THE NA62 RICH DETECTOR

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

OUTLINE

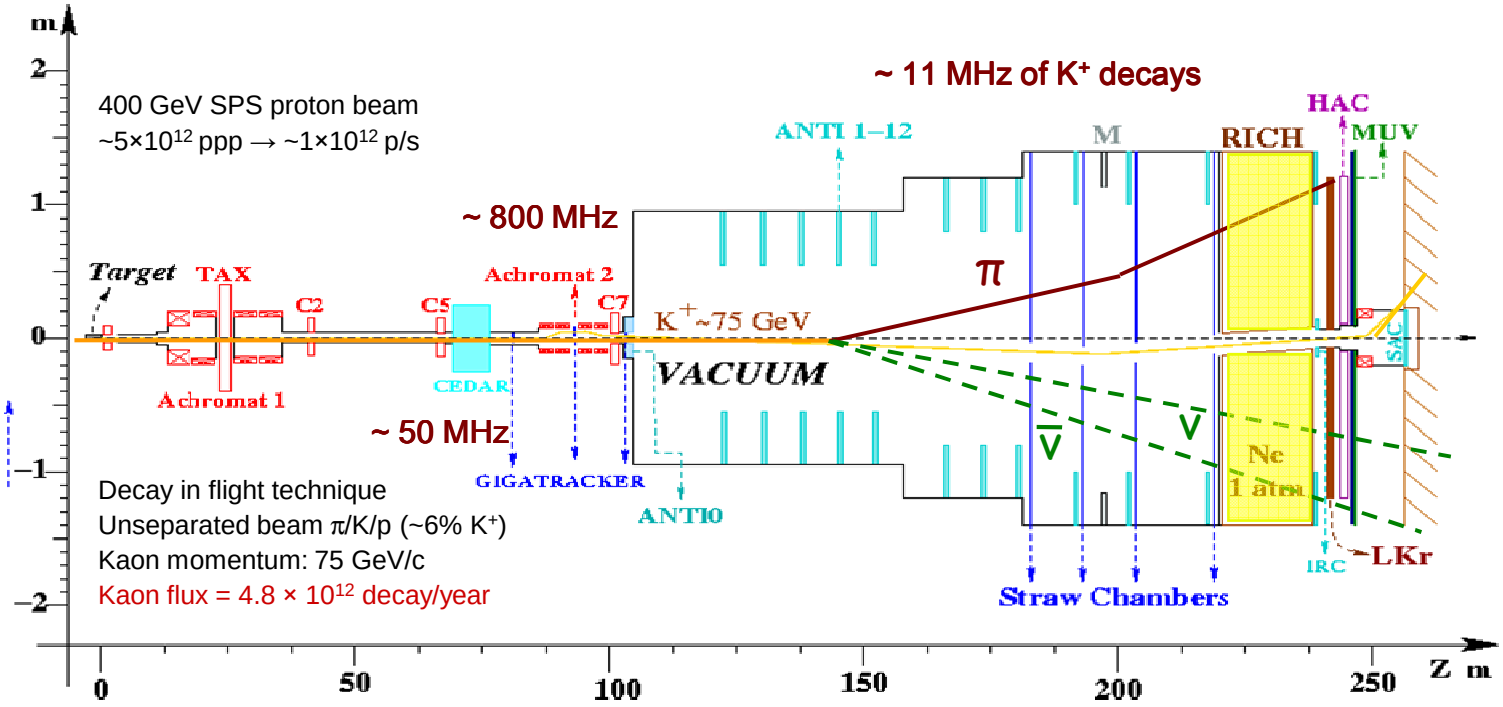
- The NA62 experiment at CERN
- The RICH detector design
- The RICH-400 prototype test beam results:

  (2009) test beam, new preliminary results!

The NA62 Experiment at CERN

NA62 ➡ 10% precision on BR($K^+ \to \pi^+ \nu\bar{\nu}$) (~100 events in 2 yrs)

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



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

RICH requirement: PID and timing

NA62 GOAL: ~100 $K^+ \to \pi^+ \nu\bar{\nu}$ events in 2 years (starting in 2012)
~10% background (signal acceptance ~10%)

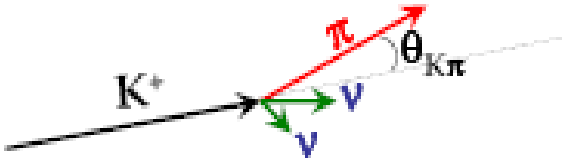
- suppress $K^+ \to \mu^+ \nu$ ($K_{\mu 2}$) background

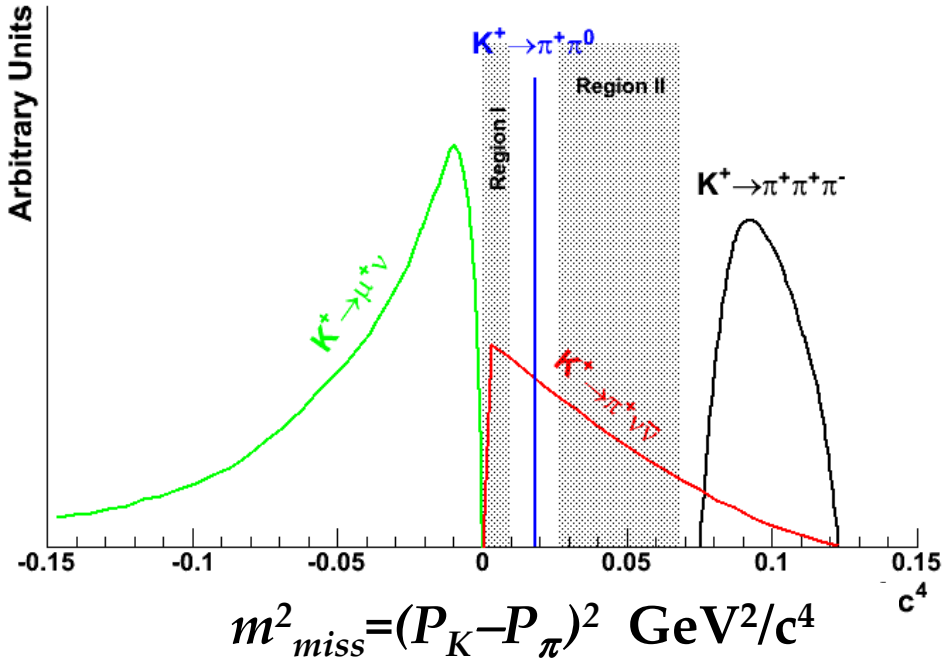
- Main background: BR = 63.4%
- Rejection factor at least 10^{-12}
  - Kinematics : ~10^{-5}
  - Muon Veto : ~10^{-5}
  - Particle Identification:

    μ suppression < 10^{-2}

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

RICH





$m^2_{miss} = (P_K - P_\pi)^2$ GeV²/c⁴

The NA62 RICH Detector

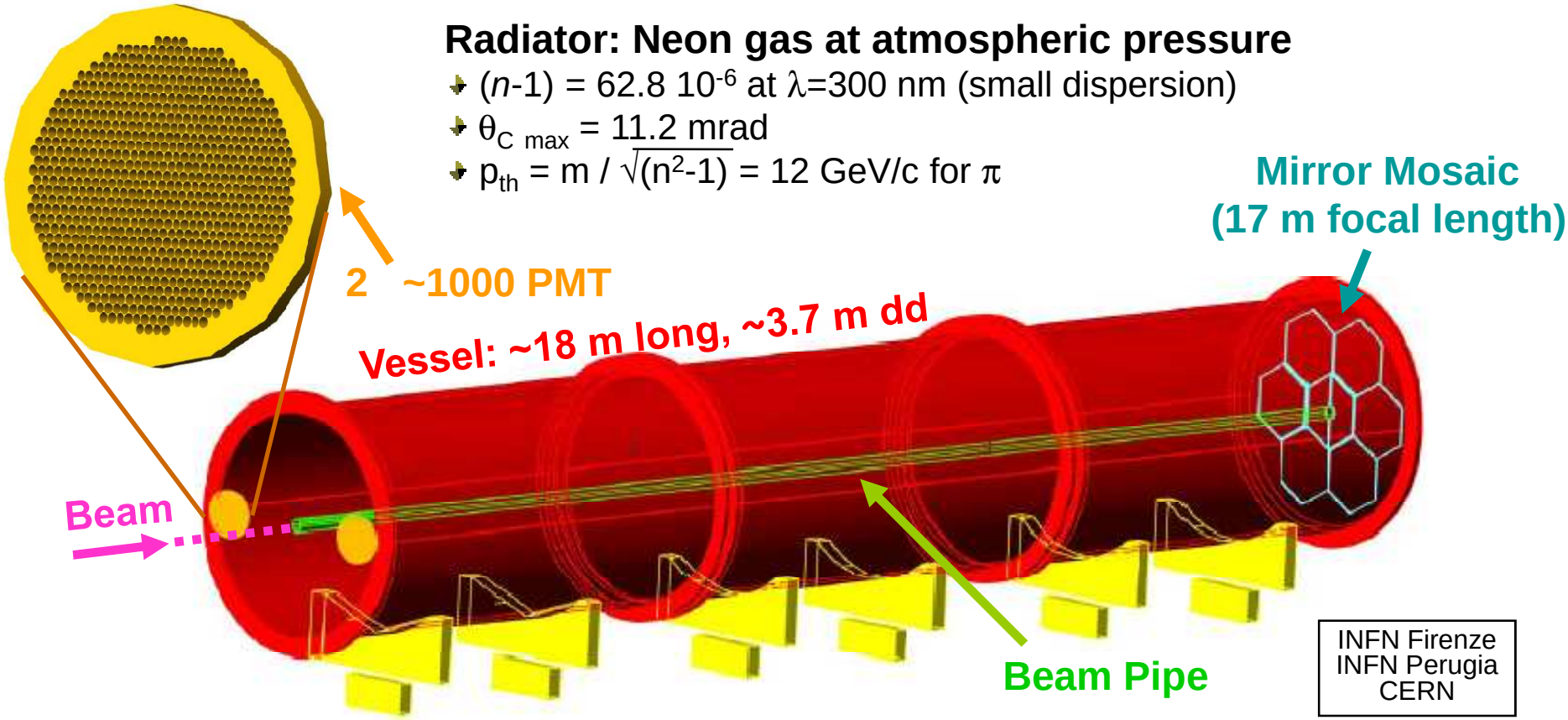
THE NA62 RICH REQUIREMENTS:

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

(Talk by G. Lamanna IEEE 2009 NSS N10-1)

Radiator: Neon gas at atmospheric pressure

- $(n\text{-}1) = 62.8\ 10^{-6}$ at λ=300 nm (small dispersion)
- $\theta_{C\ max} = 11.2$ mrad
- $p_{th} = m / \sqrt{(n^2\text{-}1)} = 12$ GeV/c for π



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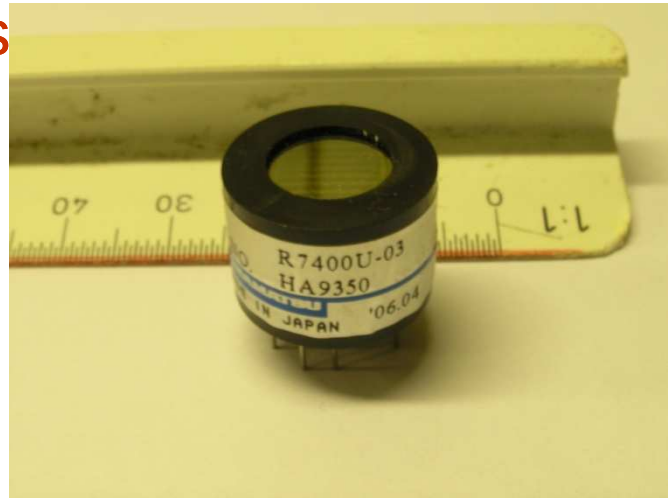
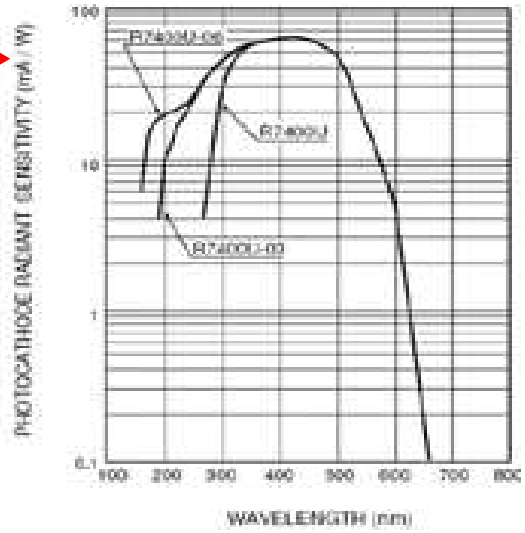
The Cherenkov light detection

Hamamatsu R7400 U-03 Photomultipliers

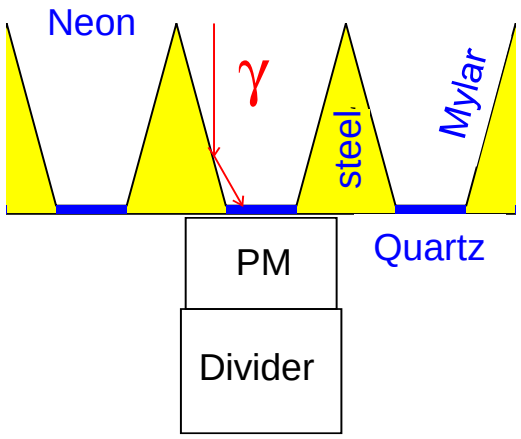


- Metal package tube, 8 dynodes
- 185 nm – 650 nm, 420 nm peak sensitivity
- UV glass window, 16 mm dd, 8 mm active dd
- Bialkali cathode
- Gain: 7×10^5 @800 V (~1.5×10^6 @900 V)
- Transit time: 5.4 ns
- Transit time spread: 0.28 ns
- Applied Voltage: 900 V (1000 V maximum)



Light Collection:

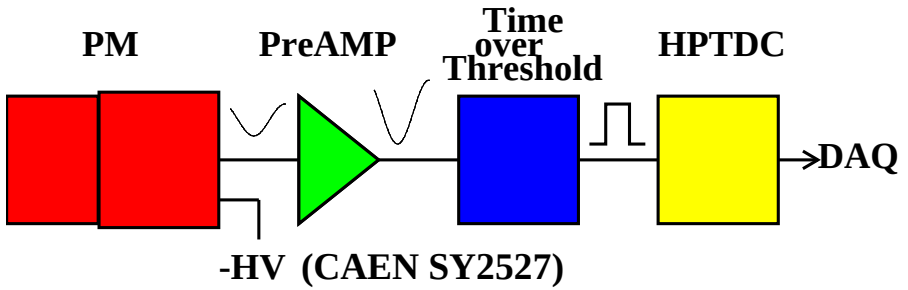
- Winston Cones covered with Mylar
- 22 mm high
- 18 mm wide (max)
- 7.5 mm wide (min)
- 1 mm thick quartz window



Front End and Readout electronics

Front End:

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



INFN PISA

Readout: based on TDC Boards

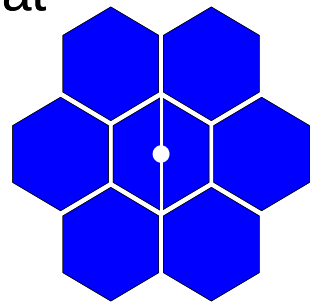
(Talk by G. Collazuol IEEE 2009 NSS N21-2)

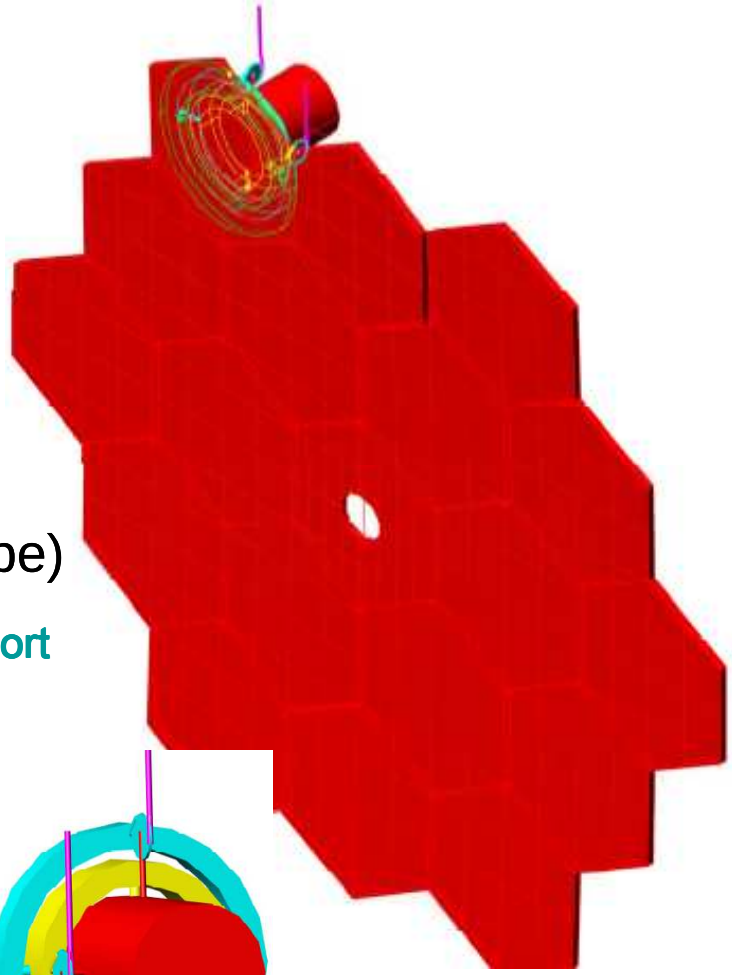
- A board (TDCB) equipped with 128 channels of TDC (HPTDC, 100 ps LSB) has been build
- The FPGA based TELL1 mother board (from LHCB) will houses 4 TDCB (512 channels)
- The trigger primitives will be constructed in parallel with the readout on the same TELL1 board (1 MHz input to L1, implemented in software)
- The TDC CAEN V1190 (128ch, based on HPTDC, 97.7 ps LSB) was also used

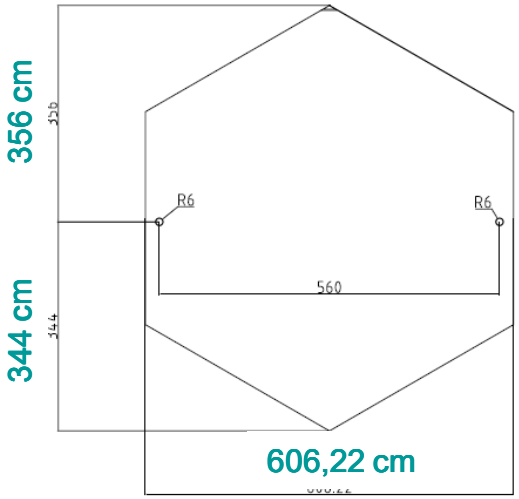
The NA62 RICH: mirror layout

Mosaic of Hexagonal Mirrors from MARCON company

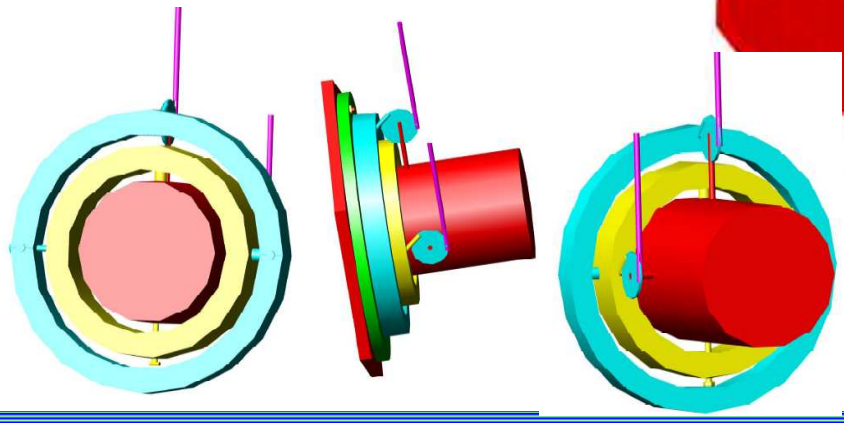
- 2.5 cm thick glass, 17 m focal length
- Aluminum deposit with MgF_2 coat
- Piezo actuators for alignment
- Carbon fiber for mirror support
  (Honeycomb structure)
- Final detector: 18 hexagonal mirrors
  + 2 half hexagons (avoid γs on beam pipe)



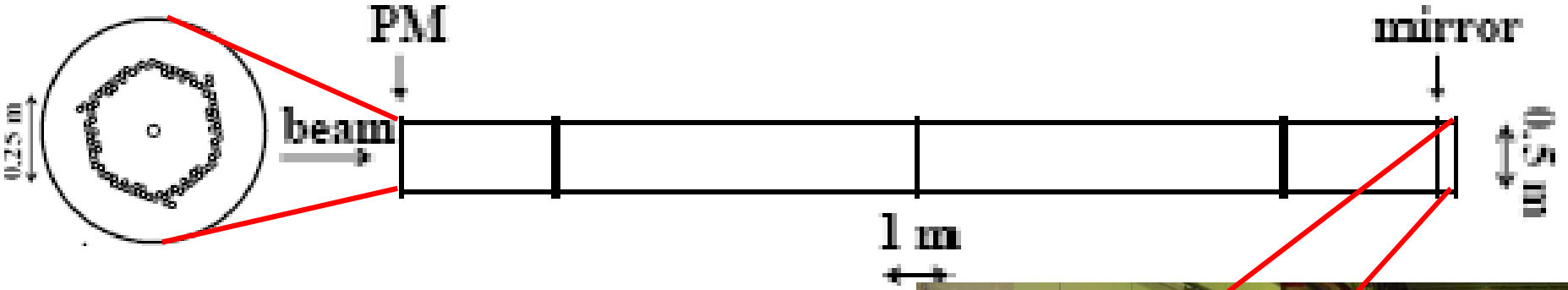




Single mirror design and support



The NA62 RICH prototype



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

30 mm

The RICH-100 prototype:

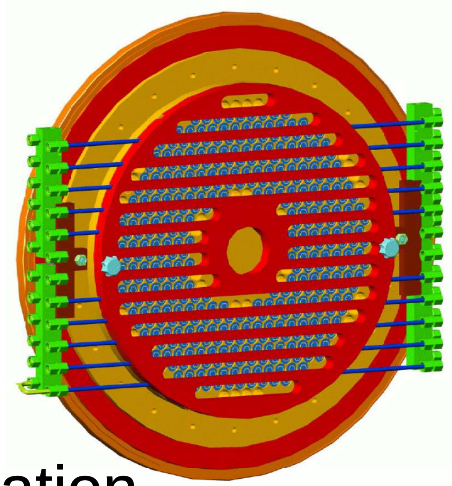
- 96 PMT Hamamatsu R7400 U03/U06
- Test Beam in autumn 2007

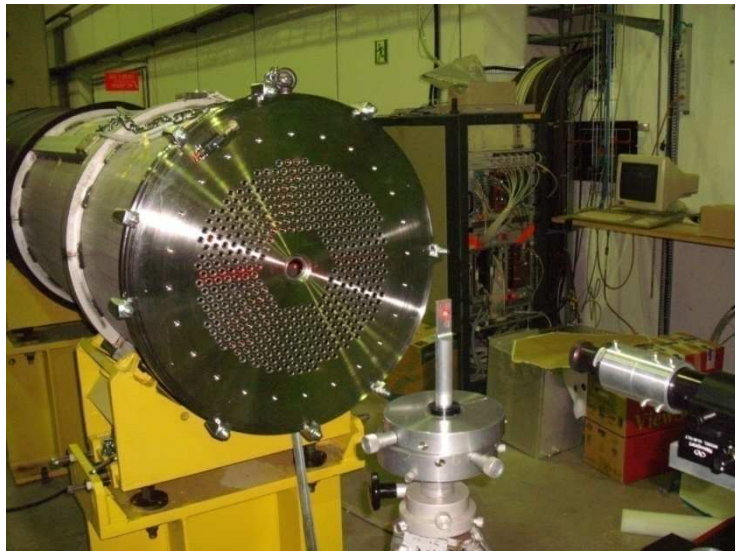
The RICH-400 prototype:

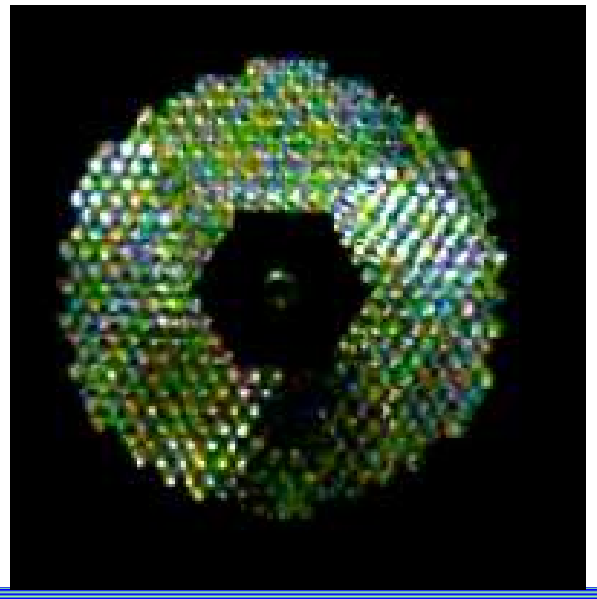
- 414 PMT Hamamatsu R7400 U03
- Test Beam in may-june 2009

The RICH-400 prototype

- PM endcap: 414 PM (20% of final detector)
- Test Beam in may-june 2009, aiming at:
  - Validate π–μ separation @ 15<p<35 GeV/c
  - Improve PM cooling (wrt RICH-100)
  - Test different mirrors
  - Test the Tell1 based read-out
- Preliminary results shown here, paper in preparation





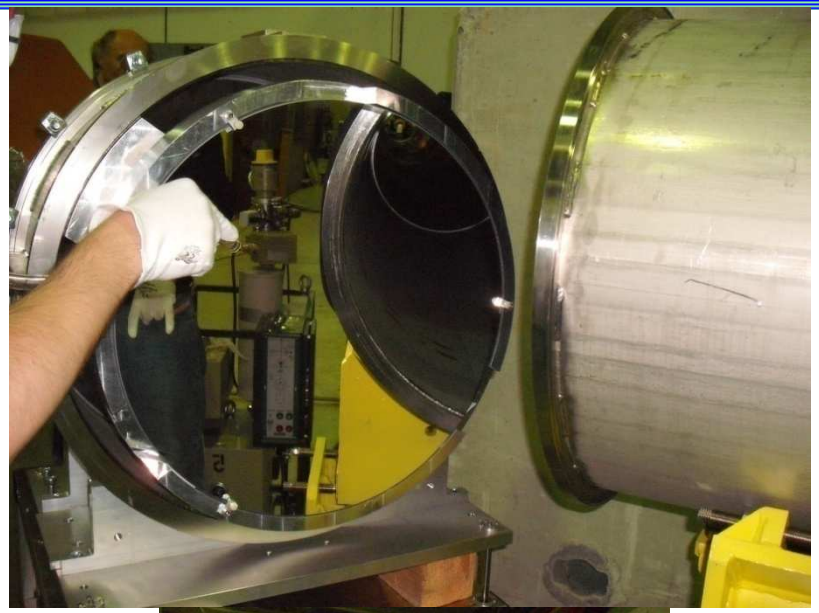


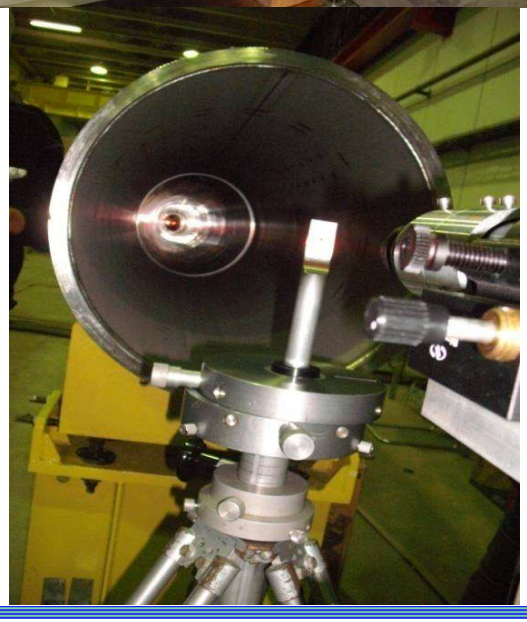
RICH-400: test beam program

- Beam: mainly π^+, 15% p, few % K^+, variable % of e^+
  - 1.5% $\Delta p/p$, negligible angular spread
- Setup at 75 GeV/c (highest momentum), check at 10 GeV/c
- Many momentum points (μ–π equivalent): each next point is a pion with the same β of the muon of the actual point
  - 1° scan: 15.2, 20.1, 26.5, 35.0, 46.2, 61.2 GeV/c
  - 2° scan: 17.7, 23.4, 31.0, 41.0, 54.2 GeV/c
  - 3° scan: 28.7, 38.0, 50.3 GeV/c
- Test prototype performance under different conditions:
  - Move the mirror, different rates, different Tell1 firmware versions, pollute the gas (oxigen and CO_2), etc
- Repeat measurements with a new mirror (final device, made by Marcon, aluminized and coated at CERN):
- Other special runs to:
  - check trigger algorithms and accidentals at higher intensities
  - measure efficiency for ring fitting

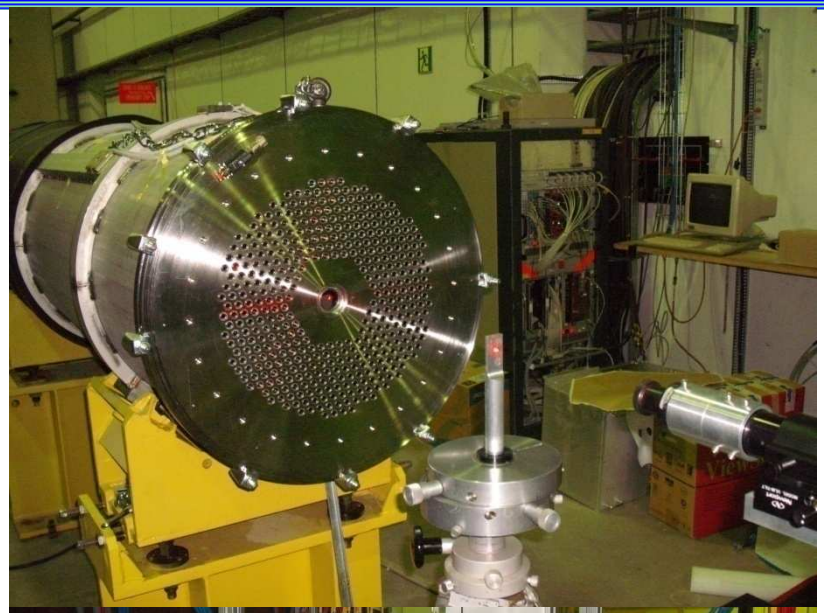
⇨ PRELIMINARY RESULTS

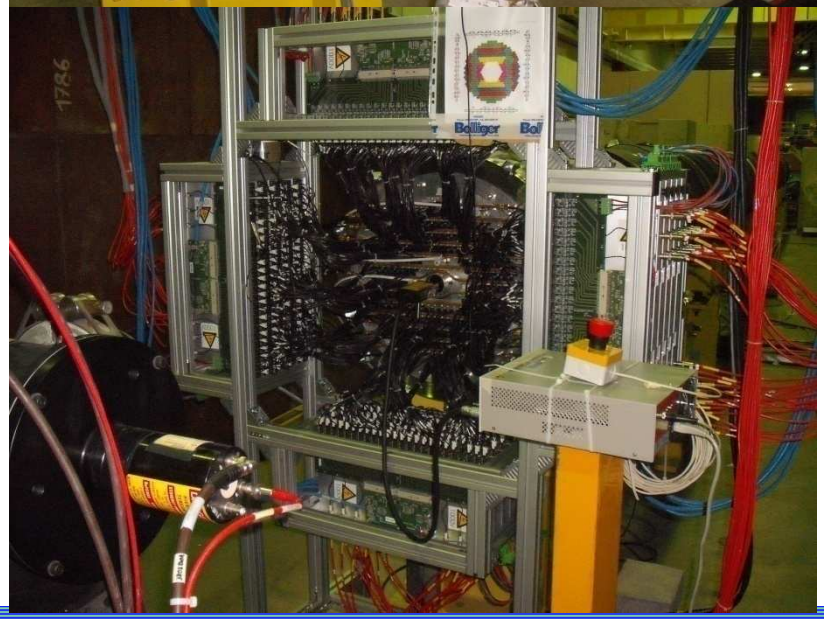
The Rich-400: mirror installation

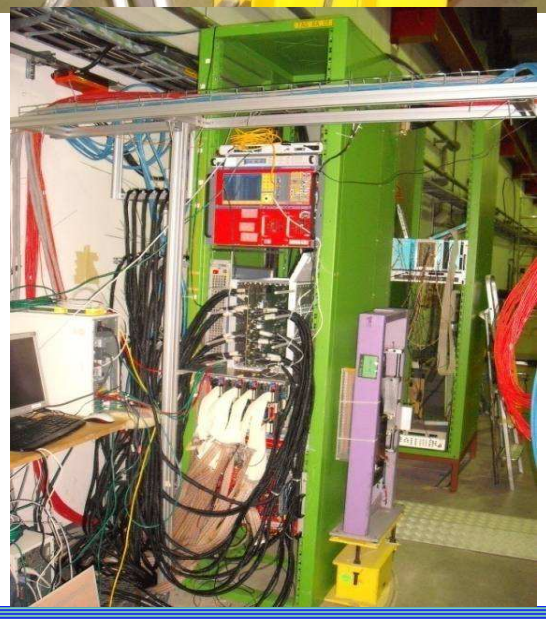




The Rich-400: PM and Electronics

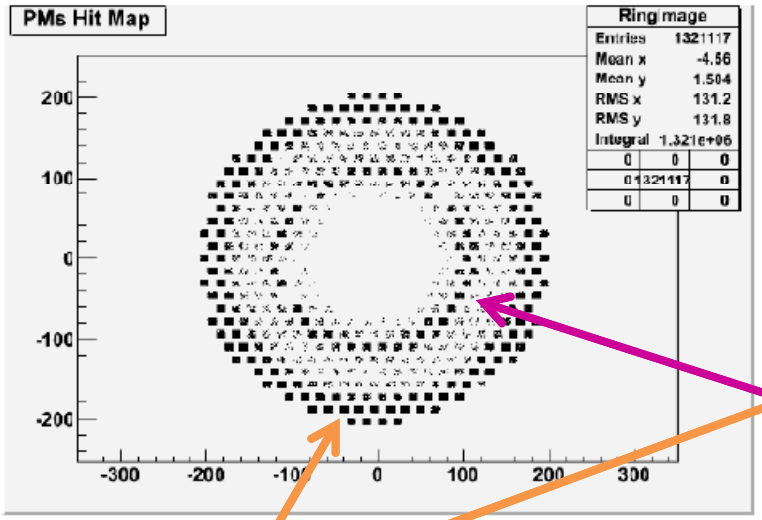




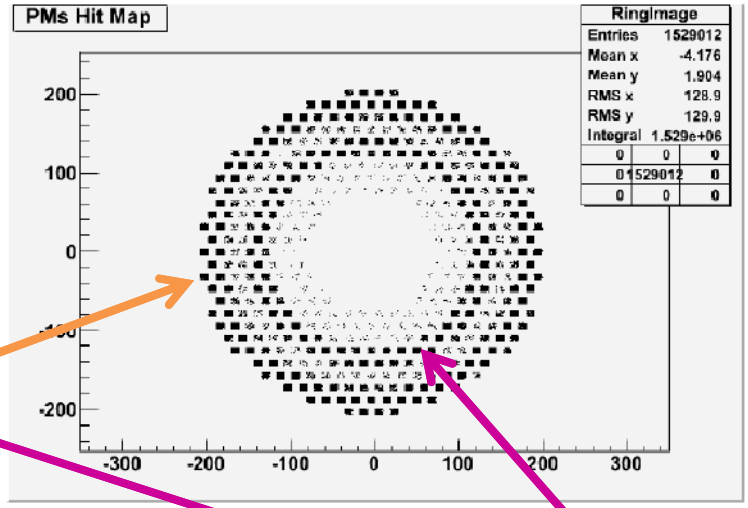


RICH-400: PM illumination

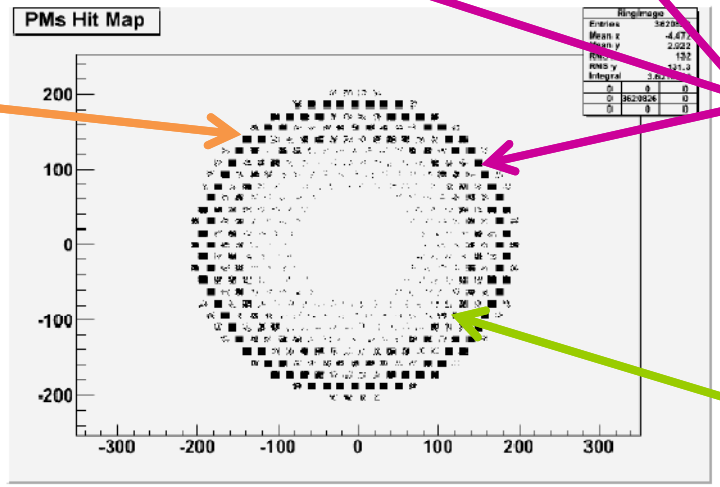
PMs illumination @ 15.2GeV/c



PMs illumination @ 17.7GeV/c



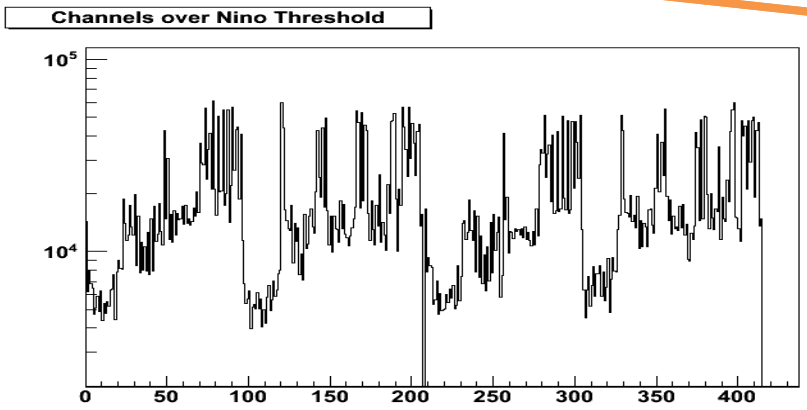
PMs illumination @ 75.0GeV/c



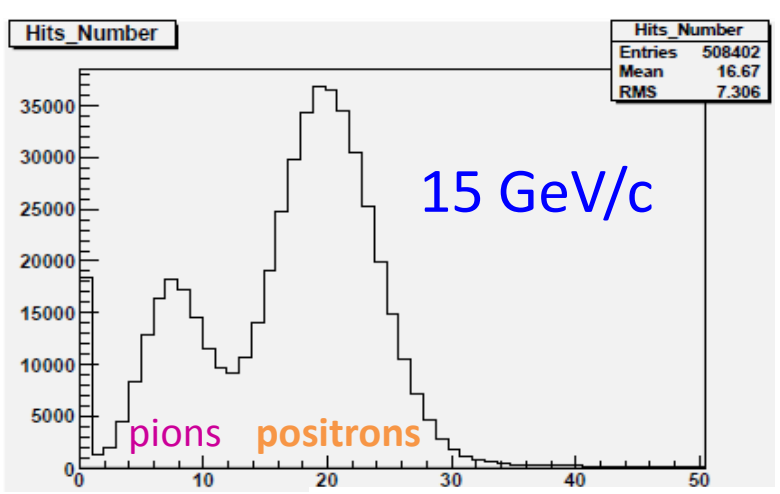
positrons

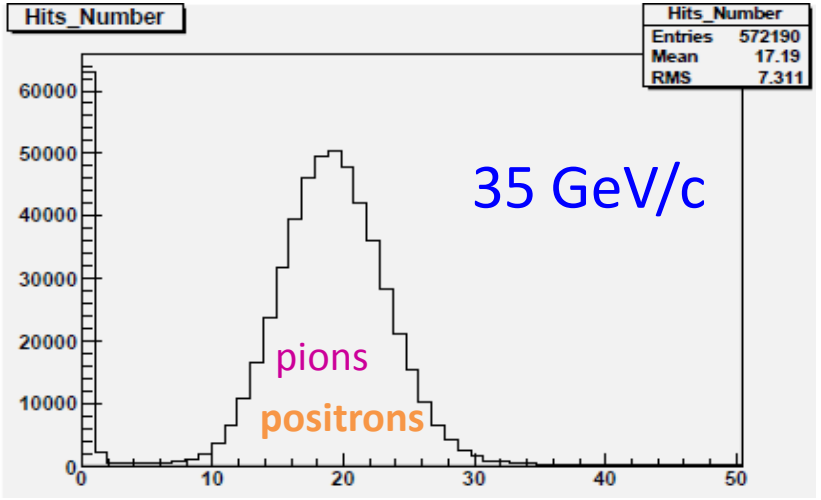
pions

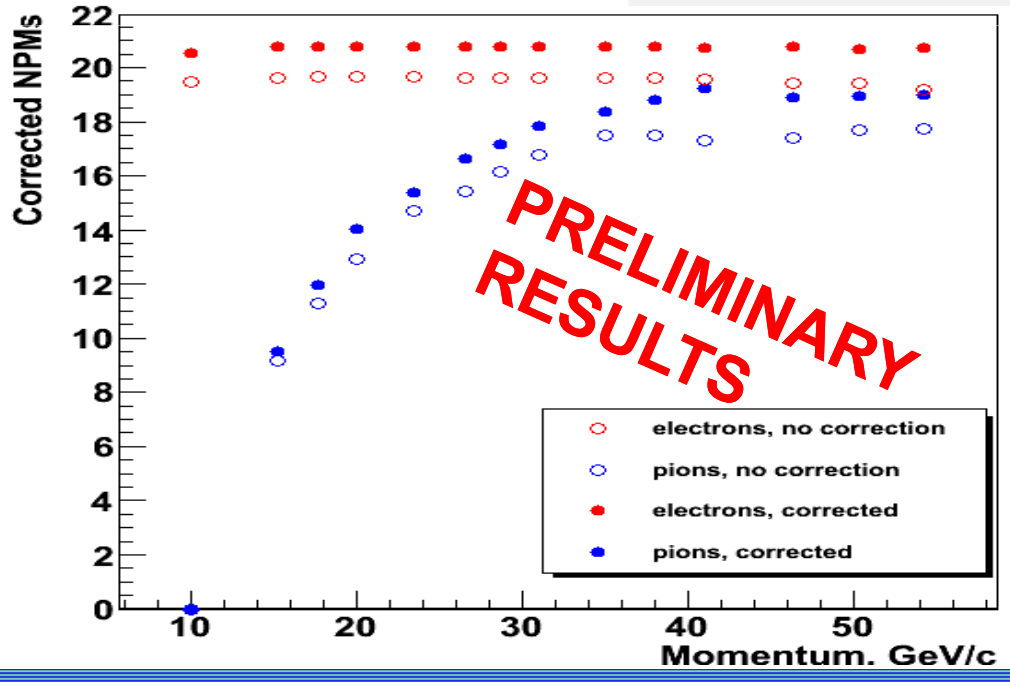
kaons



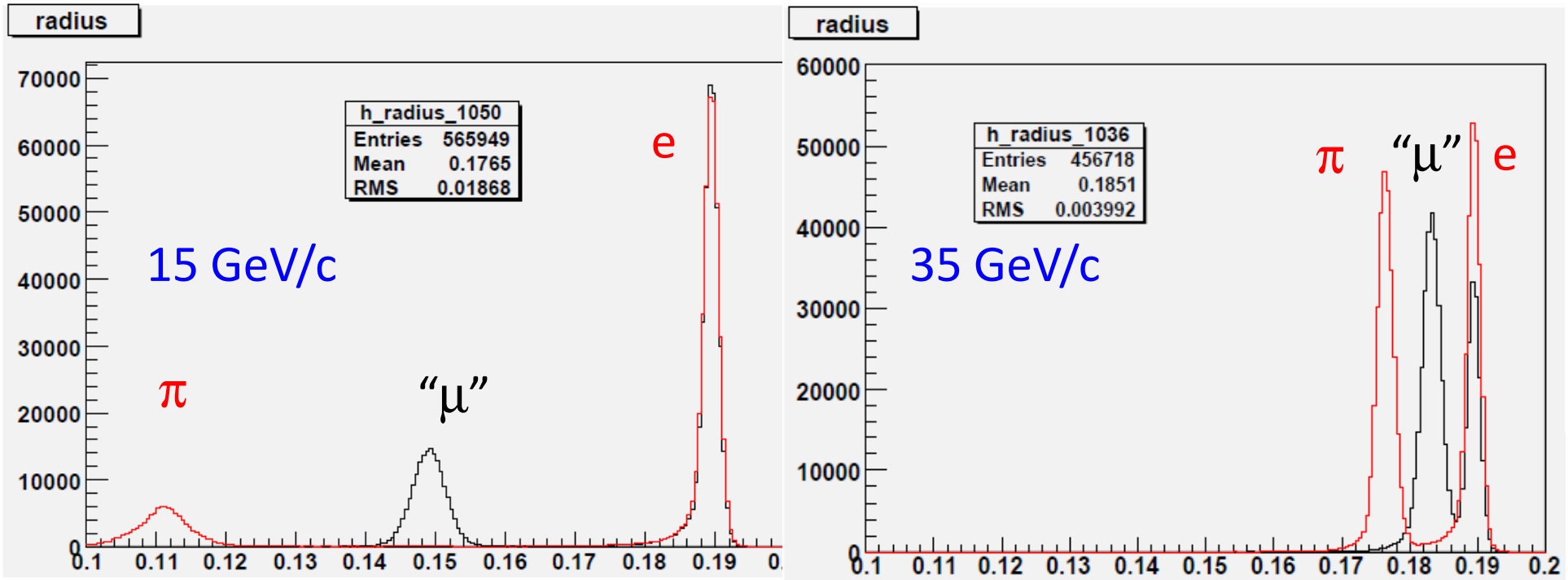
RICH-400: number of PM hits







RICH-400: π–μ separation - I

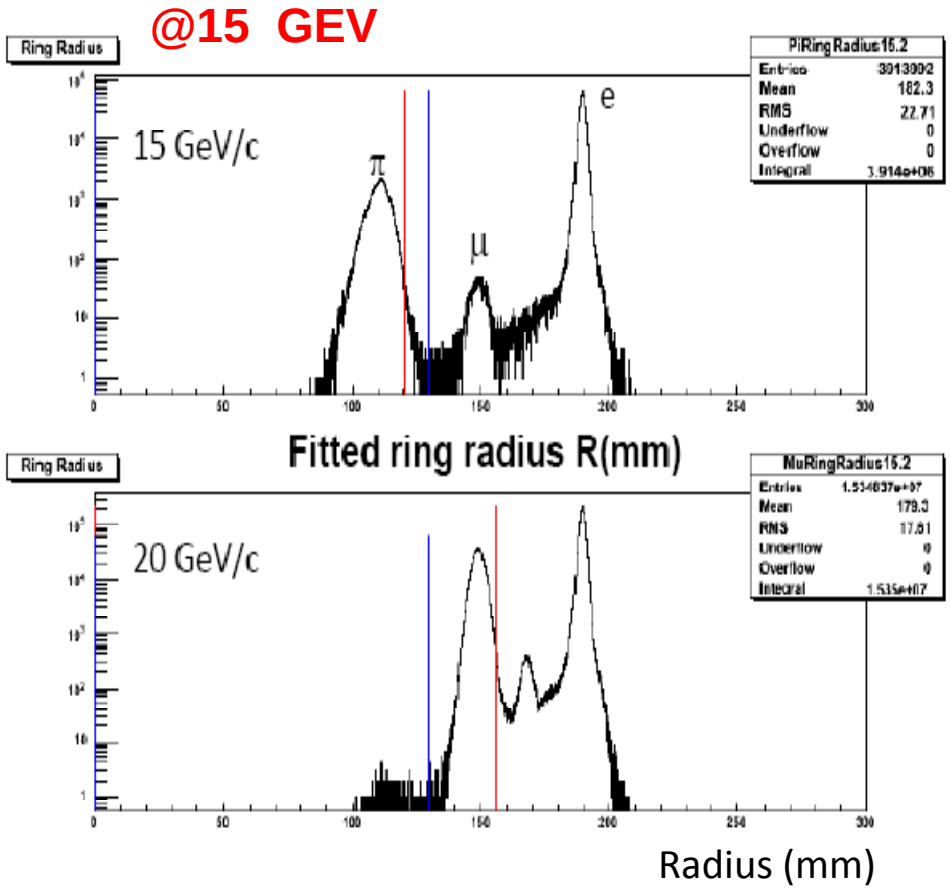


The "μ" @ 15 (35) GeV/c is a π @ 20 (46.2) GeV/c (same β)

PRELIMINARY muon suppression factor: **~0.6%**

- integrated between 15 and 35 GeV/c (flat μ spectrum)

RICH-400: π–μ separation- II



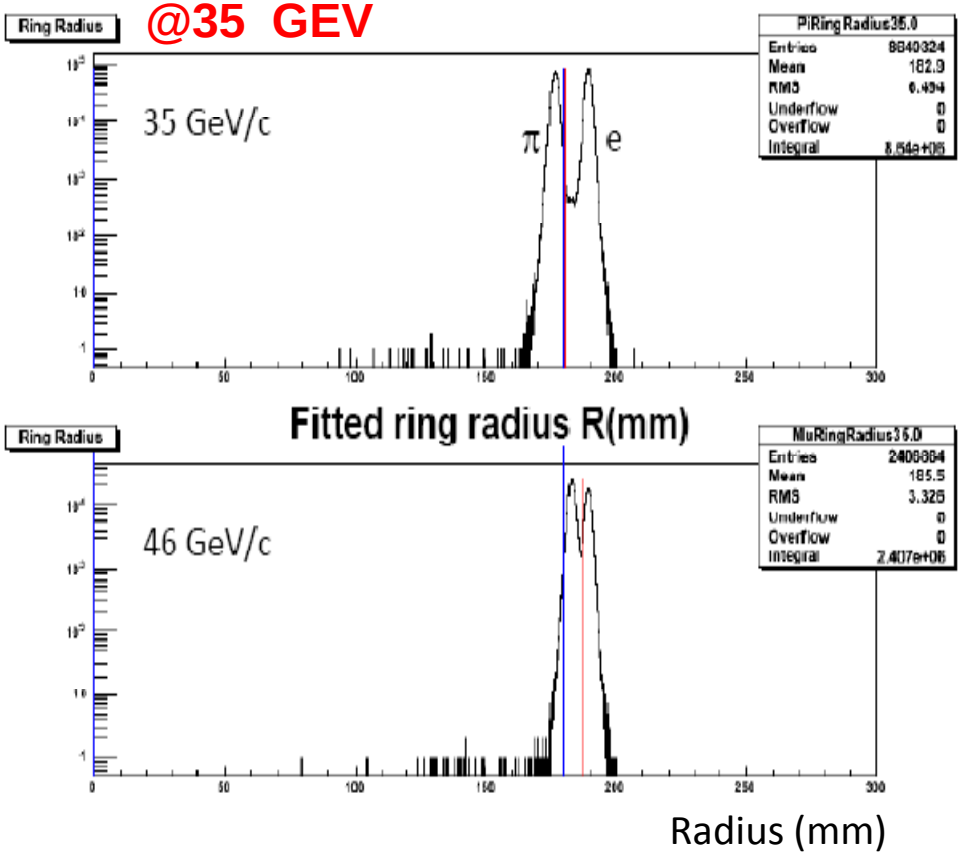
Blue line: half way between π and μ peaks

Red line: (+3σ from peak)

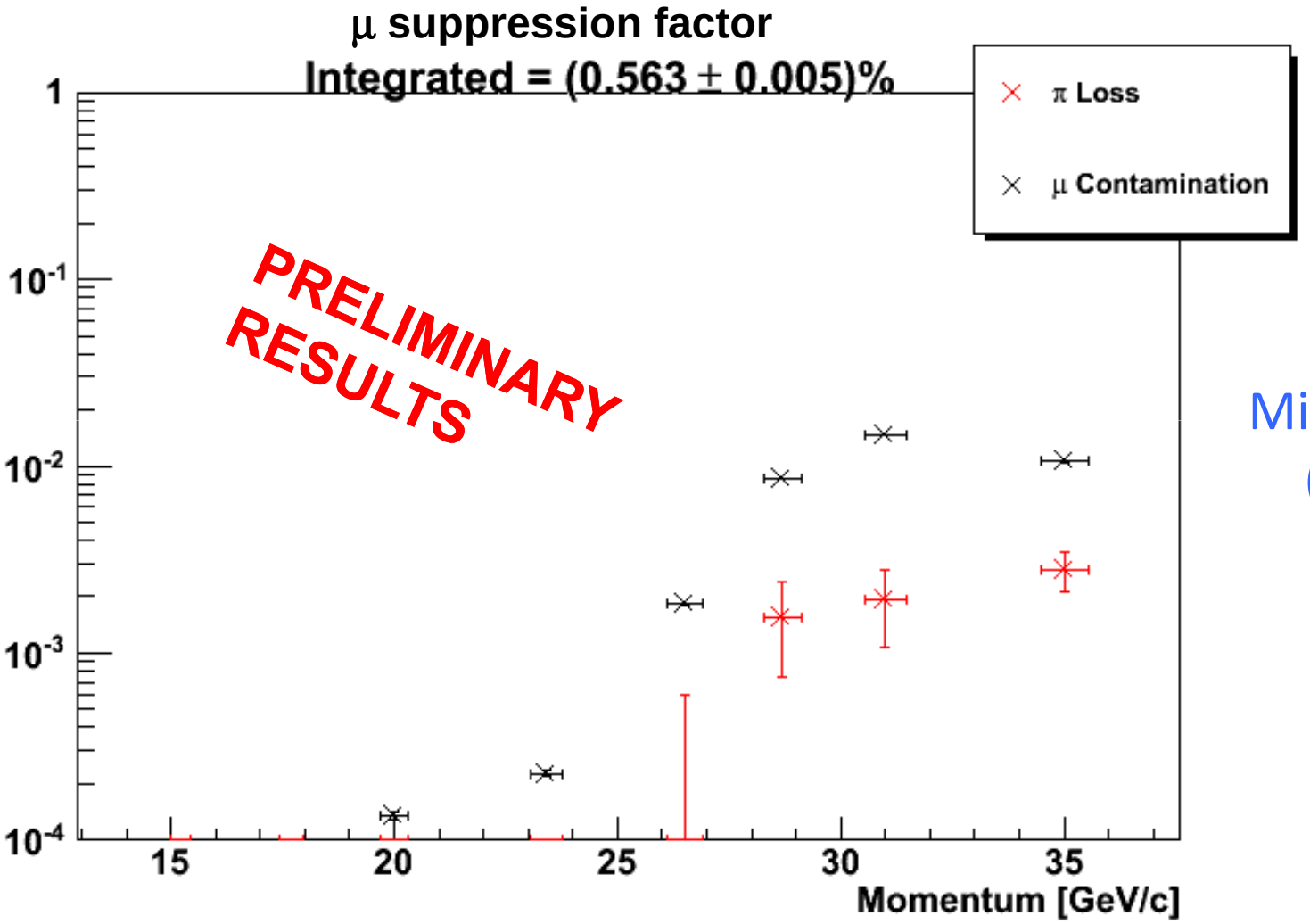
Calculate: μ contamination and π loss (under different conditions)

Mirror in (0,0)

PRELIMINARY RESULTS



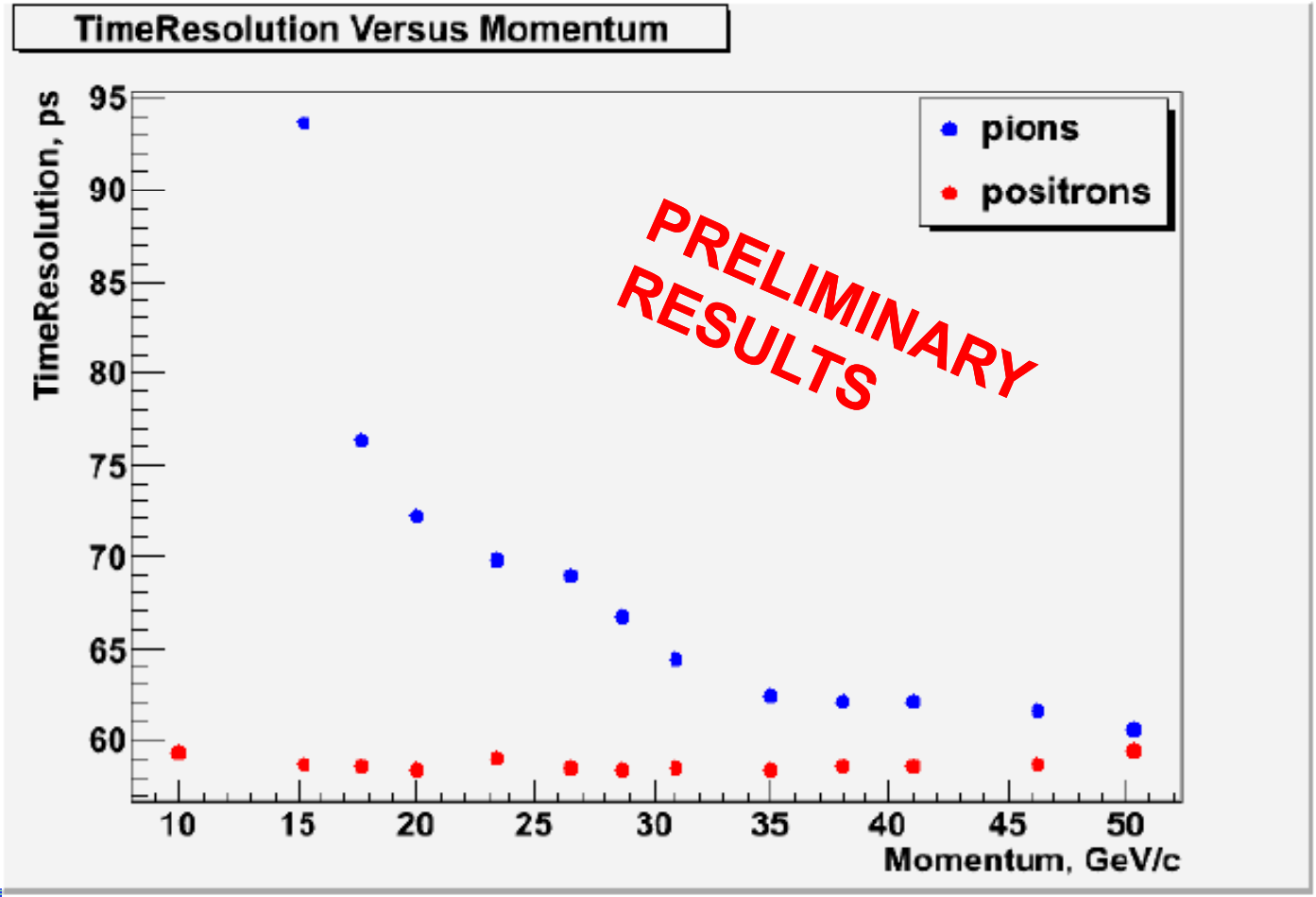
RICH-400: π–μ separation - III



Mirror in (0,0)

RICH-400: time resolution

- Rough analysis, T0 and slewing corrections in progress
- Event time resolution very good: <100 ps confirmed
- No difference observed between CAEN TDC and TELL1



Further studies

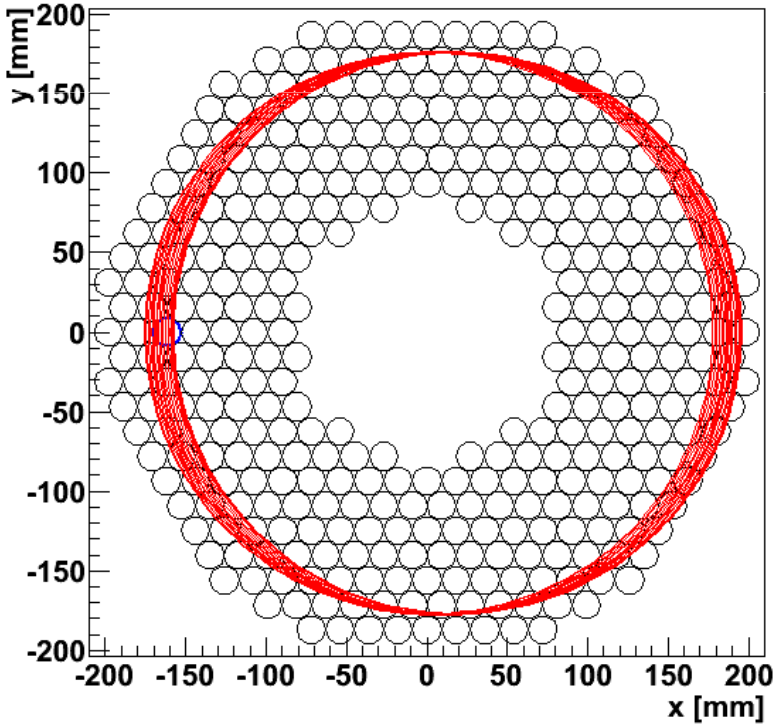
At the end of each mirrow test we polluted the Neon:

1) Oxygen: 380 ppm and 425 ppm (π momentum at 46.3 GeV/c)
   (air will surround the vessel)
2) CO_2 : 0.5% and 1% (4 steps in π momentum)
   (it will be used to clean the vessel)

Scan on several ring positions rotating the mirrow:

- Ring center moved by ~1.1 mm for each steps (16 steps in total)
- We can study the Winston cone reflectivity and the uniformity on photocathode response

Analysis is ongoing



Conclusions

A new RIng CHerenkov detector will be constructed for the NA62 experiment ($K^+ \rightarrow \pi^+ \nu\bar{\nu}$):

- It will be used for background suppression (π-μ separation)
- Essential for a precise measurement of track time for tagging pourposes and reduction of accidental background
- RICH information Used at trigger level

A test with a prototype instrumented with 400 phototubes Hamamatsu R7400 U-03 was performed in June 2009

Preliminary results shown on:

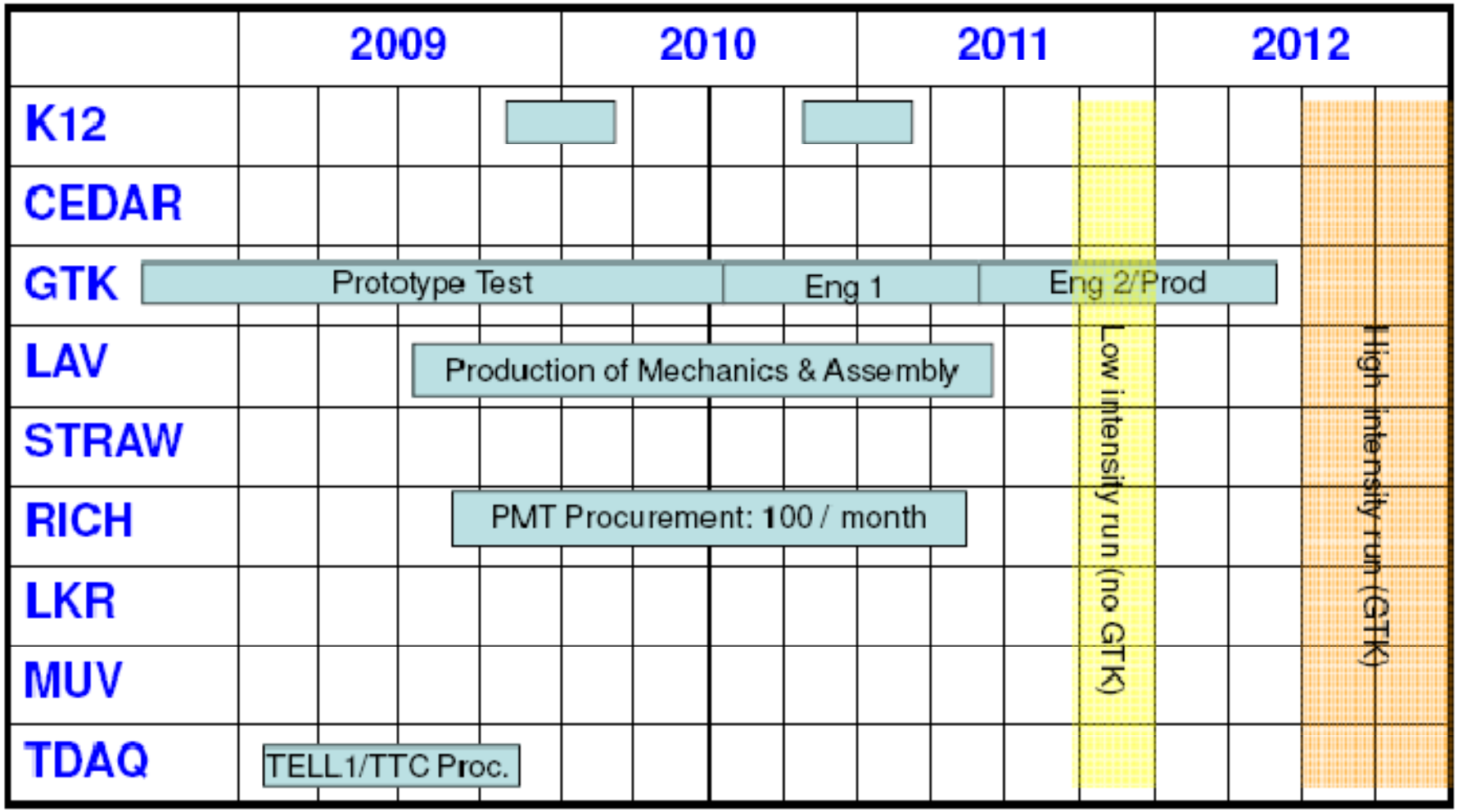
- μ suppression factor: 0.563±0.005% integrated between 15 and 35 GeV/c
- Time resolution : better than 95 ps @ any energy

Analysis is in progress and a paper is in preparation

Thank you

SPARES

NA62 Timescale



A. Ceccucci, WIN09