



The NA62 RICH detector

Giuseppina Anzivino

University of Perugia and INFN

On behalf of the NA62 RICH Group: CERN, Firenze, Perugia

Vienna Conference on Instrumentation 2010

Vienna, 15-20 February 2010

Overview

- The NA62 experiment at CERN
- The RICH detector design
- The RICH prototype test beam results:
 - ➔ The RICH-100 (2007 test beam)
 - ➔ The RICH-400 (2009 test beam)

The NA62 experiment at CERN

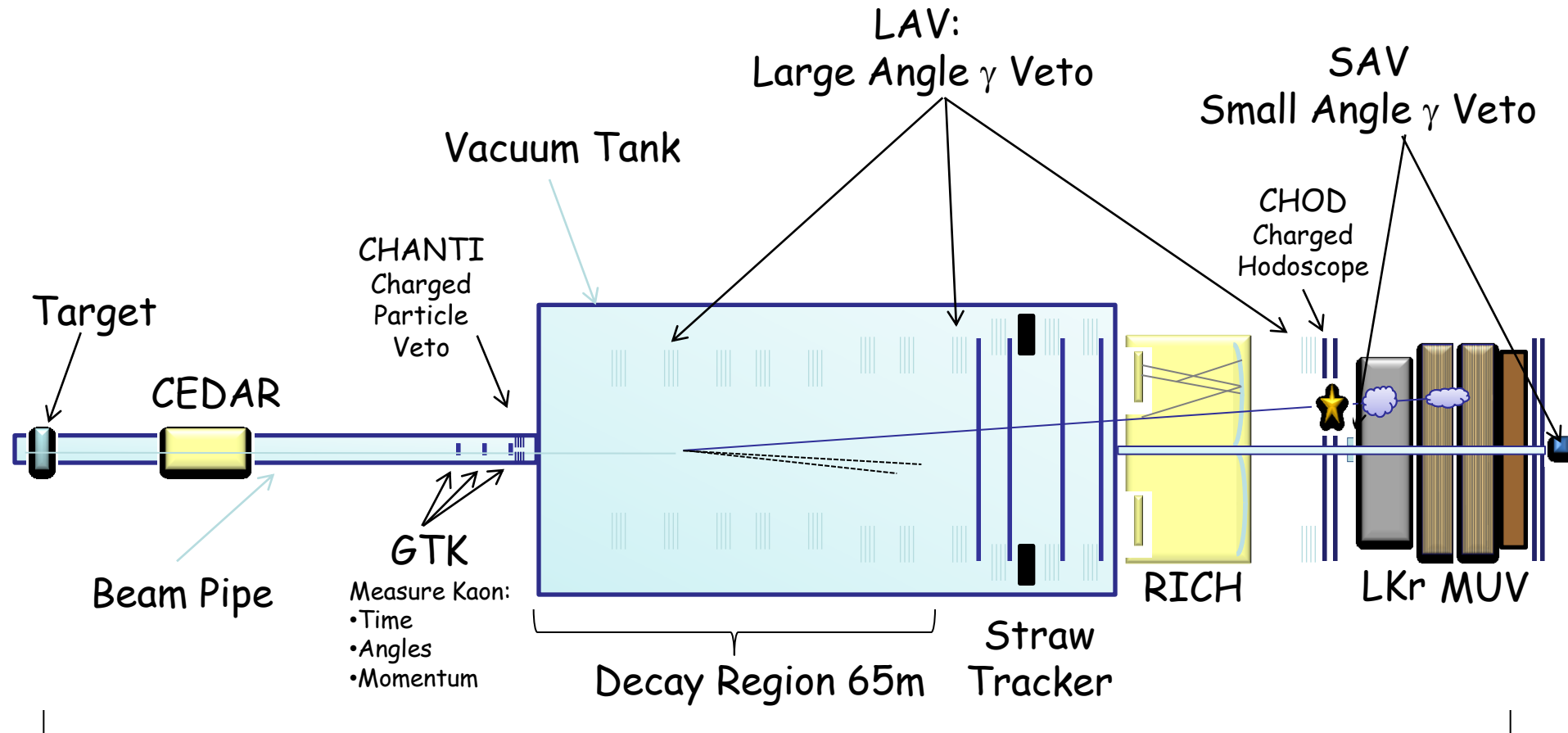
AIM:

measure $\text{BR}(K^+ \rightarrow \pi^+ \nu \bar{\nu})$ 10% precision
~ 100 events in two years of data taking

- Theoretically *very clean*, sensitive to physics beyond Standard Model
- $\text{BR}_{\text{SM}}(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (8.5 \pm 0.7) \times 10^{-11}$
(J. Brod, M. Gorbahn, PRD78, arXiv:0805.4119)
- E787/949 (BNL): $\text{BR}(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$ (7 events)
(PRL101, arXiv:0808.2459)
- Main background:
 - $\text{BR}(K^+ \rightarrow \mu^+ \nu) = 63\%$
 - $\text{BR}(K^+ \rightarrow \pi^+ \pi^0) = 21\%$

The NA62 Collaboration: Bern ITP, Birmingham, Bristol, CERN, Dubna, Fairfax, Ferrara, Firenze, Frascati, Glasgow, IHEP Protvino, INR Moscow, Liverpool, Louvain, Mainz, Merced, Napoli, Perugia, Pisa, Roma I, Roma II, San Luis Potosi, SLAC, Sofia, TRIUMF, Torino

NA62 layout



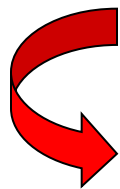
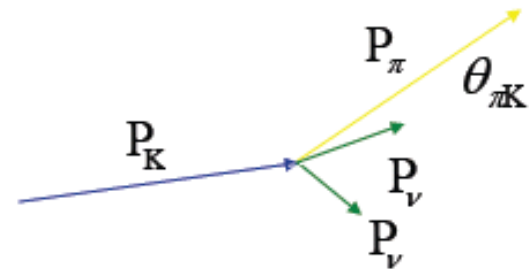
- decay in flight technique
- unseparated beam $\pi/K/p$ ($\sim 6\% K^+$)
- Kaon momentum: $75 \text{ GeV}/c$ ($\pm 1\%$)
- Kaon flux = 4.5×10^{12} decay/year

Total Length 270m

expected signal events $\sim 50/\text{y}$
(1 "year": 100 days/year, 60% overall efficiency)

RICH: PId and timing

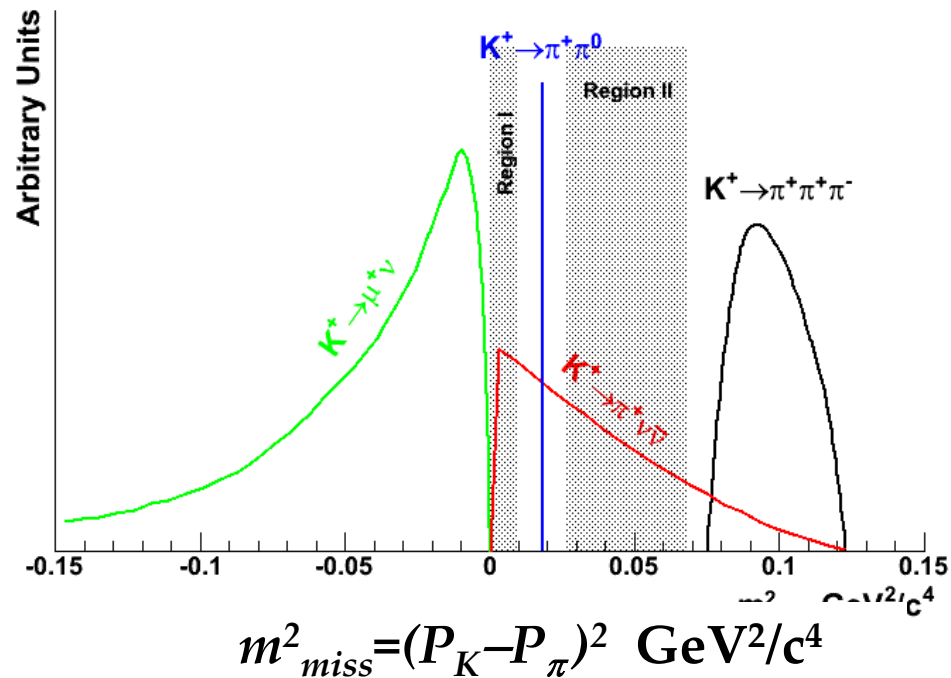
- ❖ Main background:
 - $K^+ \rightarrow \mu^+ \nu$ ($K_{\mu 2}$) BR = 63.4%
- ❖ Rejection factor at least 10^{-12}
 - ❖ Kinematics : $\sim 10^{-5}$
 - ❖ Muon Veto : $\sim 10^{-5}$
 - ❖ Particle Identification:
 - μ suppression $< 10^{-2}$



RICH



- ❖ Coincidence timing between π and K
 - time resolution: ≤ 100 ps

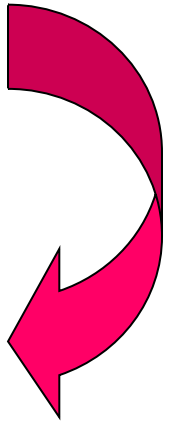


The NA62 RICH tasks

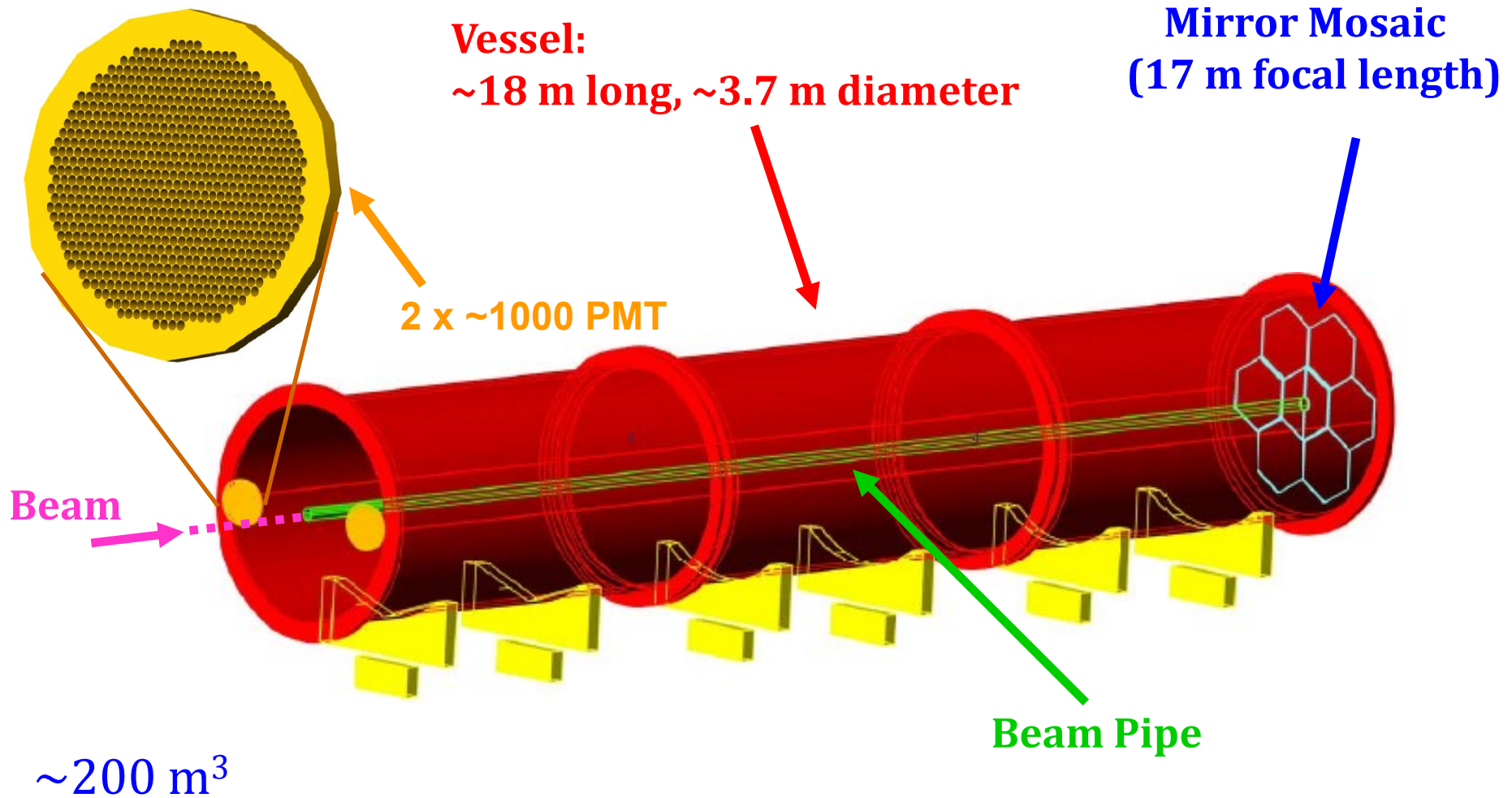
- Separate $\pi-\mu$ in $15 < p < 35 \text{ GeV}/c$ with a muon suppression factor better than 10^{-2}
- Measure pion crossing time with a resolution $< 100 \text{ ps}$
- Provide a L0 trigger for charged tracks

Radiator: Neon gas at atmospheric pressure

- ★ $(n-1) = 62.8 \cdot 10^{-6}$ at $\lambda=300 \text{ nm}$ (small dispersion)
- ★ low atomic number \rightarrow small X_0
- ★ $\theta_{C \text{ max}} = 11.2 \text{ mrad}$
- ★ $p_{\text{threshold}} = m / \sqrt{(n^2-1)} = 12 \text{ GeV}/c$ for π



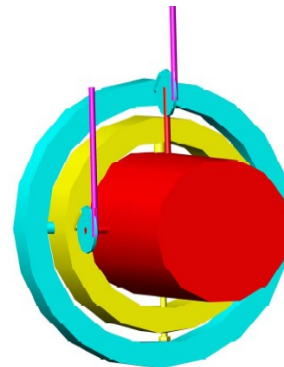
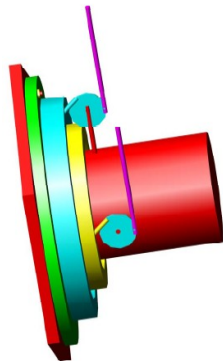
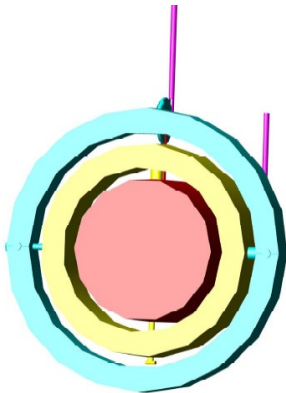
The NA62 RICH detector



Mirror layout

Mirrors from MARCON company

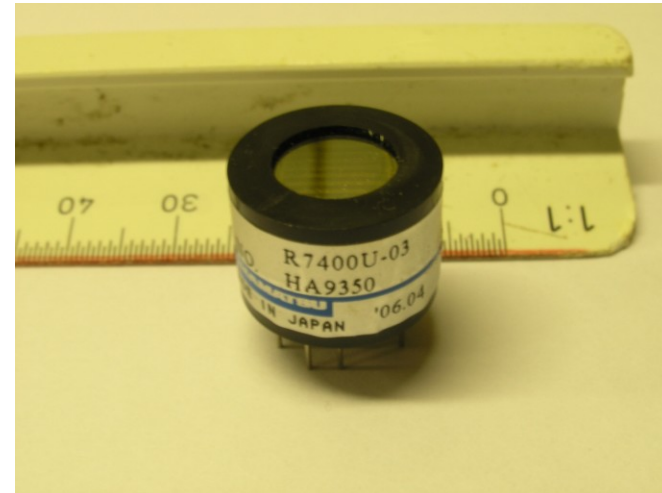
- hexagonal, inscribed in 70 cm ϕ circle
- 2.5 cm thick glass, 17 m focal length
- Aluminum deposit with dielectric coat
- Carbon fiber honeycomb structure for mirror support
- Piezo actuators for alignment
- Final detector: 18 hexagonal mirrors + 2 half hexagons (beam pipe)



Light detection

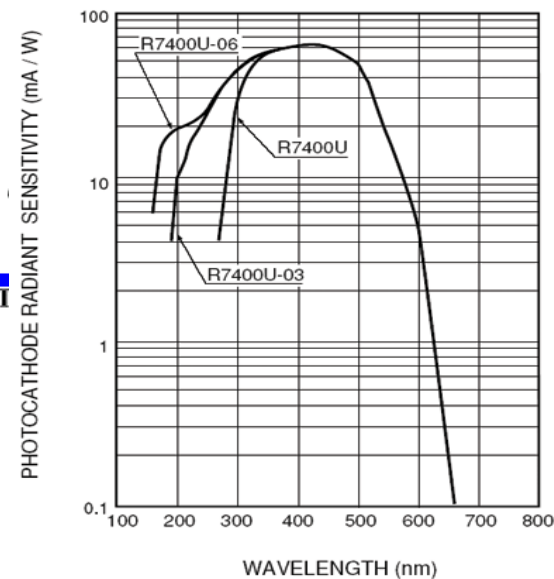
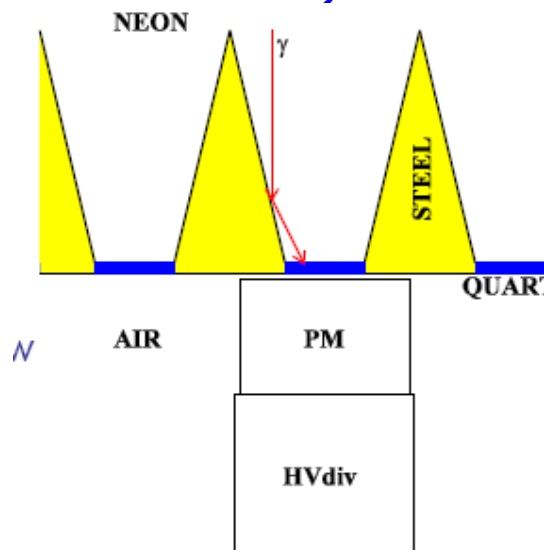
Hamamatsu R7400 U03 Photomultipliers

- Metal package tube, 8 dynodes
- 185 nm – 650 nm, 420 nm peak sensitivity
- UV glass window, 16 mm ϕ , 8 mm active ϕ
- Bialkali cathode
- Gain: 7×10^5 @800 V ($\sim 1.5 \times 10^6$ @900 V)
- Transit time: 5.4 ns
- Transit time spread: 0.28 ns
- Operating Voltage: 900 V (1000 V maximum)



Light Collection

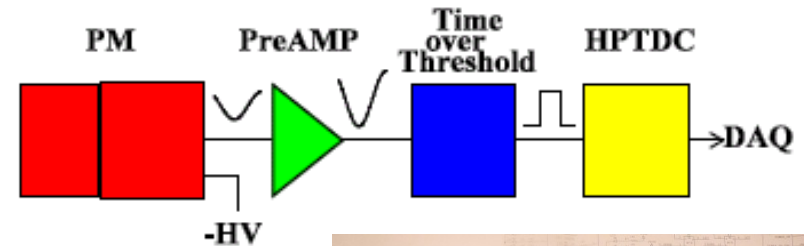
- Winston cones covered mylar
- 22 mm high
- 18 mm wide (max)
- 7.5 mm wide (min)
- 1 mm thick quartz window



Front End and Readout

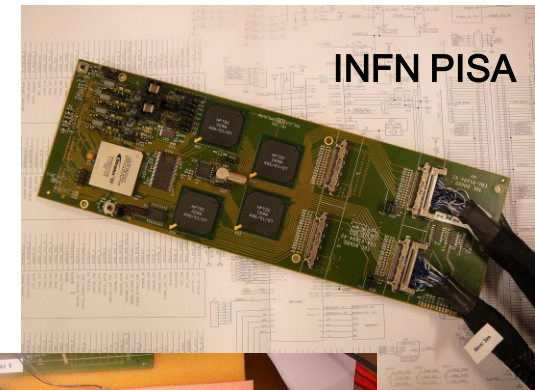
Front End:

- ❖ Custom made current amplifier
- ❖ NINO ASIC as fast Time-over-Threshold discriminator (from ALICE)



Readout:

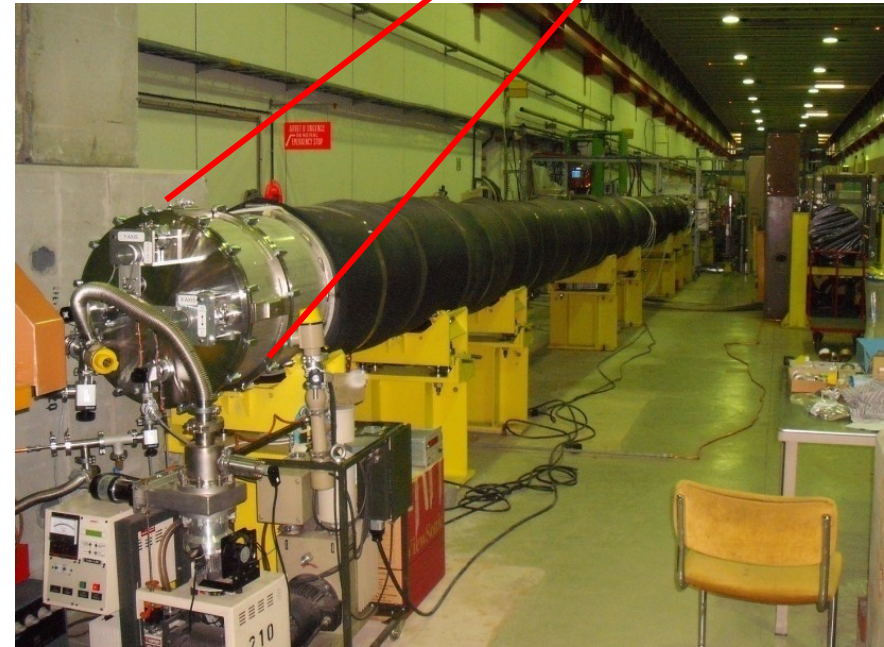
- ❖ A board (TDCB) equipped with 128 channels of TDC (HPTDC, 100 ps LSB) has been developed by INFN Pisa
- ❖ TELL1 mother board (from LHCb) will house 4 TDCB (512 channels)
- ❖ The trigger primitives will be constructed in parallel with the readout on the same TELL1 board (1 MHz input to L1)
- ❖ CAEN SY2527 crate + A1733 board power supply



The NA62 RICH prototype



- Vessel ~18 m long, ~60 cm wide
 - filled with Ne gas at ~1 atm
- One single mirror by MARCON:
 - $f = 17$ m, $d = 50$ cm, 2.5 cm thick



The RICH-100 prototype:

- 96 PMT Hamamatsu R7400 U03/U06
- Test Beam in autumn 2007

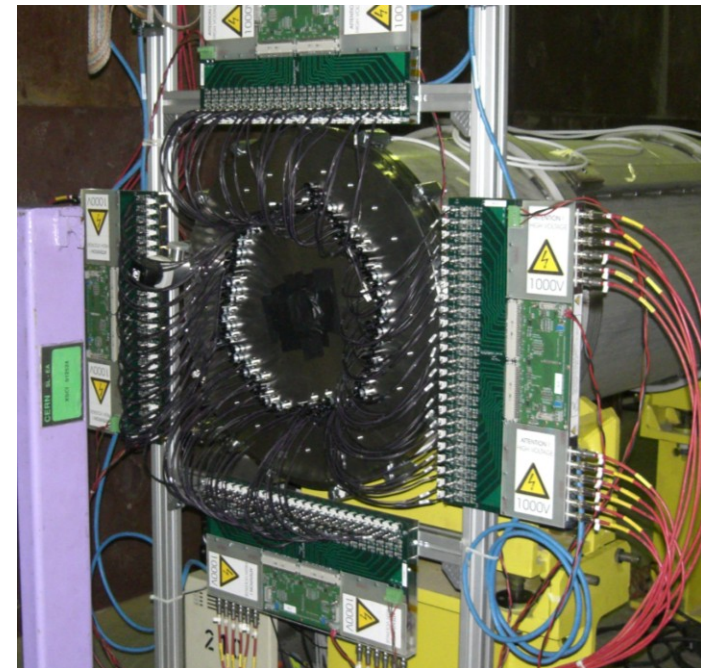
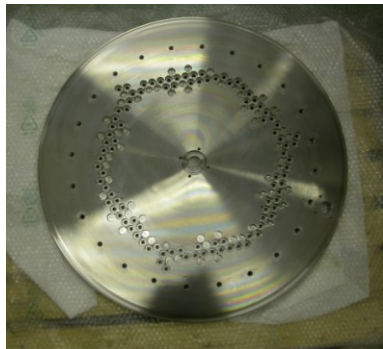
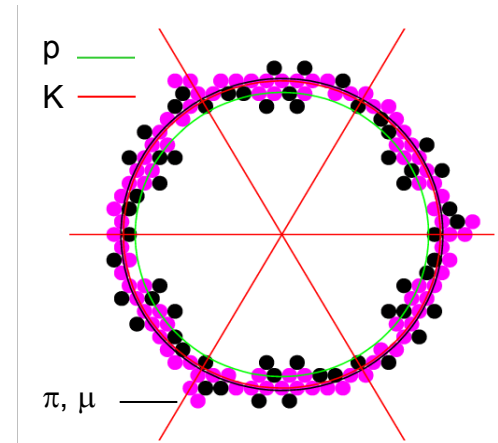
The RICH-400 prototype:

- 414 PMT Hamamatsu R7400 U03
- Test Beam in may-june 2009

The RICH-100 prototype

96 PMT Hamamatsu R7400 U03/U06
AIM

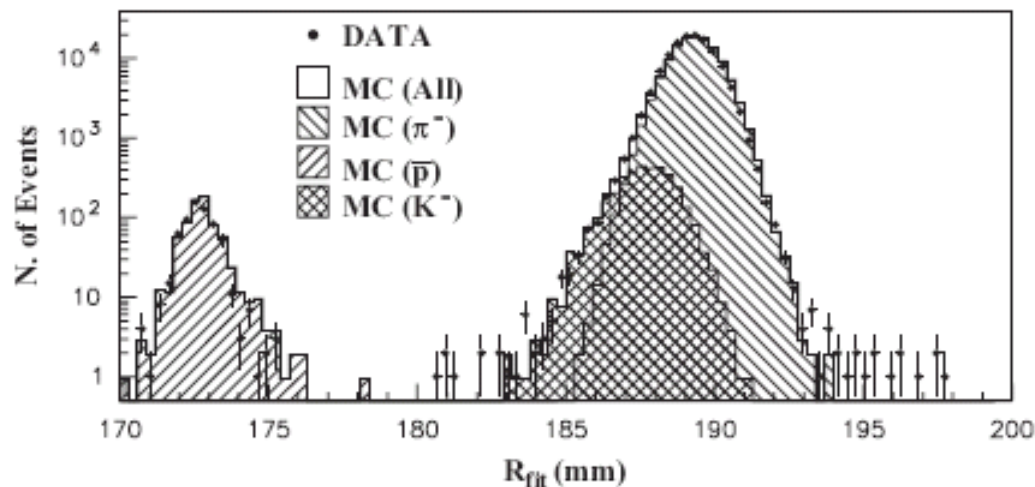
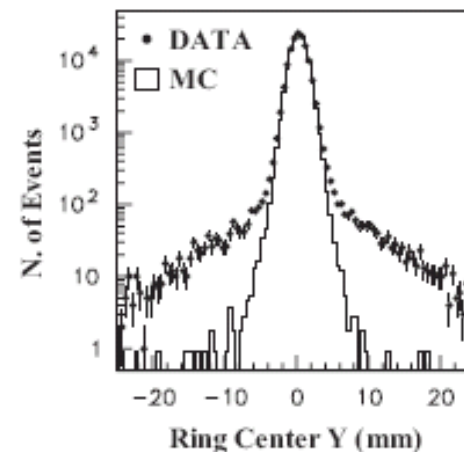
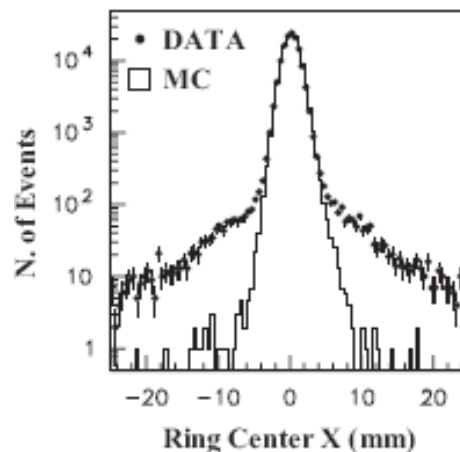
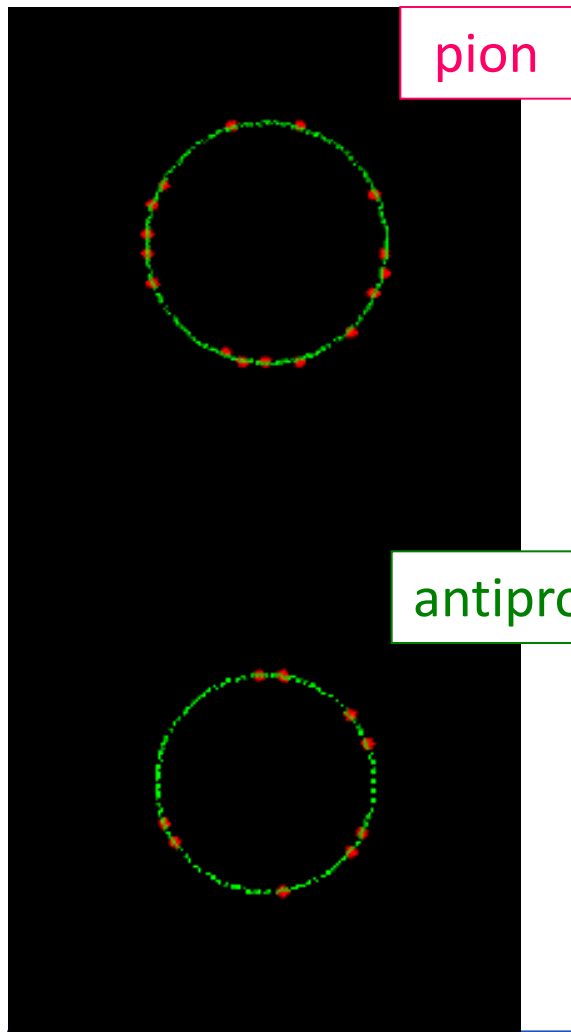
- time and Cherenkov angle resolutions
- check hit multiplicity per ring
- ❖ Test Beam in autumn 2007, results published [NIM A 593 (2008) 314]
- ❖ 200 GeV/c negative hadron beam from CERN SPS (mainly pions, ~3% K)
- ❖ Standard readout: VME TDC CAEN V1190



RICH-100 prototype - test results

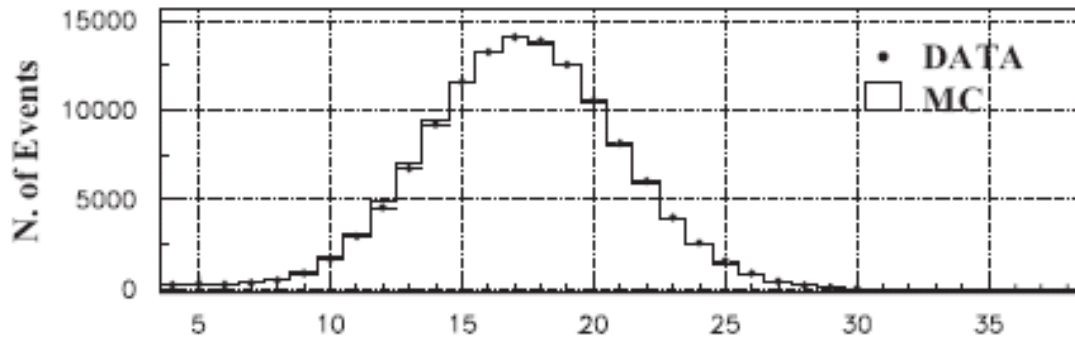
ring for π^- and \bar{p}

Fitted ring center and radius (data and MC)

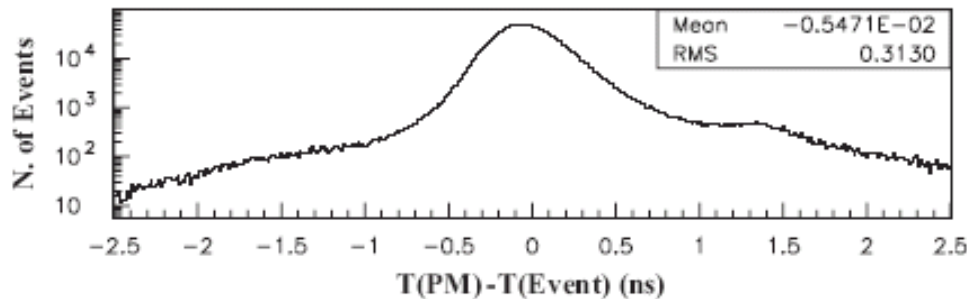


RICH-100 prototype - test results

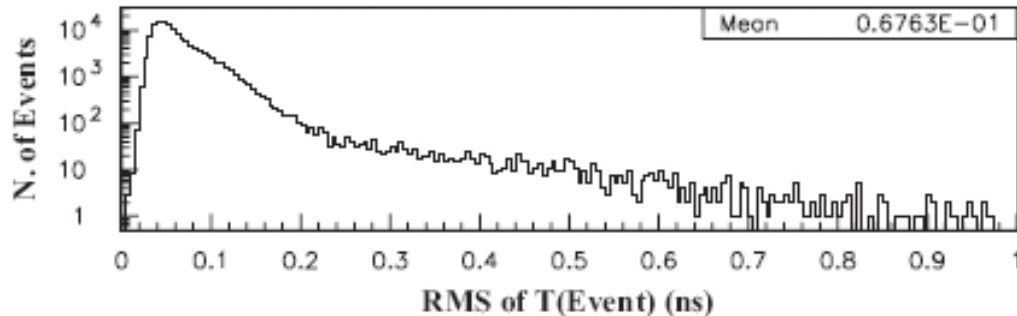
PM hit and time resolution



Number of hit PM per event
(data and MC): $N_{\text{Hits}} \approx 17$



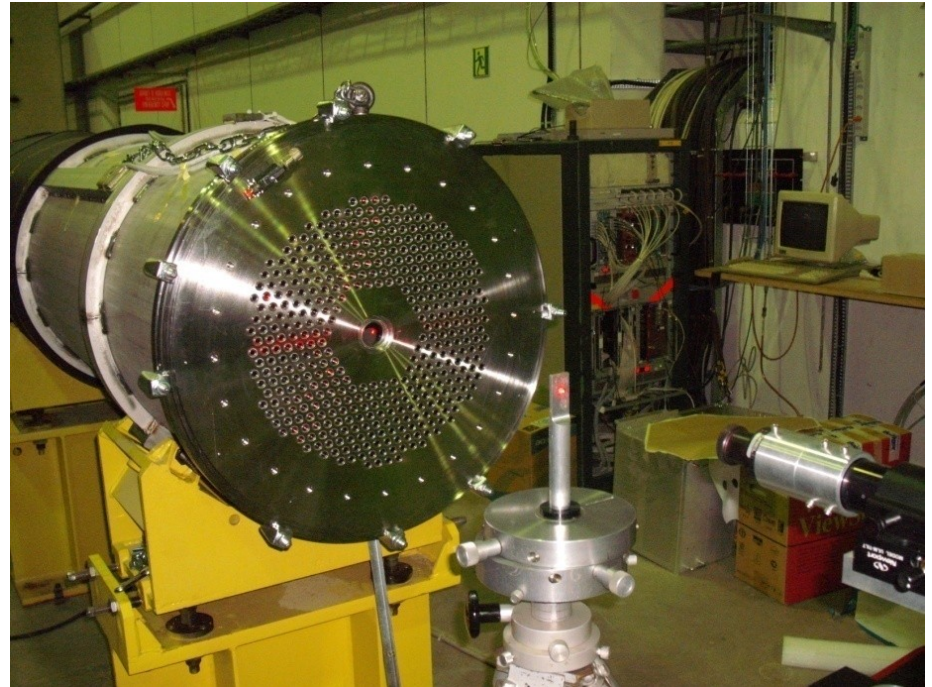
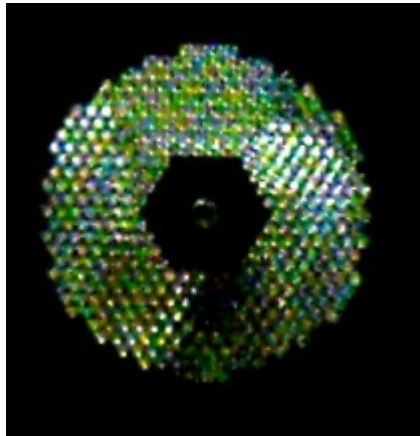
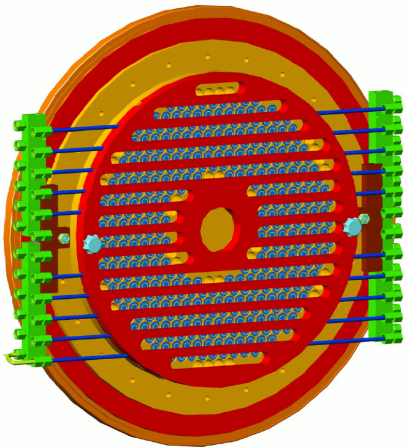
PM time - event time:
single PM time resolution ≈ 310 ps




Average event time resolution
(RMS) ≈ 70 ps

The RICH-400 prototype

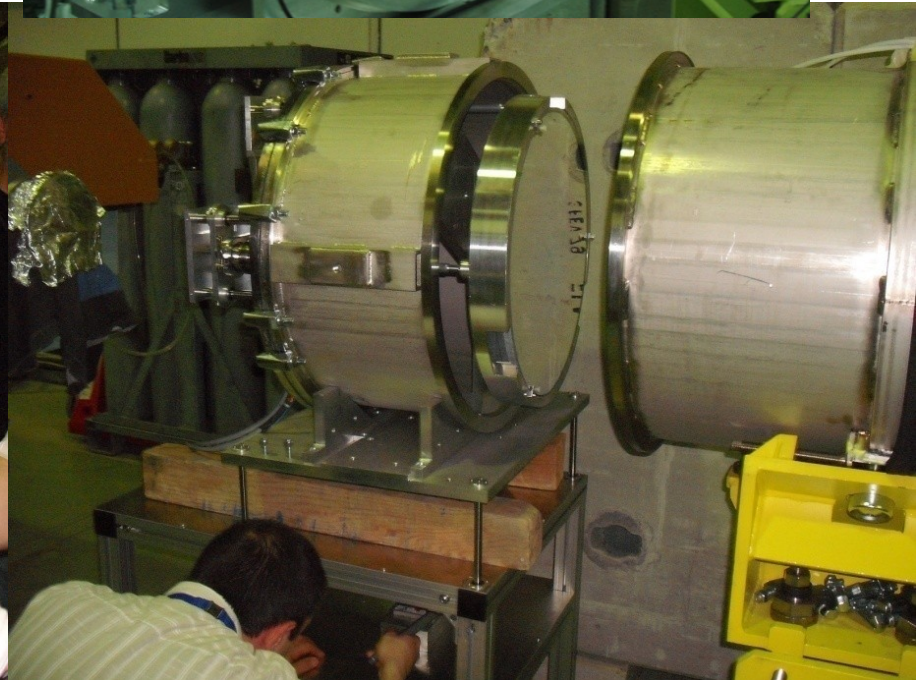
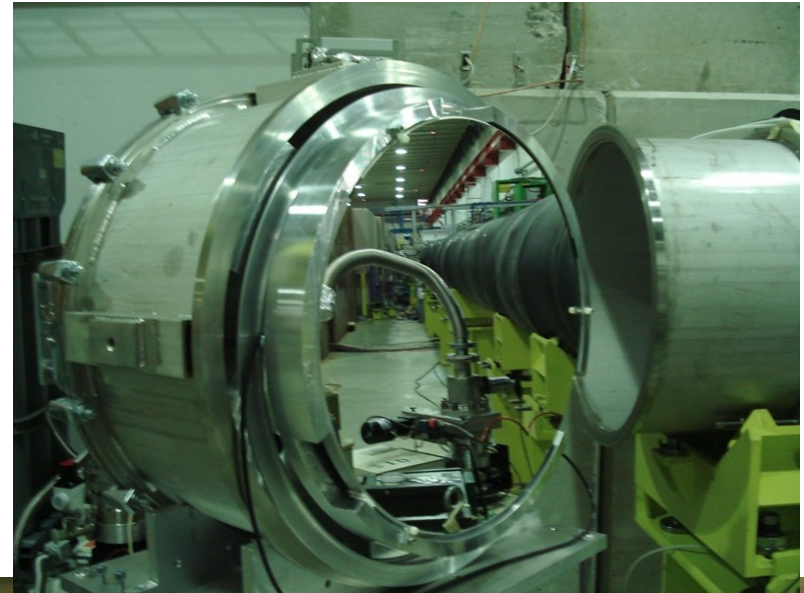
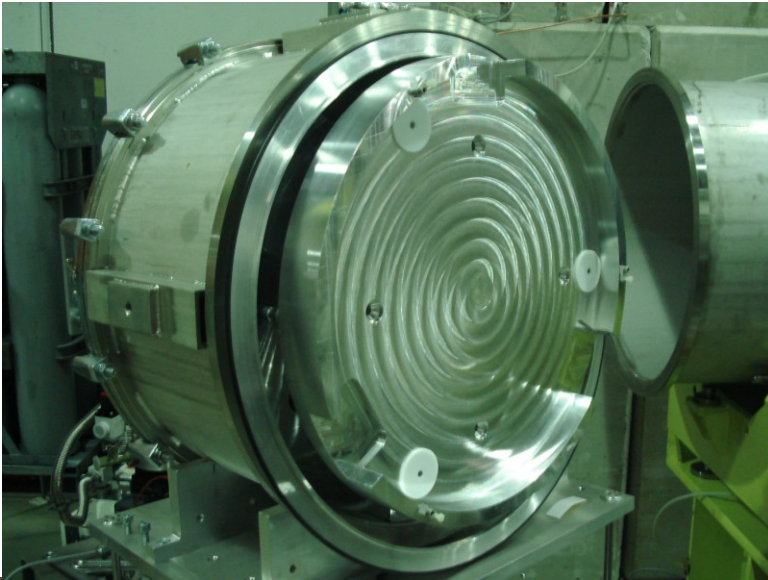
- New PM flange: 414 PM (20% of final detector)
- Test Beam in may-june 2009, aiming at:
 - Validate π - μ separation @ $15 < p < 35$ GeV/c
 - Test cooling system
 - Test new mirror
 - Test new readout
- Preliminary results shown



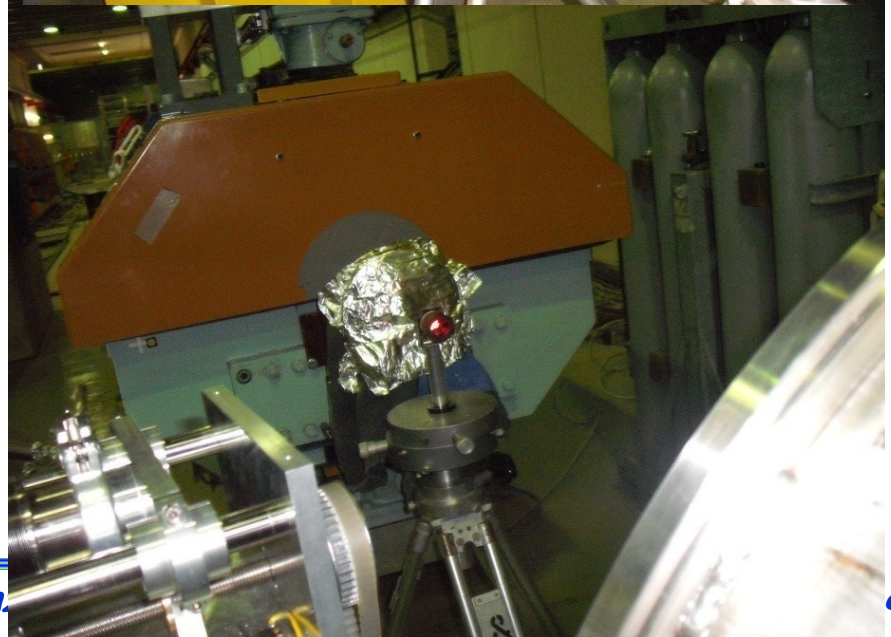
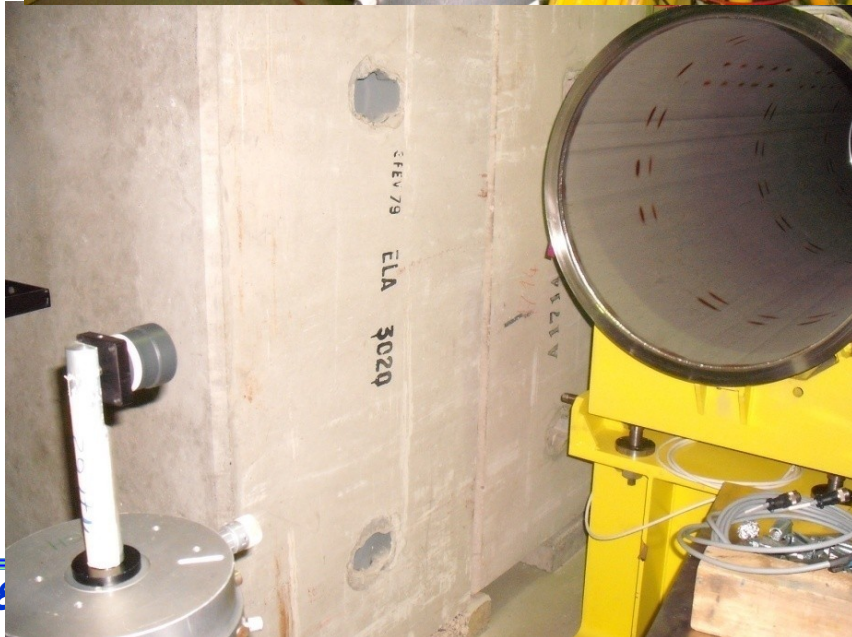
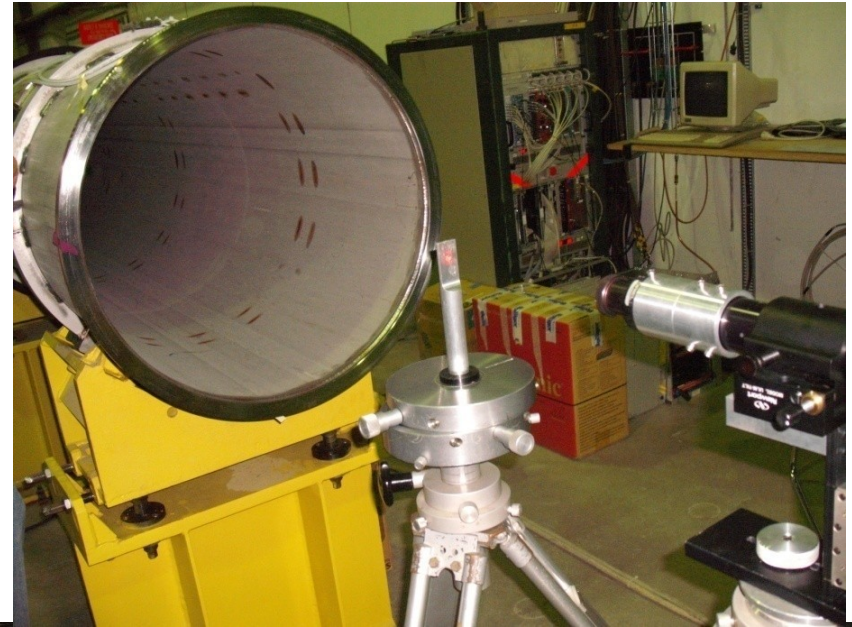
Test beam program

- * Beam: mainly π^+ , 15% p, few % K^+ , variable % of e^+ , no muons
 - $\Delta p/p \approx 1\%$, negligible divergence ($< 30 \mu\text{rad}$)
- * Momentum range 10-75 GeV
- * π - μ separation @ 15-35 GeV measured using only pions
- * Each measurement  two points in momentum:
each next point is a pion with the same β of the muon of the actual point
- * Test prototype performance under different conditions:
 - Move the mirror, different rates, different Tell1 firmware versions, pollute the gas (air and CO_2), etc...
- * Repeat measurements with the new mirror (final device, made by Marcon, aluminized and coated at CERN)
- * check trigger algorithms and accidentals at higher intensities
- * measure efficiency for ring fitting

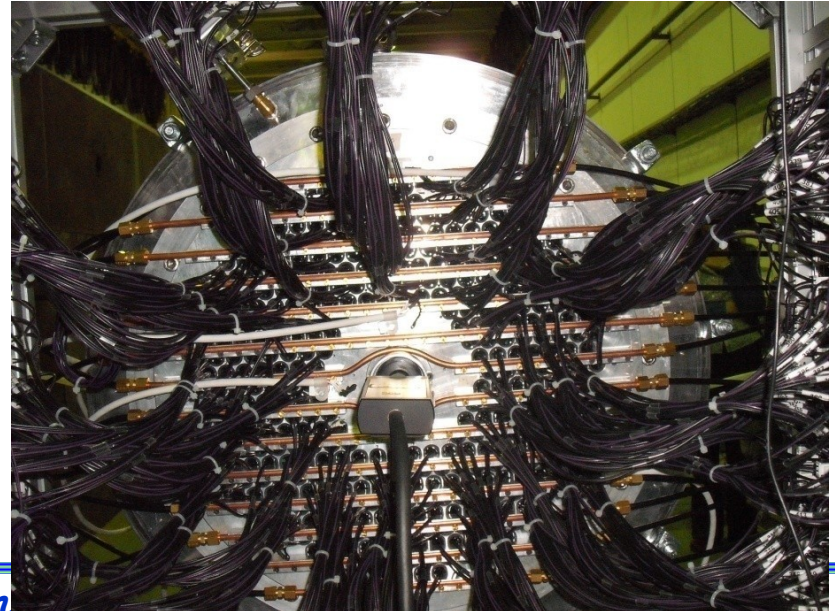
Test installation: the mirror



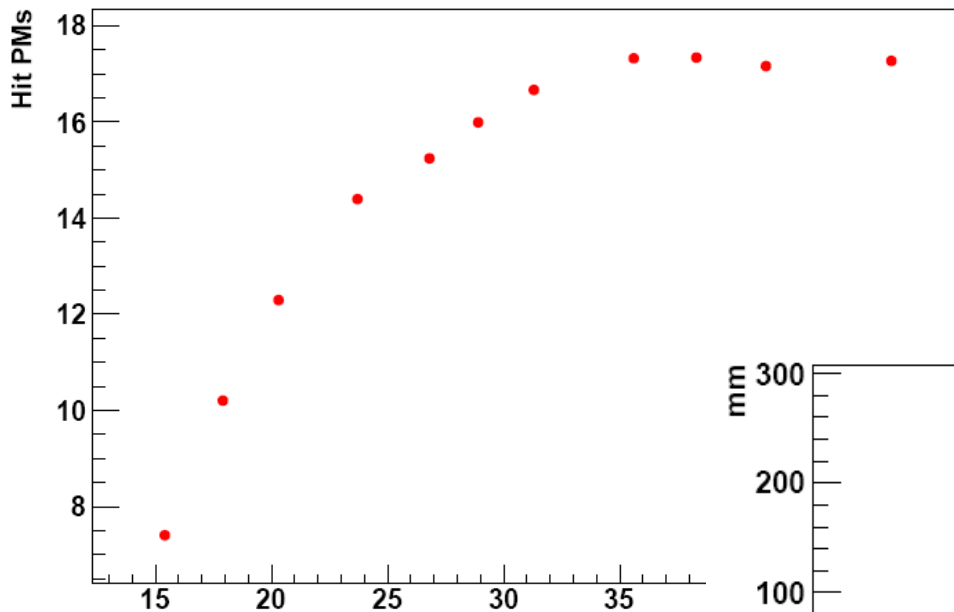
Test installation: laser alignment



Test installation: vessel closing

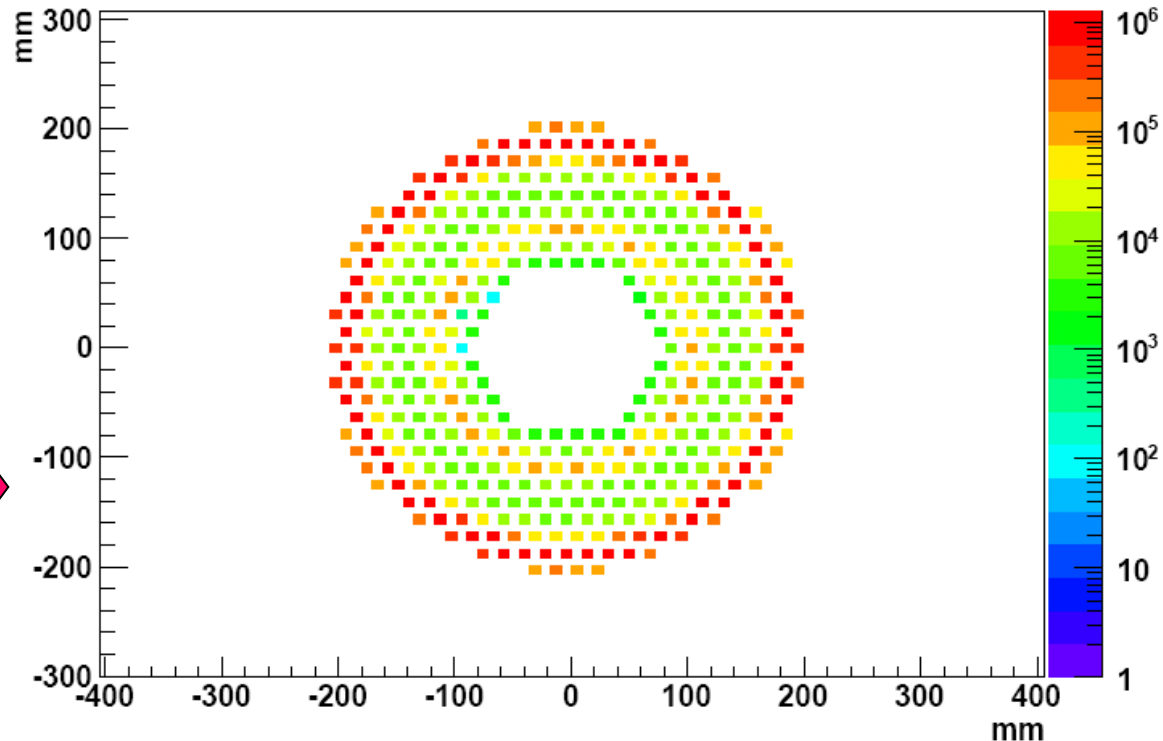


Results: PM hits and illumination



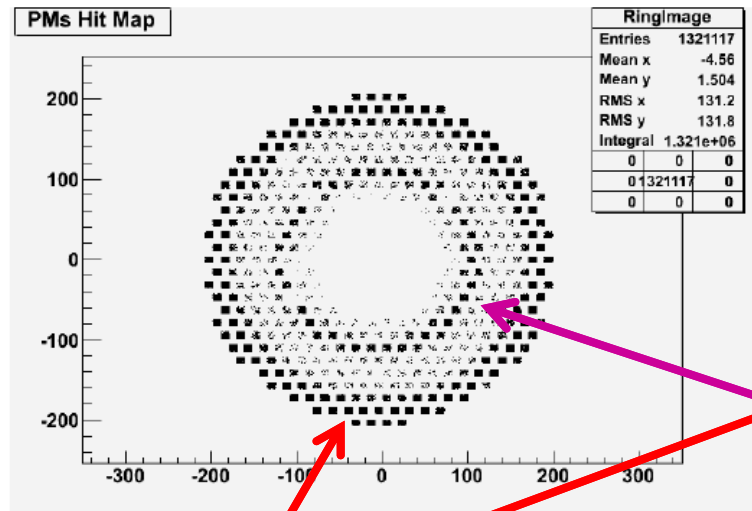
Number of hit PMs per ring vs momentum

PM illumination at 15 GeV/c

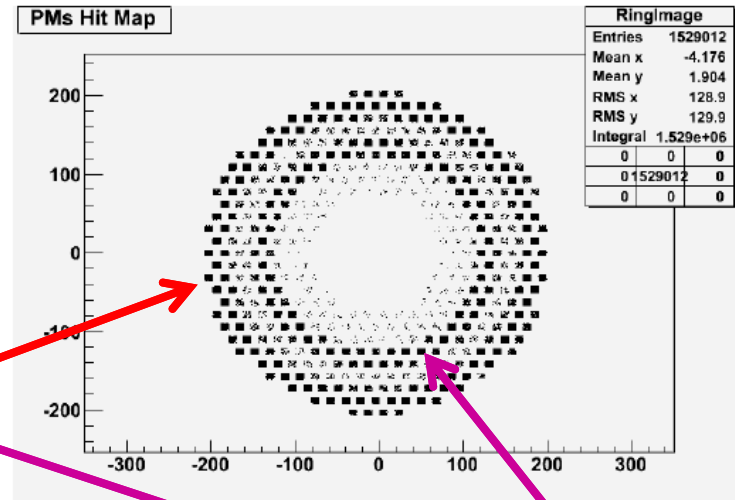


Results: PM illumination

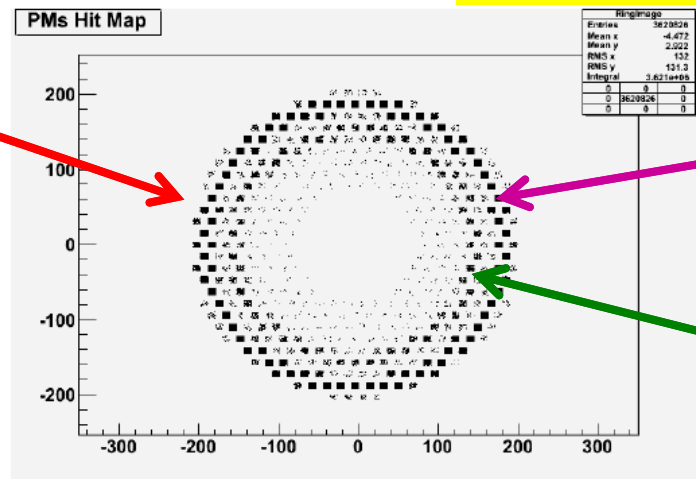
PMs illumination @ [redacted]



PMs illumination @ [redacted]



PMs illumination @ [redacted]

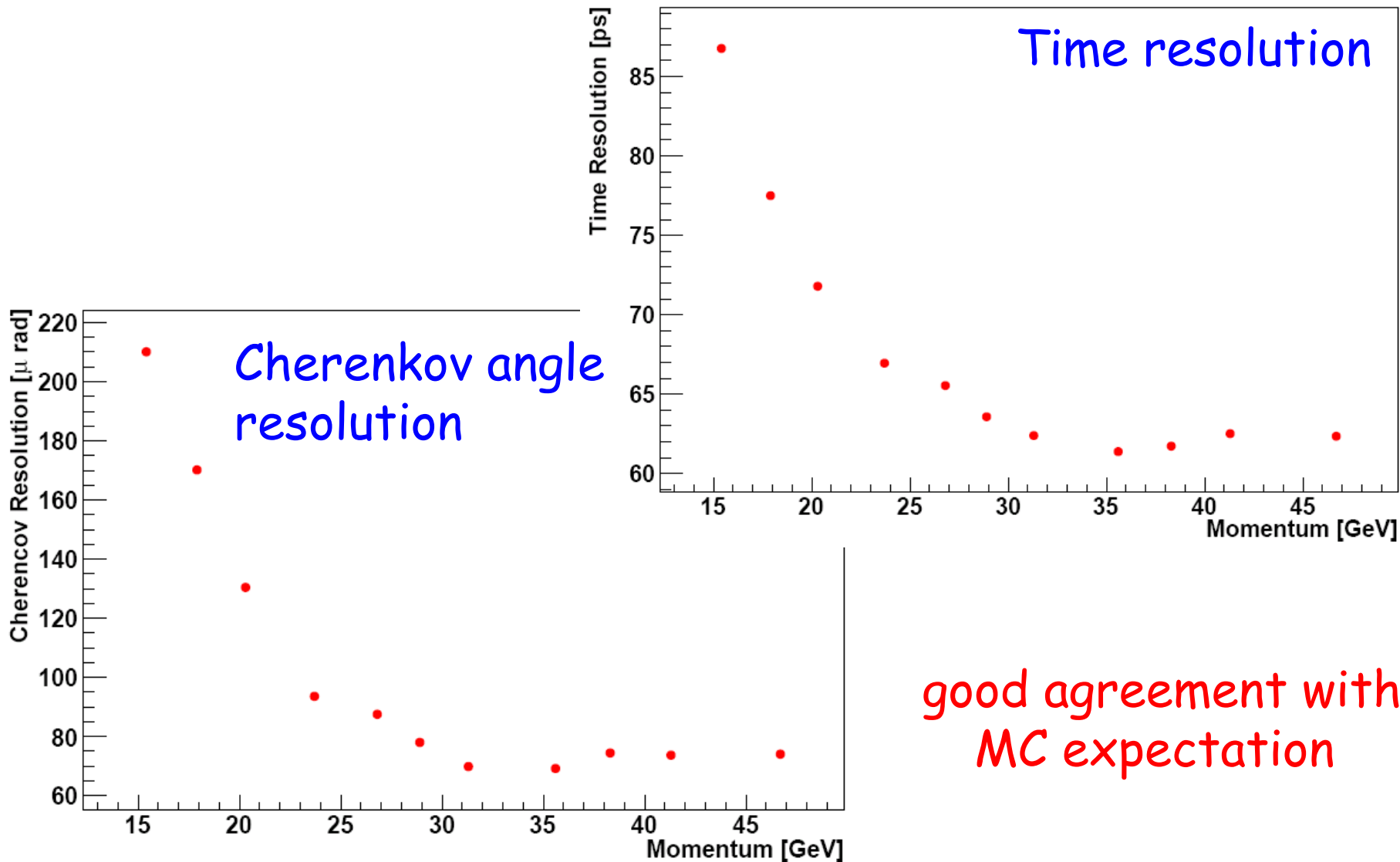


positrons

pions

kaons

Results: Time and Cherenkov angle resolution



good agreement with
MC expectation

Results: π - μ separation

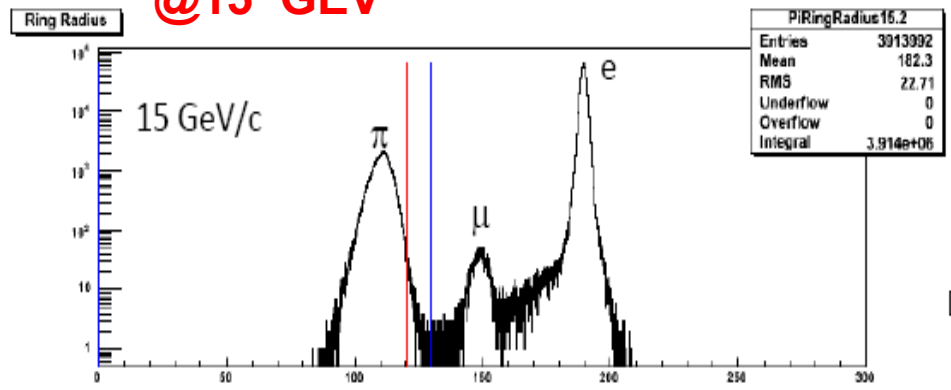
PRELIMINARY RESULTS

"nominal"

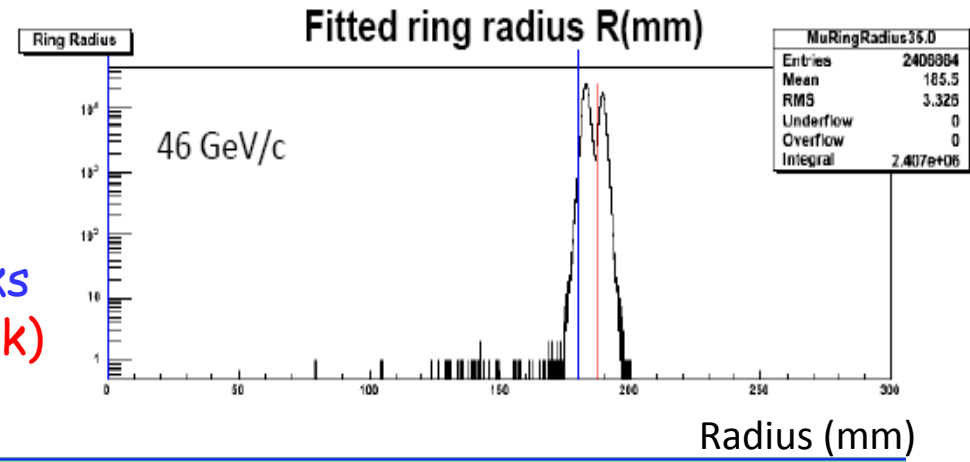
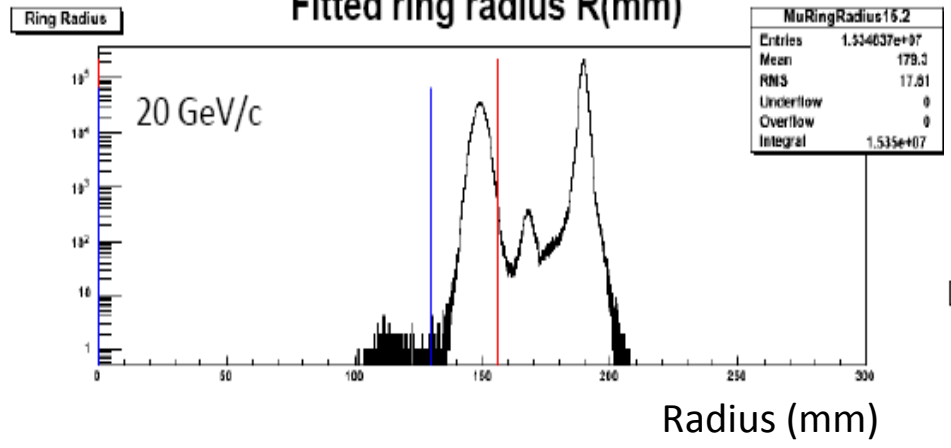
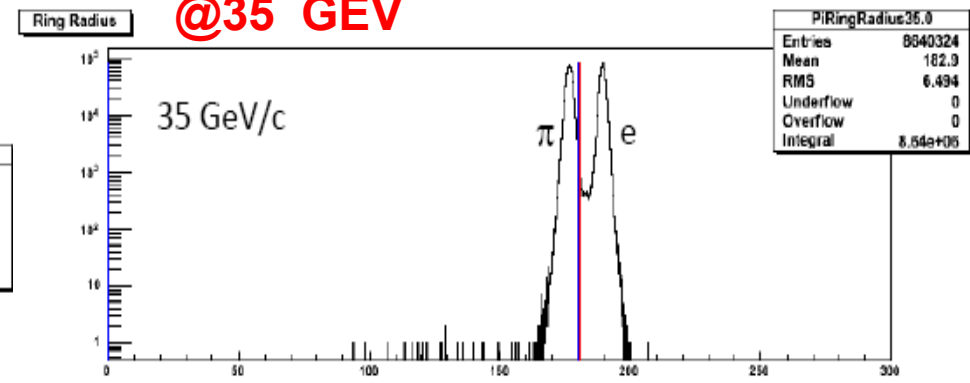
"conjugate"

The " μ " is a π with the same β as a 15 (35) GeV/c μ

@15 GEV

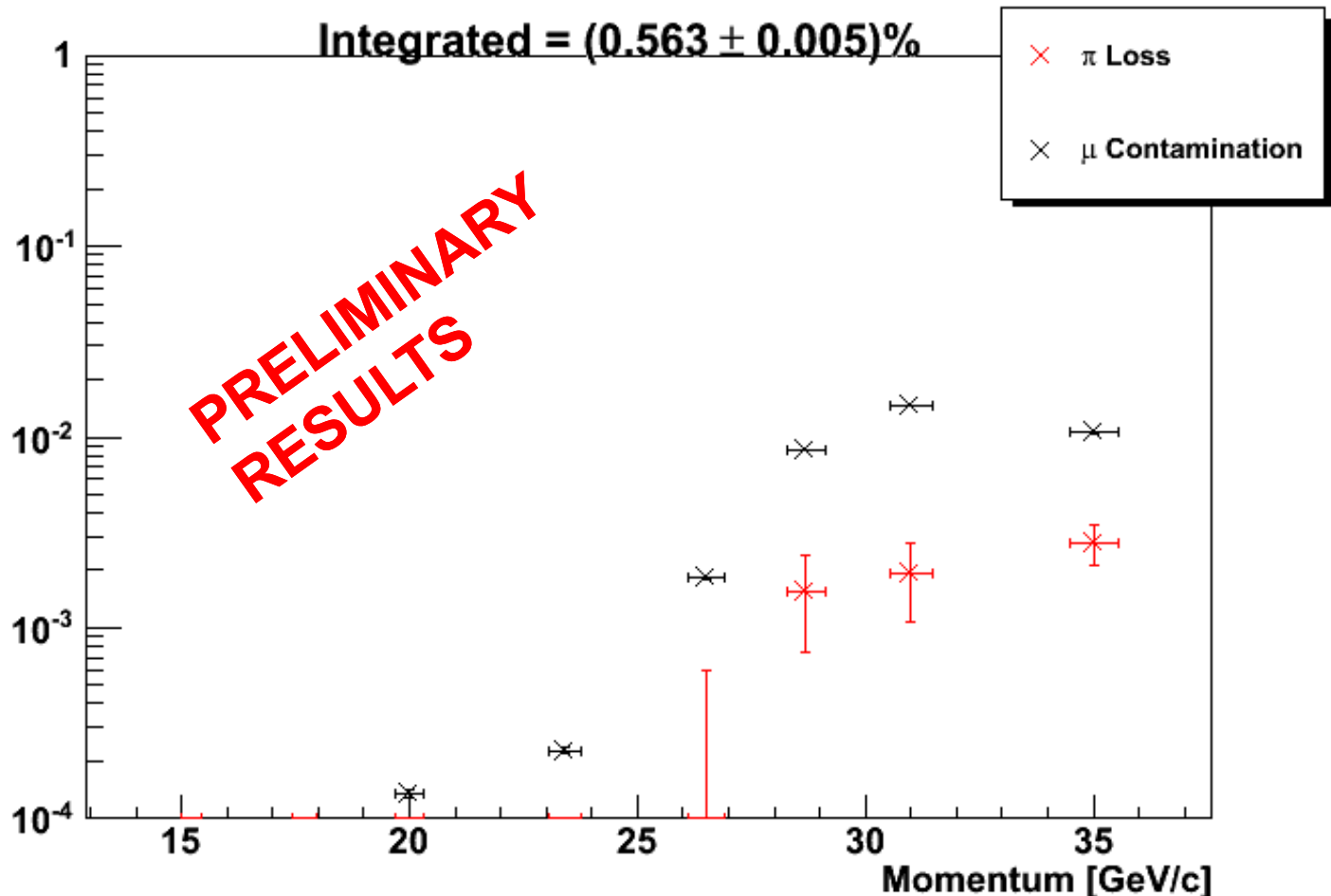


@35 GEV



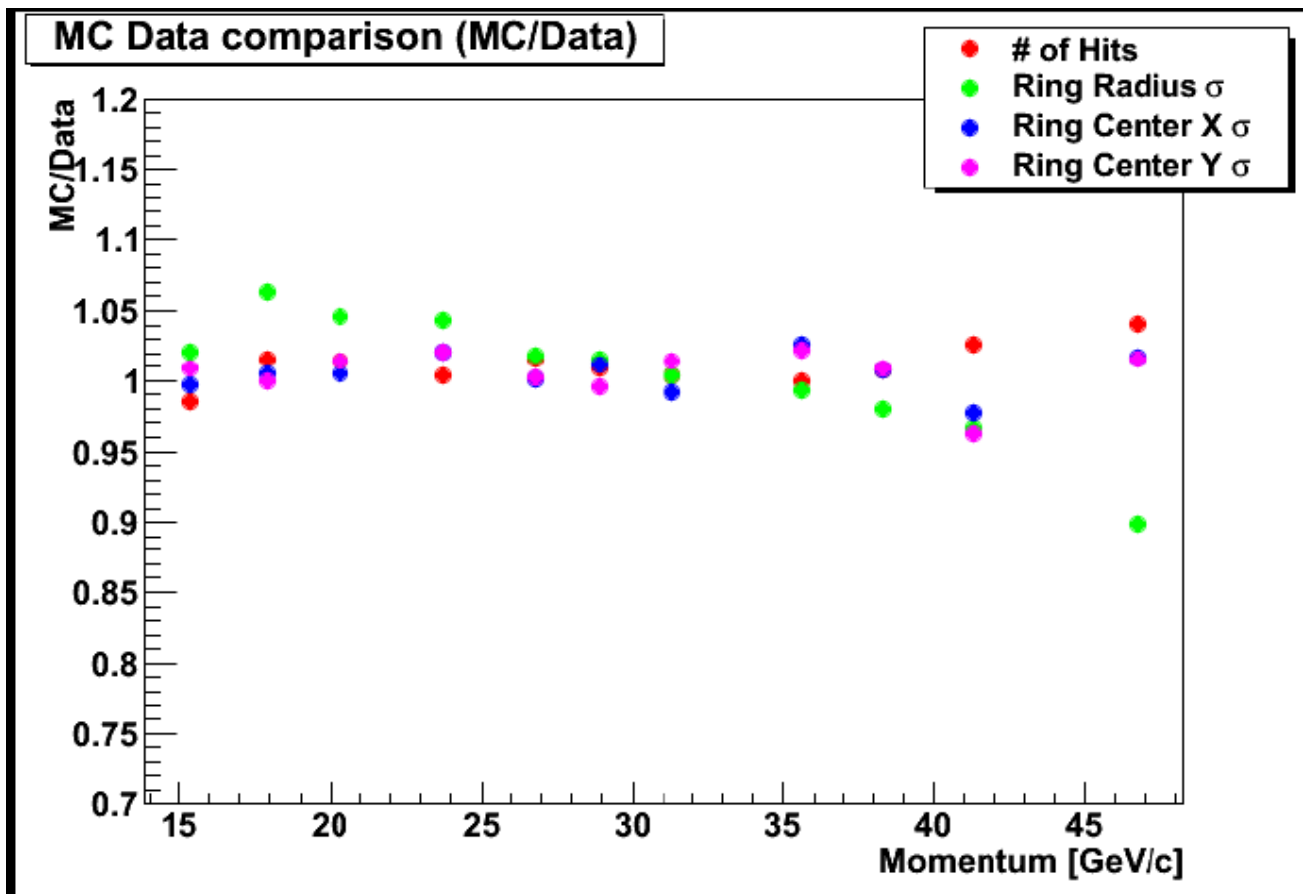
Blue line: half way between π and μ peaks
 Red line: signal definition (+3 σ from peak)
 Calculate: μ contamination and π loss

Results: π - μ separation



PRELIMINARY overall muon suppression factor: $\sim 0.7\%$
integrated between 15 and 35 GeV/c (weighted with μ spectrum)

Results: Data-MC comparison



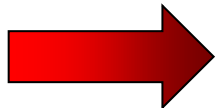
Summary and outlook

The NA62 RICH will be used for:

- background suppression (π - μ separation)
- precise measurement of track time
- first level trigger

- ❖ prototype-100 test
 - time and Cherenkov angle resolution
 - hit PM's per ring
- ❖ prototype-400 test
 - validate π - μ separation
 - test of new components (mirror, read-out, cooling...)

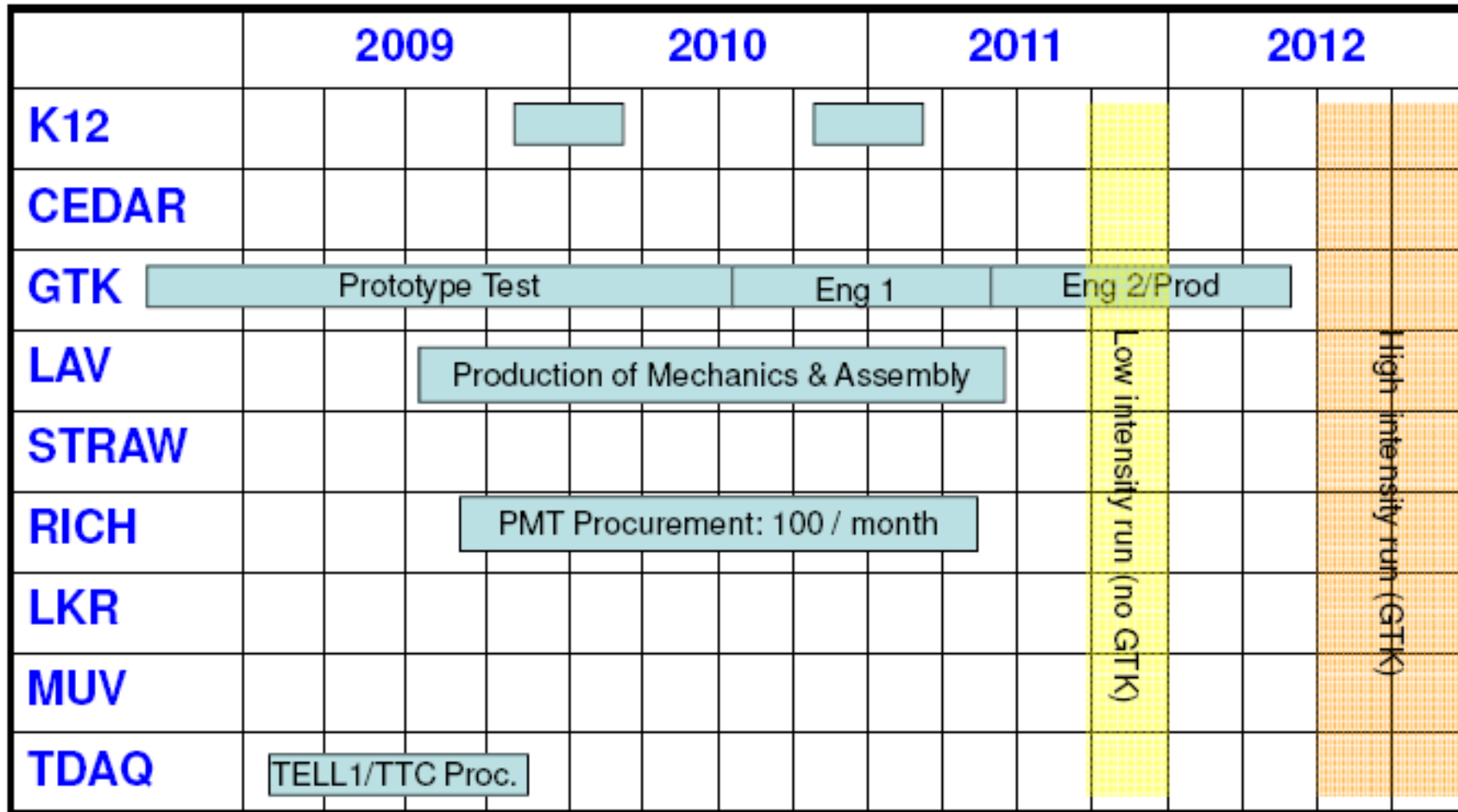
Results from the tests meet the design requirements



NA62 RICH detector in construction

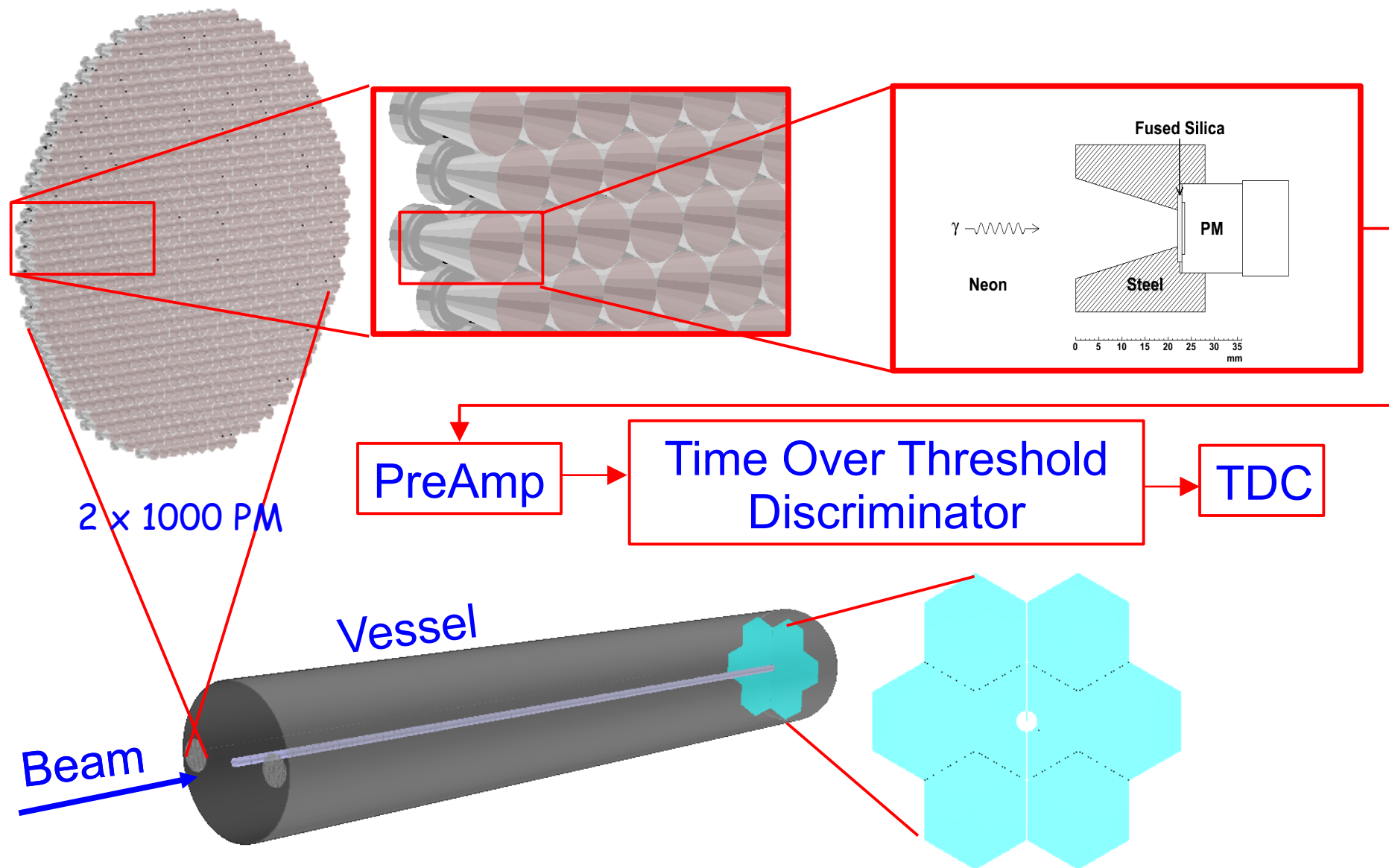
SPARES

NA62 time scale

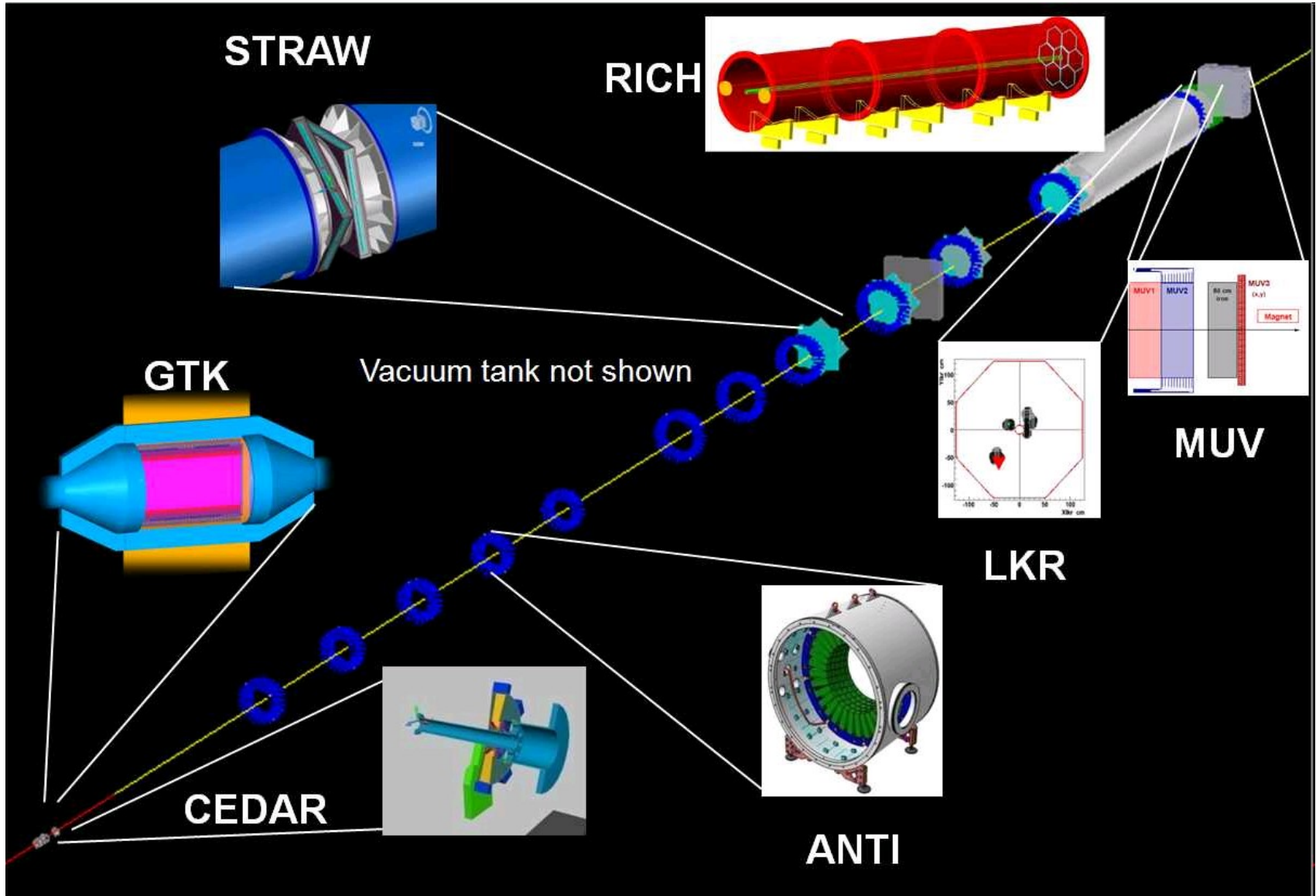


A. Ceccucci, WIN09

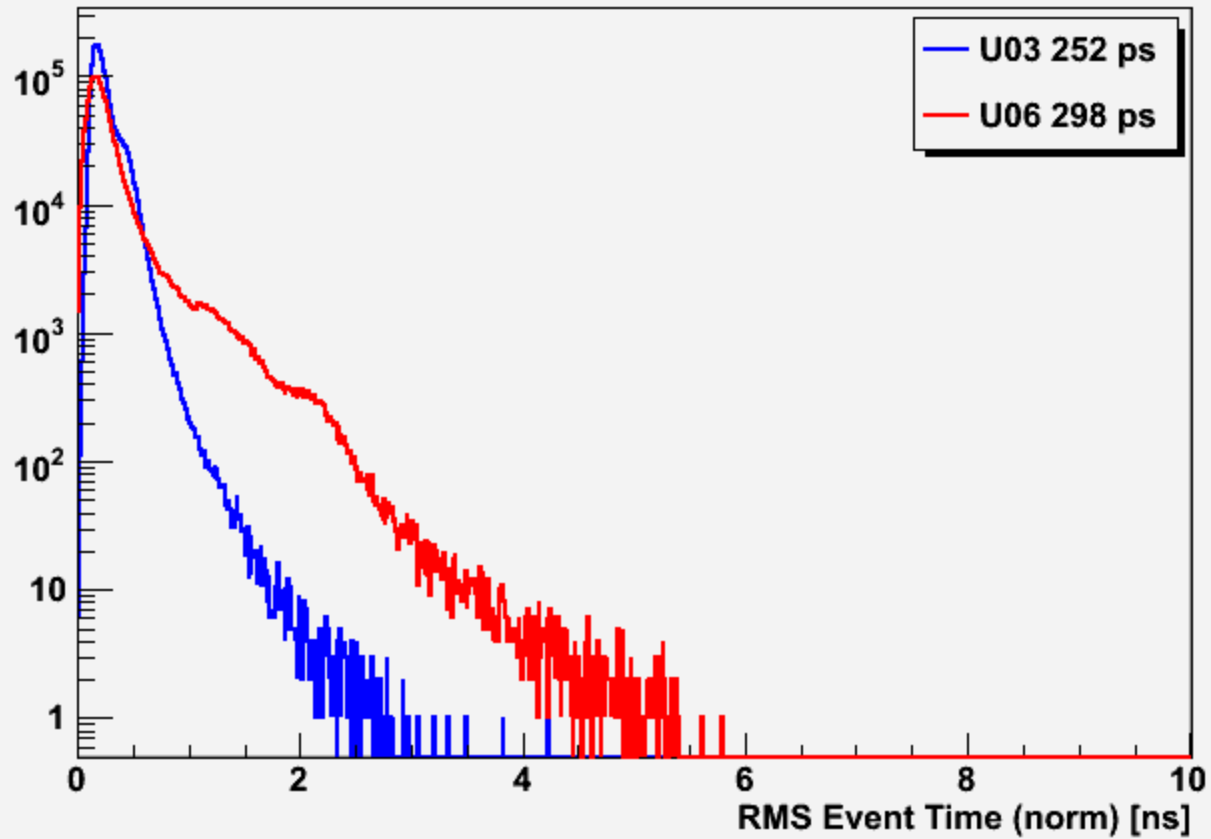
RICH - Exploded view



NA62 detectors



RUN 2104 - Time Resolution



Further studies

Pollution tests

- Oxygen: 380 ppm and 425 ppm (π momentum at 46.3 GeV/c)
(air will surround the vessel)
- CO₂ : 0.5% and 1% (4 steps in π momentum)
(it will be used to clean the vessel)

Mirror orientation

- Scan on several ring positions rotating the mirror
- Ring center moved by 1.1 mm for each step (16 steps total)
- Study the Winston cone reflectivity and the uniformity on photocathode response

Analysis is ongoing