

A TPC for a Future Linear Collider

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On behalf of the LC TPC groups:

Aachen, Berkeley, Carleton, Cracow, DESY, Hamburg, Karlsruhe, MIT, Montreal,
MPI Munich, NIKHEF, Novosibirsk, Orsay, St. Petersburg, Rostock, Saclay, Victoria

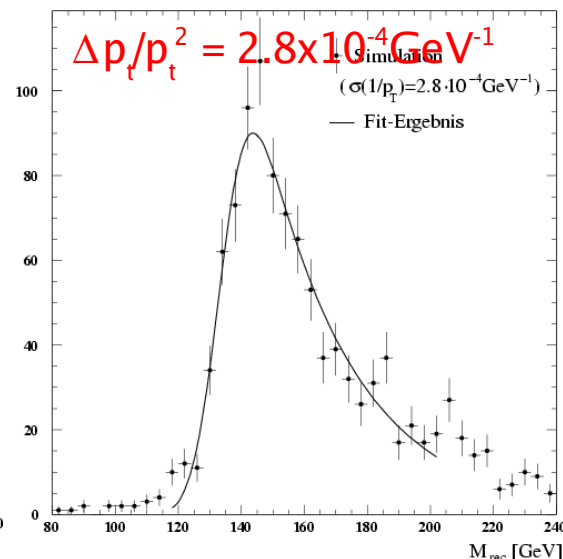
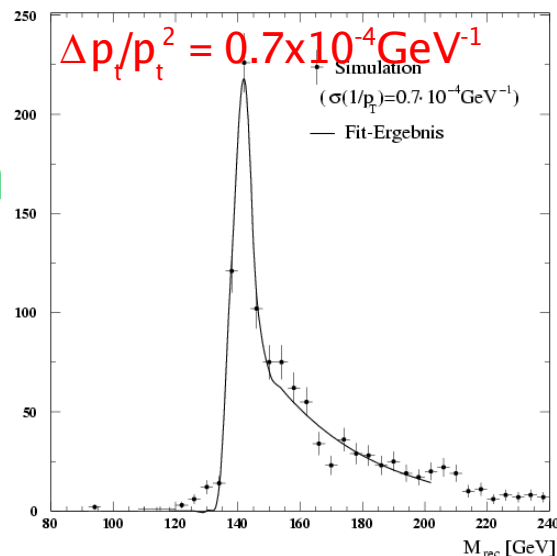
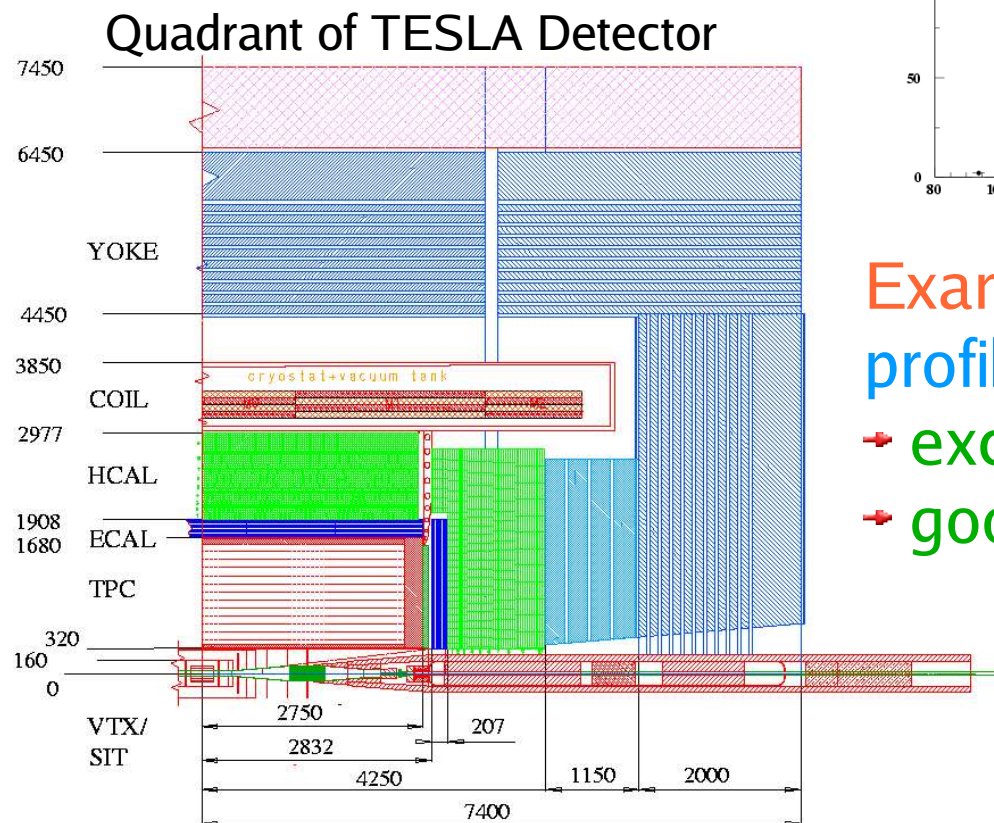
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Portland, Oregon, USA

A Detector for a Linear Collider

LC: e^+e^- collider, $m_Z \leq \sqrt{s} \leq 1 \text{ TeV}$,

$$L \leq 5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$

LC detector concepts: focus on precision



Example: Reconstruction of Higgs profile requires:

- excellent momentum resolution
- good particle identification

High resolution tracker is essential to achieve this goal

TPC (Time Projection Chamber)

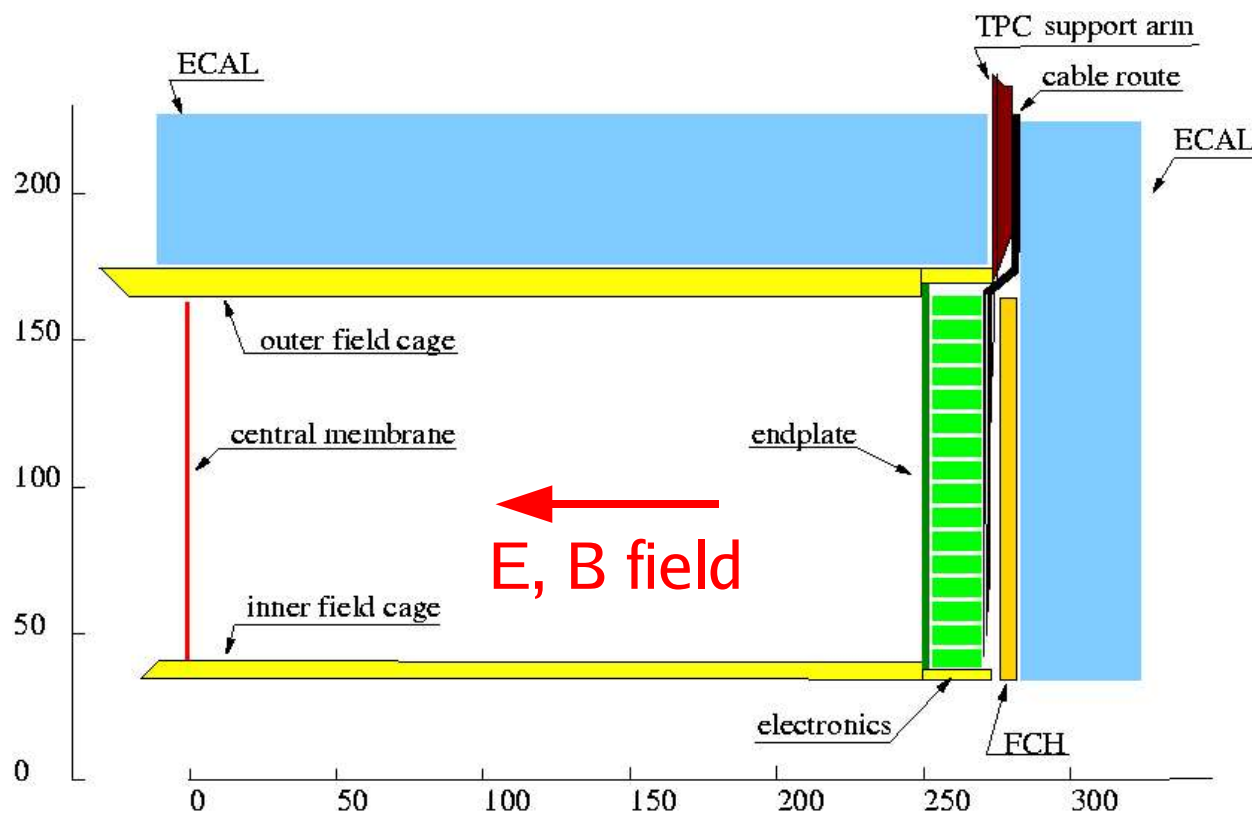
Instrument a large volume with many voxels and a minimum amount of material, 3D reconstruction, good particle identification via dE/dx

Example: TESLA TPC

- Length 5.46 m
- \varnothing 3.4 m
- Field cage $0.03 X_0$
- 1.2×10^6 channels
- 200 points per track

Envisaged precision:

- Momentum resolution: $\Delta p_t/p_t^2 = 1.5 \times 10^{-4} \text{ GeV}^{-1}$ (10 x LEP)
- Single point resolution: 100 μm
- dE/dx accuracy: 5 %



Goals of R&D Activities

- Understand and optimize novel gas amplification systems
- Optimize single point and double track resolution
- Measure performance of TPC under high magnetic fields
- Prove that systematics are under control and operation of large system is possible

In addition:

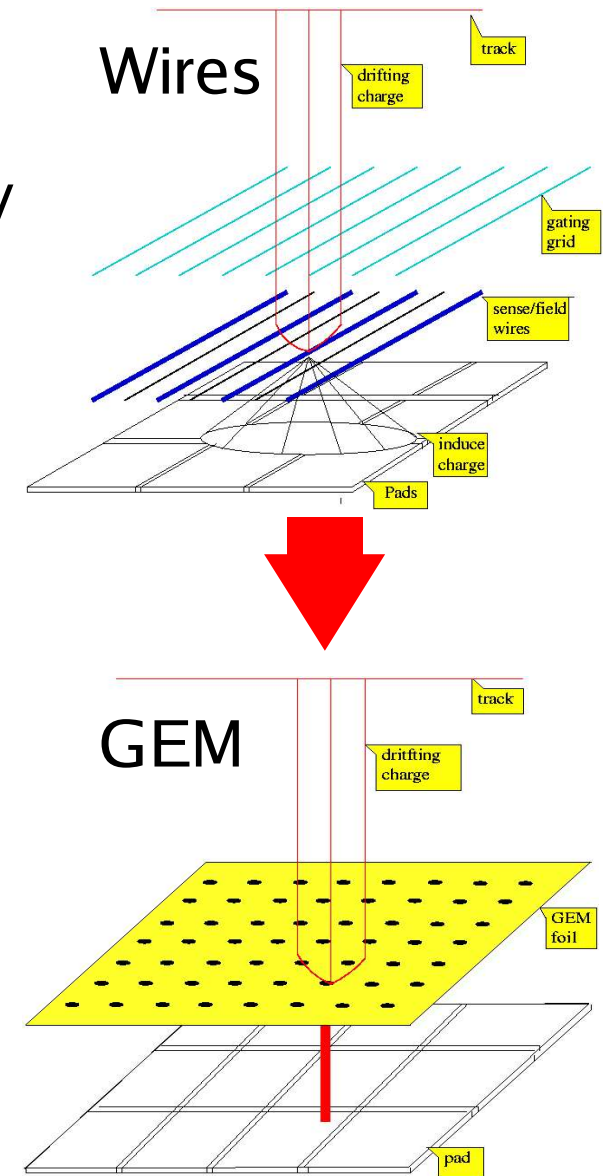
- Development of field cage: low material budget, HV stability, good field shaping properties
- Choice of gas: resolution, machine background, aging
- Design of endplates
- Readout electronics
- Calibration system

New Gas Amplification Systems

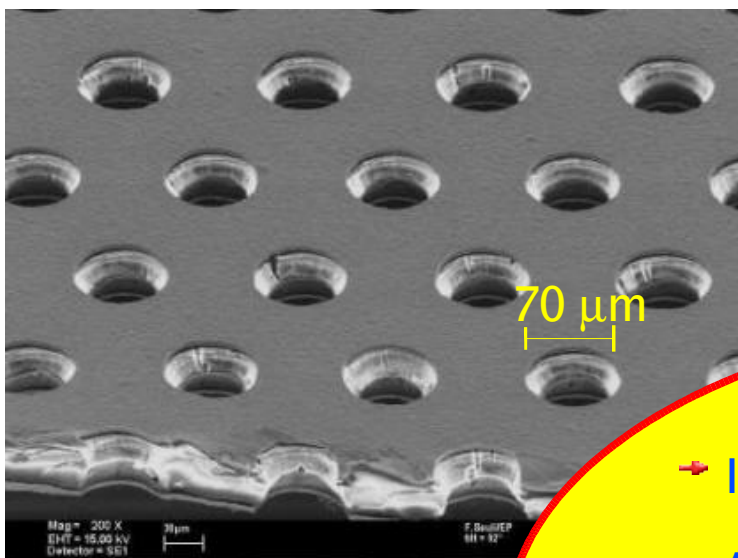
Replace conventional MWPC system (wires) by Micro Pattern Gas Detectors (MPGD):

Most promising examples:

- **Gas Electron Multiplier (GEM)** (F. Sauli, 1997)
- **Micromegas** (Y. Giomataris *et. al.*, 1996)

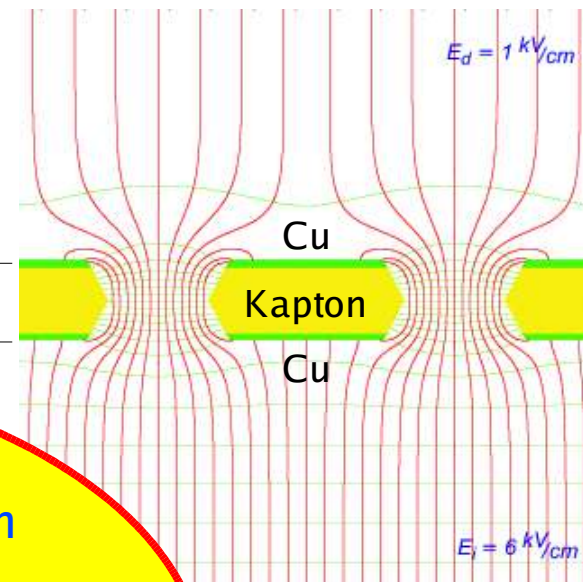


GEM and Micromegas



GEM

300-500 V

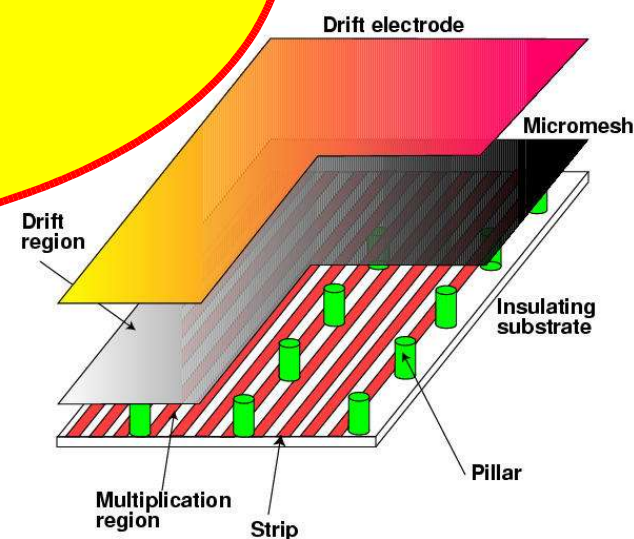


Advantages:

- Intrinsic ion feedback suppression
- Amplification structures of order $\sim 100 \mu\text{m}$
- Two-dimensional symmetry
- Fast electron signal
- Allows simpler mechanics



Micromegas



Resolution Studies with Magnetic Field

Saclay, Orsay, Berkeley



Measurement of point resolution with GEM/Micromegas amplification system in strong magnetic fields

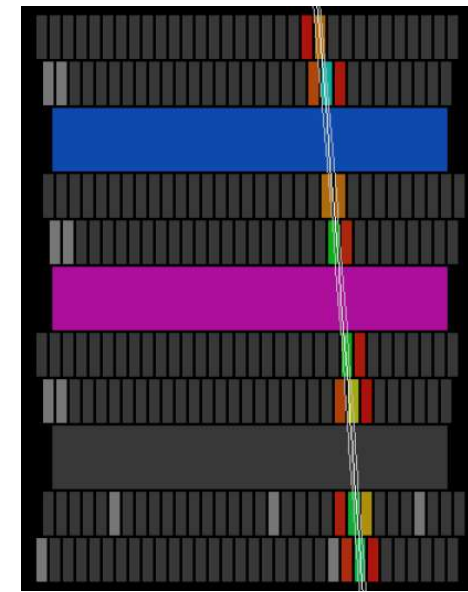
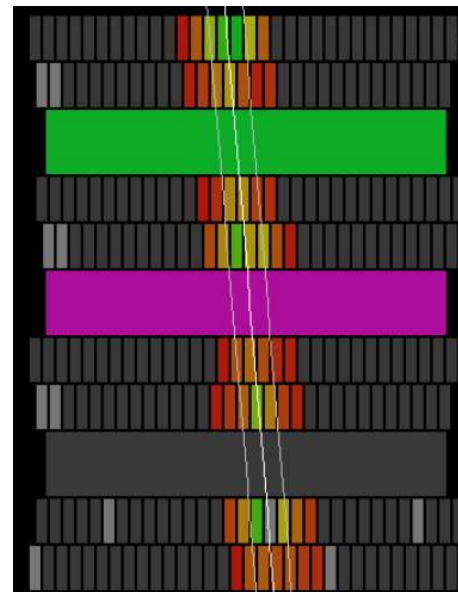
Events in P5 with ≈ 25 cm drift distance

$B = 0$ T

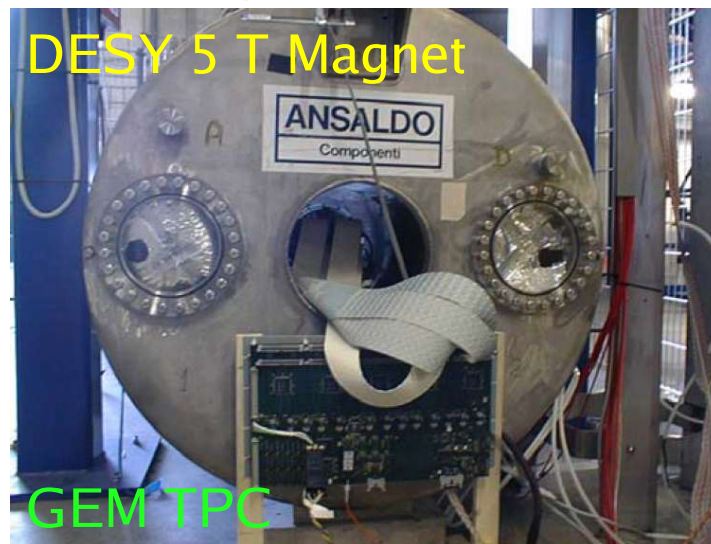
track width = 2.6 mm

$B = 5.3$ T

track width = 0.37 mm



University of Victoria, DESY

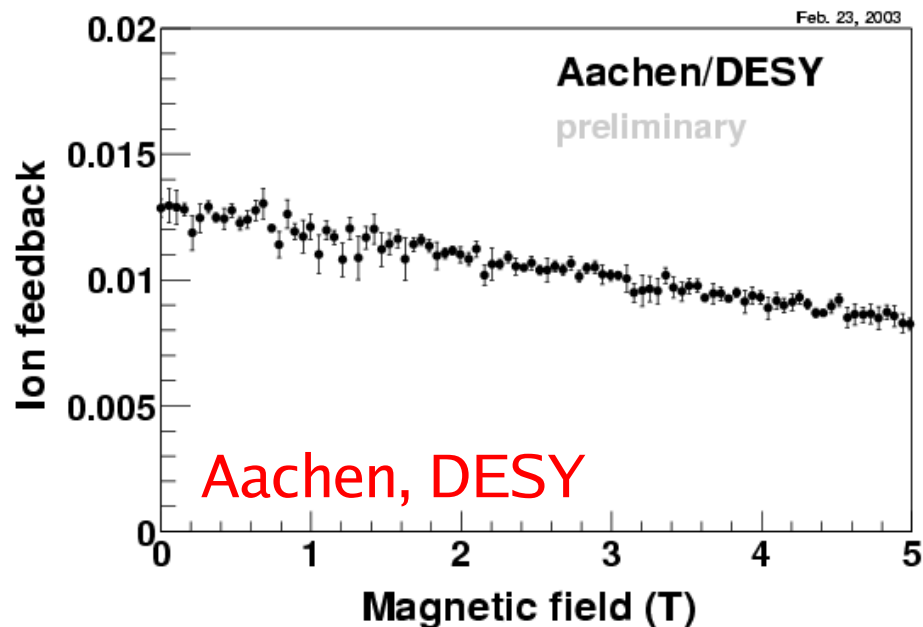


Details \rightarrow Talks by D. Karlen, V. Lepeltier

Ion Feedback in Magnetic Field

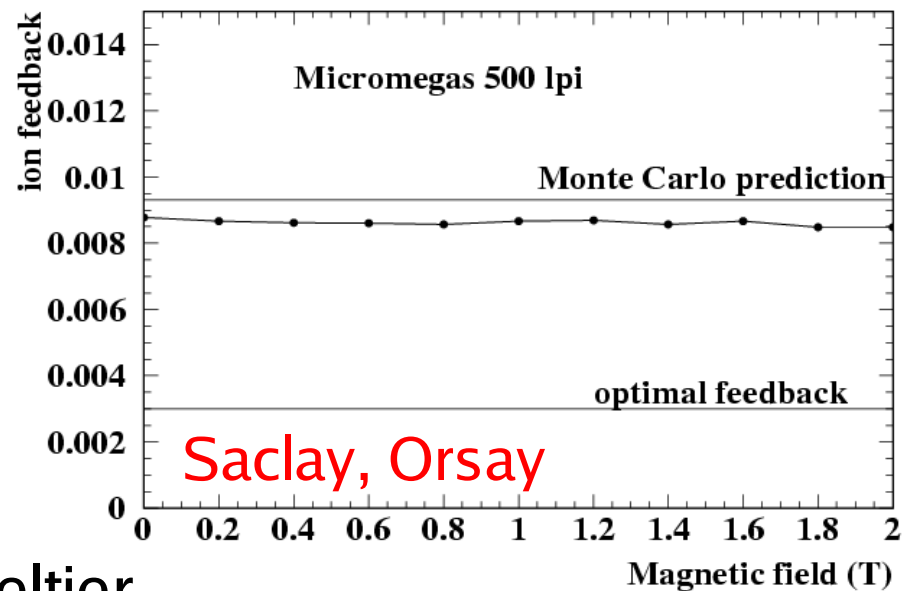
GEM:

Ion feedback decreases with magnetic field



Micromegas:

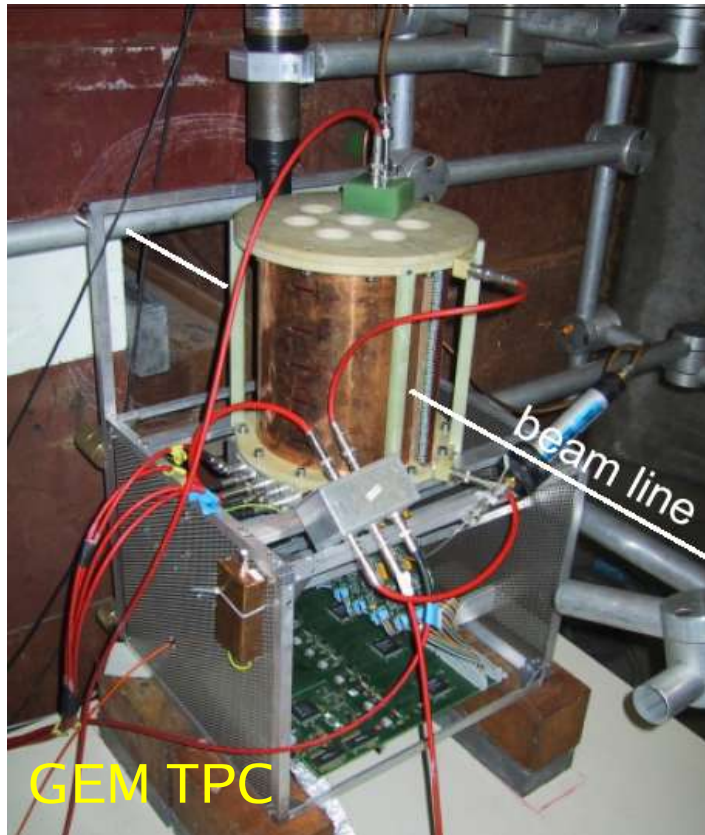
No influence of magnetic field on ion feedback



Details → Talks by J. Mnich, V. Lepeltier

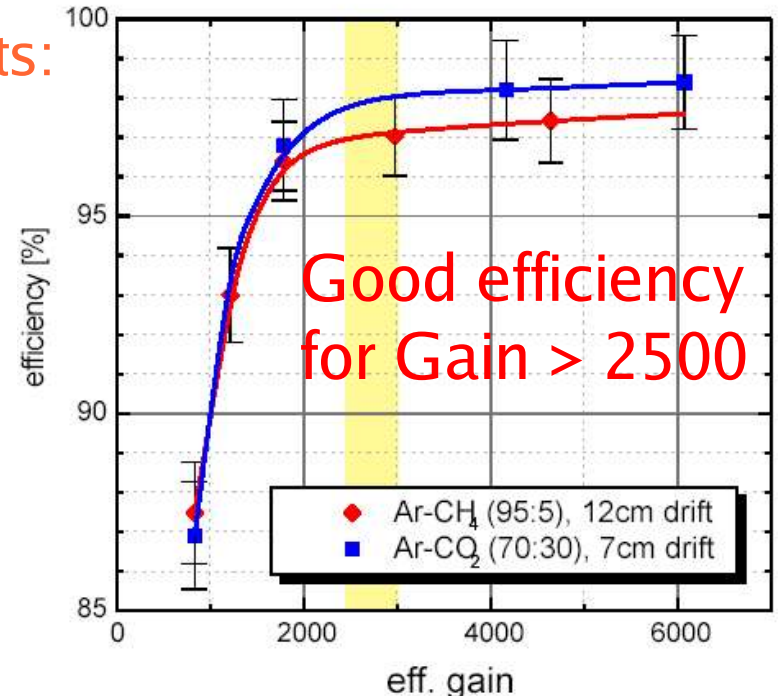
Test Beam Measurements

University of Karlsruhe, DESY Addressed questions:



- Single point resolution (various angles)
- Double track resolution
- Space charge effects
- Pad row efficiency

One of first results:
Single pad row efficiency

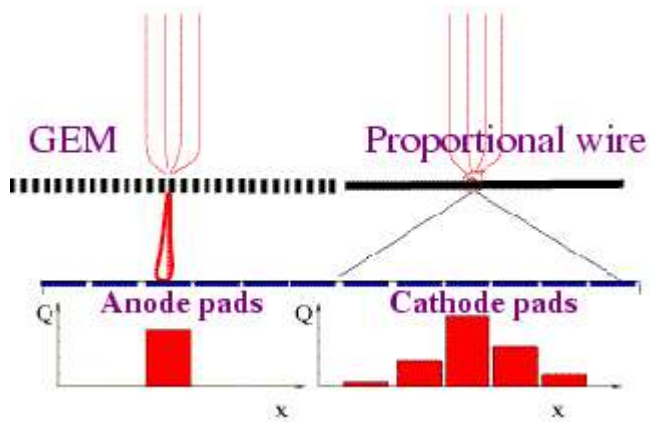


- 9 GeV p/π^\pm beam at CERN
- Max. intensity 1.5×10^3 tracks $s^{-1}mm^{-2}$

Details → Talk by S. Kappler

Many more interesting results expected in near future

New Charge Detection Developments



Disadvantage of electron signal:

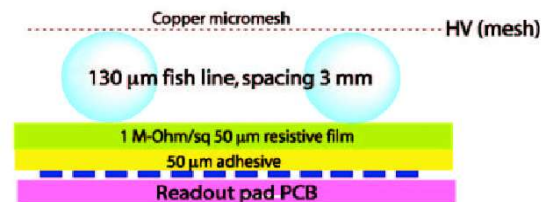
- Much narrower than induction signal
- Charge collected on one pad
- Center-of-gravity impossible

Possible solutions:

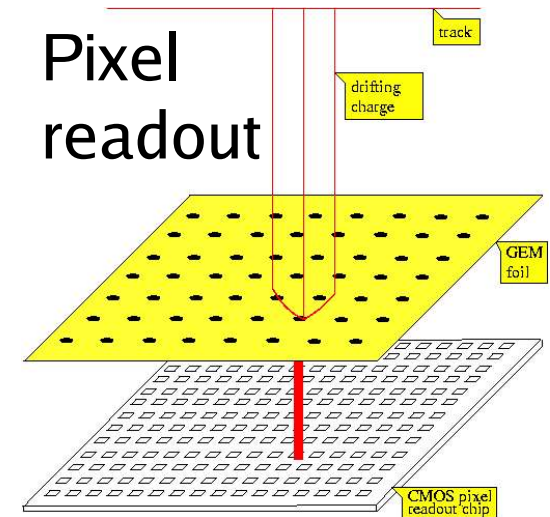
- Smaller conventional rectangular pads
- Alternative pad shapes
- Resistive or capacitive coupling of pads
- Pixel detector (small granularity)



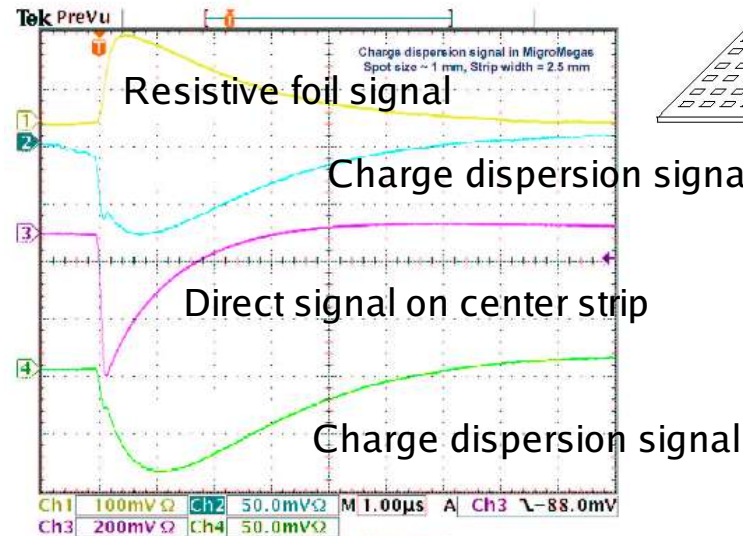
Resistive foil



Peter Wienemann



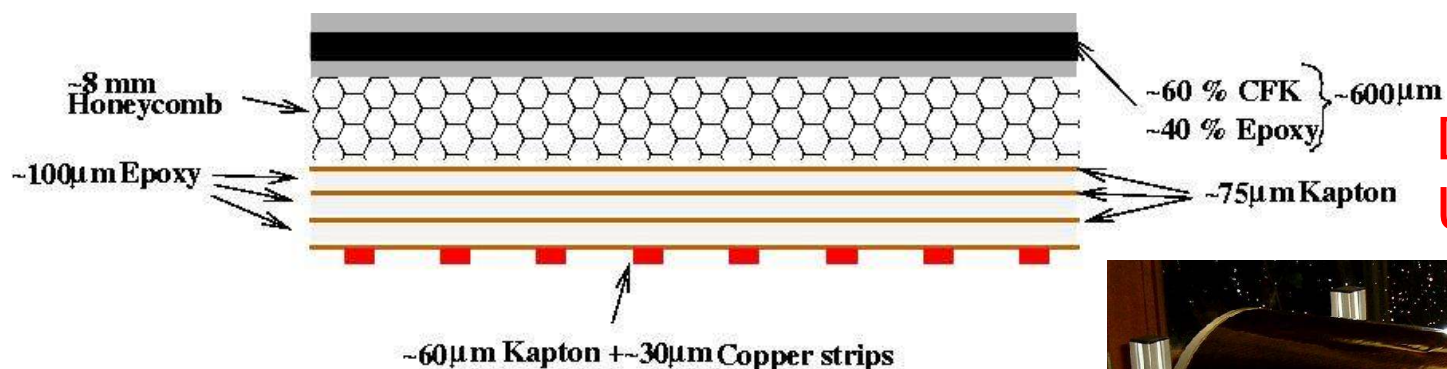
NIKHEF



Carleton,
Orsay,
Saclay

IEEE NSS 2003, Portland

Field Cage Development

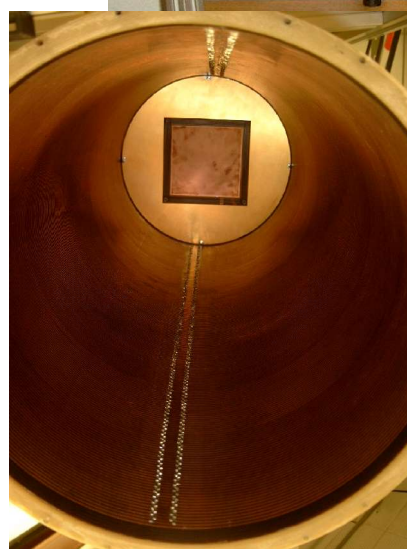
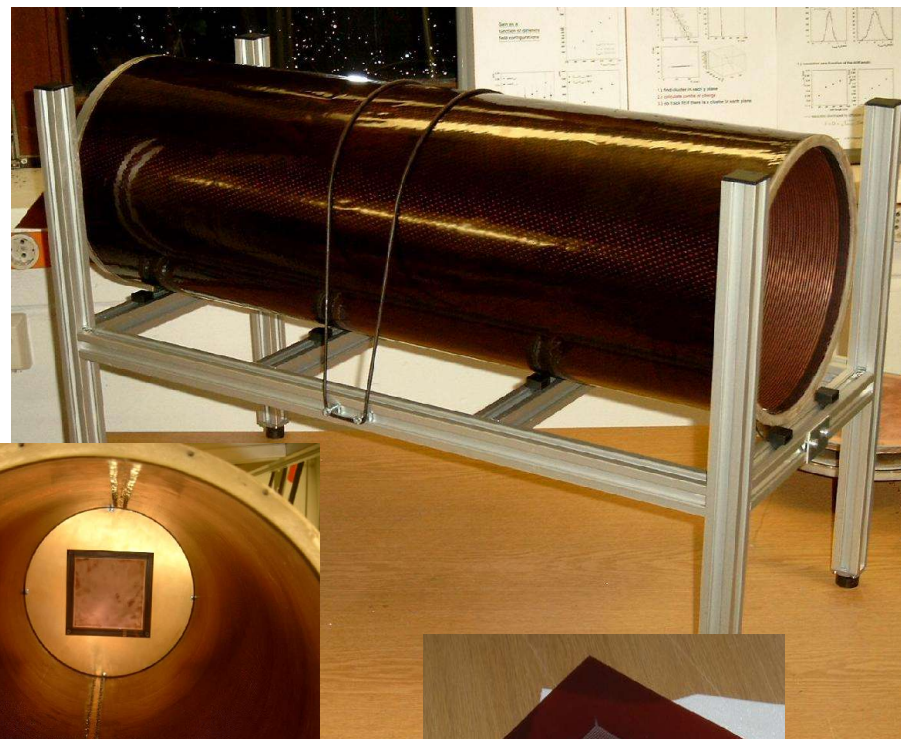


DESY,
University of Hamburg

Prototype field cage with low material budget built

Tests to be done:

- Check field homogeneity
- Compare with simulation (St. Petersburg, Aachen)
- Optimize strip layout
- Verify longterm HV stability



Summary

- A LC detector poses unprecedented requirements on the precision of its tracker. A TPC is considered to be a good choice to achieve the goal.
- A world wide LC TPC group has been formed to address this challenge
- GEMs and Micromegas are promising candidates as a replacement of conventional MWPC gas amplification systems
- Much more R&D efforts are necessary to prove that the ambitious performance goals can be achieved under operating conditions found at a LC