

18-June-2007 version1

## Outline

the global organizations

directions in gaseous tracking

development of a TPC for the central tracker

simulations of track reconstruction and noise tolerance in a TPC

forward tracking

TPC pixel readout

possible other contributions to the international effort

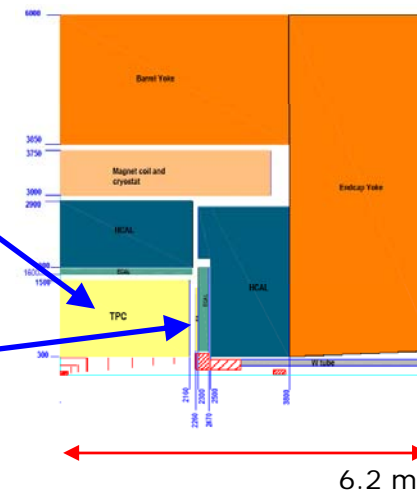
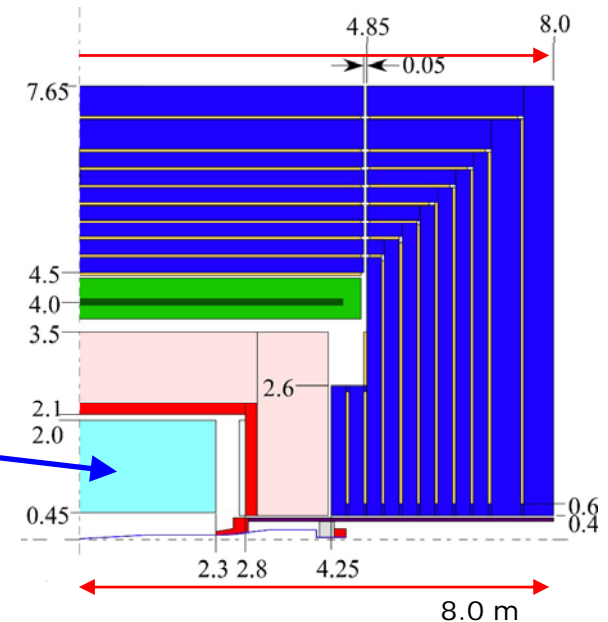
# Global programs: the concepts

A **Time Projection Chamber (TPC)** is the central tracker in 2 of the ILC detector concepts.

The **GLD** includes a 2.0 m outer radius TPC in a 3.0 Tesla field. ( $Br^2 = 12.0$ )

**Large Detector Concept (LDC)** includes a 1.58 m outer radius TPC in a 4.0 Tesla field. ( $Br^2 = 10.0$ )

In addition, the LDC design includes a **GEM technology planar tracker** covering the endcap of the TPC to define the exit point.



# Global program: the TPC collaboration

LC-TPC is the international R&D organization

providing coordination and exchange of information  
in the “small prototype” program

and collaborating to build and study  
a series of large prototypes.

LC-TPC crosses the lines of LDC and GLD.

**USA**  
Cornell  
Indiana  
LBNL  
Louisiana Tech  
Purdue (observer)

**Canada**  
Carleton  
Montreal  
Victoria

**Asia**  
Tsinghua  
CDC:  
Hiroshima  
KEK  
Kinki U  
Saga  
Kogakuin  
Tokyo UA&T  
U Tokyo  
U Tsukuba  
Minadano SU-IIT

**Europe**  
LAL Orsay  
IPN Orsay  
CEA Saclay  
Aachen  
Bonn  
DESY  
U Hamburg  
Freiburg  
MPI-Munich  
TU Munich (observer)  
Rostock  
Siegen  
NIKHEF  
Novosibirsk  
Lund  
CERN

LC-TPC milestones  
as reported at the  
Beijing Review, Feb 2007

2007-2010 small prototype  
and large prototypes

2008-2009 LP1

2009-2010 LP2

2011 Final design for ILC TPC

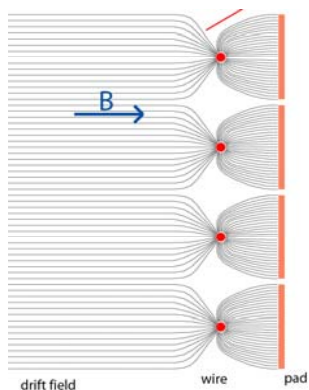
2012-2016 construction

2017 commission

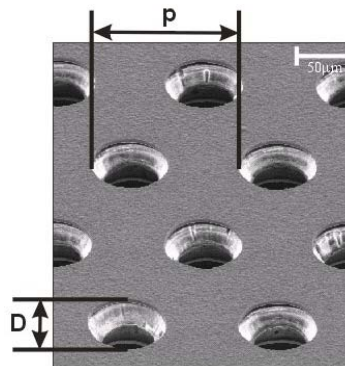
# Directions in gaseous tracking

All gaseous tracking devices work on a principle of collection ionization formed by passing charged particles, and amplifying that ionization to create a detectable signal.

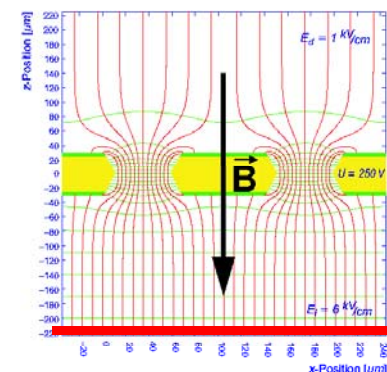
Wires have disadvantages  
 inductive signal - wide  
 wire spacing:  $\sim$  mm  
 strong  $E \times B$  effect



GEM

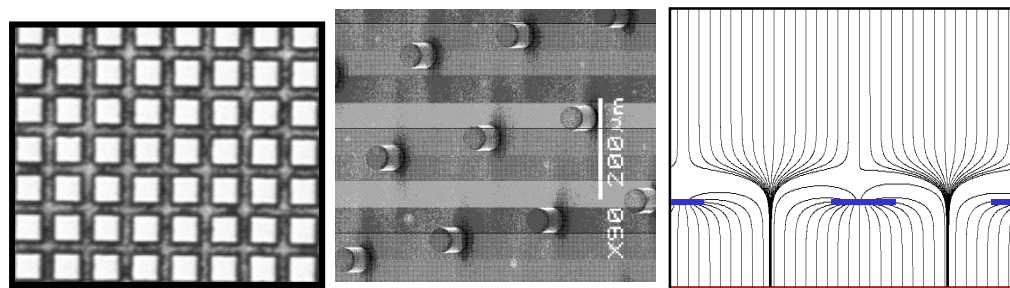


*50  $\mu$ m amplification region is displaced from the anode*



anode

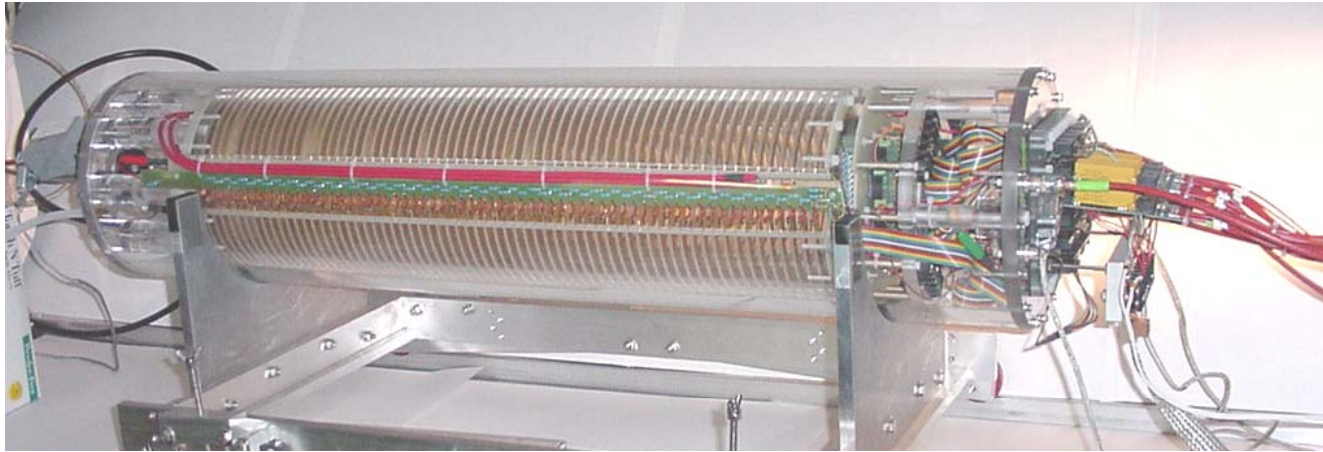
Micromegas



*50  $\mu$ m amplification region includes the anode*

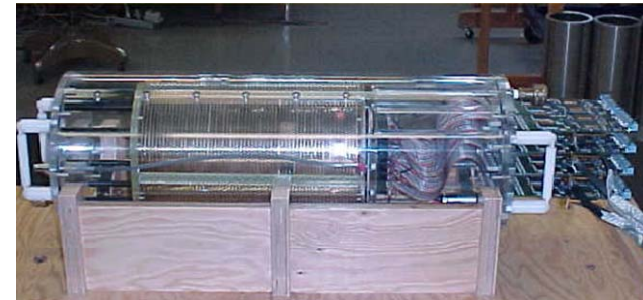
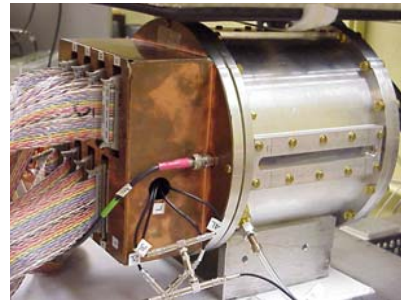
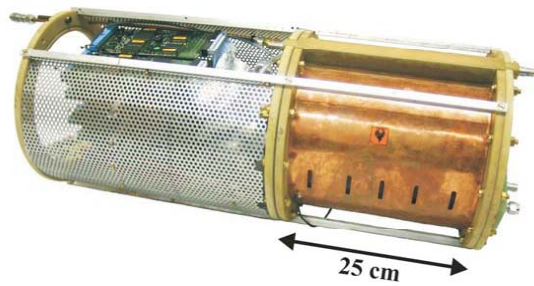
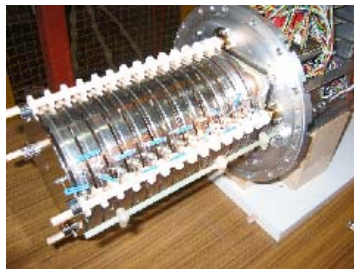
anode

# TPC small prototype program at Cornell



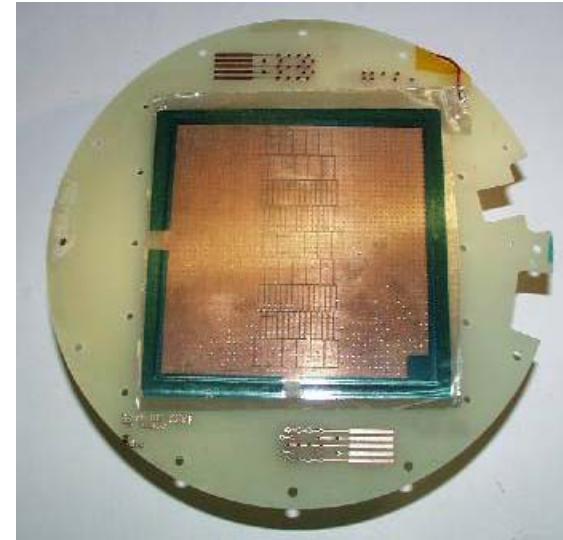
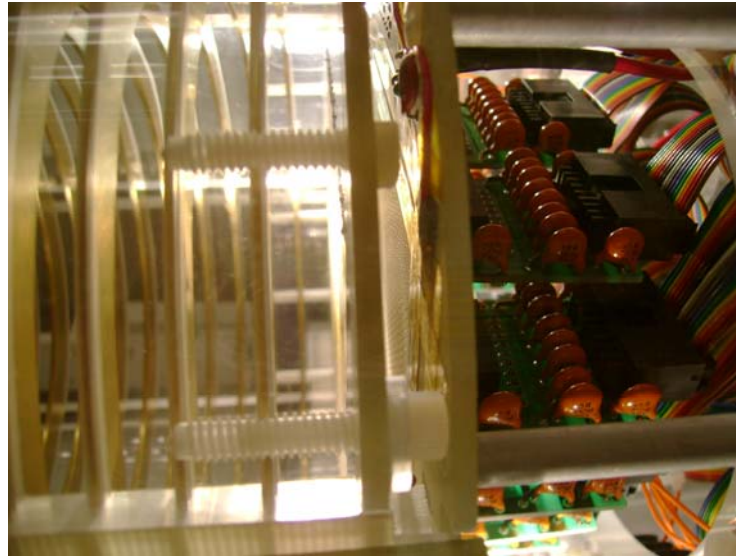
Cornell/Purdue chamber, 64cm drift, 10cm square gas amplification

selected  
other  
chambers





# TPC small prototype program at Cornell

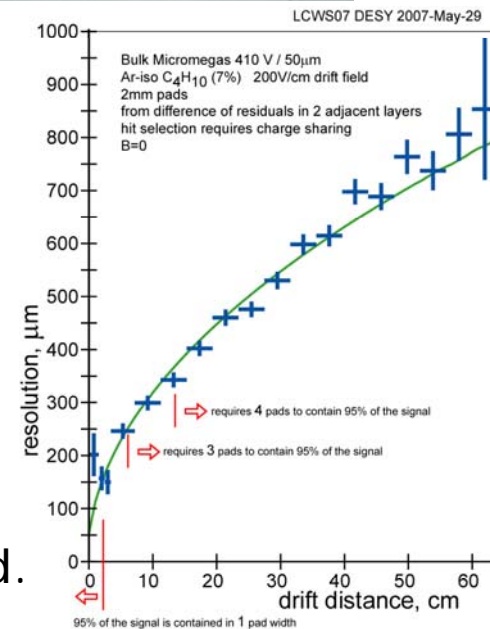


Studies with the Cornell/Purdue chamber involve independent characterization of the candidate gas amplification devices.

Shown: a “Bulk Micromegas” applied to the Cornell pad board by the Saclay group.

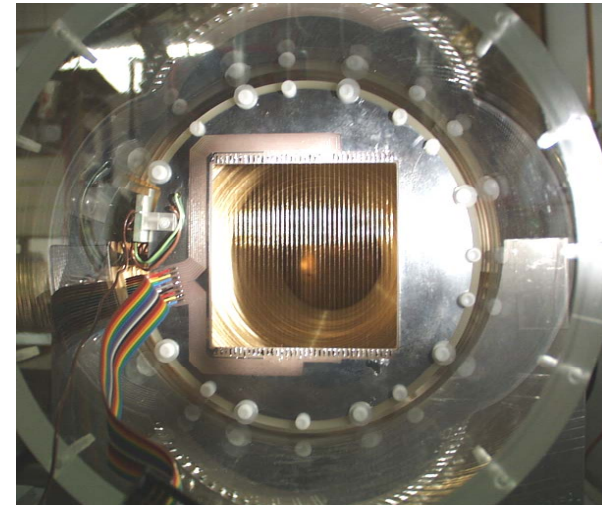
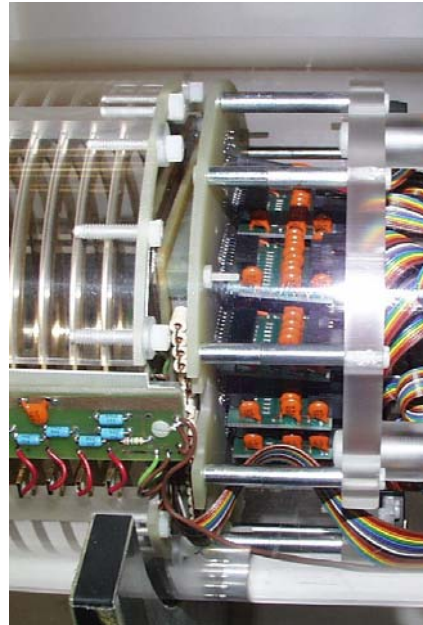
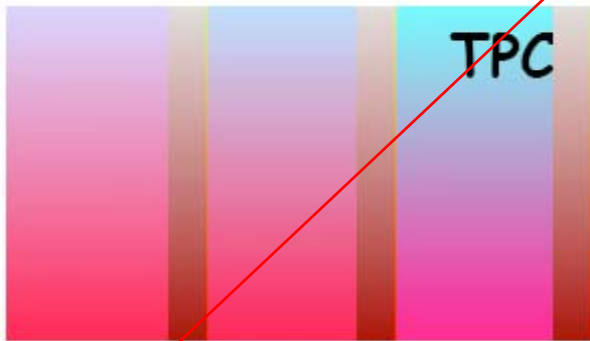
Resolution, extrapolating to zero diffusion, is  $53 \mu\text{m}$ .

There is a need for such independent measures but this program has not had access to a magnetic field.



# TPC small prototype program at Cornell

Ionization in the TPC



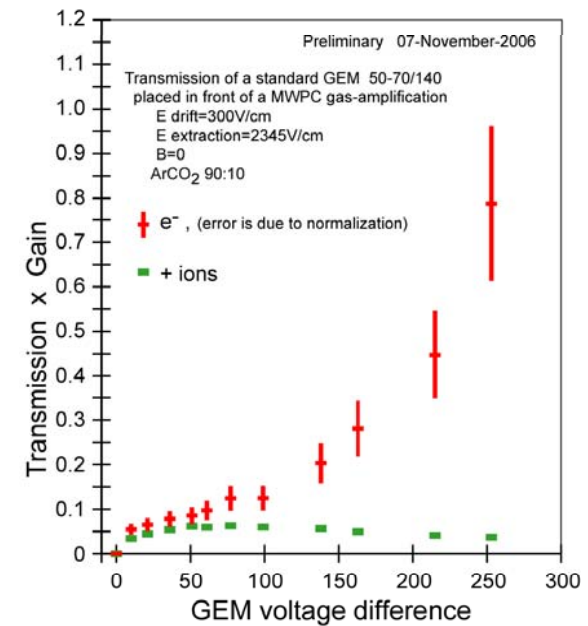
+

IP

Ions are produced at the gas amplification and drift (as sheets) into the field cage.

LCTPC is investigating ion gating technology, including a gated GEM.

Cornell/Purdue program includes measurements of ion transmission, and (future) ion feedback.



# TPC small prototype program at Cornell

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future plans

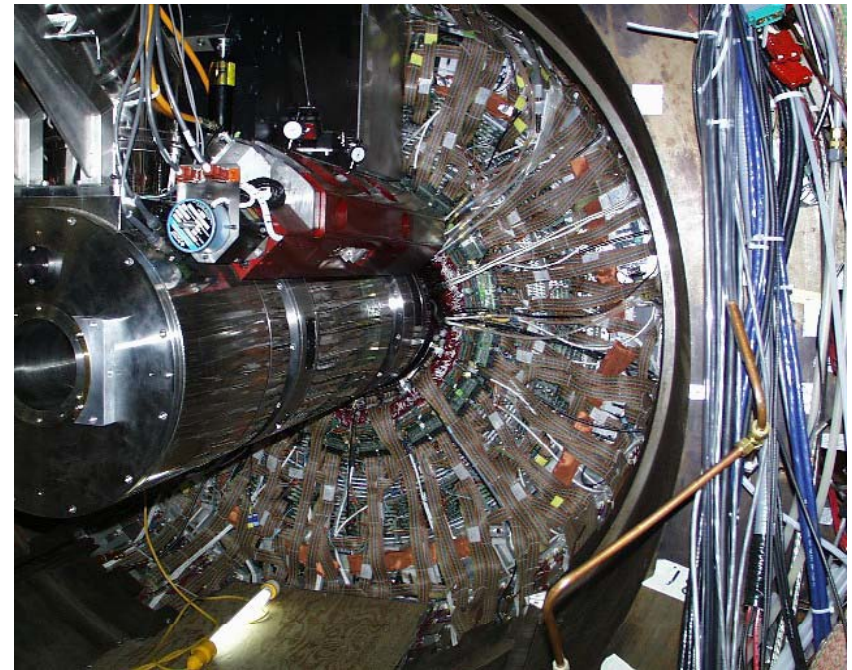
direct comparison of triple-GEM and Bulk Micromegas  
(only the Munich/CDC chamber has made these comparisons,  
there is need to duplicate these measurements)

Ion/electron transmission measurements,  
with different configuration GEM

Ion feedback measurements

a possible magnetic field run  
in the CLEO magnet  
fit into the possible CESRTA schedule

It is very important for all of these  
measurements in a magnetic field.





# MPGD development at Purdue

Purdue started with development of GEMs with 3M, ALCPG 2003.

Micromegas is commercially made by the 3M corporation in a proprietary subtractive process starting with copper clad Kapton.

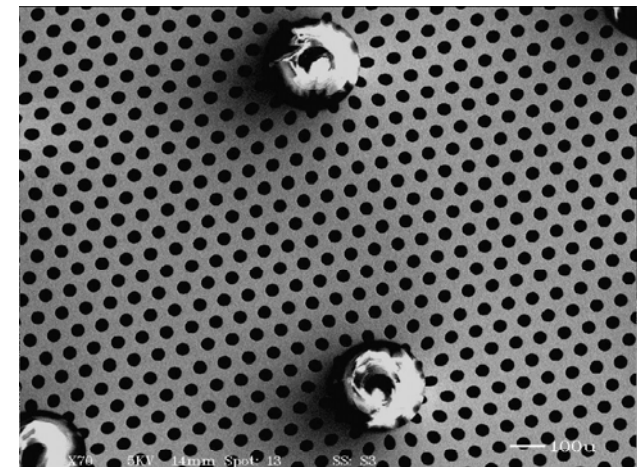
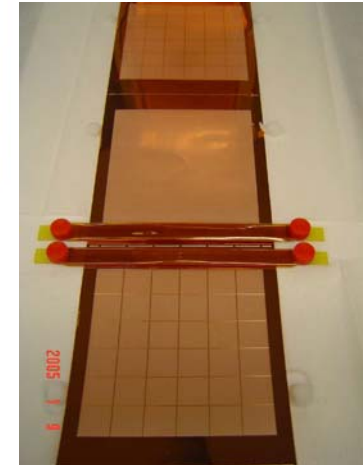
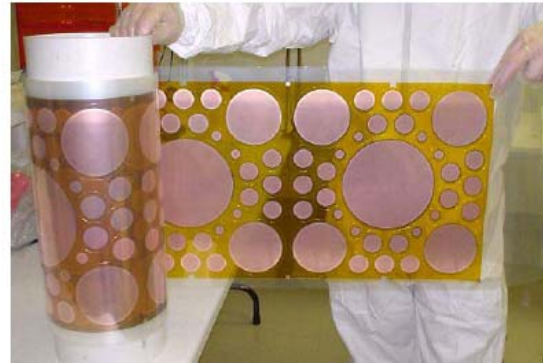
Holes are etched in the copper  
70  $\mu\text{m}$  spacing (smallest distance)  
35  $\mu\text{m}$  diameter

Copper thickness: 9  $\mu\text{m}$

Pillars are the remains of etched Kapton.  
50 mm height  
300 mm diameter at base  
1 mm spacing, square array

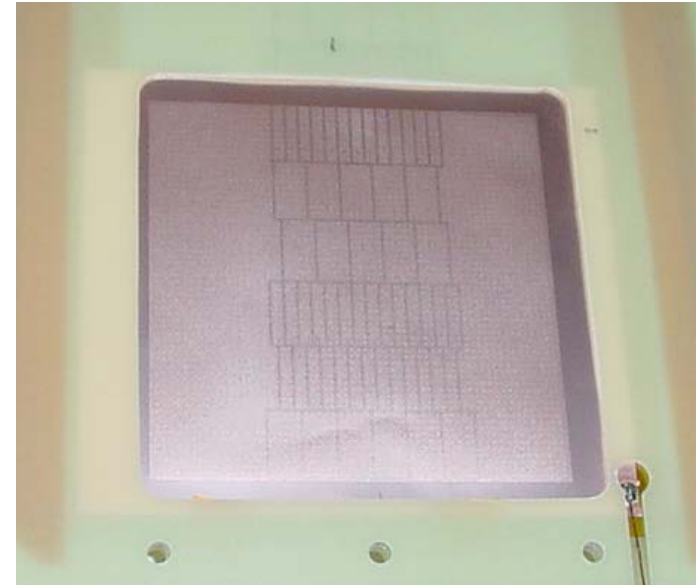
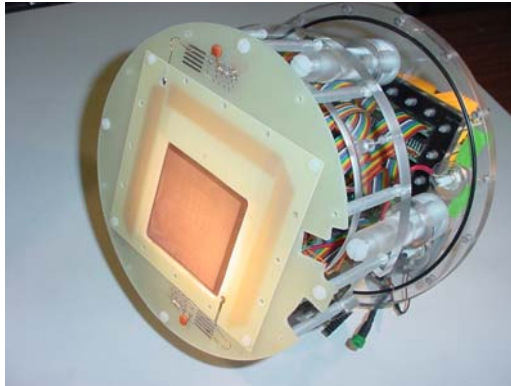
The shiny surface of the pillars is due to charge build-up from the electron microscope.

Has different physical characteristics and response compared to mesh Micromegas.



Title: Copper Electrodes  
Comment: Kirk Aradt  
Date: 03-22-2004 Time: 14:57  
Filename: PHYSICS2.TIF

# MPGD development at Purdue

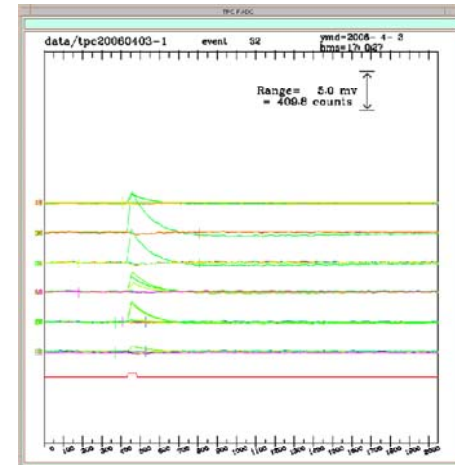


Purdue-3M Micromegas was tested at Cornell in 2006.

Pulse height is 5X that is mesh Micromegas.

This device is also used in the Berkeley VLSI TPC readout development (below).

Future/possible development  
larger area  
thinner copper  
costs ... \$123K (\$47K would be provided by Purdue)



# TPC large prototype program at Cornell

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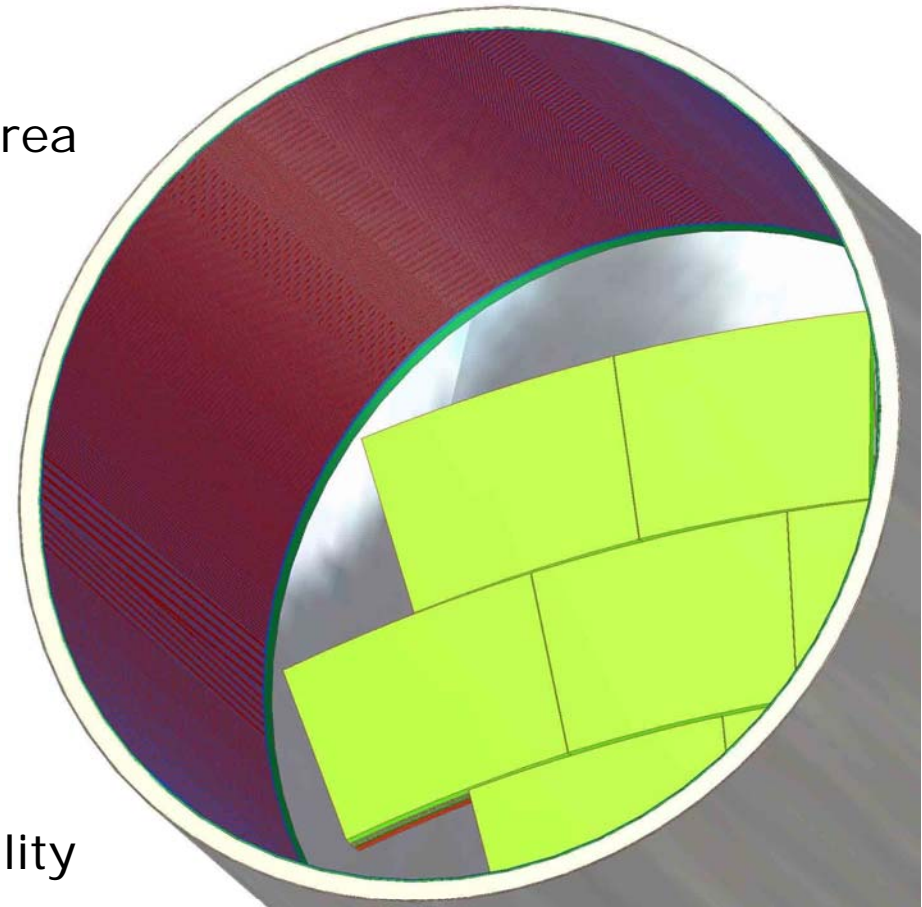
immediate goals

- issues related to tiling of a large area
- system electronics
- track finding in a large scale  
Micro-Pattern-Gas-Detector  
based readout.

60 cm drift length

80 cm diameter

a cut-out region of an ILC TPC



magnet field run at DESY, EUDET facility

This is only a 1.3 Tesla field.

There is a need for higher magnet field and ILC beam structure  
in the future to fully understand the running and data collection.

# TPC large prototype program at Cornell

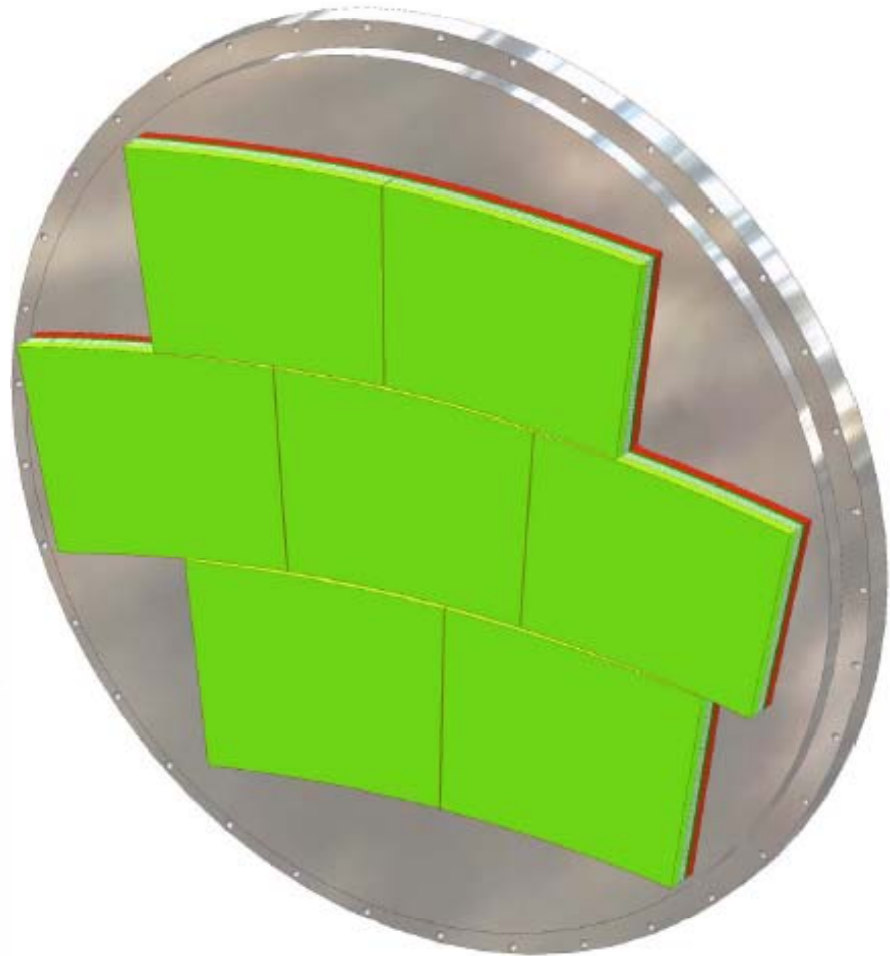
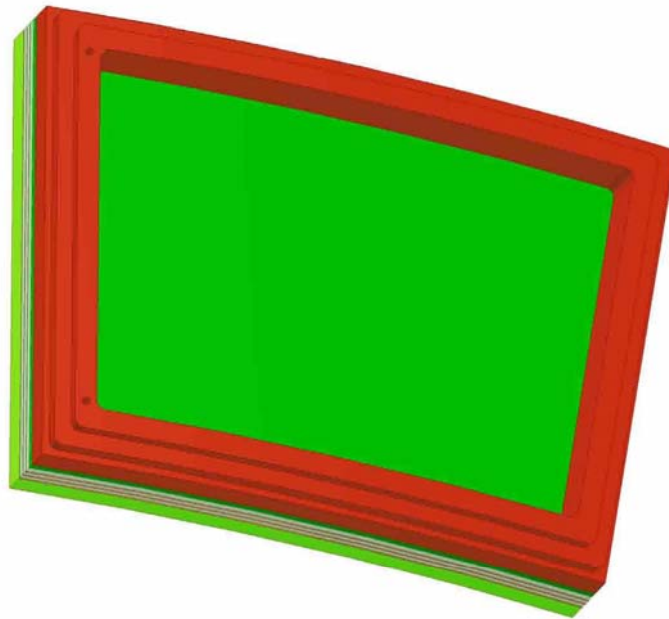
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Cornell responsibility...

- endplate
- mating module frames

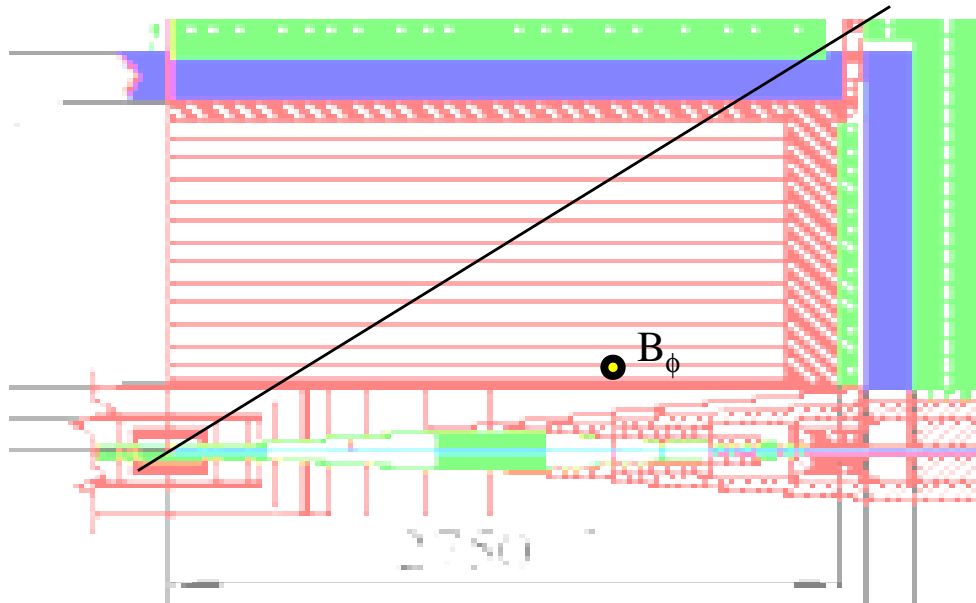
requirements...

- dimensional tolerances
- minimal material
- maximum instrumented area





# TPC large prototype program at Cornell



Momentum measurement

affected by field distortions changing the particle trajectory  
affected by field distortions changing the drifted electron trajectory.

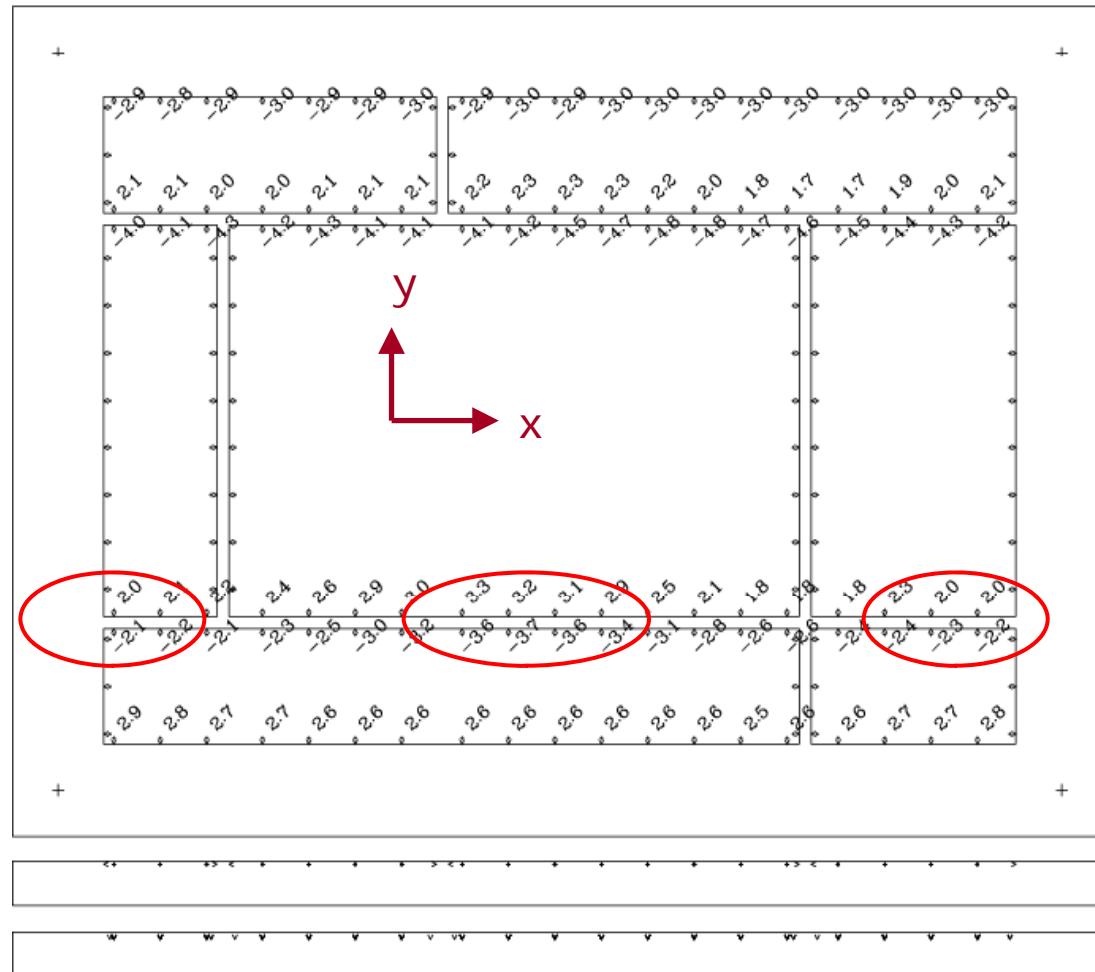
Momentum resolution requirement,  $\delta(1/p_t) < 2-5 \times 10^{-5}/\text{GeV}$ ,  
results in a requirement on the knowledge of the magnetic field  
 $\delta B/B < 2-5 \times 10^{-5}$  (above the multiple scattering dominated range).

Decouple the survey of the endplate from the survey of the magnetic field.

# TPC large prototype program at Cornell

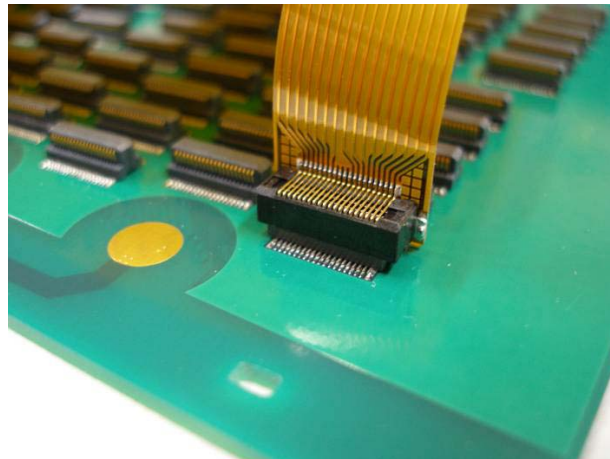
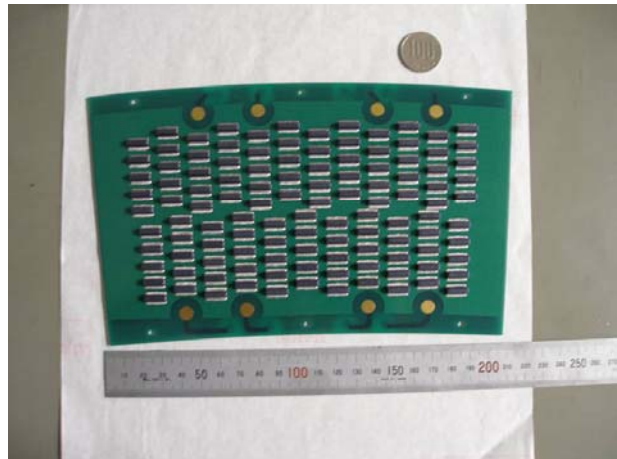
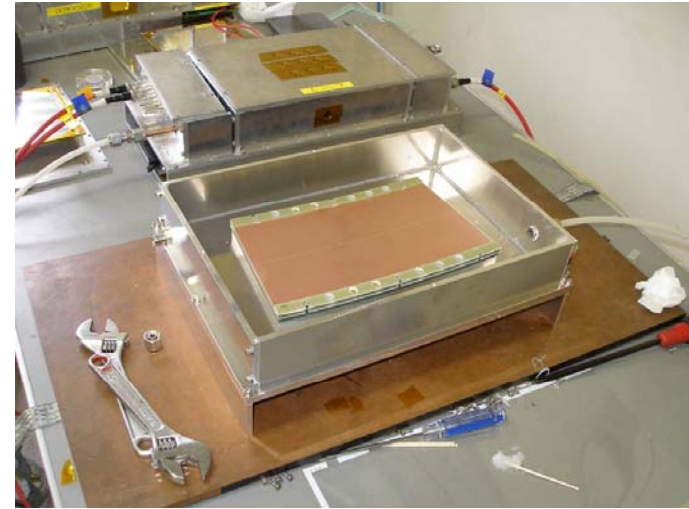
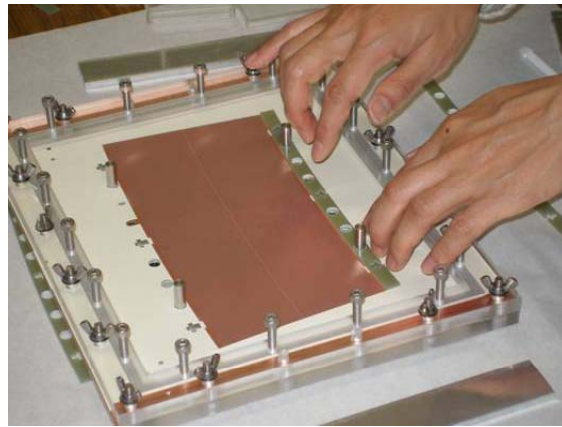
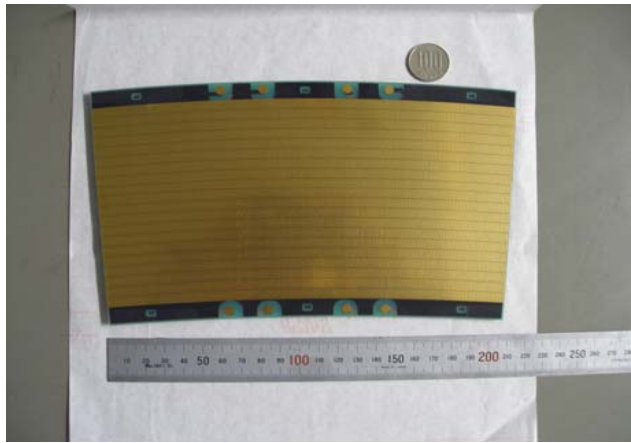
```
/home/dpp/BulkDisk/StressReliefCmm/read3/Plate3.txt  
3 machine 2  
y
```

Preliminary to producing the endplate, Cornell is studying various machining / stress relief processes.





# Large prototype, module - LC-TPC



Constructing a pre-module to mate to Cornell endplate

pad board  
stretching a GEM module in test box  
(back) connectors

Gain tests have been done.

See A. Ishikawa, LCWS07



# TPC large prototype program at Cornell

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schedule (as of May 2007)

Construct endplate and module frames - End of 2007  
Deliver and commission Jan 2008

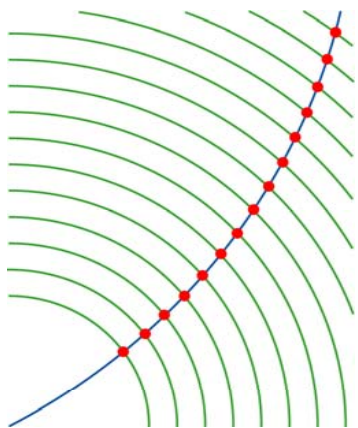
We currently plan to deliver 2 endplates  
(contingent on time and budget)  
1 - for assembly of a GEM readout in Japan  
2 - for assembly of a Micromegas readout in France

Study tracking and alignment issues 2008 - 2009

future plans

low scattering material, but high stability, construction  
for the "LP2", the last prototype before ILC detector construction  
2009 - 2010

# Background studies for the TPC, Cornell

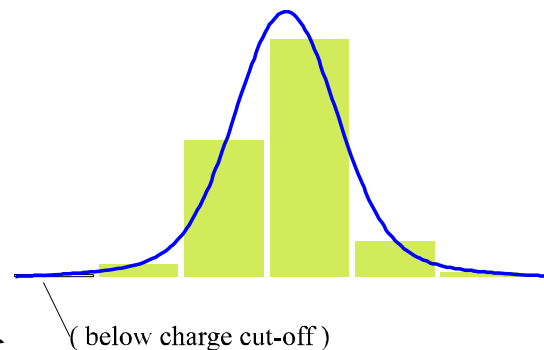


"ionization centers"

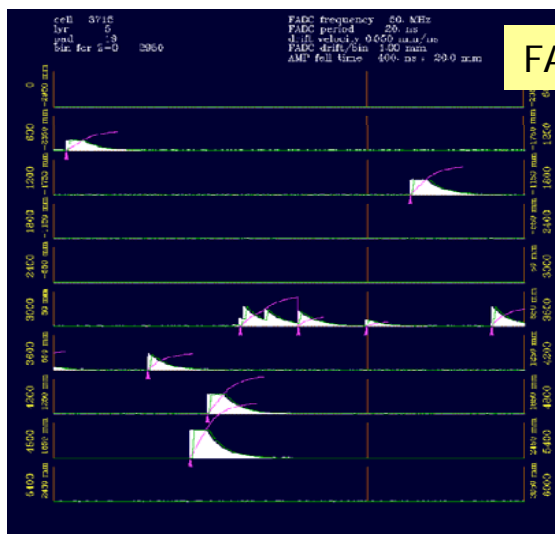
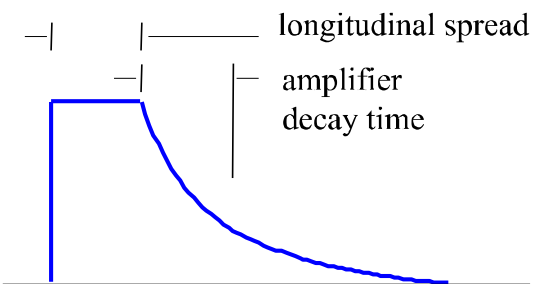
Charged particle reconstruction, in the TPC based concepts, requires full pattern recognition in the TPC. This provides a redundant system in addition to the vertex detector.

Studies of the effects of backgrounds on the ability to reconstruct tracks in the TPC require full simulation of the FADC response. Work at Cornell addresses this need.

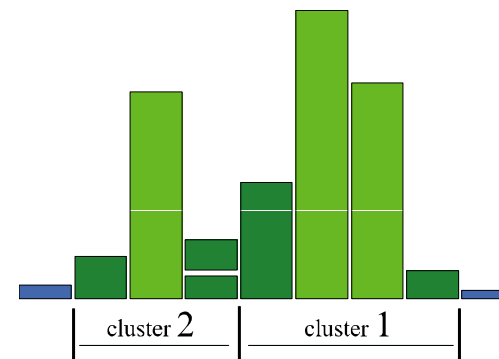
charge spread



charge signal time characteristics

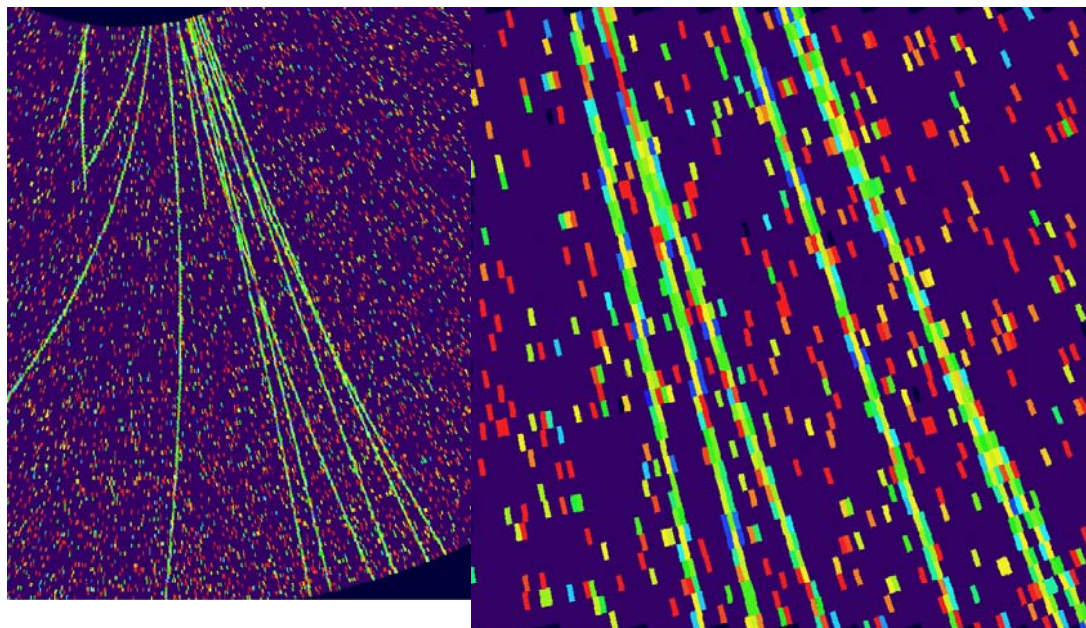


FADC response



pad cluster recognition

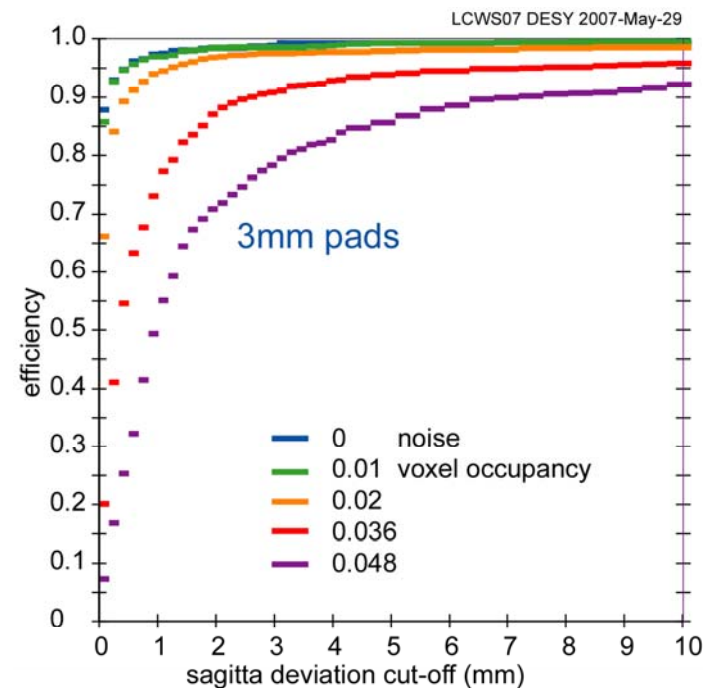
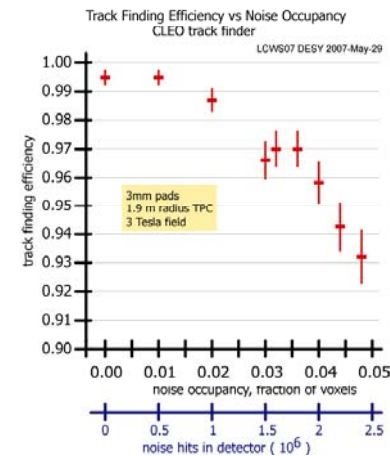
# Background studies for the TPC, Cornell



4.8% occupancy

Full simulation of the FADC response is followed by pattern recognition based on the FADC signals.

Efficiency and TPC-only resolution are unaffected at 1% (voxel) occupancy. (LCWS07)



# Background studies for the TPC - LC-TPC

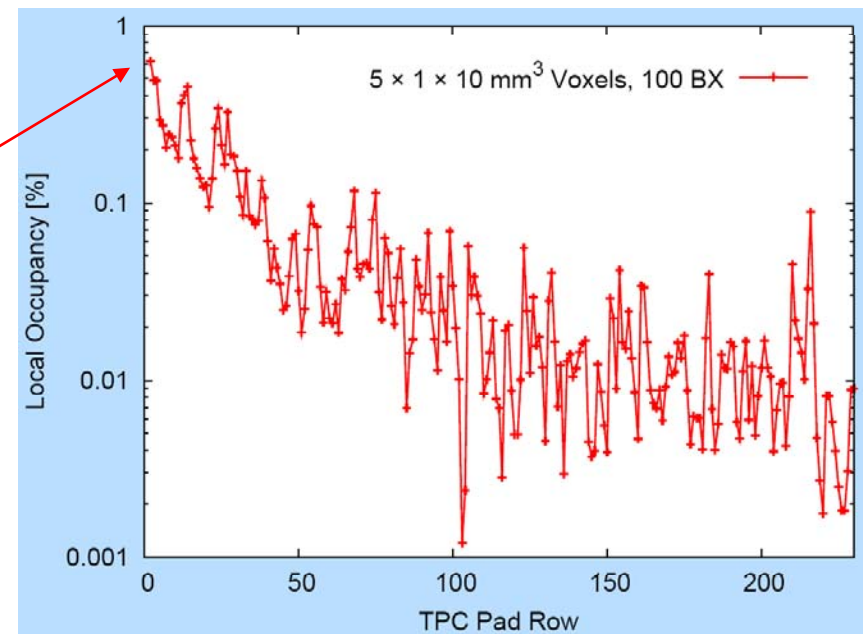
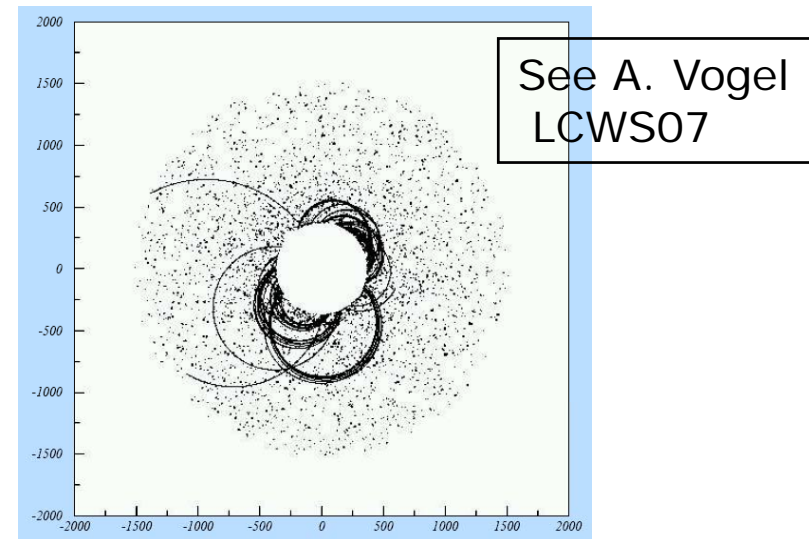
While the Cornell study indicates that a 1% uniform occupancy will not affect pattern recognition or TPC resolution,

detailed studies of expected beam-related backgrounds are required to predict the occupancy. (CPU years)

These studies are done by DESY/Hamburg, predicting 1% (maximum) occupancy.

These two studies provide the LC-TPC response to questions about occupancy.

*Occupancy < 1%, which is negligible.*





# Mokka , Marlin, LCIO

LCIO

data model & persistency

Marlin

C++ application framework

LCCD

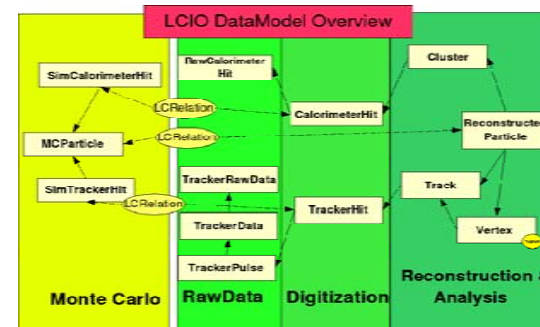
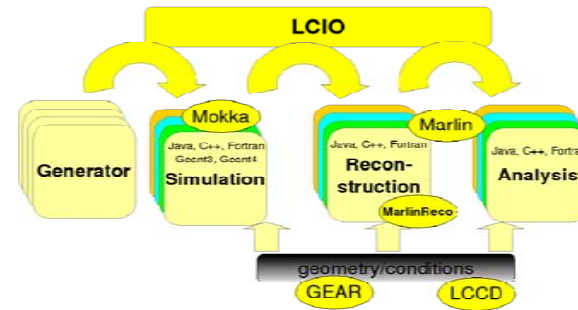
conditions data toolkit

GEAR

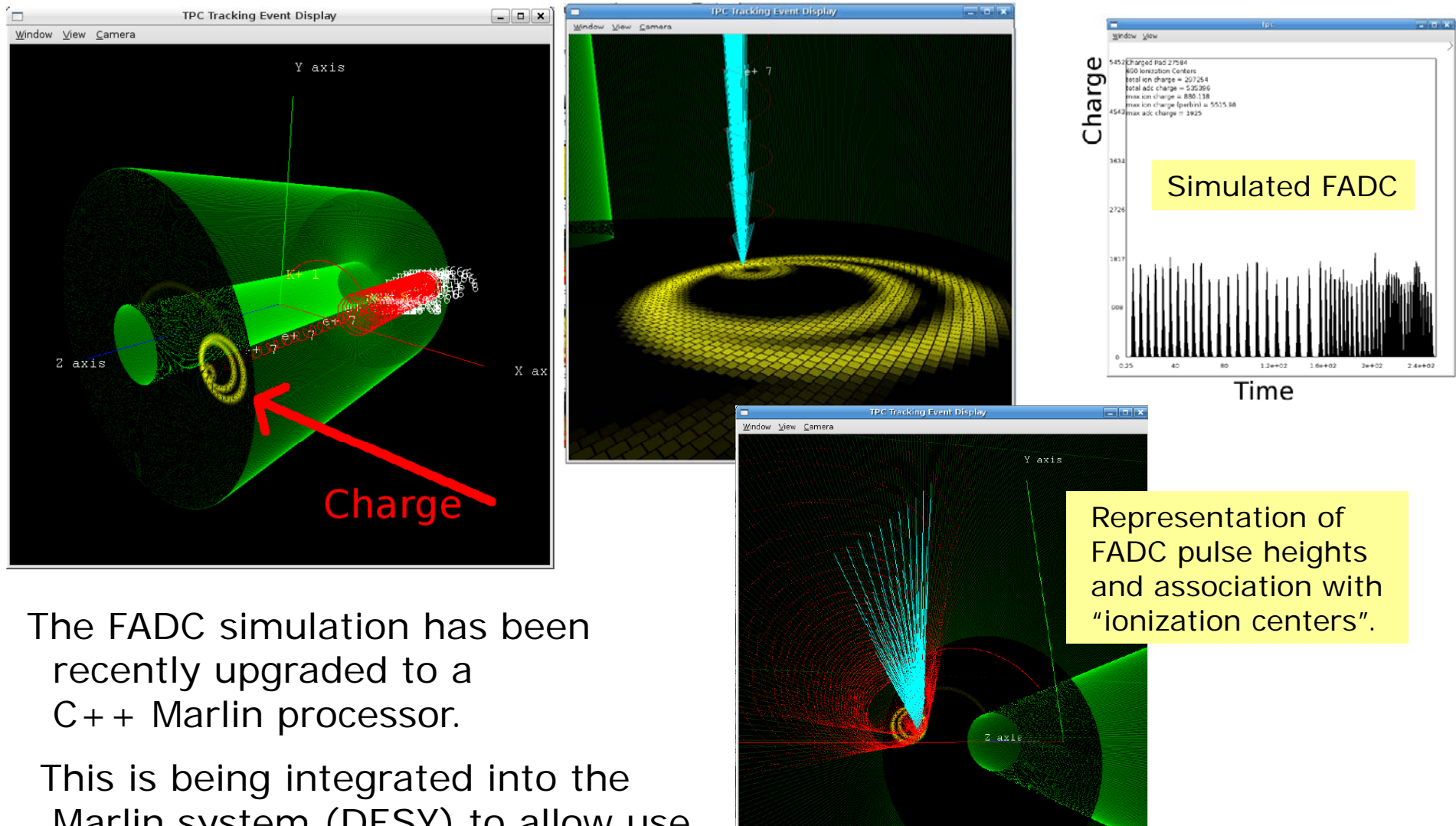
geometry description

MarlinReco

Marlin based reconstruction



# Simulation framework contributions, Cornell



The FADC simulation has been recently upgraded to a C++ Marlin processor.

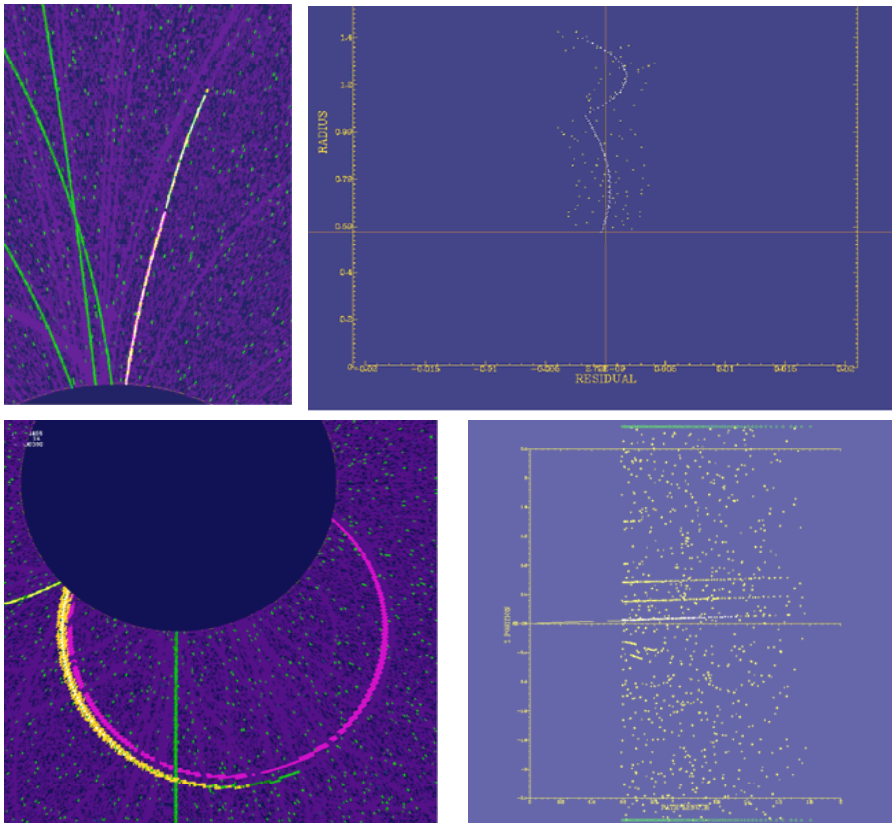
This is being integrated into the Marlin system (DESY) to allow use of the simulation in general tracking studies .

# Reconstruction within Marlin framework, Cornell

Implementation of CLEO/Cornell reconstruction in Marlin

will provide high efficiency, ability to understand and resolve pathologies (as recognized by the MarlinTPC leaders).

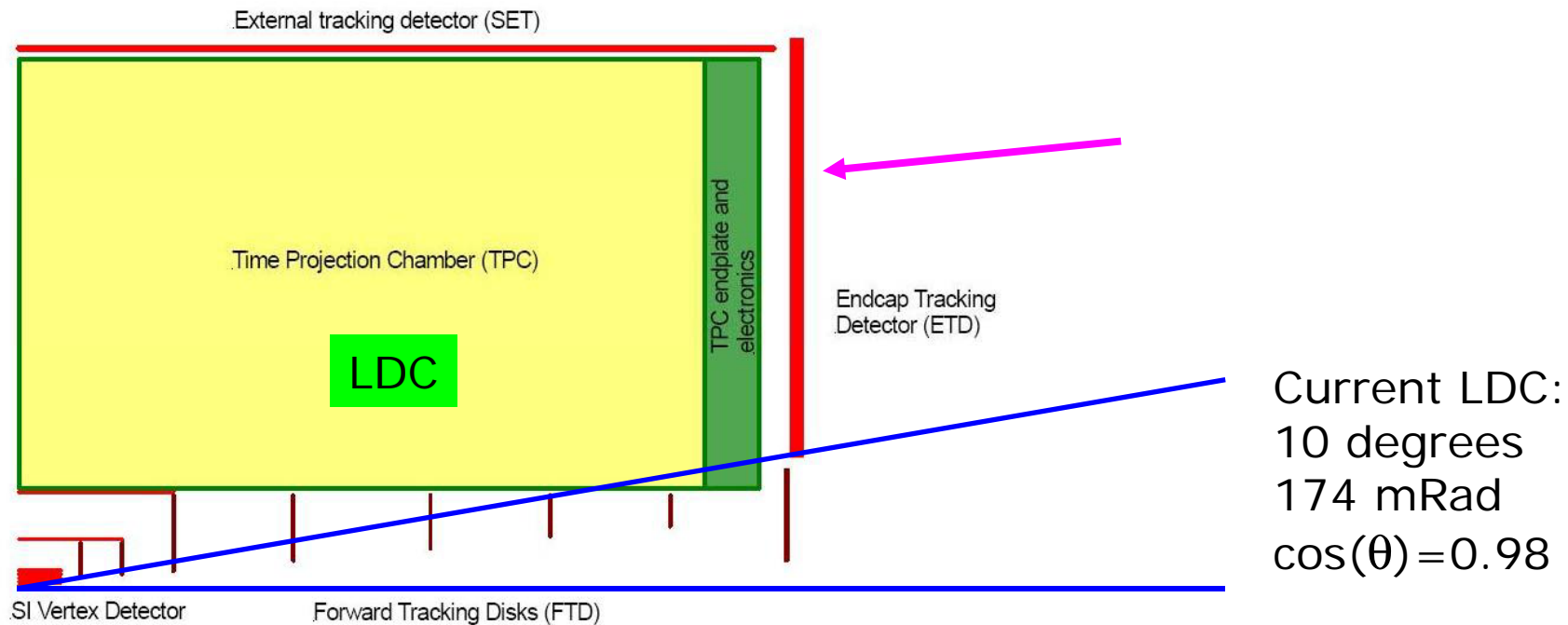
Full translation of the Cornell program will require a student/post-doc.



The current track finder in the Marlin reconstruction is preliminary.

Data structure	Processor name	input/output collection name
TrackerRawData		TPCRawData
	TrackerRawData2DataConverter	
TrackerData		TPCConvertedRawData
	PedestalSubtractor	
	ChannelByChannelCorrector	
	LinearityCorrector	
	TimeShiftCorrector	
TrackerData		TPCData
	PulseFinder	
	ChannelMapper	
	GainCorrector	
TrackerPulse		TPCPulses
	HitFinder	
	HitPRFCorrector	
TrackerHit		TPCHits
Track	TrackFinder[Method]	TPCSeedTracks
Track	TrackFitter[Method]	TPCTracks

# End-cap tracker studies, Louisiana Tech

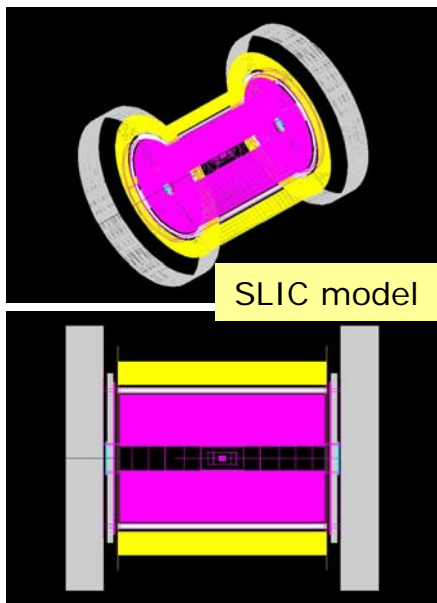


An **endcap tracking detector** is motivated by hermiticity, improvement in resolution at low angle, improved tracking in the very forward (high background) region, extension of differential Bhabha cross section beyond "LUMCAL".

Studies at Louisiana Tech (and collaborators) cover both simulation and detector prototyping



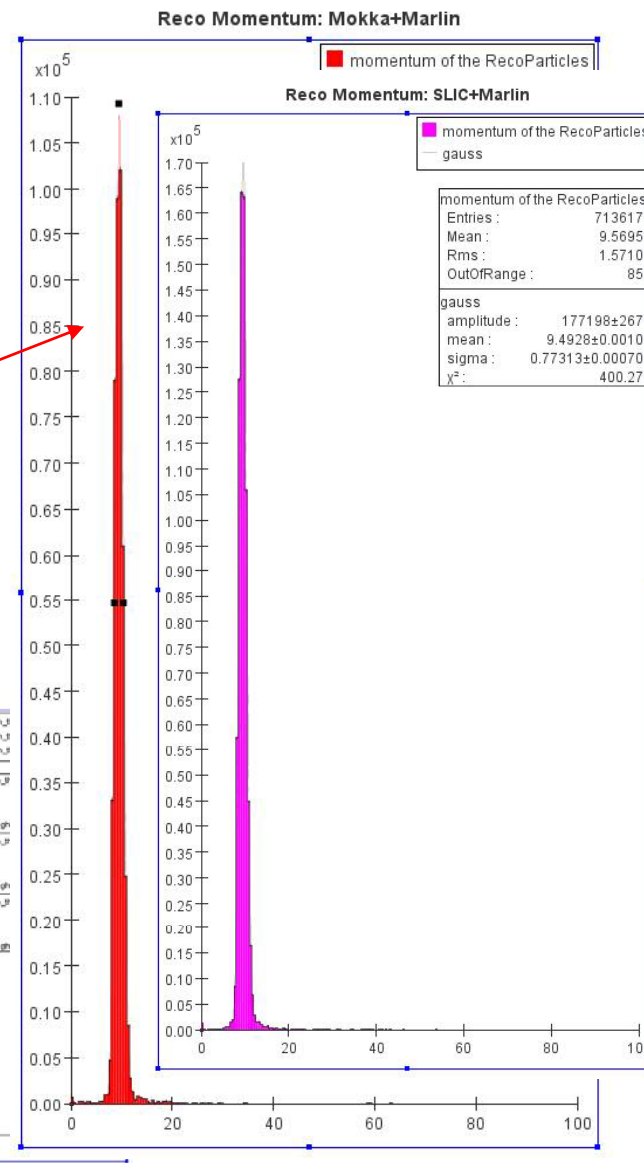
# End-cap tracker studies, Louisiana Tech



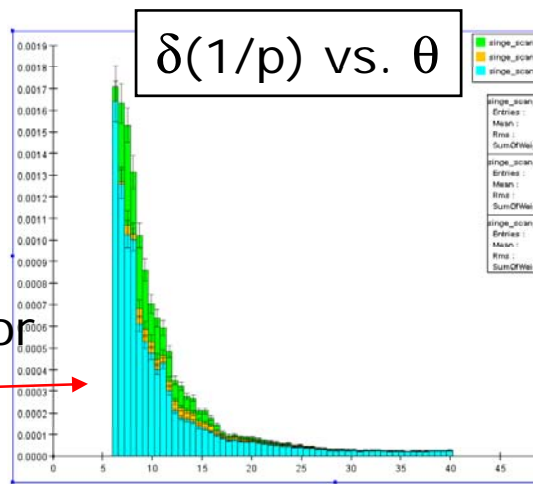
Simulations in both Mokka (Europe) and SLIC (USA)

Became a developer in Mokka/Marlin earlier than other US groups

(comparison of  $\mu$  momentum in Mokka vs. SLIC)

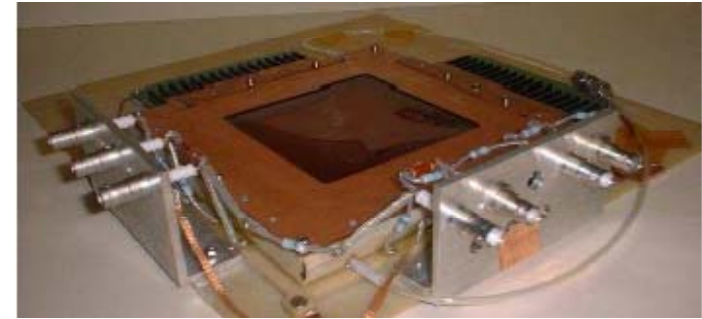


Contributions to the LDC "outline document" to evaluate effectiveness of endcap tracking detector

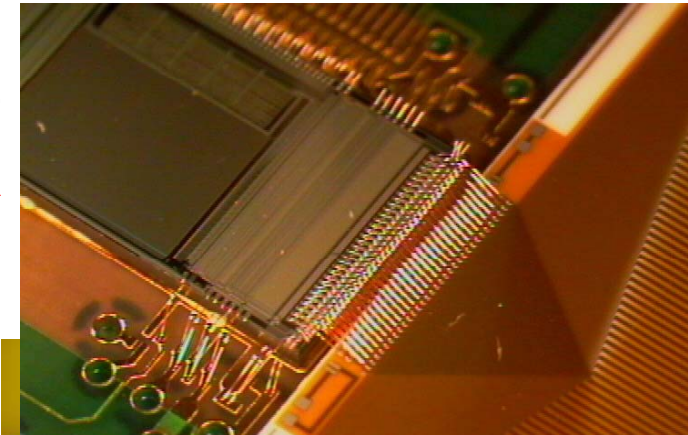


# End-cap tracker studies, Louisiana Tech

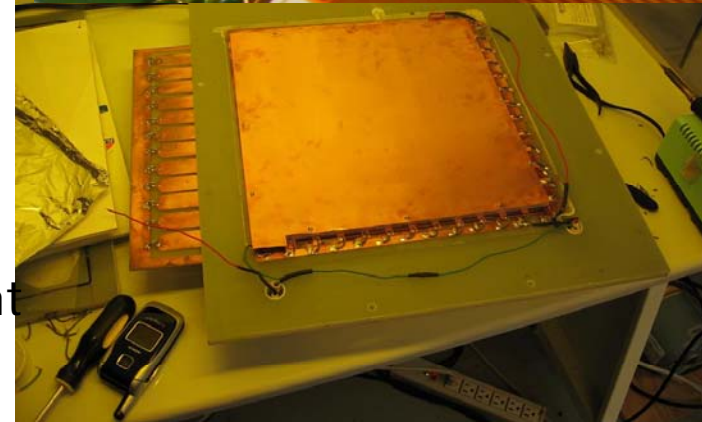
10cm x 10cm prototype built and tested  
(in collaboration with QWEAK Nuclear group at La Tech).  
pressure effects, voltage optimization



HELIX readout chip tested (mixed results)  
pursuing other preamp/digitizers (ALRO, VFAT)



30cm x 30cm chamber built in Fall 2006  
using FNAL QPA02 preamp  
Second chamber under construction,  
variable drift/gap



Design of readout board for  
endcap geometry is underway.

Addition of Indiana U. and Oklahoma U.  
test beam studies and electronics development  
forward tracking algorithms

# VLSI TPC readout, Berkeley

Pixel readout, similar in function to the TimePix readout being developed in Europe.

ATLAS pixel chip FE-13

timing: 40 MHz (25 ns) (TimePix is 48MHz)

Time Over Threshold readout  
configurable thresholds.

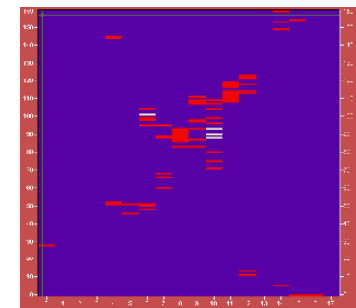
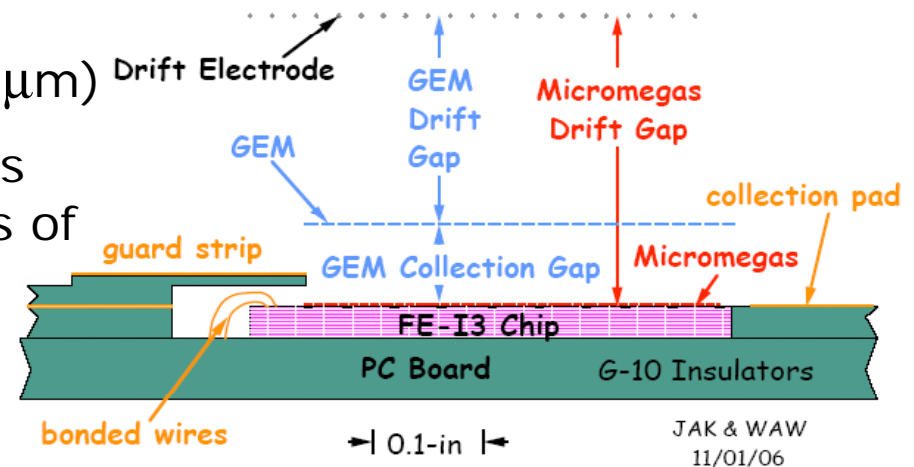
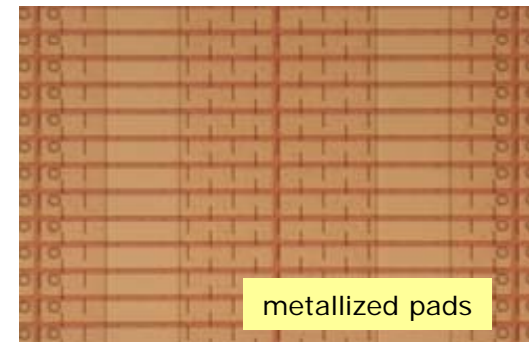
400 x 50  $\mu\text{m}$  pads (TimePix is 55 x 55  $\mu\text{m}$ )

Charge collection is on the bonding pads (may not have the (TimePix) problems of positioning the HV close to silicon.)

Requires metallization of bonding pads; metallization performed on 30 chips

Cosmic ray,  
with Double GEM gas amplification.

*Project is in early stage and may be more suited to an upgrade of an ILC TPC, as is the TimePix configuration.*



# Expansion of US LC-TPC LP involvement

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The LC-TPC program and the US presence would be strengthened by involvement of another group working in gaseous tracking.

Need for more help in large prototype

- slow control
- gas system
- calibration software tools

Beyond

- ALIRO chip evolution to 130nm technology - testing
- optical link
- readout electronics

Any of these projects would require the addition of a small group:  
Faculty, 1-2 post-doc, 1-2 students .



# Summary

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US groups have important and integral roles in the international TPC development and detector concept studies.

Future support is required to guarantee very visible US contribution in

Large prototype - including the 1<sup>st</sup> and 2<sup>nd</sup> phases endplates and possible other needed contributions

Small prototype – where important contributions can be made in ion feed back measurements and comparative gas-amplification measurements

Simulation and Reconstruction software – where the advances in reconstruction techniques can fully realize the reconstruction power of a TPC

Endplate tracking – development of the GEM device is unique to the US and selected as the base technology for LDC