Optimisation of the Ion Feedback in a GEM Setup for a TPC Readout

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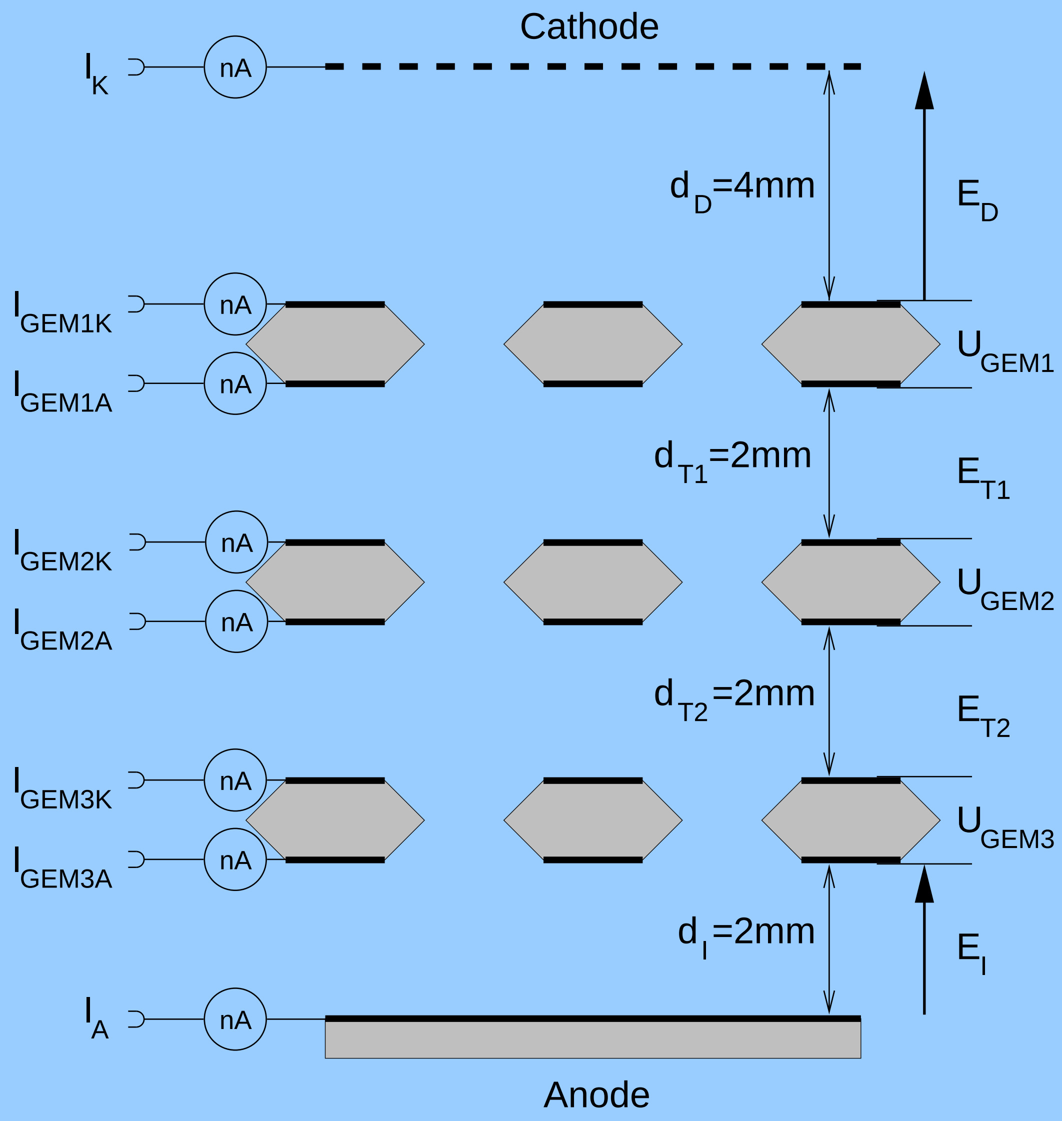
Overview

- Parametrisation of the charge transfer coefficients
- Optimisation of chamber settings
- Current and track measurements with optimized settings
- Micro Hole Strip Plates (MHSPs)
- Conclusion and outlook



- 3 GEM voltages and 4 electric fields (7 chamber parameters) determine charge transfer
- By parametrisation of measured transfer coefficients, quantities like ion feedback (IF) and eff. gain (G_{eff}) can be calculated from a set of these 7 parameters

Charge Transfer Coefficients

- Collection Efficiency

$$C^{\pm} = \frac{N_{\mathrm{e}^-,\mathrm{I}^+} \text{ collected into hole}}{N_{\mathrm{e}^-,\mathrm{I}^+} \text{ before GEM}}$$

- Extraction Efficiency

$$X^{\pm} = \frac{N_{\mathrm{e}^-,\mathrm{I}^+} \text{ extracted from GEM}}{N_{\mathrm{e}^-,\mathrm{I}^+} \text{ in GEM-hole}}$$

- Gain (single GEM)

$$G = \frac{N_{\mathrm{e}^-} \text{ in GEM-hole}}{N_{\mathrm{e}^-} \text{ collected into hole}}$$

Charge Transfer Coefficients

- Effective Gain (multiple GEMs)

$$G_{eff} = \frac{I_{\text{Anode}}}{I_{\text{primary}}} = \prod_{i=1}^{N_{\text{GEMs}}} C_i G_i X_i$$

- Relative Ion Feedback

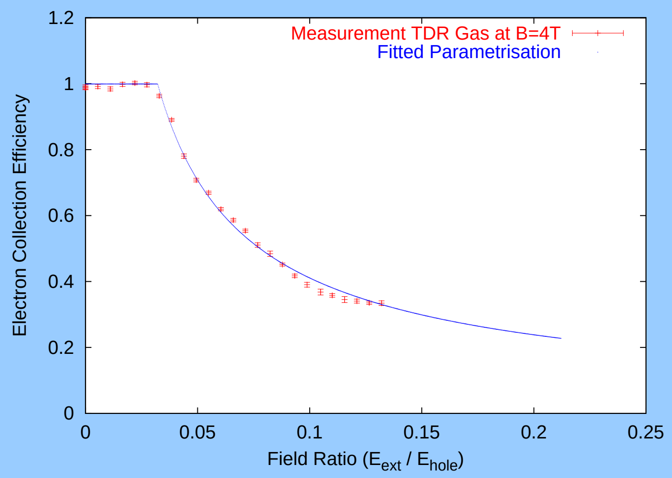
$$IF := \frac{I_{\text{Cathode}}}{I_{\text{Anode}}}$$

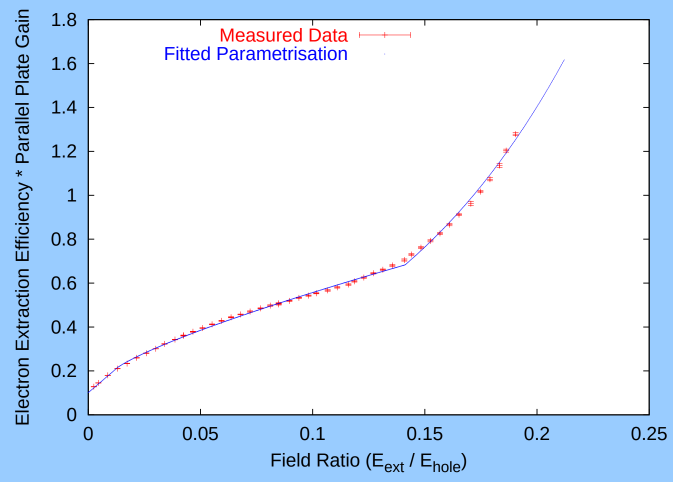
$$\Rightarrow G_{\text{eff}} \cdot IF = \frac{I_{\text{Cathode}}}{I_{\text{primary}}}$$

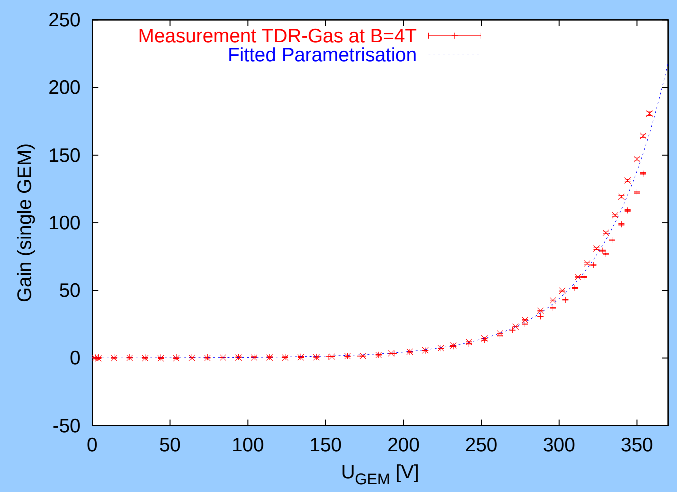
$$\boxed{\Rightarrow I_{\text{Cathode}} \approx I_{\text{primary}} \Leftrightarrow IF = \frac{1}{G_{\text{eff}}}}$$

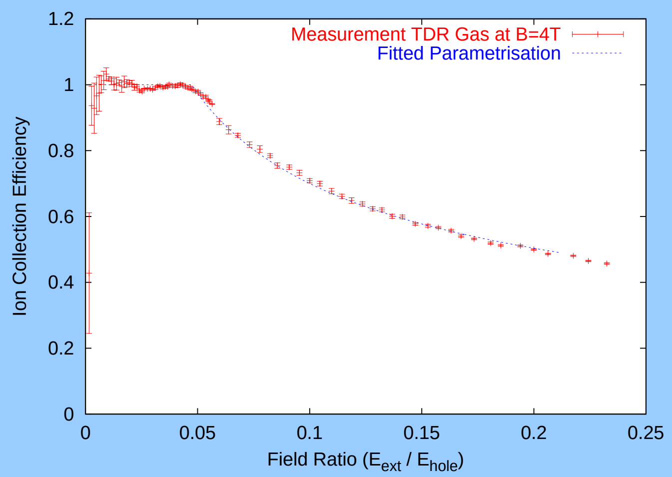
For this Analysis: $G_{eff} = 10^4 \Rightarrow$ Goal: $IF = 10^{-4}$

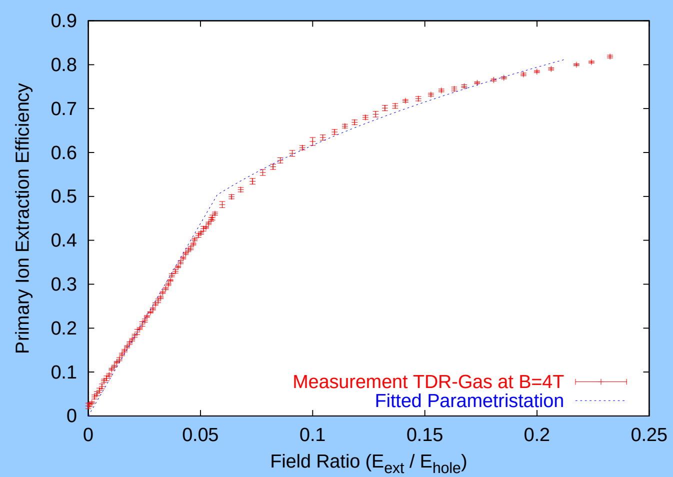
Parametrisation of Transfer Coefficients

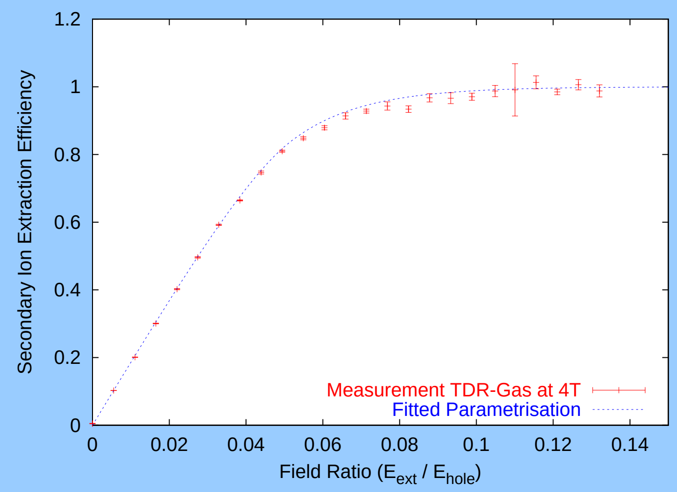










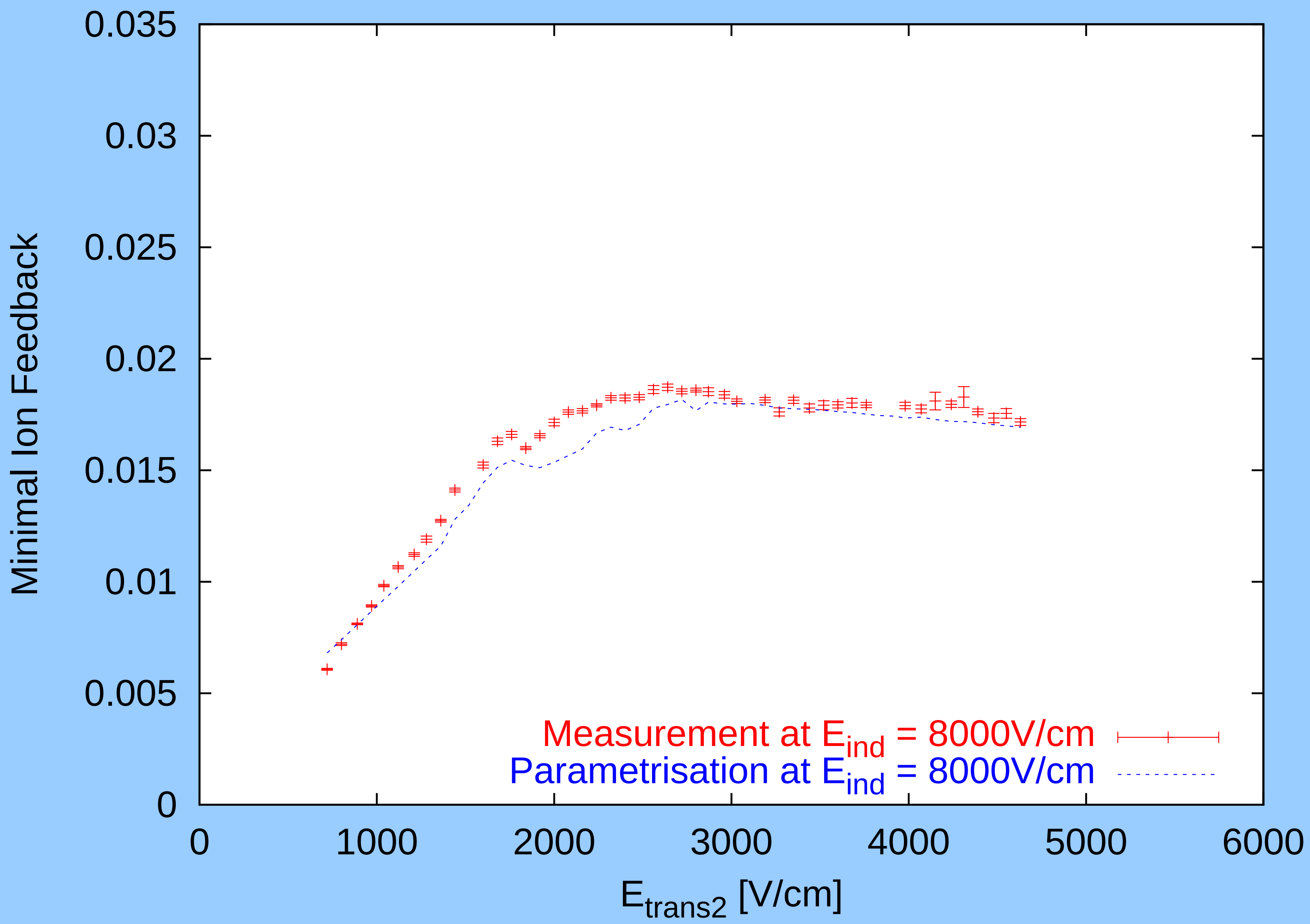


All Parametrisations for TDR Gas at B=4T!

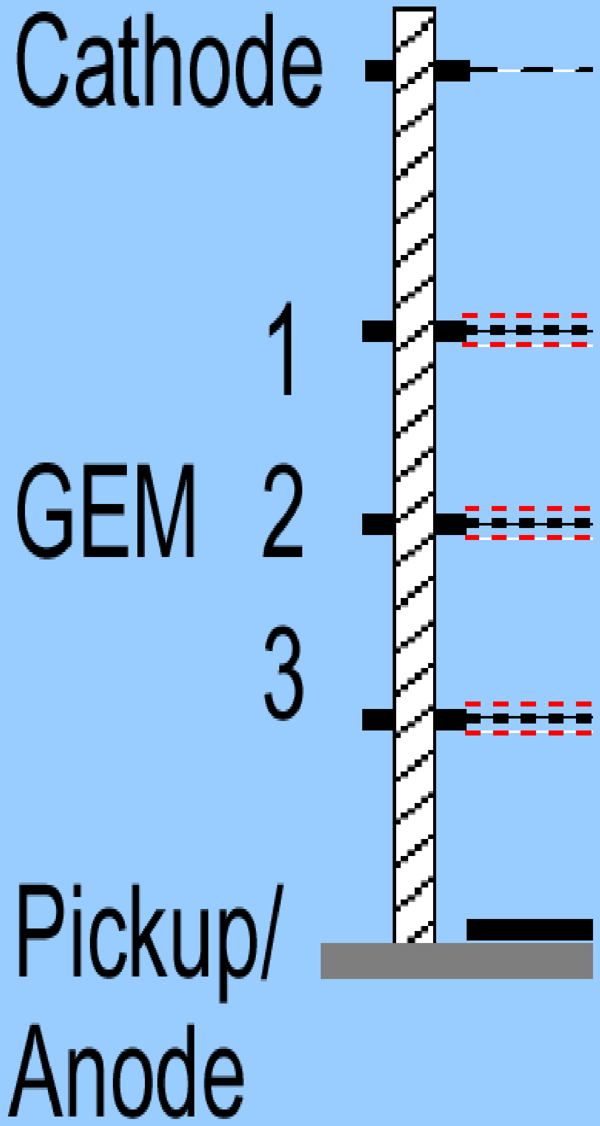
Brute Force:

- Parameter space spanned by five parameters (keeping drift and induction fields fixed) is scanned stepwise with a C program
- At every point the calculated ion feedback, effective gain and corresponding parameters are written to hard disk (root tree)
- Then the obtained data set can be searched for minima (e.g. with root macros)
- Optimized settings can then be written to a script file that controls our automated measurement application (xtc)

Example for one Parameter:



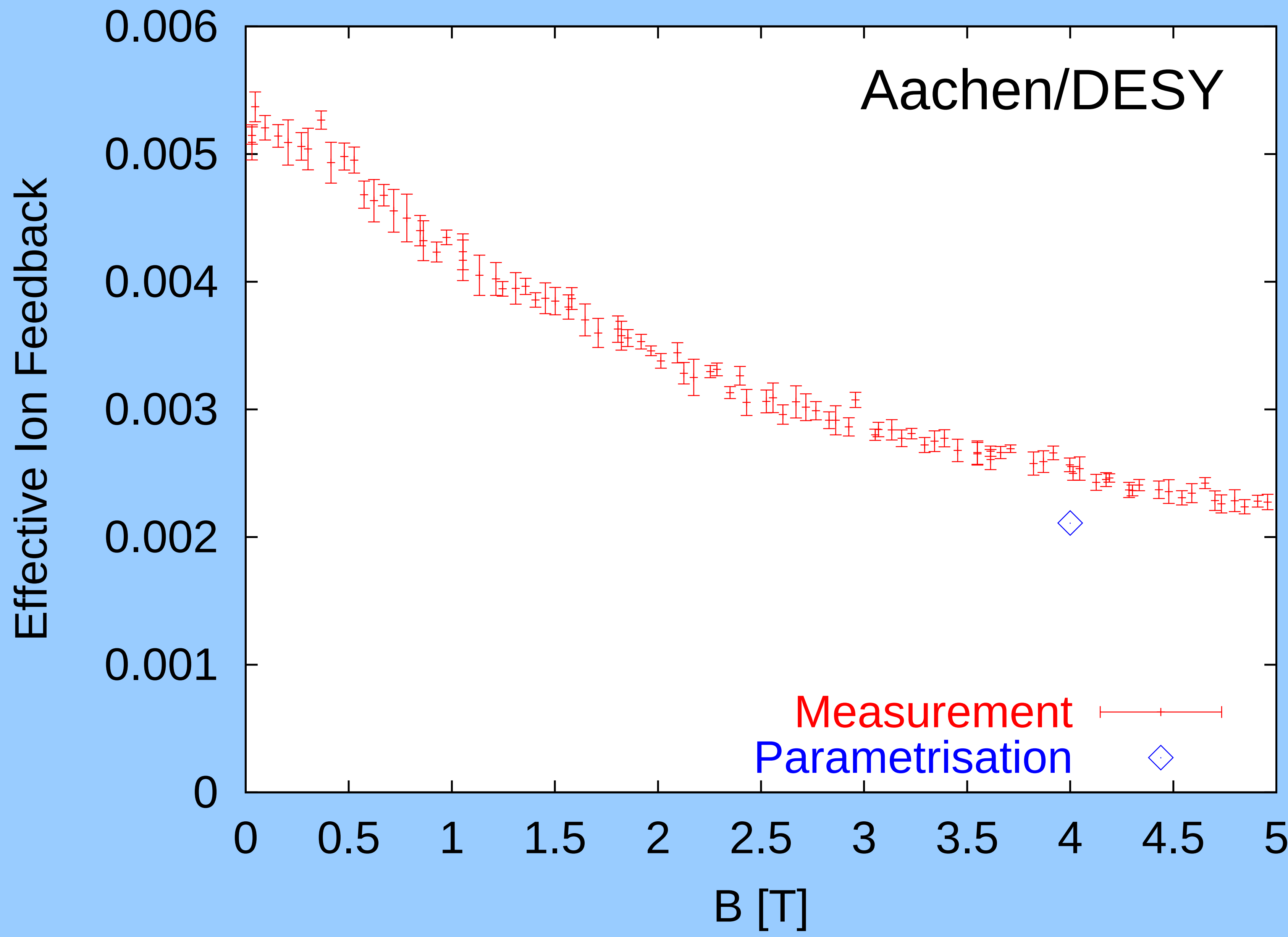
Paremeter settings at minimal Ion Feedback



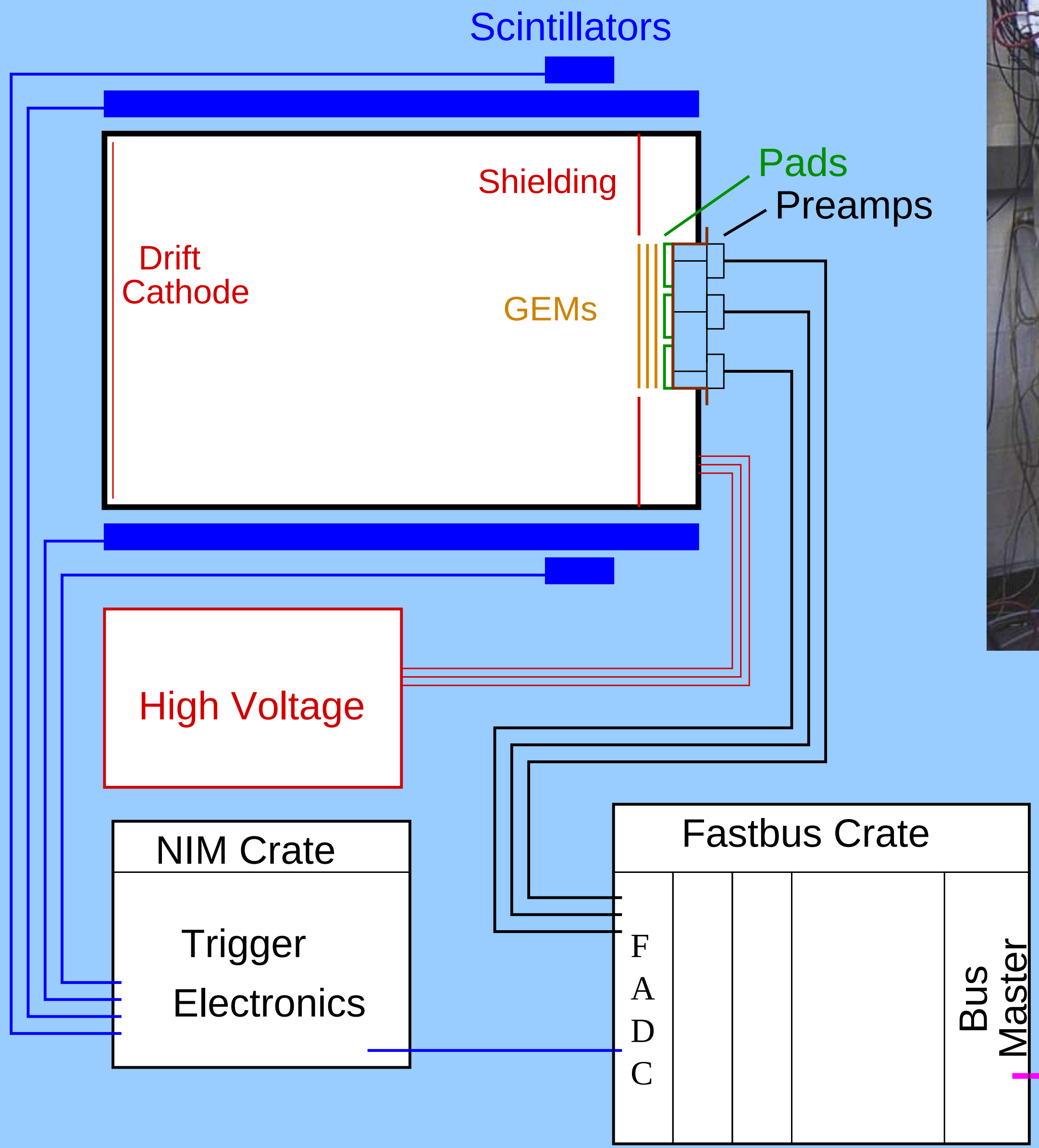
- E_{Drift}: fixed at 200 V/cm
- U_{GEM1}: small influence
- E_{Trans1}: maximal
- U_{GEM2}: small influence
- E_{Trans2}: minimal
- U_{GEM3}: maximal
- $E_{Induction}$: maximal

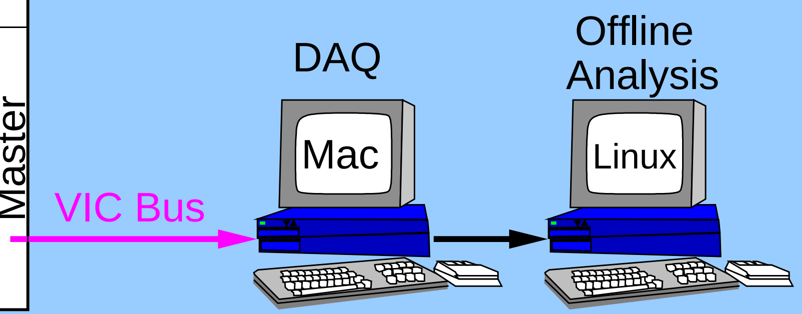
U_{GEM1} and U_{GEM2} allow variation of eff. Gain, without changing the IF.

Measurement of IF in a Magnetic Field



The Test-TPC

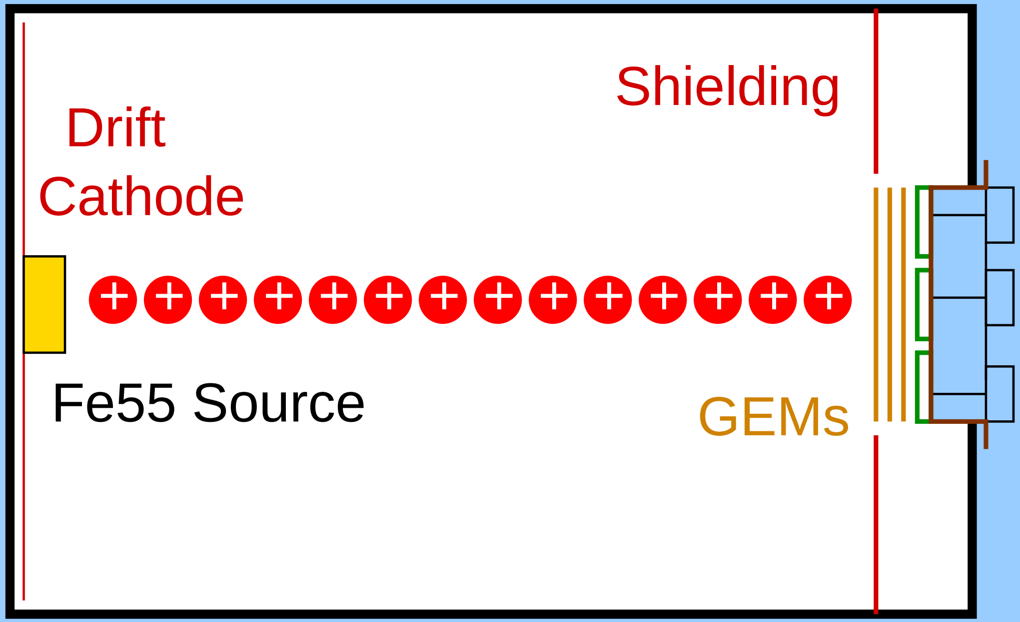

Scintillators
Shielding
Pads
Preamps
Drift
Cathode
GEMs
High Voltage
NIM Crate
Trigger
Electronics
Fastbus Crate
F
A
D
C
Bus
Master


VIC Bus
DAQ
Mac
Offline
Analysis
Linux

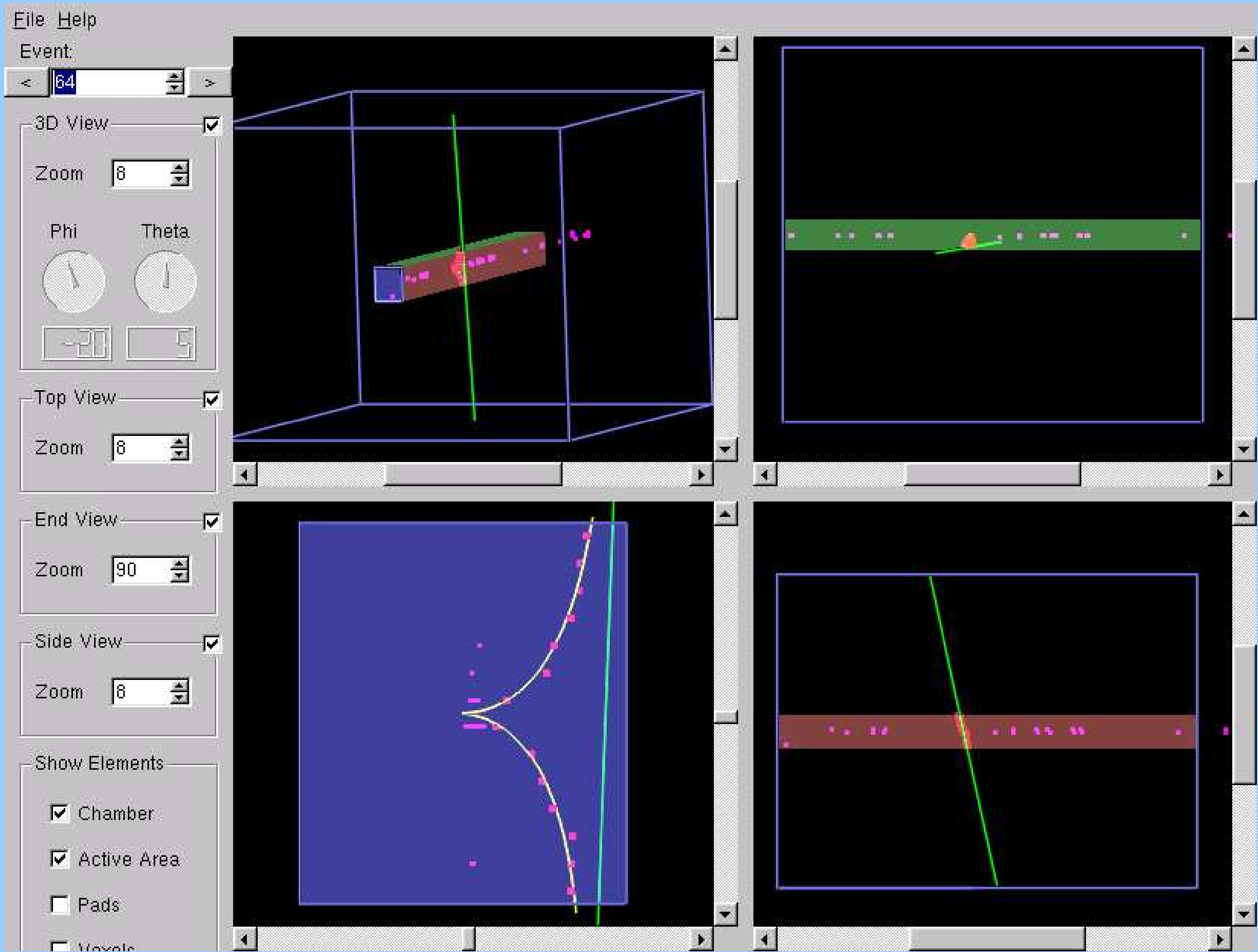
Tracks with Ion Feedback

Application of a radioactive ^{55}Fe source at the cathode exactly opposite of the readout

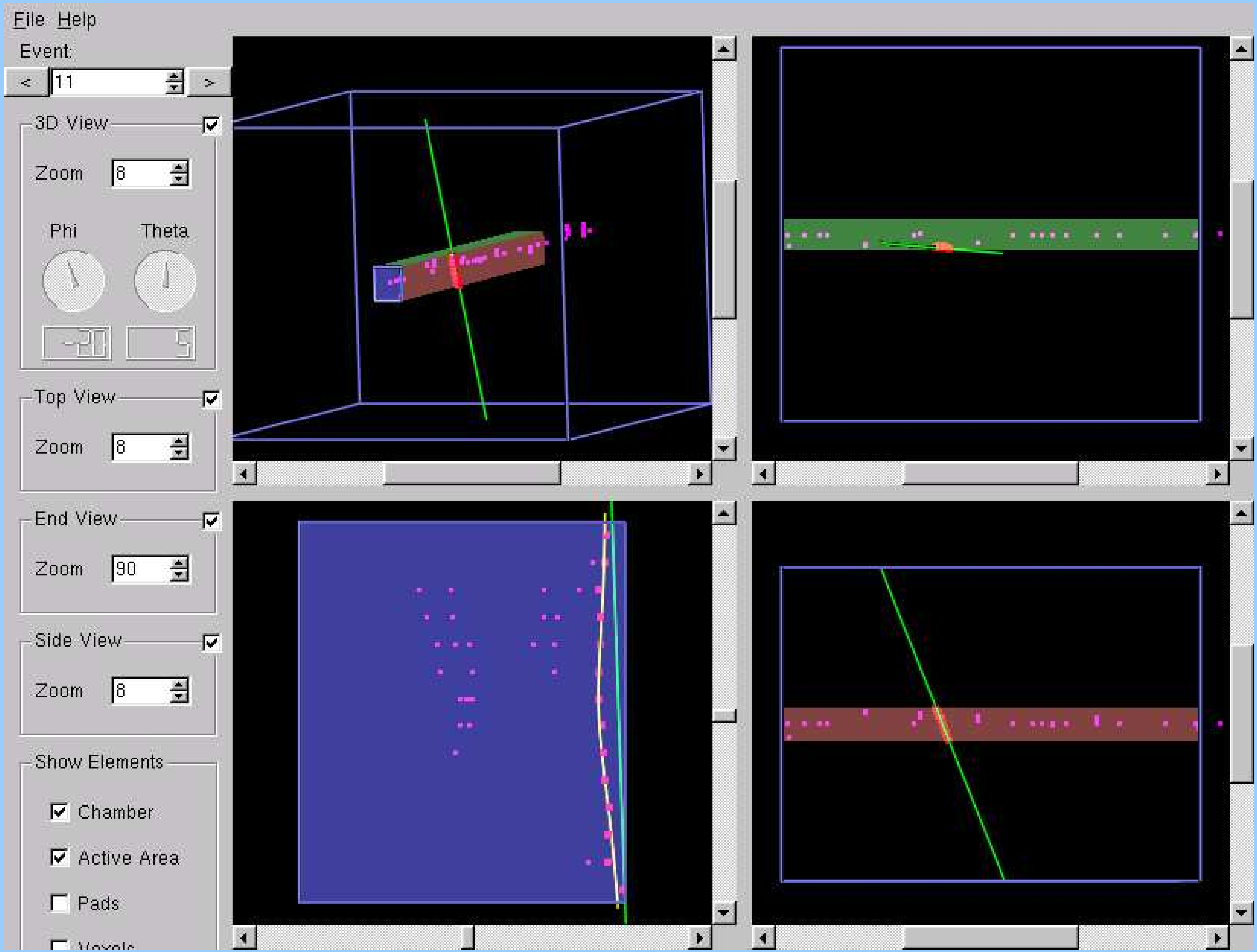
- Continuous creation of a large amount of electrons
- Forming of an ion tube between source and readout



Track Distortions by High Ion Feedback

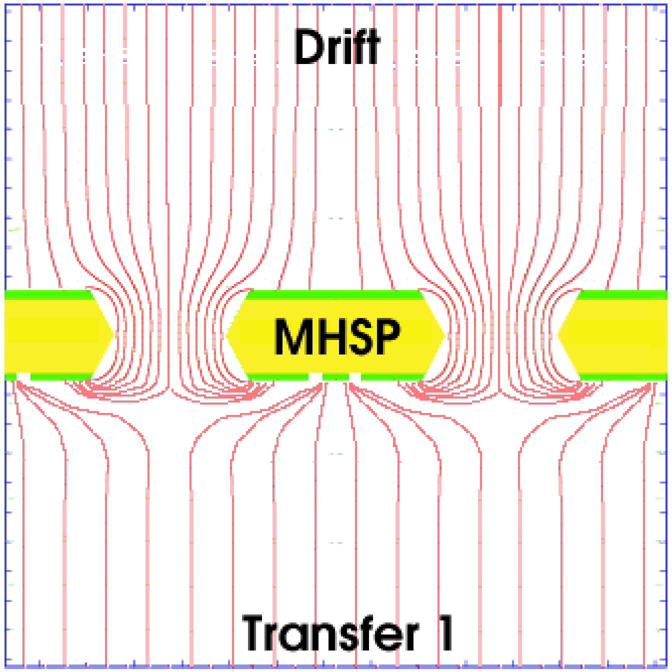


Track Distortions by reduced Ion Feedback

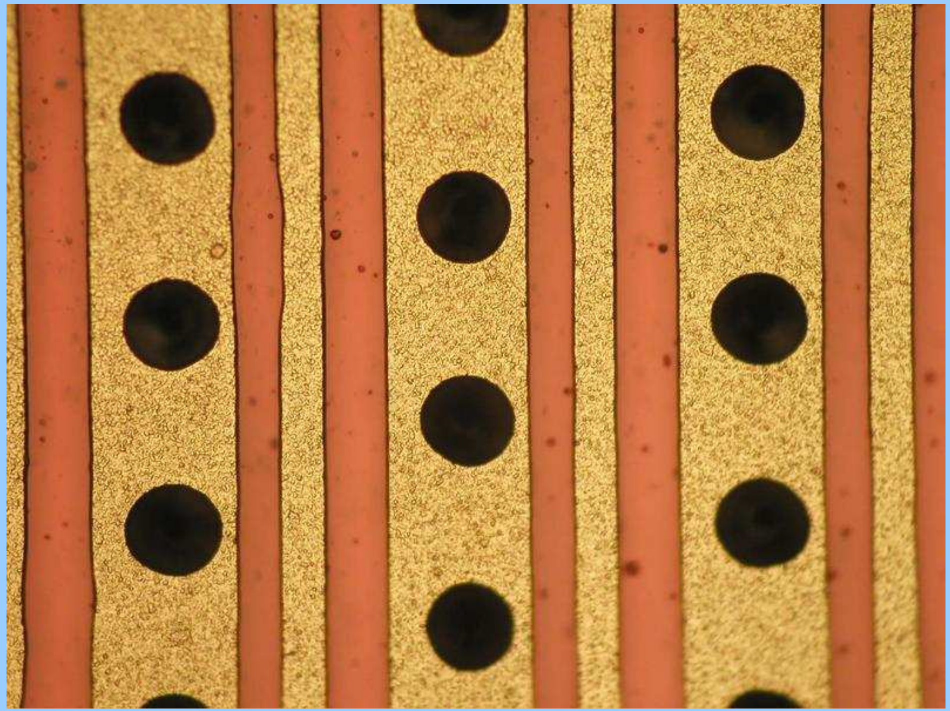


Micro Hole Strip Plates (MHSPs)

Replace the first GEM with a MHSP:

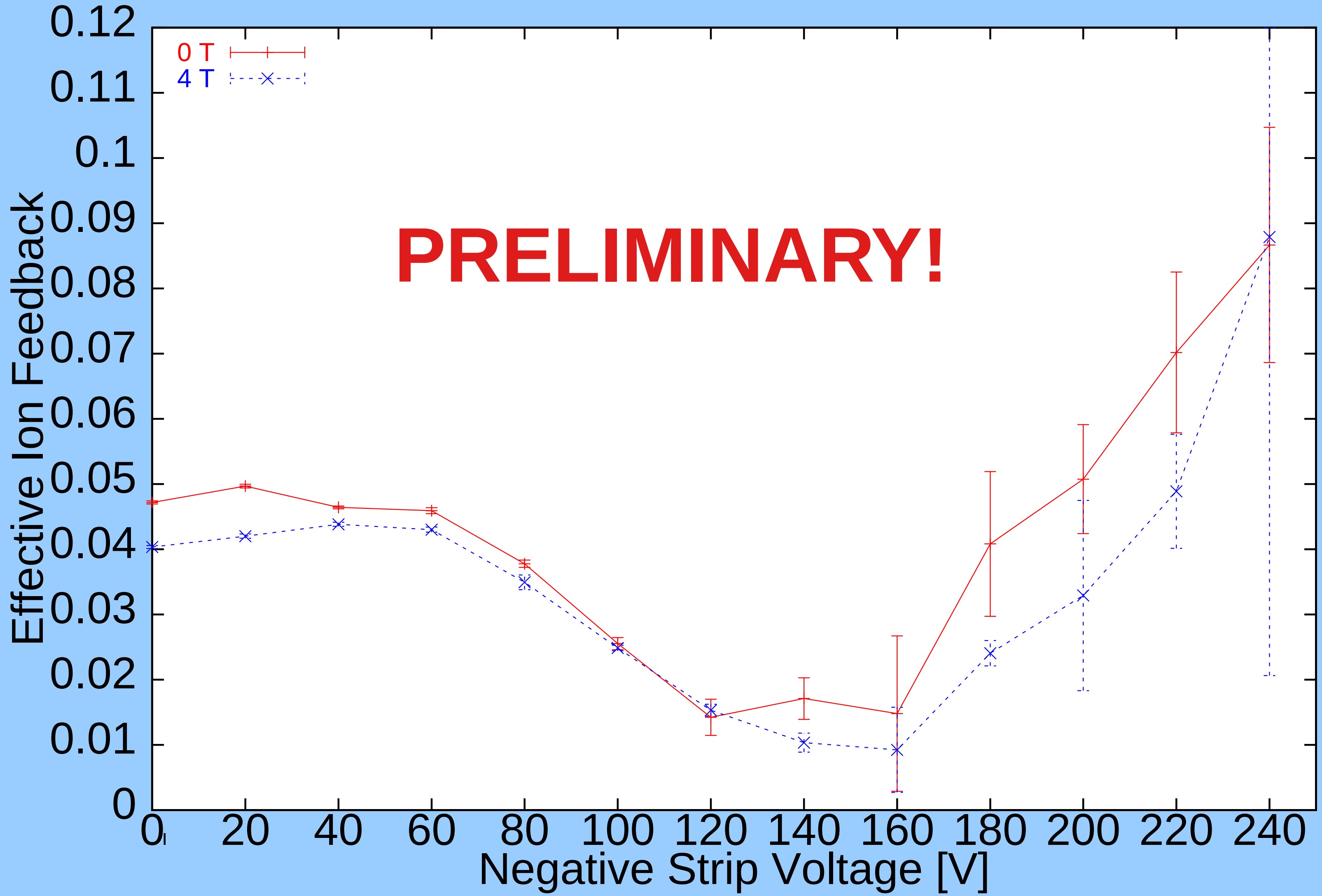


sketch



Idea: Negative strip voltage $\Rightarrow$ Ions are collected on the strips, while electrons, due to diffusion, pass.

First Measurements with MHSPs



Not yet optimised setting!

Summary and Outlook

Standard GEMs:

- The qualitative influence of the individual chamber parameters on the ion feedback is understood
- The minimum ion feedback depends strongly on the maximal reachable fields and GEM voltages
- A magnetic field of 4 T decreases ion feedback by a factor of ≈ 2
- An ion feedback $\leq 2.5 \times 10^{-3}$ was achieved with TDR-gas and is stable for $\geq$12 h (stability test without magnetic field)
- Check how settings optimized for IF affect dE/dx etc.

MHSPs:

- MHSPs offer an additional possibility for IF suppression
- First results look promising, but till now no improvement over normal GEMs is achieved
- further studies of this new technology have to be done

The goal of $IF = 10^{-4}$ seems unrealistic!!

$\Rightarrow$ check if higher ion feedback or lower effective gain are acceptable

- line of backdrifting ions of infinitesimal thickness and infinite length $\Rightarrow \vec{E} = \frac{\alpha'}{r}\frac{\vec{r}}{r}$
- $v_{drift} \propto \vec{E}$ for small fields

Equation of motion for point:

$\frac{d\vec{r}}{dt} = -M\vec{E}$ $\quad$ M is electron mobility

In polar coordinates: $\frac{dr}{dt} = -M\frac{\alpha'}{r}$

$$\Rightarrow r(t) = \sqrt{r_0^2 - \alpha t}$$

Backup: Fit 2

Start with straight line $x = ay + b$
in polar coordinates: $x = r\cos(\varphi) \quad y = r\sin(\varphi)$

$$r_0 = \frac{b}{\cos(\varphi_0) - a\sin(\varphi_0)}$$

φ does not change with time

$$\Rightarrow r(\varphi, t) = \sqrt{\frac{b^2}{(\cos(\varphi) - a\sin(\varphi))^2} - \alpha t}$$

Backup: Example for Fit