Straw Tube Development

Joint DESY/UHH perspectives in detector research

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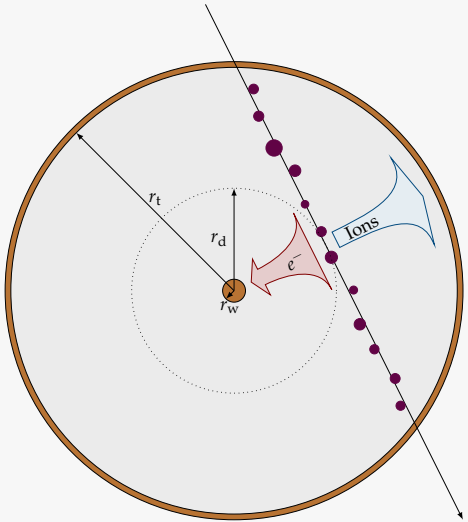
DER FORSCHUNG | DER LEHRE | DER BILDUNG

June 1 2023

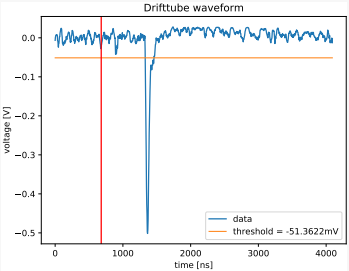
Overview

Concept of Drift Tubes



- Anode wire in the center
  typically few $10\,\mu m$ gold-plated tungsten,
  around $2\,kV$ HV.
- Cathode tube, e.g aluminum,
  typically few mm to cm diameter.
- Filled drift gas is ionized by charged particles.
- Electrons drift towards anode
  $\rightarrow$ more ionization $\rightarrow$ avalanche.
- Drift-time between t_0 and signal arrival time
  correlated to track distance to wire.

From Signal to Track



- Signal is decoupled from HV and pre-amplified $\rightarrow$ discriminator $\rightarrow$ TDC
- Drift-times up to >1000 ns
- For R&D we use an FADC-readout
  - Full knowledge of waveform
  - Threshold can be set by software offline
- Calculation of drift circles
- Pattern recognition an track reconstruction

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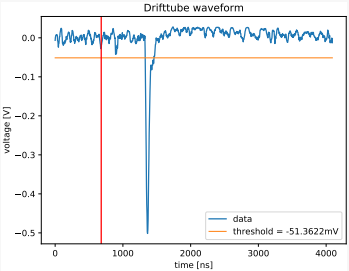

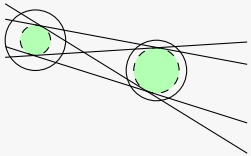

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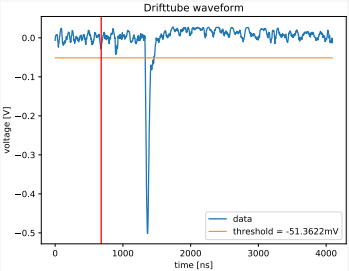

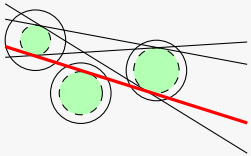

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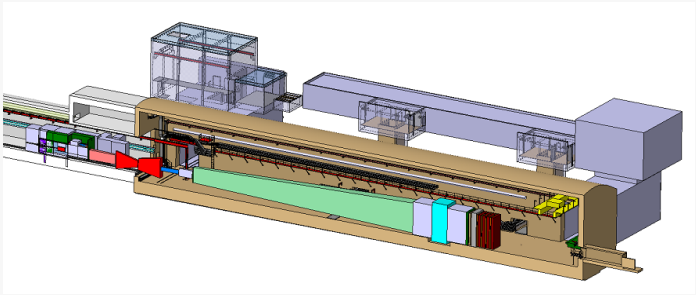
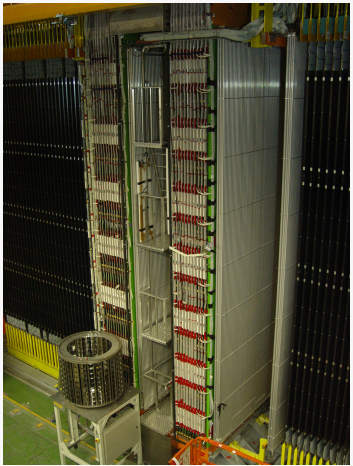
Use of Drift Tubes

- Ideal technique for large scale **tracking spectrometers**.
- Covering large apertures of a few meters.
- **What to do, if the material budged is limited?**

▷ e.g. SHiP@ECN3: $4\,\mathrm{m} \times 6\,\mathrm{m}$ spectrometer tracker behind $50\,\mathrm{m}$ decay vessel in **vacuum**.

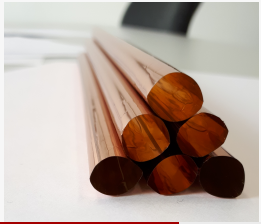




OPERA, a decade ago. . . 10000 drift tubes made at UHH

Straw Tubes

- Cathode made from thin metallized material.
- Two techniques:
  1. spirally wound (classic)
  2. longitudinally **ultrasonically welded**.
     - high strength (pressure tests with 3 bar)
     - no glued layers
     - small gas leakage
     - ▷ suitable for use in vacuum
- Successful operation in NA62.



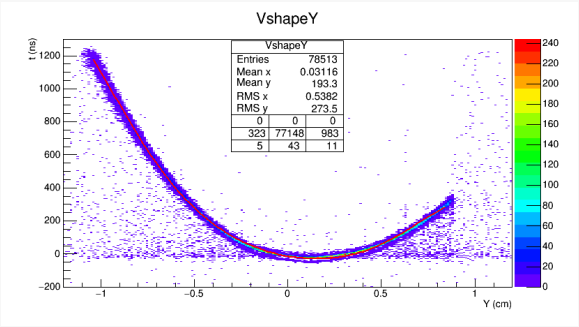
Straw tubes at UHH

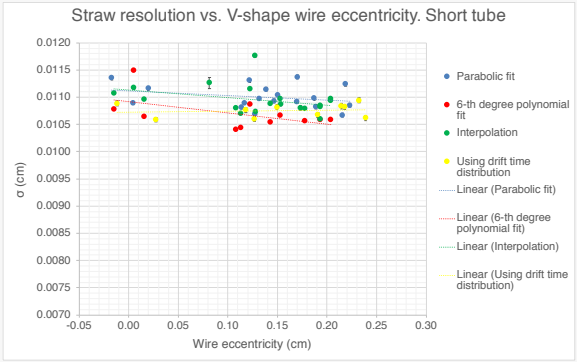
- Interested in large sensitive area with relatively low rates (10 kHz)
- Straw tubes based on NA62 design with increased length and radius
- Coated Mylar (BoPET) foil
- Produced by JINR Dubna
- Horizontal operation

Wall thickness	36 µm
Coating	Au (20 nm), Co (50 nm)
Diameter	2 cm
Length	5 m

2 cm Straw Tubes

- Hit resolution of short tubes (2 m) was measured in H2 testbeam
- ▷ tested depending on wire eccentricity





- Resolution $<120\,\mu$m was achieved for wire eccentricities up to >2 mm

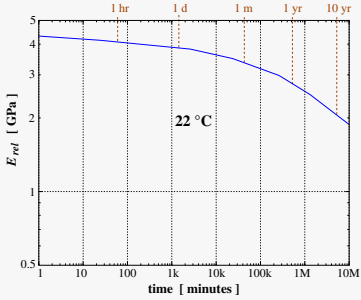
Mechanical Challenges

Main mechanical challenge:

Flowing of Mylar

- Reduction of tension to half over 10 years
- Problem for horizontal tubes

- Additional forces when vessel is evacuated and straws are under pressure



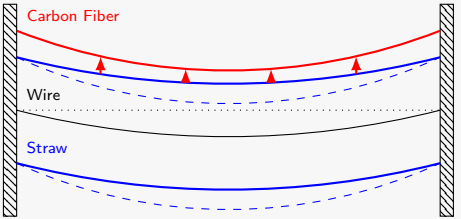
SHiP-INT-2018-001

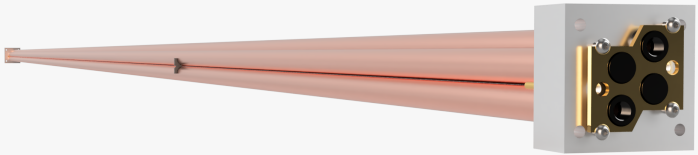
Implications

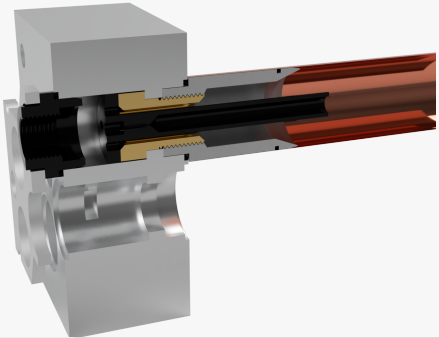
- Reduced tensions increase gravitational sagging of the straws over time
  $\Rightarrow$ changing the eccentricity of the wire
  $\Rightarrow$ electrostatic deflections!
- Reduced tensions relax load on any supporting frame, which would thus unbend
- An unbending frame pulls on the wire, which would thus rupture ($\Delta\ell_{\text{max}} \simeq 10\,\text{mm}$)

Mechanical Design

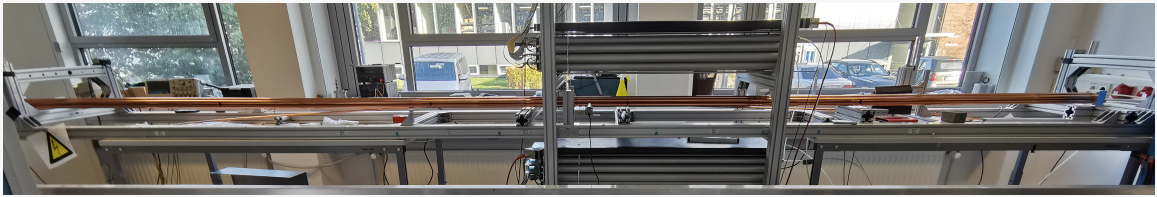
- Ansatz: support by thin carbon cables
- Carbon cable defines sagging.
- Two tubes share one cable, connection every meter.
- Gas distribution inside endplate (zig-zagging through tubes).
- Setup of first prototype with four tubes.
- Hibernation during Covid.
- Great to study long term effects (just started)

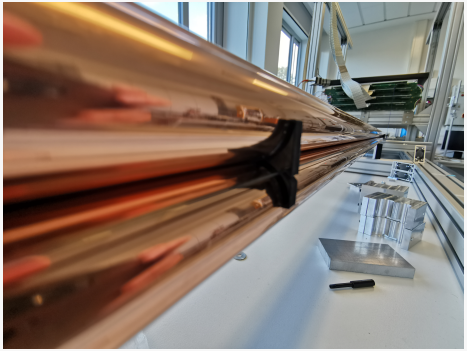






Prototype with Four Tubes





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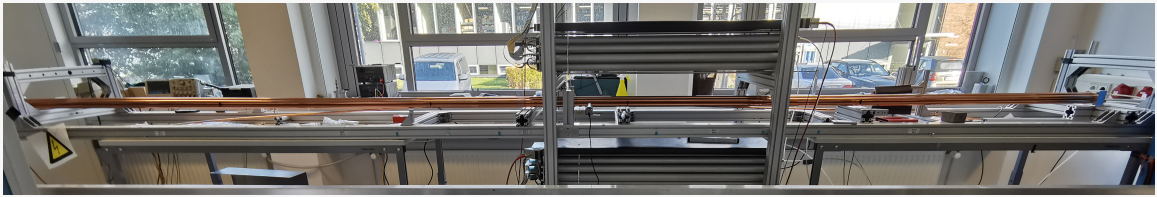

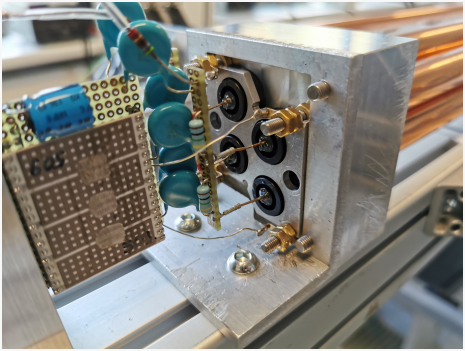

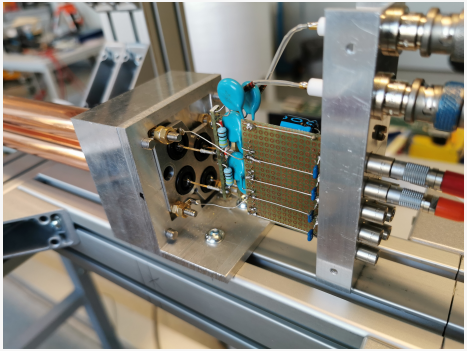

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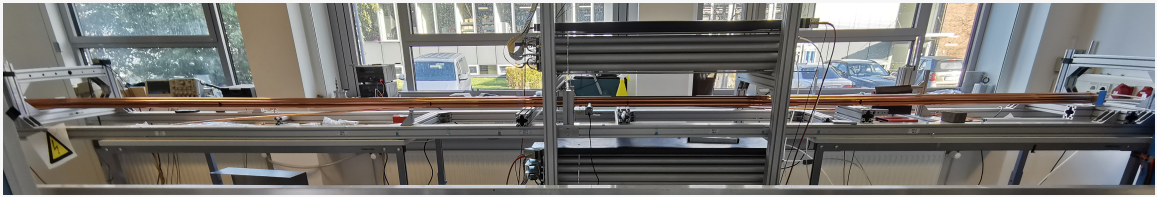
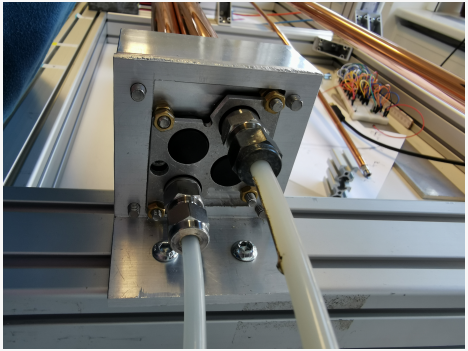
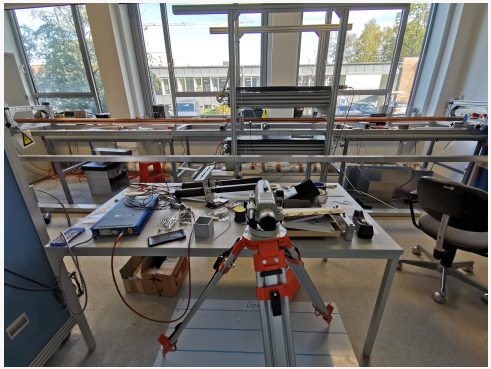
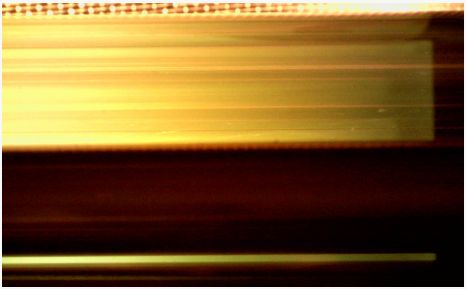


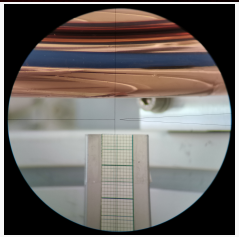


Sagging

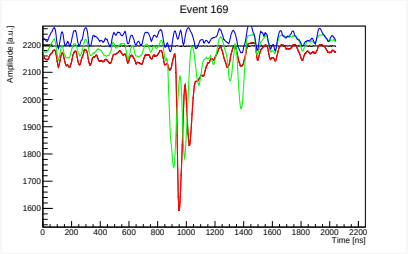
- Sagging monitored with optical level.
- Wire can be monitored with strong LEDs and optical microscope.
- All behaves as expected. Long term update soon.







Measurements



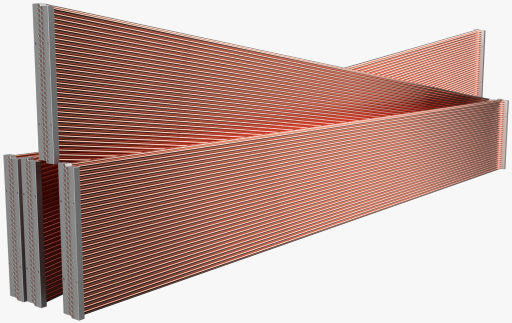
- Two different wire diameters ($30\,\mu m$ and $45\,\mu m$)
- Separate HV supply
- Signal amplified by L3 amplifier (used in OPERA)
- Signal readout by multi channel FADC
  - Auto trigger
  - External trigger (scintillators)
- Measurements with cosmics, Fe55, Sr90
- Reference detector (former OPERA test modules)

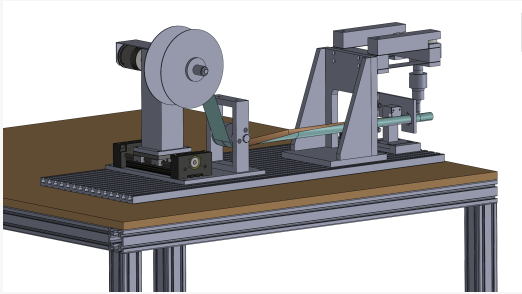
Prototype works and technology is suitable for use in large spectrometer

- Study planed if recording of (simplified) waveforms is beneficial (justifying the cost)

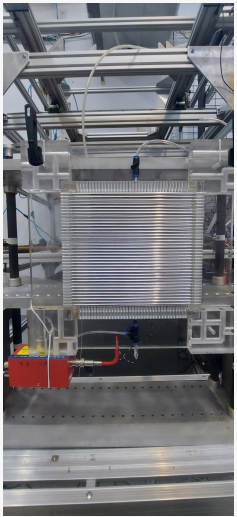
An Even Larger Prototype

- Setup of a larger modules with 64 Straws.
  - Do actual tracking in prototype.
  - Test assembly processes.
- However: Straws used so far were produced in Dubna
- Geopolitical situation makes collaboration impossible
- Started to make plans for own straw production line, will test different coatings.

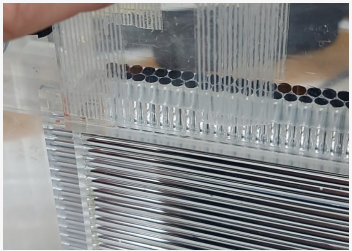


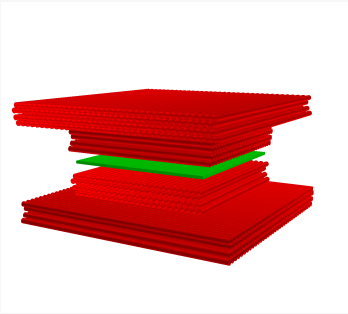


Related Activities



- Mechanical design for smaller tubes
  - 5 mm, 20 µm tubes foreseen for SAND
  - generic interest, informal experience exchange with SAND people
- Use of old drift tube modules for muon tomography
  - Muons for peace project together with IFSH
- Classic spectrometer design for AdvSND@LHC





Summary and Outlook

- First successful operation of a 5 m long straw tube with 2 cm diameter at UHH.
- Use foreseen for SHiP@ECN3 experiment.
  - recent re-design simplifies things – only 4 m width
- Planning started for own straw production setup
- Foils with different coatings waiting for new welding machine
- Setup of a larger prototype, adapted to new SHiP@ECN3 geometry
- Will include some of the R&D in the DRD1 collaboration