

First Results from the NA62 Straw Spectrometer

European Physical Society 2015, Wien

Vito Palladino - CERN

On Behalf of NA62 Collaboration

Outline

- The NA62 experiment
- The NA62 straw tracker
- Straw tracker design and electronics
- First results from the NA62 pilot run (December 2014)
- Conclusions

Outline

- The NA62 experiment
- The NA62 straw tracker
- Straw tracker design and electronics
- First results from the NA62 pilot run (December 2014)
- Conclusions

The NA62 Experiment: Motivation

- NA62 aims at measuring the Branching Ratio (BR) of the process $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ within a 10% total uncertainty (100 SM events in 2 years).
- **Theoretically clear scenario** in SM:
 - Hadron matrix element extracted from $BR(K^+ \rightarrow \pi^+ e \nu)$
 - FCNC process \Rightarrow in SM it could proceed **only** through loops, suppressed by GIM
 - $BR = (9.11 \pm 0.72) \times 10^{-11} *$
- **New Physics** may induce deviation from SM
- Experimental status^{**}:
 - E787/E949: $1.73^{+1.15}_{-1.05} \times 10^{-11}$

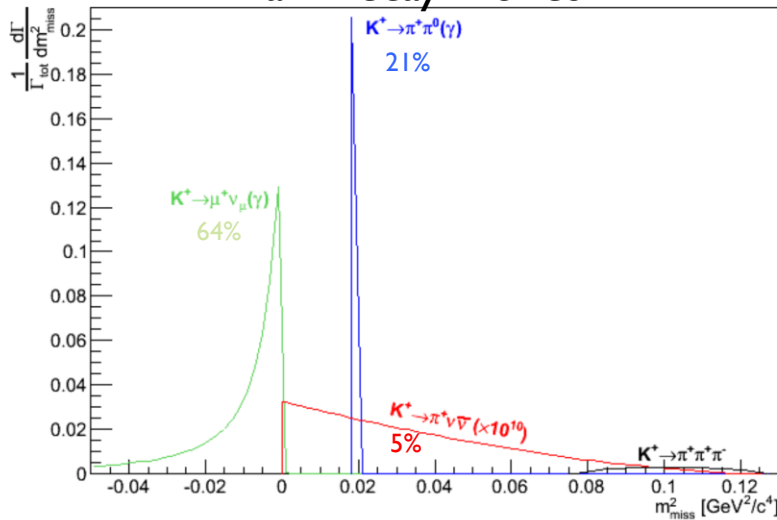
*[A.J. Buras, D. Buttazzo, J. Girrbach-Noe and R. Knegjens, arXiv:1503.02693]

**[E747/E949 collaborations, Phys. Rev. D 77, 052003 (2008), Phys. Rev. D 79, 092004 (2009)]

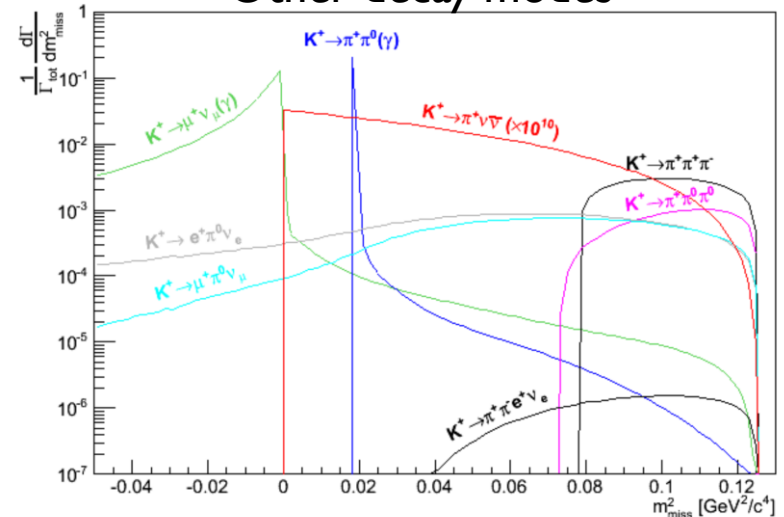
The NA62 Experiment

- Background is mainly rejected using the the squared missing mass ($m_{\text{miss}}^2 = (P_K - P_\pi)^2$), veto's and PID.

Main decay modes

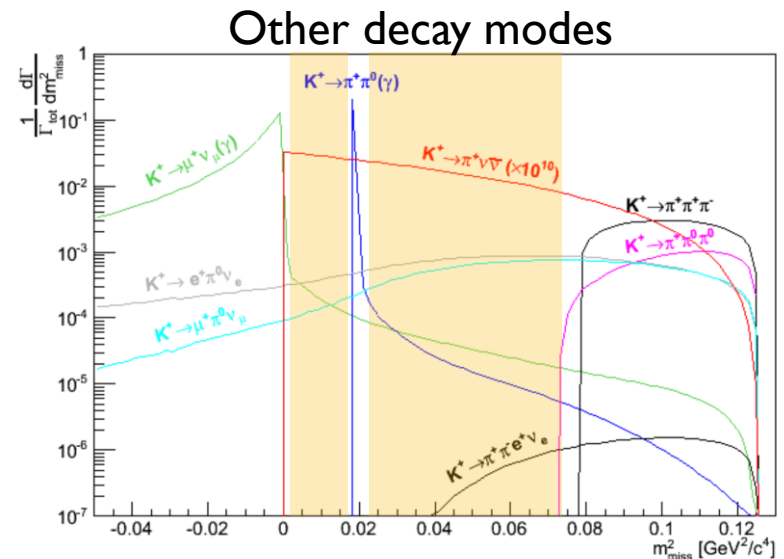
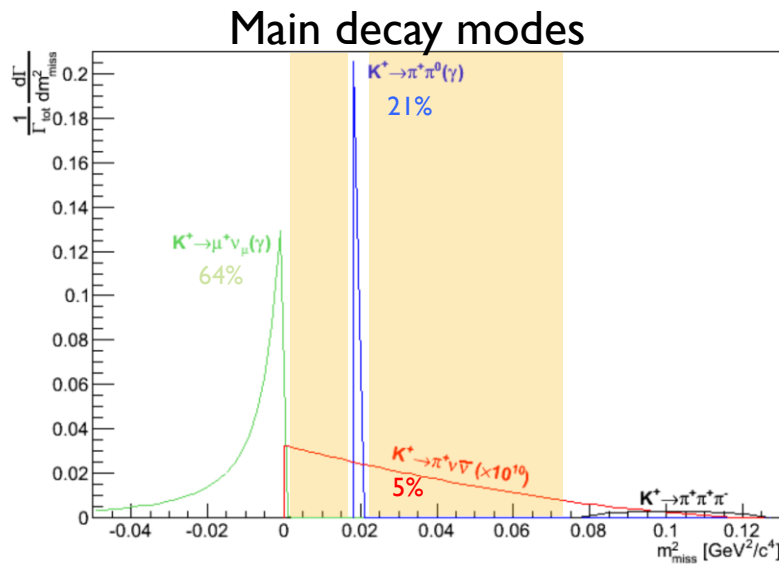


Other decay modes



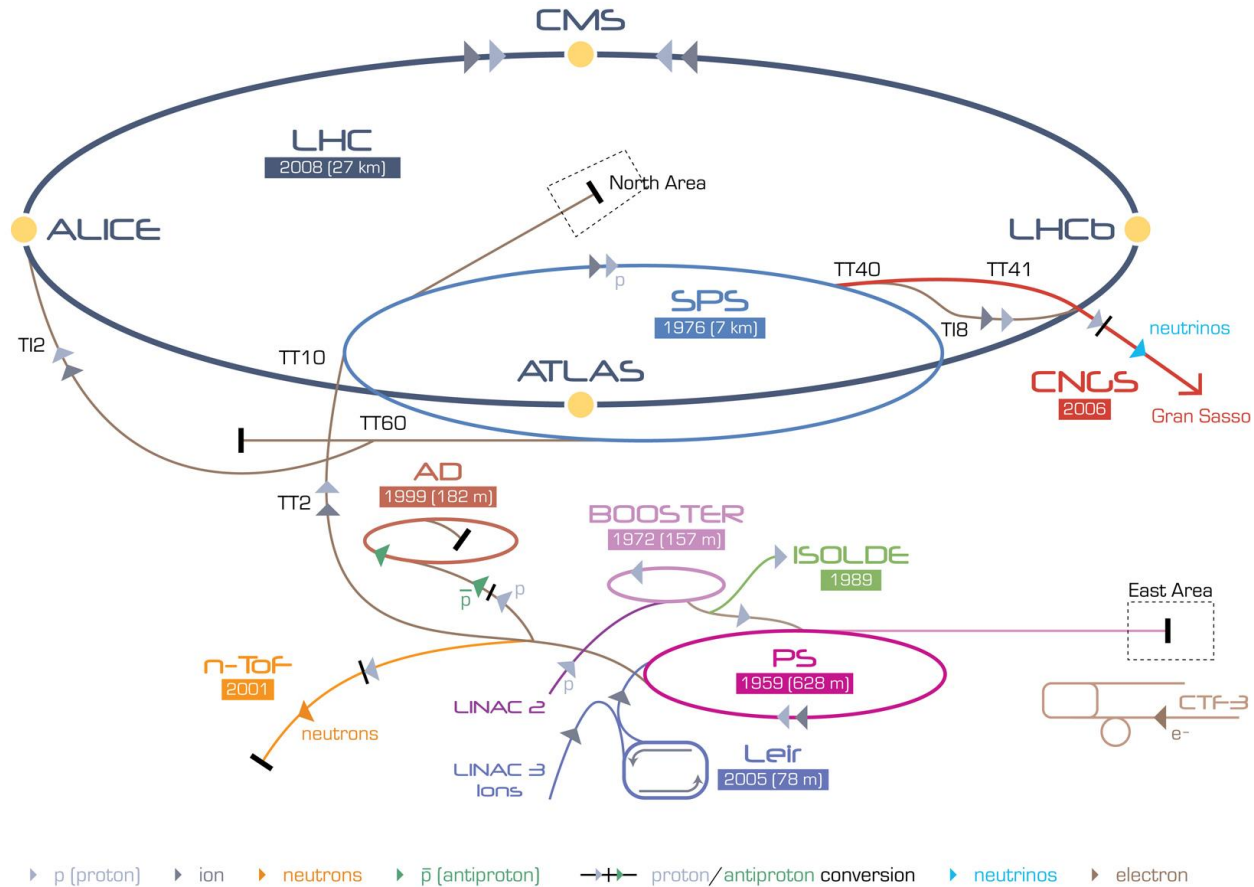
The NA62 Experiment

- Background is mainly rejected using the the squared missing mass ($m_{\text{miss}}^2 = (P_K - P_\pi)^2$), veto's and PID.



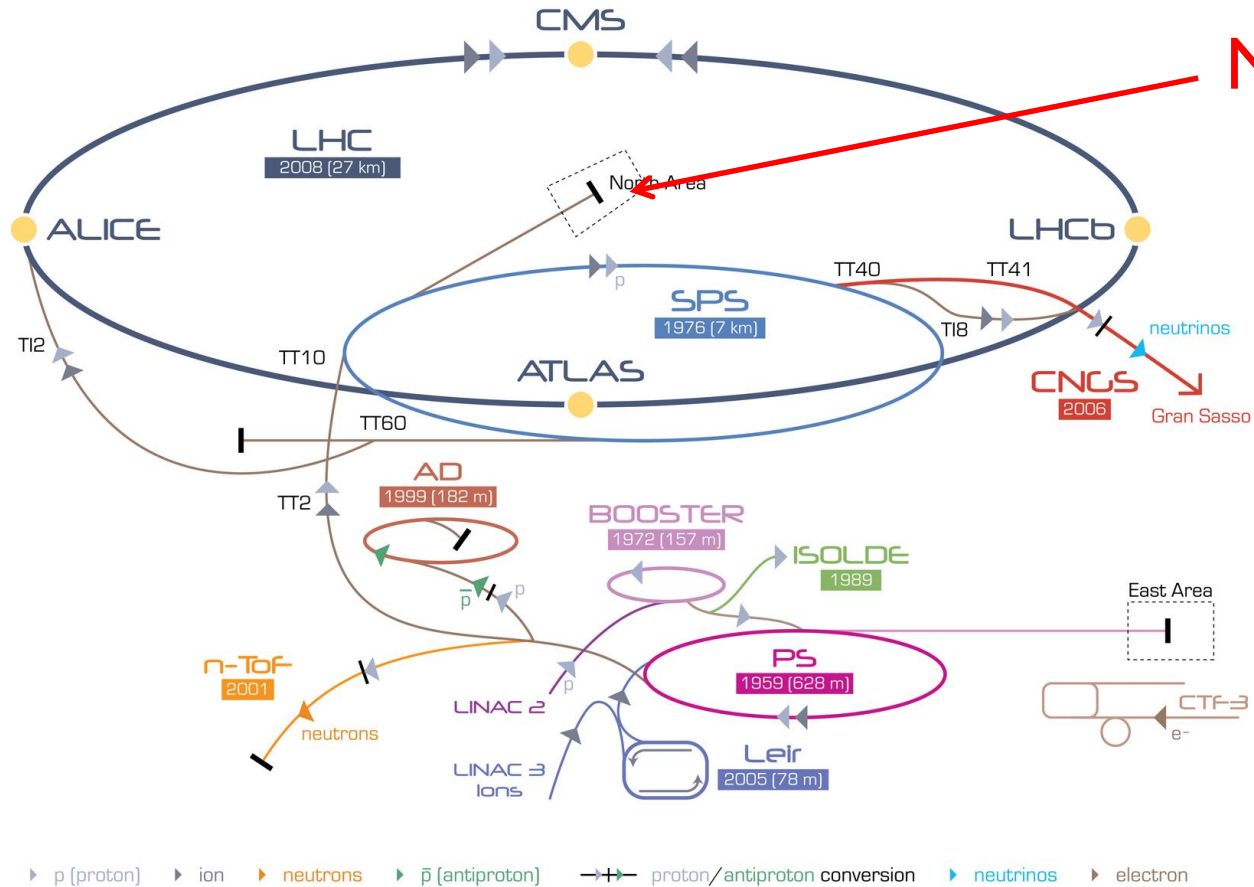
- 2 regions cut: ~92% of background is closed kinematically.

The NA62 Apparatus



LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron
 AD Antiproton Decelerator CTF-3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice
 LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

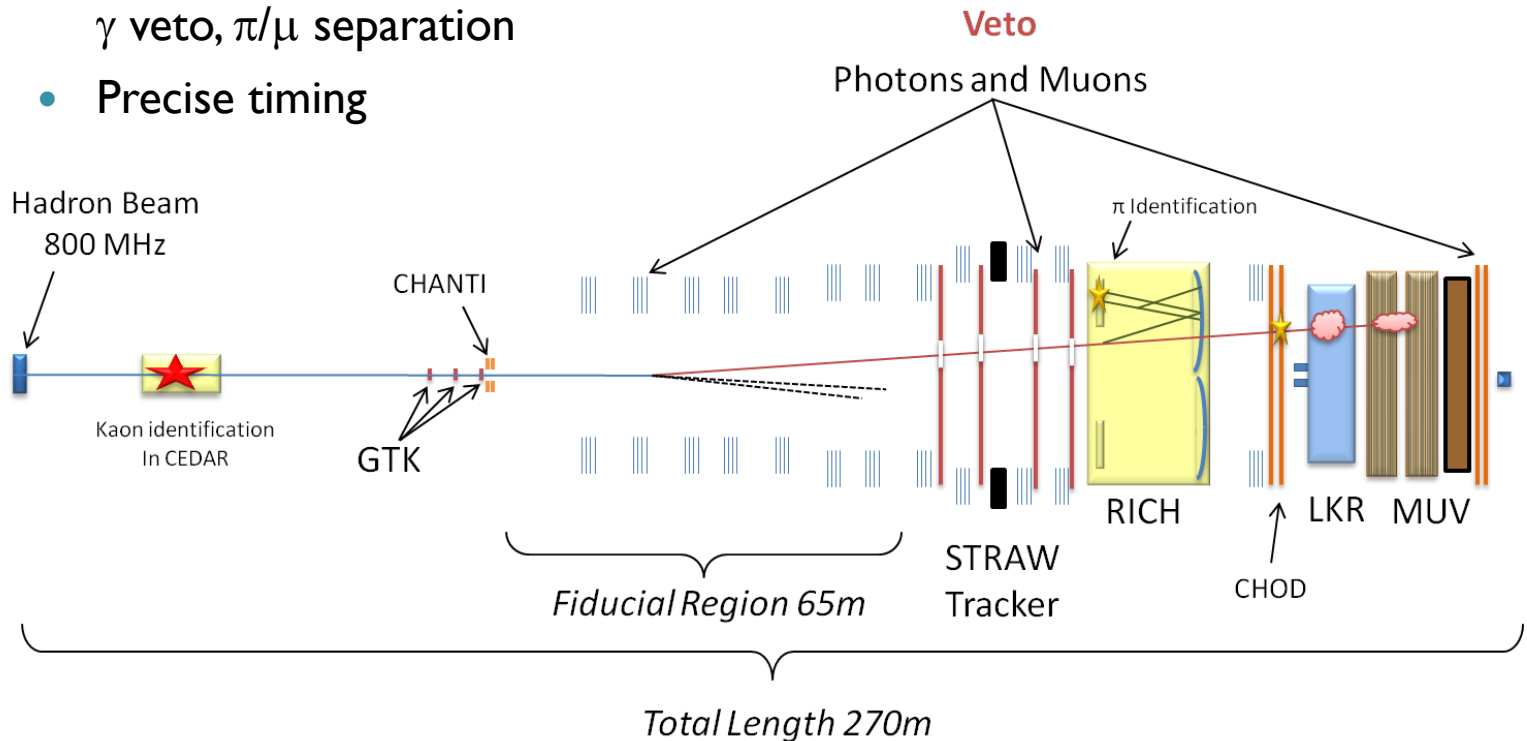
The NA62 Apparatus



LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron
 AD Antiproton Decelerator CTF-3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice
 LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

The NA62 Apparatus

- Guidelines of NA62 apparatus design:
 - High intensity => Rare decay
 - 3×10^{12} protons per pulse
 - 10MHz of K decay in the fiducial region
- High Energy beam (unseparated 75GeV secondary SPS hadronic beam) => γ veto, π/μ separation
- Precise timing

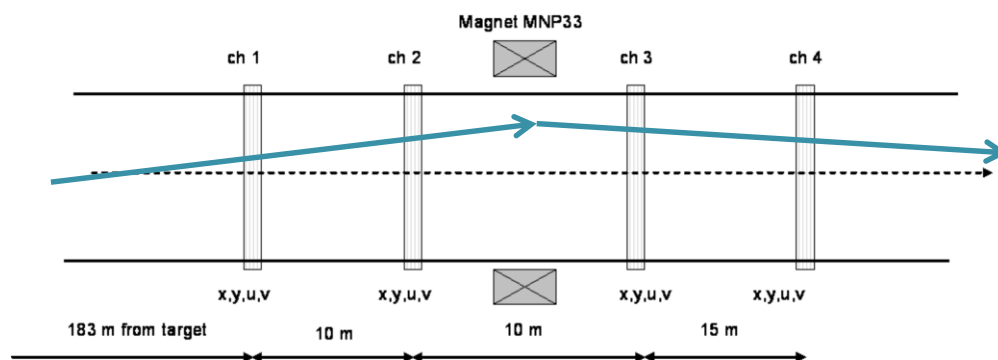


Outline

- The NA62 experiment
- **The NA62 straw tracker**
- Straw tracker design and electronics
- First results from the NA62 pilot run (December 2014)
- Conclusions

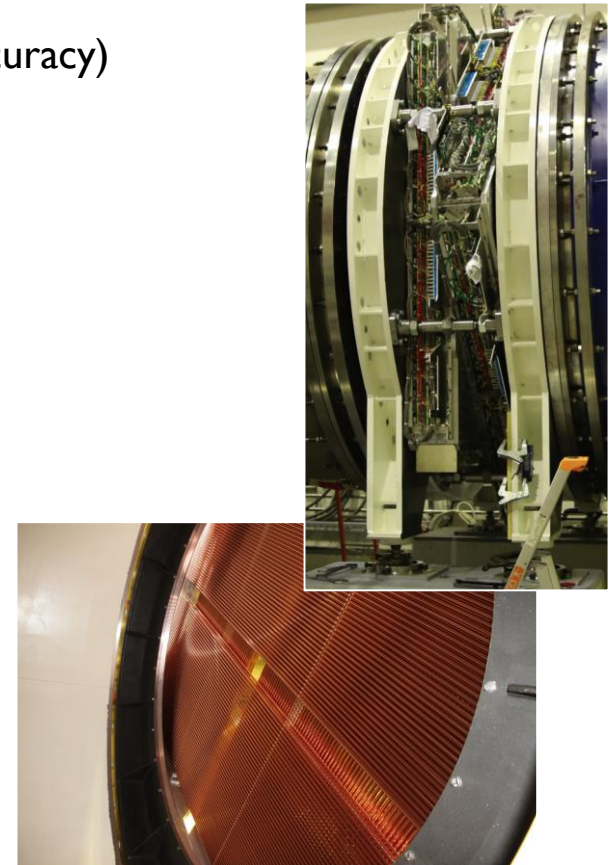
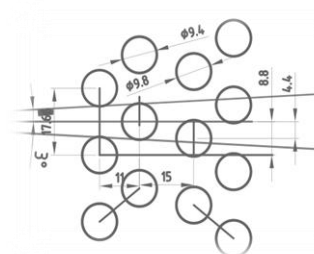
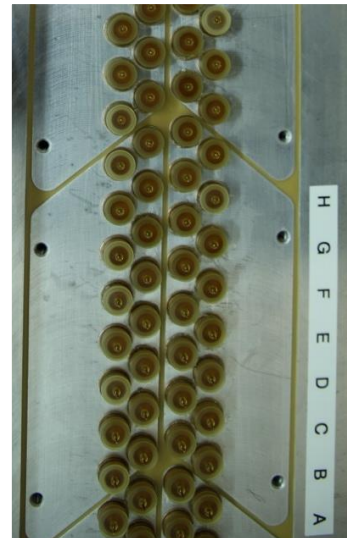
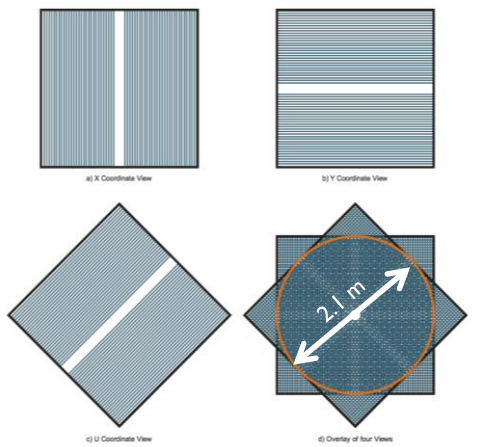
The Straw Detector

- Challenging detector:
 - Operate in vacuum ($< 10^{-5}$ mbar)
 - Low material budget ($< 0.5\%X_0$ per station)
 - $\Delta P/P \leq 1\%$
 - $\Delta\Theta_{K\pi} \leq 60\mu\text{rad}$
 - Single view resolution: $130\mu\text{m}$
 - Full reconstructed coordinate resolution: $80\mu\text{m}$



The Straw Detector

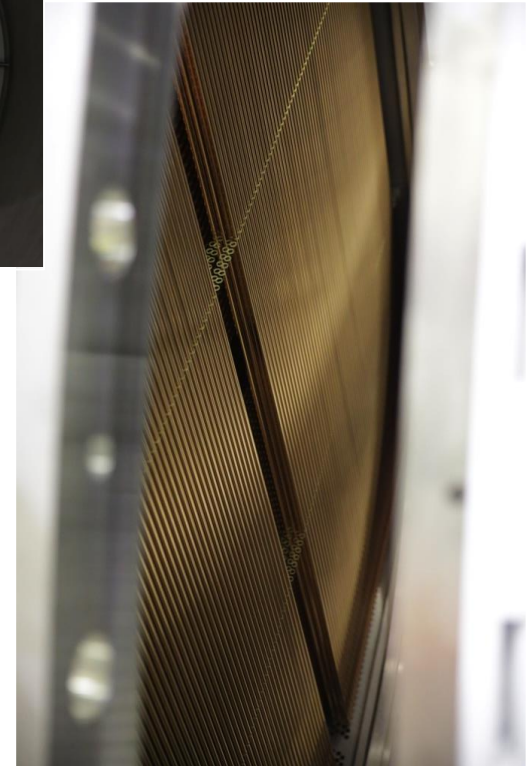
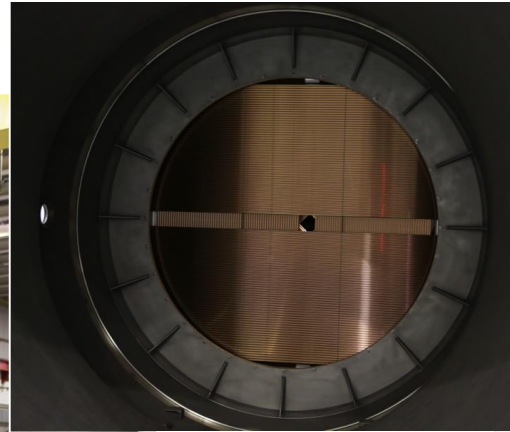
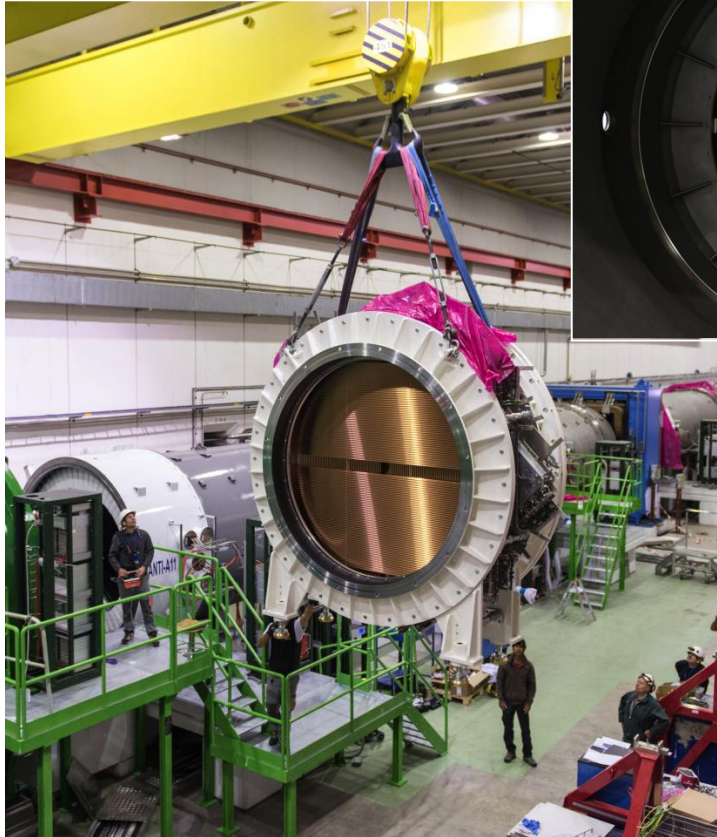
- 4 views per station
- 7168 mylar straws ($\varnothing 9.8\text{mm} \times 2.1\text{ m}$), Cu-Au metallization (50-20nm)
- 15 km of ultrasonic welding in vacuum
- 30 μm gold-plated inner wire (200 μm position accuracy)
- Gas mixture Ar-CO₂ 70:30
- 10-15mbar overpressure
- ~460l/h total flow



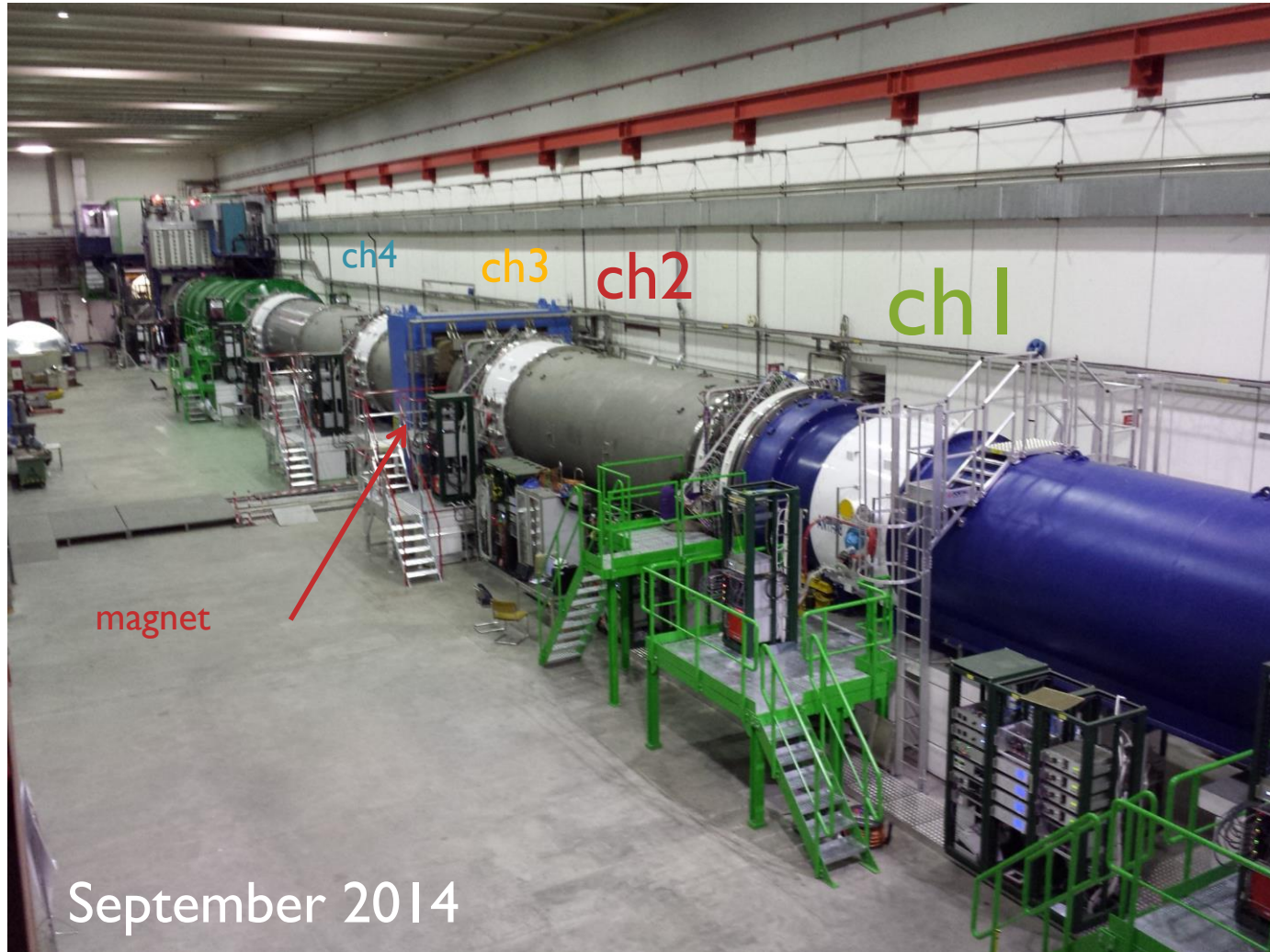
The Straw Detector Milestones

- *2007*: first preliminary meeting
- *2010*: construction&test of a proof of concept prototype
- *2010*: first prototype of the front-end board
- *2011*: straw massive production starts
- *2011*: straw readout board 6U prototype
- *2012*: technical run (module 0 installed on the beam-line)
- *September 2014*: last station installed
- *October-December 2014*: NA62 Pilot Run

Straw Tracker in Place



Straw Tracker in Place



September 2014

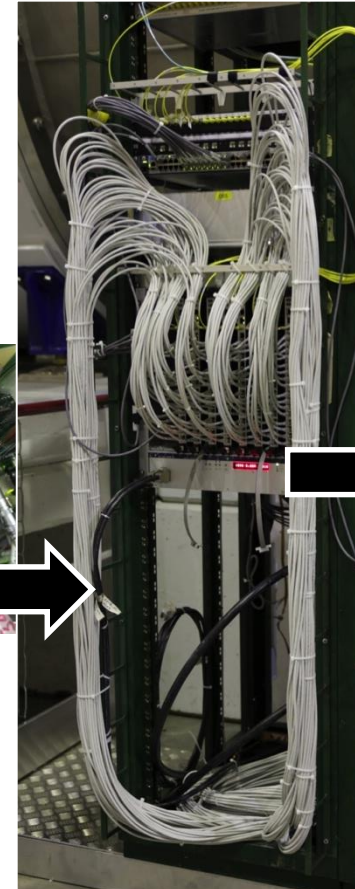
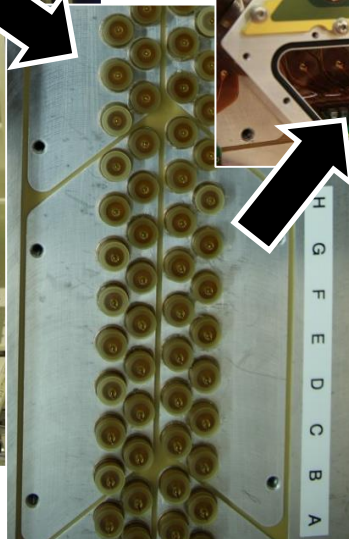
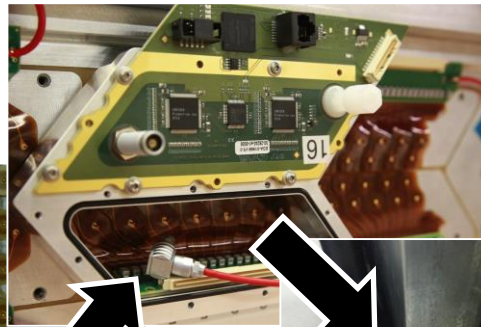
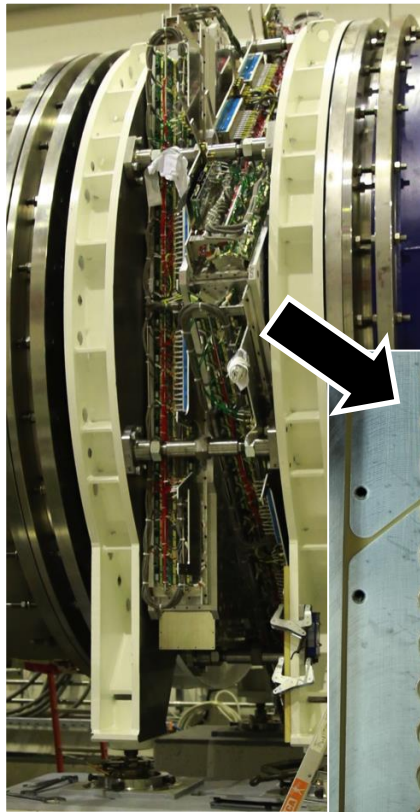
Outline

- The NA62 experiment
- The NA62 straw tracker
- **Straw tracker design and electronics**
- First results from the NA62 pilot run (December 2014)
- Conclusions

Front-End and Readout

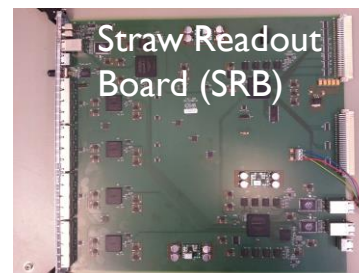
- Front-End Electronics (FEE) is connected to the anode trough a flexible PCB connector called WEB.
- The FEE board (COVER) must be able to:
 - Precise timing (0.23ns time resolution)
 - Provide a fast readout and data handling (maximum rate per straw foreseen near the beam **~500kHz**)
 - Provide vacuum tightness in case one of the straw breaks
 - Fast link to the Readout Board
- The Straw Readout Board (SRB) is designed to handle the data coming from 16 COVERs and **match** them with the Level0 trigger. Extra logic is foreseen in order to **monitor** the detector activity and behavior. Data are then sent to the PC farm to be used in the Level1 trigger logic and stored.

Front-End and Readout



PC FARM

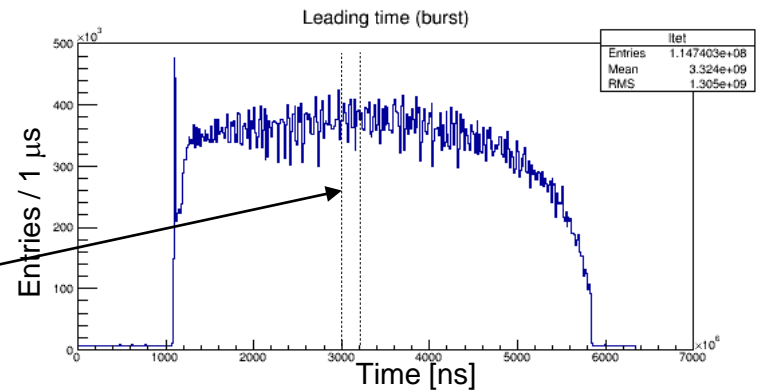
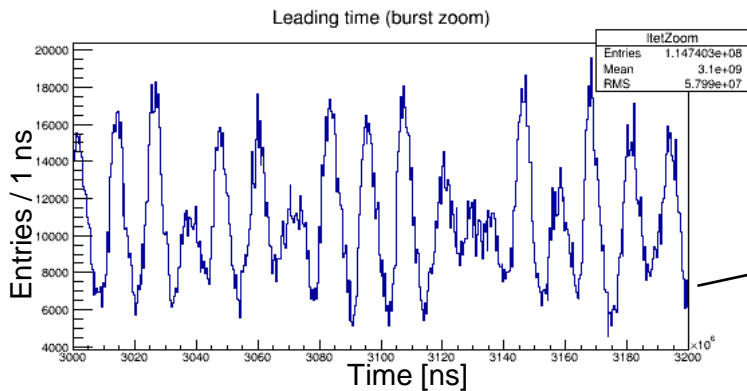
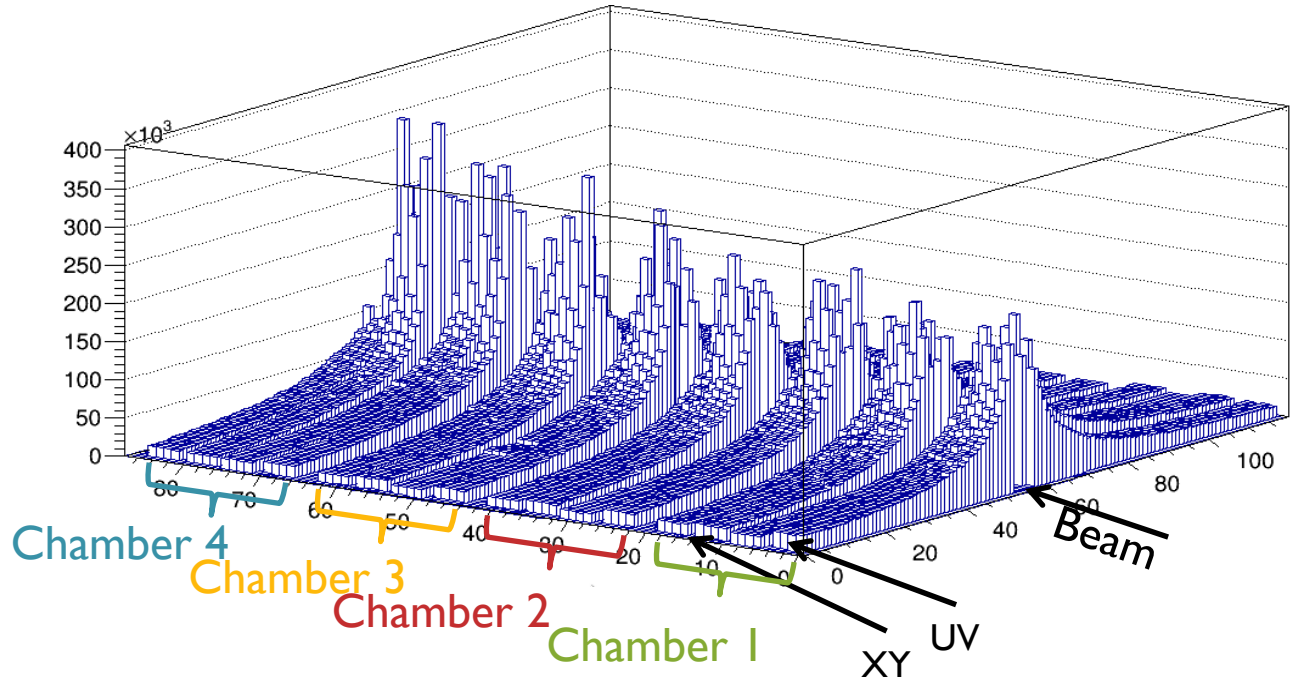
16 straws per COVER
 30 COVERS per view
 8 Readout boards per chamber



Outline

- The NA62 experiment
- The NA62 straw tracker
- Straw tracker design and electronics
- **First results from the NA62 pilot run (December 2014)**
- Conclusions

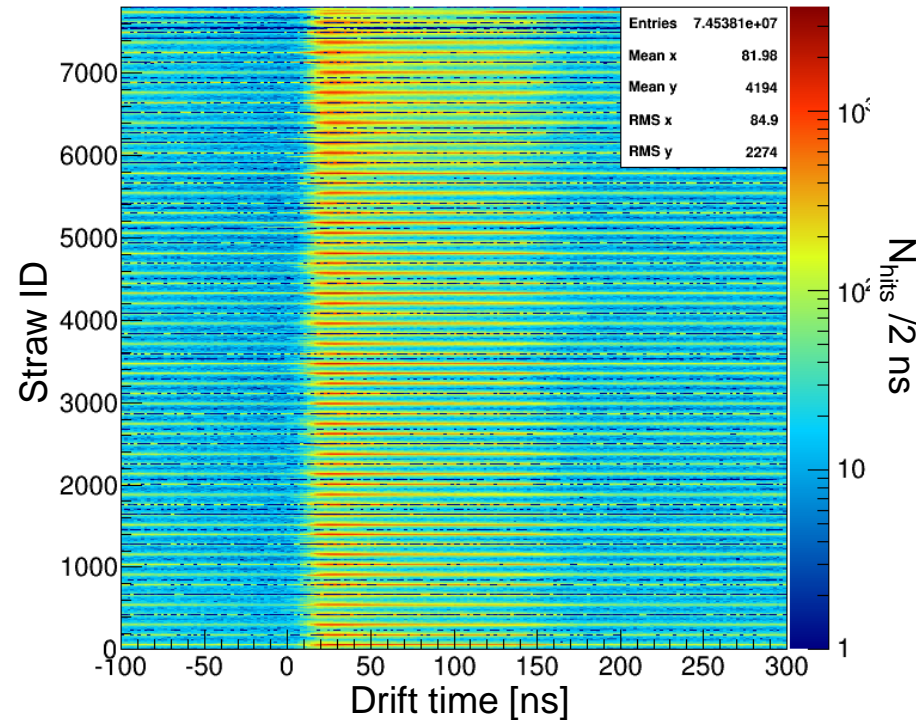
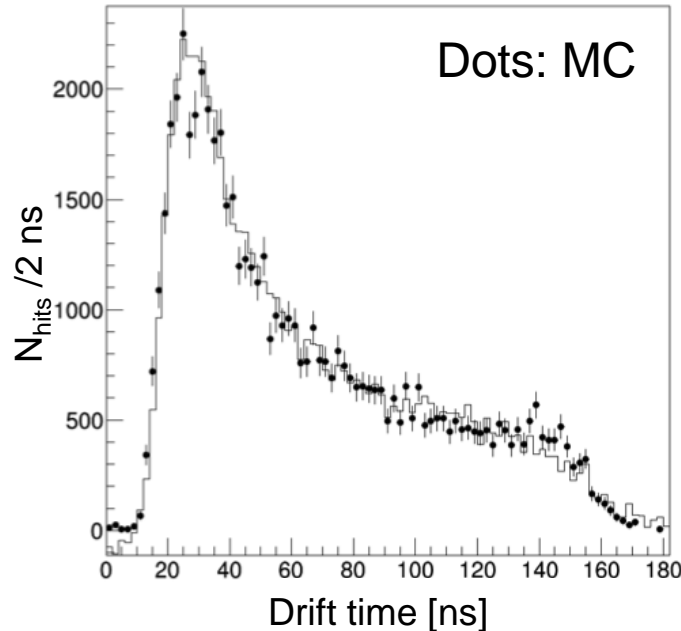
Online Monitor



Calibration

- Radius-time calibration curve (r-t curve) ✓
- Time alignment ✓
- Geometrical alignment
 - Magnetic field map

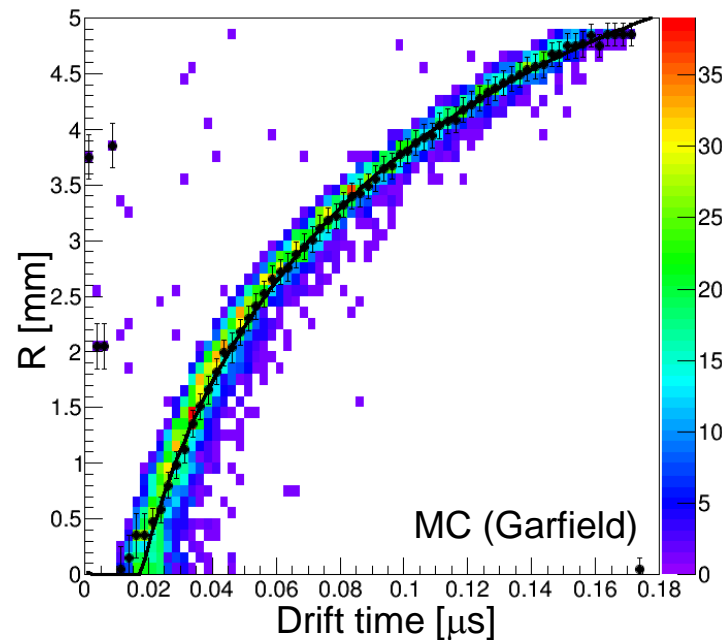
Time Alignment (leadings)



- Time alignment of the detector is performed using the cumulative distribution of the leadings
- Alignment resolution ~ 5 ns

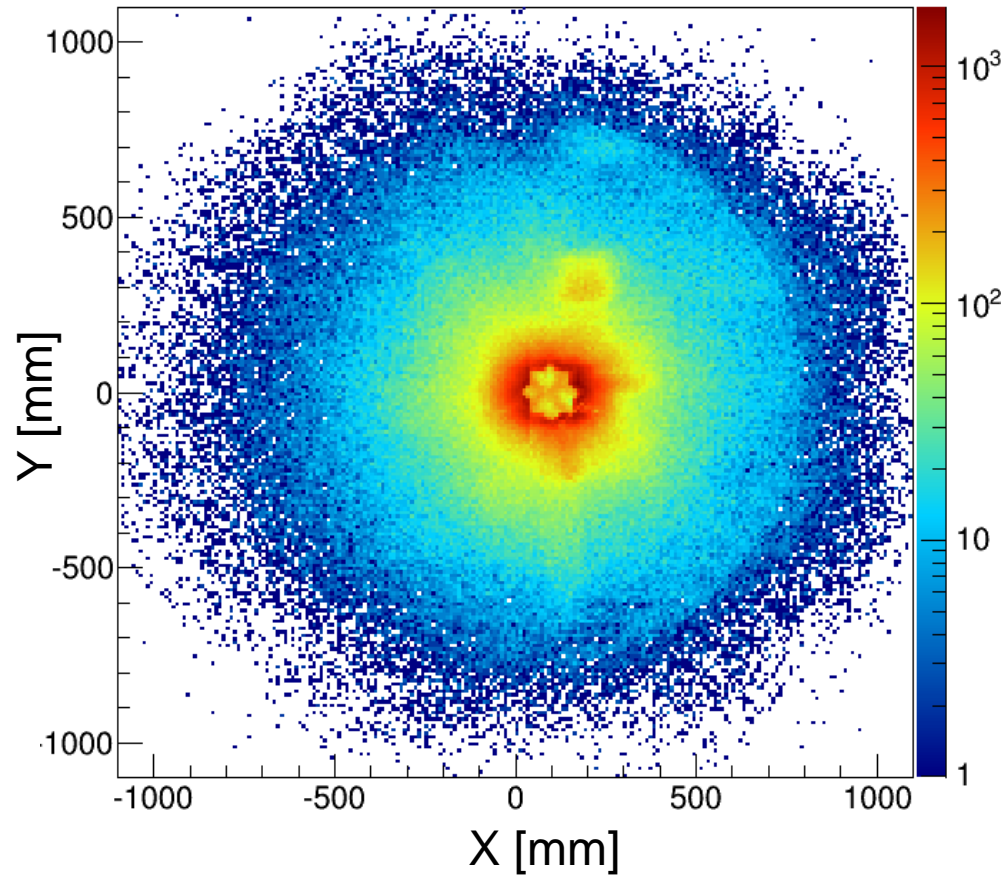
Calibration: r-t curve

- Preliminary r-t curve has been computed using a Garfield simulation
- A fundamental improvement will be the straw-by-straw calibration using Muon runs (\rightarrow uniform straw illumination) and *auto-calibration* method



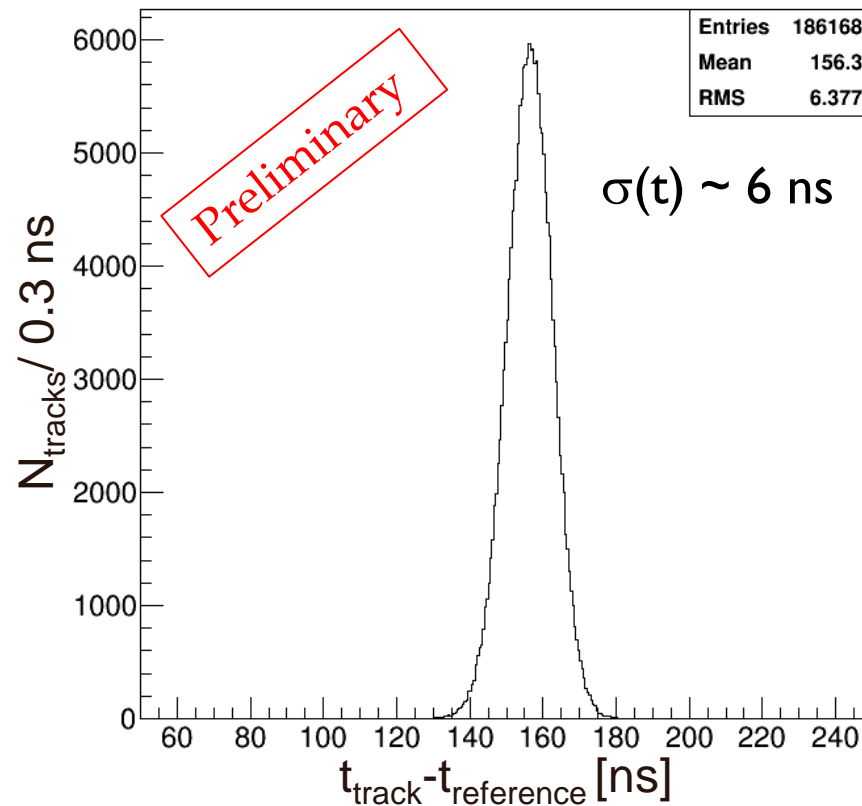
Chambers Illumination

- Tracks reconstructed at the height of **chamber I**



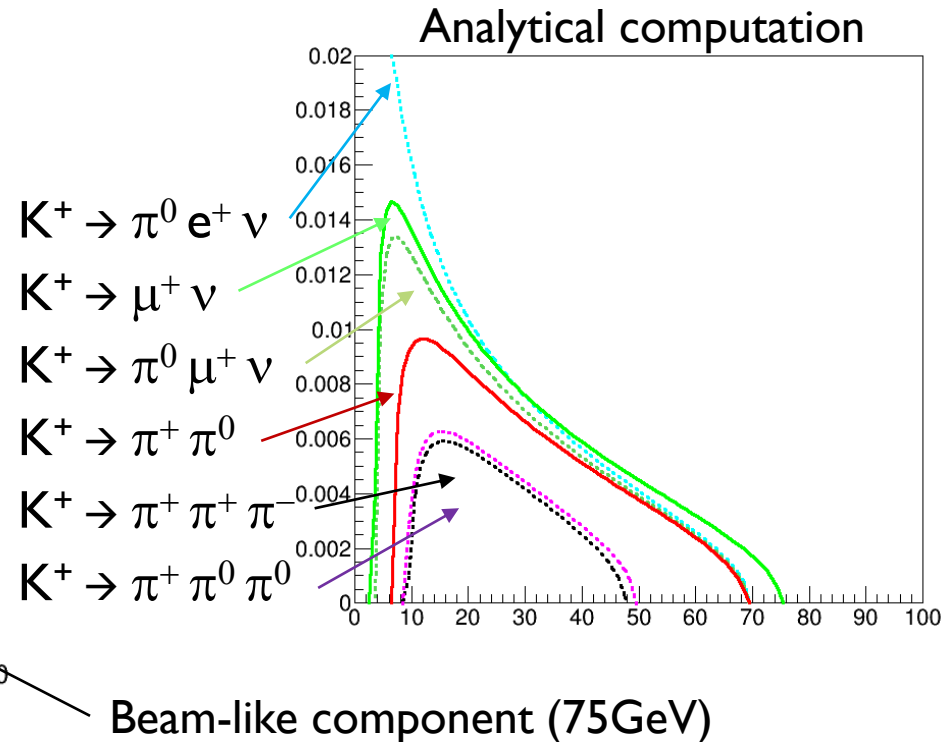
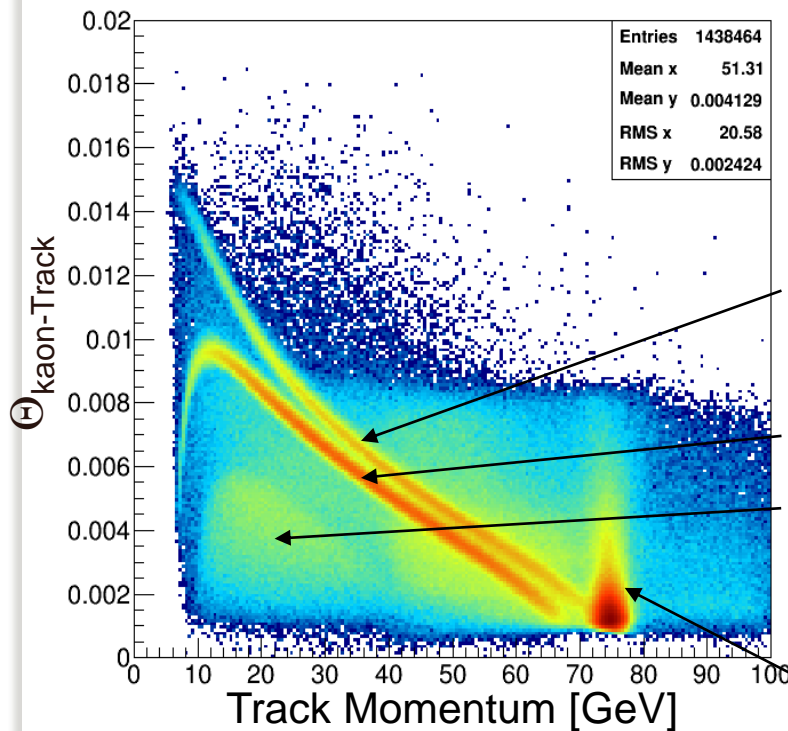
Track Time Resolution

- After reconstruction the time resolution using the trailings belonging to the same track has been computed.



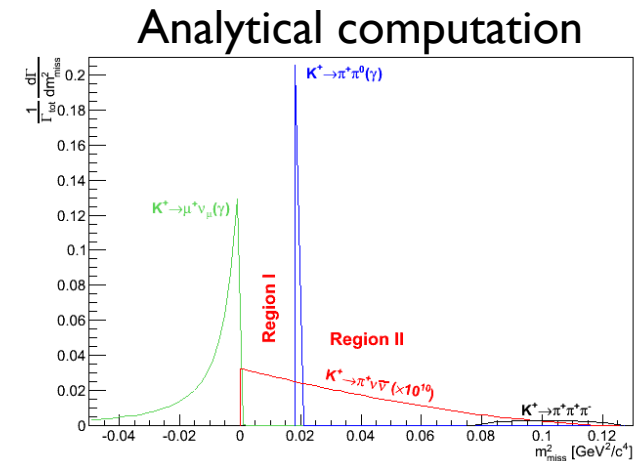
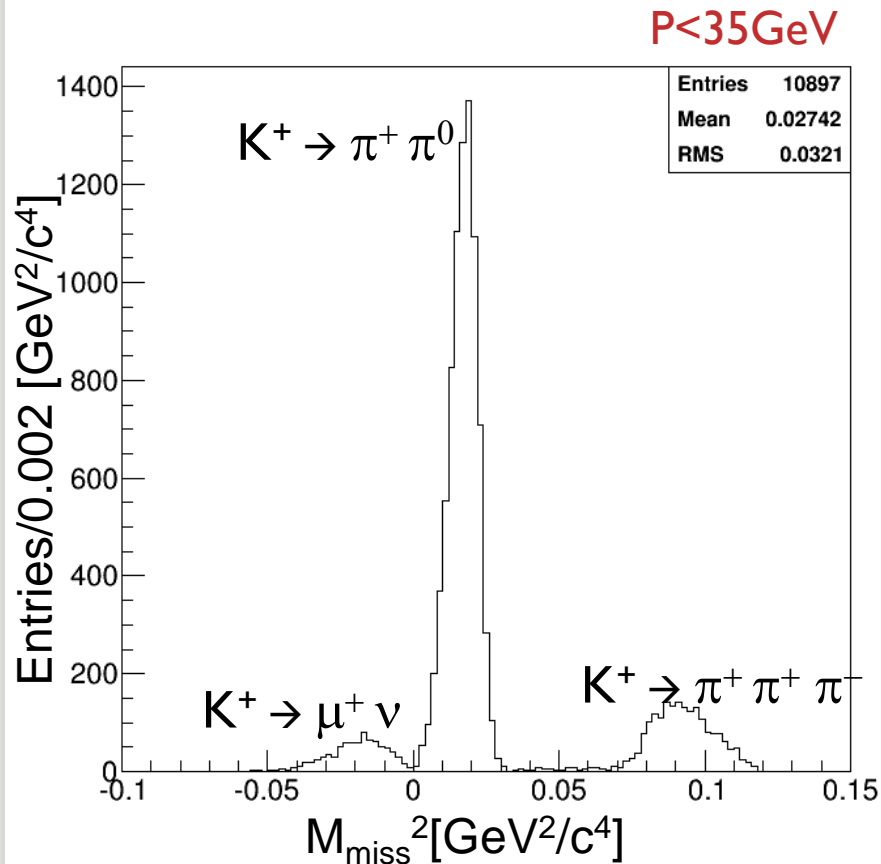
Single Track Events

- One track reconstructed within 40ns from the reference time,
- Kaon direction: *nominal beam position*.



Missing Mass Reconstruction

- Single track events



Outline

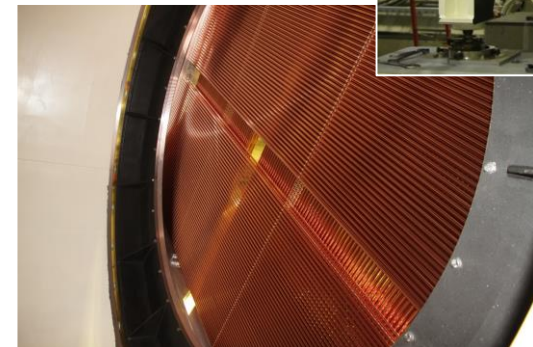
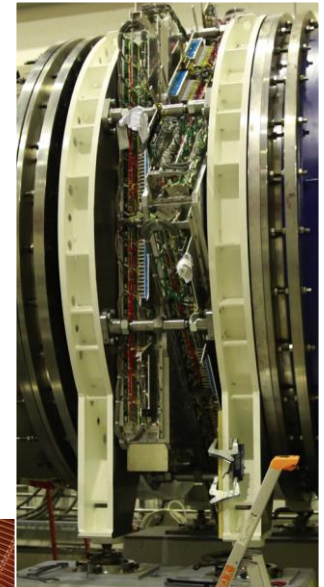
- The NA62 experiment
- The NA62 straw tracker
- Straw tracker design and electronics
- First results from the NA62 pilot run (December 2014)
- **Conclusions**

Conclusions

- The STRAW detector is (almost) fully commissioned and operational
- Fundamental improvements are needed to reach the design specifications:
 - Geometrical alignment procedure (mapping of the magnetic field)
 - Straw-by-straw calibration curve
- Preliminary results are within specifications
- The first NA62 physics run is ongoing (end run: mid November) → consolidation of the spectrometer readout and monitoring

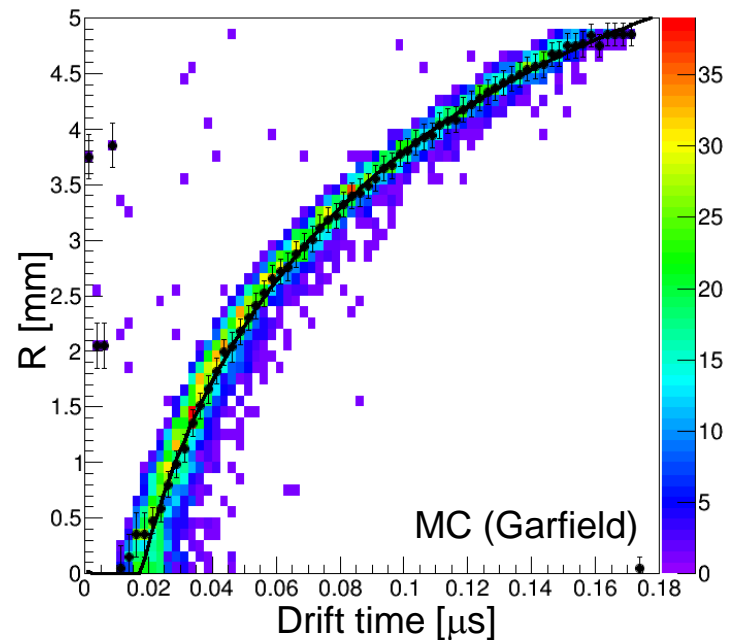
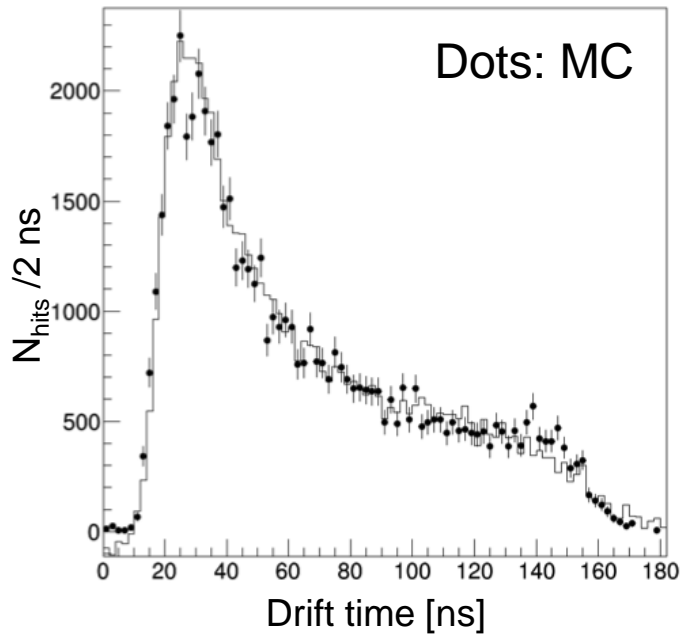
Straw Detector

- 4 views (XYUV) per station
- 7168 mylar straws ($\star 9.8\text{mm} \times 2.1\text{ m}$), Cu-Au metallization (50-20nm)
- $30\ \mu\text{m}$ gold-plated inner wire ($200\ \mu\text{m}$ position accuracy)
- Gas mixture Ar-CO₂ 70:30
- 15 km of ultrasonic welded straws



Calibration: r-t curve (Autocalibration)

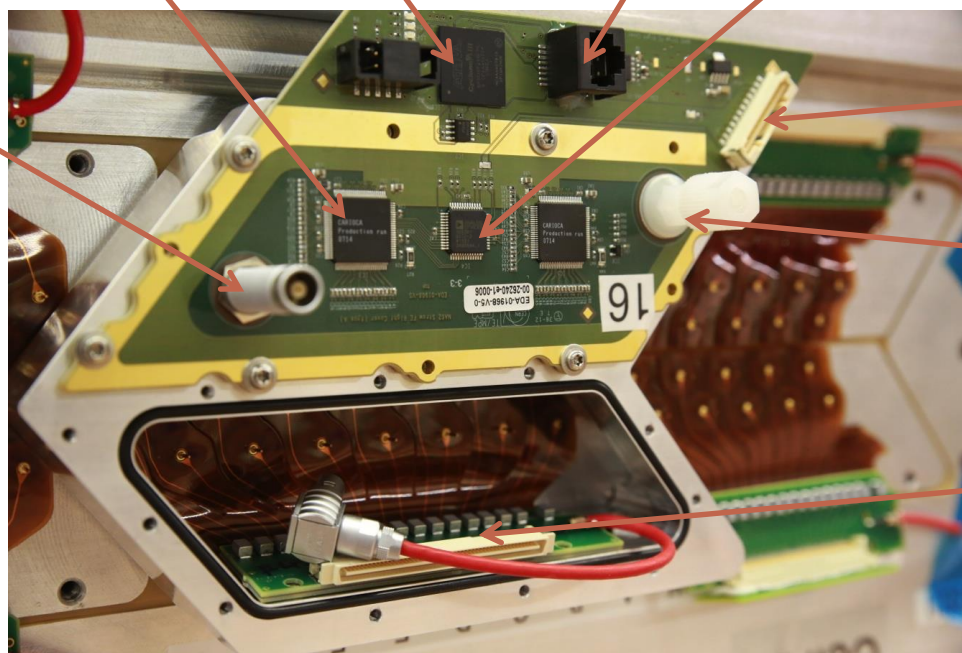
$$r(t) = \frac{R}{N_{tot}} \int_0^t \frac{dn}{dt'} dt'$$



Front-End: COVER

- FEE board is directly connected to the station and physically close the gas volume providing the feed-through for HV and gas flow.

CARIOCA (FPGA) TDC Link DAC for thresholds setting



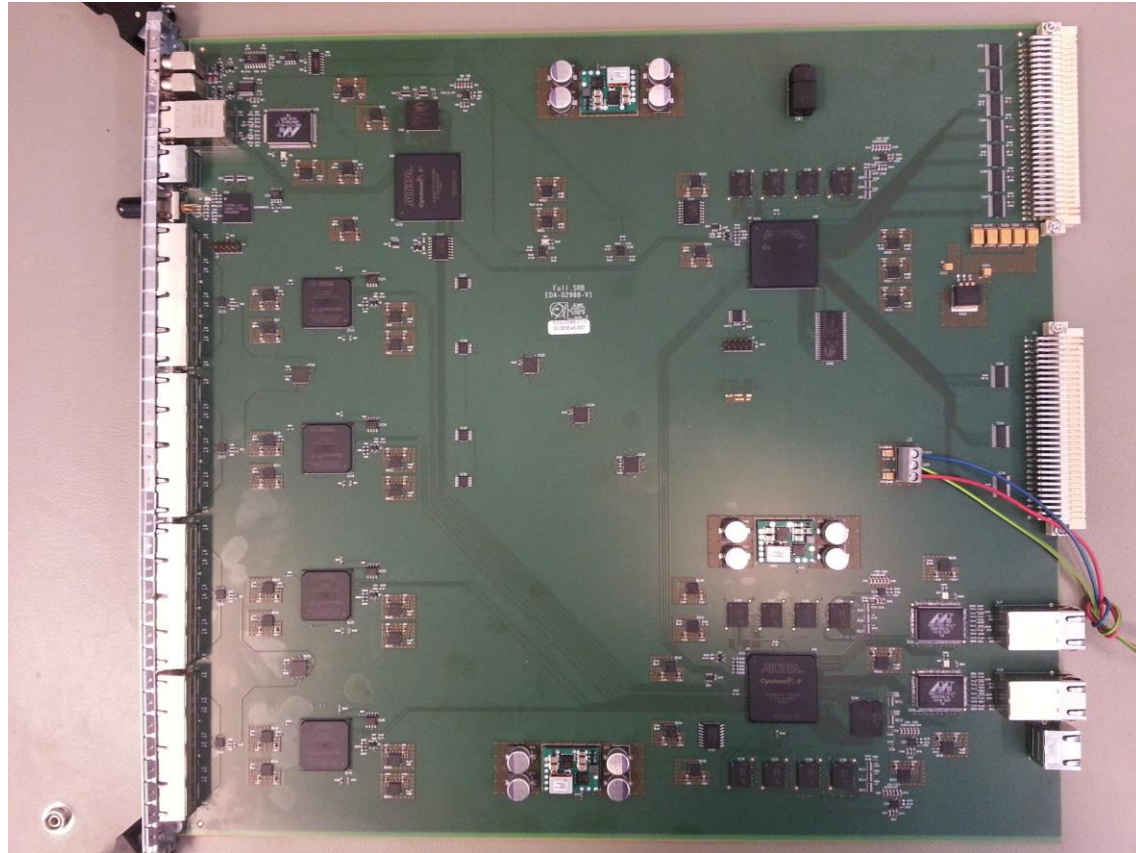
HV feed through

COVER
power supply

Gas mixture
feed through

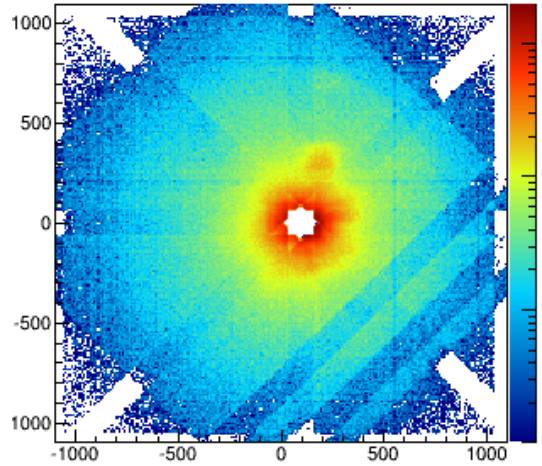
WEB

Read-out: SRB

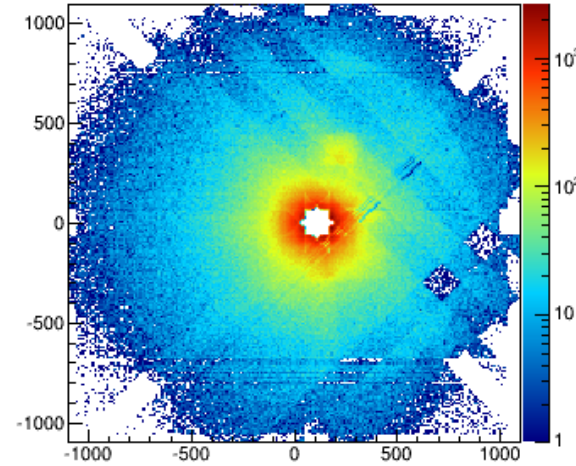


Chambers Illumination

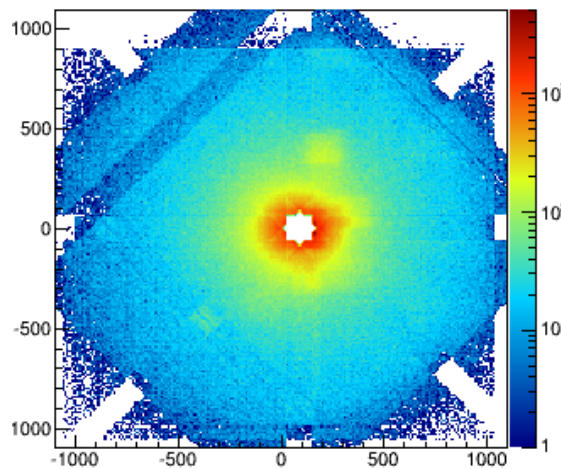
Chamber 1



Chamber 2



Chamber 3



Chamber 4

