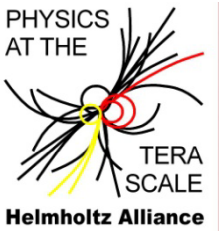
Development of a TPC for a Linear Collider

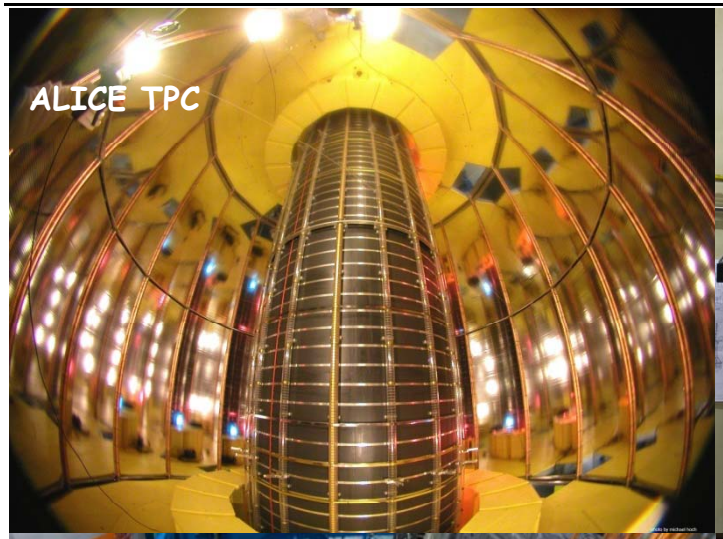
K. Desch • Universität Bonn • 04/04/2008

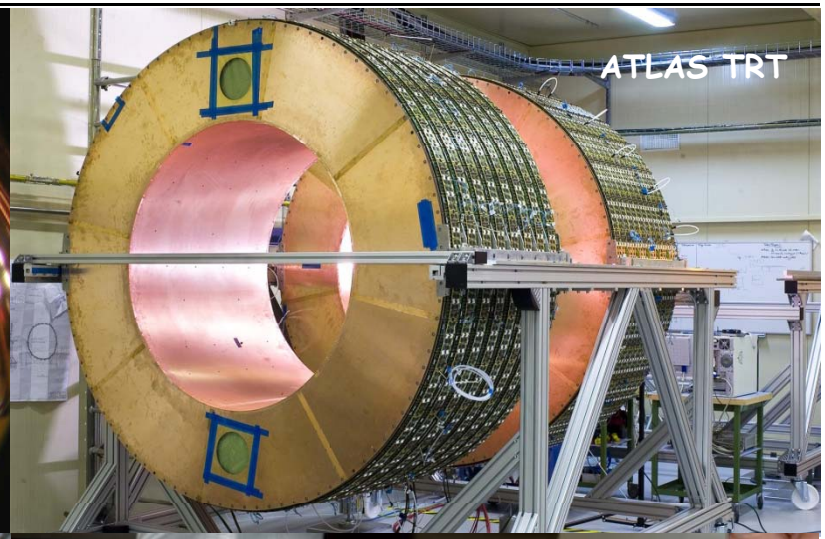
1st Detector Workshop of the Helmholtz-Alliance "Physics at the Terascale"
Universität Karlsruhe

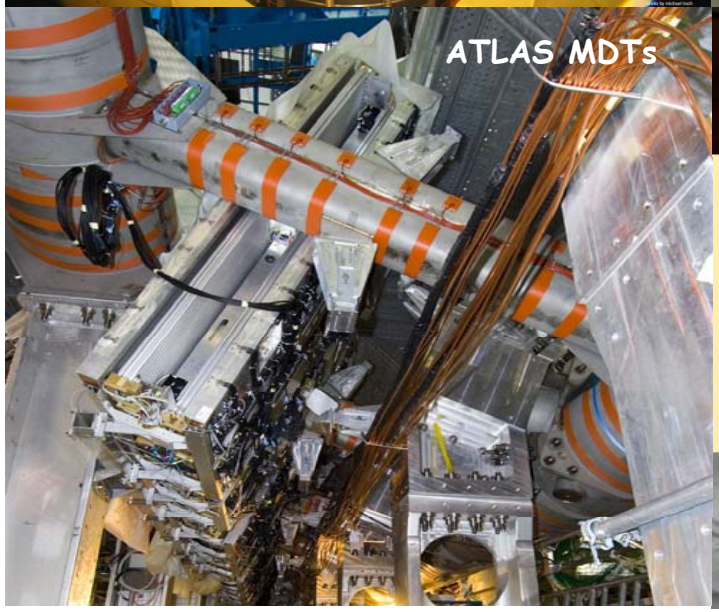


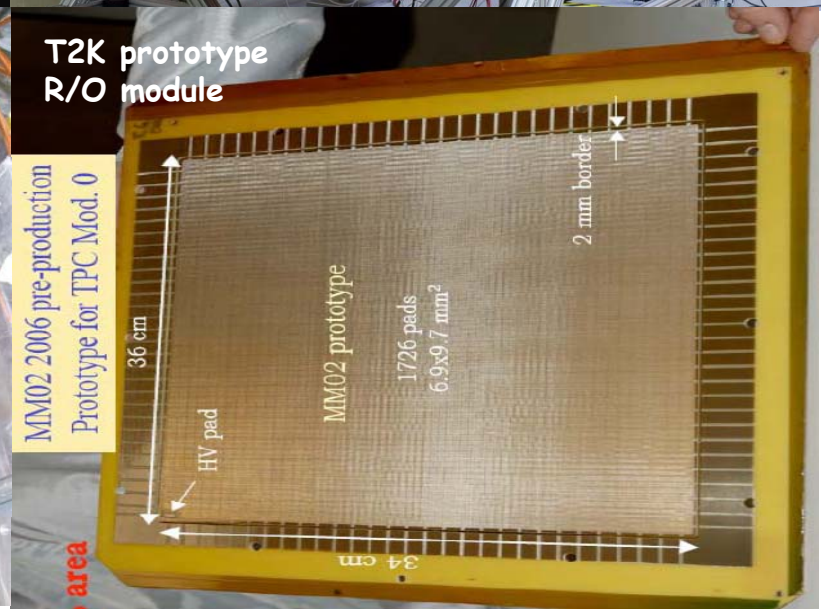
universitätbonn

Gaseous detectors are not dead!



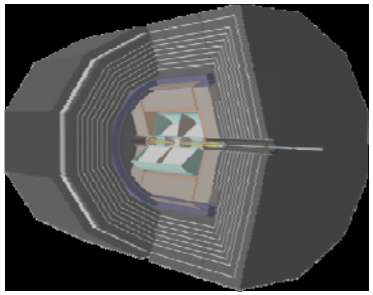




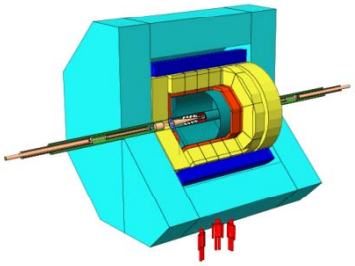


gas is thin…

Detector Concepts for ILC

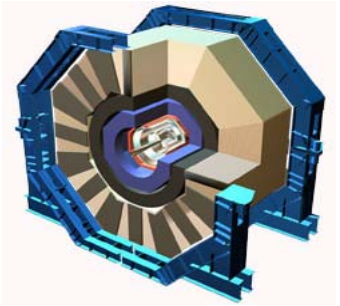


GLD
PFA-CAL
TPC (3T)

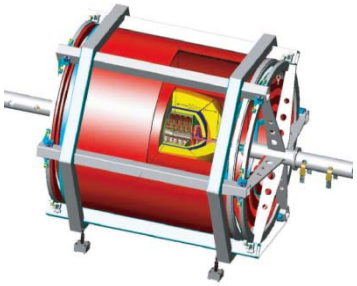


IDC
PFA-CAL
TPC (4T)

ILD



SiD
PFA CAL.
Si-Tracker (5T)

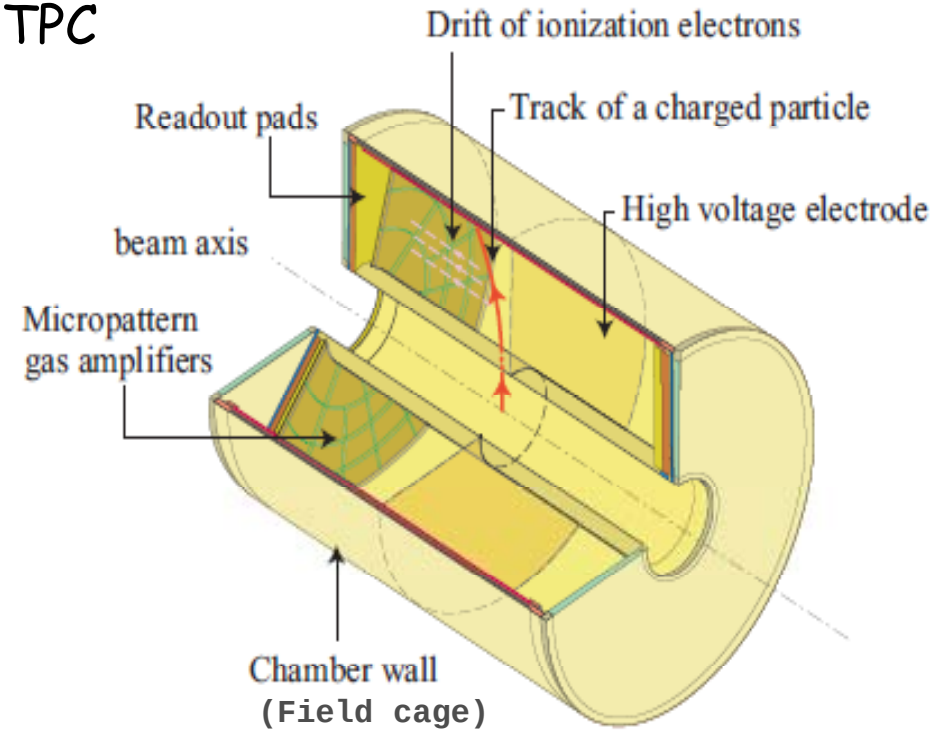


4-th
Compensation-Cal
Gaseous tracker
(also Si-?)
(3.5T, double coils)

Linear Collider TPC

Traditional TPC with MWPC: limited space resolution,
No true 2D symmetry, ExB effects
⇒ use Micro-Pattern Gas Detectors (MPGD) ("micro" = 50-150 μm)

TPC

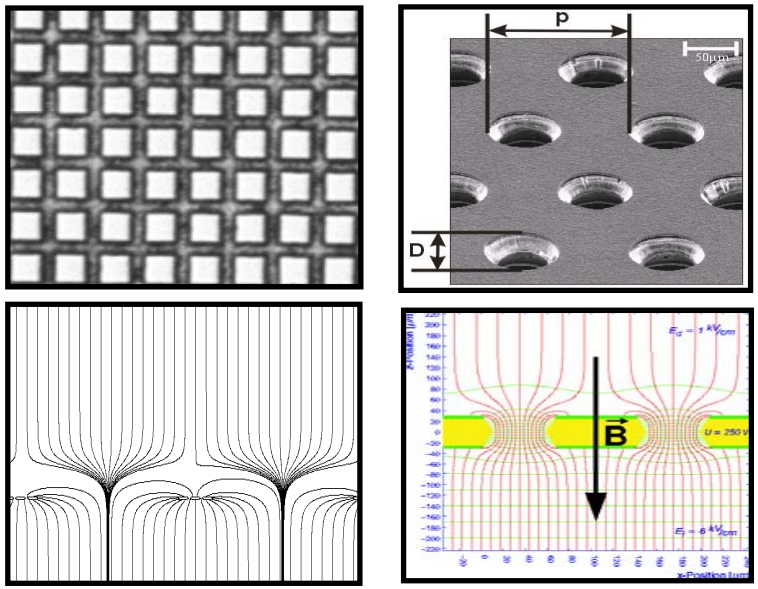


LC TPC: R=2m L=4-5 m

Gas amplification

MicroMEGAS

GEM



Readout schemes:
- small pads (~1x4mm²)
- pixels (~100x100μm²)

LC-TPC: Requirements

Size	Inner radius 30cm, outer radius 158cm, length 4.32m
Momentum Resolution	$\delta(1/p_t) < 10^{-4}$ / GeV
Solid angle coverage	Up to at least $\lvert\cos\theta\rvert \leq 0.98$
TPC material budget	$< 0.03\ X_0$ to outer fieldcage in r $< 0.30\ X_0$ for readout endcap in z
Number of readout pads	$>10^6$ per endcap
Pad size/ no. of padrows	About for a total of 200 pad rows
Single point resolution in r-φ	<~100 μm
Single point resolution in r-z	2 mm
2 track resolution in r- φ	< 2mm
2 track resolution in r-z	< 5mm
dE/dx resolution	5%
Performance robustness	Full precision/ efficiency in backgrounds with 10% total occupancy

LCTPC Collaboration

Memorandum of Agreement

on the Formation of the LCTPC Collaboration

Americas

Carleton Univ & TRIUMF, Ottawa, ON K1S 5B6, Canada
Univ. de Montreal, Montreal, PQ H3C 3J7, Canada
Univ. of Victoria & TRIUMF, Victoria, BC V8W 3P6, Canada
Cornell Univ., Ithaca, NY 14853-5002, USA
Indiana Univ., Bloomington, IN 47405, USA
Lawrence Berkeley National Lab., Berkeley, CA 94720-8153, USA
Louisiana Tech Univ., College of Eng.&Sience, Ruston, LA 71272, USA

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Hiroshima Univ., Higashi-Hiroshima, Hiroshima 739-8526, Japan
KEK, Tsukuba, Ibaraki 305-0801, Japan
Inst. of Space&Astron.Science, Jap.Aerosp.Expl.Ag., Kanagawa 229-8510, Japan
Kinki Univ., Higashi-Osaka, Osaka 577-8502, Japan
Kogakuin Univ., Hachiohjii, Tokyo 192-0015, Japan
Saga Univ., Faculty of Science and Engineering, Honjo, Saga 840-8502, Japan
Tokyo Univ. Agriculture and Technology, Koganei, Tokyo 184-8588, Japan
Univ. of Tokyo, ICEPP, Tokyo 113-0033, Japan
Univ. of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan
Minadanao State Univ., Iligan City 9200, Philippines

Europe

IIHE (Inter-university Institute for High Energies) ULB-VUB, B-1050 Bruxelles
LAL, IN2P3 and Univ. de Paris-Sud, F-91898 Orsay, France
IPN, IN2P3 and Univ. de Paris-Sud, F-91405 Orsay, France
CEA Saclay, DAPNIA, F-91191 Gif-sur-Yvette, France
RWTH Aachen, D-52056 Aachen, Germany
Univ. Bonn, D-53115 Bonn, Germany
DESY Hamburg, D-22603 Hamburg, Germany
EUDET, D-22603 Hamburg, Germany
Albert-Ludwigs Univ., D-79104 Freiburg, Germany
Univ. Hamburg, Inst. für Experimentalphysik, D-22761 Hamburg, Germany
Univ. Karlsruhe, D-76128 Karlsruhe, Germany

recognized by

DESY-PRC,
ILC-GDE & WWS on LC physics & detectors (periodic reviews)

German Groups:

Aachen
Bonn
DESY
Freiburg
Hamburg
Karlsruhe

LCTPC objectives

1. Provide a basic evaluation of the properties of an MPGD TPC and demonstrate that the requirements (at ILC) can be met using small prototypes (Demonstration Phase).
2. Design, build and operate a "Large Prototype" (of large number of measured points) at the EUDET facility in DESY (Consolidation Phase).
3. Start working on an engineering design for aspects of the TPC at ILC (Design Phase).

Current major project: construction of Large Prototype (LP)

as a common infrastructure to study major design issues

on a realistic system

Start of operation planned for Summer/Fall 08 at DESY

Current Activities of D-Groups

DESY
- Coordination (hosts LP infrastructure + testbeam)
- Construction + Commissioning of LP Field Cage (EUDET)
- Slow Control
- Background Studies, Software + Simulation

Aachen
- Mobile Gas System for Testbeams, support

Bonn
- GEM+Pixel-Readout (Timepix) (EUDET)
- DAQ + Pad R/O electronics (ALTRO)
- Module Construction
- Software + Simulation

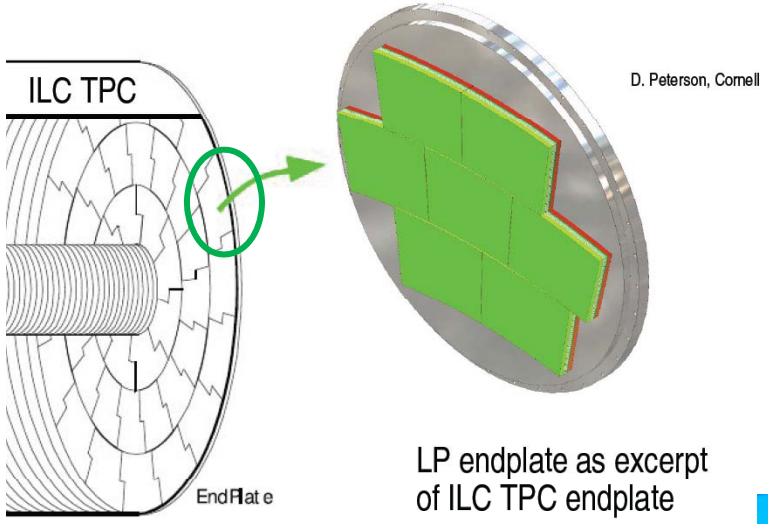
Freiburg
- GEM+Pixel-Readout (Timepix) (EUDET)

Mainz
- Timepix R/O FPGA-electronics

Siegen
- Testbeam preparation (Slow Control), Prototyping

Rostock
- Pad R/O electronics (TDC development) (EUDET)
- Slow control

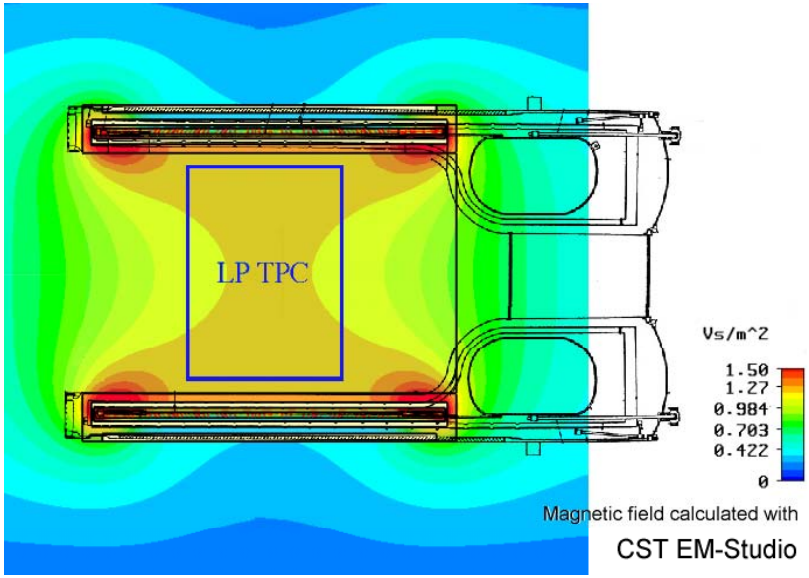
The Large Prototype at DESY



LP endplate as excerpt of ILC TPC endplate

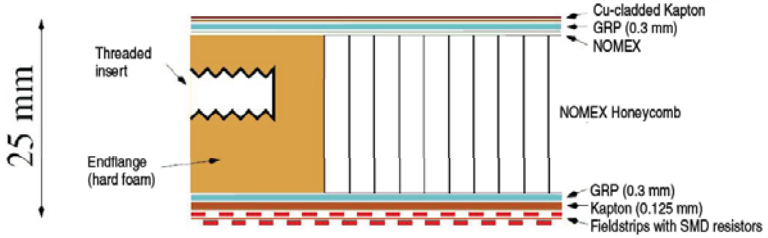
- Common prototype of 42 groups
- Drift length 60 cm
- Diameter 80 cm
- 7 exchangable modules

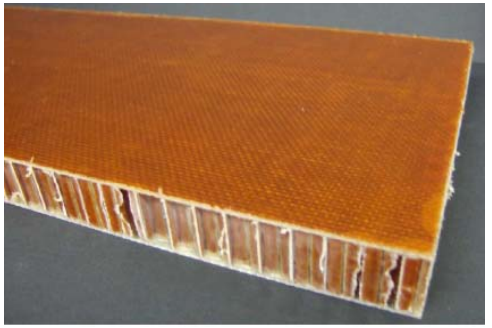
Inside solenoid with 1.25 T (PCMAG)



Fieldcage construction (DESY)

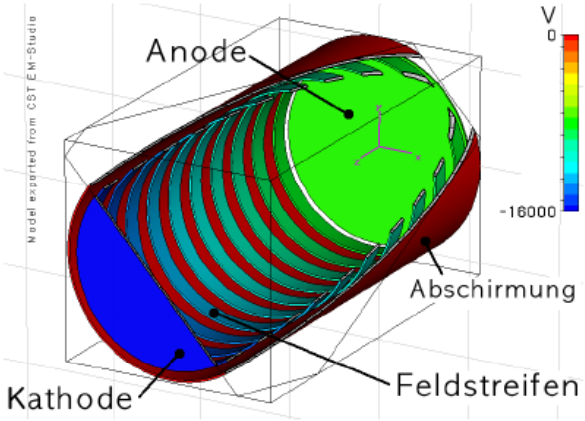
Requirements:
Realistic material budget ⇒ Composite material

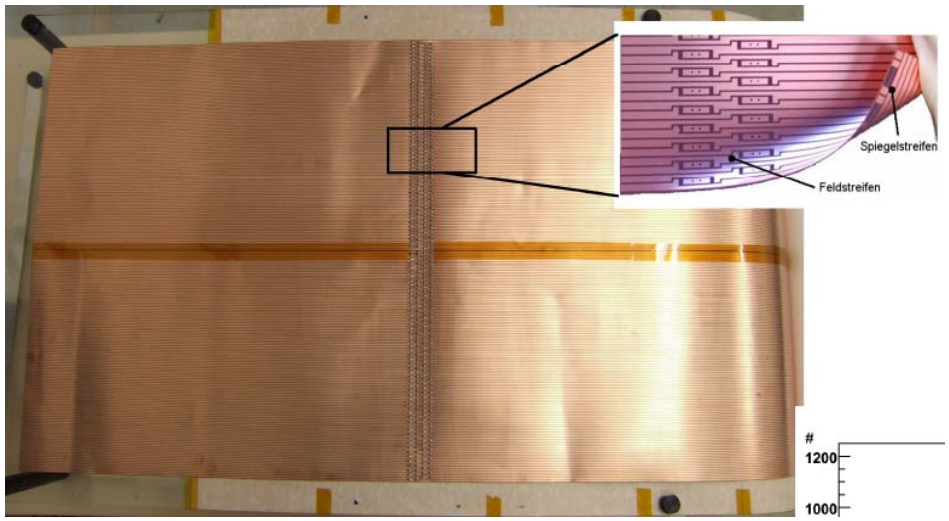




1.3% X_0

Field homogeneity < 10^{-4} ⇒ Field simulations, Field shaping

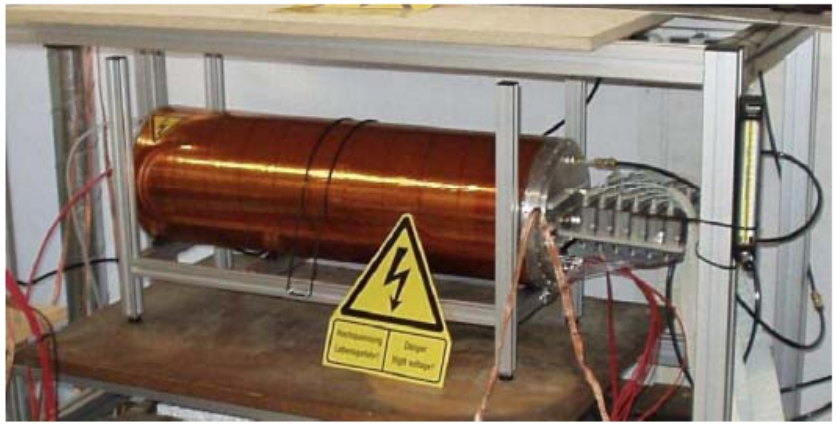




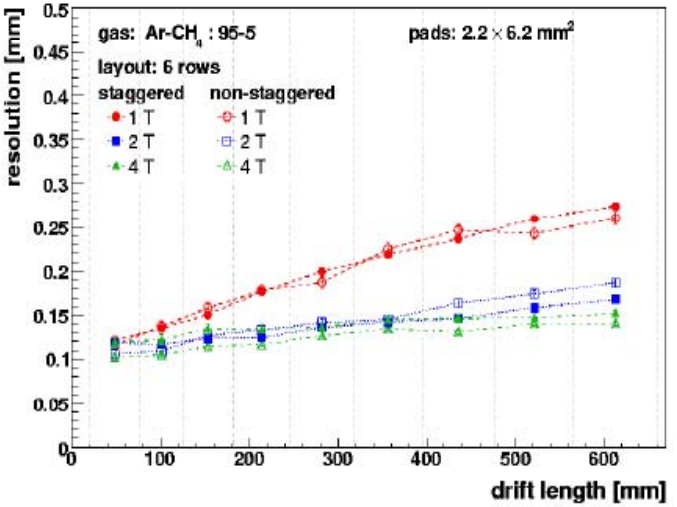
field strip foil (60x230cm²) with resistor chain

further activities DESY

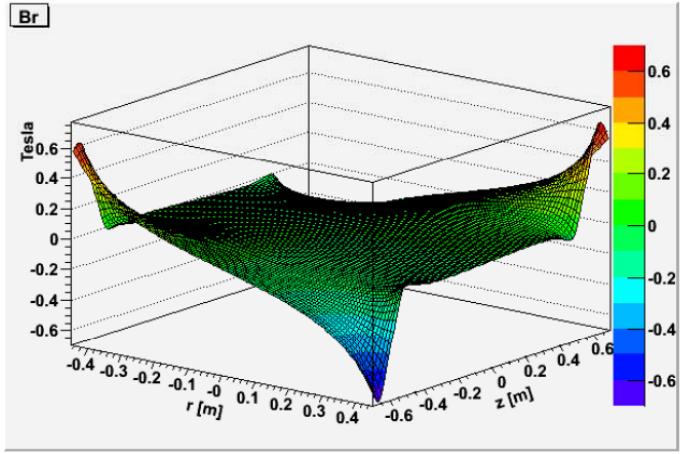
- GEM readout studies

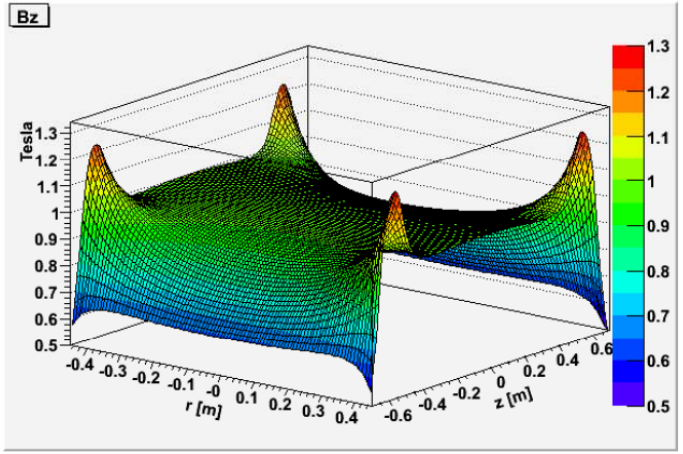


MediTPC



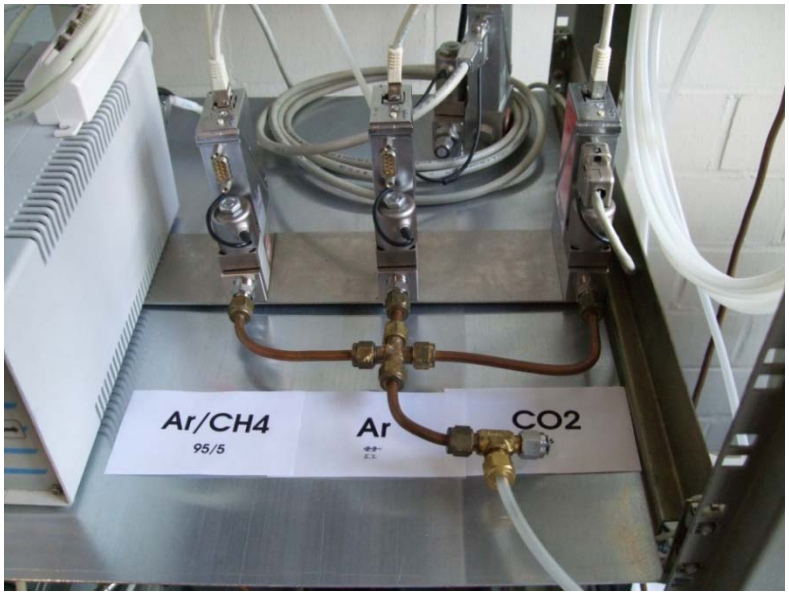
- PCMAG field map



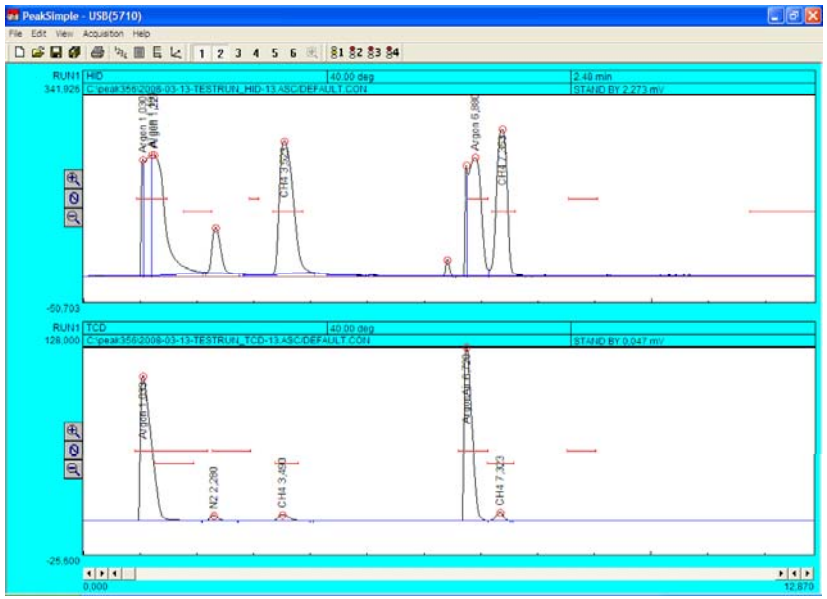


Aachen

- flexible and mobile gas system
- mixing of arbitrary gas compositions
- analysis with gas chromatograph
- currently first measurements
- later this year: construction and test

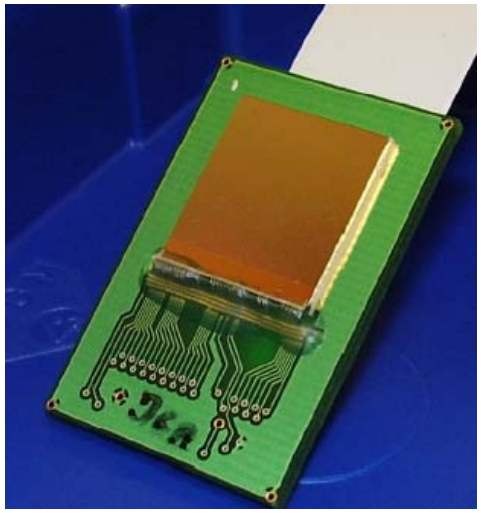


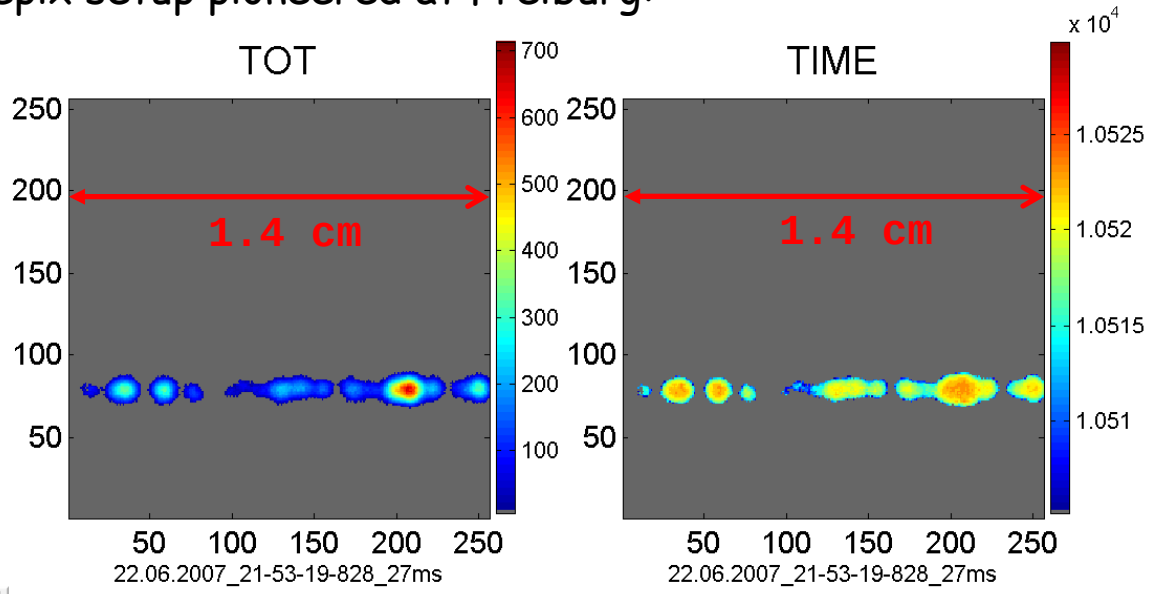
First measurements with gas chromatograph

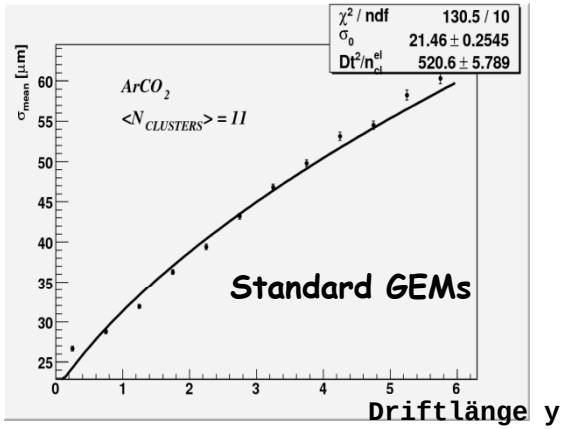


"Pixel TPC" (Bonn, Freiburg, Mainz)

Principle: replace pad plane below MPGD structure by a CMOS Pixel-R/O Chip (no Si-detector!!!)
3-GEM+Medipix/Timepix setup pioneered at Freiburg:



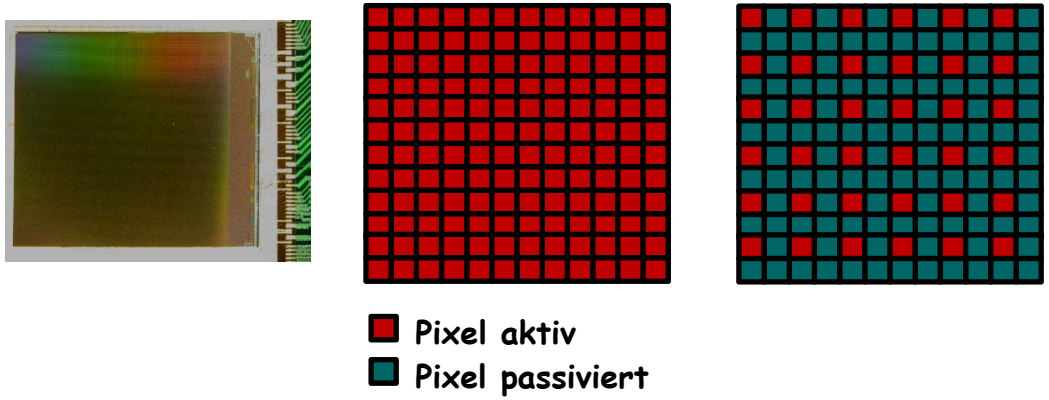




Results:
- point resolution at 0 drift length: ~25 µm
- studies of different GEM types
- time resolution ~10ns (~300µm in $ArCO_2$)
- …and many more

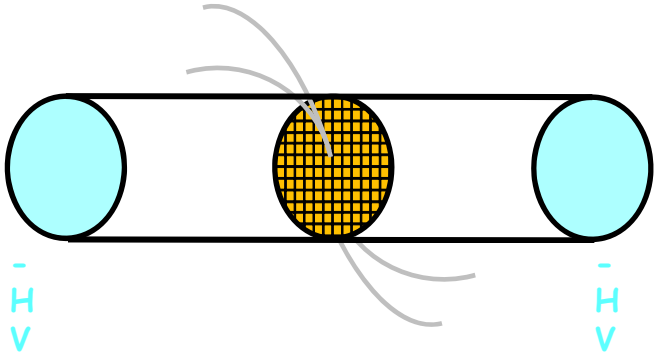
Freiburg: current + future activities

- post-processing of Timepix to combine/enlarge pixels

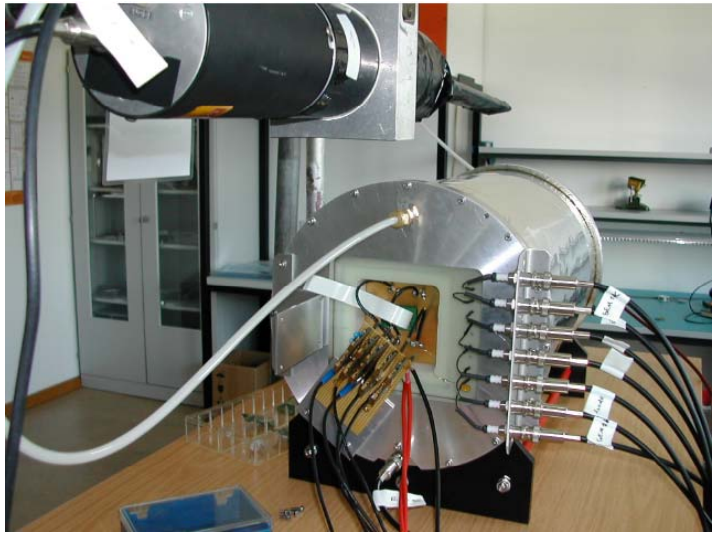


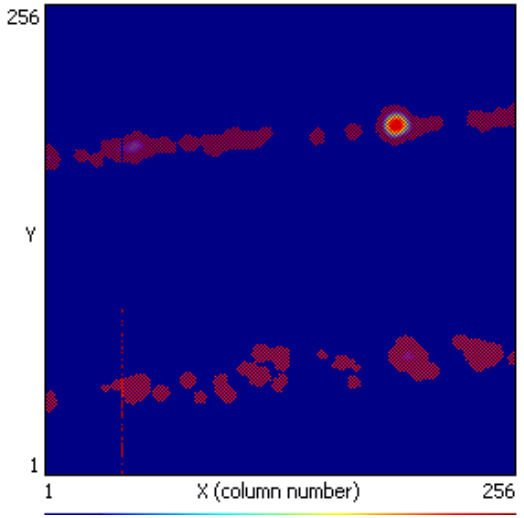
- N_2 laser + photocathode test (single electron eff., ion feedback)

- Simulation studies (e.g. „inverse TPC")

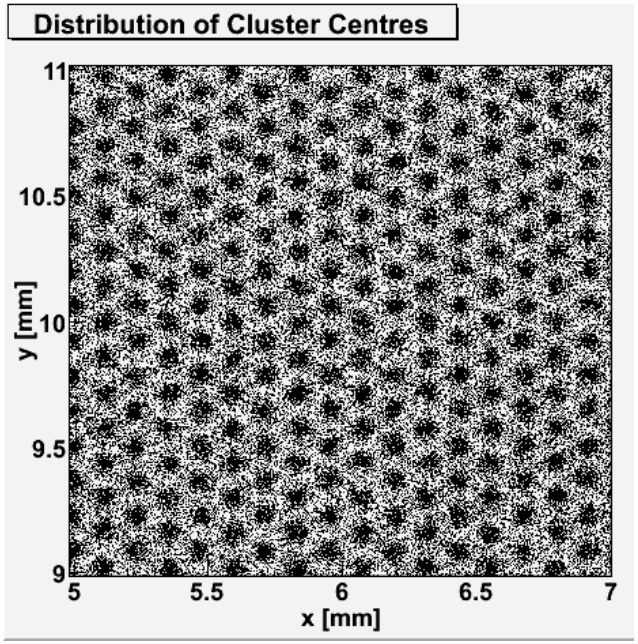


Bonn: Pixel-TPC with 25cm drift

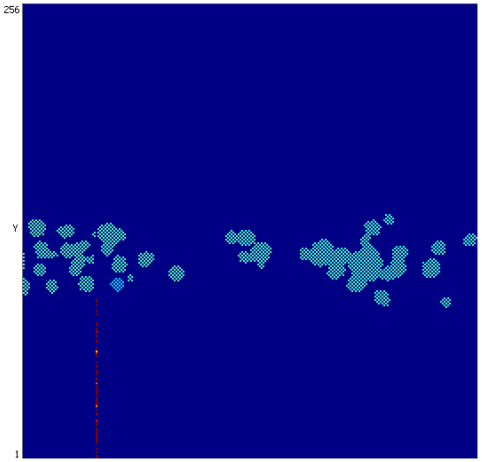




double track (cosmic)



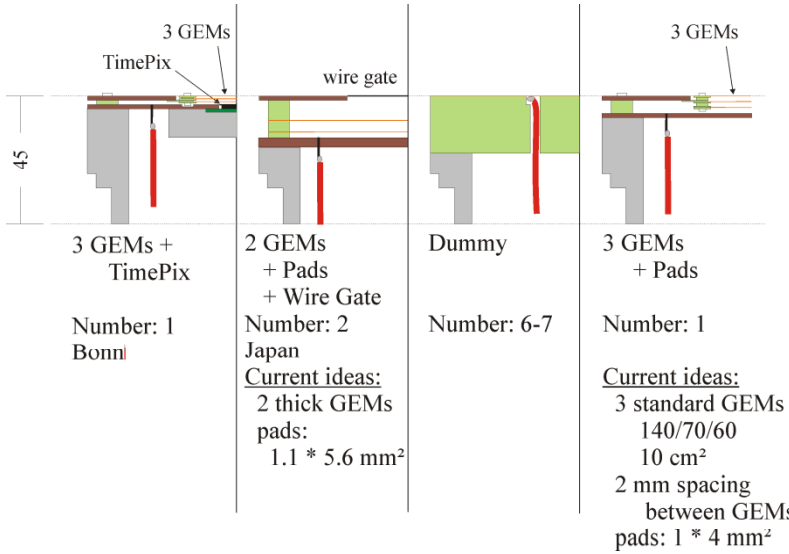
each GEM-hole visible
$\Rightarrow$ proof of single-electron efficiency

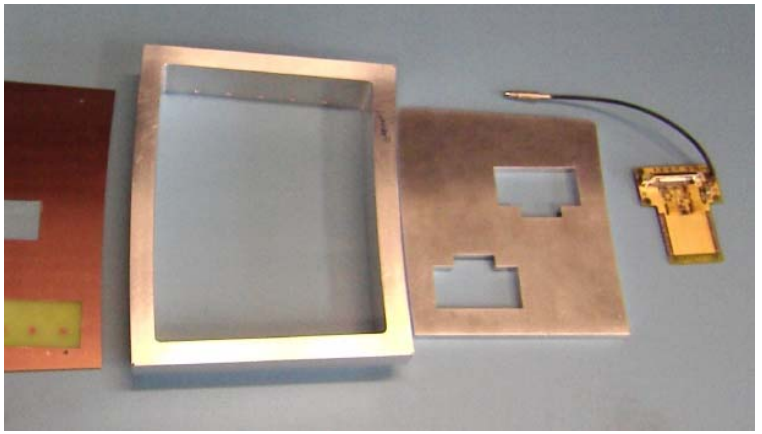


Sr source β track after ~25cm drift

Bonn: other activities

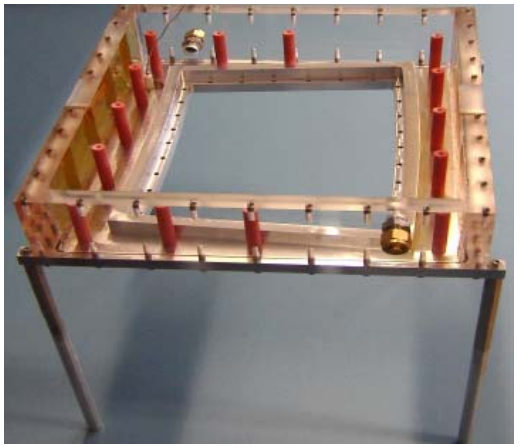
- construction of „EUDET module“ (8 Timepix chips)
- pad module + dummy modules for LP





- LP module test chamber
- ALTRO electronics commissioning
- Trigger/DAQ
- Software (MarlinTPC)

Plans: contribute to design of „Timepix2“
InGrid technology
(within RD51 collaboration)



Mainz

(recently joined)

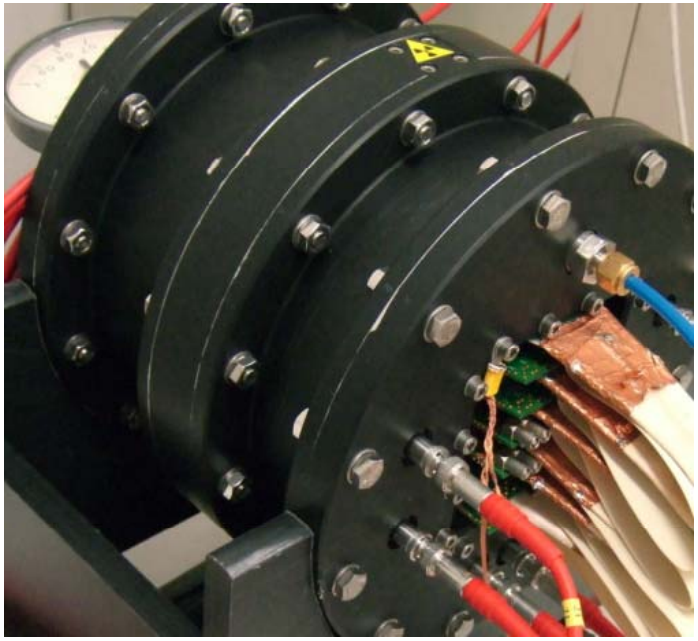
- FPGA-based readout-system for TimePix („HEP-compatible")
- fast multi-chip readout
- testbeam participation

Siegen

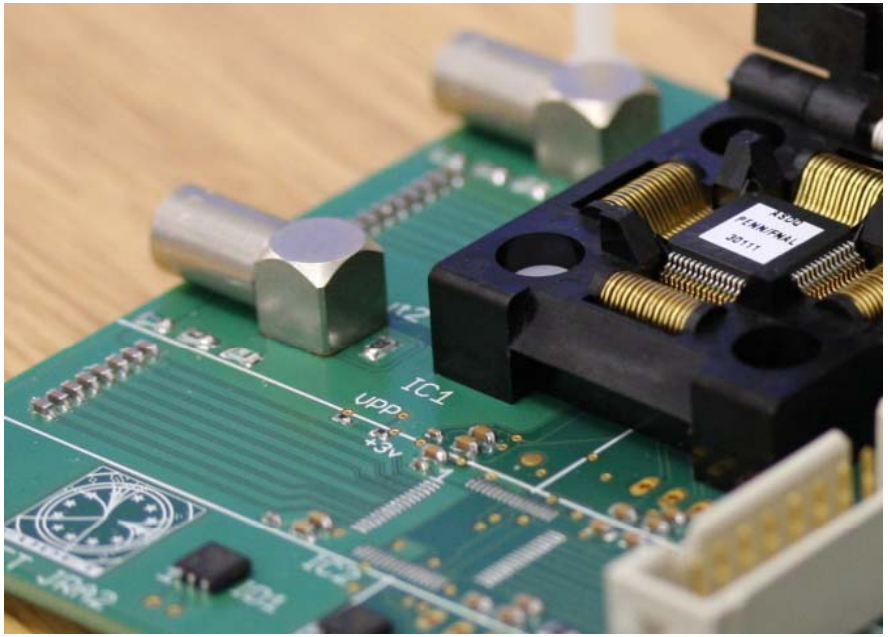
- testbeam preparation, slow control (PhD+Bachelor student (part-time) at DESY)
- in-house prototyping, gas-system, preamp design, cosmic trigger

Rostock

- development of alternative TPC r/o electronics
- based on precise time sampling + charge-to-time conversion
- test of system with prototype board and in-house test chamber
- participation in testbeam preparation (postdoc+student at DESY)



Rostock test chamber



Test board for R/O electronics

Role of Alliance for LC-TPC (goals)

- more coherent collaboration of German groups in LC-TPC
- exchange know-how on various system aspects
- use of Alliance infrastructure:
  - testbeams
  - magnets
  - gas systems
  - (existing) r/o electronics + DAQ/trigger systems
  - benefit from chip design infrastructure for new electronics developments („Timepix2", new electronics for pad-readout)

Summary - Conclusions

- Broad German participation + responsibility in world-wide LCTPC collaboration
- In spite of possible ILC delays well defined R&D programme
- While well focussed towards LC application, LC-TPC R&D also has a large „generic R&D" component with broader applicability (gaseous vertex detectors „GOSSIP", WIMP/$0\nu2\beta$ detection, Super-B?, hadron physics, X-ray polarimetry, imaging?, …)
- Alliance can help to strengthen ties between German groups
- Benefit from Alliance infrastructure (testbeams, DESY infrastructure (magnets), chip design, mobile equipment, …)