



A New GEM Module for a Large Prototype TPC: Status and Plans

By

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The goal of this talk is to present you with the development of the design of a new GEM readout module for a Large Prototype TPC that is going on at DESY



Summary



Introduction to the Large Prototype (LPTPC)



Motivation & Goals of a new readout module



Design and production of the module

- Backframe
- Framing Structure
- GEMs
- Pad Plane



Future Plans & Conclusions




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In this talk I would like to introduce the LPTPC to the one of you that don't know this device yet

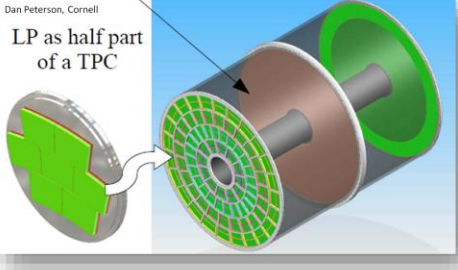
I'll then proceed motivating the need for the development of a new GEM-based readout module for this TPC, following with the description of the design effort and the production plans of this device

I'll then conclude my talk illustrating some of our future plans

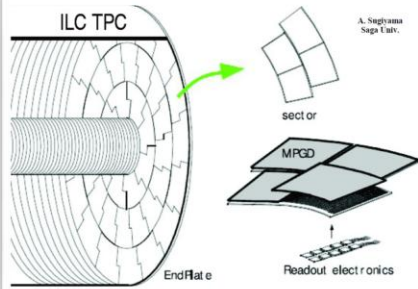


Basics - A prototype for an ILC TPC


Dan Peterson, Cornell

LP as half part of a TPC



ILC TPC



A. Sengupta, SLAC

Main Goals of the Large Prototype

- Develop technologies and expertise to build a TPC based tracker for the ILC
- The LP simulates a section of this TPC
- Benchmark detector to test and compare different solutions

Some interesting features

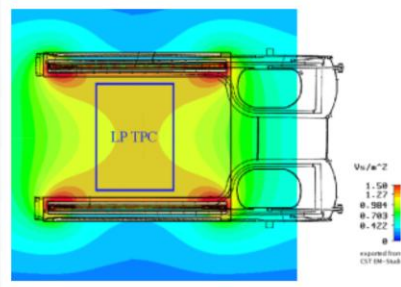
- MPGD based gas amplification system
- Analog (pads) or digital (silicon pixels) readout system

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The LPTPC is part of the effort to develop technologies and expertise to build a TPC based tracker for an ILC detector.

The LP simulates a section of this detector to benchmark different solutions (left hand side picture).

For the following of this talk I will only list two of the features that we are interested to test using this device, namely an MPGD based gas amplification system readout with both analog (Pads + ADC) or digital (silicon pixel) electronics



Field Cage designed and produced by DESY

- 60 cm drift length, 72 cm inner diameter
- Field Quality: $10^{-4} < \Delta E / E < 10^{-3}$
- Operational since the end of 2008
- Designed to fit inside PCMAG

PCMAG

- Superconductive Solenoidal Magnet with standalone LHe Cooling and low mass coil supplied by KEK.
- 1 Tesla Magnetic Field

Now I want to present you with some more details of the LPTPC. The field cage of this detector has been designed and produced by DESY. On the left hand side the picture shows this field cage during the final fase of the production. This field cage has been hosted and operated since the end of 2008 in a Superconductive Magnet called PCMAG, supplied by KEK. The field map inside and around the solenoid is shown on the right hand side

LPTPC Endplate – Some Features

- Designed and produced at Cornell
- Aluminum Alloy
- Accommodates 7 identical modules that can be equipped with different technology solutions

The Modules

- Cornerstone shape , 20-24 cm wide, 17 cm high

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The anode endplate of the LP has been designed at Cornell by Dan Peterson and features seven holes for seven identical modules that can be equipped with the different technologies solutions to be tested. On the left hand side you can see one of the 3d rendering of this device. In the middle picture, on the other hand, you can see this same device built and installed inside the LP equipped with one Micromegas module.

This talk is focused on the development of a GEM-based readout module to be installed on this endplate. Each of this module is shaped like a corner stone, and can be installed in any position in the endplate. A 3d rendering of this device is shown on the right hand side picture



Basics – Modules already tested



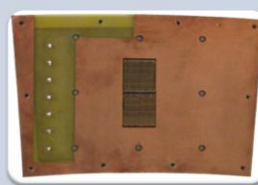
Micromegas

- Built at Saclay
- Readout with T2K Electronics
- With naked and coated pads



Asian GEM

- Built in Japan and China
- GEM stretched from the top and bottom
- Two GEM stack
- Pad Readout with Altro Electronics



Bonn GEM

- Developed at Bonn University
- Stack of 3 10X10 cm standard CERN GEM
- Pad Readout with Altro Electronics
- Timepix readout with integrated electronics

21/09/2009

Prepared by Stefano Caiazza.
Email: stefano.caiazza@desy.de

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Up to now the LP has been used to test three different kinds of modules, three different technological solutions:

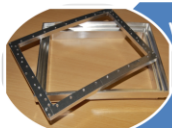
The Micromegas Module built by Paul Colas and his group at Saclay, with both naked and resistive coated pads

The Asian GEM module, with a two GEM stack, each of this GEMs stretched only from the upper and lower side, and produced in Japan, readout with naked pads

The Bonn Module featuring standard 10X10 Cern GEMs with both a pad readout system with ALTRO electronics or a silicon pixel readout with integrated electronics (the picture refers to the Timepix module yet to be tested on the LPTPC)



Desy Module – Why do we need a new one!



We want to test a large area 3-GEM stack module with an optional gating element, and a self supporting framing structure minimizing the dead space.

No Large Area Triple GEM

- The Asian Module only features a two GEM stack with a possible gating
- The Bonn Module uses small 10x10 GEM

New solutions for framing

- The Asian GEMs are stretched, not framed.
- The stretching is applied only from the top and bottom side to minimize dead space
- We want to achieve the same dead space and material budget reduction using a full frame

No gating and Ion Backdrift studies done

- Gating element foreseen in the Asian GEM module but no test performed as yet (first test maybe this spring)

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This said, why do we need another module. What do we want to test that cannot be tested with the others?

We want to test a large area, 3 GEM stack module with an optional gating element, and a self supporting framing structure minimizing the dead space.

Why this can't be done with what we already have:

The Asian GEM only features a two GEM stack, while the Bonn module only uses small GEMs.

Moreover the Asian GEMs use a novel system to build the GEM stack, only stretching those GEMs from the top and bottom side. We want to achieve similar results in terms of dead space and material budget reduction using a full frame

Finally we want to develop and test new gating techniques compatible with the operations of a GEM module and we would like to test and compare the ion backdrift suppression of different technologies.



Desy Module – Main Design Features



Large Area three GEM stack + possible gate (GEM or otherwise)

- Use a custom designed GEM as big as the module itself
- GEMs designed to allow for a 4-GEM stack

Self supporting ceramic frame

- Each GEM is framed with a ceramic frame, much smaller than traditional GRP frames

Modularity

- Each GEM is independently framed and can be easily mounted or removed from the stack

Pad Readout System

- Traditional pad readout system with analog electronics (ALTRO)
- Flexible design, may allow for use of different readout systems in future

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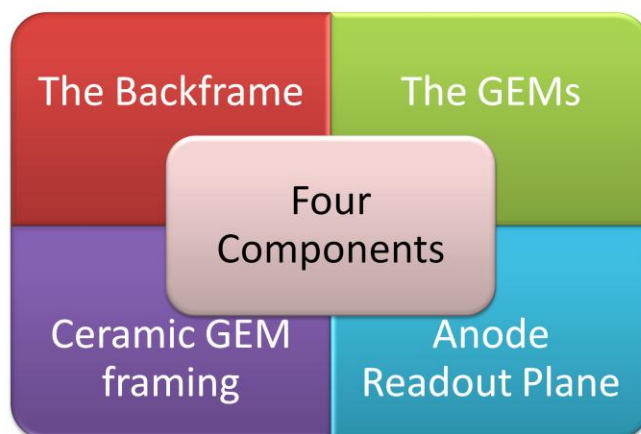
From the goals I just described we got our design features

This module features a large area three GEM stack, with the possibility to add a fourth element, GEM based or otherwise, used as a gating device.

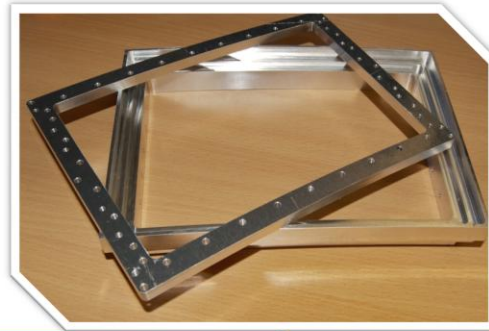
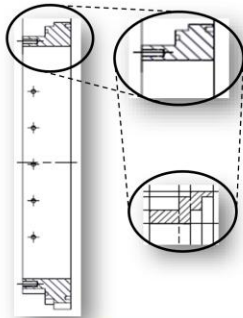
To frame each GEM we used a ceramic framing structure. Each of the GEMs may be framed independently to be exchanged easily if need arises.

Finally we choose a traditional pad readout system for our module, but the design is flexible enough that the same frame and GEM design could be applied later to different readout systems.

We decide



Now I want to get in some more details on the design of this detector.
 This detector is composed of four main elements:
 The backframe, The GEMs, The Framing structure and the Pad plane



Goal

- Basic designed done at Cornell, customized at Desy
- Increase the area available on the connector side
- Customized to fit dowel and screw holes to align and fix the pad plane and the GEM stack

Production

- First trial piece produced at Desy, now being test for gas tightness

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The backframe of the LP modules was designed at Cornell with the Endplate that hosts them. We customized this design to increase the available area on the connector side, as you can see from the left hand side picture where I have emphasized the major changes we made to the original designed. Moreover we added screw and dowel holes to fix and align all the element of the module, backframe, pad plane and framed GEMs

Limit the unsupported areas of the GEMs

- Gain uniformity limited by the GEM sagging: we want to limit the unsupported areas of the GEM
- To limit the unsupported areas we need to include supporting beams inside the foil area

Increase the sensitive area

- Sensitive area limited by the presence of supporting materials (more important in the ϕ direction)
- To increase the sensitive area we need to reduce the width of the framing and supporting structure

Standard solution: GRP frame

- Well established techniques
- Frame width of ~ 1 cm to avoid the bending



One solution: GEM Stretching

- Tested on the Asian GEM modules
- No material in the ϕ direction
- No support inside the GEM surface: big sagging especially on the sides.
- Total dead area: ~ 44 cm²

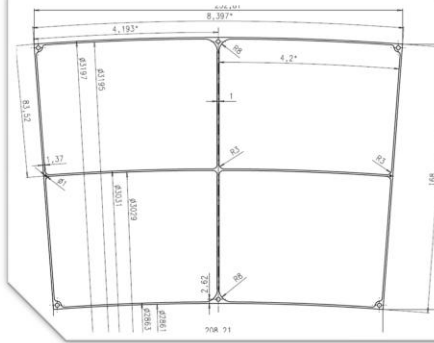
One of the most important features of our design is the GEM framing structure. Our goal in the development of this element of our project was to create a structure which can support and frame the GEM, increasing the sensitive area, reducing the dead space and the amount of material used and supporting as much of the GEM area as possible, keeping that flat and stable

The standard solution for this kind of frames is a wide fiberglass frame outside the GEM area with thin spacers in the middle of the GEM area (see COMPASS experiment)

Another solution has been devised by the Asian GEM group I mentioned earlier and it consists in stretching the GEM on the top and bottom sides only leaving everything else unsupported



GEM Framing: Our Solution



Full frame system

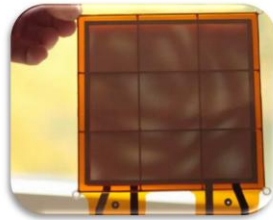
- GEM supported on all sides and from the inside
- To increase the sensitive area we need to reduce the width of the framing and supporting structure

Solution: Ceramic frames

- To meet both requirements we need an insulating material which can be made thinner remaining as resistant as normal GRP frame
- Alumina Ceramics is almost 4 times stiffer than GRP

Previous studies

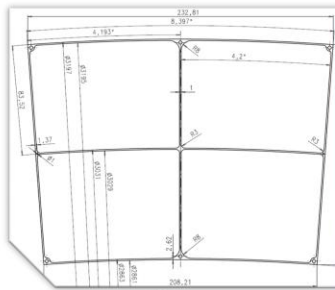
- We already tested at DESY standard GEM foil framed with ceramic grids
- We compared the profile of the GEM foils with GRP and ceramic framing
- This study is being finalized



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Our solution is an evolution of the fiberglass framing. Our supporting structure frames the module on the outside but also features spacer-like structures on the inside. To reduce the width of the framing structure we decided to use a material stronger than fiberglass, thus we choose ceramics. The Alumina Ceramics we choose is 4 times stiffer than the GRP which allows for a consistent reduction on the amount of material necessary to support the GEM. This solution has already been tested on standard 10X10 GEM and proved successful, now we are trying to use the data we acquired to develop a bigger frame for the LP module



Dimensions

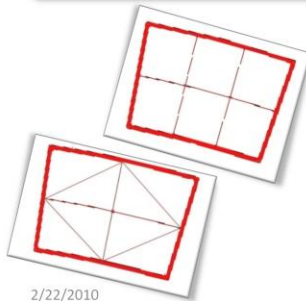
- 1.0 mm substrate thickness
- 1.0 mm widths of the frame beams
- As big as the module itself (~22 x 17 cm)
- Dead material surface: ~10 cm²

Fixing and align the frame

- 2 dowel holes for alignment
- 6 screwholes for fixing with nylon screws

Internal Grid Pattern

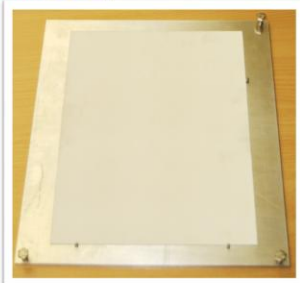
- We evaluated many different patterns
- We choose a simple cross-like structure
- We can test the effect of both vertical and horizontal bars on the detector efficiency
- Other grid pattern will be tested later



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The frame we are designing is as big as the module itself, with a substrate thickness of 1 mm and the frame beams, both the horizontal and vertical ones 1 mm wide. To align and fix the structure to the module we included 2 dowel holes and 6 screwholes where we are going to fit nylon screws. With this system we will avoid glueing the pieces which is of great importance in the test phase where you would like to exchange parts or replace pieces which are damaged during operations. At this moment we are focussing on a simple grid like pattern where we can test the effect of both the horizontal and vertical beams.



Raw Alumina Tiles

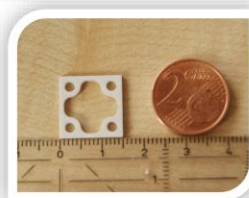
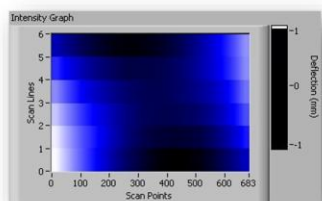
- 450 pieces where ordered and delivered
- Each tile is 272 x 200 cm

Survey of the Raw tiles

- Flatness measurement
- The deflection from a flat surface vary between 300 μm and 2 mm

Laser Cutting

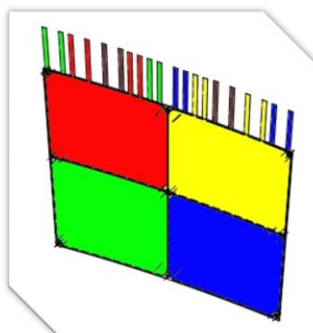
- The flattest tiles will be sent to a firm specialized in laser cutting
- Tests on the cutting of this ceramic have already started



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To produce these frames we bought 450 raw tiles and, after a survey of the flatness we are going to laser cut them into the due shape



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Segmentation

- 4-fold segmentation on one side
- Each section $\sim 94 \text{ cm}^2$, like a standard CERN GEM
- Section gaps aligned with the frame grid patterns
- Gaps dimension chosen to match the grid size

Power supply

- Each GEM section has 4 power contacts (20 contacts in total)

Other Features

- Standard hole size, $70 \mu\text{m}$, and pitch, $140 \mu\text{m}$
- $50 \mu\text{m}$ kapton foil
- Chemical etching with standard double mask process
- Custom size to use all the available space in an endcap module

Production

- 5 GEM are in production to perform the first tests

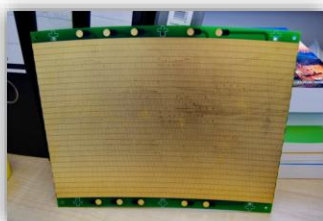
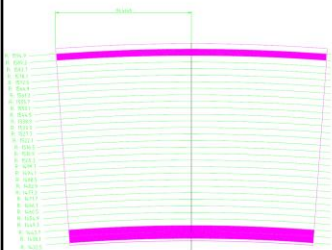
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The next step in the development of this module is the production of the GEM foil. This GEM foil has been customly designe, with 4 copper segment on one side to reduce the sparking risk and section gaps with the same shape of the ceramic frame to glue them together out of the sensitive area. Because we need to power up each of the GEM section from the pad plane side we need a total of 5 electrical contacts per GEM. But because we are going to stack 4 GEM over one another and we would like to use a single layout to build all the GEM we need a total of 20 contacts for each of the GEMs. Finally we want to save as much space as possible on the module sides so we could only place the electrical contacts on the upper and lower side. Of these we could only choose one, otherwise the contacts on two adjacent modules, which are only 1 mm apart, could touch each other or generate sparks. We choose the upper side because is the longer one.

At the moment we ordered 5 GEMs for production



Anode Readout Plane: Design



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In collaboration with Bonn University

- The design is still in his infancy

Pad size

- 1.26 x 5.85 mm
- 28 rows
- 4839 pads
- Row gap between row 14 and 15 aligned with the GEM segmentation gap

GEM Power supply

- Supplied from power pads 4 x 0.50 mm on the PCB itself
- Using the ceramic structure to separate the power from the readout pads

A spare pad plane to start

- The chinese colleagues of Tsinghua University kindly gave us a spare pad plane for the Asian GEM module that we are going to use for the first tests

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Finally we got to the Pad plane design.

This design is still in his infancy and it's done in collaboration with Bonn University.

The pad plane features almost 5000 channel, each connected to a pad 1.26 X 5.85 mm. We decided to create a small gap between row 14 and 15 aligned with the GEM segmentation gap.

To start our measurement in the meantime our colleagues of Tsinghua university have kindly given us one of their spare modules to mount our equipment



Conclusion



What has been done

- Studied the ceramic framing on small GEMs
- The GEM and the frame design are complete and the devices are in production
- The anode pad plane has been conceptually designed, the finalization of the design is ongoing

What is to do

- By mid-March we want to start the cutting of the Ceramic Frames
- By mid-April we may have our GEM
- Following we want to adapt one of the spare pad plane of the Asian GEM module to mount our modules
- In the next months we will also proceed developing and producing our own dedicated pad plane

Finally we can start measuring

- Maybe at the end of the spring (with a collective finger crossing)

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To conclude this presentation I want to summarize what have been done, and what is yet to do