DEVELOPMENT OF SCALABLE ELECTRONICS FOR TORCH TIME-OF-FLIGHT DETECTOR

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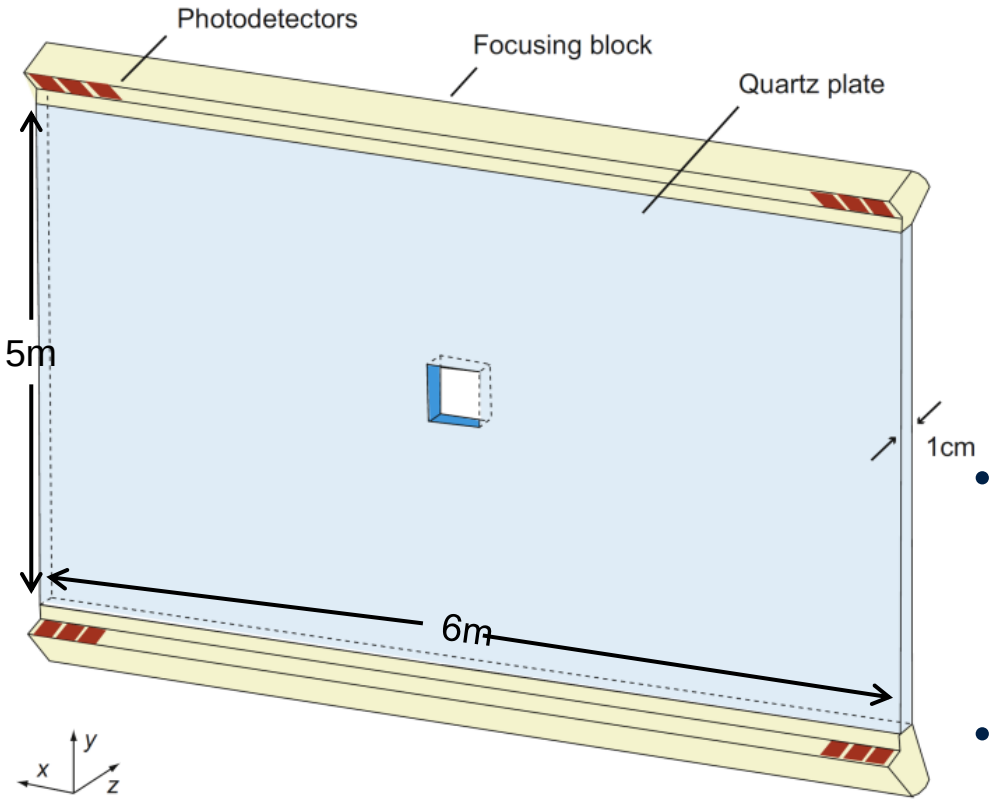
on behalf of the TORCH Collaboration (University of Oxford, University of Bristol and CERN)

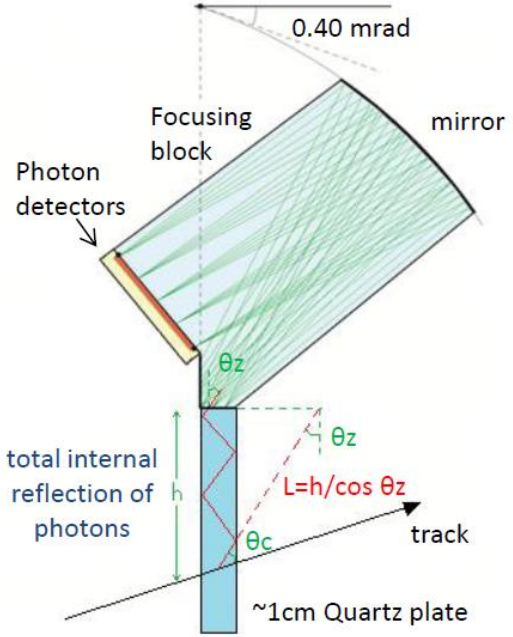
Outline

- TORCH design and principles
- Photon detection
- Development of electronics
- Future work

Time Of internally Reflected Cherenkov

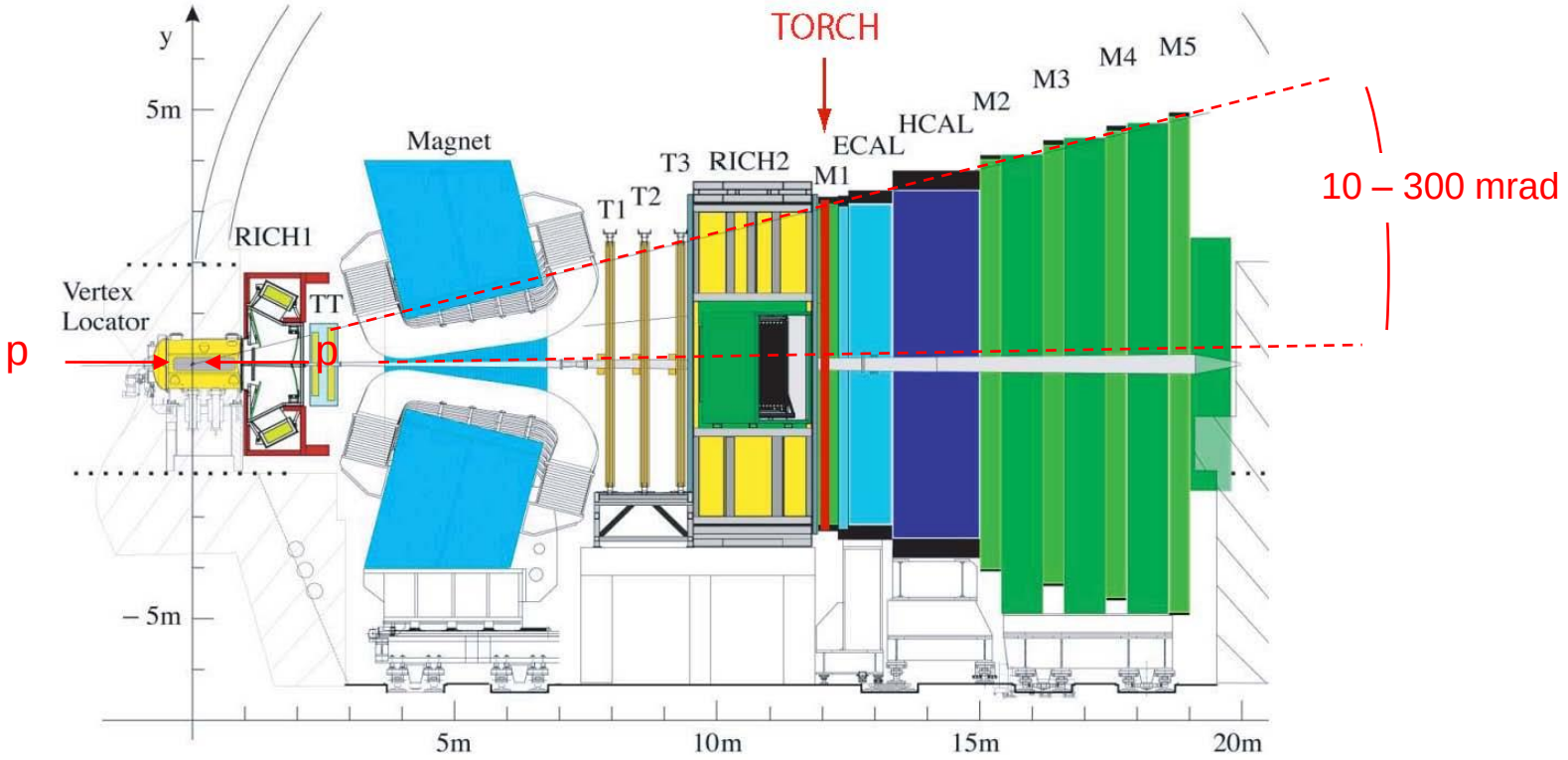


The basics of the TORCH design



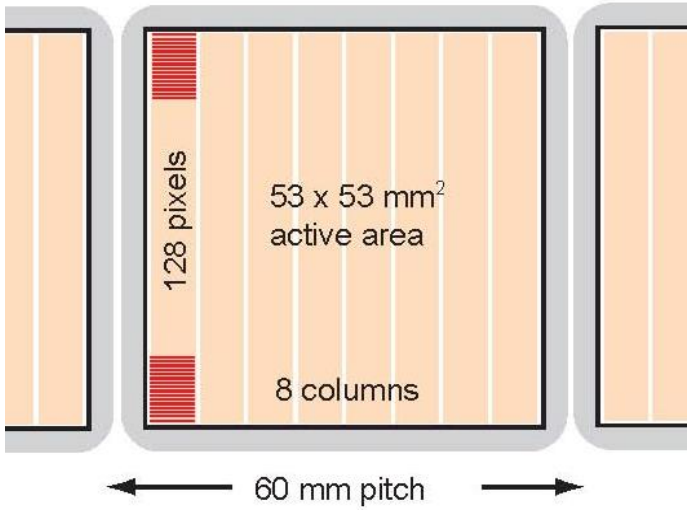
- Low-momentum particle identification up to 10GeV/c through Time-Of-Flight measurement
- Utilises Cherenkov light for fast signal production
- Needs an overall 70ps time resolution for single photons in the detector

TORCH in LHCb



Candidate location for TORCH in LHCb *[1]*

Photon Detection



Required granularity of the final TORCH MCP.

- Uses Micro Channel Plate as photon detector
- Final device requires:
  - Stable gain performance up to at least 5C/cm^2
  - Granularity equivalent to 8x128 pixels
  - 53x53mm^2 active area, 60mm pitch
- Development of MCP-PMTs underway by Photek, UK

PHOTEK
ENVISAGE THE FUTURE

Development in Electronics: Background

Previous system [2]

⇧ *Development-board -based readout*

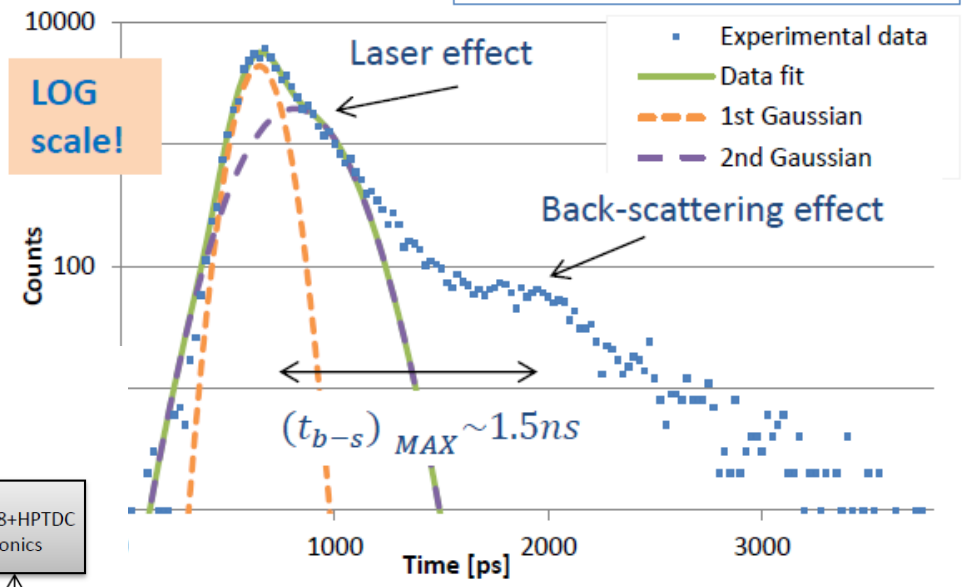
⇦ *16-ch board*

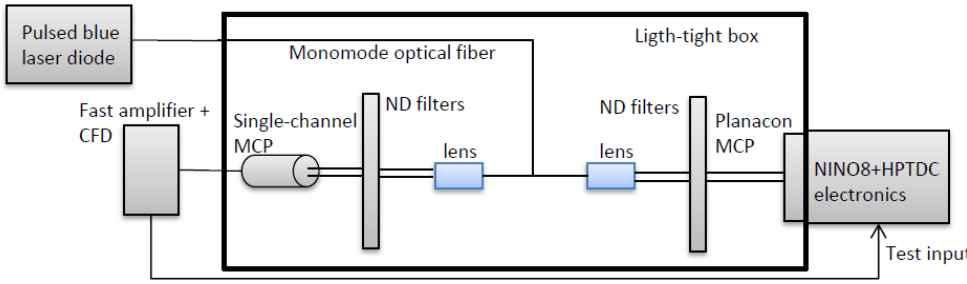
Custom front-end electronics (NINO8+HPTDC)

START signal: time reference from single-channel MCP (<20ps) coupled to CFD and injected on a test channel of the NINO+HPTDC electronics

STOP signal: Planacon

$\sigma_{NINO+HPTDC}$ ~77ps





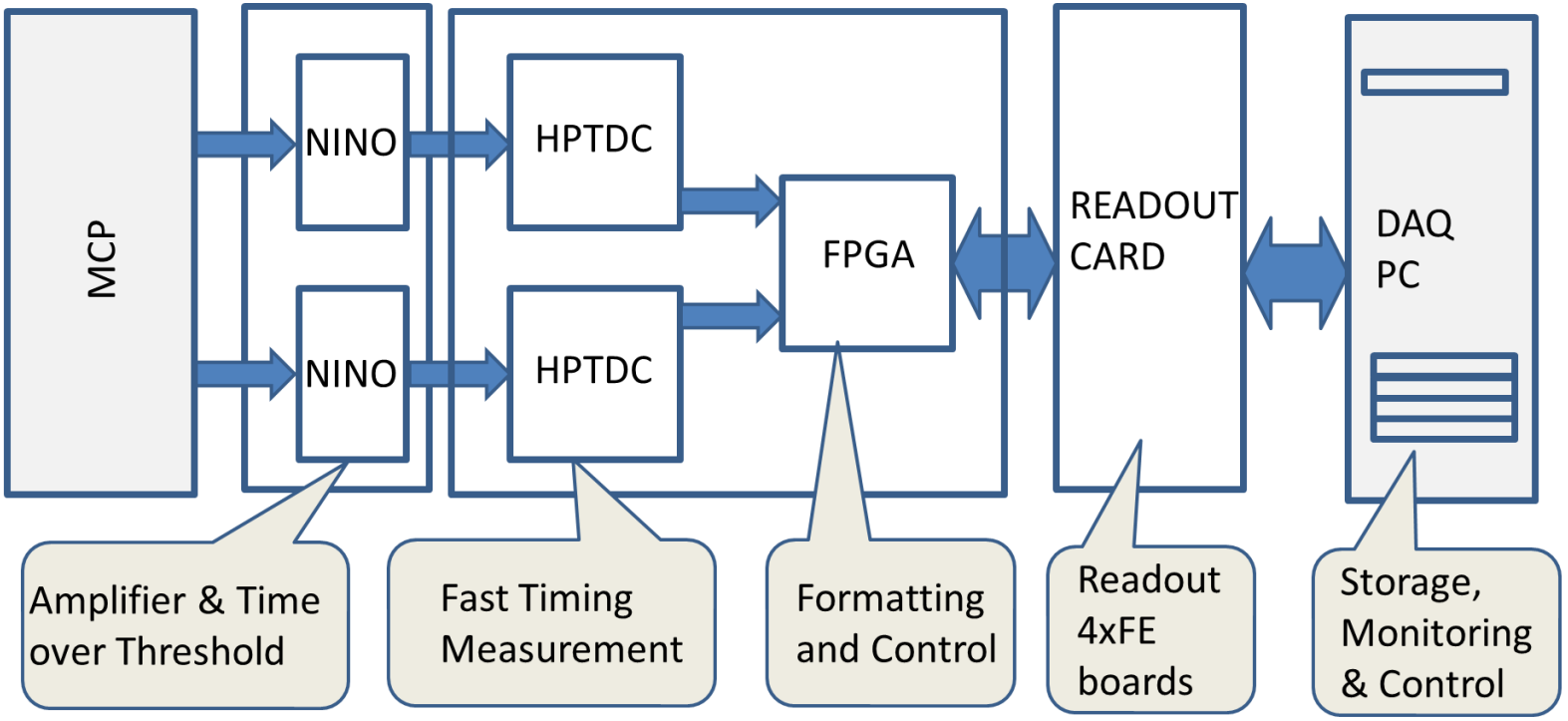
No corrections for time-walk nor for INL.

Test setup and results at CERN, currently instrumented with a Photonis 8x8 MCP and 16-ch electronics [3].

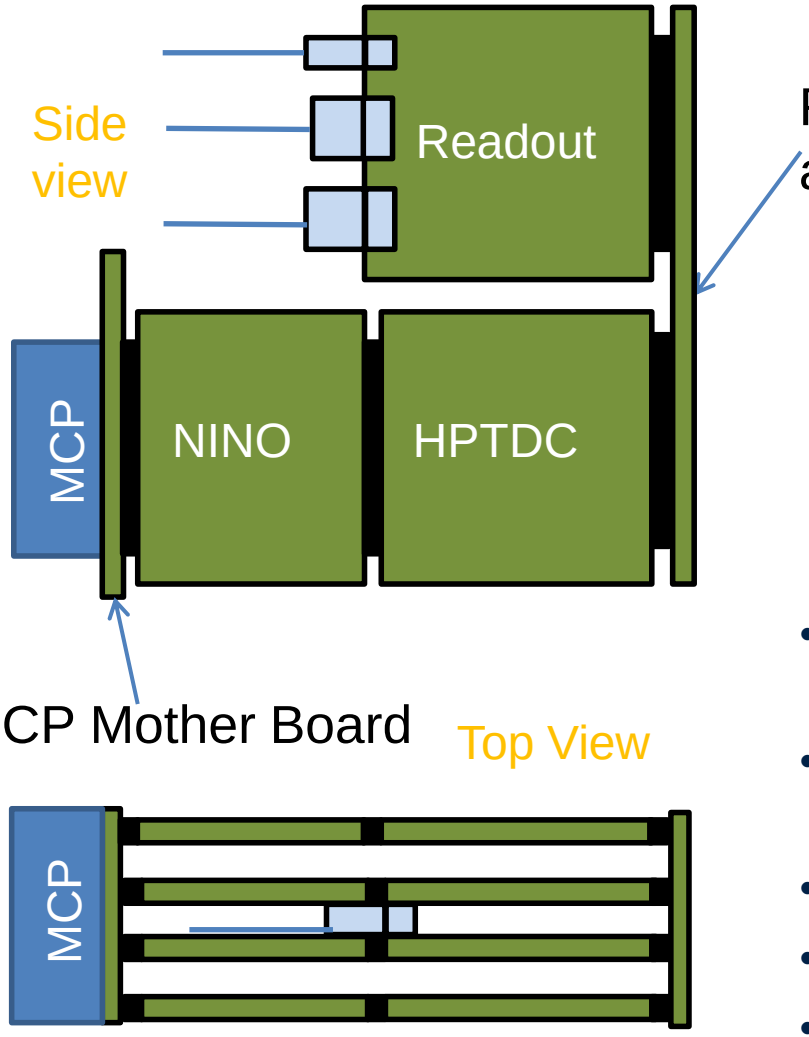
Development in Electronics: Goals

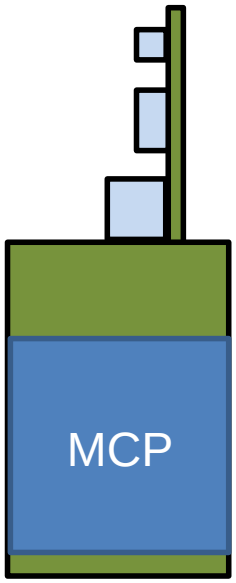
- Time-of-flight measurement of 8x64 channels per MCP, charge sharing technique applied to achieve the 8x128 equivalent granularity
- Fit within the 60mm dimension of a photon detector
- Overall timing resolution requirement is 70ps per single photon, electronics and MCP need to provide 50ps per channel [2]
- Scalable design to suit different iterations of MCPs through stages of their development
- Flexible readout to be compatible with an experiment readout framework, e.g. LHCb

Main Data Flow



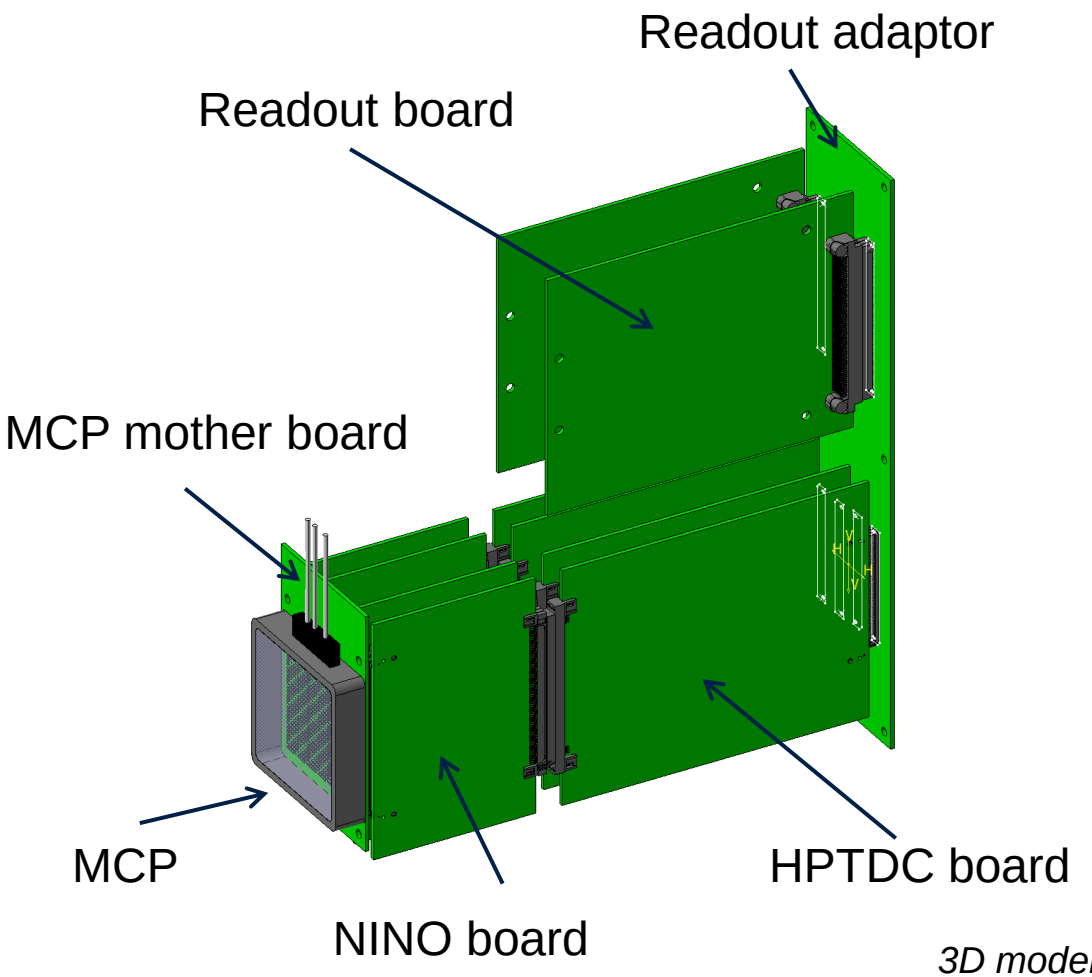
Modularity

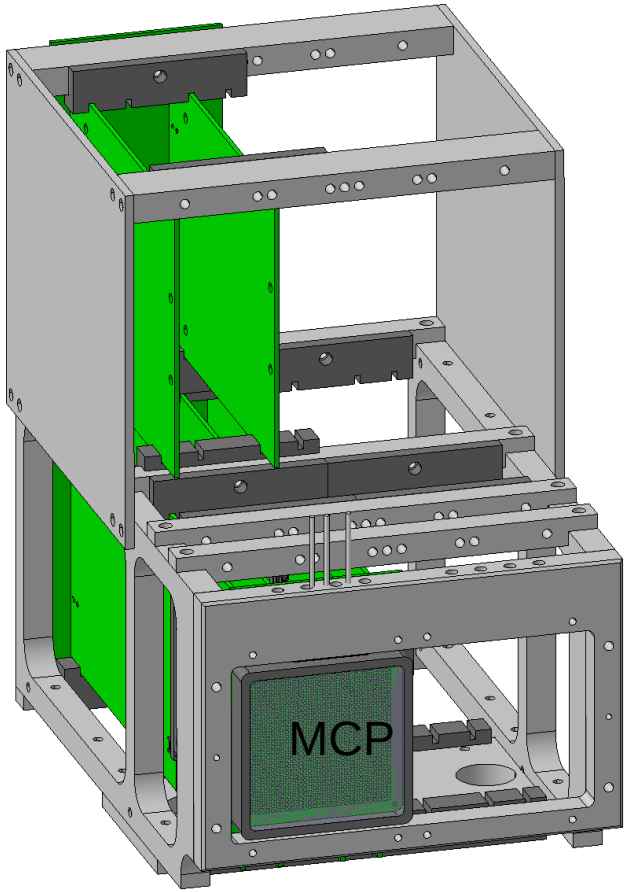




- One MCP attached to mother board
- Up to 8 NINO and HPTDC boards (64-ch per board)
- One readout adaptor
- One or more readout board
- Powered by a single 5v supply
- 2.5kV HV to MCP.

Assembly





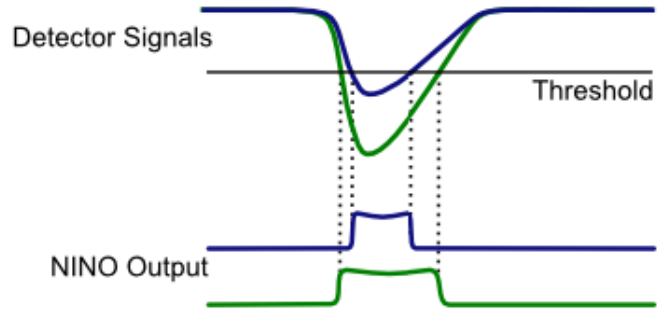
3D model produced by C. Frei, CERN

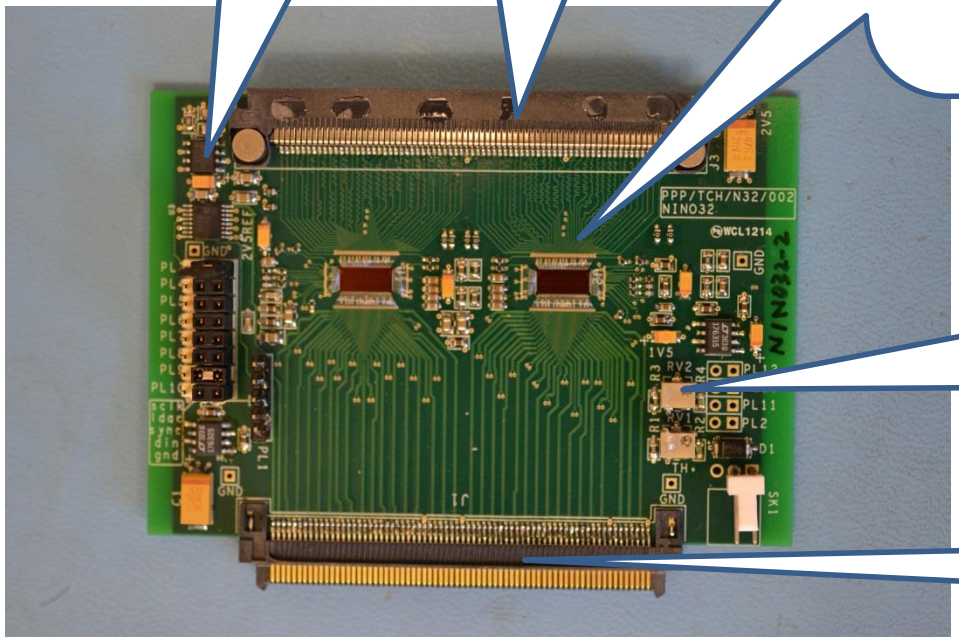
Analogue Front End – NINO

DAC – Setting threshold

Input – negative phase only

2 x **NINO** - Time Over Threshold Measurement [3], 64-ch board

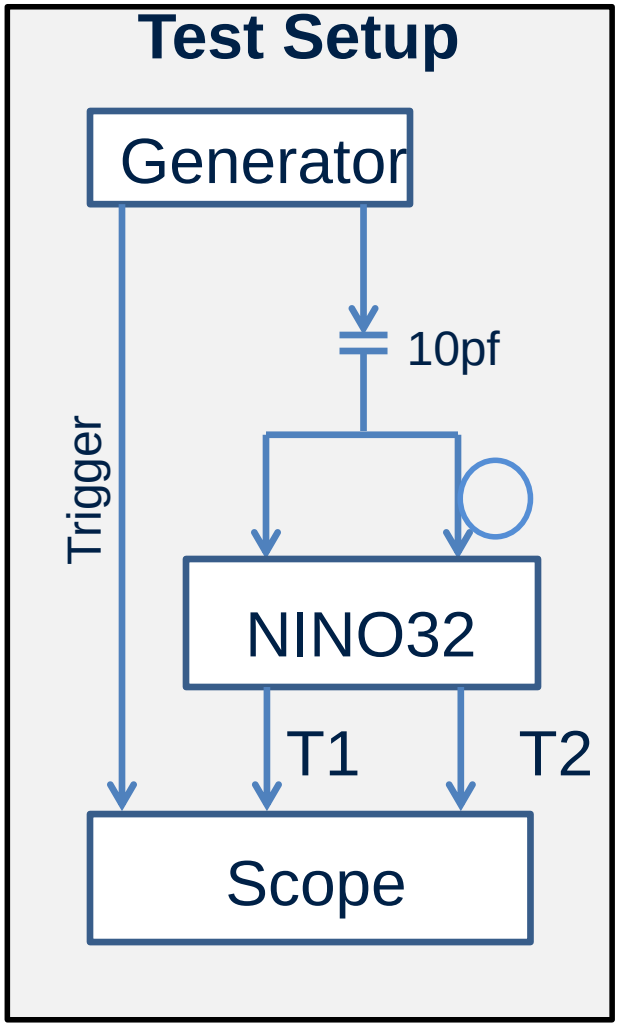


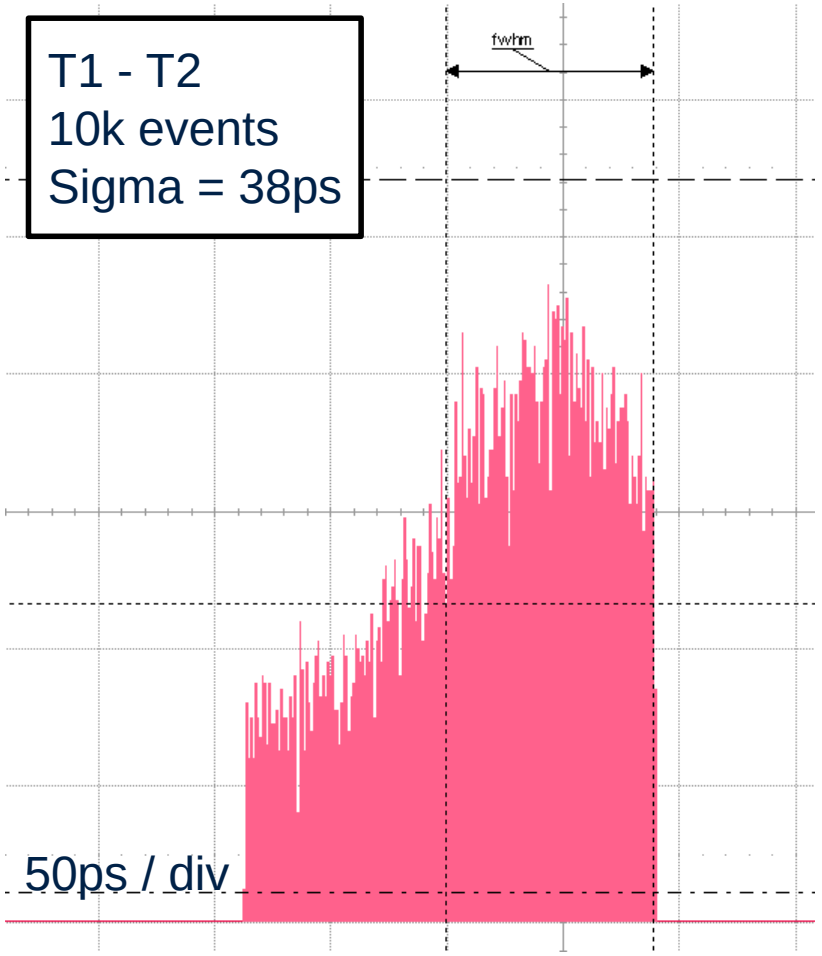


Potentiometer – threshold quick settings

LVDS output, DAC control and **power**

NINO32 Performance





Time resolution = $38/\sqrt{2}$ = 26.8ps

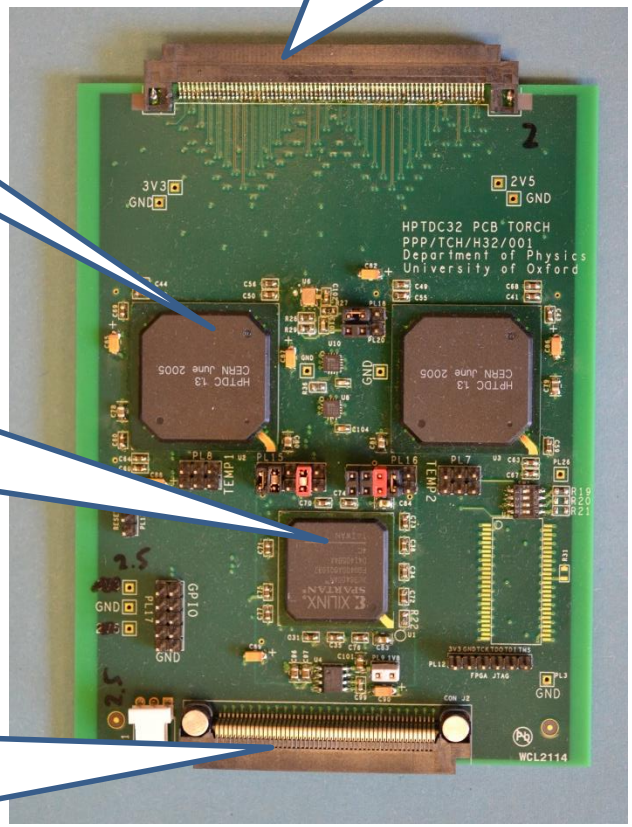
HPTDC Board – Time to Digital Conversion

LVDS input from **NINO**

2x **HPTDC**[4] ASICs, 64-ch board

Spartan3AN
HPTDC configuration and control
Data formatting and buffering

Power
Input: clock, trigger, serial slow control, fast control
Output: TDC data, all signals in LVDS



HPTDC board – Additional Features

- On-board HPTDC readout control
- Local HPTDC configuration and start up
- Buffering with FPGA
- Decoding slow control command from Readout board
- Offline INL corrections for HPTDC

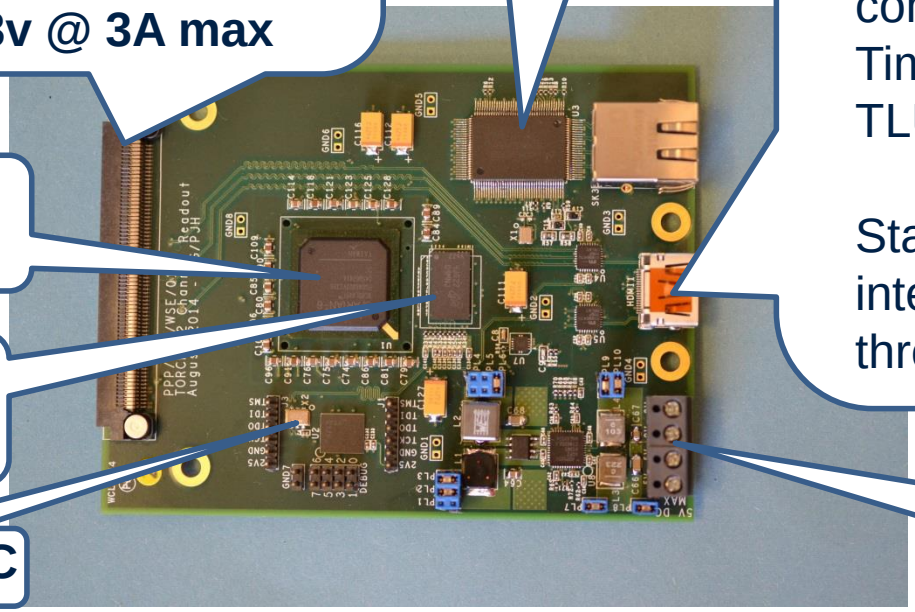
Readout Board

LVDS I/O
Fan out 4 x clocks, 4 x triggers and 52 pairs of LVDS I/Os
Standalone JTAG for TDC board
2.5v and 3.3v @ 3A max

Gigabit Ethernet PHY

HDMI Connector
External clock and 3 bi-directional LVDS pairs, pinout compatible with Timepix3 Telescope TLU.

Standard LEMO/ SMA interface are available through adaptor.



Spartan6 LX45T

1Gbit DDR3 RAM

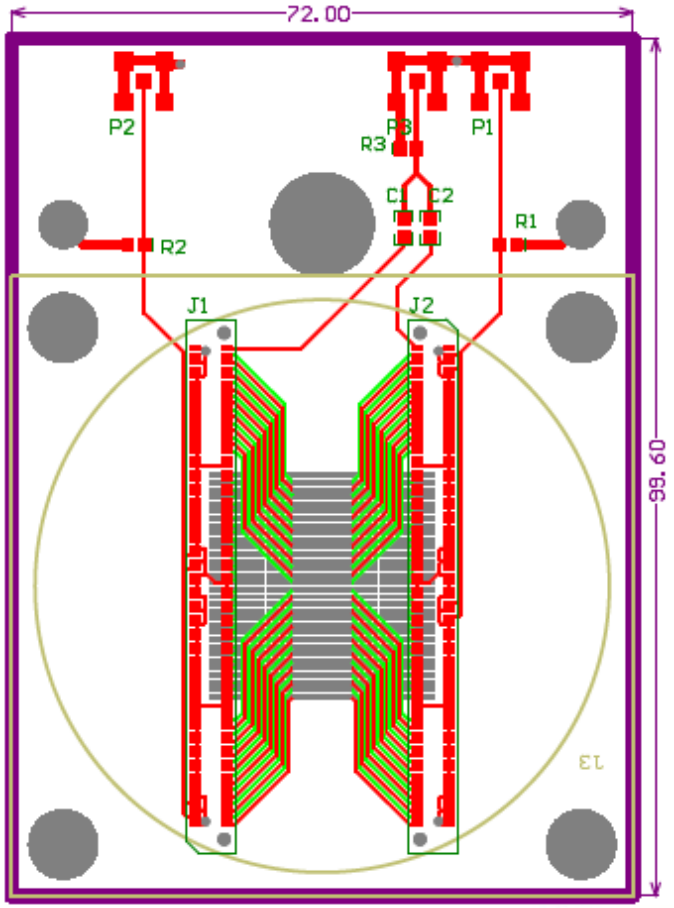
200MHz OSC

Single 5V power supply

Readout Scheme

- Existing scheme: fixed size, block-based readout
  - Readout a fixed number of 32-bit words from one TDC board, then move to the next board
  - Padding is used when buffer under-run
- Event-based readout is under development
  - Readout board will keep track of event numbers
  - Associate data from all TDC boards with an event number and sent as one group

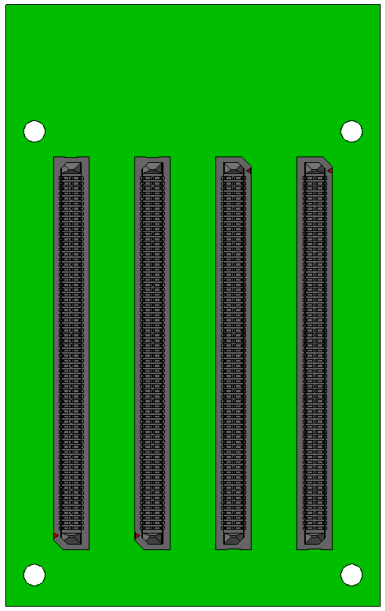
Photek MCP Mother Board



Photek MCP mother board

- For a Photek MCP prototype, circular tube, 32x32 pixel
- 8 pads are grouped together in the coarse (horizontal) direction, equivalent to 4x32
- Connection to MCP provided by Anisotropic Conductive Film (ACF)
- SMAs to inject calibration signal and a start time signal

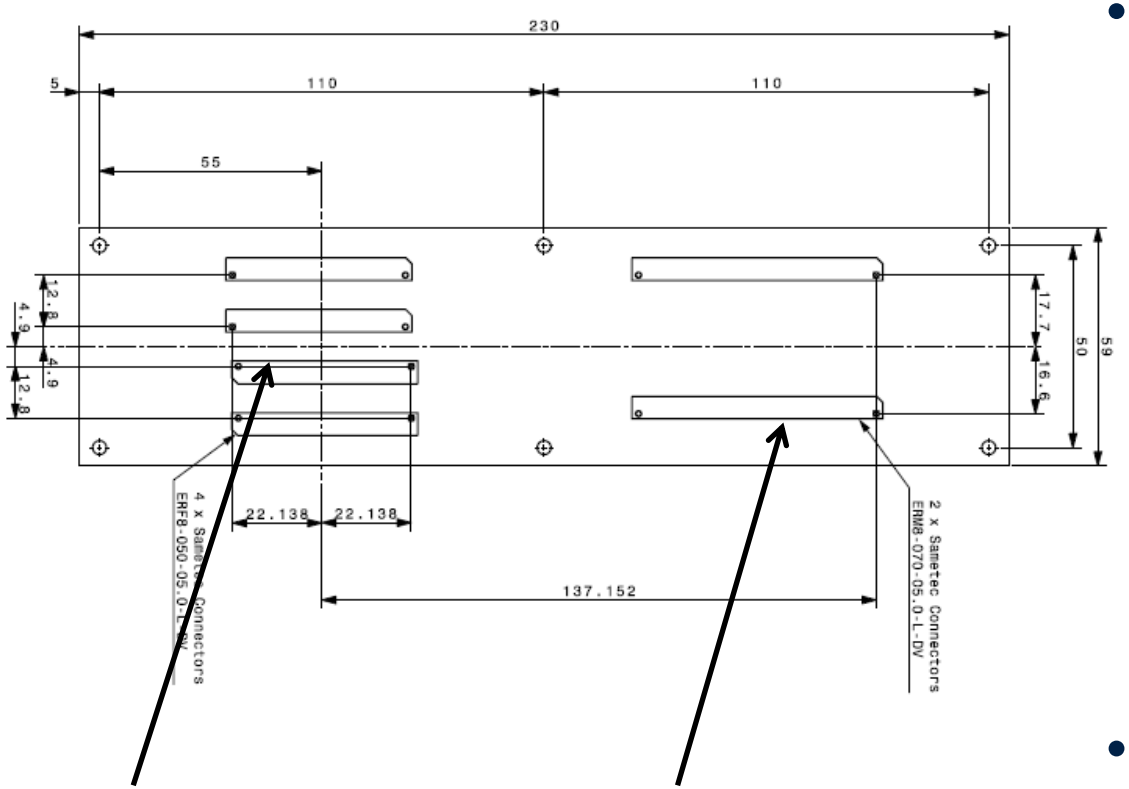
Photonis MCP Mother Board



A Mechanical drawing of Photonis 32x32 MCP mother board

- Mother board under development for Photonis 32x32 MCPs
- 4 pads are grouped together in the coarse direction, providing equivalent to 8x32 channels
- Connection to MCP provided by conductive glue
- SMAs to inject calibration signal and a start time signal
- Provide AC coupling between MCP and NINO

Readout Adaptor



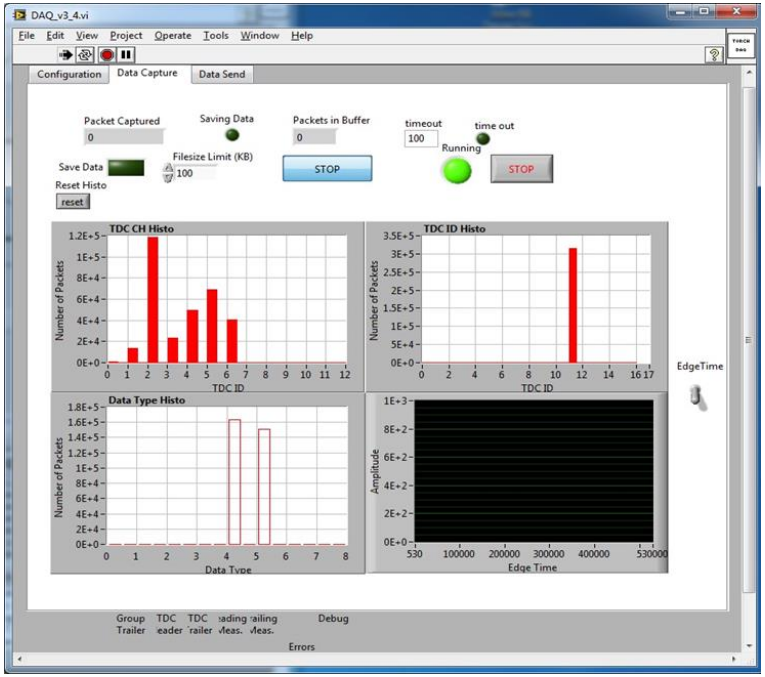
Connectors for 4 HPTDC boards, pitch and position match mother boards

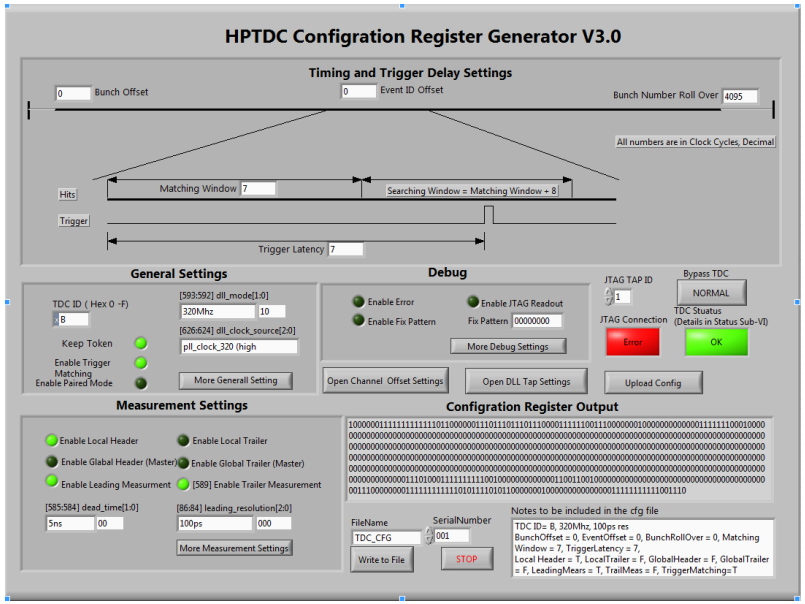
Connectors for 2 readout boards

- A mechanical design that is compatible with both Photek prototype and Photonis 32x32 MCP,
- PCB layout to follow up.

DAQ

Labview-based DAQ with online monitoring, control (bottom) and configuration (right).

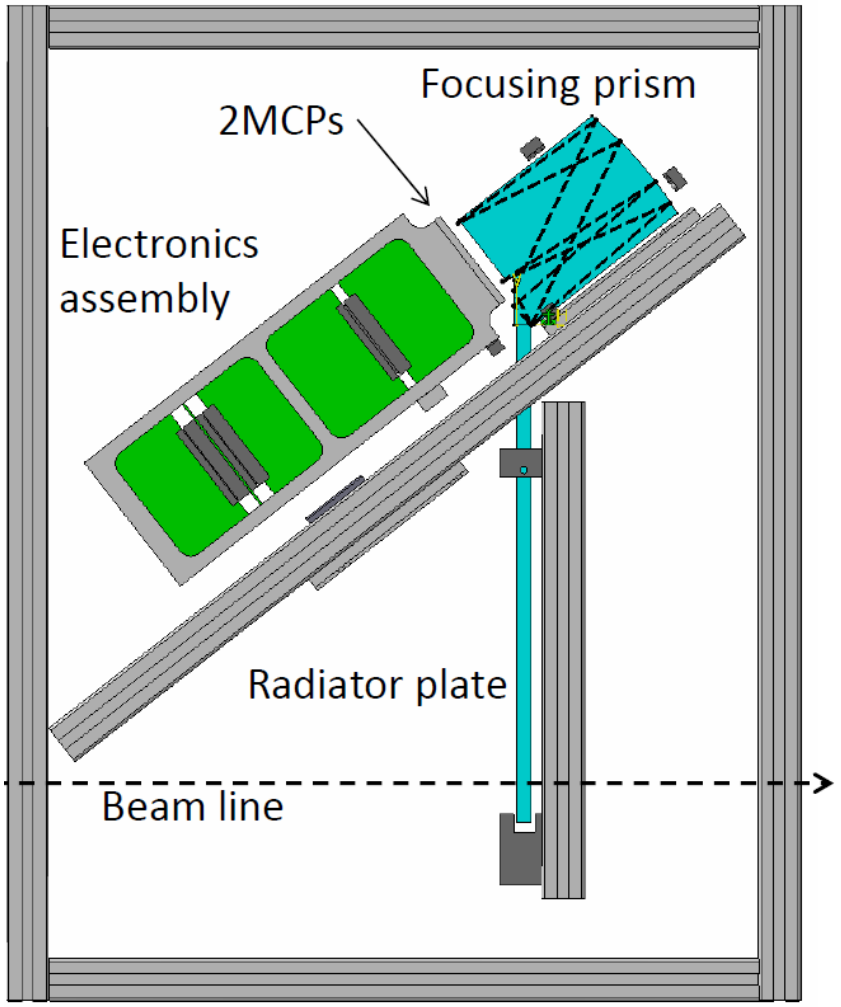




All analysis, correction and calibration systems are offline

Future work

- Test beam
  - SPS at CERN in October-November 2014 and PS at December 2014
  - Radiator plate (1x12x35cm³) has been ordered
  - Focusing prism - Fused Silica
  - Test commercial Photonis MCP as well as costume Photek prototype
  - 4 NINO + 4 HPTDC + 1 Readout board, 256 channels
- Final square 8x64 MCP to be delivered in 2 years time.



The End, Thanks!

References

[1] *A. Papanestis, et. al., The RICH detector of the LHCb experiment, in Proceedings of TIPP 2014.*

[2] Gao et al., Development of Precision Time-of-Flight Electronics for LHCb TORCH, Journal of Instrumentation 9 (2014) C02025.

[3] L. Castillo García, et al., *iming performance of a MCP photon detector read out with multi-channel electronics for the TORCH system*, in proceedings of 14th ICATPP Conference.

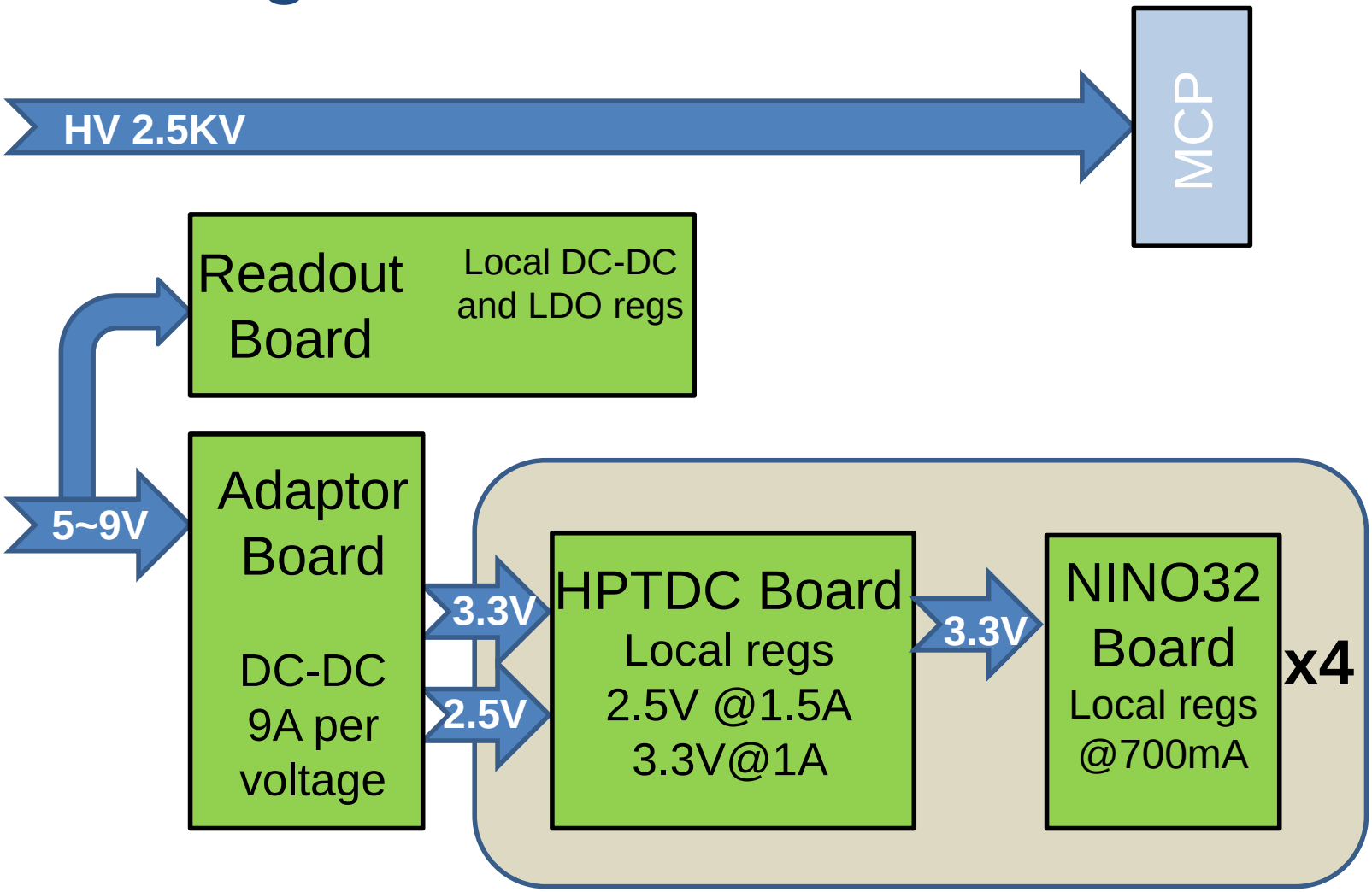
[4] *E. Cowie, et. al., TORCH – a Cherenkov based Time-of-Flight Detector, in Proceedings of TIPP 2014.*

[5] F. Anghinolfi, P. Jarron, A.N. Martemiyanov et al., NINO: an ultra-fast and low-power front-end amplifier/discriminator ASIC designed for the multigap resistive plate chamber, Nucl. Instr. and Meth. A 533 (2004) 183

[6] M. Mota, J. Christiansen, S. Débieux et al., *A flexible multi-channel high-resolution Time-to-Digital Converter ASIC*, IEEE Nucl. Sci. Symp. Conf. Rec. 2 (2000) 155.

Backup Slides

Powering Scheme



NINO32 Performance Backup