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Lea Caminada (PSI|UZH)

Activities of PSI HEP Group

Fostering Swiss collaboration towards a future circular collider – 7.9.2021

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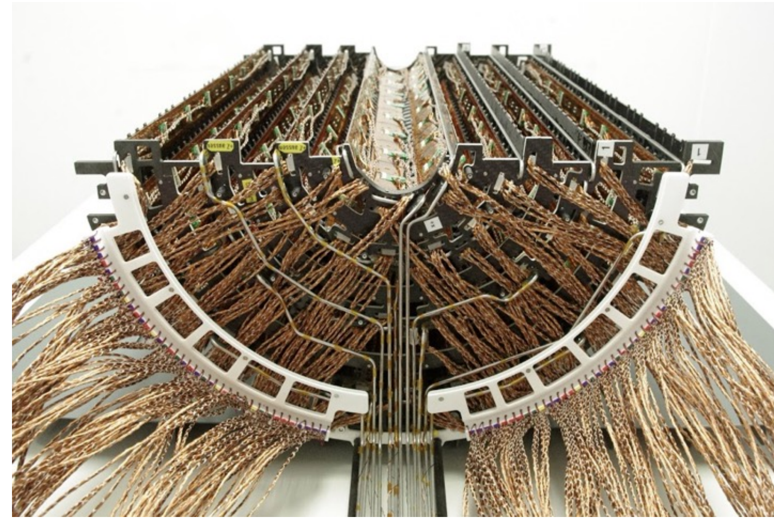
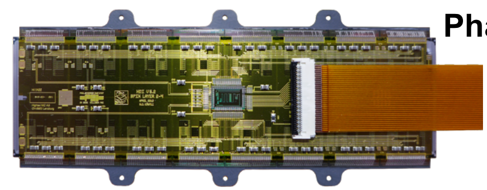
HEP group at PSI

- One of the groups within the Laboratory of particle physics (LTP) at PSI
- Currently 6 senior scientists, 2 postdocs, 3 PhD students (1 ETH, 2 UZH), 1 technician and electronics engineer (with LTP electronics group)
- CMS experiment at LHC and mu3e experiment at PSI

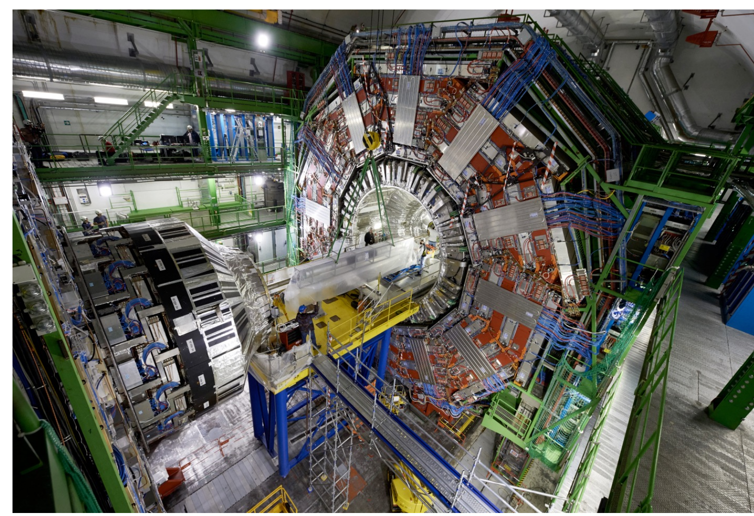
Activities in CMS

- CH consortium (PSI,ETH,UZH) led design, construction, integration, commissioning of original and Phase-1 CMS pixel detector
  - Major parts built at Swiss institutes with components from local industry
- Key contributions to pixel detector operation, calibration, performance monitoring, local reconstruction, tracking and vertexing
- Physics analysis, in particular B and Higgs physics
- Responsible (together with UZH) for design and construction for extended pixel detector (TEPX) for CMS Phase-2





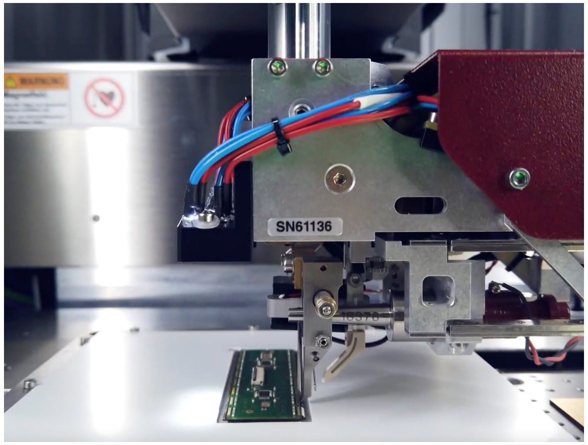
Phase-1 Pixel Detector



Key competences in pixel detector development

- Design of hybrid pixel detectors
  – Readout chip design for high-rate, high-radiation applications
  – Design of planar silicon sensors
  – Hybrid module design
  – System conception of pixel control and readout
  – Design of DAQ system for module testing
  – Light-weight detector mechanical structures

- Detector construction
  – In-house bump-bonding and wire-bonding
  – Instruments for wafer-level testing of readout chips and sensors
  – Module assembly lines (manual and robotic)
  – Integration of full detector systems (with access to clean room facilities)
  – Detector installation within CMS



Current R&D activities

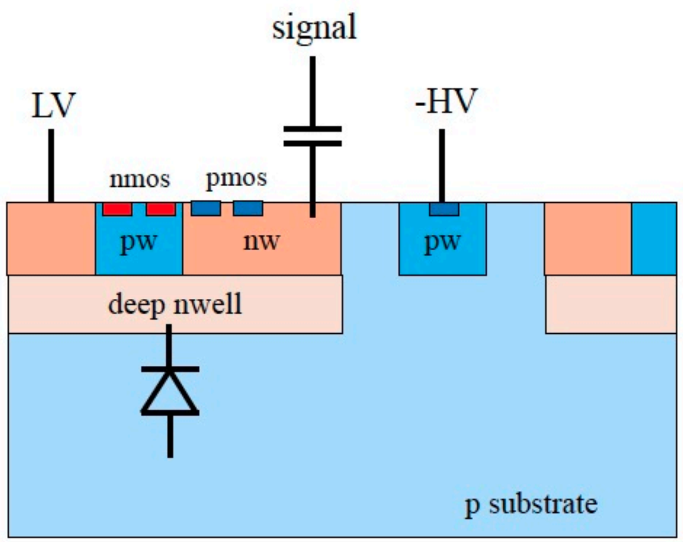
- Development of radiation tolerant Depleted Monolithic Active Pixel Sensors (DMAPS) for high-rate applications
  - in close collaboration with ETH (group of Rainer Wallny) and UZH (group of Florencia Canelli)
  - Partner organization in AIDAinnova WP5

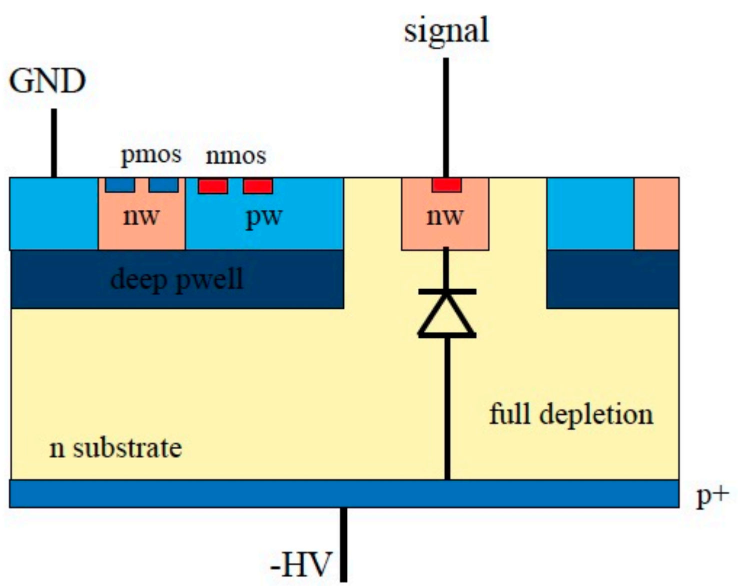
- Development of readout electronics for fast silicon timing detectors (with time resolution < 30ps)
  - in close collaboration with UZH (group of Ben Kilminster)

- For future upgrades of the CMS experiment, future collider experiments, in-house experiments and other applications

DMAPS activities

- Started work on DMAPS in 2018
  - Evaluated several technologies. Now following two with own chip submissions
- Short/medium term aims
  - Gain experience with DMAPS
  - Gain experience with ToA measurements
  - Extend radiation hardness of DMAPS to "moderate" levels (a few 10^{15}Neq/cm^2)





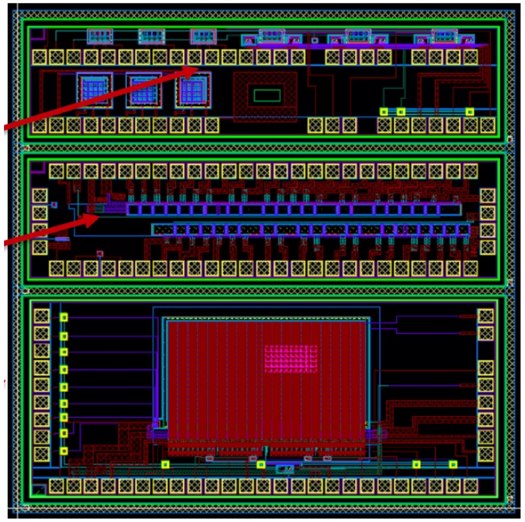
Large Fill Factor (area of collection electrode)
Large sensor capacitance, but shorter drift paths and homogenous electric field
TSI, AMS, LFoundry150, …

Small Fill Factor
Small sensor capacitance, but longer drift paths and low field regions
LFoundry110, ESPROS, TowerJazz, …

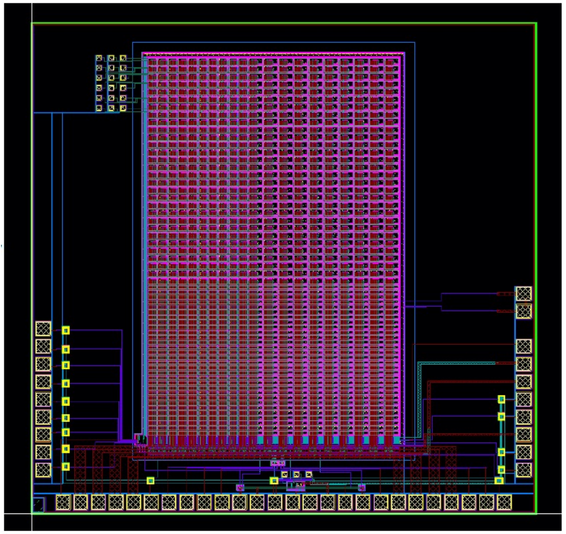
PAUL SCHERRER INSTITUT PSI TSI

- 180nm HV process derived from former IBM/AMS process
- First MPW submission on standard substrate received in May 2020
  - Sensor and transistor test structures
  - 5x5 mm^2 test chip with 20x40 pixels
- Prototype run (shared with KIT, Ivan Peric) in June 2021
  - 2 types of high-resistivity silicon (200 Ωcm and 8 kΩcm)
  - Extra implant to create isolated n-wells
  - Sensor and transistor test structures, PLL, I2C interface, ADC, DAC
- Submission of first larger-size chip early 2022

Test structures MPW 2020



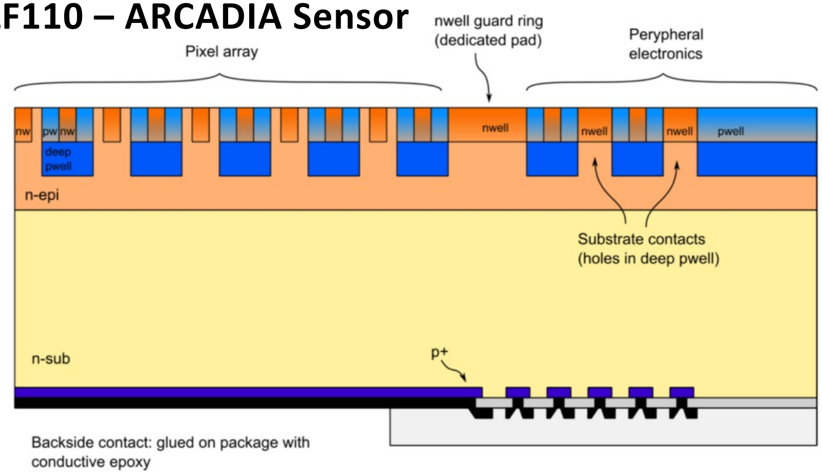
Pixel chip Prototype run 2021



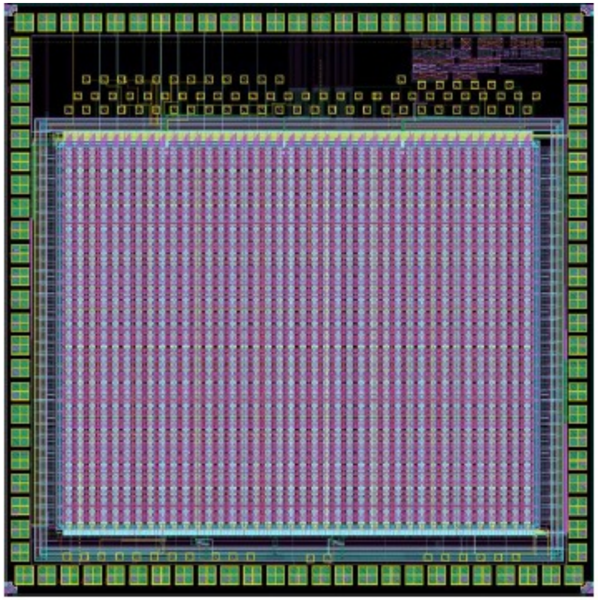
LFoundry110 – Monolithic Timing Chip (MOTIC)

- LF110 process modified by ARCADIA collaboration (INFN CSNV Call Project)
  - Design of charge collection node and backside processing in Torino
  - Thinned wafers (300, 100, 50 μm)
- First submissions of test structures in LF110 without modifications
- MOTIC
  - Pulse height and time of arrival is measured
  - Two chips of 5x5 mm²: MOTIC A (with varying preamplifiers) and MOTIC B (with varying charge collection electrodes)
- Diced chips received in August 2021

LF110 – ARCADIA Sensor



MOTIC A

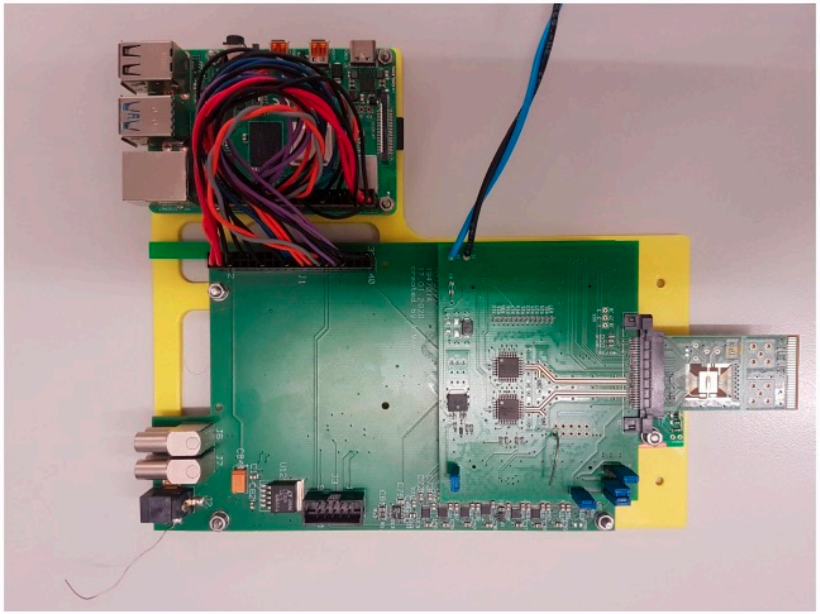


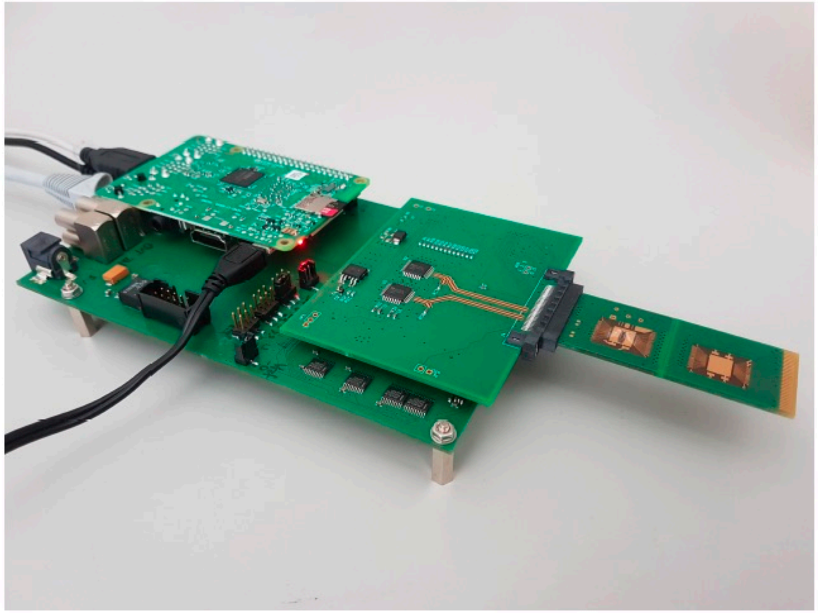
Pixel timing chip

- 4D tracking in future experiments requires detector with excellent spatial and temporal resolution
- Generic R&D for readout electronics for fast silicon sensors
  - Hybrid detectors with LGAD sensors
  - ToA in DMAPS
- Study of different TDC designs
  - TDC technology already exists, but needs to be adapted to constraints in HEP
    - Fit within pixels
    - Low power consumption
    - Radiation tolerance
- Effort at PSI started in 2019
  - Submitted and received three different TDC designs
  - Two technologies: LF110 and UMC110

Pixel timing chip

- Characterization of different designs currently ongoing
  – First results promising
- Test pixels that can be connected to sensors are also available
- One TDC version implemented in MOTIC chip
- Next step is design of prototype pixel chip (30x30 pixels with size of 100x100μm^2)





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Summary

PSI HEP group has key competences

… in design construction and operation of hybrid silicon pixel detectors

… track and vertex reconstruction

… physics analysis

Exploring new approaches for future tacking detectors

… DMAPS

… electronics for fast timing

Interest for application in future particle physics experiments