PACIFIC
a readout ASIC for the LHCb Scintillating Fibre Tracker

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On behalf of the LHCb SciFi Collaboration

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LHCb Upgrade

increase the luminosity to $2 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$ to boost significantly the physics reach

- more severe radiation environment
- 40MHz readout triggerless
- 5× current occupancy

the current Tracking Stations
(Gas Straw Tube Tracker + Silicon Tracker)
 replaced by
Scintillating Fibre Tracker

total area 340m$^2$, resolution < 100µm
Scintillating Fibre Tracker (SciFi)

- 250µm diameter scintillating fibre wound into a 6-layer 2.5m-long fibre mat
  - one end equipped with a mirror
  - read out by SiPM arrays (single channel: 250µm × 1.625mm, 104 pixels)

- 3 × Tracking Stations => 524,000 SiPM channels

More related talks:
- SciFi: A large Scintillating Fibre Tracker for LHCb by Ulrich Uwer
  23/5/2017 TIPP parallel section
- Characterisation of the Hamamatsu silicon photomultiplier arrays for the LHCb Scintillating Fibre Tracker Upgrade by Axel Kuonen
  23/5/2017 TIPP parallel section

Schematic of the SciFi module
Design Challenges for the Readout ASIC

- handle the long-tail SiPM signals with high detector occupancy?
  - minimize the spillover effect
  - reduce dead time
  - sufficient response plateau

- in total 524,000 SiPM channels to be read out at 40MHz?
  - most efficient way to digitize and process the data
  - low power consumption
PACIFIC: a low Power Asic for the sCIntillating FIbre traCker

- 64-channel current mode input
- configurable fast shaper: minimize spillover
- interleaved gated-integrators per channel: minimize dead time
- 2-bit non-linear digitisation per channel: minimum data for sufficient tracking information
- adjustable input anode DC voltage (4-bit DAC, 50mV/LSB)

Power consumption <10mW/channel
CMOS 130nm Technology

Next version: 320MHz SLVS differential output
Prototype

2013.05  2013.11  2014.08  2015.08  2016.09  2017.03  2018 - 2019

PACIFICr0  PACIFICr1  PACIFICr2  PACIFICr3  PACIFICr4  PACIFICr5

preamplifier only  single channel full analog chain  8-channel full analog chain  8-channel single-ended output full design  64-channel single-ended output full design  64-channel differential output full design

mass production & detector installation

expected back in May

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X.Han
Preamplifier

- double feedback **current conveyor** (50Ω input impedance, 250MHz bandwidth)
- 4× selectable gains at the output mirror
- closed loop **transimpedance amplifier** to convert current into voltage

![Block diagram of the PACIFIC preamplifier](image)

PACIFICr4 preamplifier linearity measured with charge injection
Fast Shaper

- **double pole-zero cancellation for the SiPM signals**
  - first pole-zero cancels the slow component from SiPM capacitance and quenching resistor
  - second pole-zero cancels the fast component from trace parasitics and input impedance

- **parameters tunable via slow control registers** to adapt to different types of SiPMs

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SiPM signal before the shaper stage

40ns/div

SiPM signal after the shaper stage

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block diagram of the PACIFIC shaper

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5/23/2017

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Interleaved Gated Integrators

- one integrator is working, while the other is reset: minimum dead time
- integration synchronized with the system clock

block diagram of the PACIFIC interleaved gated integrators

PACIFICr4 integrator response measured with light injection

~14ns integration plateau with ≤10% signal variation
Digitisation

- analog signal digitized by three threshold-tunable comparators per channel
- three thresholds based on the cluster algorithm
  - low threshold: noise suppression
  - middle threshold: cluster candidate
  - high threshold: single channel clusters

sketch of a typical cluster produced when particles passing through the SciFi detector

cluster?

Yes! Yes! NO. Yes! NO.
Light Injection Result

- 5ns-width light pulse generated by vertical-cavity surface-emitting lasers (VCSEL)
- using SciFi custom SiPM arrays

PACIFIC threshold scan result: clear photo-peak steps
Test Beam at DESY 2017

- DESY beamline T22, Feb 2017
- 1~6 GeV electrons (maximum rate @ 2 GeV) continuous beam
Cluster Size & Spatial Resolution

- Cluster size distribution
  - X-axis: Cluster size [Channels]
  - Y-axis: Clusters
  - Range: 0 to 6

- Spatial resolution
  - Y-axis: Entries
  - X-axis: Residual [µm]
  - Gaussian least squares fit: $\sigma = (89.6 \pm 0.4) \mu$m
  - Data

Preliminary
Conclusions and Future Plans

- a low power ASIC designed for the LHCb Scintillating Fibre Tracker
  - configurable fast shaper
  - minimum integration dead time
  - 40MHz readout
  - 2-bit data per channel to encode signal amplitude

- the full design prototype has been evaluated in the test beam at DESY in Feb 2017

- a new version with SLVS differential output submitted and will be back soon

- plan to launch engineering run at the end of 2017
Thank you!

Questions?