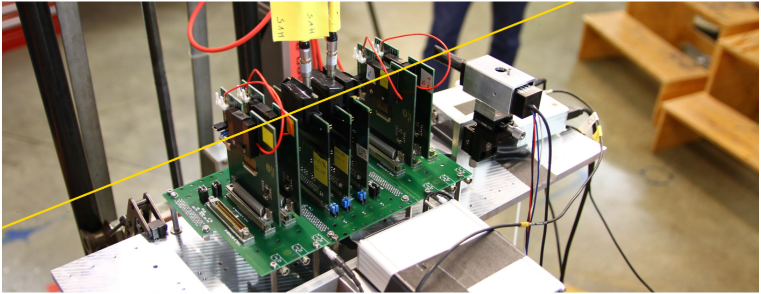

ETH High Rate Beam Telescope

presented by: Michael Reichmann
coauthors: Felix Bachmair, Dmitry Hits

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Motivation

Goal:

- testing of different types of diamond sensors for rate dependence (up to 100 MHz)

Conditions:

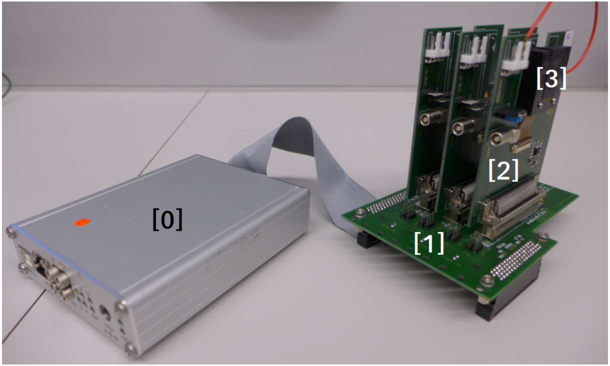
- beam line PIM1 at PSI (Paul Scherrer institute)
- continous pion beam with a flux of up to 10 MHz/cm^2 and momenta of 100-500 MeV

Requirements:

- small, flexible and modular system
  - reduce multiple scattering
  - easy to tear down, fast setup
- high rate continuous data taking
- scalable trigger area
  - high efficiency in the DUT
- precise trigger timing

The Telescope

General Setup

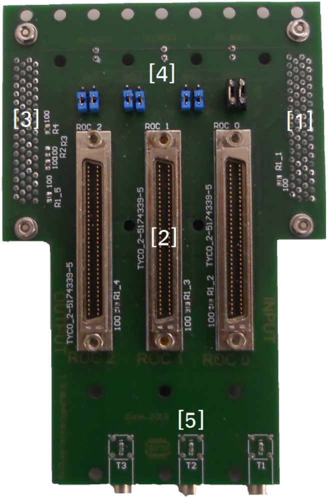


- [0] DTB (Digital Test Board): interface to a computer
- [1] Motherboard: main frame of the telescope
- [2] Adapter Planes: interface to the single pixel chips
- [3] CMS Pixel Chip (analogue or digital)

CMS Pixel Chips

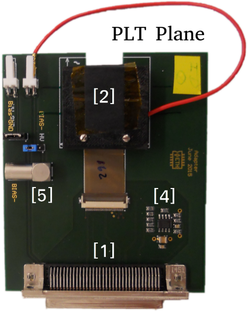
	PSI46v2	PSI46dig	PROC600
Chip size	$7.9 \times 10.0\,\mathrm{mm}^2$	$7.9 \times 10.3\,\mathrm{mm}^2$	$7.9 \times 10.6\,\mathrm{mm}^2$
Pixel size	$150 \times 100\,\mu\mathrm{m}^2$	$150 \times 100\,\mu\mathrm{m}^2$	$150 \times 100\,\mu\mathrm{m}^2$
Pixel array	52×80	52×80	52×80
Pixel charge readout	analogue	digitised	digitised
Readout	multi level 40 MHz	160 MBit/sec	160 MBit/sec
Hit rate	$80\,\mathrm{MHz/cm}^2$	$120\,\mathrm{MHz/cm}^2$	$600\,\mathrm{MHz/cm}^2$
Radiation Tolerance	200 kGy	1 MGy	6 MGy
In-time threshold	3500 e	$<$ 2000 e	$<$ 2000 e
Fast-OR trigger	yes	no	yes

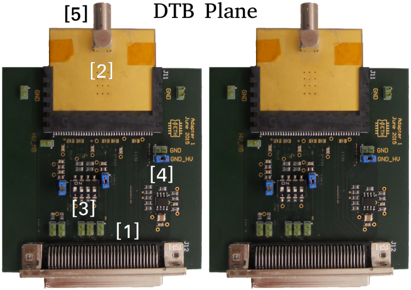
Motherboard



- [1] input: SCSI connector to the DTB
- [2] sockets for the adapter planes
- [3] output (optional): SCSI connector to another motherboard
  - daisy-chainable
- [4] token jumpers:
  - blue = plane used
  - black = plane skipped
- [5] output of the fast-OR trigger signal

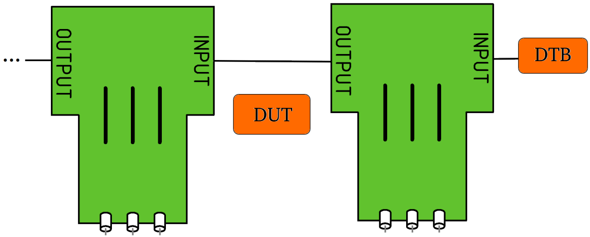
Adapter Planes





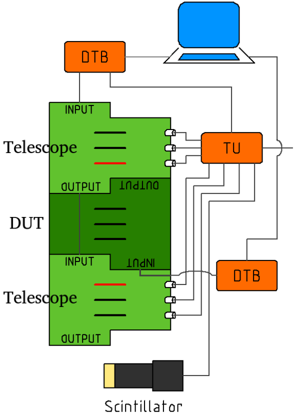
- [1] SCSI connector to MB
- [2] CMS pixel chip
- [3] bit switch for I^2C address
- [4] fast-OR amplifying circuit
- [5] sensor bias input

Modularity



- chain several motherboards together into a single big telescope
- can only chain one chip type (analogue or digital)
- number of planes per motherboard is also variable

Diamond Pixel Setup



- telescope: two motherboards with analogue chips
- DUT: single motherboard with diamonds sensors on digital chips
- Scintillator: precise trigger timing (fast-OR depends on clock, usually 40 MHz)
- trigger: coincidence of the two planes closest to the DUT (red) and the scintillator

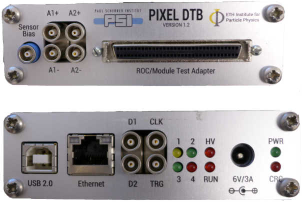
Datataking

The Digital Test-Board

- FPGA including soft Token Bit Manager (TBM) emulator
- clock and external trigger inputs
- connectors: USB, low voltage and scsi
- LEMO high voltage input for biasing the sensors
- internal ADC

Figure : DTB inside

Figure : DTB front and back



pXar

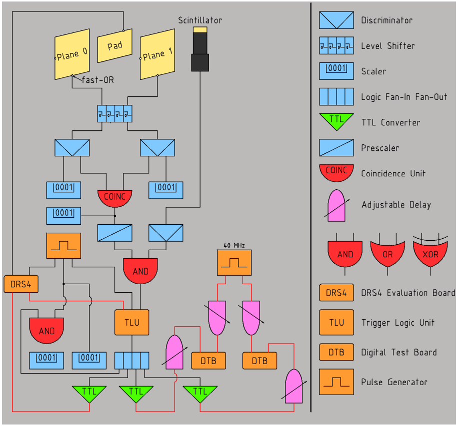
- short for Pixel eXpert Analysis Readout
- software for communication between the telescope and a computer
- pXar-core libraries: programming and readout information of the the CMS pixel chips
- python CLI (Command Line Interface) to perform simple tests

EUDAQ

- portable, modular and cross-platform DAQ framework
- developed for the EUDET Pixel Telescope
- can combine data streams from several different devices into an event based data stream
- using pXar core libraries
- adapting software to our purposes with help of DESY

- readout of diamond pad sensors with DRS4 Evalution Board
  - adding a producer for the DRS4 as extension to EUDAQ

Trigger logic



- coincidence between a fast-OR of planes before and after the DUT
- AND of scintillator and fast-OR coincidence as trigger
- global external clock with adjustable delays
- busy signal after each trigger to avoid event misalignment
  - useful for events with many pixels hit

Commissioning

Inclusion of the analogue pixel chip

Trigger and clock timing

WBC scan

```
pxarCore =>> wbcScan

wbc      yield

090       0%
091       0%
092       0%
093       0%
094       0%
095       0%
096       0%
097       0%
098       0%
099       0%
100       2%
101      20%
102      98%
103       8%
104       0%
105       0%

ROC STATISTICS:
wbc      roc0     roc1     roc2     roc3
100      0        2        0        0
101      6        12       10       4
102      60       92       96       56
103      2        6        6        0
104      0        0        0        0

TRIGGER PHASE:
3        |||| 8.9%
4        |||||||||||||||||||||||||||||||||||||||||||| 89.0%
5        | 2.1%
```

- ROC saves bunch crossing when particle hits the sensor
- programmable setting called wbc (wait bunch crossing)
- trigger only validates if time the trigger takes back to the ROC matches the wbc setting
- automated wbc scan using the pXar CLI
- detailed information about the hit yield (event has at least one hit) for every connected ROC
- information of the trigger phase (relative timing of the trigger compared to the clock)

Analysis

Plane alignment

Event alignment

Tracking

Diamond Pads

Conclusion

Outlook

- use the OSU TU (Trigger Unit) as single device to process all triggers
- two preinstalled setups for pad and pixel tests
- synchronise DTB clock with the beam clock at PSI (40 $\rightarrow$ 50 MHz)
- save scintillator signal with the DRS4
  - particle identification by time of flight
- increase resolution by tilting the telescope planes
- using PROC600 as chip for the telescope
- test PSI-ROC4SENS - a ROC without threshold