# Muon TPC status

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# Reminder

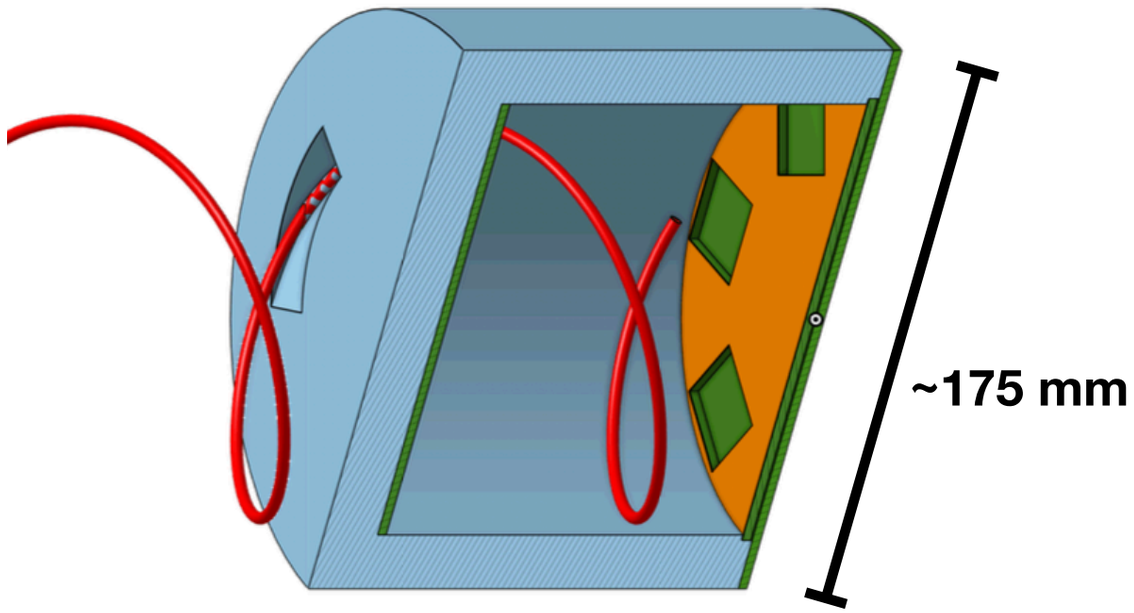
- We are developing a detector to characterize the muon trajectory at the injection, in the beam commissioning phase

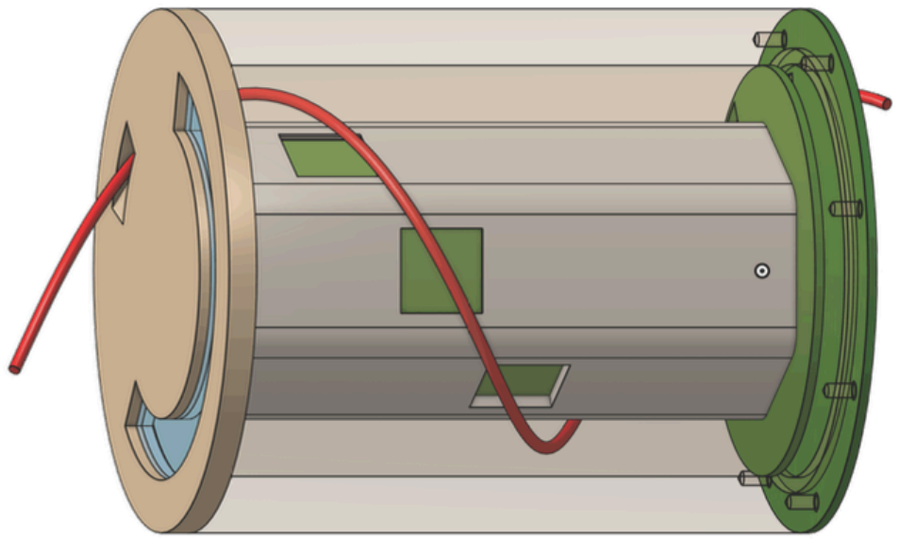
- Challenges:

  - very light
  - high granularity
  - high rate

- Proposed technology:

  - gas TPC with GridPix readout
  - 2 geometries under study (conventional & radial)



# Challenges and R&D plans

- High-rate capabilities of the GridPix
  - tests with a high-activity x-ray source
- Possibility of operating at sub-atmospheric gas pressure for reduced ionization rate and MS
  - tests with a dedicated prototype
- Mounting of thin Silicon Nitride entrance windows
  - design and tests in collaboration with Silson Ltd

# R&D Status

- In December, we had an accident with the GridPix sensor used for previous tests

  - broken HV connection and further damage of the mesh in a recent attempt to fix it

- While waiting for a new sensor (schedule unclear):

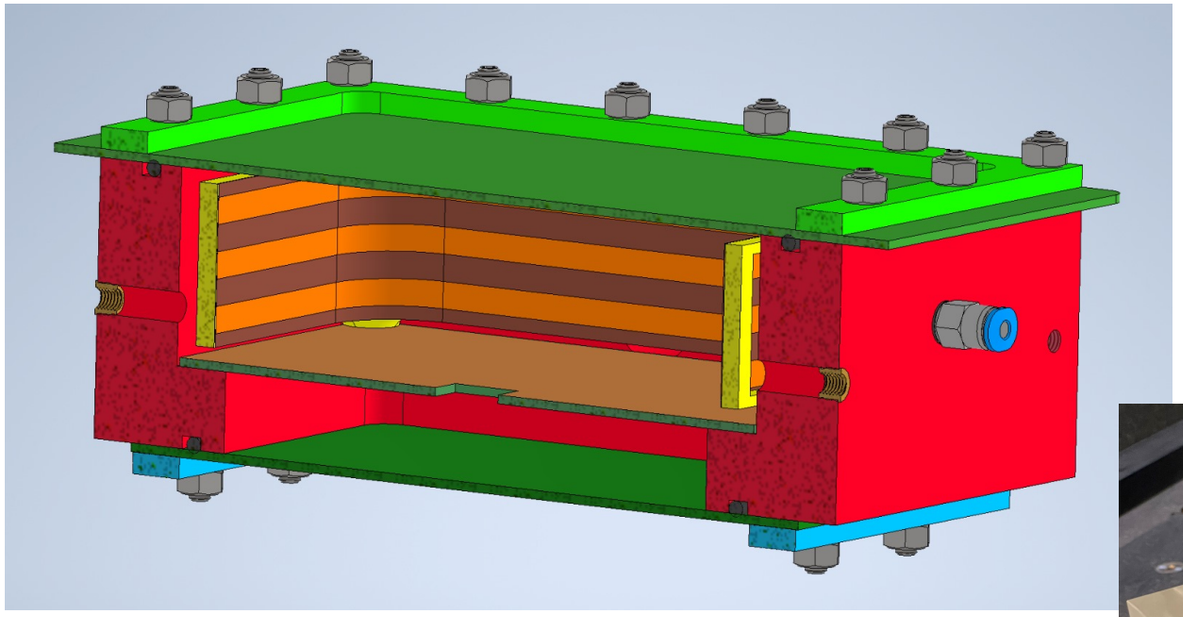
  - preparation of a prototype for low-pressure tests (design completed, construction ongoing)

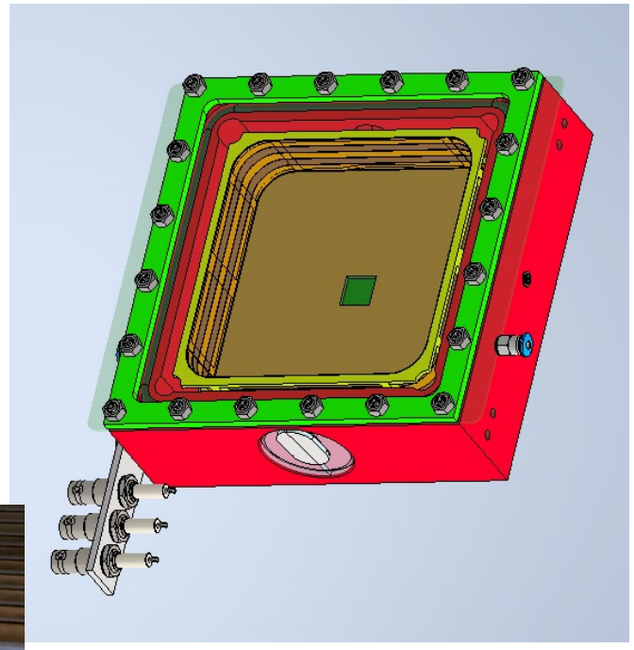
  - design of the mechanical supports for the final detector (started)

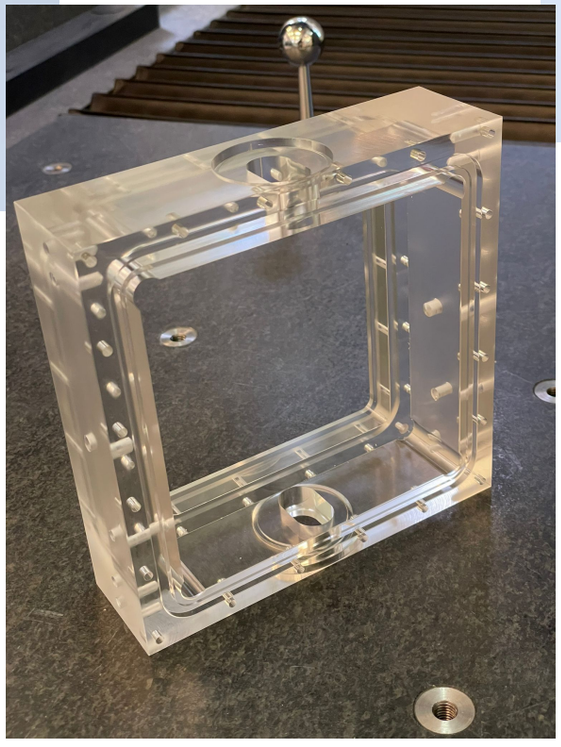
*N.B. procurement of the GridPix in the short term is a problem because of no recent productions, but a new production facility in Bonn is almost ready and it should guarantee the procurement for the construction of the final muTPC*

# Prototype

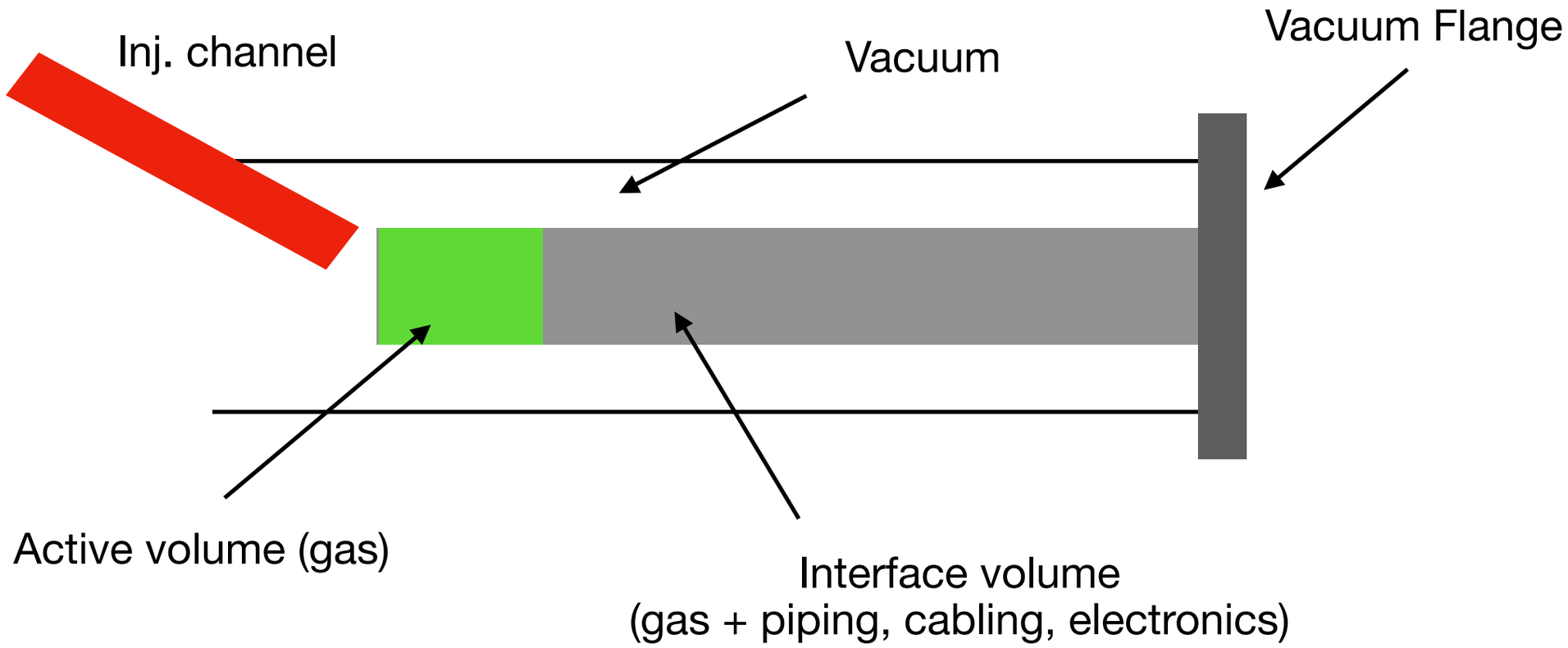
- We are preparing a small GridPix TPC, to be used for further gas mixture characterization and low-pressure studies





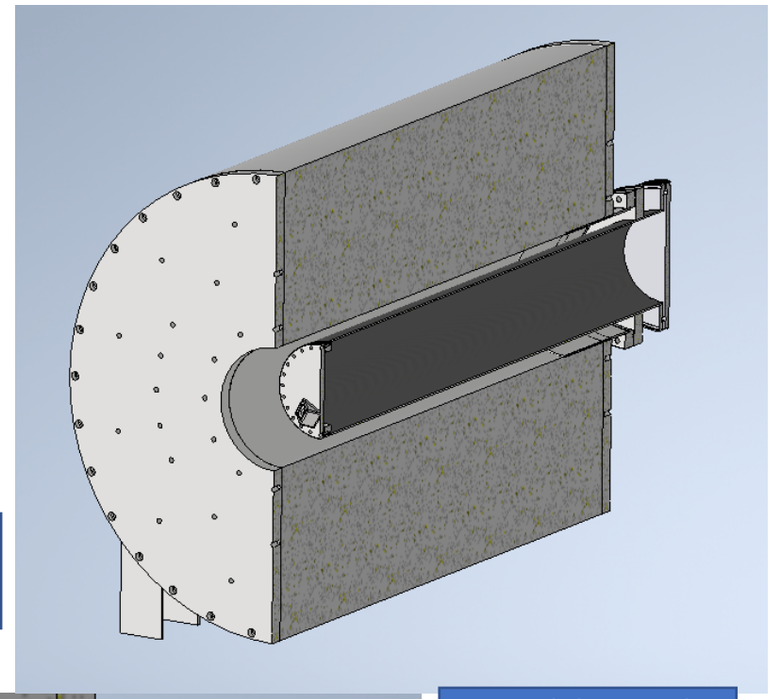


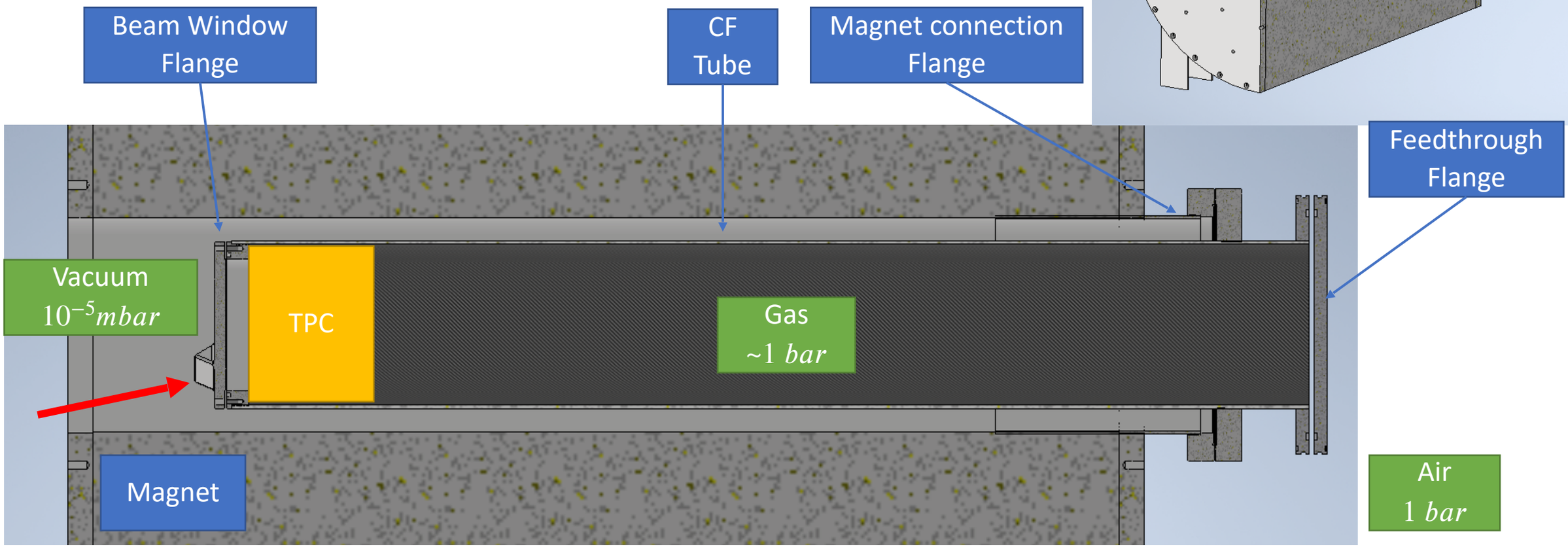
# Detector design and integration



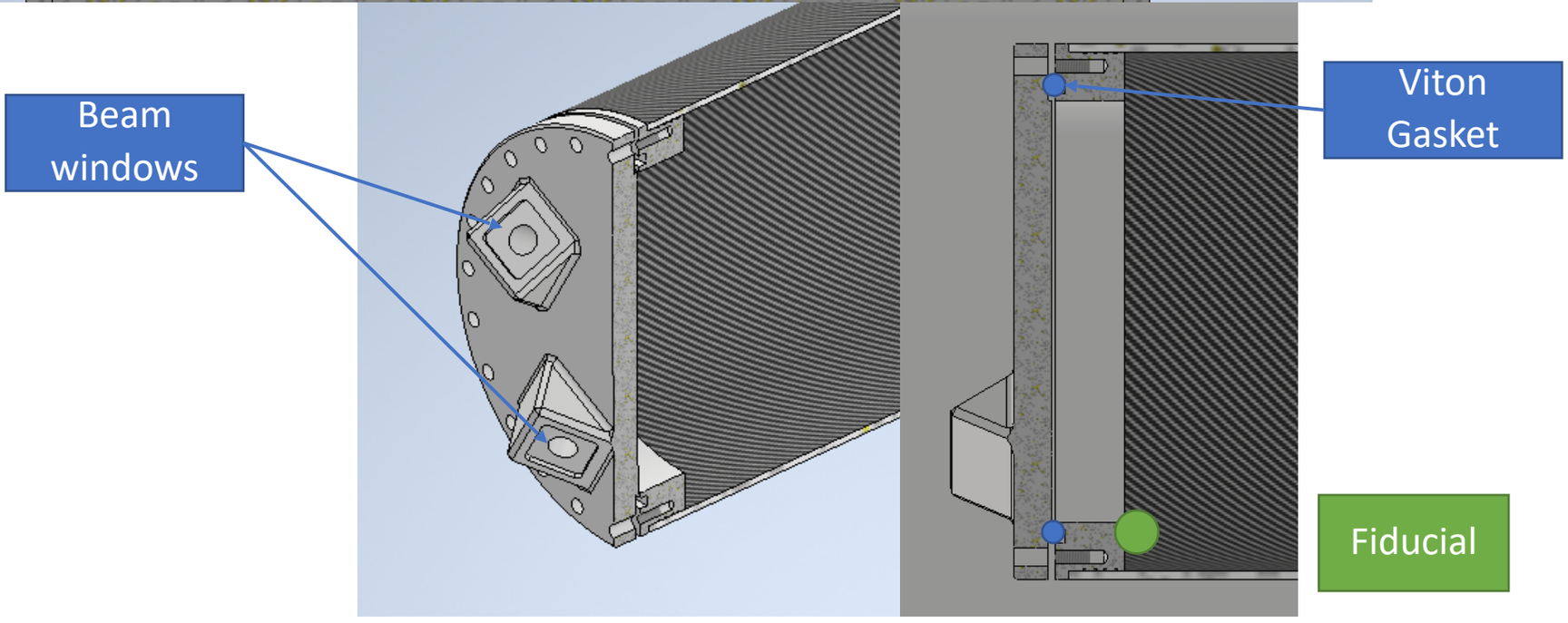

- Max. overall outer radius: 75 mm (80 mm minus some margin)
- Optimal inner radius of the active volume: 65 mm (beam envelope)
- Anchoring and vacuum sealing at Z = + 500 mm (on downstream side)
- Entrance of active volume at Z = -395 mm (where CW and CCW trajectories cross)
- Z > -450 mm, including external structures (flanges, windows, etc.)

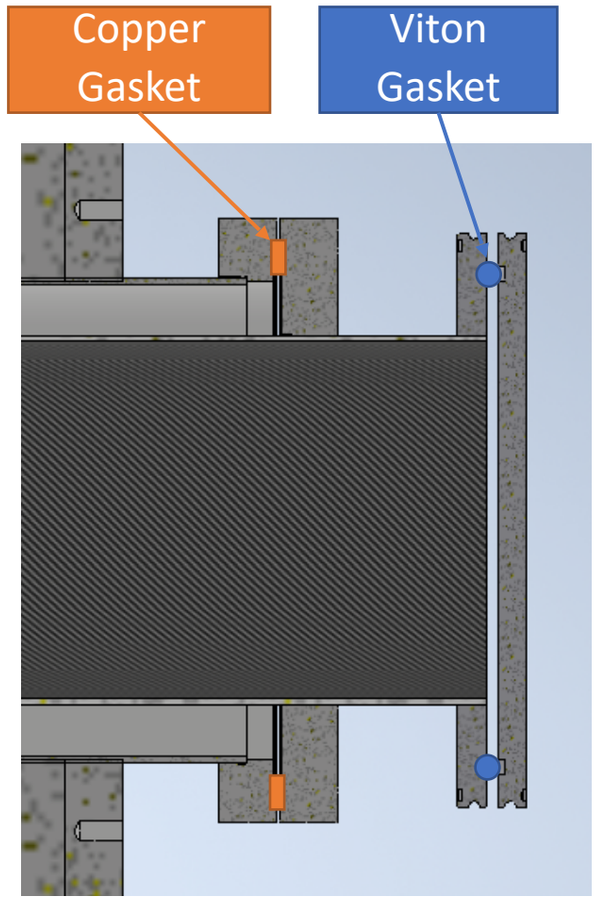
# TPC sketch




Beam Window Flange
CF Tube
Magnet connection Flange
Feedthrough Flange
Vacuum $10^{-5} mbar$
TPC
Gas ~1 $bar$
Magnet
Air 1 $bar$

# Some details

# Discussion

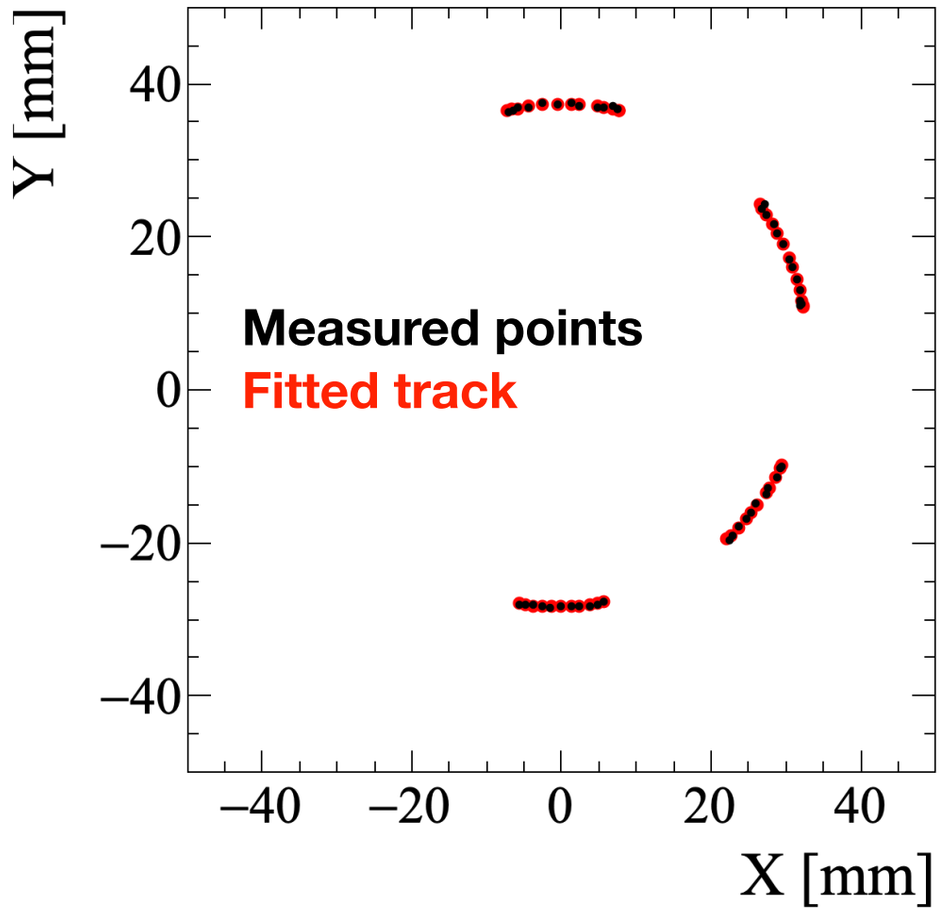
- Some delay in R&D due to an accident with the GridPix sensor
- Waiting for a new sensor, we are going on with prototype construction and design activities
- Interaction with PSI technicians will be needed in the next future to better define the integration with the PSC magnet (flanges, sealings, etc.)

# Backup

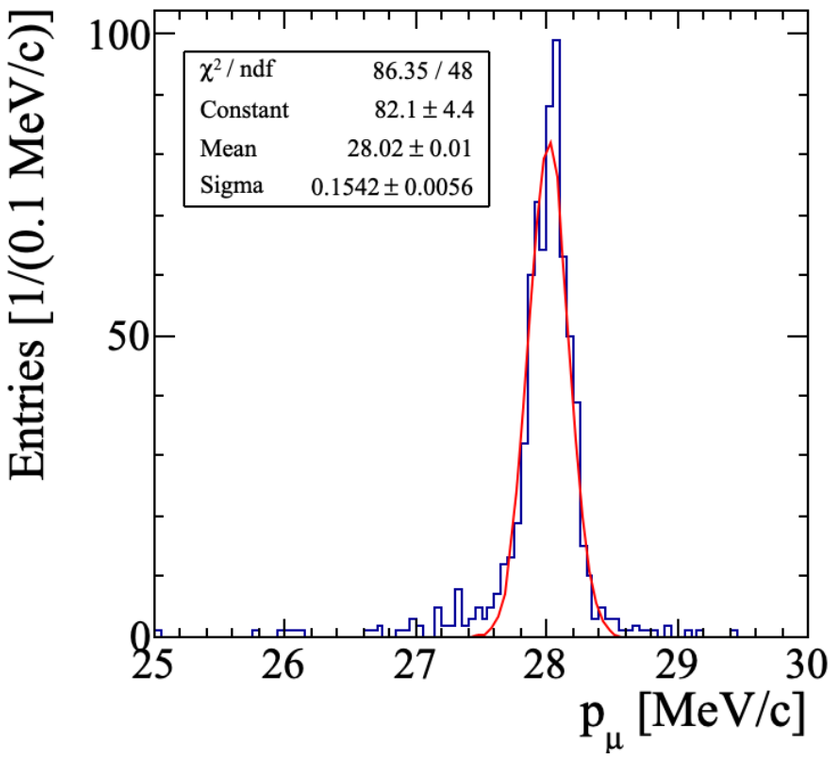
# Simulations

CAVEAT: still using the BEN magnet field

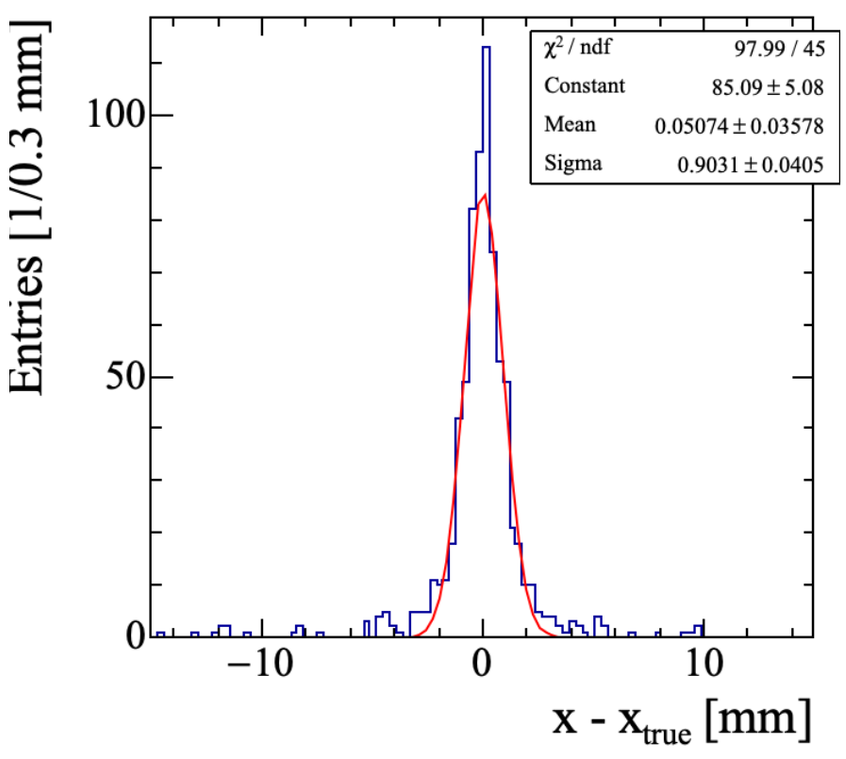
- Preliminary simulation for the **radial configuration** with He:$C_4H_{10}$ (90:10) @ 0.4 bar, with inputs from the 2022 beam test results:
  - 0.5% momentum resolution can be almost achieved also in this configuration
  - angular resolution suboptimal for a full characterization of the phase space, but should be ok for alignment purposes



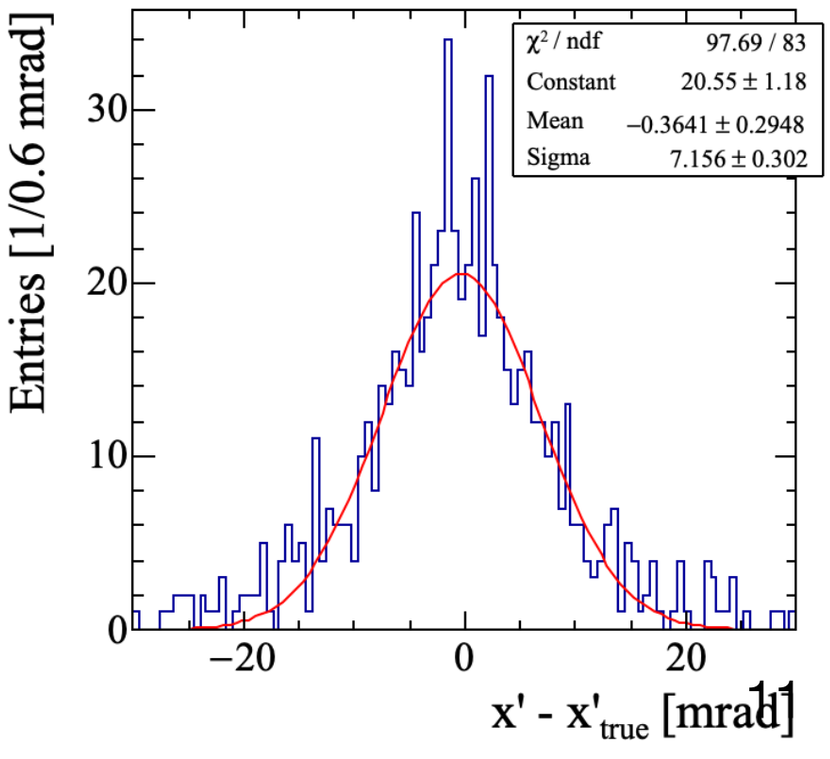

σ = 0.55%




σ = 0.9 mm



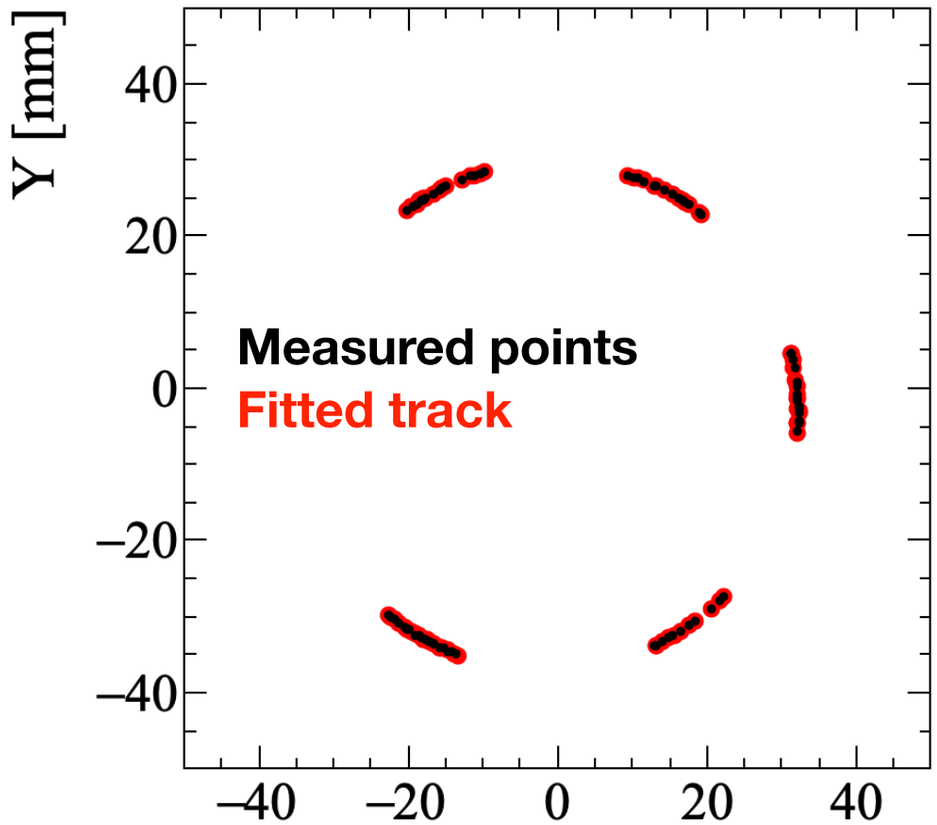

σ = 7.2 mrad



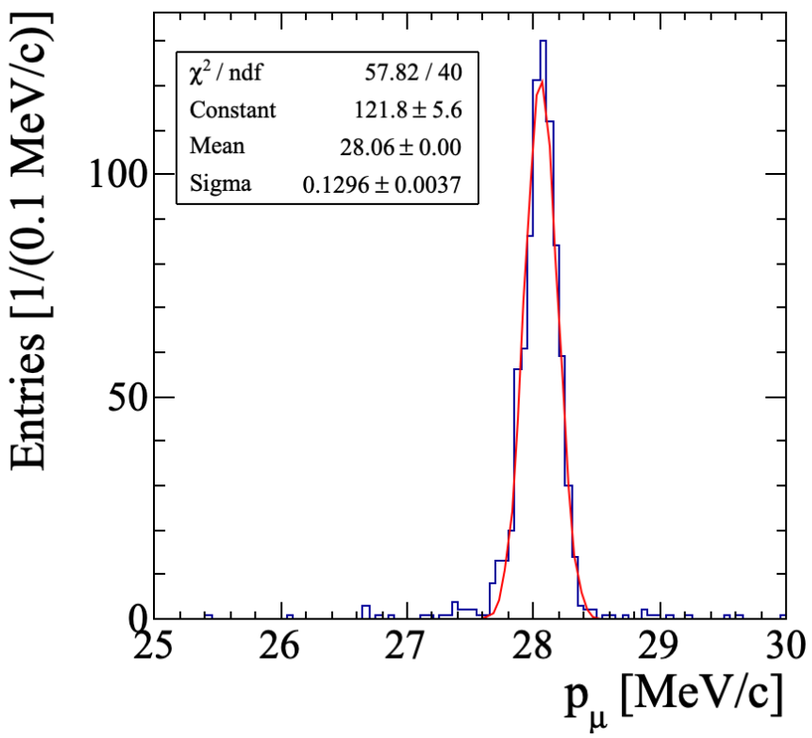
# Simulations

CAVEAT: still using the BEN magnet field

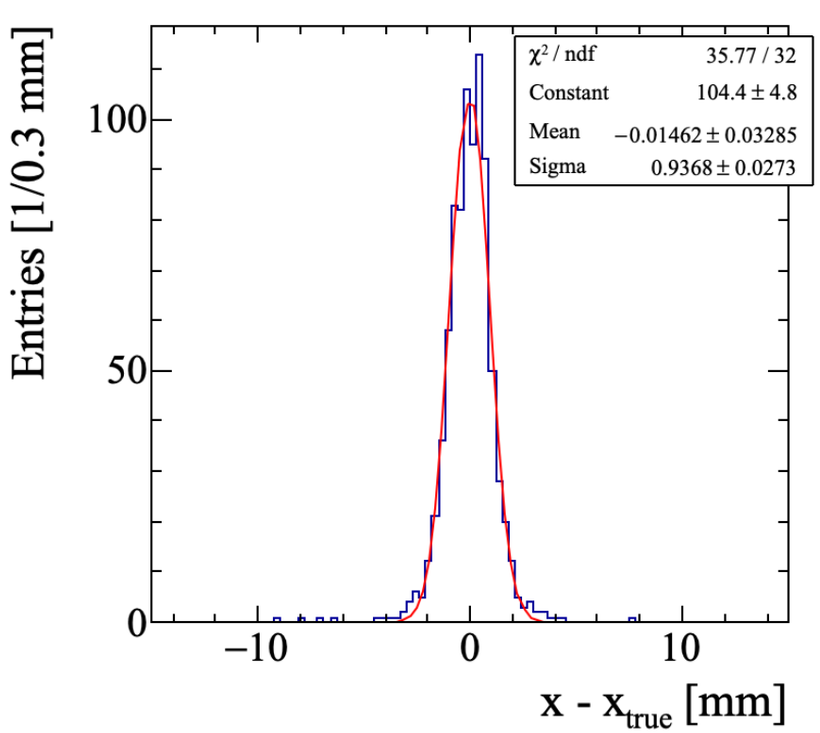
- Preliminary simulation for the **longitudinal configuration** with He:$C_4H_{10}$ (90:10) @ 0.4 bar, with inputs from the 2022 beam test results:
  - 0.5% momentum resolution can be almost achieved also in this configuration
  - angular resolution suboptimal for a full characterization of the phase space, but should be ok for alignment purposes



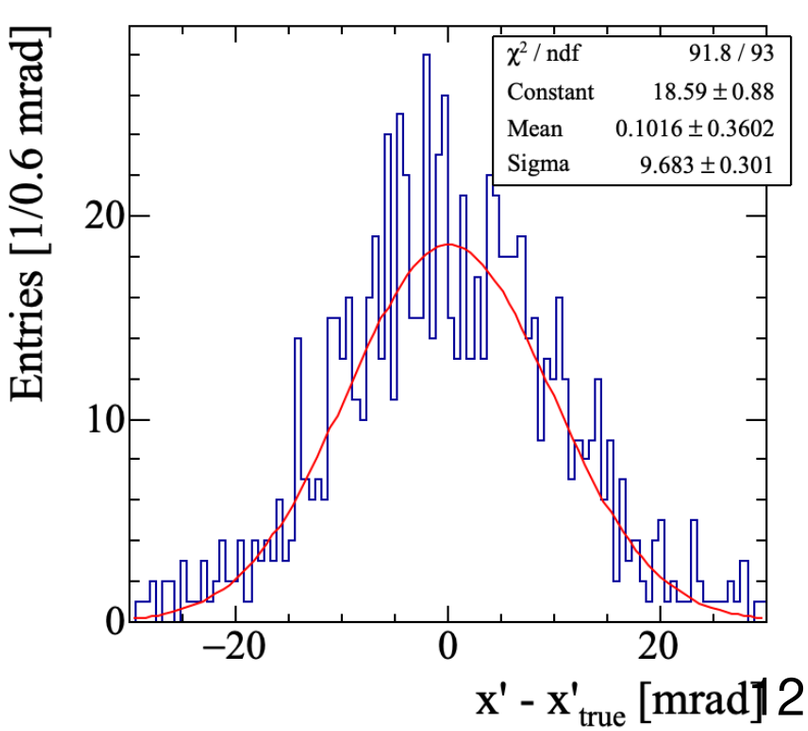

**σ = 0.46%**




**σ = 0.94 mm**



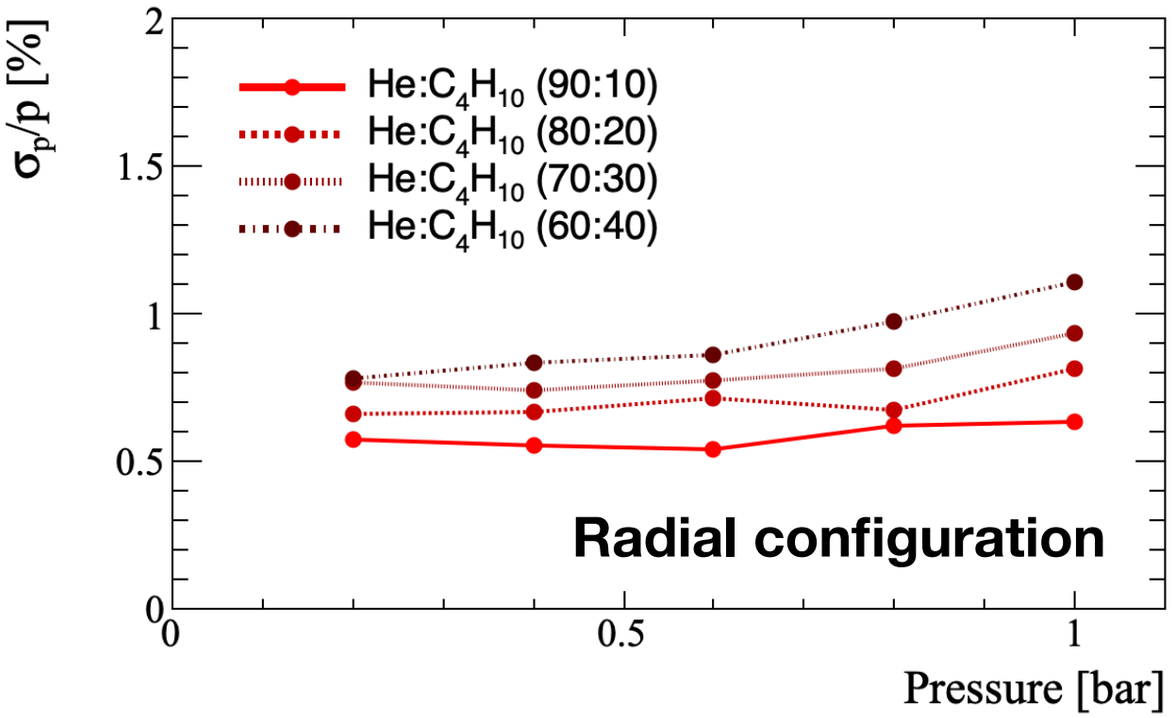

**σ = 9.7 mrad**

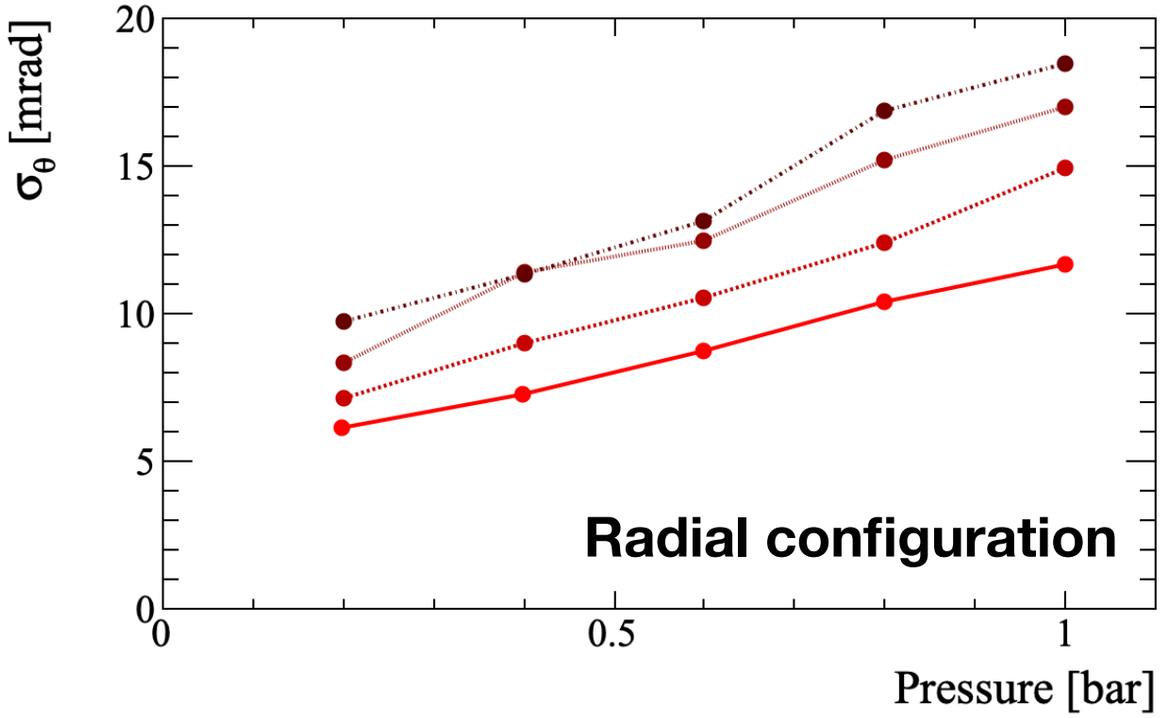


# Simulations

CAVEAT: still using
the BEN magnet field

- Angular resolutions are dominated by the multiple scattering in the gas (with subleading contributions from electron diffusion in the gas and scattering in the entrance window):
  - try with **subatmospheric pressure** (to be tested later this year)
  - diffusion worsens and hit rate drops significantly with lower pressure, there could be an optimum of around 0.5 bar



# Possible issue at high rate

- The GridPix has a spark protection layer, on top of the TimePix chip, with ~10 GOhm resistance
  - acts as a resistor in series to the detector capacitance
  - at high rates, the induced currents generate a drop in the GridPix voltage —> gain drop
- In July 2022 the GridPix was tested up to ~ 20 nC/s
  - visible loss of gain, but small impact on efficiency
  - expect ~ 20x more in the muEDM precursor experiment —> effect can be relevant
- Possible countermeasures:
  - work at low pressure (reduced ionization)
  - gas additives to increase the surface conductivity
  - in the very worst case, we could be forced to change the readout technology (e.g. standard Micromegas)

# Longitudinal vs. Radial

- Longitudinal geometry provides best resolution along x-y
  - best option to measure muon momentum
  - conventional geometry, simpler to build and operate
- Radial geometry provides best resolution along z-$\varphi$
  - best option to measure muon angles
  - unconventional geometry, more difficult to build, relevant difficulties in event reconstruction due to large E x B effects
- Spoiler: resolution differences are mitigated in presence of multiple scattering, making the two options equivalent
  - we are concentrating on the simpler longitudinal option