

The SHiP Spectrometer Straw Tracker

CERN BDF and SHiP Workshop Berlin @Home

Daniel Bick

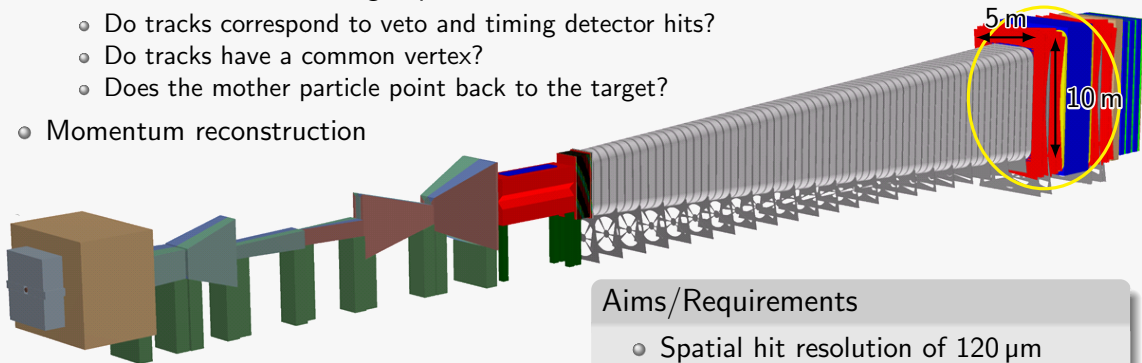


Universität Hamburg
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March 27 2020

- 1 The Spectrometer Straw Tracker
- 2 Straw Tubes
- 3 Tracker Stations
- 4 SST Mechanics and Designs
 - UHH Design
 - Prototype
- 5 Summary and Outlook

- Reconstruct tracks of charged particles
 - Do tracks correspond to veto and timing detector hits?
 - Do tracks have a common vertex?
 - Does the mother particle point back to the target?
- Momentum reconstruction



Aims/Requirements

- Spatial hit resolution of $120\ \mu\text{m}$
- Hit efficiency $> 99\%$
- Operated in vacuum
- Minimize multiple scattering

Suitable technique

- Ultra-light straw drift detectors
- Straw tubes based on NA62 design with increased length and radius
- Welded Mylar (BoPET) foil
- Produced by JINR Dubna

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

- Operated with Ar/CO₂ @1 bar
- Shorter tube tested in 2017
testbeam: [CERN-SHiP-INT-2019-005](#)



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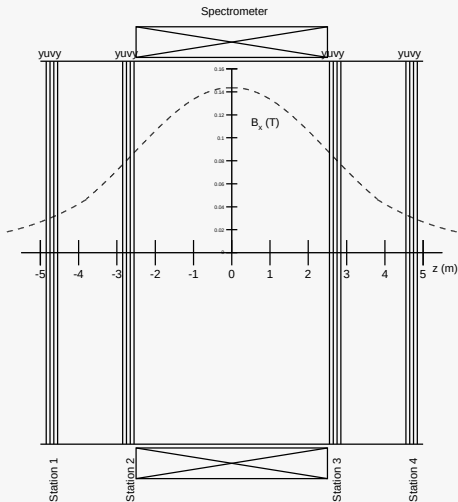
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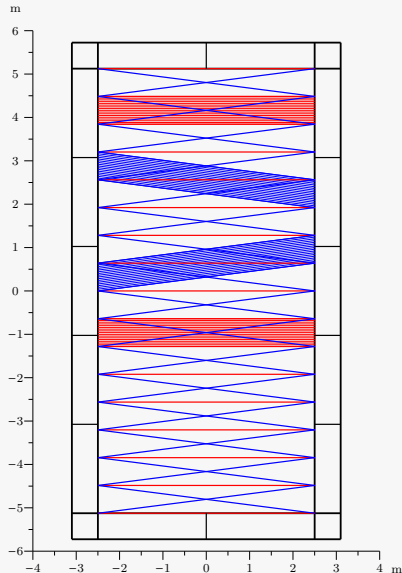
But adding more challenges ...

- Handling of straws
- **Flowing of Mylar**
- Increase of sagging over time
- Dynamic forces on support frame over time (bending)

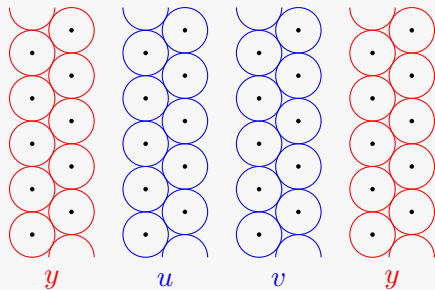




- Located at the end inside the vacuum vessel
- Aperture: $5 \text{ m} \times 10 \text{ m}$
 - width constrained by spatial distribution of muon background
- Large dipole magnet
 - $B_{\text{max}} \simeq 0.14 \text{ T}$ in x -direction
 - Field integral 0.65 Tm
- A pair of tracking stations on each side
- ▷ Four identical stations
- 4 views per station: $y u v y$

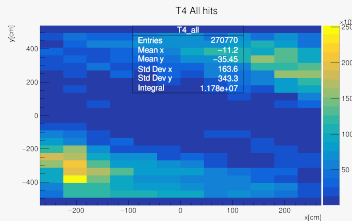
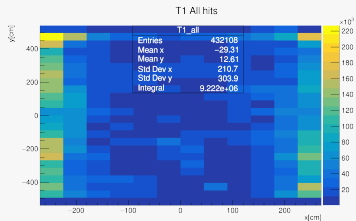


D. Bick (UHH)

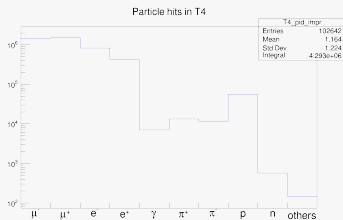
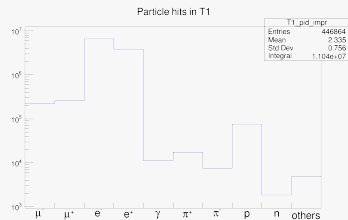


Four identical stations

- Each station has four views: $y \ u \ v \ y$
- y -views: horizontal straws of 5 m length
- u - and v -views are rotated by a stereo angle $\sim 5^\circ$
- 2 layers per view (depending on final design)
- 16 000 straws altogether

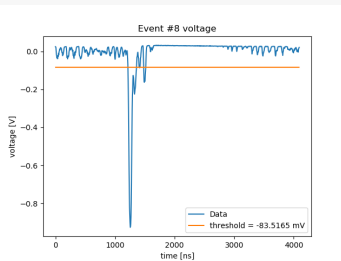


• $\mathcal{O}(10^7)$ hits/station/second



	Max. Rate kHz/Tube	Avg. Rate kHz/Tube
T1	6.68	3.88
T2	1.09	0.63
T3	1.97	1.05
T4	1.77	1.07

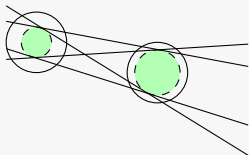
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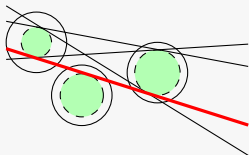
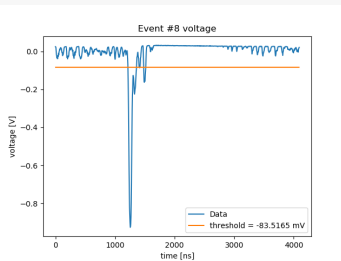


- Triggerless readout → all signal are sent to DAQ
 - Offline matching of hits
 - Time between t_0 (e.g. from timing detector) and start of signal: drift time
- ⇒ corresponds to drift distance

Precise measurement of t_0

- Chip development by FZJ → see D. Arutinov's talk
- Under investigation: possibility to also use
 - Time over threshold
 - Total charge
 - (Part of the) waveform





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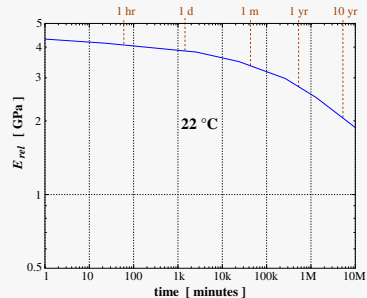
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Main mechanical challenge:

Flowing of Mylar

- Reduction of tension to half over 10 years
[SHiP-INT-2018-001](#)

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



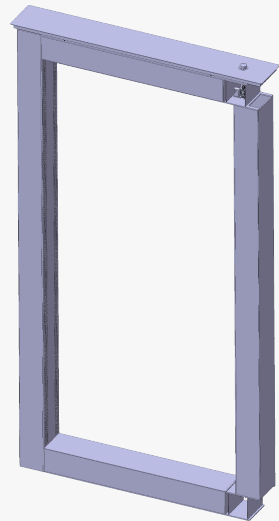
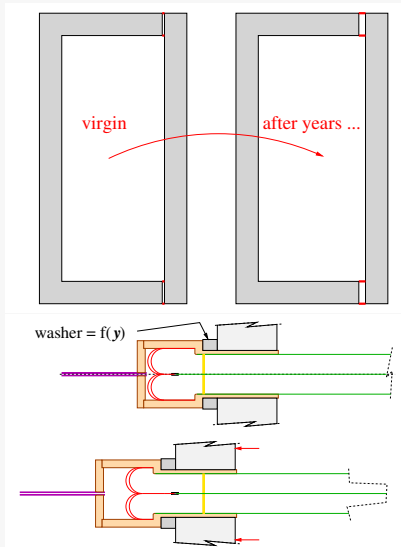
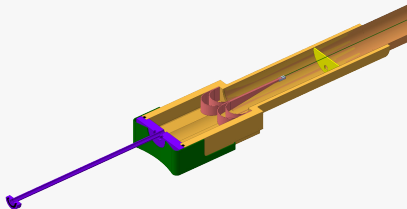
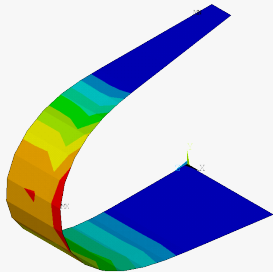
Implications

- 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 ($\Delta \ell_{\max} \simeq 10 \text{ mm}$)

Three alternative designs

- 1 Constant force springs and adjusted pulling
 - Decouple tension of the wire from the straws
 - Increase pulling on the straws over time to compensate for relaxation
- 2 Cemented pack
 - Glue straws together for self-support, thus reducing sagging (*boost bending stiffness*)
 - No external traction on straws, only overpressure
 - Increase of length due to Mylar creeping within elastic region of the wire
- 3 Suspended bridge design
 - Very stiff frame to minimize unbending when Mylar relaxes → wire is safe
 - Additional carbon fibers to suspend straws, thus defining the sagging

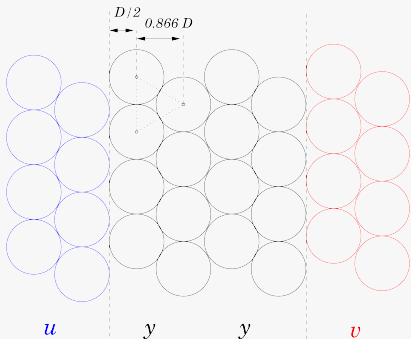
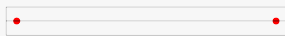
Constant Force Springs + Expandable Frame



Single straw



Two cemented straws



- Based on PANDA idea
- Straws are glued together for stabilization
- 64 or more straws on top in a pack form a module
- Only lightweight support structure needed, no external traction and thus no forces on frame
- Started to produce small scale (short) prototype

Allowed range of the 5 m wire

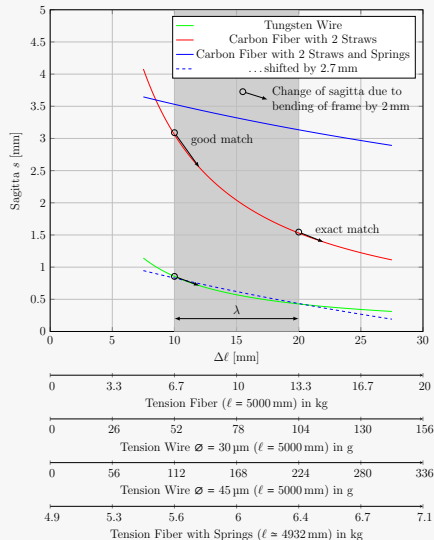
- for a minimum traction to avoid electrostatic deflections $\Delta \ell_{\min} = 10 \text{ mm}$
- elastic limit $\Delta \ell_{\max} = 20 \text{ mm}$
- corresponding sagitta s between 1 mm and 0.5 mm

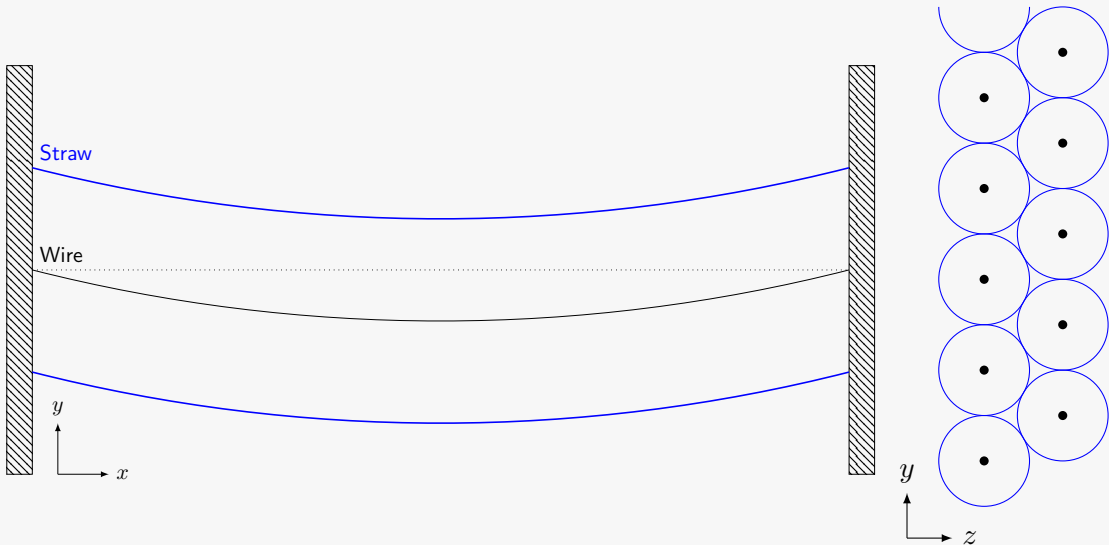
Straw

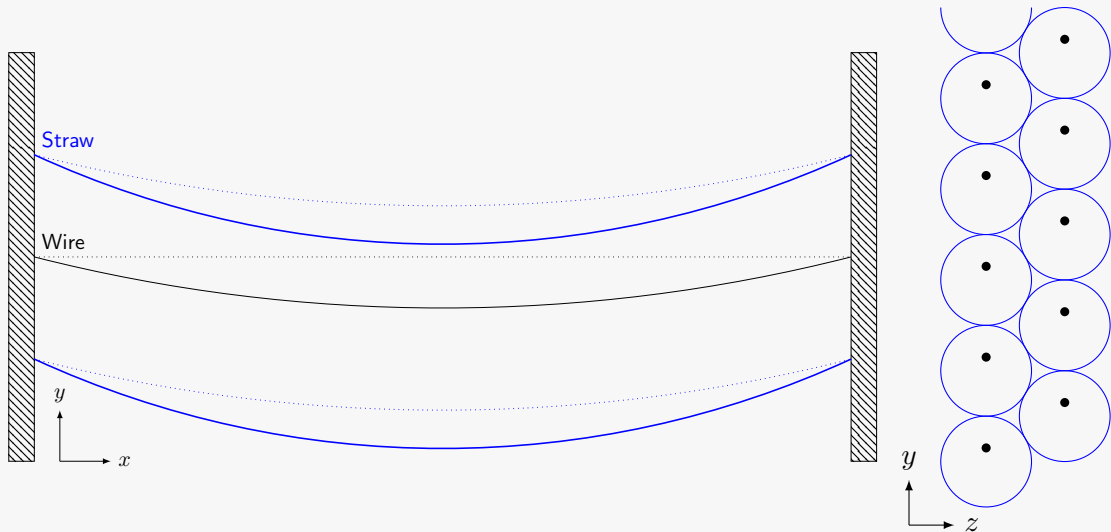
- for $s = 1 \text{ mm}$, straw must be pulled with 10 kg
- this increases to 2 mm when tension halves
- frame unbends and pulls further on wire

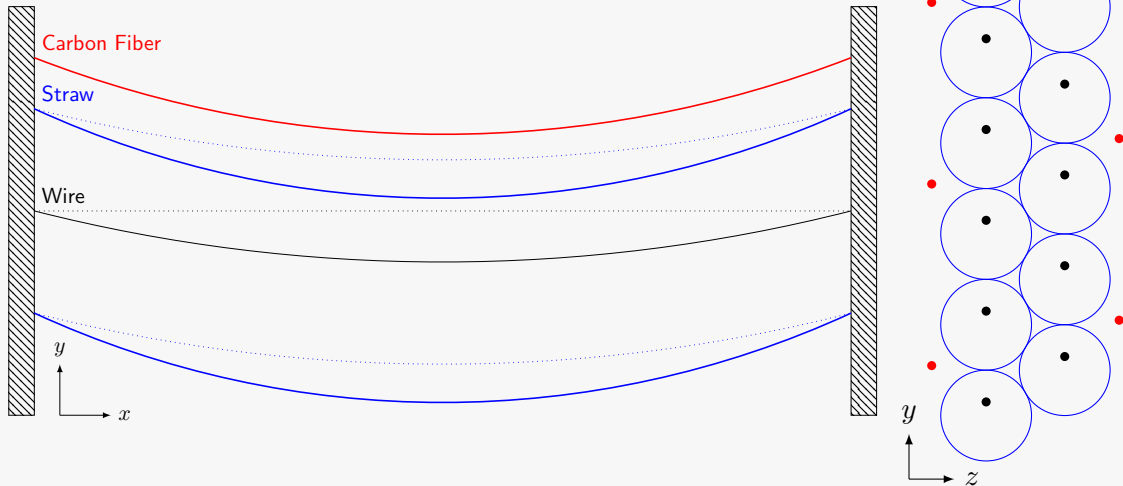
Solution: define sagging of straw by a carbon fiber

- One fiber supports two straws

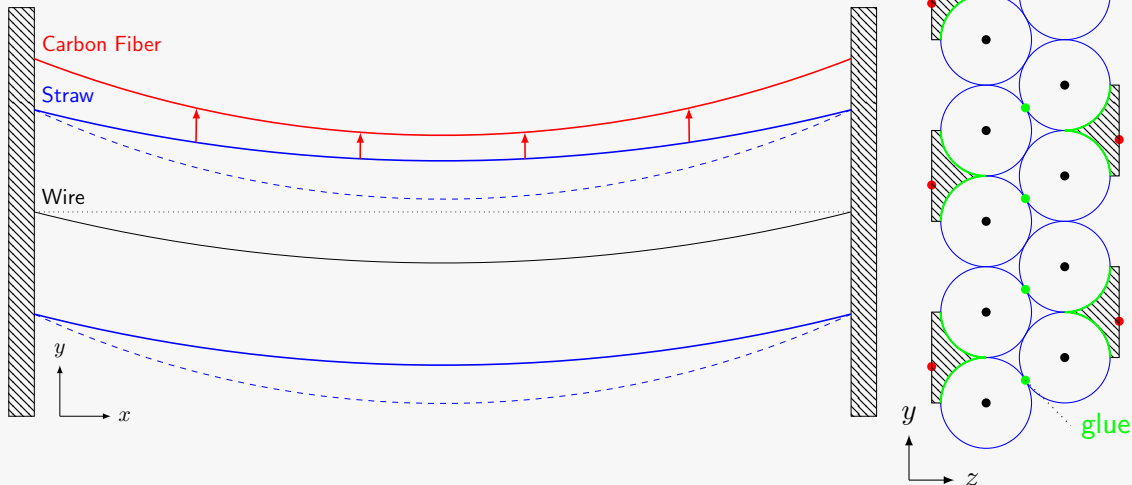




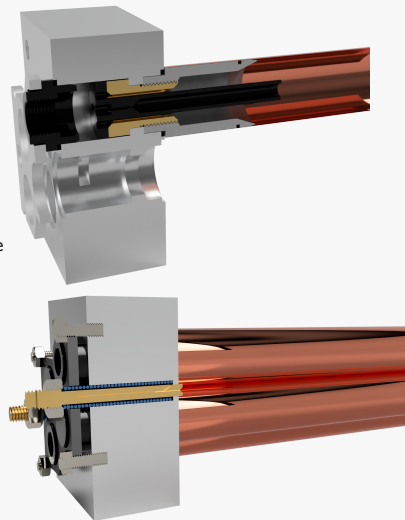
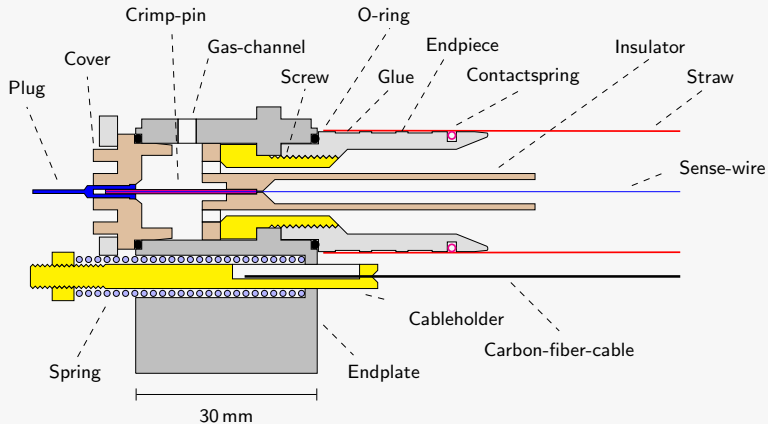


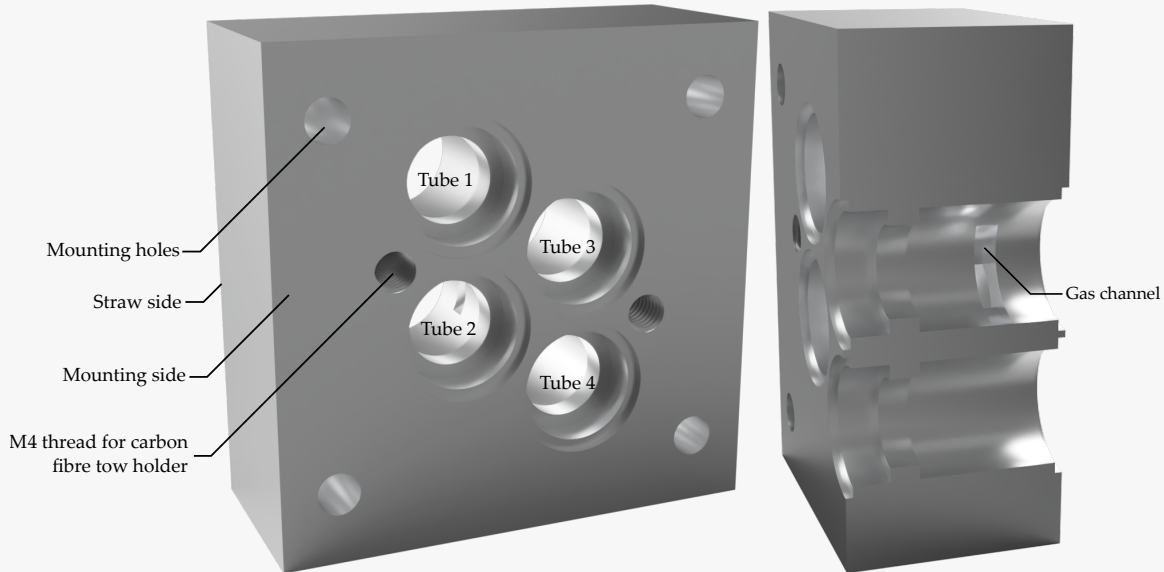


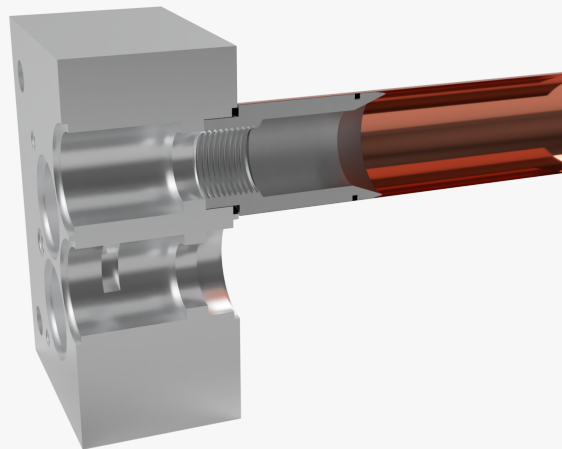
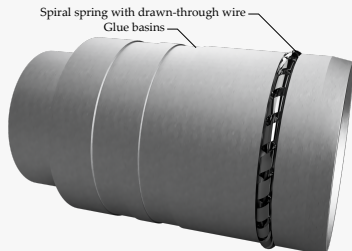
The Suspension Bridge Design

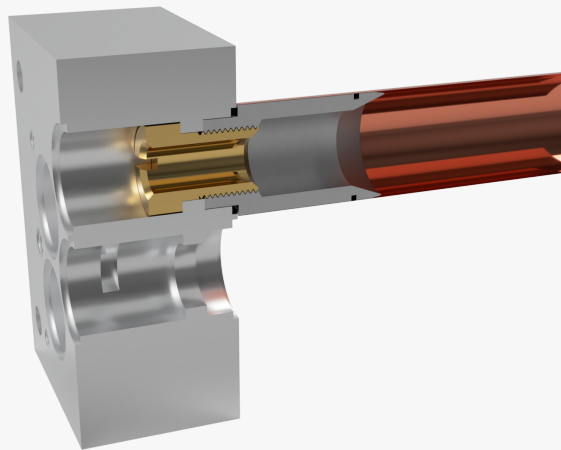
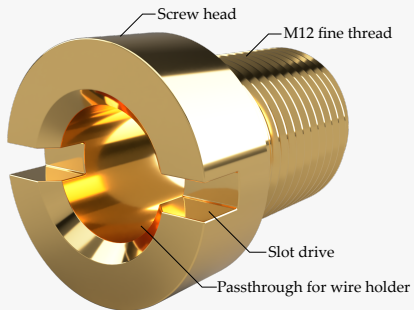


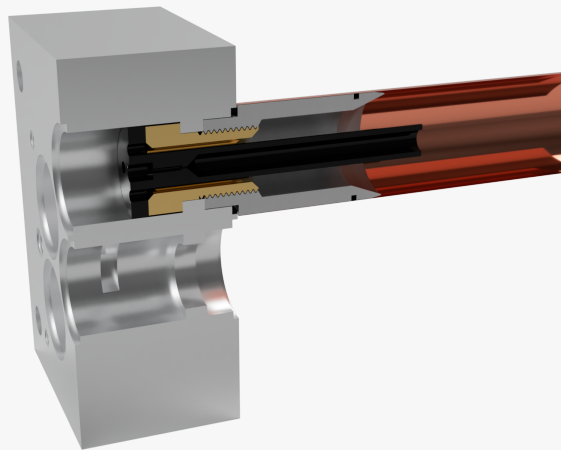
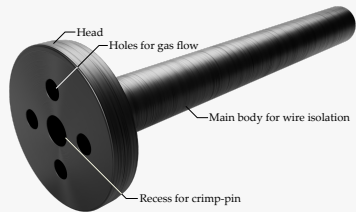
- Based on OPERA Experience

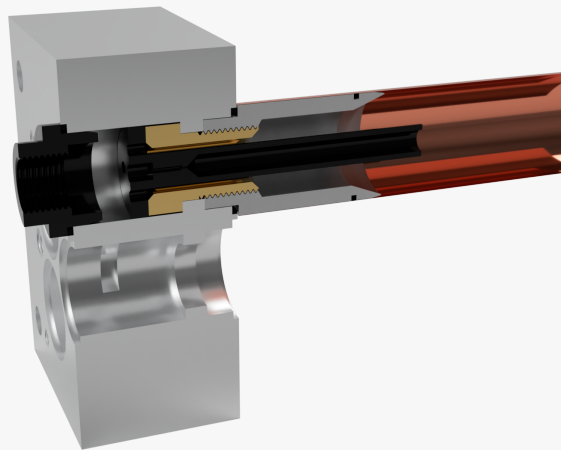
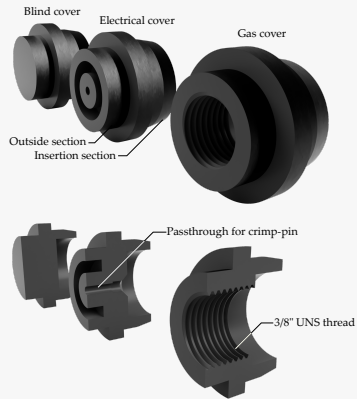




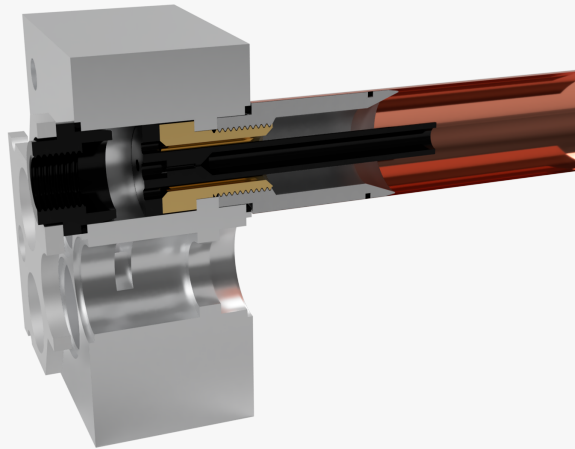
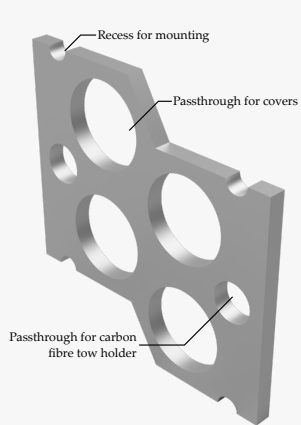




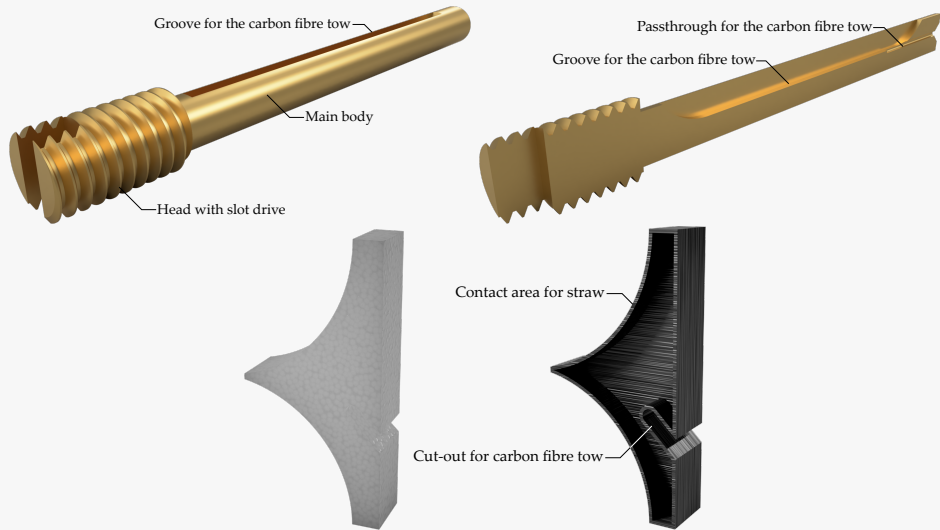




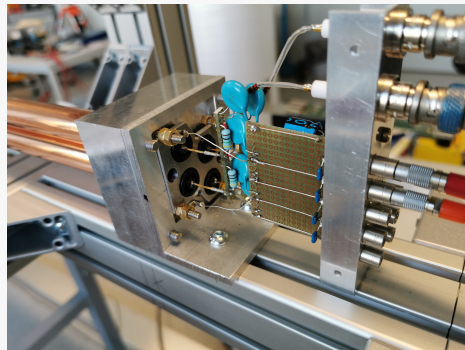
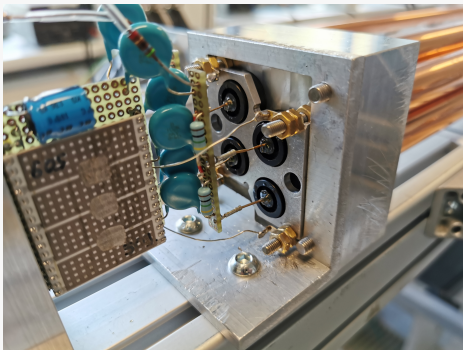
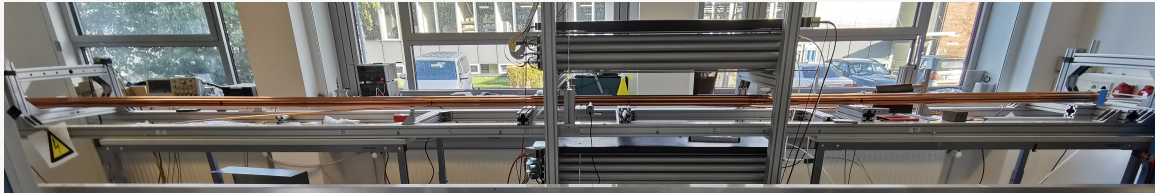
Installation of a Straw



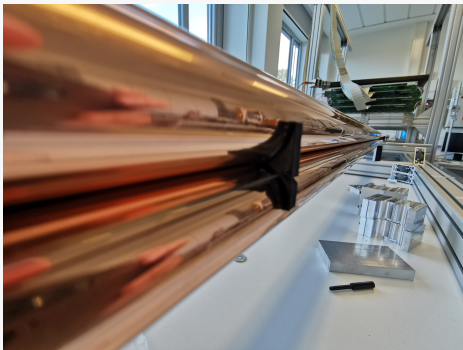
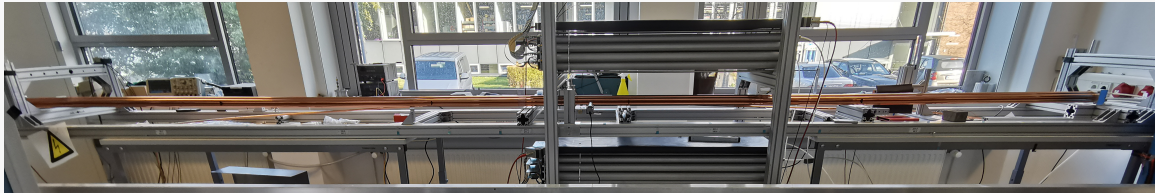
Adding the Suspension



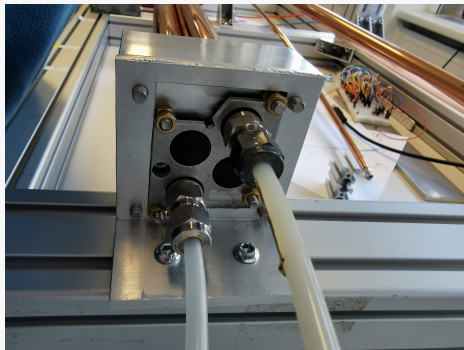
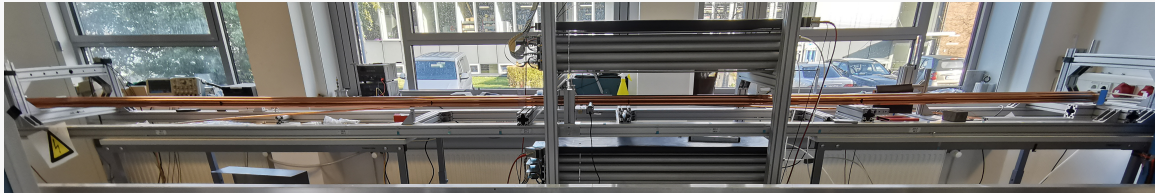
Prototype with Four Tubes

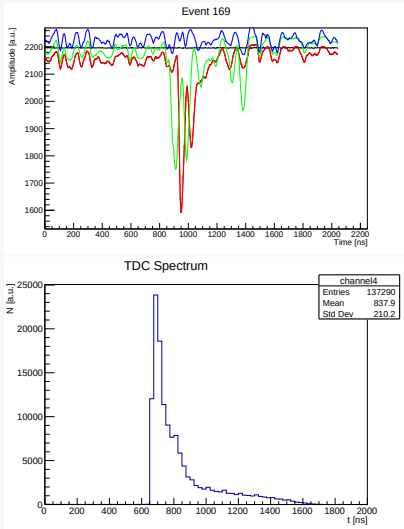


Prototype with Four Tubes



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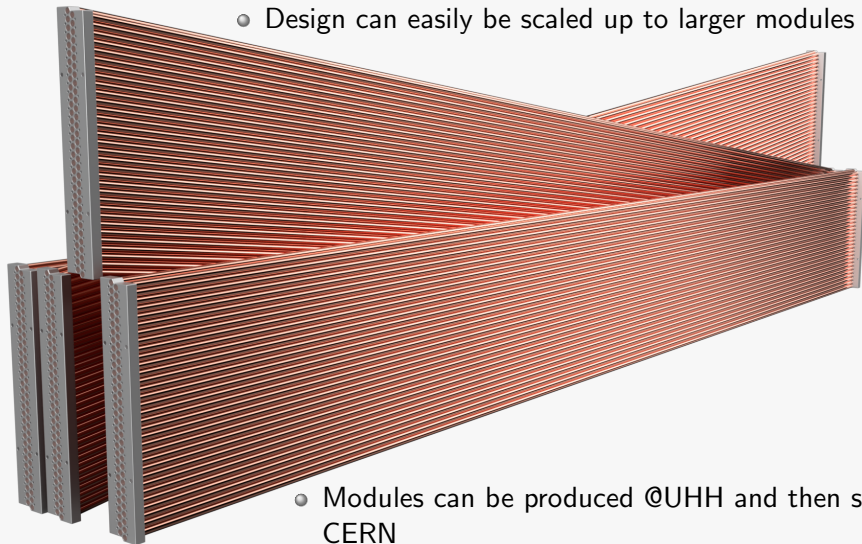




- Two different wire diameters ($30\ \mu\text{m}$ and $45\ \mu\text{m}$)
- Separate HV supply
- Signal amplified by L3 amplifier (used in OPERA)
- Signal readout by multi channel FADC
 - Auto trigger
 - External trigger (scintillators)
- Reference detector (former OPERA test modules)

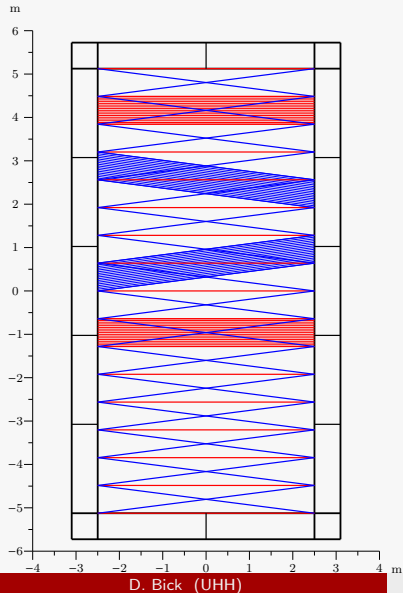
Future Steps

- Intensive testing with prototype
 - HV, wire diameters, gas, attenuation, ...
- Study impacts of varying tensions etc.
- Will include a spring to reduce nervousness



- Design can easily be scaled up to larger modules

- Modules can be produced @UHH and then shipped to CERN



- Modules for a stack of 32×2 tube in a view
- Stereo views: shift by one module height over the width
- Module can be mounted from the side into a frame

Active height	10.25 m
Active widths	5.0 m
Module height	64 cm
Straws per module	64
Sequence of 4 stereo views	<i>y-u-v-y</i>
Stereo angle	$127 \text{ mrad} = 7.3^\circ$
Horizontal modules per view	16
Stereo modules per view	15
Straws per station	3968
Total number of straws	15872

- Technology well suited but mechanics challenging
- Vivid R&D ongoing
- Alternative designs under study
 - converge to one design for TDR
- Working prototype @UHH
 - Concept based on well established technology from NA62 and OPERA
 - First ever working 5 m long prototype now operating in our lab
 - Concept documented in [CERN-SHIP-INT-2019-006](#)
 - Next step: design of a 64 strawtube module
- Rough design for a frame exists (more a proof of concept) → further work needed



FZJ (DE)



UHH (DE)



MEPhI (RU)



PNPI (RU)



SPPU (RU)



SCHOOL OF DATA ANALYSIS

YSDA (RU)



TSNU (UA)



JINR



CERN