

Particle Telescope with Timepix3 Pixel Detectors

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Pavel Broulím¹, Petr Burian^{1,2}, Vjačeslav Georgiev¹, Benedikt Bergmann²

¹) Faculty of Electrical Engineering, University of West Bohemia, Czech Republic

²) Institute of Experimental and Applied Physics, CTU in Prague, Czech Republic

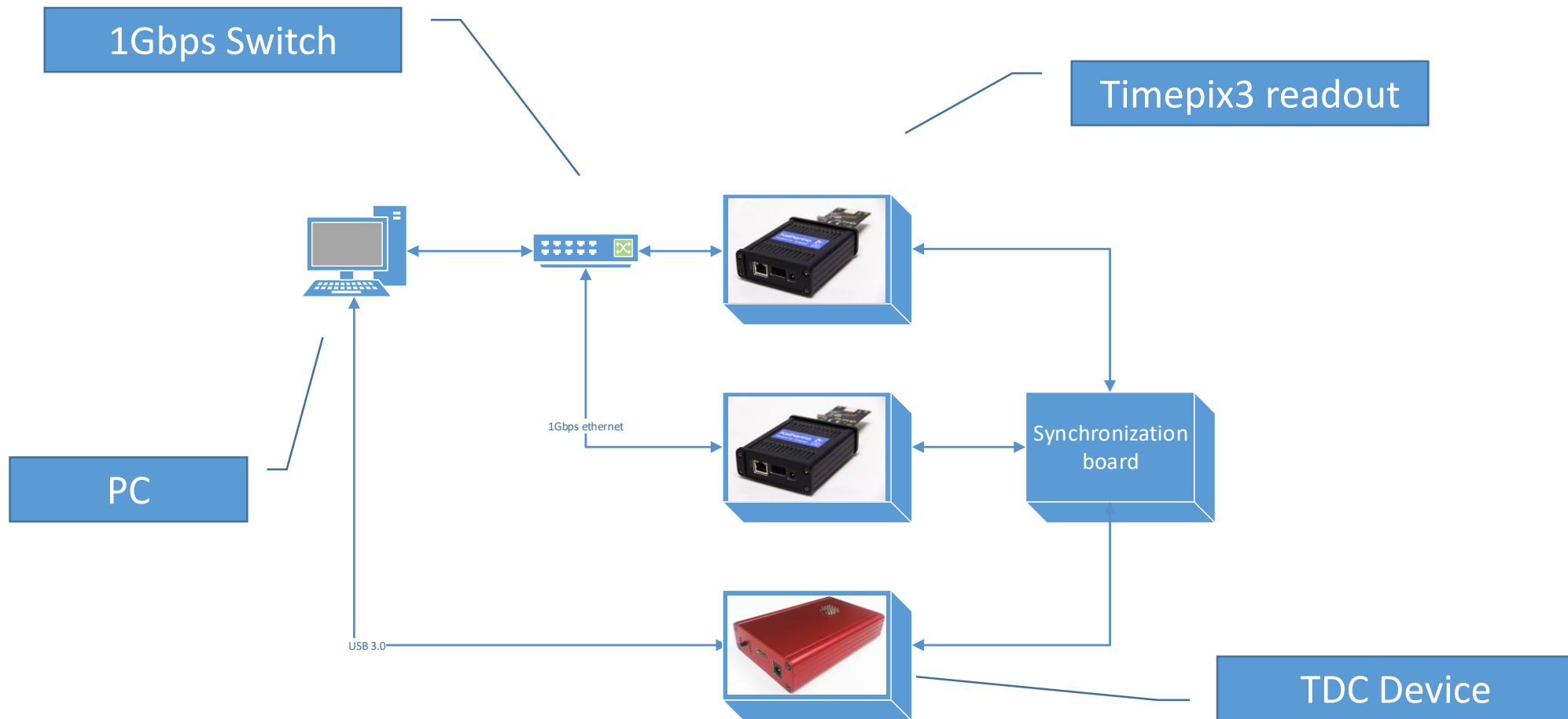
Outline

- ▶ Motivation
- ▶ Particle telescope
 - ▶ Timepix3 ethernet readout
 - ▶ Synchronization board
 - ▶ TDC device
- ▶ Experimental set-up
- ▶ Measurements
 - ▶ Coincidence clusters
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- ▶ Summary

Motivation

- ▶ Timepix3 → Increasing demands
 - ▶ Clock synchronization
 - ▶ Signal delays
 - ▶ Time resolution
- ▶ One device usable for separate measurement (with one detector) or connected with other readouts → No need extra hardware (readout) for telescope)
- ▶ Different distances between detectors
- ▶ Possibility of stacking devices (2, 3, 4... readouts)

Particle telescope – block diagram



- ▶ Very high data rate from each detector (1Gbps ethernet)
 - ▶ Usage of PC per each readout is a good option
 - ▶ PCs can be in completely different places

Katherine: Ethernet Embedded Readout Interface for Timepix3

- ▶ Readout for one Timepix3 device
- ▶ Both polarity of high voltage for bias ($\pm 300\text{V}$)
- ▶ Gigabit Ethernet Interface (approx. 15Mhits/s)
- ▶ Dimension: roughly 100x80x28
- ▶ Enough computing power for user purpose:
 - ▶ Approximately 8000 ALMs in FPGA free to use
 - ▶ Dual-core ARM Cortex-A9 processor
 - ▶ 1GB DDR3 RAM
- ▶ In more details: on Thursday presentation “Katherine: Ethernet Embedded Readout Interface for Timepix3” by Petr Burian



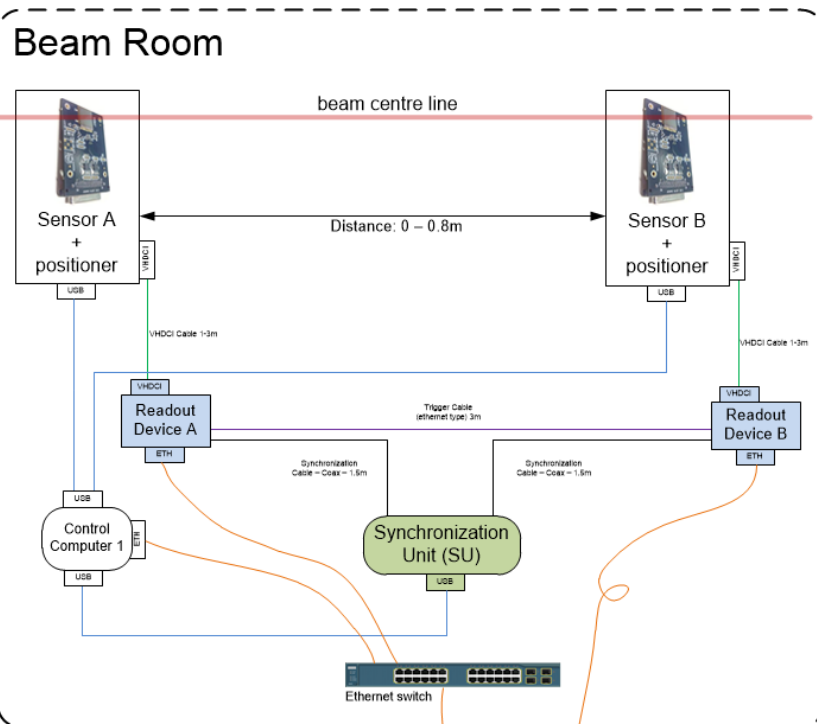
TDC and synchronization board

- ▶ Time-to-Digital Converter (TDC)
 - ▶ 4 channel + 1 synchronization channel, USB 3.0 communication
 - ▶ LSB resolution 13ps, dynamic range up to 7s
 - ▶ 1 return channel → possibility of stacking or measuring propagation delay of a transmission line (useful for timestamp synchronization – 2 TDCs needed)

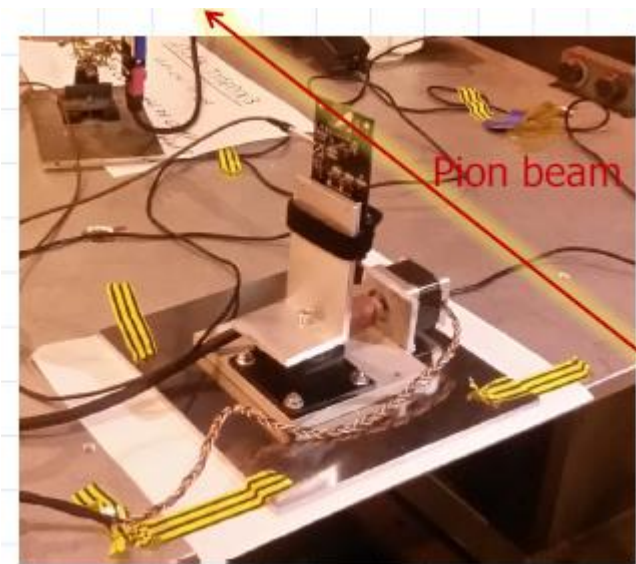
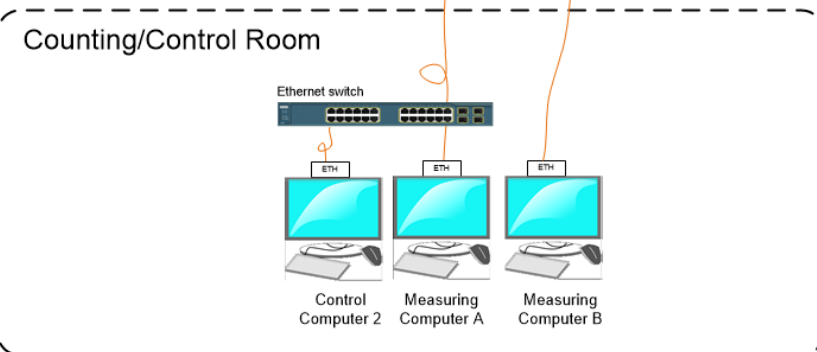


- ▶ Synchronization board
 - ▶ Up to 4 Timepix3 ethernet readouts
 - ▶ Connection through GPIO port on Timepix3 readout
 - ▶ Provides clock signal for each readout and synchronization signals with matched lengths for TDC from readouts

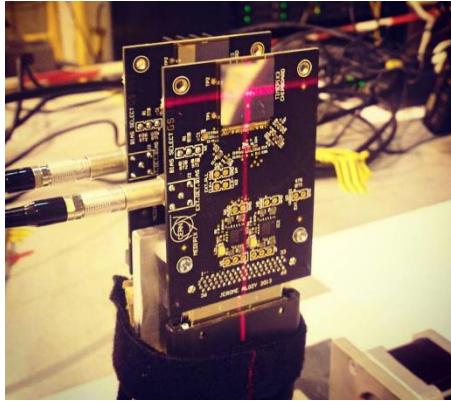
Experimental set-up at SPS (CERN)



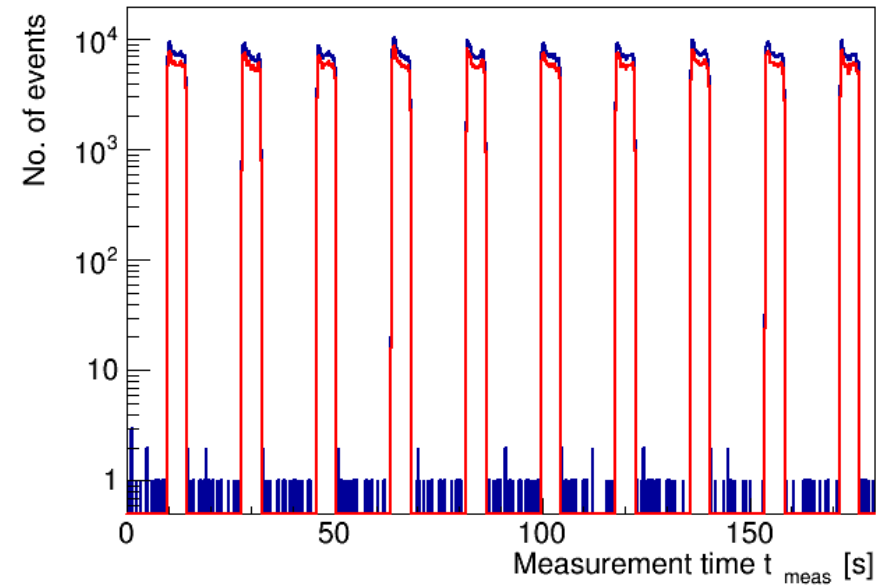
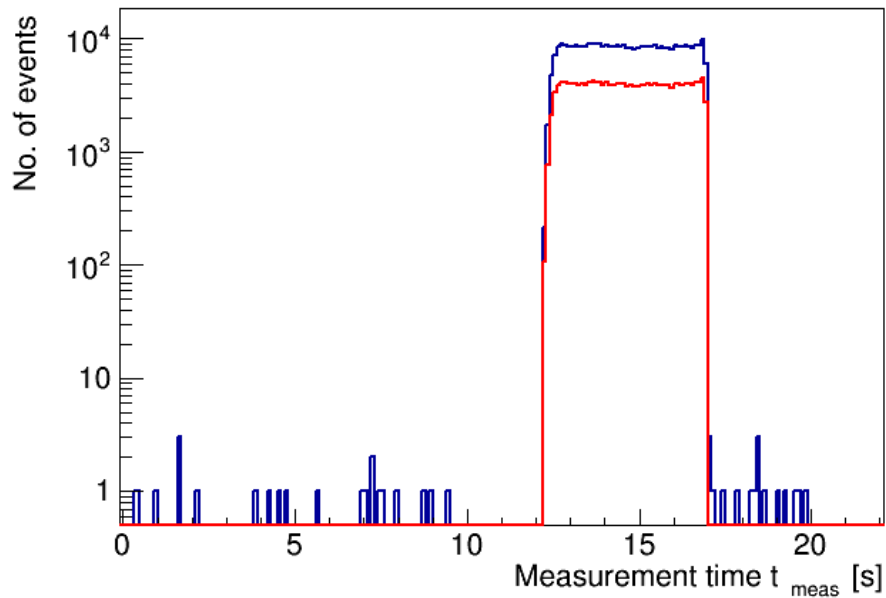
- ▶ Test beam – 120GeV Pions
- ▶ 500 μm thick silicon sensors
- ▶ Common clock source for both sensors
- ▶ Master detector triggers (starts shutter) the second one
- ▶ Phase of clocks and shutters measured by TDC device with high time resolution



Coincidence clusters

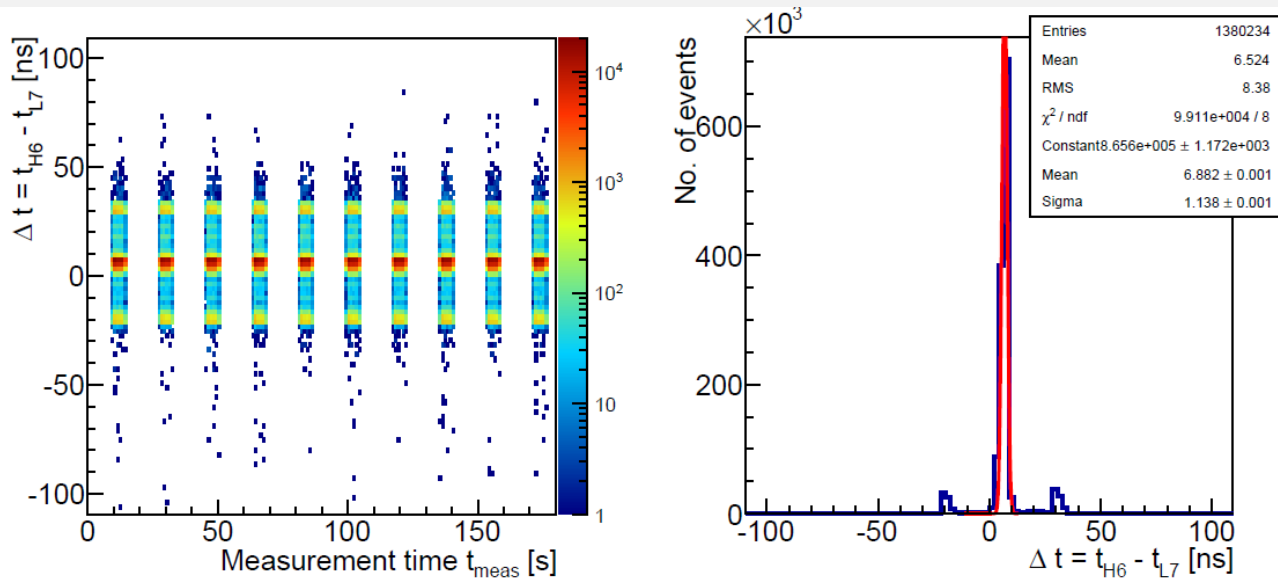


- ▶ Bunches
 - ▶ All clusters
 - ▶ Coincident clusters

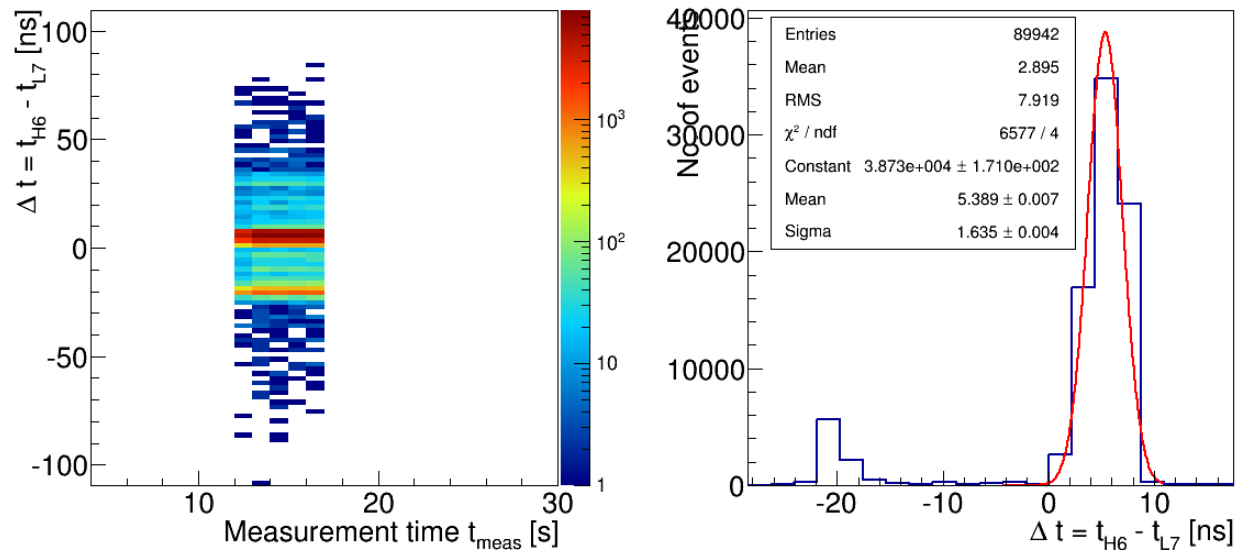


- ▶ Bunch detail:
 - ▶ All clusters
 - ▶ Coincident clusters

Clock stability



- ▶ Main peak:
 - ▶ Mean = 6.524 ns
 - ▶ FWHM = 2.68 ns
 - ▶ 2 additional peaks at ± 25 ns.



- ▶ Main peak:
 - ▶ Mean = 5.4 ns
 - ▶ FWHM = 3.9 ns
 - ▶ 1 additional peaks at -25 ns.

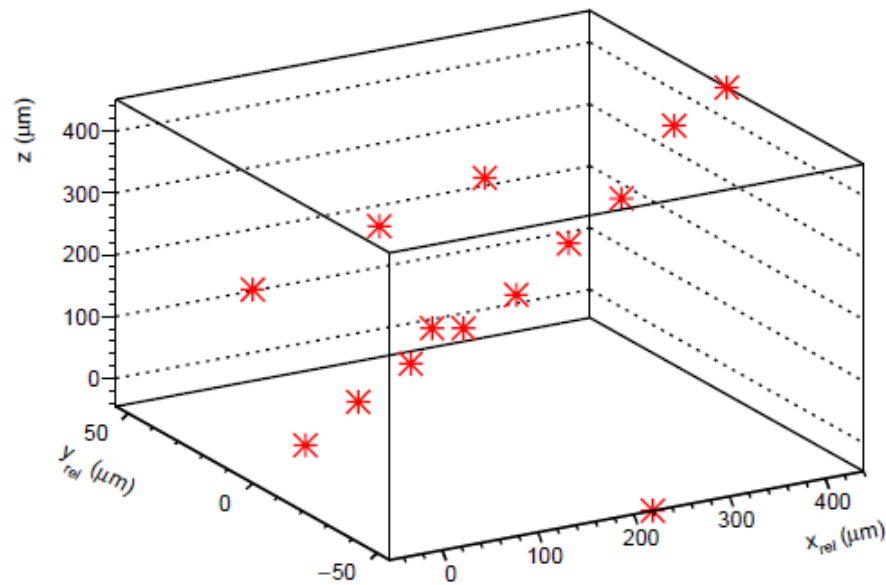
Coincidence event

▶ $\frac{dE}{dx} = 0.32 \frac{keV}{\mu m}$

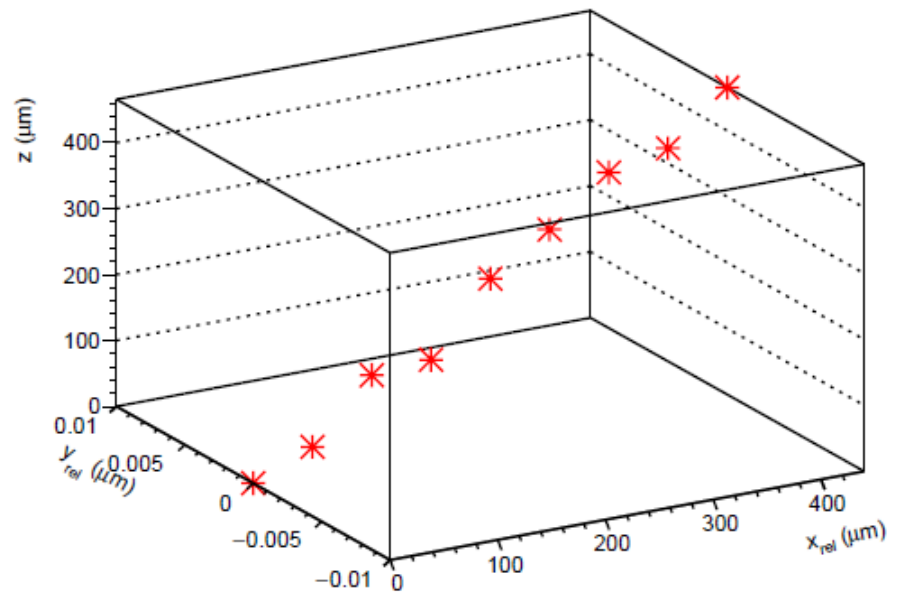
▶ $\Theta = 41.9^\circ$

▶ $\phi = 2.1^\circ$

Layer 1: relative coordinates



Layer 2: relative coordinates



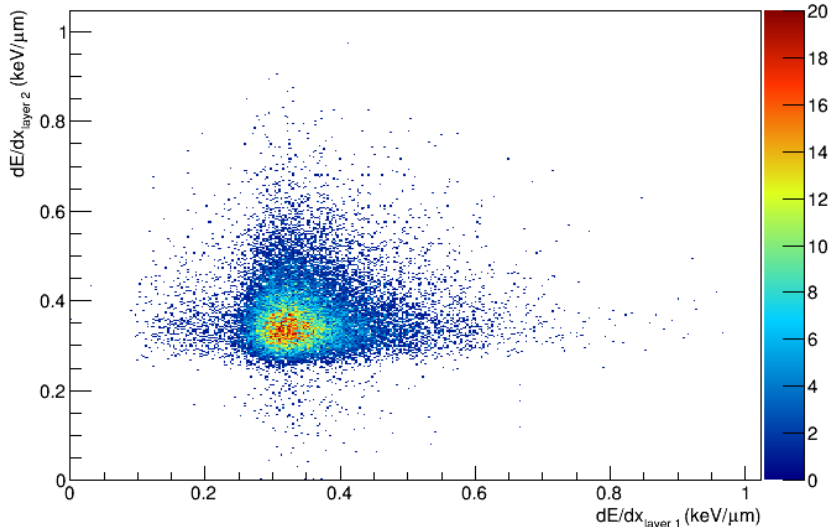
▶ $\frac{dE}{dx} = 0.32 \frac{keV}{\mu m}$

▶ $\Theta = 41.9^\circ$

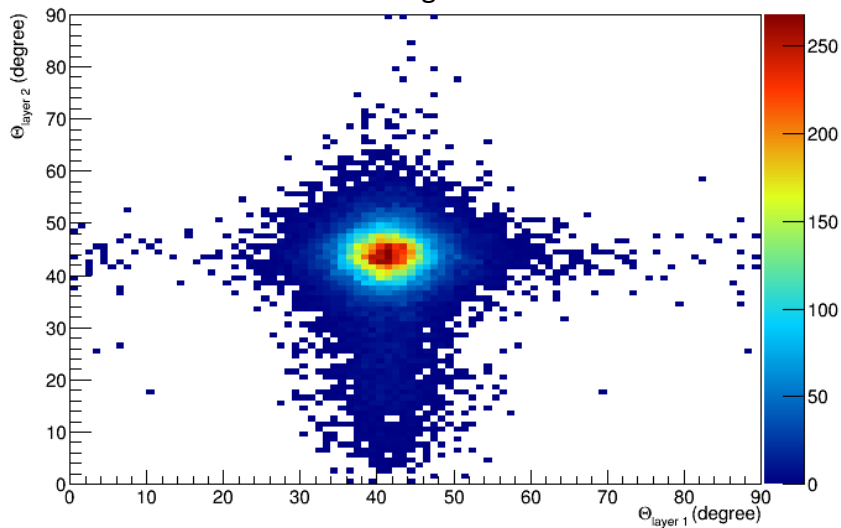
▶ $\phi = 3.5^\circ$

Concurrent tracks

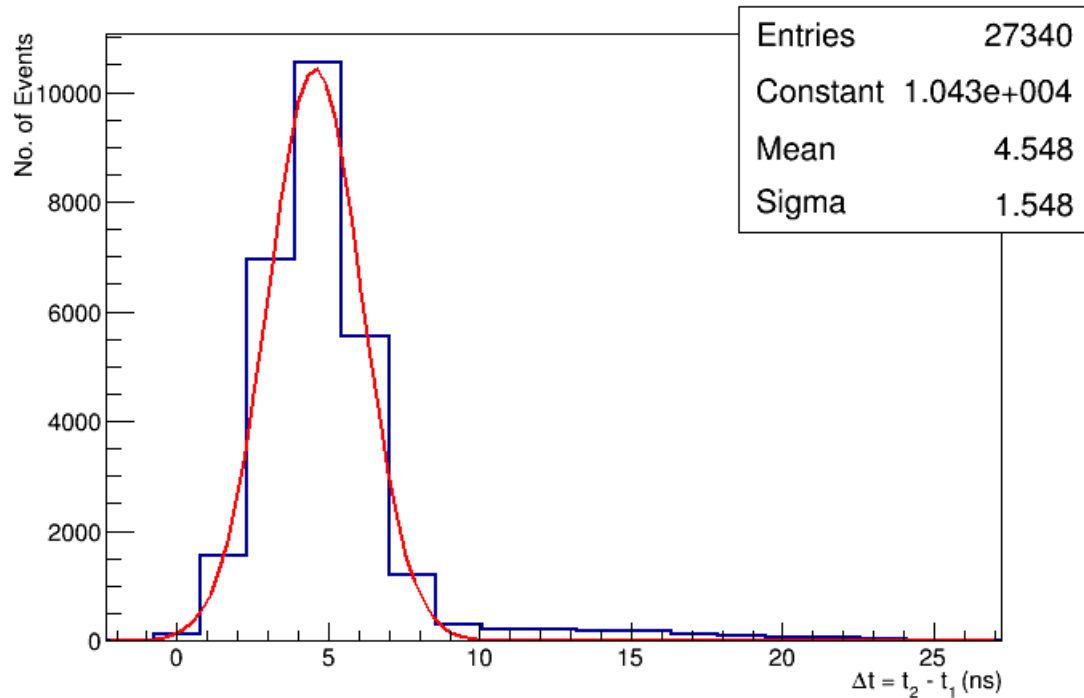
Stopping Power



Elevation angles

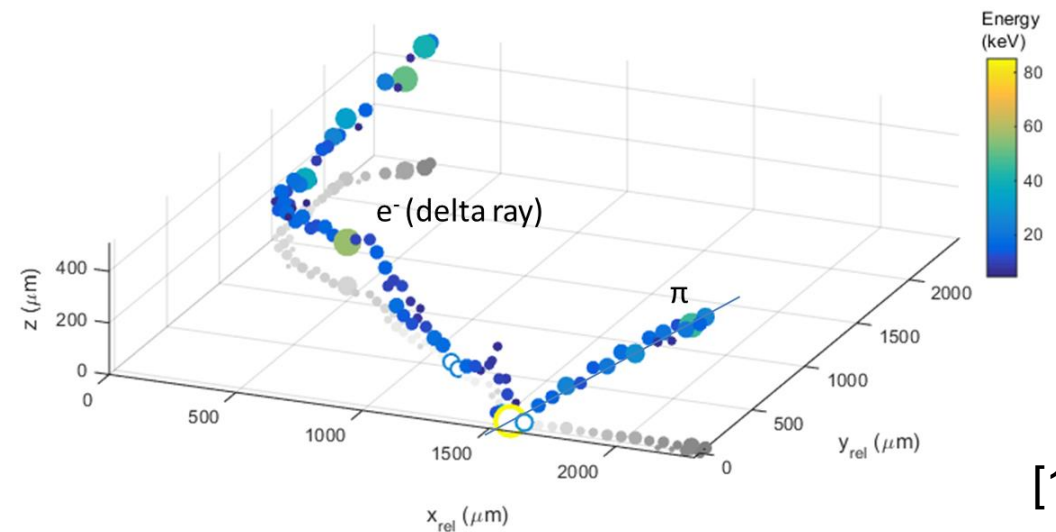
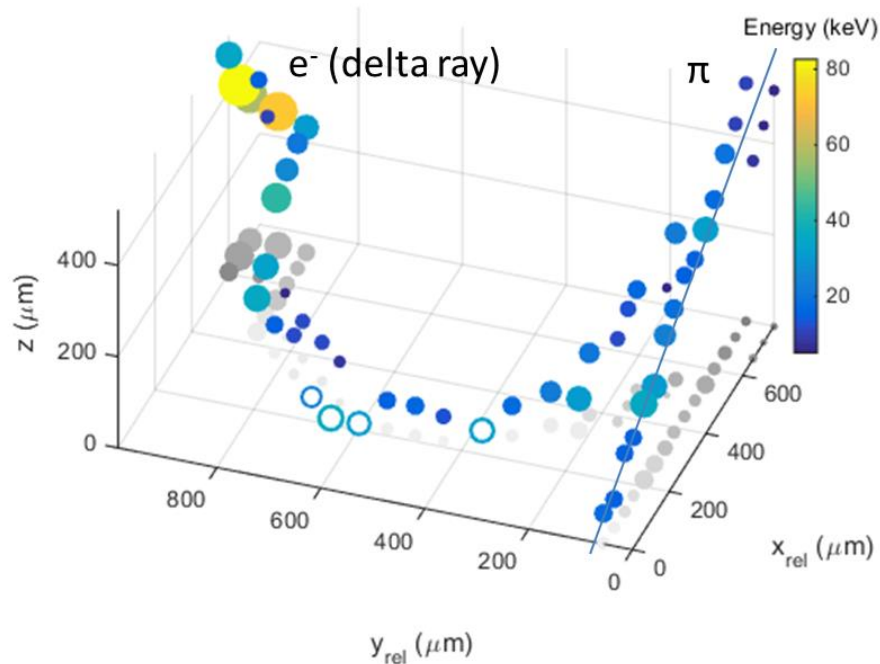


- ▶ Spectrum of time-differences between layer 2 and layer 1:
 - ▶ Resolution $\sigma = 1.548$ (resolution of fToA)
 - ▶ Offset due to 80 cm particle motion (2.67 ns)
 - ▶ Offset of measuring chain $\sim 1.8\text{ns}$



3D Trajectory reconstruction

- ▶ Reconstructed trajectories:
 - ▶ Measurement at the SPS (CERN), 120GeV Pions
 - ▶ 175V and 230V sensor bias voltage

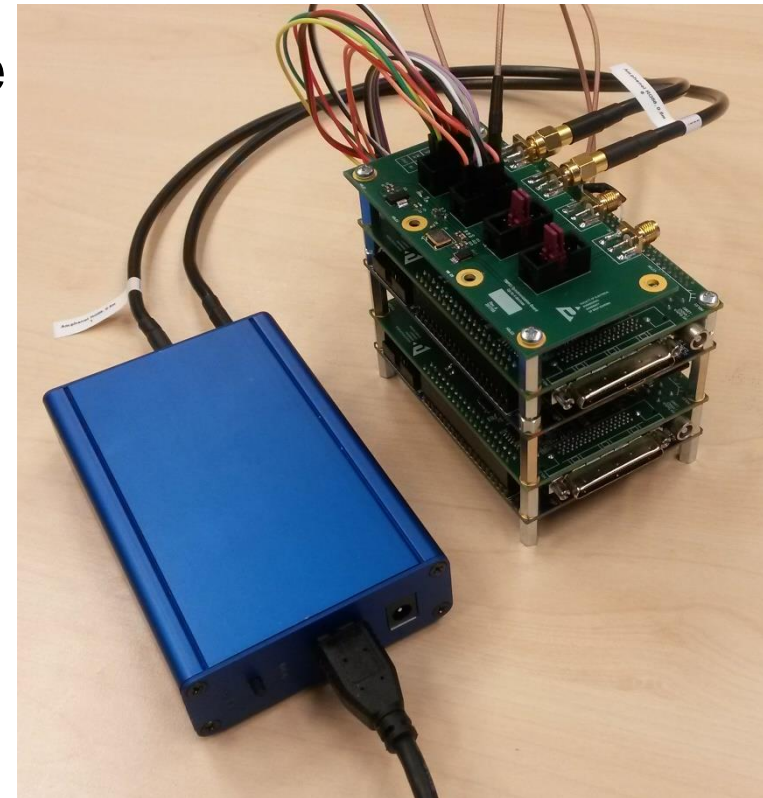
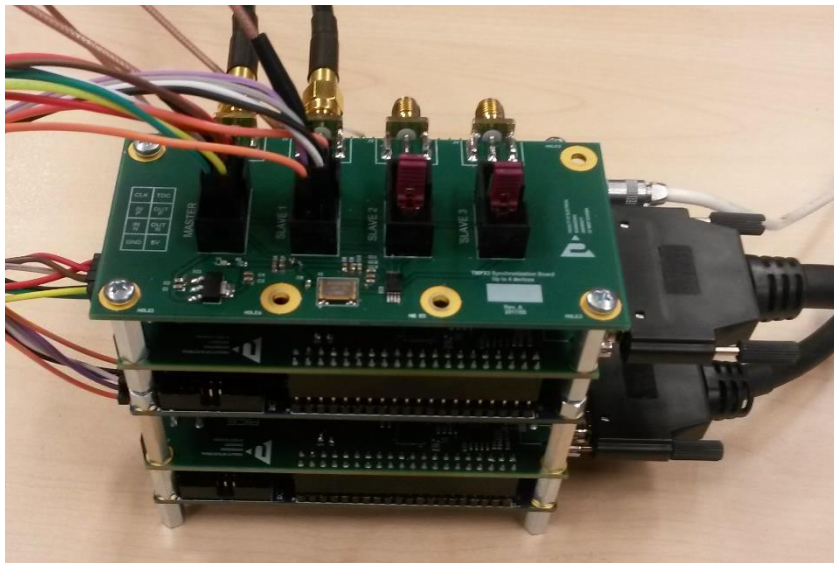


[1]

[1] Bergmann, B., Pichotka, M., Pospisil, S. et al. Eur. Phys. J. C (2017) 77: 421.
doi:10.1140/epjc/s10052-017-4993-4

Summary

- ▶ Concept was already tested at SPS at CERN
- ▶ Distance between detectors can vary
- ▶ Synchronization accuracy: $\sim 1.5\text{ns}$
- ▶ Up to 5 readouts (detectors) in telescope
 - ▶ Now only 4 (limited by sync board)





Thank you for your attention

Pavel Broulím / broulimp@rice.zcu.cz

Petr Burian, Vjačeslav Georgiev, Benedikt Bergmann