The CHarged ANTIcounter for the NA62 experiment at CERN

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On behalf of NA62 collaboration

Highlights

- The NA62 experiment
- The CHarged ANTIcounter (CHANTI)
  1. Purpose
  2. Requirements
  3. Technological choice
  4. Prototype construction
  5. Measurements
  6. Conclusions

The NA62 experiment

Measure the $K^+ \rightarrow \pi^+ \nu\nu$ B.R. with high accuracy

Physics motivations

Extract the V_{td} matrix element with a ~10 % error

A precise test of SM -> sensitive to new physics

Theory: $(8.5 \pm 0.7) \times 10^{-11}$ 8% error
Experim. $(1.73^{+1.15}_{-1.05}) \times 10^{-10}$ 7 candidates at BNL E787+E949

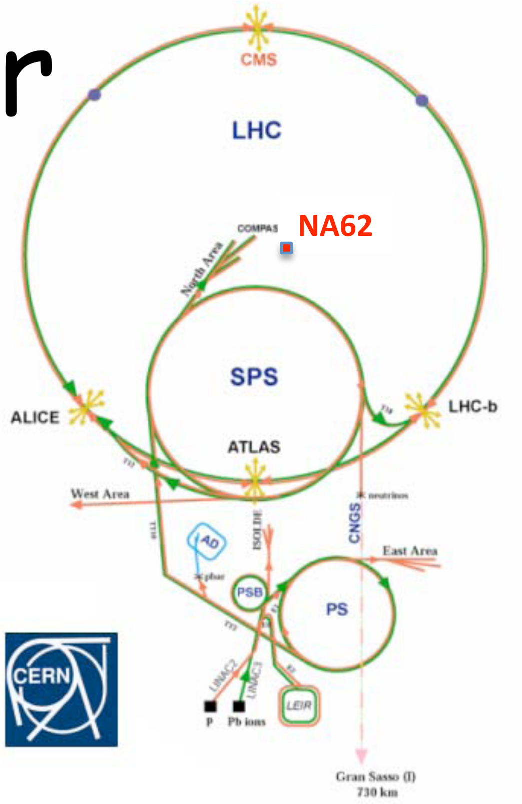
<u>Goal: to collect ~100 decays with S/B ~ 10 (two years)</u>

Signal signature very weak: just one π^+ track
Very low B.R. -> high intensity kaon beam, 10^{12} background rejection power

VETO detectors and redundancy in the background suppression

The NA62 detector

Located at the CERN SPS



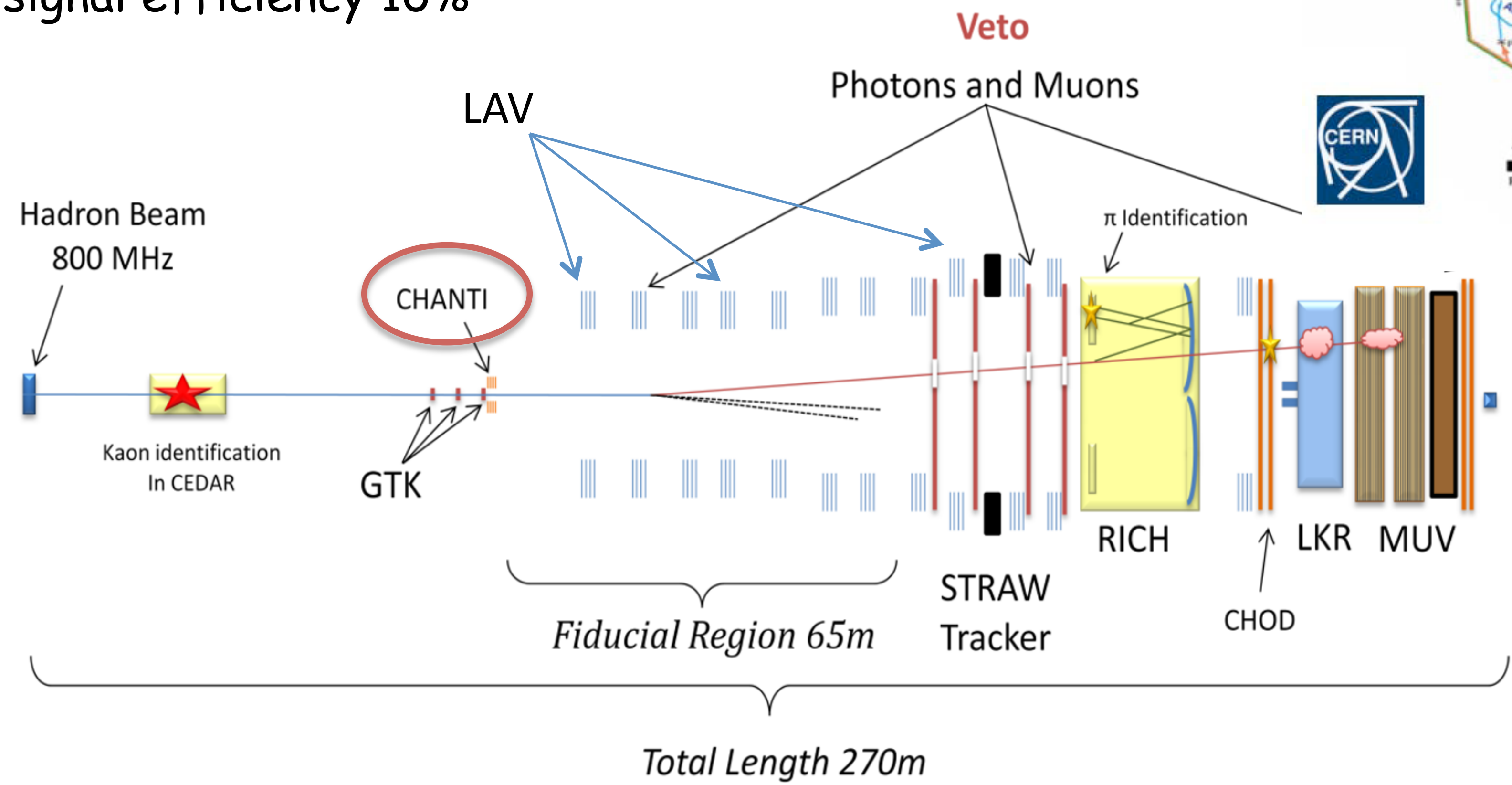
Unseparated Beam:

-> Momentum 75GeV/c

-> Kaon beam percentage ~6%

-> # Kaons decays 4.8×10^{12}/yr (40MHz)

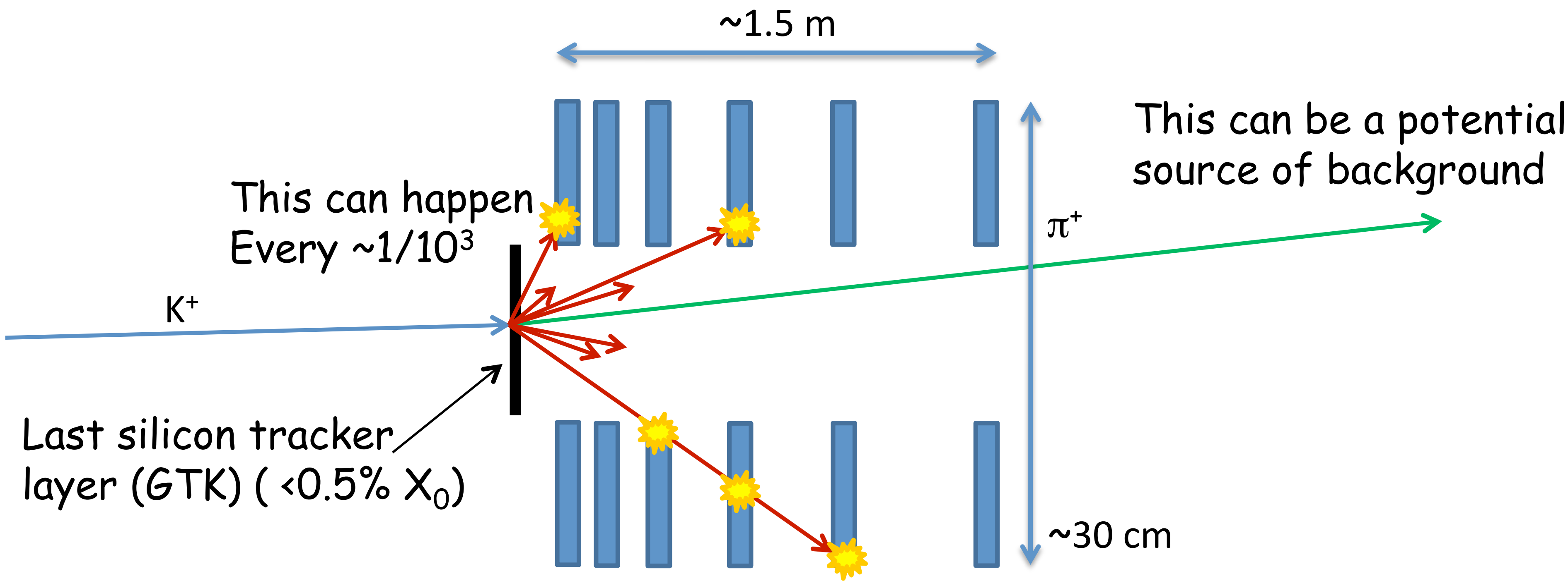
-> signal efficiency 10%



Beginning of DATA TAKING:2013

CHANTI purpose

To reduce critical background induced by beam inelastic interaction with collimator and Si beam tracker



Inelastic interactions can be identified detecting the large angle products using a set of "guard rings"

Six stations allow to cover hermetically the angular region between 34 mrad and 1.38 rad (for interactions coming from the center)

95% of inelastic interactions can be detected by CHANTI.

REQUIREMENTS

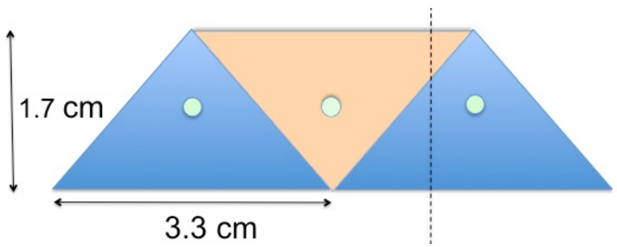
- Good time resolution (1ns)
- Good rate capability (up to some tens kHz/cm^2)
- Low out-gassing (vacuum)
- X-Y coordinate (for timing correction)

Note: the 6 counters can be used as tracker, with few mm spatial resolution, to monitor beam halo muons close to the beam

Technological choice (I)

Scintillator bars with WLS fibers read by Si Photomultiplier

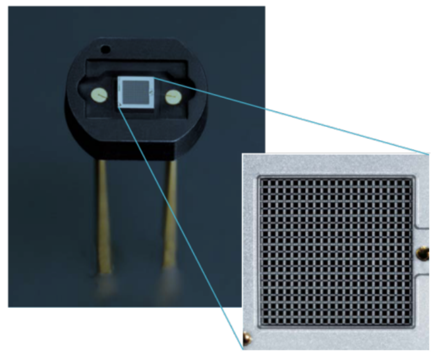
Scintillators: triangular shape for a gap-free and self-sustaining structure
Improve space resolution



WLS fibers: allow the SiPM-scintillator coupling with excellent optical properties

SiPM low power consumption -> fine to operate in vacuum
high rate capability and excellent time resolution

Each station is made of two X-Y layers composed of 22 and 24 scintillators bars
Total number of channels: 276



Technological choice (II)

Scintillator: polystyrene produced NICADD_FNAL by extrusion with 0.25 mm TiO_2 coating and ~1.8 mm hole

Main characteristics:
- Good LY (100% of Kuraray SCSN-81)
- Radiation hardness (5% degradation after 1 Mrad γ)
- Fast response (few ns)
- Low cost

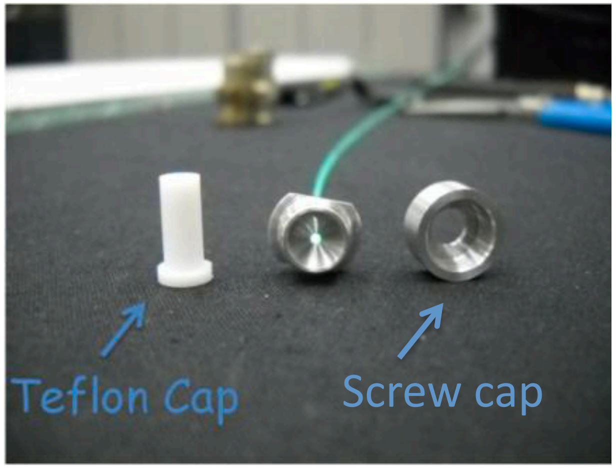
WLS fiber: BCF92 multi-clad: fast emission time (2.7 ns) mirrored at one side.

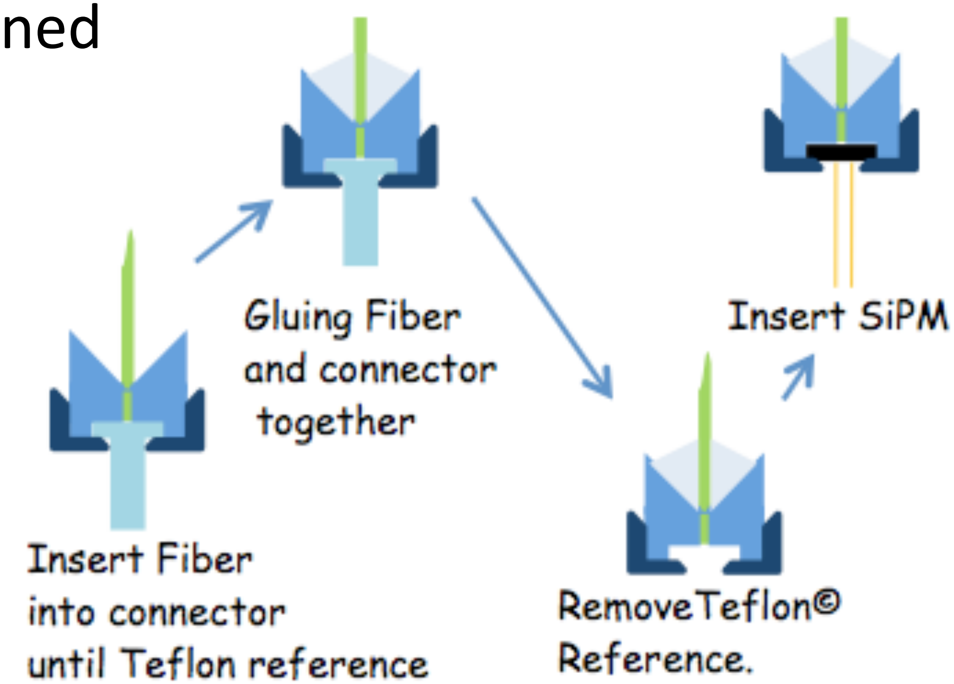
Silicon photomultiplier:

Hamamatsu MPPC S10362 13-50C
- 1.3 mm side
- 50 μm cell side
- Fill factor 61.5 %
- #cells: 676

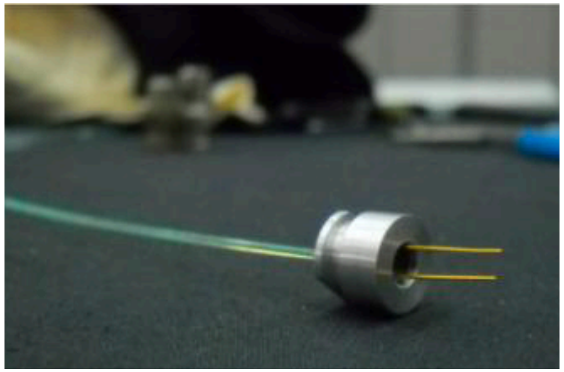
Prototype : the fiber-SiPM connector

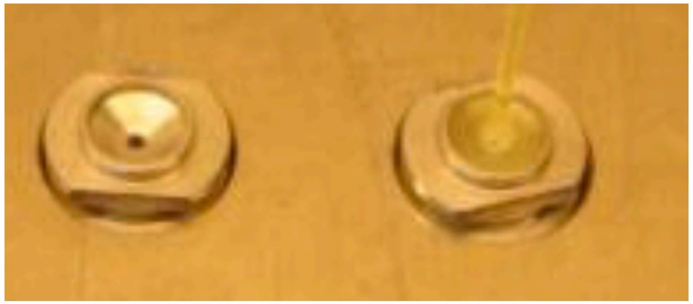
A custom connector has been designed





A Teflon cap define the reference plane for the fiber It used to protect the polished side of the fiber during transport and handling.
Fiber is glued using a small amount of ARALDITE 2011





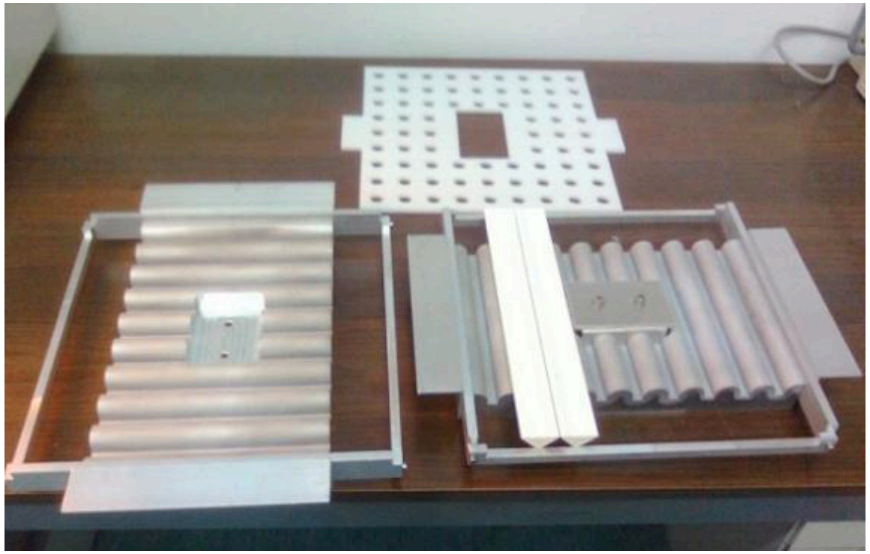
A 50 μm tolerance in the fiber-SiPM coupling is reached

Prototype : fibers-scintillator coupling

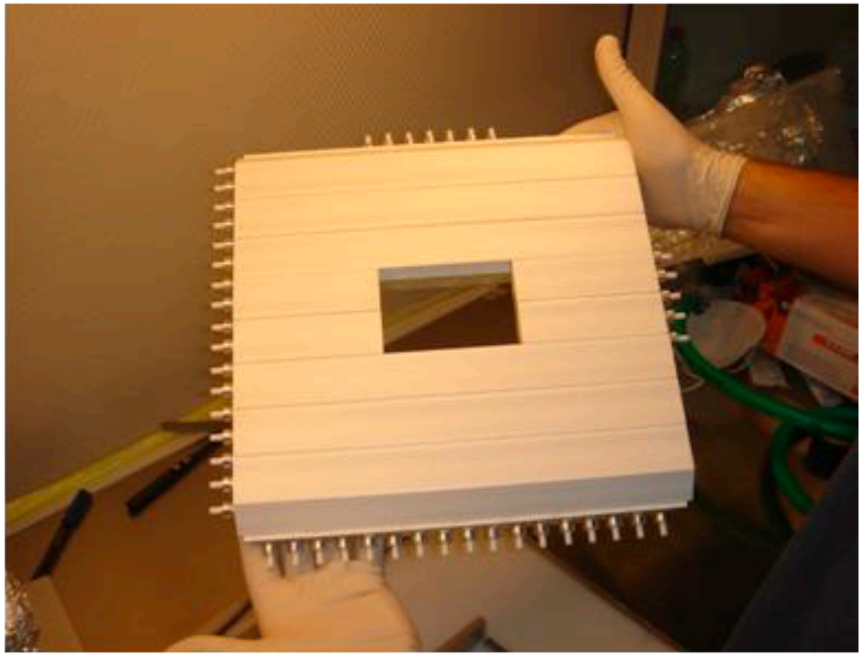
Fibers are glued into the scintillator bars using a low out-gassing SCIONIX Silicon Rubber optical glue, to improve the optical coupling between scintillator and fiber. (~50% improvement)

The glue is injected from the bottom using a syringe to reduce the probability to produce air bubbles.

Prototype assembling



Bars are precisely glued together using a custom reference jig



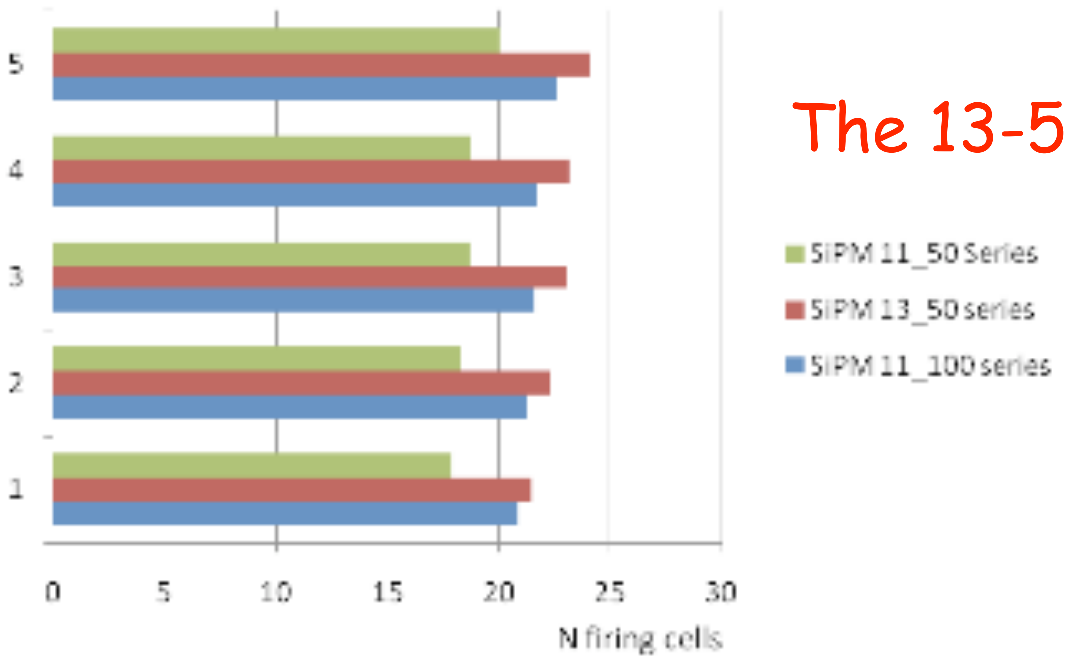
Preliminary measurements

- SiPM model selection
- Photo-electron yield estimation
- Time resolution

SiPM model selection

Three different Hamamatsu MPPC were tested. The number of photoelectron of 5 SiPM of each type was measured using a Sr^{90} source as reference, at the Vop bias voltage

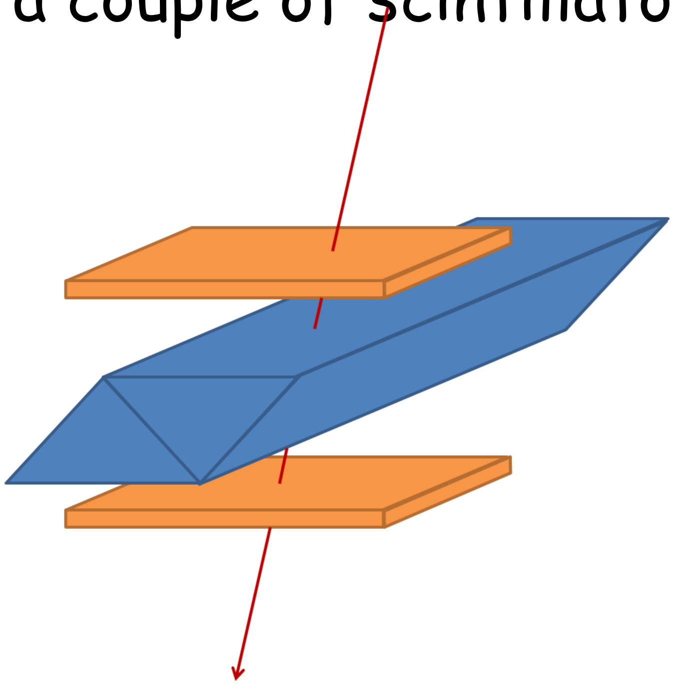
MPPC	Side size (mm)	Cell size (μm)	#cells	Fill factor(%)
13-50	1.3	50	676	61.5
11-50	1	50	400	61.5
11-100	1	100	100	78.5

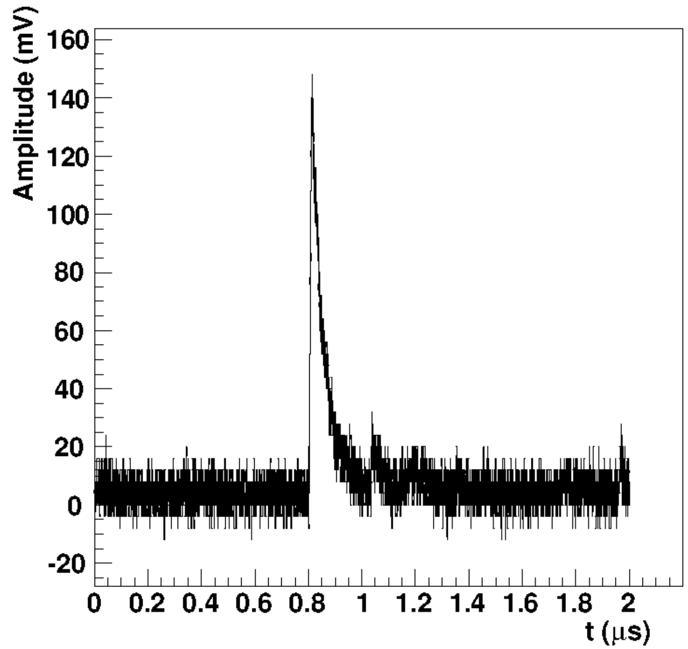


The 13-50 type has the greatest PeY

Photo-electron yield

We selected the response to perpendicular cosmic rays, of a couple of scintillators (plane)



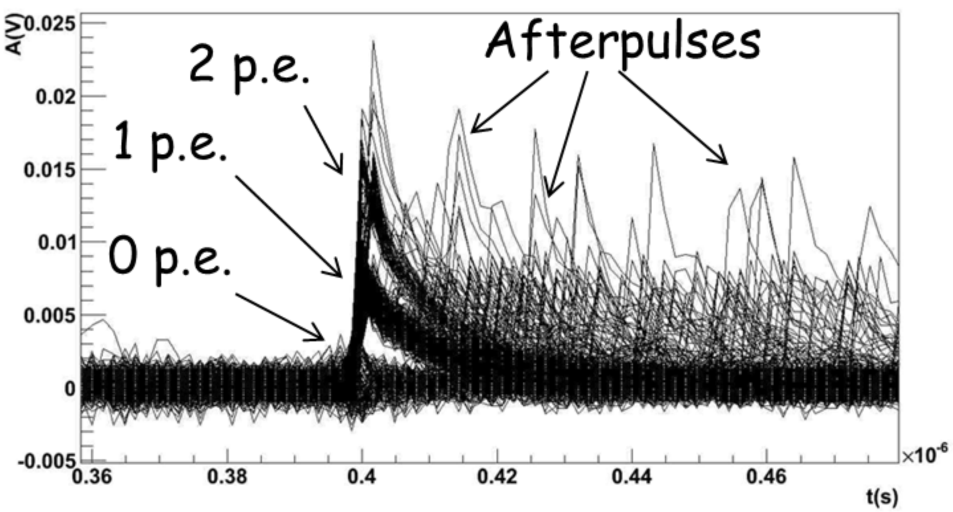


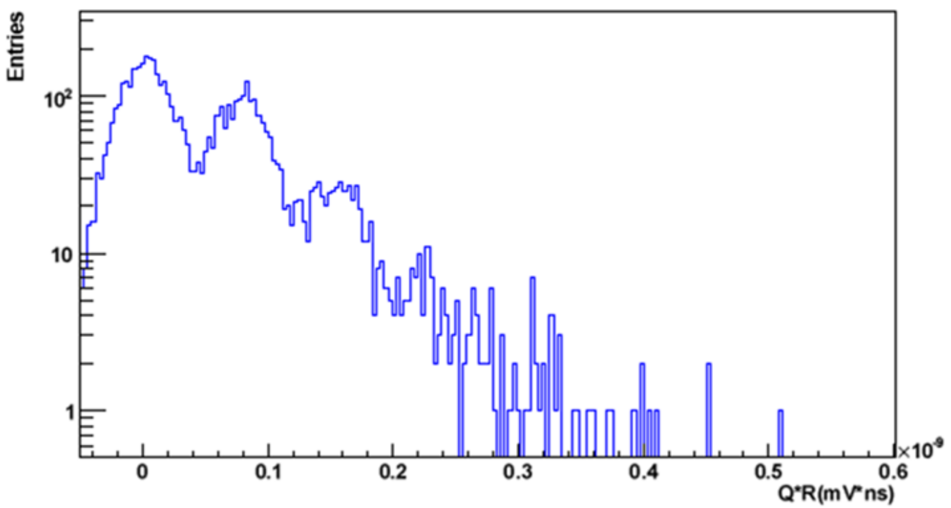
Fast 20X amplification after 1.5 m coaxial cable

NPeY/plane = Npe1+Npe2 = Q1/Q1(1pe)+Q2/Q2(1pe) ~ constant

Dark spectrum

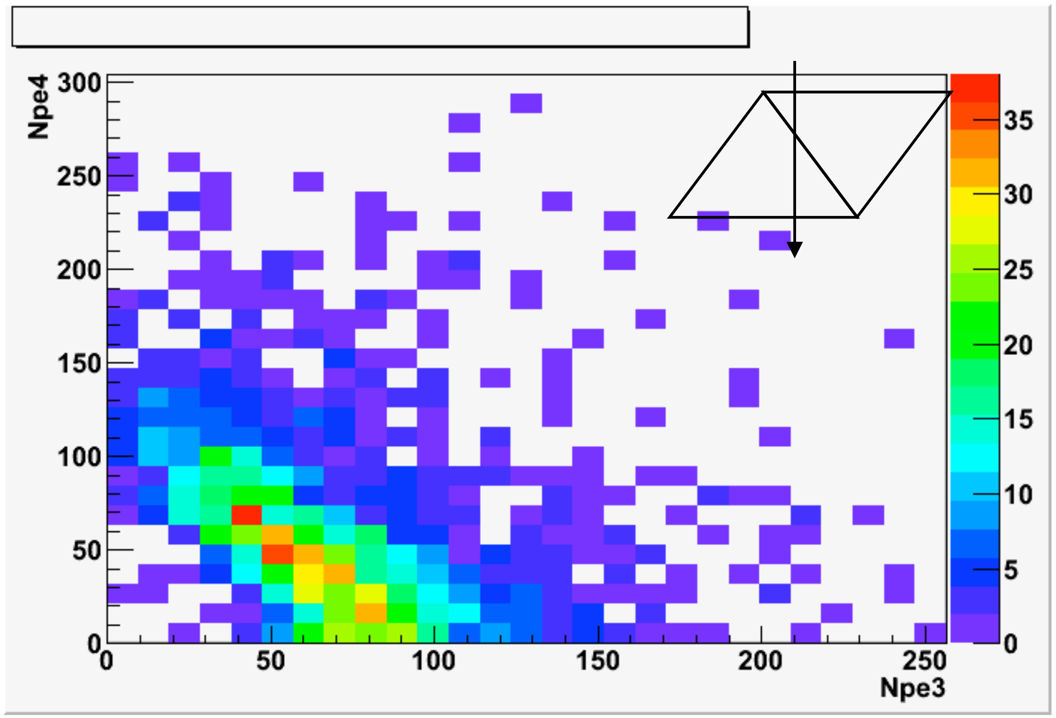
The single photoelectron charge measured using dark spectrum

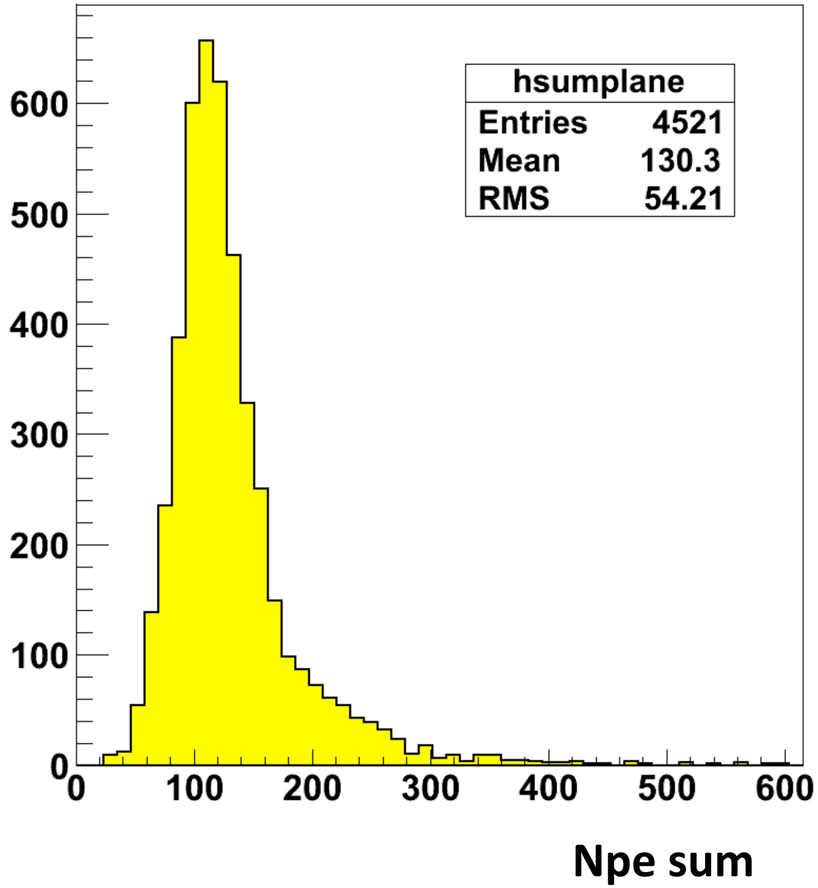




PeY Response

- Clear anti-correlation observed, due to the triangular shape of the bars
- O(100) photoelectrons summing the two bars
- ~25 p.e./ MeV



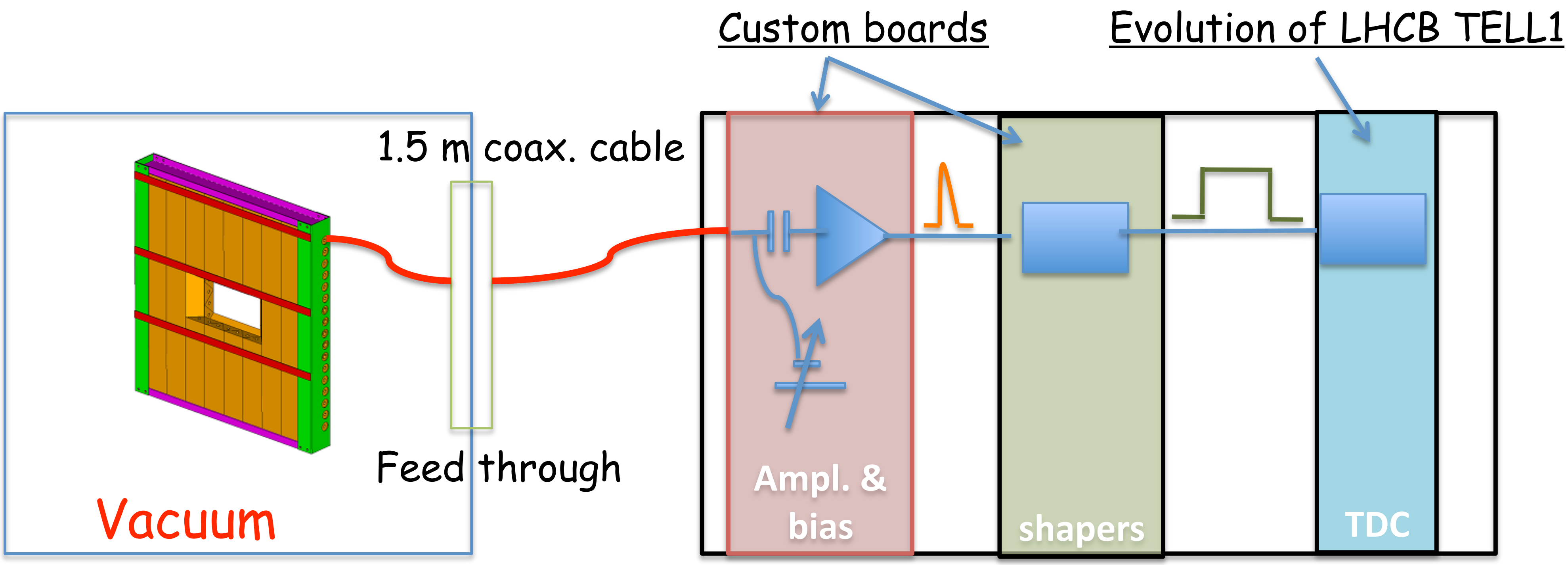


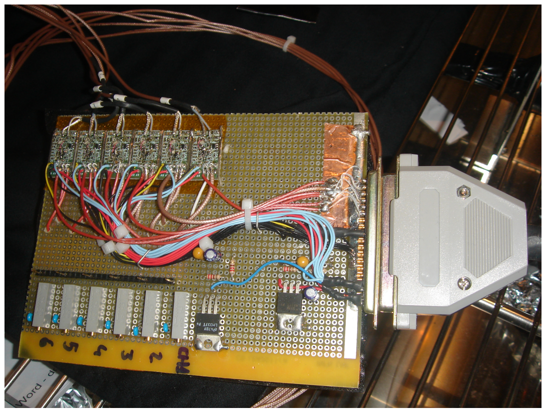
Time resolution

We measured time resolution with an experimental setup similar to the final one:

- Pre-amplification after 1.5 m of coaxial cable (to avoid to insert amplifier inside the vacuum)
- No direct charge but Time Over Threshold available for slewing correction

Front-end electronic in NA62





20 X fast amplifiers &
Individual-adjustable
SiPM bias voltage:
O(mV) resolution
0.1% stability

Time Over Threshold
LVDS shapers

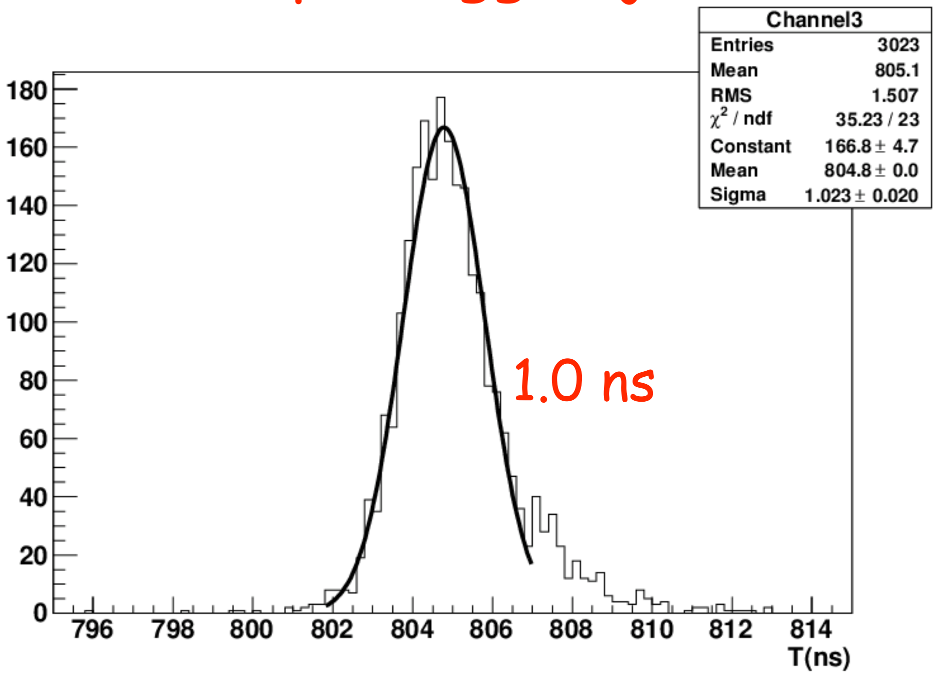
HP-TDC onTELL62
board(512 channels)

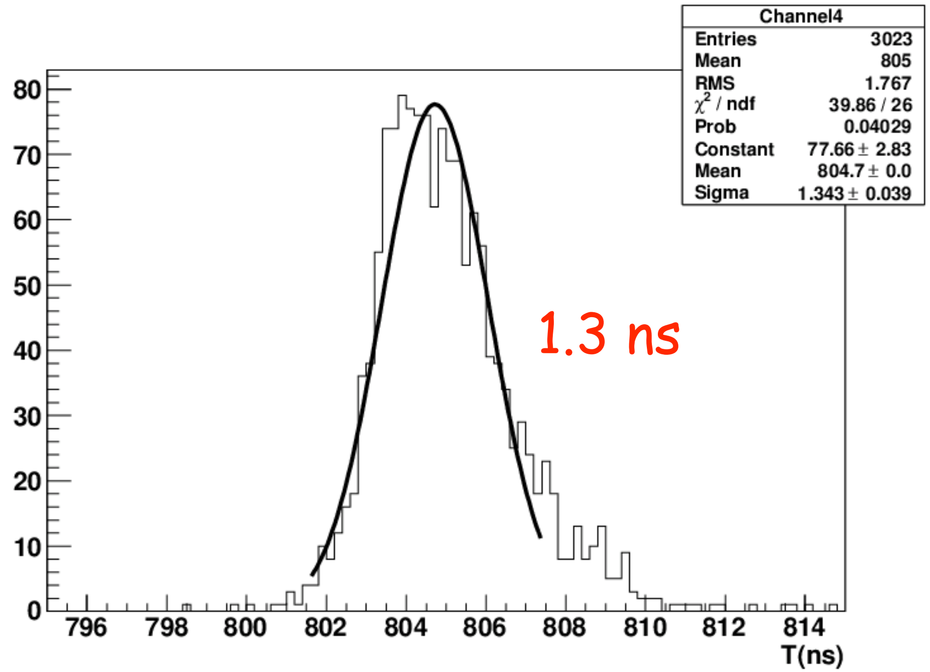
Time resolution raw

We acquired signal with a oscilloscope (5 Gs/s, 500 MHz BW)

Both charge and TOT available, 200 ps resolution

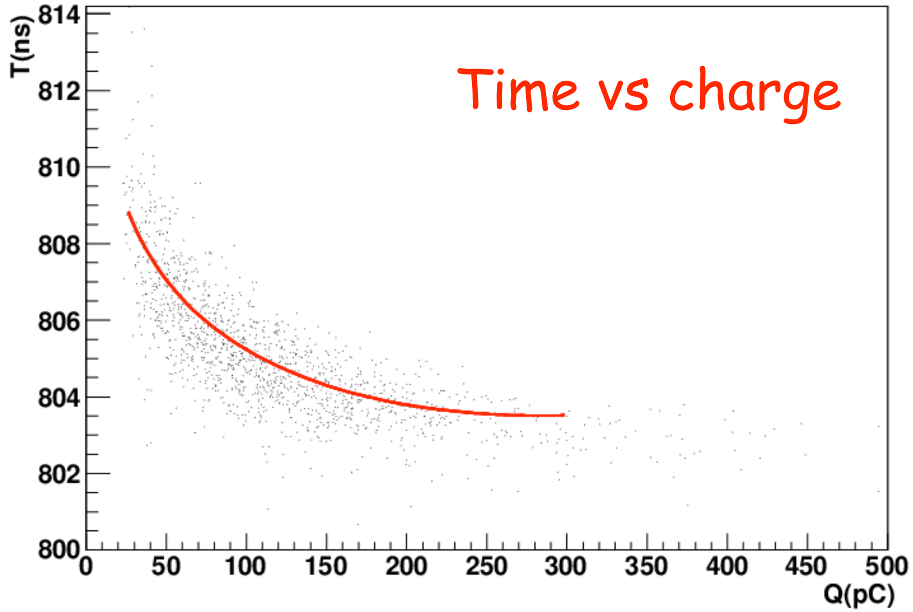
- No time slewing correction
- O(15) pe threshold
- O(400) ps trigger jitter measured independently

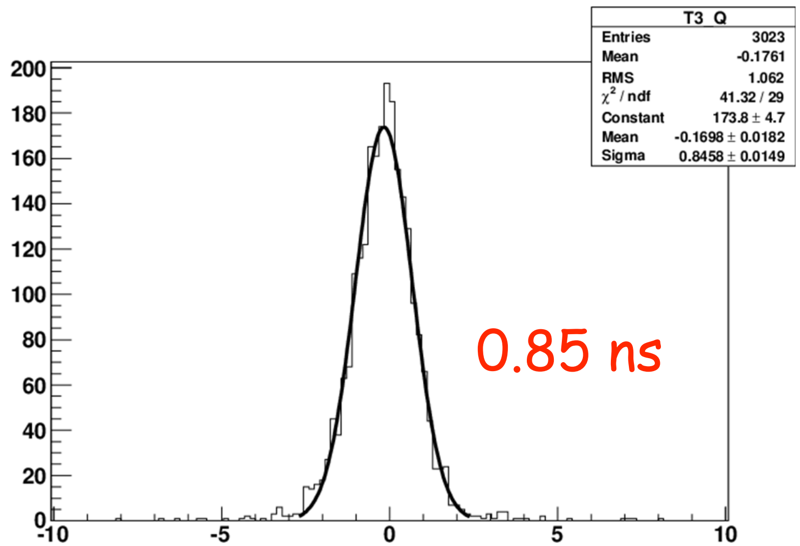


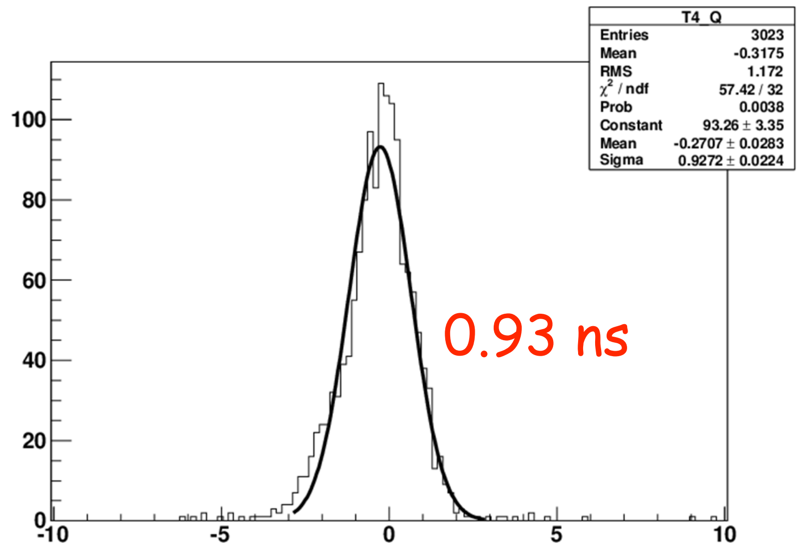


Time slewing correction

- Fit of time vs charge parameterization
- Time correction improves time resolution on single channels

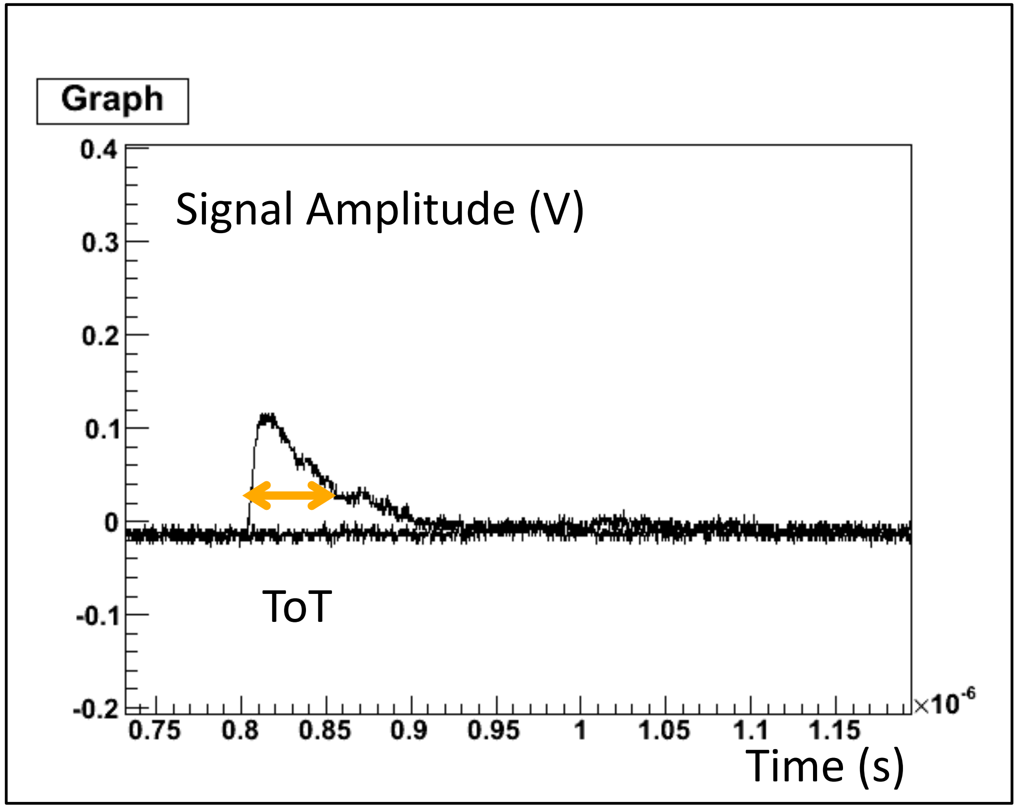


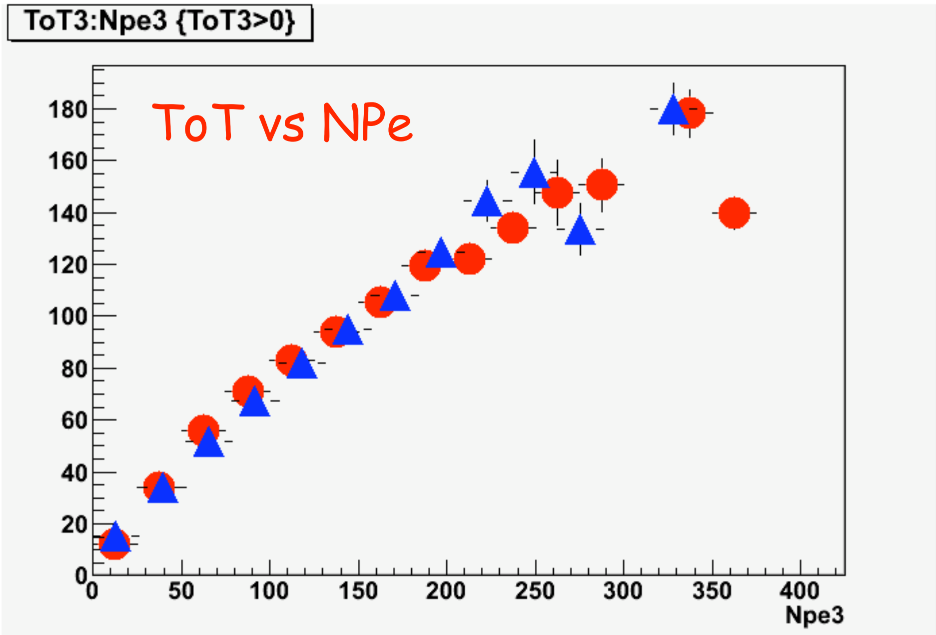




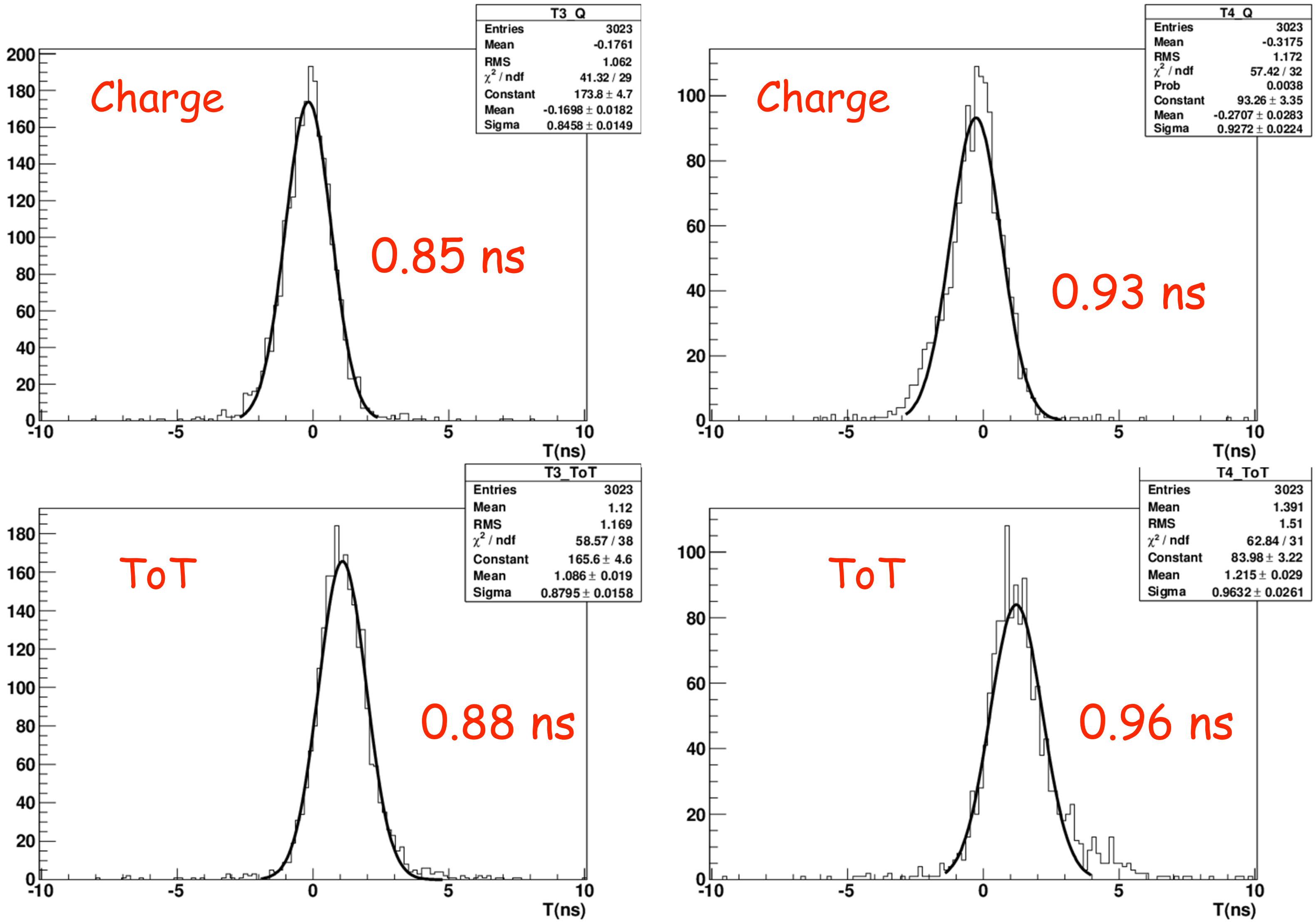
ToT vs Charge

- Software implementation of a ToT with known features of the LNF ToT board
- Checks of ToT vs Q
- Try to use ToT instead of Q to correct for time slewing

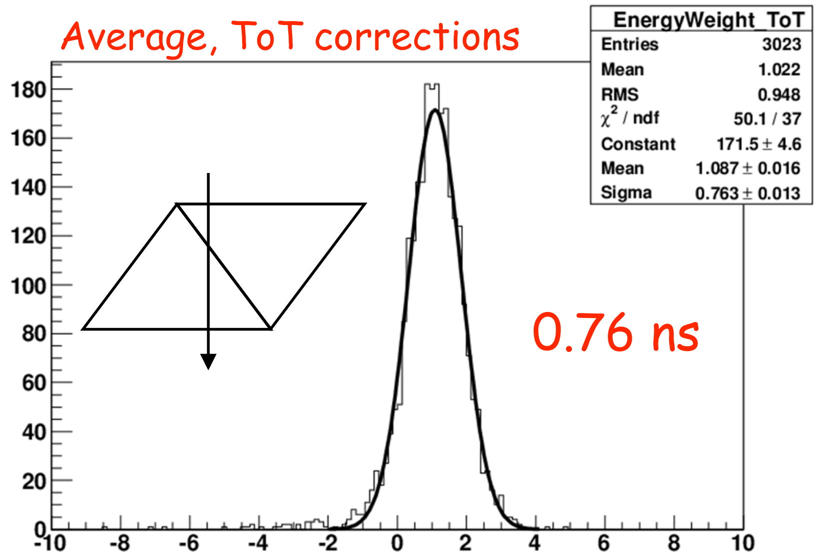


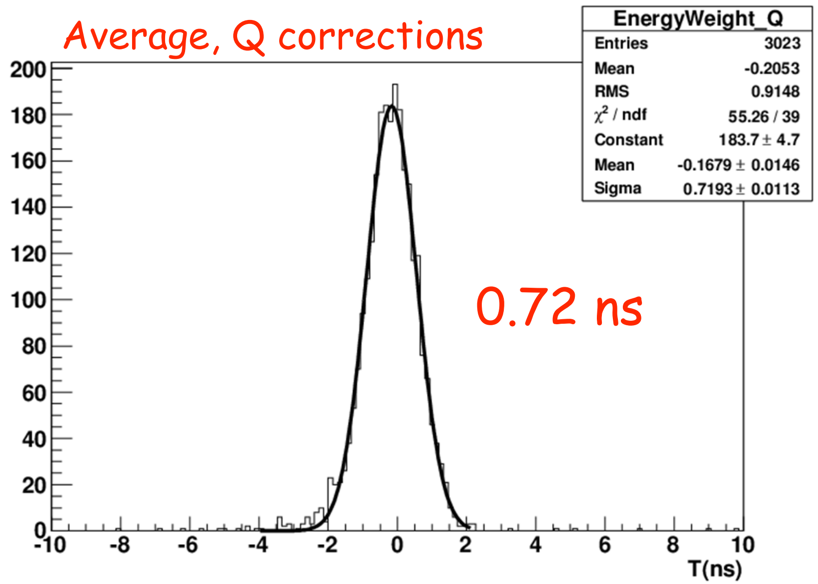


Time resolution: ToT vs Q



Realistic time resolution





- After proper individual channel t0 subtraction time of the event will be given by the first fired channel or by the average.
- Almost same result of using ToT or Q to correct for time slewing
- O(400) ps from trigger not subtracted
- But data taking at fixed position along the bar. Expect 1.5 ns/sqrt(12) = 430 ps if we will not be able to correct for xy position of the hit (e.g. for multiplicity reasons)
- O(750) ps conservative time resolution for the detector

Conclusions

- We designed a detector to veto inelastic background
- A first complete prototype station has been constructed
- The best SiPM type has been chosen
- Measured “realistic” time resolution is 750 ps, better than needed
- Out-gassing measurement show out-gas rates compatible with vacuum requests
- Electronic prototype board successfully tested

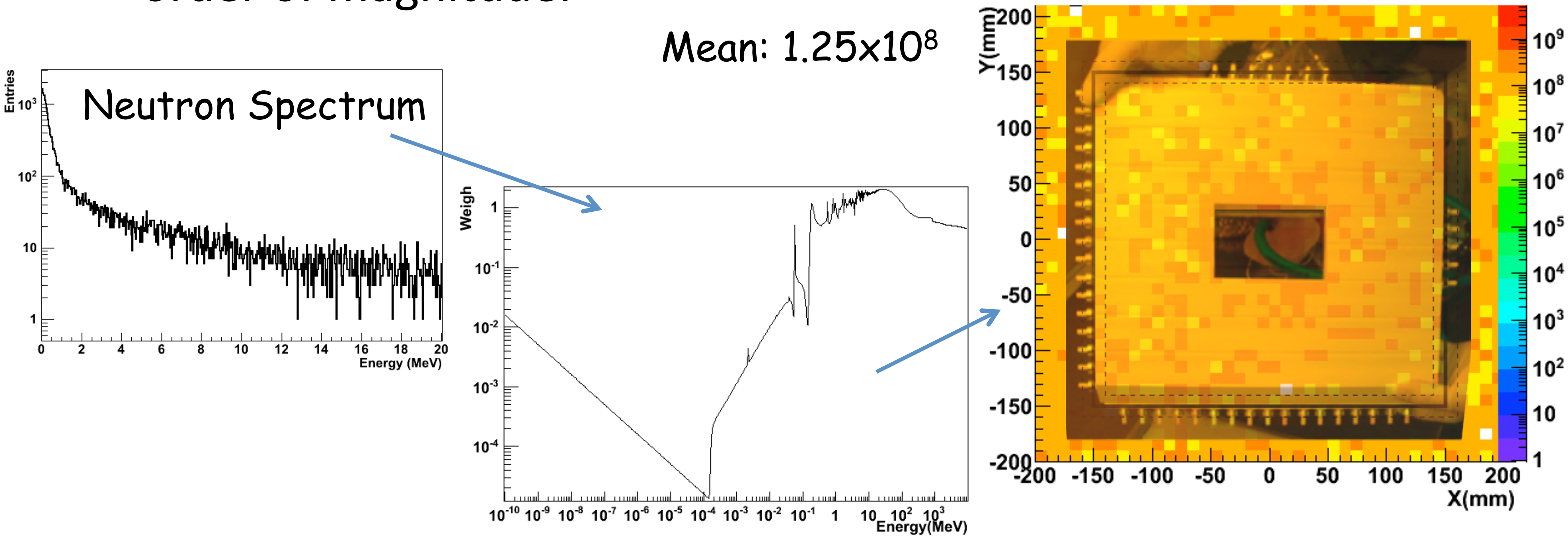
Spares

Radiation hardness

By Monte Carlo simulation we estimate the two main neutron contributions: primary protons on the target and from inelastic interactions with GTK. We expect 10^8 $n_{eq}/cm^2/yr$ from each

From literature an integrated flux of $4x10^8$ n_{eq}/cm^2 is known to be acceptable.

Reaching I.F. of 2-3 $x10^9$ n_{eq}/cm^2 increase the dark current of one order of magnitude.

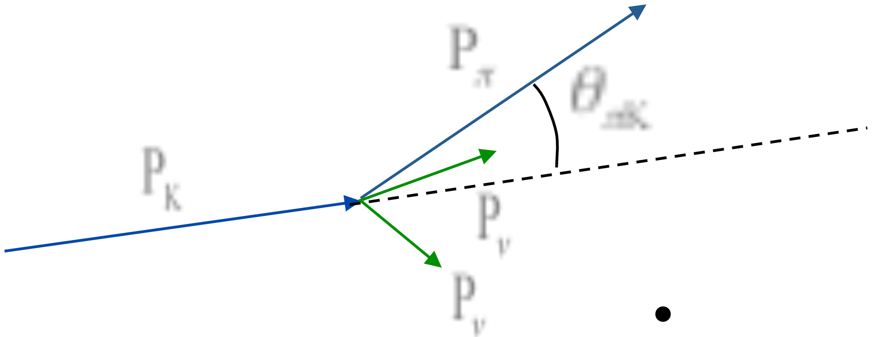


Measurement strategy

- **in flight decay technique, high momentum kaons**
  → no beam background w.r.to stopping kaon experiments
  → improvement in the π^0 induced background
- **kinematical reconstruction → two and tree body bk supp**
- **precise timing → to match the π^+ with the right K^+**
- **almost hermetic photon vetos → π^0 rejection**
- **particle id. → K/π (primary beam) and π^+/μ^+ (final decay)**

1. Kinematic rejection: GTracker, Straw Chambers Spectrometer
2. Precise Timing: Cedar, GTracker, Rich
3. Photon Vetos: ANTI 1-12,LKr cal.,SAC,IRC
4. PId: Rich, Cedar, muon Veto

Kinematic reconstruction



$$m^2_{miss} \cong m^2_K\left(1-\frac{|P_\pi|}{|P_K|}\right)+m^2_\pi\left(1-\frac{|P_K|}{|P_\pi|}\right)-|P_K||P_\pi|\theta^2_{\pi K}$$

Requirements:

- low mult. scattering

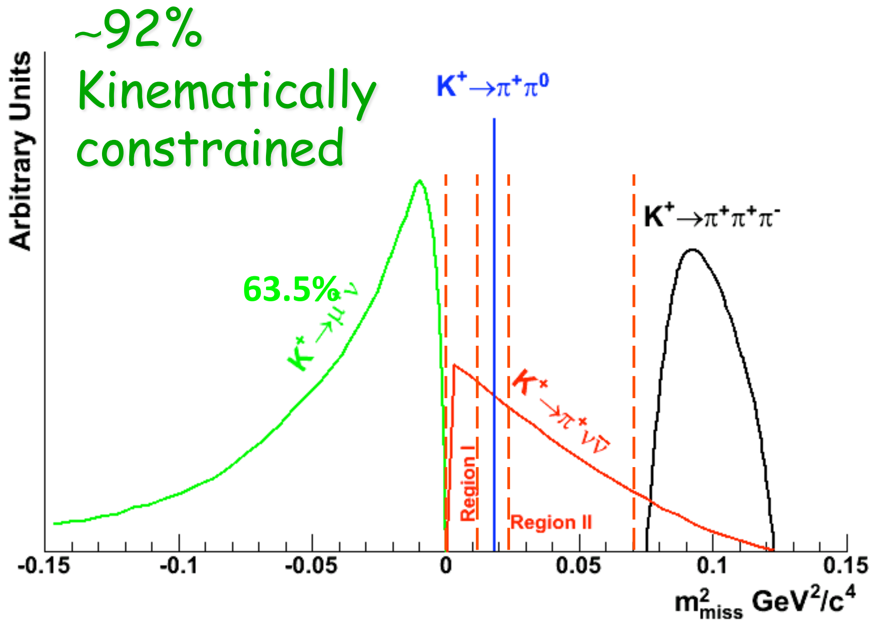
→ low mass tracker operating in vacuum

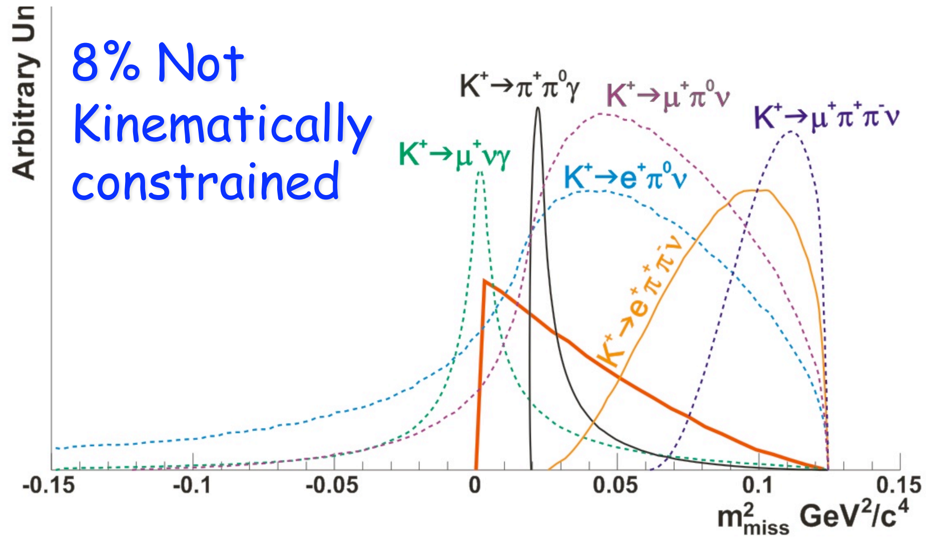
- good space resolution (~100 μm)

Detectors:

- GigaTracker
- Straw Chamber Spectrometer

two bk free regions





Particle Identification and photon VETO

Rejection factor needed: 10^{12}

Table of rejection factors for two body decays

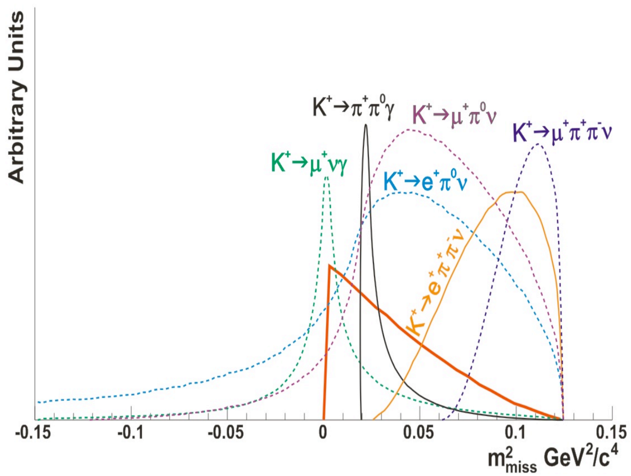
decay	R.F.
$K^+ \rightarrow \pi^+\pi^0$	10^4
$K^+ \rightarrow \mu^+\nu$	10^5

high efficiency detectors:

Photon veto: for **$K^+ \rightarrow \pi^+\pi^0$ supp.**

RICH and MUON VETO
for muon suppression

Not constrained decays (8%)



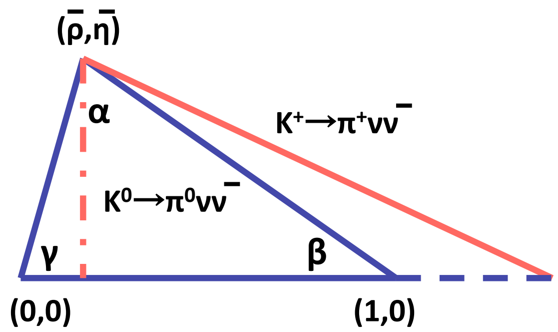
other possible source of background:

- ***beam related***
- ***beam interaction with the last GT station or with the residual gas***

Relevance of a precise measurement

1) Extract the V_{td} matrix element with a ~10 % error

2) Accurate determination of unitarity triangle independent of that executed within the B system

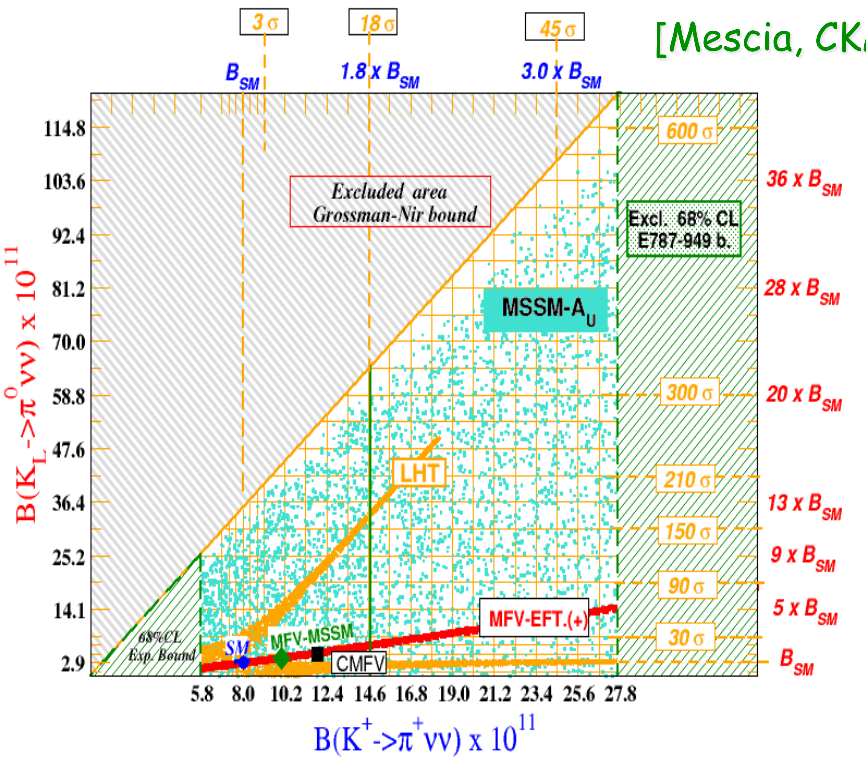


If LHC discovers new particles the BR measurement will provide a very helpful tool to discriminate among different models

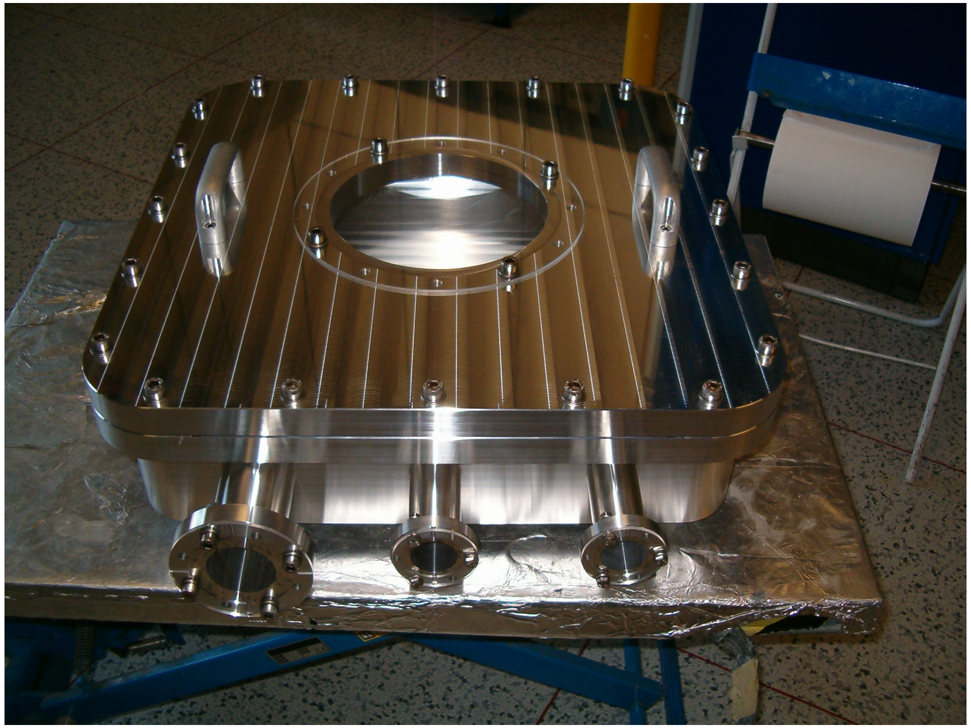
A precise test of SM -> sensitive to new physics

New physics effects could be seen without significant signals in $B_{d,s}$ decays and, in specific scenarios, even without new particles within the LHC reach

[Mescia, CKM06]



Vacuum tests

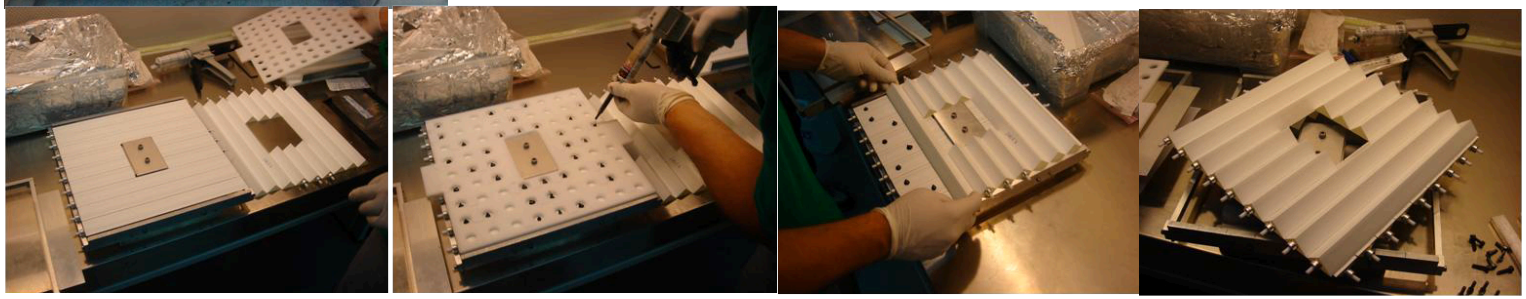


The prototype was tested under vacuum

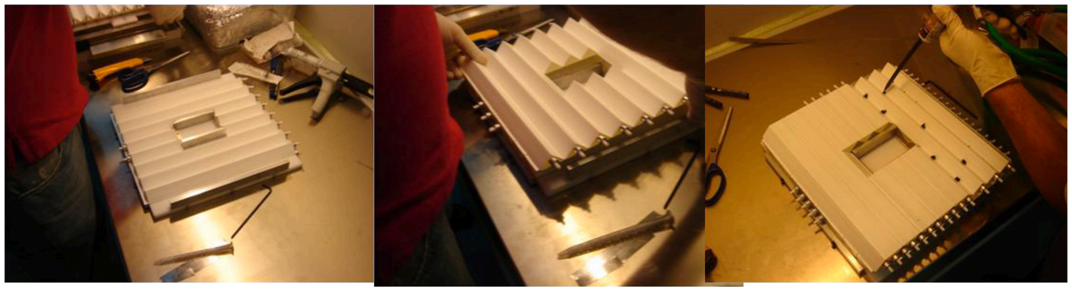
The results are compatible with the NA62 out-gas limit

Prototype assembling

Once all the bars are produced, they are glued together forming two layers with fibers running perpendicularly



FIRST DAY



Second day