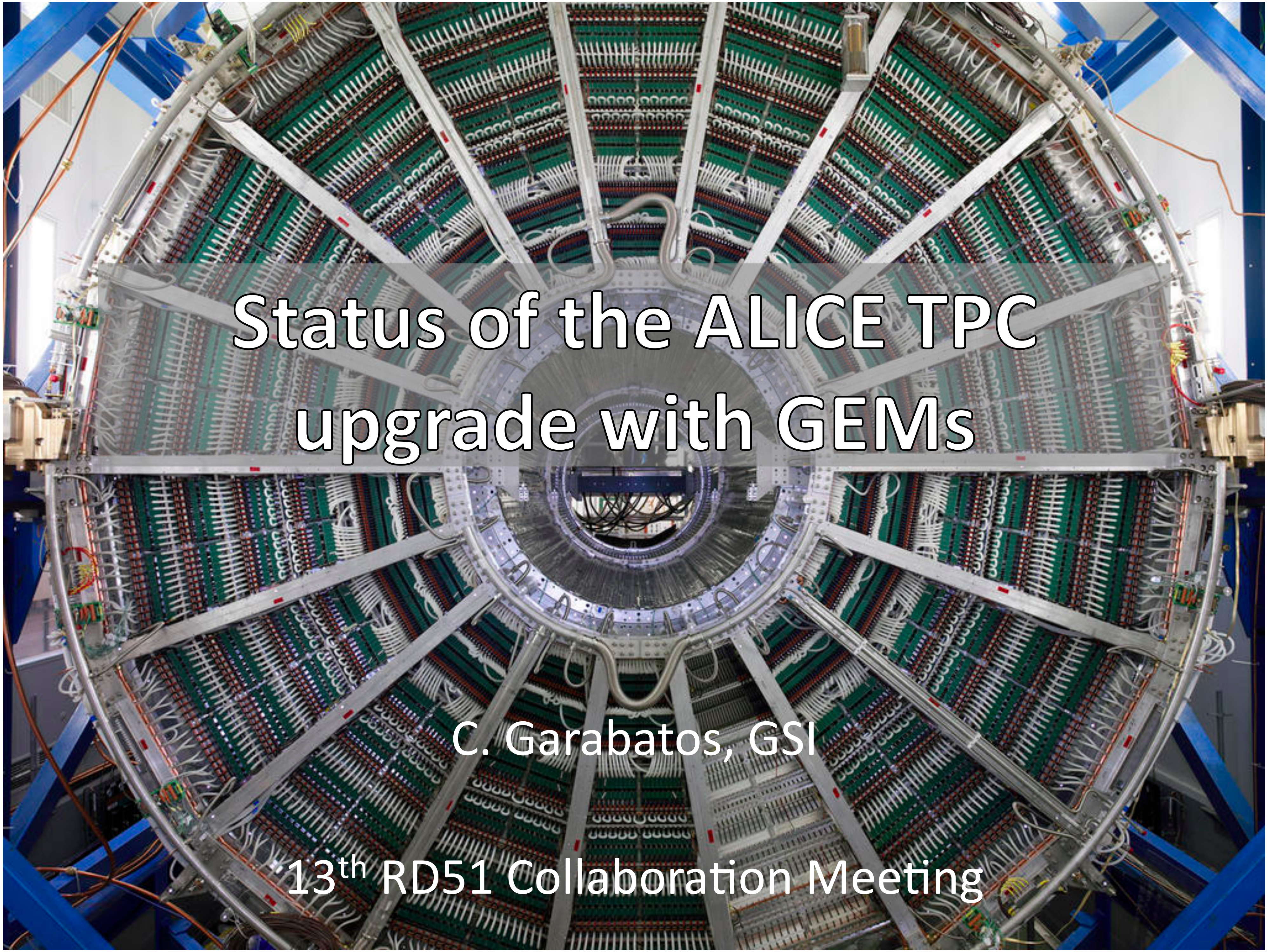


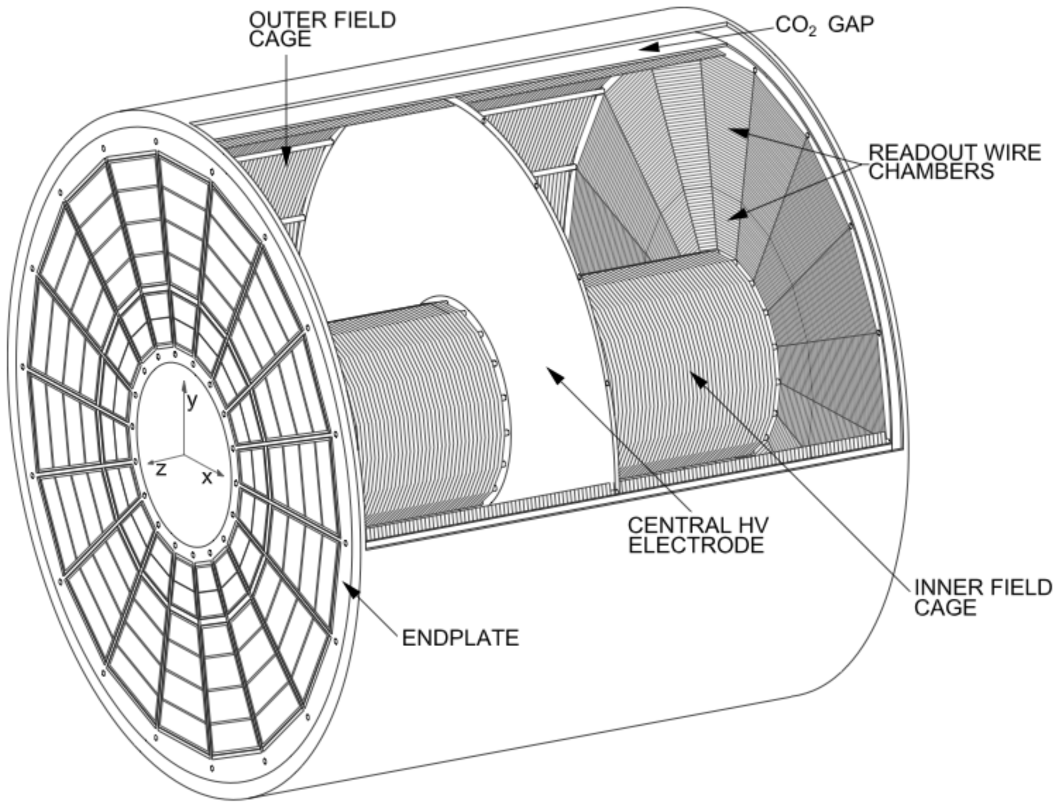
Status of the ALICE TPC upgrade with GEMs

C. Garabatos, GSI

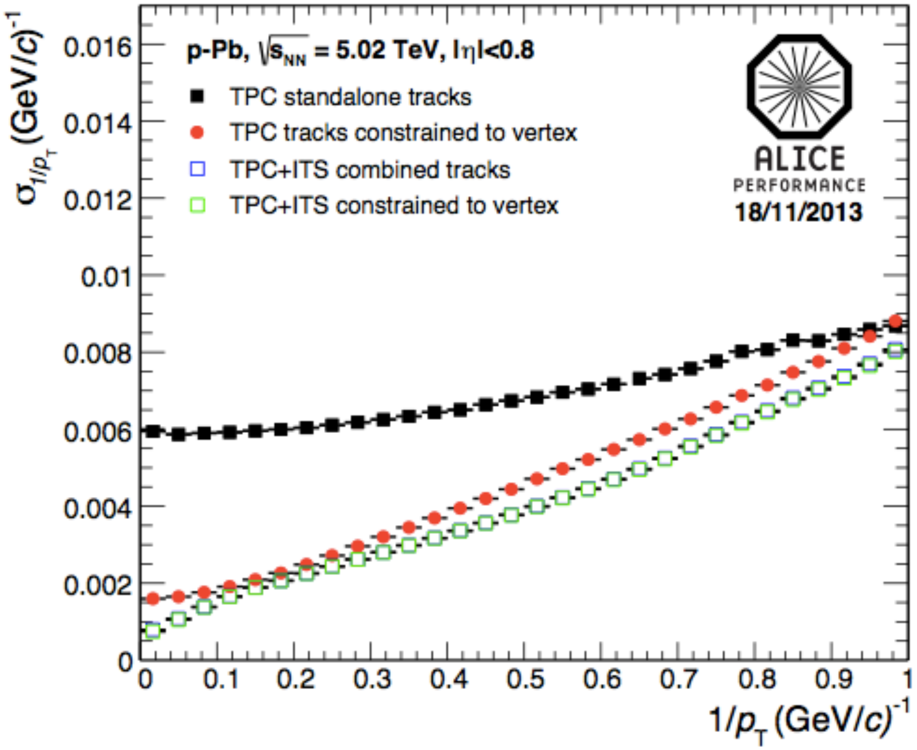
13th RD51 Collaboration Meeting

The largest TPC

- 5 m x 5 m, 90 m^3
- 100 kV in CE
- ~90 µs drift time
- 2x2x18 = 72 ROCs
- 557 568 readout pads
- Gain 7000-8000
- Noise ~700 e^-
- X/X_0 = 3.5 % near η=0
- ~250 µm matching resolution with inner tracker



Momentum resolution of current TPC

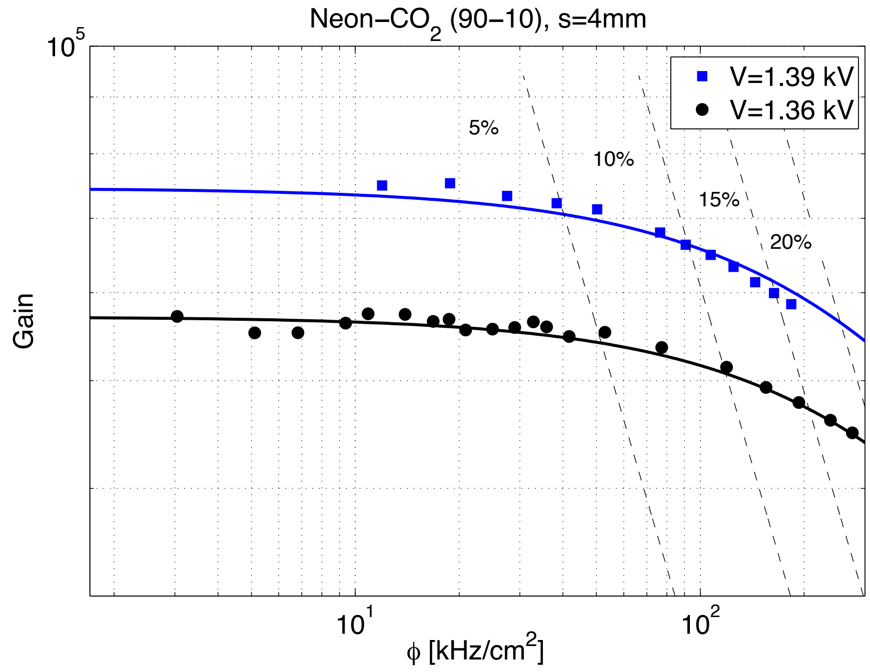


Or, in other words:

- $\sigma_{p_T}/p_T \lesssim 3.5$ % at 50 GeV/c
- $\sigma_{p_T}/p_T \lesssim 1$ % at 1 GeV/c
- Matching to external detectors significantly improves resolution at high p_T

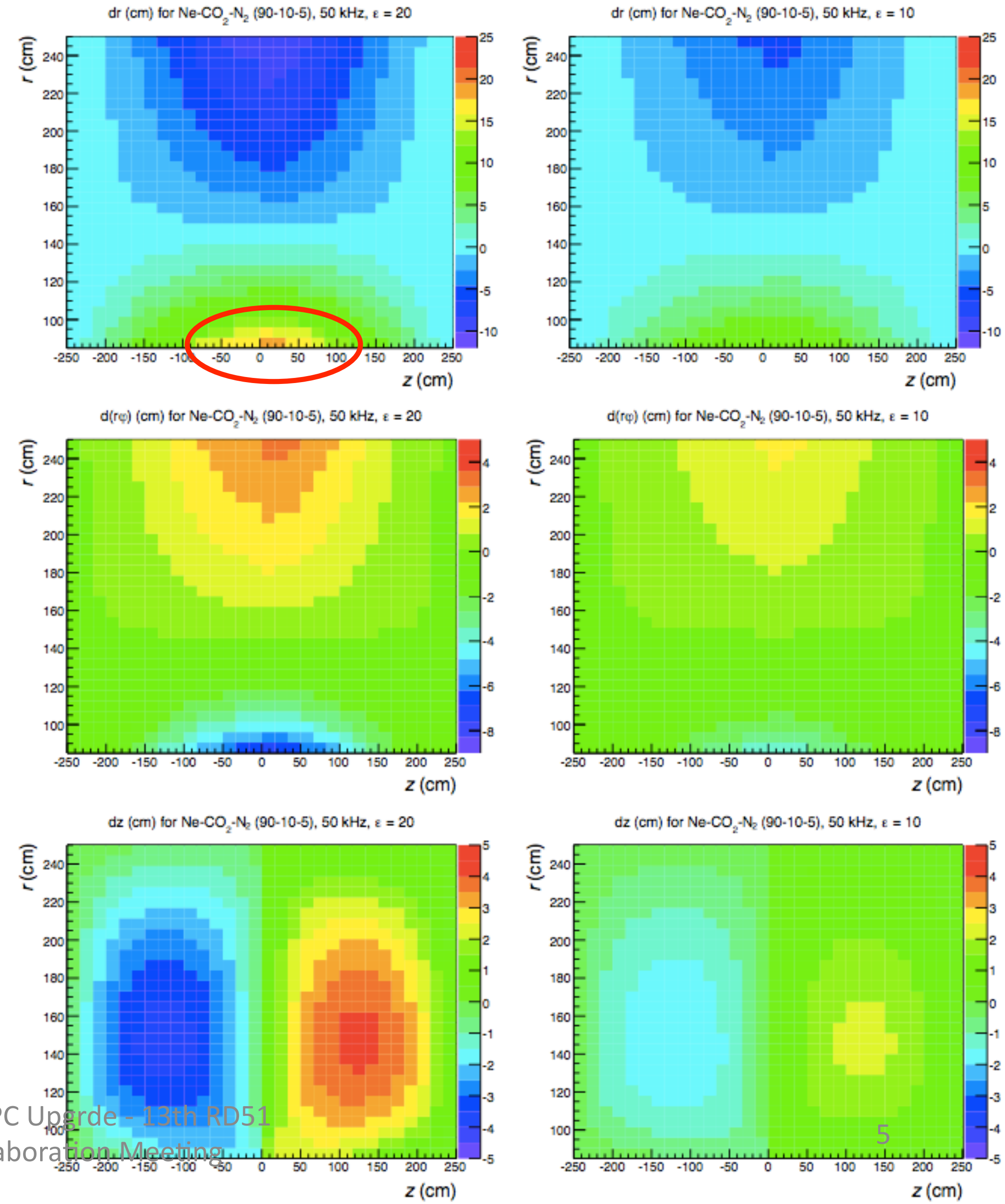
LS2 upgrade of the TPC

- LHC 2020 (RUN 3): expect 50 kHz Pb-Pb collision rate
- With a gating grid, only 3 kHz can be achieved
  - GG must stay closed while ions from the avalanche reach the wires, otherwise 10% of them escape and would produce ~ 1 m distortions in the drift volume
- In addition, at ~100 kHz/cm^2 the space charge near the anode wires would affect dE/dx resolution



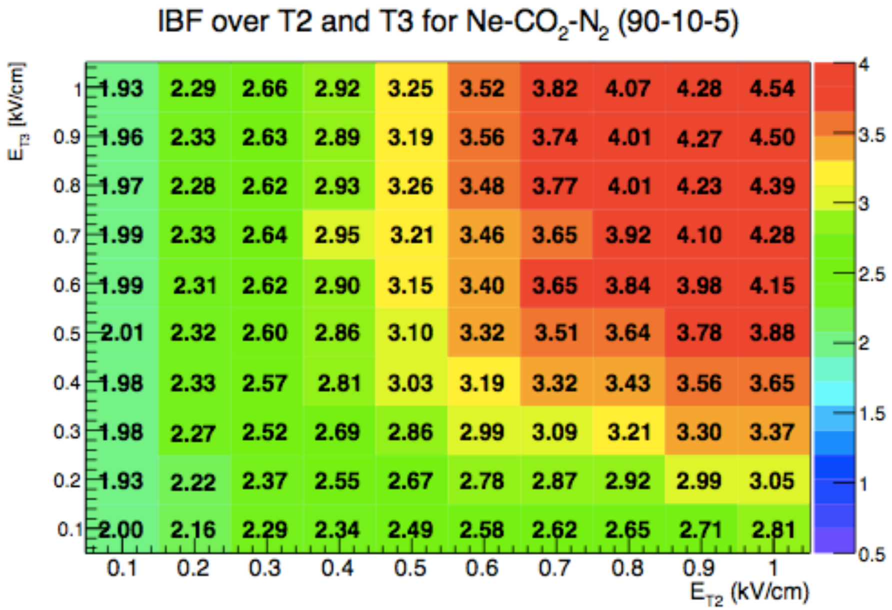
The Ion Back-Flow challenge

- GEMs are good at blocking ions from invading the drift volume, but this 'good' is not good enough
- We aim at IBF ~ 1% at gain 2000
  - ε ~ 20
  - Gas: Ne-CO_2-N_2 (90-10-5)
- Then, distortions of up to 20 cm must be corrected for
  - At inner radii, near the central electrode

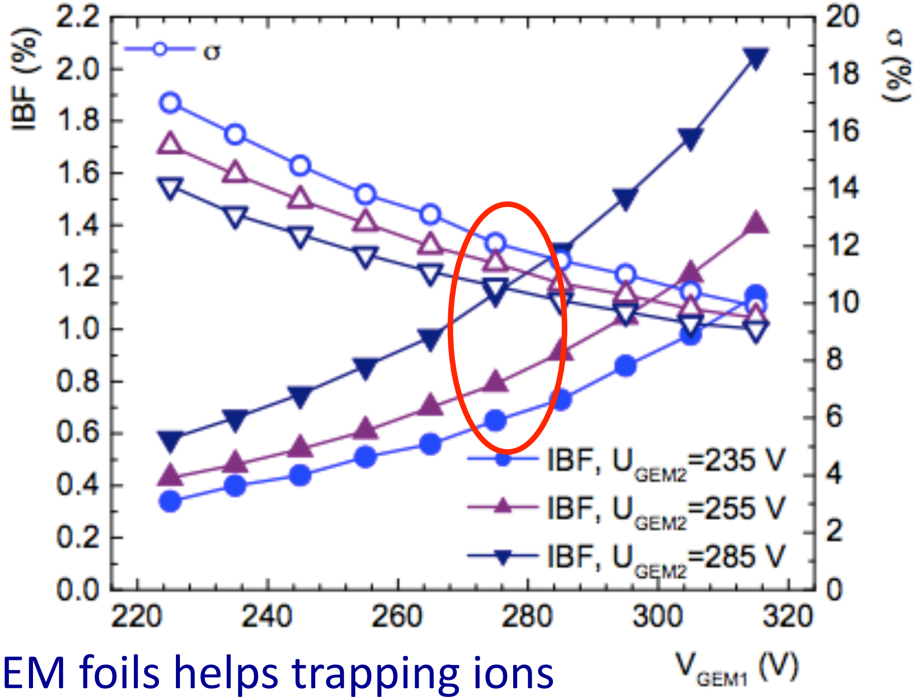


Minimise IBF with quadruple GEM stacks

S-S-S-S



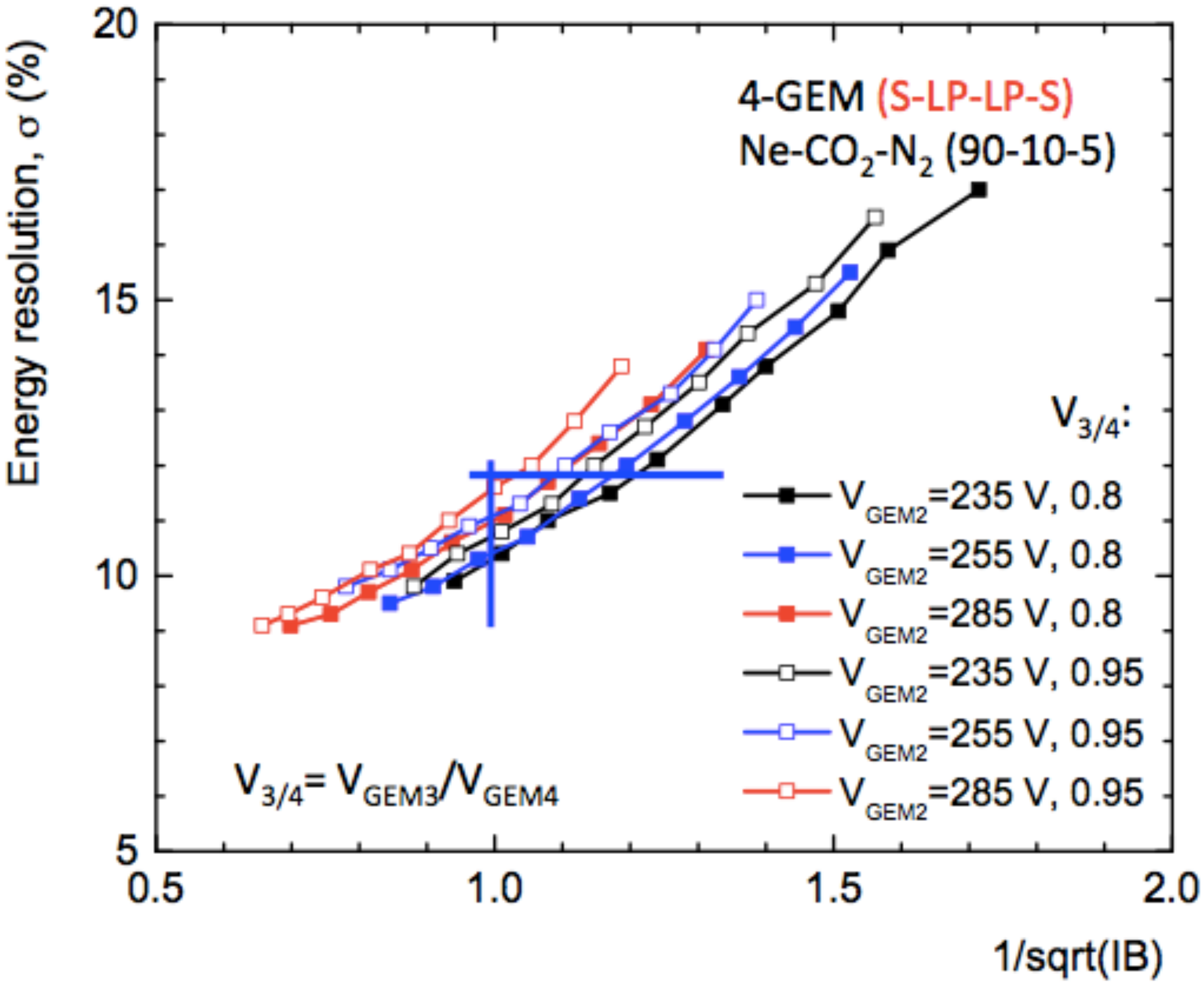
S-LP-LP-S



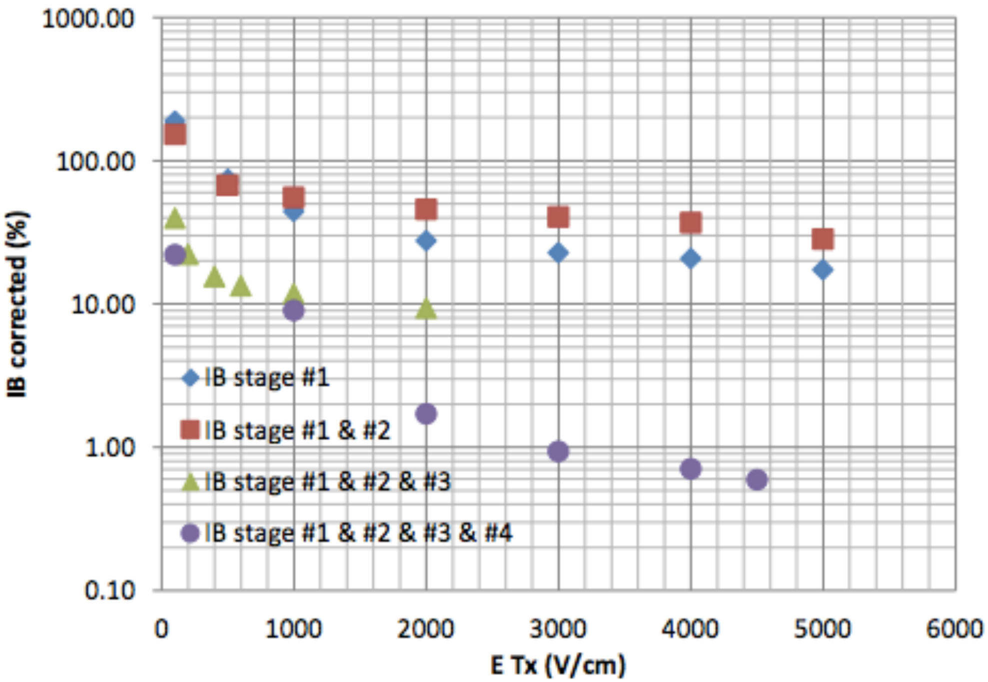
- Asymmetric field above and below a GEM foils helps trapping ions
  - A quadruple GEM stack is used to best arrange this trap
- Misalignment between holes of different foils also helps blocking ions
  - Use a combination of Standard and Large-Pitch GEMs (140 and 280 μm)
- Gain in increasing order
- However, if ions are blocked, then electrons are lost (same Maxwell for both), the latter resulting in deterioration of dE/dx
- IBF ~ 0.8% and σ ~ 12% are just fine

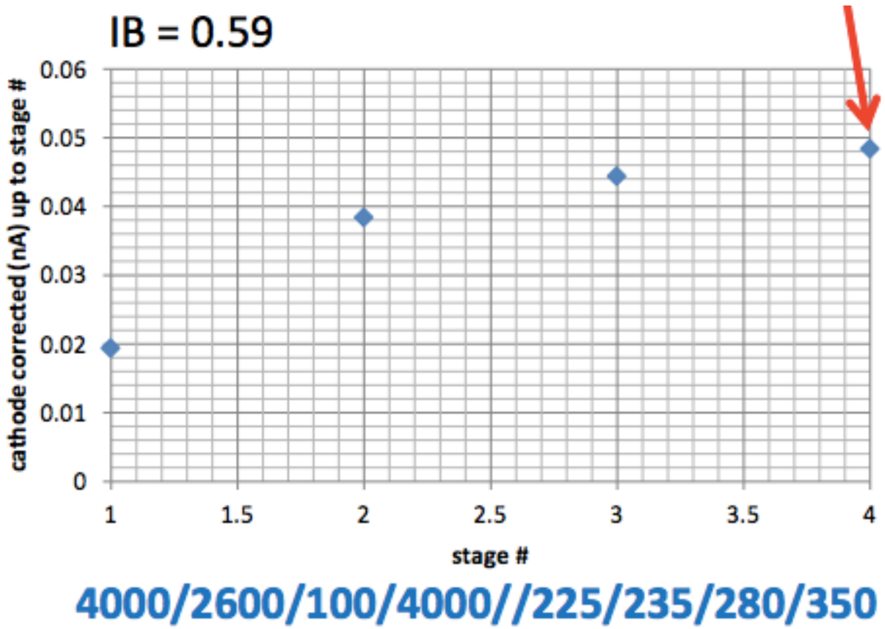
$n_e - n_{ion}$ correlation

- $\sigma \sim \sqrt{n_e}$
- e^- transparency ~ IBF
- Working region identified



Differential measurements on IBF

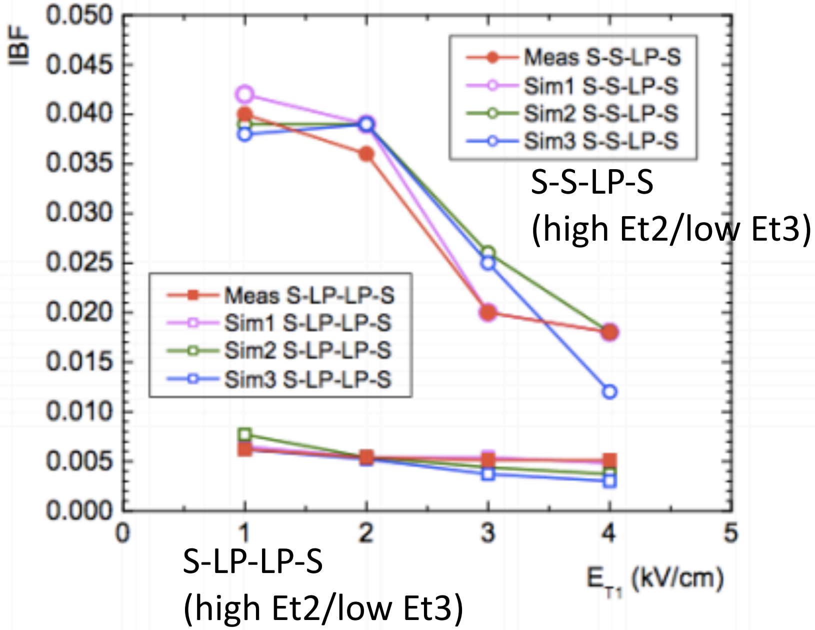




- Measure currents at various stages, foil by foil
  - collection, transmission, extraction efficiencies can be scanned this way

Simulations: IBF comparison to measurements

- Agreement of IBF for several configurations
  - 3 GEM and 4 GEM systems, different pitch, E_T



Comparison to Taku

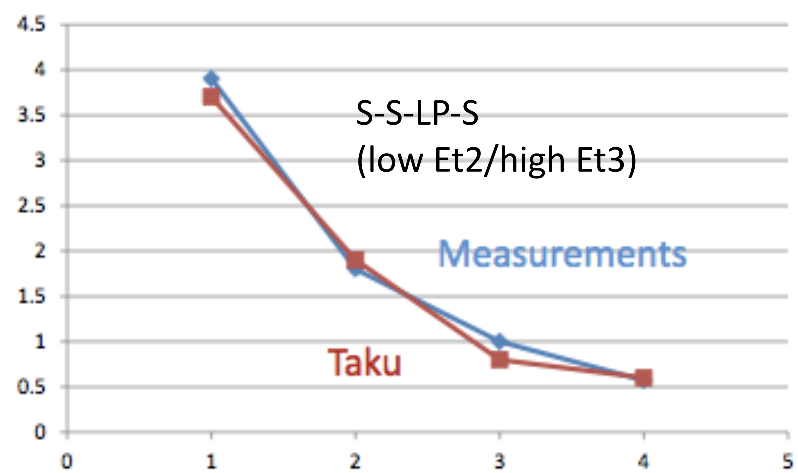
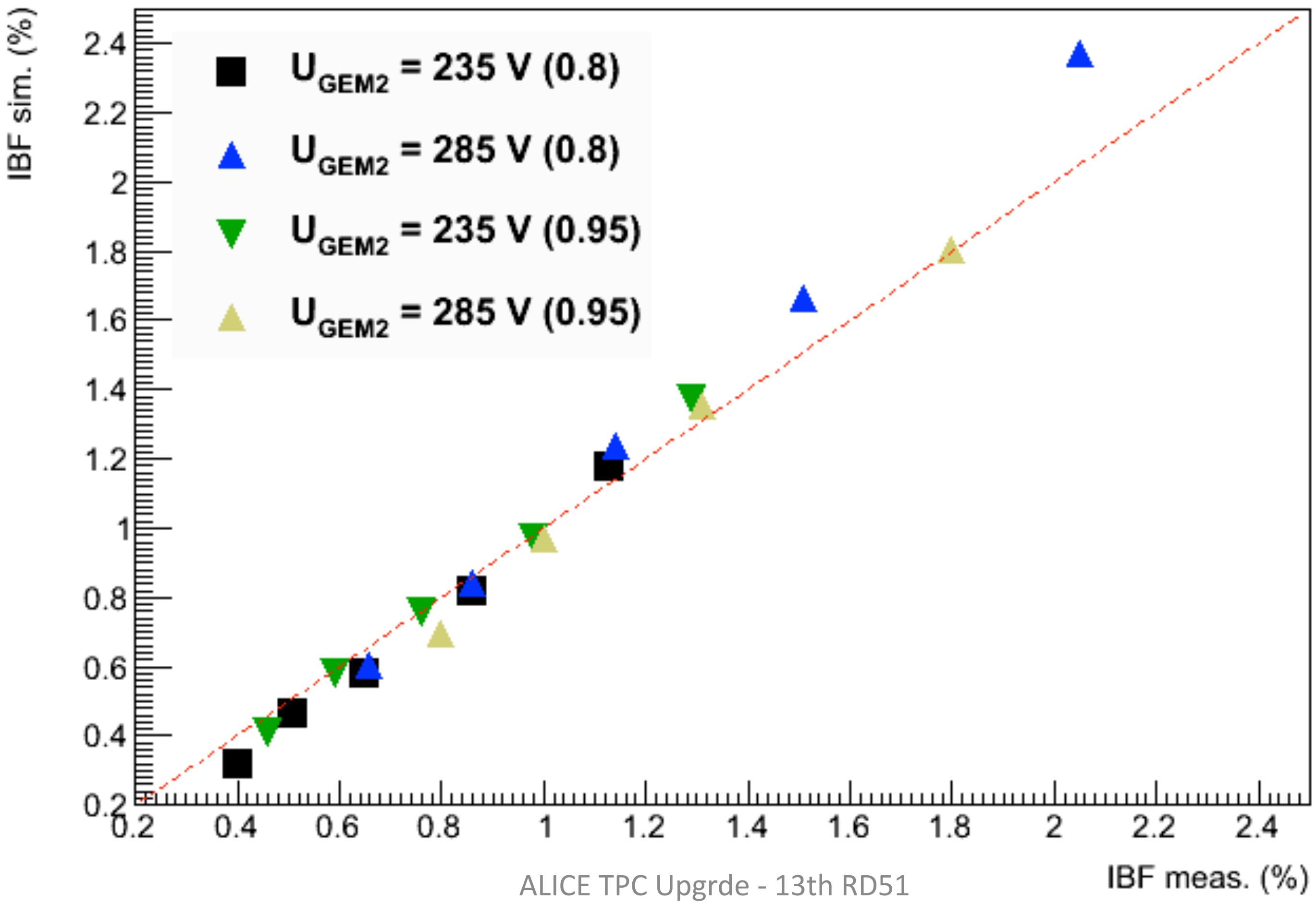


Figure 5.13: Comparison of ion backflow calculations with measurements as a function of E_{T1} in Ne-CO_2-N_2 (90-10-5) for two quadruple GEM configurations. The comparison has been done for $E_{T2} = 3.7$ kV/cm, $E_{T3} = 0.2$ kV/cm and $E_{Ind} = 4$ kV/cm. In the measurements the gain is adjusted to 2000, and the simulations follow the same settings. Close circles: measurements with a S-S-LP-S arrangement. Open circles: corresponding simulations performed with three different sets of foil misalignment. The voltages across the GEMs are 220, 270, ~275 and ~280 V, respectively. Closed squares: measurements with a S-LP-LP-S arrangement. Open squares: corresponding simulations performed with three different sets of foil misalignment. The voltages across the GEMs are 230, 280, ~290 and ~320 V, respectively.

Alignment tuned
In simulations

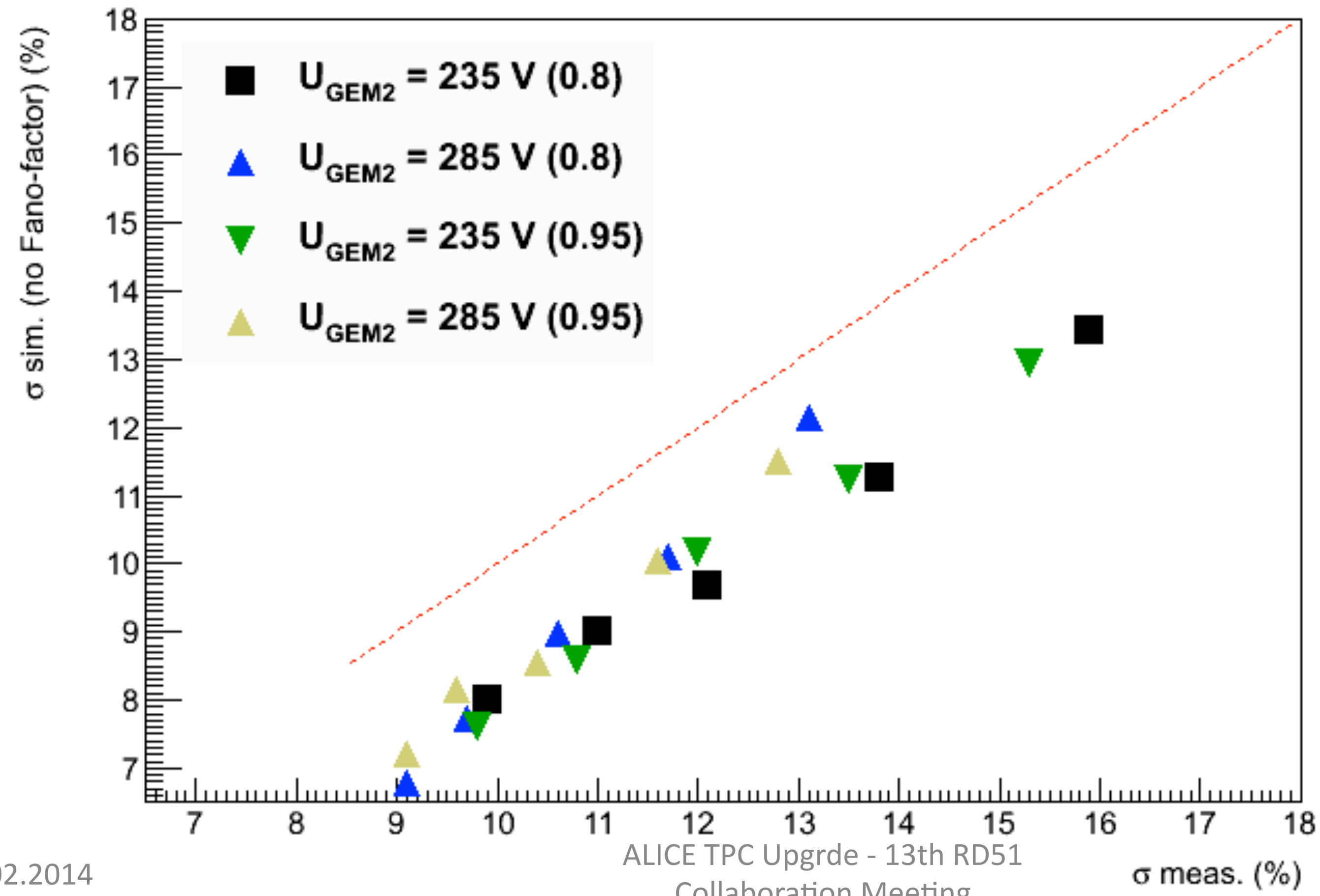
Simulations: IBF comparison to measurements

- Agreement for several configurations of a S-LP-LP-S system
  - Different V_{GEM1}, V_{GEM2} setting



Simulations: energy resolution

- Correlation is OK. Simulations gives 2-3% better resolution (for 5.9 keV in Ne-CO_2-N_2).

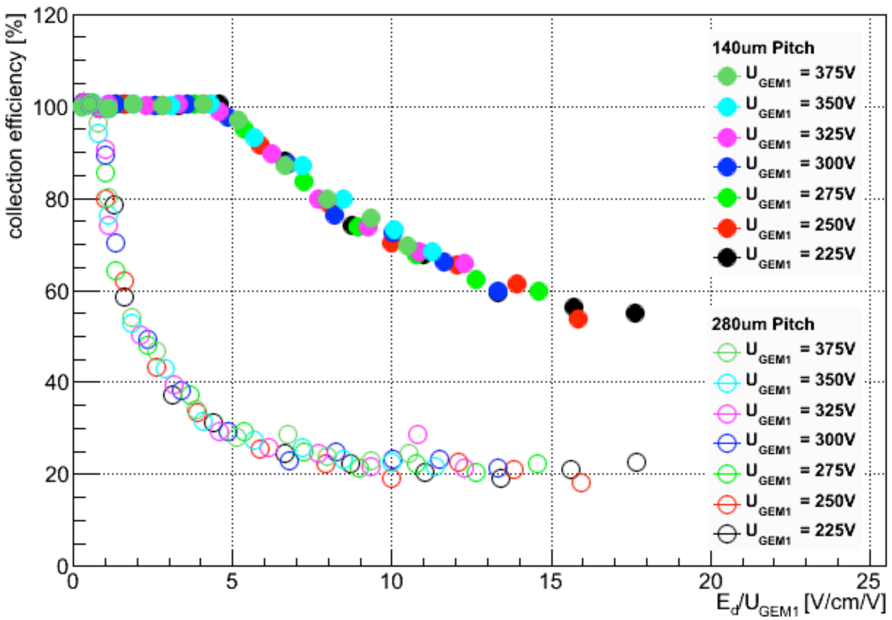


S-LP-LP-S

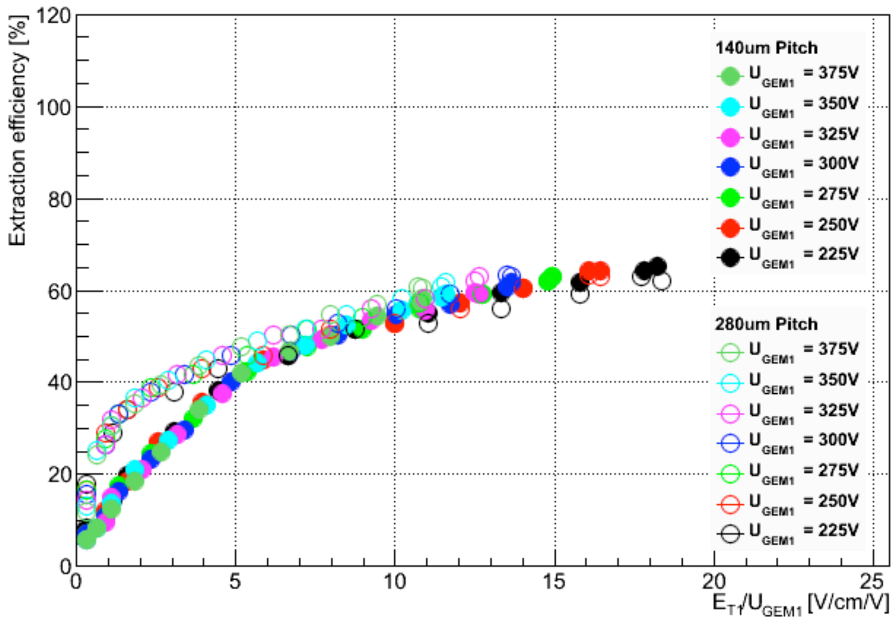
Collection, extraction

- Motivation is to parameterize gain, IBF, and resolution vs. U_{GEM}, E_d, E_t, pitch
- Observe substantial dependence on pitch in 1 and 2 GEM systems

Collection vs. E_d/U_{GEM1}



Extraction vs. E_T/U_{GEM2}

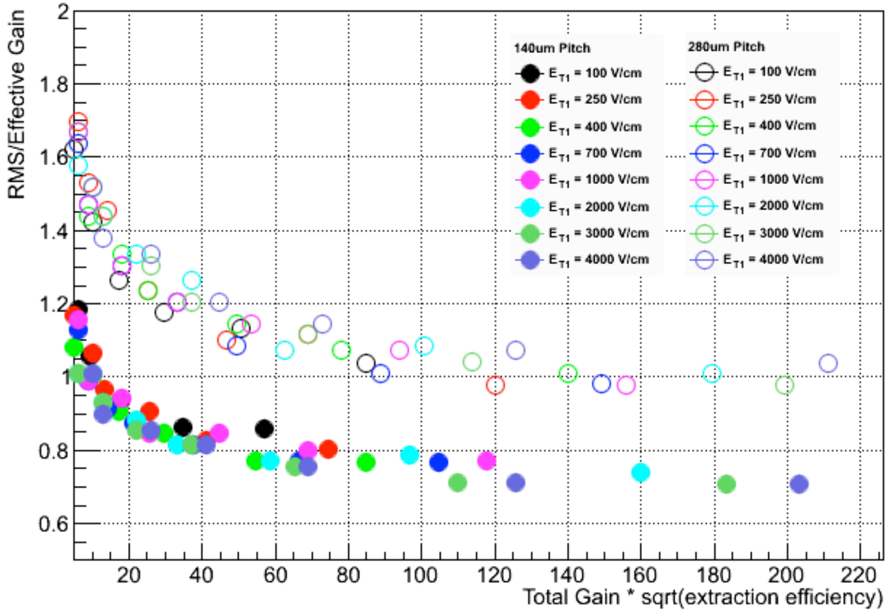


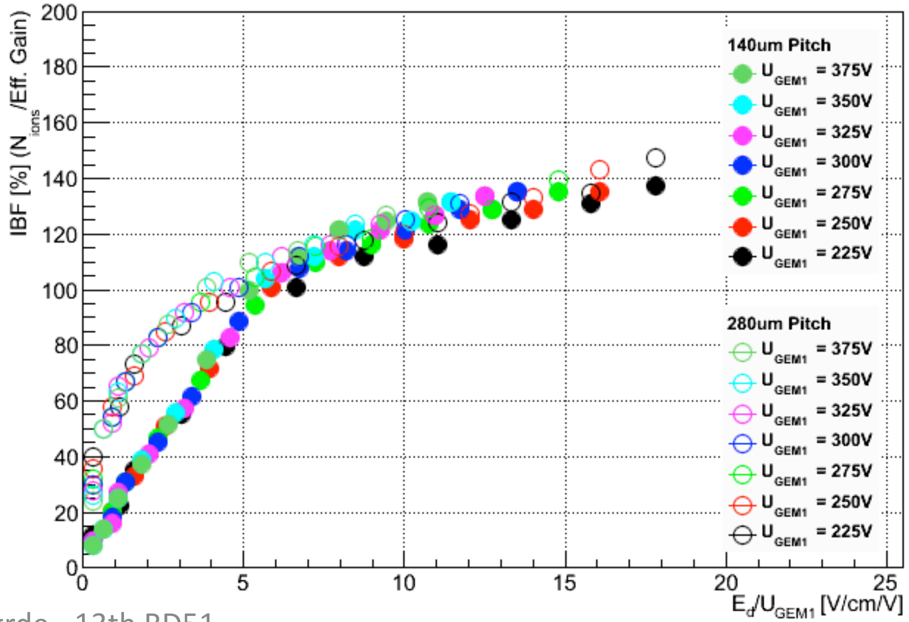
Energy resolution, ion transparency

- Motivation is to parameterize gain, IBF, and resolution vs. U_{GEM}, E_d, E_t, pitch

RMS/Gain vs.
Total Multiplication*sqrt(collection)

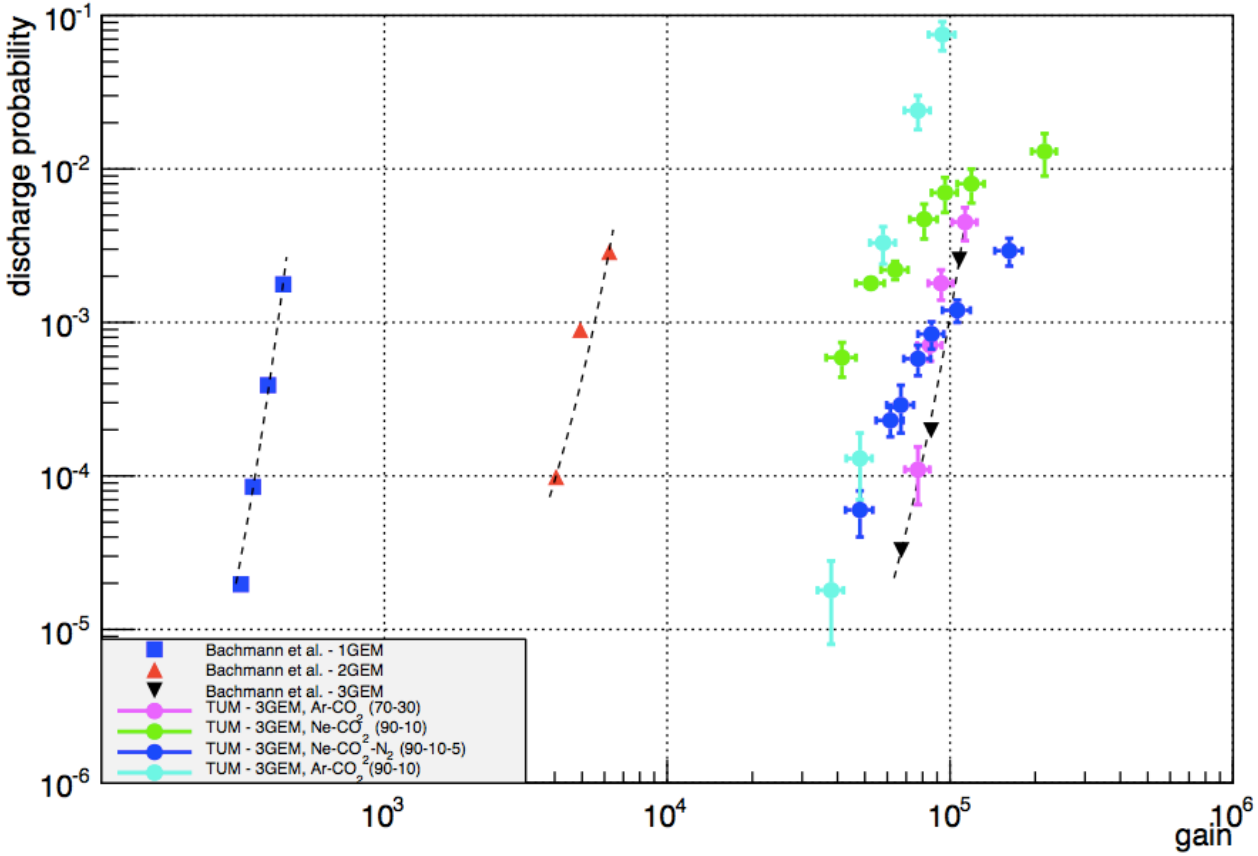
# of ions in drift/Effective Gain
vs. E_d/U_{GEM1}





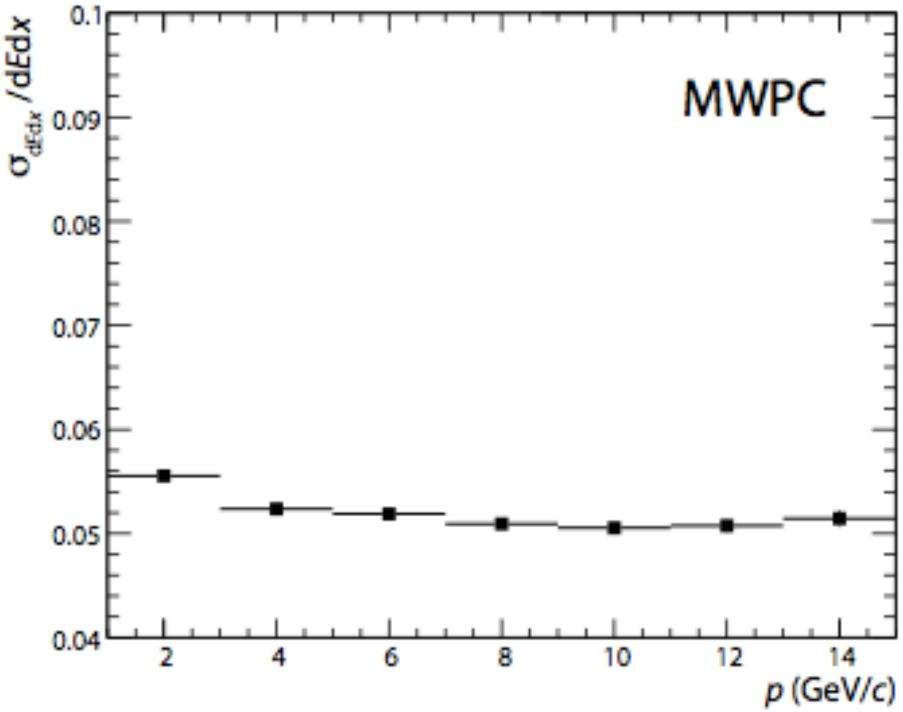
Discharge probability studies

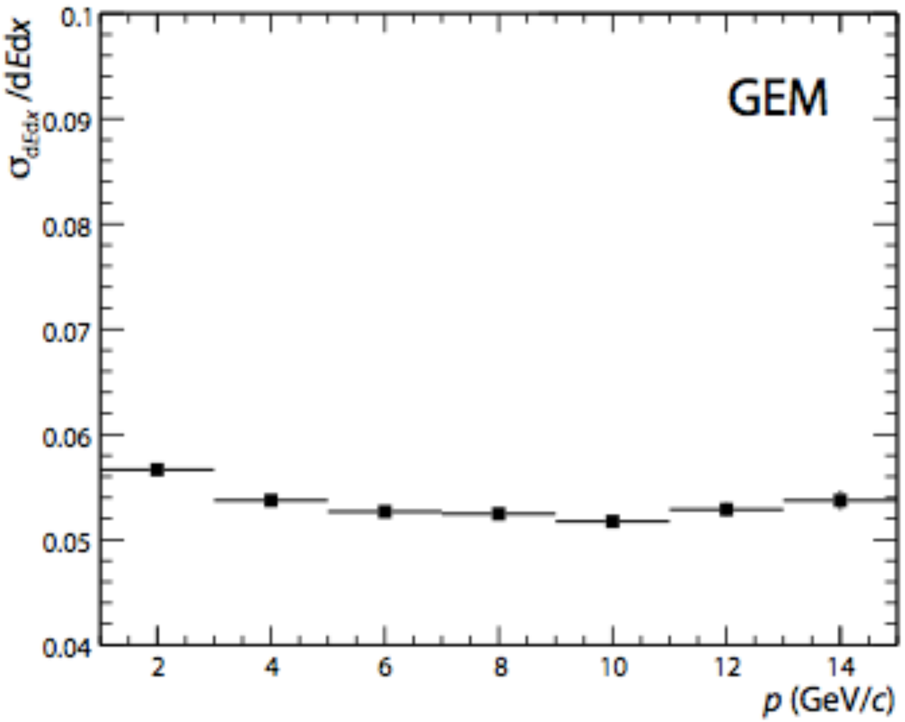
- Reproduced CERN results at high gains for Ar-CO_2 (70-30)
- N_2 brings up one order of magnitude to Ne-CO_2
- Ne mixtures show a different slope
- To be measured: behavior at nominal gains
- S-LP-LP-S with IBF settings



☞ Note: our baseline gas mixture is Ne-CO_2-N_2 (90-10-5)

GEM TPC performance: dE/dx

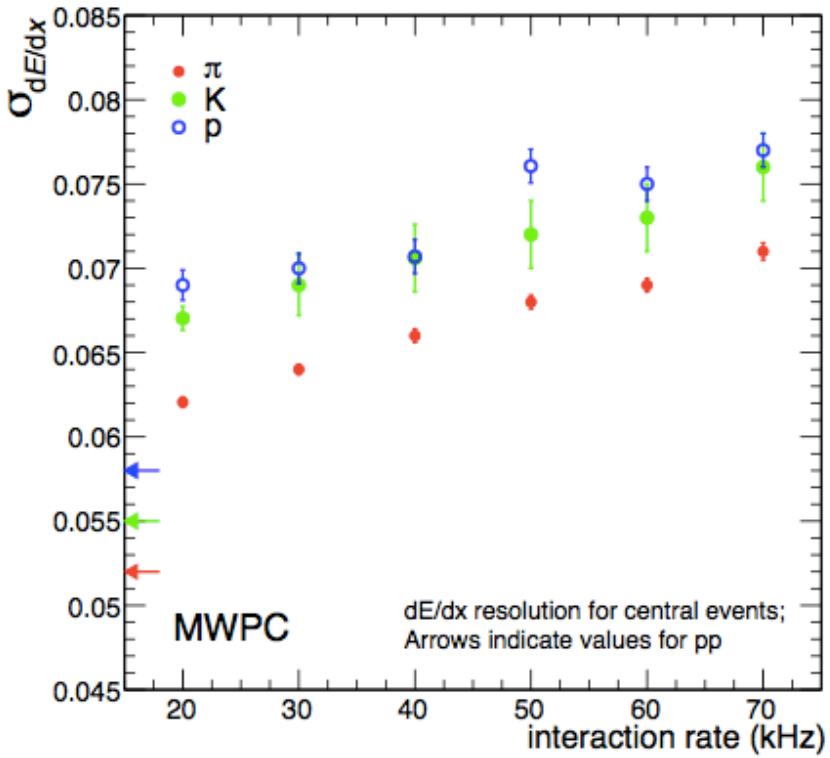


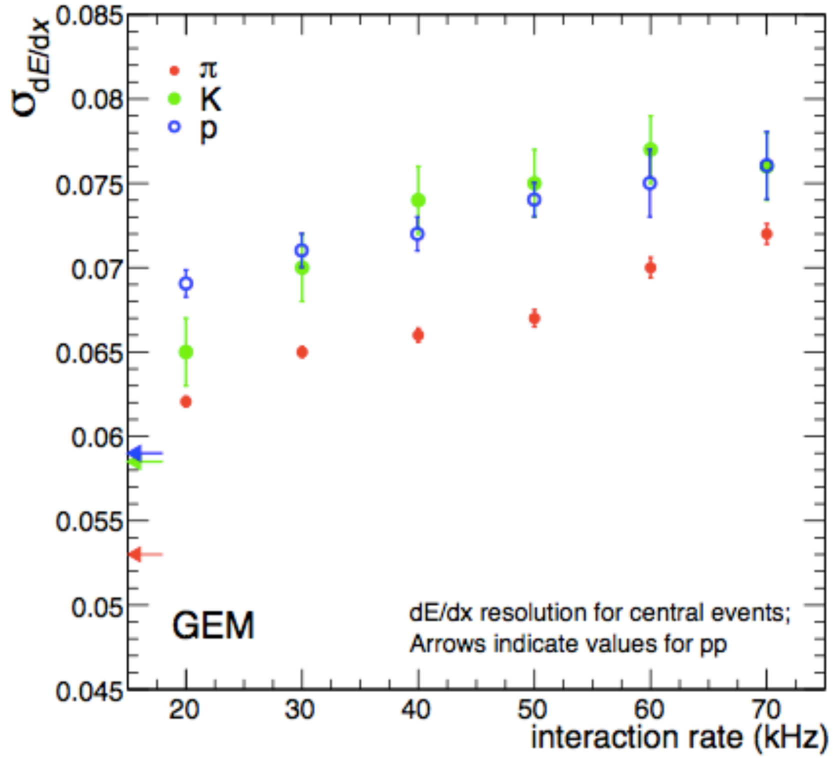


No difference between MWPC and GEMs
at low multiplicities

dE/dx resolution with pile-up

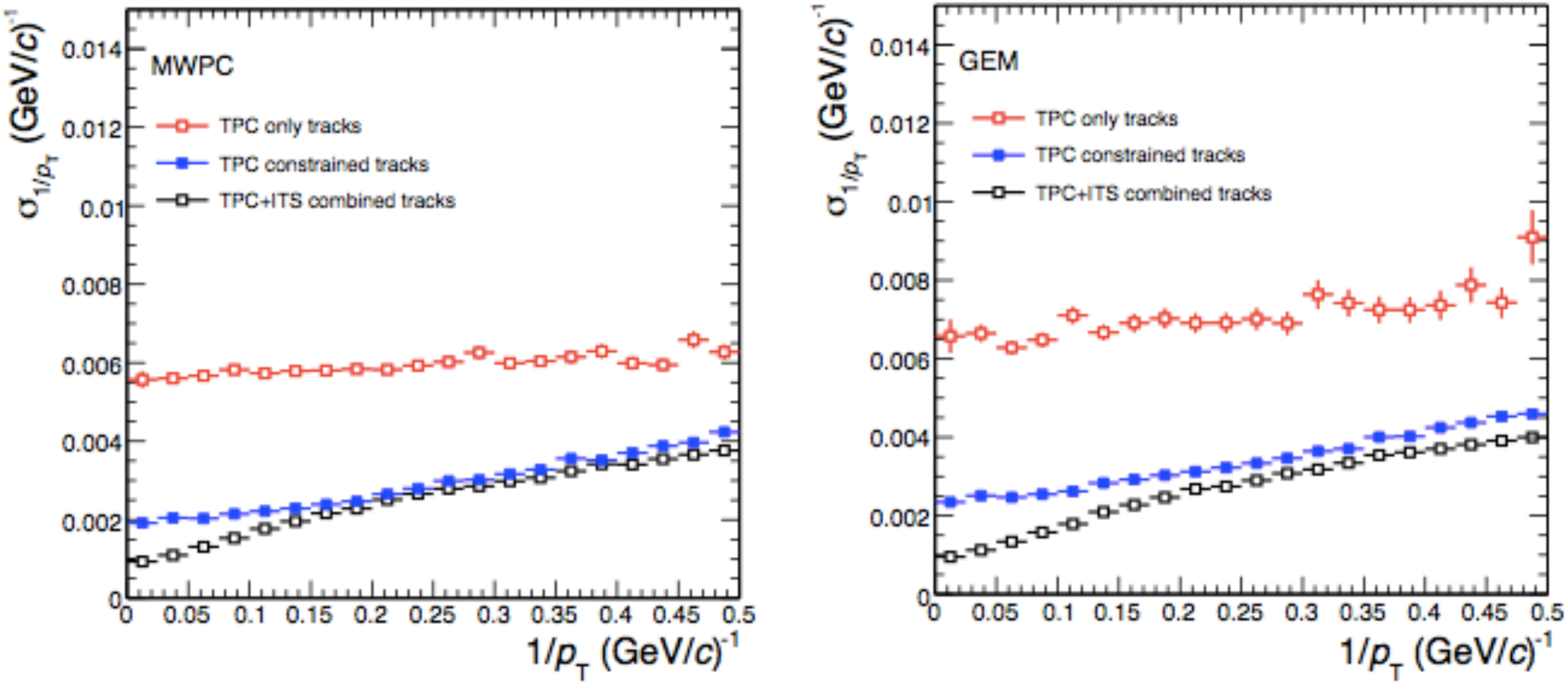
Simulated central Pb-Pb events at 5.5 TeV: full MC, with pile-up





- Slight deterioration as function of occupancy due to cluster overlaps
- Similar dependence on multiplicity in MWPC and GEM

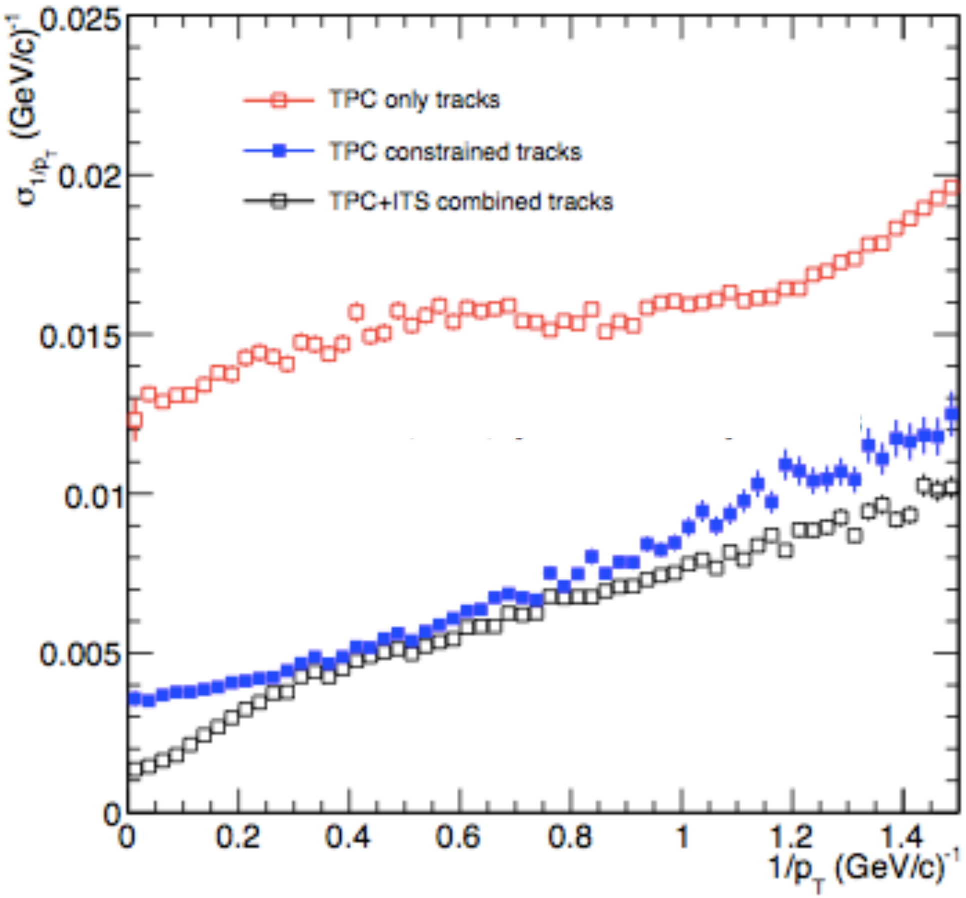
GEM performance: momentum resolution
(high rate, but no space charge distortions here)



- GEMs produce no PRF, so clusters originated near the chambers induce signals in only one pad
- At high multiplicities this helps occupancy and overlap of clusters
- No need to replace the pad geometry!

GEM performance: momentum resolution with distortions

- Residual space-charge distortions are corrected in this example by matching the tracks to inner and outer detectors
- Not the final word



Correction of local remaining residuals

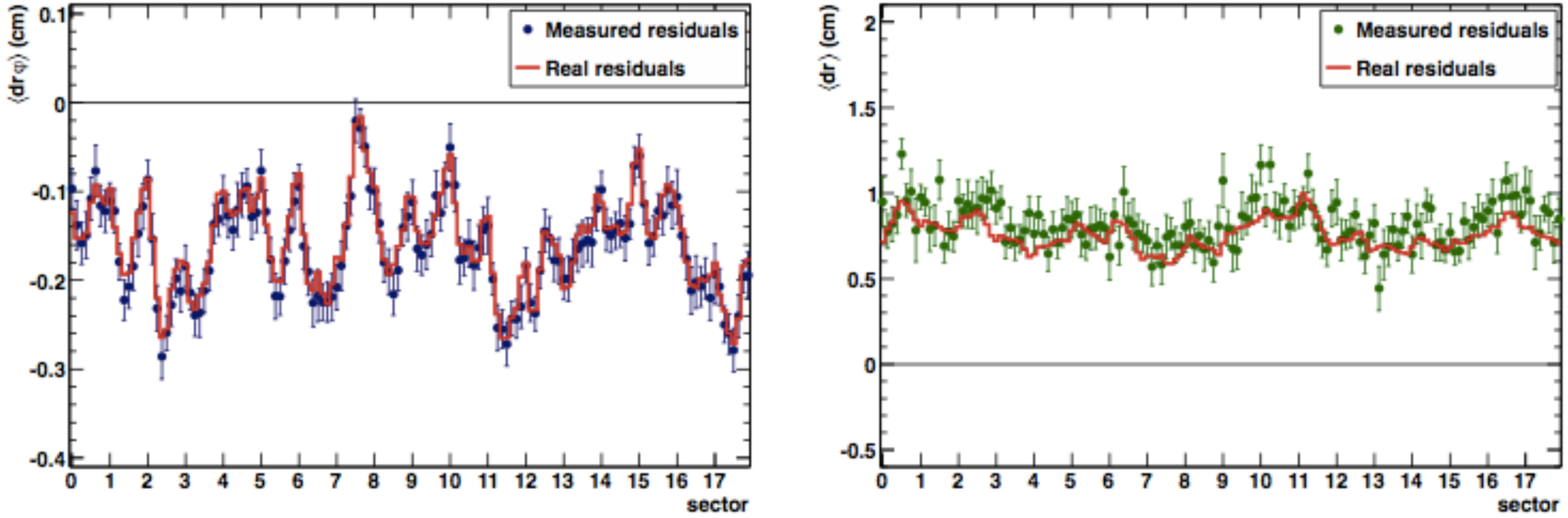


Figure 8.9: Comparison of measured and real residual distortions for one specific fluctuation scenario and a region with largest residual distortions. Left: $r\varphi$-distortions, right: r-distortions.

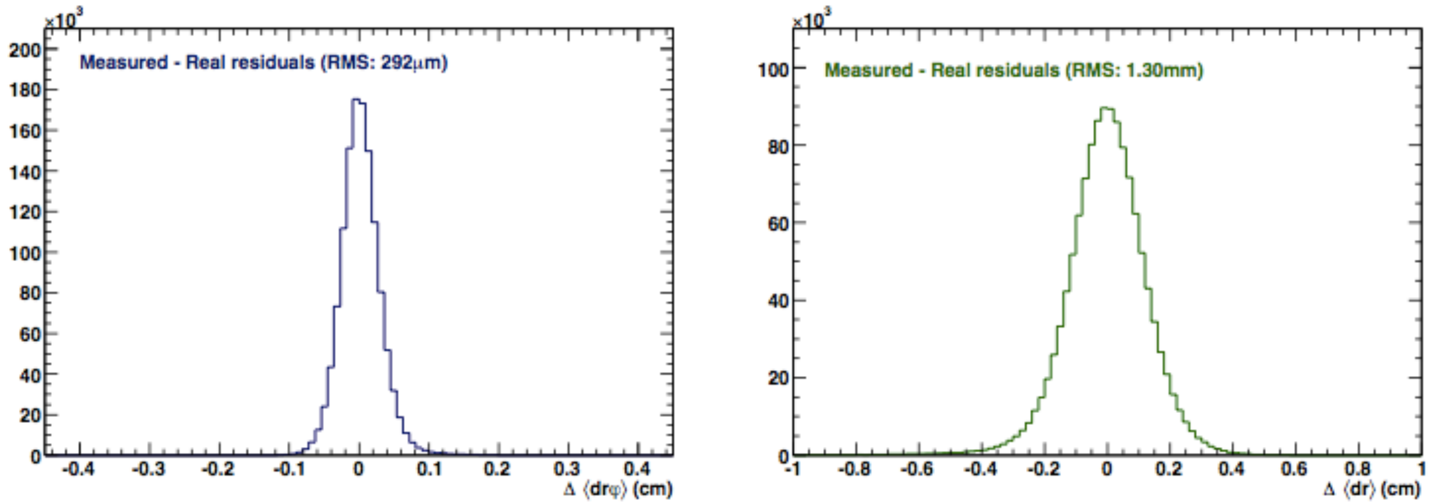
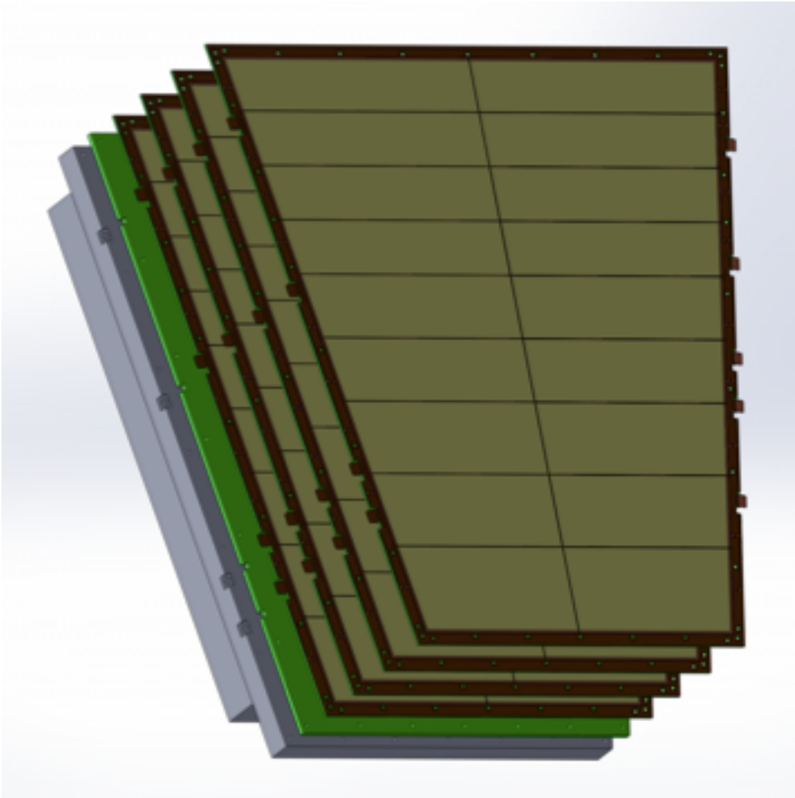


Figure 8.10: Distribution of measured minus real residual distortions for all fluctuation scenarios integrated over full acceptance of the TPC. Left: $r\varphi$-distortions, right: r-distortions.

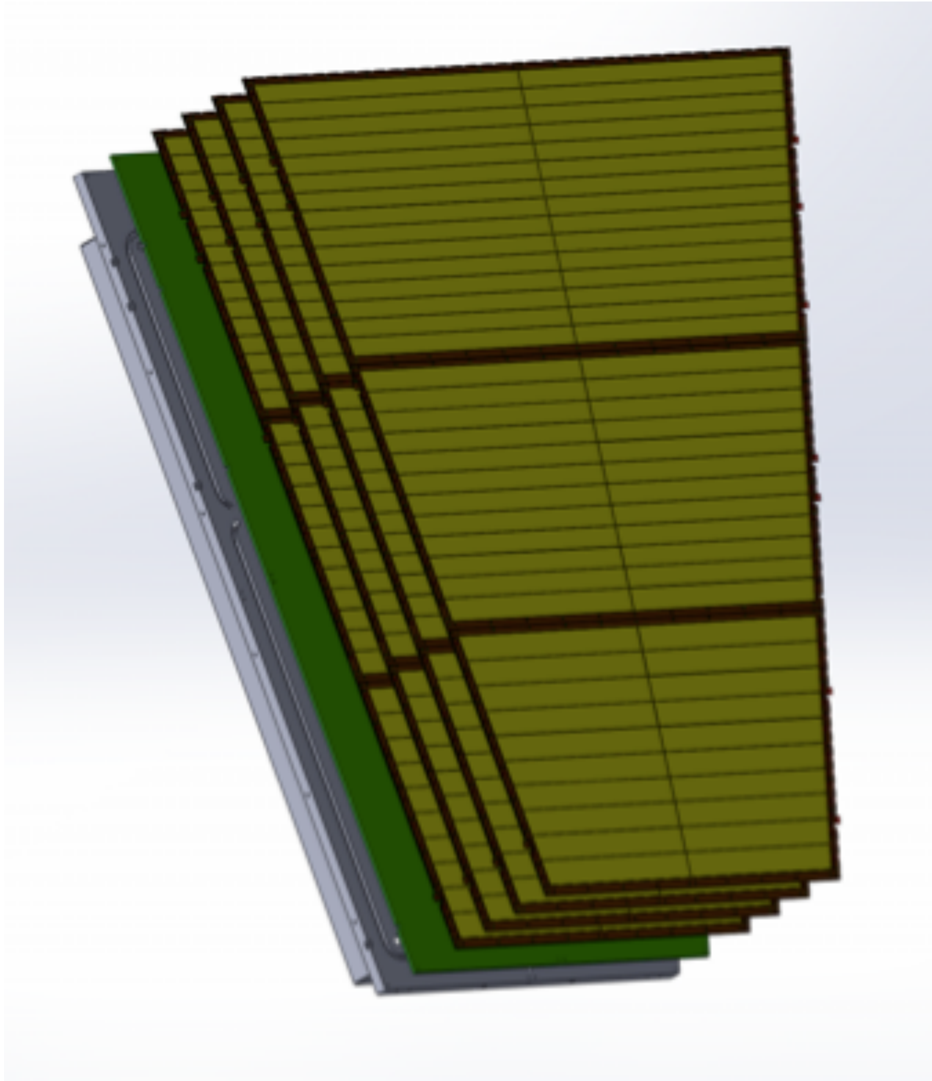
Conclusions

- A GEM system (S-LP-LP-S) for the ALICE TPC has been found that fulfills the requirements for RUN 3
  - R&D still ongoing, including other arrangements
- Advanced techniques used to perform online space-charge corrections
- TDR to be submitted 'one of these days'

Backup

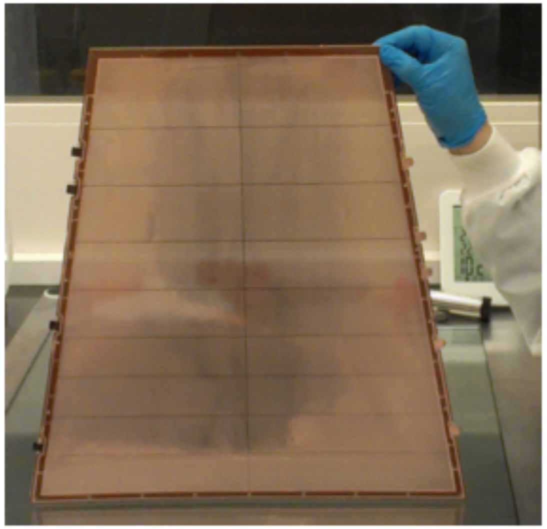


IROC

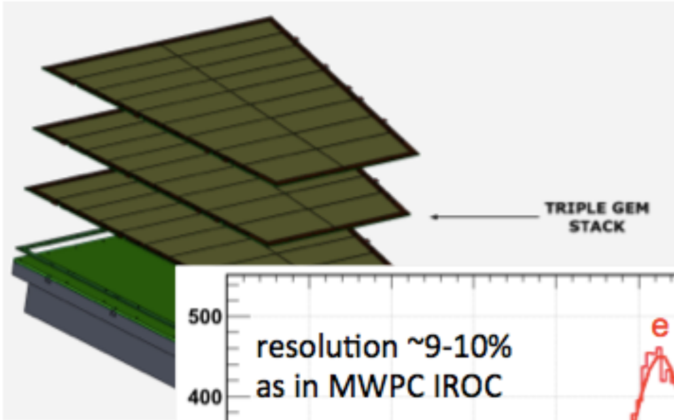


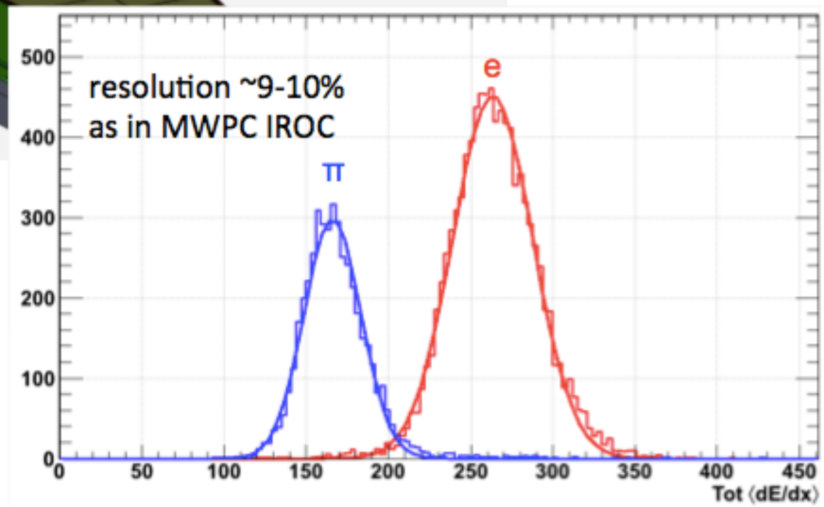
OROC

intrinsic performance: dE/dx



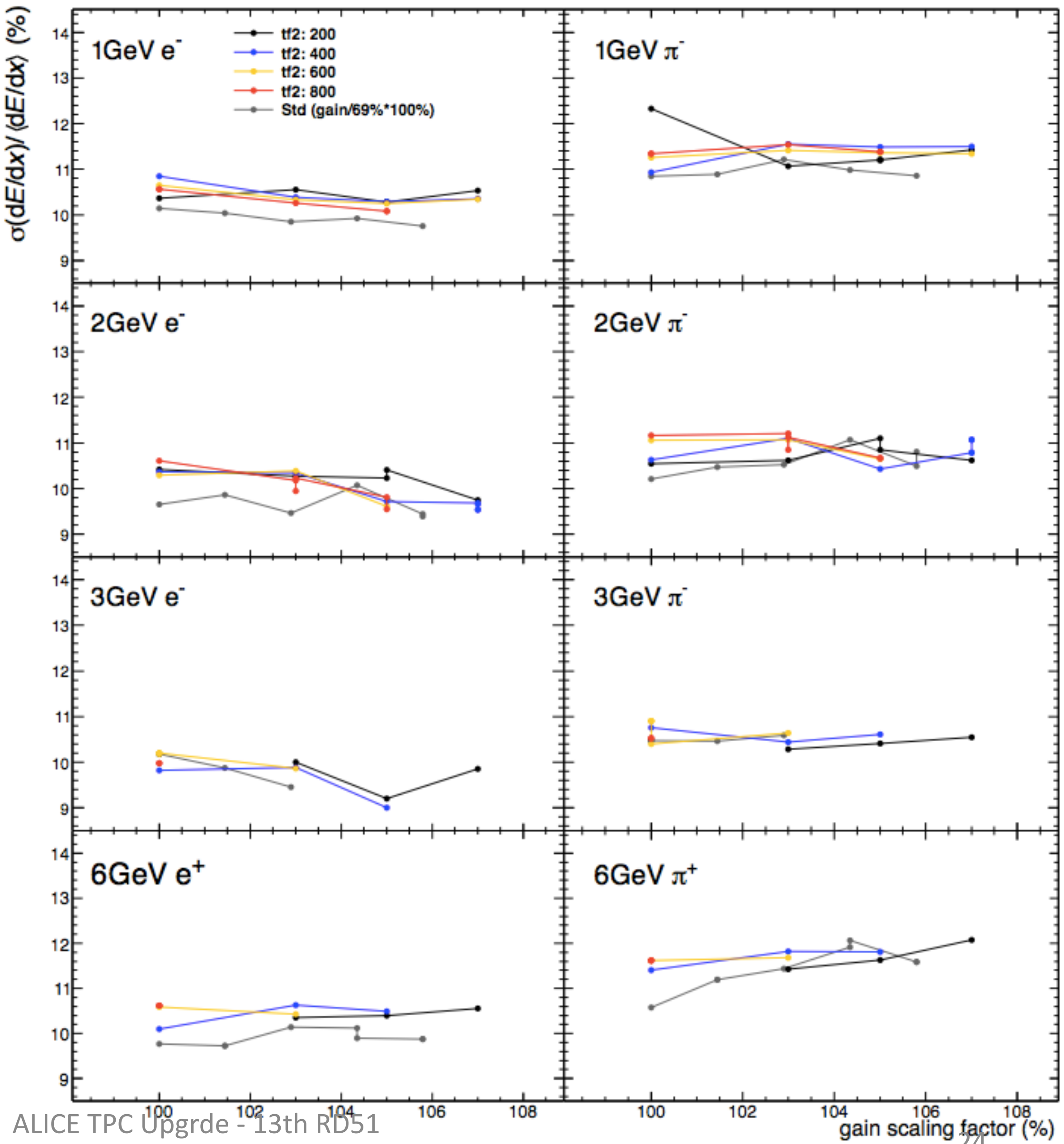
IROC GEM foil at TUM lab





- Same resolution in GEM-based readout chambers as in MWPC
- Confirmed in PS test beam with 3-GEM IROC prototype
- 4-GEM IROC prototype tests planned for 2014

- Test beam results on dE/dx for a triple GEM under various configurations



dE/dx resolution vs. transmission efficiency

- dE/dx resolution as a function of the electron transmission (of the 1st GEM layer)
- At efficiency = 0.5 σ(5.9 keV) goes from 8.5 to 12%
  - i.e. 20 % and 28 % FWHM respectively
  - Assuming a 1/sqrt(n_e) dependence of the resolution