



CERN und LHC

Daten und Fakten

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Leiter der Gruppe 'Education'



Prelude

Ziele der CERN-Forschung

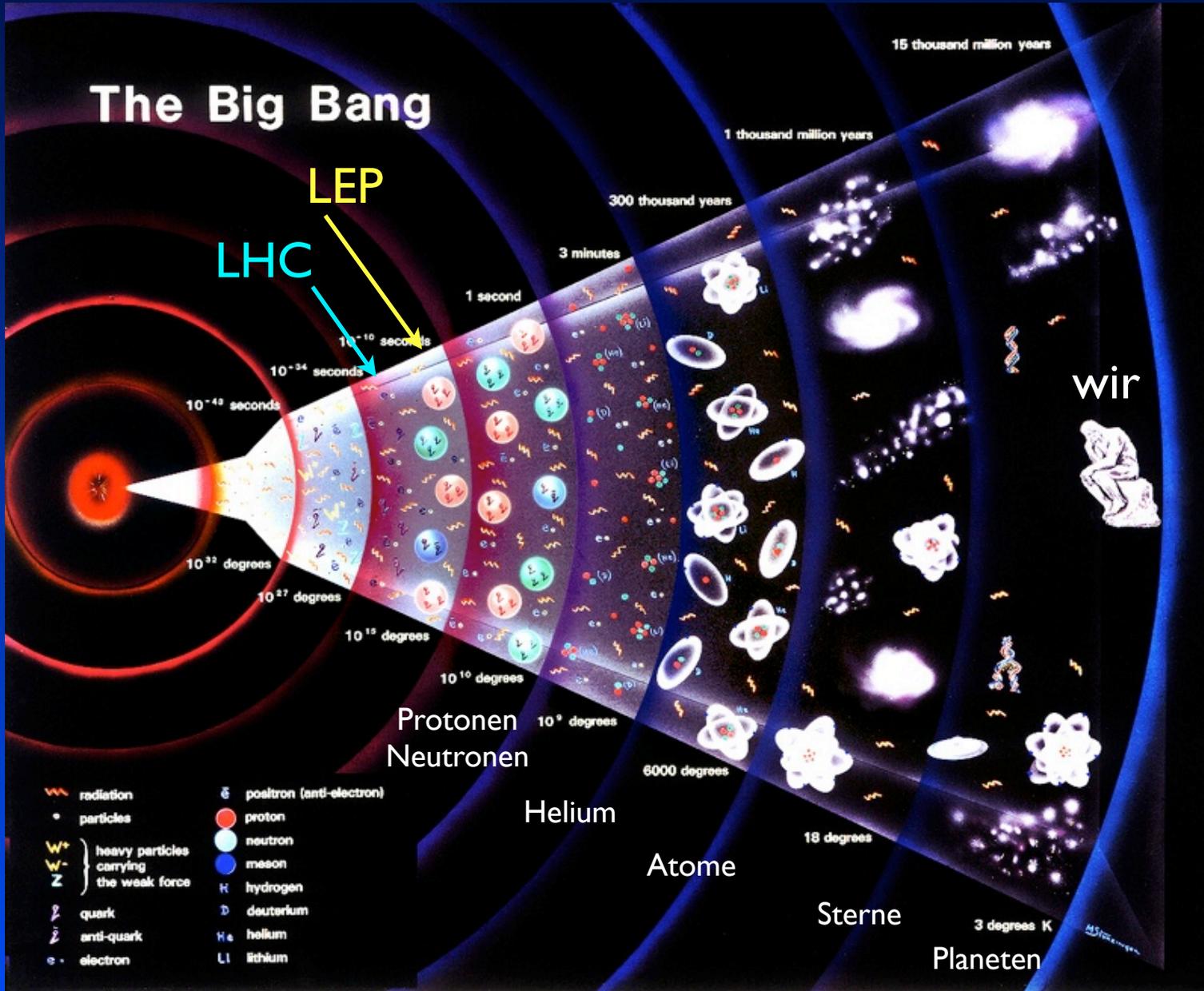
Bausteine der Materie

Wechselwirkungen

Evolution der Materie



Evolution der Materie während des Urknalls





100 Jahre Teilchenphysik: Die bekannten Bausteine des Universums

Three families of particles

	1	2	3	
Electric charge				
+2/3	 UP	 CHARM	 TOP	Q u a r k s
-1/3	 DOWN	 STRANGE	 BOTTOM	
0	 ELECTRON- NEUTRINO	 MUON- NEUTRINO	 TAU- NEUTRINO	L e p t o n s
-1	 ELECTRON	 MUON	 TAU	

Stabil (sehr) kurzlebig



Die Massen der Elementarteilchen sind sehr unterschiedlich

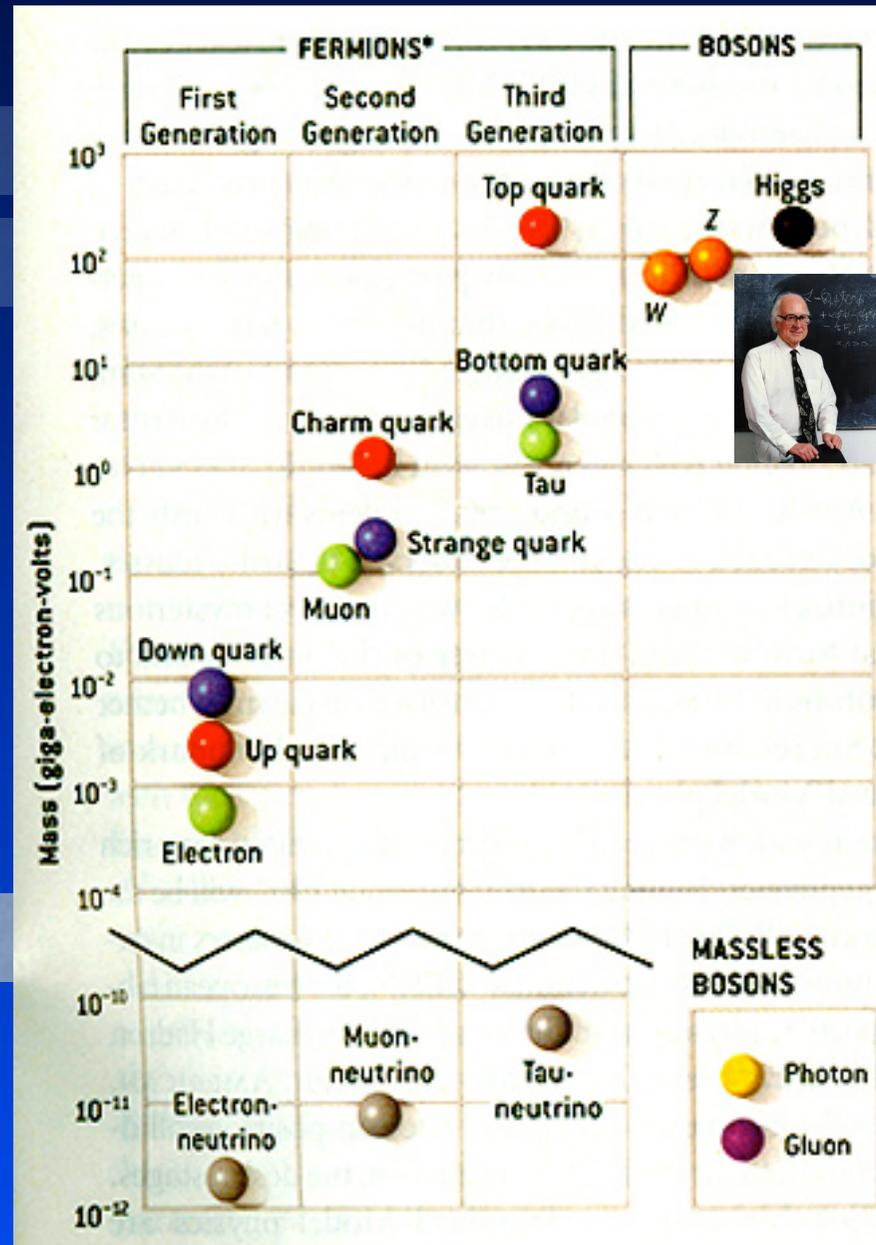
1 TeV →

100 GeV →

1 GeV →

1 MeV →

0.01 eV →



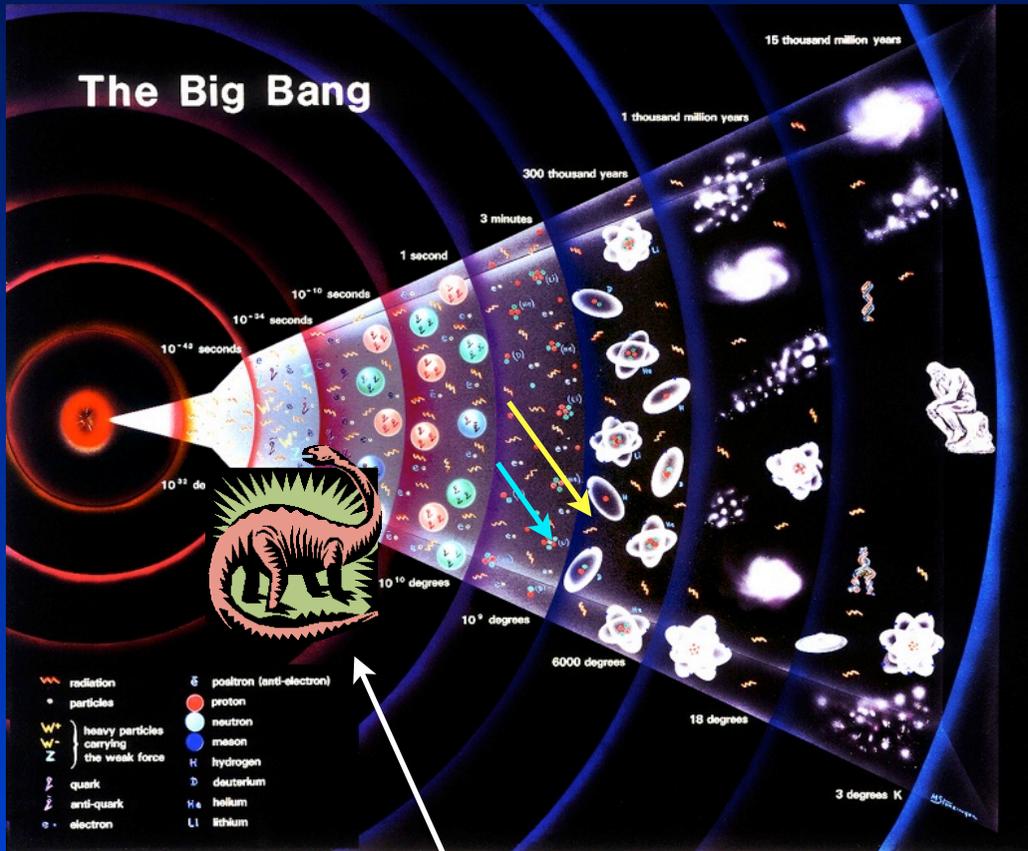
LHC

LEP

Umgebungstemperatur



Dunkle Materie ?



“Dinosaur” particles -
left over from the Big Bang ?



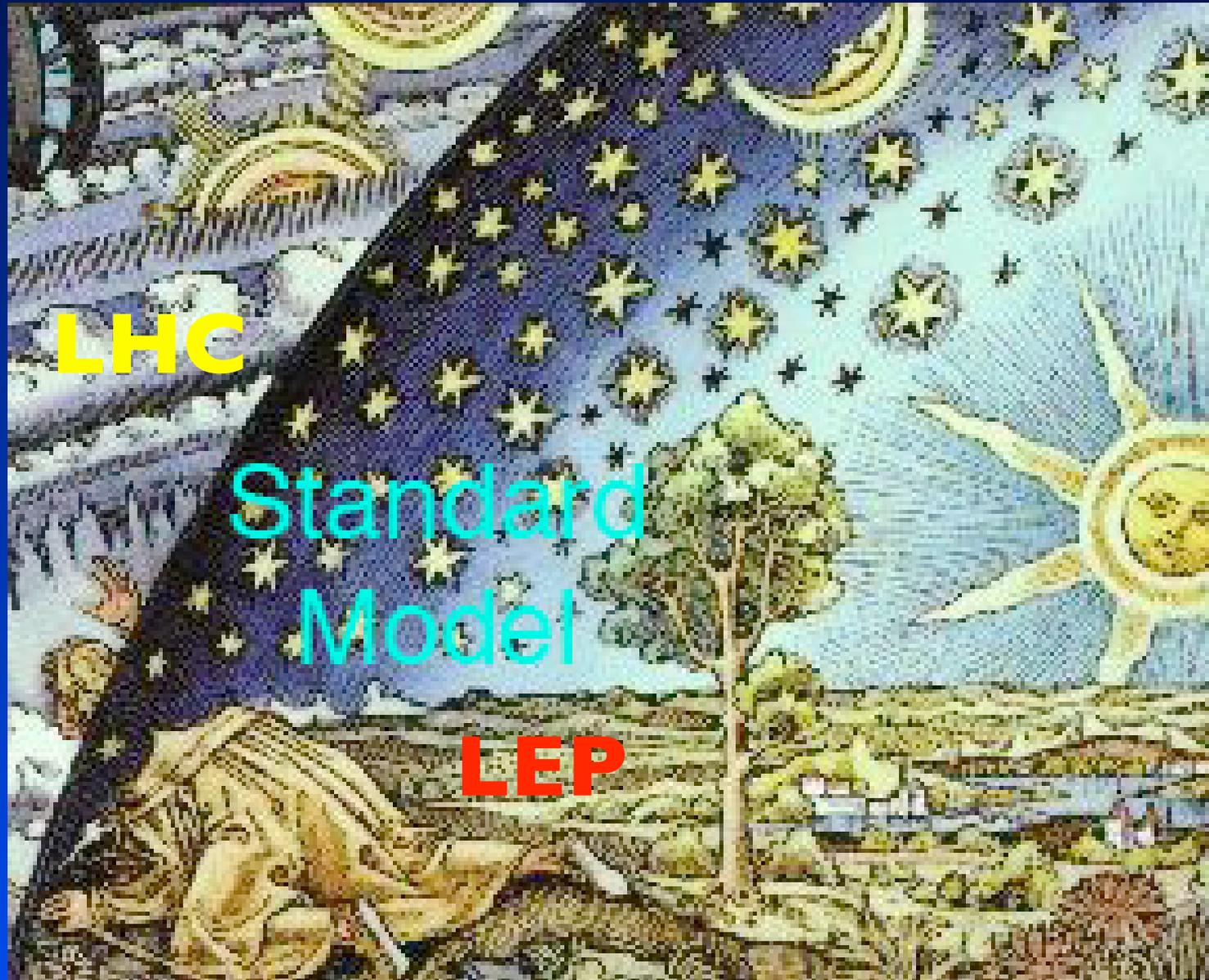
Rotation der Galaxien



Gravitationslinsen



LHC vs LEP : Der erste Schritt in die Welt 'jenseits des Standard-Modells'



LHC

**Standard
Model**

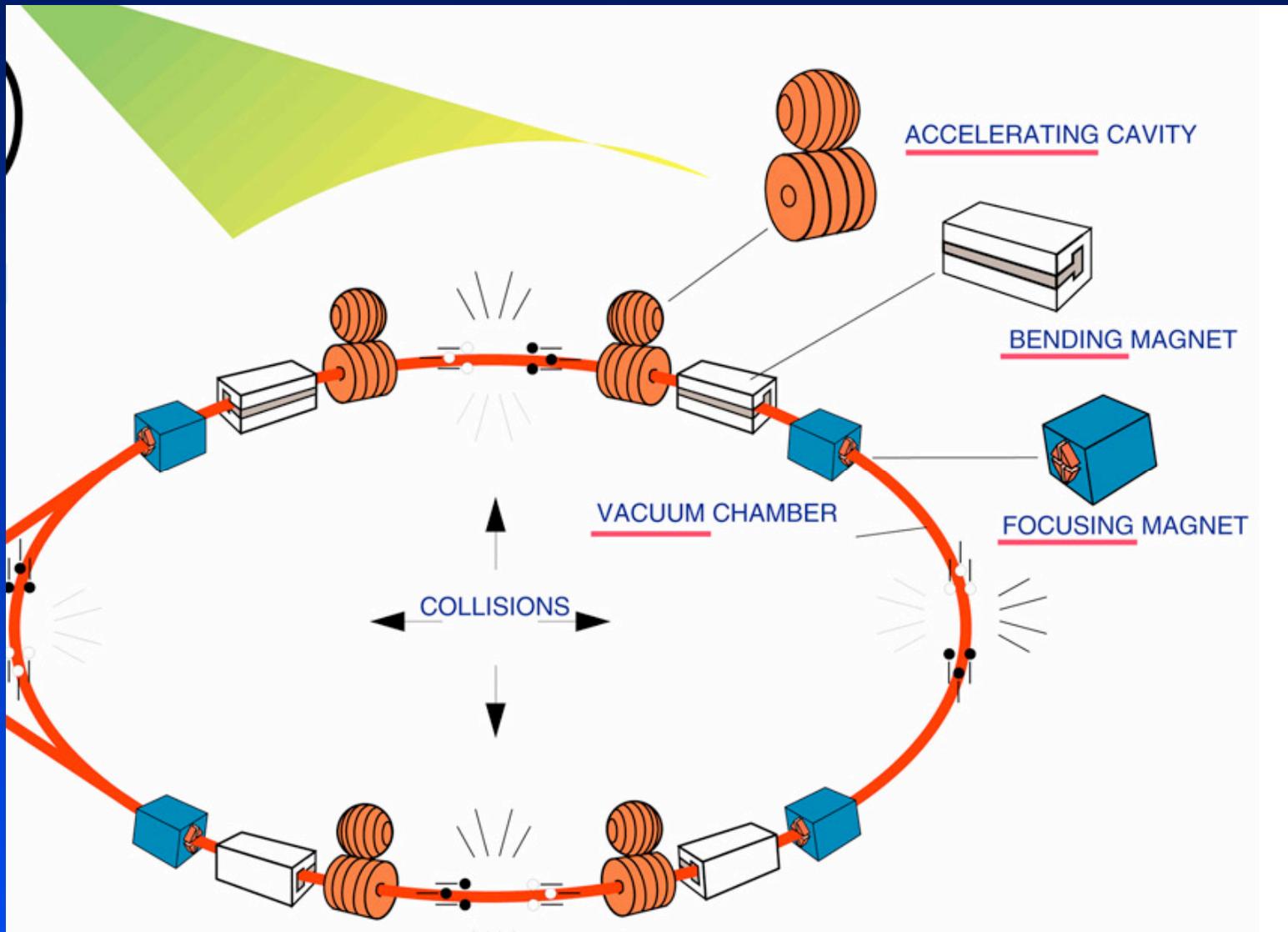
LEP



Wie kann man
die ersten Momente des Universums
im Labor studieren?

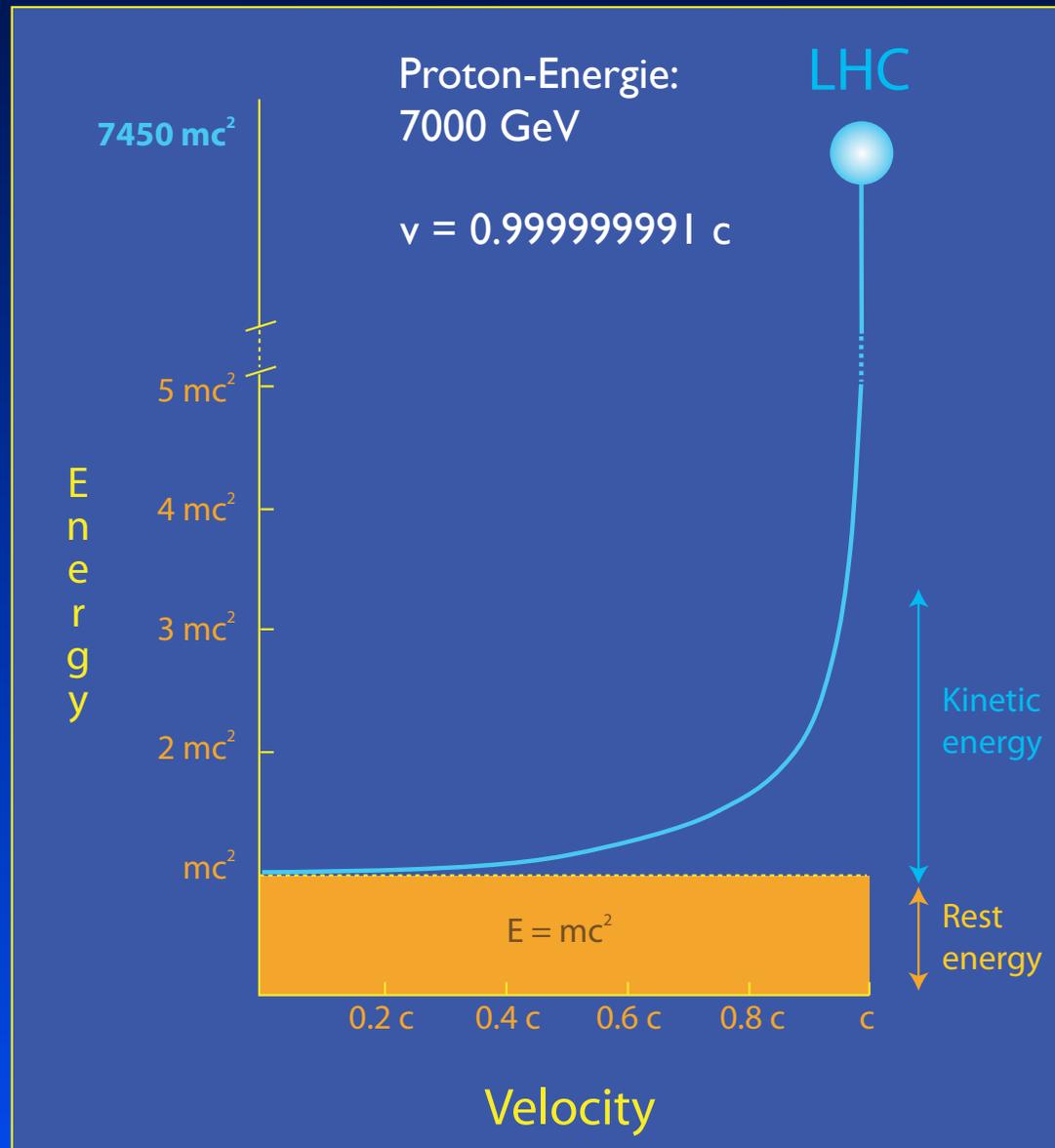


- 1 - Beschleunigung von Teilchen (z.B. Protonen)
- 2 - Kollisionen erzeugen hohe Energiedichten
- 3 - Detektoren registrieren die produzierten Teilchen





Beschleunigte Protonen "transportieren" Energie



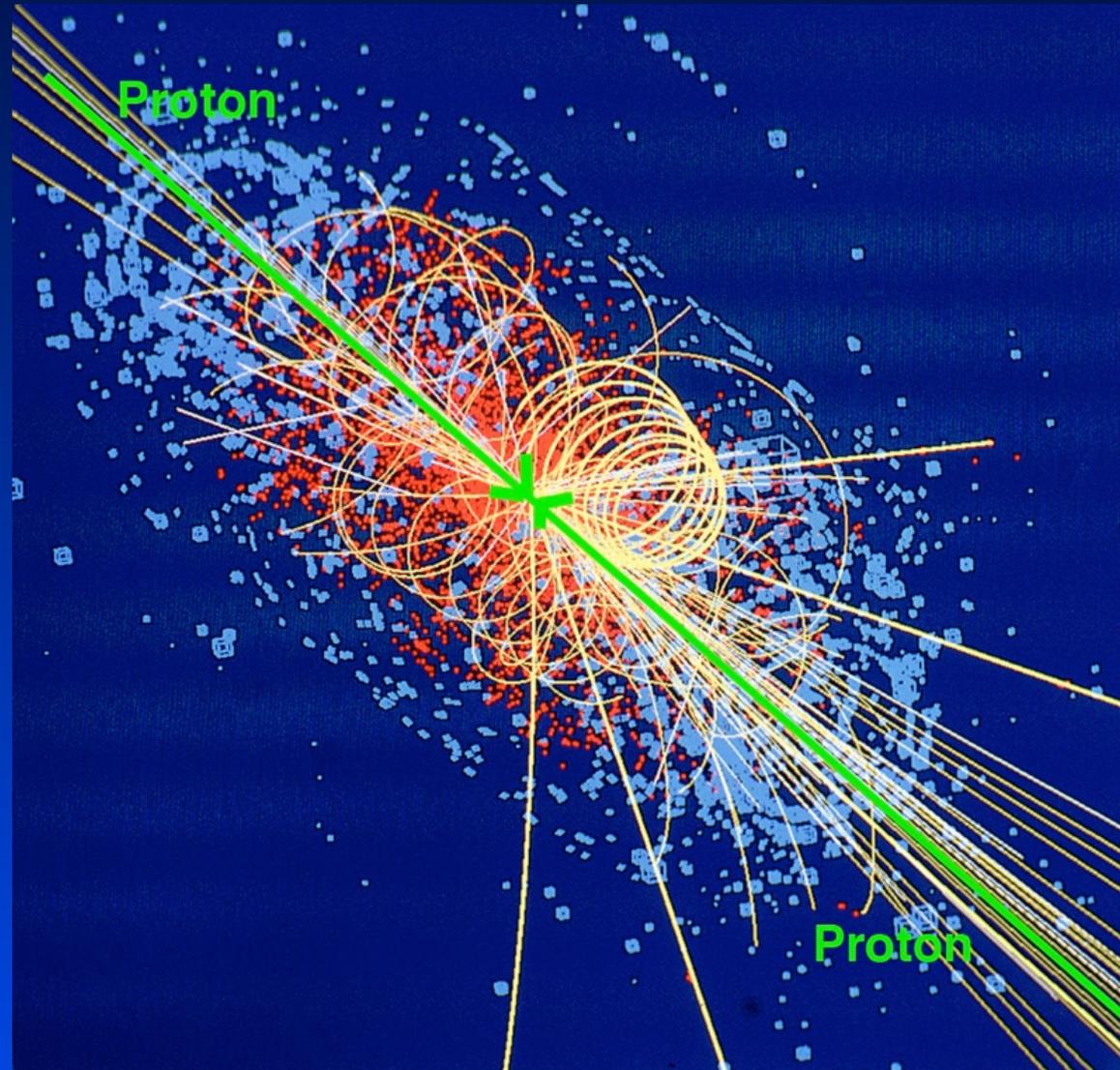


Wenn beschleunigte Protonen kollidieren,
wird die Bewegungsenergie in neue Teilchen umgewandelt





Einige Teilchen existierten nur kurz nach dem Urknall



Simulation: Produktion eines Higgs-Teilchens



Die Aufgaben des CERN

Beschleuniger

Konstruktion

Betrieb

Experimente

Infrastruktur

Beitrag zu Konstruktion und Betrieb

Gastgeber

7125 Wissenschaftler (2005)
aus 85 Ländern



Finanzierung

%

The Twenty Member States of CERN



Member States (Dates of Accession)

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

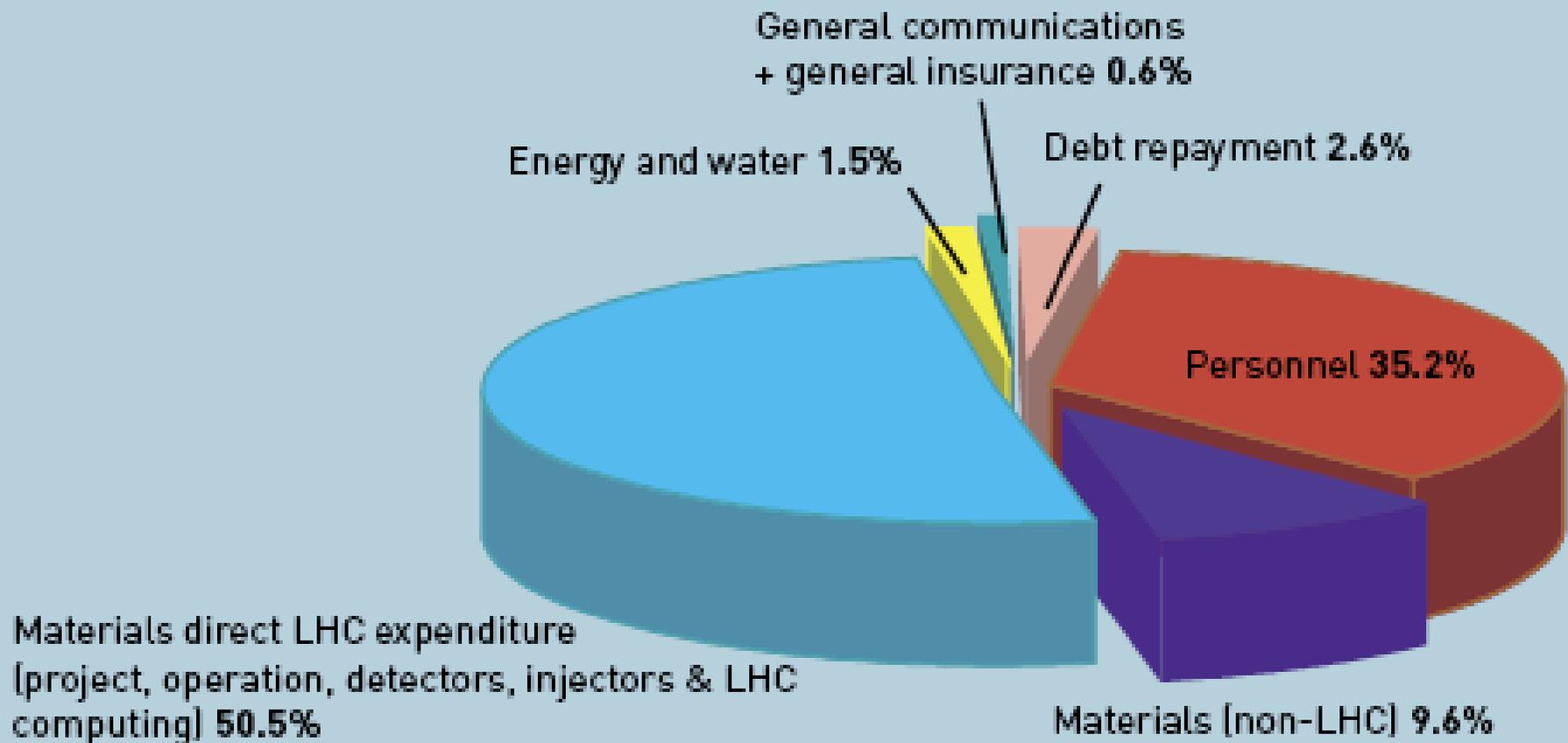
CERN AC/DI/MM - ES368 1999 - 15/6/99

Austria	2.18
Belgium	2.65
Bulgaria	0.19
Czech Republic	0.72
Denmark	1.69
Finland	1.26
France	15.90
Germany	20.12
Greece*	1.39
Hungary	0.85
Italy	12.43
Netherlands	4.24
Norway	1.86
Poland	1.82
Portugal	1.11
Slovak Republic	0.32
Spain	7.68
Sweden	2.59
Switzerland	3.20
United Kingdom	17.80



Finanzierung

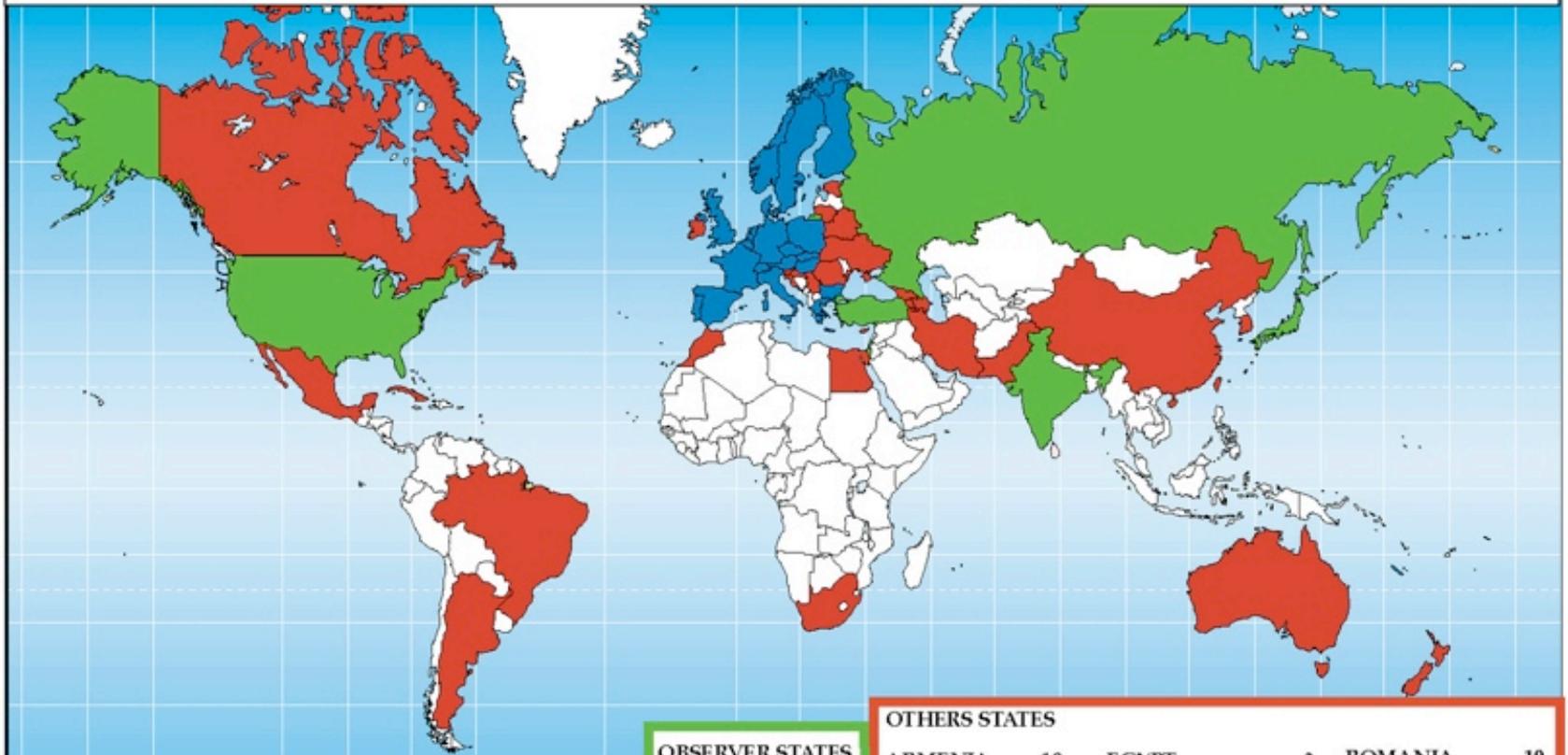
2005



Total 1 365.65 MCHF



Distribution of All CERN Users by Institute on 8 September 2004

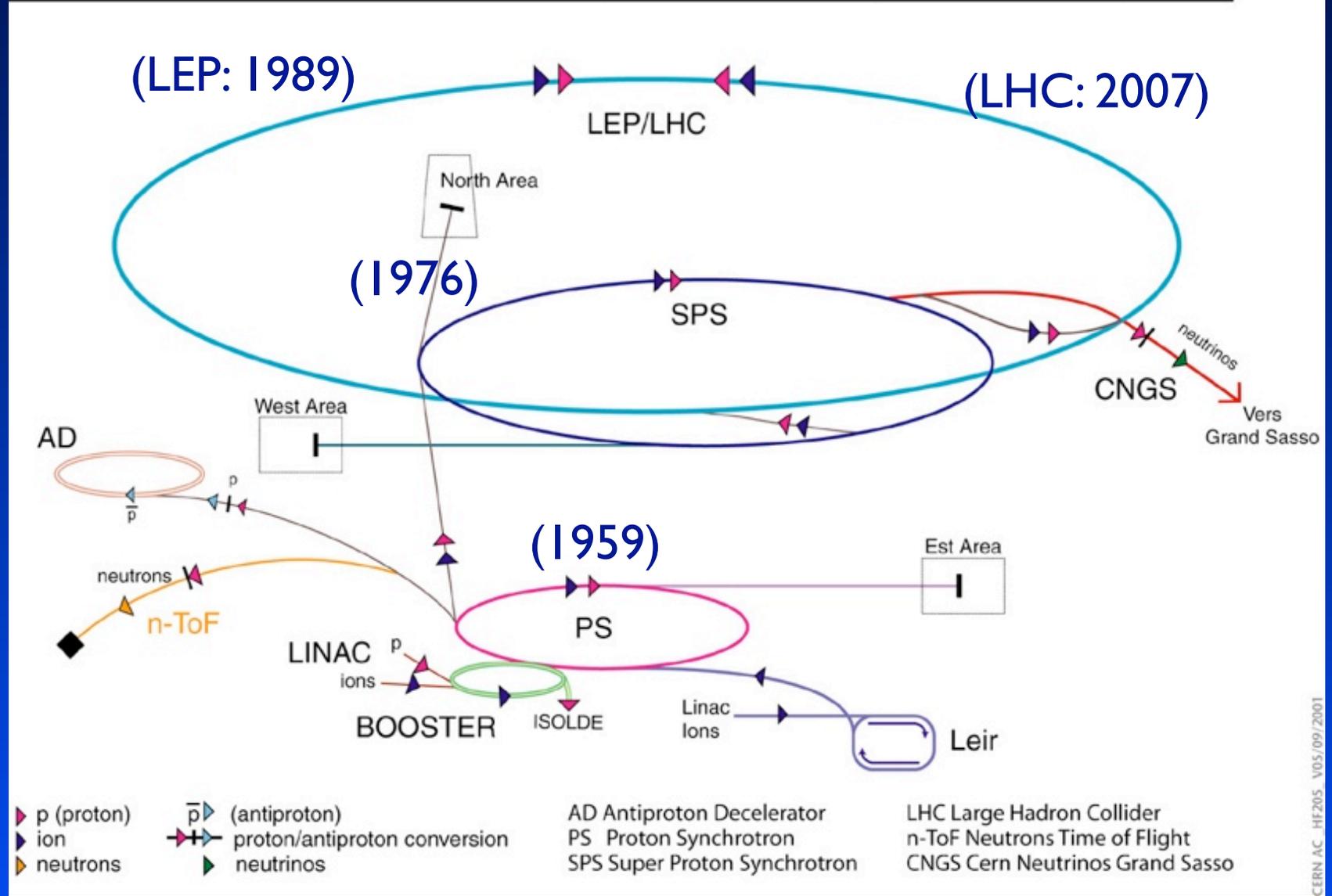


MEMBER STATES			OBSERVER STATES		OTHERS STATES					
4419			INDIA	62	ARMENIA	10	EGYPT	3	ROMANIA	19
AUSTRIA	GERMANY	PORTUGAL	ISRAEL	33	ARGENTINA	1	GEORGIA	6	SLOVENIA	6
BELGIUM	GREECE	SLOVAKIA	JAPAN	94	AUSTRALIA	10	CROATIA	15	TAIWAN	20
BULGARIA	HUNGARY	SPAIN	RUSSIA	774	AZERBAIJAN	2	IRELAND	6	UKRAINE	11
CZECH REPUBLIC	ITALY	SWEDEN	TURKEY	24	BRAZIL	29	IRAN	4	YUGOSLAVIA	11
DENMARK	NETHERLANDS	SWITZERLAND	USA	634	BELARUS	14	KOREA	19	SOUTH AFRICA	2
FINLAND	NORWAY	UNITED KINGDOM	1621		CANADA	69	LITHUANIA	1		
FRANCE	POLAND				CHINA	55	MOROCCO	8		
					CUBA	3	MEXICO	15		
					CYPRUS	5	NEW ZEALAND	2		
					ESTONIA	6	PAKISTAN	11		
										363



CERN baut die grössten Beschleuniger der Welt

Accelerator chain of CERN (operating or approved projects)





LHC Meilensteine

- | | |
|-----------|--|
| 1976 | First idea |
| 1984 | R+D starts |
| 1987 | Proto-Collaborations |
| 1989 | First public presentation by DG |
| 1994 | Approval of LHC project |
| 1996-1998 | Approval of experiments
(ATLAS, CMS, ALICE, LHCb) |
| 2007 | Construction complete |



Large Hadron Collider



Large Hadron Collider

Umfang

26 659 m





Large Hadron Collider

Magnete

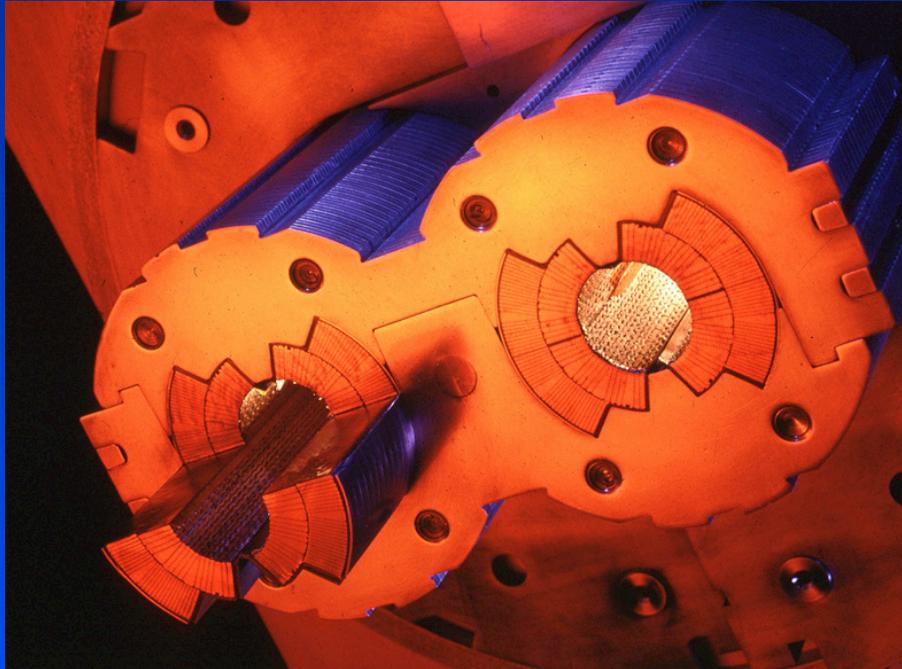
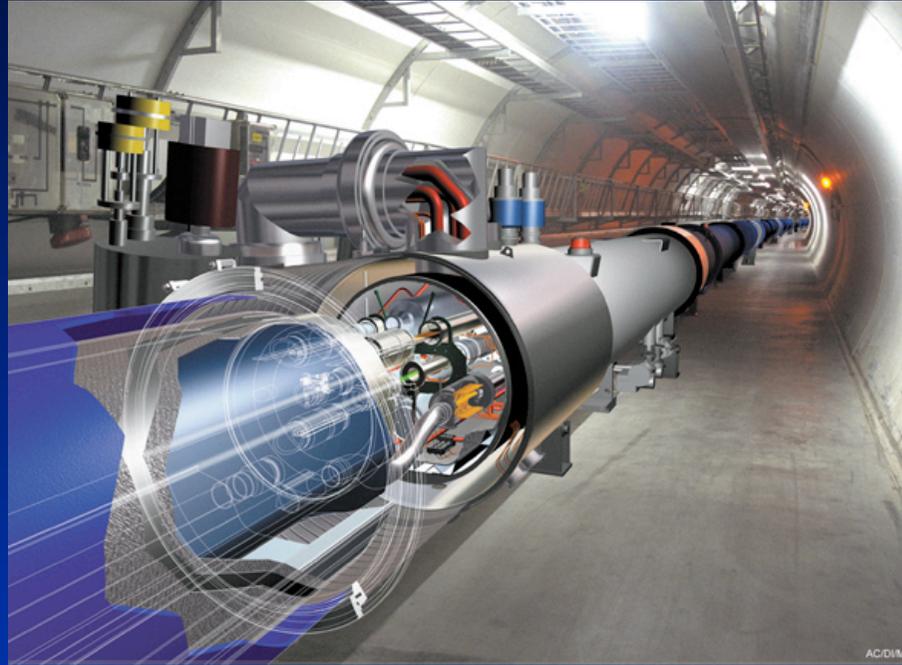
9300

Dipole

1232

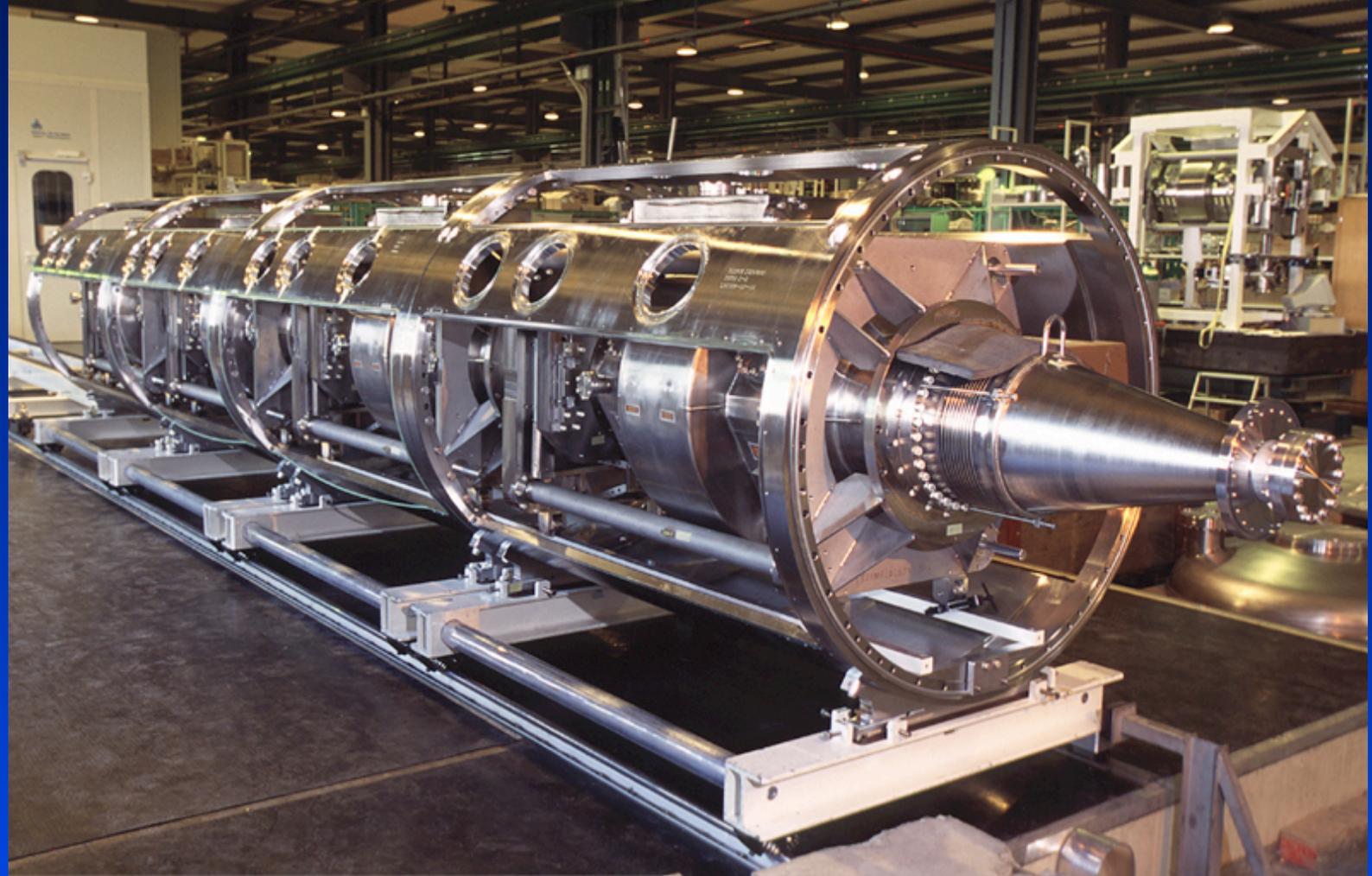
Magnetfeld (max.)

8.33 T





Large Hadron Collider



RF Kavitäten

2 x 8



LHC Dipol - Magnete (1232)

2-in-1 Design

Zwei gegenläufige Protonenstrahlen
im gleichen Magnet

Betriebstemperatur

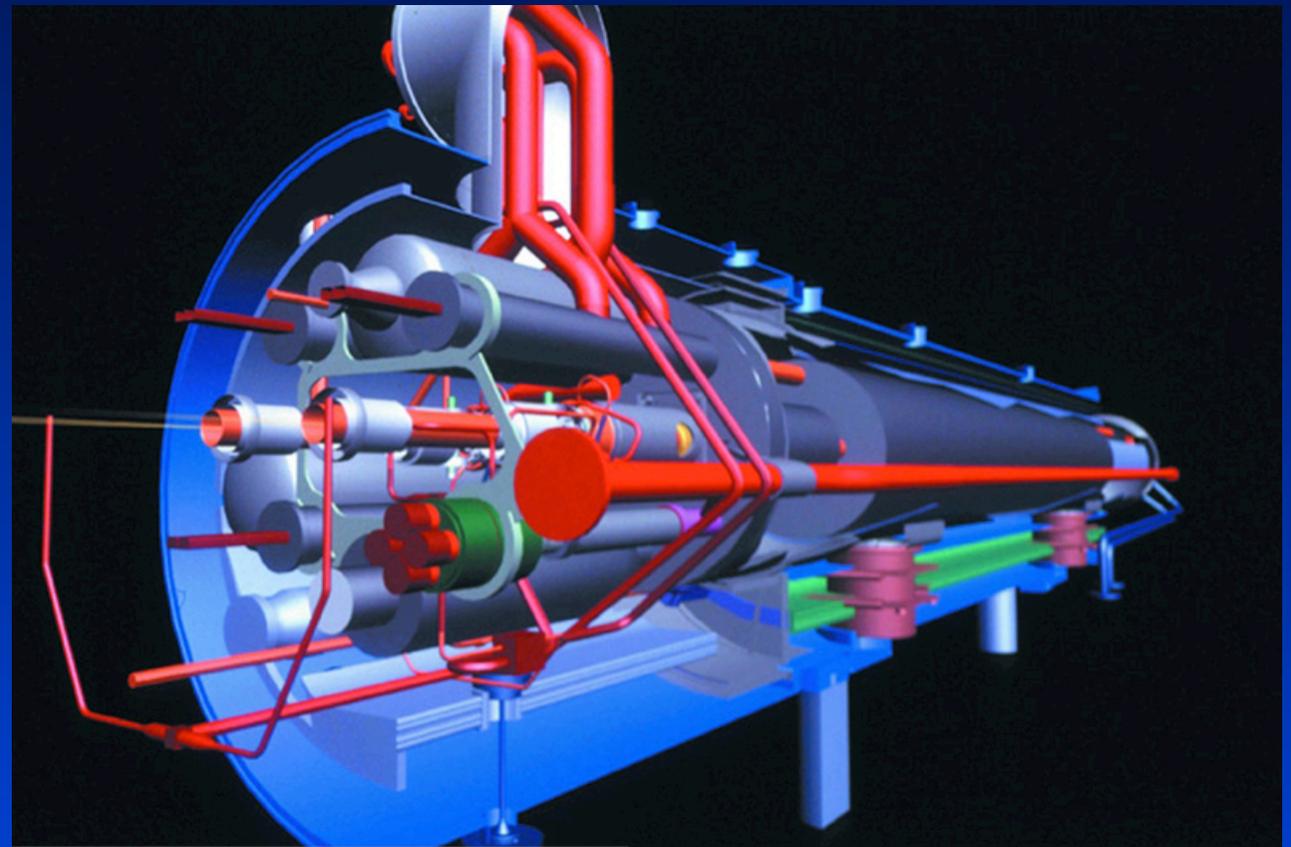
Superfluides Helium: 1.9 K

Max. Magnetfeld

8.33 T

Vakuum

10^{-13} atm
(6500 m³)



Länge: 14.3 m

Gewicht: 35 t

Spulen: Nb-Ti

40,000 vakuum-dichte Verbindungen

96 t Helium

8 Kühlaggregate (18 kW)

2 Wochen Abkühlzeit (36,800 t)



LHC

Beschleuniger-Daten

Endenergie:

Protonen

7 + 7 TeV

Blei-Ionen

575 + 575 TeV

Teilchenzahl:

2808 bunches x 10^{11} Protonen

Kollisionen pro Sekunde:

600 000 000

Strahlenergie

100 Mega Joule

Stromverbrauch

120 MW

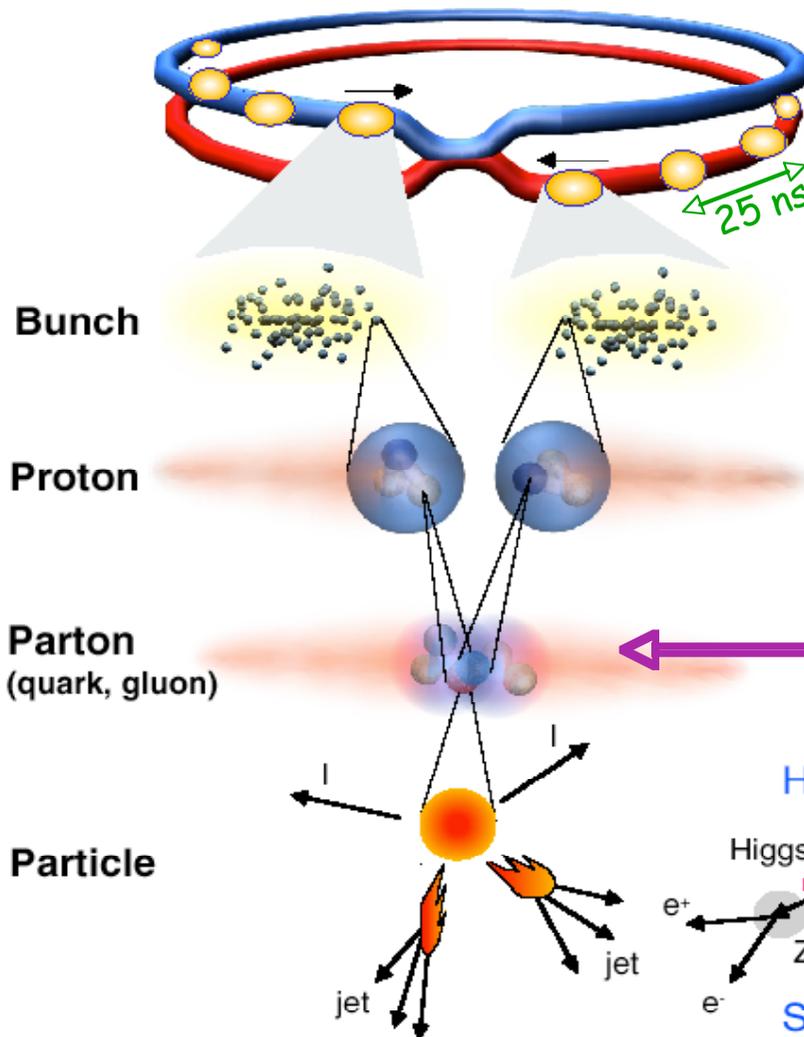


LHC Kosten

LHC Maschine	4 700 Mio CHF
Experimente (CERN-Anteil, ~ 20 %)	1 100 Mio CHF
Datenverarbeitung (CERN-Anteil, ~ 20 %)	250 Mio CHF



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 :

$$N = L \times \sigma (pp) \approx 10^9 \text{ interactions/s}$$

Mostly soft (low p_T) events

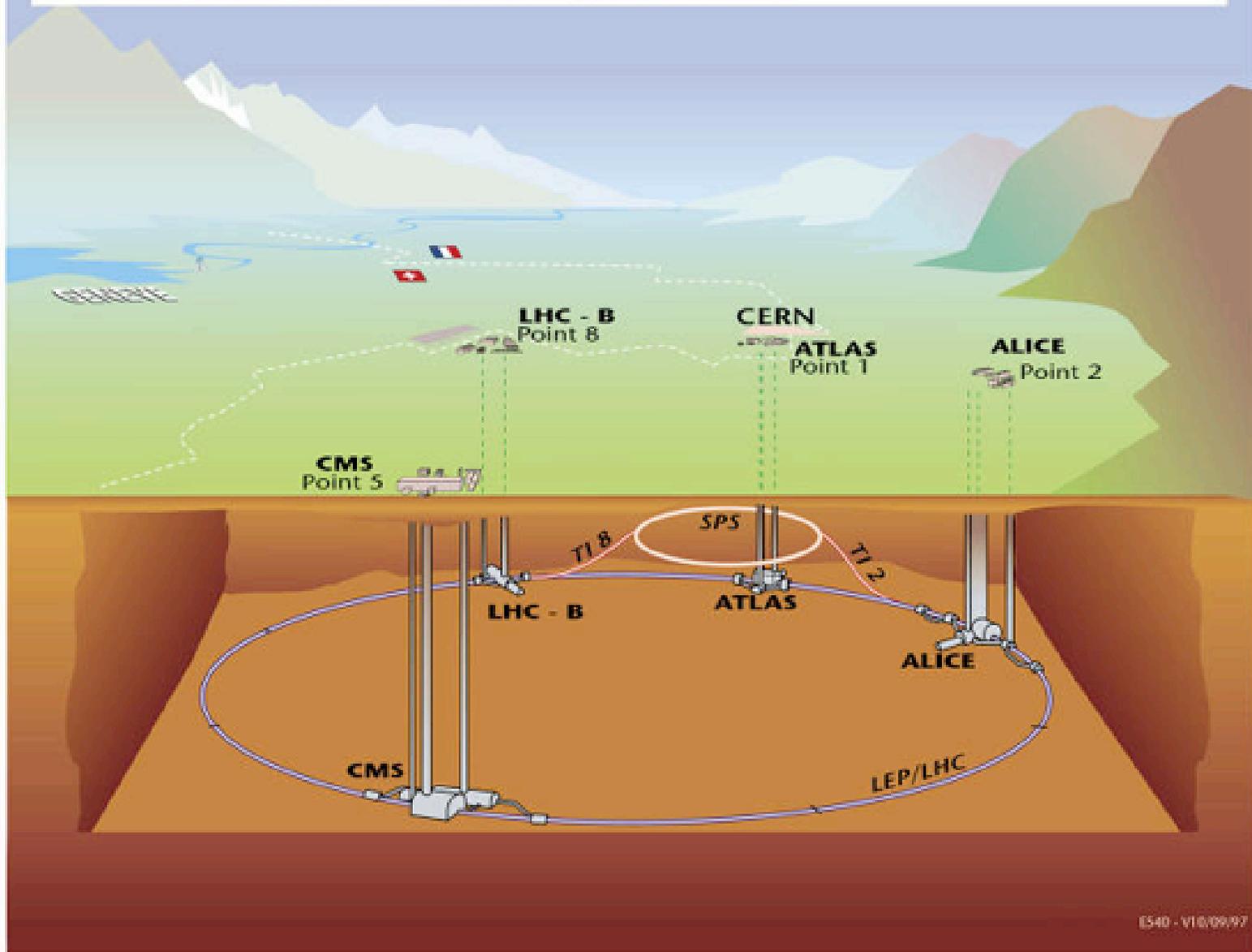
← Interesting hard (high- p_T) events are rare

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



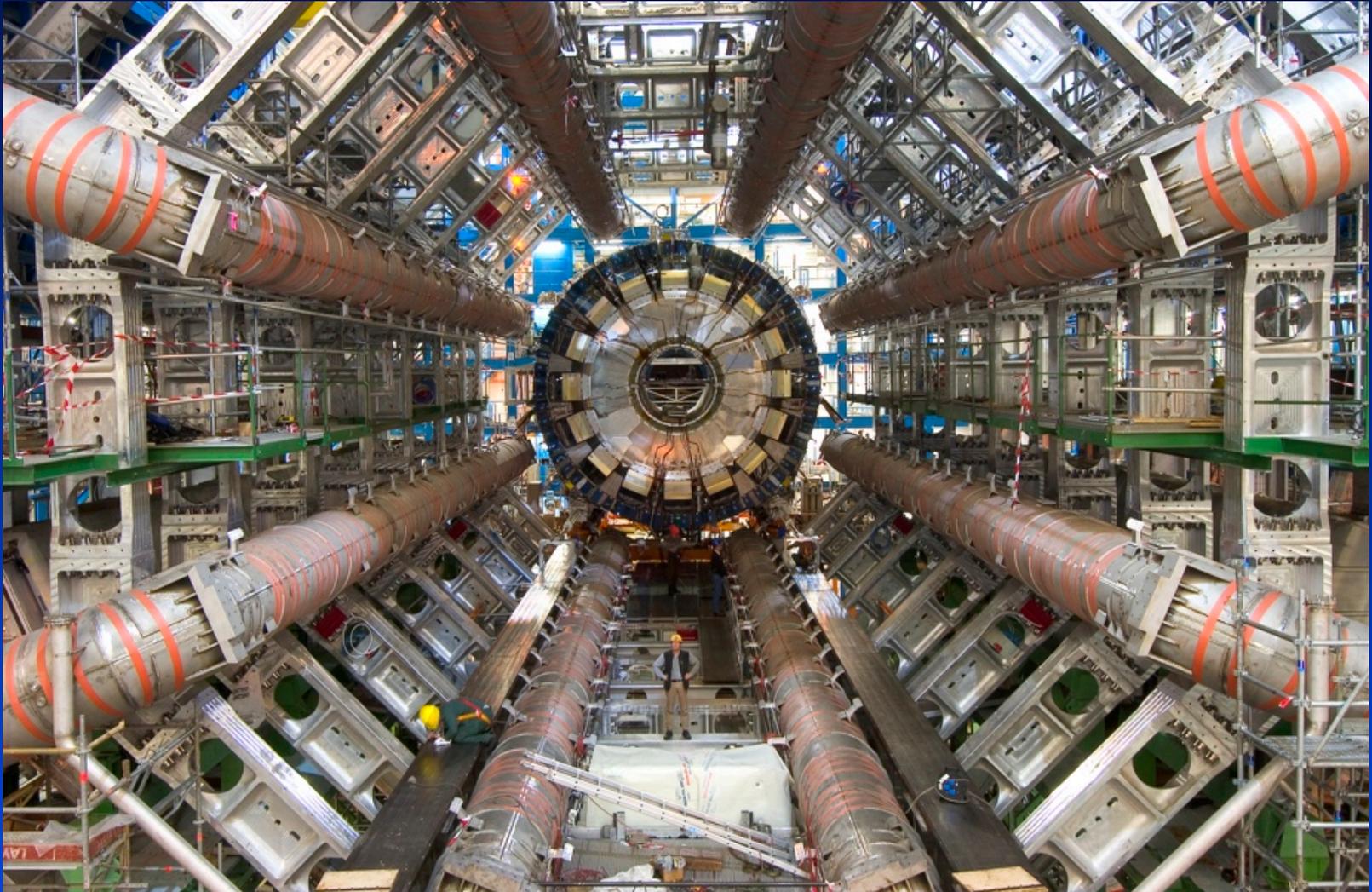
LHC Experiments

Overall view of the LHC experiments.





ATLAS





ATLAS



34 Länder - 2500 Wissenschaftler



ATLAS



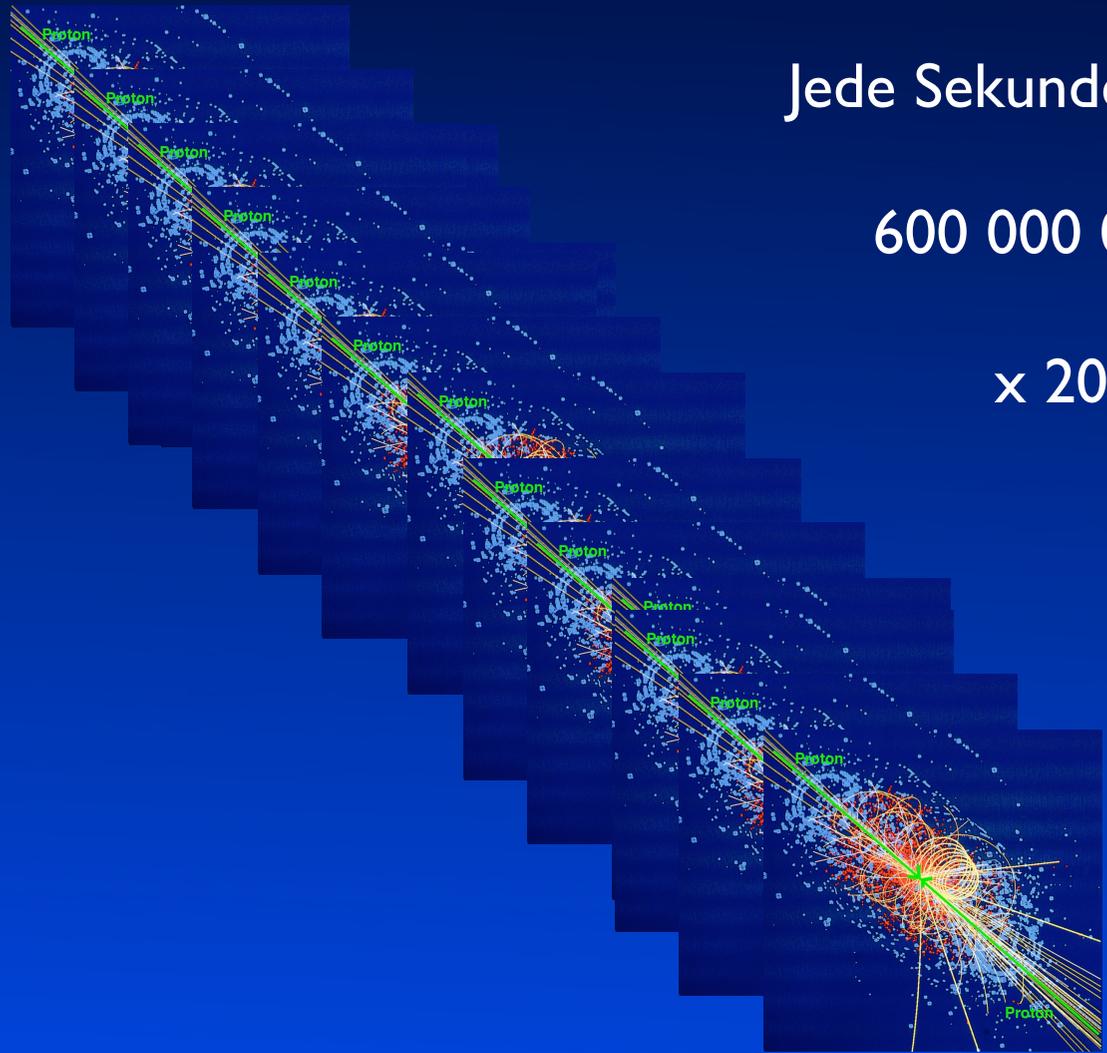


CMS





LHC und die Daten-"Tsunami"



Jede Sekunde -

600 000 000 Ereignisse -

x 20 000 000 Sensoren

Datenfilter

1 : 10 000 000

Datenspeicher

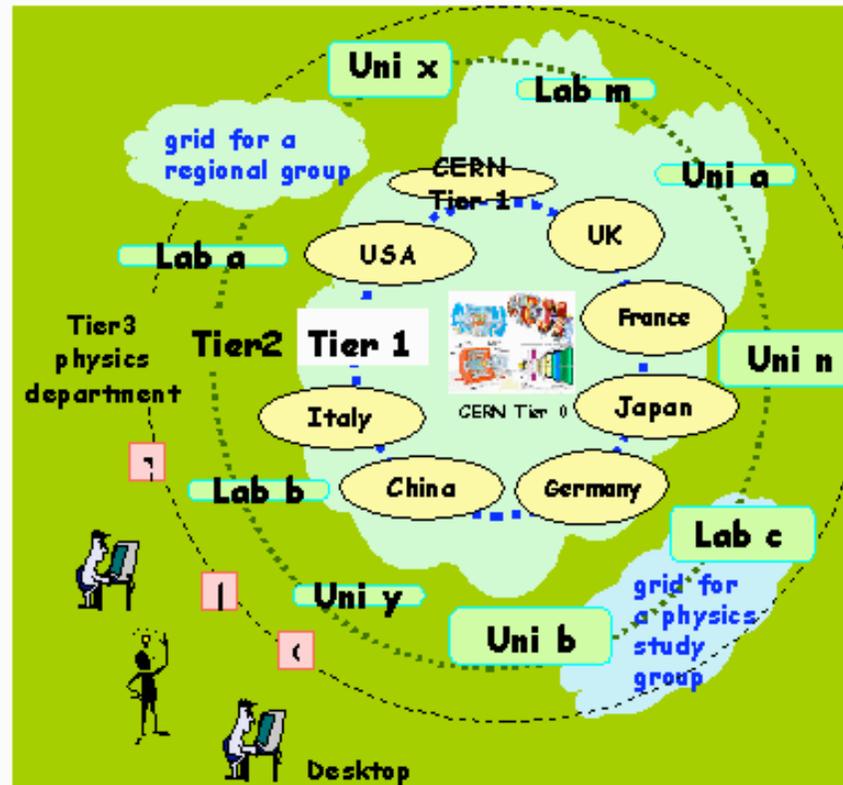
10 000 TB per year
(~ 1% of global information)



GRID



The LHC Computing Grid



16/4/2004

Storage Resource Sharing with CASTOR

4

~10,000 PCs am CERN

~90,000 PCs in LHC Grid-Ländern