The European Physical Society Conference on High Energy Physics (EPS-HEP)

The GigaTracKer of the NA62 experiment at CERN

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on behalf of GTK group

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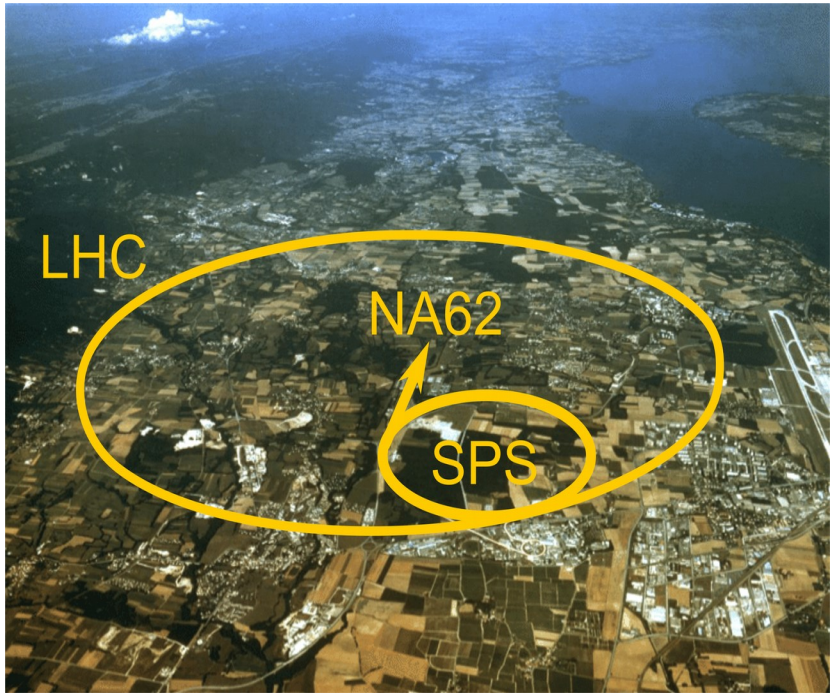
Outline

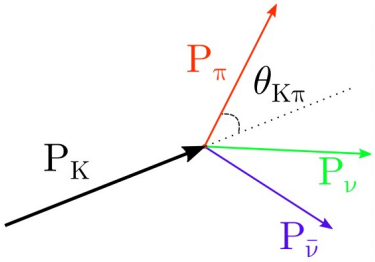
- The NA62 Experiment
- The GigaTracKer
- Performances
  - Kinematics
  - Time-stamping resolution

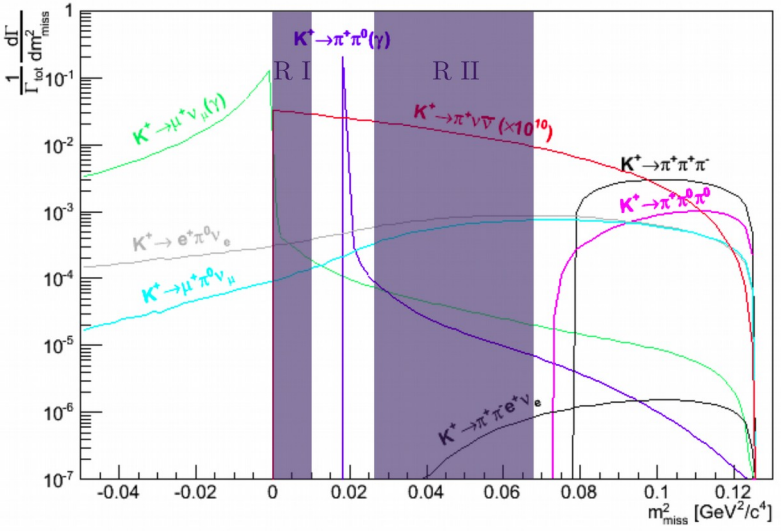
The NA62 experiment



NA62 – fixed target kaon experiment at the CERN SPS

Main goal: measurement of the BR($K^+ \to \pi^+ \nu\bar{\nu}$) with 10% precision using novel kaon-in-flight technique.
SM prediction: $\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) = (8.4 \pm 1.0) \times 10^{-11}$
Most discriminating variable: $m^2_{miss} = (P_{K^+} - P_{\pi^+})^2$ requires precise measurements of kaon and pion momentum

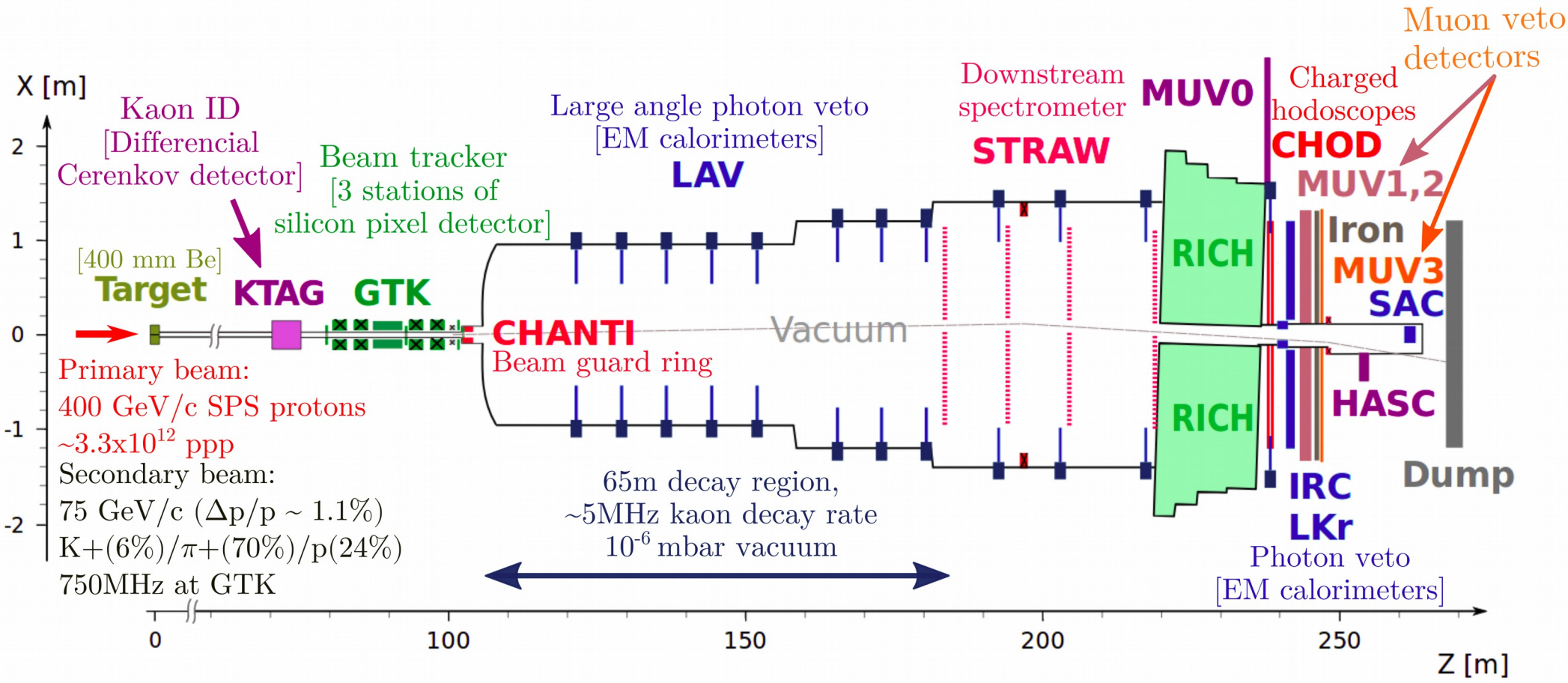




~30 institutes, ~200 participants from:

Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna, GMU-Fairfax, Ferrara, Firenze, Frascati, Glasgow, Lancaster, Liverpool, Louvain, Mainz, Moscow, Napoli, Perugia, Pisa, Prague, Protvino, Roma I, Roma II, San Luis Potosi, Sofia, Torino, TRIUMF, Vancouver UBC

Detector overview



[NA62 Detector Paper, JINST 12 (2017), P05025]

The GigaTracker

Beam spectrometer

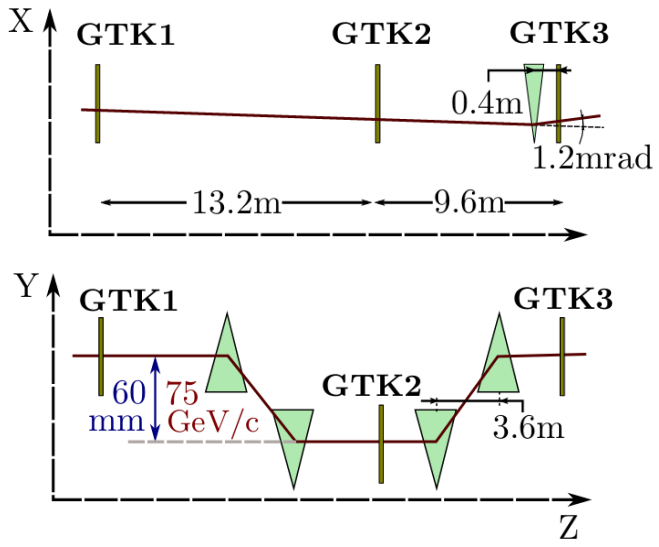
- Measures momentum, angle and time-stamp of all beam tracks
- Sustains high particle flux
- Minimized material budget

Design

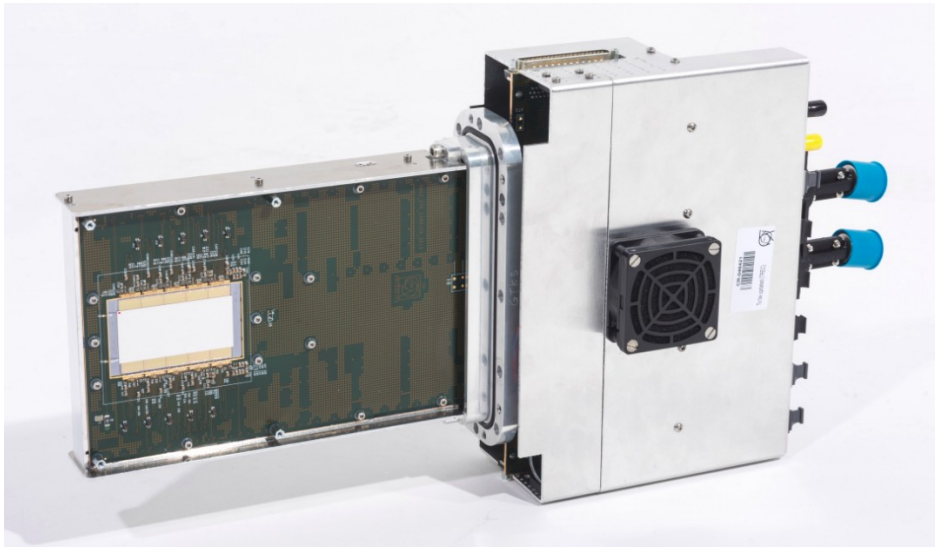
- Three planes of Si hybrid pixels
- Installed in beam pipe vacuum: ~10^{-6} mbar
- Replaced after 1 year at full intensity

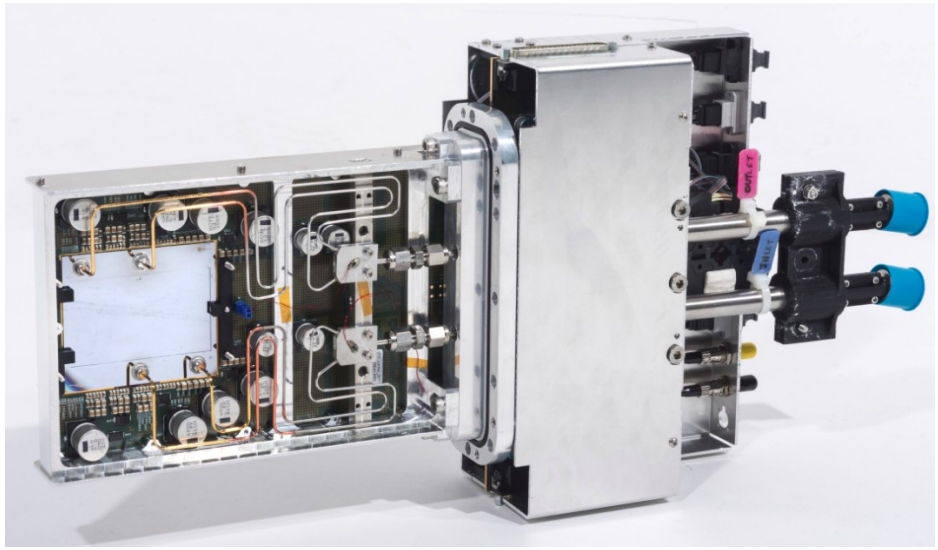
Nominal specifications:

Beam rate	750MHz-1GHz
Peak particle flux	2.0 MHz/mm^2
Peak radiation	4.5×10^{14} 1MeV n_{eq}/cm^2/200 days
Efficiency	99%
Momentum resolution	0.2%
Angular resolution	16μrad
Pixel time resolution	200ps RMS
Material budget	0.5%X_0



The GigaTracKer

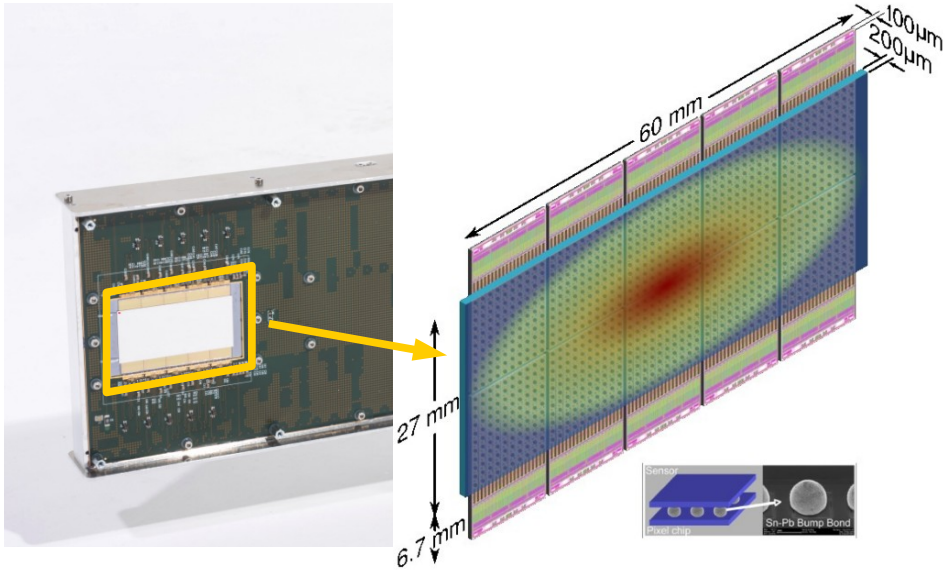




Detailed description can be found arXiv:1904.12837

The pixel matrix

TDCPix Sensor



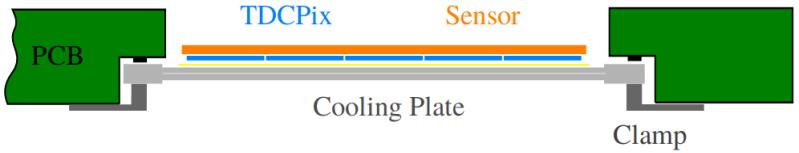
Sensor:
- n-in-p and p-in-n
- 27×60 mm²
- 200 μm thick (0.2% X_0)
- Bump bonded to 10 chips

Bump-Bonding:
- Sn-Ag bumps
- Benzocyclobutane deposited to avoid discharges

TDCPix:
- IBM 130nm CMOS technology
- 100 μm thick (0.1% X_0)
- 1800 pixels of 300 × 300 μm²
- Time resolution: <200ps
- Peaking time: 5ns
- TDC bin size: 97ps
- SEU mitigation

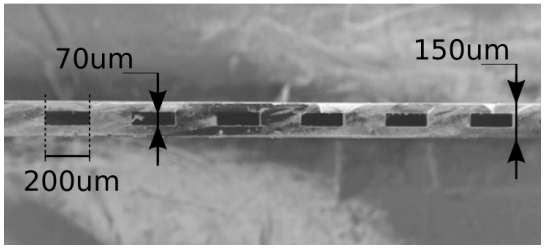
Detailed description can be found arXiv:1904.12837

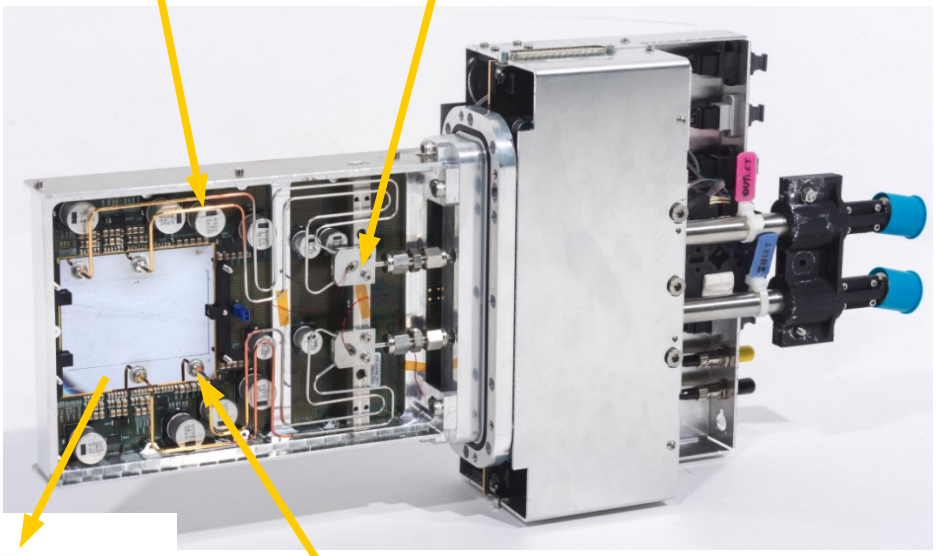
Cooling plates



Cooling plate:

- Micro-channel technology – first application in HEP
- Fabricated by CEA Leti
- 210 μm thick (0.2% X_0)
- 70x80 mm²
- Liquid coolant C_6F_{14}
- Front-end electronics and sensor at <5°C





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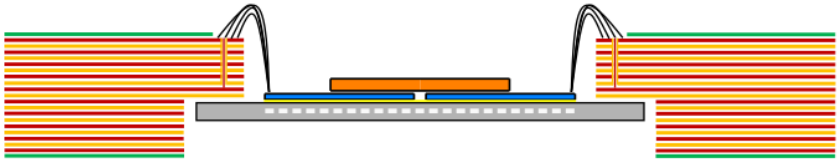
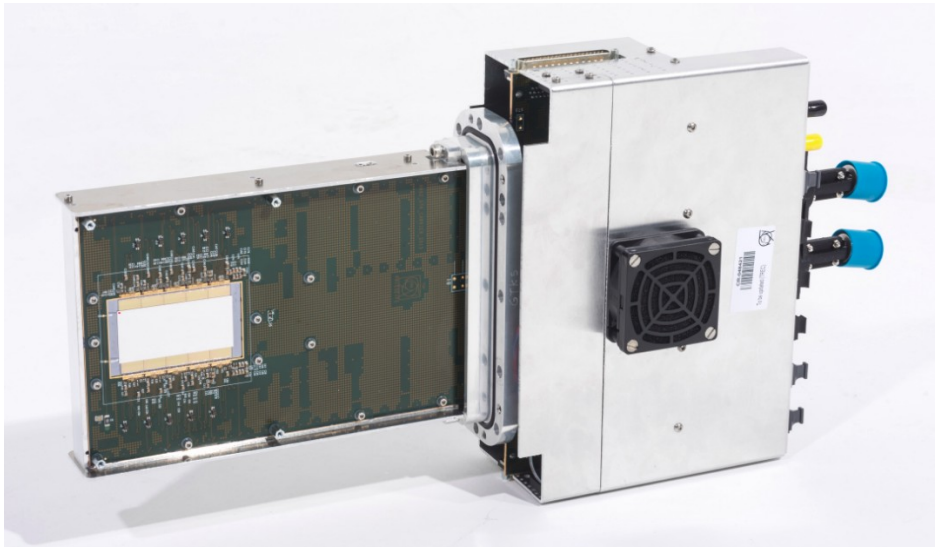
Electrical Integration





PCB:

- Chips, sensor and cooling plate assembly hosted in the countersink of the carrier board
- 14 layers T-shaped PCB
- 40 differential 3.2 Gb/s signals over 30cm

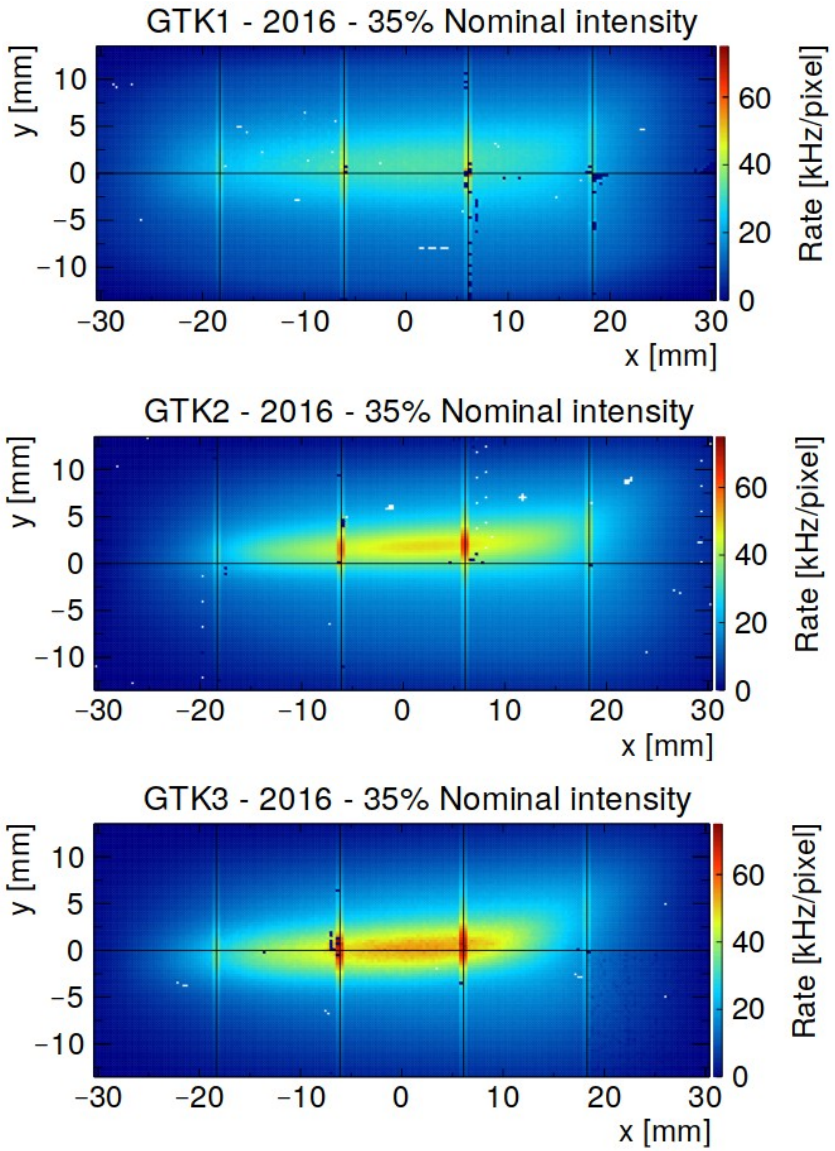
Wire bonding:

- TDCPix wired bonded to PCB
- Dense bonding scheme with 73 μm pitch on TDCPix (1450 bonding pads in PCB)
- Power, Clock, Config, Data transmitted

Detailed description can be found arXiv:1904.12837

Performances

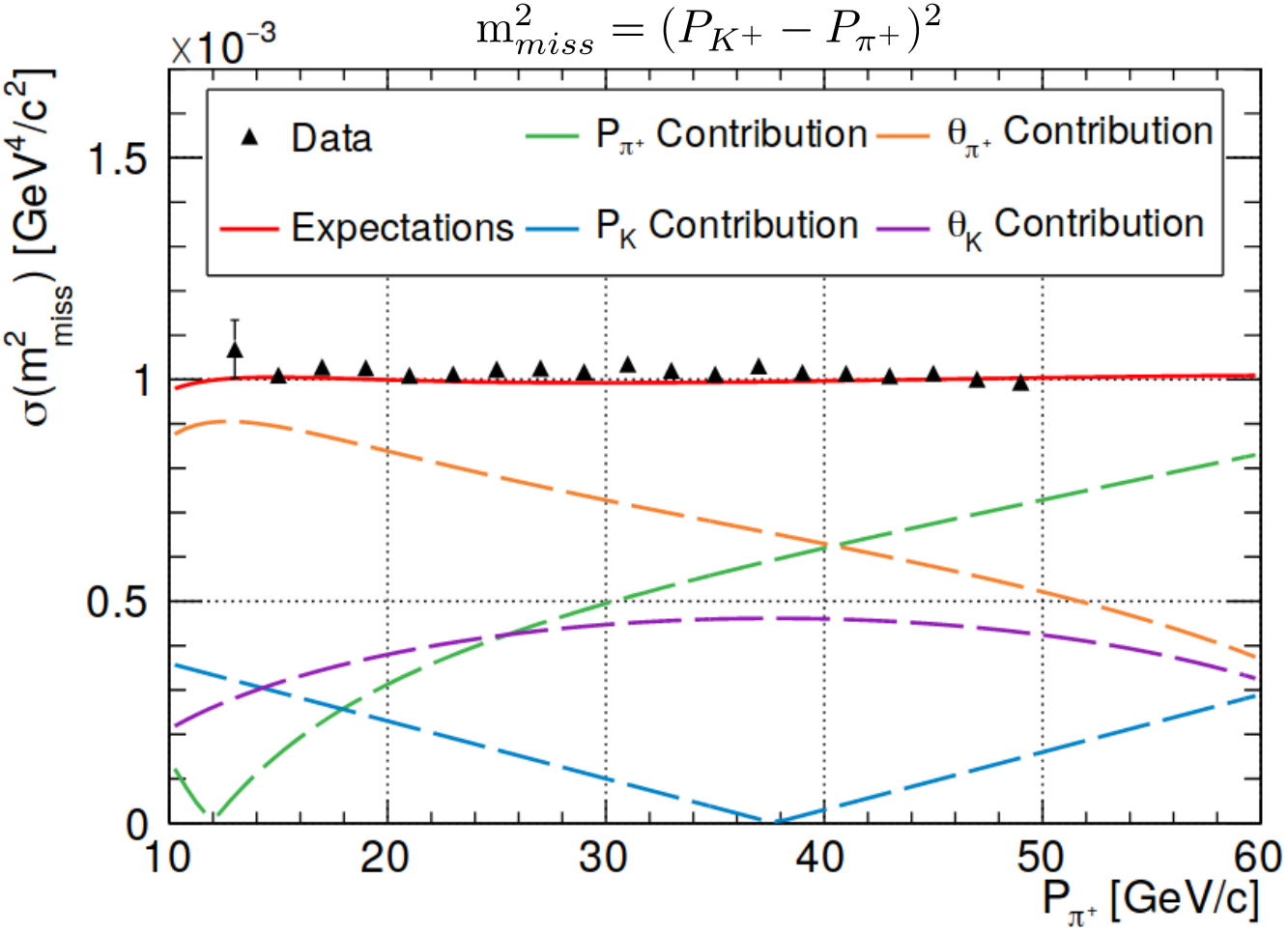
- Fully operational since September 2016 (first station installed in 2014)
- Few noisy/dead pixels (< 100 per station) at the end of 2017
- Beam intensity in 2016 around 35% of nominal. In 2017 the intensity reached 65% of nominal.



Kinematics

Physics performance from a sample of $K^+ \to \pi^+\pi^0$ matches design performance

$$m^2_{miss} = (P_{K^+} - P_{\pi^+})^2$$



Time Resolution at Sensor bias of 100 V

Conditions

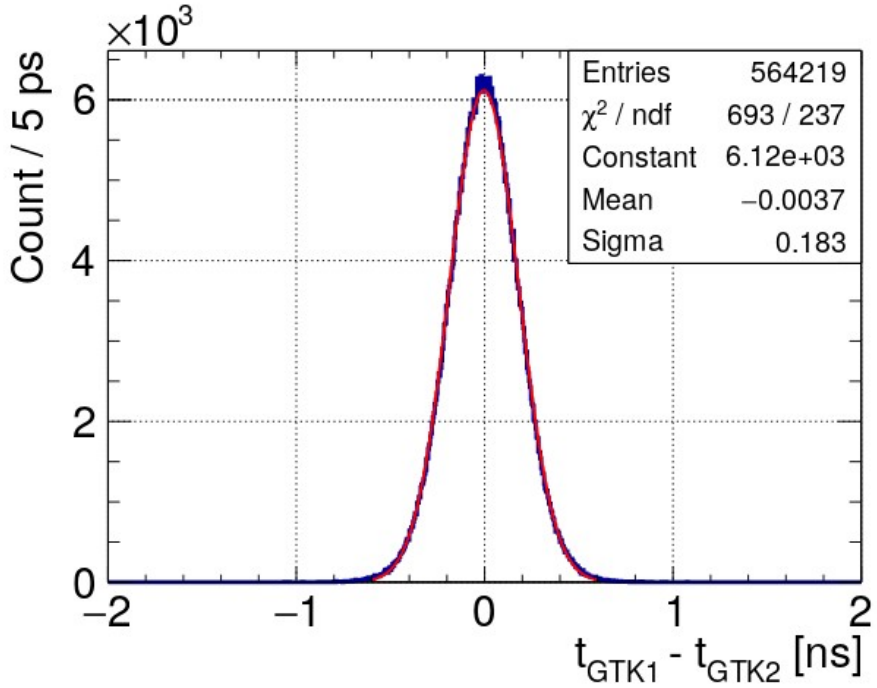
- At detector installation in 2016
- Sensor Type: n-in-p
- Operation bias: 100 V

Two Measurement Methods

- Time difference between GTKs KTAG RICH ($\sigma_t < 100$ ps)
- Time difference between the 3 GTK stations

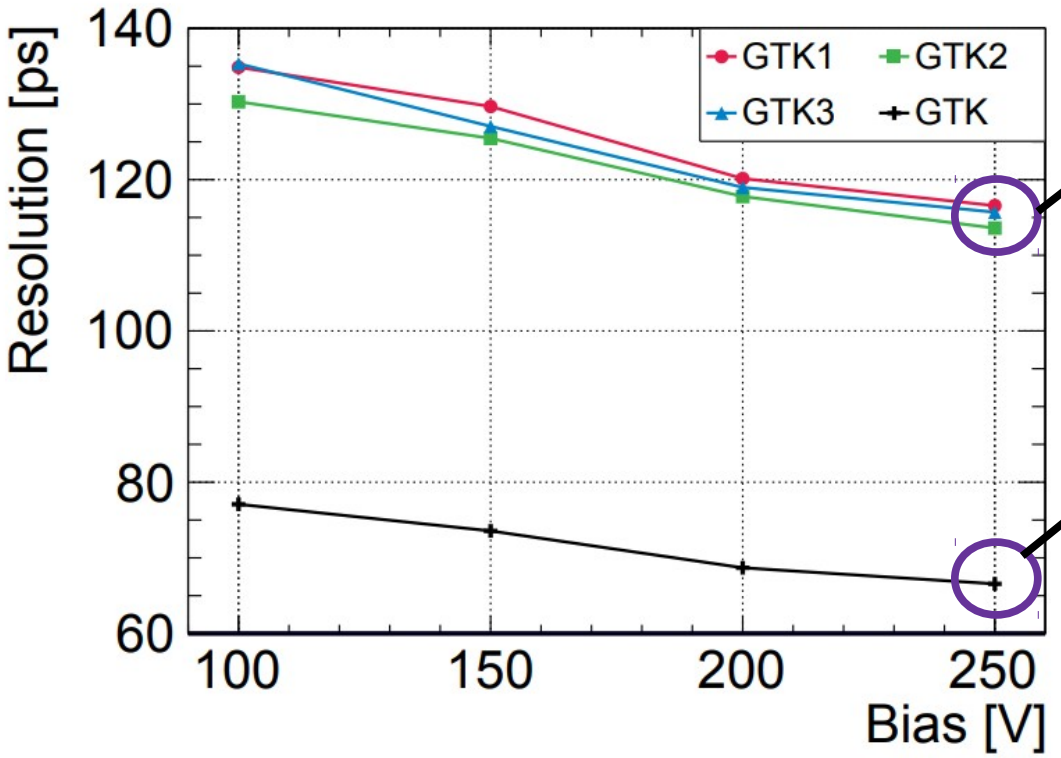
Results

- Hit time resolution: 130 ps
- Track time resolution: 75 ps
- Design resolution matched



GTK1	132.0 ps
GTK2	127.1 ps
GTK3	129.2 ps

Time resolution vs bias voltage



115 ps hit time resolution at 250V

65 ps track time resolution at 250V

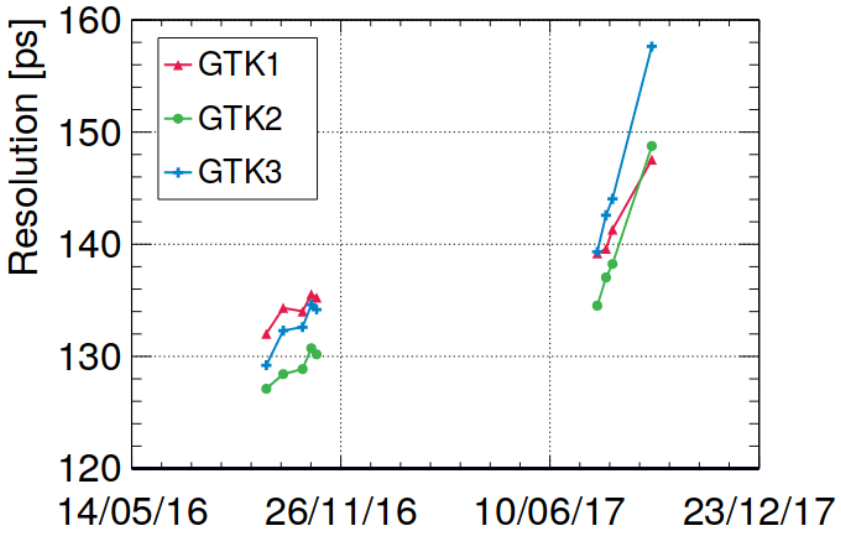
Conditions

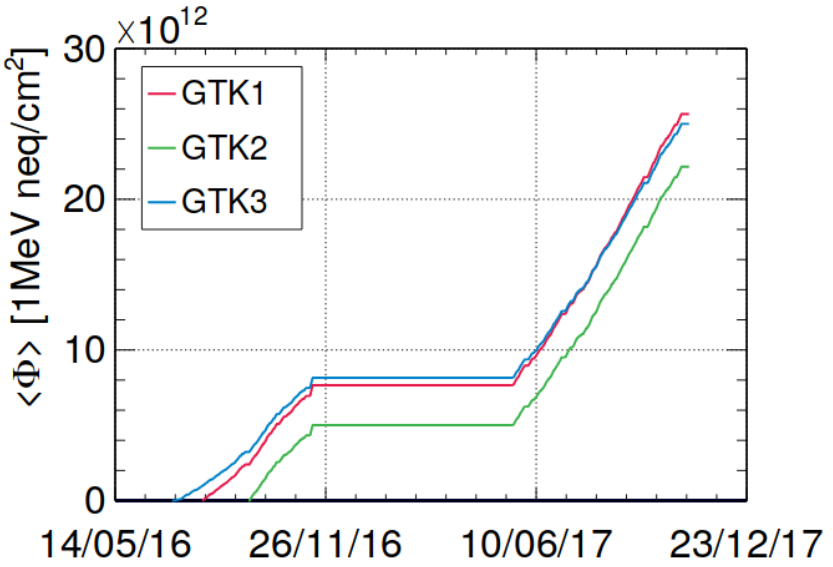
- Data collected at end of 2016 run, with n-in-p sensor

Results

- Weak improvement (15%) of the time resolution from 100 V to 250 V
- Charges collected faster but TDCPix pre-amplifier peaking time is fixed (5 ns) and larger than collection time

Time resolution stability over 2016 and 2017





- Degradation of time resolution of up to 25 ps (20%)
- Performances still better than design ones
- Origin not fully understood as many events occurred over 1.5 year
- Radiation is certainly a degradation factor

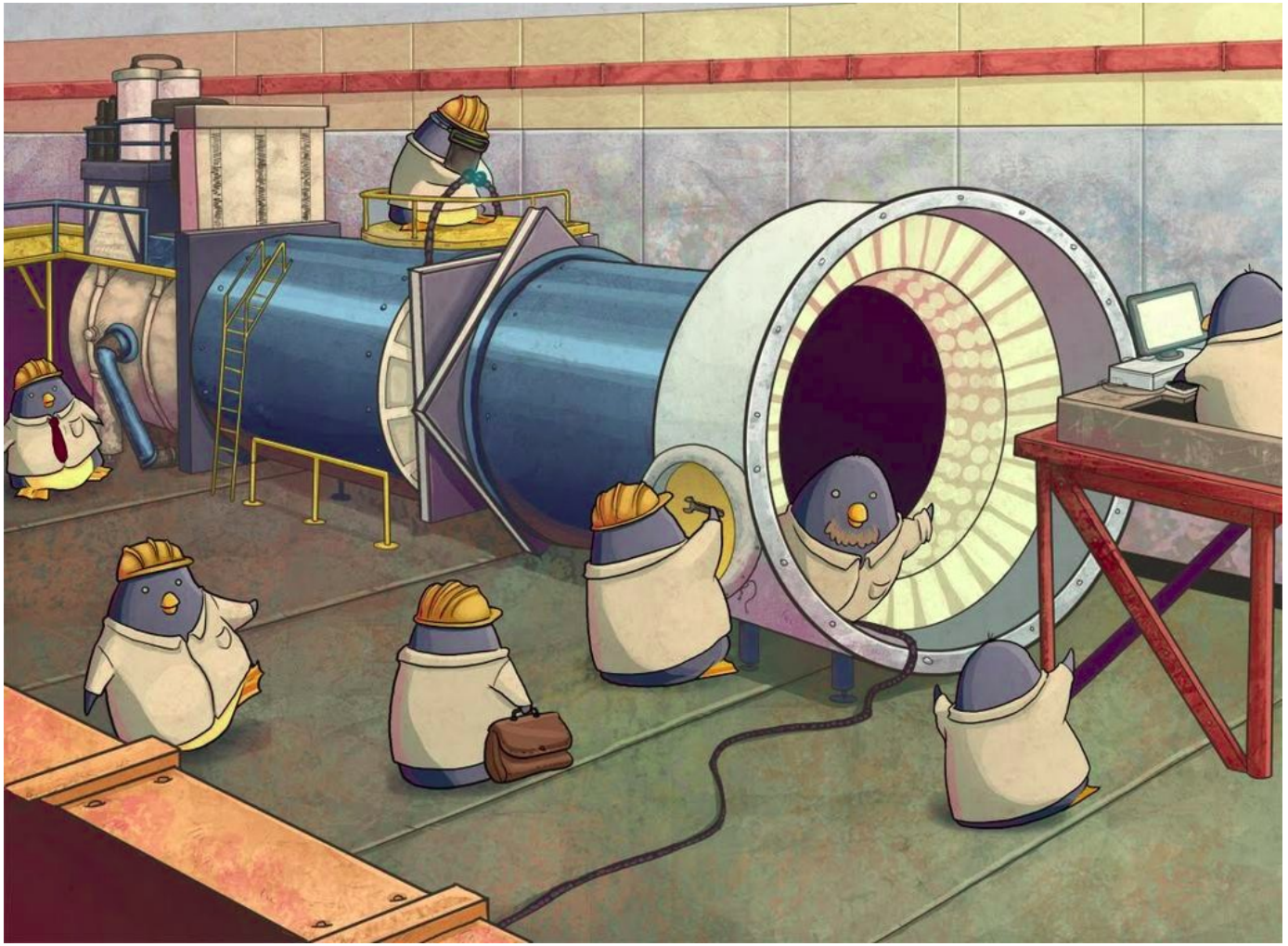
Summary

- The GigaTracKer is the NA62 **4D beam tracker** and is **essential** for the precise measurement of BR($K^+ \to \pi^+ \nu\bar{\nu}$)
- The detector is fully operational since 2016 and successfully took data until the end of Run 2
- The single hit time stamp resolution of **115 ps** was achieved, **surpassing** the design resolution
- Innovative **low mass cooling plate** with silicon micro-channel was implemented (first implementation in HEP)

Prospects:

- Analysis of data collected in 2018 is ongoing
- NA62 will run after LS2

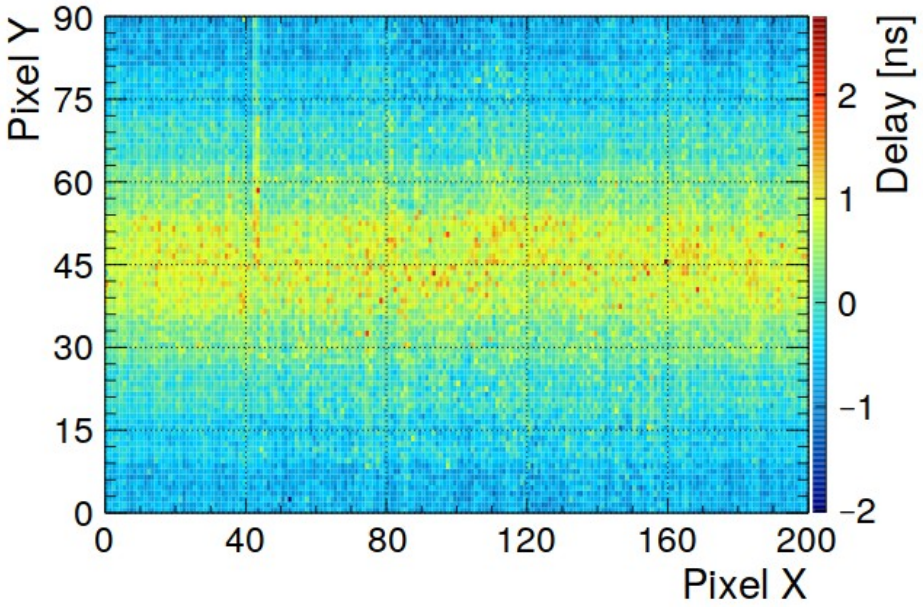
Thank you for your attention!

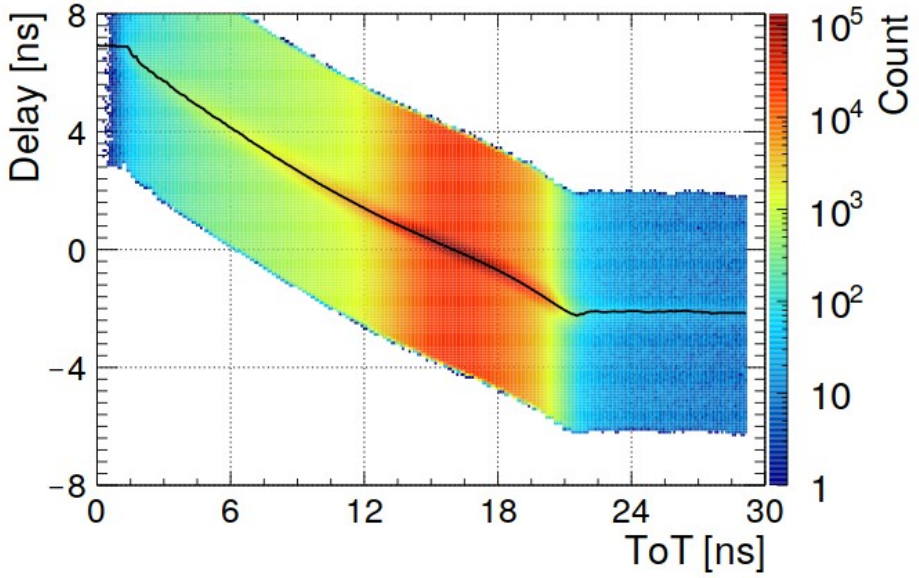


[Backup]

Time calibration

- Individual pixel delay (54k)
- Chip time walk (1 delay per ToT bin)
- Reference time: KTAG (70 ps resolution)





Efficiency

- GTK efficiency: 97%, which corresponds to 99% station efficiency
- Measured with $K^+ \rightarrow \pi^+\pi^+\pi^-$ sample during 8 hours of data taking in October 2017