

Electronics for Physicists

Analog Electronics

Chapter 0; Lecture 01

Frank Simon

Institute for Data Processing and Electronics

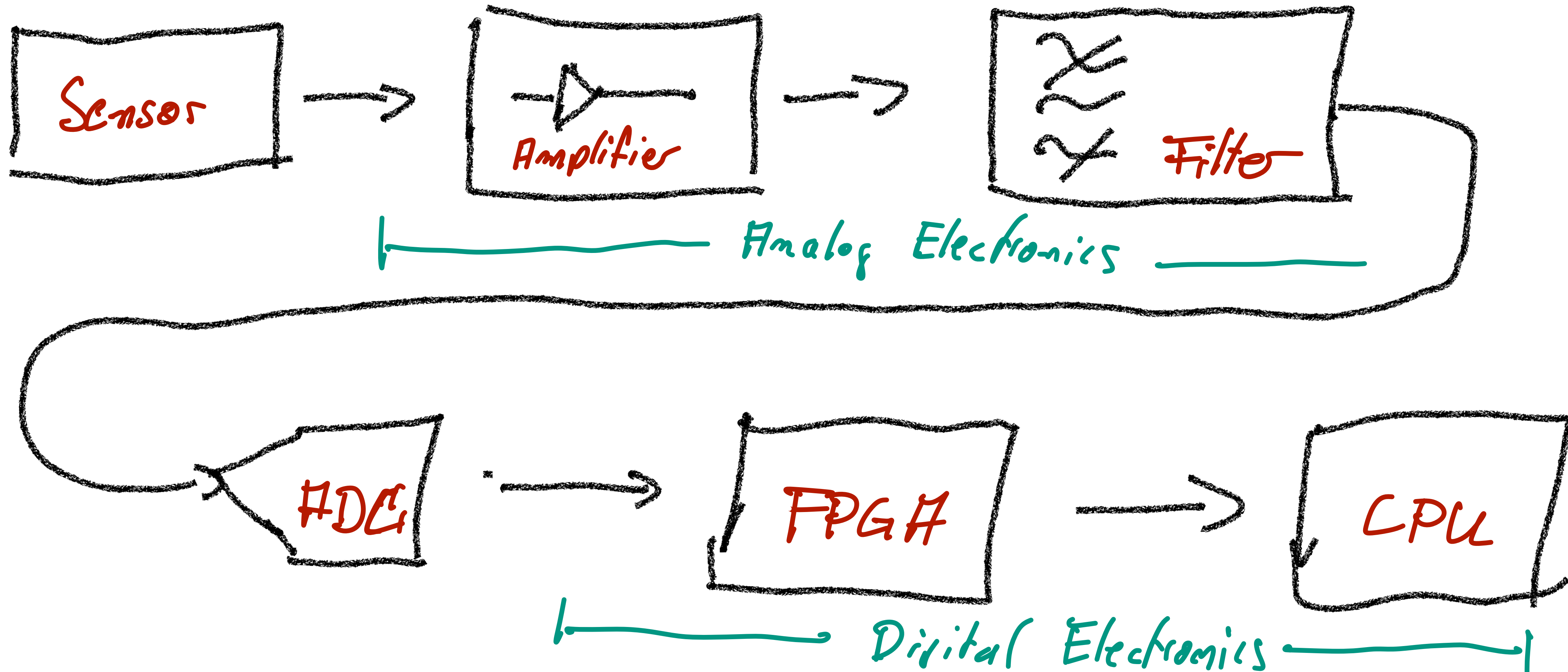
24.10.2023

KIT, Winter 2023/24

Preamble

- Date & Time: Tuesday (Analog), Thursday (Digital), 8:00 - but swaps in several weeks
 - Currently planned deviations from this cycle:
 - 26.10. Analog also Thursday this week
 - 21.11. / 23.11. Swap Digital (Tue) <-> Analog (Thu)
 - 29.11. No Analog - cancelled or digital?
 - 12.12. / 14.12. Swap Digital (Tue) <-> Analog (Thu)
- Practical course: “Exercises” for the lecture - analog and digital electronics (and combined) experiments
Wednesday afternoon, starting 14:00. First meeting: November 8. ***Separate ILIAS registration required!***
- Exams: Analog and Digital can be taken as separate exams, or as one combined exam if you have taken both courses (the default) - in this case with correspondingly larger credits
- ILIAS as “Repository” for slides, tool for communication
 - Lecture script (from Prof. Weber) available as background information

- Readout chain for high energy physics as an example



- Subdivided into Chapters - often spanning across multiple lectures

1. Basics
2. Circuits with R, C, L with Alternating Currents
3. Diodes
4. Operational Amplifiers
5. Transistors - Basics
6. 2-Transistor-Circuits
7. Field Effect Transistors
8. Additional Topics
 - Filters
 - Voltage Regulators
 - Noise

- Number systems
- Boolean algebra
- Basic logic modules
- From transistor to logic module (CMOS)
- Essential circuits (combinational logic)
- Minimization of circuits
- Memory (sequential logic)
- Finite state machines
- Programmable logic (main focus FPGA)
- Hardware description languages (main focus VHDL)
- Digital /analog- & analog/digital-converters (various methods)

Who we are - and what we do

Institute for Data Processing and Electronics: Campus North, Geb. 242



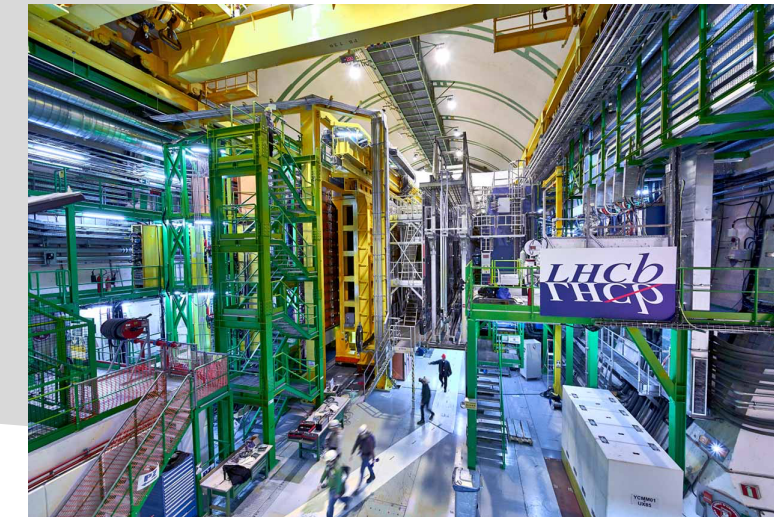
Research at IPE

Experiments - International Collaborations - Examples

KATRIN
Karlsruhe



LHCb
CERN, Switzerland

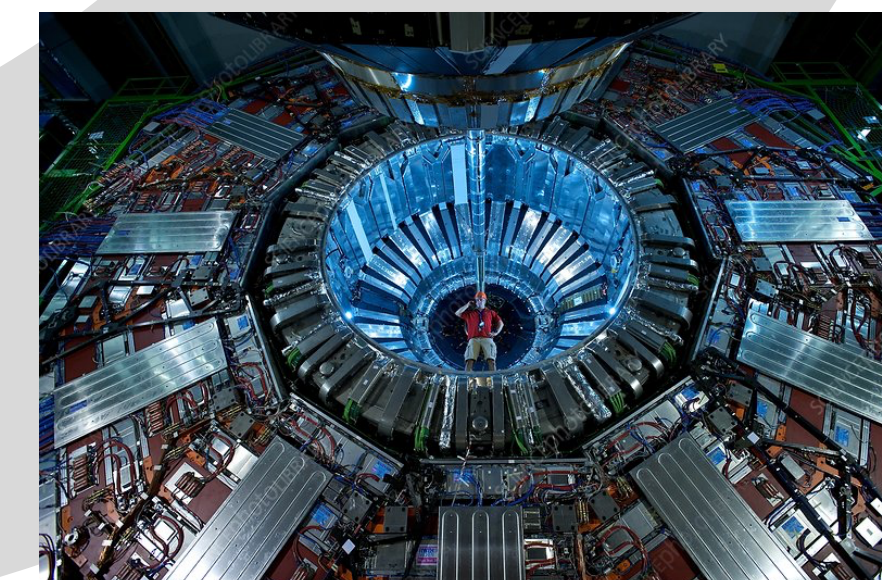


ECHo
Heidelberg

DARWIN

DARWIN

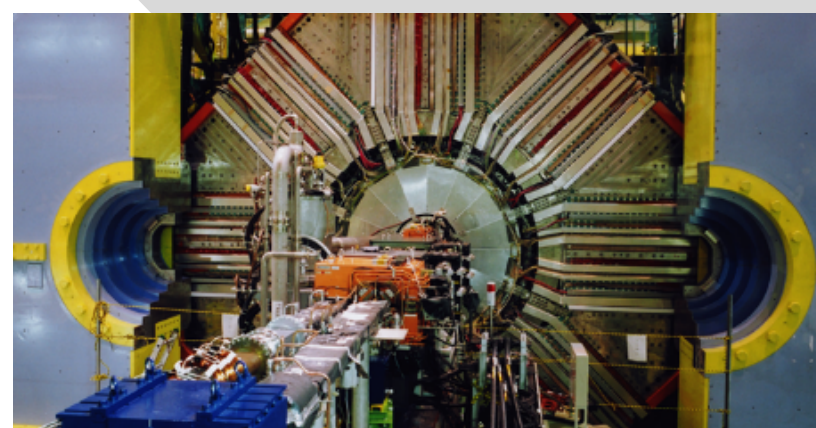
CMS
CERN,
Switzerland



IceCube
South Pole



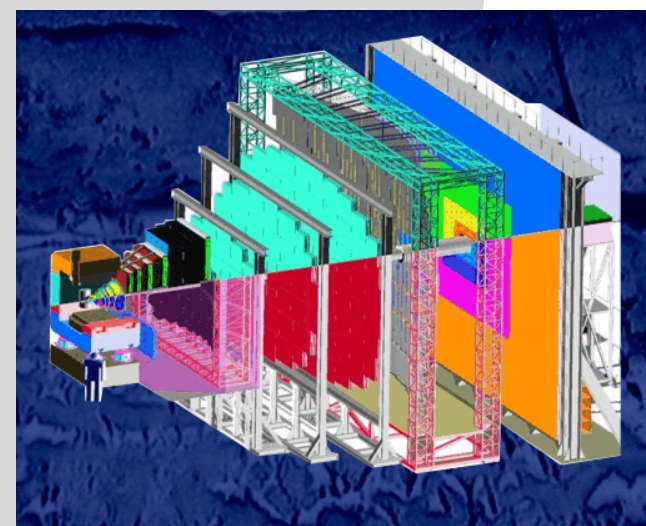
Belle II
Japan



Pierre Auger Observatory
Argentina

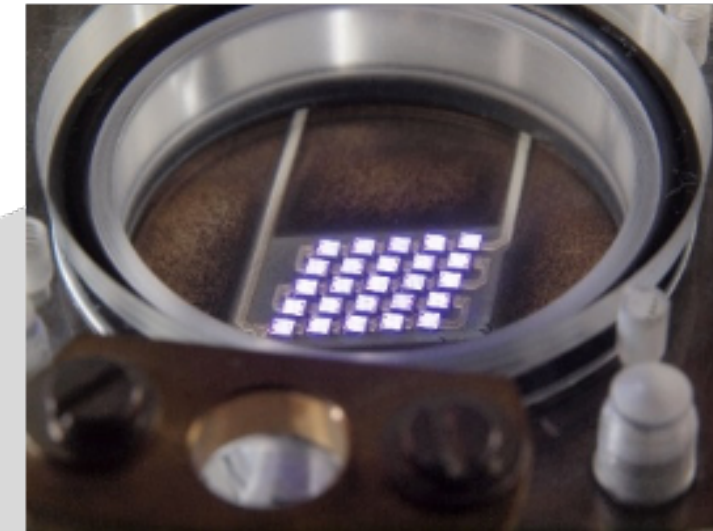


CBM at FAIR
GSI Darmstadt





Quench Detection System
for high current leads and superconducting magnets



UV-LED Module
World-record in power density 484 W/cm^2

SENSOLUTE
SMART SENSOR SOLUTIONS



Sensolute GmbH
Founded in 2006
Product: Micro vibration sensor



Molch
Over 25 years of cooperation with Pipetronix
Licence fees > 6 M€



TT Project Kryo Sensor
Prof. Dr. Steffen Grohmann

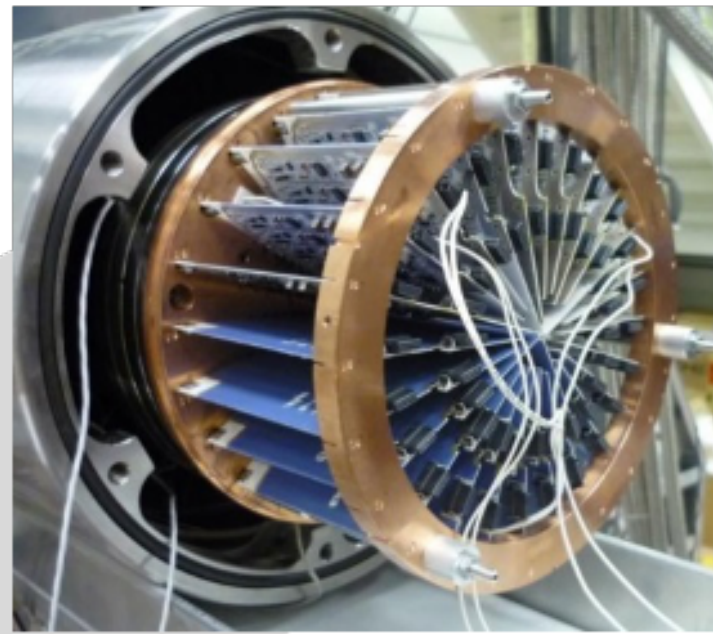
WEKA
CRYOGENICS



3D-USCT for multi-center study in China
KIT Innovationspreis 2018
PD Nicole Ruiter



SC magnet safety &
quench detection



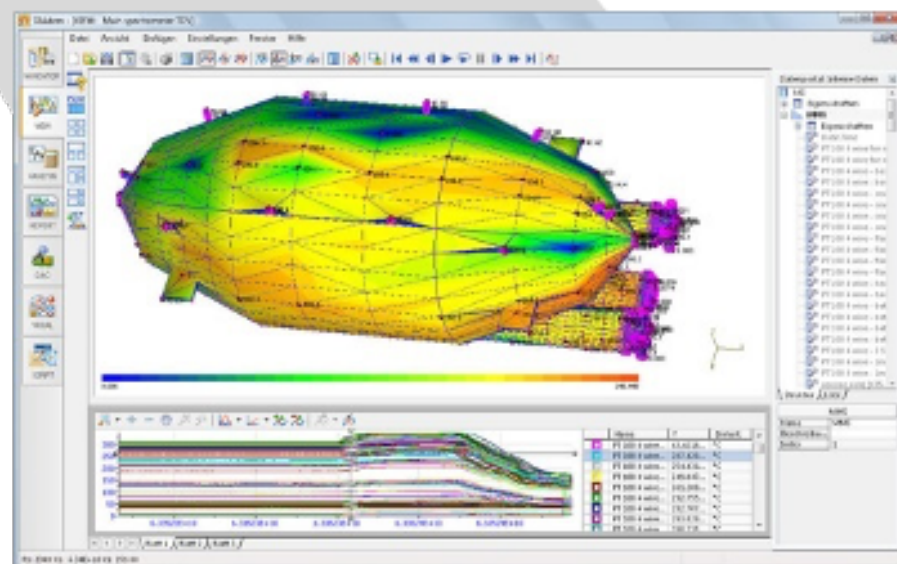
Detector electronics



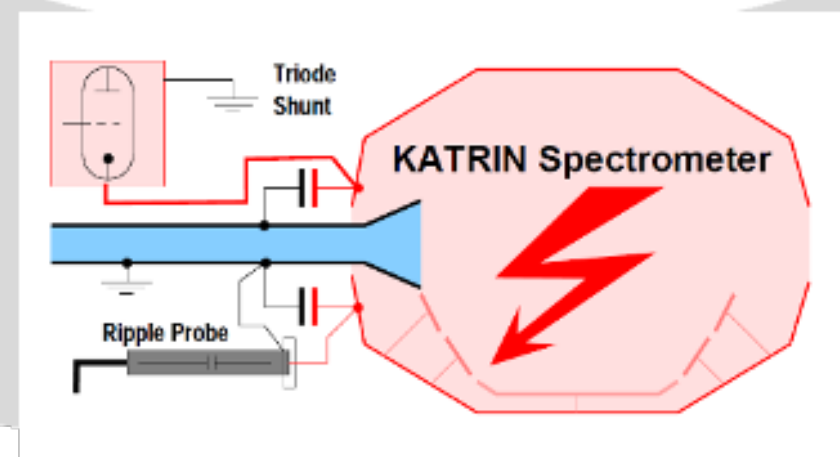
Data acquisition



Data management &
IT infrastructure



Slow control &
monitoring



HV precision regulation

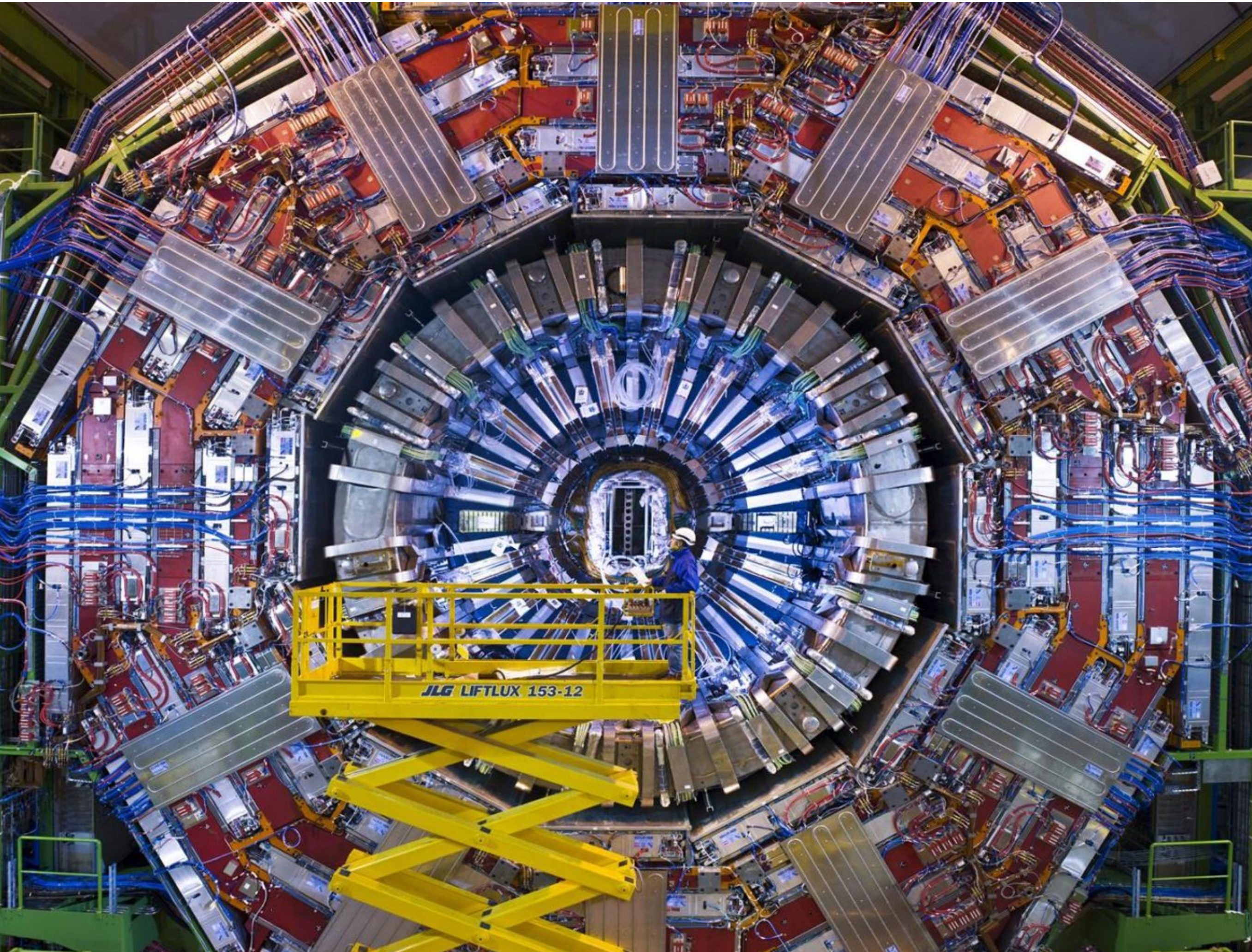


HV Safety Concepts

Future project now taking shape:
Quantum sensors (MMC) to
dramatically improve neutrino mass
sensitivity. Key roles of IPE

- Quantum sensor production & test
- Multi-channel readout system for quantum sensors - also relevant for qubits / quantum computing

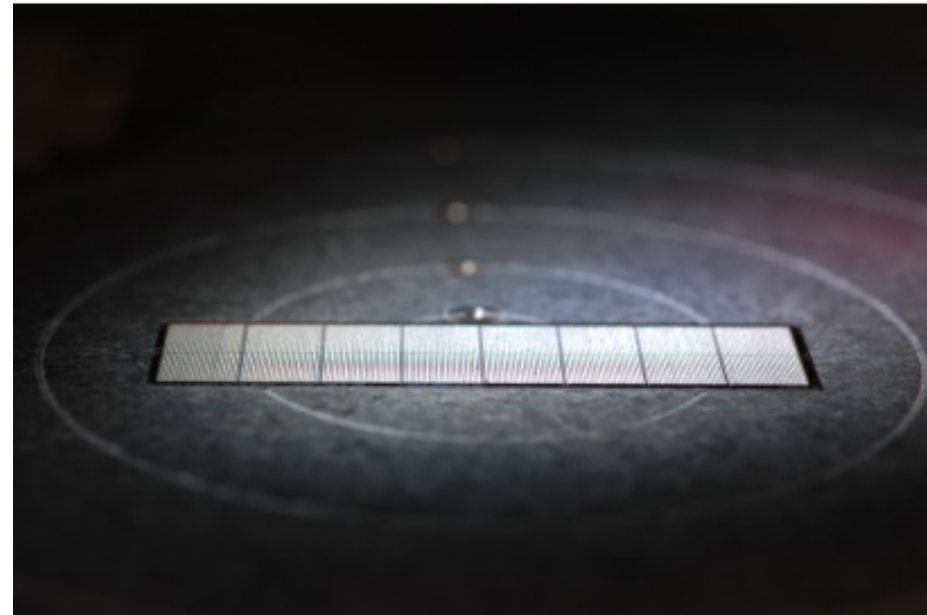
- CMS Experiment at LHC



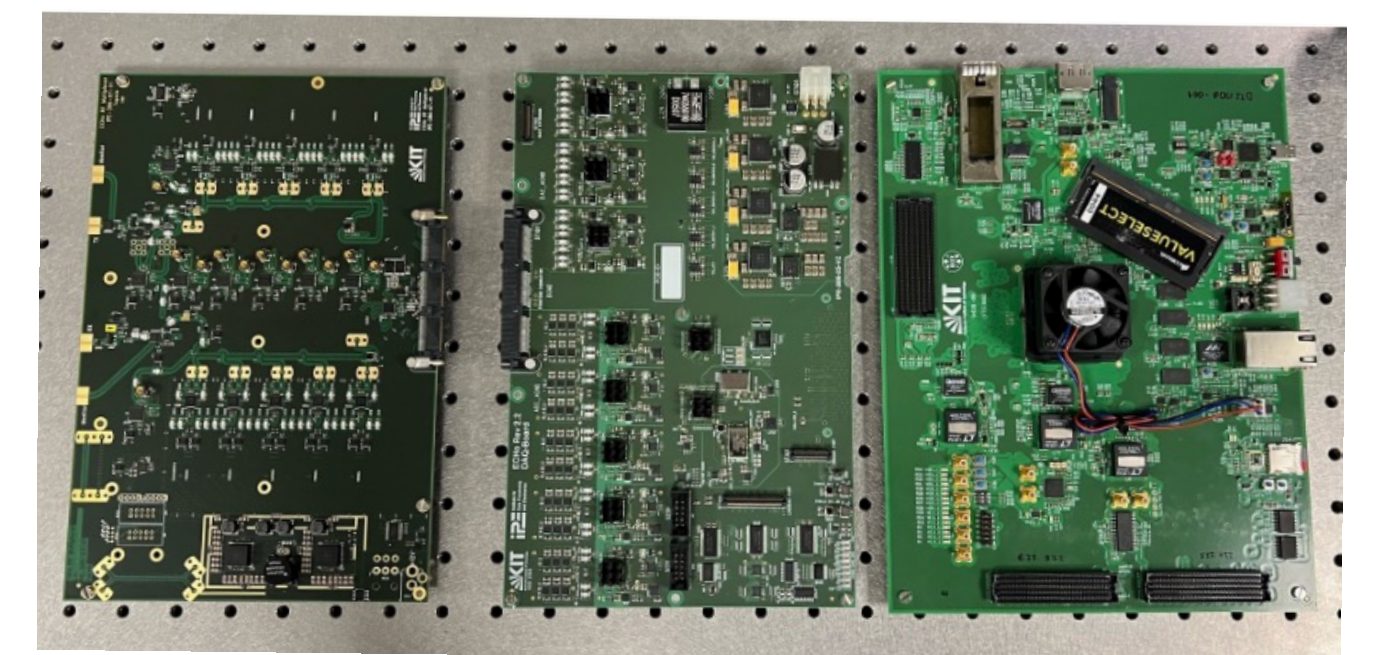
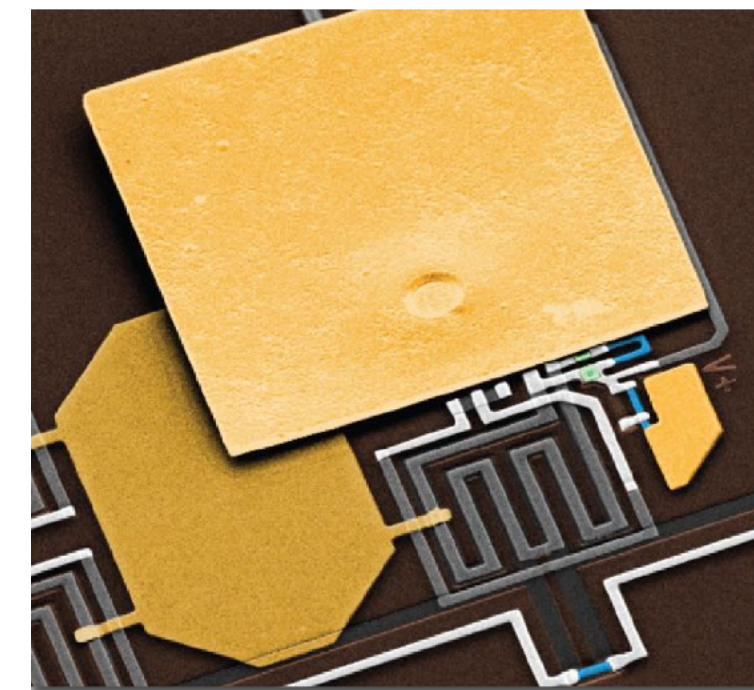
- Silicon sensor R&D
- Pixel detector construction
- L1 Track Trigger
- High Granularity Calorimeter HGCal



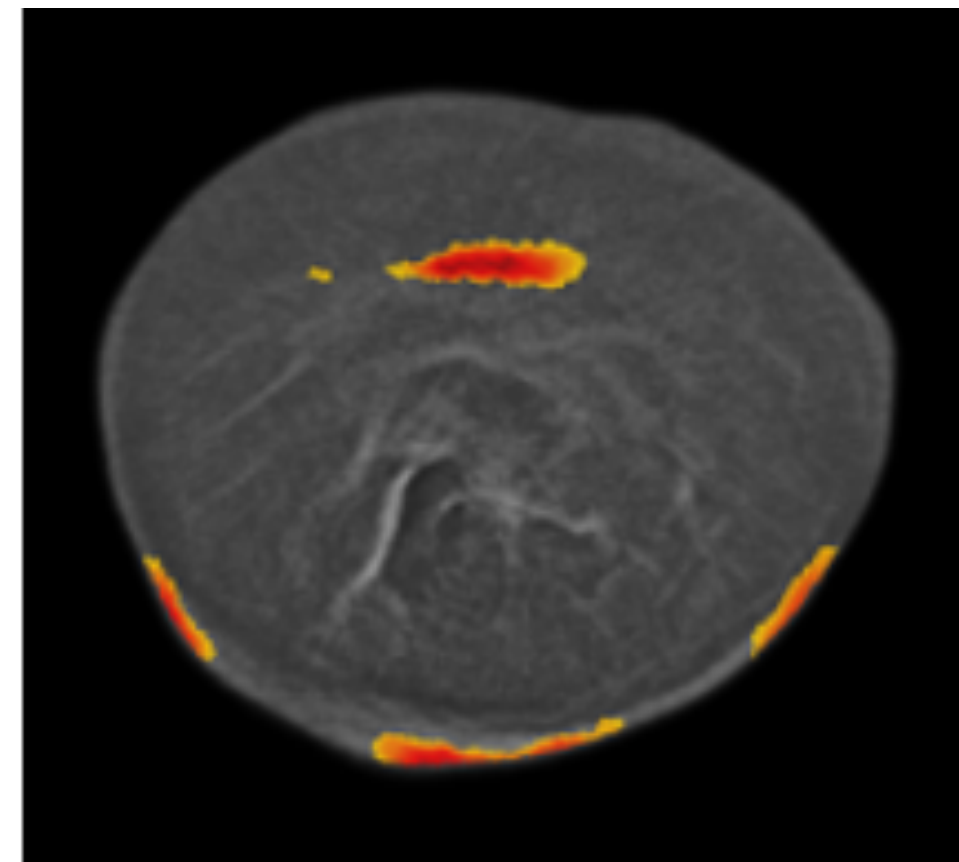
- Silicon sensors, packaging and interconnects



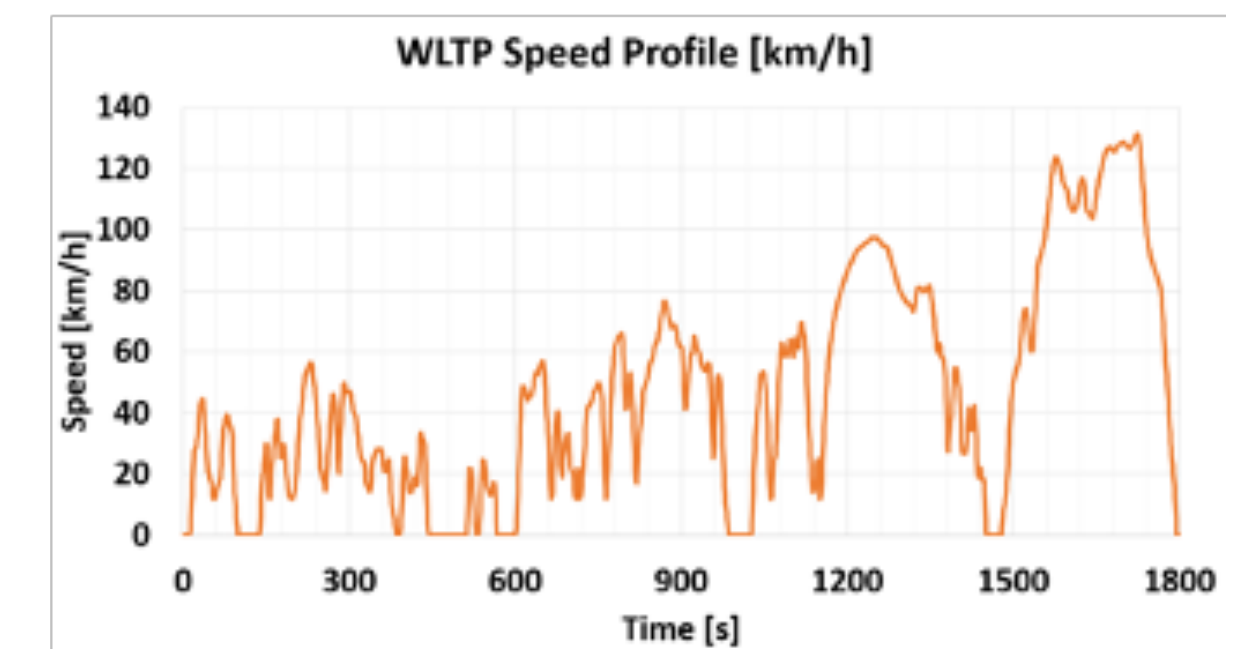
- Production & readout of superconducting sensors and qubits



- Ultrasound CT for breast cancer diagnosis

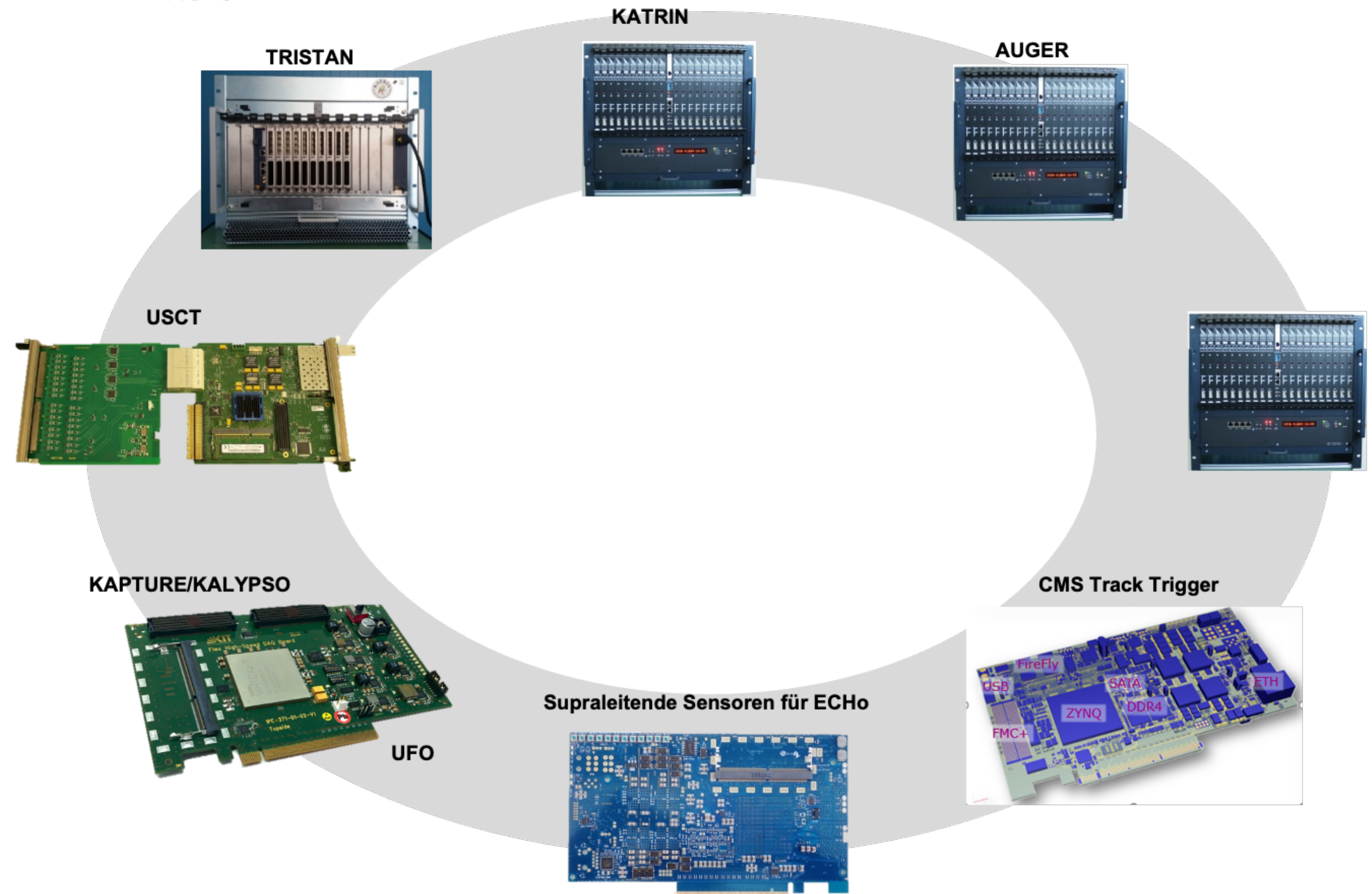


- Test systems for Li-Ion batteries for BEVs



Research at IPE

A particular Focus: Data Acquisition

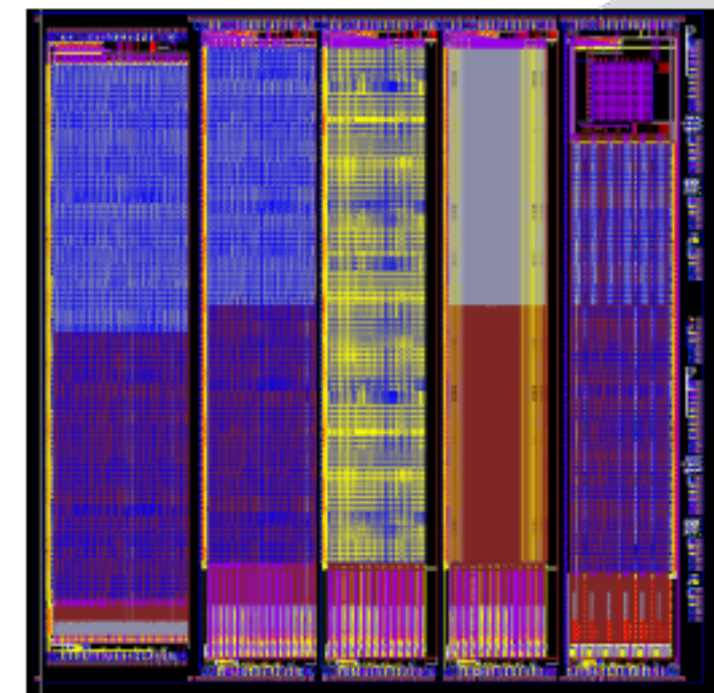


Beam diagnostics - also using AI to control accelerators.

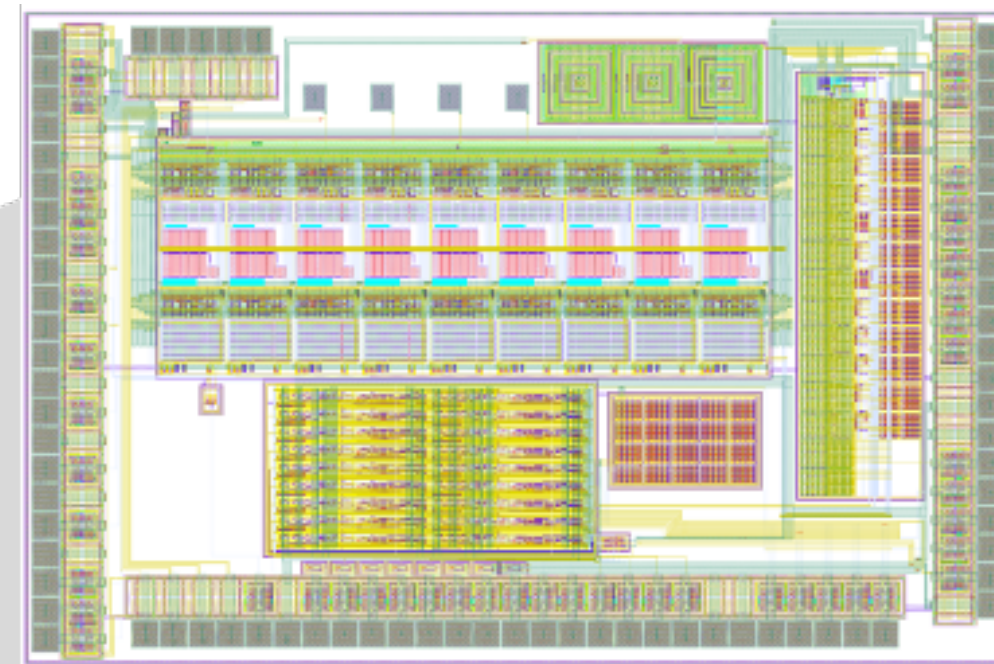
Near future: Possible application in the SuperKEKB/Belle II beam abort system.

Research at IPE

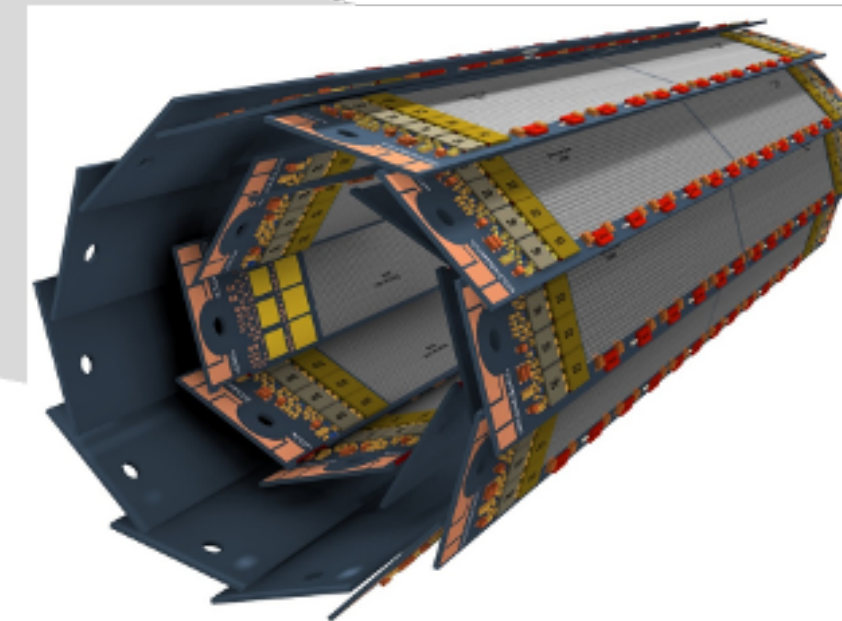
A particular Focus: ASIC Laboratory



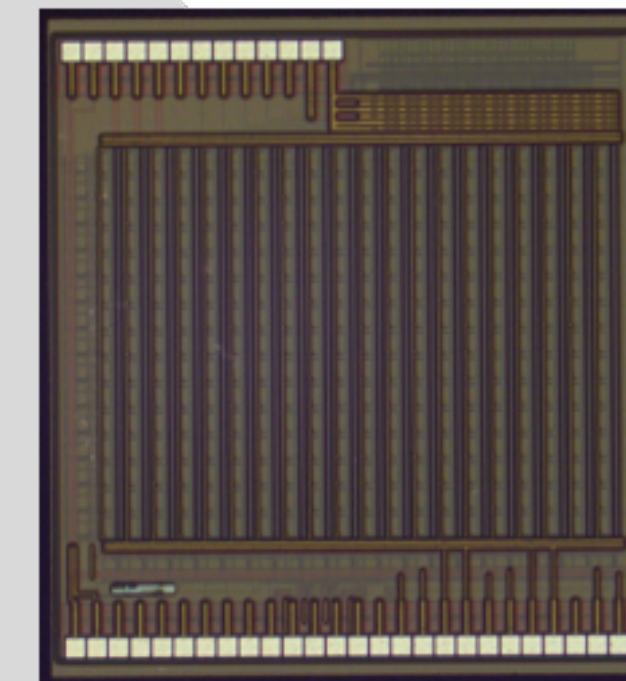
Monolithic sensors in LFA15 process



ADC in 350nm AMS (HVCMOS)



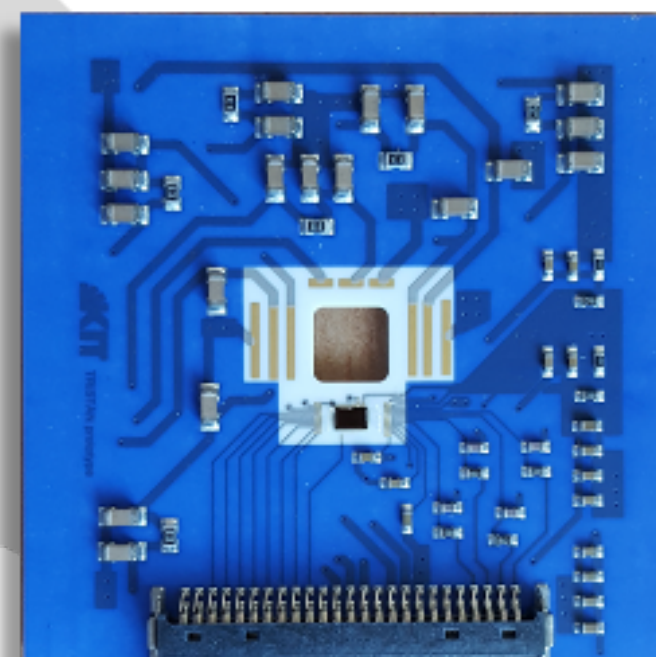
Belle-II



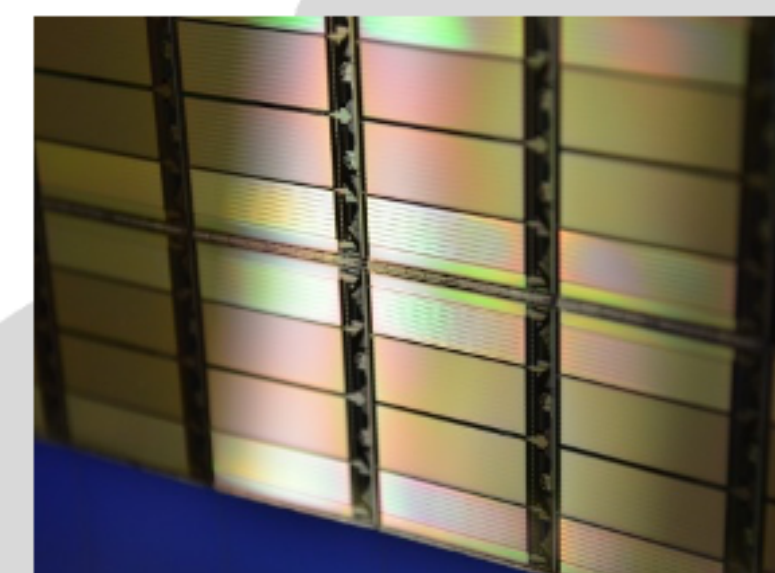
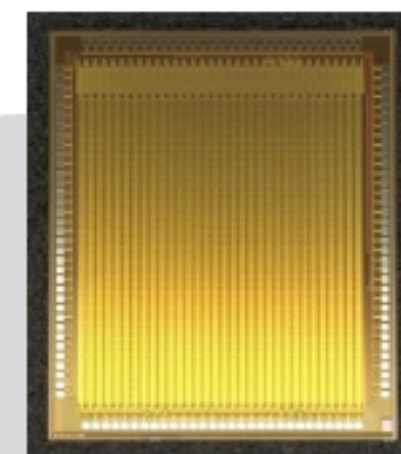
SiPM



CCPD



MuPix



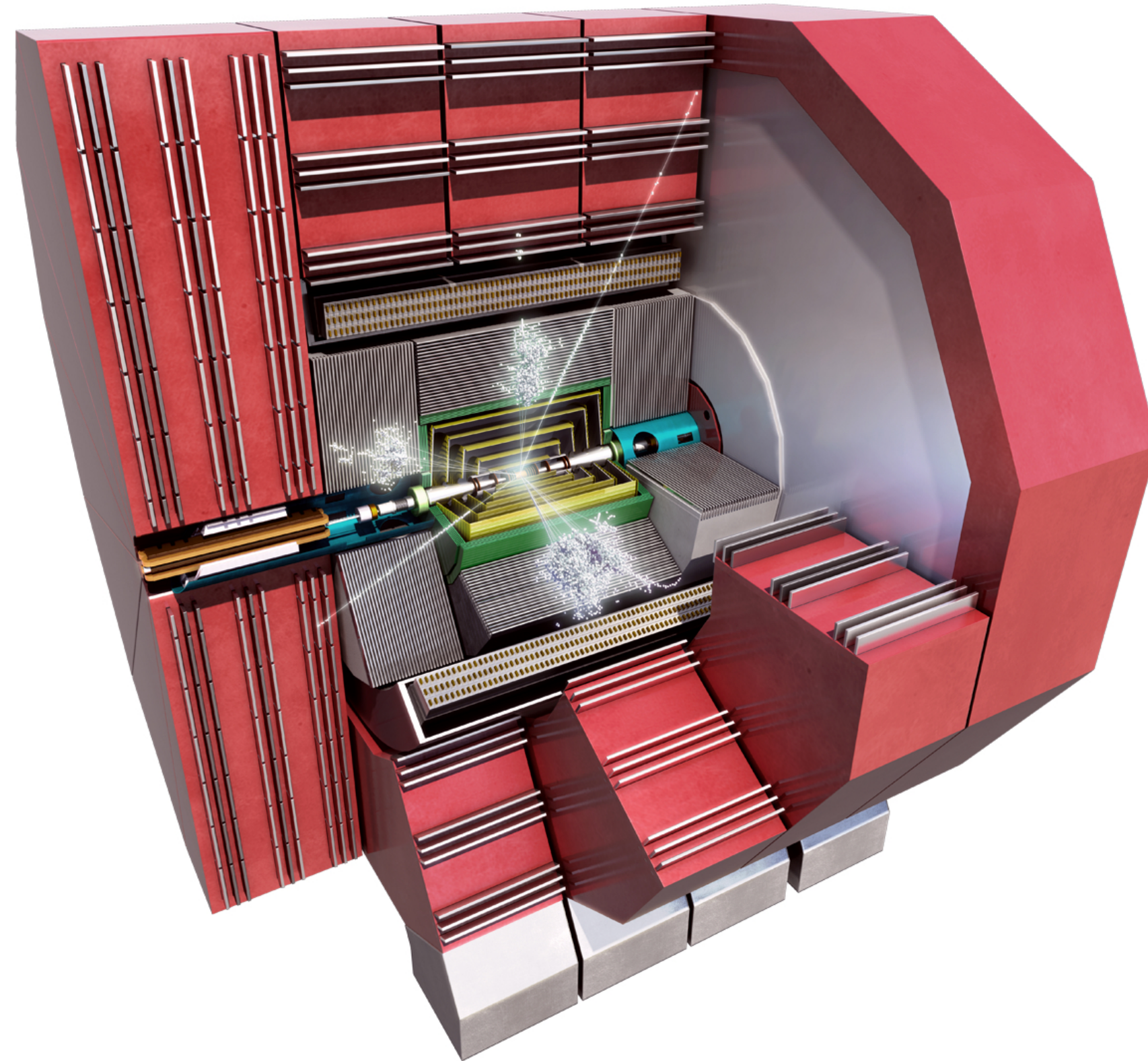
Sensor in AMS aH18 (180nm)

Now developing the
sensor for the LHCb
Phase IIb upgrade:
Installation 2033

Developing Concepts for the Future

Detectors & DAQ for FCC at CERN and other Applications

- Highly granular 5D - Calorimetry for Higgs Factories

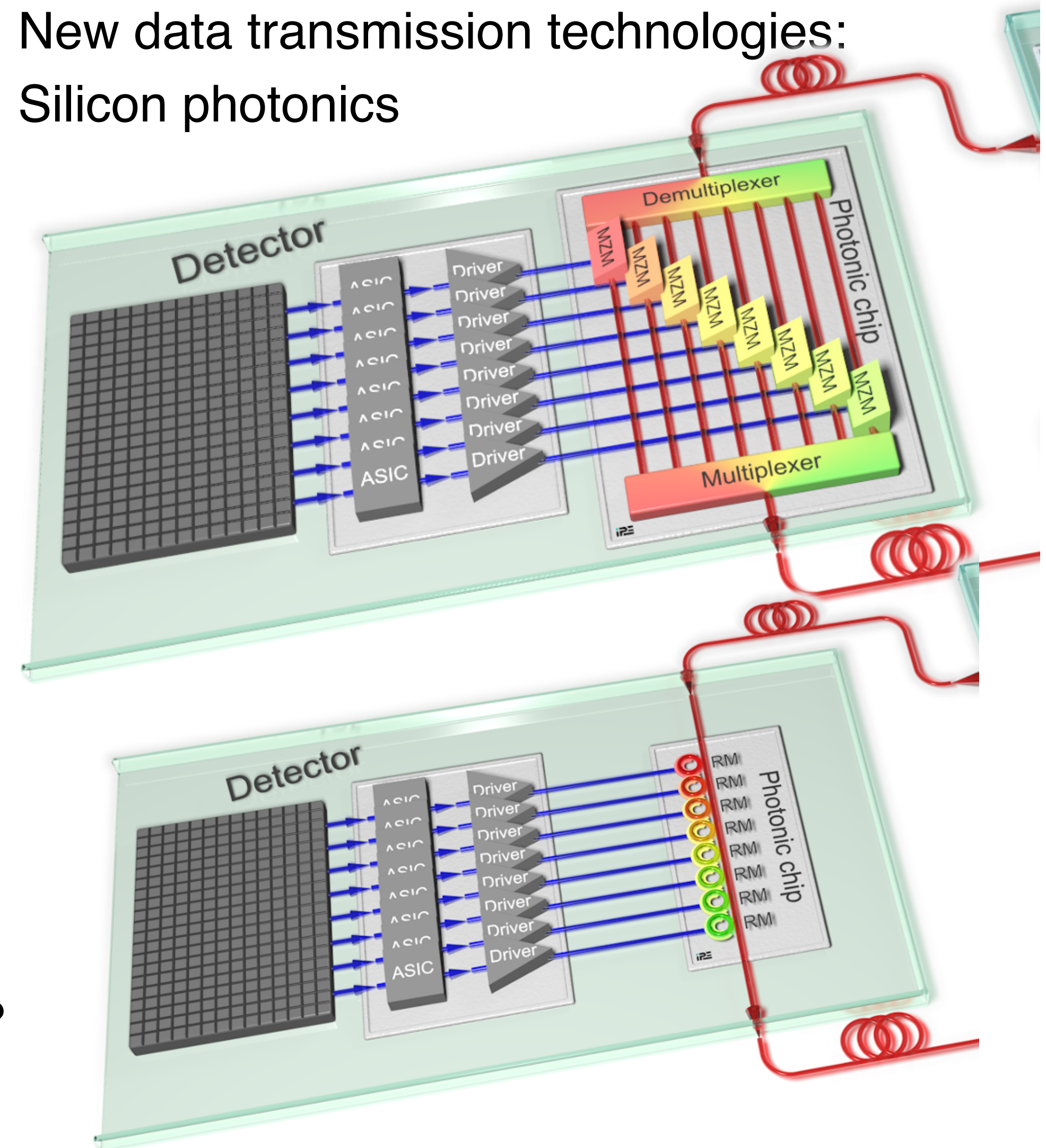


Re-thinking the readout concepts:

Do we need a trigger? Which processing speed, data bandwidth?

How to use the data? -> AI-based algorithms!

- New data transmission technologies:
Silicon photonics



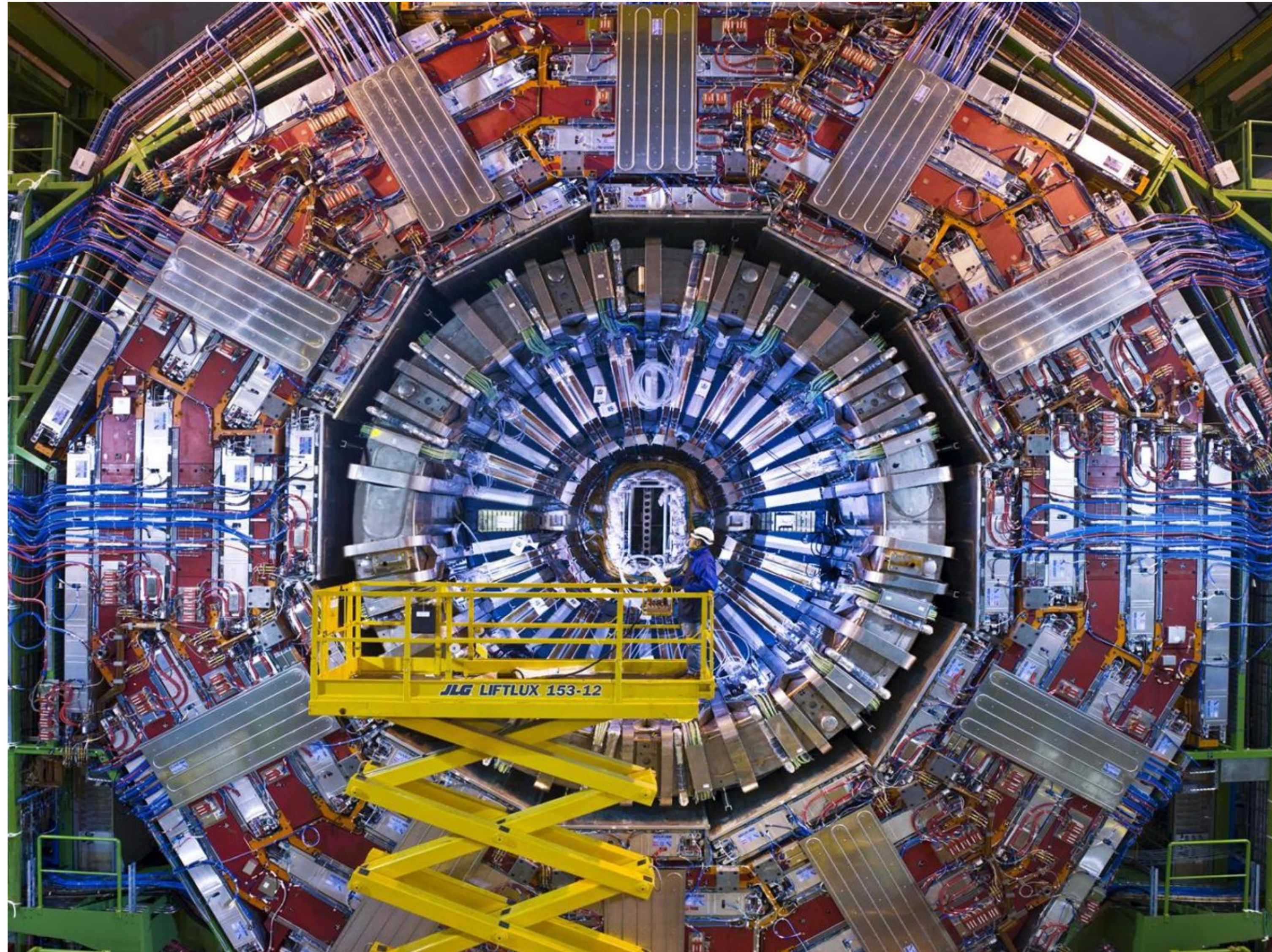
Introduction

Electronics & Us: A few examples

- How many electronic devices do carry around with you right now?

Electronics in Basic Research

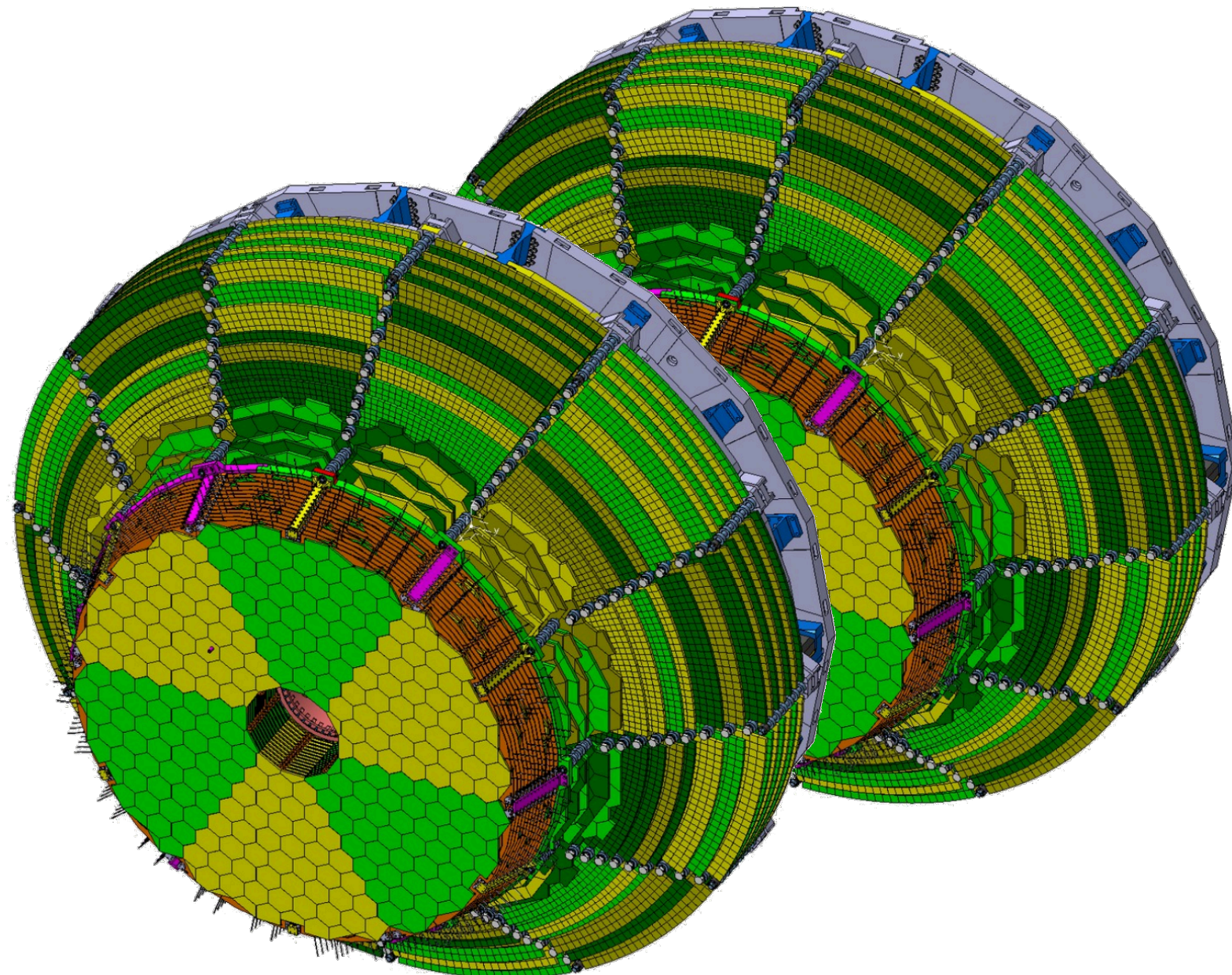
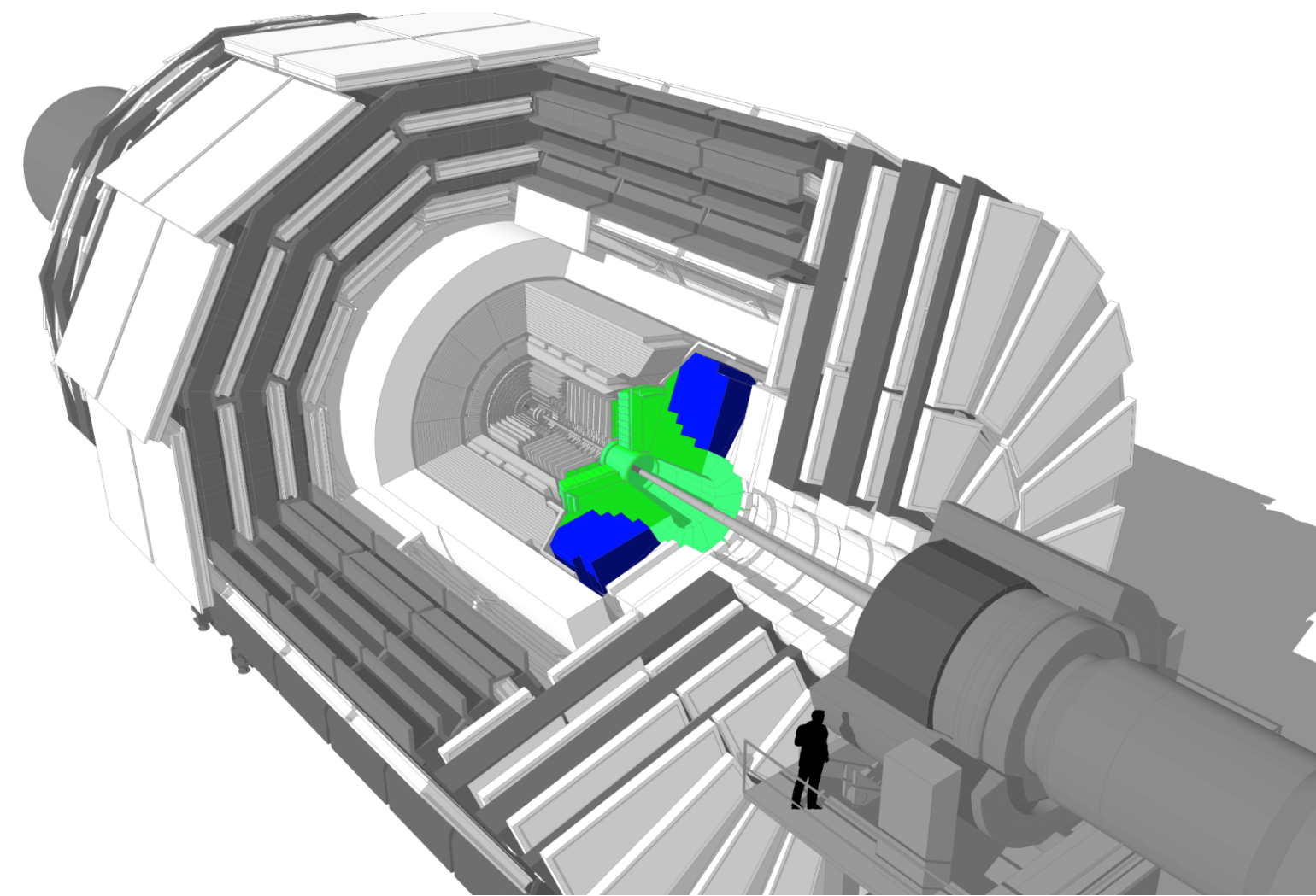
High-Energy Physics: Pushing the absolute Limits



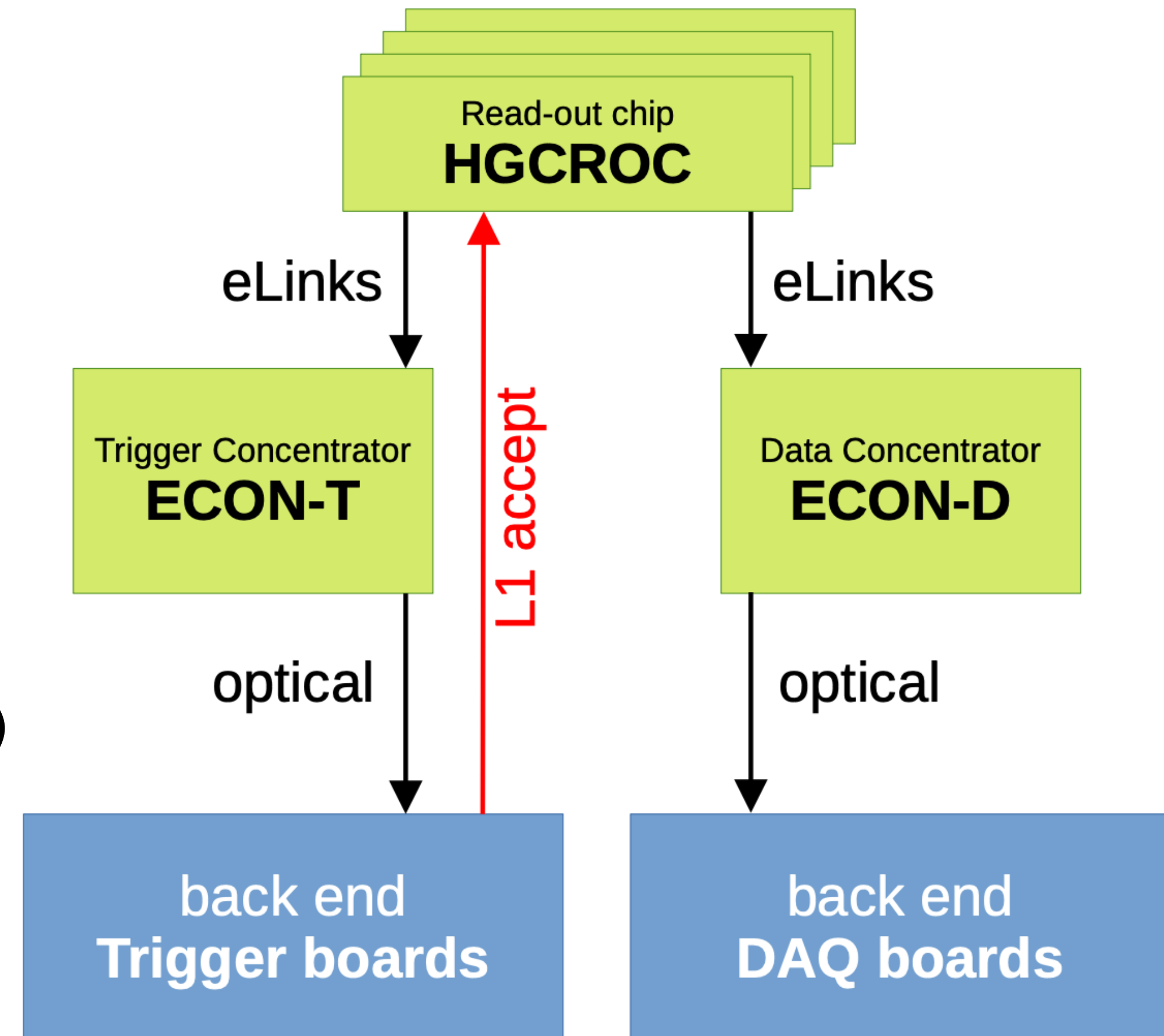
Reading out the CMS HGCAL

A CMS Example

- A new calorimeter: Silicon sensors ($\sim 600 \text{ m}^2$), SiPM-on-tile ($\sim 400 \text{ m}^2$)



40 Tb/s (!)

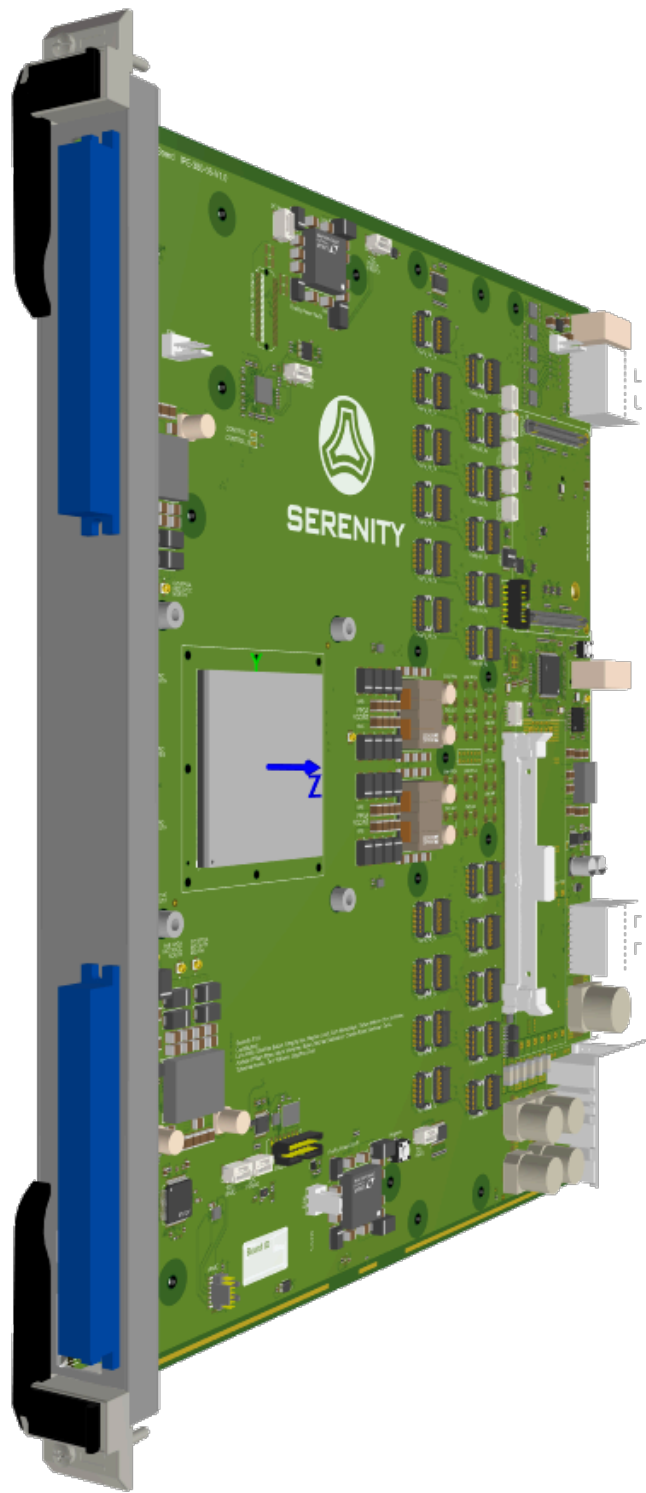


Reading out the CMS HGCAL

A CMS Example

- 40 TB/s in perspective: internet traffic at DE-CIX (internet exchange point in Frankfurt):

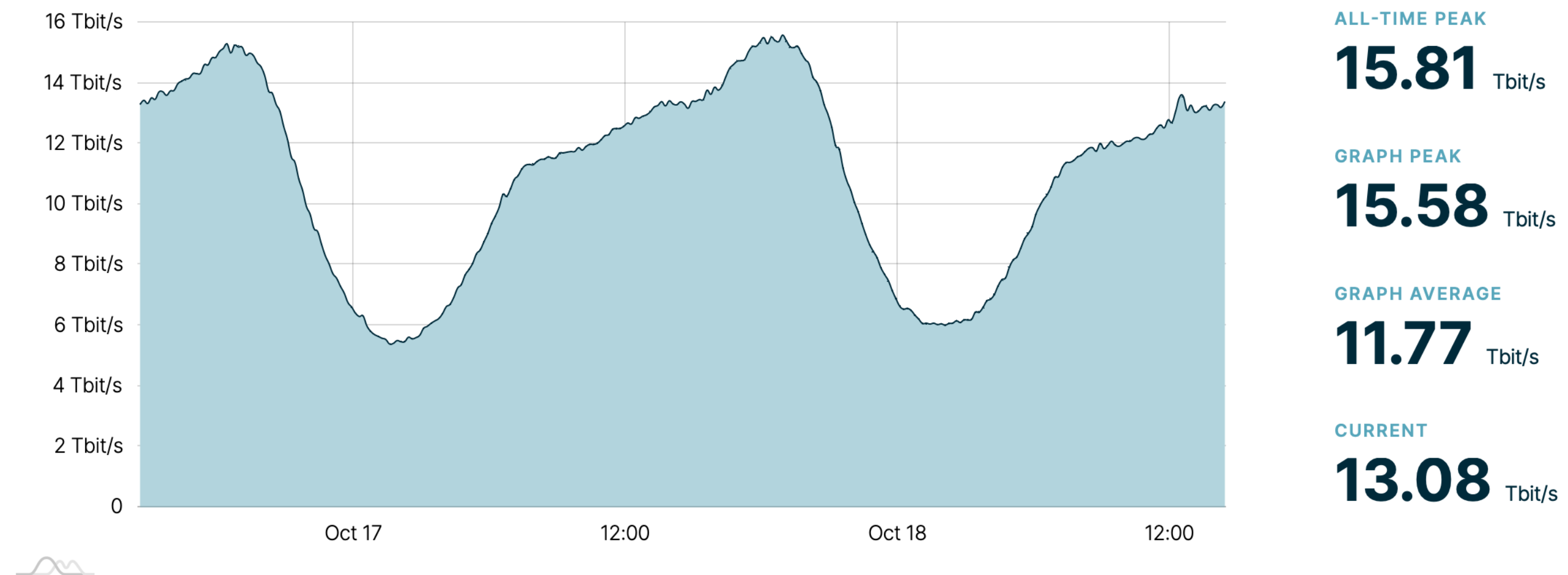
How we handle this:



Serenity S1 DAQ board
developed at IPE

124 25 Gb/s fiber links
powerful FPGA for
online processing

Traffic Frankfurt – 2 days



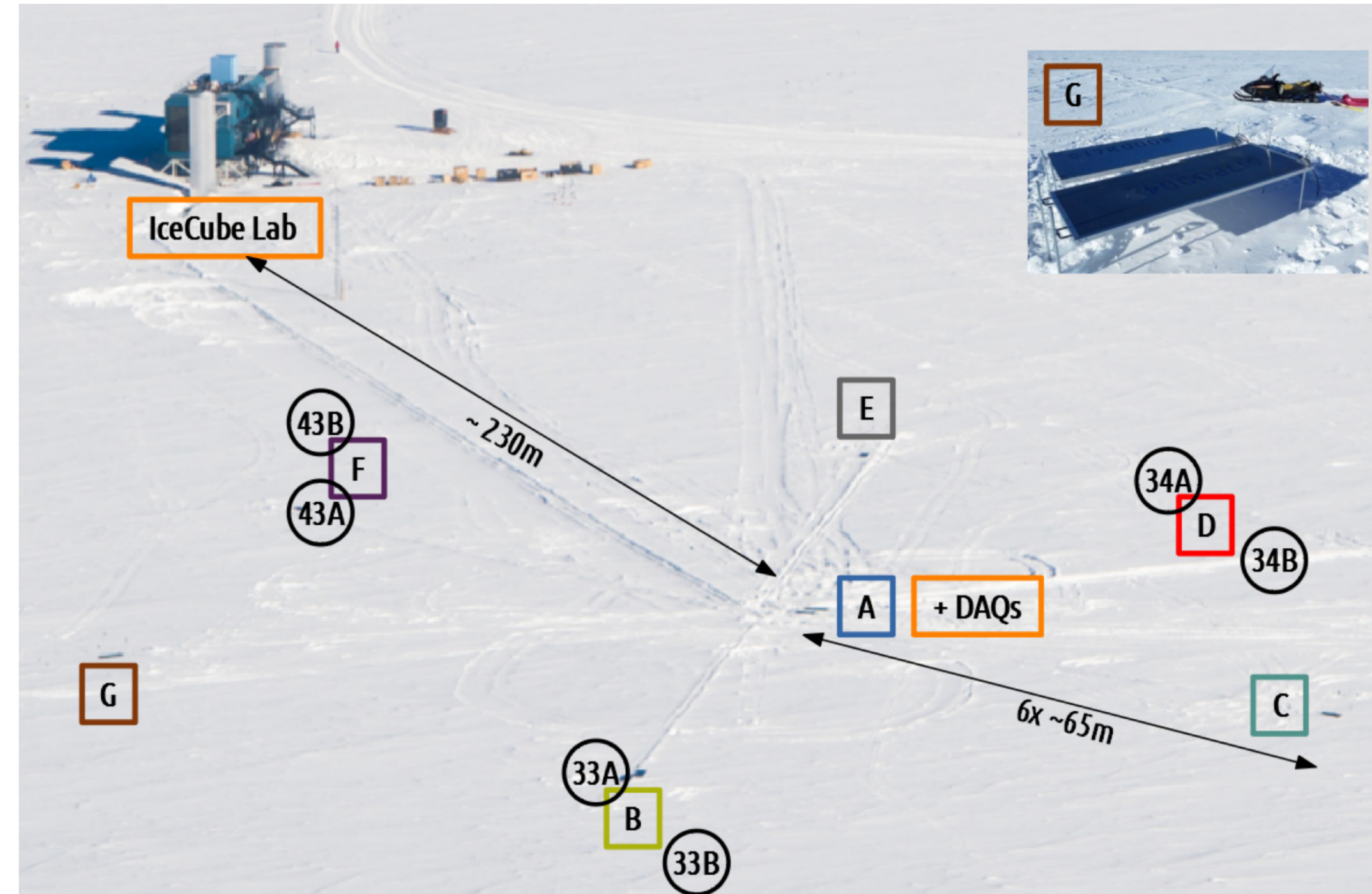
42 TPG Stage 1 Serenity S1 boards for the trigger stream

300 Serenity S1 boards total for HGCAL trigger & data



Electronics in Basic Research

Astroparticle Physics - Exotic Conditions



Next Lecture: Analog 02 - Chapter 01

Thursday, October 26 - same time, same place.

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