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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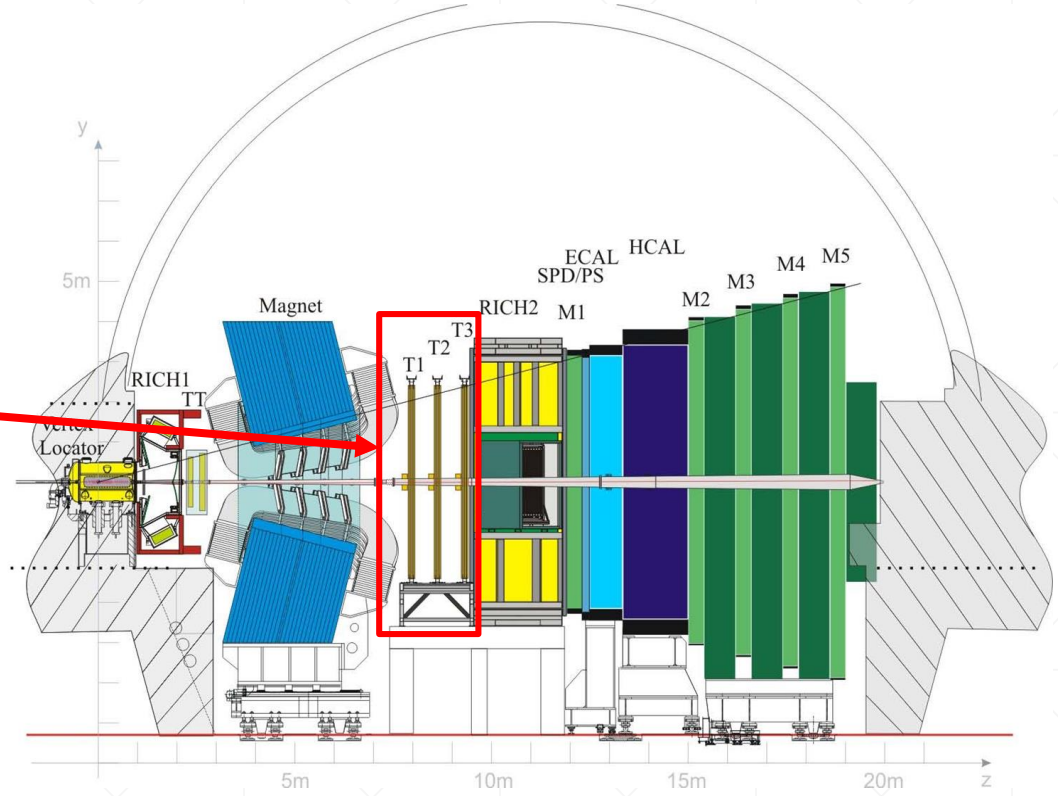
LHCb Upgrade

increase the luminosity to $\mathbf{2\times10^{33}cm^{-2}s^{-1}}$ 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 $\mathbf{340m^2}$, resolution < **100μm**

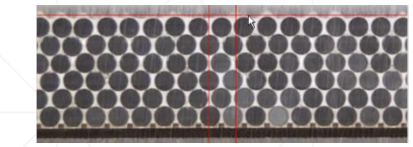


Schematic view of the current LHCb detector

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, 104pixels)

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



cross section of the fibre mat

Schematic of the SciFi module

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

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

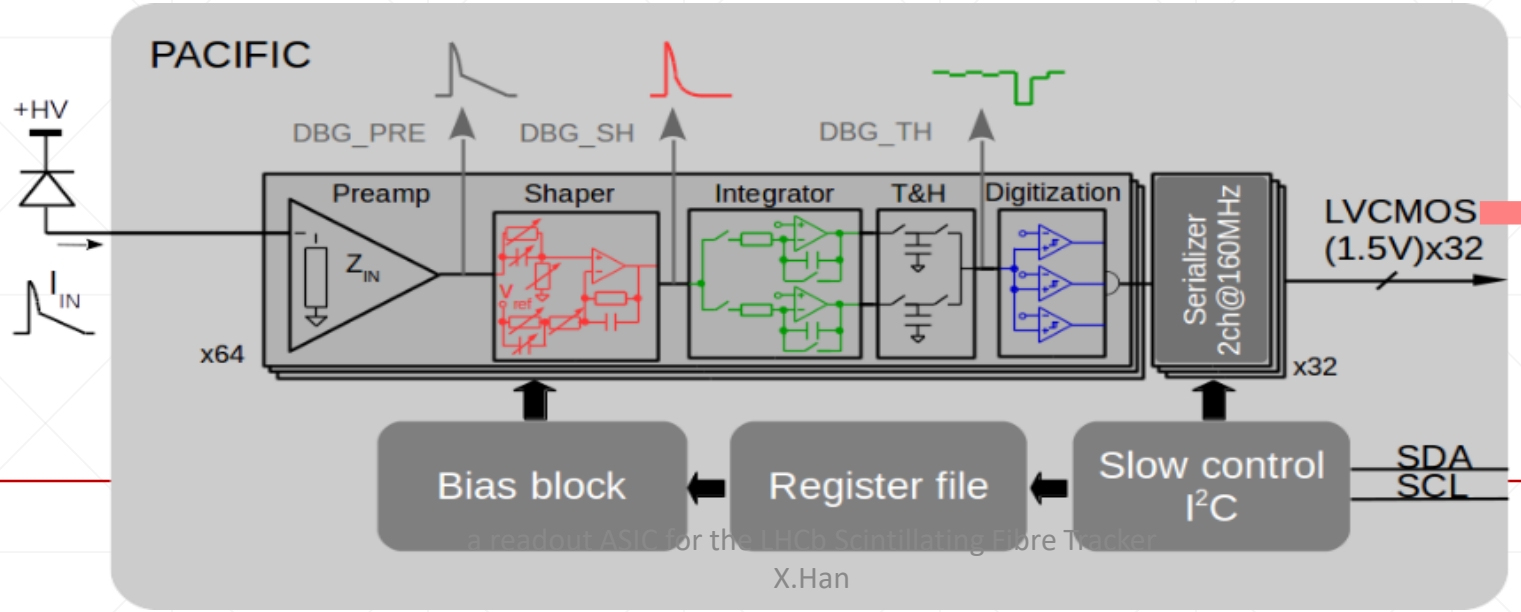
- in total 524,000 SiPM channels to be read out at 40MHz ?
  - ✓ most efficient way to digitize and process the data
  - ✓ low power consumption

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)

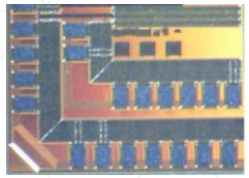
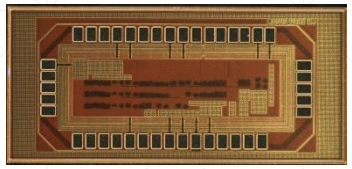
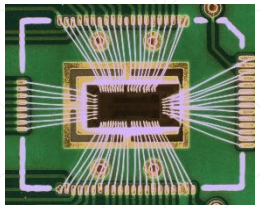
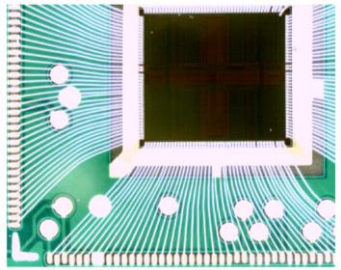
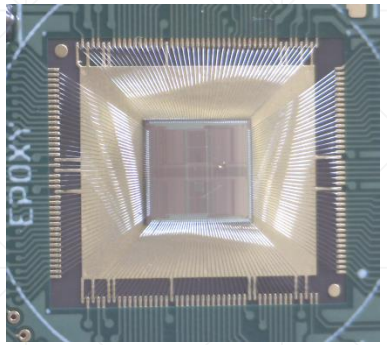
power consumption <10mW/channel

CMOS 130nm Technology



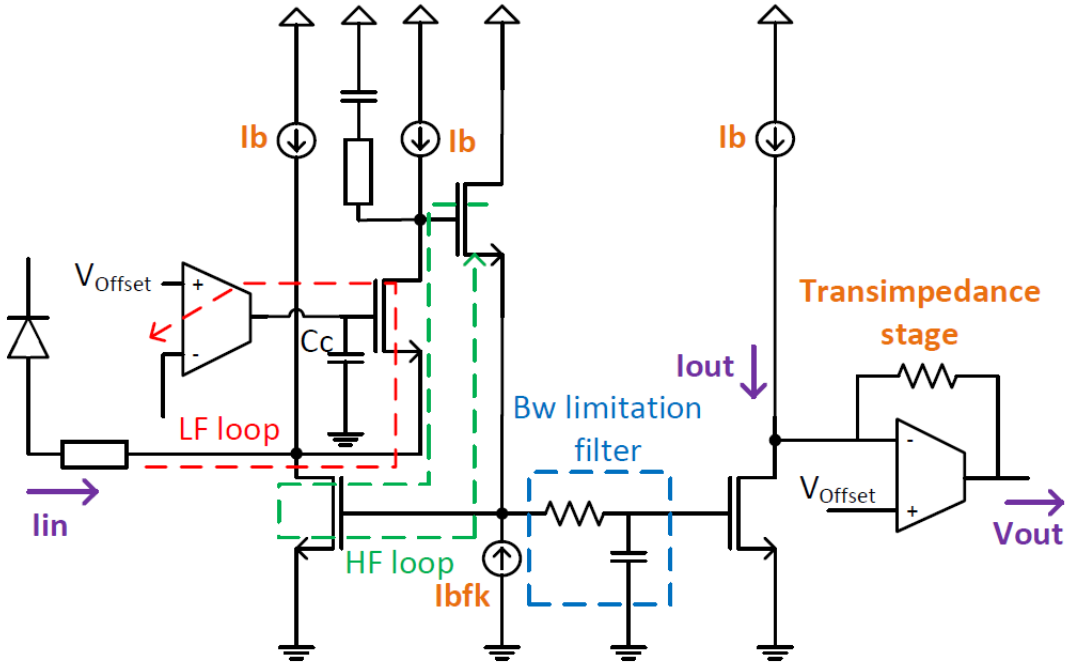
next version:
320MHz SLVS
differential output

Prototype

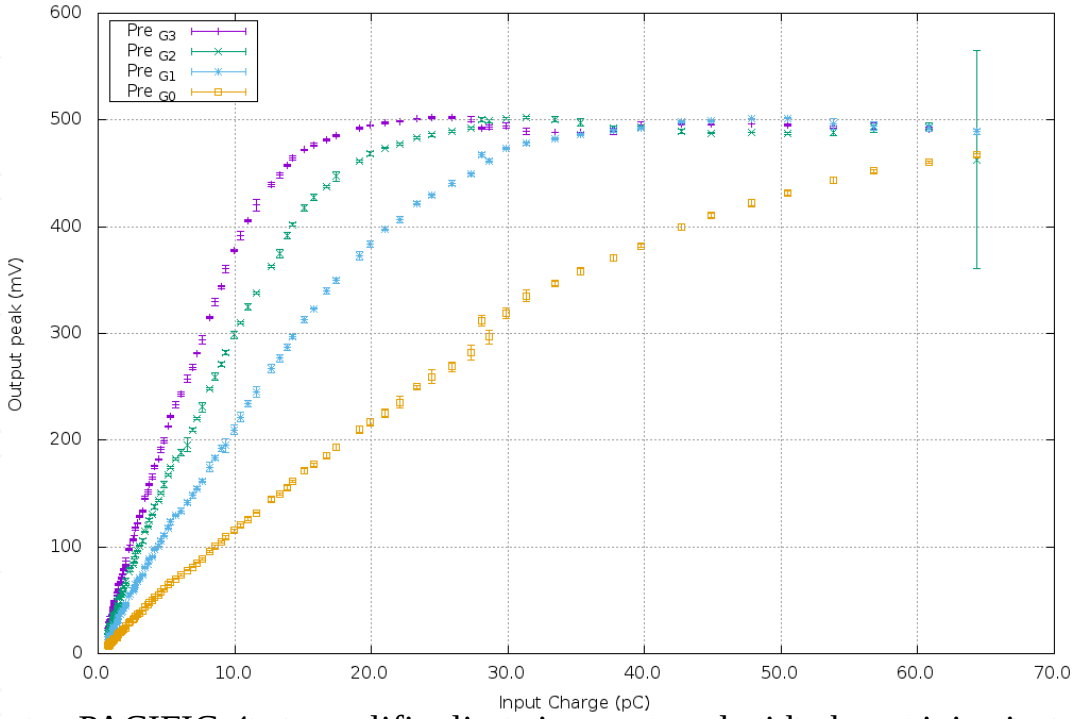
2013.05	2013.11	2014.08	2015.08	2016.09	2017.03	2018 - 2019
PACIFICr0	PACIFICr1	PACIFICr2	PACIFICr3	PACIFICr4	PACIFICr5	
preamplifier only	single channel full analog chain	8-channel full analog chain	8-channel single-ended output full design	**64-channel single-ended output full design**	64-channel differential output full design	
					expected back in May	mass production & detector installation

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



PACIFICr4 preamplifier linearity measured with charge injection

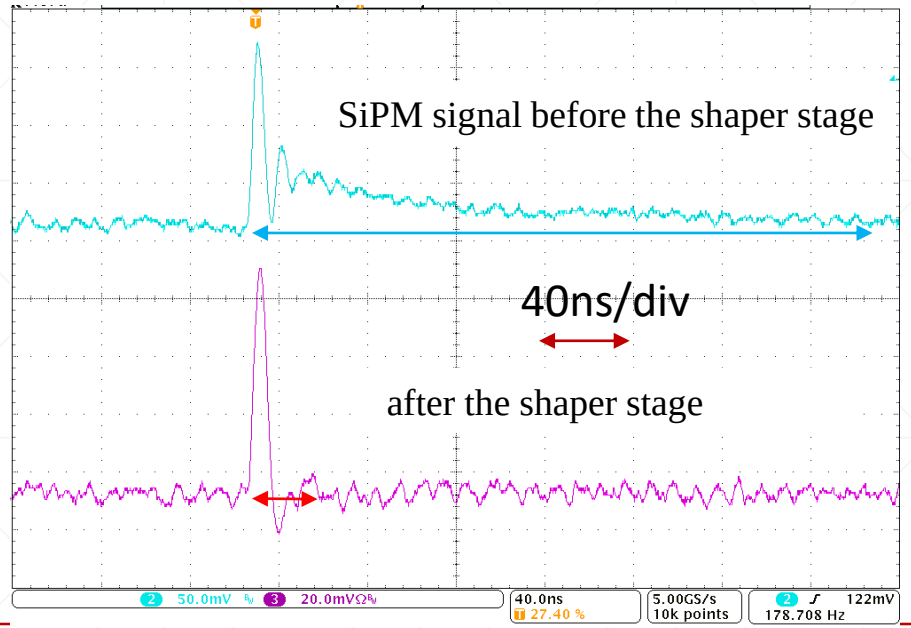
Fast Shaper

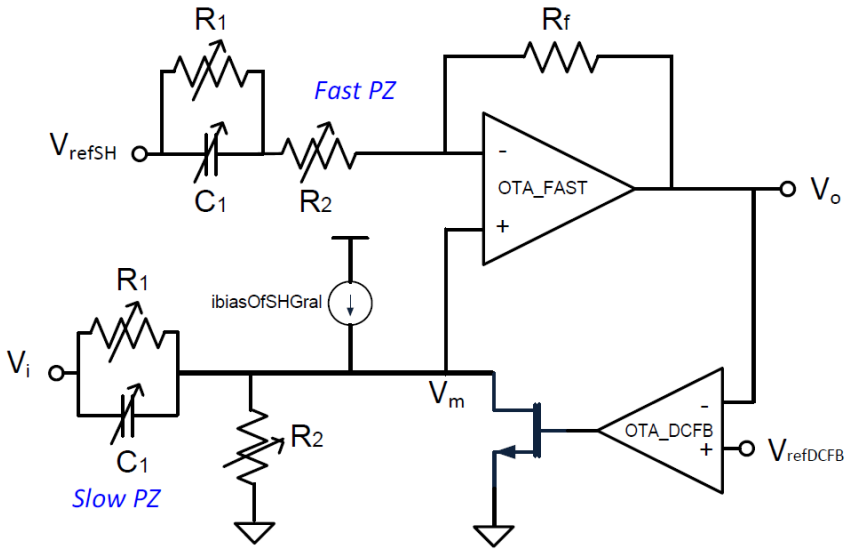
- **double pole-zero cancellation for the SiPM signals**

✓ 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

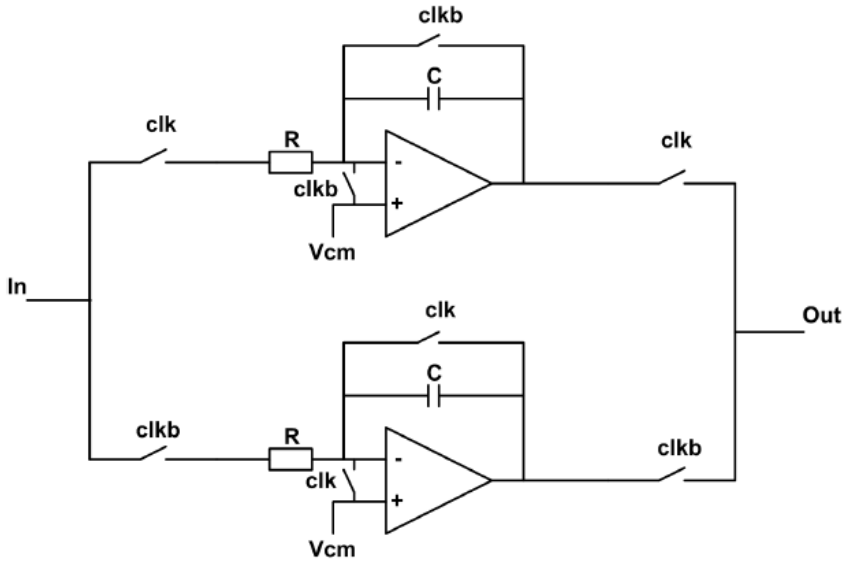




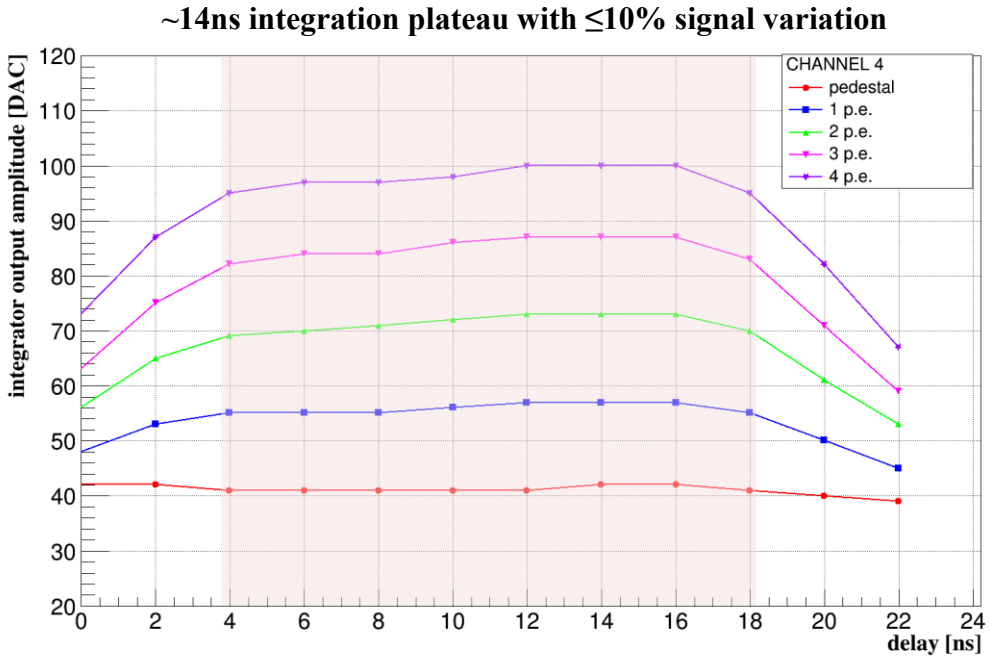
block diagram of the PACIFIC shaper

Interleaved Gated Integrators

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



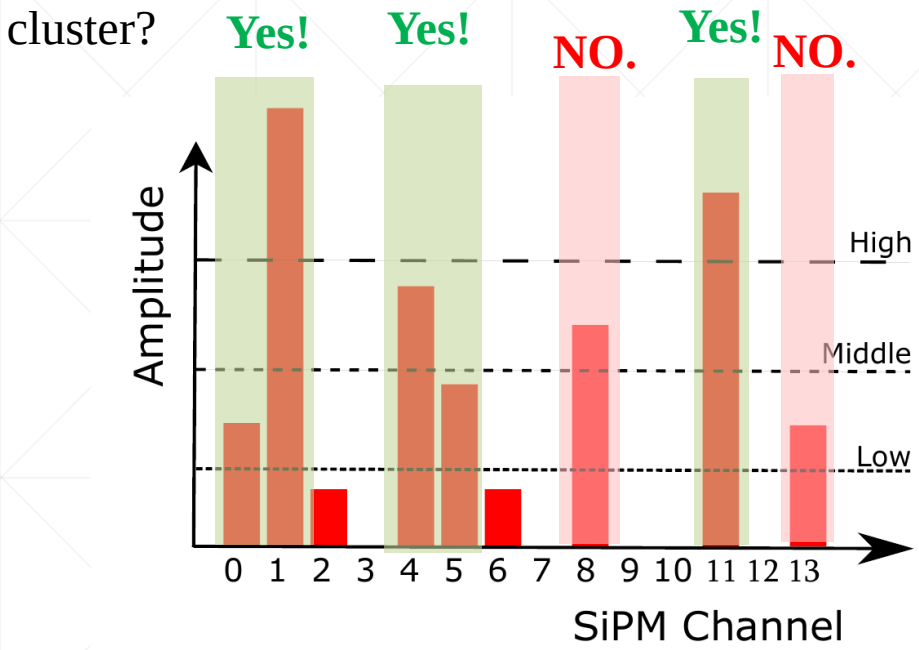
block diagram of the PACIFIC interleaved gated integrators

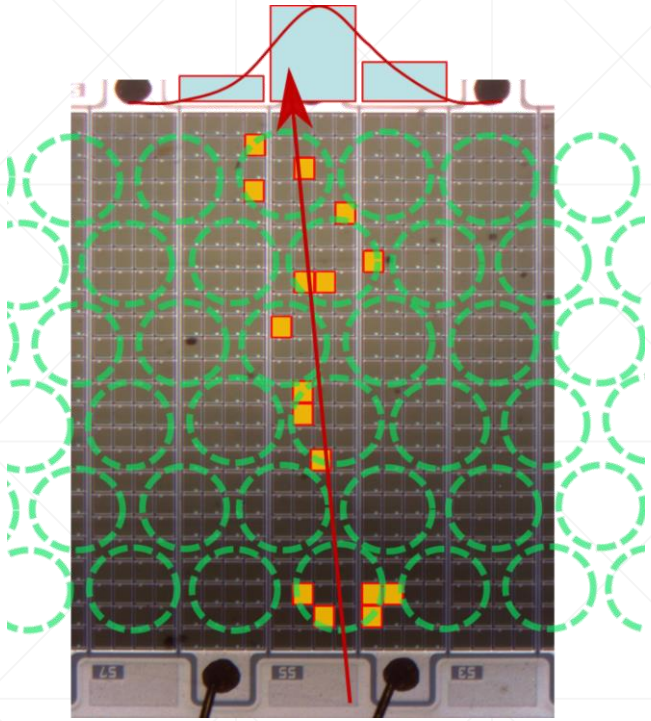


PACIFICr4 integrator response measured with light injection

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

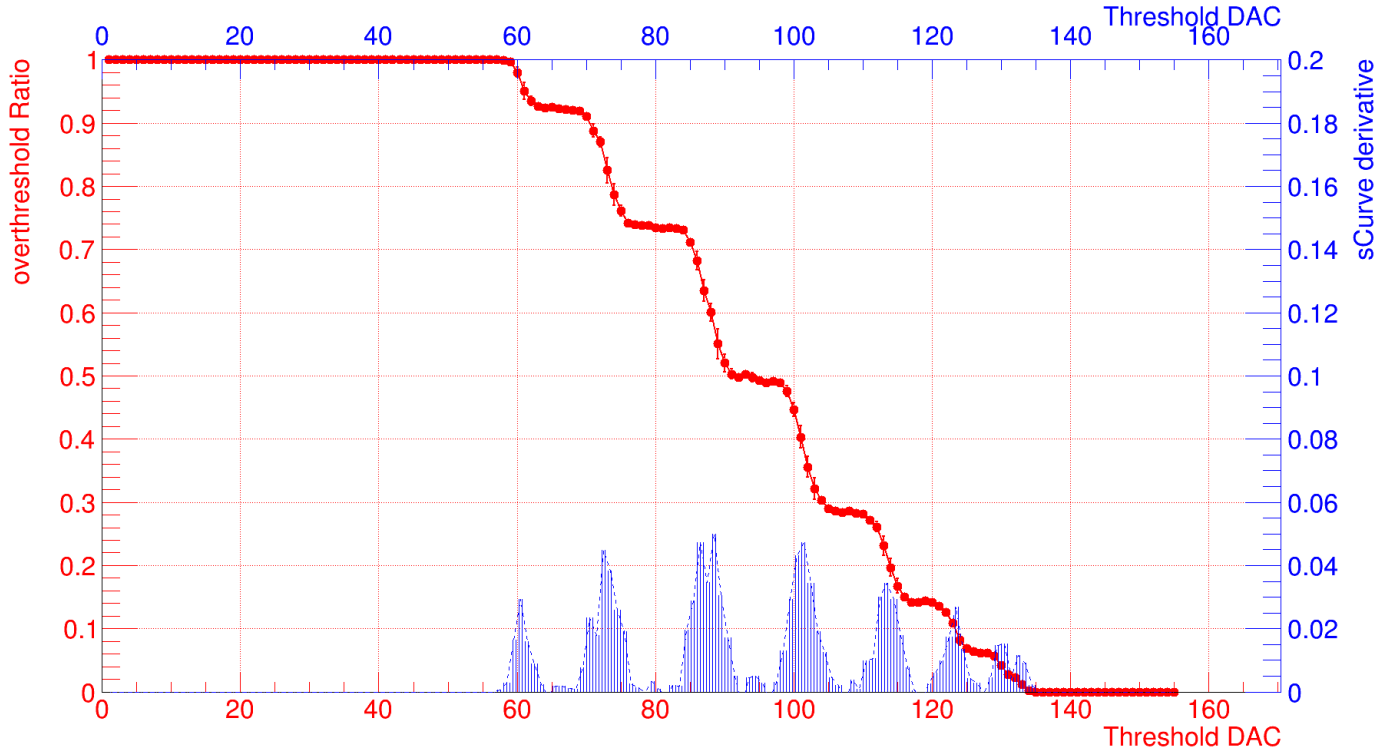




sketch of a typical cluster produced when particles passing through the SciFi detector

Light Injection Result

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



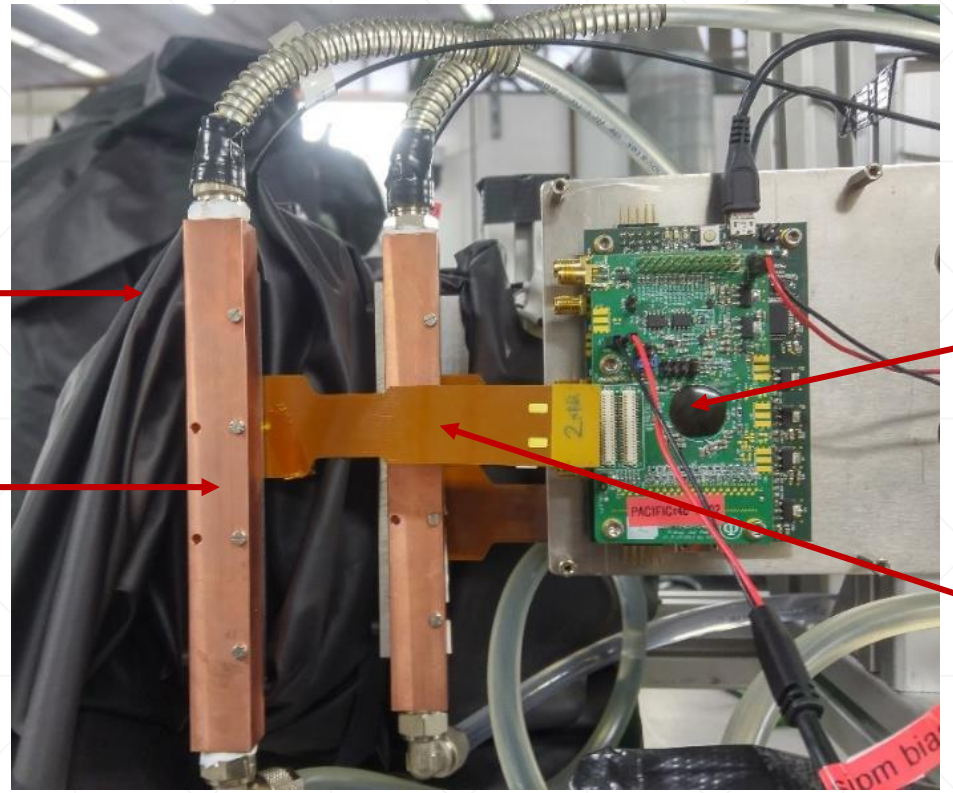
PACIFIC threshold scan result : clear photo-peak steps

Test Beam at DESY 2017

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

SciFi prototype module
covered in black blanket for light tightness

cooling bar
to keep the SiPM temperature stable

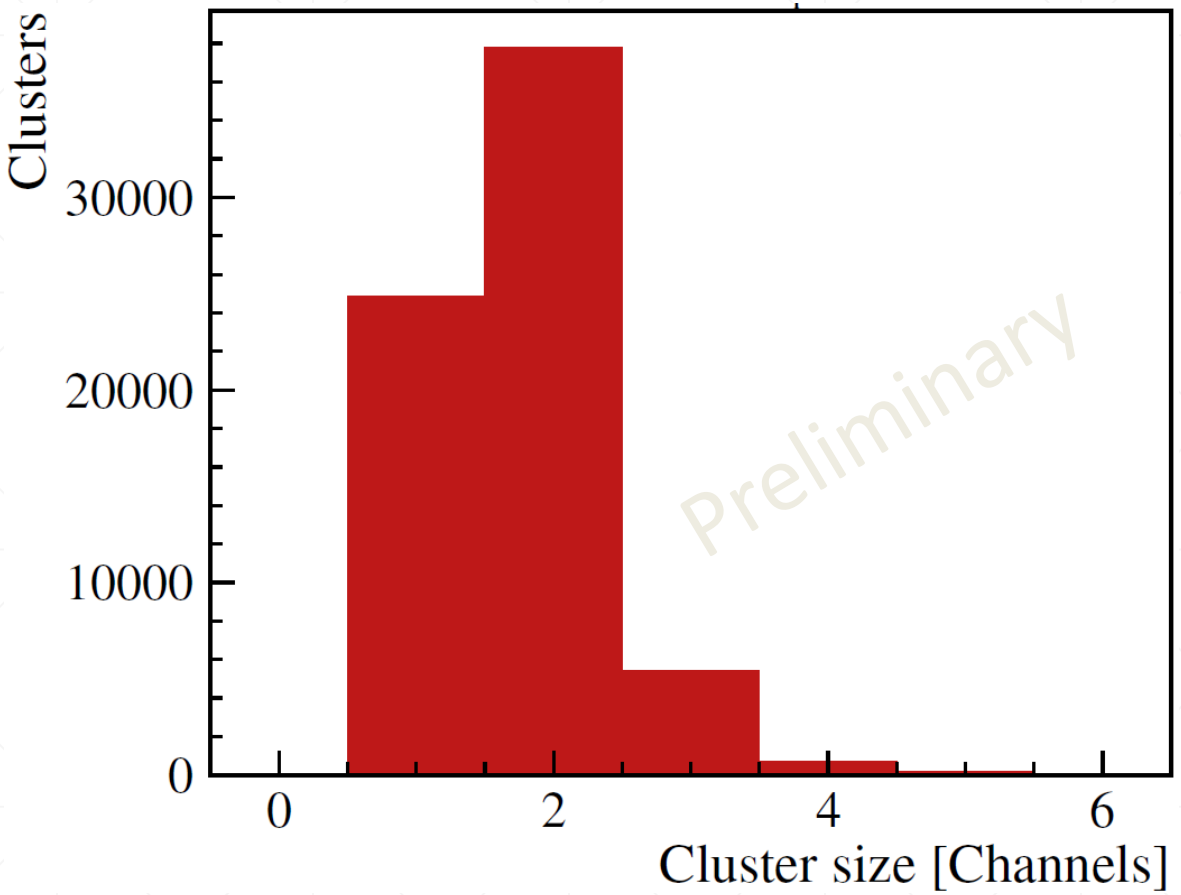


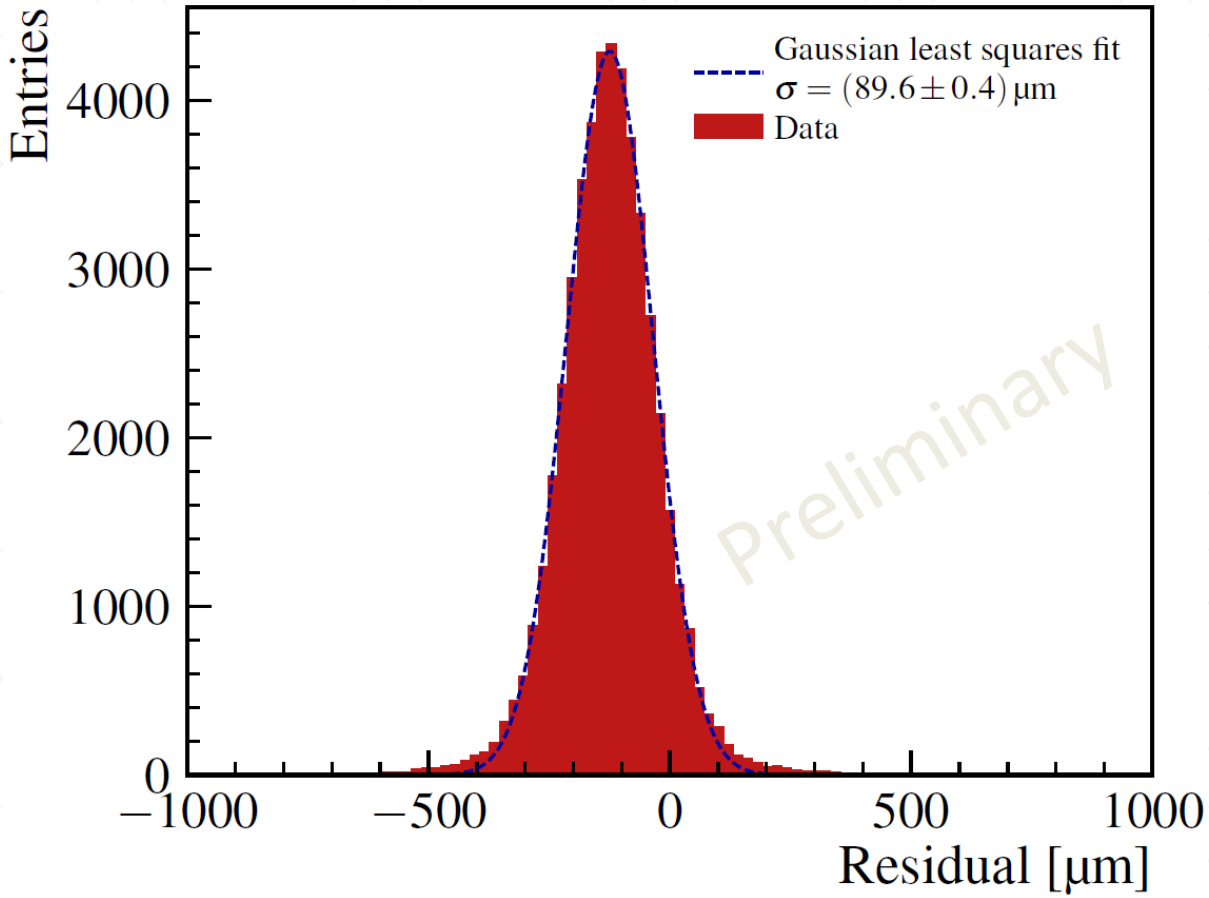
wire-bonded PACIFICr4
with glob top

SciFi SiPM array
with flex cable

SciFi module read out by custom SiPM arrays and PACIFICr4

Cluster Size & Spatial Resolution





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?