Introduction to ATLAS

- **part 1: ATLAS Detector (and LHC)**
- part 2: Physics programme in ATLAS
- part 3: Event Reconstruction and
  Physics Performance
- part 4: Physicists’ tools
  analyses in ATLAS

UNIVERSITAS BERGENSIS

Wolfgang Liebig

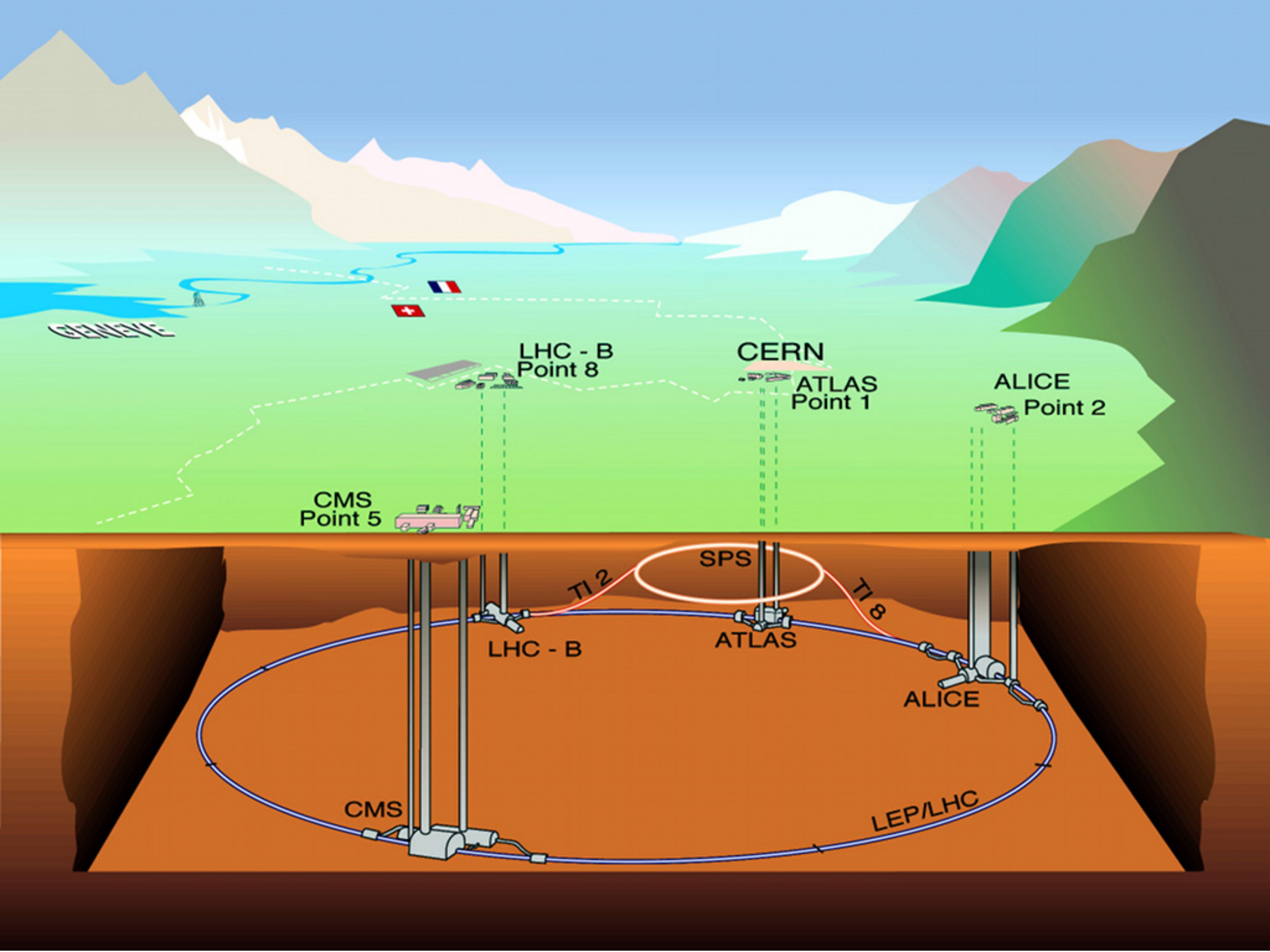
Part 1: Collider and Detector

- The Collider: LHC
  - design, performance, status
- ATLAS structure, detector concepts
- Inner tracking detectors
- Calorimetry
- Muon chambers (and ATLAS magnets)
- Trigger
- Simulation
- (Construction of ATLAS)

LHC Project

- LHC collides 2 beams of protons
- Protons chosen to maximise beam energy and intensity
  - TeVatron: proton+anti-protons
  - LEP: electron+positron
- Beam energy 3.5 TeV
  - designed to become 7 TeV after upgrade to machine's internal protection (2013/2014)
  - TeVatron: 0.98 TeV
- "Luminosity" 10^{34} cm^{-2}s^{-1}
  - so high that more than 1 proton pair collides per bunch crossing
  - actually ~23 collisions-per-crossing (called "pile-up") increasing the chances to see rare, interesting physics processes
  - TeVatron: 3×10^{32} cm^{-2}s^{-1}
- Machine integrated in CERN's existing accelerator complex
  - Proton Synchrotron (PS), SuperPS inject to LHC (serve other expt's too)
  - existing tunnel of Large Electron-Positron collider (LEP) re-used

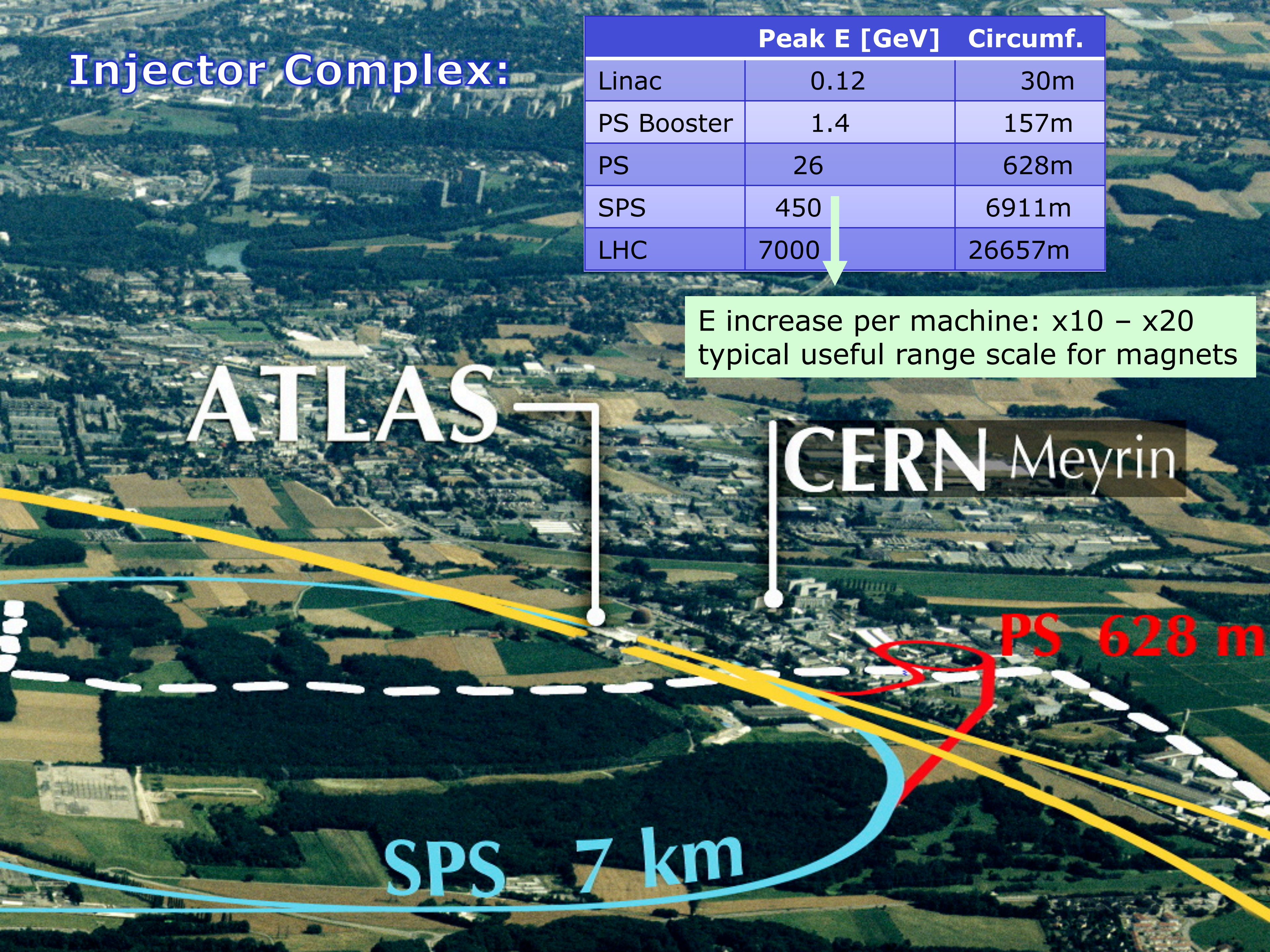
Photo: CERN-MI-0807031


GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 2
TI 8
LHC - B
ATLAS
ALICE
CMS
LEP/LHC

Injector Complex:

	Peak E [GeV]	Circumf.
Linac	0.12	30m
PS Booster	1.4	157m
PS	26	628m
SPS	450	6911m
LHC	7000	26657m

E increase per machine: x10 – x20
typical useful range scale for magnets



Collider Basic Concepts

- **Magnetic fields** for controlling or bending of charged particles
  - curvature in homogeneous field

$$\rho = \frac{p_\perp}{q|B|}$$

  - helpful formula: el. charge in collider units

$$e = 0.2998 \left(\frac{\mathrm{GeV}}{c} \right) T^{-1} m^{-1}$$

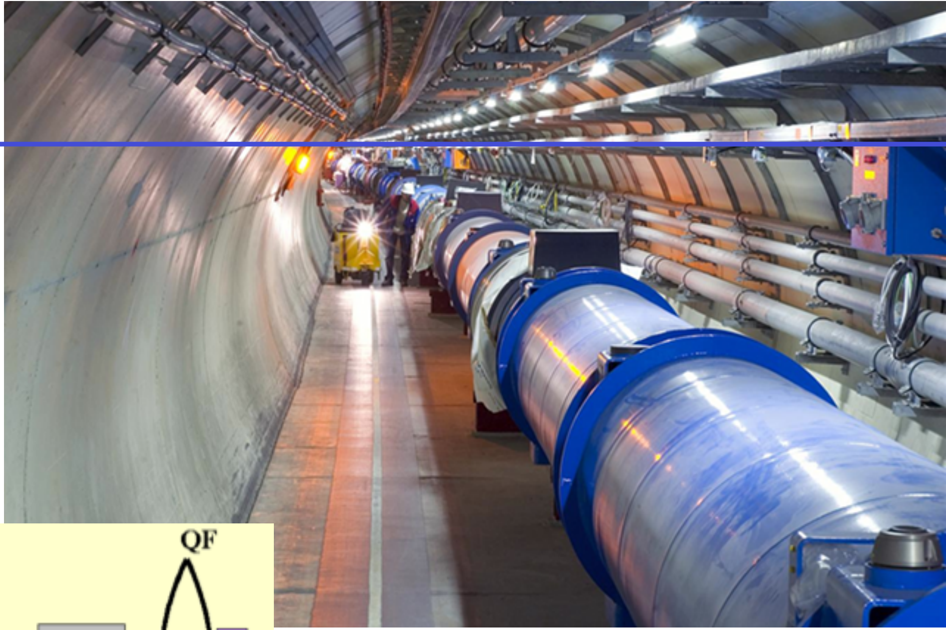
- beams of charged particles in circular LHC tunnel (ρ~3km)
  - di-pole magnets create homogeneous field inside beam pipe
  - quadrupoles and higher order shape beam in both transverse directions
- same concept used in experiments (solenoids)
  - infer p_T from measurment of ρ

- **Cross-section** σ expresses the likelihood of interaction between particles
  - unit is pb, fb (rare processes at LHC)
  - independent of collider performance
- **Luminosity** characterizes collider performance
  - number of particle intersections per second normalised to beam cross section area

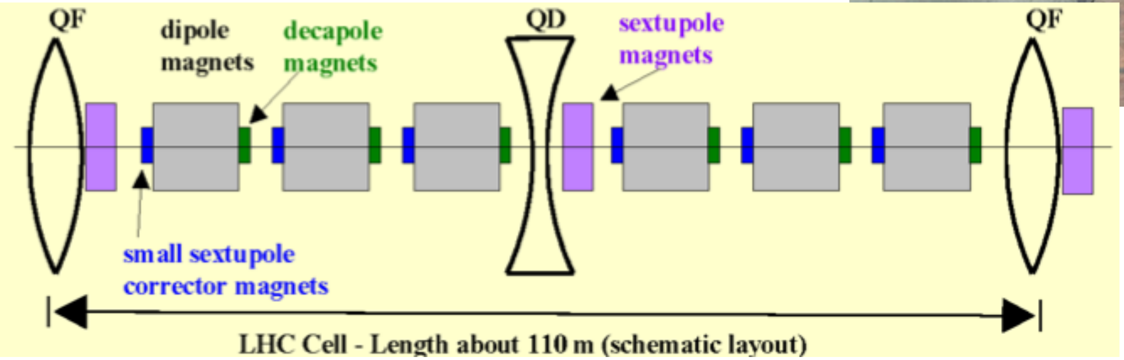
$$L = fn\frac{N_1 N_2}{A}$$

  - quantity to maximise: time-integrated luminosity recorded by experiments
- **Rate** given by L × σ
  - helpful unit: lumi in pb^{-1}, fb^{-1}
  - $1\mathrm{fb}^{-1}$ is 1000 × more than $1\mathrm{pb}^{-1}$

LHC Machine



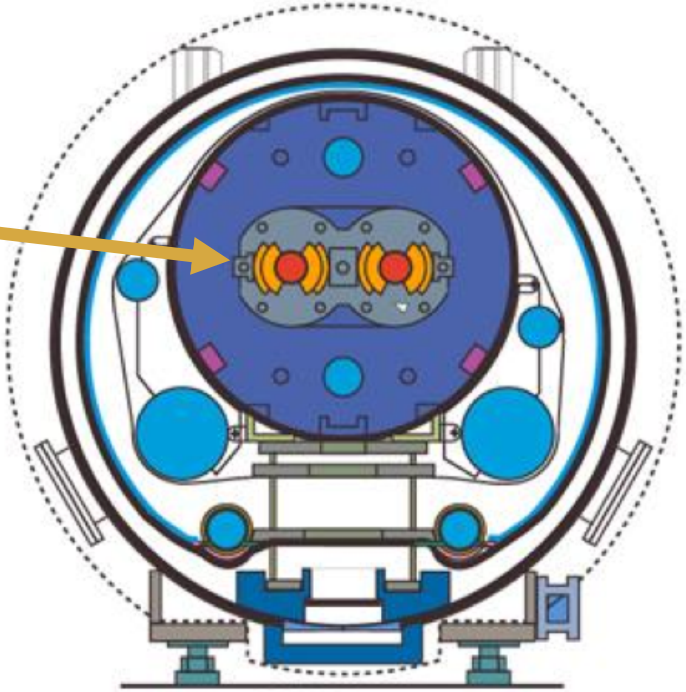
- LHC organised in octants
  - 2.9km each, operationally independent
  - 154 dipoles (inside the big blue tubes)
  - 50 quadrupoles, corrector magnets…
- 100m arc cells



  - dipoles keep beams on circular path, quadrupoles keep it focussed
  - higher order magnets correct for non-uniformities at end of dipoles
- Between octants: interaction points, beam dump etc.
  - straight sections O(200m)
  - tunnel access, ventilation

LHC Magnets

- Superconducting dipoles
  - magnetic field of 8.3 Tesla in 1232 magnets, each 15m long
  - cooled to 1.9K, largest cryogenic system in the world (nb: universe is 2.7K)
  - field is in fact a dual dipole (same charge beams in opposite directions)
- Stored energy (magnets)
  - 7 MJ per dipole, ~10 GJ in all magnets
  - equivalent of 2.4t TNT explosives
  - quench protection is a challenge
- Stored energy (beams)
  - another 2x362 MJ stored in 7 TeV beam



LHC
B = 8.3 T
Bore : 56 mm

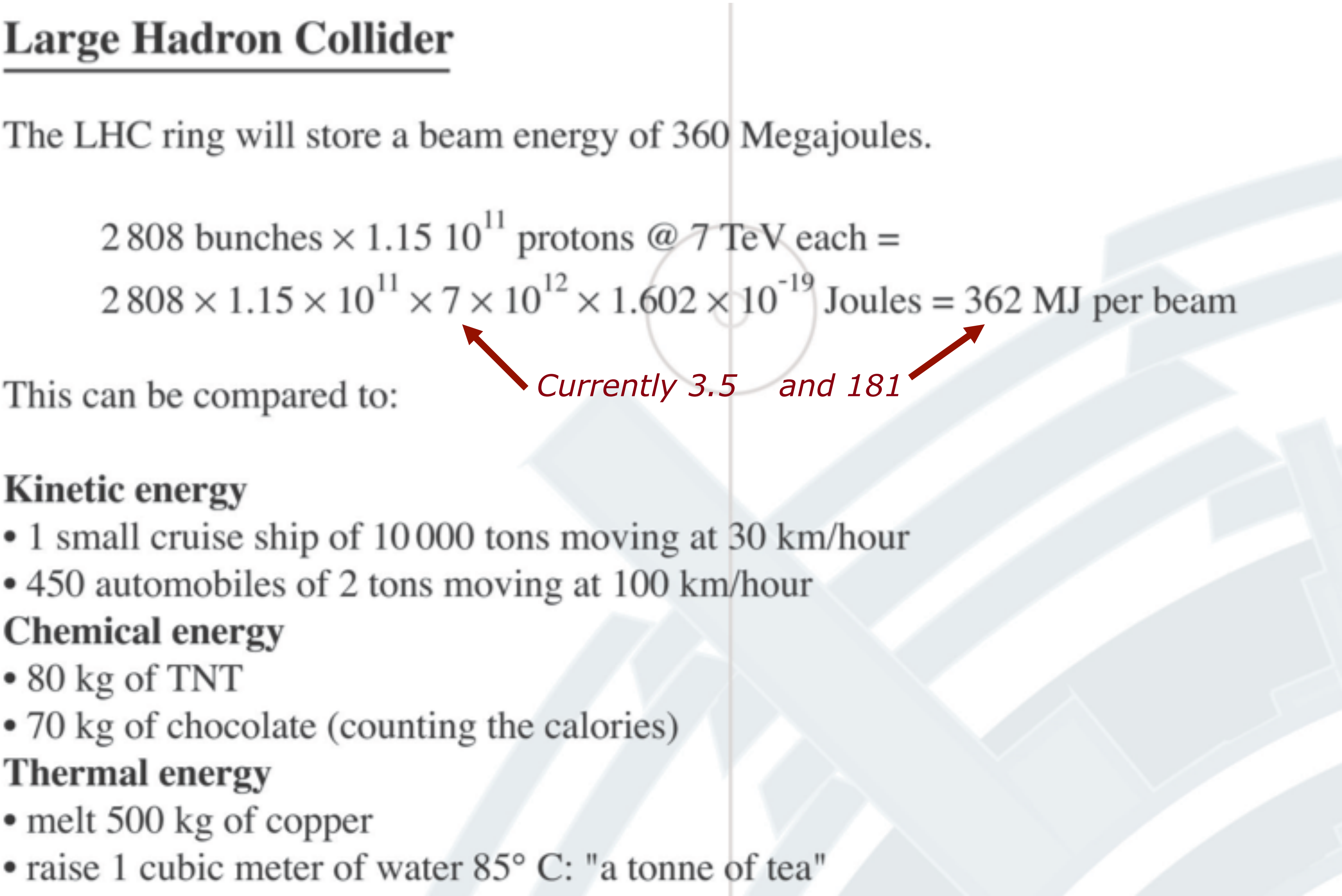
→ *Accelerator will seriously damage itself if uncontrolled quench or beam dump*

LHC Quench Protection

- Quench: phase transition from super to normal conduction
  - small energy dissipations by SC sufficient to cause quench:
    too fast ramping (eddy currents), small movements, beam loss
  - conductor becomes resistive (more heat!)
  - normal conduction spreads quickly and cooling (helium) evaporates
- coils are protected: voltage drop detection
  - quench all coils with heaters and divert current around the magnet
  - energy discharged into resistors
  - rapid process taking O(1s)

Slide from CERN Visits Service

Stored Beam Energy



Large Hadron Collider

The LHC ring will store a beam energy of 360 Megajoules.

$$2\,808 \text{ bunches} \times 1.15\ 10^{11} \text{ protons @ 7 TeV each} =$$

$$2\,808 \times 1.15 \times 10^{11} \times 7 \times 10^{12} \times 1.602 \times 10^{-19} \text{ Joules} = 362 \text{ MJ per beam}$$

Currently 3.5 *and 181*

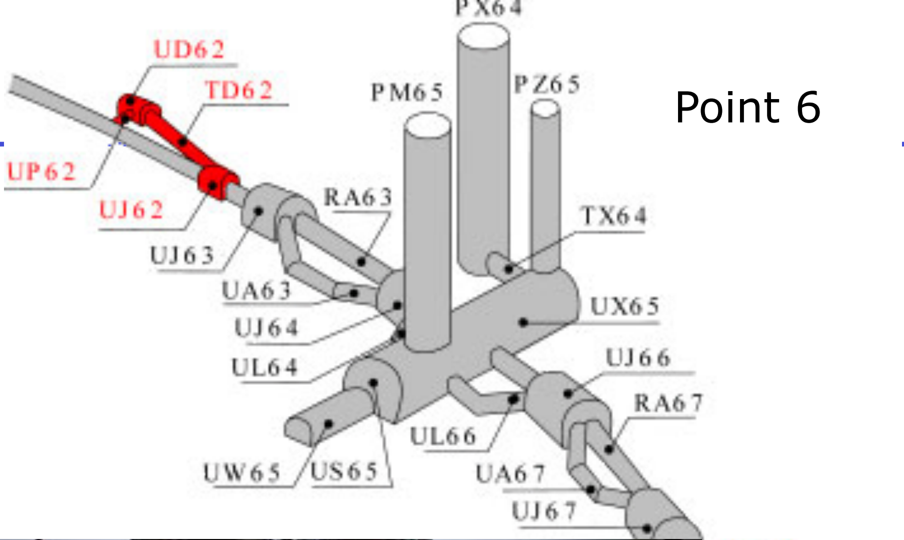
This can be compared to:

Kinetic energy
- 1 small cruise ship of 10 000 tons moving at 30 km/hour
- 450 automobiles of 2 tons moving at 100 km/hour

Chemical energy
- 80 kg of TNT
- 70 kg of chocolate (counting the calories)

Thermal energy
- melt 500 kg of copper
- raise 1 cubic meter of water 85° C: "a tonne of tea"

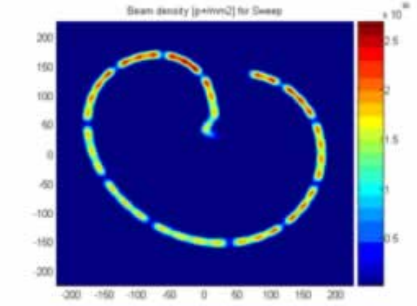
LHC Beam Dump



Point 6

- Regular beam dump
  - to make way for new fill
  - ideally after 12-24h when L~50%
- Beam losses
  - slow: beam lost over several turns
  - fast: beam lost within single turn
- Stored energy 362MJ: protection needed against beam loss!
  - Beam loss monitors react 40ms (1/2turn) and trigger beam dump for next round
  - Passive protection against single-turn loss by system of collimators and absorbers
- Beam dump installed near point 6
  - fast kicker magnets direct beam out
  - other magnets spray beam onto graphite

Photo: CERN-AC-0807025

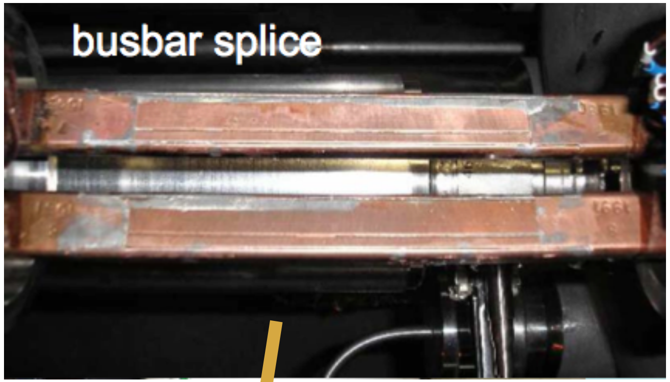


LHC Timeline and Commissioning

- 1994 approved by CERN council, followed by detailed dipole design
- 2000 LEP stopped and dismantled, making way for LHC installation
  - and for digging the experimental caverns prior to ATLAS & CMS installation
- 2001 budget crisis after cost of dipoles exploded, one part of the solution was to stretch the LHC construction over more years
- 2006/7 LHC largely installed, except fighting some cryogenics problem and repairing faults in some of the quadrupoles
  - another year of delay
- 2008 magnets fully cooled down
  - huge operation with ~2 month/sector and time shifts between sectors
- single beams sent through full 27km LHC on Sept 10th 2008
- 9 days later: uncontrolled quench in ~100 magnets, damages
  - see next slides, repairs and warm-up/cool-down
- Dec 2009: beams back, pilot run at injection energy ($\sqrt{s}=900$ GeV)
- Mar 2010: collisions at $\sqrt{s}=7$ TeV
  - since then machine performance increased in huge steps, above expectation

2008 Accident and Repair

- while ramping sector 3–4 to 5 TeV, a welded interconnection quenched
  - faulty welding left residual resistance 200nΩ
  - not included in quench protection
  - interconnection (“busbar”) evaporised and punctured helium cryostat
  - expansion (i.e. explosion) after swirling of different temperature coolants
- Repair and Countermeasures
  - 39 dipole, 14 q-pole replaced
  - careful analysis of all interconnects
  - 6500 new detectors for busbar quench
  - new helium pressure release ports
- Time scales
  - 14 months of repair/upgrade
  - not all sectors have helium pressure release ports, therefore E_{beam} **limited to 3.5 TeV** as precaution
  - warm up other sectors, install in 2013



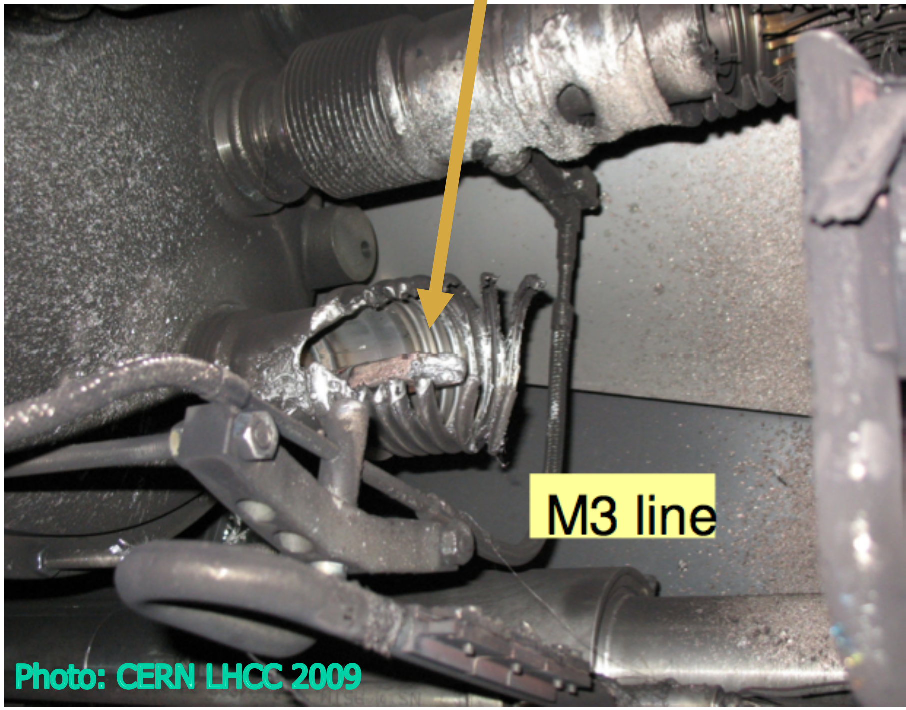
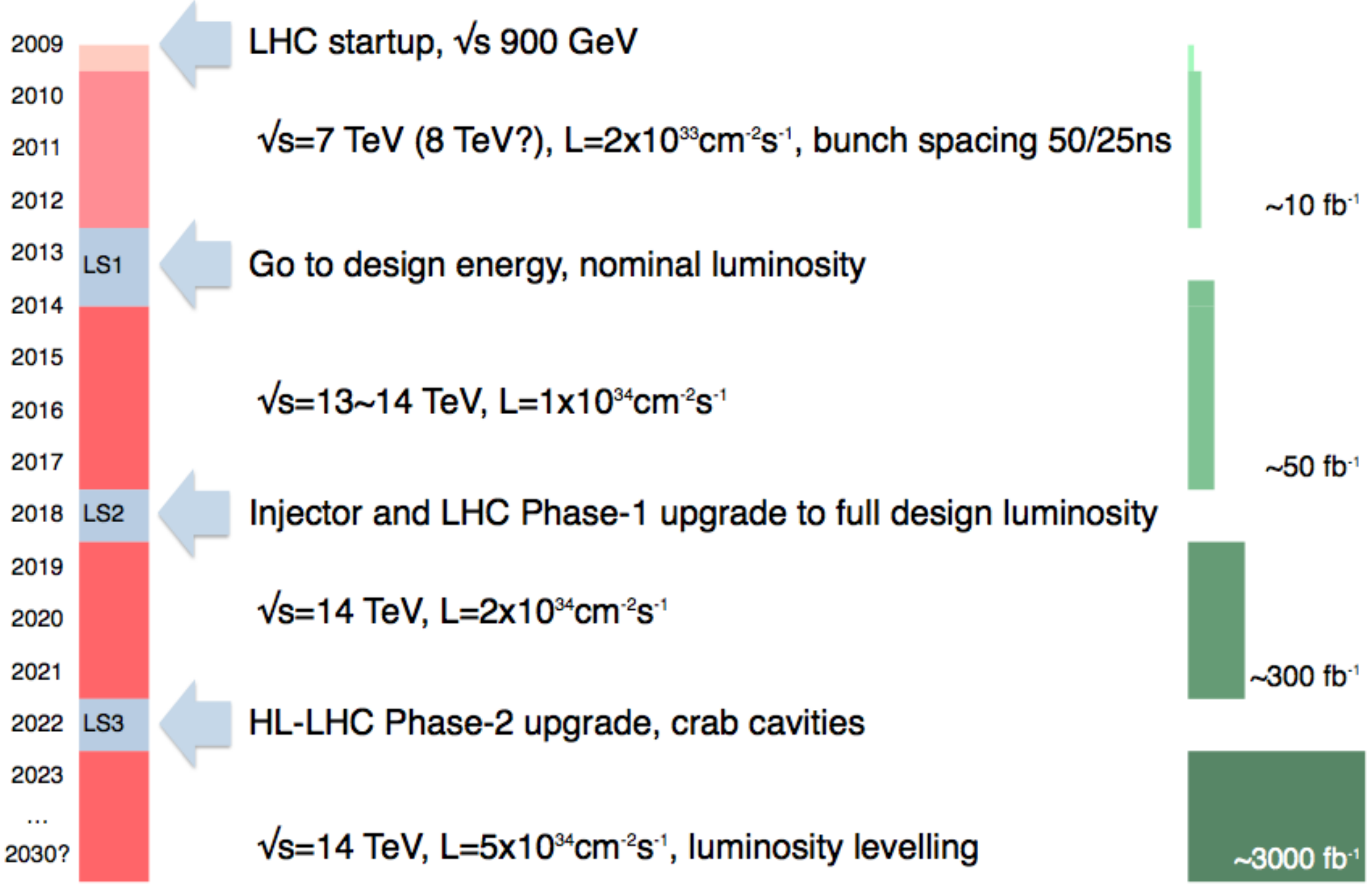


Photo: CERN LHCC 2009

LHC *draft* plan



LHC startup, √s 900 GeV

$\sqrt{s}$=7 TeV (8 TeV?), L=$2\times10^{33}cm^{-2}s^{-1}$, bunch spacing 50/25ns

Go to design energy, nominal luminosity

$\sqrt{s}$=13~14 TeV, L=$1\times10^{34}cm^{-2}s^{-1}$

Injector and LHC Phase-1 upgrade to full design luminosity

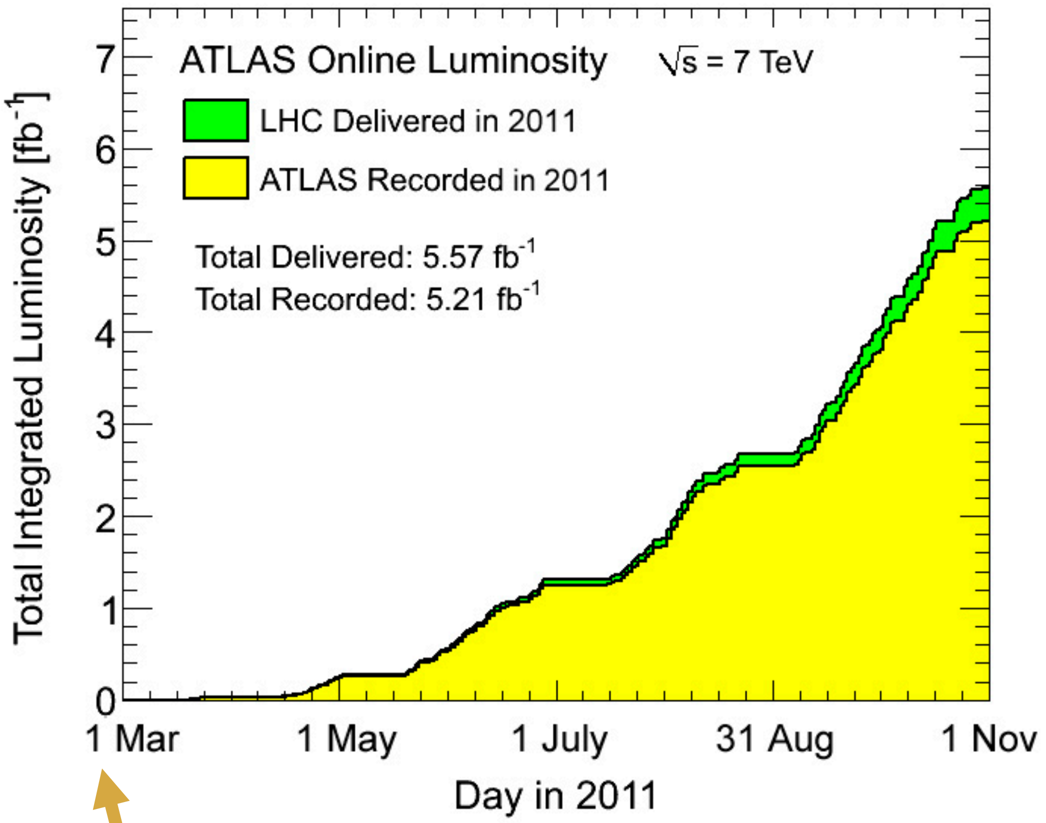
$\sqrt{s}$=14 TeV, L=$2\times10^{34}cm^{-2}s^{-1}$

HL-LHC Phase-2 upgrade, crab cavities

$\sqrt{s}$=14 TeV, L=$5\times10^{34}cm^{-2}s^{-1}$, luminosity levelling

Current Machine Performance

- 2010 and 2011 each had a marvellous performance
  - 40pb-1 at end of 2010
  - 5.2fb-1 at end of 2011
- periods of stable data-taking intersected with machine developments (MD)
  - e.g. more bunches, smaller collision angle, focussing…
- significant change in machine conditions after every MD
  - more pile-up, shorter timing (now 50ns collision frequency) higher trigger thresholds
- ATLAS took data efficiently
  - fast readiness after stable beam, few detector problems



2010 gave 0.040 fb-1

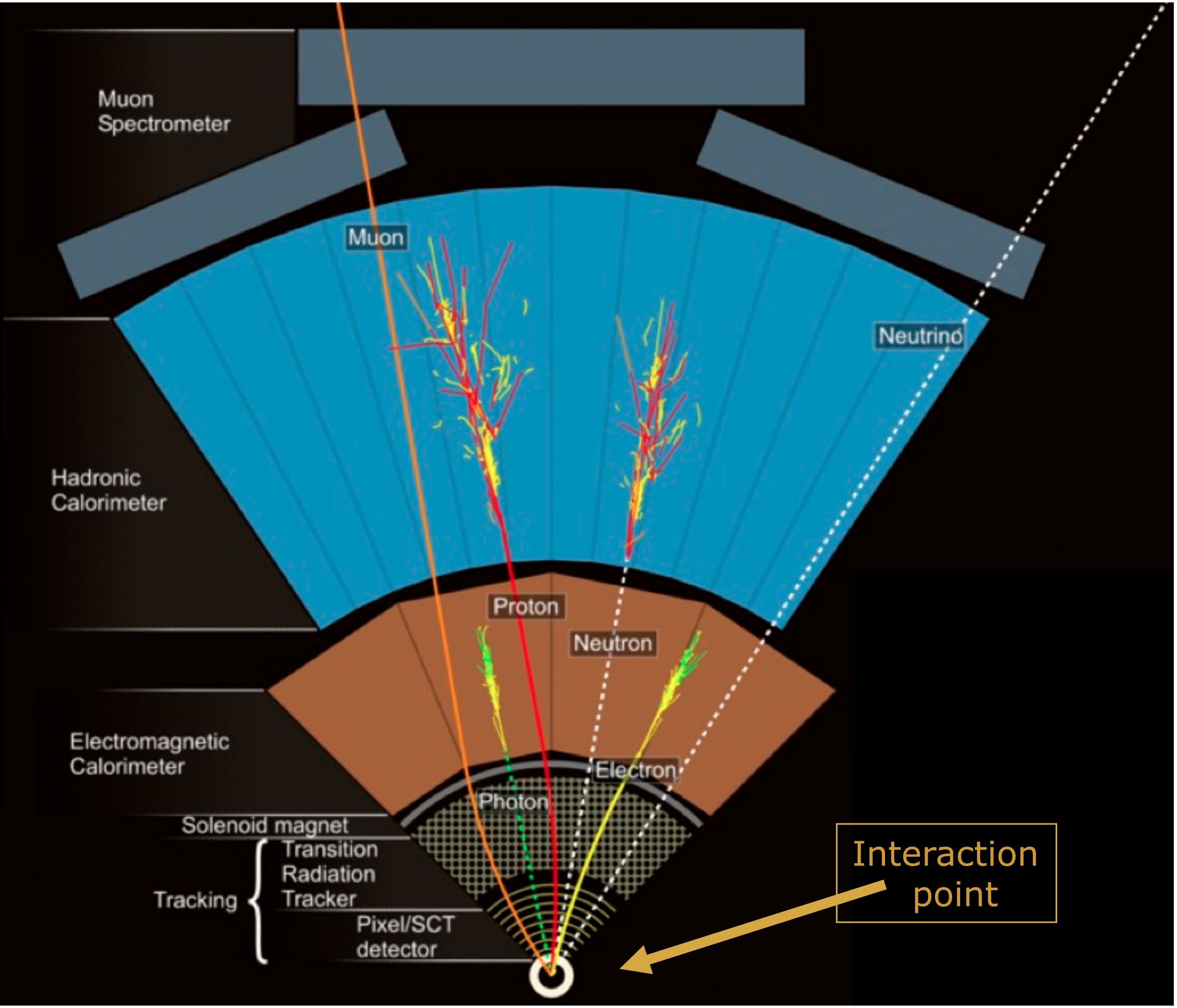
The Detector…

ATLAS: General-Purpose Detector

- LHC covers broad physics programme
  - ATLAS and CMS are “general purpose experiments”: QCD, rare hadron decays, standard model bosons and especially the search for the Higgs boson and other heavy particles
  - other experiments have dedicated physics programme: LHCb (B-decays and CP violation), ALICE (heavy ion physics), TOTEM (diffractive σ), LHCf (detector development), MøDAL (monopoles)
- ATLAS detector designed to measure all particles with optimal performance and maximal acceptance under LHC design conditions. Implies:
  - cope with harsh machine conditions and extreme event signatures
  - trigger is challenging
  - detector huge and consists of many individual systems
  - event reconstruction, calibration, monitoring all are challenging
  - high complexity of simulating collision events in ATLAS

Detector Layout Principles

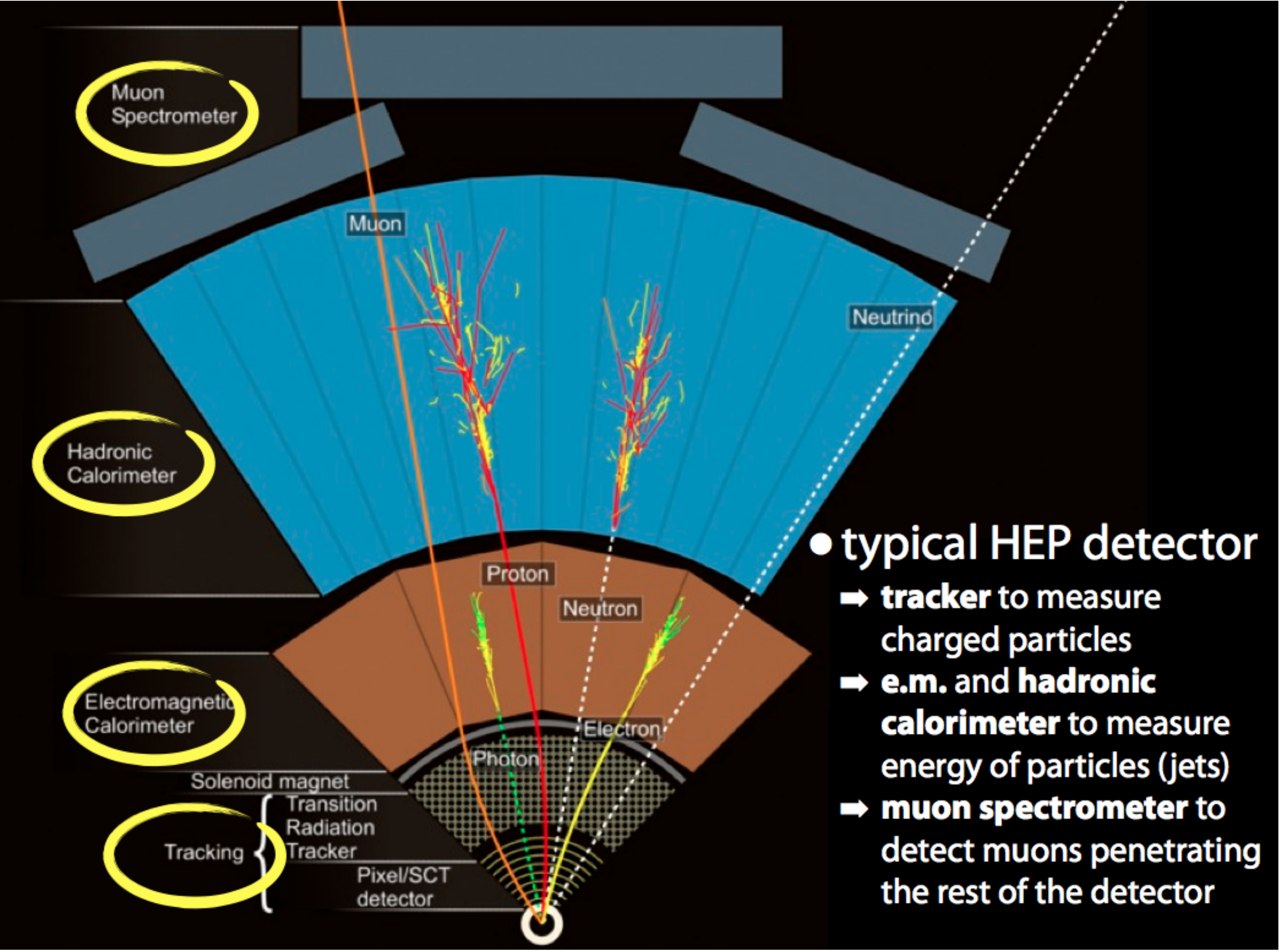
Typical HEP detector: **combination** of different detection and measurement principles



Interaction point

2011

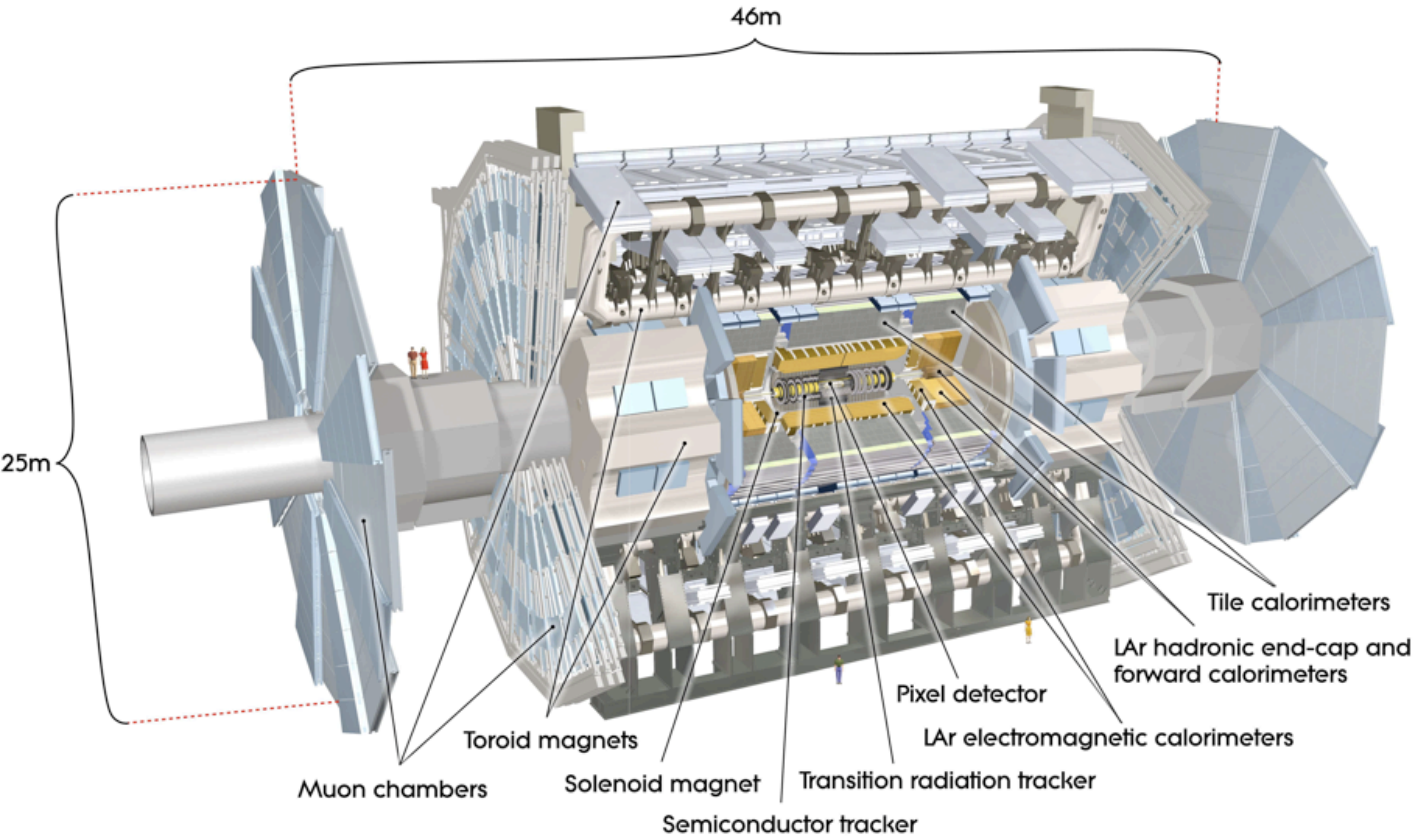
Typical HEP Detector



- typical HEP detector
  - ➡ **tracker** to measure charged particles
  - ➡ **e.m.** and **hadronic calorimeter** to measure energy of particles (jets)
  - ➡ **muon spectrometer** to detect muons penetrating the rest of the detector

Graphics: ATLAS outreach & M. Elsing

ATLAS Overview



Detector Concept: Remarks

- Momentum conservation in transv. plane exploited by cylindrical design so-called **barrel** and two **end-cap** geometries for each system
- **Magnetic spectrometers**: bend charged particle trajectories, trackers inside B-field measuring the particle momentum
  - ATLAS has a 2T central solenoid and 3 outer toroid fields
- Hermetic **calorimeters** stop particles and measure their energy
  - sufficient thickness to fully contain O(TeV) particles
  - important to be able to use transv. momentum conservation constraint
- Measurement performance goals have then driven the design, however:
- Challenges of radiation hardness, trigger capabilities, cost limits etc it was often necessary to design a **composite system**
  - for instance Muon Spectrometer comprises 4 different detector types
- Event reconstruction is a **combination** of all systems
  - all need to be fully operational to avoid loss of physics-quality data, not much redundancy in the system

Lectures will come back to each point in detail…

Particles in a Detector

- Particles interact with matter: aim and devil of collider detectors
  - detection influences particle
- Different types of interaction processes:
  - energy loss by ionisation (charged particles)
  - energy loss by pair production (neutral)
  - energy loss by bremsstrahlung
  - elastic scattering (charged)
  - hadronic interactions
  - cherenkov and transition radiation

Basis of tracking detectors in ATLAS

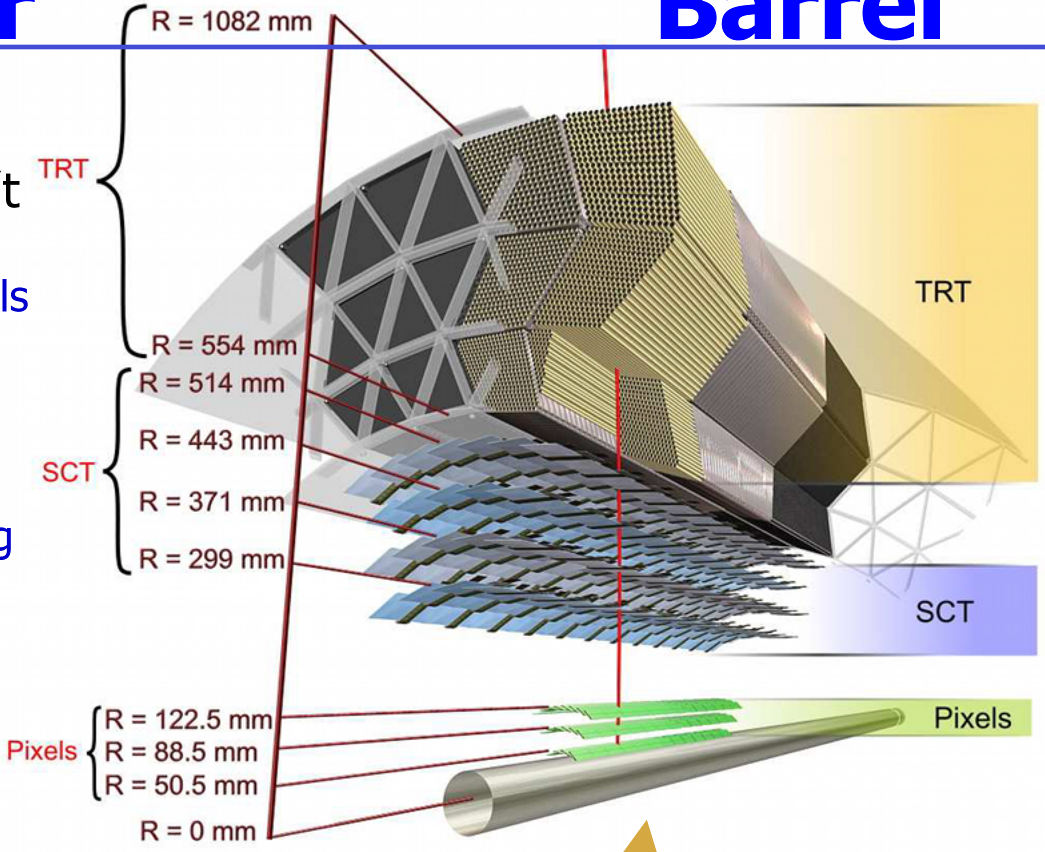
Perturbations to precise tracking, reduce tracking performance

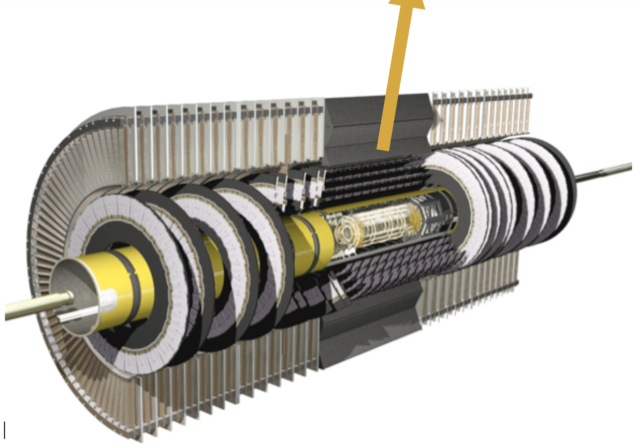
- Calorimeters: particles create showers through all of the above processes in a cascade
  - ATLAS: **sampling** = shower dimensions are measured by interleaved active layers
- Amount of material in tracker and calorimeter thickness quantified in terms of **radiation length** and **nuclear interaction length**

For details see MSc course on detectors and later in this lecture and PDG: http://pdg.lbl.gov/2011/reviews/rpp2011-rev-passage-particles-matter.pdf

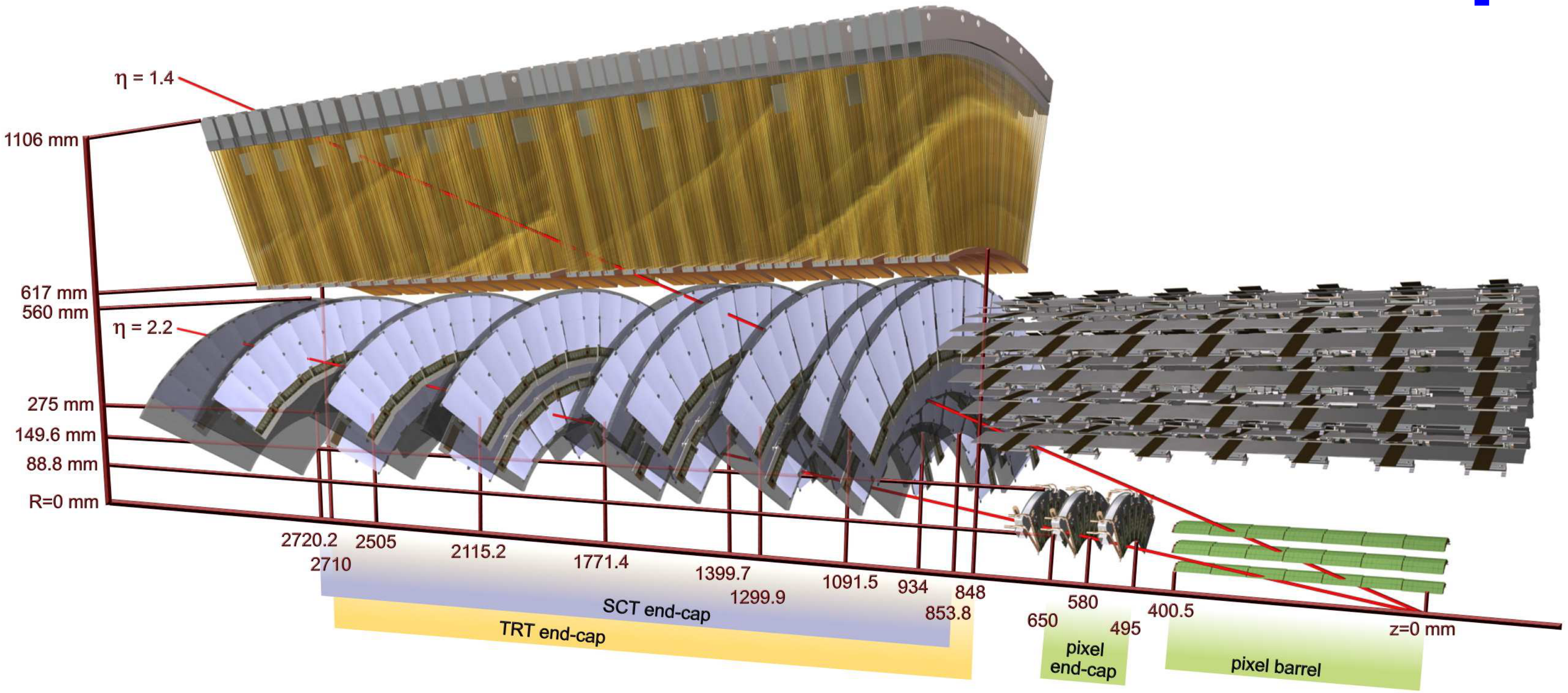
Inner Detector Barrel

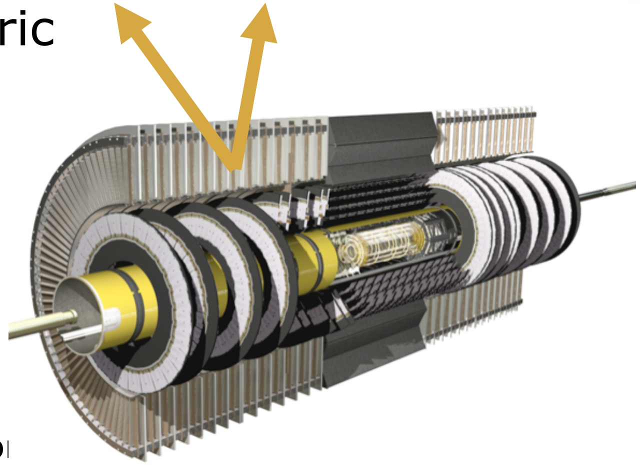
- Pixels: semi-conductor with 2-dimensional position meas't
  - 50x400 µm pixel size
  - 3 layers with modules, 80M channels
- SCT: semi-conductor tracker, small angle stereo strips
  - 4 additional layers
  - strips on sensor with 80 µm spacing
  - 2nd dimension determined by stereoscopic arrangement
- TRT: drift tube detector
  - 298k "straw" drift tubes
  - provides 1-d position, e/pi identification (optionally trigger)
- Systems measure the coordinate in bending plane (more precisely)
  - precise momentum measurement and extrapolation to interaction point





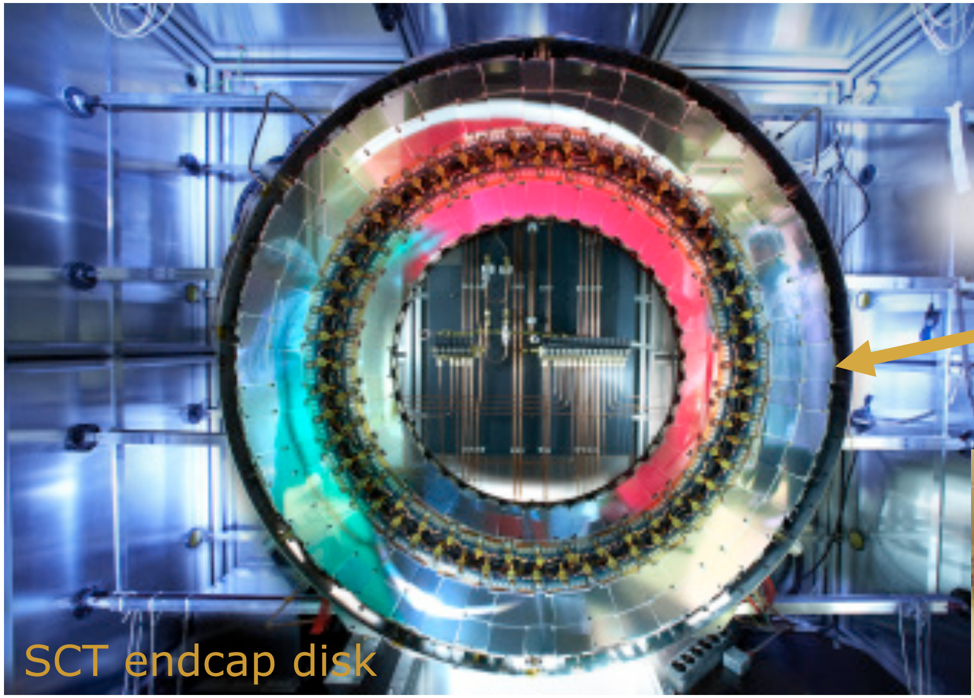
Inner Detector Endcap

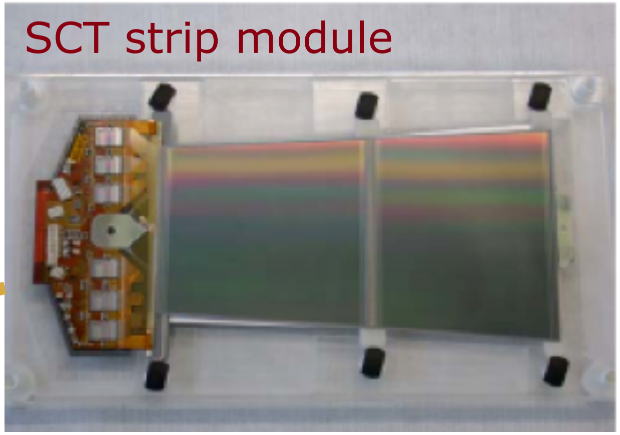




- layers continued as disks with concentric modules or straws
- hermetic coverage up to $|\eta|=2.5$
  - polar angle expressed as pseudorapidity $\eta = -\ln(\tan(\Theta/2))$

Inner Detector


SCT endcap disk


SCT strip module


SCT+TRT barrel

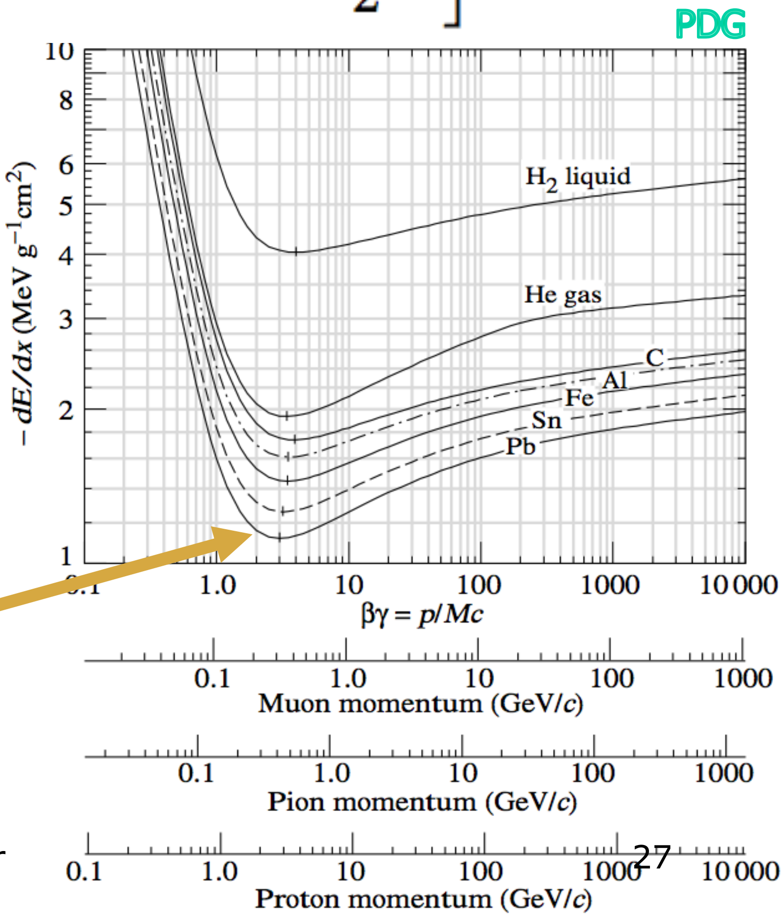
- pictures from 2006/7 testing and installation

Energy Loss by Ionisation

- Energy loss by ionization depends very specifically on traversed medium as well as particle type and its momentum
- Mean energy loss per unit length described by Bethe-Bloch formula:

$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_ec^2\beta^2\gamma^2T_{\mathrm{max}}}{I^2} - \beta^2 - \frac{\delta(\gamma\beta)}{2}\right]$$

$\beta\gamma$: velocity of particle
z: charge of particle
Z: atomic number of medium
A: atomic number of medium
I: mean excitation E of medium
T_{max}: max. E transfer per interaction
$\delta(\beta\gamma)$: density effect correction
K/A: 0.3071 MeV cm^2/g

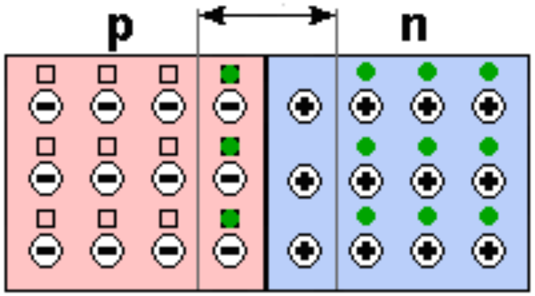


Minimum ionization

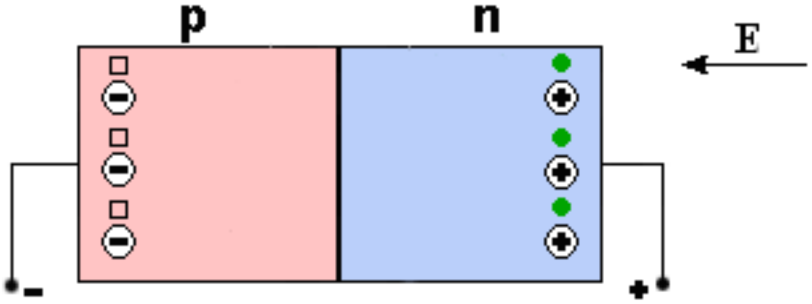
material	Min. Ion
1m air	0.22 MeV
300µm Si	0.12 MeV
1mm steel	1.1 MeV

Principle of Silicon Tracking

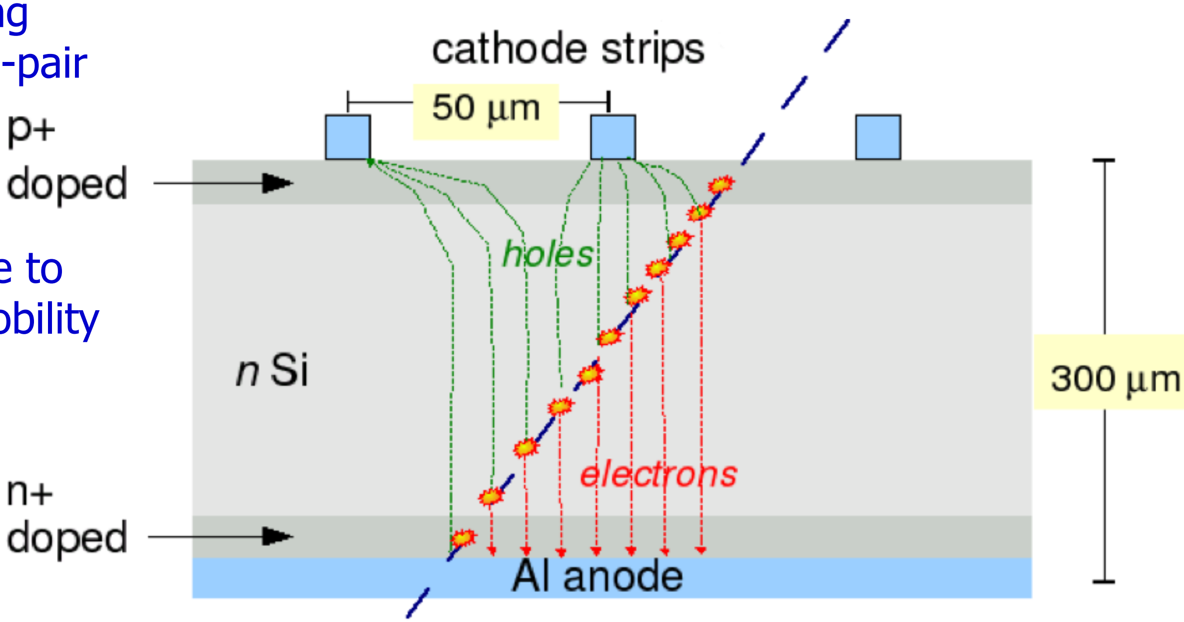
- The p-n junction
  - p+ donors in Si lattice provide free electrons
  - n– acceptors in Si lattice provide “holes”
  - depletion zone forms at p–n junction



- reverse bias voltage depletes p-n junction fully
  - depleted zone is non-conducting



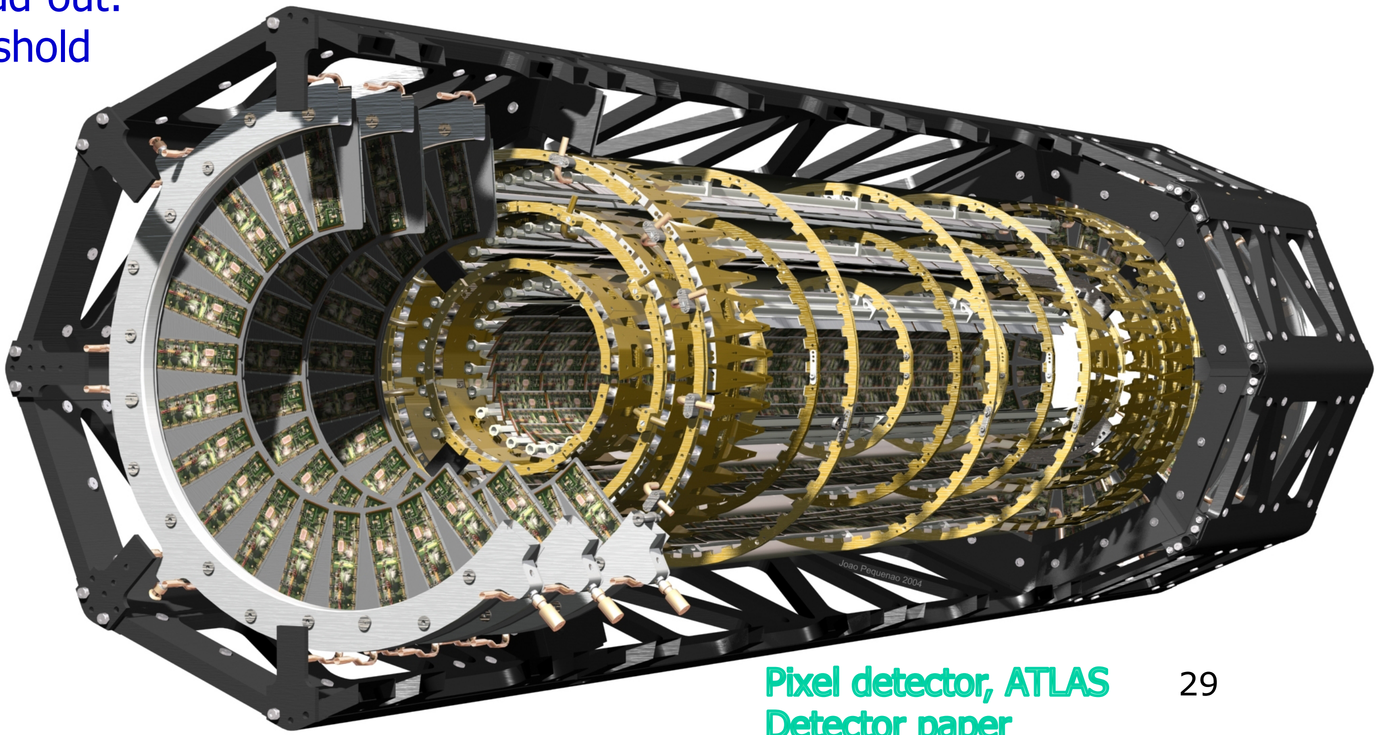
- fully depleted p-n junction is used as tracking detector
  - depleted zone is non-conducting
  - high Si density and low e^--hole-pair creation threshold (3.6eV) allow signals from thin (300μm) detectors
  - fast charge collection (5ns) due to thin detector & high charge mobility



2011

Pixel and SCT in ATLAS

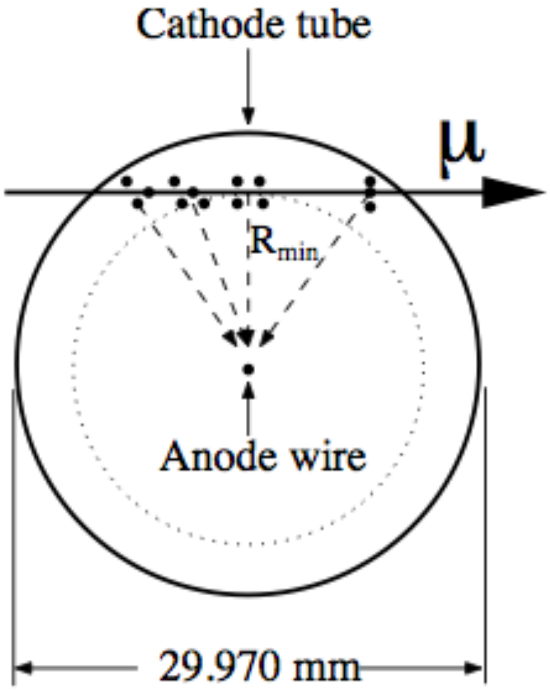
- radiation hardness: Si damaged by years of operation near collisions
  - e.g. leakage current, trapped charge, type inversion from n to p doted
  - counteracted by increasing reverse bias voltage and thermal cooling (-10^{o})
  - on-module electronics also made radiation hard (chips are silicon wafers too!)
- Lorentz angle correction: charge drift in Si biased by 2T magn. field
  - projective charge collection guaranteed by mounting module with tilt=Lorentz angle
- Analogue vs. digital signals
  - Pixel has analogue read-out: hit location and deposited ΔE
  - SCT has digital read-out: hit location if threshold passed



Pixel detector, ATLAS Detector paper

Drift-tube detectors

- standard technique using gas ionization, charge avalanche in strong field
- **drift time** is measured wrt. time offset t_0
  - LHC clock plus particle's time of travel
- known (=calibrated) drift velocity e.g. v_D~30ns/mm defines **drift circle**
  - together with hypothesised track direction it constrains the track's position
- genuinely 1-dim measurement
  - 2nd coordinate provided by other detectors (Pixel+SCT in the case of TRT drift tubes)



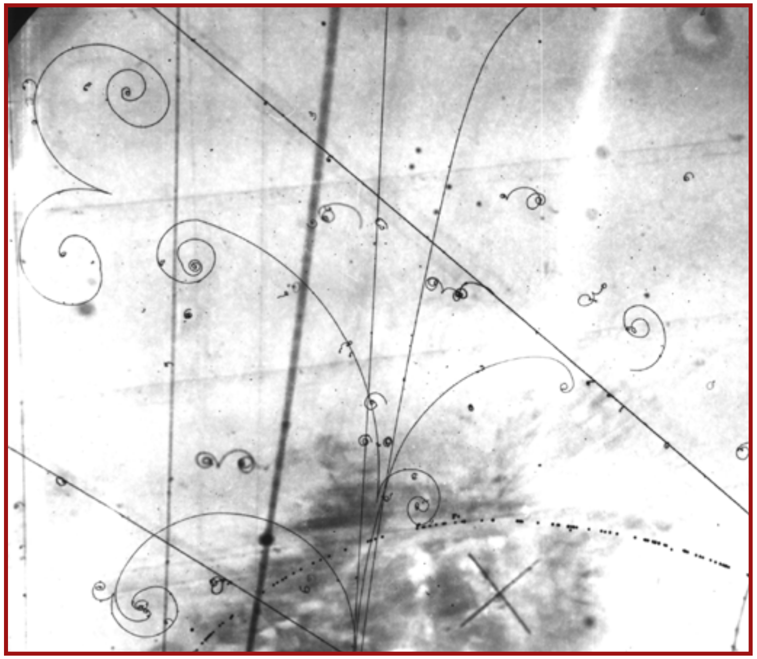
- **transition radiation** measured for TRT, allowing to discriminate e^- from hadrons
  - photon radiation when ultrarelativistic particles (e^-) pass dielectric-foil-to-air boundary near tubes
  - photons create additional charge, higher threshold passed
- r_{min} defines drift circle
  - left-right ambiguity!
  - solved by tracking algorithms using hits from near-by tubes

Radiation Length Concept

concerns both Tracking and Calorimeters

- **radiation length** X_0:
  mean distance over which e^- loses 63% of its energy by bremsstrahlung

  (63% after fraction $1/e$ retained by electron, bremsstrahlung is dominating process at high p)
- also relevant for photons:
  survival probability (against pair prod.) is $1/e$ over 7/9 X_0's
- **nuclear interaction length** λ:
  mean free path of hadrons between strong-force collisions
- Typically $\lambda \gg$X0 exploited in HEP calorimeters so that hadronic showers are locally separated from el-mag. showers

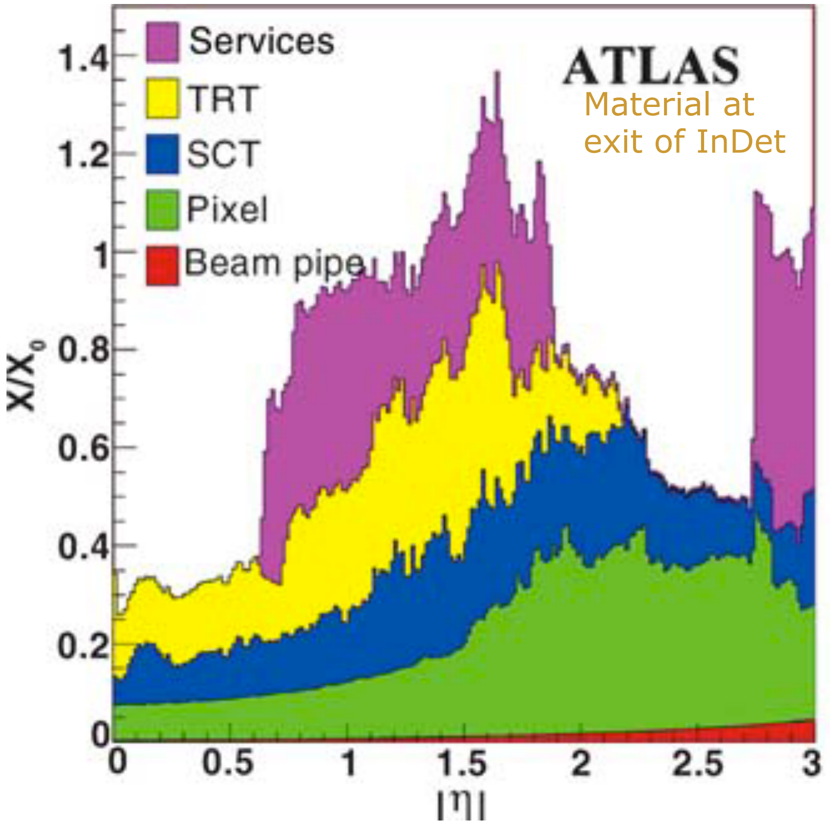


material	**X_0** [cm]	**λ** [cm]
Be (beam pipe)	35.3	
Si (Pixel,SCT)	9.4	45.5
carbon fibre	~25	
Fe (Tile cal.)	1.8	16.8
Pb (el-m cal.)	0.6	17.1

Photo: teachers.cern.ch

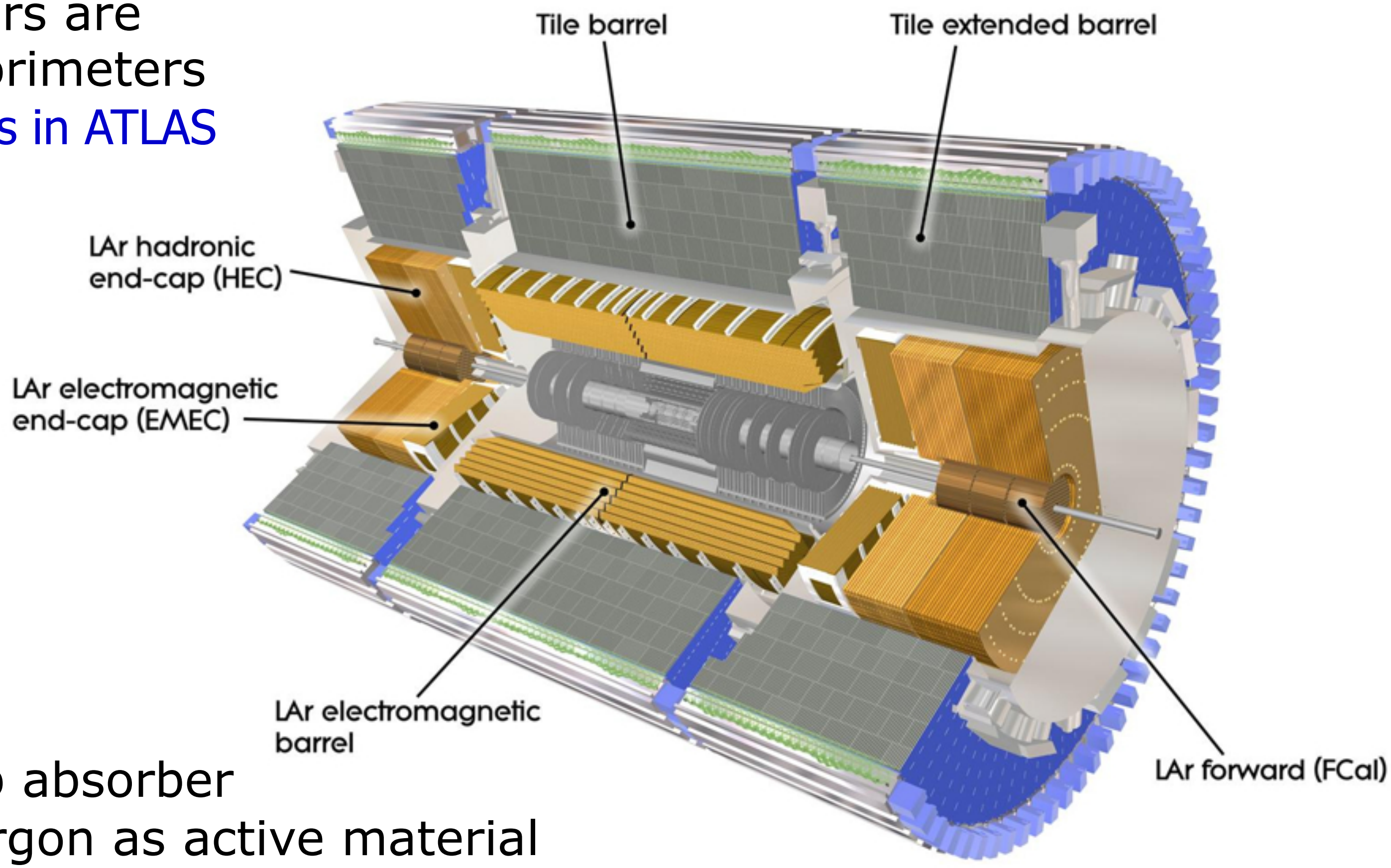
Radiation Lengths in ATLAS

- The tracker material amounts to a significant fraction of X_0 (and 10–20% of λ)
  - most of it comes from dead material: support, cooling, electronics, insulation
  - e.g. only 0.003 X_0 per 300µm Si sensor
- negatively affects performance of tracker and calorimeters
  - increased probability for e– to radiate, γ to convert and hadrons to shower in tracker — before reaching calorimeter
- calorimeters, on the other hand, need to have dense material:
  - 1 TeV e– requires 30 X_0 ≈ 17cm Pb in el-magn. (EM) calorimeter
  - 1 TeV pion requires 11 λ ≈ 2m Fe or Cu in hadr. calorimeter



ATLAS Calorimeters

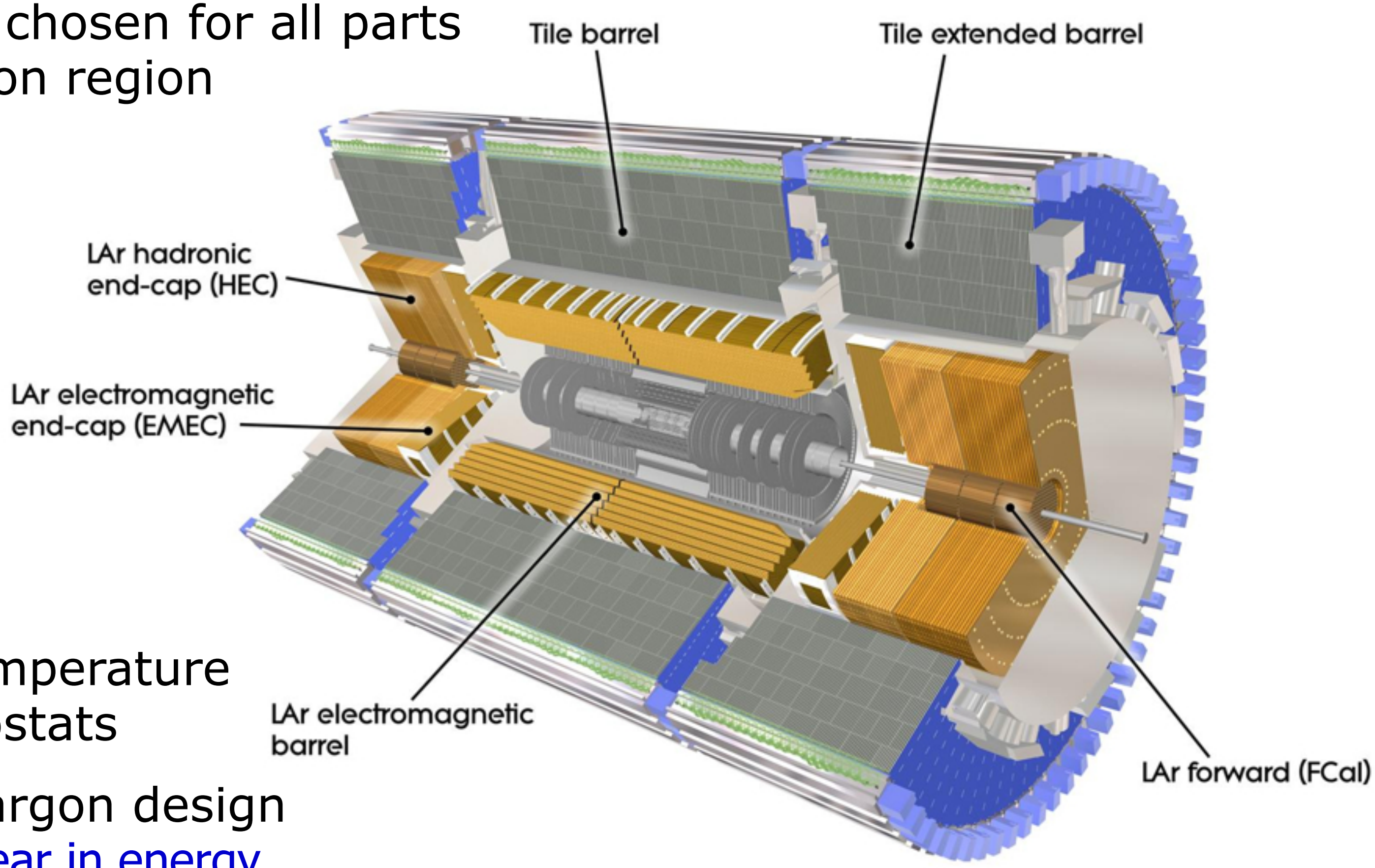
- all calorimeters are sampling calorimeters
  – i.e. no crystals in ATLAS



- "**LAr EM**": Pb absorber with liquid argon as active material
- "**Tile**": steel absorber with scintillating tiles as active material
- "**LAr HEC**": Cu absorber with liquid argon
- "**LAr forward**": Cu and W absorbers with liquid argon

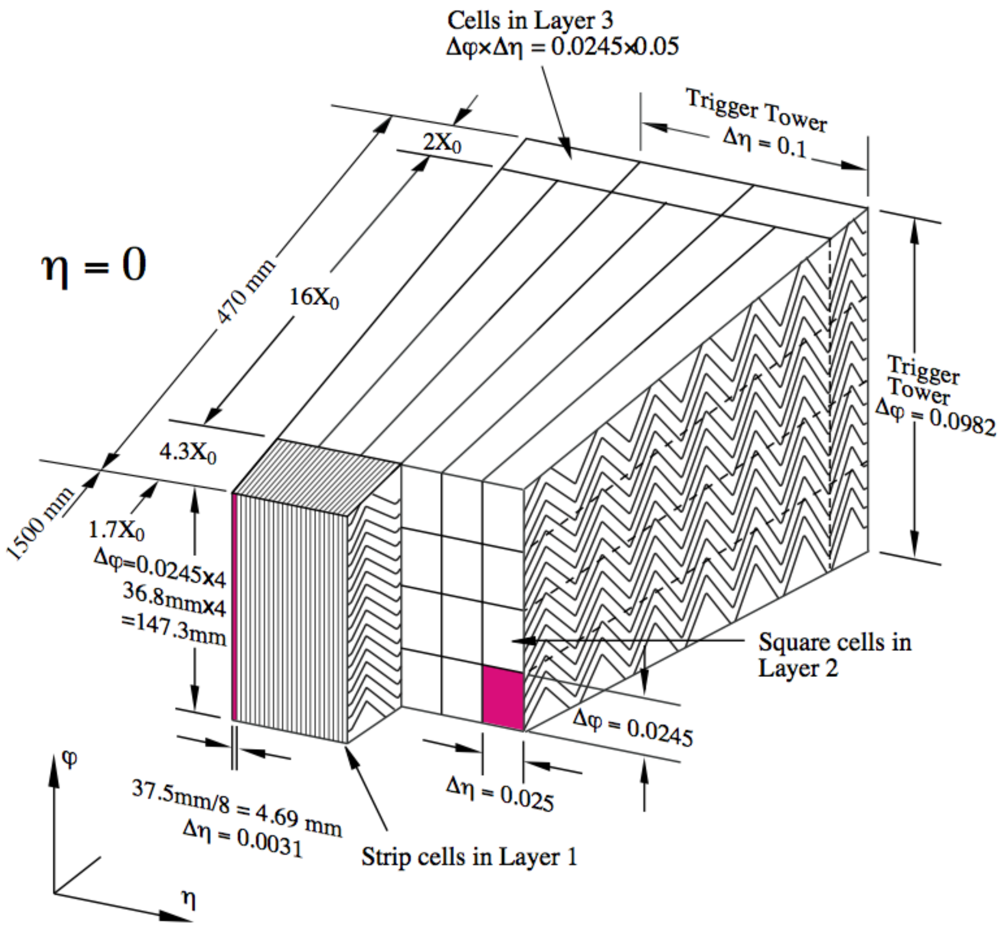
ATLAS Calorimeters

- **LAr design** was chosen for all parts close to interaction region and beam
  - i.e. areas of high flux and radiation



- LAr operating temperature ~89K: large cryostats
- Choice of liquid argon design
  - response very linear in energy
  - time stability and especially radiation hardness

Electro-magnetic Calorimeter

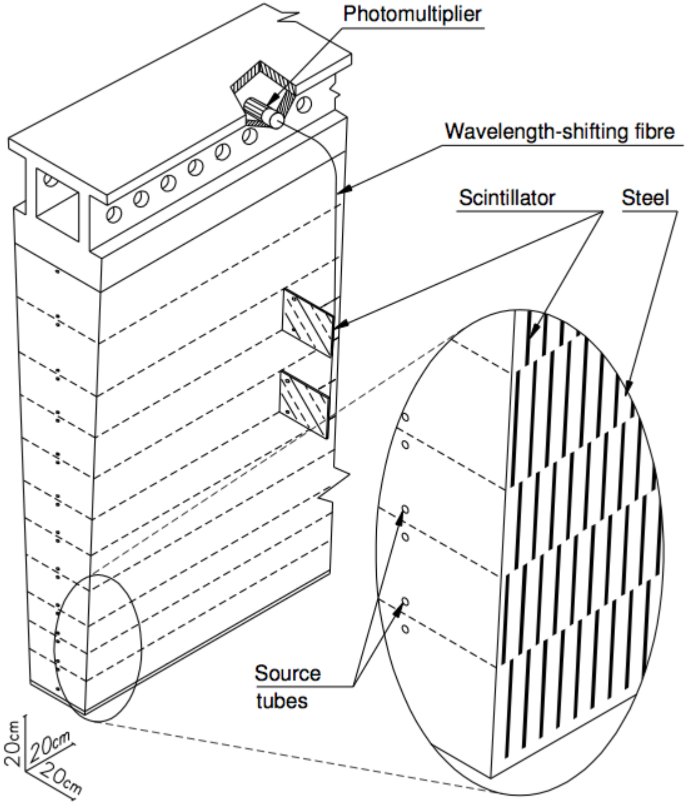


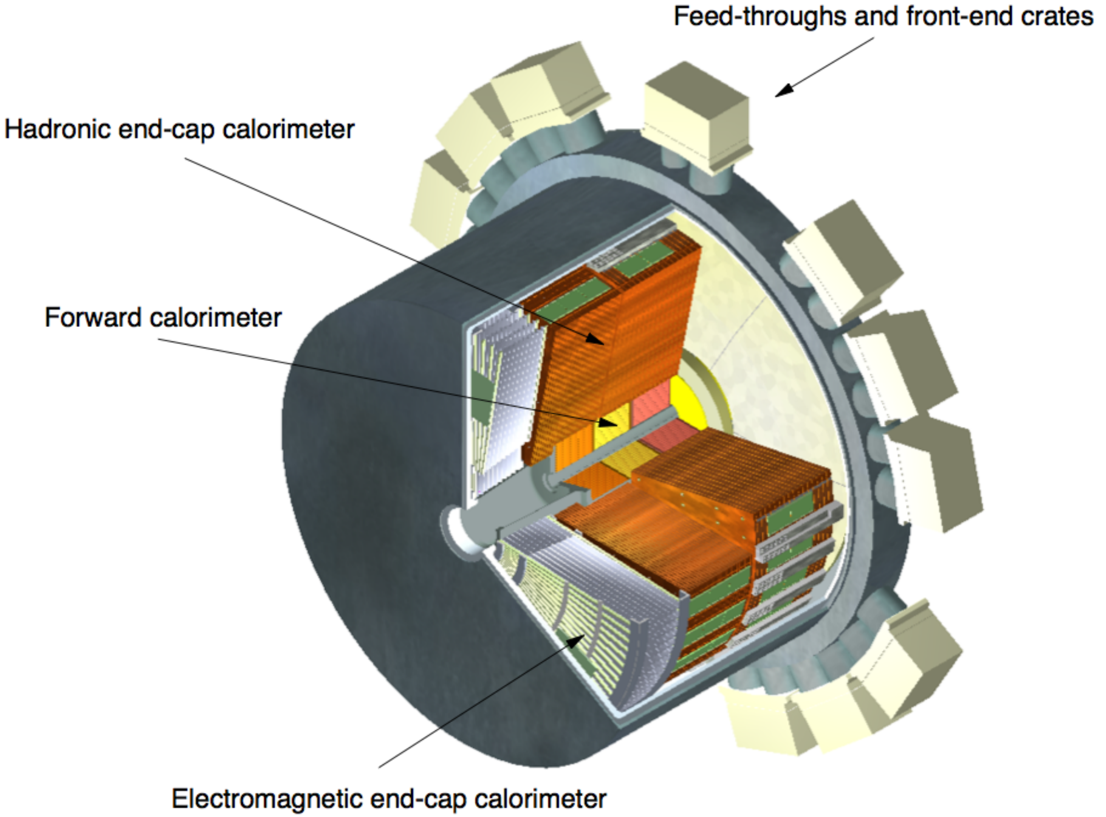
- Accordion geometry of absorber in barrel
  - improves energy linearity and homogenity in ϕ
- radial thickness is 22.3 X_0
- provides electron/photon triggers
- photon distinguished from e^- by absence of track or presence of conversion
- Forward EM calo uses radial tiles for Pb/LAr layers

Hadronic Calorimeter

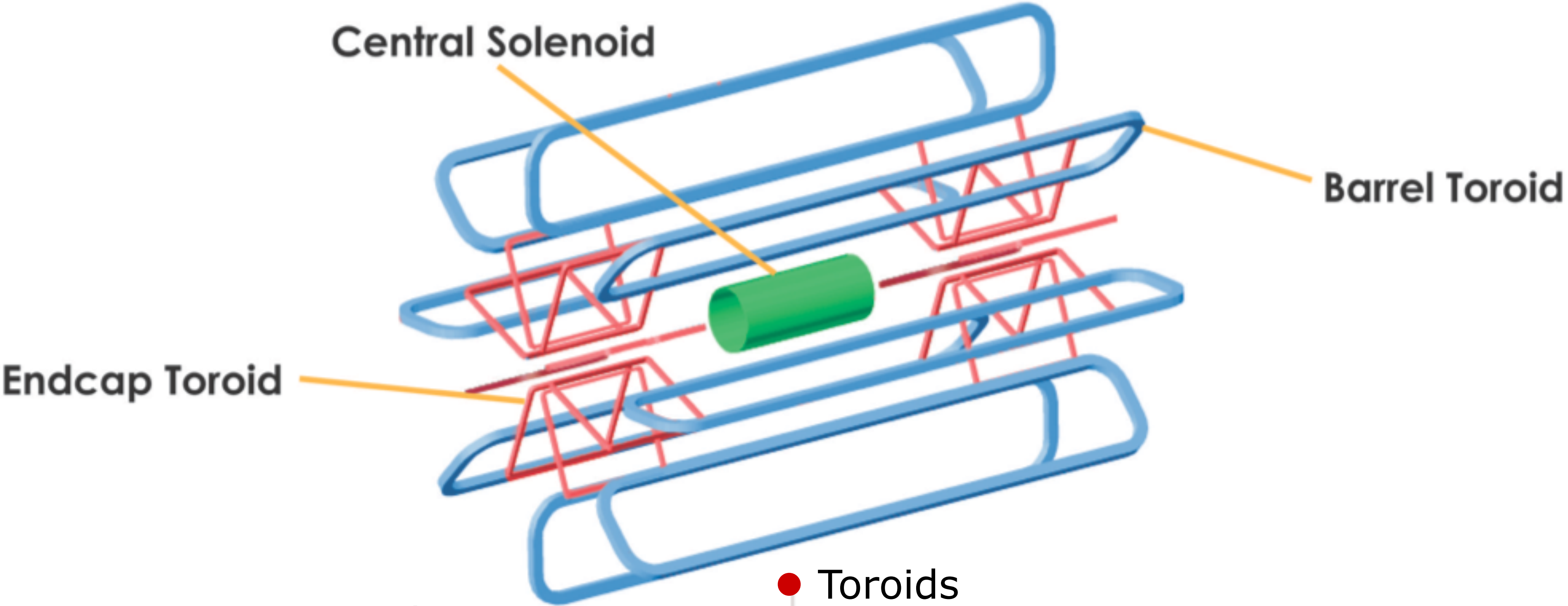
- Tile (extended) barrel
  - radial tiles orth. to beam line
- nucl. int. length λ~7.4
- Trigger capabilities

- Endcap calorimeters:
  - housed in single cryostate
- highly hermetic: up to |η|=4.9





ATLAS Magnet System

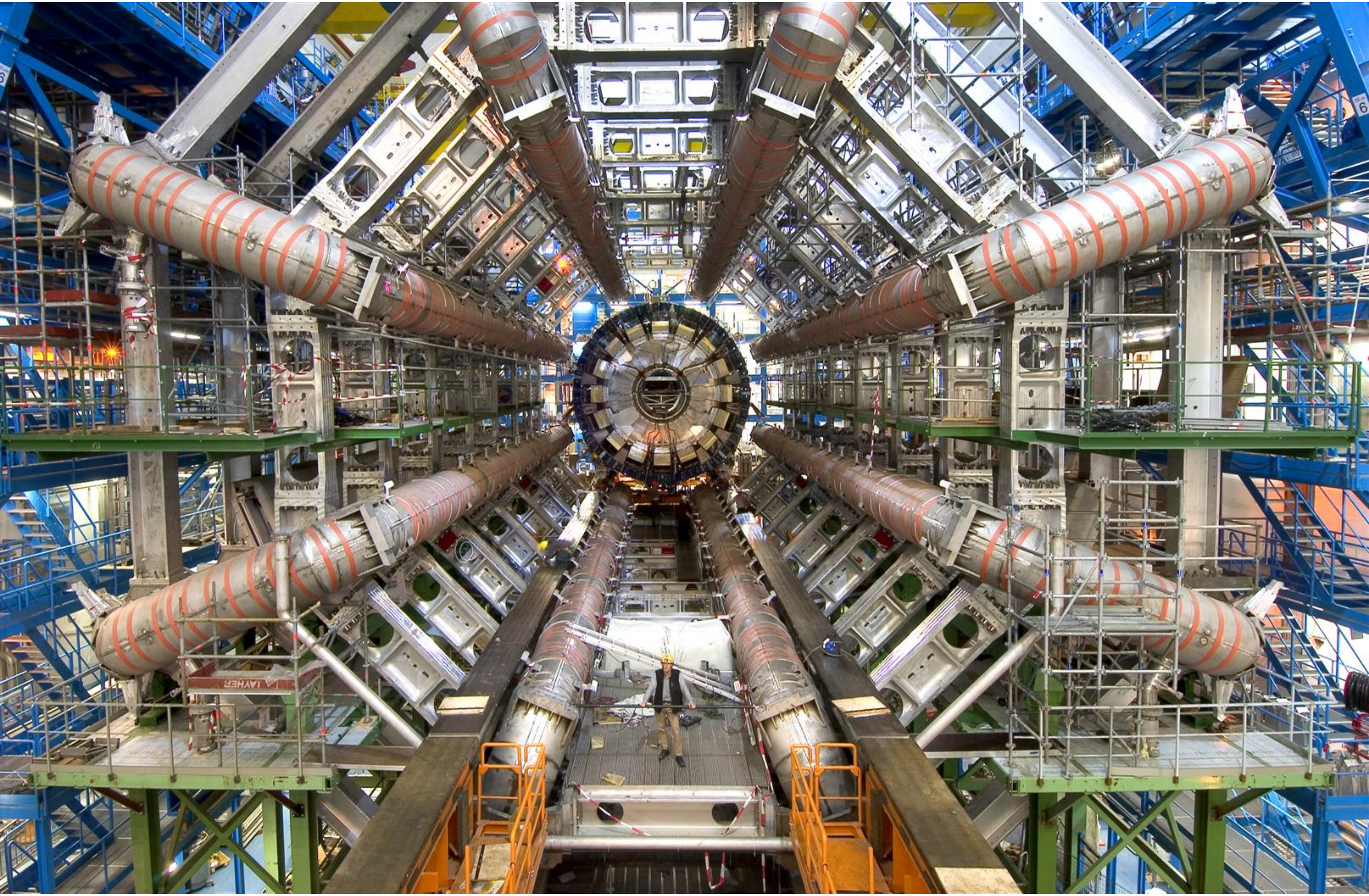


- Central Solenoid:
  - 5.3m long, 2.4m diameter, 4.5cm thick
  - Field strength 2T, current 7.73 kA
  - field lines parallel to detector axis
  - homogeneous field over most InDet

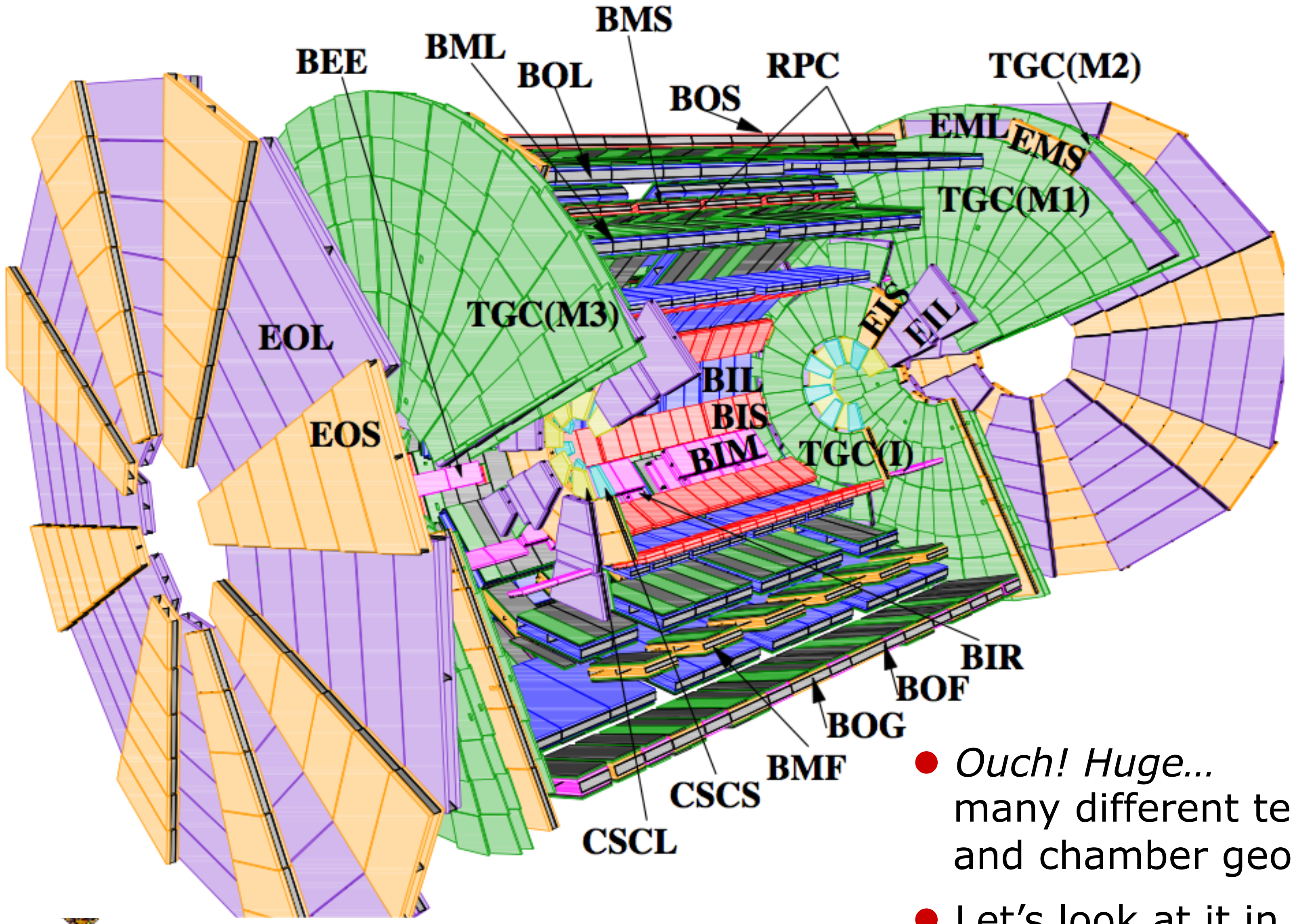
- Toroids
  - 25.3m long, 20m outer diameter (barrel)
  - 4T field on superconductor, 0.5T average
  - 20.5kA current, ~1GJ + 2x0.25GJ stored E
  - 4.7K operating temperature
  - field lines in plane orthogonal to beam axis inhomogeneous field

Note: inner detector and muon spectrometer have their bending planes orthogonal to each other

ATLAS Magnet System



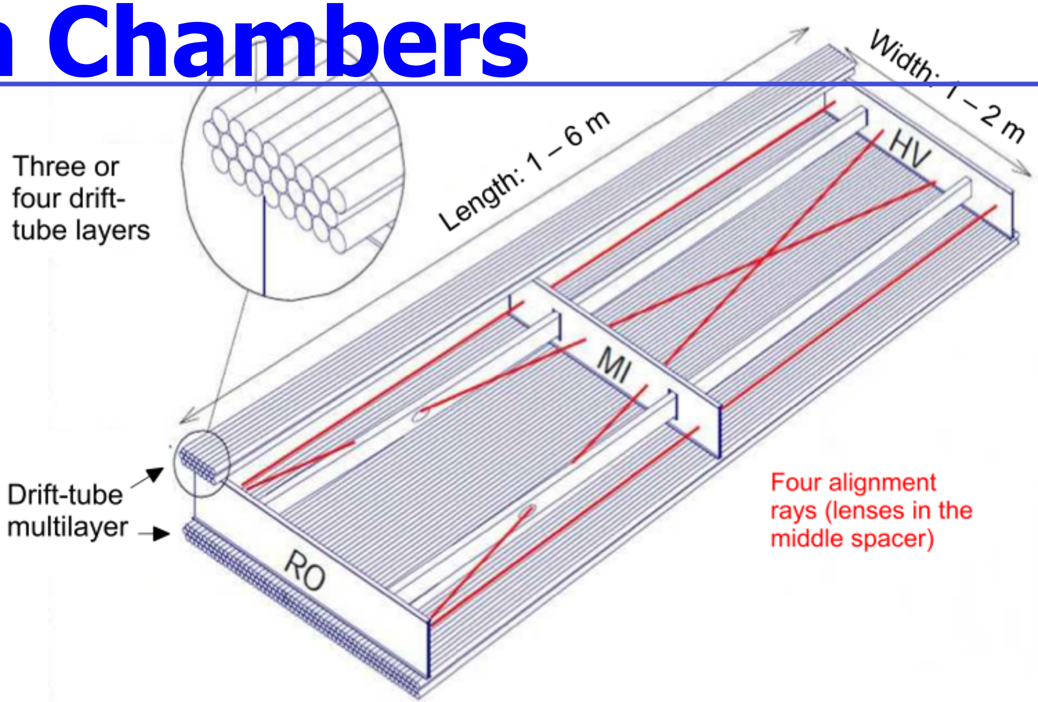
Muon Spectrometer

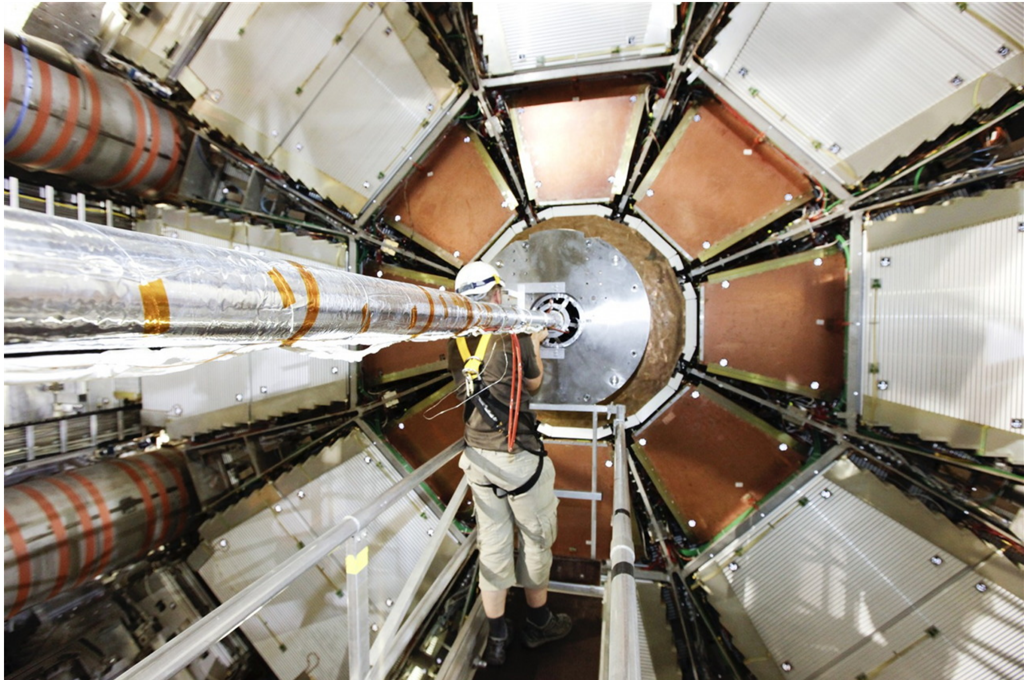


- *Ouch! Huge…*
  many different technologies and chamber geometries
- Let’s look at it in detail

Muon Precision Chambers

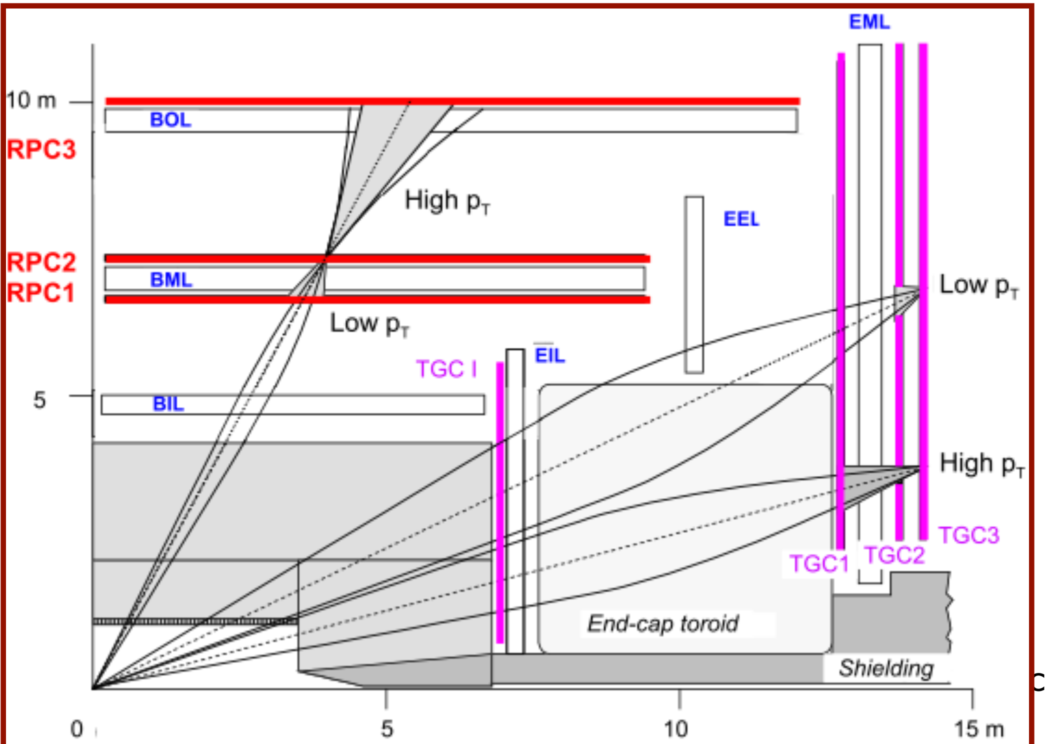
- Monitored Drift Tubes **(MDT)**
- tubes of 3mm ⦸ measure drift circles with ~80μm resolution
- 1171 stations with 2 multi-layers of tubes, length varies 0.85–6.5m
- dedicated optical alignment system in place to guarantee precision
  - 3-point optical path within and between stations
- Cathode Strip Chambers **(CSC)** instead of MDT in |η|>2.0
  - region of high rates ≤1000Hz/cm
  - CSC are multi-wire proportional chambers with 2-dim segmented cathode planes

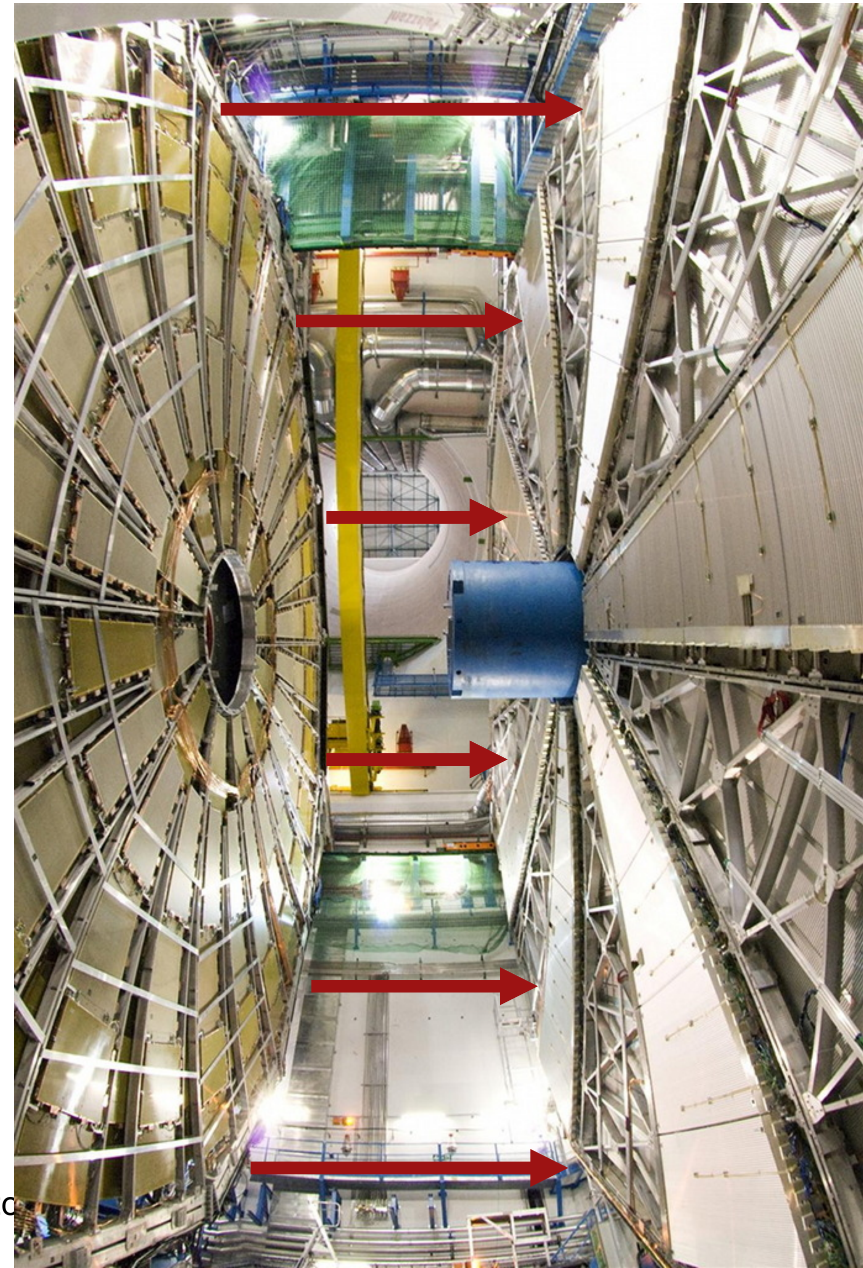




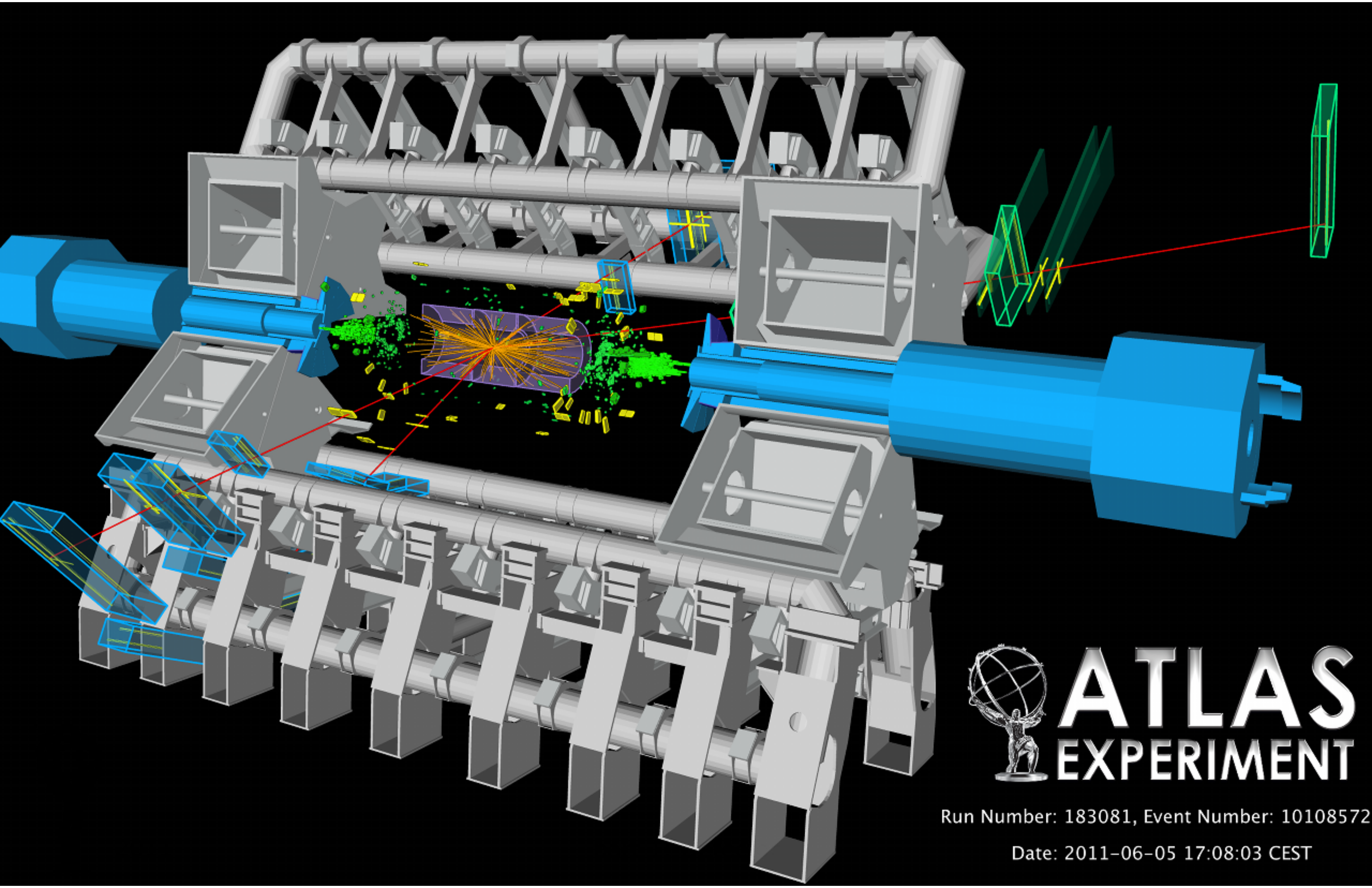
Muon Trigger Chambers

- Resistive Plate Chambers **(RPC)** – barrel only
- Thin Gap Chambers **(TGC)** – endcap only
- “glued” onto MDT stations
- provide second coordinate



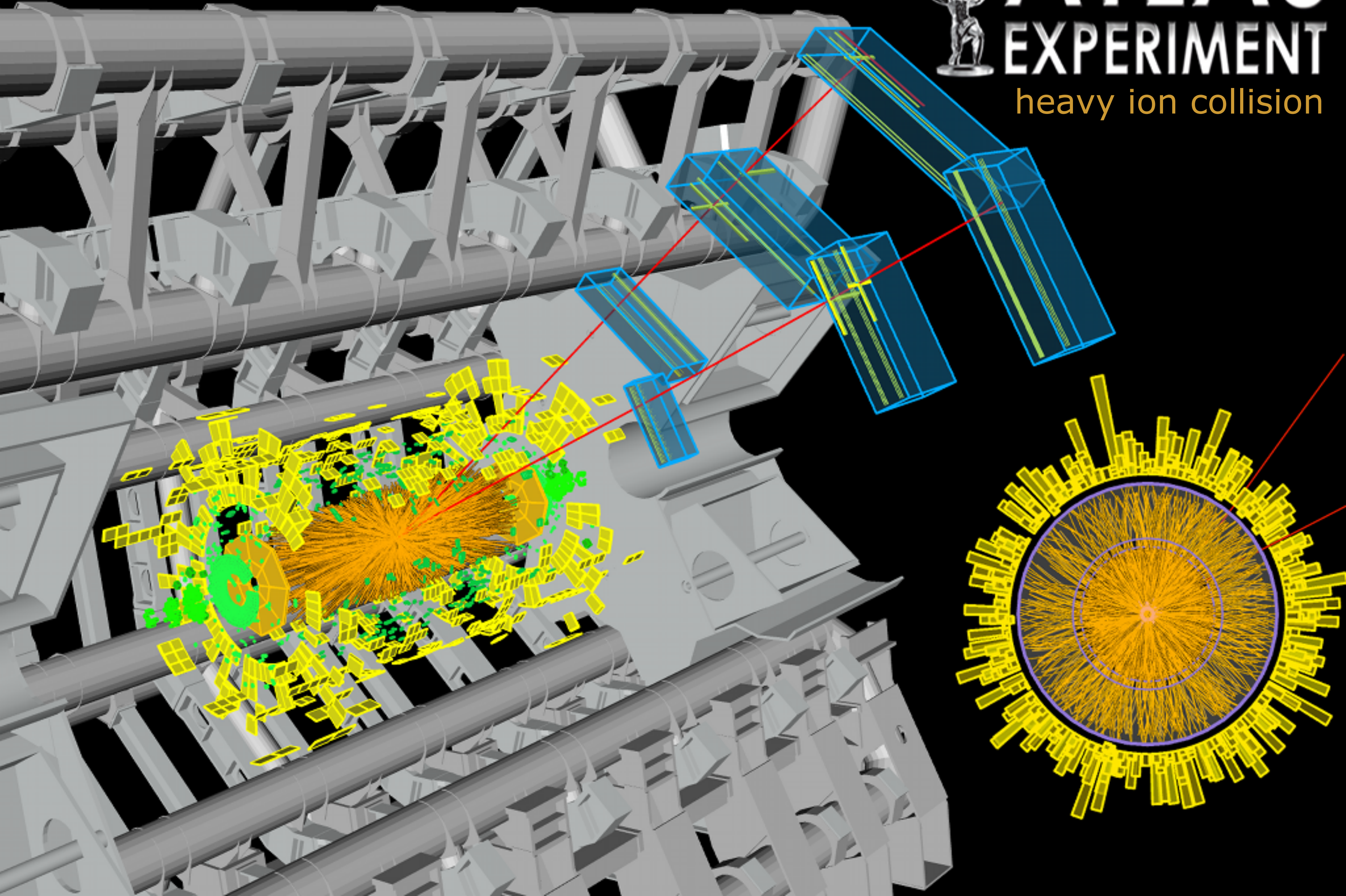


Muon Spectrometer at Work



Run Number: 183081, Event Number: 10108572

Date: 2011-06-05 17:08:03 CEST

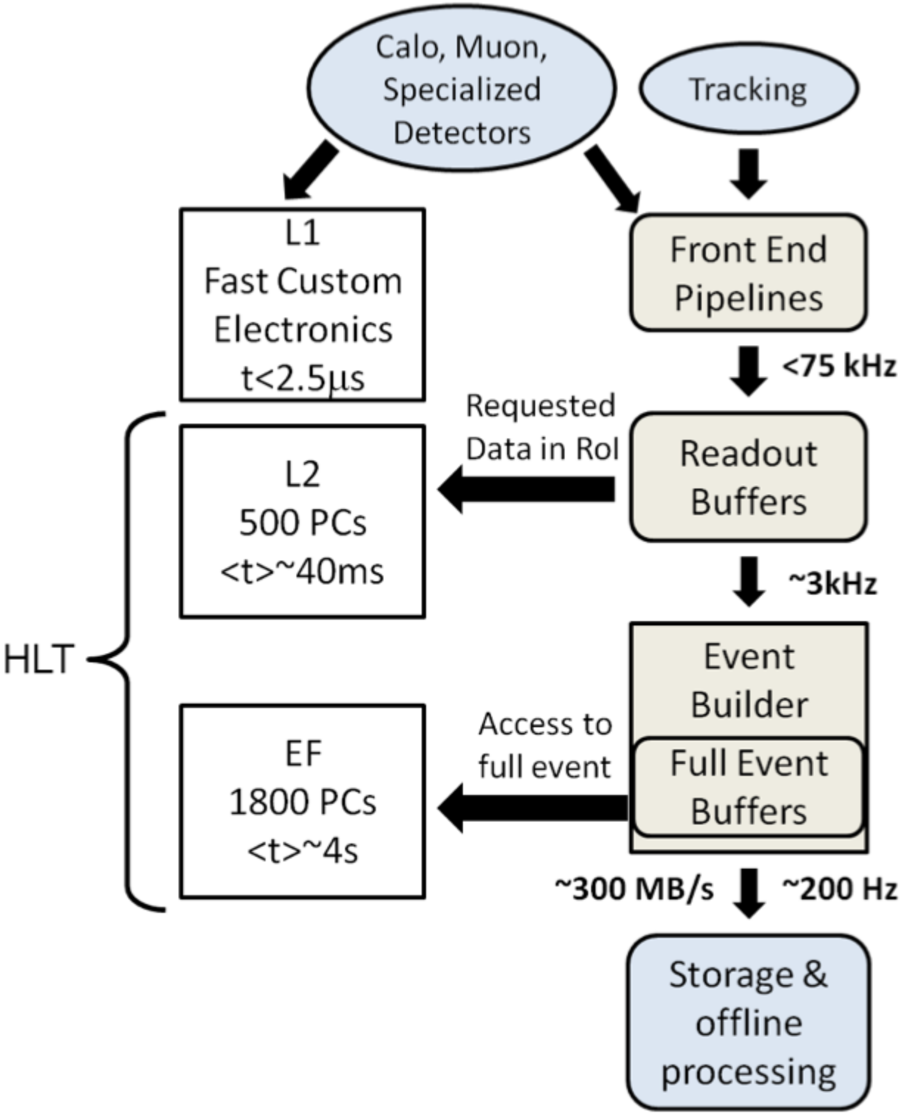


Run 169226, Event 379791
Time 2010-11-16 02:53:54 CET

ATLAS
EXPERIMENT

heavy ion collision

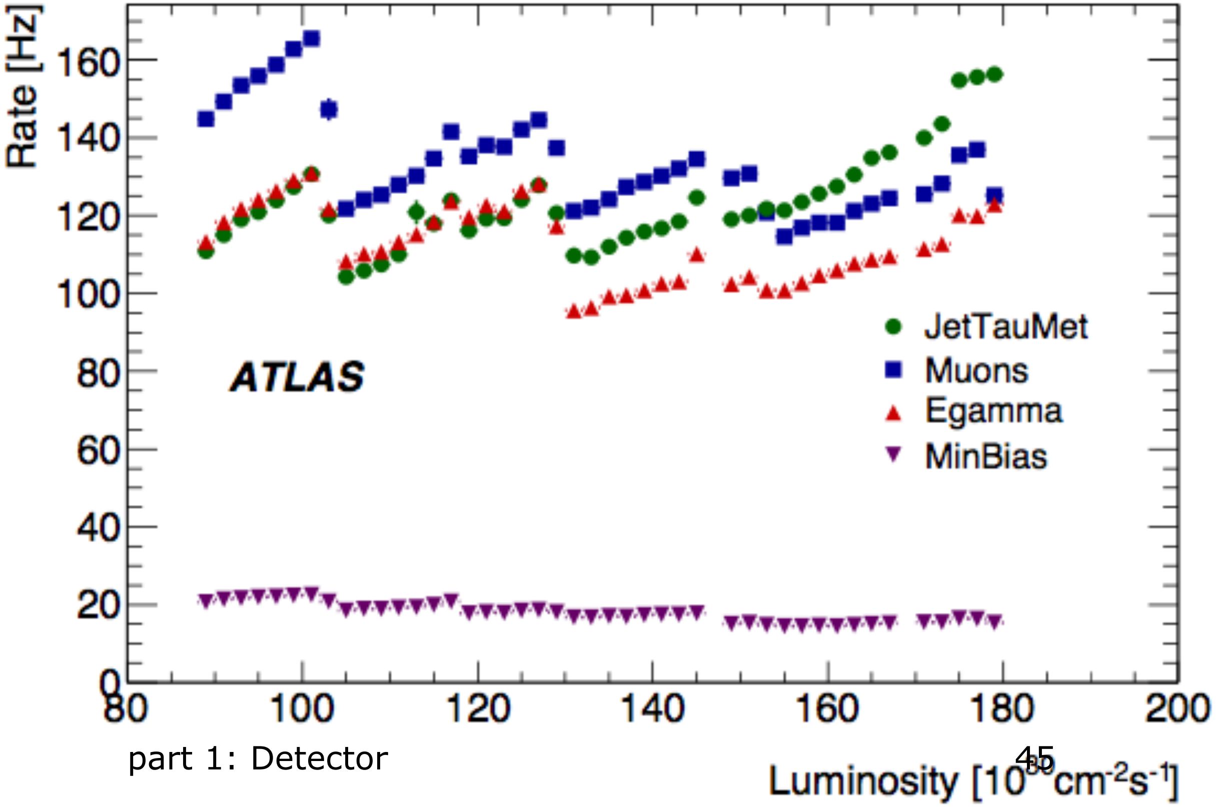
Trigger



- Rate of hard scattering events is ~10^9 Hz at LHC design lumi
- 200…400Hz can be saved for physics analyses
  - restrictions by offline processing power and disk size
- Challenge is to catch the rare interesting event when it appears
  - if it is discarded, it is lost forever
- Fast hardware needed
  - dedicated muon chambers, precision chambers and inner tracker too slow
- Time-optimized versions of reconstruction algorithms used
- "Region of Interest"
  - event size and processing time reduced by restricting to region around triggered object

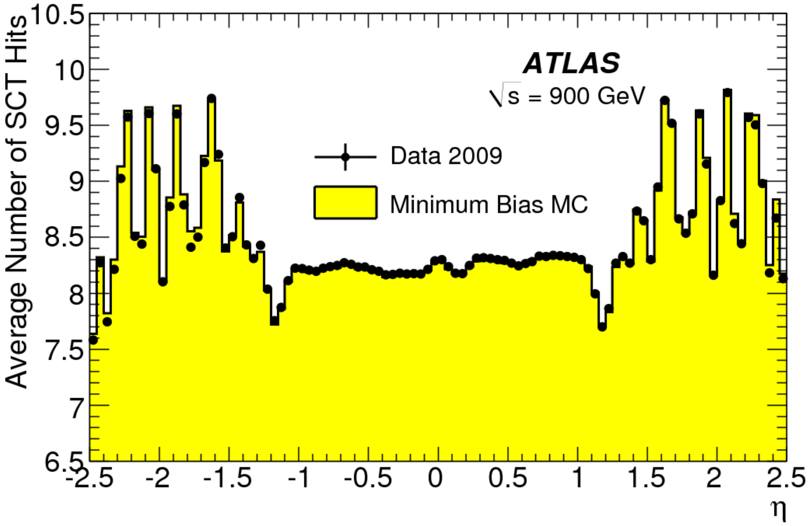
Trigger Aspects

- Rate reduction comes at a price:
  - pre-scaling: apply arbitrary filter
  - kinematic threshold: drop low pT (less interesting physics)
  - isolation: drop what is more likely background
- LHC regularly increases lumi or changes machine conditions
  - trigger has to prepare and react, e.g. raise p_T thresholds by few GeV
- Trigger chains are kept decoupled
  - minbias / electron / muon / jet
  - streams formed
- each trigger chain has target quota
  - e.g. reserve 1% for pre-scaled MinBias even at high lumi

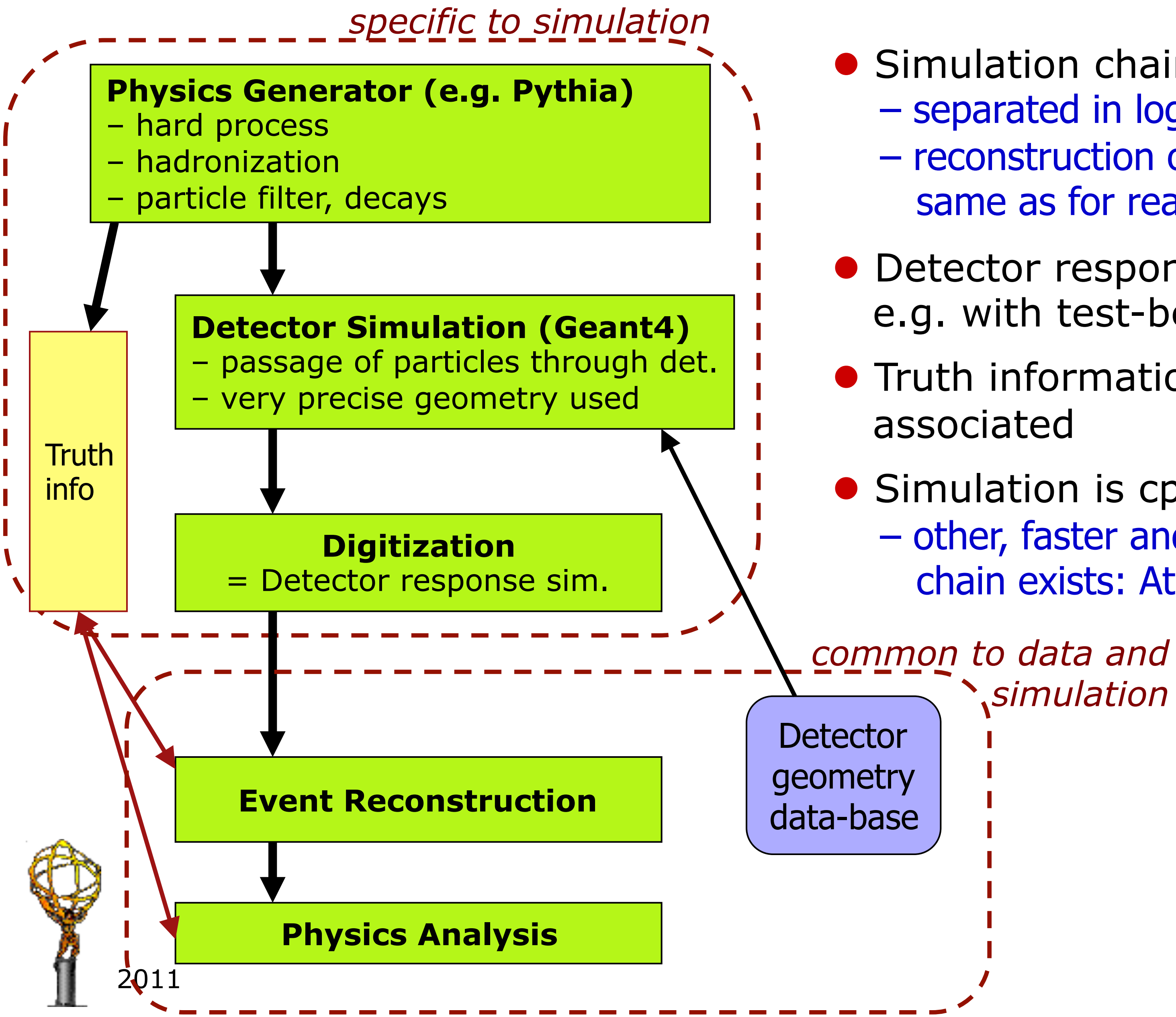


Simulation

- simulation of collisions in ATLAS is part of the experiment:
  - conception phase (long time ago): decisions about optimal detector design
  - preparation phase: setting up reconstruction software, physics analyses etc up to a full "dress rehearsal"
  - data analysis: interpretation of physics results
- based on Monte-Carlo methods: within given production ratios, phase space, decay lifetimes and detector resolution the interaction processes follow random decisions
  - in the limit of high statistics, the exact physics quantity and detector performance distributions are reproduced
  - ideally even those not used as input p.d.f.
- ATLAS simulation describes data extremely well
  - right from the start: features in SCT number of hits on track as published few weeks after 900 GeV pilot run in 2009



Principle Event Simulation in ATLAS



specific to simulation

Physics Generator (e.g. Pythia)
– hard process
– hadronization
– particle filter, decays

Detector Simulation (Geant4)
– passage of particles through det.
– very precise geometry used

Digitization
= Detector response sim.

Truth info

common to data and simulation

Detector geometry data-base

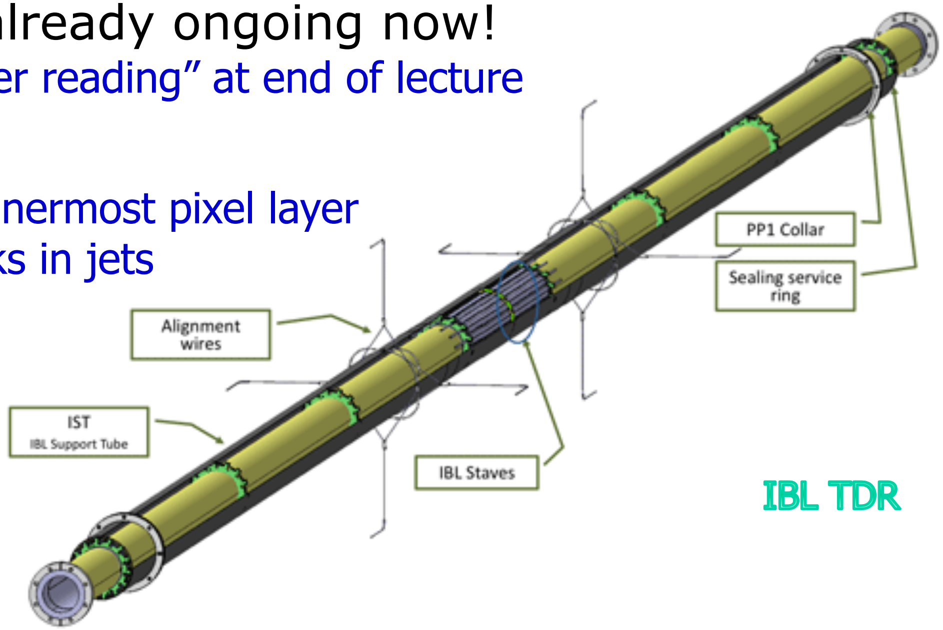
Event Reconstruction

Physics Analysis

- Simulation chain:
  - separated in logical steps
  - reconstruction of simulated event same as for real data
- Detector response tuned e.g. with test-beam data
- Truth information remains associated
- Simulation is cpu-intensive
  - other, faster and less accurate chain exists: Atlfast

ATLAS Upgrade

- Modifications planned for ATLAS:
  - replace parts which will not cope with collisions beyond L=10^{34}cm^{-2}s^{-1}
  - replace parts that will die of radiation
  - replace parts where better technology (and still funding) available
- HEP Detector design, construction, installation operates on long time scales ➔ activites are already ongoing now!
  - here only few brief examples. See “further reading” at end of lecture
- Insertable B-layer (IBL) 2013
  - thinner beam pipe will allow additional innermost pixel layer
  - improves reconstruction of vertices, tracks in jets
  - realizes advancements in pixel detector and cooling technologies
- Tracker replacement ~2018
  - cope with L=5 × 10^{34}cm^{-2}s^{-1}, and pile-up factors of 200
  - build on experience with InDet and IBL
- Muon spectrometer partial replacements
  - in the area of trigger chambers and inner wheels (where flux is high)
  - plans are in early phase

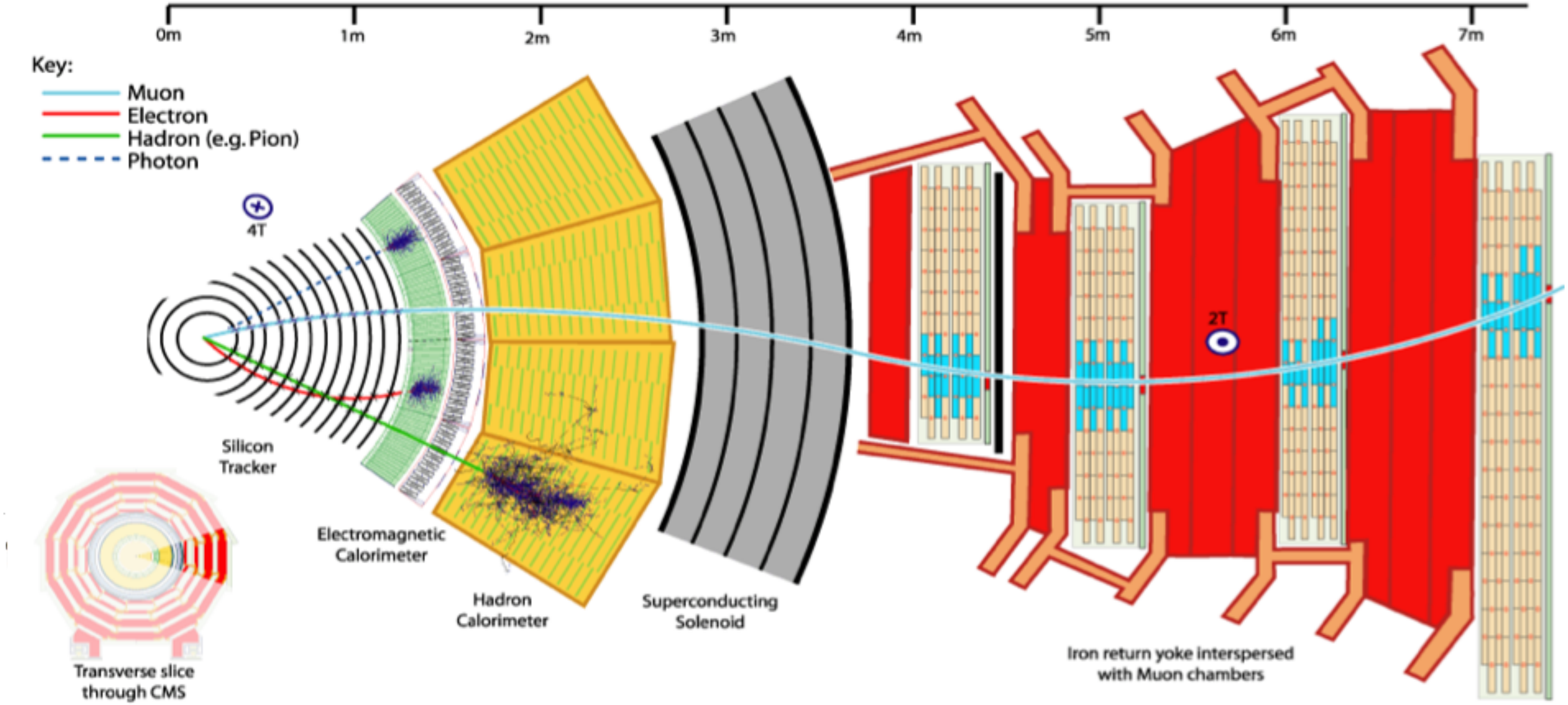


IBL TDR

ATLAS and CMS

ATLAS and CMS have a very similar physics programme, follow the same collider detector principles. Differences exist in:

- magnet system: 4T solenoid, housing all calorimetry
- muon tracker in iron return yoke: very compact
- inner tracker is all-silicon (pixels+strips)
- EM calorimeter is of $PbWO_4$ scintillating crystals



Summary

- Discussed basic characteristics of the LHC collider and the structure and experimental principles of the ATLAS detector
  - ATLAS exploits state-of-the-art technology to measure positions, energy and momenta of particles from collisions at the LHC
  - a lot of different technologies are used and features needed in order to fulfill requirements from machine and physics at the same time
- Next Lecture will be about physics analysis with the ATLAS detector
- With detector and physics outlined third lecture will put things together and discuss how physics objects are made from the detector signals, methods to achieve optimal performance etc

Further Reading

LHC facts, photos, operation…
http://cern.ch/lhc

ATLAS Detector and Performance, 2008 *JINST* **3** S08003
http://iopscience.iop.org/1748-0221/3/08/S08003

ATLAS Upgrade Plans, Talk by A. Salzburger at E. Arik Memorial 2011
http://indico.cern.ch/contributionDisplay.py?sessionId=5&contribId=61&confId=117804

ATLAS Ins. B-Layer Technical Design Report, CERN-LHCC-2010-013
http://cdsweb.cern.ch/record/1291633

General Purpose Detectors for the LHC, D. Froidevaux and P. Sphicas, Ann.Rev. Nucl. 56, 2006
http://www.annualreviews.org/doi/abs/10.1146/annurev.nucl.54.070103.181209

ATLAS construction (more videos on www.atlas.ch –> multimedia)
http://www.atlas.ch/multimedia/downloads/Built-in-3minutes.mov