THE NA62 RICH DETECTOR

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11th International Conference on Advanced Technology and Particle Physics

Villa Olmo, Como 5-9 October 2009

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

OUTLINE

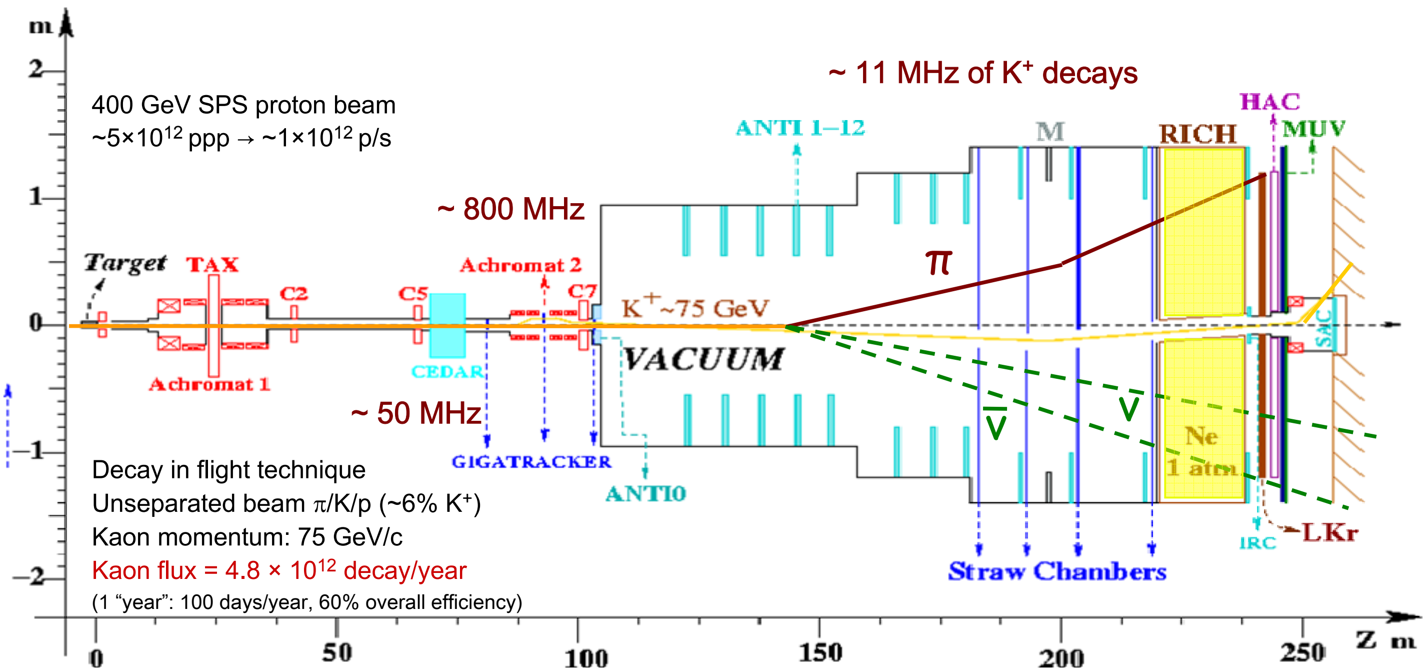
- The NA62 experiment at CERN
- The RICH detector design
- The RICH prototype test beam results:
  - The RICH-100 (2007 test beam)
  - The RICH-400 (2009 test beam)

NEW PRELIMINARY RESULTS

The NA62 Experiment at CERN

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

- 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 background: $BR(K^+ \to \mu^+ \nu) = 63\%$; $BR(K^+ \to \pi^+ \pi^0) = 21\%$



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*

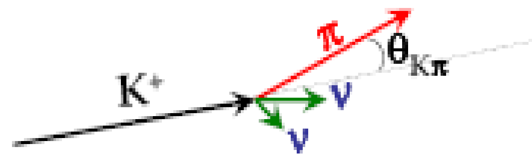
RICH requirement: PID and timing

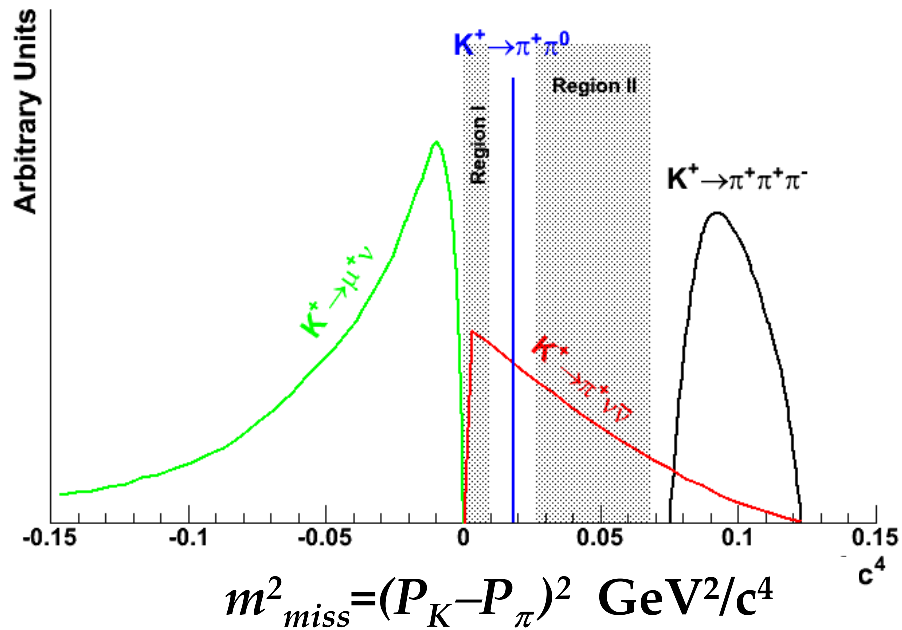
NA62 GOAL: ~100 $K^+ \to \pi^+ \nu \bar{\nu}$ events in 2 years (starting in 2011)
~10% background (signal acceptance ~10%)

➡ 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

  RICH

  - Time resolution: ≤ 100 ps

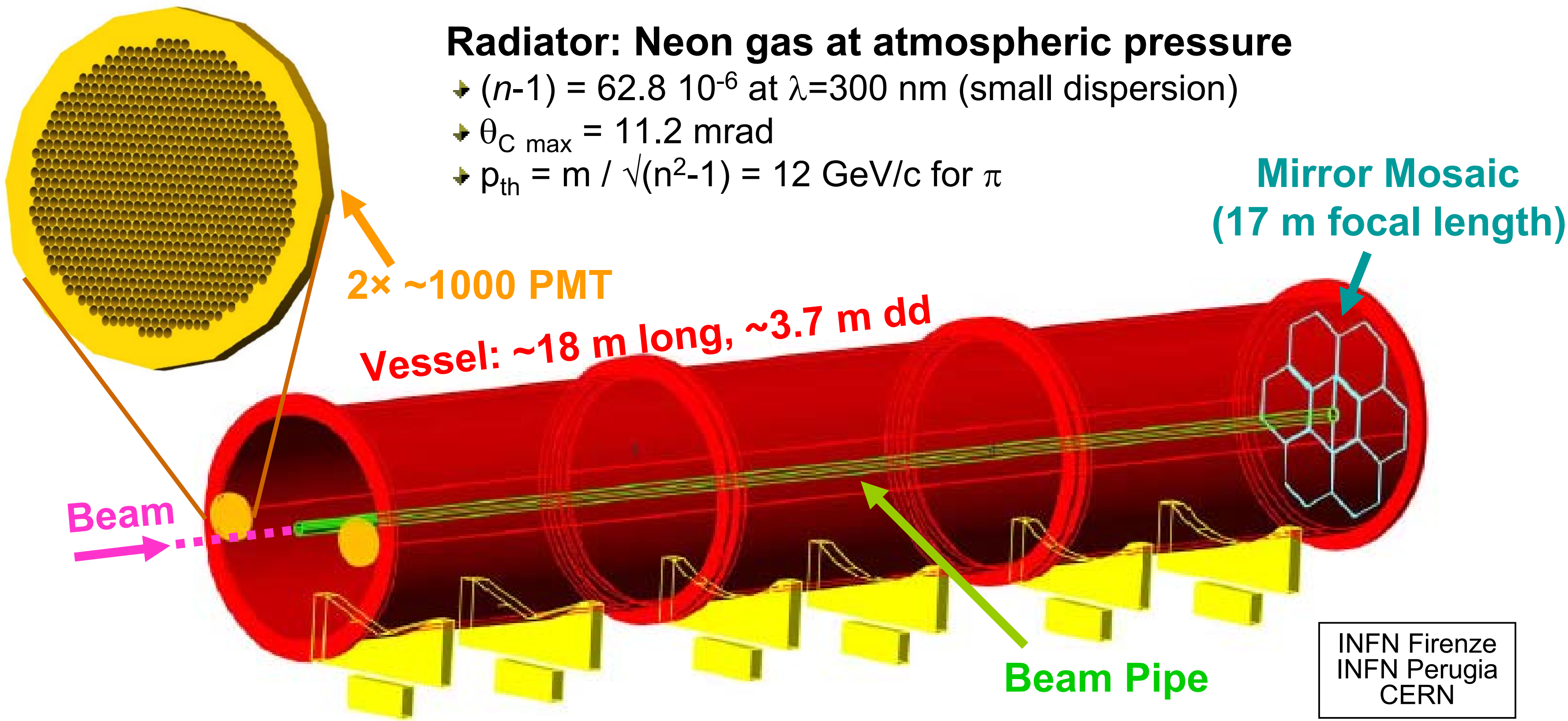
The NA62 RICH Detector

THE NA62 RICH REQUIREMENTS:

- Separate $\pi-\mu$ 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

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
- $p_{th} = m / \sqrt{(n^2-1)}$ = 12 GeV/c for π

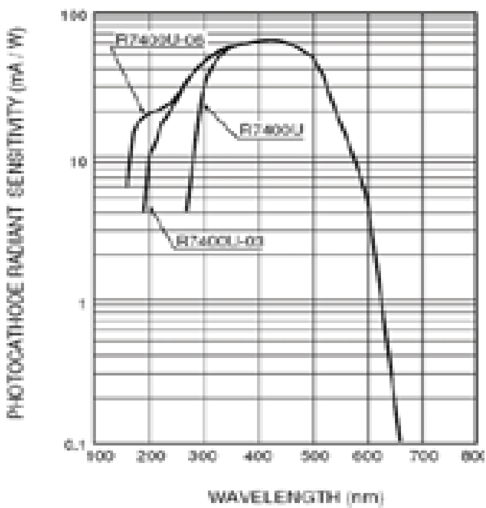


INFN Firenze
INFN Perugia
CERN

The Cherenkov light detection

Hamamatsu R7400 U03 Photomultipliers

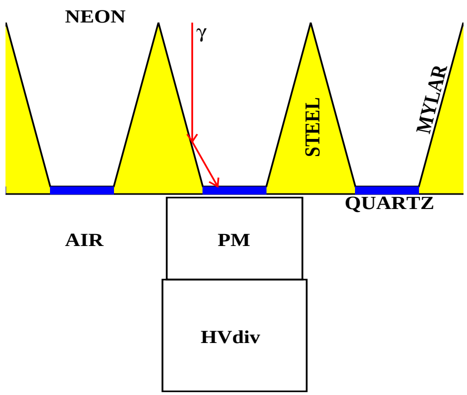
- Metal package tube, 8 dynodes
- 185 nm – 650 nm, 420 nm peak sensitivity
- UV glass window, 16 mm dd, 8 mm active dd
- Bialkali cathode
- Gain: 7×10^5 @800 V (~1.5×10^6 @900 V)
- Transit time: 5.4 ns
- Transit time spread: 0.28 ns
- Applied Voltage: 900 V (1000 V maximum)



Hamamatsu R7400 U06: quartz window (165-650 nm)

Light Collection:

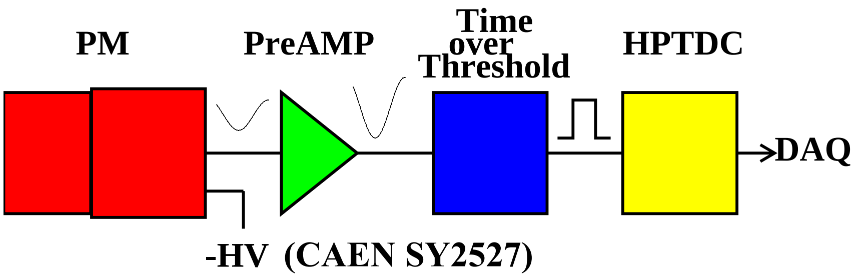
- Winston Cones covered with Mylar
- 22 mm high
- 18 mm wide (max)
- 7.5 mm wide (min)
- 1 mm thick quartz window



Front End and Readout electronics

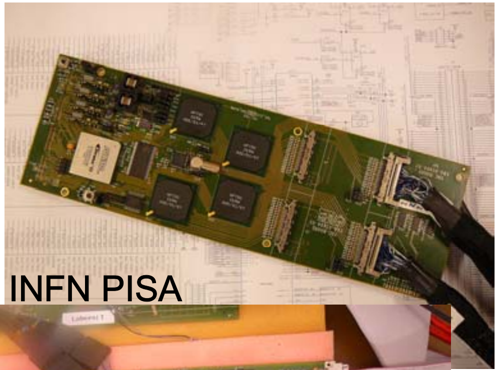
Front End:

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



Readout: based on TDC Boards

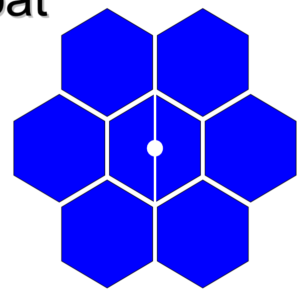
- A board (TDCB) equipped with 128 channels of TDC (HPTDC, 100 ps LSB) has been build
- The FPGA based TELL1 mother board (from LHCB) will houses 4 TDCB (512 channels)
- The trigger primitives will be constructed in parallel with the readout on the same TELL1 board (1 MHz input to L1, implemented in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

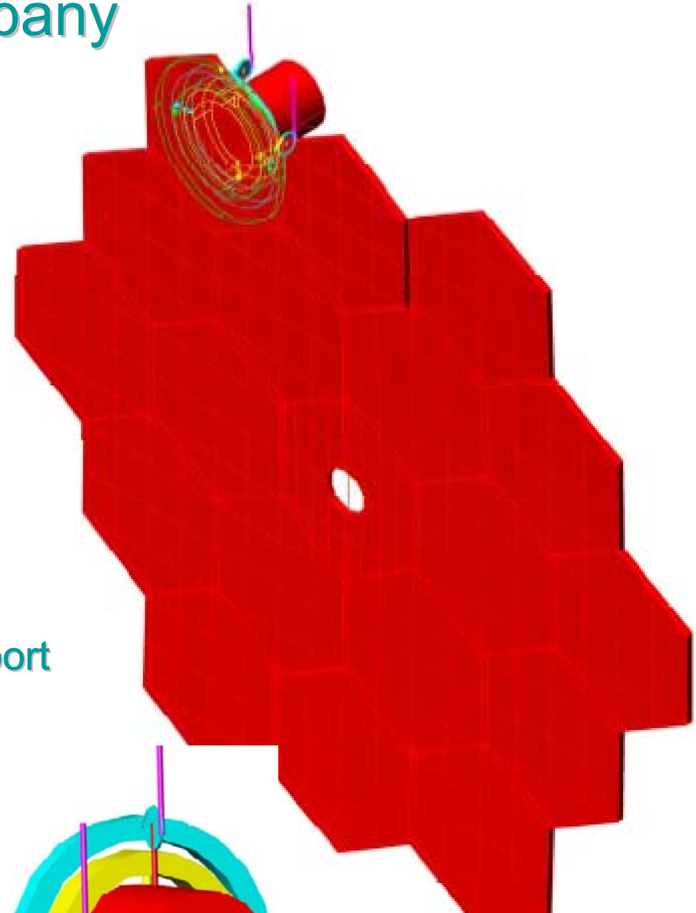

INFN PISA

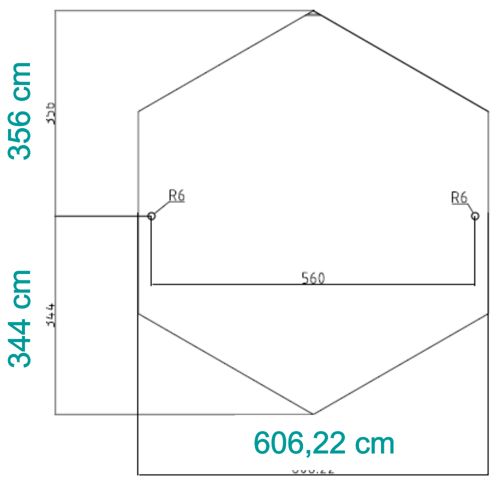
The NA62 RICH: mirror layout

Hexagonal Mirrors from MARCON company

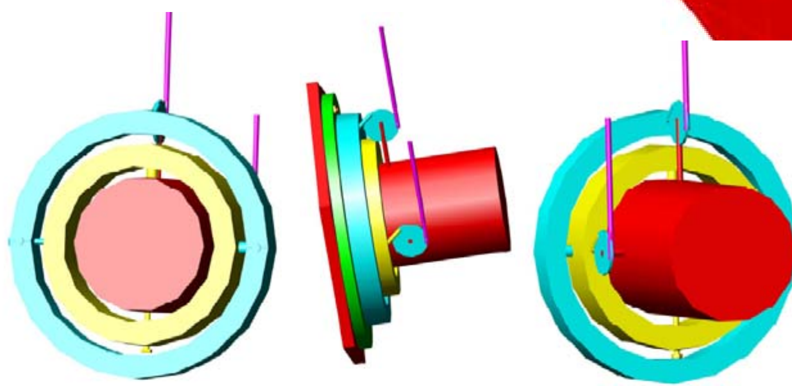
- 2.5 cm thick glass, 17 m focal length
- Aluminum deposit with MgF_2 coat
- Honeycomb structure
- Piezo actuators for alignment
- Carbon fiber for mirror support
- Final detector: 18 hexagonal mirrors
  + 2 half hexagons (beam pipe)



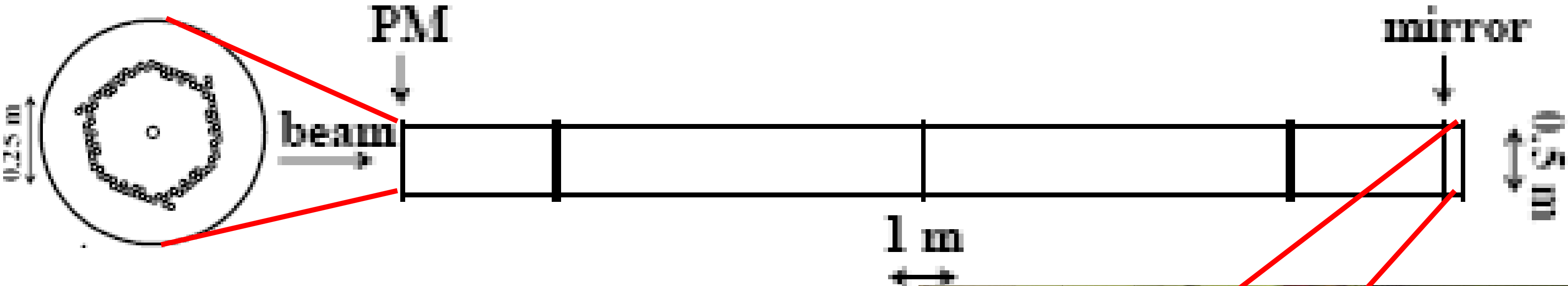


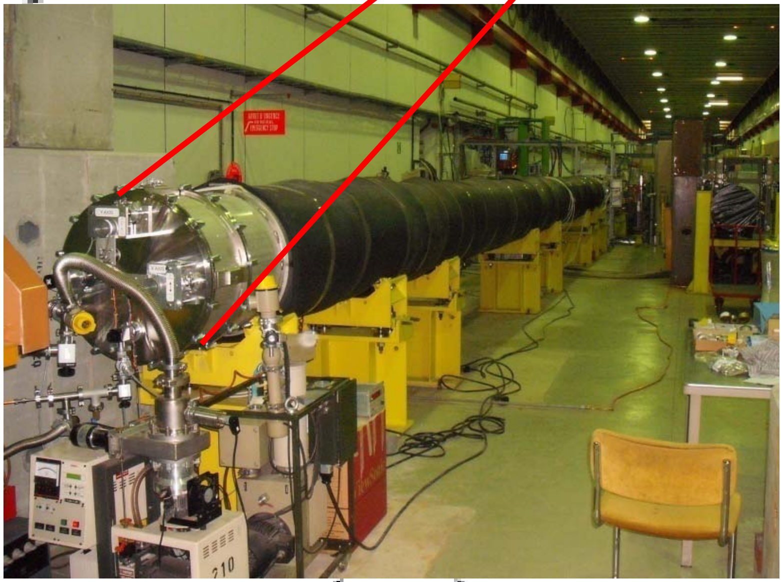


Single mirror design and support



The NA62 RICH prototype





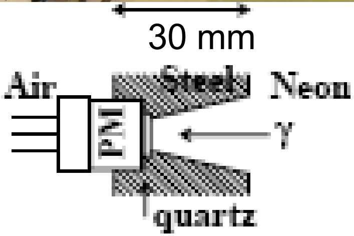
- Vessel ~18 m long, ~60 cm wide
  - filler with Ne gas at ~1 atm
- One single mirror by MARCON:
  - f = 17 m, d = 50 cm, 2.5 cm thick

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



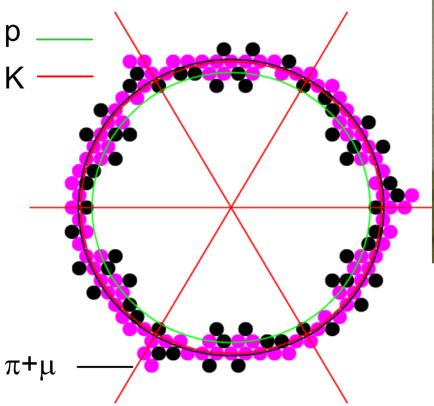
The RICH-100 prototype

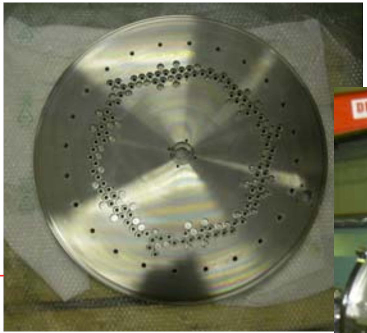
The RICH-100 prototype: 96 PMT Hamamatsu R7400 U03/U06

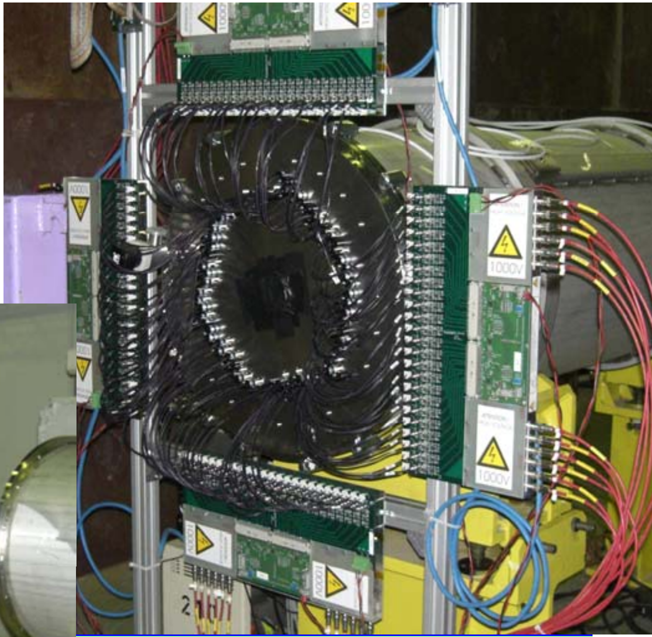
- Test Beam in autumn 2007, results published in: NIM A 593 (2008) 314
- 200 GeV/c negative hadron beam from CERN SPS (mainly pions, ~3% K)
- Standard readout: VME TDC CAEN V1190 (97.7 ps LSB)
- Aim: check hit multiplicity per ring, time and Cherenkov angle resolutions

Results in agreement with MC expectations → U03 PM chosen

- *Number of PM hit per event* $N_{Hits} \approx 17$
- *Time resolution* $\Delta t_{Event} \approx 70\ ps$
- *Cherenkov angle resolution* $\Delta\theta_c \approx 50\ \mu\,rad$



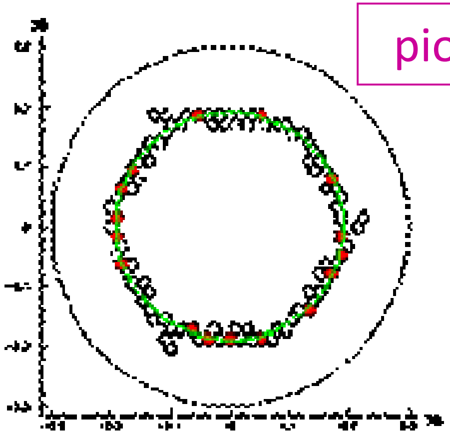




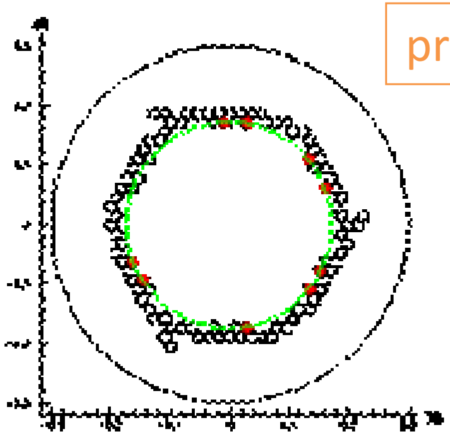
The RICH-100 test results:

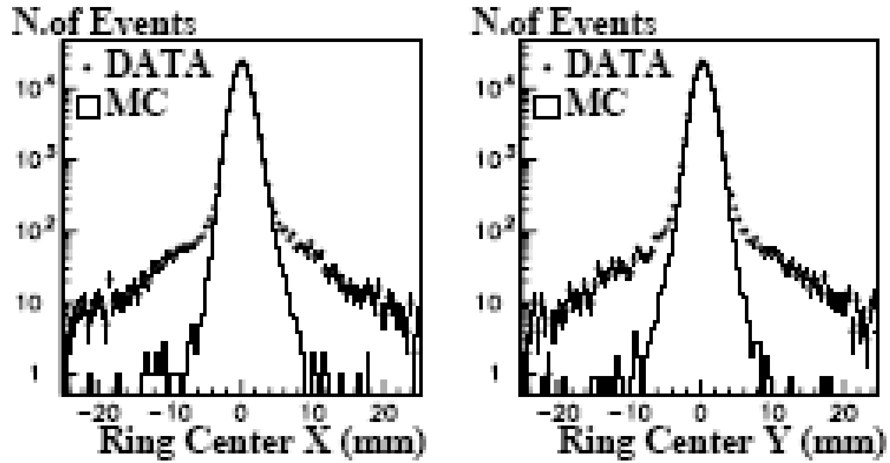
rings and radius distribution

pion

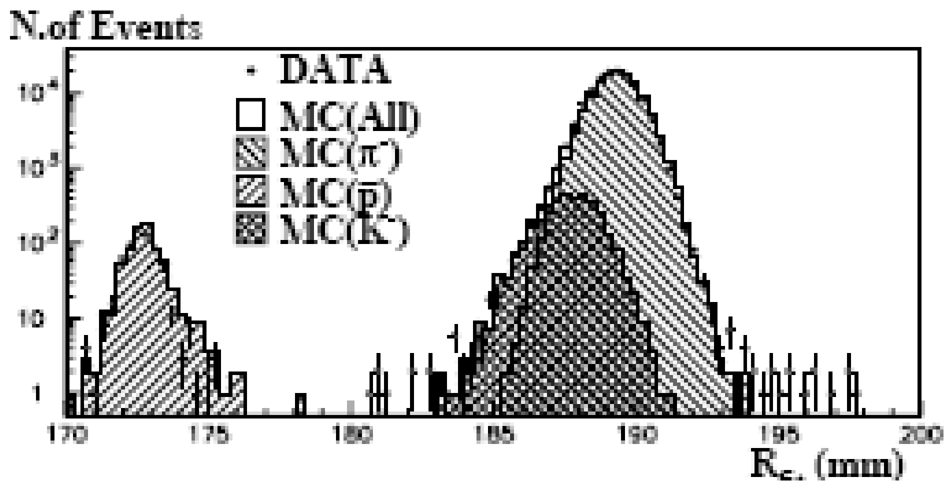


proton



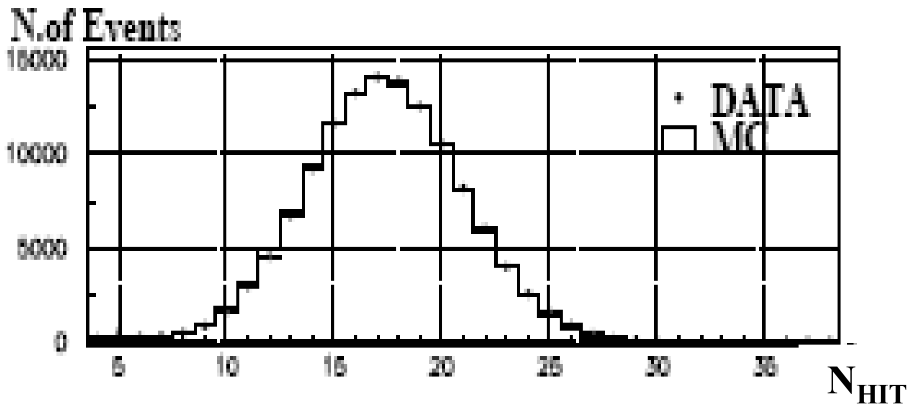


Fitted ring center and radius (data and MC)

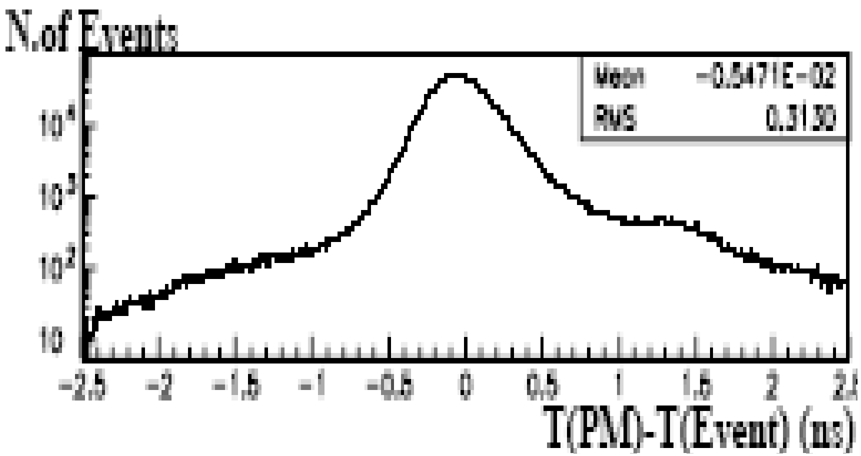


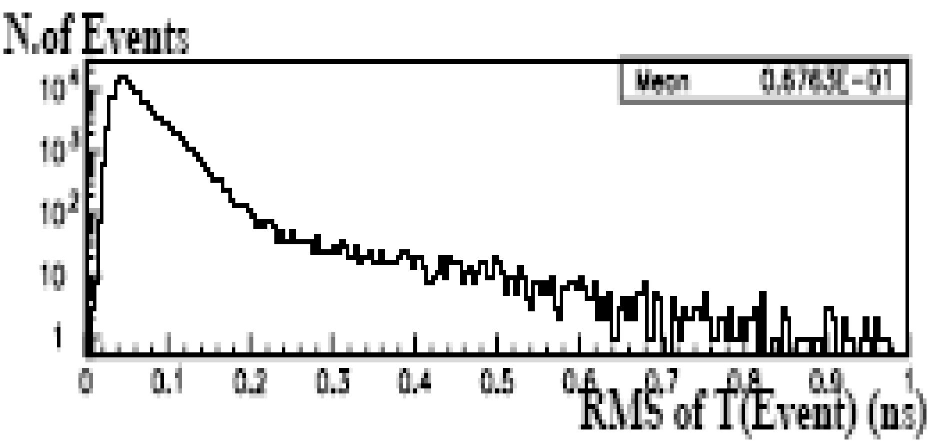
The RICH-100 test results:

PM hits and time resolution



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



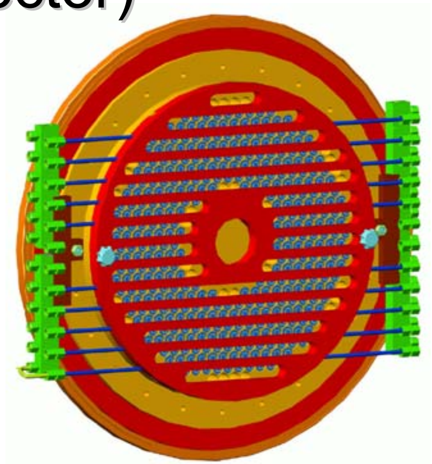


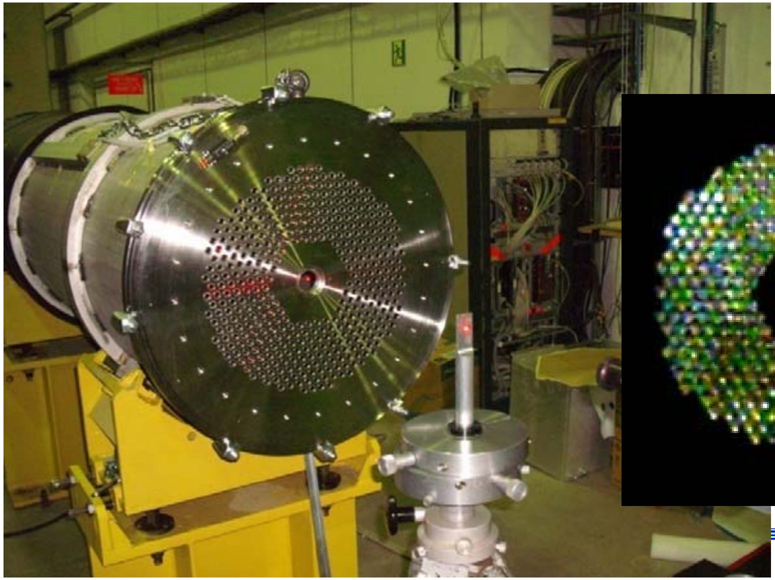
Time difference PM-event: average PM time resolution ≈ 310 ps

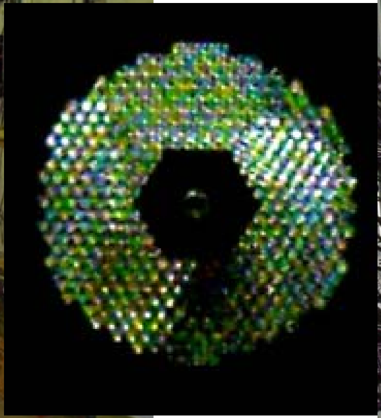
Average event time resolution (RMS): $\Delta t_{Event} \approx 70$ ps

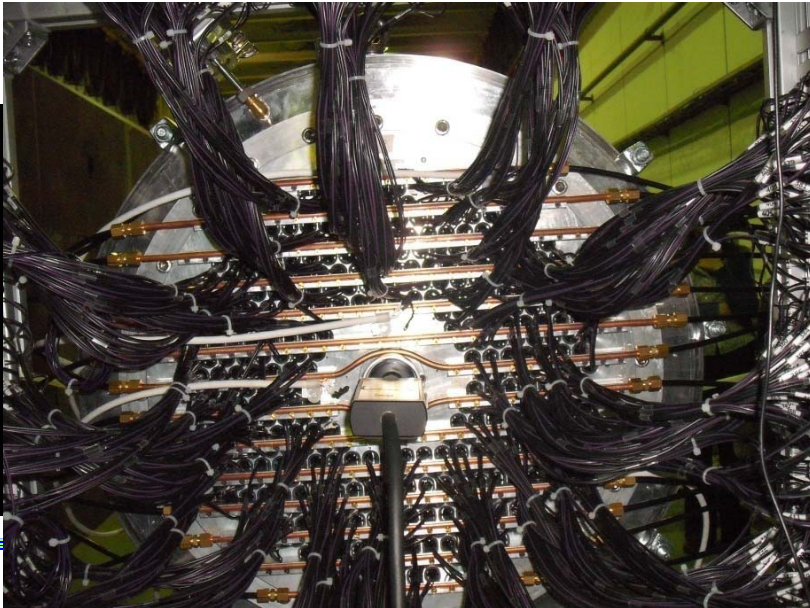
The RICH-400 prototype

- PM endcap changed: 414 PM (20% of final detector)
- Test Beam in may-june 2009, aiming at:
  - Validate $\pi-\mu$ separation @ $15<p<35$ GeV/c
  - Improve PM cooling
  - Test new mirror
  - Test new readout (Tell1 based)
- Preliminary results shown, paper in preparation







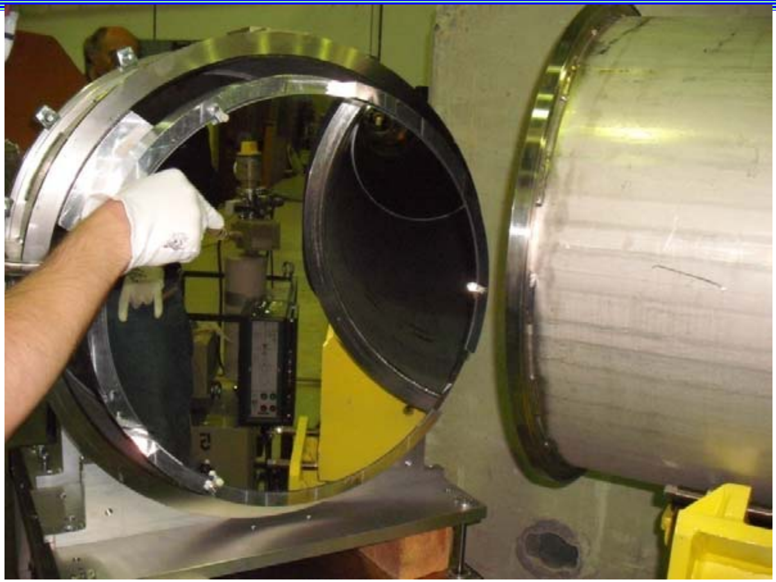


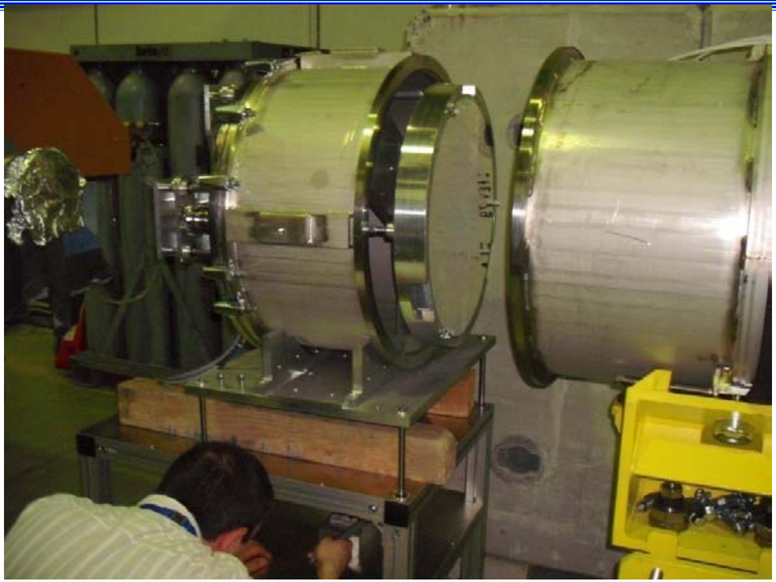
RICH-400: test beam program

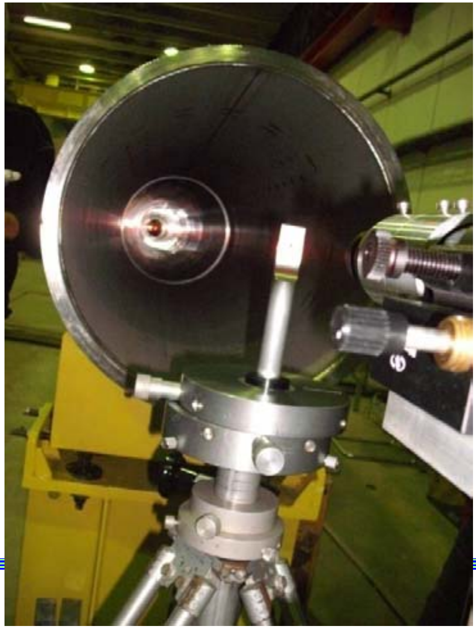
- Beam: mainly π^+, 15% p, few % K^+, variable % of e^+
  - 1.5% $\Delta p/p$, negligible angular spread
- Setup at 75 GeV/c (highest momentum), check at 10 GeV/c
- Many momentum points ($\mu-\pi$ equivalent): each next point is a pion with the same β of the muon of the actual point
  - 1° scan: 15.2, 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 (air and CO_2), etc
- Repeat measurements with the new mirror (final device, made by Marcon, aluminized and coated at CERN):
- Special runs:
  - check trigger algorithms and accidentals at higher intensities
  - measure efficiency for ring fitting

⇨ PRELIMINARY RESULTS

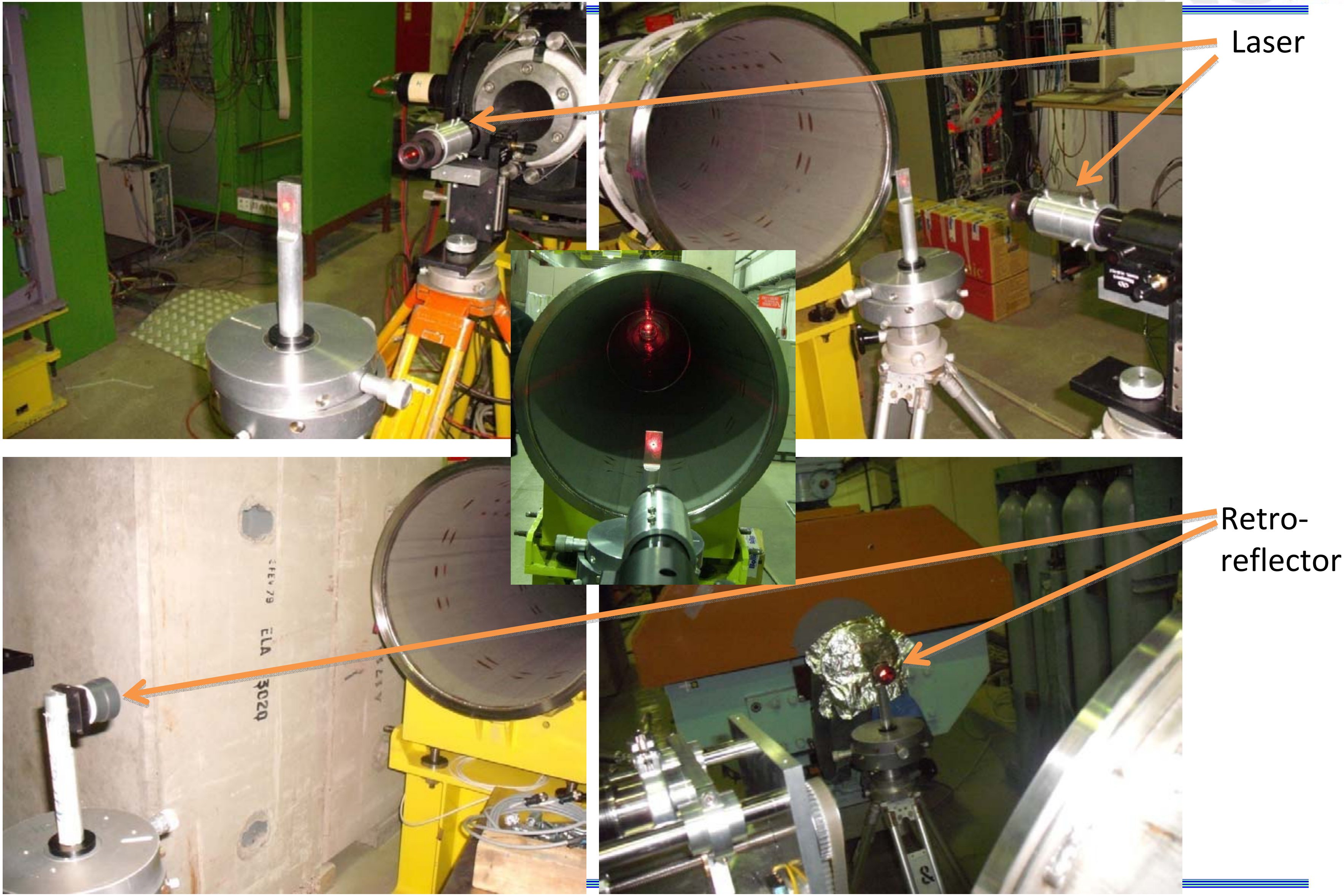
The Rich-400: mirror installation



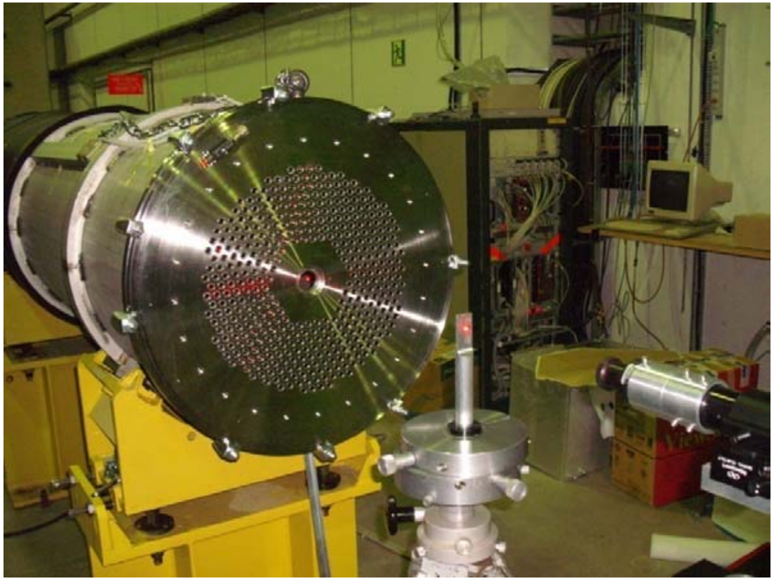




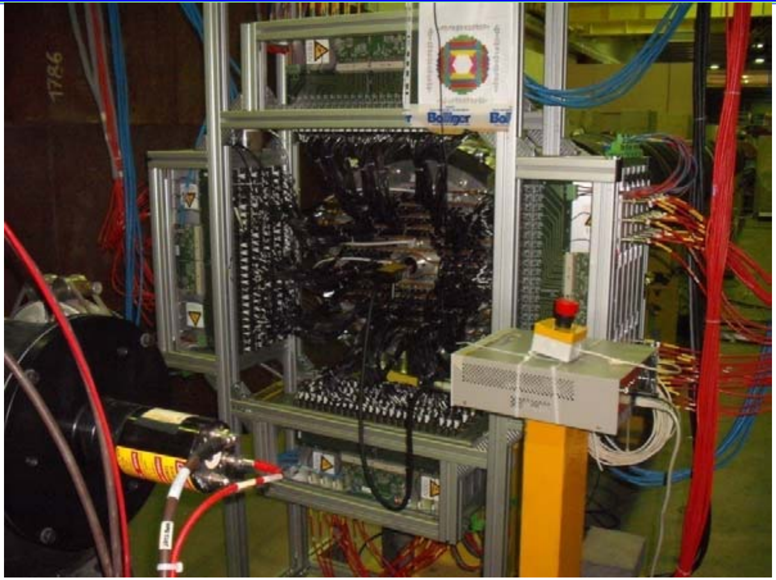
The Rich-400: laser alignment

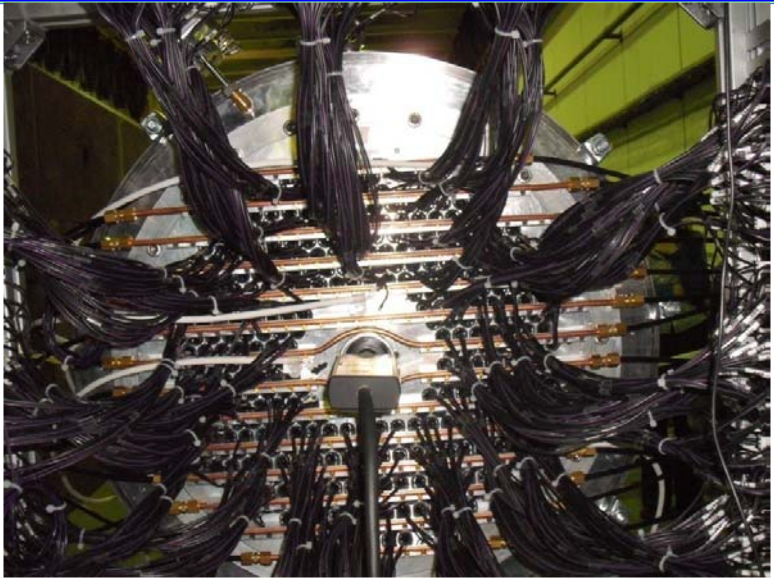


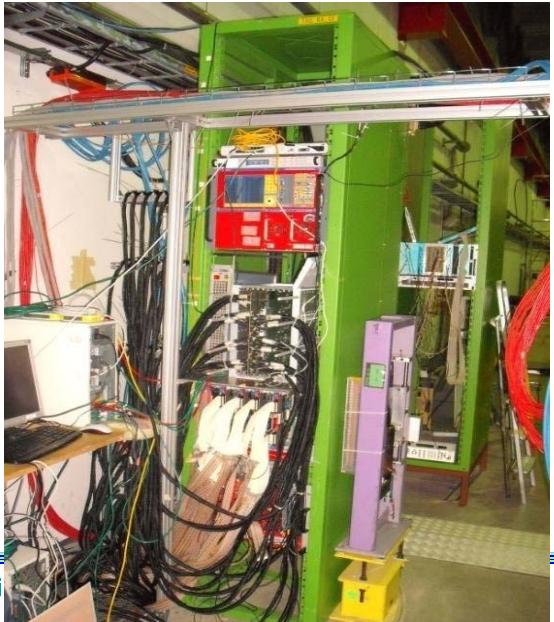
The Rich-400: vessel closing

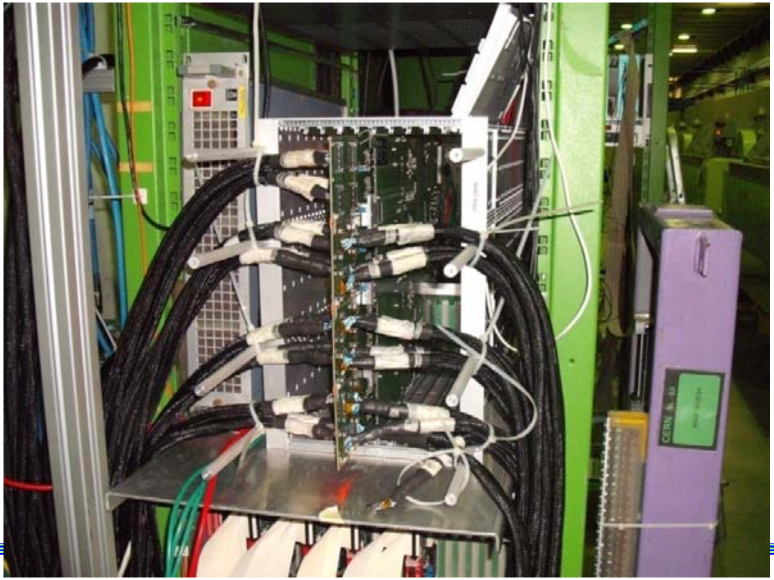


The Rich-400: PM and Electronics



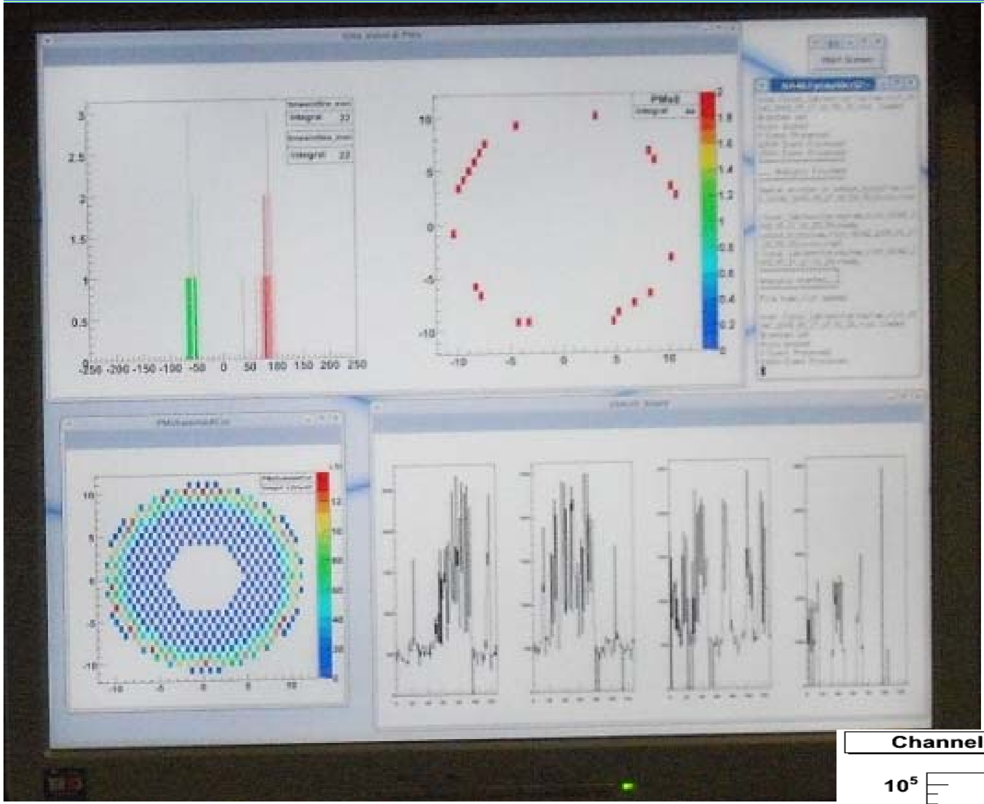




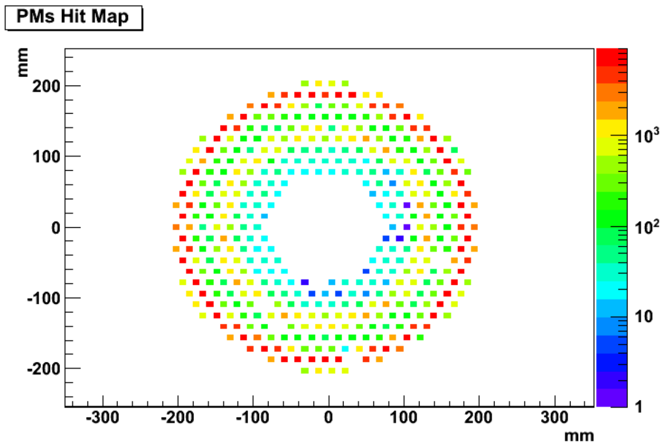


TELL1 Board

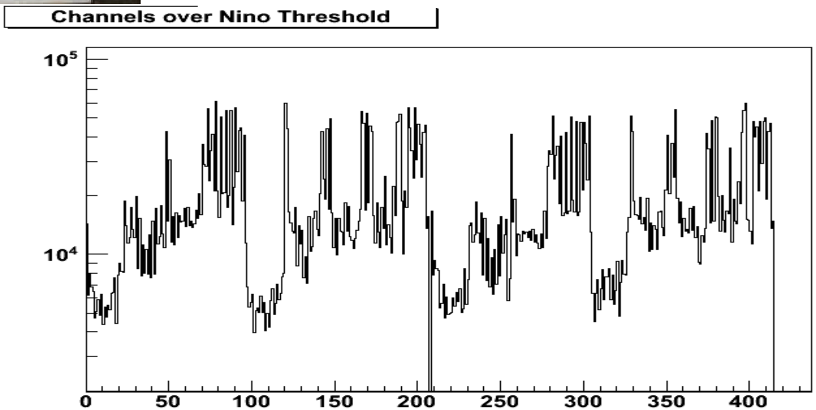
RICH-400 Prototype: the first data



Online Monitor

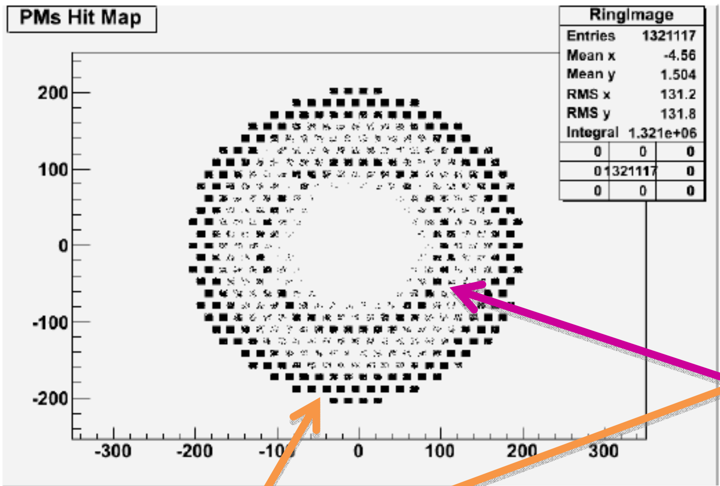


PM Hit maps:
100% channels working
(1 known missing channel)

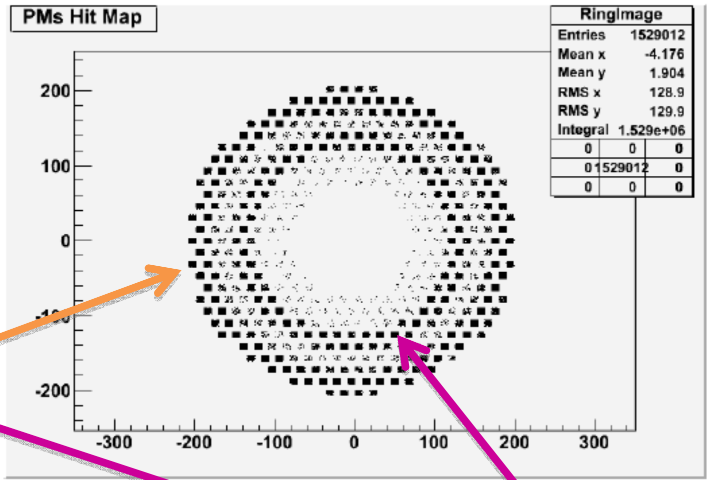


RICH-400: PM illumination

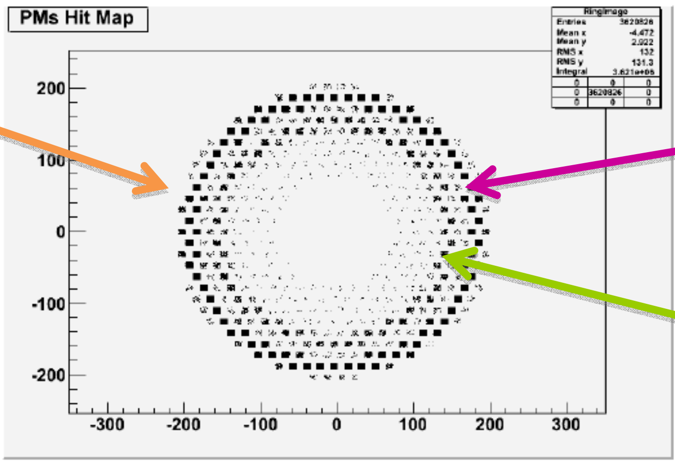
PMs illumination @ 15.2GeV/c



PMs illumination @ 17.7GeV/c



PMs illumination @ 75.0GeV/c

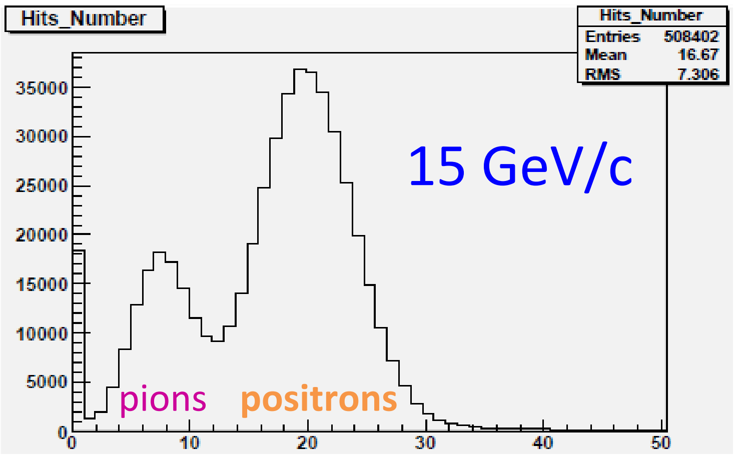


positrons

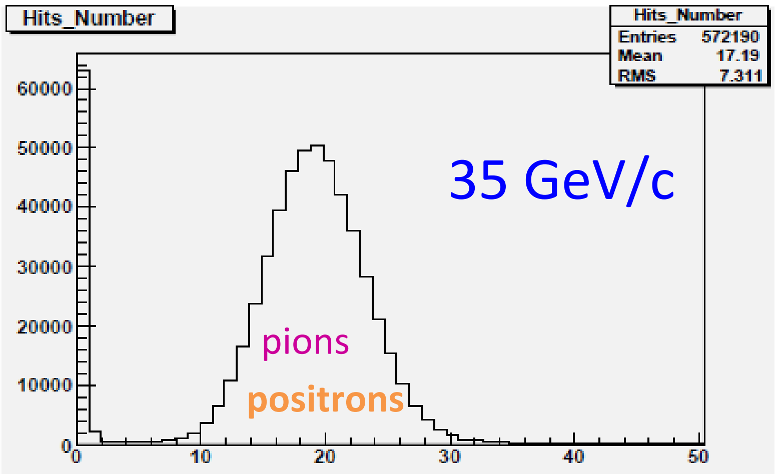
pions

kaons

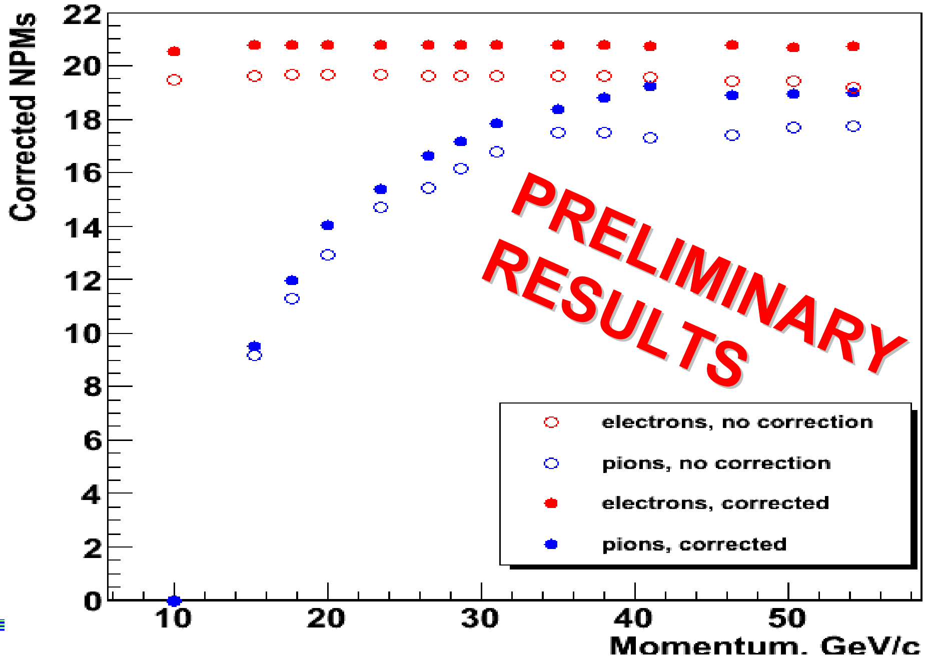
RICH-400: number of PM hits



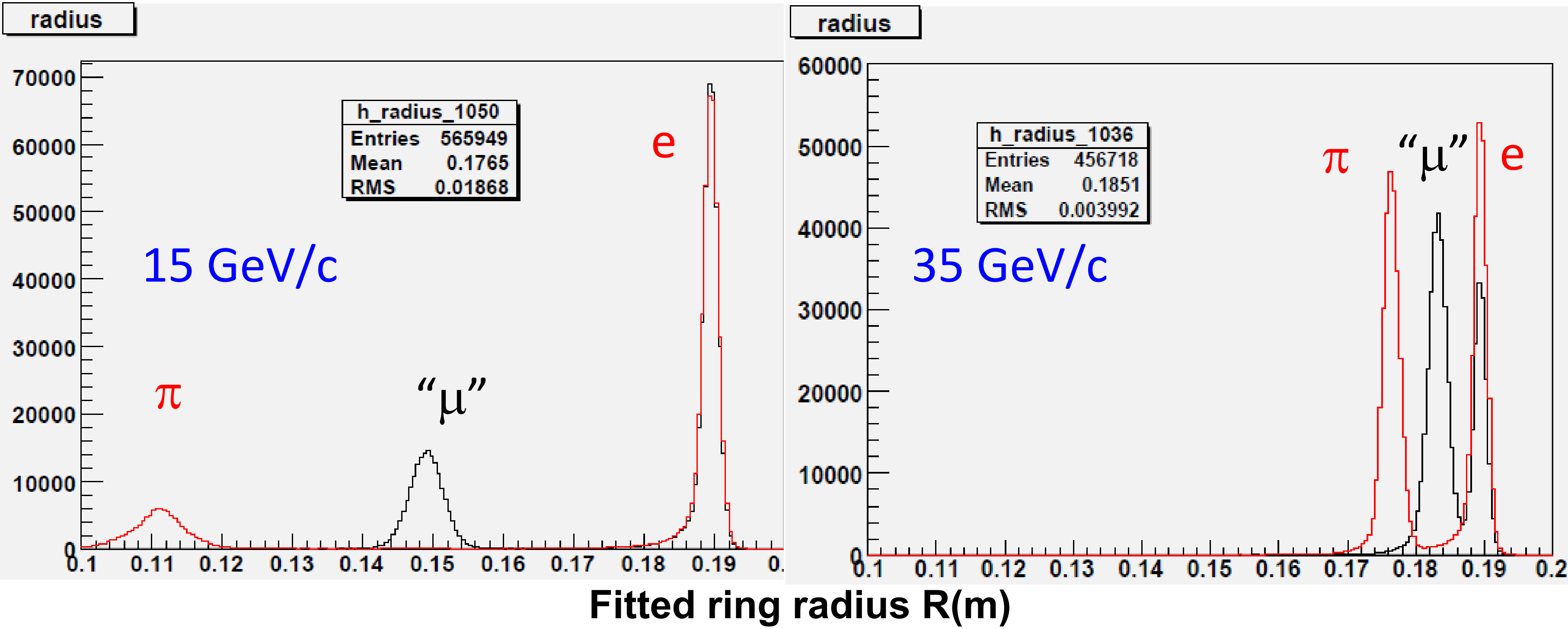
PM hits



PM hits



RICH-400: $\pi-\mu$ separation - I



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

PRELIMINARY muon suppression factor: **~0.7%**

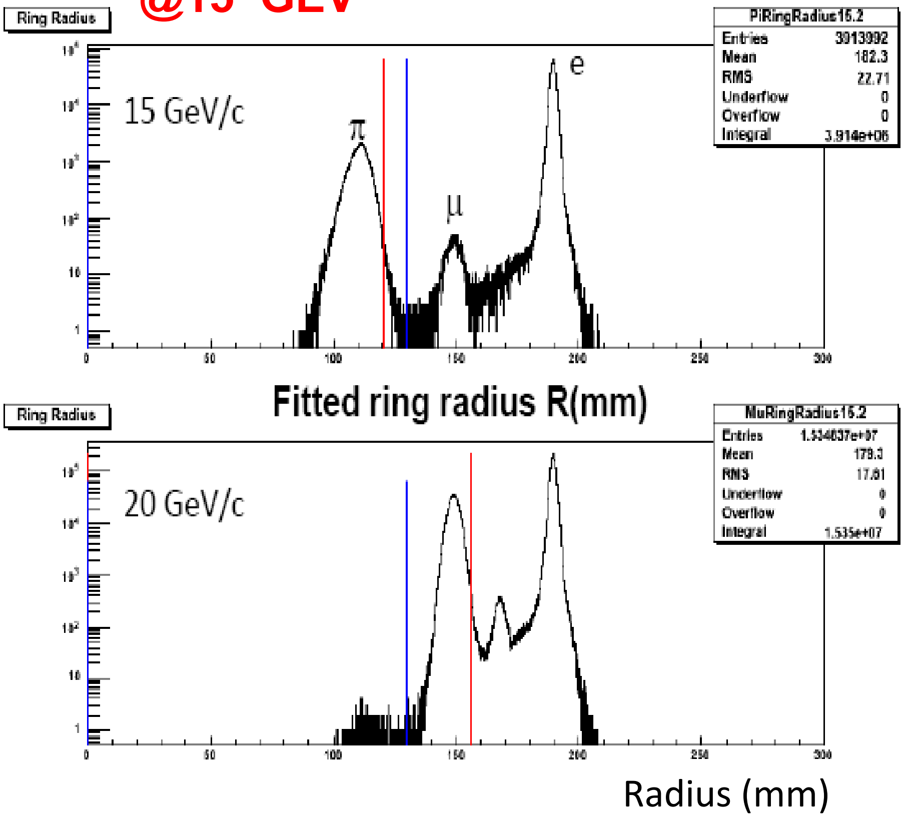
- integrated between 15 and 35 GeV/c (flat μ spectrum)
- change mirror orientation, change cuts

RICH-400: $\pi-\mu$ separation- II

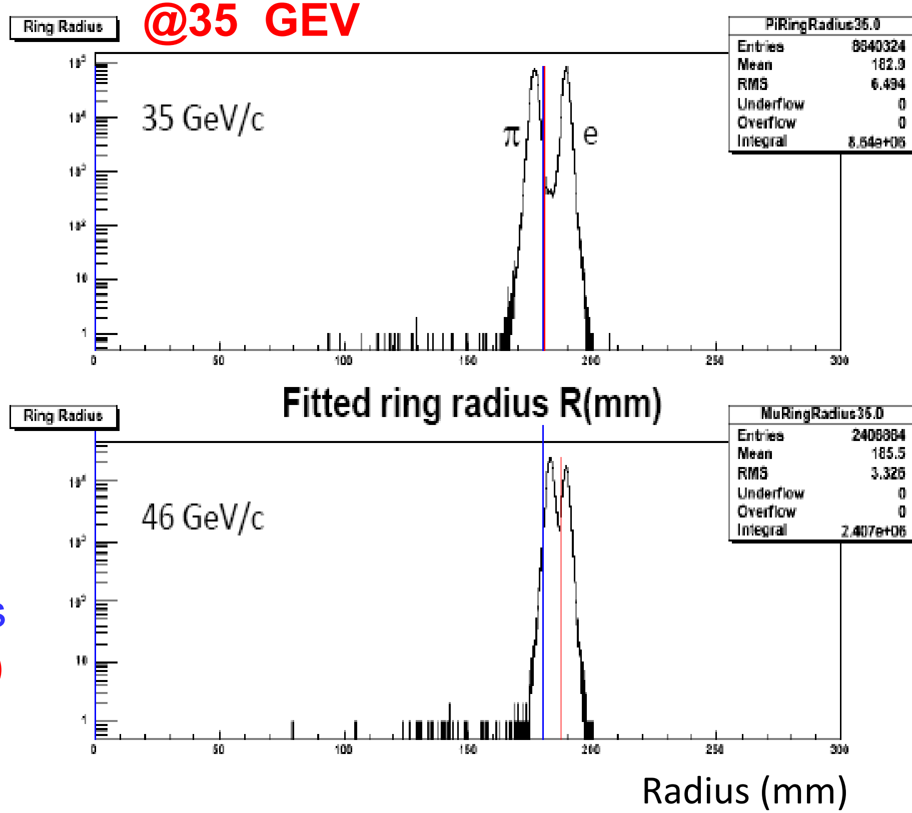
PRELIMINARY RESULTS

Mirror in (0,0)

@15 GEV



@35 GEV

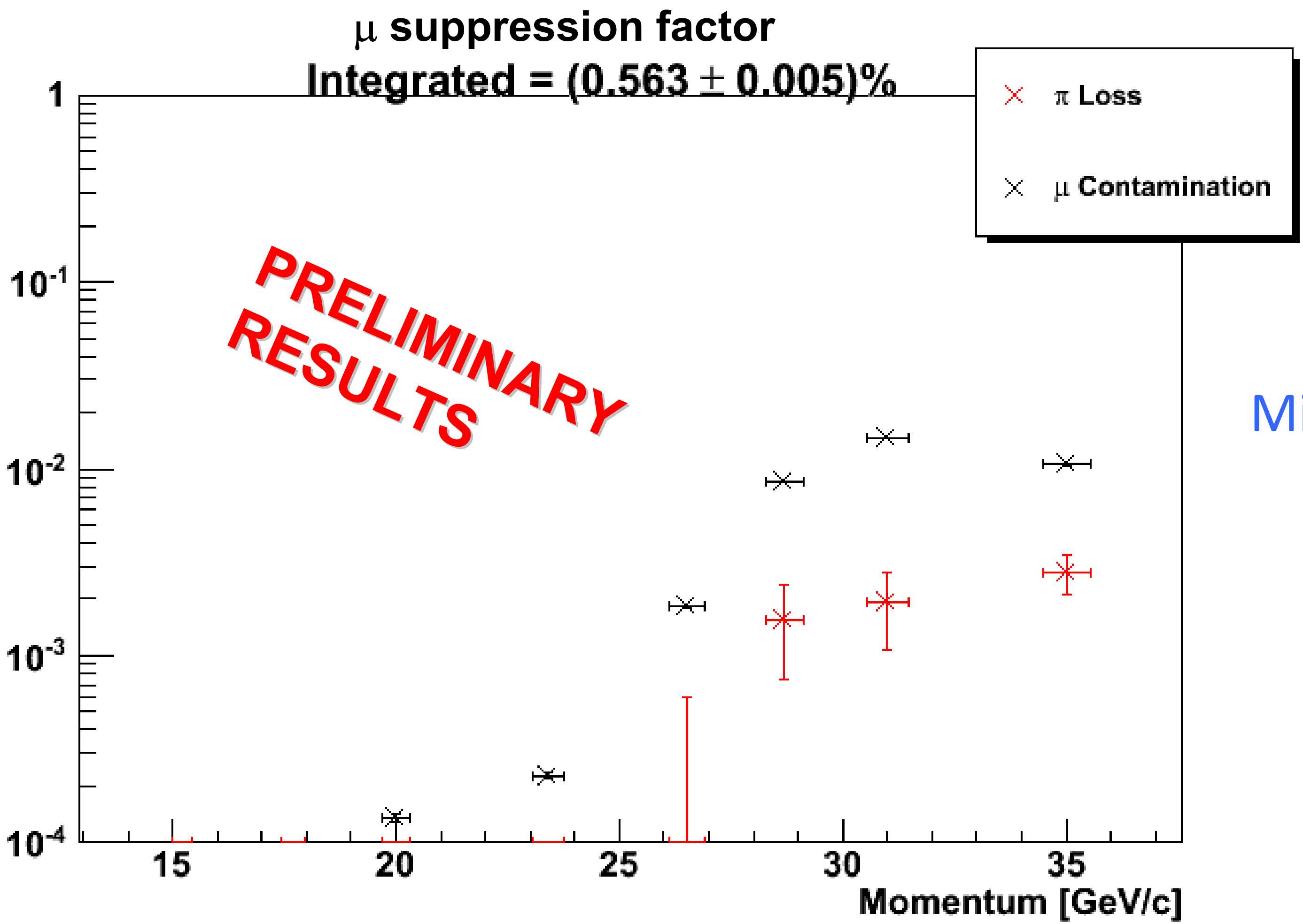


Blue line: half way between π and μ peaks

Red line: signal definition (+3σ from peak)

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

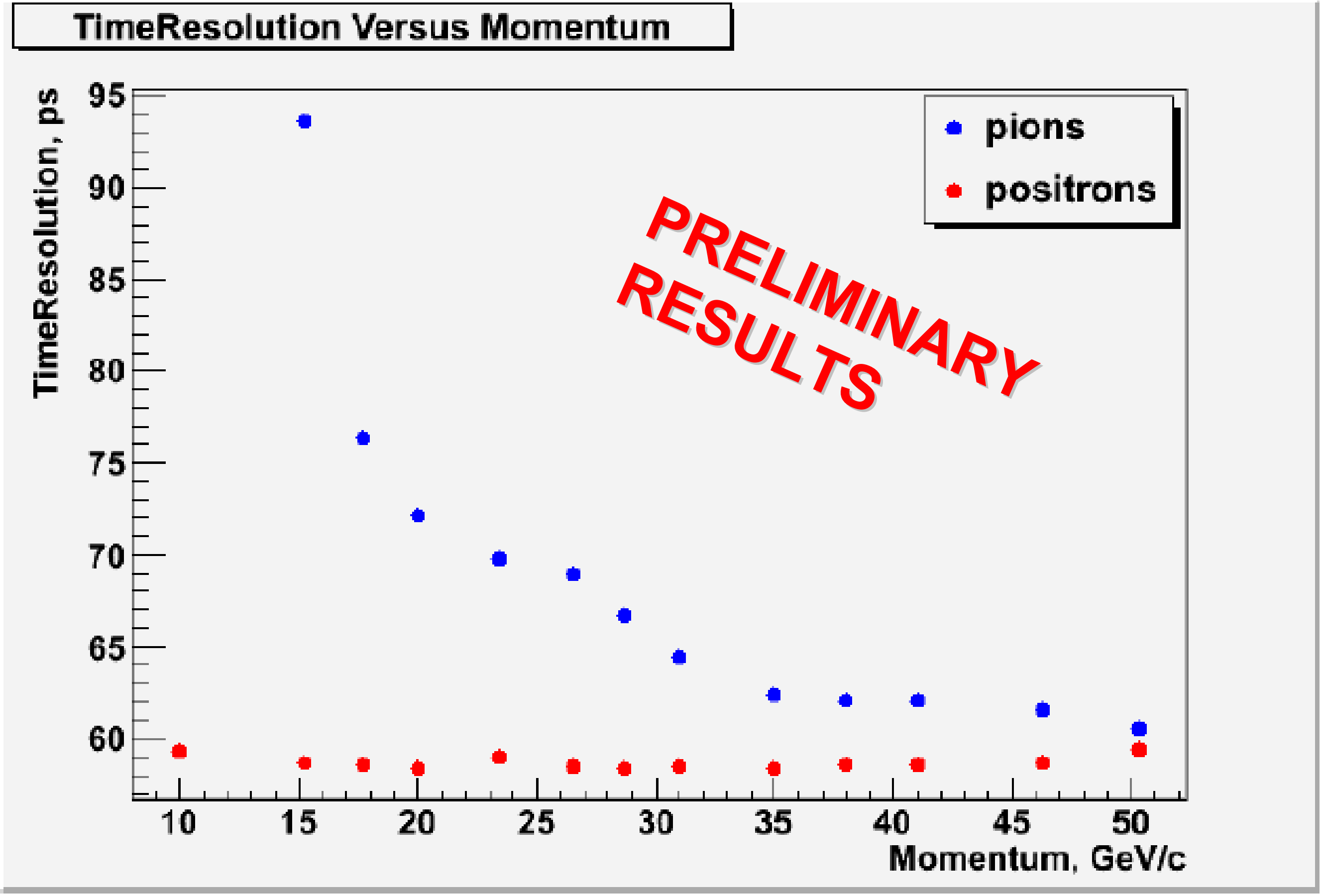
RICH-400: $\pi-\mu$ separation - III



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



SPARE

NA62: experimental contest

- Past experiments exploited K decays at rest to measure $K^+ \to \pi^+ \nu \bar{\nu}$
  - Low event statistics due to small acceptance
- Advantages of K decays in flight, i.e. higher energy (NA62: P_K=75 GeV/c):
  - The number of protons is not a limit
  - More K in the beam, thanks to higher production cross sections ($K^+ > K^-$)
  - Better $K^+ \to \pi^+\pi^0$ background rejection, due to higher electromagnetic energy deposition in γ veto (O(10 GeV))
  - Lower accidental background: good kaon to hadron separation (no need for separated K beam)
  - At P_K = 75 GeV/c the K/π ratio, as well as the fraction of accepted K wrt the total flux, is maximized: this is achieved by optimizing the present standard beam line, assuming 3×10^{12} ppp primary proton beam @ 400 GeV
- 2/3 of the final state is invisible:
  - Redundant measurements of K and π kinematical variables are required in order to keep background events under control
  - Particle ID is fundamental: μ identification and γ and charged particles rejection (veto) are very important

NA62 Proposal: ~100 evts, S/B=10 (2 years, starting in 2011)

NA62: trigger & DAQ

- Quasi-triggerless paradigma: L0 hardware and L1 software
- High trigger efficency (>95%)
- Acquisition losses < 10^{-8}
- Fully monitored system: inefficiency, dead time and Xoff recording
- Low random veto probability: very high online time and double pulse resolution
- Integrated Trigger and DAQ fully digital system
- Readout without zero suppression for candidates
- Scalability in terms of bandwidth
- As uniform as possible for most detectors
- Exploit as much as possible existing and commercial solutions developed for existing or new experiments

detector	Rate (MHz)
CEDAR	50
GTK	800
LAV (total)	9.5
STRAW (each)	8
RICH	8.6
LKR	10.5
MUV	9.2
SAC	1.5

- L0 input rate: ~10MHz
- Conditions on LKr, MUV and RICH multiplicity can reduce the rate ~ 1 MHz

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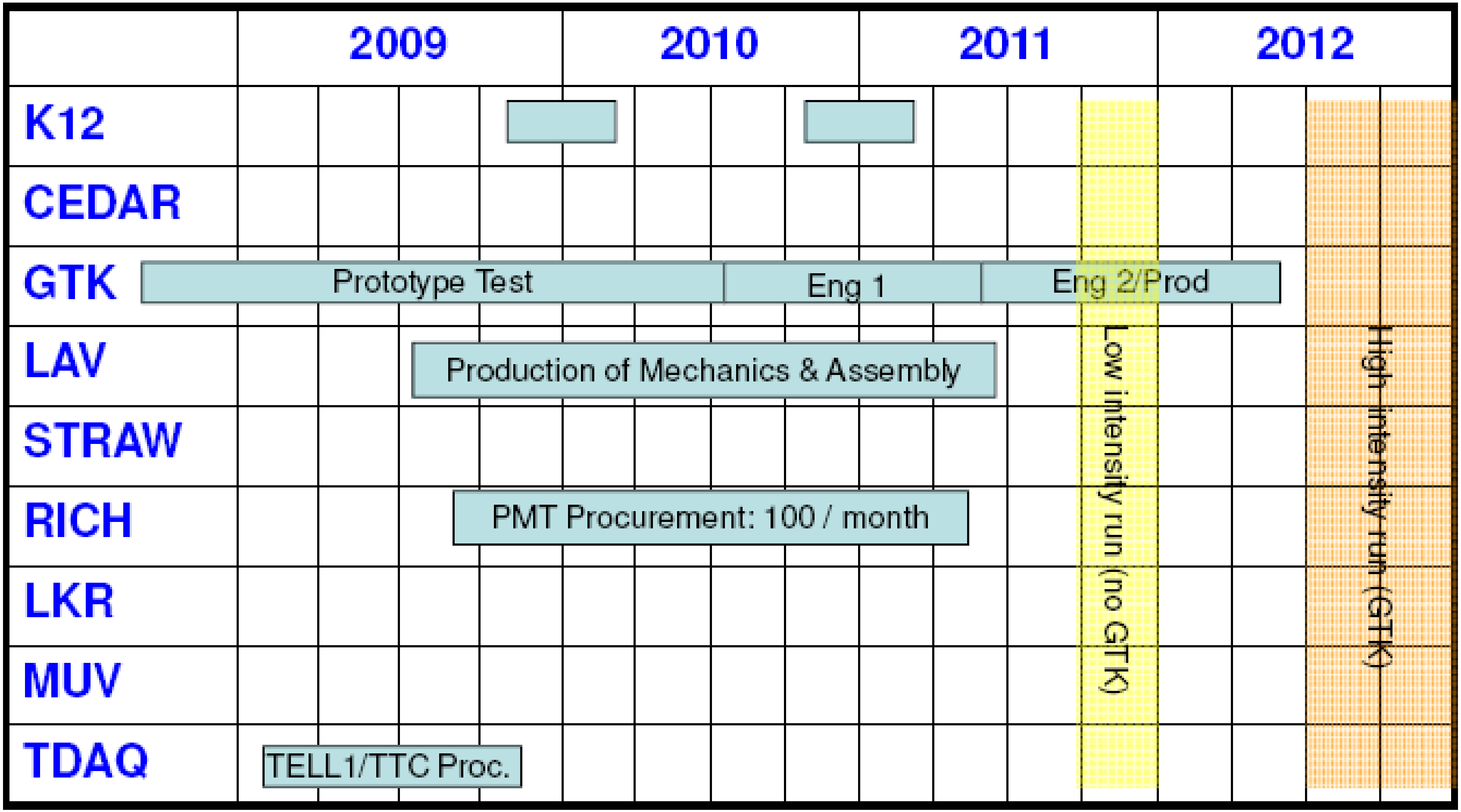
NA62 Timescale



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