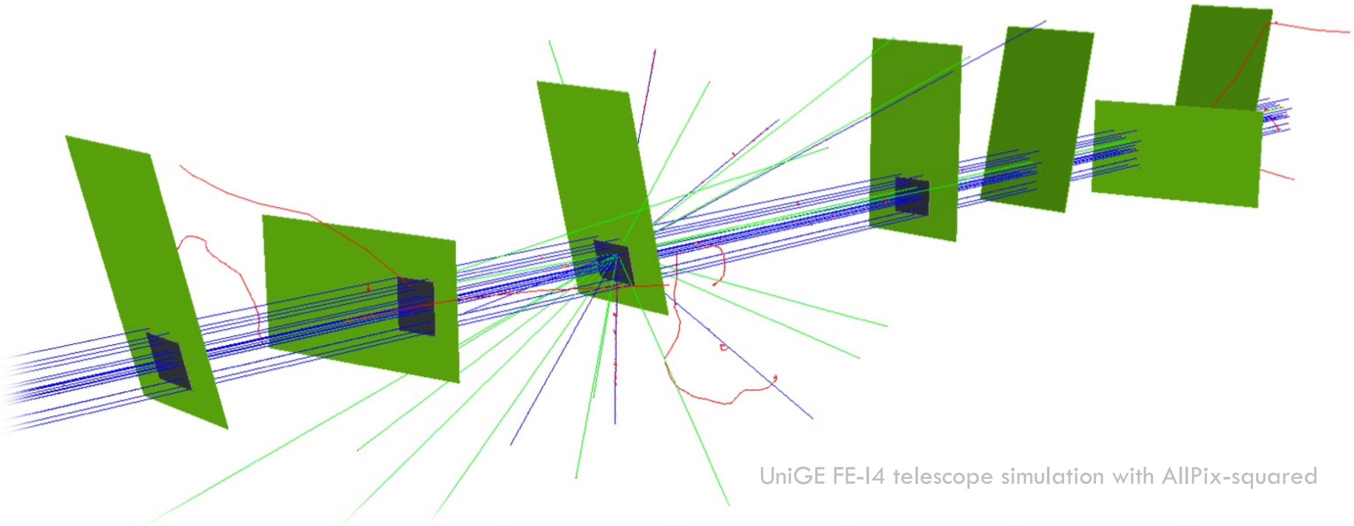
The UNIGE FE-I4b particle telescope

and one year of users data



UniGE FE-I4 telescope simulation with AllPix-squared

6th BTTB Workshop 2018
16-19 January, Zurich

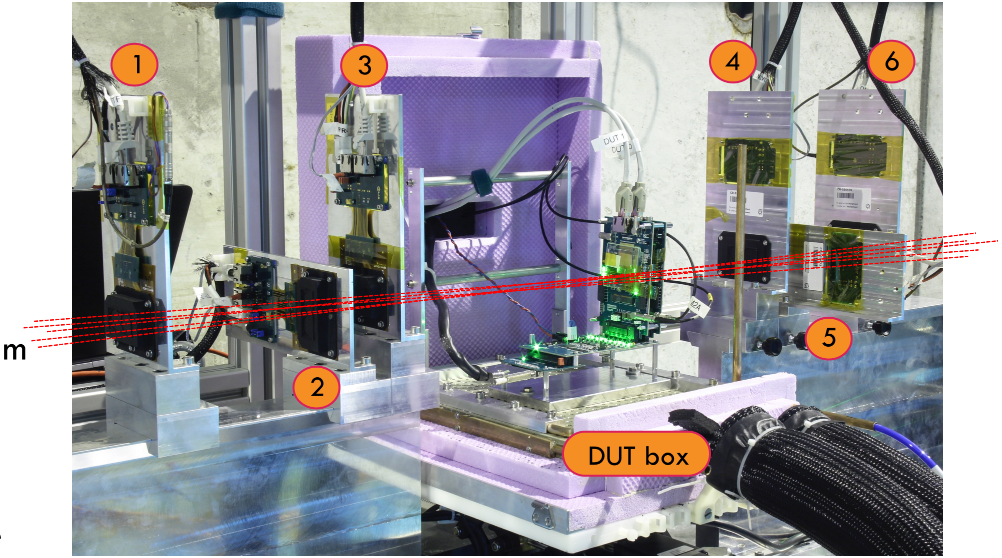
Mateus Vicente (UNIGE/CERN)
on behalf of UNIGE telescope group and ATLAS ams CMOS collaborators

UNIGE FE-I4b Telescope

"Permanently" installed at CERN SPS

mvicente@cern.ch – 17/01/18

- Paper: M.Benoit et al., JINST11 (2016) no.7, P07003
- 6 telescope planes
  - **FE-I4b** + **IBL planar pixel sensors** (200µm n^{+}-in-n)
    - 40MHz sampling, 4 bit ToT, trigger based
      - HitOr bus of the first and last telescope planes (AND or OR) triggering data read-out
      - Arbitrary mask to focus on DUT region
- DUT box with X and Y positioning, relative to the beam
  - Down to **-20 degC** on powered DUT (H35DEMO)
- HSIO II + RCE generation 3 DAQ system
  - **DAQ system** connected to a Linux server running the DAQ GUI, slow control, and online monitoring.



UNIGE FE-I4b Telescope

”Permanently” installed at CERN SPS

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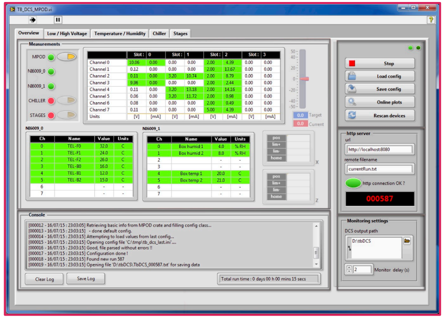
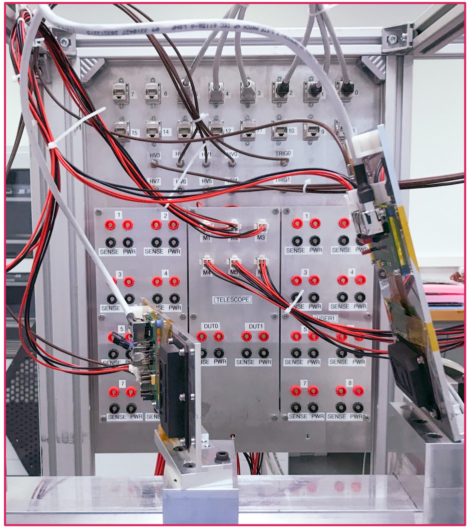
- Detector Control System - Slow control and monitoring
  - Central **LabView GUI** for the **DCS**
  - **Remote access** to all devices/services
  - **Monitoring and logging** of HV, temperature, position, and etc…
- Easy **patch panel** for user data/HV/LV/etc connections
- Wiener MPOD crate (HV/LV power supply)
  - **LV** - 8 channels – 120 V_{max} – 100 mA_{max}
  - **LV** - 16 channels – 8 V_{max} – 10 A_{max}
  - **HV** - 8 channels – 1 kV_{max} – 8 mA_{max}

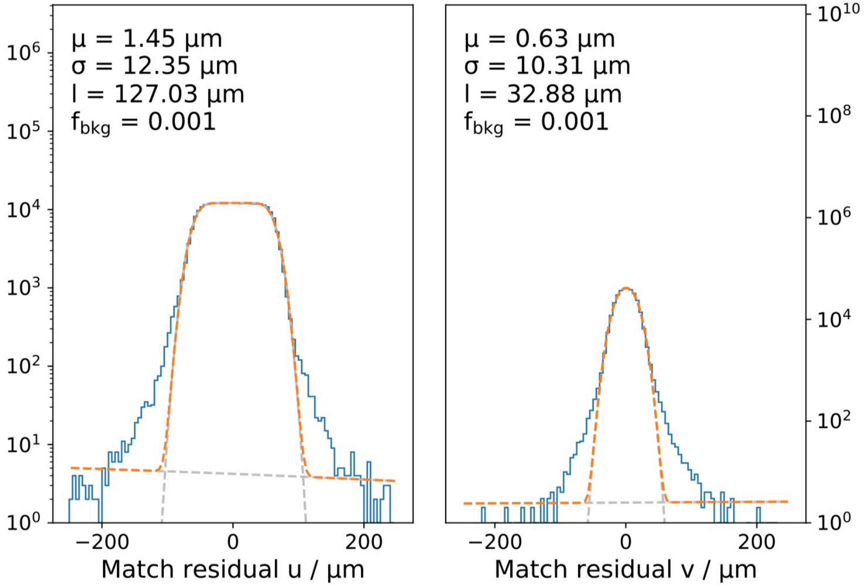




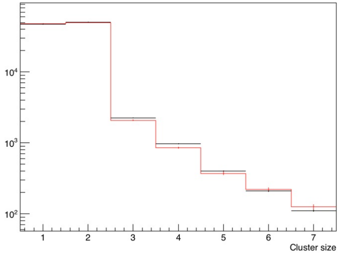
Telescope features

What to expect?

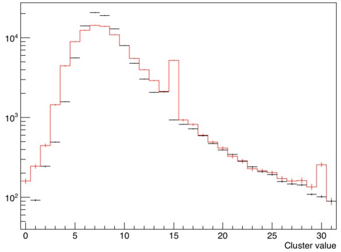
- Average detection efficiency per plane of **99.4%**
- Trigger rate (to be improved with new FELIX DAQ system)
  - **18.3 kHz** without DUT
  - **5.7 kHz** with FE-I4 size DUT
- Spatial resolution
  - σ_X = 11.7 µm and σ_Y = 8.3 µm (calculated)
  - σ_X = **12.35 µm** and σ_Y = **10.31 µm** (measured at DUT)
- AllPix-squared simulation for verification (**work-in-progress**)



Cluster size distribution



Cluster ToT distribution



Telescope/DUT integration

and a few user examples

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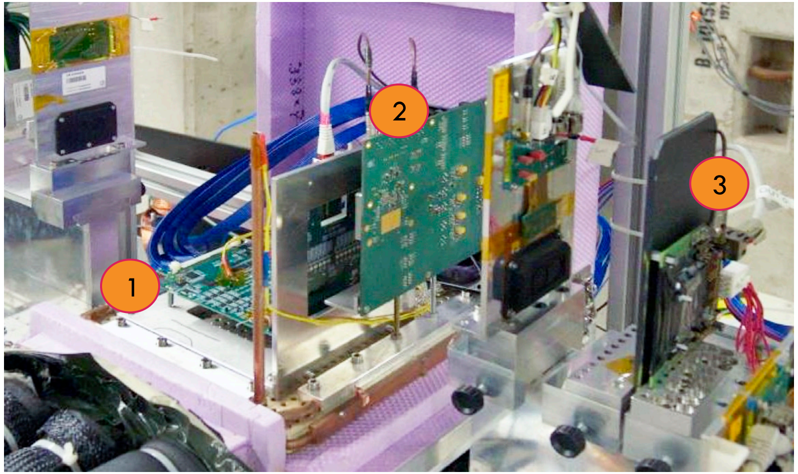
- **Plug&Play** for devices based on the **FE-I4b**
  - Read-out of up to **12 FE-I4b** user devices
- Users DUTs with dedicated DAQ
  - Trigger/Busy scheme
  - SBM Trigger/Acknowledge handshake
  - Trigger timestamp and offline sync
- Example picture (at FERMILAB 2017)
  1. H35DEMO capacitively coupled to FEI4
  2. Monolithic H35DEMO (trigger/busy scheme)
  3. FE-I4b planar assembly bump-bonded at ANL

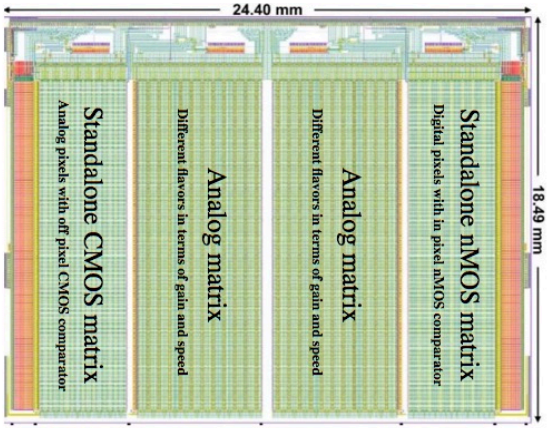


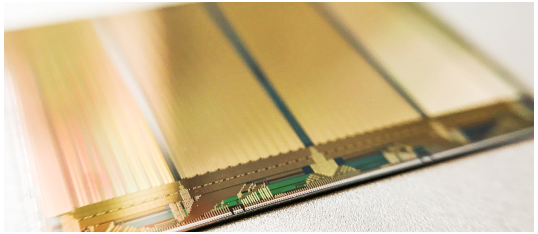
Collaborating institutes

The H35DEMO chip

HV-CMOS monolithic/hybrid prototype

- Pixel Sensor chip implemented in a **350 nm HV-CMOS** process
  - Pixel pitch of **50x250 um** (matching FE-I4 ROC footprint)
  - Different pixels and readout types
- Monolithic **nMOS matrix:**
  - Digital pixels with in-pixel nMOS comparator
  - Two flavors: with and without Time Walk compensation
- **Analog matrices** (2 arrays to be **coupled** to a FE-I4B ROC):
  - Different flavors in terms of gain and speed
- Monolithic **CMOS matrix:**
  - Analog pixels with off-pixel CMOS comparator
    - One (two) comparators on the left (right) sub-matrix





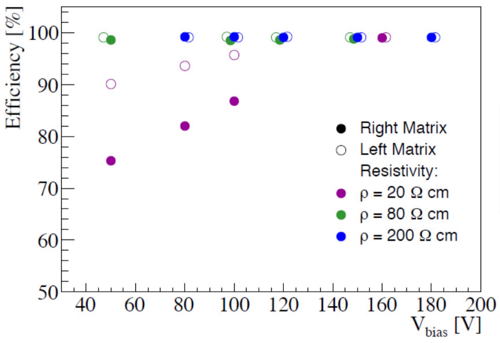
H35DEMO chip
Design: R. Casanova (IFAE), I. Peric (KIT) and E.Vilella (Uni. Liverpool)

H35DEMO Test-beam results

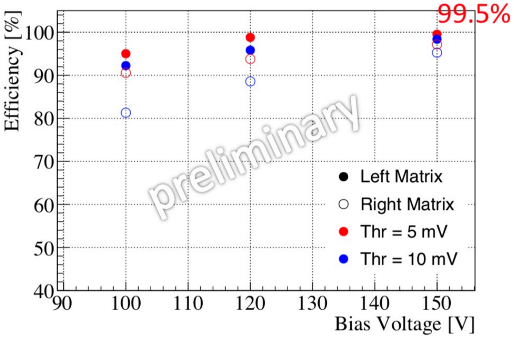
Monolithic CMOS pixel matrix

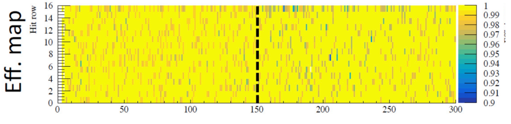
- IFAE readout system (for the **CMOS matrix**)
  - S.Terzo et al., JINST 12 (2017) no.6, C06009
- **Fermilab** in **April 2017**
  - Un-irradiated H35DEMO
- **SPS** in **September 2017**
  - **5e14** and **1e15** $\mathbf{n_{eq}cm^{-2}}$

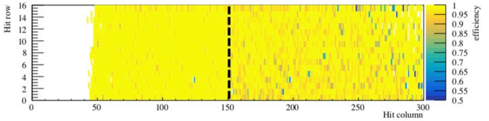
Un-irradiated

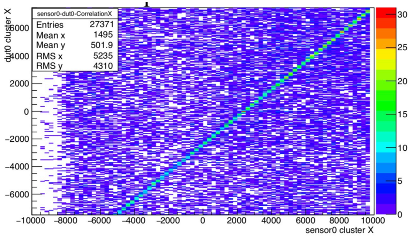


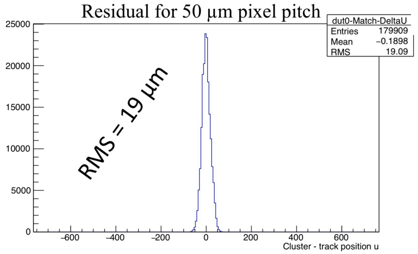
Irradiated







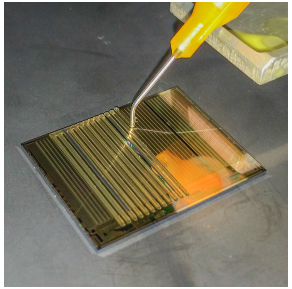


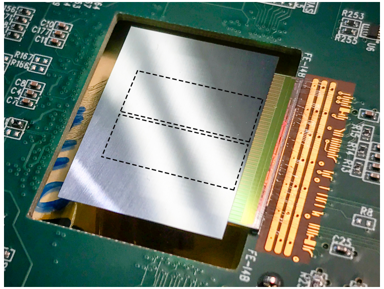


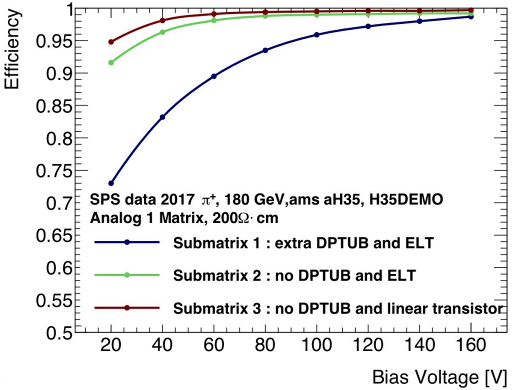
H35DEMO Test-beam results

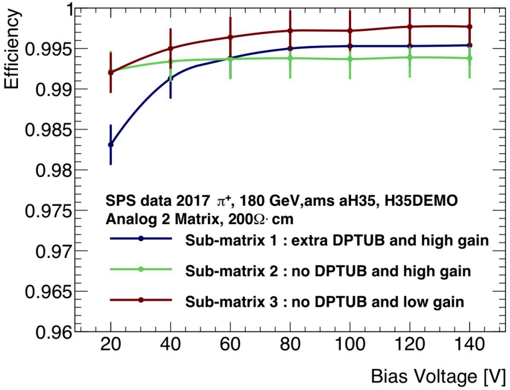
Capacitively coupled analog pixel matrices

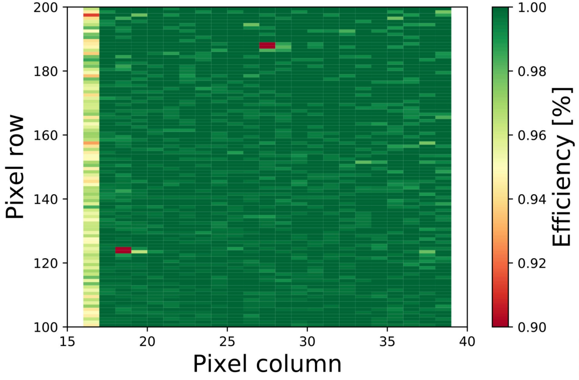
- Testbeam campaign at SPS
  - **120 GeV protons** beam
  - Samples with **3** different **resistivities**
    - + voltage and threshold scans
- **High efficiency** for all 3 pixel types in both analog matrices
  - Final results @ **arXiv:1712.08338v1**







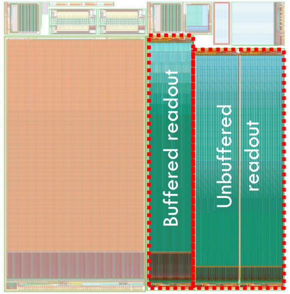


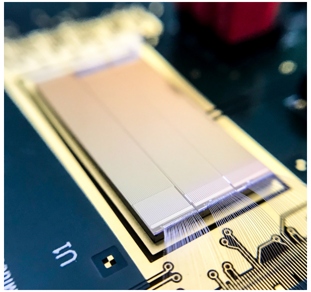


ATLASPix Test-beam (preliminary) results

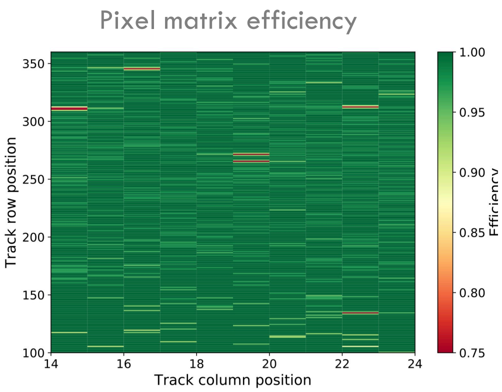
New monolithic, full size, demonstrator chip

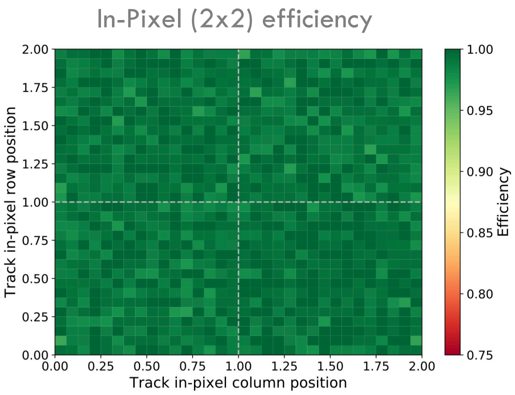
- ams aH18 **180 nm** HV-CMOS process
- Buffered matrix:
  - **Parallel-pixel-to-buffer architecture**
  - 56 × 320 pixels, **60μm×50μm** pitch
- Unbuffered matrix:
  - **Column-drain architecture**
  - 25 × 400 pixels, **130μm × 40μm** pitch

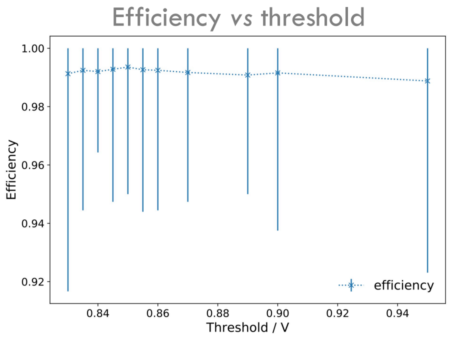


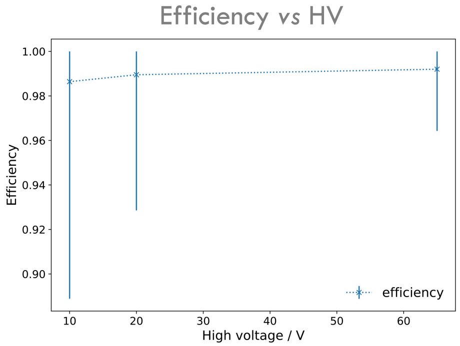


Designed at KIT, IFAE, Geneva, Heidelberg, Liverpool









Felix DAQ system development

The Front-End Link eXchange interface system

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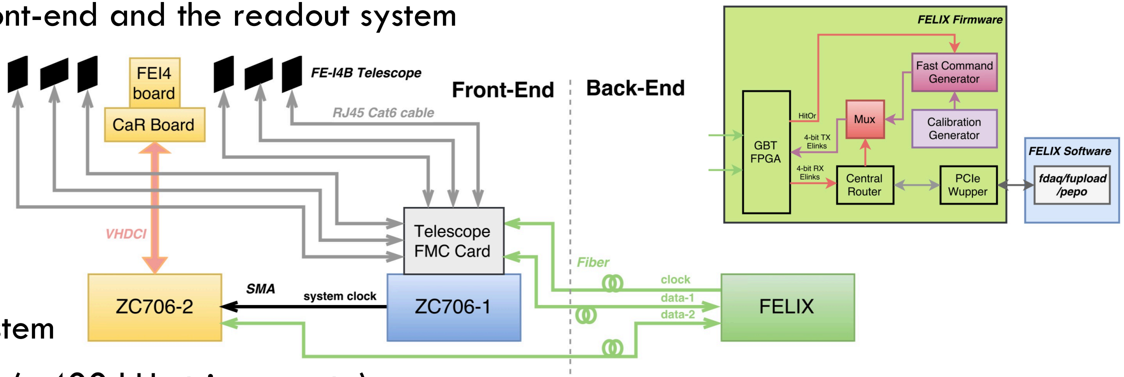
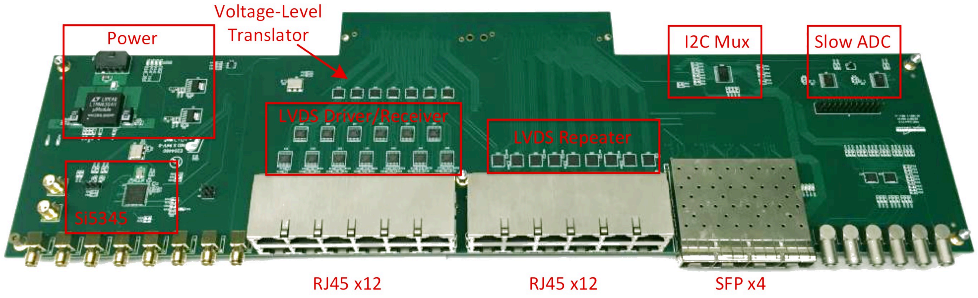
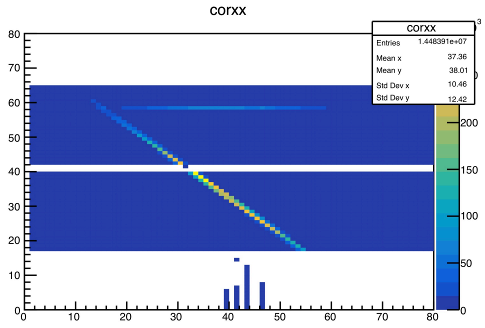
- **FELIX:** Interface between the detector front-end and the readout system
  - **PCIe** based system developed for the Phase-I and HL-LHC upgrade
  - Three **GBT links** on FELIX back-end
    - 1x clock distribution
    - 2x data transmission
- Successfully **integrated** with **CaRIBOu** system
- Recorded every particle in the SPS beam (~400 kHz trigger rate)







The Thin-TOF PET scanner

The TT-PET project

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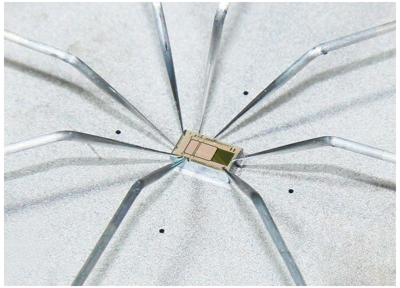
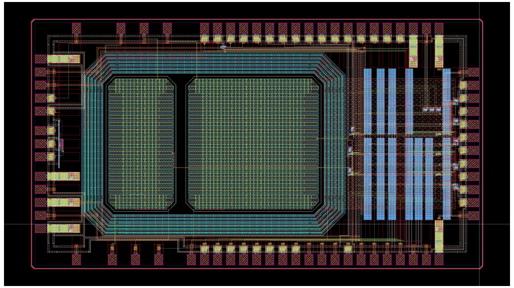
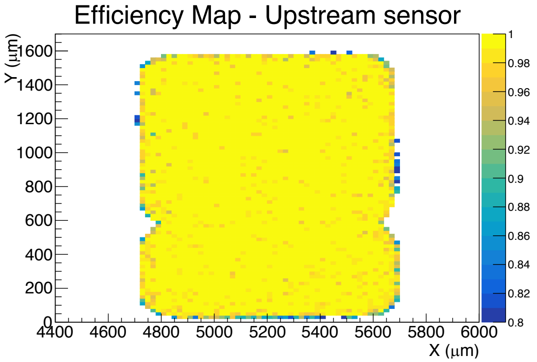
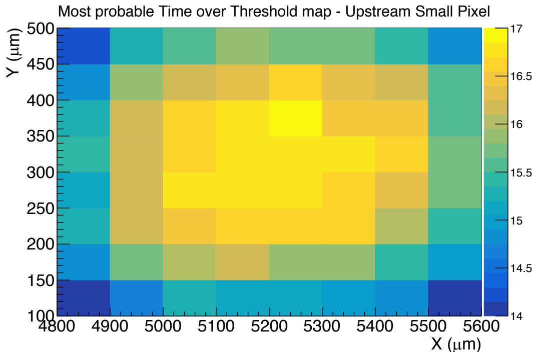
- A **compact** and **thin Time Of Flight PET** detector for small animals with Depth-Of-Interaction measurement capability
  - Total thickness of **2 cm**
  - 3D photon-detection granularity of **1.0 x 1.0 x 0.2 mm^3**
- TT-PET monolithic sensor
  - Stand-alone readout
  - Full depletion of **100µm** sensor thickness for substrate resistivity ≥ 500 Ωcm
  - Time resolutions of ~**100ps** (MIPs)









Summary and conclusions

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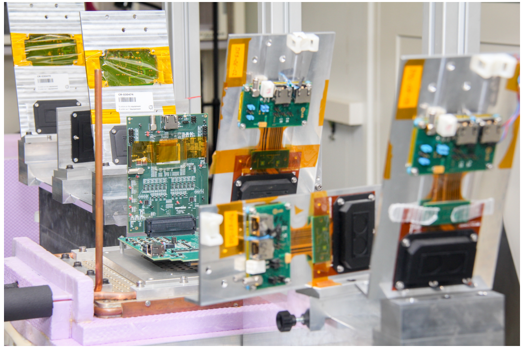
- UNIGE FE-I4 particle telescope
  - Installed most of the time at SPS
    - Going for a second period at the Fermilab Testbeam Facility
  - Services for the DUT HV/LV, temperature, position, etc...
    - All accessible remotely with a LabVIEW GUI for control and monitoring
    - Scriptable scans, such as high voltage
      - Practically no need for an in-situ shift
  - ~5 kHz trigger rate with ~11µm spatial resolution
  - Multiple ways for telescope/DUT integration



H35DEMO on the UniGE FE-I4 telescope

- User results
  - H35DEMO monolithic and capacitively coupled results shows uniform efficiency over the pixel matrix over 99.5%
  - New ATLAXPix already shows good efficiency, although further investigation is still needed (testbeam campaign at Fermilab starting at end of January
  - The Felix system was integrated to readout the telescope planes and DUT (via CaRIBOu) and measure all particles on the SPS beam
  - TT-PET project successfully used the telescope tracks reconstruction to map the detection efficiency on their detector, showing high and uniform efficiency.
- The telescope is always being improved with the feedback from the users