Performance simulation studies for the ALICE TPC GEM Upgrade

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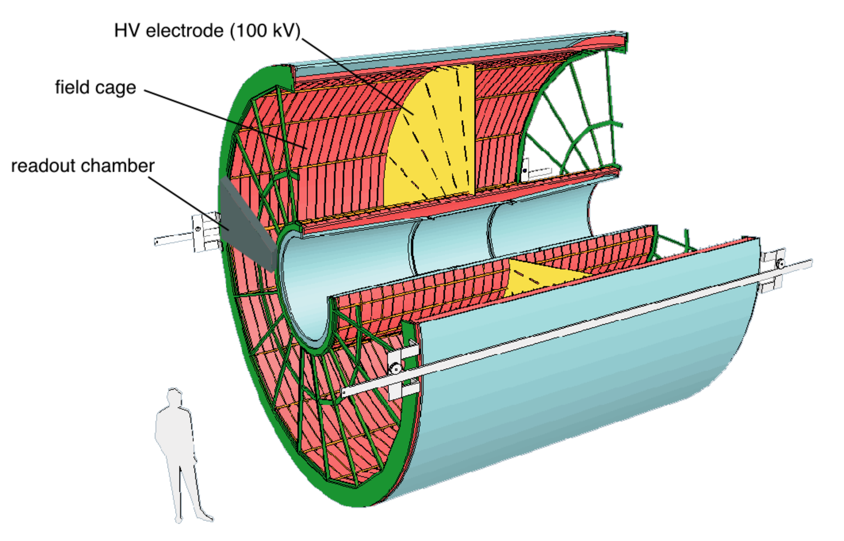
ALICE

Introduction

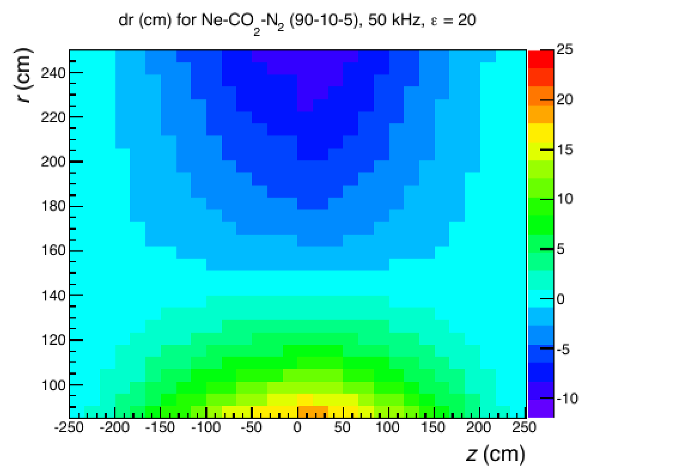
The present ALICE TPC

- Main tracking detector of ALICE
- Detects charged particles by their ionization: an electric field projects electrons onto a segmented readout with MWPC amplification
- Ion backflow (IBF) suppressed by gating grid which limits operation to $\sim$ 3.5 kHz.



GEM upgrade

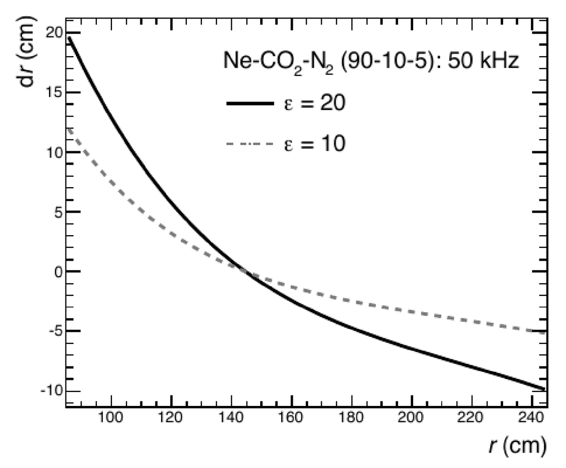
- Goal: Make use of the full expected 50 kHz Pb-Pb rate in run 3 of the LHC (2019) which precludes the use of a gating grid
- Solution: use Gas Electron Multipliers (GEMs) for amplification
- Settings using 4 GEM planes have been found that will suppress 99% of IBF while maintaining the required detector performance



Integrated distortions in the r coordinate as a function of position

Space charge distortions

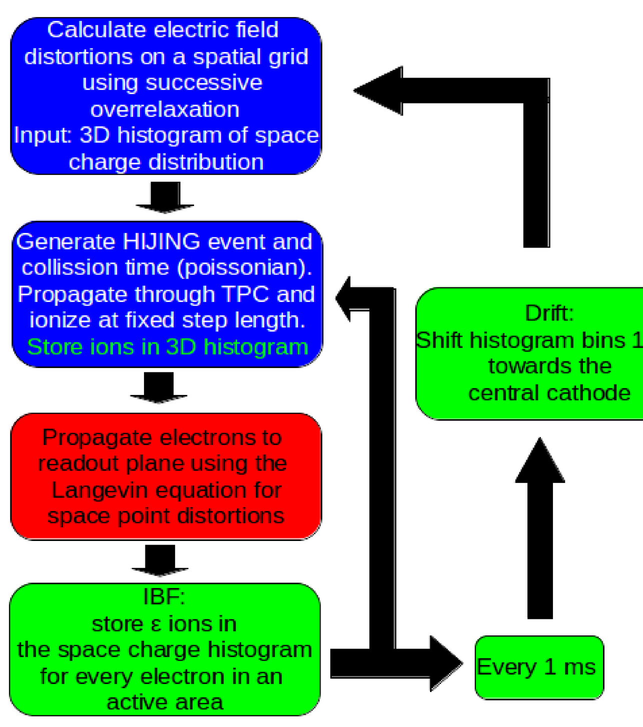
- IBF characterized by ϵ : the amount of remaining IBF ions for every electron entering the amplification structure
- Expected gain of 2000: 1% IBF $\rightarrow \epsilon = 20$
- Slow drift of ions $\rightarrow$ space charge from $\sim$ 7500 events occupies the TPC at a given moment leading to large space charge distortions
- Distortions in r are shown in the 2 right plots but the space charge also leads to distortions in $r\phi$ (due to $E \times B$) and z.

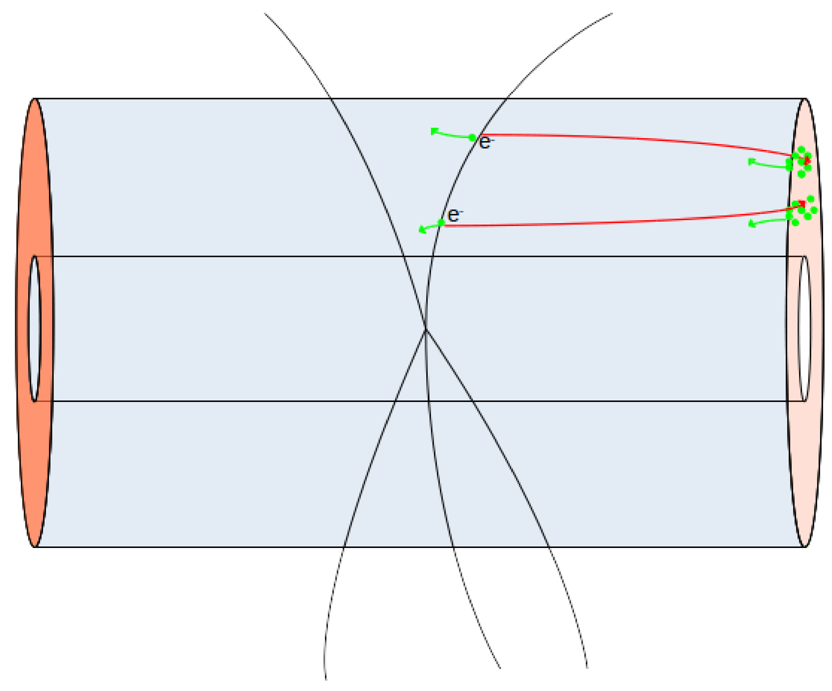


Integrated distortions in r as a function of position in r at $z \approx 0$ cm

Simulation of the space charge distortions

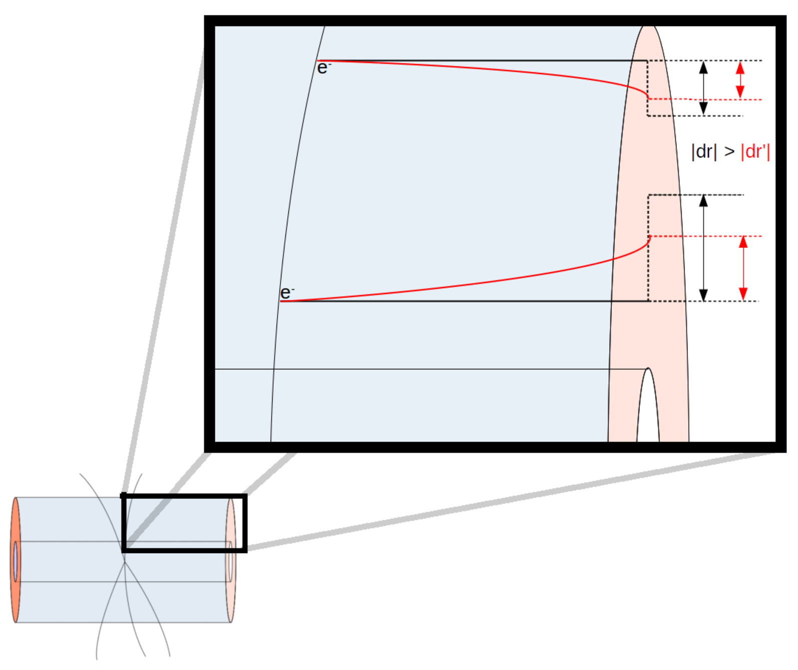
- How large is the impact of fluctuations (in collision rate, multiplicity, etc.)?
- How do the distortions vary in time?
- How often does the space charge description need to be updated to get sufficient accuracy in the corrections?

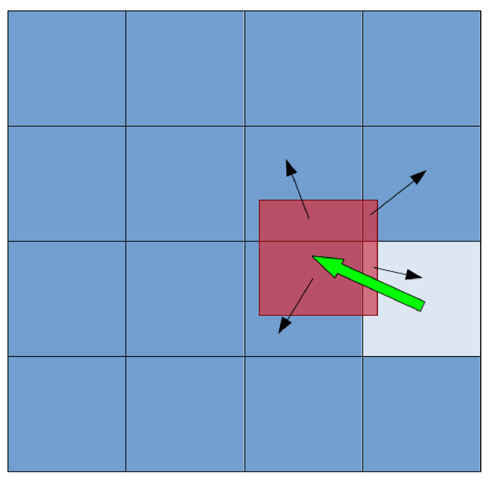




Electron drift

Drifting electrons are treated individually by the simulation. During drift they are deflected towards mid radii where the distortions decrease since the potential gradients are smaller there. Integrating the distortions along the electron trajectory is needed to correctly estimate the distortions



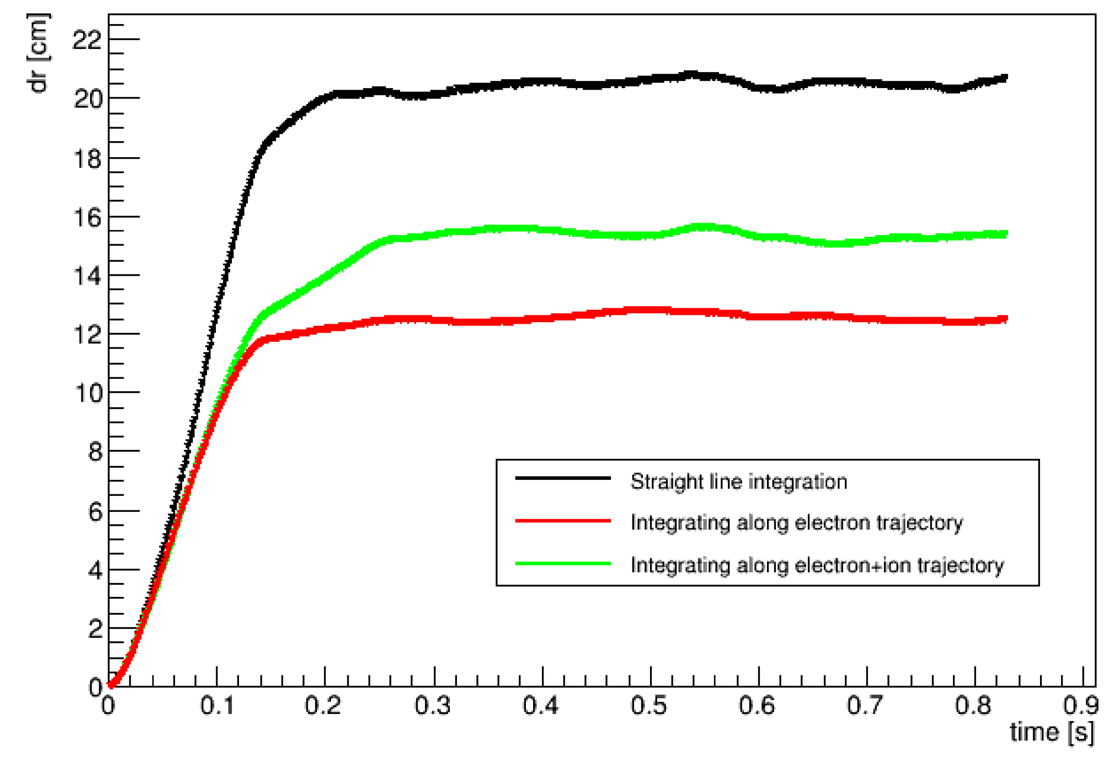


Ion drift

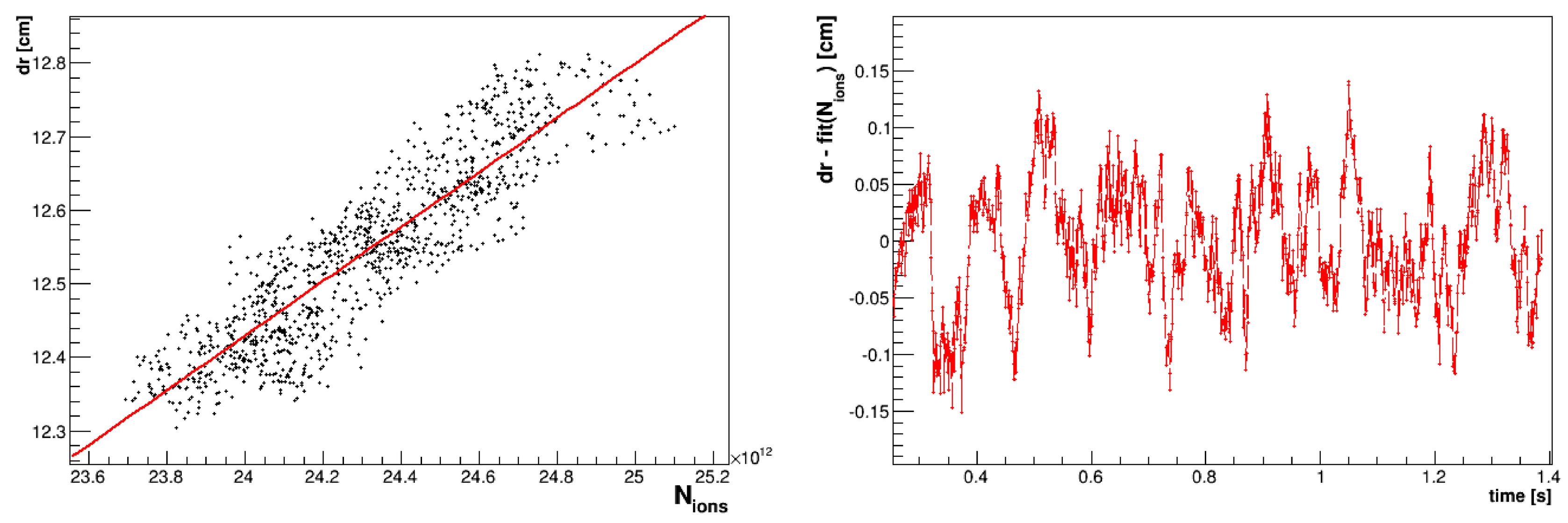
- The ion density is binned in 3D. Each bin is treated as one ion sitting in the middle of the bin and drift using the Langevin equation
- Opposite effect compared to electrons: field distortions deflect ions outwards
- Defocusing of space charge results in smaller gradients which in turn lead to smaller electron distortions

Simulation results

- Starting with an empty TPC, the distortions rise as the chamber gets filled with ions and settles around an average value once the chamber is full. Variations of the distortions due to multiplicity and rate fluctuations can then be observed.
- Distortions as a function of time are shown below, evaluated at a point close to the inner field cage (r=100cm) and the longest possible drift distance. This is the point where the distortions reach their largest value.
- When electron and ion deflection are taken into account distortions drop, showing that the effects are smaller than initial estimates.



Distortions as a function of time. The distortions go down as proper integration paths are switched on

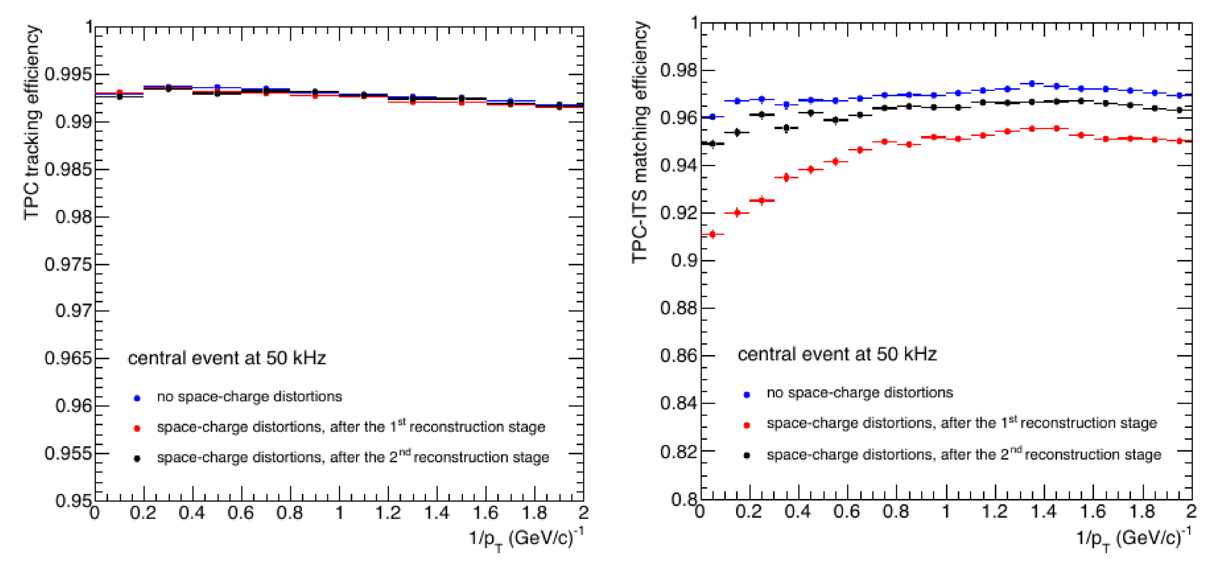


Left: Distortions as a function of the total number of ions in the TPC, $\sigma \approx 0.12$ cm.

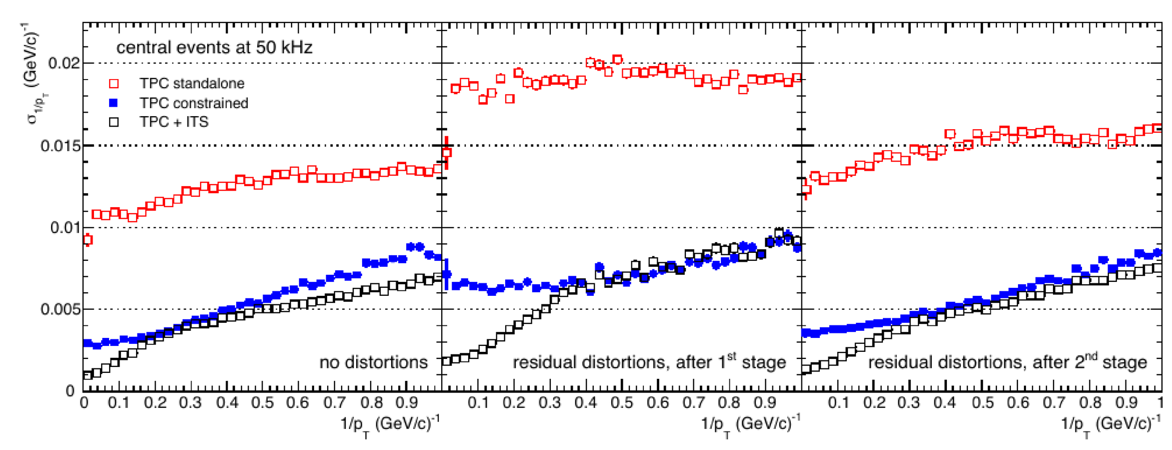
Right: Remaining distortions after subtracting fit from left plot $\sigma \approx 0.05$ cm.

Corrections and calibrations

- A two stage reconstruction process will be implemented, where the corrections are derived by using cluster residuals between TPC tracks and the corresponding tracks measured in external detectors.
  1) First stage corrections need to have sufficient accuracy to allow track matching to external detectors and to reduce data by removing measurement points not associated to tracks. A long term (updated in intervals O(15 min)) average map will be used for distortion corrections here.
  2) The second stage aims at restoring the intrinsic spatial and momentum resolution of the detector. A high resolution distortion map updated every 5ms will be used.
- After the first reconstruction stage, a deterioration of the momentum resolution compared to the ideal case can be observed. This is however restored after the second stage.



TPC tracking efficiency (left) and matching efficiency to external detectors (right)



Momentum resolution in the ideal case without distortions (left) and after the first (middle) and second (right) reconstruction stages

Conclusions

- A simulation has been developed to study the time dependence of the spatial distortions due to the remaining IBF; should be compared to data
- Studies using Geant 3 to capture ionization fluctuations are ongoing
- Studies of distortion corrections show that the momentum resolution can be recovered

References

Upgrade of the ALICE Time Projection Chamber. Technical Report CERN-LHCC-2013-020. ALICE-TDR-016, CERN, Geneva, Oct 2013.

Addendum to the Technical Design Report for the Upgrade of the ALICE Time Projection Chamber. Technical Report CERN-LHCC-2015-002. ALICE-TDR-016-ADD-1, CERN, Geneva, Feb 2015.