Studies with the Cornell/Purdue Prototype TPC

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Information available at the web site: http://www.lepp.cornell.edu/~dpp/tpc_test_lab_info.html
http://www.physics.purdue.edu/msgc

* presentation at Berkeley TPC Workshop 08-April-2006
* presentation at ECFA 2005 Vienna 24-November-2005
* presentation at ALCPG Snowmass 23-August-2005
* presentation at LCWS05, Stanford 21-March-2005
* presentation at TPC mini-workshop, Orsay 12-January-2005
* presentation by Gino Bolla, at Berkeley March-2005

This project is supported by
the US National Science Foundation (LEPP cooperative agreement, REU program)
and by the US Department of Energy (Purdue HEP group base grant)
and an LCDRD consortium grant

Topics

Modifications to the TPC since the Vienna meeting

Purdue-3M Micromegas

Description of the Micromegas

Resolution measurements with Ar CO_2 and Ar iso-C_4H_{10}

Preparations for the ion feedback measurements

Double layer field cage termination transparency

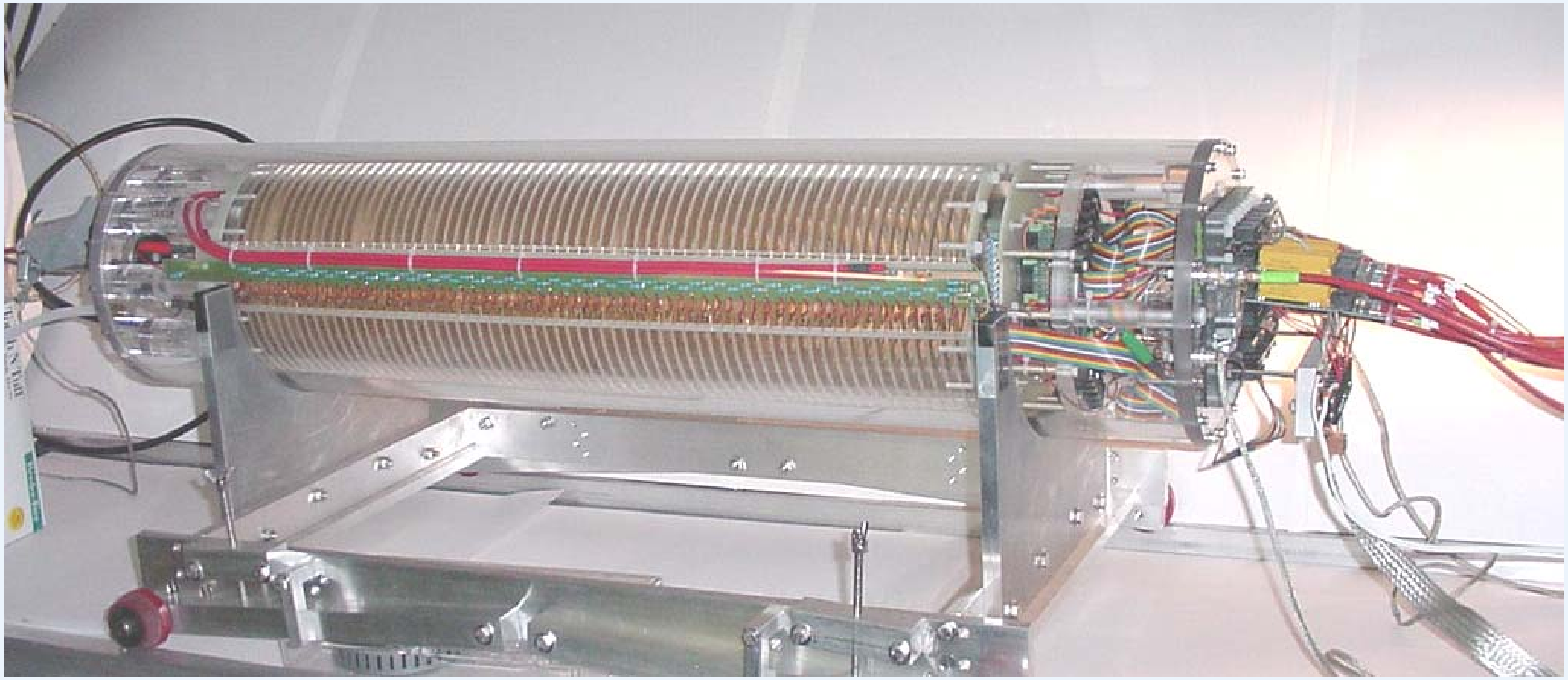
Ion feedback demonstration with wire gas-amplification

TPC

14.6 cm ID field cage - accommodates a 10 cm GEM
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 trimming the termination bias voltage.

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

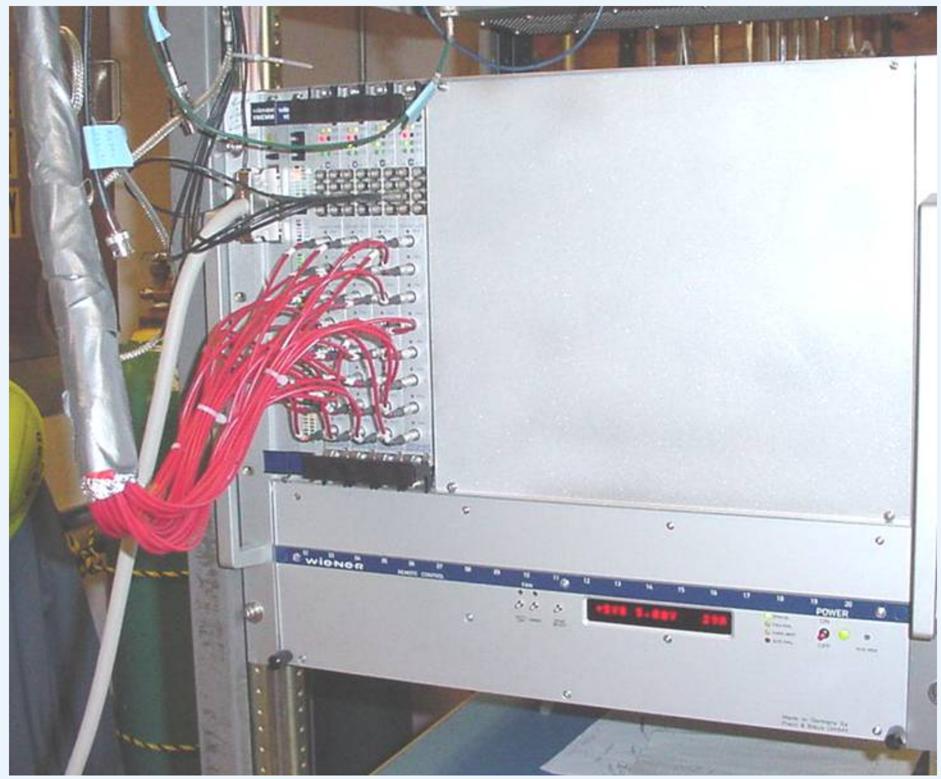


Electronics upgrade

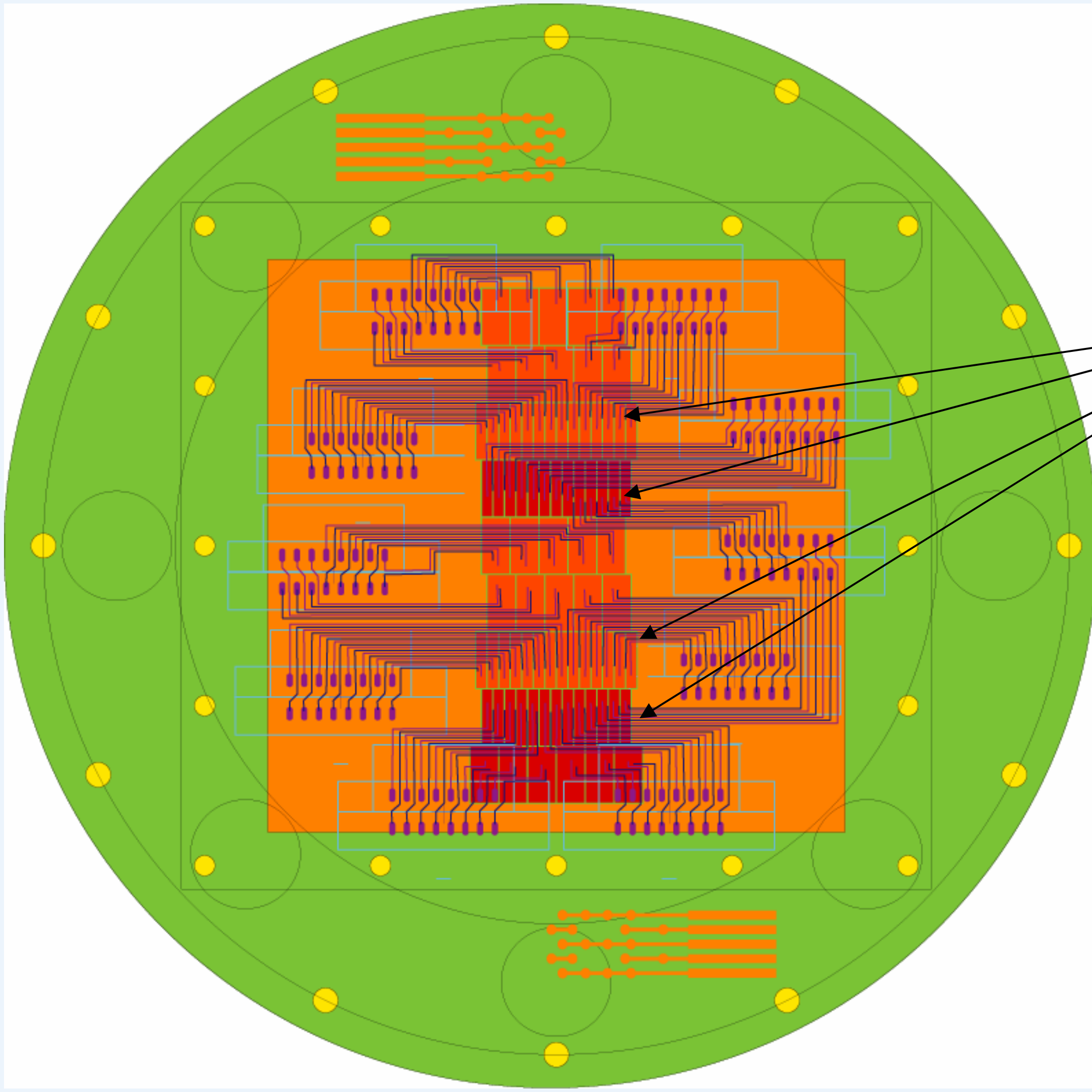
High voltage system:
- -20 kV module, 2 channels available
- -2 kV module, 4 channels available
- +2 kV module, 4 channels (new)

  previously used
  a NIM modules for +2kV

Readout:
- VME crate
  - PC interface card
    - LabView
- Struck FADC
  - 56 channels
  - 105 M Hz
  - 14 bit
  - +/- 200 mV input range
    (least count is 0.025mV)
  - NIM external trigger input
  - circular memory buffer



TPC Improvements:



+2 kV HV module
(part of CAEN system)

FADC channels increase from 32 to 56 channels

Pad board with 2 mm pads.

4 layers of 2mm pads
5 layer of 5mm pads
for track definition

80 pads on the board

These tests are the first use of the new components.

We instrument the lower 6 layers (56 pads);
the Micromegas is 6 cm square.

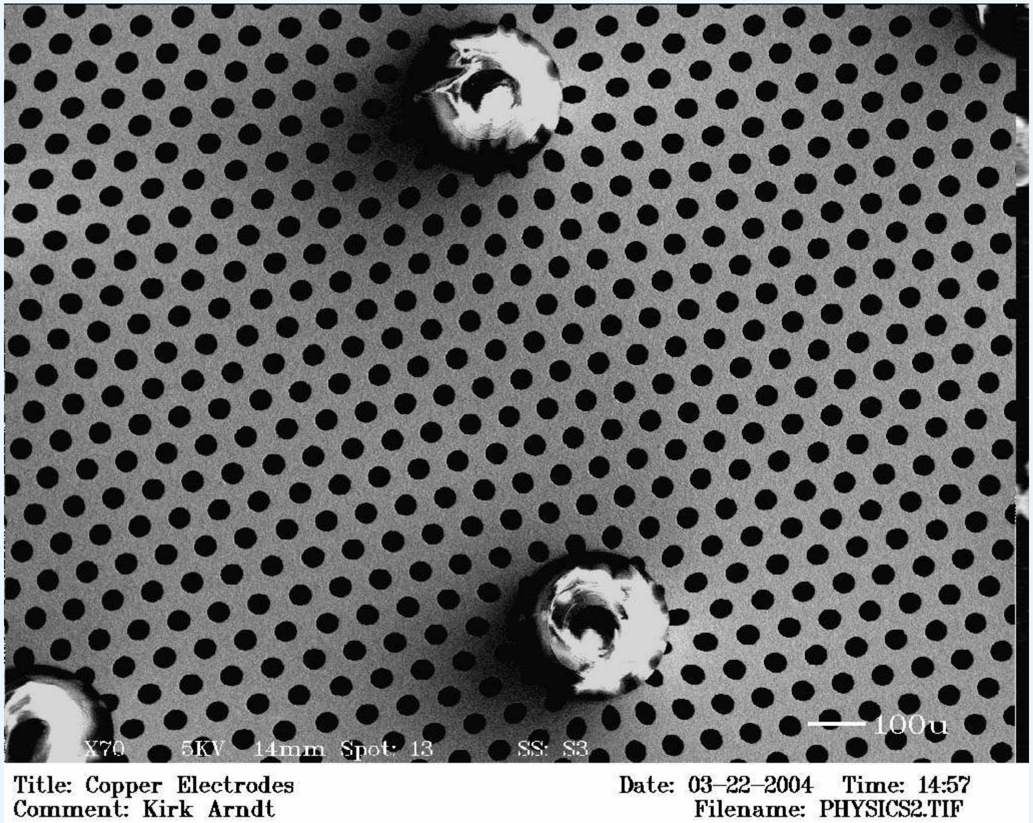
Purdue-3M Micromegas

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 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.

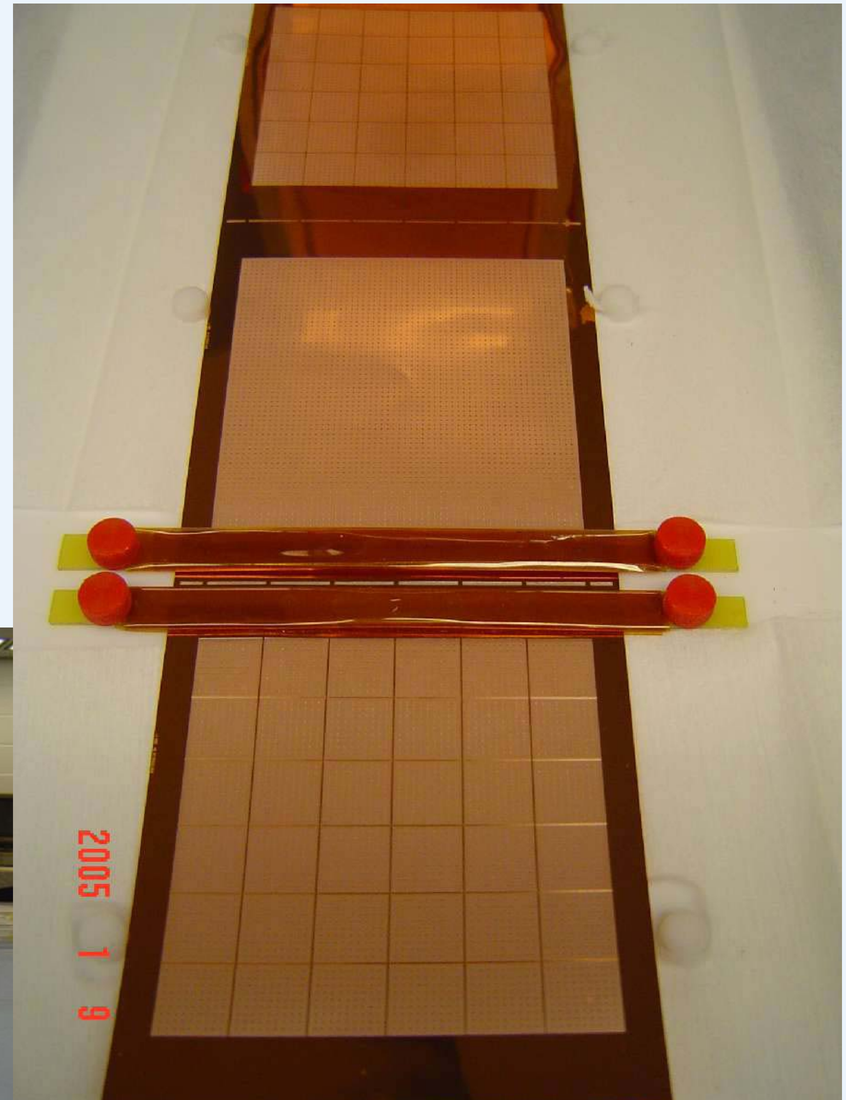
Purdue-3M Micromegas

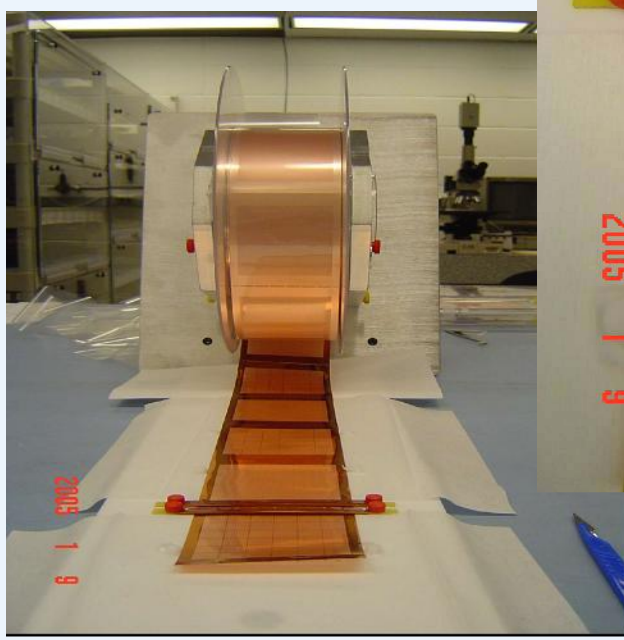
Devices are delivered on a roll.

There are 2 designs,
with and without the extra stand-off ribs.
(The designs alternate on the roll.)

Active area is 6 cm square.

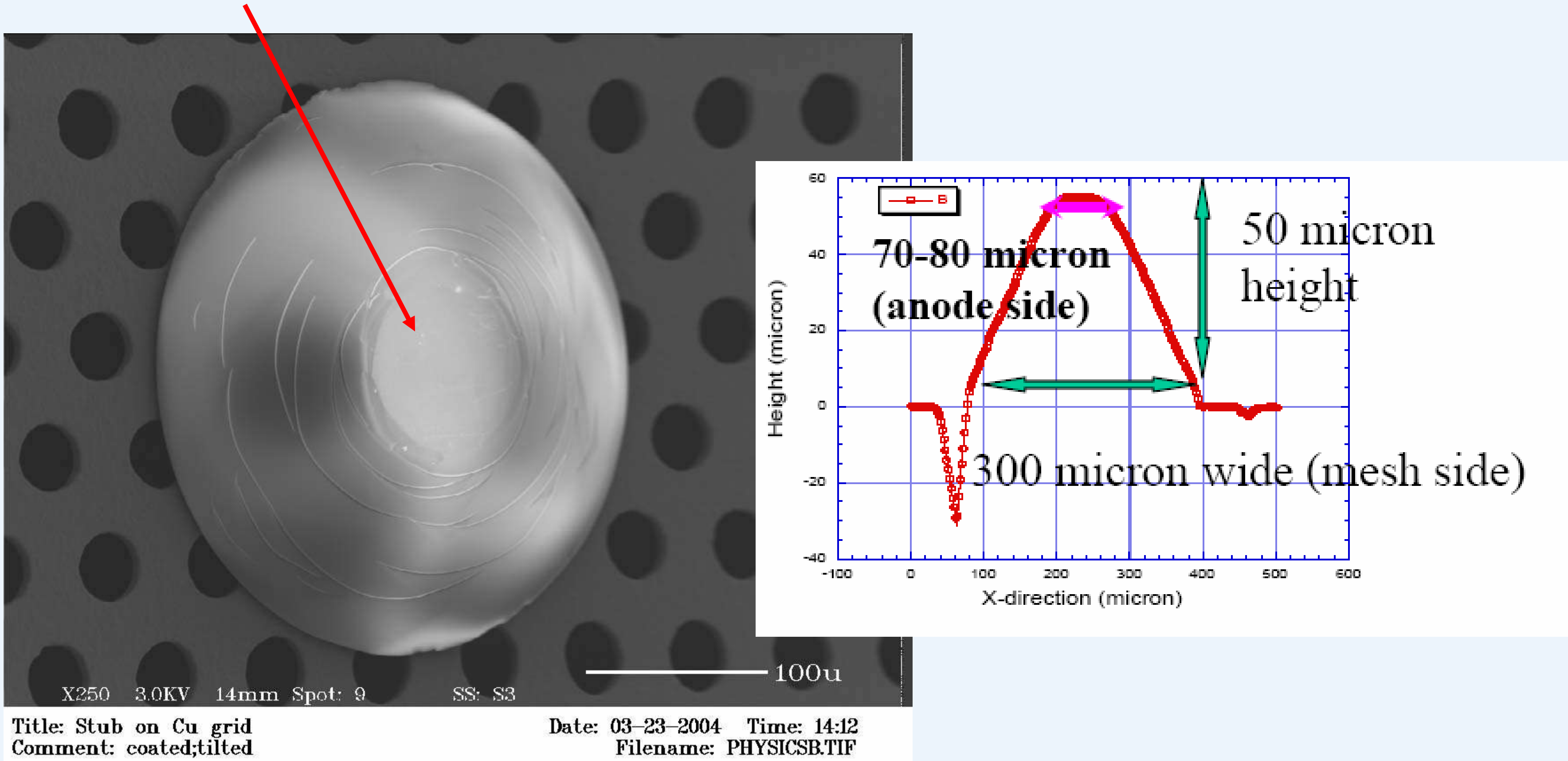
We are testing a
device without ribs.



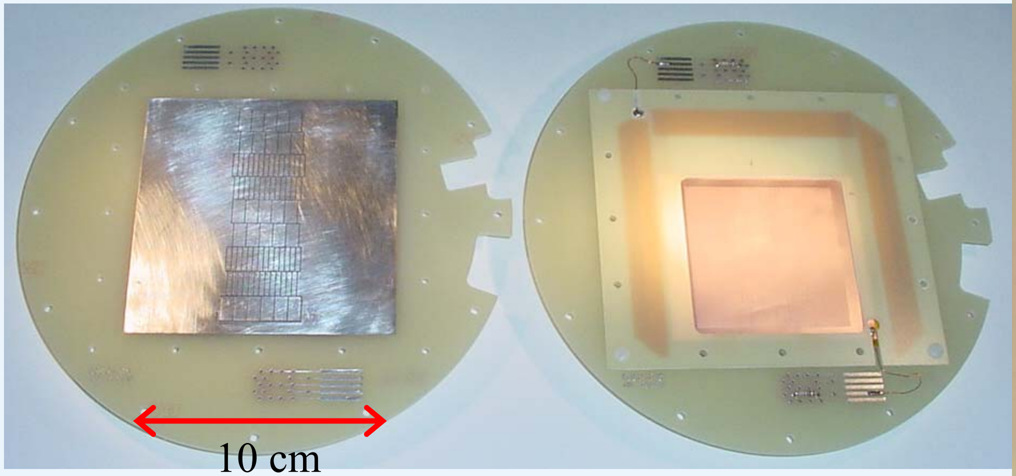


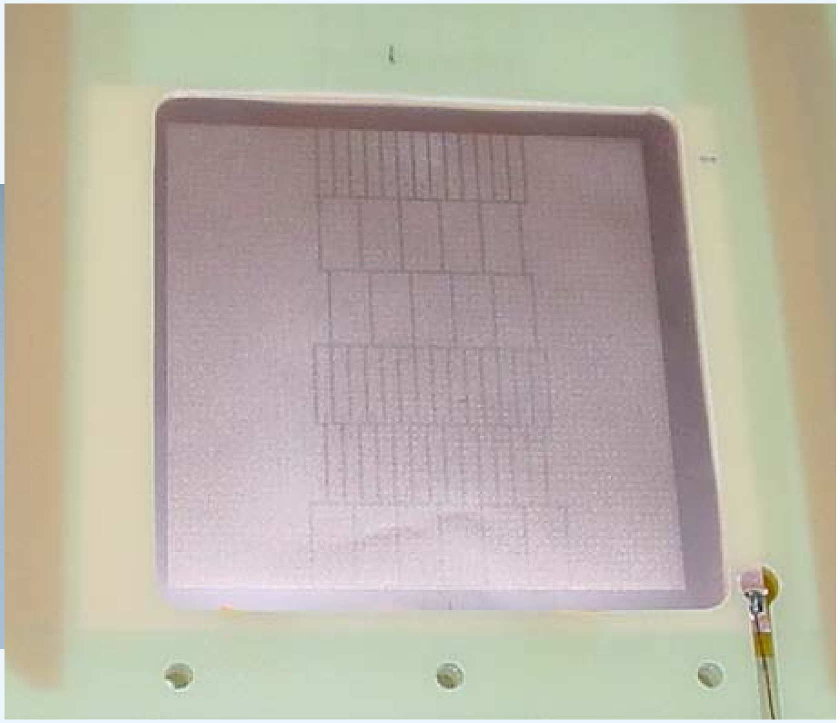
Purdue-3M Micromegas

High magnification photo shows the flat contact section of the pillar.



Micromegas amplification





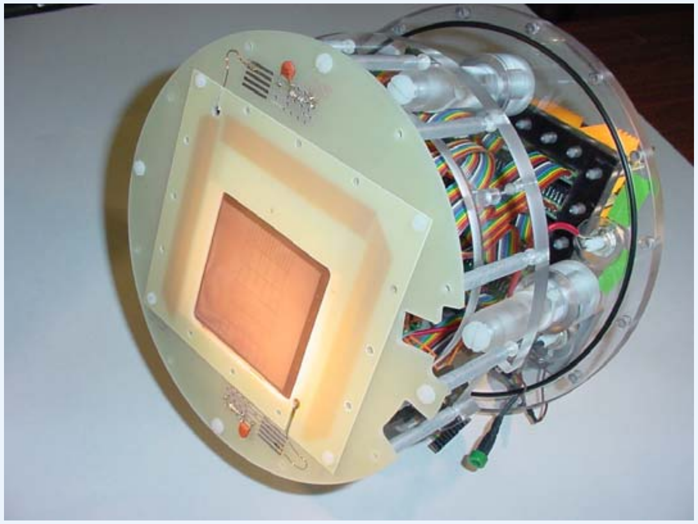
Plastic frame holds the Micromegas until electrostatic force pulls it in at about 250V.

The wrinkle flattens at about 400V.

56 pad readout

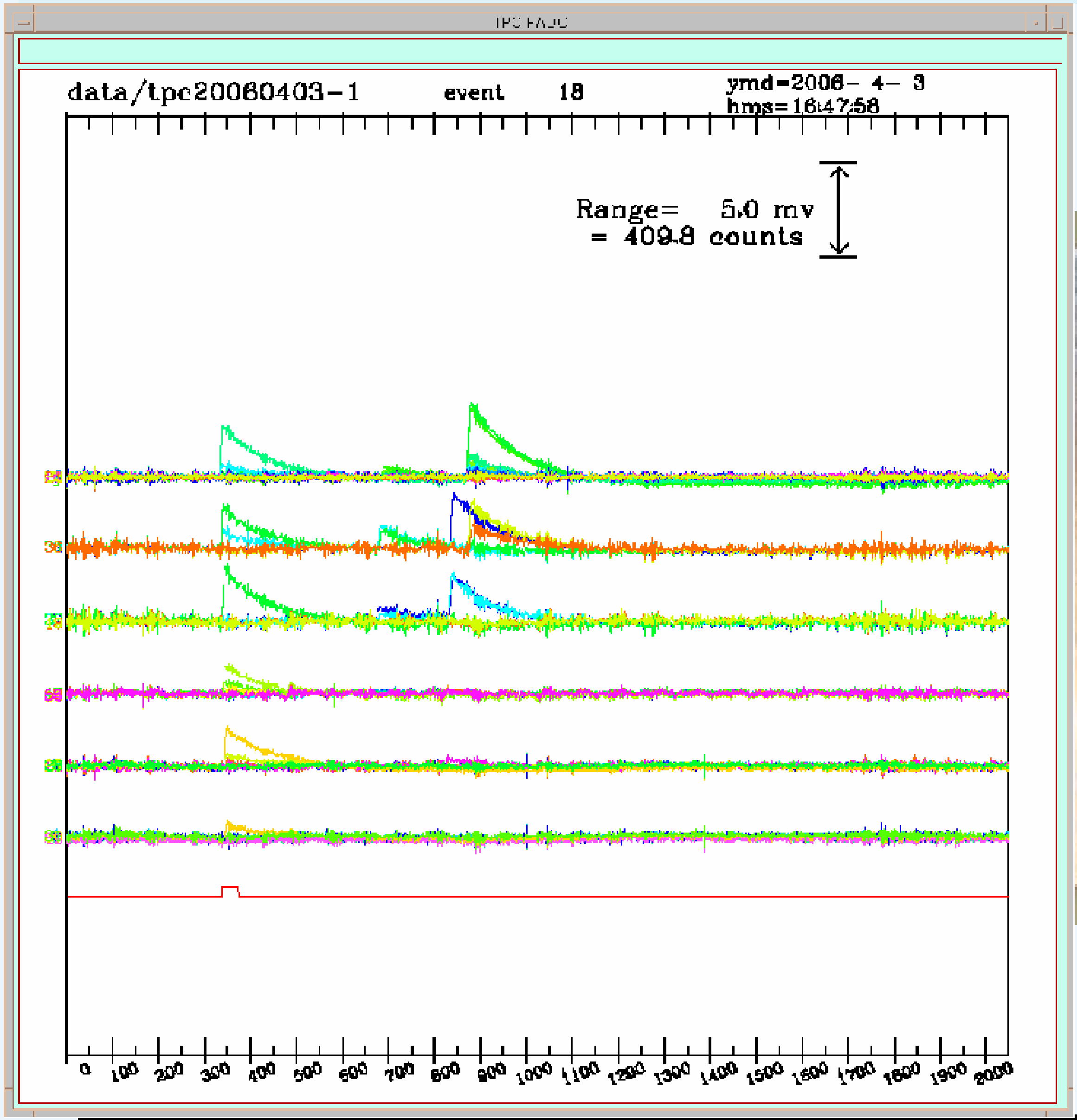
Pillars are located in a 1mm square array.
All pads are located at integer x 1mm spacing.

The single 2mm pad layer (at top)
is used to define the track angle.

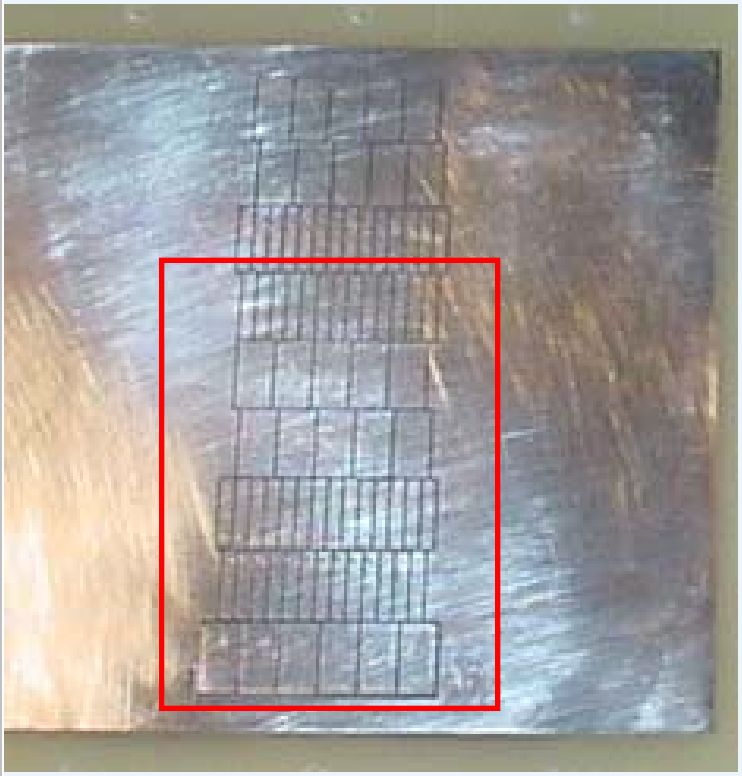


We measure the residual difference from the pair of layers.

Micromegas event - raw

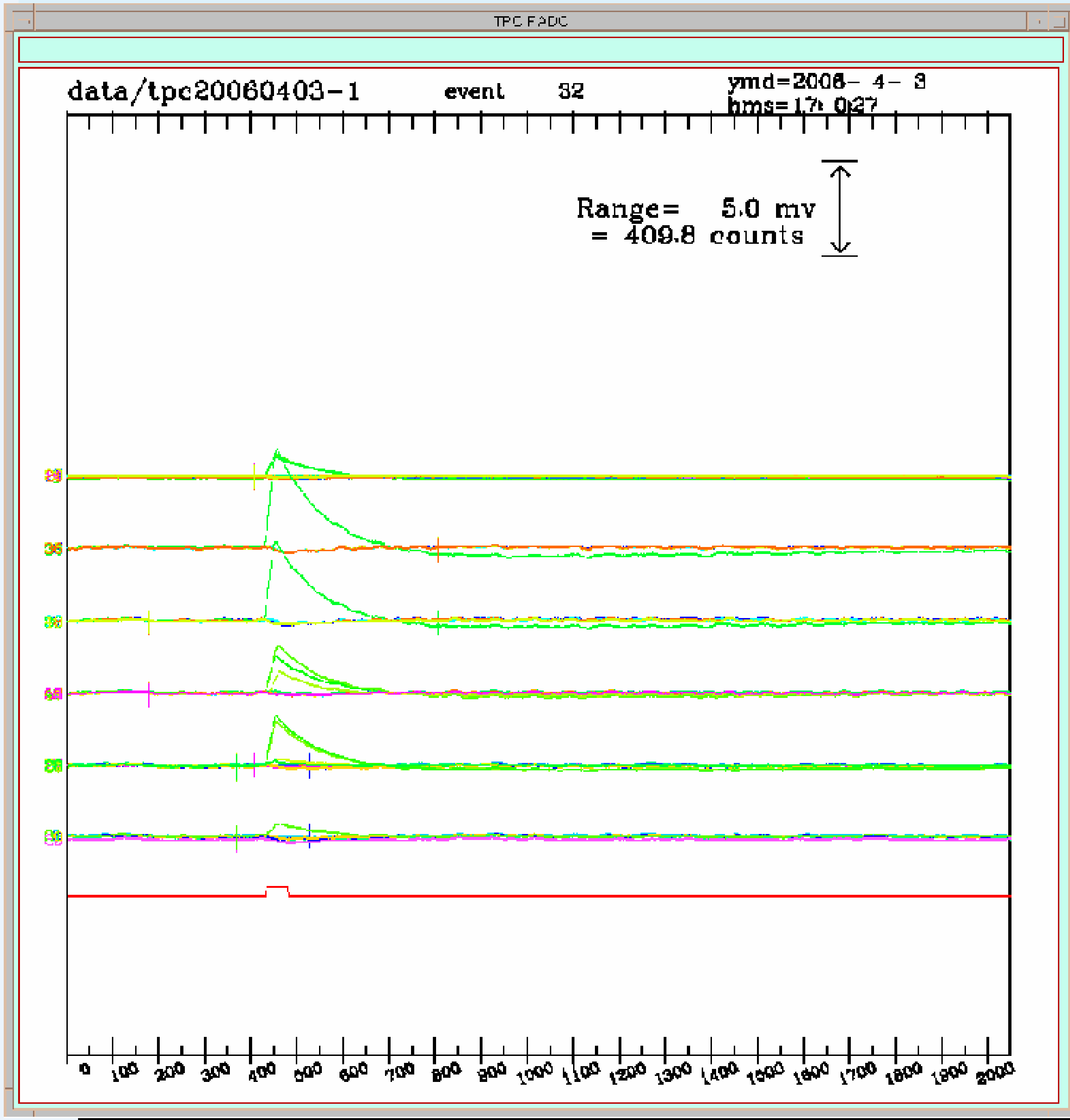


ArCO$_2$ (10%) , 300V/cm
Micromegas: 430V / 50 μm

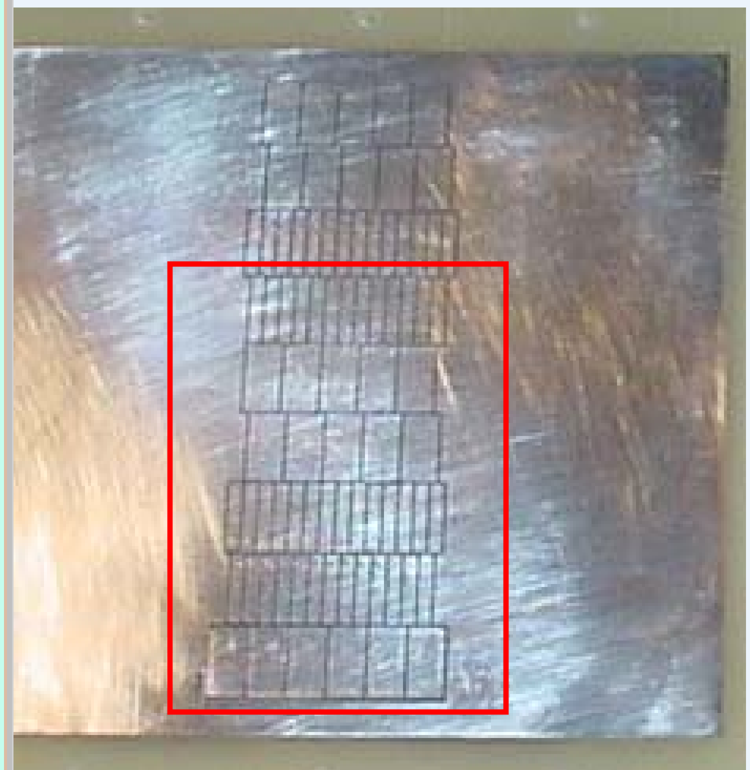


25 MHz , 40 ns
2048 time buckets (81.92 μs)

Micromegas event – smoothed (but no common mode subtraction)

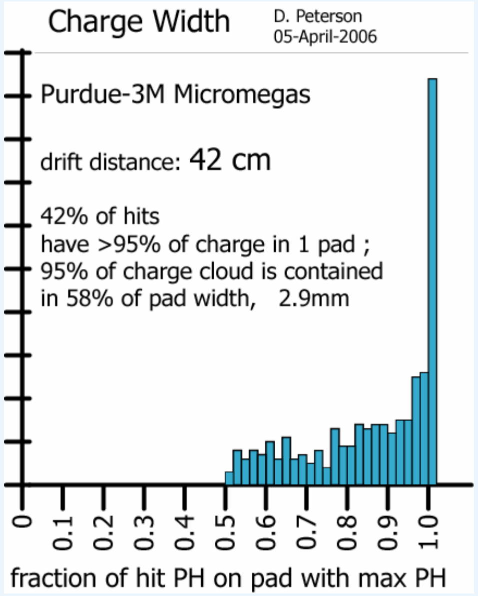


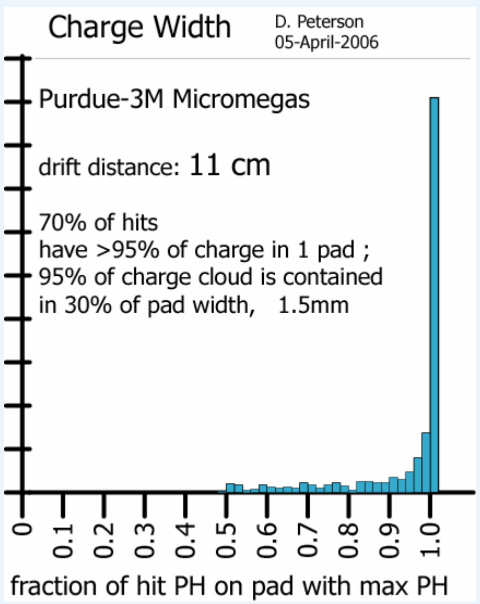
$ArCO_2$ (10%) , 300V/cm
Micromegas: 430V / 50 µm

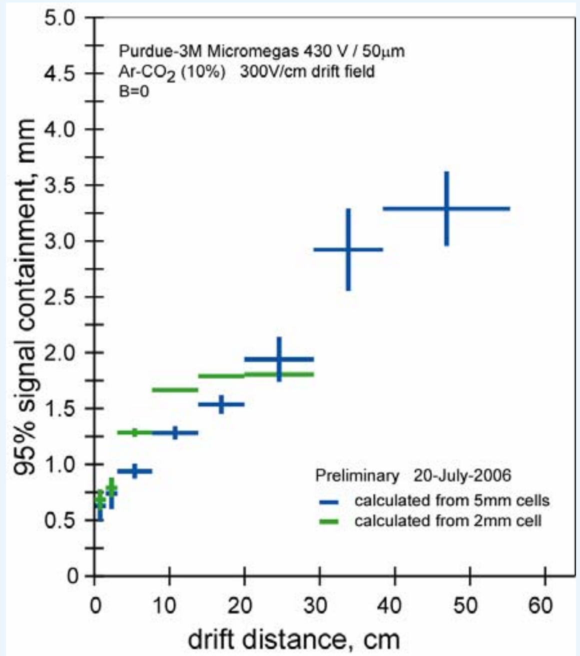


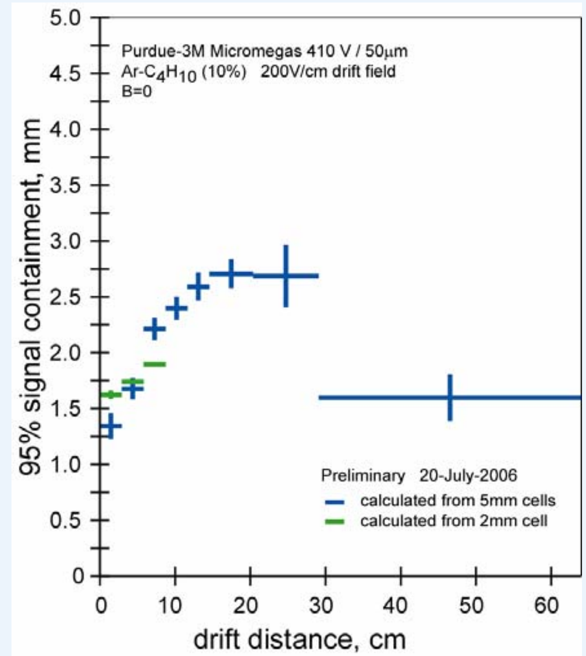
25 MHz , 40 ns
2048 time buckets (81.92 µs)

charge width – pad distribution



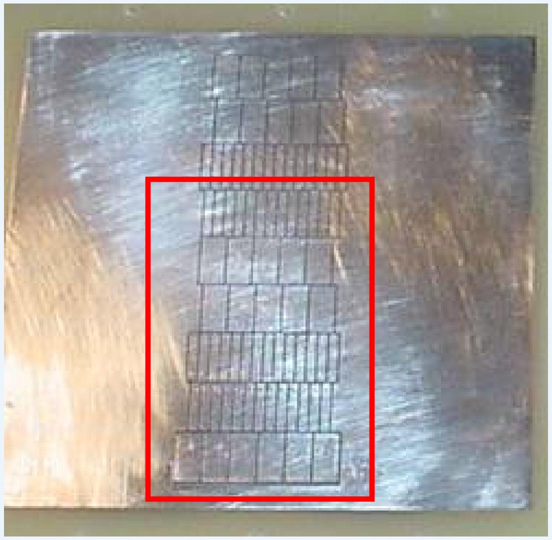






The Ar iso-C_4H_{10} charge width is not increasing above 20 cm drift.
This may be because the trigger only covers 26cm; tracks with drift > 26cm are due to other tracks in the event.
These may be due to tracks at longer drift distance or may be due to delayed tracks correlated with the trigger track.
The event selection includes requirements that may reject hits with width > ~ 3mm , thus leaving only the delayed tracks.

hit resolution (2mm pad)



find tracks

require time coincident signals in 5 layers

find PH center using maximum PH pad
plus nearest neighbors (total 2 or 3 pads)

fit, deweighting the 5mm pad measurements

track selection

require
all (3) 2mm pad layers
"non-edge" hits in the adjacent 2mm layers
charge sharing in the adjacent 2mm layers
(< 95% of charge on one pad)

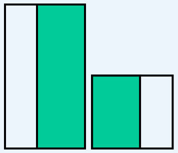
measure

RMS of difference in residual
for the adjacent 2mm layers

correct with : $\sigma = \text{RMS} / \sqrt{2}$

As the charge width is less than the pad width, particularly for drift < 15 cm in $ArCO_2$, when charge is observed on adjacent pads, that charge is not centered on each on the pads.

The charge center of the pads for 2-pad hits is not the geometric center of the pads.



We use the center of an "effective pad width" which gives the best resolution.

Hit Resolution

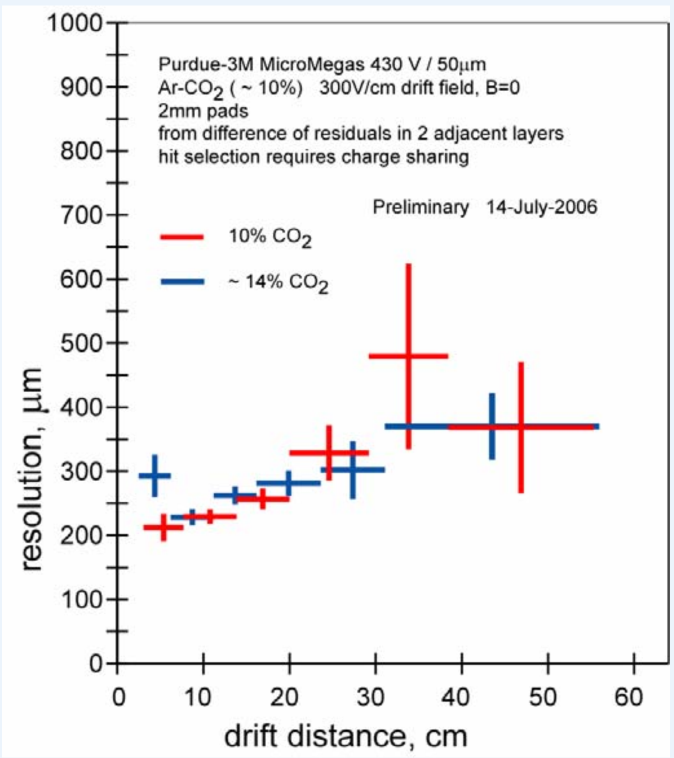
Ar CO_2 (10%) at 430 V

Gain is uncertain

$\simeq$ 10x gain of 1-GEM $ArCO_2$ at 410 V

$\sigma_0 \simeq$ 170 µm , with C_d=.023/√cm, N = 18

(ignoring the low drift bin for 14% CO_2)



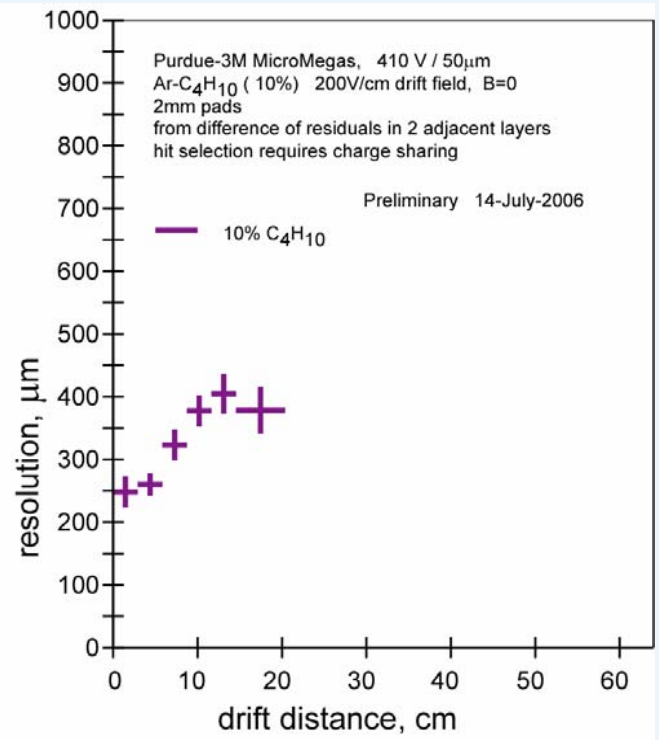
Ar iso-C_4H_{10} (10%) at 410 V

Gain is uncertain

$\simeq$ 6x gain of Micromegas with CO_2 at 430 V

$\sigma_0 \simeq$ 180 µm , with C_d=.048/√cm, N = 23

(ignoring the low drift bin)



Sparking / Discharging

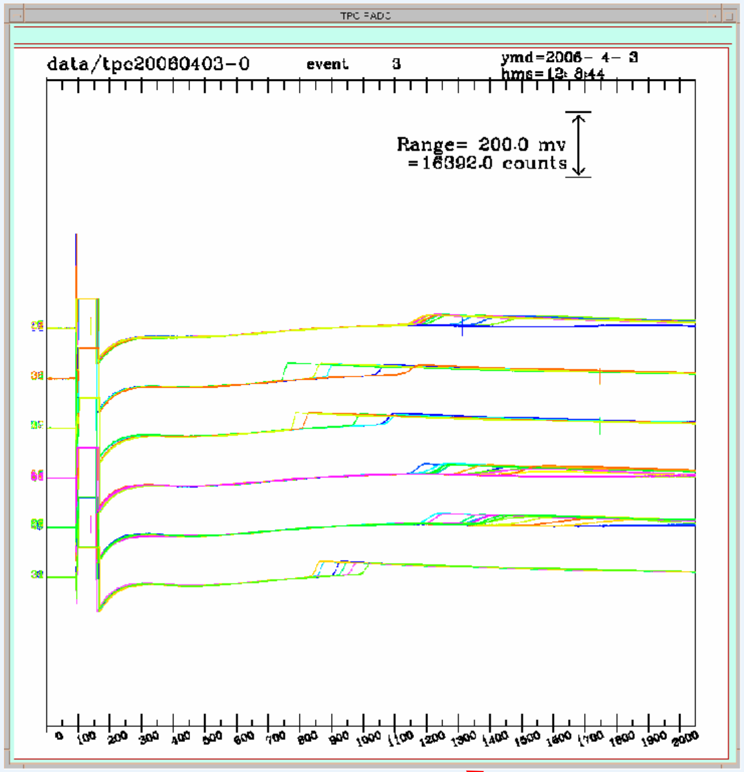
There was an initial training period to get from 400 V to 430 V, ~ 2 hours.

The trip circuit was set at 40 μA, for the minimum duration, less than 20 μs.

Sparks that tripped the HV occurred about 1 per 2 days after the first couple days.

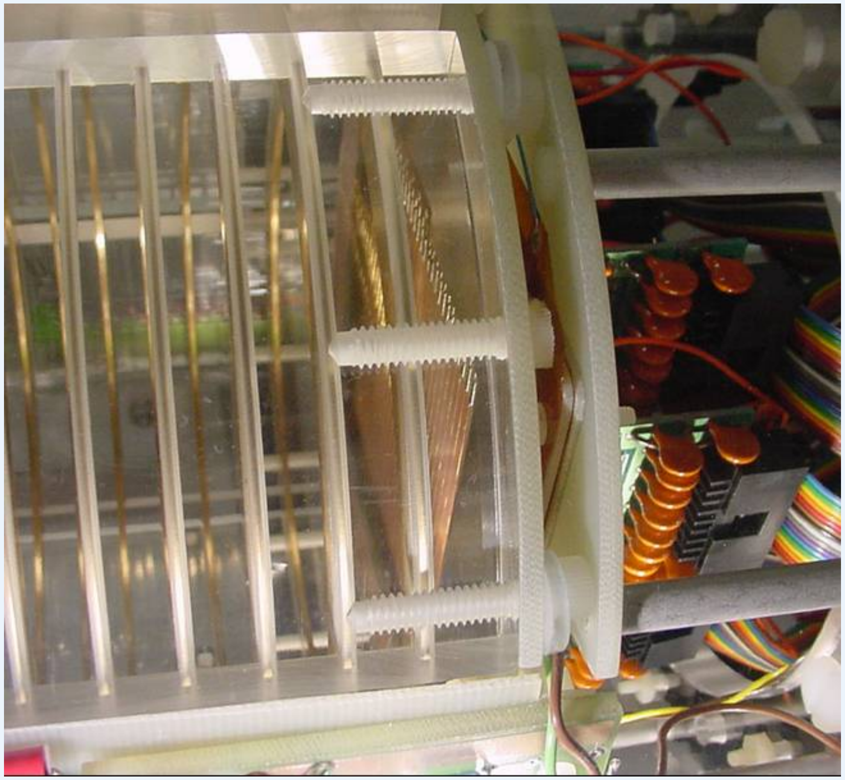
The trip setting was changed to10 μA, for 0.2 sec.

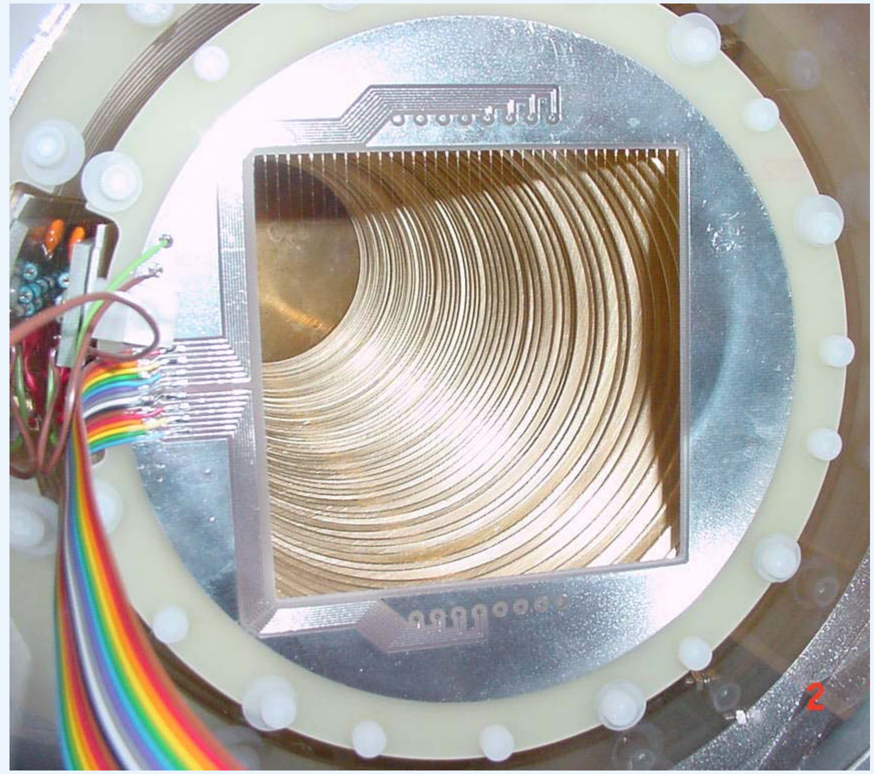
Ran for 10 days at 430 V, no trips.



A new occurrence are the events as shown. (Note 200mv scale)
These could be due to the Micromegas.
These could be an external problem.
They fake a scintillator trigger or are in-time with a scintillator trigger.

Ion Feedback Measurement



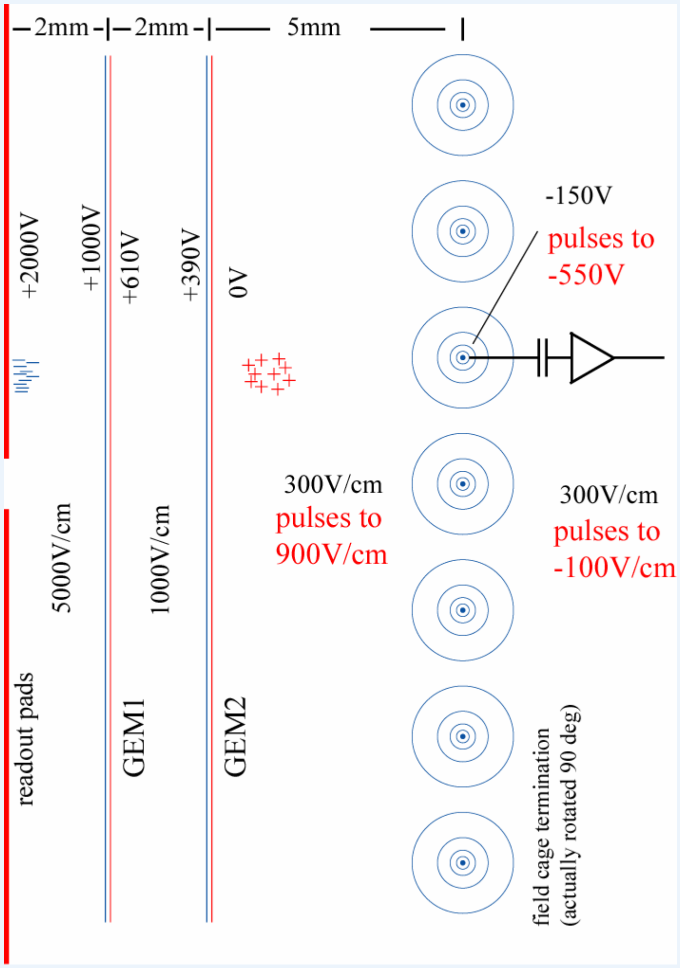


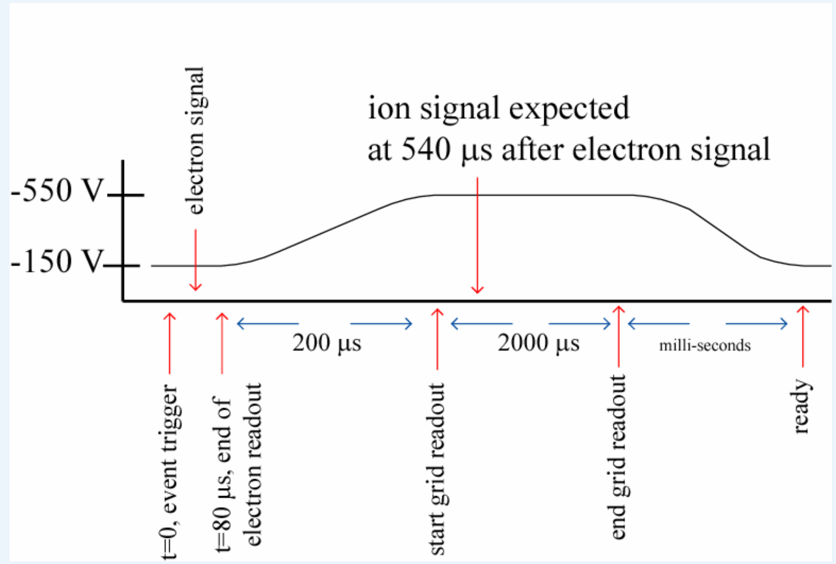
Positive ions are created in the amplification and drift back into the field cage.

We will attempt to measure the ion feedback on the field cage termination plane, for individual tracks.

The method differs from that used by Saclay/Orsay on MicroMegas and by Aachen on GEM.
For those measurements, a source was used to create ionization. Current was measured on the cathode.

Ion Feedback Measurement

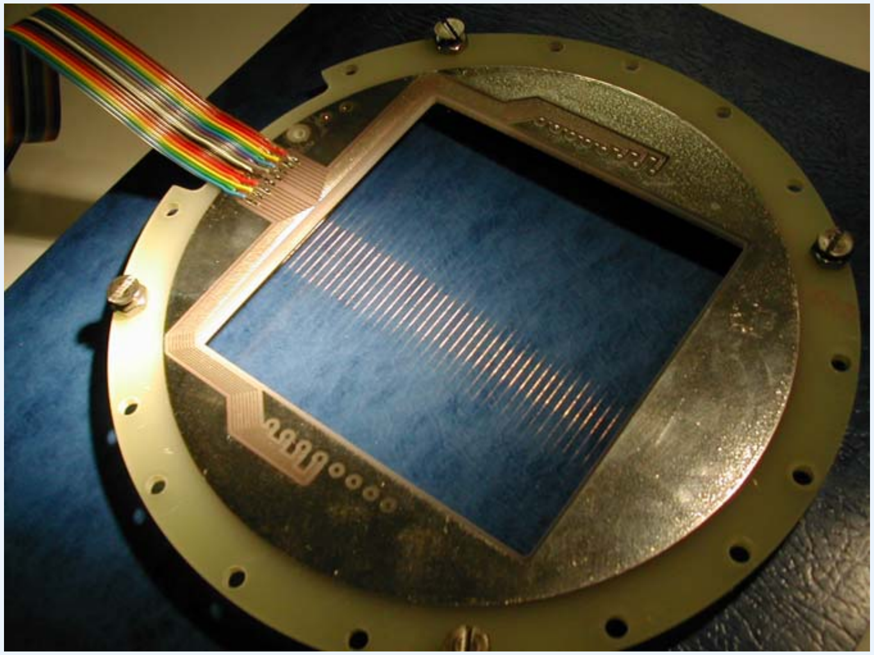




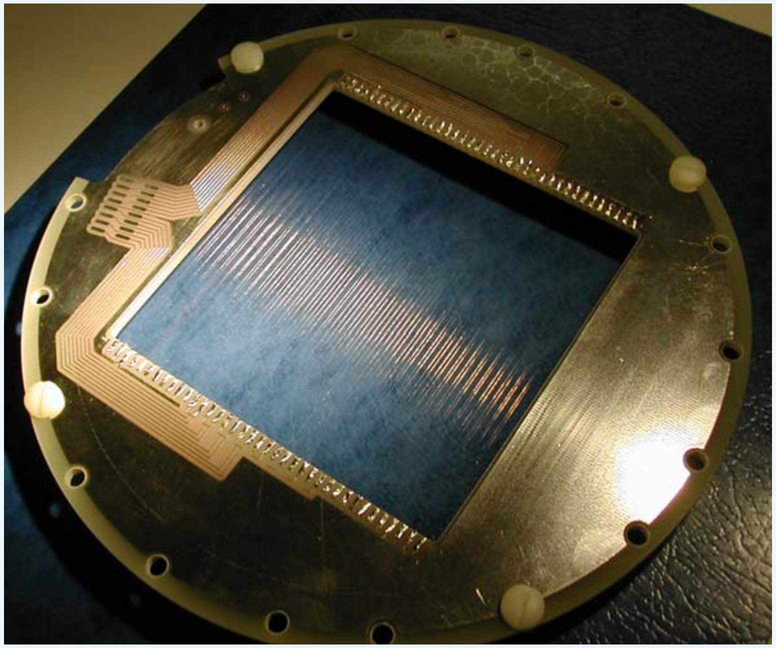
Require small ion drift time to reduce diffusion.
(Expect ~7 μs diffusion at 540 μs drift.)

Require large ion drift time because
the amplifiers saturate during the voltage ramp.
New amplifiers will have a recovery time
within this drift time.

Ion Feedback Measurement, field cage termination



single wire-layer



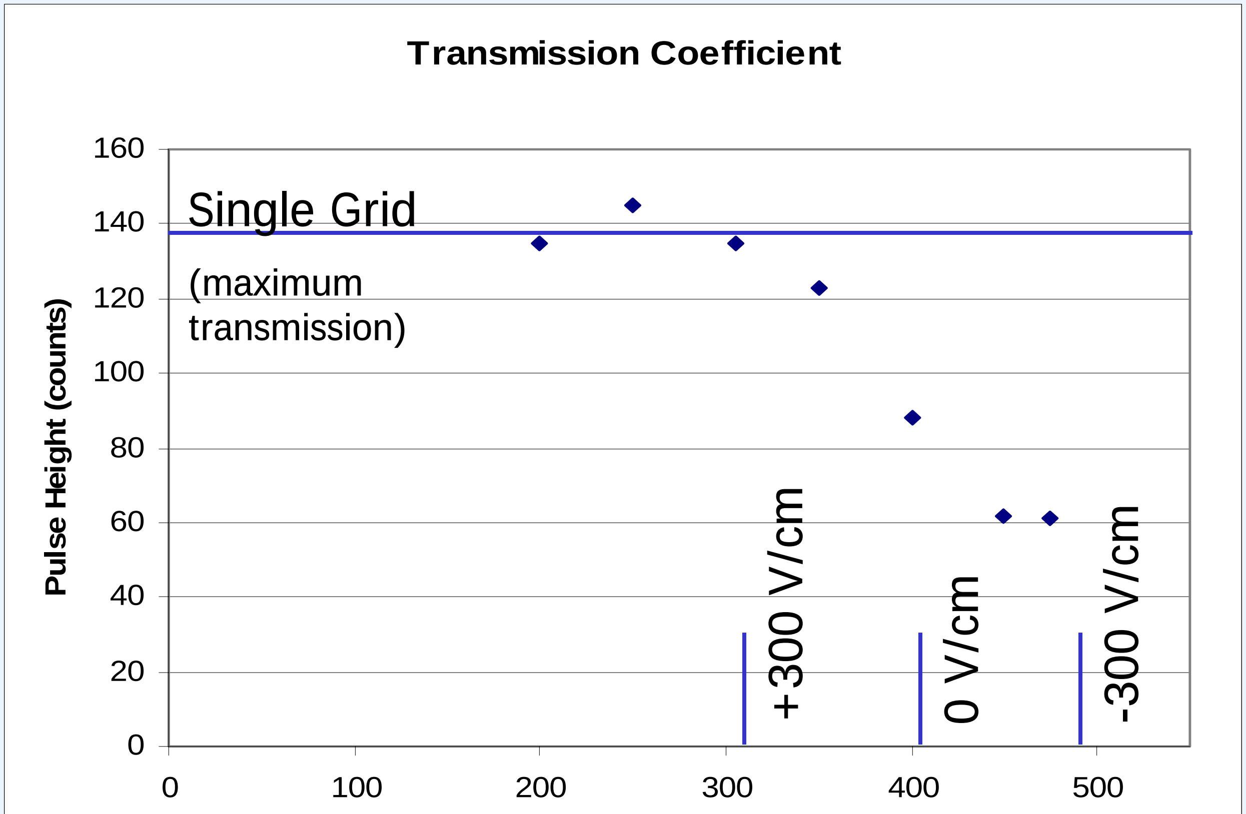
double wire-layer
3.2 mm separation

The single wire-layer field cage termination (shown on slide 16 and above) would not have captured the ions.

When the bias is changed on the wires, it would only distort the neighboring field; it would not create a reverse direction field.

A new double wire-layer field cage termination ensures that there is a reverse direction field.

Field cage termination electron transmission



Bias potential on the field cage termination layer on the readout side (- volts) , with the layer on the drift side at -401 V.

Tests were performed with the Purdue-3M Micromegas installed.

Installed double layer field cage termination.

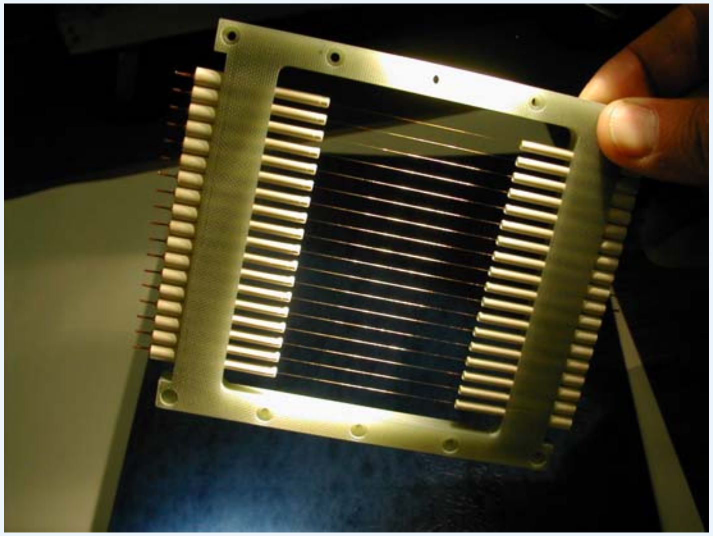
Varied the voltage difference between the layers.

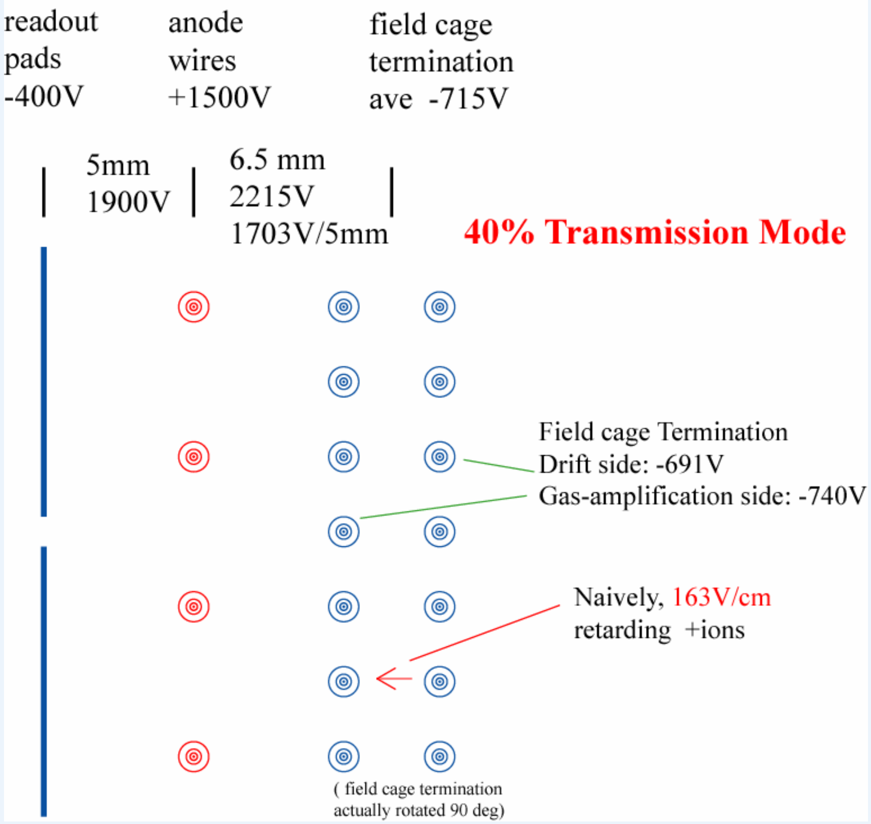
Measure pulse height at the anode pads.

~40% transmission at -450 V
(150V more negative)

~60% of the ion feedback should be captured by the field cage termination wires

Ion feedback, initial tests with wire amplification





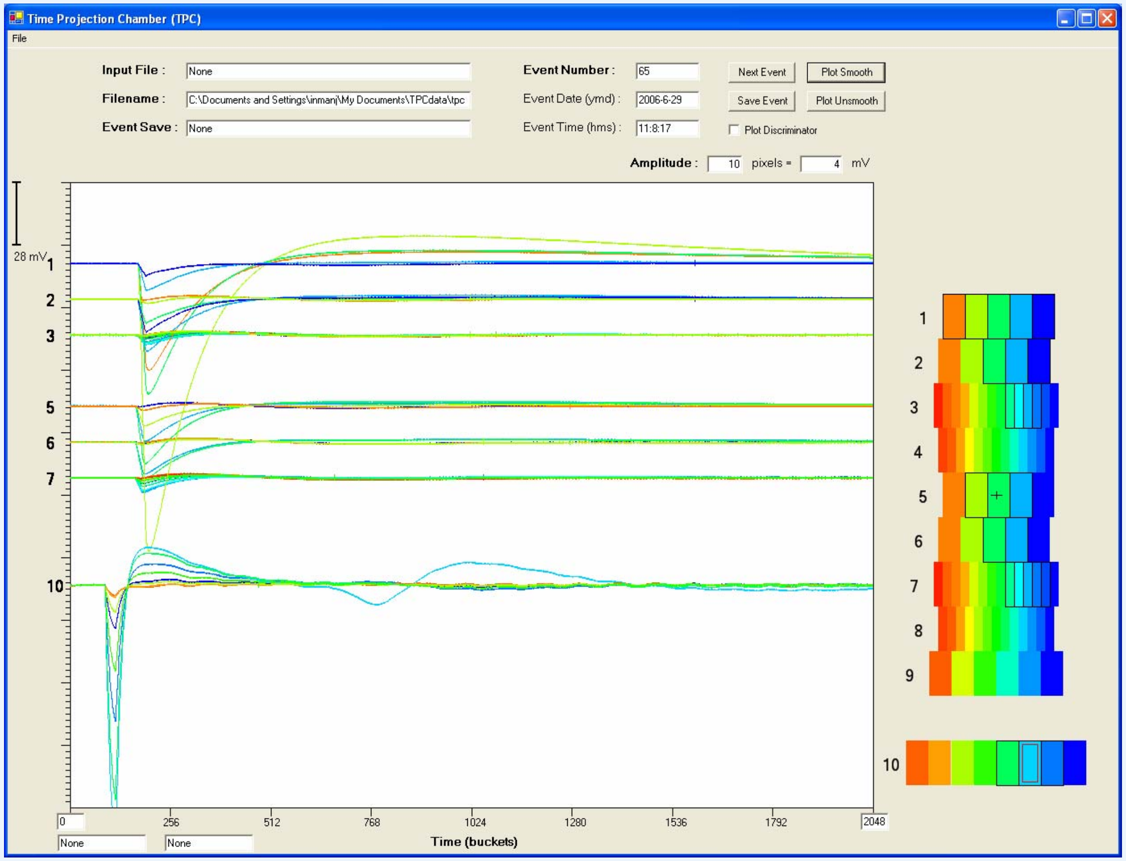
Use the wire amplification for initial tests because it has a predictable, and large, ion feedback fraction.

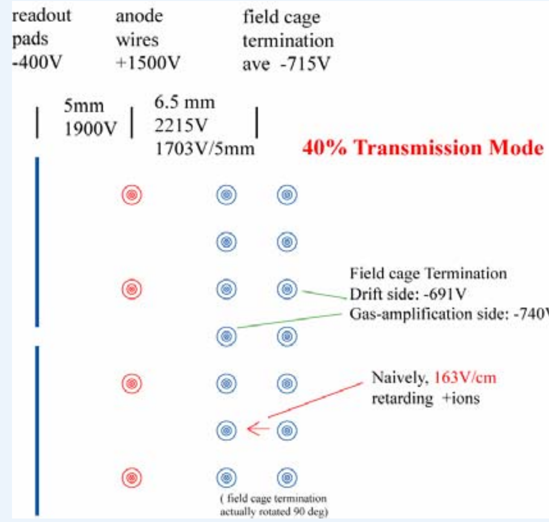
Use the partial transmission mode of the field cage termination because the bias pulsing circuit, and gated electronic amplifiers that can tolerate the pulsing, are not ready.

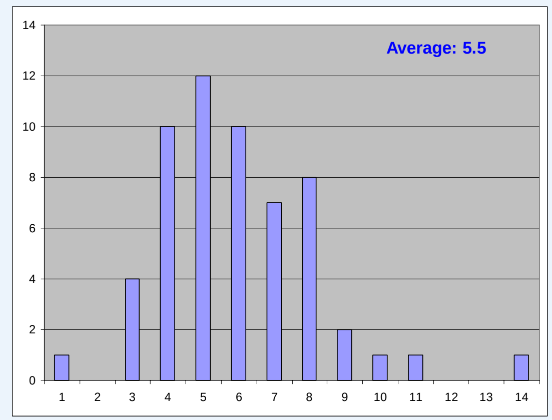
The ion feedback signal will be measured on the instrumented field cage termination layer.

Naively, the ion drift time is $T=(.5cm) / [1.535cm^2/(V\ sec) \times 3406\ V/cm] = 124\ \mu s$, but this does not account for the potential difference in the radial field regions, which is necessary to see the signal.

Ion feedback, 40% transmission



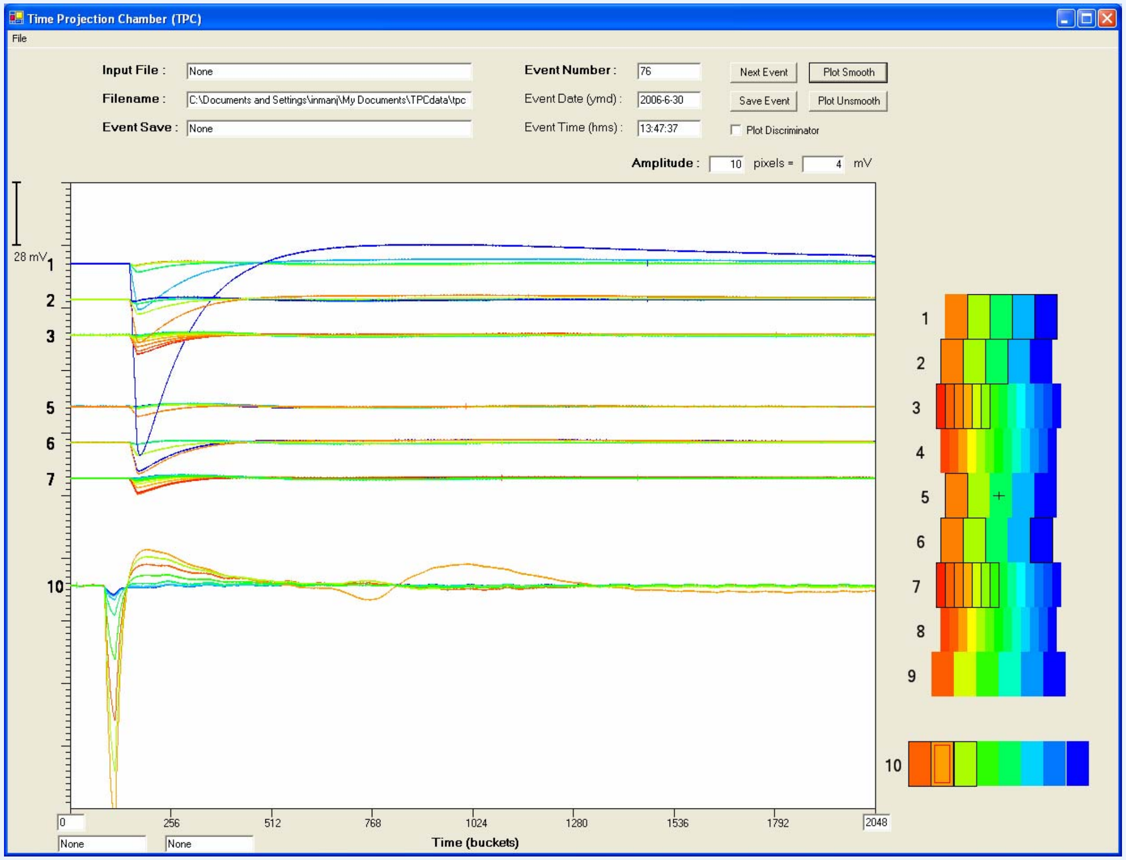


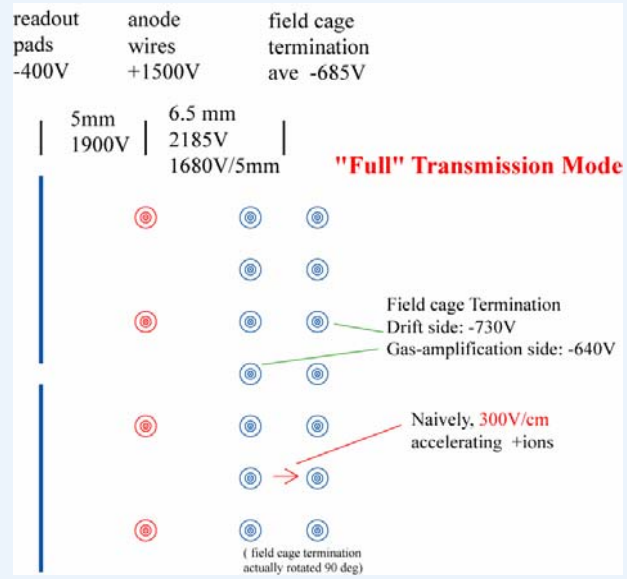


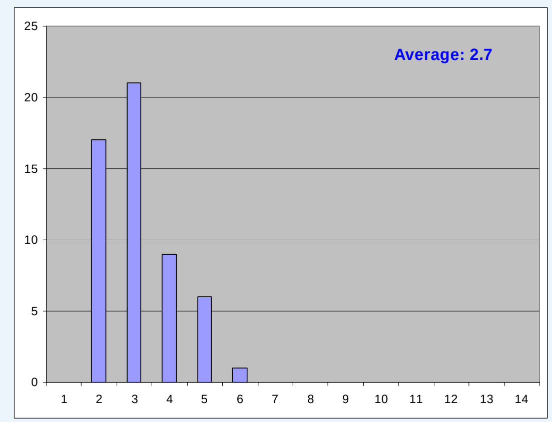
Upper traces are the cathode pad rows. (25 MHz, 82 μsec full width)
Bottom traces are the instrumented field cage termination cathode wires. (3.125 MHz, 650 μsec)
The fast, in-time, wire signal is on all wires; it is inductive.

There is a second pulse, 203 μsec later, with average relative pulse height of 5.5%.
The delayed pulse is in one channel, typically the peak channel of the inductive pulse.

Ion Feedback, “full” transmission







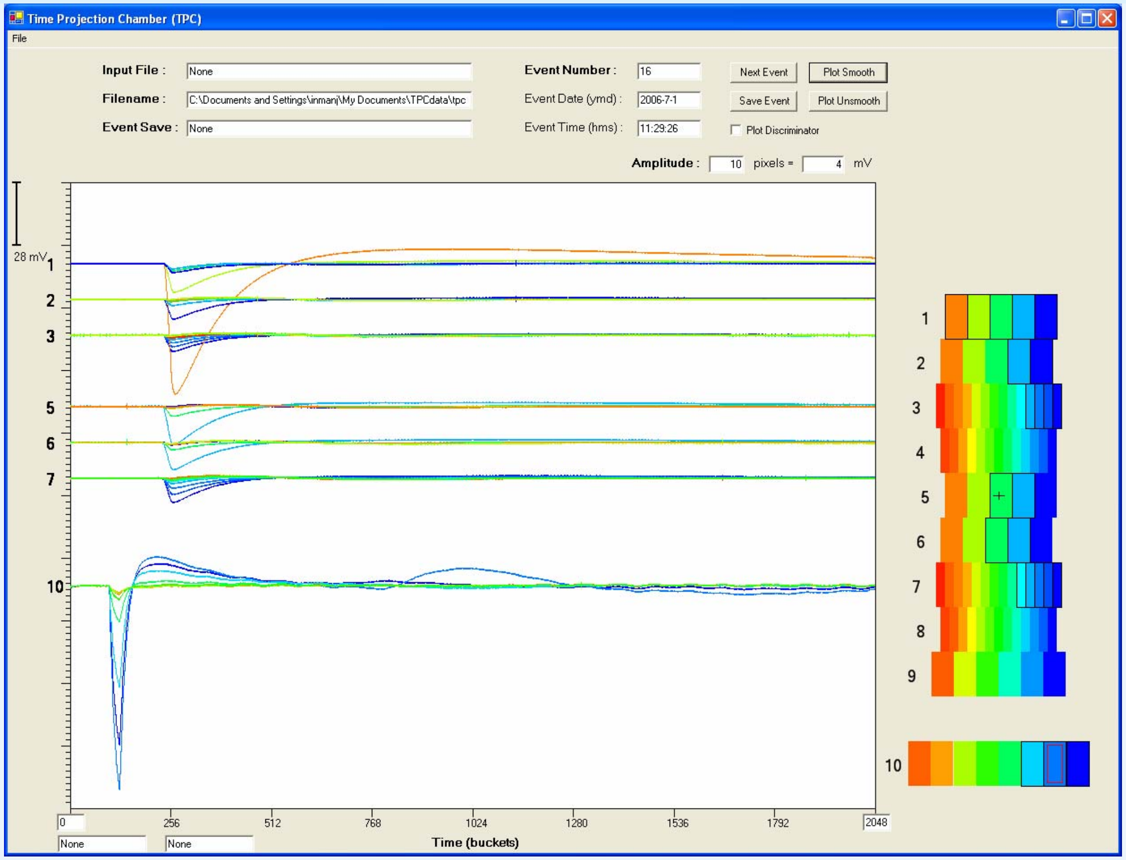
With +300V/cm between the layers of the field cage termination, expect more transmission. (Measured full transmission for electrons.)

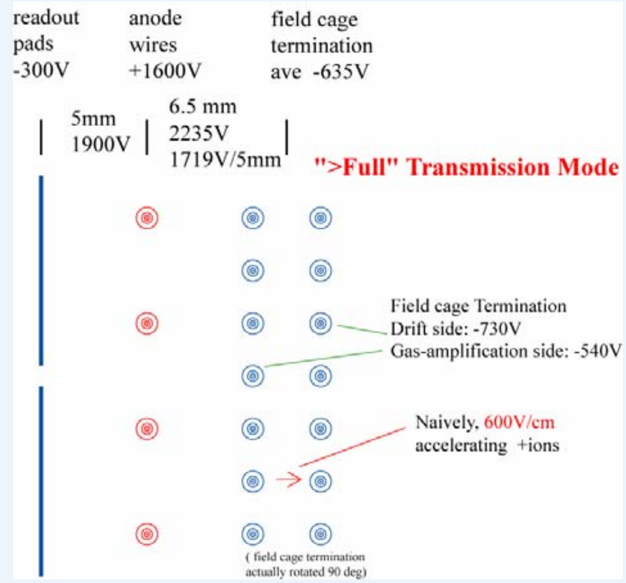
The pulse delay is 208 μsec (vs 203).

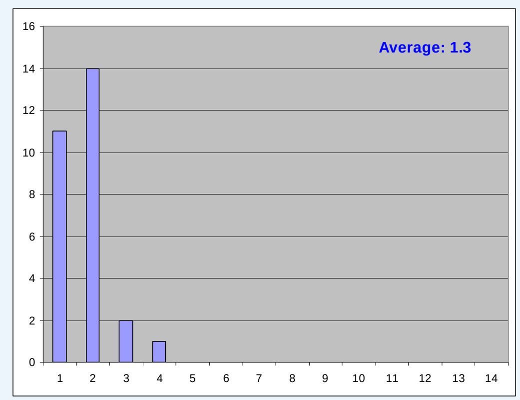
The relative pulse height is 2.7% (reduced from 5.5%).

The channel with the delayed pulse is consistent with the track seen on the pads.

Ion Feedback, “>full” transmission





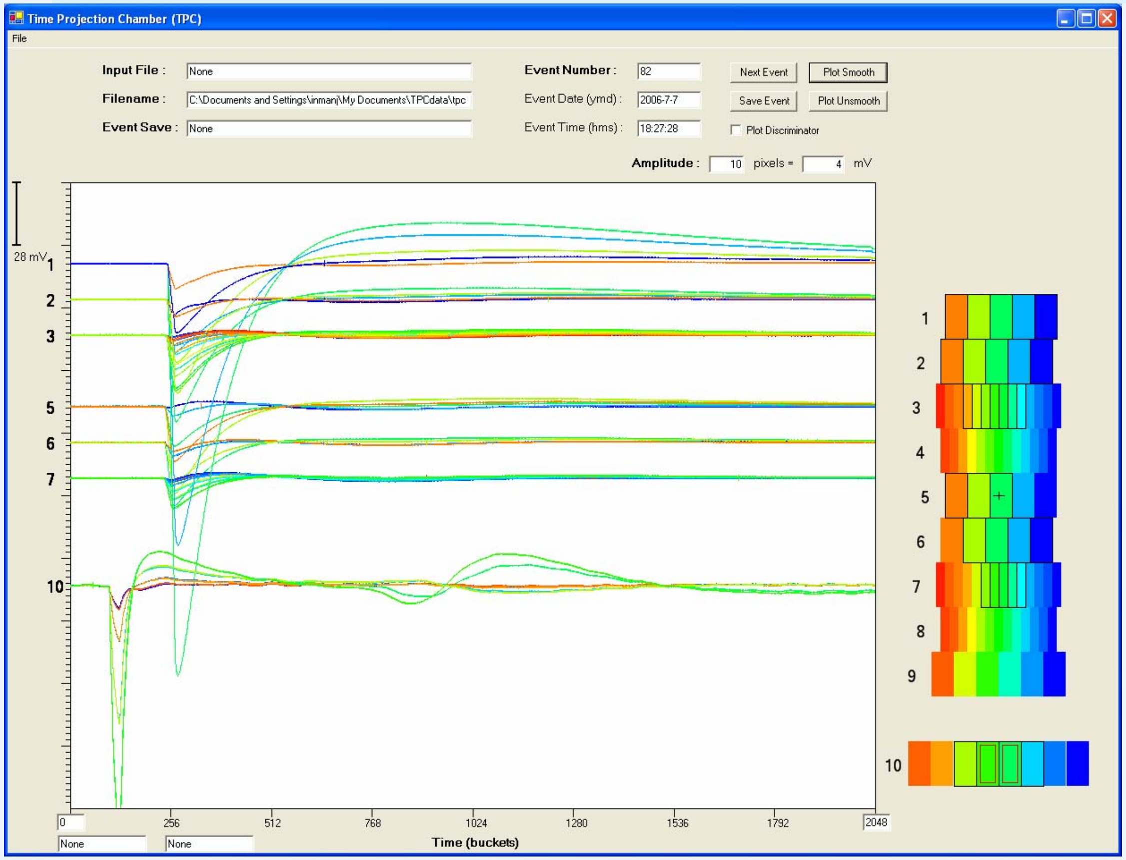


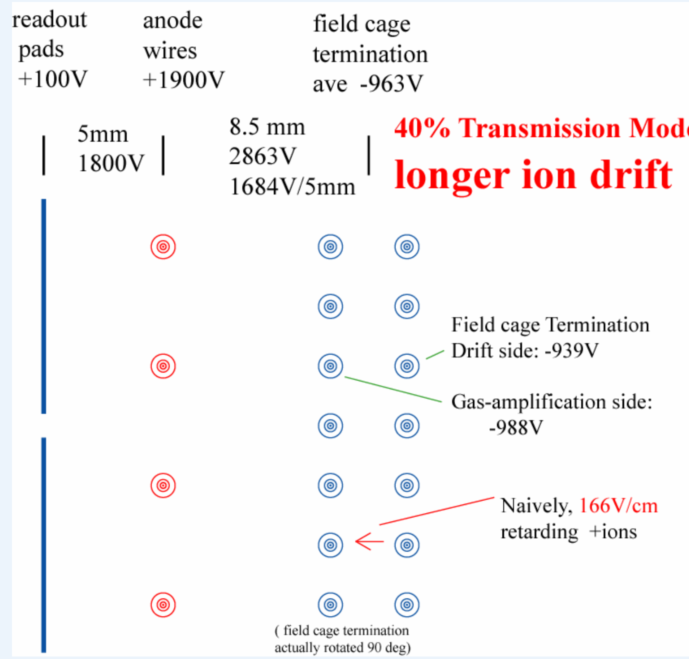
With +600V/cm between the layers of the field cage termination, expect to further increase transmission, and reduce collection.

The pulse delay is 210 µsec (vs 203).

The relative pulse height is 1.3% (reduced from 5.5%, 2.7%).

Ion Feedback, variation with ion drift distance





Test that the delay time increases with ion drift distance; any electronic source will have a constant time.
Again, with ~40% transmission, -166V/cm, in the field cage termination,
but with the field cage termination-to-anode spacing is increased to 7mm (from 5 mm), x 1.4 .

Pulse delay increases to 246 μsec , σ=6 μsec , (from 203 μsec), x 1.2 .

Summary / Outlook

We have operated the Purdue-3M Micromegas in a TPC.

Observed charge width (95% containment/ 6σ) at drift=0 0.6mm in Ar CO_2 (10%)
1.3mm in Ar iso-C_4H_{10} (10%)

Resolution extrapolates to about 170 μm with B=0, in both Ar CO_2, Ar iso-C_4H_{10}

Sparking/discharging is not a serious problem.

We have completed initial studies for ion feedback measurements.

We see a signal with wire amplification (with about 50% feedback) .
A pulsing bias supply for the field cage termination is being developed.
Gated preamps for the field cage termination are being developed.

The signals will be very small.
Comparative measurements of GEMs and Micromegas will require high gain,
and may require averaging the signal of the predicted channels for many events.

A "bulk Micromaegas" is being prepared on one of our pad boards by Paul Colas.

We have a new display package and analysis program in Microsoft C++.