

# Comparison of z-resolutions

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## Timepix3-based GridPix:

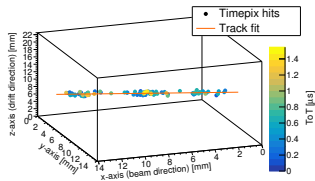
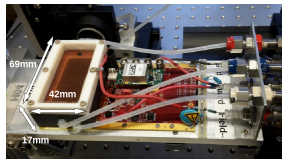
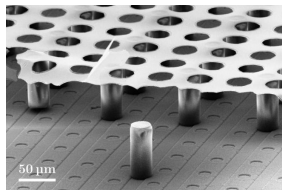
- Micro-pattern gaseous detector with grid aligned to pixels
- 65K  $55\ \mu\text{m} \times 55\ \mu\text{m}$  sized pixels

## Timepix3 compared to its predecessor:

- Improved time resolution of 1.56 ns
- Simultaneous time and charge (ToT) measurement

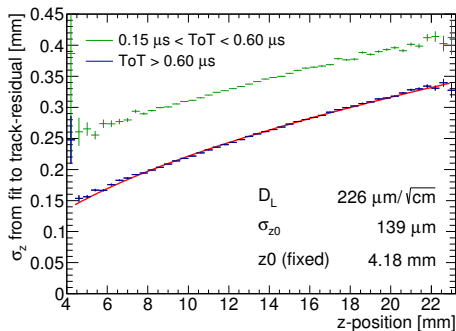
## Test beam with single chip Timepix3 detector with field shaping, guard electrode using 2.5 GeV electrons at ELSA facility (Bonn)

- T2K TPC gas ( $\text{Ar}:\text{CF}_4:\text{iC}_4\text{H}_{10}$  95:3:2)
- drift field is 280 V/cm



# z-resolution with single chip GridPix detector

Resolution  $\sigma_z$  determined by longitudinal diffusion coefficient  $D_L$  and resolution at zero drift distance  $\sigma_{z0}$ :  $\sigma_z^2 = \sigma_{z0}^2 + D_L^2(z - z_0)$

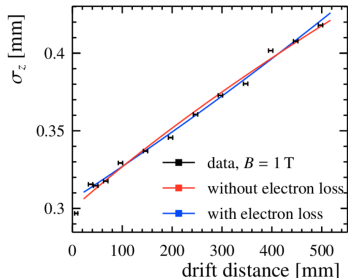
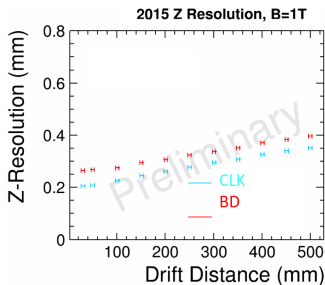
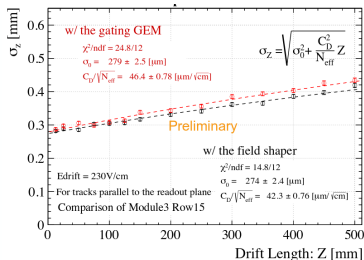


Measured  $D_L = 226 \mu\text{m}/\sqrt{\text{cm}}$  (Magboltz predicts  $201(5) \mu\text{m}/\sqrt{\text{cm}}$ )  
and  $\sigma_{z0} = 139 \mu\text{m}$  ( $168 \mu\text{m}$  if including  $\text{ToT} < 0.60 \mu\text{s}$ )

# Experimental z-resolutions for pad readouts

Resolution of pad readouts in Large Prototype are comparable

From presentation in LCTPC 2nd Analysis meeting



# Comparison of hit resolution

resolution  $\sigma_z$  is given by  $\sigma_z^2 = \sigma_{z0}^2 + \frac{D_L^2 z}{N_{\text{eff}}}$  where  $D_L = 225 \mu\text{m}/\sqrt{\text{cm}}$

	B-field (T)	$\sigma_{z0}(\mu\text{m})$	$N_{\text{eff}}$
Pixel from testbeam	0	168	1

From single chip prototype

# Comparison of hit resolution

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	B-field (T)	$\sigma_{z0}(\mu\text{m})$	$N_{\text{eff}}$
Pixel from testbeam	0	168	1
Pixel extrapolated to 6 mm	0	22	60

$N_{\text{eff}} = 60$  as per the expected number of electrons

# Comparison of hit resolution

resolution  $\sigma_z$  is given by  $\sigma_z^2 = \sigma_{z0}^2 + \frac{D_L^2 z}{N_{\text{eff}}}$  where  $D_L = 225 \mu\text{m}/\sqrt{\text{cm}}$

	B-field (T)	$\sigma_{z0}(\mu\text{m})$	$N_{\text{eff}}$
Pixel from testbeam	0	168	1
Pixel extrapolated to 6 mm	0	22	60
ILD simulation	3.5	400	$\sim 8$

Values currently in simulation, agrees roughly with the ILD design goal of  $\sigma_z$  between 0.4 mm - 1.4 mm for 0 - full drift. With these goals, other gasses with a higher longitudinal diffusion remain an option



# Comparison of hit resolution

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	B-field (T)	$\sigma_{z0}(\mu\text{m})$	$N_{\text{eff}}$
Pixel from testbeam	0	168	1
Pixel extrapolated to 6 mm	0	22	60
ILD simulation	3.5	400	$\sim 8$
DESY GEMs	1	306	30

From thesis Felix Mueller, simple fit, at  $B = 1 \text{ T}$

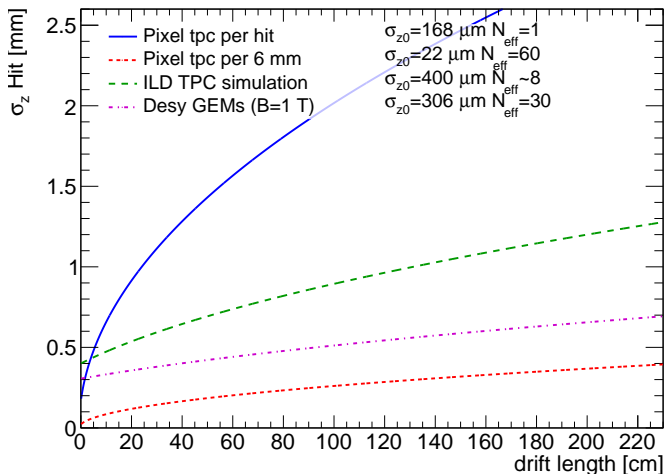
# Comparison of hit resolution

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	B-field (T)	$\sigma_{z0}(\mu\text{m})$	$N_{\text{eff}}$
Pixel from testbeam	0	168	1
Pixel extrapolated to 6 mm	0	22	60
ILD simulation	3.5	400	$\sim 8$
DESY GEMs	1	306	30
Asian GEMs with gating		279	22

Z resolution of the Asian module with 2016 data with gating GEM as presented in LCTPC 2nd Analysis meeting

# Comparison of hit resolution



## z-resolution of track

For linear fits with  $N$  equally spaced points with the same errors, the uncertainty at the first and last point is given by <sup>1</sup>

$$\sigma_z^{\text{track}} = \frac{2\sigma_z^{\text{hit}}}{\sqrt{N}} \quad (1)$$

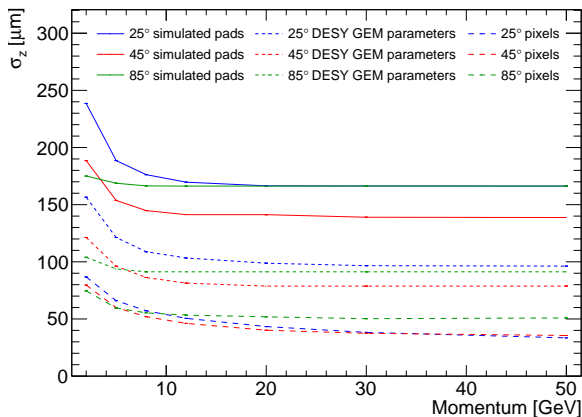
This is the case for high momentum tracks perpendicular to the beam at the inner and outer TPC radius, and we expect:

	$\sigma_z^{\text{hit}}$ at full drift	$\sigma_z^{\text{track}}$
pixel TPC	3.05 mm	50 $\mu\text{m}$
pixel TPC per 6 mm	0.37 mm	
ILD TPC simulation	1.24 mm	164 $\mu\text{m}$
TPC with DESY GEM parameters	0.70 mm	94 $\mu\text{m}$

<sup>1</sup>see e.g. Blum and Rolandi, *Particle Detection with Drift Chambers* or Keisuke Fujihef  
[Time Stamping: CDC/TPC Comparison Studies](#)

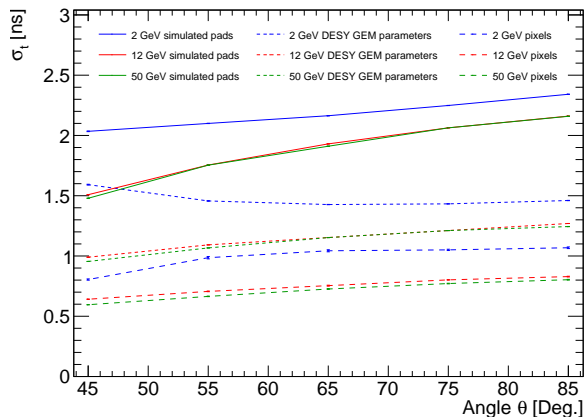
# From ILD simulation

using single muon tracks



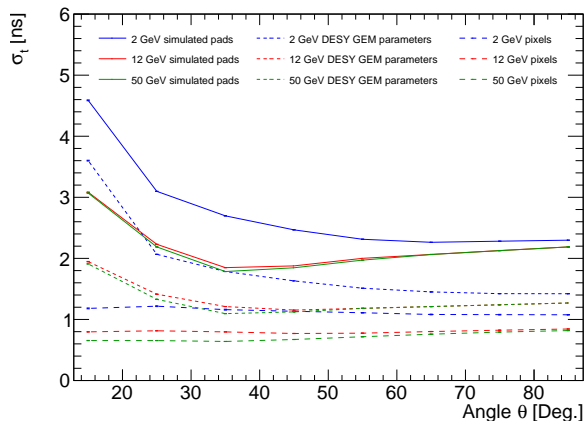
The simulated resolution at 85° is in good agreement with the calculated values of 164, 94 and 50  $\mu\text{m}$ .

# Timing from ILD simulation using SET



Timing using silicon external tracker  $\sigma_z^{\text{SET}} = 50 \mu\text{m}$  and a drift velocity of  $78 \mu\text{m}/\text{ns}$  with  $7 \cdot 10^{-6}$  ( $16 \mu\text{m}$ ) systematics, neglecting multiple scattering

# Timing from ILD simulation using SIT



Timing using silicon external tracker  $\sigma_z^{\text{SET}} = 35 \mu\text{m}$  and a drift velocity of  $78 \mu\text{m}/\text{ns}$  with  $7 \cdot 10^{-6}$  ( $16 \mu\text{m}$ ) systematics, neglecting multiple scattering

# Conclusions

The track resolution was calculated to be:

	$\sigma_z^{\text{hit}}$ at full drift	$\sigma_z^{\text{track}}$	$\sigma_t$
pixels	3.05 mm		
pixels per 6 mm	0.37 mm	50 $\mu\text{m}$	0.80 ns
ILD TPC sim.	1.24 mm	164 $\mu\text{m}$	1.25 ns
DESY GEM parameters	0.70 mm	94 $\mu\text{m}$	2.15 ns

Parameters from experimental results were used to simulate the z and time resolution, which was found to be in agreement with calculations