# Development of a TGEM-TPC for the J-PARC E15 experiment

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**A Time Projection Chamber (TPC) with Thick Gas Electron Multipliers (TGEMs) has been developed for an inner tracker of the J-PARC E15 experiment, a deeply-bound kaonic nuclear states search. A TGEM is used for the amplification of the TPC in order to realize a self-supporting structure in a limited space.**

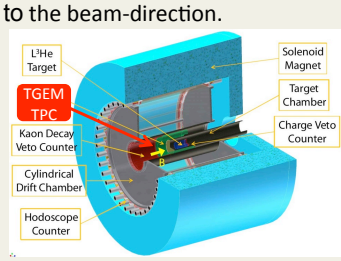
## Requirements for the Detector

The E15 experiment aims to search for a deeply-bound Kaonic nuclear state $K^-pp$ via the $p\Lambda$ decay mode. Recently, theoretical progresses on the $K^-pp$ cluster indicate the importance of another decay mode, i.e., $p\pi\Sigma$. In order to realize an efficient measurement of the decay mode $K^-pp \rightarrow p\pi\Sigma$, we need to install a new vertex detector in our baseline detector system. The requirements of the new detector system are as follows:

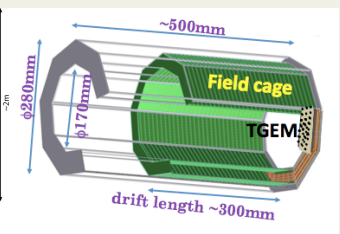
- spatial resolution in beam-direction < 1 mm
- low material budget in the detector acceptance
- smallness & compactness

## Design of the Detector

We chose the Time Projection Chamber (TPC) as the technology for the innermost tracking detector. A drift-direction of the TPC is parallel to the beam-direction.




**TPC install position**




**TPC design**

- multilayer TGEM structure for amplification
- pad size : 20 mm x 4 mm / # of pad : 144 ch
- Double-sided Flexible PCB for field strip [8 mm strip / 10 mm pitch]
- gas : P10 at 1 atm

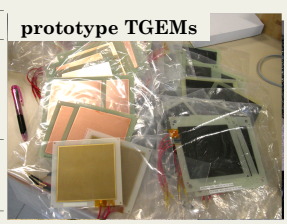
## TGEM Development

In order to realize the compactness and robustness of the detector, we selected, a Thick Gas Electron Multiplier (TGEM), for the signal amplification, stage of the TPC. We studied the performance of the TGEM using 13 types of prototype TGEMs, with an active area of 10 × 10 cm²; these TGEMs were produced by REPIC Corp., Japan.

**geometrical parameters of TGEMs.**

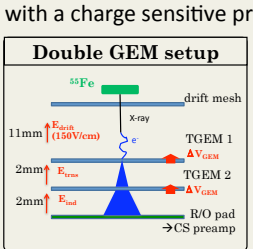
| TGEM# | electrode | insulator (mm) | thickness (mm) | hole diameter (mm) | pitch (mm) | rim size (mm) |
|---|---|---|---|---|---|---|
| 1 | Cu | FR4 | 0.2 | 300 | 0.6 | 0.05 |
| 2 | Cu | FR4 | 0.2 | 500 | 0.6 | - |
| 3 | Cu | FR4 | 0.4 | 300 | 0.6 | - |
| 4 | Cu | FR4 | 0.4 | 300 | 0.6 | 0.03 |
| 5 | Cu | FR4 | 0.4 | 300 | 0.6 | 0.05 |
| 6 | Cu | FR4 | 0.4 | 300 | 0.7 | 0.1 |
| 7 | Cu | FR4 | 0.4 | 500 | 0.6 | - |
| 8 | C | FR4 | 0.4 | 300 | 0.7 | - |
| 9 | C | FR4 | 0.4 | 300 | 0.6 | - |
| 10 | C | G10 | 0.4 | 300 | 0.6 | - |
| 11 | C | CEM3 | 0.4 | 300 | 0.6 | - |
| 12 | C | FR4 | 0.6 | 300 | 0.7 | - |
| 13 | C/Cu | FR4 | 0.4 | 300 | 0.6 | - |

**prototype TGEMs**

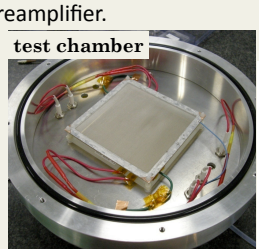


Basic performance studies were carried out with a double-TGEM configuration using a test bench that consisted of a gas chamber housing, a voltage divider with a resistor chain, and a read out pad with a charge sensitive preamplifier.

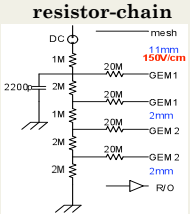
**Double GEM setup**



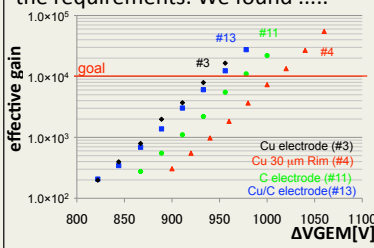

**test chamber**



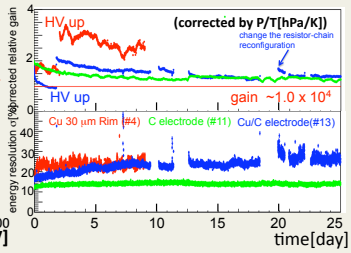
**resistor-chain**




Effective gain is required to be more than $10^4$ , and the stability of the gain with, for stable operation of the TPC, energy resolution should be within 10% per day. we found the carbon-electrode TGEM(#11) satisfied the requirements. We found .....




**effective gain of double TGEM**

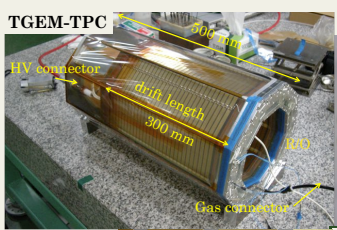



**long term stability**

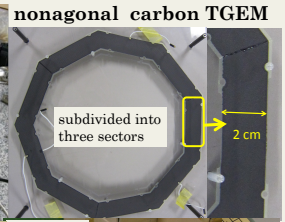
## TGEM-TPC

The TPC consists of an end-cap TGEM chamber which uses a double/ triple-TGEM structure and a field cage filled with P10 gas at atmospheric pressure. For the TPC front-end electronics, preamplifier cards ASD ASICs developed for the ATLAS experiment are used, i.e., we obtain only the beam-direction information from the TPC.

**TGEM-TPC**




**nonagonal carbon TGEM**

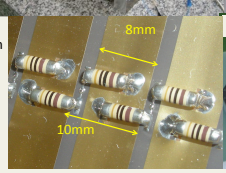



**field cage**

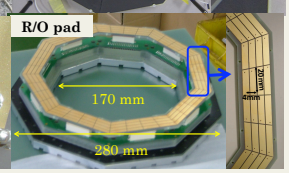
- $E_{drift}$ = 150 V/cm
- double sided
- Flexible PCB
- 8mm strip
- 10mm pitch

**Gas**

- P10
- flow = 1 atm

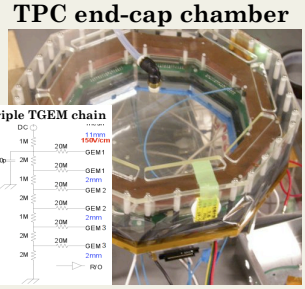



**R/O pad**

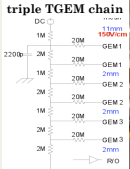


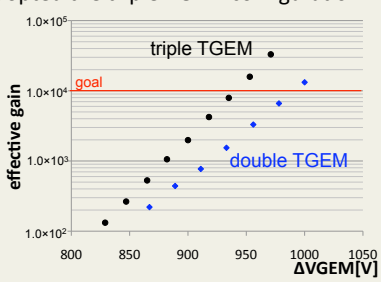

We have studied the performance of the amplification stage of the TPC. The gain of nonagonal carbon-TGEMs achieved more than $10^4$ both with double- and triple-TGEM configurations. In order to realize stable operation of the TPC, we have adopted the triple-TGEM configuration.

**TPC end-cap chamber**



**triple TGEM chain**




**effective gain of TGEM in TPC**

## Summary and Outlook

- We are developing a thick-GEM (TGEM) TPC.
- Several types of prototype TGEMs were studied, and we found a carbon-electrode TGEM satisfies the requirements for stable operation of the TGEM-TPC.
- Effective gain of $10^4$ is achieved with nonagonal TGEMs.
- In order to study the basic performances of the TPC, we are planning beam tests at SPring-8/LEPS in this autumn.