## Readout system for the Micro-Vertex-Detector of PANDA

#### Marvin Peter

From Justus-Liebig-Universität Giessen For the  $\overline{\mathsf{P}}\mathsf{ANDA}$  collaboration





panda

### PANDA CM Prague 2023











MVD of PANDA	at	FAIR
0000		

ToASt Frontend ASIC

## The Micro-Vertex-Detector of the PANDA Experiment at FAIR



#### 

## Strip Sensors

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Readout System



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## Strip Sensors

Barrel sensor	
Thickness	$285\mu{ m m}$
Strips	$896 \times 512$
Pitch	$65\mu{ m m}$
Readout	every 2nd strip
Stereo angle	90°



Wedge sensor	
Thickness	$285\mu{ m m}$
Strips	786 per side
Pitch	$45\mu{ m m}$
Readout	every 2nd strip
Stereo angle	$15^{\circ}$



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Summary 00

# Strip Sensors

- > Double sided strip sensors w/ AC-coupled microstrips
- > Manufactured by CiS in Erfurt
- > Small sensors used for prototyping
- More information: Thu, 16:45 - Nils Tröll







## Torino Amplifier for silicon Strip detectors (ToASt) Frontend ASIC

- > 64-channel charge sensitive, self triggering amplifier
- > ToT method for digitization
- > Per-channel calibration
- > Developed in Turin, functionality verified



Specification	Min	Max	Unit
Input capacitance	2	16	pF
Max rate per strip		50	kHz
Input charge range	1	40	fC
Max noise		1500	e-
Peaking time	50	>=100	ns
Channels per chip	64		
Reference clock		160	MHz
Charge resolution	8		bits
Time resolution (pk-pk)		6.25	ns
Time resolution (r.m.s.)		1.8	ns
Power consumption		256	mW
Chip dimensions	3.2	4×4.41	$mm^2$



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# Torino Amplifier for silicon Strip detectors (ToASt) Frontend ASIC

- > Thresholds and ToT current can be adjusted globally (coarse) and for each channel (fine)
- Readout of 8 channels of each region to FIFO
- > Packing of all data in each time frame

(12 bit at  $160\,\mathrm{MHz}\sim25.6\,\mathrm{\mu s}$  rollover)



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## ToASt Test PCB

- First time connecting PANDA sensors to ToASt January 2023 in Turin
- > Test readout system based on Xilinx ML605
- > Test measurement with  $^{90}\mathrm{Sr}$  source is promising







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## New Readout Electronics

- > Designed at KIT in Karlsruhe
- > Based on HighFlex readout card
- > Features Module Data Concentrator
- > First MDC architecture designed on FPGA





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## New Readout Electronics

- > Readout based on PCIe Gen 3, compatible to any PC
- Data can be streamed directly to GPU (NVIDIA GPUDirect)
- > Up to 120 Gb/s data throughput for simultaneous readout of multiple ToASt





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# Module Data Concentrator (MDC)

- > Readout of up to 12 ToASt
- > Dynamic configuration of number of active ToASt and high-speed links
- > Non-active links kept in low-power mode
- Intelligent multiplexing logic to balance the data occupancy between the serial links
- > Frame number alignment



#### MDC architecture implemented

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# Module Data Concentrator (MDC)

#### Data stream format



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## ToASt Configuration

- > MDC works as PCIe device in Linux
- > Configuration is mirrored and synched with ToASt chips
- > Read/write of different addresses for configuration

NOVOUS 🗇 Terminal Y		Feb 22 10/31 .
s 01		kalgere@kalgere.
Configuration		
CLOBAL Registers		
	00000833 08858175	
6038: 0000038d 00000324	00000240 00000318	- 16 Clobal registers
60391 00000625 00009125	00000355 00000071	
Channel Registers		9
Repton 8		
60591 00000055 00000015	00000416 00000015	
60681 00000436 00000018	00000410 00000410	
BegAan 1		
00001 00000000 00000018	00000436 00000838	
00451 00000035 00000015	00000436 00000035 1	
00001 00000035 00000018	00000110 00000111	
Changel Registers		
	00000414 00000010	
2 00491 00000435 0000019	00000410 00000810	
A0/91 00000035 00000015	00000416 00000815	
61881 00000034		A regions divided
Channel Bretaters		
Beddan 3		
	CONCULTS CONSISTS 10	
41281 00000438 0000018	00000410 00000010	/// Lin & channels each
41491 00000035 00000018	(1000110 010111 18	
×		
Changel Registers		
61001 D0000000 D0000018	00000110 000000110	
61691 00000035 00000018	00000416 00000818	
41781 00000d35 00000018	00000416 03935818	
01001 01001034		
	/	
A103: 0000000 0000018	CONCELLA CONTRACTO	
61981 00000035 00000018	00000410 00000010	
01251 00000036 00000018	CONCULIA CONTRACTOR	
rhanal metaters		
	/	
01411 0000000 0000018	00000110 00001111	
61491 00000435 00000018	00000416 00000810	
61741 00000035 00000018 62831 00000036	00000416 000558138	
Channel Breistern		
62881 00000000 0000018	00000436 00000038	
0.7591 00000235 00000018	00000110 000000118	
41141 44444214 4444401	200000110 00000010	
62281 00000035 0000018 52381 00000035 00000018	ceeced10 09800838	
02201 00000030 00000038 02301 00000035 00000018 02401 00000030	concodio conconita	
02291 000000250 000000050 02391 000000255 000000018 02491 000000255	concolia ossossia	

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## **ToASt Configuration**

- Full control with graphical user interface (PyQT6)
- Save / load configuration of single or multiple ToASt boards
- Status indicator shows MDC / ToASt configuration mismatch

			×
File			
Save ToASt Config Ctrl+S			
Load ToASt Config Ctrl+L			
000 - 10	ection Read Ar	aain Suhmii	
	reading freed by	300110	

		MVD GUI Version 1.0.0		_ = ×
Tools				
ToASt Status				
ToASt		Information	Config	
000				
(re.) write all cou	atio (re.) read all conf			
(ce) write an cor	-ig- (reynead an conn	9 9		

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## ToASt Configuration in GUI

- > Grey: Disabled / initial
- > Green: All good
- > Yellow: Edited / not synced
- > Red: Mismatch

Toar	st Config	- 0	×
Parameter	Value		14 I
35 🕒 CSA gain boost Vbias			
36 💛 Preamp feedback pMOS Ibias			Тор
37 🗢 Preamp feedback nMOS Ibias			То
38 🗢 Preamp ishift			
39 🗢 PTA Ibuť			-
40 – PTA pMOS Ibias			
41 - PTA nMOS Ibias	11111		
42 - Region 7 disable			
43 – Region 6 disable			
44 O Region 5 disable			
45 - Region 4 disable			
46 - Region 3 disable			
47 O Region 2 disable			
48 - Region 1 disable			
49 - Region 0 disable			
	and according to the		
000 - ID	conf. correction Read	Again Subm	15. I
			.1

1					
	ToASt		Information	Config	
	000				
		fig (re-) read all co			

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## ToASt Calibration

- > Use of testpulse generated by ToASt
- > Calibration registers for each channel
- > Calibrate by:
  - Gain (time over threshold / charge)
  - Offset
  - Threshold (s-curve fit)



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## ToASt Calibration in GUI

- > Automatic sweep over calibration parameters
- > Taking mean and sigma of time-over-threshold
- > Automatic calibration, results saved in a file
- > Calibration result can be applied to config

	ch_id	ib_calib	tot_calib	tot_m	tot_s
0		7.872		247.106247	24.895483
1		7.872	16	260.700012	52.442476
2		7.872	16	236.500000	33.547547
3		7.872	16	477.549988	35.351764
4		7.872	16	347.125000	22.471620
315	59	16.000	16	268.087494	51.616437
316	60	16.000	16	465.168762	78.924939
317	61	16.000	16	46.493752	29.506731
318	62	16.000	16	341.924988	18.321488
319	63	16.000	16	332.824982	25.258684
[320	rows x	5 columns	]		

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## Online Data Display

- > Already displaying data inside GUI
- > Performance will be optimized
- > More options will be implemented
  - Single channel histogram
  - Calibration fits
  - Toggle full / avg over frames



### MVD of $\overline{P}ANDA$ at FAIR 0000

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# Online Data Display

### Future features in development:

- > 2D heatmap from 2 perpendicular strip layers
- > Interactive channel matching
- > Live update



Readout System

## Beamtime Preparation

- > Synchronization with other hardware:
  - External clock
  - External trigger, reset and epoch counter
- > Design software:
  - Graphical user interface
  - Online analysis
  - Automatic configuration and calibration
- > In-Lab test of the system:
  - Tests with source
  - Data integrity tests
- > Beamtime tests this year at COSY with 3 GeV/c protons - first time beam time test of ToASt in beam

## Summary

- > Test PCB of ToASt connected to small strip sensor
- > Graphical user interface already has basic functionality
- > More features to be implemented, more bugs to be fixed
- > Upcoming beamtime at COSY

## The Micro-Vertex-Detector of the $\overline{P}ANDA$ Experiment at FAIR

#### Why is it needed?

- > Primary and secondary vertex reconstruction
- > Improve momentum reconstruction
- > support **PID** via dE/dx
- > Event building in continuous data stream

#### **Requirements:**

- > Spatial resolution
- > **Time** resolution < 10 ns
- > Continuous readout
- > Radiation tolerance  $\sim 10^{14}\,{\rm n_{eq.}/cm^2} \text{ and } 100\,{\rm kGy}$
- > Limited material budget  ${\sf X}/{\sf X}_0 \leq 1\,\% \text{ per layer}$
- $\boldsymbol{\succ} \geq$  4 hits per track
- > Operation at room temperature
- > Routing and services from the back

## Strip Sensor Details



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## Strip Sensors

- > All required strip sensors tested and delivered
- > Quality checks with probing station in Gießen by Nils Tröll utilizing:
  - LCR-Meter Sourcetronic ST2826
  - Voltage supply Keithley 2410
- > Tested: leakage current, depletion voltage and capacitance





## **ToASt Details**

Input capacitance 2 - 16 pF Max rate per strip  $50 \, \text{kHz}$ Input charge range 1 - 40 fC Max noise  $1500 e^{-}$ Peaking time 50 - 100 ns Channels per chip 64 Channel pitch 66 um Reference clock 160 MHz 8 bits Charge resolution Time resolution 6.25 ns (pk-pk) 1.8 ns (r.m.s.) **Output** drivers  $2 \times 160 \, \text{MS/s}$ Max power consumption (estimated, full TMR)  $360 \,\mathrm{mW} \,(5.6 \,\mathrm{mW/ch})$ (estimated, no TMR)  $257 \,\mathrm{mW} \,(4 \,\mathrm{mW/ch})$ Die size  $3.24 \times 4.41 \text{ mm}^2$ Pads position On two sides only

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ToAst configuration and "error protection" architecture



ToAst configuration and "error protection" architecture



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