# Performances of the NA62 RICH Detector

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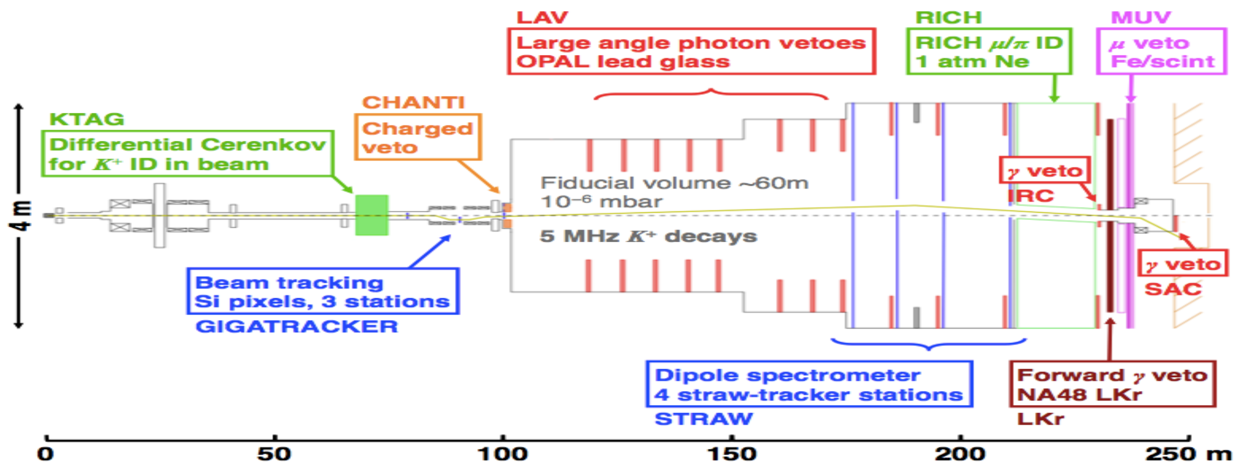
ICHEP2016CHICAGO

38th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS
AUGUST 3 - 10, 2016
CHICAGO

# The NA62 Challenge

(for more details see the talk of M. Moulson in the Quark and Lepton Flavor Physics parallel session )

Measure the BR of the ultra-rare Kaon decay $K^+ \to \pi^+ \nu\bar{\nu}$ with 10% accuracy collecting ~100 SM events in 3 years of data taking

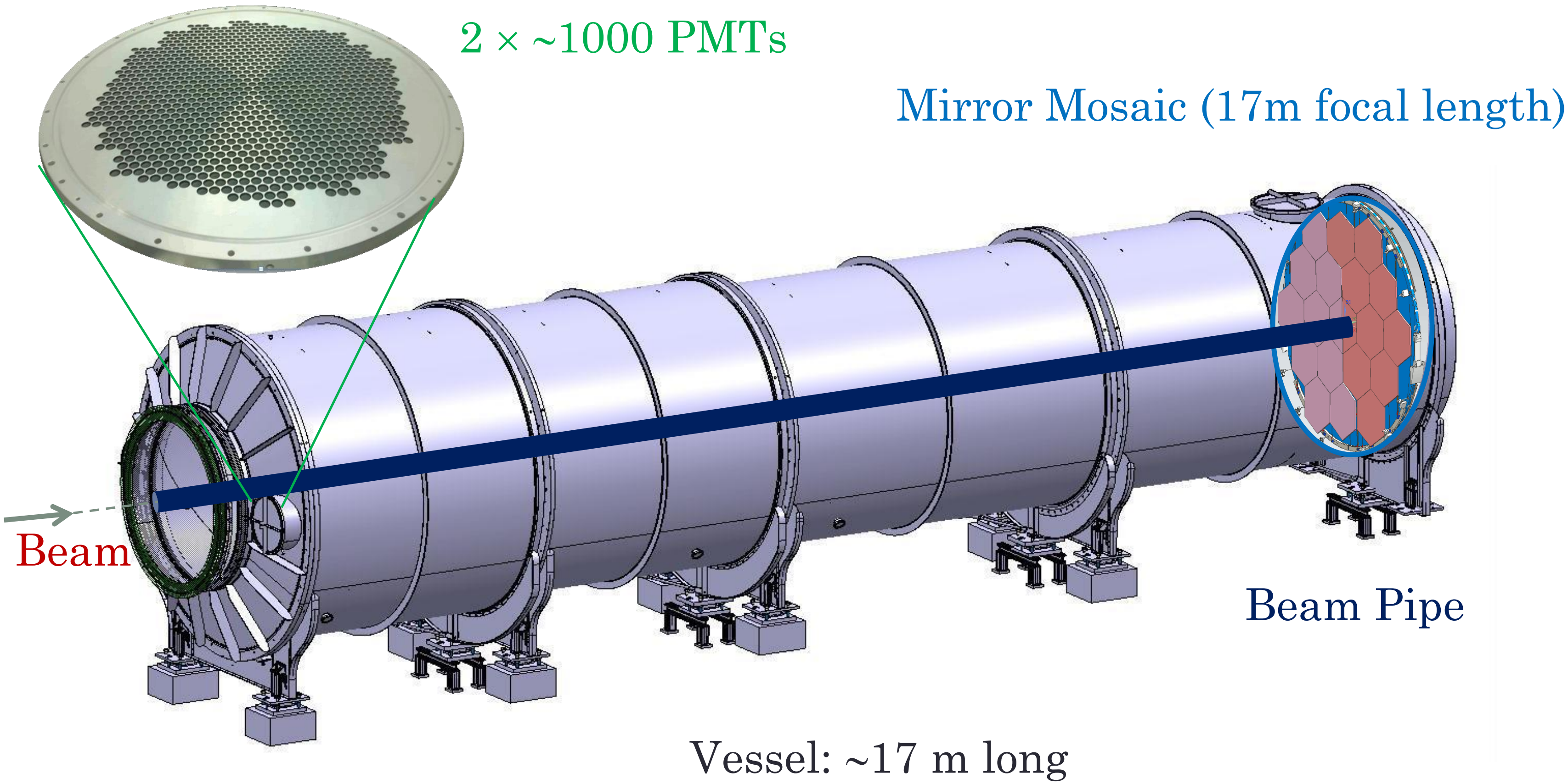



$BR_{SM}(K^+ \to \pi^+ \nu\bar{\nu}) = (8.4 \pm 0.6) \times 10^{-11}$

[Buras et al. arXiv:1503.02693], [Brod et al. Phys. Rev. D 83,034030 (2011)]

Suppression of decay channels with BR $\geq 10^{10}$ $BR(K^+ \to \pi^+ \nu\nu)$ and similar experimental signature: $BR(K^+ \to \mu^+ \nu) = 63.4\%$

# THE RICH DETECTOR

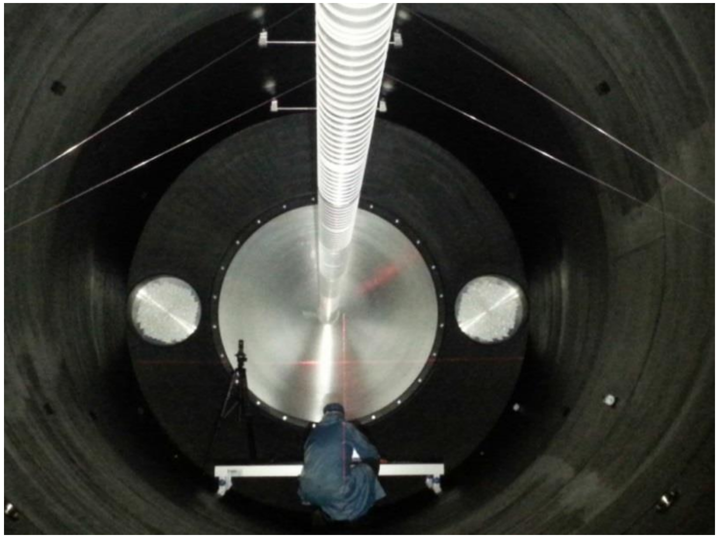



- μ contamination in the π sample ≤ 1% between 15 and 35 GeV/c
- measurement of the π crossing time with a resolution ~100 ps
- L0 trigger for a charged track

# VESSEL AND RADIATOR

RICH vessel has an overall volume of 200 $m^3$

- Vacuum proof tank 17 m long in structural steel
- 4 cylindrical sections of decreasing diameter (4→3.4 m) and different lenghts
- beam pipe (∅ 168 mm) going through
- thin Al entrance and exit windows



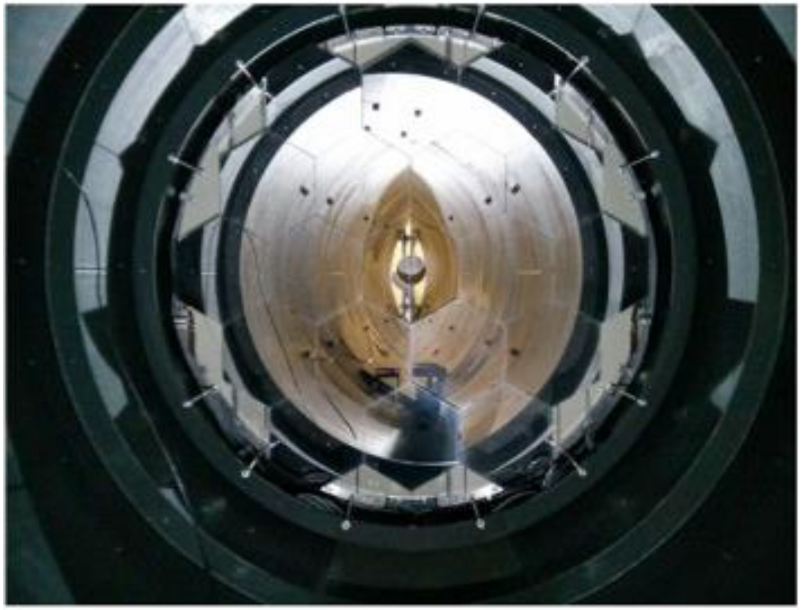
- Neon slightly above $p_{atm}$
- $(n-1) = 62.8\times10^{-6}$ at $\lambda = 300$ nm
- $p_{threshold} =$ 12.5 GeV/c for $\pi$
- good light trasparency
- low chromatic dispersion

RICH performances rather immunes to impurities: no gas renewal

# MIRROR LAYOUT

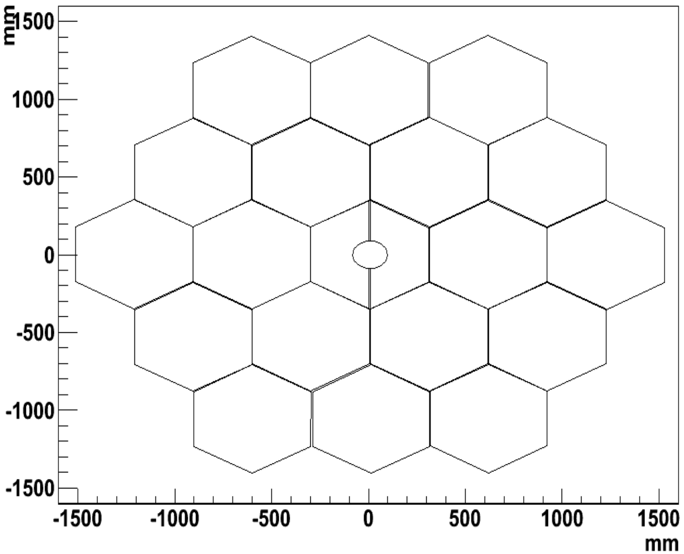
A mosaic of 20 spherical mirrors used to reflect the Cherenkov light

- 18 hexagonal mirrors (35 cm side)
- 2 semi-hex with pipe hole



2.5 cm thick glass coated with Al

Thin dielectric film added



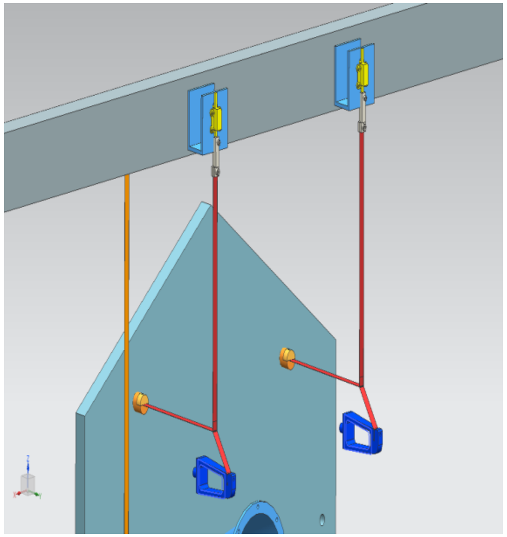

Optical parameters

- R=(34.0±0.2) m
- Average reflectivity ~ 90% (195-650 nm)
- $D_0 \leq 4$ mm

# Mirrors Support and Alignment System

Al honeycomb structure, 5 cm thick, divided in two halves

- Mirrors supported by a dowel inserted in the back of the mirror
- Two aluminium ribbons keep the mirror in equilibrium and allow its orientation
- A third vertical ribbon is used to avoid mirror rotations



Piezo motors allow a remotely controlled orientation



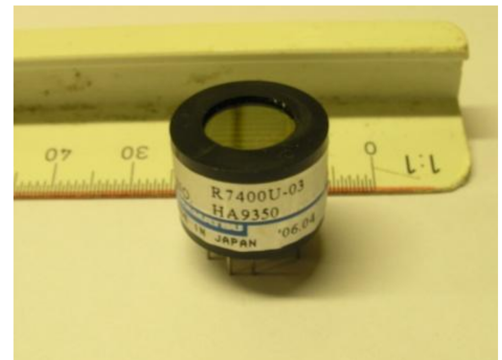
F. Bucci

# Photo-Detection System

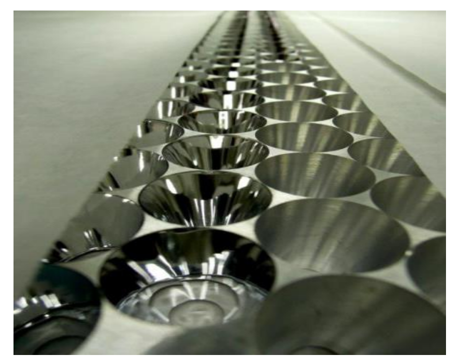
Reflected light is collected by 1952 PMTs with 18 mm pixel size

PMTs are assembled in a compact hexagonal packing

- Hamamatsu R7400U-03
- UV glass window, 16 mm ∅ (8 mm active ∅)
- Custom made HV divider
- Sensitivity range 185-650 nm (420 nm peak)
- Gain $1.5\times10^{6}$ at 900 V
- Q.E. ~ 20% at peak
- 280 ps time jitter (FWHM)




- Winston cones with aluminized mylar foil used to optimize light collection
- Quartz windows separate neon from air

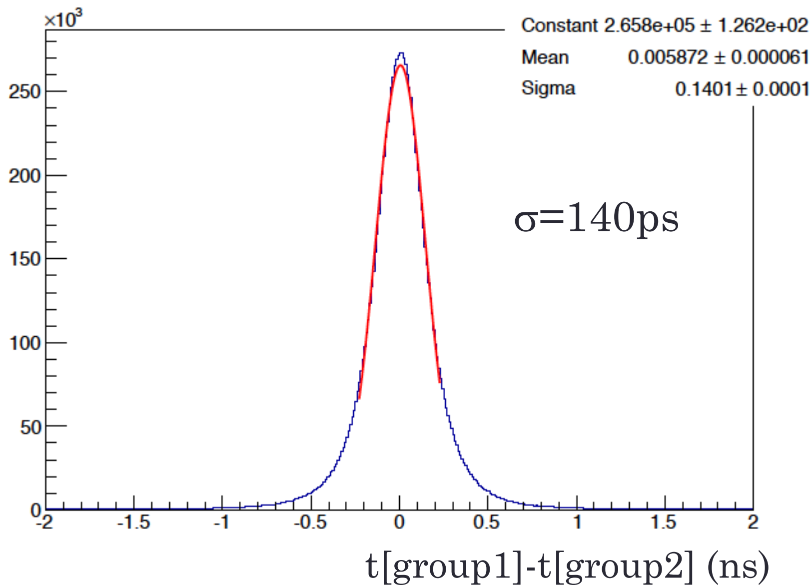


The RICH TDAQ system is based on custom made FE boards and Tel62

# Time Resolution

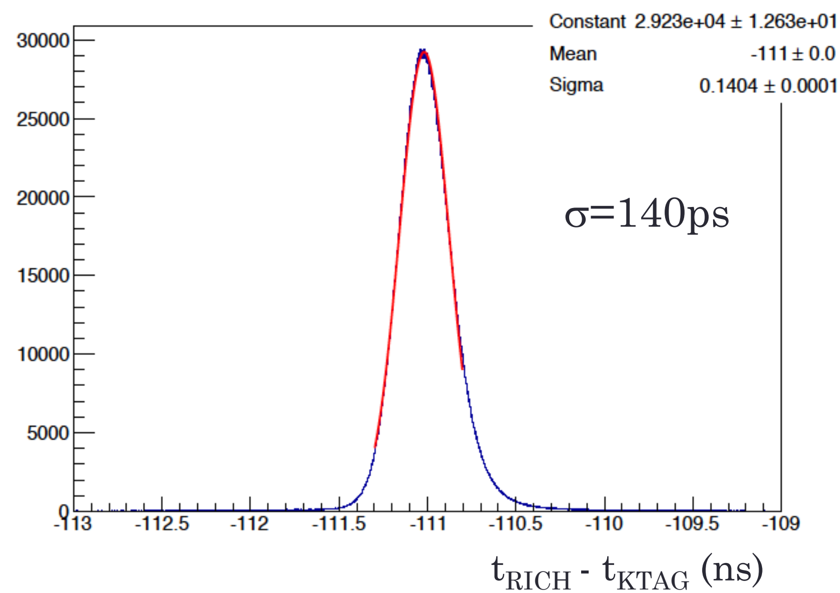
The RICH event time resolution is ~ 70 ps

The intrinsic RICH time resolution




- Detected photons of one Cherenkov ring are divided in two groups
- Time difference of each group is plotted
- Time resolution of the full ring is ~0.5× σ

Time difference btw the average time of a Cherenkov ring and the KTAG time

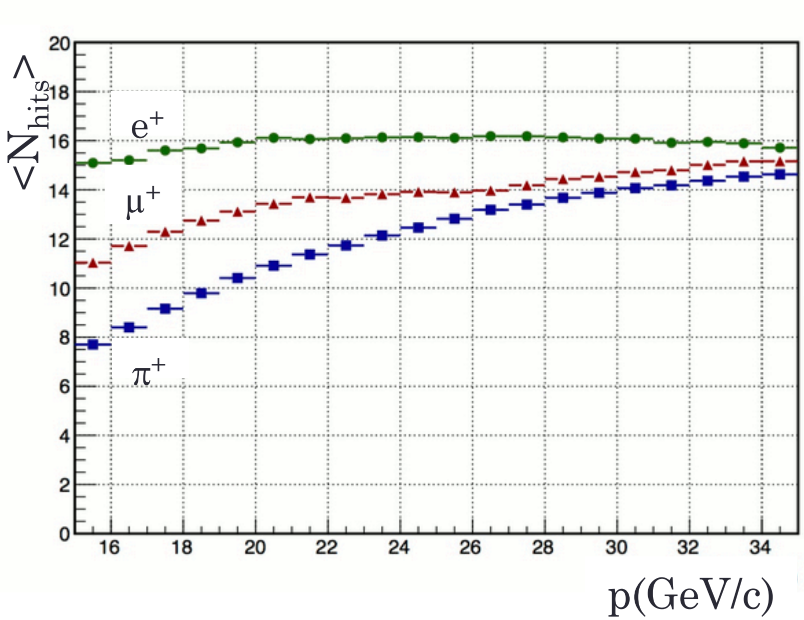



Remaining systematic uncertainties in the time offsets

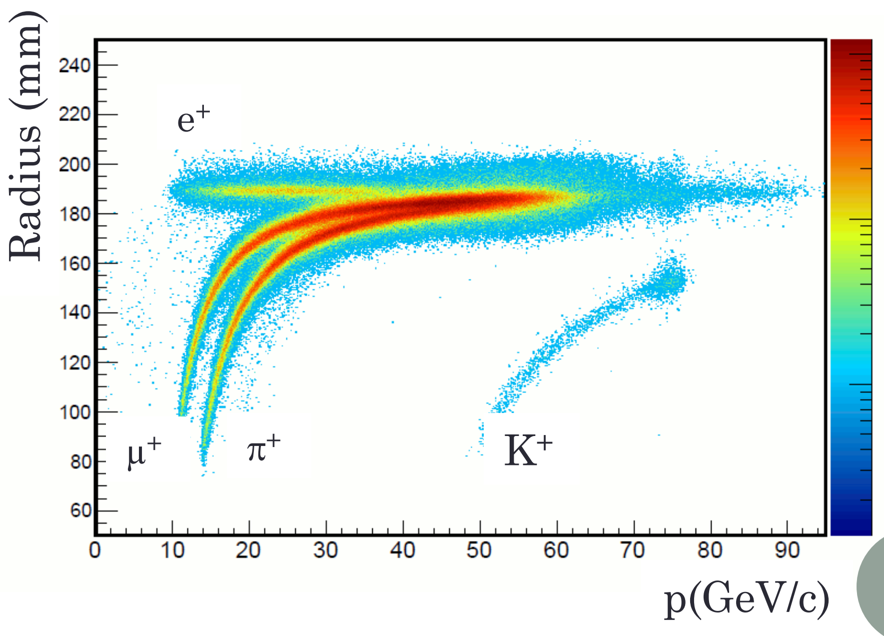
# RICH Particle Identification

Samples of charged pions, muons and electrons selected using calorimetric and spectrometer information

Number of hits per Cherenkov ring as a function of particle momentum



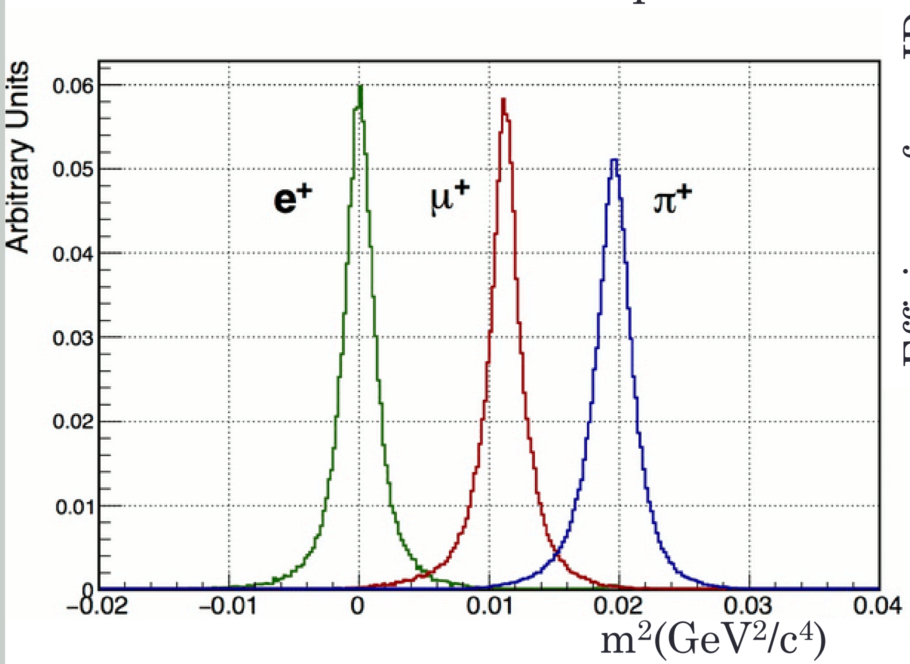

The Cherenkov ring radius as a function of momentum



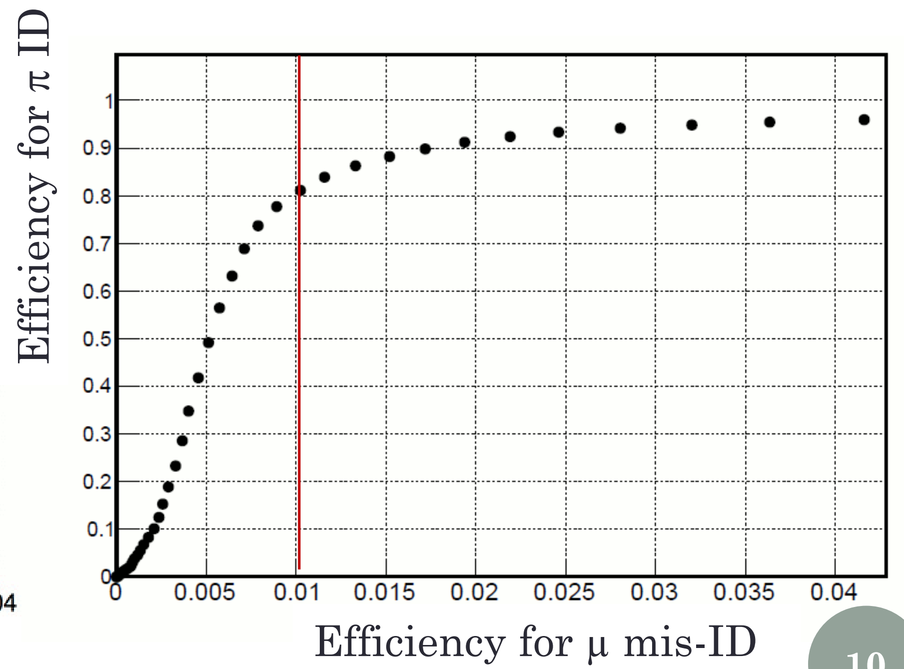
# π-M Separation

For 80% π ID efficiency a 1% μ mis-ID efficiency is observed

Squared particle mass reconstructed using the velocity from the RICH and the momentum from the spectrometer




Pion identification efficiency as a function of muon mis-identification



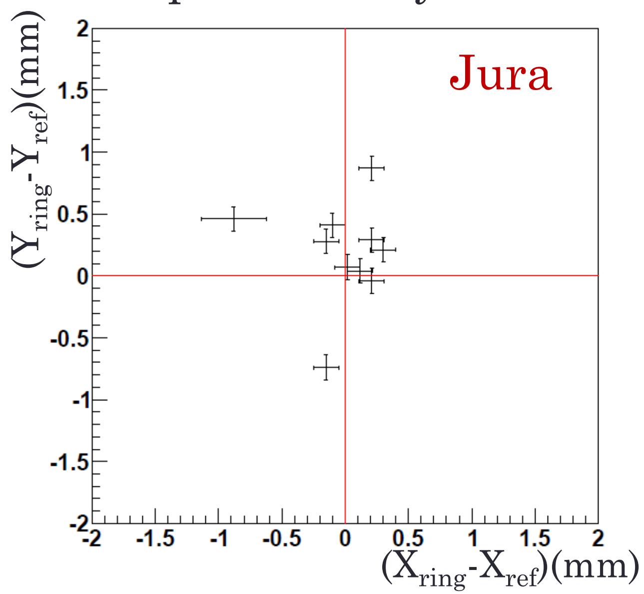

Preceding results are quoted in the NA62 detector paper in preparation

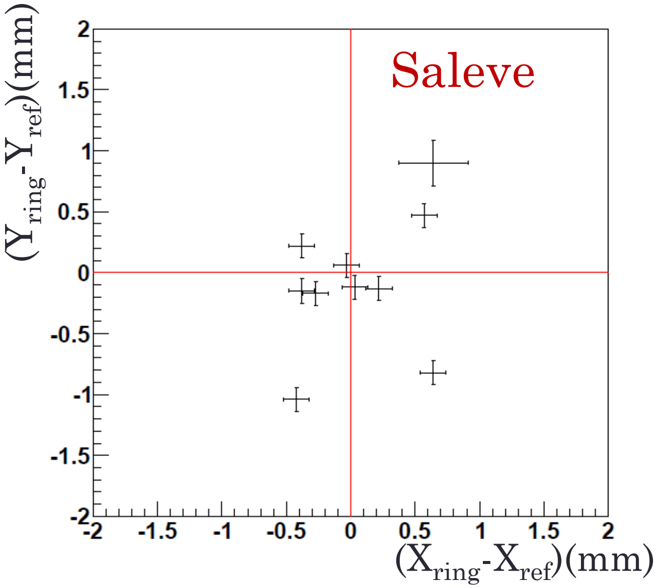
# Mirrors Alignment

In 2014 and 2015 the RICH mirrors alignment was not optimal

Remotely align mirros using information from 2016 data

- Select rings fully contained in a single mirror
- Consider the reflection of the track off the mirrors and extrapolate the reflected track to the PMT disk
- Compare the position of the ring center on the PMT disk with the position predicted by the extrapolation

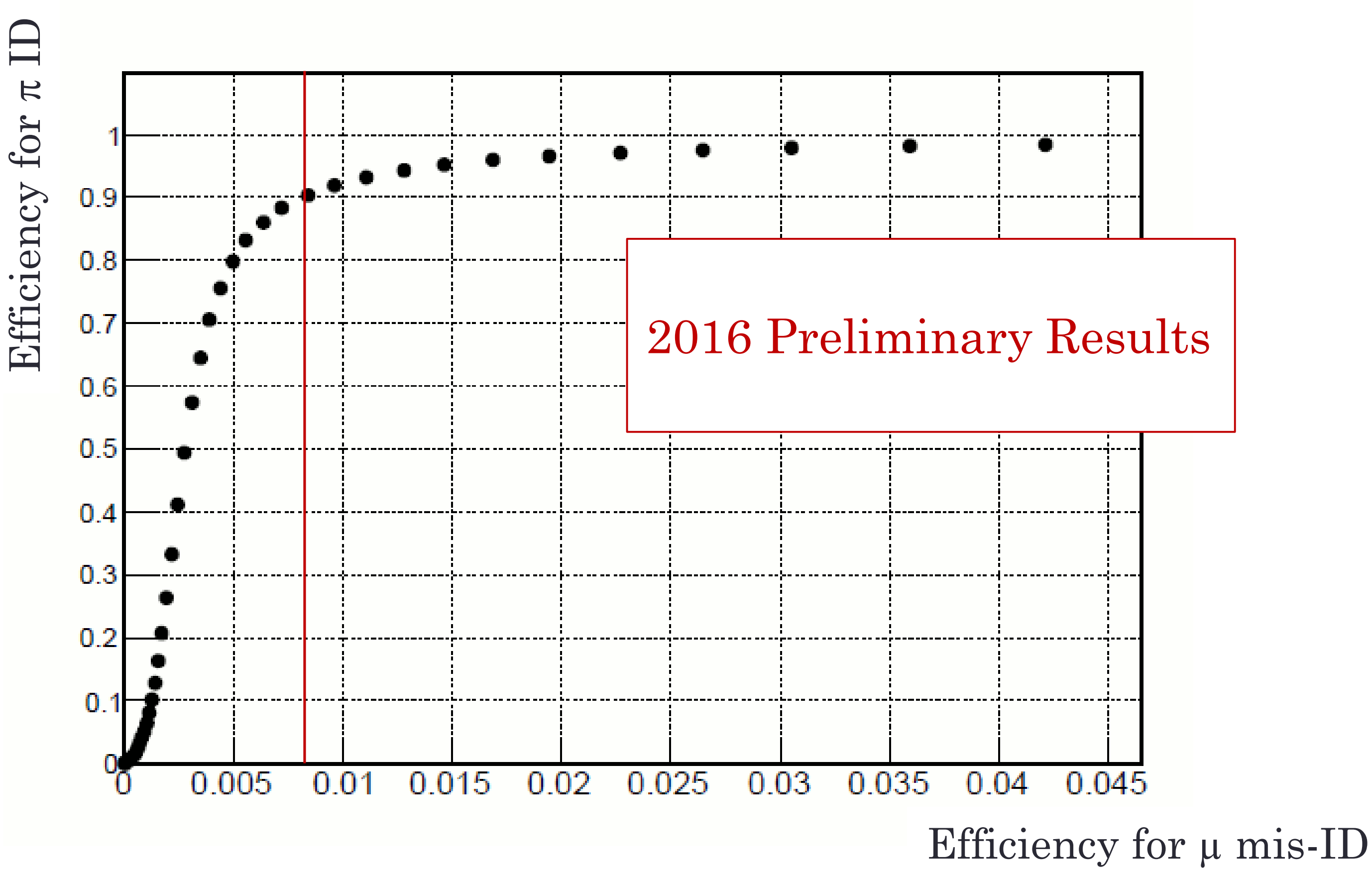



All mirrors aligned within 1 mm with respect to the reference

# 2016 Preliminary Results

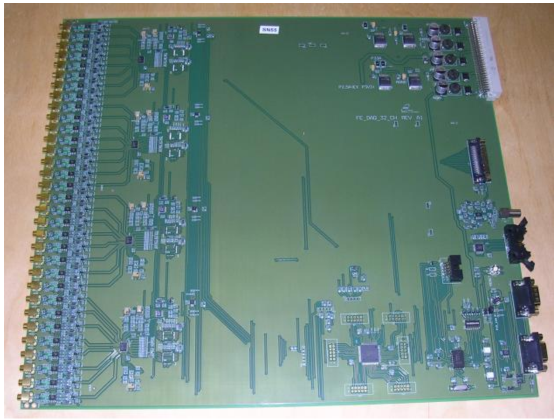
For 90% π ID efficiency a 0.8% μ mis-ID efficiency is observed



# Conclusions

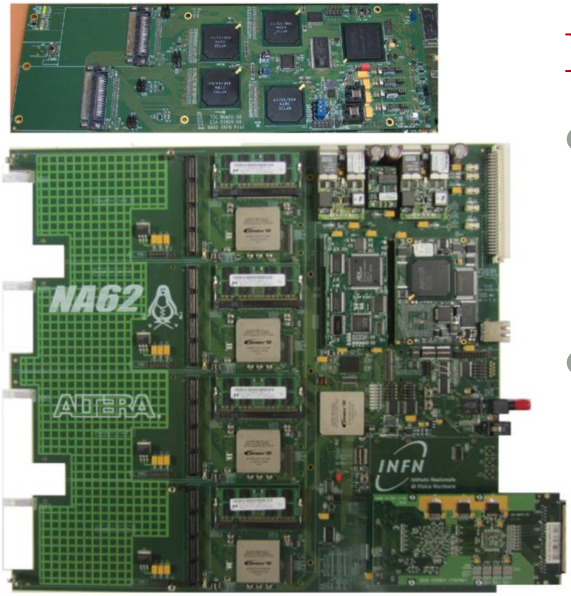
- The NA62 RICH is a far demanding object
- The detector was constructed and fully commissioned in time for the NA62 data taking
- The measured performances fulfill all the requirements:
  - Time resolution ~ 70 ps
  - Muon mis-ID efficiency < 1% for 90% pion ID efficiency

# FRONT-END AND READ-OUT SYSTEM



RICH front-end

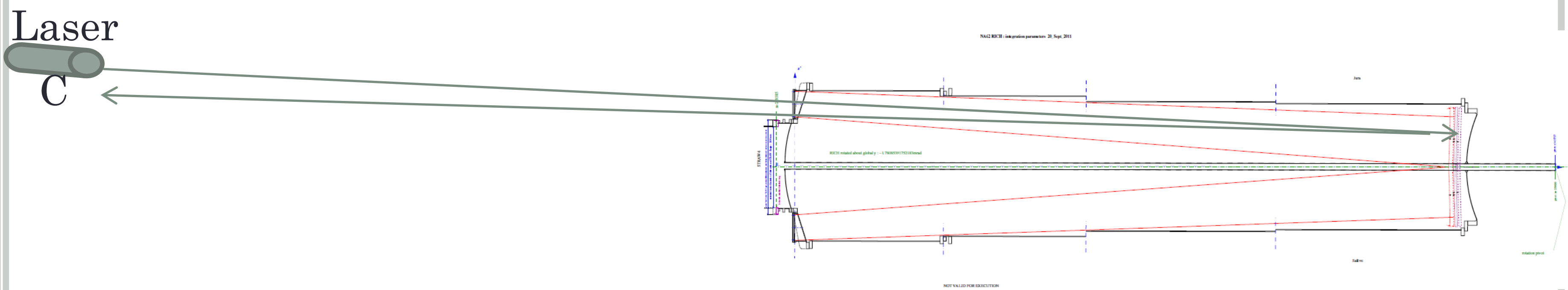
- Custom-made current amplifiers with differential output
- NINO chips used as discriminators
- 64 boards
- Each boards has 32 channels




RICH read-out:

- 128 channels TDC daughter Boards (TDCB), each one housing 4 CERN HPTDC (High Performance TDC)
- 5 TEL62 mother boards (4 for the 2000 PMTs, 1 for the multiplicity read-out used to produce the L0 trigger), each one housing 4 TDCBs

# Ideal Procedure




- The laser is placed in the Center of Curvature C of the mirror mosaic
- The reflected laser beam must come in the same position as the source
- Changing the laser beam angle with  C as pivot, all the mirrors of one mosaic half can be illuminated and aligned

What about if C is not accessible?

Put in C the **optical image** of the laser