Addendum 2026 to the LCTPC MoA

Revised 05022026

The LCTPC Memorandum of Agreement (MoA), the groups which have signed it and the yearly Addenda are available at http://www.lctpc.org/e9/e56939/. The MoA was revised in 2016 and can be found at the above link. Updates in the collaboration are documented in the yearly Addenda.

The activities since those reported in the Addendum 2025 consisted of regular workpackage meetings, but no new test-beam results. The Addenda at http://www.lctpc.org/e9/e56939/ also gives a brief history the organization of the LCTPC collaboration.

What has been learned after two decades of R&D was shown in the Addendum 2025.
–the MWPC option ruled out,
–the resistive-anode charge-di¡spersion technique demonstrated,
–the MicroMegas option without resistive anode ruled out,
–gas properties well measured and the drift-gas selected,
–the best possible point and momentum resolution achieved,
–reliable assemblies of GEM-modules and MicroMegas-modules developed,
–CMOS pixel RO technology successfully demonstrated,
–the dE/dx and dN/dx resolutions measured,
–gating device developed,
–two-phase CO2 cooling verified. Therefore the baseline options are MicroMegas with resistive anode and standard electronics, GEM with standard electronics, and Pixel (= MicroMegas integrated on a Timepix chip). Below is a table of the estimates for the ILD TPC. The digital option with a Pixel TPC gives the best performance. [1]. [2] [3] [4]

EXAMPLE: Large ILD TPC for pad/*pixel* electronics.

Parameter	
B-field	3.5T
Geometrical parameters	r_{in} r_{out} z 329 mm 1777 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	$\simeq 10^6$/1000 per endcap
Number of pixels/timebuckets	$\simeq$ *10^9/1000 per endcap*
Pad pitch/ no.padrows	$\simeq$ 1$\times$ 6 mm^2 / 220
$\sigma_{\rm point}$ in $r\phi$	$\simeq$ 60 μm for zero drift, $<$ 100 μm overall
$\sigma_{\rm point}$ *in* $r\phi$	$\simeq$ *0.055mm/$\sqrt{12}$ for zero drift,0.4mm for max drift*
$\sigma_{\rm point}$ in rz	$\simeq 0.4 - 1.4$ mm (for zero – full drift)
2-hit separation in $r\phi$	$\simeq$ 2 mm
2-hit separation in $r\phi$	$\simeq\leq$ 0.8 *mm*
2-hit separation in rz	$\simeq$ 6 mm
2-hit separation in rz	$\simeq\leq$ 0.7 *mm*
dE/dx,dN/dx resolution	$\simeq$ 5 %
dE/dx,dN/dx resolution	$\simeq$ 2.5(3.0) *%* *template fit(truncation method)*
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 1\times10^{-4}$/GeV/c (TPC only)
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq$ *0.8$\times$ 10^{-4}/GeV/c (60% cov, TPC only)*

[1] The momentum resolution is proportiontal to 1/B according to Gluckstern's formula.(*see: R. L. Gluckstern, NIMA 24 (1963) 381-389*). At a B-field of 2T for Z-peak running for FCC-ee, the momentum resolution is therefore 3.5/2 times the value in the Table, i.e., 1.75 (2) $\times10^{-4}$/GeV/c (TPC only) and *1.4 $\times$ 10^{-4}/GeV/c (60% cov, TPC only)*

[2] The point resolution, 0.1 mm was assumed to be the same for GEM and MicroMegas. The value for the pixel option was assumed to be 0.055mm/$\sqrt{12}$ for zero drift and 0.4mm for maximum drift (B=0 asumed to be conservative): see page 7 of talk at the ILCX2021 workshop https://agenda.linearcollider.org/event/9211/contributions/58794/attachments/37527/58794/ILCX_pixelTPC_2021.pdf.

[3] The overal tracking resolution (including silicon tracking) is $\simeq 2 \times 10^{-5}$.

[4] Using the valuesfor the pixel version shown in Peter Kluit's talk on Thursay noon at the LCTPC collaboration meeting https://agenda.linearcollider.org/event/10902/)

•Some recent reports or workshops were:
•European Strategy forum on Particle Physics https://europeanstrategy.cern
•CEPC https://arXiv.org/abs/2203.09451
•The Physics Briefing Book https://arxiv.org/pdf/2511.03883
•The CEPC Reference Detector https://arxiv.org/pdf/2510.05260
•Huirong Qi at ILD meeting https://agenda.linearcollider.org/event/10890/

•Detector for FCC-ee is under study.
•'TPC RD for circular colliders' by Paul Colas on 20250114 at the 8th FCC Physics Workshop at CERN' https://indico.cern.ch/event/1439509
•Talk by Daniel Jeans on 20241218 https://agenda.linearcollider.org/event/10557/contributions/56005 attachments/40138/63634/TPC-BG-update-ild-swana-dec2024.pdf
•Assessment of large-scale accelerator projects at CERN - Report of ESG WG2a https://cds.cern.ch/record/2947728
•Plenary ECFA meeting https://indico.cern.ch/event/1567662
•ILC Newsline https://newsline.linearcollider.org/
•LC@CERN Workshop https://indico.cern.ch/event/1602105/
•9th FCC Workshop https://indico.cern.ch/event/1588696/