TPC Development by the LCTPC Collaboration for the ILD Detector at ILC

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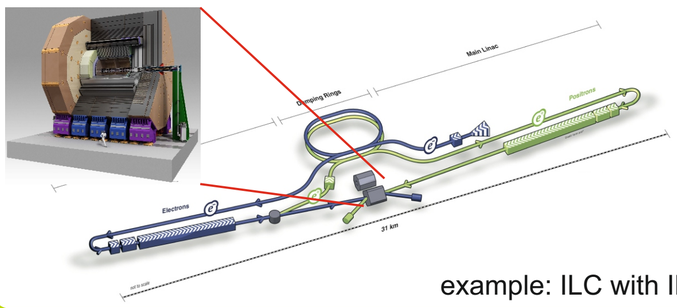
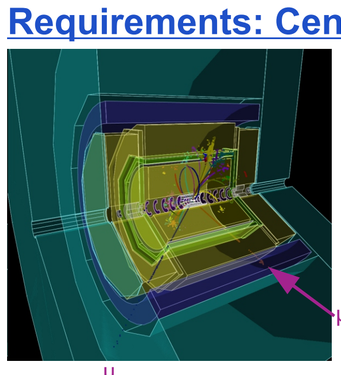
Project: Lepton Collider as Higgs Factory

International Linear Collider (ILC) /
Chinese Electron Position Collider (CEPC) /
Future Circular Collider (FCCee)
are e^+e^- colliders with:
$\sqrt{s}$ = 90 GeV – 1 TeV / 90-240 GeV
Overall length of 21-50 km / 100 km



example: ILC with ILD

Requirements: Central Tracker



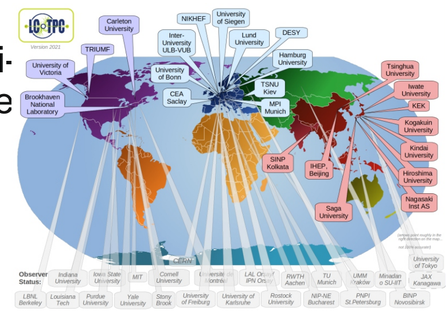
Requirements are driven by benchmark processes, in the case of ILD the most stringent measurement is the momentum resolution of the Higgs-recoil: $\partial(1/p_t) \sim 10^{-5}$ /GeV/c.

For the TPC this results in $\partial(1/p_t) \sim 10^{-4}$ /GeV/c throughout the complete drift. These requirements can only be fulfilled by a high precision TPC. [1]

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	$\simeq 5$ %

Collaboration: LCTPC

LCTPC-collaboration studies MPGD detectors for the ILD-TPC:
24 Institutes from 11 countries

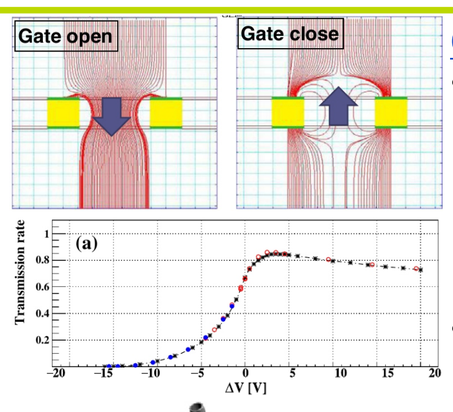


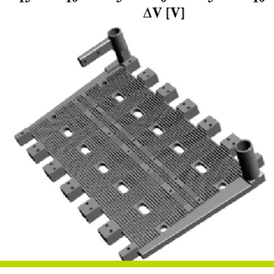
Various gas amplification stages are studied: GEMs, Micromegas, and GridPixes.

MPGDs in TPCs
- Ion backflow can be reduced significantly
- Small pitch → reduction of E×B-effects
- No preference in direction

Test Setup ‚Large Prototype' at DESY

Built to compare different detector readouts under identical conditions and to address integration issues
- PCMAG: B ≤ 1 T, bore diameter: 85 cm
- Electron test beam: E = 1- 6 GeV
- LP support structure
- Beam and cosmic trigger
- LP Field Cage Parameter [2]
  length = 61 cm, inner diameter = 72 cm
  made of composite materials: 1.24% X_0
- End Plate with 7 module windows
  → size ≈ 22 × 17 cm^2 each
- Si-tracker ‚LYCORIS' inside magnet walls
  → spatial resolution: σ = 7 μm [3]



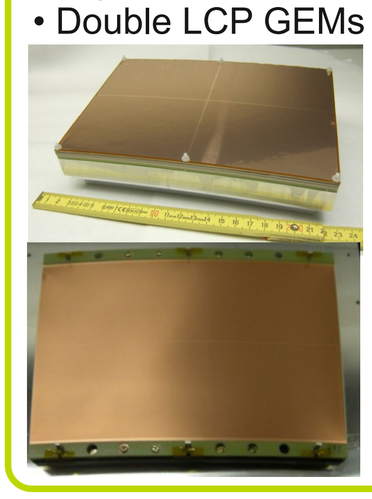


Common Developments

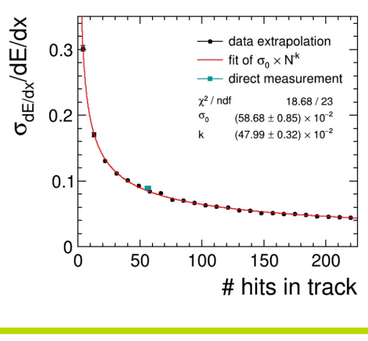
- GatingGEM: gating possible at ILC because of bunch train structure: gating GEM has large holes (Ø 300 μm) and thin strips inbetween (30 μm).
  → electron transparency of 82 % and good ion blocking power proven [4]
- Electronics: developed 10,000 channels of readout electronics based on ALTRO and sALTRO ASICs
- Cooling unit: 2-phase CO_2 closed loop with 60 bar pressure; cooling plates for modules 3D-printed in aluminum
- Next step: Common module with same pad plane, gatingGEM and sALTRO.

Modules with Gas Electron Multipliers

Two implementations:
- Triple CERN GEMs on thin grids [5]
- Double LCP GEMs (100 μm thick) [6]

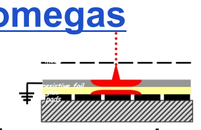


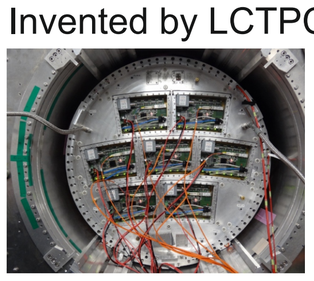
Guard ring to minimize field distortions.



Modules with Resistive Micromegas

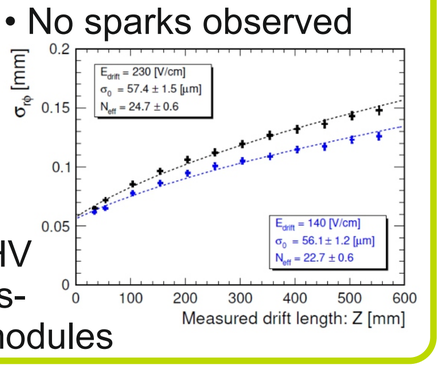
Invented by LCTPC group [7]



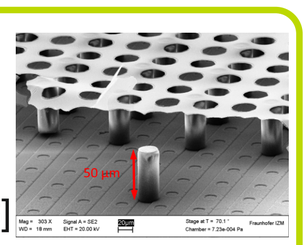


- Allows for larger pads with same spatial resolution
- No sparks observed

New design with inverted HV configuration:
Mesh grounded resistive layer on HV
=> reduces field distortions between modules

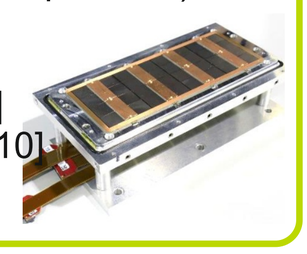


Modules with GridPixes



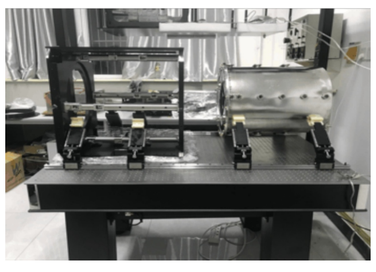
Micromegas stage built by photolithographic post-processing on top of pixel readout ASIC Timepix(3) [8]
→ pixel pitch 55μm×55μm
- Lower occupancy → easier track reco
- Removal of δ-rays and kink reconstruction
- Improved dE/dx (4% seems possible)
- No angular pad effect

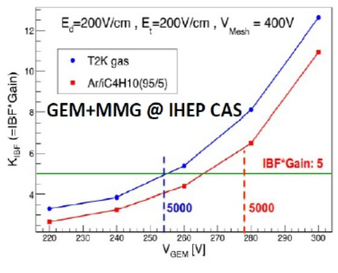
Testbeams with GridPixes
160 GridPixes (Timepix) [9]
32 GridPixes (Timepix3) [10]
successfull.



Modules with GEMs and Micromegas

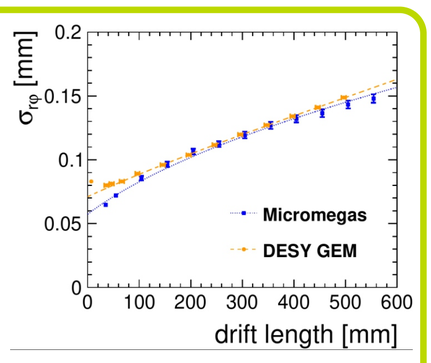
Proven to have low ion backflow
=> Studied in context of CEPC or FCCee
Setup in Beijing
to optimize the ion backflow
to test new low power readout ASICs
to study tracking performance with UV-laser





Summary and Outlook

- All pad based technologies have a very similar tracking performance
- Next step: Building a common module to compare technologies in a next generation module
- Synergies with T2K / ALICE / CEPC / EIC enable continued R&D and profiting from their experience and R&D. LCTPC is open for groups interested in applications beyond the scope of ILC.
- In particular we are starting an effort to investigate the feasibility of a MPGD-TPC at CEPC and FCCee in more detail (mostly ion backflow and track distortions corrections.)
- Numerous simulation studies to be done to optimize the detail design of the final detector. (e.g. number of ADC bits, pad sizes, etc.),
  but also new ideas for old challenges are welcome.



[1] ILC TDR vol. 4
[2] JINST 5: P10011, 2010
[3] JINST 16: P10023, 2021
[4] NIM A956 (2020) 163331
[5] NÌM A856 (2017) 109-118
[6] NIM A608 (2009) 390-396
[7] NIM A581(2007) 254
[8] NÌM A535 (2004) 506-510
[9] IEEE TNS 64 (2017) 1150
[10] NIM A956 (2020) 163331