ALCOR: a mixed-signal SiPM readout ASIC for Cherenkov and cryogenic detectors

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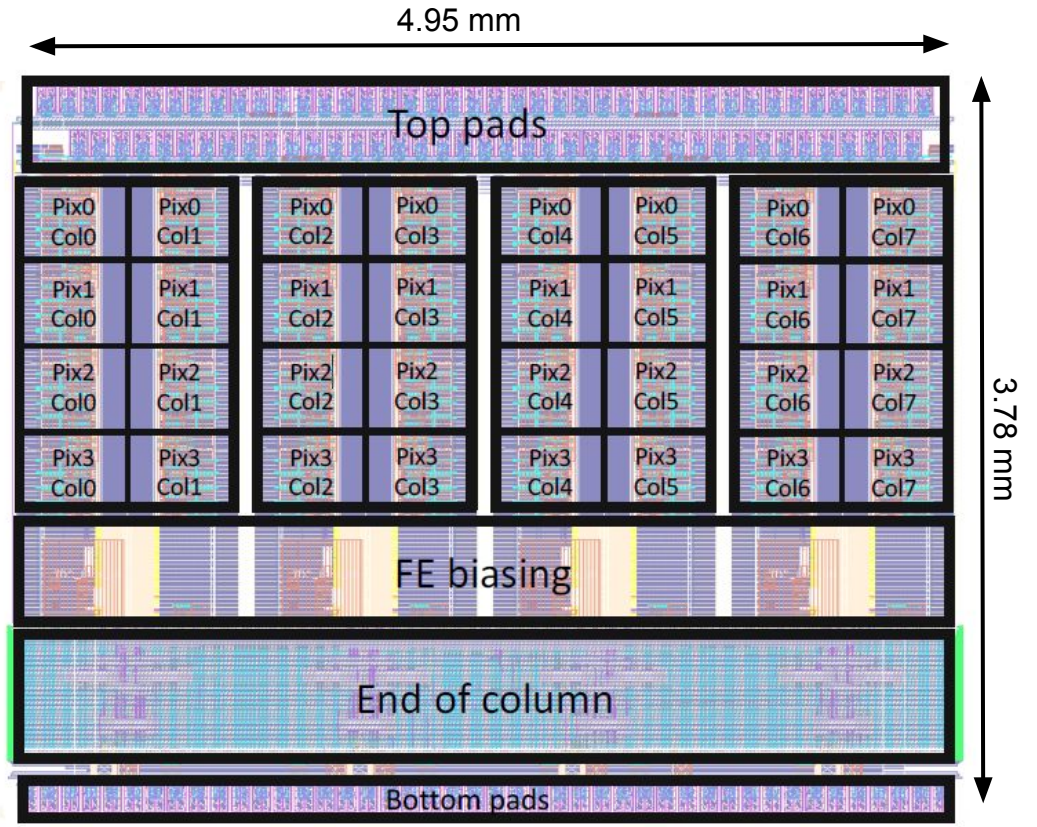
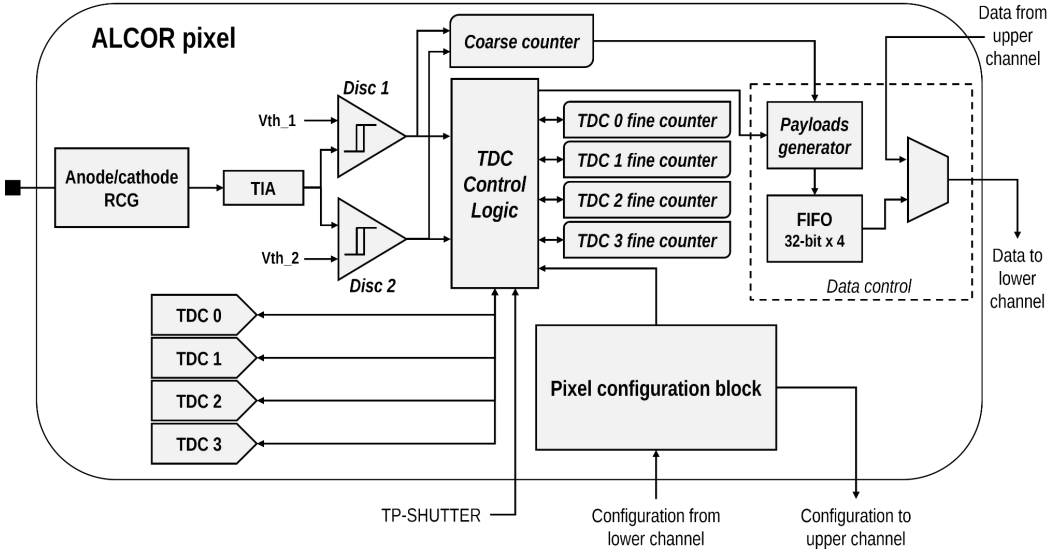
ALCOR (**A** **L**ow Power **C**hip for **O**ptical Sensor **R**eadout)

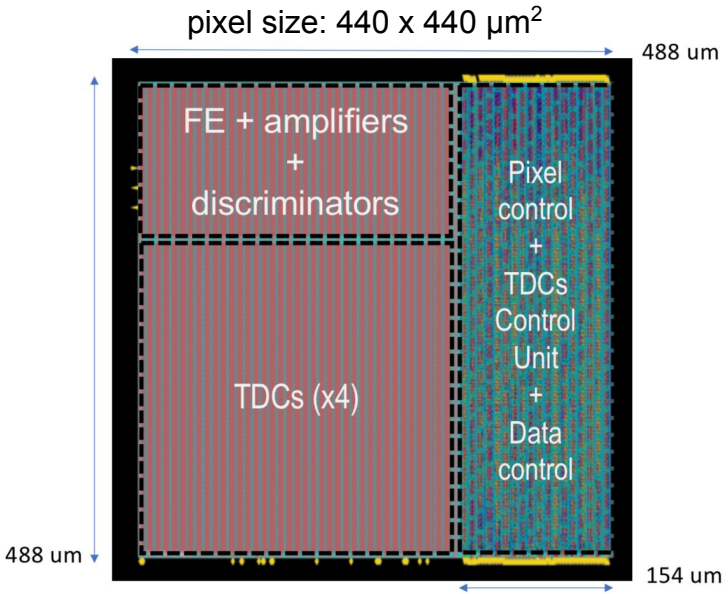
Mixed-signal ASIC for SiPM readout with **single-photon sensitivity**

- **32-pixel** matrix (8x4) providing signal **amplification**, **conditioning** and **digitization**
- Time measurement: **ToA** + **ToT** or **Slew-Rate** information for **time walk correction**
- **Triggerless** readout scheme with **fully digital output**: 32-bit event word, 4 LVDS 320 MHz DDR Tx links
- Power consumption **~10-12 mW/channel**
- 0.11 µm CMOS technology



Pixel architecture



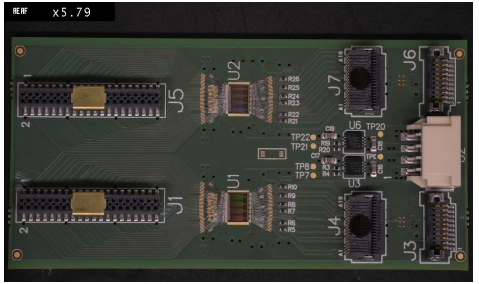


- **Dual-polarity RCG input stage** current conveyor (**Z_{in} = 10-20 Ω**) + **TIA** with 4 gain settings
- **2 leading edge discriminators** with independent (and per pixel) threshold settings (6-bit DAC)
- **4 TDCs** based on **analogue interpolation** with **25-50 ps** time-bin (at 320 MHz clock frequency)
- Pixel control logic handles TDC operation, pixel configuration, operating mode and data transmission
- TP-**Shutter** to inhibit events digitization (synchronous now, asynchronous with ns time window in next version)

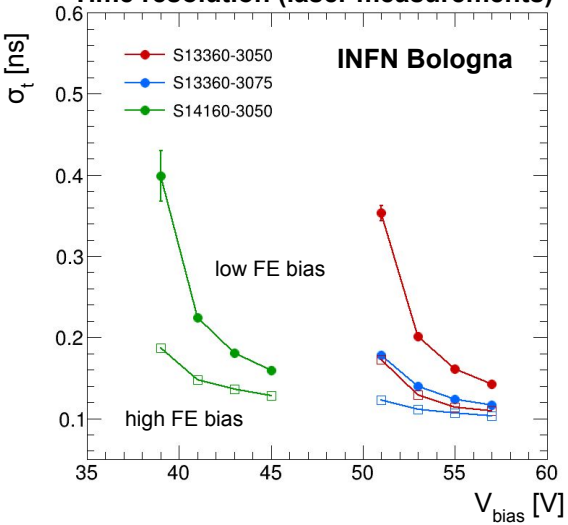
Results highlights

- First version developed for the readout of SiPMs at **cryogenic temperatures**, in the framework of **DarkSide** (ALCOR v1, 2020)
- Adopted for the readout of SiPM sensors of the **ePIC dRICH** detector at EIC and extensively used within the dRICH Collaboration since 2021 (ALCOR v2, 2023)

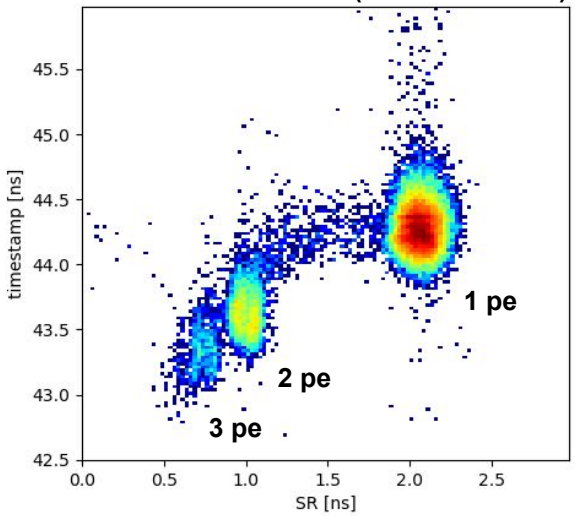
dRICH ALCOR-FE-DUAL



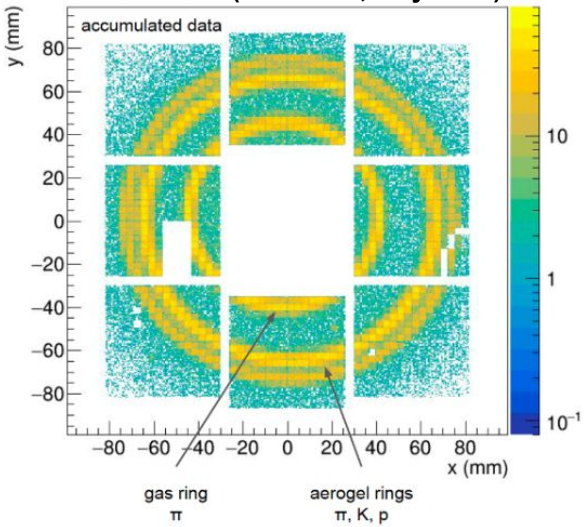
Time resolution (laser measurements)



Time walk correction (SlewRate mode)

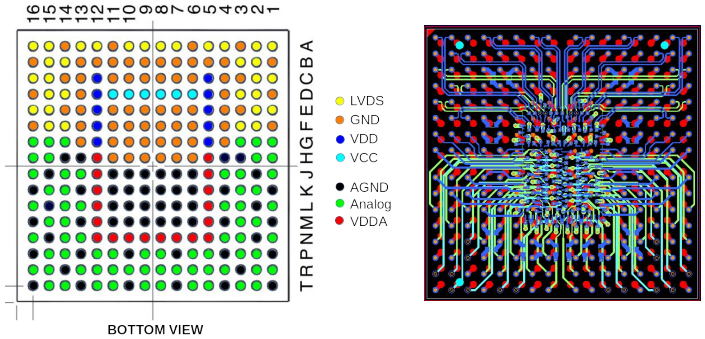


Beam test with prototype dRICH and PDUs (CERN-PS, May 2024)



32 FE-DUAL (64 ALCOR, **2048 channels**)
SiPM: HPK **S13360-3050** and **S13360-3075** (3x3 mm^2, T = -30/-40°C)

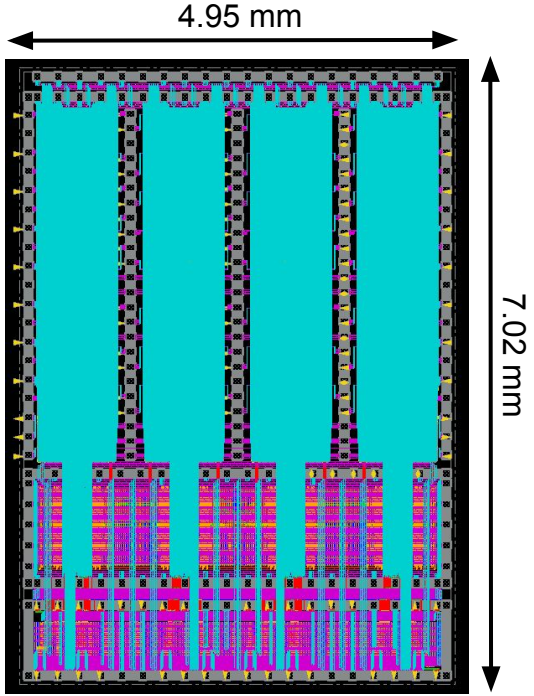
ALCOR for ePIC



ALCOR v3: **64-channel** ASIC (8x8 matrix) inside **BGA package** (256 balls, 17x17 mm^2, 1 mm pitch)

- Amplifier with **increased bandwidth** to improve time resolution, approaching 100 ps at low V_{bias}
- **Hysteresis discriminator** to avoid re-triggering on slow tail with very low thresholds
- New clock frequency: **394.08 MHz** (4x EIC clock frequency)
- **Digital shutter** to inhibit pixel digital logic to **cut out-of-time DCR signals** and reduce data throughput (~10.2 ns EIC bunch spacing, **2-3 ns** time window → 3x-5x data reduction before ALCOR digitization)

Tape-out on 31st March 2025



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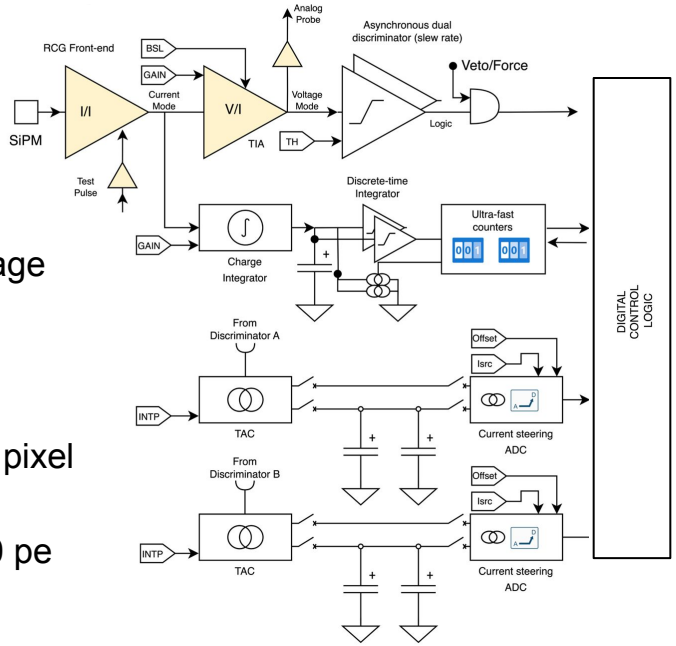
ALCOR for DUNE

DENEB (**D**UNE Integrated **E**lectronics for **Ne**utrino **B**eams): readout ASIC for the **GRAIN** Liquid Argon Detector (DUNE) → detection of Argon scintillation light with coded masks/UV lenses + **SiPMs**:

- Electronics operating from **T = 300 K** to **T = 77 K**
- ToA with a resolution of **100-150 ps** with a threshold of 0.5 pe
- **Photon counting** in each event window (dynamic range **> 100 pe**)
- Limited number of cables entering the cryostat



Start from ALCOR architecture, new features:

- **1024 channels** (32x32 pixel matrix, area ≈ **20x20 mm^2**), BGA package
- ALCOR FE with improved response at **cryogenic temperatures**
- Operation at **87 K** → **P < 15 mW/ch**, **power gating**
- Programmable **data-link sharing** among pixel columns
- **Time:** TAC + SAR ADC → faster conversion capability and reduced pixel dead time (backward compatible with ALCOR Wilkinson ADC)
- **Charge:** discrete-time charge integrator with 0.25 pe resolution, 500 pe dynamic range, up to 50 simultaneous pe

1024-channel demonstrator tape-out scheduled for the end of 2025