Studies of straw tube aging

- Results of aging tests of FT straws performed so far
- Aging of the LHCb straw tubes
- Conclusions and further steps

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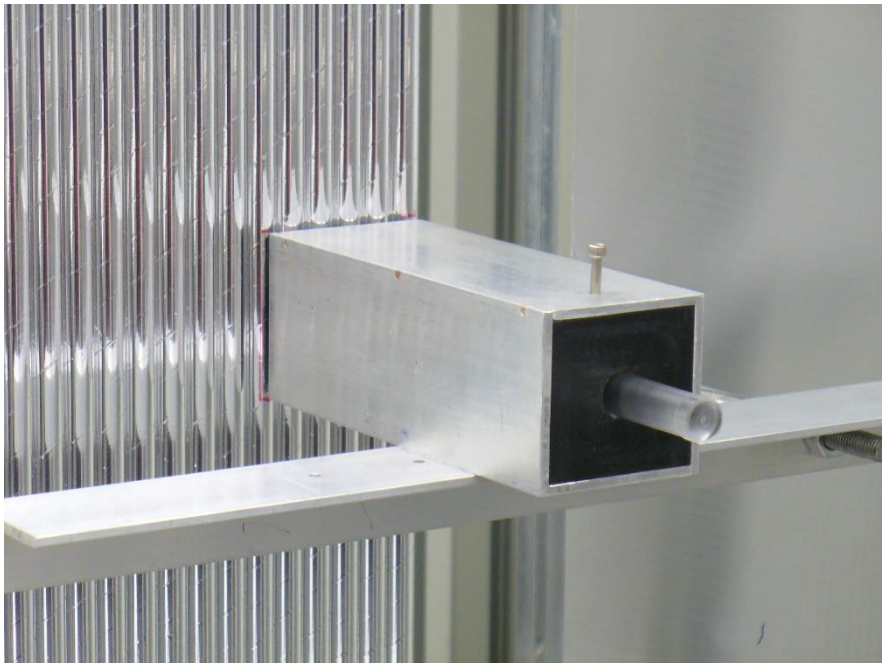
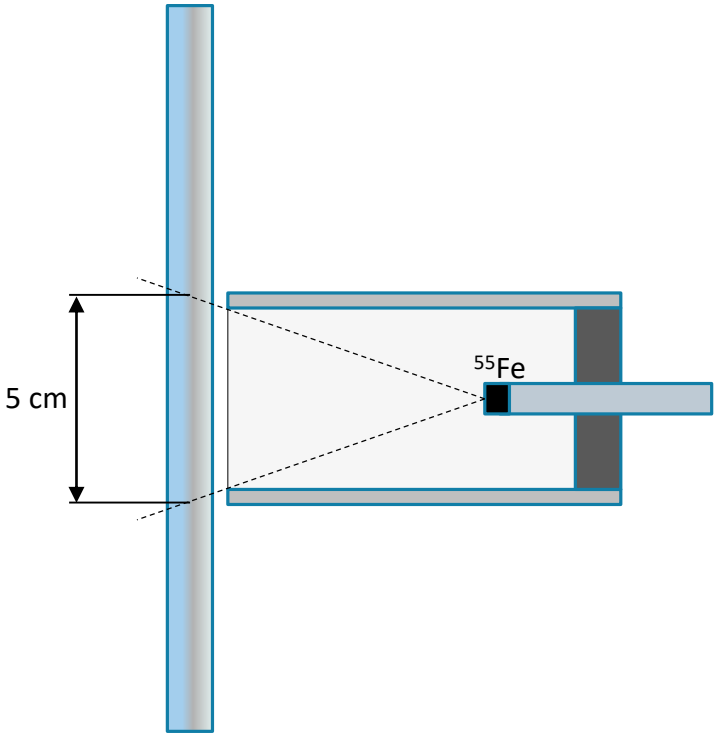
1st aging test (spring 2019)

- Collimated ^{55}Fe source
- 4 straws irradiated, each on a length of 5 cm
- Irradiation period 44 days, accumulated charge 0.36 C/cm





Operating conditions and monitored parameters

Operating conditions:

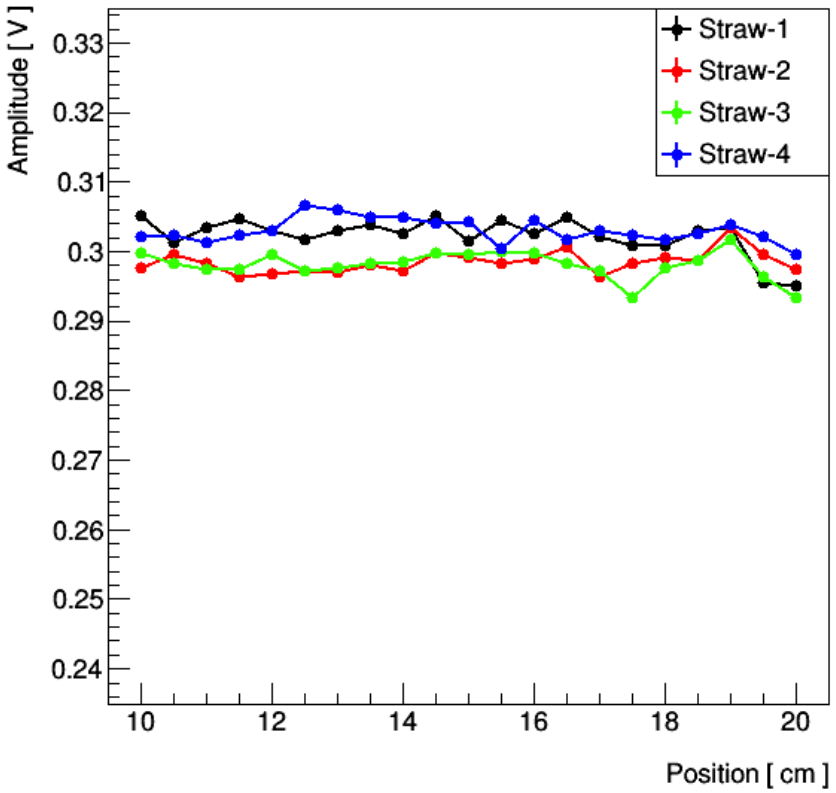
- Gas mixture: Ar+CO_2 (90:10) at 2 bar
- Gas flow: 1 volume exchange/hour
- HV: 1850 V, gas gain: ~5×10^4

Monitored:

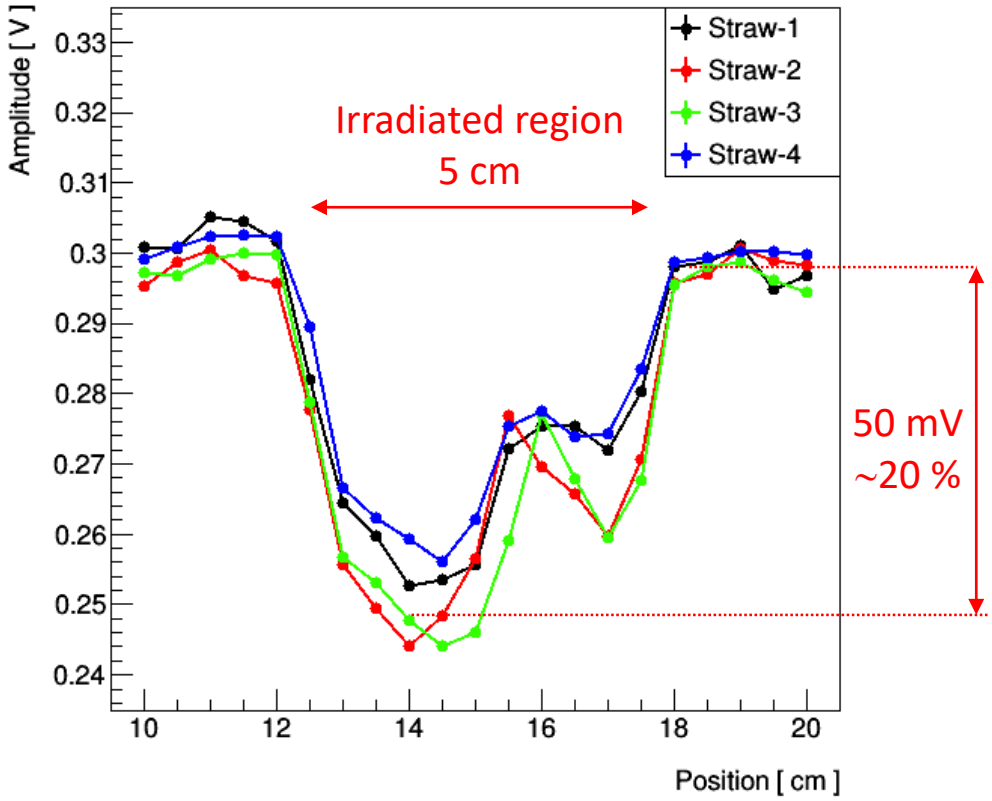
- Rate: ~ 300 kHz/straw (~ 60 kHz/cm) registered with the TRB
- Current: ~ 500 nA/straw monitored with precision of 0.1 nA
- Amplitude of pulses: monitored with a scope
- Amplitude of pulses as a function the position along the straw was measured for accumulated charges: 0.0, 0.085, 0.194 and 0.36 C/cm

Amplitude vs. coordinate along straw

New (Q/l = 0 C/cm)

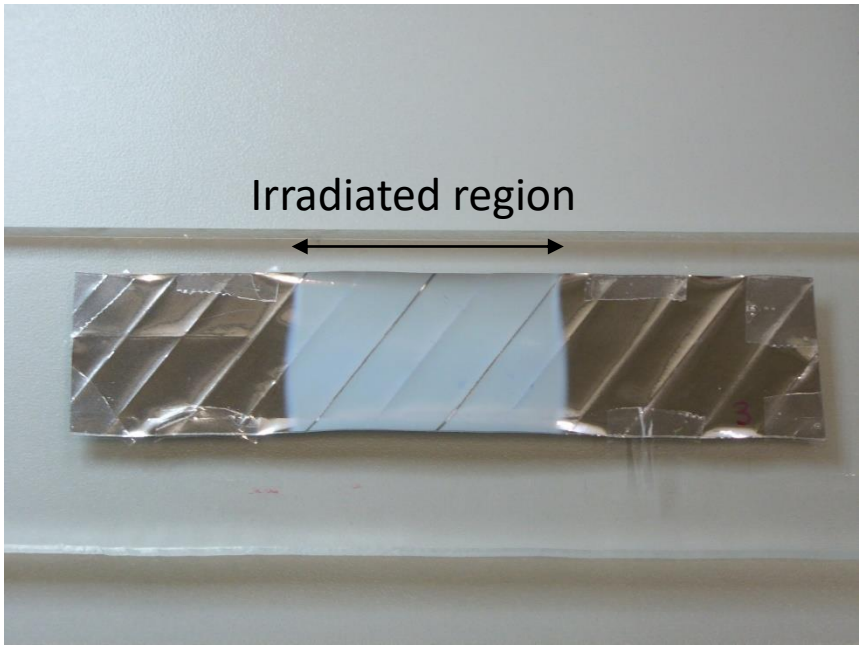


Irradiated (Q/l = 0.36 C/cm)

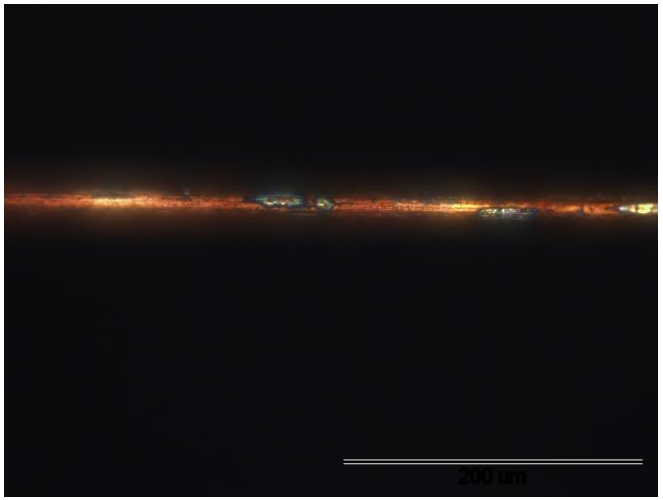


Deposits on straw and on anode wire

Irradiated **straw material**



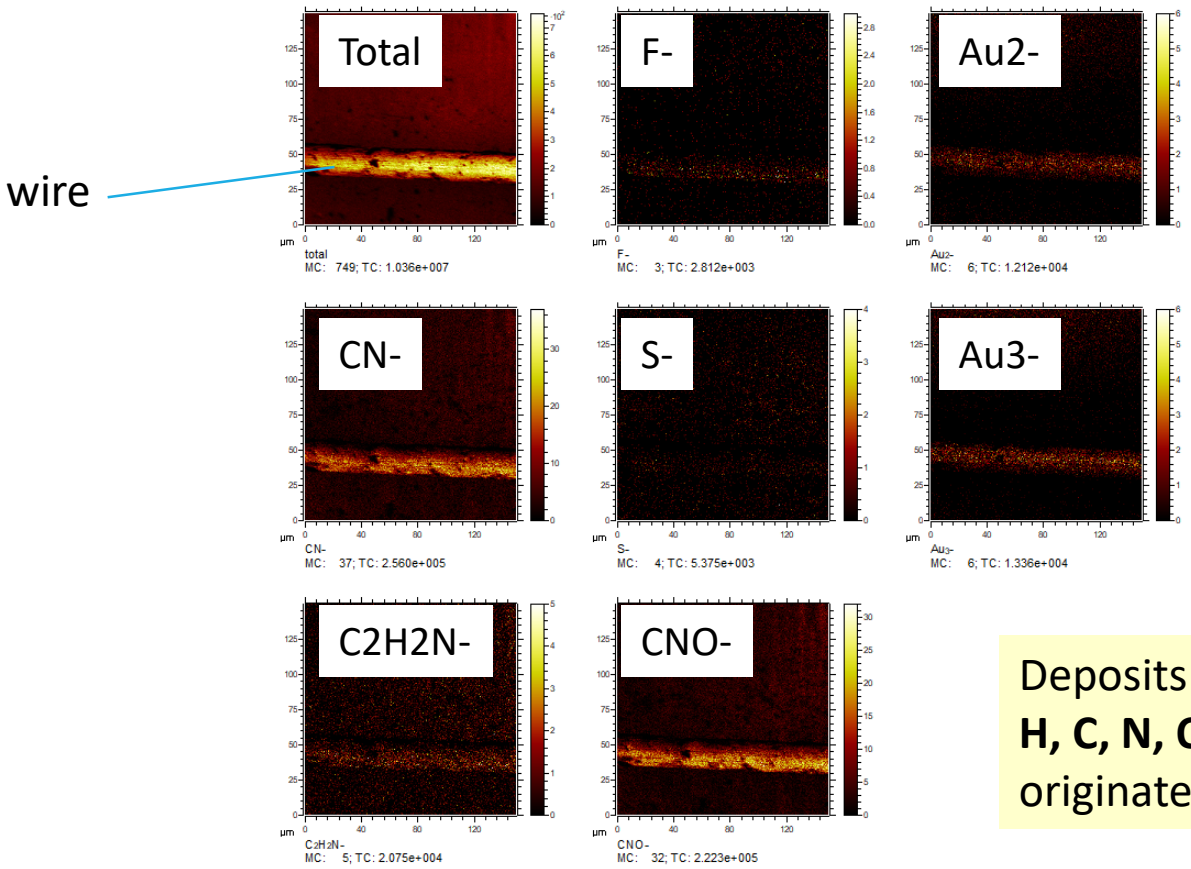
Irradiated **anode wire**



New

Analysis of deposits by TOF-SIMS

- Deposits on the irradiated wires and on the Mylar foil were analyzed by the TOF-SIMS (Time Of Flight - Secondary Ion Mass Spectrometry).



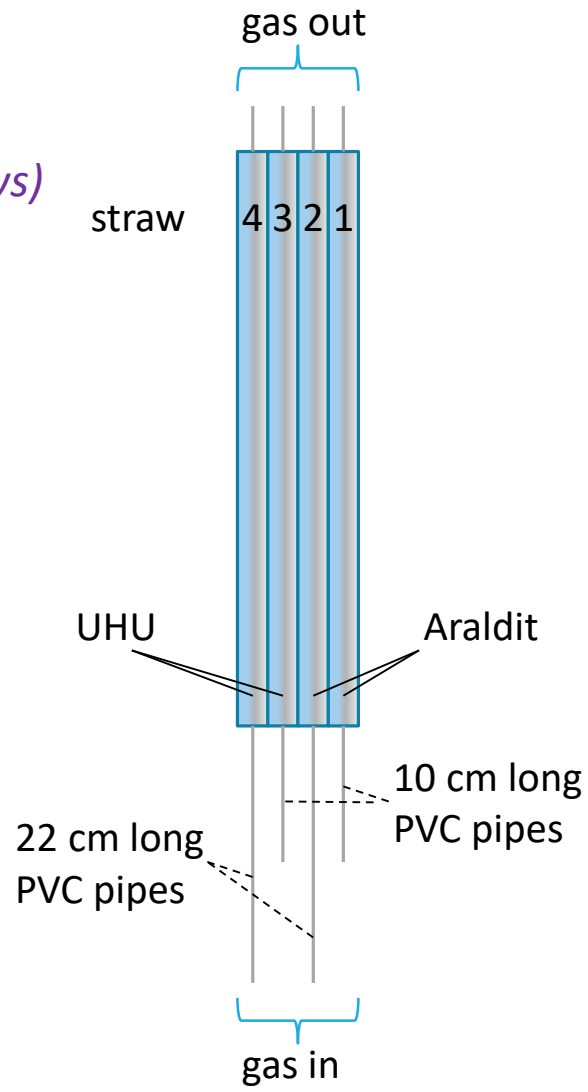
Deposits on wires contain **H, C, N, O** atoms which can originate from **organic compounds**

Organoleptic check of irradiated straws

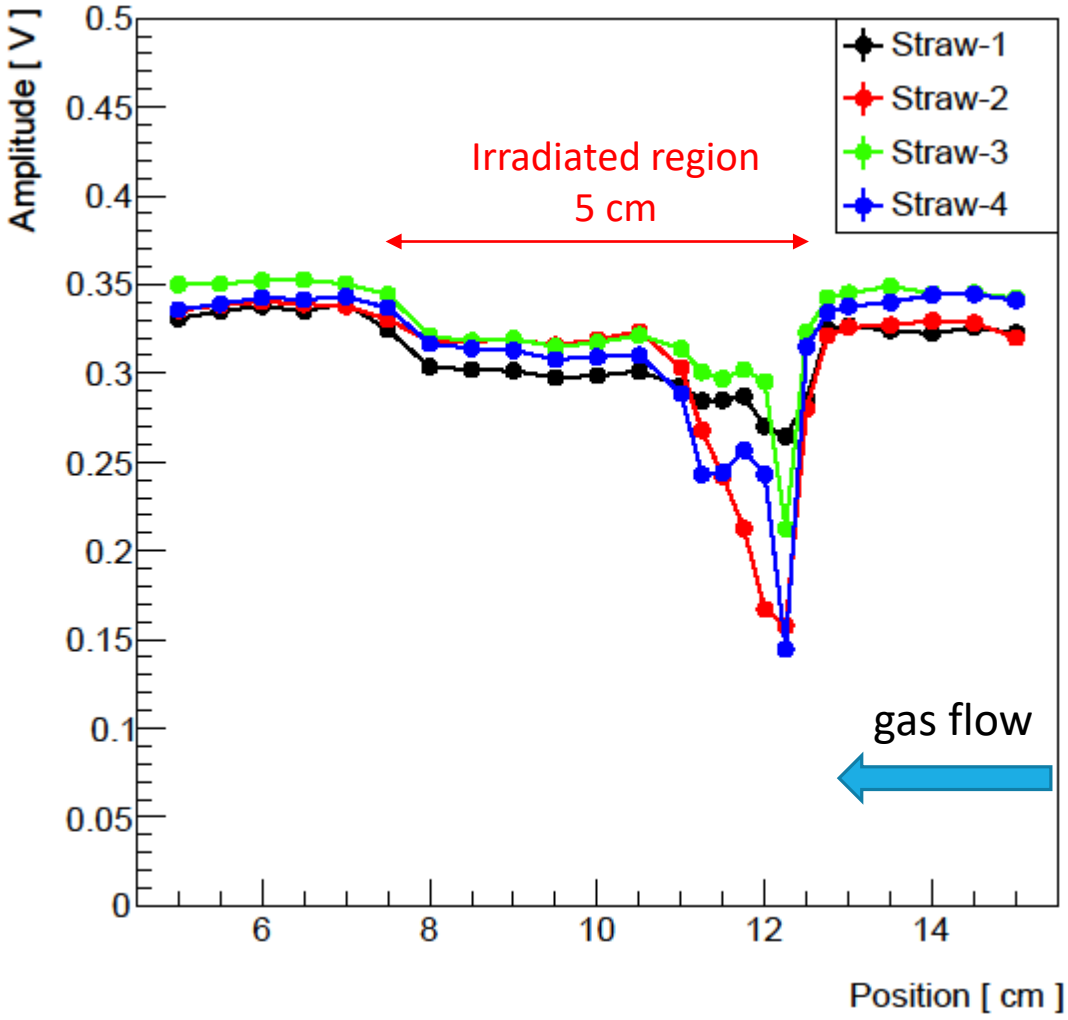
Two component epoxy adhesive **UHU Endfest 300** used to glue the end plugs into straws turned out to have sticky surface. This shows that the ingredients have not been properly bonded **(expired adhesive ?)**

2nd aging test (spring 2020)

- 2 straws glued with **UHU Endfest 300** *(used so far)*
- and another 2 with **Araldit AY103-1 + hardener 991**
  (epoxy adhesive used in the LHCb Outer Tracker straws)



Amplitude vs. position for Q/l= 0.63 C/cm



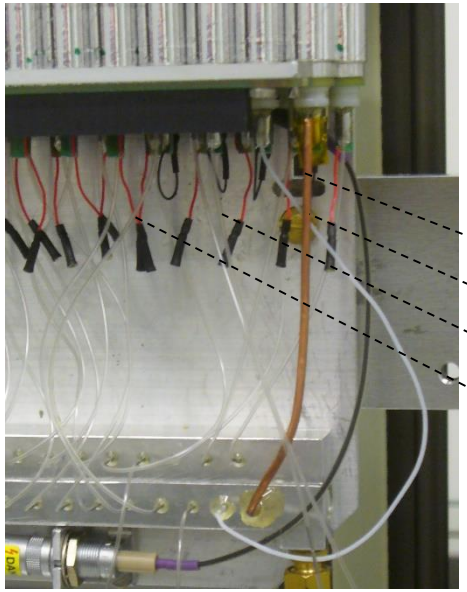
PVC pipe	Glue
long	> Araldit
short	
long	> UHU
short	

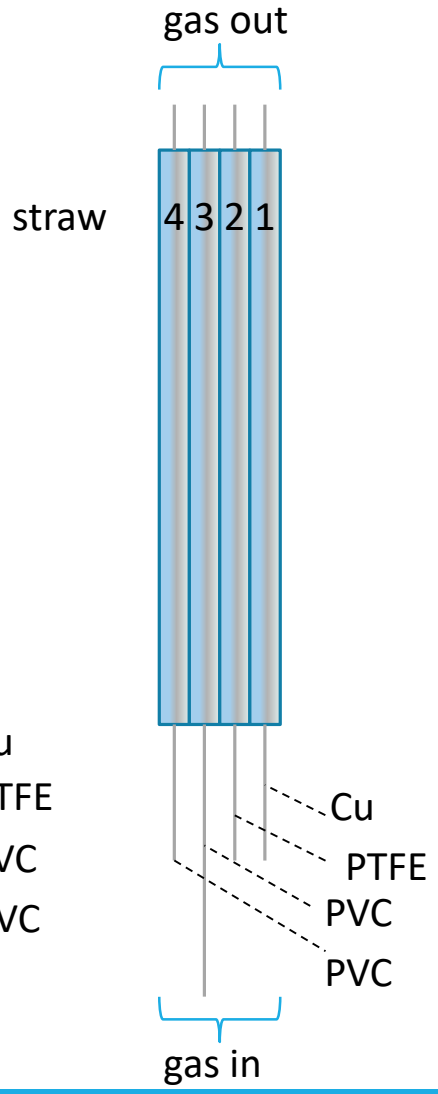
- larger amplitude drop upstream of the gas flow
- larger amplitude drop for shorter PVC pipes (higher gas flow)
- no significant difference between UHU and Araldite

3rd aging test (autumn 2020)

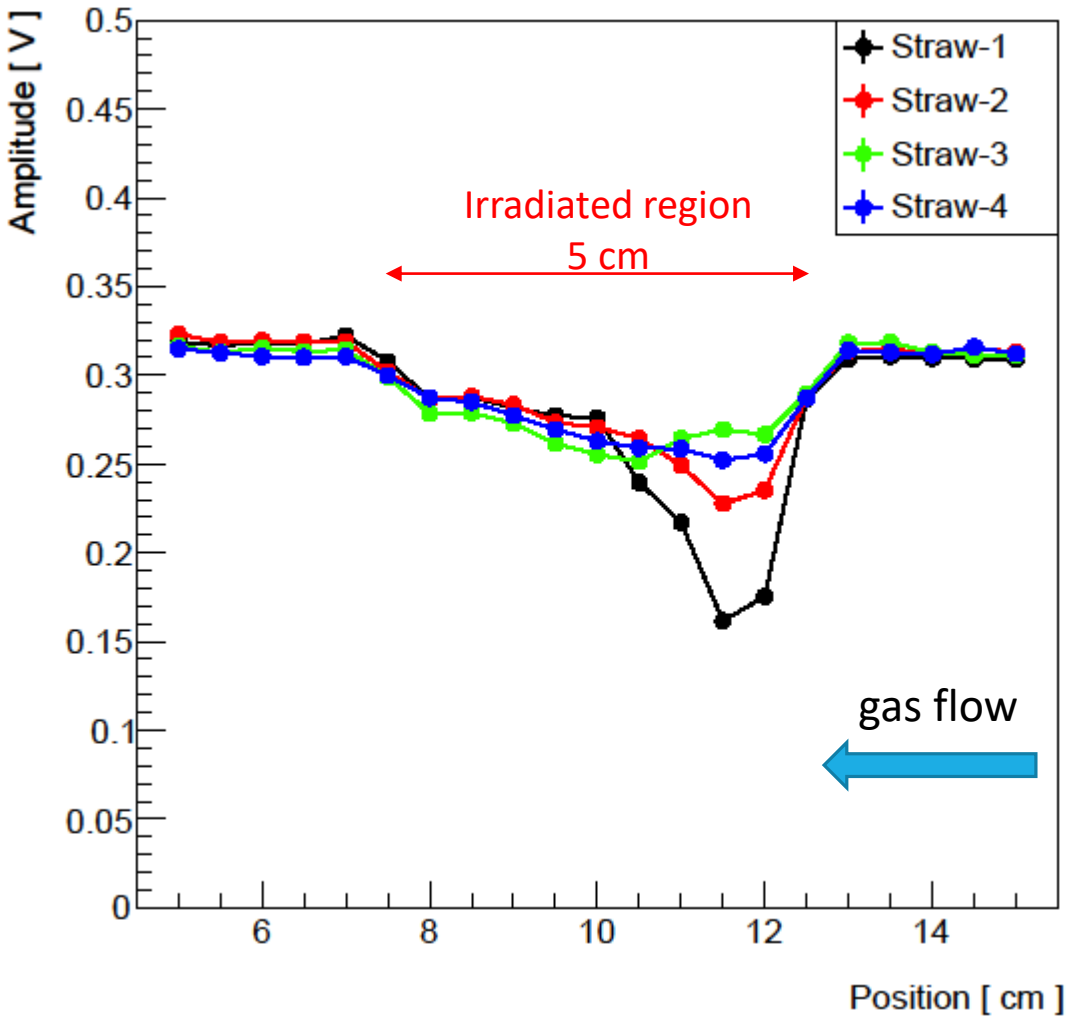
- straws glued with **Araldit AY103-1 + hardener 991**
- gas pipes used at the inlet to the straw:
  - Straw 1 - **copper capillary tube (Øin = 0.6 mm)**
  - Straw 2 – **PTFE (Teflon) tube (Øin = 0.56 mm)**
  - Straw 3 – **PVC tube (Øin = 0.5 mm) l = 24 cm**
  - Straw 4 – **PVC tube (Øin = 0.5 mm) l = 12 cm**

> the same gas flow





Amplitude vs. position for Q/l= 0.36 C/cm



gas pipe

Cu

PTFE

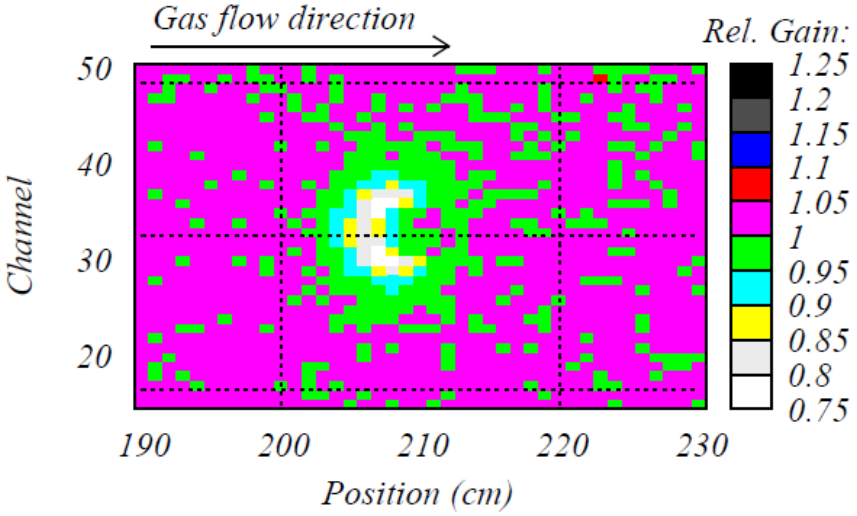
PVC

PVC

- no significant difference between PTFE and PVC pipes
- amplitude drop larger for Cu pipe (due to higher gas flow or higher contamination by outgassing from Araldite?)

Aging of the LHCb straw tubes

- Straw tubes: Ø 4.9 mm, 25 μm W/Au wire, Ar-CO2 (70%-30%)
- Gluing and sealing of the straws with Araldite AY103-1 +hardener HY991
- Detected aging at moderate intensities in laboratory tests (after straw mass production was completed)
- The gain loss up to 25% for integrated dose of 0.1 mC/cm at intensity of 2 nA/cm
- Aging upstream the source
- Lower gas flow- lower aging
- Wire inspection: deposits of carbon



position of the source

For more details see:
S. Bachman et al., NIM A617 (2010) 202,
N. Tuning et al., NIM A 656 (2011) 45

Cause of the aging in LHCb straws

- No aging observed for straws sealed with o-ring instead of the Araldite
- Also no aging for Araldite replaced by Tra-Bond 2115
- Outgassing of the araldite AY103-1 identified as the cause of observed aging (probably outgassing of plastifier: di-isopropyl-naphthalene contained in AY103-1).
- Negative correlation observed between the aging rate and the production of ozone.

LHCb OT aging remedies

- Adding ~1 % O_2 to Ar-CO_2 (increasing ozone concentration)
- Lowering gas flow (ozone is transported away more slowly)
- Longterm flushing the modules
- Heating the modules
- HV training

Conclusions and further steps

- The PVC pipes appear to be not responsible for the observed aging (replacing them with PTFE or Cu does not reduce aging).
- The observed effects - carbon deposits on wires, higher aging upstream the source and at lower gas flow – same as in LHCb straws.
- The Araldite AY103-1 was shown to be the cause of aging in LHCb straws. This probably also ahppens in our straws.

We plan:

- to check, if the HV training removes the deposits on wires (as in LHCb),
- glue straws with Tra-Bond 2115 and test them for aging.