Revisiting the parameters - TPC

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For the LCTPC collaboration

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ILD-Meeting

The performance goals

ILC – DBD (2013)

Parameter			
Geometrical parameters	r_{in}	r_{out}	z
	329 mm	1808 mm	$\pm$ 2350 mm
Solid angle coverage	up to $\cos\theta \simeq 0.98$ (10 pad rows)		
TPC material budget	$\simeq 0.05$ X_0 including outer fieldcage in r		
	< 0.25 X_0 for readout endcaps in z		
Number of pads/timebuckets	$\simeq$ 1-2 $\times 10^6$/1000 per endcap		
Pad pitch/ no.padrows	$\simeq 1\times 6$ mm^2 for 220 padrows		
σ_{point} in $r\phi$	$\simeq 60$ μm for zero drift, < 100 μm overall		
σ_{point} in rz	$\simeq 0.4 - 1.4$ mm (for zero – full drift)		
2-hit resolution in $r\phi$	$\simeq 2$ mm		
2-hit resolution in rz	$\simeq 6$ mm		
dE/dx resolution	$\simeq 5$ %		
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 10^{-4}$/GeV/c (TPC only)		

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The performance goals

ILD LOI (2010)

Size	$\phi = 3.6$m, L = 4.3m outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\sim 0.04X_0$ to outer fieldcage in r
	$\sim 0.15X_0$ for readout endcaps in z
Number of pads/timebuckets	$\sim 1{\times}10^6/1000$ per endcap
Pad size/no.padrows	$\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout)
σ_{point} in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$, modulo track ϕ angle)
σ_{point} in rz	$\sim$ 0.5 mm (modulo track θ angle)
2-hit resolution in $r\phi$	$\sim$ 2 mm (modulo track angles)
2-hit resolution in rz	$\sim$ 6 mm (modulo track angles)
dE/dx resolution	$\sim$ 5 %
Performance	$>$ 97% efficiency for TPC only ($p_t >$ 1GeV/c), and
	$>$ 99% all tracking ($p_t >$ 1GeV/c) [87]
Background robustness	Full efficiency with 1% occupancy,
	simulated for example in Fig. 4.3-4 (right)
Background safety factor	Chamber will be prepared for 10 $\times$ worse backgrounds
	at the linear collider start-up

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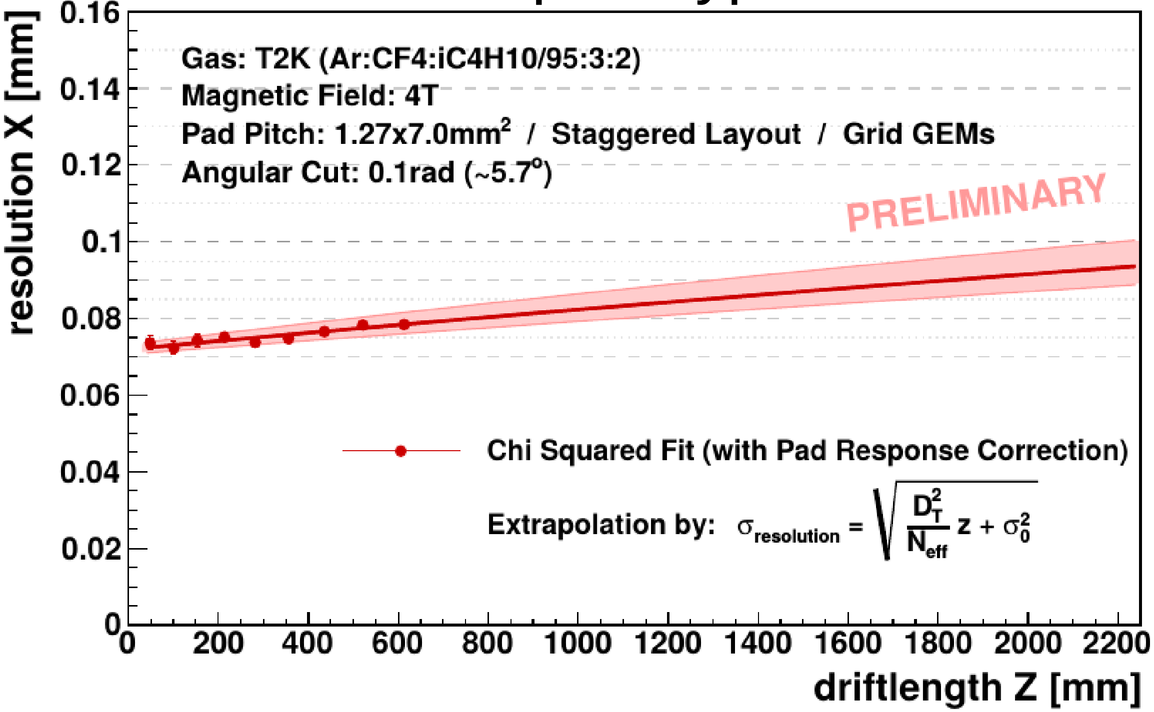
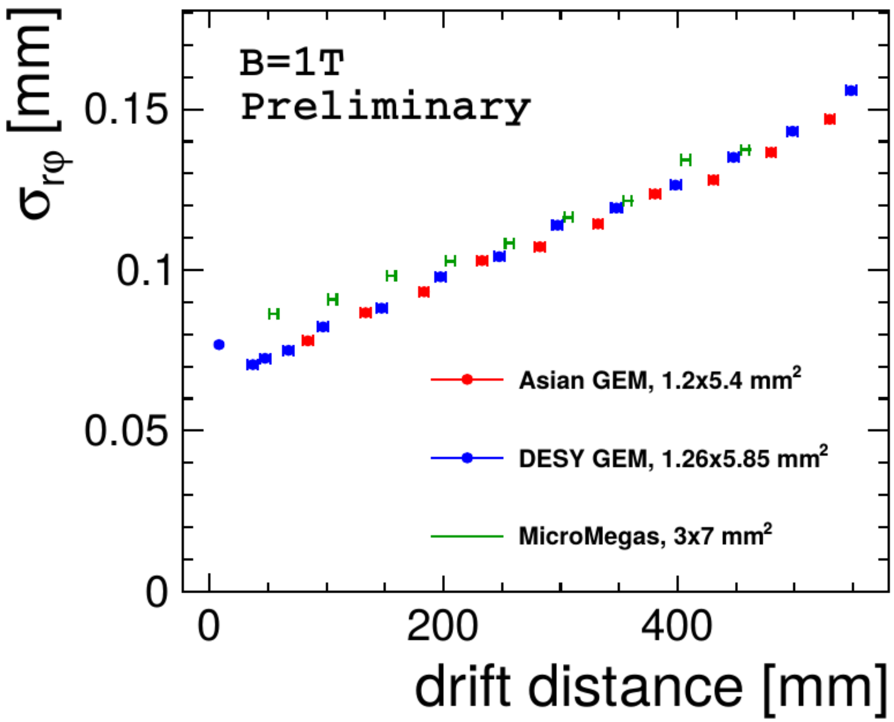
Single point resolution - rϕ

Small prototype



One Module



Still discussing the details of how to reconstructing hits.

We have a detailed analytical formula for the spatial resolution, which helps to extrapolate the results to other conditions.

Caveats: Single point res. – rϕ
Momentum resolution p_T

* Single point spatial resolution is only true for very stiff tracks following the direction of pads
  → If tracks have an angle, the single point resolution degrades with tan ϕ. (Bending tracks with angle have lower momenta and are well measured anyway.)

$$\sigma_{r\varphi} = \sqrt{\sigma_{0,r\varphi}^2 + \frac{L^2}{12 \cdot N_{eff}} \cdot \tan^2(\varphi - \varphi_0)}$$

* Implementation of ion gate still under discussion –> May loose 20 % of e^- => 10 % degradation of spatial resolution.

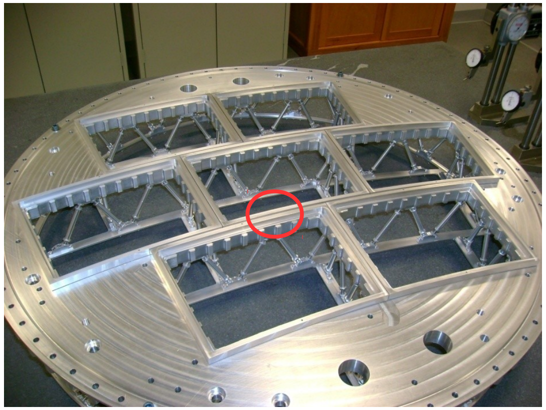
* Single point spatial resolution is not true for points close to the module boundaries.

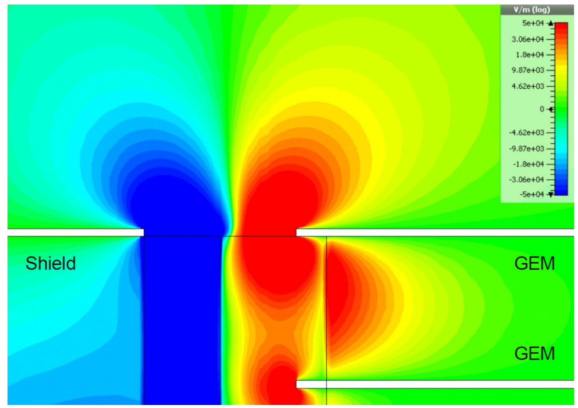
* We haven't looked at the impact of inhomogeneous fields (in particular B) yet. Code for correction has been implemented, but not yet tested.

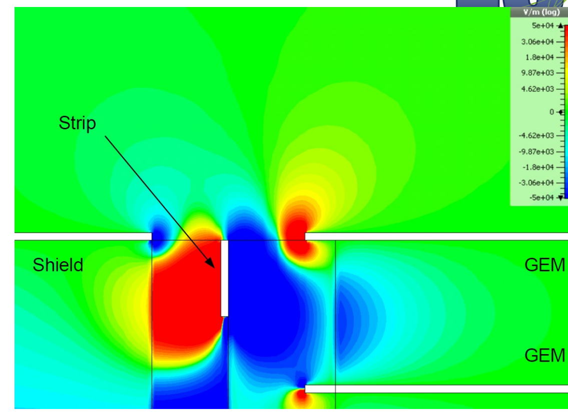
* Solution to some issues: pixelized readout? - Still some time to go. A module with 50% coverage is under construction – not final design.

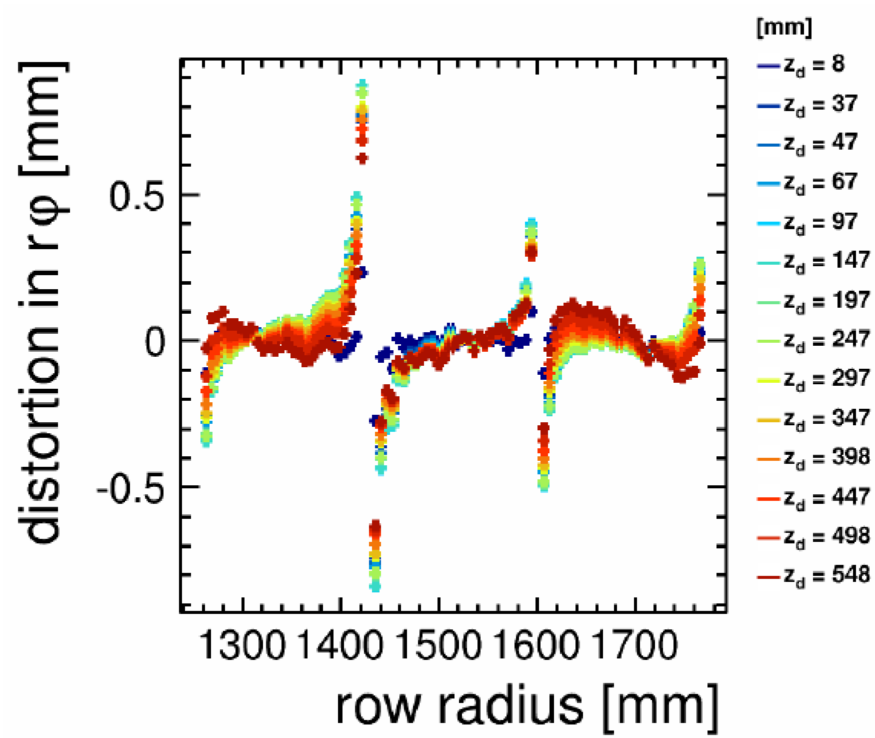
* What impact have dead regions? (ILD simulation)

Module Boundaries



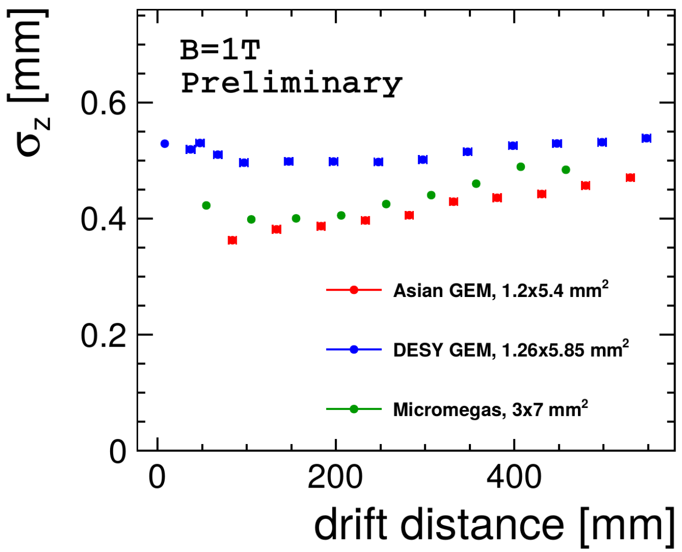


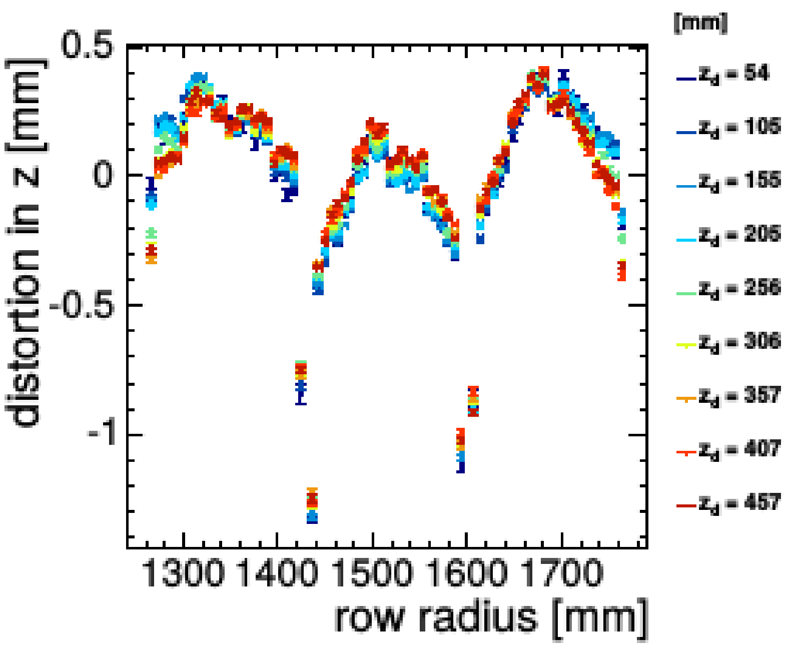




* We see the effects of field distortions at boundaries.
* It would be best to suppress it on hardware level.
  → new modules planned with gating grid
  → introduce a small field cage?
* Effects can also be taken into account with track model when fitting. Code exists, principle was tested with field distortion inside modules with a laser setup in small prototype.

Single point resolution - z





* First shot – hasn't been studied yet in detail.
→ looks good for the first 60 cm
* Extrapolation even more difficult:
→ A longer drift distance would be interesting.
* The electronics settings haven't been optimized yet.
* We also see distortions, but we think it will be manageable.
* Will be different, when the gating grid has been implemented.

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2-Track/Hit resolution

There are different interpretations of this requirement:

From: Every hit must be separated in $r\phi$

To: Tracks are not in the same z anyway and can be easily separated in 3D.

It would be great if ILD/optimization-/PFA-group could give us some guidance:

What is the benchmark physics process?

What is the jet structure, energy range of particles that need to be separated?

How much (which length) of the tracks have to be separated?

What is possible/necessary in rz-plane? Larger pads possible at outer r?

First measurements with a laser show, that 2mm are possible for short drift.

Probably possible only in simulation for the time being.

Rate at DESY testbeam too low.

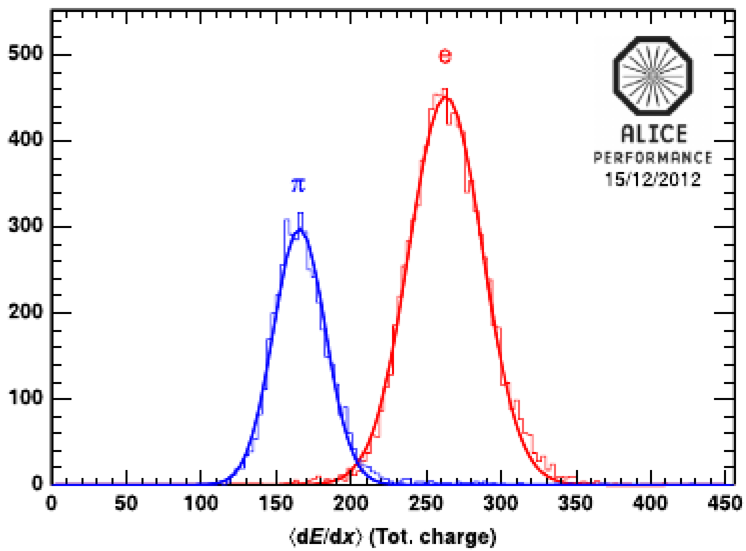
Resistive MM: How well can the hits be reconstructed in a dense environment. (Signal on side pads is delayed).

DE/dx

Hard limit is 3 % because of statistical fluctuations of primary ionization.
Additional degradation because of gas gain fluctuation.

Tested in lab with ^{55}Fe: MM-modules about 15 % RMS at 6keV
– but T2K TPC reached 7% rms (degradation because of resistive layer?)

ALICE has done tests with triple GEM modules (and our electroncis)



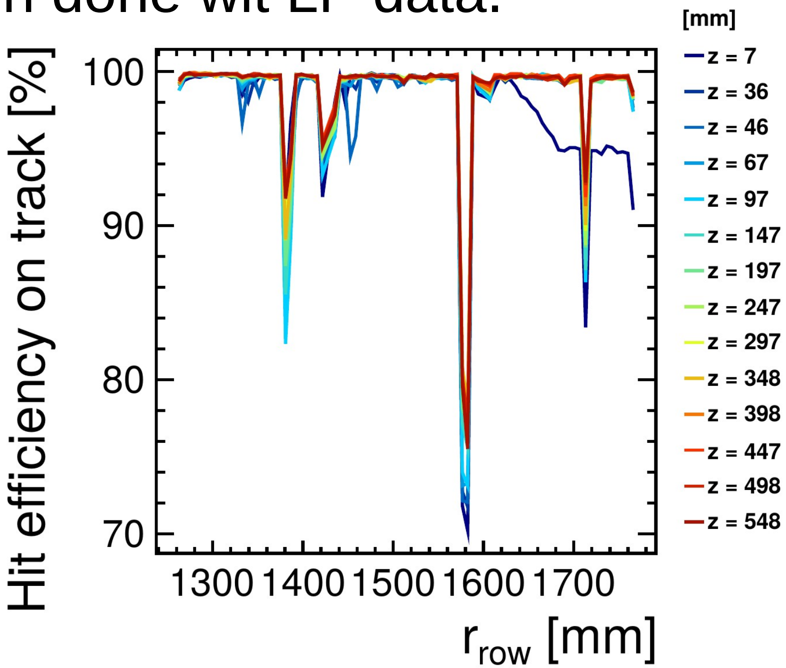
=> dE/dx ~ 5 % (achieved at LEP) seems possible, but not yet proven.

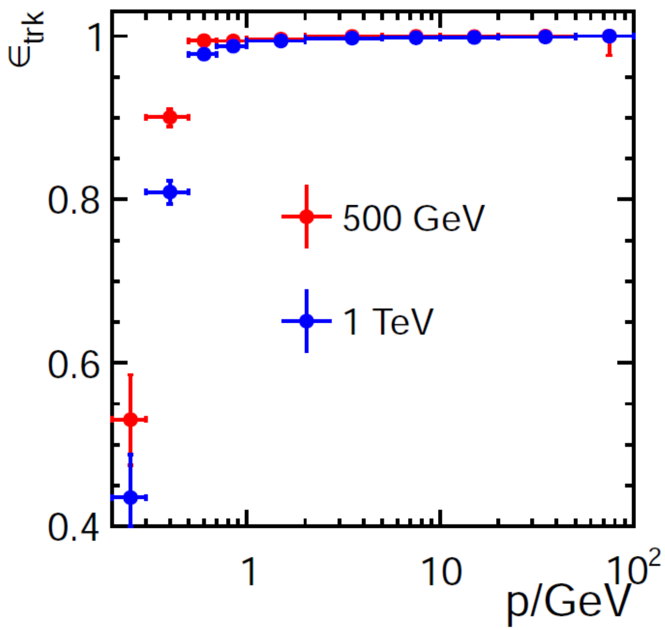
It would be interesting to the see the benefit of dE/dx in a physics analysis. Some simulations have started.

Measurements difficult, because one has to control many parameters before reaching the interesting level.

Efficiency and stability

First hit efficiency on found tracks has been done wit LP data.





Track efficiency for $t\bar{t} \rightarrow$ 6 jets (DBD)

To measure track efficiency with LP, we need an external tracking device.

Long term efficiency/stability has to be studied:
Some sparking has been observed with GEMs in T2K gas – we have to quantify it!
Aging? Rate at ILC seems to be too low, but we better check.

Construction

* Material budget looks feasible: LP has about 1.2 % X_0 and is about the same size of the inner field cage

* Endcap looks also feasible – detailed simulations show, that and endcap can be built with sufficient rigidity and low amount of material.

* Some material has not been put into the models: Cooling, laser calibration system, resistor chain, ...

* We haven't looked at how to construct the cathode.

=> We have no drawings of final ILD field cage yet.

Calibration

We have just general ideas, but have not tested anything yet.
In the next field cage possibly a laser system could be installed.

For testing an external tracking device similar to the Si-strip detectors in ILD would be very important. Then we could improve many studies.

Learning from ALICE.
They want to calibrate track distortions of 10 cm to reach spatial resolutions of 300 µm.

In ILD the Z-peak running is important for calibration.

Things to remember, when changing the radius, length

Obvious:

• Degradation of momentum resolution (of course Glückstern ...)

• Worse dE/dx

But also keep in mind, that:

• Space charge situation changes

• Pattern recognition efficiency changes