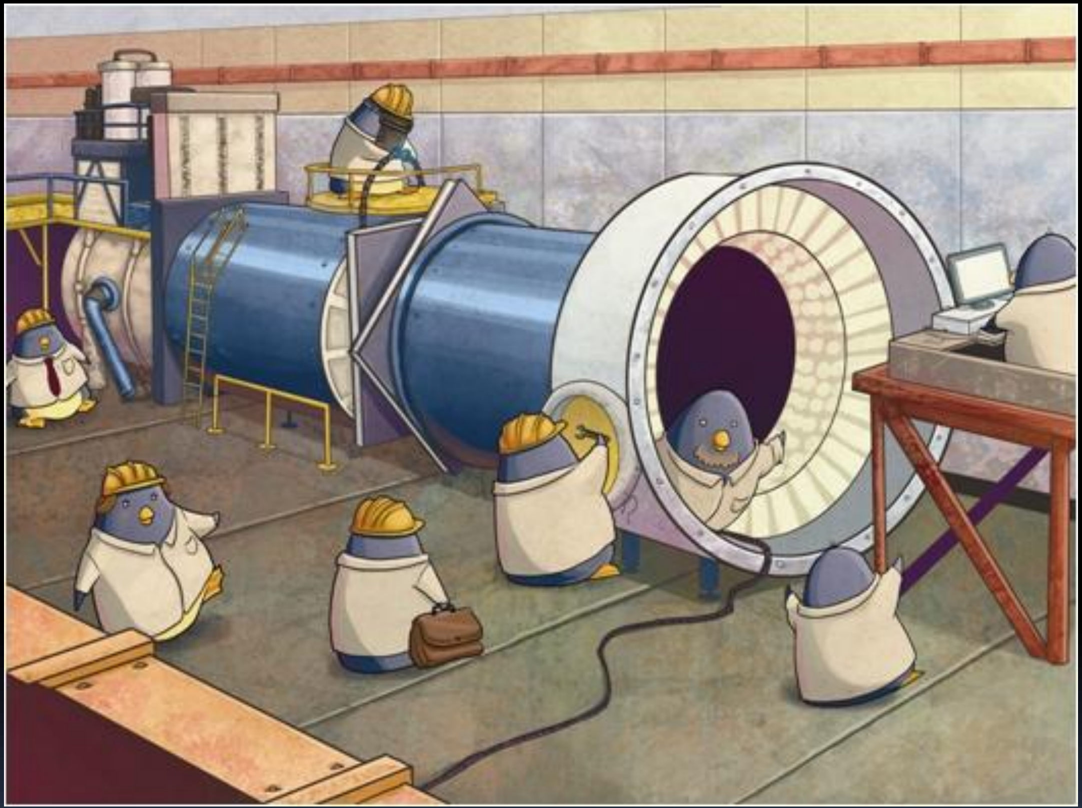
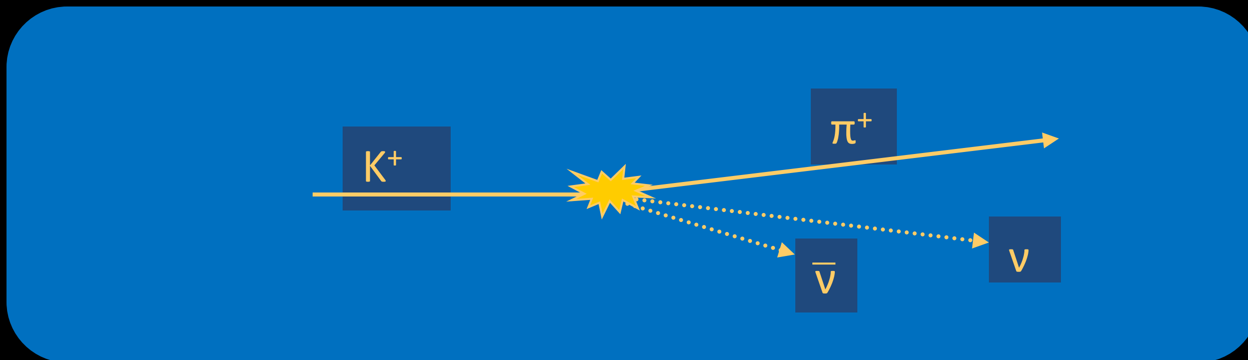
NA62 Straw detector read-out system

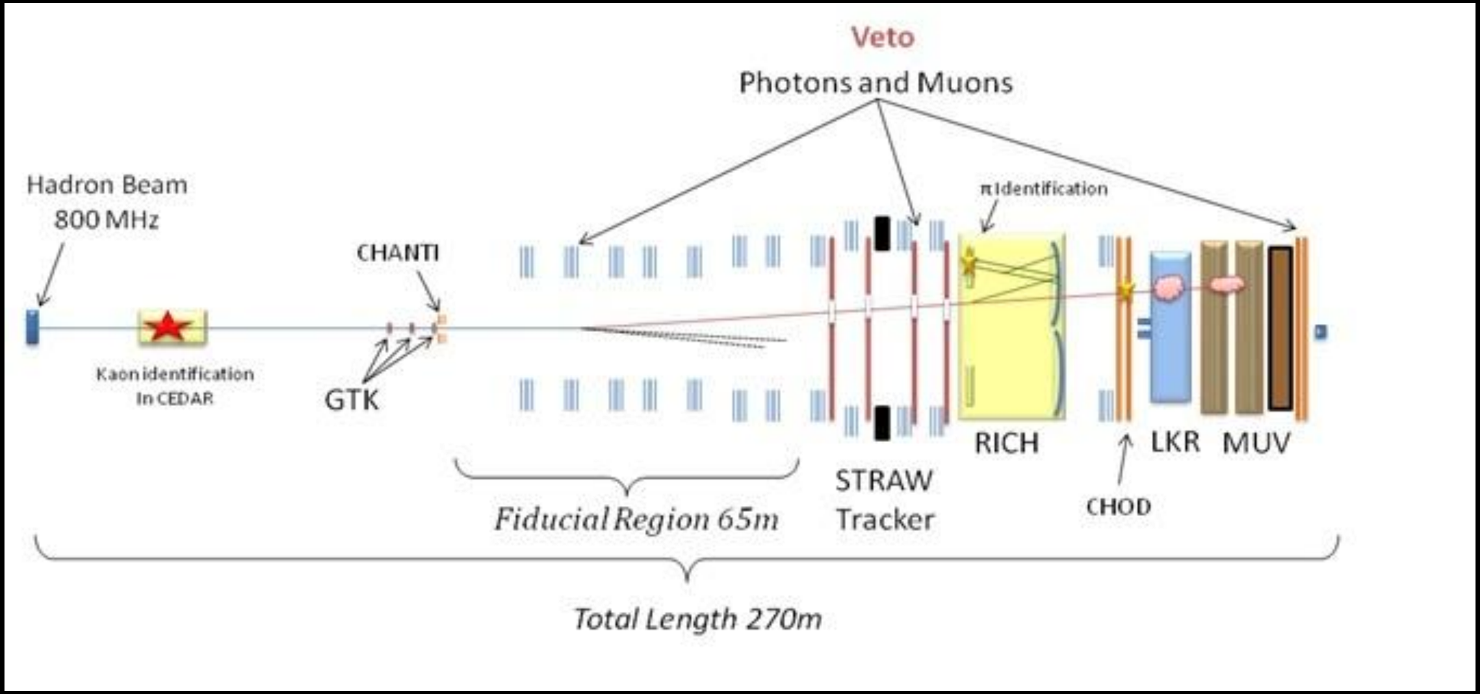
- Introduction to NA62
- NA62 layout
- Straw detector
- Requirements for straw detector electronics
- Readout electronics
  - frontend
  - backend
- Grounding and shielding
- Triggering
- Plans



NA62

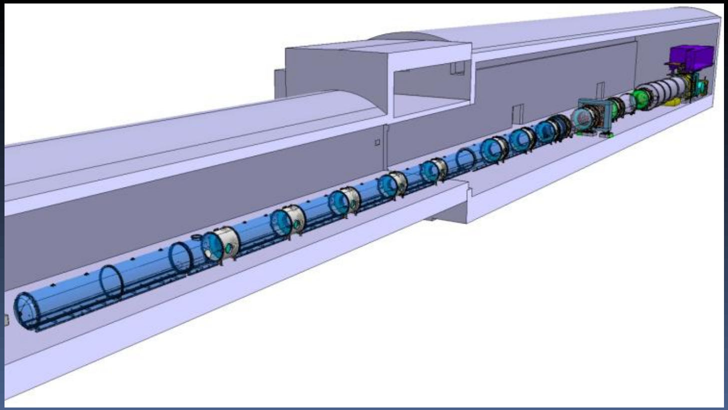


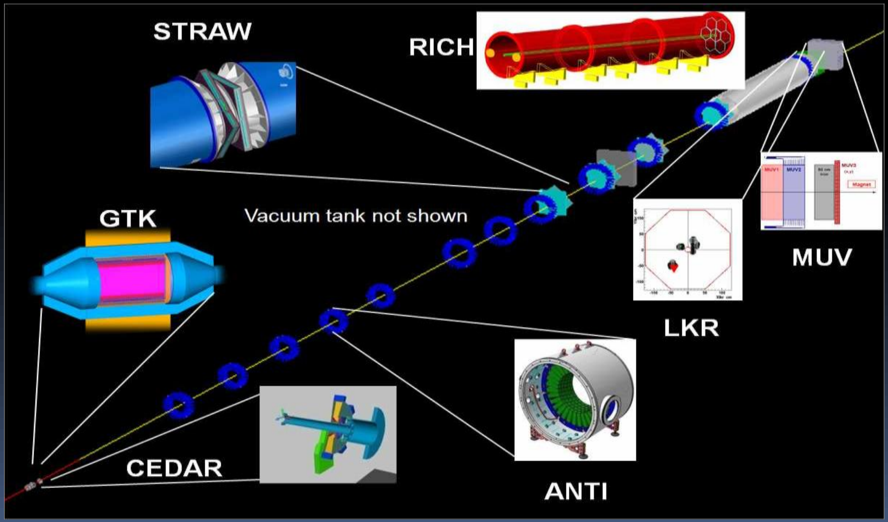
- Measure the Rare Decay K+ -> (pion+) + neutrino + antineutrino (BR of 10^{-10})
- ~100 events in the lifetime of the experiment
- Extreme background (~1 GHz incoming rate, up to 10MHz detectors)
- Principle
  - Generate Kaons (needed total 10^{13} K^+)
  - Let them decay (~65 meters long tube)
  - Observe product
    - signal acceptance
    - background suppression



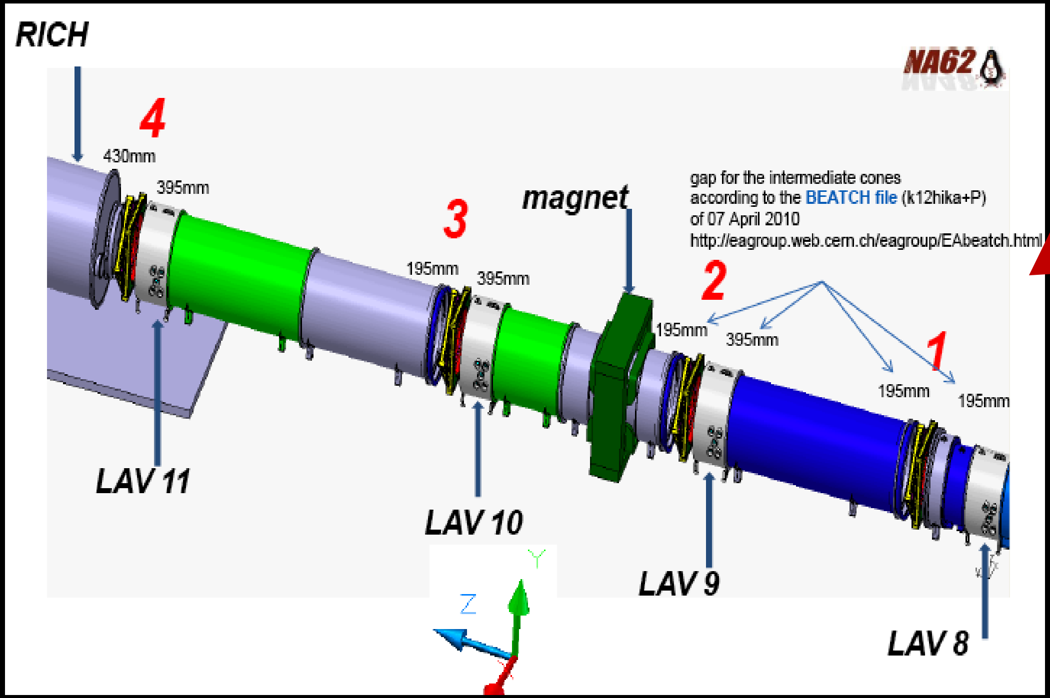
Veto
Photons and Muons
Hadron Beam
800 MHz
π Identification
CHANTI
Kaon identification
In CEDAR
GTK
RICH
LKR
MUV
STRAW
Tracker
CHOD
Fiducial Region 65m
Total Length 270m

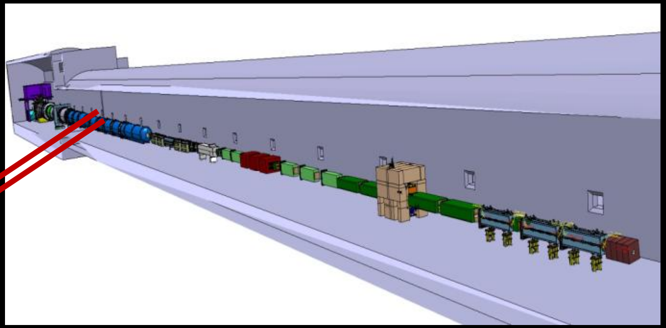
NA62 layout





STRAW
RICH
GTK
Vacuum tank not shown
MUV
LKR
CEDAR
ANTI

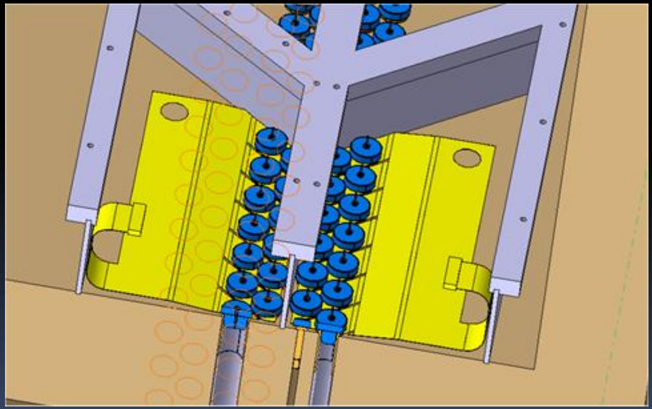




- Straw detector is
  - Pion Spectrometer
    - Tracking
    - Momentum
    - 2 chambers before magnet
    - 2 chambers after magnet
  - Recently
    - VETO function
    - Eventually can contribute to trigger
- Straw detector operates in vacuum (blue tube)
  - Low mass , no influence on observed particles

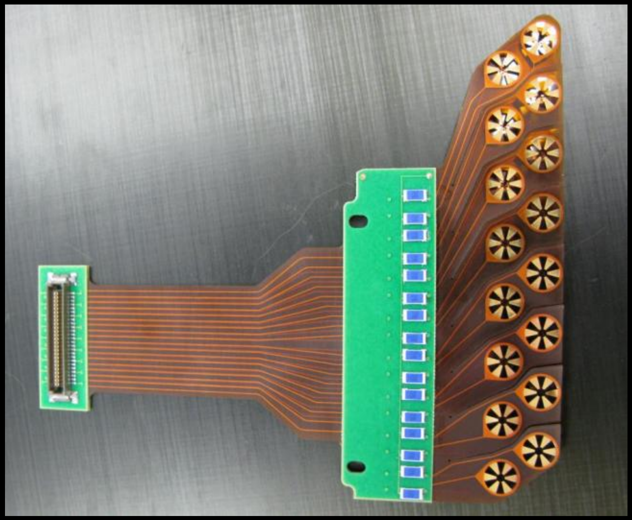
Straw detector

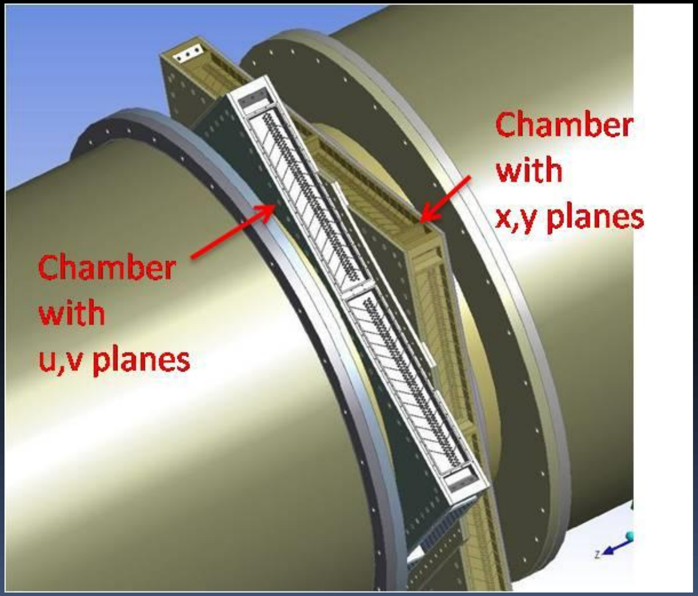
- Straw construction
  - Tube 2.1 meter * 9.8mm
  - 36 μm thin PET foils PET = polyethylene terephthalate
  - coated on the inside with 0.05 μm of Cu and 0.02 μm of Au
  - The anode wire (Ø=30 μm) is gold-plated tungsten
- Straw function
  - Proportional (drift) chamber
  - Measure particle distance from wire by drift time
  - Operates in vacuum
  - 1 bar working gas
- Straw electrical properties
  - Propagation time full length ~7ns
  - Resistivity of anode 50 Ohm
  - Resistivity of cathode 70 Ohm
  - Metal few atomic layers, electrical properties determined by surface effects, no skin effect
  - Straw is very lossy transmission line
    - 50 % of signal from far end
  - Impedance frequency dependent
    - 1000 Ohms up to 1MHz, 330 Ohm at 20 MHz



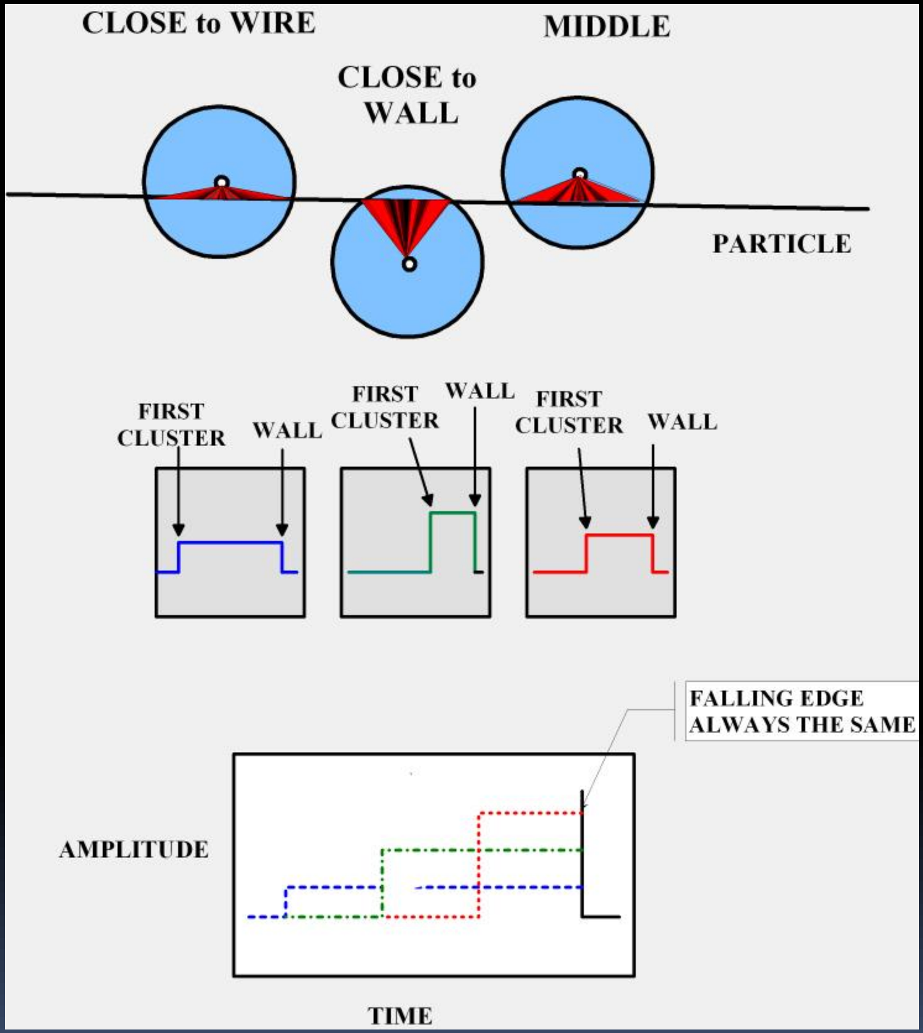
Straw detector

- Basic readout unit of 16 straws
  - Common electronics control, gas, LV, HV, signal return, etc
  - 8 straws from 2 layers
- 4 layers of straws form a ‘view’
  - 480 straws if all installed
  - 30(15*2) groups of 16(8*2) straws
  - Hole in the middle for beam
- View is a system readout unit
  - Data
  - Control
  - Services, DCS
  - Grounding, shielding, ‘earth’
- 4 views form a ’chamber’
  - X,Y,U,V
  - 4*480 = 1920 straws
- 4 chambers
  - 2 before magnet, 2 after
  - In total 1920*4 = 7680 straws (but hole for the beam)

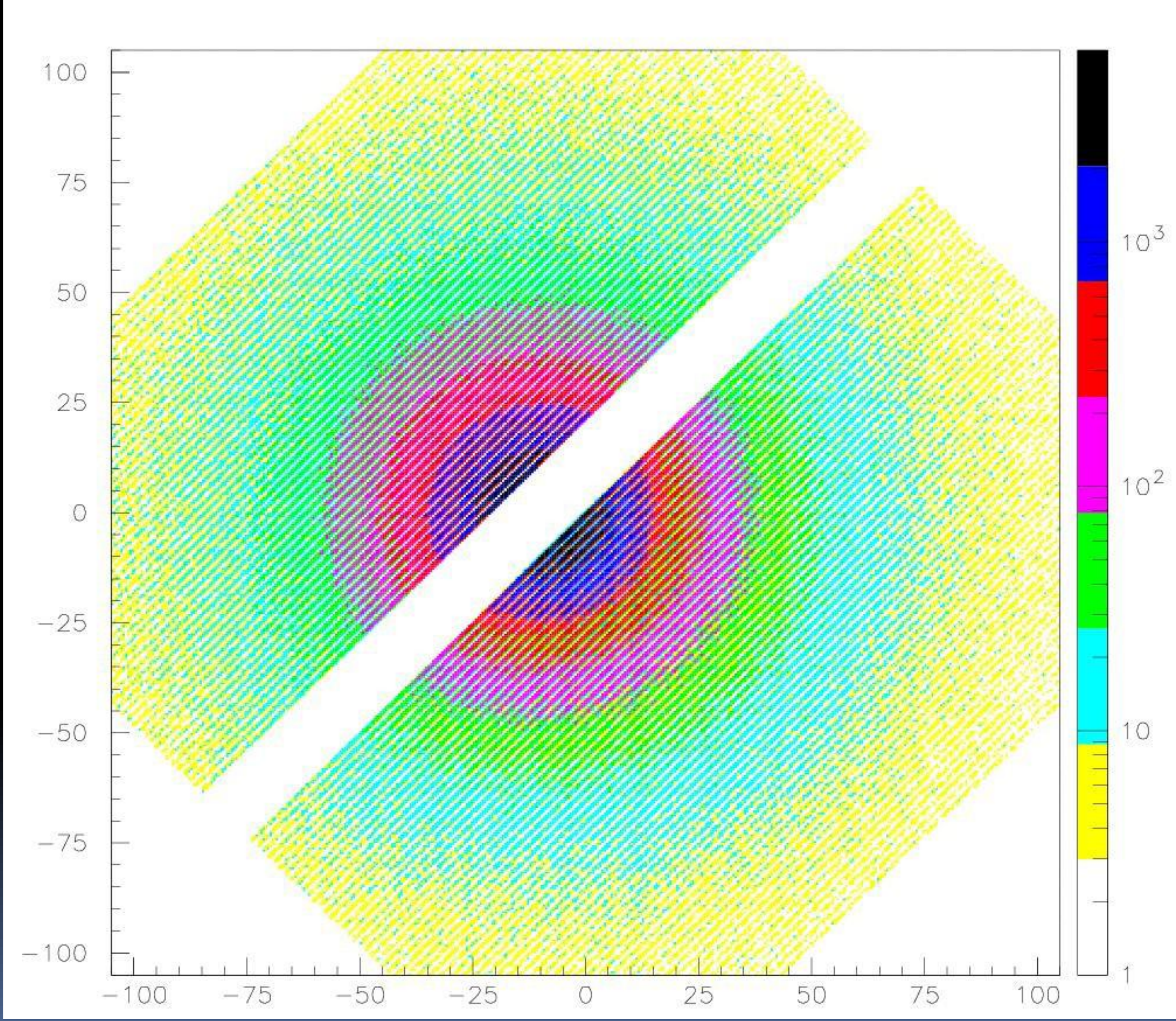




Straw function



- Falling edge has the same time for all straws on track.
- Rising edge gives the arrival time of the first cluster
- The closer is the track to the wall, the bigger is the signal (clusters closer)
- Don't want to see clusters => shaping must be chosen in relation to gas properties
- Tracks from drift time measurement.


100
75
50
25
0
−25
−50
−75
−100
−100
−75
−50
−25
0
25
50
75
100
10^3
10^2
10
1

NA62 Straw tracker electronics

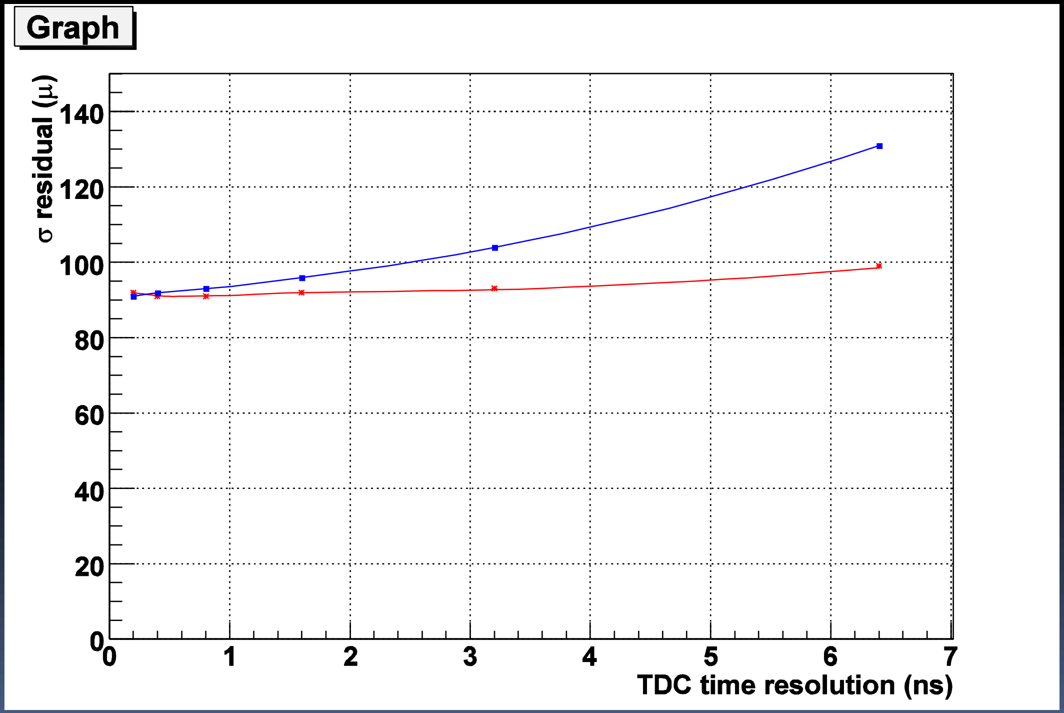
Requirements on straw tracker from electronics point of view

- Good quality data (drift time)
  - 130 um resolution for single straw
  - Efficiency -> 100%
  - This is required
    - For all distances from the wire
    - All along the length of straw
- Low noise
- Low crosstalk
- efficiency and resolution versus rate
  - Ion tail cancellation
- Integration in global DAQ and TTC
- Reliable and stable operation with tools for monitoring

- Readout chain
  - ‘classical’ for time measurement
  - Frontend
    - PA+SH+BLR+COMP
    - CARIOCA chip as a baseline (LHCb)
    - Other possibilities under study (including discrete electronics)
  - Backend
    - TDC + storage and event management
    - Frontend control, online monitoring

NA62 straw tracker electronics

- Required spatial resolution 130 um
- Needed TDC resolution
  - ‘fast’ gas Ar/CO2 (70:30), muon test beam
  - On X is bin (not resolution)
  - Blue, unknown R-T dependence
  - Red, known R-T dependence



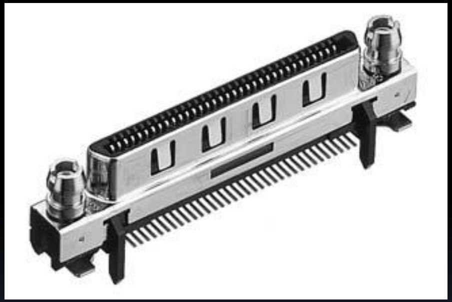
NA62 straw tracker FrontEnd electronics

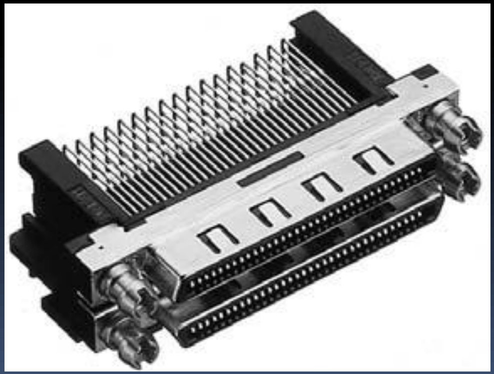
- Front end PCB
  - ➢ Gas tight PCB using blind vias (bottom faces working gas)
  - ➢ thick PCB to ensure mechanical stability
  - ➢ High voltage connection integrated on the board + HV filter
  - ➢ gas feedthrough
  - ➢ numerous configurable GND connections to try different grounding scheme with detector

NA62 straw tracker FrontEnd electronics

- Front end board functionality
  - Two CARIOCA chips (16 straws) for signal processing
  - 12-bit DAC with I2C control for threshold setting
  - LVDS buffers for outputs (to avoid current imbalances to feed-back to frontend)
  - Even and odd test pulse buffers
  - Power ~8V/0.12A
  - HV filter and connector

- Front end connectivity
  - Data to DAQ on 16 differential (LVDS) lines for group of 16 straws
  - Control from DAQ on 5 differential lines (I2C, TP)
  - Power 8V
  - DCS – temperature sensors and power sensing lines
  - changing connectors for HONDA VHDCI, 68 pins





NA62 straw tracker BackEnd electronics

- Backend readout requirements
  - Measure arrival time of rising and falling edges
    - TDC resolution 1-2ns
    - Minimum width of pulse (<50 ns)
    - Time between pulses depends on straw rate
  - Control
    - Threshold setting for each straw
    - Even/odd test pulses
  - Event management and online monitoring
- ‘triggerless’ system for straw, everything buffered till higher level trigger decision
- Data rate
  - Max rate per straw 0.5MHz
  - Mean rate 33kHz
  - Need to store 32 bit clock ID from SPS START_OF_BURST + 8 bit ‘fine’ time + rising/falling edge + straw ID 9 bits
  - 33kHz * ~50 bits = 1.65Mbit/straw; 740Mbits/view
- Desired functionality split to 2 boards
  - Straw Readout Board (SRB)
    - TDC implemented in readout FPGA
    - Receives precise clock and “Start Of Burst” signal from SPS
    - Frontend control
    - Online monitoring
    - Sends data to TELL1 over 1 optical fiber
  - TELL1
    - Developed for LHCB, adapted for NA62 (TEL62)
    - Event building
    - Event management
    - Receives full NA62 TTC control

NA62 straw tracker data flow

1 chamber contains 2 modules

1 module contains 2 views

1 view is a smallest readout system

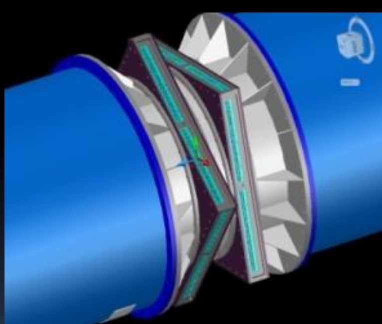
30 FE boards for 1 view

(2 groups of 15 boards)

2 Straw Readout Boards

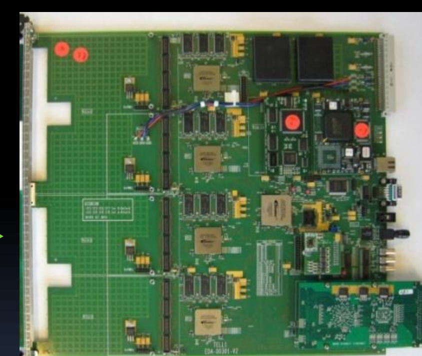
2 fibers

TEL62 Serving 2 chambers (2x4 views)



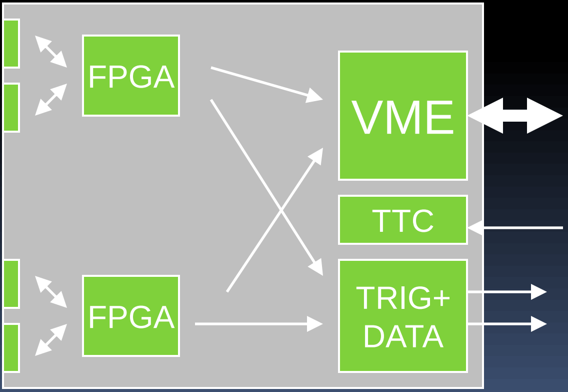
STRAW READOUT & CONTROL

STRAW READOUT & CONTROL



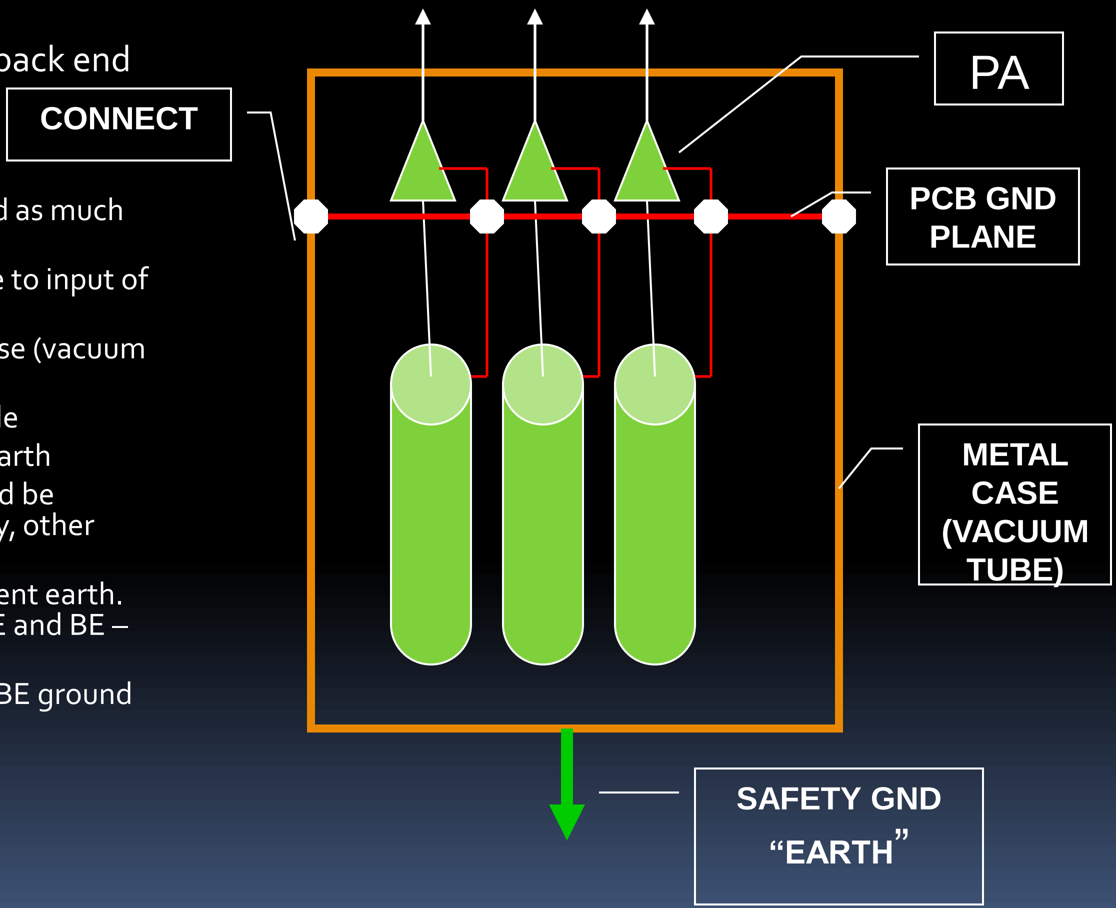
NA62 straw tracker readout board (SRB)

- TDC
  - Integrated in readout FPGA with bin 1.6 ns
- TTC interface for precise clock and phase and reset signal for clock ID counter at SPS Start_Of_Burst
- Serving 14 FE boards
- 9U VME board with control and monitoring through VME bus
- Data to TELL1 sent via optical link
- Eventual trigger L0 sent via optical link
- 2 needed per view
- 8 per station
- 32 needed for detector
- Scaled-down version in 6U VME finishing design
- Plan to produce and used for tests before end of 2010



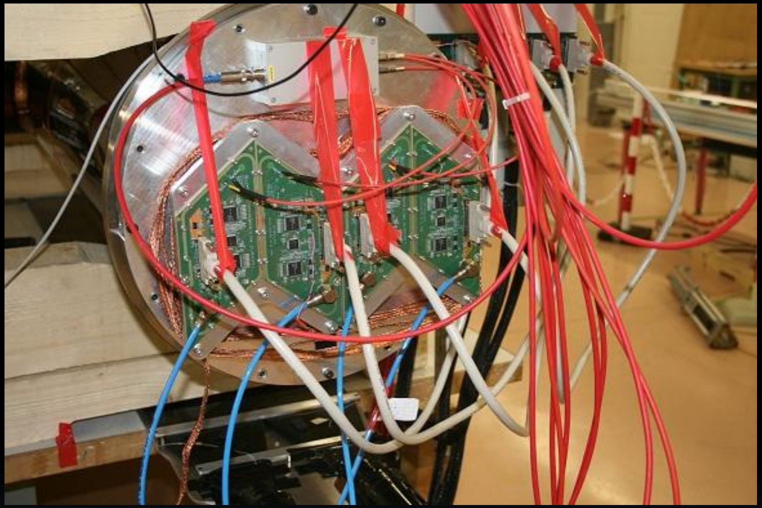
External crosstalk, grounding and shielding

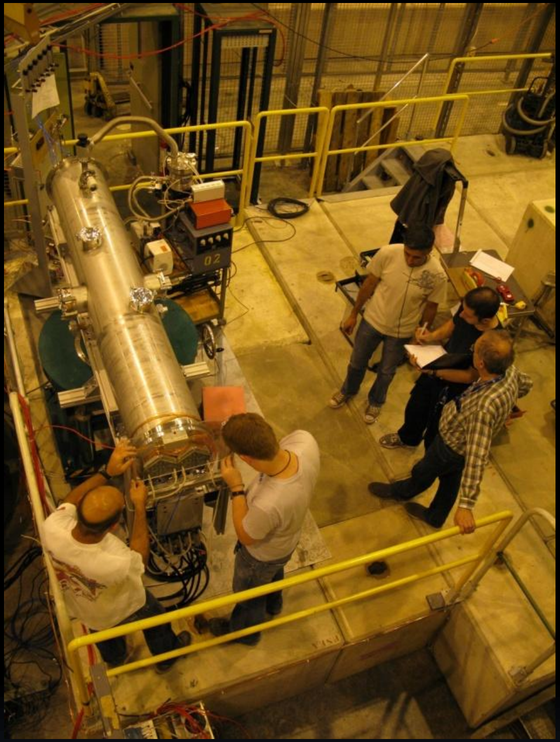
- Interference with external objects
- Voltage potential between front and back end
- Safety ground
- Design
  - Straw signal returns must be separated as much as possible
  - All SigRet connected at PCB level close to input of preamp
  - The same point connected to metal case (vacuum tube)
  - Straws connected to GND only on 1 side
  - Metal case connected to experiment earth
  - All shields (data, control, LV, HV) should be connected on both sides; 1 side directly, other through dumping impedance
  - Backend (crate) connected to experiment earth. This provides the same potential for FE and BE – important for data transmission
  - No direct connection between FE and BE ground apart EARTH => no GND loops



NA62 straw tracker electronics

- Used for lab tests and testbeam 2010
- Waiting for analysis of testbeam data

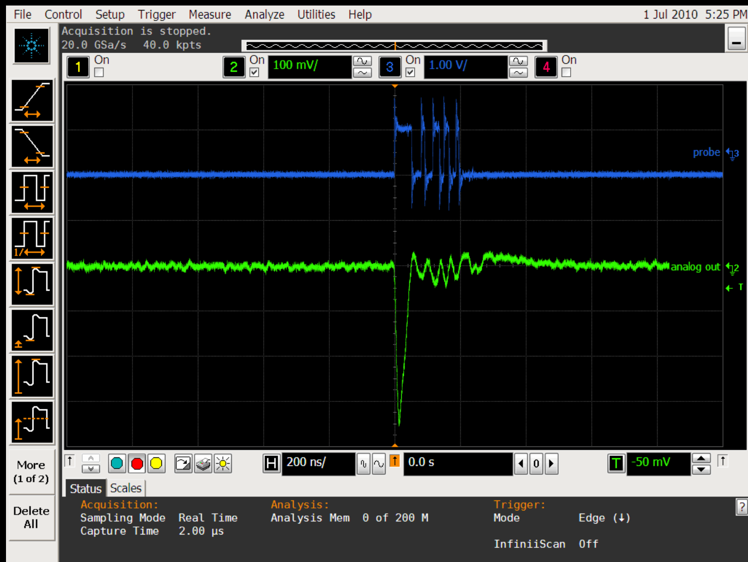


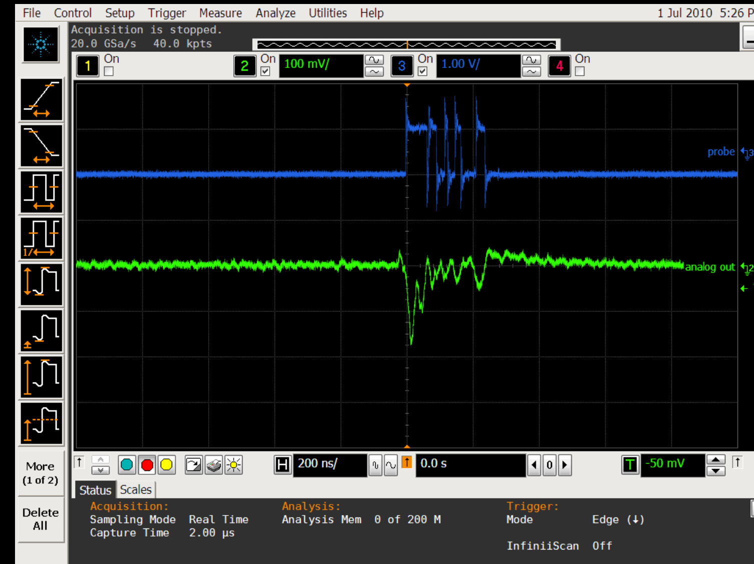


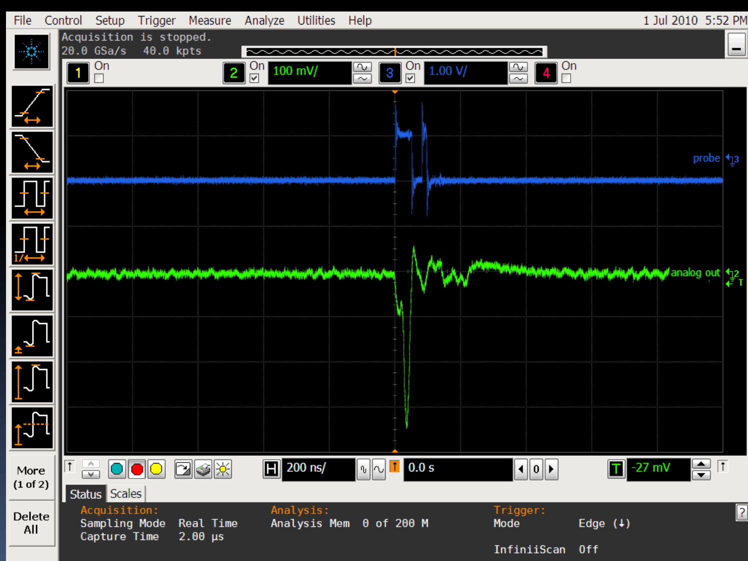
- Problems
  - CARIOCA too fast shaping even with fast gas
    - Signal overcompensated
    - Reacts to primaries
    - CO_2:iso => Ar:CO_2
    - ~7 pulses => 1-2 pulses
    - Spatial resolution compromised but still OK

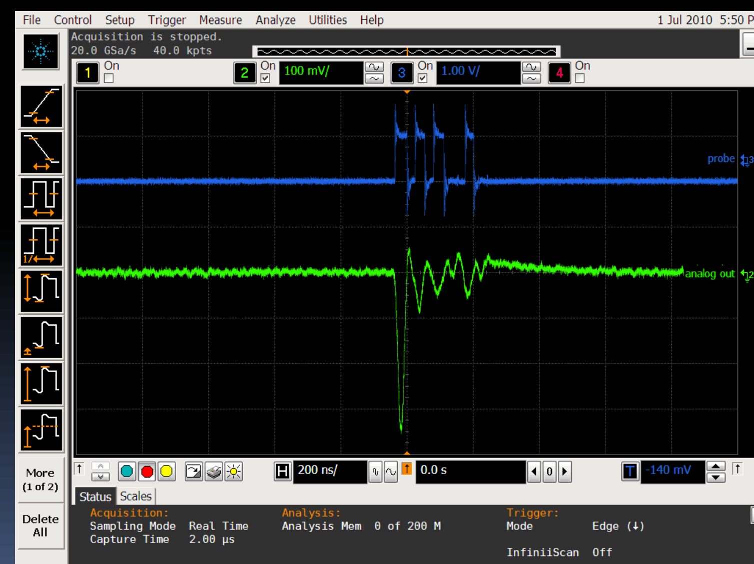
- Problems
  - Cables
    - heavy and rigid, not easy to handle
    - Always perpendicularly connected otherwise EMC compromised
    - Crosstalk

Slow gas analog and comparator outputs



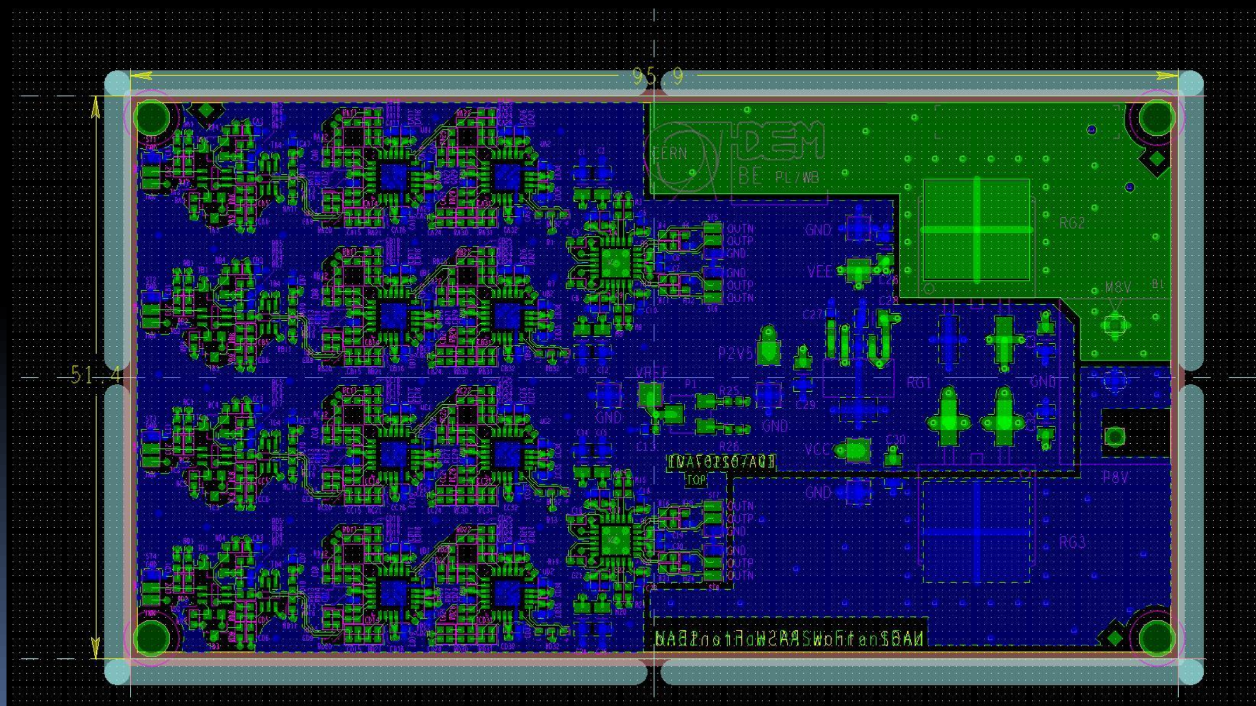




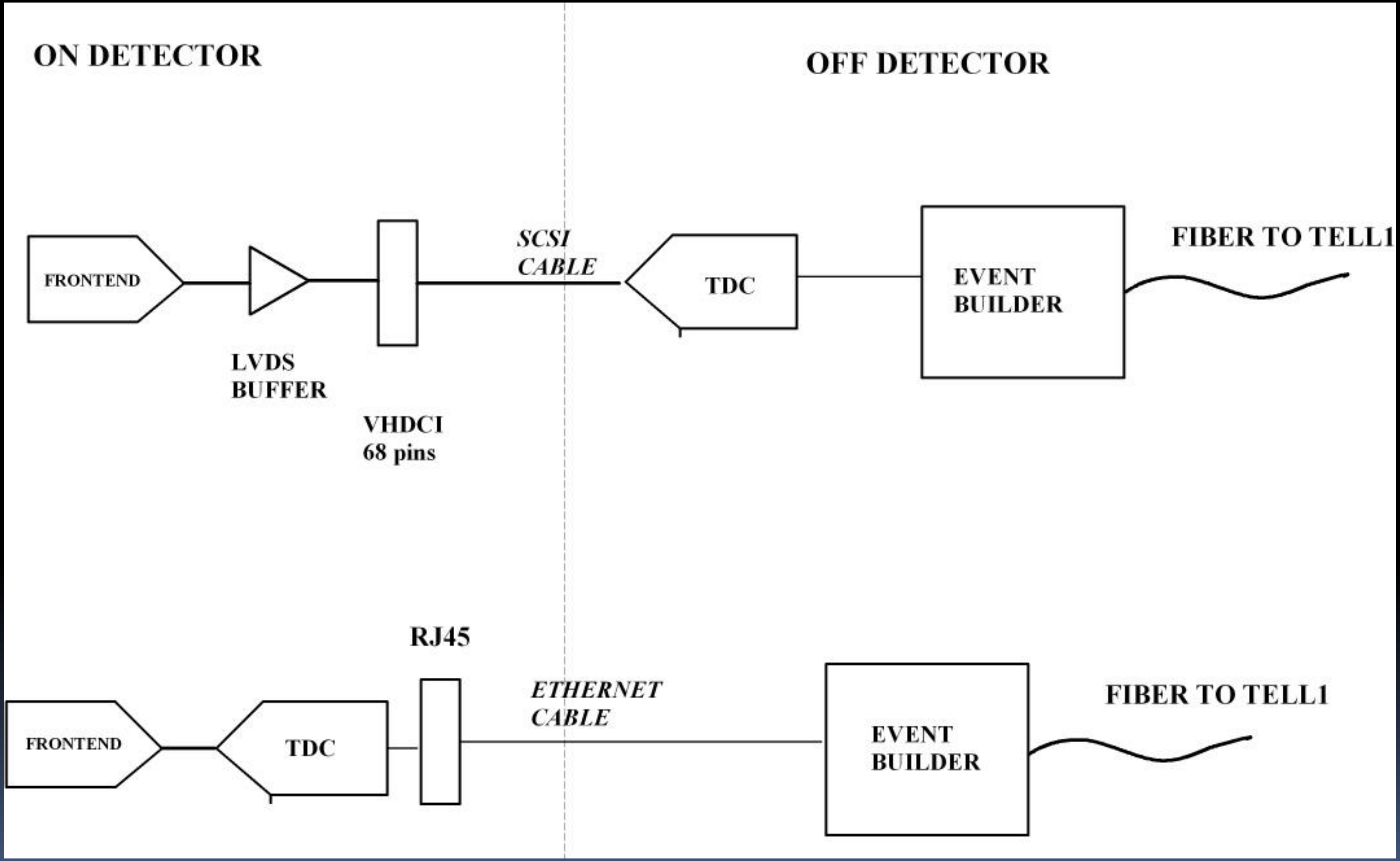


Frontend status

- CARIOCA still baseline
- We consider also
  - GASII
    - Characterization of the chip
    - Measurement with detector prototype
  - discrete electronics
    - Design and layout done, functional 4-channel demonstrator submitted to production

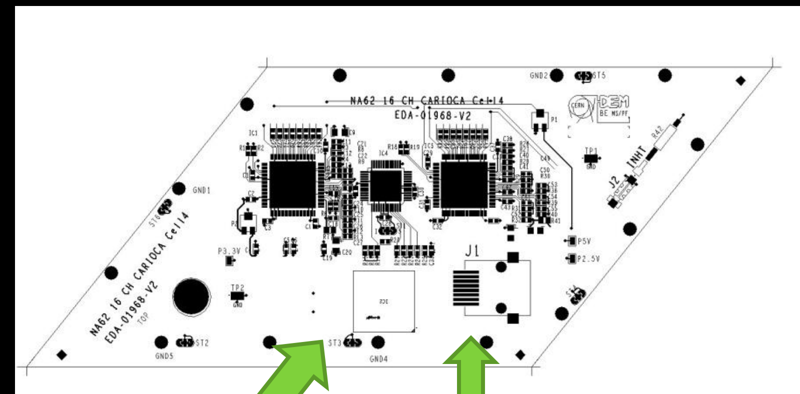


NA62 straw tracker FrontEnd electronics (new ideas)



NA62 straw tracker FrontEnd electronics with RJ45 connector

- Front end connectivity
  - ethernet connector (RJ45) 4 differential lines
  - Data to DAQ on 1 differential (LVDS) line for group of 16 straws
  - Control from DAQ on 1 differential line
  - precise clock 40 MHz
  - 1 differential line spare (output for high rate straws?)
  - Power 8V and DCS on separate connector
- Use standard halogen free ethernet cable
- Design near finish
- Production and test before end of year



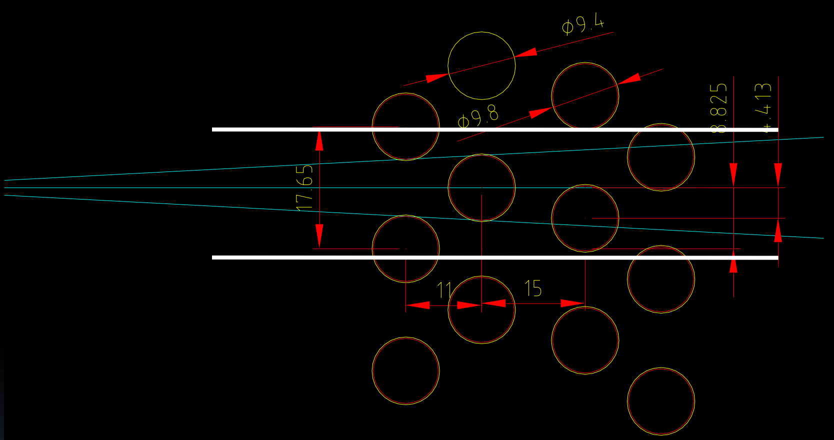
TDC and serializer CYCLONEIII FPGA in 256 pins FBGA package

SMD RJ45 Vertical connector

NA62 straw tracker fast VETO/trigger

- Straw readout board
  - Signal falling edge the same in a 'view' due to arrival of the last cluster and the same distance from the straw end
  - 4 straw planes in a view
    - Split view to 'corridors'
    - Size depends on trigger granularity
    - Require at least 2 straws with the same falling edge to validate track in the corridor
    - Window order ~1ns
    - Send corridor number and time to trigger logic
- Trigger logic (custom board or TELL1)
  - Collects numbers from all 4 views
  - Opens timing window > 7 ns due to propagation time in different views
  - If there are hits from different views in the window, send corridor X,Y,Z and timestamp to straw central trigger
  - Straw central trigger generates VETO on multiple charged tracks or trigger on 1 good pion track

Corridor example



Plans

- Finish characterization and testing of the frontend
- Decision on frontend in December/January
- In parallel, test TDC on and off FE-board with CARIOCA chip
- Decision on TDC in December/January
- Development and preproduction of final FE beginning 2011
- Develop and produce small readout system