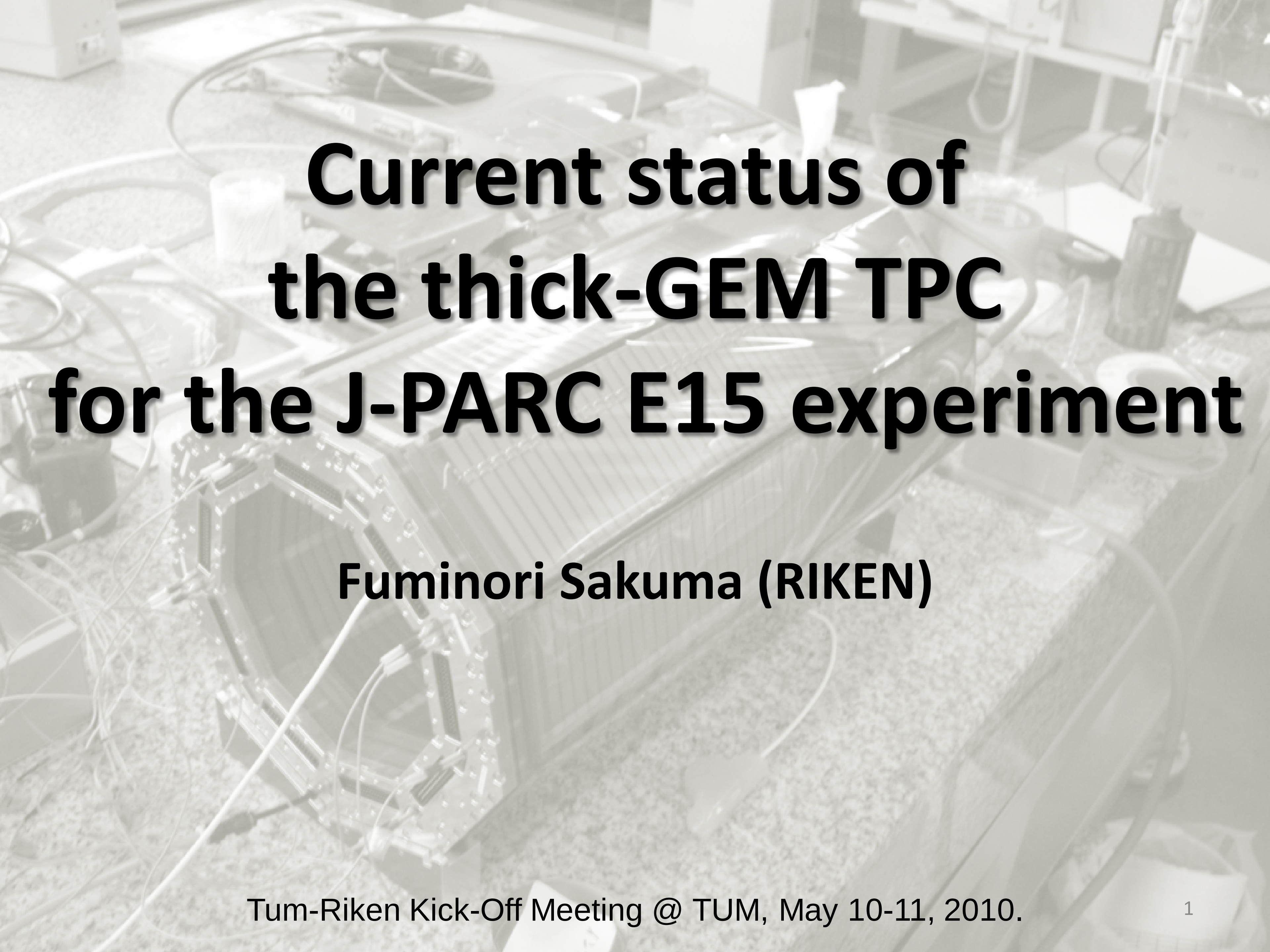


Current status of the thick-GEM TPC for the J-PARC E15 experiment

Fuminori Sakuma (RIKEN)

Tum-Riken Kick-Off Meeting @ TUM, May 10-11, 2010.

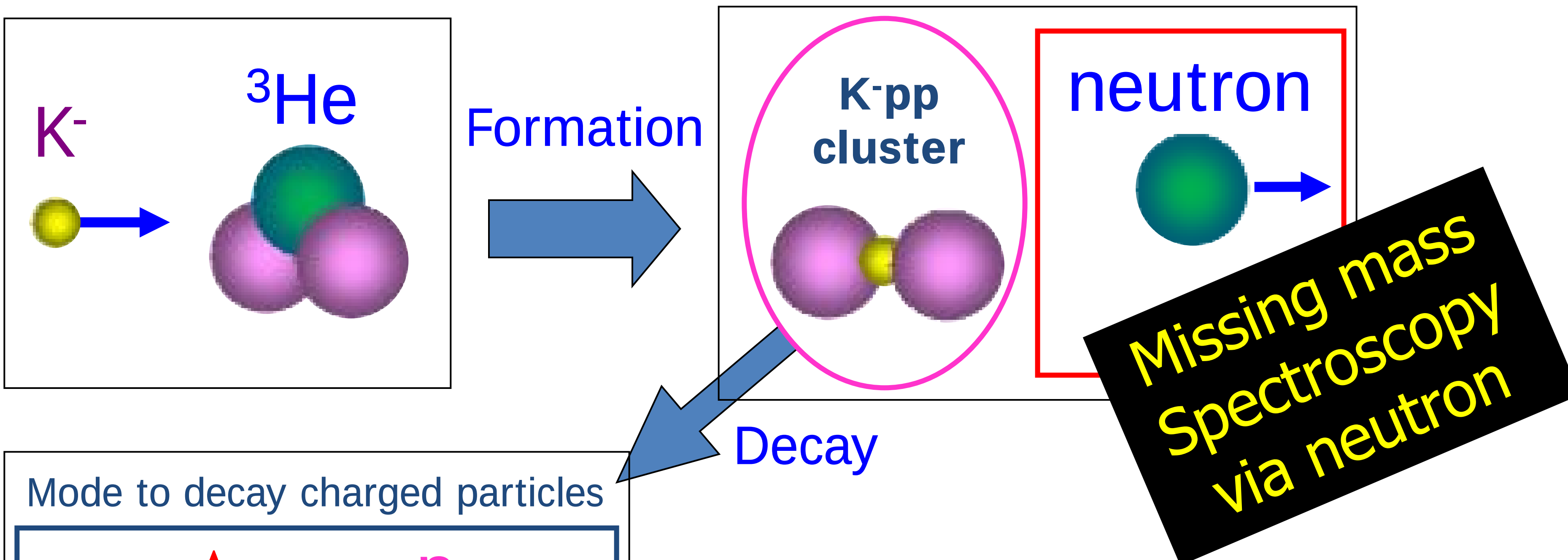
Contents

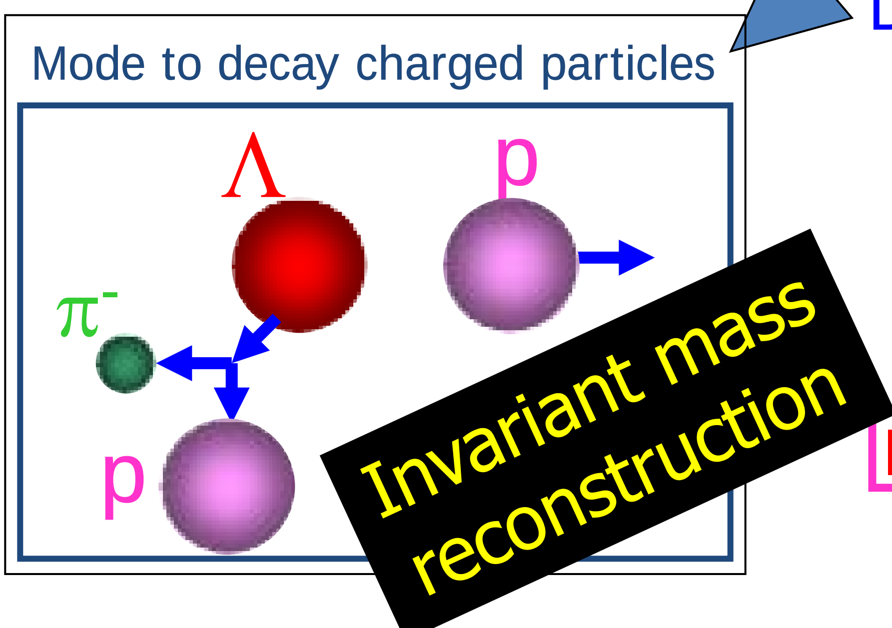
- Introduction
- TGEM-TPC for the J-PARC E15 exp.
- Thick GEM (TGEM)

  goal: gain ～10^4 with stable operation in P10 @ NTP
- Results of TGEMs in P10 @ NTP
  - Cu-electrode TGEMs
  - C-electrode TGEMs
  - C/Cu-electrode Hybrid TGEMs
- Summary

J-PARC E15 Experiment

search for K-pp bound state using $^3He(K^-,n)$ reaction





exclusive measurement by

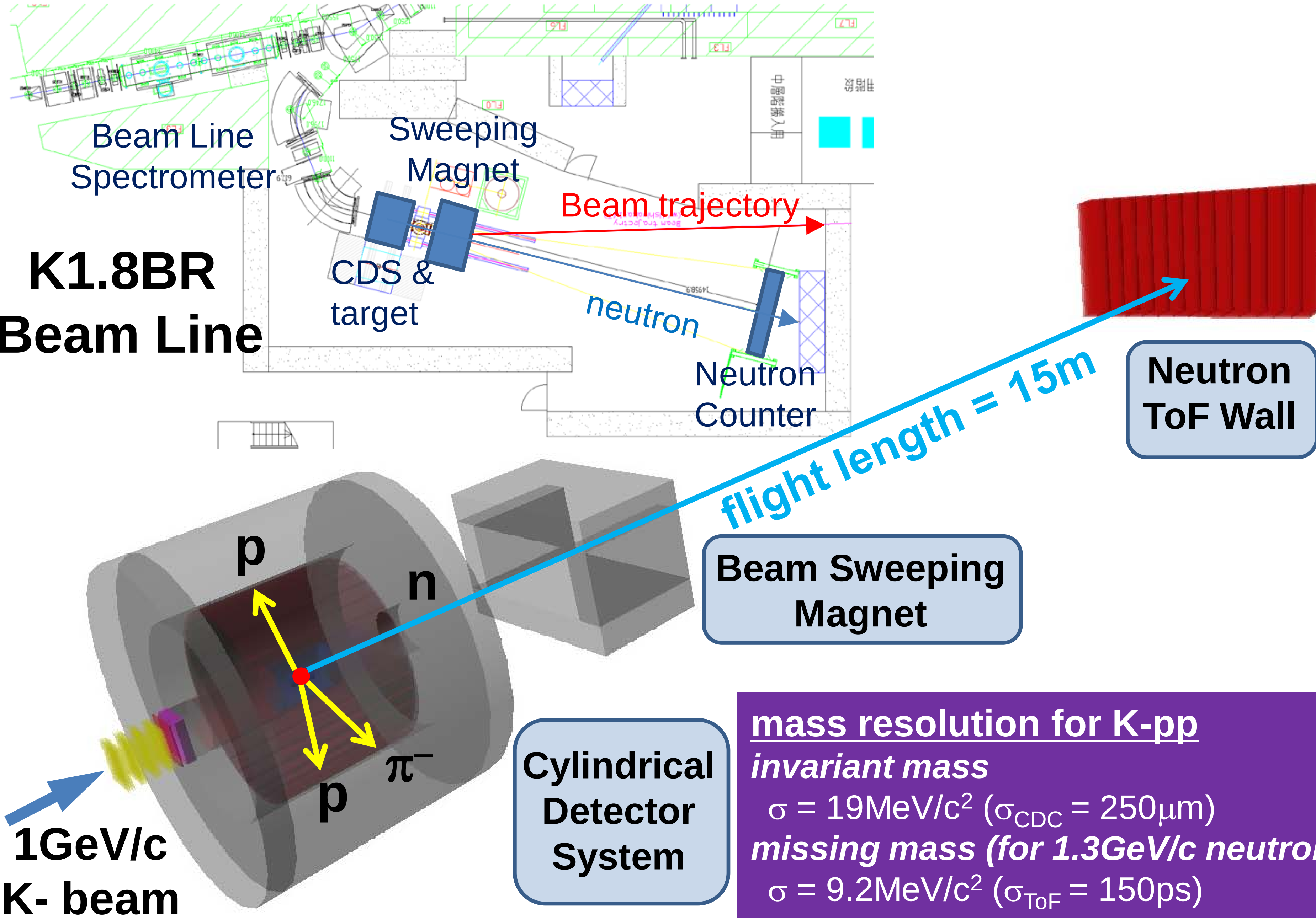
Missing mass spectroscopy

and

Invariant mass reconstruction

at J-PARC

J-PARC E15 Setup



mass resolution for K-pp

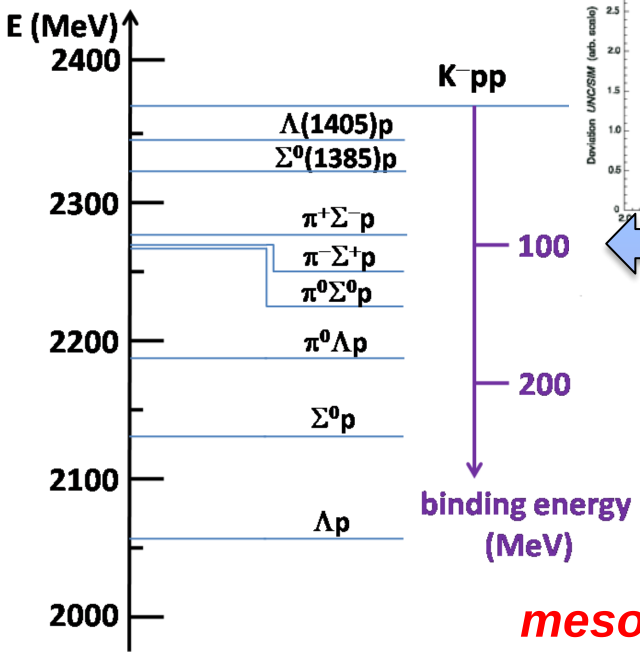
invariant mass

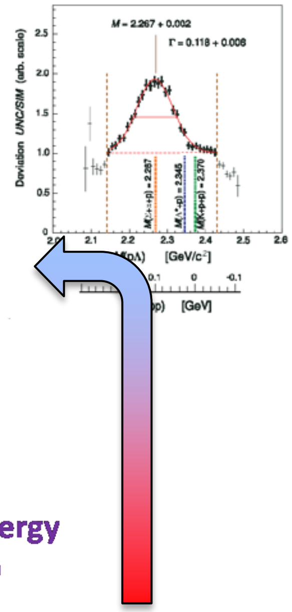
σ = 19MeV/c^2 (σ_{CDC} = 250μm)

missing mass (for 1.3GeV/c neutron)

σ = 9.2MeV/c^2 (σ_{ToF} = 150ps)

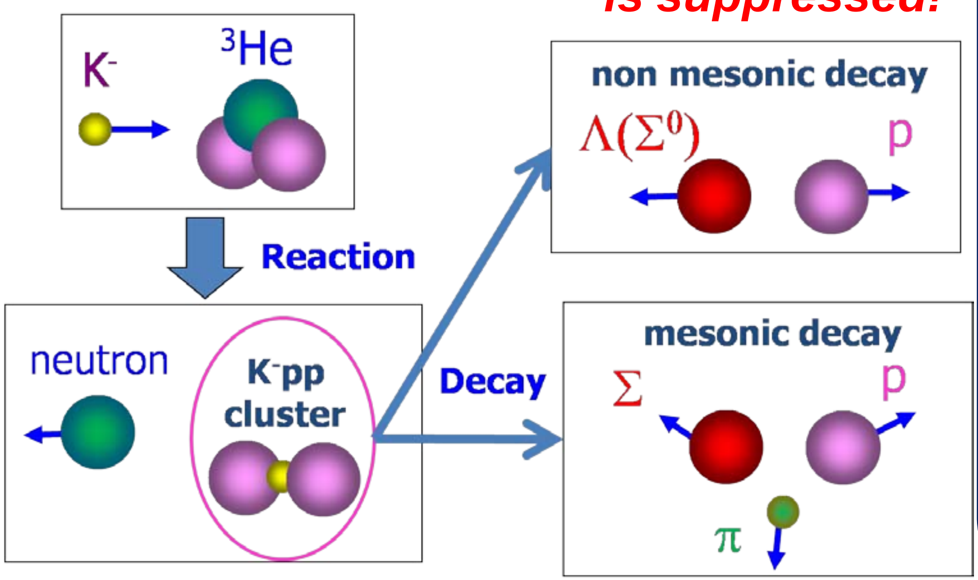
measurement of mesonic decay-mode of K⁻pp

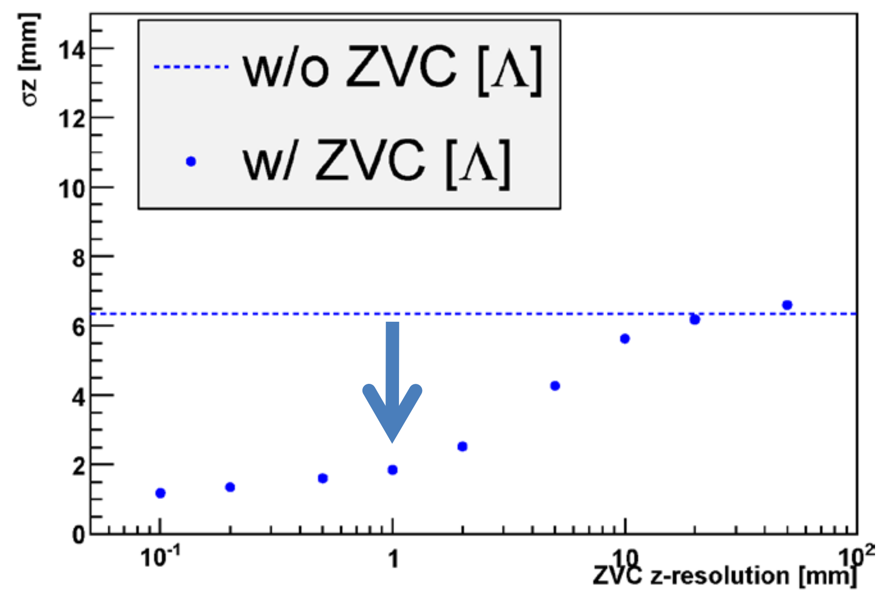




important to measure not only
non-mesonic decay mode
but also mesonic decay mode

mesonic mode is suppressed!





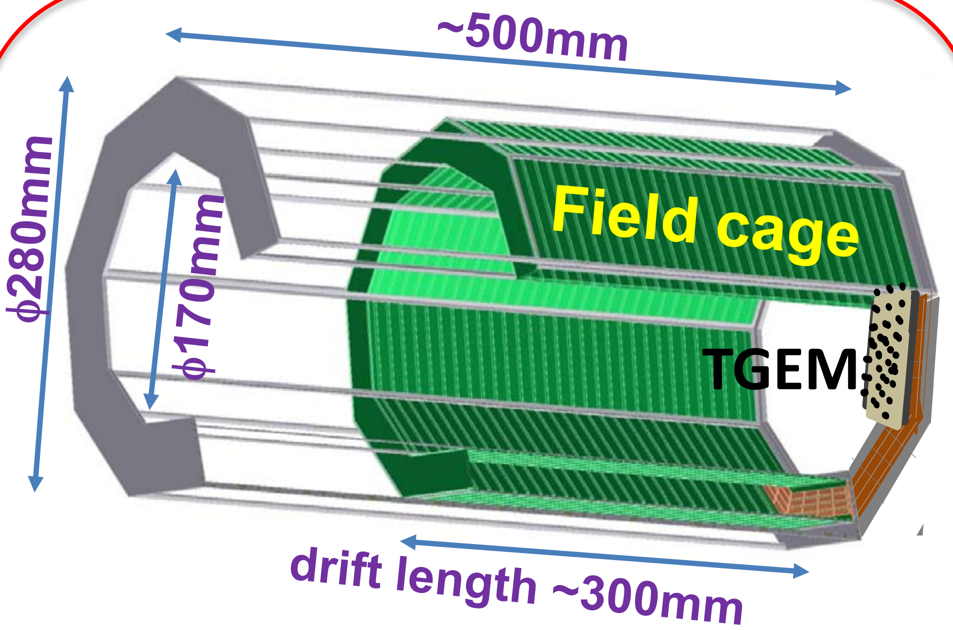
Thick-GEM TPC
improves z-resolution

TGEM-TPC
for the J-PARC E15 exp.

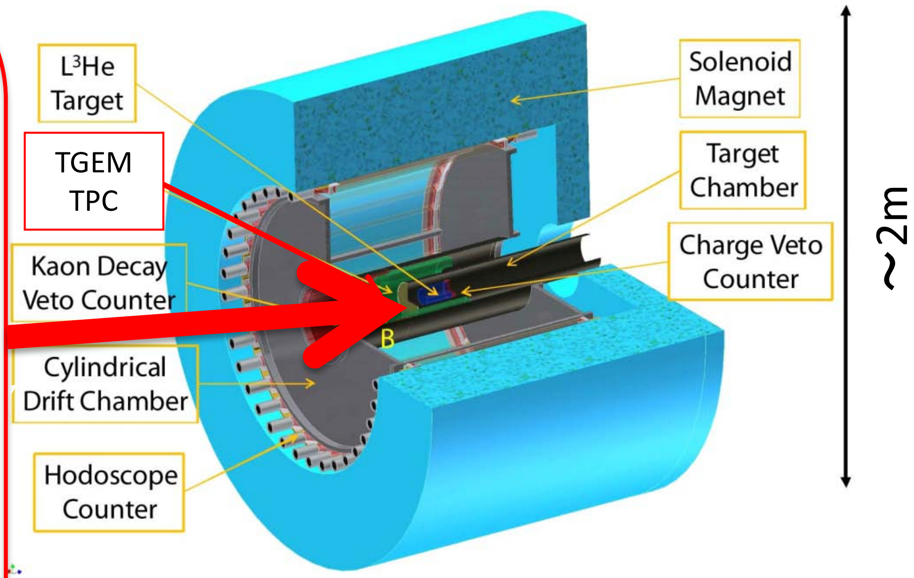
TGEM-TPC for the J-PARC E15 exp.

●TGEM-TPC is located at the center of Cylindrical Detector System

•located between CDC and target-chamber
•cover the CDC acceptance of AUVA
•minimum materials in the acceptance
•1mm spatial resolution in the z-direction

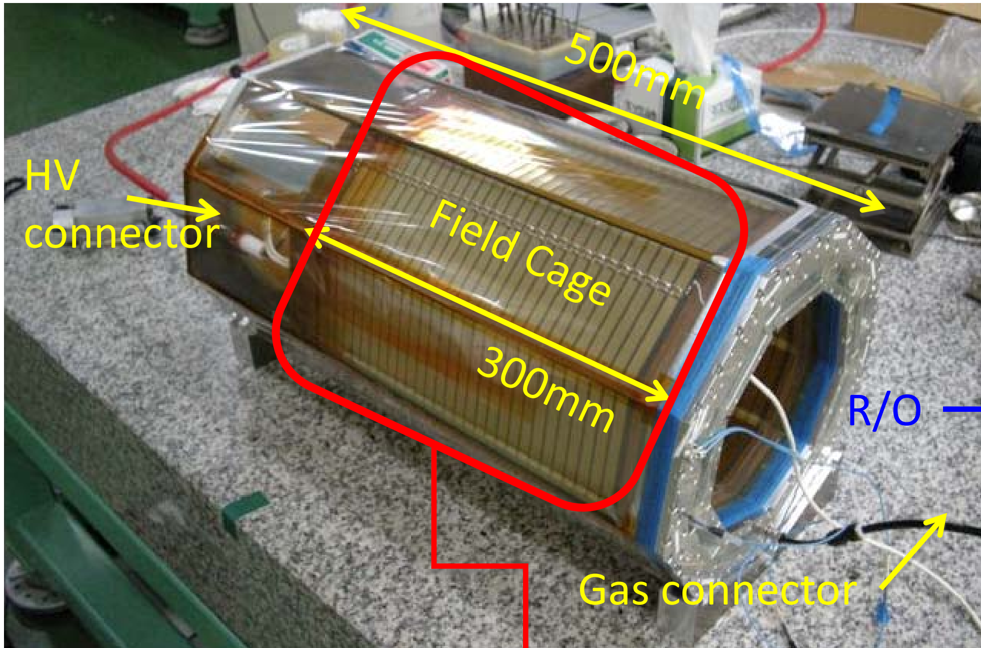


TGEM-TPC
filled with P10 gas at atmospheric pressure



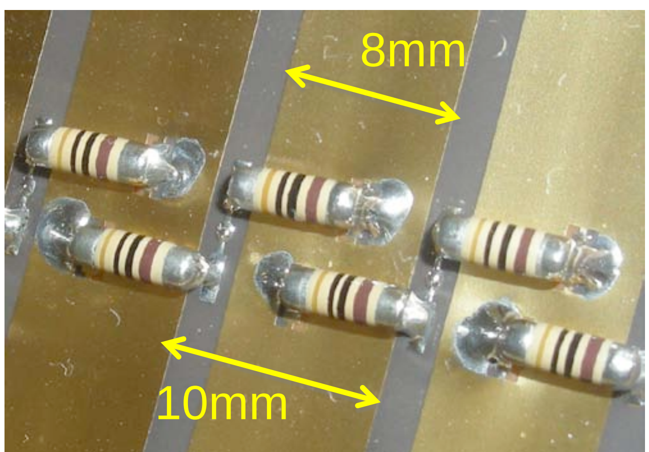
Cylindrical Detector System

completed TGEM-TPC



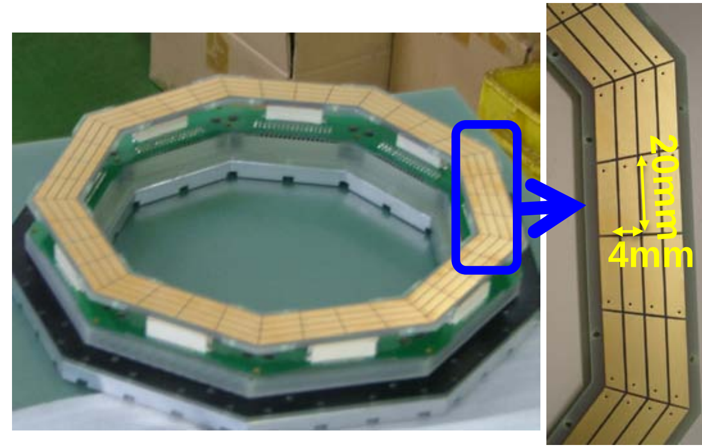
field strip

- double sided
- FPC
- 8mm strip
- 10mm pitch



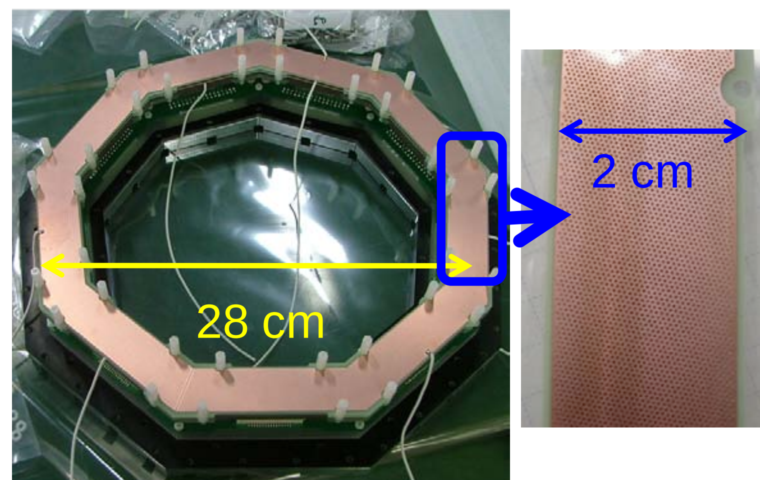
R/O

pad size 4mm×20mm



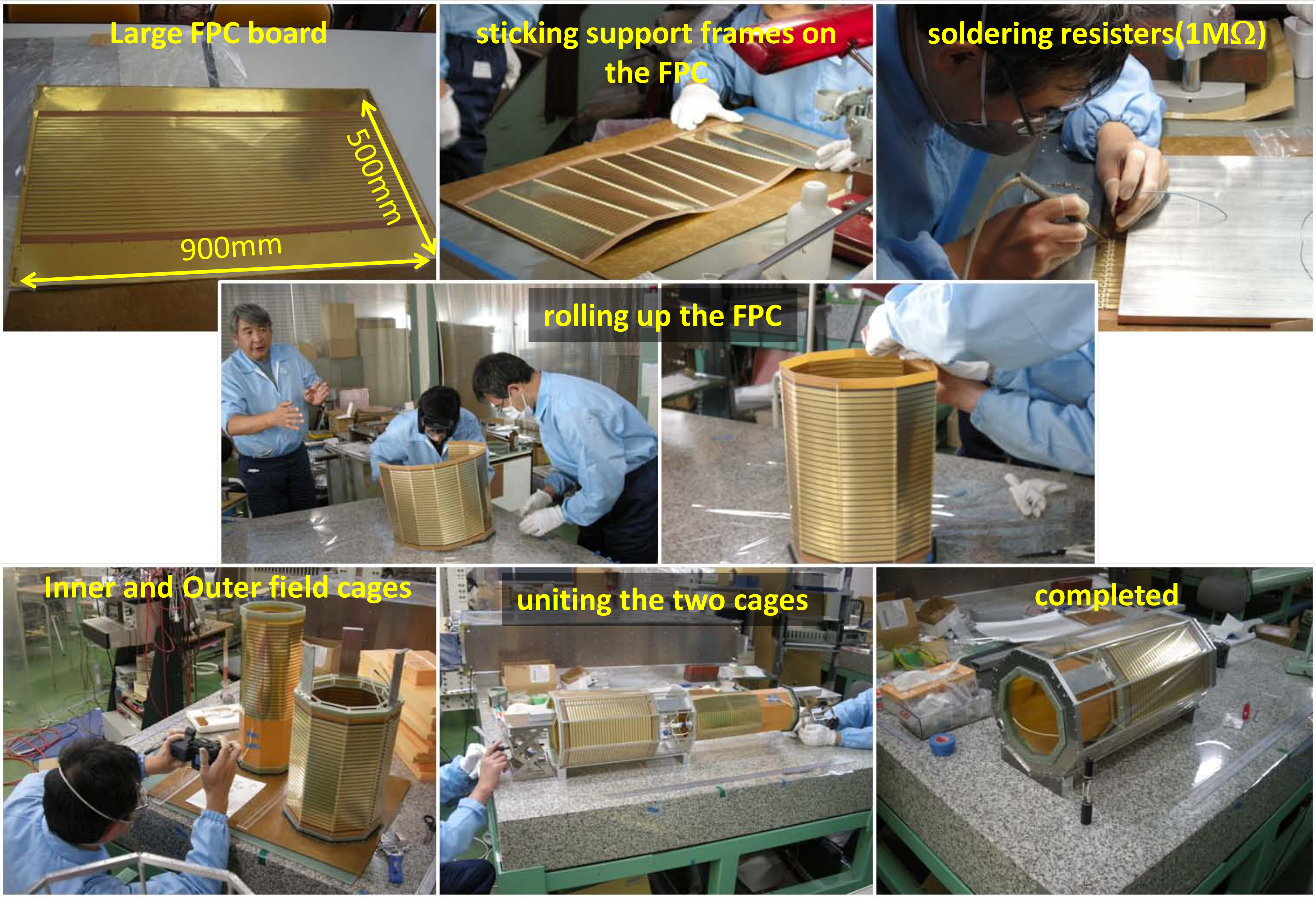
# of pad = 4×4×9 = 144

TGEM

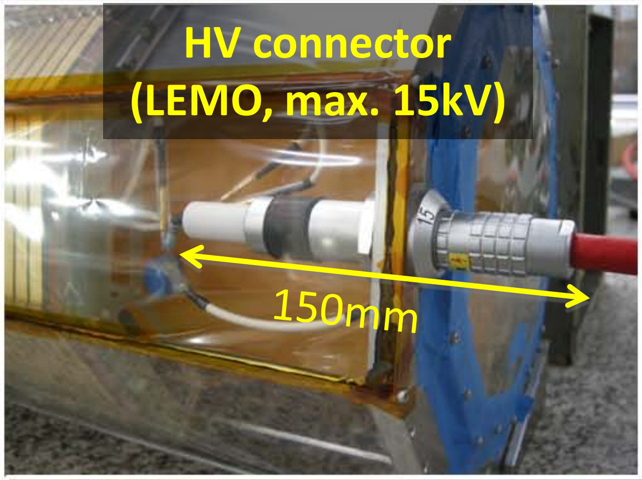


non-necessity of support-structure!

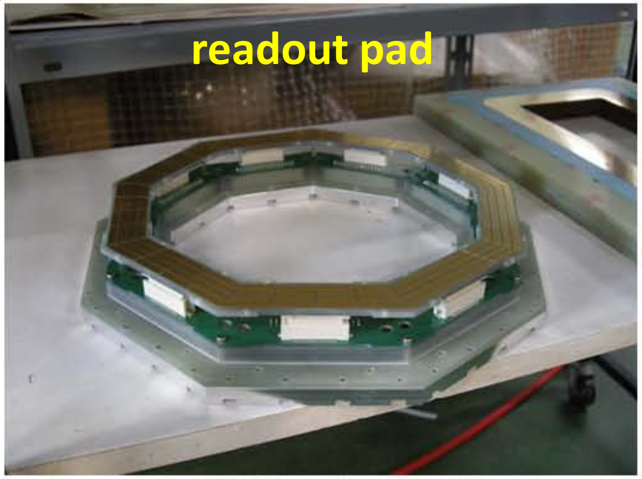
making of Field Cages

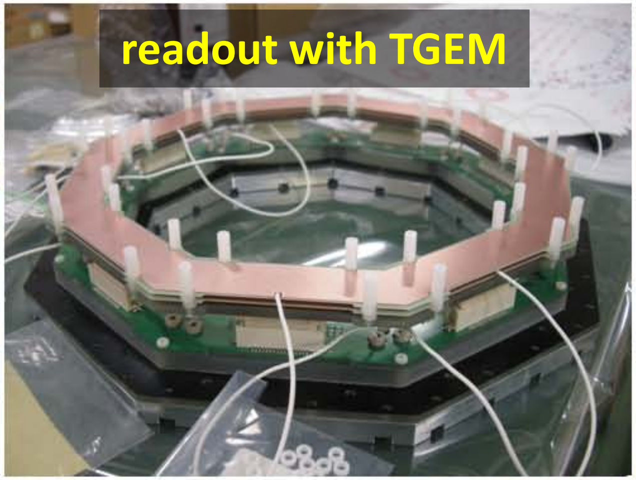


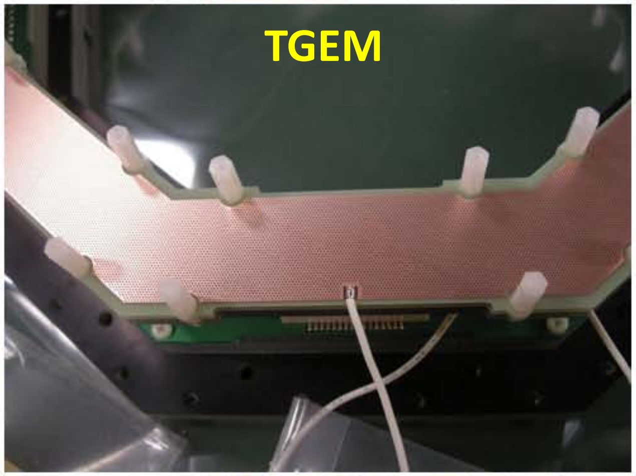
HV & Readout

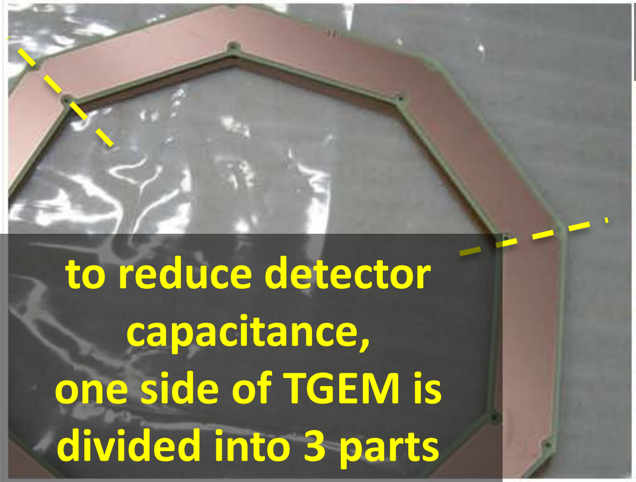

HV connector
(LEMO, max. 15kV)
150mm

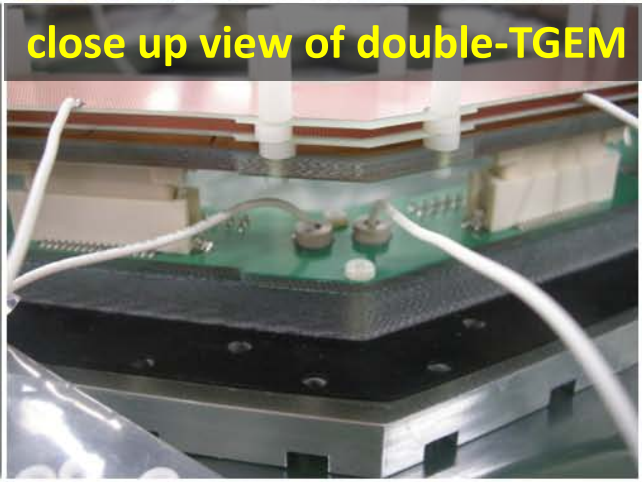

preamp attachment (test)

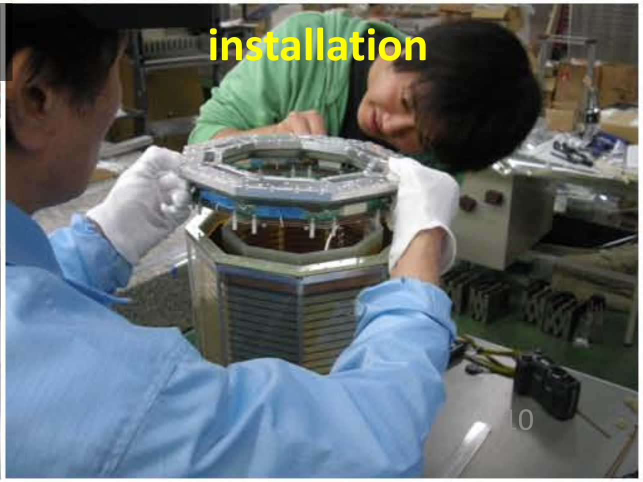

readout pad


readout with TGEM

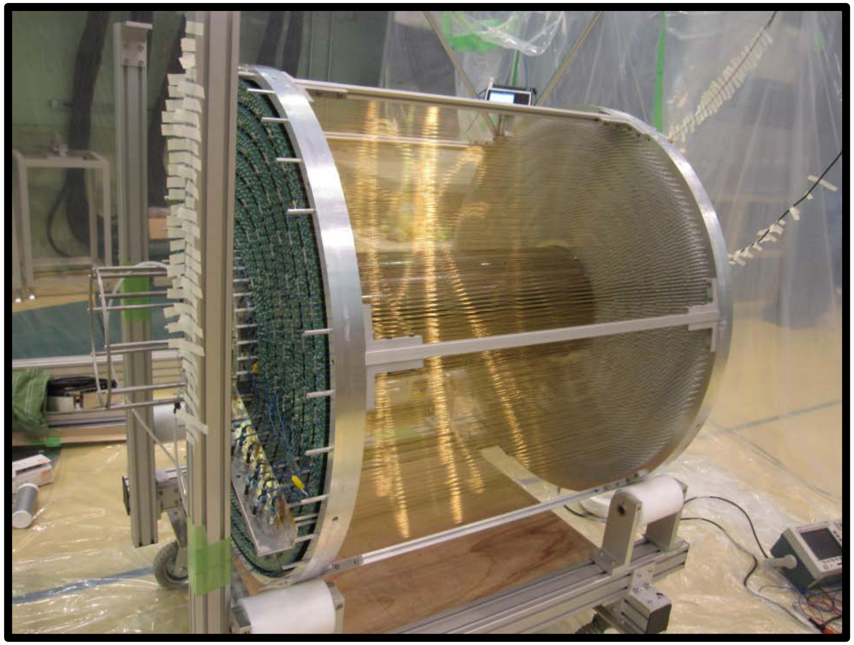

TGEM

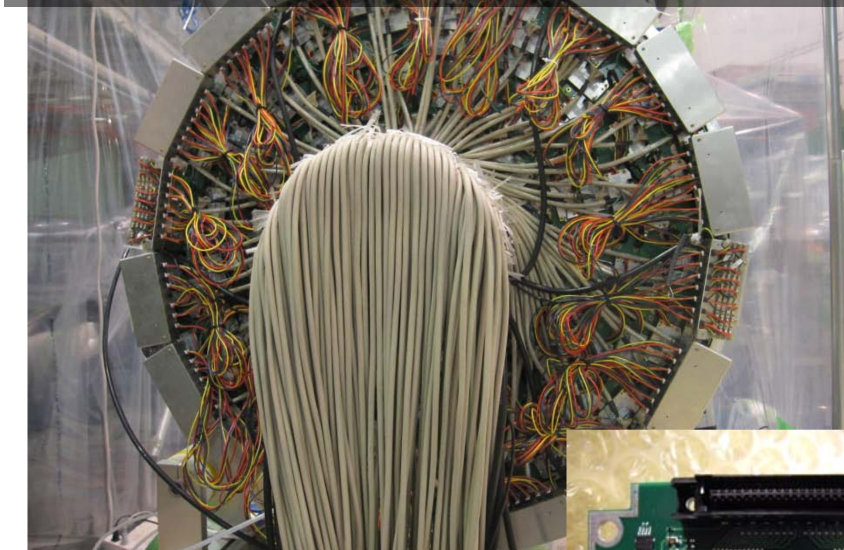

to reduce detector
capacitance,
one side of TGEM is
divided into 3 parts


close up view of double-TGEM

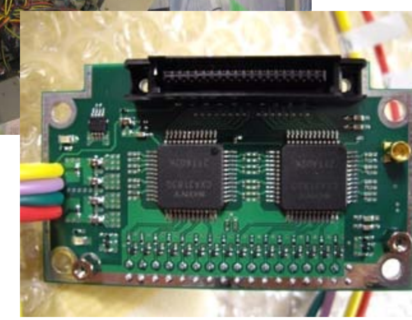

installation

Readout Electronics is the same as that of CDC





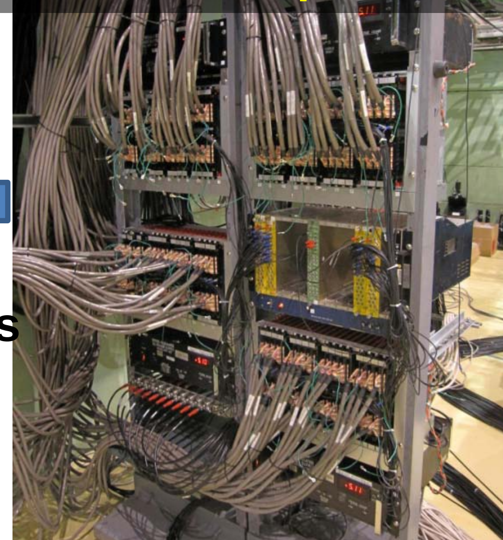
preamp cards and cables are attached



- Chip : CXA3183Q
  (SONY, low noize ASD IC,
  ~~τ=16nsec)~~ τ=80nsec
- Output : LVDS differential
- Gain : 0.8V/pC at preamp
- 4x4=16ch

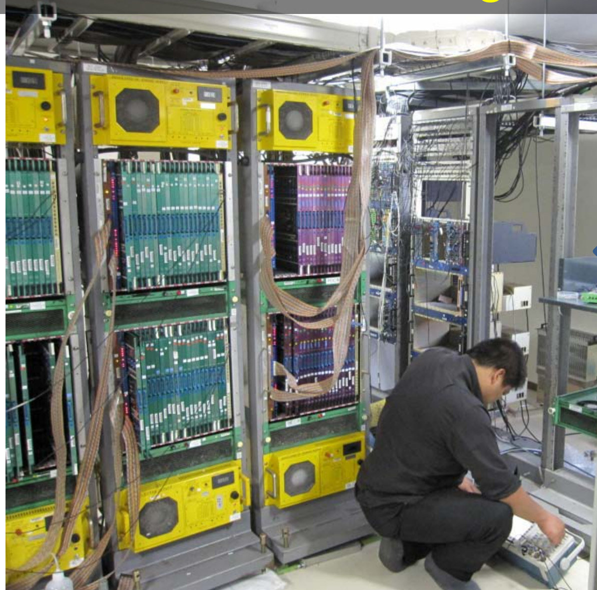
LVDS
8m cables

LVDS→ECL converters at the exp. hall



ECL
60m cables

TDC's in the counting room



We measure only time info. with the TPC!

gas

limit of HV module : 15kV
GEM HV : 4kV
drift length : 30cm

→ **maximum drift-field voltage : ~350V/cm**

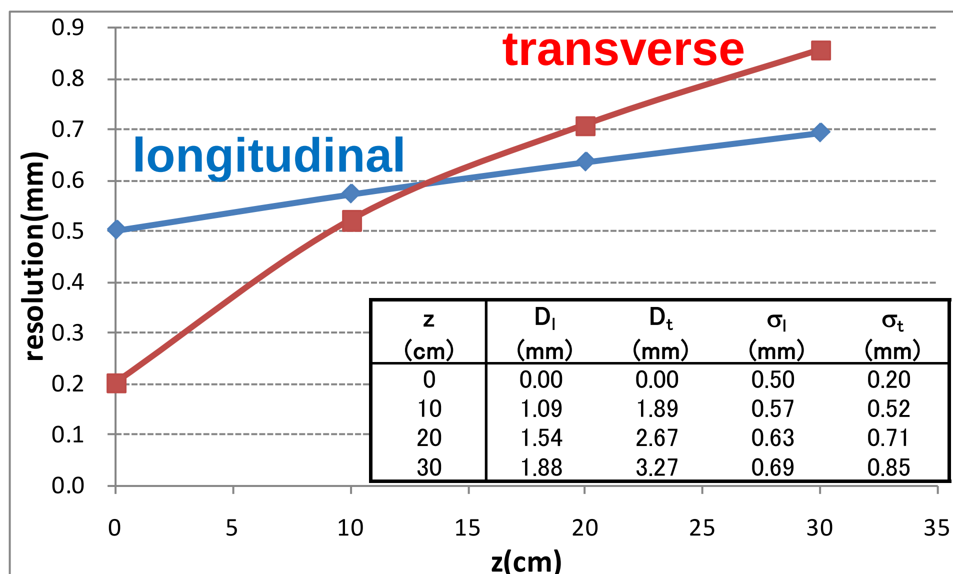
We choose P10 (Ar/CH_4=90/10) for the TGEM-TPC gas

expected resolution

$$\sigma_x^2 = \sigma_0^2 + \frac{C_d^2 \cdot z}{N_{eff}}$$

σ_x : total resolution
σ_0 : resolution w/o diffusion
C_d : diffusion constant
z : drift distance
N_{eff} : effective number of electrons

- E = 150V/cm
  → C_{dl} = 0.34mm, C_{dt} = 0.60mm
- σ_{0l} = 0.5mm
- σ_{0t} = 0.2mm
- N_{eff} = 38.7*0.4(cm) = 15.5



z (cm)	D_l (mm)	D_t (mm)	σ_l (mm)	σ_t (mm)
0	0.00	0.00	0.50	0.20
10	1.09	1.89	0.57	0.52
20	1.54	2.67	0.63	0.71
30	1.88	3.27	0.69	0.85

ϕ-direction resolution is limited by pad size, e.g.,
20.0/sqrt(12) = 5.8mm
So we use only z-direction info.

Thick GEM (TGEM)

goal: gain ∼10^4 with stable operation

What is TGEM ?

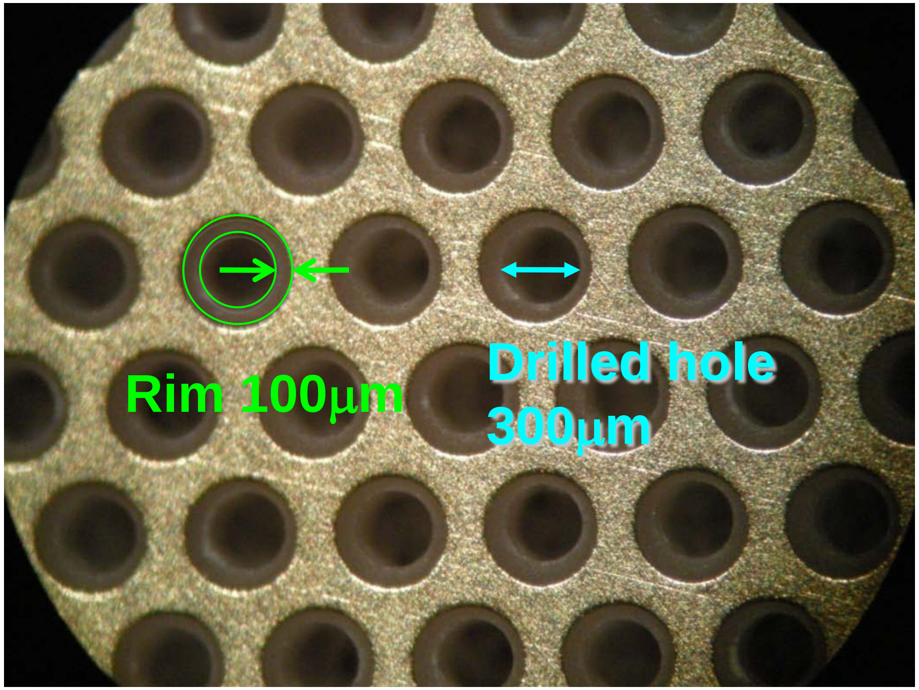
Thick-GEM is …

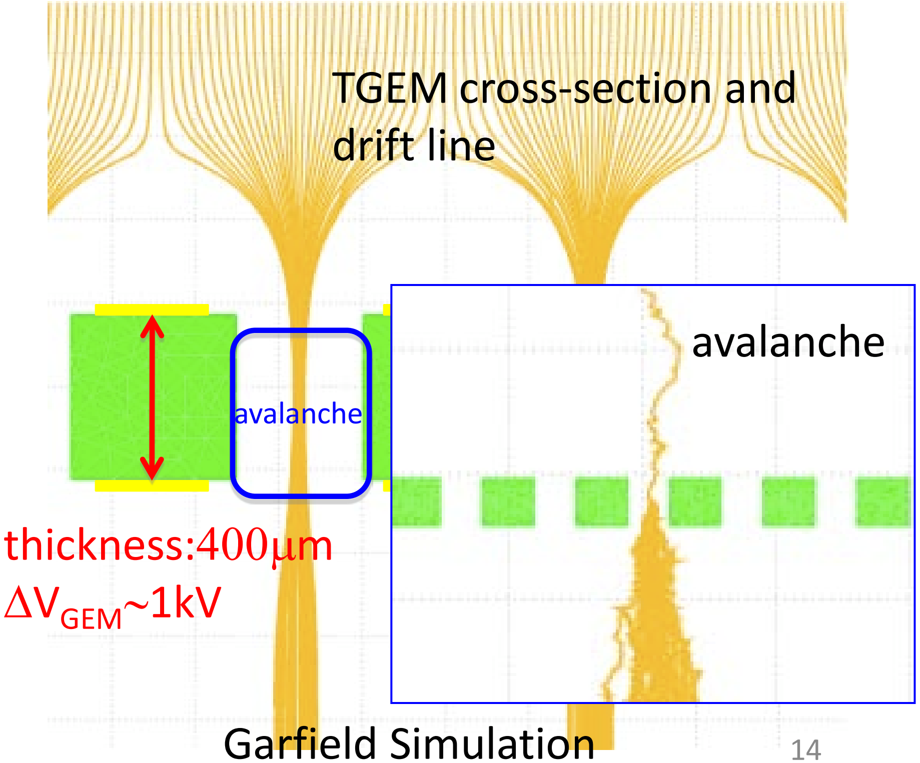
●**cost-effectively fabricated from double-clad G10 plates, using standard printed circuit board (PCB) techniques**

●holes are mechanically drilled (and, if necessary, the hole's rim is chemically etched to prevent discharges)

●a robust, simple to manufacture, high-gain gaseous electron multiplier

●easy to operate and feasible to cover large areas, compared to the standard foil GEM

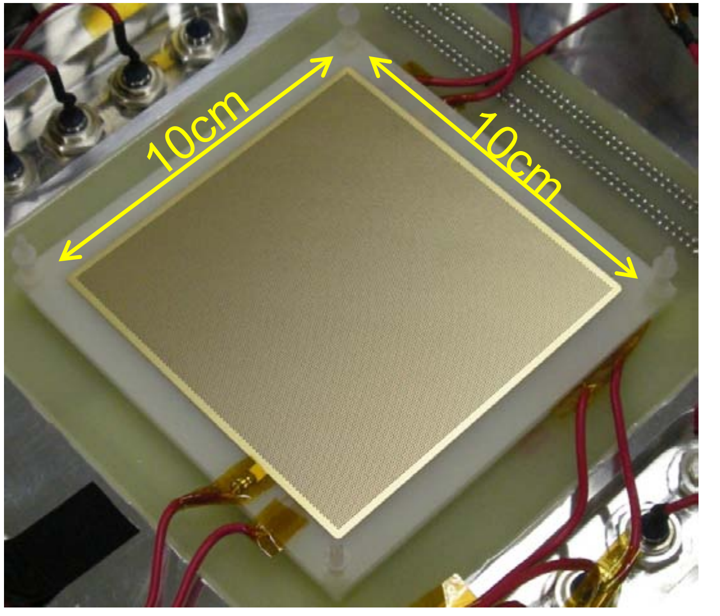




TGEM prototypes

goal

- gain～10^4 @ P10, NTP (double TGEMs)
- stabile operation for a month, with gain fluctuation within ~a few ten % for a month & a few % for a day



many groups have reported TGEMs work successfully, but actually **it's NOT so easy to operate TGEM with high gain stably!**

- they use small TGEMs, e.g. ~3x3cm^2
- most of them don't discuss stability of TGEM

We have studied basic TGEM behavior and performance.

TGEM prototypes @ RIKEN

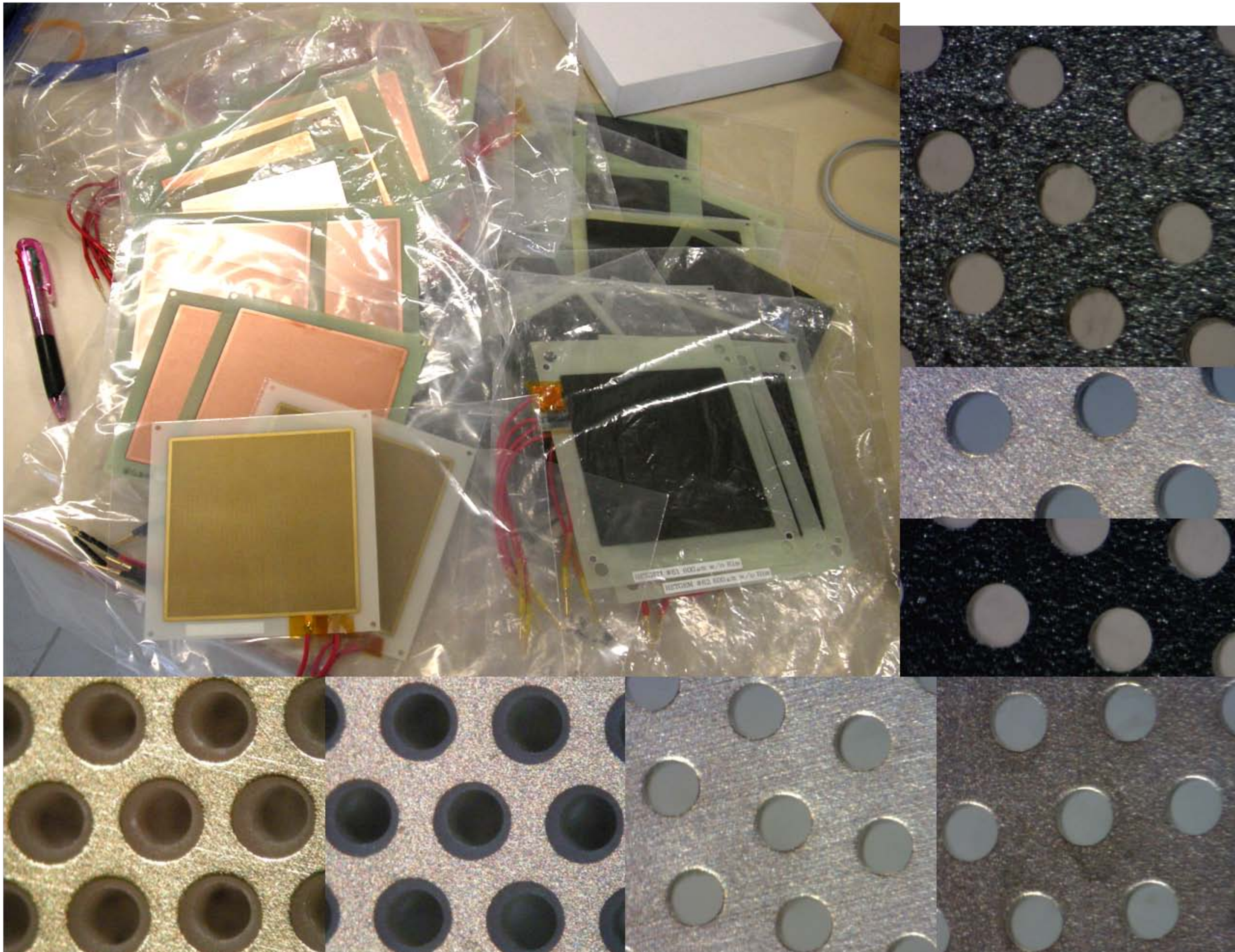
produced by REPIC corp. and TOUKAI DENSHI KOUGYOU corp.

No.	Electrode	Insulator	Thickness[μm]	Hole–diameter[μm]	Rim[μm]	
1	Cu	FR4/UV	200	300	50	×2
2	Cu	FR4/UV	200	500	–	×2
3	Cu	FR4/UV	400	300	–	×5
4	Cu	FR4/UV	400	300	30	×2
5	Cu	FR4/UV	400	300	50	×2
6	Cu	FR4	400	300	100	×2
7	Cu	FR4/UV	400	500	–	×2
8	C	FR4	400	300	–	×4
9	C	FR4/UV	400	300	–	×7
10	C	G10	400	300	–	×2
11	C	CEM3	400	300	–	×2
12	C	FR4	600	300	–	×2
13	C/Cu	FR4/UV	400	300	–	×4

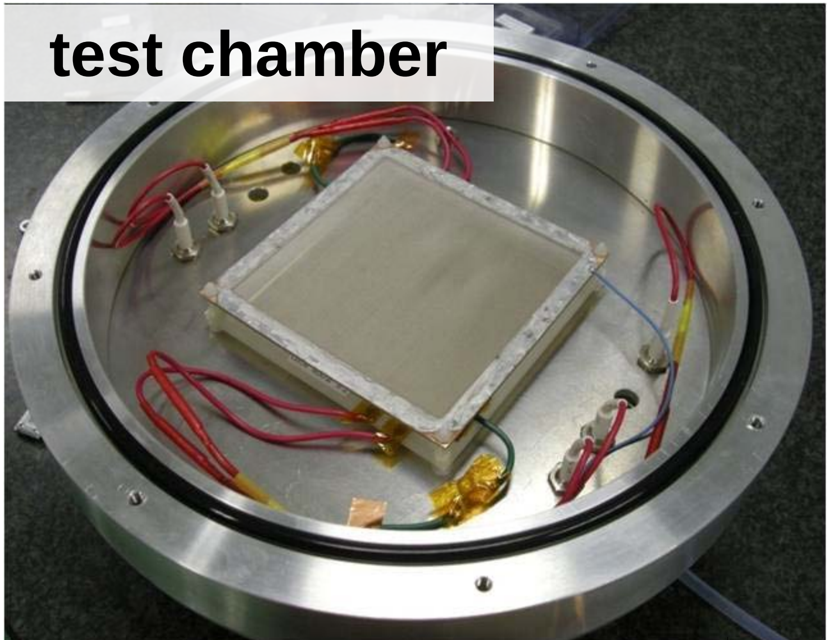
size : 10cm x 10cm

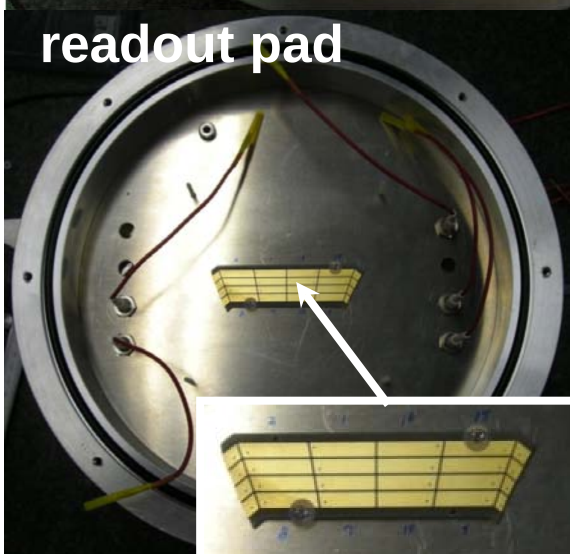
Total 40

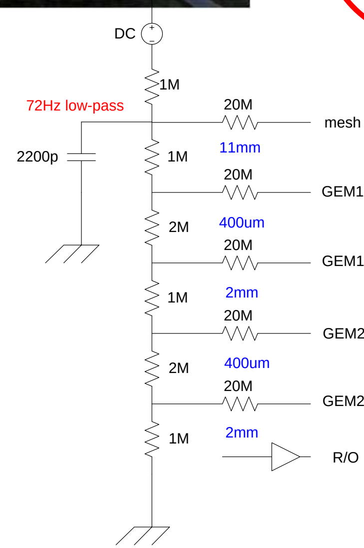
many TGEM prototypes

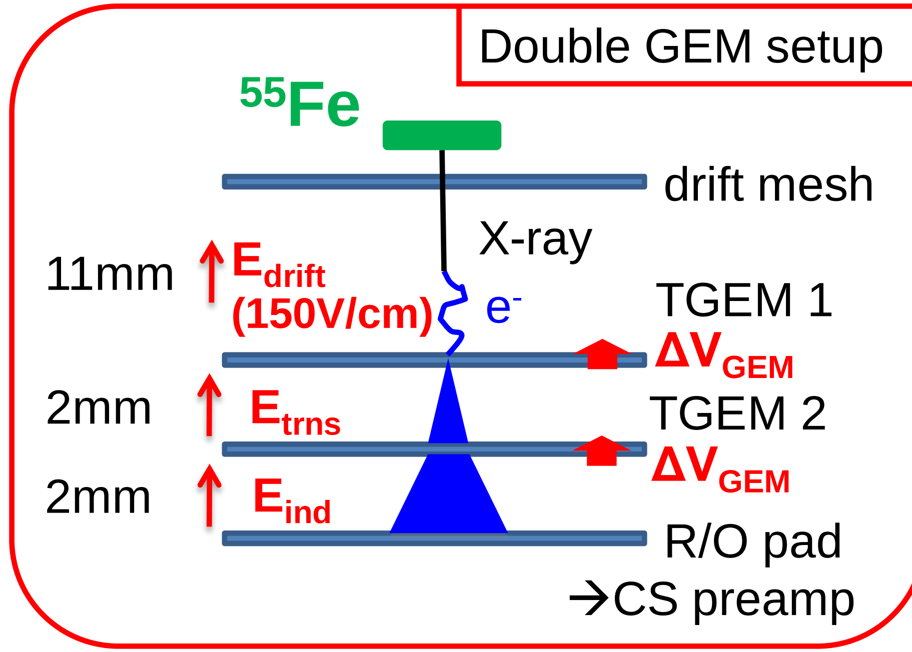


Test bench setup









- **double TGEMs**
- **Gas : P10 at 1atm, normal temperature**
- **HV divider with resistive chain**

→ Ratio of $\Delta V_{GEM}/E_{trns}/E_{ind}$ is const.

Results of TGEMs

Cu-electrode TGEM

No.	Electrode	Insulator	Thickness[μm]	Hole−diameter[μm]	Rim[μm]	Max gain
1	Cu	FR4/UV	200	300	50	$\sim 10^3$
2	Cu	FR4/UV	200	500	−	−
3	Cu	FR4/UV	400	300	−	$\sim 10^4$
4	Cu	FR4/UV	400	300	30	over 2×10^4
5	Cu	FR4/UV	400	300	50	over 2×10^4
6	Cu	FR4	400	300	100	over 2×10^4
7	Cu	FR4/UV	400	500	−	$\sim 10^3$

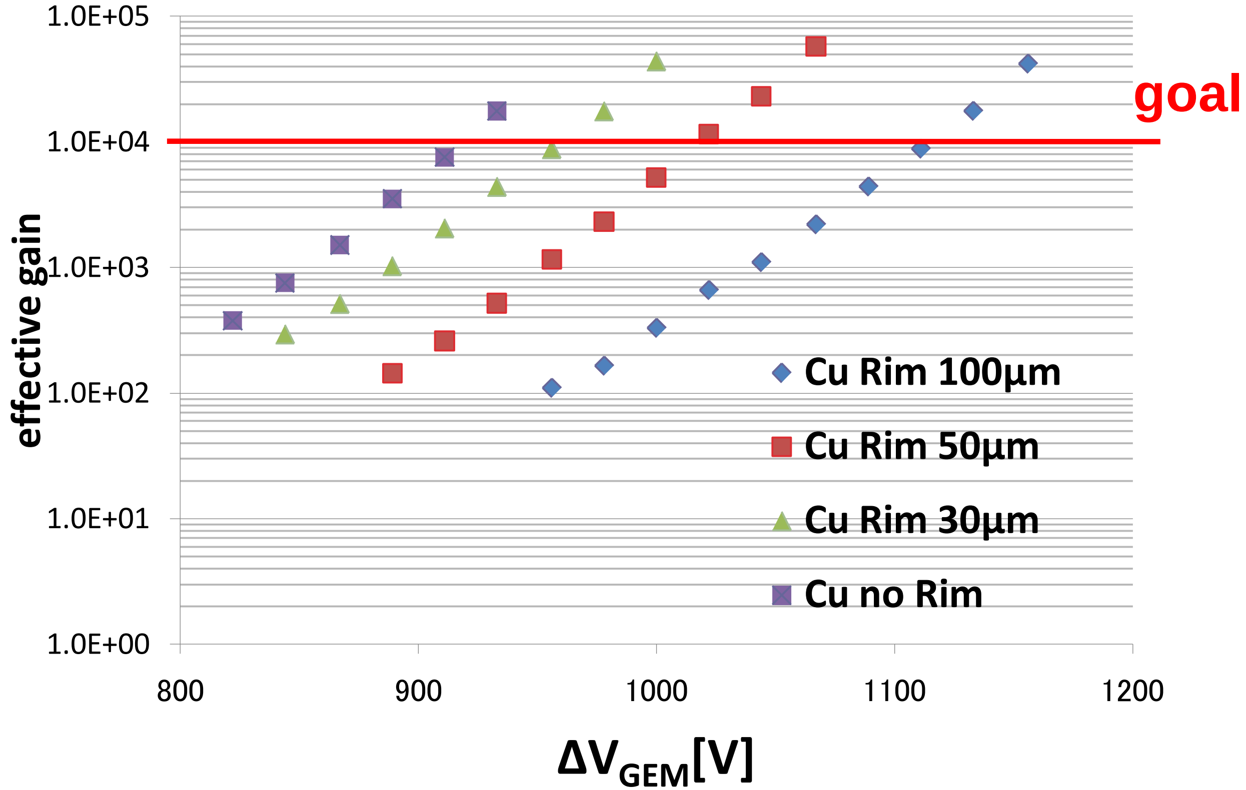
Rim of 50,100μm : Weizmann method (drilling + masked etching)
Rim of 30μm : CERN method (drilling + resist etching)
w/o Rim (#3) : w/ hydrogen peroxide - sulfuric acid etching

TGEMs with thickness of 400μm and hole diameter of 300μm achieve maximum gain of 10^4

dependence on rim size

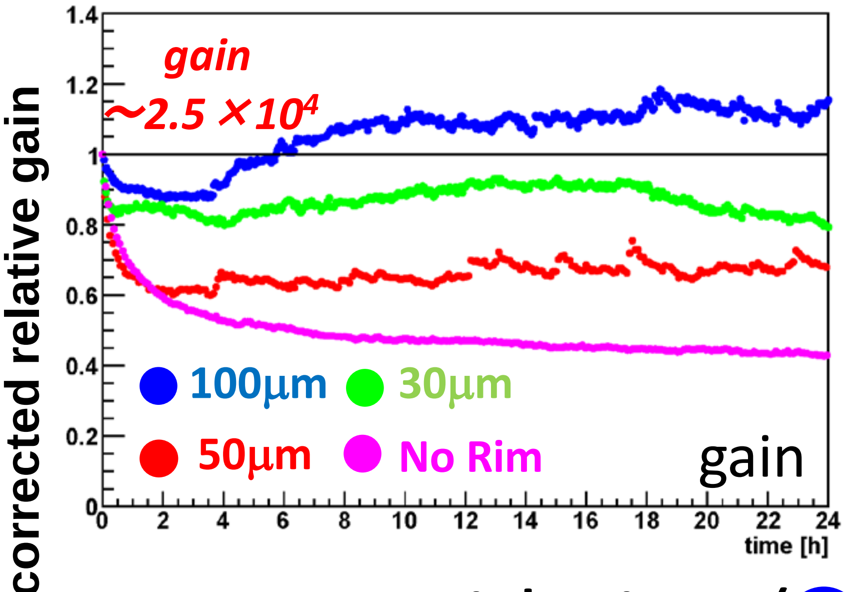
the limits of gain around 10^5 is caused by reather limit (source = ^{55}Fe).

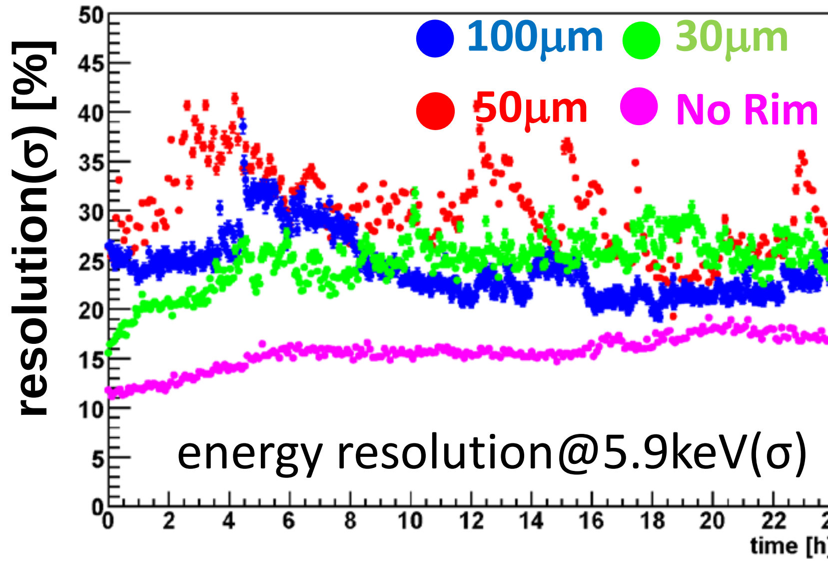
E_{drift}=150V/cm				
ΔV_{GEM} (V)	:	E_{trans} (V/cm)	:	E_{induct} (V/cm)
1	:	2.5	:	7.5



TGEM with larger rims requires higher voltage, but enables higher gain

gain and resolution stability (24h)





TGEMs with rims (●,●,●) are **NOT so stable**

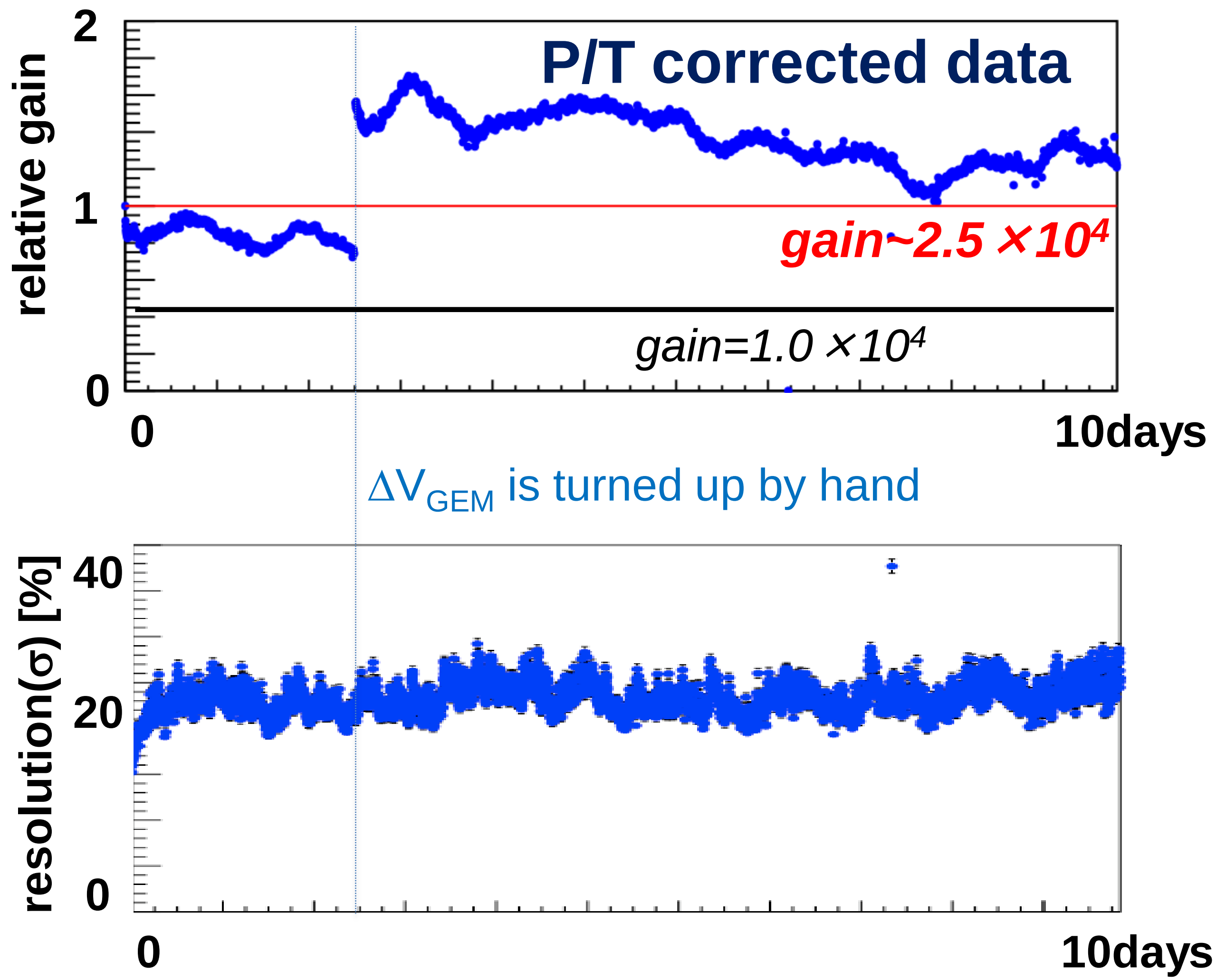
TGEM without rims (●) is **stable**

●initial drop of gain is caused by charge-up (polarization?) of the insulator?

●**instability of TGEMs with rims is caused by charge-up of the insulator not metalized.**

●mismatch of the center of the etched and drilled holes and incomplete round-shape of rims cause the instability.

long term stability (30μm rims TGEM, 10days)



- TGEM with 30μm rims can be operated with gain of more than 10^4 for the long term @ P10, NTP
- gain stability is within ~50%/week & ~10%/day

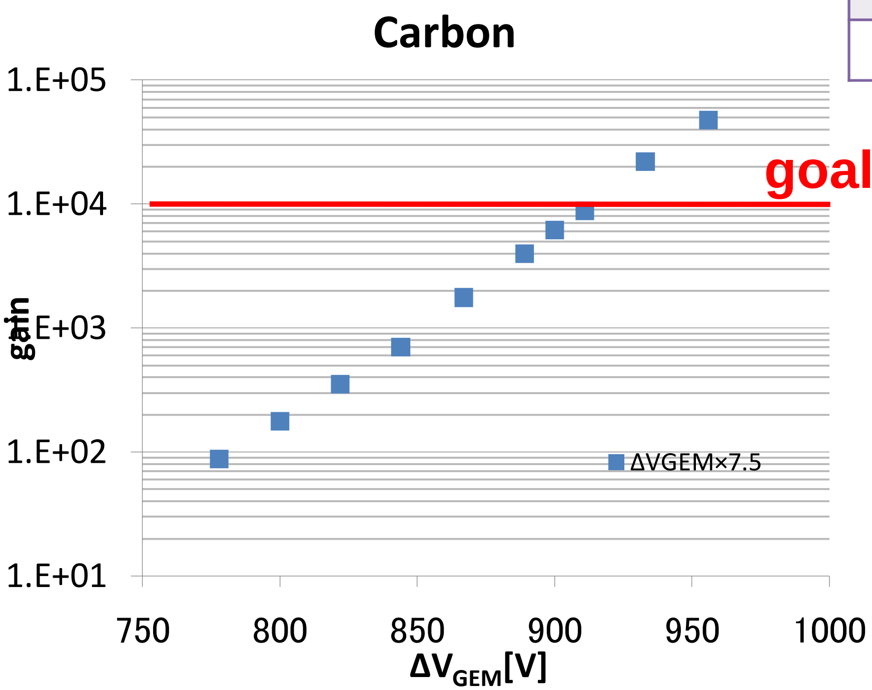
C-electrode TGEM

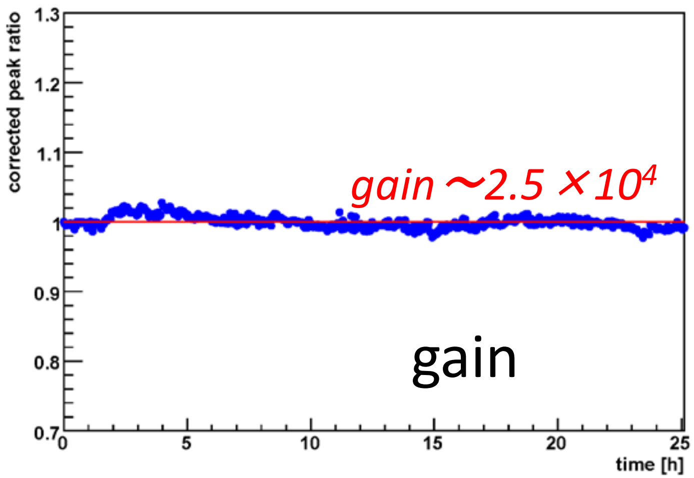
- To avoid the effects of rims, we are developing a new resistive-electrode TGEM (RETGEM) which has electrodes coated with **graphite paint**.
- RETGEMs have an advantage of being fully spark-protected.

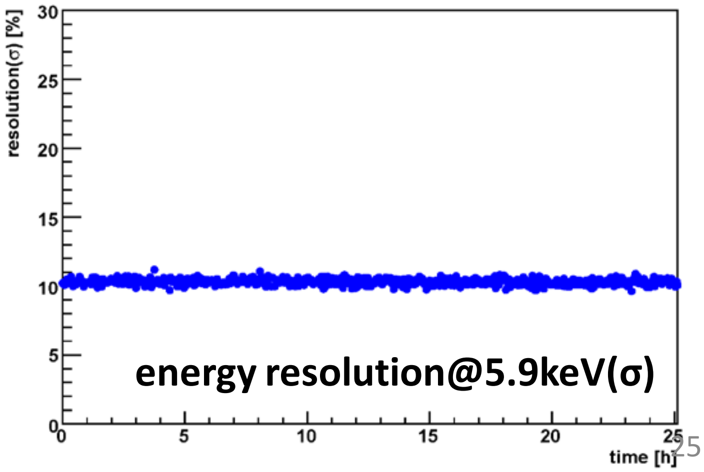
No.	Electrode	Insulator	Thickness[μm]	Hole–diameter[μm]	Rim[μm]	Max gain
8	C	FR4	400	300	–	over 2×10^4
9	C	FR4/UV	400	300	–	–
10	C	G10	400	300	–	$\sim10^3$
11	C	CEM3	400	300	–	over 2×10^4
12	C	FR4	600	300	–	$\sim10^2$

Results of the first sample

E_{drift}=150V/cm				
ΔV_{GEM} (V)	:	E_{trans} (V/cm)	:	E_{induct} (V/cm)
1	:	2.5	:	7.5







It seemed that C-electrode TGEMs

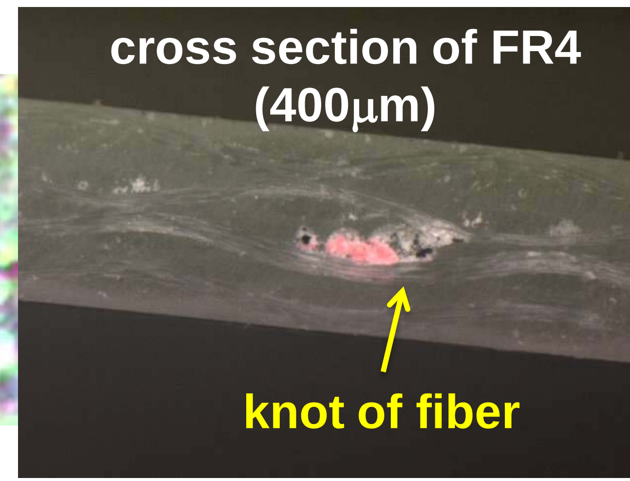
work excellent!!!

However...

carbon TGEMs have no reproducibility at all !!!

only first 2 out of 11 samples of RETGEMs work !!!

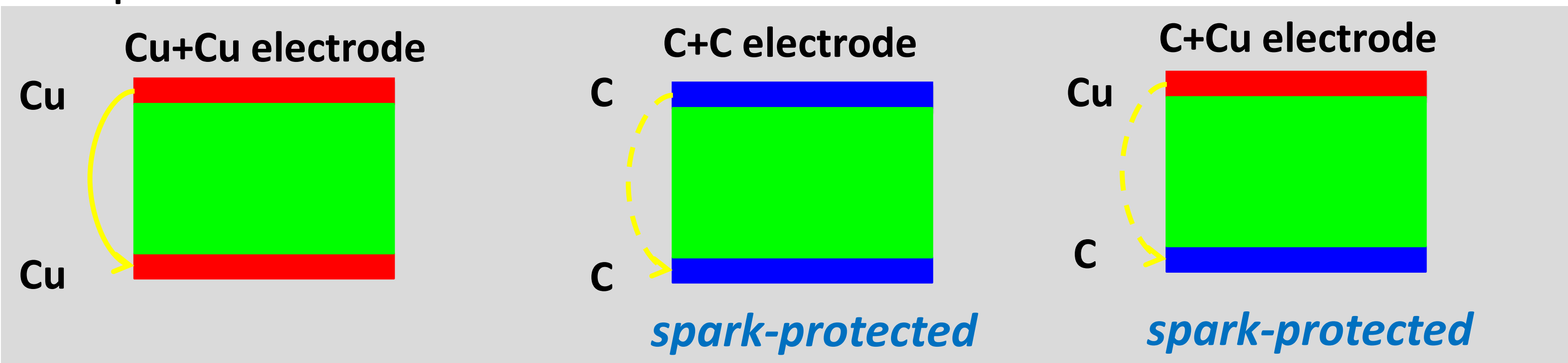
- discharge from burrs arising from drilling process
  (but these can be removed using antistatic-brush)
- carbon attachment inside the holes caused by knot of FR4 fiber



→now, we have been studying another insulator of CEM3 not FR4/G10

C/Cu-electrode Hybrid-TGEM

- In principle, if one side of electrode is resistive then that would be spark-protected.

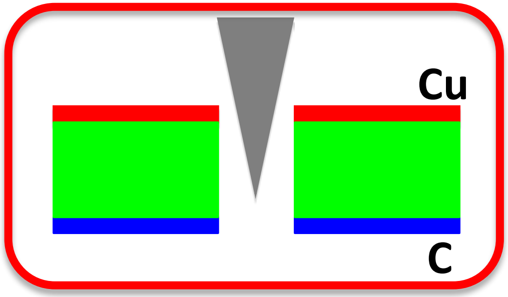


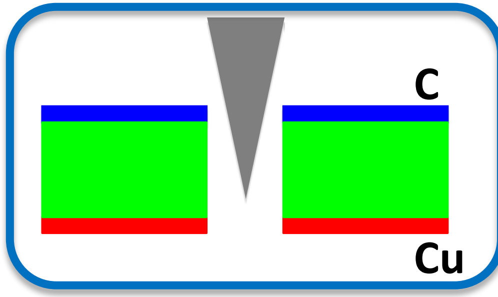
- Hybrid-TGEM would have a possibility of reduction of carbon attachment inside the holes.

No.	Electrode	Insulator	Thickness[μm]	Hole−diameter[μm]	drill	
13	C/Cu	FR4/UV	400	300	Cu→C	×2
	C/Cu	FR4/UV	400	300	C→Cu	×2

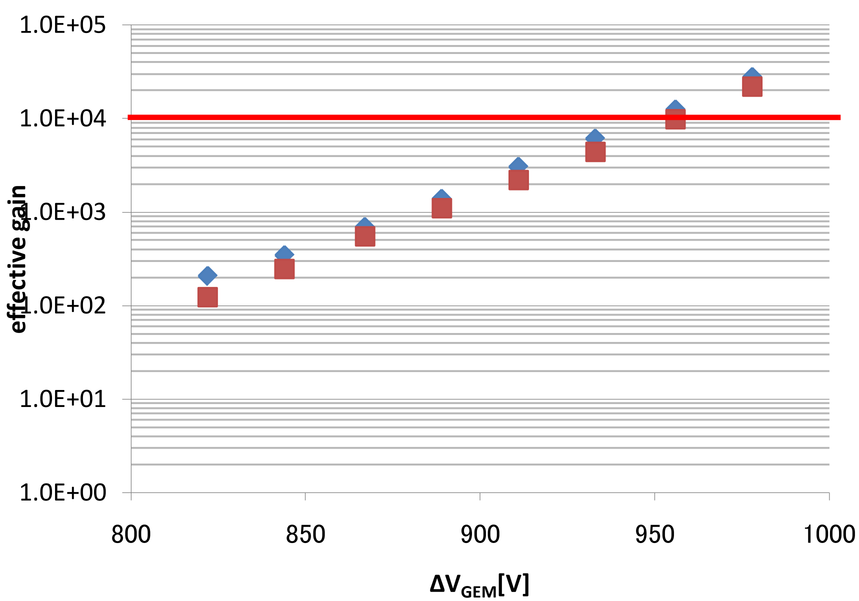
Results of C/Cu-electrode Hybrid TGEM

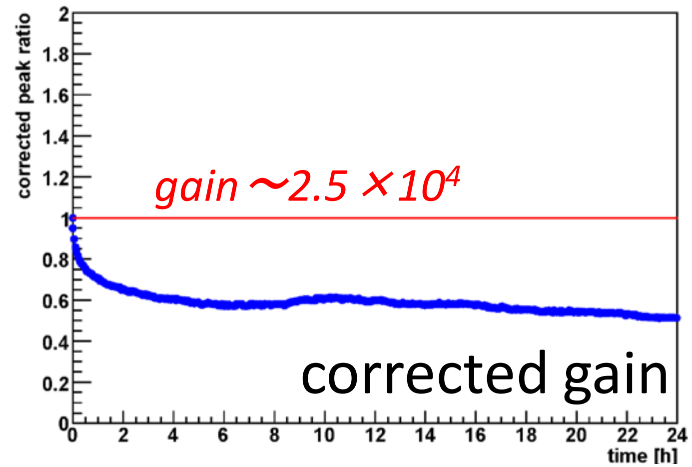
We tried 2 drilling directions,
i.e. Cu→C and C→Cu

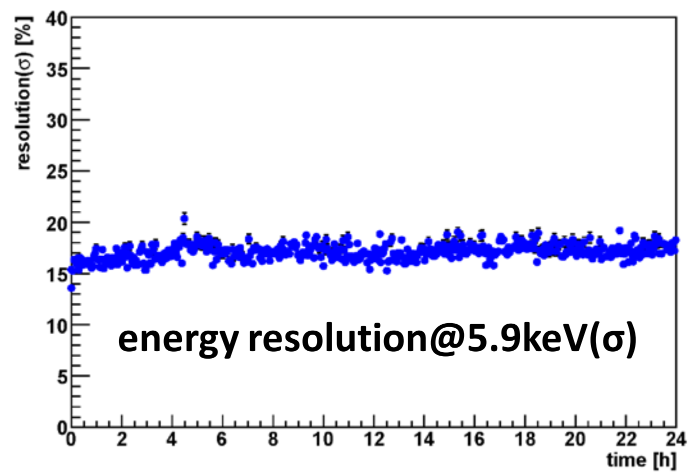




E_{drift}=150V/cm				
ΔV_{GEM} (V)	:	E_{trans} (V/cm)	:	E_{induct} (V/cm)
1	:	2.5	:	7.5

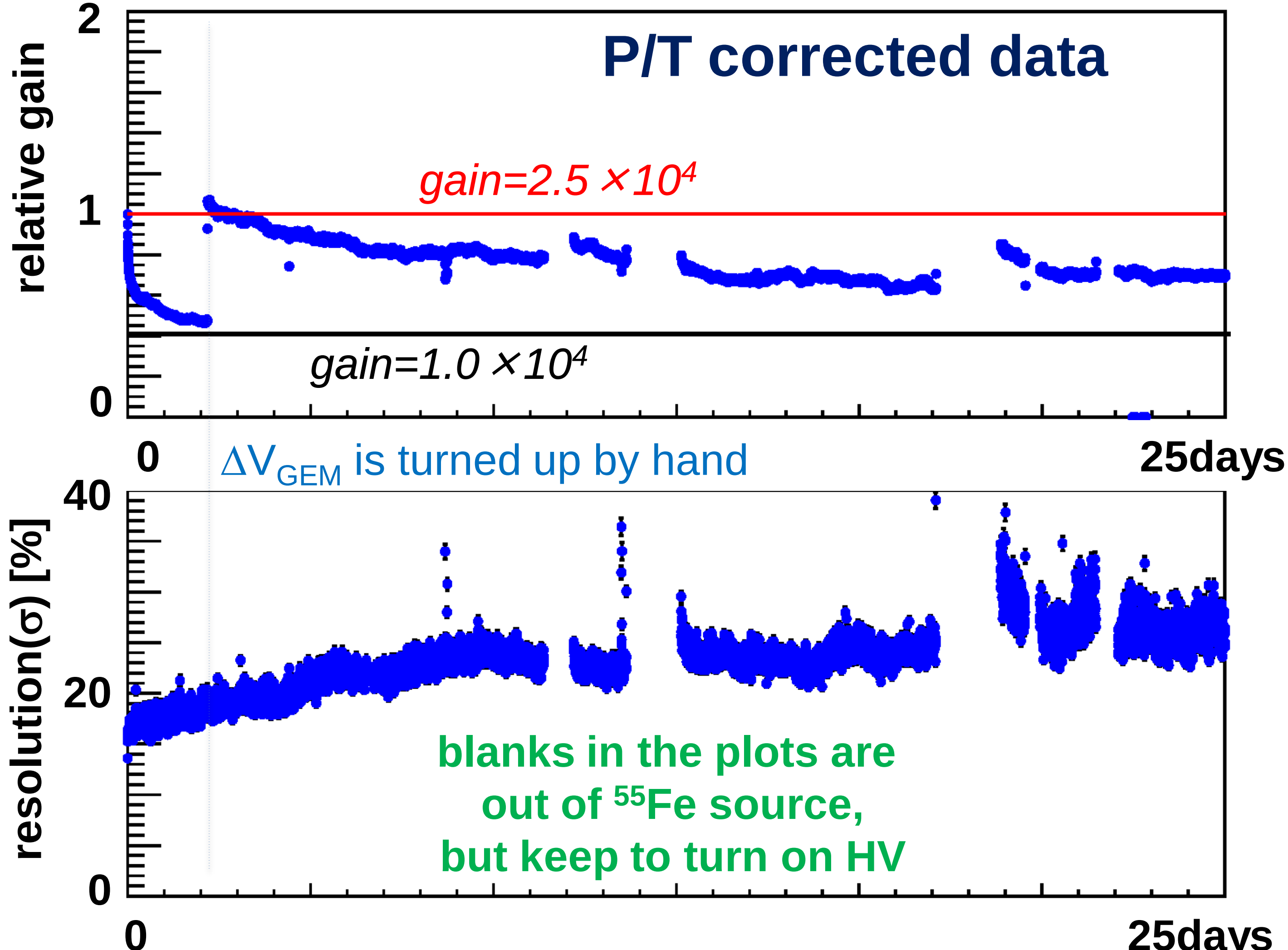






The 2 fabrication methods work similarly

long term stability (hybrid TGEM, 25days)



- hybrid TGEM can be operated with more than gain of 10^4 for the long term @ P10, NTP
- gain stability is within ~20%/week & ~5%/day

Summary

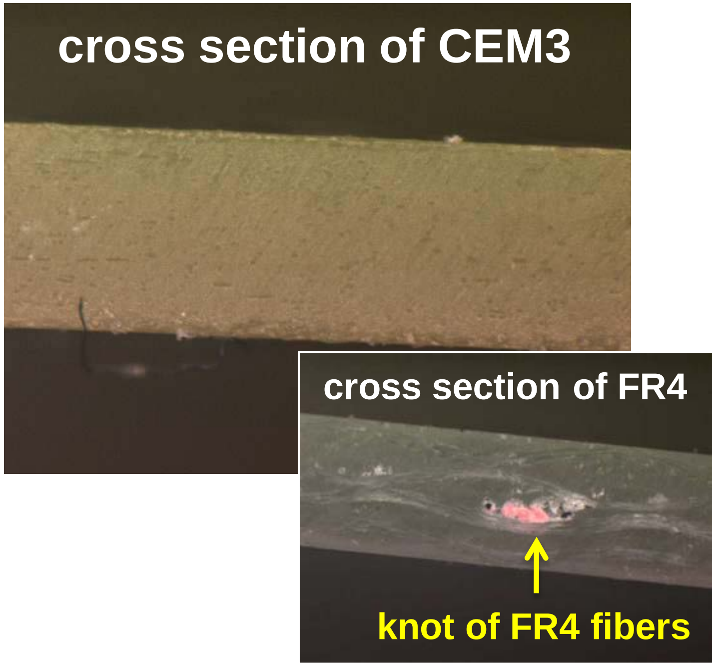
- We have been developing a **TGEM-TPC** for the J-PARC E15 upgrade
- **TGEM-TPC was completed, and commissioning will be started soon**
- **Cu electrode TGEM with 30μm rims** can be operated with gain of more than 10^4 for the long term rather stably @ P10, NTP
- **C-electrode TGEM** is far from goal...
- **C/Cu electrode TGEM** can be operated with gain of more than 10^4 for the long term stably @ P10, NTP

C electrode TGEM with CEM3 insulator

A cross section of CEM3 is very clean compared with that of FR4.

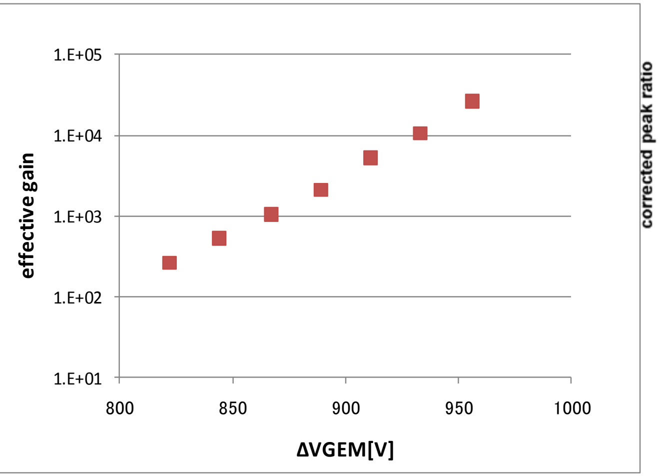
↓

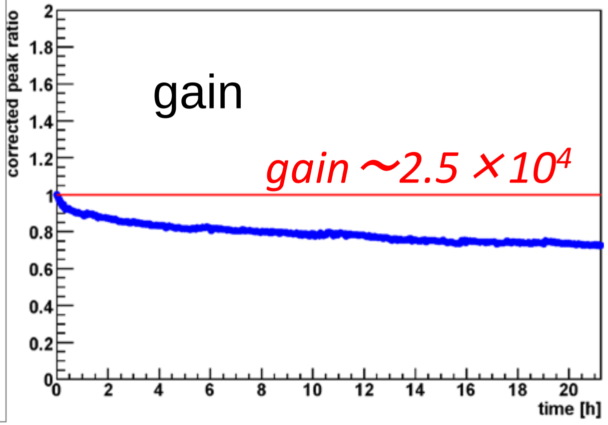
reduction of carbon attachment inside the holes

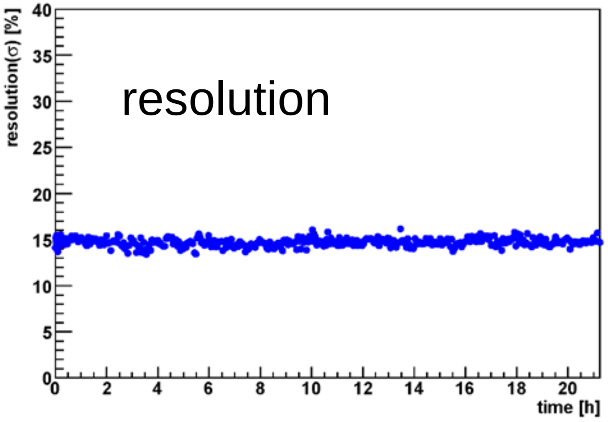


●Now we are investigating reproducibility of CEM3 RETGEM

●A disadvantage of CEM3 RETGEM is its flexibility







How to make Rims

There are 2 ways

Weizmann method

drilling + masked etching

Advantage:

large rims can be made easily

Disadvantage:

difficult to center etched and drilled holes

CERN method

drilling + resist etching

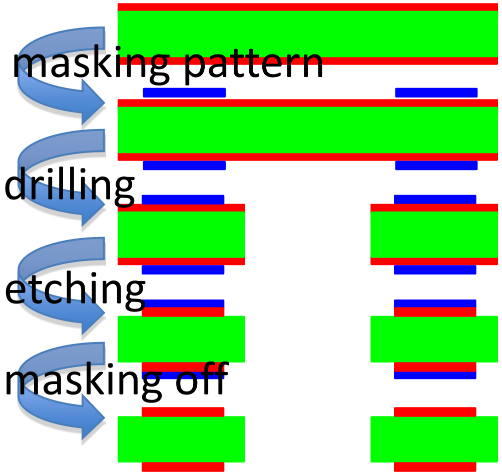
Advantage:

center of etched and drilled holes are the same

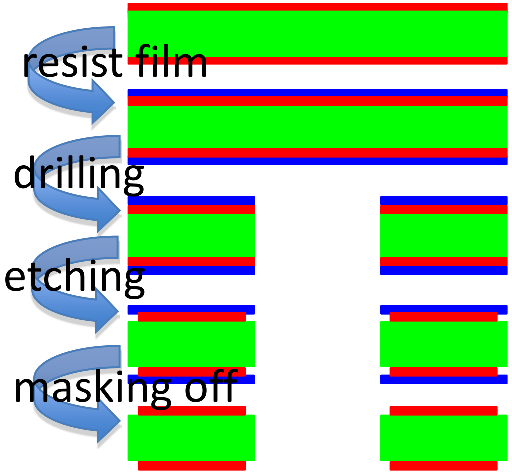
Disadvantage:

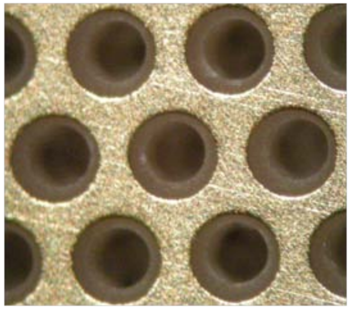
difficult to make large rims

Weizmann method

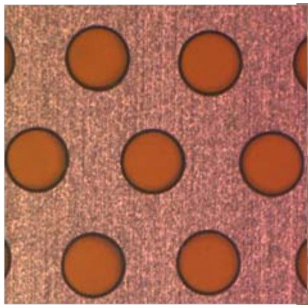


CERN method

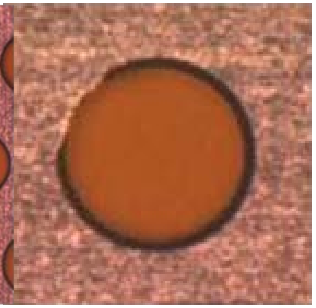




Weizmann



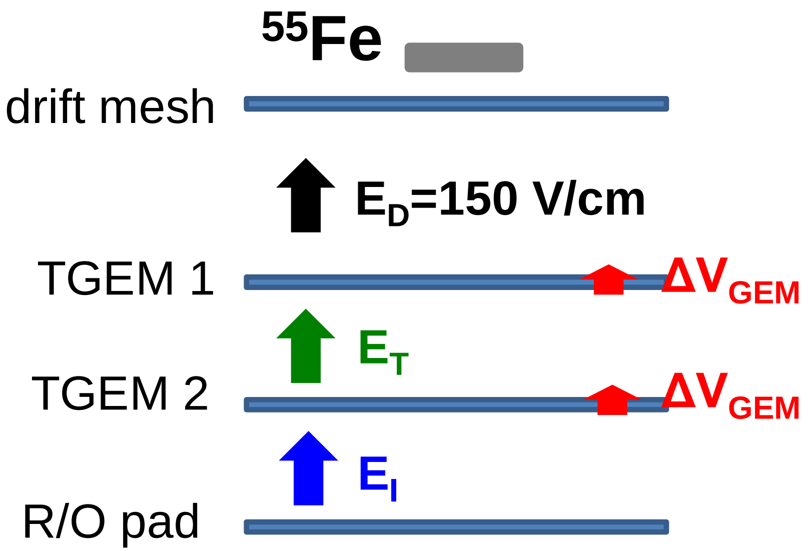
CERN

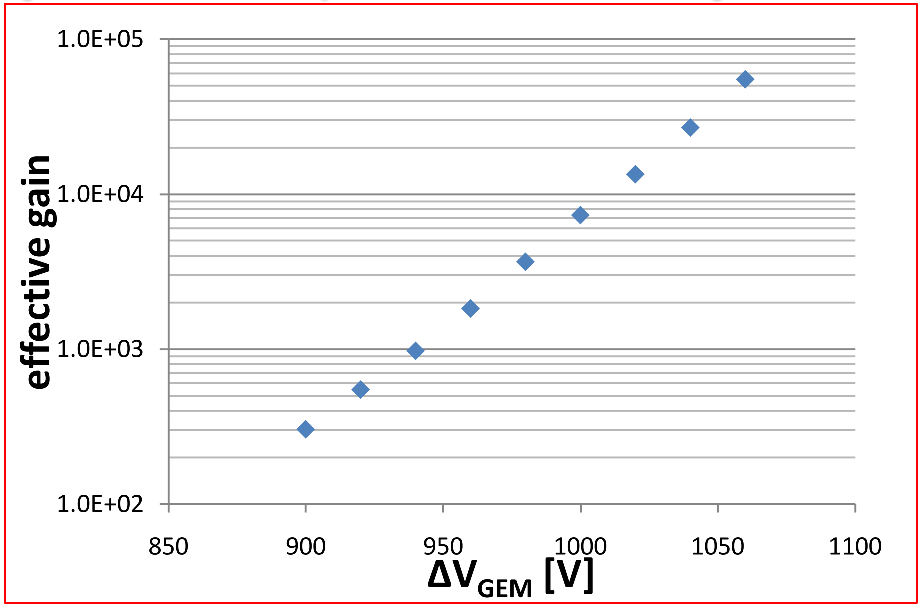


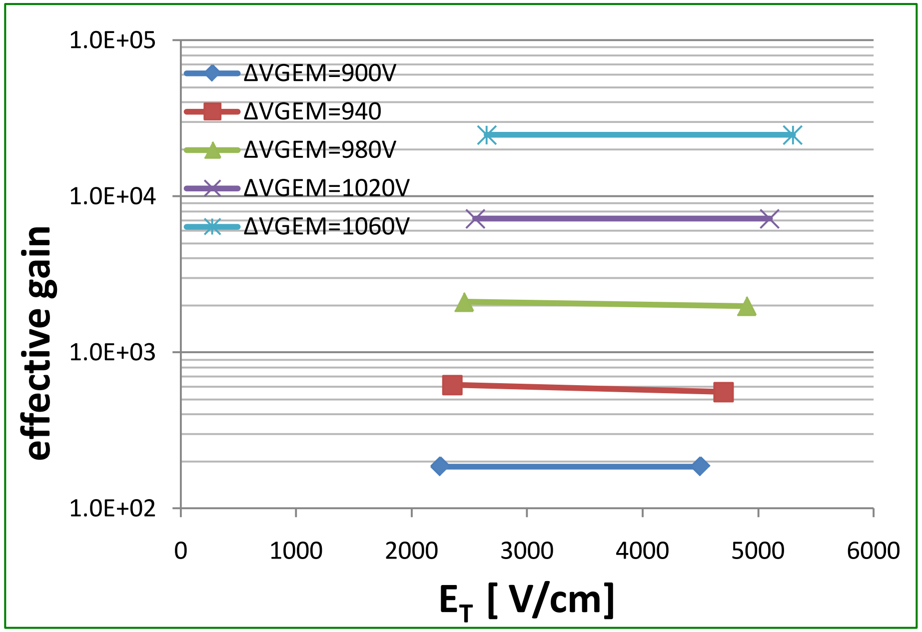
(failure)

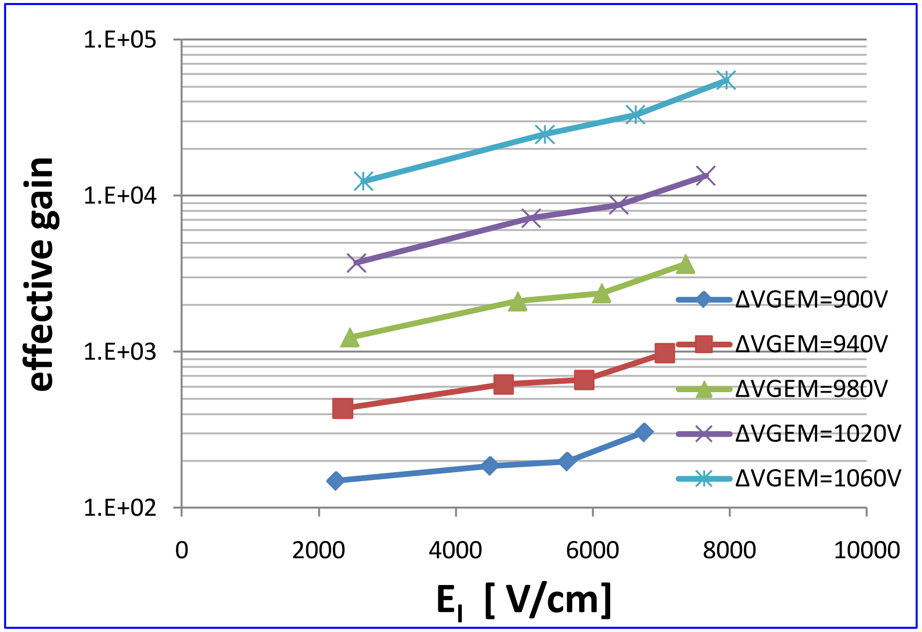
It's known that large rims cause instability of TGEMS, although those enable TGEMs to reach high gain.

ET, EI dependence (Rim 30μm TGEM)

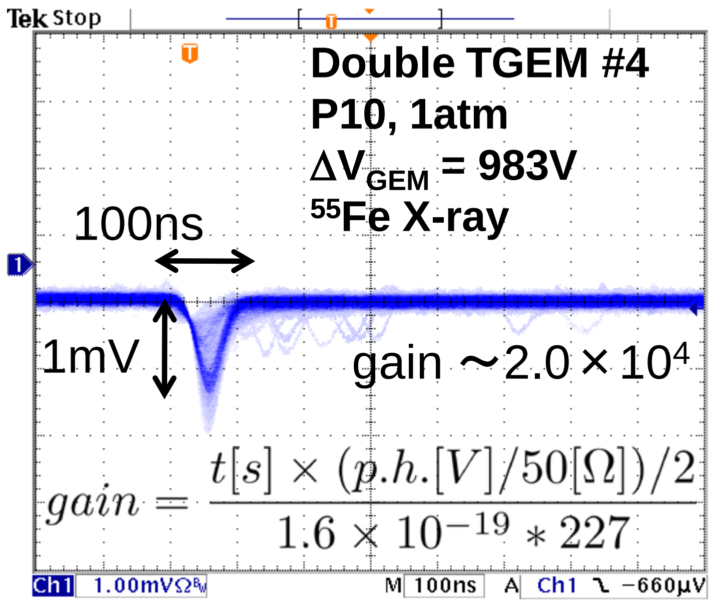




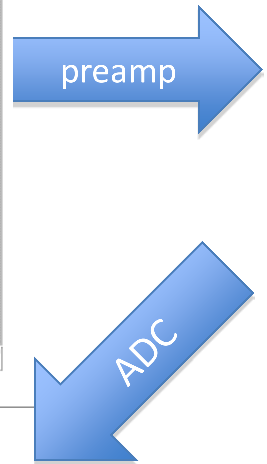


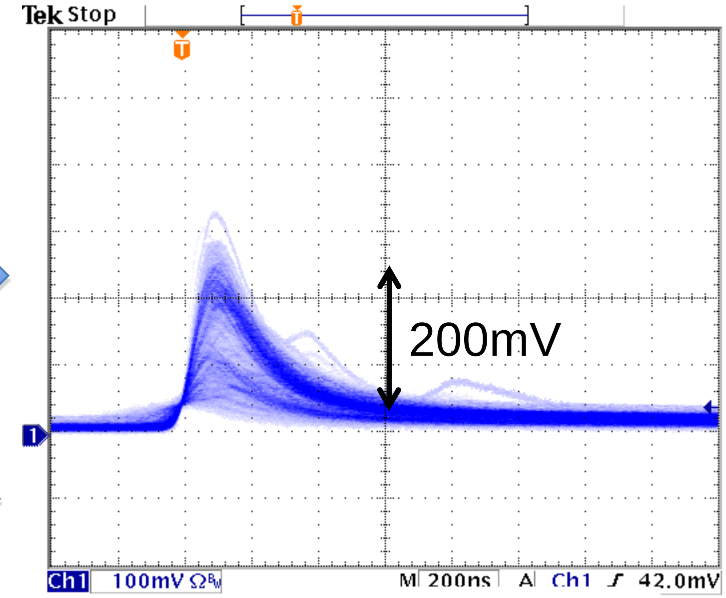


signals and goal of the studies

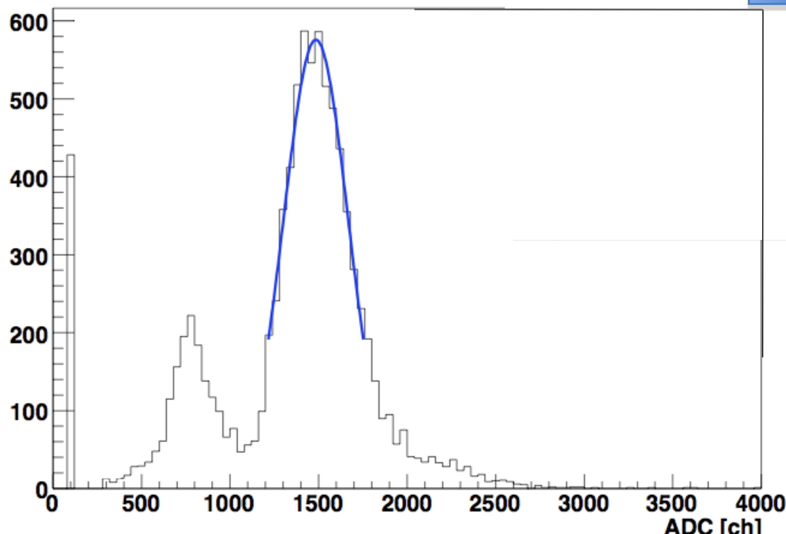


raw signal





preamp out



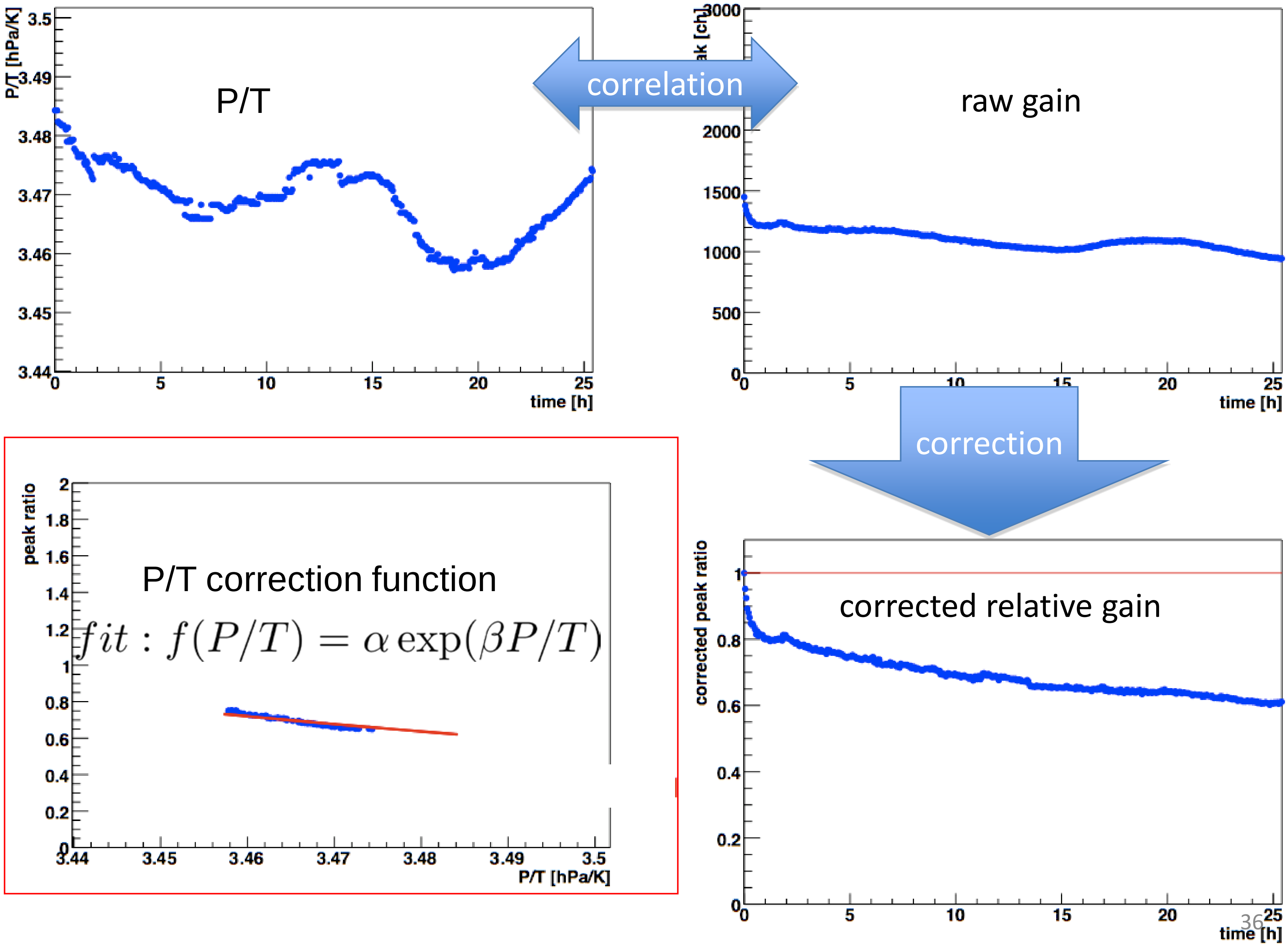
ADC spectrum

goal for of TGEM study

in consideration of TPC operation,

- **effective gain ~ 10^4**
- **long time stability of gain and resolution**

P/T correction of gain



after-treatment of C-electrode TGEM

We tried many items to make the C-electrode TGEMs work

- ethanol cleaning → ×
  - does not improve at all
- plasma etching → △
  - improves a little bit, but it's not perfect
  - does not remove burrs of carbon
- removing burrs with resist-film and/or antistatic-brush → △
  - removes burrs, but does not improve
- steam cleaning → ×
  - does not improve at all
- polyimide etching → ?
  - effects are depend on material of the insulator
  - and also depend on etching time
- change insulator (FR4/UV→CEM3) → ?
  - CEM3 TGEMs work good, but that are after polyimide etching
    (we did not check the without the etching)

We have to study more

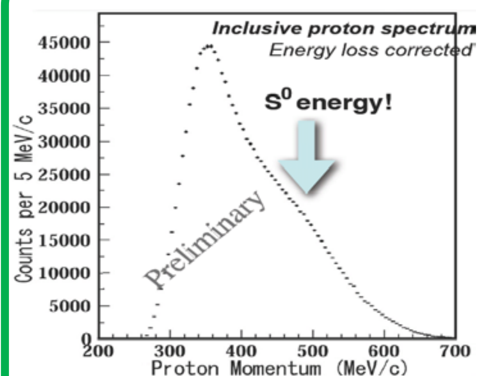
Outlook

- Nonagonal TGEMs (w/o rims and Cu-rim-30μm) and Hybrid-TGEMs for the TPC were produced, and studies have started now.

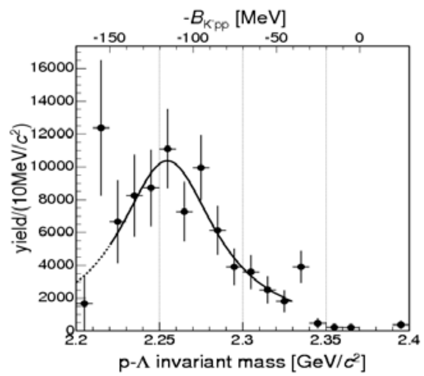
- Development of Carbon TGEMs will be continued in the year 2010.

Physics Motivation

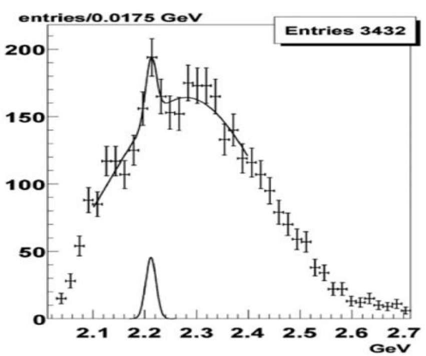
deeply-bound kaonic nuclear states exist?



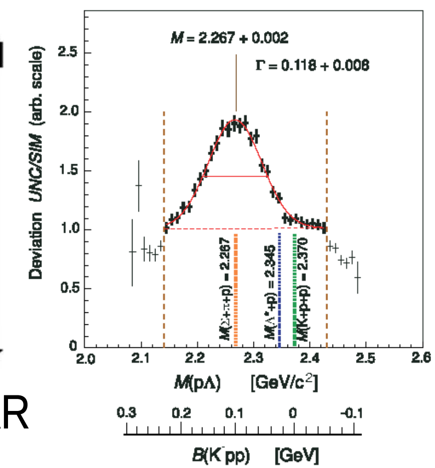
E549@KEK-PS



FINUDA@DAΦNE

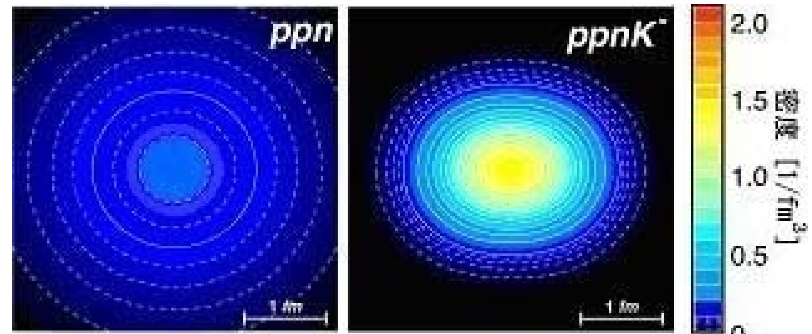


OBELIX@CERN-LEAR

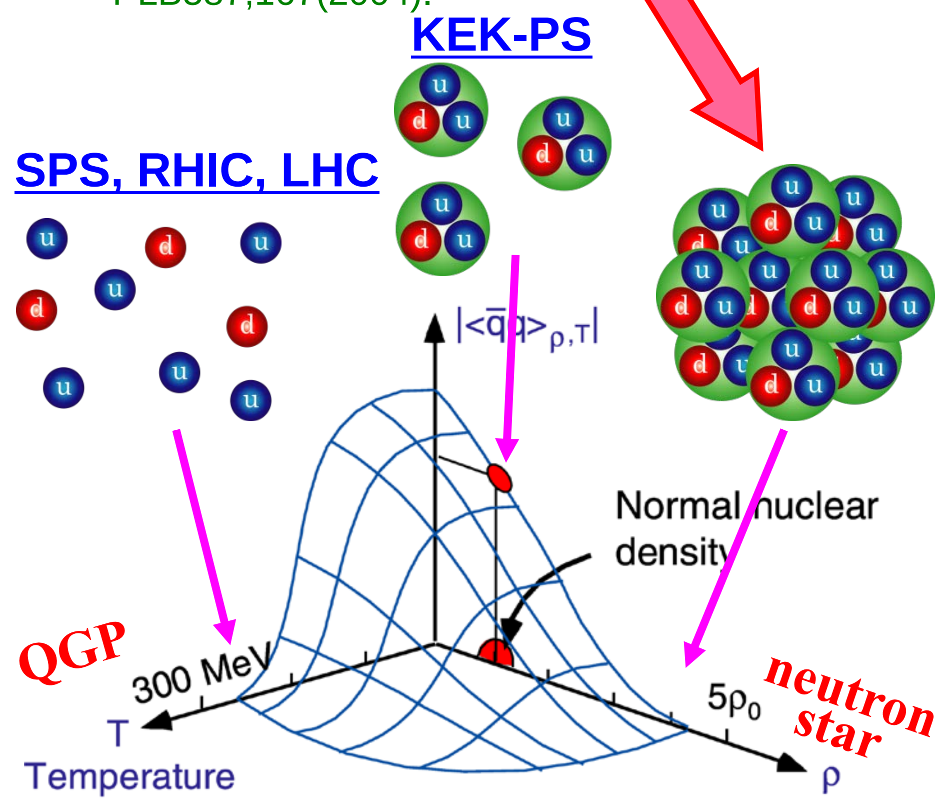


DISTO@SATUREN

We need conclusive evidence!



T.Yamazaki, A.Dote, Y.Akiaishi PLB587,167(2004).



W.Weise NPA553, 59 (1993).