The making of . . . *1990 - 2009*

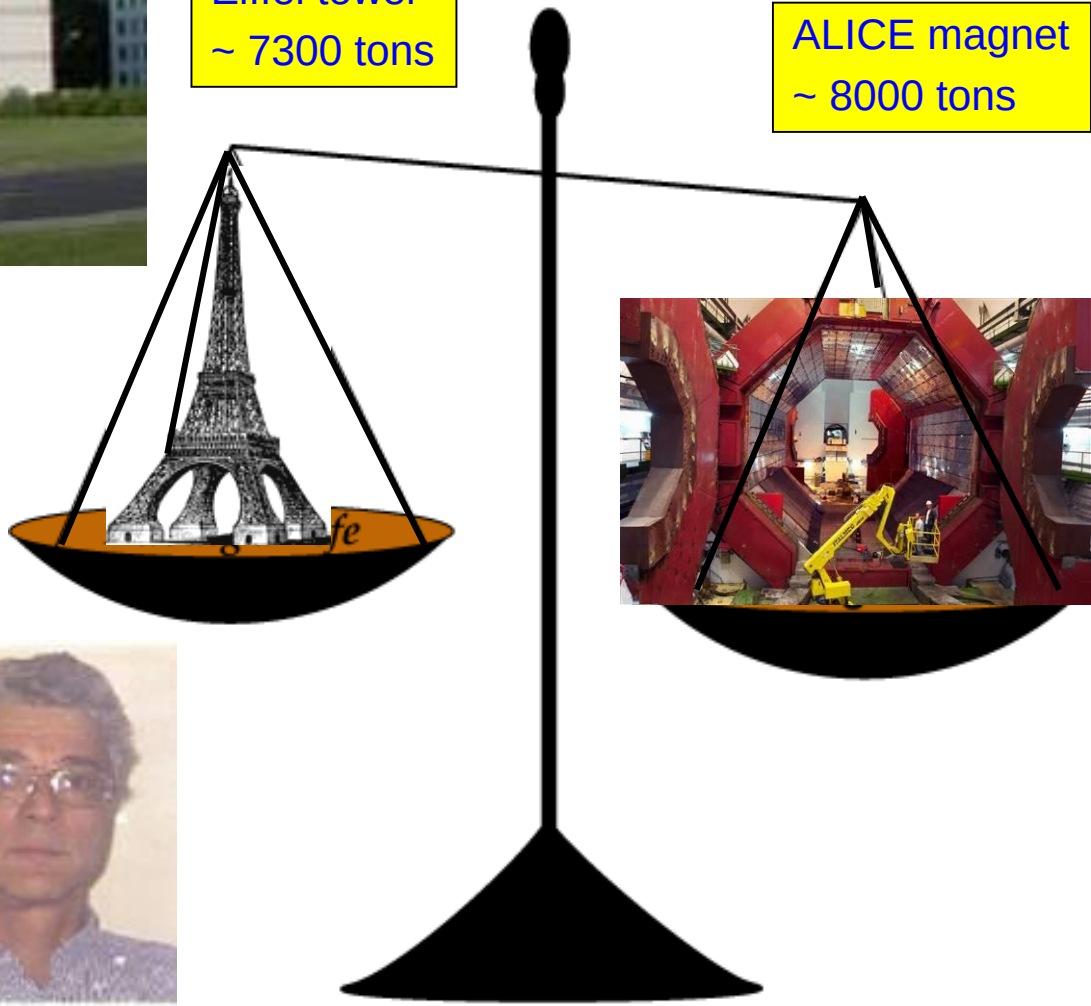
ALICE

A Large Ion Collider Experiment

- **Experiments at LHC are**
  - ⇨ **Big**
  - ⇨ **Heavy**
  - ⇨ **and took a looong time …**

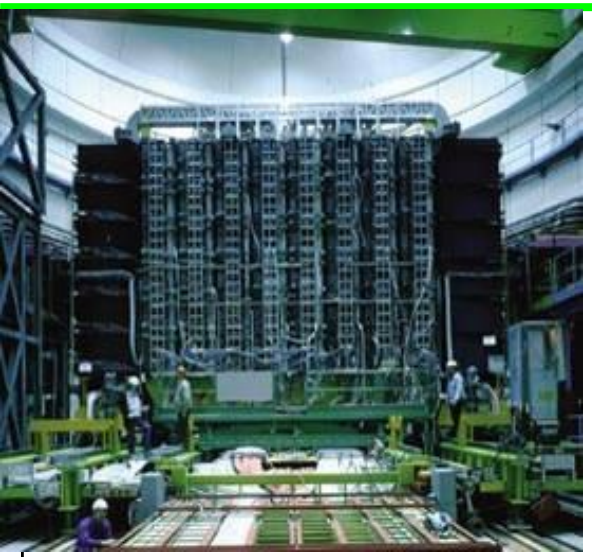
Eiffel tower
~ 7300 tons

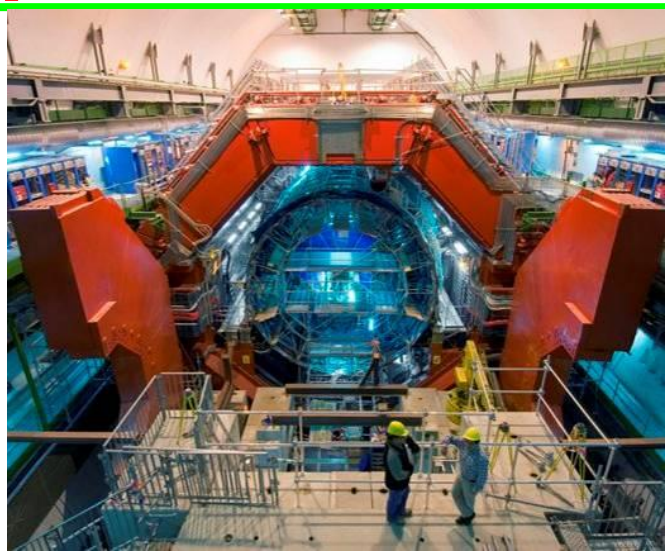
ALICE magnet
~ 8000 tons

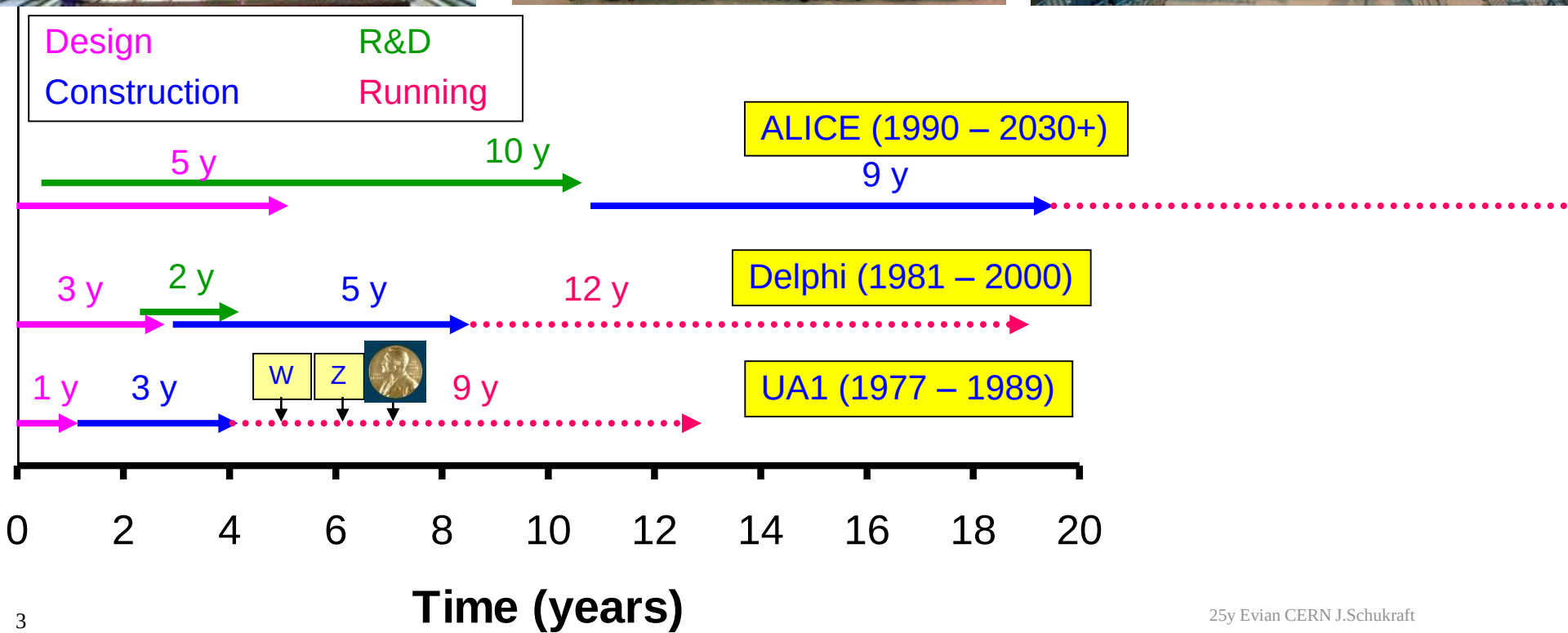


1990 → 2009

The Life of Collider Experiments







The Making of ALICE

- Pre-History
  - ⇨ **1984**: Large **Hadron-Collider** discussed — Lausanne: pp machine in LEP tunnel
  - ⇨ **1986:** start of "Heavy" Ion Physics (Sept 1986) — Light ions, ^{16}O and ^{32}S at SPS/AGS
  - ⇨ **1987:** first mention of LHC as **Large-Hadron** Collider — LRPC La Thuile (large hadron=^{208}Pb)
- Conceptual Studies
  - ⇨ **1990:** RHIC approved fo
    - ✪ call for experiments Lo
  - ⇨ **1990: First ideas** devel

.. LHC is also capable as a collider for heavy ions ..

The physics potential of this possibility has not been considered ..

'Heavy Ion **Collider best p**

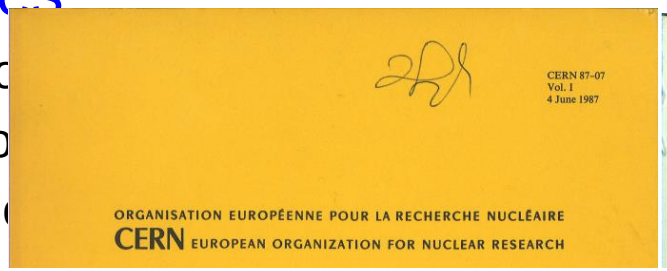
LHC is unique in many resp

✪ Conclusion Experimen

'A **general purpose detecto**

impossible at LHC. Actually,

could be developed'


CERN 87-07
Vol. I
4 June 1987

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

PROCEEDINGS OF THE
WORKSHOP ON
PHYSICS AT FUTURE ACCELERATORS

La Thuile (Italy) and Geneva (Switzerland)
7 – 13 January 1987

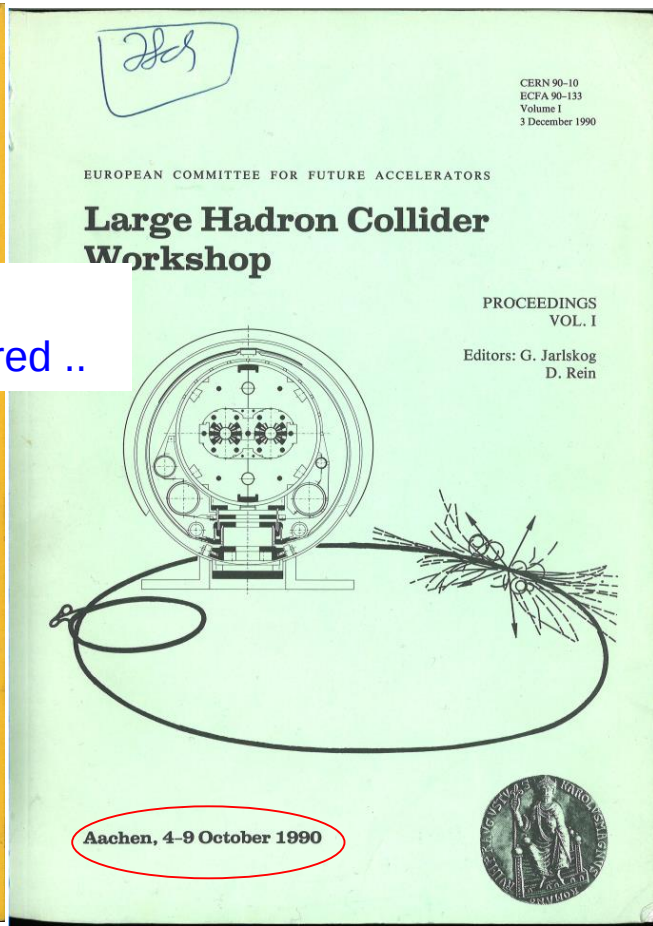
Vol. I

Table 2

Collider parameters

Machine		$\sqrt{s}$ (TeV)	L ($cm^{-2} s^{-1}$)
LHC	pp	16	$10^{33} \rightarrow 10^{34}$
	ep	1.3	10^{32}
		1.8	10^{31}
CLIC	e^+e^-	2	$10^{33} \rightarrow 10^{34}$

The LHC is also capable of being used as a collider for heavy ions; for example, collisions of oxygen nuclei could be obtained at a centre-of-mass energy of 128 TeV and a luminosity of 2.5×10^{26} $cm^{-2} s^{-1}$ with the present injection system, and improvements could give heavier ions and higher luminosities. The physics potential of this possibility has not been considered, neither has fixed-target operation; and no further thought has been given to the


CERN 90-10
ECFA 90-133
Volume I
3 December 1990

EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS

Large Hadron Collider Workshop

PROCEEDINGS
VOL. I

Editors: G. Jarlskog
D. Rein

Aachen, 4–9 October 1990

First "ALICE" meeting, 27 years ago..

Minutes of the 1st meeting on heavy ion / pp min. bias physics at LHC

The following is a short summary of the presentations and discussions taking place during the first meeting on a Heavy-Ion-Experiment at LHC held on Thursday, 13.12 1990 at CERN. The intention of this meeting was to initiate a serious experimental effort towards a heavy ion detector capable of measuring ultra-relativistic heav attended by over 60 physicists. Copies of the transparencies and other related material will be send to the participants as annex to these minutes by mail.

experimental areas will be finalized by end '91

- The design of the experimental areas will be finalized by end '91. The overall lay-out of an experiment should exist by then, if the caverns are to be built as well as the need for a Letter of Intent by end

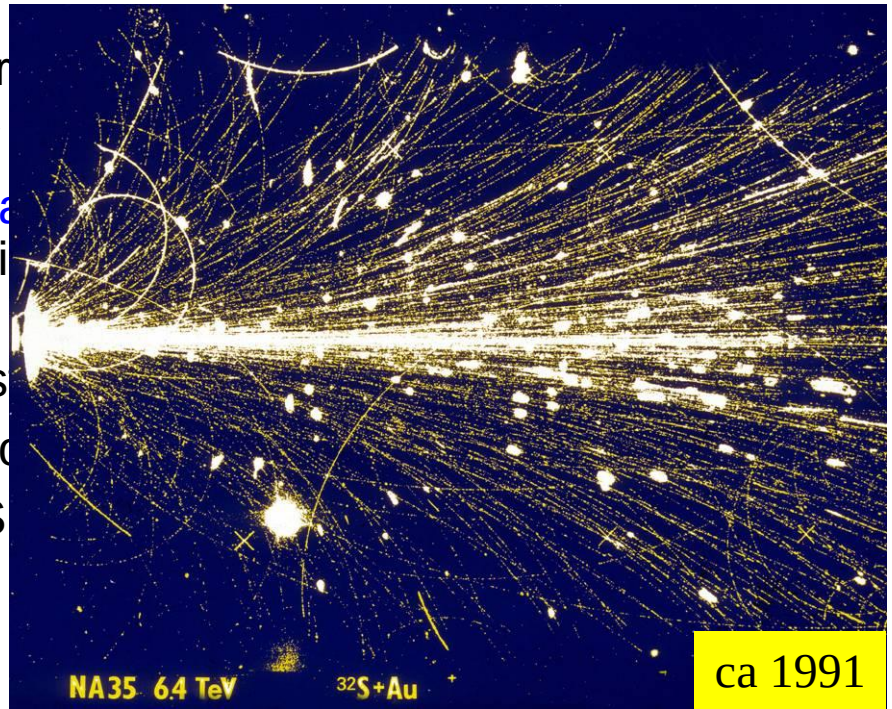
start of physics operation foreseen for 1998

schedule of the LHC, i.e. even if the start of physics operation, presently foreseen for 1998, should slip somewhat, the extra time will be used to stretch the construction schedule of the machine (and the detectors) rather then to delay the start of construction

.. should it slip, we stretch the construction schedule ..

Challenges

- Challenges for the Heavy Ion community in early '90's
  - ⇨ huge extrapolation from SPS to LHC (^{32}S at 20 GeV -> ^{208}Pb at 5500 GeV)
    - ✪ **x 7** in mass, **x 300** in energy (3 GeV Adone -> 1 TeV e^+e^- ILC)
    - ✪ => large uncertainties in what to expect (e.g. 2000 < dN_{ch}/dy < 8000)
  - ⇨ limited experience in building large detectors
    - ✪ 'pilot' detectors (1986- 1990) assembled largely from existing detectors (Bevalac, ISR, CERN fixed target expts, ...)
  - ⇨ no previous example of a truly 'general pur
    - ✪ AGS/SPS/RHIC: several complementary
    - ✪ significant conceptual (& sociological) cha all observables & people in a si
  - ⇨ resources (money and people) incredibly s
    - ✪ ongoing data analysis of SPS light ion pr
    - ✪ building 2nd generation experiments for S
    - ✪ RHIC approved in 1990, dedicated to HI,
    - ✪ **little left for LHC preparations…**



ca 1991

Detector Design Criteria

- Experimental Constraints & Solutions

⇨ **extreme particle density** ($dN_{ch}/d\eta$ ~ 2000 – 8000)

✪ high **granularity**, **3D**(x,y,z) detectors, large **distance** to vertex

e.g. emcal at **4.5 m** (typical is 1-2 m !)

⇨ **large dynamic range** in p_t: from very soft (**0.1 GeV**) to fairly hard (**100 GeV**)

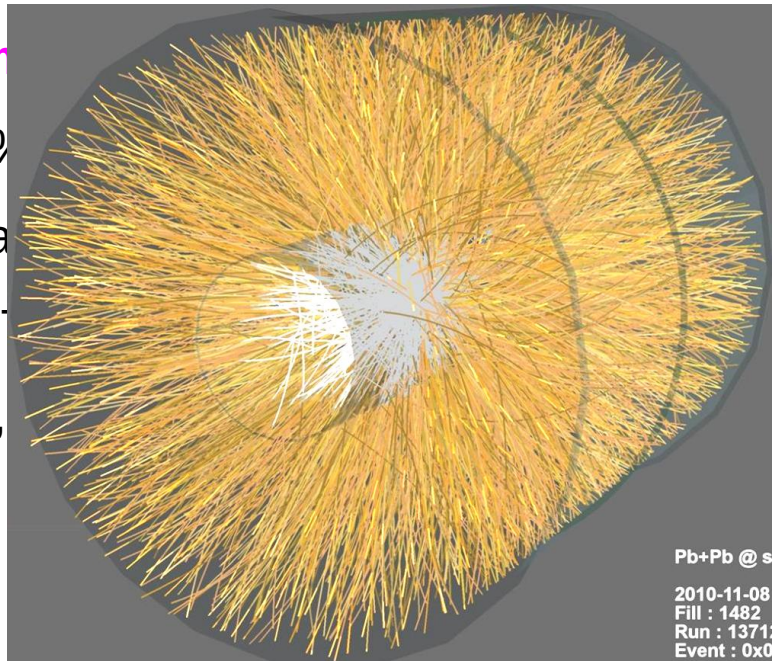
✪ **thin** det, **modest field** (low p_t), large **lever arm**

ALICE: **< 10%X_0** in r < 2.5 m (typical is 50-100%

⇨ both **partons & hadrons** matter: hadrons are pa

✪ **PID**: use of essentially all known technologies (T

dE/dx (gas + silicon), Cherenkov & transition rad., topological reconstruction



⇨ **modest** Luminosity and interaction **rates**

✪ allows slow detectors (TPC, SDD), moderate radiation hardness

The Making of ALICE

- Pre-History
  - ⇨ **early 80's**: LHC first discussed
  - ⇨ **1986:** start of Heavy Ion Physics at SPS & AGS
  - ⇨ **1990:** RHIC approved
- Conceptual Studies
  - ⇨ **1990: First ideas** developed for HI@LHC (Aache

⇨ **1992: Expression of Interest** (Evian)

- ✪ 1) **modified LEP experiment** (Delphi): **impossible**
- ✪ 2) **pp experiment** (CMS): **seemed promising**

  in particular for hard probes

  => **Atlas** & **CMS** heavy ion groups
- ✪ 3) **dedicated** general purpose **HI detector**

  => **ALICE**

First slide of H.I. Evian presentation

Expression of Interest
for a dedicated heavy ion experiment
at the LHC

R. Boskovic Institute, *Zagreb*, **Croatia**
Inst. of Exp. Physics, Slov. Acad. of Science, *Kosice*, **CSFR**
Physics Inst., Czech. Acad. of Science, *Prague*, **CSFR**
IPN, *Lyon*, **France**
Lab. de Phys. Corpusculaire, College de France, *Paris*, **France**
CRN, CNRS-IN2P3 & Univ. of *Strasbourg*, **France**
G.S.I., *Darmstadt*, **Germany**
Inst. für Kernphysik, Univ. of *Frankfurt*, **Germany**
Phys. Dept., Univ. of *Giessen*, **Germany**
Phys. Dept., Univ. of *Heidelberg*, **Germany**
Phys. Dept., Univ. of *Marburg*, **Germany**
MPI-Physik, *München*, **Germany**
Phys. Dept., Univ. of *Münster*, **Germany**
Phys. Dept., University of *Athens*, **Greece**
Variable Energy Cyclotron Centre, *Calcutta*, **India**
Weizmann Inst., Dept. of Physics, *Rehovot*, **Israel**
Phys. Dept., University and INFN, *Bari*, **Italy**
Phys. Dept., University and INFN, *Catania*, **Italy**
Phys. Dept., University and INFN, *Padova*, **Italy**
Phys. Dept., University la Sapienza and INFN, *Roma*, **Italy**
Phys. Dept., University and INFN, *Torino*, **Italy**
NIKHEF, *Amsterdam*, the **Netherlands**
Univ. of *Utrecht* (RUU), the **Netherlands**
Univ. of *Bergen*, **Norway**
Inst. of Nucl. Physics, HEP Lab., *Cracow*, **Poland**
JINR, *Dubna*, **Russia**
INR, *Moscow*, **Russia**
ITEP, *Moscow*, **Russia**
Kurchatov Inst., *Moscow*, **Russia**
C.I.E.M.A.T *Madrid*, **Spain**
Div. of Cosmic and Subatomic Phys., Univ of *Lund*, **Sweden**
CERN, *Geneva*, **Switzerland**
Phys. Dept., Univ. of *Geneva*, **Switzerland**
Phys. Dept., University of *Birmingham*, **U.K**

Early Designs

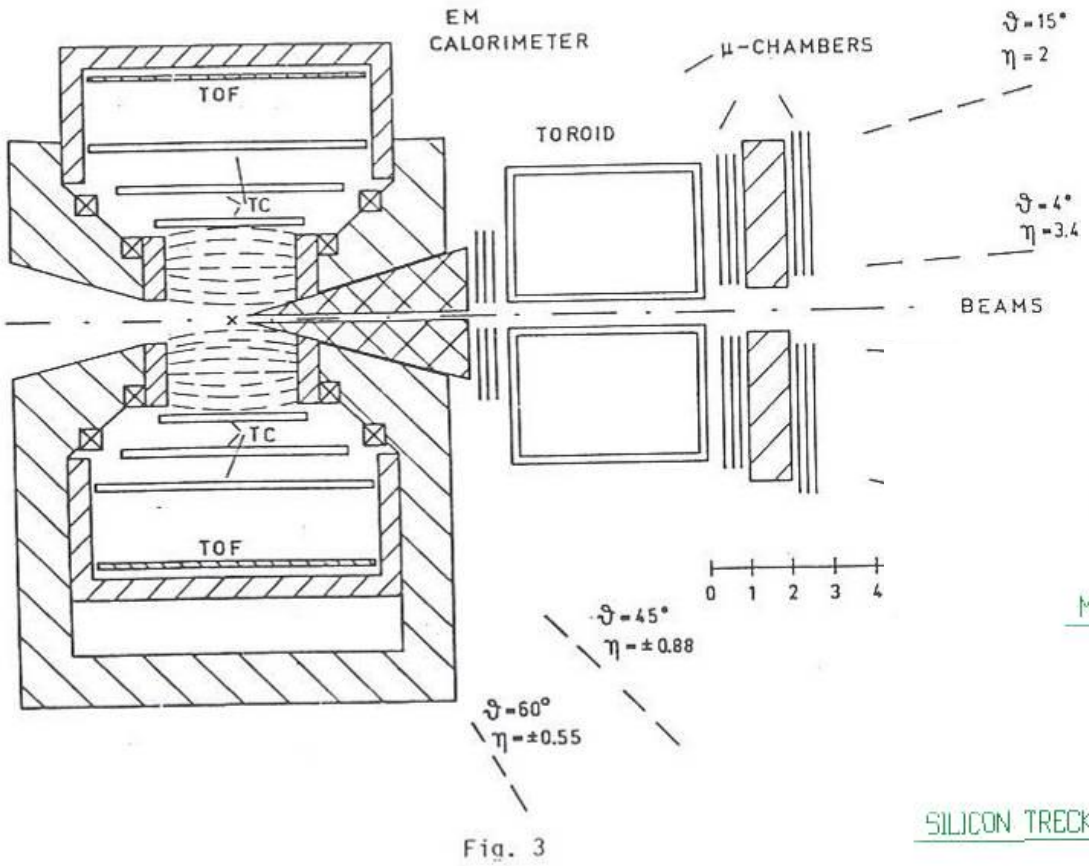
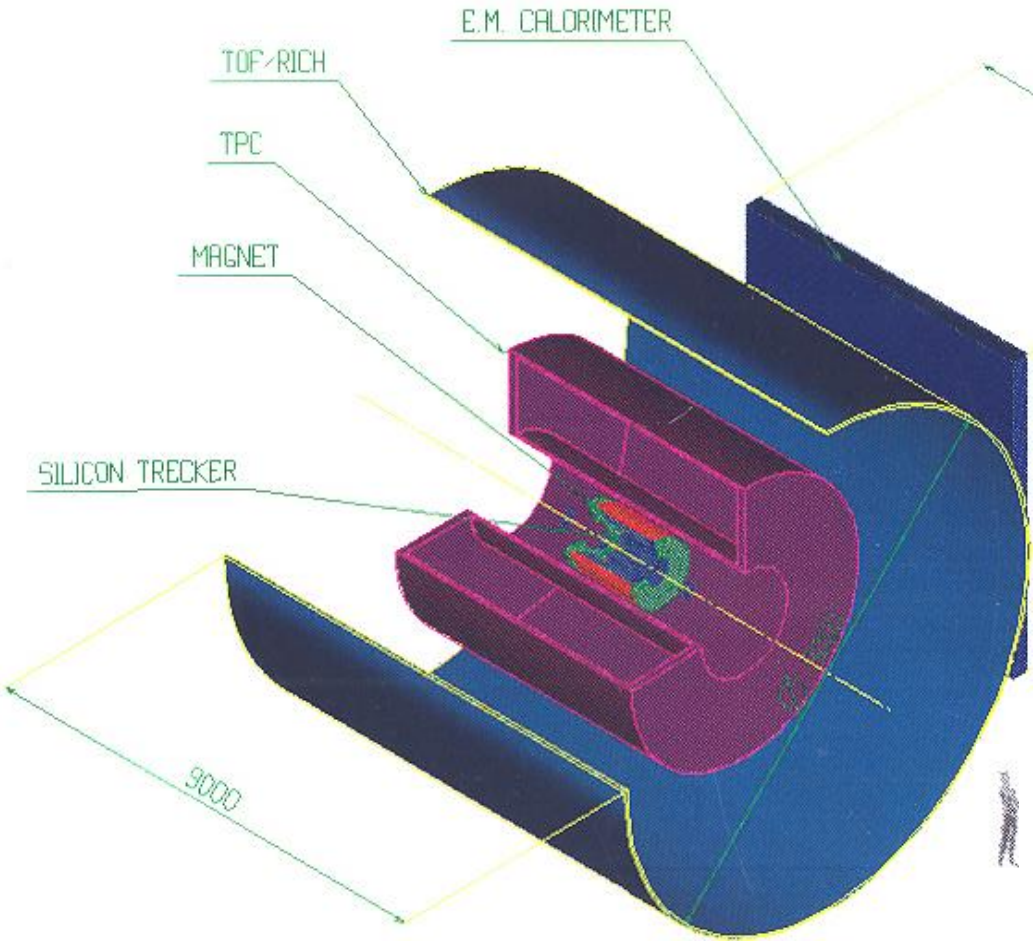


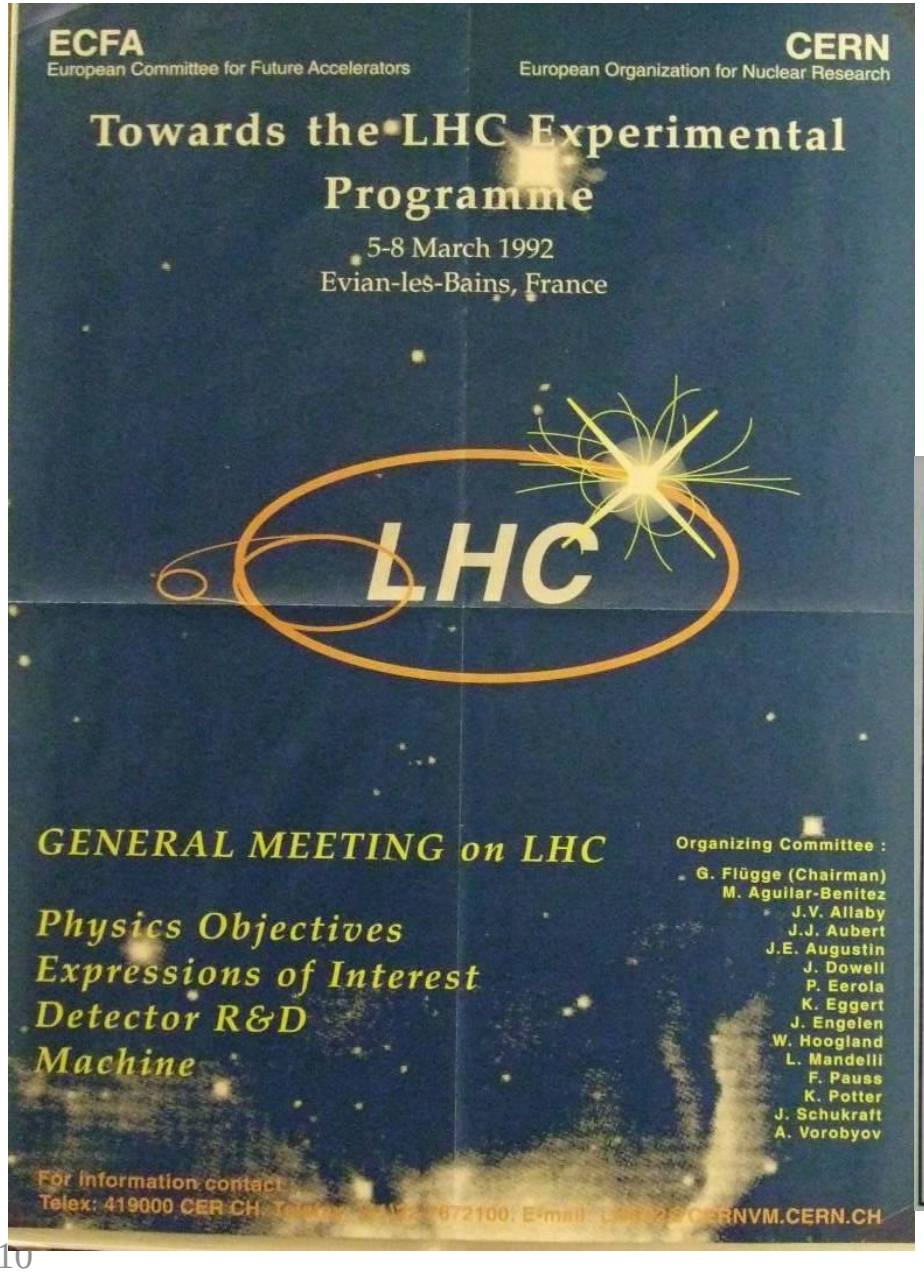
Fig. 3

1992 Design (Evian)
no muons
thin (<17%X_0) and small **solenoid**



1990 Design (Aachen)
open axial field **magnet**
(AFS/ISR, + NA38 muons)

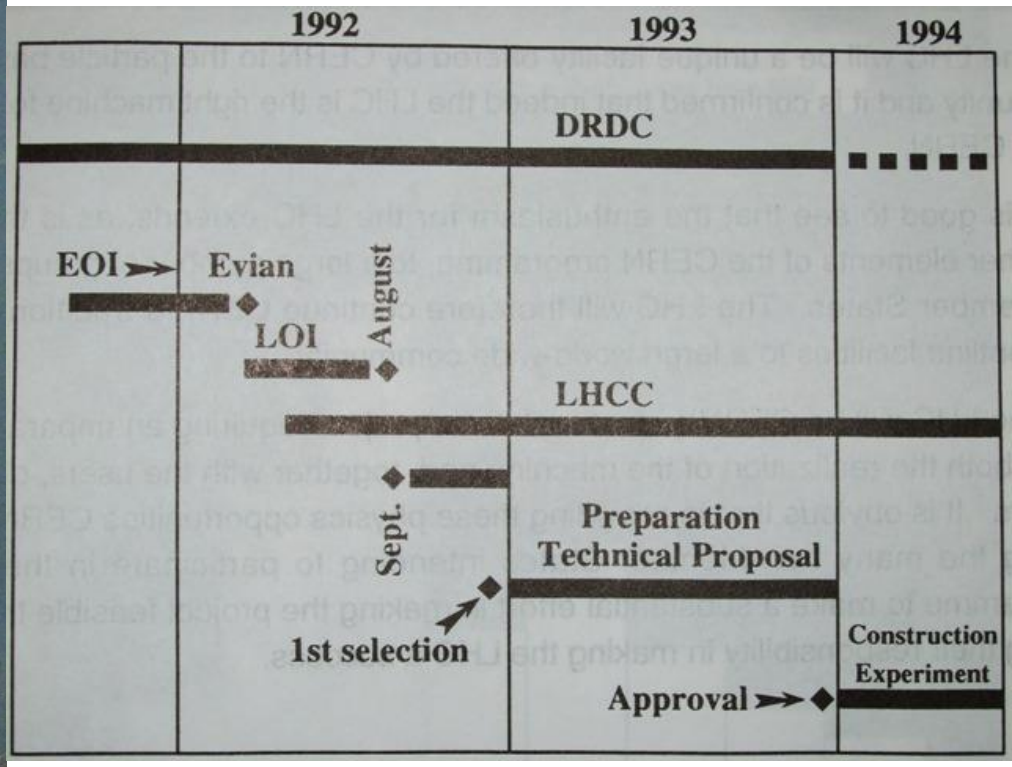
Evian Workshop 1992



Summary by C. Rubbia:

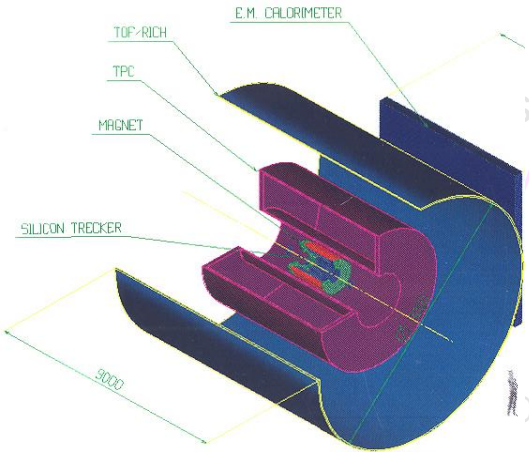
Construction: '94

1st beam: '98



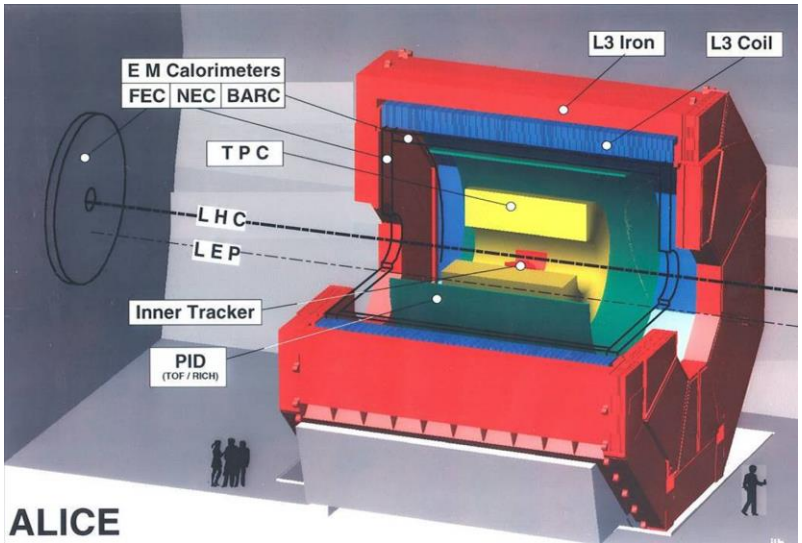
The Making of ALICE

- Pre
  - ⇨ ear … ;ed
  - ⇨ 198 … ysics at SPS & AGS
  - ⇨ 199
- Cor
  - ⇨ 199 … l (Aachen)
  - ⇨ 1992: Expression of Interest (Evian)

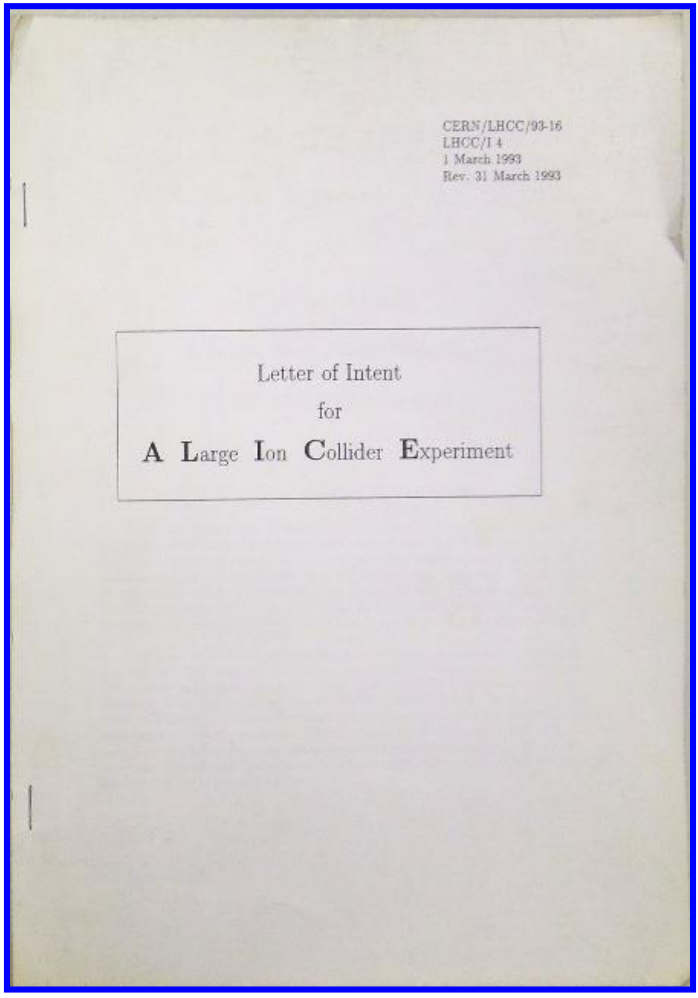


- **Design** and R&D
  - ⇨ **1993: Letter of Intent** (central detector)

230 people, 42 Inst.



"A Large Ion Collider Experiment"


CERN/LHCC/93-16
LHCC/I 4
1 March 1993
Rev. 31 March 1993

Letter of Intent
for
A Large Ion Collider Experiment

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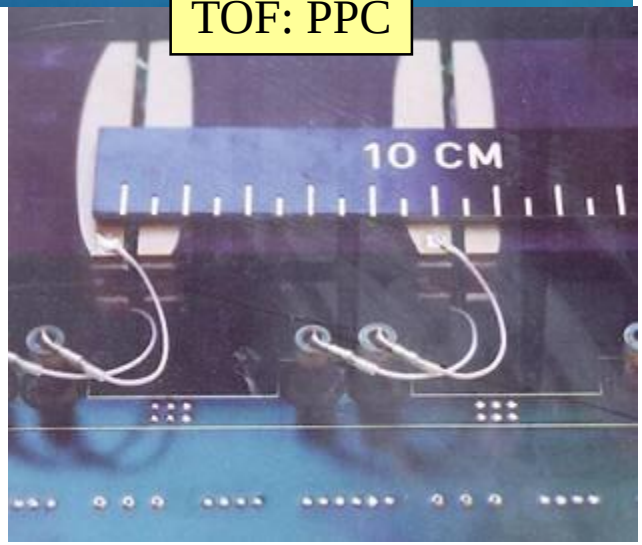
  - ⇨ **1992: Expression of Interest** (Evian)
- Design and **R&D**
  - ⇨ **1993: Letter of Intent**
  - ⇨ **1990 – 2002+: Detector R&D**



ALICE R&D

1990-2002+:Strong, well organized, well funded LHC R&D

Inner Tracking System (ITS)

- Silicon Pixels (RD19)
- Silicon Drift (INFN/SDI)
- Silicon Strips (double sided)
- low mass, high density interconnects
- low mass support/cooling

RHIC RHIC

PID particle Identification

- Pestov Spark counters
- Parallel Plate Chambers
- Multigap RPC's (LAA)
- low cost PM's
- CsI RICH (RD26)

RHIC RHIC

TPC

- gas mixtures (RD32)
- new r/o plane structures
- advanced digital electronics
- low mass field cage

RHIC

DAQ & Computing

- scalable architectures with COTS
- high perf. storage media
- GRID computing

em calorimeter

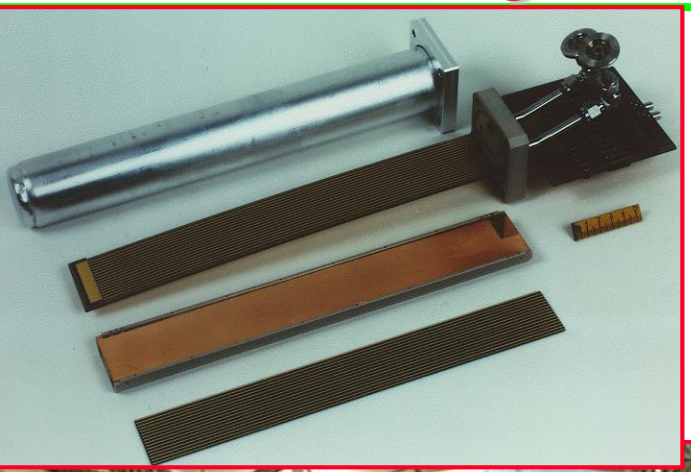
- new scint. crystals (RD18)

misc

- micro-channel plates
- rad hard quartz fiber calo.
- VLSI electronics

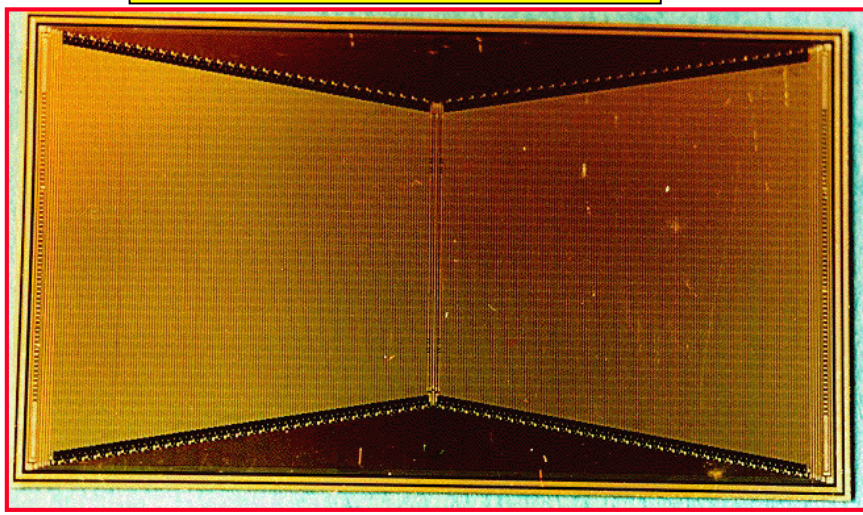
• **R&D made effective use of long (frustrating) wait for LHC**
• **was vital for all experiments to meet LHC challenge !**

Early Prototypes (1991-1998)



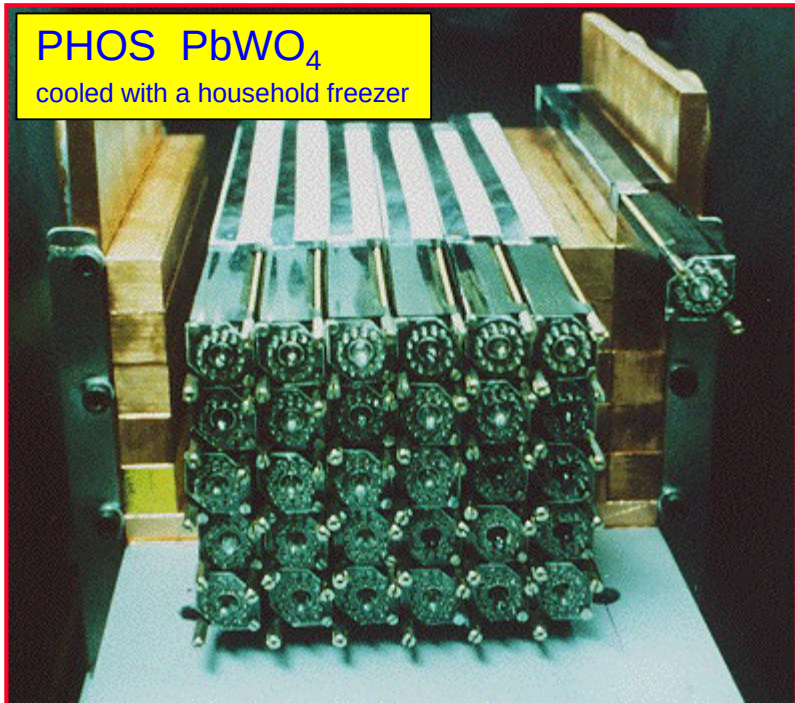
Pestov TOF

Silicon Drift Detector SDD



1998: TPC FC proto (1:2.5)

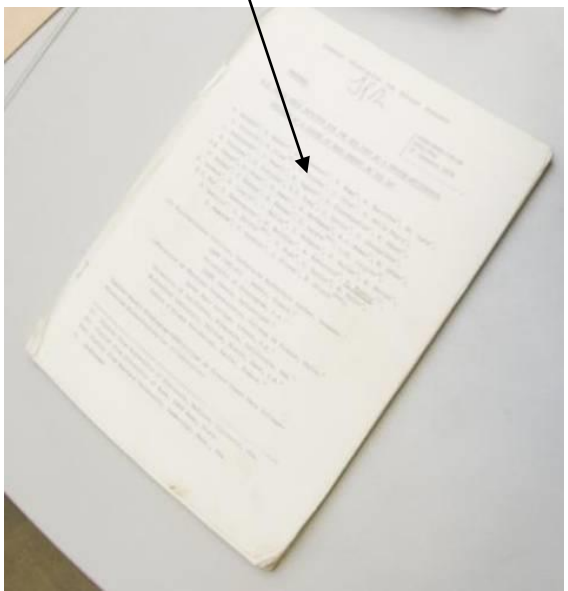
PHOS $PbWO_4$
cooled with a household freezer



Paper and Committee work..

UA1 proposal (154 p.)
sub. Jan '78, approved June '78

Delphi LoI, TP, 7 Addenda (500 p.)



Alice:
EoI
LoI + 1 Add
TP + 3 Add
13 TDR's + 4 Add
3 Vol PPR

4586 p.

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  - ⇨ **1992: Expression of Interest** (Evian)
- **Design and R&D**
  - ⇨ **1993: Letter of Intent**
  - ⇨ **1990 – 2002+: Detector R&D**
  - ⇨ **1995-2008**: **Technical Proposals & Technical Design Reports**
- **Construction & Installation & Comissioning**
  - ⇨ **2000 – 2007:** Bulk of construction
  - ⇨ **2002 – early 2008:** Installation
  - ⇨ **2007 – 2009:** detector commissioning in situ

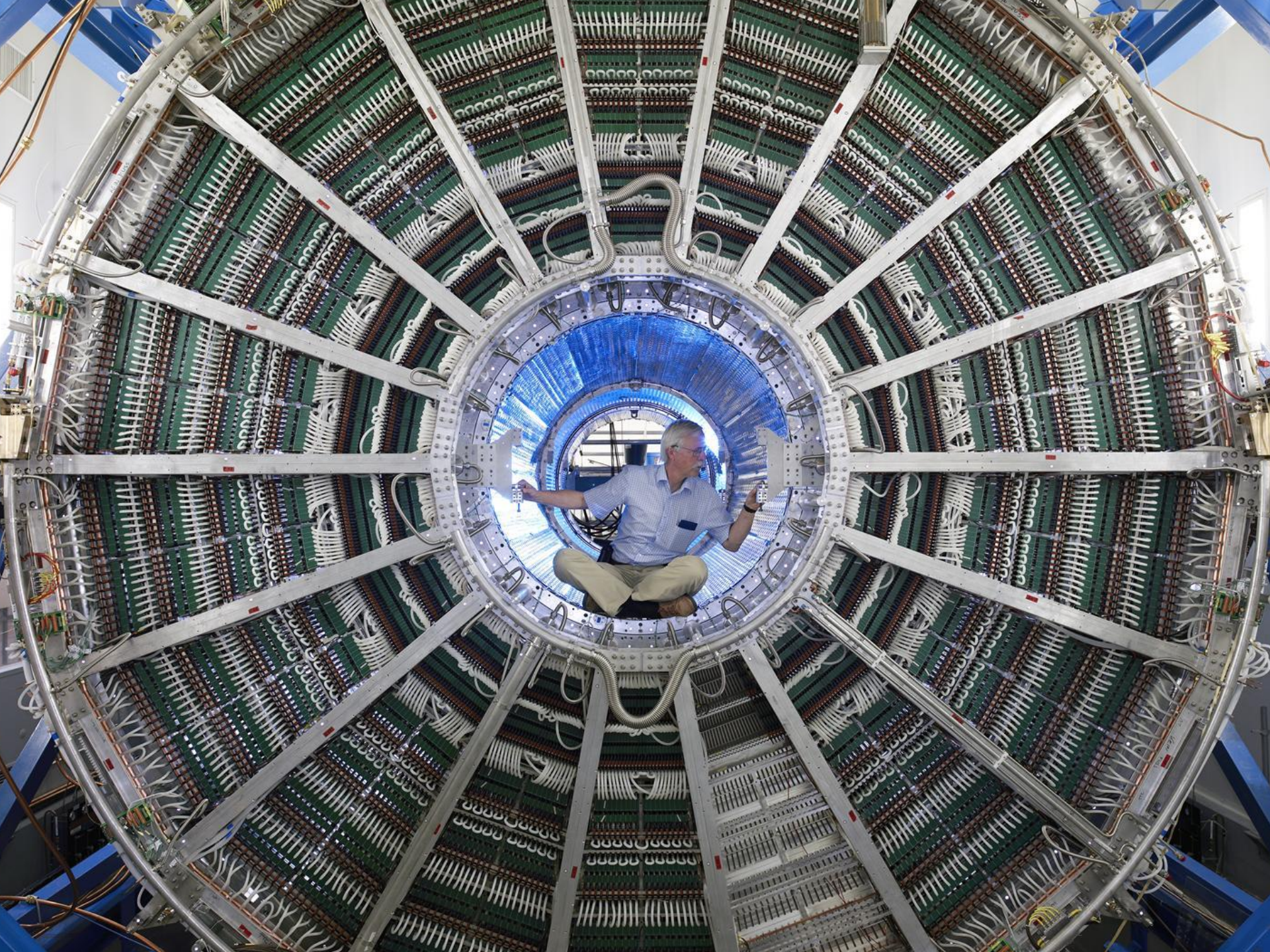
finished only in 2010/11 (TRD/EMCAL)

Spring Cleaning in 2001

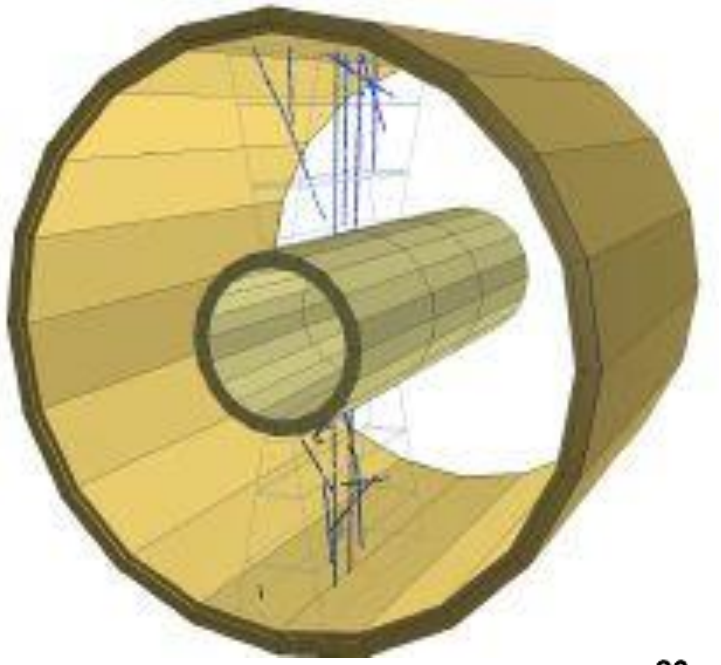

The ALICE
magnet end 2001:
ready for the experiment to move in!

TPC

2002-2006: ~ 5 years of
TPC Construction & Assembly
single unique piece, 'artisan' production

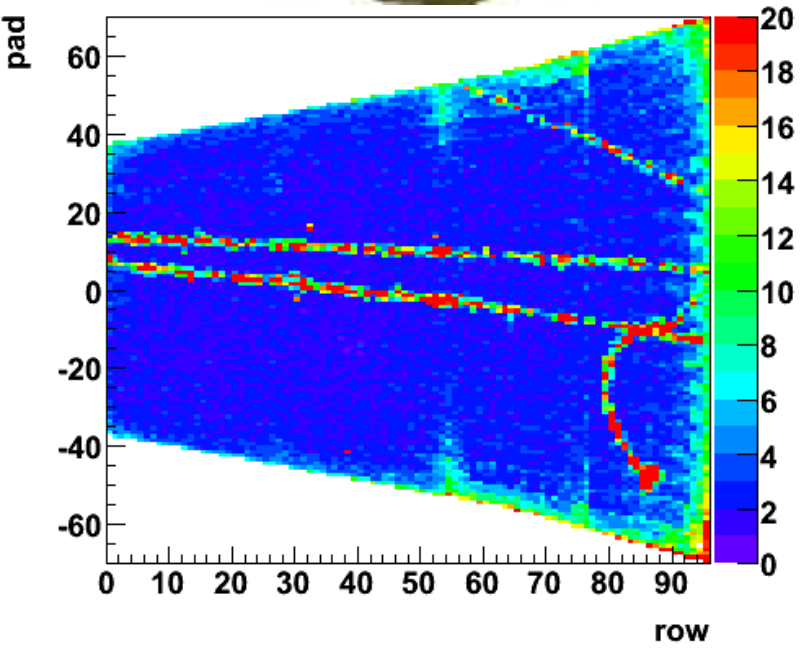


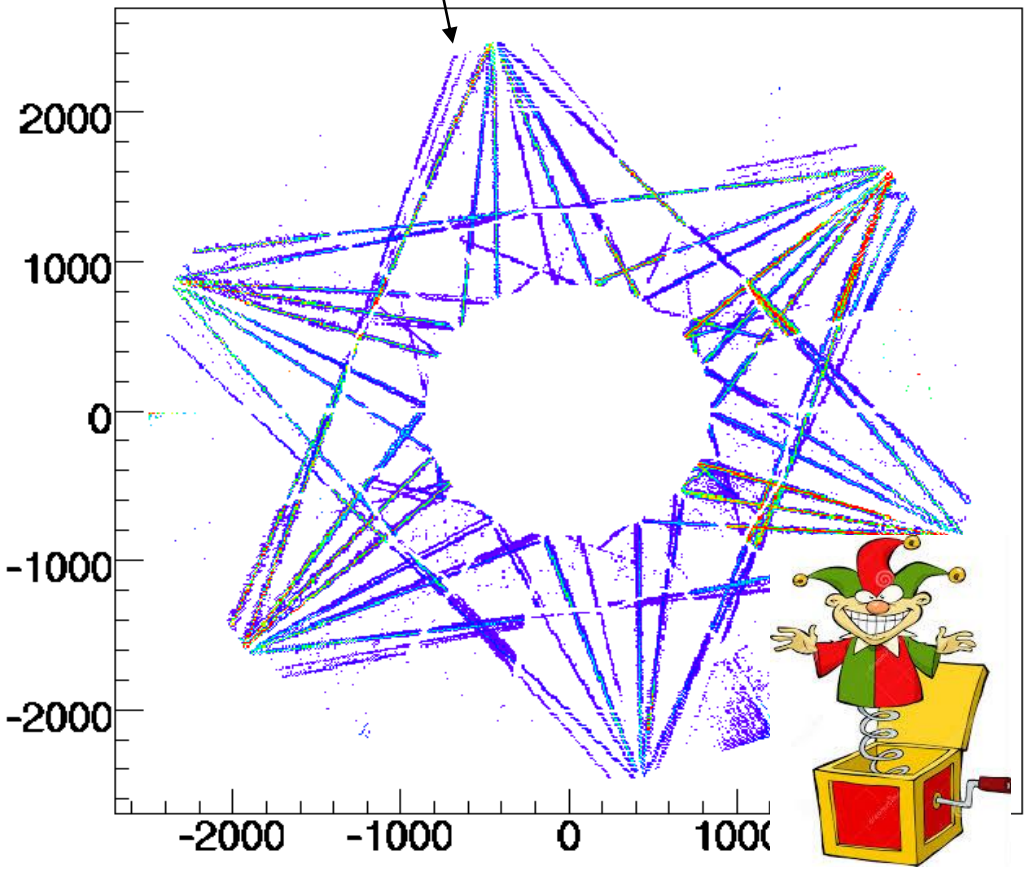
First TPC Tracks

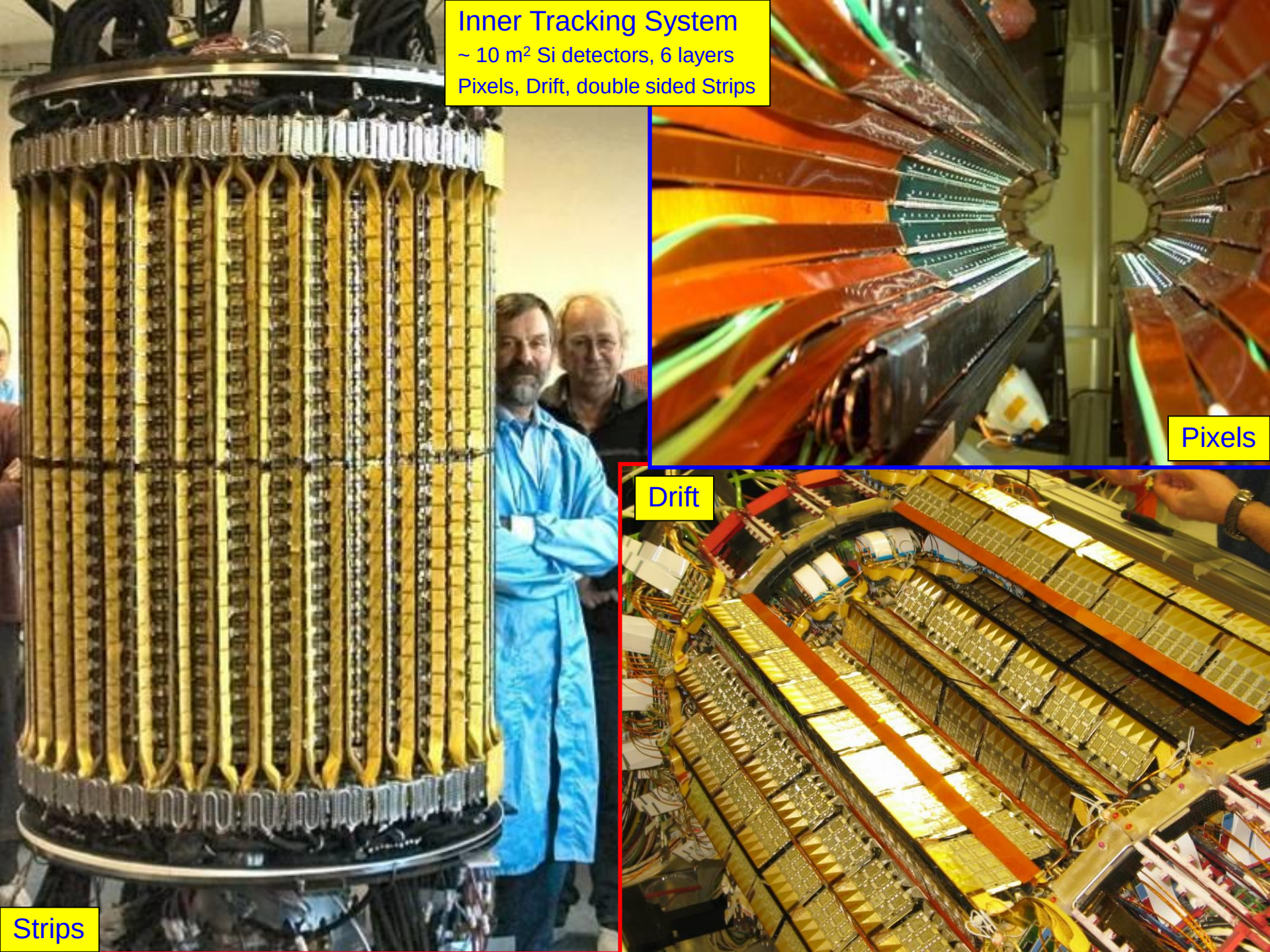


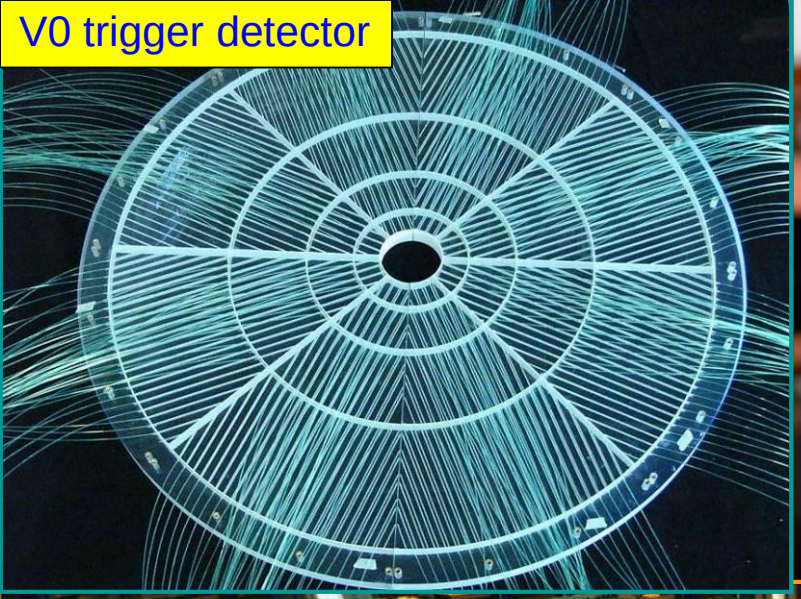
16 May 2006

First cosmic and laser tracks !

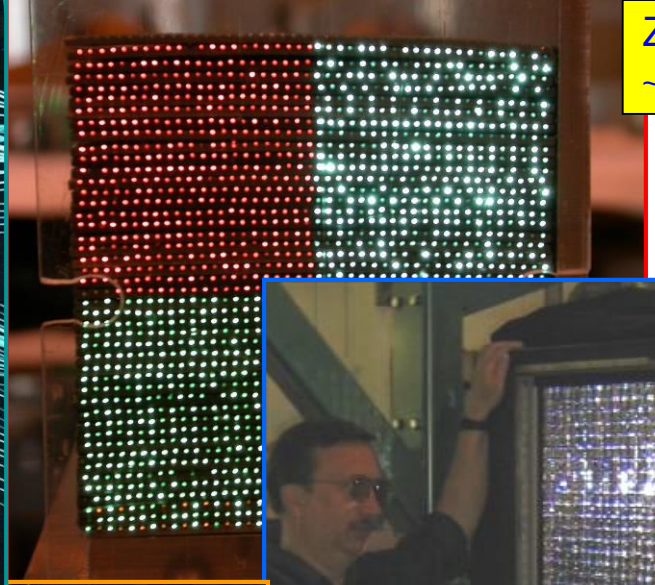





Inner Tracking System
~ 10 m² Si detectors, 6 layers
Pixels, Drift, double sided Strips
Pixels
Drift
Strips



V0 trigger detector



Zero Degree Calorimeter

~ 100 m in the machine tunnel

PHOS module

~ 20,000 $PbWO_4$ crystals

TOF strip production

~ 150 m^2, 150,000 channels

Muon Magnet Coils

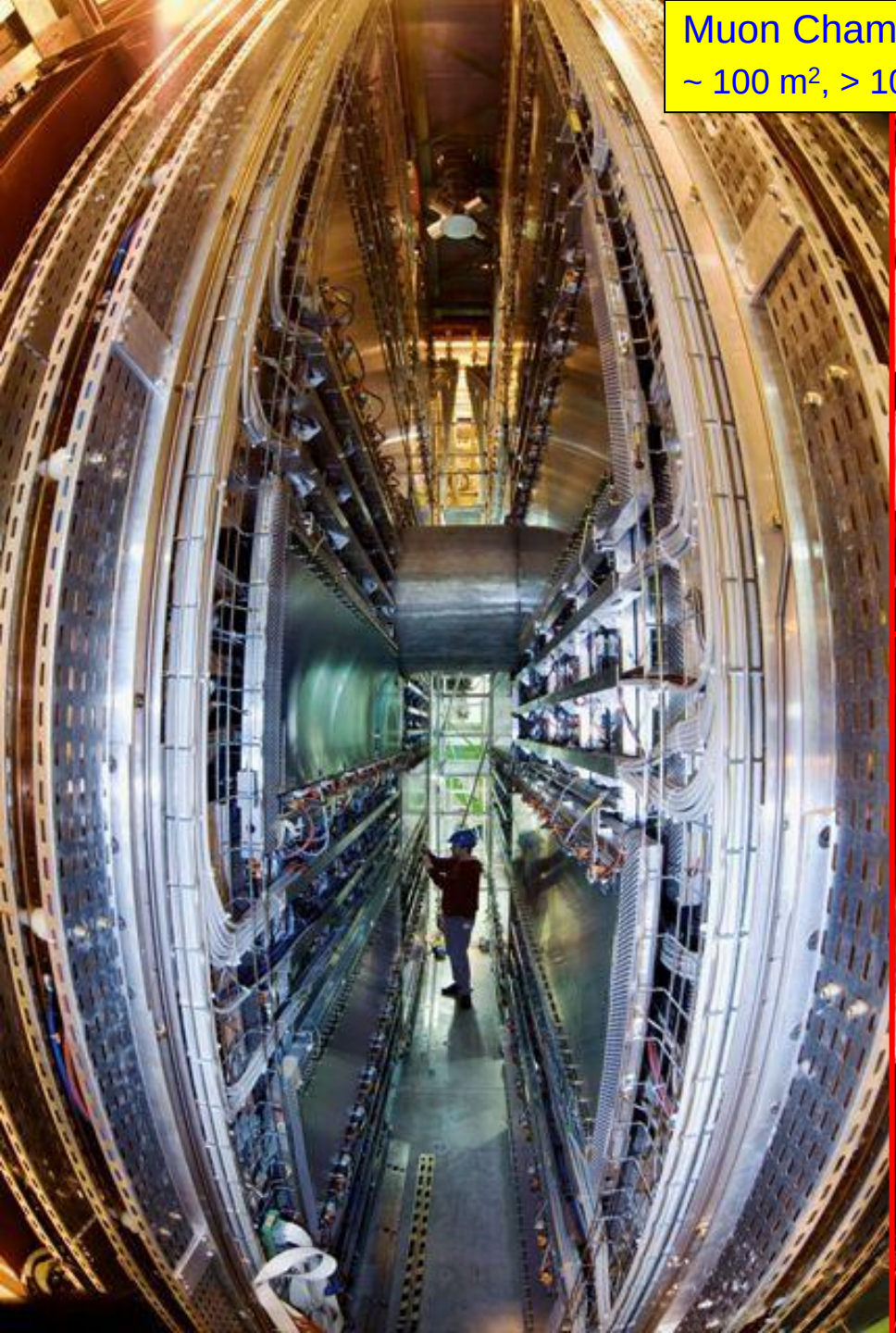
and barely over L3 …

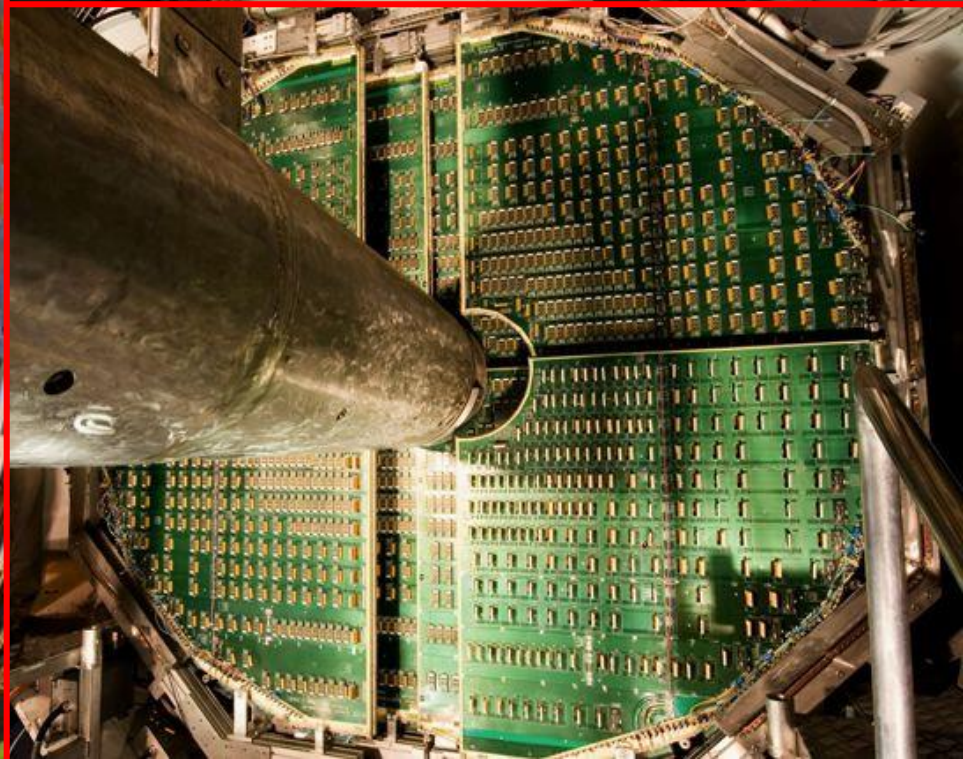
fitting barely under the bridge..

Sept 2003: Arrival of Dipole Coils after ‘Tour de France’

Muon Chambers

~ 100 m^2, > 10^6 channels





Landslides and other Disasters

2007: Landslide closed the Mt Blanc tunnel

2 days before transport of emcal frame => several weeks delay

2004/5: Political Landslide in Ukraine

almost closed the microcable production plant in Kharkov

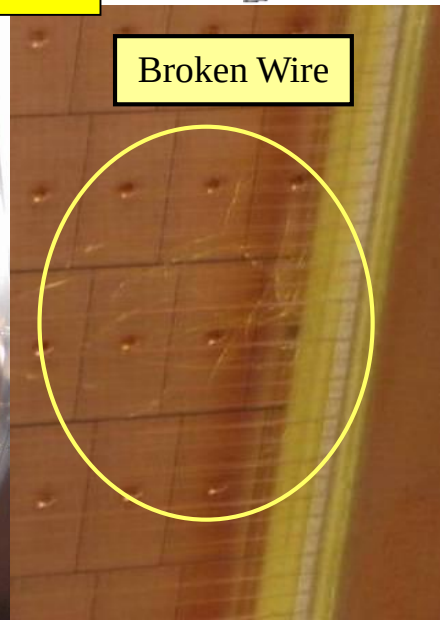
2006: SPD is feeling the heat…

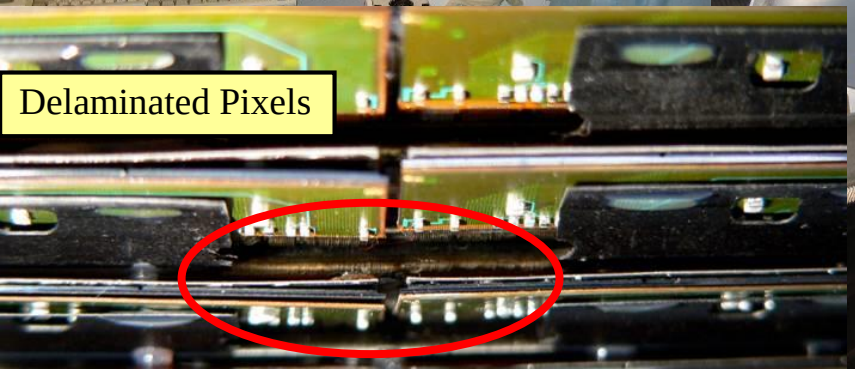
March: Fire in SPD production clean room

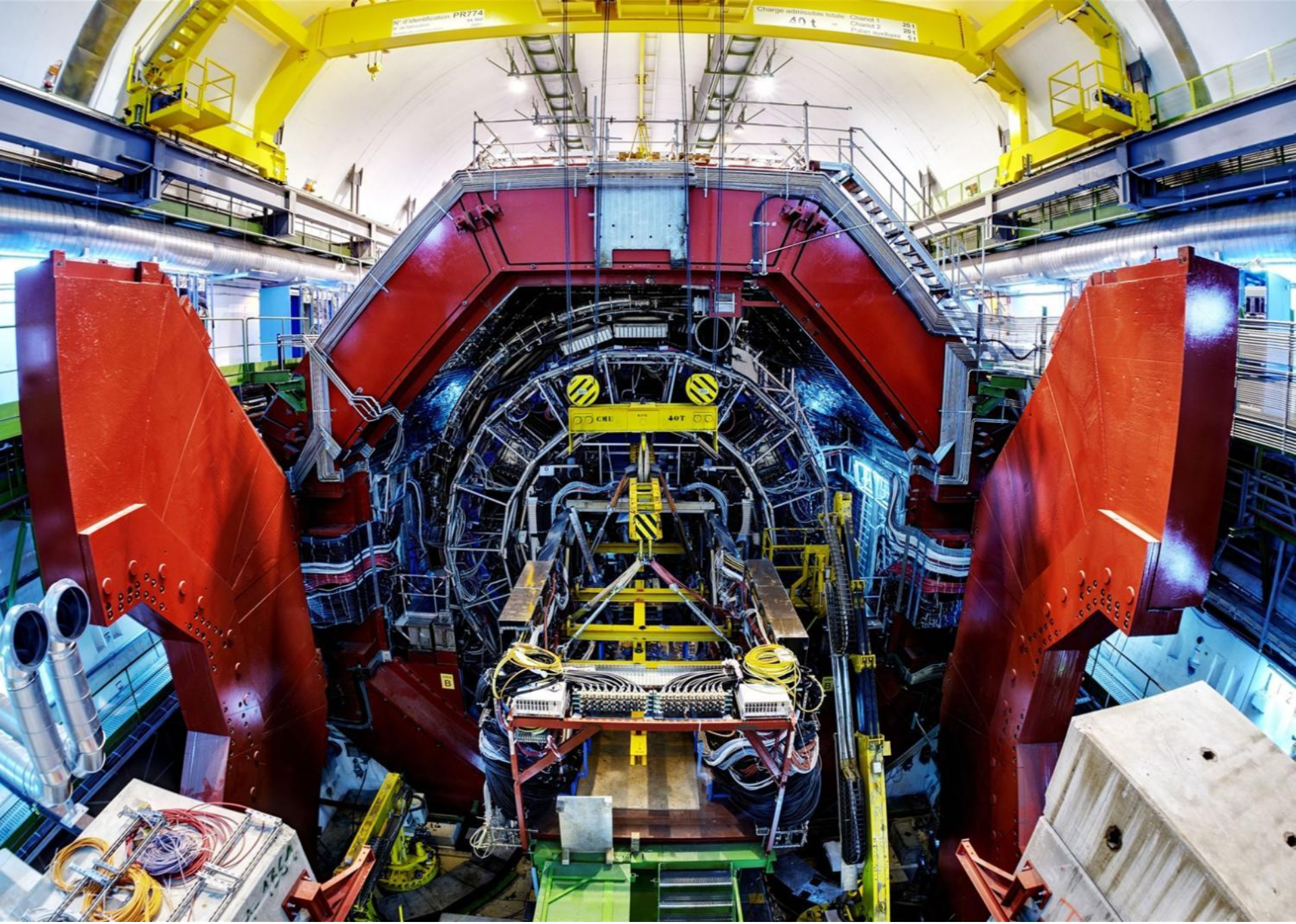
May: delamination of sector by overheating

2006: Broken wire in TPC

surgical operation to replace chamber

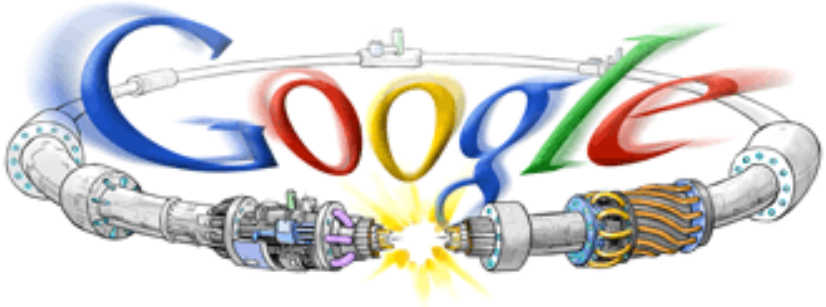


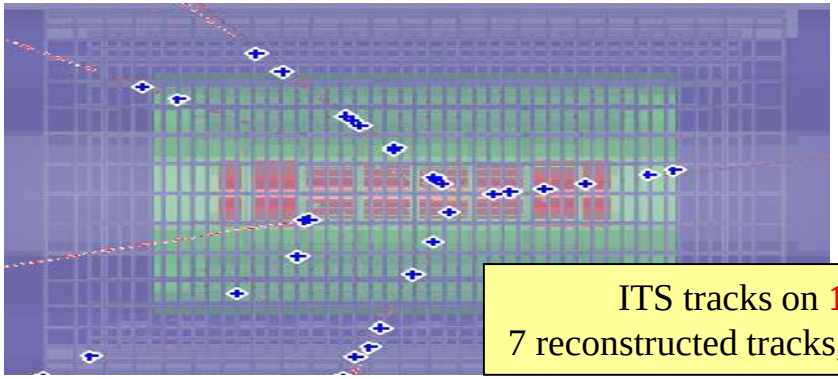



CMU
40T

Fast Forward to

- September 2008:
  - ⇨ LHC starts





ITS tracks on **12.9.2008**
7 reconstructed tracks, common vertex

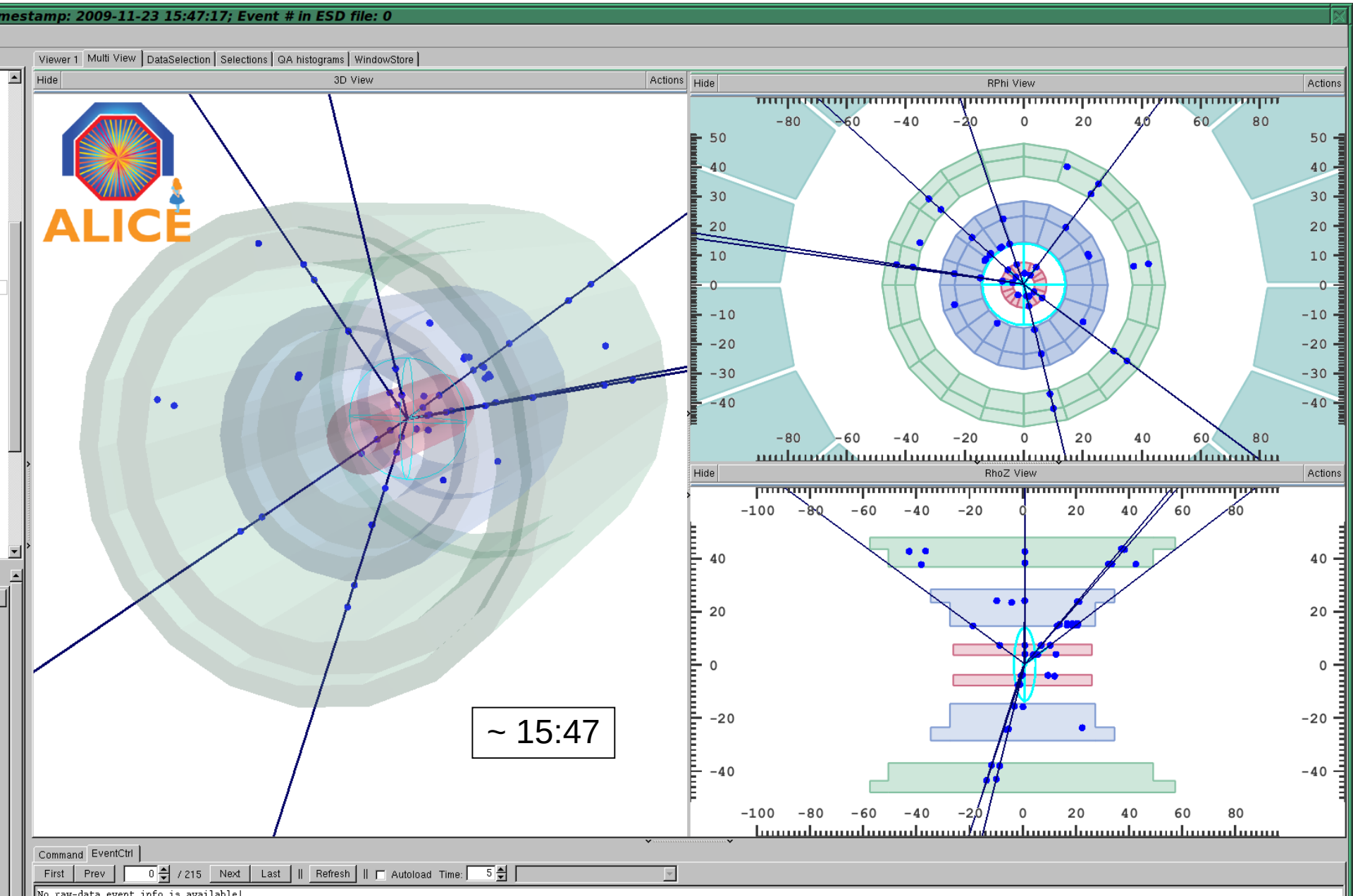
- November 2009:
  - ⇨ Start of Physics @ LHC

Magnet accident **19.9.2008**

First collisions at LHC: 23 November 2009

some anxious minutes waiting for collisions..

The first ‘event’ pops up in the ACR



Relief and jubilation..

Collisions in ALICE !!

Physics exploitation of ALICE had started for good !

~ 15:48

.. and some celebration..

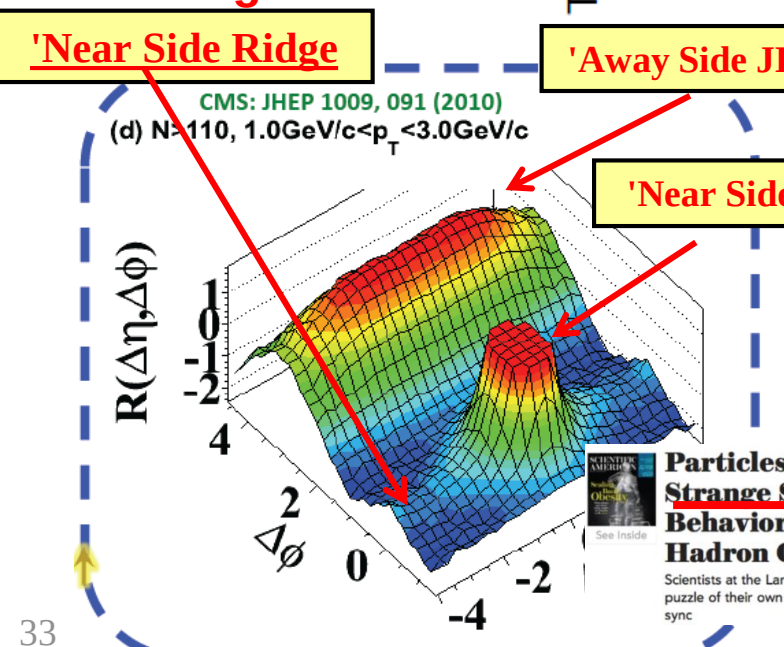
Heavy Ion Physics@LHC: a 'Smashing' Success

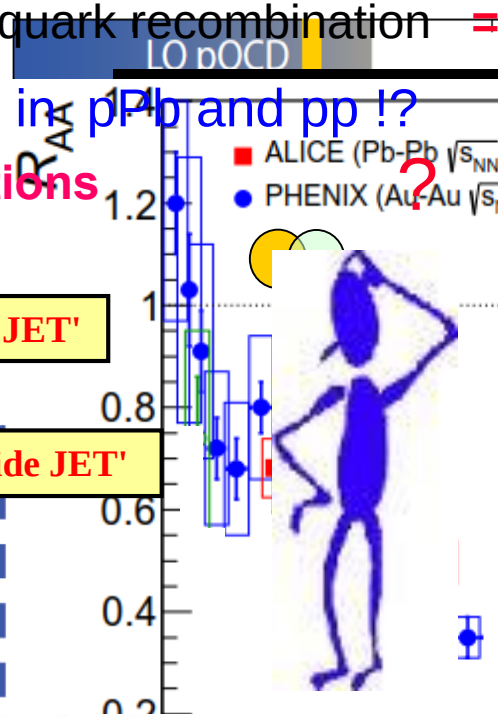
- QGP precision measurements
  - ⇨ almost frictionless ideal liquid: $1/4\pi < \eta/S < 2/4\pi$
  - ⇨ very strongly interacting: $\hat{q} = 1.9 \pm 0.7\ GeV^2/fm$

η/S = shear viscosity /Entropy

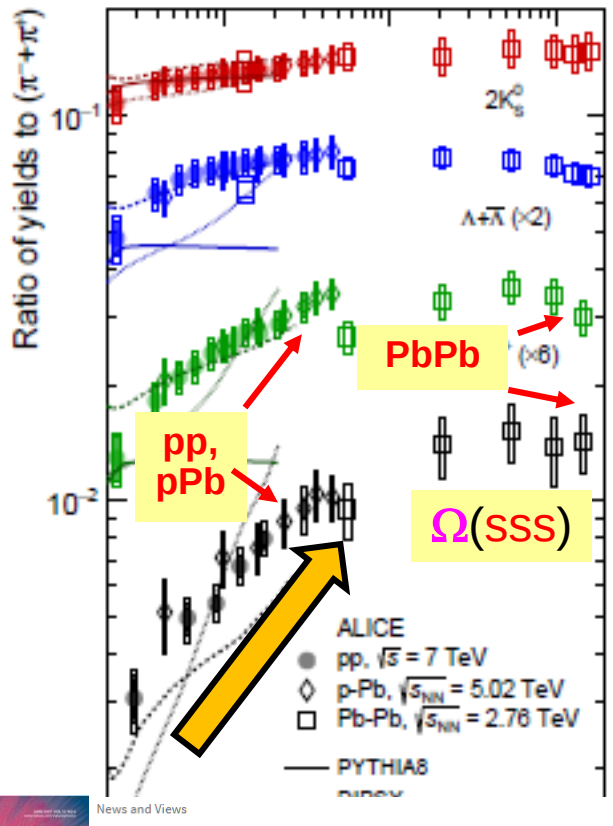
q = opacity ('stopping power')

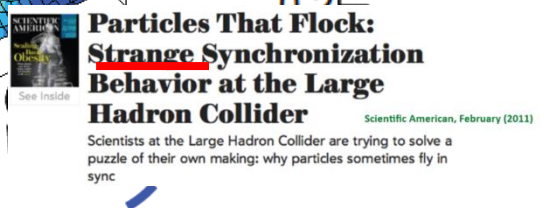
- Deconfinement
  - ⇨ sequential **Υ suppression** =
  - ⇨ **J/Ψ enhancement** via charm quark recombination =
- **Surprise:** 'QGP-like' signals in pPb and pp !?
  - ⇨ **collective 'flow-like' correlations** ?
  - ⇨ **strangeness enhancement**

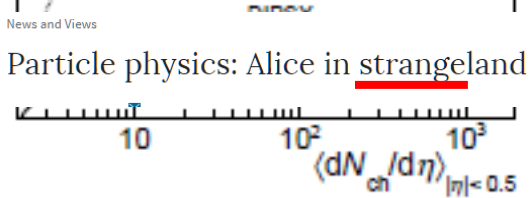




Strangeness Enhancement







ALICE Collaboration	1993	2017
Members	~230	~1900
Countries	19	42
Institutes	42	180

ALICE