Der ATLAS Muon Detektor
LHC Computing

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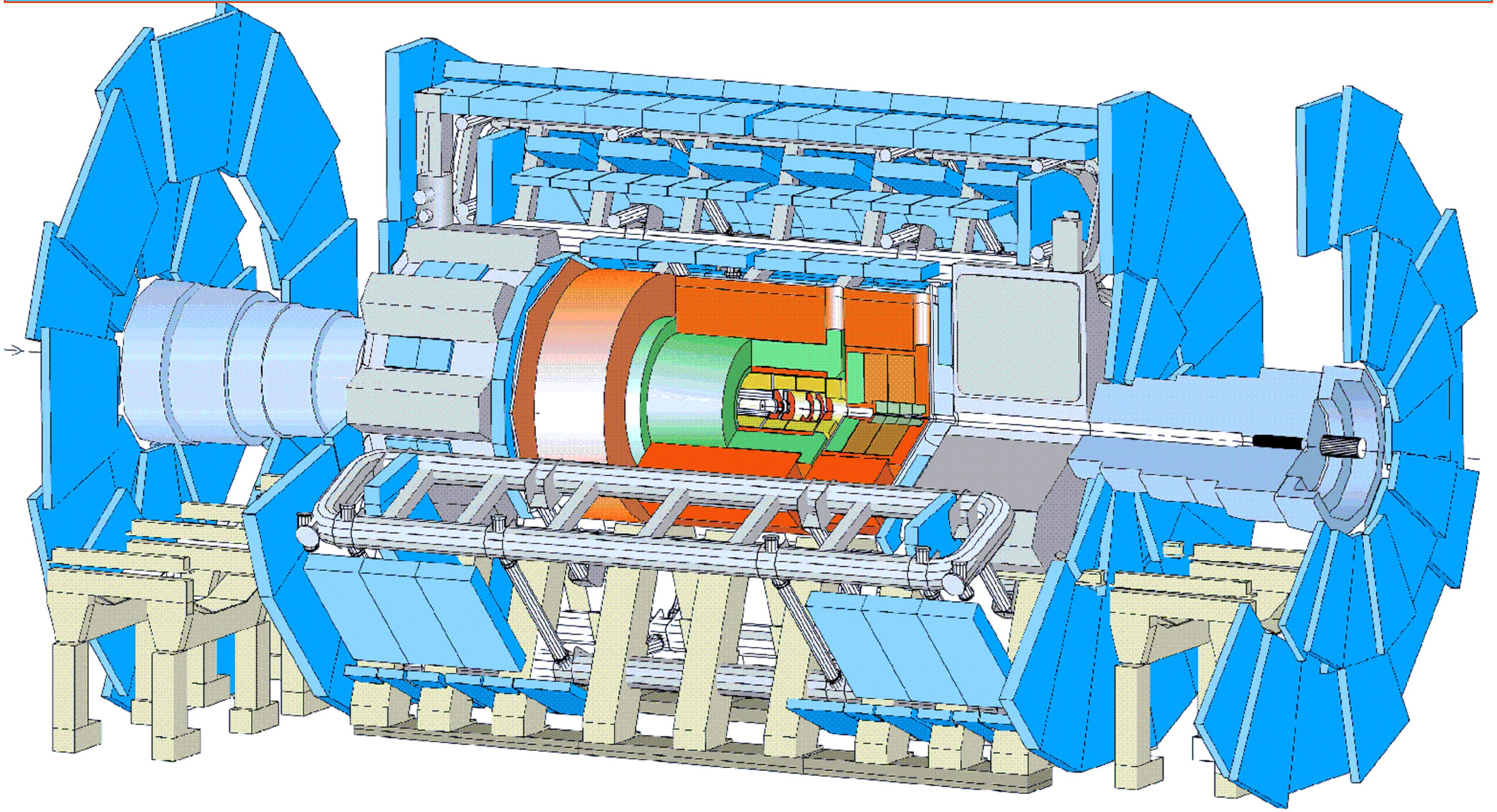
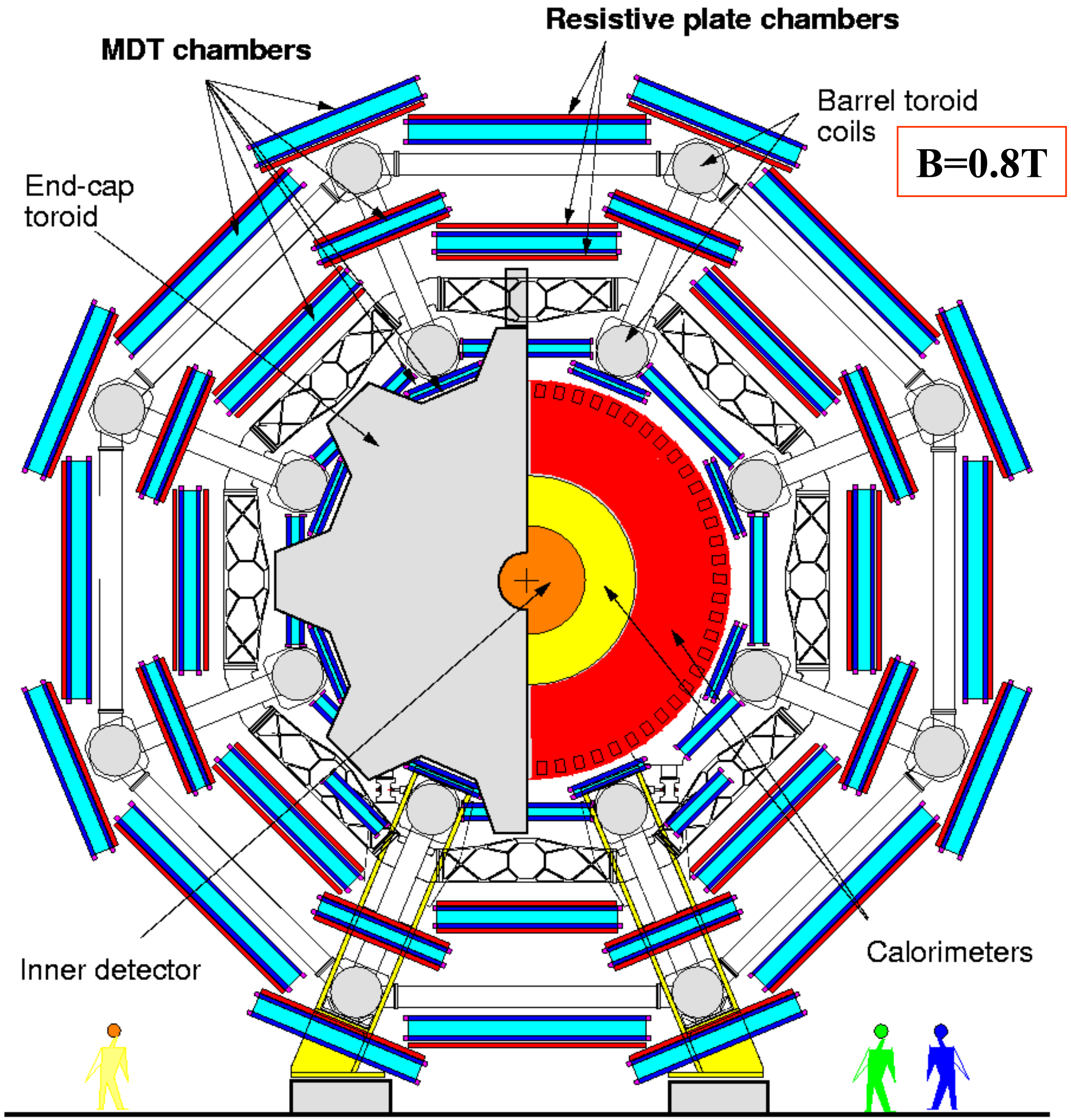
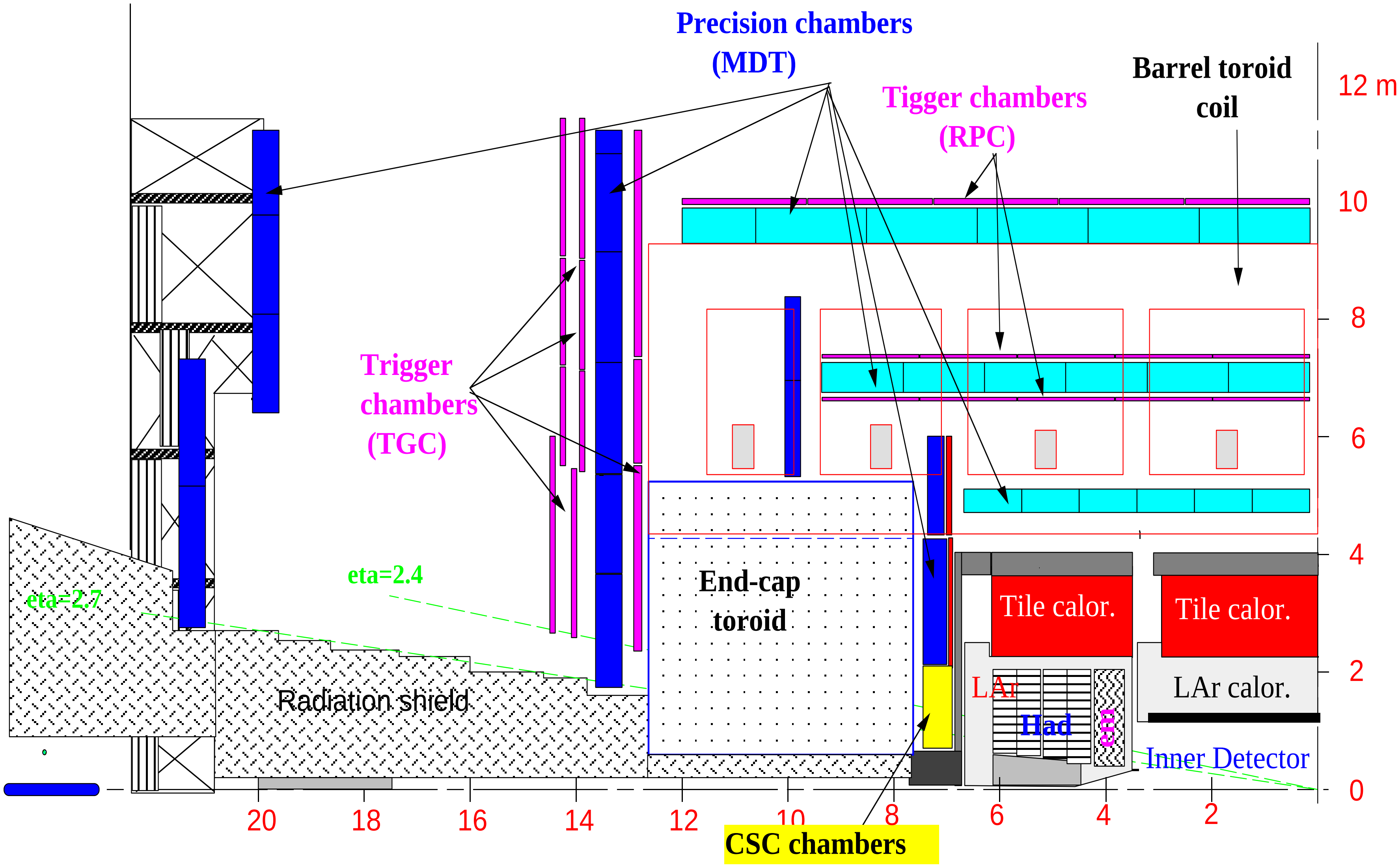
RWTH Aachen

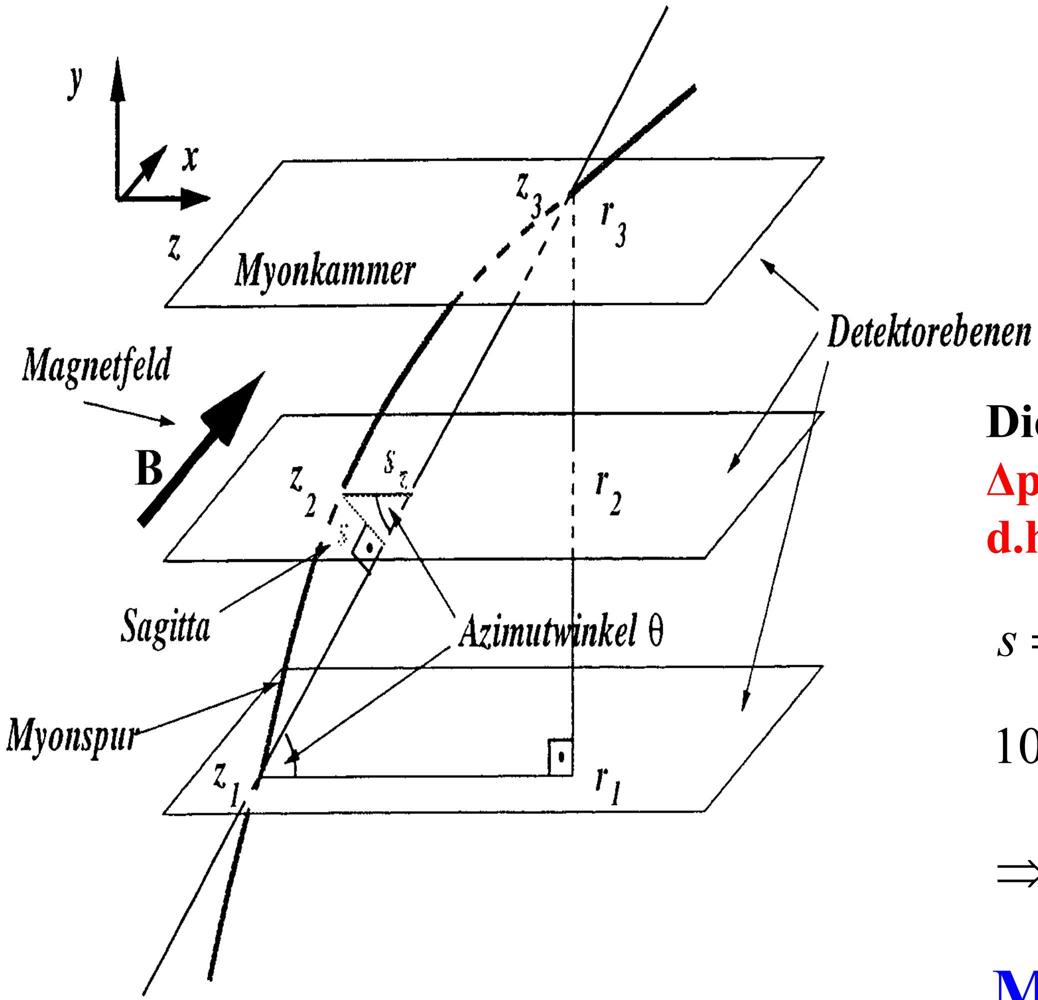


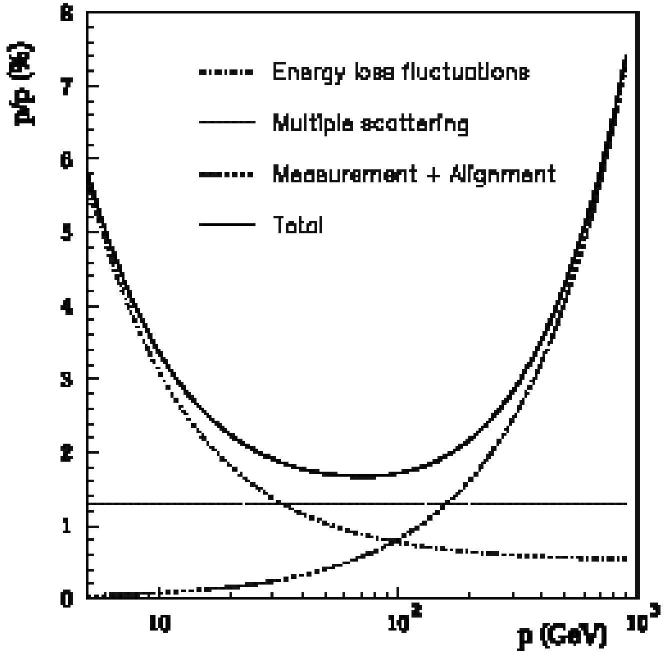

Resistive plate chambers
MDT chambers
Barrel toroid
coils
B=0.8T
End-cap
toroid
Inner detector
Calorimeters

ATLAS Muon Spectrometer



MDT
Spur-Messung





Die angestrebte Impulsauflösung beträgt:

$\Delta p_T/p_T < 10^{-4}$ p[GEV] für p_T > 300 GeV
d.h. 10% Genauigkeit für eine 1 TeV Spur

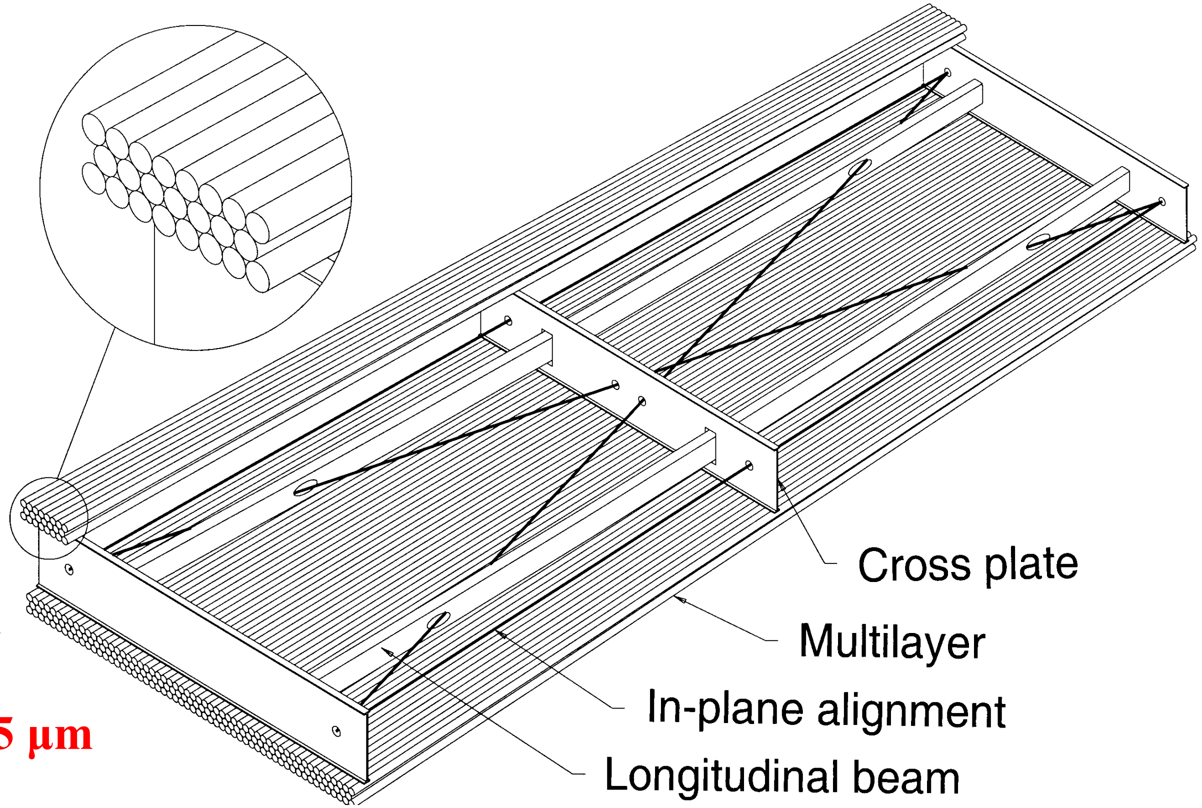
$$s = 0.3\frac{B \cdot L^2}{8 \cdot P} = 0.3\frac{0.8 \cdot T \cdot (5m)^2}{8 \cdot 1000 GeV} = 0.75mm$$

$$10\%\ Genauigkeit \Rightarrow \sigma_s = 75\mu m$$

$$\Rightarrow \sigma_z = \sqrt{\frac{2}{3}} \cdot \sigma_s = 60\mu m$$

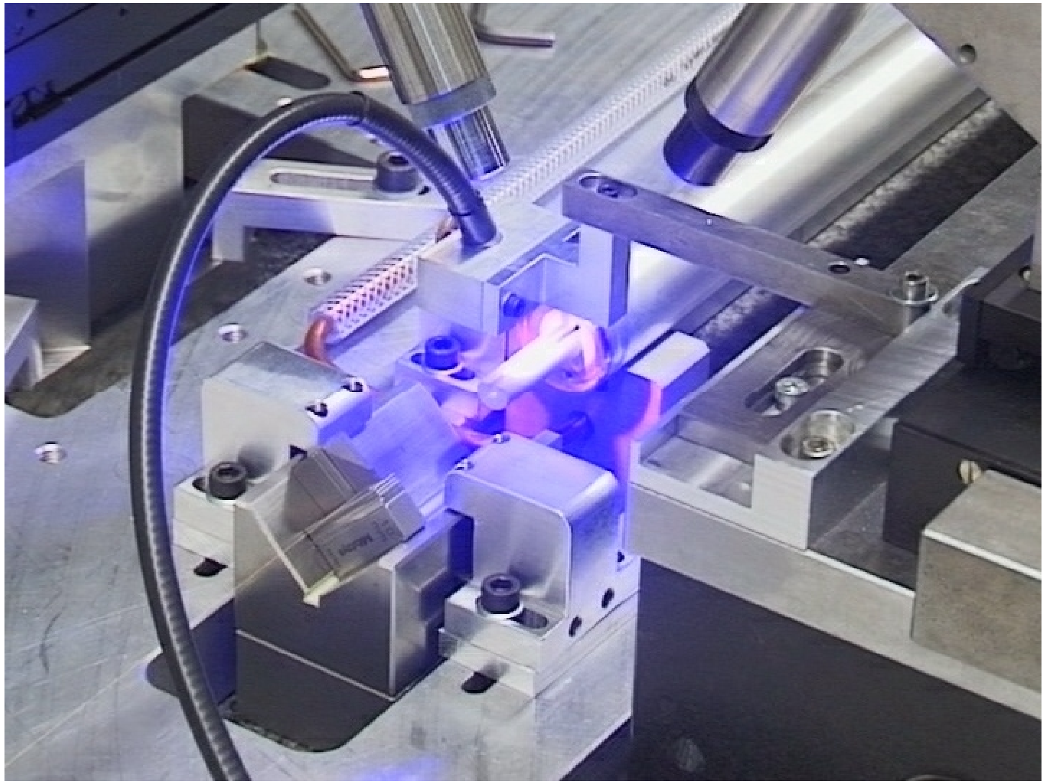
Messgenauigkeit: 50 µm

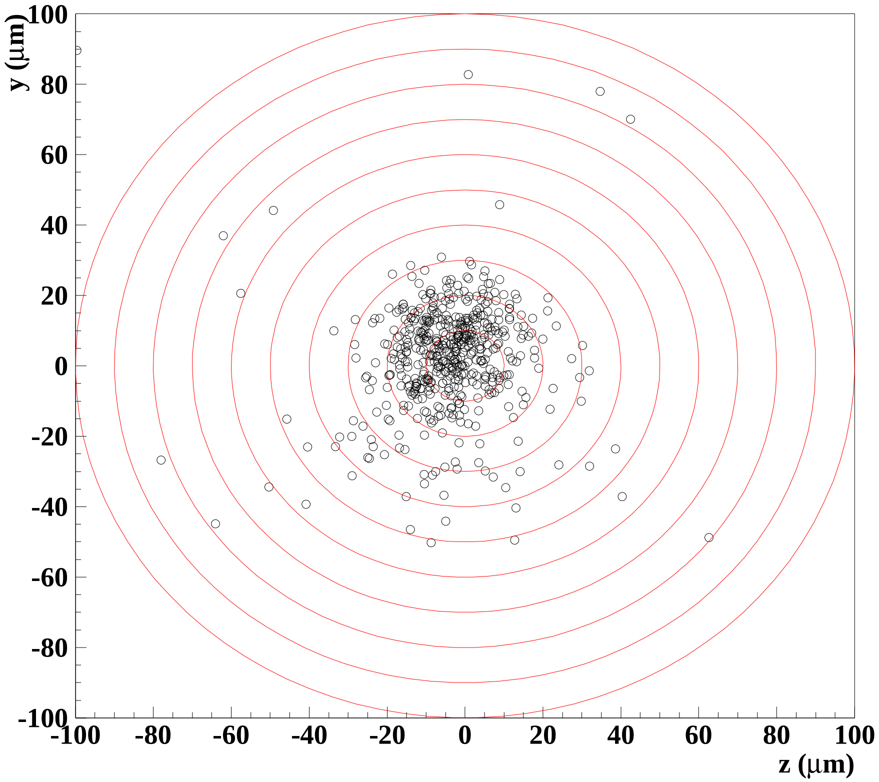
MDT Kammeraufbau



- **Driftröhren, gefüllt mit Ar-CO_2 Gas bei 3 bar.**
- **Einzelrohrauflösung: 80 µm**
- **6 Messpunkte/Kammer →35 µm**
- **Anforderung an die mechanische Präzision: 30 µm**
- **Die zu überdeckende Fläche beträgt ca. 5500 m^2 dafür werden ca. 1200 MDT Kammern benötigt.**
- **Kammerlängen: 70 - 630 cm**
- **Es müssen ca. 370.000 Rohre produziert werden !**

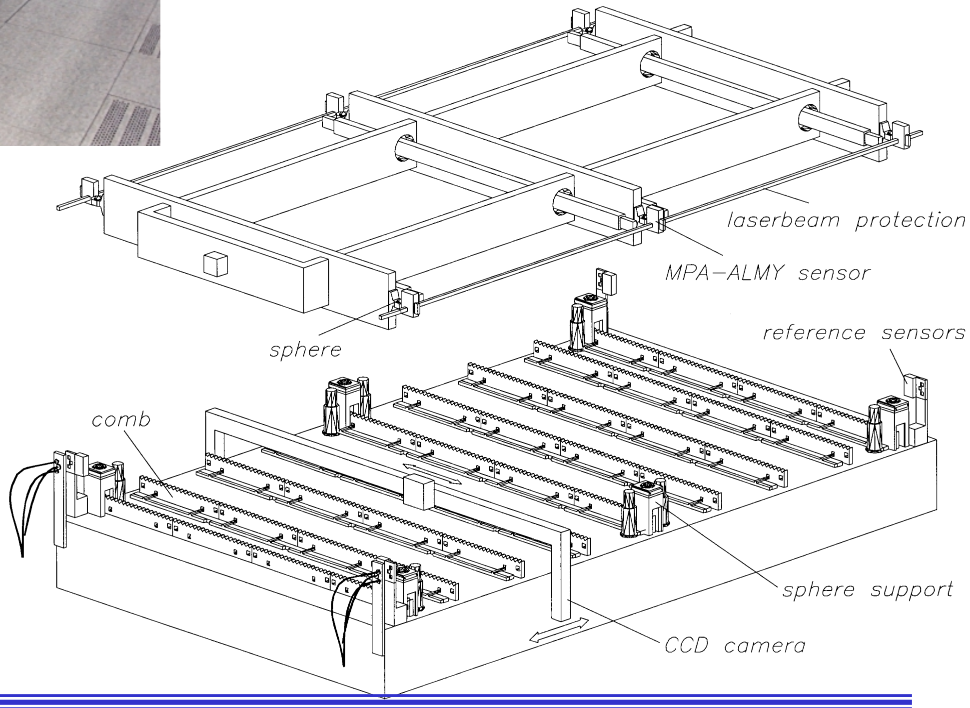
Produktion & Qualitätskontrolle der Driftröhren



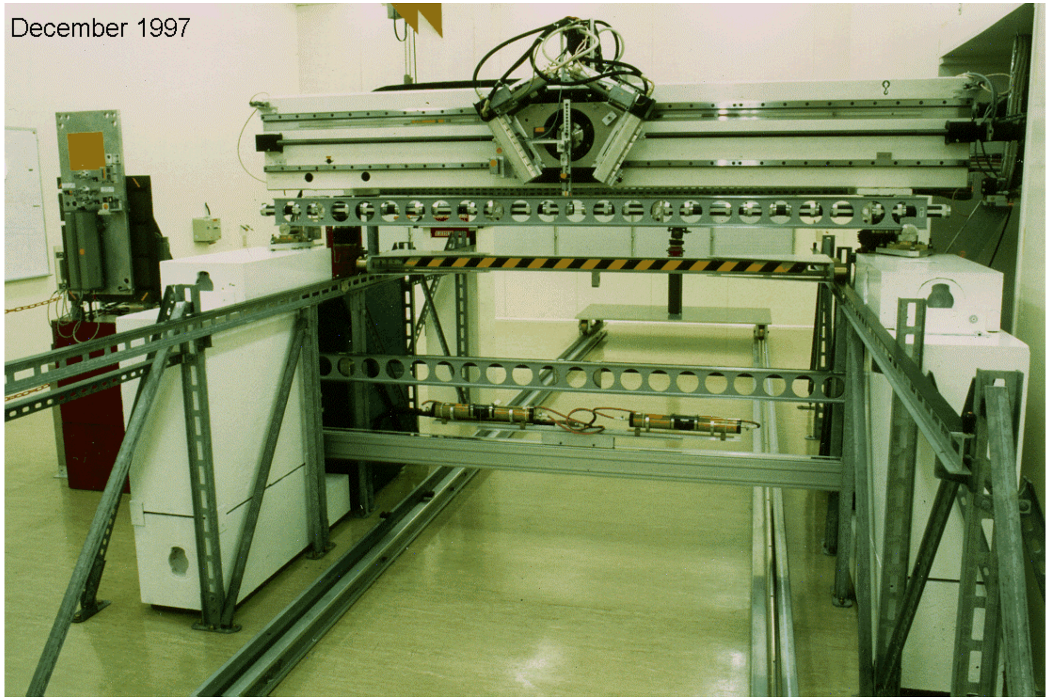


$\sigma(y) = \sigma(z) = 10\ \mu m$

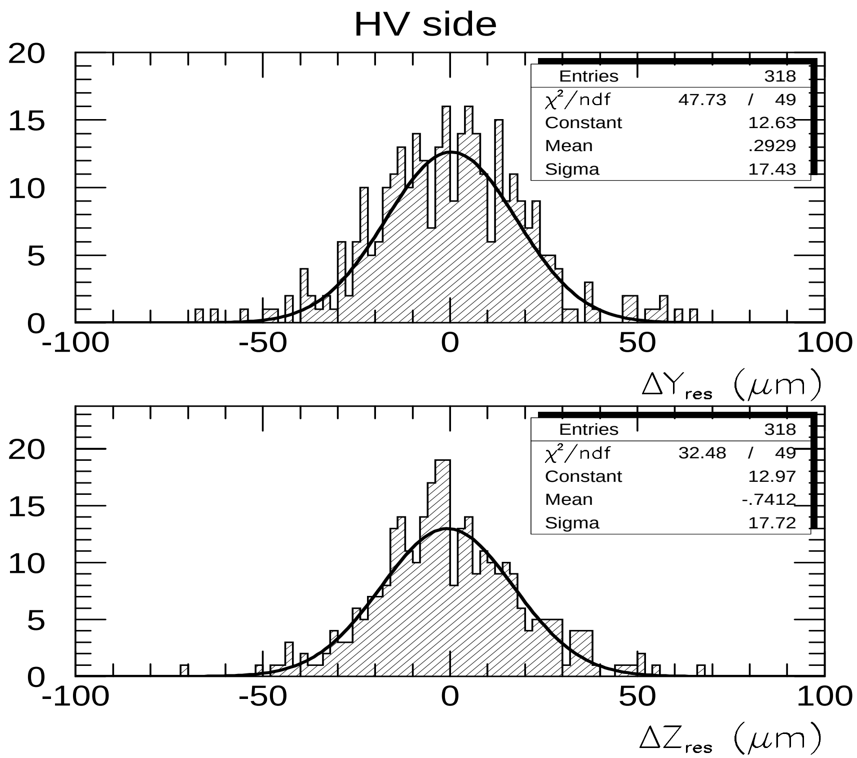
MDT Kammerbau



- **Aufbau der Kammer in einem Reinraum der Klasse 50.000**
- **Temperaturstabilisiert auf ±1 Grad**
- **auf einem Granittisch mit einer Ebenheit < 5 µm**



Röntgen der 1. BOS Kammer am CERN



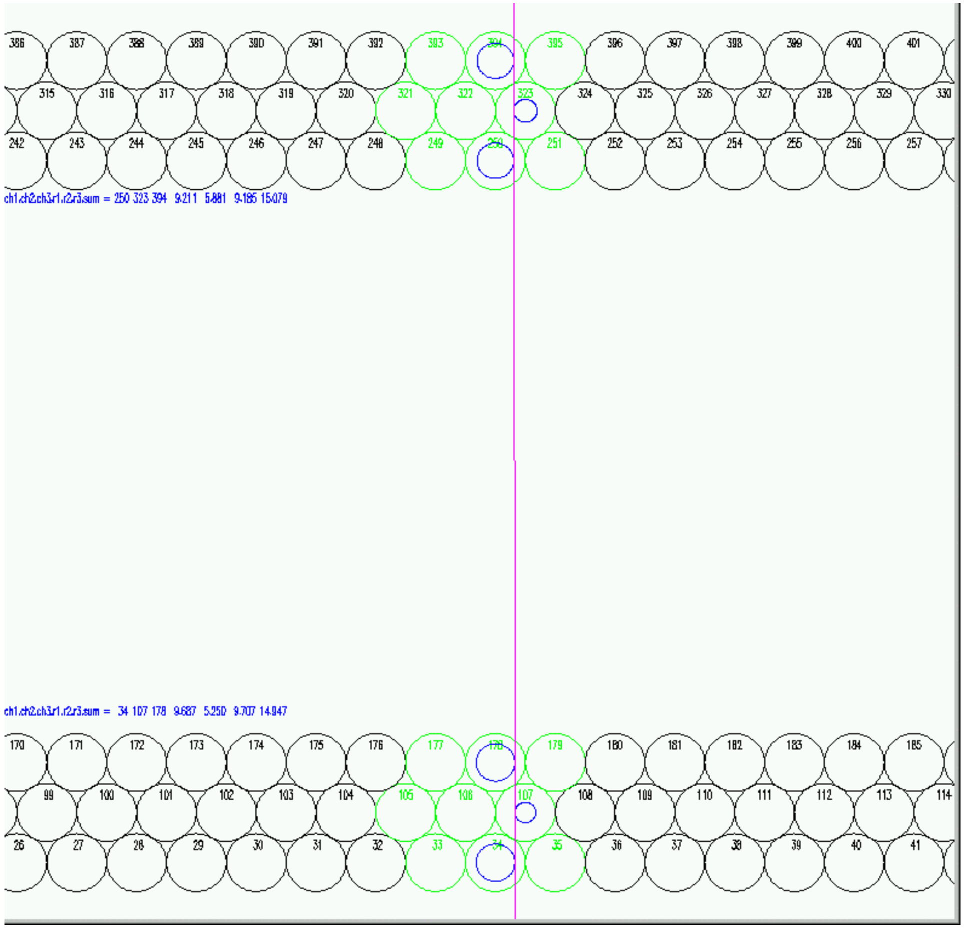
$$\Delta y = 0 \pm 17 \mu m$$
$$\Delta z = 0 \pm 18 \mu m$$

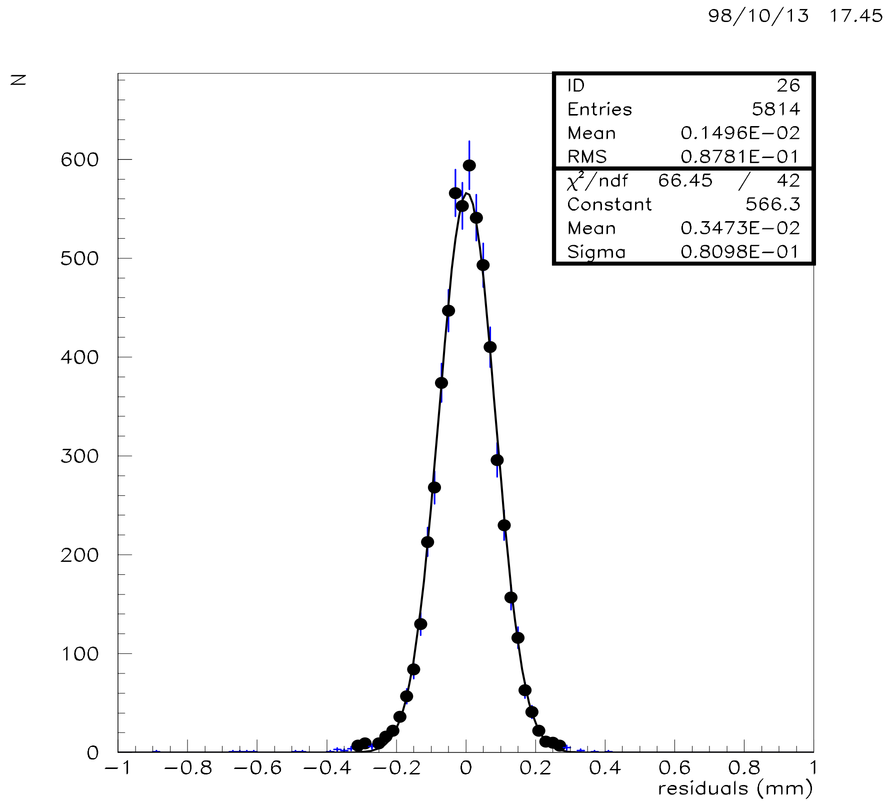
Die 1. BOS Kammer im Test-Beam am CERN

Die 1. BOS Kammer im Test-Beam am CERN

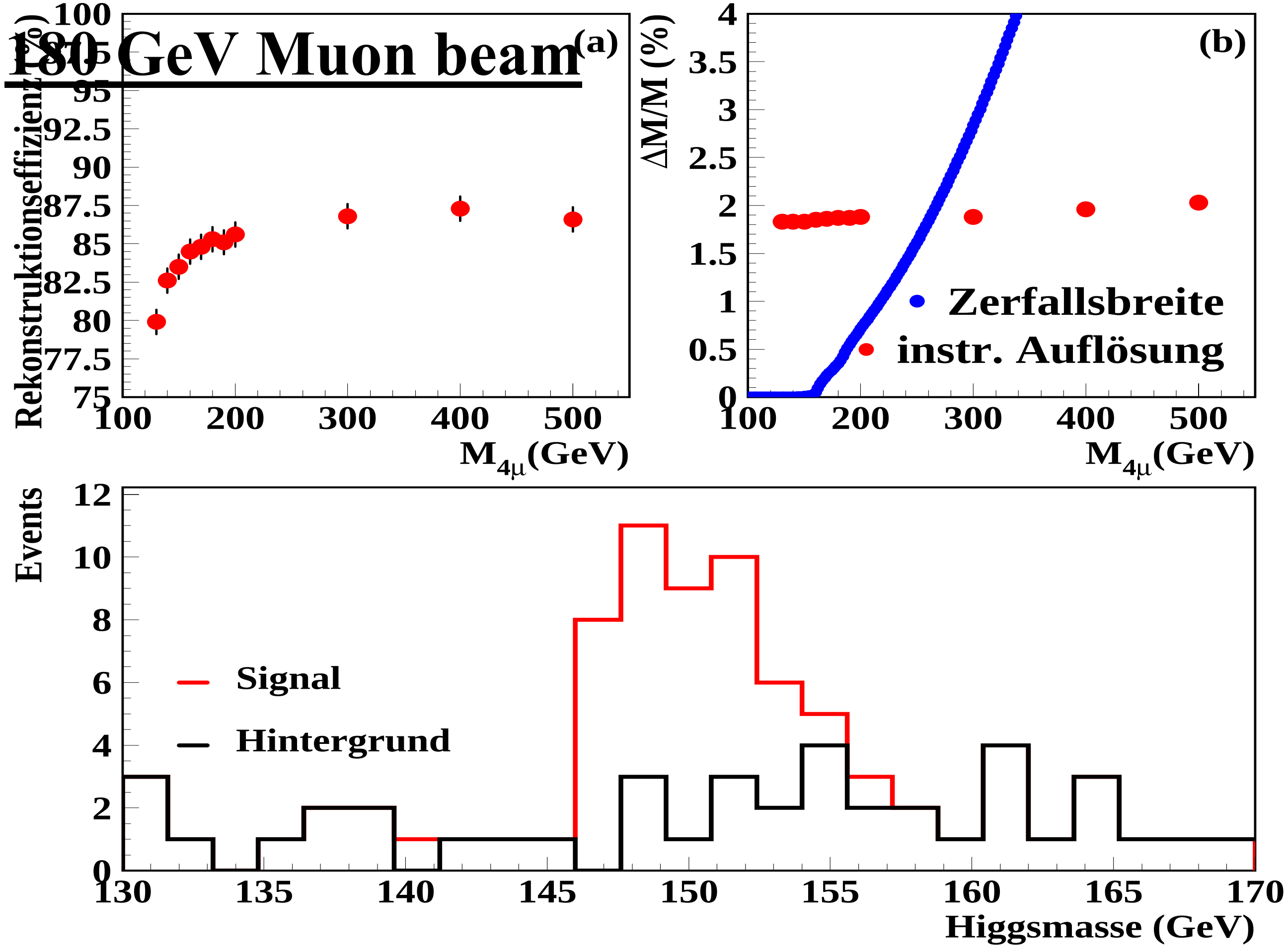
180 GeV Muon beam

Auflösung einzelner Rohre: 80 µm
→ 35 µm Spurauflösung

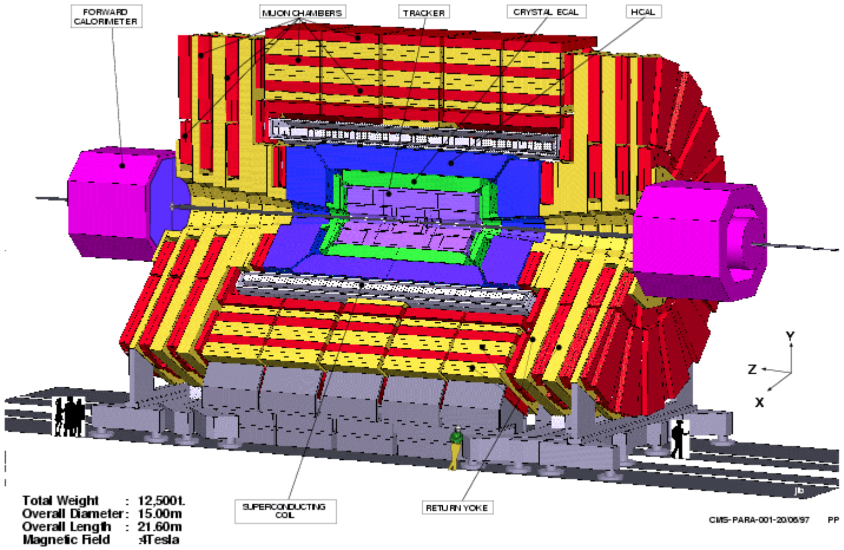


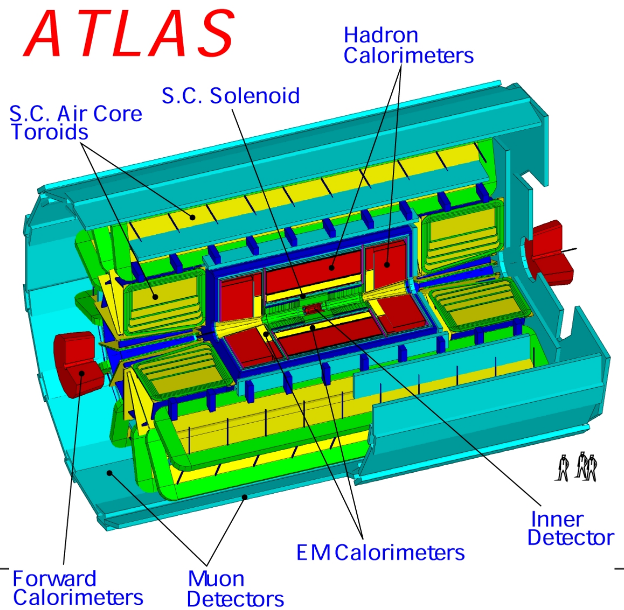


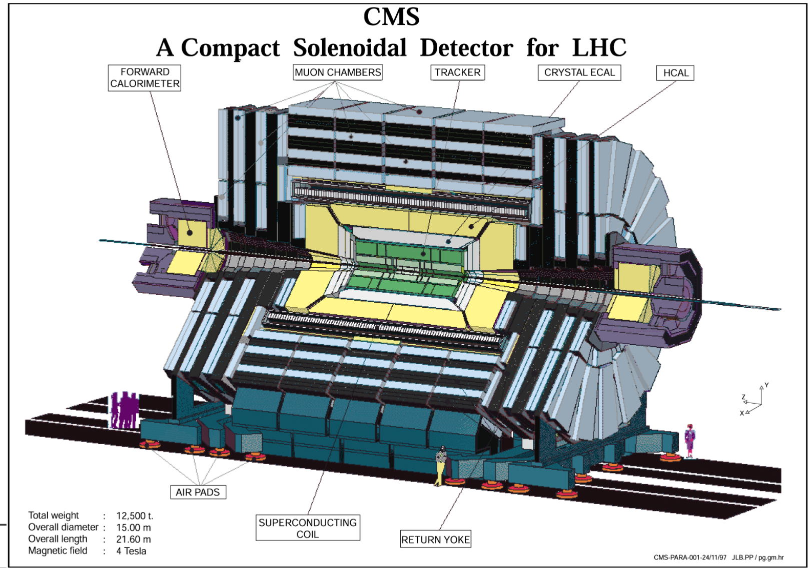
$H \rightarrow ZZ,\ Z \rightarrow \mu\mu$



CMS Muon Detektor & Montage

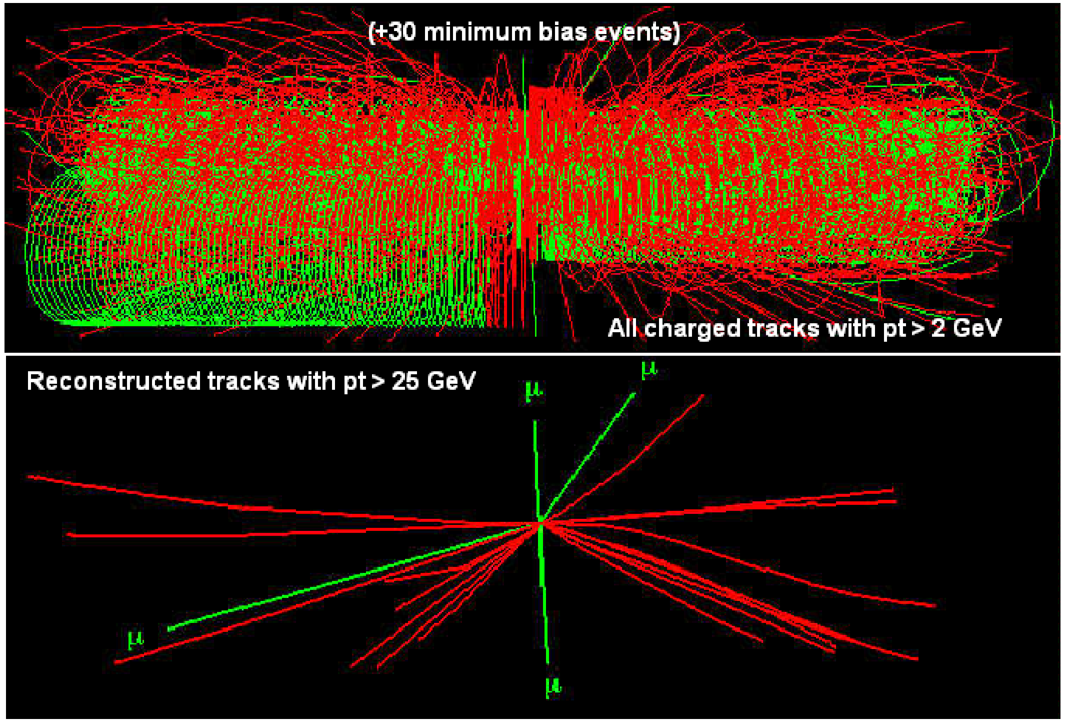


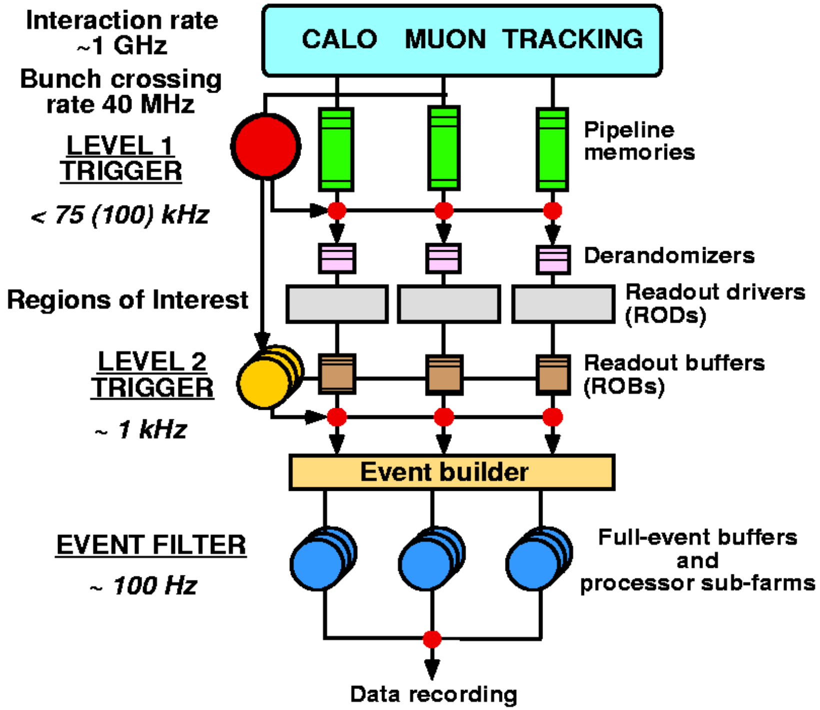




Magnets(s)	Air-core toroids + solenoid in inner cavity Calorimeters outside field 4 magnets	Solenoid Calorimeters inside field 1 magnet
Inner Detctor	Si layers (pixels and strips) TRD $\rightarrow$ particle identification B = 2 T $\sigma/p_T \sim 5 \times 10^{-4} p_T(\mathrm{GeV}) \oplus 0.01$	Si layers (pixels and strips) No particle identification B = 4 T $\sigma/p_T \sim 1.5 \times 10^{-4} p_T(\mathrm{GeV}) \oplus 0.005$
EM calorimeter	Lead-liquid argon $\sigma/E \sim 10\%/\sqrt{E(\mathrm{GeV})}$ Longitudinal segmentation	$PbWO_4$ crystals $\sigma/E \sim 2-5\%/\sqrt{E(\mathrm{GeV})}$ No longitudinal segmentation
HAD calorimeter	Fe-scintillator + Cu-liquid argon $> 10\ \lambda$ $\sigma/E \sim 50\%/\sqrt{E(\mathrm{GeV})} \oplus 0.03$	Cu-scintillator $> 5.8\ \lambda$ + tail catcher $\sigma/E \sim 65\%/\sqrt{E(\mathrm{GeV})} \oplus 0.05$
Muon spectrometer	Air $\sigma/p_T \sim 7\%$ at 1 TeV achieved by spectrometer alone	Fe $\sigma/p_T \sim 5\%$ at 1 TeV achieved by combining with inner det.

Computing for the LHC experiments
10^8 elec. channels/experiment





Higgs decay in 4 muons: 1 in 10^{13} events
Trigger: 10^9 events/s $\Rightarrow$ 100 events/s $\Rightarrow$ tape

LHC Computing: Event Sizes

	Aleph	Babar	CDF	CMS
Evt size (MB)	0.25	0.05	0.25	1.
Evt rate (Hz)	1.	100	75	100
Data vol (TB/y)	1.	100	450	2000
Disk sp (TB)	0,5	60	100	1000
Collab.	300	500	600	2000

from E. Augé, EPS 2001

Computing capacity for all LHC experiments

	CERN	RCs	Total	CERN today
CPU (kSI95)	2560	4970	7530	20
Disk (PB)	2.4	8.7	11.1	0.025
Tapes (PB)	17.6	20.3	37.9	

Total initial cost : 240 MSF

from CERN/LHCC/2001-004 (report of LHC Computing Review)

CINT95 is a set of eight benchmark applications written in C which perform compute-intensive applications such as artificial intelligence, compressing and uncompressing files in memory, string and prime number manipulation, database, and graphic compression. The SPECint95 (SI95) is the geometric mean of the eight normalized ratios (one for each integer benchmark).

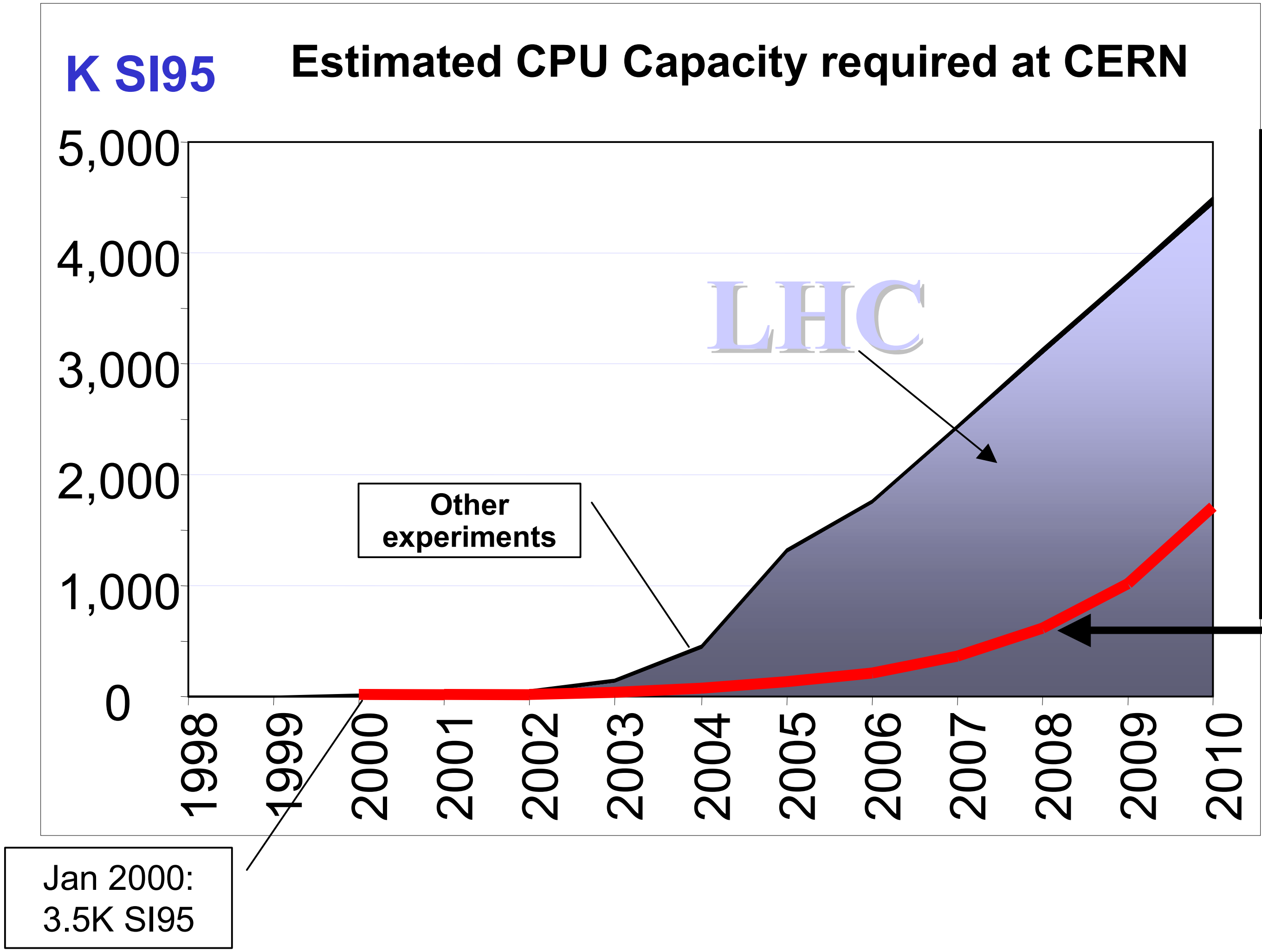
PIV 2 GHz ⇔ 100 SI95

LHC Prototype capacity (at CERN)

year	2001	2002	2003	2004	2007
Processors					
# of boxes	200	400	800	1200	
CPU (kSI95)	13	33	85	160	2560
Disks					
# of disks	200	400	800	1600	
capacity (TB)	16	44	120	320	2400
Tape robot					
capacity (TB)	30	120	350	600	

from E. Augé, EPS 2001

Complex Data = More CPU Per Byte



Moore's law – some measure of the capacity technology advances provide for a constant number of processors or investment

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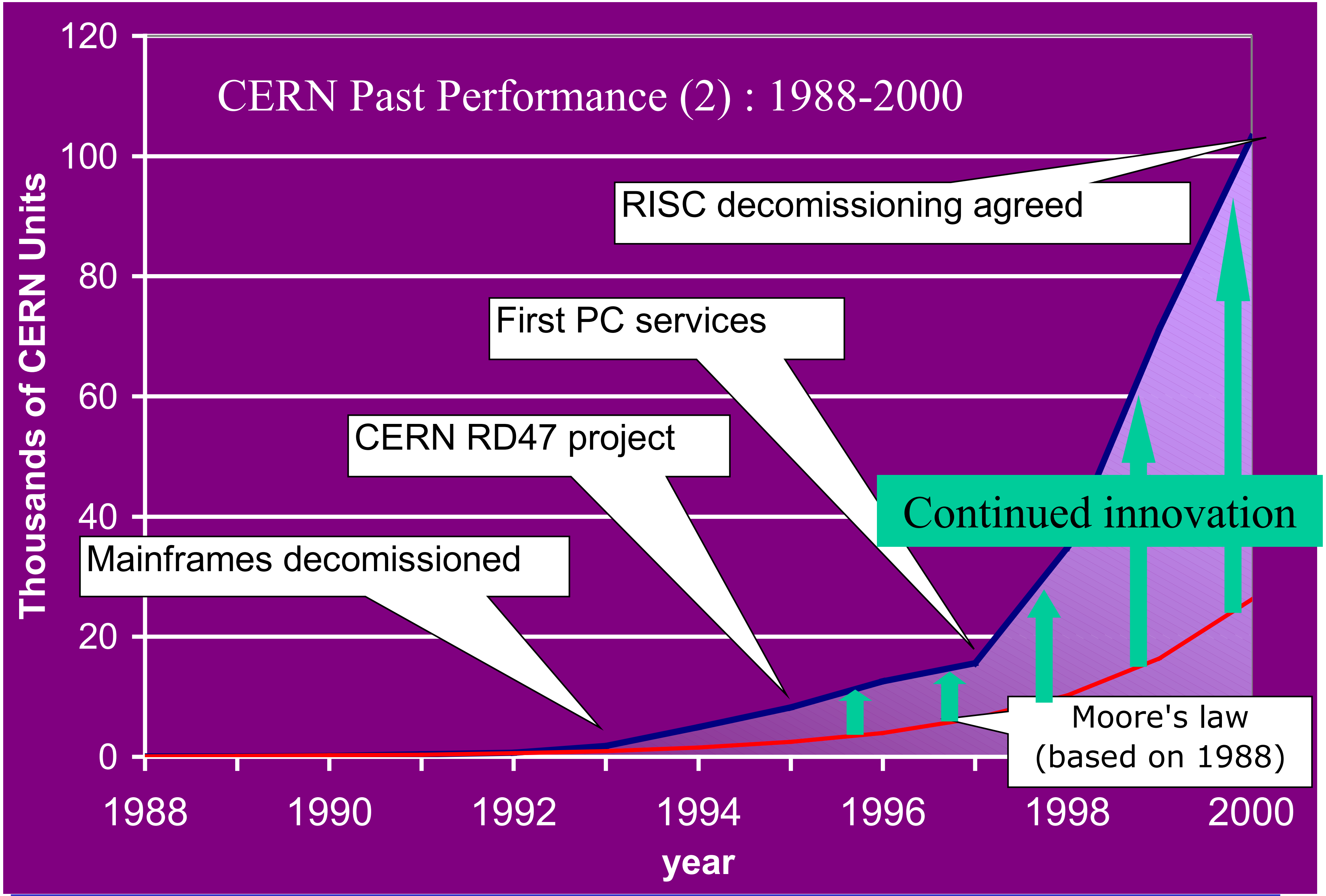


from L. Maiani, EPS 2001

- **5 years ⇒ factor 10 on CPU power of each PC**
- **buy 10 times more boxes than present**

  … and manage them ! ⇒ GRID
- **similar statement with disk but…**

Limited bandwidth between disk and CPU !

Factor <10 in 10 years, partly with parallel access (RAID)

10 GB @ 1MB/s = 3 hours = 1% of 1 year of Aleph data

1 TB @ 100 MB/s = 3 hours = 0.05% of 1 year of CMS data

You should know which data you want before getting them

You should precisely tell to the computer system

Optimizing disk - memory transfers → OO Software

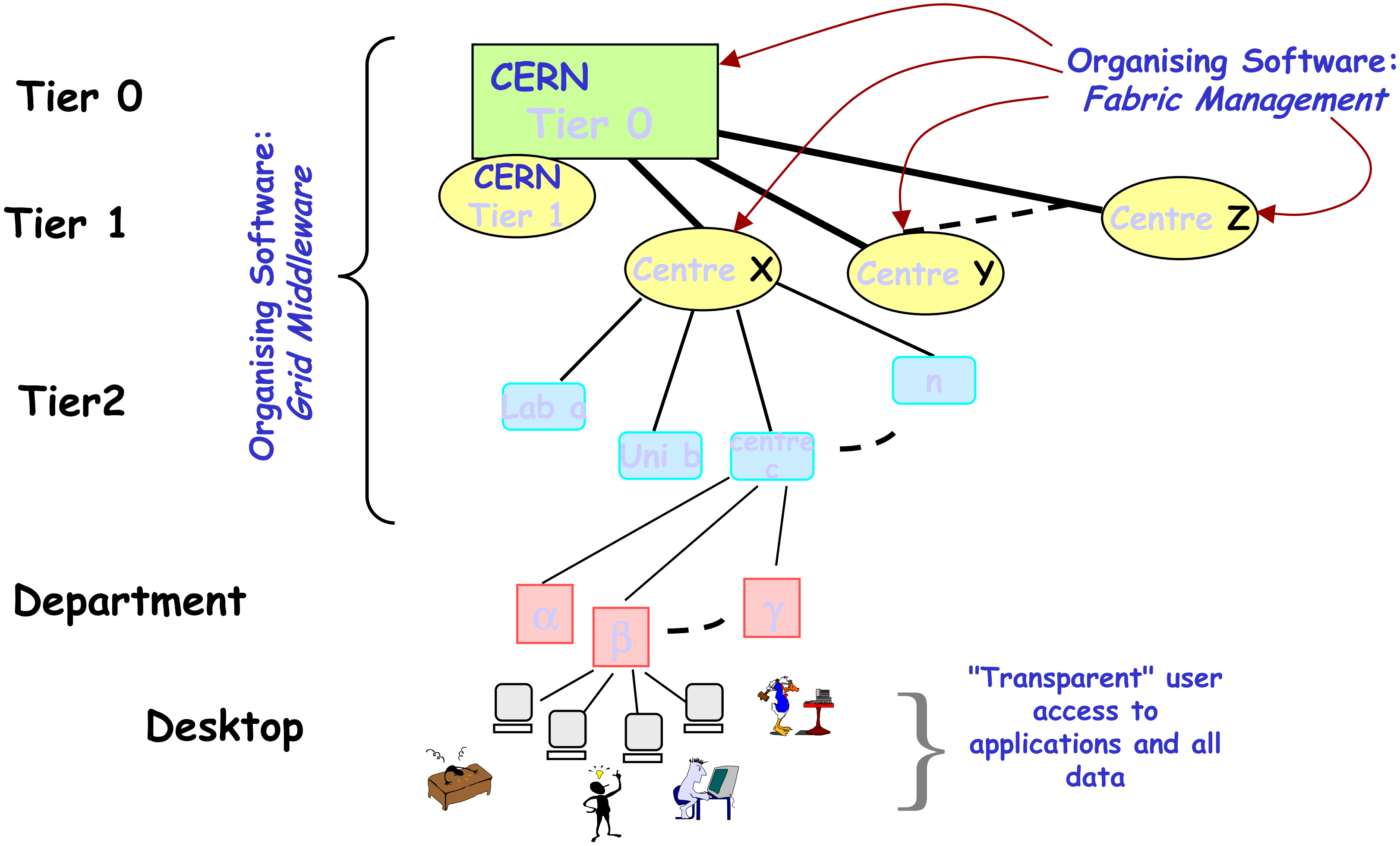
- « Old times » :
  – read the full event records (sequentially)
  – unpack the full event record → user program
  – use only a few bytes among thousands

  → Waste of bandwidth, CPU (unpacking)

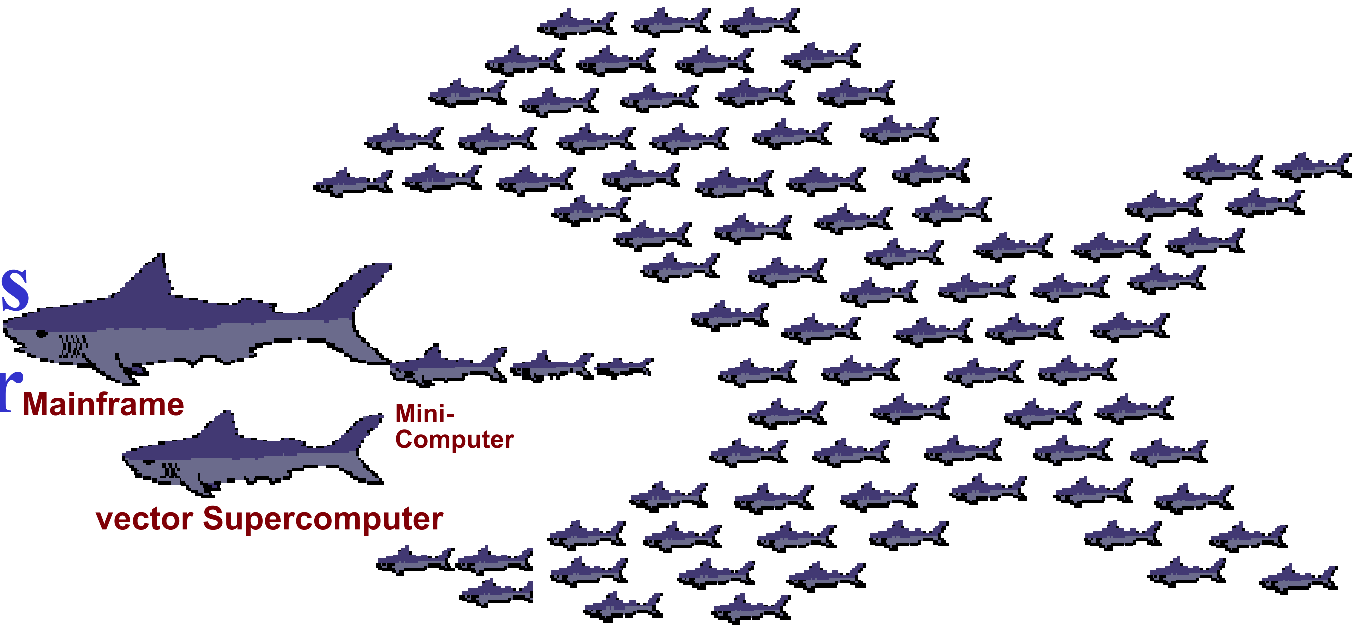
- Already some clever tricks in previous experiments

- but new tools are a necessity
  C++, ROOT, Objectivity, …

The LHC Computing Model



Processor farms : the 90's supercomputer



NOW

Found at the NOW project (http://now.cs.berkeley.edu)

- PC+Linux: the new supercomputer for scientific applications
- Principle well established; farm examples abound

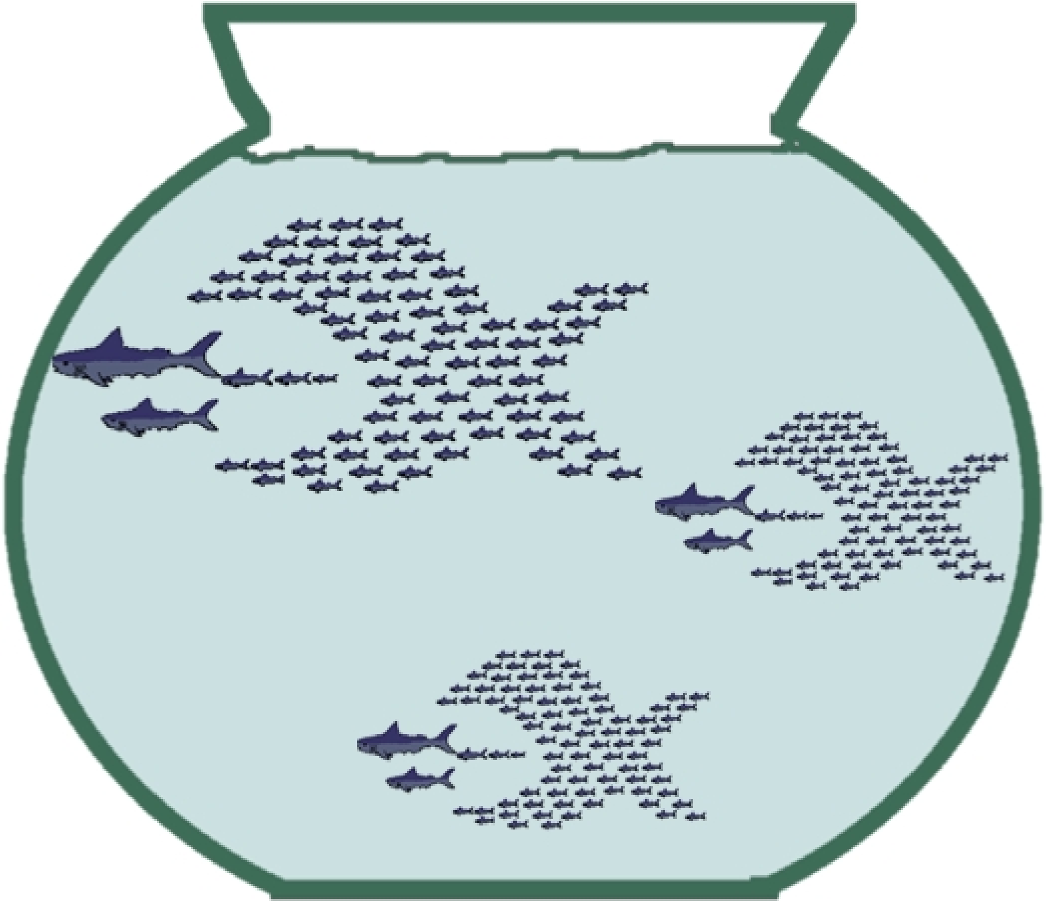
obswww.unige.ch/~pfennige/gravitor/gravitor_e.html

www.cs.sandia.gov/cplant/

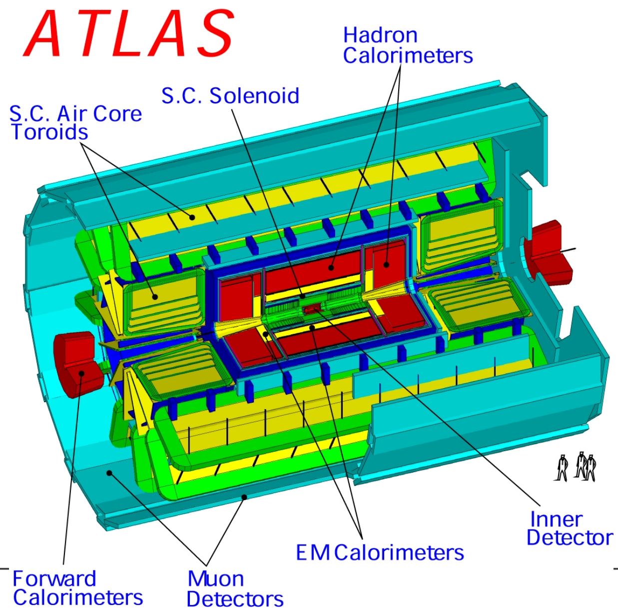
now.cs.berkeley.edu

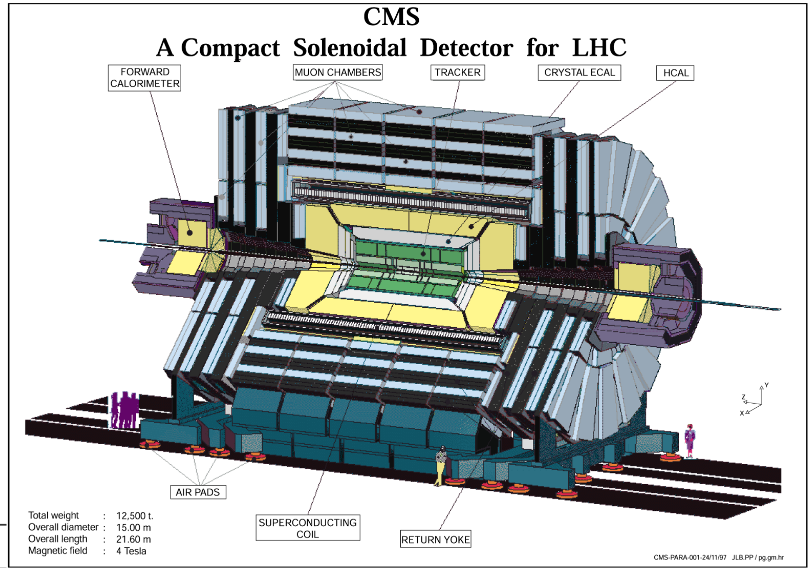
www.ncsa.uiuc.edu/General/CC/ntcluster/

After commodity farms what next?



Fusion of data communication, data processing and data archive global resources : Grid approach ?





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Higgs Boson at the LHC

- **SM Higgs boson can be discovered at ≈ 5 σ after ≈1 year of operation ($10 fb^{-1}$/ experiment) for m_H ≈ 150 GeV**
- **Discovery faster for larger masses**
- **Whole mass range can be excluded at 95% CL after ~1 month of running at $10^{33} cm^{-2} s^{-1}$.**