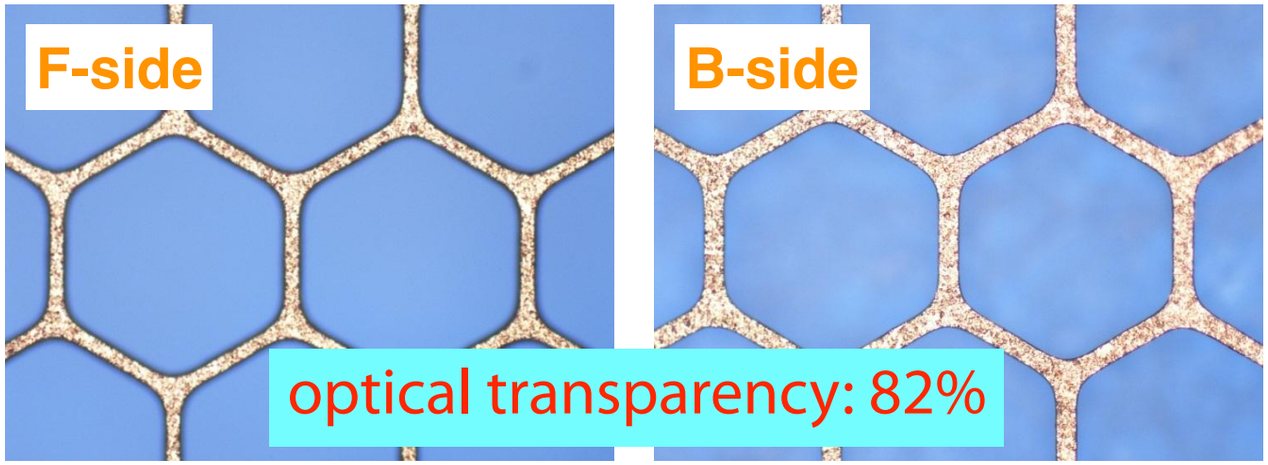
Short report on framing/ assembly tests of LP1 module-sized large-aperture Gate-GEM

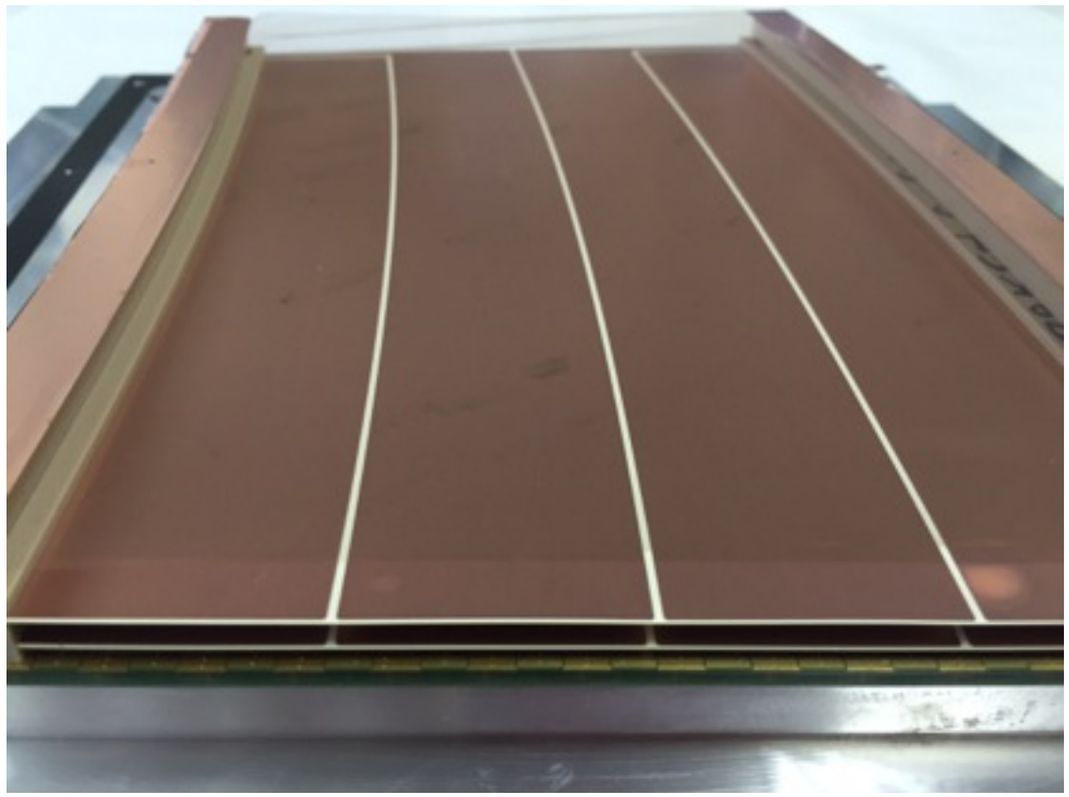
Katsumasa Ikematsu (Saga U.)

LCTPC WP meeting #227 (10 September, 2015)

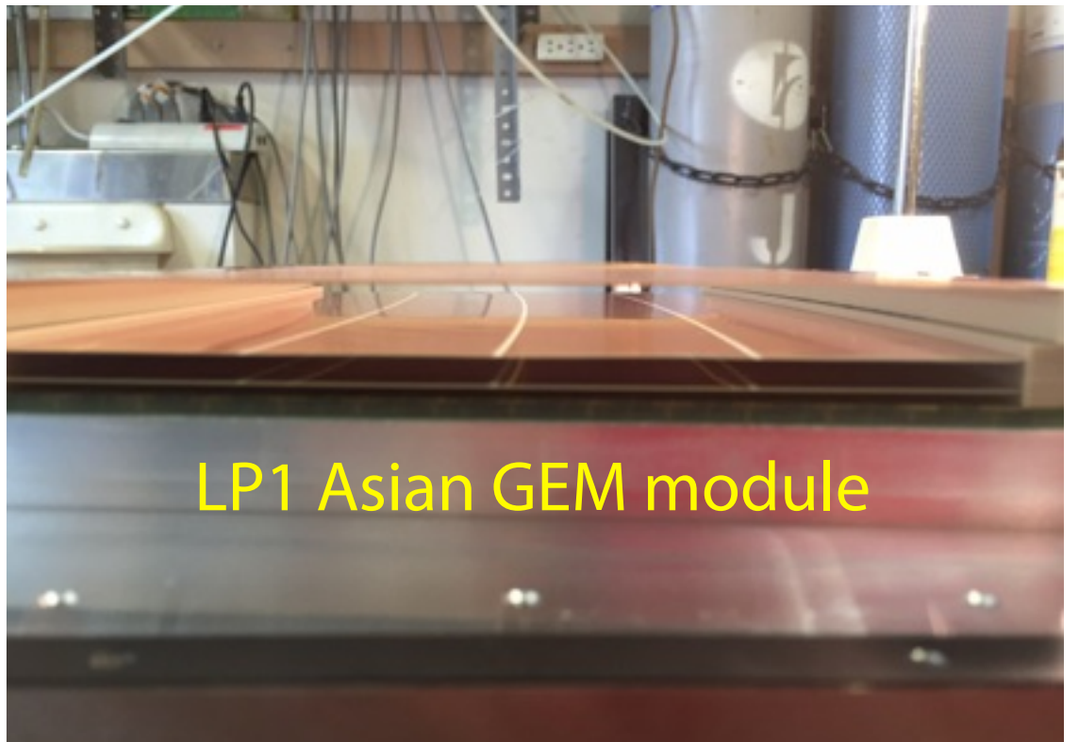
R&D highlight after ALCW2015



Large-aperture Gate-GEM
(Fujikura Type 4 - 17 x 22 cm^2)



mounted at 1cm above the 1st Amp-GEM



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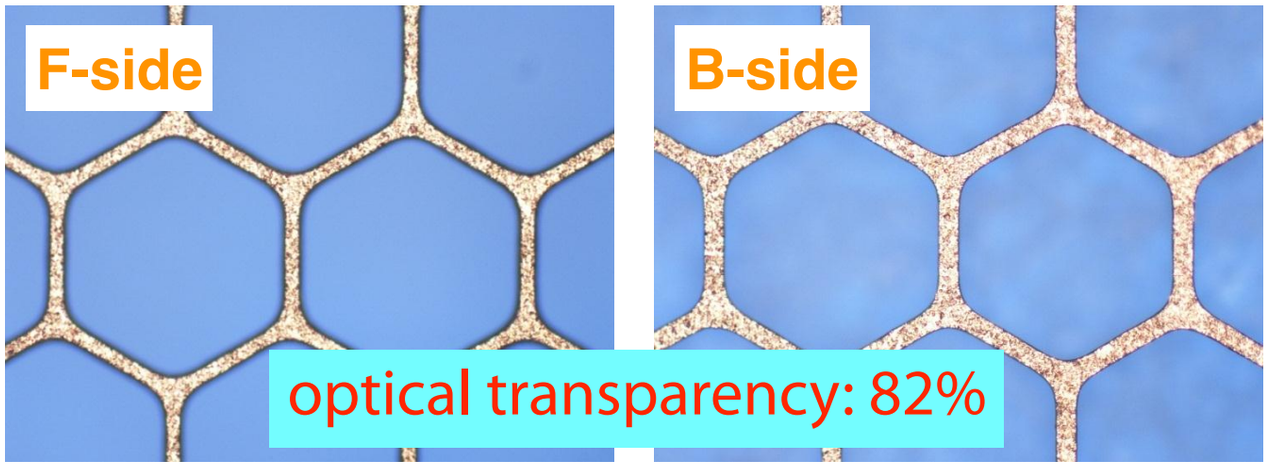
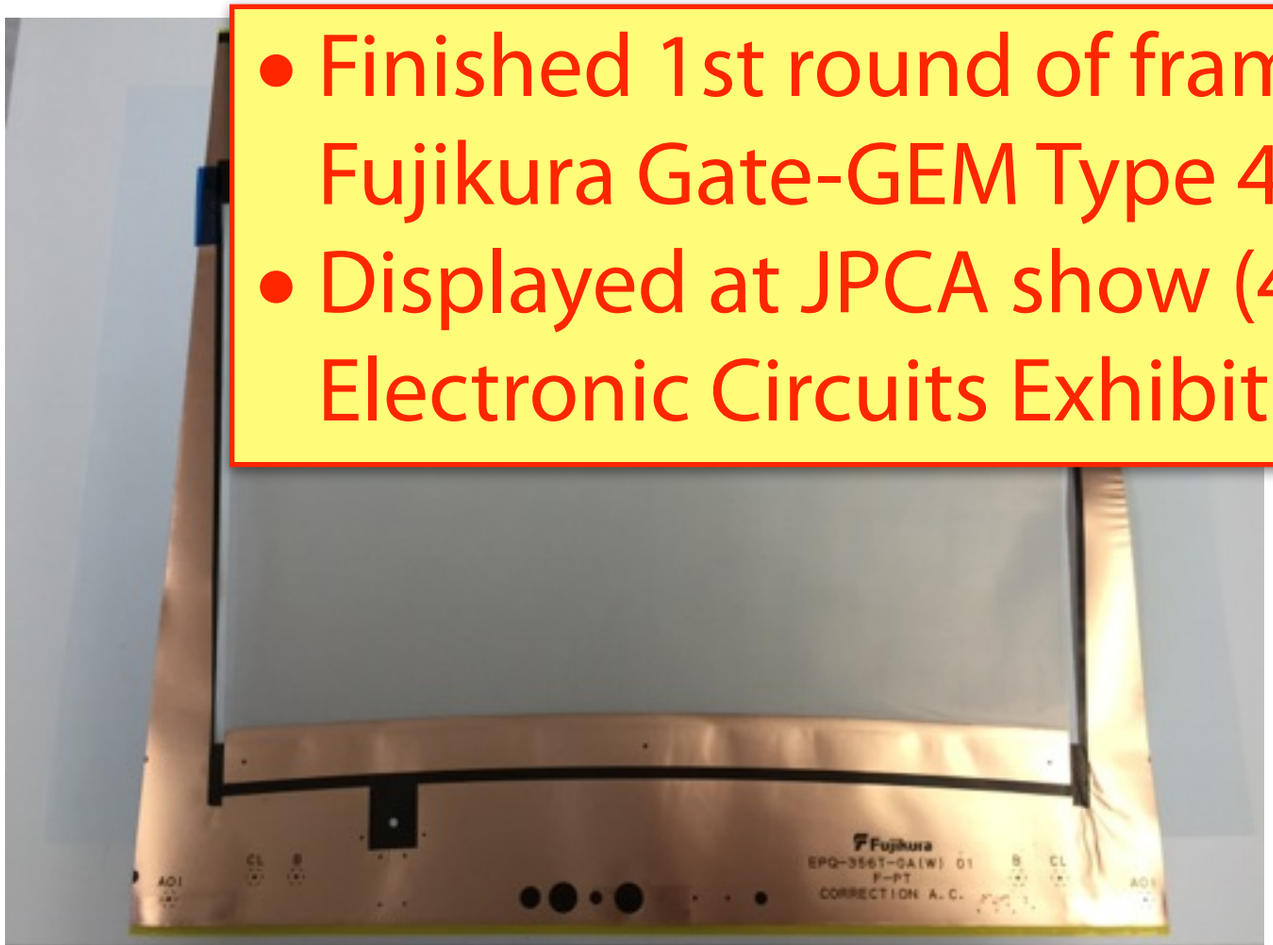


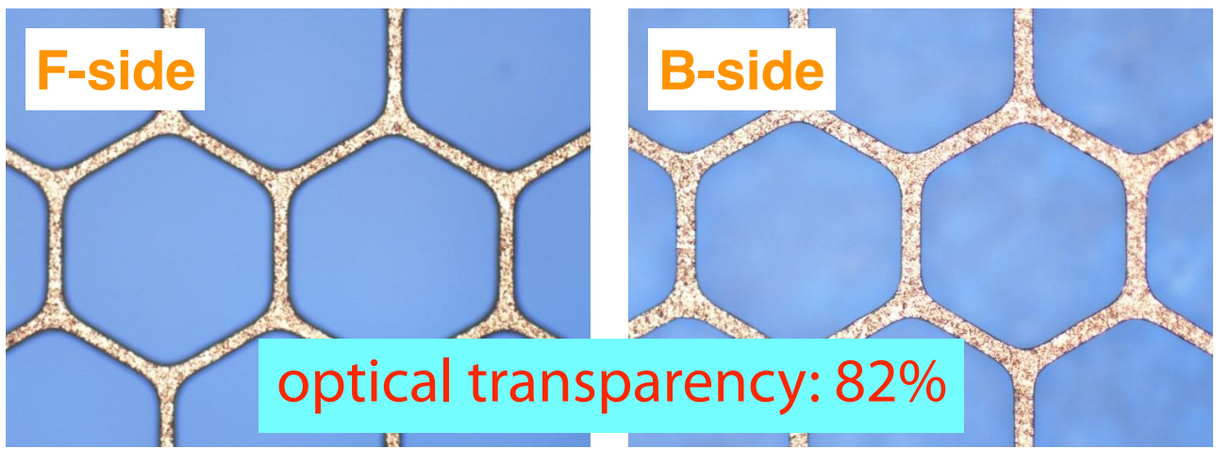
Large-aperture Gate-GEM
(Fujikura Type 4 - 17 x 22 cm^2)

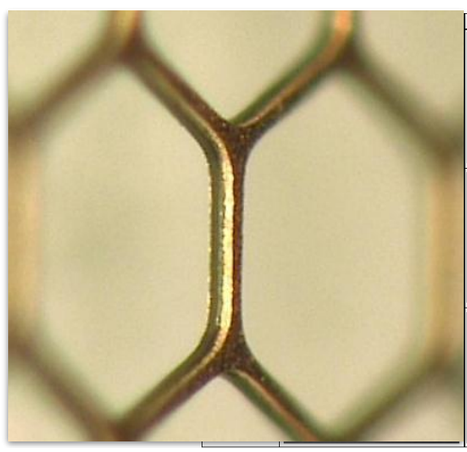
- Finished 1st round of framing/assembly tests for Fujikura Gate-GEM Type 4 (LP1 module sized)!
- Displayed at JPCA show (45th International Electronic Circuits Exhibition) in June

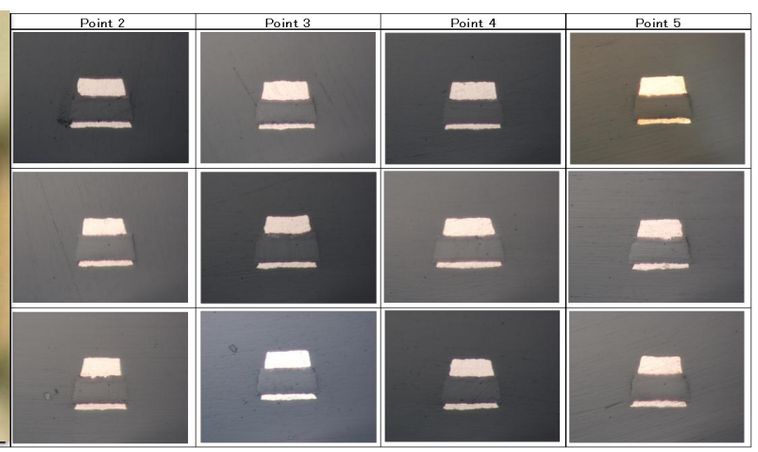


Large-aperture Gate-GEM sample

- **High optical transparency = Minimize rim width of GEM holes**
  - Gate-GEM should be satisfied that the insulator thickness is 12.5 μm, the hole diameter is less than 300 μm, and the aperture ratio is over 80 % in 17 x 22 cm^2 size.
  - structure of the foil is honeycomb, the electrode rim width should be under 35 μm.
- **Applied production technology of flexible printed circuits (FPC)**
  - adopt a process that forms the 30 μm circuits on one surface of a copper clad laminate firstly, then removes the polyimide by using the circuit as a mask, and the copper in through hole is removed by copper etchant at last.
  - employed UV-YAG laser which is low productivity, high machining accuracy, and good at a high taper angle.
  - challenge for mass production is the yield ratio which is not stable in the 17 x 22 cm^2 size due to the cleanliness in current process environment.

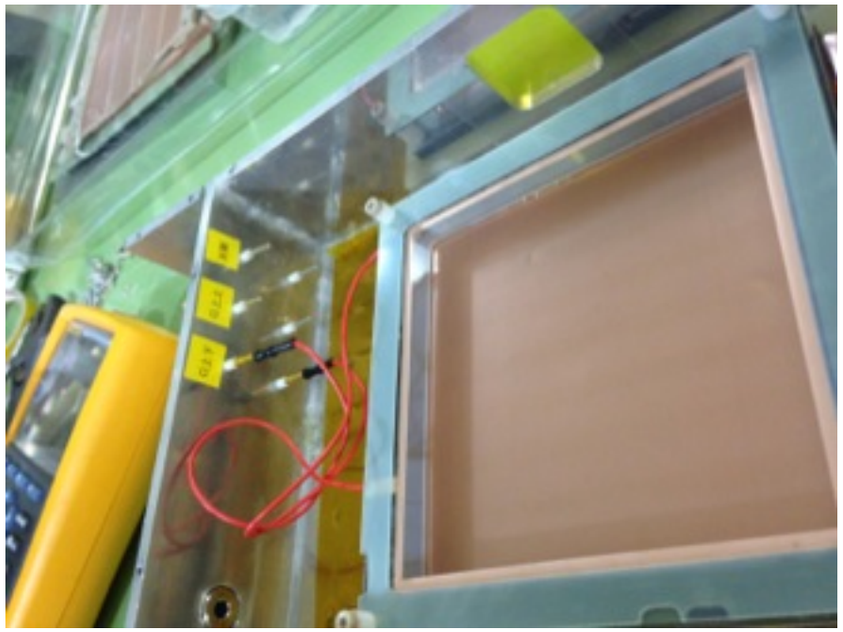




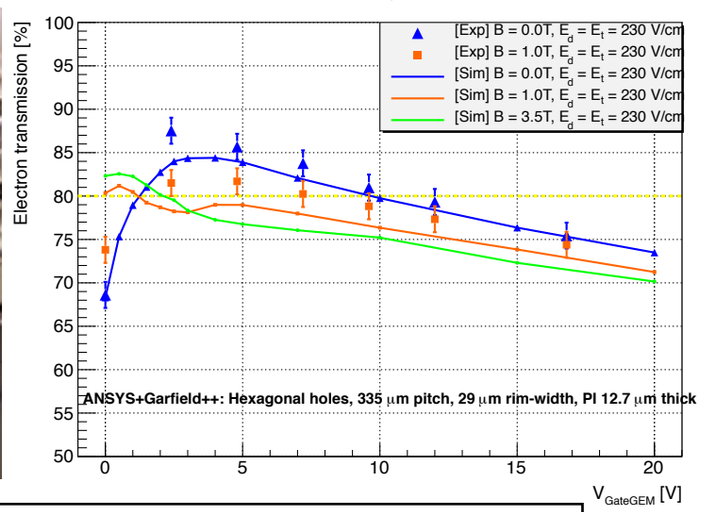


Toward module performance test

JFY2014: basic studies
done by 10 x 10 cm^2 sample

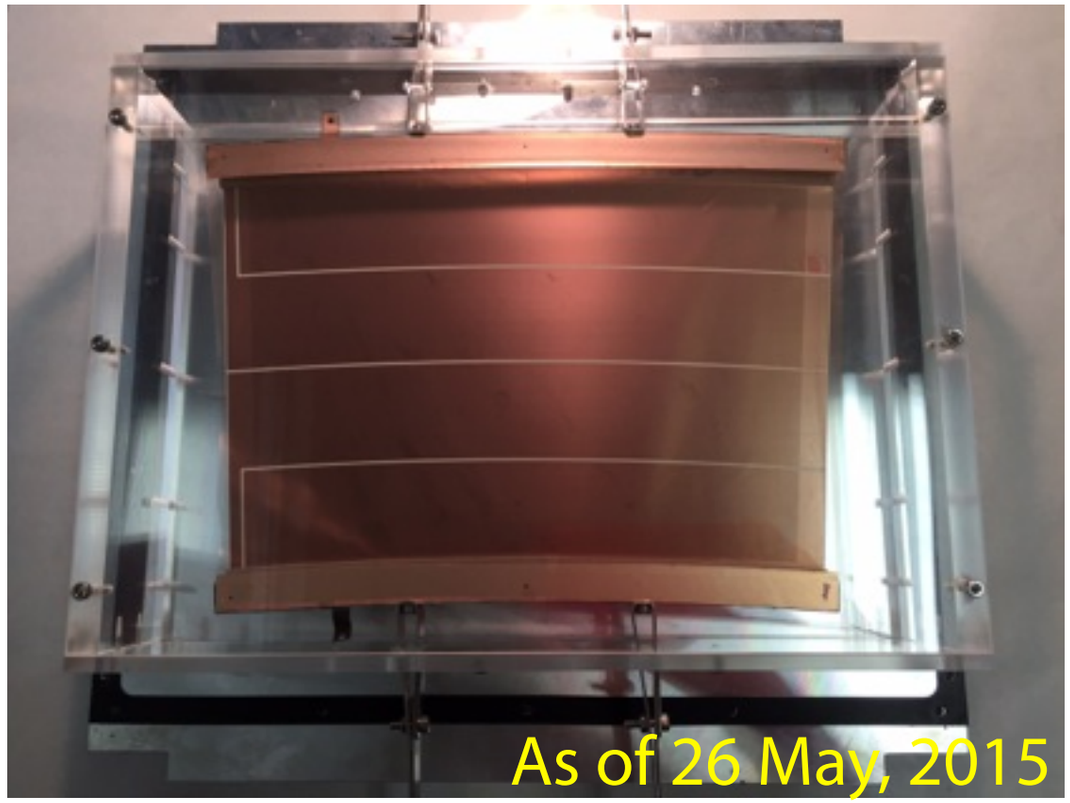


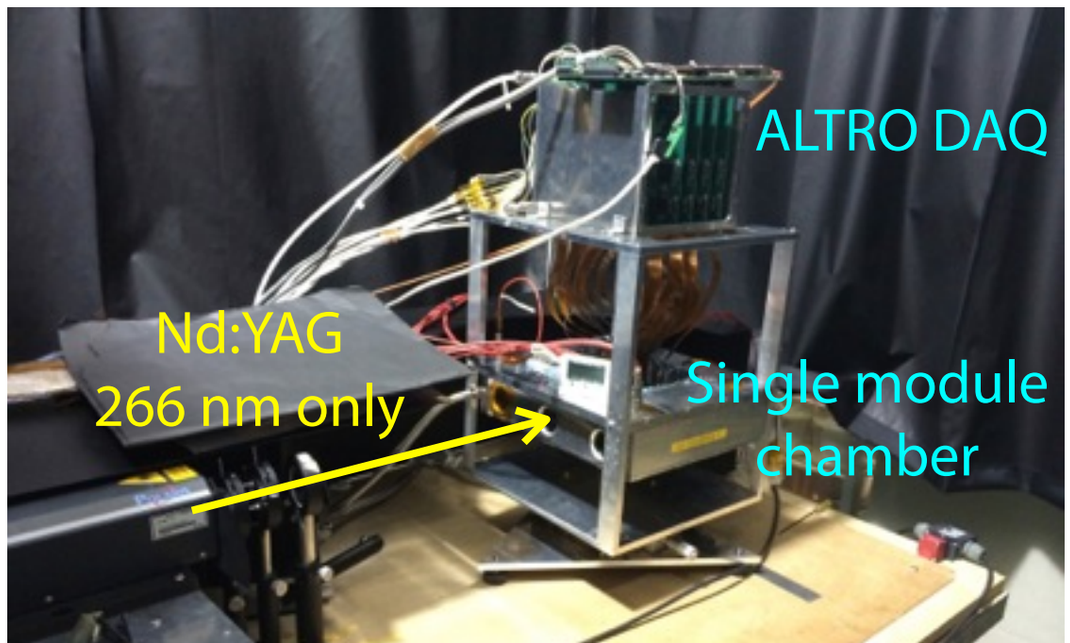
Exp vs Sim (Fujikura Type 3)



Evaluation of the measurement results by using the ANSYS-Garfield++ simulation was performed, and **extrapolation to 3.5 T shows acceptable 80% electron transmission** for the resolution requirement of ILD-TPC

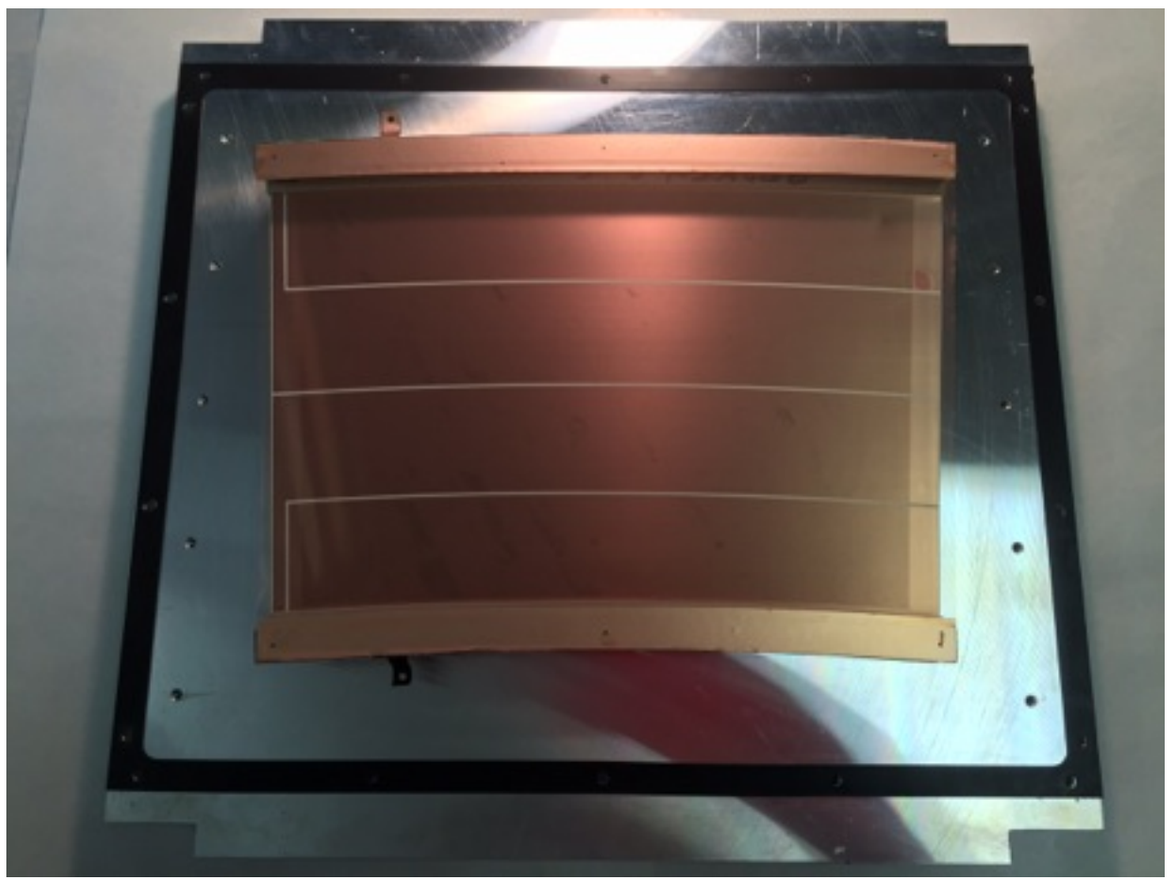
JFY2015: LP1 module
integration/engineering studies

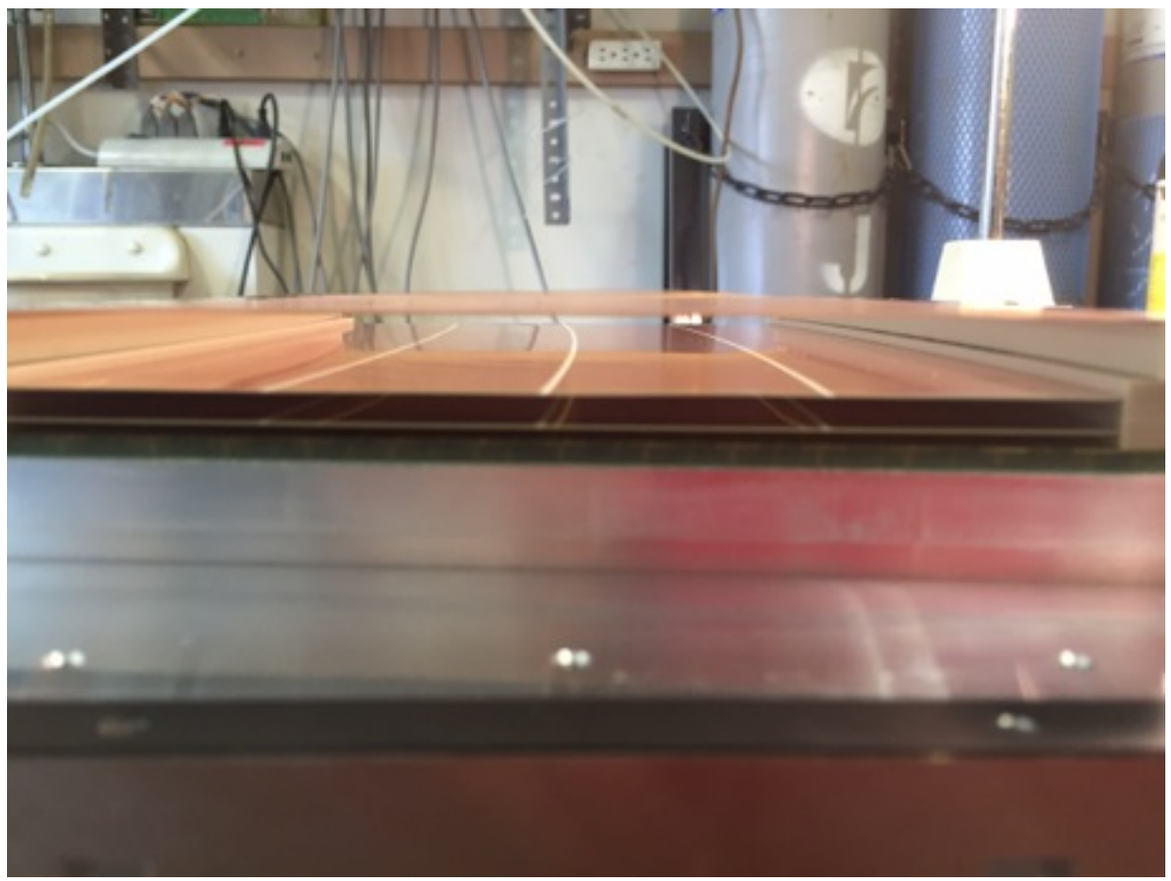




LP1 module w/ Gate-GEM for JPCA show

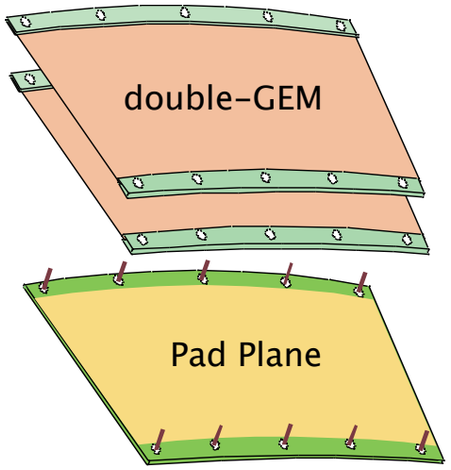
- **Finished 1st round of framing/assembly tests for Fujikura Gate-GEM Type 4 (LP1 module sized)**
  - 2 sheets of 1st batch and 4 sheets of 2nd batch in hand at Saga
  - used 3 sheets for framing/assembly tests, then established mount/dismount scheme for very thin foils
  - need further study for stretching/gluing procedures (constraints for tests: number of PEEK frame!)
  - D. Arai and A. Koto (Fujikura Ltd.) visited Saga, then picked up one Asian LP1 module equipped with Fujikura Gate-GEM Type4 for the exhibition

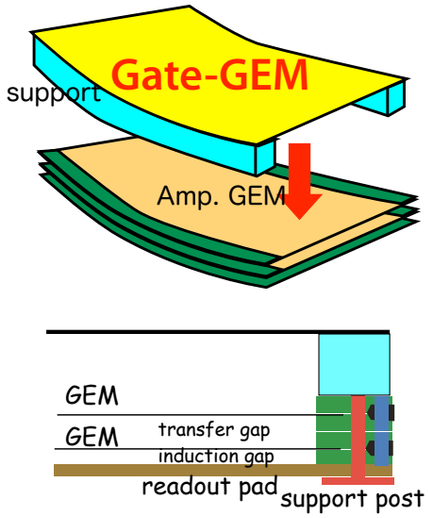


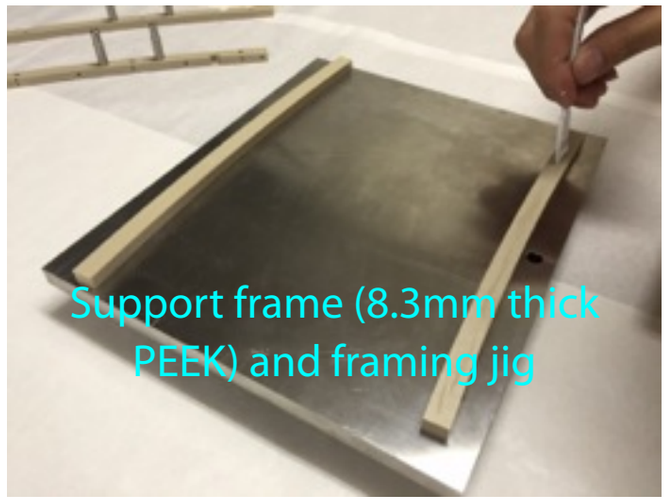


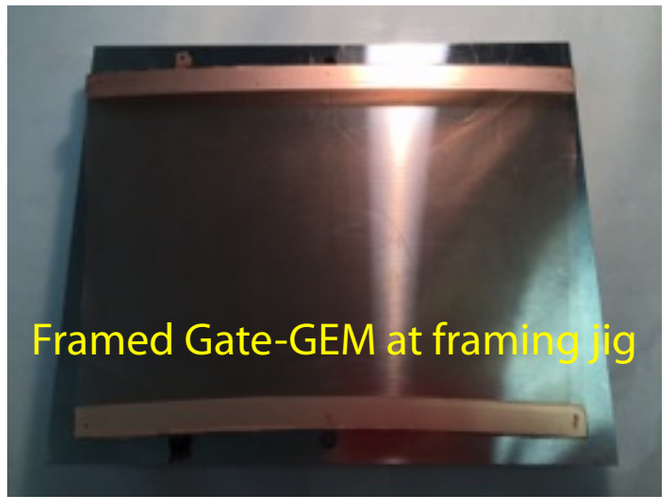
Framing/assembly tests for LP1 module Gate-GEM

PEEK Support Frame



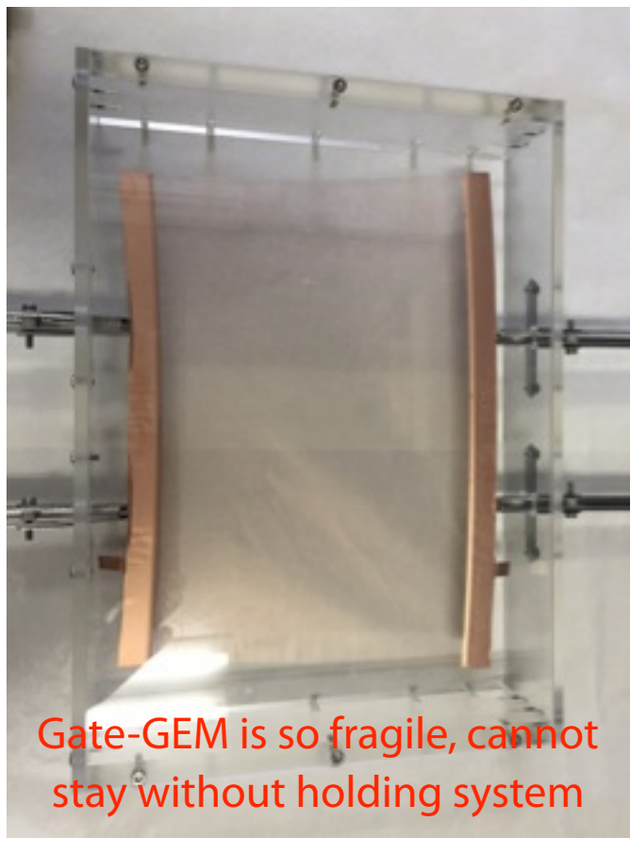


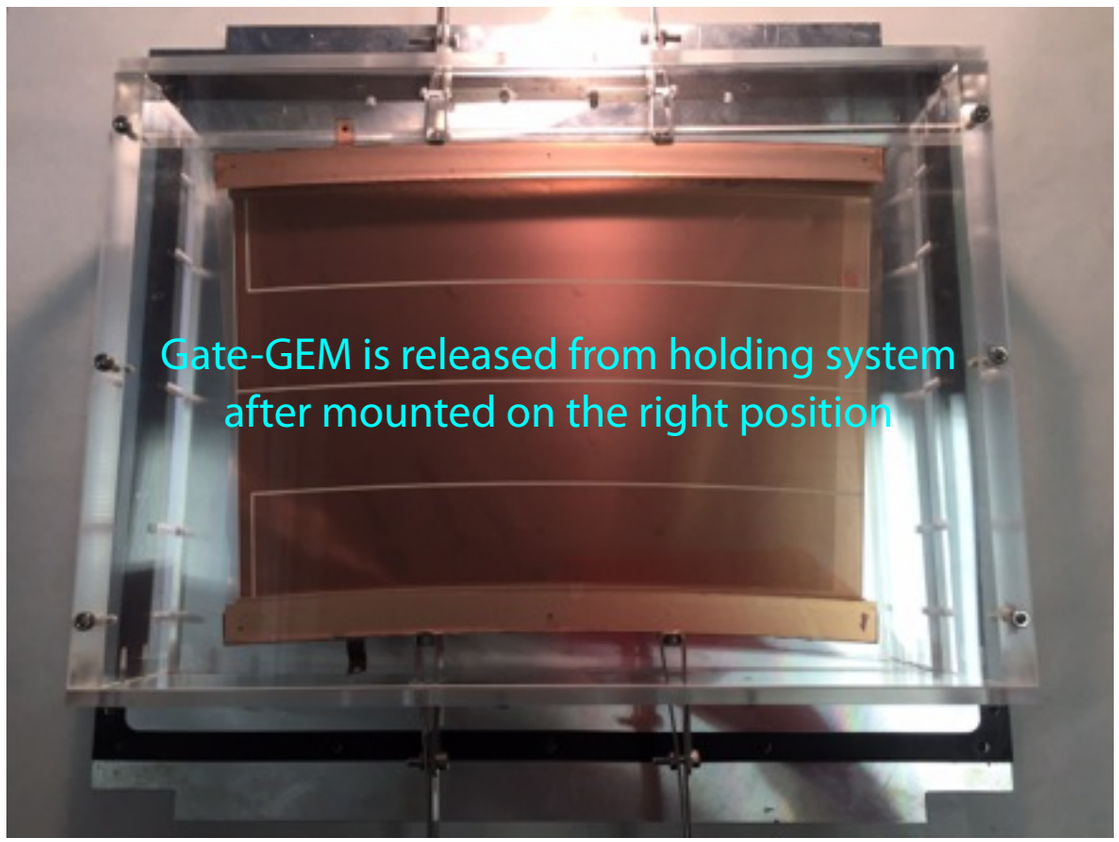




Optimized to reduce the insensitive area on the sides of the modules which point towards the detector center since particles from the interaction point flying between the modules may not be detected if they are very stiff

LP1 Asian module has no frame along the sides and extends the sensitive area up to the edge of the backframe!





LP1 module w/ Gate-GEM for JPCA show

- **JPCA show 2015 (45th International Electronic Circuits Exhibition)**
  - was held from 3 June to 5 June at East Exhibition Hall and Conference Tower, Tokyo Big Sight
  - Exhibition Theme: "Mount, Connect, Manufacture, and Expand"
  - objective is to contribute to the advancement of the electronic circuit industry and all related fields by presenting an exhibition of products, knowledge and solutions related to the electronic circuits and packaging technologies used in all electronic devices, IT devices and equipment, as well as the design, testing and logistics of large electronics (printed electronics, stretchable electronics, etc.).
  - Number of exhibitors : 676 (500), Number of booths: 1402 (1500) - () is expected number in 2015: Over 120,000 visitors! Qualified visitors from key business categories.
  - Asian LP1 module equipped with a large-aperture Gate-GEM (Fujikura Gate-GEM Type4) was displayed by Fujikura Ltd.

LP1 module w/ Gate-GEM at JPCA show

LP1 Asian module equipped with Fujikura Gate-GEM
Type 4 attracted much attention in the exhibition!

Since it attracted endless stream of visitors in the Fujikura Ltd.'s booth,
these pictures were taken at the end of 3 days exhibition.

Gate-GEM development will appear in a newspaper (Nikkan Kogyo Shimbun)

Schedule of LP1 module Gate-GEM study

- **Immediate goal: MPGD 2015 (The 4th International Conference on Micro-Pattern Gas Detectors): 12 - 15 October, 2015 at Trieste**

  - Should be shown single module performance results (electron transmission measurements by 55Fe under 0T, point resolution measurements by UV-laser, comparison with ANSYS/Garfield++ simulation study etc.)

- **Toward MPGD 2015**

  - 1st round of framing/assembly tests at Saga: done
  - JPCA show 2015 (3 - 5 June): done
  - MPGD 2015 abstract submission by both Katsumasa and Daisuke: deadline 14 June: done
  - 1st working product delivery and framing/assembly: mid-August ==> end-September
  - Electron transmission measurement by 55Fe under 0T at Saga: postponed
  - Point resolution measurement by using UV-laser tracks under 0T at KEK Fuji B4: postponed
  - (JPS 2014 Autumn Meeting: 25 - 28 September at Osaka City Univ.)

Backup

Remaining Issues

Ion Gate: The most urgent issue

***We need a ion gate*:** To prevent the backflow of positive ions from the gas amplification region of the MPGD modules to the drift space of TPC. Distortions by the primary ions at ILC are still negligible.

***Options of ion gate*:**

GEM gate:

Mechanically most friendly to the current MPGD modules

A simulation has shown that the ion stopping power is sufficiently high → < 10**-4 at around 10V reversed biases
Need to confirm by measurements ; who can do this?
Electron transmission: Can be high with large optical opening
Under study; How far need to go; >80%?
Distortion due to the large GEM holes?
To be studied with a laser beam (and then in beam test)

Traditional wire gate:

Known to work with high electron transmission (LEP etc.),
Distortion due to the radial wires?
-> To be studied with a laser beam soon
Mechanical issues to mount on the MPGD module.

Wire mesh or grid:

A solution never have been tested.
High ion suppression with a accessible reverse voltage?
Mechanical issues to mount on the MPGD module.

Medium size Gate GEM of about the 80% optical transmission have been fabricated in Japan by two different fabrication processes. A measurement of the electron transmission has been measured for one type of the product. Next measurement scheduled in July.

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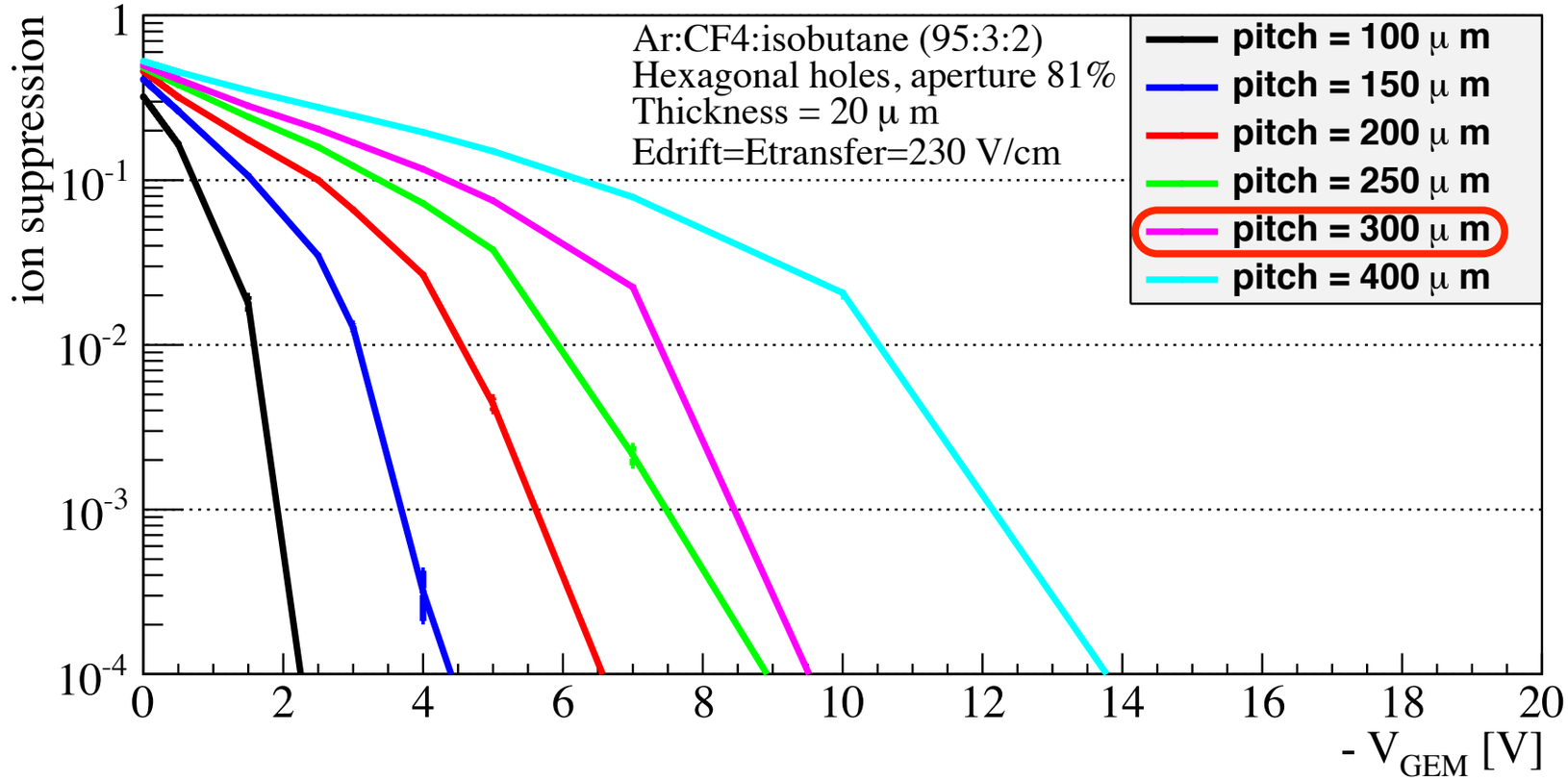

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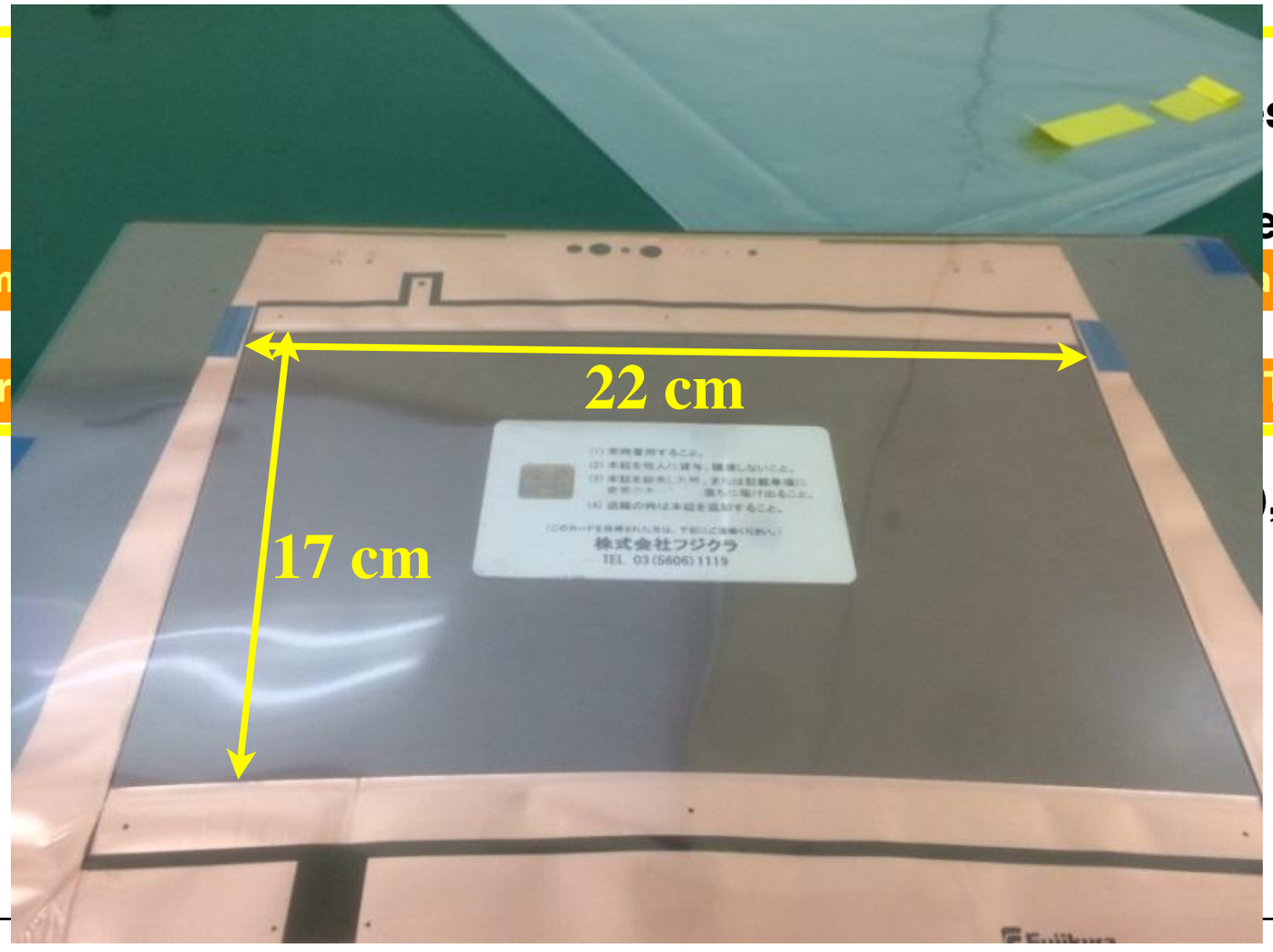

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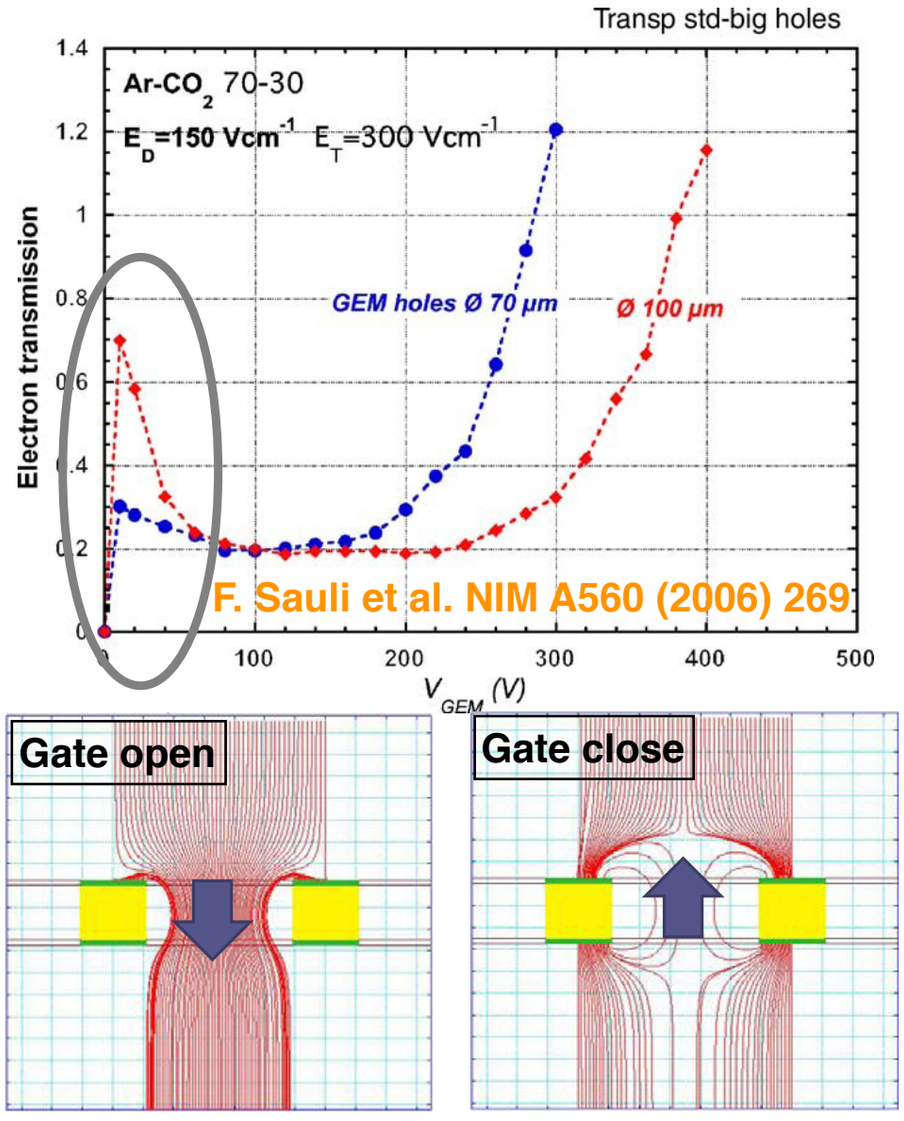
GEM as a gating device

- **GEM operated in low voltage mode**
  - Electron transmission film = without a function of gas amplification
  - Gate having a GEM-like structure (initially proposed by F. Sauli in 2006)
    - Gate-GEM can easily be used as a closed gate by reversing the electric field in GEM hole
  - GEM-gating device would be most adapted for the module structure of ILD-TPC!



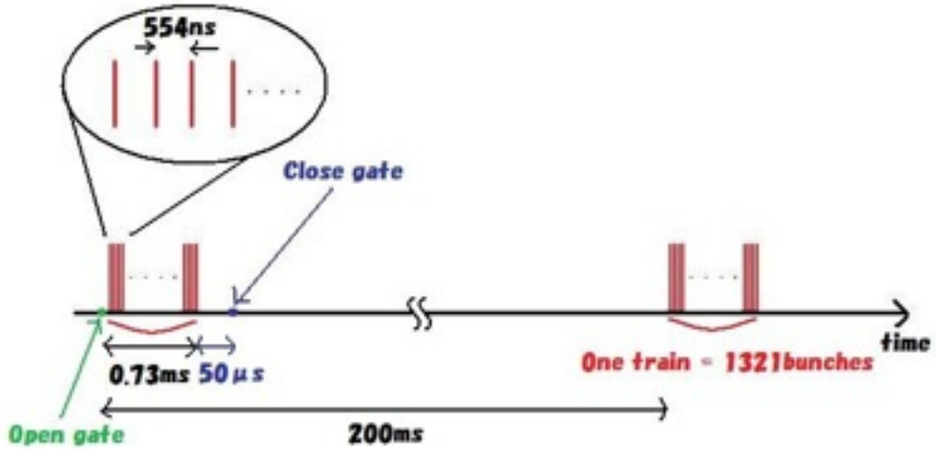
- **Requirement for Gate GEMs of ILD-TPC**
  - **Goal: 80% electron transmission** = corresponding the **deterioration in the spatial resolution ~O(10%)** for the ILD-TPC nominal electric field configuration
  - Operated in a 3.5 T axial magnetic field, and in a gas with a high mean free time (τ) of drift electrons between collisions with gas molecules => Motion of electrons is strongly restricted to the direction of the magnetic field => **high optical transparency of the gate is required** to ensure its high transmission rate of the electrons in the open state

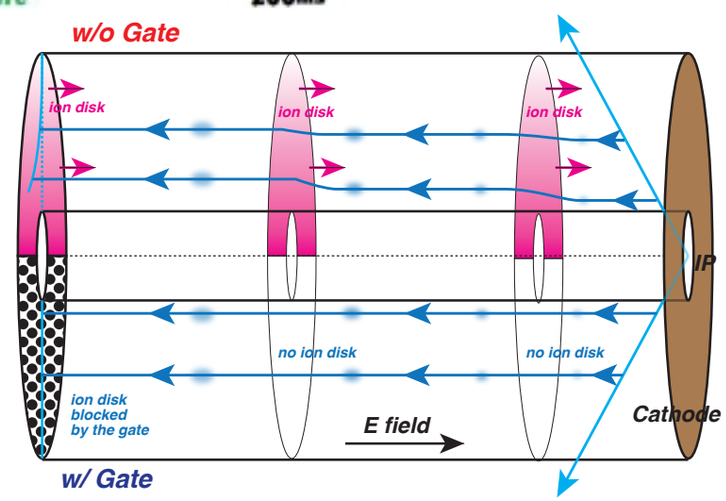
ordinary amplifying GEMs (e.g. CERN standard): not suitable because of their poor optical transparency

Positive ion feedback in ILD-TPC

High performance of tracking by the TPC relies strongly on the quality of the electric field in the drift volume!

- **Positive ions drifting back into the gas volume**
  - Well known issue for wire chambers based TPCs (traditional MWPCs)
  - Even though the amount of back drift ions is much smaller for MPGD amplification, still be significant with a high track density like ILC background conditions (e.g. ILC beam expected to produce large amount of beamstrahlung = e^+e^- pair background)
- **In the case of ILD-TPC**
  - Bunch-train structure of the ILC beam (one 1 ms train every 200 ms) => Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume
  - 3 discs co-exist and distorted the path of seed e^-
  - Simulations: a **gating system is required** to reach the tight momentum resolution requirements in the nominal running conditions of ILC
    - The ions have to be neutralised during the 200 ms period between the crossings





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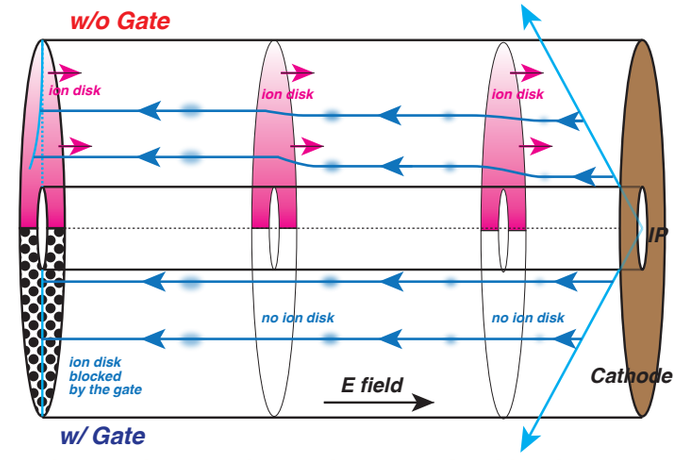
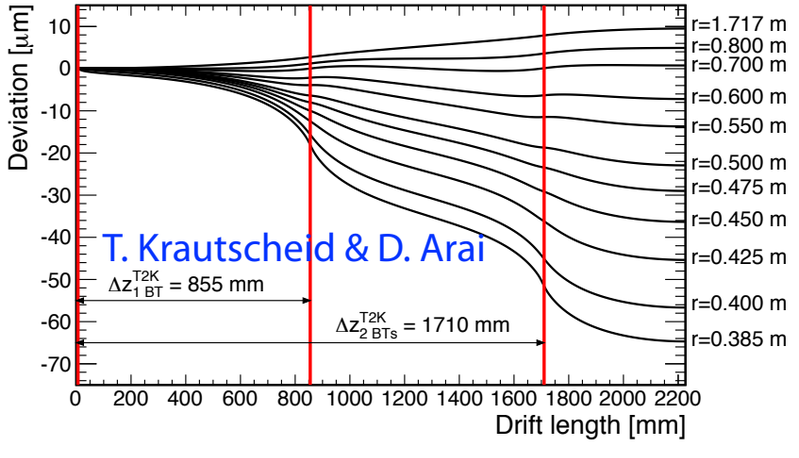
  - Bunch-train structure of the ILC beam (one 1 ms train every 200 ms) => Ions from the amplification will be concentrated in discs of about 1 cm thickness near the readout, and then drift back into the drift volume
  - 3 discs co-exist and distorted the path of seed e^-
  - Simulations: a **gating system is required** to reach the tight momentum resolution requirements in the nominal running conditions of ILC
    - The ions have to be neutralised during the 200 ms period between the crossings



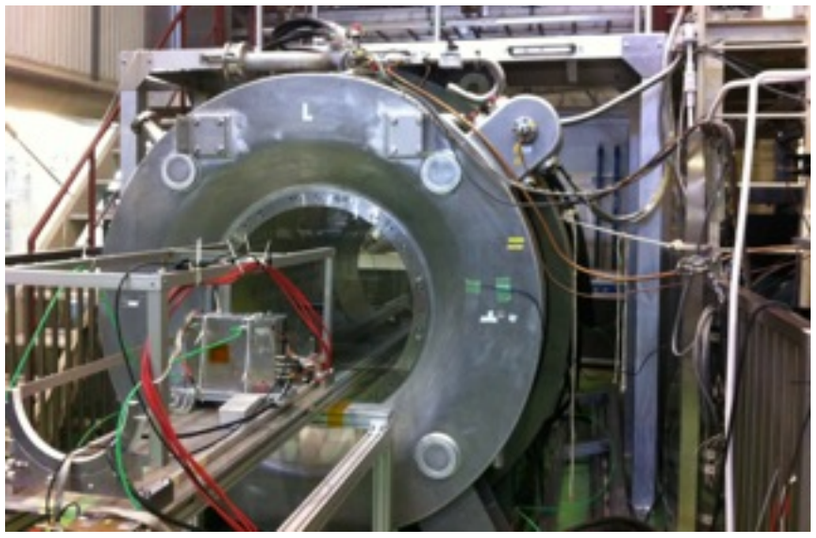
Charge density depends on ion feed back ratio!

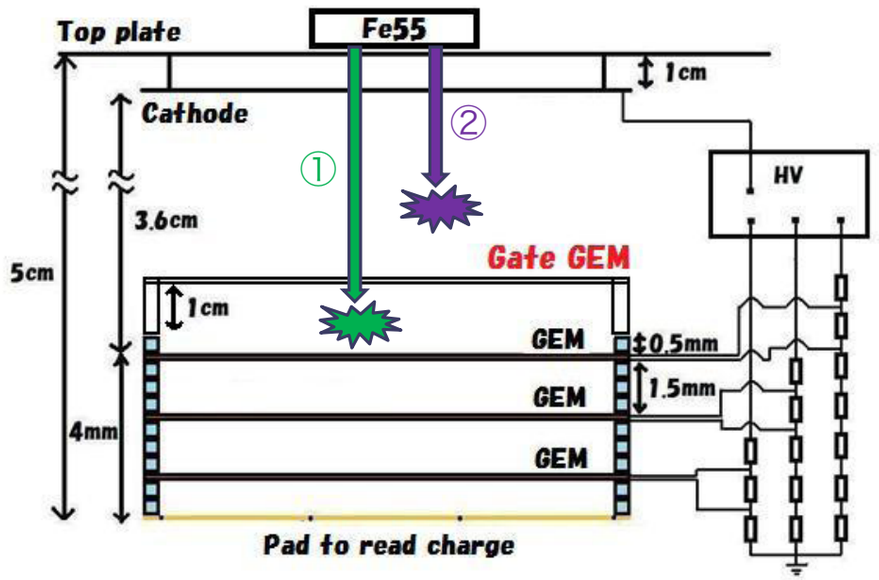


Electron transmission measurement

Motion of electrons is strongly restricted to the direction of the magnetic field => need measurements under high magnetic field!

- **Measurement method**
  - by comparing **signal charge passing through the Gate-GEM** to **signal without Gate-GEM** using a small test chamber irradiated with an ^{55}Fe source, which is installed in a 1 T MRI type super-conducting solenoid at KEK cryo center





using a CERN standard GEM readout (triple stack) and one of Fujikura Gate-GEM samples placed 10 mm above

- **Case (2)**: the conversion happens in the drift region, so that the produced electrons have to pass the gate and the signal is affected by the gate transmission
- **Case (1)**: a small portion of the X-rays are converted in the region between the gate and the amplification GEM, which produces signal without any effect of the gate
- **Electron transmission**: calculated as the ratio of the two signals