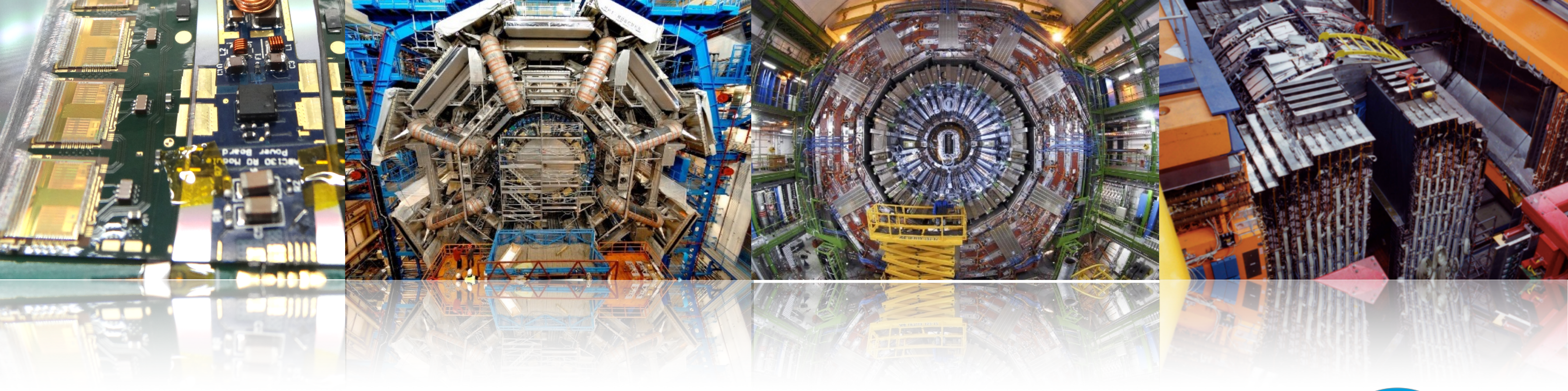


Detectors for High energy Physics

Ingrid Maria Gregor, Simon Spannagel

Part 1

DESY Summer Student 2025

Overview

I.	**Detectors for Particle Physics**	Ingrid	
II.	**Interaction with Matter**	Simon	*Thursday*
III.	**Calorimeters**	Ingrid	
IV.	**Tracking Detectors** • Gas detectors • Semiconductor trackers	Simon	*Friday*
V.	**Examples from the real life**	Ingrid	

9:30 - 10:15
15 min break
10:30 - 11:15
15 min break
11:30 - 12:15

Disclaimer

- Particle Detectors are very complex, a lot of physics is behind the detection of particles:
  - particle physics
  - material science
  - electronics
  - mechanics, ….

- To get a good understanding, one needs to work on a detector project ...

- This lecture can only give a glimpse at particle detector physics, cannot cover everything
- Biased by our favourite detectors !

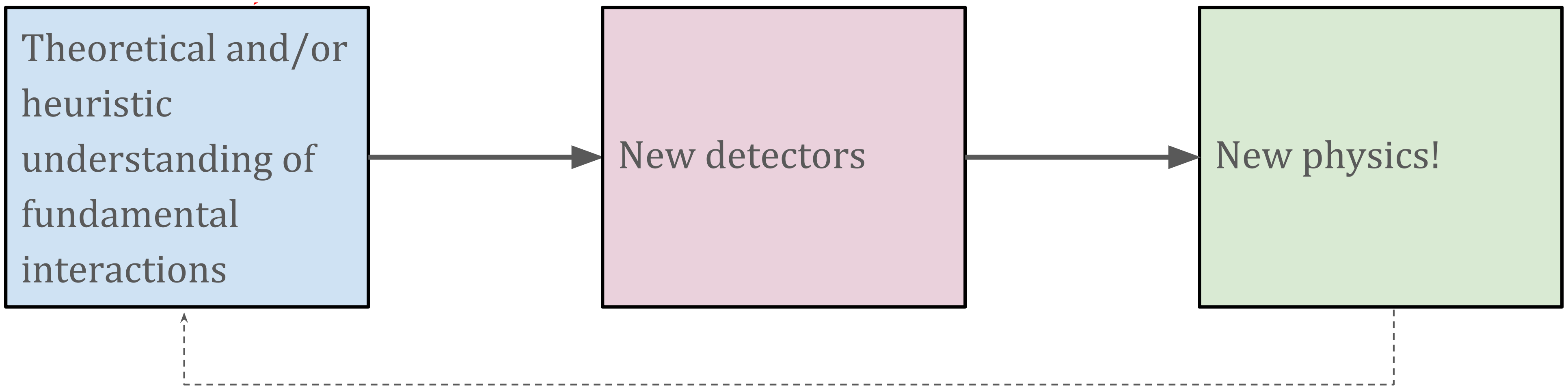
Pic: DC Comics

Maybe not the ideal detector physicist

I. Overview: Detectors for particle physics

Why Study Detector Physics ?

- Particle and nuclear physics discoveries are driven by **detector innovation**.
- And you need *fundamental understanding* to drive innovation



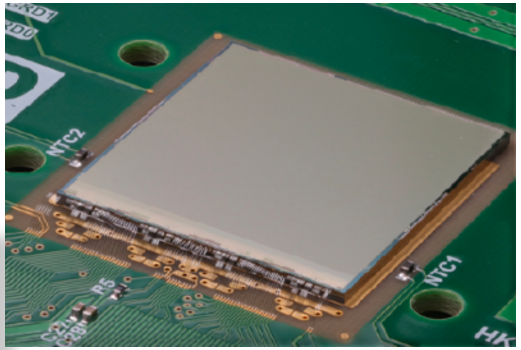
Instruments = Detectors

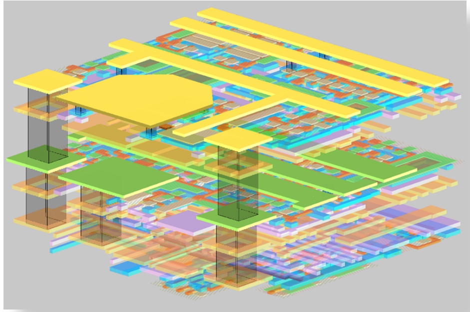
for particle physics / photon science / medicine / societal applications

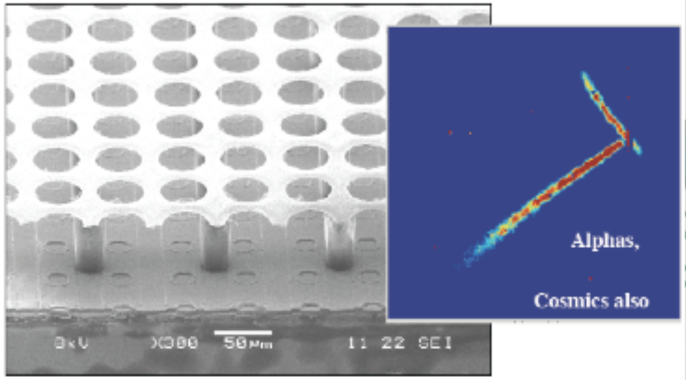
- what is the underlaying principle
- how do they work
- how precise can they measure

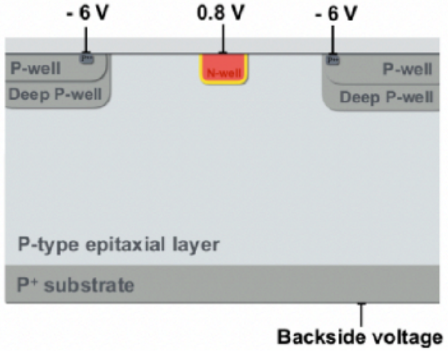
HEP Detector R&D

- Many different new or advanced detector technologies are under investigation:
  - new pixel sensor technologies (planar, 3D sensors, diamond, CMOS)
  - new silicon strip technologies
  - silicon photomultipliers (SiPM)
  - radiation hard silicon sensors (far future?)
  - micro-pattern gas detectors
  - heavy fibres, new scintillating crystals
  - new diamond devices for luminosity monitoring
  - high resolution calorimetry (EM and Hadronic; PFA, analog vs. digital ….)
  - quantum detectors
  - optimal detector geometry
  - magnetic field configurations...



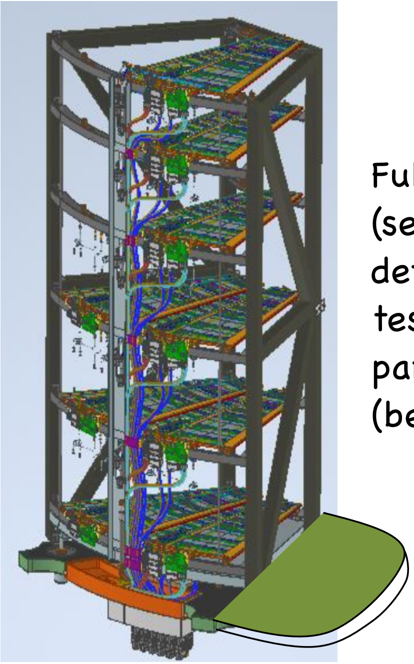




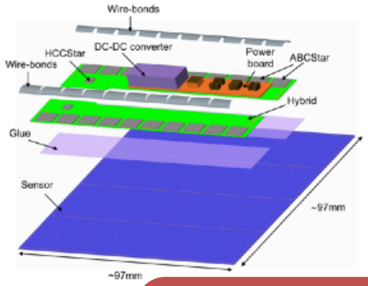


- Extensive amount of studies of all this new technologies to qualify them
  - Opportunities for master and PhD theses

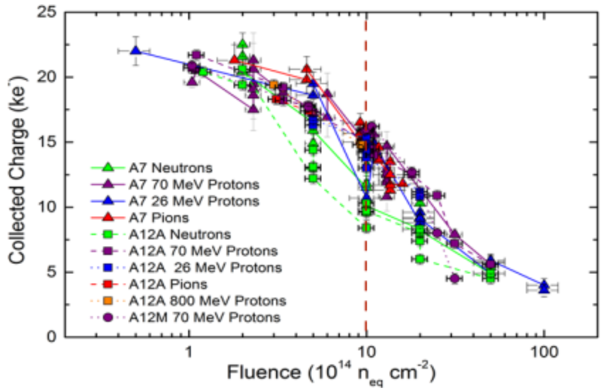
Detector Development Cycle



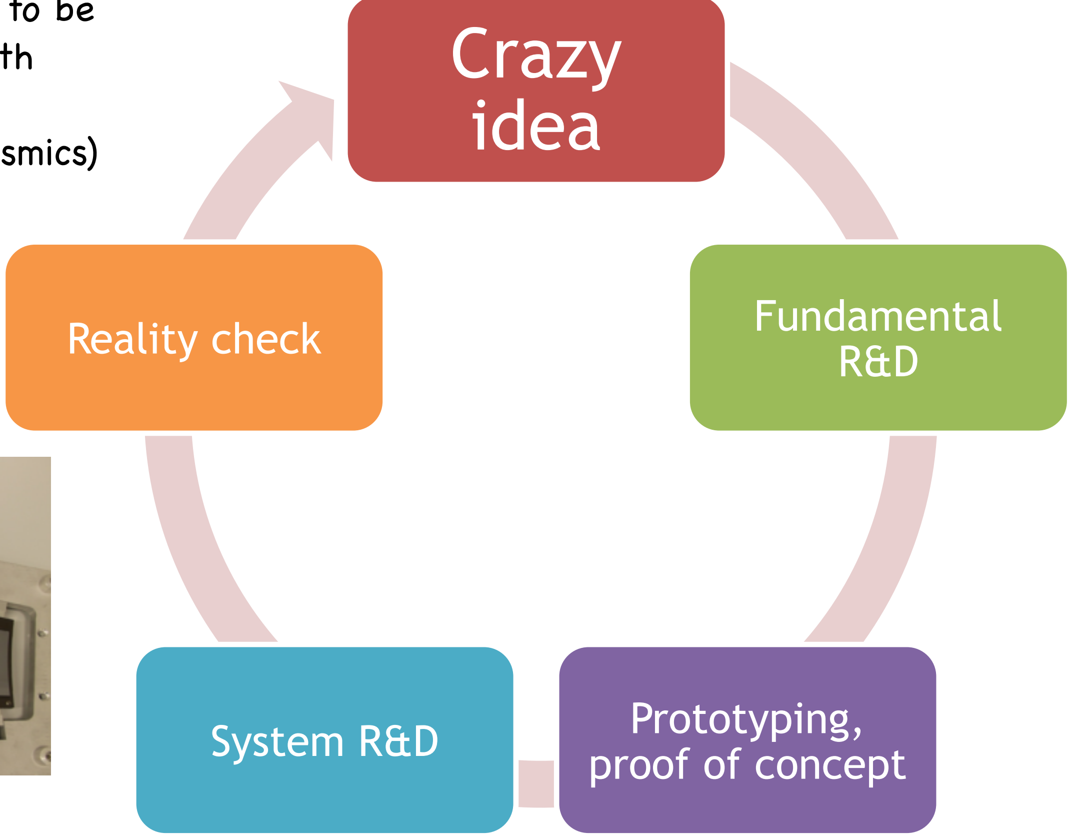
Full system (segment of detector) to be tested with particles (beam, cosmics)

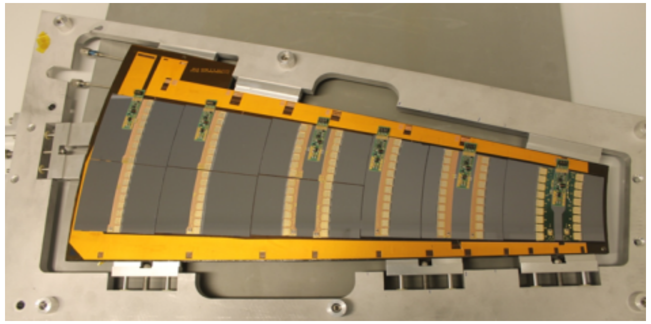


Crazy-idea-detector: use glue to build the detector….

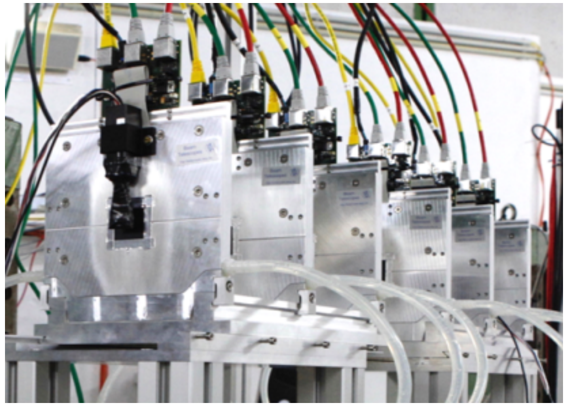


Does the crazy-idea-detector "see" passing particles. Simulations!





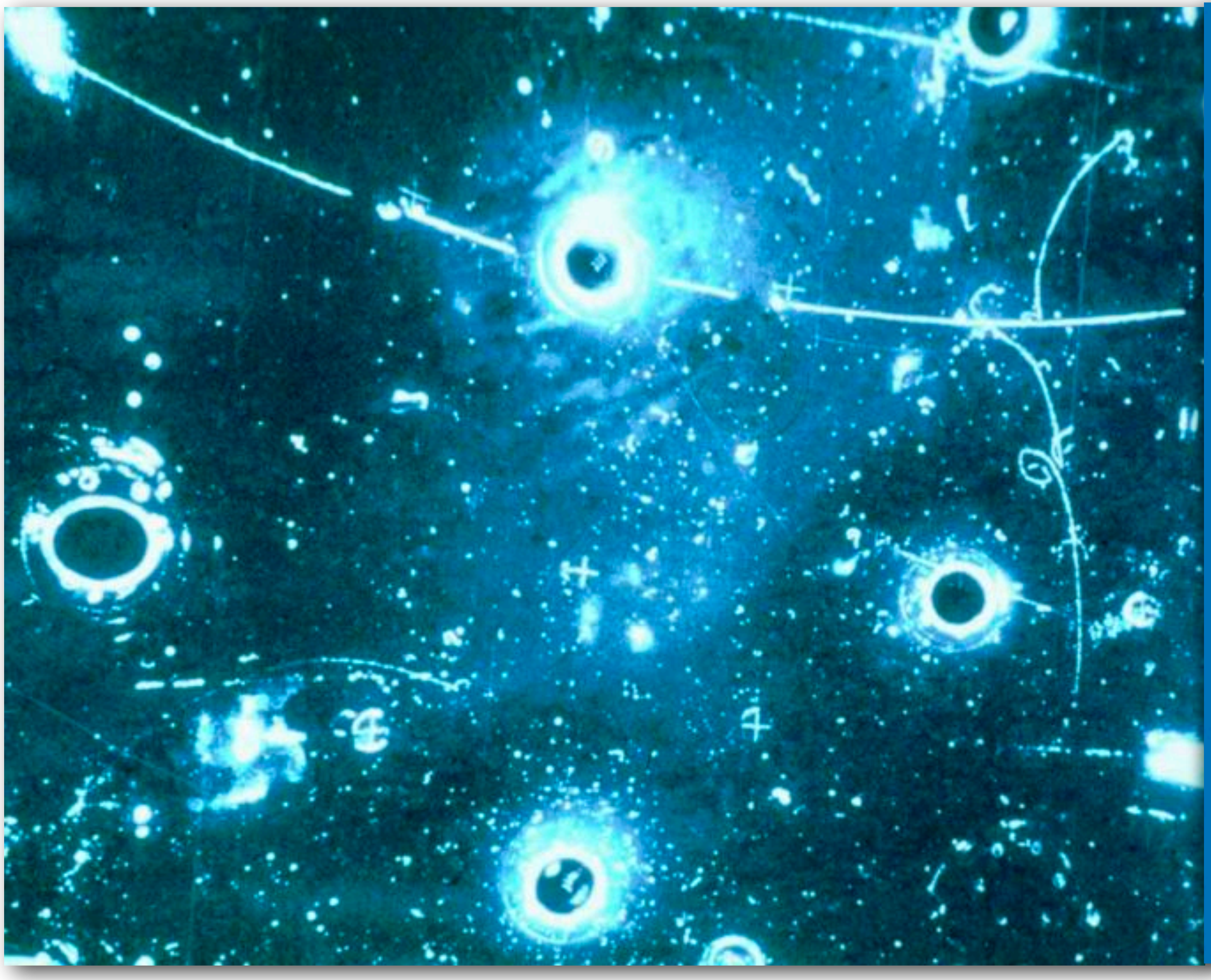
Towards large-size systems incl. cooling, powering, monitoring ….

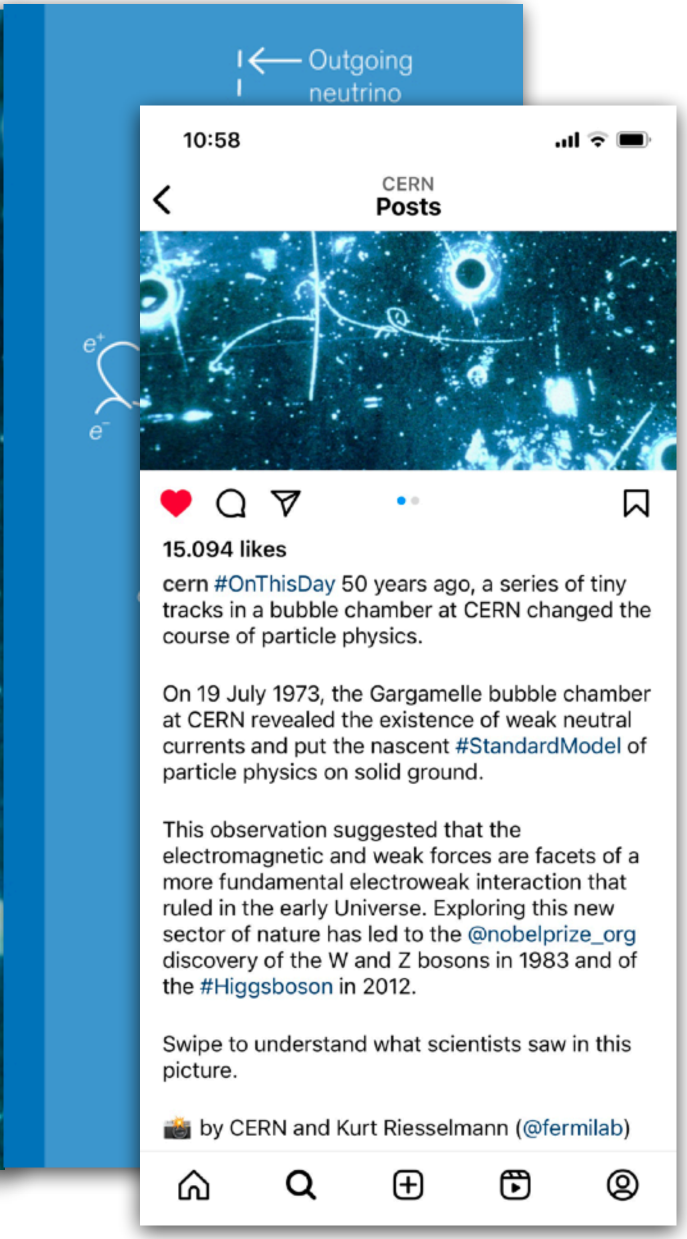


Can we build a small-size detector out of it ? Test with "real" particles!

Discovery of neutral currents

Gargamelle, 19. July 1973

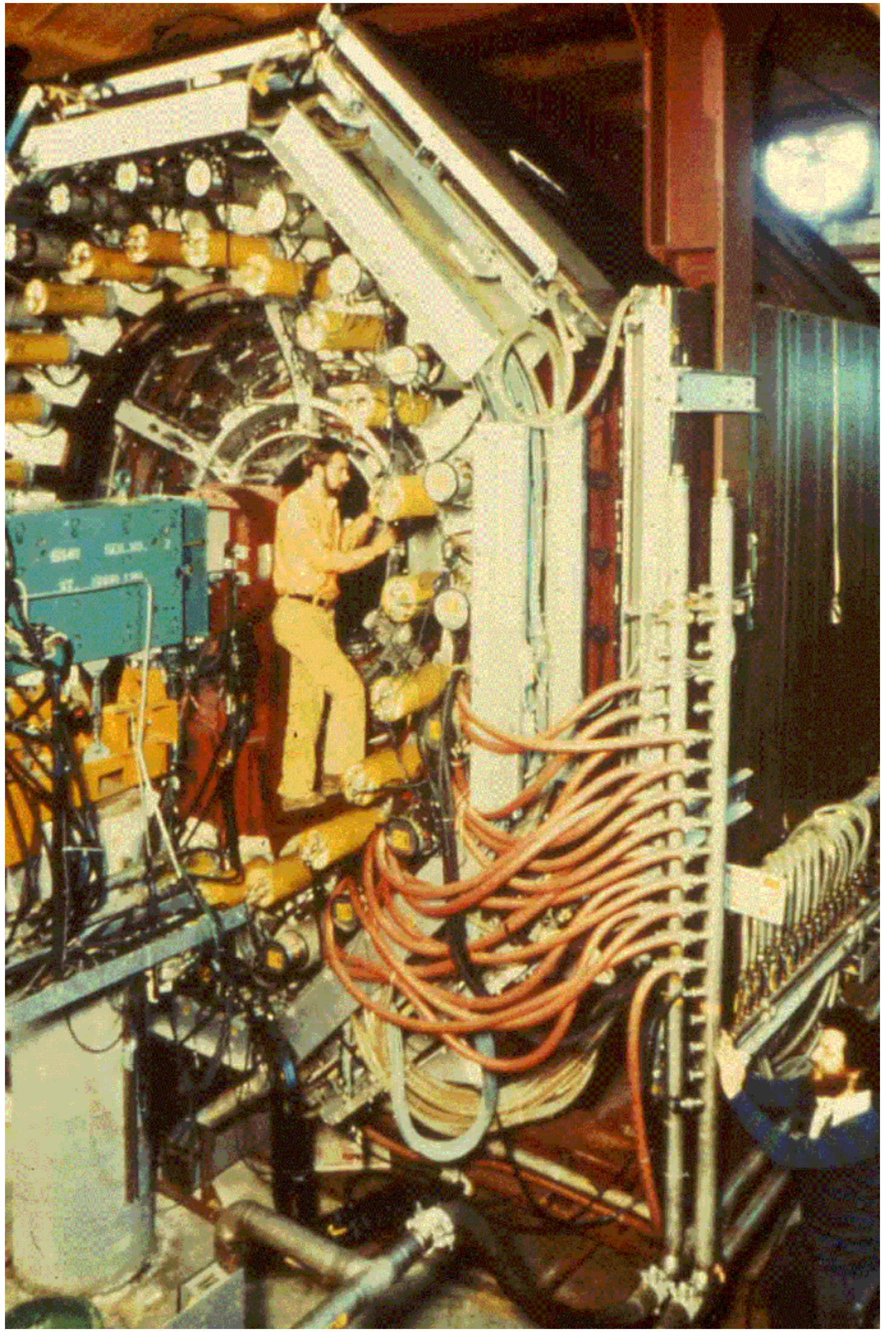




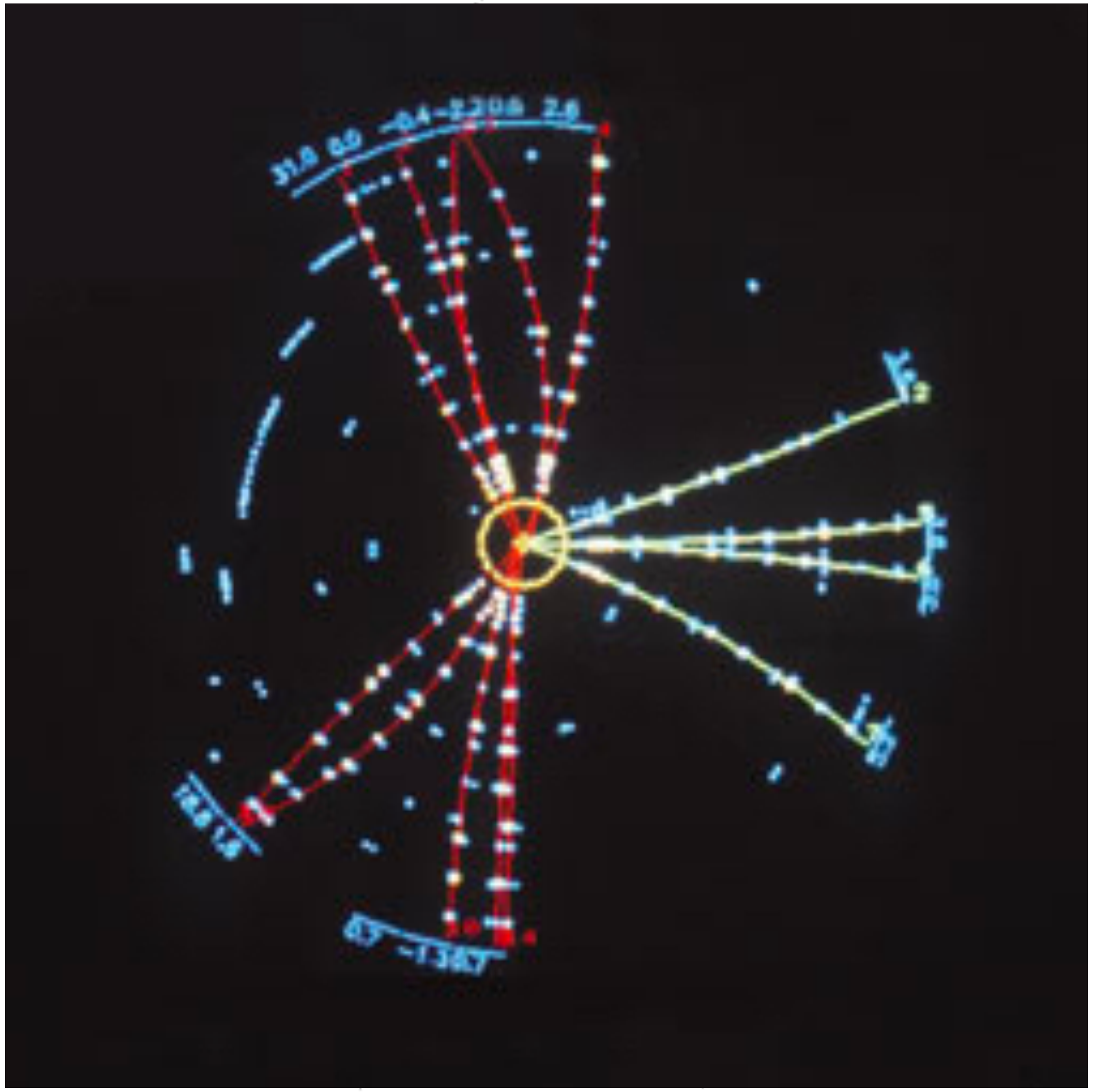
Mark-I Detector@SLAC

- Mark I detector: first 4π detector

Discoveries of the J/ψ particle and tau lepton, which both resulted in Nobel prizes (for Burton Richter in 1976 and Martin Lewis Perl in 1995)



Discovery of the Gluon



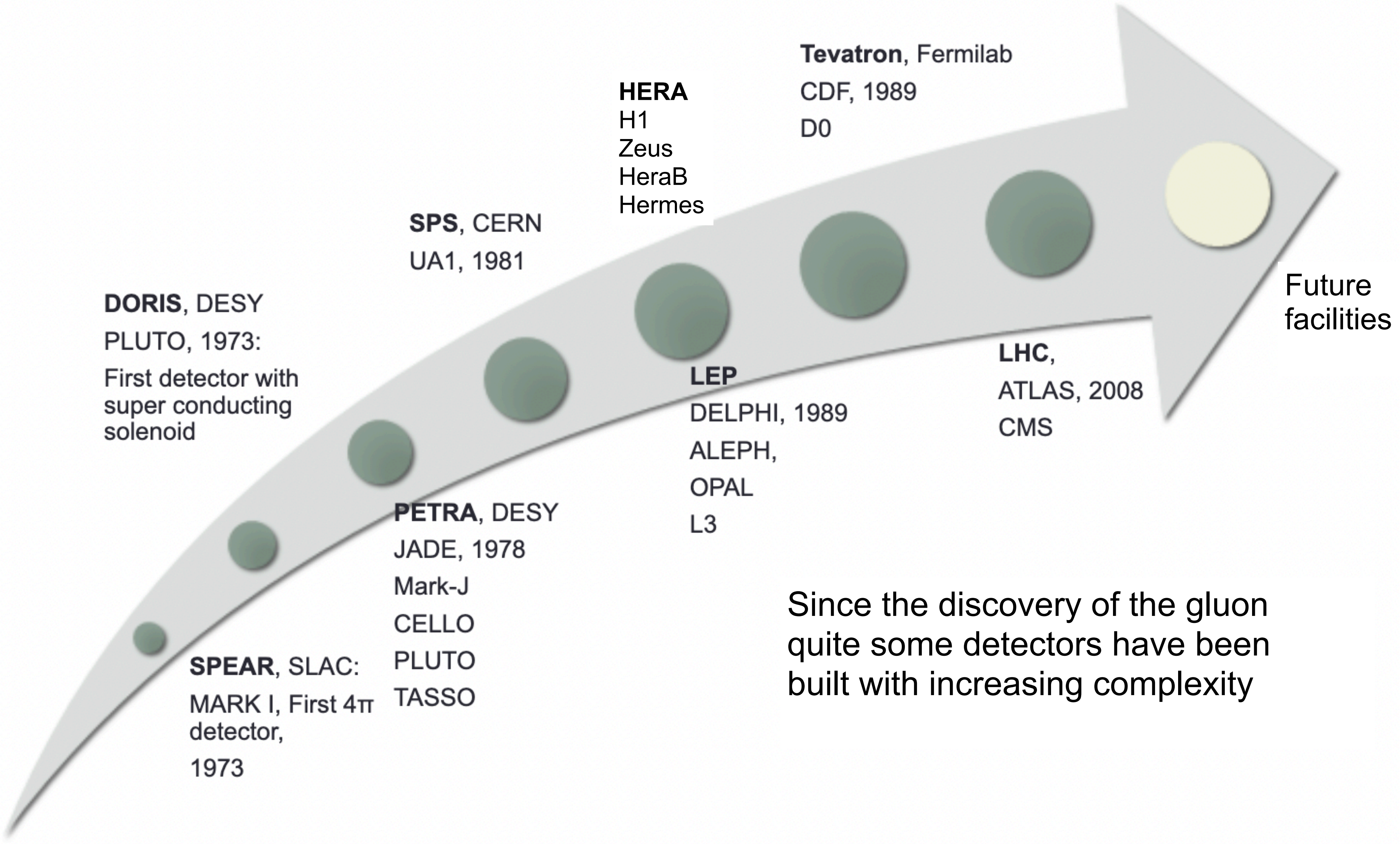
- Field theory predicted that the outgoing quarks radiate field quanta (gluons)
  -> 3 jet events

The quantum of the strong force was discovered and studied at lepton colliders.

Birthday of the gluon: 18.06.1979 at the electron-positron collider PETRA.

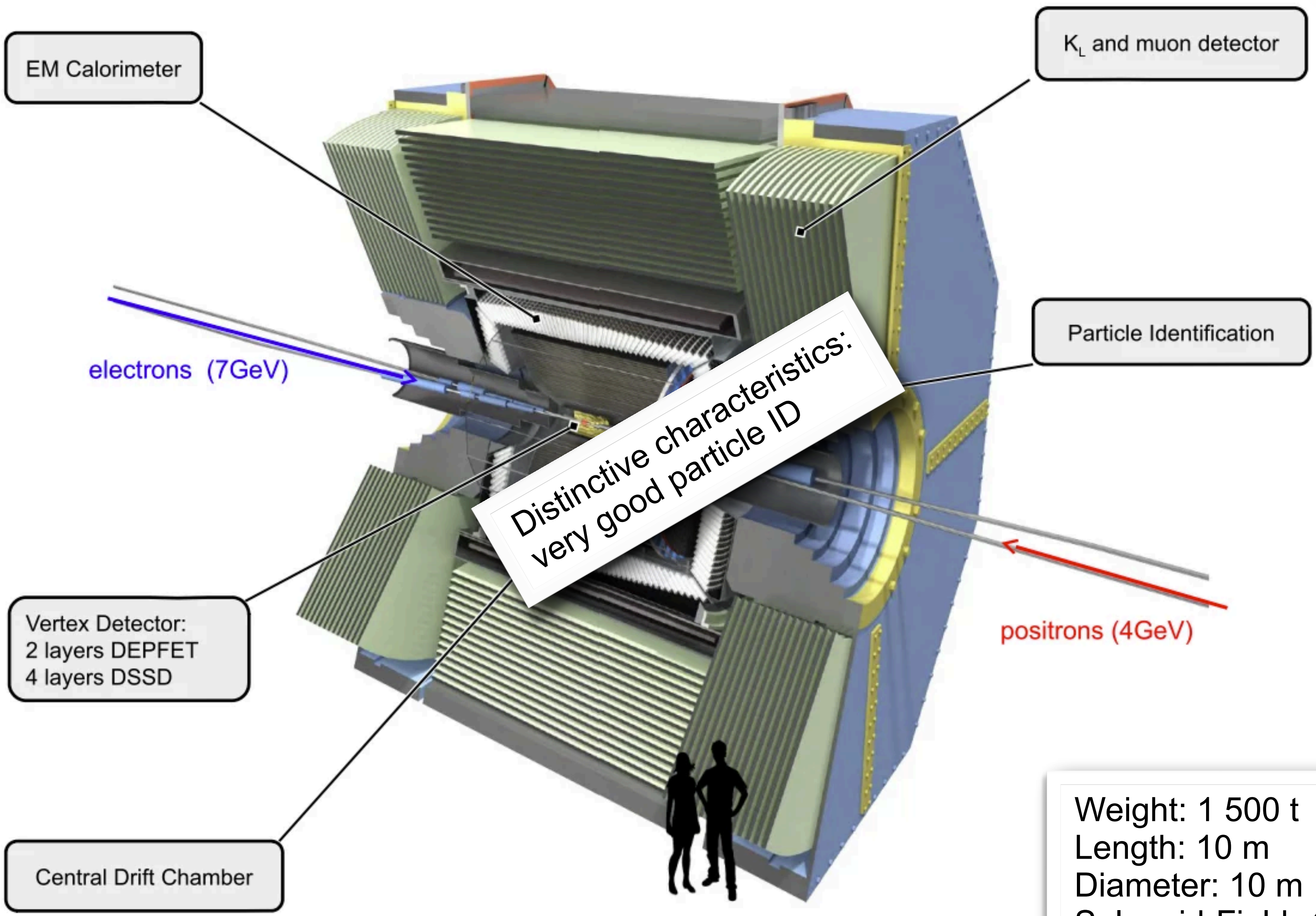
JADE, Mark J, PLUTO and TASSO

Evolution of Detectors



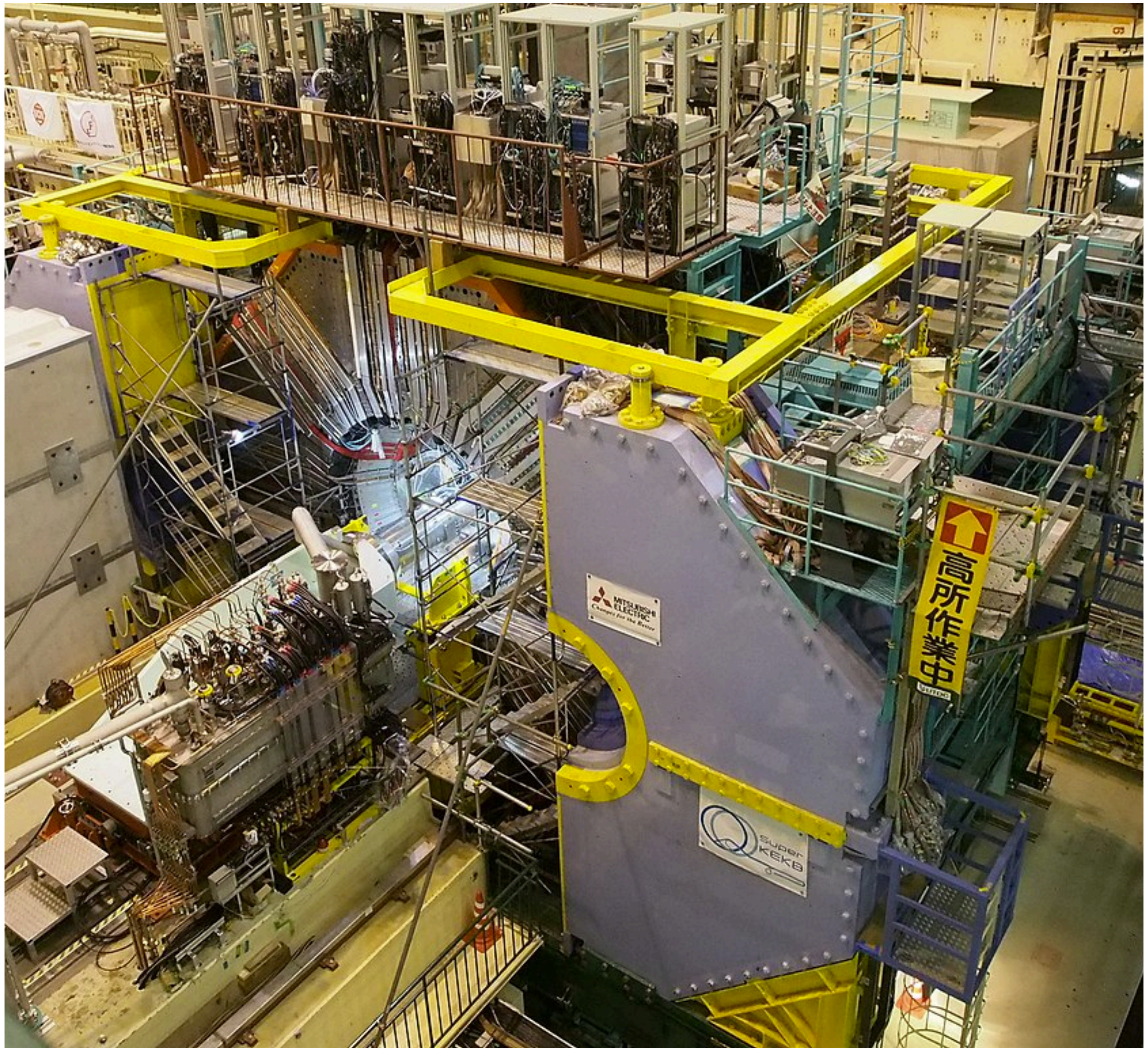
Since the discovery of the gluon quite some detectors have been built with increasing complexity

BELLE@KEK



Weight: 1 500 t
Length: 10 m
Diameter: 10 m
Solenoid-Field: 4 T

BELLE@KEK



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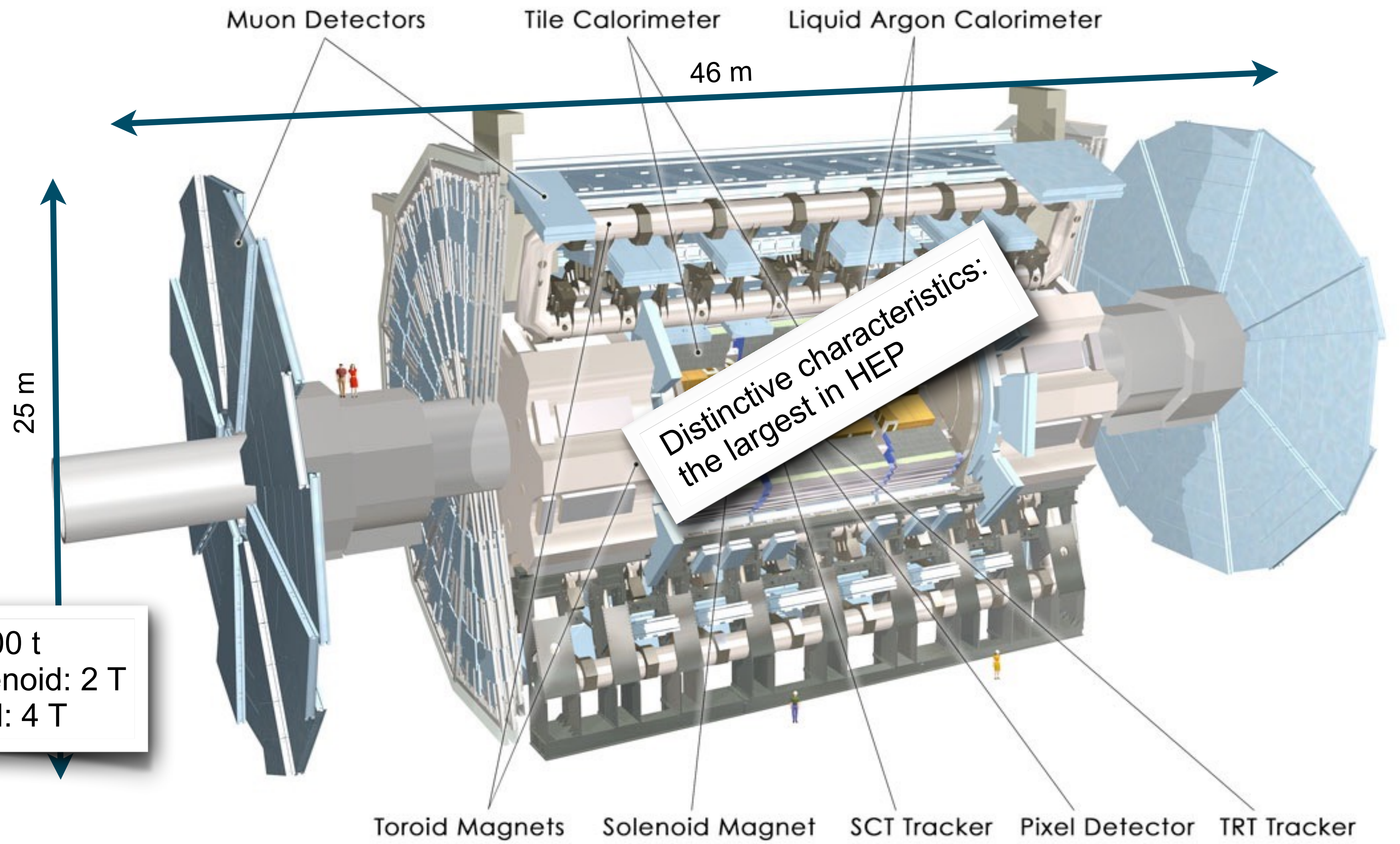
MITSUBISHI ELECTRIC
Changes for the Better
Super KEKB

ATLAS@LHC



Weight: 7 000 t
Central Solenoid: 2 T
Muon-Toroid: 4 T

Illustration: CERN

ATLAS Cross Section

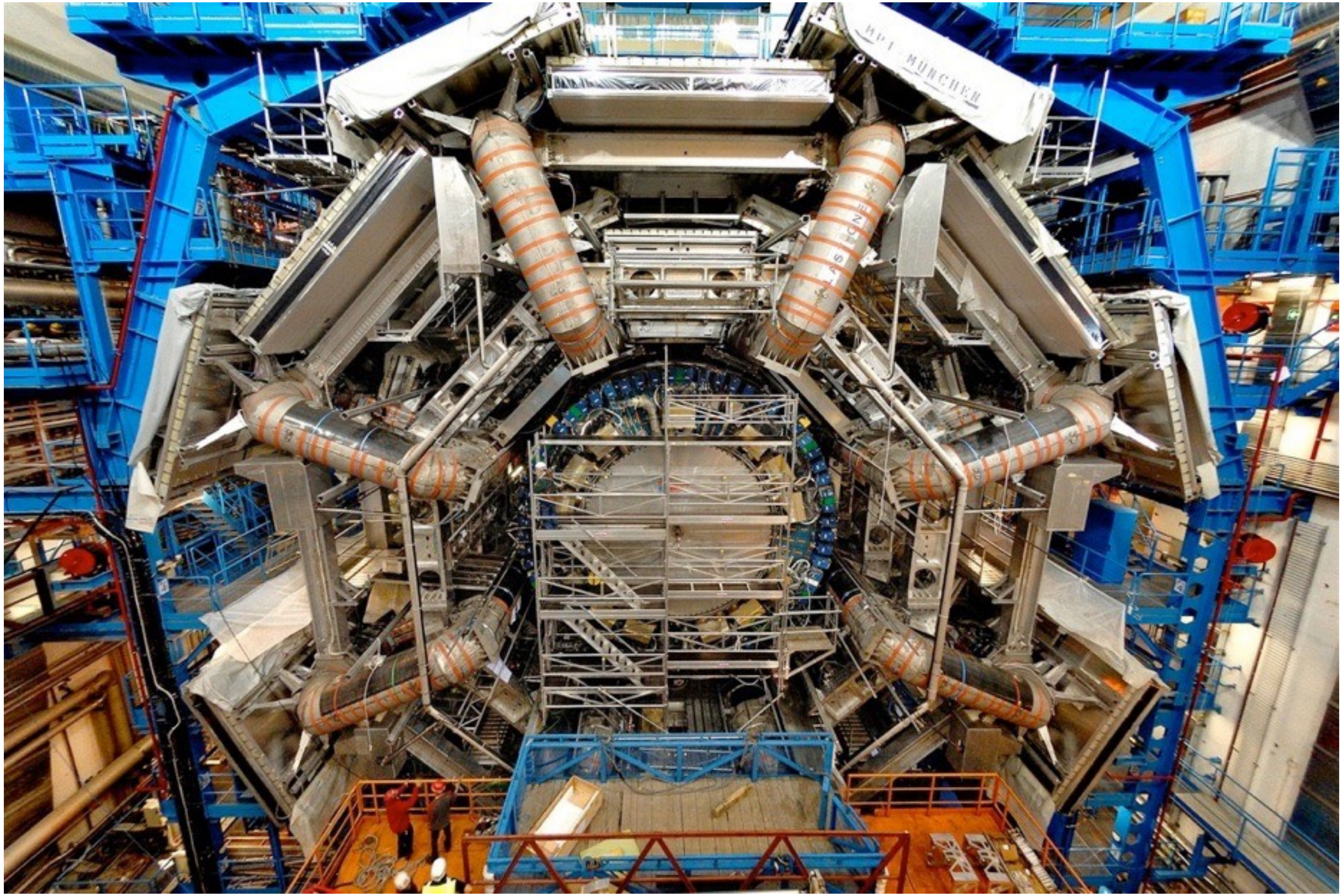
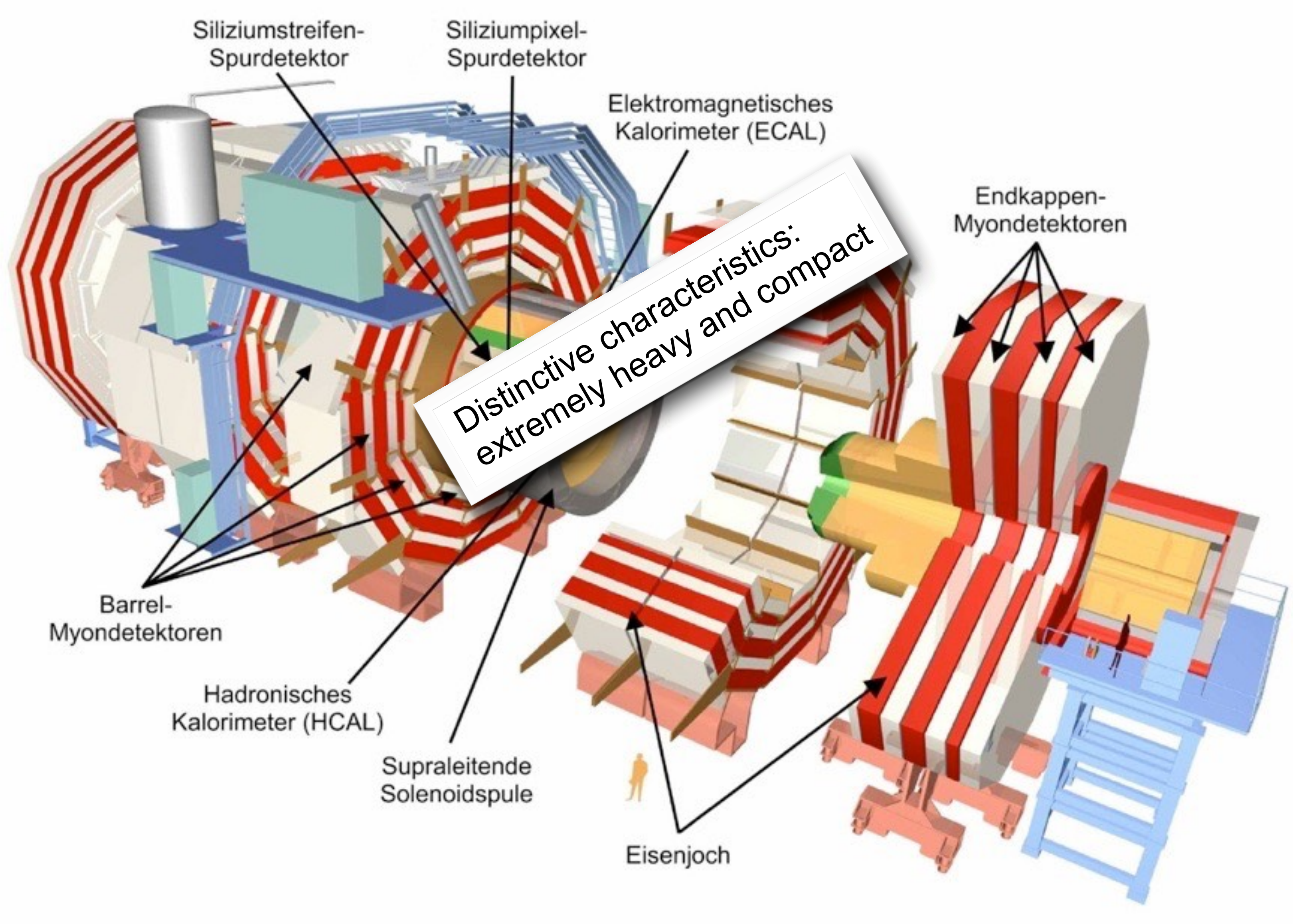


Foto: CERN

CMS@LHC



Weight: 12 500 t
Length: 21.5 m
Diameter: 15 m
Solenoid-Field: 4 T

CMS Cross Section

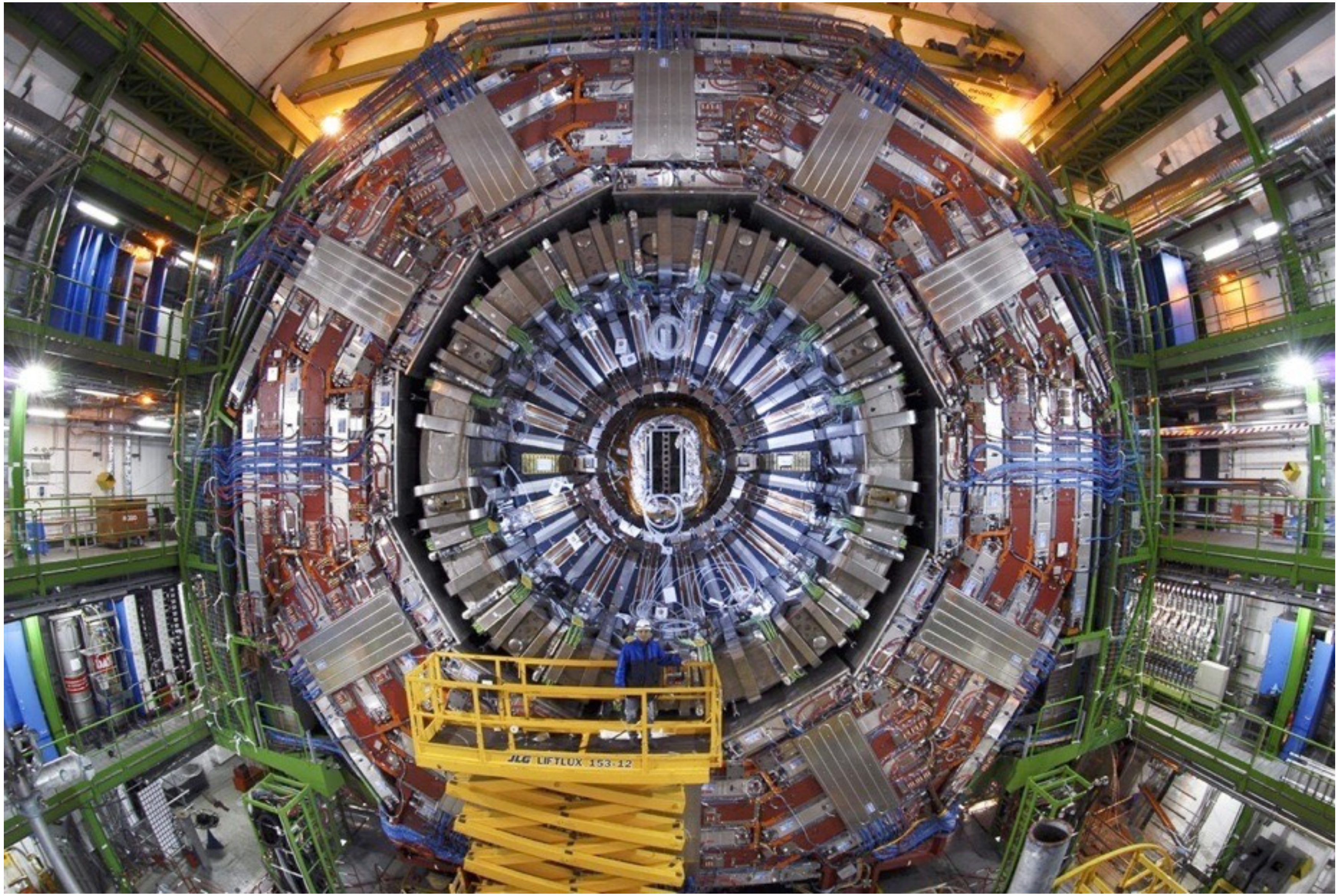
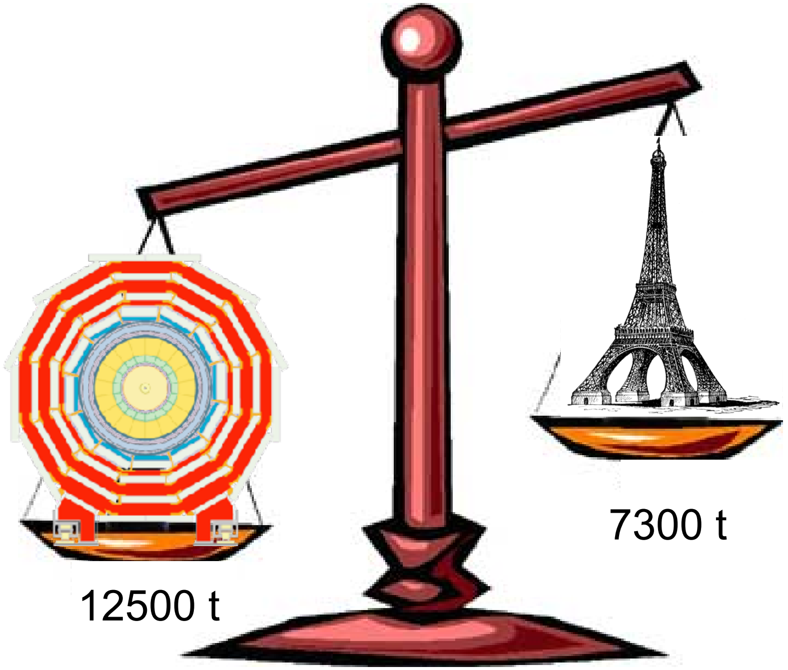


Foto: CERN

Size and Weight

Brandenburger Tor in Berlin

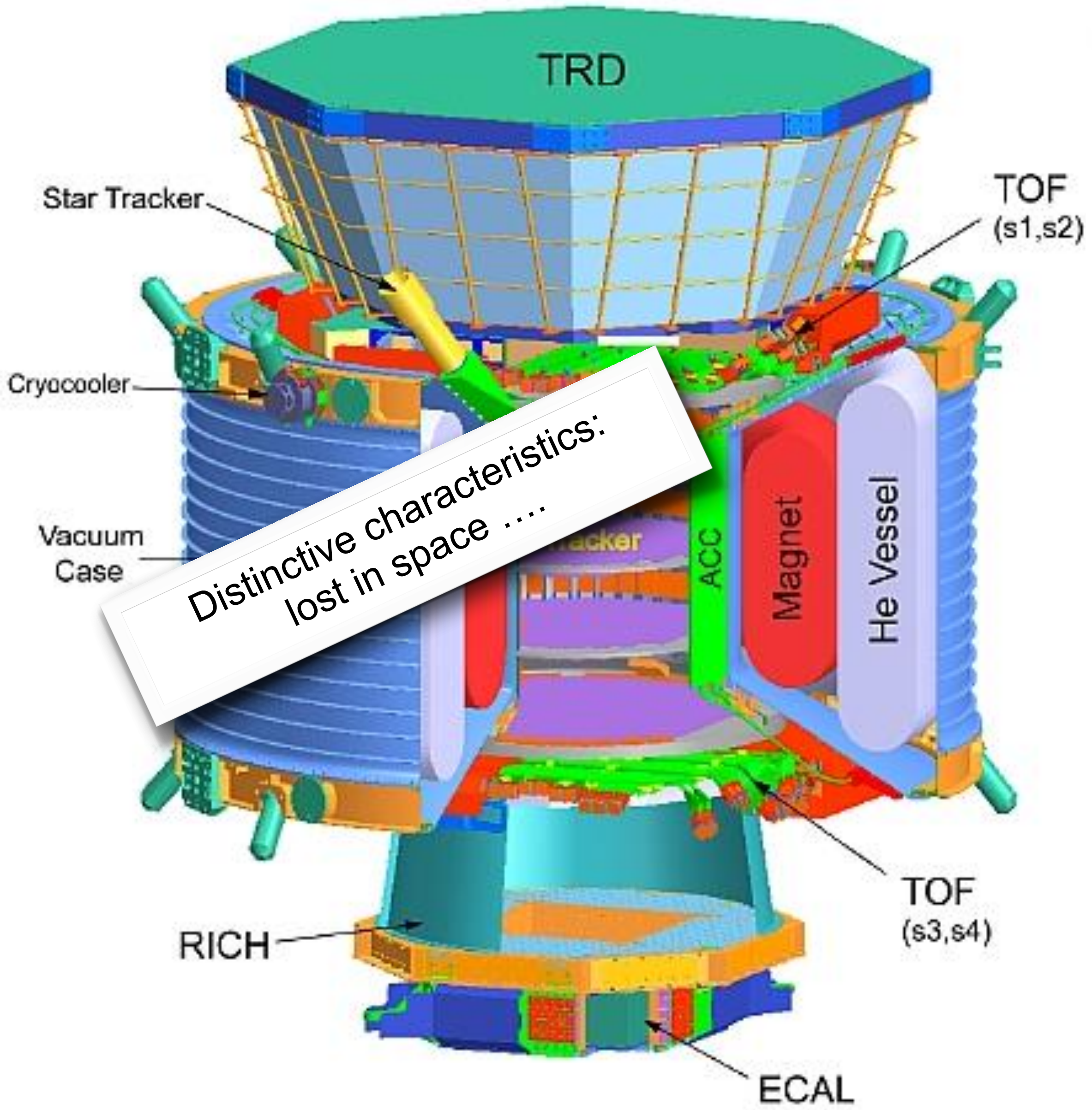


CMS is 65% heavier than the Eiffel tower

In Hamburg

AMS@ISS

Weight: 6700 kg
Length: 6 m
Diameter: 6 m
Solenoid-Field: 1.5 T



Distinctive characteristics: lost in space ….

picture: AMS collaboration

Icecube Experiment

Example: ATLAS at CERN

Full movie: ATLAS experiment - Episode 2 - The Particles Strike Back
http://cds.cern.ch/record/1096390?ln=en