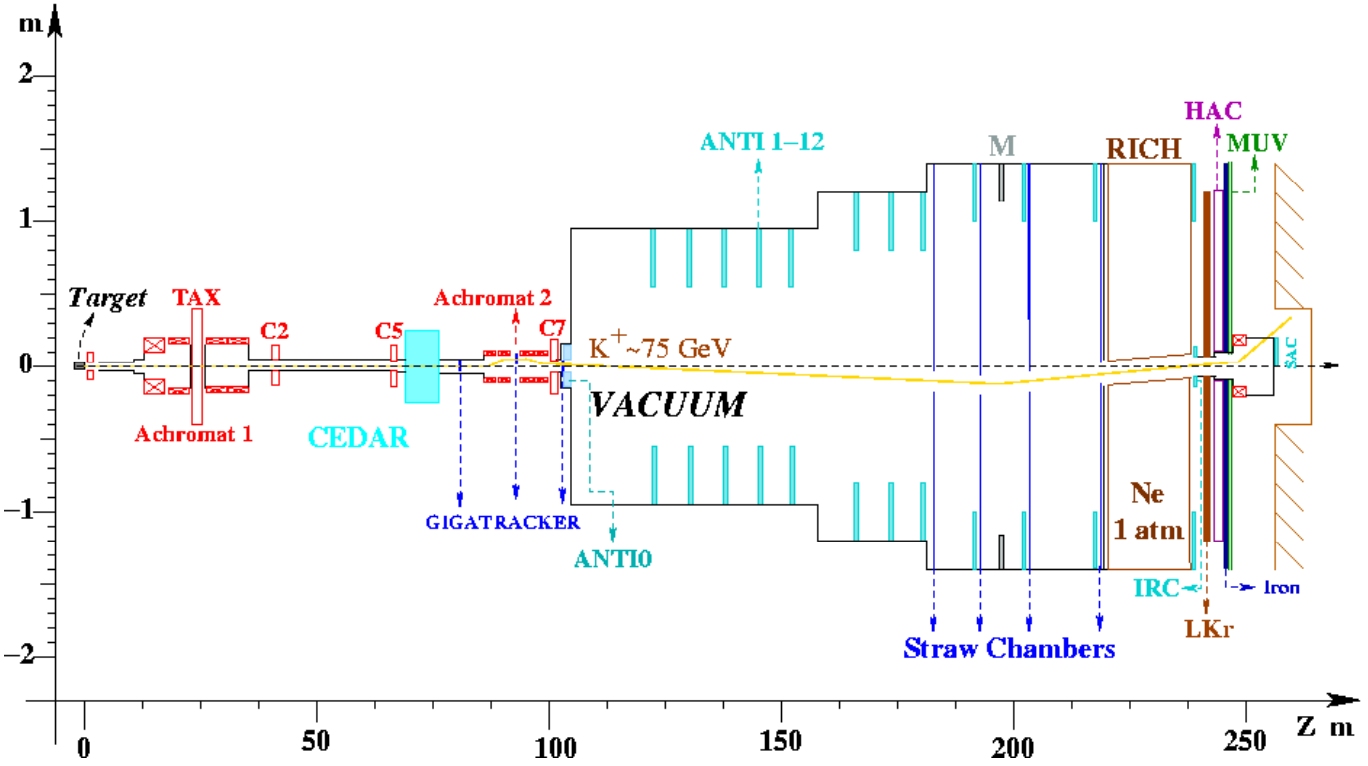
The NA62 RICH Detector

M.Lenti
(INFN Firenze)
on behalf of the RICH working group

- The NA62 requirements for a RICH
- The RICH detector
- The RICH-100 prototype: 2007 test beam results
- The RICH-400 prototype

The NA62 RICH: requirements

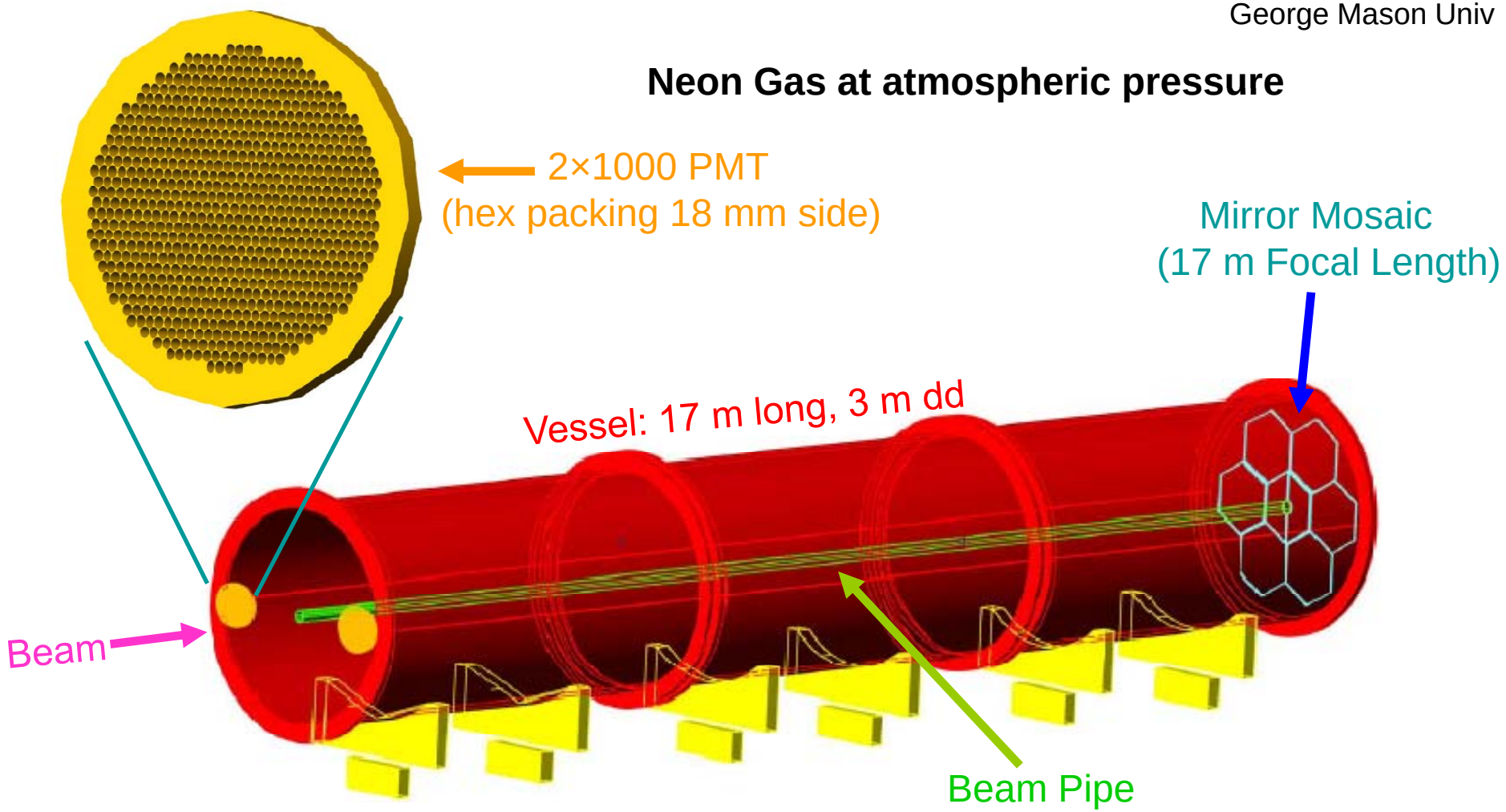
- Separate π–μ at 5×10^{-3} for 15<p<35 GeV/c
- Track time at 100 ps (to avoid pile-up with the Gigatracker)
- Main Charged Trigger



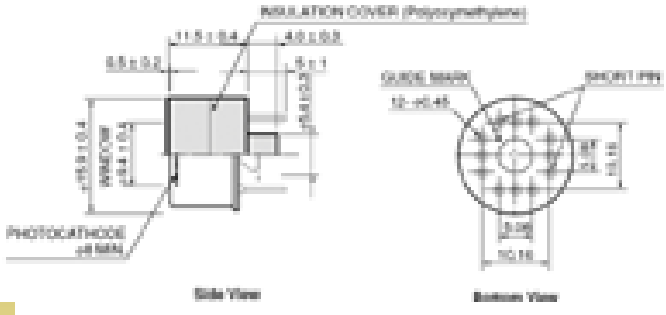
The RICH Detector

INFN Firenze
INFN Perugia
CERN
Univ.S.Luis Potosi
TRIUMF
George Mason Univ

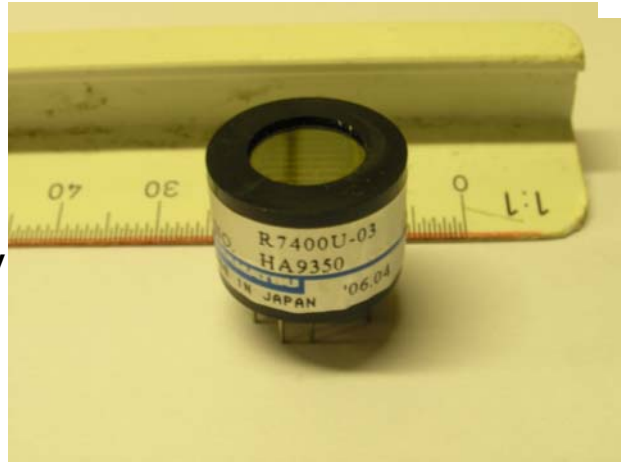
Neon Gas at atmospheric pressure

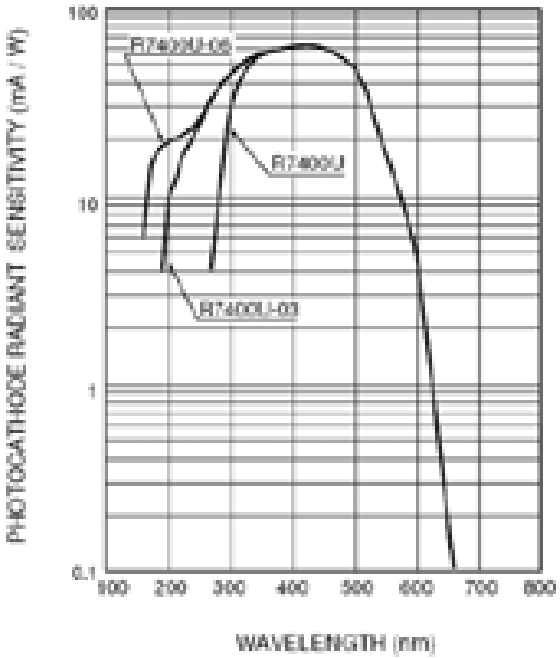


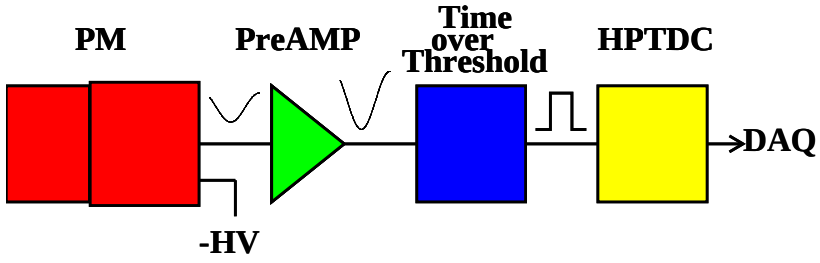
The PhotoMultiplier



- Hamamatsu R7400 U03
- Metal package, 8 dyn
- 16 mm dd (8 mm active)
- 185 nm – 650 nm
- 420 nm: peak sensitivity
- UV glass window
- Bialkali cathode
- Gain: 7 x 10^5 (typ.)
- Transit time: 5.4 ns (Transit time spread: 0.28 ns)
- Applied Voltage: 800 V (1000 V max)



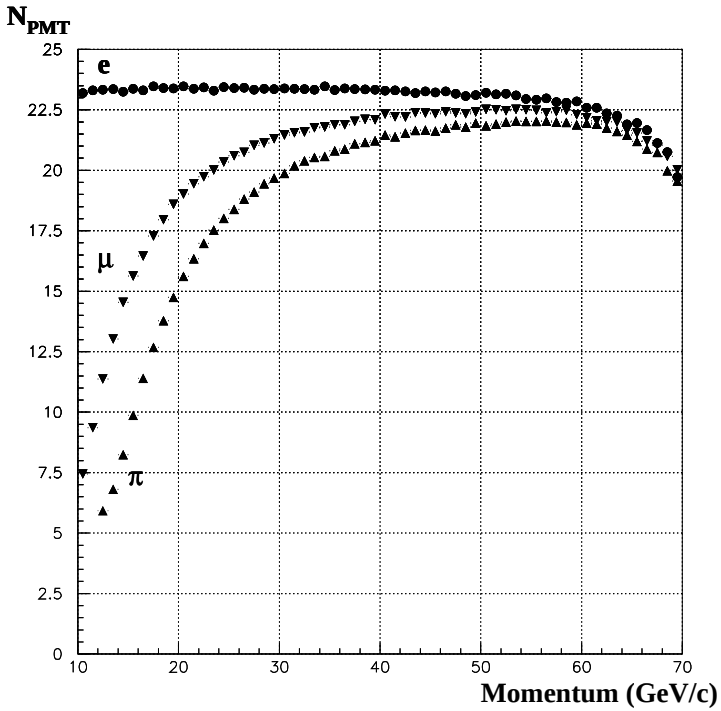




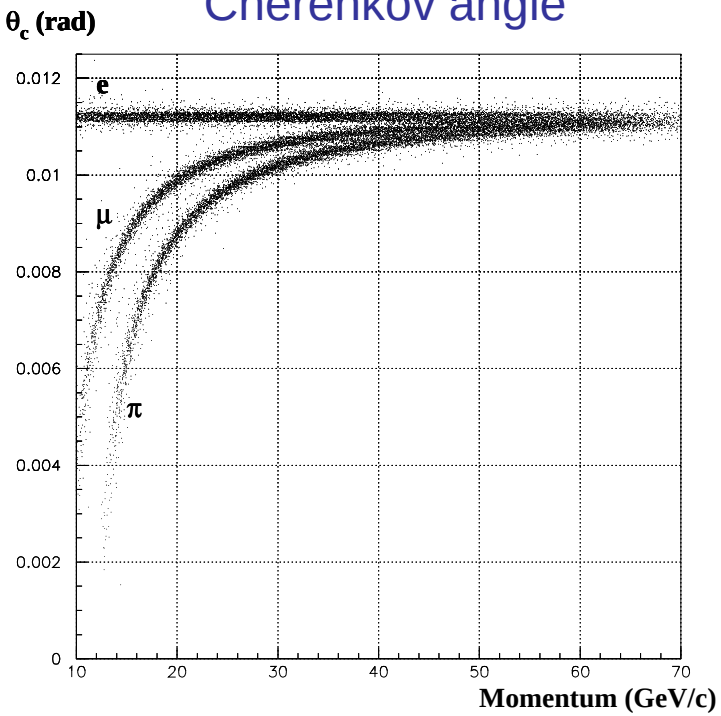
- NINO ASIC as fast Time-over-Threshold discriminator
- HPTDC with 100 ps LSB
  - ➢ CAEN V1190 (128ch) for 2007 test
  - ➢ TELL1 board (from LHCb) final

The RICH: simulation

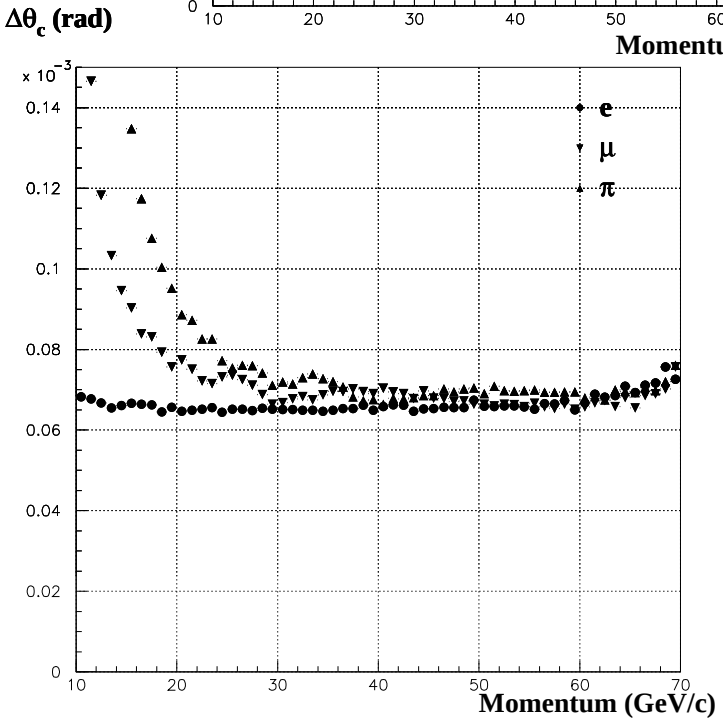
N. of hits



Cherenkov angle

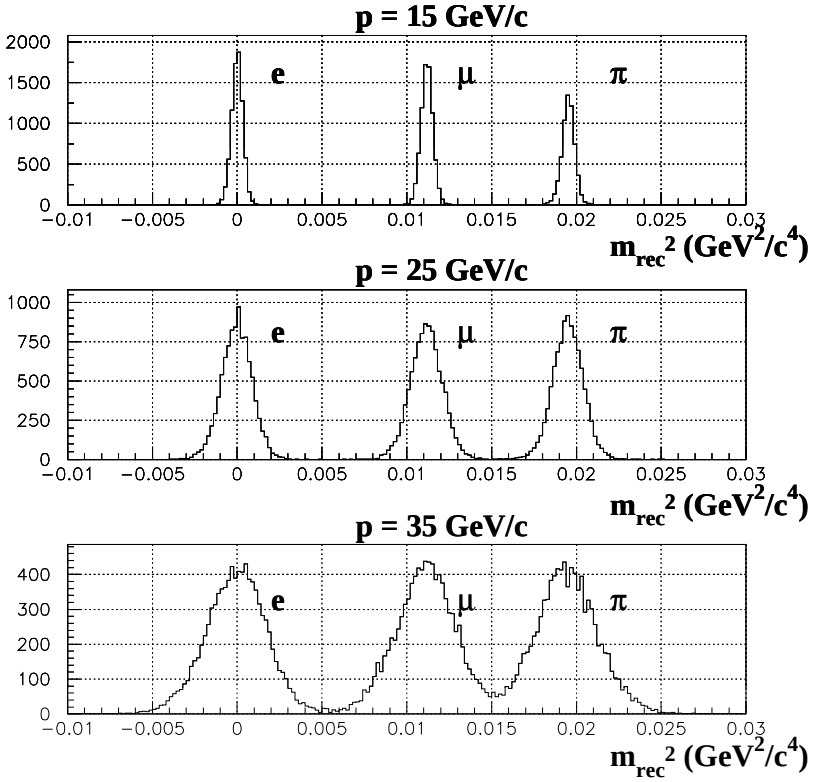


Cherenkov angle resolution

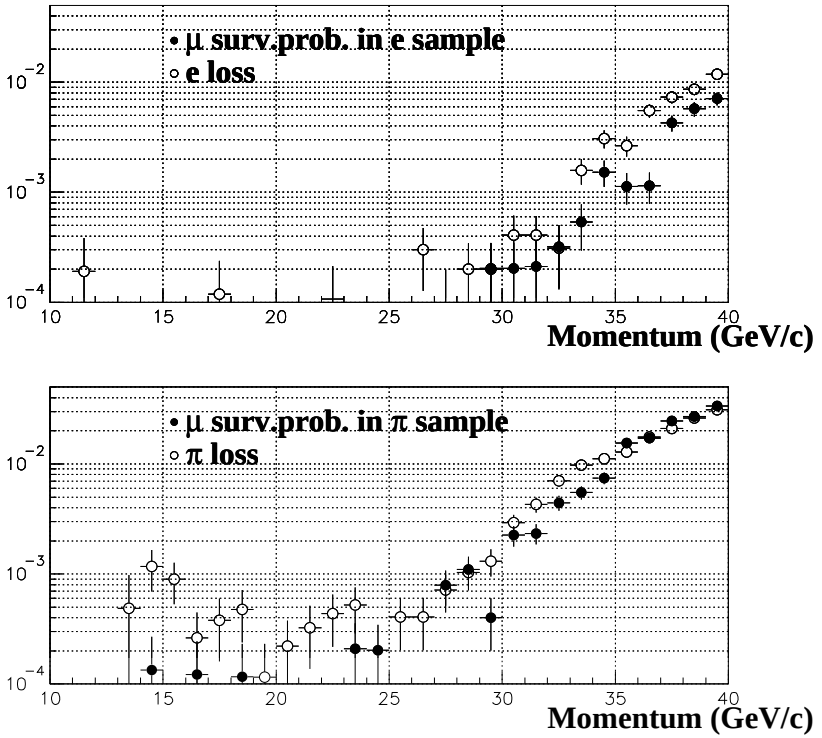


Simulation: particles separation

$$m_{rec}^2 = p^2\left(\vartheta_{\max}^2 - \vartheta_c^2\right)$$

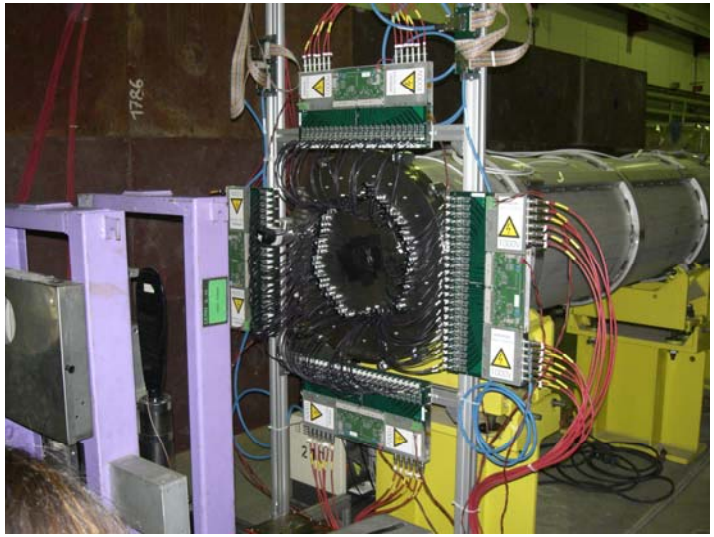


Momentum from the spectrometer



Muon suppression in π sample (15<p<35 GeV/c): 1.3×10^{-3}

RICH-100 prototype: 2007 Test Beam



96 PMT
Hamamatsu R7400

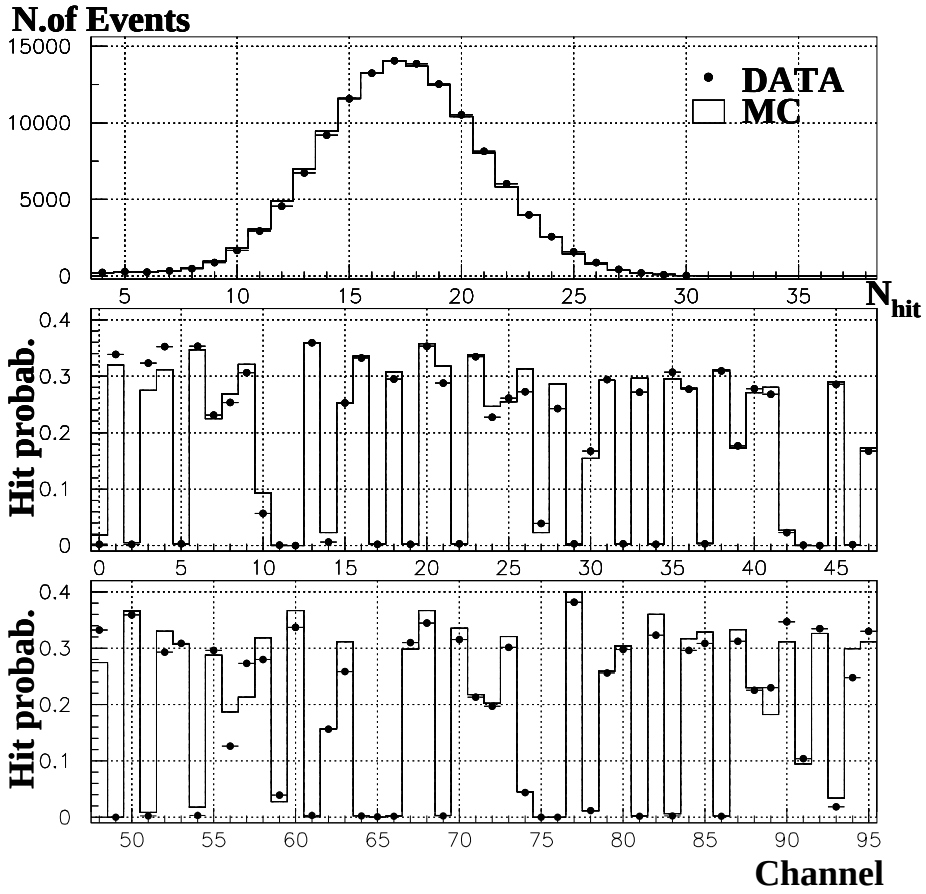
CERN
ECN3 Cavern
K12 beam line
(NA48-NA62)

17 m long
60 cm wide
vessel (partly recuperated at CERN, partly brand new) filled with Neon at atm. pressure

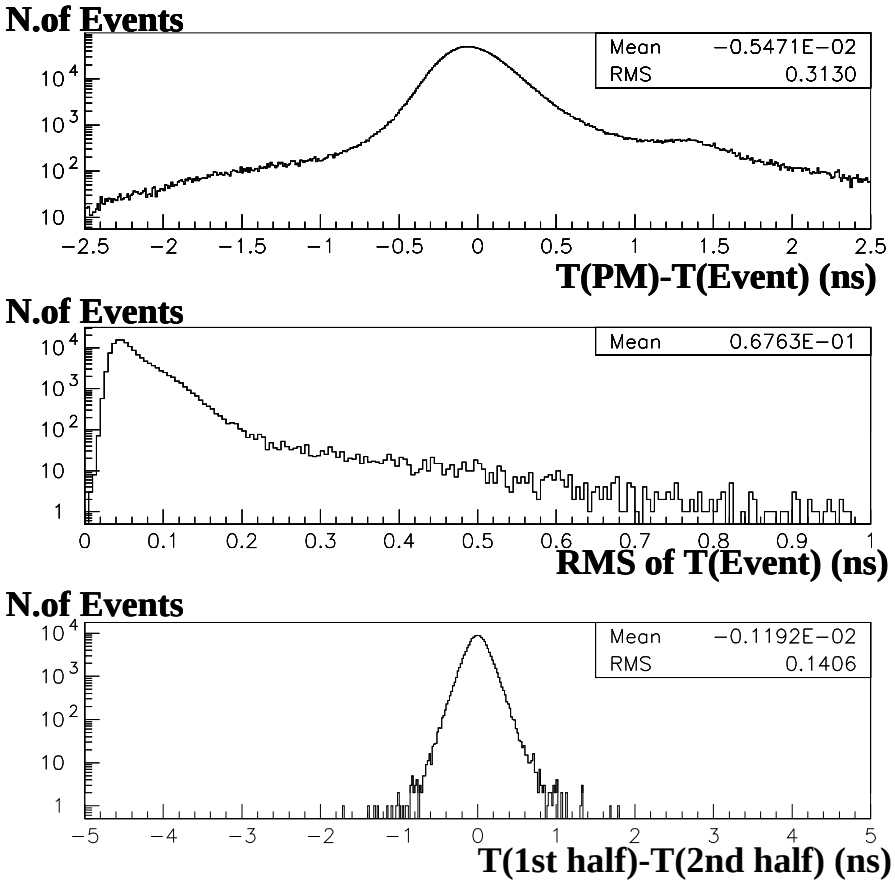
200 GeV/c negative hadron beam from CERN SPS (mainly pions)

17 m focal, 50 cm wide, 2.5 cm thick glass mirror by MARCON

RICH-100: 2007 Test Beam results

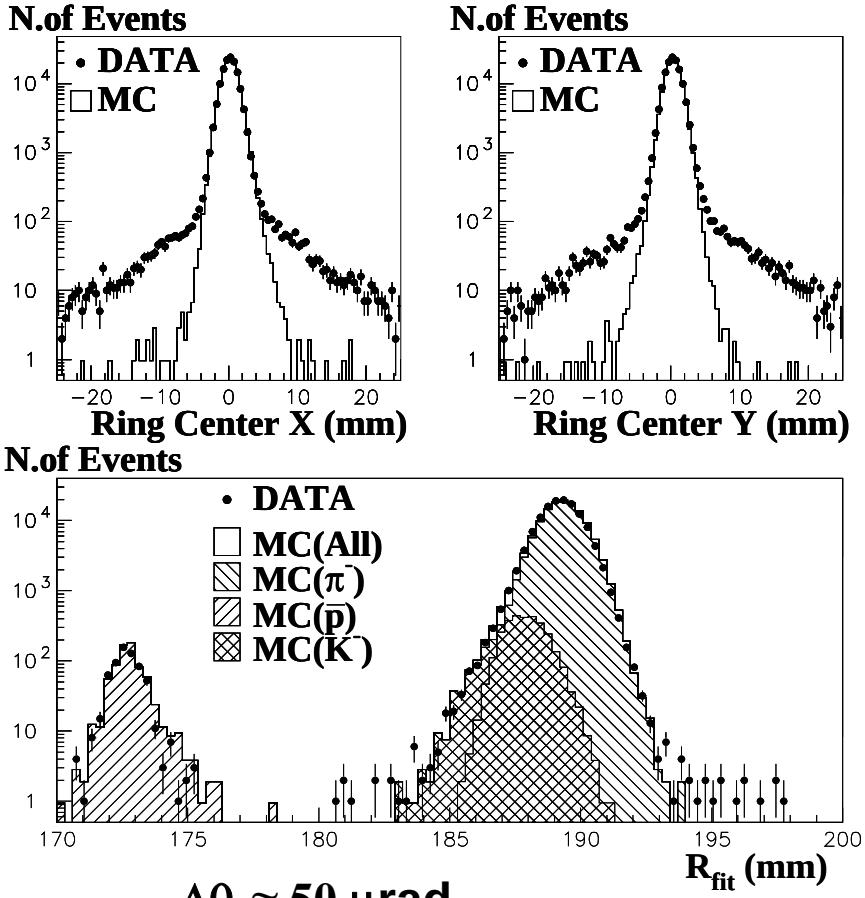


$N_{Hits} \approx 17$



$\Delta t_{Event} \approx 70$ ps

RICH-100: 2007 Test Beam results



$\Delta\theta_c \approx 50$ μrad
(biased by PM geometry)

$N_{Hits} \approx 17$

$\Delta t_{Event} \approx 70$ ps

Nuclear Instruments and Methods in Physics Research A 593 (2008) 314–318

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Construction and test of a RICH prototype for the NA62 experiment

G. Anzivino [a,1], C. Biino [b], A. Bizzeti [c,2], F. Bucci [c,3], P. Cenci [a], R. Ciaranfi [c], G. Collazuol [d,4], V. Falaleev [e], S. Giudici [d,5], E. Iacopini [c,3], E. Imbergamo [a], M. Lenti [c,*], M. Pepe [a], R. Piandani [a,1], M. Piccini [e], M. Raggi [f], A. Sergi [a], M. Veltri [c,6]

[a] Sezione dell'INFN di Perugia, I-06100 Perugia, Italy
[b] Sezione dell'INFN di Torino, I-10125 Torino, Italy
[c] Sezione dell'INFN di Firenze, I-50019 Sesto Fiorentino, Italy
[d] Sezione dell'INFN di Pisa, I-56127 Pisa, Italy
[e] CERN, 1211 Geneve 23, Switzerland
[f] Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy

ARTICLE INFO

Article history:
Received 16 May 2008
Accepted 19 May 2008
Available online 28 May 2008

Keywords:
RICH
PID
Timing

ABSTRACT

A RICH prototype has been constructed and tested. The detector was cylindrical, 17 m long and 60 cm diameter, filled with neon gas at atmospheric pressure. A spherical mirror with 17 m focal length was used and 96 photomultipliers were placed in the mirror focal plane. The prototype was exposed to a 200 GeV/c momentum negative beam derived from the CERN SPS in the 2007 fall. The performances of the detector in terms of Cherenkov angle resolution, number of photoelectrons and time resolution are presented.

1. Introduction

The NA62 experiment [1] has been proposed at CERN in order to measure the branching ratio of the ultra-rare decay $K^+ \to \pi^+\nu\bar{\nu}$. The main background is $K^+ \to \mu^+\nu$ which must be suppressed by a factor 4×10^{-13} in order to have a background to signal ratio smaller than 10%: this goal can be accomplished by a combination of kinematical cuts and by pion–muon separation. According to the MC simulation of the experiment, a kinematical suppression of 8×10^{-6} can be reached. A muon rejection factor of 10^{-5} can be achieved exploiting the different penetration probability through matter of the two particles. A further 5×10^{-3} suppression factor can be provided by a Ring Imaging CHerenkov (RICH) detector.

The momentum range over which pions and muons must be identified by the RICH is between 15 and 35 GeV/c; the best pion–muon separation is achieved when the lowest accepted momentum is close to the Cherenkov threshold. As full efficiency is achieved only at a momentum about 20% higher than the threshold, the latter has to be 12.5 GeV/c for a pion, i.e. the index of refraction n must be such that $(n-1) \approx 60 \times 10^{-6}$. Neon gas at roughly atmospheric pressure fulfills this requirement and also guarantees a small dispersion [2]. On the other hand, the tiny $(n-1)$ implies a small number of emitted Cherenkov photons per unit length and therefore a long radiator is mandatory. A 10 m long neon RICH was built and operated by the SELEX experiment [3] and a longer one was proposed by the CKM collaboration [4]. The available space for the RICH in the NA62 experiment setup is about 18 m: a detector of about this size is foreseen.

In a RICH detector [5] the Cherenkov light, emitted at an angle θ_c by a charged particle of velocity βc larger than the speed of light in the crossed medium (c/n), is imaged by means of a spherical mirror onto a ring on its focal plane. The ring radius r is related to the Cherenkov angle as $\theta_c = r/f$ for small n (as it is the case for gas radiators), where f is the mirror focal length. The relation between Cherenkov angle and momentum p of a charged particle of mass m is given by

$$\theta_c^2 = \theta_{c\,MAX}^2 - m^2c^2/(m^2c^2 + p^2) \qquad (1)$$

where $\theta_{c\,MAX} = \sqrt{2(n-1)}$ is the Cherenkov angle for $\beta = 1$. The θ_c resolution must be better than 80 μrad in order to achieve the requested pion–muon separation.

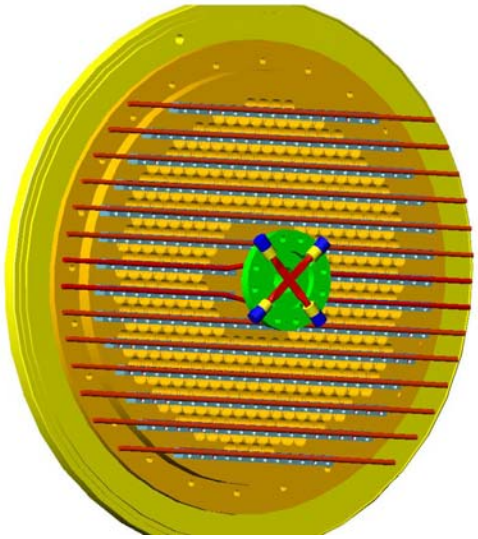
Besides pion–muon separation, the NA62 RICH detector must fulfill two other very important tasks: provide the time of pion crossing with 100 ps resolution (in order to suppress accidental

* Corresponding author. Tel.: +39 055 457 2270.
E-mail address: lenti@fi.infn.it (M. Lenti).
[1] Dipartimento di Fisica dell'Università di Perugia, I-06100 Perugia, Italy.
[2] Dipartimento di Fisica dell'Università di Modena e Reggio Emilia, I-41100 Modena, Italy.
[3] Dipartimento di Fisica dell'Università di Firenze, I-50125 Firenze, Italy.
[4] Scuola Normale Superiore di Pisa, I-56127 Pisa, Italy.
[5] Dipartimento di Fisica dell'Università di Pisa, I-56127 Pisa, Italy.
[6] Dipartimento di Fisica dell'Università di Urbino, I-61029 Urbino, Italy.

0168-9002/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2008.05.029

The RICH-400 prototype

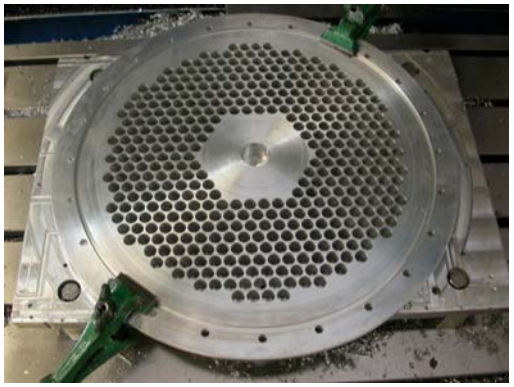
- PM endcap changed
- 414 PM (20% of final detector)
- Validate π–μ separation in 15<p<35 GeV/c
- Improve PM cooling



Test scheduled: Oct 19 – Nov 12, 2008

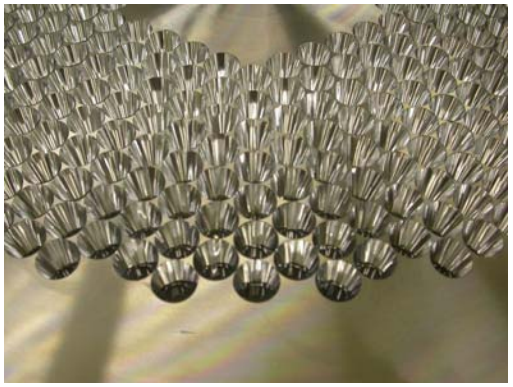
Postponed to 2009 (LHC incident...)

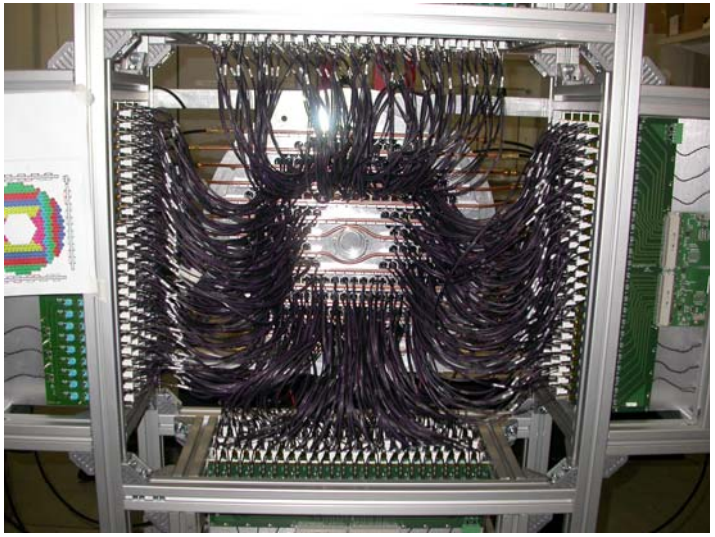
RICH-400



PM holder

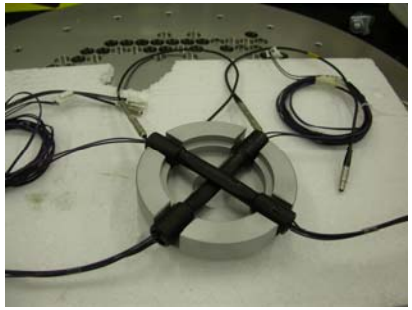
PM endcap





Electronics and cooling

Trigger counters



Conclusions and Schedule

- A very demanding RICH is needed for NA62
- A valuable project has been developed
- A prototype has been tested in 2007
- An improved prototype will be tested in 2009
- About two years needed from “green light” (if money available immediately)

➢ PMT production > 100/month

➢ Mirror production > 1/month

➢ Vessel procurement and installation: two years

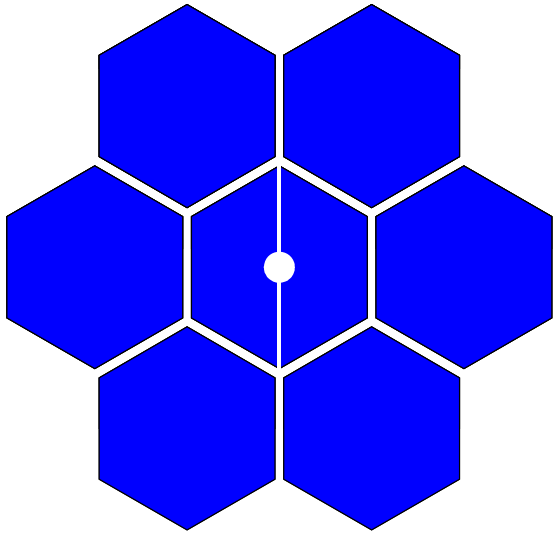
SPARES

The RICH: costs

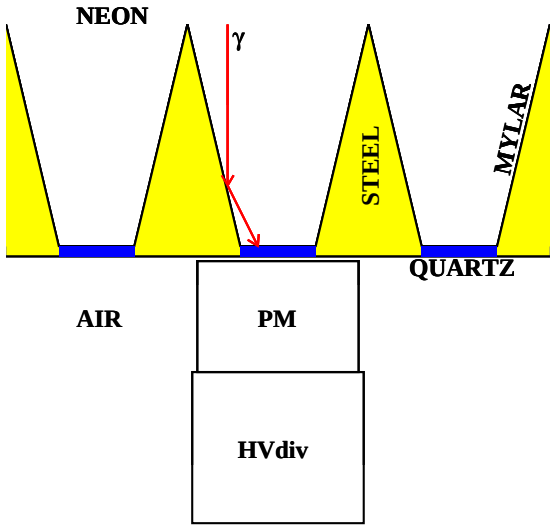
Issue	Quantity	Unit prize (€)		Sub-Total (€)
Vessel	1	-	CERN	200 K
Gas system	-	-	CERN	50 K
Thermal isolation	-	-	CERN	50 K
T and P probes	-	-	CERN	30 K
PM R7400U-03 + base	2000	350	INFN(30%)	700 K
Mirrors	12	≈20000	INFN	250 K
Quartz windows	2000	7.5	INFN	15 K
PM mechanics	-	-	INFN	20 K
Mirror mechanics	-	-	INFN	25 K
HV (2 PM per ch)	1000	300	INFN	300 K
FE electronics	2000	40	INFN	80 K
TDC (Tell1 based)	2000	50	INFN	100 K
Racks, LV, cables	-	-	INFN	60 K
TOTAL	-			1880 K

The Mirrors

- Hexagonal Mirrors
- 17 m focal length
- 1 m diameter
- 2.5 cm thick glass
- D_0 < 4 mm
- Aluminum deposit with MgF_2 coat
- MARCON company
- piezo actuators for alignment



The light collection



Winston Cones
covered with Mylar:

- 22 mm high
- 18 mm wide (max)
- 7.5 mm wide (min)

1 mm thick quartz window

Simulation: N.of Photoelectrons

$N_{p.e.} = N_0 L \sin^2 \vartheta_c$

$L = 1700$ cm

$N_0 = 370\ \mathrm{eV}^{-1}\mathrm{cm}^{-1} \varepsilon_{mirror} \varepsilon_{geom} \varepsilon_{coll} \varepsilon_{transp} \int \varepsilon_{Q.E.}(E) dE$

$\varepsilon_{mirror} \approx 0.85$ (Mirror reflectivity)

$\varepsilon_{geom} \approx 0.90$ (Honeycomb acceptance)

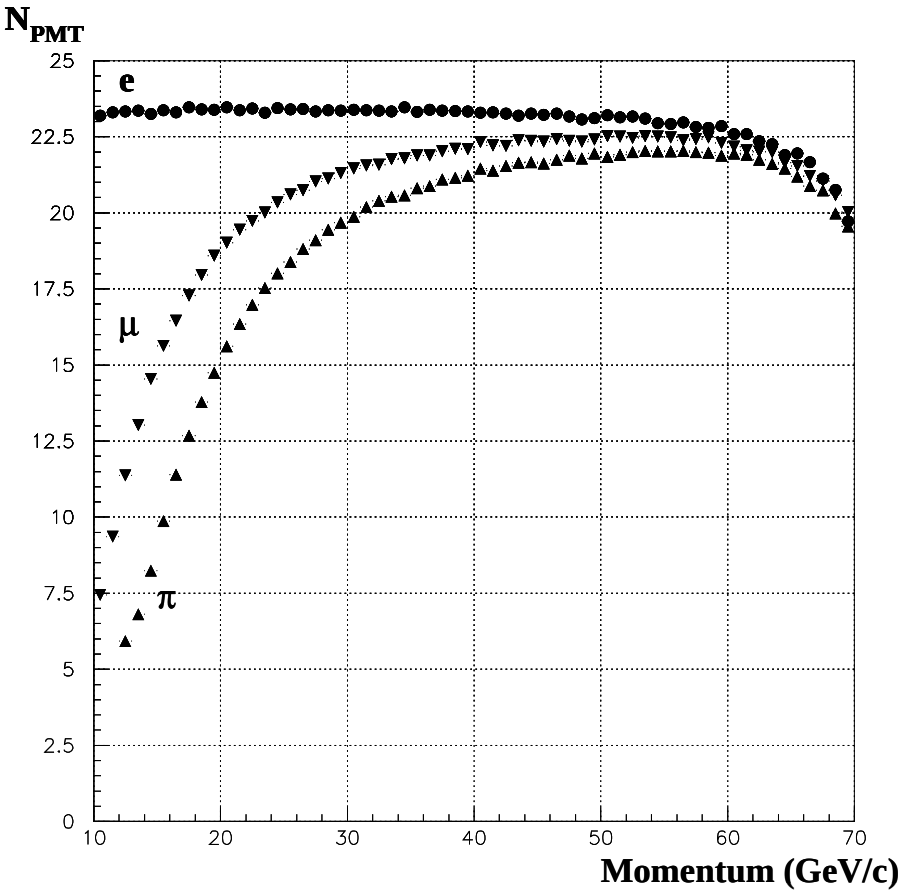
$\varepsilon_{coll} \approx 0.85$ (Winston cones ligth collection eff.)

$\varepsilon_{transp} \approx 0.90$ (Quartz windows transparency)

$\int \varepsilon_{Q.E.}(E) dE \approx 0.60$ eV (R7400U-03 quantum eff.)

$N_0 \approx 130\ \mathrm{cm}^{-1}$

$N_{p.e.} \approx 28 > N_{Hits}$



Simulation: ϑ_c resolution

Single hit resolution

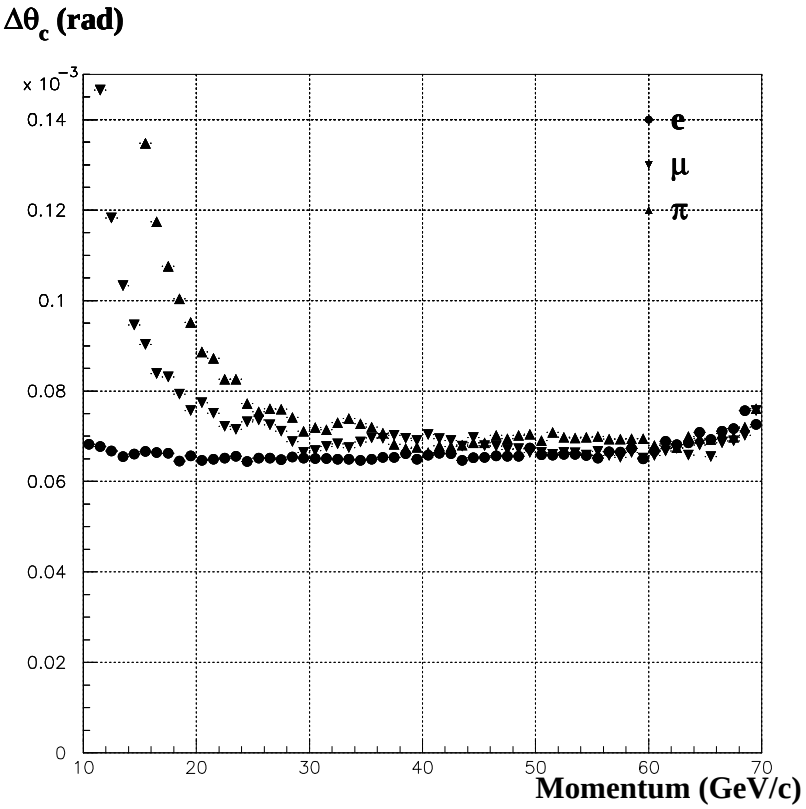
$$\Delta\vartheta_c(\text{granularity}) = \frac{s}{4f} = \frac{18\ \text{mm}}{4\times 17\ \text{m}} = 265\ \mu\text{rad}$$

$$\Delta\vartheta_c(\text{dispersion}) = \frac{\Delta n}{\vartheta_c} = 125\ \mu\text{rad}$$

$$\Delta\vartheta_c(\text{mult.scatt.}) = 55\ \mu\text{rad} \times \frac{35\ \text{GeV/c}}{p}$$

$$\Delta\vartheta_c(\text{mirror}) = \frac{D_0}{16f} = \frac{4\ \text{mm}}{16\times 17\ \text{m}} = 15\ \mu\text{rad}$$

$$\text{Total resolution} \approx \frac{\Delta\vartheta_c(\text{single hit})}{\sqrt{N_{hits}}} \approx 65\ \mu\text{rad}$$



The RICH-100 prototype

- 17 m long, 60 cm wide vessel
- Mirror by MARCON: f = 17m, d = 50 cm, 2.5 cm thick
- 96 PMT Hamamatsu R7400
- Neon at atm.pressure