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A new gas system for the Würzburg cosmic ray facility

Pipe Studies

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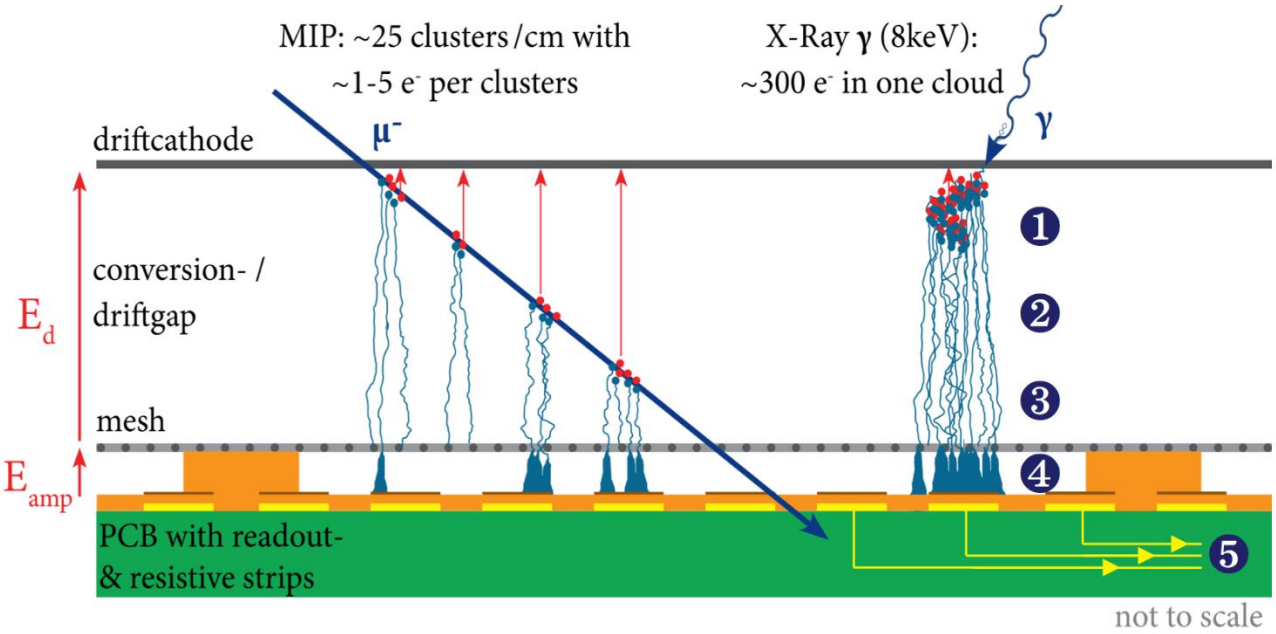
MOTIVATION

- RnD on gaseous particle detectors is being done in Würzburg
- Effects of small gas contaminations not yet fully investigated
- The new gas system will be able to regulate small concentrations of O_2 and H_2O (ppm to 1%) and measure them at the exhaust

Motivation – Effect on Performance

- Both Water and Oxygen influence the detector performance
  - Oxygen is highly electronegative and free electrons can get lost due to attachment to it
  - Water influences the high-voltage stability of the detector

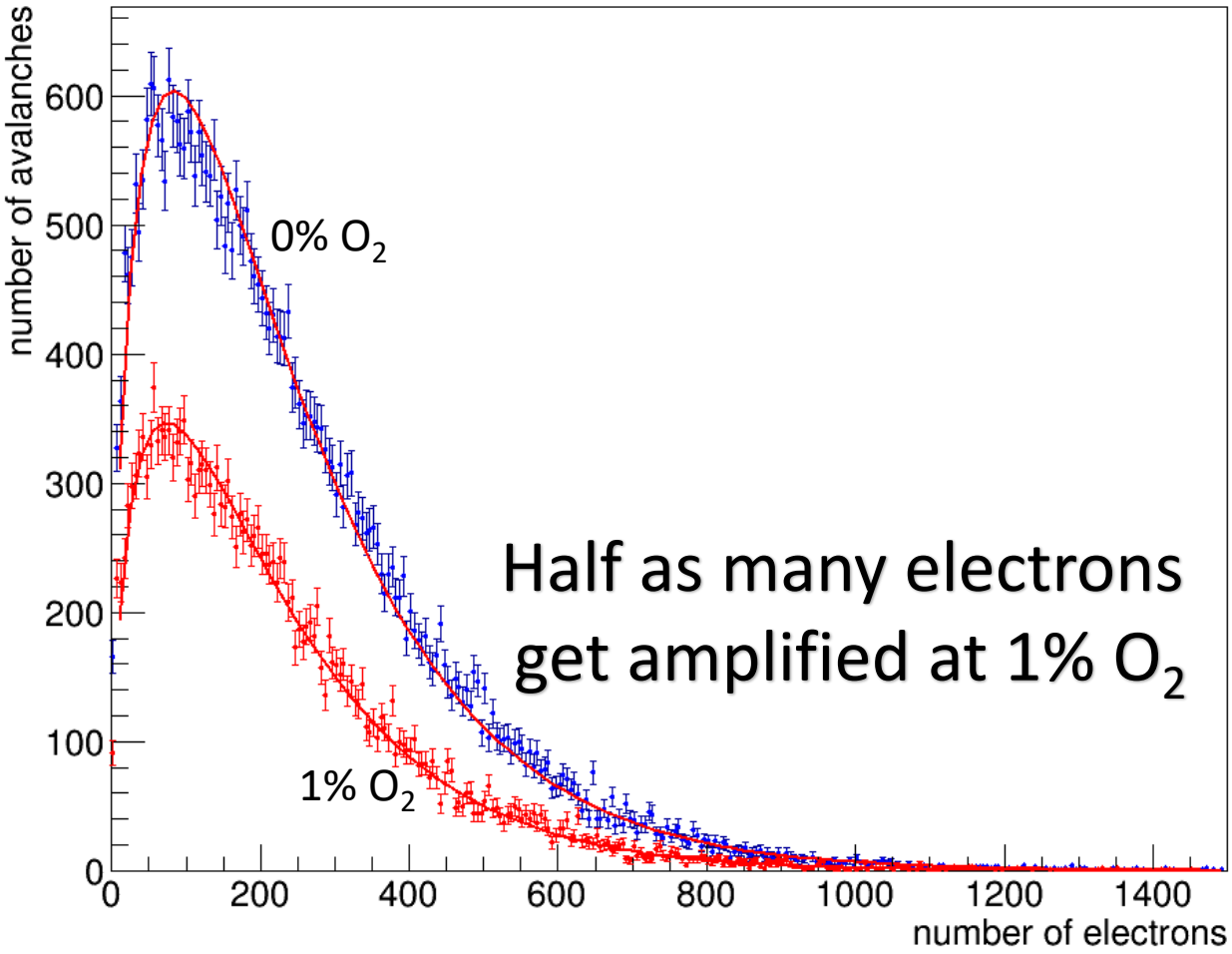


Motivation – Effect on Performance

Simulations in Garfield have been done:

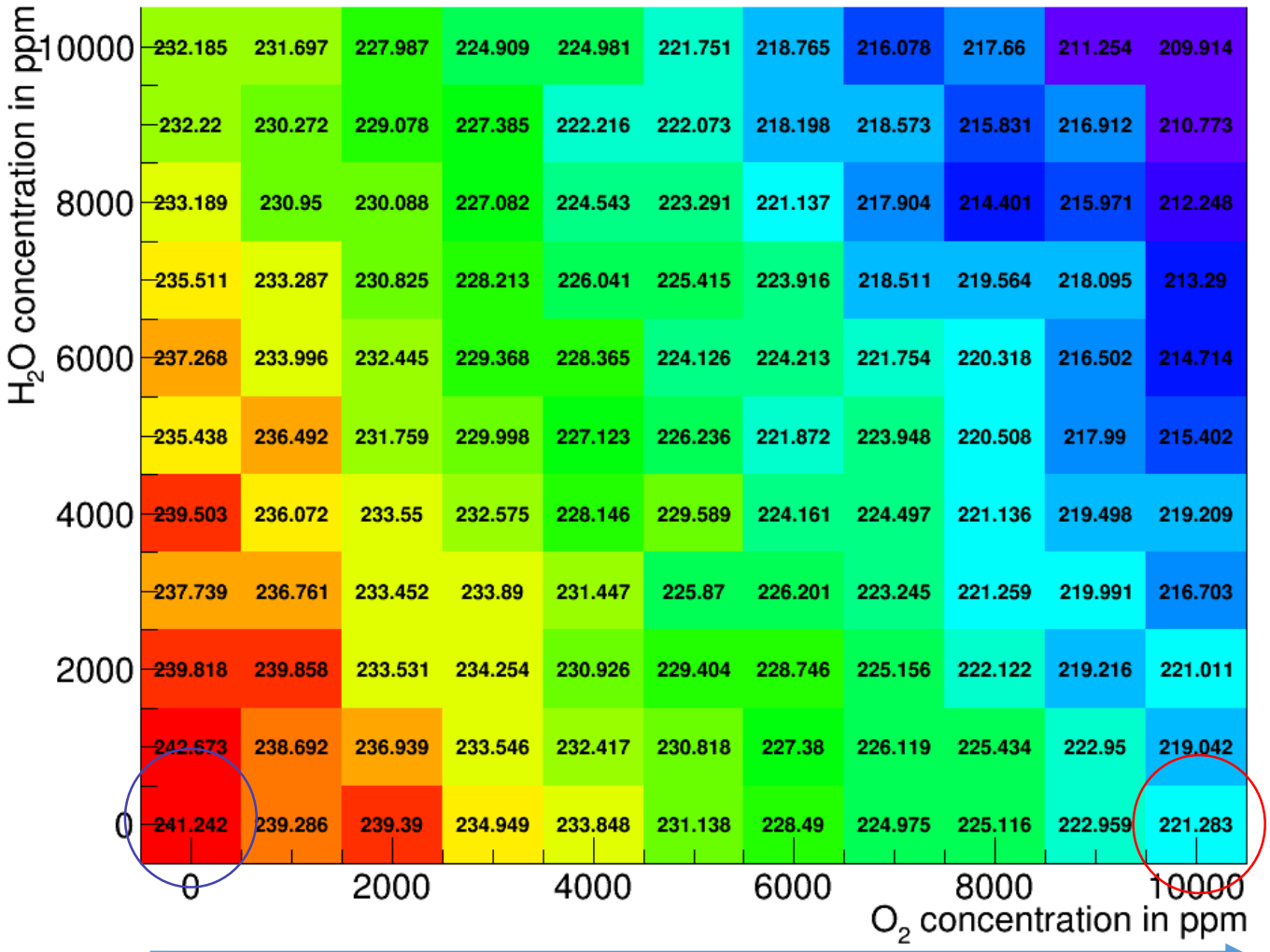
- Includes full Micromegas field structure
- Base gas mixture is 93:7 Ar:CO_2
- Penning transfer is disabled
- 5000 muon events have been simulated
- Incident muon creates primary electrons
- Every electron is tracked through the detector and amplification is simulated
- Both gain and number of amplified primaries are important values

Comparison of Oxygen Levels



The Simulation Grid (Gain)

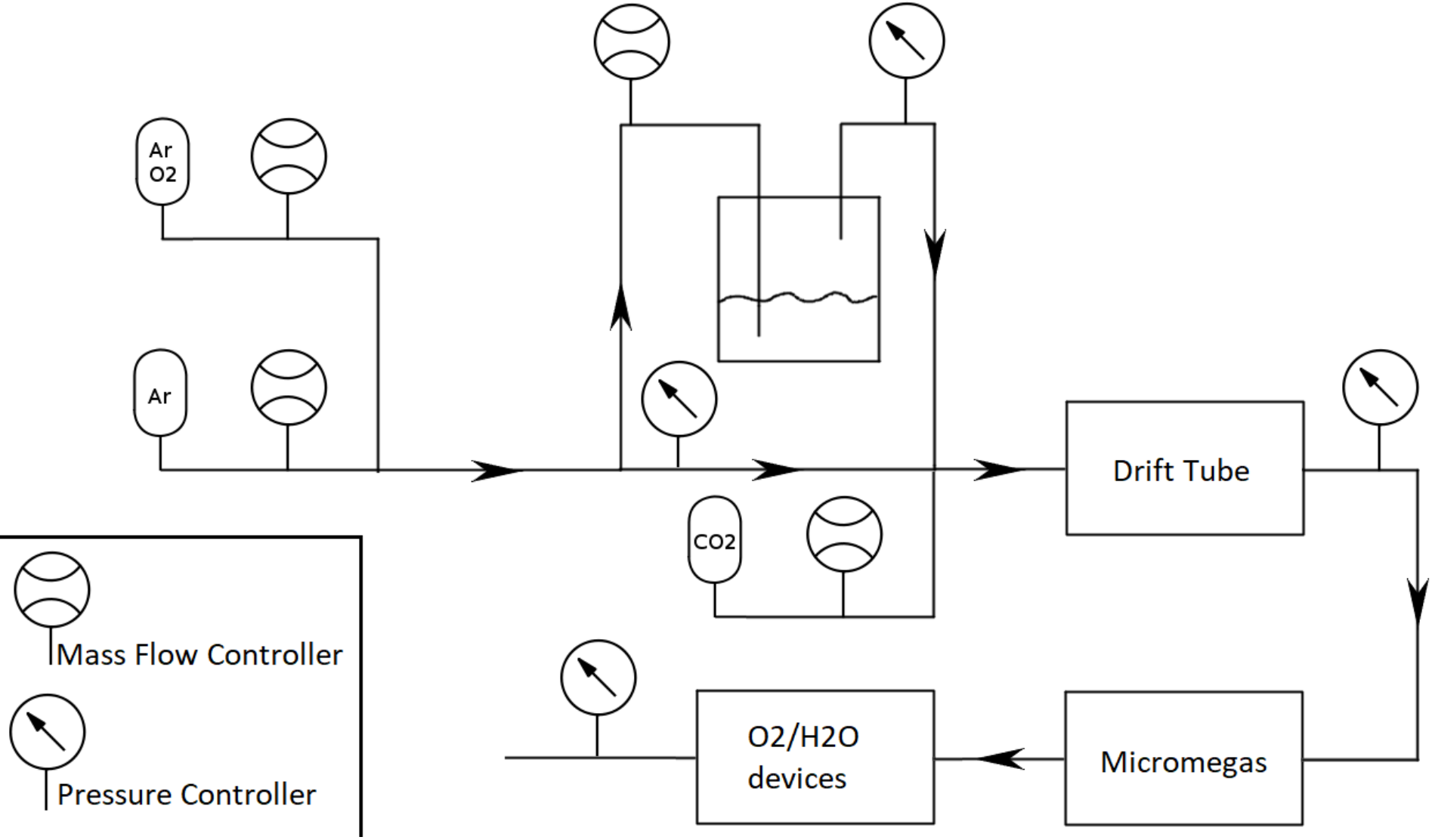
10000 ppm = 1%



about -5%

about -10%

The Gas System schematics



The Gas System

- Systech Illinois ZR800:
  - 0.1ppm – 100% O_2
  - 0.2% relative uncertainty
- Systech Illinois MM400:
  - 20ppm-2.4% H_2O
  - 2 ppm or 0.5% uncertainty

Commissioning Phase

- First tests have been done to verify the purity of the gas before any contaminations are added on purpose
- About 20 ppm O_2 and 400 ppm H_2O are already present.
- Conjecture: any remaining plastic tubing could allow exchange
- Test: remove all plastic – only metal pipes
- Result: <1 ppm O_2 and <1 ppm H_2O

Test of Plastic Tubing

- Plastic tubing is very common in experiments using gaseous detectors
- Therefore, the question of which material to use to minimize contamination is of utmost importance
- Being able to quantify expected contamination is also important
- The following plastic tubing has been tested

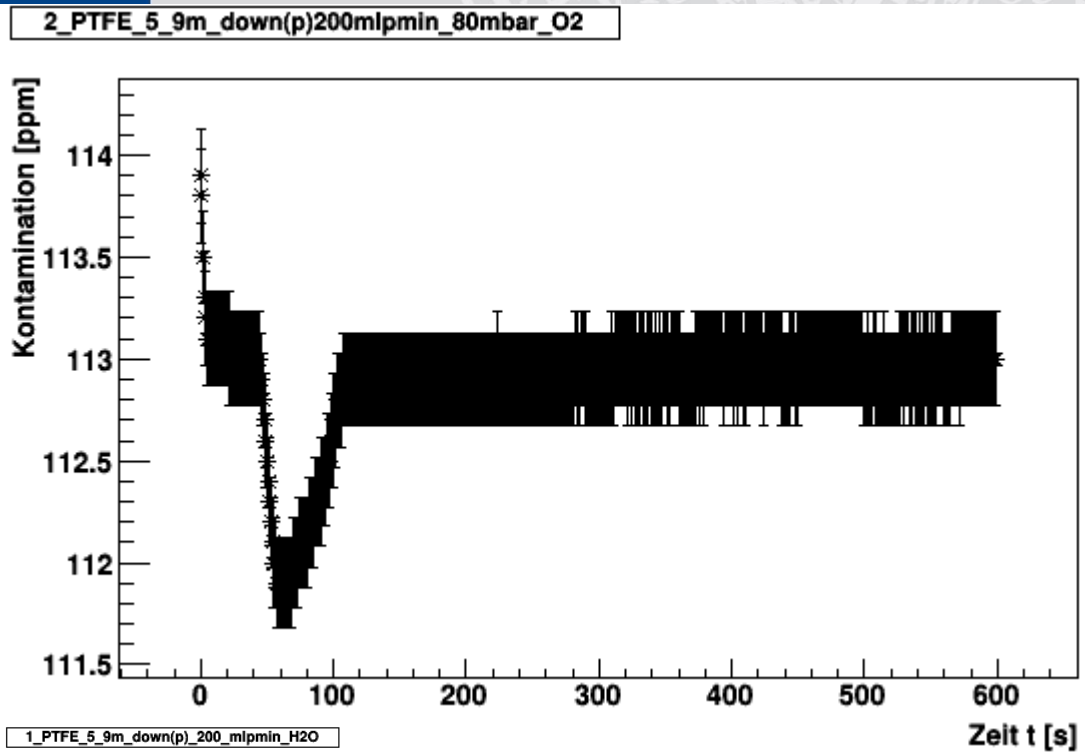
Material	Inner Diameters [mm]	Wall thickness [mm]
PTFE	3.7, 4.0, 4.5, 5.0	1.15, 1.0, 0.75, 0.5
PU	4	1
PVC*	4	1
PFA	4	1

*ordered, but too soft to be connected to the system

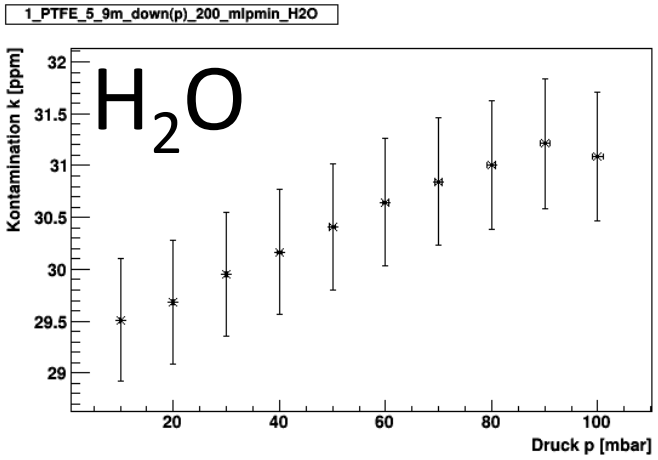
Test of Plastic Tubing - Procedure

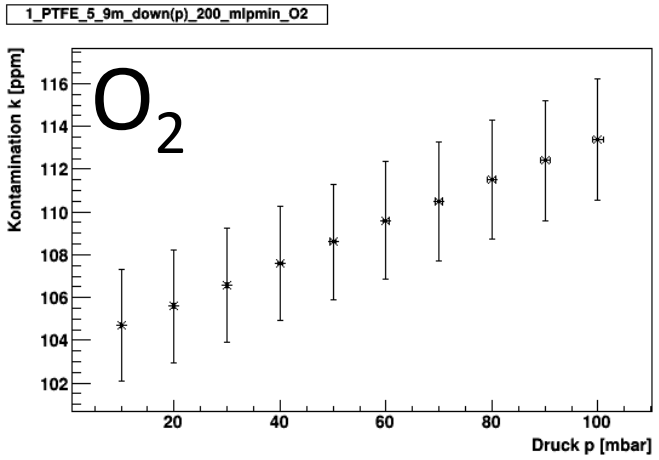
- 10 m of each type of pipe is available, cut to 1, 2, 3, 4 m (not everything has been measured)
- For each piece, uncontaminated gas is flushed at different flows and pressures:
  - Flushing at 200 ml_s/min for a few hours
  - 200…20 ml_s/min in steps of 20 ml_s/min at 50$mbar_g$
  - 20…200 ml_s/min in steps of 20 ml_s/min at 50$mbar_g$
  - 10…100 $mbar_g$ in steps of 10 $mbar_g$ at 200 ml_s/min
- Readings of both Oxygen and Water concentrations are taken every second
- Following measurements have been taken by a BSc. student

Tests of Plastic Tubing – Measurements (Pressure)

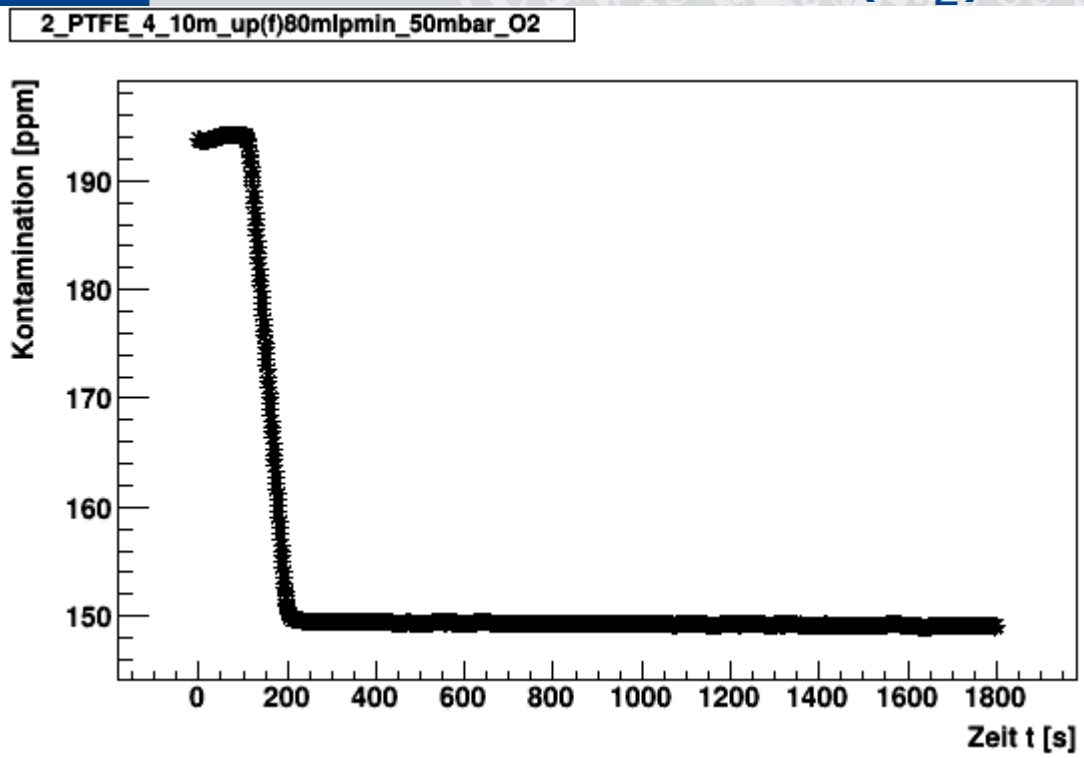


- Pressure change in the measurement devices can be seen
- Guess: Change in calibration factor leads to slight change of output



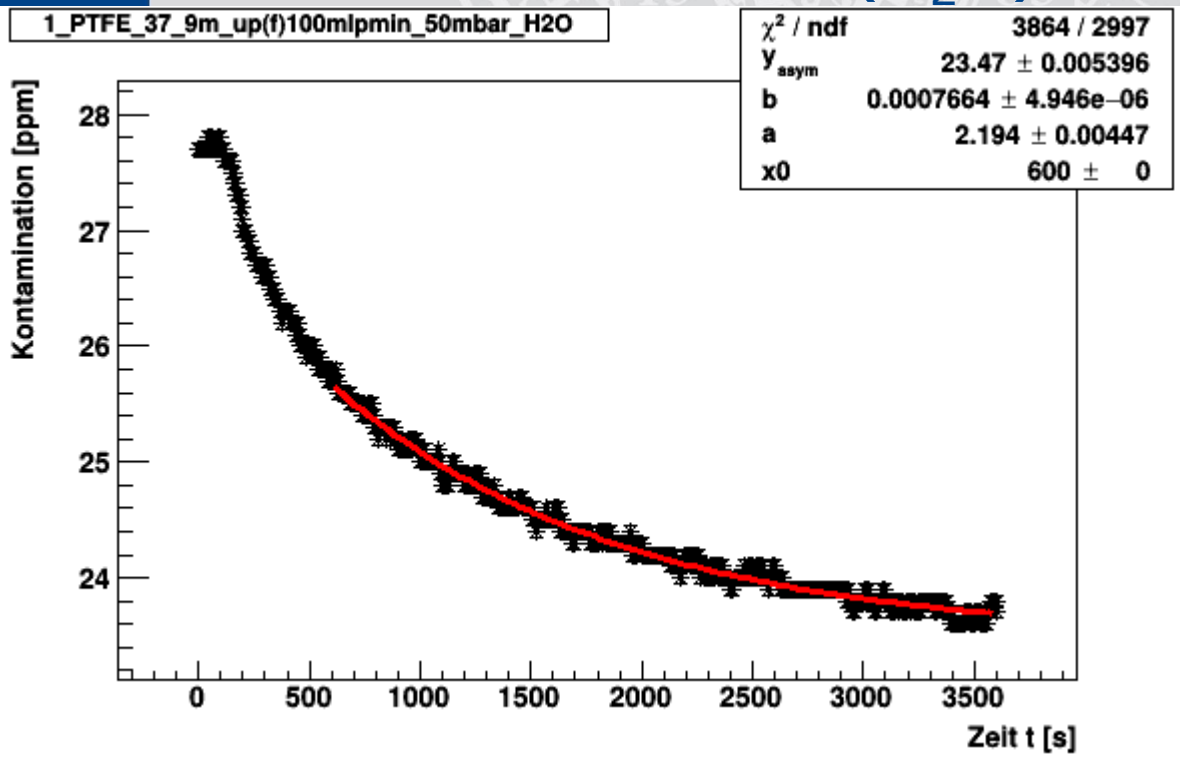


Tests of Plastic Tubing – Measurements (O_2)



- Concentration change almost instant
- After that, the concentration stays constant
- Just reading out the last measurement is enough

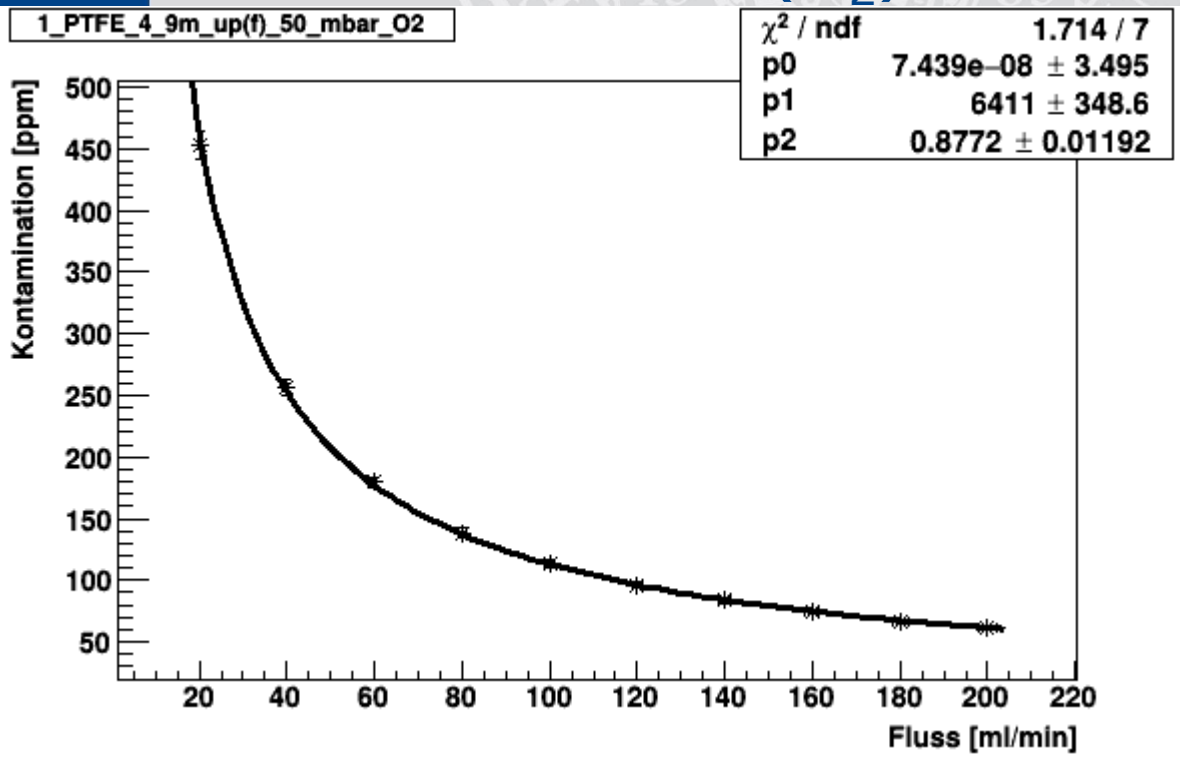
Tests of Plastic Tubing – Measurements (H_2O)



$$c = y_{asym} - \mathrm{a} \cdot \mathrm{e}^{\mathrm{b} \cdot (t - x_0)}$$

- Changes are taking a long time
- Fit appropriate, with x_0 fixed
- It seems like there are both a short and a long change rate
- Therefore, the first part is taken out of the fit

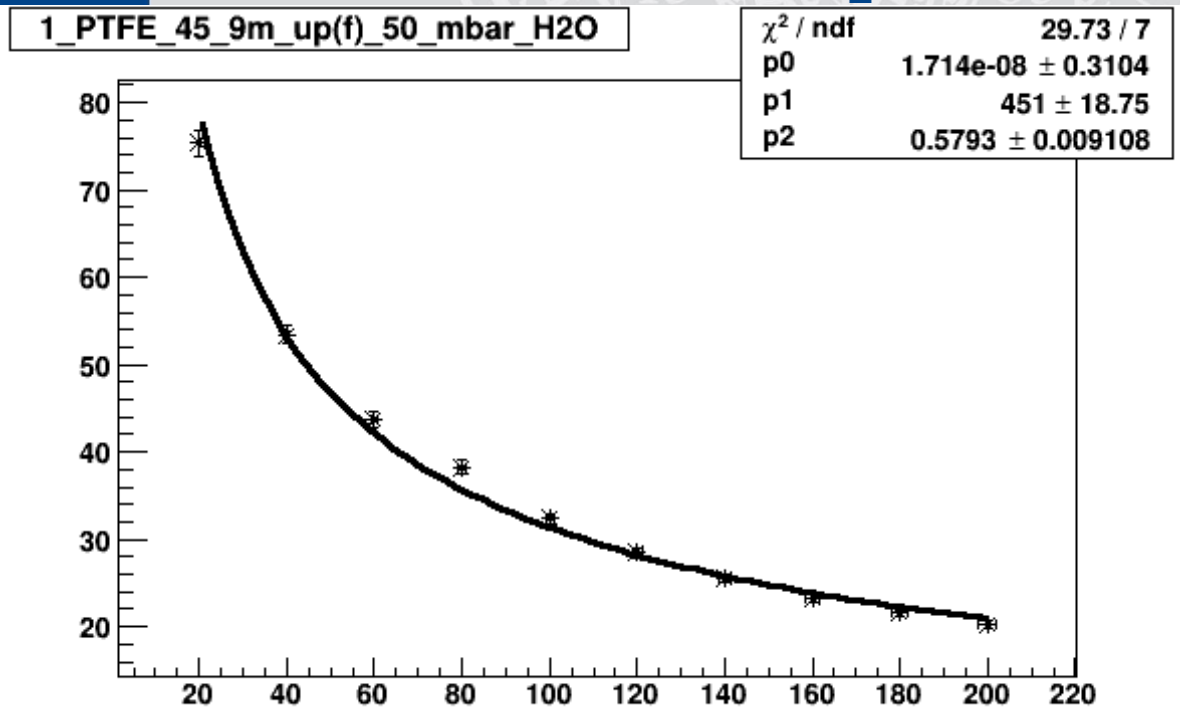
Tests of Plastic Tubing – Flow Dependence (O_2)



$$c = p_0 + p_2 \cdot x^{-p_1}$$

- Guess: contamination depends on time in the pipe (about linear)
- Fit a power function
- Check for constant offset (other sources!)
- Scale factor p_2 is a property of the pipe:
  - Material
  - Length
  - Wall thickness

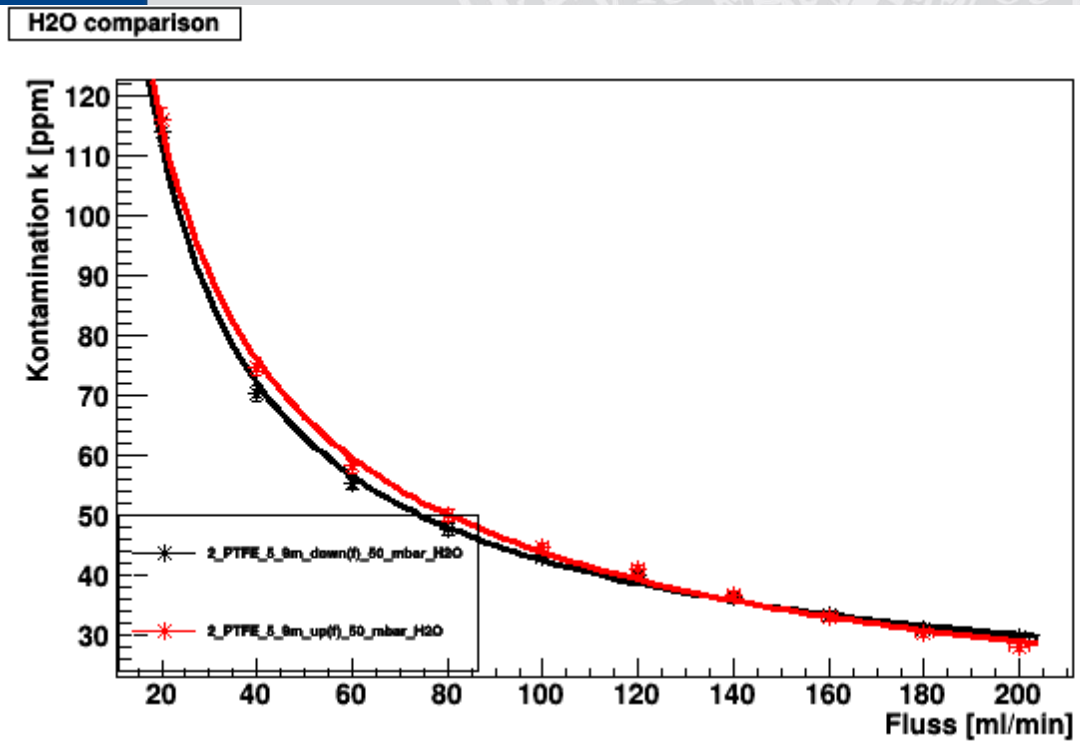
Tests of Plastic Tubing – Flow Dependence (H_2O)



$$c = p_0 + p_2 \cdot x^{-p_1}$$

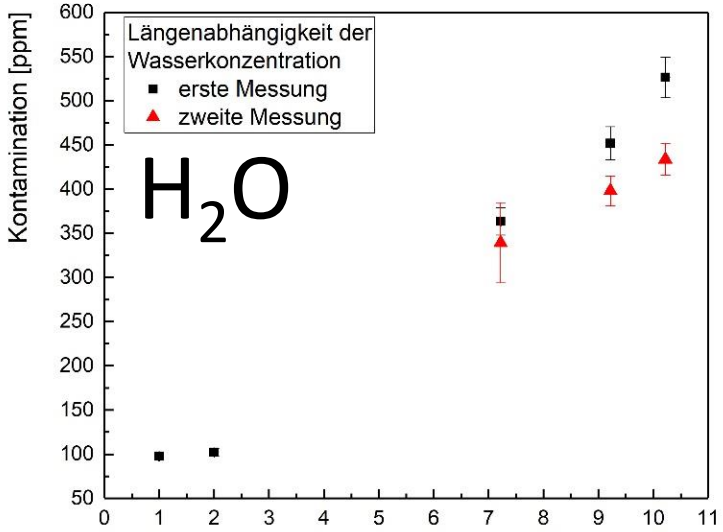
- Fit worse than in the case of O_2
- Square root dependence, not linear!
- Hint at different mechanism for contamination
- Comparison between two measurements of the same pipe might be interesting

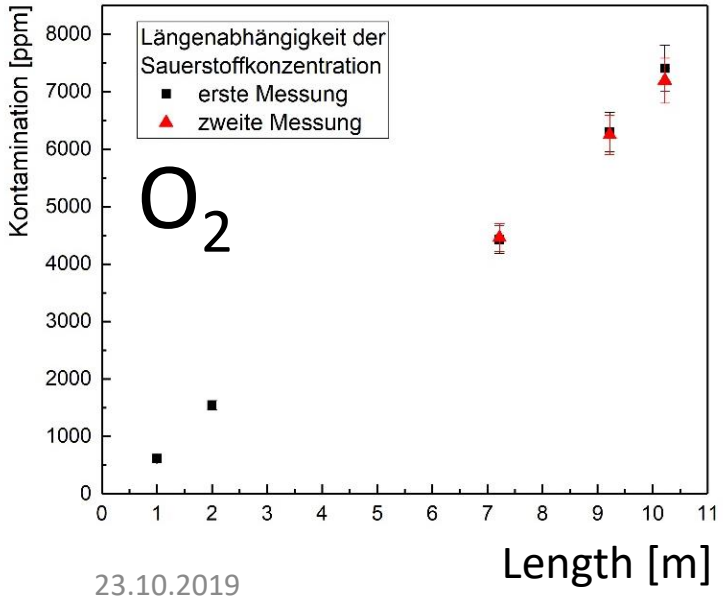
Tests of Plastic Tubing – Flow Dependence compared (H_2O)



- Same pipe in both curves
- Measurements one right after the another
- Black is going down, red is going up
- Because of less influence from open air, the up(flow) measurement will be used further
- Problem: Air humidity in the room is neither controlled nor tracked!

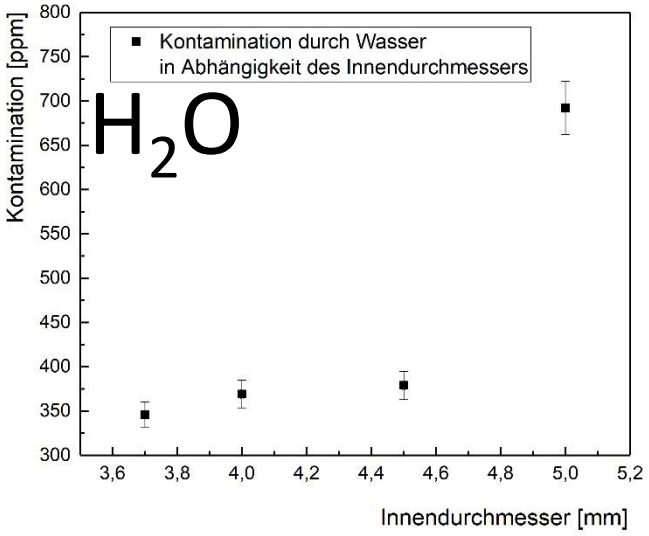
Tests of Plastic Tubing – Length

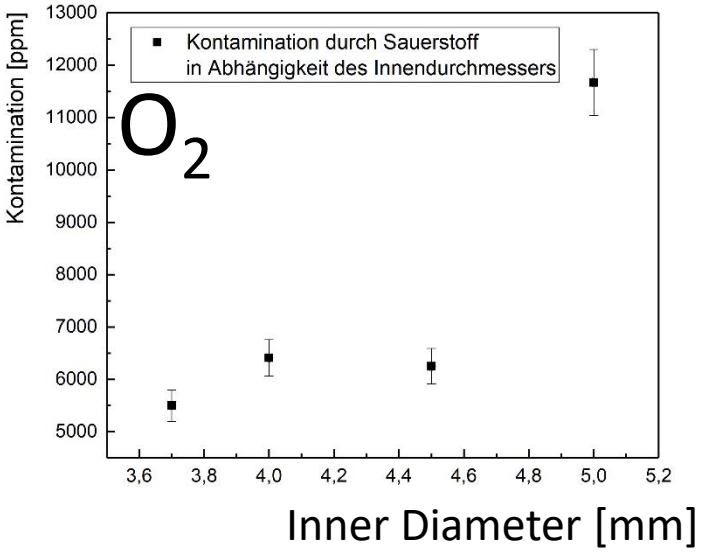




- Black and red are:
  - Same pipe (PTFE, 6x4mm)
  - p_2 extracted from up(flow) measurements
  - Two different days (each flushing, down(flow), up(flow), down(pressure))
- O_2 is almost perfectly repeatable
- H_2O is not, air humidity logging is being worked on

Tests of Plastic Tubing – Inner Diameter





- Inner diameter is not too important for contamination if small enough
- Seems like a plateau, with the contamination decreasing towards the lower diameters and increasing towards the higher
- Those are all 6mm outer diameter tubing variations available, 2 metric, and 2 imperial

Tests of Plastic Tubing – Material

Material	p_2 of O_2	p_2 of H_2O
PTFE	6400±350	340±15
PFU	450±255	800±240
PFA*	3660±190	770±110

*PFA measured at 6m and scaled by a factor 1.5

- PTFE and PFA show similar behaviour
  - Better at H_2O than at O_2 by an order of magnitude
  - PFA has a less pronounced difference between the two contaminations
- PFU is susceptible to H_2O but less so to O_2
- Choice of pipe depends on the contamination you want to reduce, but the best choice would be metal!

Conclusions

- The new gas system in the Würzburg cosmic ray facility is now ready for precise measurement and is producing first results
- This prompted an investigation into the permeability of piping of different material and thickness
- The first results have been shown here
- The studies have a general relevance for all gaseous detector systems
- Goal: measuring the effect of O_2 and H_2O on detector performance

A big thank you to our scientific workshop and thank you for your attention!