

# Studies of Charge Broadening in Multi GEM Structures and Development of a TPC

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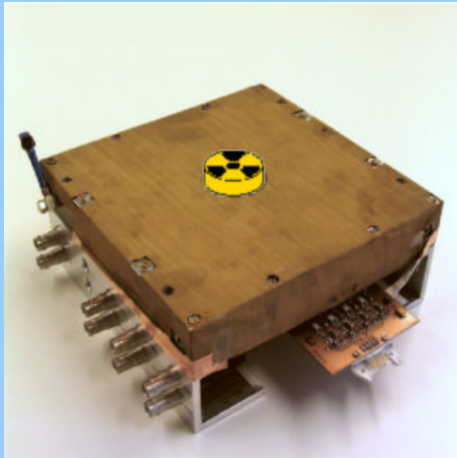


## Determination of the Cluster Width from a GEM Structure

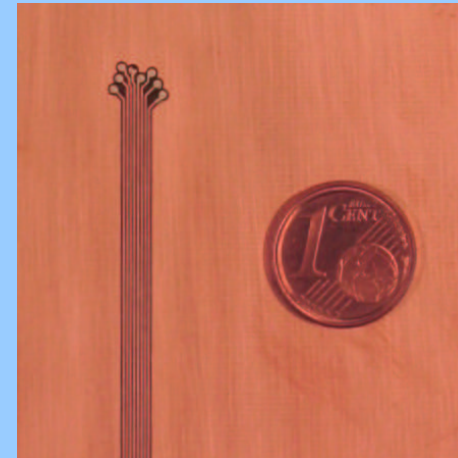
- two evaluation methods:
  1. wide anode strips ( 800  $\mu\text{m}$  pitch)
  2. narrow anode strips ( 300  $\mu\text{m}$  pitch)
- cluster width as a function of the magnetic field

## TPC Prototype

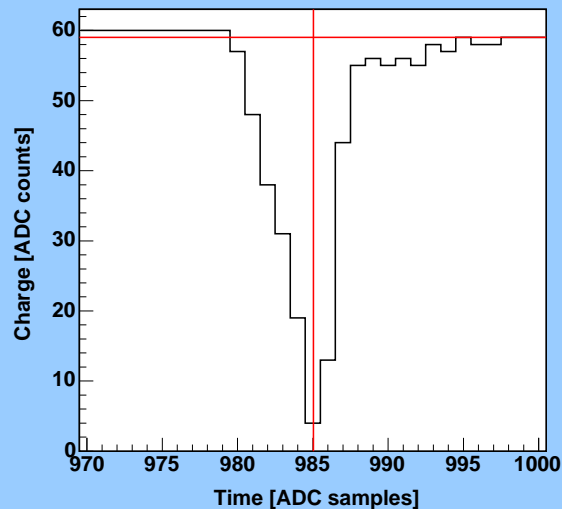
- design of the field cage
- construction



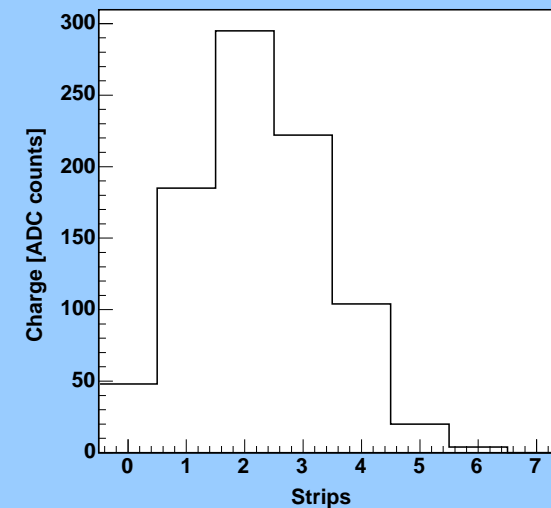
$^{55}\text{Fe}$  source



300  $\mu\text{m}$  pitch

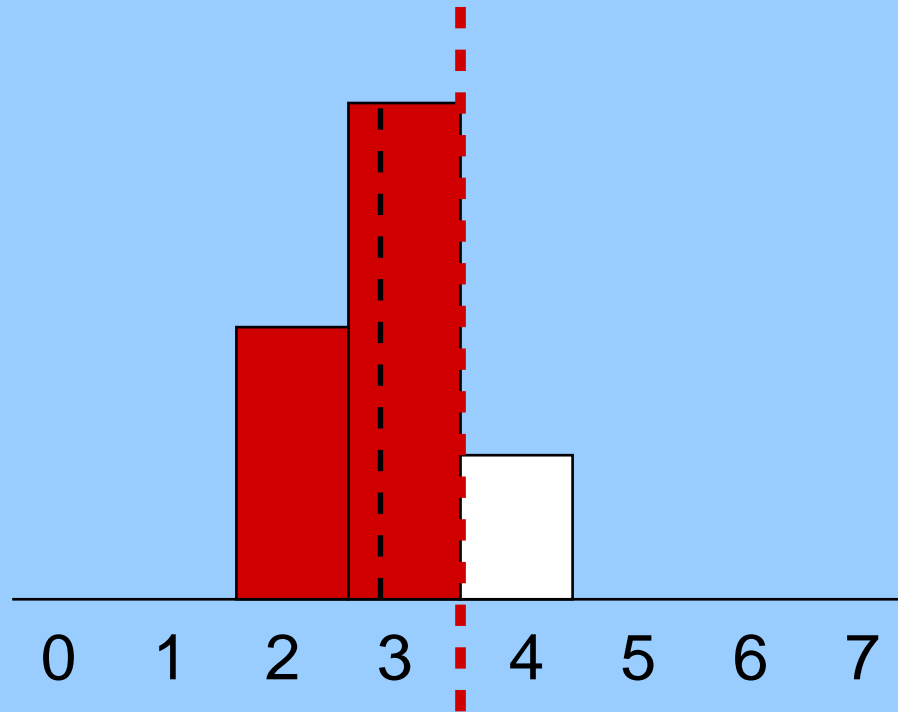


pulse on one strip



spatial distribution for one event

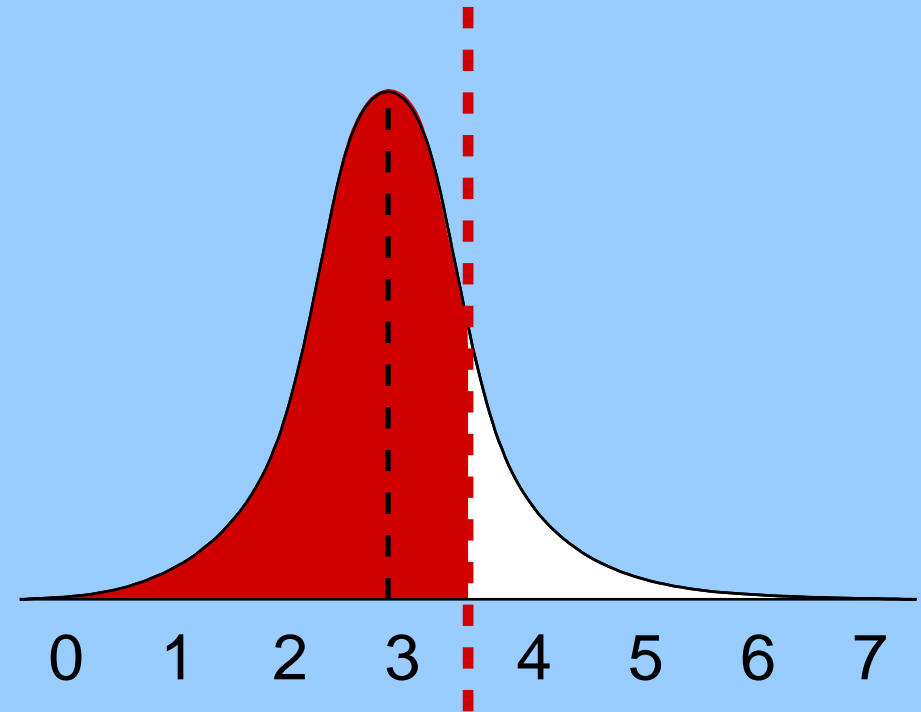
experimental data:



$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i}$$

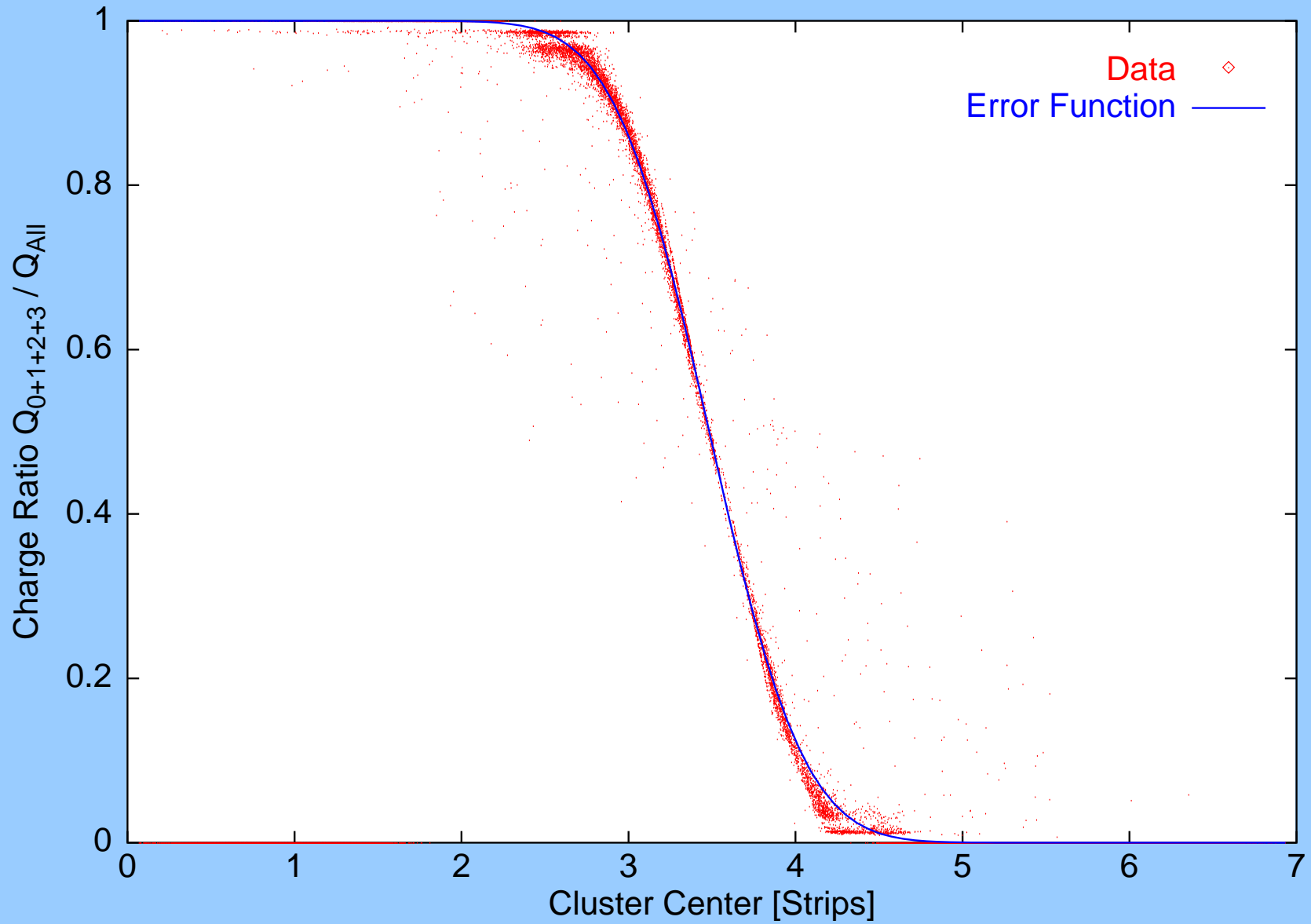
$$R = \frac{Q_0 + Q_1 + Q_2 + Q_3}{\sum Q_i}$$

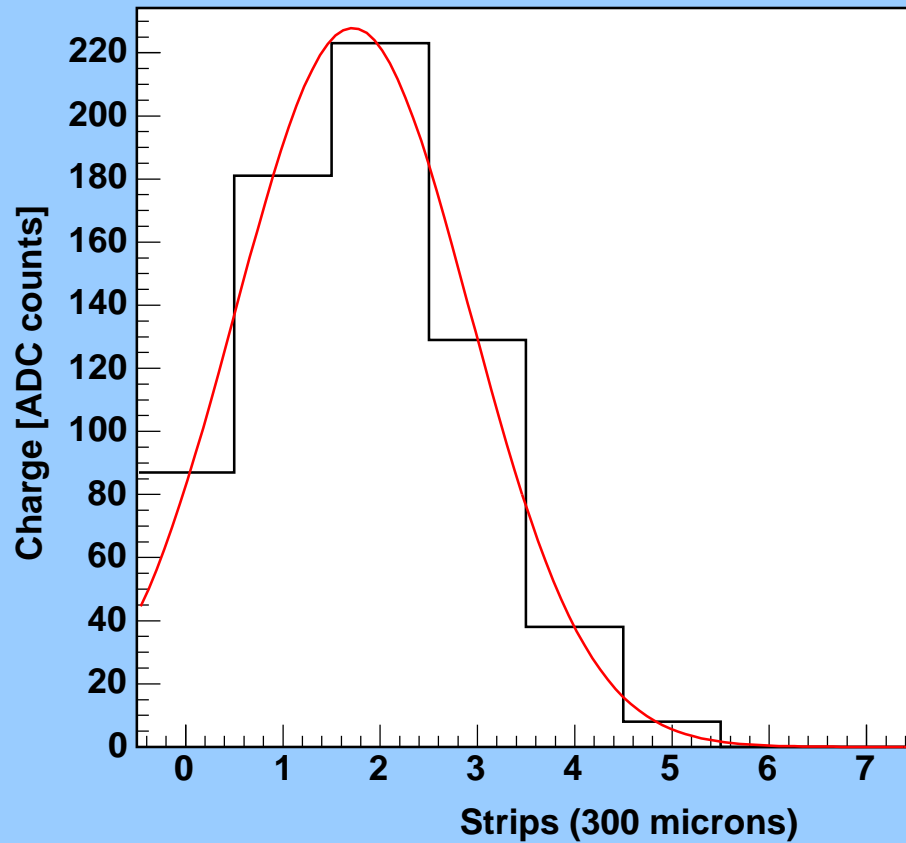
expectation:



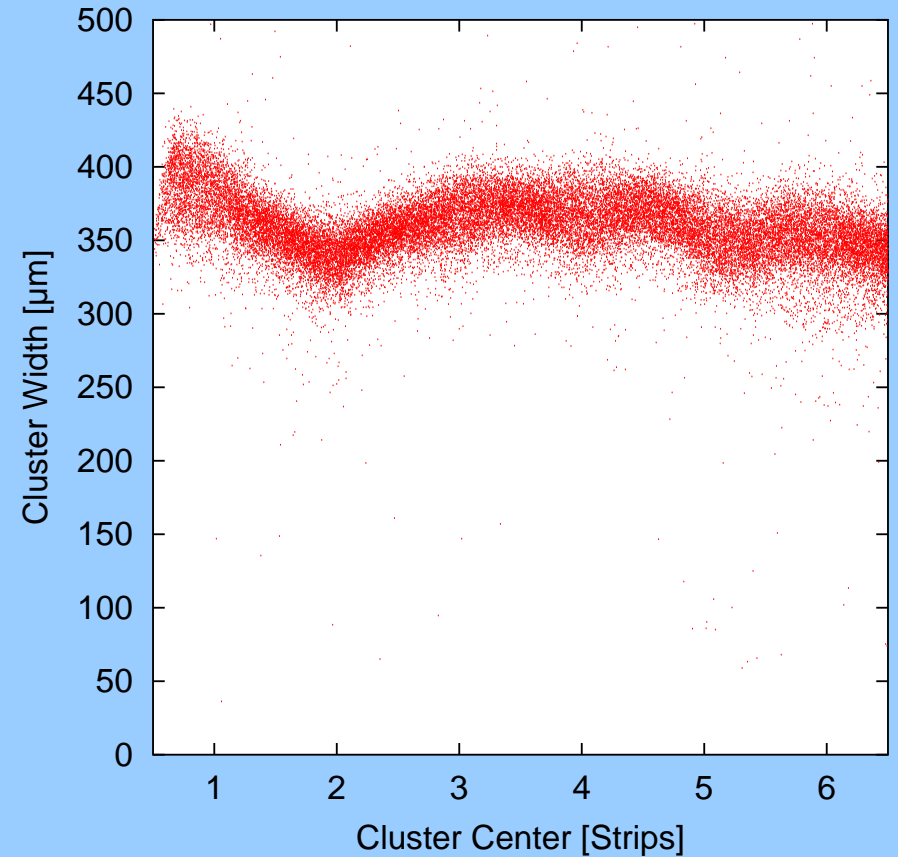
$$R = \int_{-\infty}^{3.5} \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x-\bar{x})^2}{2\sigma^2}\right) dx$$

$$= \frac{1}{2} \left[ 1 + \operatorname{erf}\left(\frac{3.5-\bar{x}}{\sqrt{2}\sigma}\right) \right]$$

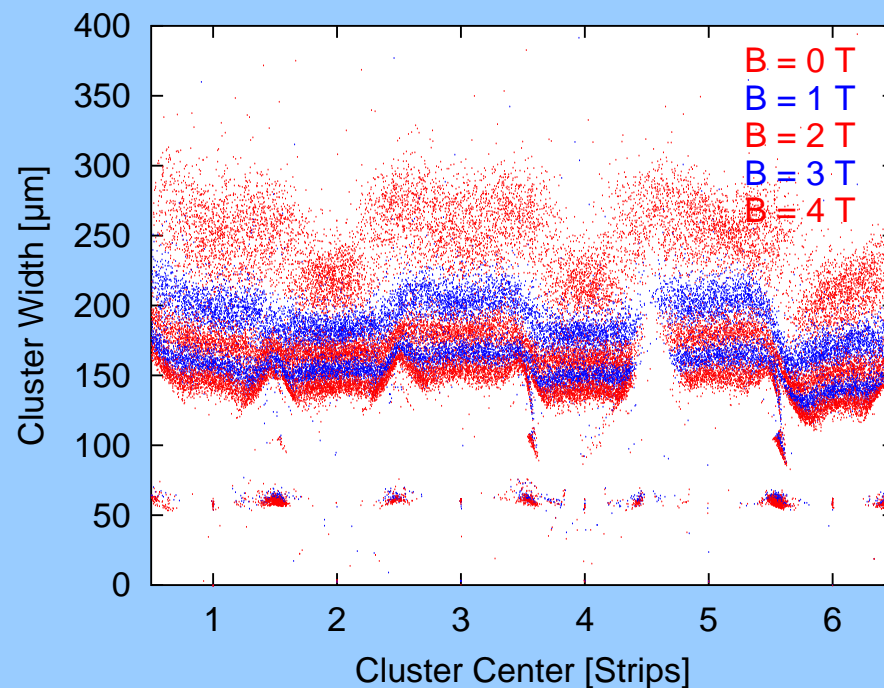
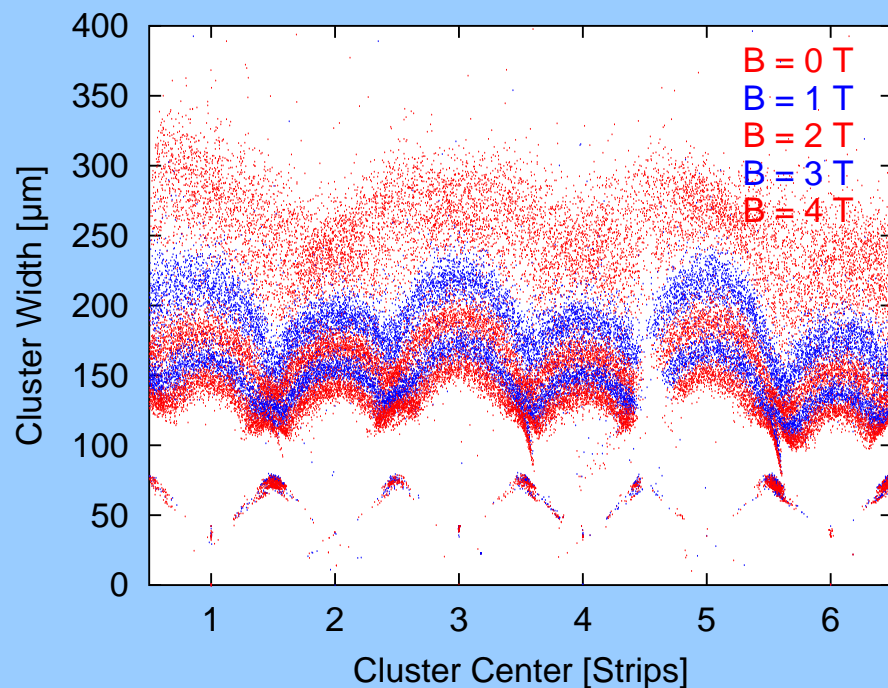




fit data with  
gaussian using  $\bar{x}$  and  $\sigma$

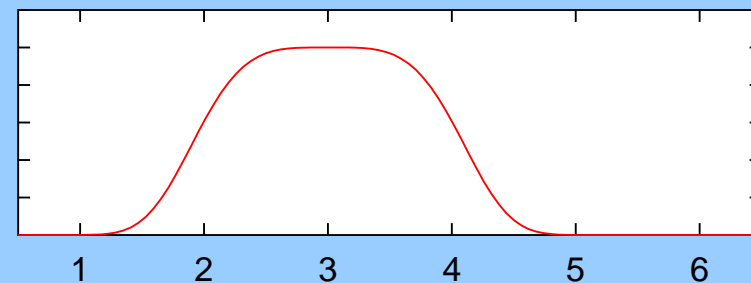
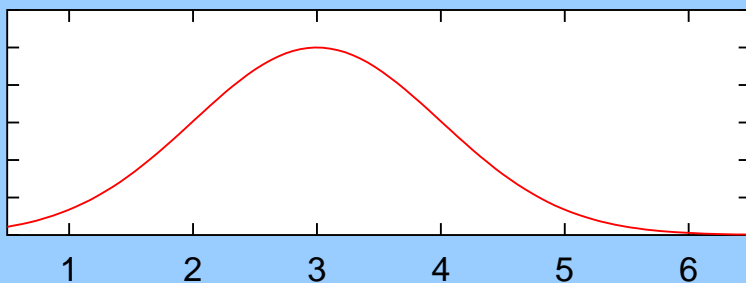


data points for  
30 000 events

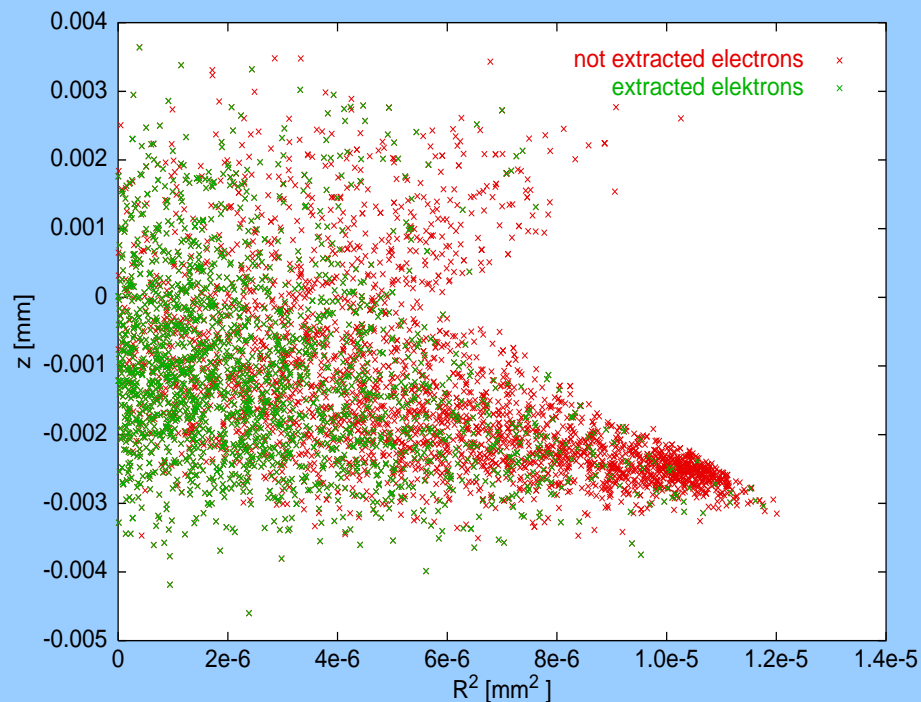


$$Q(x) = a \exp\left(-\frac{1}{2} \left|\frac{x-\bar{x}}{\sigma}\right|^2\right)$$

$$Q(x) = a \exp\left(-\frac{1}{2} \left|\frac{x-\bar{x}}{\sigma}\right|^4\right)$$



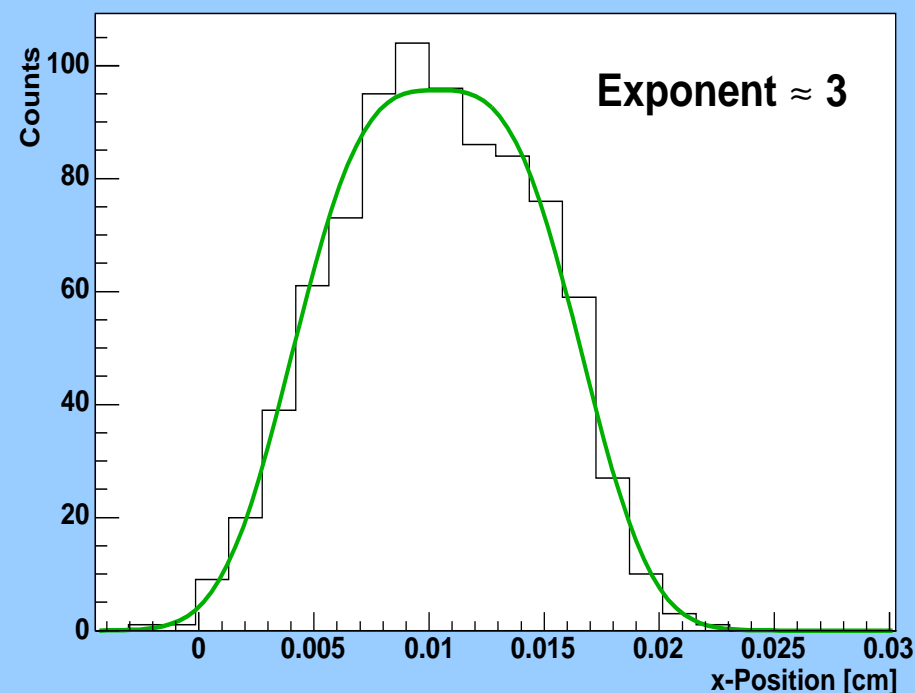
simulation of gain with MAXWELL and GARFIELD:



secondary electrons

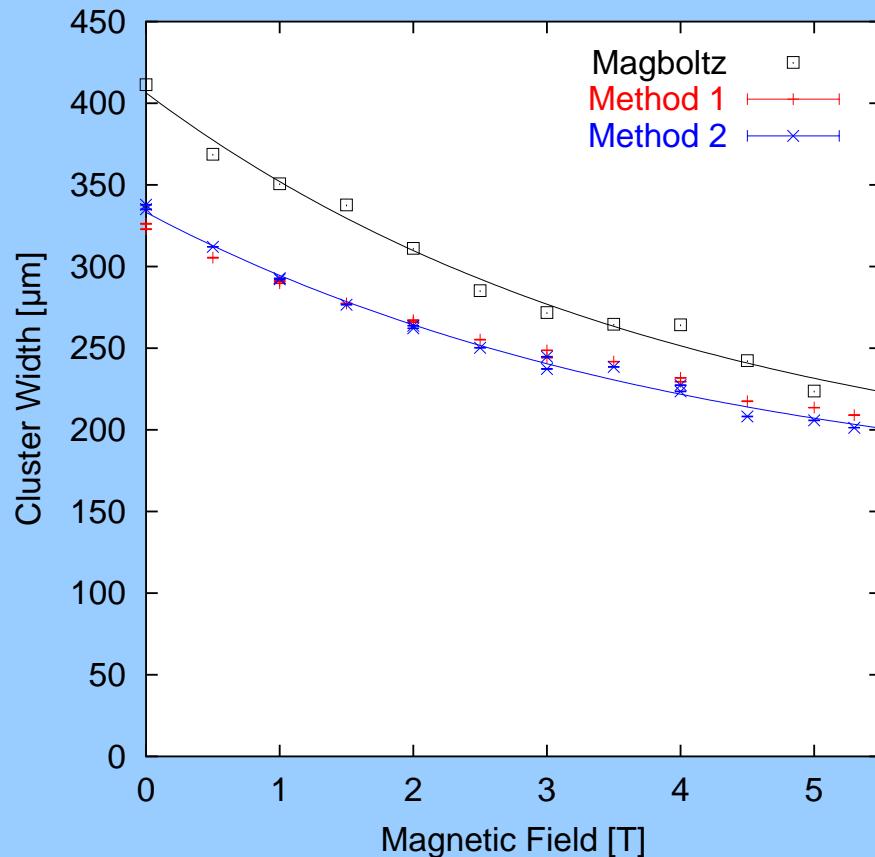
red: not extracted

green: extracted



charge distribution 200  $\mu\text{m}$   
after GEM hole





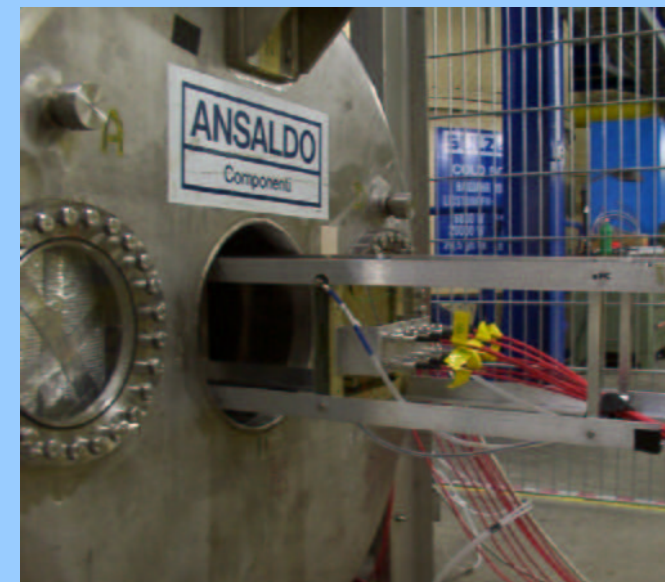
measurements with 5 T magnet  
at DESY Hamburg

- E / B field dependence (caused by diffusion):

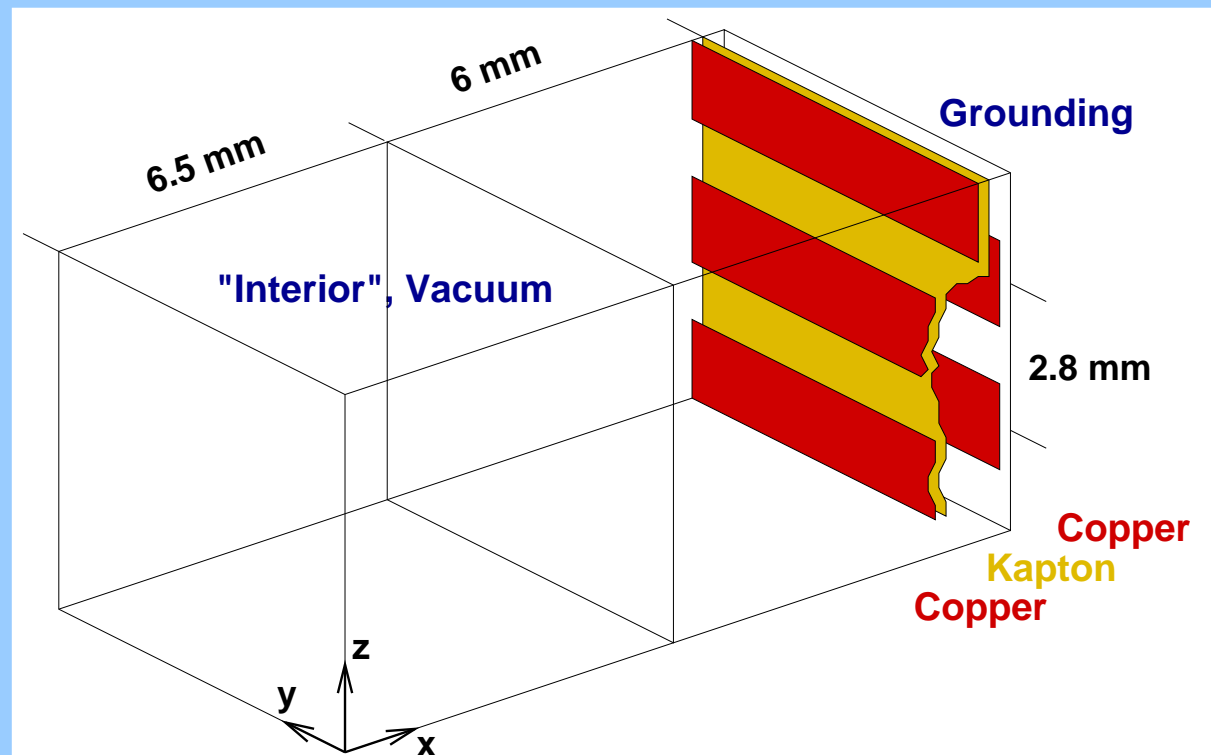
$$\sigma_{\text{diff}} \propto \frac{1}{\sqrt{1 + \omega^2(B)\tau^2(E)}}$$

- MAGBOLTZ simulation accounts for different electrical fields in GEM structure.
- MAGBOLTZ overrates transverse diffusion!
- working on quantitative understanding

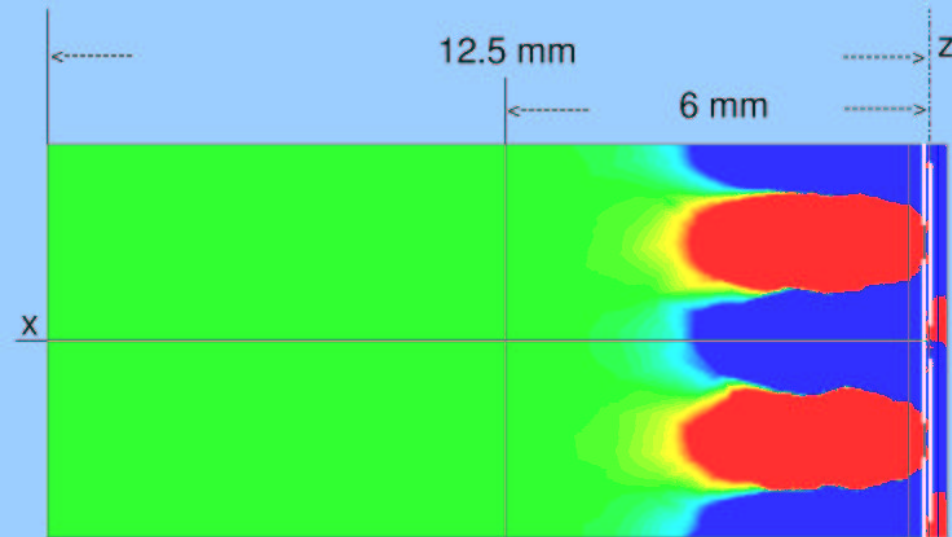
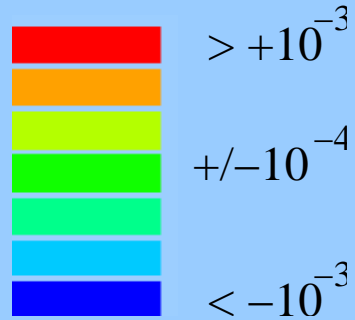
- 5T solenoid magnet at DESY:  
280 mm bore
- „small“ field cage for measurements  
in magnetic field
- usage of SMD resistors as  
voltage divider  $\Rightarrow$  minimal pitch = 2.8 mm
- materials with low density required (radiation length)
- existing GEM readout from Test TPC should be used
- HV supply with 30 kV, upper GEM with 4 kV



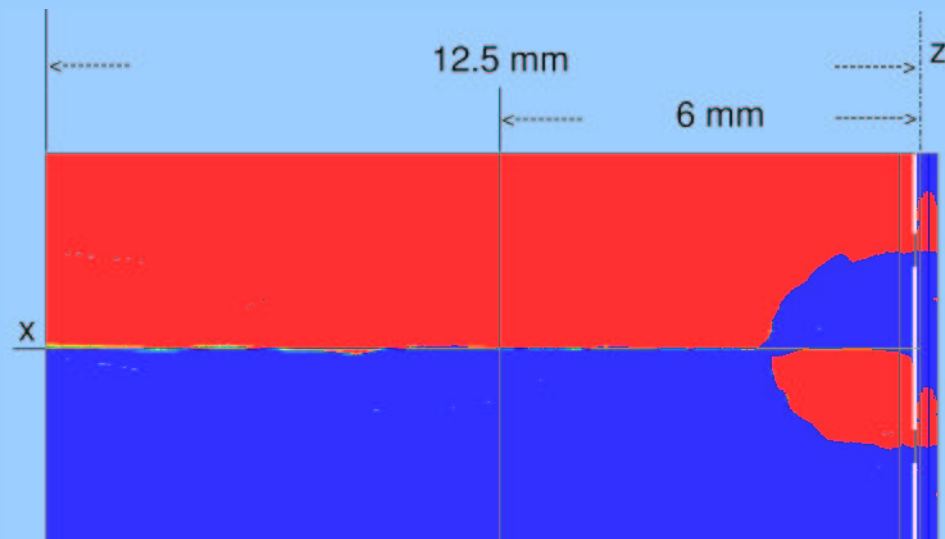
- optimisation of the field cage
- simulations of strip geometry with Maxwell 3D:  
copper strips on one or both sides,  
different ratios of strip width and distance with fixed pitch (2.8 mm)



$\Delta E / E$

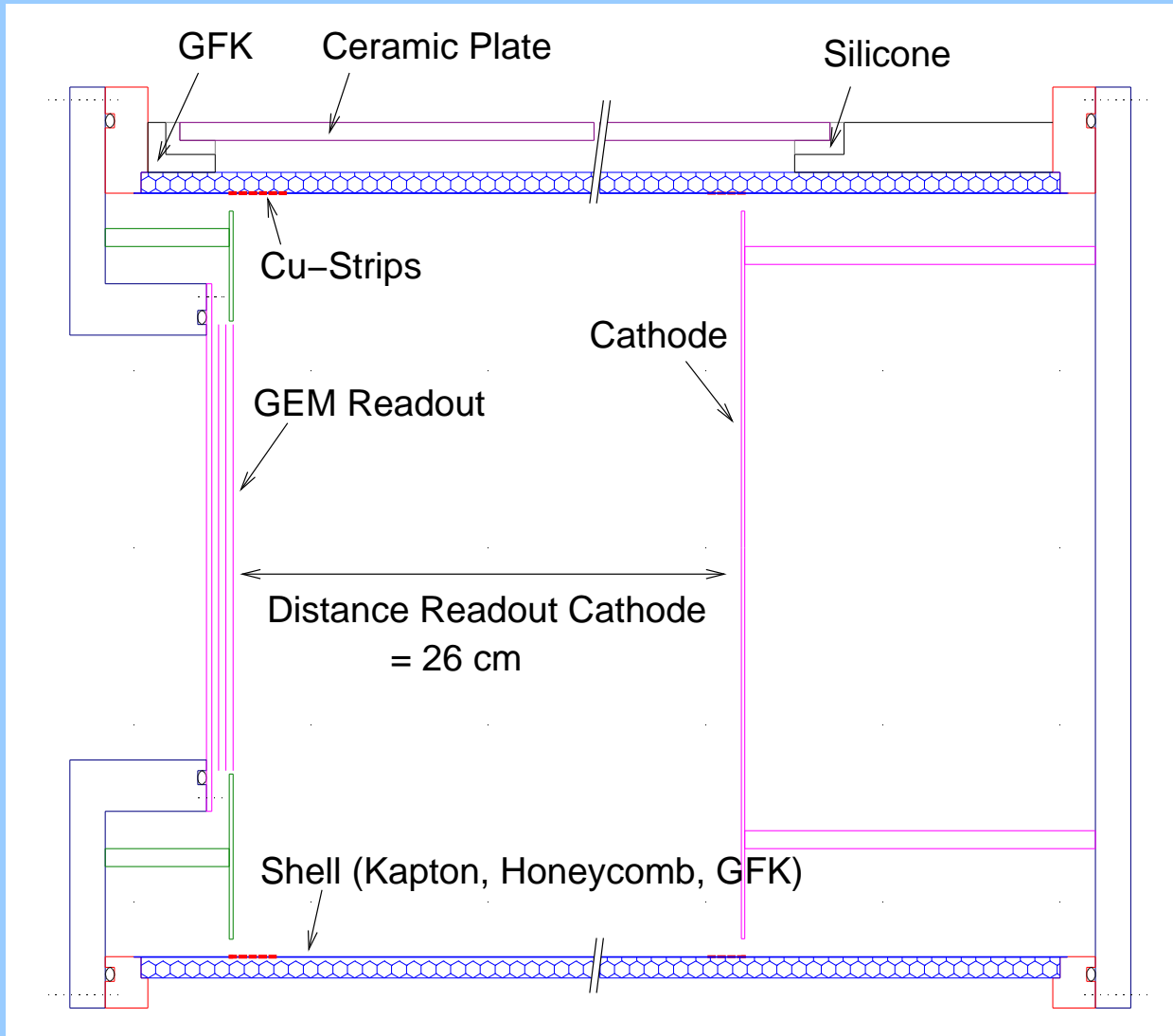


$E_{parallel}$ , strips on both sides



$E_{parallel}$ , strips on one side

Cu strips:  
width 2.3 mm  
distance 0.5 mm



$\varnothing = 260 \text{ mm}$

pitch = 2.8 mm

$R = 4.7 \text{ M}\Omega \text{ (SMD)}$

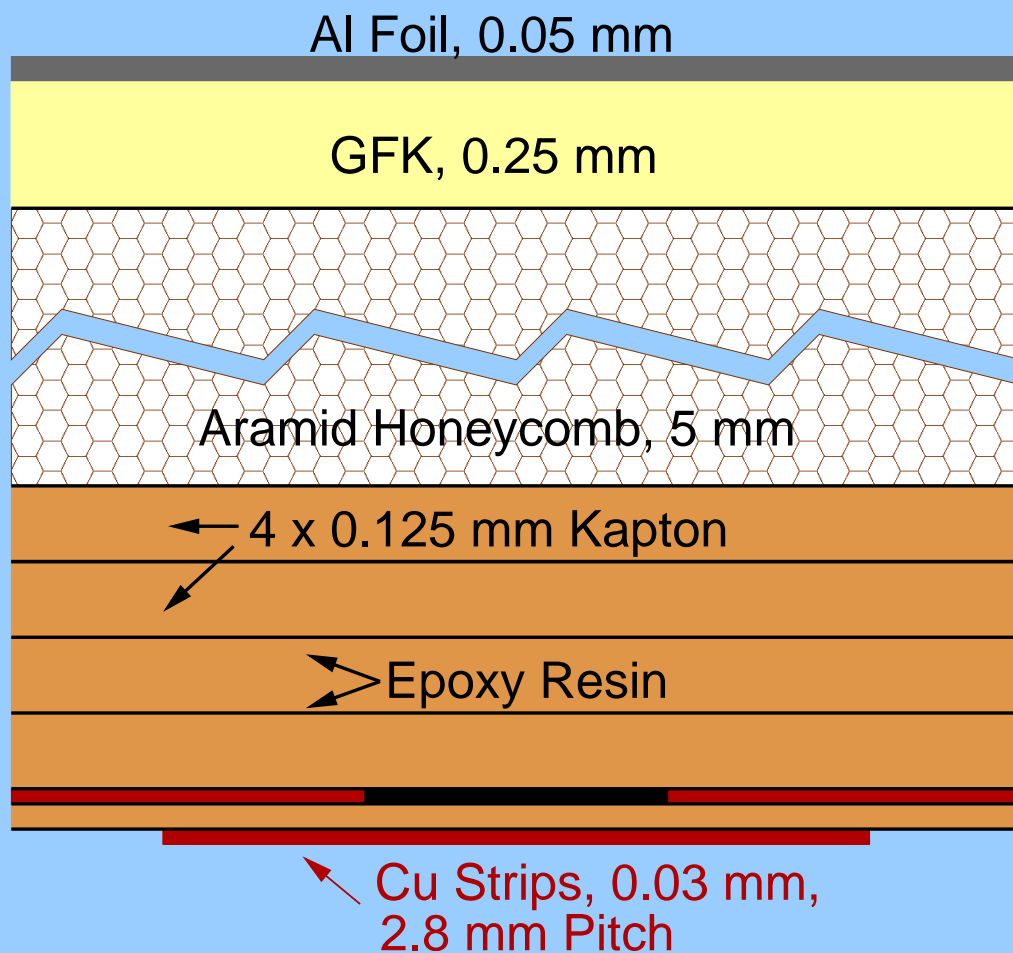
$\Delta U_{max} = 26 \text{ kV}$

$\ell_{drift} = 26 \text{ cm}$

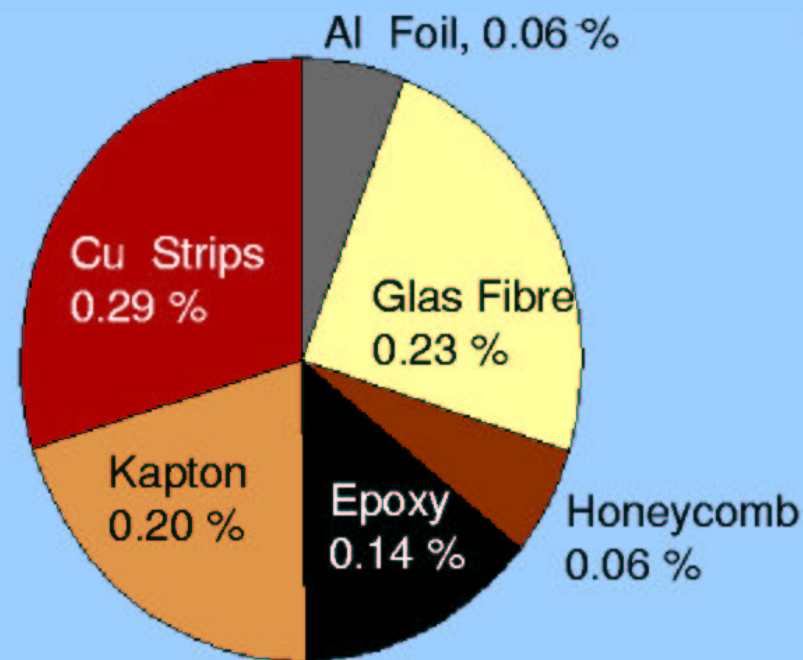
$E_{max} = 1000 \text{ V/cm}$

$\delta U_{max} = 277 \text{ V/strip}$

xz profile of the TPC prototype

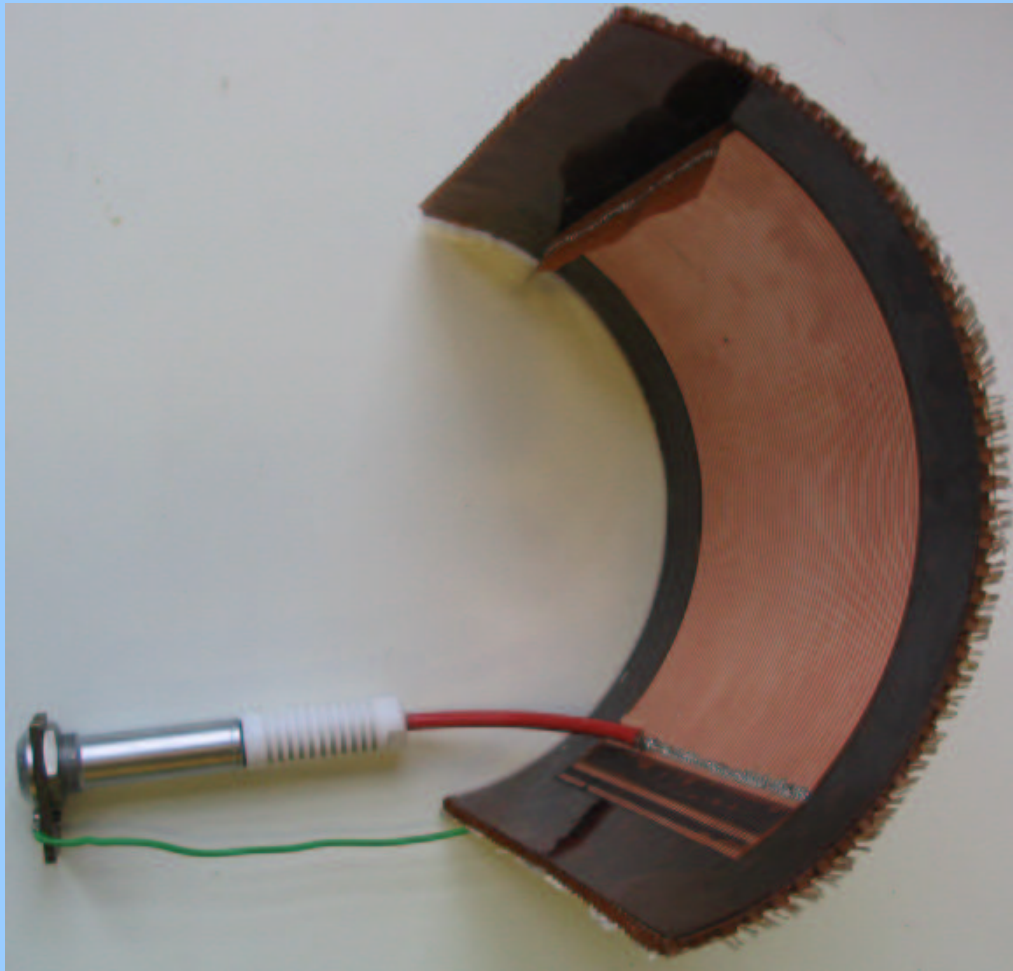


fraction of radiation length



altogether 1% radiation length

⇒ 3 % radiation length possible (TESLA)



test of dielectric strength of the sandwich structure:

$U = 30 \text{ kV}$  one week without trip

final strip design: inside: width 2.0 mm, distance 0.8 mm  
outside: width 1.8 mm, distance 1.0 mm

## ■ Charge Broadening

- ◆ reduction of cluster width in magnetic field

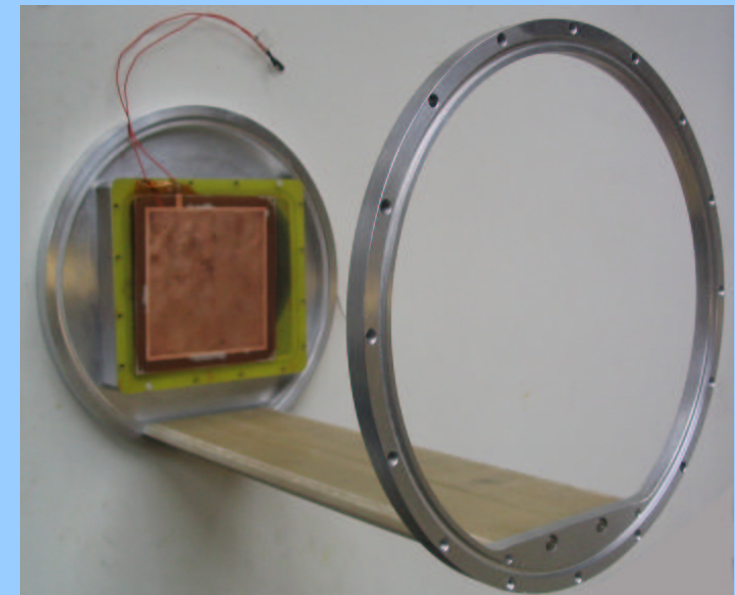
⇒ from  $\sim 330 \mu\text{m}$  ( $B=0\text{T}$ ) to  $\sim 200 \mu\text{m}$  ( $B=4\text{T}$ )

(suppression of diffusion)

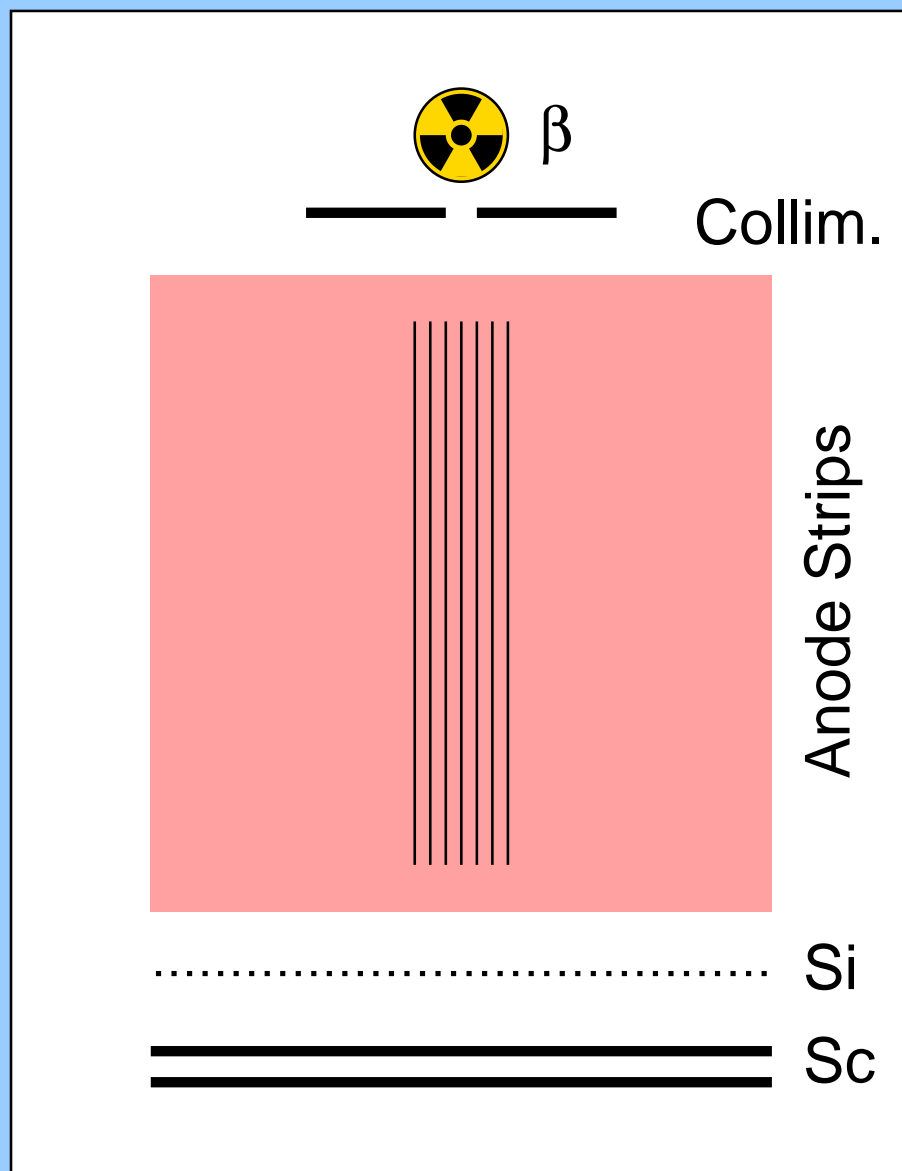
- ◆ indication of non gaussian charge distribution

## ■ TPC Prototype

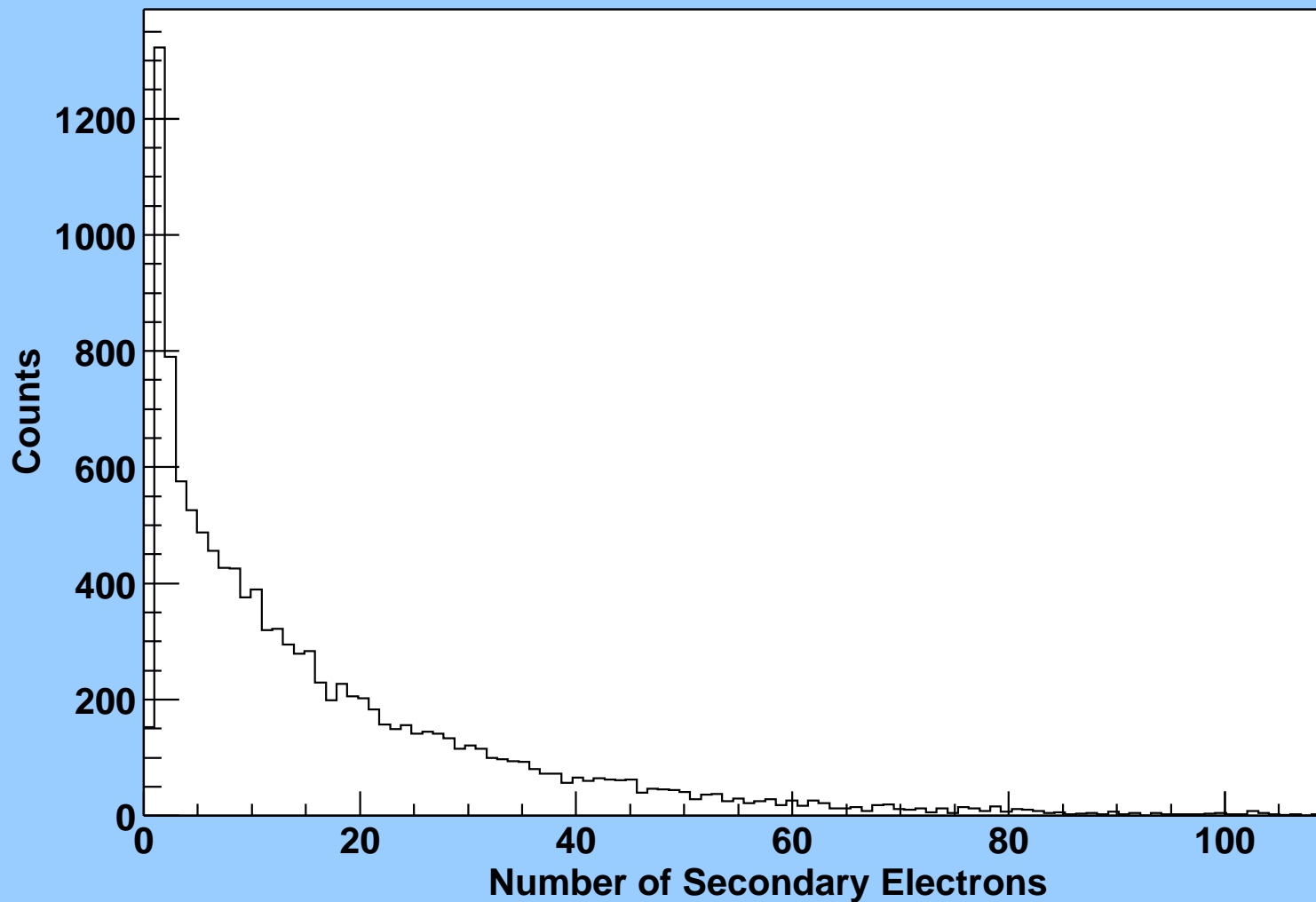
- ◆ design finished
- ◆ construction ongoing
- ◆ 3 % radiation length in reach



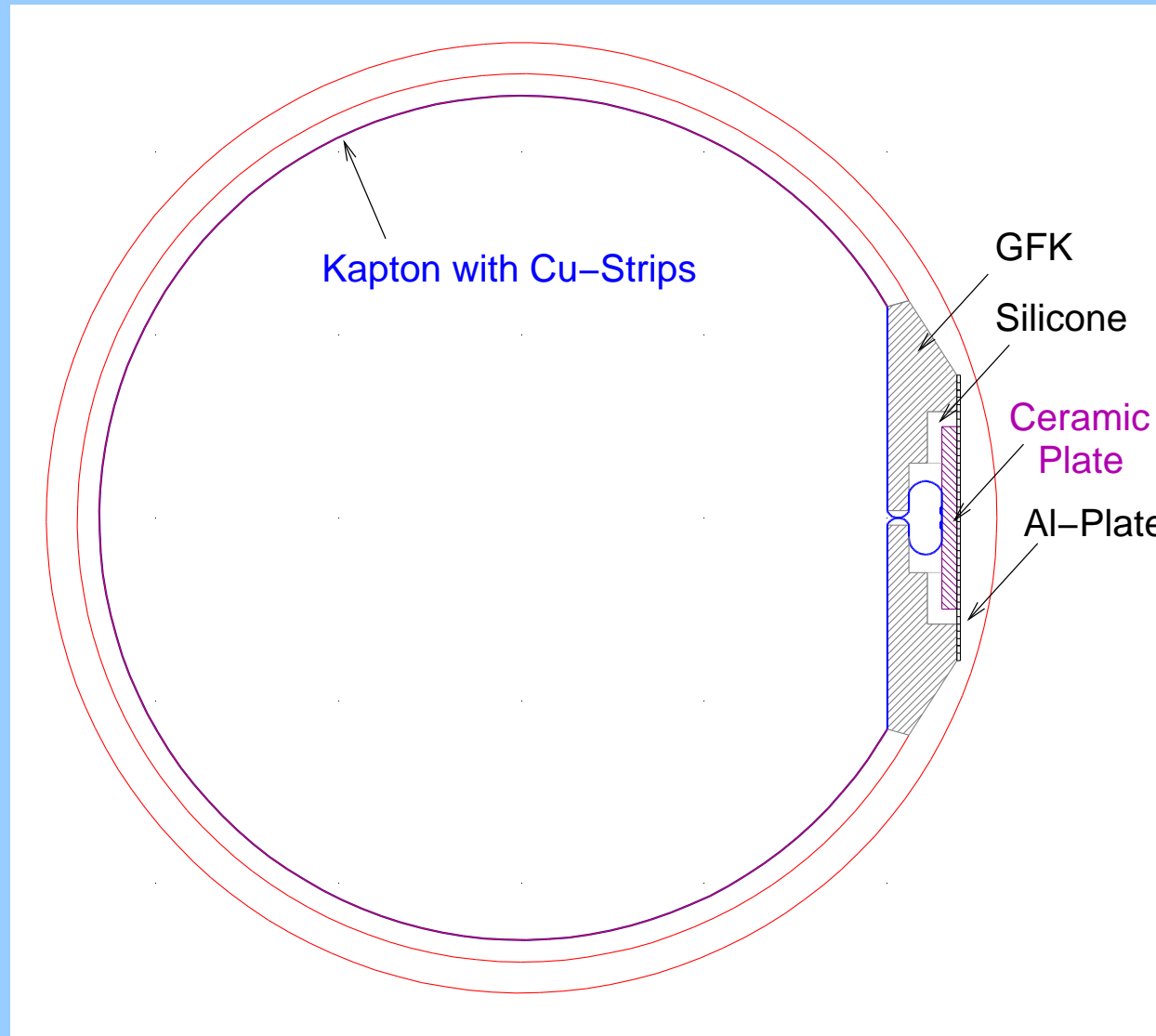




- build a hodoscope with silicon modules:
  - determination of particle trajectory
  - determination of spatial resolution of GEM readout
  - optimisation of pad parameters
  
- first data taking with TPC prototype



gain of one primary electron is inhomogeneous!



xy profile of the field cage