

# The Physics inside TPCGEMSimulation

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## 4 Modules:

1. Primary ionisation
2. Drift of electrons
3. Gas amplification with GEMs
4. Electronics (shaper, ADC)

Optional module: Ion Backdrift

**Goals:** Study influence on the spatial resolution of a TPC of

- GEM settings
- Pad response, pad geometry
- Ion backdrift ...

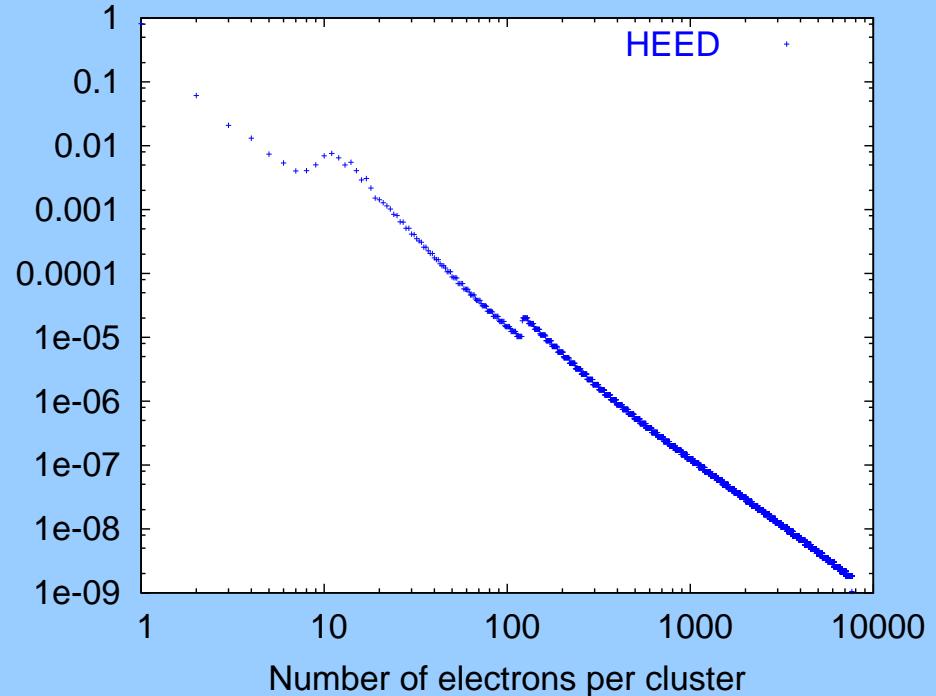
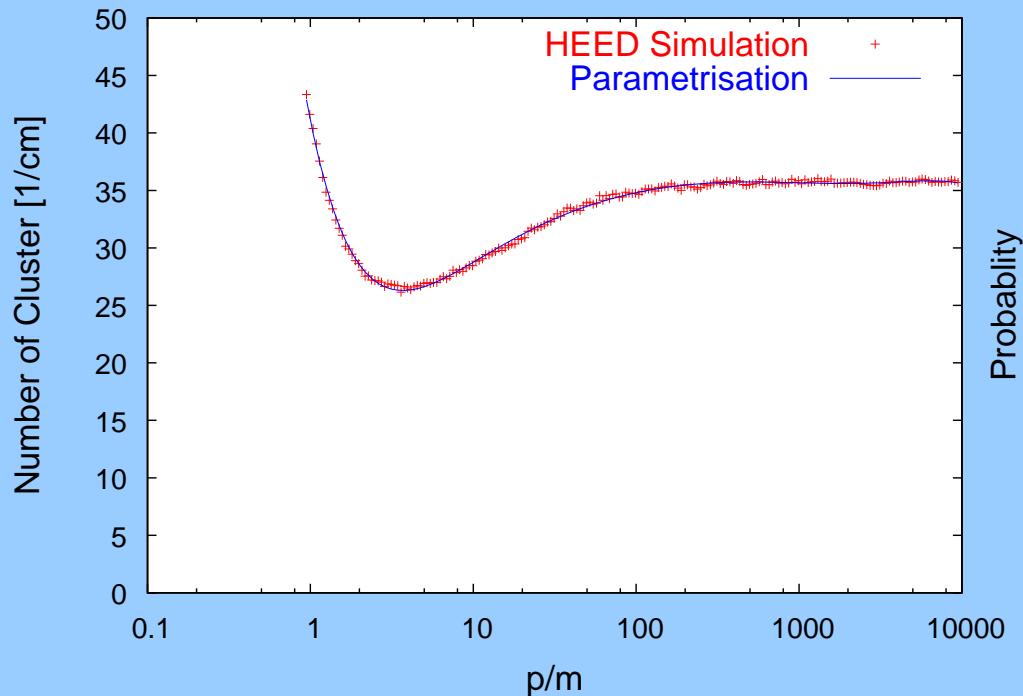
# Creating Primary Ionisation



HEED: Simulation tool for primary ionisation:

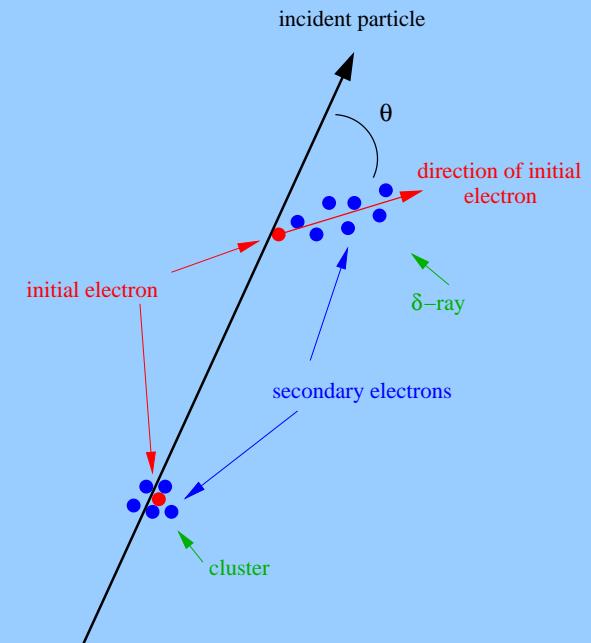
→ Parametrisation of:

- Number of cluster per cm
- Number of electrons per cluster
- Range and energy of  $\delta$ -electrons



# $\delta$ -electrons: Selection Criterion

- Spatial resolution of TPC:  $100 \mu\text{m}$ 
  - range of  $\delta$ -ray  $\geq 100 \mu\text{m}$
  - minimum # of  $e^-$  in cluster to be called  $\delta$ -ray
  
- Angle to particle track:  
 $\cos^2 \theta = \frac{E_\delta}{E_p} \rightarrow \text{mostly } 90^\circ$

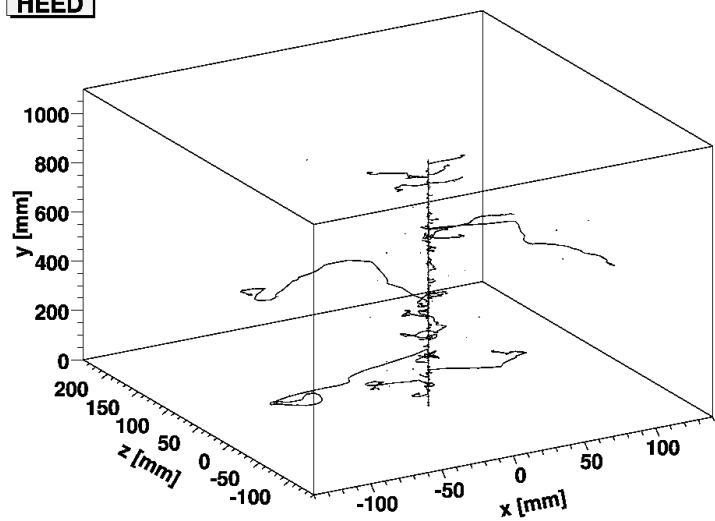


## Multiple scattering: empirical parameters

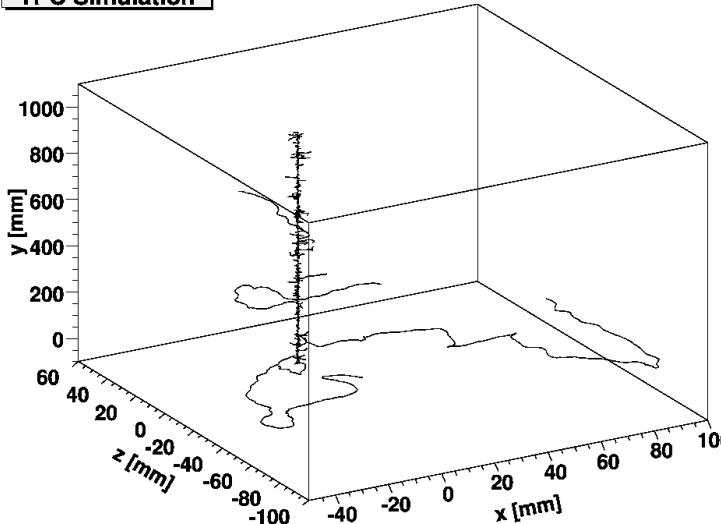
- opening angle of cone:  $\pi/6$
- “scattering length”: new direction every  $30 e^-$

# $\delta$ -electrons: Multiple Scattering

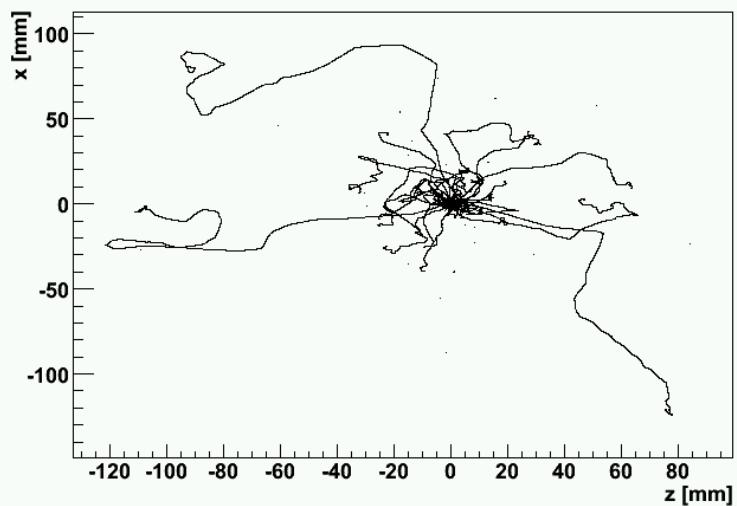
HEED



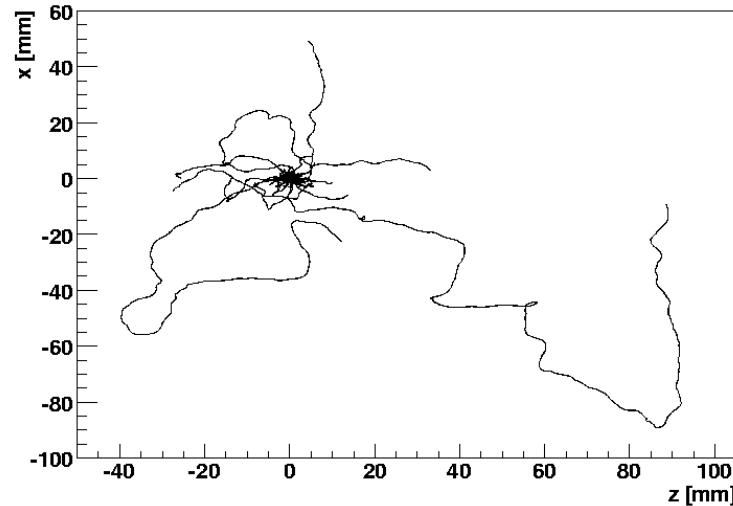
TPC Simulation



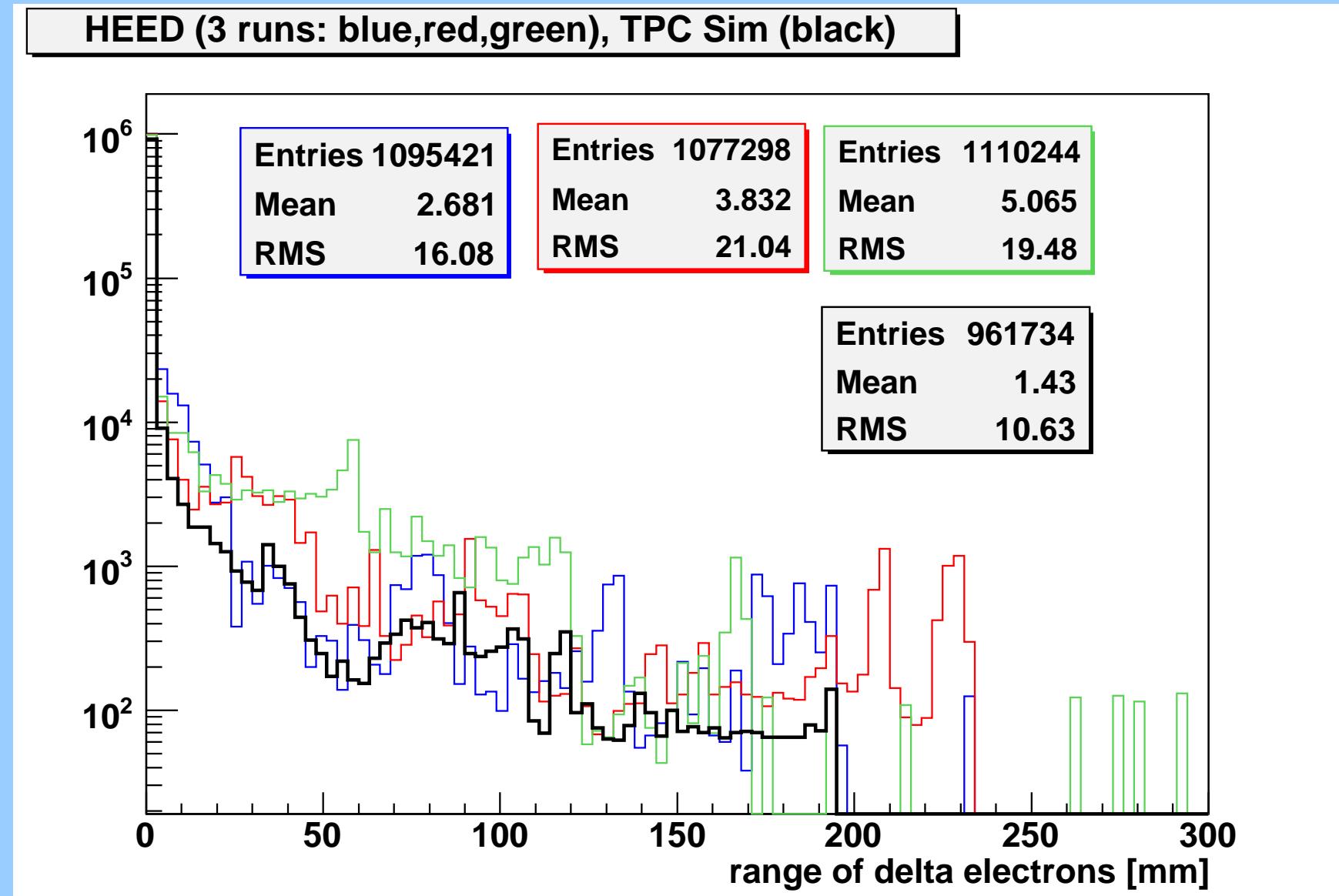
HEED



TPC Simulation

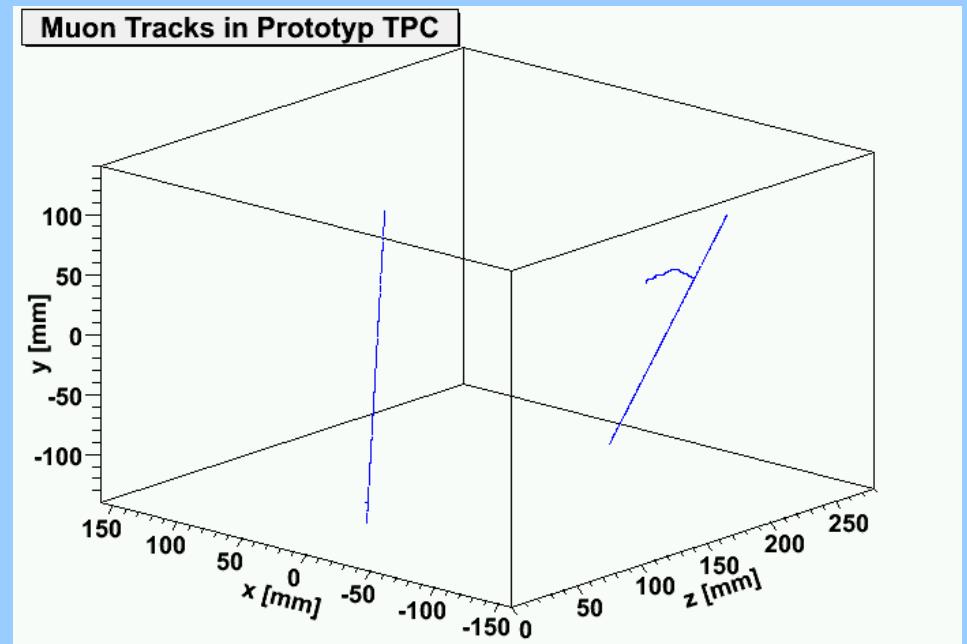
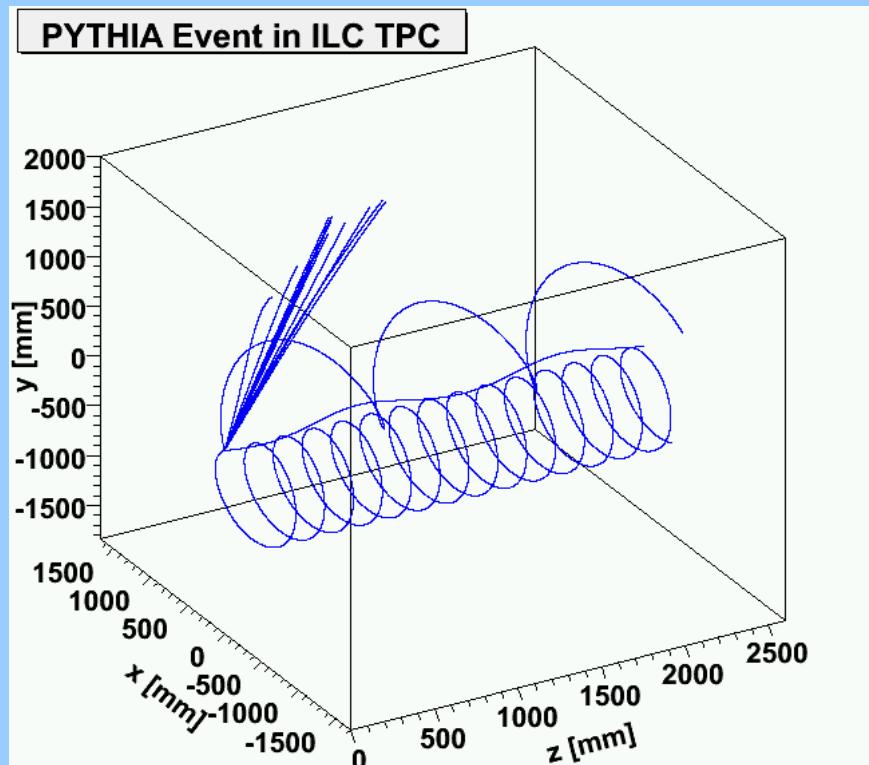


# $\delta$ -electrons: Traveling Ranges



# Creating a Track

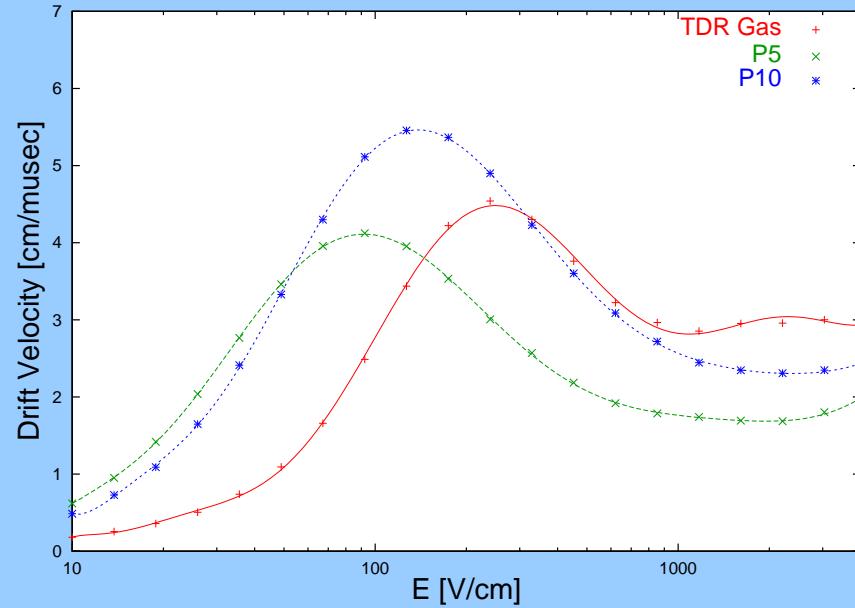
- Randomly choose distance to next cluster (exponential)
- Choose # of  $e^-$  in this cluster
- Position  $e^-$  on track (B=0: straight line, B $\neq$ 0: helix)
- $\delta$ -electrons with angle to track + multiple scattering



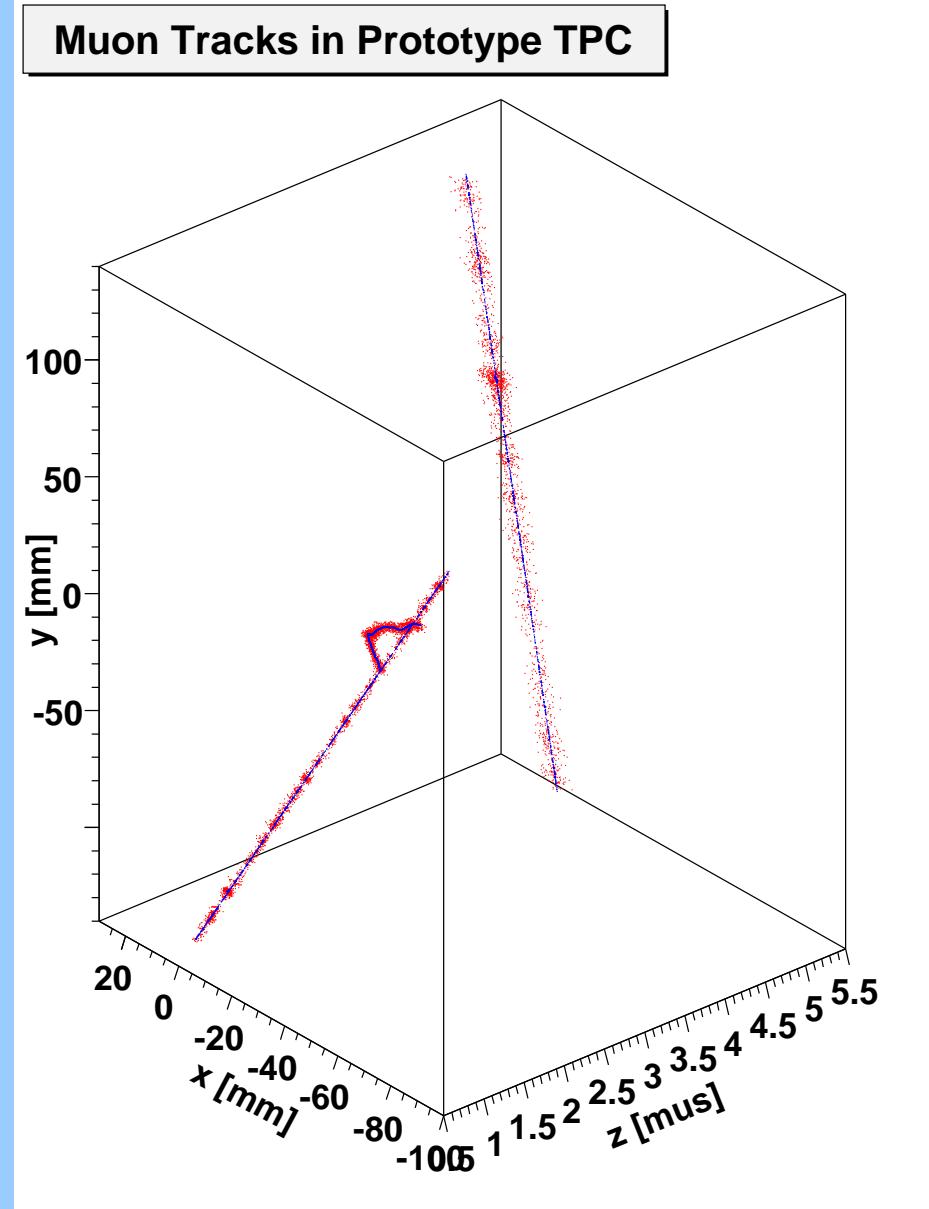
# Drifting of Electrons



Parametrise gas properties  
simulated with MAGBOLTZ



Dice coordinates after drifting  
according to longitudinal and  
transverse diffusion

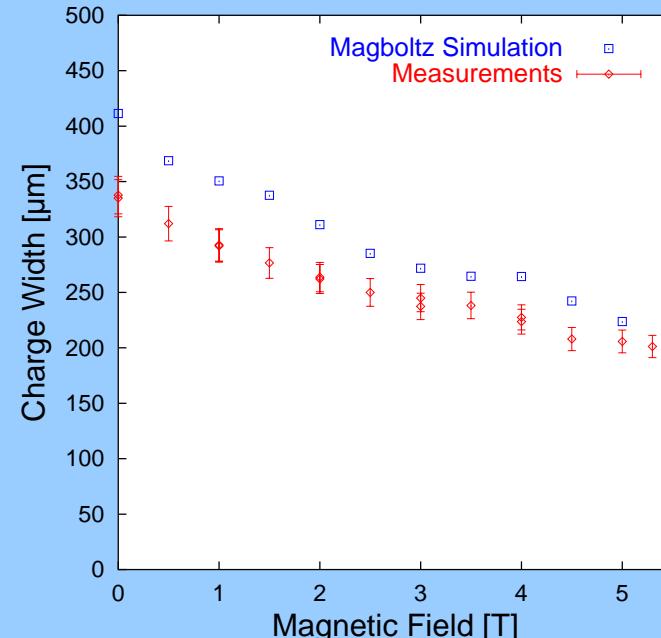
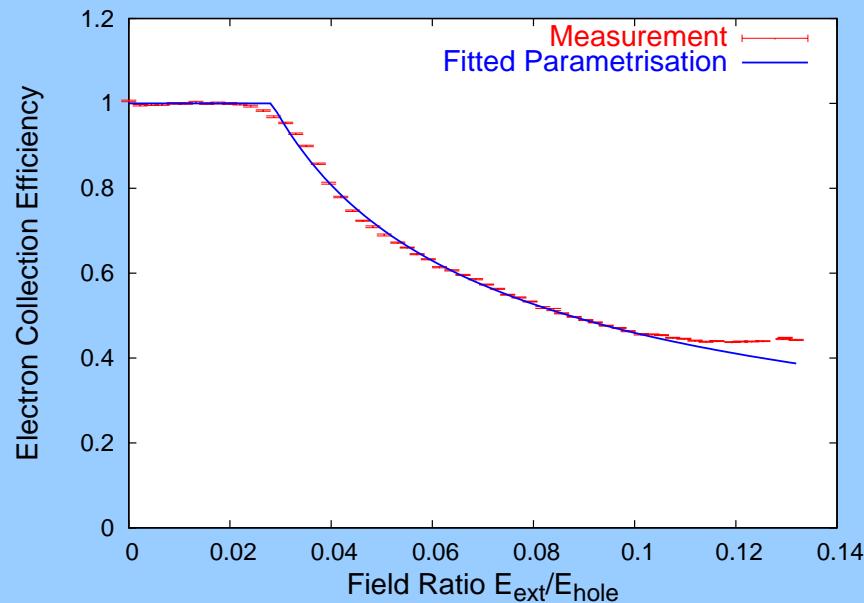


# Amplification with GEMs: Inputs



From measurements:

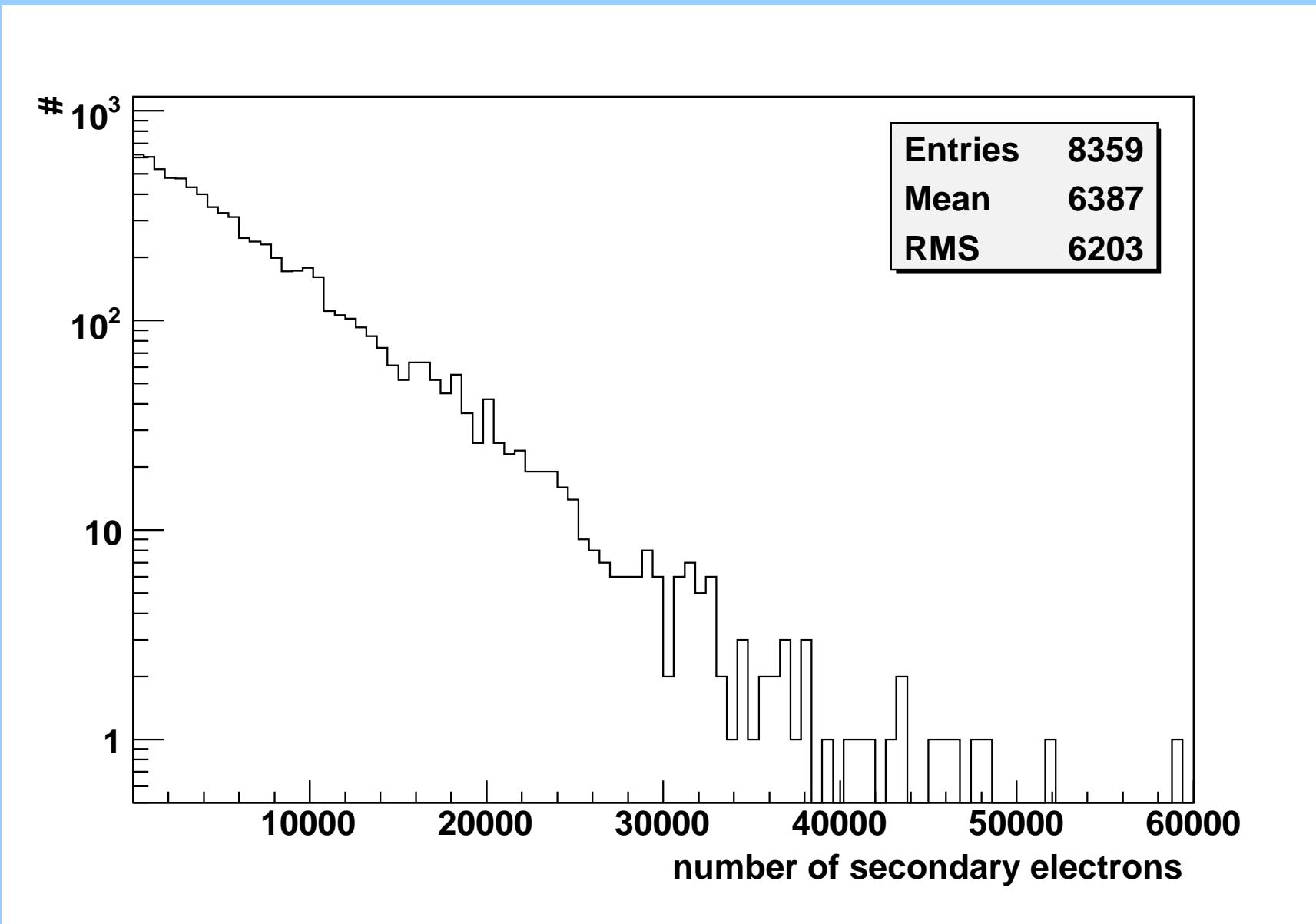
1. Parametrisation of charge transfer in triple GEM structure: collection, gain, extraction
2. Charge broadening only due to diffusion between GEMs  
→ Simulate diffusion with Magboltz



## Statistics for one electron in the GEM structure

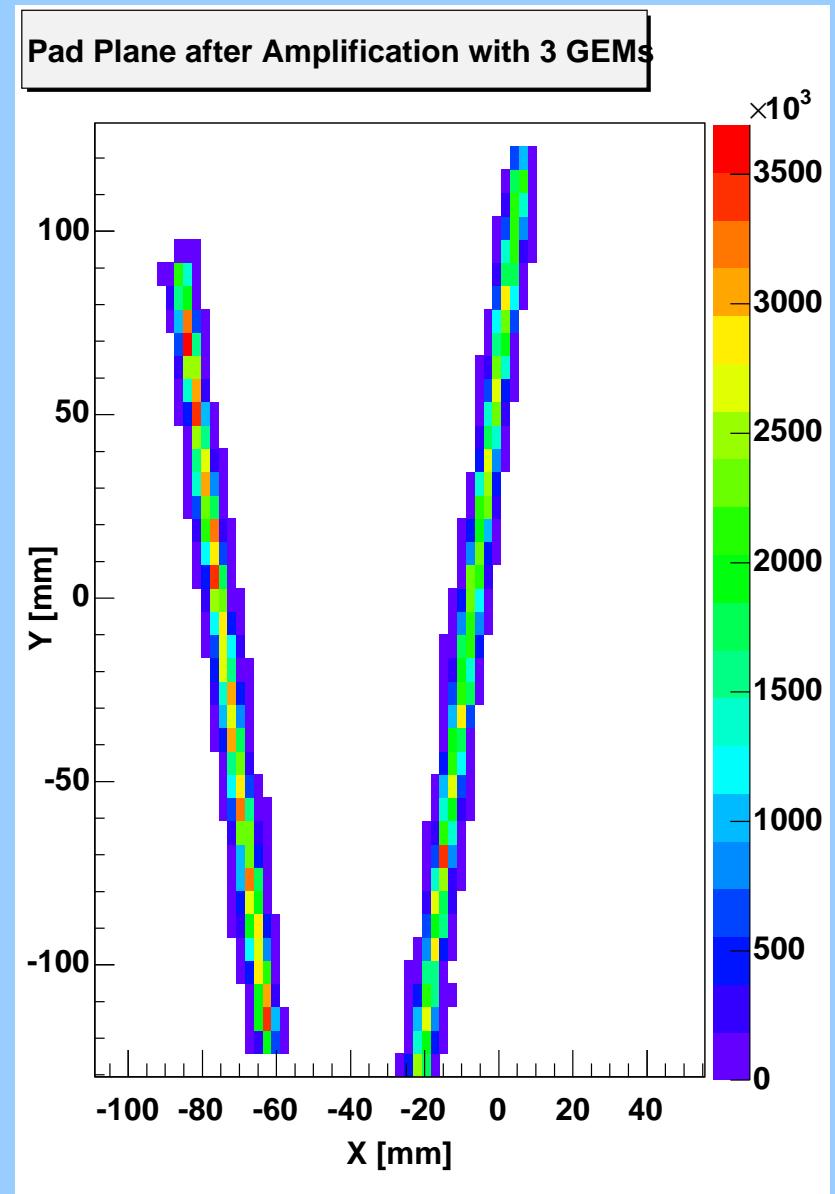
	after step	number of electrons	average efficiency or gain
GEM 1	collection	1	1
	gain	70	65
	extraction	24	0.35
	attachment	22	0.921
GEM 2	collection	14	0.66
	gain	1165	66
	extraction	389	0.35
	attachment	358	0.921
GEM 3	collection	245	0.66
	gain	17255	68
	extraction	9202	0.54
	attachment	7322	0.796

# # of secondary $e^-$ from one primary $e^-$



# Amplification with GEMs: Method

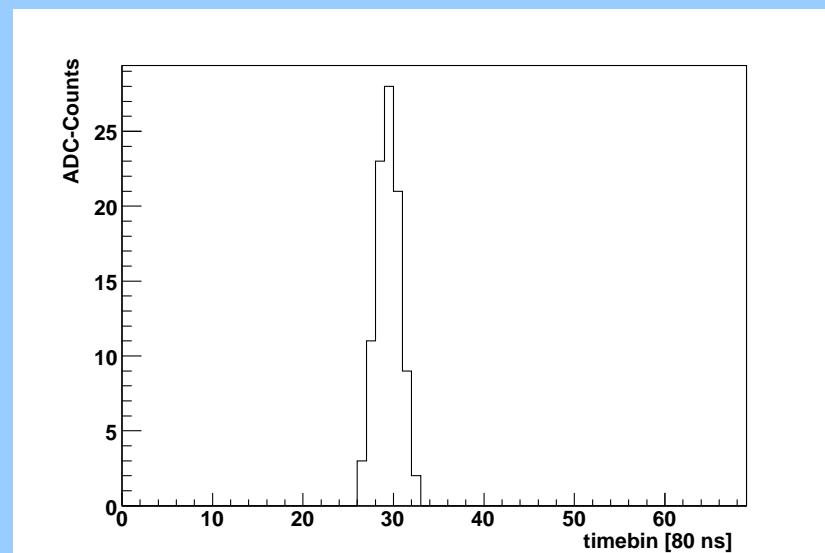
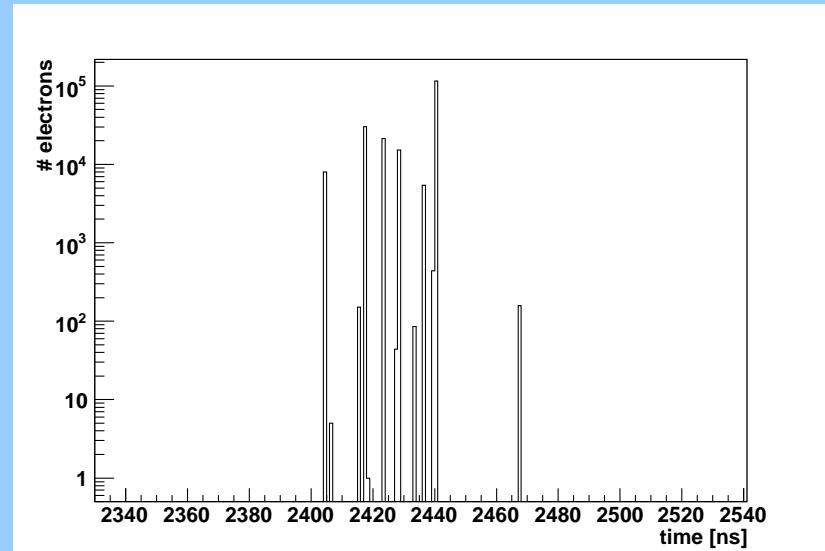
- Calculate number of secondary  $e^-$  from charge transfer combined with binomial statistics
- Integrate over 2D gaussian with sigma of charge cloud to get charge on pads  
→ Voxel information:  
charge on channel  $c$   
at time  $t$



# Electronics: Shaping and ADC



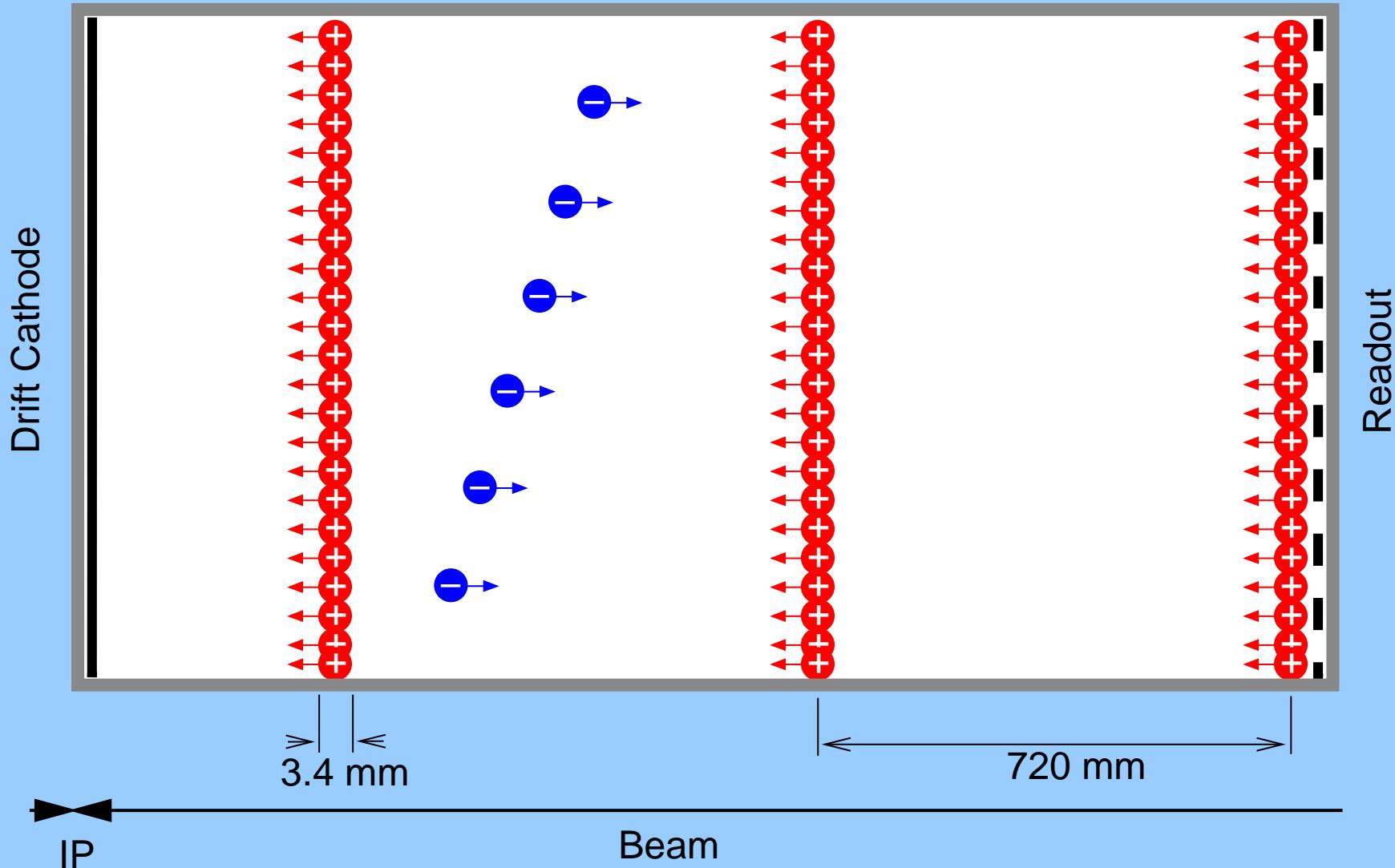
- Determine center of gravity of charge in time
- Apply shaping function (Gaussian at the moment)
- Fill electrons into time bins by integrating over every ADC bin
- Normalise charge with ADC range



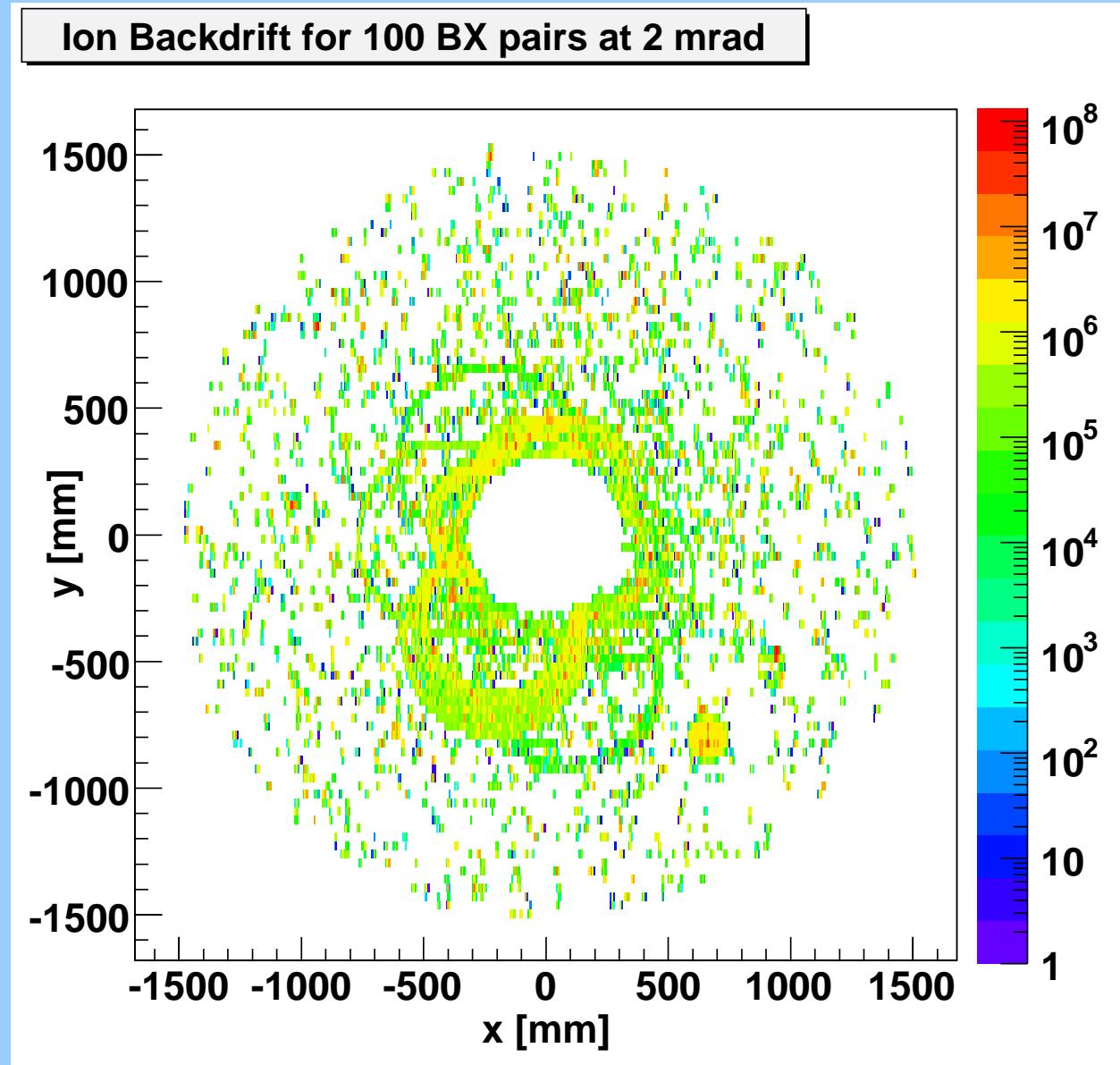
# Ion backdrift in ILC TPC (1)



One ion slice per bunch train mainly due to background



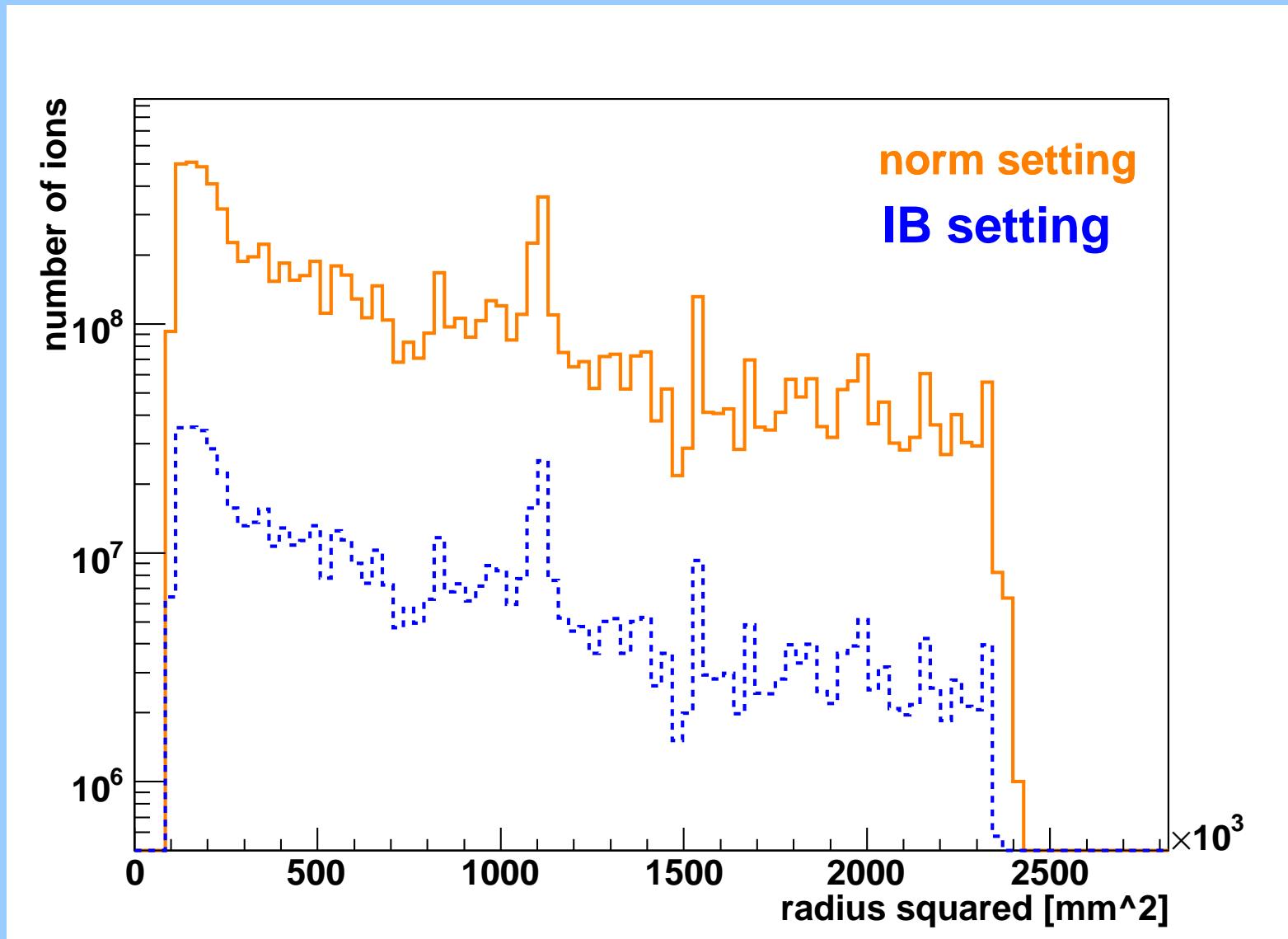
## Back drifting ions from pad plane



# Ion backdrift in ILC TPC (3)



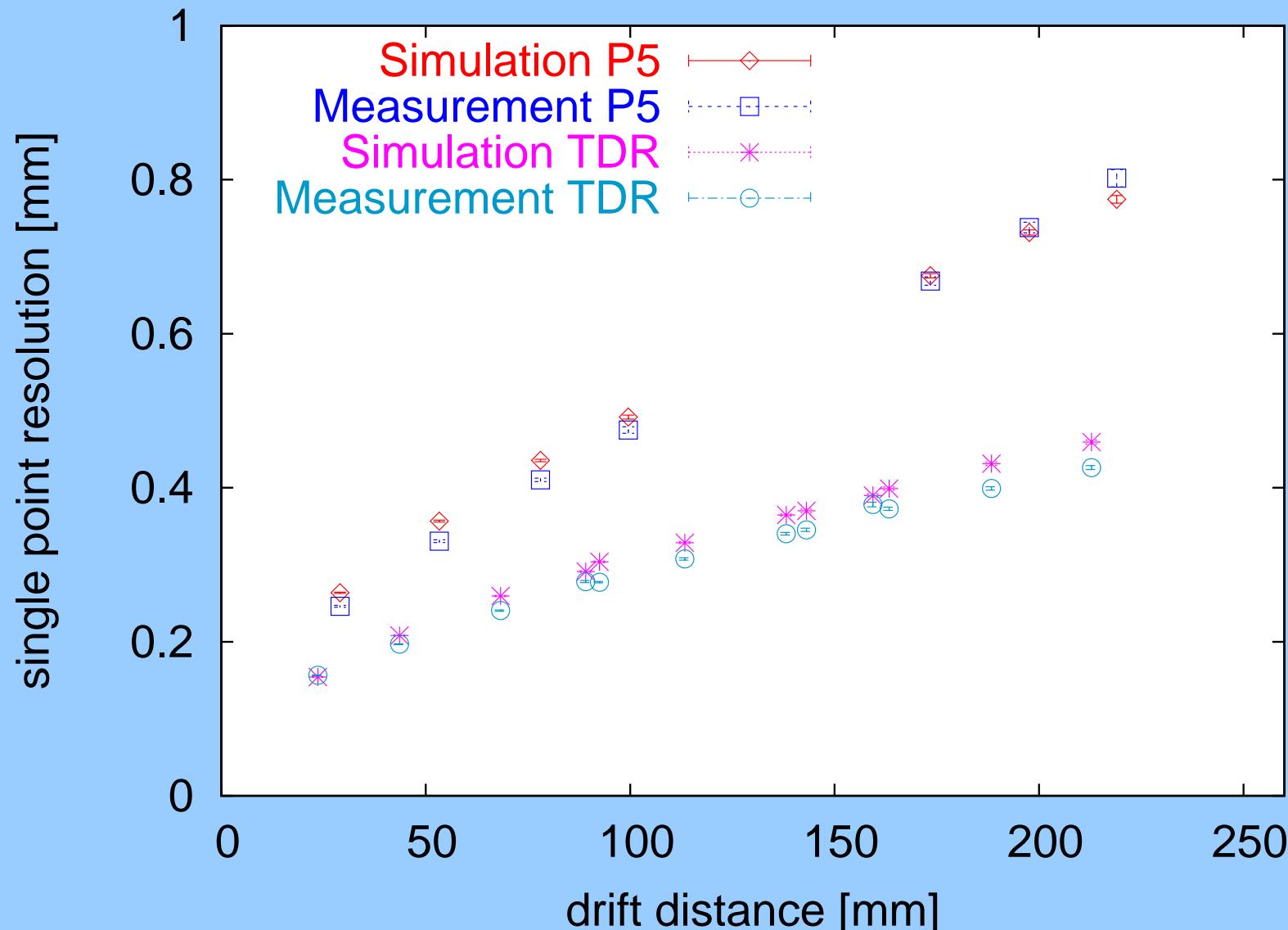
Radial distribution of charge from 100 BX pair background



# Resolution in $x$ at 0T



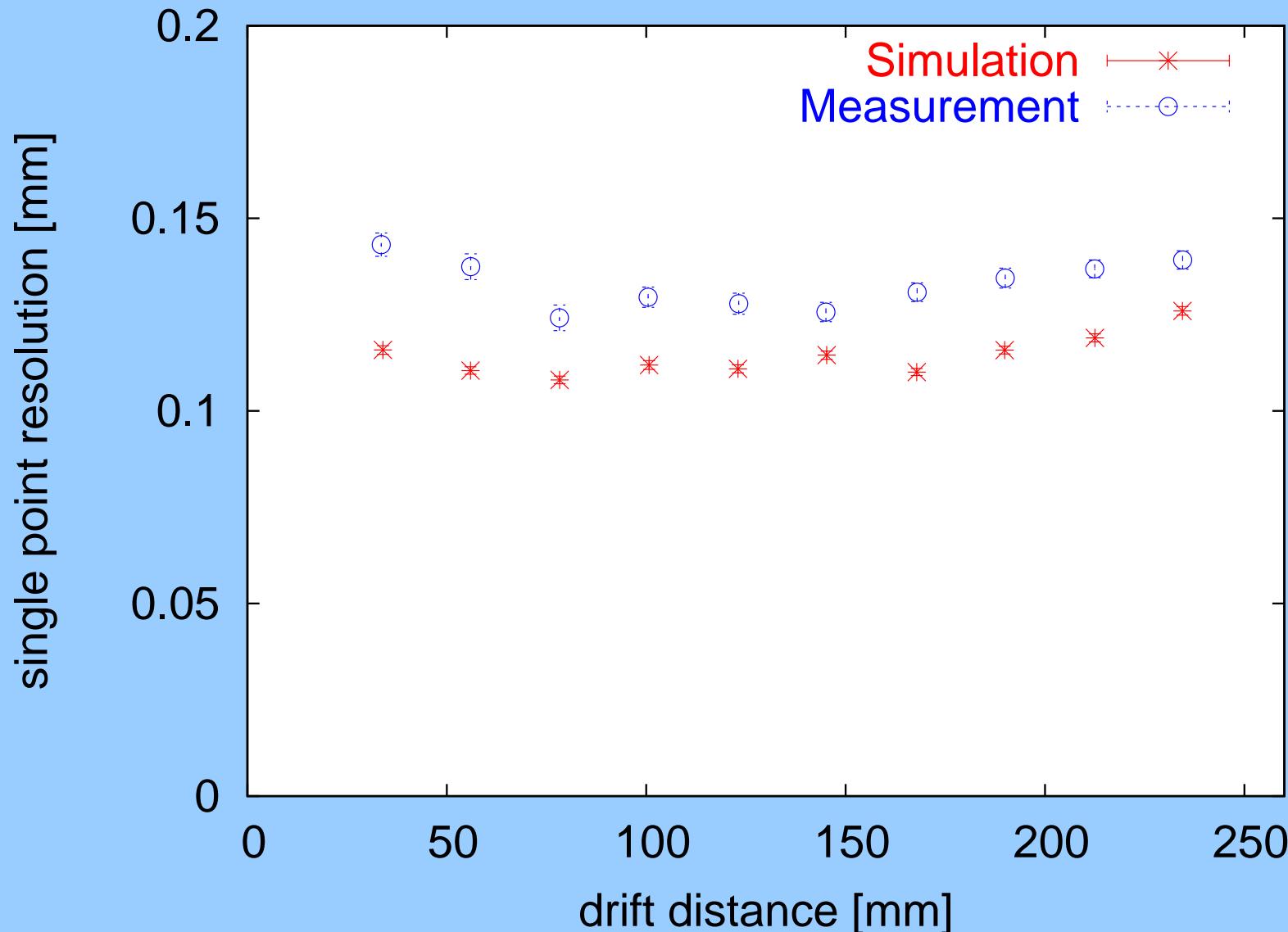
$1.27 \times 6.985 \text{ mm}^2$  Pads, TDR + P5 Gas, 0T, DESY Testbeam



# Resolution in $x$ at 4T



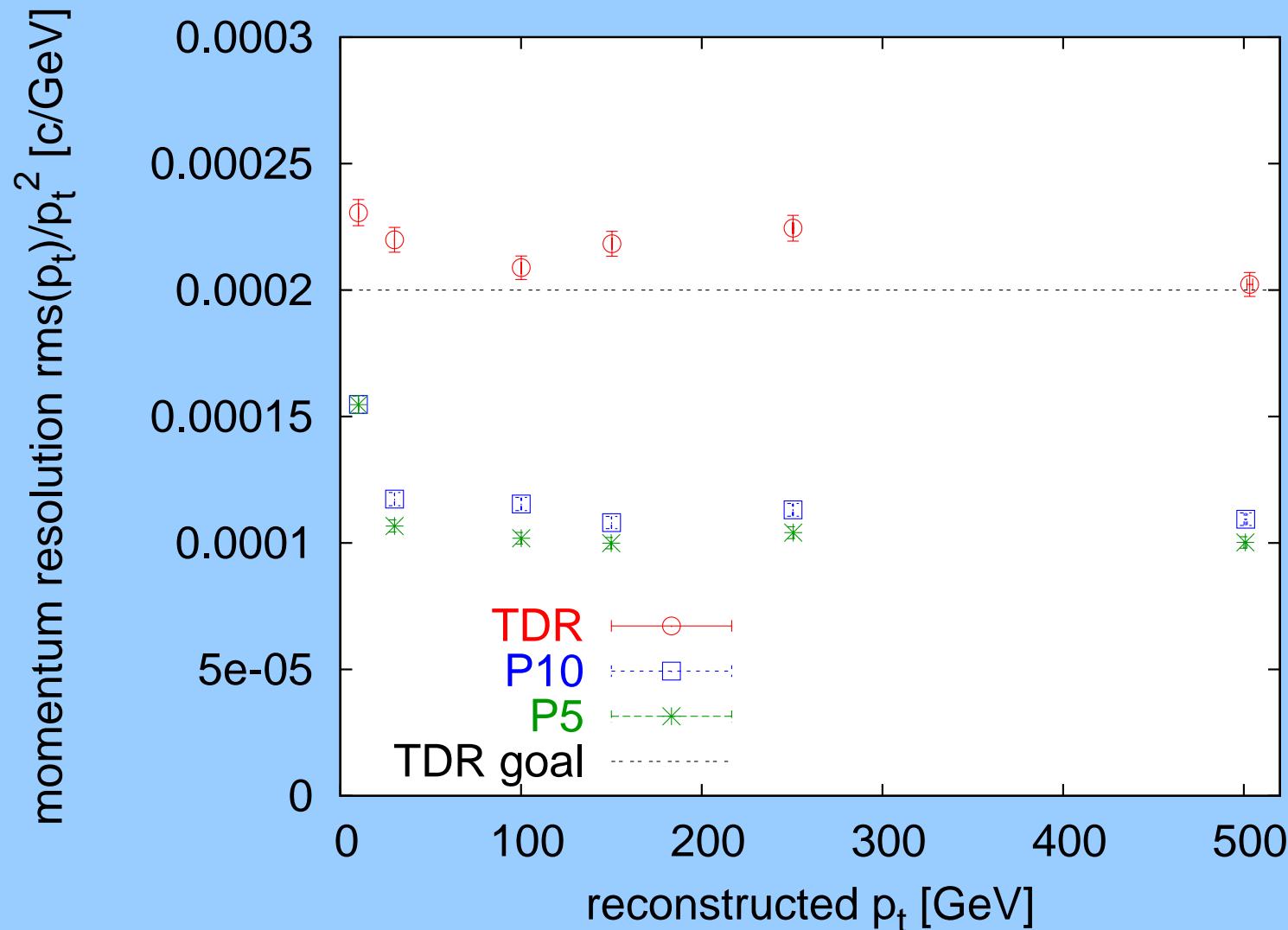
$1.27 \times 6.985 \text{ mm}^2$  Pads, TDR Gas, 4T, DESY Magnet



# Momentum Resolution ILC TPC



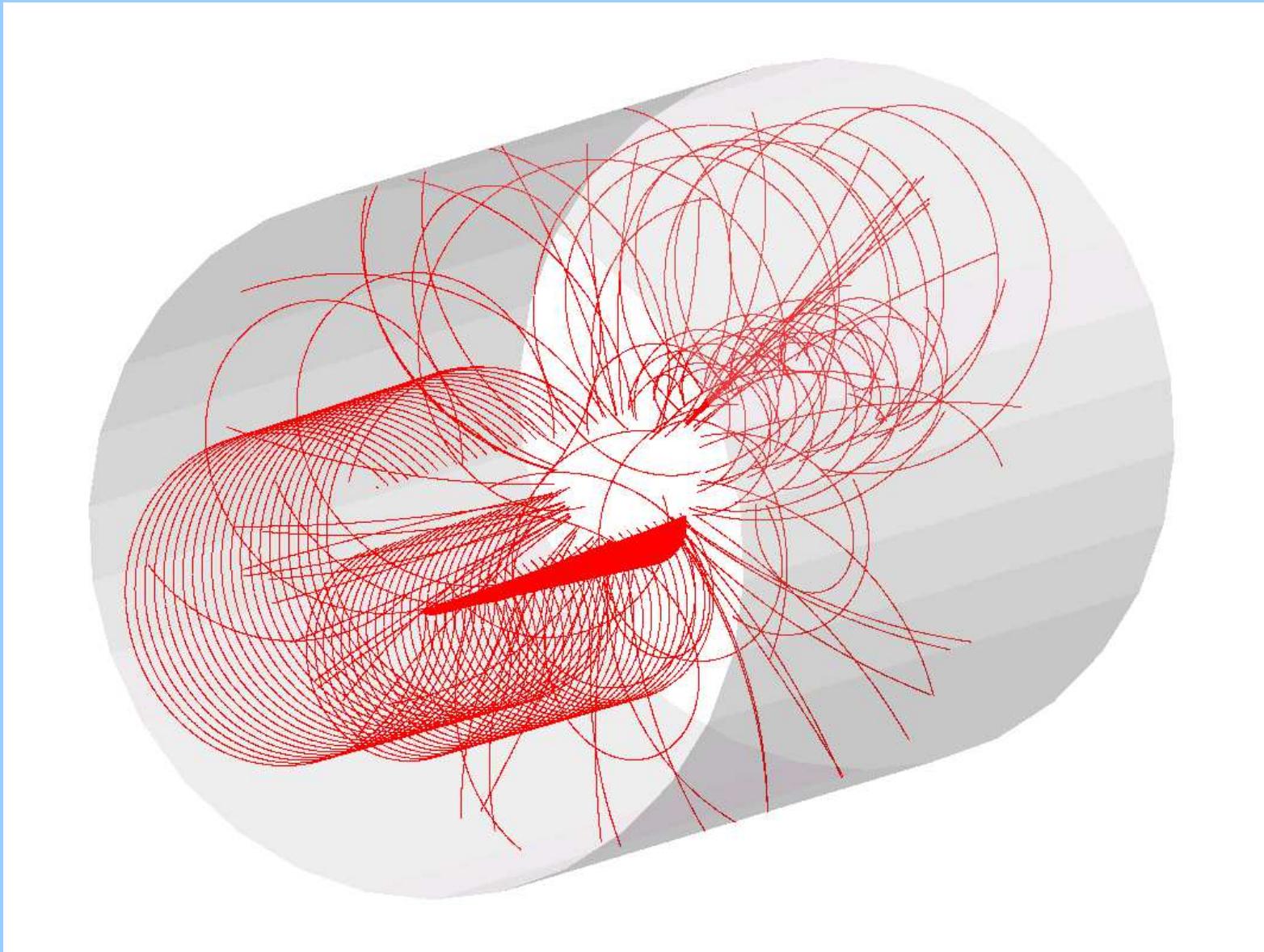
$1.0 \times 7.0 \text{ mm}^2$  Pads, 4T,  $R_{\text{TPC}} = 1680 \text{ mm}$ ,  $L_{\text{TPC}} = 2500 \text{ mm}$



# Large Data Sets: $t\bar{t}$ Events



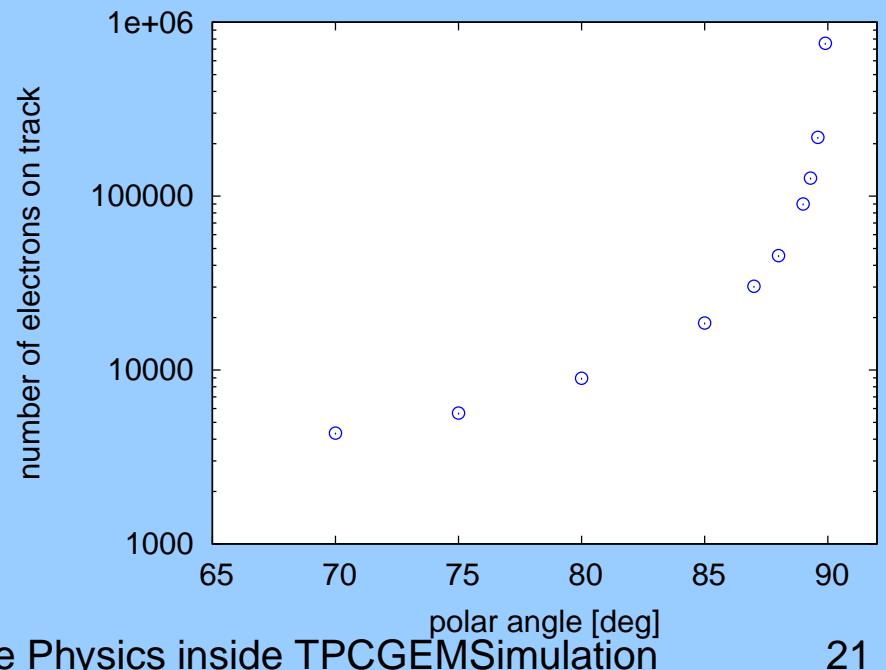
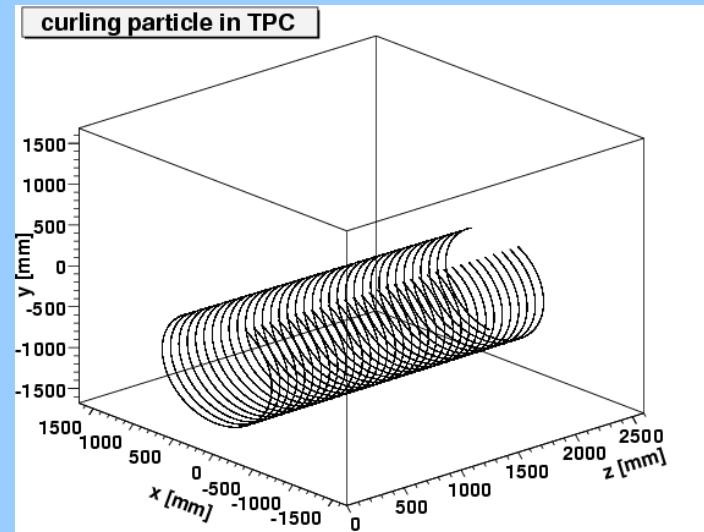
High track multiplicity can be handled:



# Special Treatment for low $p_t$ particles



- Problem:  
Large amount of primary  $e^-$
- Solution:  
Simplify curlers  
→ store only every 10th  $e^-$   
make up for it before  
amplification
- Criterion for curler:  
 $p_t \leq 1 \text{ GeV}$ ,  
polar angle  $\geq 88^\circ$



# Comparison: ROOT vs LCIO



Computing time and disk space for 10  $t\bar{t}$  Events:

file format	ROOT		LCIO / Marlin	
simulation step	computing time	file size [MB]	computing time	file size [MB]
TPClonisation	37s	55	1min 46s	123
TPCDrift	59s	129	4min 51s	287
TPCPads	9min 30s	69	47min 53s	358
TPCElectronics	24s	11	25min 42s	365
total	11min 30s	264	80min 12s	1133
one run (LCIO)	-	-	30min 30s	364

→ ROOT 3 times faster and uses less disk space

# Conclusion

## Advantages:

- Simulation independent from large simulation packages
- Amplification with GEMs (accounts for different settings)
- Relatively fast for detailed simulation
- Magnetic fields and 3D tracks possible
- Many input parameters for systematic studies ...

## Disadvantage:

- Only simple rectangular pad geometry
- Limited sets of GEM parametrisation available
- So far only 3 gas mixtures
- No link to MOKKA ...