



Terabytes in Milliseconds

Taming the world's largest data output at CERN

Dr. Axel Koester, IBM



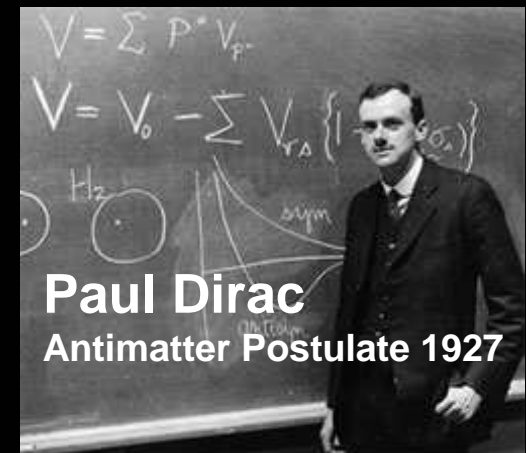
CERN

Conseil Européen pour la Recherche Nucléaire
European Organization for Nuclear Research

CERN Business

High Energy Physics ($E=mc^2$)

- What is the Universe made of?
- Wherefrom comes mass?
- Where is all the Antimatter?

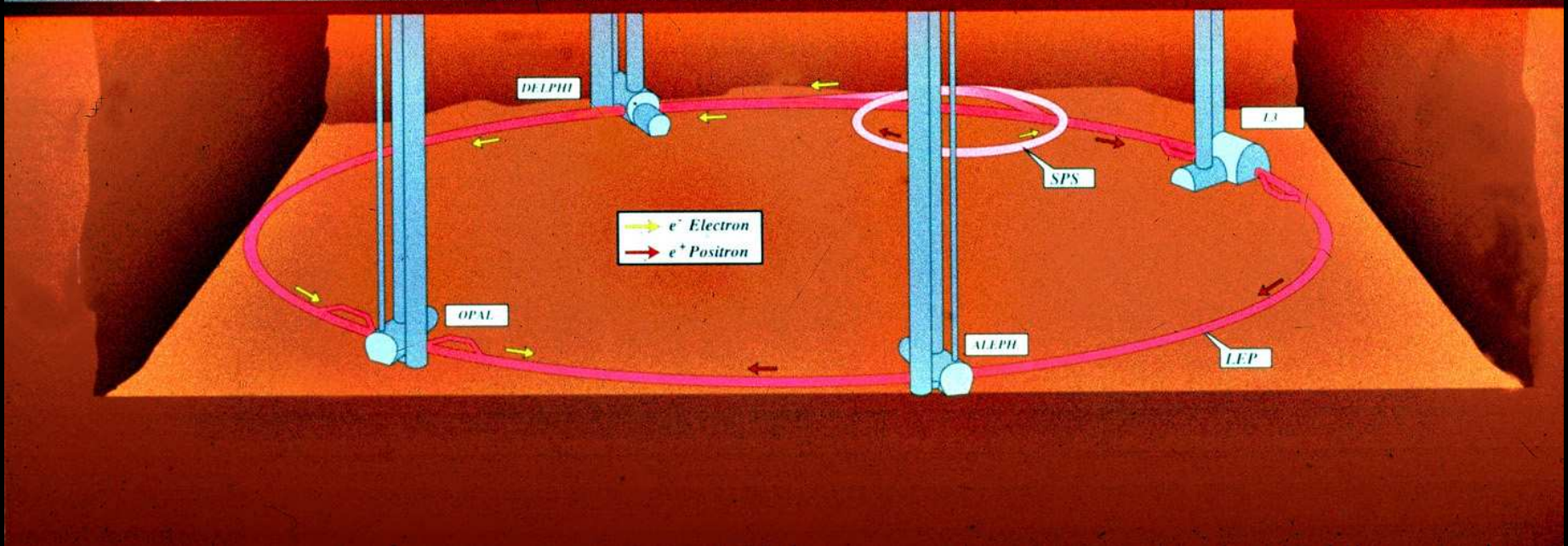
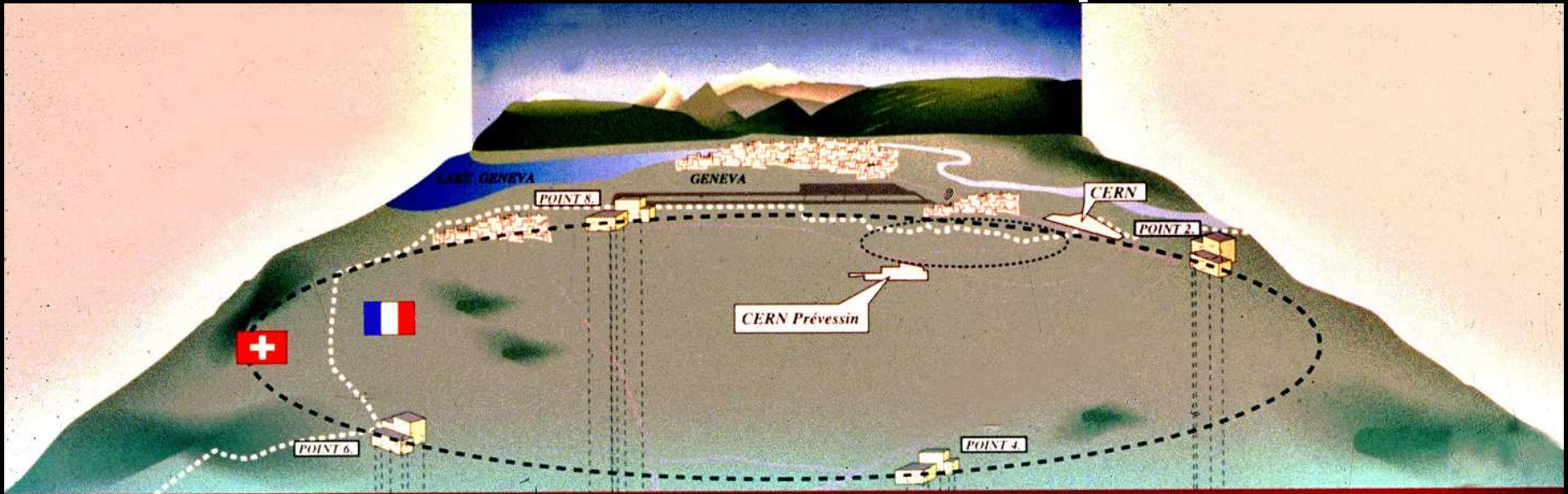


CERN Large Hadron Collider : 27 km Ring Ion Accelerator



Circumference ~27km

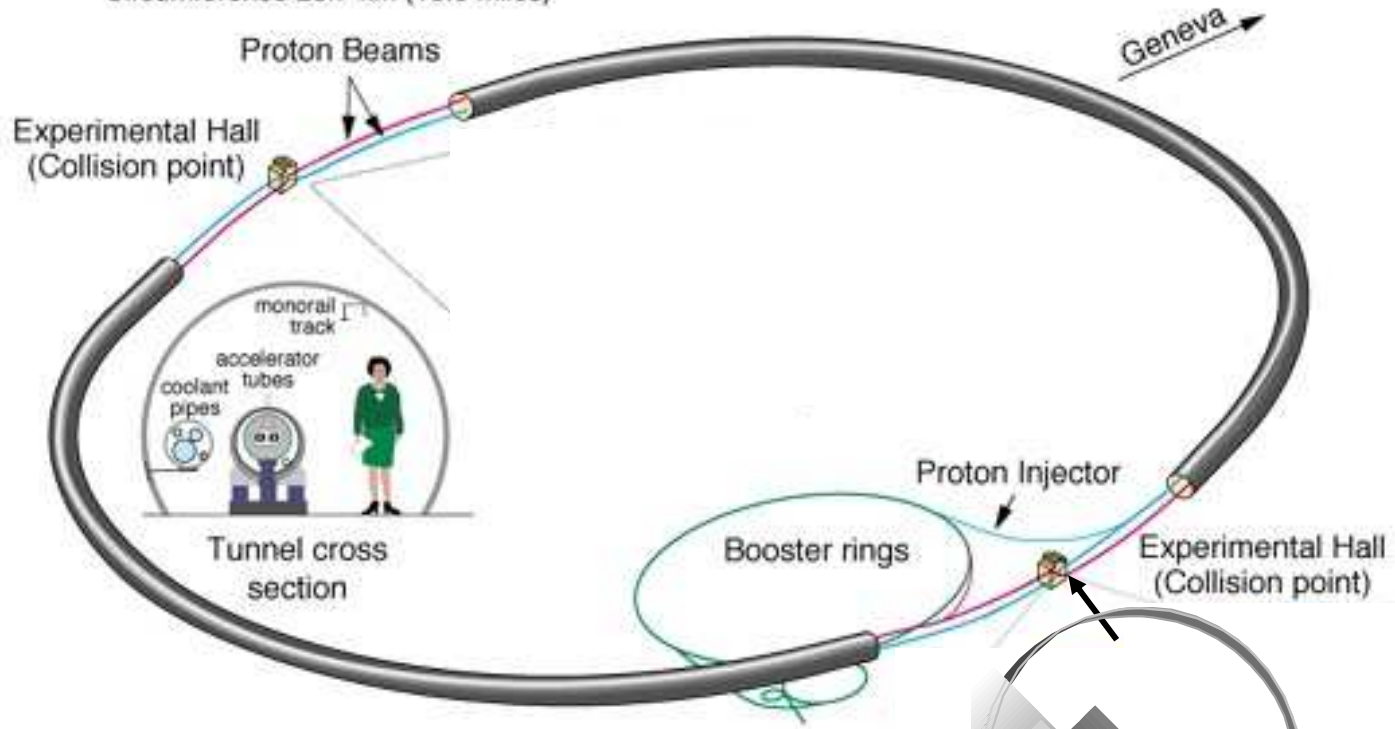
Depth 70~100m



Buried, undisturbed by outside noise, solar wind, etc.

Large Hadron Collider at CERN *Hadrons = "Heavy" particles*

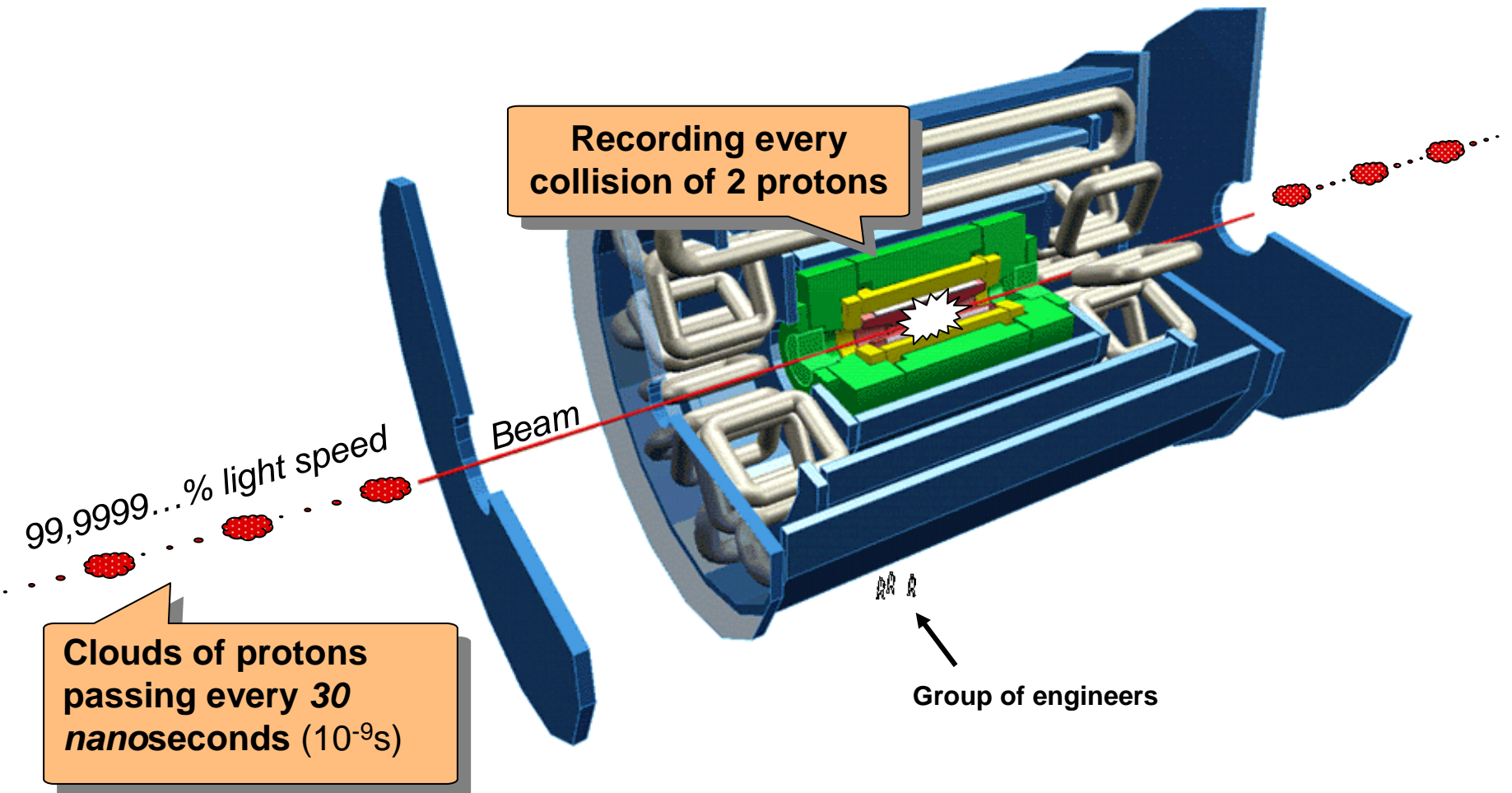
Circumference 26.7 km (16.6 miles)



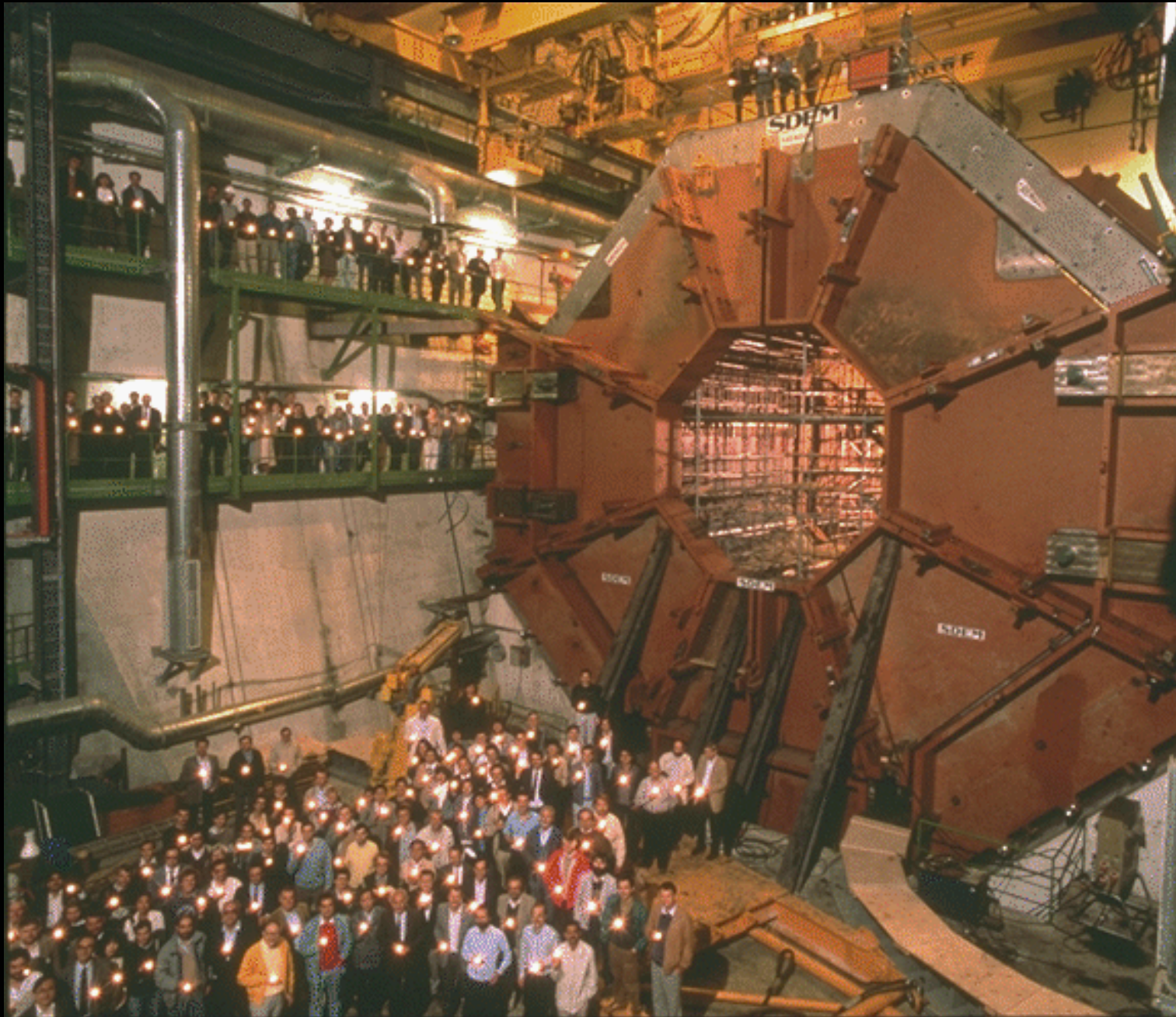
What happens here?

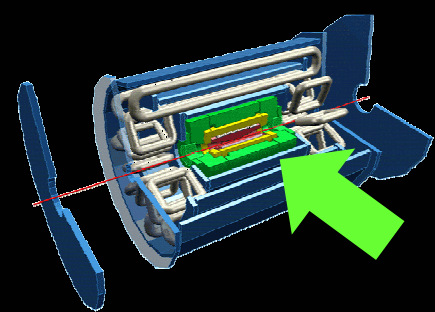
ATLAS Detector

a giant, 3-dimensional "video camera" for proton/proton collisions:

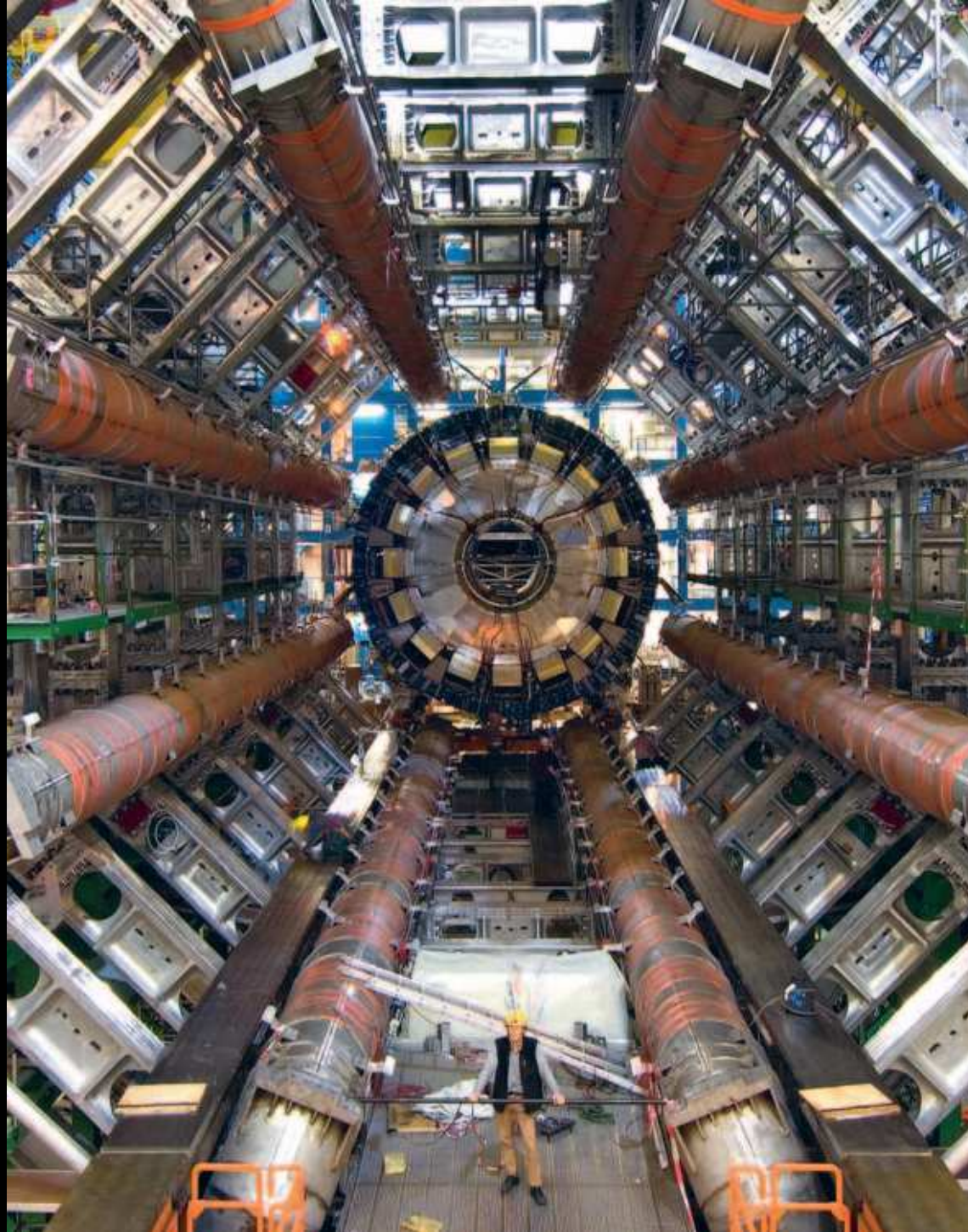


L3, the 'little' predecessor of ATLAS





ATLAS
46m x Ø 25m
7000 t





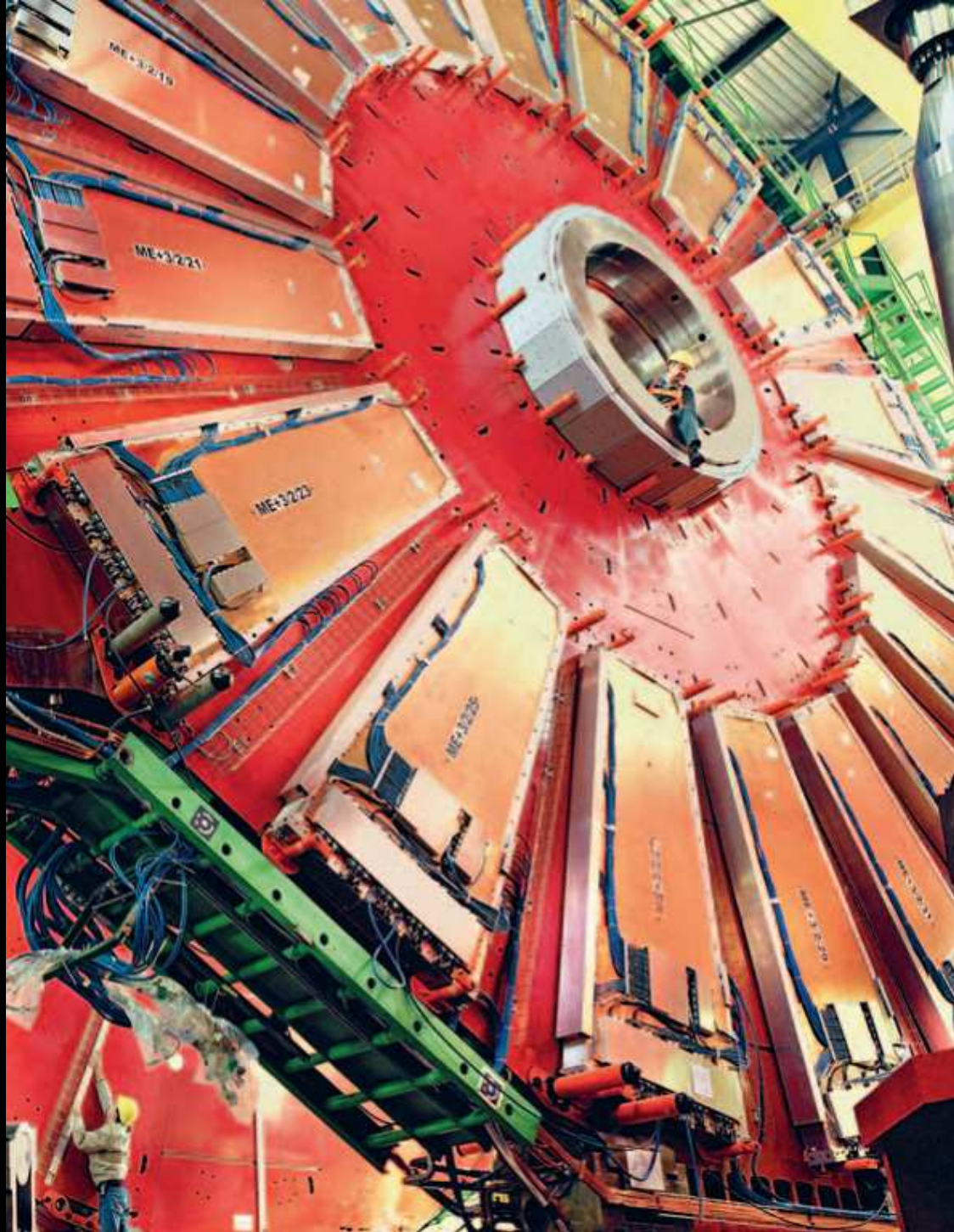


C.M.S


21m × Ø 15m

12.500 t

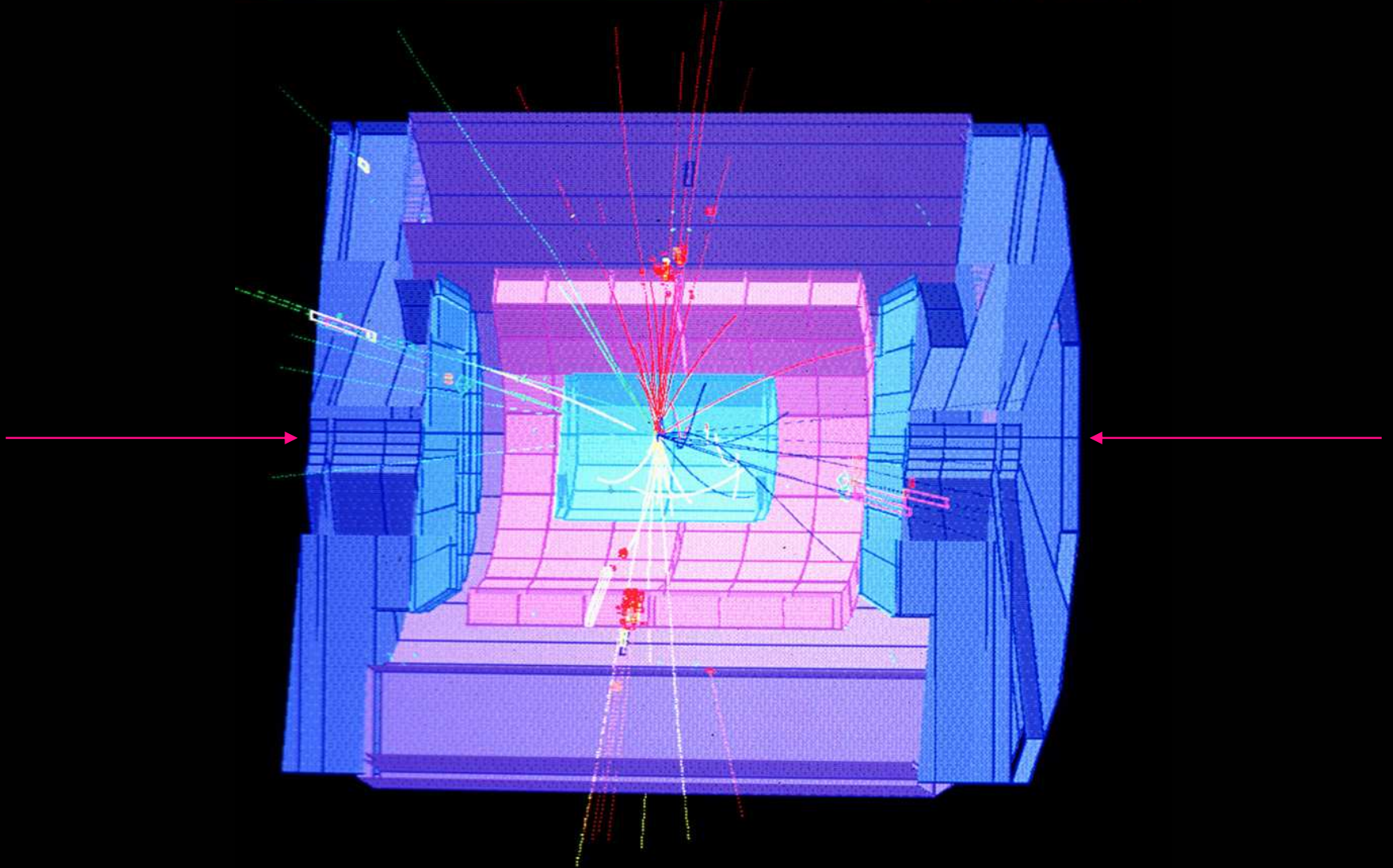
"Compact"



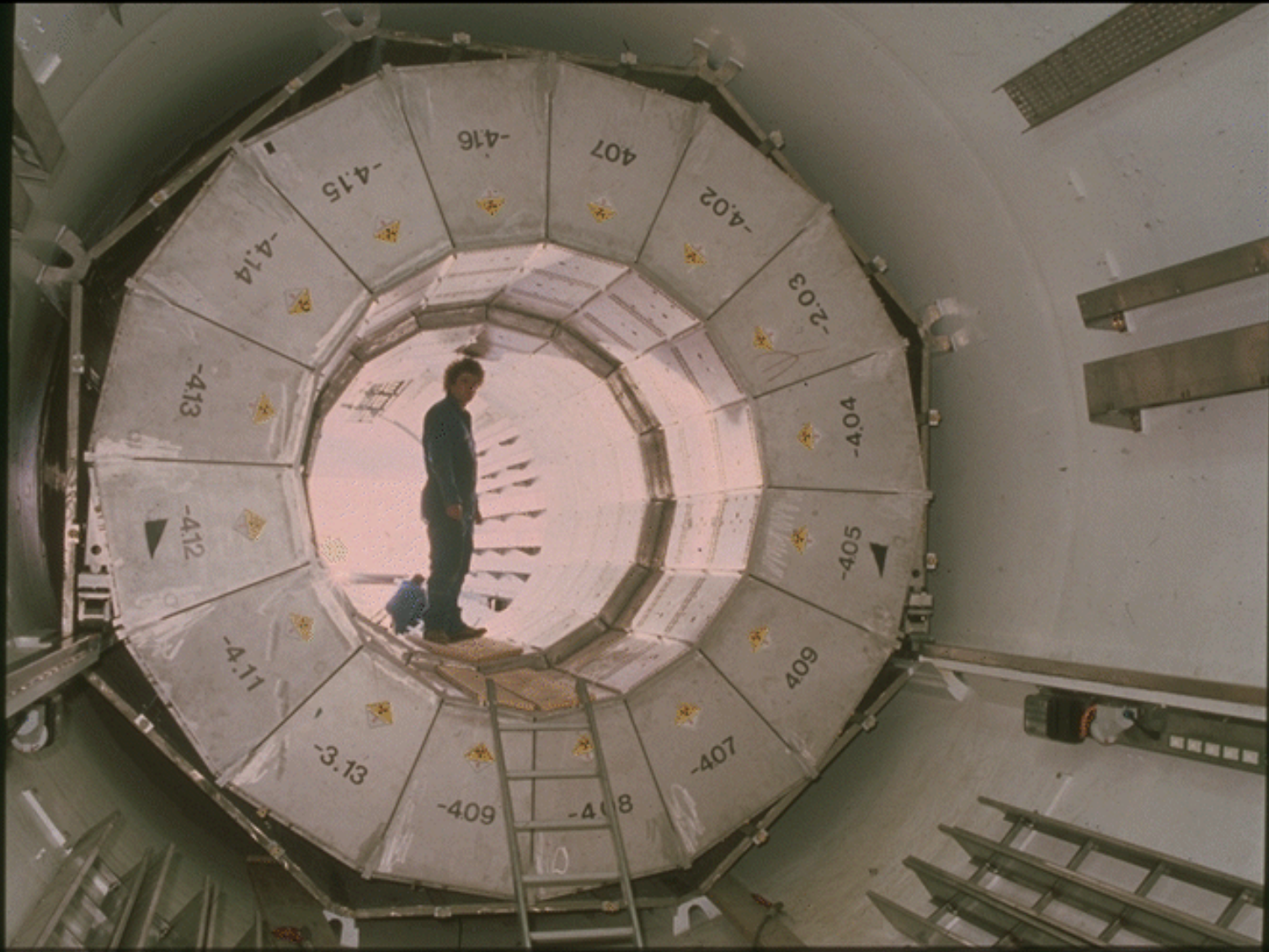
Realtime snapshot of collision fragments

 DELPHI Run: 67777 Evt: 16923
Beam: 80.7 GeV Proc: 9-Jul-1996
DAS: 9-Jul-1996 Scan: 10-Jul-1996
12:13:57 DST

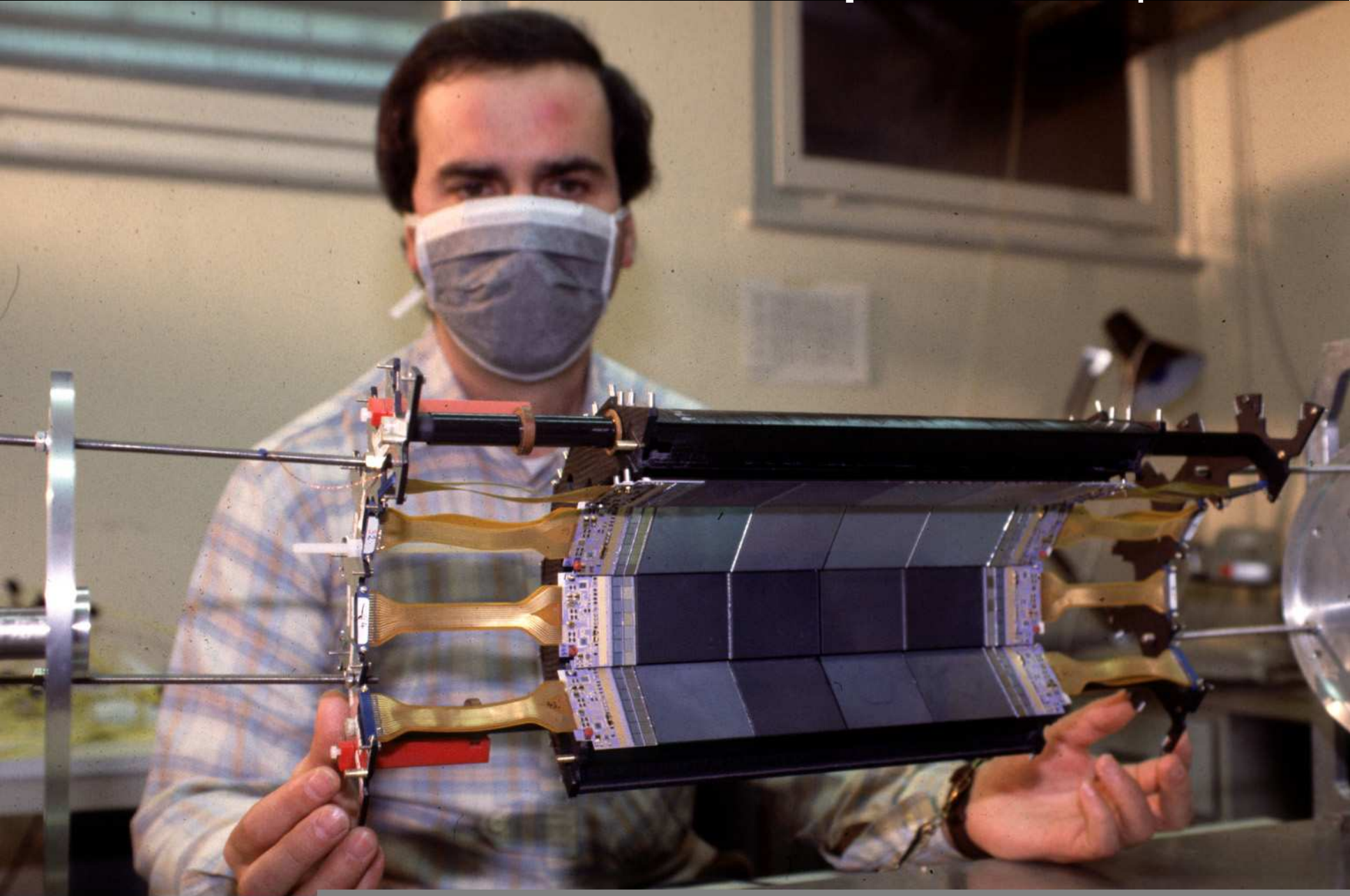
	TD	TE	TS	TK	TV	SL	PK
Act	0	104	0	87	0	0	0
	(155)	(371)	(0)	(87)	(28)	(0)	(0)
Deact	0	0	0	1	0	0	0
	(0)	(0)	(0)	(1)	(0)	(0)	(0)



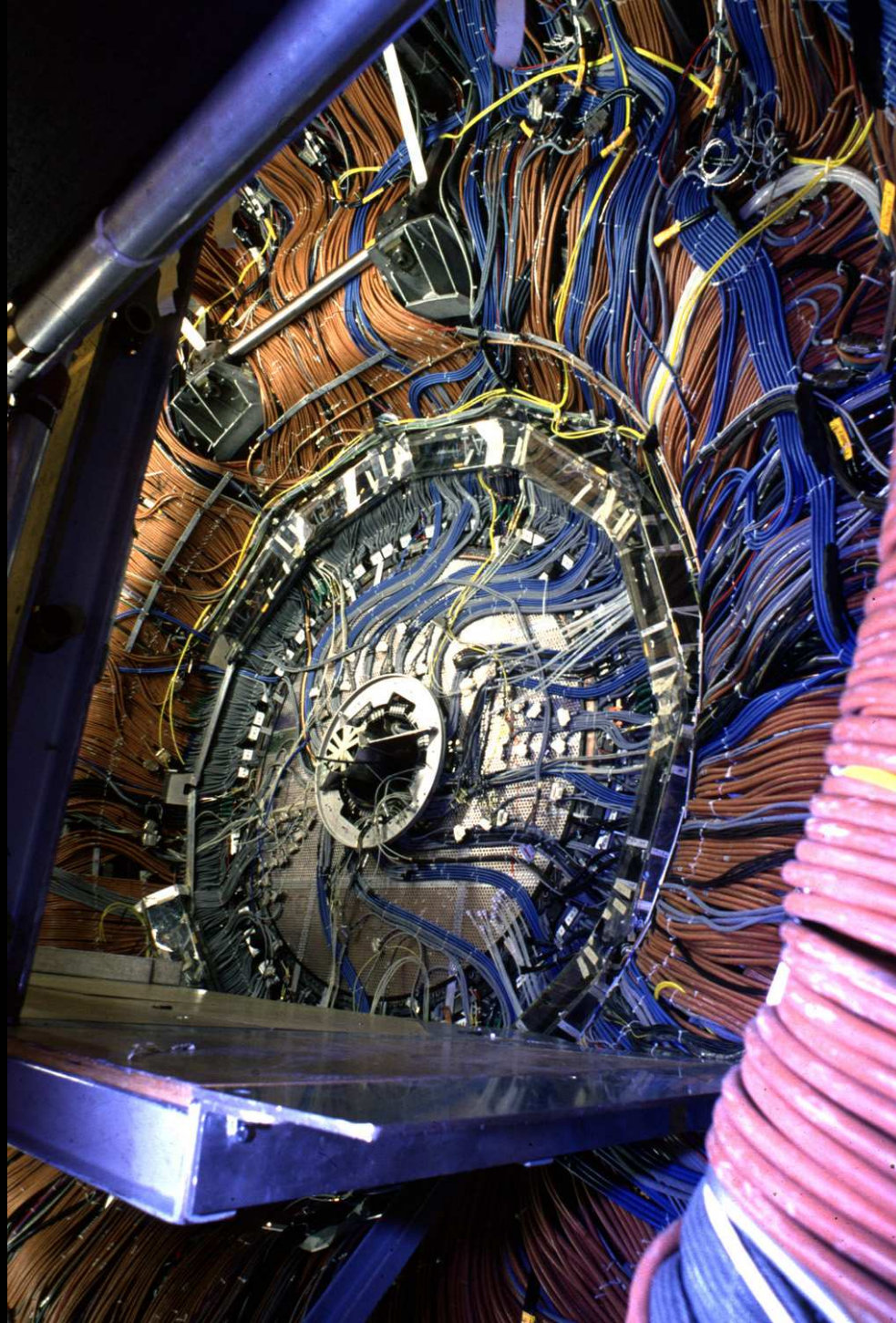
Detector inside: filled with particle "cameras"



Near the core, each "camera pixel" is $\sim 1 \mu\text{m}^2$



**Each 'pixel' is
cabled with a
high-speed
recorder:**

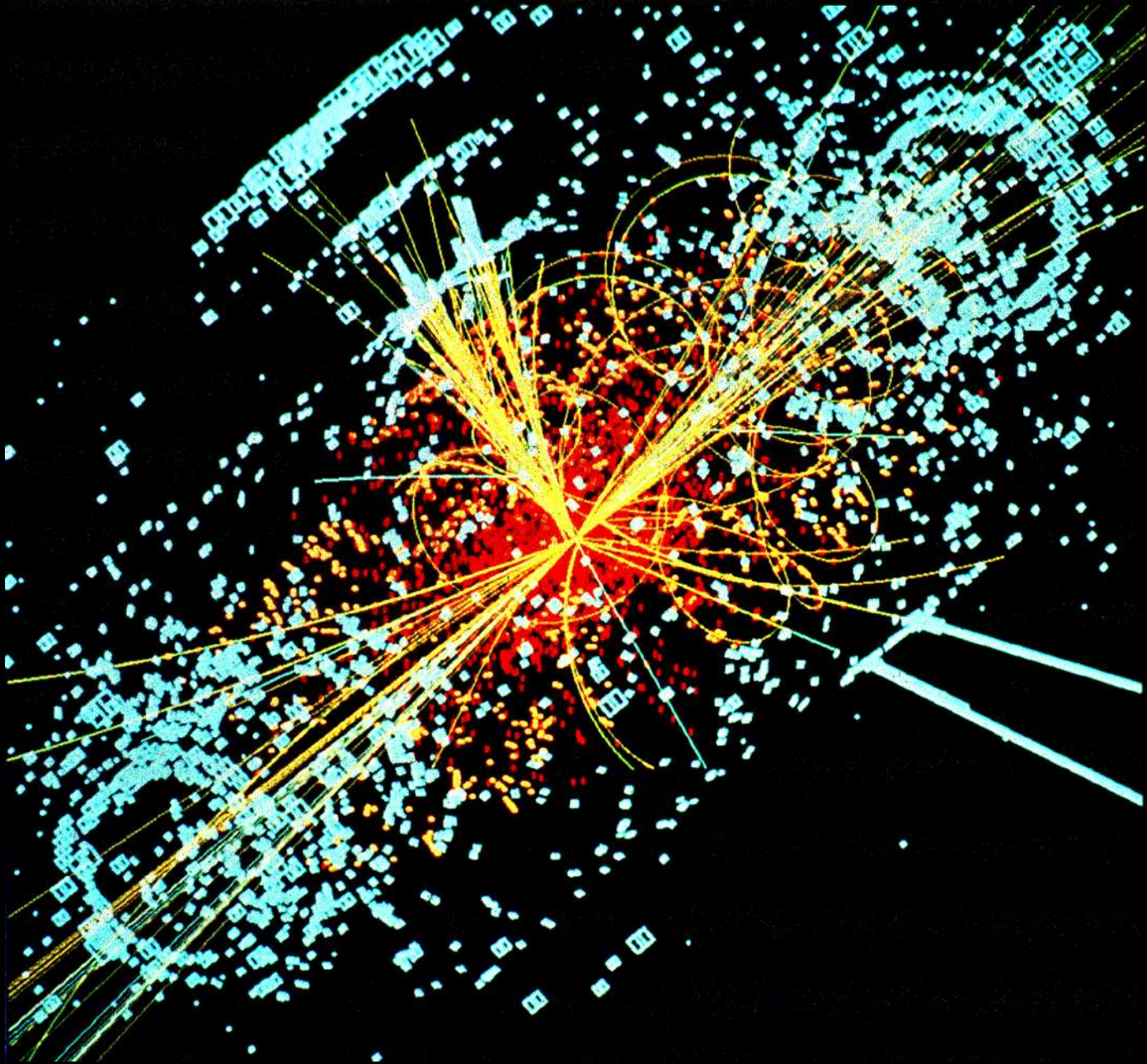


**All cables
are equally
long (40m)**

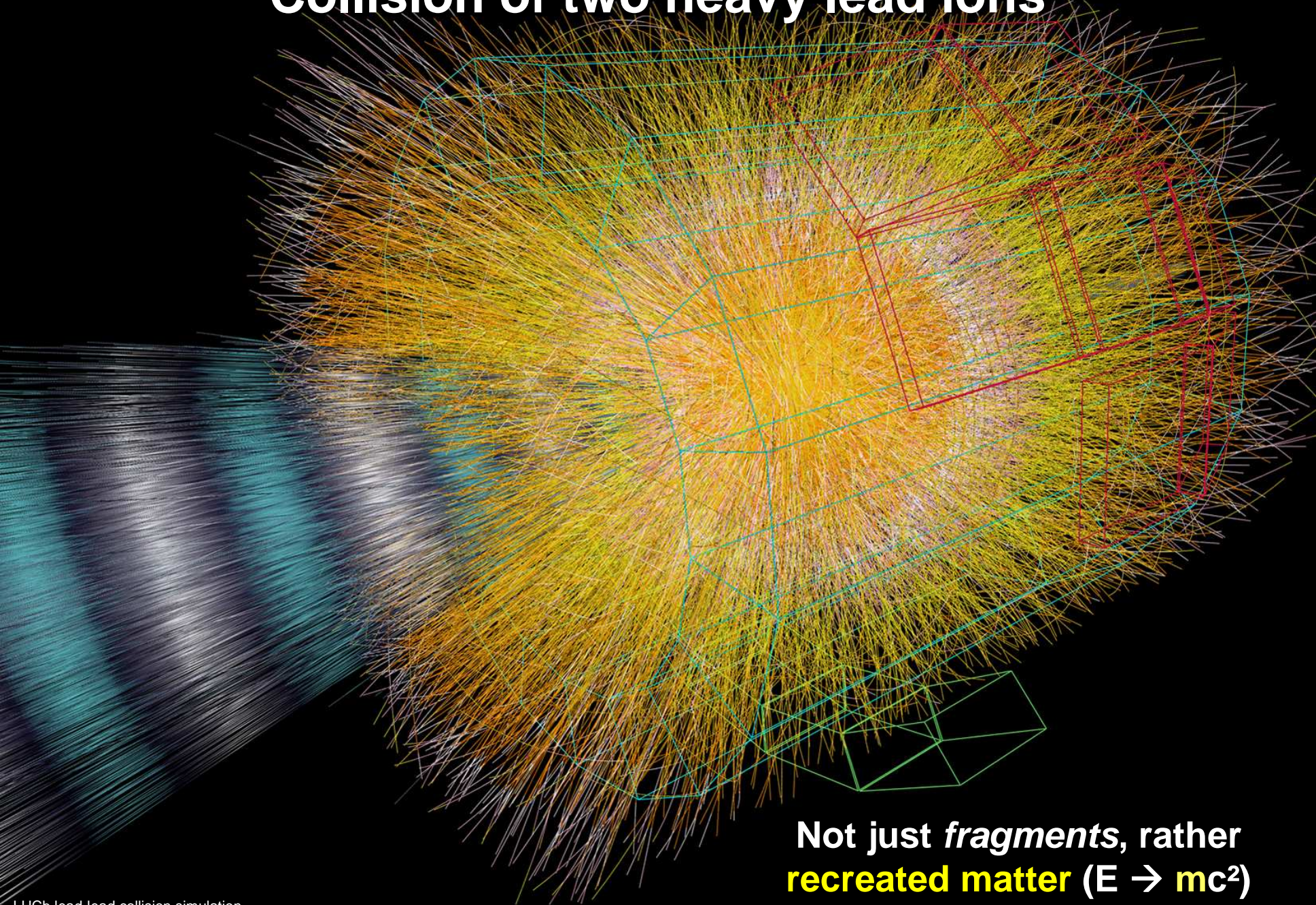
Cables run into the signal processing house



3D view: Each blue square is a triggered 'pixel'



Collision of two heavy lead ions



Not just *fragments*, rather
recreated matter ($E \rightarrow mc^2$)

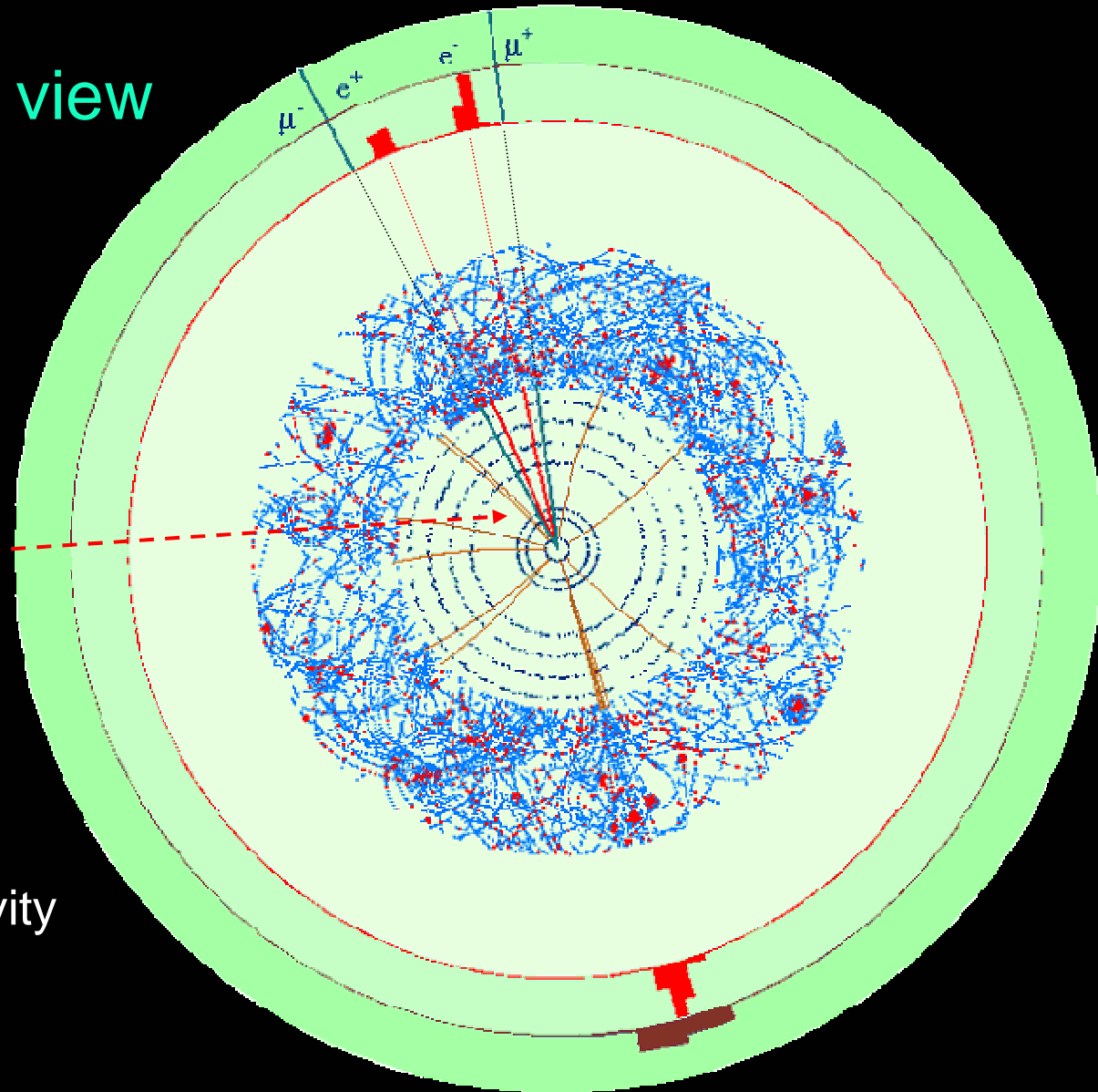
Every collision event is unique

Cross section view
of a collision
snapshot:

This is an
"interesting"
recorded collision:

It reveals the
nature of the *weak*
force and radioactivity

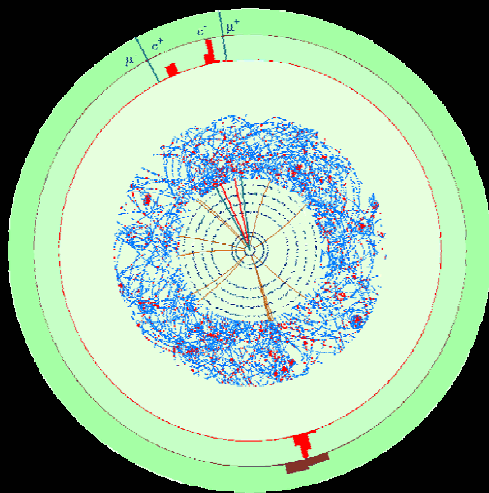
$p^+ \rightarrow ZZ \rightarrow e^+e^- \mu^+\mu^-$



Scale of the challenge

CERN: "1 interesting event is buried in a background of 10^{13} events"

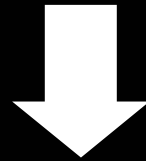
ATLAS will produce 30 million events / sec = 1 interesting in 4 days



× 30 mio/s

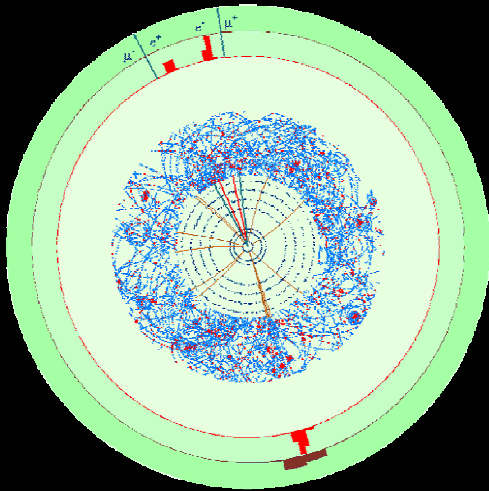


~100 MB(raw) / event
× 30 mio events / sec



3 Petabyte per second

Scale of the challenge



Online processing & selection

~100 MB(raw) / event
× 30 mio events / sec

Keep promising
candidates only

1-2 MB / event
× 100 events / sec

3 Petabyte per second

10 Terabyte per day

(1 Petabyte after 100 days)

Data analysis in a **Grid** environment

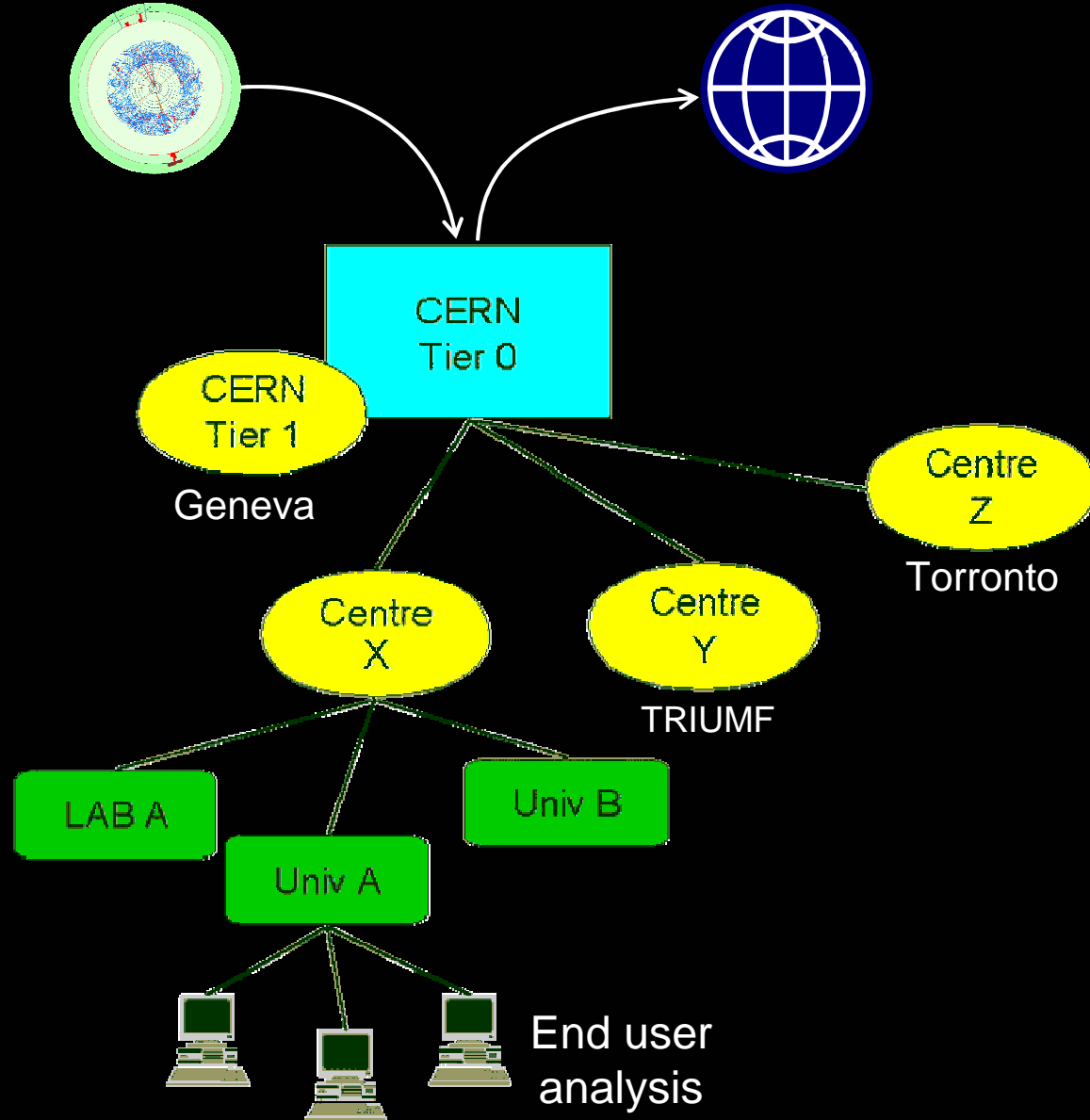
One Tier 0 site for data taking

ATLAS (Tier 0+1) in 2007:
400 TB disk, 9 PB tape,
700.000 SpecInt95 cpu power

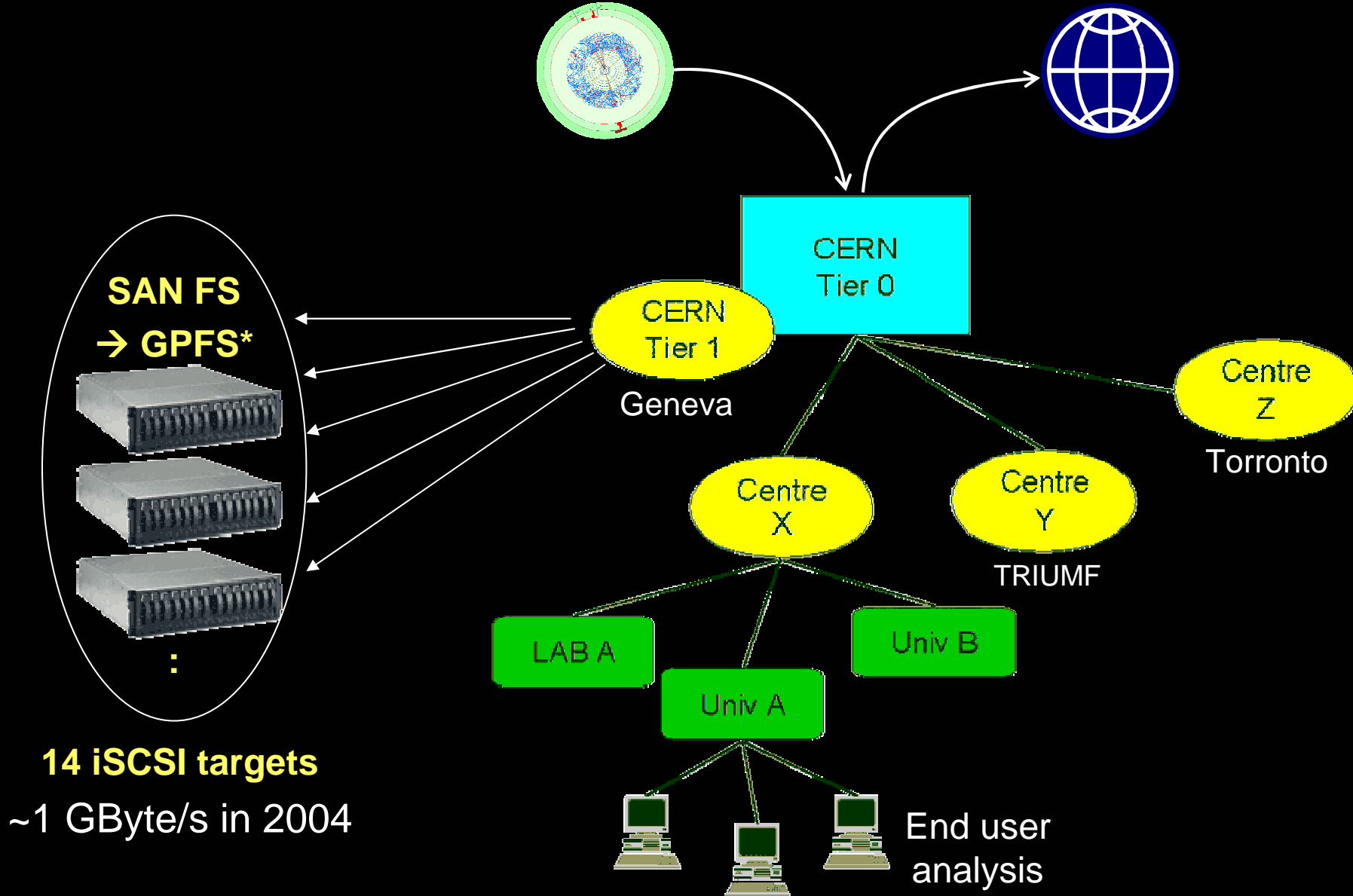
Multiple Tier 1 sites for reconstruction & simulation

400 TB disk, 2 PB tape
200.000 SpecInt95 cpu power

Tier 2 sites for user analysis

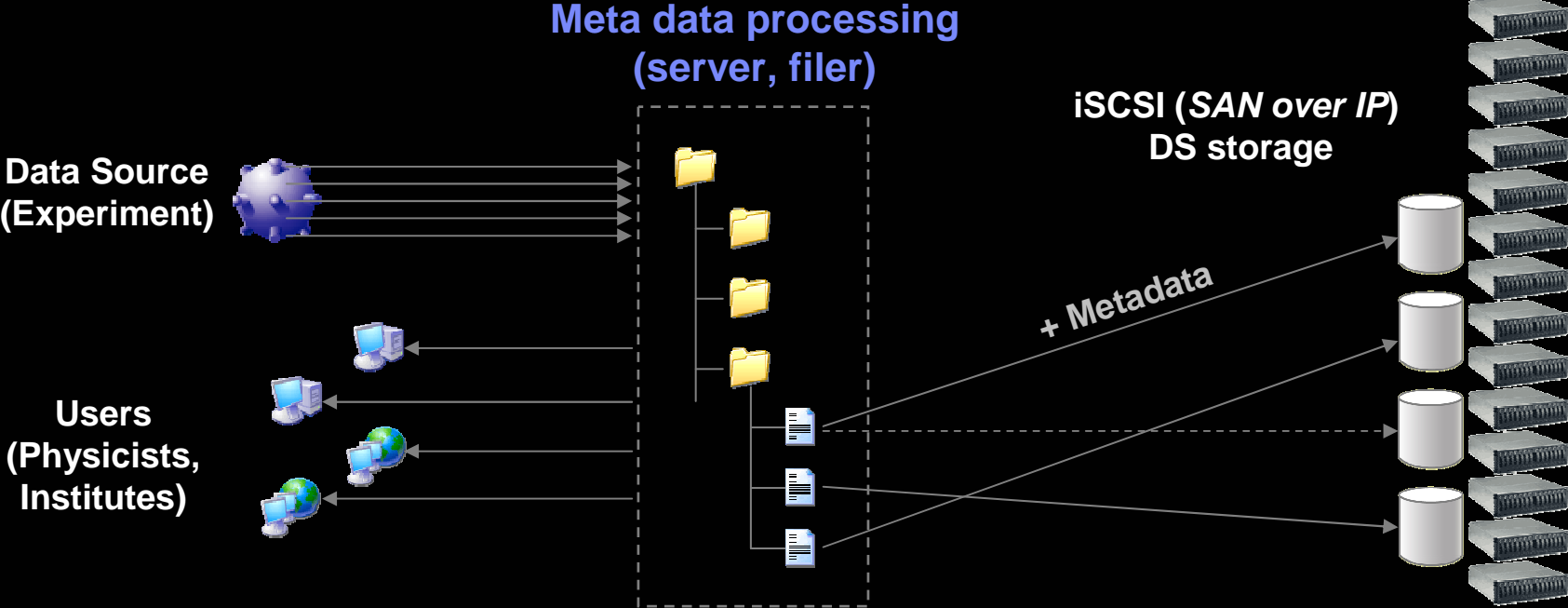


Data analysis in a **Grid** environment



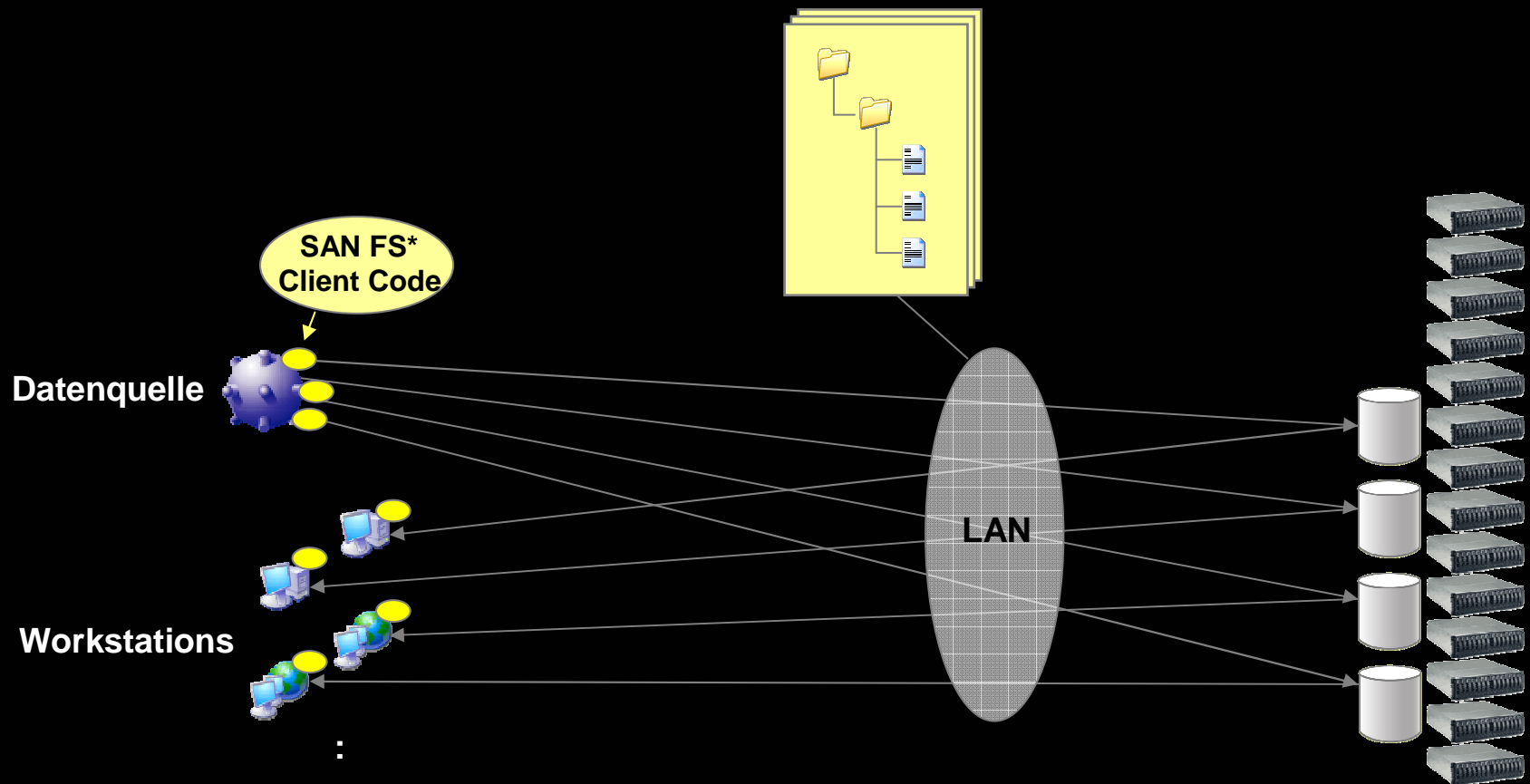
*SAN File System, later replaced by IBM General Parallel File System

Data Distribution, Sharing and Archiving



Eliminate the Server- or "Filer" Bottleneck

File System Metadata Coordinator



*SAN File System, later replaced by IBM General Parallel File System

2004: 1GB/s "scale out" NAS built from Commodity Parts

Benchmark

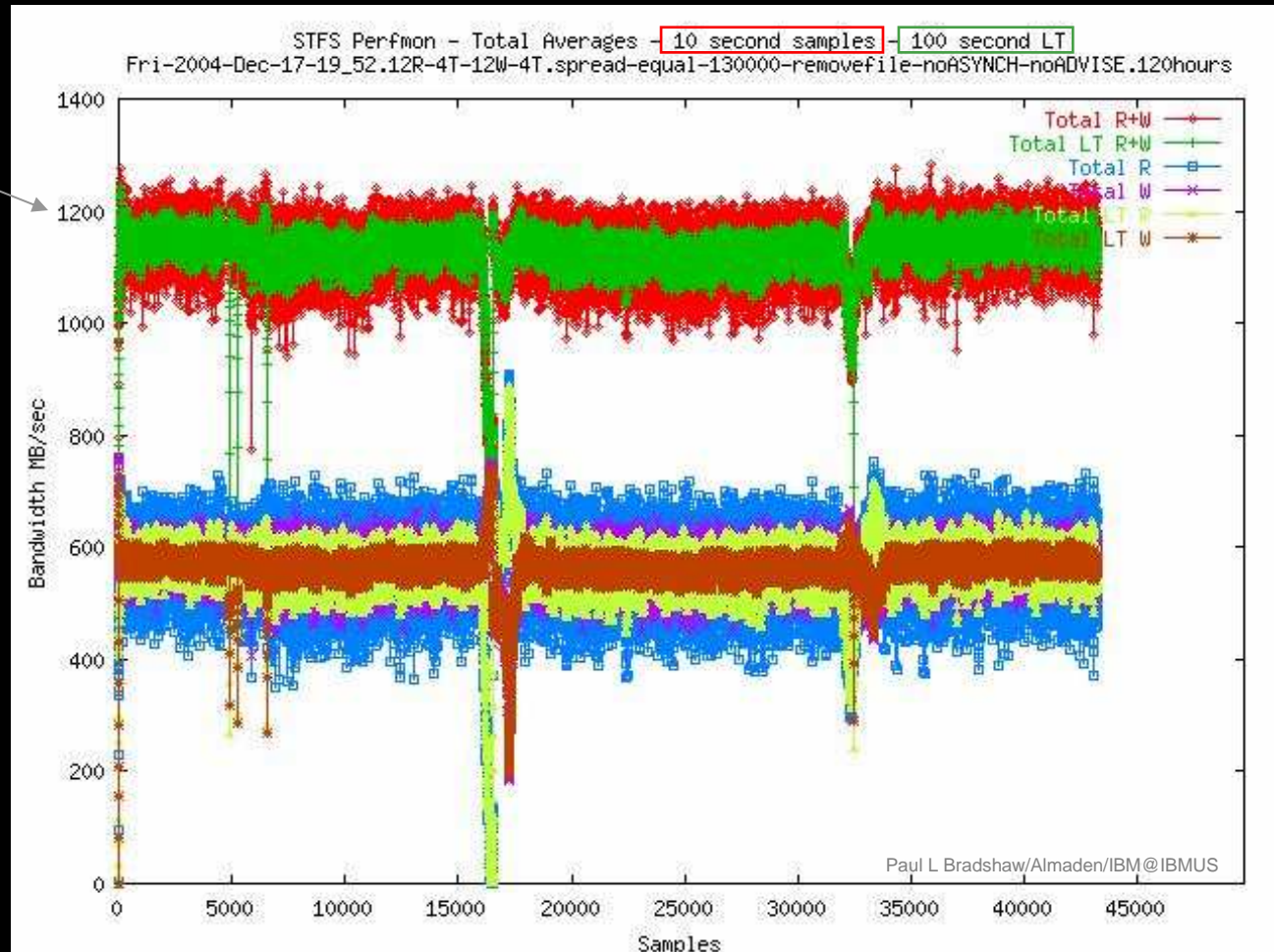
Average 1,13 GB/sec
over 120h (5 days)

457 Terabyte transmitted
Expectations exceeded

Setup

2 SAN FS metadata servers,
24 clients (12 doing writes, 12
doing reads, 4 threads each),

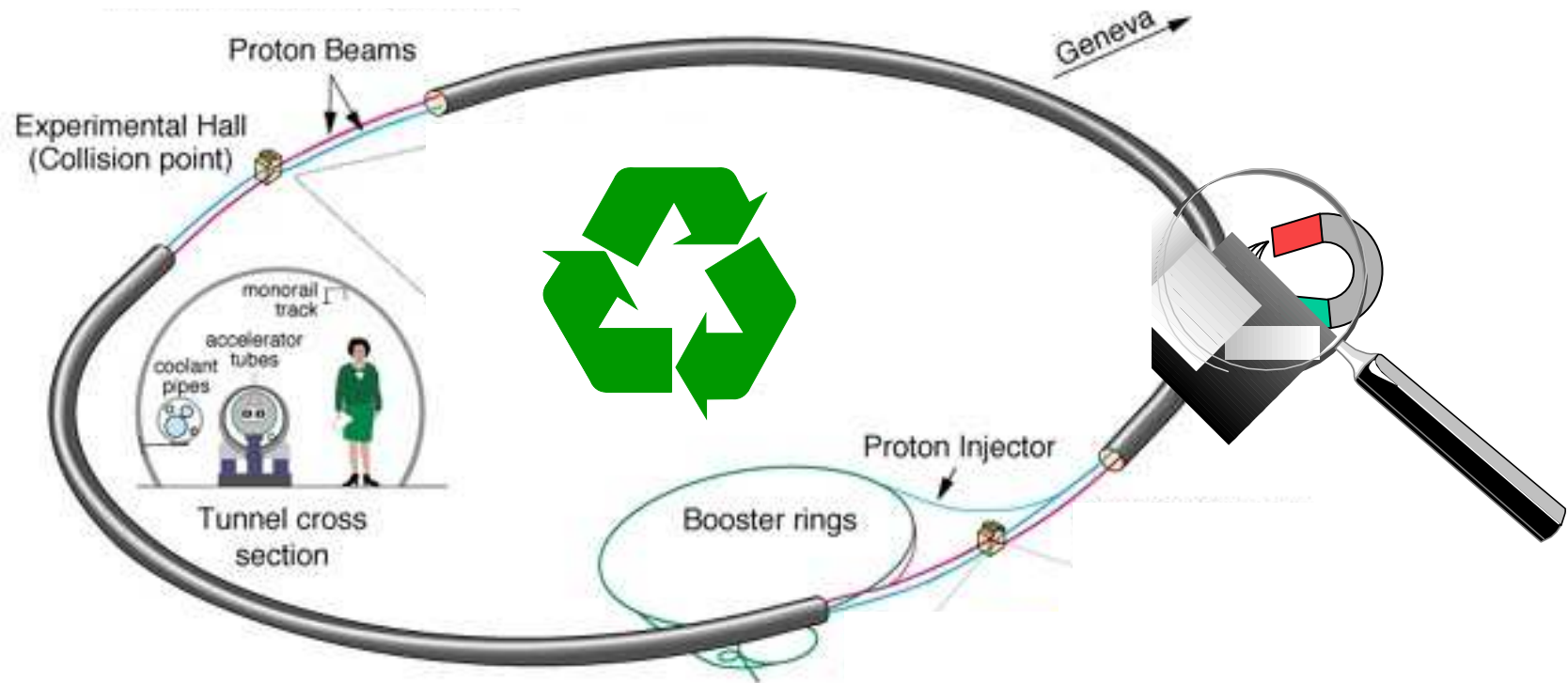
14 iSCSI storage units on a
1 Gb ethernet LAN (no fibre
channel storage)



Magnet Technology

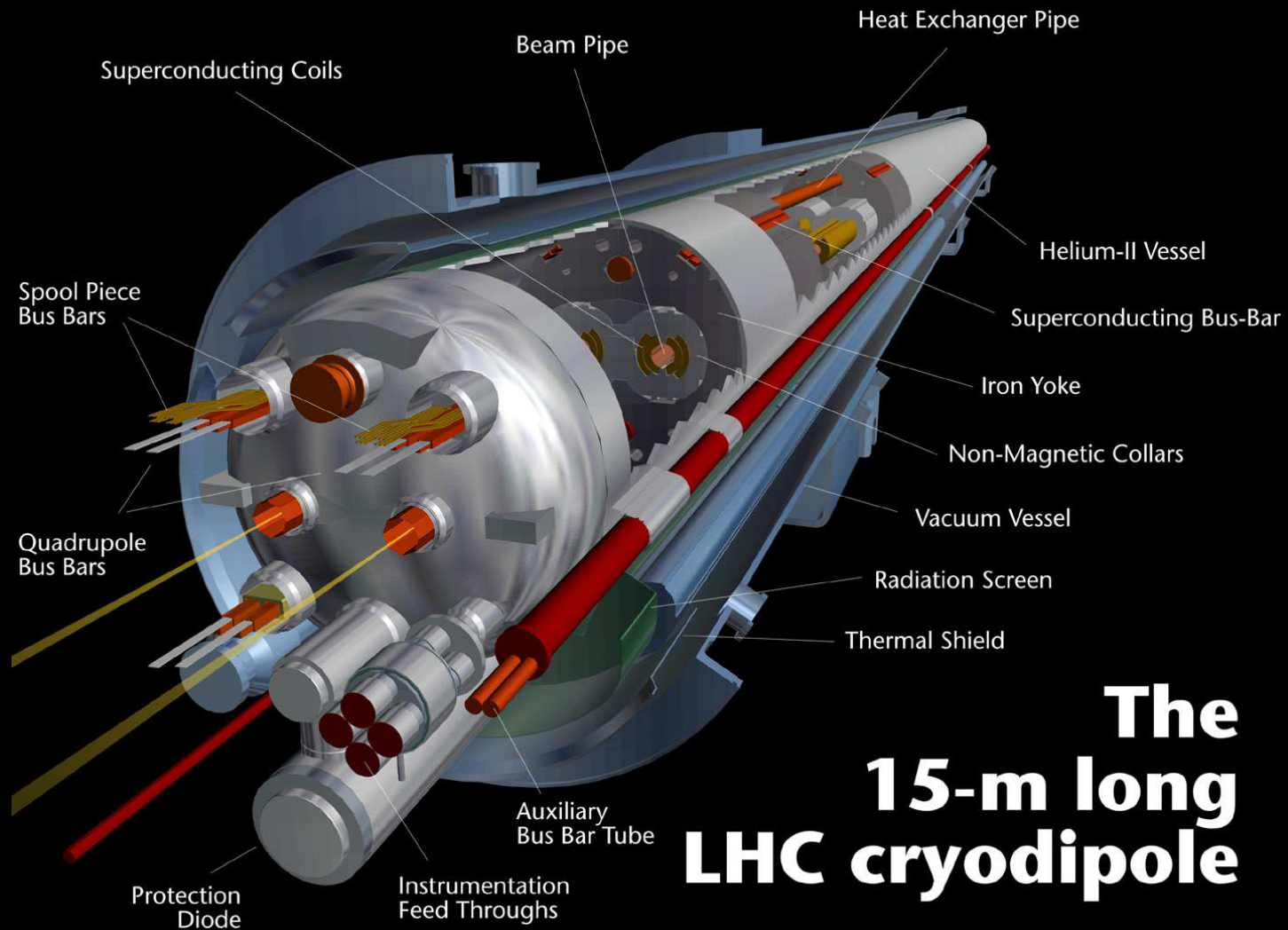
Proton Recycling

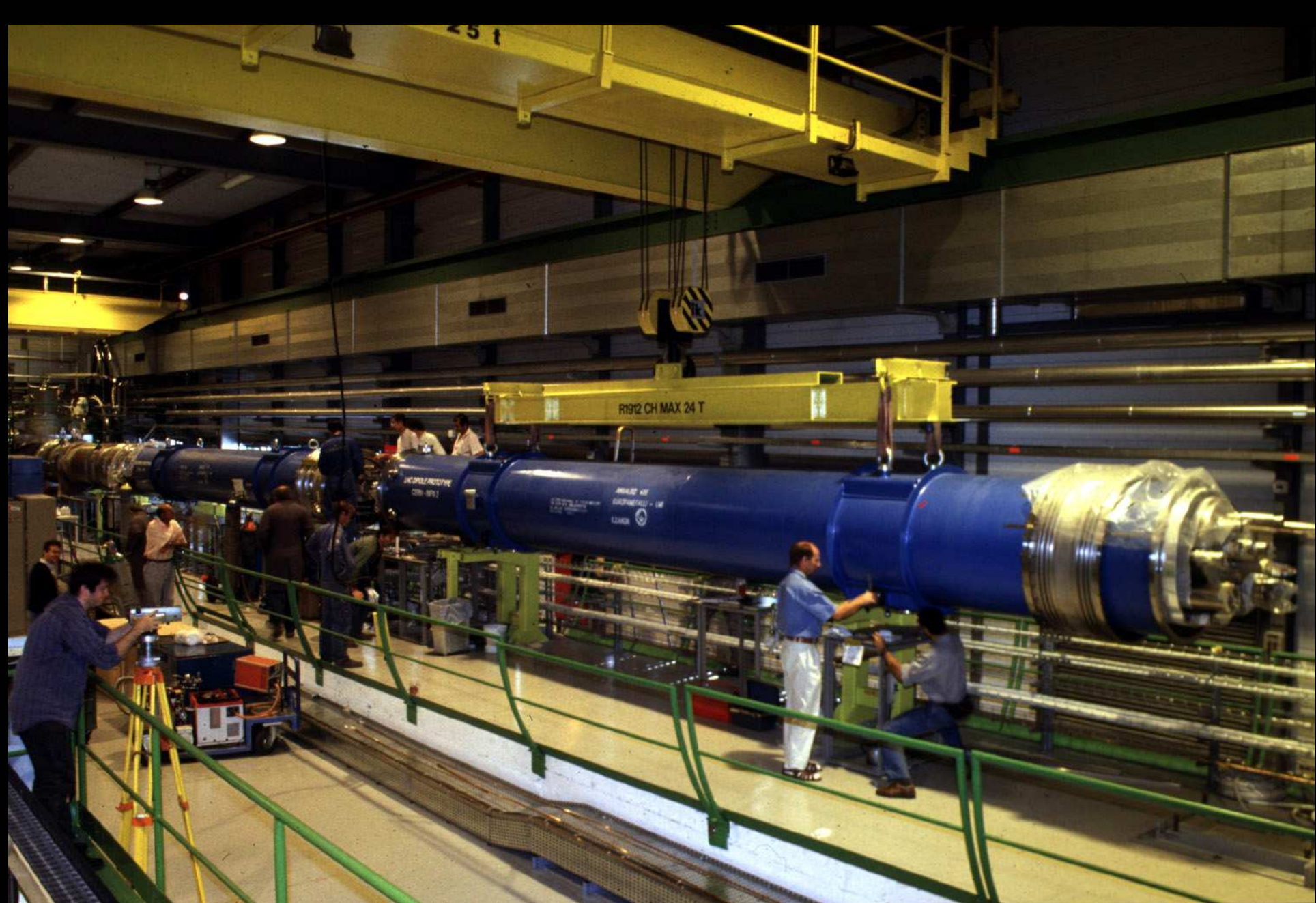
Charged Protons are deviated by a very homogeneous magnetic field



An LHC magnet:

44 tons, 15.000 Amps per wire, max. 10 Tesla,
bathing in -272°C liquid Helium





Testing a string of three LHC magnets

2500 Dipole Magnets (44t) waiting outside



~2500 Dipoles, ~1300 Multipoles

One 44t LHC magnet is lowered into the pit



A special transporter picks up the magnet



The electric transporter in the tunnel



Final assembly at 1/10 mm precision (across 27km)



Are the results worth the effort?

- We don't know yet – our grand-children will tell us ...
- Some side effects of the "technology draw":
 - The World Wide Web (in 1993) -----
 - New cooling techniques
 - Medical Scanners (PET)
 - New isolation materials
 - Precise tunnel measuring
 - Lithography (used for chip production)
 - ...



Sir Tim Berners-Lee
"Inventor" of the WWW

The Holy Grail : **HIGGS** Particle



Physicists are hunting down this strange particle responsible – in theory – for the phenomenon "*MASS*".

Einstein's Relativity Theory and Max Planck's Quantum Mechanics only fit together with the HIGGS mechanism.

If we don't find it, we must re-think the universe.





Images Source: CERN

More information:

<http://www.youtube.com/user/CERNTV>

<http://www.weltmaschine.de>