Gaseous Tracking

Daniel Peterson, Cornell University

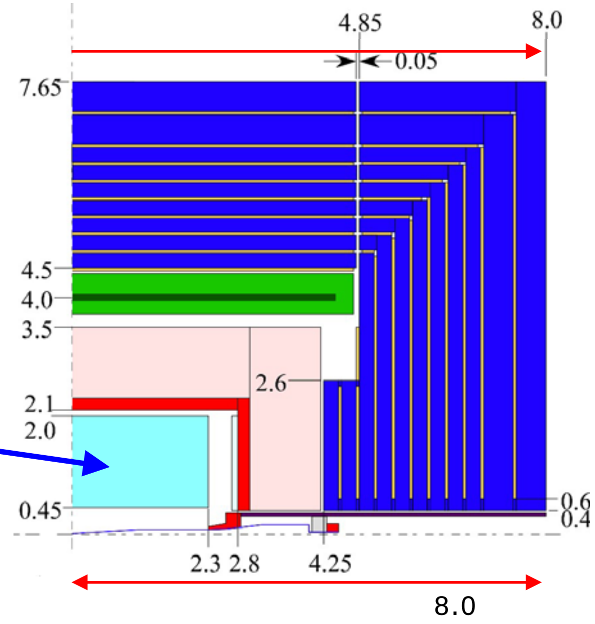
16-June-2007 version

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

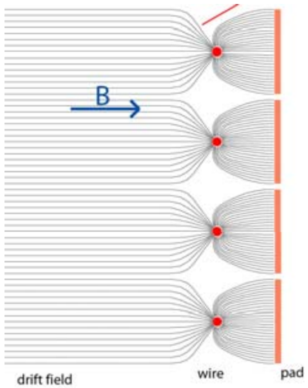
2012-2016 contruction

2017 commission

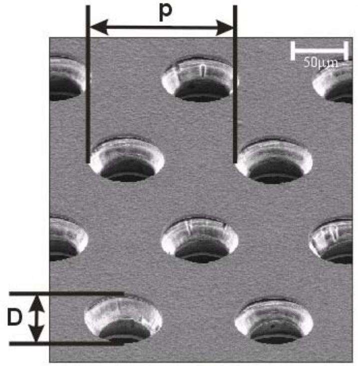
Directions in gaseous tracking

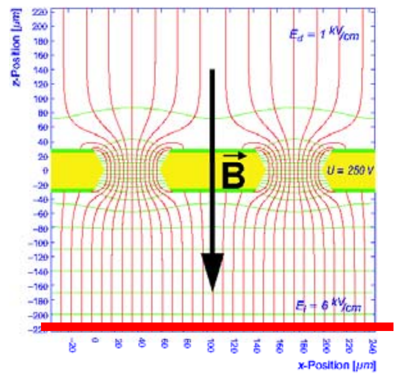
All gaseous tracking devices work on a principle
of collection ionization formed by passing charged particles,
and amplifying that ionization to create a detectable signal.

Wires have disadvantages
inductive signal - wide
wire spacing: ~ mm
strong ExB effect



GEM

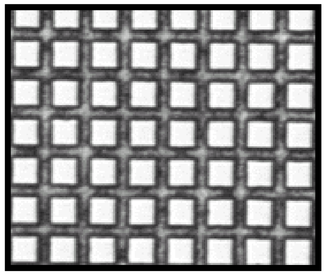


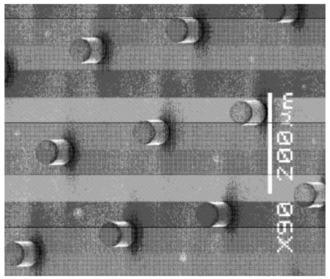


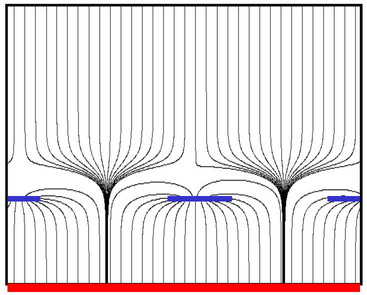
50 μm amplification region is displaced from the anode

anode

Micromegas





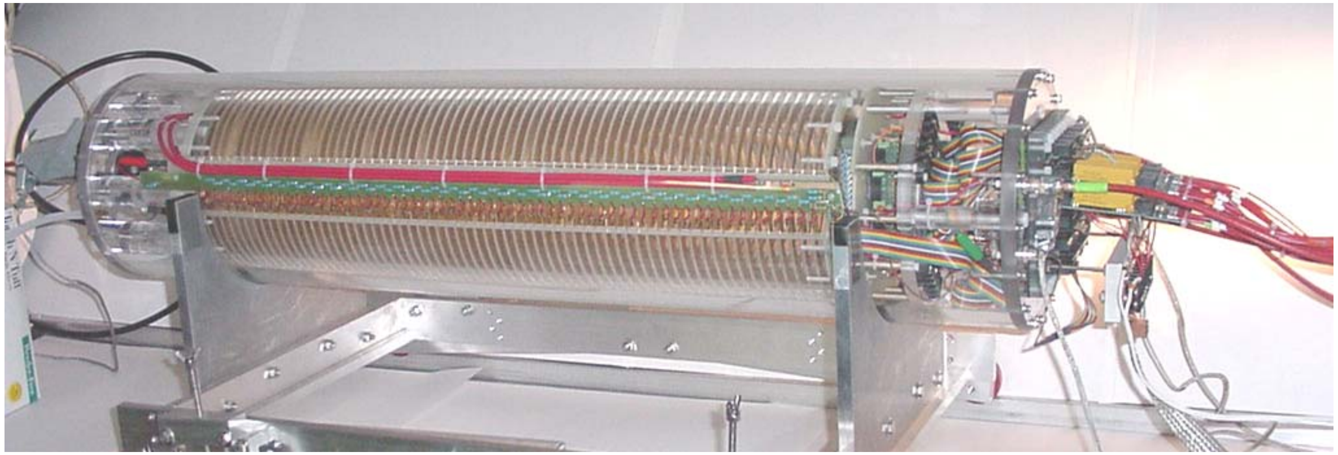


50 μm amplification region includes the anode

anode

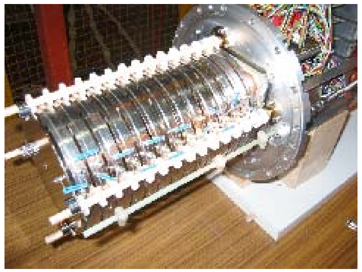
CORNELL UNIVERSITY LEPP
LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

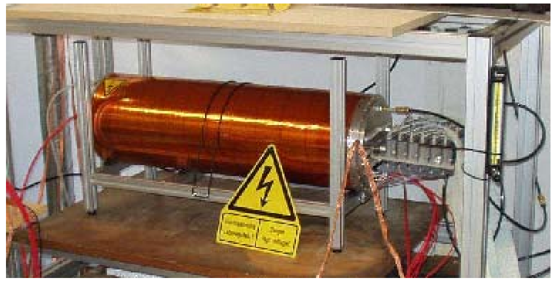
TPC small prototype program at Cornell

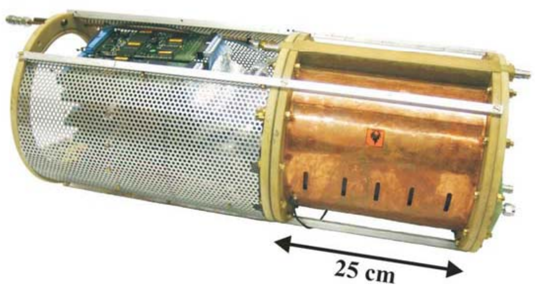


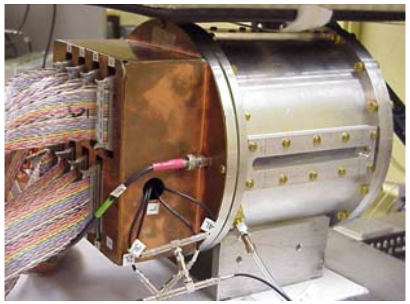
Cornell/Purdue chamber, 64cm drift, 10cm square gas amplification

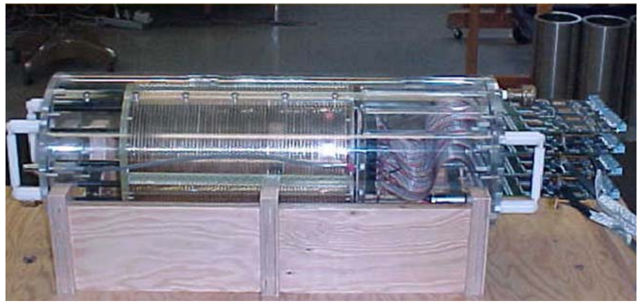
selected other chambers



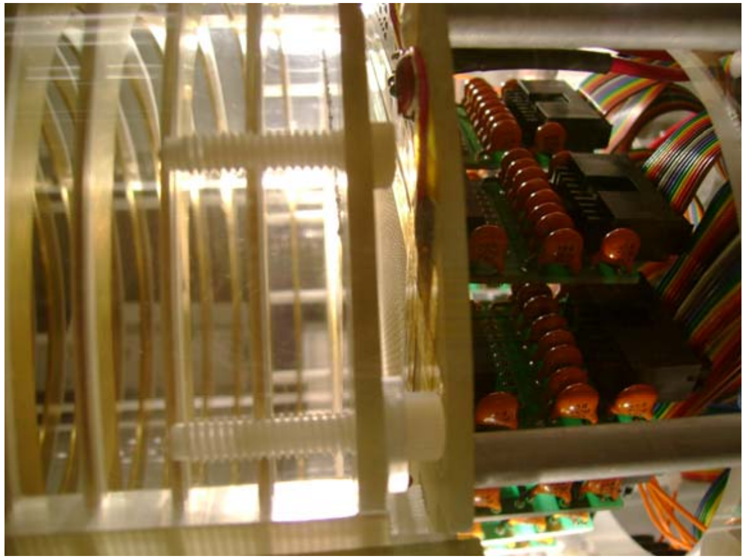


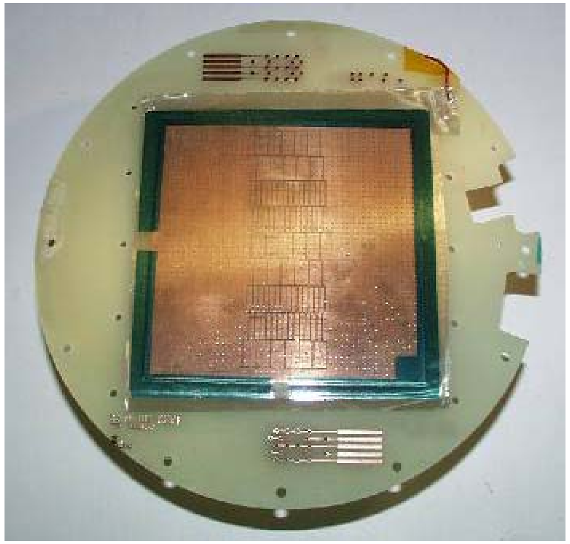






TPC small prototype program at Cornell



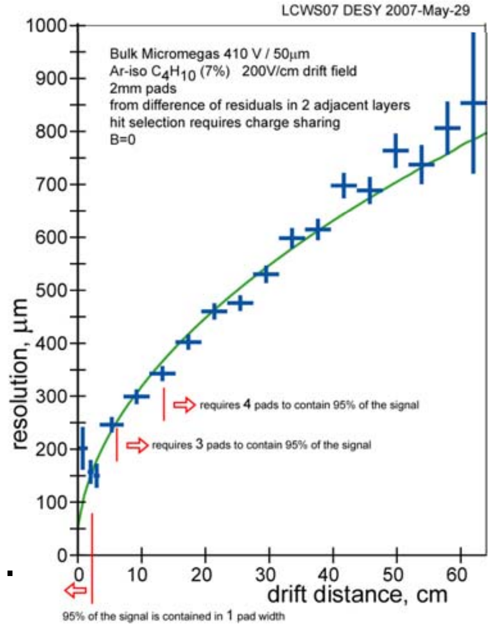


Studies with the Cornell/Purdue chamber involve independent characterization of the candidate gas amplification devices.

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

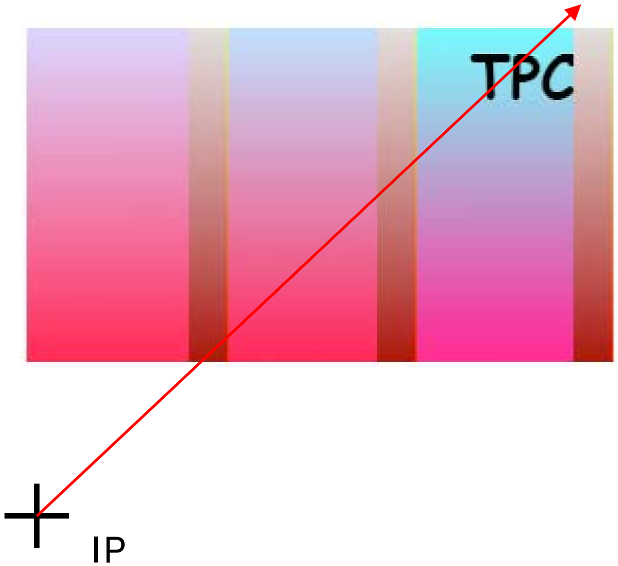
Resolution, extrapolating to zero diffusion, is 53 μm.

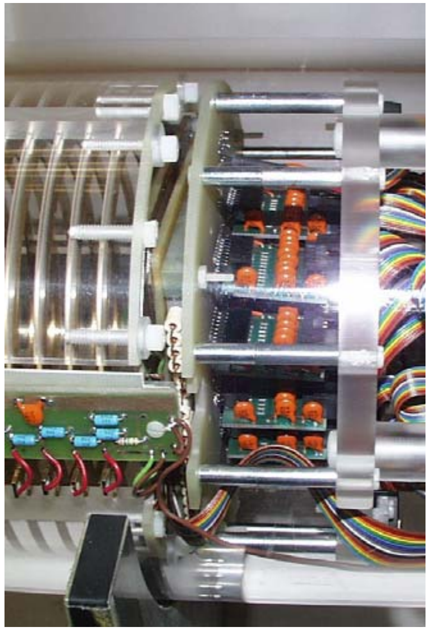
There is a need for such independent measures but this program has not had access to a magentic field.

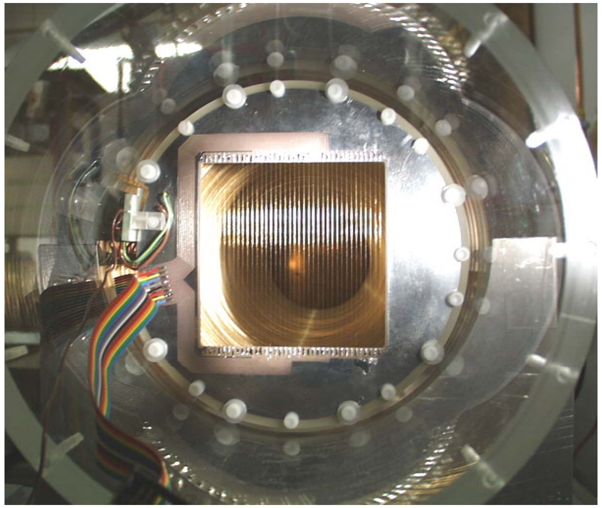


TPC small prototype program at Cornell

Ionization in the TPC



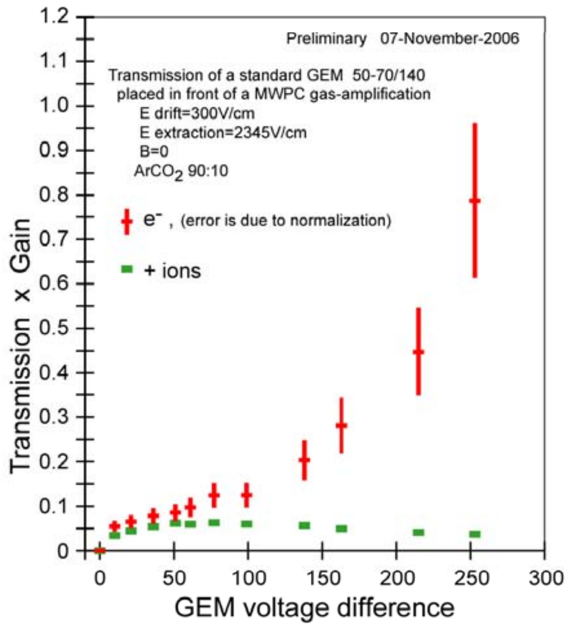




Ions are produced at the gas amplification and drift (as sheets) into the field cage.

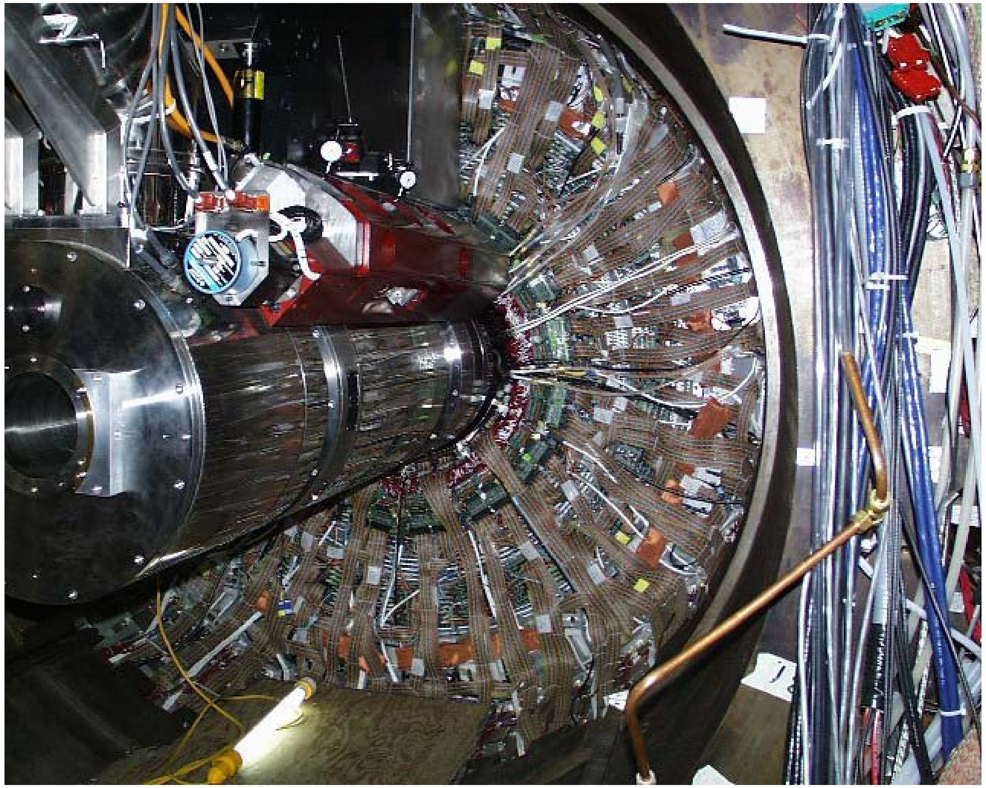
LCTPC is investigating ion gating technology, including a gated GEM.

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

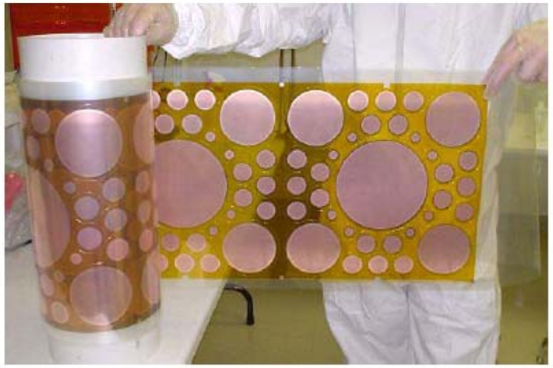


TPC small prototype program at Cornell

future plans...
- the magnet run
  - transmission
  - direct comparison of 3-GEM and Bulk Micromegas



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.

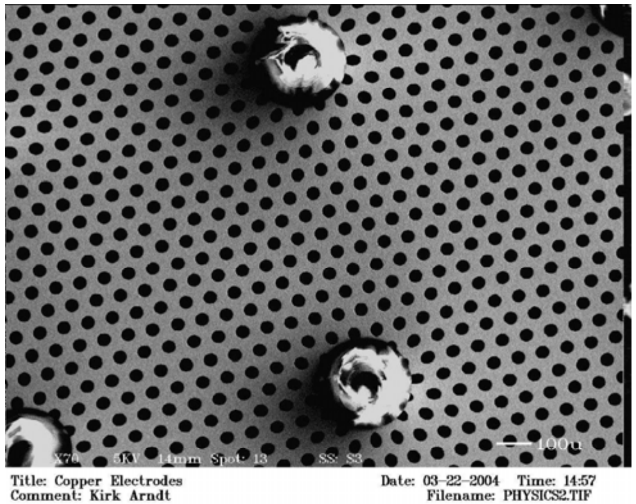
Holes are etched in the copper
- 70 µm spacing (smallest distance)
- 35 µm diameter

Copper thickness: 9 µm

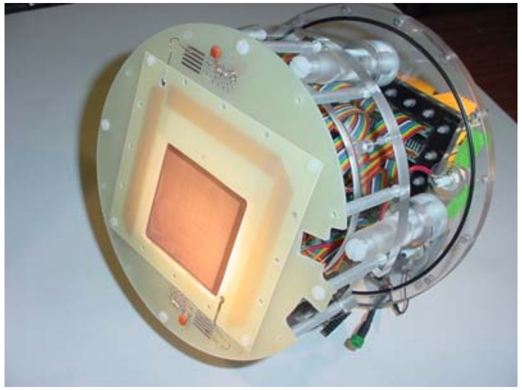
Pillars are the remains of etched Kapton.
- 50 mm height
- 300 mm diameter at base
- 1 mm spacing, square array

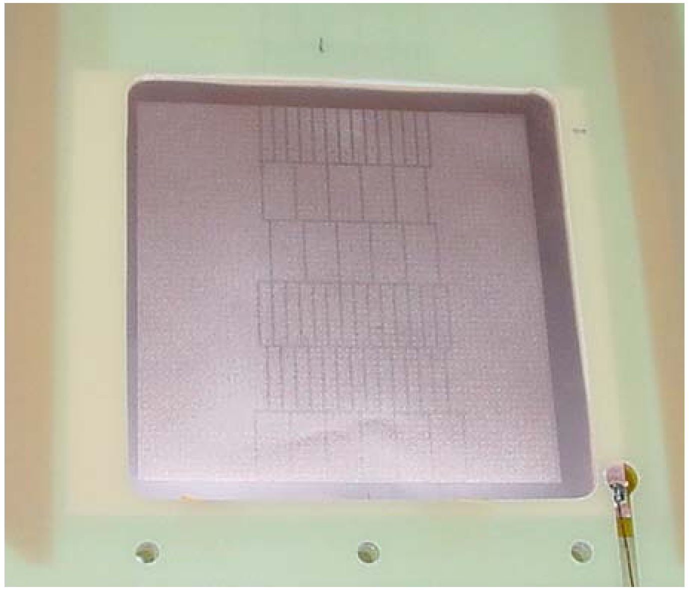
The shiny surface of the pillars is due to charge build-up from the electron microscope.

Has different physical characteristics and response compared to mesh Micromegas.



MPGD development at Purdue

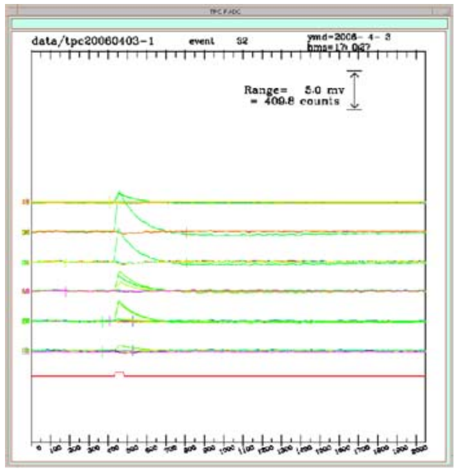




Purdue-3M Micromegas was tested
at Cornell in 2006.

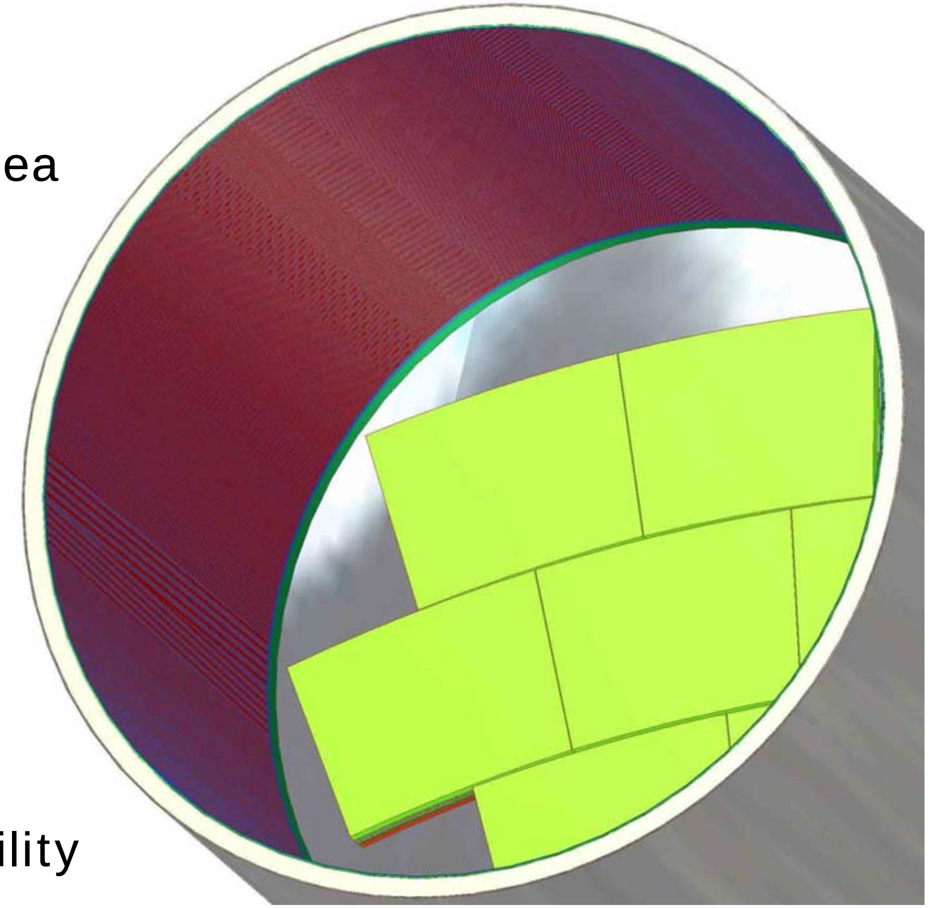
Pulse height is 5X that is mesh Micromegas.

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



immediate goals

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

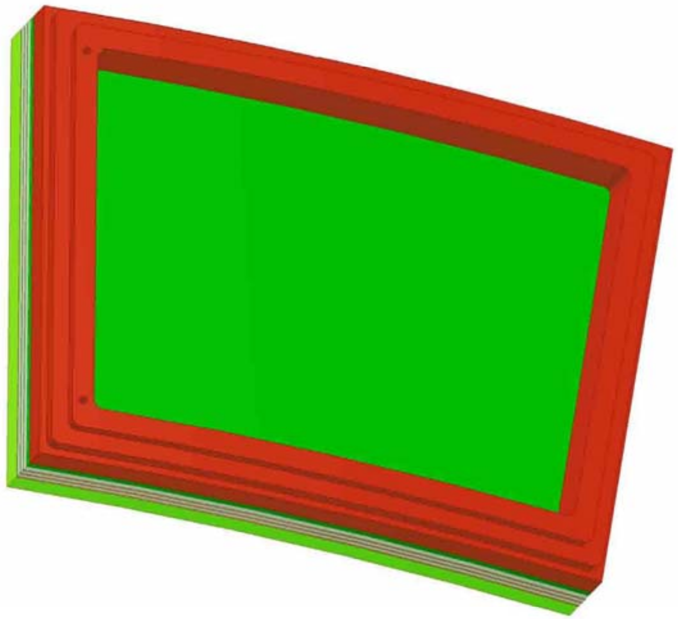
60 cm drift length
80 cm diameter
a cut-out region of an ILC TPC

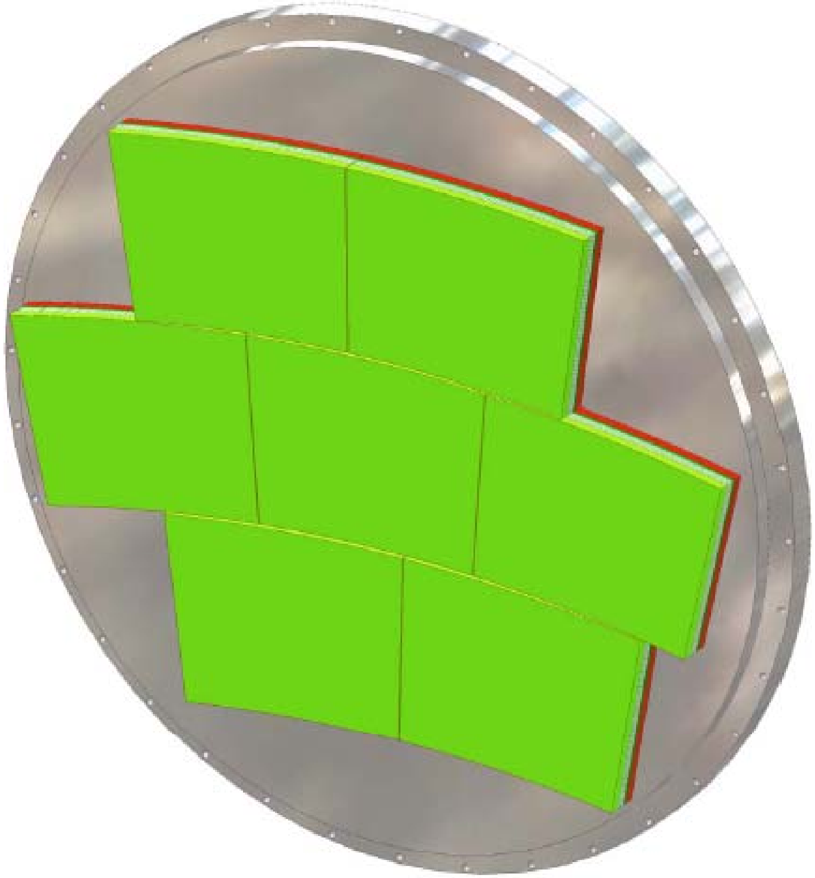
magnet field run at DESY, EUDET facility
This is only 1.3 Tesla.
need for higher magnet field and ILC beam structure in the future

TPC large prototype program at Cornell

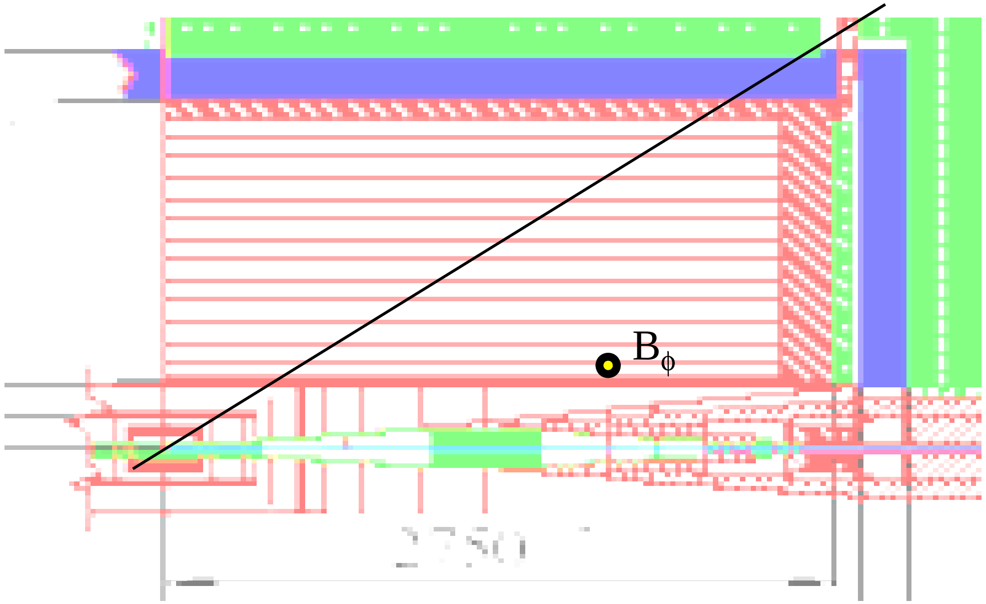
Cornell responsibility

- endplate
- mating module frames





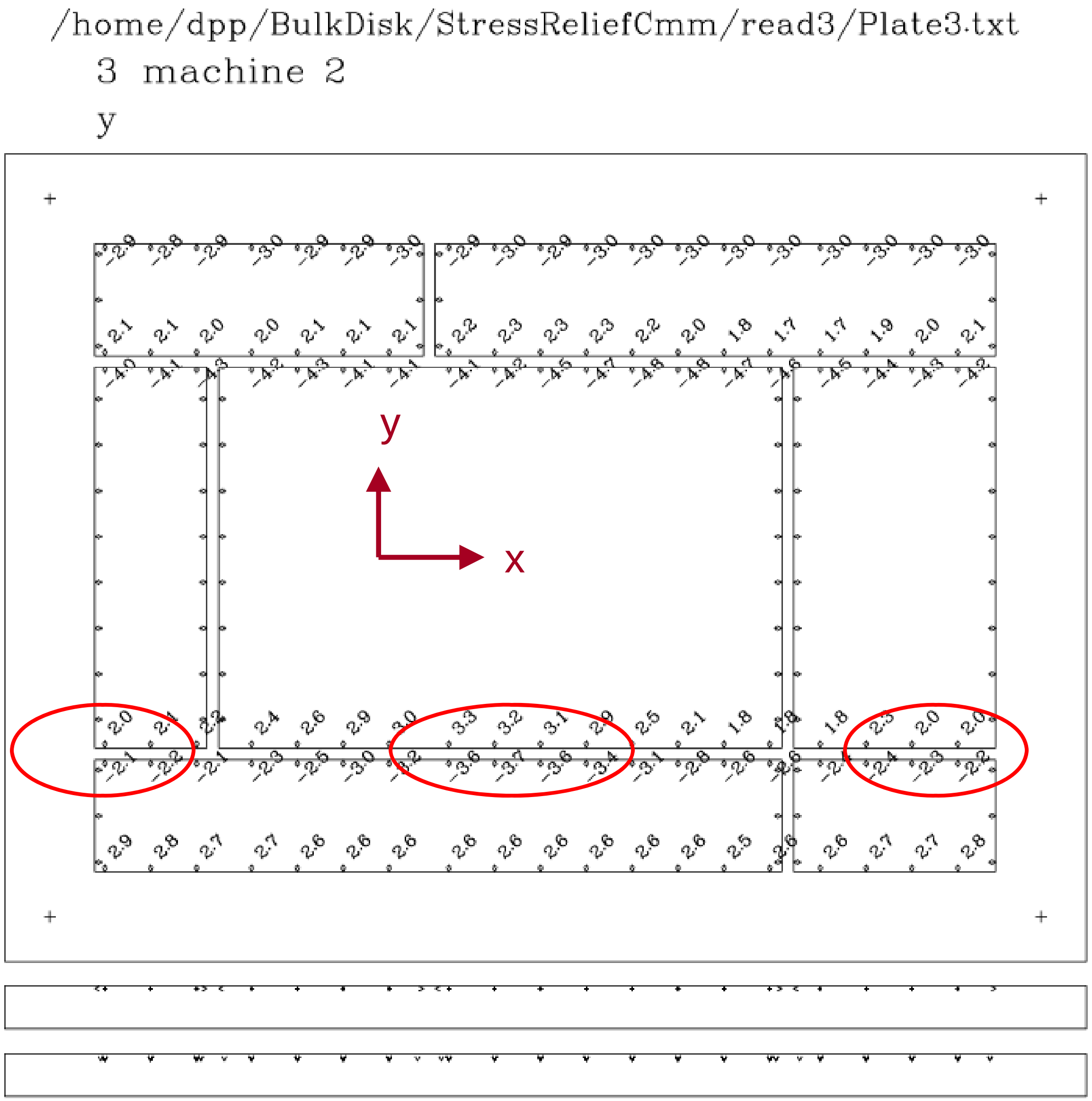
TPC large prototype program at Cornell



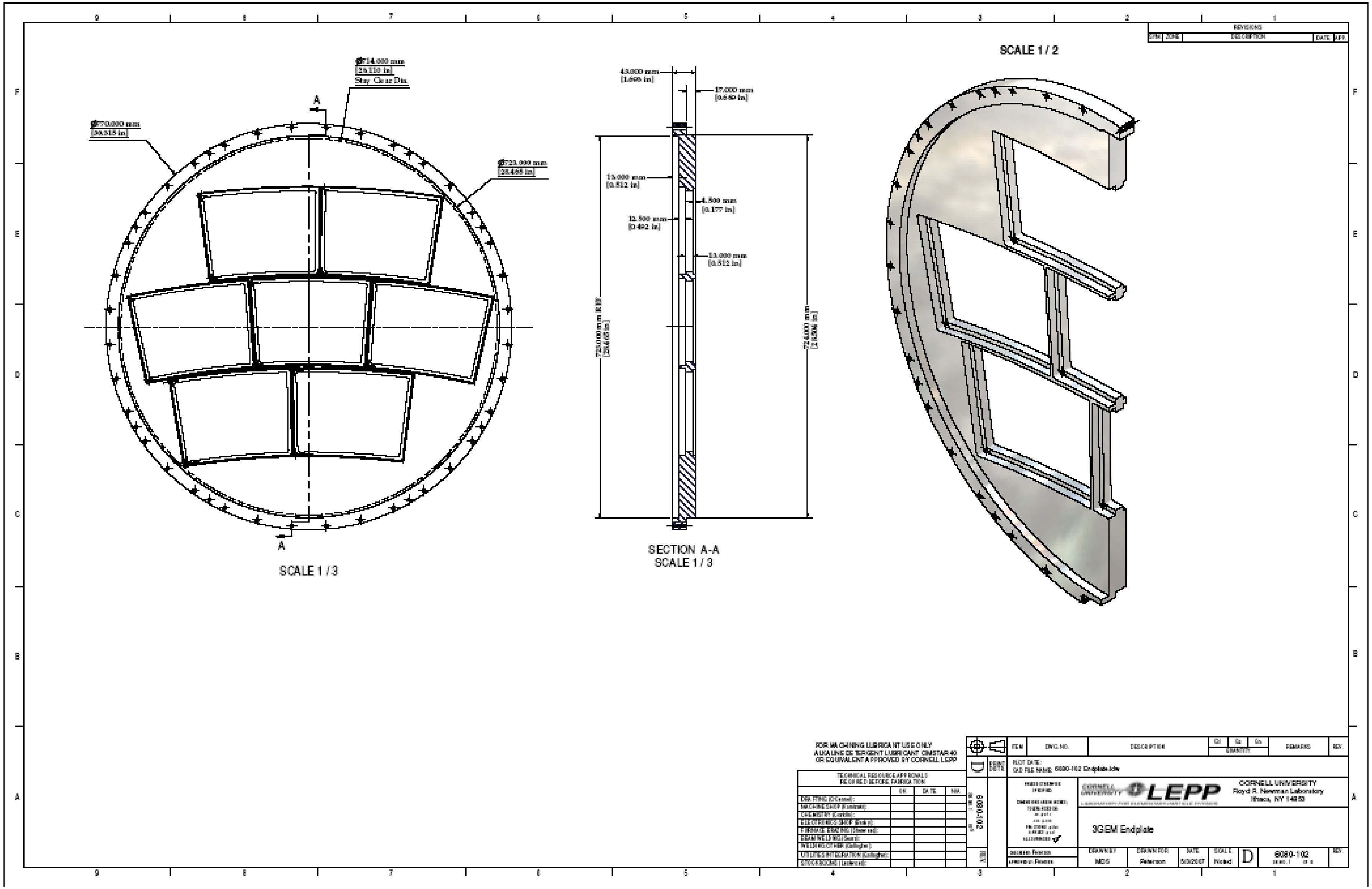
discussion of requirements for
decoupling the survey of the endplate
from the survey of the magnetic field
due to the $\delta(1/p_t) < 2\text{-}5 \times 10^{-5}/\text{GeV}$

TPC large prototype program at Cornell

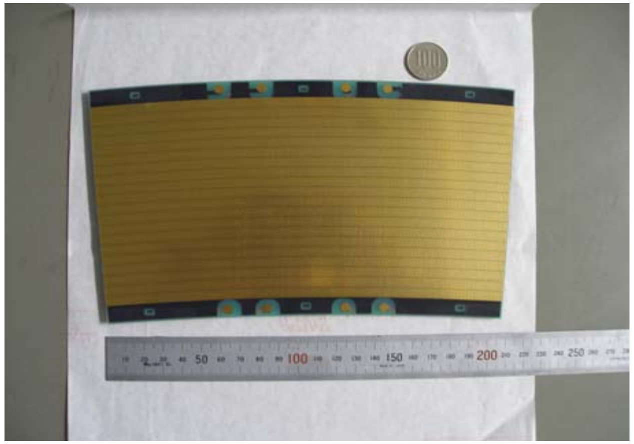
Studies of machining procedure

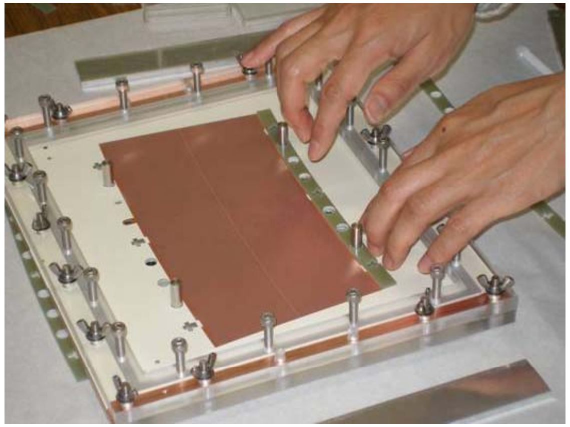


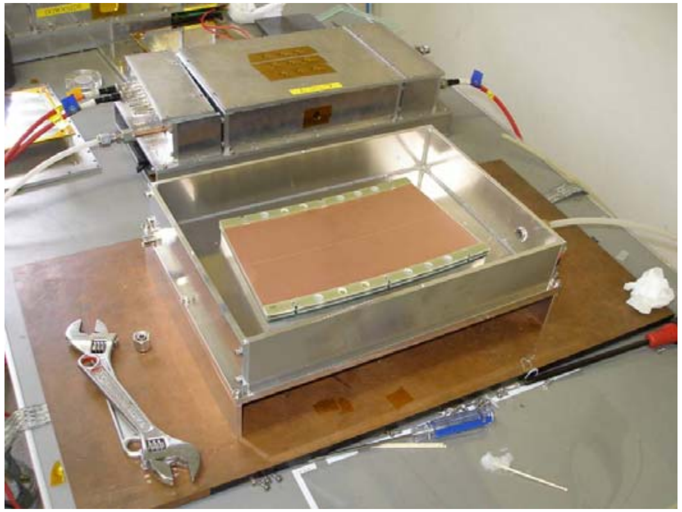
TPC large prototype program at Cornell

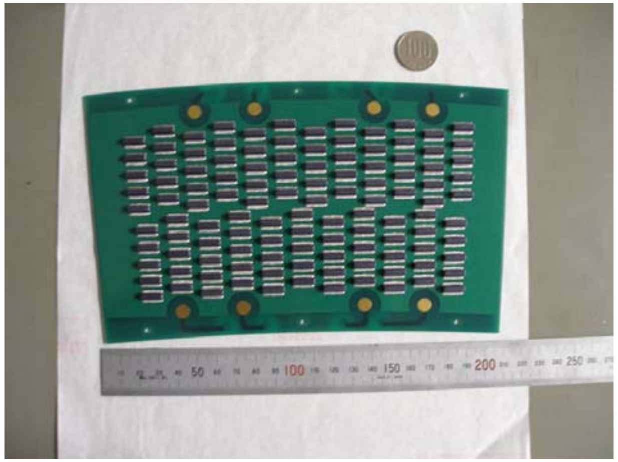


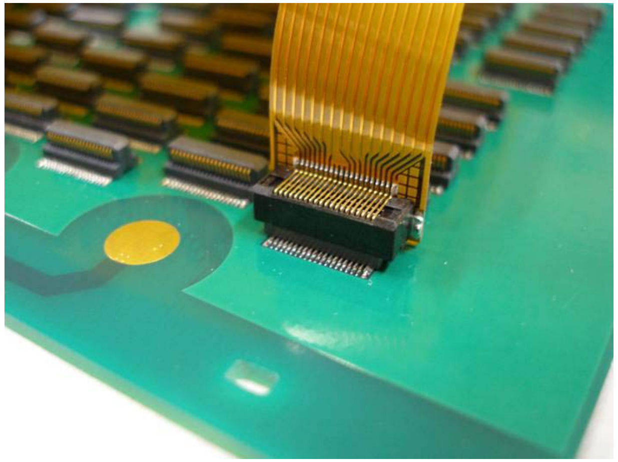
LC-TPC: the large prototype, module











Constructing a pre-module.

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

Gain tests have been done.

See A. Ishikawa

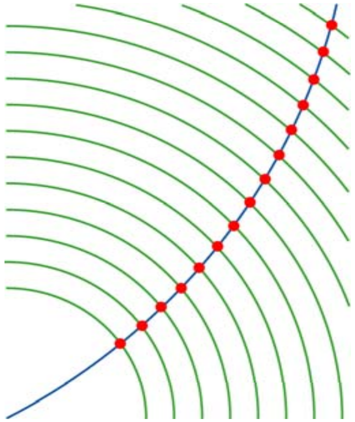
TPC large prototype program at Cornell

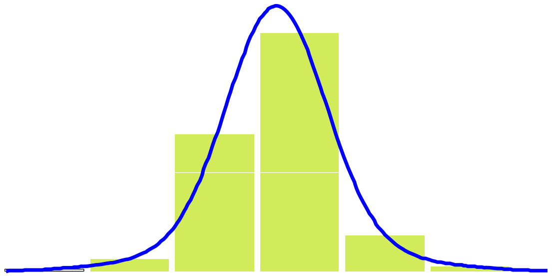
schedule

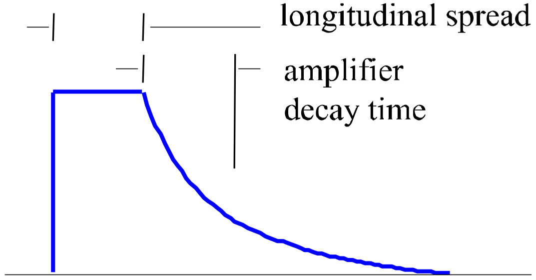
future plans

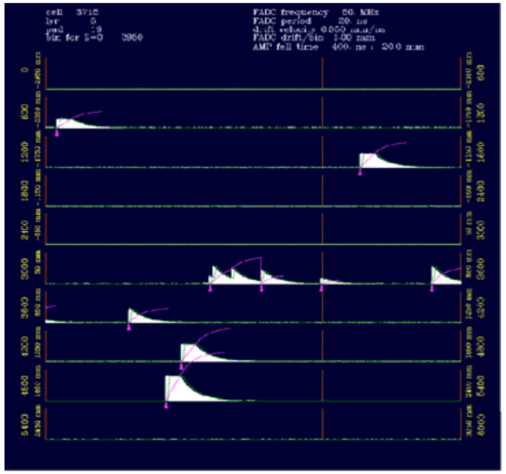
low scattering construction

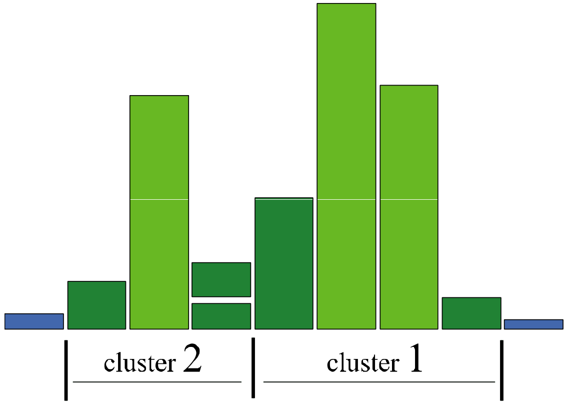
Background studies for the TPC



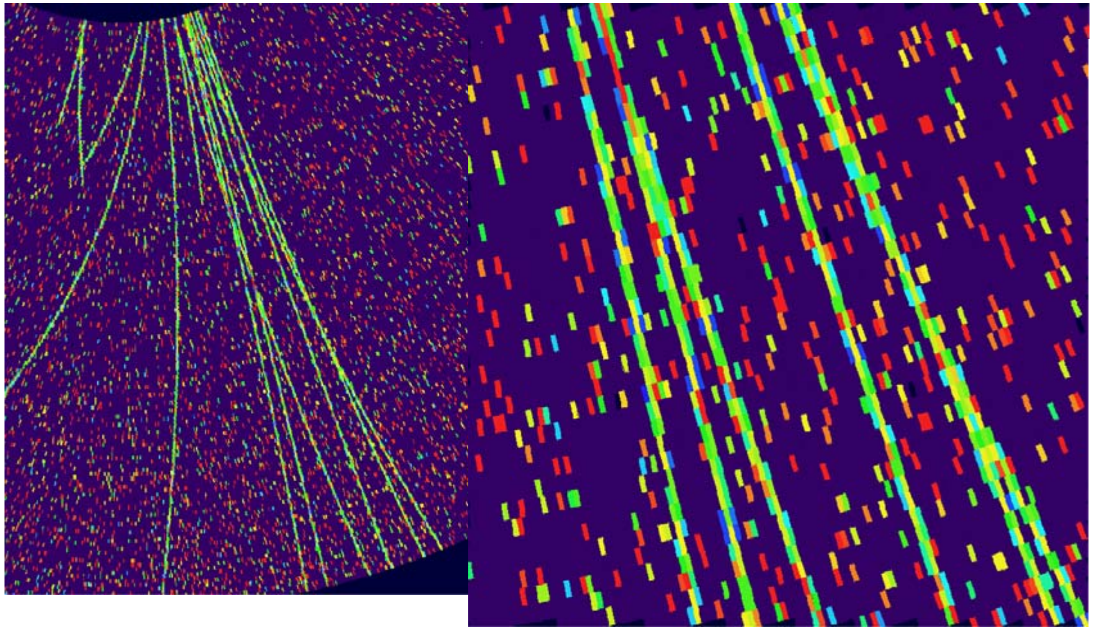


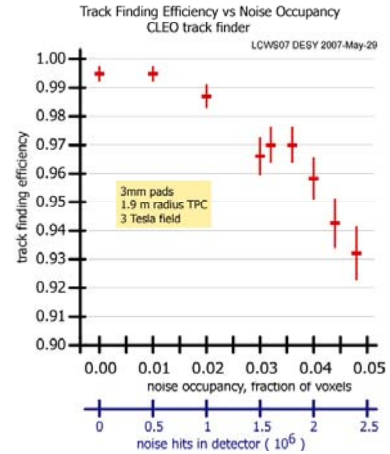


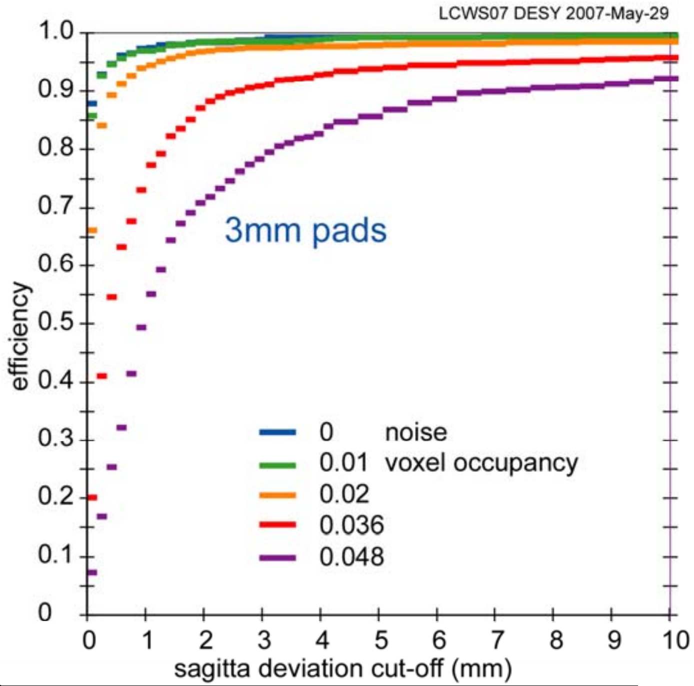




Background studies for the TPC

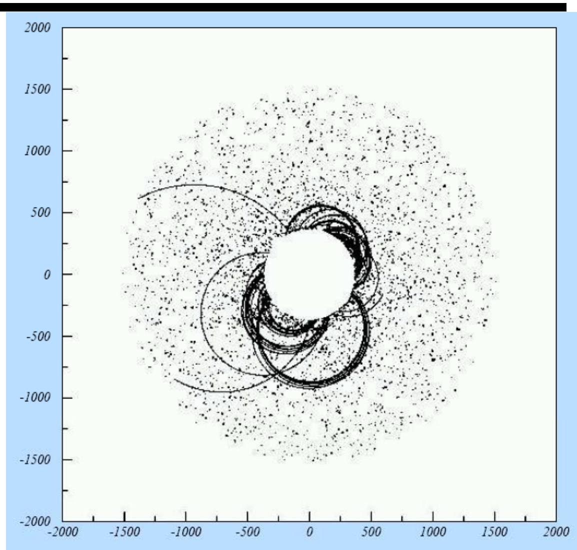






Background studies for the TPC

See A. Vogel LCWS07

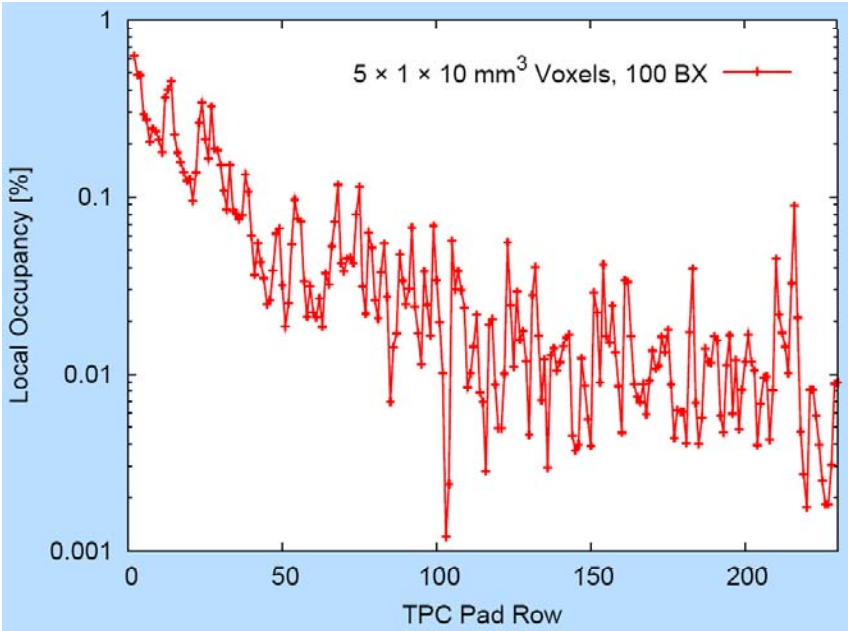


While the Cornell study indicates that a 1% uniform occupancy will not affect pattern recognition or TPC resolution,

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 form the LC-TPC response to questions about occupancy.



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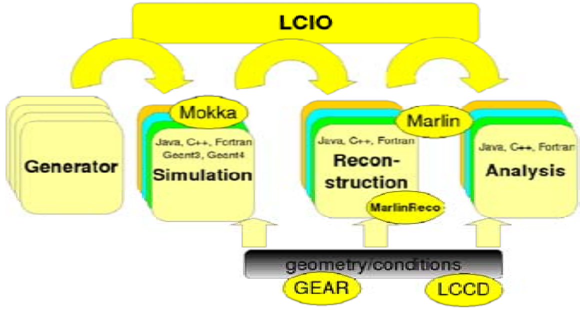
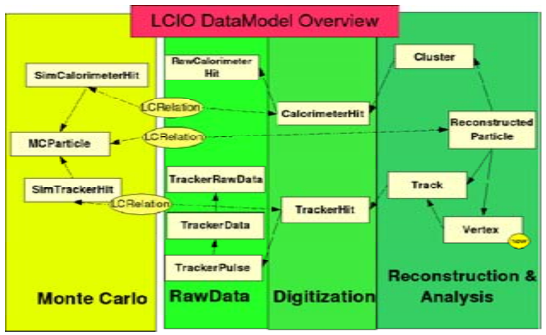
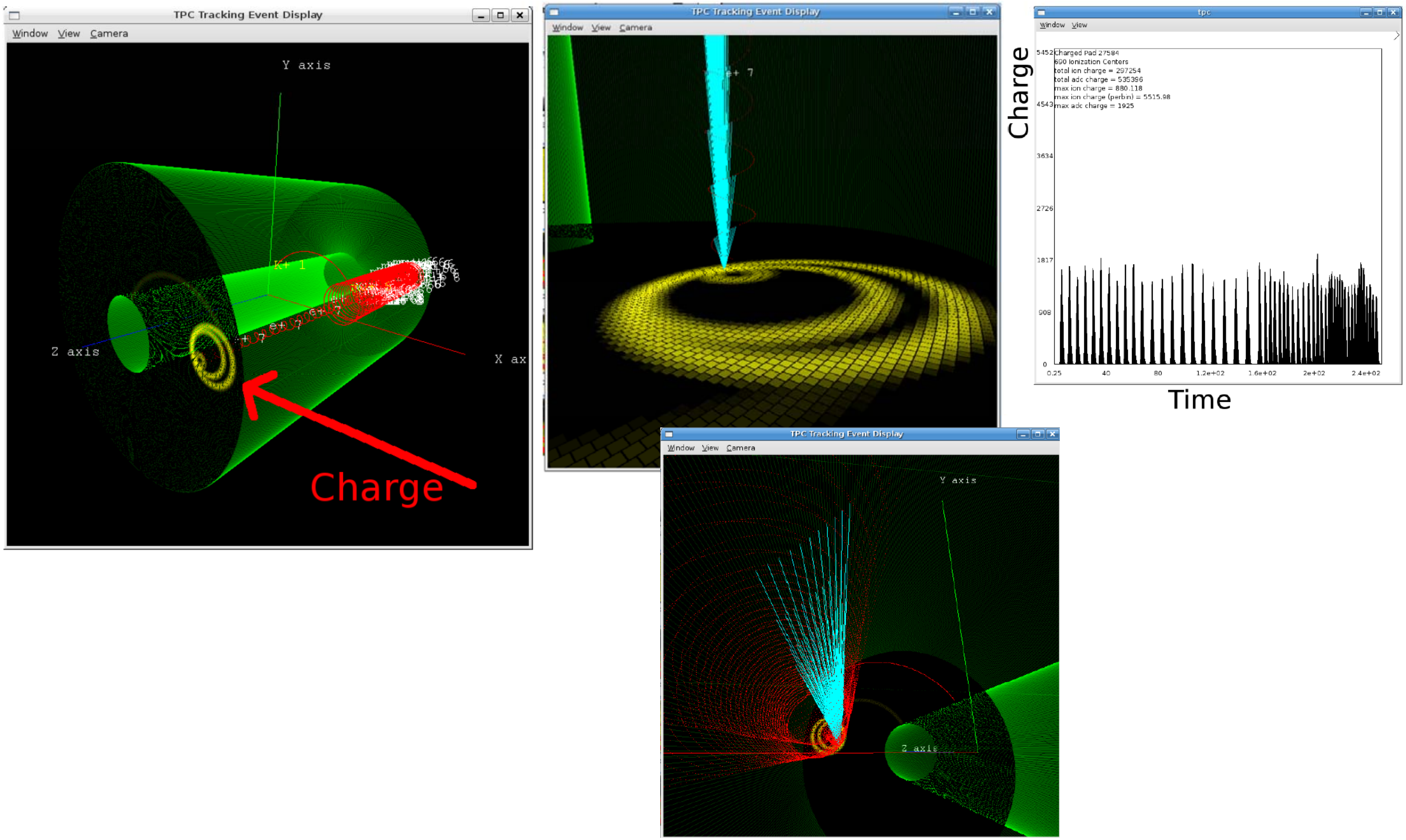
Mokka , Marlin, LCIO

LCIO
  data model & persistency
Marlin
  C++ application framework
LCCD
  conditions data toolkit
GEAR
  geometry description
MarlinReco
  Marlin based reconstruction





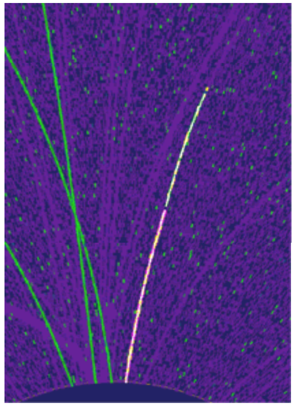
Simulation framework contributions

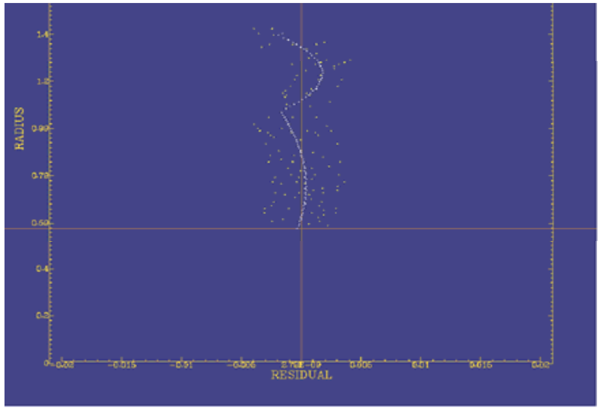


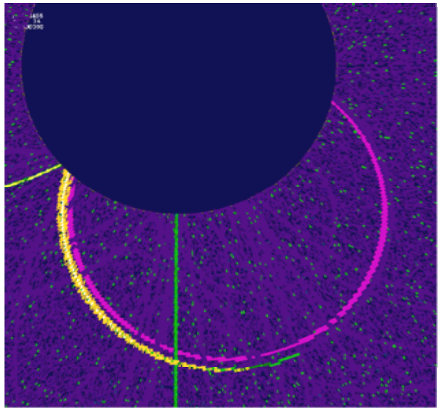
Reconstruction within Marlin framework

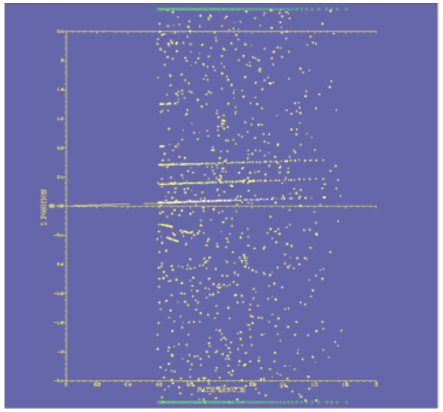
Implementation of CLEO/Cornell reconstruction in Marlin

student ...
post-doc ...



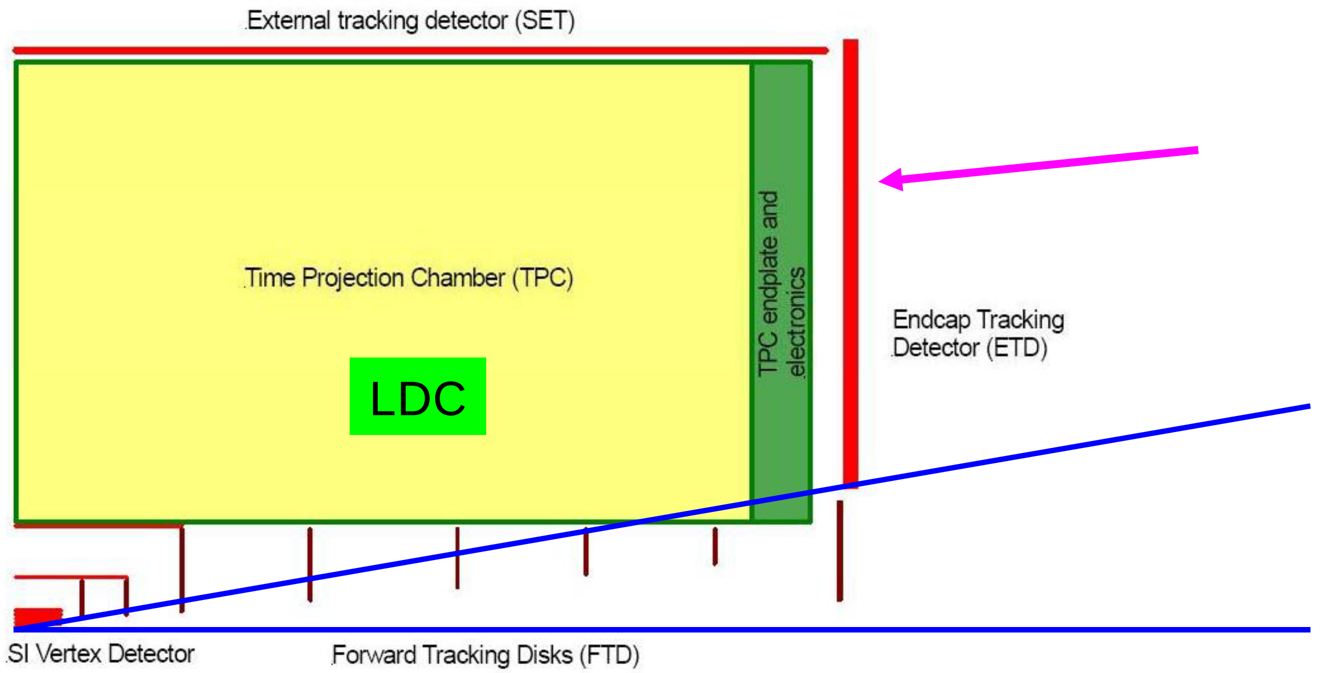






Data structure	Processor name	input/output collection name
TrackerRawData		TPCRawData
	TrackerRawData2DataConverter	
TrackerData		TPCConvertedRawData
	PedestalSubtractor	
	ChannelByChannelCorrector	
	LinearityCorrector	
	TimeShiftCorrector	
TrackerData		TPCData
	PulseFinder	
	ChannelMapper	
	GainCorrector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

End-cap tracker studies at Louisiana Tech

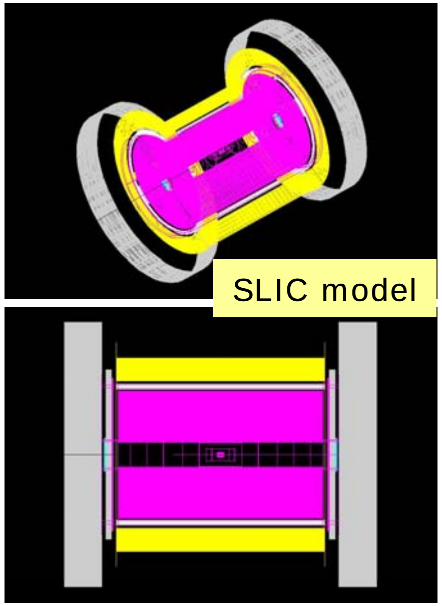


Current LDC:
10 degrees
174 mRad
cos(θ)=0.98

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

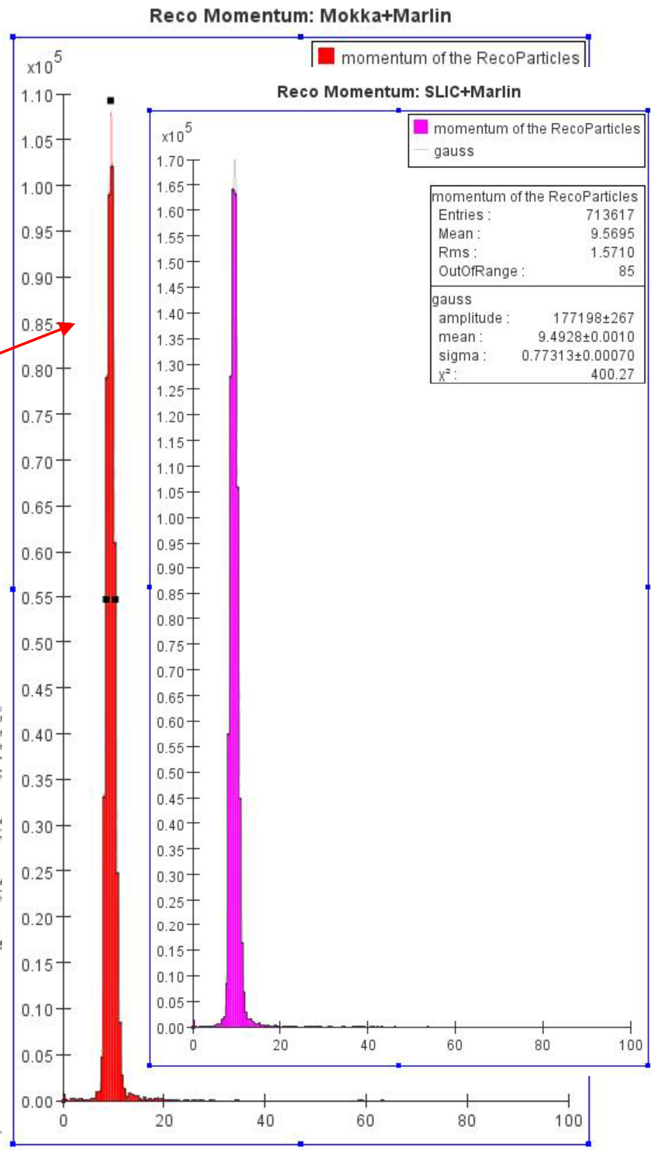
End-cap tracker studies at Louisiana Tech



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

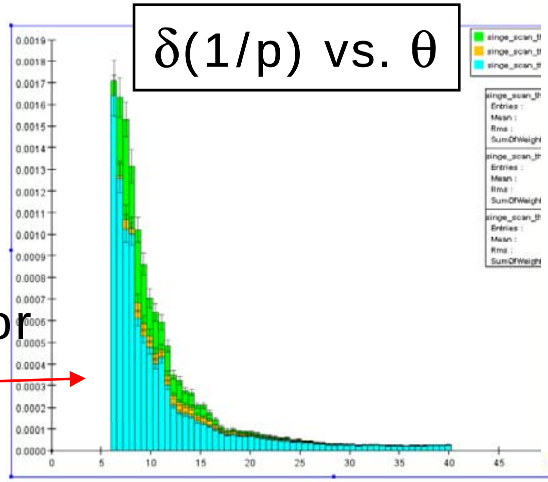
Became a developer in
Mokka/Marlin earlier than
other US groups

(comparison of μ momentum
in Mokka vs. SLIC)



Contributions to the
LDC "outline document"

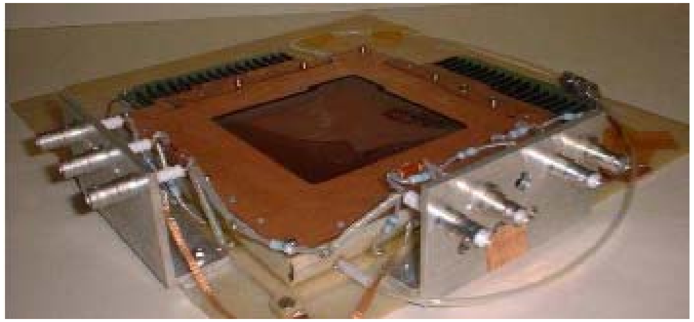
to evaluate effectiveness
of endcap tracking detector



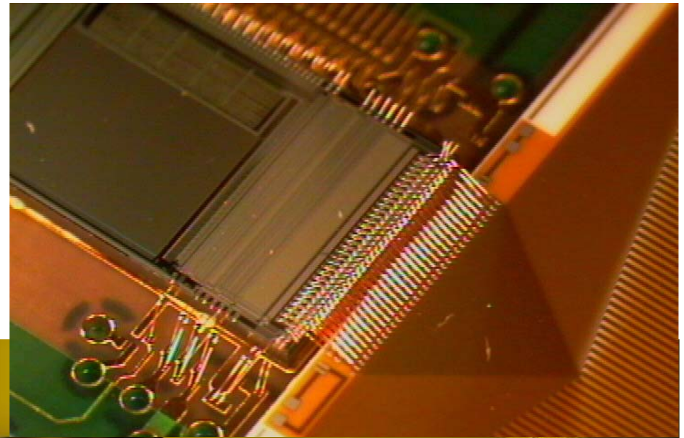
End-cap tracker studies at Louisiana Tech

10cm x 10cm prototype built and tested
(in collaboration with QWEAK Nuclear group at La Tech).

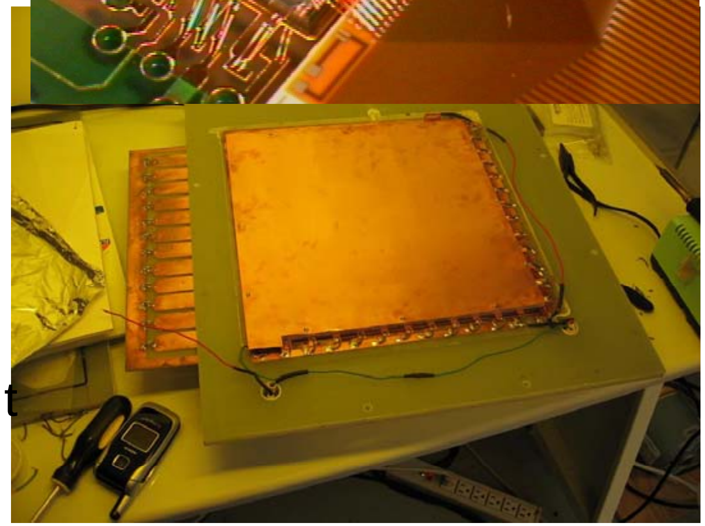
pressure effects, voltage optimization



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

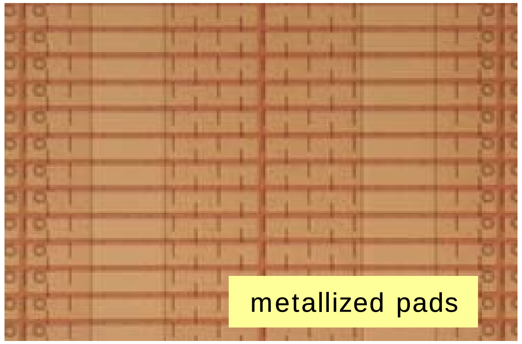


Design of readout board for
endcap geometry is underway.

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

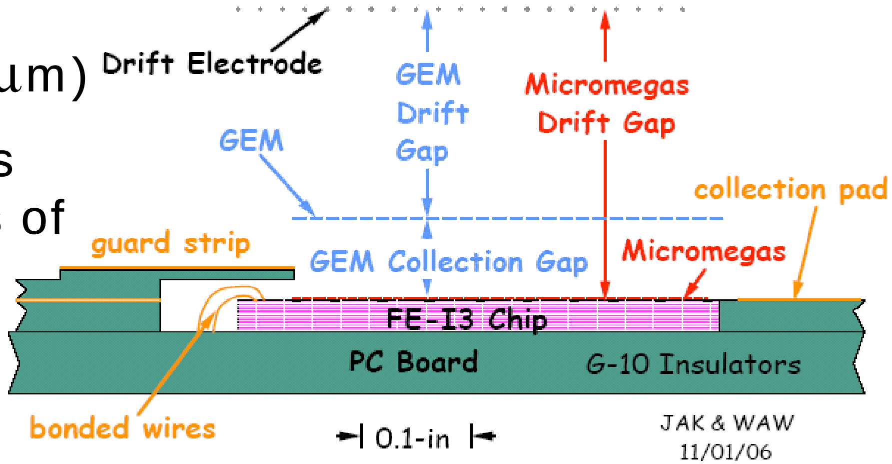
VLSI TPC readout at Berkeley

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.

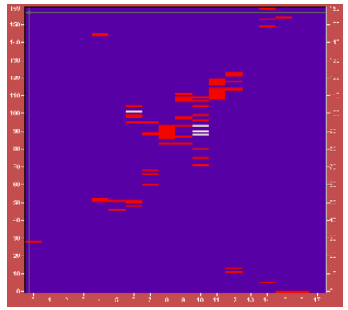
400 x 50 μm pads (TimePix is 55 x 55 μm)



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 LCTPC LP involvement

Need for more help in large prototype

slow control
gas system
calibration software tools

Beyond

altro chip evolution to 130nm technology – testing
optical link
readout electronics

Summary

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 1st and 2nd 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