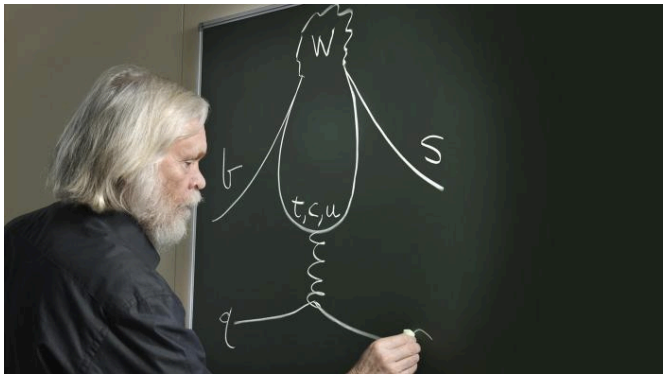
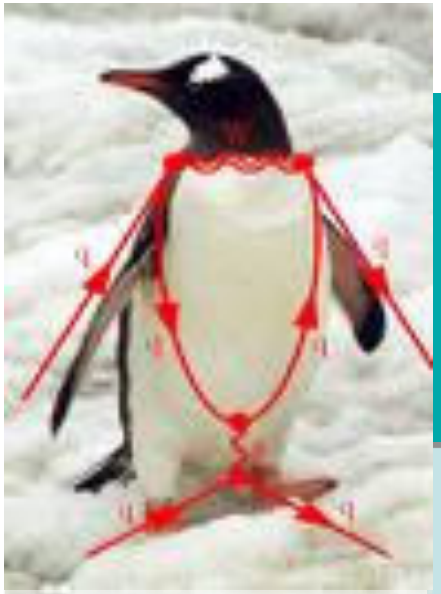
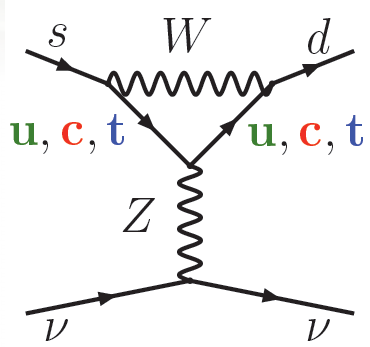




NA62 @ CERN: misura del decadimento raro $K^+ \longrightarrow \pi^+ \nu \bar{\nu}$

Cristina Biino - INFN Torino

CdS, Torino, 30 Giugno 2016



The penguin diagrams

NA62 Collaboration

•Birmingham
•Bristol
•Glasgow
•Liverpool

TRIUMF
UBC

Mainz

•Prague

•IHEP
•INR
•JINR

UC Louvain

Bratislava

CERN

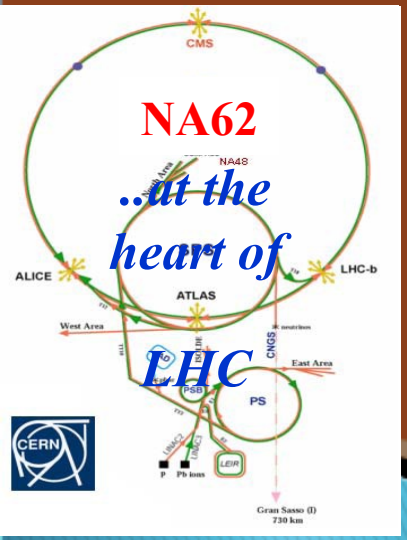
Bucharest

•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

235 Collaborators

NA62 Goal

$$K^+ \to \pi^+ \nu\nu$$

- Ultra rare FCNC: s → d transition, hard GIM suppression
- Theoretically clean (no hadronic uncertainties)

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

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

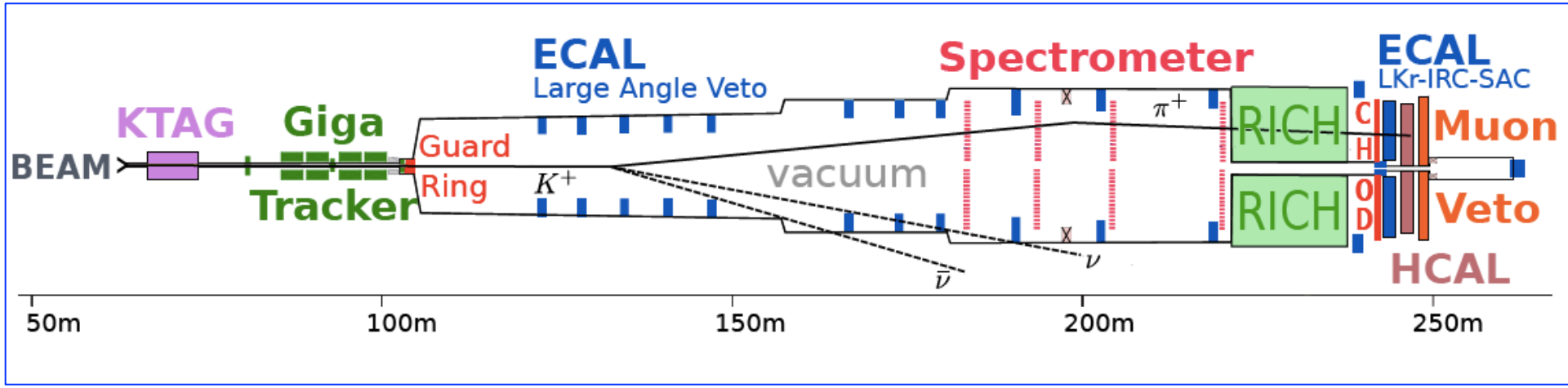
(E787/949): (7 events)

**[Buras, 1503.02693]*

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

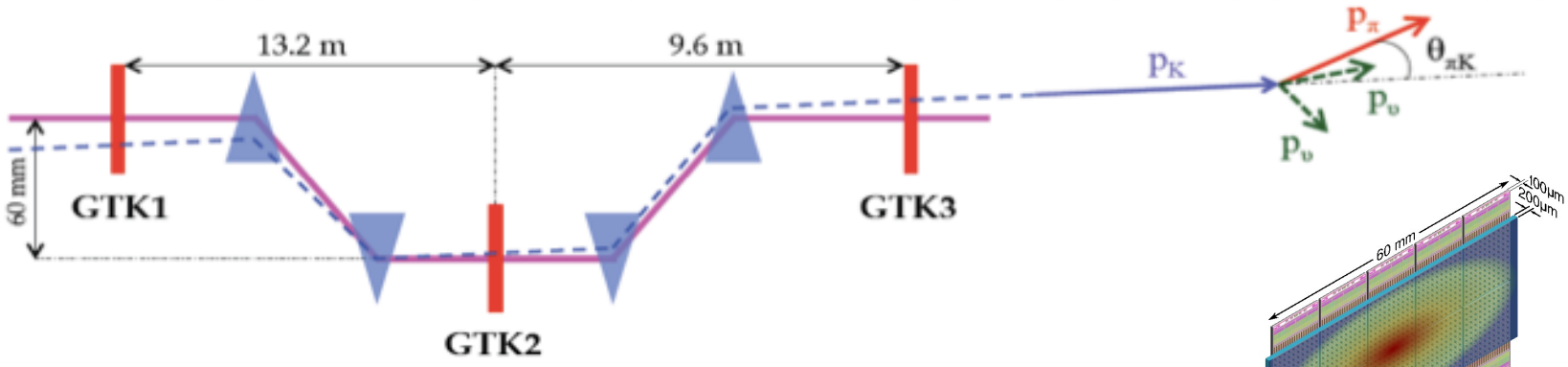
Deviation from SM predictions would **signal New Physics!**

NA62 Apparatus



Lo spettrometro del fascio: il Gigatracker

CERN, Ferrara, Louvain-la-Neuve, Torino



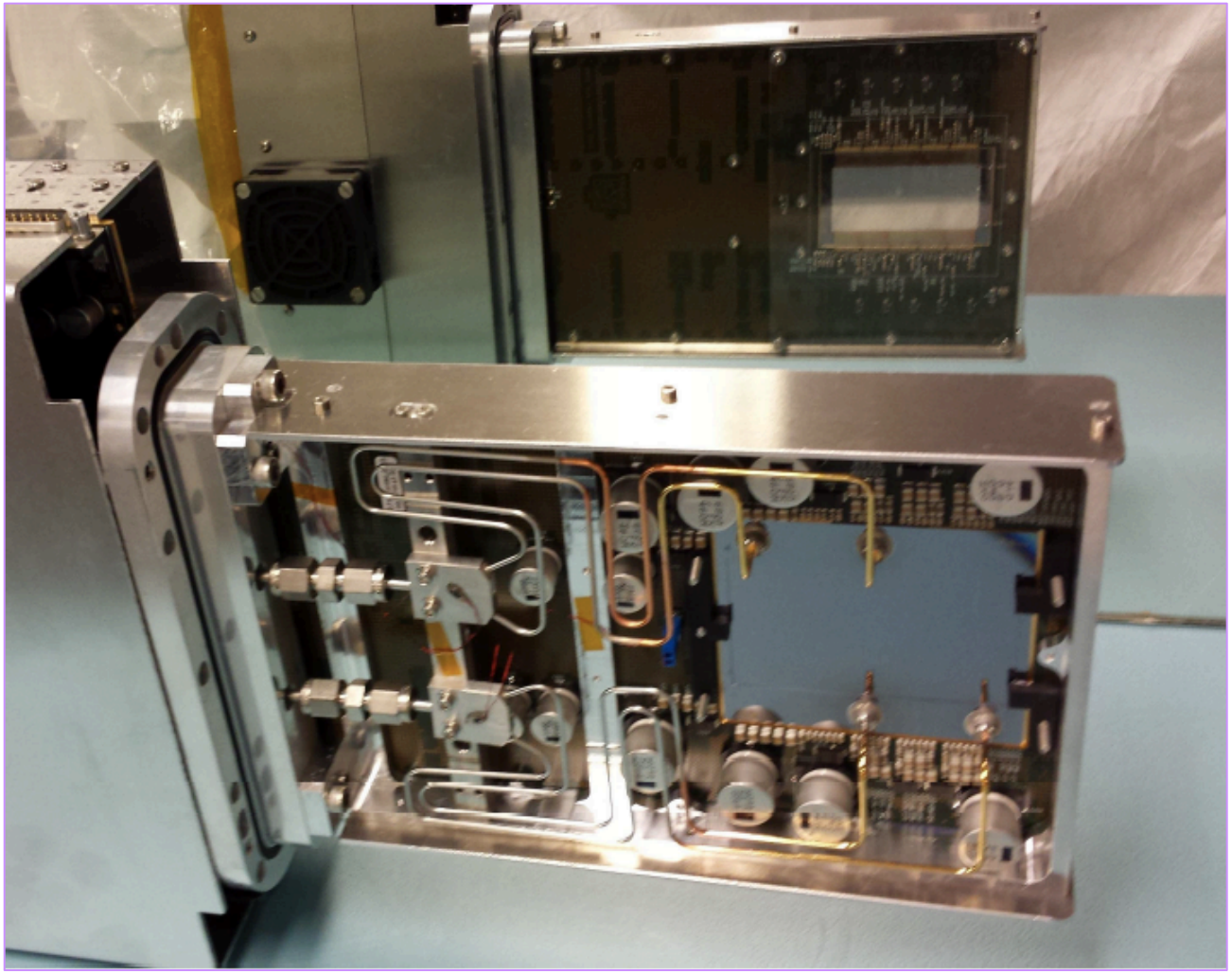
GTK: 3 stazioni di Si-pixel per definire tempo, direzione e momento di tutte le particelle del fascio

Specifiche GTK:

- Montato 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;

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

Gigatracker: components overview

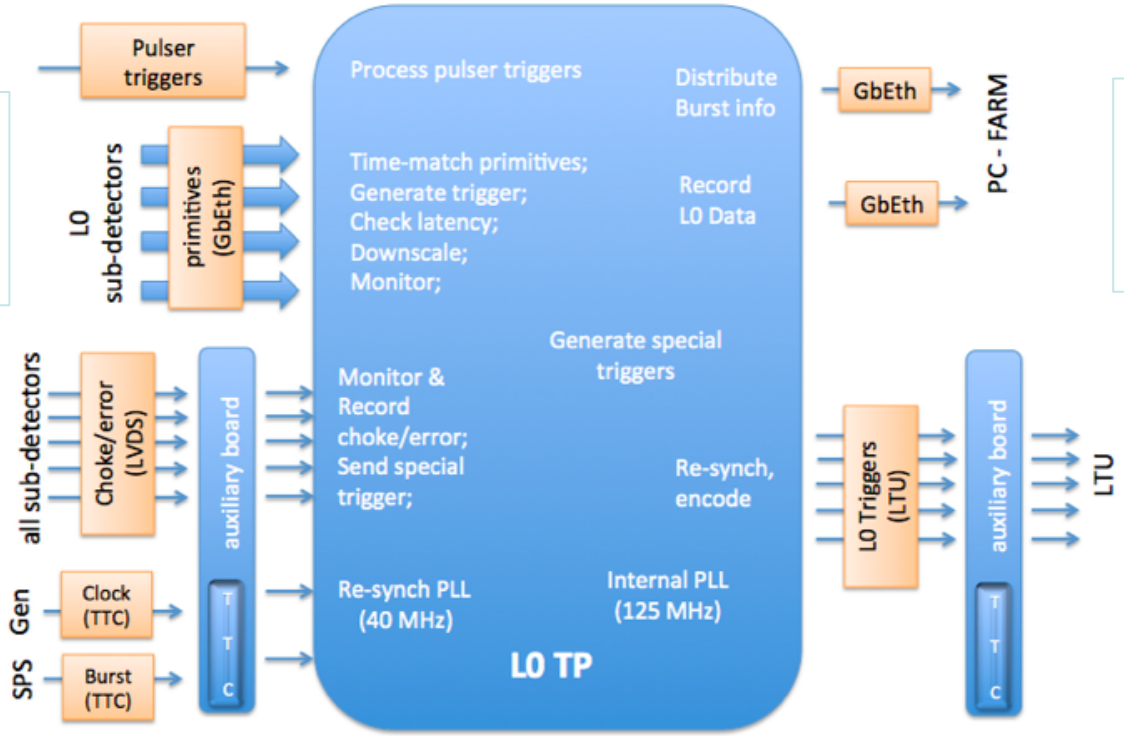


- Carrier
- Assembly (Chip + Sensor)
- Cooling Plate

Trigger: L0 fully commissioned

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

10 MHz x 7 sources



1 MHz to PC farm and detectors

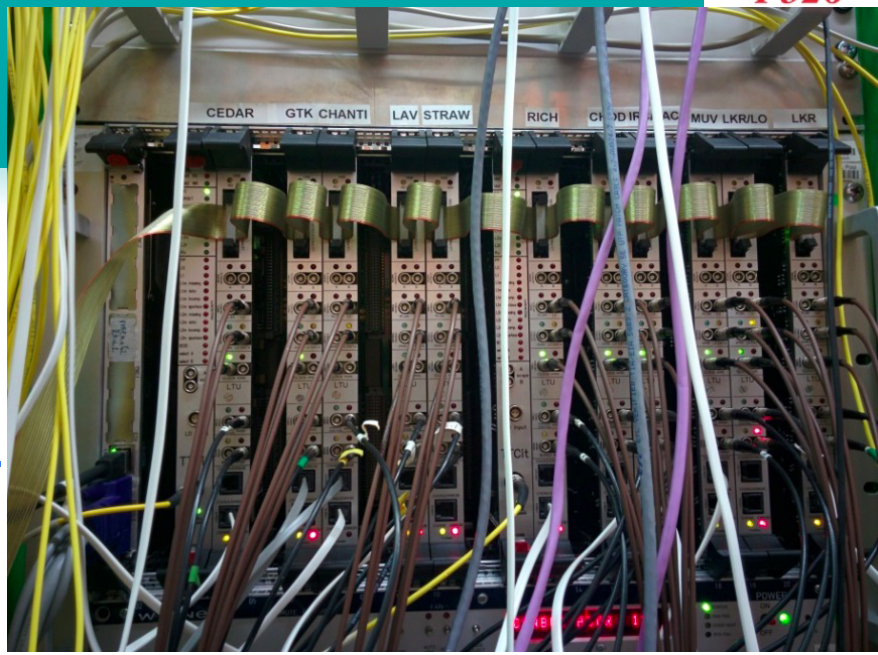
2014 — **Commissioning Pilot run**

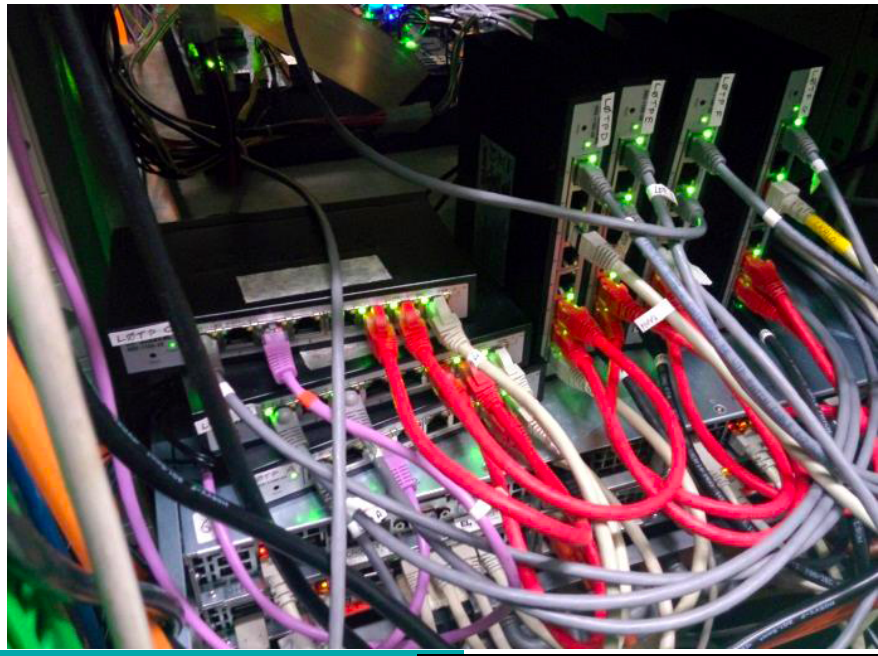
2015 — **First Run with complete system**

2016 — **First year of Physics Run**

Trigger L0: R/O

Torino board



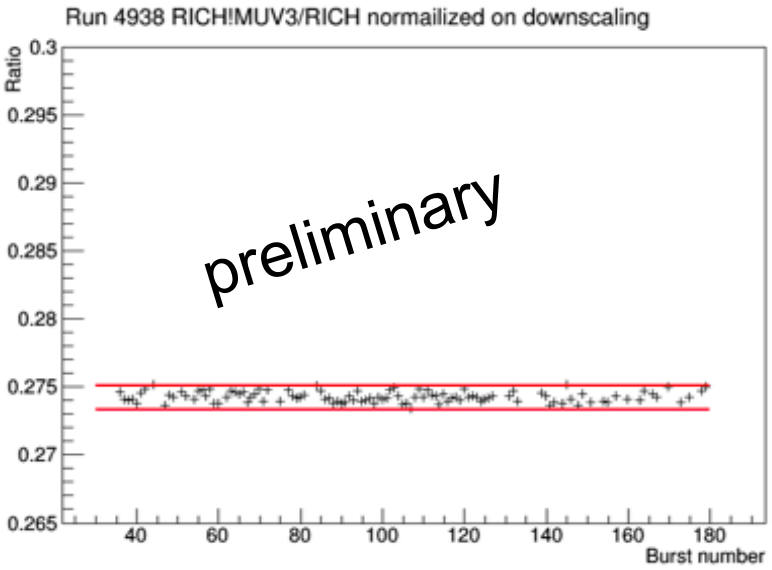


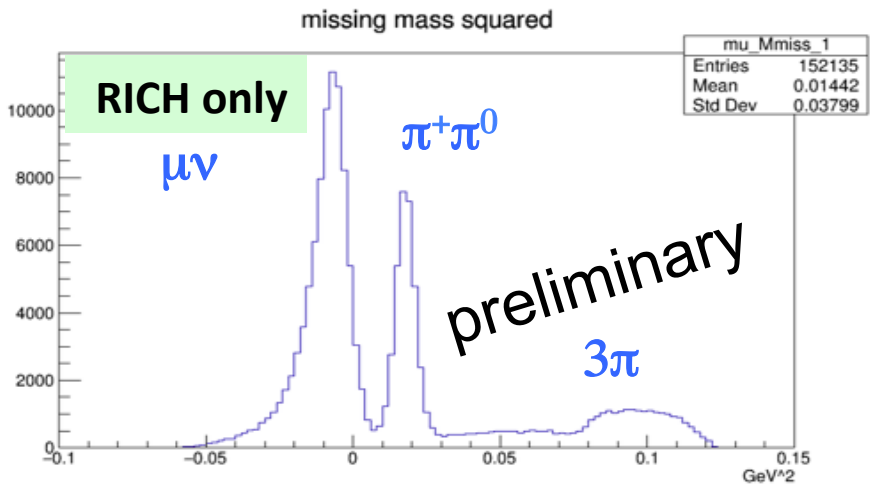
Trigger System

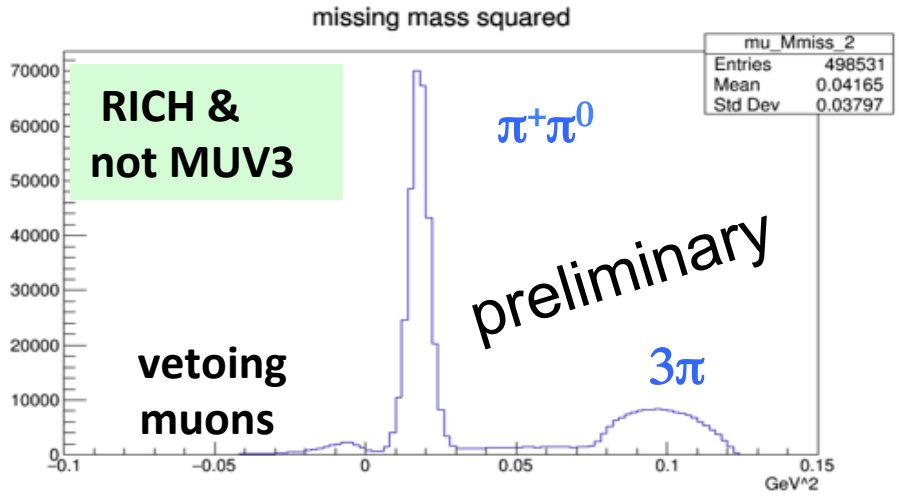
- **L0TP in FPGA-based board (*and PC-based flavours in the Ferrara development board*)**
- **TDCB-based trigger primitives generated from LAV, MUV1-2/3, RICH, CHOD , NHOD, LKr-L0 system also deployed**

L0 – 2016 Data Analisi

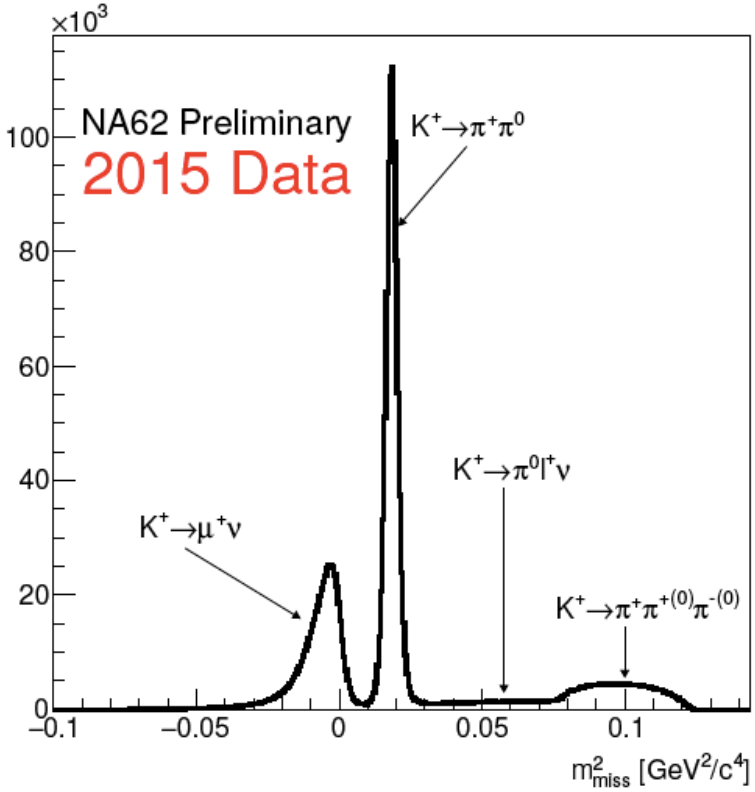
- **10 MHz** input rate
- **1 MHz** output rate
- **7** different sources
- Detectors Time realignment up to **100 ps**
- 8 different trigger masks in parallel
- Control sample to measure trigger eff. online
- Pulsers to calibrate Calorimeters
- choke/error system to monitor detector status
- **1 ms** maximum latency

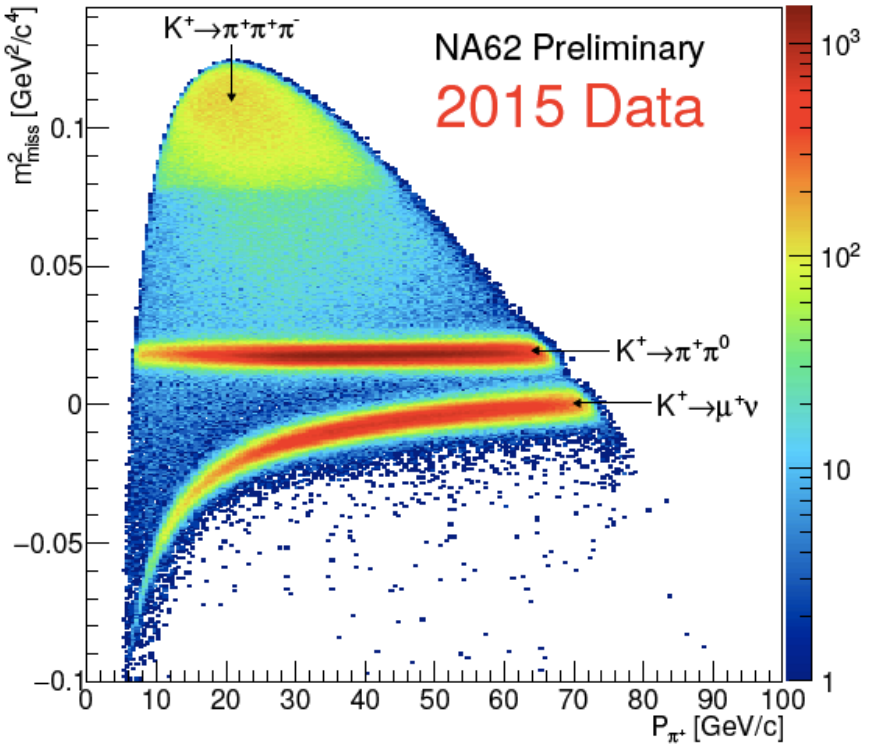






Analisi

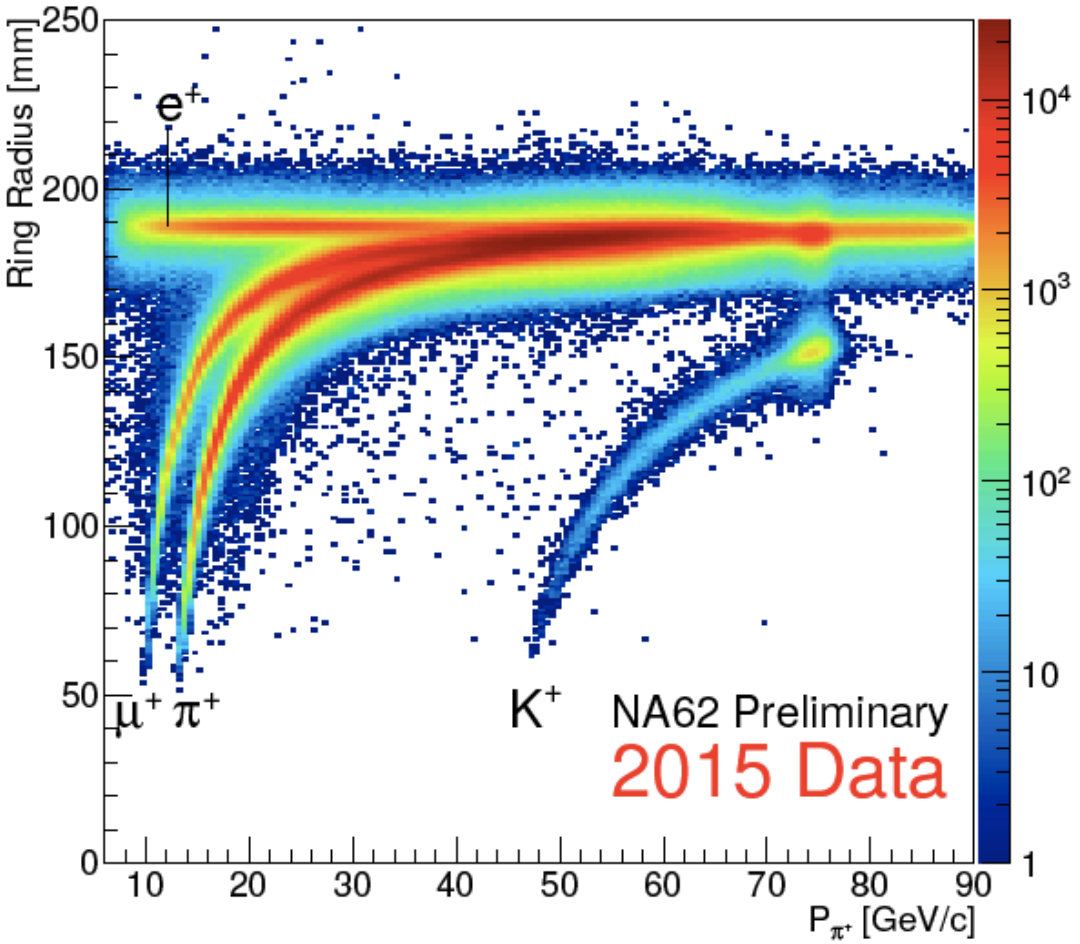




- 15 < p_π < 35 GeV/c to suppress $K^+ \rightarrow \mu^+\nu$
- $K^+ \rightarrow \pi^+\pi^0$ selected using LKr
- Resolution close to design
- Background rejection aimed: 10^4 - 10^5, measured in 2015: 10^3

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 μ^+ rejection for 80% π^+ efficiency
- Calorimeter: 10^4-10^6 μ^+ rejection for 90-40% π^+ efficiency (cut)



Conclusions

- $K^+ \rightarrow \pi^+ \nu \nu$ is a key channel to **search for New Physics**
- NA62 aims to measure the branching ratio with a **10% precision**
- NA62 commissioned and tested up to nominal beam intensity
- Data taking has **started**
- Preliminary study of the quality of the data taken in 2015 at low intensity shows:
  - **timing** performance close to design
  - m^2_m **resolution** close to design
  - bkg rejection promising
  - π/μ separation from **RICH** close to design
  - separation from **calorimeters** promising
  - π^0 **rejection** promising (limited by statistics)
- **More data** are being taken at the moment

Anagrafica 2016-2017

Situazione 2016 (4.5 FTE)+(2.2)*:

R.Arcidiacono (20%)
C.Biino: (30%)
S.Garbolino (50%)
F.Marchetto (70%)
E.Menichetti (100%)
M.Rolo (0%)
D.Soldi (100%)

P.Trapani (20%)
B.Bloch (100%)*
P.Jarron (100%)*

Situazione 2017 (4.8 FTE)+(2.2)*:

R.Arcidiacono (20%)
C.Biino (40%)
M.Boretto (100%)
A.Filippi (30%)
F.Marchetto (70%)
E.Menichetti (100%)
E.Migliore (20%)
M.Rolo (0%)
D.Soldi (100%)

P.Trapani (20%)
B.Bloch (100%)*
P.Jarron (100%)*

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.

SPARE

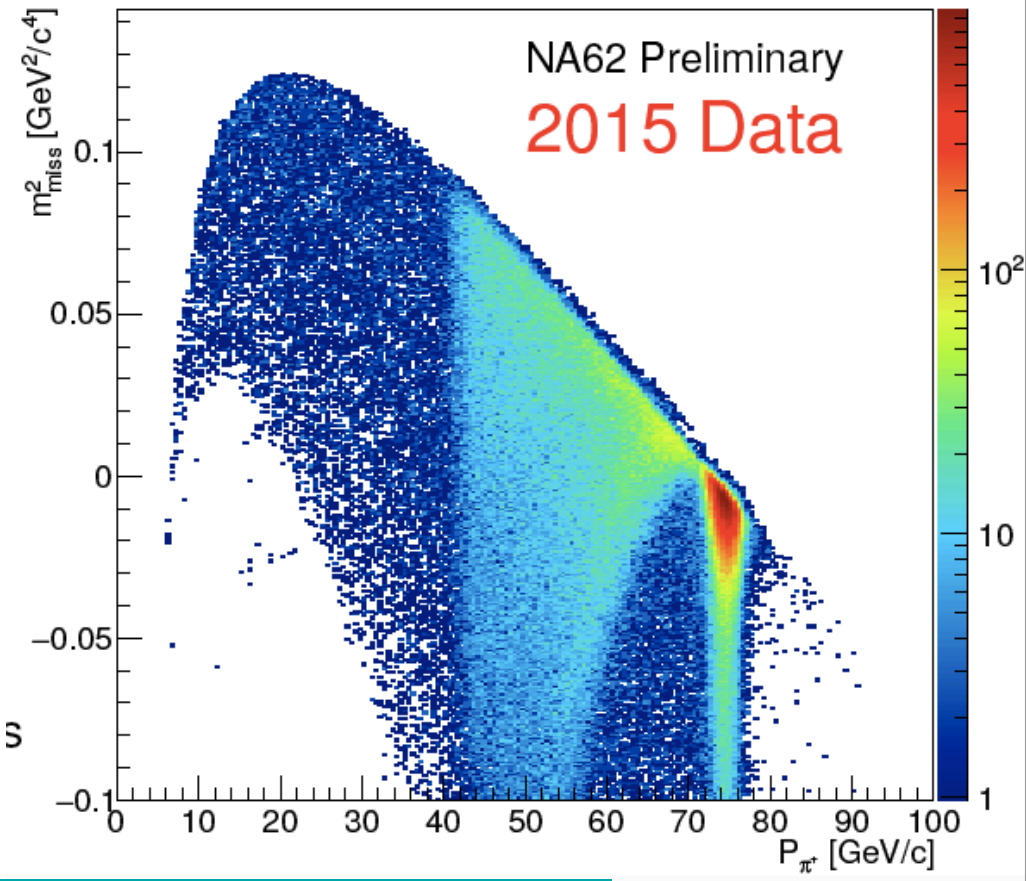
Analisi of Beam Background

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

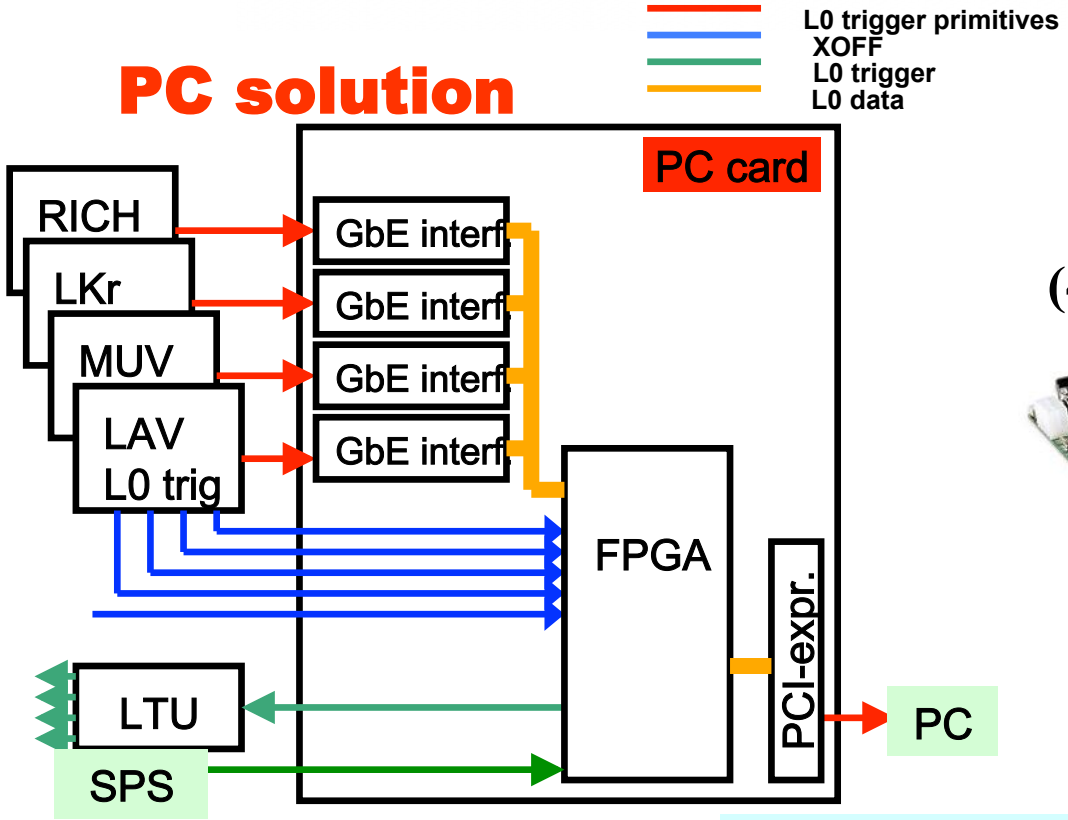


Trigger: L0 fully commissioned

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

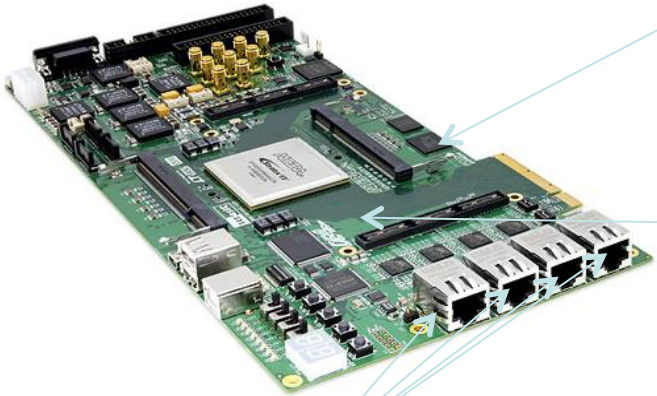
L0 (hardware): 10 → 1 MHz

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

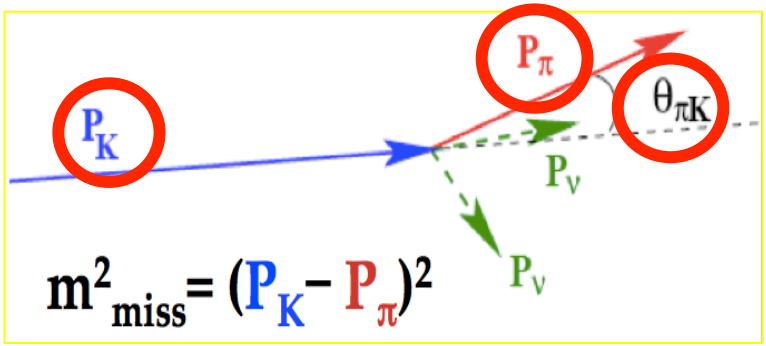
trigger L0

optical fibers dal chip

Trigger System

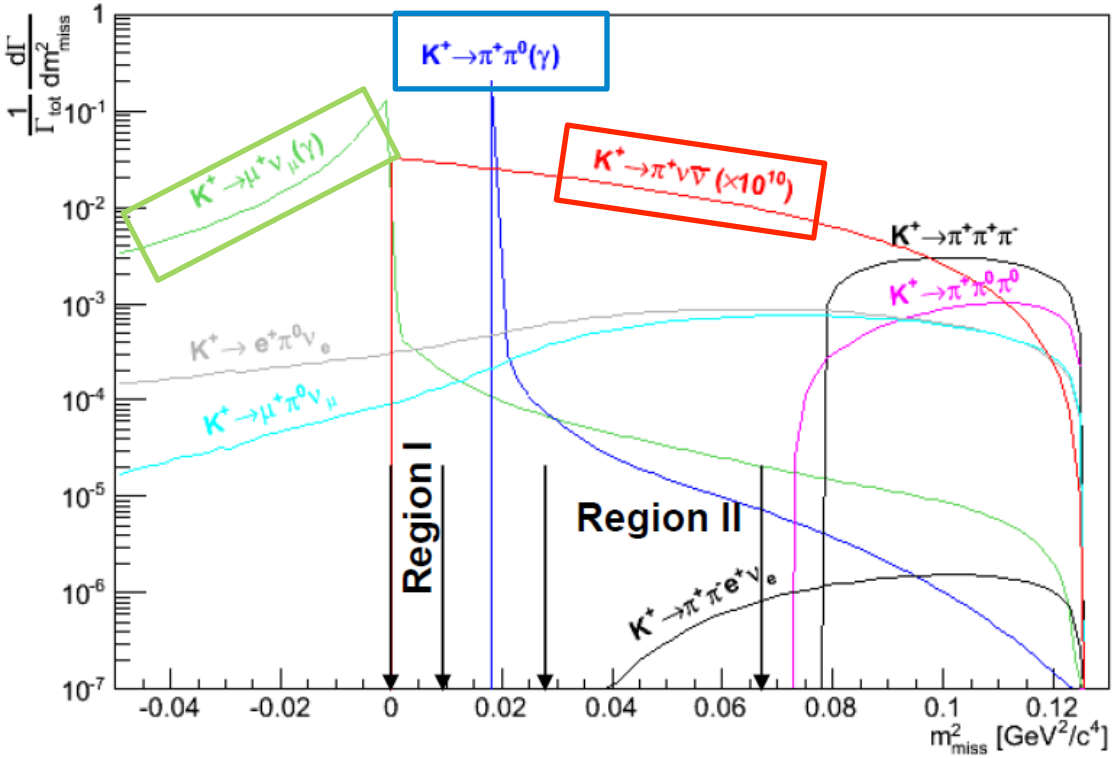
- **L0TP in both FPGA-based (and PC-based flavours in the Ferrara development)**
- **TDCB-based trigger primitives generated from LAV, MUV1-2/3, RICH, CHOD , NHOD, LKr-L0 system also deployed**

Cinematica: Segnale e Fondo



- Calorimetry to veto extra particles
- Very light trackers to reconstruct the K^+ and the π^+ momenta
- Full particle identification

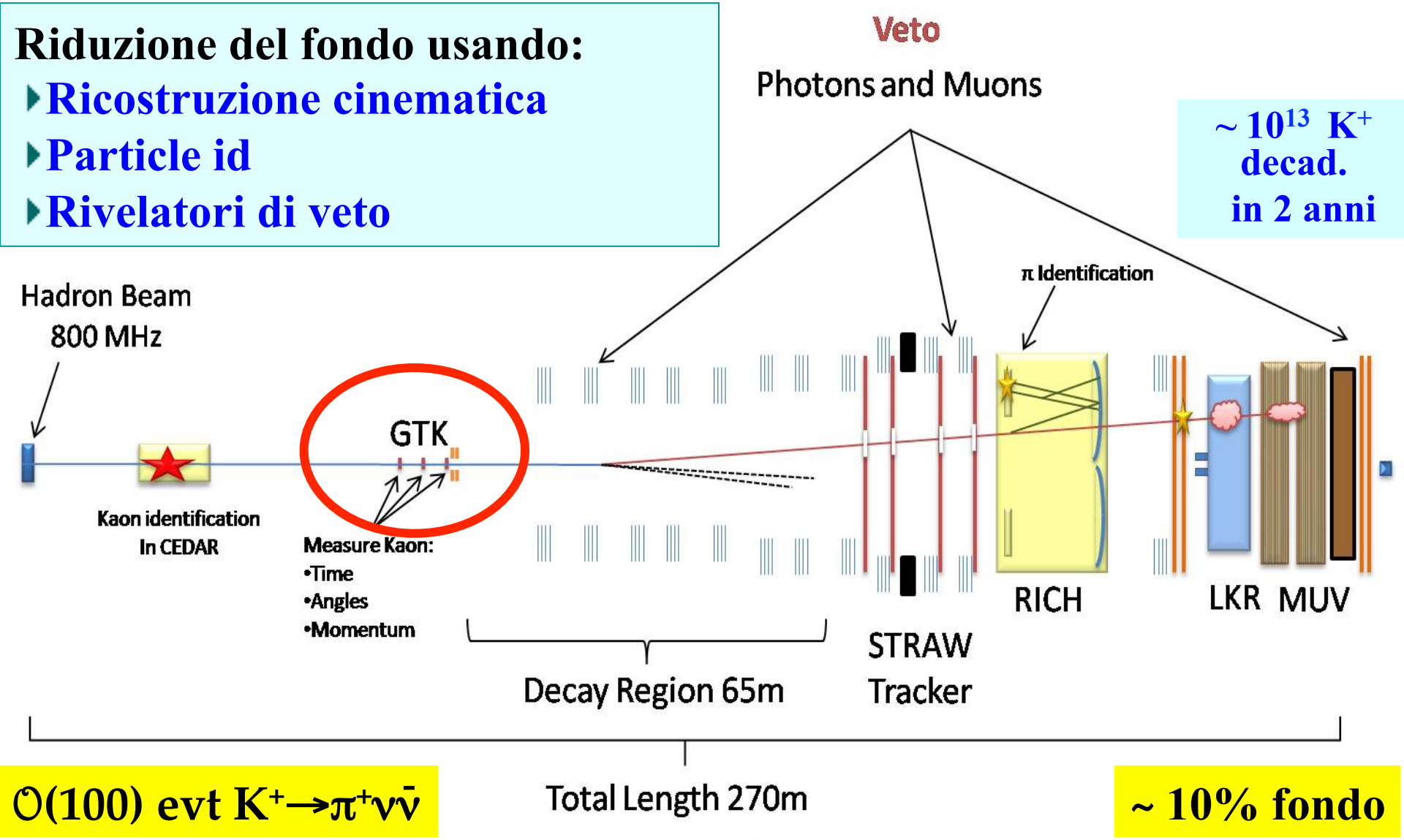
- Definizione regione segnale
- $K^+ \to \pi^+\pi^0$ ci obbliga a dividerla in due parti (Regione I and Regione II)



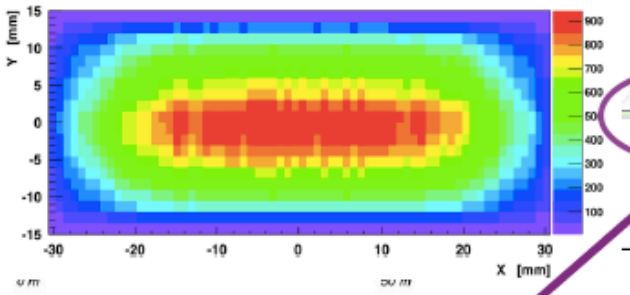
NA62- il layout del rivelatore

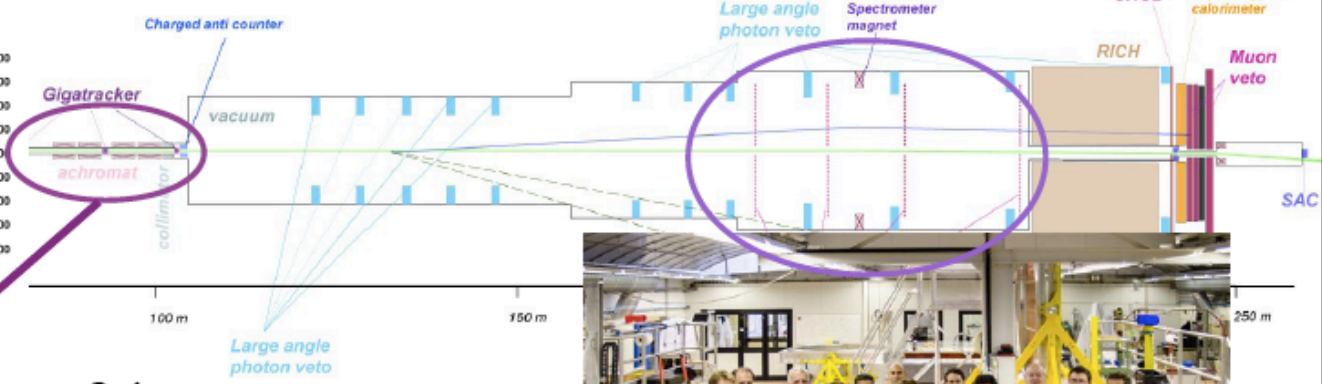
Riduzione del fondo usando:

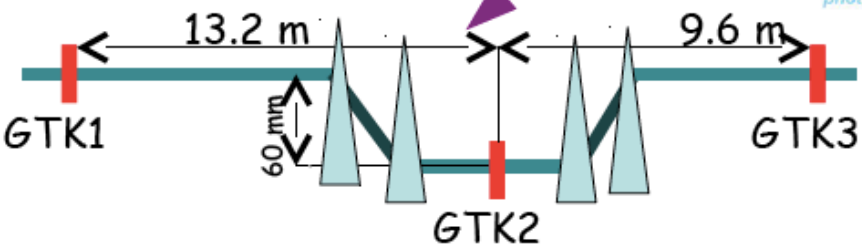
- **Ricostruzione cinematica**
- **Particle id**
- **Rivelatori di veto**

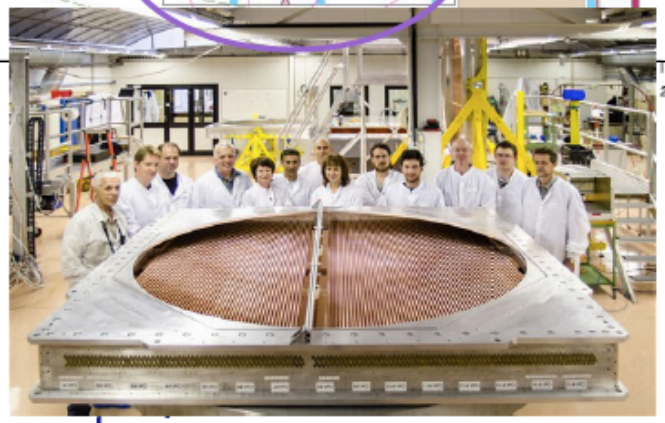


NA62 - cinematica









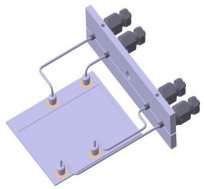
- Momentum resolution: $\sigma(p_K)/p_K \sim 0.2\%$
- Angular resolution: 16 μrad
- 200 μm sensor + 300 μm chip
  <0.5% X0
- Time resolution ~200 ps/station

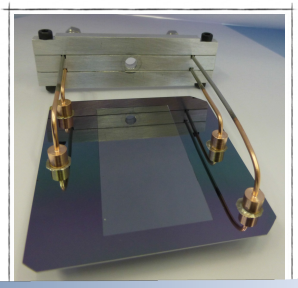
- Spectrometer in vacuum
- Straw tubes: 4 chambers, 4 views/ chamber, 4 staggered layers/view
- Momentum resolution
  $\sigma(p)/p \sim 0.3\% \oplus 0.007\% * p(GeV/c)$
- 2 views operated during TR

Resolution on M^2_{miss} ~0.001 GeV^2/c^4

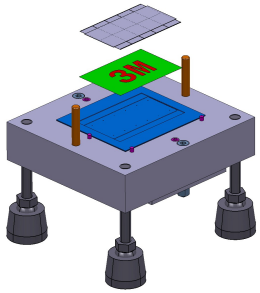
Il Gigatracker: montaggio

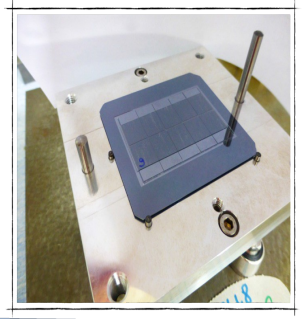
Soldered fluid connectors



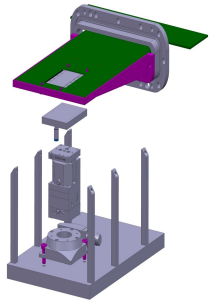


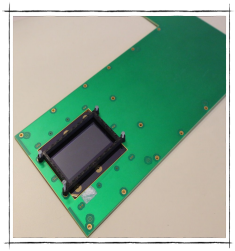
Thermal Interface



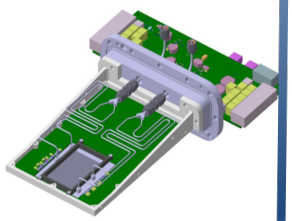


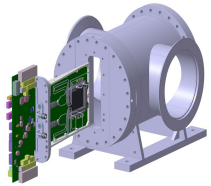
Mounting to Carrier Board





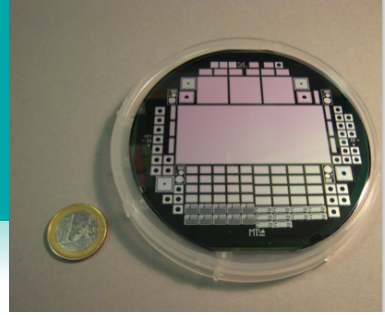
Installation



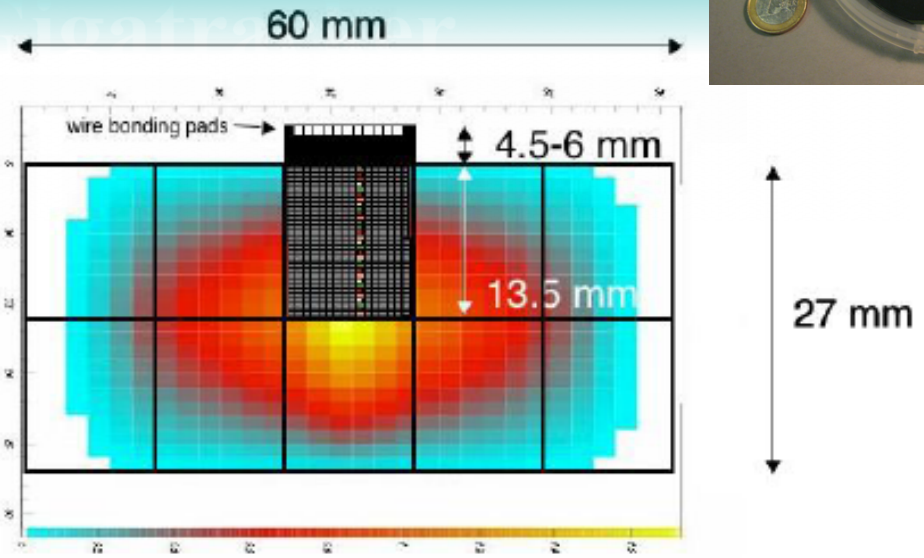


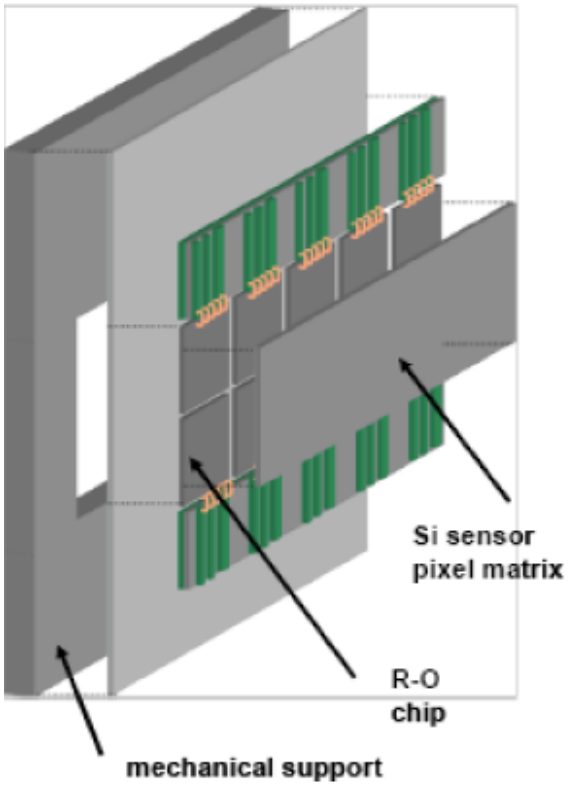
GTK Position	TDCpix Thickness (micron)	Cooling Plate
1	250	P10
2	100	New production
3	100	New production

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

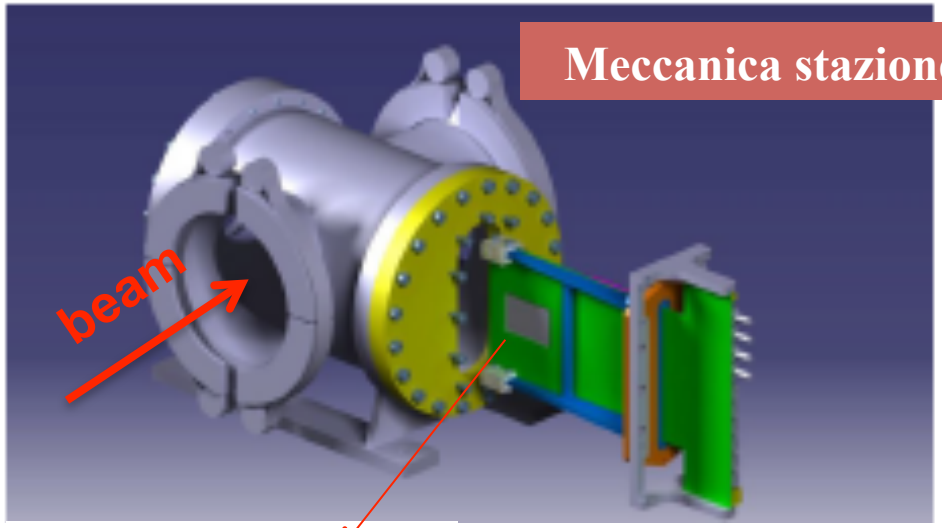
Il Gigatracker

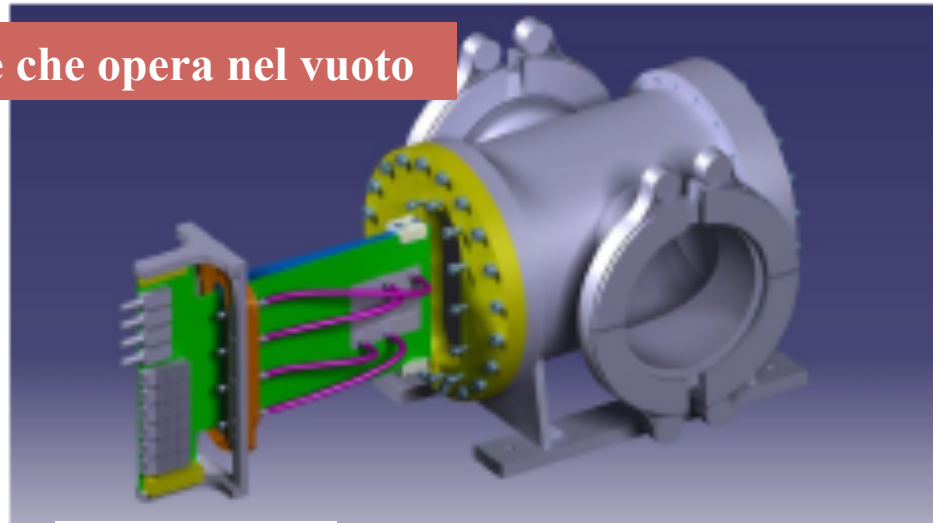
Impegno di Torino: Front end per il GigaTracKer (GTK)

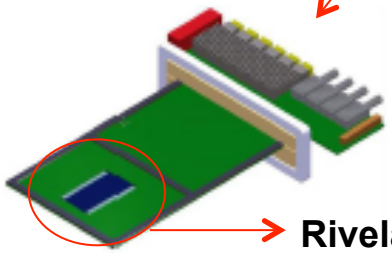
con Ferrara, CERN, UCL (Louvain-la-Neuve,Be)

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

Meccanica stazione che opera nel vuoto

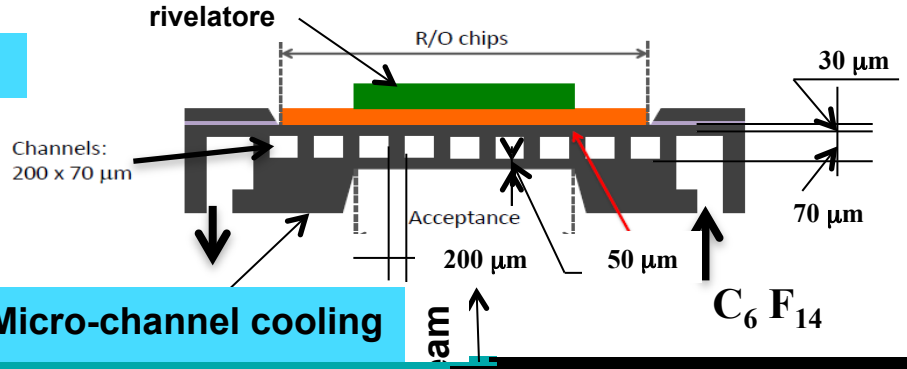






Rivelatore (60x27) mm²

Sketch del rivelatore

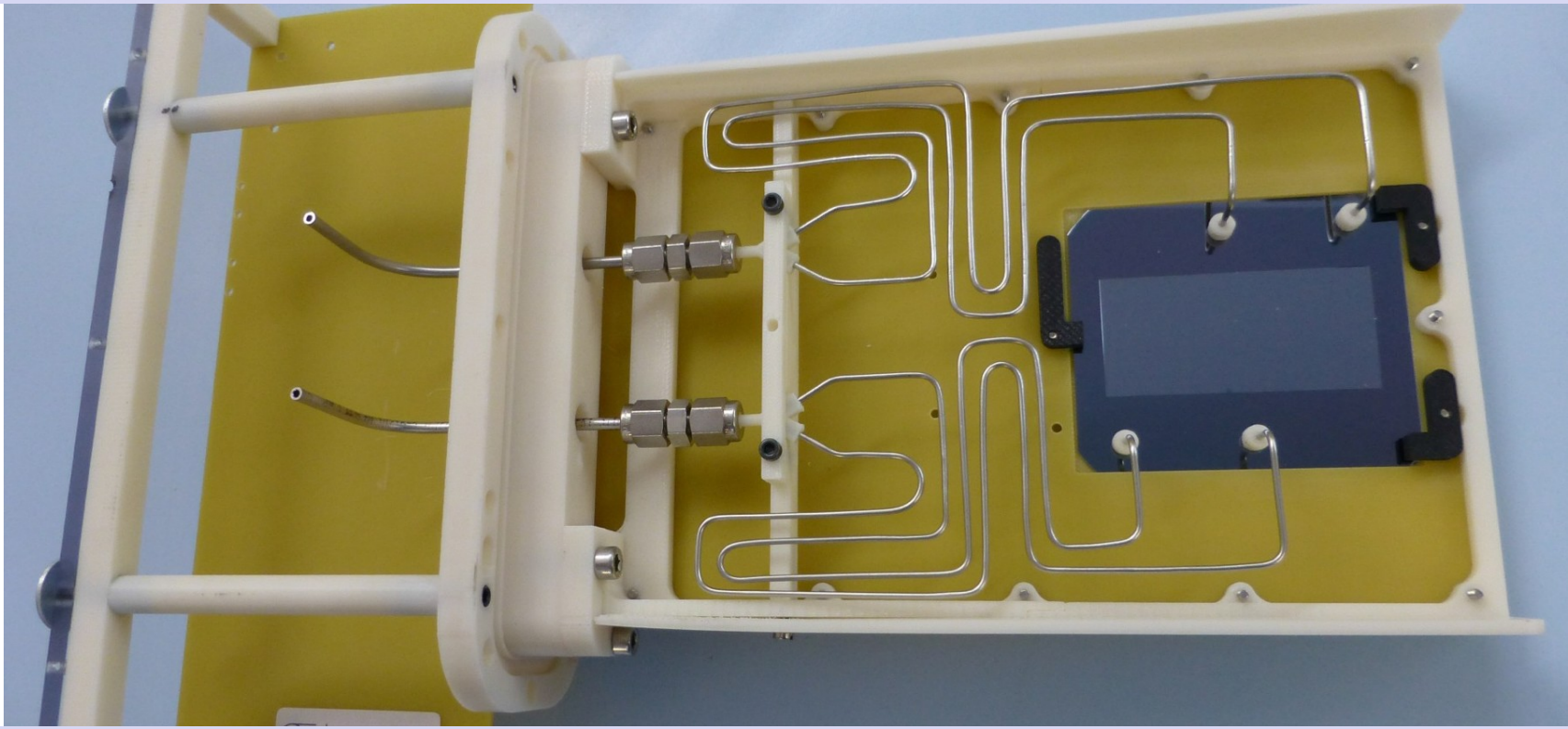


Baseline design: 150 parallel cooling channels (200 μm × 70 μm, C_6F_{14})

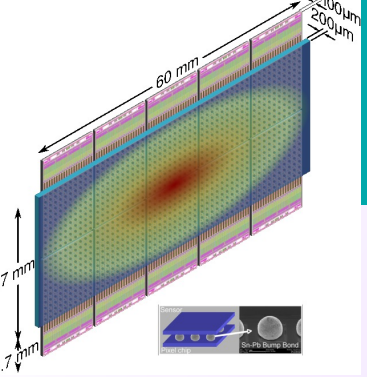
Micro-channel cooling

Il Gigatracker: 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

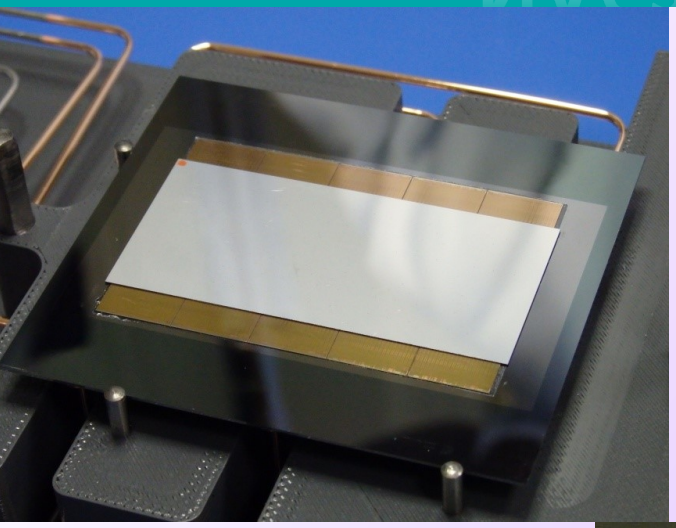


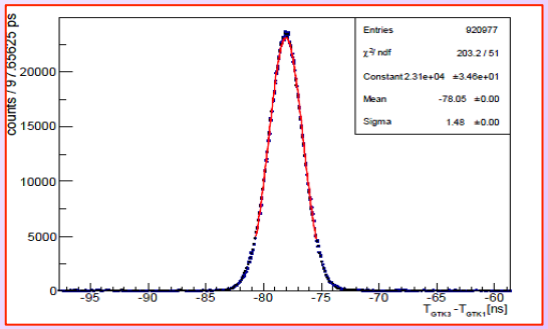
NA62 – Gigatracker

CERN, Ferrara, Louvain-la-Neuve, Torino

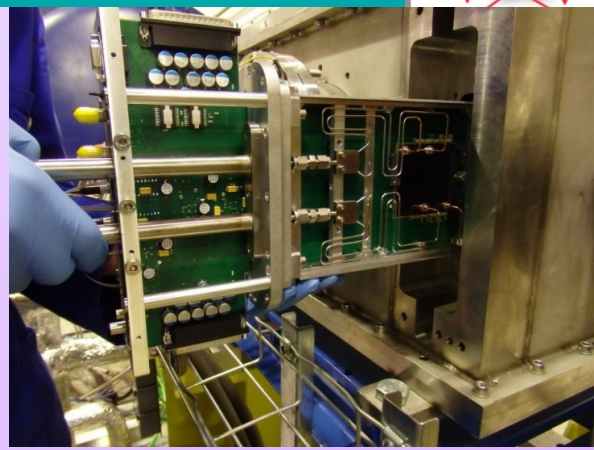
- The ASIC chip,TDCpix, has been fully characterized
- Bump-bonding with 100 microns TDCpix thickness achieved
- Carrier boards designed and fabricated
- Micro-channel cooling achieved
- Mechanical integration
- Cooling plant constructed, installed and commissioned
- DAQ cards installed and tested
- In GTK Data acquired in with the other NA62 detectors
- 2 full stations of Gigatracker installed, third expected end of July (need spares)

NA62 – Gigatracker

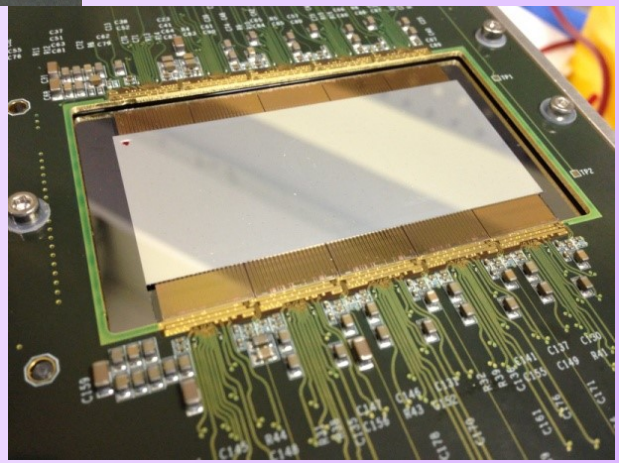




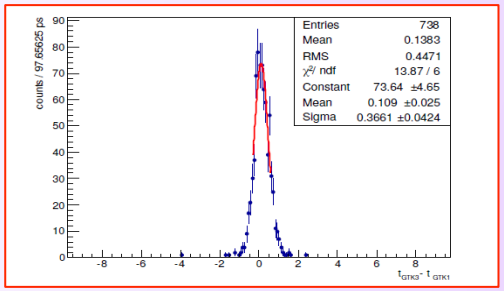
GTK3 – GTK1
Before any correction



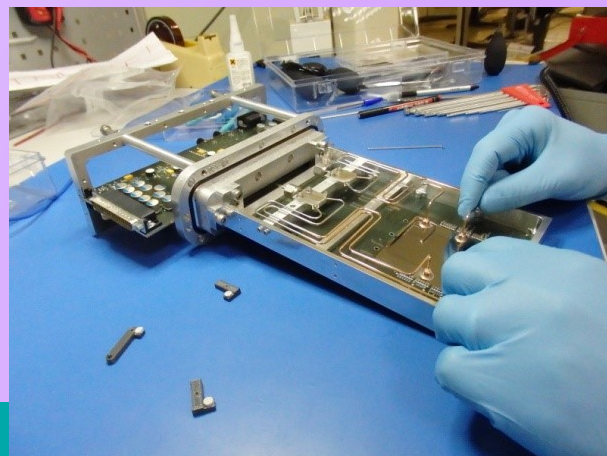
Installed in K12 beam on November 6



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



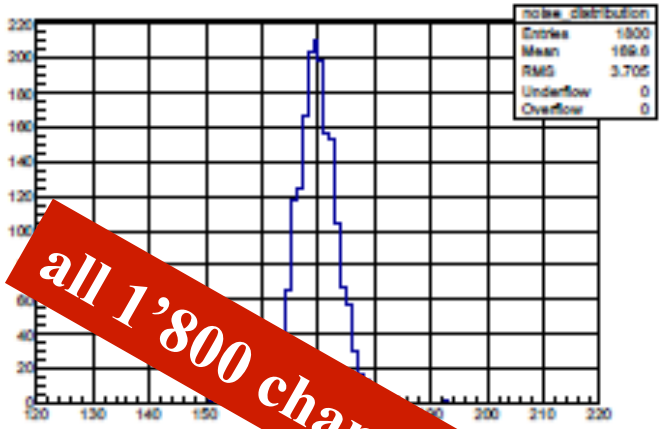
Time resolution~ 260 ps /station
In line with expectations for HV= 200 V

Il Gigatracker status: ASIC tests

- The ASIC tests show that the chip is working as expected.
- GTK carrier board designed and ordered
- The chip thinning and bump bonding has been successfully tested on dummy chips.

The remaining work is on a tight time plan, but the most difficult technical issues have been mastered

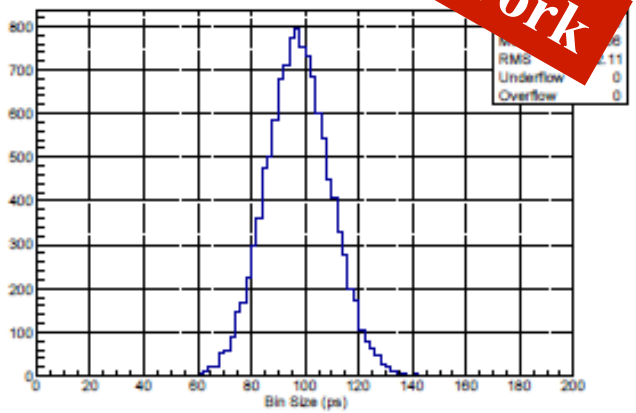
Equivalent Noise Charge



all 1'800 channels work

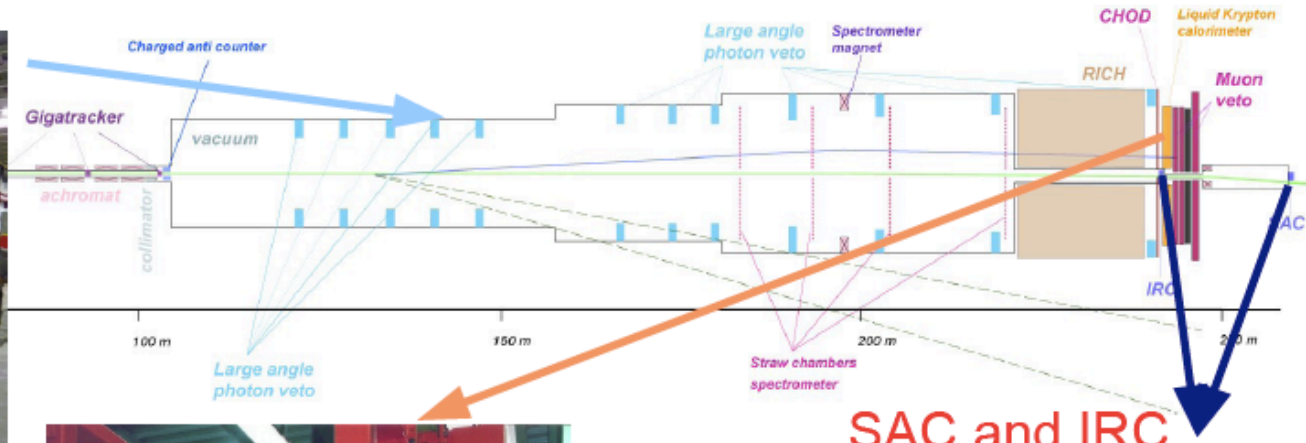
ENC ≈

Distribution of Leading Fine TD



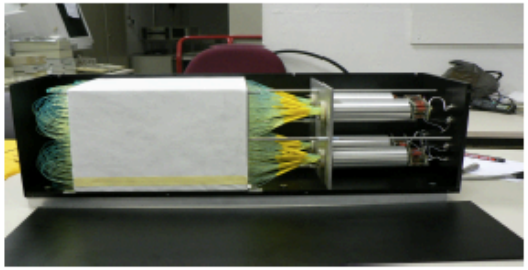
=> $\sigma_t \approx$ 50 ps RMS

NA62 – veto per i fotoni



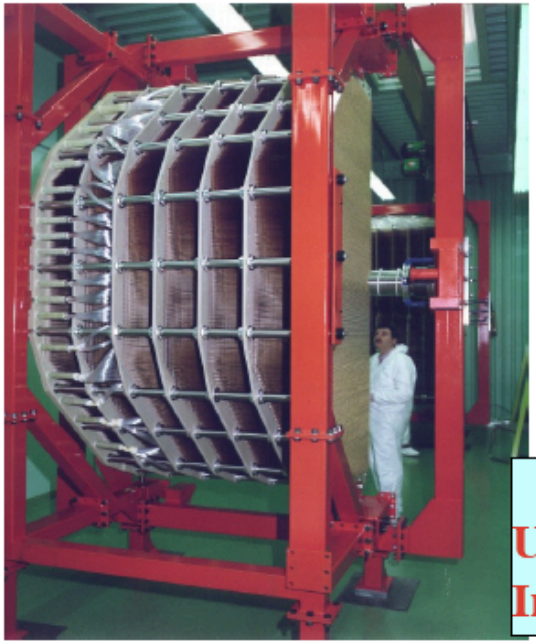
SAC and IRC

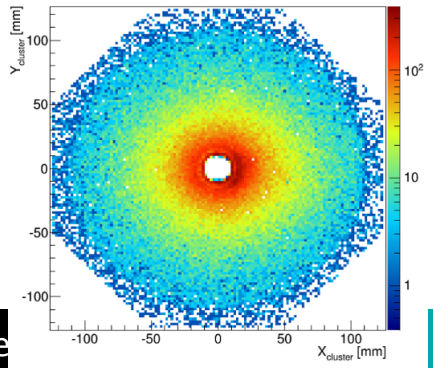
– shashlyk type detectors
– FADC RO



LAV

- 12 stations in vacuum
- Angles from 8.5 to 50 mrad
- Lead glass from OPAL

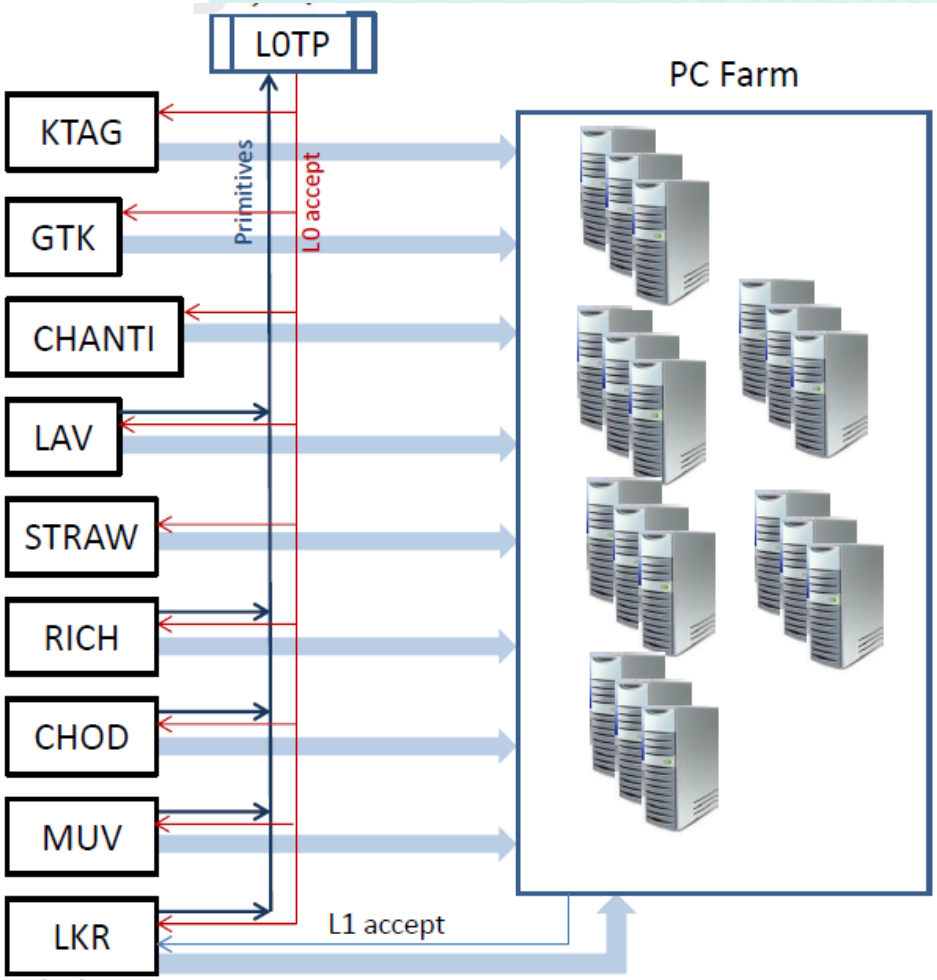




LKr

Using the NA48 EM callorimeter
Inefficiency for E_γ>10GeV $\eta < 8*10^{-6}$

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.