Pixel TPC gating and double grid studies

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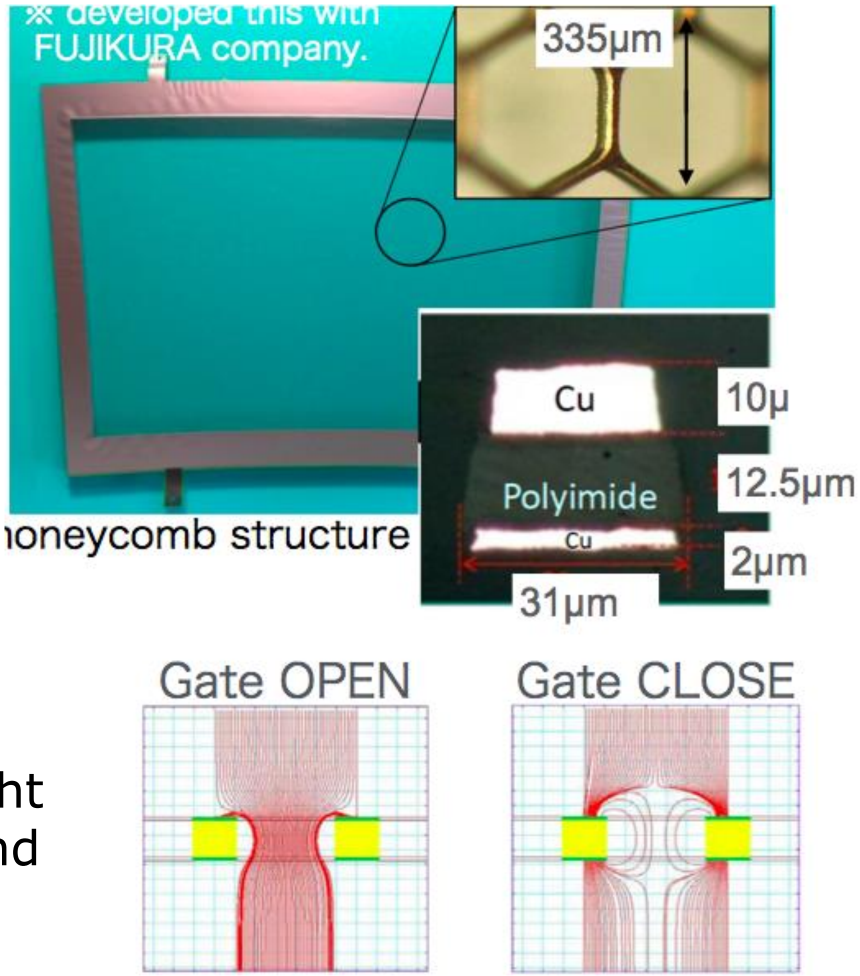
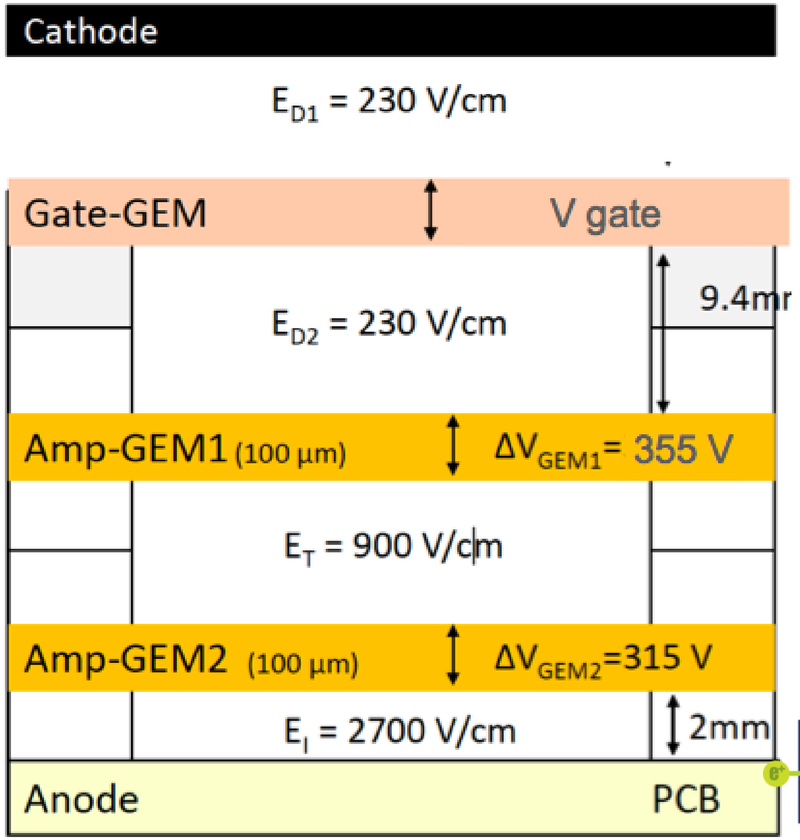
- Studies Pixel TPC Gating (a la ILD)
- Studies Pixel TPC with double grid; a grid on top of the GridPix

Pixel TPC gating

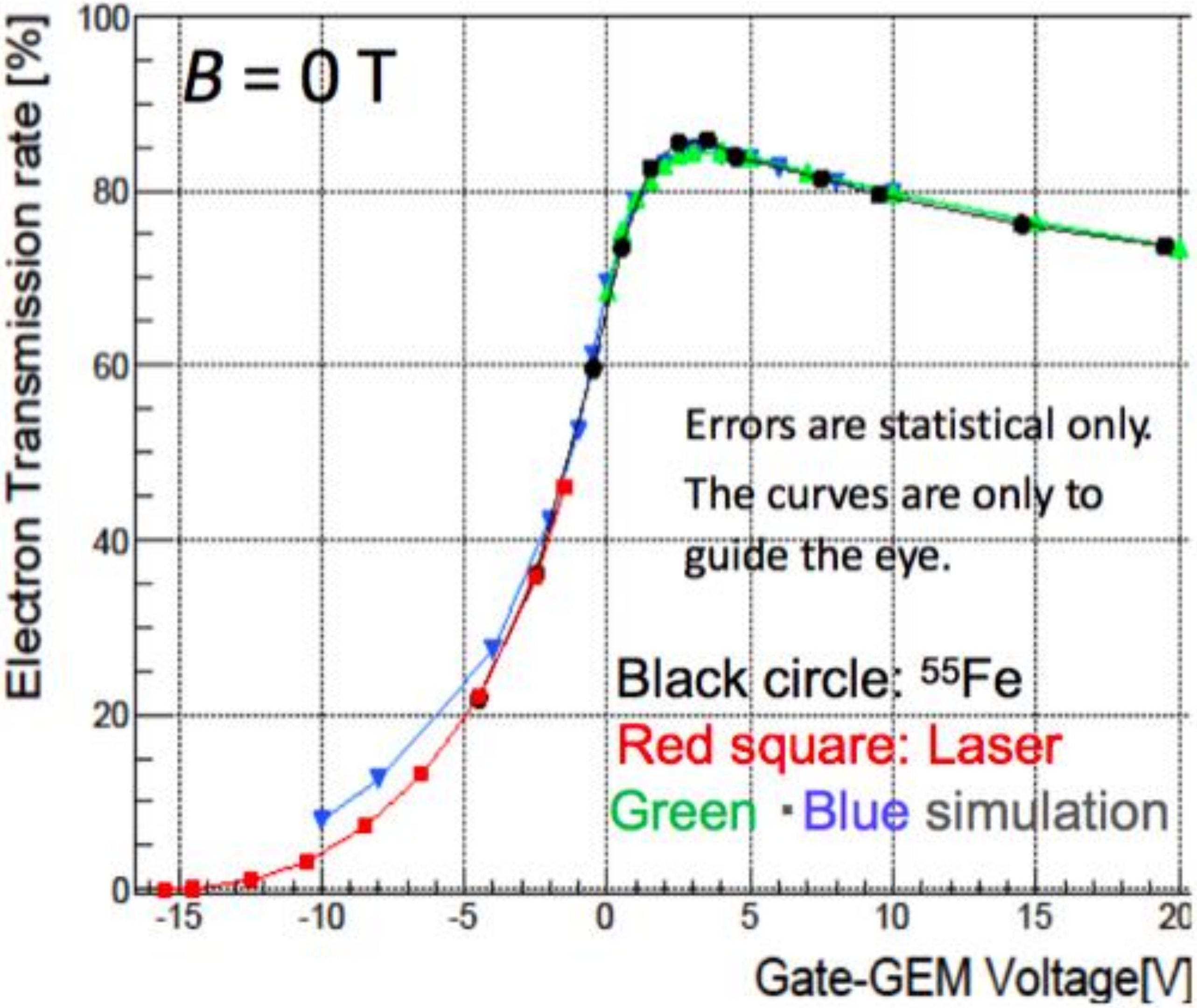


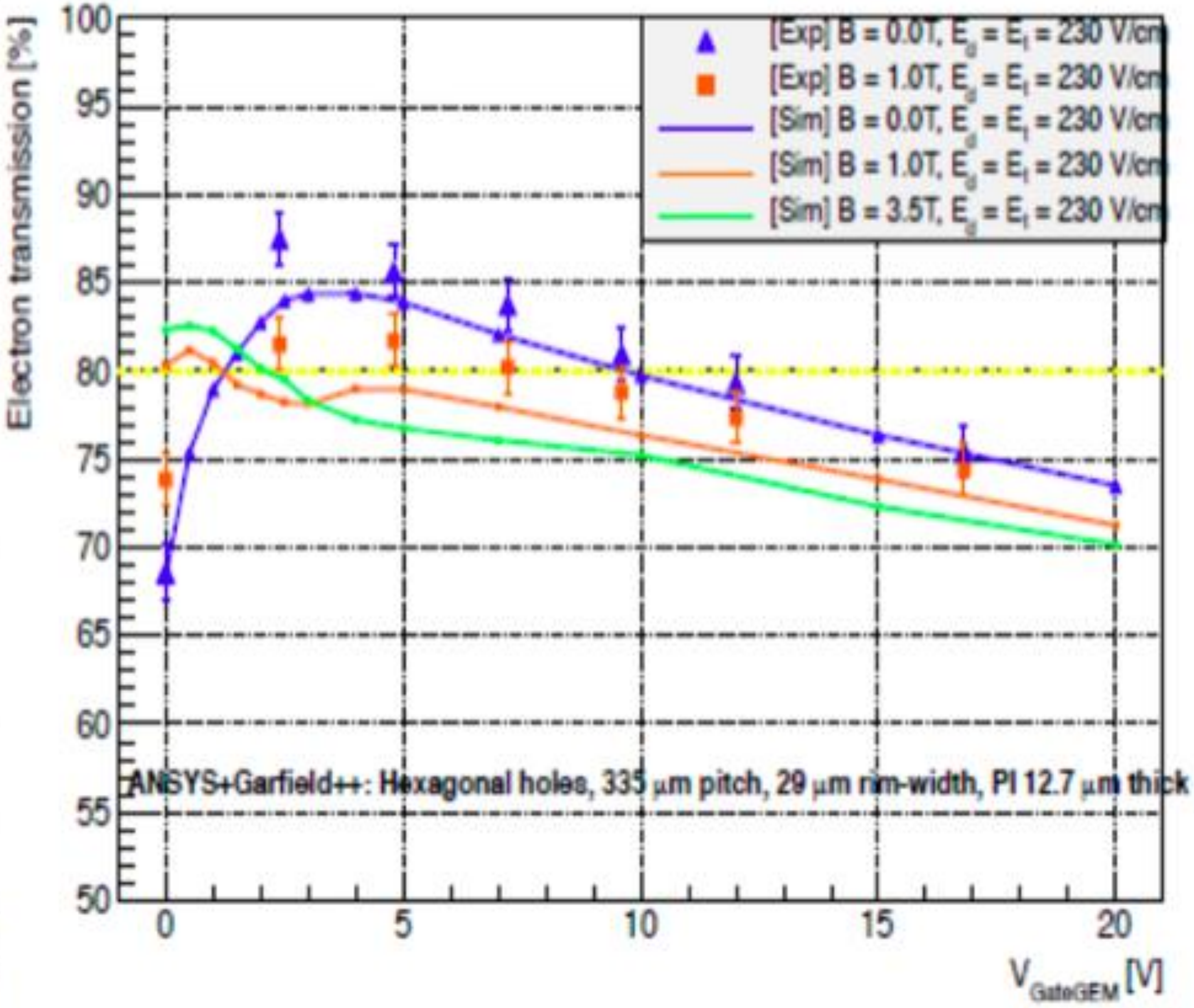
Plots do not have the right geometry and deform …

- LCWS19 presentation ILD gating GEM
  Yumi Aoki (KEK)



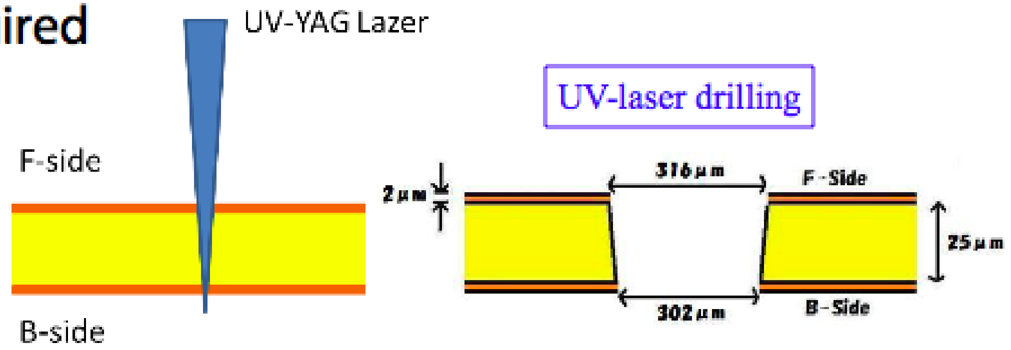
Transparancy Gate



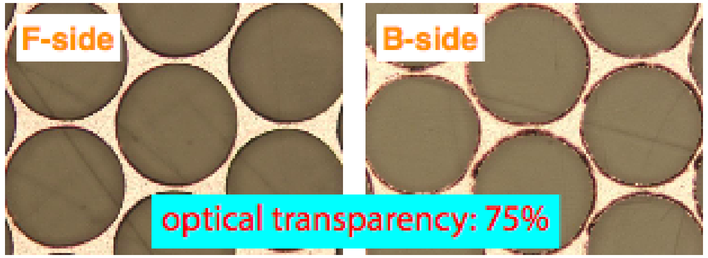


Large-aperture Gate-GEM samples

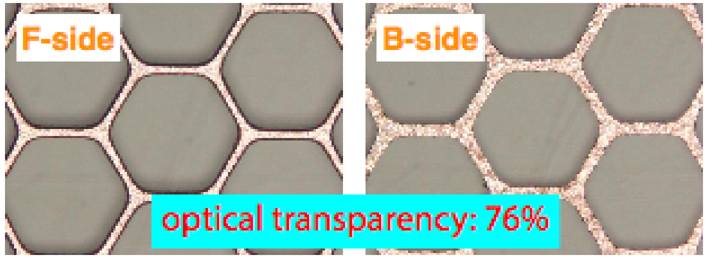
- **High optical transparency = Minimize rim width of GEM holes**
  - To achieve high electron transmission: 30 µm rim width & 330 µm pitch in honeycomb structure (= 85~90% optical transparency) required



- **R&D by D. Arai (Fujikura Ltd.)**
  - Thanks for his tremendous efforts!!!
- **Fujikura Gate-GEM Type 0 sample**
  - Round holes / UV- laser ablation technology (1 cm x 1 cm)
  - 15 µm (F-side) - 30 µm (B-side) rim width with PI thickness 25 µm: hard enough!



- **Fujikura Gate-GEM Type 2 sample**
  - Hexagonal holes / Ni-plating process (9 cm x 9 cm)
  - 30(F) - 40(B) µm rim width & 300 µm pitch with PI thickness 12.5 µm

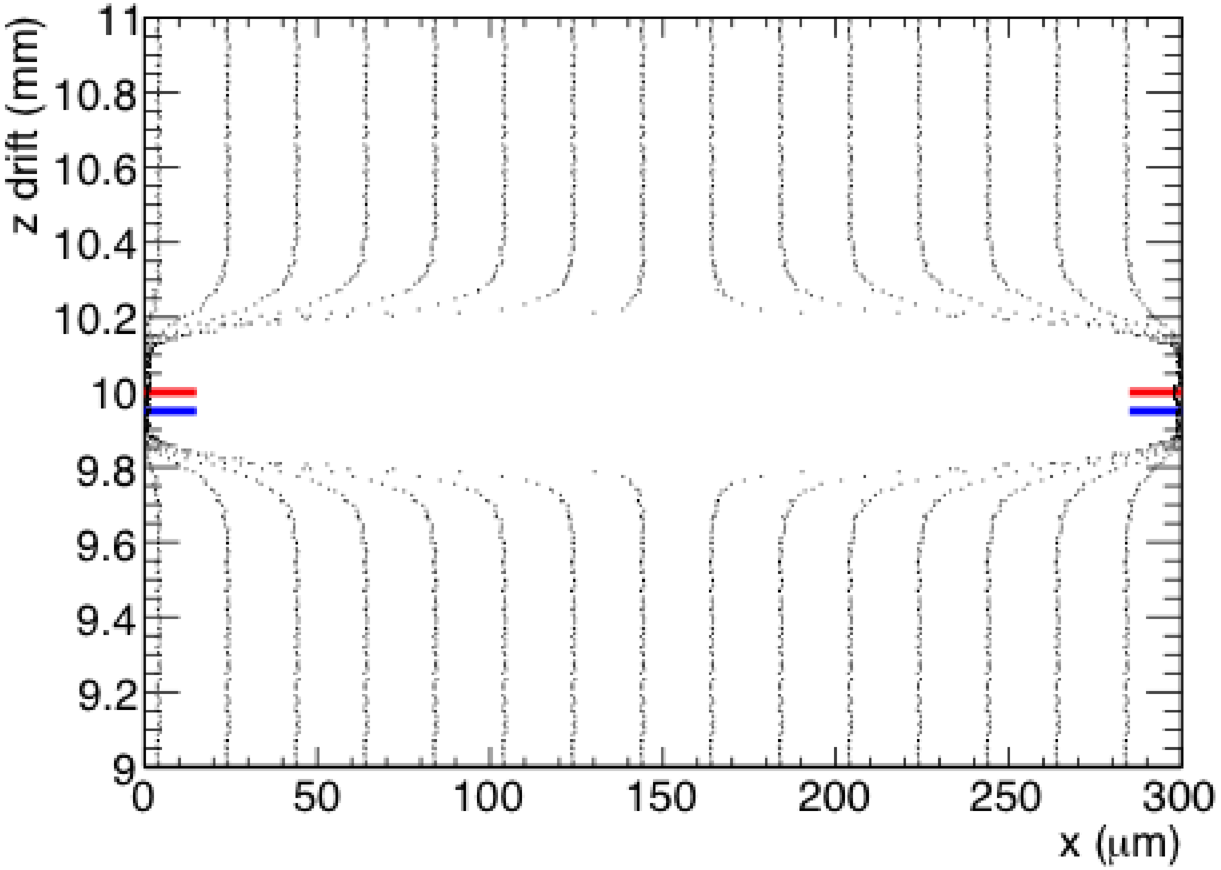


Modeling the Gating device

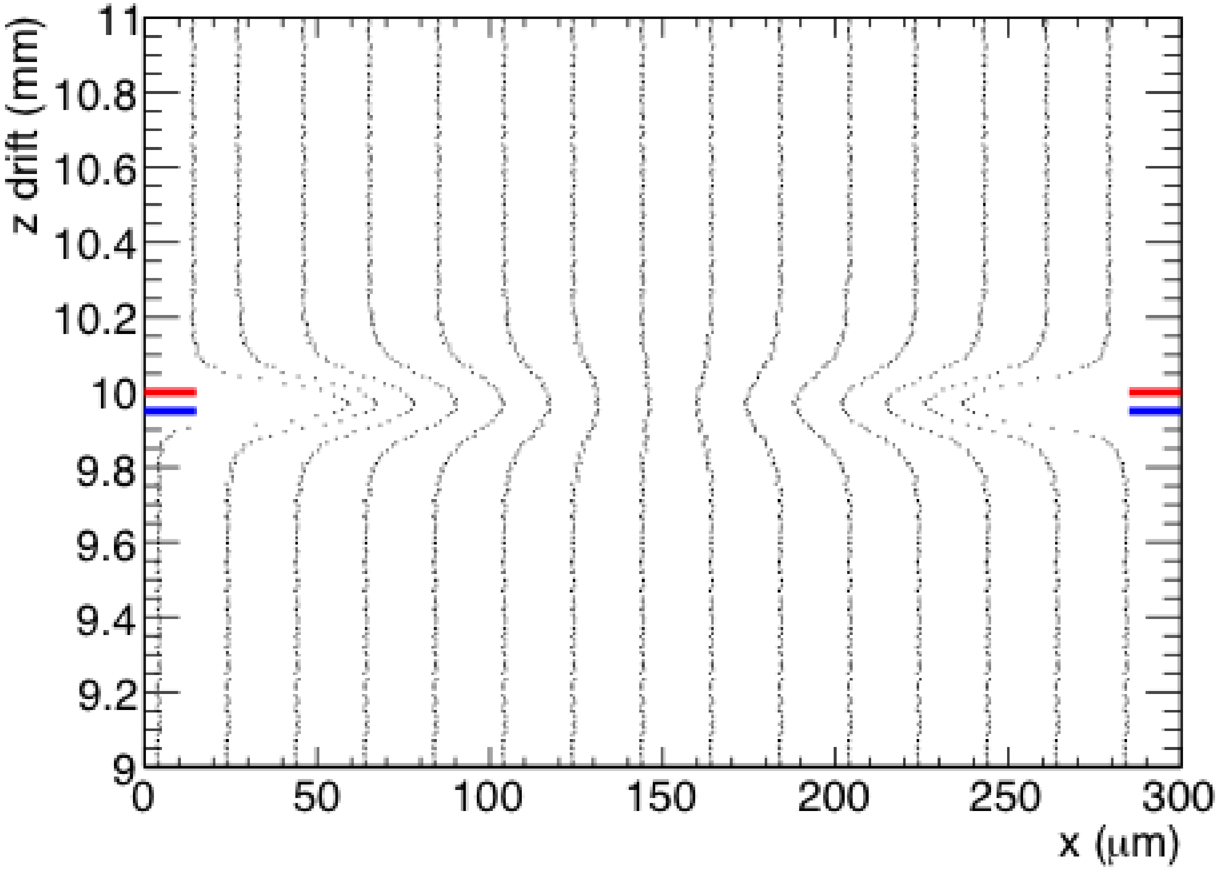
- Making E field calculations for the device with approximate dimensions
  - Make rectangular grid with 300 μm spacing and rim 30 μm. So optical transparancy 81%.
  - The two planes are put 50 μm apart (a bit further than the Japanese Gate).
  - There is a central voltage V_c applied that should correspond to the potential of the field without the gating device (here 250 V/cm). And a voltage difference dV that is controlled to switch the gate
  - The upper part of the gate is at 10 mm and the lower at 9.95 mm from the bottom plate (ground). The anode is 550 mm away.
  - Exact expressions for the E field of rectangular (plates) are used; by using mirror charges the ground is put at $z = 0$. By adding and subtracting charges a grid with holes is created.
- Questions: how can we minimize distortions? How precise should we control voltages and dimensions (how flat should the gate be mounted)?

Trajectories in Gating device

Gate closed -30 V

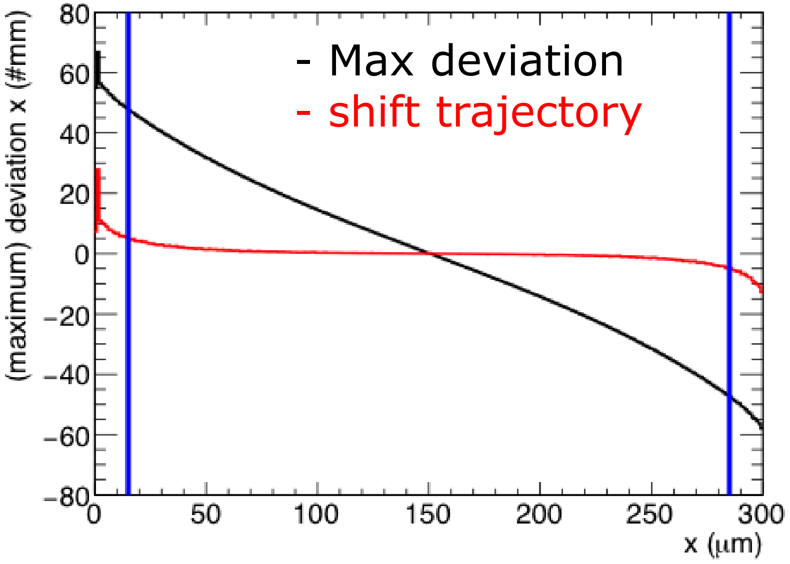


Gate open 1+1.5 V

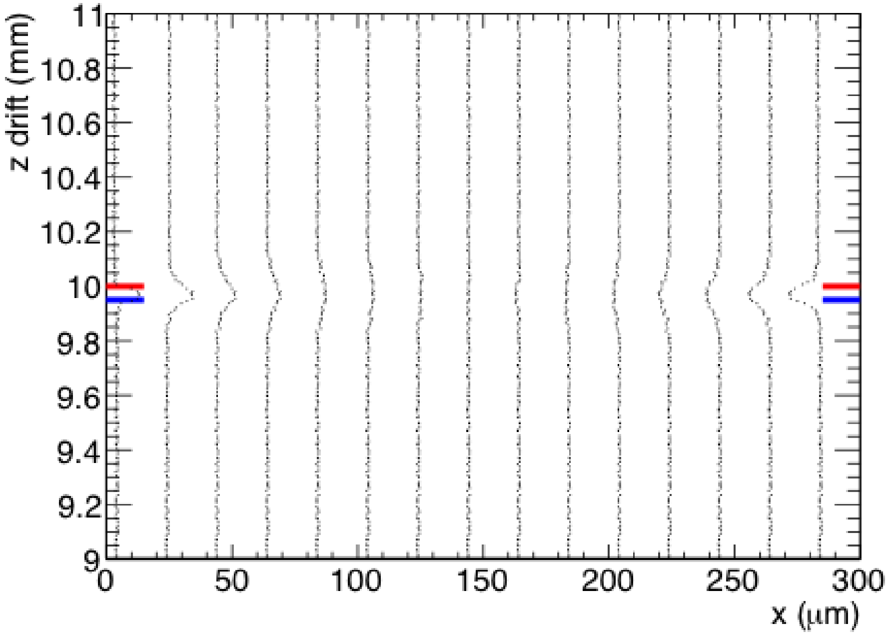


Trajectories in Gating device

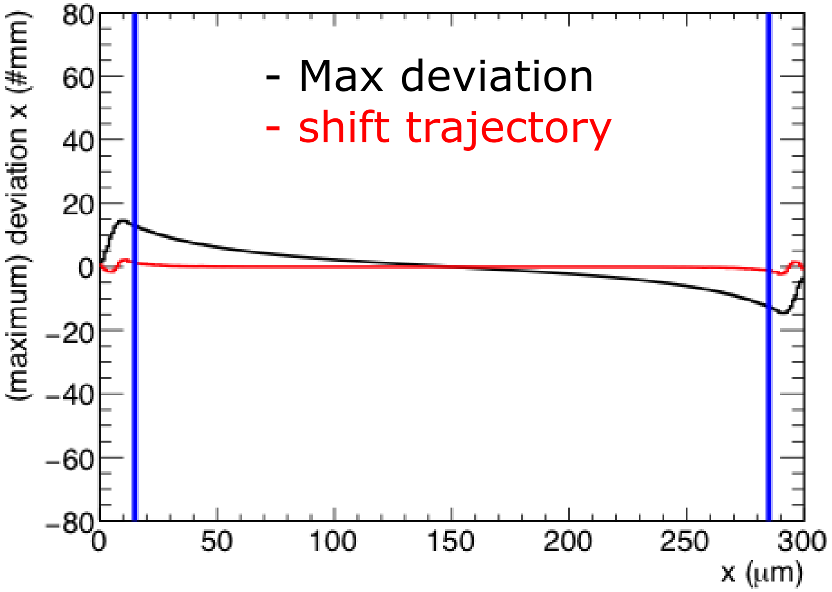
Gate open 1+1.5 V



Gate open 0.1+1.5 V



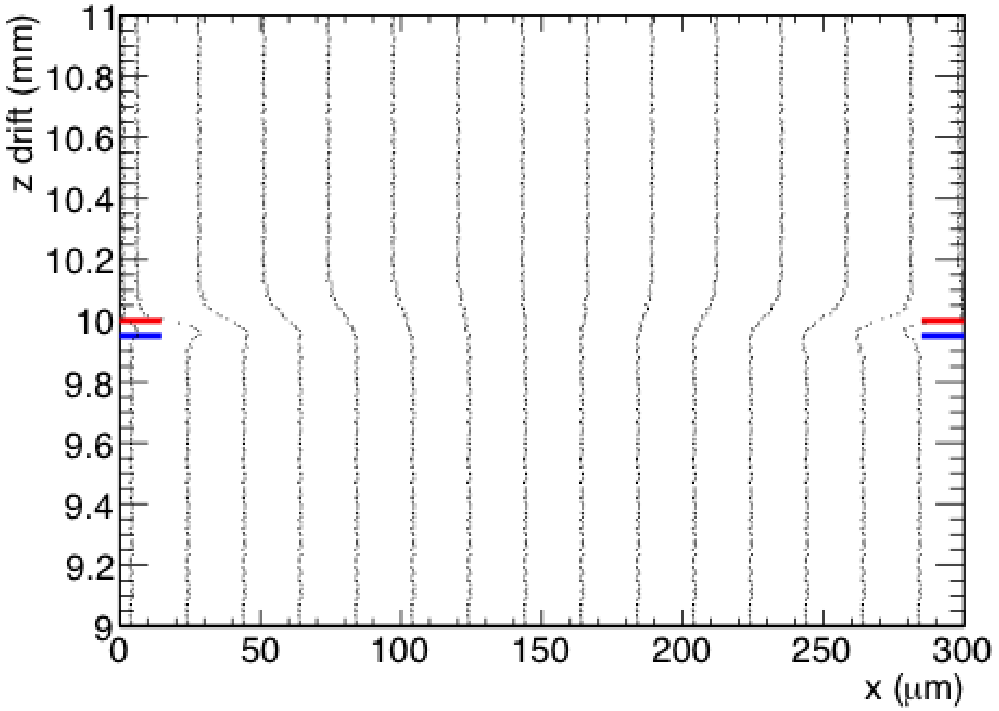
Gate open 0.1+1.5 V

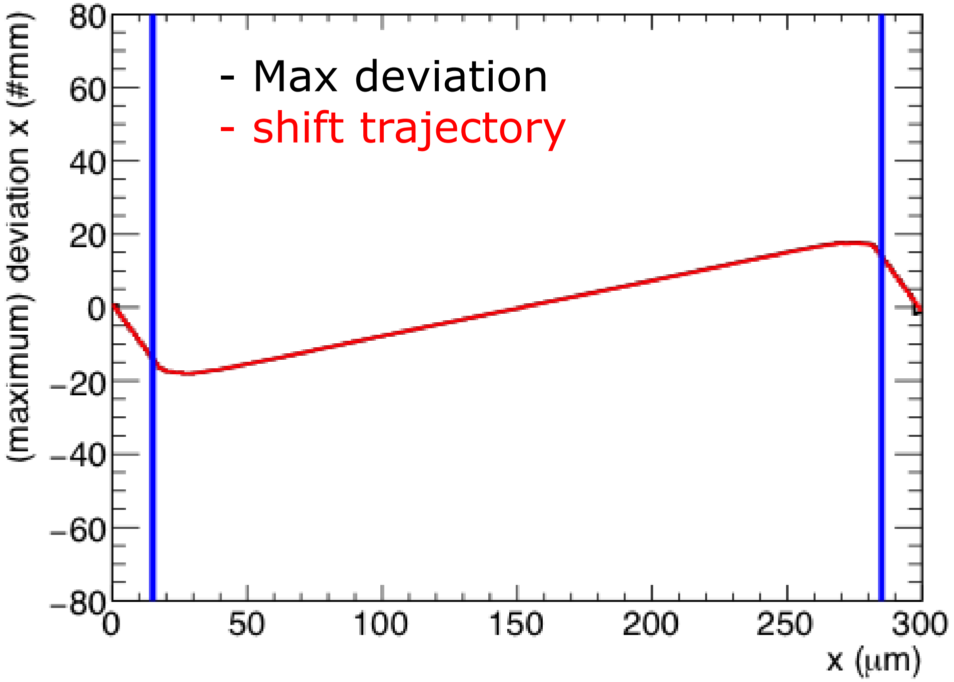


To open gate stay close to nominal field (and potential)
Deformations are smaller < 20 μm for dV = 0.1 V
Note that large maximum deviations will lead to ExB distortions

Deformed Trajectories in Gating device

Gate open 0.1+1.5 V
mismatch 10 V middle gate





This means that the voltage of the Gate should be correct up to 5-10 V or the gate should be mounted with a precision of < 0.2-0.4 mm (250 V/cm). In that case the deviations remain less than < 20 μm

Conclusions: Gating device

In order to keep deviations/deformations smaller than 10-20 μm:

1. The potential difference dV over the gate should be kept very close to the nominal field (times distance) plus/minus 0.1 V
   This means that one should not tune the gate Voltage for the highest efficiency/transparancy, but use the above specification
2. The central voltage of the Gate V_c should be correct up to better than 5-10 V
3. The gate should be mounted with a precision of better than 0.2-0.4 mm in z

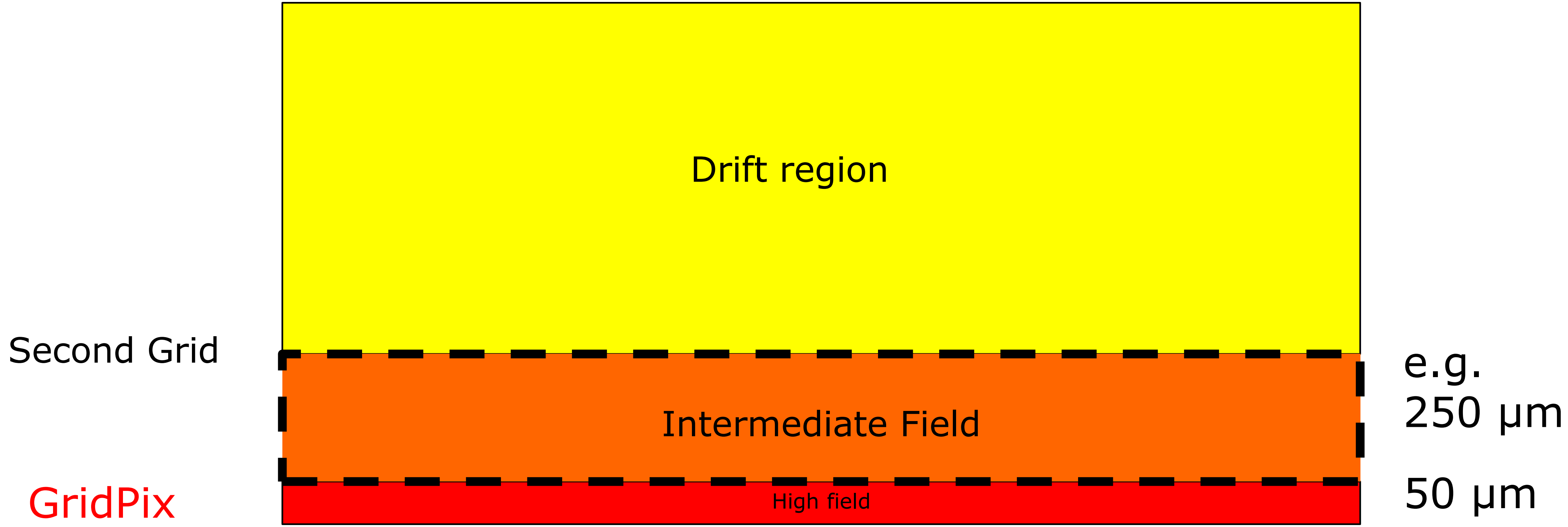
- These specification can be achieved with the proposed gating device
  - controlling of the potential difference to 0.1 V is feasable
  - the tuning of the central voltage to better than 10 V is not difficult; the tuning of the Guard wires of the 8-Quad module was already a few Volts

- It is usefull to mount a gate on the current module and measure deformations as a function of dV and V_c

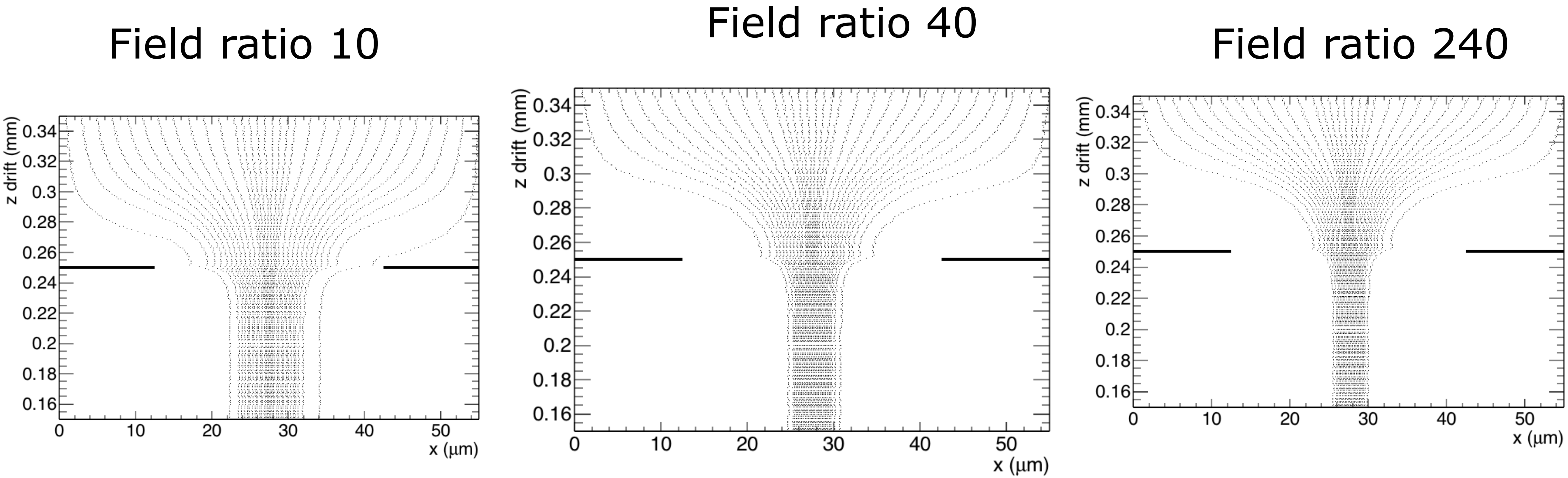
Pixel TPC with double grid to reduce the ion back flow

- Question: can one reduce the Ion Back Flow of a GridPix detector?
- We could design a GridPix detector using a double grid
- The idea is that by creating two field regions, one with a medium field and one with a high field (our standard Grid Pix) one could reduce the ion backflow in two stages.
  - The high field avalanche region has a measured IBF of 1.3%
  - The aim is to reduce the IBF by another factor 100
  - The second Grid replaces the Gating device and is always operational

Design of a double Grid



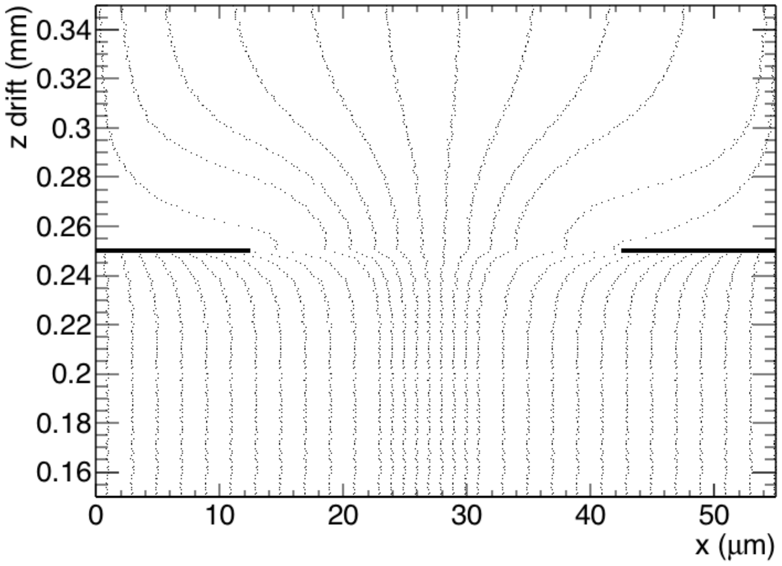
In (down) flow trajectories second Grid



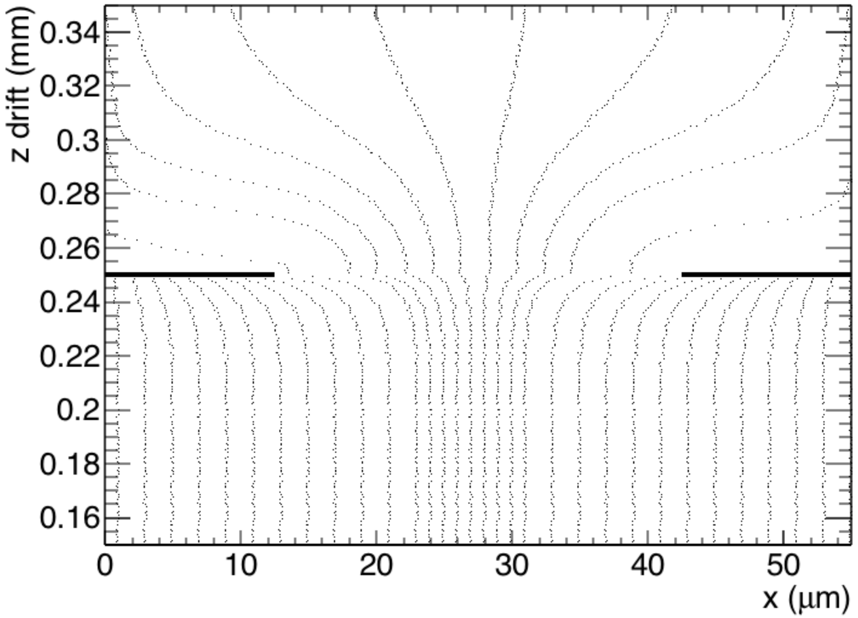
Geometry: second grid at 0.250 mm (z); Cathode at 550 mm
Standard GridPix pitch 55 μm and hole 30 μm
Field ratio = mean Field (0-0.250 mm)/ mean Field z (2-550 mm)
Electron tracking without diffusion:
σ (rms) size of funnel (focussing E field) = 2.6-1.5-1.1 (Fr 10,40,240)

Backflow (up) trajectories second Grid

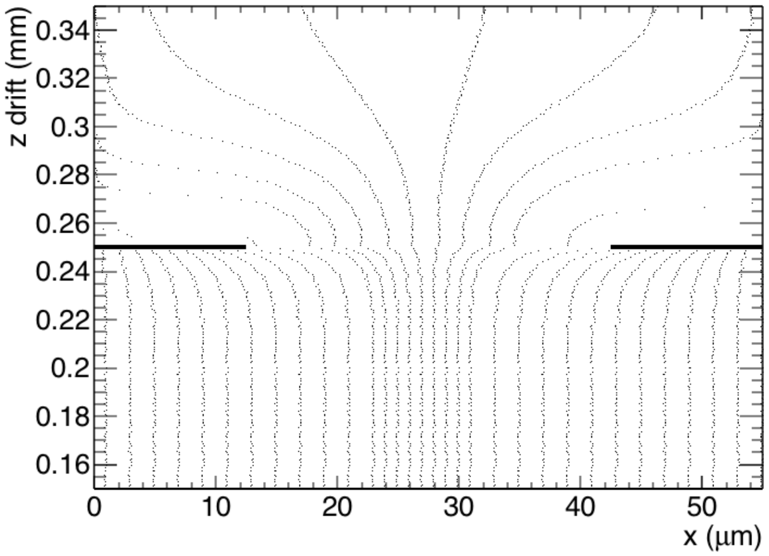
Field ratio 10



Field ratio 40



Field ratio 240



Here the trajectories of ions from the bottom upwards are shown
The differences between the different field ratios are small

Modeling of ion back flow

Modeling of the ion backflow is based on the measurements for a standard GridPix with FR 240. The ion backflow was measured to be 1.3%.

The Ion BackFlow is sensitive to the diffusion in the high field region.
The electron funnel size is 1.1 μm just from the field focussing.
For the GridPix (gap 50 μm) one expects an electron diffusion of 150-200 μm/√cm. This gives a smearing of the funnel of about 10-14 μm.
The calculated IBF corresponds to 1.3% for a smearing of 15 μm.
So this agrees reasonably well with expectations.

The performance IBF of the top grid.
What happens is that the back flowing ions that make it through the lower grid that runs at FR240 will be flat distributed if one is 60-100 μm or more above it.

IBF of the second grid

The performance IBF of the second grid.
What happens is that the back flowing ions that make it through the lower grid that runs at FR240 will be flat distributed if one is 60-100 μm or more above it.

The field ratio should not be too high to avoid gas amplification in the top grid. Therefore we leave out the FR240 point.

IBF (%) FR 40	FR 10
1.2	3.5

Transparancy of the grid

Another important aspect is the electron transparancy.
Using the simulation this can be calculated.

Transparancy (%) FR 240	FR 40	FR 10
100.	100.	99.0

It is important to choose a FR with a high (electron) transparancy so with FR of 40 or higher.

Further reflections on the gap size

Another important aspect is diffusion that takes place in the intermediate field region. For the T2K gas this can be at most 400 μm/√cm. The gap is the distance between the two grids.

Smearing σ (μm) gap 1 mm	gap 250 μm	gap 60 μm
126	63	31

So in case of a 1 mm gap there is a sizeable probability that the neigbour pixels detect the avalanche.
So a smaller gap is preferable.

Ion backflow for a double grid

Here calculations for the IBF of the two grids in case one has a total FR of about 240 – normal GridPix operation. For the simulations the FR of the top grid was put at 16. The lower Grid(Pix) was at FR 16 too. Total FR 256.

Ion backflow	Hole 30 µm	Hole 25 µm	Hole 20 µm
Top grid	2.2%	1.2%	0.7%
GridPix	5.5%	2.8%	1.7%
Total	$12\ 10^{-4}$	$3\ 10^{-4}$	$1\ 10^{-4}$
transparancy	100%	99.4%	91.7%

In order to reach IBF*Gain ($2\ 10^{3}$) below one has to choose a slightly smaller hole size of 25 or 20 microns.

Conclusions: double grid

The Ion Back Flow can be significantly reduced by putting a grid with a identical pitch and hole size on top of the Gridpix.

A device placed e.g. at 60-250 μm above the GridPix and ran with a Field ratio of 16 (top) and 16 (lower) would do an excellent job.
The electron transparancy would be over 99 (91)% and the IBF would go down from 1.3% to 3 (1) 10^{-4} for a hole size of 25 (20) μm.

This would solve the issue of IBF at CEPC and ILC.

We could do a test at Nikhef mounting this grid on top of the Gridpix (holes 30 μm) and measure the electron transparancy and the IBF and test the prediction on the previous slide.

It would be interesting to think about a post-processing step to integrate the two grids.