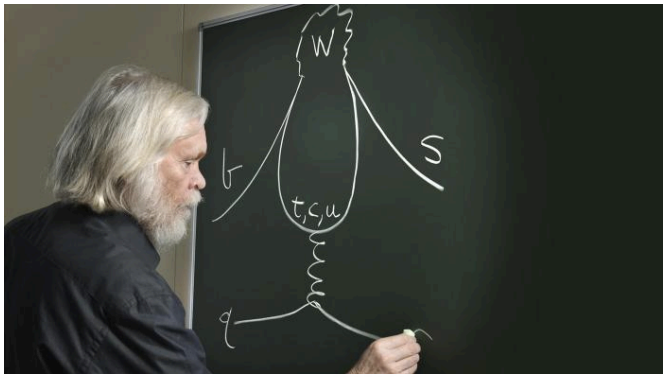
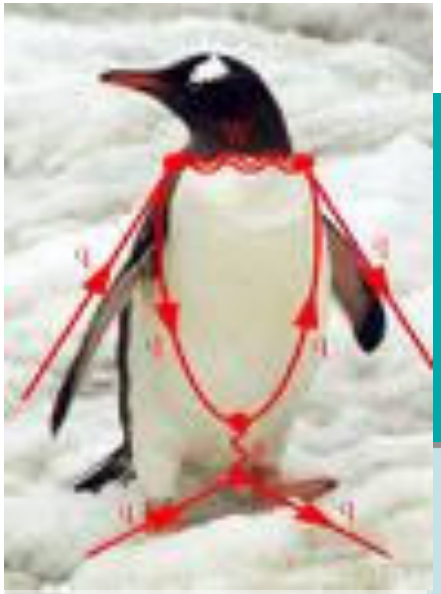
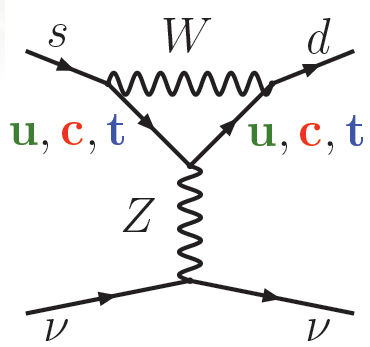


# NA62 @ CERN: misura del decadimento raro $K^+ \longrightarrow \pi^+ \nu \bar{\nu}$

**Cristina Biino - INFN Torino**

**CdS, Torino, 30 Giugno 2017**




**The penguin diagrams**

# NA62 Collaboration

•Birmingham
•Bristol
•Glasgow
•Liverpool

TRIUMF
UBC

Mainz

•Prague

•IHEP
•INR
•JINR

UC Louvain

Bratislava

CERN

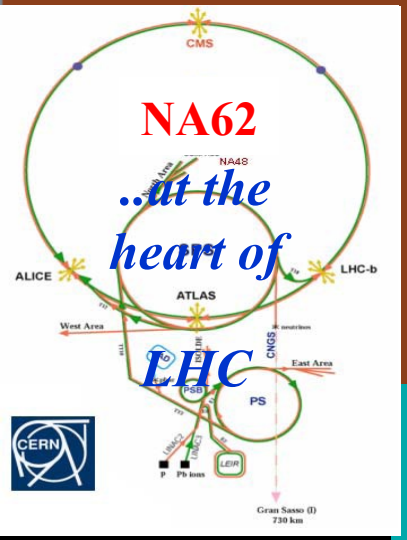
Bucharest

•George Mason
•SLAC
•UC Merced
•BU
•BNL

•Ferrara
•Florence
•LNF
•Naples
•Perugia
•Pisa
•Rome I
•Rome II
•Turin

Sofia

San Luis Potosi


**NA62**
***..at the heart of LHC***

# NA62 Goal

**NA62 IS AN INTENSITY FRONTIER EXPERIMENT:**

$$K^+ \rightarrow \pi^+ \nu\nu$$

- Ultra rare FCNC: s → d transition, hard GIM suppression
- Theoretically clean (negligible hadronic uncertainties)

**Previsione teorica*:** $BR(K^+ \rightarrow \pi^+ \nu\bar{\nu}) = 8.4 \pm 1.0 \times 10^{-11}$

**Misura sperimentale:** $BR(K^+ \rightarrow \pi^+ \nu\bar{\nu}) = 1.73^{+1.15}_{-1.05} \times 10^{-10}$

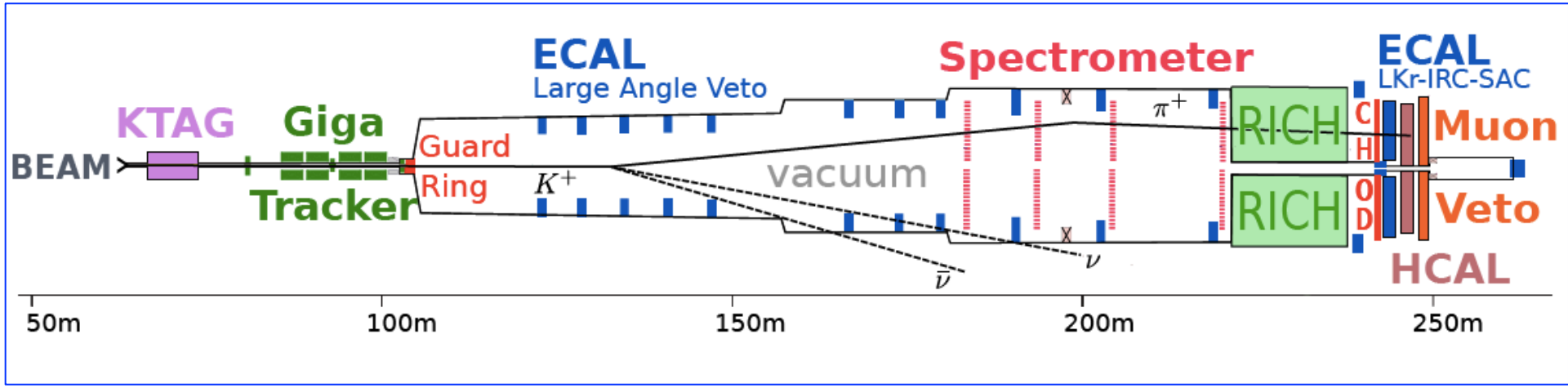
(E787/949): (7 events)

*[Buras, 1503.02693]

**NA62 aims to measure to 10% or better → more than 100 $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ events before LS2**

Deviation from SM predictions would **signal New Physics!**

# NA62 Apparatus

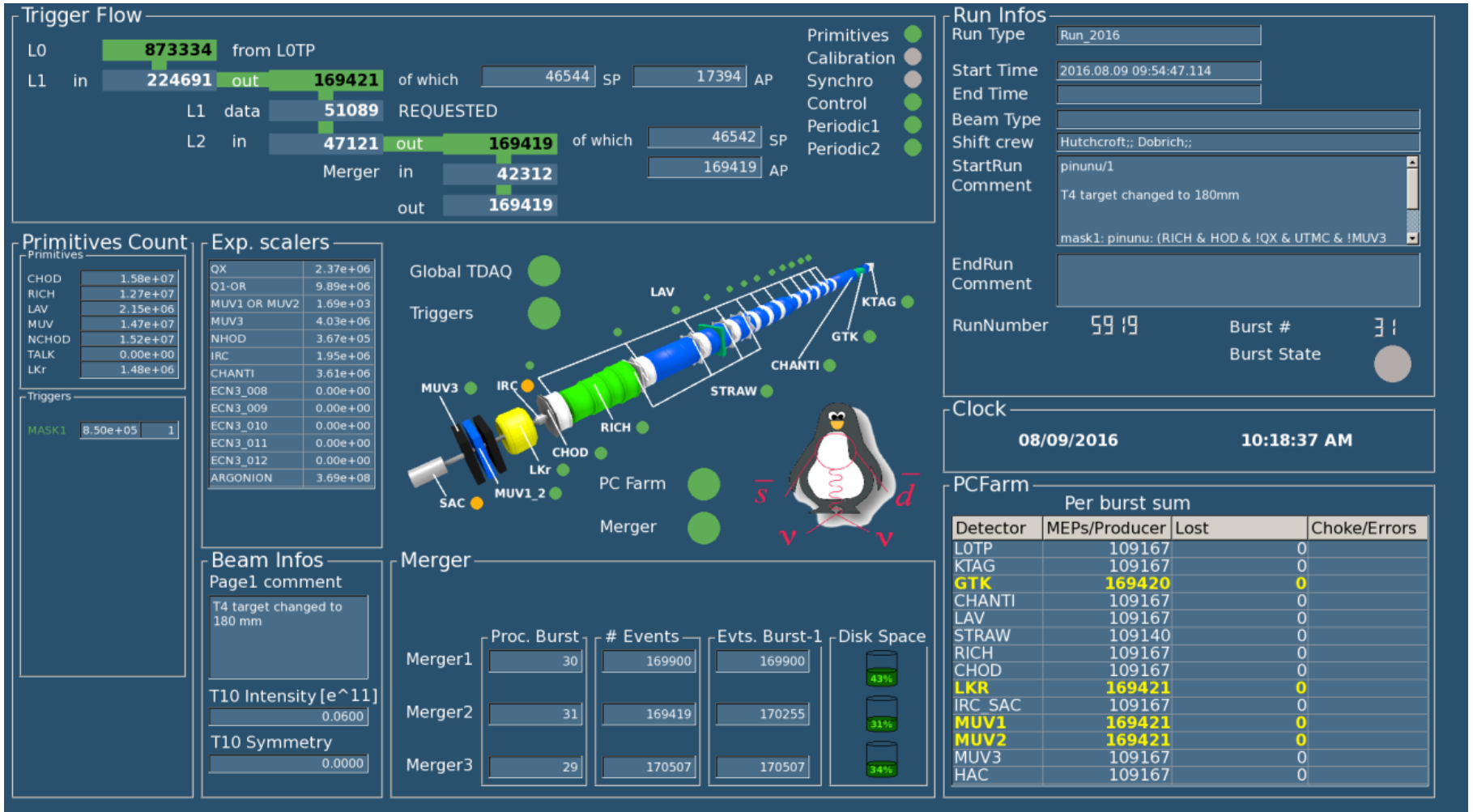




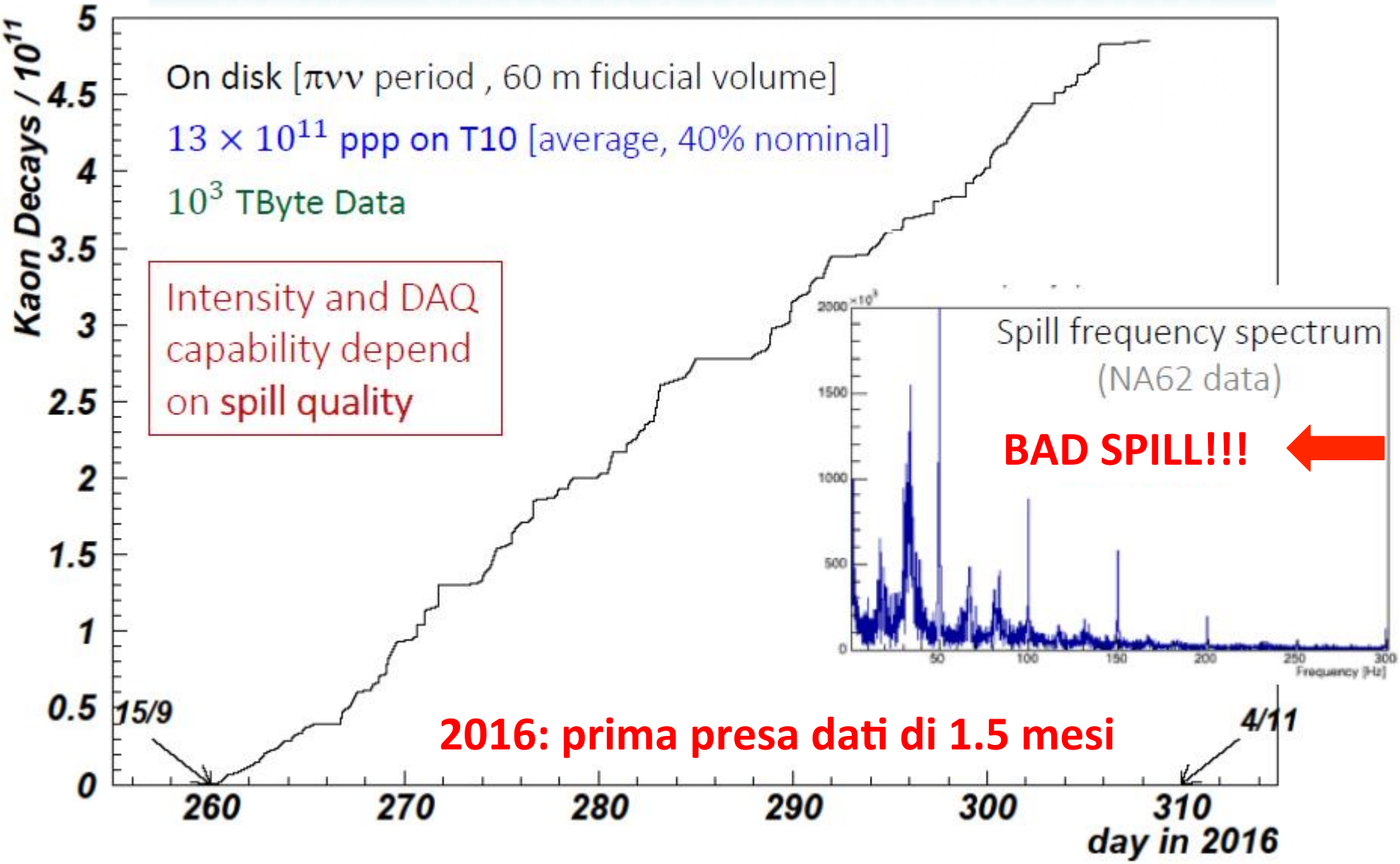
# DAQ-Trigger online monitor

## Main tool for people on shift

## Presa dati 2016-2017-2018 …and after LS2

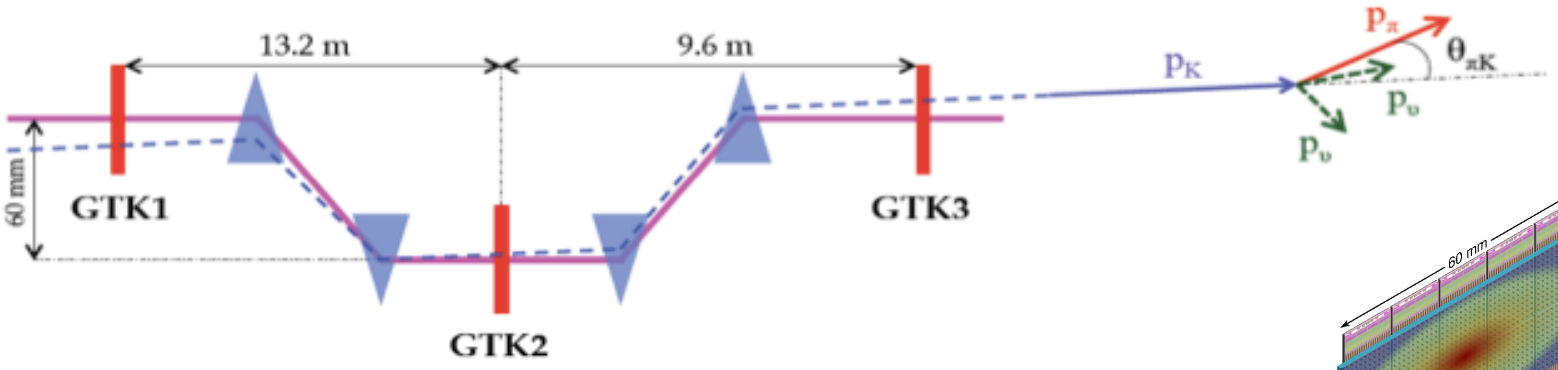


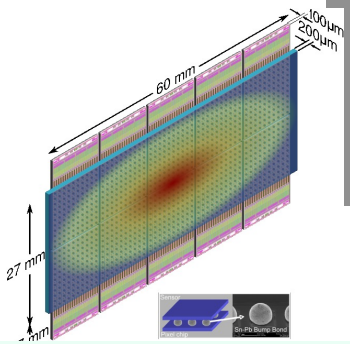
# NA62: statistica raccolta nel 2016



# Lo spettrometro del fascio: il Gigatracker

CERN, Ferrara, Louvain-la-Neuve, Torino




**GTK: 3 stazioni di Si-pixel per definire tempo, direzione e momento di tutte le particelle del fascio**

- Montate nel tubo a vuoto del fascio;
- Sostenere **rate alto** e non uniforme (~1.5 MHz/mm$^2$ al centro, 0.8-1.0 GHz);
- Minimizzare scattering multiplo e interazioni adroniche;
- Danno da radiazione → sostituire sensori almeno ad ogni presa dati

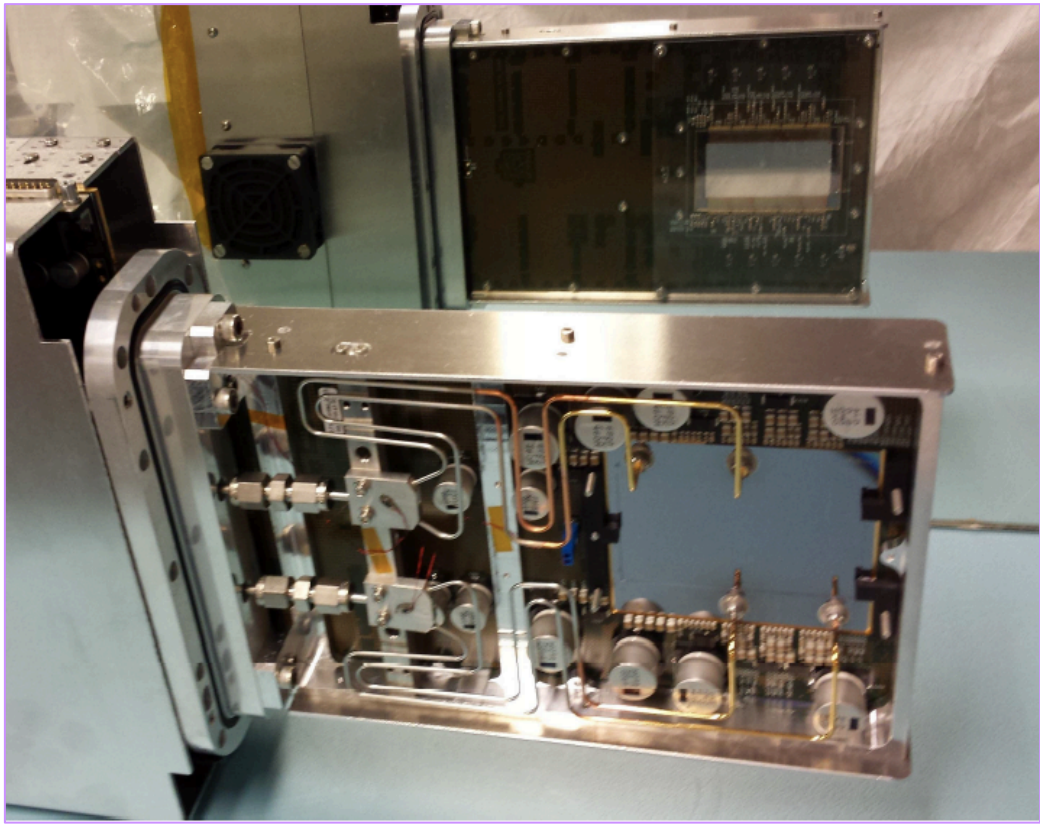
- $X/X_0$<0.5% per stazione ;
- sensori p-in-p ;
- pixel size 300x300 $\mu m^2$ ;
- $\sigma(\theta_K)$ ~16 $\mu$rad ;
- $\sigma(p_K)$ ~0.2 GeV/c ;
- $\sigma$ (t)~ 200 ps/stazione (~150 ps per una traccia)

**GTK completato nel 2016 con 3 stazioni, letto a L1-trigger!**

# Gigatracker: components overview

- Carrier issues solved & modifications to ease wire-bonding (chip to carrier) done
- Assembly problems solved: chip thickness no longer a problem 100 um
- Cooling Plate procurement has some issues (because of the large size & micro-manufacturing process yield far from 100%)

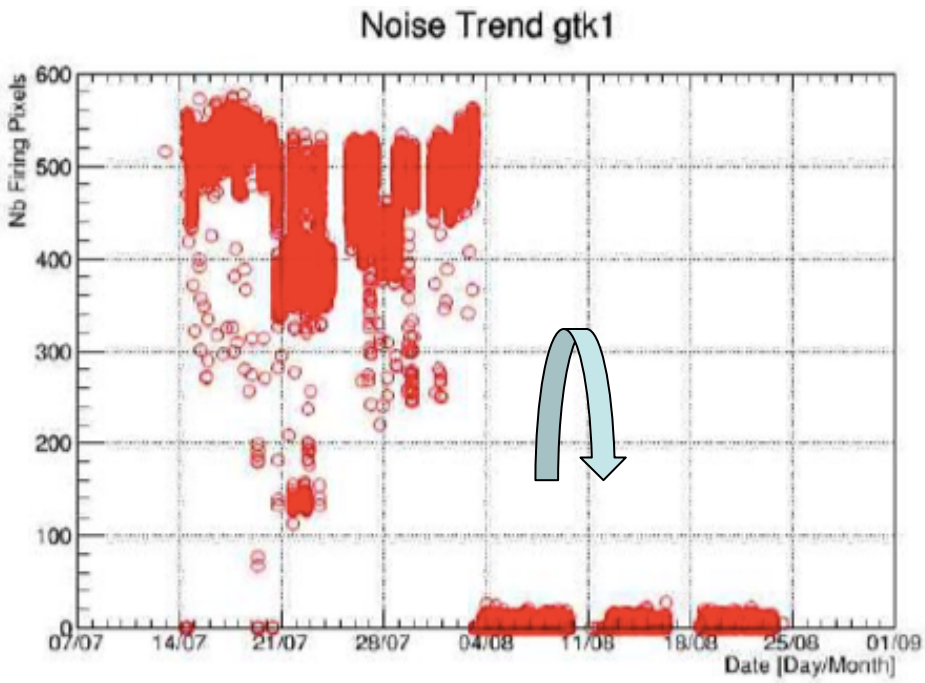
- Noise issue in 2015 (220 MHits/s), solved !!!



# Gigatracker: how the noise disappeared

- In 2015 we had some Noise issue (220 MHits/s)
- Problem solved after applying 3 changes:

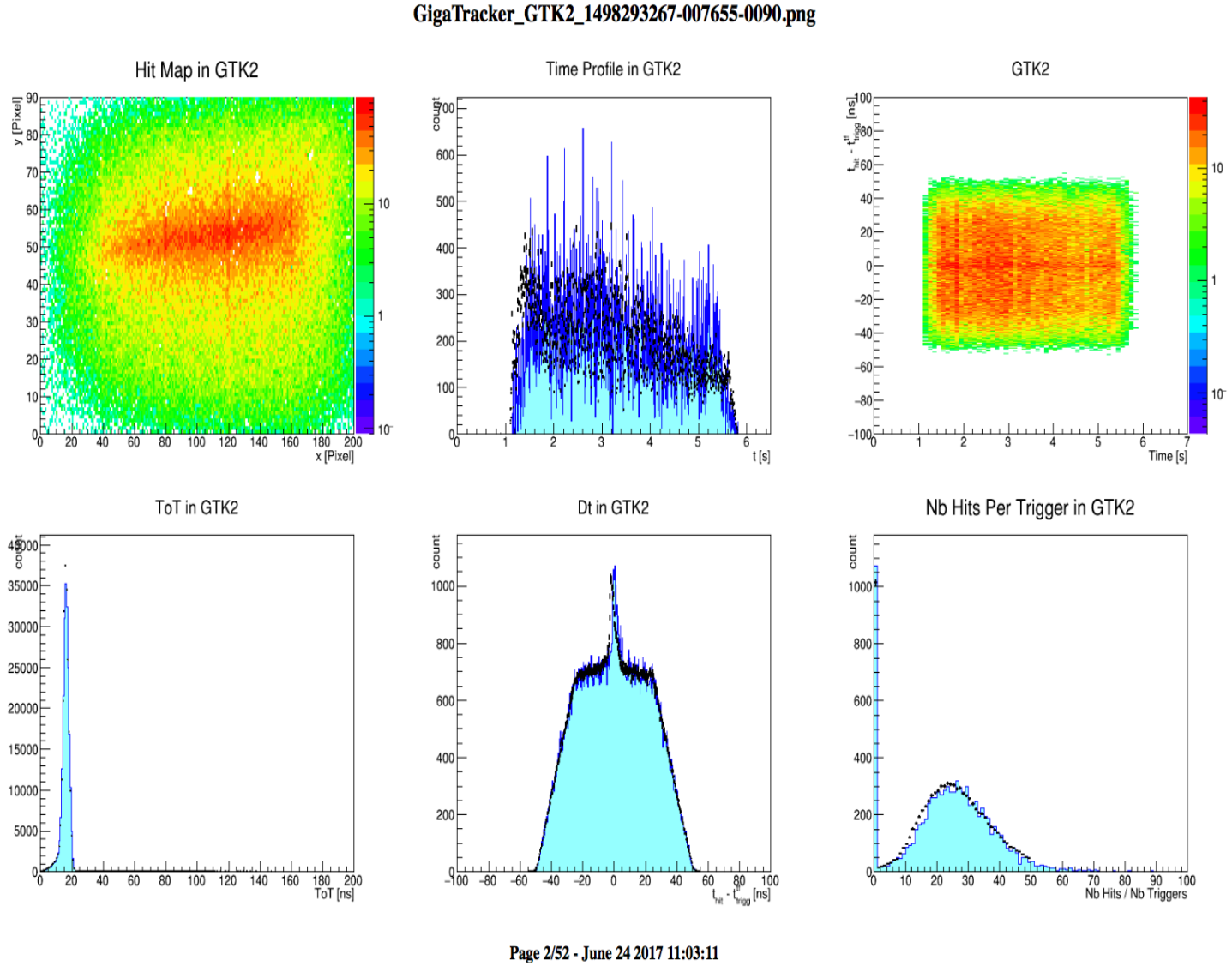
- Tipo di sensore: da sensore "p-in-n" ➔ a sensore "n-in-p"
- I nuovi sensori (e I chip) sono stati ricoperti di BCB (benzocyclobutene), isolante per impedire il formarsi di scariche tra i due elementi
- Dicing dei sensori dal retro per ridurre corrente di leakage.

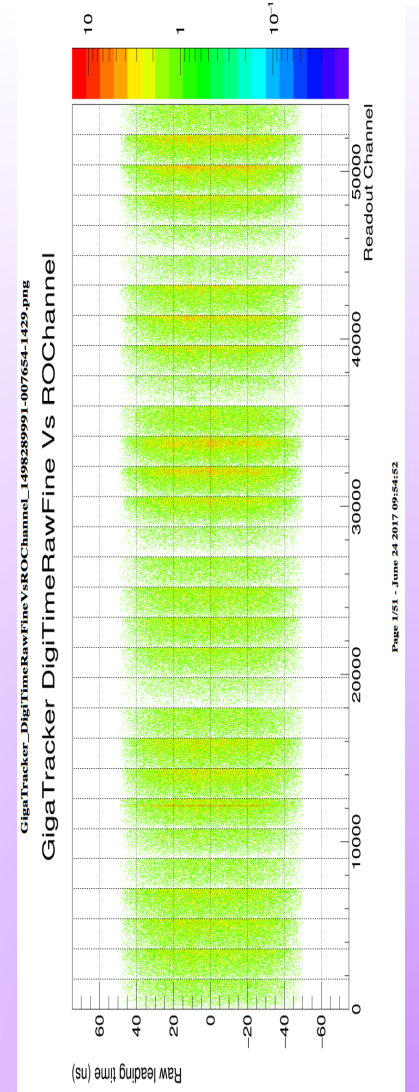



p-in-n sensor
old sensor dicing
no BCB coating

n-in-p sensor
new sensor dicing
BCB coating

# Gigatracker: 2017 online plots



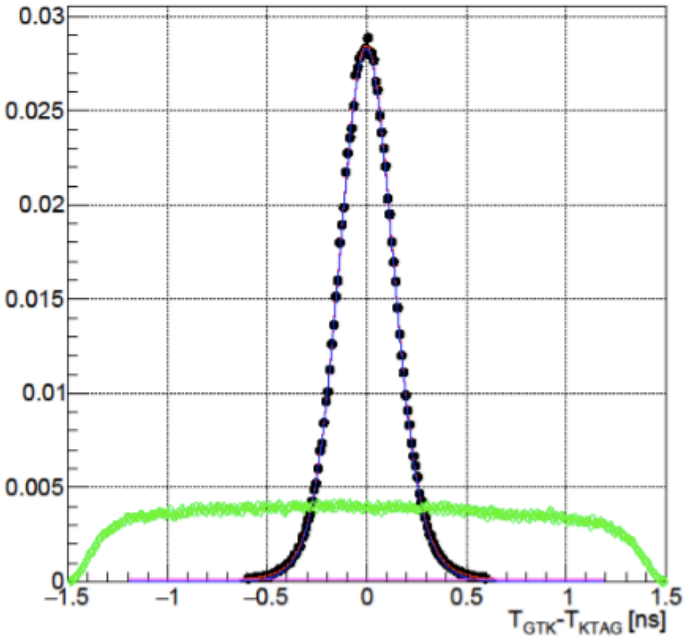
# Gigatracker: prestazioni 2016

Utilizzando un sample di $K^+ \rightarrow \pi^+\pi^+\pi^-$ ricostruiti si osserva che:

- **La risoluzione temporale è di ~135 ps per hit e quindi di ~80 ps per traccia prendendo come riferimento il KTAG.**
- La **risoluzione spaziale** è quella attesa e cioè di **~16 mrad** per ognuna delle viste (piano x-z e y-z), prendendo come riferimento le tre tracce misurate con le STRAWS.

**K-π matching**

$\sigma(T_{GTK} - T_{KTAG}) \sim 135$ ps

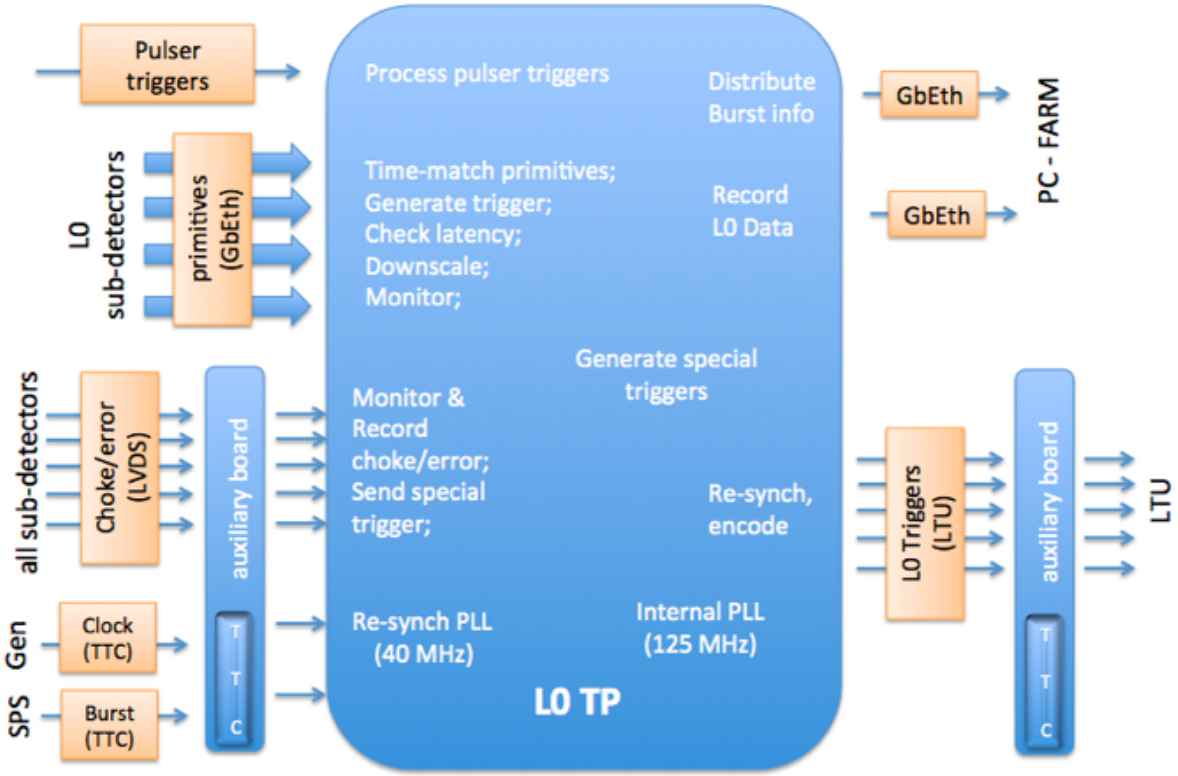



- L'**efficienza** per tracce con tre hit è del **90%**; l'inefficienza è dovuta ad un 2.5% irriducibile (*) e l'altro 7.5% e' *under study*
- Il **DAQ sta funzionando ad alti rate (500kHz)**, non e' il fattore che limita la presa dati

# Trigger: L0 fully commissioned

**Torino-exclusive project, in use since 2014, by Dario Soldi (our PhD student, now Similfellow @CERN)**

| L0TP characteristics: | |
|---|---|
| Sources | 7 |
| Inputs | >10 MHz<br>~560 MB/s |
| Outputs | ~1 MHz |
| Masks | 16 |
| Latency | < 1 ms |
| Dead Time | 75 ns |

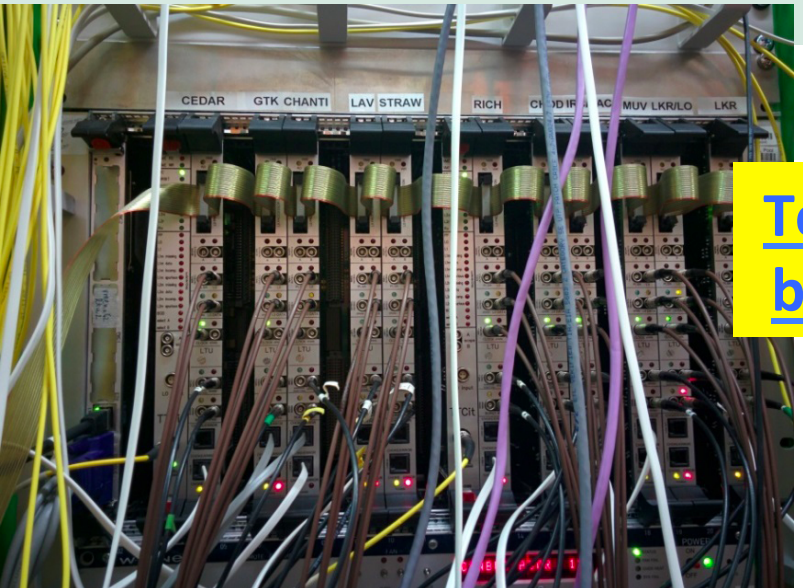



**Main issue in 2016 was due to the beam structure: spikes in the beam profile generating sudden spikes > 15 MHz of input rate.**

# Improvements with respect to 2016

- 12.5 MHz maximum mean input rate;
- 8 different trigger masks working together;
- Depending on the quality of the burst: few data lost due to the too high input rate;

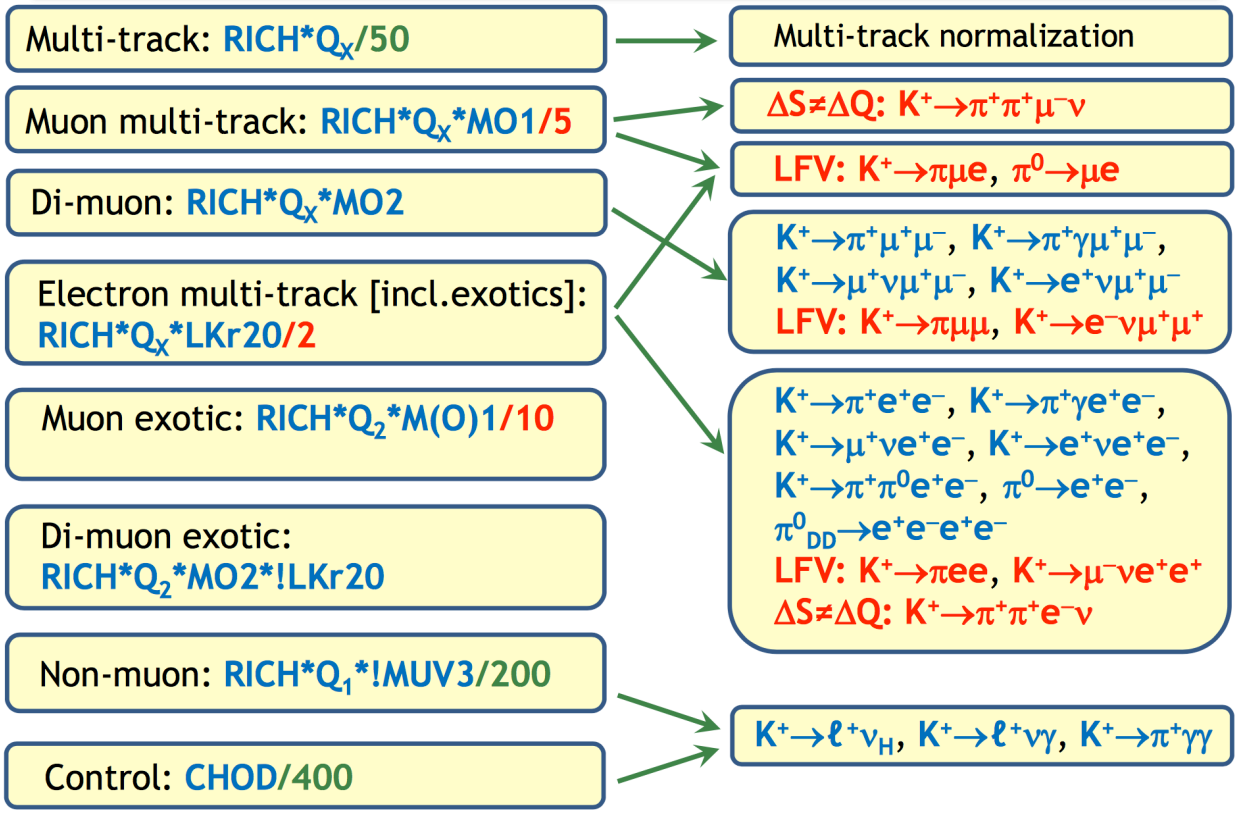
- 17.5 MHz maximum mean input rate;
- 16 different trigger masks working together;
- Choke system to stop the data acquisition when the input rate is too high;
- Automatic restart during the burst when the input rate is sustainable.




Torino board

# L0 – 2017 Data Analisi

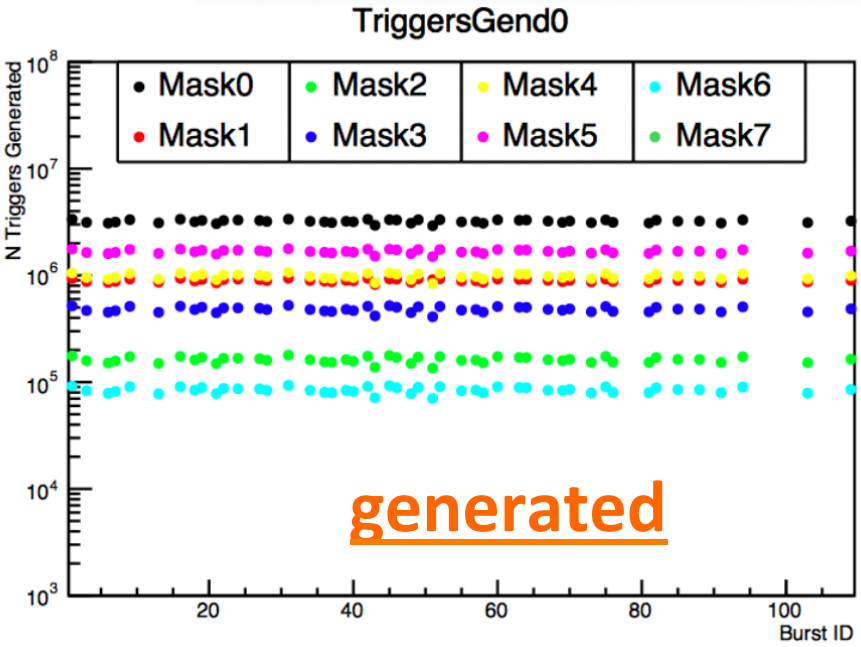
## Standard data taking in 2017 – Not only πνν data-sample



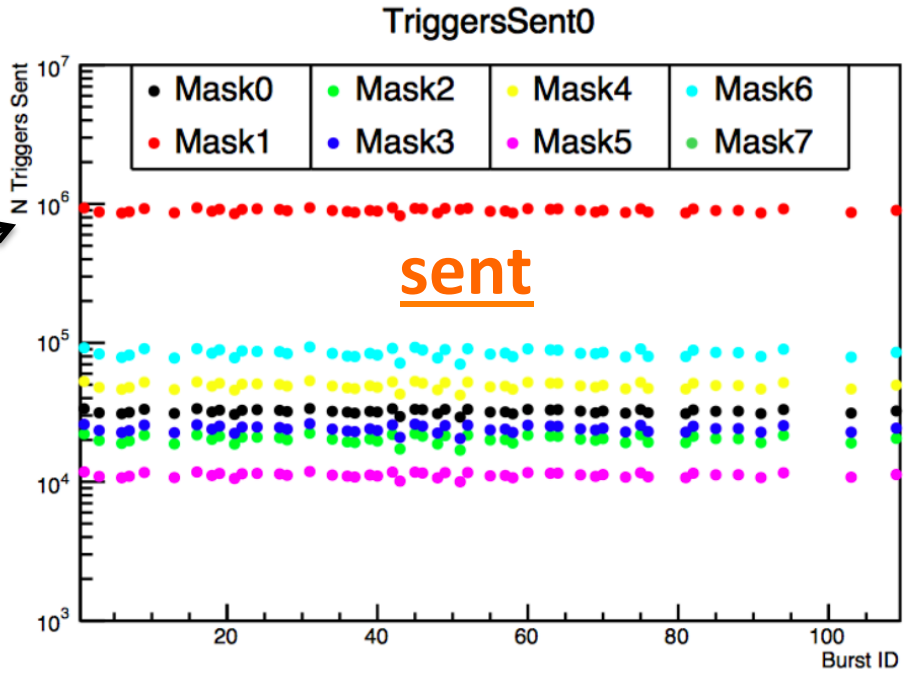

**Plus:**

**Calibration, Synchronisation, Random and Periodics triggers;**

# L0 – 2017 - Stability

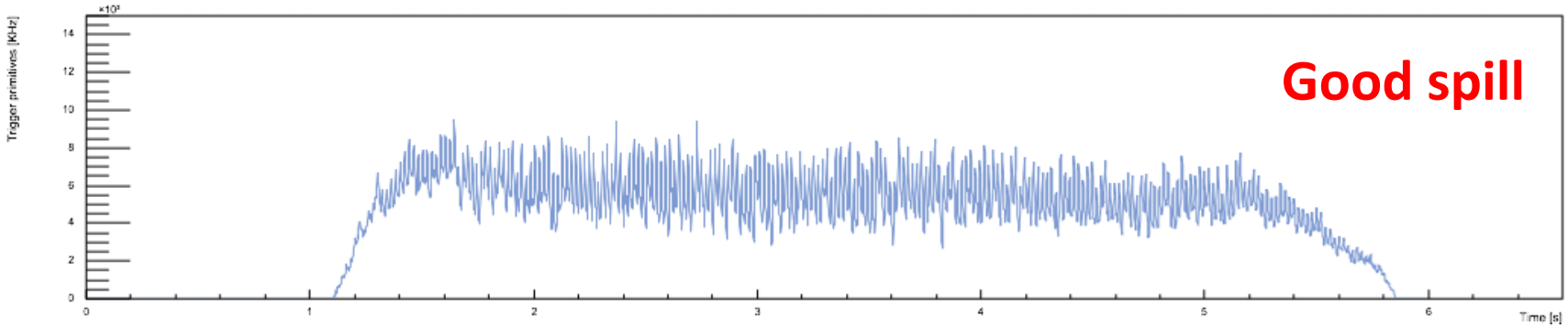



Trigger πνν

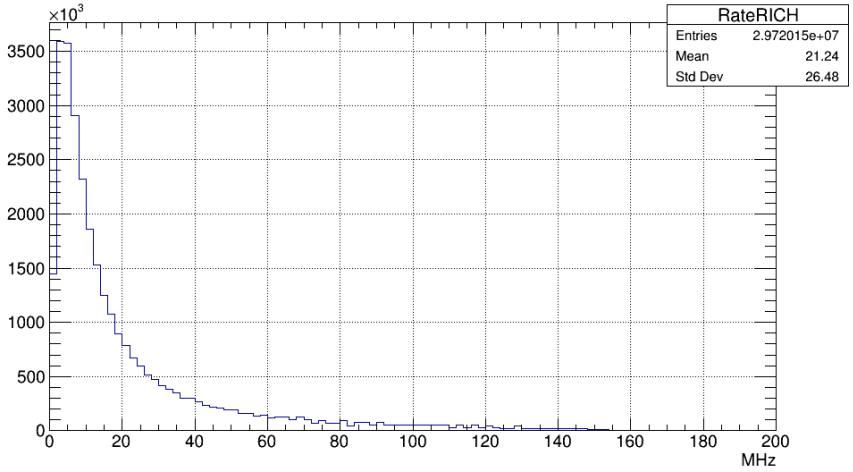


# L0 – 2016 Data Analisi

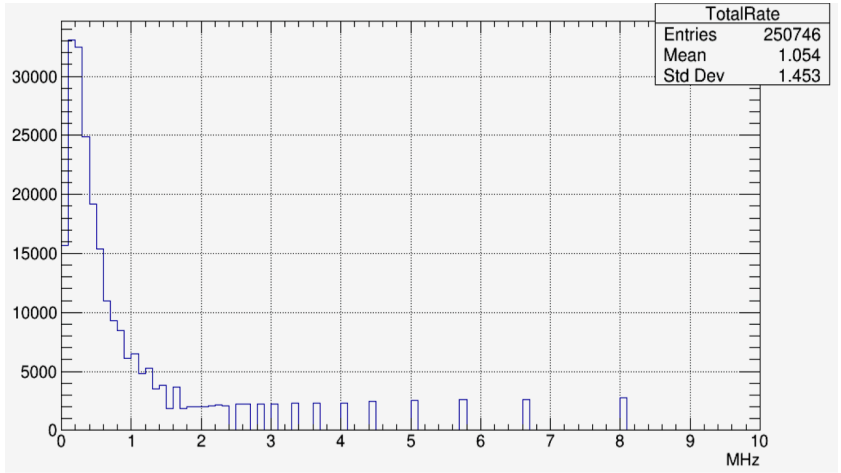
## Beam Profile




## Instantaneous input rate [MHz]




## Instantaneous output rate [MHz]



# Trigger conclusions

- After the first data taking in 2016, some improvements have been implemented in order to sustain the high input rate of the NA62;
- **The system is working with high stability:**
  - **Maximum input rate 57% more than the design value;**
  - **Output rate reached the designed value;**
  - **No major problems, efficiency > 99.0%**

**L0TP is collecting πνν events!**

# NA62 DAQ Activities during EYETS

## Torino project by Marco Boretto, our new PhD student

- **30 PC cluster: OS migration to CentOS7**

**- All computers used in data acquisition migrated to the latest Linux distribution provided by CERN**

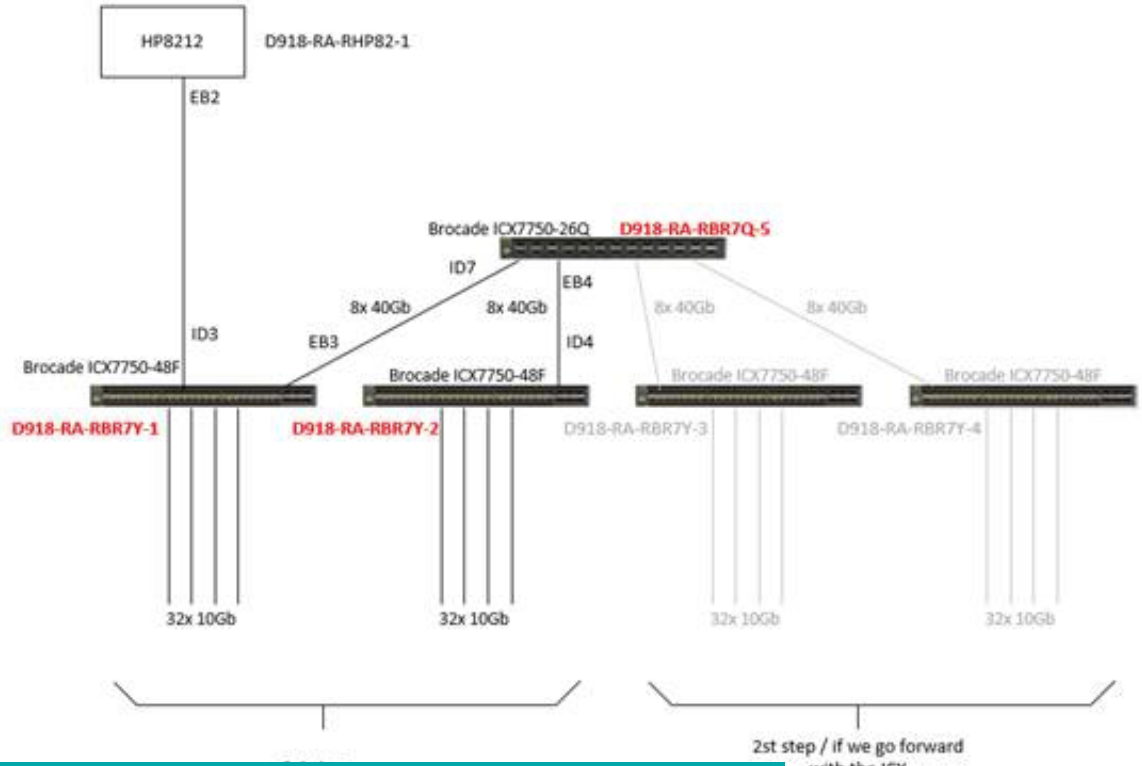
- **Network refurbishment**
  - **Spare ports available**
  - **All connections updated to 10 Gb**

- **Introducing a new CDR sw for transferring data from the experiment to CASTOR**

- **Exploited the new File Transfer System (FTS) technology provided by CERN/IT**
- **WEB Monitoring of files transfer**
- **NA62 is the first experiment to use this technology**

# NA62 PC farm: Upgrade della rete

- Una nuova infrastruttura di rete per connettere il rivelatore e il cluster di PC per High Level Trigger è stato installato
- Il nuovo sistema si basa su 5 routers che si comportano come uno solo



# Anagrafica 2017-2018

La situazione del manpower continua ad essere il problema principale per NA62.

Mai ottenuto (mantenuto) il livello di personale previsto in fase di approvazione.

Situazione aggravata dai problemi di distorsione della VQR (esperimento di precisione → molto lavoro poche pubblicazioni…)

**Situazione 2017 (4.8 FTE)+(2.4)*:**

R.Arcidiacono (20%)
C.Biino (40%)
M.Boretto (100%)
A.Filippi (30%)
E.Menichetti (100%)
E.Migliore (20%)
D.Soldi (100%)
P.Trapani (20%)
E.Durisi (20%)

F.Marchetto (70%) → * 0%
B.Bloch (100%)*
P.Jarron (100%)*

# NA62 - Richieste 2018

## Lab. elettronica: 3 m.u. firmware test on electronics of Gigatracker

Per NA62, attualmente in presa dati per i prossimi due anni, abbiamo costruito il rivelatore a pixel Gigatracker con alta risoluzione temporale, di momento e di direzione dei kaoni del fascio di alta intensità' (1.5 MHz/mm^2).

**Abbiamo ricevuto una proposta di interesse dall'Olanda,** e pensiamo che potrebbe essere interessante utilizzare il GTK di NA62 per studi interdisciplinari (per es. per usarlo come rivelatore per tomografia con protoni). Potremmo quindi, all'interno dell'esperimento NA62, fare alcuni upgrades e tests. **Saremmo interessati ad avere un tecnico "esperto" di firmware per aiutare in una possibile presa dati, per es. 2-3 mesi di Richard Wheadon.**

**DOMANDA DI UTILIZZO DEI SERVIZI DI BASE**

Data della richiesta:

| Lab. Tecnologico | Lab. Elettronica | Centro di Calcolo | nuova richiesta | richiesta di continuazione |
|---|---|---|---|---|
| | ✓ | | | |

Esperimento: NA62

Responsabile locale: C.Biino

Responsabile dell'attivita': F.Marchetto

Descrizione dettagliata dell'attivita' richiesta

Per l'esperimento NA62, attualmente in presa dati per i prossimi due anni, abbiamo costruito il rivelatore a pixel Gigatracker con alta risoluzione temporale, di momento e di direzione dei kaoni del fascio di alta intensita' (1.5 MHz/mm^2). Abbiamo avuto una proposta di interesse dall'Olanda, e pensiamo che potrebbe essere interessante utilizzare il GTK di NA62 per studi interdisciplinari (per es. per usarlo come rivelatore per tomografia con protoni). Potremmo quindi, all'interno dell'esperimento NA62, fare alcuni upgrades e tests.

Saremmo interessati ad avere un tecnico "esperto" di firmware per aiutare in una possibile presa dati, per es. 2-3 mesi di Richard Wheadon.

| PLANNING | | | | | | | | | | | | MILESTONES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subattivita' | G | F | M | A | M | G | L | A | S | O | N | D | Data-mese | Descrizione |
| | | | ✓ | ✓ | ✓ | | | | | | | | | |

| Tecnici e tecnologi attualmente assegnati all'attivita' | | | | | Richieste di supporto tecnico per | | | |
|---|---|---|---|---|---|---|---|---|
| INFN | | ALTRI ENTI | | | | l'anno: | | |
| Nome | mesi/U | Ente | Nome | mesi/U | Tipologia | N. | mesi/U | |
| | | | | | Tecnici mecc. /elettr/CdC | | | |
| | | | | | Disegnatori meccanici | | | |
| | | | | | Microsaldatori | | | |
| | | | | | Tecnologi progett. mecc. | | | |
| | | | | | Tecnologi elettronici/CdC | | | |
| Wheaton Richard | 3 | | | | Tecnologi microelettronica | | | |

Note:

Richiesta di 3 mesi anche non consecutivi e non necessariamente marzo-aprile maggio.
Proposta isolante indicativa ma possiamo organizzare per fare dei test in altri periodi.

# SPARE

# NA62 - Richieste 2017

*NB: inizio presa dati 04.2017*

**Richiesta preventiva:**

**a) Officina Meccanica/Lab. Tecnologico:**

- **3 m.u. costruzione di componenti meccanici**
- **3 m.u. montaggio rivelatori GTK (prevalentemente al CERN)**

**b) Lab. elettronica: 3 m.u. test wafer su probe station (al CERN)**

## DOMANDA DI UTILIZZO DEI SERVIZI DI BASE

Data della richiesta: 26.06.2016

| Lab. Tecnologico | Lab. Elettronica | Centro di Calcolo |
|---|---|---|
| ✓ | ✓ | |

| nuova richiesta | richiesta di continuazione |
|---|---|
| | ✓ |

Esperimento: NA62

Responsabile locale: Cristina Biino

Responsabile dell'attivita': Flavio Marchetto Ernesto M

Descrizione dettagliata dell'attivita' richiesta

Le richieste sono tutte preventive, nel senso che il prossimo anno si dovrebbero assemblare un bel po' di rivelatori.
Ci aspettiamo che la maggior parte sia fatta al CERN. Ma puo servire aiuto dalla sezione.
Richiesta:
a) officina meccanica: 3 m.u. costruzione di componenti meccanici
3 m.u. montaggio rivelatori GTK (prevalentemente al CERN)

b) Lab. tecnologico: 3 m.u. test wafer su probe station (al CERN)

| PLANNING | | | | | | | | | | | | | MILESTONES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subattivita' | G | F | M | A | M | G | L | A | S | O | N | D | Data-mese | Descrizione |
| | | | ✓ | ✓ | ✓ | | | | | | | | | officina meccanica: 3 m.u. costruzione di componenti meccanici |
| | | | | ✓ | ✓ | ✓ | | | | | | | | officina meccanica: 3 m.u. montaggio rivelatori GTK (prevalentemente al CERN) |
| | | | ✓ | ✓ | ✓ | | | | | | | | | Lab. tecnologico: 3 m.u. test wafer su probe station (CERN) |

| Tecnici e tecnologi attualmente assegnati all'attivita' | | | | | | Richieste di supporto tecnico per | | |
|---|---|---|---|---|---|---|---|---|
| INFN | | ALTRI ENTI | | | | l'anno: | 2017 | |
| Nome | mesi/U | Ente | Nome | mesi/U | | Tipologia | N. | mesi/U |
| | | | | | | Tecnici mecc. /elettr/CdC | 1 | 6 |
| | | | | | | Disegnatori meccanici | | |
| | | | | | | Microsaldatori | 1 | 3 |
| | | | | | | Tecnologi progett. mecc. | | |
| | | | | | | Tecnologi elettronici/CdC | | |
| | | | | | | Tecnologi microelettronica | | |

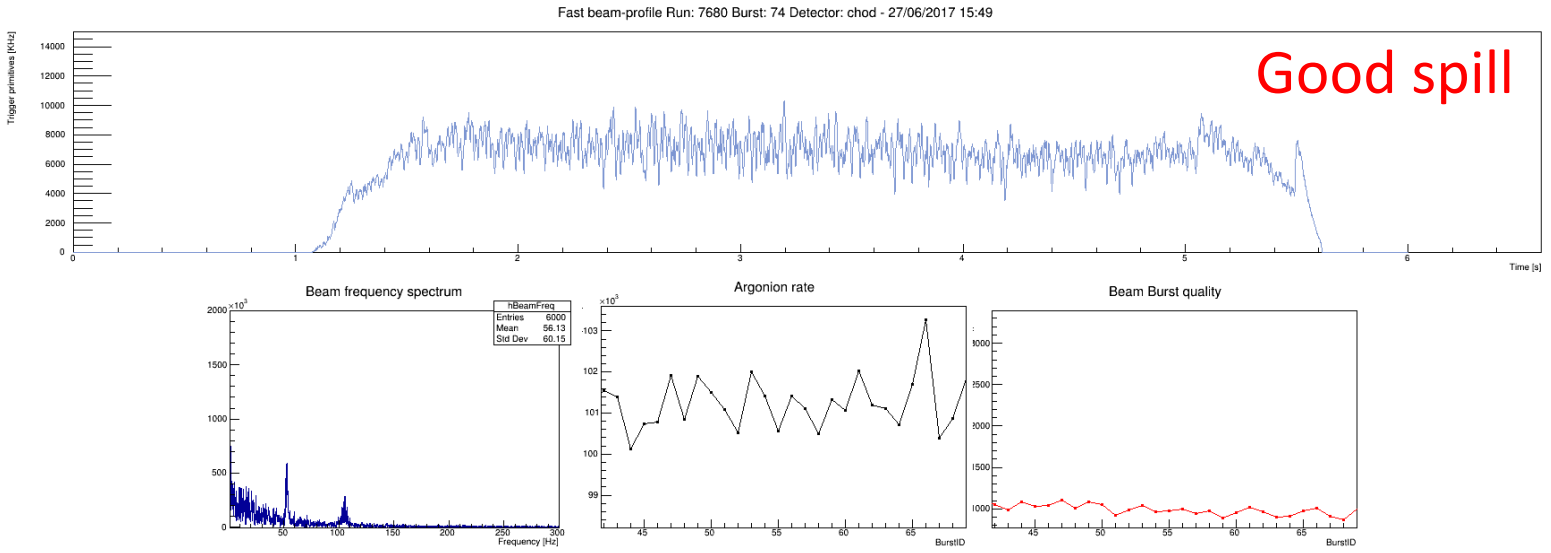
Note:

Le richieste di NA62-2017 sono tutte essenzialmente preventive, nel senso che il prossimo anno si dovrebbero assemblare un bel po' di rivelatori per il Gigatracker (silicon pixel detector). Ci aspettiamo che la maggior parte sia fatta al CERN. Ma puo' servire aiuto dalla sezione.

Questo modulo sostituisce quello che ho inviato 4 ore fa, c'era un errore.

# Run 2017

- 15/5 – 22/10 con il rivelatore completo
- Trigger L0 completo (anche calorimetrico, con diverse soglie di energia)
- Trigger PiNuNu (non downscalato) + triggers per esotici
- Presa dati stabile (3x campione 2016)
- Privilegiare stabilità rispetto a statistica, ad es. 60% di intensità nominale (dipendente dalla qualità dell'estrazione del fascio)



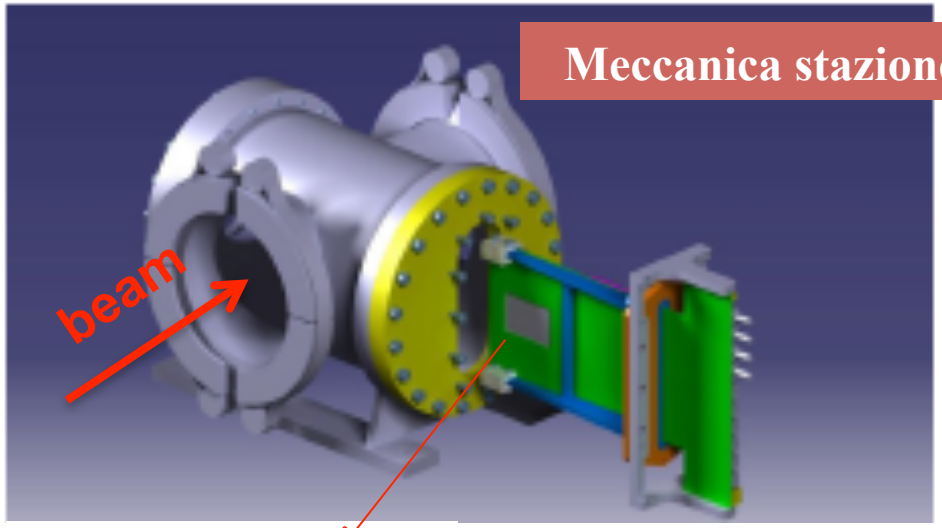
# Il Gigatracker

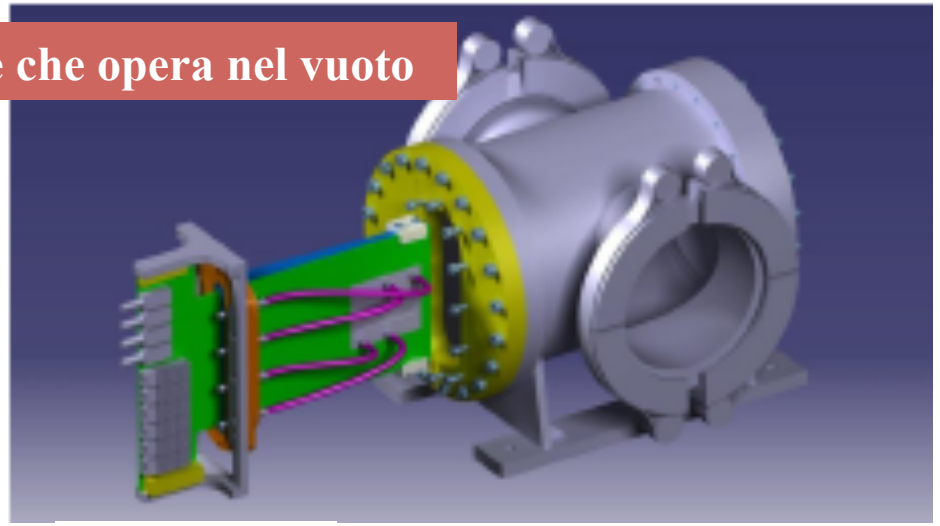
## Impegno di Torino: Front end per il GigaTracKer (GTK)

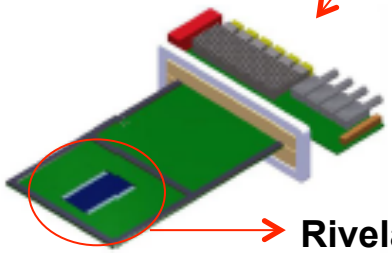
## con Ferrara, CERN, UCL (Louvain-la-Neuve,Be)

**Stima costo rivelatore: ~ 3 MCHF (INFN: 40%, CERN: 40%, Louvain: 20%)**

**Meccanica stazione che opera nel vuoto**

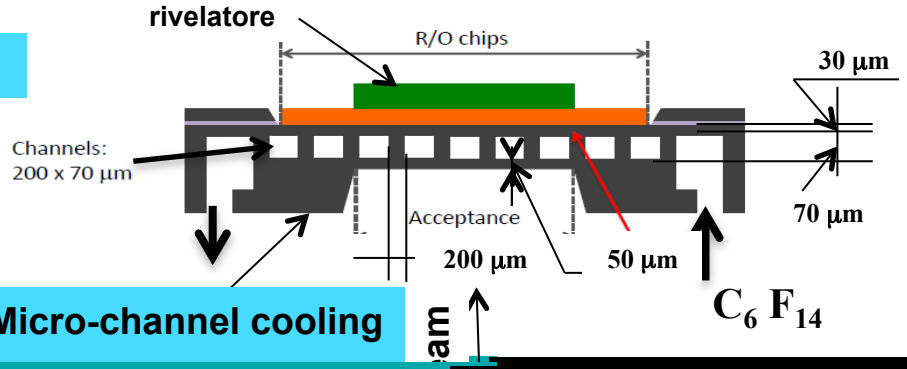




Rivelatore (60x27) mm²

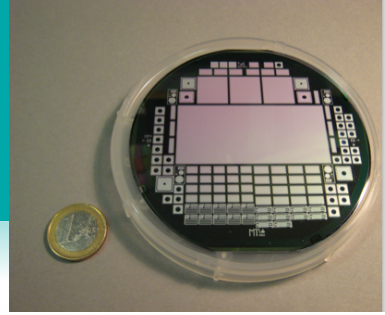
**Sketch del rivelatore**



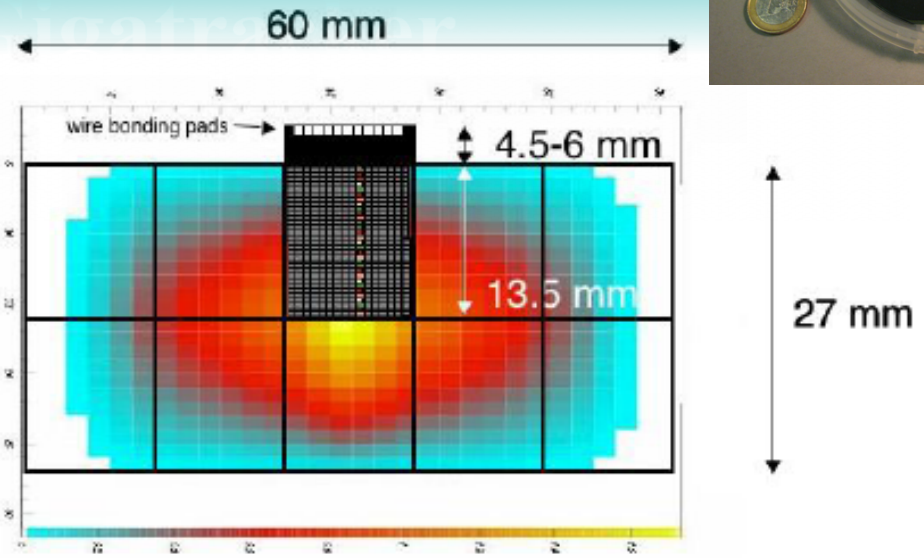

**Baseline design: 150 parallel cooling channels (200 μm × 70 μm, $C_6F_{14}$)**

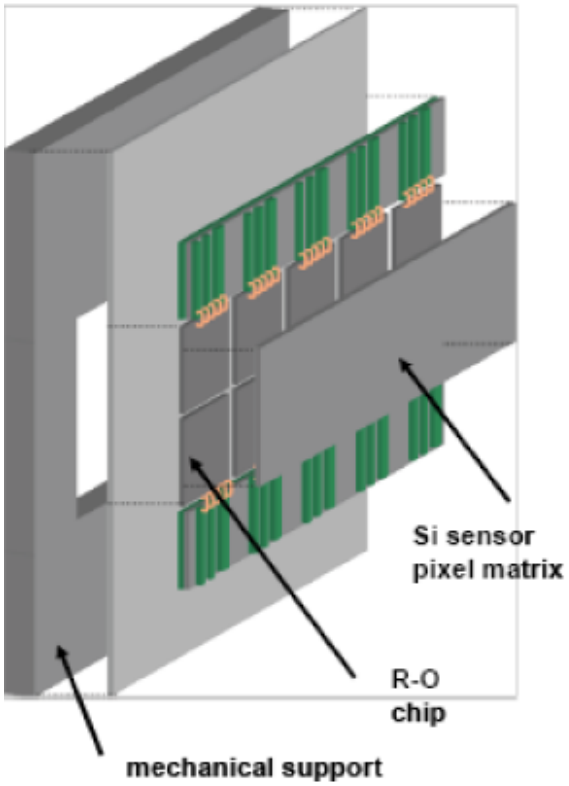
**Micro-channel cooling**

# Il Gigatracker



**Ogni stazione è una matrice di 18000 Si-pixel (300x300 μm²) di spessore pari a 200 μm letta mediante 10 chip ASIC bump-bonded alla matrice**




**ASIC per il readout dei pixel in tecnologia CMOS(IBM) 0.13μm**

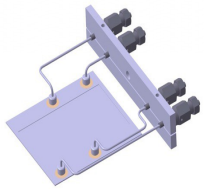
**End-of-Column TDC; preampli-discri nell'area del pixel e TDC alla fine della colonna: 1 TDC per n pixel**

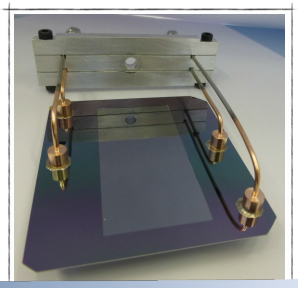
**a) ASIC chip from IBM**

**b) Bump-bonding tender by IZM**

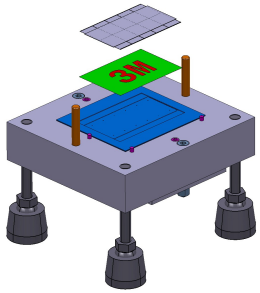
# Il Gigatracker: montaggio

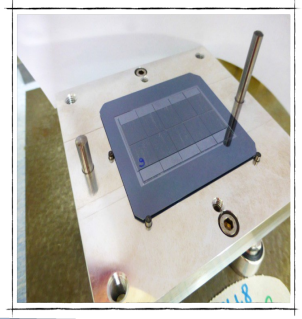
**Soldered fluid connectors**



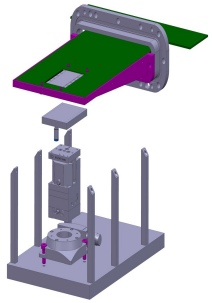


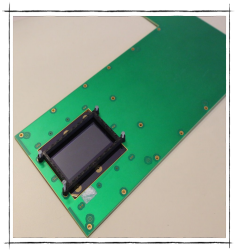
**Thermal Interface**



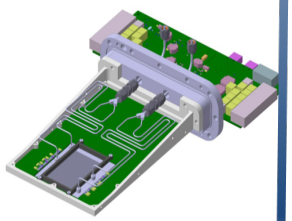



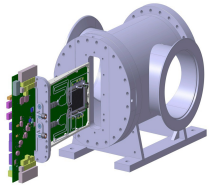
**Mounting to Carrier Board**





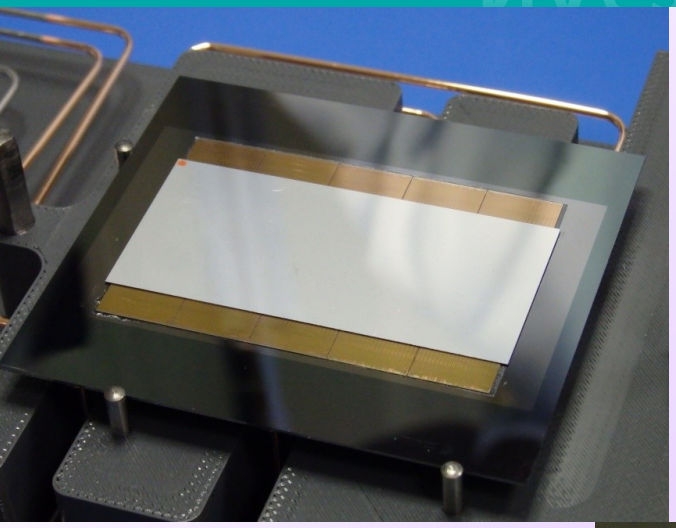
**Installation**

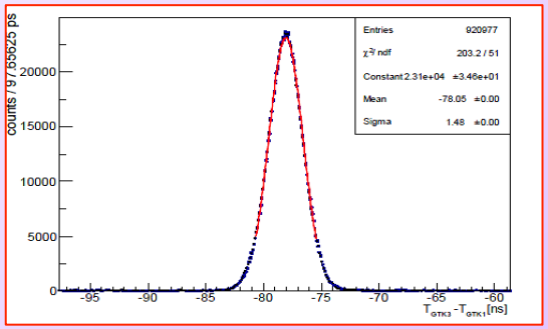




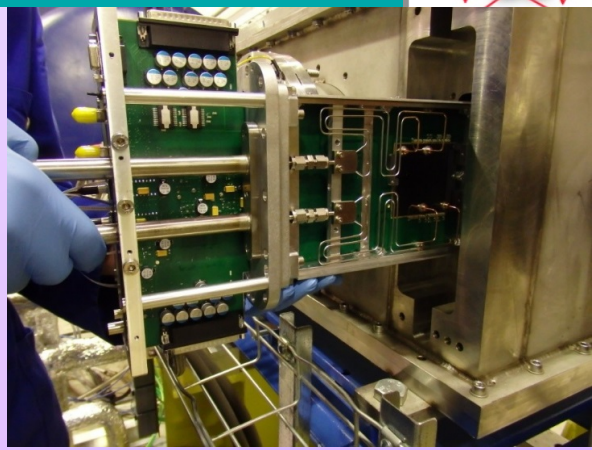
| GTK Position | TDCpix Thickness (micron) | Cooling Plate |
|---|---|---|
| 1 | 250 | P10 |
| 2 | 100 | New production |
| 3 | 100 | New production |

# NA62 – Gigatracker

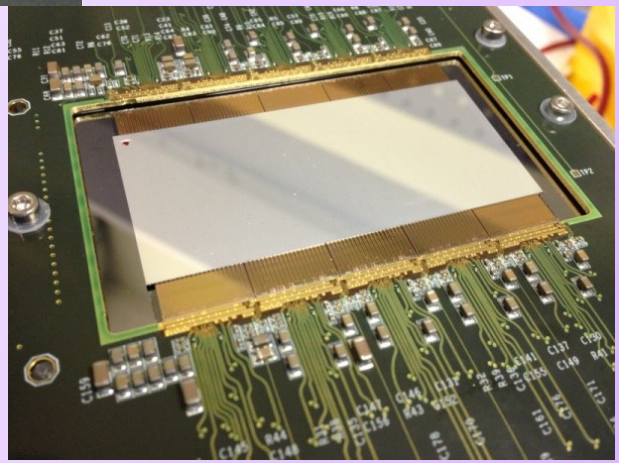




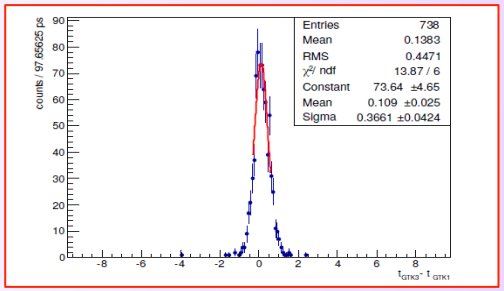

**GTK3 – GTK1**
**Before any correction**



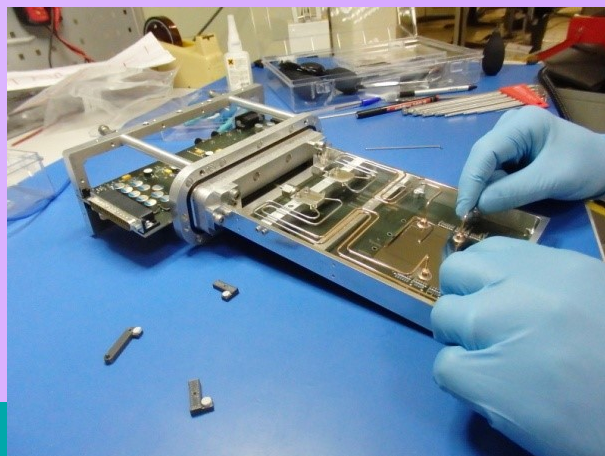
**Installed in K12 beam**



**Tests on several single-chip assemblies confirms that the ASIC chip is fully functional and that the bump-bonding efficiency is better that 99%.**



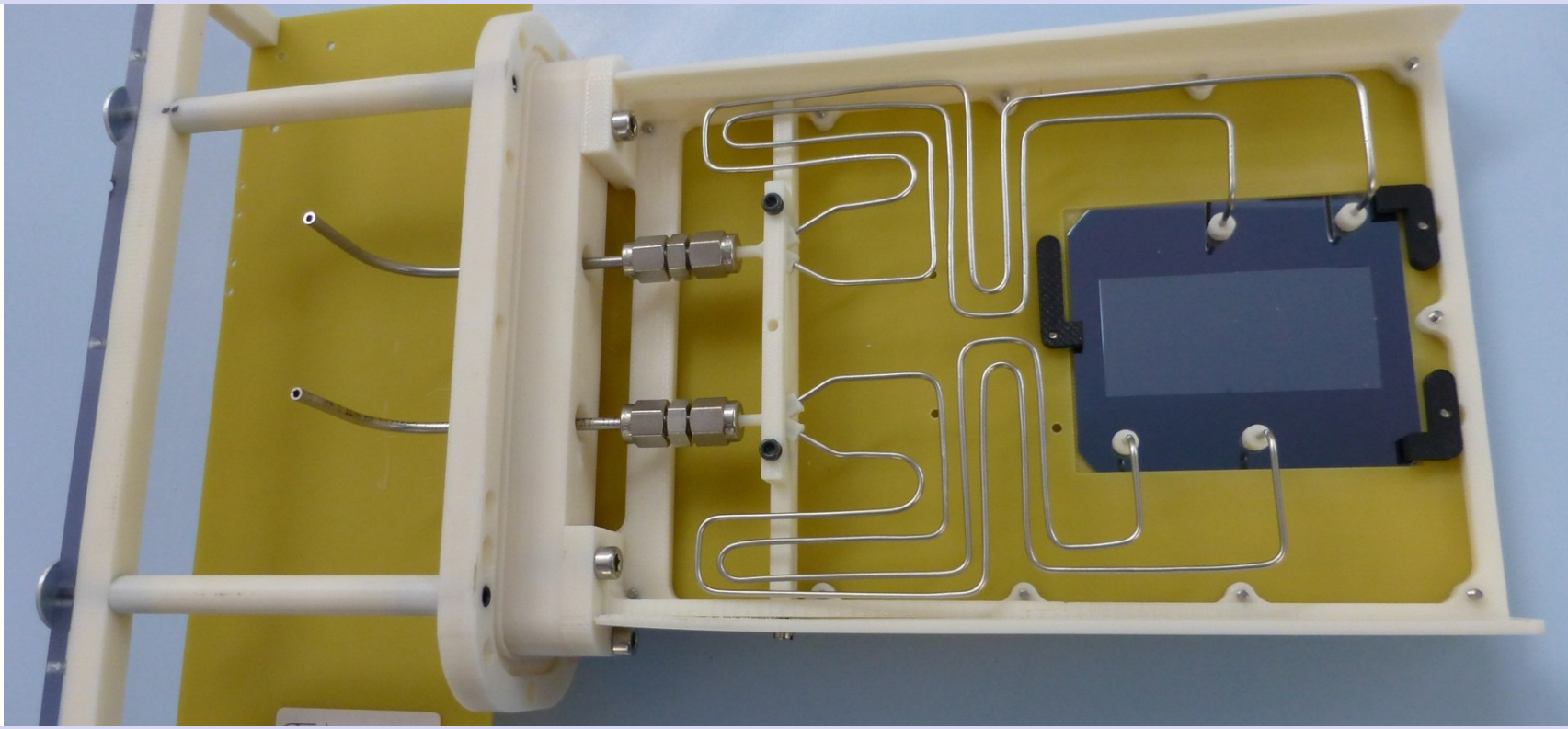

**After correction**



**Time resolution~ 260 ps /station**
**In line with expectations for HV= 200 V**

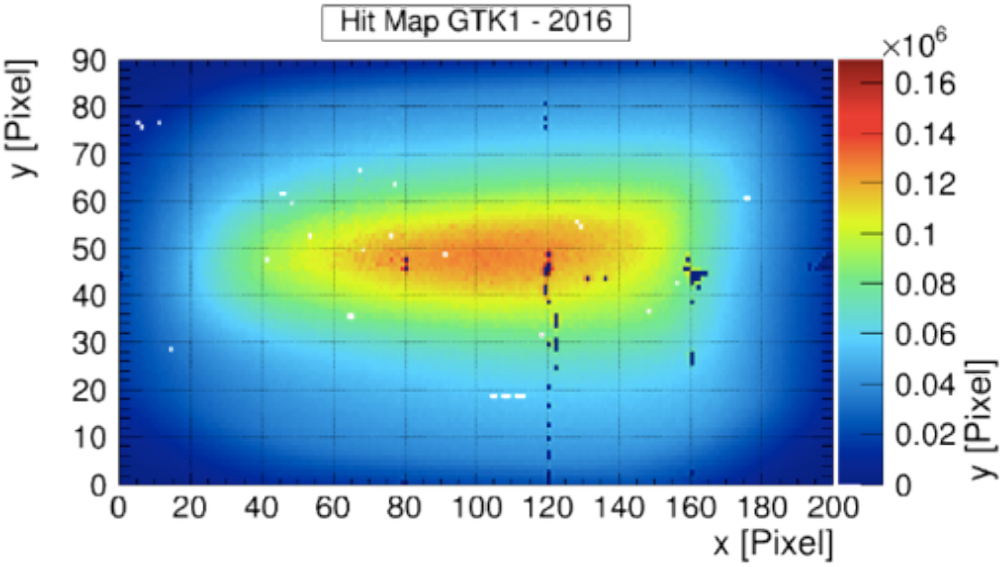
# Il Gigatracker: microcooling

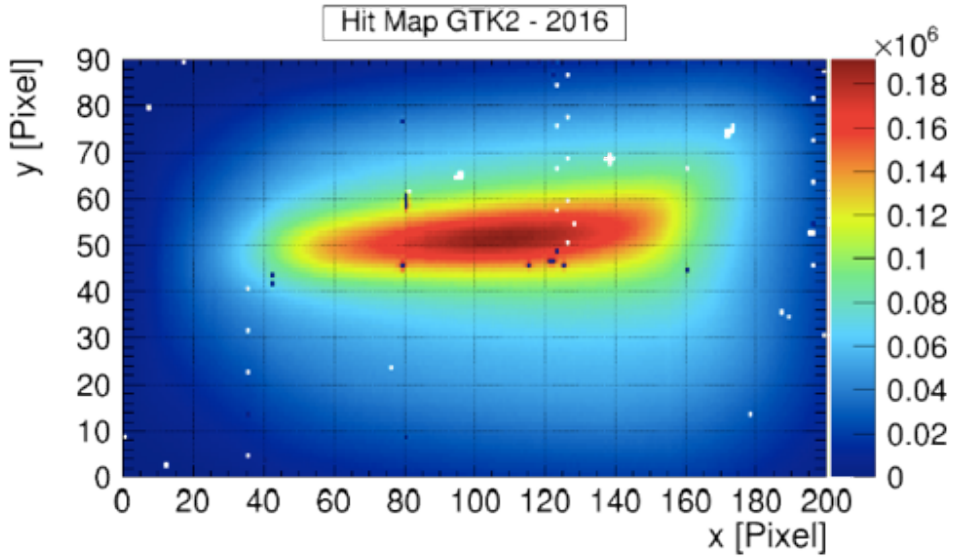
**Cooling plant:** the construction of the cooling station is proceeding as planned. The company (Delta-Ti Impianti, Italia) has completed the design phase, and beginning the station's assembly; expected at CERN in August.

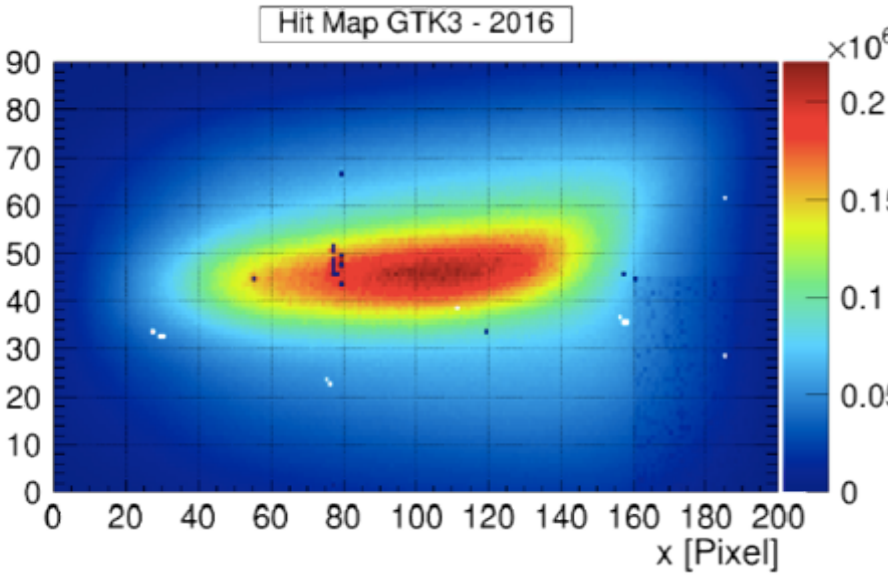


**GTK- Micro-channel assembly plates:** the delivery of assembly plates from LETI is proceeding as expected

# Gigatracker: in 2016

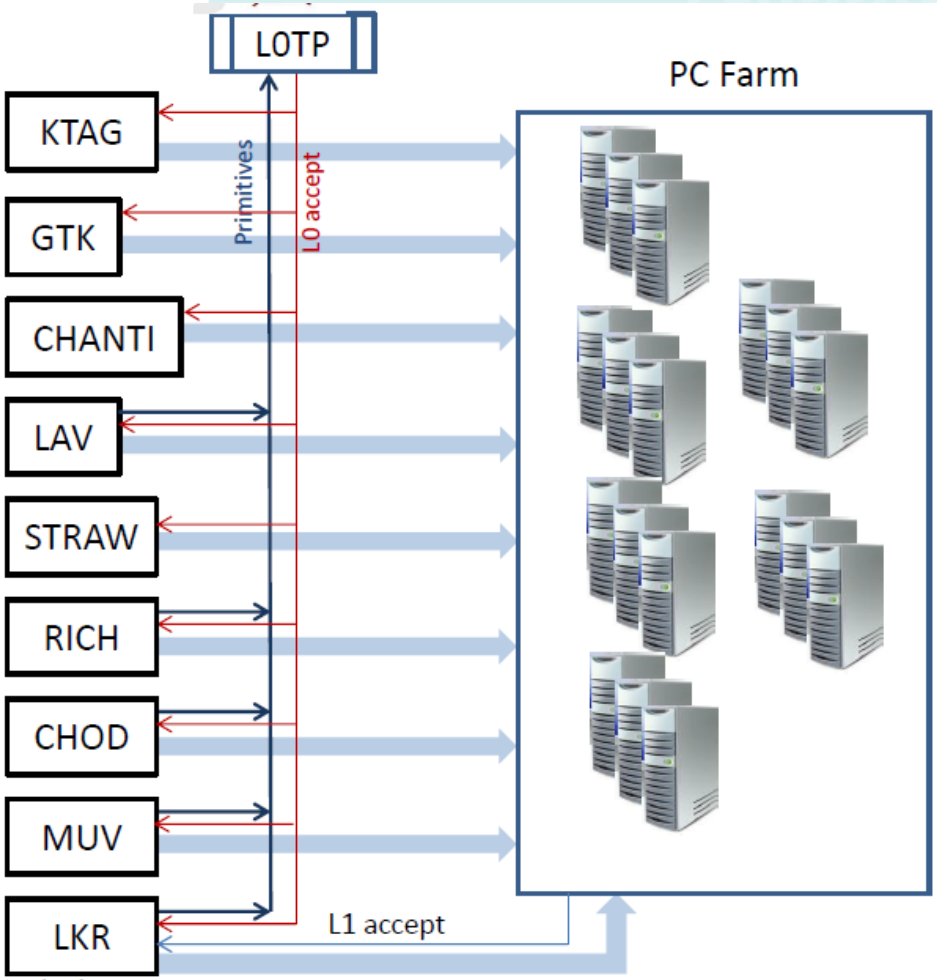



**Using better sensors in 2017**

# Trigger & DAQ



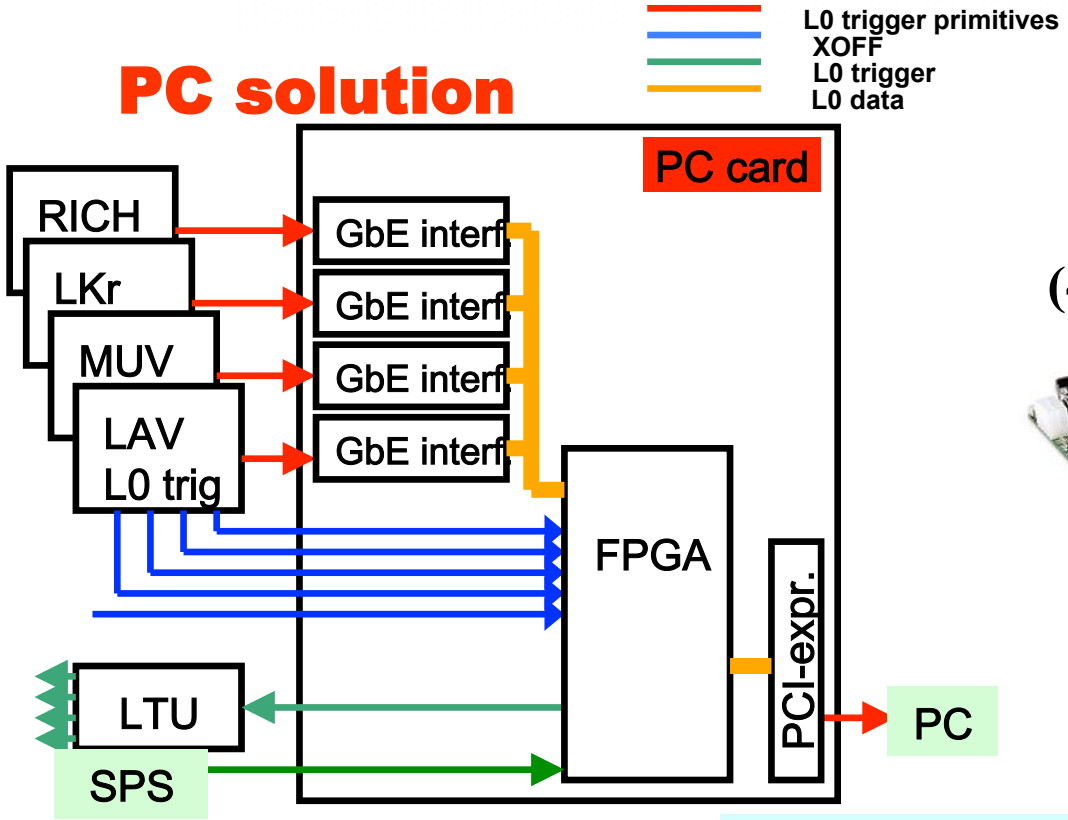

- Trigger:
  - L0 (hardware): 10 → 1 MHz
  - L1/L2 (software): 1 MHz → 20 KHz
- DAQ: 20 KHz
  - L0 trigger for :
    - Single charged particle topology
    - Energy in hadron calorimeter / no muons
    - No photons
- L0 Trigger commissioned.
- DAQ commissioned at full intensity.

# Trigger: L0 fully commissioned

**Torino-only project (PhD Dario Soldi), in use since 2014**

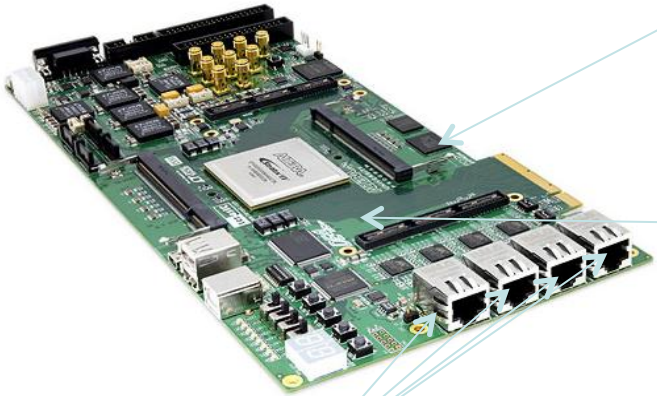
**L0 (hardware): 10 → 1 MHz**

*Ferrara project: only backup/development*




**Terasic Stratix Development Board (4 GbE links only): 1 in Fe**

**PC card**



**schedina da infilare qui**

**La scheda modificata ha 8 ingressi GbE. L0 ha bisogno di 7 ingressi (sono i 7 rivelatori usati per formare L0: Chod , LKr, MUV1-2/3, LAV, Rich, NHOD) + 1 output**

# Trigger L0: R/O

**1 scheda R/O per ciascun chip → 30 schede**

**Torino**

**trigger L0**

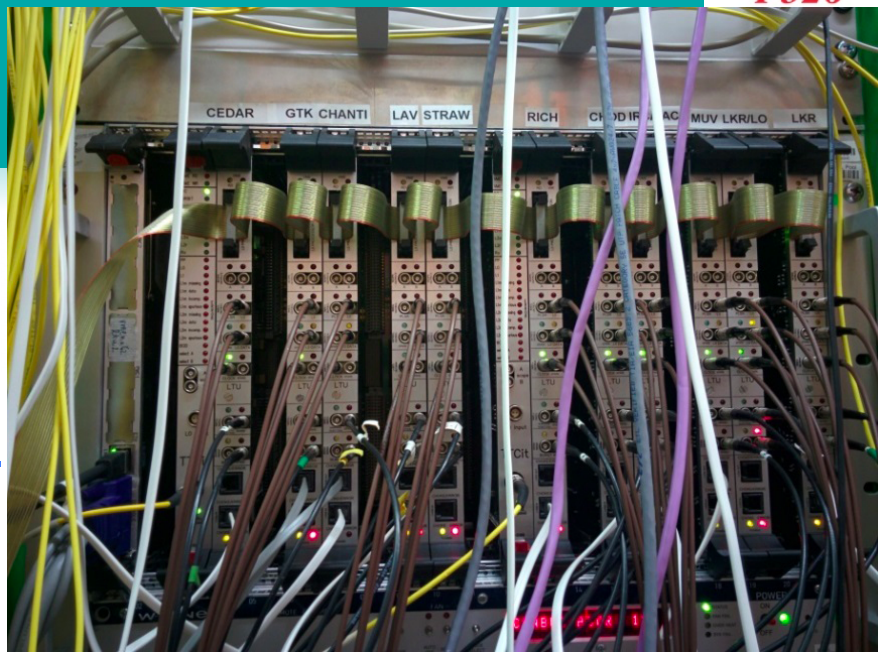
**optical fibers dal chip**

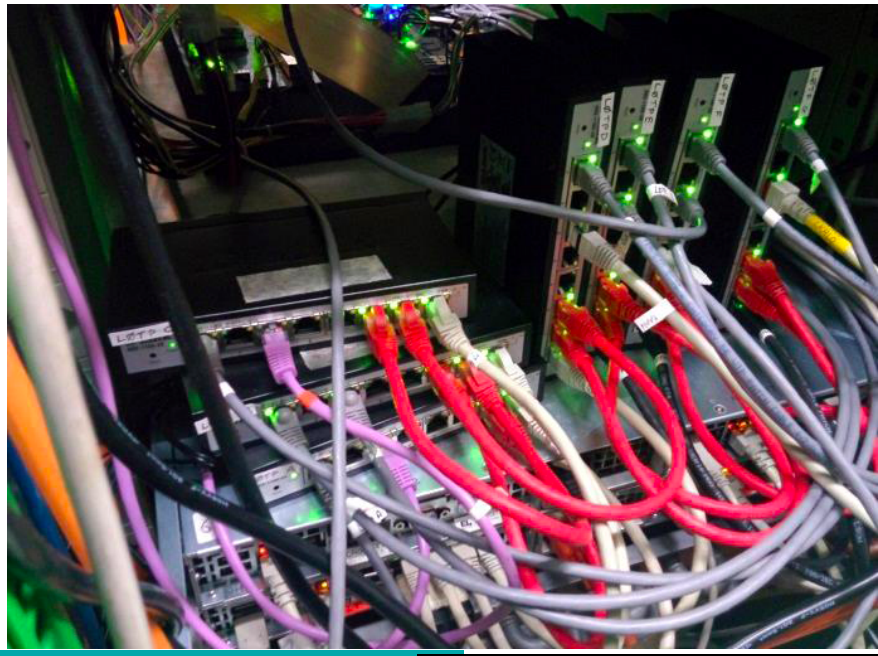
**Trigger System**

- **L0TP in both FPGA-based (and PC-based flavours in the Ferrara development)**
- **TDCB-based trigger primitives generated from LAV, MUV1-2/3, RICH, CHOD , NHOD, LKr-L0 system also deployed**

# Trigger L0: R/O

Torino board

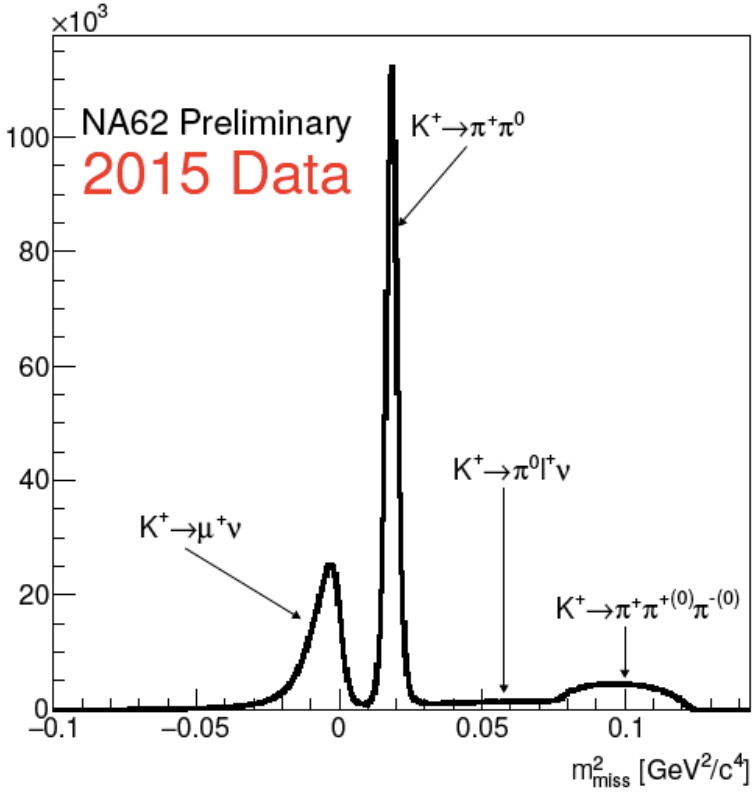


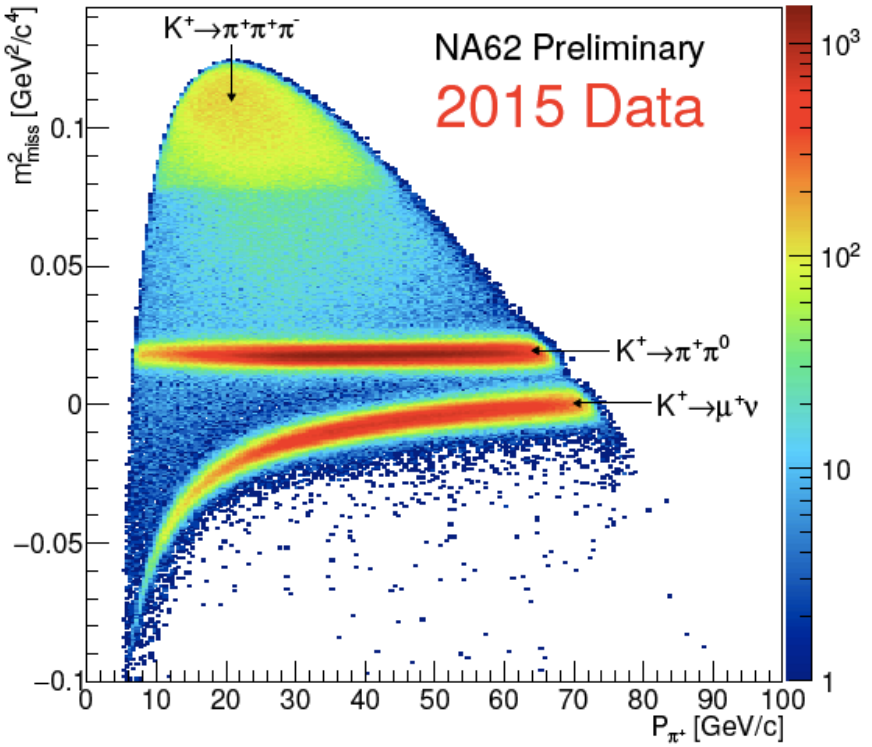



**Trigger System**

- **L0TP in FPGA-based board (*and PC-based flavours in the Ferrara development board*)**
- **TDCB-based trigger primitives generated from LAV, MUV1-2/3, RICH, CHOD , NHOD, LKr-L0 system also deployed**

# Analisi

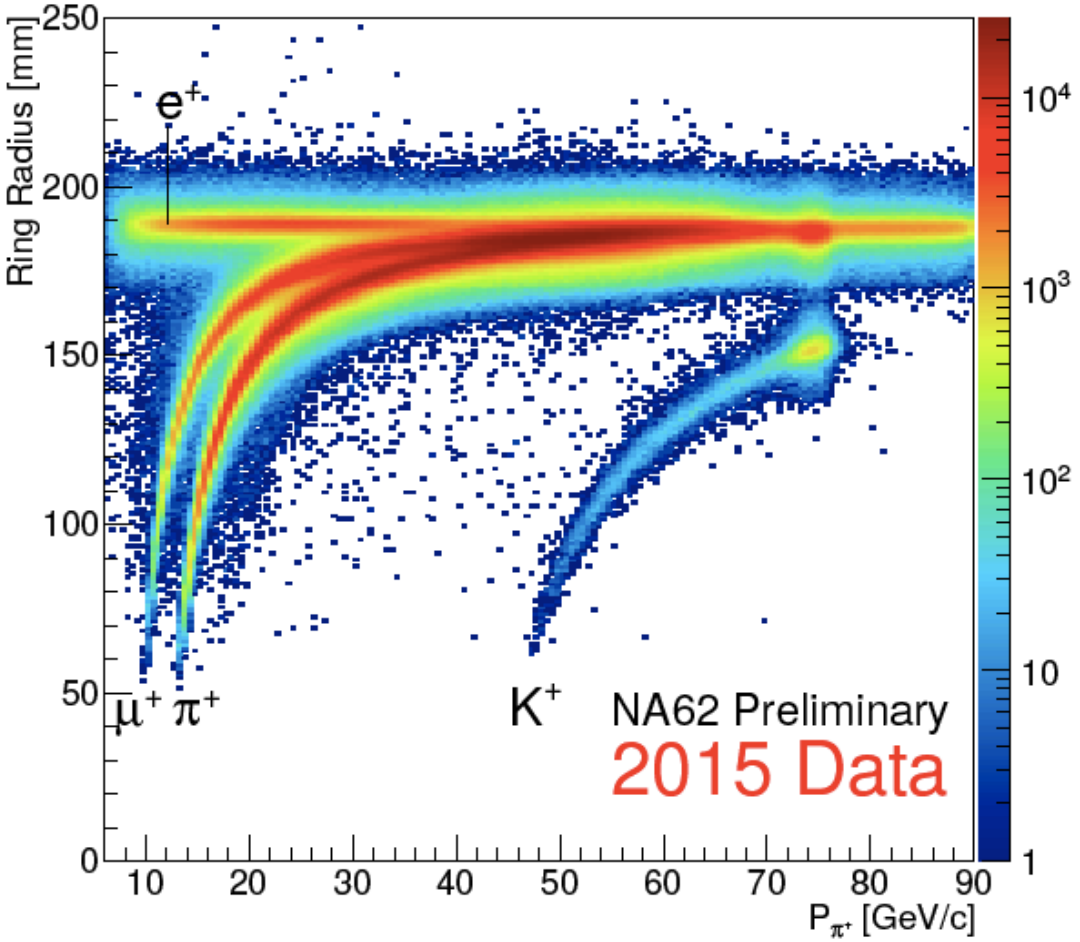



- 15 < $p_\pi$ < 35 GeV/c to suppress $K^+ \rightarrow \mu^+\nu$
- $K^+ \rightarrow \pi^+\pi^0$ selected using LKr
- Resolution close to design
- Background rejection aimed: $10^4$ - $10^5$, measured in 2015: $10^3$

# Analisi

- Goal: $10^7$ muon rejection to reduce $K^+ \rightarrow \mu^+\nu$
- $15 < p_\pi < 35$ GeV/c: best RICH performance
- Pure sample of pion and muon selected using kinematics
- RICH: $10^2$ $\mu^+$ rejection for 80% $\pi^+$ efficiency
- Calorimeter: $10^4$-$10^6$ $\mu^+$ rejection for 90-40% $\pi^+$ efficiency (cut)



# Analisi of Beam Background

## Candidate Selection

- Single downstream track
- Energy deposits in Calorimeters
- Beam track: NOT Kaon

## Timing

- Kaon ID <100 ps
- Beam Track <200 ps
- Downstream Track <200 ps
- Calorimeters ~ 1-2 ns