The RICH detector of the NA62 experiment

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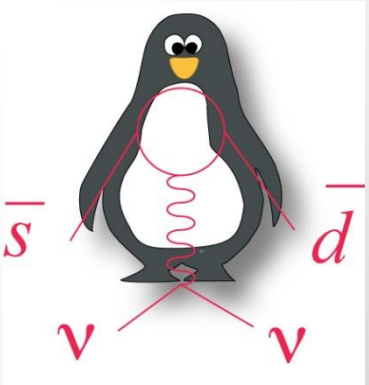


Outline

- NA62 experiment at CERN
- RICH requirements
- RICH detector
  - vessel
  - mirrors
  - photodetectors
  - front-end electronics
  - readout system
- RICH performance in the Commissioning Run
- Conclusions

NA62 experiment

Rare kaon decays:

- ✓ Indirect searches for New Physics (NP) beyond Standard Model (SM)
- ✓ Complementary to LHC

NA62 at SPS CERN:

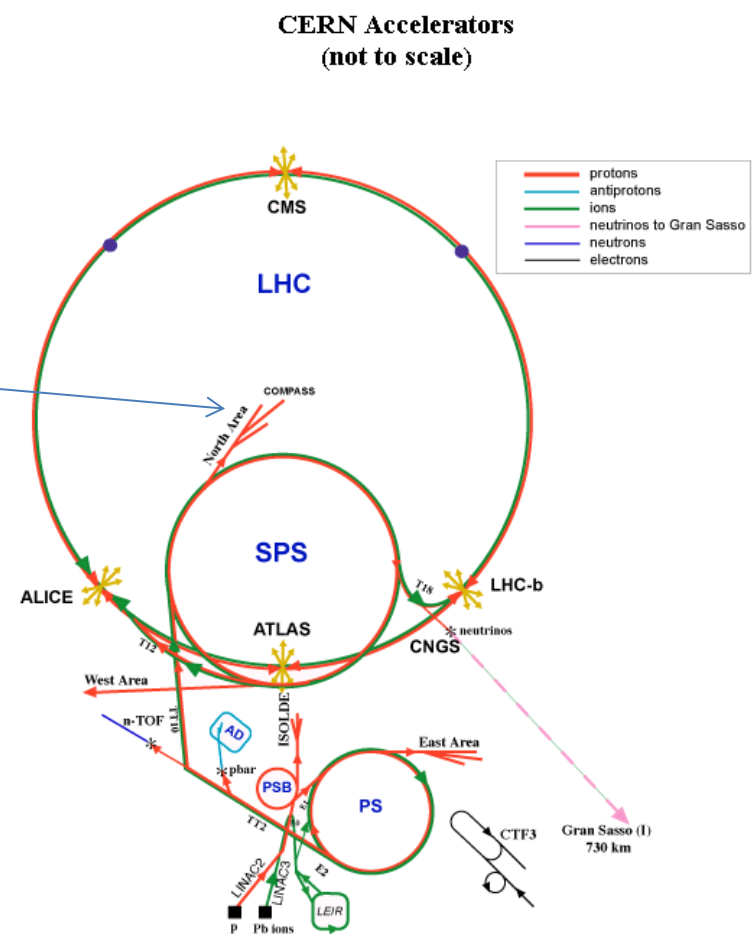
- ✓ Last generation kaon experiment
- ✓ Main goal: measurement of the $K^+ \to \pi^+ \nu\bar{\nu}$ decay with ~10% precision (~100 events in 2 years of data taking)

$K^+ \to \pi^+ \nu\bar{\nu}$ decay:

- ✓ Theoretically clean: $BR_{SM} = (9.11 \pm 0.72) \cdot 10^{-11}$ (A. Buras et al. arXiv: 1503.02693)
- ✓ Strongly suppressed in SM (FCNC)
- ✓ Sensitive to NP

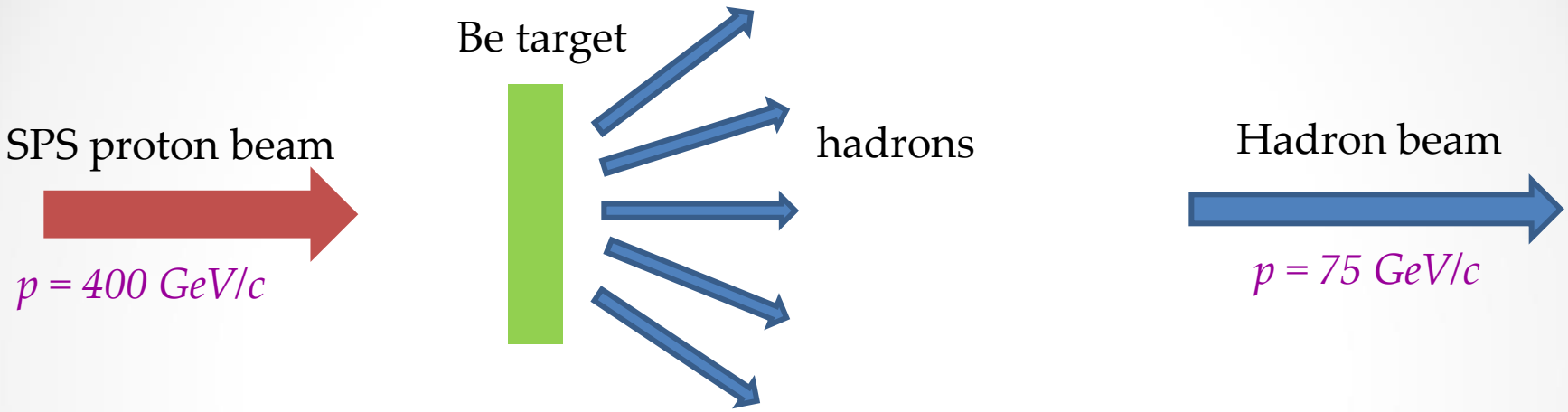
NA62 timeline:

- ✓ 2012-2014: detector installation
- ✓ 2014 (Oct-Dec): Commissioning Run
- ✓ 2015-2017: data taking

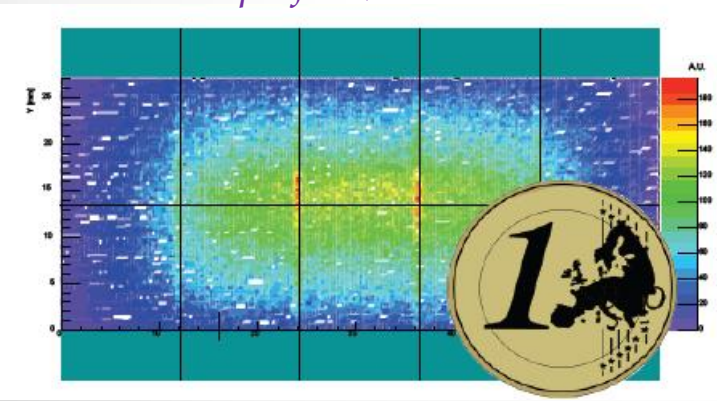


LHC: Large Hadron Collider
SPS: Super Proton Synchrotron
AD: Antiproton Decelerator
ISOLDE: Isotope Seperator OnLine DEvice
PSB: Proton Synchrotron Booster
PS: Proton Synchrotron
LINAC: LINear ACcelerator
LEIR: Low Energy Ion Ring
CNGS: Cern Neutrinos to Gran Sasso

From SPS to NA62



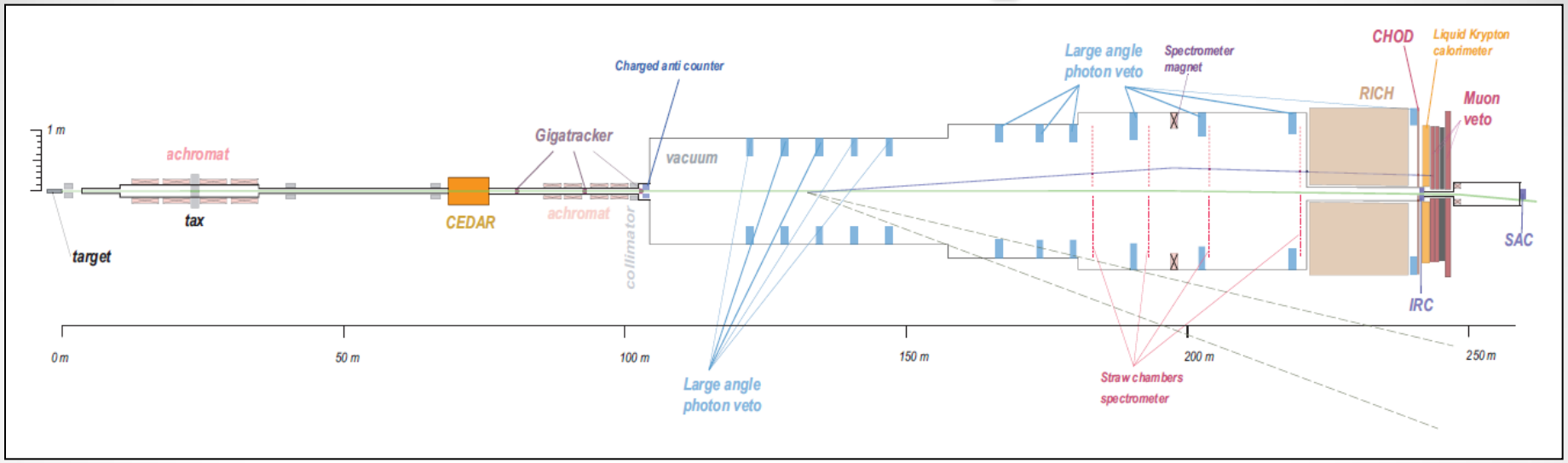
Hadron beam profile (Monte Carlo simulations)



Hadron beam:

- p = 75 GeV/c
- Mostly pions and protons
- 6% kaons (K+)
- 800 MHz

NA62 setup



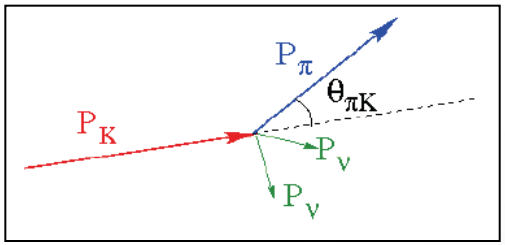
- ~4.8 * 10^{12} kaon decays per year (inside the 65m long fiducial region)
- ~10% efficiency
- ~50 signal events per year

NA62 setup:

- ✓ Decays-in-flight technique
- ✓ Detect K^+ and π^+
- ✓ Reject backgrounds at the ~10^{10} level

NA62 basic principles:

- ✓ High intensity + fast timing
- ✓ Kinematic selection
- ✓ Particle ID
- ✓ Photon rejection



$BR(K^+\to\pi^+\nu\bar{\nu}) \sim 9\cdot10^{-11}$

Main backgrounds:

- $BR(K^+\to\mu^+\nu_\mu) \sim 0.64$
- $BR(K^+\to\pi^+\pi^0) \sim 0.21$

RICH requirements

Particle ID (pion identification, to suppress $K^+ \rightarrow \mu^+ \nu_\mu$ background):

- provide a muon suppression in the pion sample at the ~10^{-2} level in the momentum range 15 GeV/c < p < 35 GeV/c

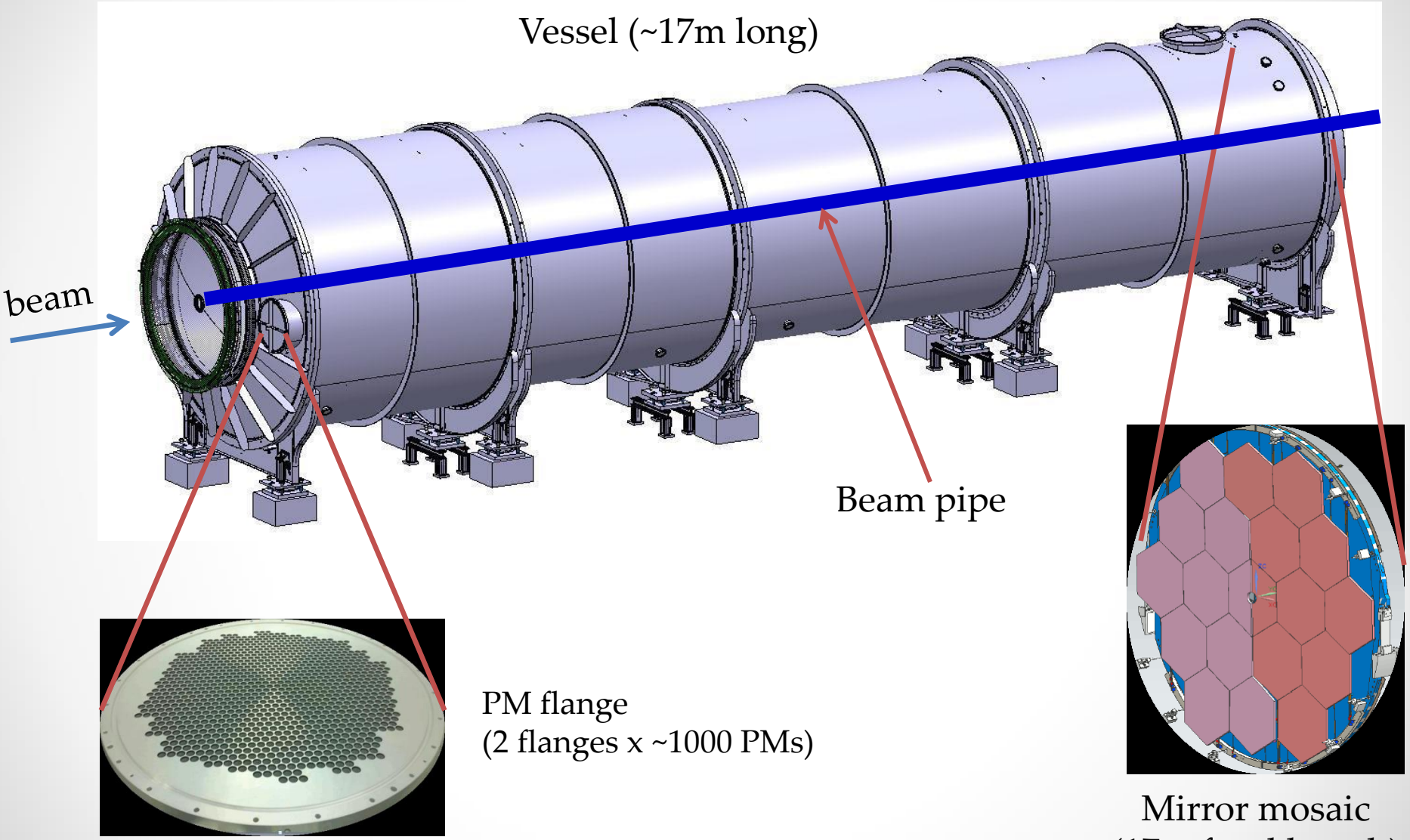
Fast timing (pion time measurement, to match kaon and pion tracks):

- Measure the pion crossing time with the resolution ~100ps

L0 trigger:

- Produce a L0 trigger pulse for a secondary charged track

RICH layout


Vessel (~17m long)
beam
Beam pipe
PM flange
(2 flanges x ~1000 PMs)
Mirror mosaic
(17m focal length)

RICH vessel

Vessel:

- 17m long
- 4 cylindrical sections with decreasing diameter (4 .0 to 3.4 m)
- Beam pipe going through
- Thin Al windows (entrance, exit)
- Vacuum proof

Radiator:

- Ne at ~atmospheric pressure and room temperature
- $(n-1) = 63*10^{-6}$ at $\lambda = 300$ nm
- Pion threshold: p = 12 GeV/c

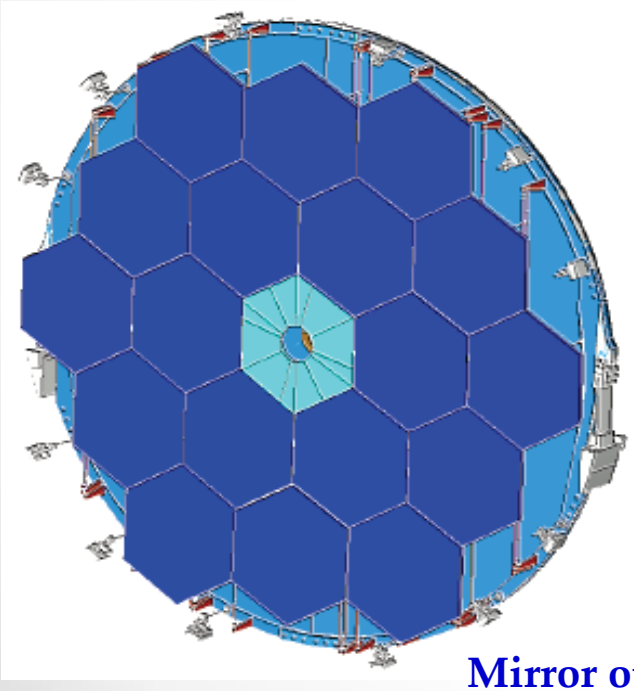
Operation:

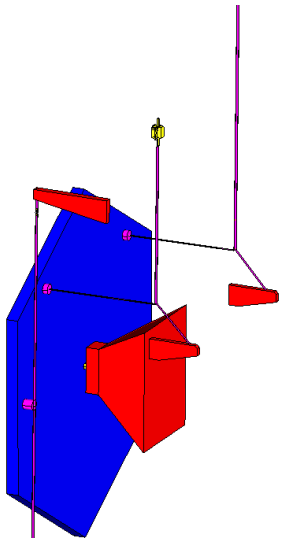
- Sealed gas volume (without renewal)

RICH mirrors

RICH mirrors:

- 18 hexagonal mirrors (35cm side)
- 2 semi-hexagonal mirrors (around the beam pipe)
- Made of 2.5cm thick glass
- Al coating
- Thin dielectric film to improve reflectivity





Mirror mosaic and assembly

Mirror support system:

- 5cm thick honeycomb panel
- Mirrors are supported by the dowel connected to the support panel
- two Al ribbons allow for the mirror orientation
- One Al ribbon to prevent mirror rotation
- Two piezo motors to rotate mirrors remotely

Mirror optical properties:

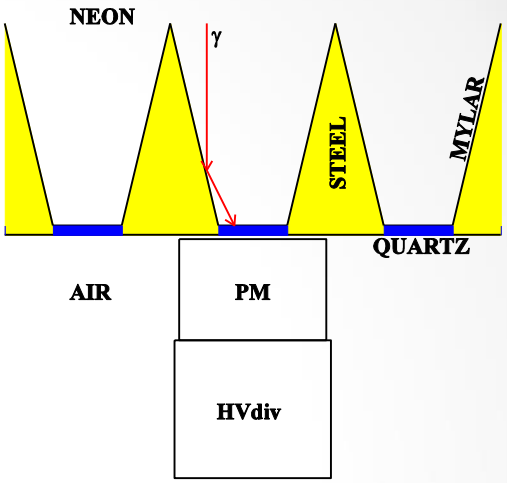
- R = 34m
- Reflectivity > 90% (λ = 195-650 nm)
- $D_0 \leq 4$mm

Light collection

- ✓ **1952 PMs (Hamamatsu R7400 U03) assembled into two Al discs at the upstream endcap**

- ✓ Winston cones covered with Mylar:
  - 22 mm high
  - 18 mm wide (max)
  - 7.5 mm wide (min)

- ✓ 1 mm thick quartz windows to separate PMs from Neon



PM disc

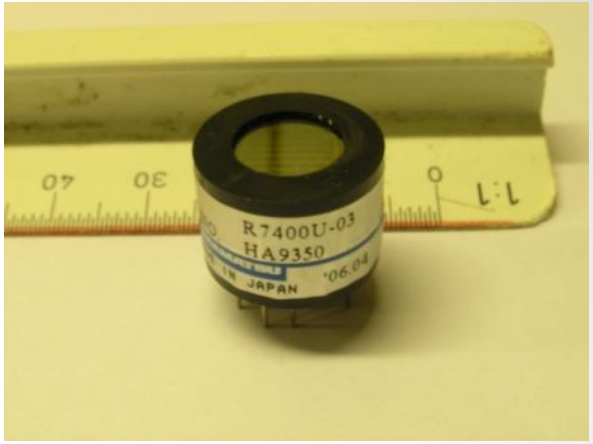
Mylar for Winston cones

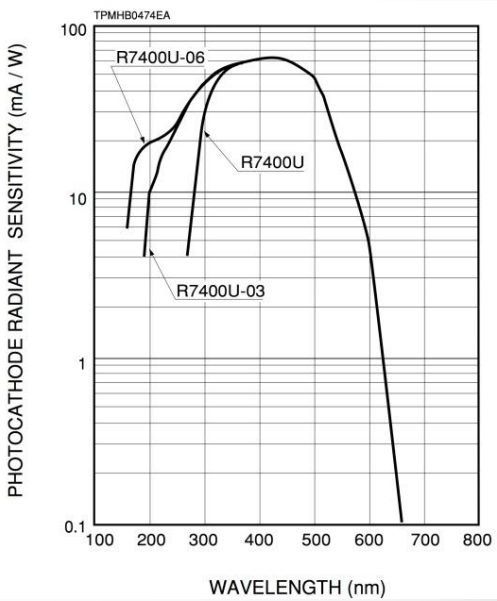
Winston cones

Light detection

Hamamatsu R7400 U03 PMs:

- External diameter 16mm
- Active diameter 8 mm
- UV glass window
- Custom-made HV divider
- 185-650n m sensitive range
- Peak sensitivity @ 420 nm
- Gain $1.5*10^6$ (HV = 900 V)
- QE ~20% (@ 420 nm)
- Transit time spread 0.28 ns (FWHM)

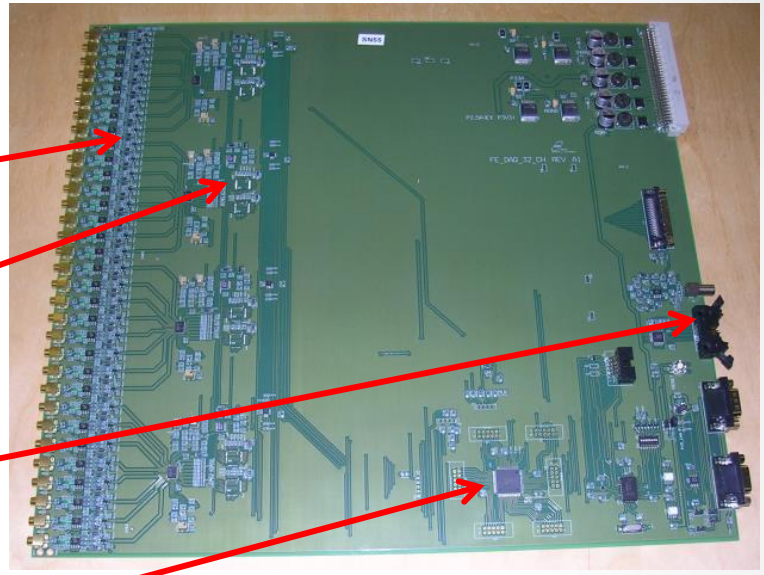




FE electronics

64 FE boards x 32 channels per board

FE board



FE board:

- Custom-made amplifiers
- NINO chips (discrimination, signal stretching)
- multiplicity output (for the L0 trigger)
- ELMB (embedded local monitor board) for remote control and monitoring

NINO: developed by ALICE experiment (CERN)

ELMB: developed by ATLAS experiment (CERN)

Readout system

Data readout: 4 mother boards x 4 daughter boards x 128 channels per board

L0 trigger: 1 mother board with 1 daughter board

Mother board (TEL62):

- development of TELL1 (LHCb experiment at CERN)
- Houses up to 4 daughter boards
- Buffers data
- Produces trigger primitives

Daughter board (TDCB):

- FPGA-based TDC board
- Contains 4 CERN HPTDC (high performance TDC)

RICH commissioning

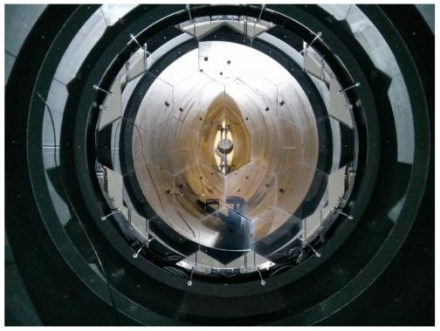
Commissioning run in 2014:

- RICH installation completed at the beginning of the run
- Two months of data taking (Oct-Dec)
- Beam intensity ~5% of the nominal
- Track information was not available during the run

Mirror installation in progress

RICH vessel

PM disc



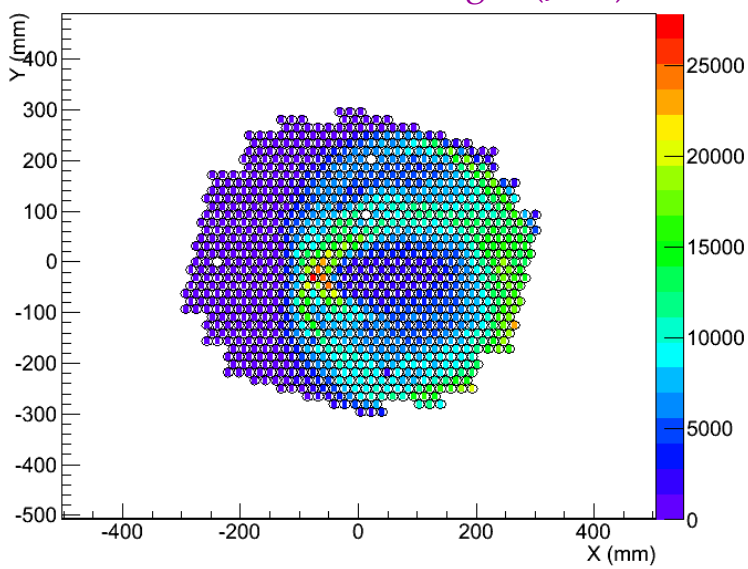
Mirror mosaic

RICH PM illumination

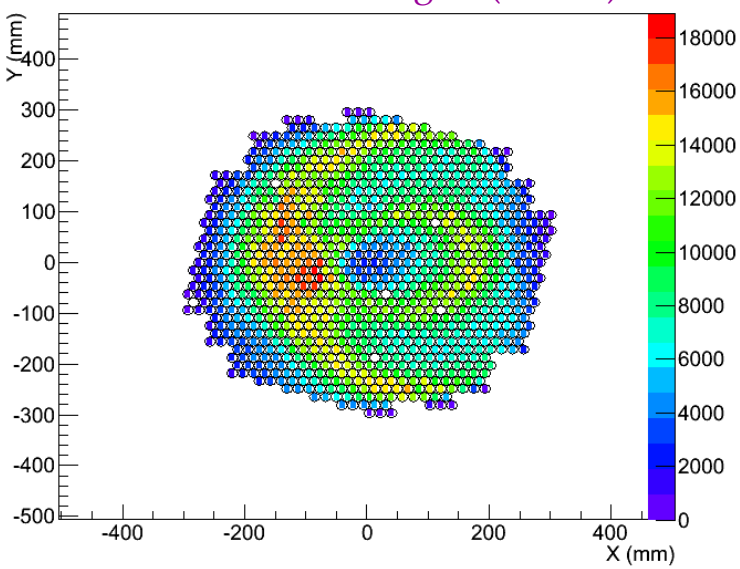
Data sample:

- Select π^+ sample from $K^+ \rightarrow \pi^+\pi^0$ decays (nominal beam parameters for K^+, π^0 momentum reconstructed from LKr information, π^+ reconstructed from the decay kinematics)

PM illumination for flange 1(Jura)

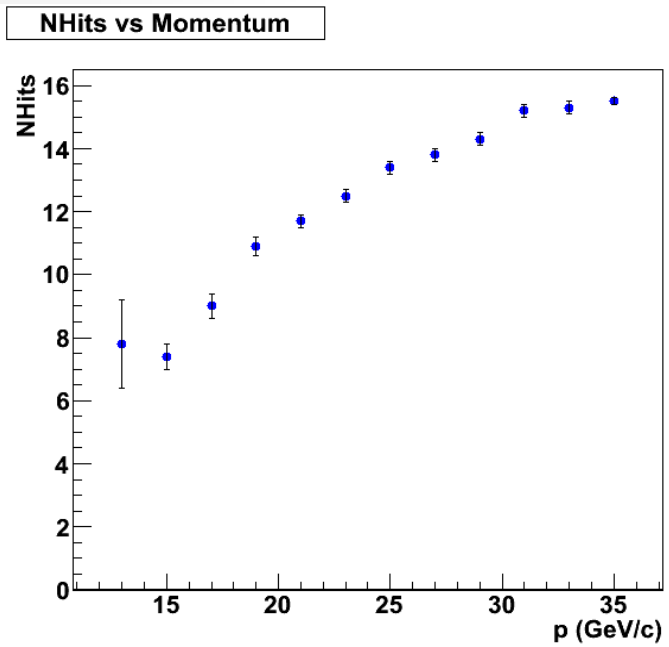


PM illumination for flange 2 (Saleve)

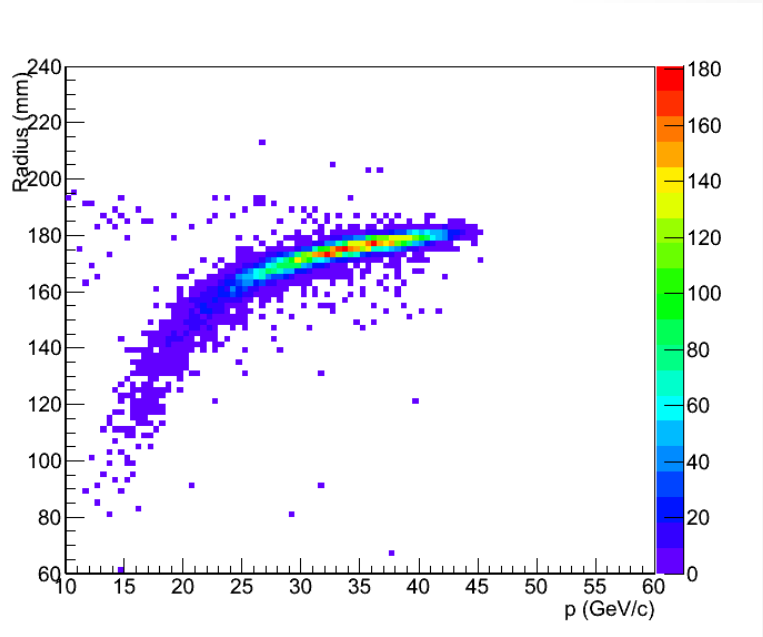


Multiplicity and ring radius

Multiplicity vs momentum



Ring radius vs momentum

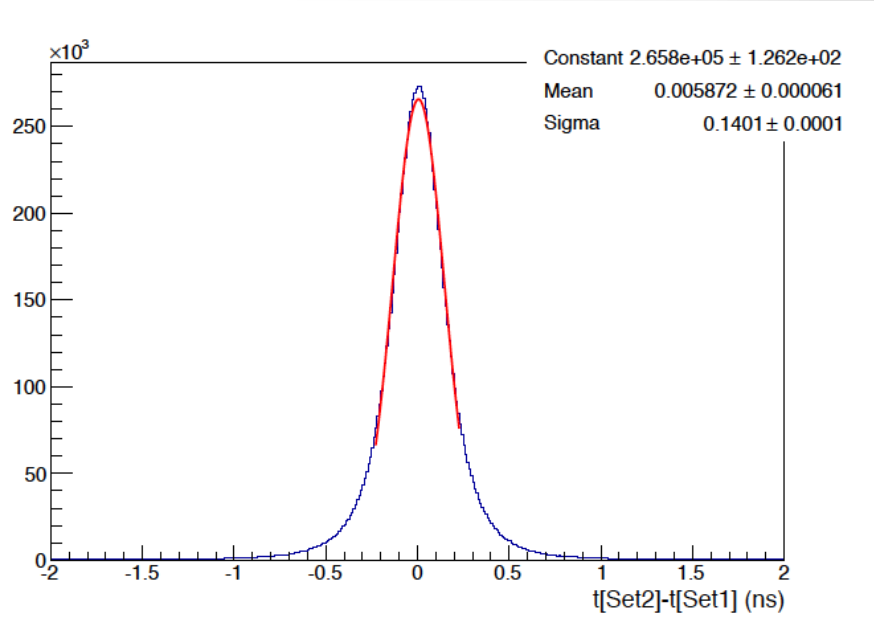


Multiplicity and ring radius in agreement with expectations

Time resolution

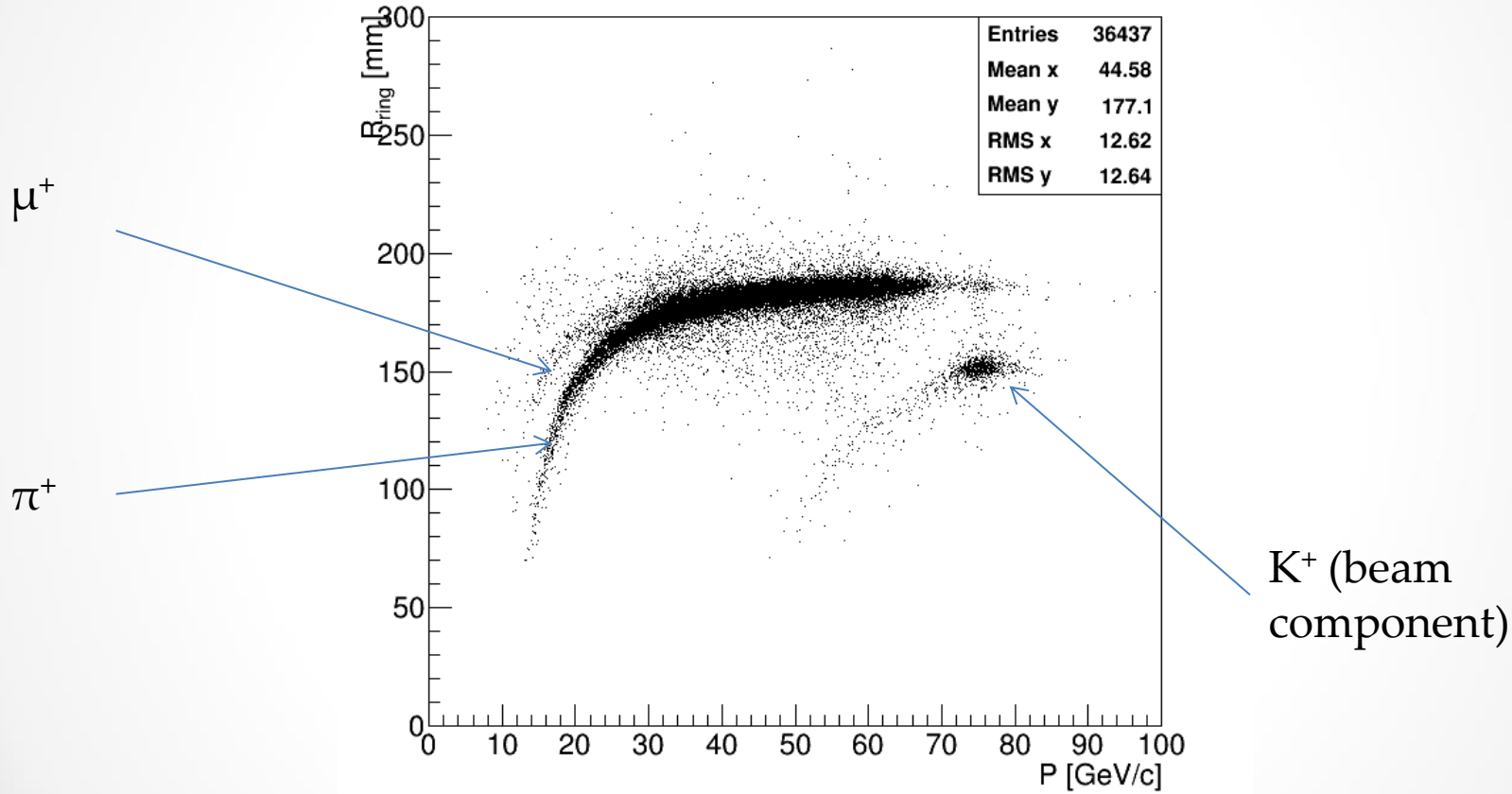
Independent time resolution measurement:

- Select π^+ sample
- Split hits into two groups
- Calculate average time for each group
- Plot the difference of average times
- Fit with the gaussian
- RICH time resolution is ~0.5*σ



RICH event time resolution ~70ps

First data with tracks



Data analysis in progress

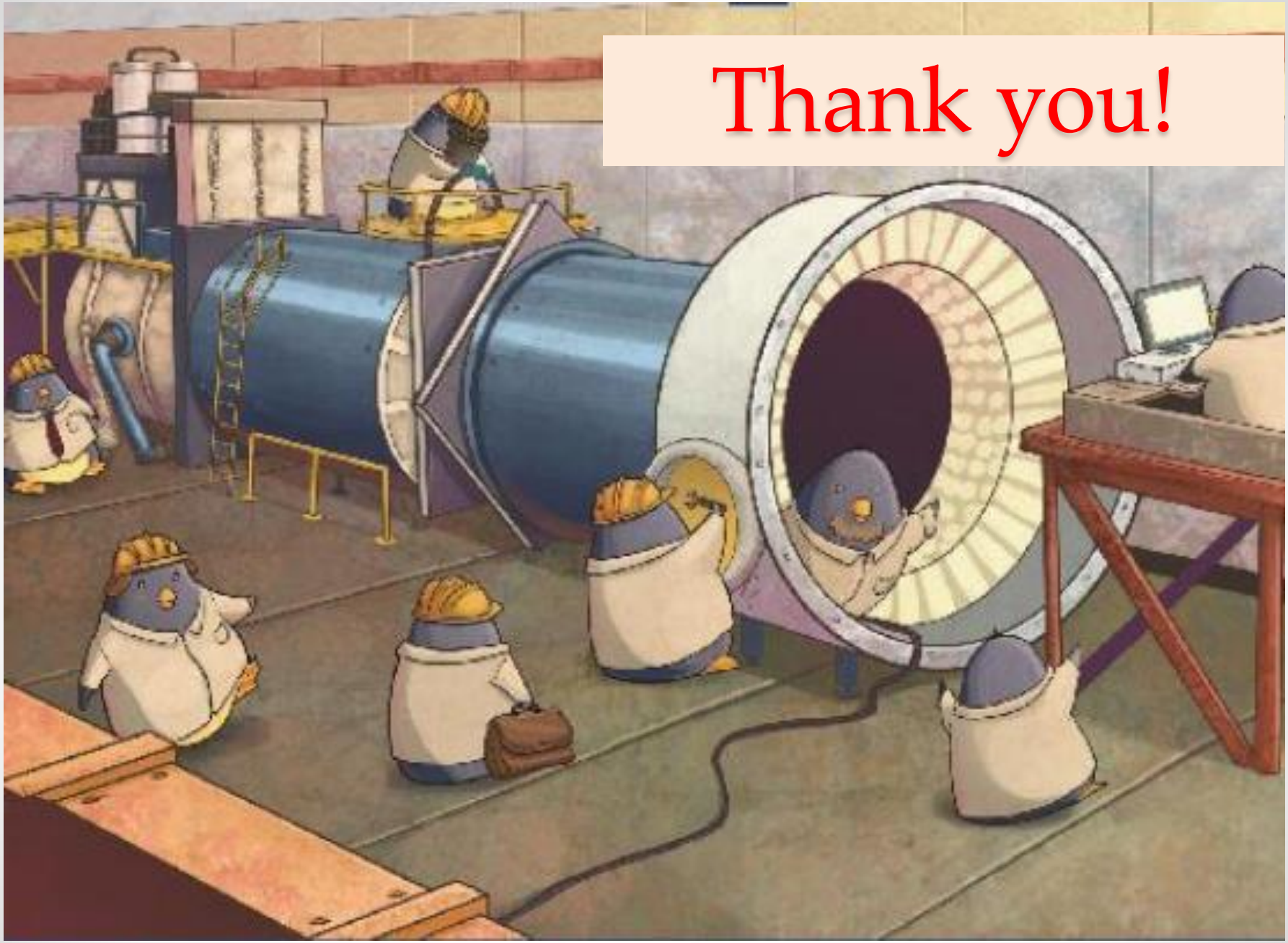
Conclusions

RICH in 2014:

- installation completed
- successfully commissioned
- Two months of data taking
- First data show reasonable performance
- Data analysis in progress

RICH in 2015:

- More detailed information about the performance
- Ready for physics runs


Thank you!

spare