Electronics engineers at CERN

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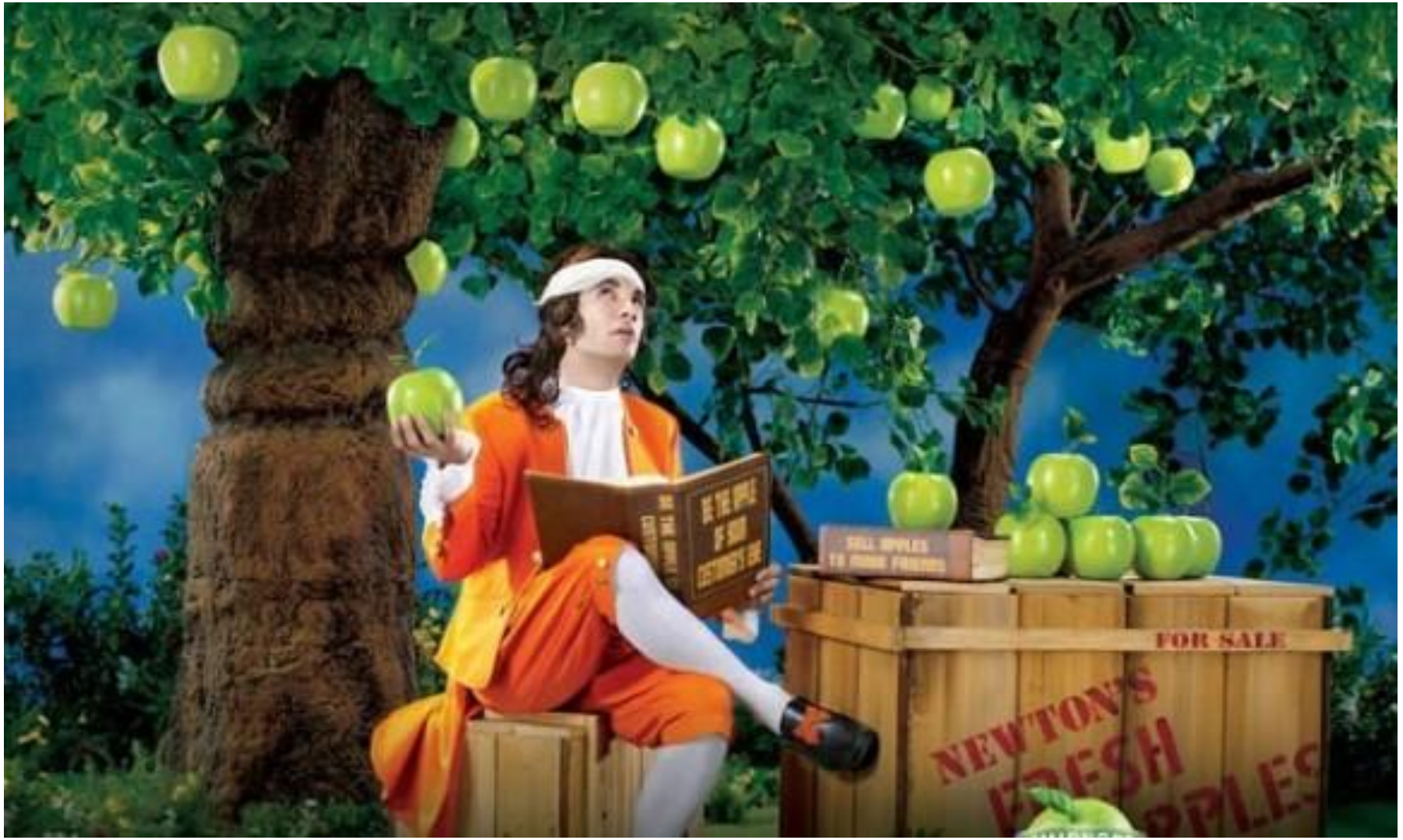
experiments ATLAS and NA62

"There are 10 times more engineers and technicians employed by CERN than research physicists. Why?

Engineers are vital to CERN's activities – to push the boundaries of experimental physics, they're building some of the most advanced machines in the world."

Instrumentation in experimental physics

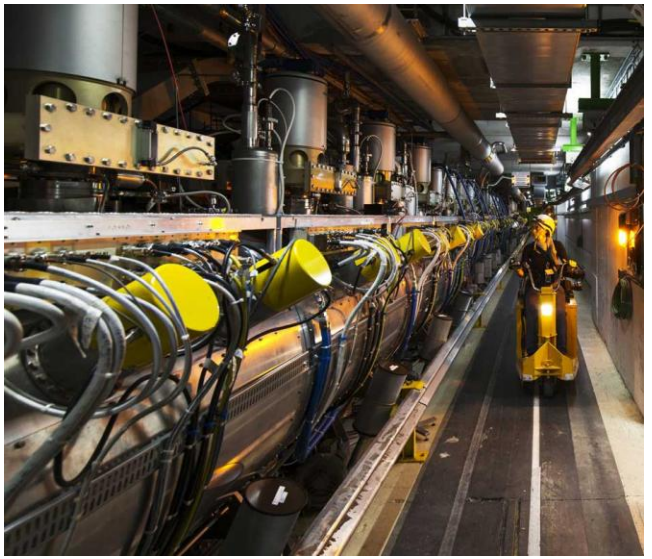


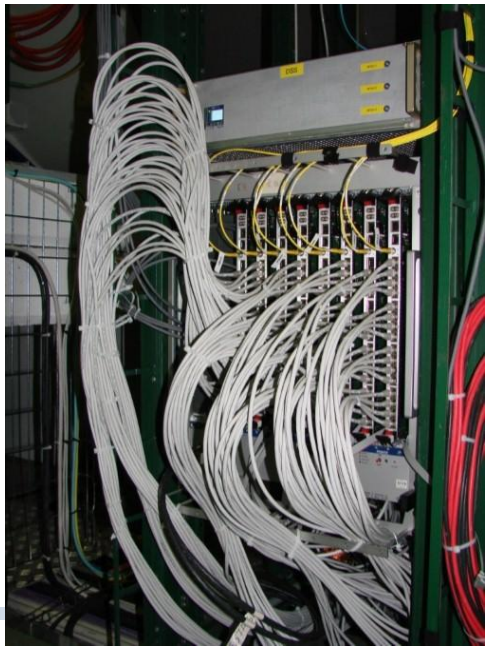
Instrumentation in experimental physics

Instrumentation in experimental physics

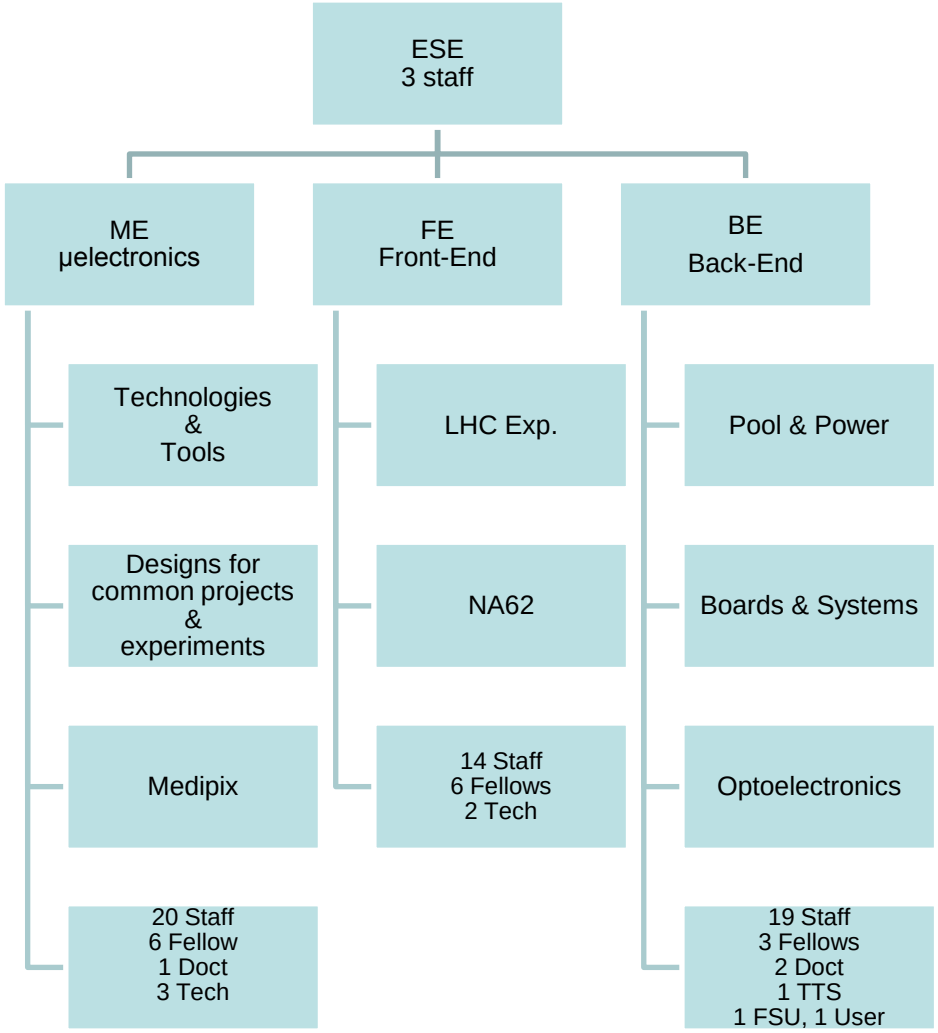
Electronics engineers at CERN

- Staff
  - Accelerators
    - RF
    - Power supplies
    - Magnets
    - Control and monitoring
  - Experiments (PH-ESE group)
    - Architecture and system design
    - Chip design
    - Front-end
    - Back-end
    - Services
    - Electronics POOL
  - General support
- External
  - Usually for building, running and supporting experiments
  - Both long and short term





ESE at a Glance



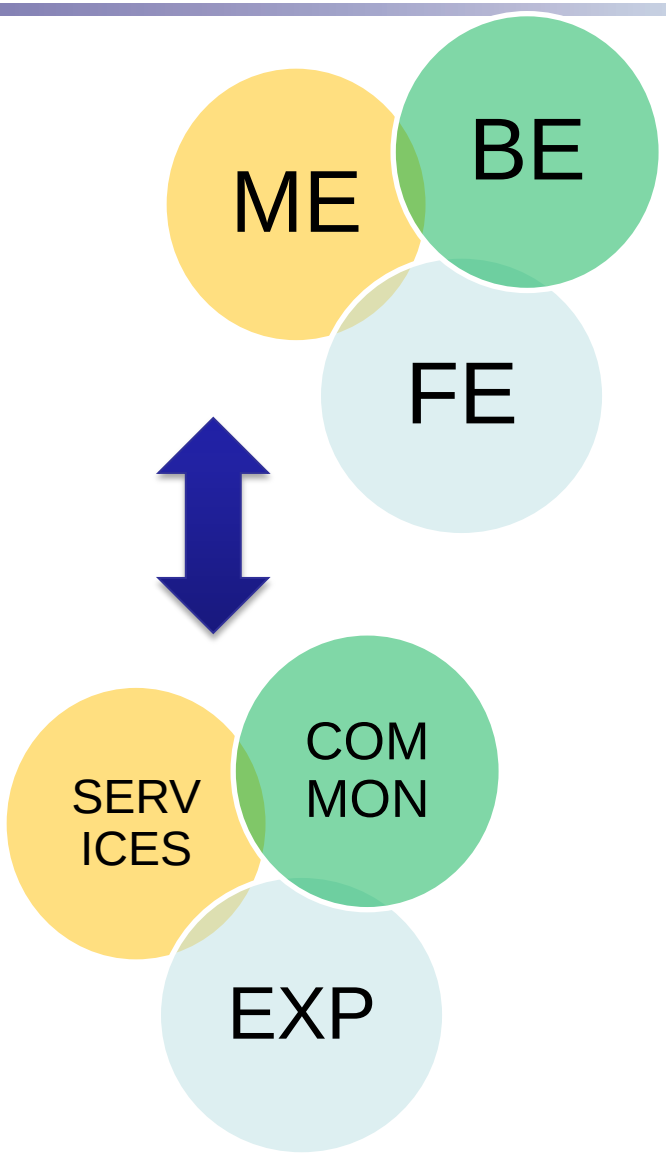
- 56 Staffs (+ Evelyne [PH-DI])
  - 39 Engineers
  - 9 Technical Engineers
  - 8 Technicians
- 15 Fellows
- 3 Doctoral Students
- 3 Technical Students
- 1 TTS technician
- Plus a number of people working with us
  - From other departments, experiments and a few retired people

Devoted technician

Tests of the gas quality for ATLAS/TRT endcap wheel and refilling

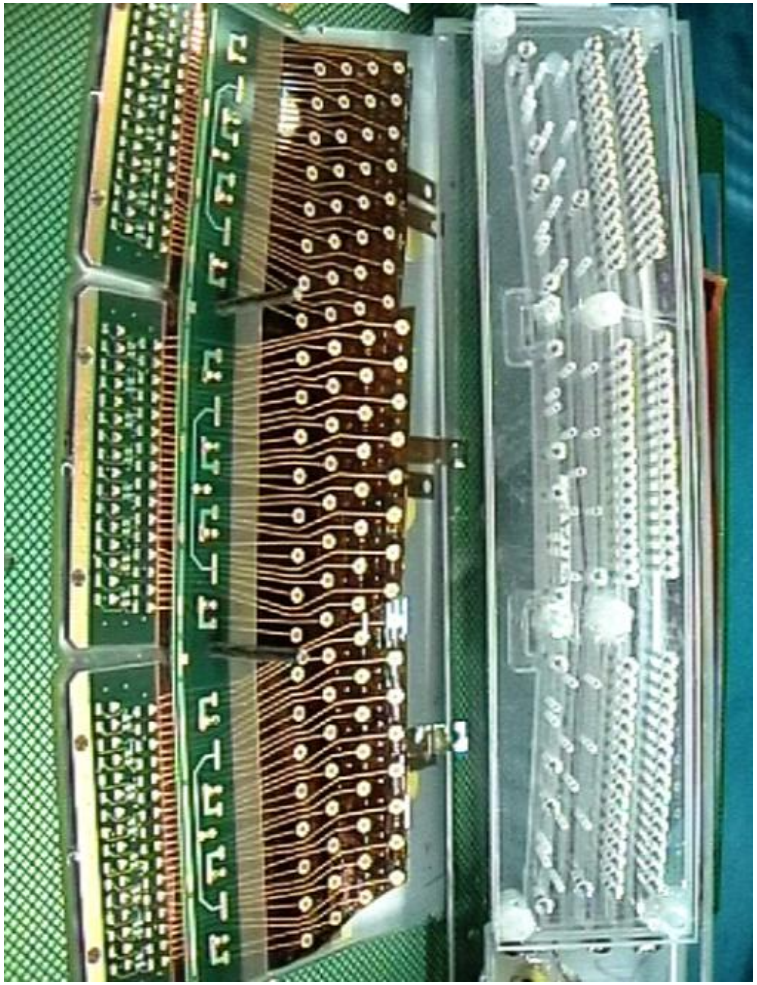
ESE at a Glance

- 3 sections
  - Microelectronics ME
  - Backend BE
  - Frontend FE
- Three categories of projects
  - Services
  - Common projects
  - Specific experiments or projects related
- Projects are often handled in more then 1 group
- We are involved in a number of projects
  - No way to go through all in a reasonable time
  - A lot of details can be found on the Seminar page and also on the TWEPP page
    - https://indico.cern.ch/category/1591/ & http://twepp-workshops.web.cern.ch/TWEPP-Workshops/



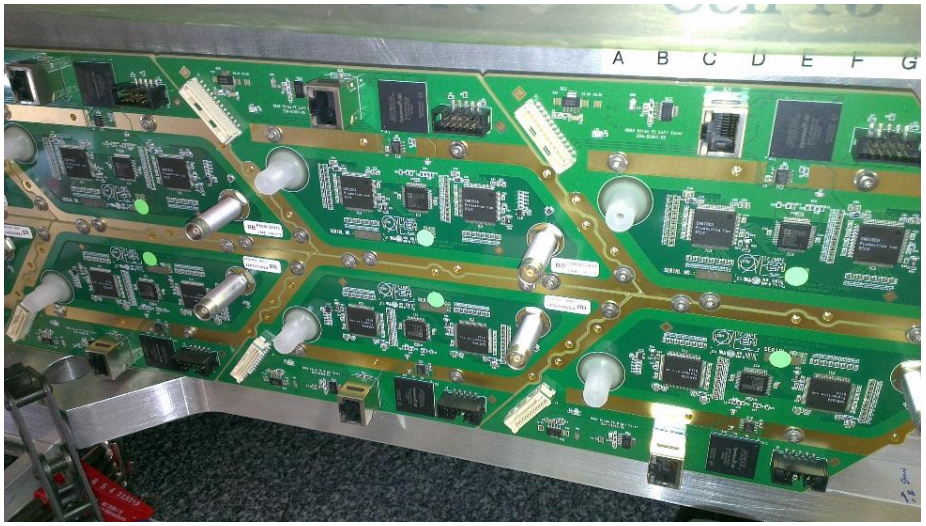
ESE at a Glance

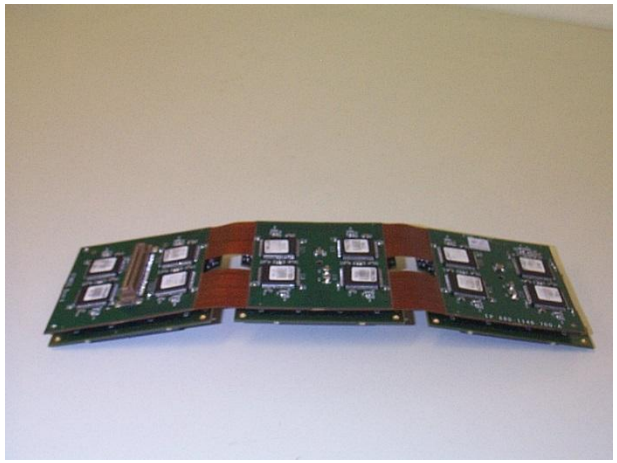
- CAE software
  - CADENCE
    - Chip design
    - System design
      - SPB (including Allegro PCB and AMS mixed simulator)
      - INCISIVE
      - ORCAD (includes MICROSIM PSPICE)
  - ALTIUM
  - Gerber editors
  - JTAG for active testing of PCBs
- All FPGA vendors ALTERA, XILINX,…
- EM simulators
  - ANSYS (ANSOFT) - MAXWELL, 2D/3D extractors, Siwave, etc
  - HFSS
  - More for physicists
- Mathematics
  - Mathcad, Mathematica, Matlab
- Design language
  - Chips Verilog (VHDL started)
  - System mostly VHDL (USA users Verilog)

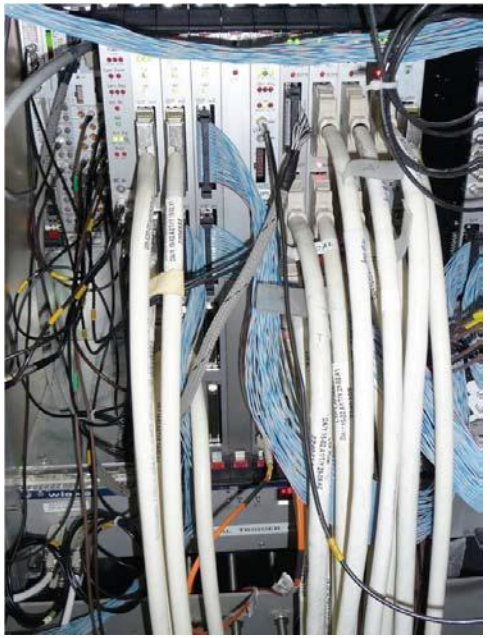


ESE at a Glance

- What kind of electronics experiments need ?
- On detector electronics
  - Long-term reliability
  - Impossible to repair
  - must often work in
    - Radiation environment
    - Strong magnetic fields
    - Confined space
  - Material density limited to do not disturb experiment
  - Far away from backend electronics – up to 100m
  - Limited access
  - Safety for underground projects
- Off detector electronics
  - Often still underground but safe place
  - If underground – safety still issue







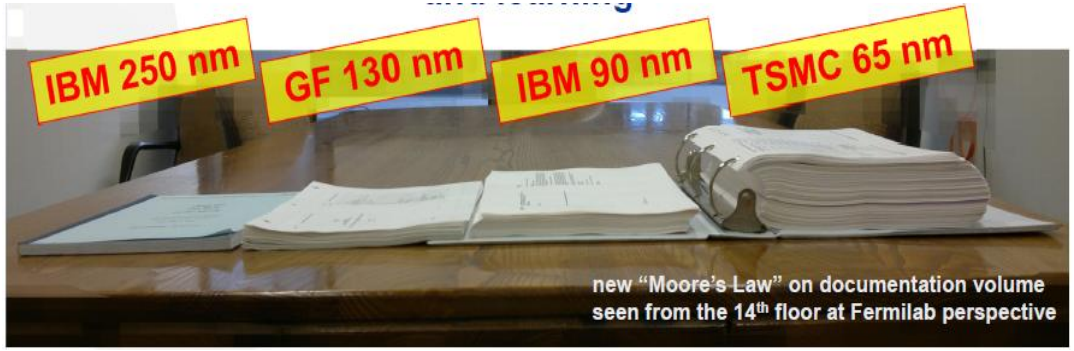
PH-ESE-BE

- **Mandate**: Specify, design, test, qualify, produce, install and maintain back-end (off-detector) electronic systems in collaboration with CERN experiments: Systems, Circuit Boards, Crates, LV power supplies and Optical Links.
  Make available to CERN-approved projects a wide range of modular electronics and measurement equipment for short to medium term rental (E-pool).

- Electronics Pool
  - Renting electronics equipment
  - Continuous work: several 1000's equipment's to be handled and tested
  - Evaluation of new equipment
  - Procurement of new equipment
- Power Supplies and Crates
  - Power supplies for experiments – specification, procurement and repairs
  - Crates – specification , procurement and repairs, VME, NIM, CAMAC
  - Move from VME standard – xTCA?
- xTCA evaluation project
  - µTCA and ATCA for VME replacement
  - µTCA crate spec. defined in 2014
- Projects for experiments
  - Data transfer and formatting
  - Feature extraction and trigger

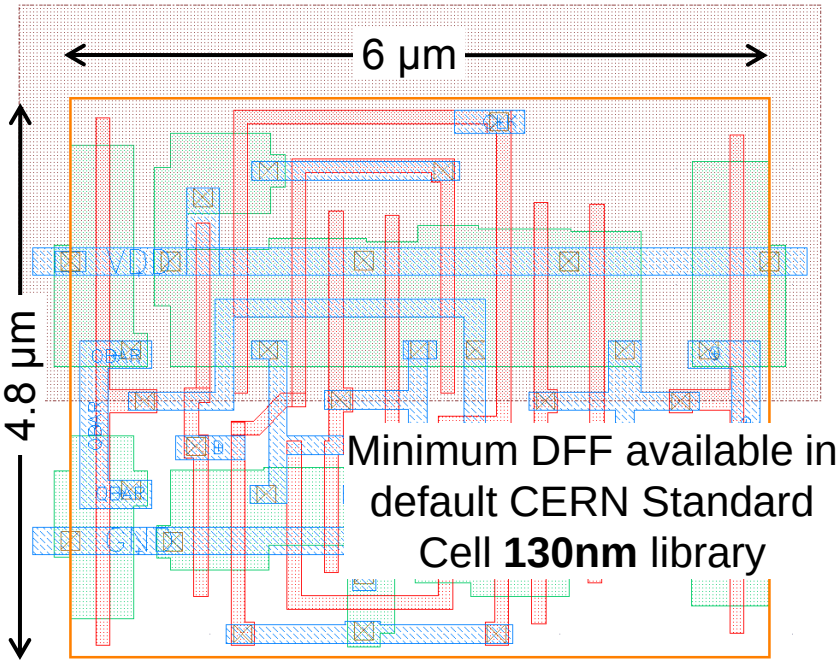
Mandate: Design, test, qualify, produce, and support analog/digital front-end ASIC's for CERN experiments.
Specify in collaboration with experiments, design, qualify, produce and support common radiation hard components.
Micro electronics services to HEP community.

- IC technologies
  - New contract with TSMC for 65 nm and 130 nm CMOS technologies
    - Radiation qualification
    - Making available design kits
    - Organizing training
    - Taking care of the orders etc.
  - Contract with IBM for 250 and 130 nm transferred to MOSIS
  - IC tester
  - Xray irradiation machine
    - Total Ionizing Dose (TID) effects at different temperatures - from cryogenic to more than 100 degrees C
  - Maintain libraries and IP blocks
    - ADC, memory generator, triplicated logic
- ASICs design for different projects, both common and experiments

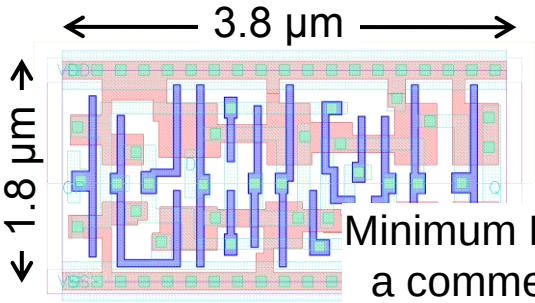


- Physical specs:
  - "Mainly" Low power transistors
  - Row Height is fixed to 2.4 µm
  - Well Tap library
- Maximum frequency < ~700 MHz (@1.5V)
- Encounter Library Characterizer (ELC) used:
  - Full Synopsis library:
    - lib, ecsm, ecsm_si and ccs
    - delays, static and dynamic power
    - Corners:
      - 1.2V : -55C FF, 25C TT and 125C SS
      - 1.5V : -55C FF, 25C TT and 125C SS
  - Verilog library
  - LEF files
  - HTML documentation
- ~50 cells are available in the library

- Used in Medipix3RX



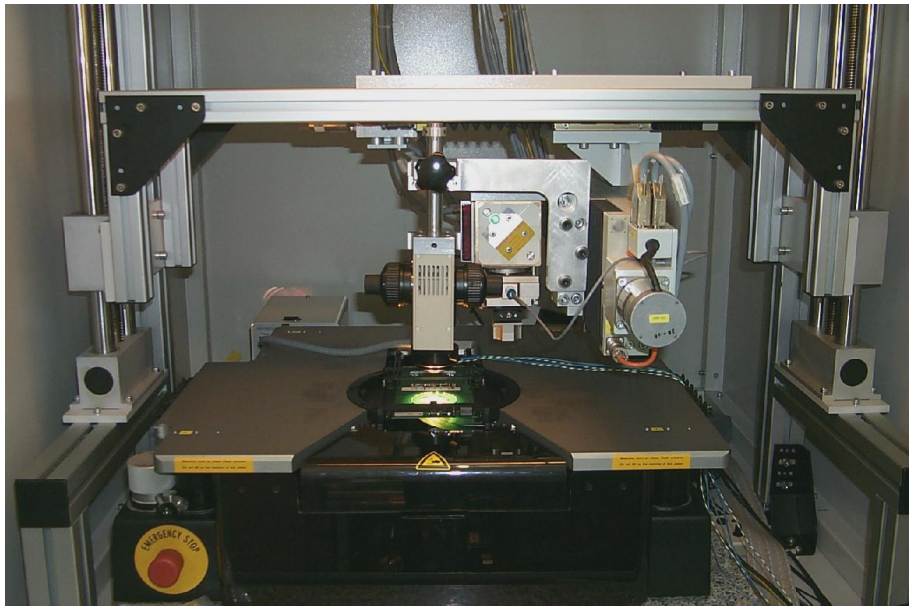
Minimum DFF available in default CERN Standard Cell **130nm** library

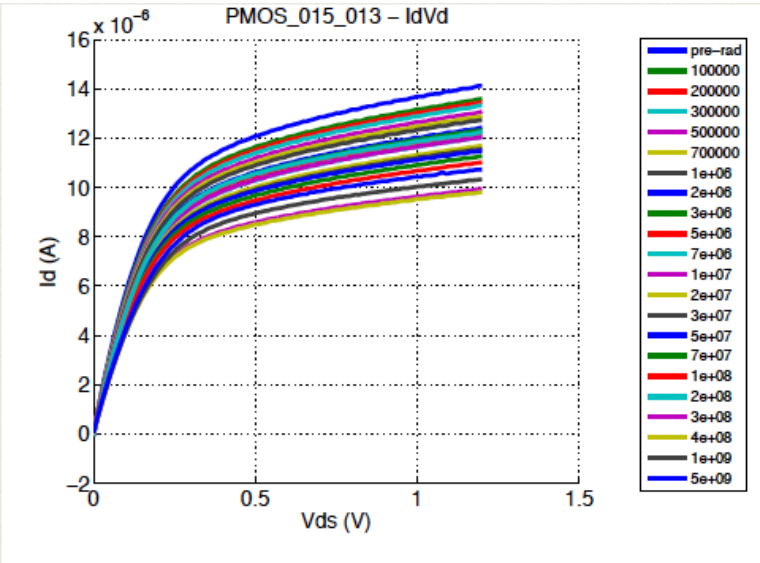


Minimum DFF available in a commercial Standard Cell **65nm** library

x4 smaller !!!

- *XRay machine and radiation results*



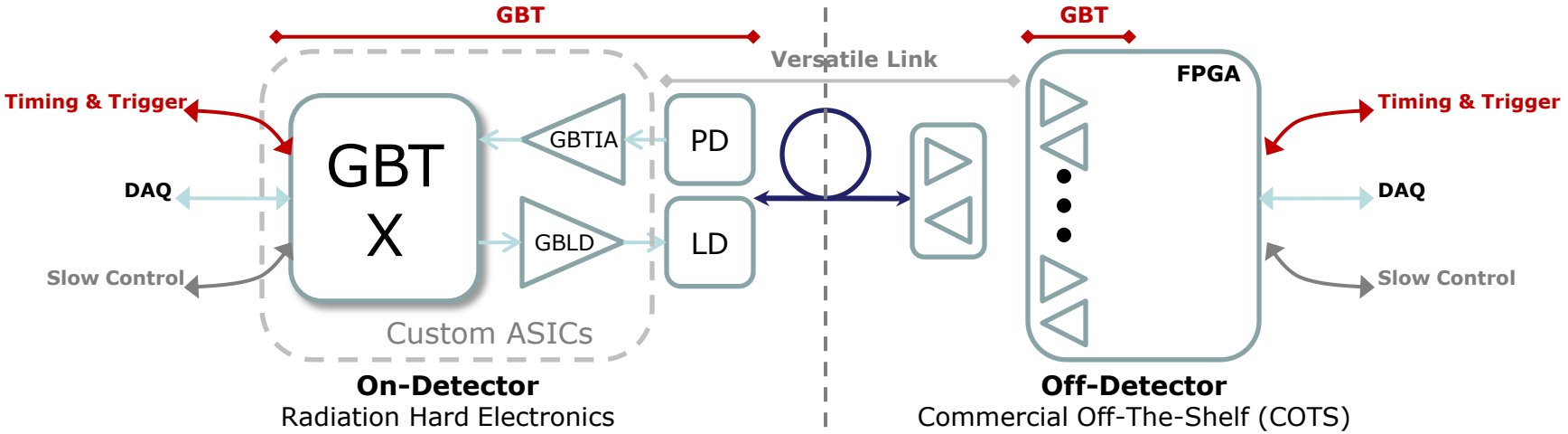


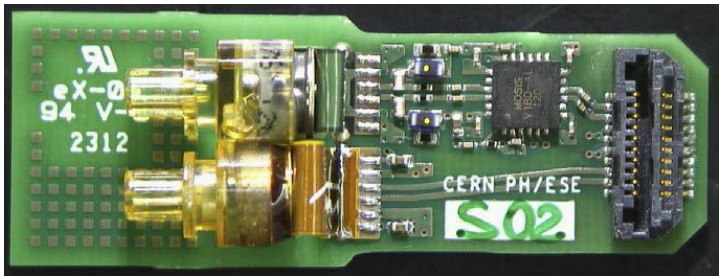
- **Mandate**: Specify, design, test, qualify, produce, install, commission and maintain on-detector front-end systems in collaboration with CERN experiments. Specify and participate in design of required front-end ASIC's.

- Normally involvement for a lifetime of the experiment
  - Research and Development of the detector itself
  - Research and Development of the readout electronics including services (cables, power supplies, data extraction, etc)
  - Construction and procurement of the full readout system
  - Support

Common Projects

- Radiation tolerant bi-directional optical link



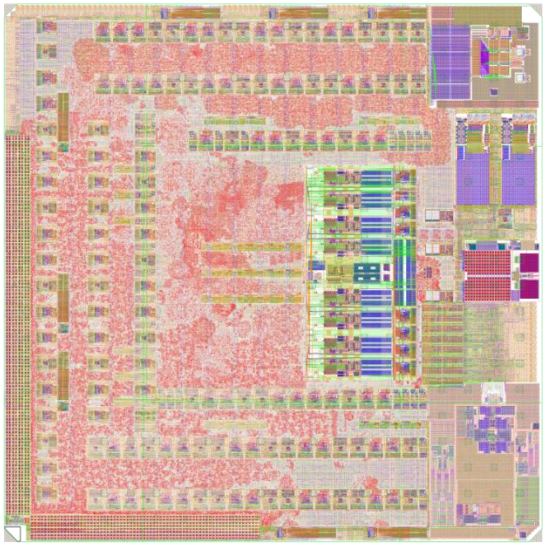


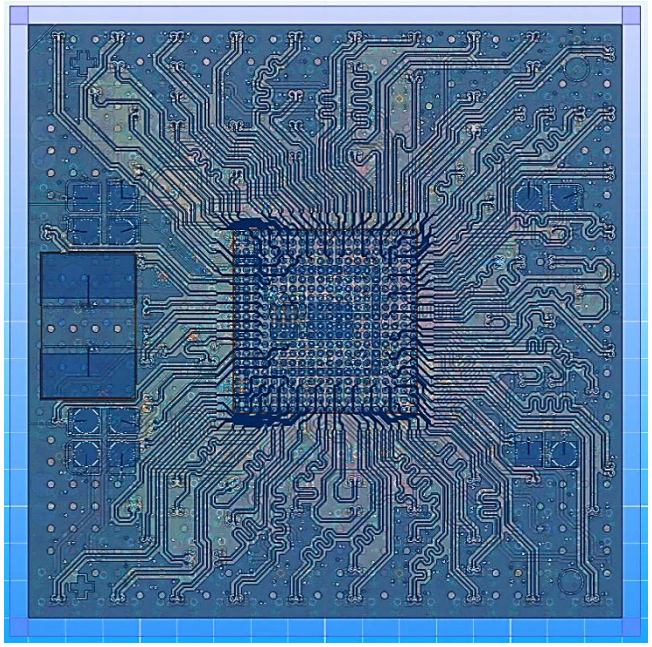
Optical components - Versatile Link Project

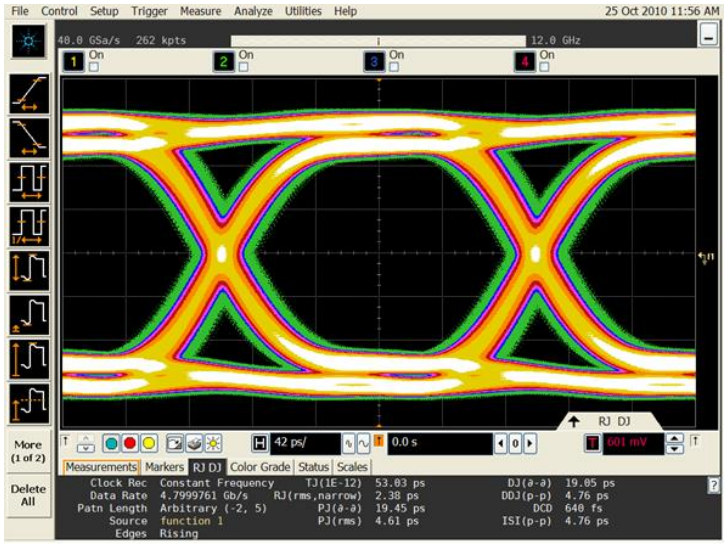
- Laser diode,
- PIN diode
- optical fiber
- connectors

Common Projects

- Radiation tolerant bi-directional optical link
  - High speed serializer and deserializer chip - GBT project
  - 4.8 Gb/s transceiver GBTX at 130nm CMOS - pictures
  - 2015 will be tough as there will be 60000 GBTX and GBLD, 15000 GBTIA and GBT-SCA

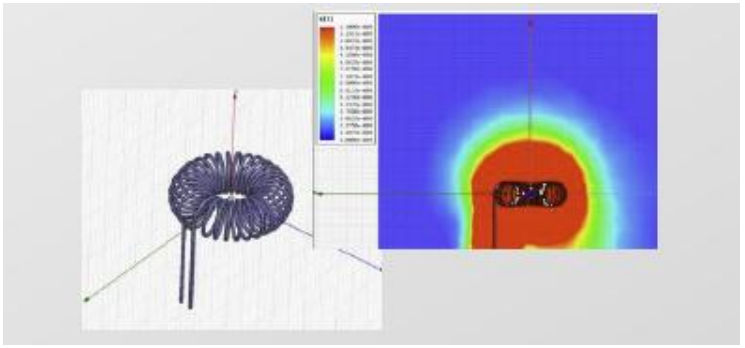


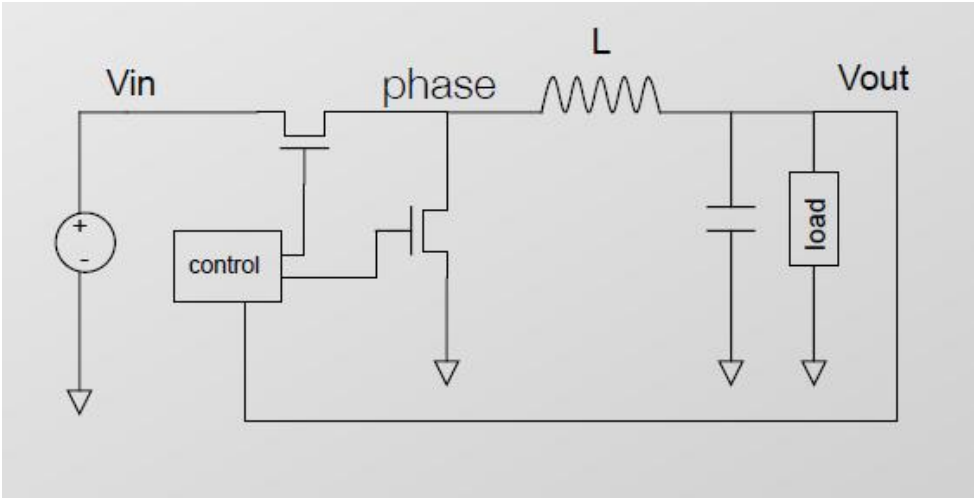


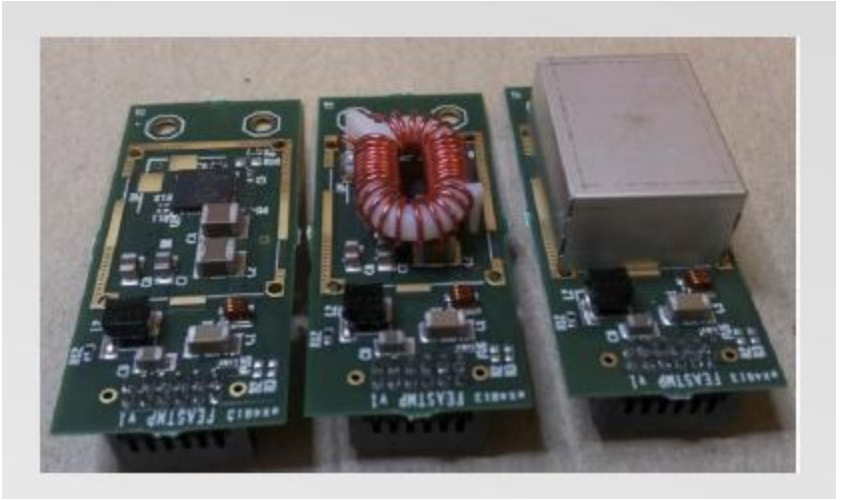


Common Projects

- Radiation hard and magnetic tolerant DC-DC converters
  - Power wasted in cables can be more then 80% total!
  - Bulky and expensive cables, lot of material disturbing experiment
  - Difficult to regulate remotely supply voltage ~1V
  - Radhard controller + aircore coil



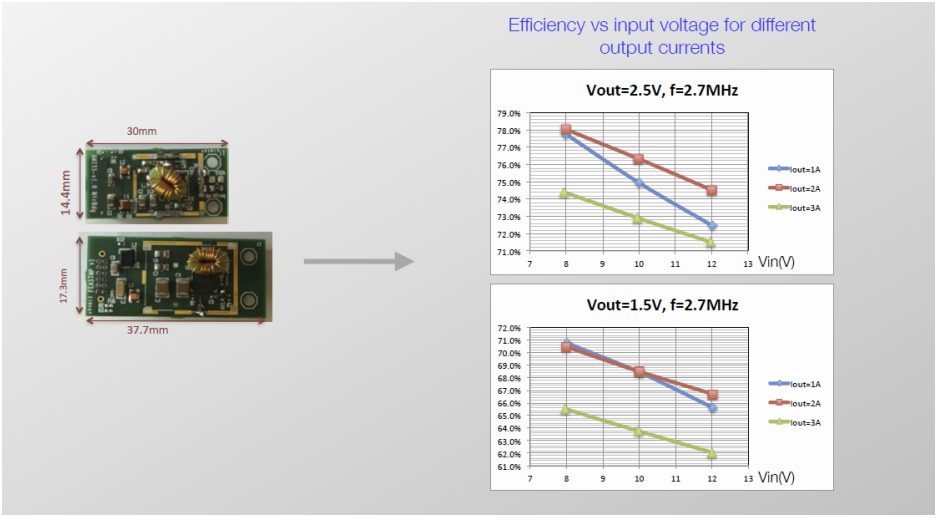


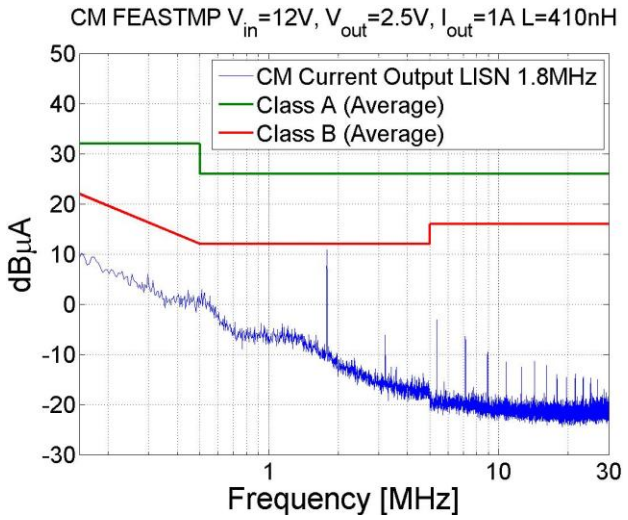


Common Projects

- Radiation hard and magnetic tolerant DC-DC converters
  - Final ASIC produced
  - Production process started (10000 – 15000 to be produced)

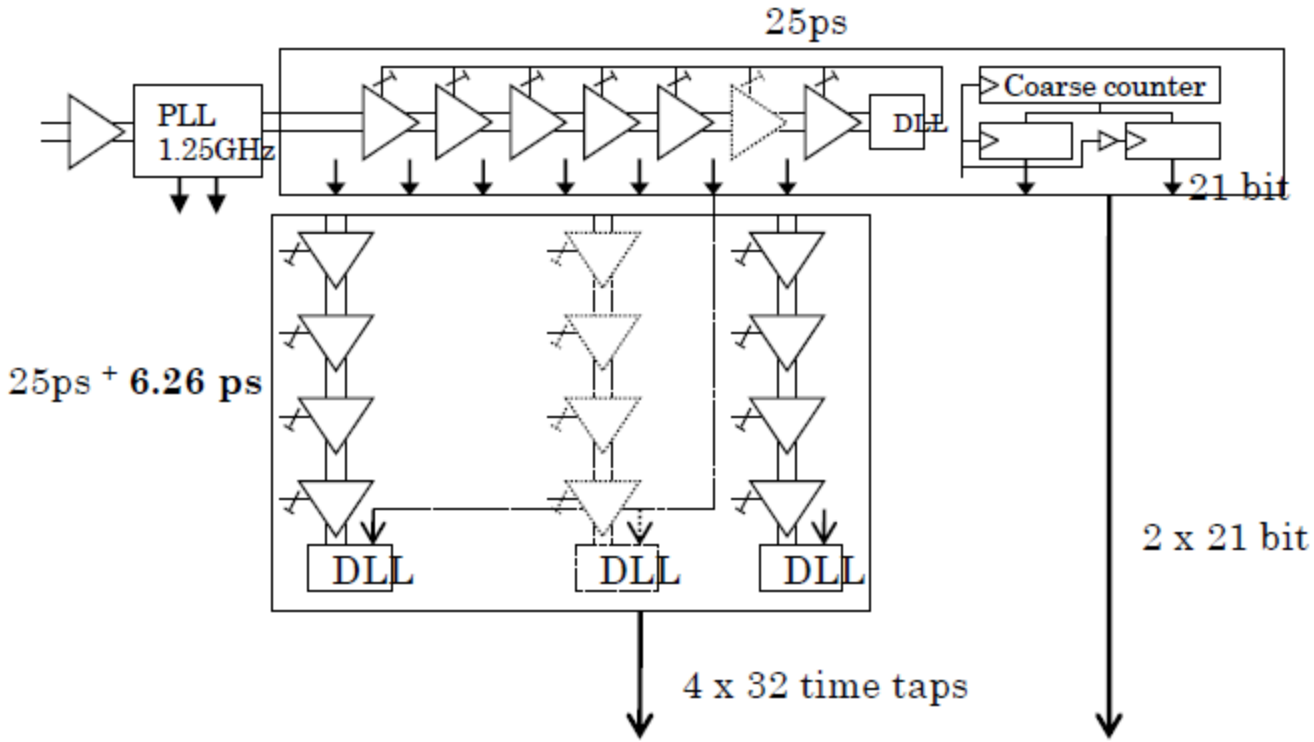
Midway upon the journey of ~~our life~~ DCDC design
I found myself within a forest dark,
For the straightforward pathway had been lost...
Dante, inferno





Common Projects

- High resolution TDC development
  - Design of of a 64-channel high resolution TDC (a few *ps*)
  - Transfer of the basic cell from 130 to 65 nm technology
  - Delay Locked Loop (DLL) based



Work for Experiments

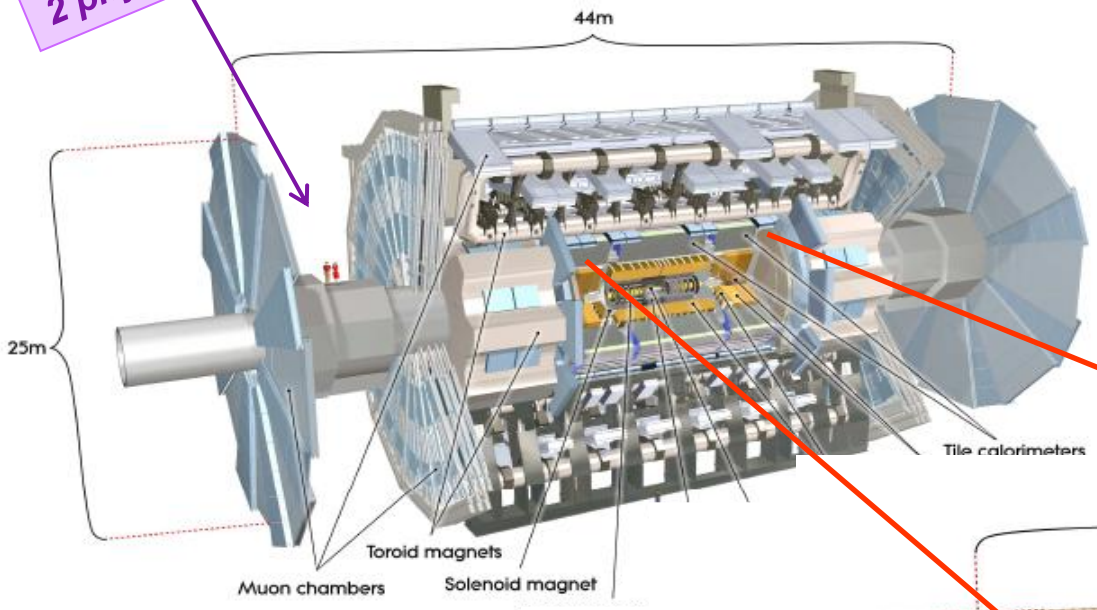
- ALICE
  - Electronics coordination
  - ITS upgrade project
    - Monolithic pixel development
    - Electromechanical design
- ATLAS
  - Electronics coordination
  - ALFA (change of position)
  - Tracker upgrade
    - ABC130 chip available
  - Central Trigger upgrade
  - ATLAS ROS
- CMS
  - Electronics coordination
  - TCDS (CMS TTC) upgrade
  - Backend electronics and optical links for new pixel detector
  - Optical transmitters for calorimeter trigger upgrade
  - Beam condition/radiation monitoring
  - GEM readout electronics
  - Tracker upgrade
  - Pixel phase 2
- LHCb
  - Electronics coordination
  - Velopix development
    - Including FE ASIC

Work for Experiments

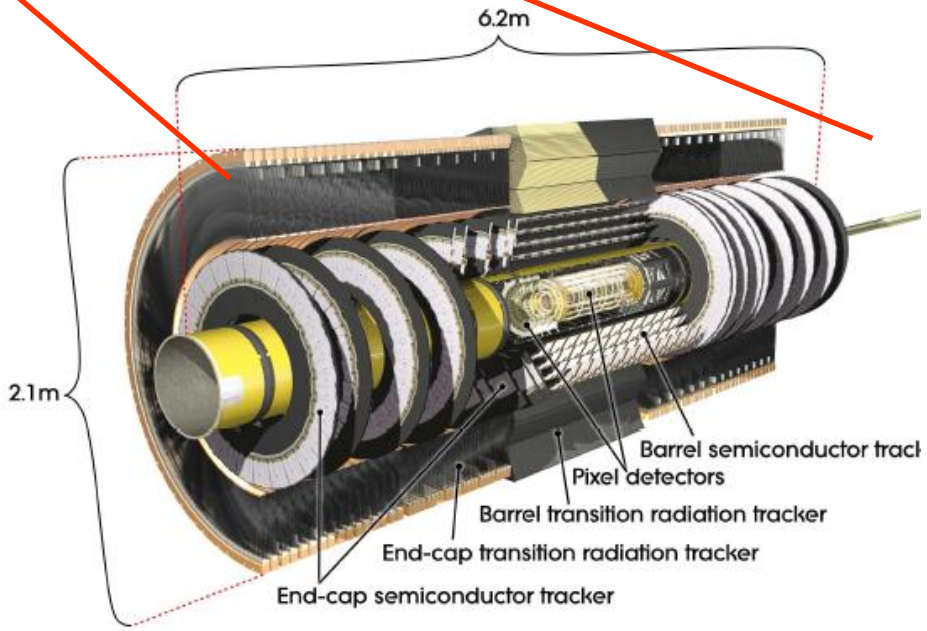
- TOTEM
  - Electronics coordination
- NA62 (seen before)
  - Straws readout
  - LKr calorimeter readout electronics
    - Seminar last December
    - Installation work with the help of pool
  - GigaTracker
    - TDCPIX available. Seminar last month
    - Front-end hybrids and services
- Medipix
  - Several chips (Medipx3, Timepix3, Smallpix, Clicpix)
  - TSV work with Leti
- LCD
  - Pixel development
  - Pulsed power
- Beam loss and radiation monitoring
  - For BE and DGS
  - 2 ASICs dev.

Work for Experiments – ATLAS TRT

2 physicists

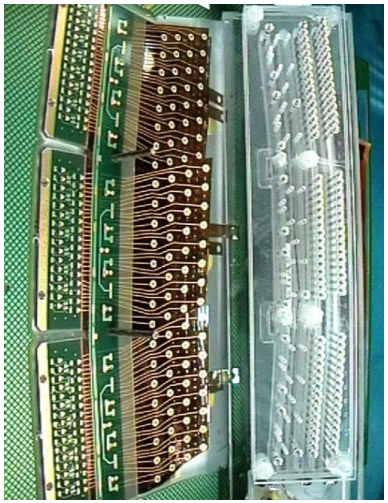


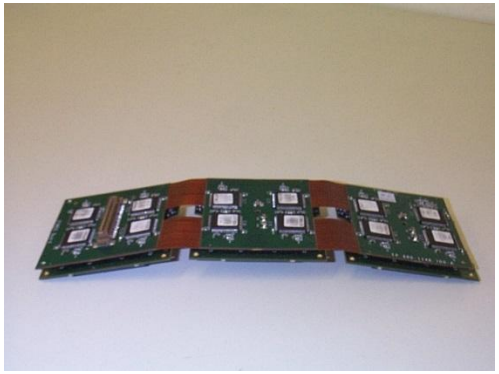
The ATLAS Inner Detector (ID)

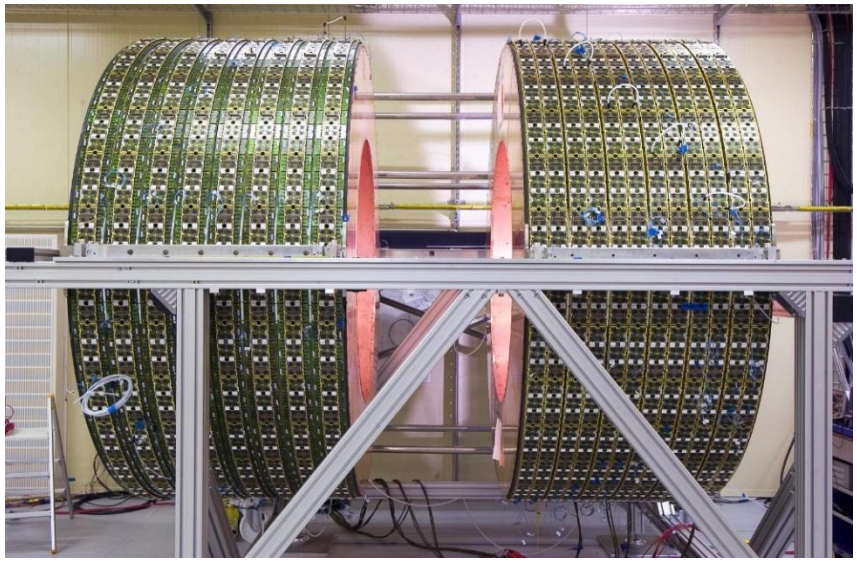


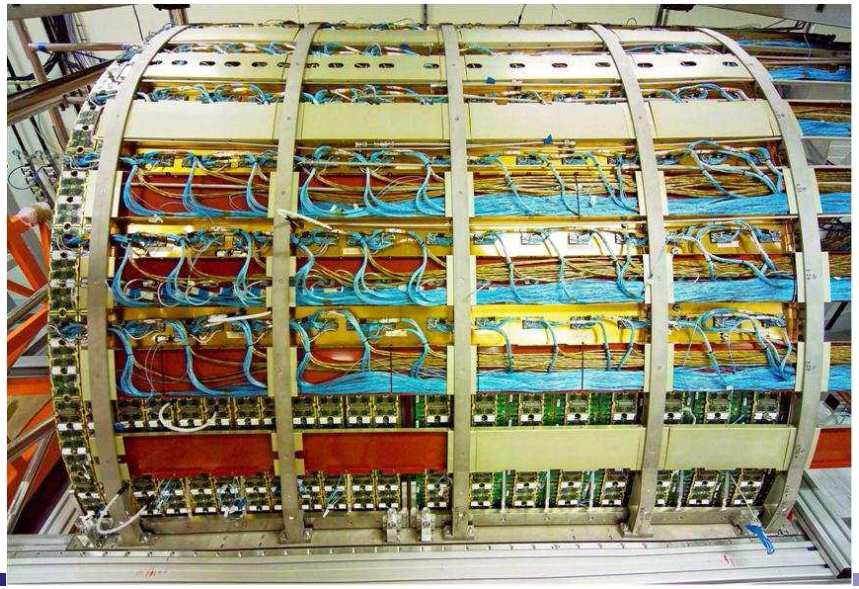
- Provides charged particle tracking for particles above 0.5GeV, $|\eta| < 2.5$
- Electron identification for particles with $|\eta|<2$ and $0.5 < p_T < 150$ GeV
- Surrounded by solenoid B = 2T
- Consists of Pixel detectors, Semiconductor Tracker and Transition Radiation Tracker (TRT)

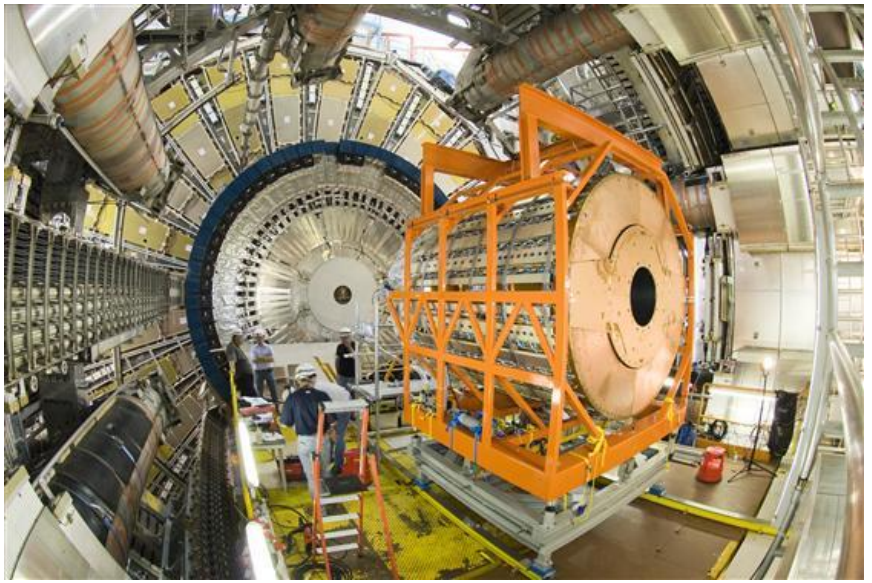
Work for Experiments – ATLAS TRT

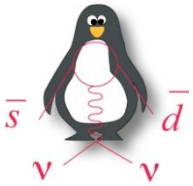


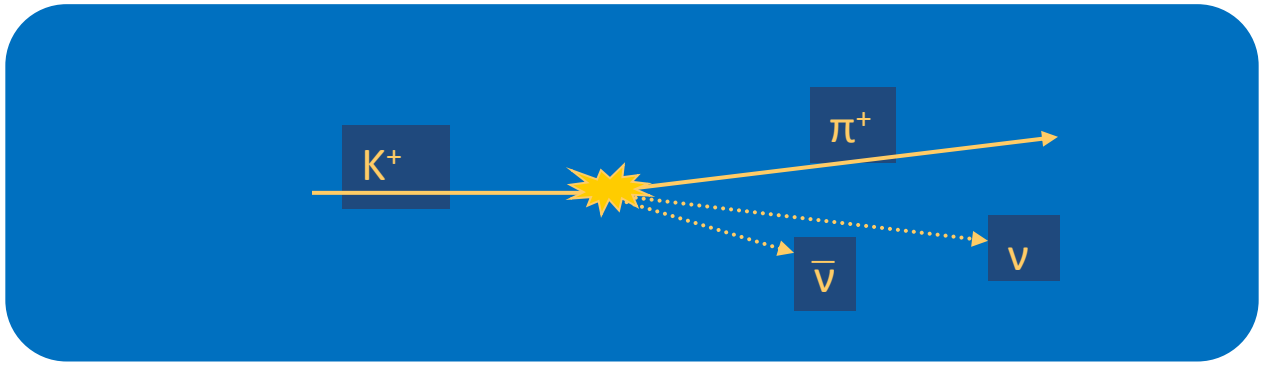


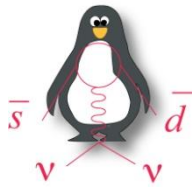






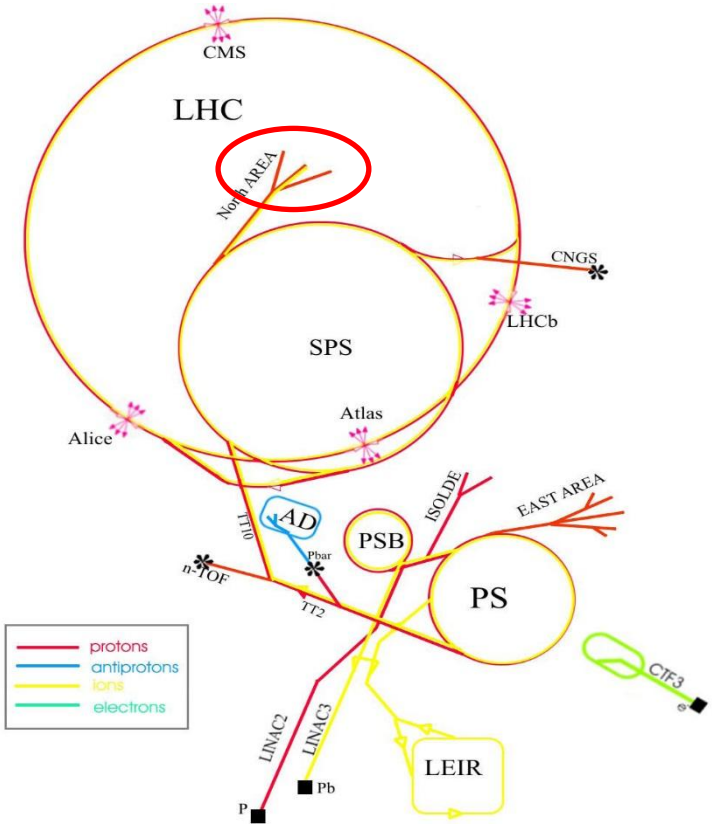




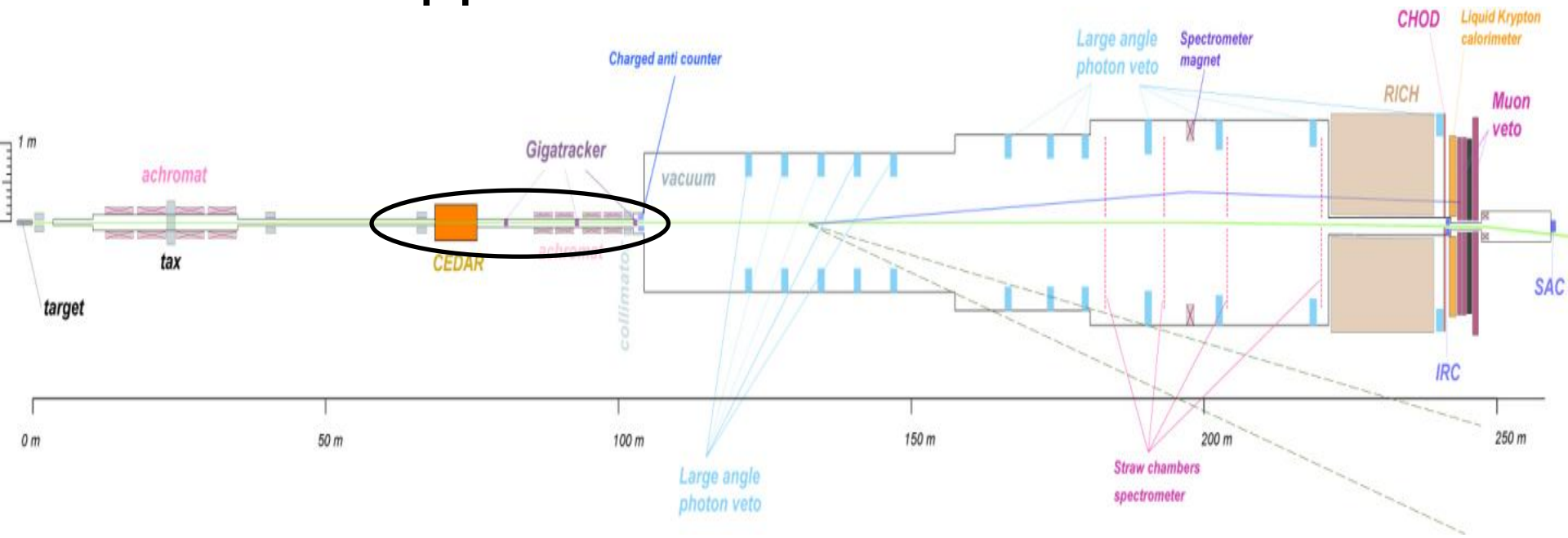


- Measure the Rare Decay K+ -> (pion+) + neutrino + antineutrino (BR of $10^{-10)}$
- ~100 events in the lifetime of the experiment
- Extreme background (~1 GHz incoming rate, up to 17MHz detectors)
- Principle
  - Generate Kaons (needed total 10^{13} K^+)
  - Let them decay (~65 meters long tube)
  - Observe product
    - signal acceptance
    - background suppression

NA62 Apparatus



NA62 Apparatus

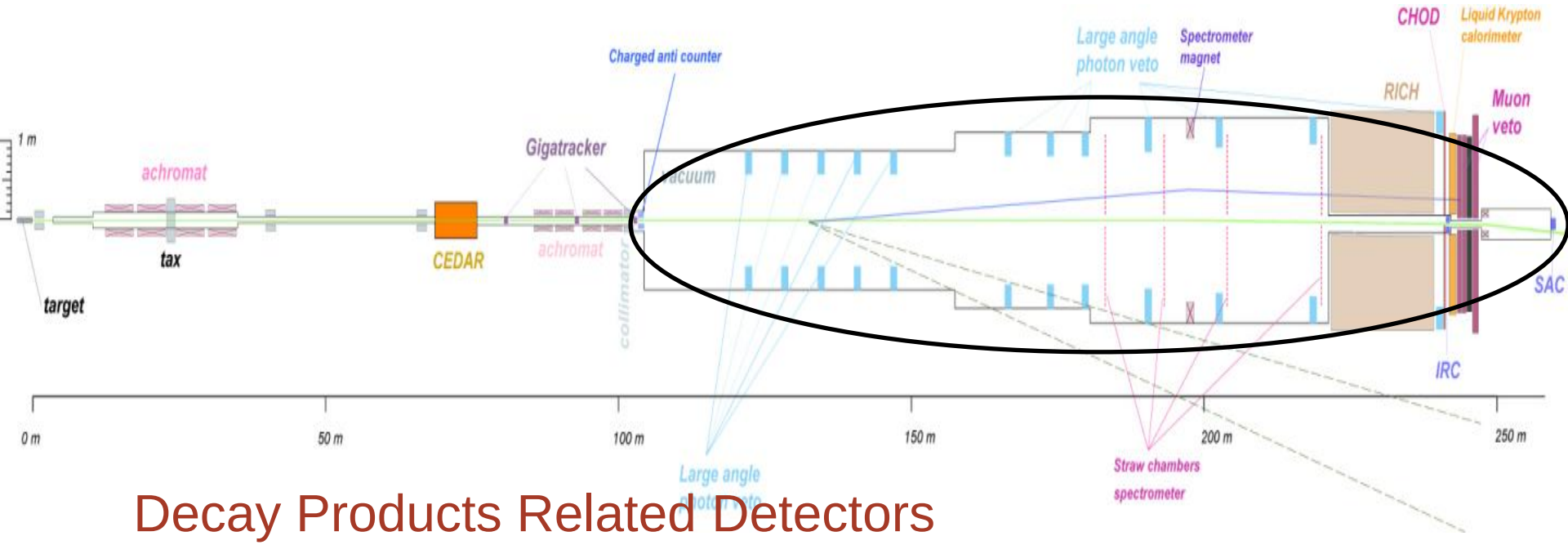


Beam Related Detectors

Tracking, timing and Kaon identification

- KTAG
- GTK

NA62 Apparatus



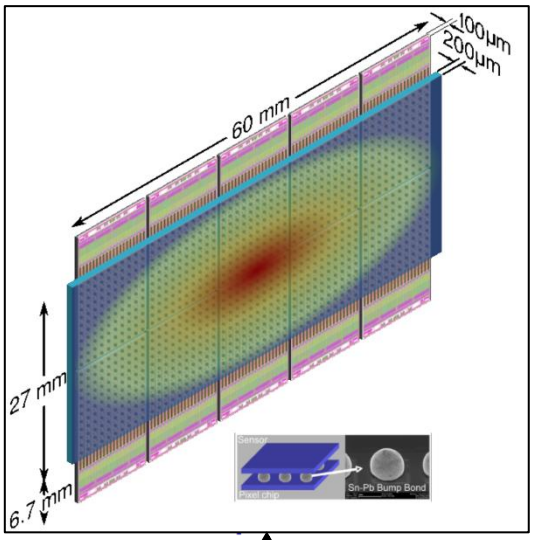
Decay Products Related Detectors

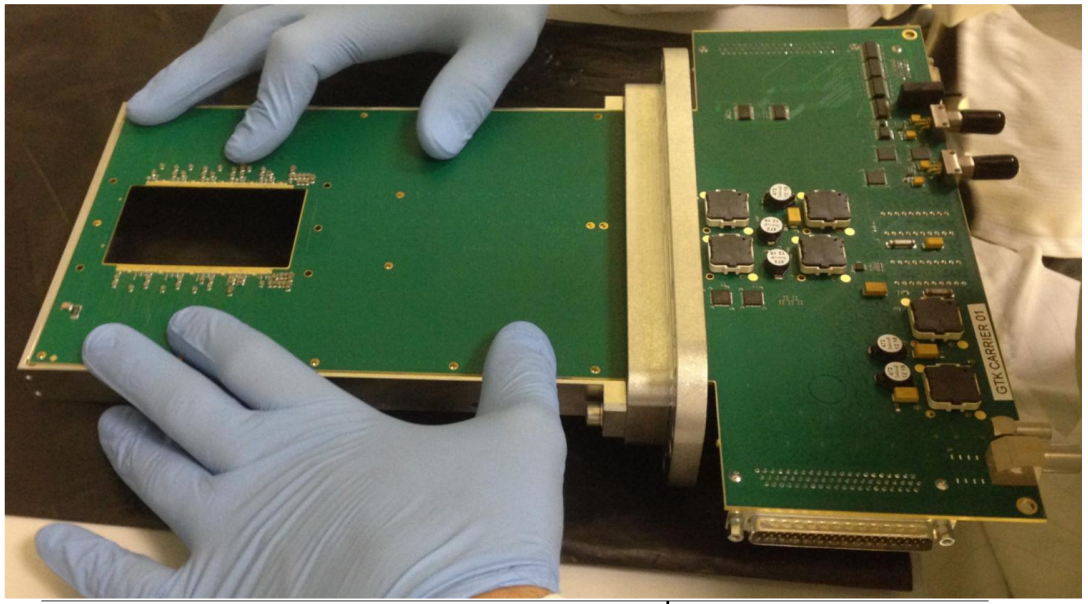
Tracking, PID and energy measurement

- CHANTI
- LAV, IRC and SAC
- STRAW
- LKr
- CHOD
- MUVs

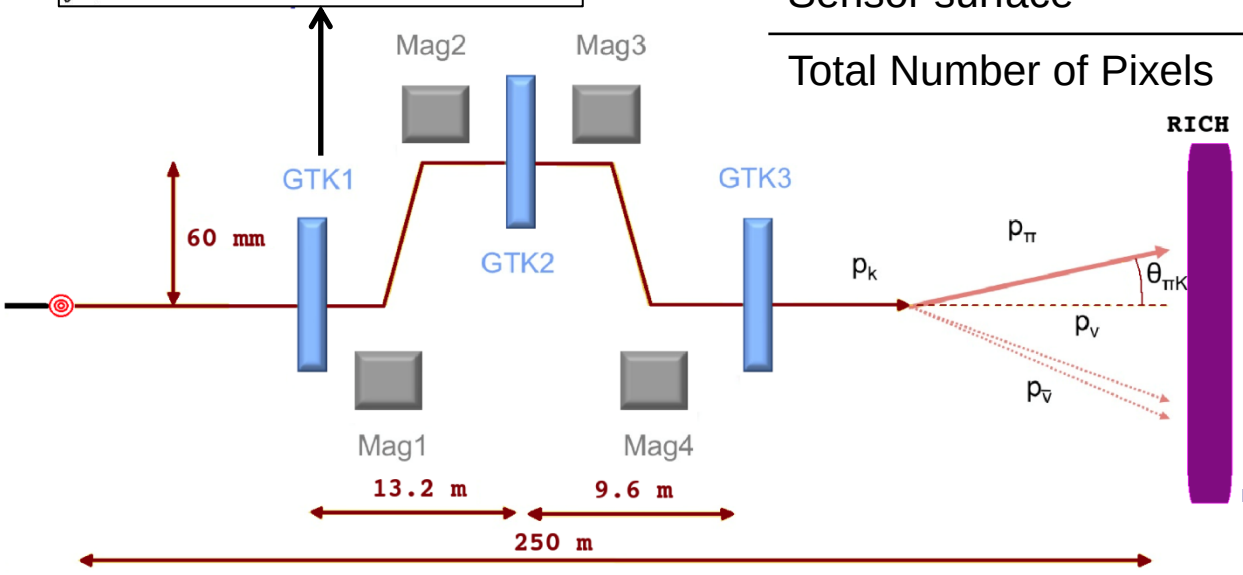
Ideal event

GigaTracKer

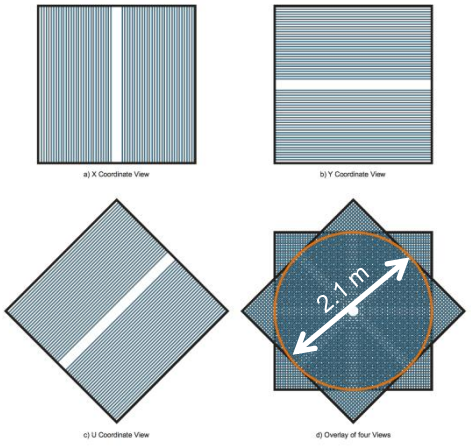




Sensor surface	27 x 60 mm^2
Total Number of Pixels	54 k

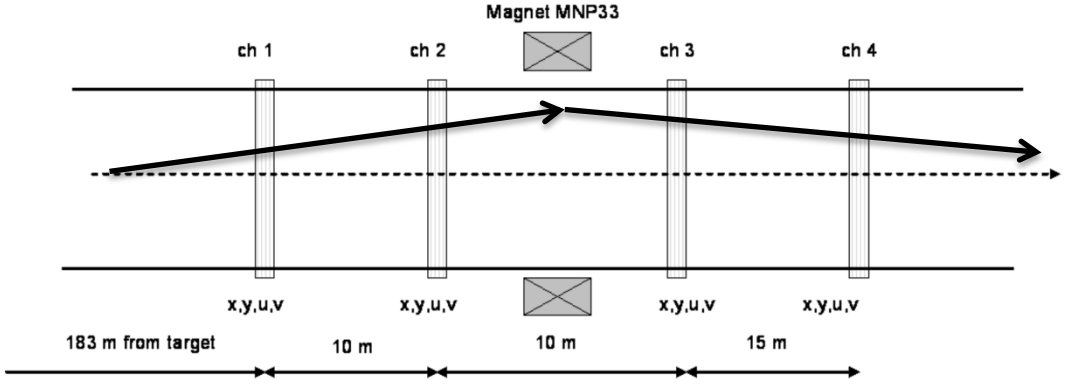


Straw Tracker



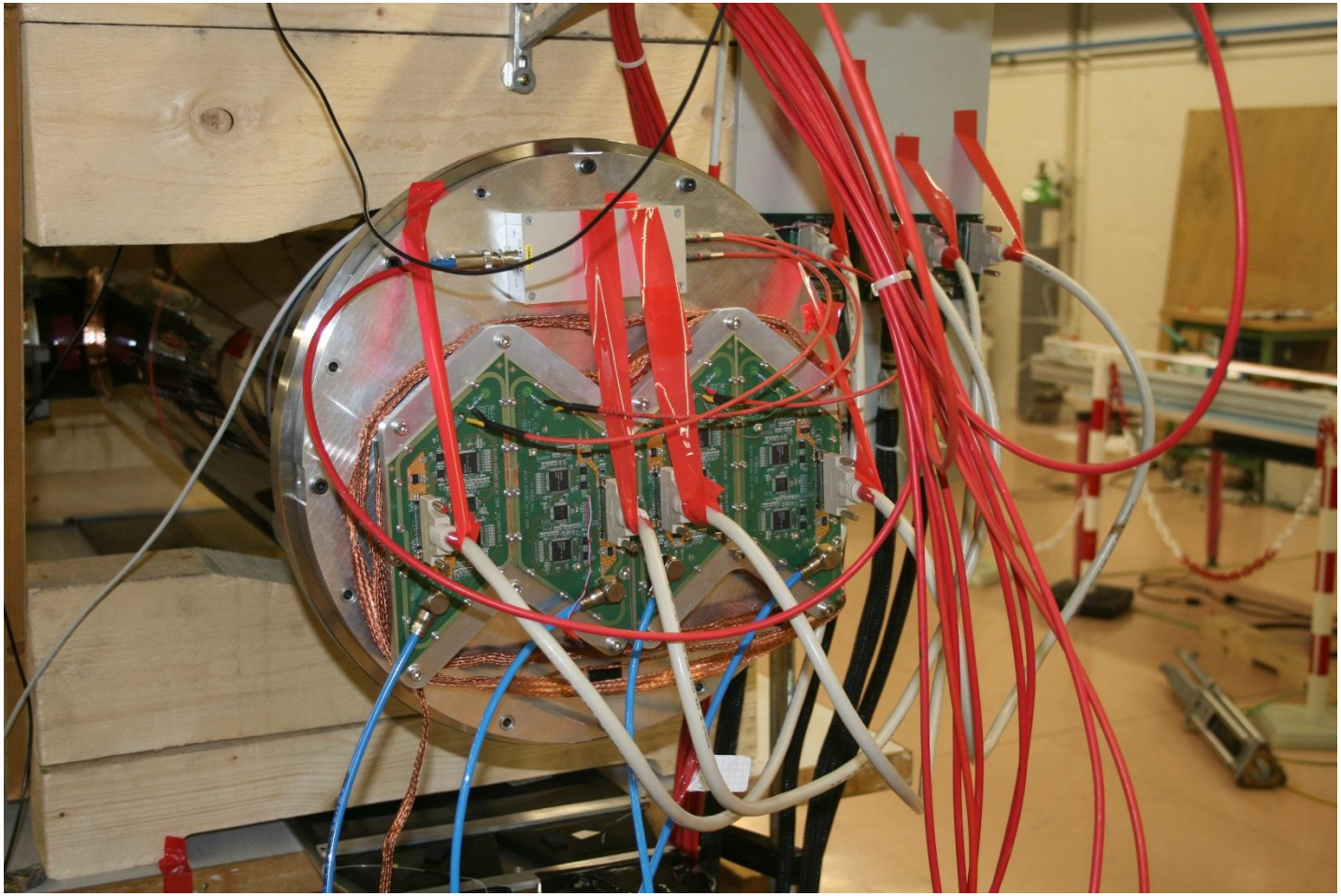
Requirements and Characteristics

Beam Rate (over all)	15 MHz
Max Straw Rate	700 kHz
Material Budget	≤0.5% X_0
$\Delta P/P$	<1%
Single Wire Resolution	~130 μm
Total Number of Straws	7168



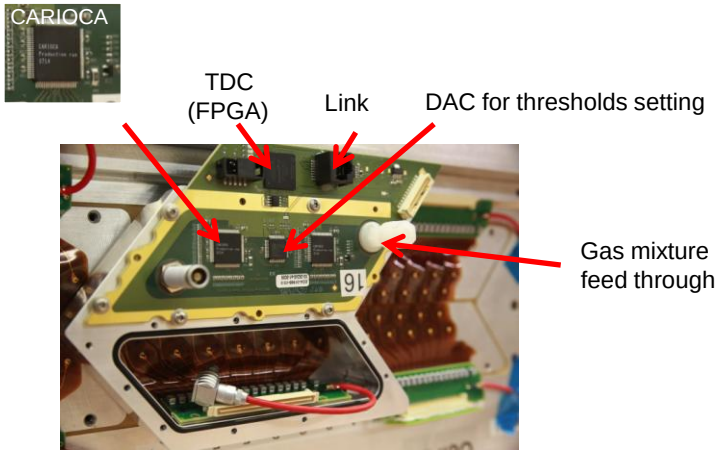
D, CERN

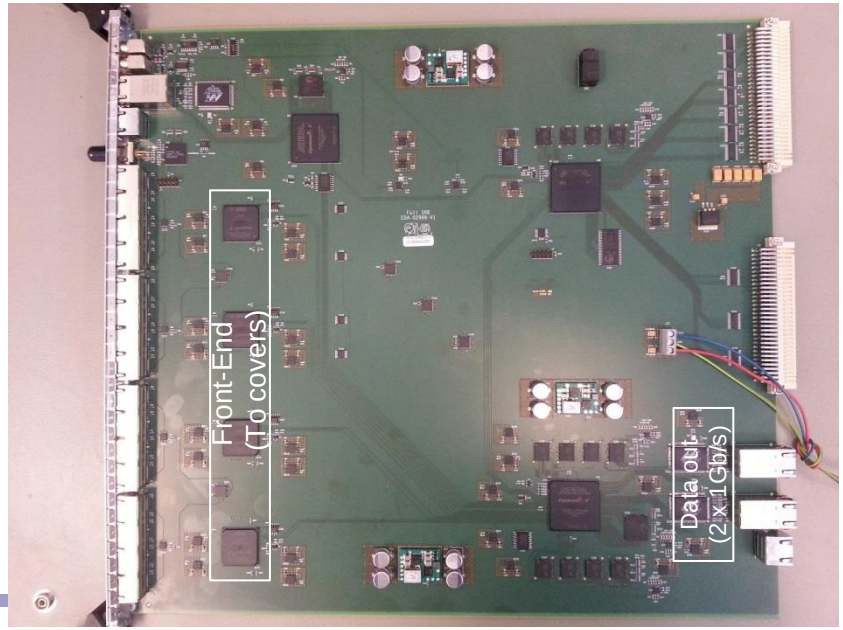
NA62 – straw prototype



Front-end and

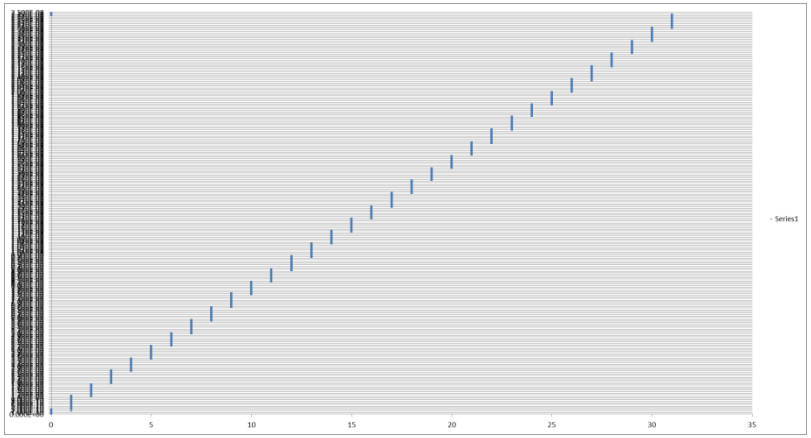
- COVER:
  - analog signal processing and discrimination (CARIOCA)
  - 32-TDCs integrated in FPGA (0.7ns bin)
  - directly connected the station and *physically seal* the gas volume providing the feed-through for HV and gas flow.
- SRB:
  - standard VME-9U
  - reading out of 16 COVERS
  - trigger matching
  - L0 trigger generation
  - data delivery to PC-farm
  - independent on line monitoring
  - time alignment tuning

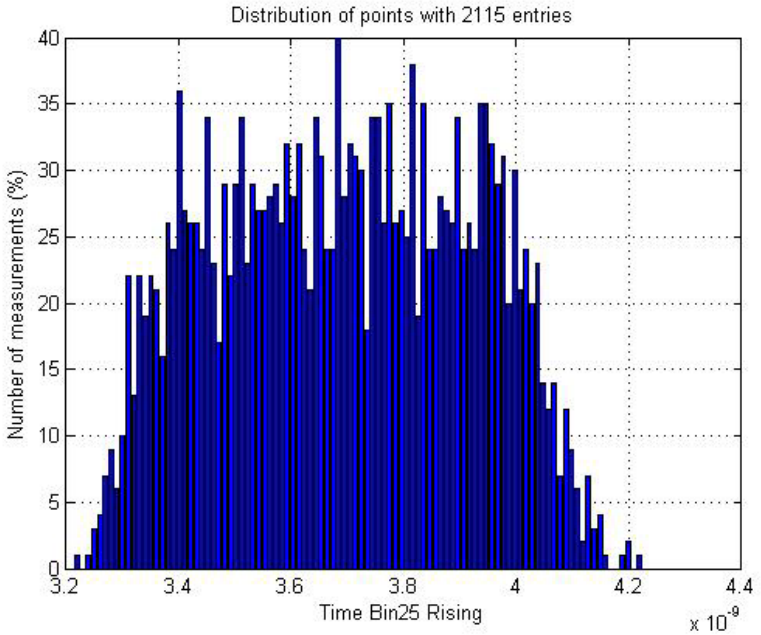




TDC in FPGA

- TDC performance measured on FPGA alone
  - '0' integral non-linearity
  - 70 ps differential non-linearity caused by signal routing



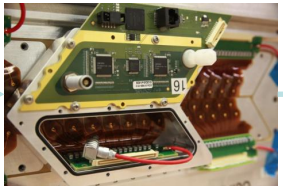


Straw Tracker

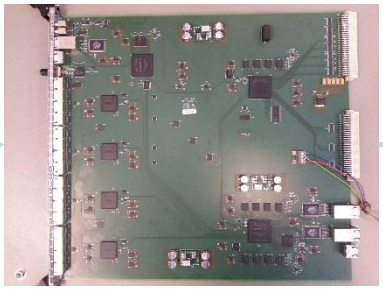
Characteristics

COVERs/View	30
SRB (Gran Tot)	32
Channels/COVER	16

16 straws



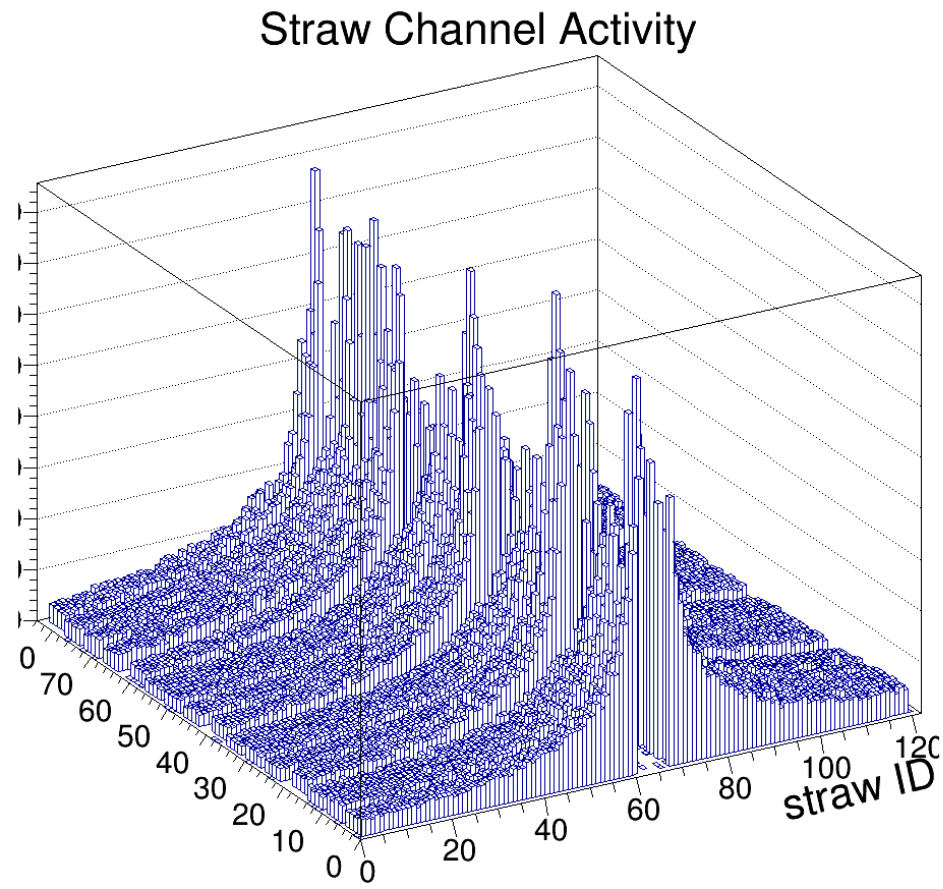
16 COVERS

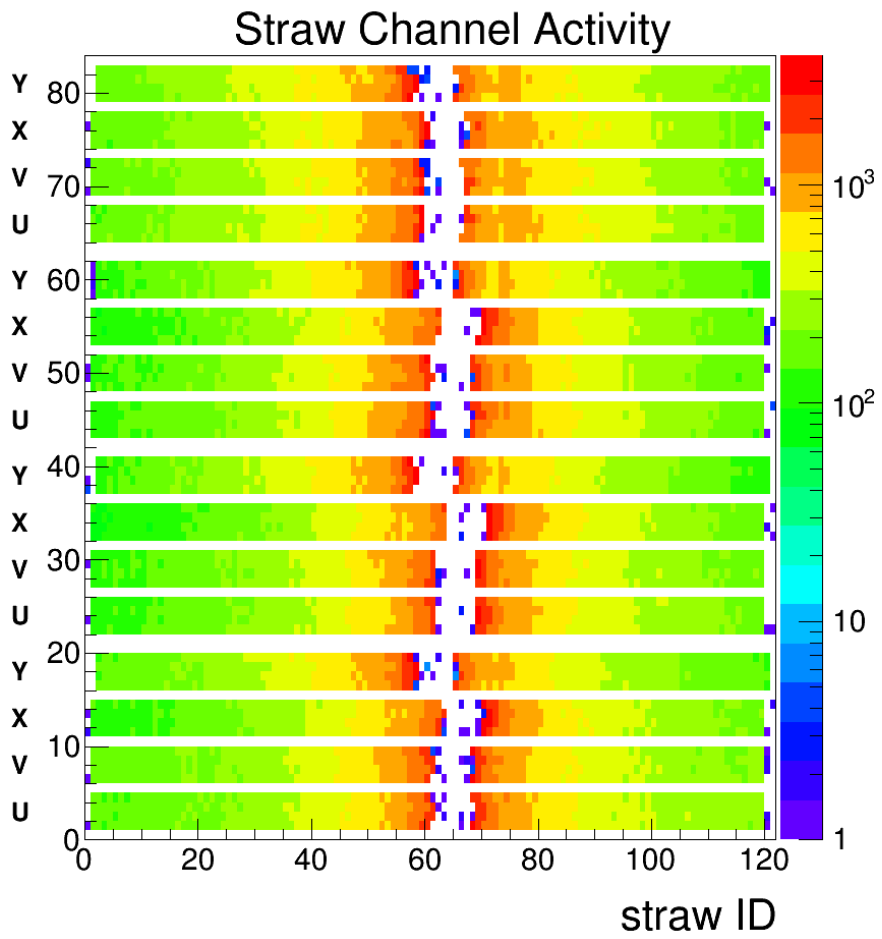


8 SRBs

PC Farm

NA62 – beam profile by straw detector





How to get to CERN

- Another talk, but
- Don’t be afraid! There are nice people at CERN ready to share they knowledge
- Numerous possibilities
- Visits from High schools, Universities
- Practically every electronics engineer has got a summer student or technical student or doctoral student or fellow
- CERN NEEDS CREATIVE PEOPLE WITH FANTASY WHO CAN DREAM AND MAKE THEIR DREAMS TRUE!