

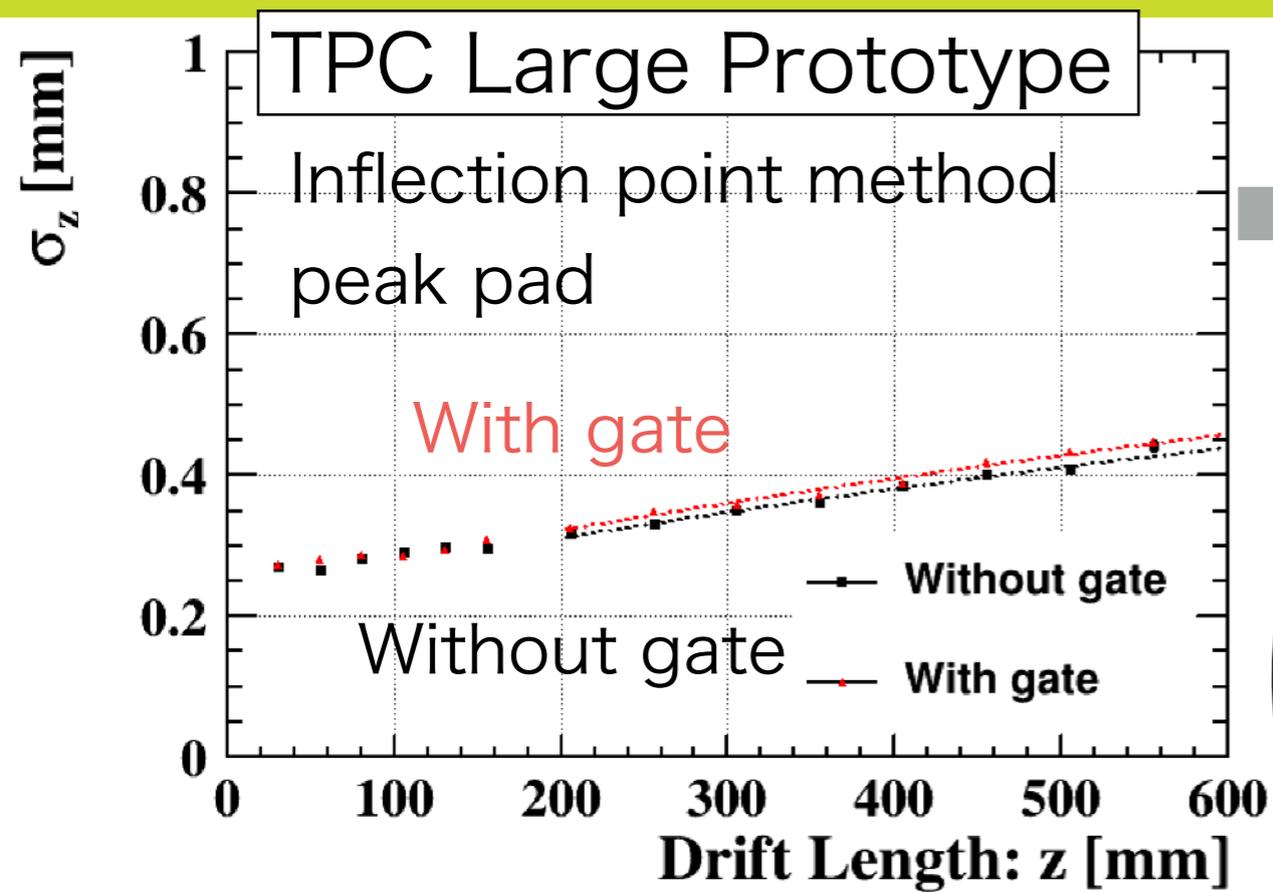
z resolution study of ILD-TPC with Gating Device

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Can we achieve z resolution goal?



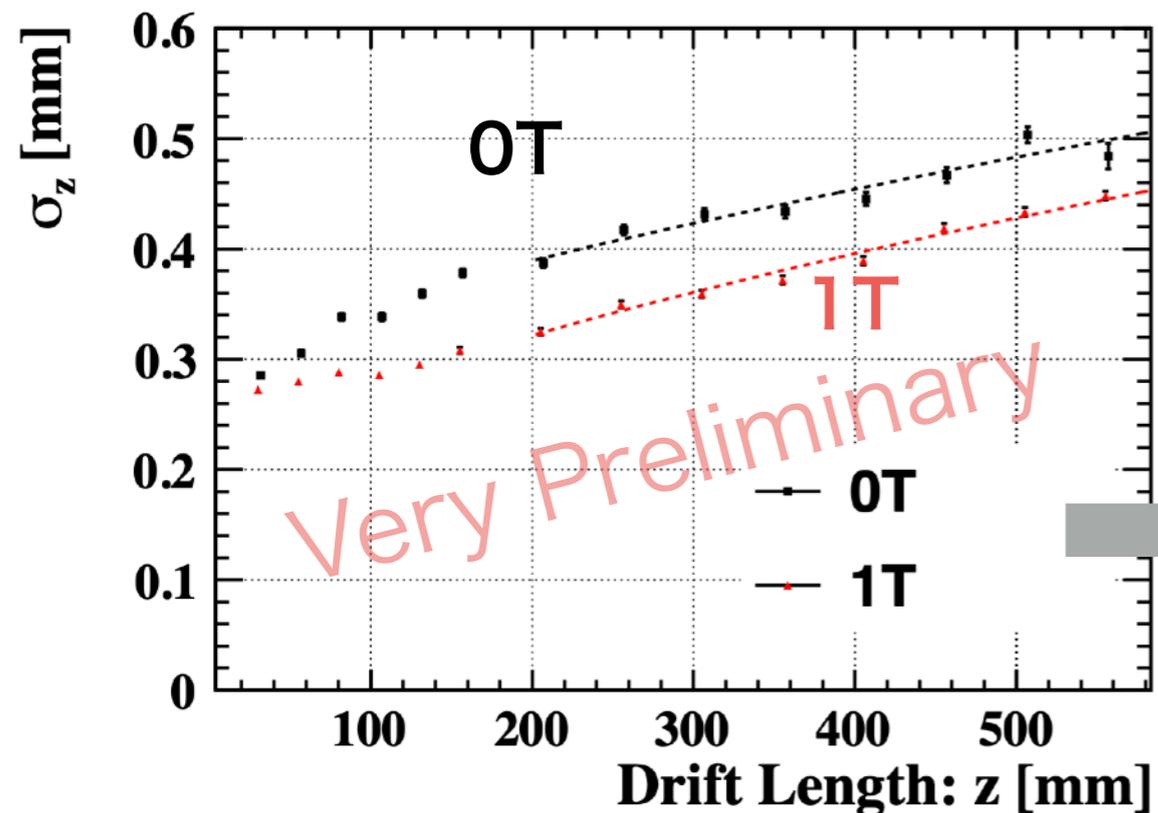
Real-size TPC

$$\sigma_z = \sigma_z(z, \cancel{B})$$

$$\sigma_z = \sqrt{\sigma_0^2 + (C_{dL}^2 / N_{eff}) z}$$

	σ_0 [μm]	$C_{dL} / \sqrt{N_{eff} \mu\text{m} / \sqrt{\text{cm}}}$
With gate	219 ± 7	52.3 ± 0.9
Without gate	228 ± 7.7	48.2 ± 1.1

$$z=220\text{cm} \rightarrow \sigma_z=0.8 \pm 0.1 \text{ mm}$$



This assumption is correct?

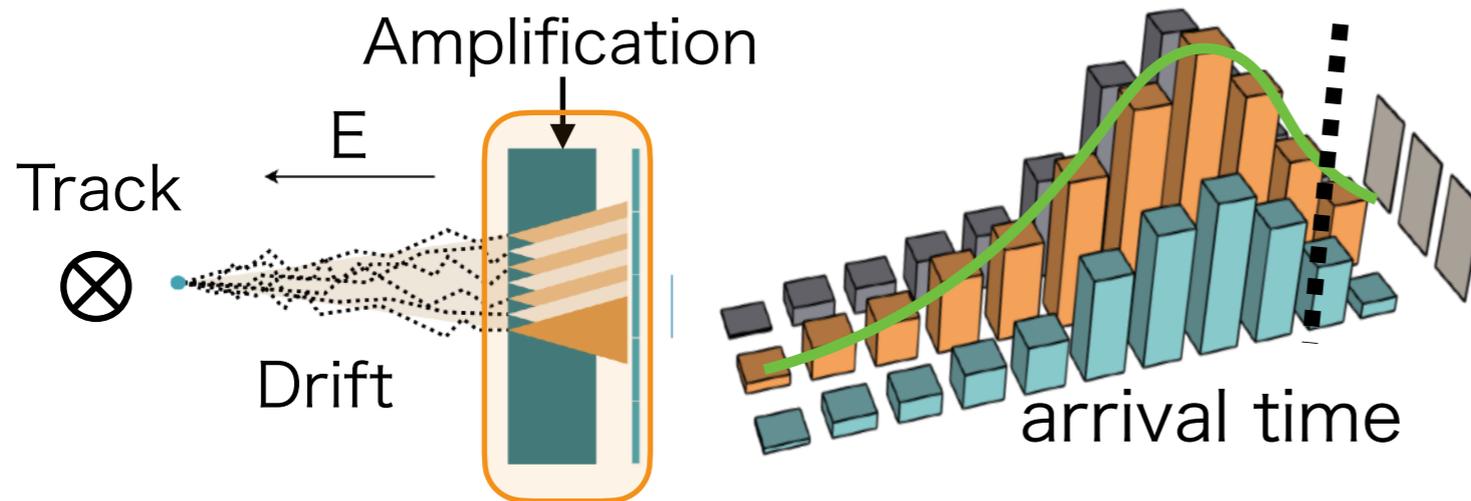
	σ_0 [μm]	$C_{dL} [\mu\text{m} / \sqrt{\text{cm}}]$
0T	283 ± 12	51.9 ± 1.9
1T	219 ± 7.4	52.3 ± 0.9

Significantly different! ~20%

$\rightarrow z$ resolution seems to depend

on B field

z resolution & pulse

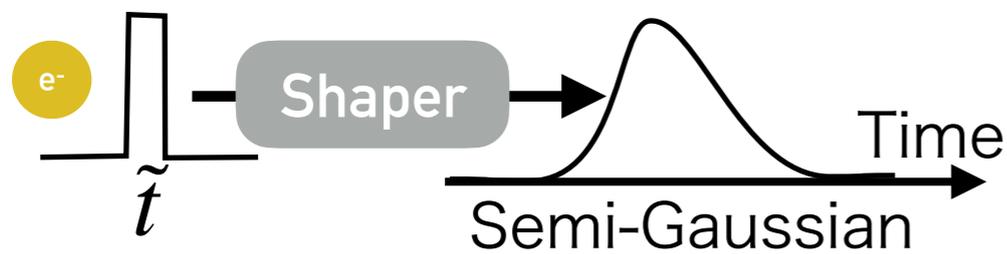


Pulse shape affect the z-resolution

What determines the pulse?

Assumption The average pulse shape is determined only by the properties of the shaper and the longitudinal diffusion

Arrival time spread

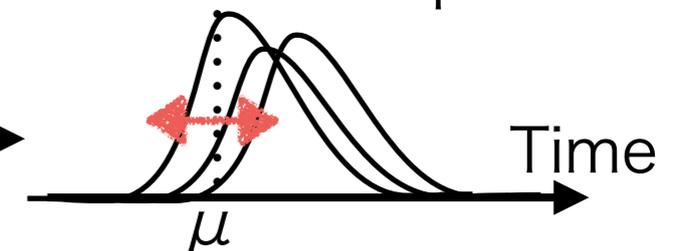


unipolar-shaper signal function

$$f(t, \tilde{t}) = \frac{1}{n! \left(\frac{t_{pk}}{n}\right)} \left(\frac{t - \tilde{t}}{t_{pk}/n}\right)^n e^{-\left(\frac{t - \tilde{t}}{t_{pk}/n}\right)} \cdot \theta(t - \tilde{t})$$

n : shaper parameter , t_{pk} : peaking time

A superposition of pulses



Convolution



$$g(\tilde{t}) = \frac{1}{\sqrt{2\pi\sigma_t^2}} \exp\left(-\frac{(\tilde{t} - \mu)^2}{2\sigma_t^2}\right)$$

We can get the "longitudinal diffusion" as a standard deviation : σ_L

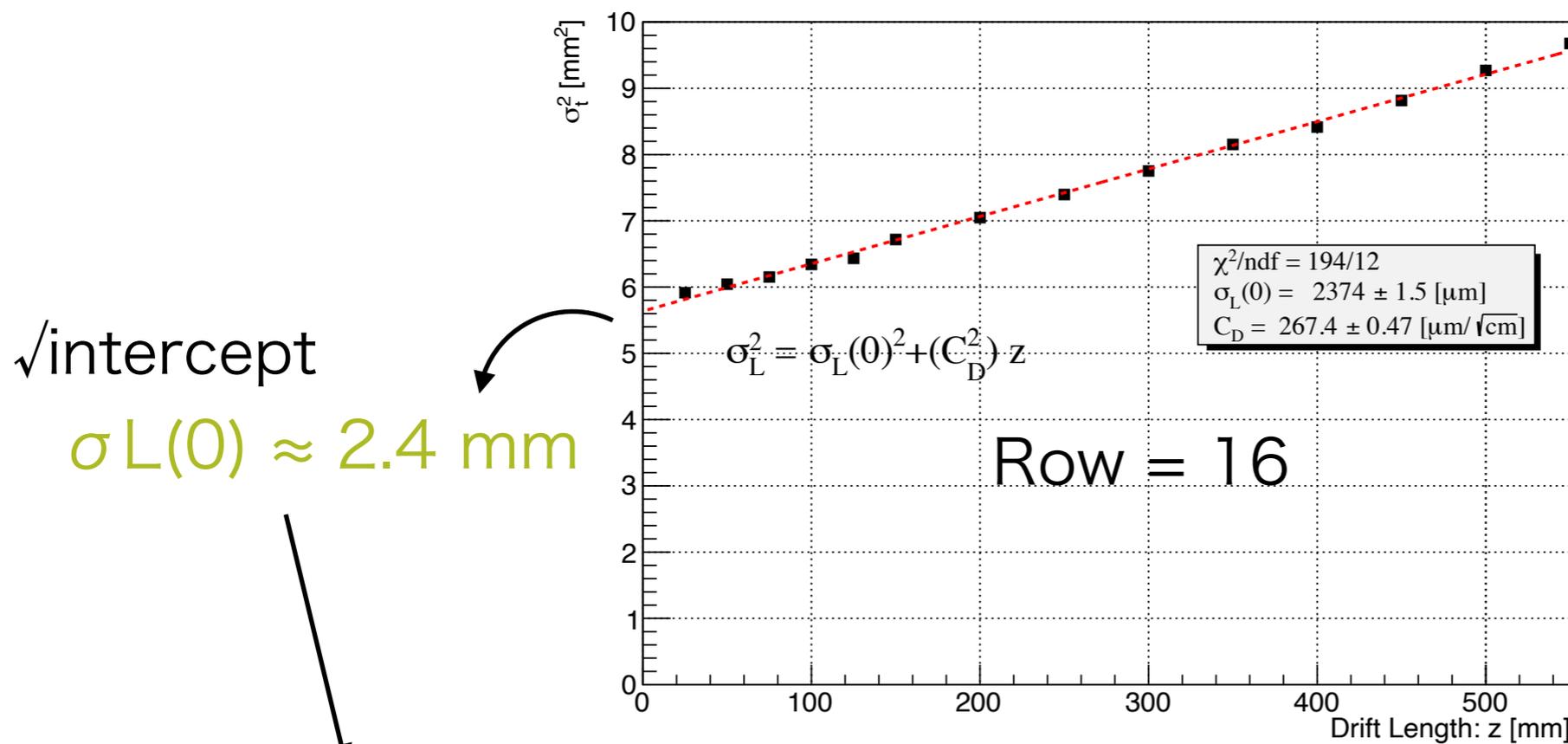
$$\sigma_L^2 = \sigma_0^2 + C_{dL}^2 \cdot z$$

$$\sigma_t = \sigma_L / v_{drift}$$

C_{dL}: Diffusion constant

CdL Result (With nominal shaper parameters)

By using convolution method, we calculated C_{dL} of test beam data
 (From spec sheet) Input : $n = 3$, $tpk = 120$ ns



$C_{dL} \approx 267.4 \text{ um}/\sqrt{\text{cm}}$

Difference between theory : $\sqrt{(2.374 \text{ mm})^2 - (1.082 \text{ mm})^2} = \underline{2 \text{ mm}}$

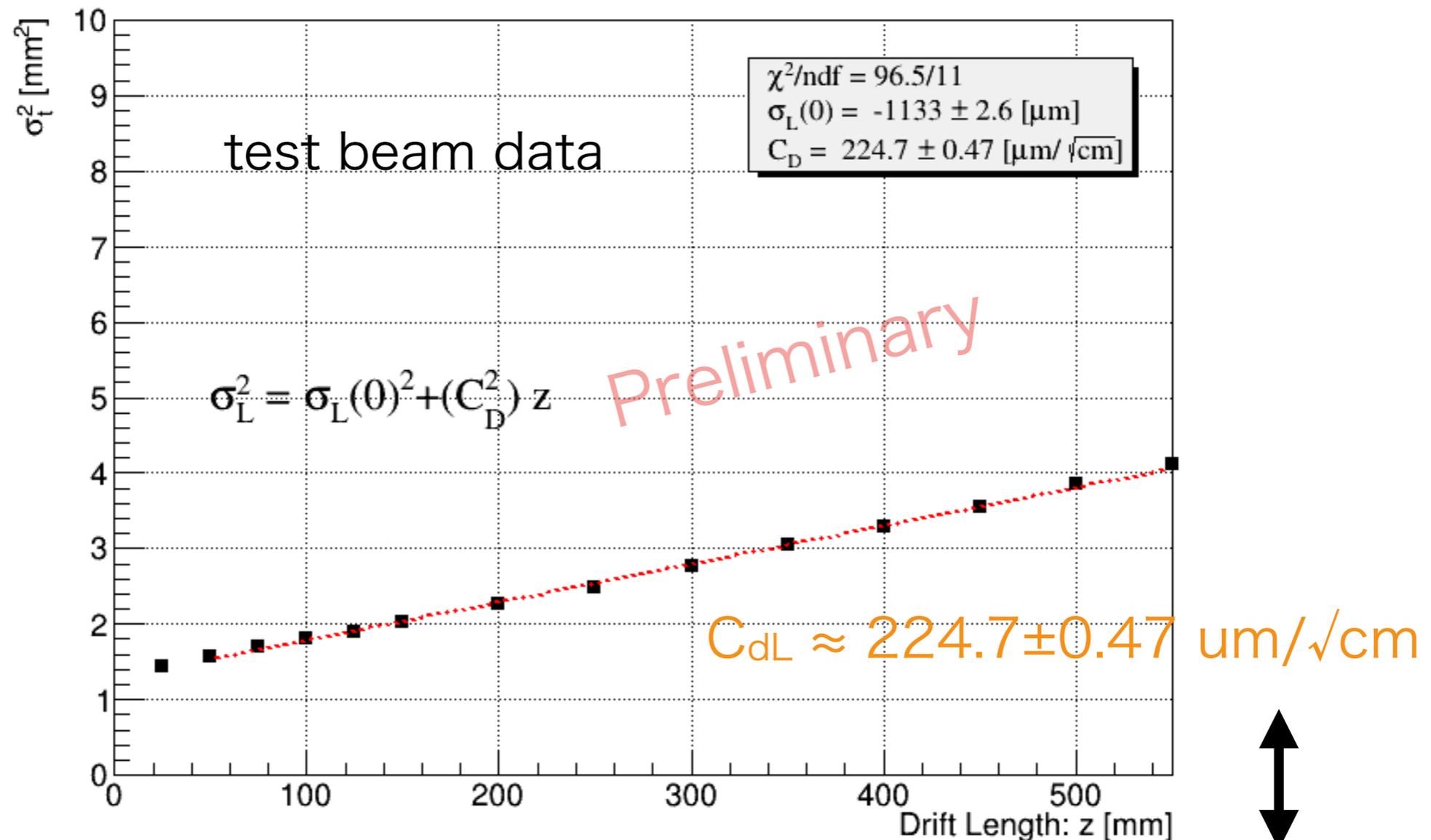
Magboltz Simulation

	1 T	0 T
Temperature[K]	291.28	291.11
Pressure[hPa]	1010.79	1007.29
$C_{dL}[\mu\text{m}/\sqrt{\text{cm}}]$	226.1 ± 1.54%	224.4 ± 2.64%

Inconsistent with Garfield++ simulation

Retry with Adjusted shaper parameter

Input : $n = 3$, $tpk = 135$ ns, Row = 16 (Specification sheet: $tpk = 120$)



Magboltz: $C_{dL} = 226 \pm 1.5\%$

This method of C_{dL} estimation is rather sensitive to the input shaper parameters

What are the possible smearing effects?

Future plans

Is the pulse shape really according to spec sheet?

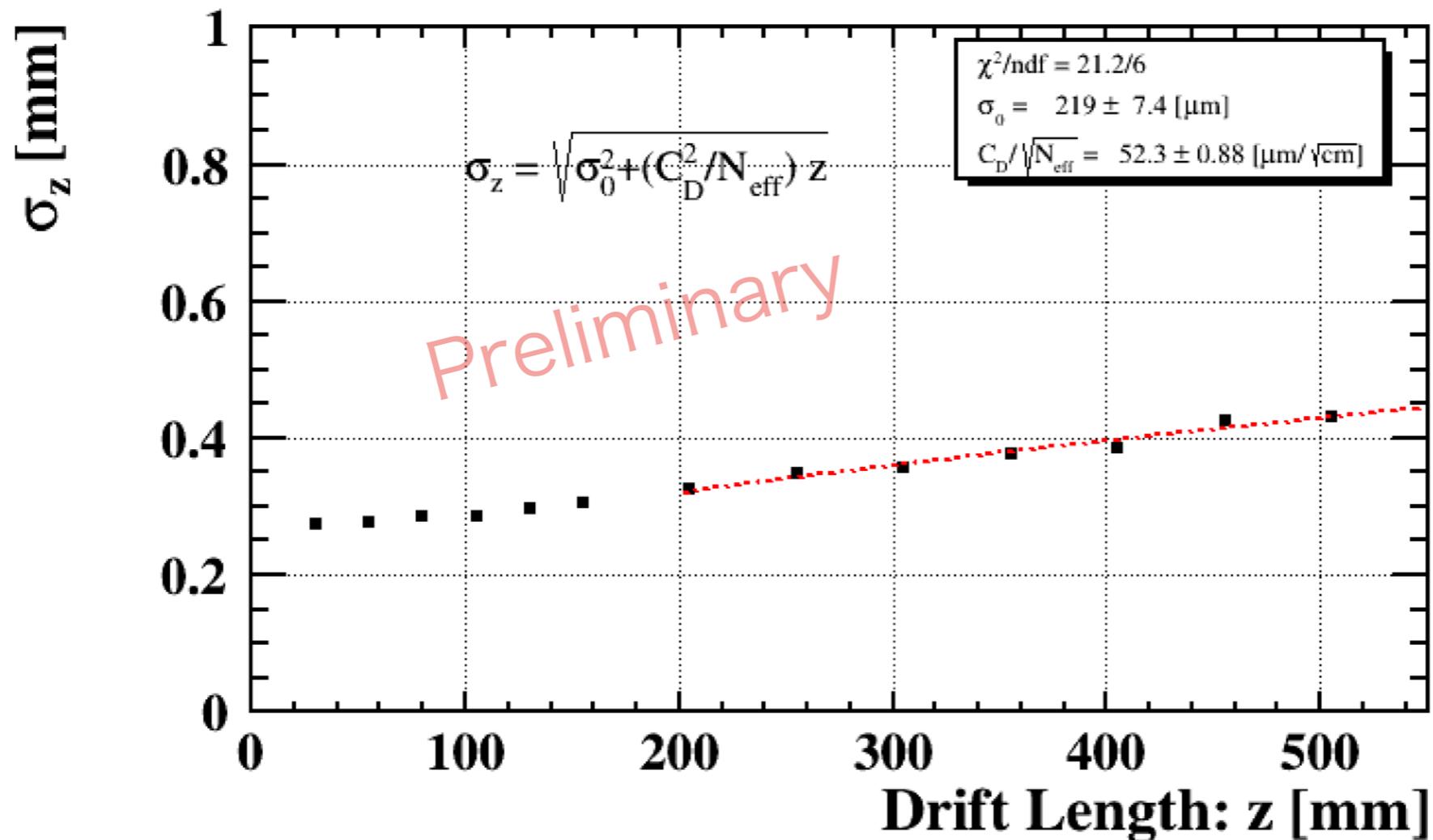
- Shaper parameter $n=3$, $t_{pk} = 120\text{ns}$ are from specification sheet

→ We are planning to measure pulse shape directly



Another way to estimate C_{dL}

If we assume that N_{eff} is the same as in the $r\phi$ resolution at same time, we can also estimate C_{dL} from the analysis of z resolution



$N_{\text{eff}} = 23.9 \pm 0.7$ (From $r\phi$ analysis)

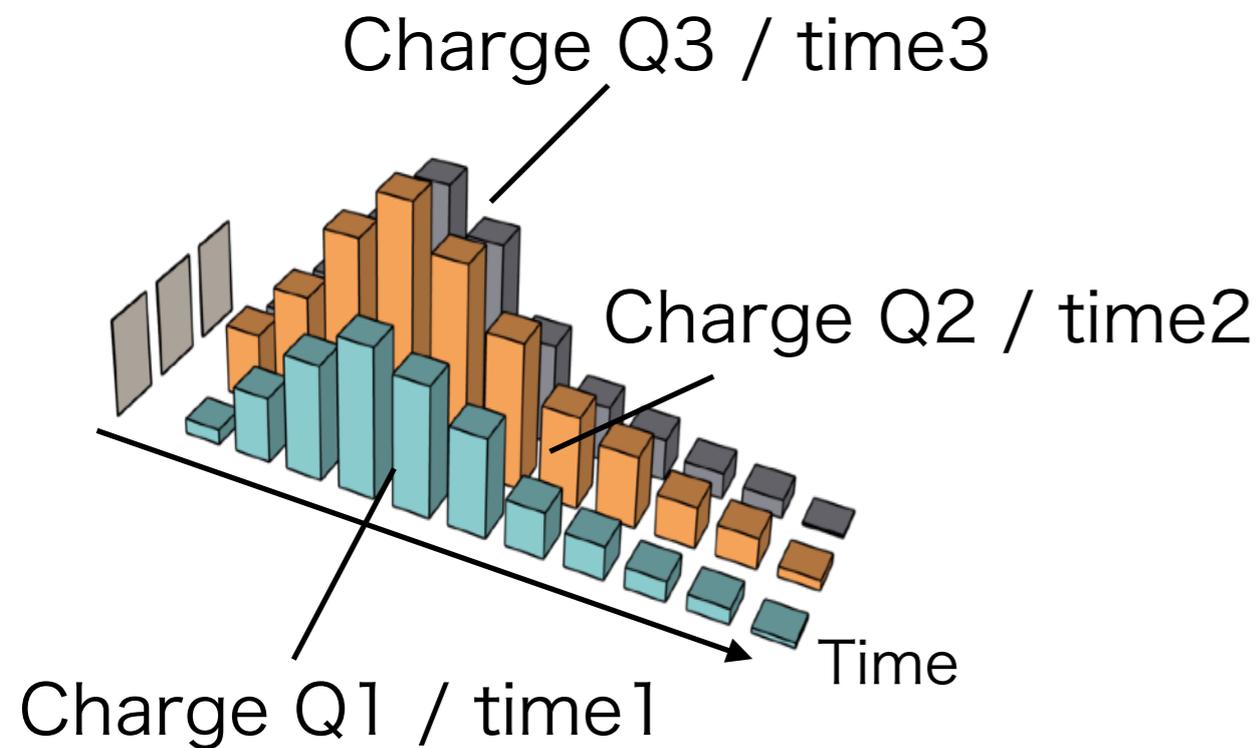
$C_{dL}/\sqrt{N_{\text{eff}}} = 52.3 \pm 0.9 \text{ }\mu\text{m}/\sqrt{\text{cm}}$

$C_{dL} \sim 256 \text{ }\mu\text{m}/\sqrt{\text{cm}}$

Improve time calculation method?

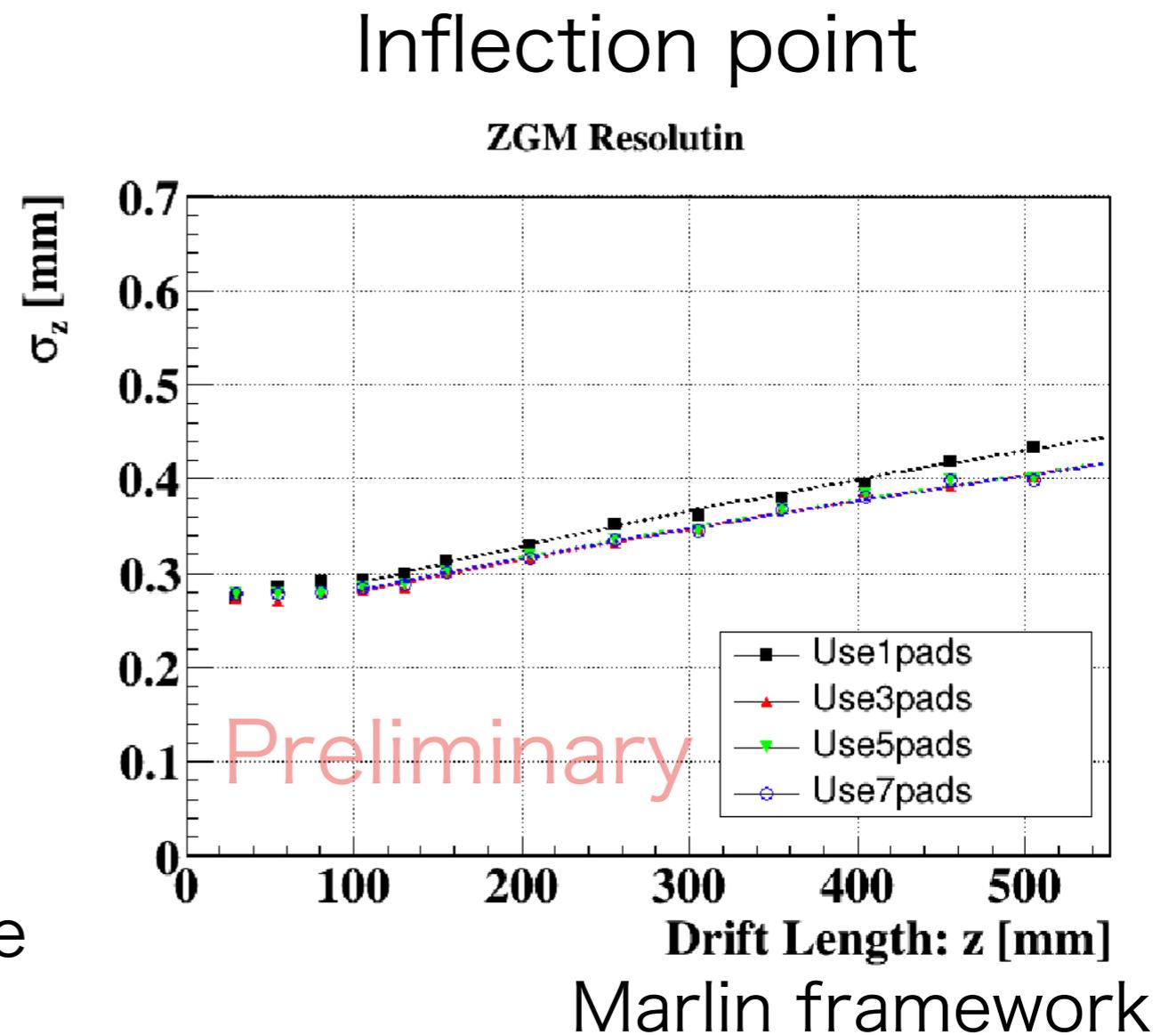
Time Calculation Method Comparison

Comparison of z resolution for various pad numbers



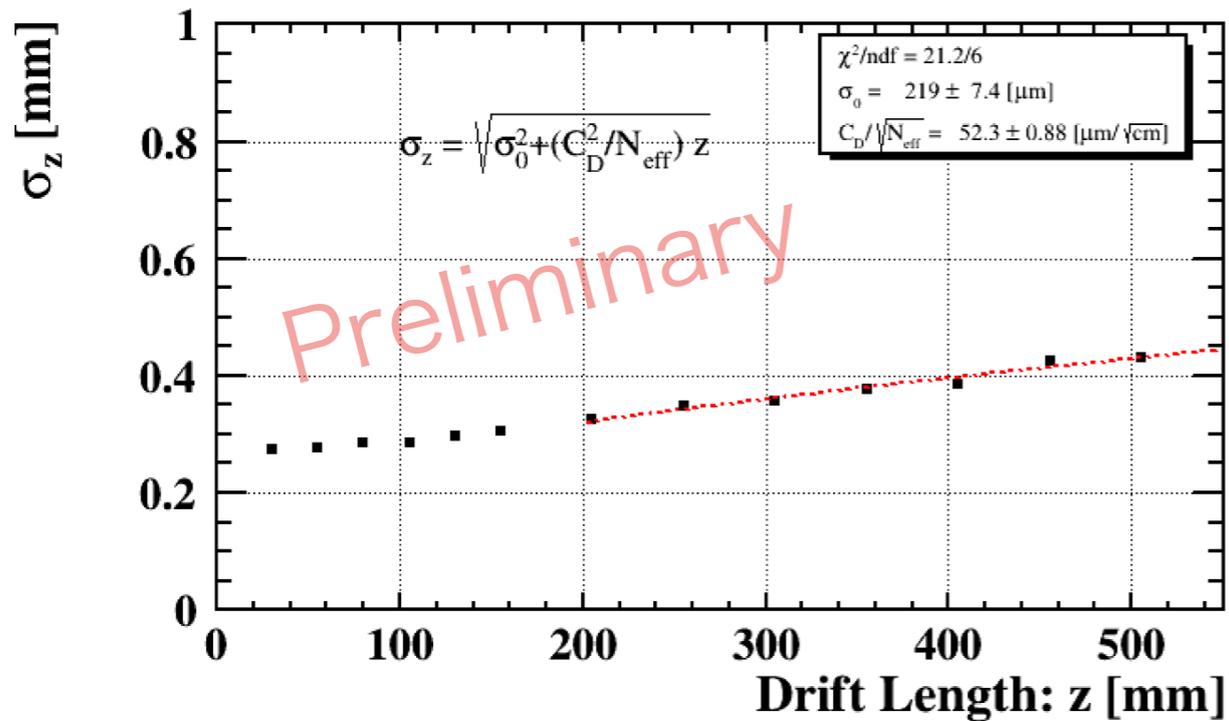
$$\frac{1}{\sum_i Q_i} \sum_i Q_i \times time_i$$

Add pulse time weighted by charge

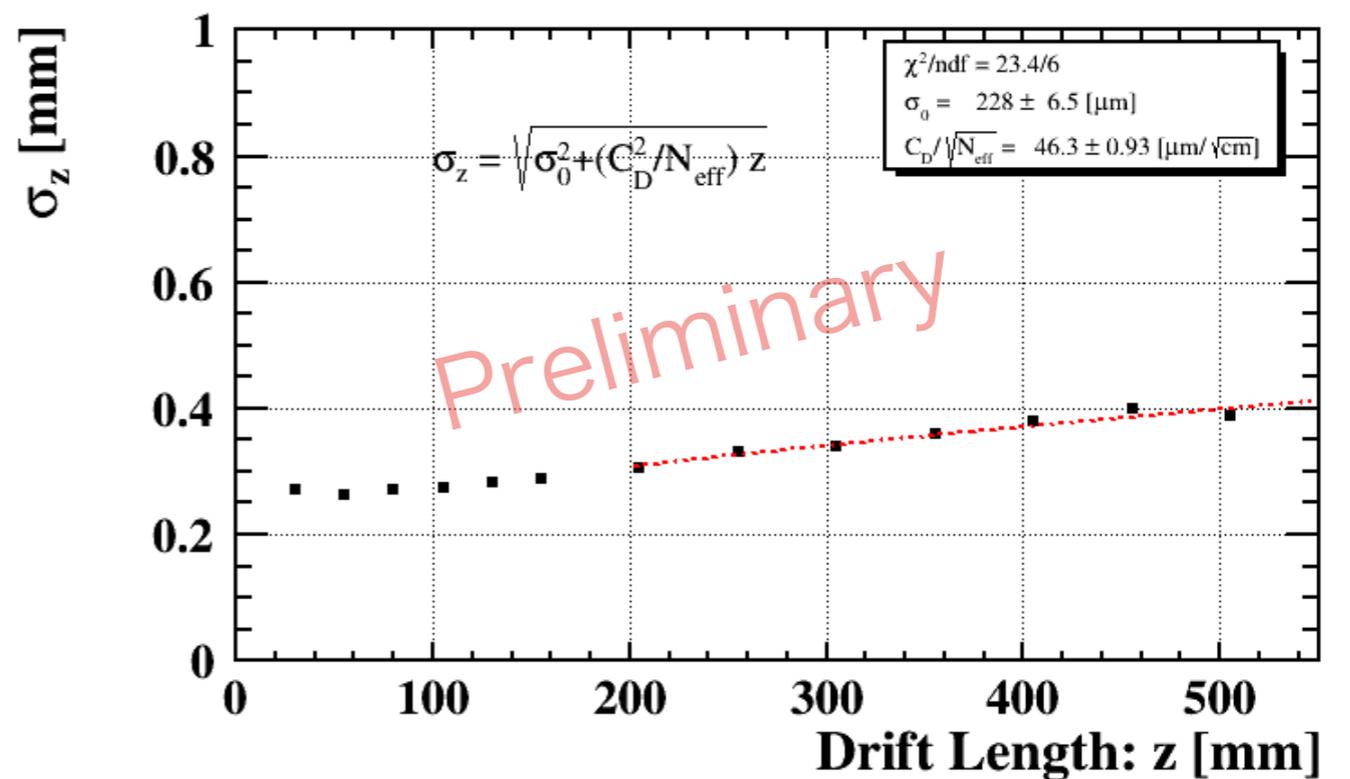


z resolution using 3 pads or more is better than when using 1 pad

Re-estimate C_{dL}



Using 1 pad



Using **All** pad

$N_{\text{eff}} = 23.9 \pm 0.7$ (From $r\phi$ analysis)
 $C_{dL}/\sqrt{N_{\text{eff}}} = 52.3 \pm 0.88 \mu\text{m}/\sqrt{\text{cm}}$

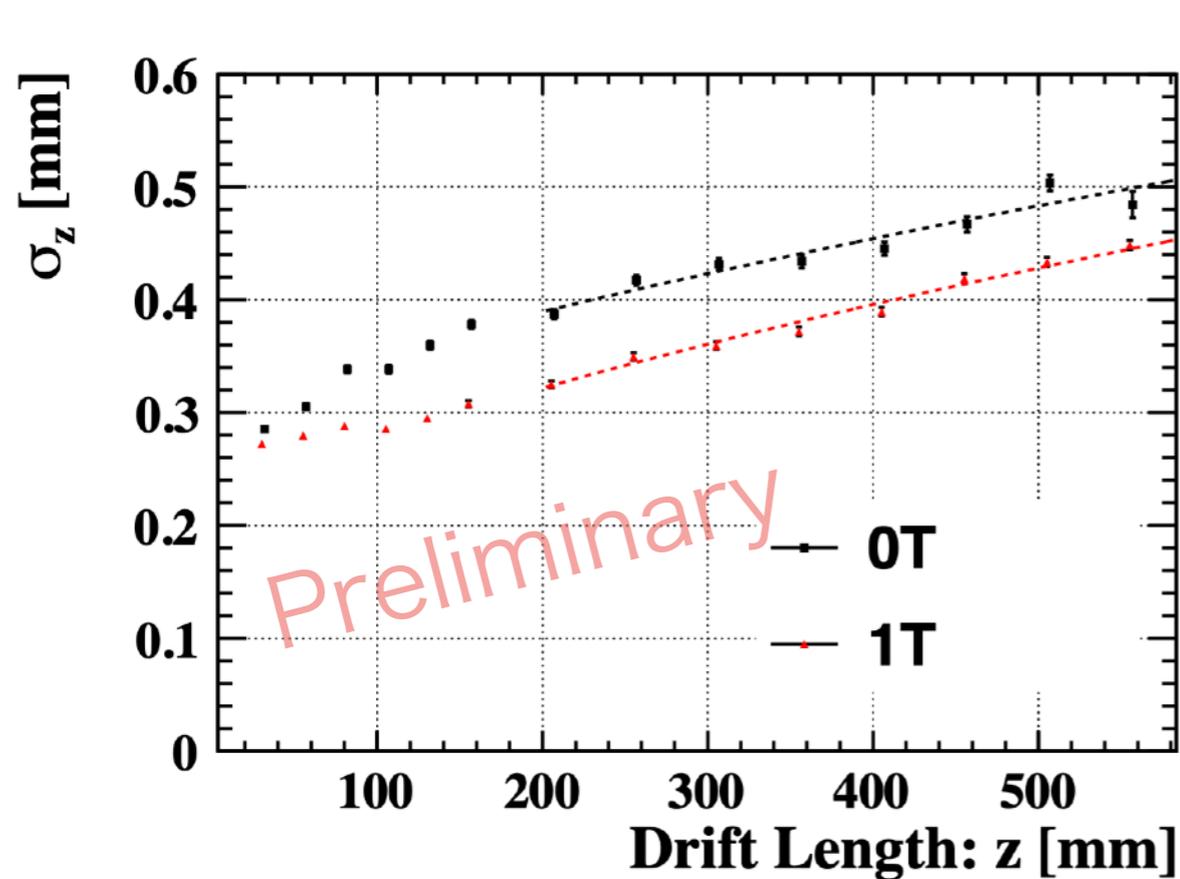
$C_{dL} \sim 256 \mu\text{m}/\sqrt{\text{cm}}$

$N_{\text{eff}} = 23.9 \pm 0.7$ (From $r\phi$ analysis)
 $C_{dL}/\sqrt{N_{\text{eff}}} = 46.3 \pm 0.93 \mu\text{m}/\sqrt{\text{cm}}$

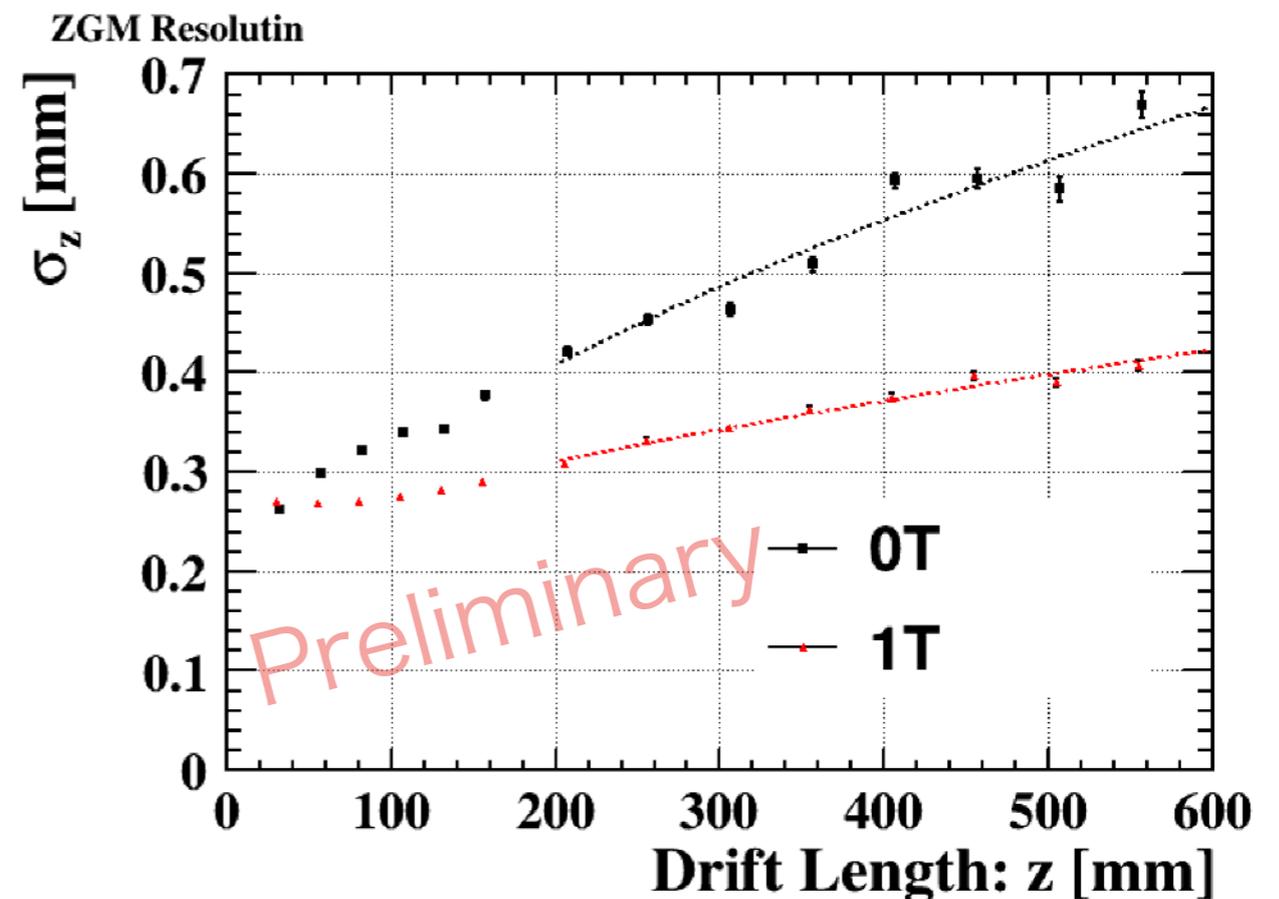
$C_{dL} = 226.3 \pm 5.6 \mu\text{m}/\sqrt{\text{cm}}$

Consistent with Magboltz simulation

Re-estimated the z resolution



Using 1 pad



Using **All** pad

- The z resolution with 0T is worse than using 1 pad though the z resolution with 1T is better.

This is caused by the method of combining pulse information?
Add pulse time weighted by charge → susceptible to electronic noise in particular for tail pads in the hit in question

Conclusion

- ✓ We performed the beam test with the gating device
- ✓ We improved the z coordinate estimation method
- ✓ With improved method, the resultant CdL value turned out to be consistent with Magboltz simulation

Future work

- * Is the $t_{pk} = 120$ correct? → We are planning to measure ALTRO output pulse shape
- * Improve the method to combine pads