TPC R&D at Cornell and Purdue

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Further information available at the web sites:
- http://www.lepp.cornell.edu/~dpp/linearCollider/largePrototype.html
- http://www.lepp.cornell.edu/~dpp/linearCollider/tpcTestLabInfo.html

* presentation at LCWS DESY
* presentation at ECFA Valencia
* presentation at ALCPP Vancouver
* presentation at Berkeley TPC Workshop
* presentation at ECFA 2005 Vienna
* presentation at ALCPP Snowmass
* presentation at LCWS05, Stanford

- 30-May-2007
- 07-November-2006
- 18-July-2006
- 08-April-2006
- 24-November-2005
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- 21-March-2005

Bulk Micromegas
electron and ion transmission
demonstration of ion signal
Purdue-3M Micromegas

This project is supported, in part, by the US National Science Foundation (LEPP cooperative agreement) and by the US Department of Energy (Purdue HEP group base grant) and an LDRD 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, \( B=0, \text{Ar-isoC}_4\text{H}_{10}(7\%) \)
  a Purdue/3M Micromegas, \( B=0, \text{Ar-isoC}_4\text{H}_{10}(7\%) \)
  a triple-GEM, \( B=0, \text{TDR gas:Ar-CH}_4(5\%)-\text{CO}_2(2\%) \)
  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

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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 0.025 mV)
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
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-iso C₄H₁₀ (7%).

Bulk Micromegas measurements, Ar-iso C₄H₁₀ (7%), were shown at DESY 2007. Current measurements have fully instrumented pad board and higher statistics.
Measurements with the Purdue-3M Micromegas, using Ar-CO2 (10%) were shown at Vancouver 2006.

Current measurements are with Ar-iso C₄H₁₀ (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.
Triplet-GEM amplification

10 cm

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 ??

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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** $D = 0.0390 \text{ cm/}(\text{cm})^{1/2}$.

( 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

iso \( \text{C}_4\text{H}_{10} \) 7% 5%

\( E_{\text{drift}} \ V/cm \) 200 220

\( D \ cm/(cm)^{1/2} \) 0.039 0.0480

\( \sigma \ mm \) 0.83 0.918

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Drift velocity / Gain

Ar-CH₄(5%)-CO₂(2%), 220V/cm, expect 43 mm/μs. Observed time for a maximum drift 64.7 cm is (370 FADC time buckets) x (40 ns/bucket), or 43.7 mm/μs.

Ar-isoC₄H₁₀(7%), 200V/cm, expect ~39 mm/μs. Observed time for a maximum drift 64.7 cm is (405 FADC time buckets) x (40 ns/bucket), or 39.9 mm/μs.

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

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

**Bulk Micromegas** (7% C₄H₁₀, 410V) = 0.81

3-GEM (Ar-CH₄(5%)-CO₂(2%), 315V/GEM)

**Purdue Micromegas** (Ar-isoC₄H₁₀ (7%), at 400V) = 3.6

**Bulk Micromegas** (7% C₄H₁₀, at 410V) correcting by x10 per 60V, gain ratio (equal V) = 5.3
hit resolution (2mm pad)

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 $\sigma$
$\sigma = \frac{\text{RMS}}{\sqrt{2}}$
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 dependent)
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 fit is to the data, with same conditions, shown at LCWS DESY 2007

The results are very similar.

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

use $D = 0.0415 \text{ cm/(cm)}^{1/2}$.

result: $n = 17.4 \pm 0.5$

$\sigma_0 = 53 \pm 36 \text{ } \mu m$

$\chi^2$/dof = 1.7
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 \times 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)
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.
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).
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.

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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.
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\textsubscript{2})
3) machine to 250 mm (0.010 inch) oversize,
4) stress relief (rapid immersion in liquid N\textsubscript{2})
5) machine to drawing dimensions
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”
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.