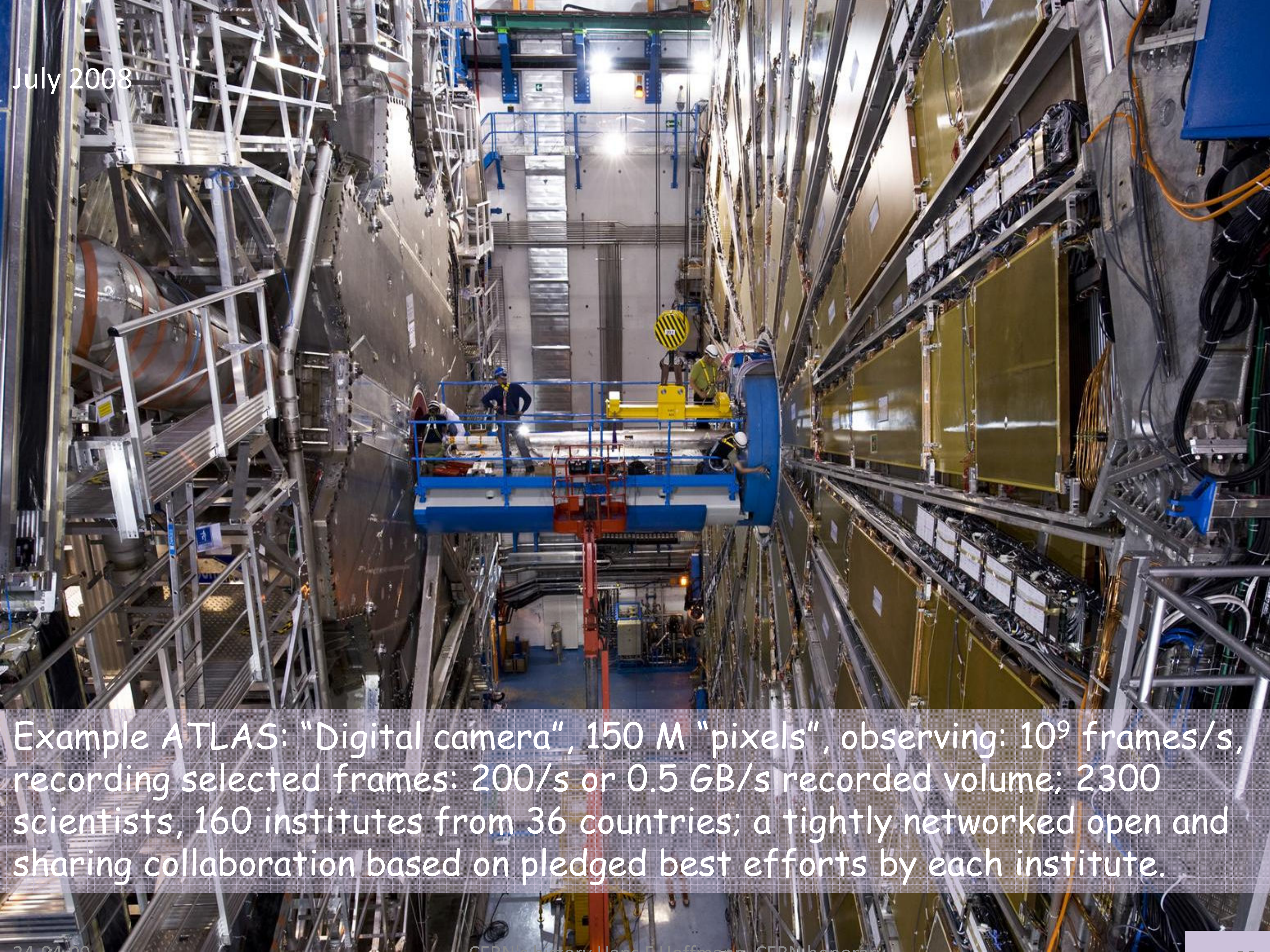
Mostly soft (low p_T) events

Interesting hard (high-p_T) events are rare



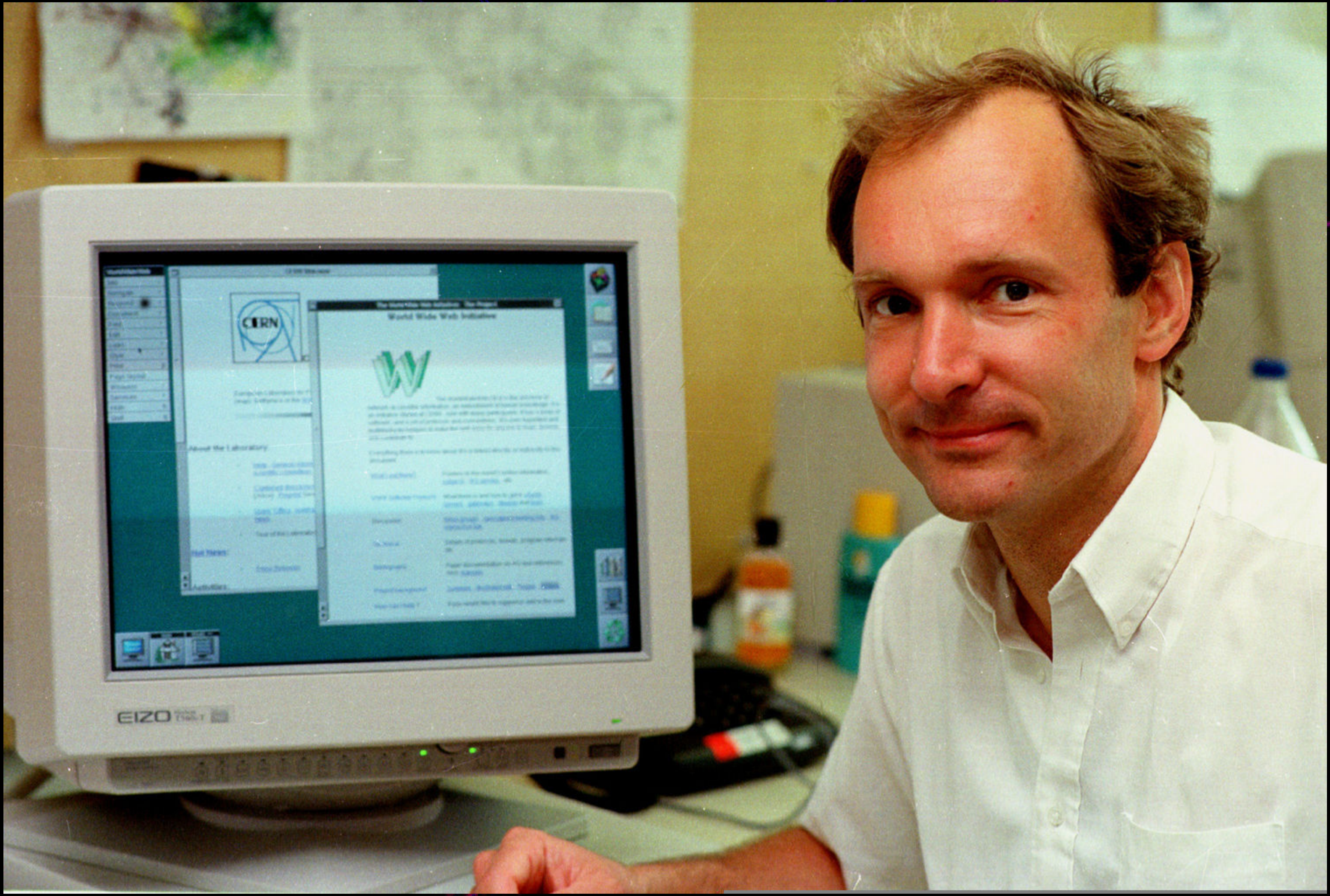
Selection of 1 in 10,000,000,000,000


Overall view of the LHC experiments.
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC
ES40 - V10/09/97
L3
Magnet
-B



Example ATLAS: "Digital camera", 150 M "pixels", observing: 10^9 frames/s, recording selected frames: 200/s or 0.5 GB/s recorded volume; 2300 scientists, 160 institutes from 36 countries; a tightly networked open and sharing collaboration based on pledged best efforts by each institute.

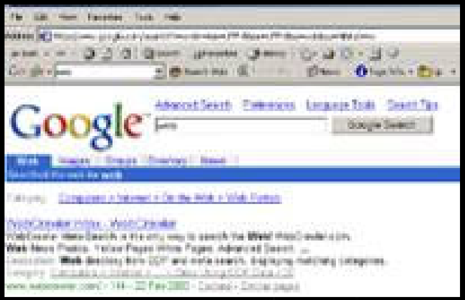
And have you heard of the… Web?



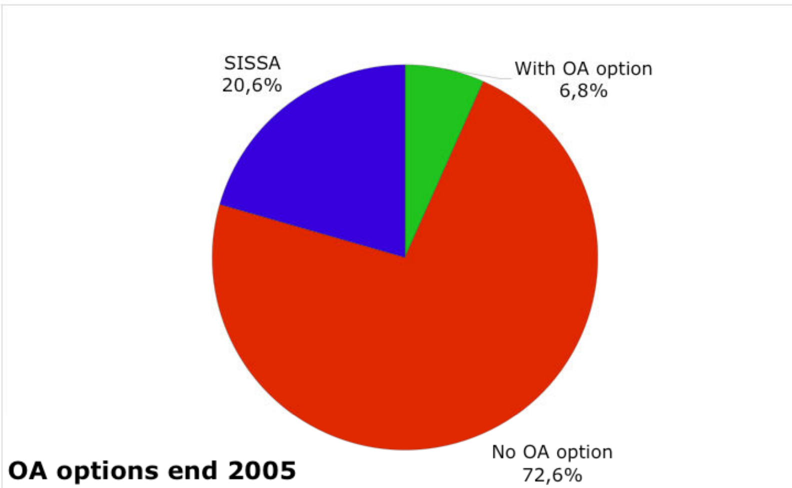
What is the Grid?

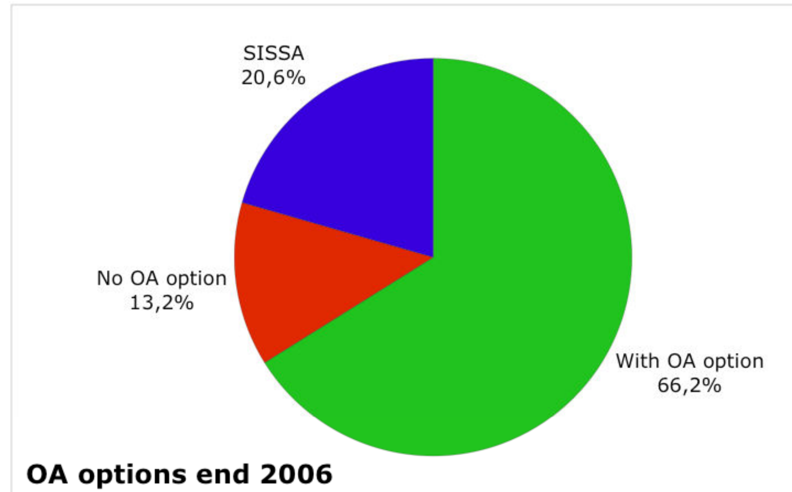
The World Wide Web provides seamless access to information that is stored in many millions of different geographical locations

In contrast, the Grid is an emerging infrastructure that provides seamless access to computing power and data storage capacity distributed over the globe.



Open Access Publishing in Particle Physics





20 000 scientific journals today; millions of articles/year →OA with common use copyright

Green OA: institute mandates authors to publish OA in their repository

Gold OA: pay journal for editing, QA and making available as OA journal

Particle Physics: long tradition of publicly curating data world-wide-PDG

- SCOAP3: consortium to pay authors fees
- > 95% of pp-publications: open access today
- “green”: institutional repositories > 95%

CERN as an Educator

Bringing Nations Together

Conclusions to CERN

Scientifically CERN has had some beautiful successes and some important missed opportunities.

CERN is a European success and a global laboratory

Nobody asked for WWW: Ignition and basis for an ITC-industry that turns over several 1000 billion $/year – equivalent to the GDP of a nation like UK, F, DE; the ITC revolution changes the way science is done fundamentally

CERN's immediate future is the physics of the LHC

The longer term future will depend on the excellent scientists CERN will attract and their innovative ideas

Knowledge is the capacity to act, the potential to start something*

The value of knowledge increases with its use

(Fundamental) scientific knowledge must be freely available (WSIS I: scientific community), "5th freedom" or "free movement of knowledge" for publicly funded research

When addressing great challenges, obtaining, sharing of all relevant knowledge is indispensible

Balance IP laws between the rights holder's interests and the public interest, consistent with the country's level of development