Calibration of the Outer Tracker and OT time simulation model

Tracking workshop

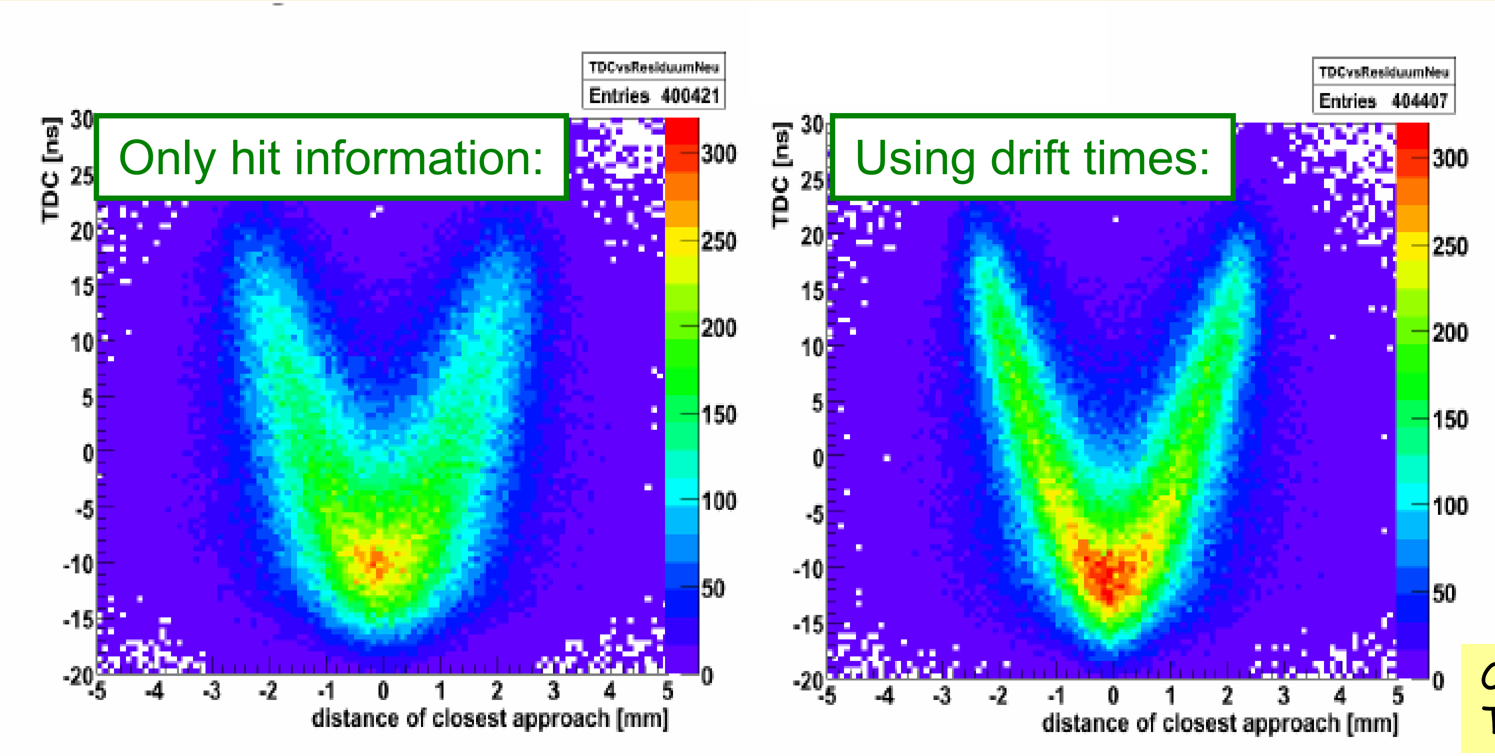
Heidelberg

16/02/2009

Sebastian Bachmann

Motivation I:

Currently the calibration of the OT is restricted to estimate the T0 and the rt-relation:



Courtesy by T. Bartesch

But to understand the detector performance (including correlations between observables!) you need more information.

Motivation II:

In the given framework there is no way to test whether the calibration obtained

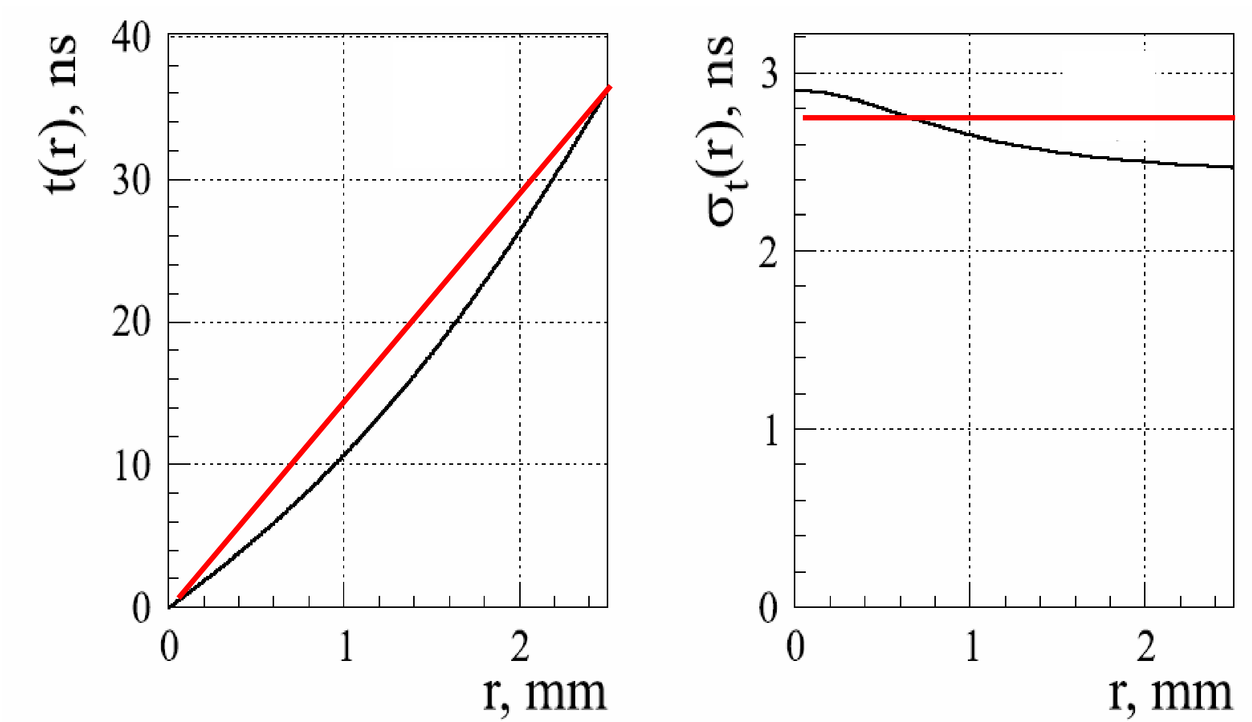
1. reproduces real conditions.
2. is the "best we can get out of our detector".

We propose to implement a refined digitisation model, that allows to

1. test the calibration procedure on MC.
2. test the impact of correlations (e.g. between spatial resolution and drift time) and non-linear effects on the tracking performance.

Current implementation of OT times

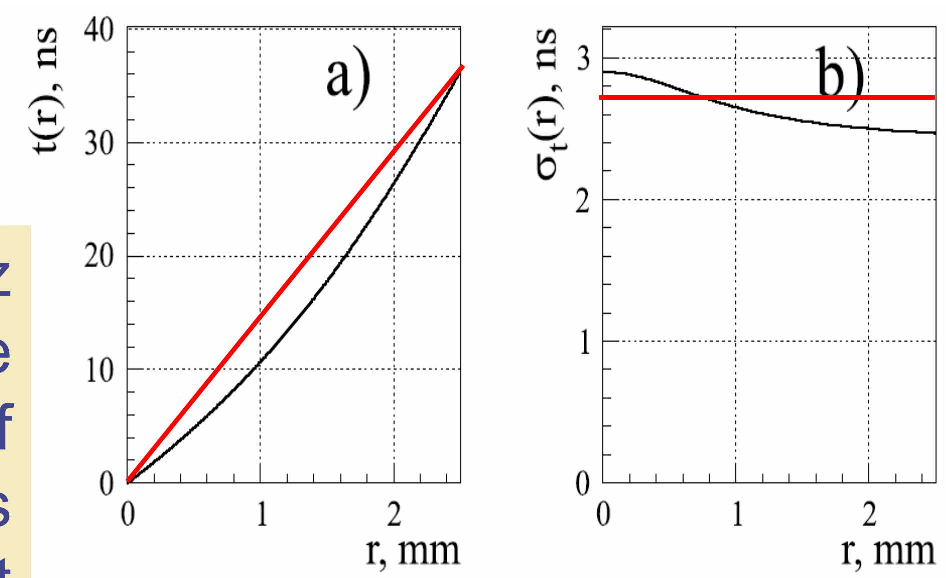
Using test beam data…



… and approximates them linear.
(similar for efficiency, cross talk, afterpulses…)

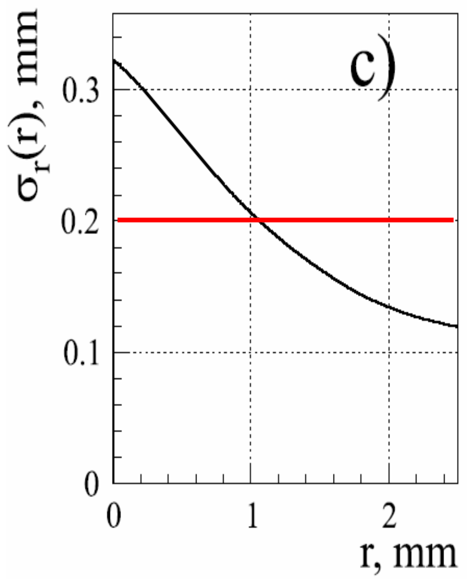
Problems with current implementation

Using the linear Ansatz fails to reproduce the correct dependence of the spatial resolution as a function of the drift radius:



$\oplus$

$$\sigma_r(r) = \frac{\sigma_t(r)}{dt(r)/dr}$$



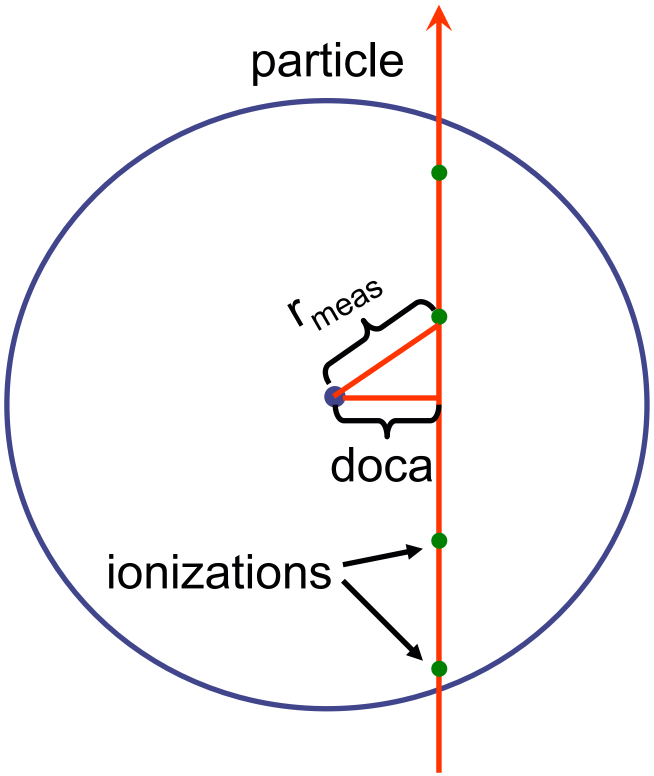
Sebastian Bachmann
University of Heidelberg

Problems (cntd.)

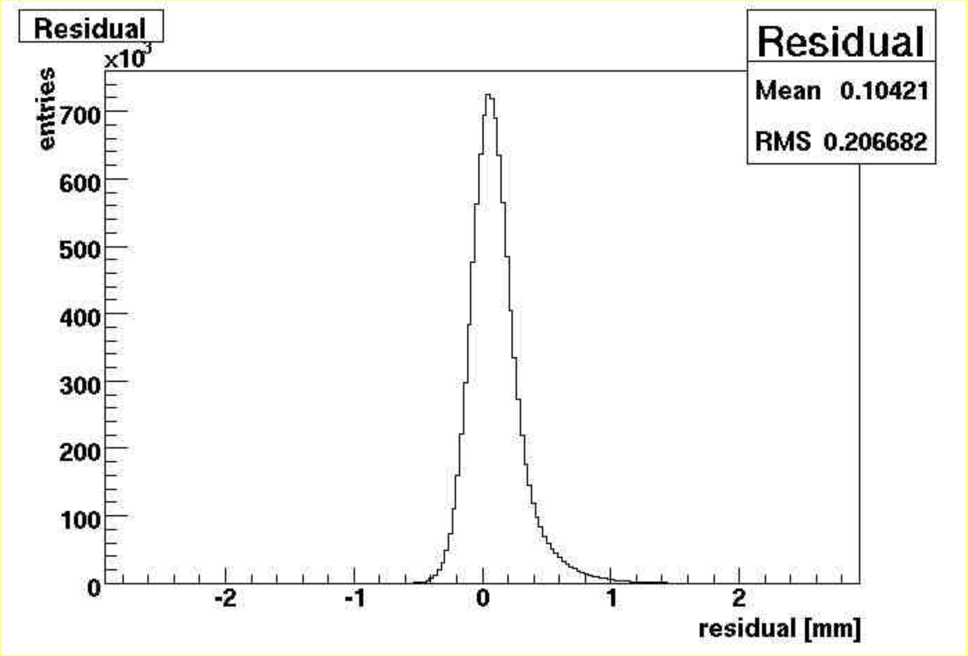
Measured drift time Is always positive:

⇒

Residual is asymmetric and the mean value is shifted!



Residual



This effect is not taken into account.

Proposal for a refined model:

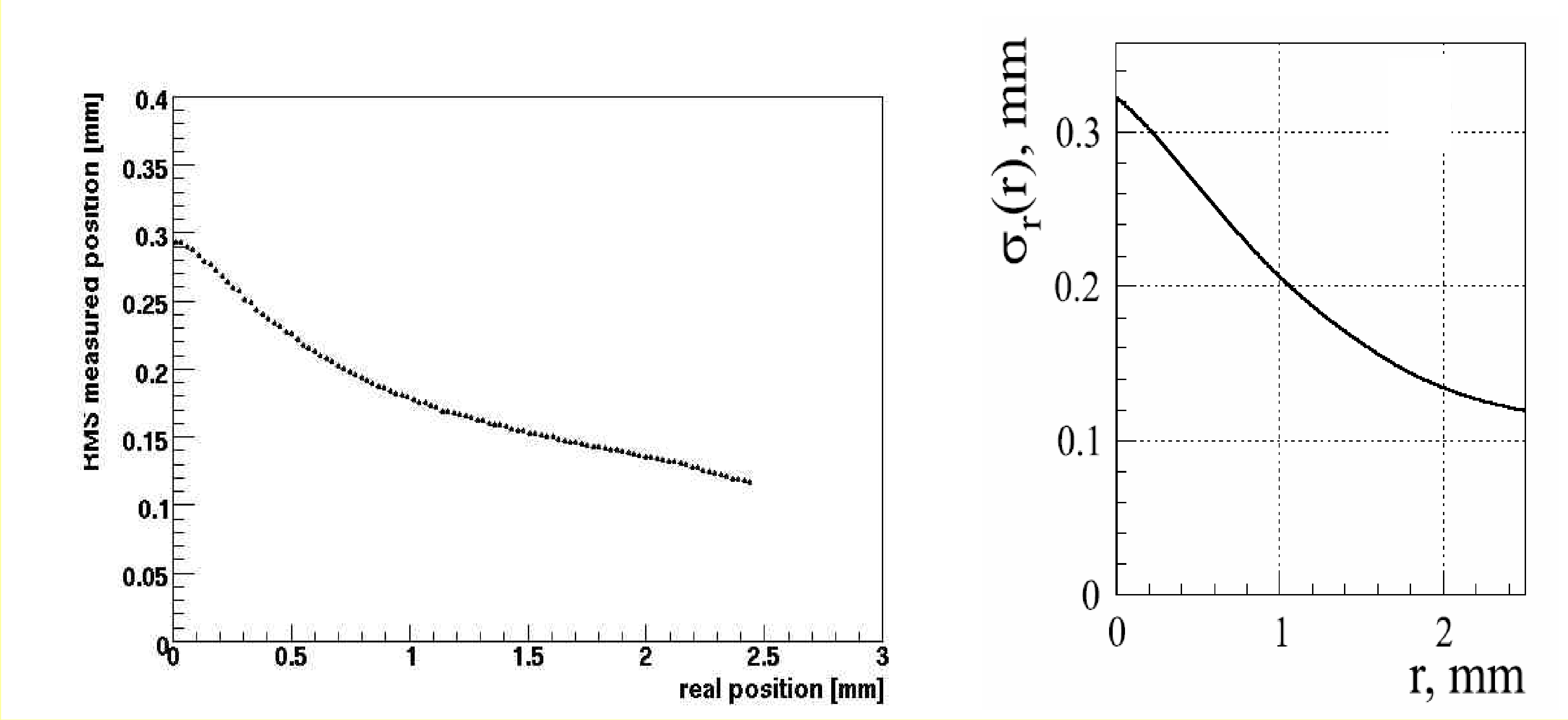
- Refined model uses a correct treatments of physical and statistical processes in straw tubes, i.e.
  - → primary and secondary ionization
  - → drift and diffusion of electrons
  - → gas amplification process
  - → impact of electronics
- Here: results from a Toy MC
- For a detailed description of model see talk in T-rec meeting from 08/08/2007.

Resolution vs. position

Spatial resolution vs. particle position

Left: Result from toy MC

Right: Parametrisation obtained from test beam data



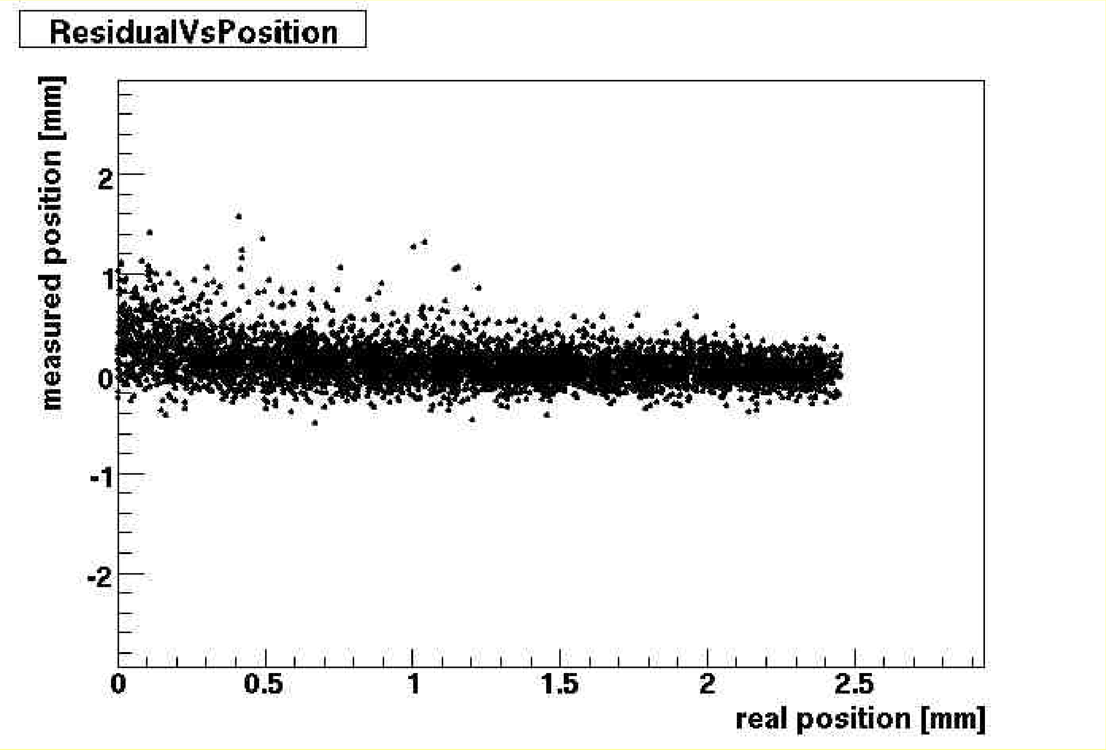
Sebastian Bachmann
University of Heidelberg

Results: Residual vs. Position

<u>Consequences:</u>

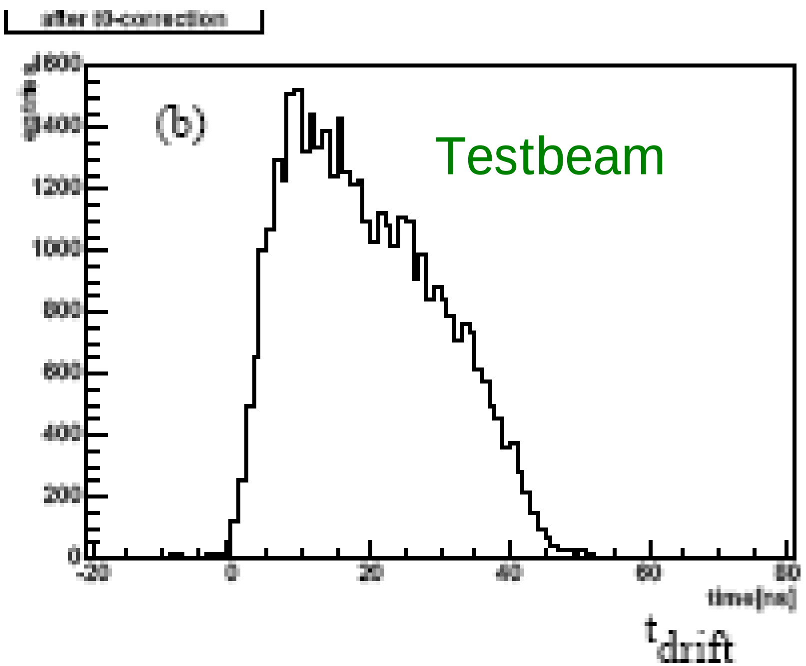
1. Detector response is non-uniform:
2. Shift of residual is most relevant for particles traversing the straw close to the wire.

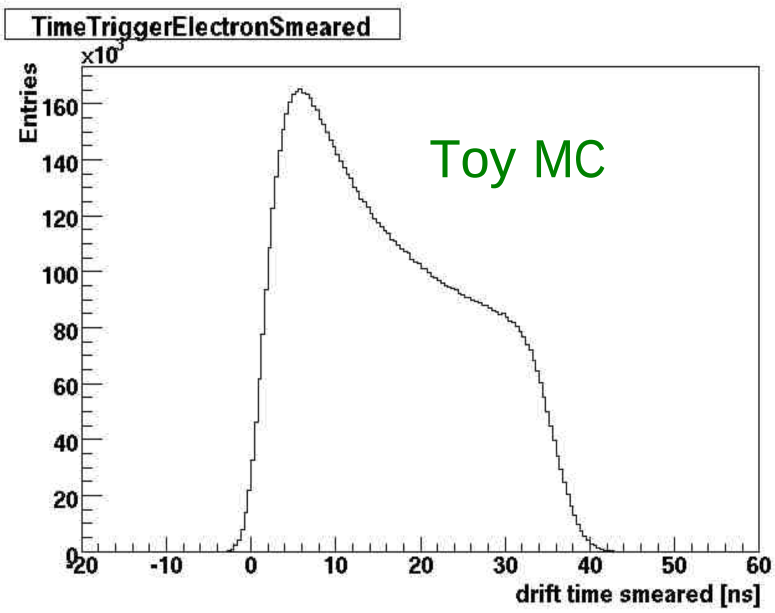
→Is there an impact on track reconstruction?



Drift time spectrum

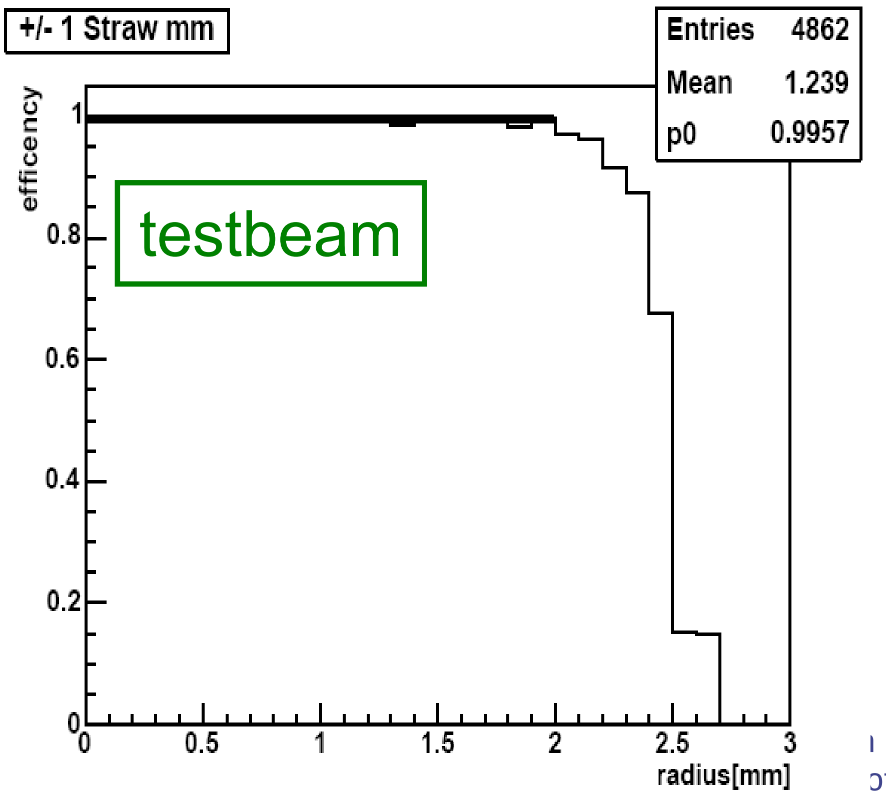
The toy MC gives a reasonable description of the drift time spectra
→ might be used to test calibration procedure



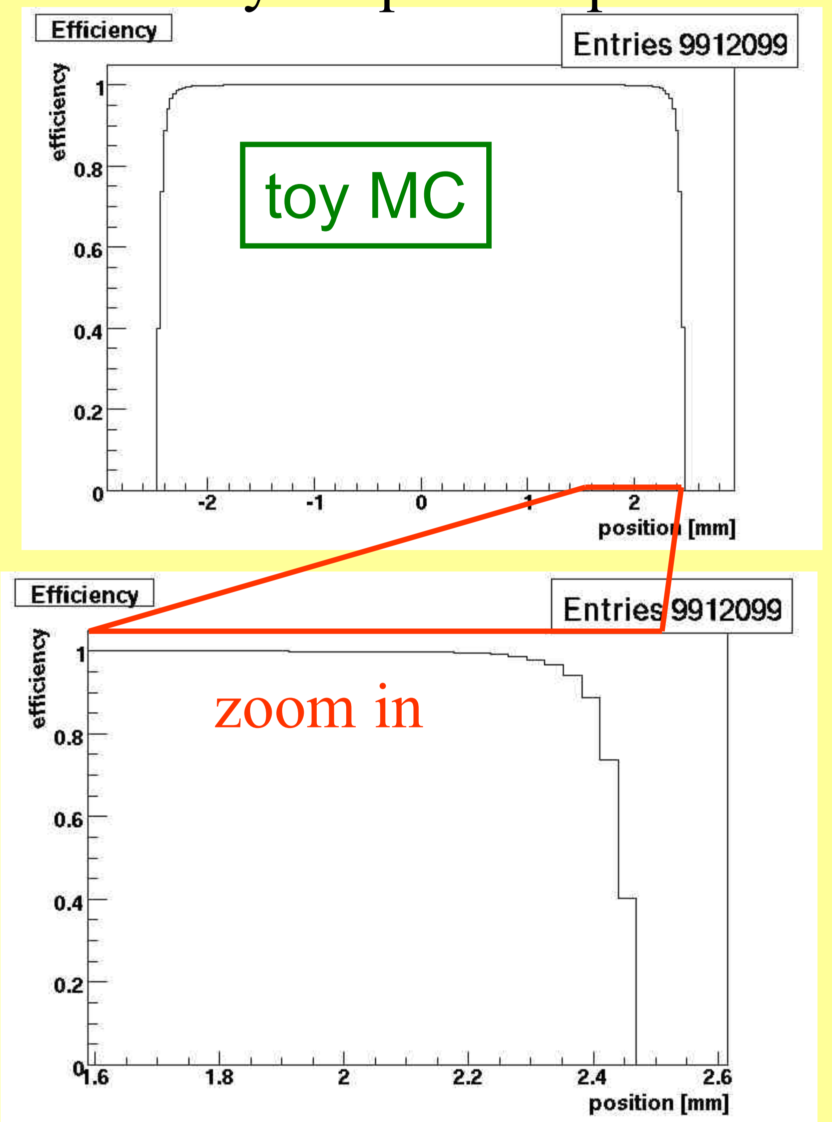


Efficiency vs. drift radius

Efficiency drop close to cathode as track length is reduced, i.e. the number of primary electrons is small.



Efficiency vs. particle position

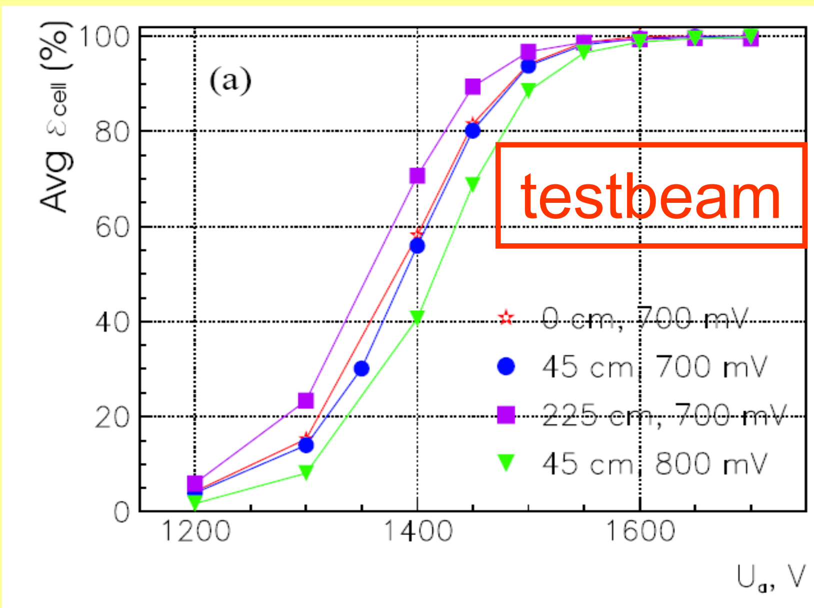


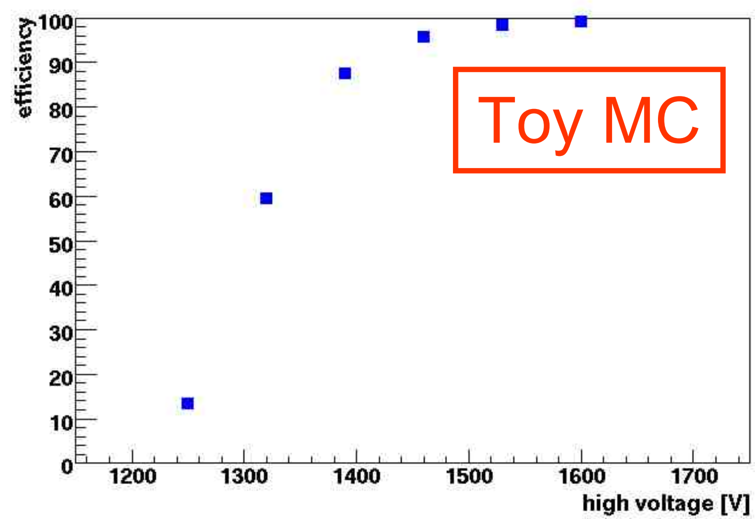
Efficiency vs. gas gain

→ Dependence of efficiency on gas gain can be simulated.

→ Can be used to treat module-to-module variations of gas gain.

Efficiency vs. high voltage





Correlations: X-talk and after-pulses

- Crosstalk and after-pulses depend both on the signal amplitude and are therefore highly correlated.

→ As the gas amplification process is included in the simulation these correlations can be handled correctly by the refined digitisation model.

Summary

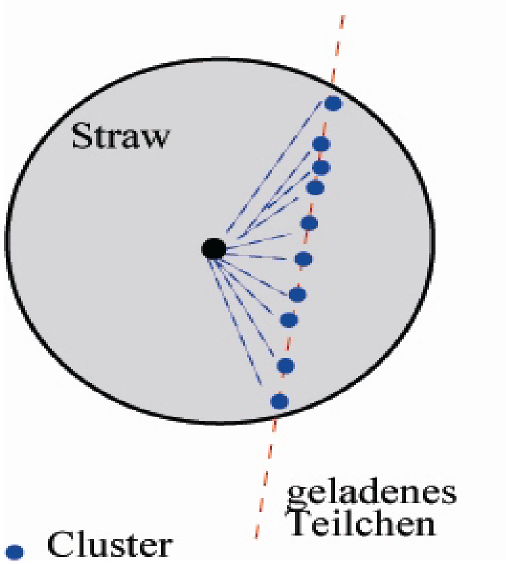
Results from a digitisation model for the OT have been presented, based on a correct description of the physical and statistical processes in a straw tube.

Steps to profit from the model could be

1. Optimize calibration procedure to extract rt-relation.
2. Study impact on the tracking performance.
3. Establish a procedure to extract parameters for digitization from data.
4. Use them for an improved description of the OT in simulations.

Backup slides

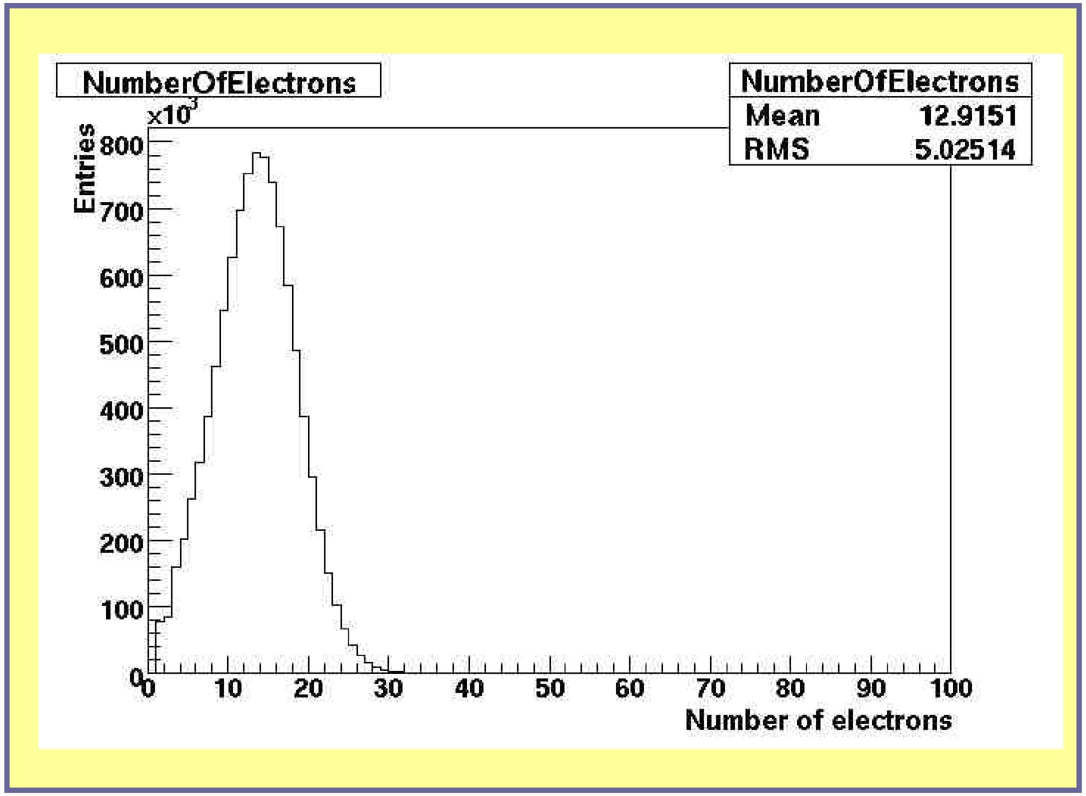
Primary ionization



Number of primary ionizations n_p along trajectory of MIP follows Poisson statistics.

Ionization density taken from literature:

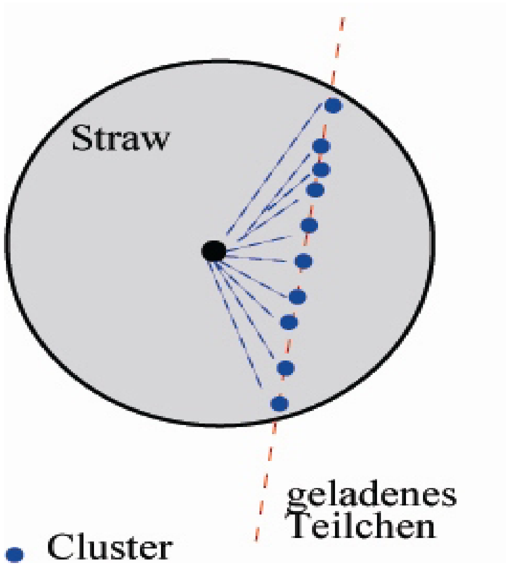
$n_p = 28\ cm^{-1}$ (for Ar/CO_2, 70/30)

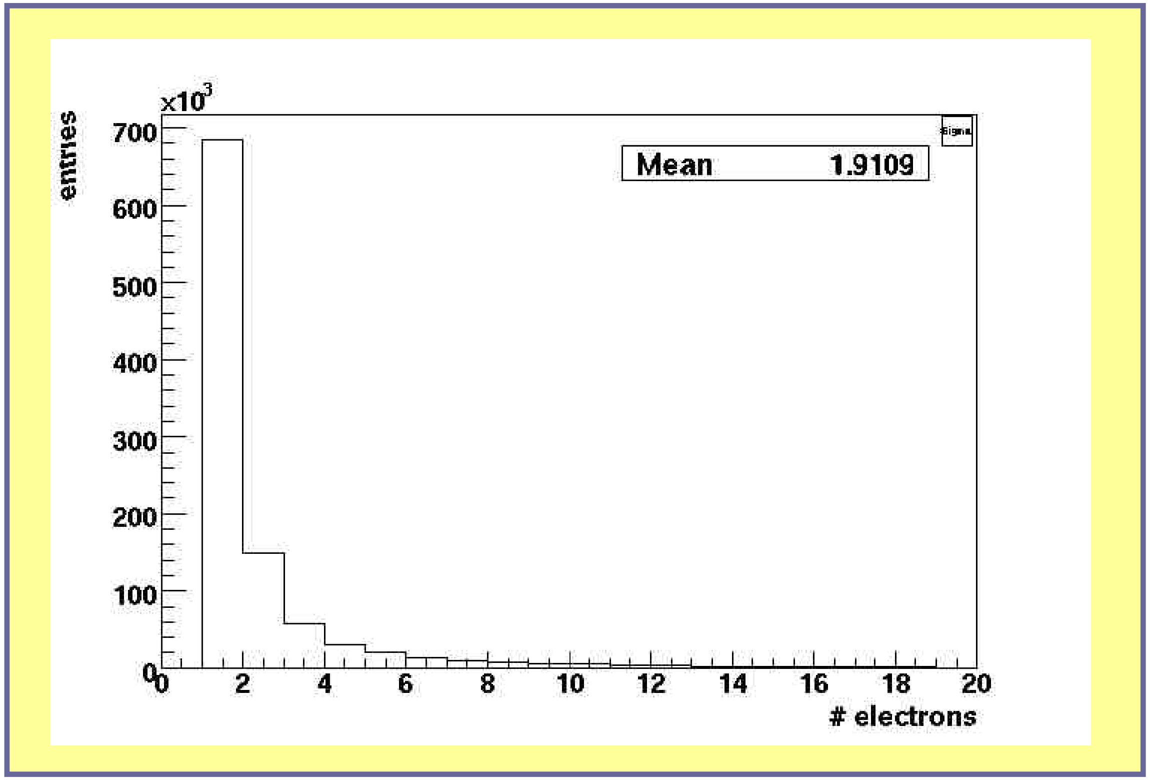


Secondary ionization

Electron from ionization has sufficient energy to ionize more atoms/molecules.

Number of secondary electrons n_s follows Approximately a distribution $\sim 1/n_s^2$.
(for details see: W.Blum, L.Rolandi
'Particle detection with drift chambers)





Drift and diffusion

Electrons released by ionisation drift to anode.

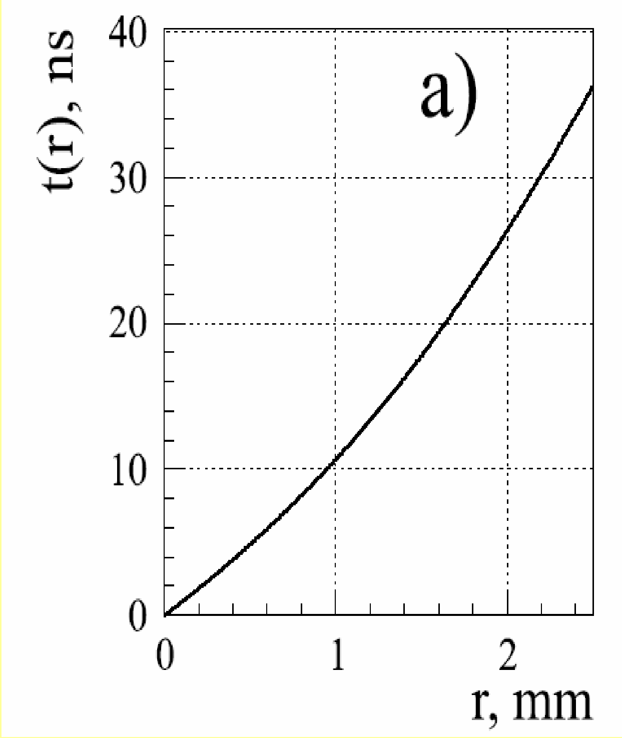
The relation between the position of the ionisation and the arrival time is given by the rt-relation.

Due to diffusion the arrival time is smeared with

$$\sigma_{diff} \sim \sqrt{t}$$

Diffusion constant is estimated by Garfield calculations.

rt-relation
(from test beam data)



Gas amplification process

Gas amplification factor for a single electron follows a Polya-distribution:

$$P(n) = \frac{1}{b\bar{n}} \frac{1}{k!} \left(\frac{n}{b\bar{n}}\right)^k e^{-\frac{n}{b\bar{n}}}$$

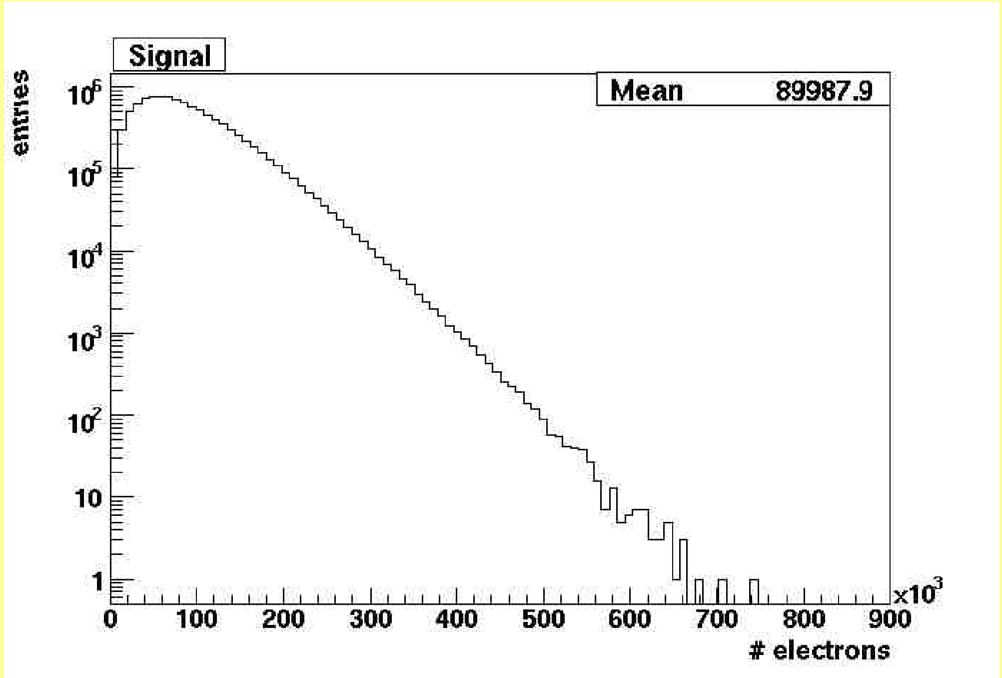
$$k = 1/b - 1$$

$$b = 0.4$$

$\bar{n}$: average gain

(for details see:
W.Blum, L.Rolandi
'Particle detection with drift chambers)'

Gas amplification factor



Signal from a MIP

Number of electrons in signal is given by:

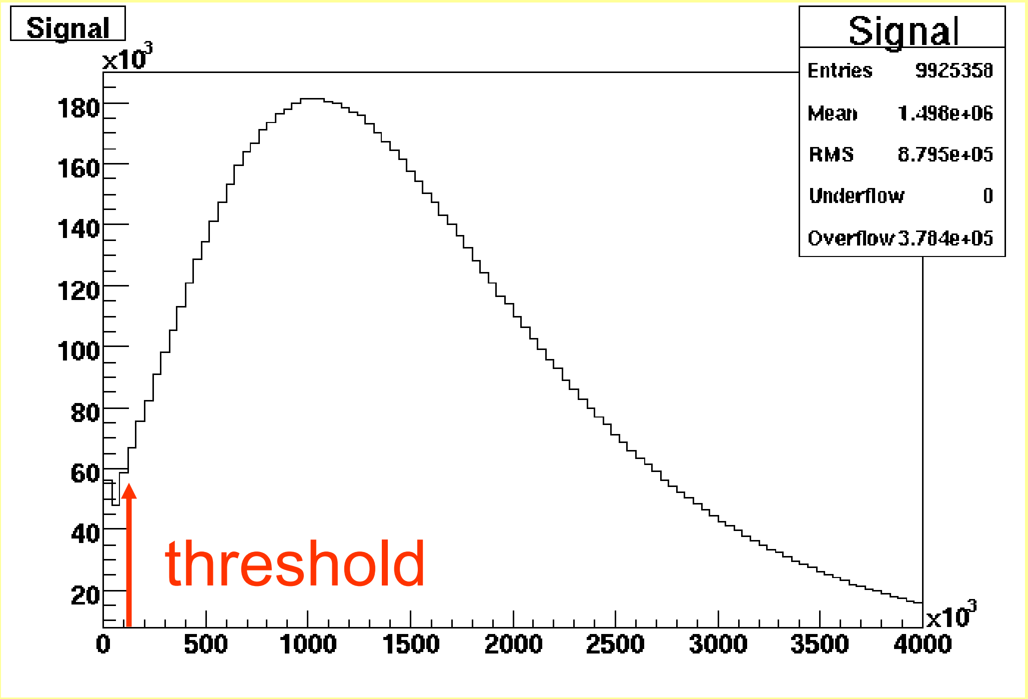
$$n_{tot} = \sum_{i=1}^{n_p} \left(\sum_{j=1}^{n_s} n_j^{Polya} \right)$$

n_p : number of primaries

n_s : number of secondaries

n_j^{Polya} : Gas amplification factor

Pulseheight distribution



A hit is produced if the signal exceeds a certain threshold. The hit threshold is the first free parameter in this model.

Sebastian Bachmann
University of Heidelberg

Impact from electronics

- A hit is only produced in case of a signal exceeding the hit threshold.

  → Hit threshold S_{min} is the first free parameter in this model.
- Electronics creates an additional time jitter.
- This time jitter is independent of the drift time.

  → The arrival time of the trigger electron is smeared by σ_e.

  → σ_e is the second free parameter in this model.

Tuning parameters

- In total two parameters have to be adapted to fit time resolution:
  - Hit threshold
  - Time jitter σ_e
- For the subsequently shown results no further fine tuning has been done.

Time resolution vs. particle position