Monitoring Detectors for Transport Parameter Studies

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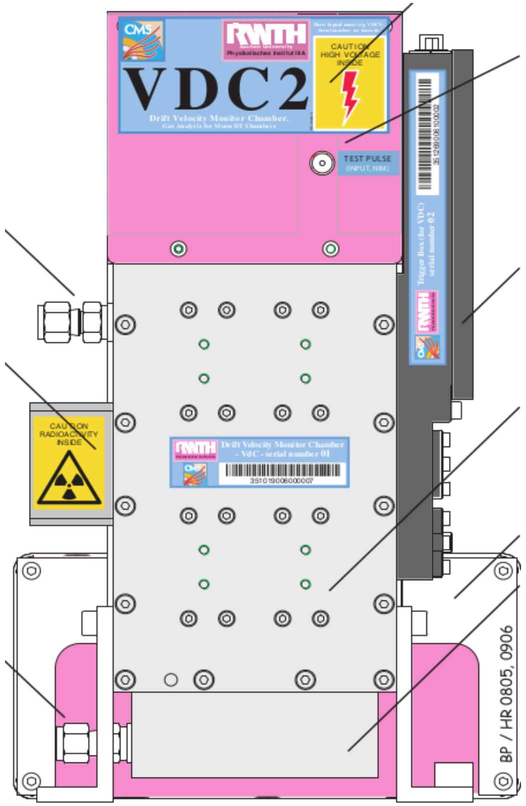
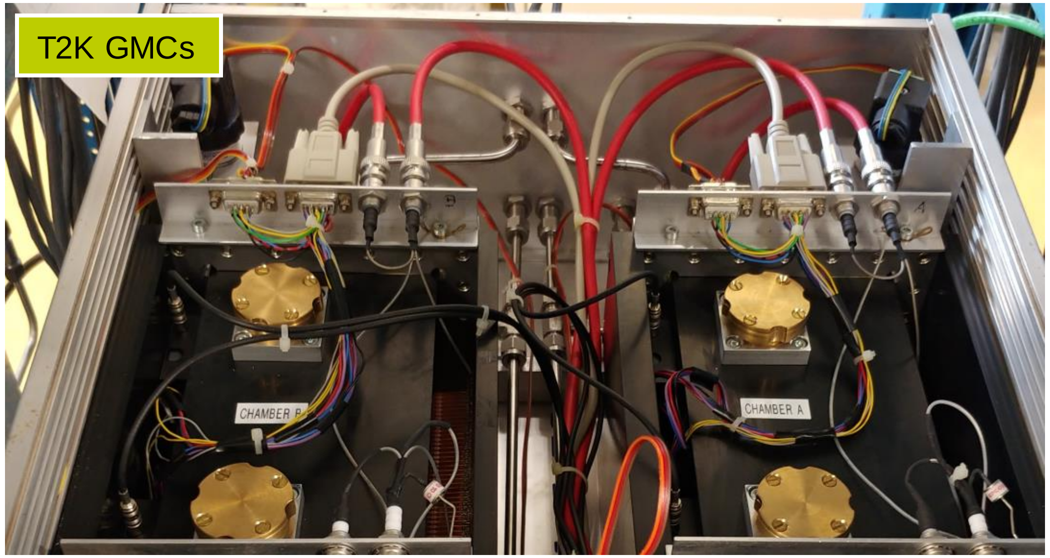
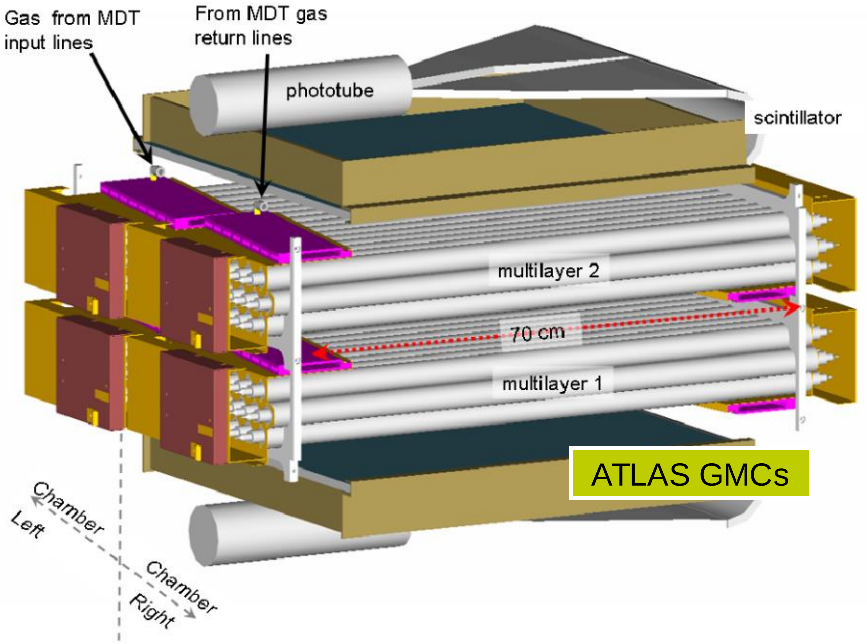
Monitors for Full-Scale Drift Chambers

CMS VDCs



T2K GMCs





ATLAS GMCs

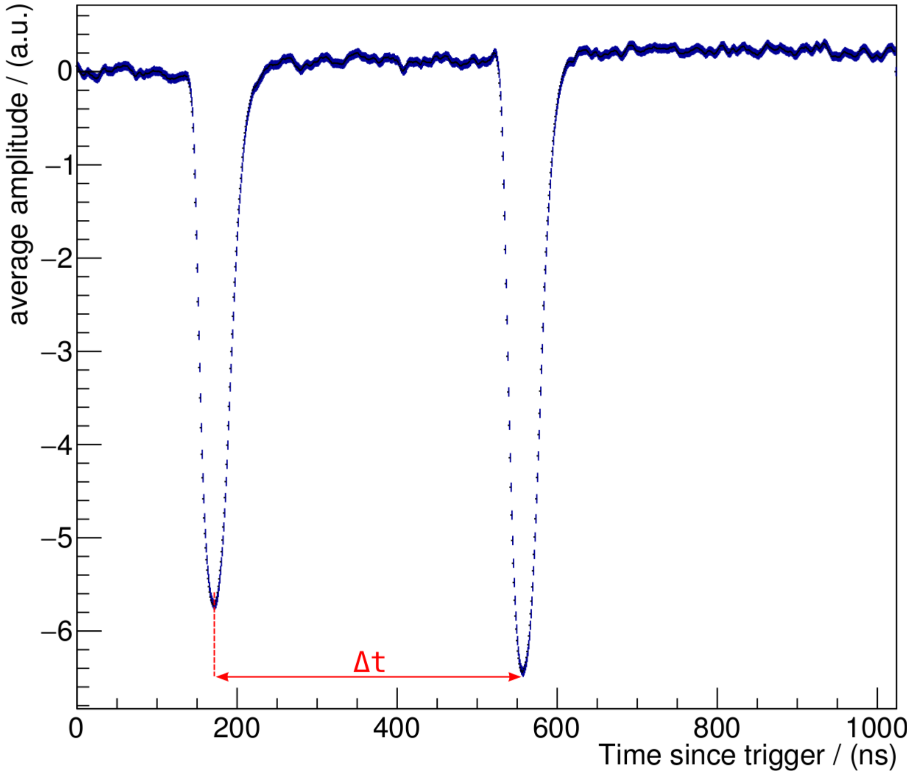
doi:10.1016/j.nima.2017.12.032

Ensure short- and long-term continuity of host detectors

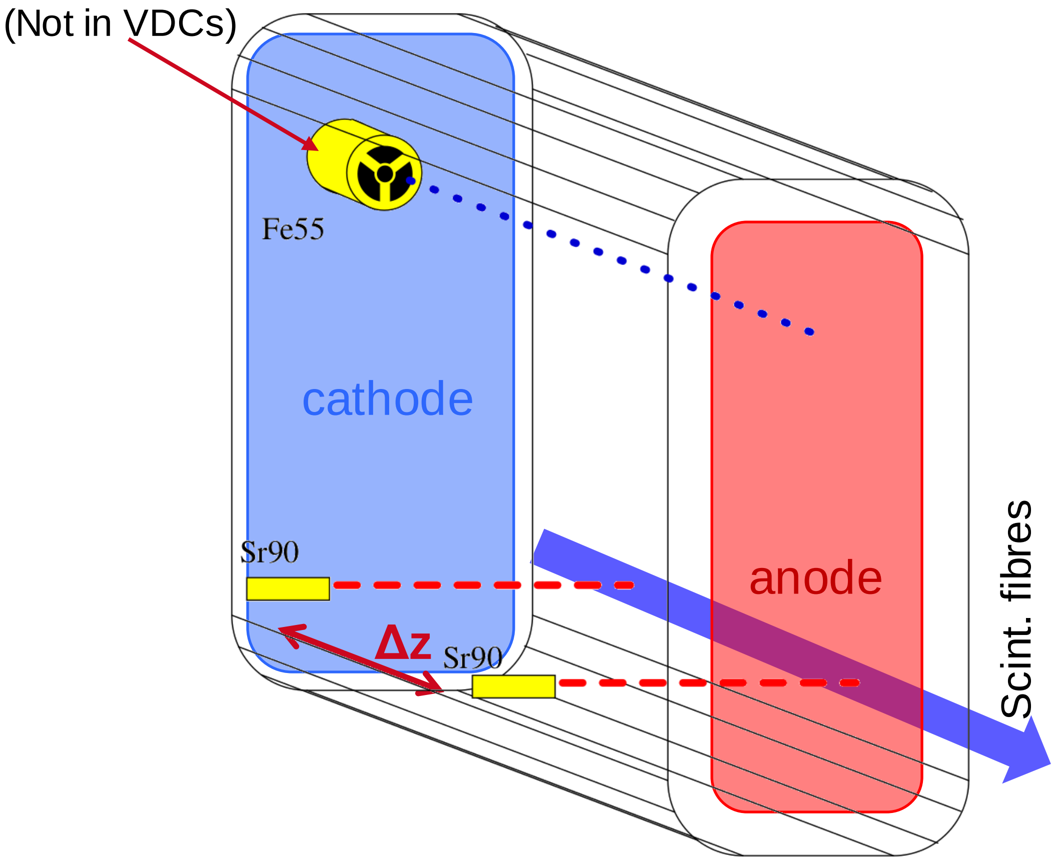
- Monitor gas quality of host detector gas system
- Continuous calibration:
  - Inverted reconstruction-event chain, i.e. known track positions
  - Can be used to reconstruct transport parameters
- (Relatively) small size

Miniature versions of full-scale detectors

Operation Principle: Drift Velocity (and Gain)



Gas gain:
Mono-energetic events from xray source (^{55}Fe)



Drift Velocity

- Time delta between tracks of defined distance
  - β-electrons create ionization tracks
  - Lasers liberate electrons at photocathodes
- Effectively measures v_d in central region between ^{90}Sr sources

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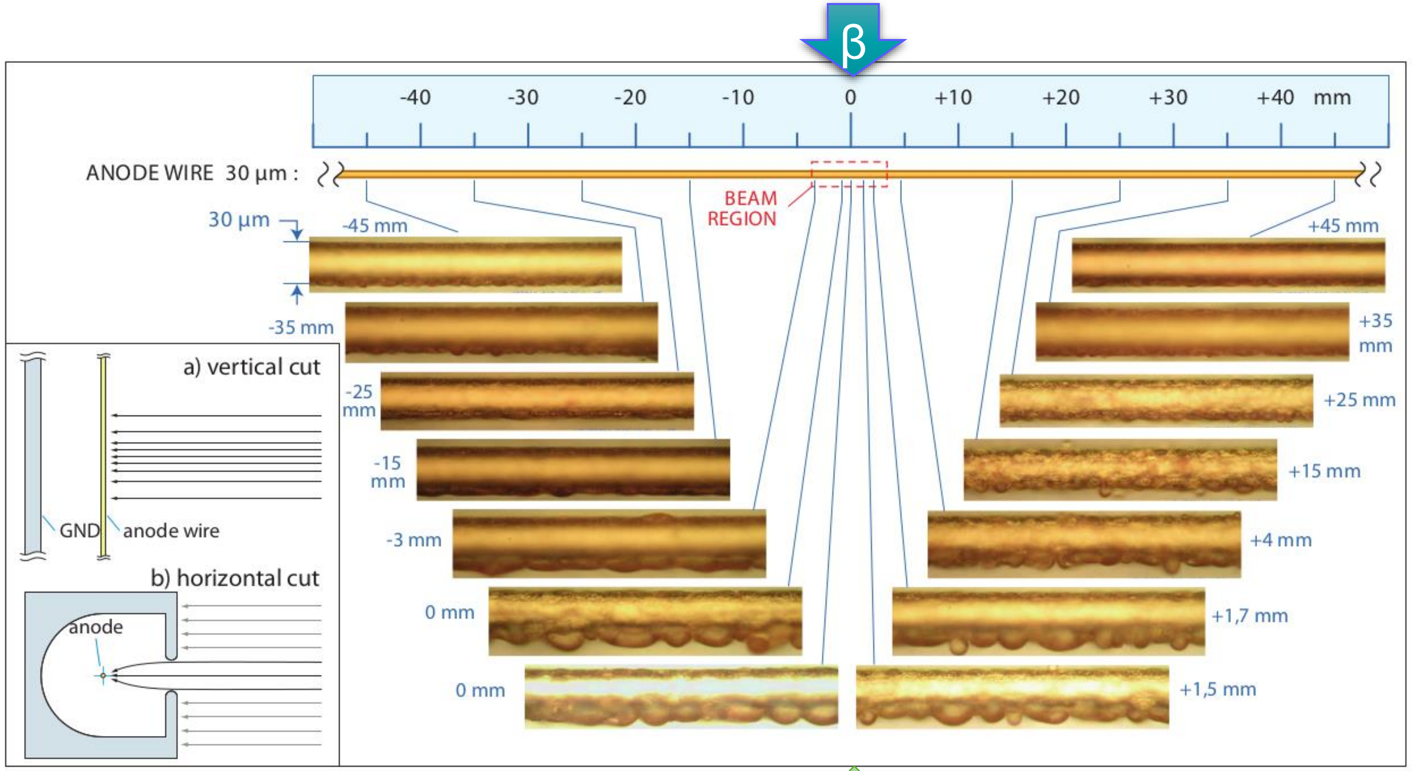
Ageing

- Built with same or comparable gas multiplication stages
- Can have exchangeable parts:
  - Invasive investigations possible
  - Exploring full operational range

Higher and controllable rate

- Extrapolation of ageing



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C, O and Si deposits on VDC anode wire

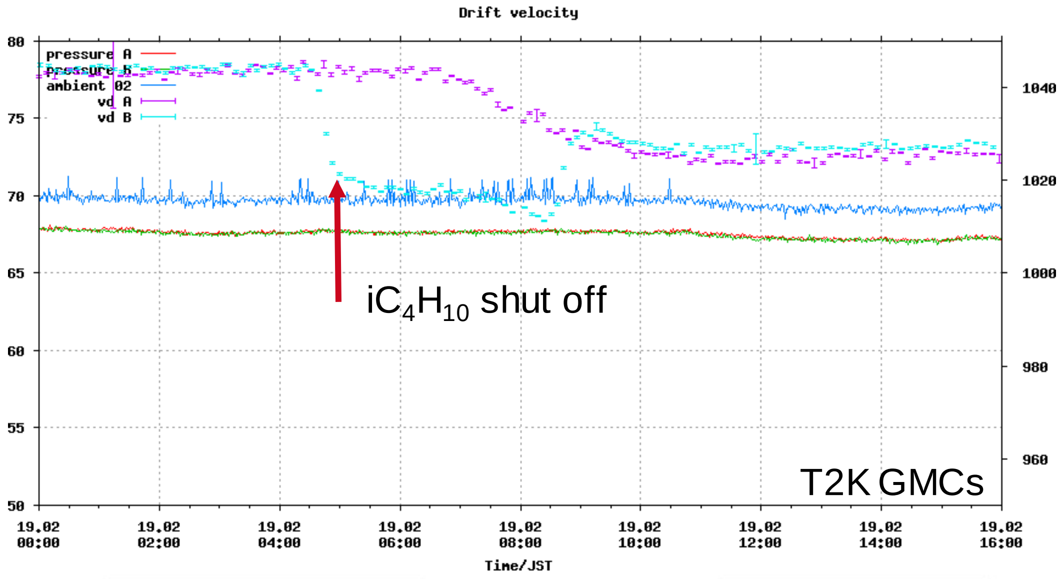
Same MicroMegas as in T2K TPCs

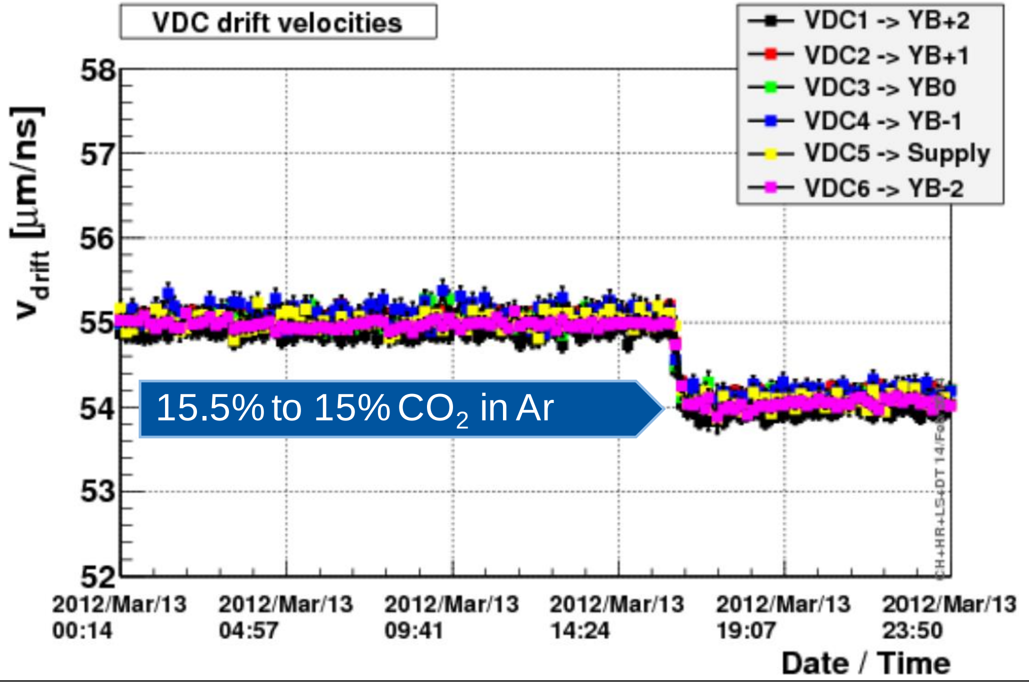
Drift Velocity Monitors

Low latency reaction to anomalies

- Small inner volumes can be flushed at much higher rates than host detectors
  - T2K TPCs completely exchange gas every ~5hrs
  - Every ~20min for GMCs
- Sample gas from various sources
  - Supply gas
  - Return gas
  - Different segments of a detector
- *Run at different fields*
- *Exchangeable radioactive sources*

Gas monitoring chambers can be used to study electron transport parameters at changing fields.





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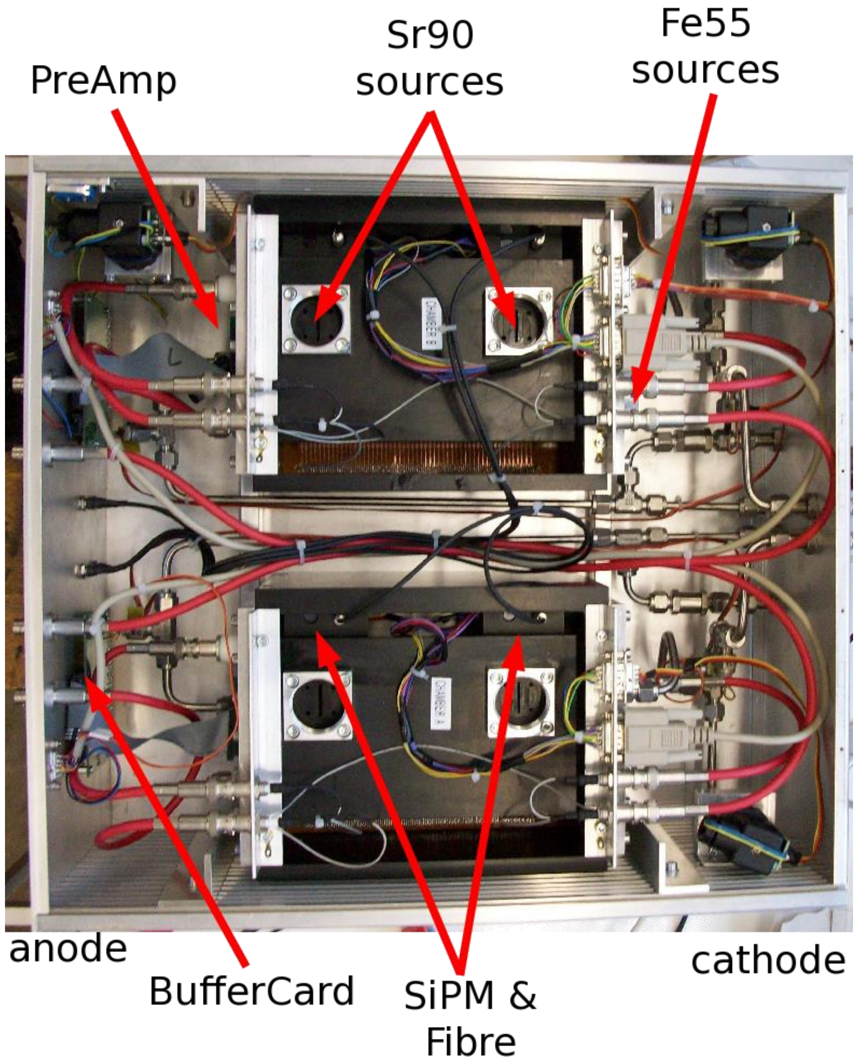
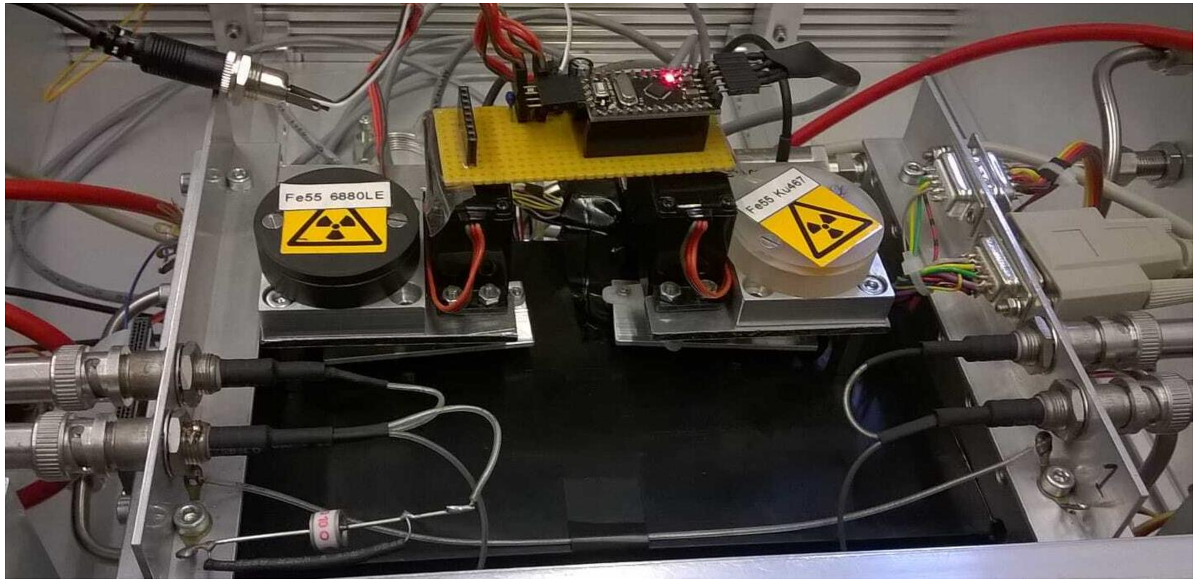
The Gas Monitoring Chambers of the T2K Experiment

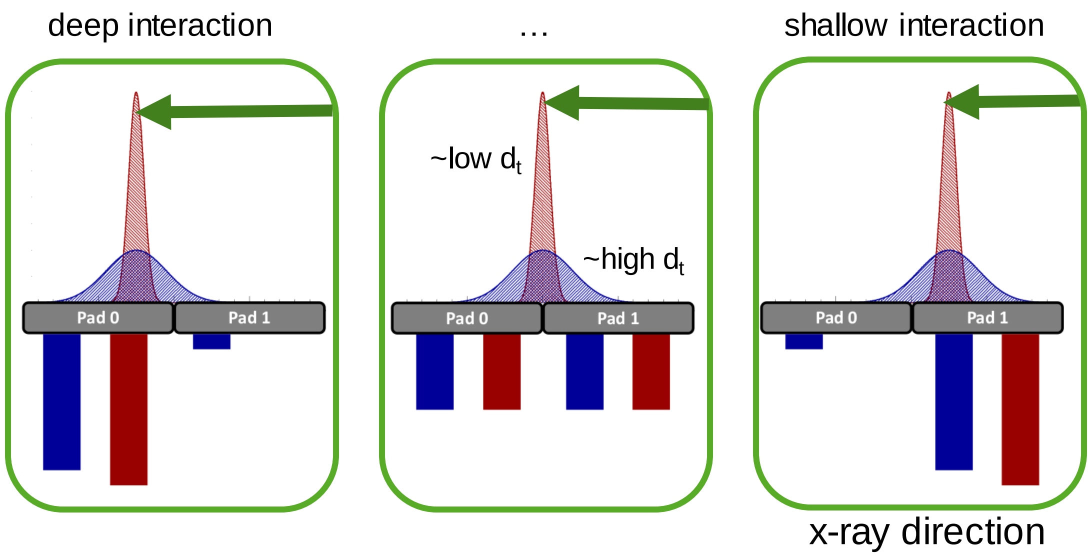


- Sources outside of gas volume
  - Can be replaced with different emitter (e.g. x-ray)
- ^{55}Fe sources to create point-like mono-energetic clouds at different drift distances

Enables measurement of transverse diffusion.

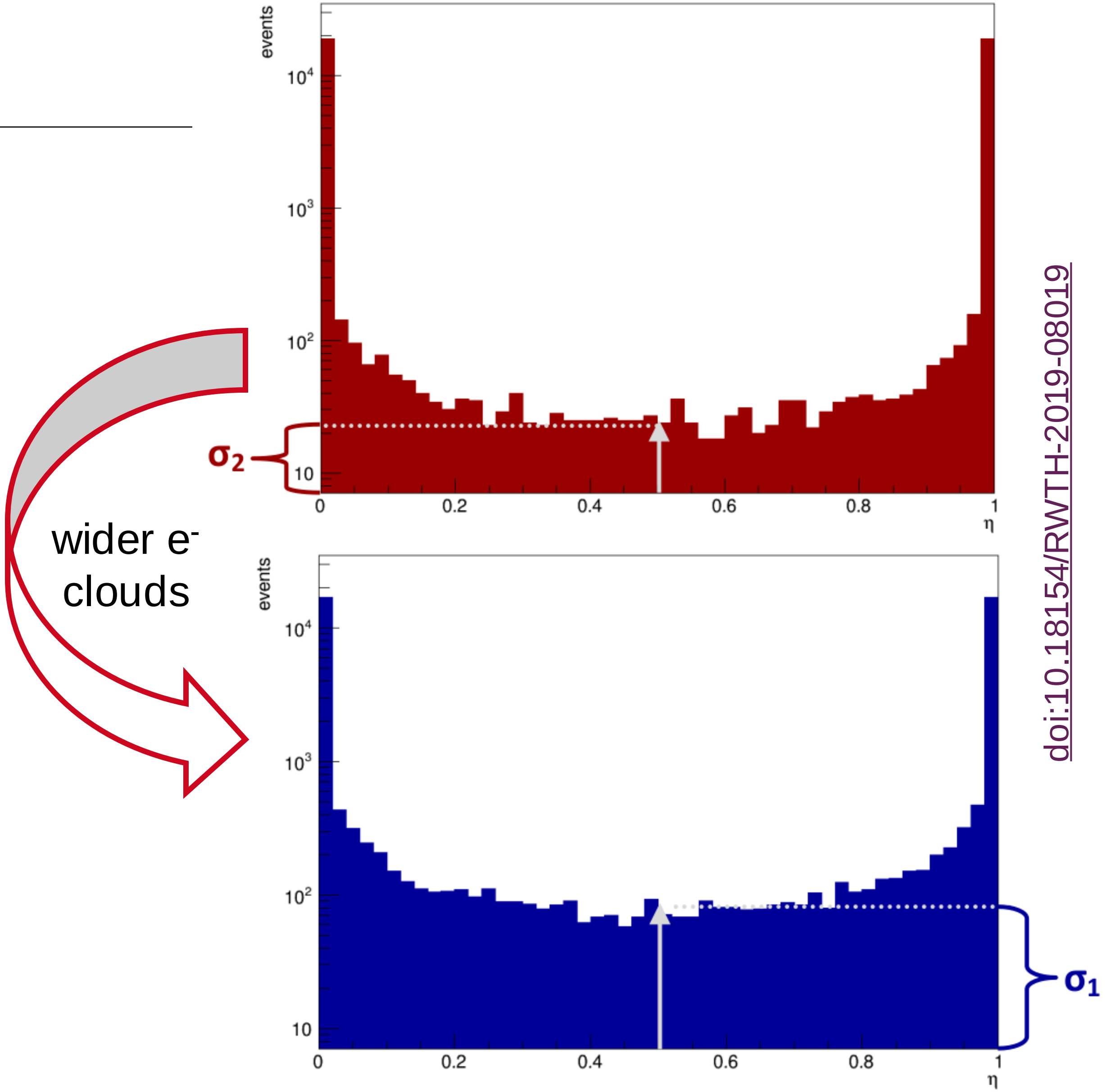


Transverse Diffusion in T2K Gas



- Point-like events generated above two pads
- Charge distribution more evenly distributed across pads for wider electron clouds:

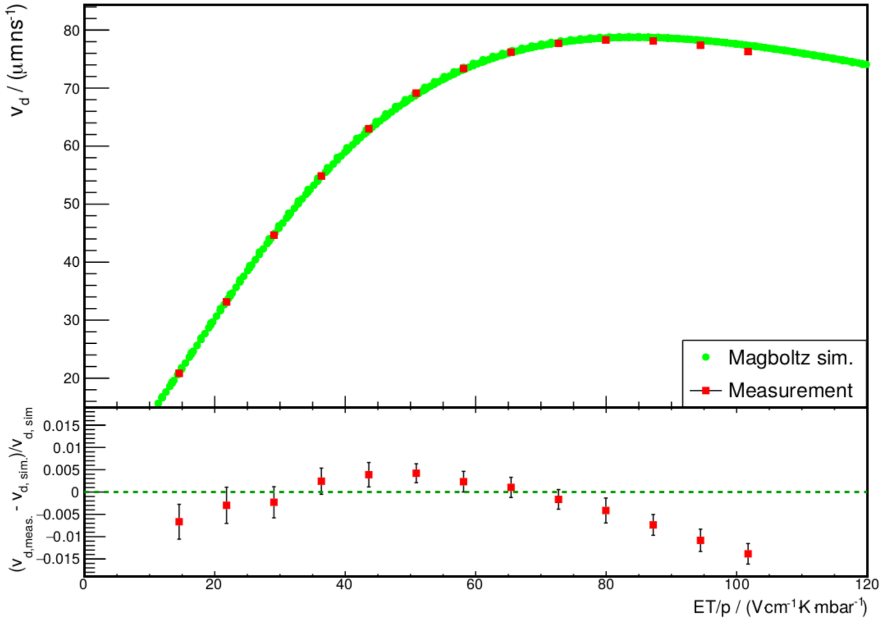
$$\eta = \frac{Q_0}{Q_0 + Q_1}$$

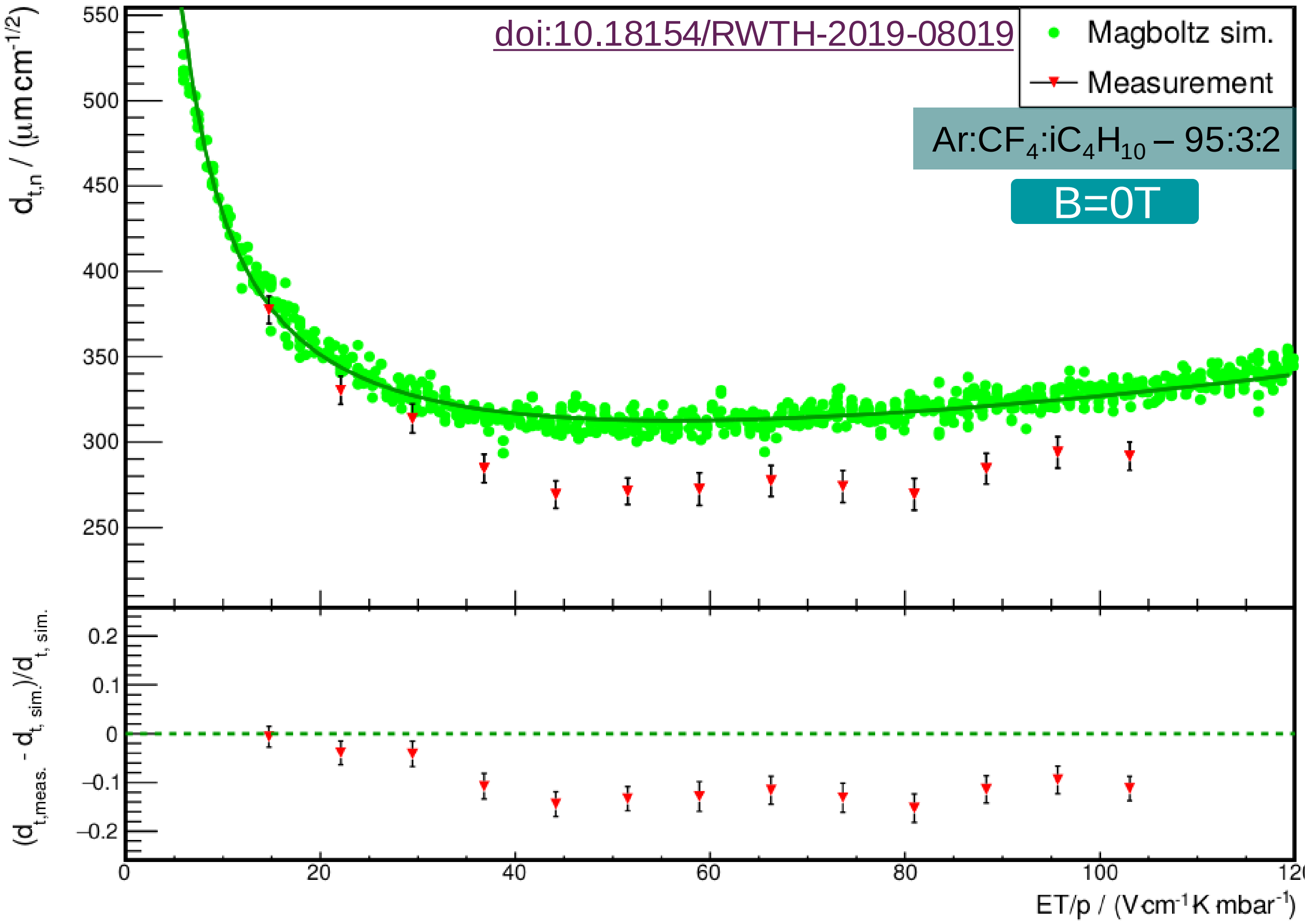


doi:10.18154/RWTH-2019-08019

Transverse Diffusion in T2K Gas

- Shape of d_t curve looks reasonable
- 10-20% deviation from simulation
- v_d precision ~1%





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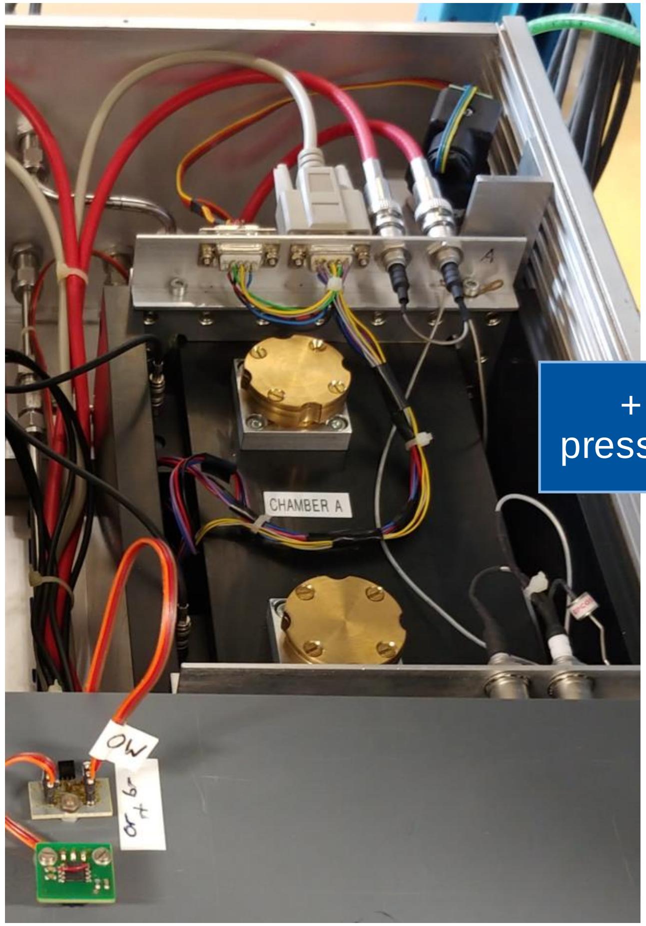
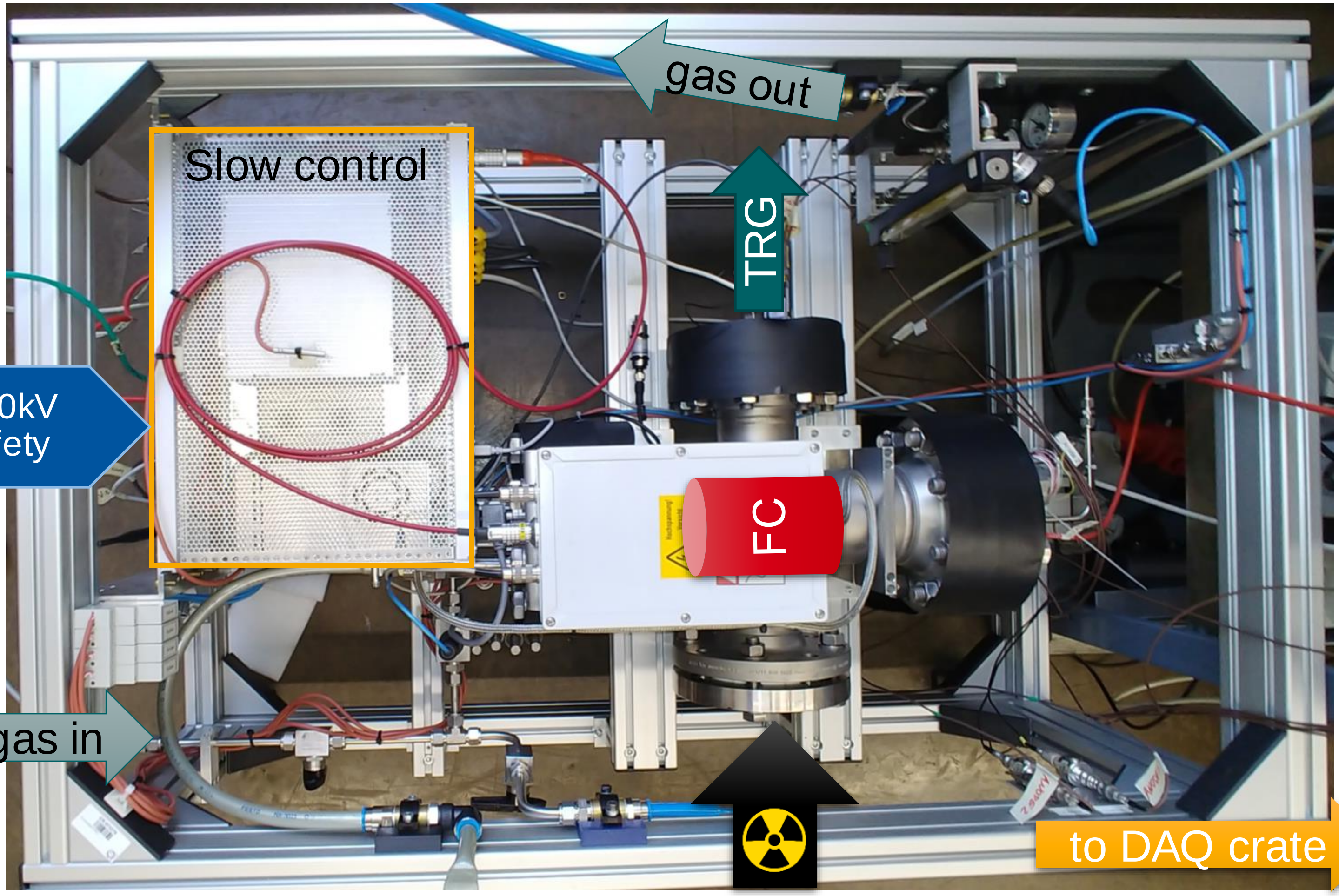
A Gas Monitoring Chamber for High Pressure



+ 10 bar pressure safety

+ 30kV safety



arXiv:2005.03636 [physics.ins-det]

High **P**ressure **G**as **M**onitoring **C**hamber - HPGMC

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Gas Density Corrections

- Gas density affects almost every transport parameter
- Most drift gas mixtures behave ideal up to 10 bar
- Electrons "see" reduced field, by number density

Scale drift field

$$E \rightarrow \frac{E}{N} \propto E\frac{T}{p}$$

magnitude	scaling ($n = N/N_0$)
electron, ion drift velocity v_d	$v_d(E/n)$
electron, ion diffusion coefficients $D^*_{L,T}$	$\frac{1}{\sqrt{n}} D^*_{L,T}(E/n)$
attachment coefficient η	$n \cdot \eta(E/n)$ ^{*a}
Light transparency $\mathcal{T}$	$\exp(-n\Pi_a L^*)$
scintillation probability P_{scin}	$\frac{1}{1+n\tau k}$
particle range R	R/n
Fano factor F_e, W_I, W_{ex}	$\sim$ constant
charge multiplication coefficient α	$n \cdot \alpha(E/n)$ ^{*b}
secondary scintillation coefficient Y	$n \cdot Y(E/n)$ ^{*b}

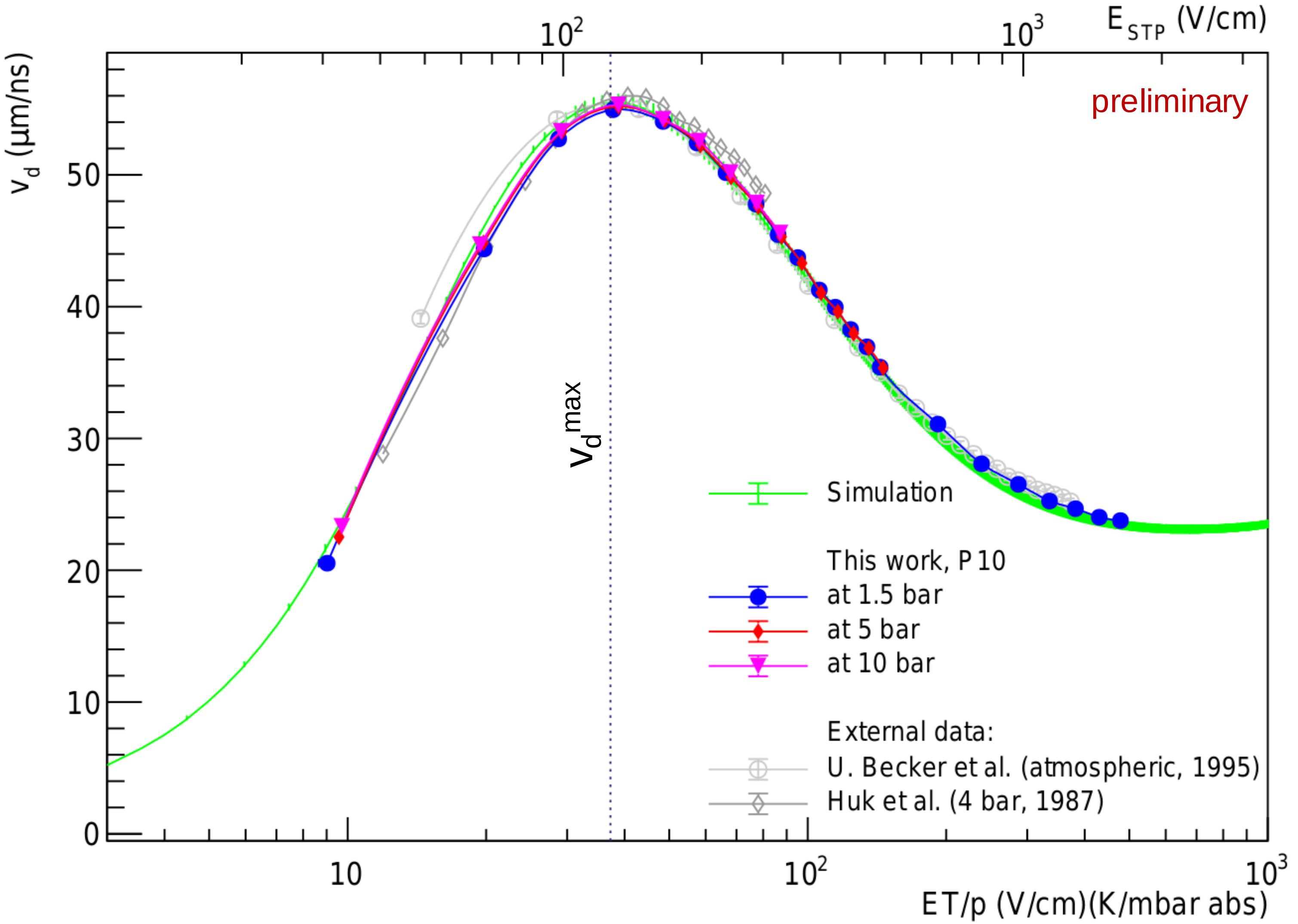
[D. Gonzalez-Diaz, F. Monrabal, S. Murphy *Nucl.Instrum.Meth.A* 878 (2018) 200-255]

P10 Measurement in HPGMC

P10 Gas: Ar + 10% CH_4

- 10 bar pressure range covered
- Data corrected for pressure is self-consistent
- Matches with available external data
- Simulation provided by MagBoltz v11.9

Pressure scaling in T/p verified over a range of 10 bar



P10 ratios

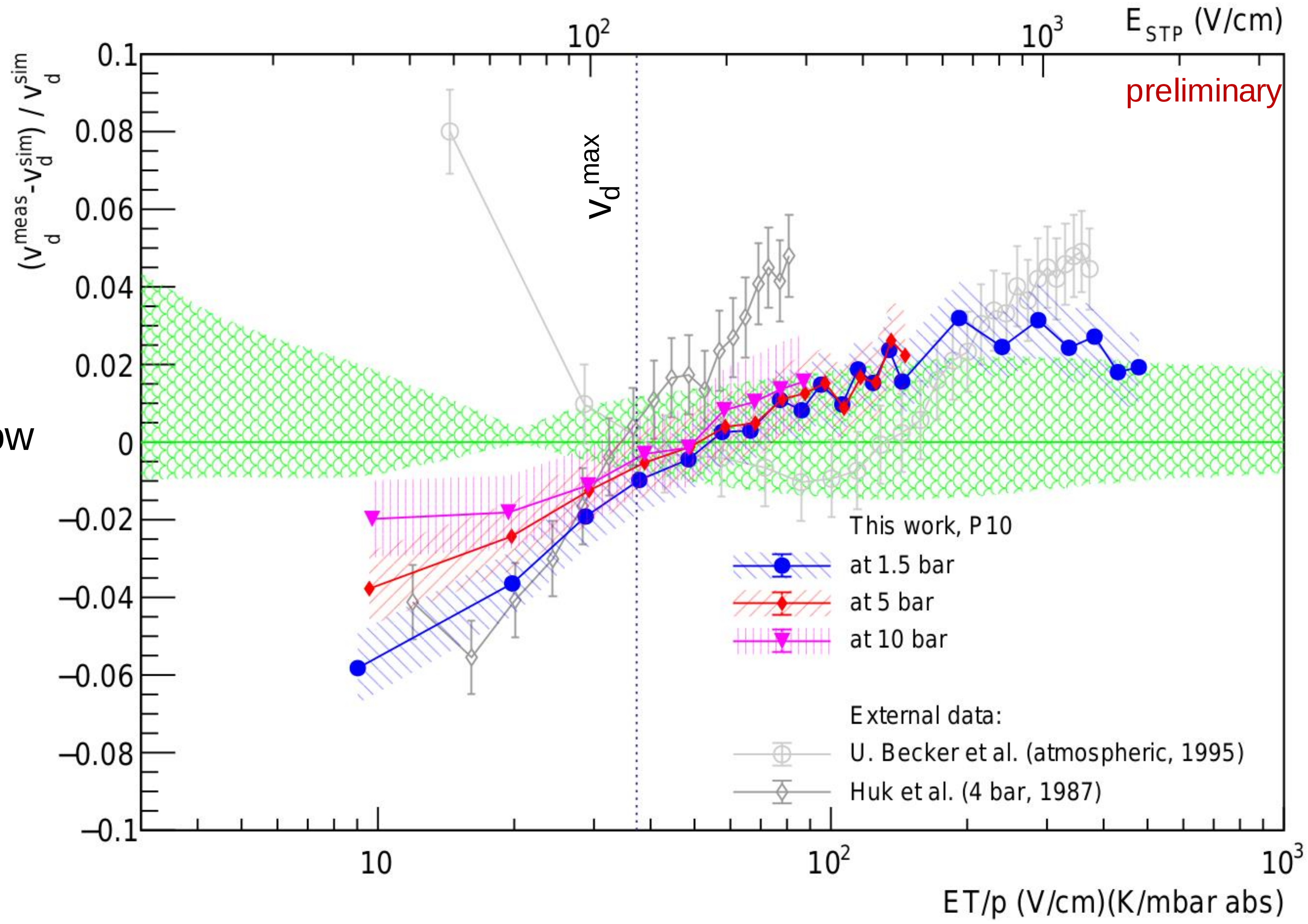
Simulation and measurements of v_d

- Underestimated at low fields
- Overestimated at higher fields
- Crossing point slightly behind v_d^{max}

Gas purity check at 1.5bar

- ~2% v_d^{max} reduction in 7 days w/o gas flow
- Recovery in ~ 24h at nominal flow
- Mixing uncertainties and sim. stat. errors added as bands to zero-line

Simulation and data agree at the few-% level.



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Conclusion and Outlook

In-house gas mixing

Many large experiments run small detectors as low-latency monitors
- Often already collect electron transport parameters
- Small scale and replaceable parts make them an ideal playground for new ideas

Gas Monitoring Chambers can be used for transport parameter measurements
- Designed for fast precision measurements of drift velocity
- Transversal diffusion with slight modifications of measurement setup
- (not shown) Longitudinal diffusion from waveform of anode signal

We *are* taking requests! ☺
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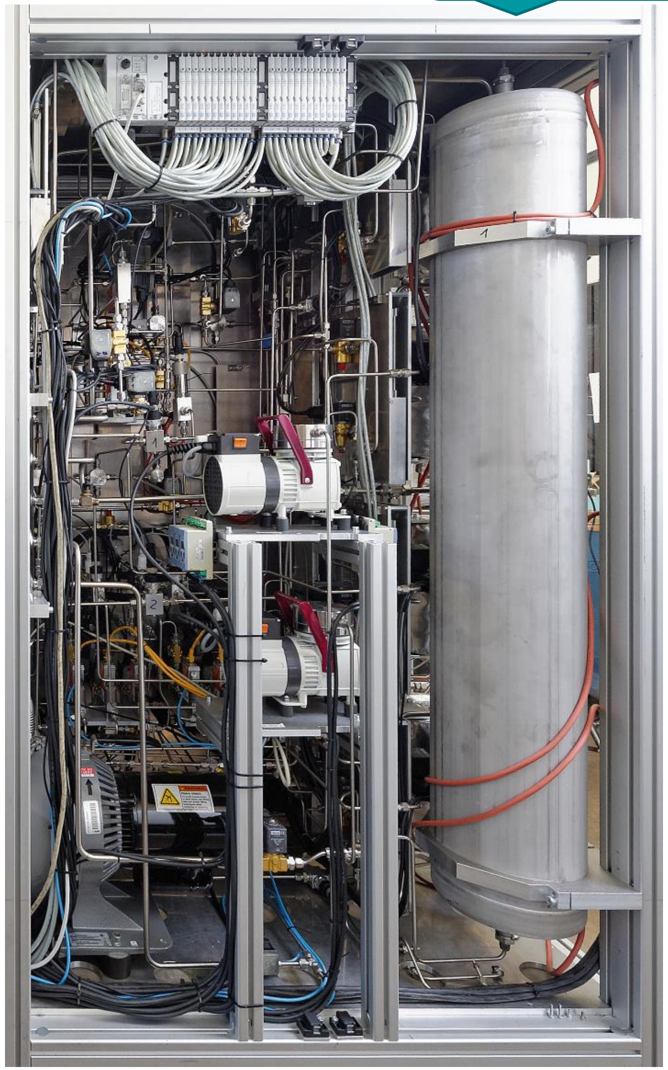

J. Steinmann, https://publications.rwth-aachen.de/record/465404

Thank You!

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Sources

The drift velocity monitoring system of the CMS barrel muon chambers
- doi:10.1016/j.nima.2017.12.032

Time Projection Chambers for the T2K Near Detectors
- doi:10.1016/j.nima.2011.02.036

A Gas Monitoring Chamber for High Pressure Applications
- e-Print: 2005.03636 [physics.ins-det]

Streamlined Calibrations of the ATLAS Precision Muon Chambers for Initial LHC Running
- doi:10.1016/j.nima.2011.12.086

Measurements and simulation of drift gas properties for the time projection chambers of the T2K experiment and for future neutrino experiments
- doi:10.18154/RWTH-2019-08019

Backup

Longitudinal Diffusion T2K Gas