TPC R&D at Cornell and Purdue

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Further information available at the web sites:
http://www.lepp.cornell.edu/~dpp/linear_collider/large_prototype.html
http://www.lepp.cornell.edu/~dpp/linear_collider/tpc_test_lab_info.html

* presentation at LCWS DESY	30-May-2007	Bulk Micromegas
* presentation at ECFA Valencia	07-November-2006	electron and ion transmission
* presentation at ALCPG Vancouver	18-July-2006	demonstration of ion signal
* presentation at Berkeley TPC Workshop	08-April-2006	Purdue-3M Micromegas
* presentation at ECFA 2005 Vienna	24-November-2005	
* presentation at ALCPG Snowmass	23-August-2005	
* presentation at LCWS05, Stanford	21-March-2005	

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the US National Science Foundation (LEPP cooperative agreement)
and by the US Department of Energy (Purdue HEP group base grant)
and an LCDRD consortium grant (NSF and DoE).
This project is in cooperation with LC-TPC.

in this talk …

- Measurements using the small prototype TPC at Cornell

  a comparison of
  - a Bulk Micromegas , B=0, Ar-isoC_4H_{10}(7%)
  - a Purdue/3M Micromegas , B=0, Ar-isoC_4H_{10}(7%)
  - a triple-GEM, B=0, TDR gas:Ar-CH_4(5%)-CO_2(2%)

  at B=0

  same chamber, pads, readout, analysis

- The endplate for the LC-TPC "Large-Prototype"

  status of design

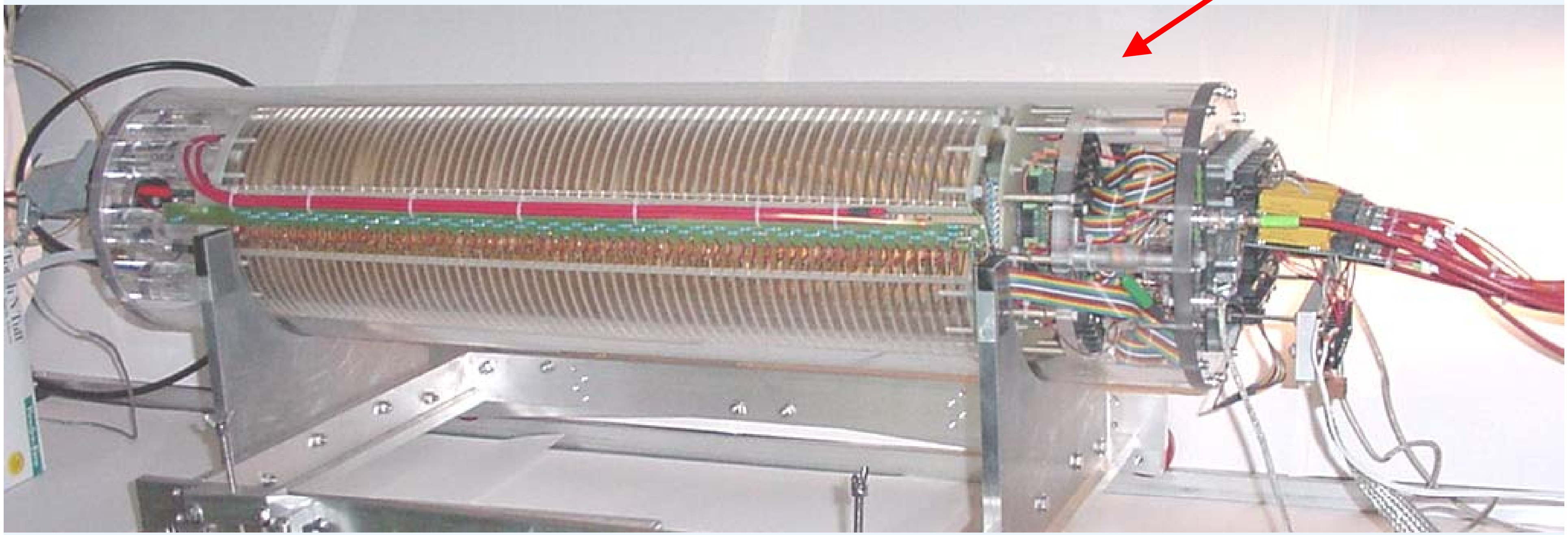
  plans for production

TPC

14.6 cm ID field cage - accommodates a 10 cm gas amplification device
64 cm drift field length
22.2 cm OD outer structure (8.75 inch)

“field cage termination” and “final” return lines for the field cage HV distribution allow adjustment of the termination bias voltage with an external resistor.

Read-out end:
- field cage termination
- **readout pad and gas amplification module**
- pad biasing boards
- CLEO II cathode preamps



Electronics

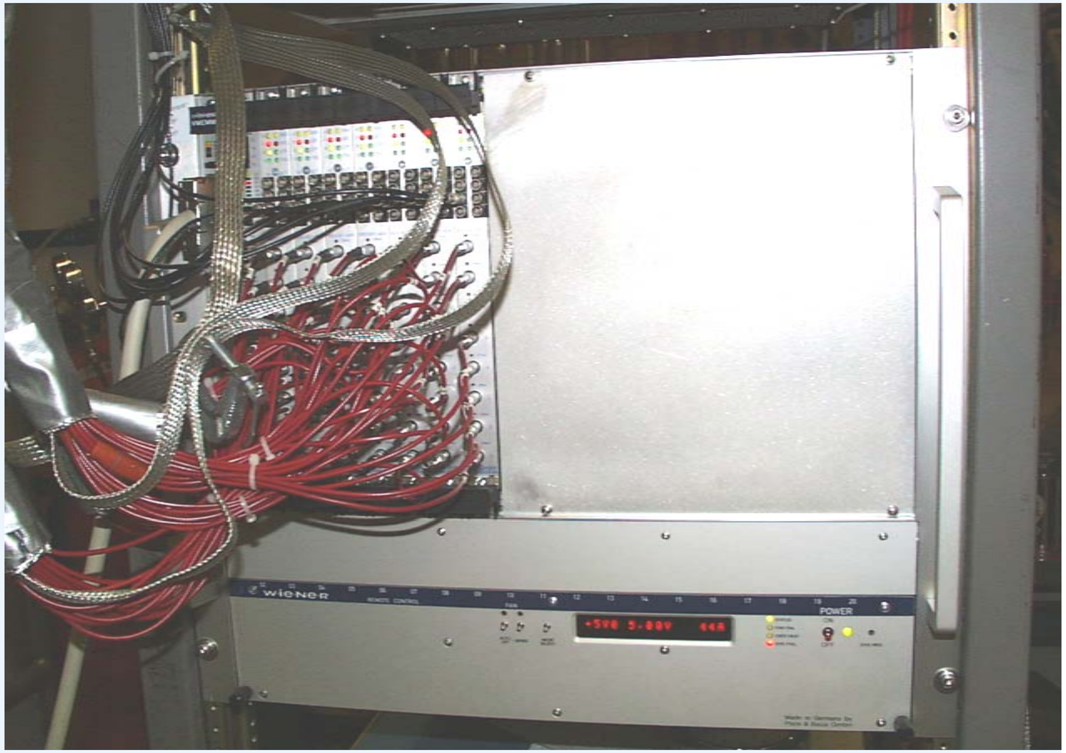
High voltage system:

-20 kV module (for the field cage)
+4 kV module (GEM and Micromegas)
-2 kV module (wire gas amplification)

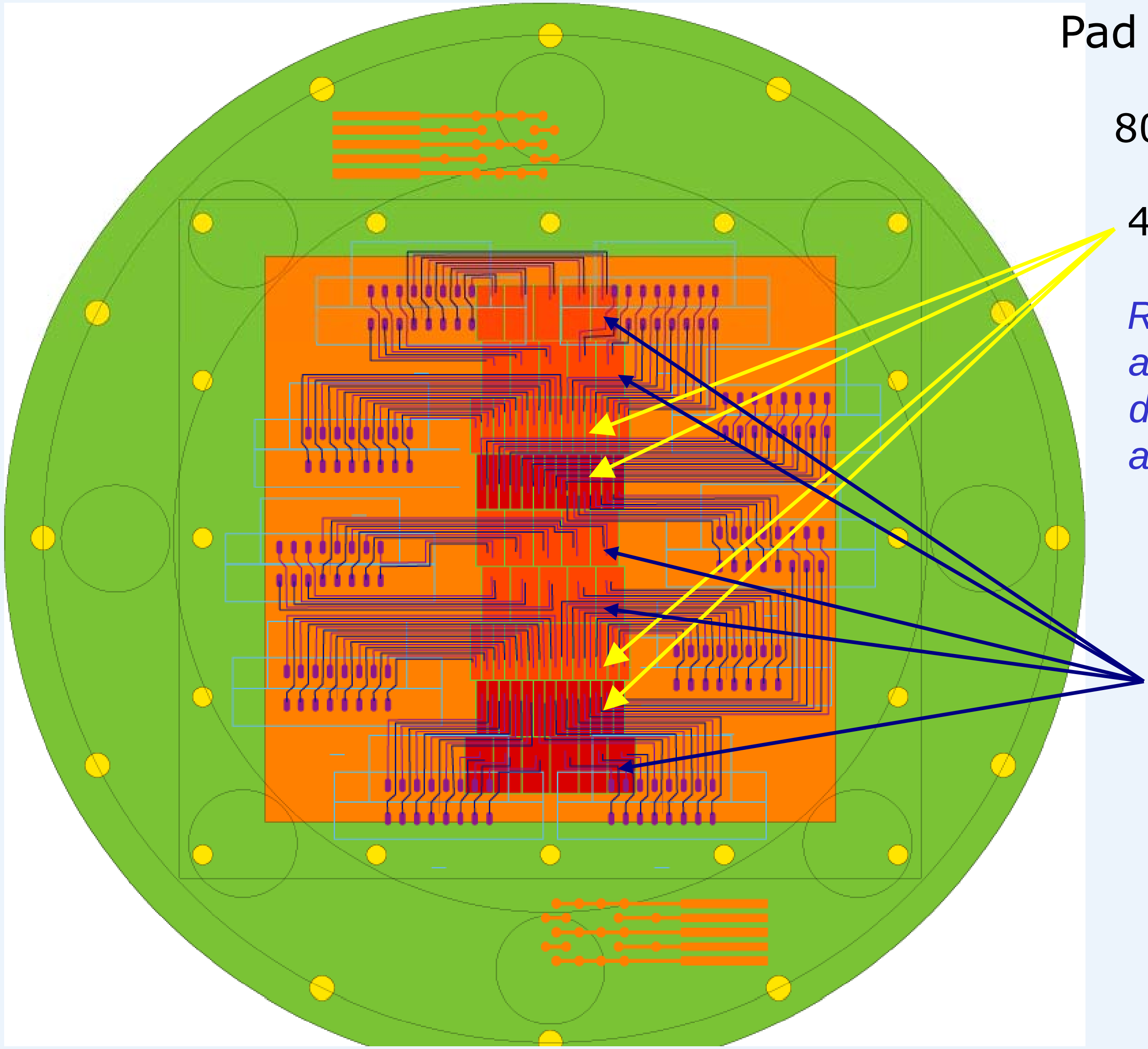
Readout:

VME crate
    PC interface card
    LabView

Struck FADC
  88 channels
  105 MHz (usually run at 25 MHz)
  14 bit
  +/- 200 mV input range
  (least count is 0.025mV)
  NIM external trigger input
  circular memory buffer



TPC pad board



Pad board with 2 mm pads.

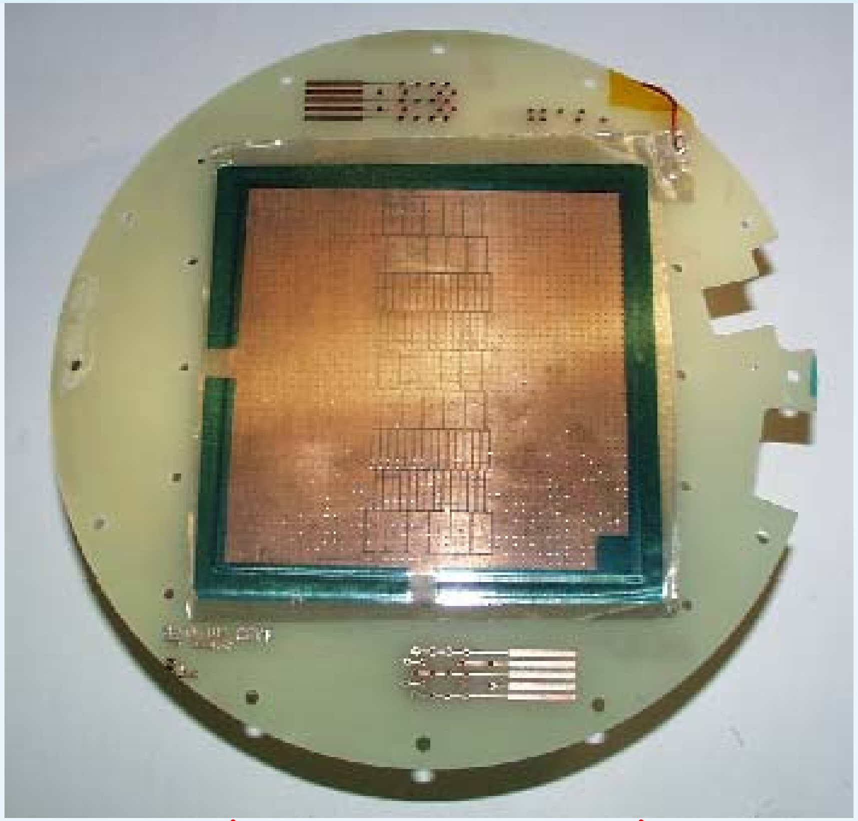
80 pads on the board

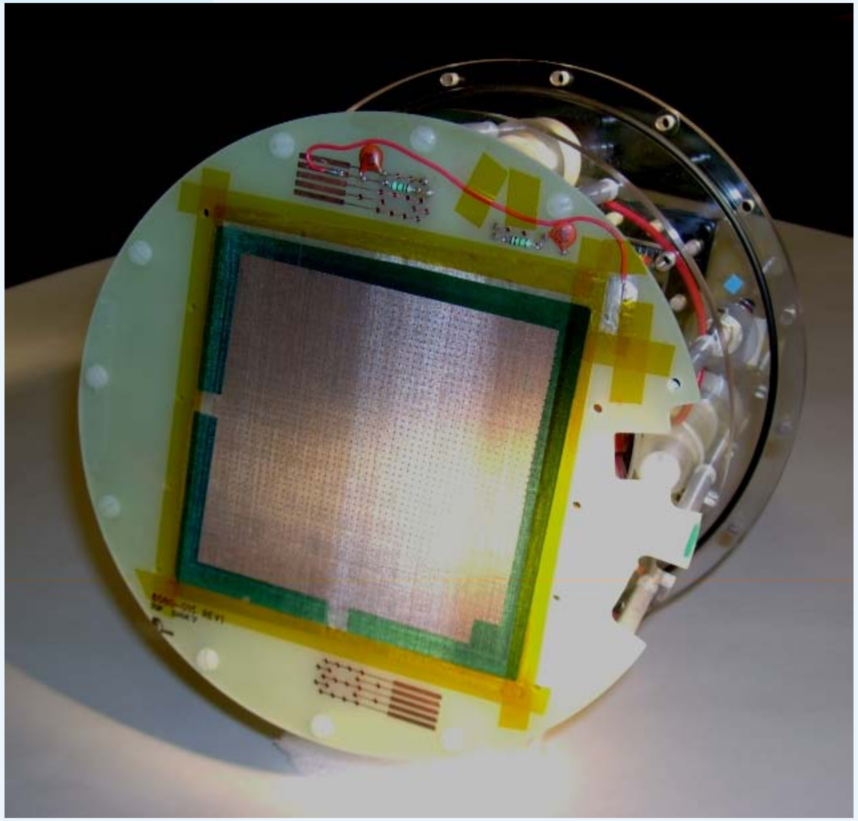
4 layers of 2mm pads

Resolution measurements are derived from the difference in residuals on adjacent 2mm pad rows.

5 layer of 5mm pads
for track definition

Bulk Micromegas amplification



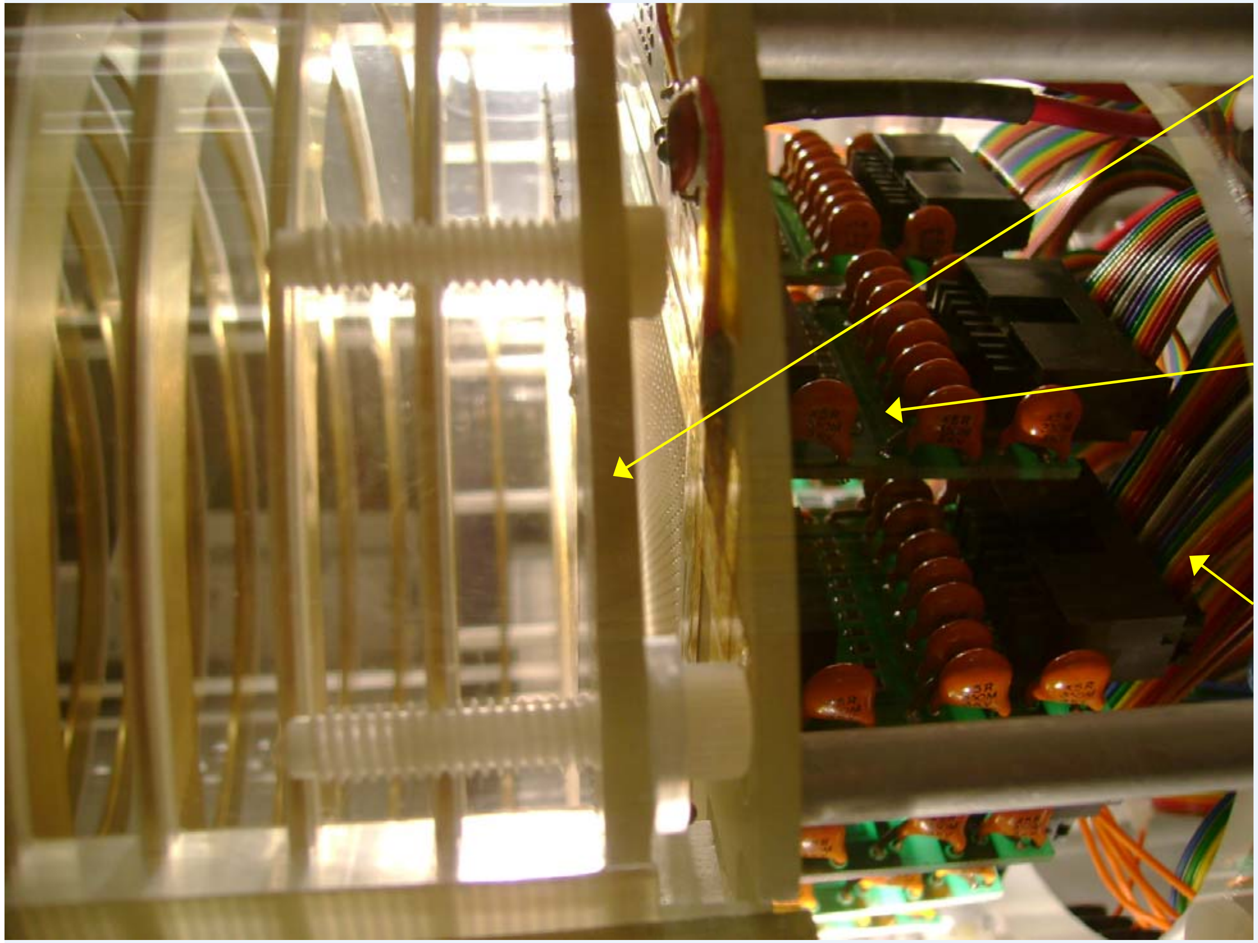


10 cm

The "bulk Micromegas", was prepared on one of our pad boards
by Paul Colas' Saclay group.

The device is a mesh supported by deposited insulators , 50 μm.

Bulk Micromegas amplification



The Micromegas is located 0.78 cm from the field cage termination.

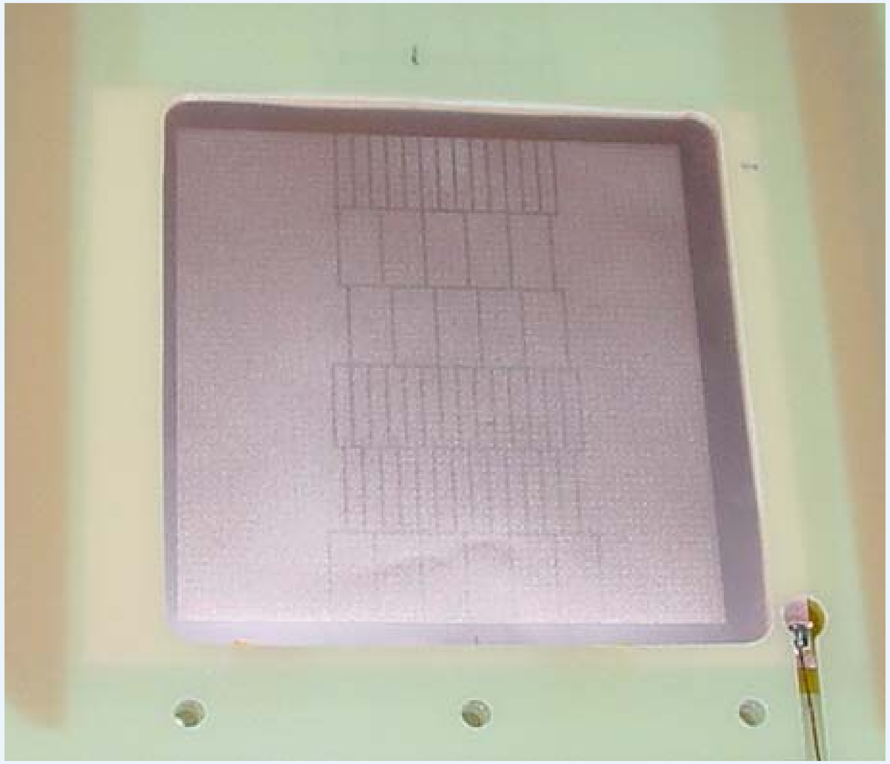
HV is distributed to the pads; note blocking capacitors, HV resistors.

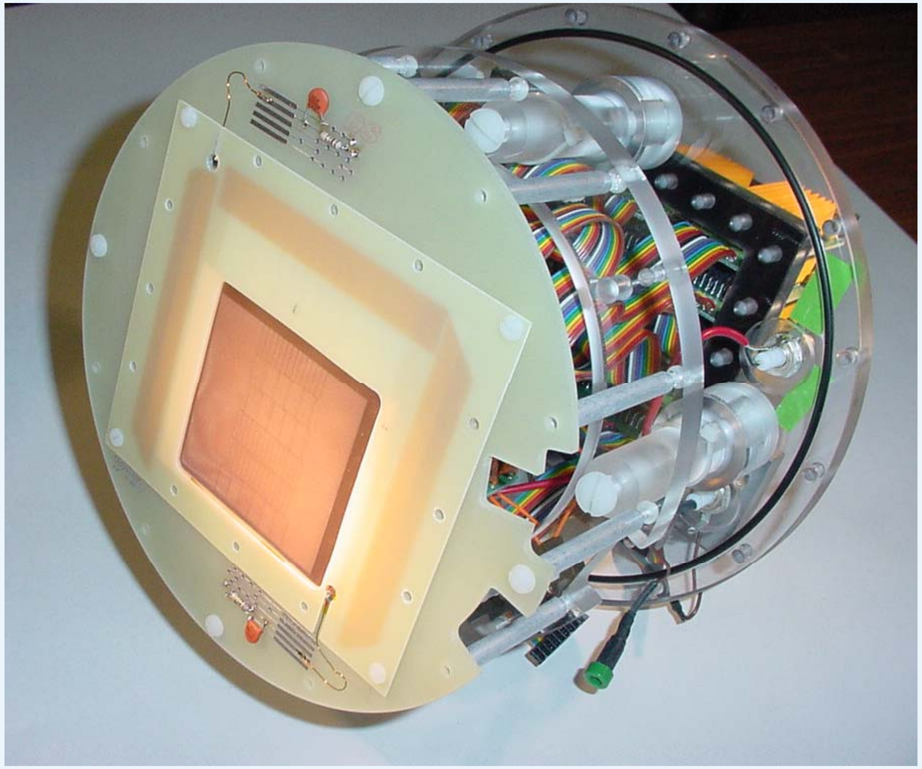
Low voltage signals routed to preamps outside (on ribbon cable).

Micromegas is at ground; pads at +410V for Ar-isoC_4H_{10} (7%).

Bulk Micromegas measurements, Ar-iso C_4H_{10} (7%), were shown at DESY 2007.
Current measurements have fully instrumented pad board and higher statistics.

Purdue-3M Micromegas amplification





10 cm

Measurements with the Purdue-3M Micromegas, using Ar-CO2 (10%) were shown at Vancouver 2006.

Current measurements are with Ar-iso C_4H_{10} (7%), 400V.

Purdue-3M Micromegas

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

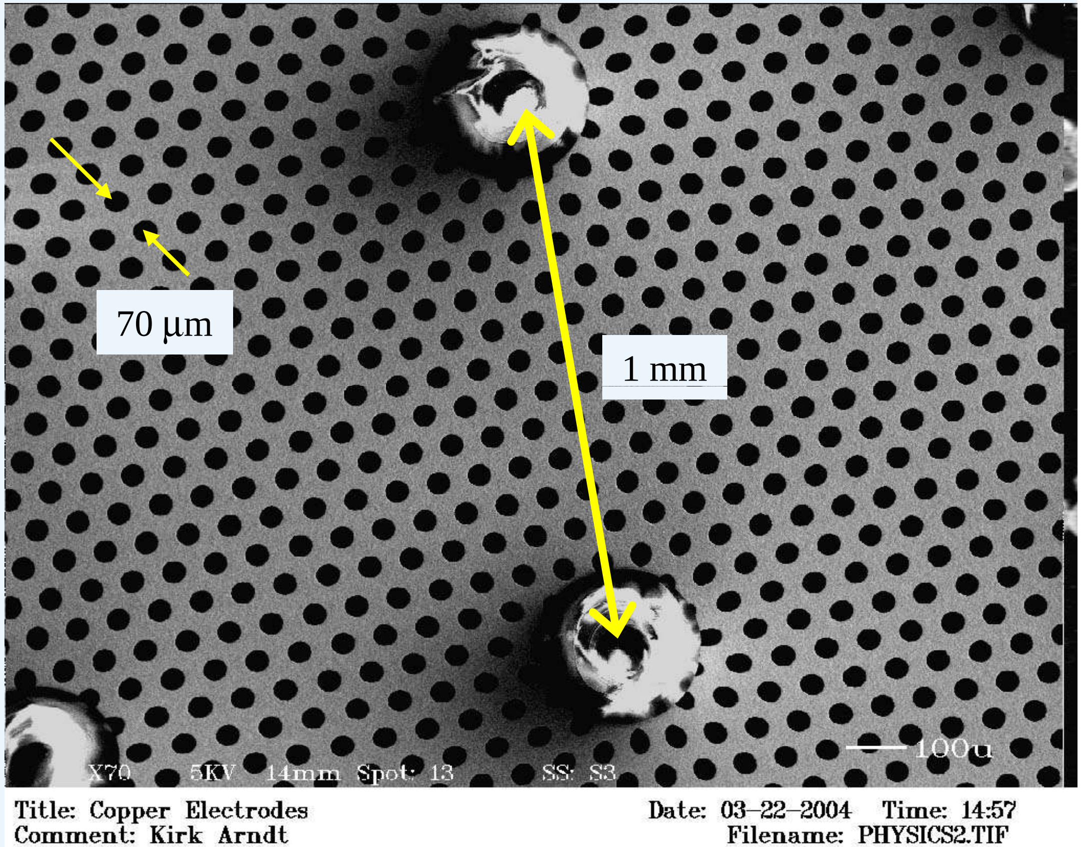
This is a very different design
with respect to the Bulk Micromegas.

Holes are etched in the copper
 70 mm spacing
 35 mm diameter

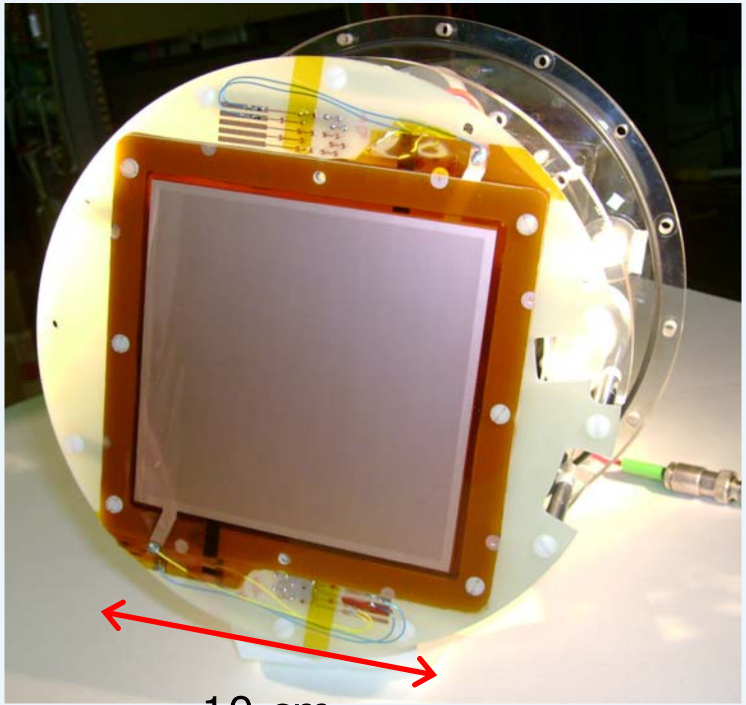
Copper thickness: 9 µm

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

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



Triple-GEM amplification

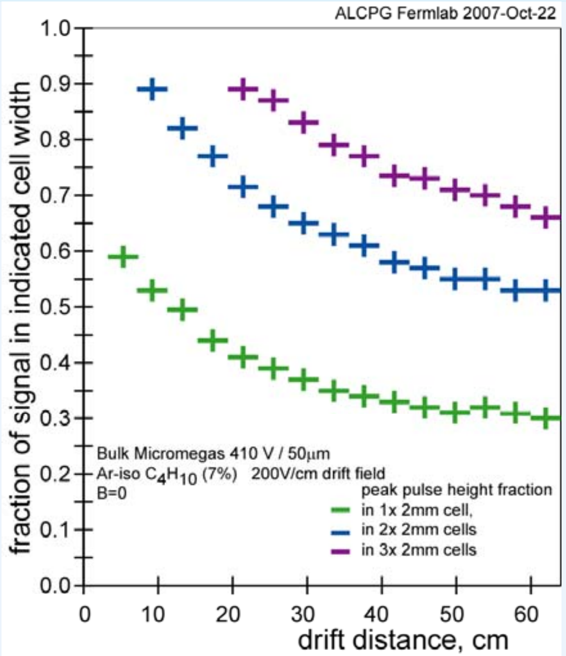


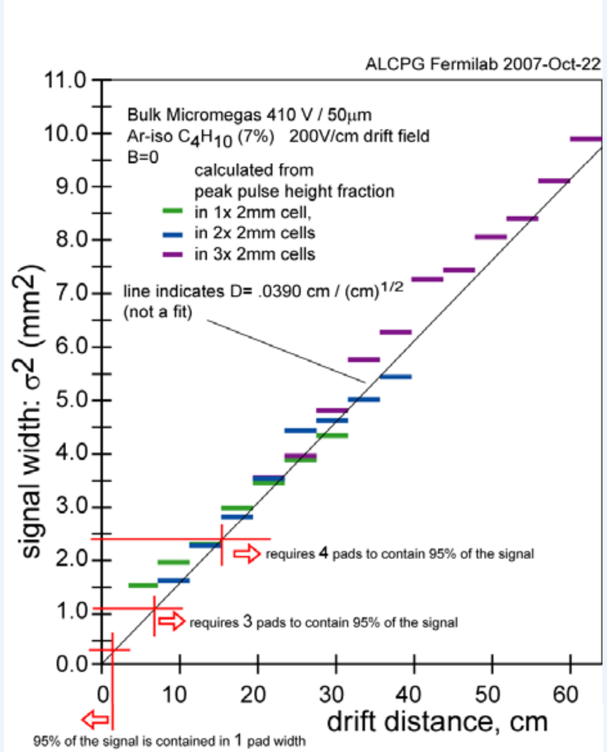
triple-GEM 315V/GEM
3 transfers .165cm, 2300V/cm, Pads @ +2100V

We typically run at very low gain:

gain estimation : taking gain of single-GEM = 70 @ 380V
running 55V lower; scale gain by $10^{\Delta V/60}$
single-GEM gain is 8.5
triple-GEM gain is ~600 ??

Charge width / diffusion





The charge width is extracted from the fraction of the total charge observed on 1,2 or 3 pads, shown above, assuming a gaussian charge distribution.

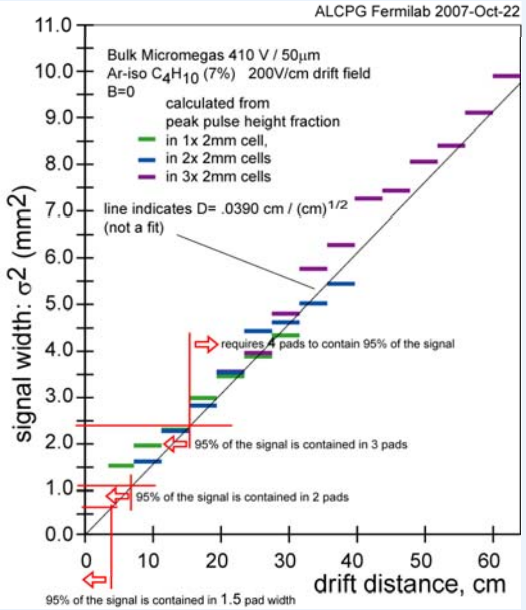
(The charge-fraction measurement in 1 and 2 pad saturates at small fraction. In that case, the highest charge-fraction is artificially high.)

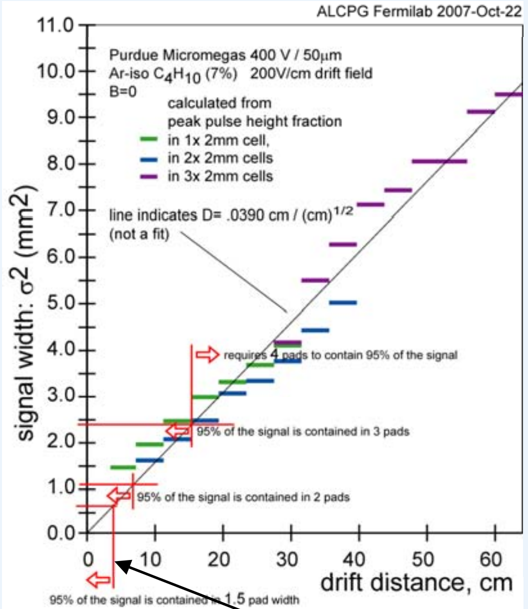
The line indicates a diffusion constant of D=.0390 cm / (cm)$^{1/2}$.

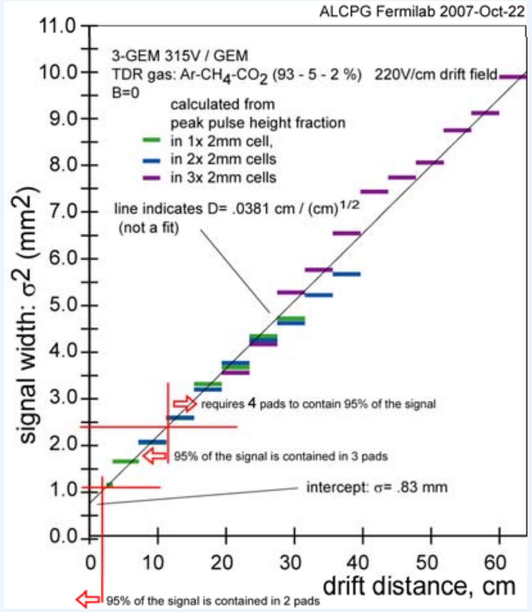
(The measured width, and diffusion constant, may be reduced by the loss of small signals due to the opposite-sign pick-up, described in an earlier talk.)

Also indicated are the number of pads that are typically contributing to a signal, indicating the number of pads that will be used in the spatial measurements.

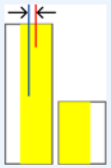
Gas property: Charge width / diffusion

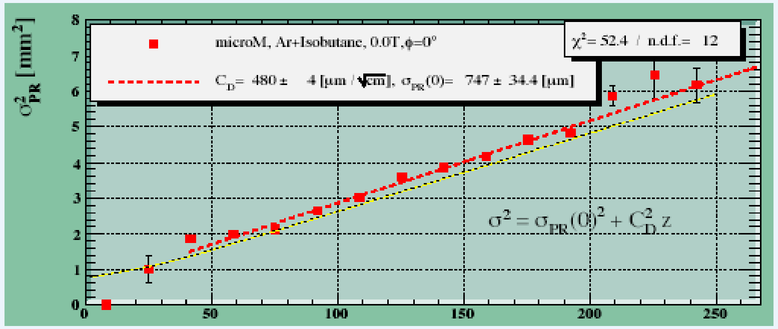






	this measurement	Colas, Vienna, 2005
iso C_4H_{10}	7%	5%
E_{drift} V/cm	200	220
D cm/(cm)$^{1/2}$	0.039	0.0480





	this measurement	Karlen, Snowmass 2005
E_{drift} V/cm	220	230
D cm/(cm)$^{1/2}$	0.038	0.0348
σ_o mm	0.83	0. 918

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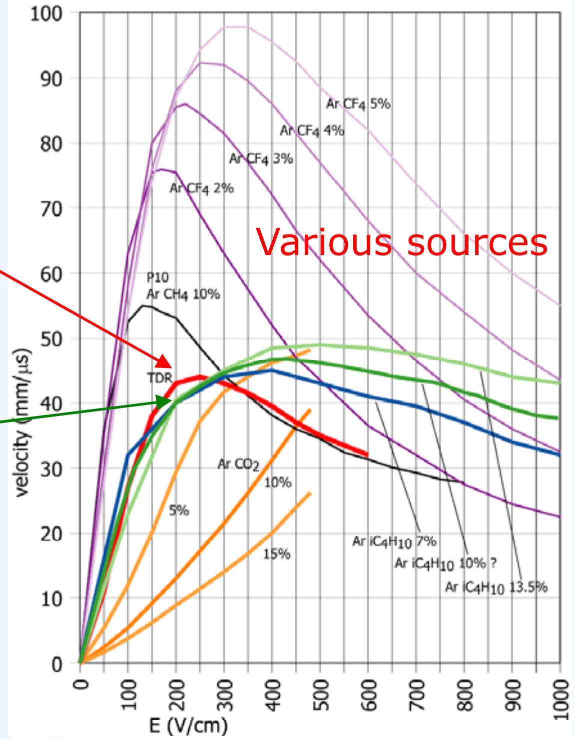
Drift velocity / Gain

Ar-CH_4(5%)–CO_2(2%), 220V/cm, expect 43 mm/μs .
Observed time for a maximum drift 64.7 cm
is (370 FADC time buckets)x(40ns/bucket),
or 43.7 mm/μs .

Ar-isoC_4H_{10}(7%), 200V/cm, expect ~39 mm/μs .
Observed time for a maximum drift 64.7 cm
is (405 FADC time buckets)x(40ns/bucket),
or 39.9 mm/μs .

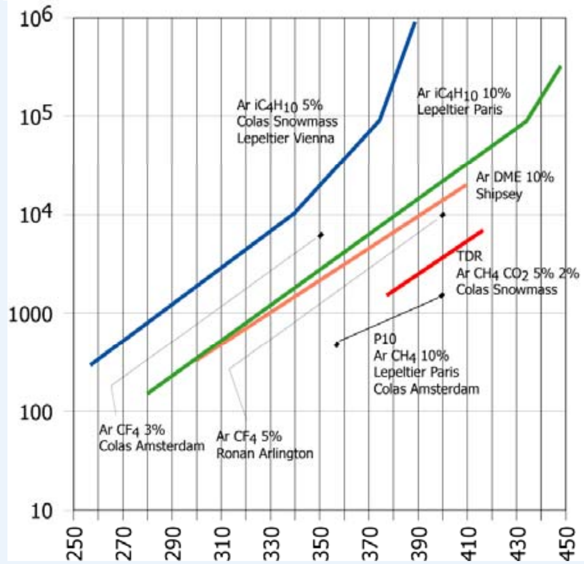


The gas gain of the triple GEM , 315V/GEM
is <u>estimated</u> at ~ 600.

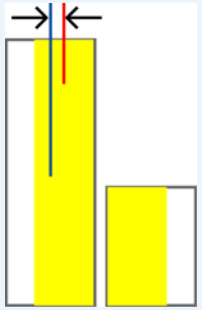
The relative gains are readily determined from
the average pulse heights.

Bulk Micromegas (7% C_4H_{10}, 410V) / 3-GEM (Ar-CH_4(5%)–CO_2(2%), 315V/GEM) =0.81

Purdue Micromegas (Ar-isoC_4H_{10} (7%) , at 400V) / Bulk Micromegas (7% C_4H_{10}, at 410V) = 3.6
correcting by x10 per 60V, gain ratio (equal V)=5.3



hit resolution (2mm pad)



Here, the containment width of the pad distribution function is small; any sharing indicates that the charge center of each pad is not the geometric center. Thus, there is a shift of the effective pad center.

find tracks

require time coincident signals in 7 layers

there are 9 layers available:

require 3 2mm-pad layer (average is > 3.9)

find PH center using maximum PH pad
plus nearest neighbors
(total 2 to 4 pads)

fit, deweighting the 5mm pad measurements

point measurement

low drift (narrow pad distribution function)

hits are corrected for an "effective pad center"

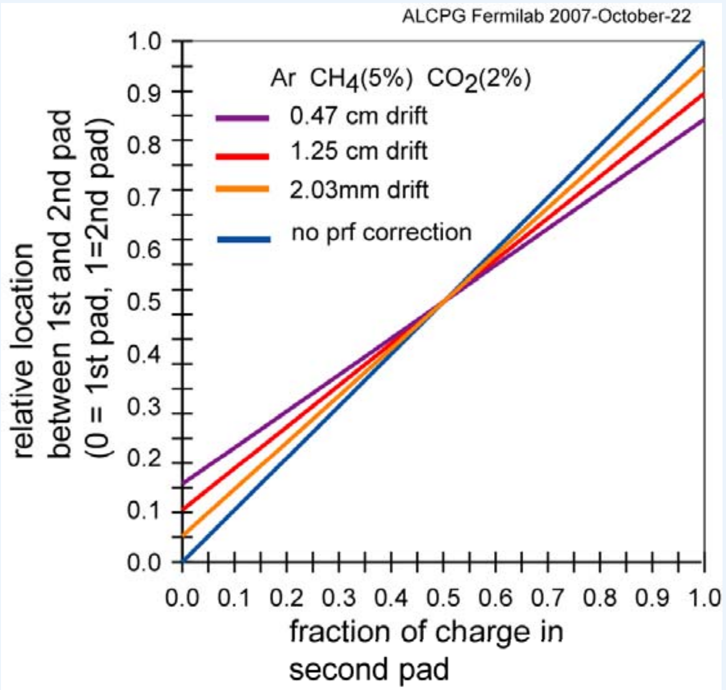
(This is not ideal, but it is what we are currently using.)

plot the resolution difference

extract the RMS of difference-in-residuals for adjacent 2mm layers pairs

extract point resolution σ

$\sigma = \text{RMS} / \sqrt{2}$



cuts, calibration

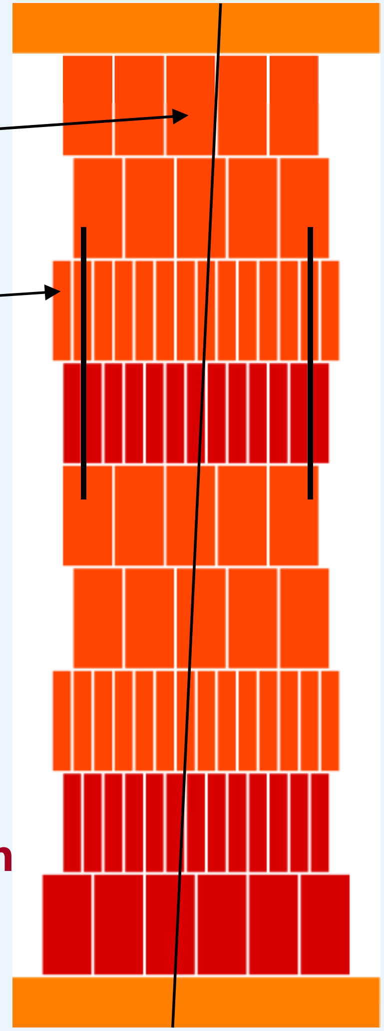
slope < 0.05
the trigger allows ~ 0.08

|x| < 11 mm
removes poorly measured edge tracks

residual in the single (2mm) layer < 0.4 mm
requires consistent hits in adjacent 5mm layers
although it is higher weighted in the fit

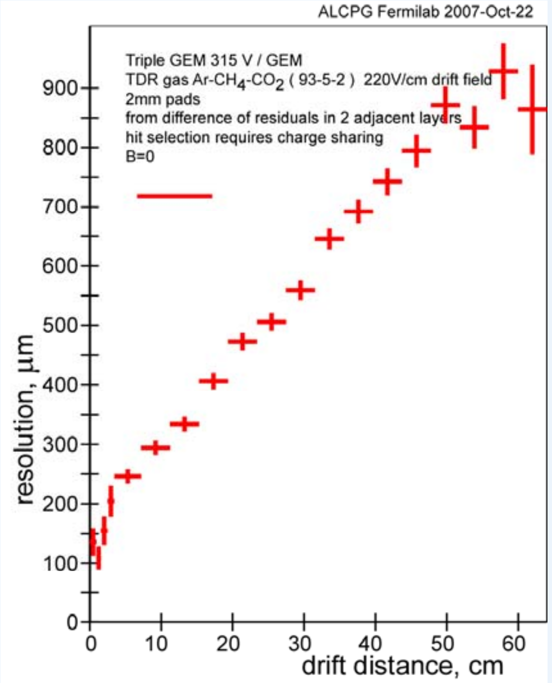
fraction of signal in 1 pad < 99%
much looser than previous analysis

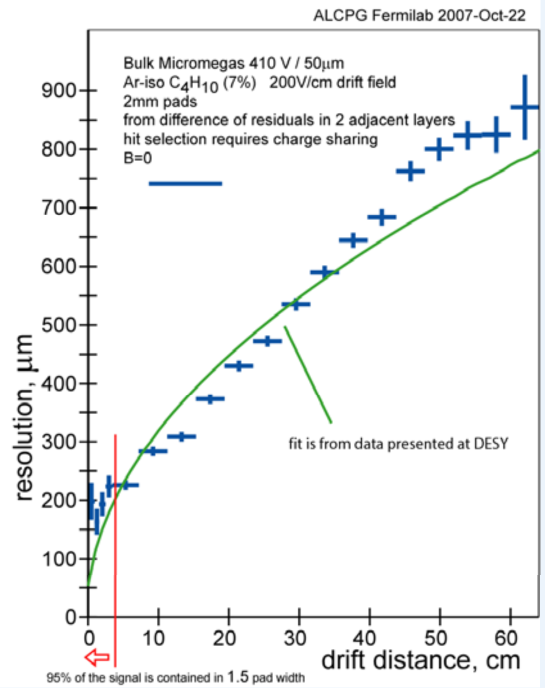
fraction of signal in 2 bins > (drift distance dependen
removes events with significant noise
distorting position measurement

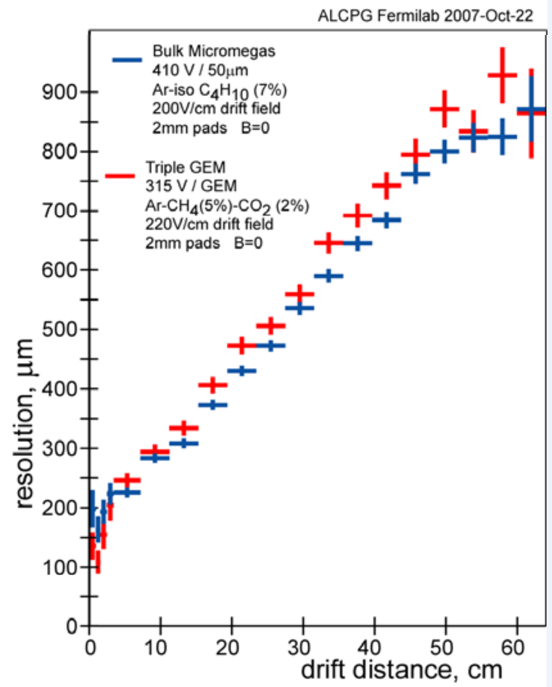


Pad-to-pad pulse height calibration (as large as ± ~30%)

Hit resolution







triple-GEM at 315V

bulk Micromegas at gain=81% of that of the triple-GEM

The results are very similar.

The fit is to the data, with same conditions, shown at LCWS DESY 2007

Fit to $\sigma=(\sigma_0^2 + D^2/n\ x)^{1/2}$

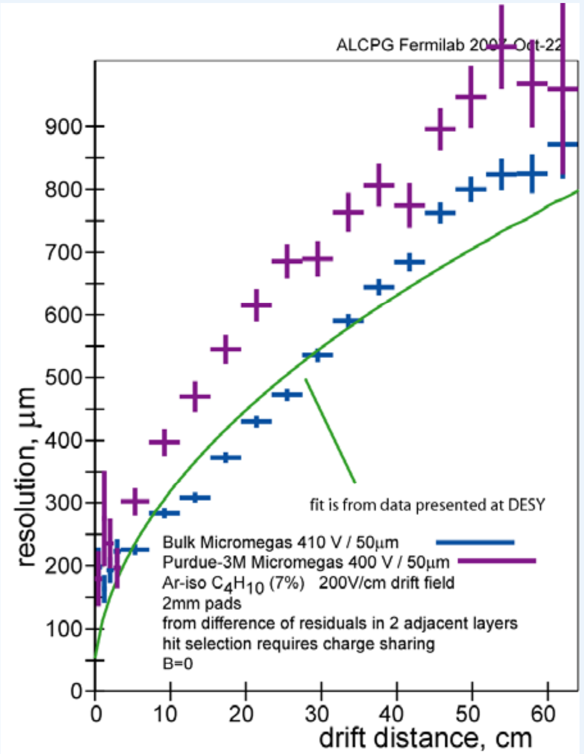
use $D=.0415\ cm/(cm)^{1/2}$.

result: $n=17.4 \pm .5$

$\sigma_0 = 53 \pm 36\ \mu m$

$\chi^2/dof = 1.7$

Hit resolution



The resolution for the Purdue-3M Micromegas is compared to that of the Bulk Micromegas.

While the gain of the Purdue-3M device is 3.6 x that of the Bulk Micromegas, the resolution is significantly worse.

The charge width (diffusion) was the same.

Presumably, there is a loss of statics due to transmission.

small TPC : summary, outlook

We show measurements of a
Bulk Micromegas, Purdue-3M Micromegas, triple-GEM.
same TPC, pads, readout analysis

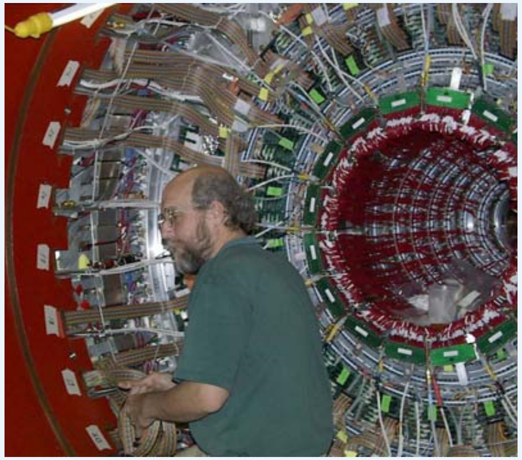
We are continuing preparations for comparative
ion feed-back measurements. (graduate student)

All measurements have been at B=0.
We are planning a run at 1.5 T

CLEO running will end April 2008 (after 28.5 years).
Cornell proposes to reconfigure CESR for
studies of a wiggler-dominated damping ring.

If this proposal is funded, we will remove
the CLEO "ZD" (5 years) and drift chamber (9 years)
from solenoid as part of the CESR reconfiguration.

This will open space in the CLEO magnet
for a small prototype run at 1.5 Tesla.
(4 weeks /year, maximum)



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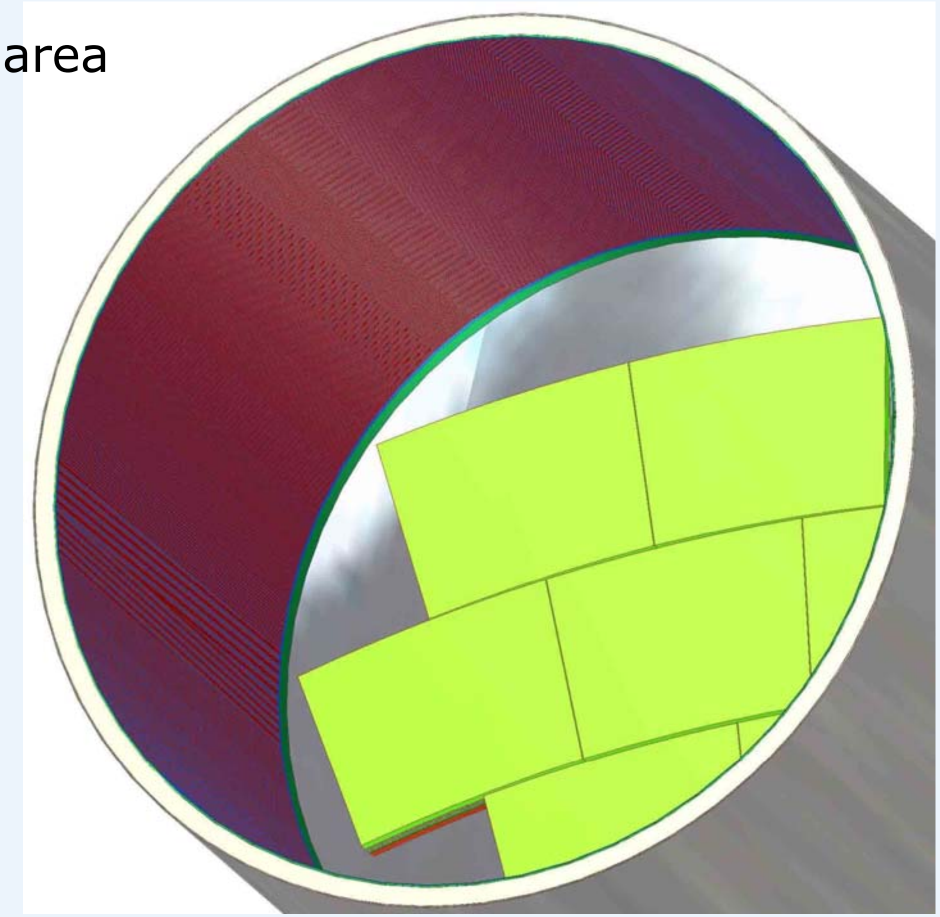
LC-TPC Large Prototype

The LC-TPC collaboration is constructing a large prototype to study

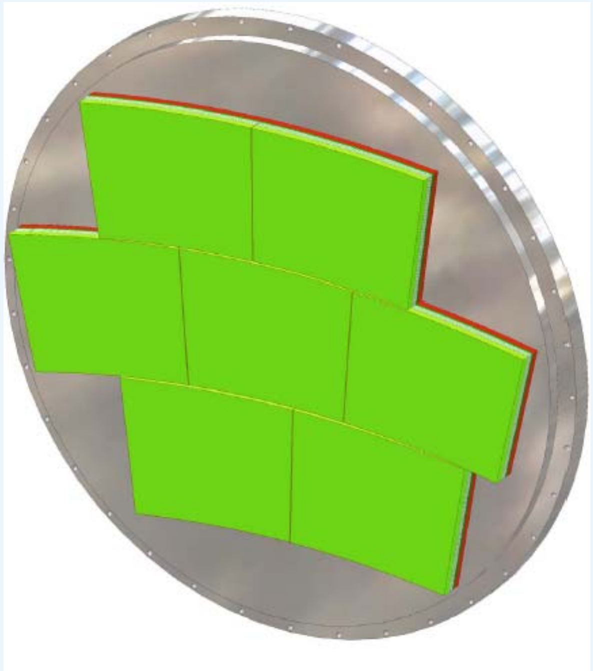
- issues related to tiling of a large area
- system electronics
- calibration methods
- track finding in a large scale Micro-Pattern-Gas-Detector based readout.

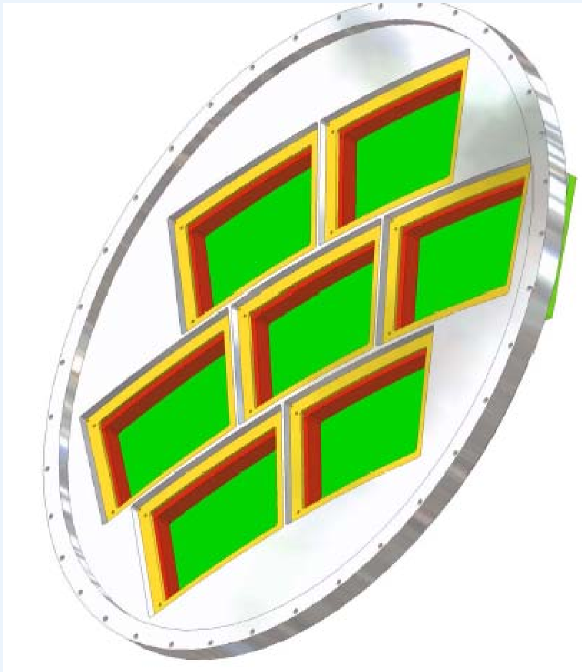


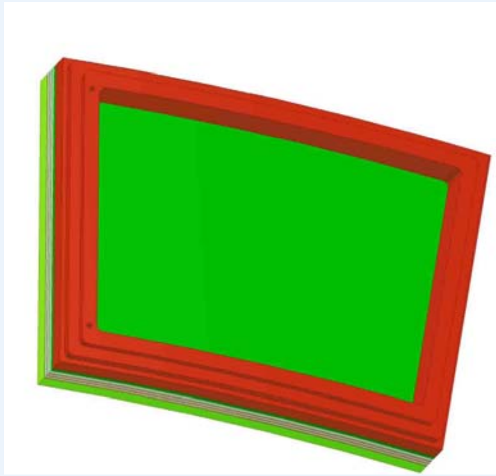
60 cm drift length
80 cm diameter
It is a cut-out region of an ILC TPC

This chamber will be operated at The EUDET facility, at DESY, starting in 2008

LC-TPC Large Prototype







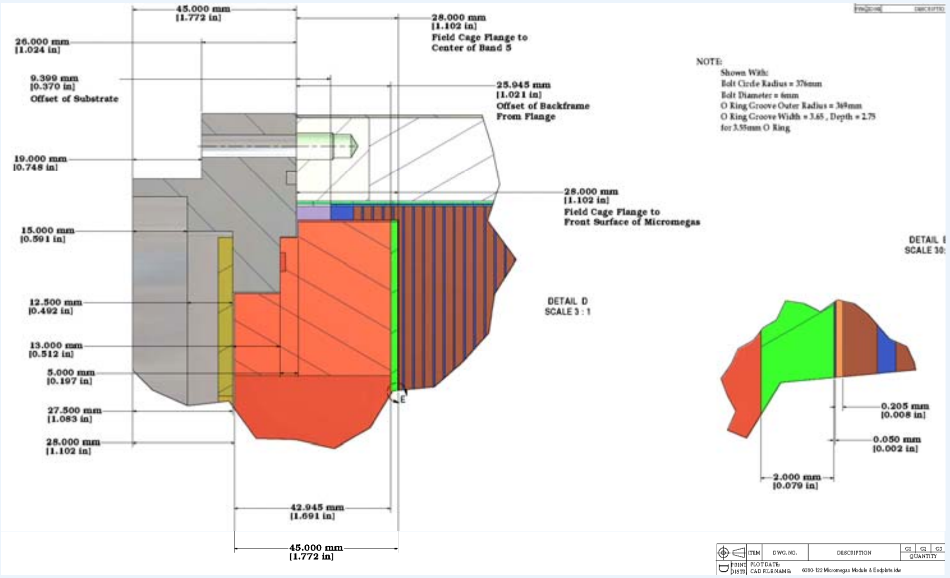
Cornell responsibility…
- endplate
- mating module frames

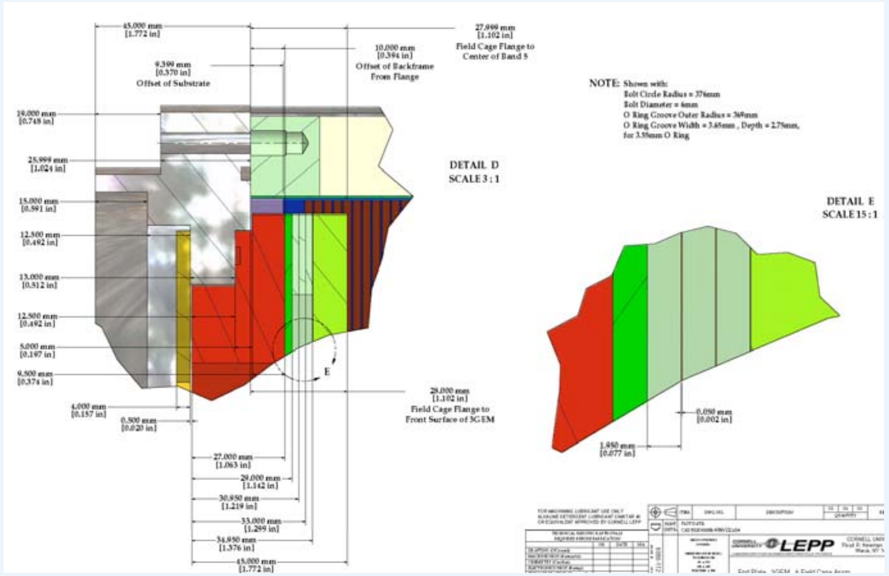
requirements…
- dimensional tolerances
- minimal material
- maximum instrumented area

Endplates are being designed in coordination with the field cage at DESY

and meeting the module requirements for Micromegas modules (Saclay) and GEM modules (Saga)

LC-TPC Large Prototype

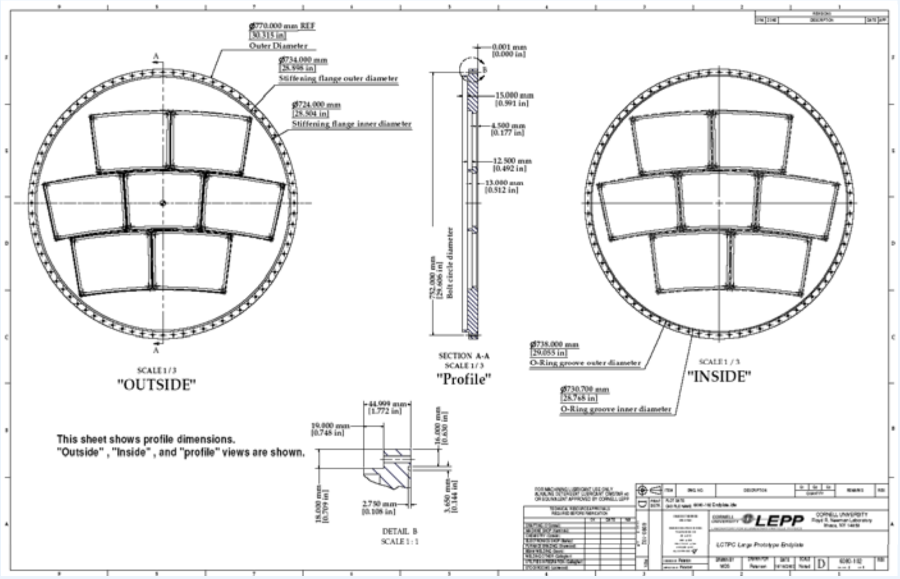


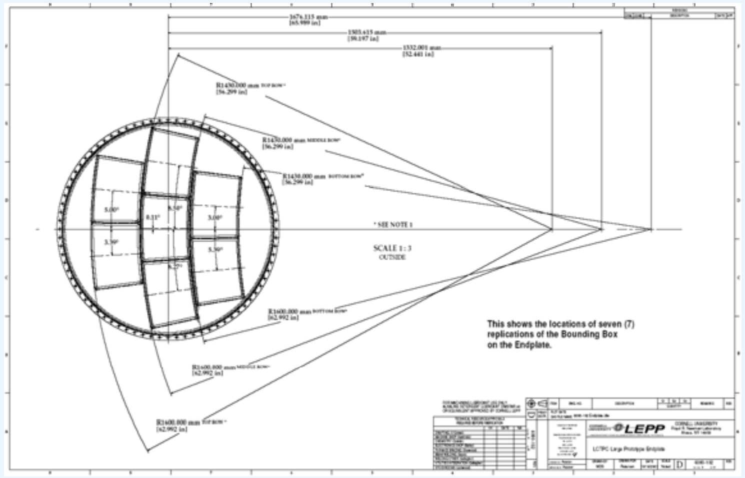


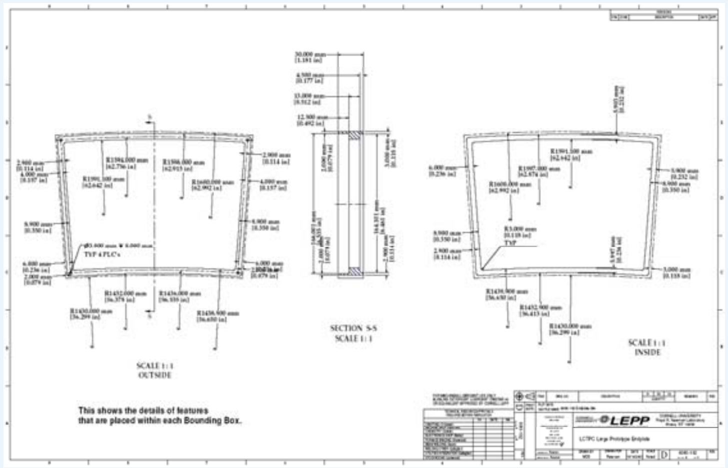
The geometry has been defined by the collaboration.

All modules will extend to a common distance into the field cage (28mm).
The drift field will end at this point, the 5th field band.
There are 4 band (additionally 5 bands in the outer layer) used for field termination shaping.

LC-TPC Large Prototype



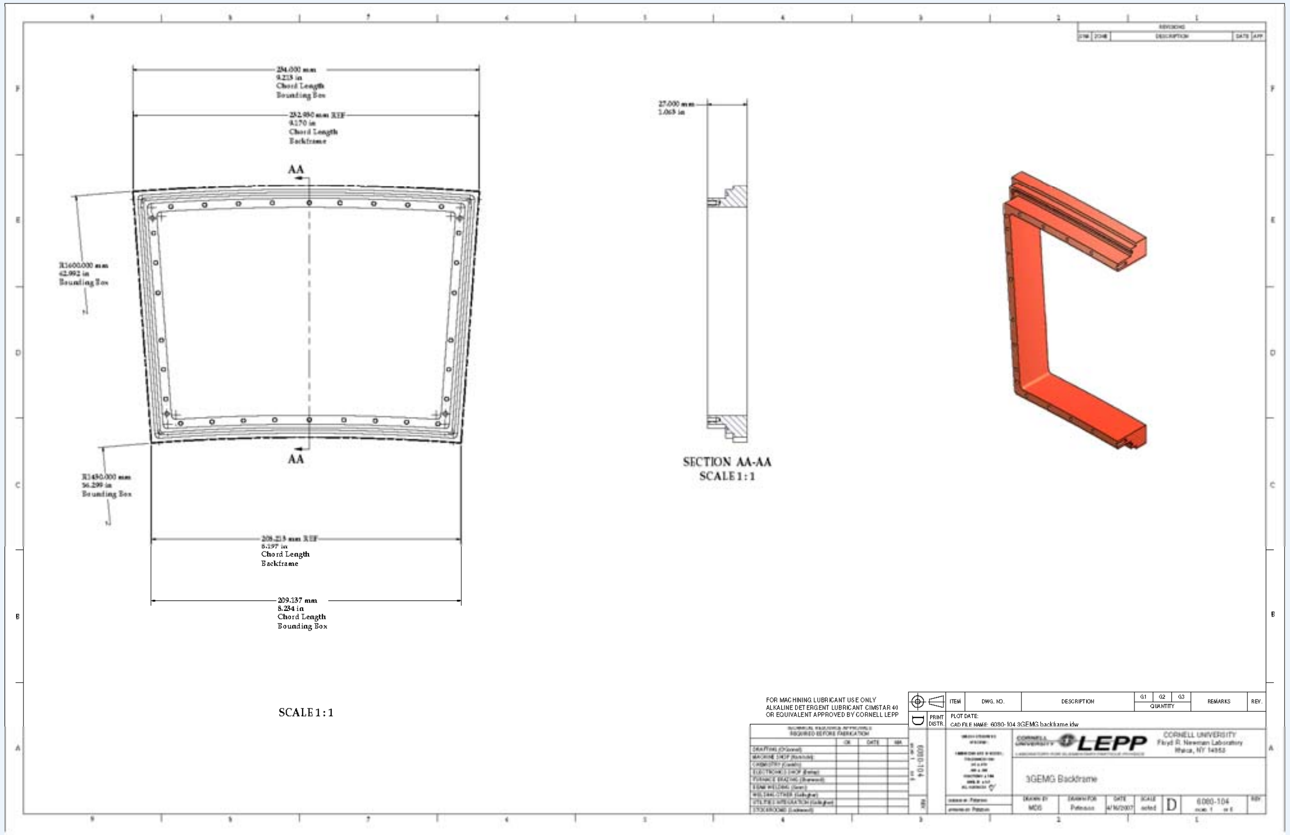




Drawing have been prepared and sent
to vendors for bidding (October 19).

The endplate provides (7) identical locations
for module installation.
The details for the installation hole are defined once.
Then the locations are defined.

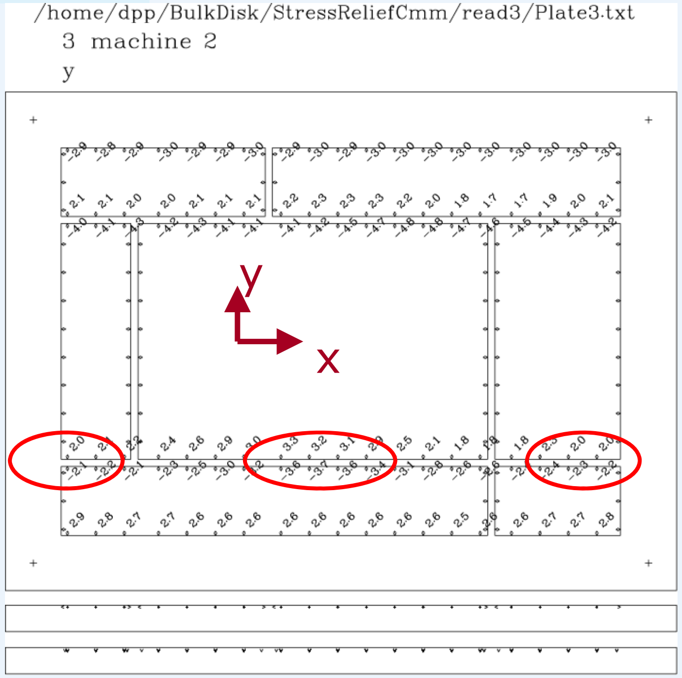
LC-TPC Large Prototype



The module “back-frame” (or “red thing”) drawing have been completed (October 22).

An initial run of (2) each, GEM and Micromegas, will be make in the LEPP shop next week. These will allow production of the first modules.

LC-TPC Large Prototype

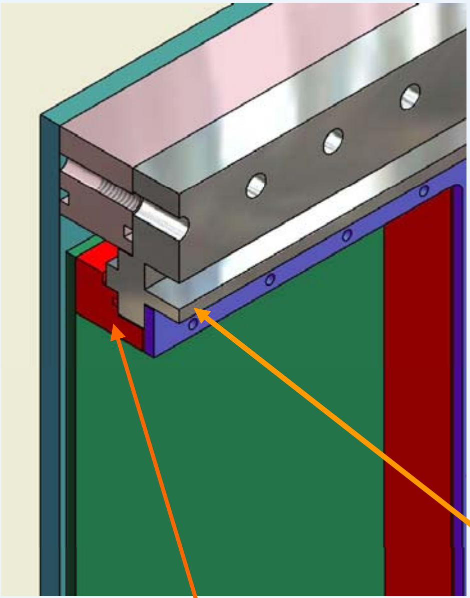


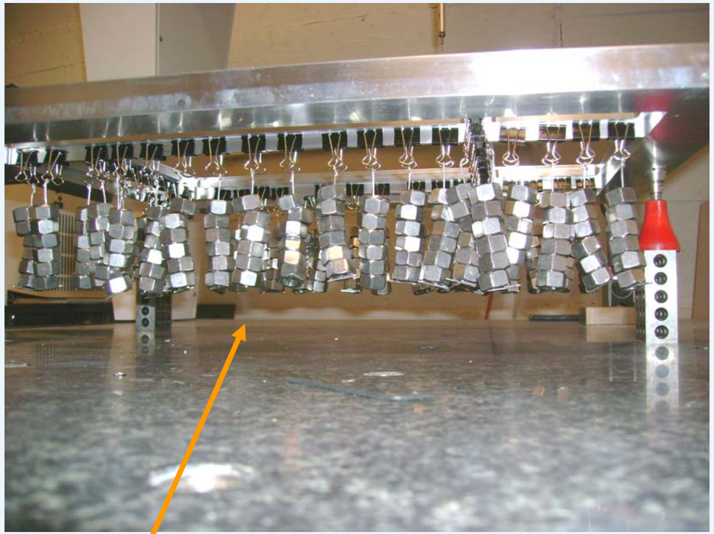
The mechanical tolerances, driven by the need to decouple position and B field calibrations, require that we define a machining process to minimize internal stresses.

A series of test plates were used to final study warping is various processes.

1) machine to 750 mm (0.030 inch) oversize,
2) stress relief (rapid immersion in liquid N_2)
3) machine to 250 mm (0.010 inch) oversize,
4) stress relief (rapid immersion in liquid N_2)
5) machine to drawing dimensions

LC-TPC Large Prototype





The o-ring seal design was tested for leaking;
the design provides satisfactory protection from oxygen contamination.

A test plate was loaded with 2.6 millibar.

Deformation was 7 μm.
The frames will be strengthened with a small increase in the "stiffening wing"

LC-TPC Large Prototype

Design of the LC-TPC “Large Prototype 1” endplate
is ready for vendor selection.

The design can be finalized during the selection process.

The module “back-frames” are ready for production.