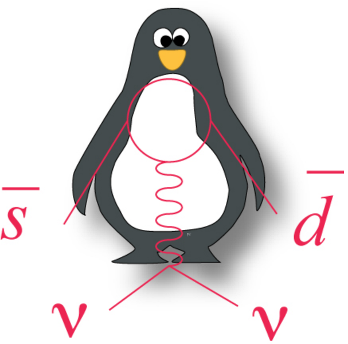


# NA62 experiment

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**INFN - Torino**

XXV Giornate sui Rivelatori – Scuola F. Bonaudi
Cogne, 23-26 Febbraio

NA62 Collaboration

CERN, Ferrara, Firenze, LNF, Napoli, Perugia, Pisa, Roma1, Roma2, Torino, UC Louvain, Sofia, Bucharest, Prague, Mainz, Birmingham, Bristol, Glasgow, Liverpool, TRIUMF, UBC, IHEP, INR, JINR, George Mason, SLAC, UC Merced, BU, BNL, San Luis Potosi

# Outline of the presentation

1. Physics motivation
2. The NA62 experiment: collaboration, beam
3. The detector: a walk through the different components
4. Time measurement
5. Level-0 trigger
6. Strategy of the data analysis
7. Conclusions

## NA62: Physics motivation

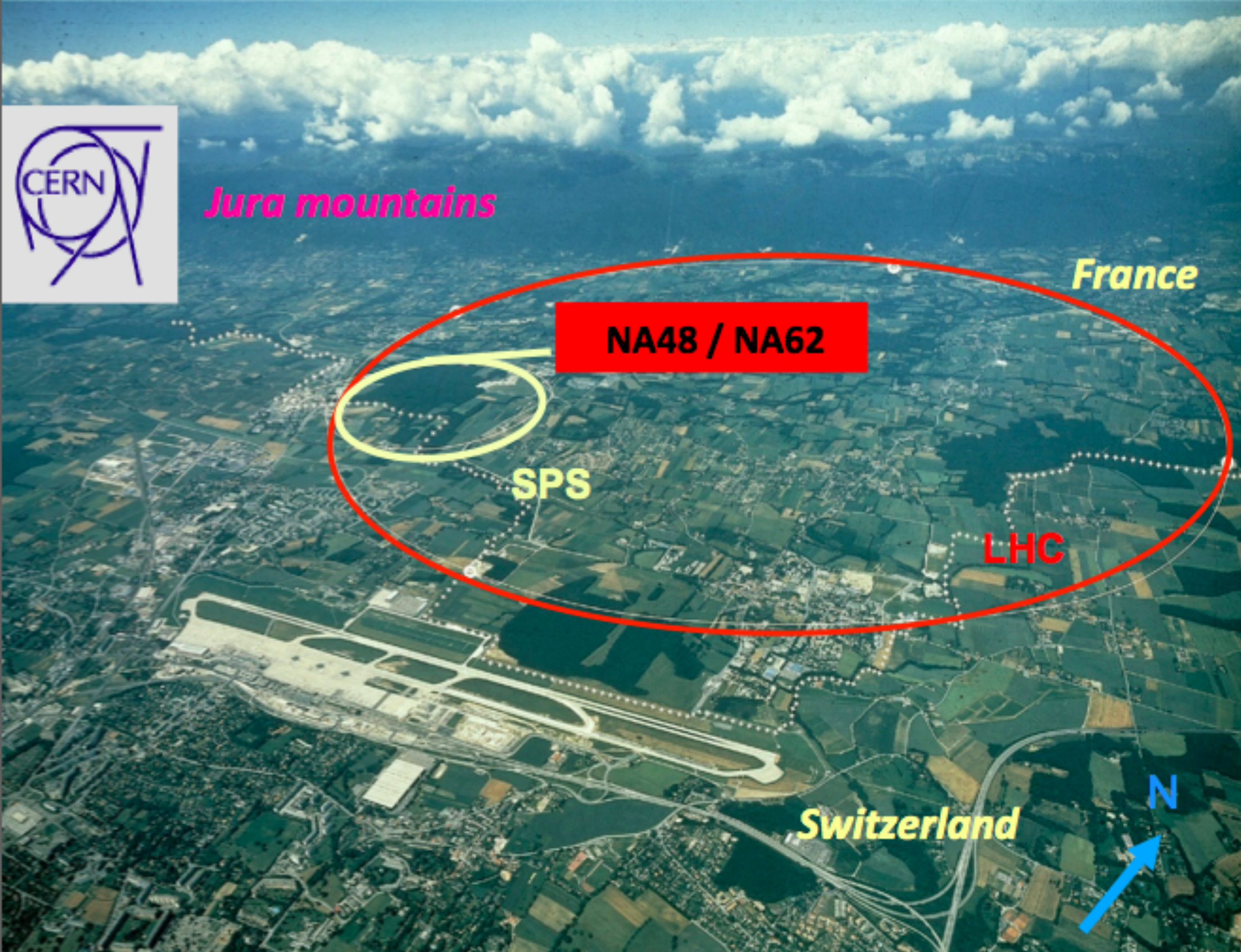
Measurement of the probability (or Branching Ratio) of the decay:

$$K^+ \rightarrow \pi^+ \nu \bar{\nu}$$

We will focus on this decay, which:

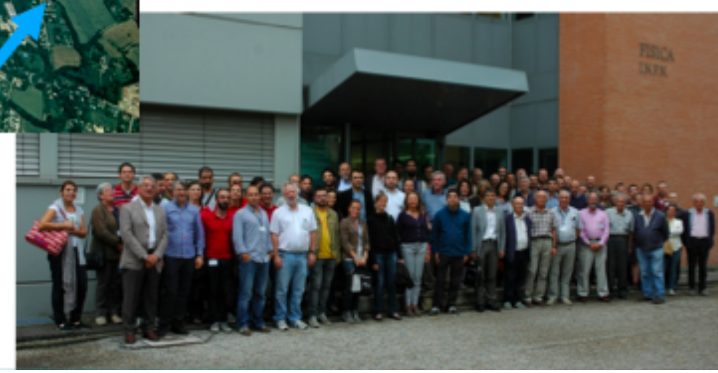
- is very, very small: $10^{-10}$ (one decay out of $10^{10}$ )
- In the framework of the Standard Model (SM) it is an important measurement

**CERN experiment at the SPS North Area**

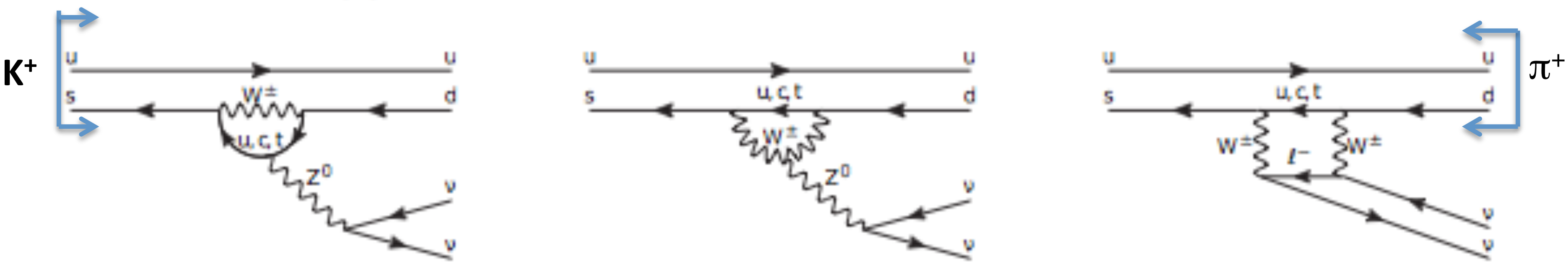



| | |
|---|---|
| 2005 | Proposal |
| 2009 | Approved |
| 2010 | Technical design |
| 2012 | Technical run (partial layout) |
| 2014 | Pilot Run |
| 2015-18 | **Physics Runs** |

~200 participants from 30 institutions



# Decay diagrams of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$




The amplitude is proportional to: $\left(\frac{m_q}{M_W}\right)^2 V_{qs}^* V_{qd}$ being q = u,c,t

It is a very rare process and the amplitude

$$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = 6 r_{K^+} BR(K^+ \rightarrow \pi^0 e^+ \nu) \frac{|G_l|^2}{G_F^2 |V_{us}|^2}$$

$$G_l = \frac{\alpha G_F}{2\pi \sin^2 \Theta_W} \left[ V_{ts}^* V_{td} X(x_t) + V_{cs}^* V_{cd} X_{NL}^l \right]$$

In the Standard Model the calculation of the BR gives:

$$\boxed{BR(K^+ \to \pi^+ \nu\bar{\nu}) = (0.911 \pm 0.072) \times 10^{-10}}$$

Experimental status: based on 7 events
E787/E949 collaborations

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

Notice how the prediction is clean: the error is 8%

$V_{td}$ is the term in $G_l$ with the larger uncertainty:

$$G_l = \frac{\alpha G_F}{2\pi \sin^2 \Theta_W} \left[ V_{ts}^* V_{td} X(x_t) + V_{cs}^* V_{cd} X_{NL}^l \right]$$

The amplitude of the t->d transition is in fact proportional to $V_{td}$

Quark-to-quark transition elements are contained in the CKM matrix:

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

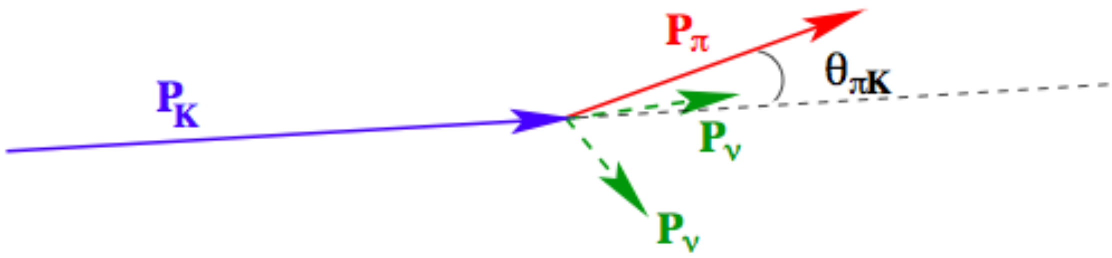
# Brief summary of the Physics Motivation

- Measurement of a very rare decay mode of the charged Kaon
- Precisely estimated in the Standard Model (SM) frame

- For comparison, the following are the most frequent decay modes:

| | |
|---|---|
| $K^+ \to \mu^+ \nu_\mu$ | 63% (known as $K_{\mu 2}$) |
| $K^+ \to \pi^+ \pi^0$ | 21% |
| $K^+ \to \pi^+ \pi^+ \pi^0$ | 6 % |
| $K^+ \to \pi^+ \pi^0 \pi^0$ | 2% |
| $K^+ \to \pi^0 \mu^+ \nu$ | 3% (known as $K^+_{\mu 3}$) |
| $K^+ \to \pi^0 e^+ \nu$ | 5% (known as $K^+_{e3}$) |
| $K^+ \to \pi^+ \pi^- e^+ \nu$ | 0.004% |

# The topology of the event is the following:




- One charged track, Kaon, coming in
- One charged track, pion, getting out
- Plus neutrino and anti-neutrino, which are not detectable

The selection of the events has to step through the following:

**1)** $\vec{P}_K$ and $\overrightarrow{P_\pi}$ have to be measured

**2)** Incoming particle has to identified as a Kaon

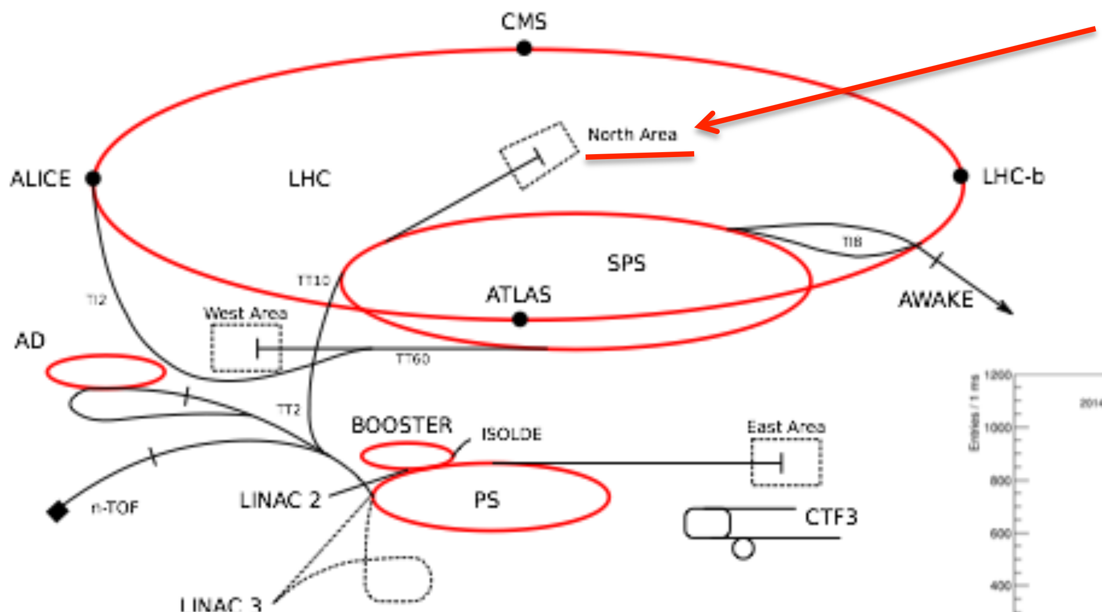
**3)** Product particle has to be identified as a pion

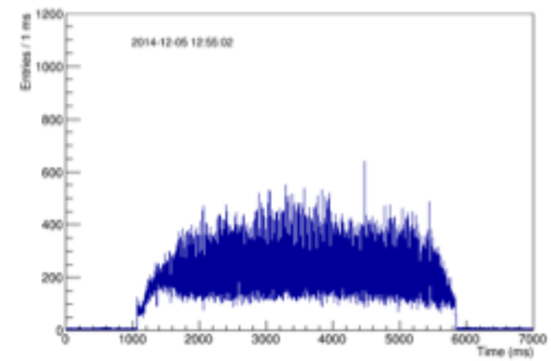
**4)** No other particles have to be produced

**5)** The incoming and product particles have to occur at the same time

# The beam

- Protons at 400 GeV/c are extracted from the SPS to the North Area



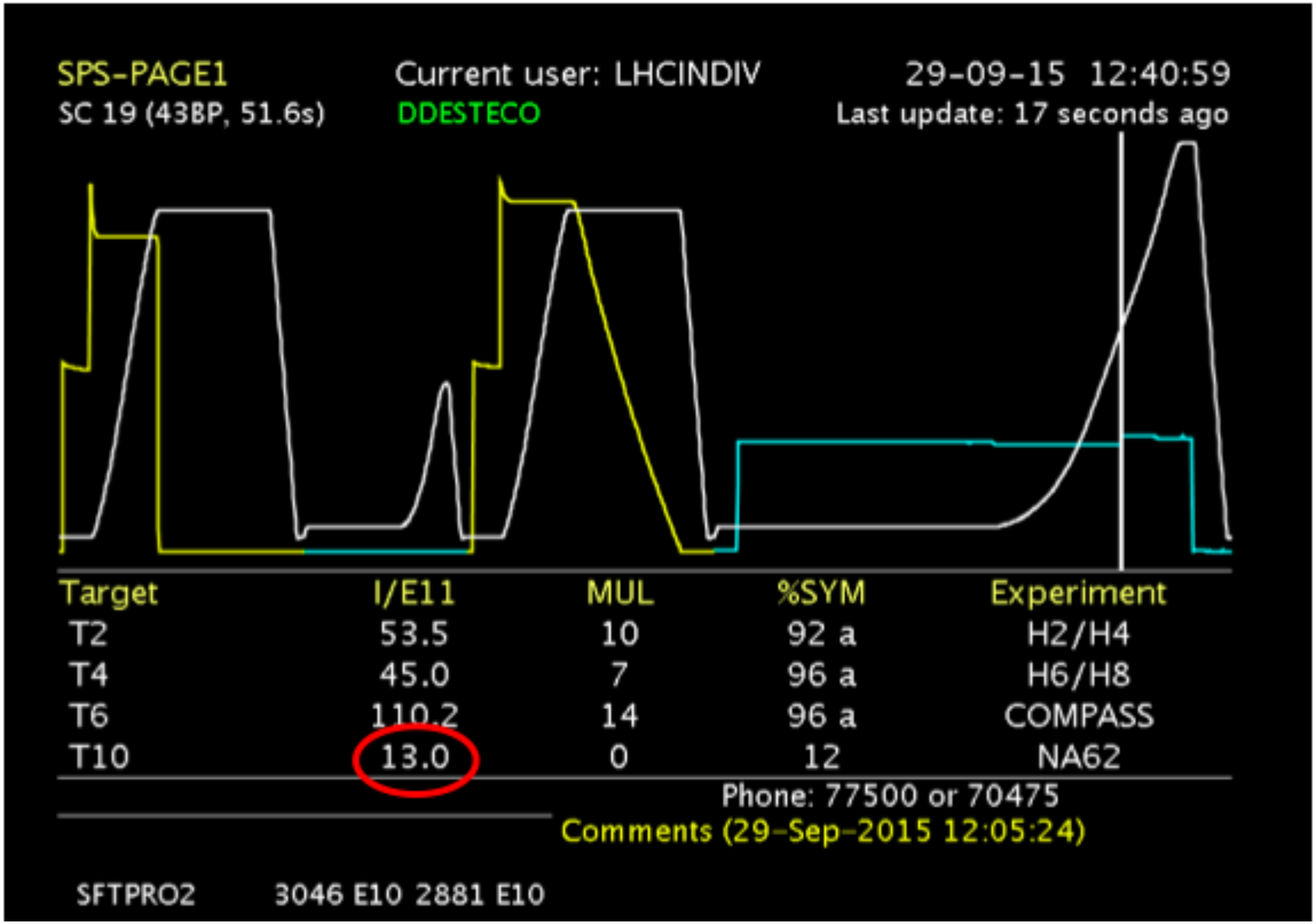

- A typical cycle of the SPS lasts 15-20 sec and the extraction is 5 sec long

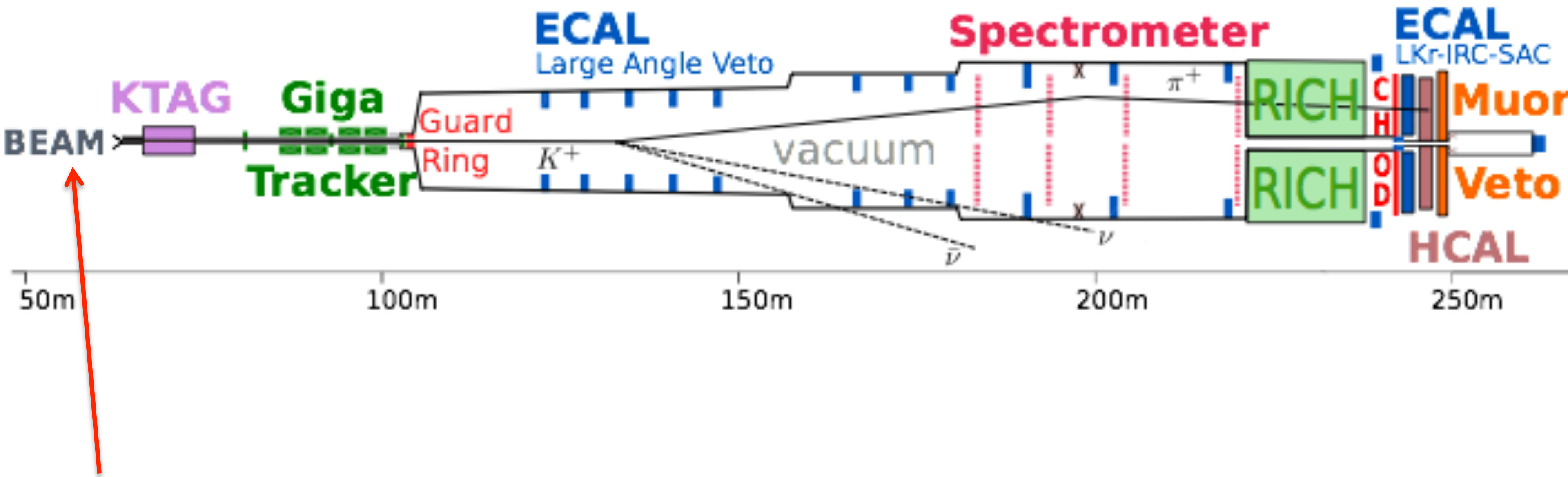
- Protons impinge on a Be target to generate a secondary un-separated beam

- Beam made of 75 GeV/c particles is transported to the NA62 experiment

- Approximately  only 7% of the particles are Kaons, the remaining are pions and protons

# SPS cycle


SPS-PAGE1
Current user: LHCINDIV
29-09-15 12:40:59
SC 19 (43BP, 51.6s)
DDESTECO
Last update: 17 seconds ago
Target I/E11 MUL %SYM Experiment
T2 53.5 10 92 a H2/H4
T4 45.0 7 96 a H6/H8
T6 110.2 14 96 a COMPASS
T10 13.0 0 12 NA62
Phone: 77500 or 70475
Comments (29-Sep-2015 12:05:24)
SFTPRO2 3046 E10 2881 E10




- (75 ±1) GeV/c positive charged particles with 7% of $K^+$ and the remaining are mostly pions and protons: $\pi^+$ : 70%; p : 23%;  $K^+$ : 7%.

- The nominal intensity is 750 Mparticles/sec
- Some fluctuations are present

- The transverse distribution of the beam is approximately a double-gaussian with a few mm width.

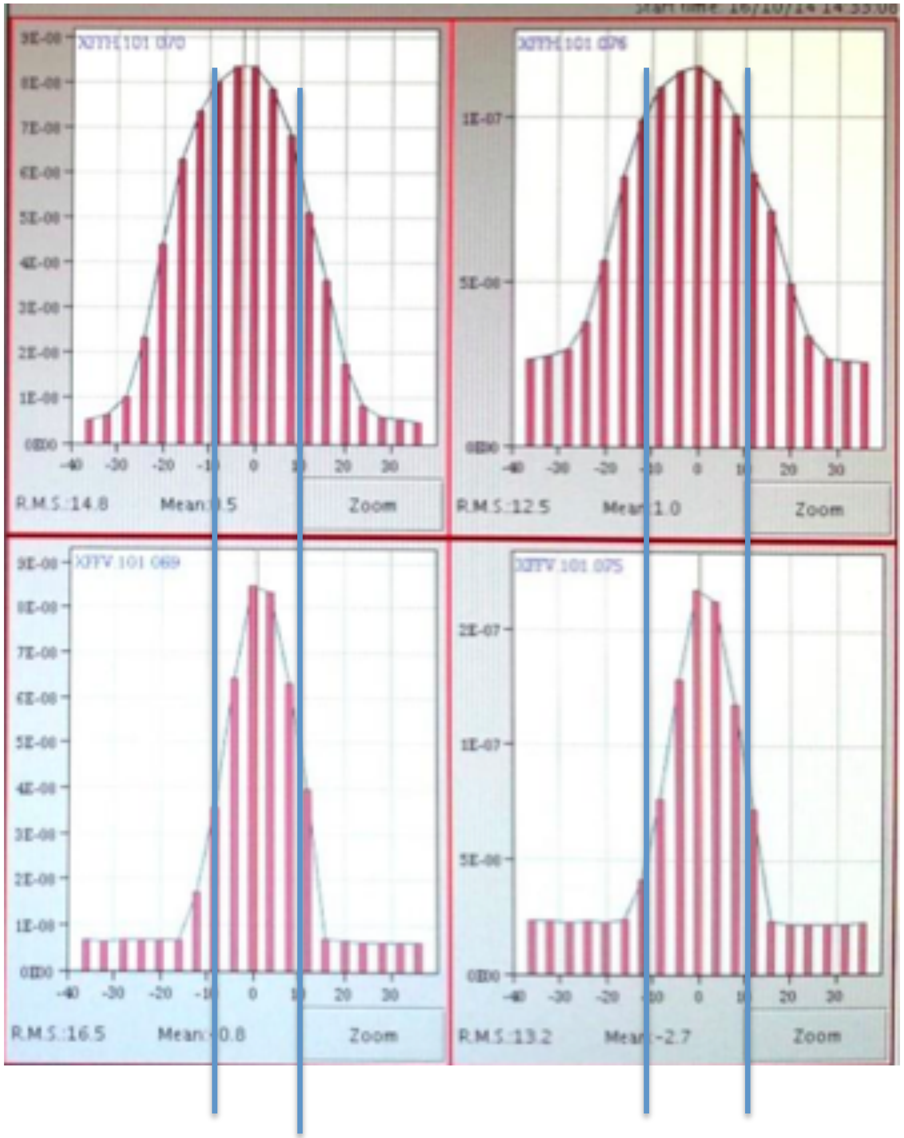
# Beam profile

before

after KTAG

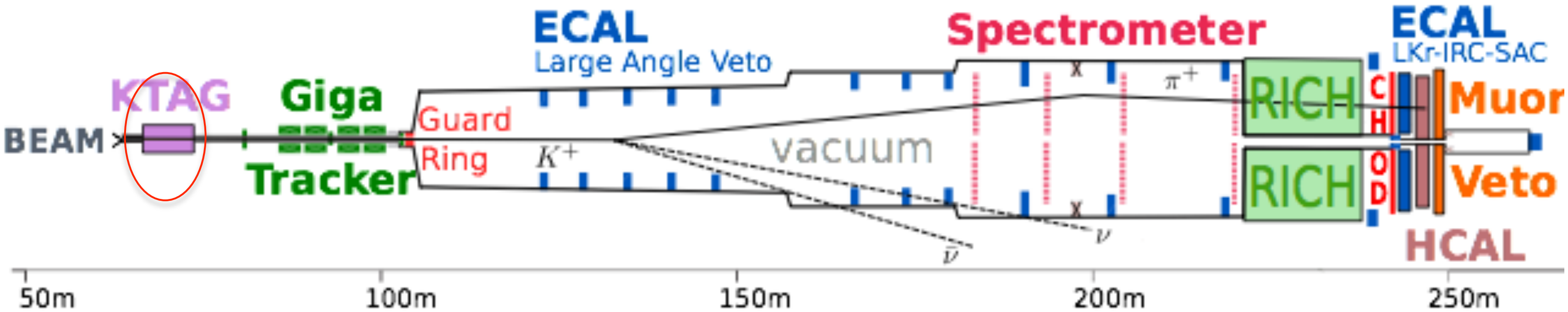
Horizontal

Vertical

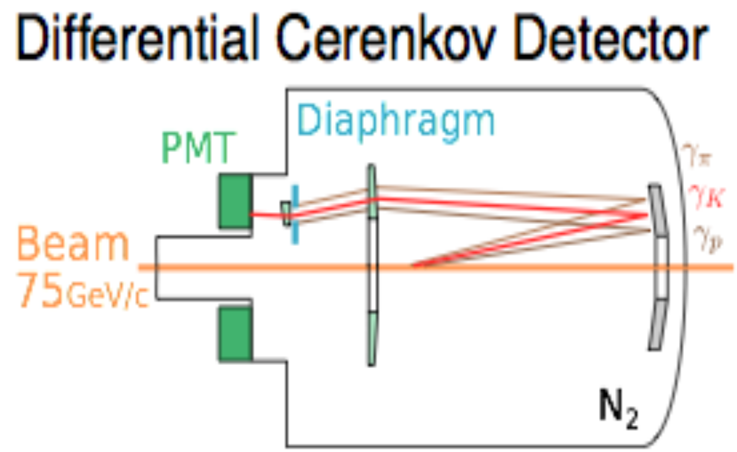



lines as at
+/- 10 mm

# KTAG: to identify the particle beam which are kaons




- Differential Cherenkov detector to **separate kaons** from **pions and protons**

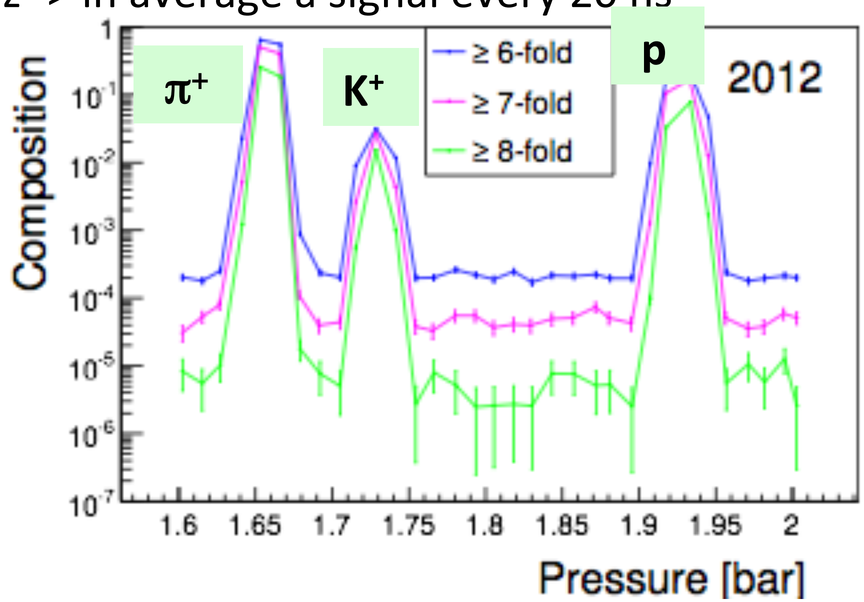



Cherenkov light is emitted with an angle of $\vartheta = \arccos(\frac{1}{\beta n})$ where β = v/c and n is the refraction index

Only rays emitted at the *correct* angle can go through the diaphragm -> in our case only kaons emit light that get to the phototubes

# KTAG

- Gas Differential Cherenkov: $N_2$ ($H_2$) -> $n_{N2}$ = 1.0002984 at 1 bar
- 
- Time resolution: better than 100 ps
- Signal rate: 50 MHz -> in average a signal every 20 ns




- Proton and pion rejection is 99.9%

- Kaon detection at 95%

# Brief summary

Up to this point we know:

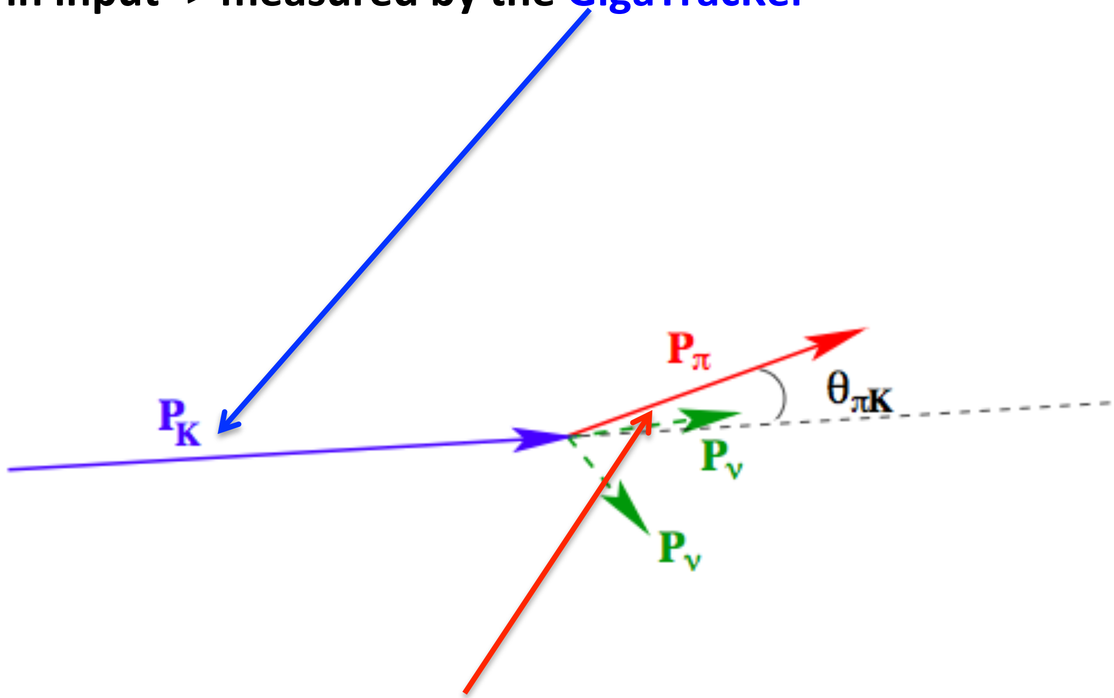
- Beam characteristics: momentum (75±1 GeV/c), composition ($\pi^+$, $K^+$, p), intensity (750 Mp/sec): kaon intensity -> 45 Mkaons/sec
- We learned how to identify Kaons (KTAG Differential Cherenkov)
- The beam dimensions (two sigmas) in the transverse plane: approximately 50 mm (horizontal) and 20 mm (vertical)

- 10% of the Kaons decay in flight inside the approximately 2m diameter tube and 100 mt long
- Approximately one kaon out of 10 decays, which corresponds to 5 Mkaon decays/sec.

# Spectrometer

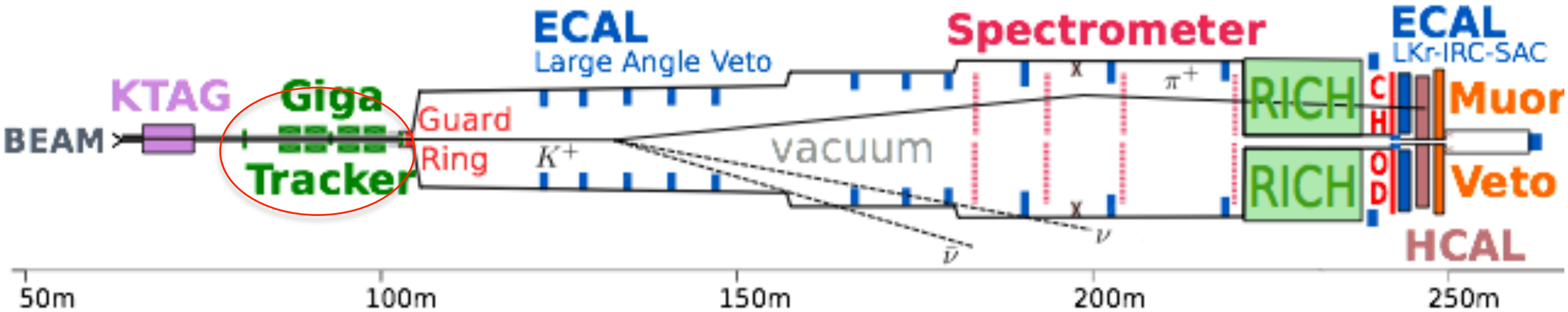
**Two components:**

**a) Beam particle in input -> measured by the GigaTracKer**



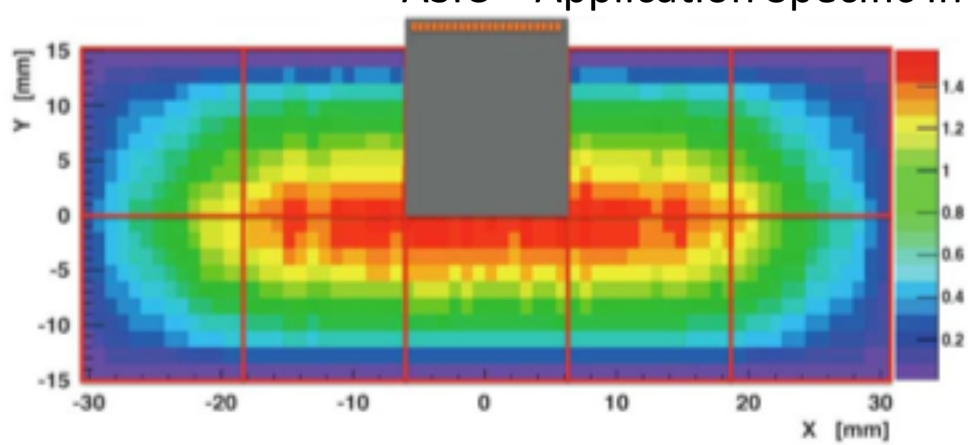

**b) decay product -> measured by the Straws**

# GigaTracKer (GTK)

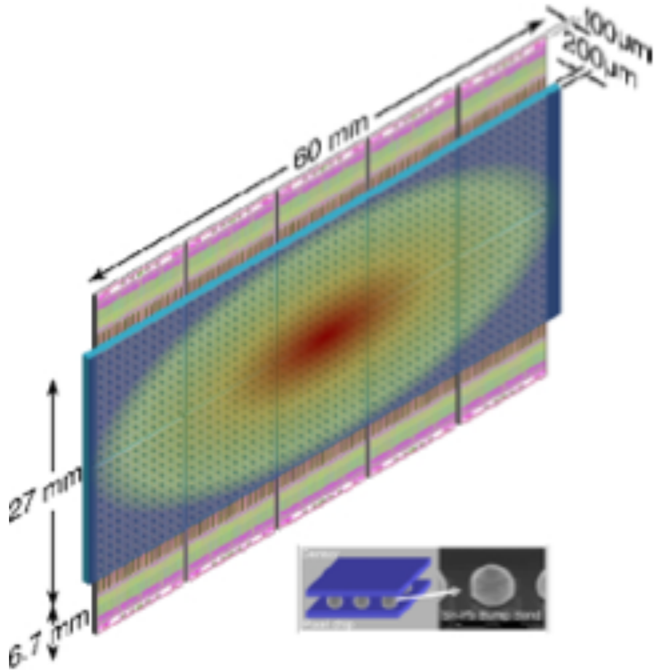


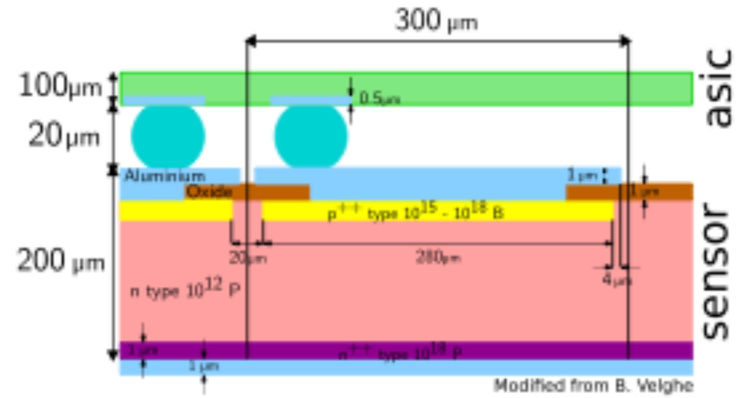

- Three stations of silicon detector p-in-n (also n-in-p are compatible)
- Each station is made of a pixel matrix of Silicon 200 μm-thick
- Pixel dimensions of (300x300) $\mu m^2$
- Sensor dimension: (60x27) $mm^2$ : 200x90 pixels -> 18000 pixels per station
- Each sensor is read-out through 10 ASIC chips (TDCpix)

ASIC = Application Specific Integrated Circuit



# GigaTracKer(GTK)

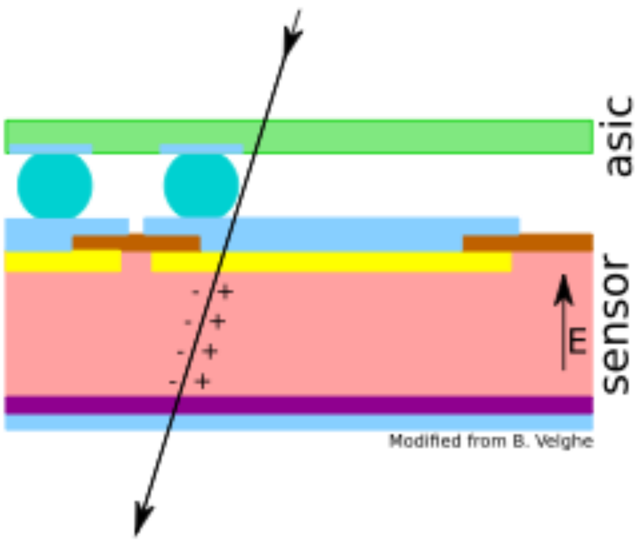


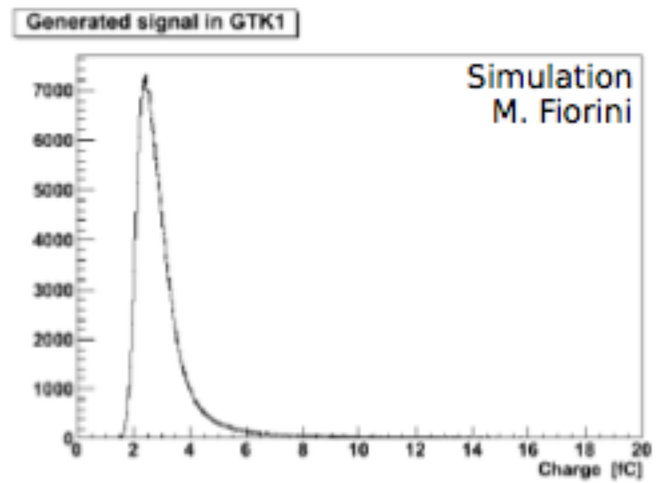




ASIC = Application Specific Integrated Circuit

- The ASIC geometry matches exactly the sensor
- At each pixel corresponds a *metallic* area (few microns) to make the contact between pixel-sensor and the electronics dedicated to the pixel
- The connection is done through a dedicated process (known as bump-bonding)

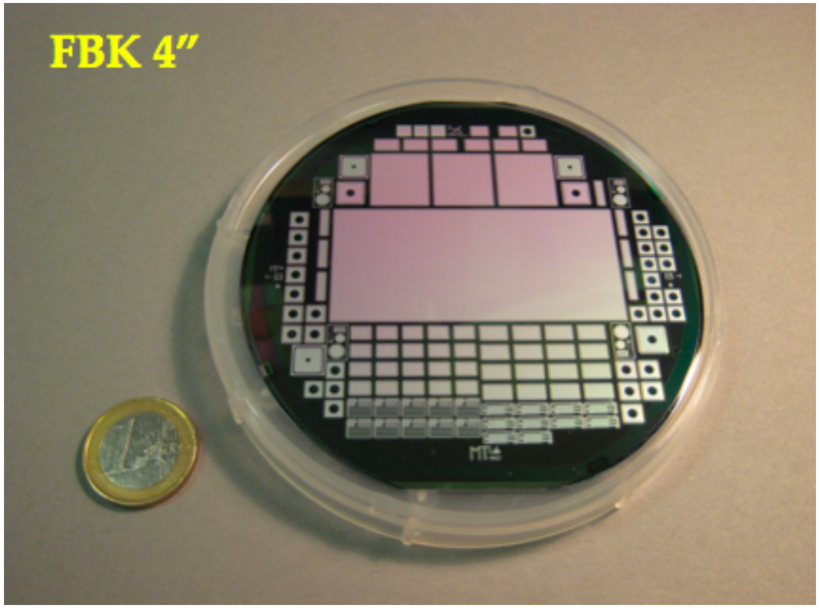
- Charged particles crossing the detector deposit energy
- Energy deposited follows a Landau distribution
- Average energy released in 200 $\mu$m of silicon by a minimum ionizing particle is approximately 72 keV
- Electron-hole (e-h) pairs are generated in the Si: one e-h pair requires 3.67 eV
- In average 20000 pairs are generated corresponding to a charge of 3.2 fC
- A $V_{bias}$ applied between at the sensor makes the charge drifting in opposite directions

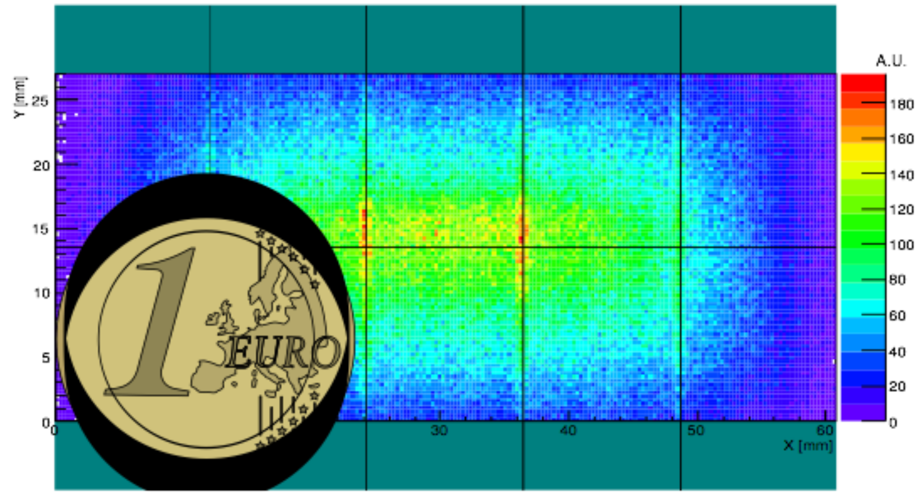


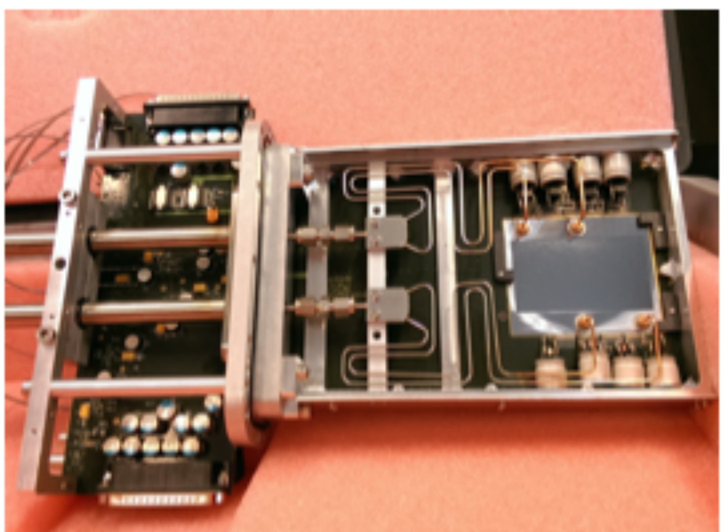




- 15000 electron-hole pairs are generated (most probable value) for each minimum ionizing particle crossing, which correspond to 2.4 fC

# GTK


FBK 4"


Y [mm]
X [mm]
A.U.
0
5
10
15
20
25
30
40
50
60
20
40
60
80
100
120
140
160
180
1
EURO



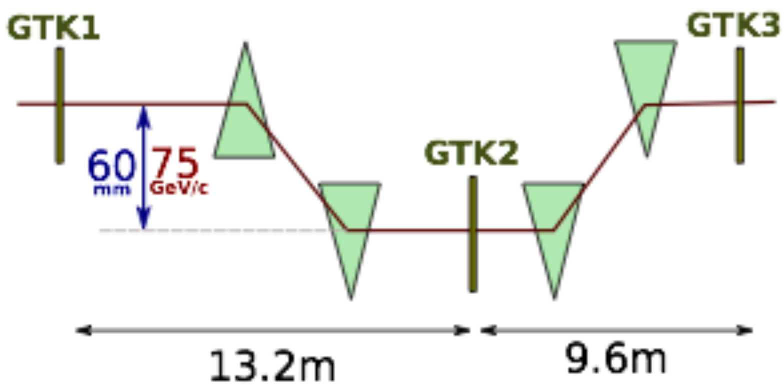
# GTK

It has been designed to measure:

a) beam particle direction with an angular resolution of 15÷20 $\mu$rad
Obtained by the following ingredients: pixel dimension, distance between stations and small amount of material of the stations.

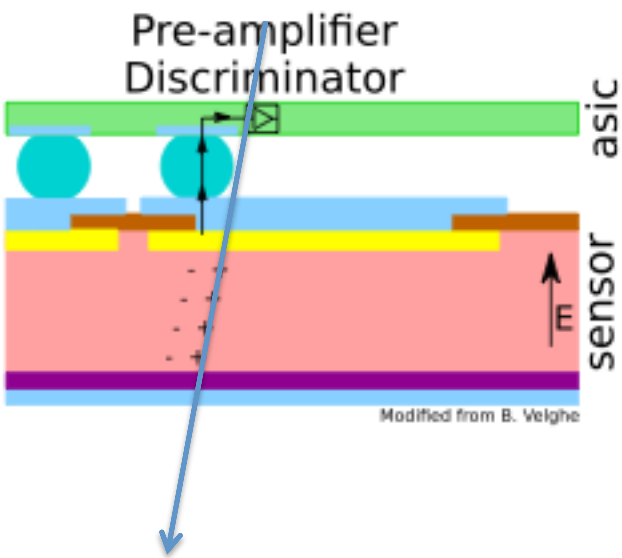
b) beam momentum with a resolution of 0.2%

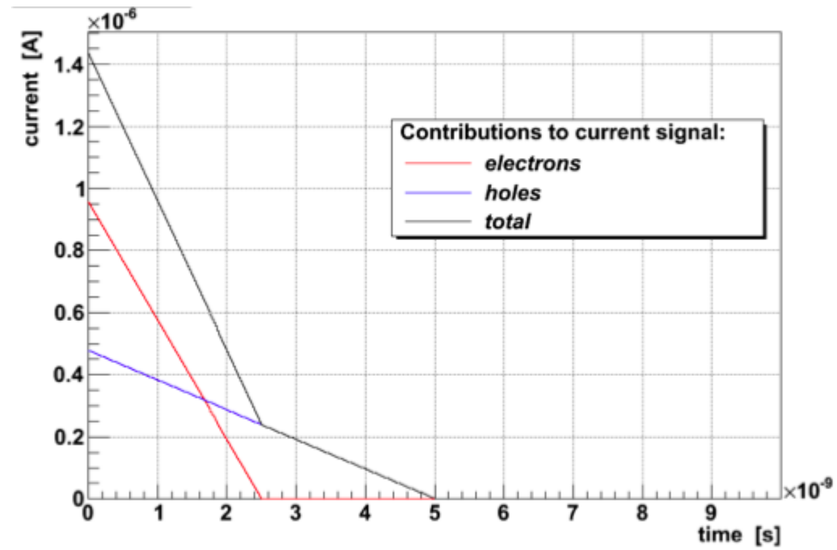
four dipoles -> achromat

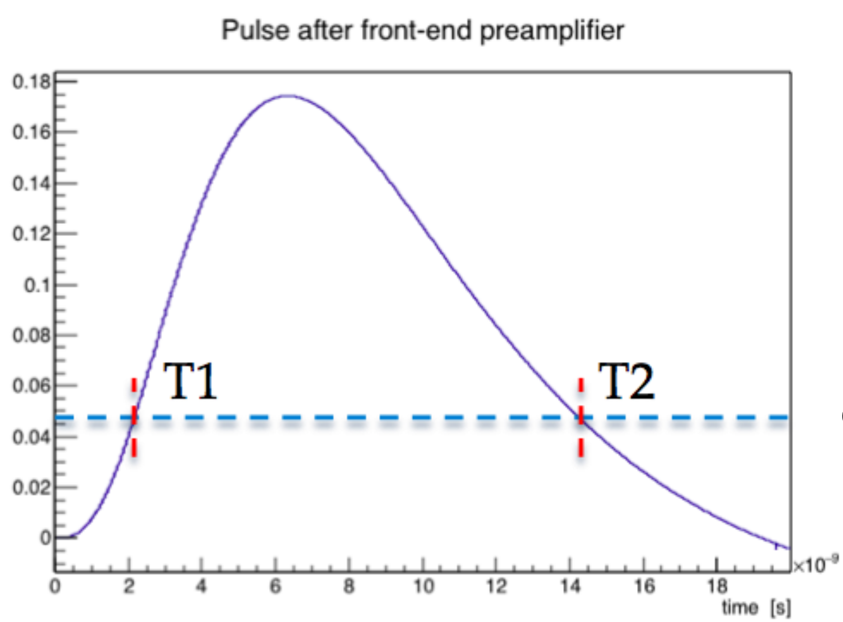



c) resolution of particle hit time of 200 psec -> track time resolution of 150 psec.

# How to precisely measure the time?




**Typical signal at the amplifier output**

**discriminator threshold**

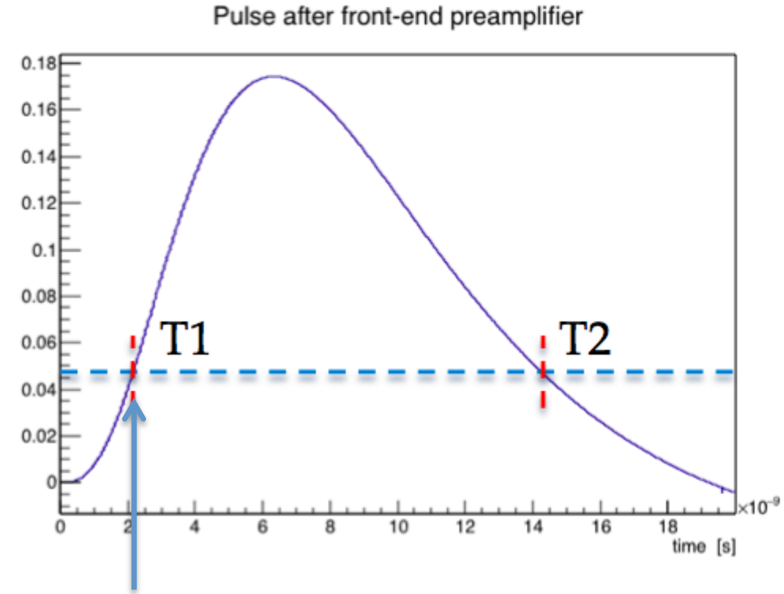
**Time measurement is spoiled by:**

a) Jitter: baseline fluctuations measured by the Equivalent-Noise-Charge (ENC): 250 e. The mitigation of this effect can only be obtained by a careful design of the front-end

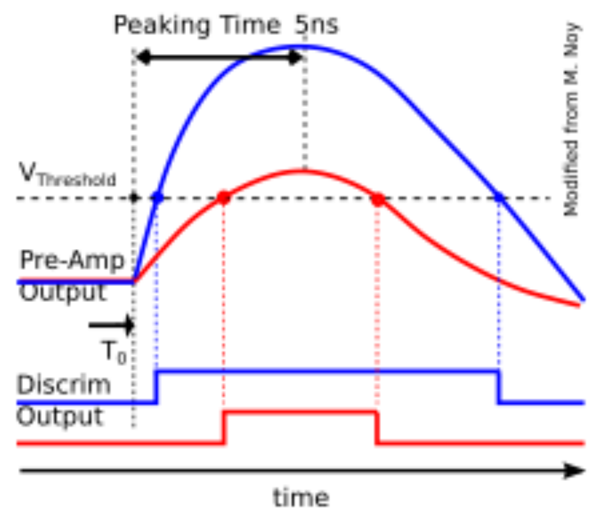
b) Time binning (100 ps)

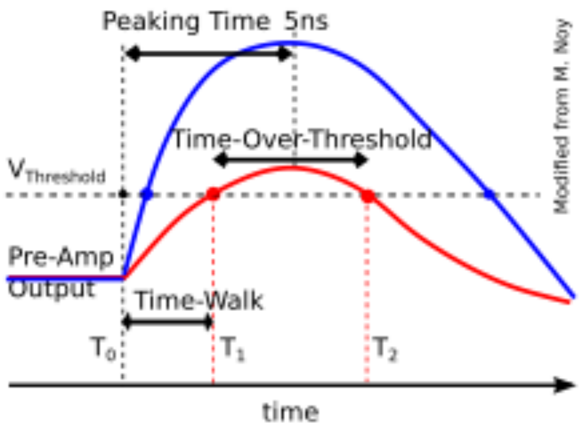
**c) Time-walk correction: fluctuation of the amplitude (Landau distribution) -> rather nasty**

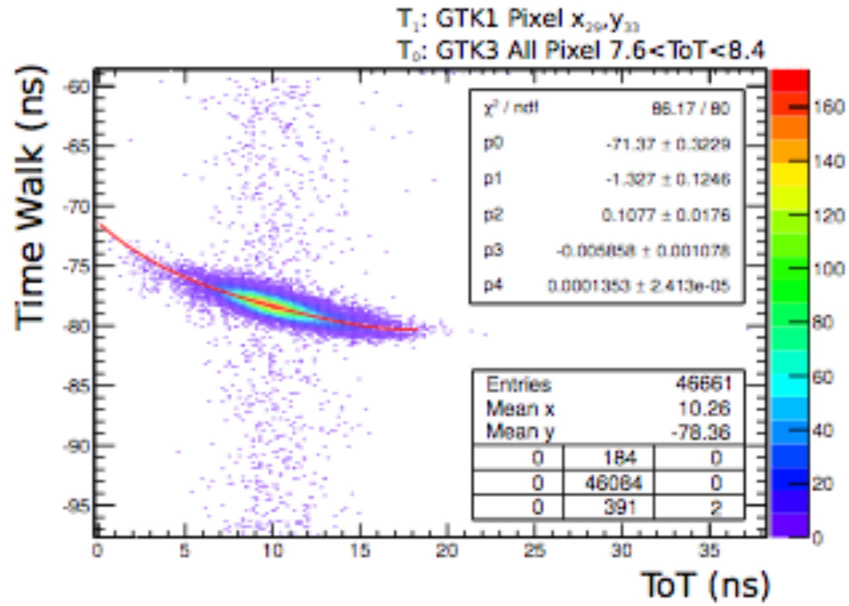
d) For a given energy deposition, local deposit can change: no mitigation is possible




**time measurement**





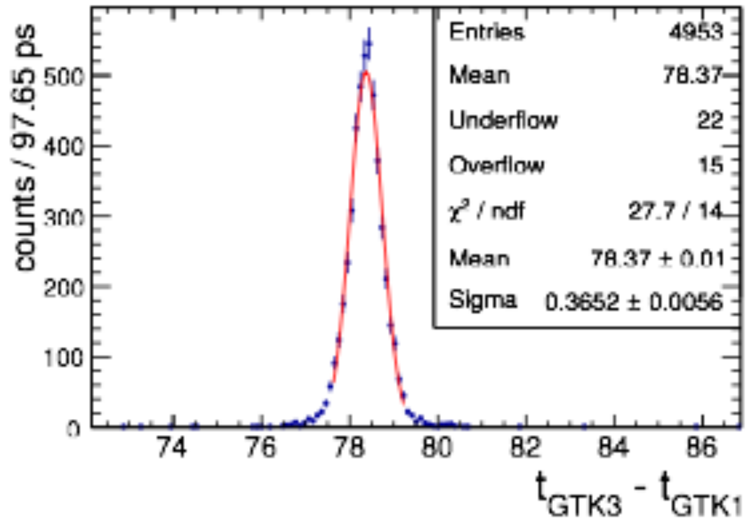

**Two classes of correction are then necessary:**

a) Time-walk correction

b) Different path-length of the signals from pixels to TDC. These are constant offsets and can be corrected for by measuring each individual delay.

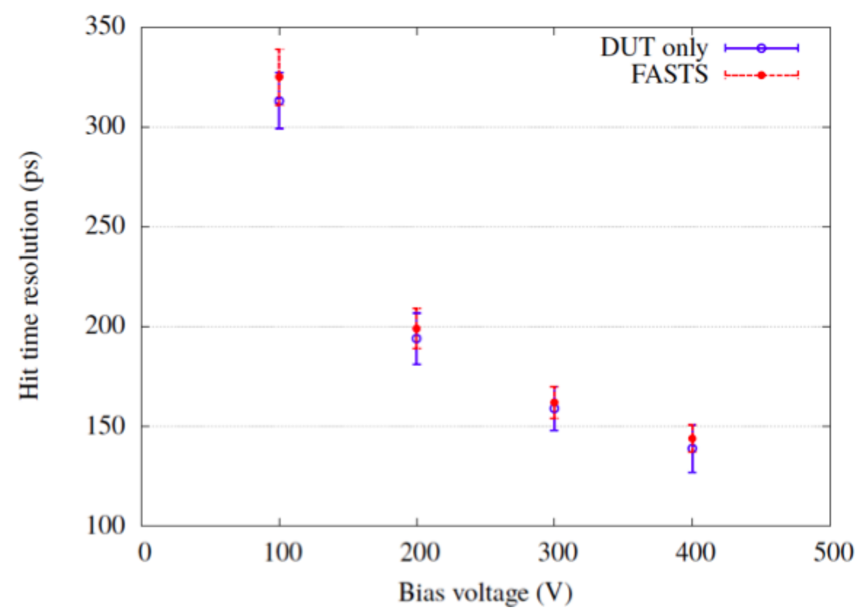
$$T_{hit} = p_1 * ToT + p_2 * ToT^2 + T_{offset}$$

# Preliminary results

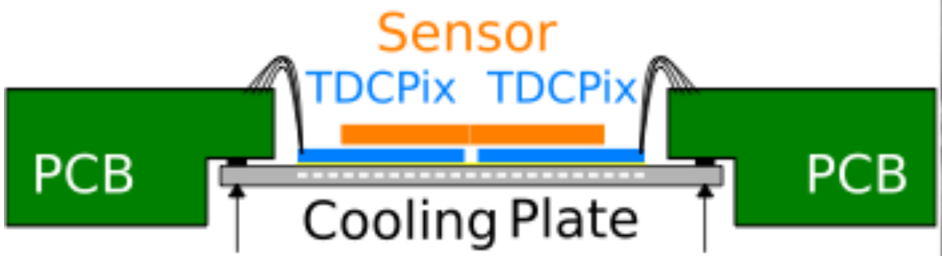


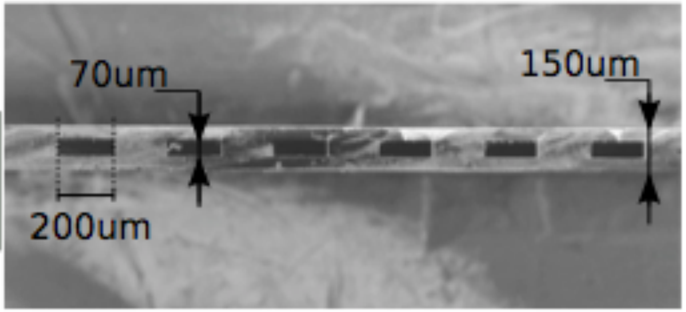

Time resolution by measuring the time difference between hits in two stations with a bias of 200 V:

$\sigma = 365 / \sqrt{2} = 260$ psec



# Cooling -> interesting *new technology*

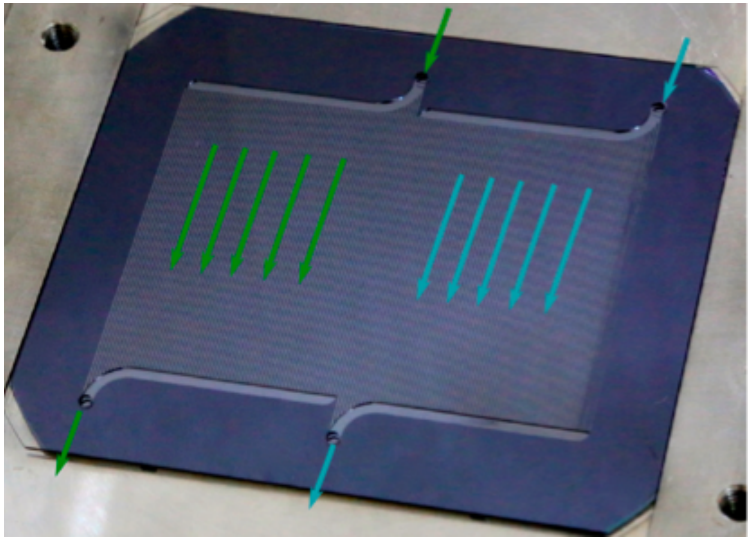


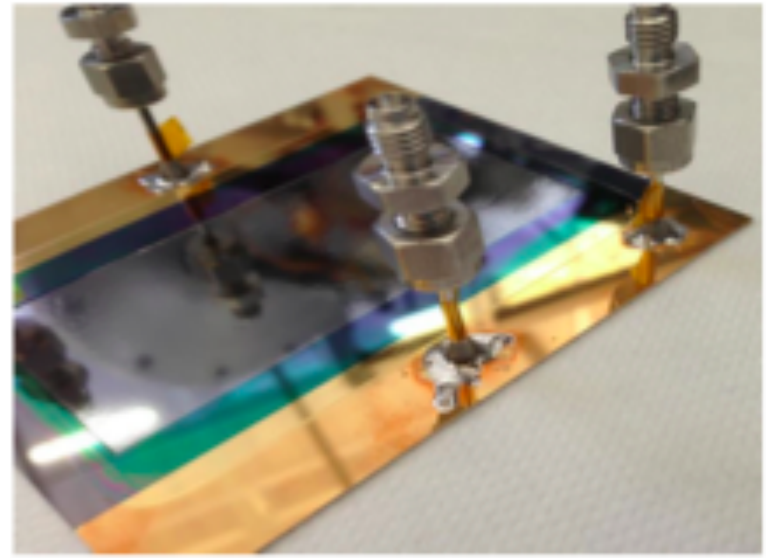



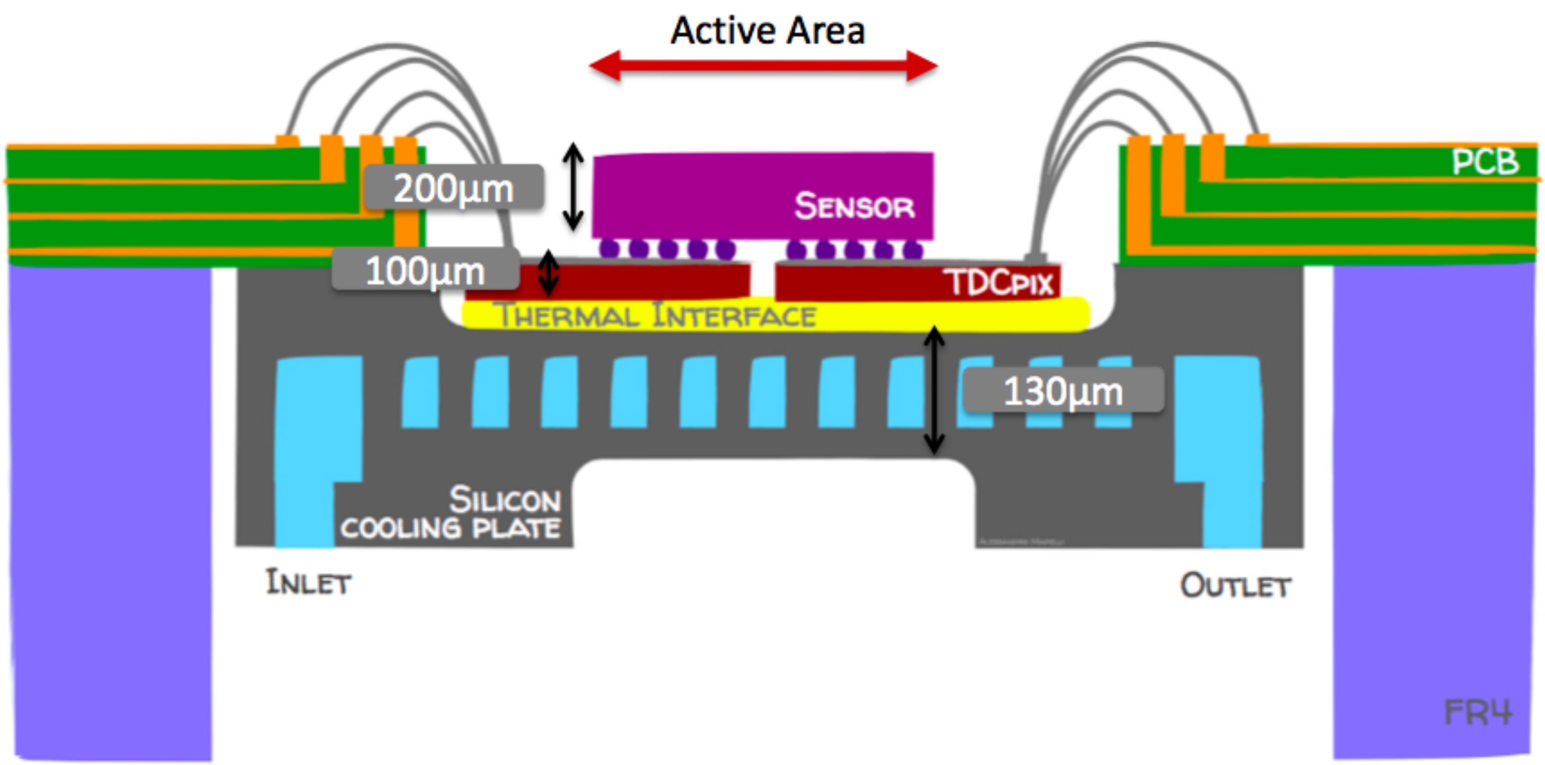

- The detector and thus the electronics is placed in vacuum
- Power consumption at 40 W per station -> necessary to extract the heat
- Use of a silicon plate glued to the ASIC. The plate is quite thin -> around 200-300 μm
- Micro-channels (200x70 μm) have been etched in a thin silicon plate
- $C_6F_{14}$ is circulated in a liquid phase to remove the heat

| **Total thickness of the detector** | |
|---|---|
| **Sensor:** | **200 μm** |
| **ASIC:** | **100 μm** |
| **Micro-channel plate:** | **250 μm** |
| **Total (all silicon):** | **550 μm** |

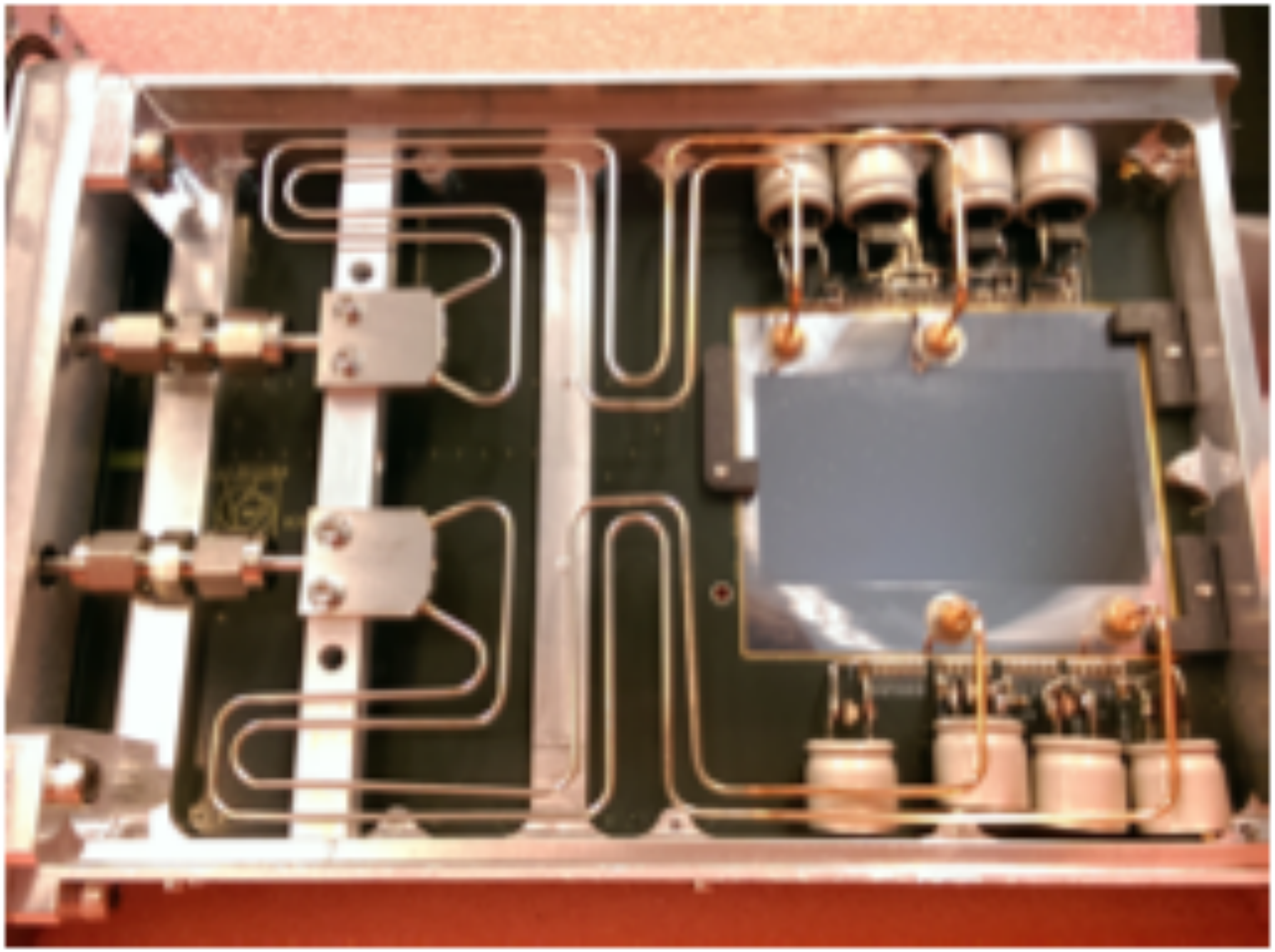
**Multiple scattering:**
$\vartheta = 14\ \mu\text{rad}$





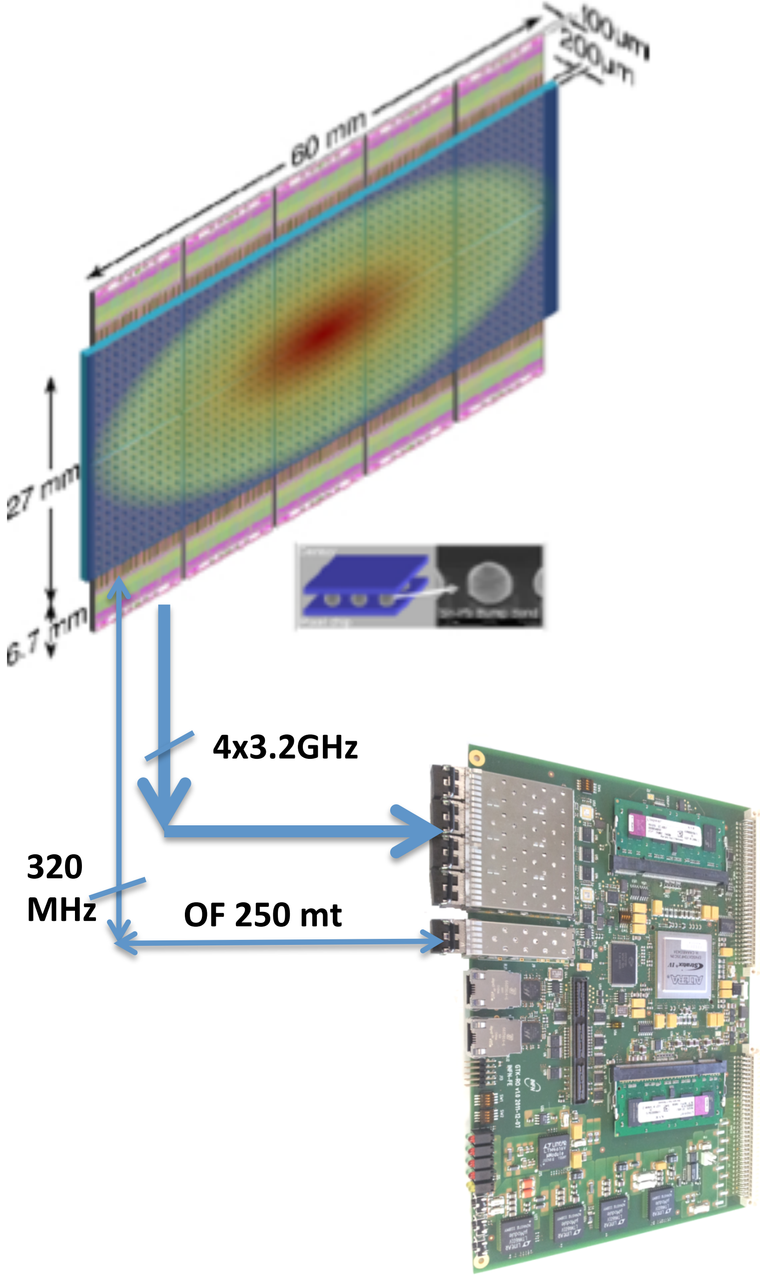

Active Area
PCB
200µm
Sensor
100µm
TDCpix
Thermal Interface
130µm
Silicon
cooling plate
Inlet
Outlet
FR4

# GTK



Picture of the assembled detector

# GTK-DAQ




- Each TDCpix chip -> 1800 pixels
- Data are transmitted to a *dedicated* DAQ system 250 mt apart
- Communication via optical fibers
- Each chip:
  - 2 lines at 320 MHz for controlling and configuring TDCpix
  - 4 lines at 3.2 GHz for data transfer
- The DAQ system is made with a card (GTK-RO) per chip
- GTK-RO is based on a FPGA (Altera-Stratix III)
- From GTK-RO cards, data are transmitted to a local PC

# GTK-DAQ setup

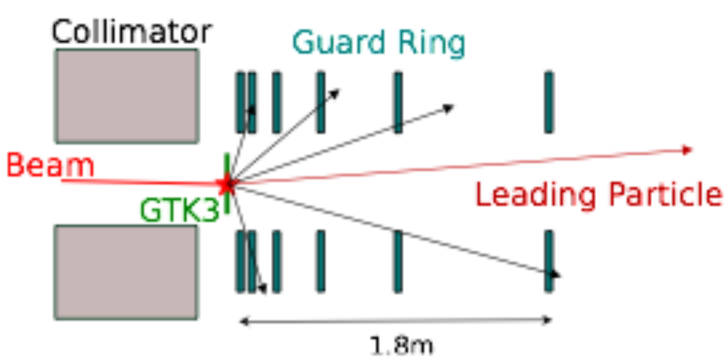
**Up to this point we discussed**

a) how to recognize the Kaons among the pletora of beam particles (KTAG)
b) how to measure direction, momentum, and time of each particle (GTK)

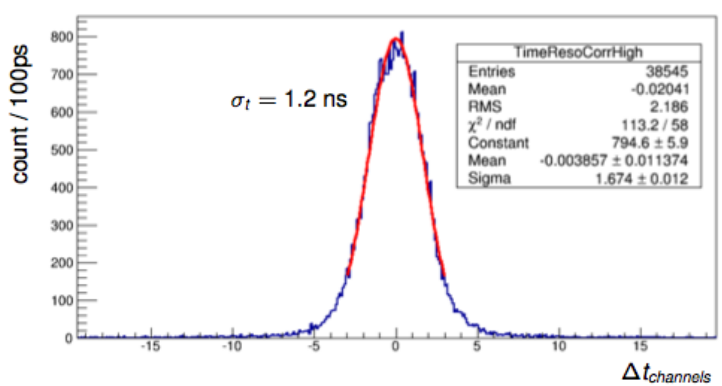
Before stepping to complete the spectrometer and discuss how to measure the decay products, I will introduce a detector placed right after the last (of three) station of the GTK. We call it CHANTI (Charge ANTI-coincidence).

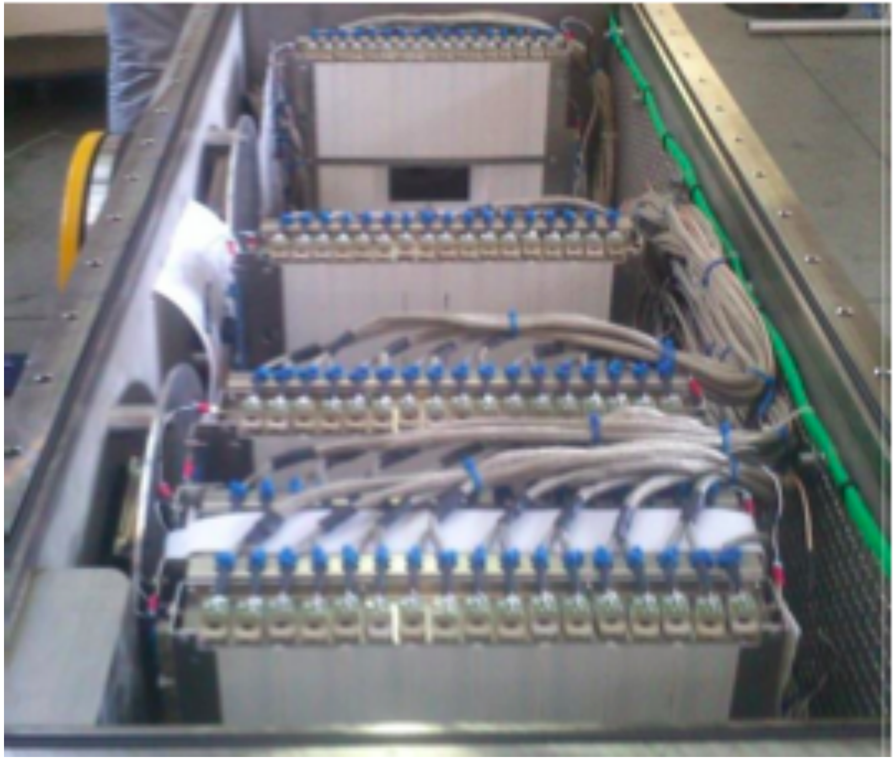
The purpose is to detect nuclear interactions of beam particle with the material of GTK3

This probability is not large but we are looking for very improbable decays




- Six guard rings of scintillators
- Read-out with fibers

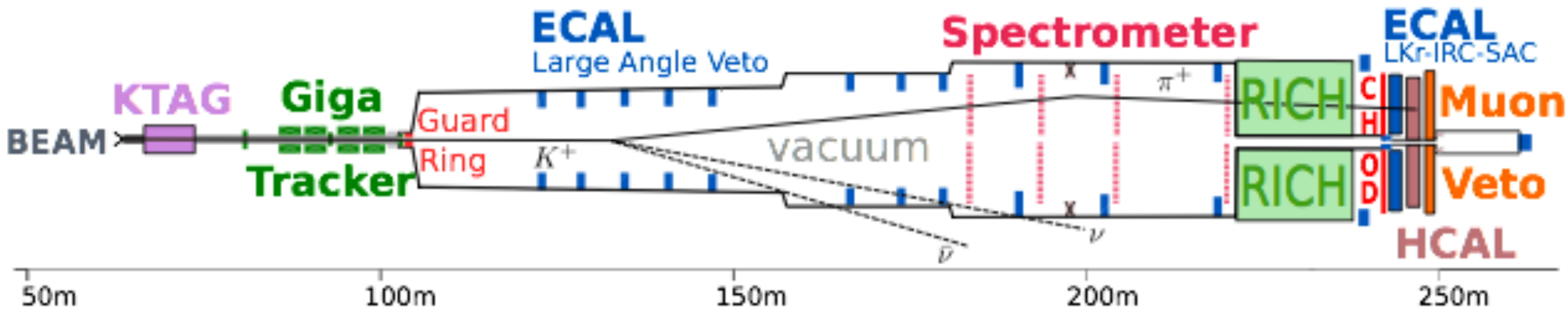




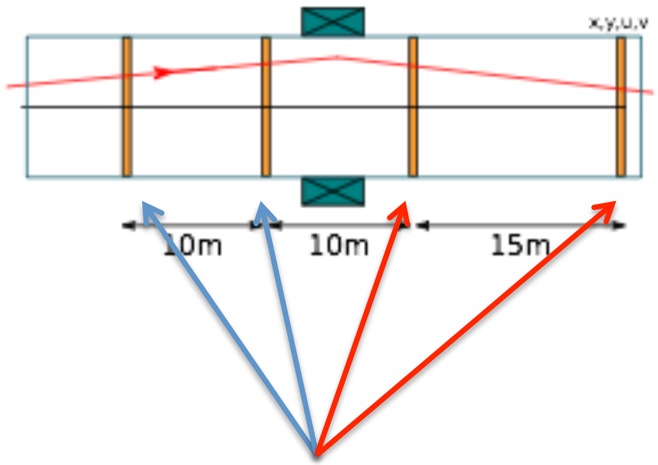
CHANTI: top view

CHANTI: side view

## Measurement of the charged decay: STRAWS

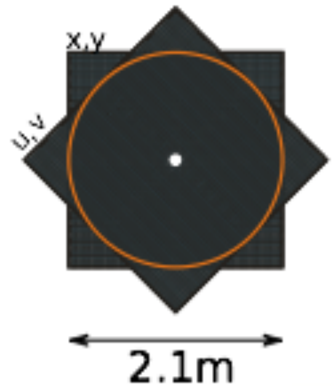


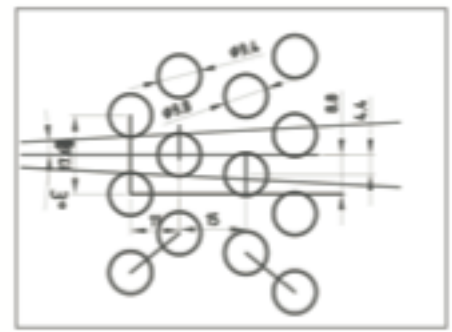





**2+2 chambers interleaved with the magnet**

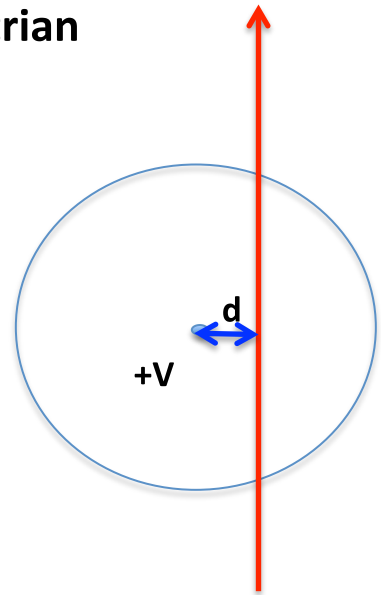
- Chambers operated in vacuum
- each chamber with 4 views -> x,y,u,v
- straws 2.1 m long and 9.8 mm diameter
- walls made of 36 $\mu$m thick PET foils coated with Cu (500 nm) and Aluminum (200 nm)
- gas Ar(70%) + $CO_2$(30%) at 1 atm
- four staggered planes per view

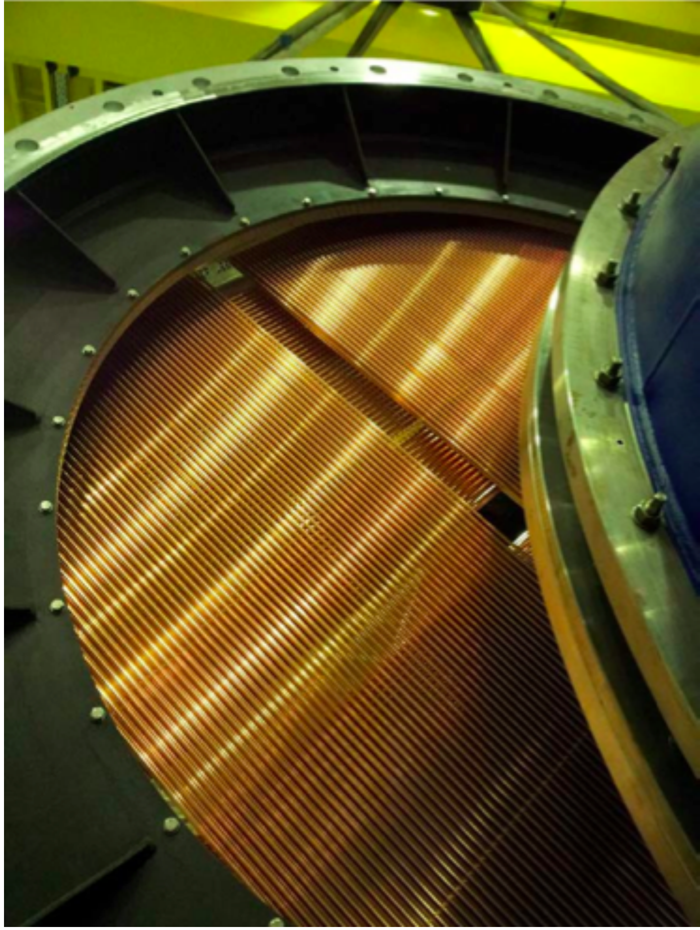


- Dipole magnet: 0.36 T -> 270 MeV/c momentum kick
- Momentum resolution: 1%
- Angular resolution: 20-60 $\mu$rad

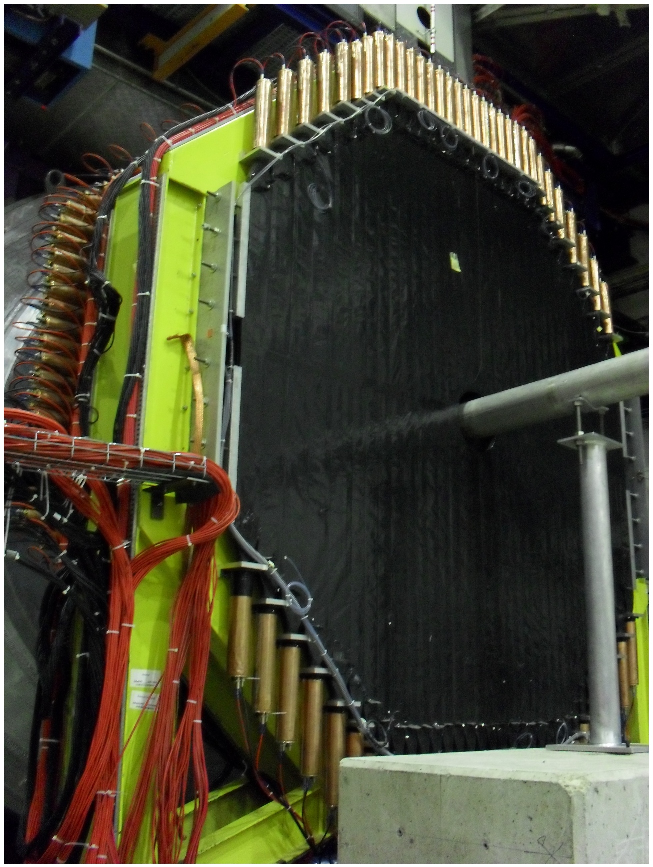
**Straws for pedestrian**



- along the pattern, the charged particle generates electron-ion pairs
- Electrons are attracted by the central wire and generate
- An electric signal is propagated through the wire to an amplifier
- The time of the signal depends on the distance, d, of the track from the wire

# Charged Hodoscope (CHOD)



- Two planes (V,H) of scintillator slabs
- Charged particles crossing the planes deposit energy
- … and form an optical signal collected by the photomultipliers
- Time coincidence of signals on Horizontal and Vertical planes is the signature of particle crossing
- Coincidences, with a time resolution of a few nsec, are used as references for starting a trigger

Up to now, we discussed:

- How the Kaons are recognized among all the beam particles -> 6% of the 750 Mparticles/sec -> KTAG
- How the beam particle momentum, direction, and time is measured (GTK)
- How the charge decay products are measured ( momentum, direction and time) (STRAWS)
- How to determine a fast time reference (CHOD)

We move now to the detectors designed to obtain

1. a hermetic detector -> vetoes for photons and charged particles ($\pi^+\pi^0$, $\pi^+\pi^+\pi^-$, etc...)
2. $\pi/\mu$ separation

# Veto system

Three main angular regions:

1. Small angle < 1 mrad -> Intermediate Ring Calorimeter (IRC) and Small Angle Calorimeter (SAC)

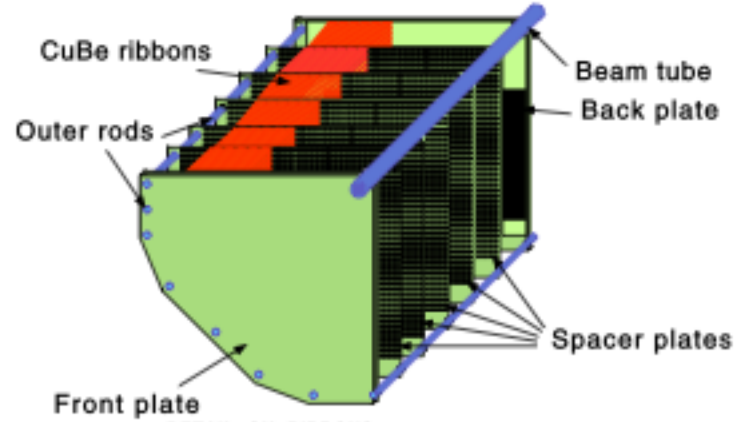
2. Medium angle: from 1 through 8.5 mrad -> Liquid Krypton calorimeter (LKr)

3. Large angle > 8.5 mrad -> Large Angle Vetoes (LAV)

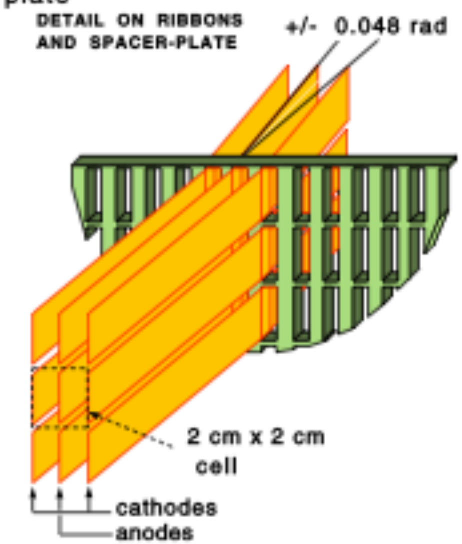
**Let's start with the medium angle: LKr**

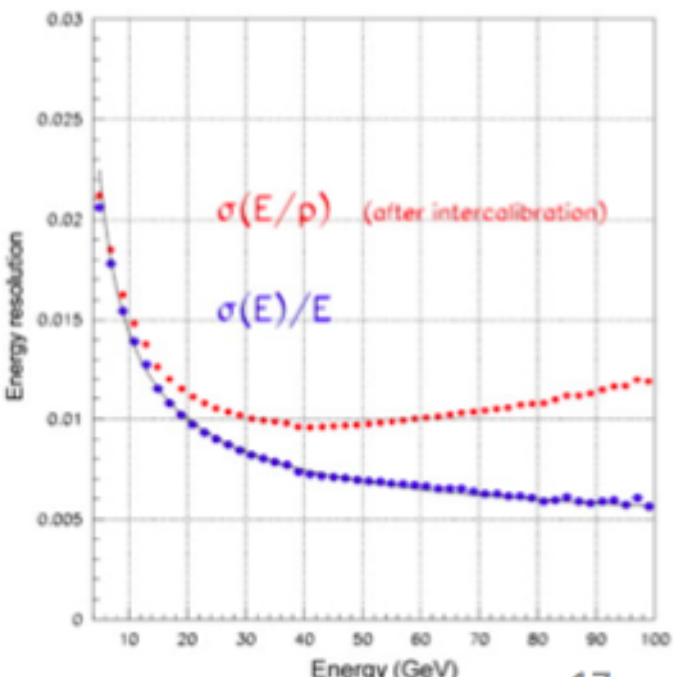
# Liquid Krypton (LKr) electromagnetic calorimeter

- It is the old NA48 calorimeter
- Homogenous medium (liquid Krypton, -153 $^0$C)
- It covers the angular region between 1 and 8.5 mrad
- Signals are generated by pairs due to the ionization of the liquid
- Measured photon detection inefficiency < $10^{-5}$ for $E_\gamma > 10$GeV




13248 2x2 cm$^2$ cells



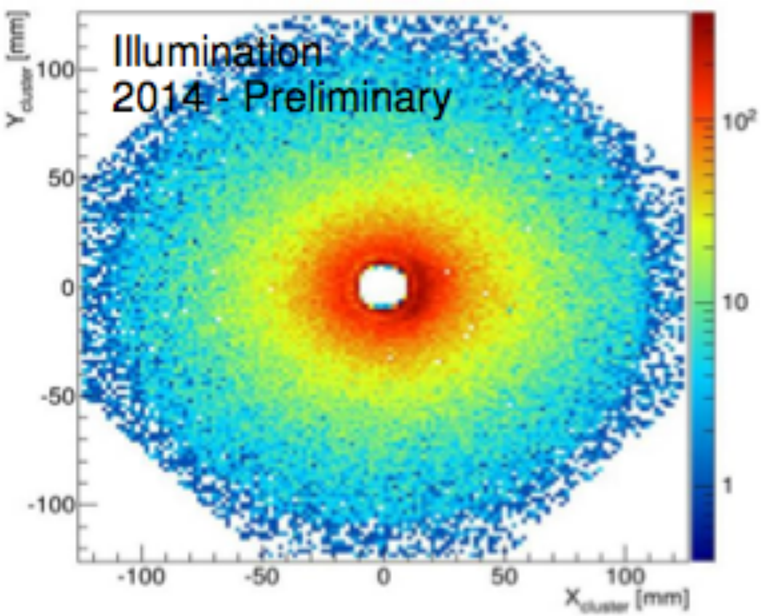

$\sigma_E/E = (3.2/\sqrt{E} + 9/E + 4.2)\%$

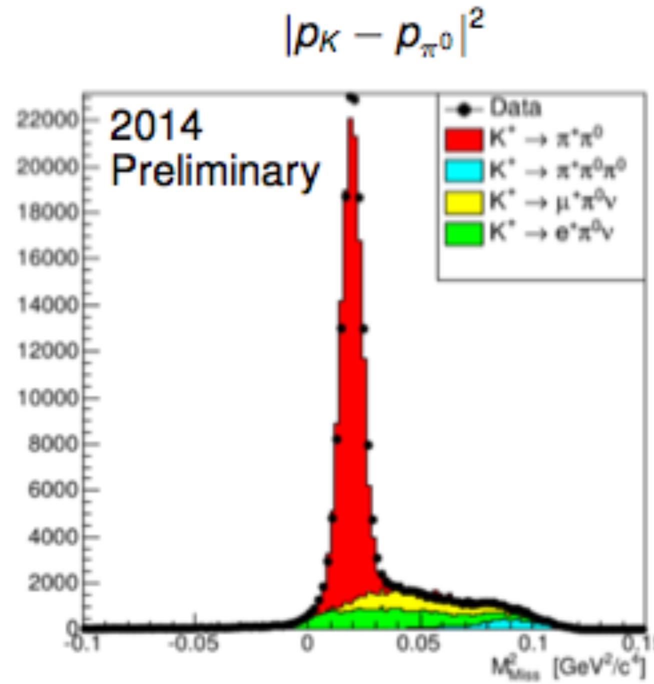
# LKr calorimeter

- **Major upgrade of the Read-out with a 40MHz 14 –bit FADC continuous sampling of the calorimeter**

## LKr - Performance

Events: $K^+ \rightarrow \pi^+\pi^0$

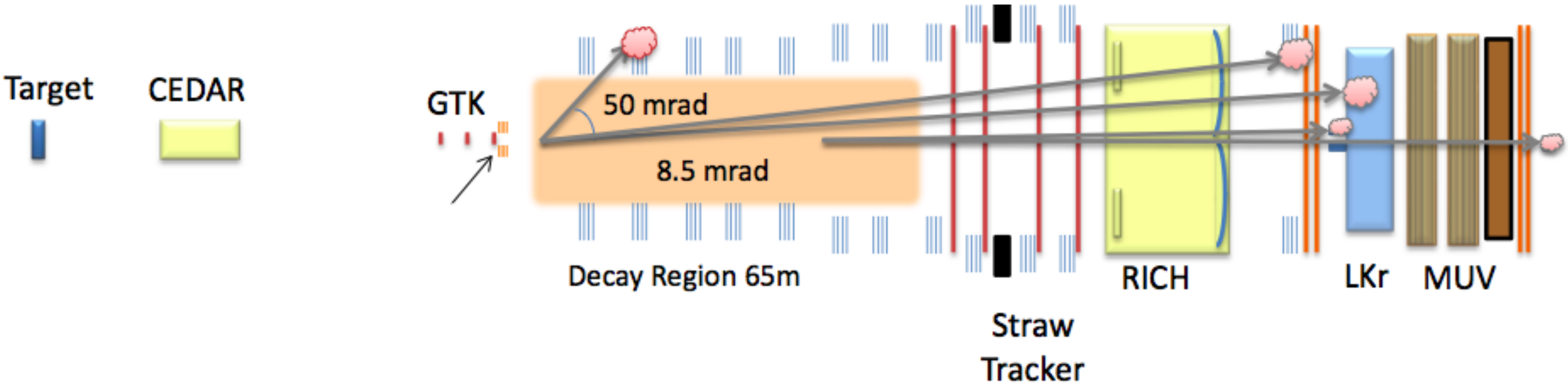



Events are selected using $\pi^0 \rightarrow \gamma\gamma$ selected with the LKr

# Large Angle Veto (LAV)

- It covers the angle between 8.5 and 50 mrad




- 12 rings displaced regularly along the decay vacuum tube
- Each ring made of 4-5 annular layers of **Pb glass** blocks (from Opal, a former LEP experiment)
- Measured detection inefficiency between $10^{-3}$ and $10^{-4}$ for >150 MeV photons
- Time resolution at 1 ns

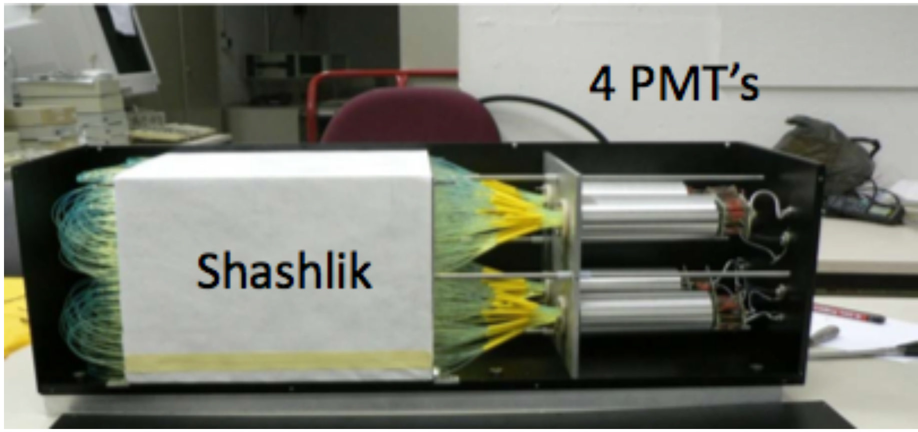
# Small angle vetoes (SAV) : IRC, SAC

## Intermediate Ring Calorimeter (IRC)

- Cover the annular region between R = 7 and 14 cm
- It is located right in front of the LKr
- It is based on a Shashlik structure
- Approximately 100 wavelength shifter **scintillating fibers** are slided in the structure
- Read-out with a PMTs

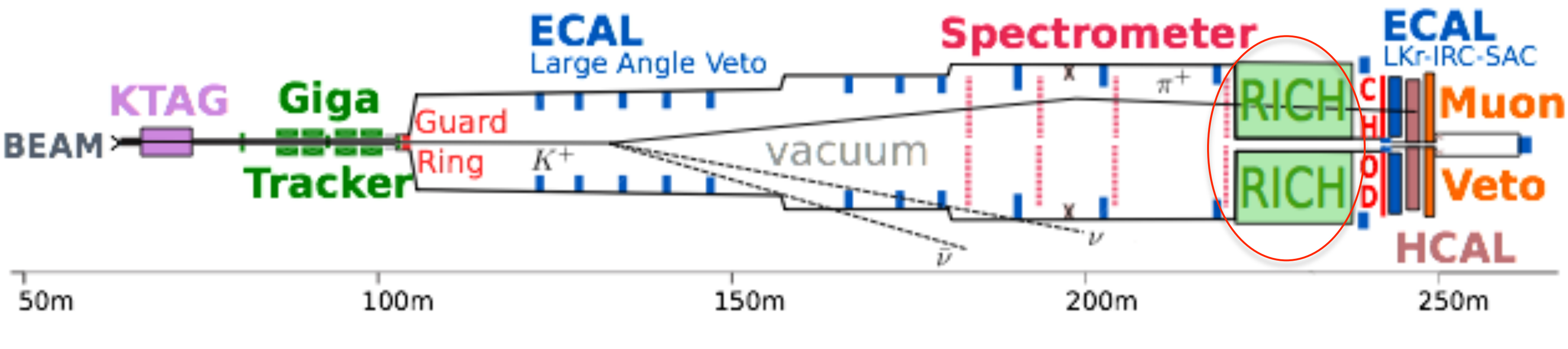
## Small Angle Calorimeter (SAC)

- Located at the very end of the detector
- (24x24) $cm^2$ Shashlik calorimeter
- Longitudinal **sandwich of lead-scintillator**
- Read out via WLS fibers with 4 PMTs
- Charged particles are swept away by a dipole magnet
- Only photons and neutrons impact the SAC

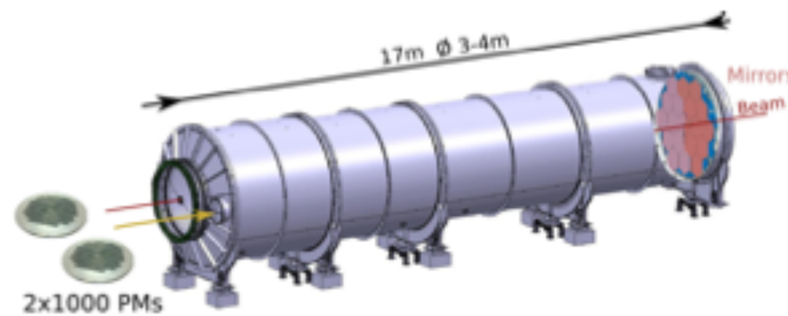


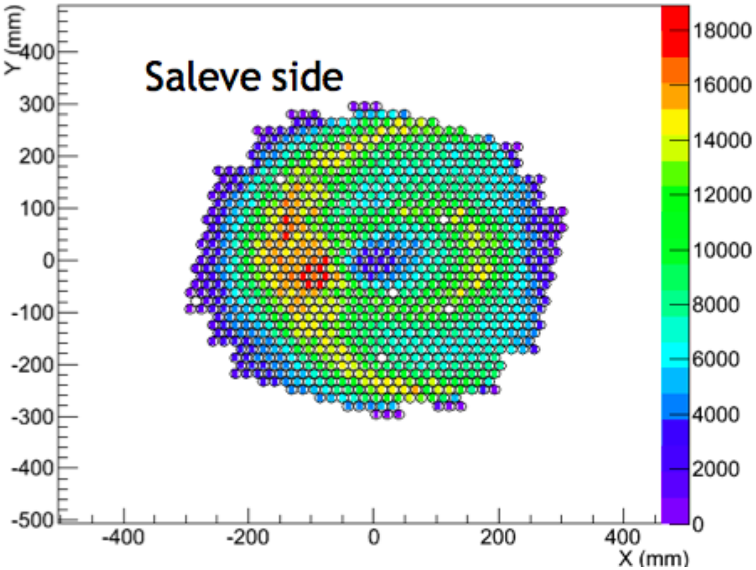
# $\pi - \mu$ separation

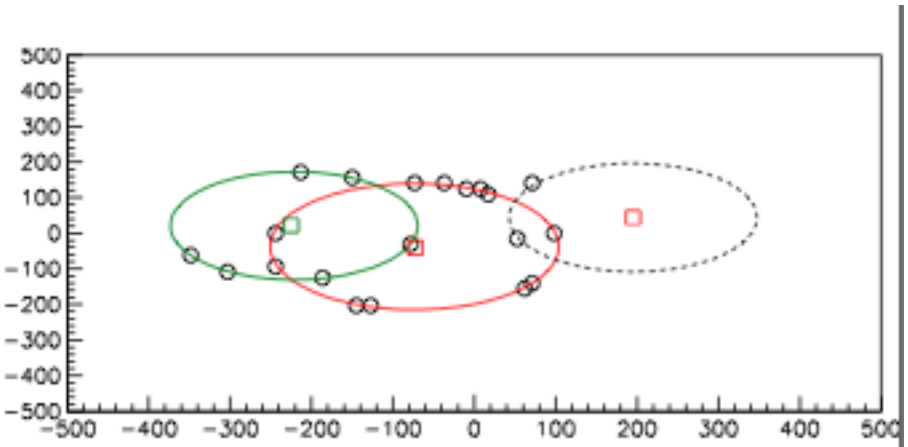
## RICH – Cherenkov counter




- 17 mt long vessel
- Ne at 1 atm -> $p_{th}(\pi)$ = 13 GeV/c
- Cherenkov is reflected on 2x1000 PMT
- From the radius of the ring, knowning the momentum, one can separate pions from muons

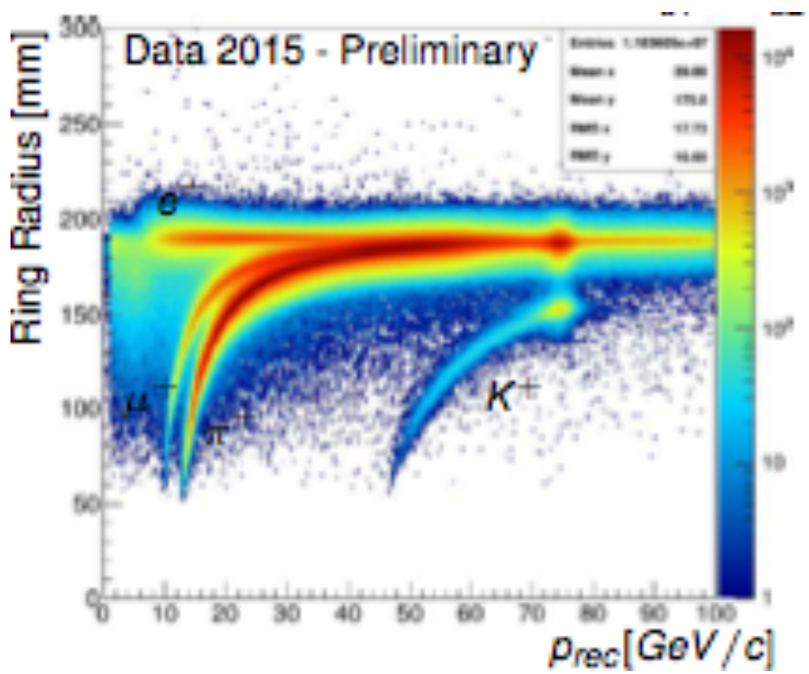


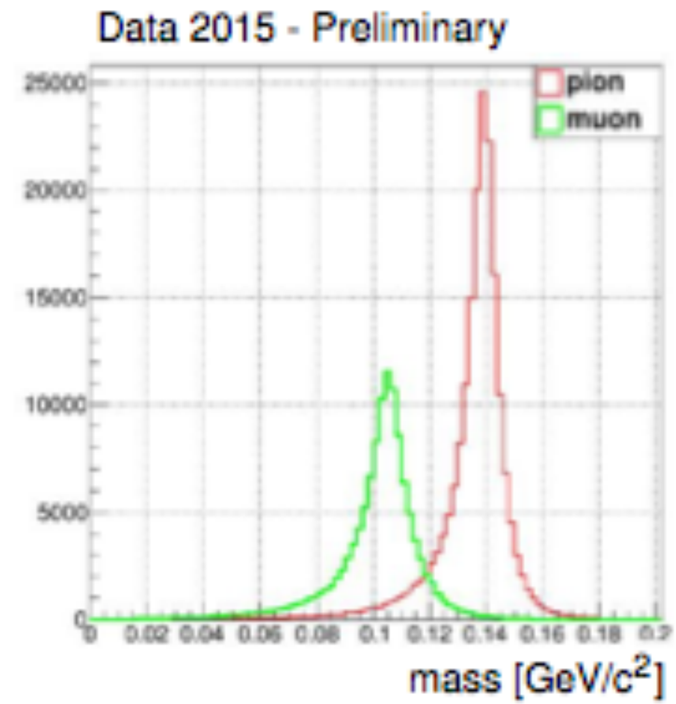


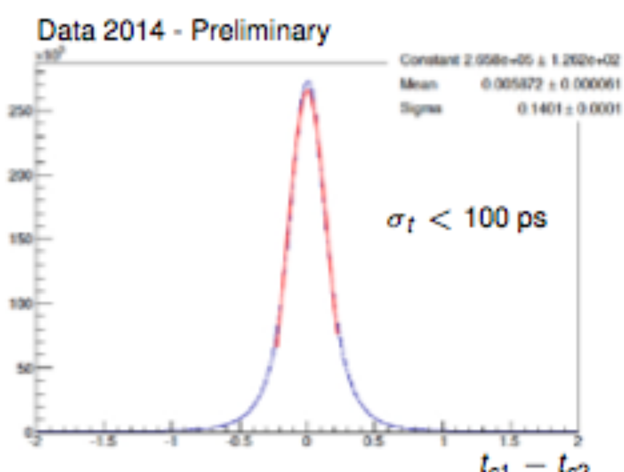




- Light reflected by the mirrors are collected by 2x1000 phototubes
- From the hit position one can determine the annular radius

Angle of the emitted Cherenkov light depends on $1/\beta$, fixed the momentum of the particle $\beta_\mu > \beta_\pi$

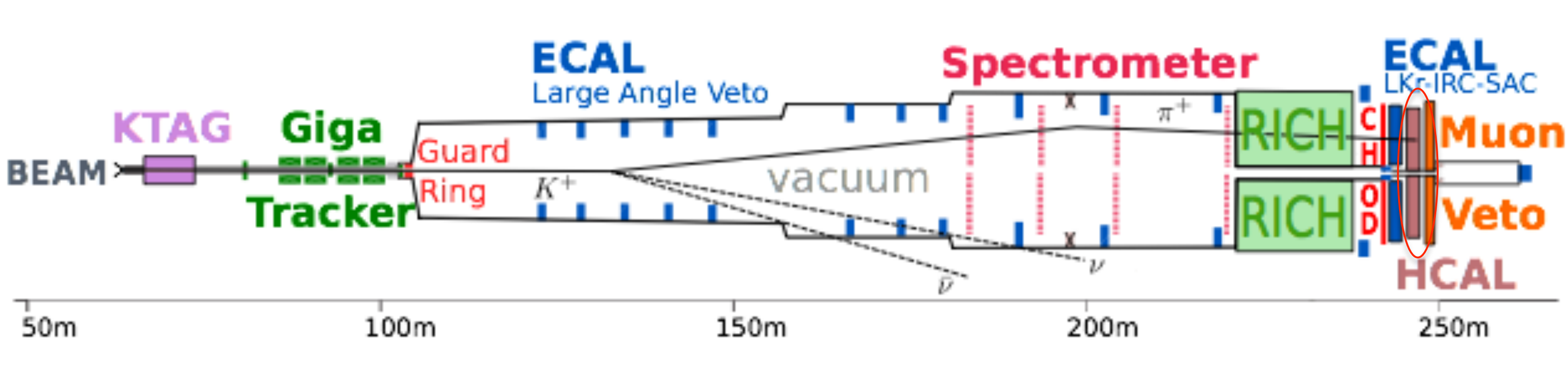


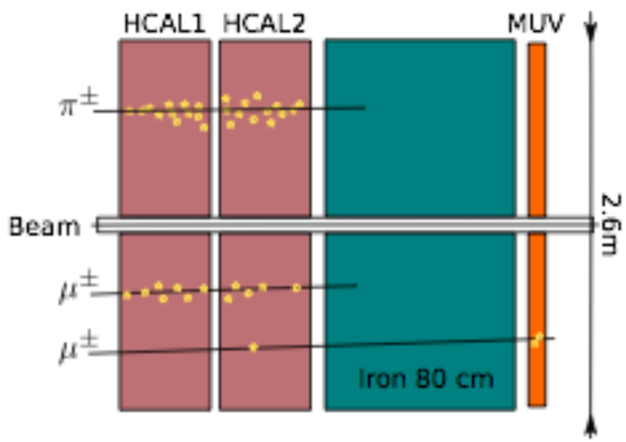



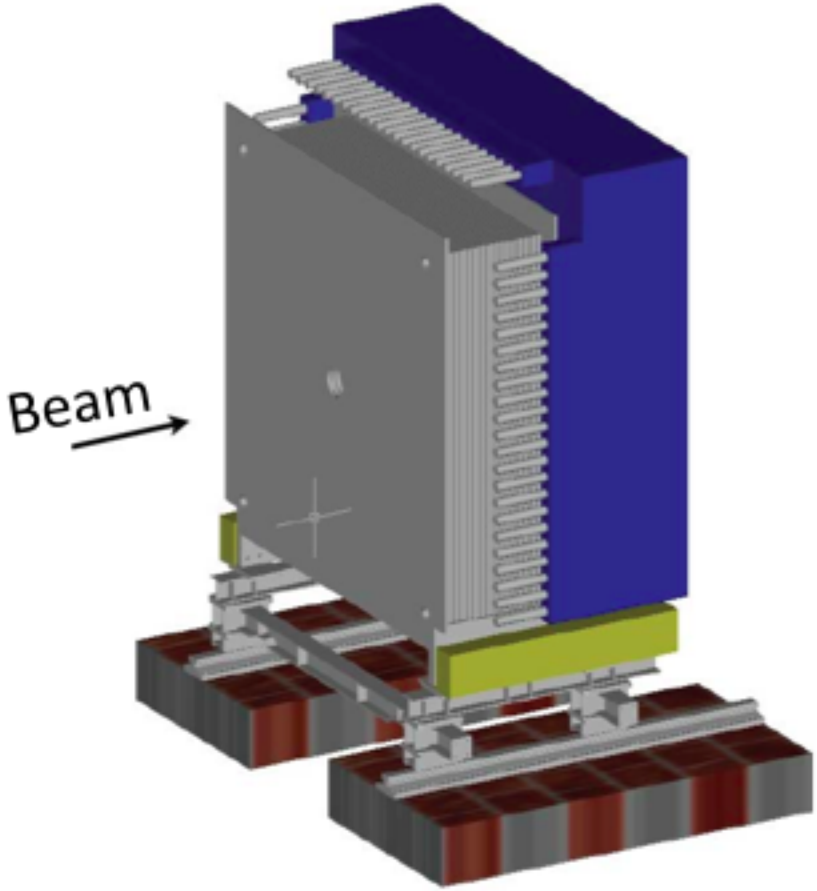

time resolution better than 100 ps

# μ − π separation: Hadron Calorimeter (HCAL)

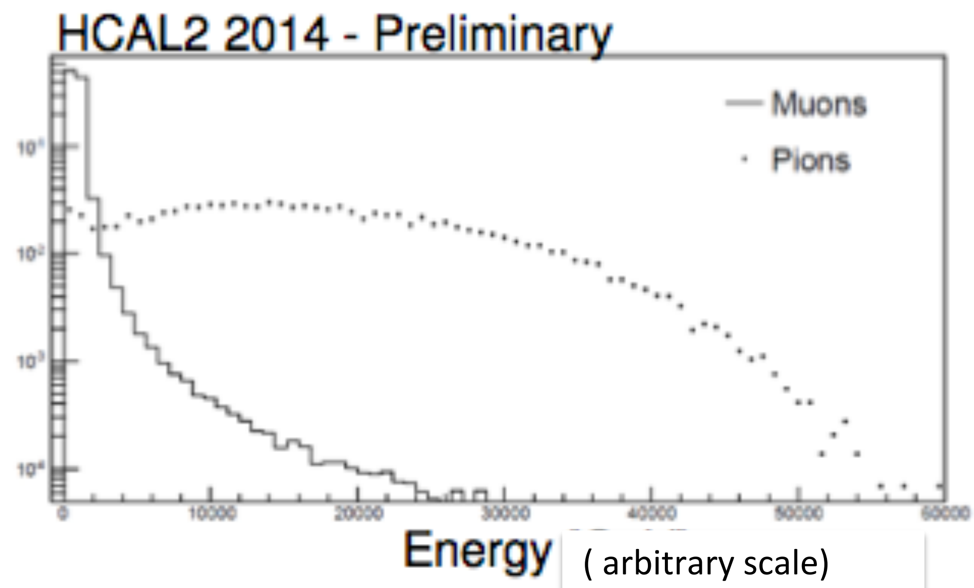



- HCAL1 and 2 are both **sandwiches of iron and scintillator layers**
- Scintillators are split in strips 6 (12) cm wide
- The total energy and also the deposited energy pattern of  in HCAL1 and 2 reflect the particle type

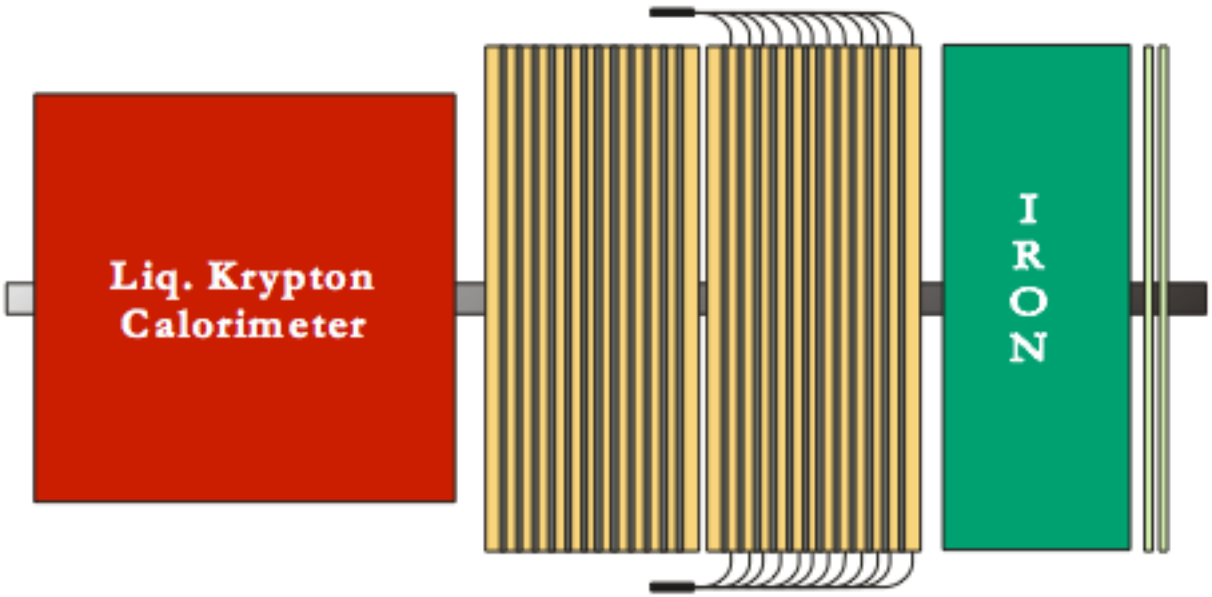



- Both, HAC1 and HAC2, are iron/ scintillator sandwiches
- HAC1 with 22 scintillator layers and HAC2 with 24
- Both scintillator layers are split into horizontal and vertical strips
- Read with PMT

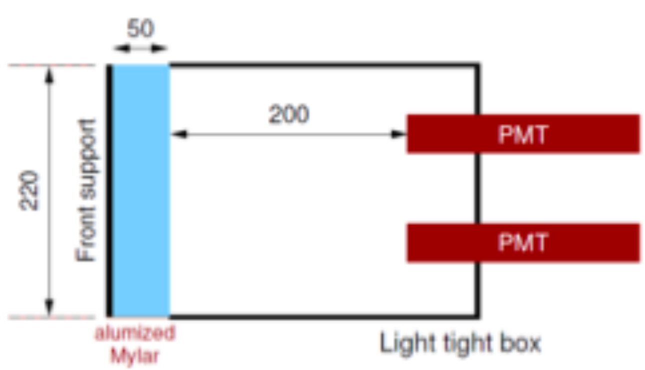



- $\pi-\mu$ separation better than $10^{-3}$
- Time resolution ≈1 ns

# $\pi-\mu$ separation: MUV3




- MUV3 made of 140 scintillator slabs 22x22 cm$^2$
- Each slab (5 cm thick) is *seen* by 2 PMTs



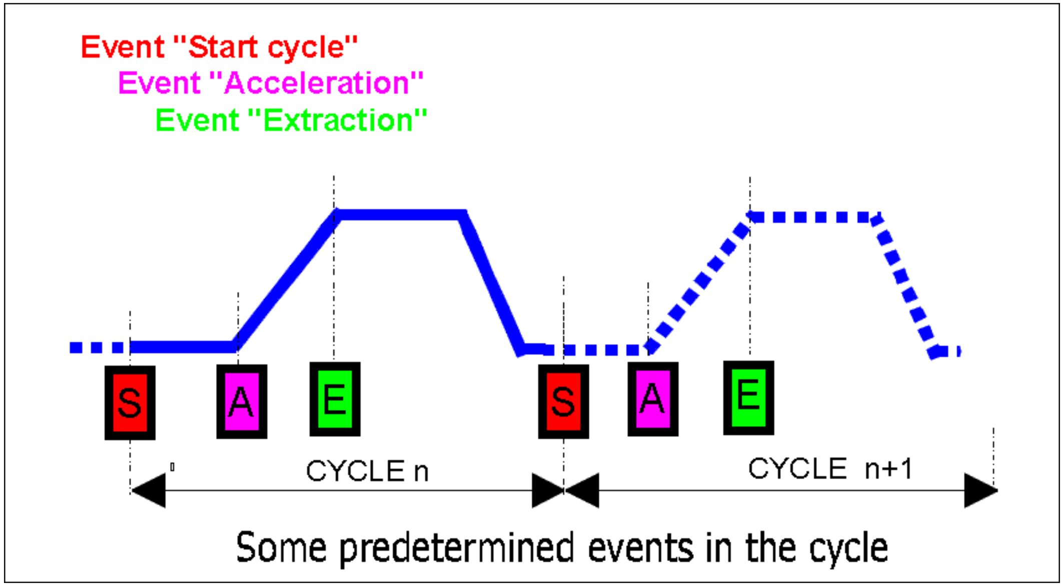
# MUV3 (cont.)

- Placed after further 80 cm of iron
- Time resolution of 0.5 ns
- Time-walk correction made with Constant Fraction Discriminators

- **We have discussed all the individual detectors (12) that constitute the NA62 experiment**
- **Before approaching the principles to minimize the background and select the candidates, it is useful spend some time to present the Trigger and Data Acquisition (DAQ)**
- **It certainly deserves some slides because the way it works is innovative**

# Time determination

- A unique source (LTU) distributes continuously a 40 MHz clock (T = 25 ns) to all the detectors
- Right before the particle extraction a reset signal (Start-of-Burst, SoB) is issued to all detectors. This signal defines the time equal zero




- At each detector, time is measured in primary units of 25 nsec (timestamps) by counting the number of clocks from the SoB at the *event*
- In fact a further sub-division of the timestamp into 8 bits (256) is done at each detector. This *finetime* corresponds to ≅ 100 ps

- A given hit in a detector is characterized by:

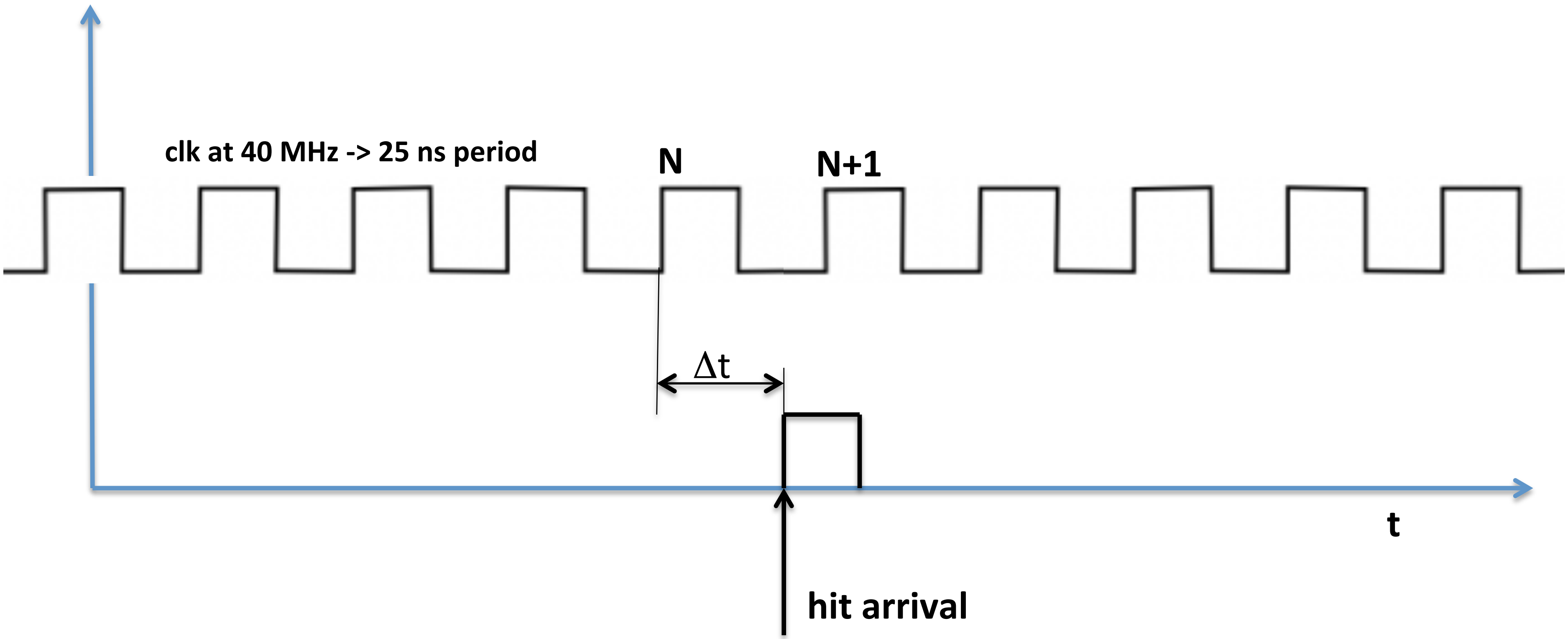
a) signal amplitude and
b) hit arrival time

- Both information are digitized by the Front-end (FADC and TDC)

- and stored in a circular buffer approximately 1 ms long ( roughly 40 k-position deep)

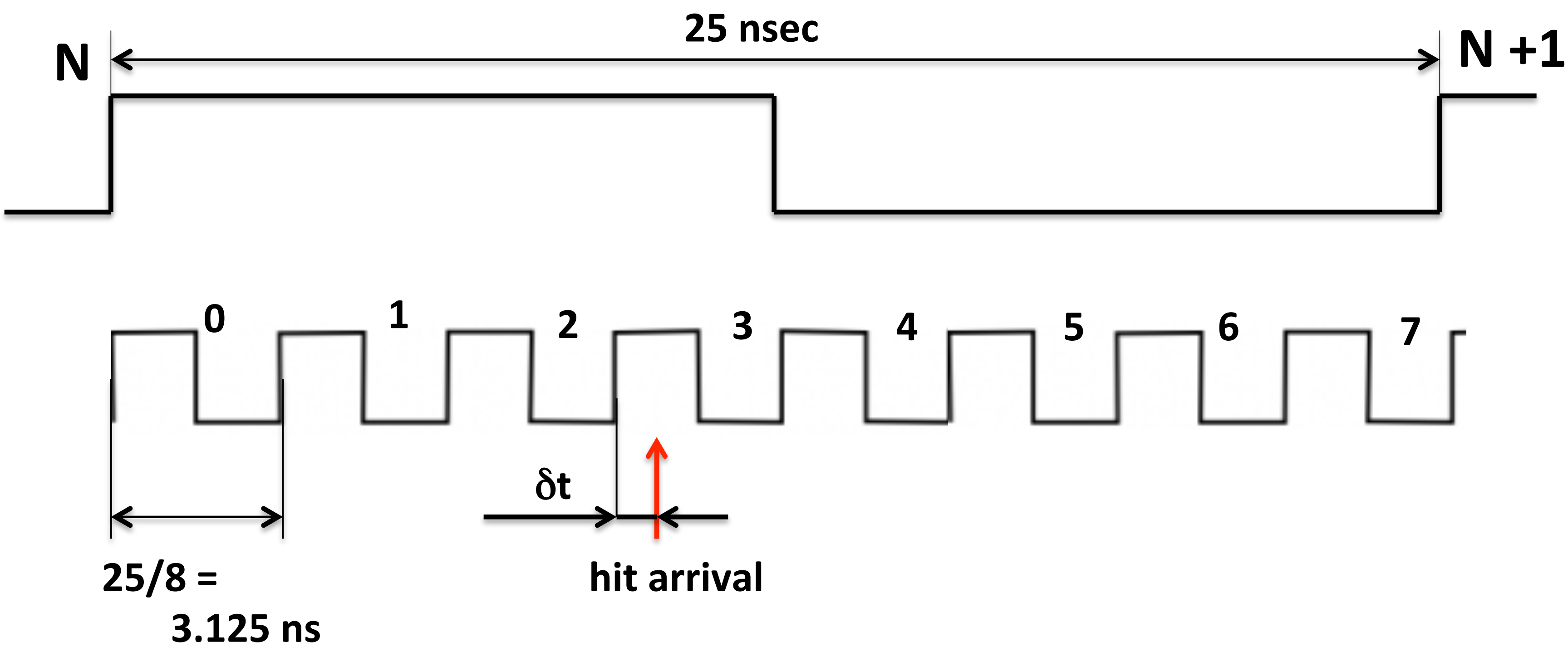
Due to different cable lengths and position of the detectors the time has to be corrected for an offset.

# Example of time determination: GTK case



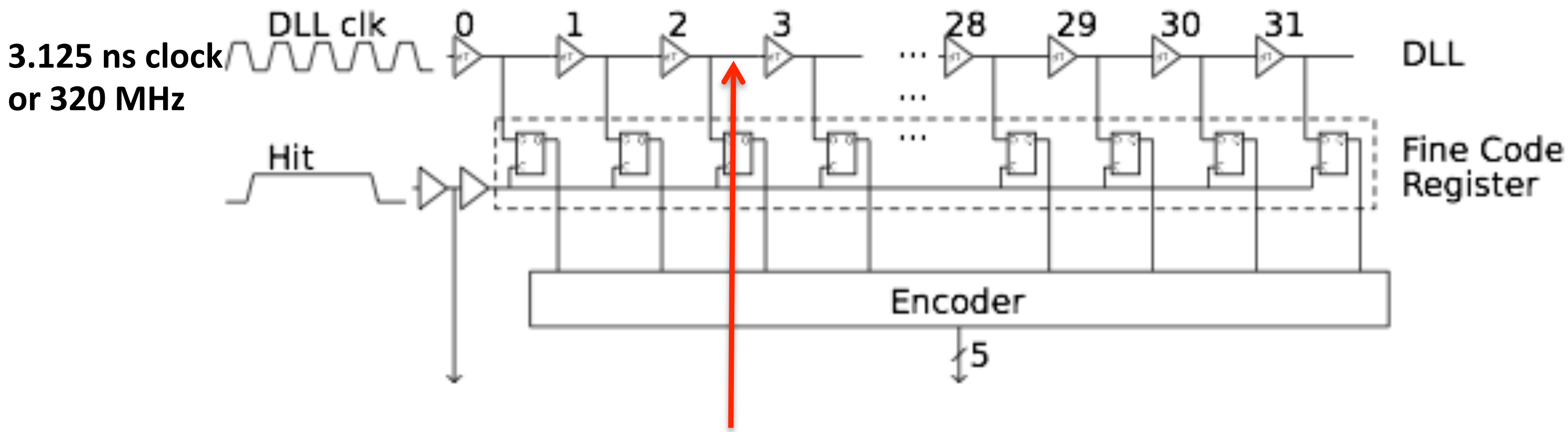

- The arrival of the hit is after N clock period, thus the time of the hit (in nsec) is: $25*N + \Delta t$
- How to measure $\Delta t$?
- A time resolution of 25 nsec would be too gross

- First step: sub-divide each 25 nsec period into 8, each clock is 3.125 nsec



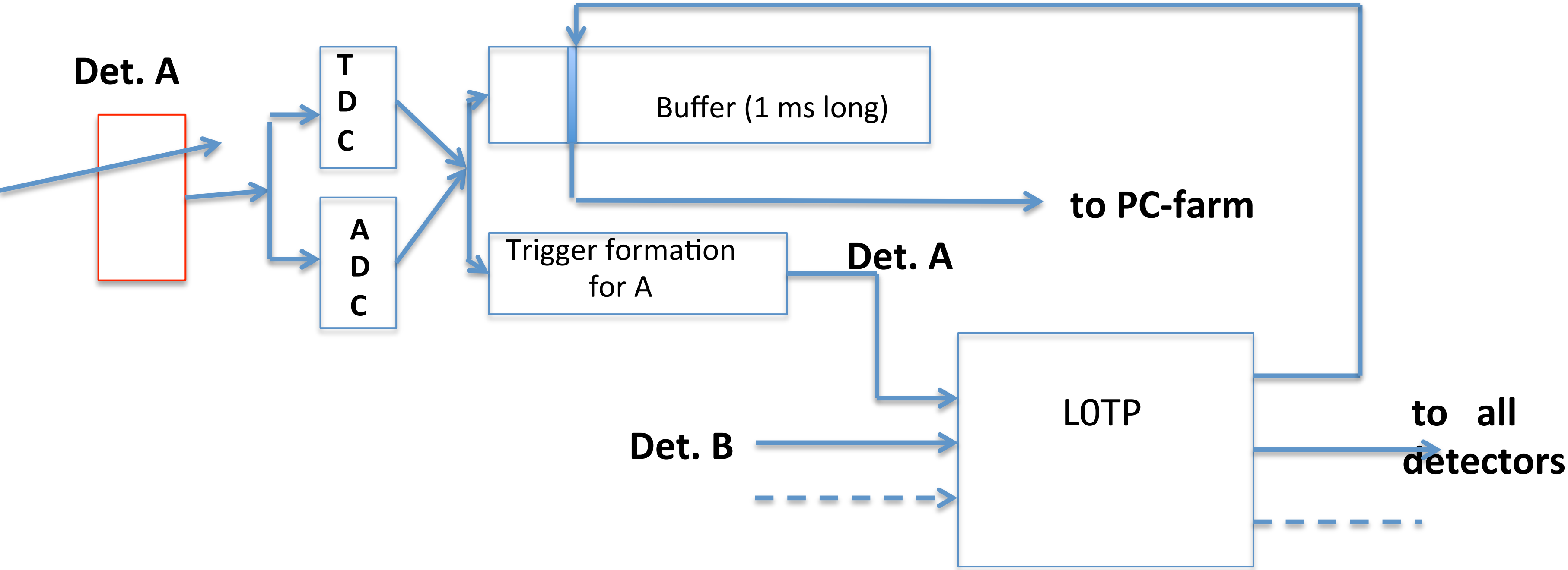

- Time is now better determined: $25*N + 3.125*2 + \delta t$
- By ignoring $\delta t$ the resolution would be 3.125 nsec
- The target was ≤ 200 psec
- Still one step to go

## TDC based on the Delay Locked Loop (DLL) architecture

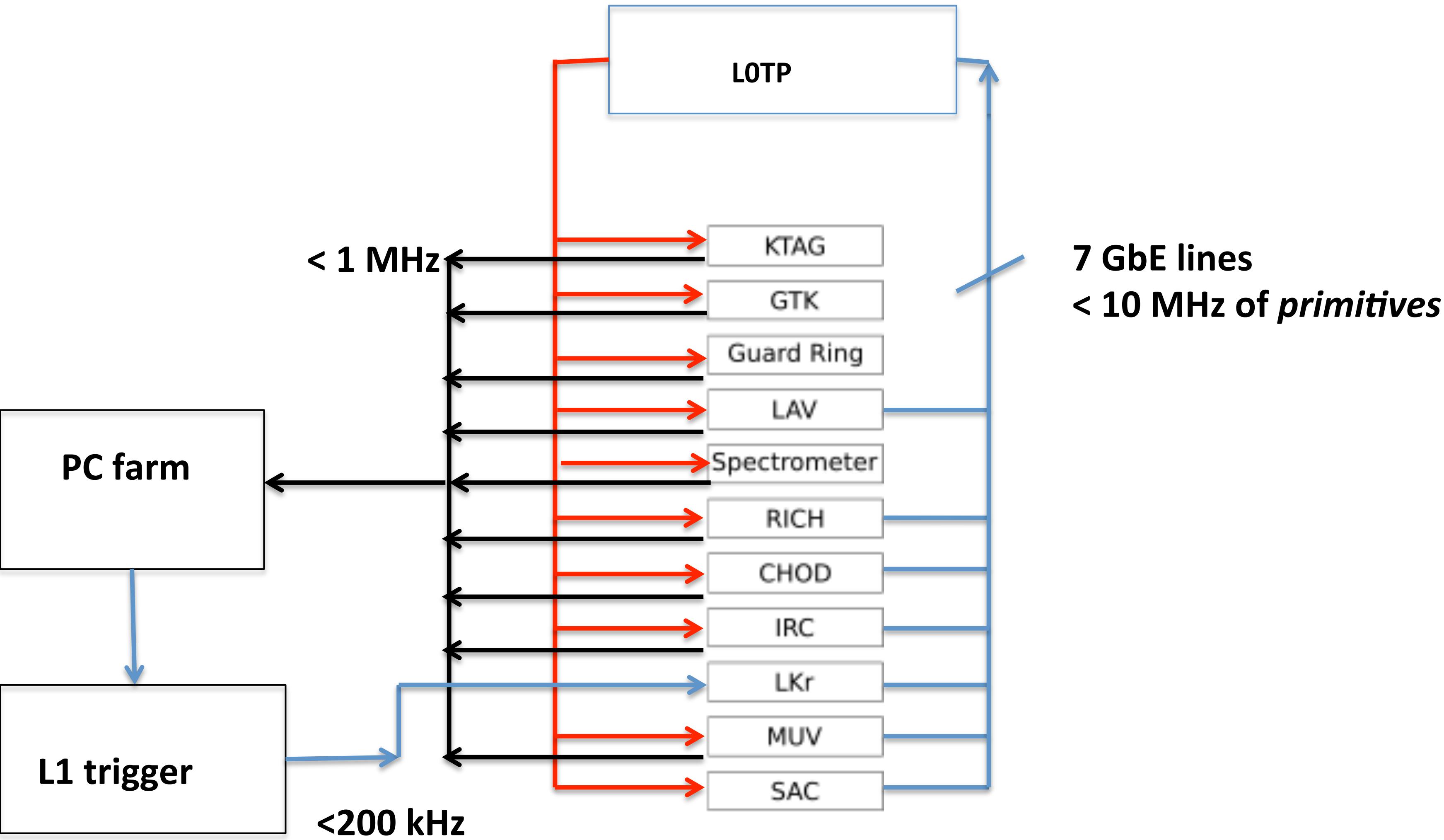



- The DLL clock period is 3.125 nsec (the one we were left in the previous slide)
- The clock is transmitted along a delay-line in 32 steps each step being delayed by 100 psec
- Imagine the hit arrives with a delay in the range between 300 and 400 psec with respect to the  DLL clock
- Thus when the hit arrives, the clock signal has been already propagated through the *delay 0, 1 and 2,* and those bits at the encoder input are high, while the followings are low.
- In this way the time is measured with a resolution of 100 psec

# Conceptual data flow (L0TP trigger)

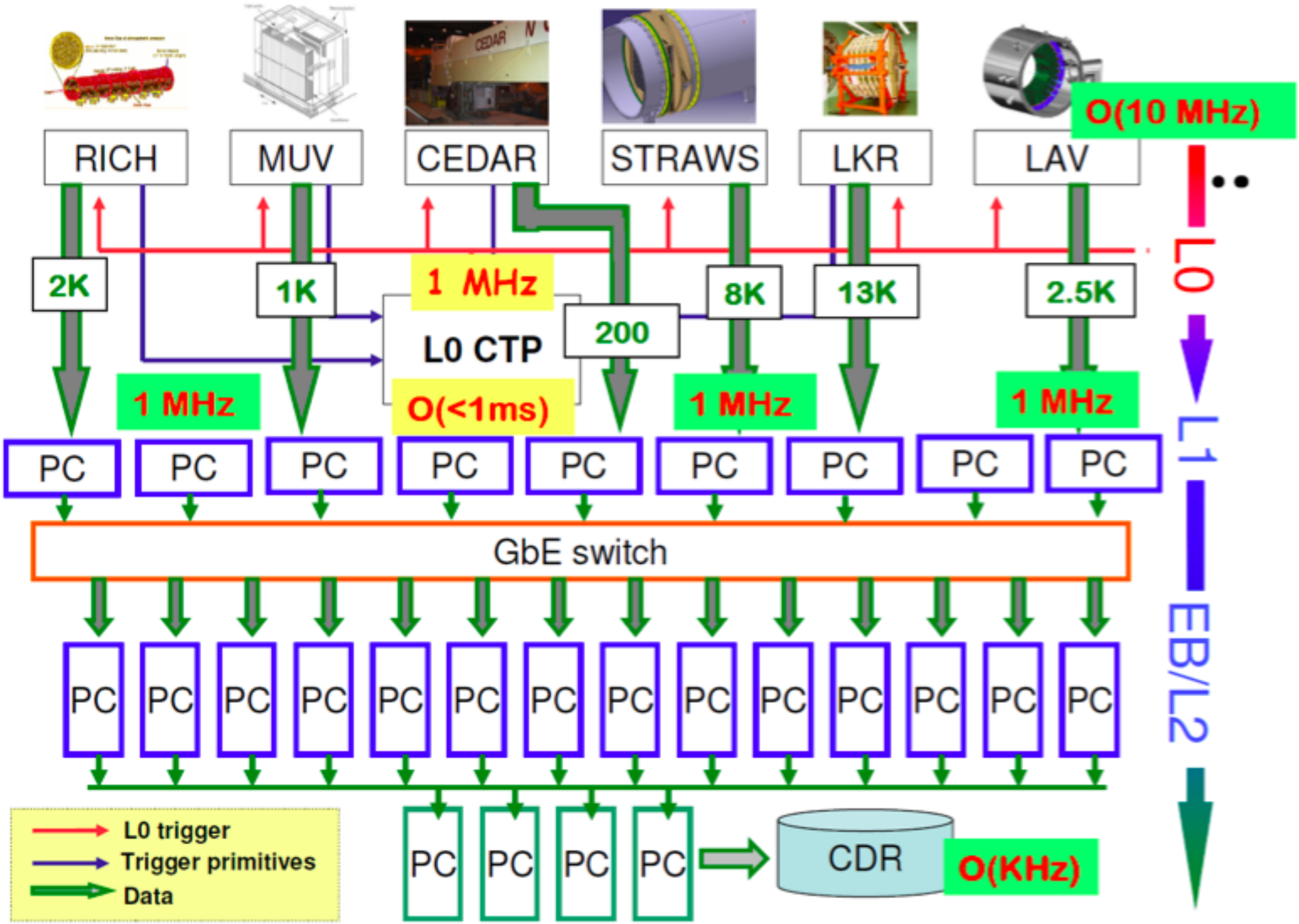



- After digitization, data from a hit are stored in a circular buffer 1ms long
- At the same time, these data concur to form a local trigger, known as *primitive* (64 bit/ primitive)
- L0TP checks the *primitives* from A,B,… against a set of masks and flags the good combinations
- These are identified, time-aligned data are extracted from the buffer and sent to the PC-farm
- Before definitely accepting the trigger, it is examined from the L1 and L2 software triggers.



L0TP
KTAG
GTK
Guard Ring
LAV
Spectrometer
RICH
CHOD
IRC
LKr
MUV
SAC
< 1 MHz
PC farm
L1 trigger
<200 kHz
7 GbE lines
< 10 MHz of *primitives*

# NA62 TDAQ - OVERVIEW



# Analysis strategy

- **Let's recall the theoretically expected Branching Ratio:**

$$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (0.911 \pm 0.072) \times 10^{-10}$$

- **Reasonable measurement at 10% level, thus would require**

  **O(100) events and Background ≈ O(10)**

- **Assuming a (*detector acceptance x signal efficiency* ) = 10%**

- **Necessary the decay of $10^{13}$ kaons in 2 years of data taking**

- **and a background rejection defined as Signal/Background ≈ $10^{12}$ to limit to O(10) the amount of Background events**

# Selection of the events

## Level 0 Trigger

- 1 charge downstream
- track identified as pion and rejected as muon
- energy in the calorimeters which is compatible with a single track being a pion

## Offline analysis

Tracking

- Track in the Gigatracker and track in the Straw which are in time and spatial coincidence (GTK, STRAW)->a *good* vertex

Particle identification

- identify as Kaon the incoming beam particle (KTAG)
- Identify as pion the produced decay particle (RICH-LKr-HCAL1,2-MUV3)

Kinematic reconstruction

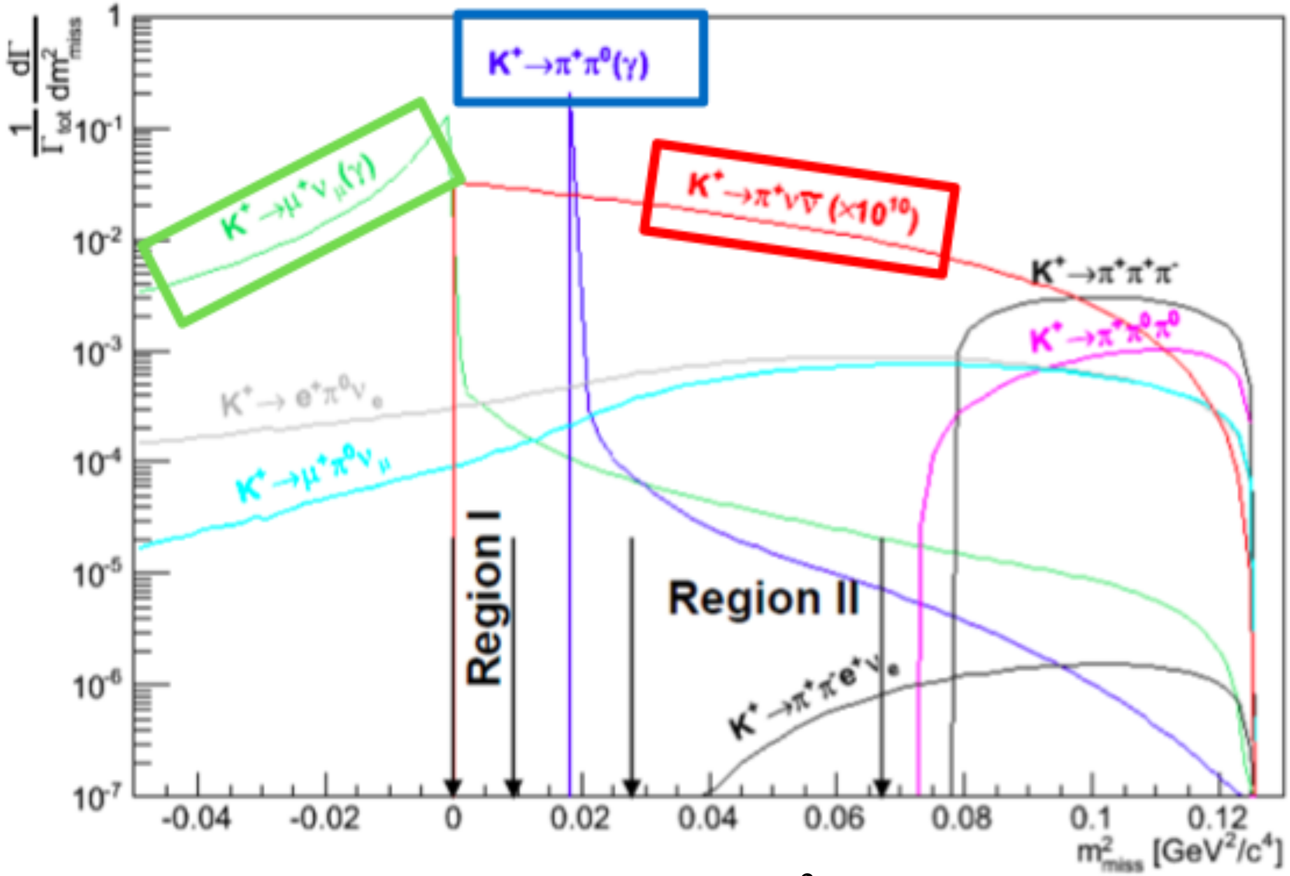
- compute K-$\pi$ vertex
- pion momentum between 15 and 35 GeV/c (STRAW) (> 40 GeV of missing energy)
- compute the missing mass $m^2_{miss} = |p_K - p_\pi|^2$

Photon rejection

- Reject the events with photons in the final state

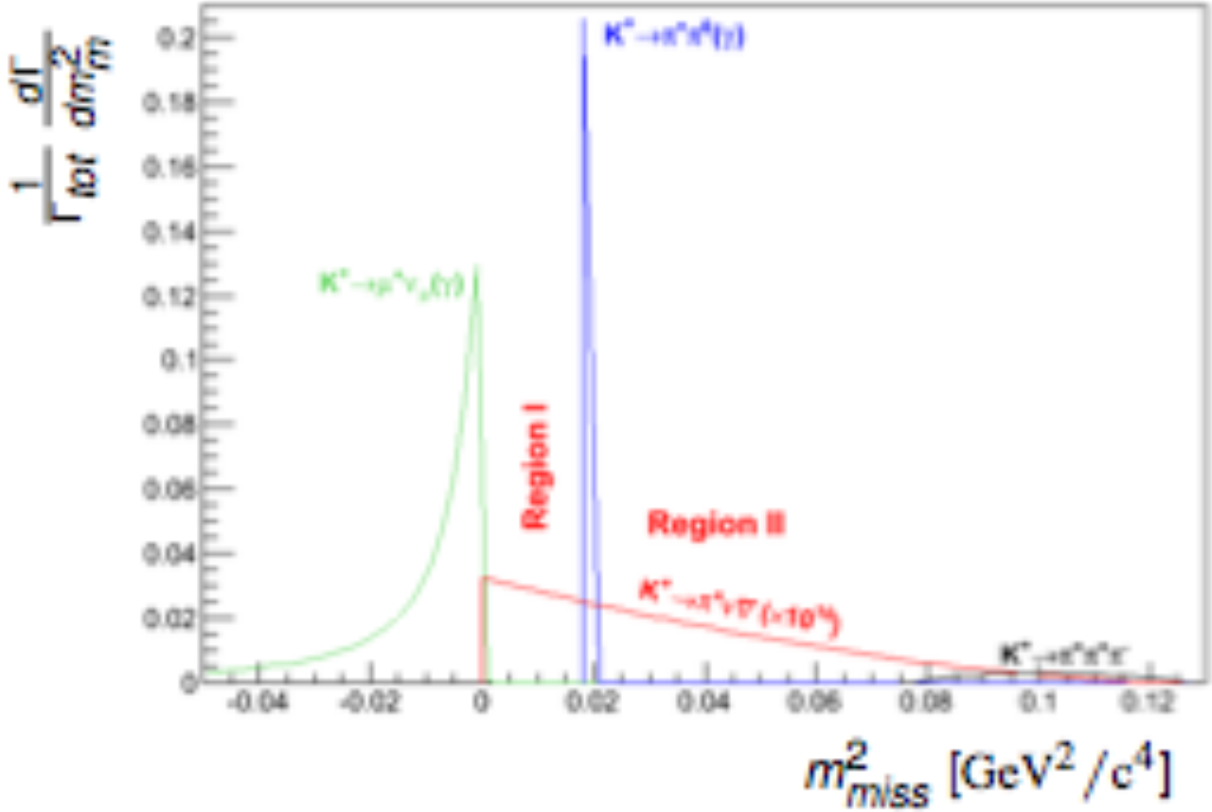
# Technique to select candidates

- **Pion momentum < 35 GeV/c**
- **then > 40 GeV of missing energy*: easy* to detect**



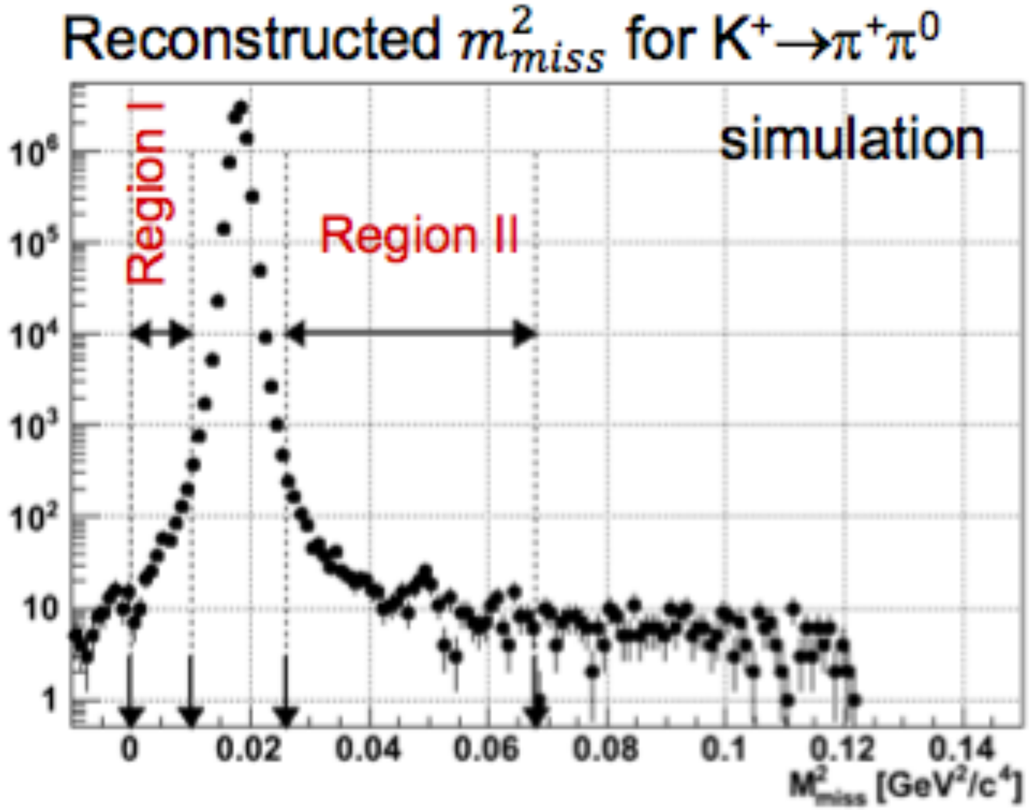

$$m^2_{miss} = \left(p_K^{(4)} - p_\pi^{(4)}\right)^2$$

linear scale

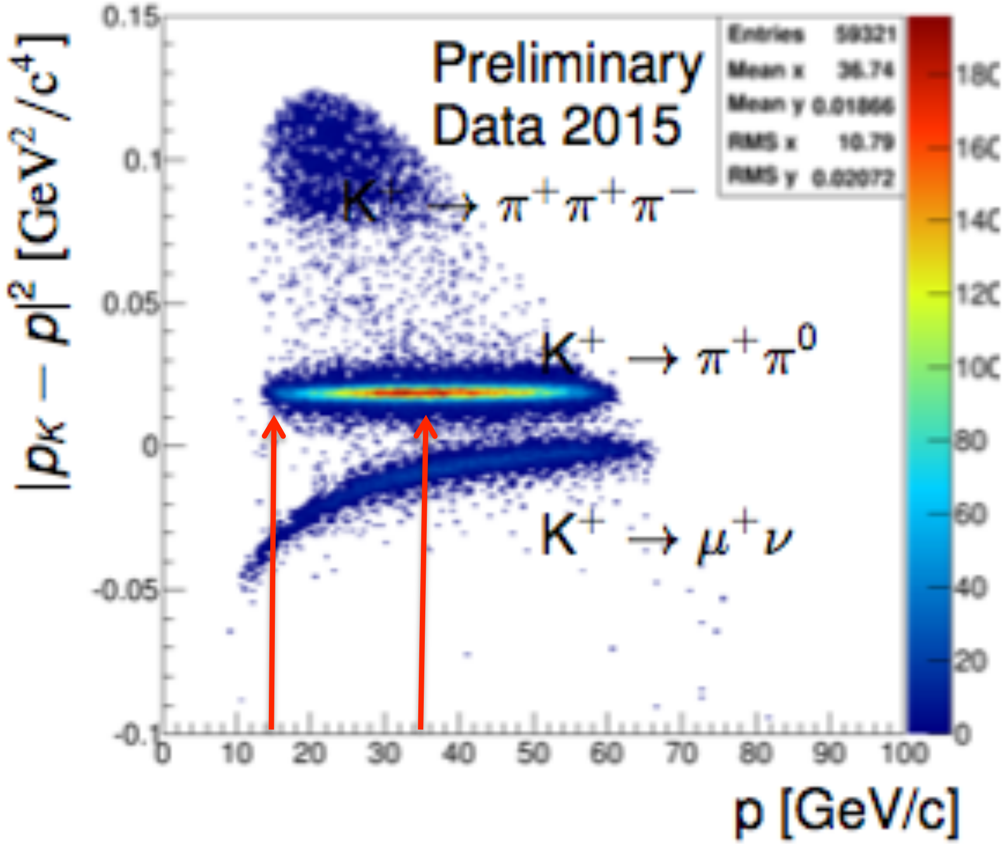



1. Reconstruct missing mass: $m^2_{miss} = |p_K - p_\pi|^2$
   with $15 < p_\pi < 35$ GeV/c
2. Check that $m_{miss}$ stays in Region I or II

## Kinematics rejection




- Kaon track resolution (GTK): 15 μrad
- Pion track resolution (Straws): 20-50 μrad



Preliminary
Data 2015
Entries 59321
Mean x 36.74
Mean y 0.01866
RMS x 10.79
RMS y 0.02072
$K^+ \to \pi^+\pi^+\pi^-$
$K^+ \to \pi^+\pi^0$
$K^+ \to \mu^+\nu$
$|p_K - p|^2$ [GeV$^2$/c$^4$]
p [GeV/c]

# NA62 Further Physics programs

- The main purpose of NA62 is the measurement of the Branching Ratio of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$
- In 2014 the detector was operated to check the performances
- In 2015 we had good periods of stable data taking. Data analysis in underway.
- At nominal beam intensity, we expect to accumulate ≈4.5x10$^{12}$ Kaon decays per year
- With the SM Branching Ratio we expect to accumulate 45 events/year

- Other measurements ( obviously in the Kaon sector) are foreseen as
  - $R_K = \dfrac{BR(K^+ \rightarrow e^+ \nu)}{BR(K^+ \rightarrow \mu^+ \nu)}$
  - Search for Lepton Flavor Violation (LFV)
  - Search for Lepton Number Violation (LNV)

# Conclusions and perspectives

- NA62 at SPS-CERN is aimed to measure the Branching Ratio of $K^+ \to \pi^+ \nu \bar{\nu}$
- The same BR is computed rather precisely in the Standard Model framework to be $(0.911 \pm 0.072) \times 10^{-10}$. Significant deviations would imply a *New Physics.*
- During these two hours, we went in some details through all the components of the NA62 detector analyzing features and giving some results from the commissioning
- We analyzed the *analysis strategies* to isolate candidate events and beat the background
- Stable data taking and large statistics is now necessary to measure the Branching Ratio.