# CERTIFICATION OF SMDT CHAMBERS FOR THE PHASE II UPGRADE OF THE ATLAS MUON SPECTROMETER

**Max Planck Institute for Physics Munich**

**Nick Meier**

# BRIEF OVERLOOK ON ATLAS MUON SPECTROMETER

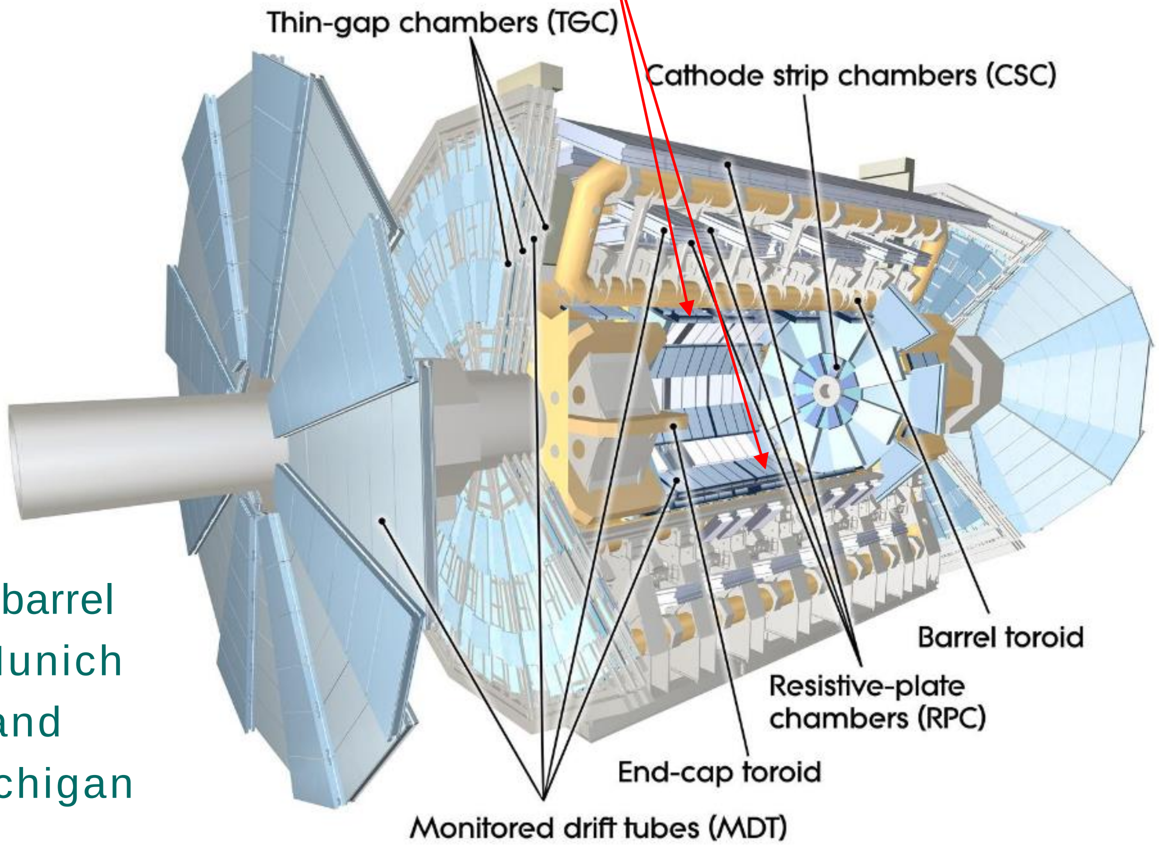
## Muon Spectrometer

- Monitored Drift Tubes Chambers (MDT)
- Resistive Plate Chambers (RPC)
- Micromegas Chamber (MM)
- Thin Gap Chambers (TGC)

## Phase 2 Muon System Upgrades

- to maintain efficiency and capability at HL-LHC
  - New thin-gap RPC
  - New trigger and readout electronics
  - 96 new BIS small-diameter MDT (sMDT) for the inner barrel
    - Designed and developed by MPI for Physics Munich
    - 50:50 constructed at MPI for Physics Munich and collaboration of University of Michigan and Michigan SU

Replacement these MDTs to sMDTs



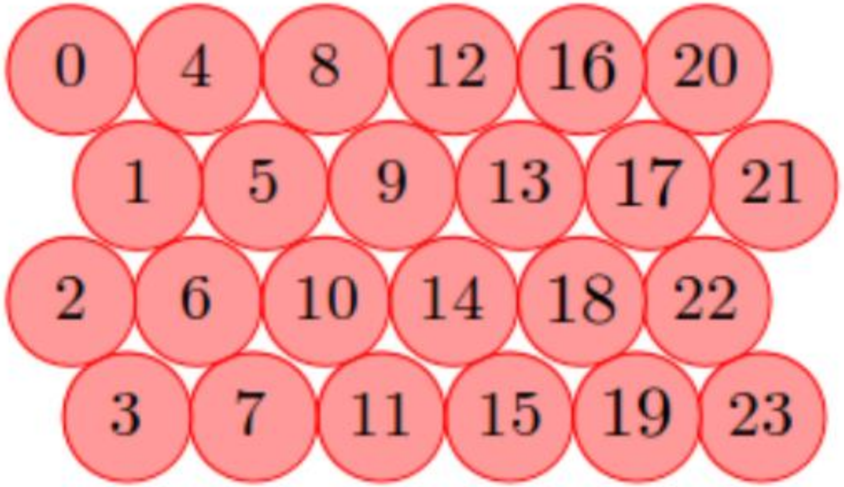
# SMDT

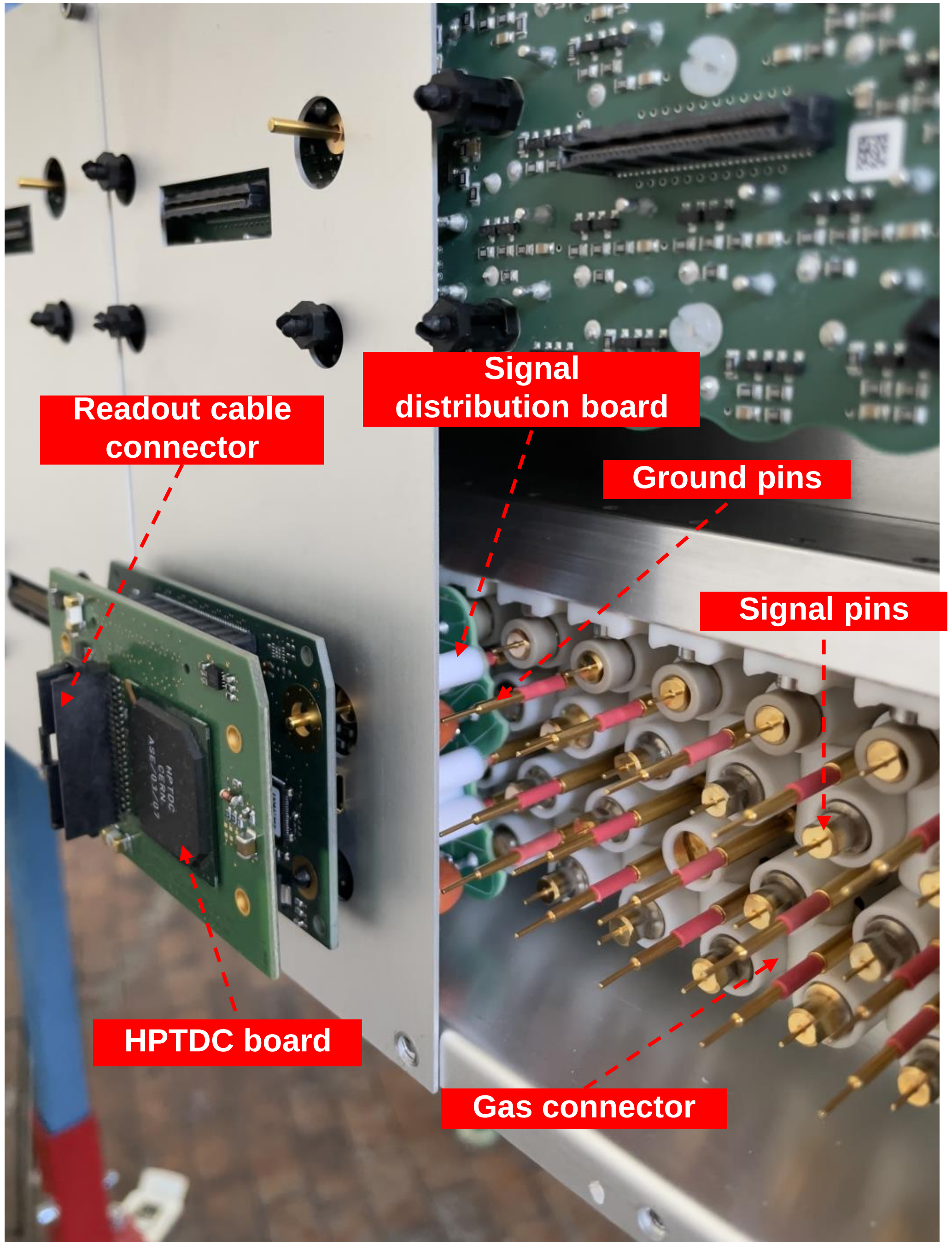
- Same nominal gas gain as in MDT
- Reducing the drift tube radius (R) by factor 2
  - ten times higher gamma background rate capability
  - Effect of space charge fluctuations suppressed at large radii
    - Gain loss due to space charge reduced proportional to $R^3$
  - 4 times lower electronics dead time (=max. drift time)
  - tube cross section exposed to the radiation reduced by effect of 2
    - No aging effects after foreseen integrated luminosity of HL-LHC

| Parameter | MDT | sMDT |
|---|---|---|
| Tube material | Aluminium | Aluminium |
| Outer tube diameter | 29.970 mm | 15.000 mm |
| Tube wall thickness | 0.4 mm | 0.4 mm |
| Wire material | gold-plated W/Re (97/3) | gold-plated W/Re (97/3) |
| Wire diameter | 50 μm | 50 μm |
| Gas mixture | $Ar/CO_2$ (93:7) | $Ar/CO_2$ (93:7) |
| Gas pressure | 3 bar (absolute) | 3 bar (absolute) |
| Norminal Gas gain | $2 \times 10^4$ | $2 \times 10^4$ |
| Wire potential | 3080 V | 2730 V |
| Maximum drift time | ~ 700 ns | ~ 190 ns |
| Average resolution per tube | 83 μm | 106 μm |
| Drift tube muon efficiency | 95% | 94% |

# BIS1-6 CHAMBERS

- 20 readout mezzanine cards on each chamber
- Every mezzanine card has 24 tubes/channels connected to it
- So every 4th channel is one layer in the chamber



# CERTIFICATION TEST PROTOCOL OF SMDT CHAMBERS

- Gas leak rate test
- Search for noisy channels
- Cosmic ray tests
  - Search for dead channels
  - Drift tube spatial resolution measurement
  - Drift tube muon detection efficiency measurement

Certification test protocol is first done at MPI Munich the production site and then after transportation to CERN BB5 construction and test facility again.

# CERTIFICATION TEST CAMPAIGN AT CERN BB5 FACILITY

- **Three chambers have been tested**
  - Stacked configuration with the Scintillator on top of the stack (3A06,6A08 and 2A02 from top to bottom)
  - The rest of the procedure is the same as at the production side in Munich
  - To see if there had been any problems or damage after transportation
  - In the first activation of chambers the current during ramping HV is closely inspected and need to fall below 50 nA to have a dark current of less then 150pA per tube
    - Sometimes increased because of humidity or damaged electronics

# GAS LEAK RATE TEST

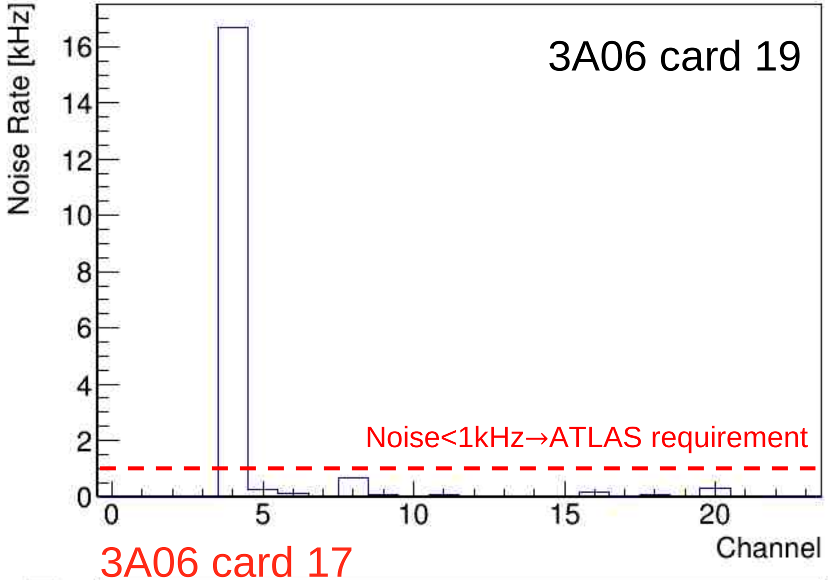
- Pressurized at 3 bar in the operating gas mixture of Ar:$CO_2$ (93:7)
- Measure pressure for every multilayer with a Baratron pressure gauge
- Measuring the temperature with 12 temperature sensors (6 on top 6 on the bottom)
- To obtain good statistic the two measurements must be at least 48 hour apart

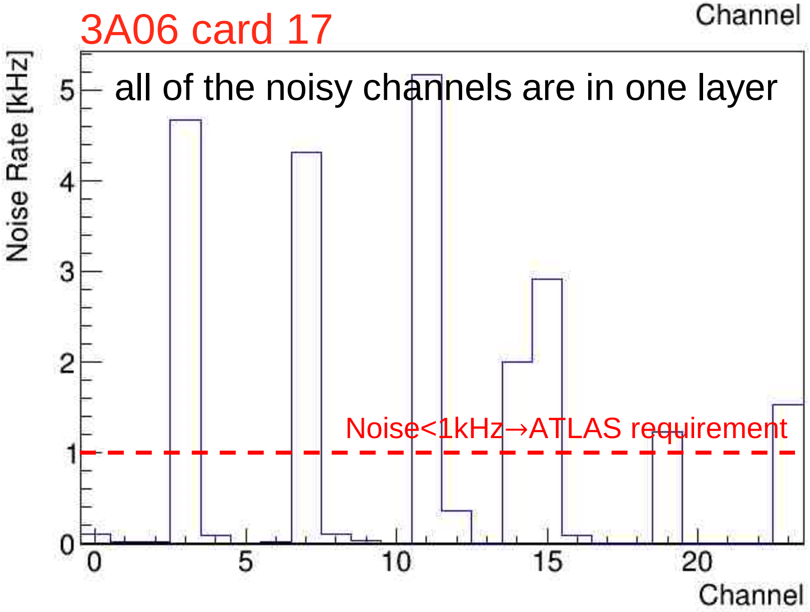
$$\Delta p\left[\frac{\mu bar}{h}\right] = \left(\frac{p_{end}(t_2)[\mu bar]}{T_{end}(t_2)[K]} - \frac{p_{start}(t_1)[\mu bar]}{T_{start}(t_1)[K]}\right)\frac{293K}{t_2 - t_1[h]}$$

- Maximum allowed value is $2n * 10^{-8}\ \frac{bar*l}{s}$ for n=464 tubes getting a maximum of 550 $\frac{\mu bar}{h}$ for an entire chamber

| Chamber[time] | $\Delta p_{ML1}\left[\frac{\mu bar}{h}\right]$ | $\Delta p_{ML2}\left[\frac{\mu bar}{h}\right]$ |
|---|---|---|
| 3A06 [98.5h] | $97 \pm 32$ | $78 \pm 30$ |
| 6A08 [60.5h] | $15 \pm 50$ | $31 \pm 50$ |
| 2A02 [356h] | $291 \pm 7$ | $263 \pm 7$ |

# SEARCH FOR NOISY CHANNELS



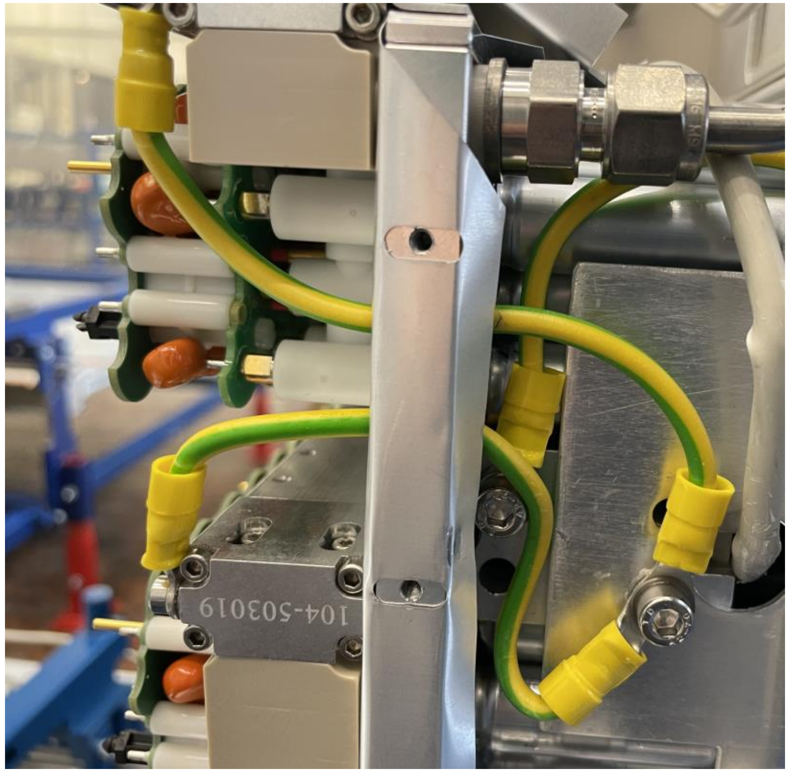




- **1 min of random trigger (50,000 triggers)**
- **Looking at a threshold of p.e. 25 [code 121] for noise above 1 kHz**
- **Problems which more often occurred**
  - Humidity
  - Damaged electronics, which can be swapped
  - Gas bar grounded incorrectly
  - Distribution of HV cables inside the chamber
    - Resolved in later chambers with shortened HV cables

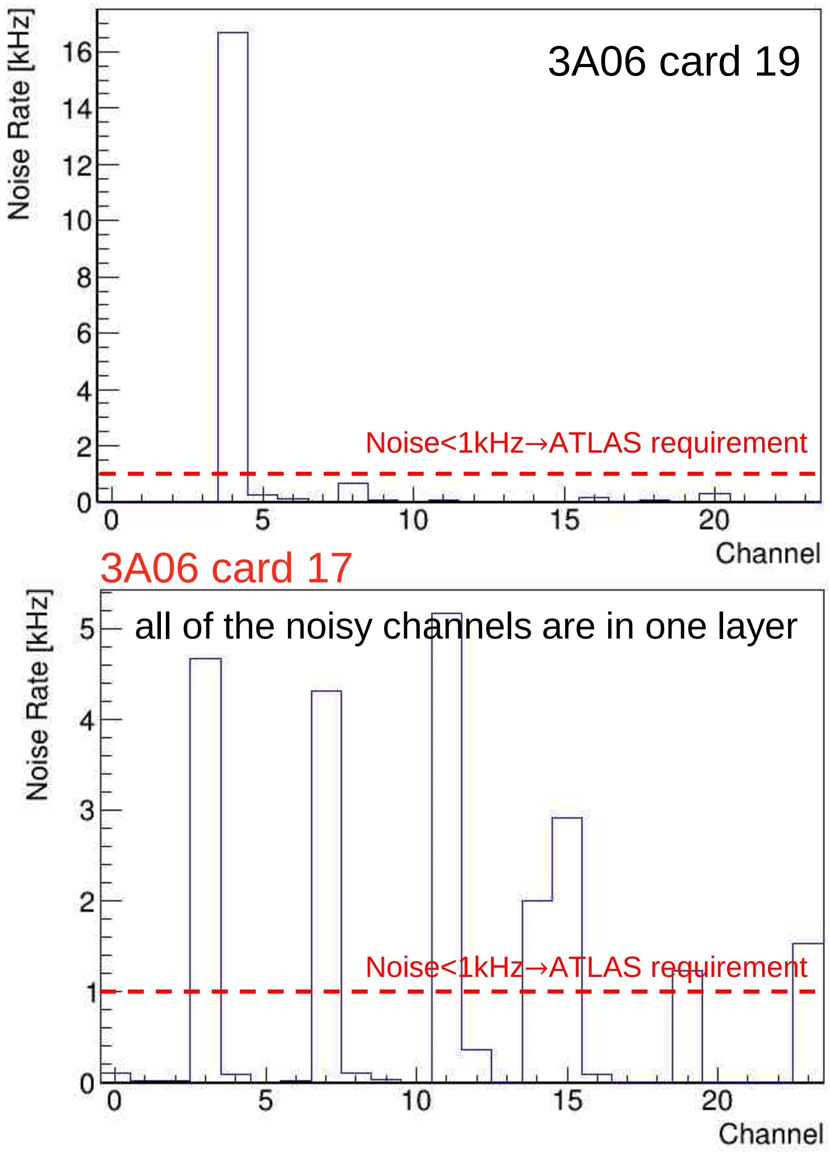
# NOISE PROBLEM FROM THE GAS BAR GROUNDING

## BEFORE DESIGN CHANGE

## AFTER DESIGN CHANGE

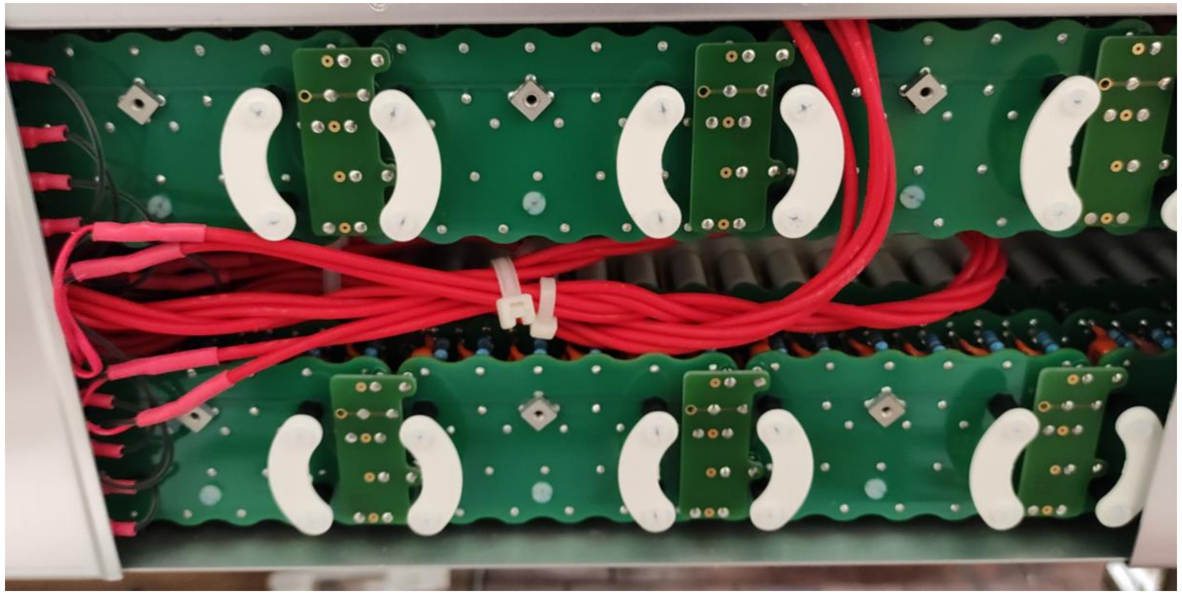



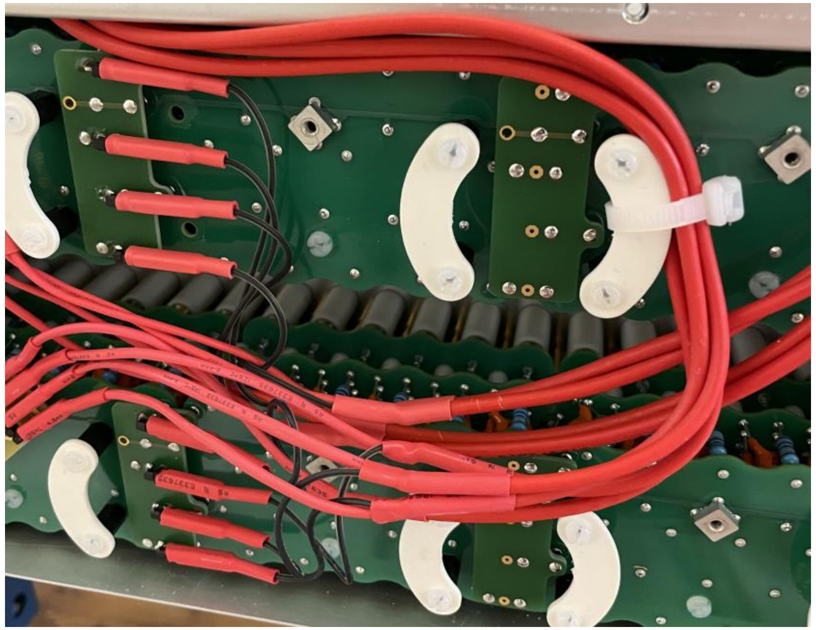

# SEARCH FOR NOISY CHANNELS

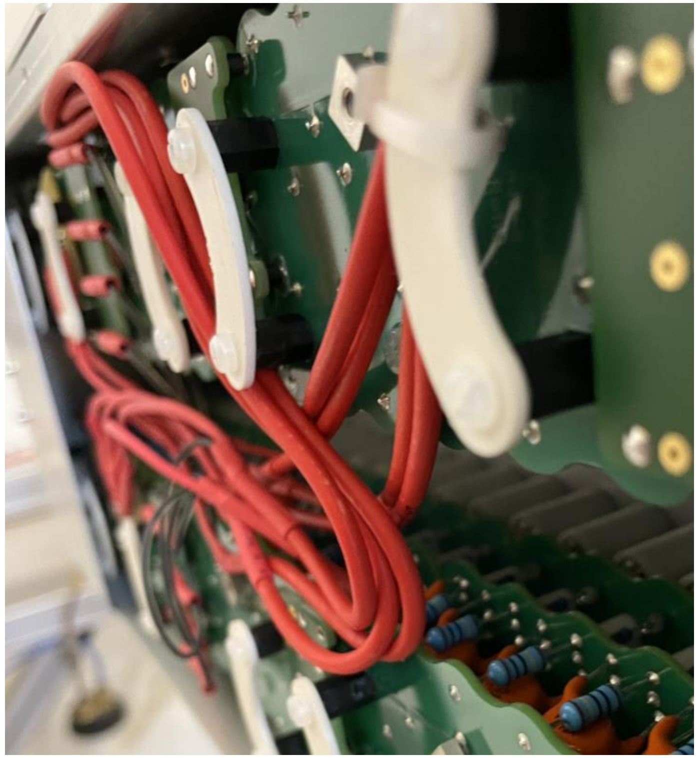



- **1 min of random trigger (50,000 triggers)**
- **Looking at a threshold of p.e. 25 [code 121] for noise above 1 kHz**
- **Problems which more often occurred**
  - Humidity
  - Damaged electronics, which can be swapped
  - Gas bar grounded incorrectly
  - Distribution of HV cables inside the chamber
    - Resolved in later chambers with shortened HV cables

Before shortening of HV cables and cable management



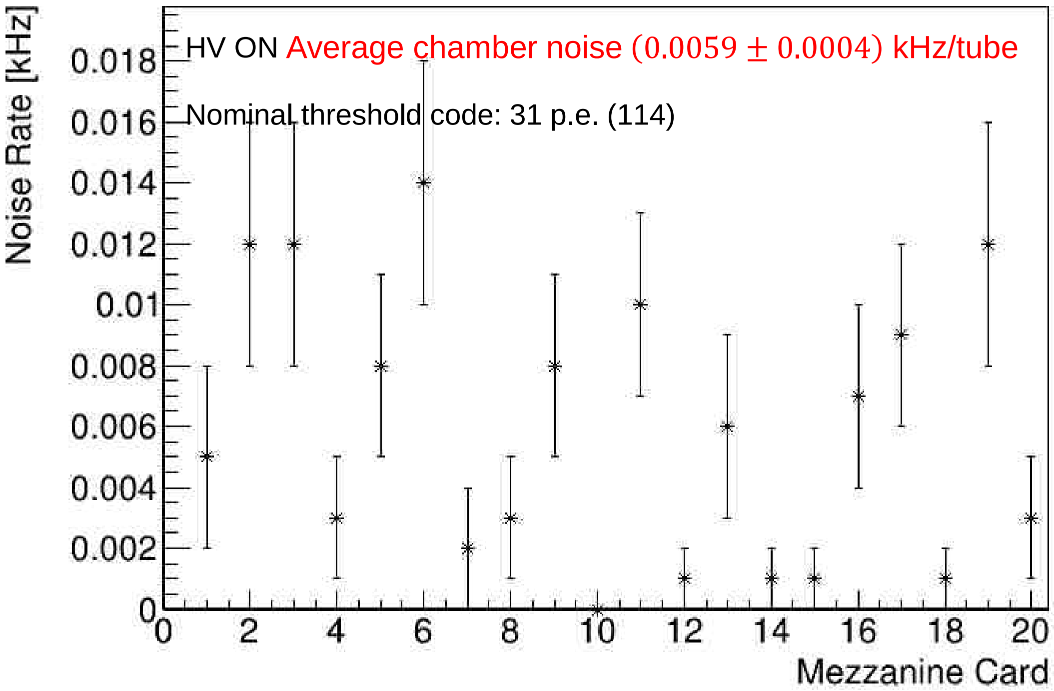




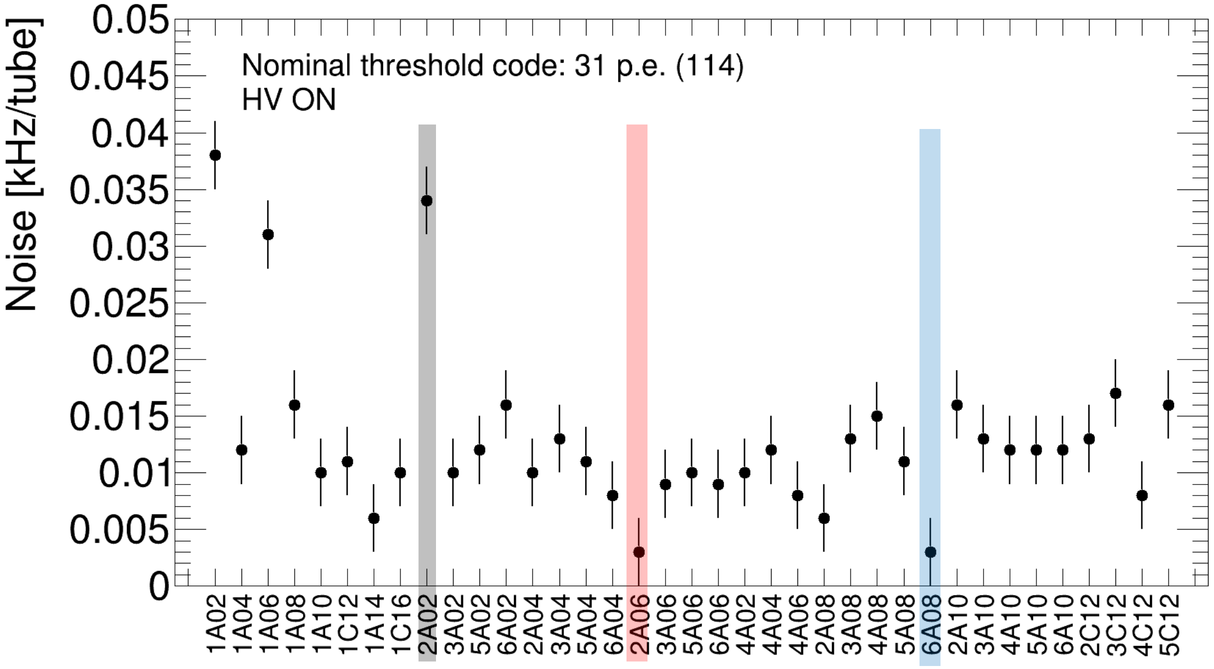
After shortening of HV cables and cable management

# NOISE RESULTS AFTER RESOLVING THE HV CABLE NOISE PROBLEMS

Chamber 2A02 tested at CERN

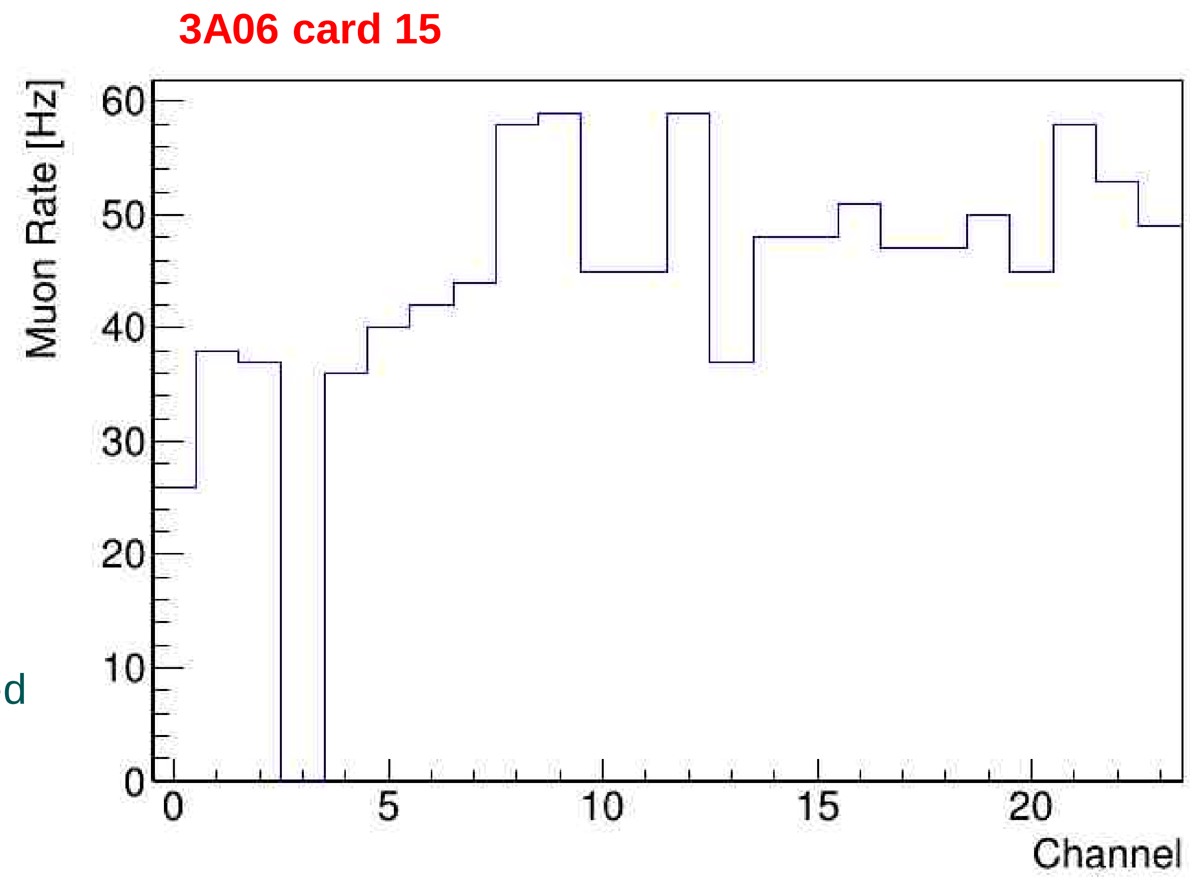



Overview of our chamber testing at MPI in Munich



# SEARCH FOR DEAD CHANNELS

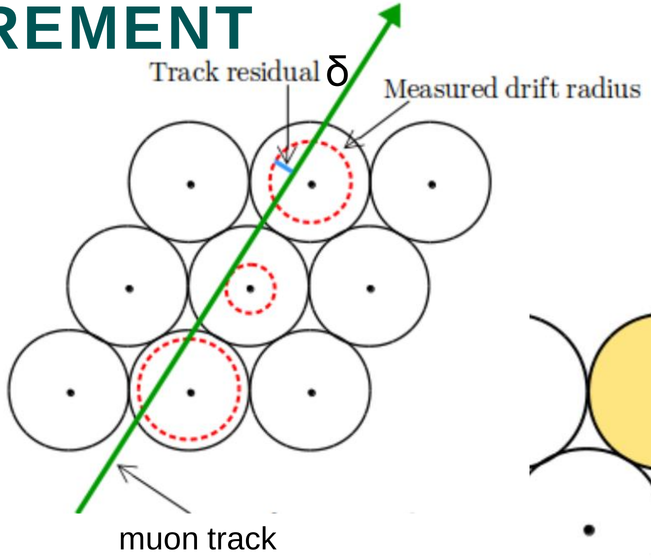
- **2-5 min of cosmic data at high threshold**
  - More time is needed with larger distance between the scintillator and the chamber
- **Looking for**
  - Dead channels
    - Real dead tubes
    - Damaged electronics, which can be replaced

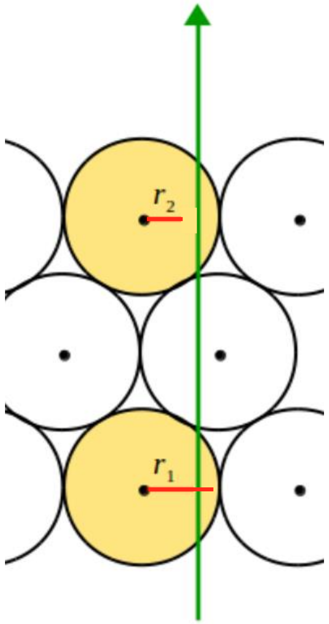


# DRIFT TUBE SPATIAL RESOLUTION MEASUREMENT

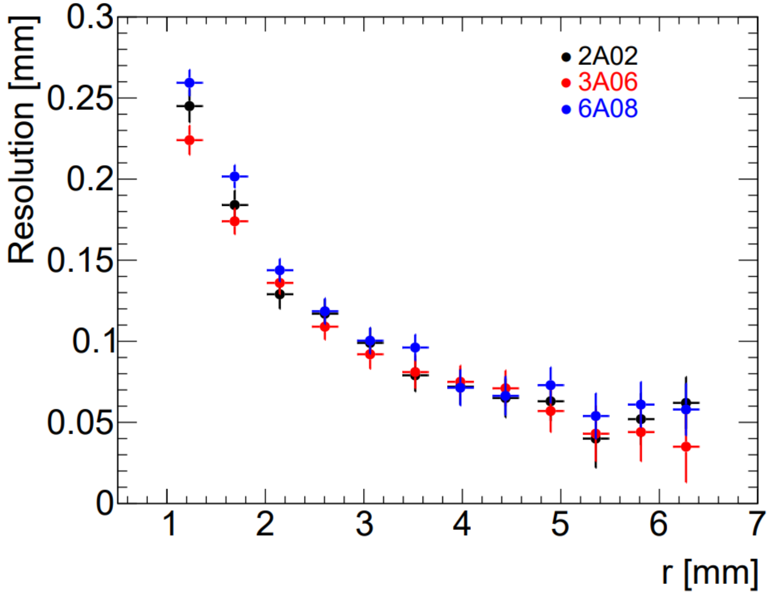
- **Reconstructing the muon tracks out of the measured radii**
- **Deviation from the track**

$$\sigma = \sqrt{\mathbf{Var}(\boldsymbol{\delta})} = \sqrt{\mathbf{Var}(\mathbf{r}-\mathbf{d})} = \sqrt{\frac{\mathbf{Var}(\mathbf{r1}-\mathbf{r2})}{\mathbf{2}}}$$

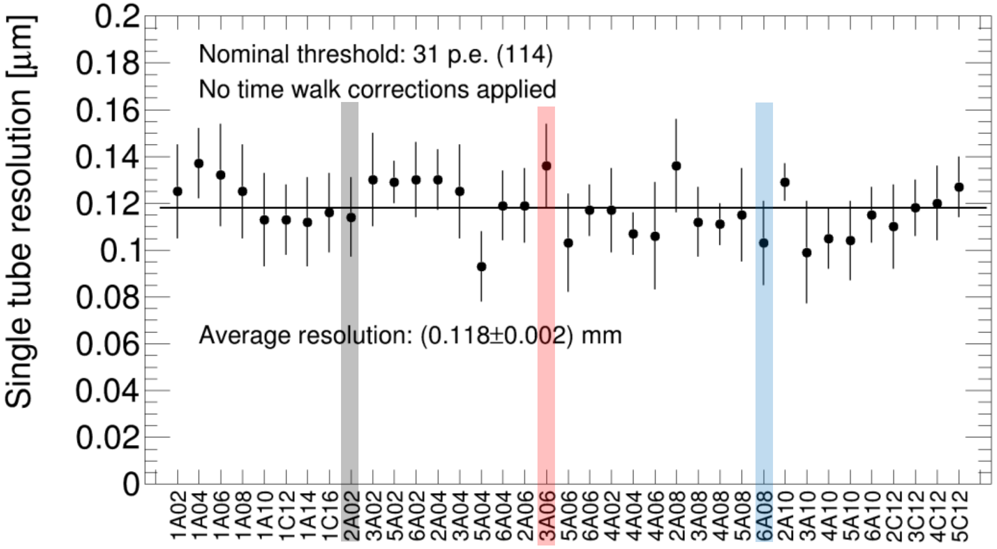



Chambers tested at CERN




Overview of our chamber testing at MPI in Munich

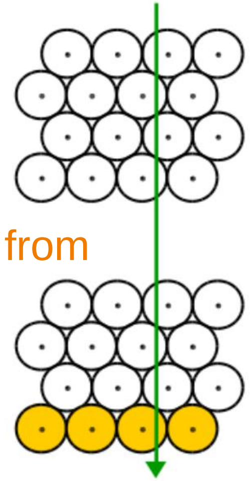


# DRIFT TUBE MUON DETECTION EFFICIENCY MEASUREMENT

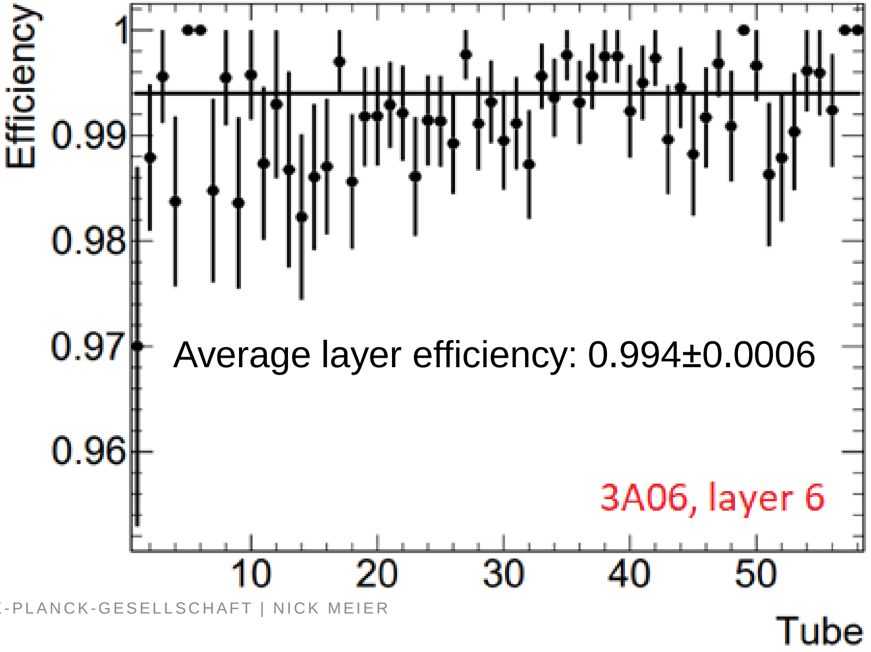
$$\varepsilon_{tube} = \frac{nr.\,of\ detected\ hits\ in\ tube\ matching\ the\ reconstructed\ tracks}{number\ of\ all\ reconstructed\ tracks\ crossing\ the\ tube}$$

- **Excluding always one layer from the muon track fits**
- **Going through every track, which goes trough one of the tubes in the excluded layer and look if there also matching a hit the tube**

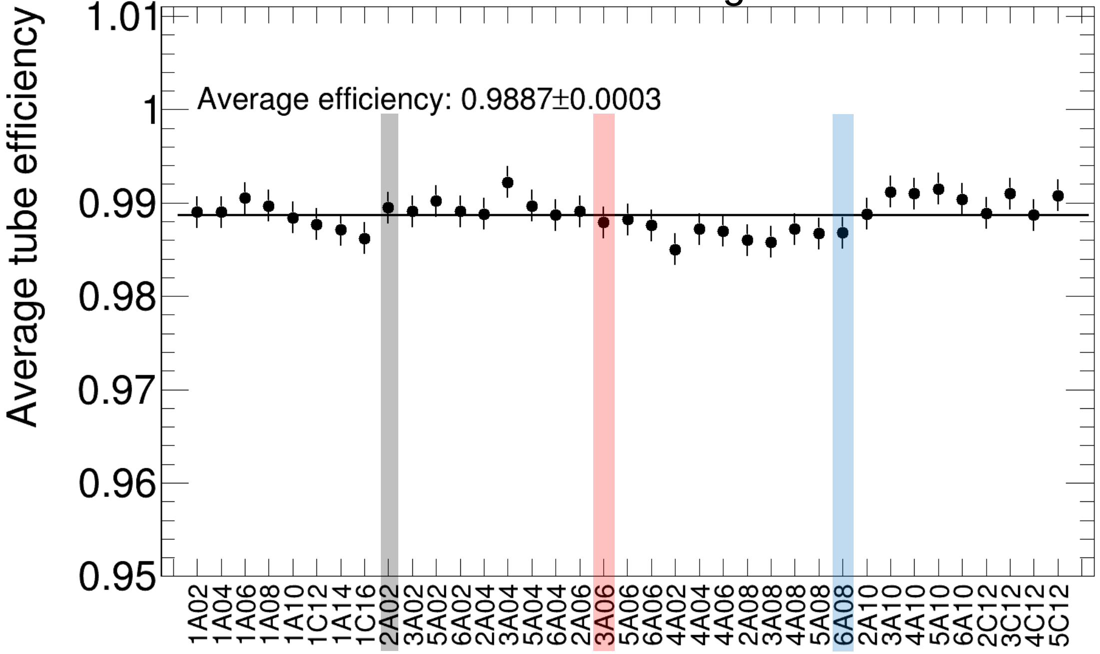
Excluded layer from track fit



Chamber 3A06 layer 6 tested at CERN




Overview of our chamber testing at MPI Munich



# SUMMARY

- All BIS1-6 chambers has been constructed at MPI Munich and shipped to CERN for the further certification test
- Same certification procedure as at the MPI Munich production site

2A02,3A06,6A08 have been tested chamber and showed the following results:

- No damage (during transport)
  - No additional dead channels
  - No increased leak rate
  - Same spatial resolution and muon detection efficiency as back at MPI Munich
- 2 days per chamber will be possible to achieve

All data and results obtained at CERN BB5 facility are compatible with the measurements from MPI Munich!