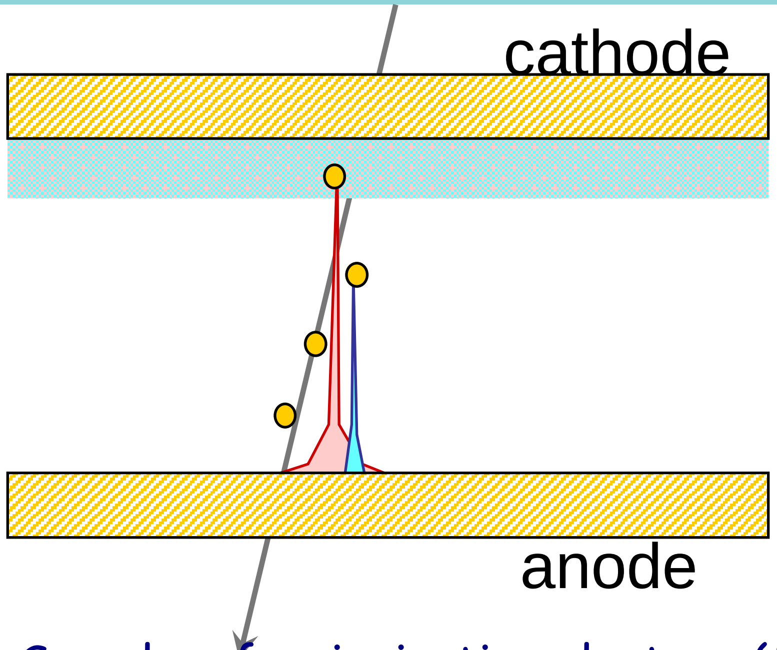
Timing Measurements of the Hadronic Shower with Multigap RPC's

- Why use multigap RPC's?
  (Transparencies stolen from C. Williams)
- Proposed set up
- Layout of read out board
- Some simulations (C. Grefe)
- Conclusion

Single Gap RPC



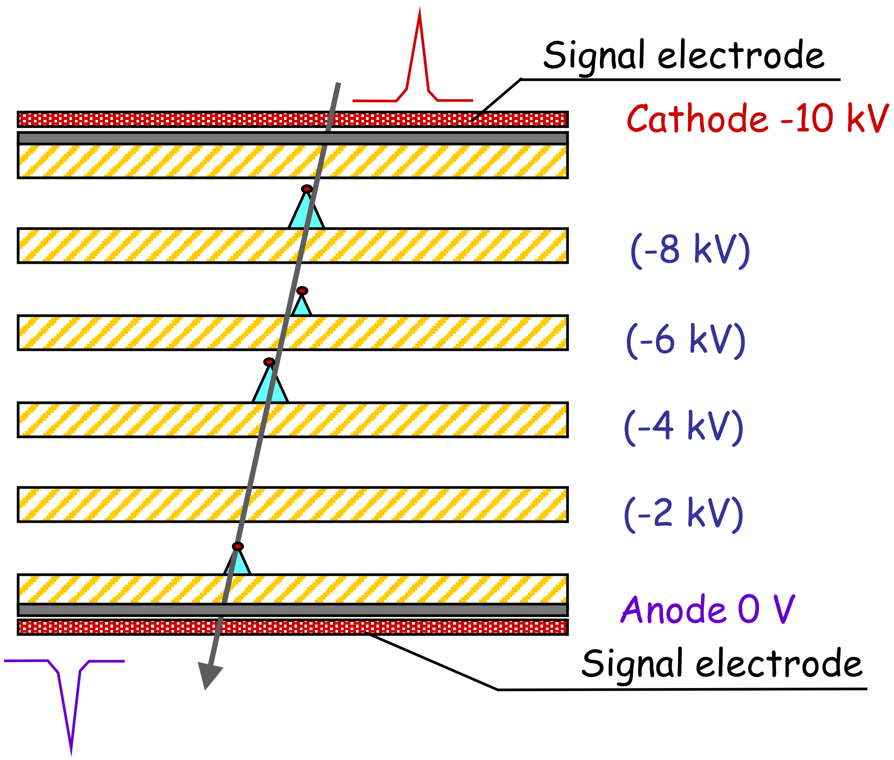
Electron avalanche grows according to

Townsend law: $N = N_0 e^{ax}$

Only avalanches that traverse full gas gap will produce detectable signals - only clusters of ionisation produced close to cathode important for signal generation

So only a few ionisation clusters (those created closest to cathode) take part in signal production - (2 mm gap RPC only ionising clusters within 0.25 mm of cathode can grow avalanches big enough to generate signal - if increase E field so that all clusters can grow big enough - we will have sparks - etc)

Multigap RPC



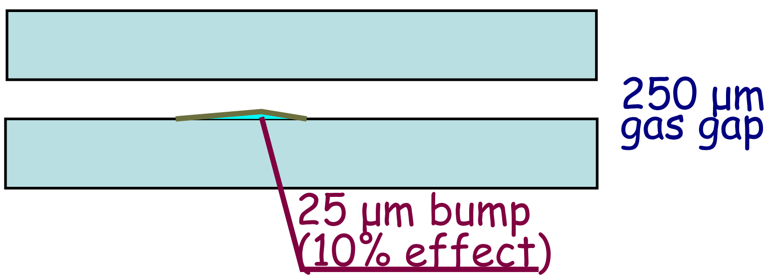
Stack of equally-spaced resistive plates with voltage applied to external surfaces (all internal plates electrically floating)

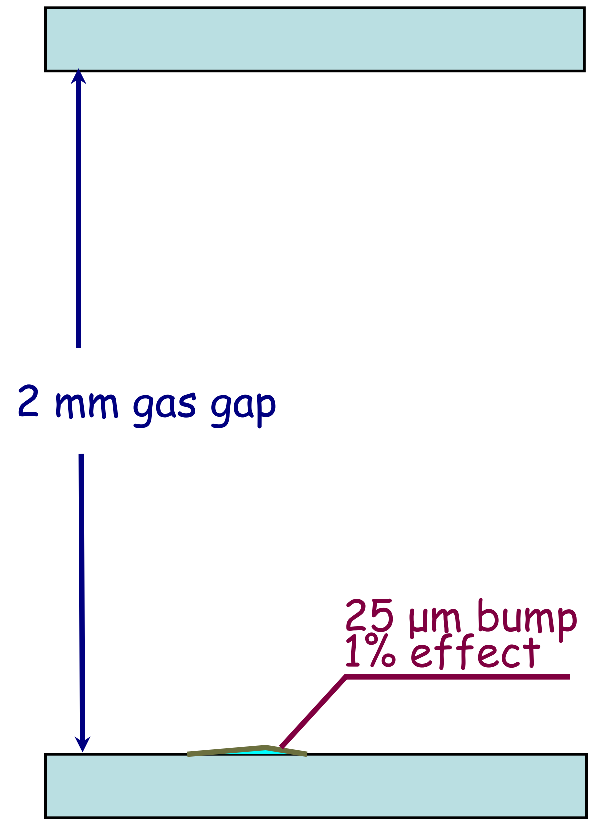
Pickup electrodes on external surfaces (resistive plates transparent to fast signal)

Internal plates take correct voltage - initially due to electrostatics but kept at correct voltage by flow of electrons and positive ions - feedback principle that dictates equal gain in all gas gaps

Effect of Small Mechanical Defaults

Gas gaps of small size need to be constructed with very tight mechanical tolerance to have uniform field.
Can we build the big plates (of detectors using normal techniques?

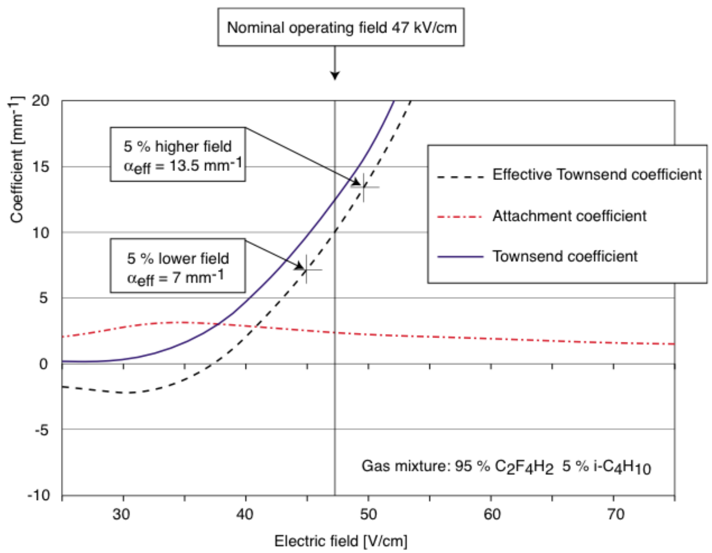




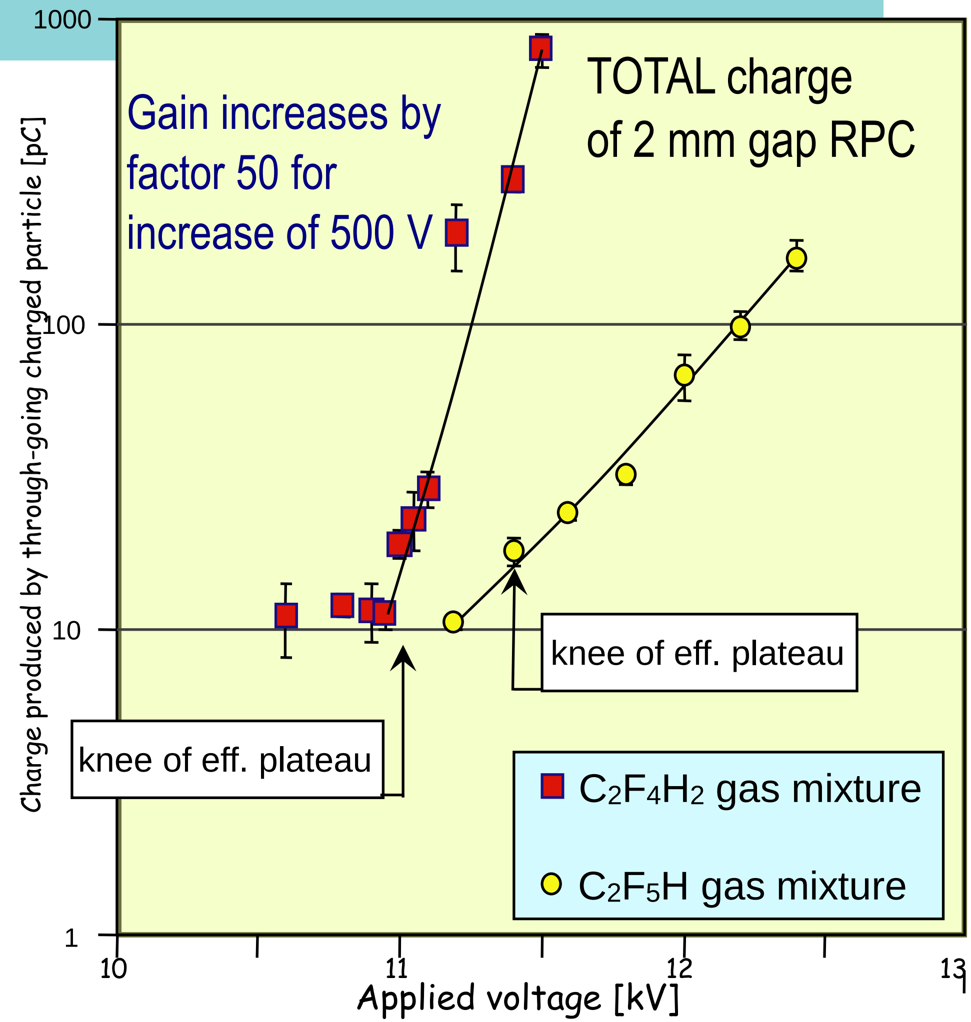
Question :
is a 25 micron bump more important in the small gap chamber or the large gap chamber?

Situation in 2mm Gap

Theory (MAGBOLTZ)



Experiment



good agreement theory/experiment

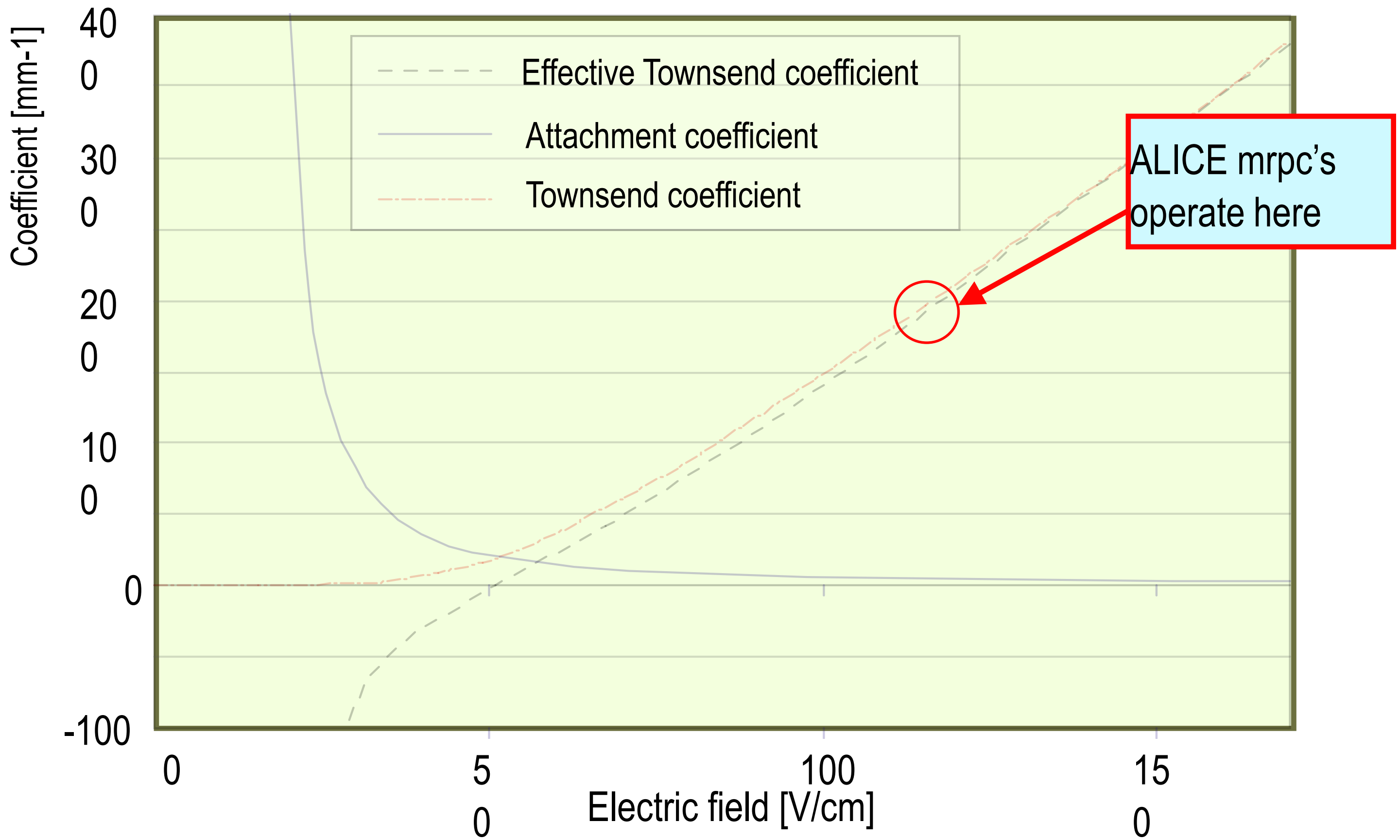
However such rapid change in gain will give very short (maybe non-existent) streamer-free efficiency plateau

2 mm parallel plate chamber will have problems with 25 micron bump (~ 1% change in field - x5 change in gas gain)

what hope for 250 micron gas gaps?

Situation in 250 µm Gap

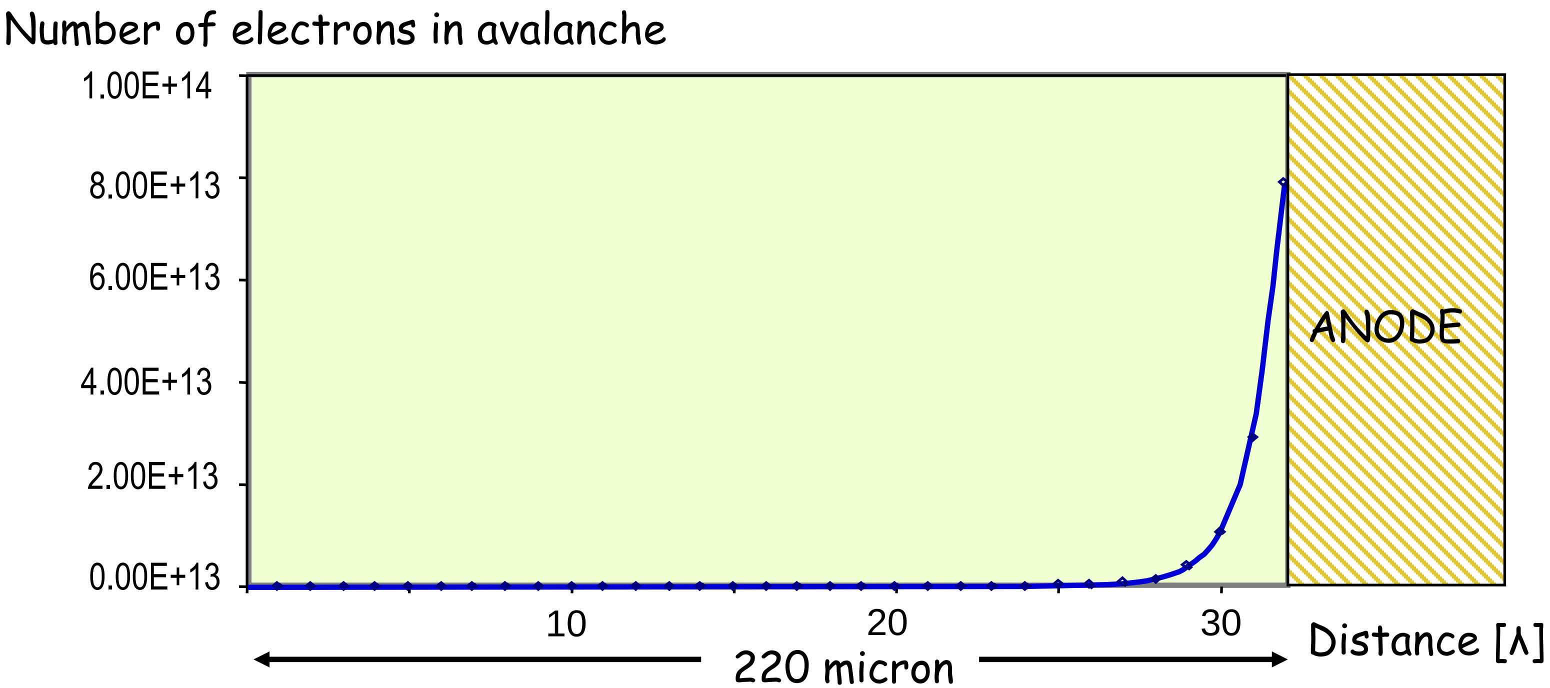
Magboltz output for 90% $C_2F_4H_2$, 5% SF_6 and 5% i-C_4H_{10}



Signal in Small Gap

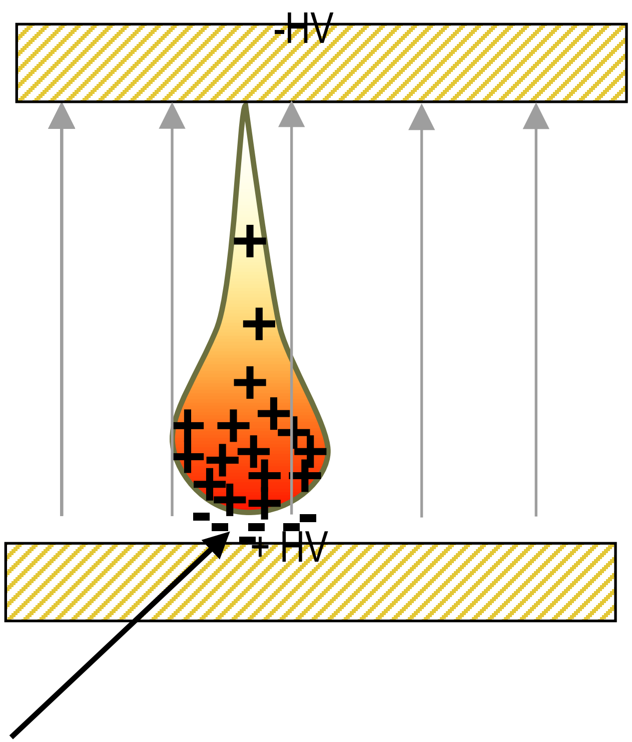
Use MAGBOLTZ program to predict Townsend coefficient and attachment coefficient in gas mixture 90% $C_2F_4H_2$, 5% iso-C_4H_{10} and 5% SF_6.
Result α = 173.4 mm^{-1} and η = 5.8 mm for a 220 micron gap MRPC

Single electron avalanching across 220 μm gap would produce ~10^{14} electrons !
(c.f. 10^8 needed for avalanche/streamer transition)



Theory ≠ experiment, what is missing?

Space Charge



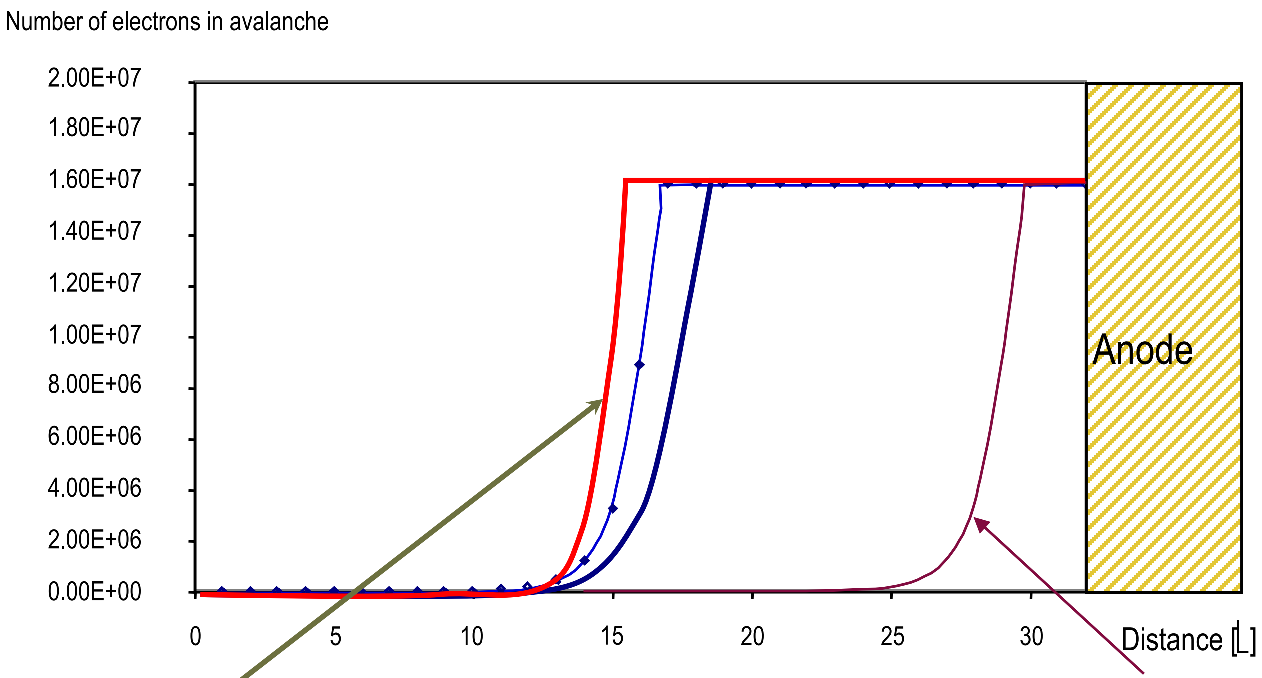
Low field region due to space charge

As the 'avalanche' grows - every time an ionising collision creates an electron, there is also a positive ion created. Since the positive ion is heavy - it is stationary (in time scale of avalanche formation). The charge of these positive ions reduces the electric field seen by the electrons in the 'head' of the avalanche. i.e. Gas gain is reduced - so avalanche grows to certain size and then growth slows down.

Small gas gaps
- field is higher
- avalanche is more dense
- space charge is more important

Simple Space Charge Model

Add 'space charge' limitation as saturation at 1.6 10^7 electrons (in reality must be less abrupt than this - but this simple model matches measurement well)



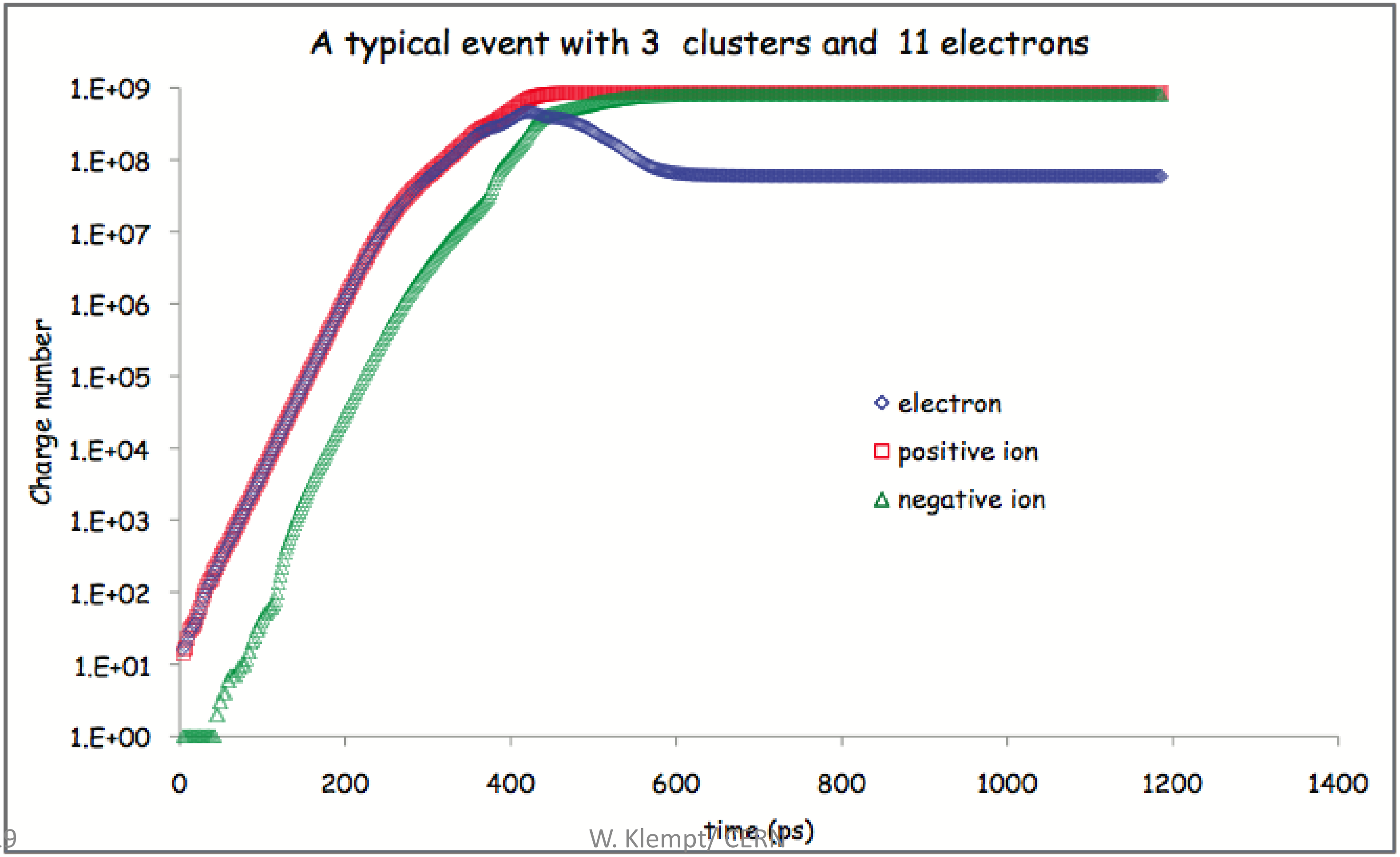
25 micron bump - higher E field - faster growth but avalanche still limited by space charge

Even avalanches that start half way across gap can produce detectable signals

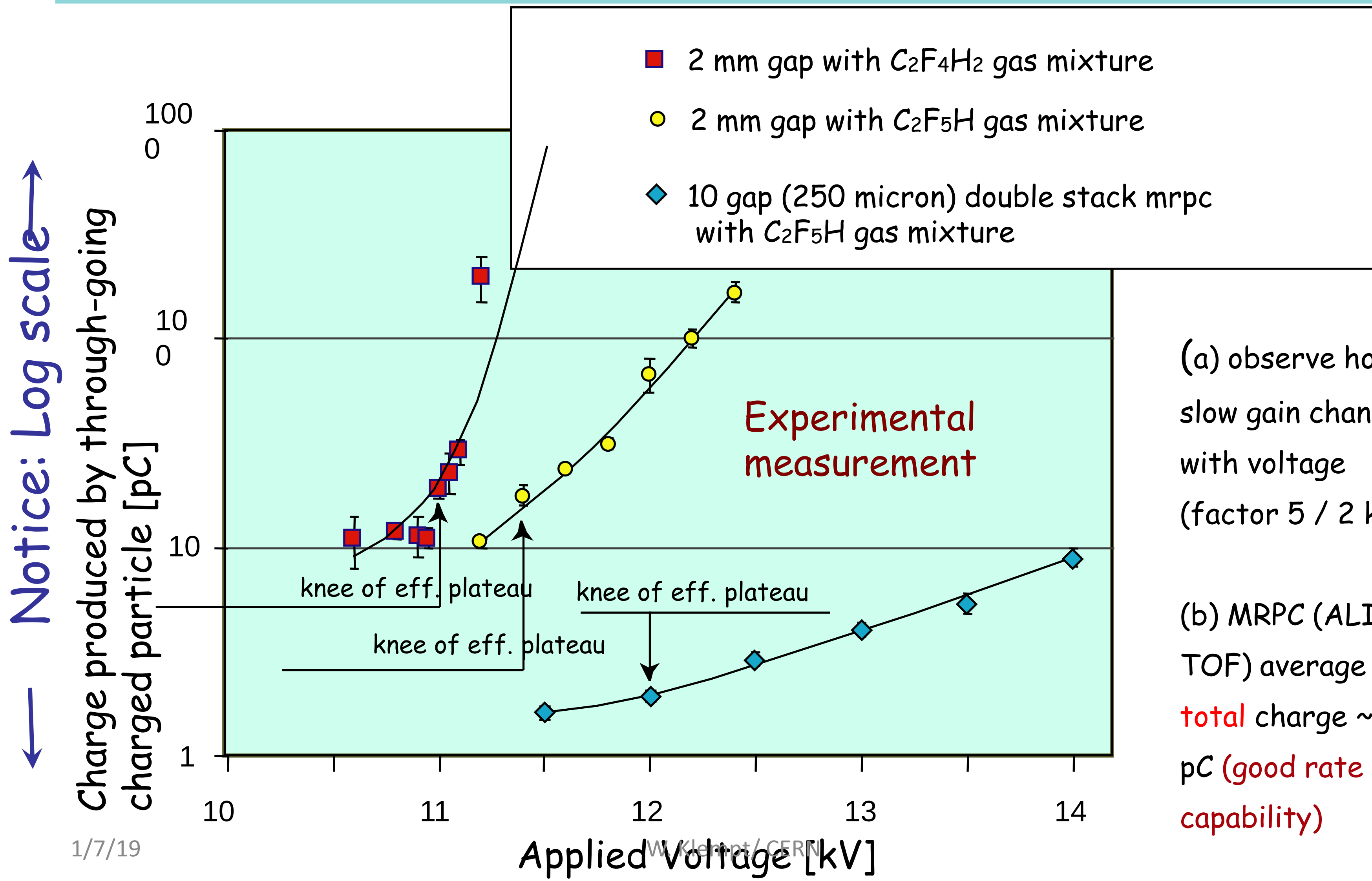
Now it is easy to see why 25 micron bump/hole does not matter - device protected by 'space charge'

Complete Simulation

In reality life is a bit more complex but
space-charge saturation effect happens



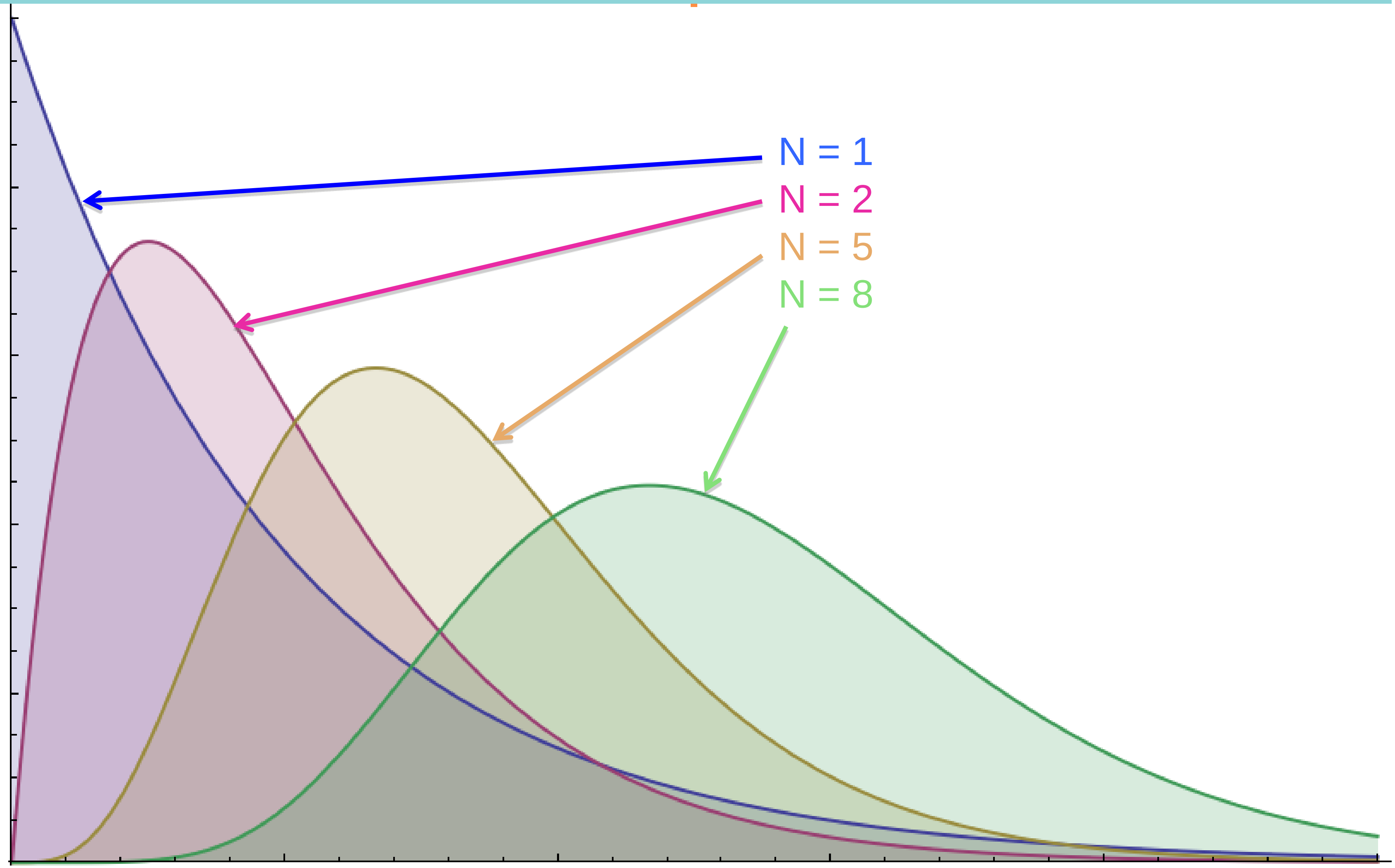
Total Charge of Various RPC's



(a) observe how slow gain changes with voltage (factor 5 / 2 kV)

(b) MRPC (ALICE TOF) average total charge ~ 2 pC (good rate capability)

Charge Distribution of one to many Avalanches

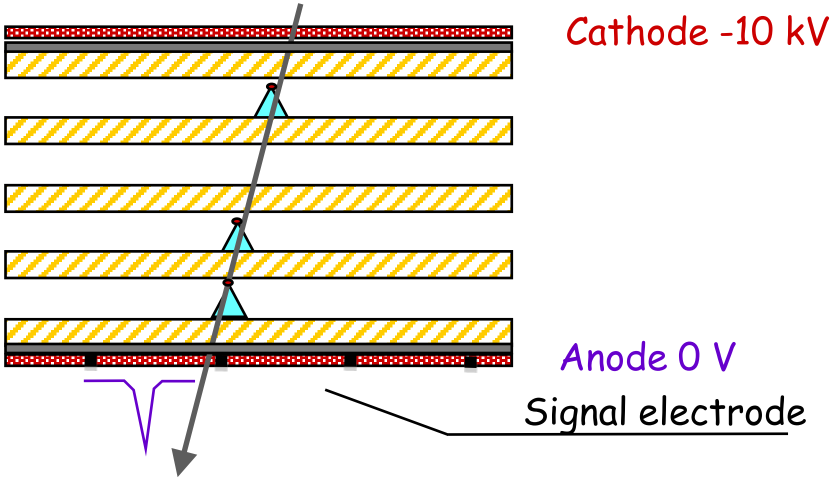


Advantages of Multi Gap RPC's

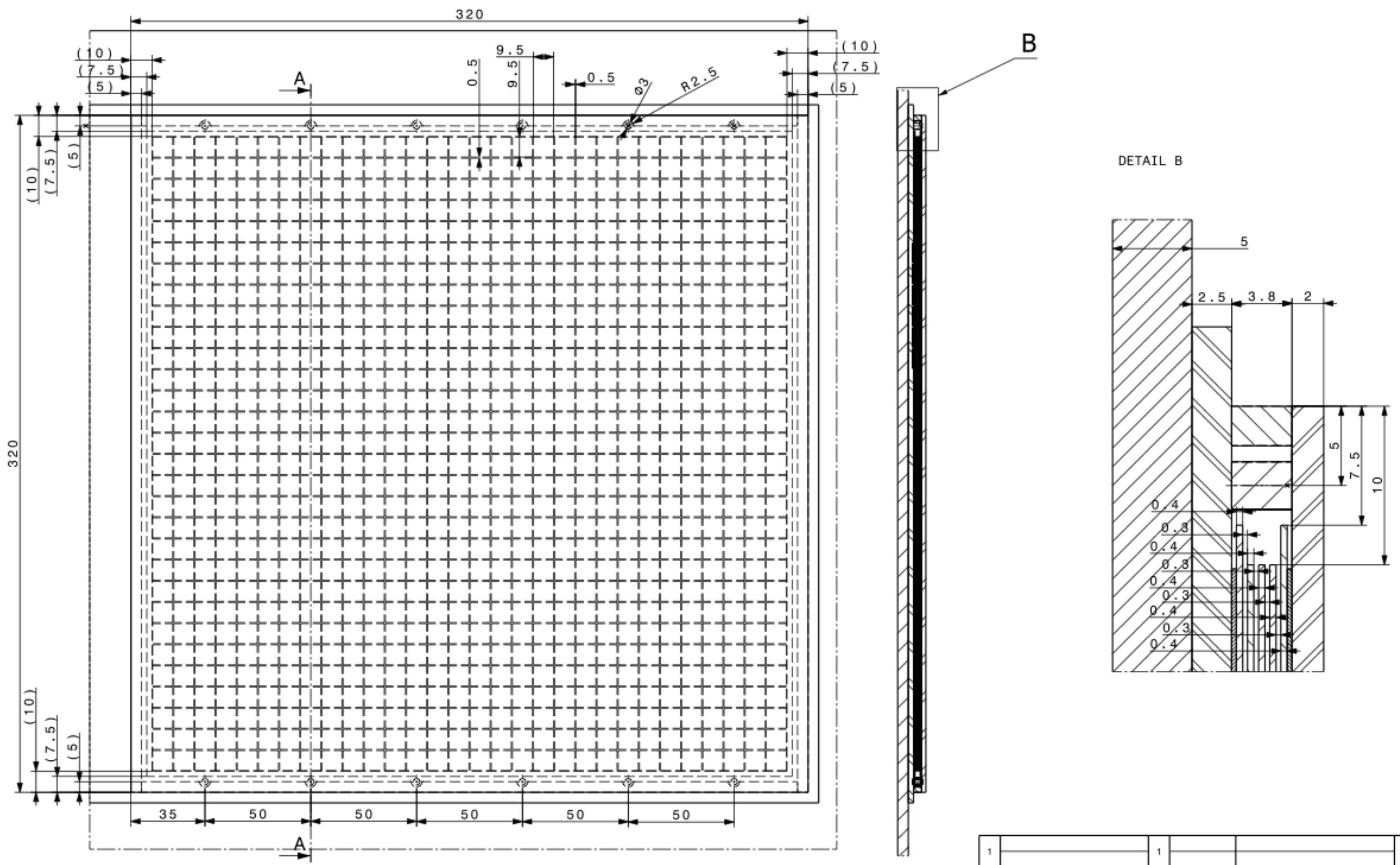
- Easy to build with many (and small) gas gaps (route to good timing)
- voltage applied only to outer surfaces of stack - all inner glass plates electrically floating (easy to build)
- avalanche growth in small gas gaps dominated by space charge
  - this relaxes mechanical constraints on size of gas gaps
  - will increase efficiency
  - also increases the fraction of total charge that appears as a fast signal (improves rate capability)
  - increases (dramatically) length of plateau. Chambers become much more stable.
- due to many separated avalanches charge spectrum gets more Gaussian => easier to set thresholds and timing resolution gets better

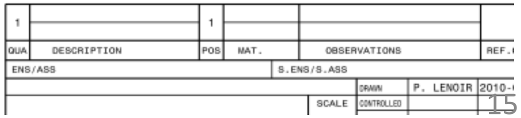
Proposed Layout

- Start with 1 plane 300 x 300 mm^2 sensitive area
- Use a 4 gap MRPC 4 x 300 µm (gas gap)+ 5 x 400 µm (float glass)
- Cell size 12.5 x+12.5 mm^2 (total 576 channels)
- Equip in first run 128 channels TDC 100 ps bin, $\Delta t \approx$ 200-300 ps
- Position in experiment : after scintillator stack, separated DAQ



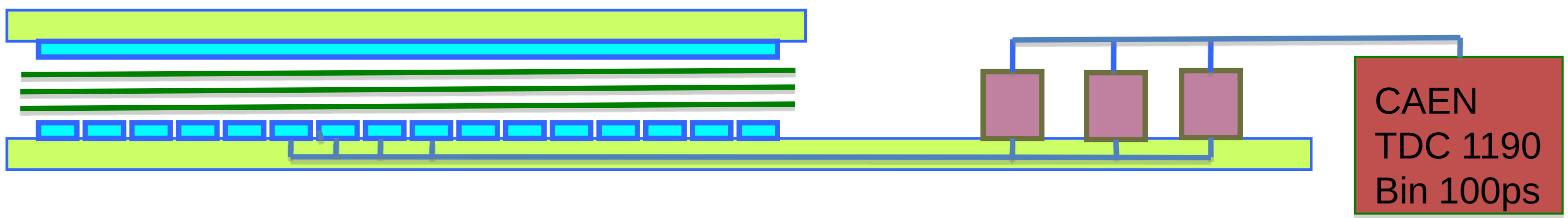
Mechanical Layout

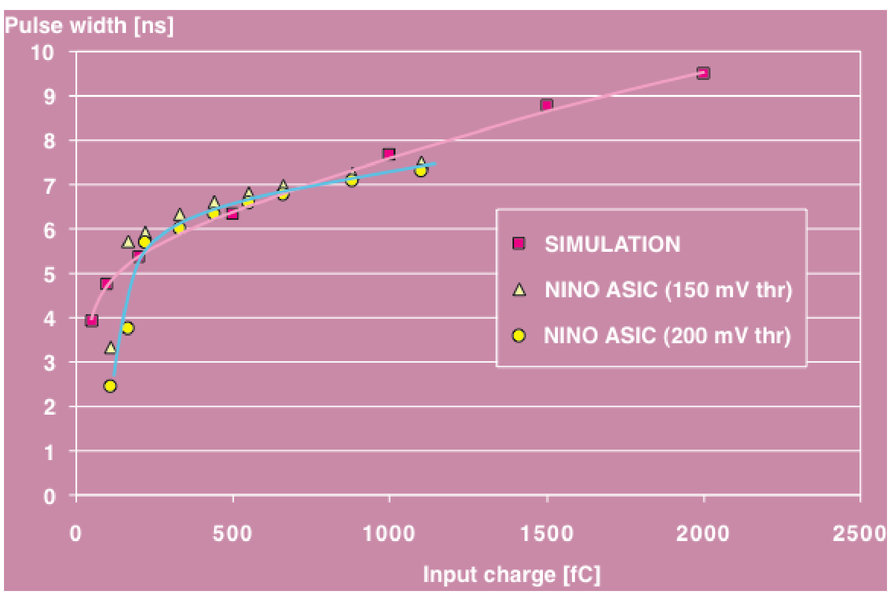




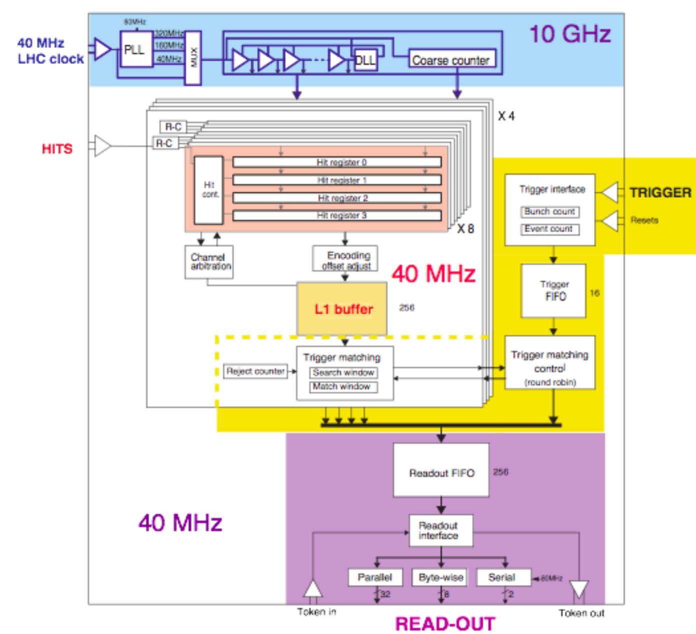
Readout Scheme

NINO ASIC

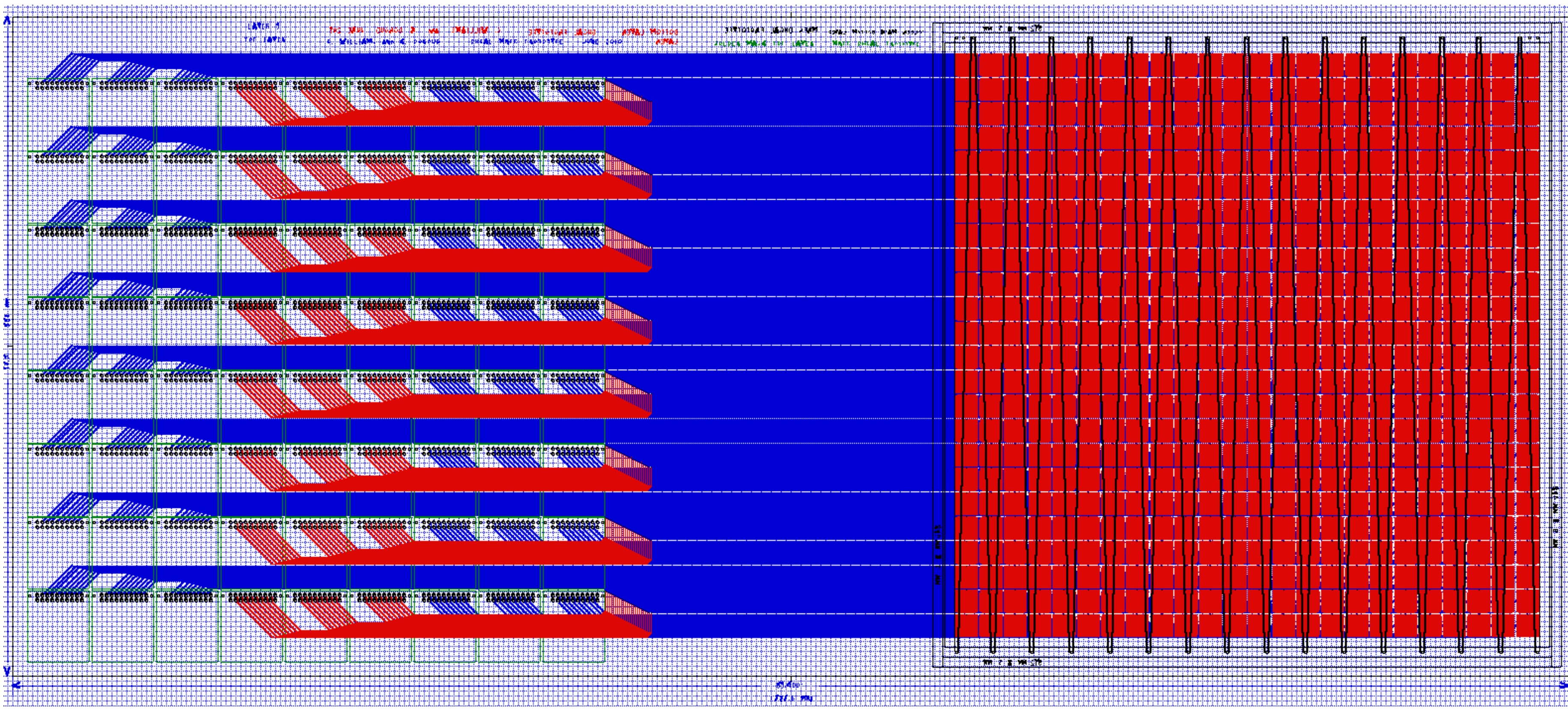




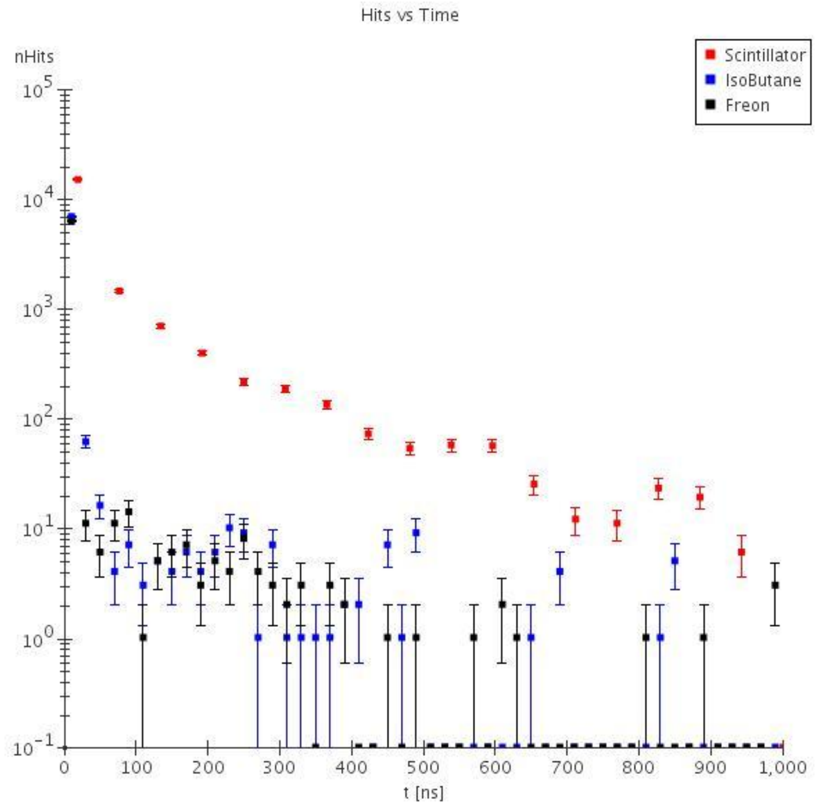
HPTDC

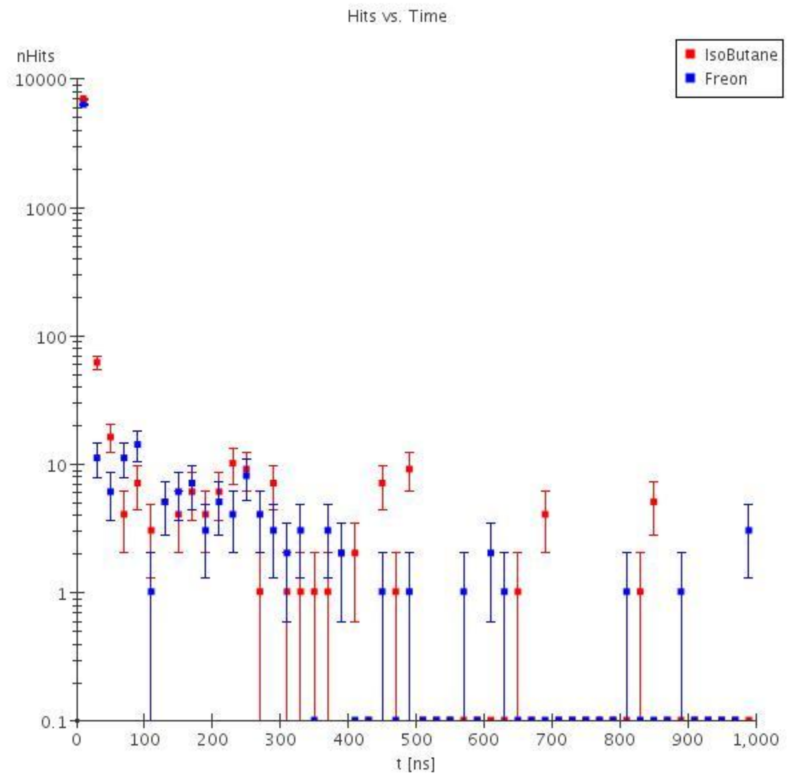


Read Out Board



Simulations (very preliminary)





Conclusions

- Multigap RPC's are reliable easy to build devices and can be made rather thin (d<4mm)
- They work in a very stable way and offer very good efficiency and excellent time resolution (100 psec is easily achievable)
- Already for the PS test beam period in Nov. 2010 a small (30 x 30 cm2) detector can be build with 24 x 24 = 576 channels. At least 128 channels could be read out with a time binning of 100psec and a resolution of ~ 200 psec.
- To measure the time spectrum of neutrons one could replace the normal Freon gas with Isobutane
- Simulation on the time spectrum have started and look promising. They should be extended.