A Large TPC Prototype for an ILC Detector

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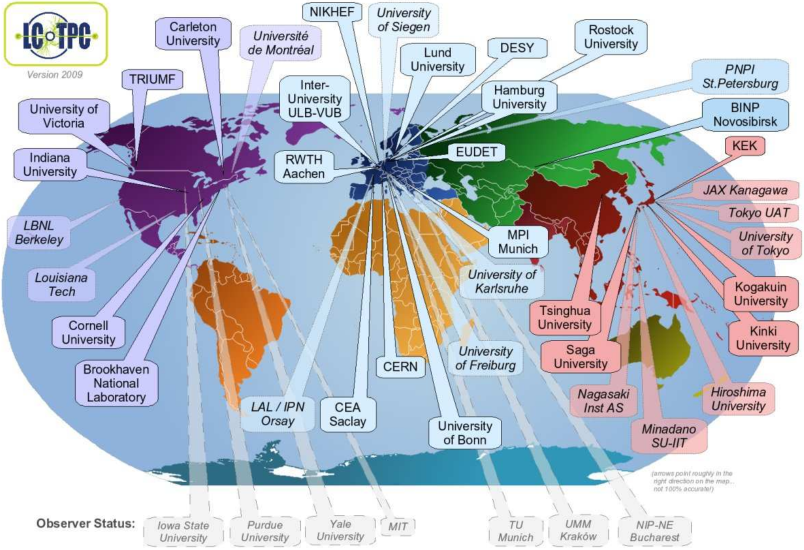
on behalf of the LCTPC Collaboration

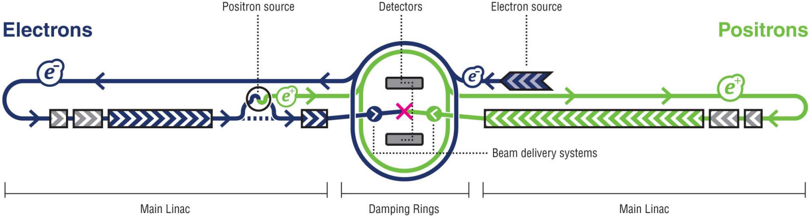
DESY Hamburg

16th February 2010

The LCTPC collaboration



Future e^+e^- Linear Collider

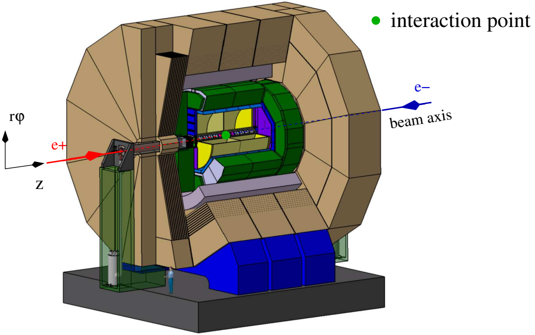


International Linear Collider - ILC

- e^+e^- collider @ $\sqrt{s} = 500\,\mathrm{GeV}$ (upgradeable to $1\,\mathrm{TeV}$)
- luminosity: $\mathcal{L} = 2 \cdot 10^{34}\,\mathrm{s}^{-1}\mathrm{cm}^{-2} \rightarrow 500\,\mathrm{fb}^{-1}$ in four years
- construction could start around 2015

- Compact Linear Collider CLiC with up to $\sqrt{s} = 3\,\mathrm{T}$
  $\rightarrow$ technical feasibility to be demonstrated

ILD Detector Concept



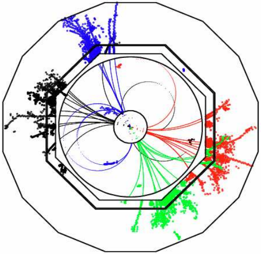
Optimized for Particle Flow

- 3.5 T solenoid with highly granulated HCAL and ECAL inside
- large Time Projection Chamber
- silicon vertex detectors
- slightly inhomogeneous magnetic field (Anti - DiD)

Why a TPC at a Linear Collider

- Particle Flow is believed to be the optimal reconstruction scheme for expected physics signatures at ILC energies
  $\longrightarrow$ requires tracking with highest precision and efficiency
  $\longrightarrow$ robust identification of every particle, even in jets

- a TPC is well suited for Particle Flow
  $\longrightarrow$ robust tracking - up to 200 space points per track (ILD)
  $\longrightarrow$ TPC is robust towards backgrounds
  $\longrightarrow$ $^{dE}/_{dx}$-measurement input to particle identification
  $\longrightarrow$ TPC has a low material budget

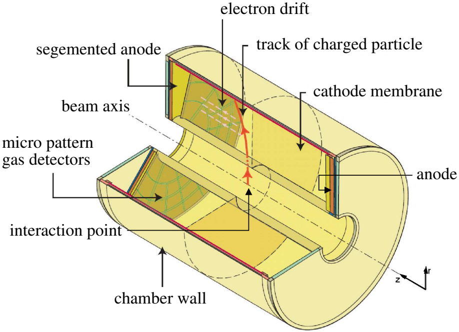


Requirements to a LC TPC

- Particle Flow reconstruction defines stringent requirements to all subdetectors
- for the TPC:

Requirements to TPC (ILD)

- size: $L = 4.3\,\mathrm{m}$ - $d = 3.6\,\mathrm{m}$
- $\sigma_{\perp}^{\text{point}} \leq 100\,\mu\mathrm{m}$
- low material budget
  - $\rightarrow$ 1 % X_0 inner wall
  - $\rightarrow$ 4 % X_0 to outer wall
  - $\rightarrow$ 15 % X_0 endcap
- operation in DID field



$\Rightarrow$ performance about ten times better compared to previous TPCs

Road map of the TPC R&D for an LC

- LCTPC collaboration aims at the development of the TPC of a LC collider detector
- performance goals require substantial improvements of traditional readout techniques
  → new technique: readout with micro pattern gas detectors

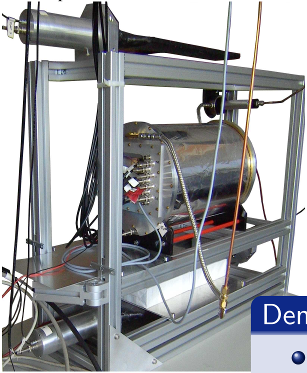
R&D phases

1. Demonstration phase - Prospect studies:
   → operation of MPGD readout in small/medium prototypes
   → demonstration of feasibility
2. Consolidation phase - Technical studies:
   → development of large scale readout structures (ILD module)
   → operation techniques to cope with inhomogeneous B-field
3. Construction phase - Build the ILD TPC

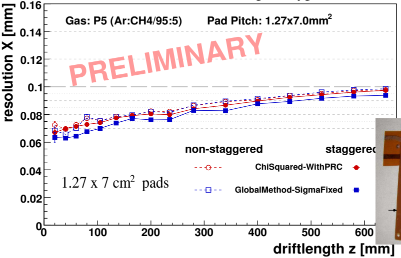
MPGD based TPC readout: Prospect Studies

- small prototypes: diameter $\leq 30\,\mathrm{cm}$ - drift length $\leq 80\,\mathrm{cm}$

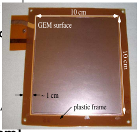
Test setup @ Bonn



Resolution Measurement with DESY prototype



10x10 cm² GEM



Demonstration Phase

- Pad - Pixel readout $\Leftrightarrow$ GEMs - Micromegas
- $\sigma_\perp \lesssim 100\,\mu\mathrm{m}$ measured
  $\rightarrow$ for drift lengths of up to $60\,\mathrm{cm}$

$\Rightarrow$ TPC with MPGD readout can reach $\sigma_\perp \leq 100\,\mu\mathrm{m}$

Infrastructure for Consolidation Phase - EUDET setup

- for the development of large scale MPGD readout structures
  $\rightarrow$ Large TPC prototype required with diameter $\mathcal{O}(1\,\mathrm{m})$
  $\rightarrow$ magnet with inhomogeneous and measured field
  $\rightarrow$ test beam with external reference detectors

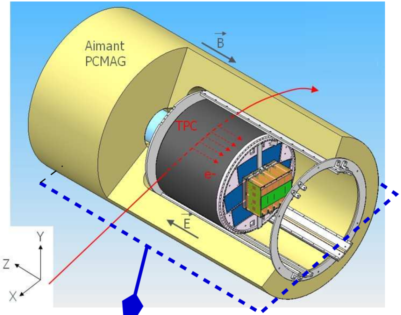
- TPC R&D setup installed at DESY e^{-} test beam
  $\rightarrow$ within the EUDET program
- superconducting magnet (PCMAG)
- silicon tracking detectors
- Large Prototype (LP) - consisting of
  $\rightarrow$ field cage with cathode

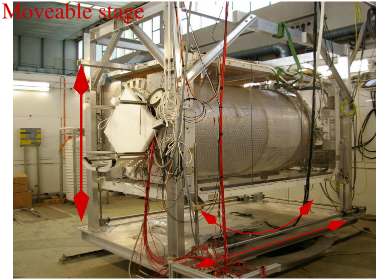
- anode end plate for LP constructed within LCTPC collaboration

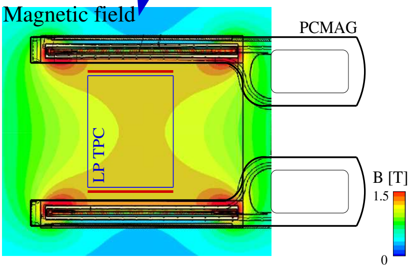
Large TPC Prototype: Testbeam Setup

EUDET setup for TPC R&D

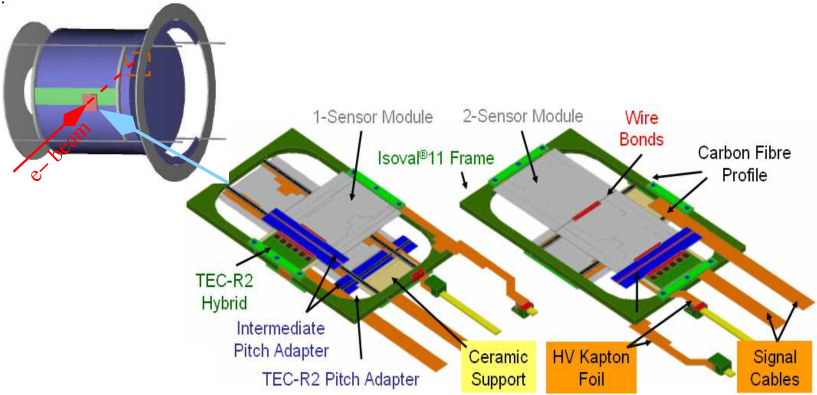
- PCMAG with $B \leq 1.25\,\mathrm{T}$
- bore diameter: $85\,\mathrm{cm}$
- LP support structure
- Test Beam e^- with $1\,\mathrm{GeV} \leq E_{\mathrm{beam}} \leq 6\,\mathrm{GeV}$







Testbeam Setup - Silicon Tracking detectors



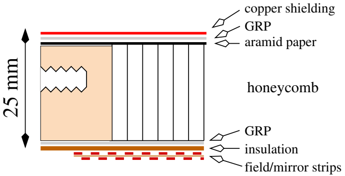
- 2 layers of Pixel modules with 20 $\mu\mathrm{m}$ spacial resolution
- two unbiased points along the trajectory <u>inside</u> PCMAG
  $\rightarrow$ for the development of TPC reconstruction algorithms in inhomogeneous magnetic fields

Large TPC Prototype: Field Cage

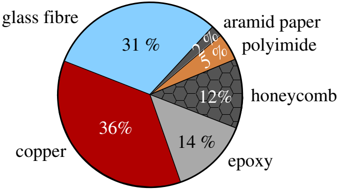
LP Field Cage Parameter

- L=61 cm - d_{inner} = 72 cm
- up to 25 kV at the cathode drift field → $E \approx 350\ {}^{V}/_{cm}$

→ structure made from composite materials



→ material budget: 1.24 % X_0



⇒ 1 % X_0 per wall within reach

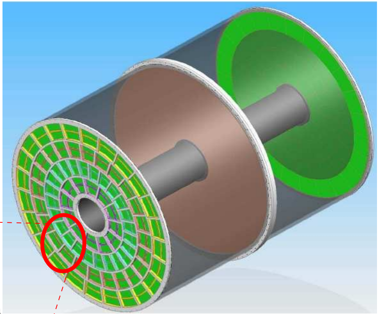
Large TPC Prototype: Anode Endplate

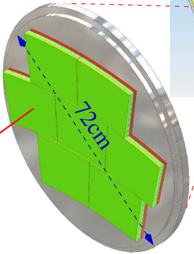
Modular Enplate

- first endplate for the LP made from Al
- 7 module windows
  $\longrightarrow$ size $22 \times 17\,\mathrm{cm}$

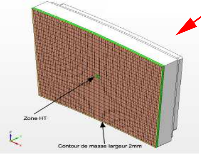
$\longrightarrow$ D. Peterson, U. Cornell

TPC @ Linear Collider Detector





Prototype module



Detector side

Large TPC Prototype: Anode Endplate

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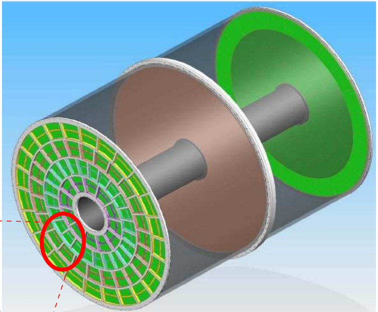
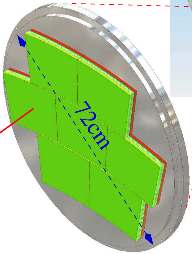
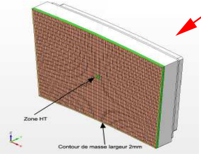
TPC @ Linear Collider Detector

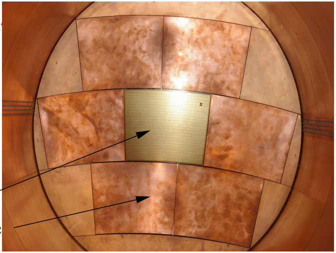




Prototype module



Detector side



micromegas

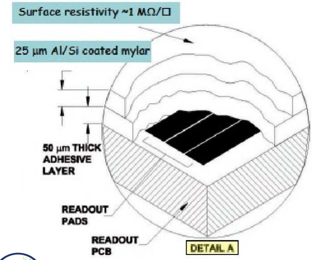
blind module

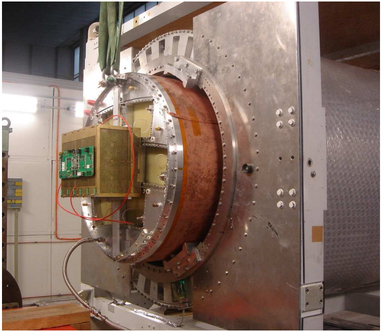
Testbeam with Micromegas Module

Micromegas Module

- 24 row with 72 pads each $3.2 \times 7\,\mathrm{mm}^2$
- resistive foil / carbon loaded kapton ($1\,\mathrm{M}\Omega/\mathrm{sq}$)
  $\rightarrow$ charge spreading over pads
- AFTER electronics (T2K)

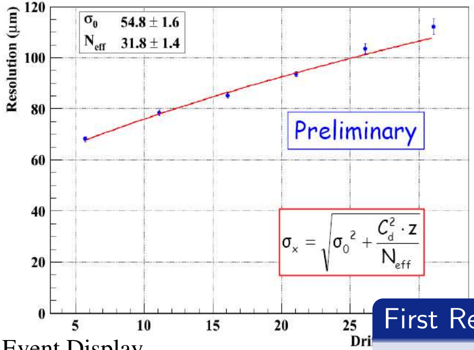
$\rightarrow$ P. Colas, CEA Saclay M. Dixit, Carleton U.



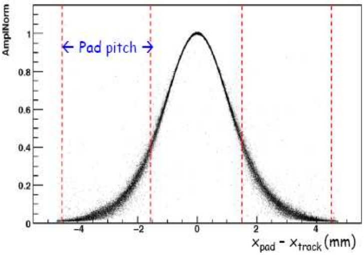


Testbeam with Micromegas Module

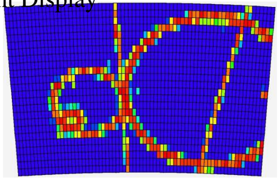
- Resolution at z=0: σ_0 = 54.8±1.6 µm with 2.7-3.2 mm pads (w_{pad}/55)
- Effective number of electrons: N_{eff} = 31.8±1.4 consistent with expectations



Charge spread over pads



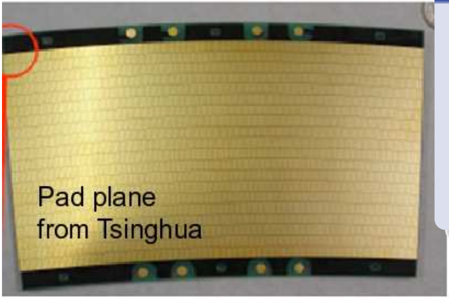
Event Display



First Results (Micromegas module)

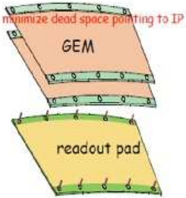
- setup: $5\,\mathrm{GeV}\,e^-$ - $B = 1\,\mathrm{T}$
  $\rightarrow \sigma_\perp(z=0) \approx 55\,\mu\mathrm{m}$
  $\rightarrow N_{\mathrm{eff}} = 31.8 \pm 1.4$
- charge spread over 2 - 3 pads

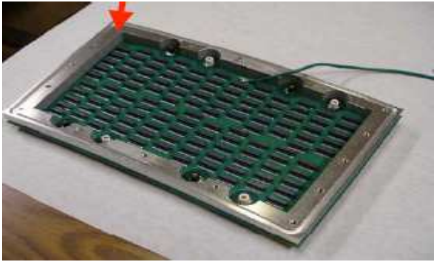
Testbeam with GEM Module



GEM module

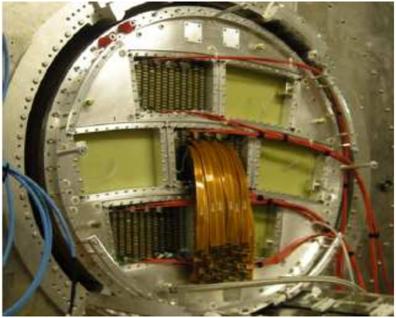
- $1.2 \times 5.4\,\mathrm{mm}^2$ pads - staggered
- 28 pad rows (176-192 pads/row)
- about 5000 ch. per module
- 6 layer PCB board
- stretched mounting of GEMs



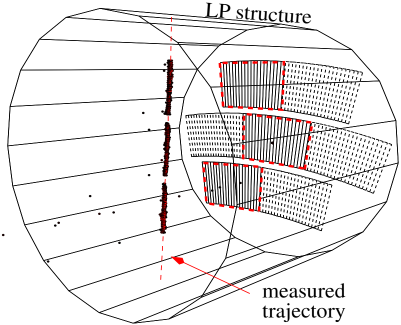


→ A. Sugiyama, Saga. University

Testbeam with GEM Module



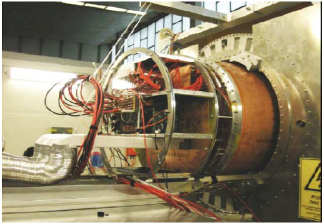
Event display with three modules



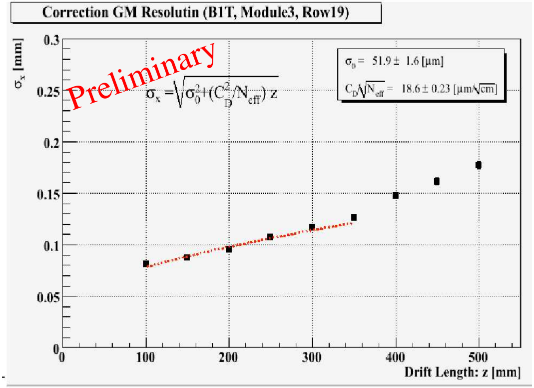
Readout Electronics

- 3 modules operated
  → in total 3200 channels used
- electronics based on the ALTRO chip (ALICE)

→ L. Joensson, LUND U.



Testbeam with GEM Module

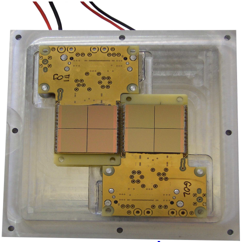


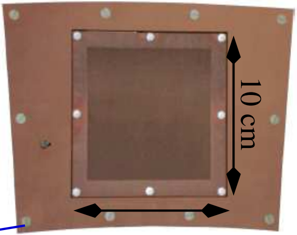
First Results (GEM modules)

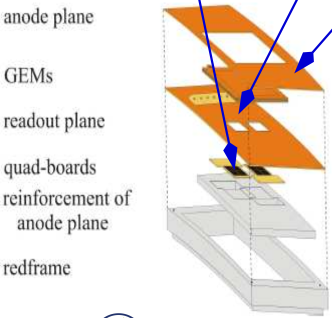
- res. parametrized as $\sigma_\perp = \sqrt{\sigma_0^2 + D^2/N_{\text{eff}} \cdot z}$
  $\rightarrow D/\sqrt{N_{\text{eff}}} = 18.5 \pm 0.2\,\mu\text{m}/\sqrt{\text{cm}} - \sigma_0 = 51.9 \pm 1.6\,\mu\text{m}$

$\Rightarrow$ GEM and Micromegas module show similar performance

GEM Structure & Timepix

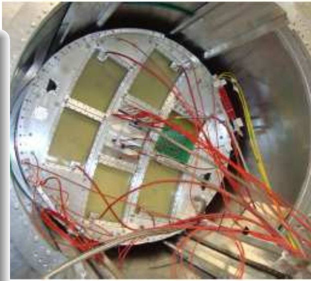






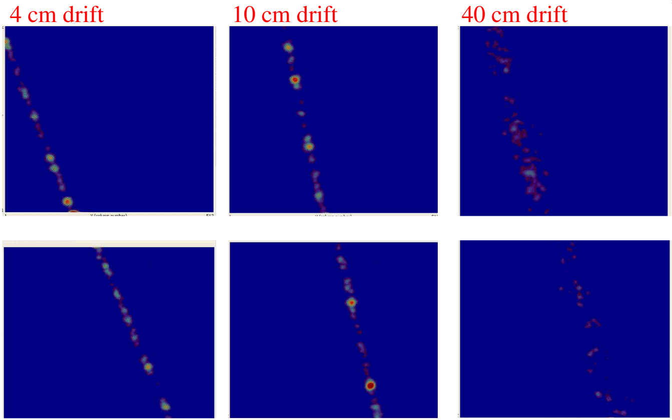
Timepix Module

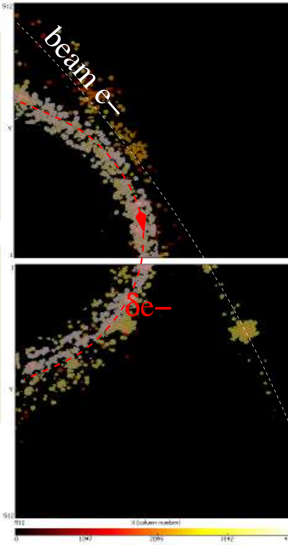
- eight chips $1.4 \times 1.4\,\mathrm{cm}^2$ each
- two quad boards
- $55 \times 55\,\mu\mathrm{m}^2$ pixel
- 65000 ch. per chip $\rightarrow$ total: $500 \cdot 10^3$



→ J. Kaminski, Bonn U.

GEM Structure & Timepix

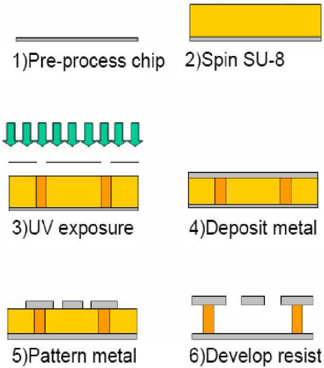


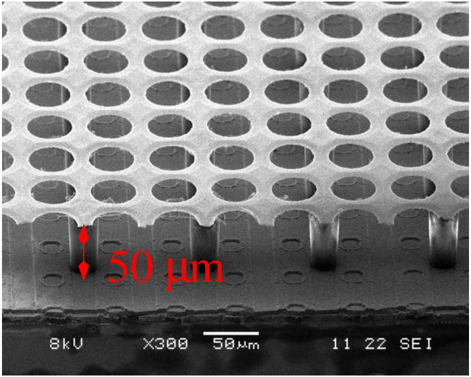


- finest granularity for a TPC readout so far
  - → single cluster detection
  - → clear identification of δ-electrons possible
  - → cluster counting to improve ${}^{dE}/_{dx}$-measurement

→ analysis of testbeam data ongoing

InGrid technology





InGrid Chip

- produced in CMOS technology
  → silicon pixel chip : 1 μm AL grid 50 μm pillars
- one hole per pixel and very flat surface

→ J. Timmermans, NIKHEF

Summary and Outlook

- LCPTPC collaboration performs R&D work for a TPC at a future e^+e^- linear collider
  → large TPC prototype built and commissioned
  → part of comprehensive setup for TPC R&D @ DESY
- GEMs and Micromegas are under investigation for the read out of an LC TPC
  → with standard pad or silicon pixel readout
- test beam campaigns in 2009 with both technologies
  → data analysis ongoing
  → first results look very promising
- further testbeam campaigns in 2010
  → 10.000 channels of ALTRO electronics for 3 GEM modules
  → up to seven Micromegas modules with AFTER electronics
  → combination with silicon tracking detectors