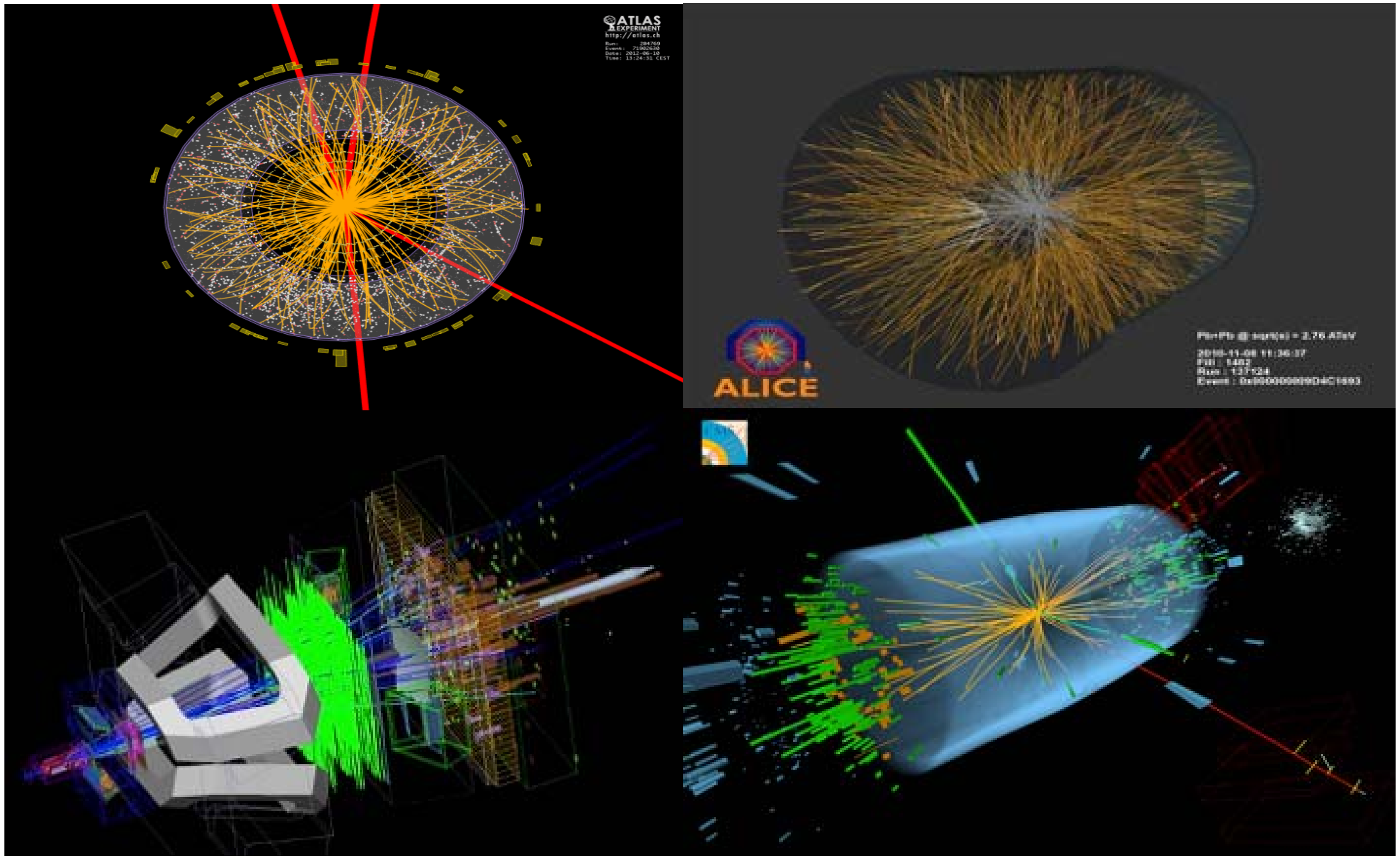

Expected needs in Electronics for the CERN Experiments

5 October 2015

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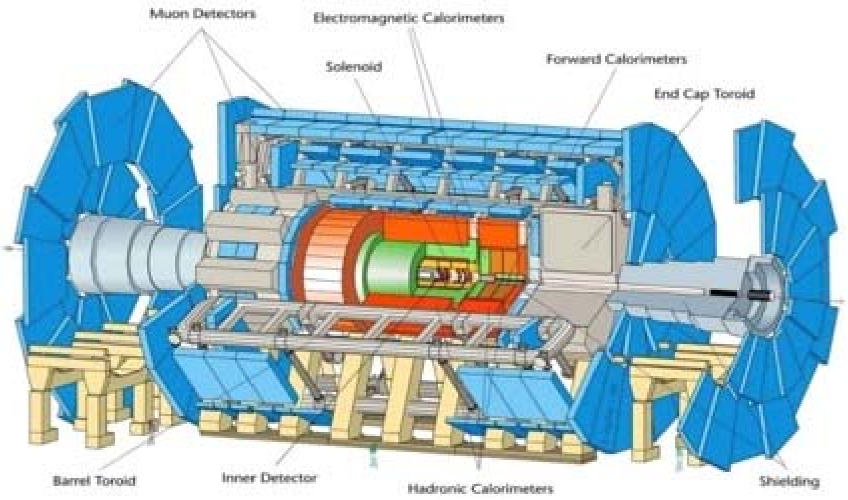
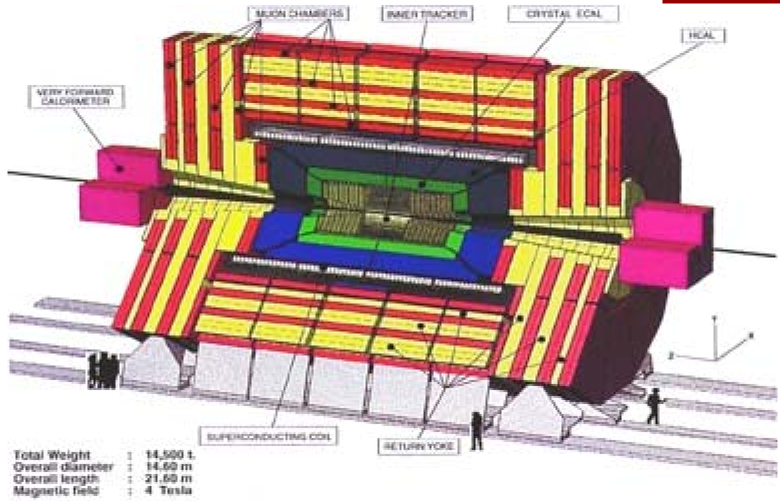
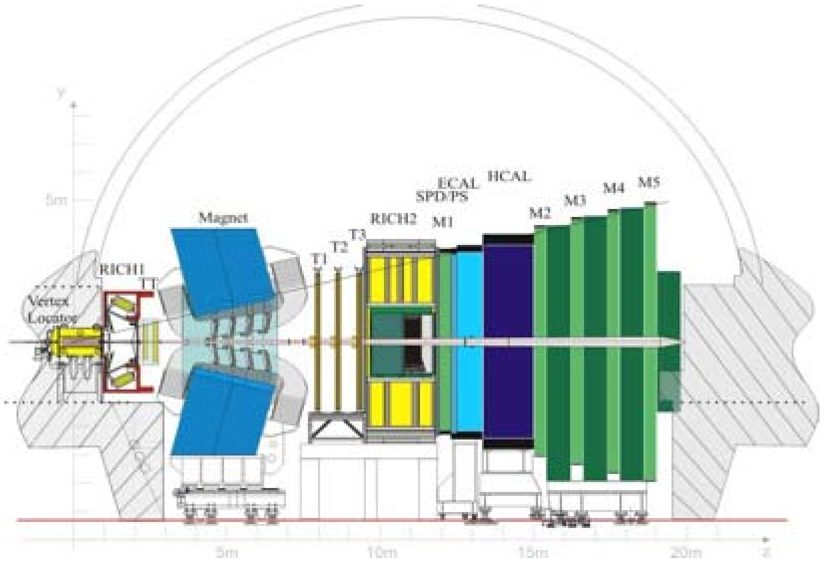
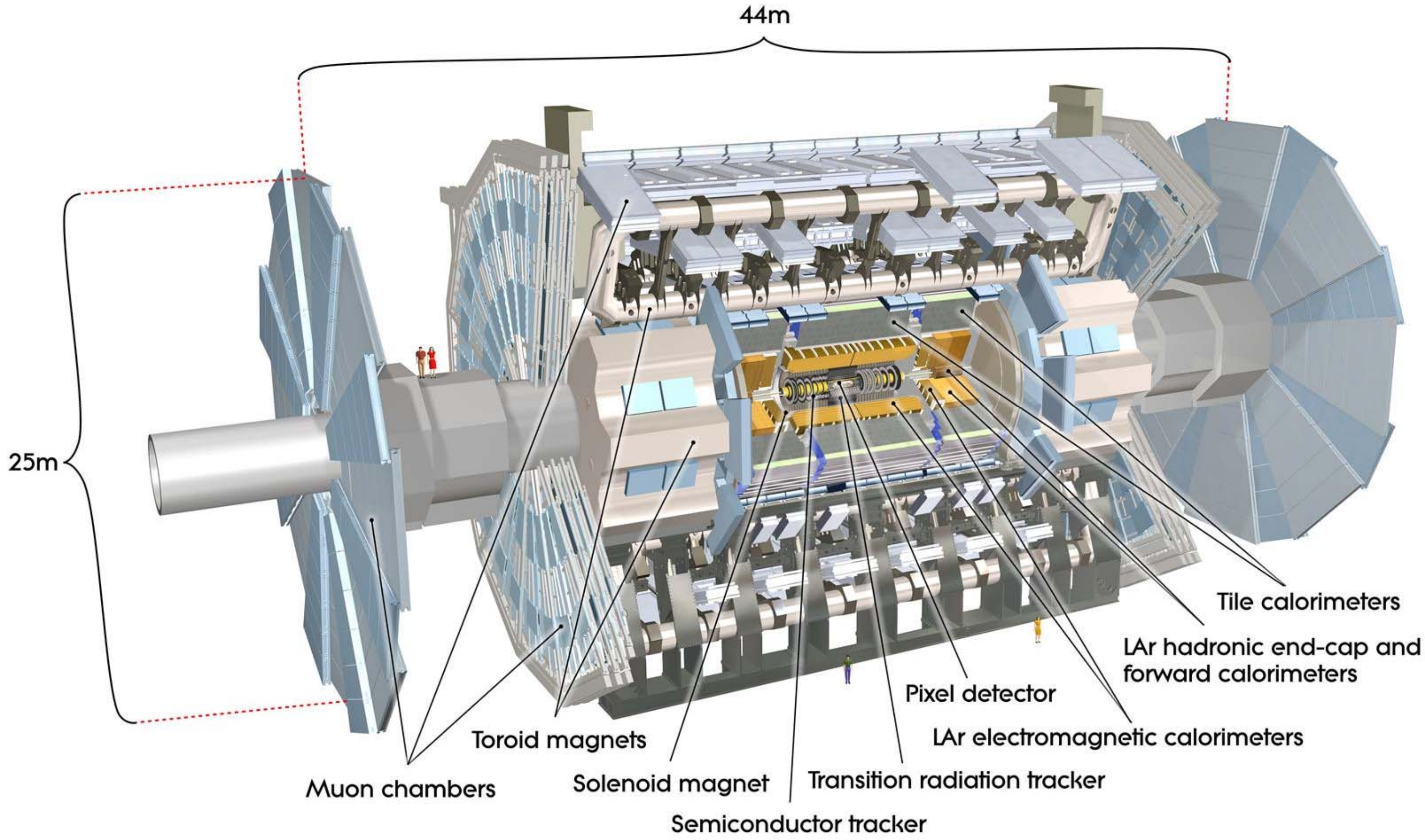
The LHC Experiments







ATLAS Detector



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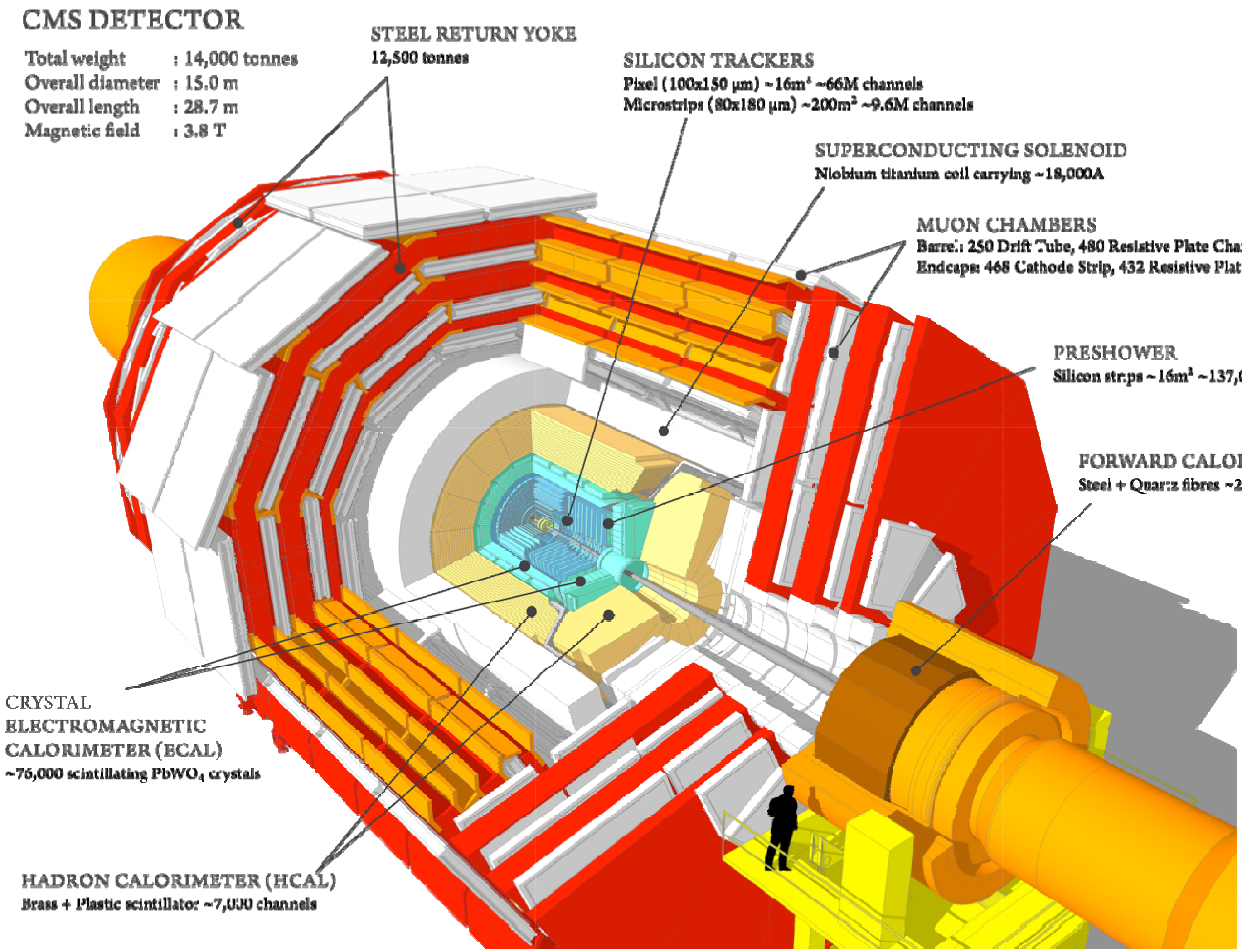
CMS Detector



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Collaborations

Last generation of HEP detectors are incredibly complex and state of the art pieces of technology

- Detector systems have increased size and complexity
  - ~100,000,000 channels
  - at least a factor 10 with respect to previous generation

- Projects span over a lifetime of 3-4 decades and involve thousands of scientists

Experiment	Countries	Institutions	Scientists
ALICE	36	131	~1200
ATLAS	38	177	~ 3000
CMS	42	182	~ 3000
LHCb	16	65	~ 700

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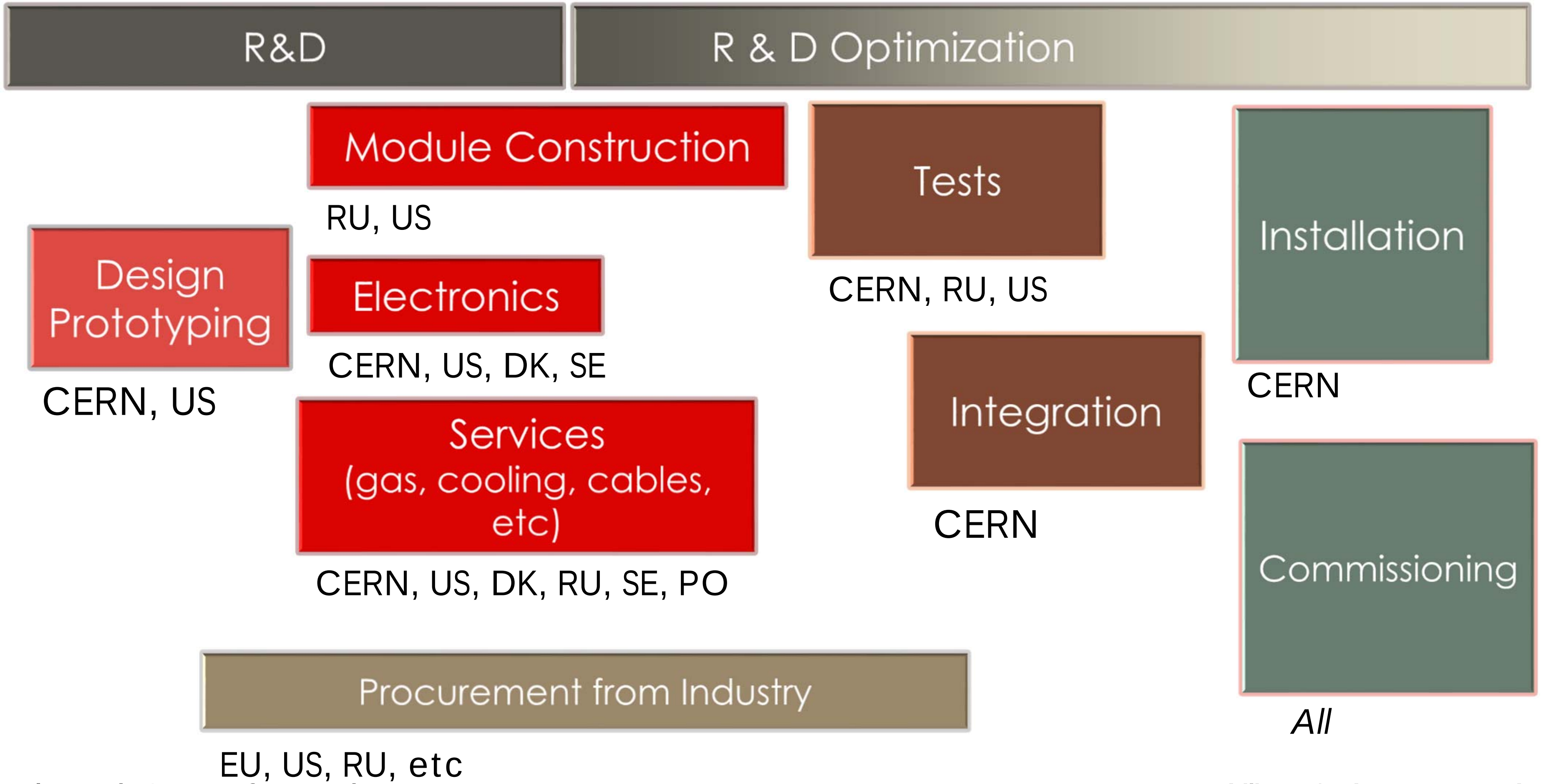
Collaborations (cont')

Large LHC Detector ***Subsystem*** *Example Case*



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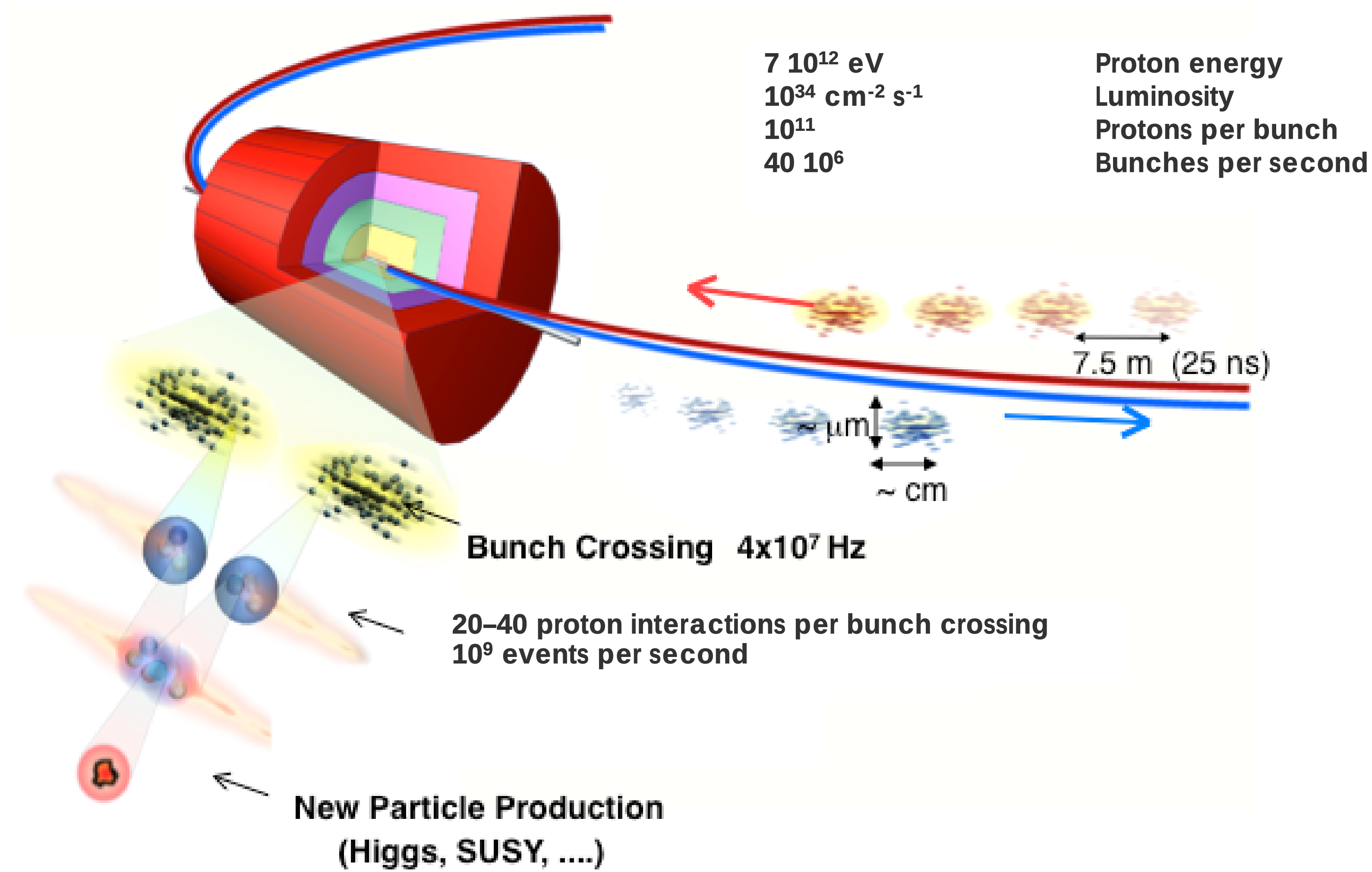
The LHC environment



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The main challenges

- $40\ 10^6$ bunches colliding every second
- 25 interactions per bunch crossing
  - 10^9 events per second
- Up to $100\ 10^6$ detector channels to be readout
  - One "event" weighs ~1 MBytes
- Complex high speed "trigger" system to select about 100,000 events per second which will be readout
  - i.e. the data are extracted from the detector
- Complex higher level selection process to reduce the number of events to be definitely stored for physics analysis
  - A few 1000's events
- Very difficult environment
  - High radiation levels. Up to 100 Mrad in the center of the detector
  - High magnetic field. Up to 4 Tesla in CMS

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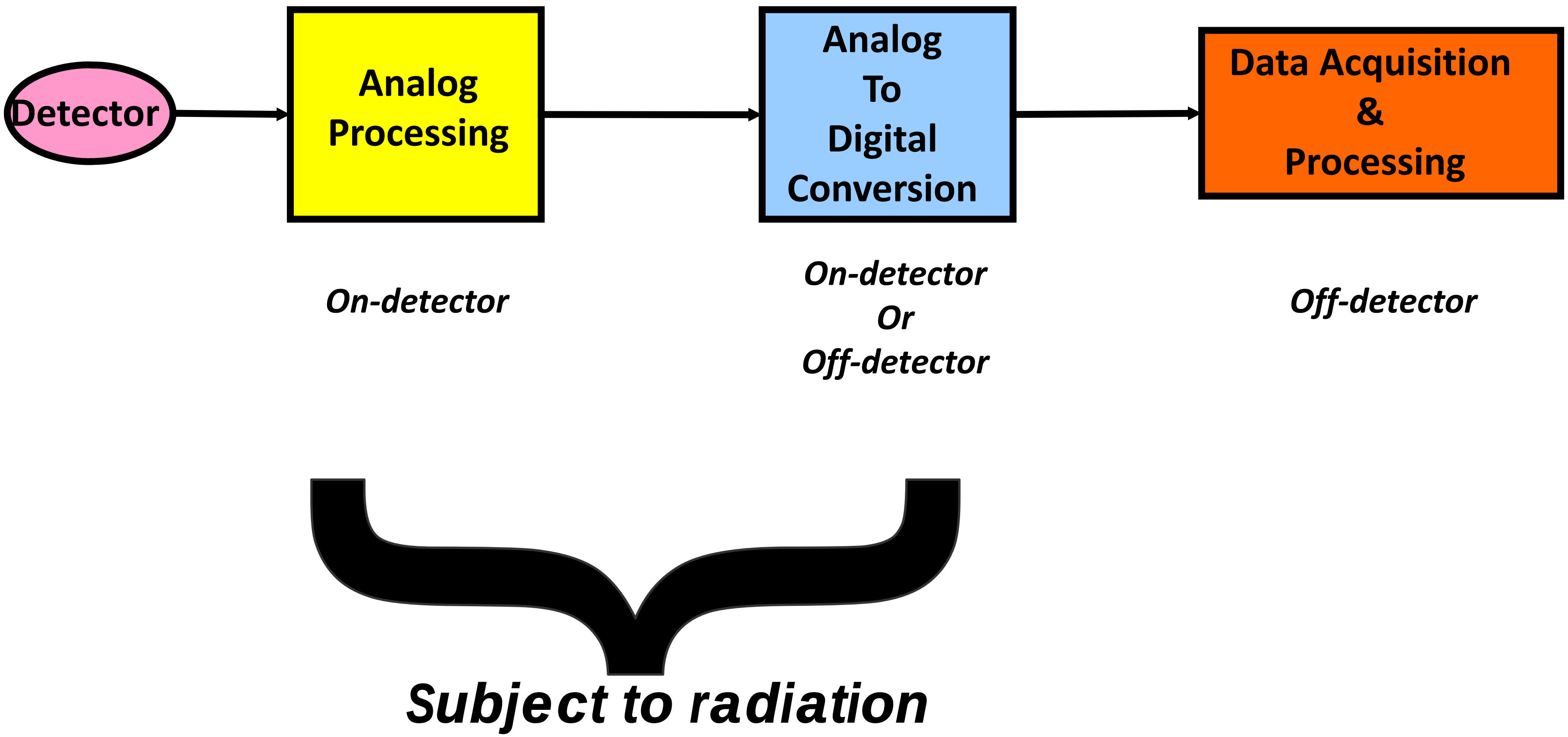
Detector Readout Electronics



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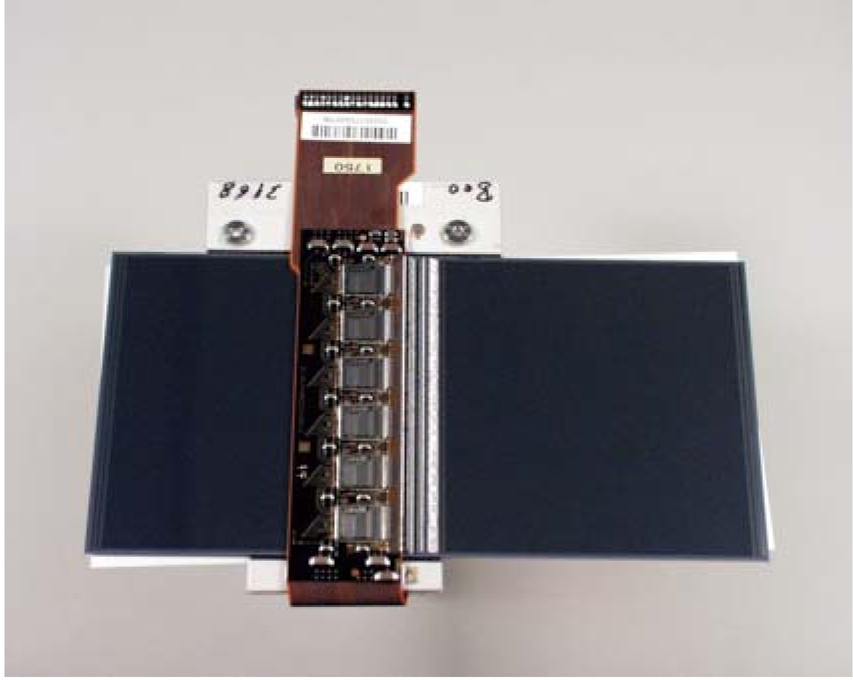
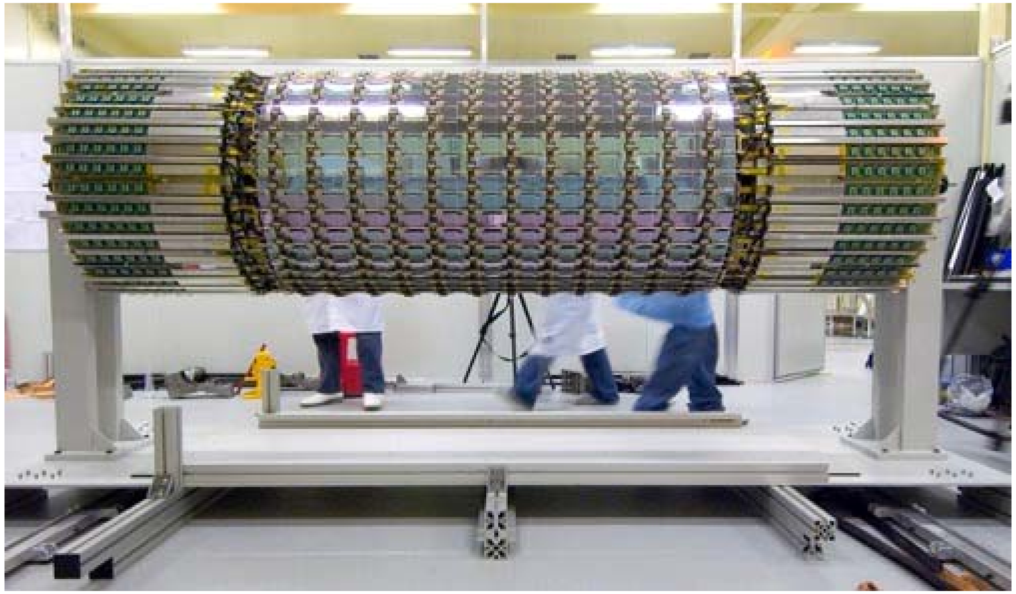
Readout Electronics can be





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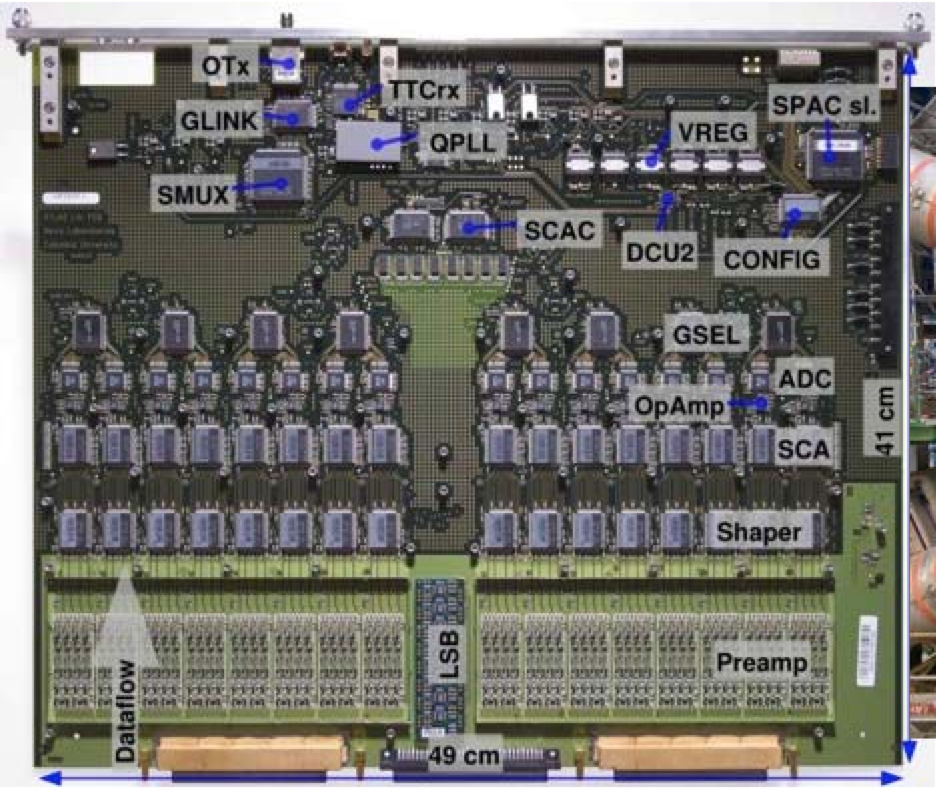
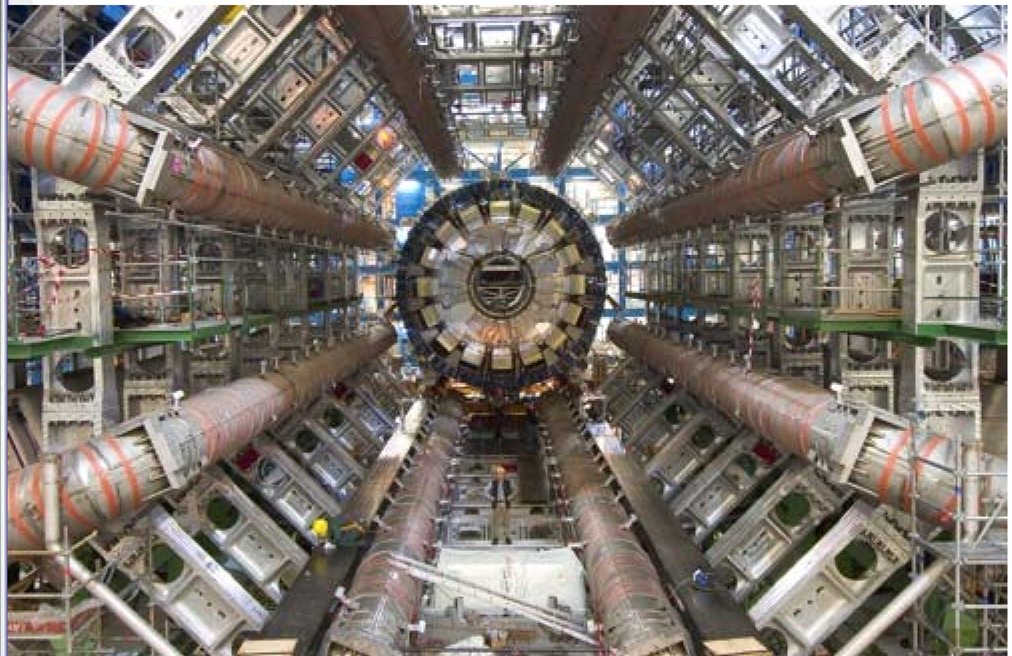
… Or it can be





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The PH Electronics Group: mandate

- Development/qualification of specific technologies required for experiments
  - Radiation hard IC Technologies: 250nm, 130nm, 65nm CMOS
  - Common building blocks: Optical links, Power conversion, Control/monitoring
  - Readout electronics of detectors: from sensors to data storage
  - Infrastructure: Crates, Racks, Power supplies
- Contribute to specific experiment systems
  - E.g. CMS tracker upgrade, ATLAS Central Trigger, ALICE Inner Tracker, LHCb Velo, NA62 Gigatracker, ...
- Make general instrumentation available to CERN users and experiments
  - Electronics pool
  - Procurement and maintenance contracts for crates and power supplies
- Electronics coordination
  - "Management" in experiments

CERN contributes ~20% to the electronics of the experiments. However more orders can go through CERN and PH-ESE (see email) is a good entry point to know about on-going projects

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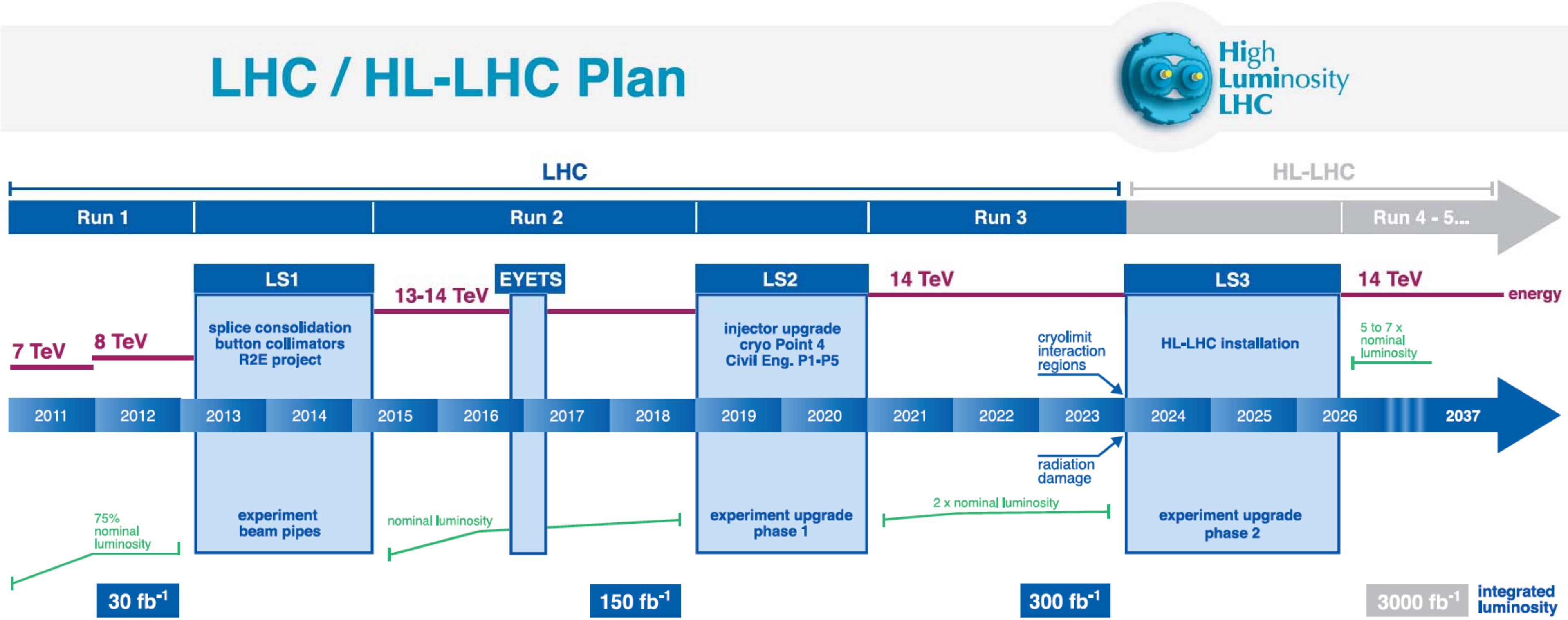
Upgrades of the LHC



- Main activity related to the LHC experiments upgrades
- Upgrades of the experiments at each long shutdown
  - LHCb and ALICE main upgrades at LS2. Significant upgrades for ATLAS and CMS
  - Major upgrades for ATLAS and CMS during LS3

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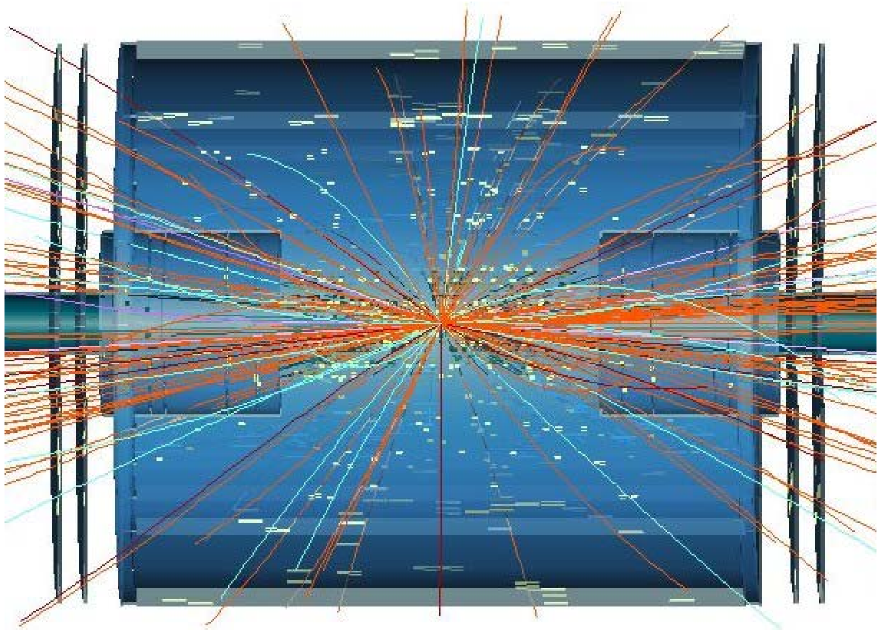
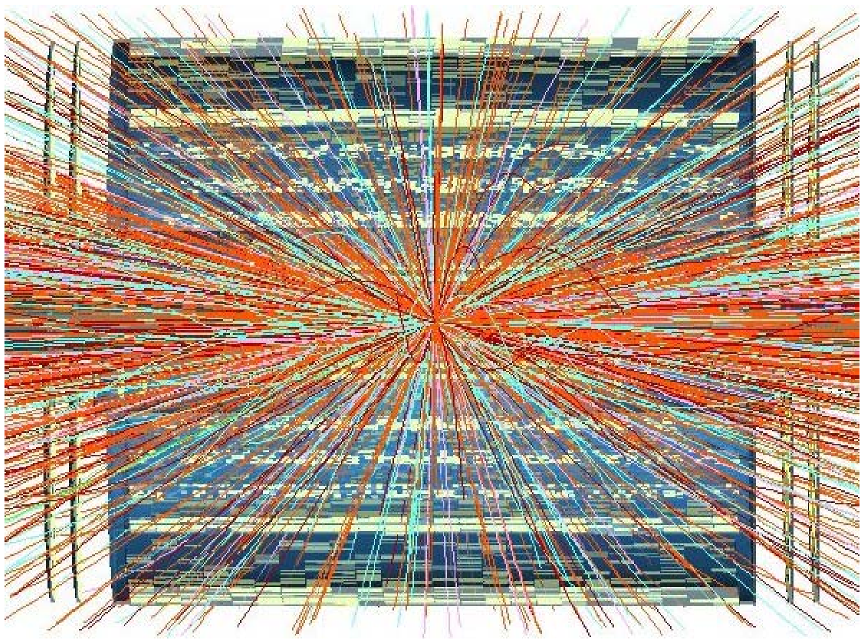
Upgrading the LHC Detectors

- The luminosity (number of particles per area and time to collide) will increase by a factor 5
- The detector occupancy will increase considerably:



LHC in 2011



HL-LHC

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Needs for next few years

- Common projects for which we are responsible
- Front-end developments for the upgrades
- Back-end developments for the upgrades
- Specific requirements for power supplies

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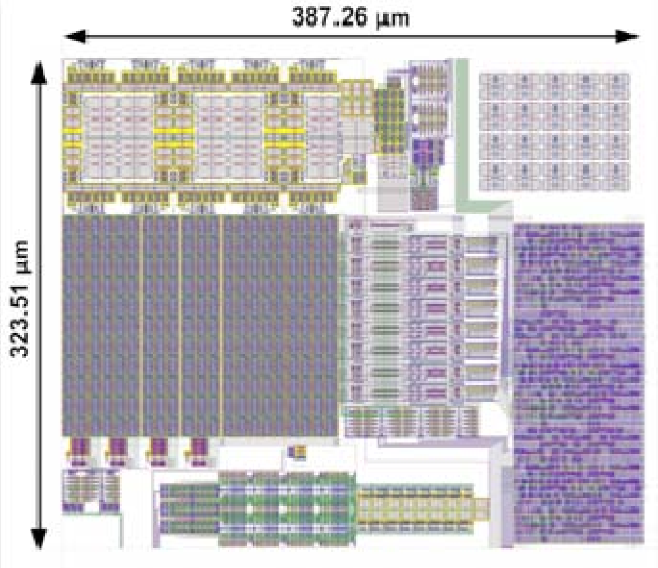
Common Projects (1)

- Support for the access to IC technologies
  - Relation with foundries and with CAE vendors
- IP blocks to be made available to the community
  - E.g. ADC, DAC, PLL,...
  - Could be designed in the community
  - **Or bought from industry**



ePLL-FM IP Block

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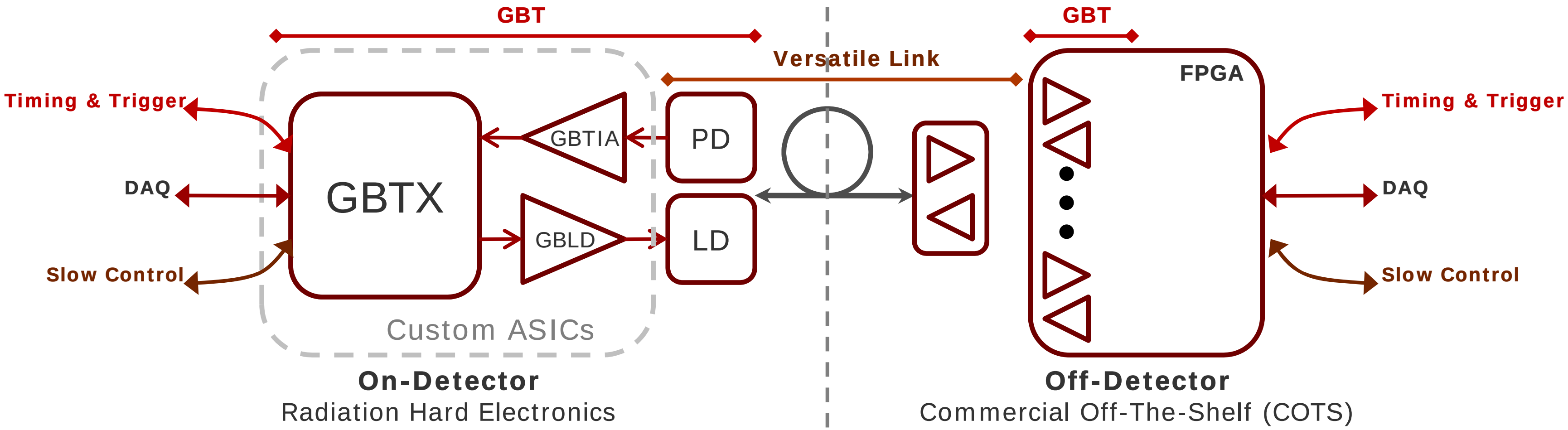
Common Projects (2)
GBT & Versatile Link



- Current version being produced (4.8 Gbps)
  - 75000 GBTX, 25000 versatile links components
- New version (lower power, higher speed [10 Gbps]) being designed
  - Production expected in 2017 – 2018

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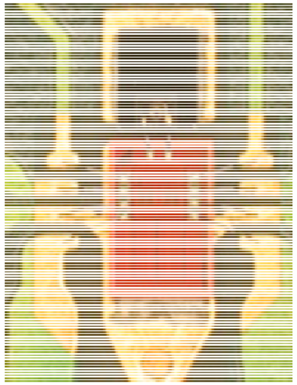
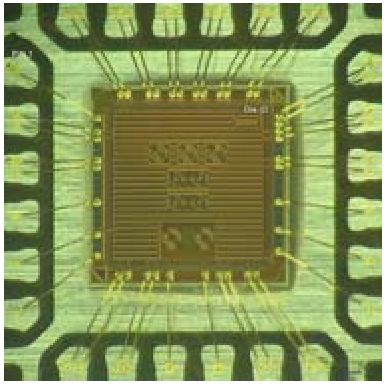
GBT and Versatile links

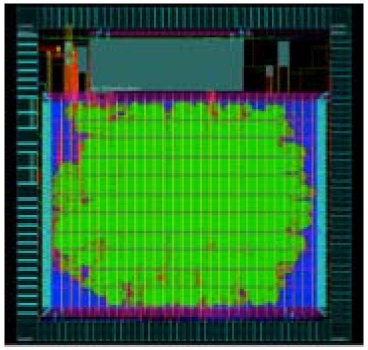
GBTIA



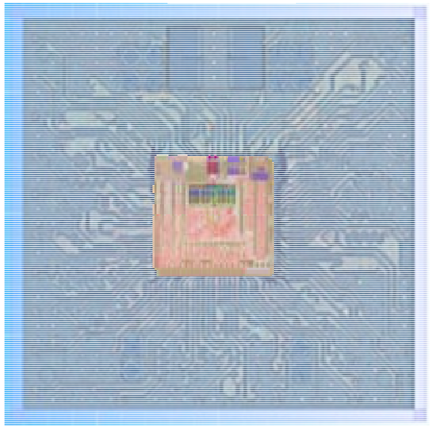
GBLD

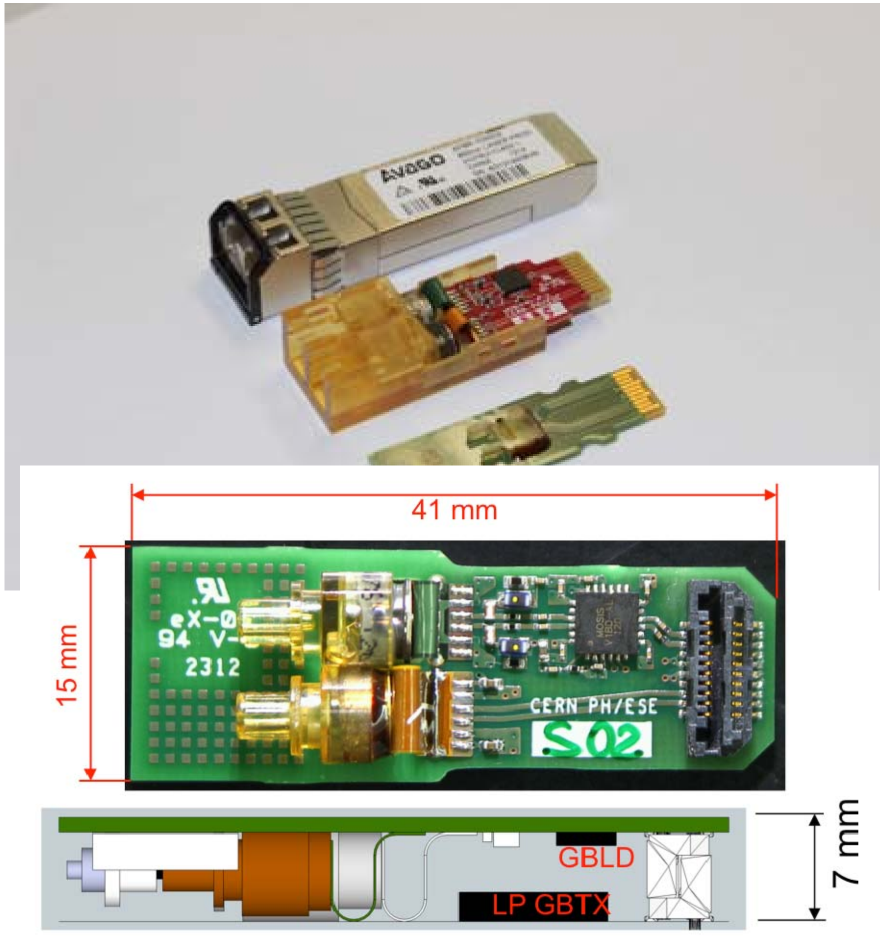


GBT – SCA



GBTX





Small Formfactor -VTRx prototype

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GBT & Versatile Links

- Needs from industry for the ASICs
  - Packaging of ASICs
  - Testing of ASICs
- Needs from industry for the Versatile Link components
  - TOSA and ROSA
  - Assembly of TOSA and ROSA with laser drivers and transimpedance amplifiers
  - Production tests
- Same needs for upgraded version in 2017 – 2018
- Fibres and optical connectors (high density) needed
  - As well as low mass cables for Gbps transmission on a few meters

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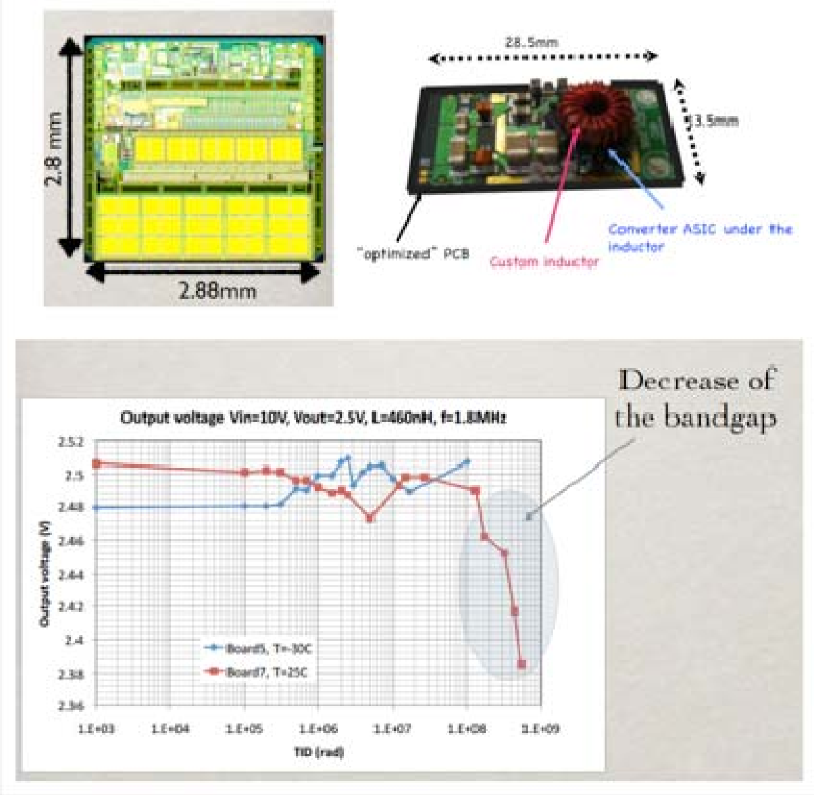
Radiation Tolerant DC-DC Converter

- Radiation-hard and magnetic tolerant (up to 4 T) POL DC-DC converters needed
- Current development good enough for the first upgrades
- Based on a radiation tolerant ASIC and an air-core inductor
- Upgraded version needed for HL-LHC
- Requirements from industry
  - Air-core inductor
  - Assembly
  - Testing



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Front-end developments

- A lot of developments for the silicon detectors readout started
  - Radiation tolerant front-end ASICs
  - Hybrids
- Industry needed for the hybrids design and production
  - Partially under CERN control
  - Market survey / Call for tender procedure
  - E.g. market survey for the CMS silicon outer tracker on-going

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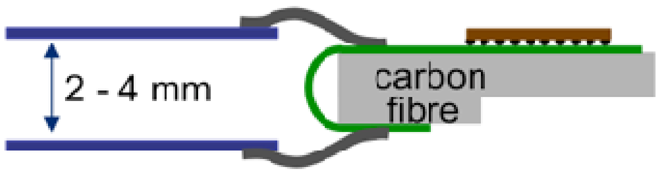
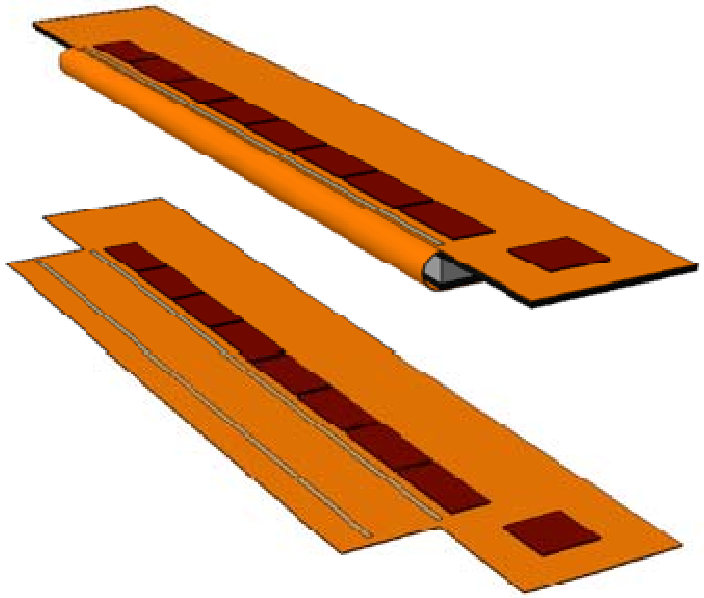
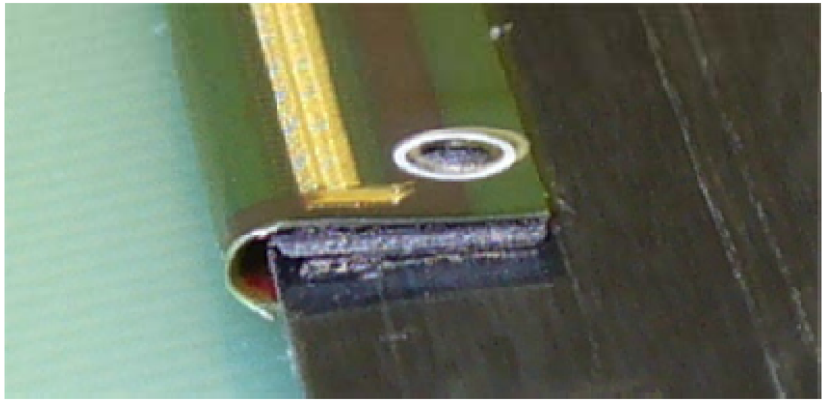
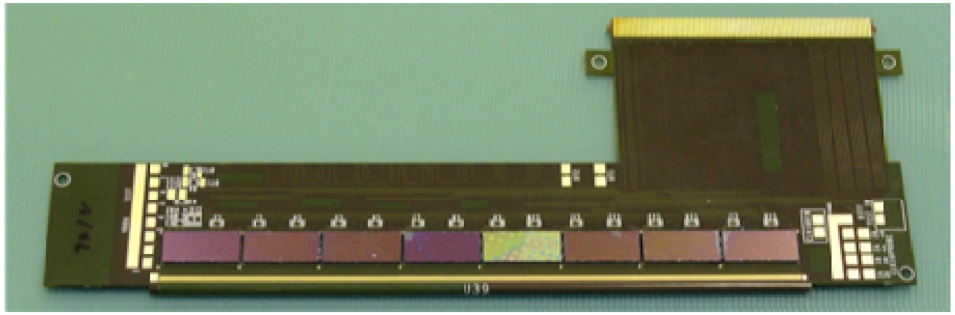
Examples of FE hybrids





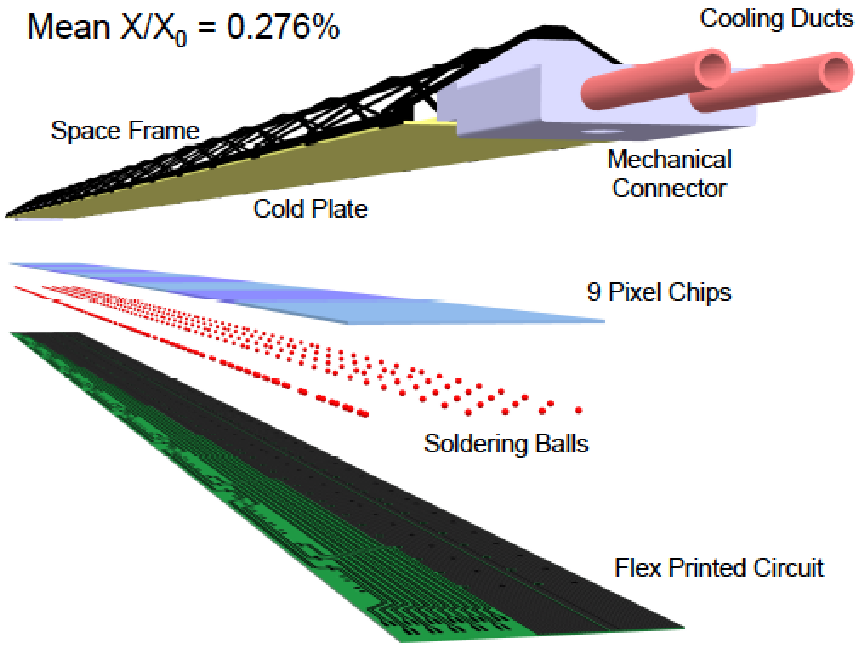
- CMS outer tracker
- Several 1000's pieces
- High density (chips on board, C4)

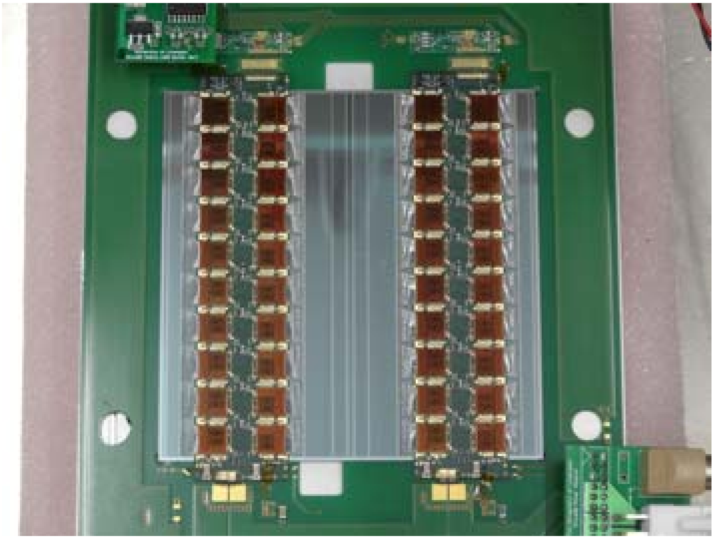




Other Front-end Hybrids

- ATLAS silicon strips
  - 2000 pieces
- ALICE Kapton tapes for the tracker upgrade





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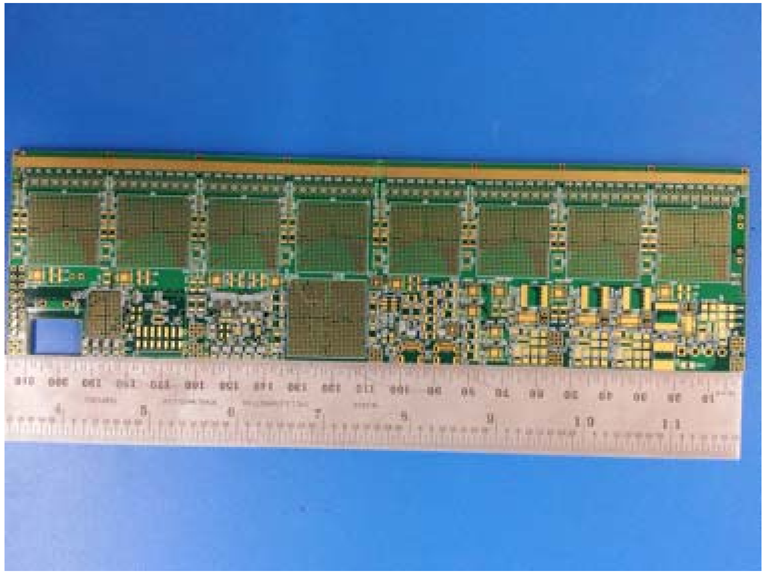
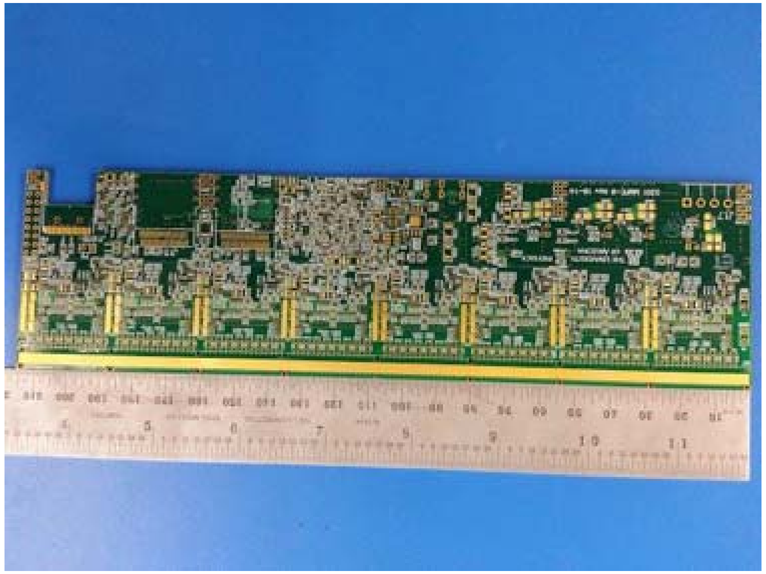
ATLAS and CMS Muon Upgrades

- Both AtLAS and CMS plan to install new muon chambers in their end-caps
- Several 1000’s front-end boards needed
  - Production, assembly and tests
  - Time scale 2018 – 2019





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Back-end Electronics

- VME (9U and 6U) mainly used in current systems
- Upgrades planning to use µTCA and/or ATCA and PCIe boards
- Crates, power supplies, ancillary modules expected from industry
  - Evaluations on-going for ATCA

14 slots ATCA shelf

12.5 kW PS

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Back-end Electronics (con't)

- Expertise in xTCA welcome
  - Shelf managers
  - IPMI
- General purpose modules
  - Hubs, switchs, CPUs
- Production, assembly and test of our specific modules
- The design of some of them could be outsourced
  - E.g. 450 VME 6U 32 channels 14-bit 40 Msps ADC subcontracted for a fixed target experiment

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Exemple of ATCA device

Picture from LAPP Annecy

- ATCA board with 3 ALTERA FPGA StratixIV
- 40 optical receiver links @ 4.8Gbps
- Readout through 10GbE Ethernet network

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Power Supplies

- Power distribution to the front-end needed
  - LV and HV
- Traditionally provided by industry
  - Main suppliers so far: CAEN, WIENER and ISEG
  - New powering schemes for the upgrades require new developments
  - Special developments needed for (moderately) radiation and magnetic tolerant devices
    - CERN to try and define as common devices as possible
- Specifications within a year or two, followed by market survey / call for tender
  - Production and maintenance

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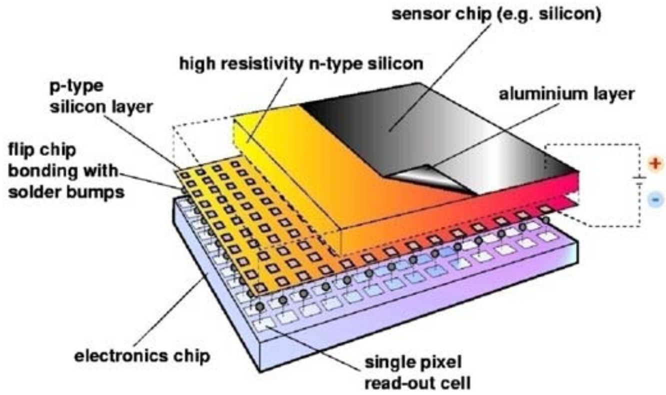
Medical Applications: Medipix

- Application of pixel detectors for imaging applications
- Several collaborations
  - Medipix 2 & 3
  - Medipix 4 being set up
- A lot of applications in industries, education and research
  - X-Ray imaging
  - Dosimetry in the ISS



Medipix3RX images: S. Procz et al.

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Conclusion

- The needs for electronics spans from radiation hard front-end ASICs to front-end hybrids, optical links, modular electronics (xTCA and PCIe) and power supplies
- Industry needed for the production and testing of custom systems but also to provide specific designs (e.g. IP blocks) or to design some modules
- In addition to a “one-shot” production, maintenance contracts are needed for some systems
  - E.g. crates and power supplies

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Back-up Slides

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Microelectronics: Technologies

CMOS 6SF

Legacy designs

CMOS 8RF-LM

Low cost technology for Large Digital designs

CMOS 8RF-DM

Low cost technology for Analog & RF designs

BiCMOS 8WL

Cost effective technology for Low Power RF designs

BiCMOS 8HP

High Performance technology for demanding RF designs

250nm CMOS

130nm CMOS

CMOS 9SF LP/RF

High performance technology for dense designs

90nm CMOS

CMOS 65nm

High performance technology for dense Low Power designs.

65nm CMOS

- Legacy technology IBM CMOS6SF (250nm)
  - Re-fabrication of old designs
  - Small number of new designs
- Mainstream technology IBM CMOS8RF-DM (130nm)
  - Technical support: CERN compiled Mixed-Signal design kit
  - Frequent MPW and Engineering runs
- Advance technology IBM CMOS9LP/RF (90nm)
  - Limited support: Project specific
- Future technology (65nm)
  - For LHC upgrade applications

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Radiation tolerant developments in 130 nm

- Readout ASICs: main developments now in 130 nm
  - Prototype readout chip for the ATLAS upgrade silicon strips
  - Pixel readout chip with one TDC per channel for a fixed target experiment (TDCPix)
- Development of a bidirectional gigabit link
  - 4 ASICx: GBTx, GBT-SCA, GBLD and GBTIA
  - 4.8 Gbps on each port
- Pictures next slides

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CERN R&D for new detectors

- RD50 http://rd50.web.cern.ch/rd50/
  - Radiation hard semiconductor devices for very high luminosity colliders
  - 49 institutes
- RD51 http://rd51-public.web.cern.ch/RD51-Public/
  - Development of Micro-Pattern Gas Detectors Technologies
  - 90 institutes
- RD53 http://rd53.web.cern.ch/RD53
  - Tools and designs needed to produce the next generation of pixel readout chips
  - 20 institutes
- CERN Neutrino platform
  - Neutrino detector R&D e.g. 2-phase large Liquid Ar TPC

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