# The *Tangerine* Project

## Towards Next Generation Silicon Detectors


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7th MT meeting (virtuell)

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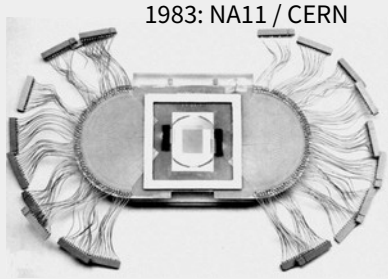
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

# Fast, High-Resolution, Low-Material Silicon Detectors




- Silicon detectors are vital in many experiments
  - Fine segmentation, fast readout: high track multiplicities
  - Precise position measurement: momentum determination
    tracking, vertexing, flavor tagging
  - Fast signal formation: particle ID, ToF
- After > 40 years still potential for innovation & improvement

**Nuclear matter physics:**
Next-generation experiments

- Reference for time-of-flight PID
- 4D tracking in high particle flux
- Minimum scattering < 0.5% $X_0$

**Particle physics:**
Precision measurements at future lepton colliders

- High impact parameter resolution
- Good time resolution ~ 1 ns
- Minimum scattering < 0.1% $X_0$

# Tangerine – Introduction

- Funded by Helmholtz M Innovation Pool (MU / MT)
  - Funding period 2021 – 2023
  - Kick-off meeting February
- New technologies open up new horizons for particle detectors:
  - MAPS in novel CMOS technologies: highly integrated, high-resolution detectors
  - LGAD/RSD sensors and ASICs: precise timing information, large-area systems
- Goals of Tangerine
  - **Establish leading role** in development & system integration for these technologies
  - Integrate hardware-based approaches for **data reduction / AI on-chip**
  - Foster expertise by networking & **training next generation** of detector physicists

# Project Structure / Work Packages

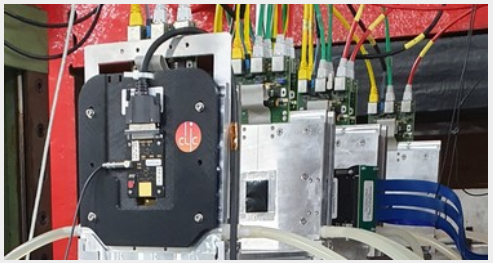
- **WP 1:** Monolithic pixel detectors in novel CMOS imaging technology
  - Low-material high-precision pixel detectors for future experiments
  - Investigate novel CMOS imaging technologies with small feature sizes
  - Development of fully-integrated detector prototype

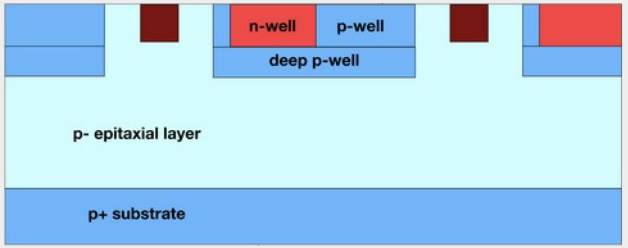
- **WP 2:** LGAD & RSD sensors for large 4D tracking detectors with high time resolution
  - Investigation of  TI-LGAD and RSD-LGAD sensors
  - Development of LGAD readout ASICs for large-area detector systems

- **WP 3:** Pixel detector innovation platform (DESY, GSI, KIT)
  - Provide training platform for future detector physicists
  - Organization of workshops & summer schools

# WP 1 – MAPS in novel CMOS Imaging Technology

- Goal: develop next-generation **low-material high-precision pixel detectors**
  - Towards detector for future Higgs factory / CBM
  - Exploring future applications for astroparticle / photon science
  - First demonstrator: beam telescope as test bed for detector R&D
- MAPS good candidate: **combine sensor & readout** in single wafer
  DTS talk: M. Deveaux
- Significant progress over past years, first large-scale applications
- Complex front-end in small pixel difficult in current technologies
- **New technology: 65 nm CIS** – first designs for HEP
  - Increase logic density, allow smaller pixels
  - Lower overall analog/digital power consumption

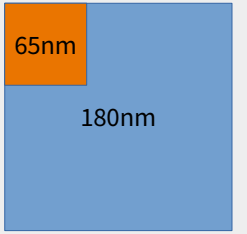






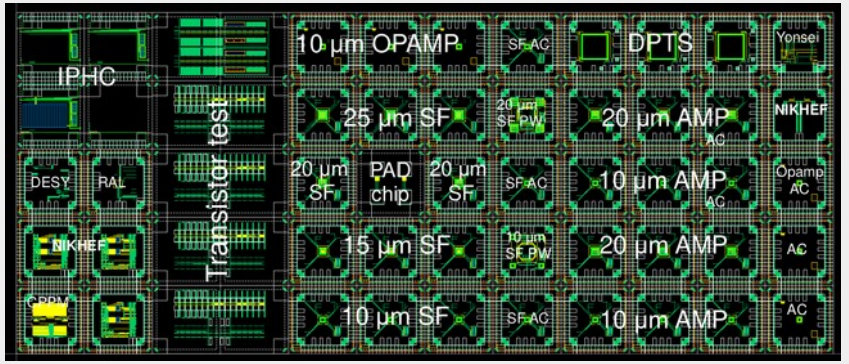


**Performance Goals for MAPS Sensor**
- Position resolution ≤ 3 µm
- Timing resolution ~ 1 – 10 ns
- Material budget ~50 µm
- Charge measurement for interpolation



# WP 1 – First Test Structures in 65 nm Imaging Process

- Formed international collaboration for common submissions to foundry
- Common design effort for first prototypes & test structures,  submitted 12/2020
  - Transistor test structures
  - Analog test pixels
  - Rolling shutter matrices
  - Front-end amplifiers




- Expected back summer 2021, preparation for testing ongoing
- Started TCAD simulations for sensor layout optimizations

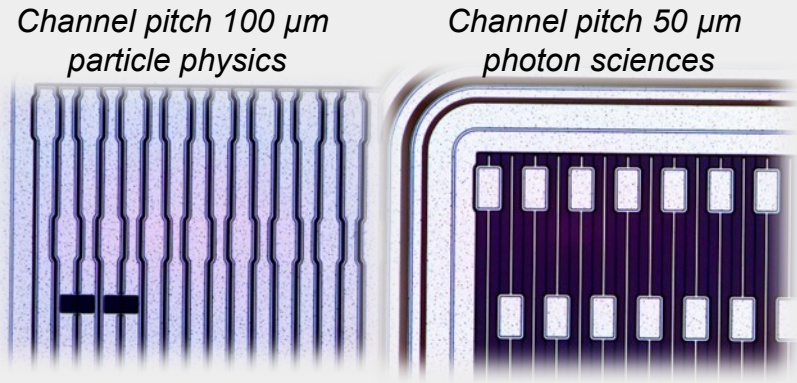
# WP 2 – Low Gain Avalanche Detectors

- First Trench Isolated (TI-LGAD)
  - Microstrip sensor layouts for photon science and particle physics
  - Status: first sensors produced

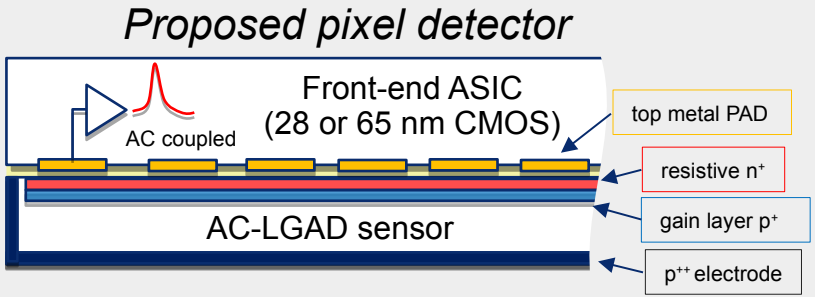
  ***Work performed in the framework of RD50***

  DTS talk: M. Patil, E. Trifonova
- Resistive AC coupling (RSD-LGAD)
  - Pixel segmentation on ASIC (pitch < 25 µm)
  - Excellent spatial resolution of ~ µm
  - Time resolution of 20 ps (by very thin sensor)
  - Excellent SNR, uniform gain of 10 - 30
  - Interconnection based on wafer-adhesive bonding
    → large production volume
  - Material-budget similar to monolithic

Very thin sensor (20 µm)
Edgeless technology




Trench isolated LGAD structure designed at KIT



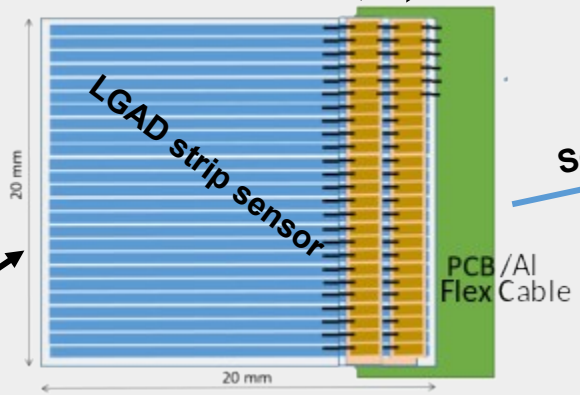
# WP 2 – 4D tracking system based on strip LGAD sensors

## Prototyping and R&D scenario

DTS talk: J. Pietraszko

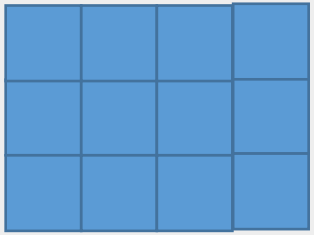
**(1) Analog ASIC Amp/Disc**
- Pitch 100µm/50µm
- Timing below 20ps
- Rates: 10 Mhz/ch; 1 GHz/cm²

**(2) TDC ASIC**
- Pitch 100µm/50µm
- Intrinsic timing below 20ps
- Rates: 10 Mhz/ch; 1 GHz/cm²




Scalability

**Larger active areas**



**Applications**

- HADES Forward Wall system
- HADES T0 barrel
- ToF systems for IonCT
- Energy Recovery Linacs (TU-DA)
- Tracking system for ee experiment
- Beam monitoring at GSI/FAIR
- T0 system for CBM @ FAIR

**LGAD Sensor production and R&D**
- Running sensor production for HADES (Q3 2021)
- Thinning 700µm → 100µm or below
- Future: Fill-factor improvements → Trench Isolated LGAD (close to 100%)

**Anticipated performance of the 4D tracking system**
- Timing resolution: 20 – 30 ps
- Material budget: 2 layers x 100µm
- Position resolution: 30µm
- Dimensions: above several cm²

# Summary

- Establish leading role in development & integration of new technologies
- Project just started, kick-off meeting coming up
- Work packages have started work already
  - WP 1: first test structures designed & submitted, preparation for testing
  - WP 2: LGAD sensors produced, preparation of ASIC design effort
- Kick-off meeting in February
  - Ongoing recruitment effort
  - Deliverable definition


DESY.