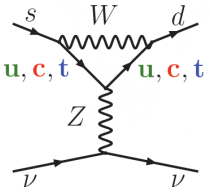
GTK status report: new GTK0 hardware

C.Biino

INFN – Torino

Incontro con referees - 27/07/2021

- Info generali
- Stato costruzione rivelatori
- Installazione e test in ECN3
- Presa dati 2021
- Stato DAQ, SW implementation vd. presentazione Alberto Gianoli



Il Gigatracker

arXiv:1904.12837

Beam spectrometer

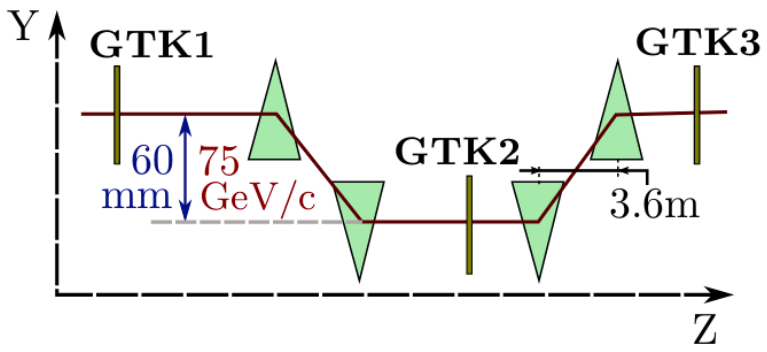
- Measures momentum, angle and time-stamp of all beam tracks
- Sustains high particle flux
- Minimized material budget

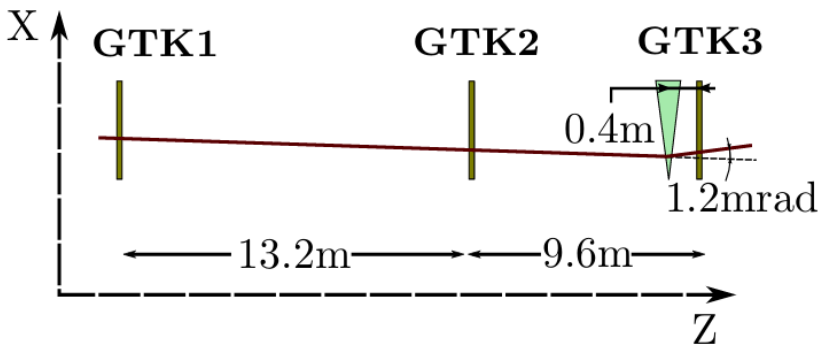
Design

- Three planes of Si hybrid pixels
- Installed in beam pipe vacuum: ~10_6 mbar
- Replaced after 1 year at full intensity

Nominal specifications:

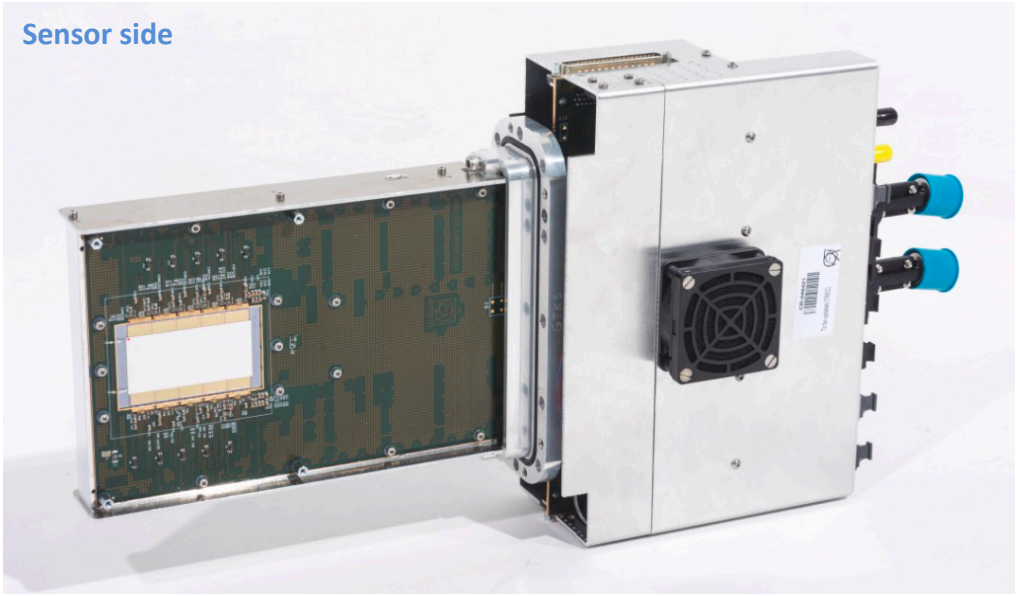
Beam rate	750MHz-1GHz
Peak particle flux	2.0 MHz/mm^2
Peak radiation	4.5×10^{14} 1MeV n_{eq}/cm^2/200 days
Efficiency	99%
Momentum resolution	0.2%
Angular resolution	16μrad
Pixel time resolution	200ps RMS
Material budget	0.5%X_0



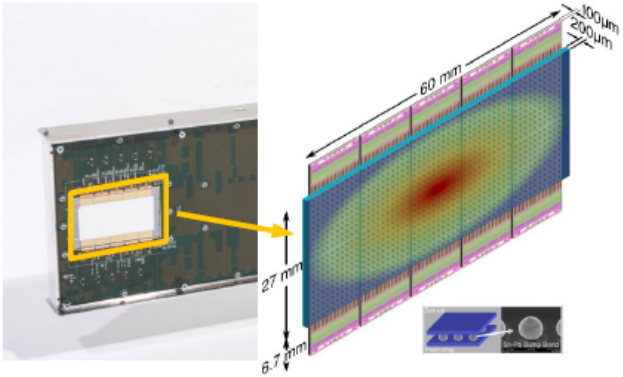


Il Gigatracker

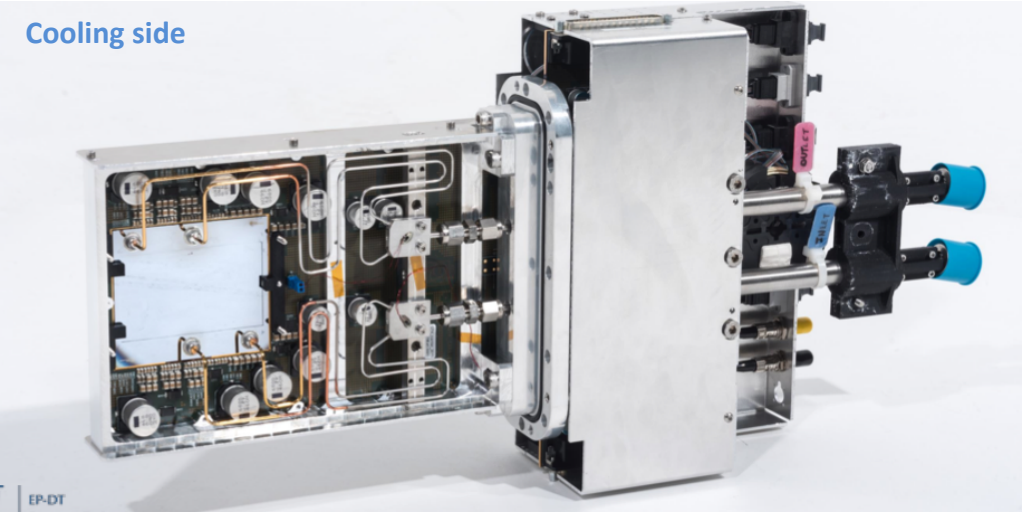
Sensor side



arXiv:1904.12837



Cooling side



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

Cooling plates

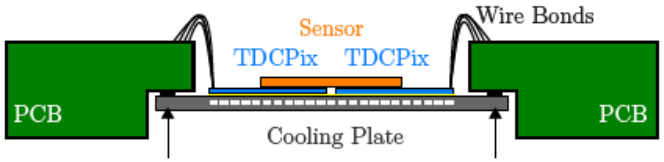
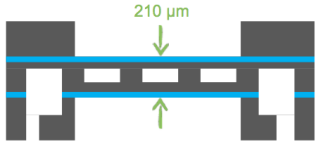
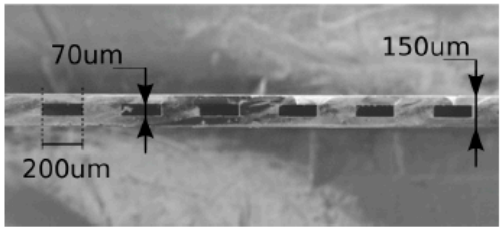


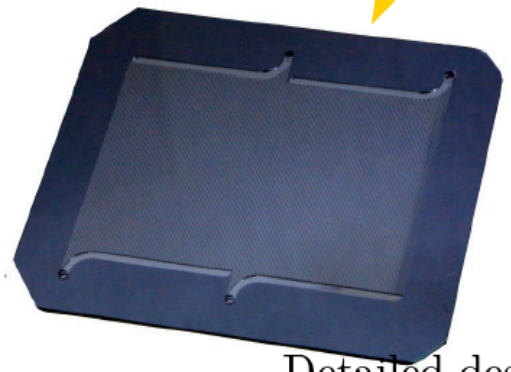
Figure 6. Schematics cross view of the assembly made of the sensor, chips and cooling pate inserted in the PCB Carrier.

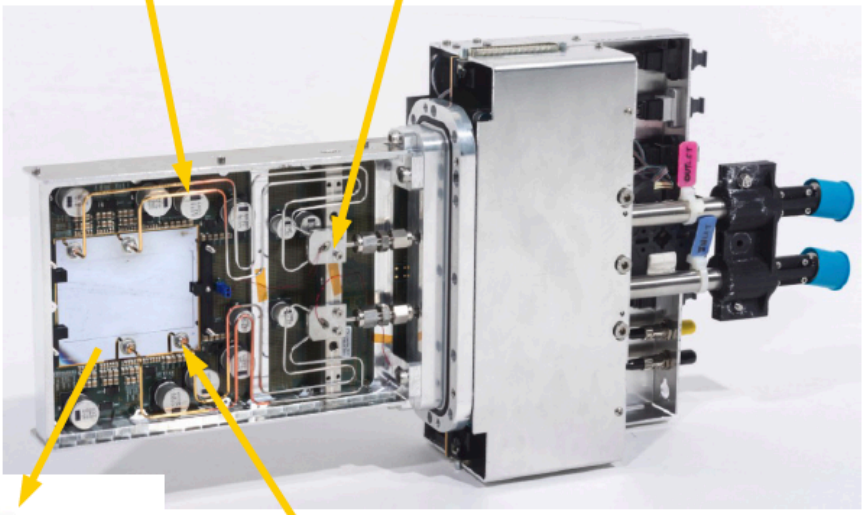


Cooling plate:

- 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

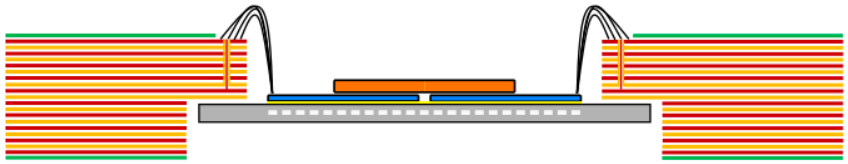






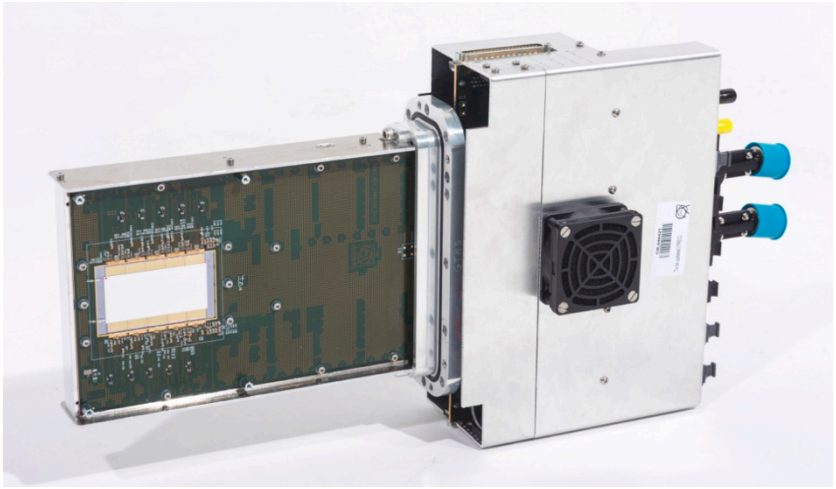
Detailed description can be found arXiv:1904.12837

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



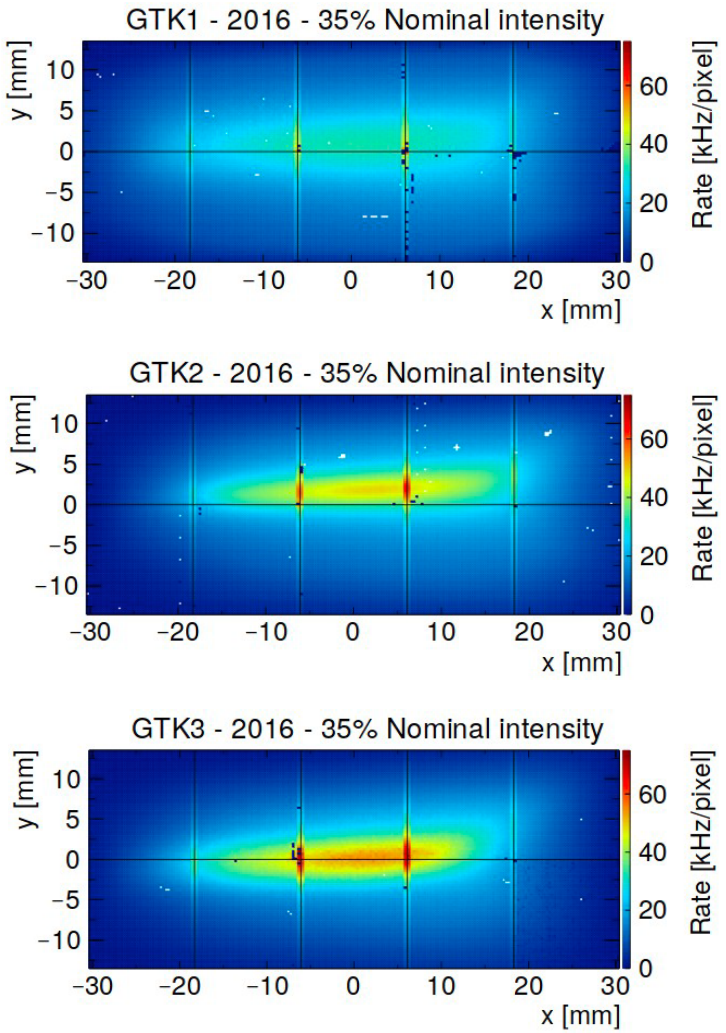
Wire bonding:

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

Performance

- 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.

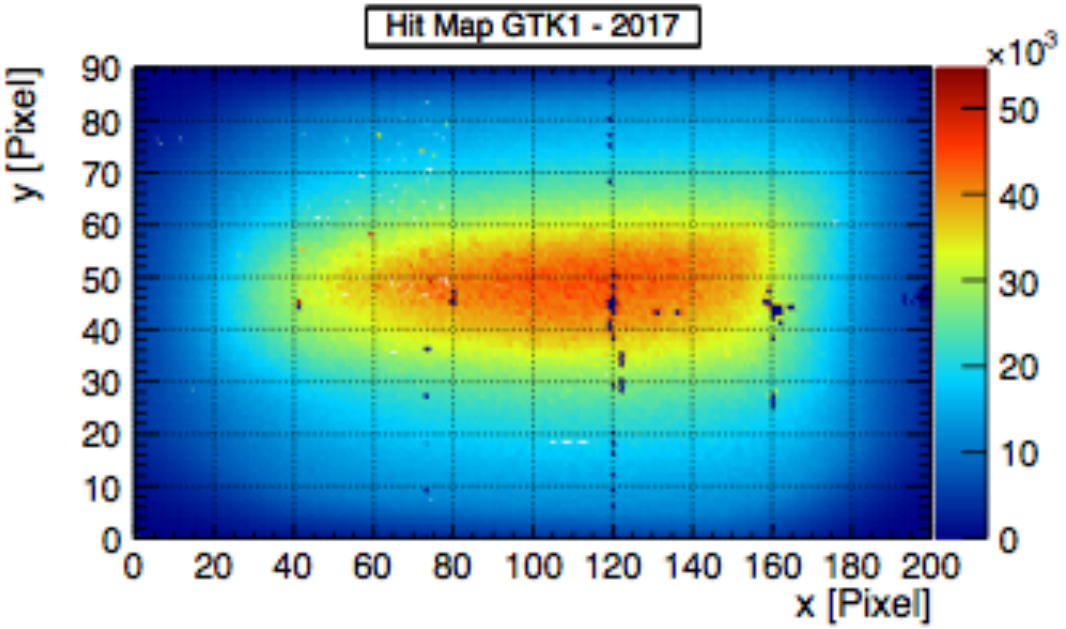
Hit map in GTK1,GTK2 e GTK3



Presa 2017

Le stazioni sono le stesse usate nel 2016 e non hanno mostrato segnale di deterioramento delle prestazioni

Hit map in GTK1 (simile comportamento su GTK2 e GTK3)



Statistica pei pixel non *funzionanti (dump non connesso)* o mascherati

	GTK1 (Chip6)	GTK2	GTK3
At Installation	21 (2)	27	9
Now	85 (66)	27	9

Time resolution in 2016 and 2017

Conditions:

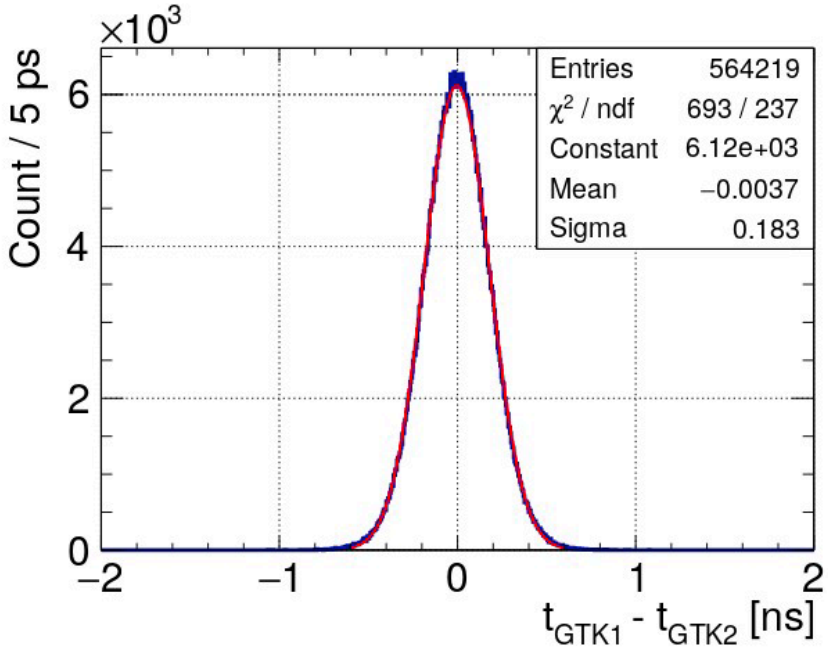
- At detector installation in 2016
- Sensor Type: n-in-p
- Operation bias: 100 V

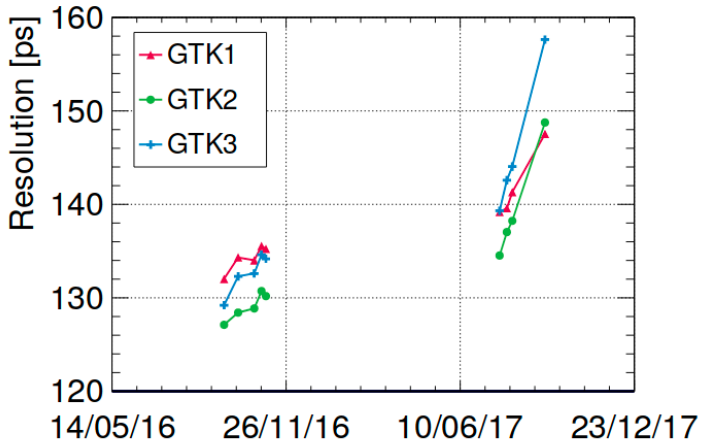
Two Measurement Methods:

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

Results in2017:

- Hit time resolution: 140 ps per hit
- Track time resolution: 78 ps
- Design resolution matched



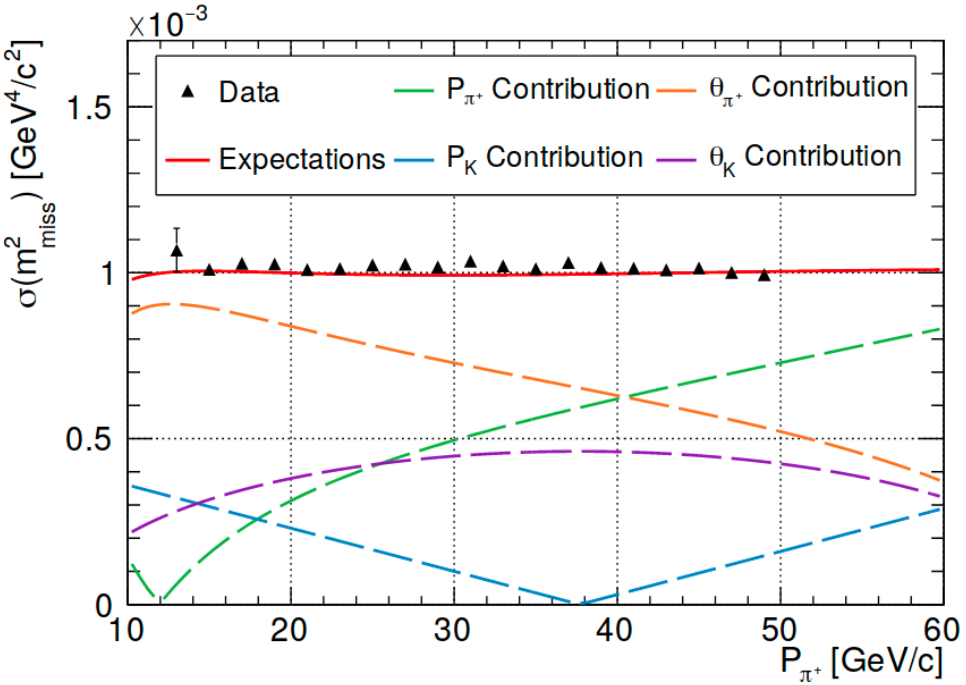


σ_t	GTK1	GTK2	GTK3	Track
2016	132 ps	126 ps	129 ps	74 ps
2017	139 ps	137 ps	142 ps	78 ps

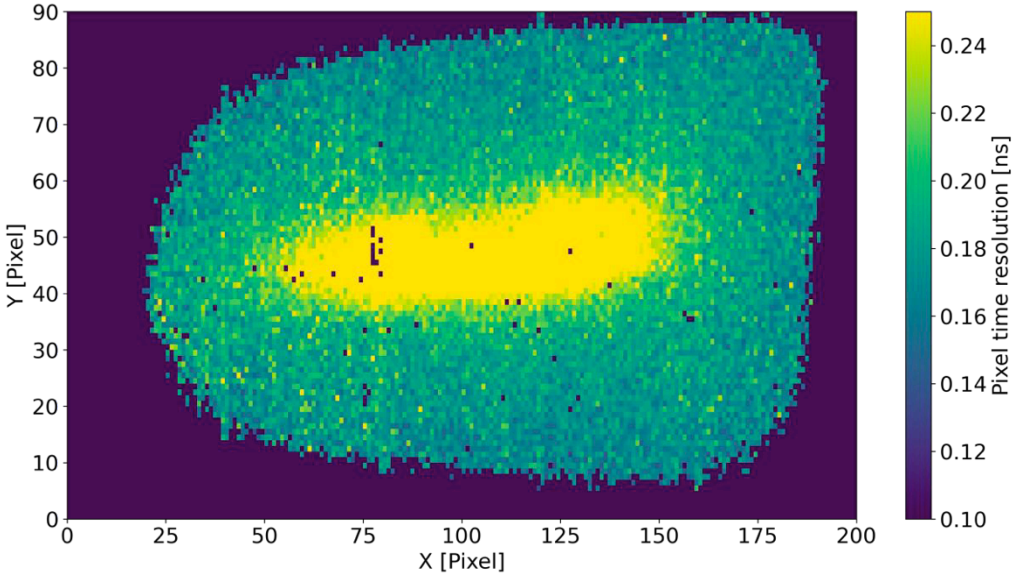
Kinematics

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

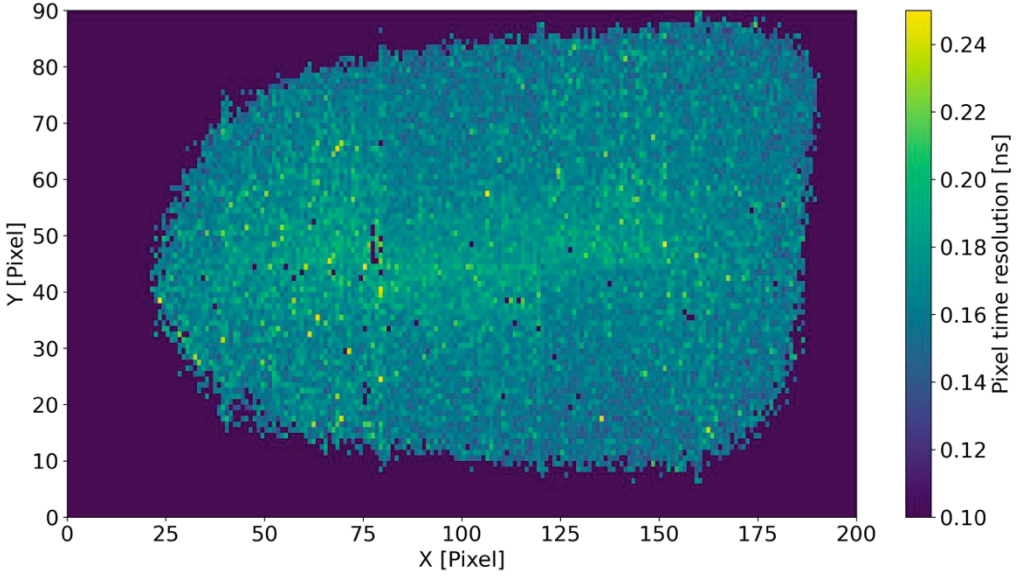
$$m^2_{miss} = (P_K - P_\pi)^2$$



Pixel Time Resolution for already used Modules



GTK7, run 9263
(bias voltage 100V)

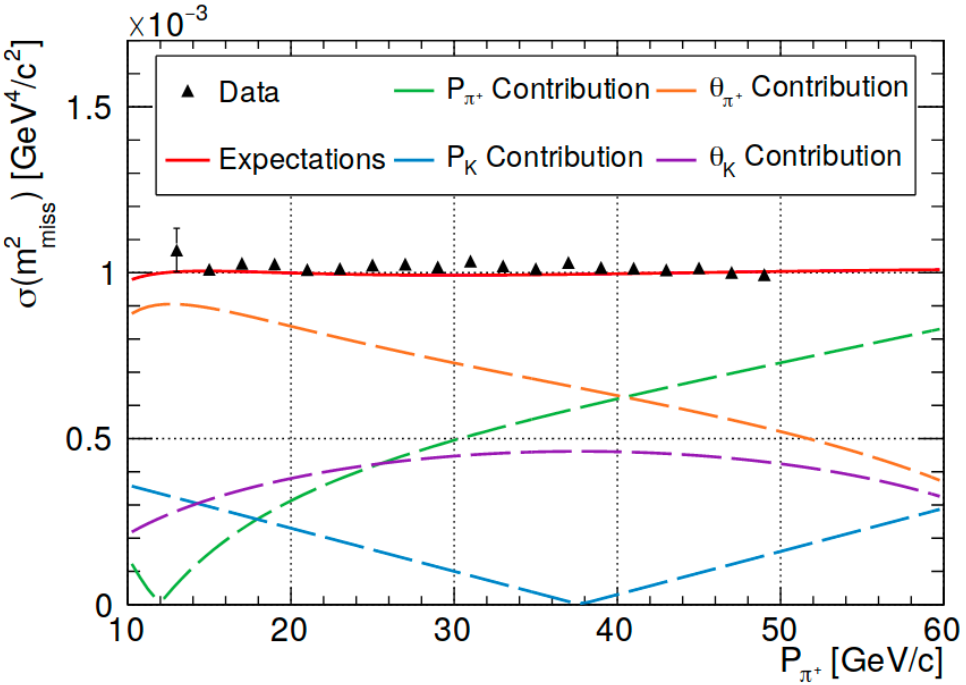


GTK7, run 9430
(bias voltage 200V)

Kinematics

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

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



GTK0 Installation

New Vessel:

✓ installed in April

Services:

✓ Extra racks for services (power, cooling, electronics) in ECN3

✓ platform mounting and refurbishing of cables and new connectors, also moving stuff from GTK2

✓ Voltage installed in April; Fibers beginning of June

✓ Test with Single chip setup done: end 2020 – beg. 2021

Available Modules:

- GTK18, 19, 20, 21, 23, 24, 25, 26 (all brand new)
- GTK10 (brand new but thicker)
- GTK12, 13, (used in 2018) , GTK7 (used in 2016, 2017, 2018)

Possible configuration aimed to use each module as much as possible:

• Redundancy of stations GTK0 & GTK1 allow us to use module GTK25

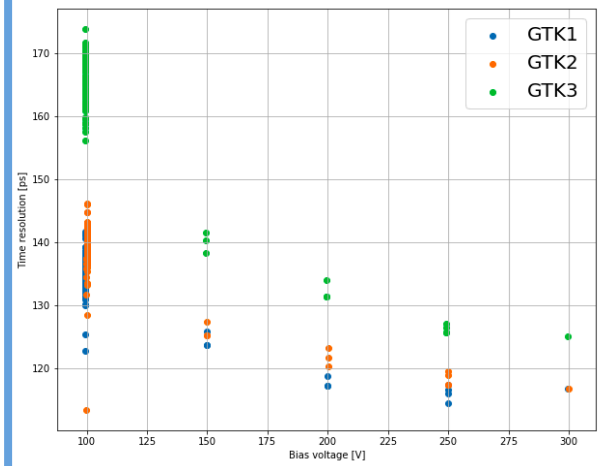
• Conservative solution to prevent issues at the beginning of the run

• From the studies of 2018 data, old modules can still have good time resolution with increased V_{bias}

Detector Installation:

✓ done in June

Time resolution for modules used in 2018



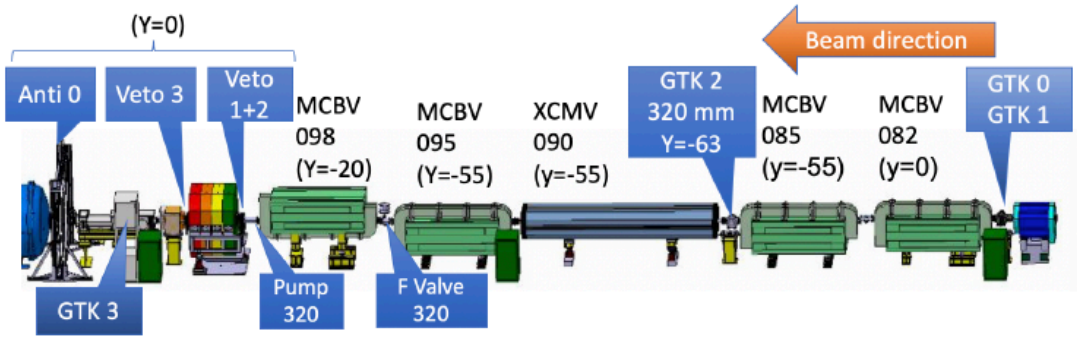
Station	Module
GTK1	GTK12
GTK2	GTK13
GTK3	GTK7

4rta stazione GTK (GTK0): recap motivazioni

To reduce the background contamination to the measurement of the decay ➔ modify the beam layout upstream of the decay volume. The main changes are: an optimized achromat; **a 4th GTK station (GTK0), placed next to GTK1** ; a new veto counter around the beam pipe before and after the collimator.

The new layout has been designed after extensive simulation to quantify the expected background reduction. The position of the various beam components and vacuum sections in the modified beam line have been determined.

The new elements of the modified beam line (vacuum sectors, etc) have been installed in March and April 2021.



Prestazioni:

- Time resolution O(+15%)
- Momentum resolution O(+25%)
- Efficiency : +3-5%
- Ridondanza e PR del beam

Risultati:

- Background(upstream)/Signal : ~~40%~~ → 10%
- Overall Background/Signal: 70% → 35-40%

4rth GTK FUNDING:

- Costo circa 220 keuro
- Quota italiana secondo MOU (45%)= 100k
- A seguito interazione in CSN1 e vista l'importanza del sistema per la collaborazione accordo nell'Agosto 2019
- ITA/CERN/Louvain: 71/71/16 kCHF
- Al cambio del momento ~65 keuro: il MOF-B 2020 esaurisce il finanziamento (visti i 30k anticipati nel 2018)

Conclusion and Future

- NA62 e il GTK sono pronti alla presa dati che sta iniziando in questi giorni
- NA62 ha migliorato di un ordine di grandezza la SES fra il 2016 e il 2017
- I fondi sono stati compresi nel dettaglio
- NA62 continua fino a LS3 ➔ 2021-2023 per una misura di precisione e «scoperta» a 5 sigma del decadimento.
- Sigma (PNN) <20%, LFV e fisica in dump mode
- Fattori realistici di guadagno in accettanza e riduzione del fondo grazie al 4rto GTK.

*** **FUTURO:** Stiamo lavorando ad un programma ambizioso di fisica dei Kaoni con un fascio di alta intensita' di K^+ e K_L

- Decadimenti rari, LVV, LNV, Dark sector ed esotici
- Stiamo preparando un White Paper
- Il nuovo programma richiede un fascio 4 volte piu' intenso di quello di NA62
- **Sara' necessario costruire un nuovo GTK entro il 2026**

*** Exciting times ahead!