Fast MRPC-TOF R&D @ U. Tsukuba

Tatsuya Chujo
(Univ. of Tsukuba)

Mini workshop on RPC at Univ. of Tsukuba, January 20, 2017

JSPS Grant:
“10 ps TOF detector R&D for high energy experiments” (FY 2015 – 2017, PI T. Chujo)

Members

- **University of Tsukuba:**
  - **T. Chujo**, **T. Nonaka** (D2), R. Aoyama (D1), T. Sugiura (D1), **K. Sato** (M1), R. Koyama(M2), **T. Ichisawa** (B4), **H. Kato** (B4)
- **Tsukuba Technology University:**
  - **M. Inaba** (pre-amp, detector design)
- **JAEA:**
  - H. Sako, S. Sato
- **KEK:**
  - K. Ozawa, K. Aoki

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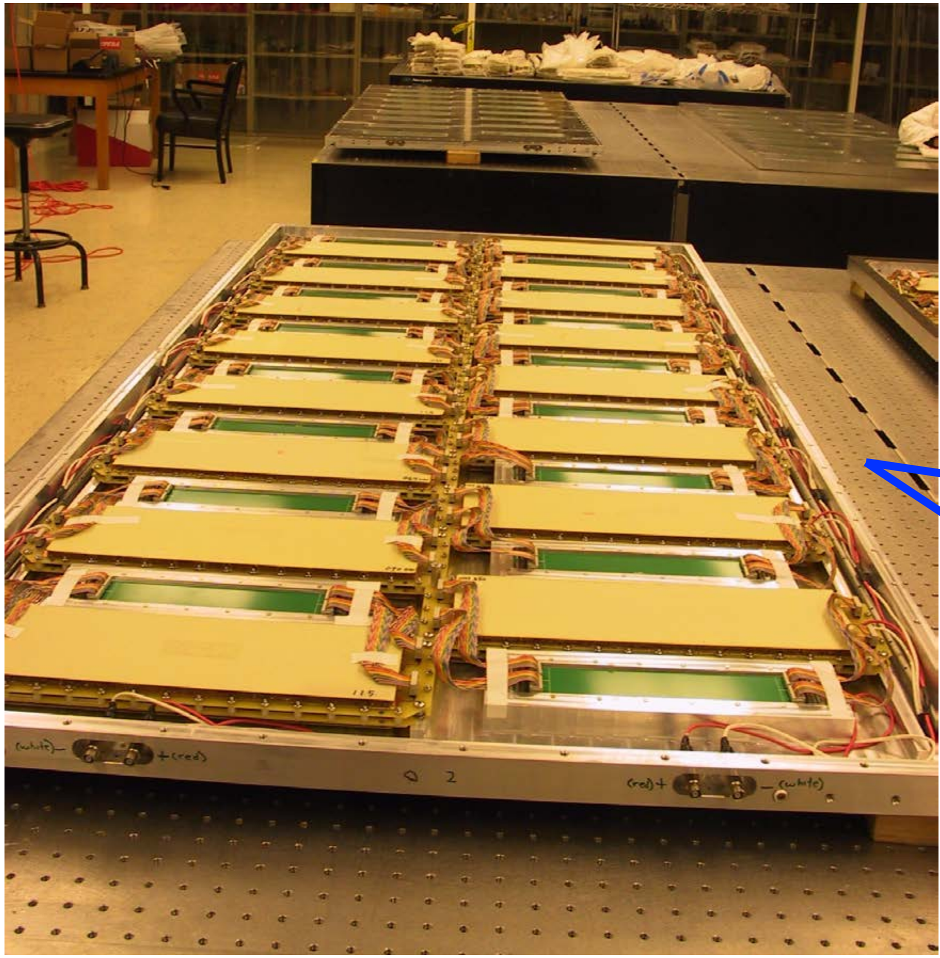
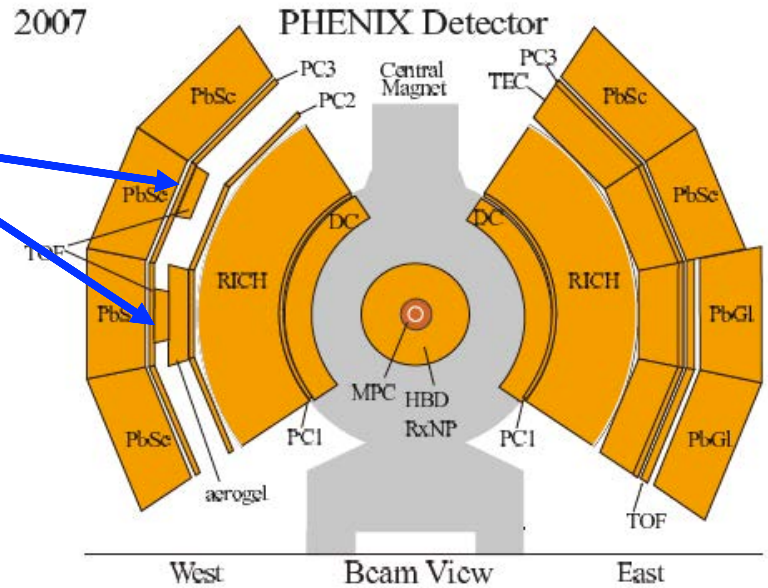
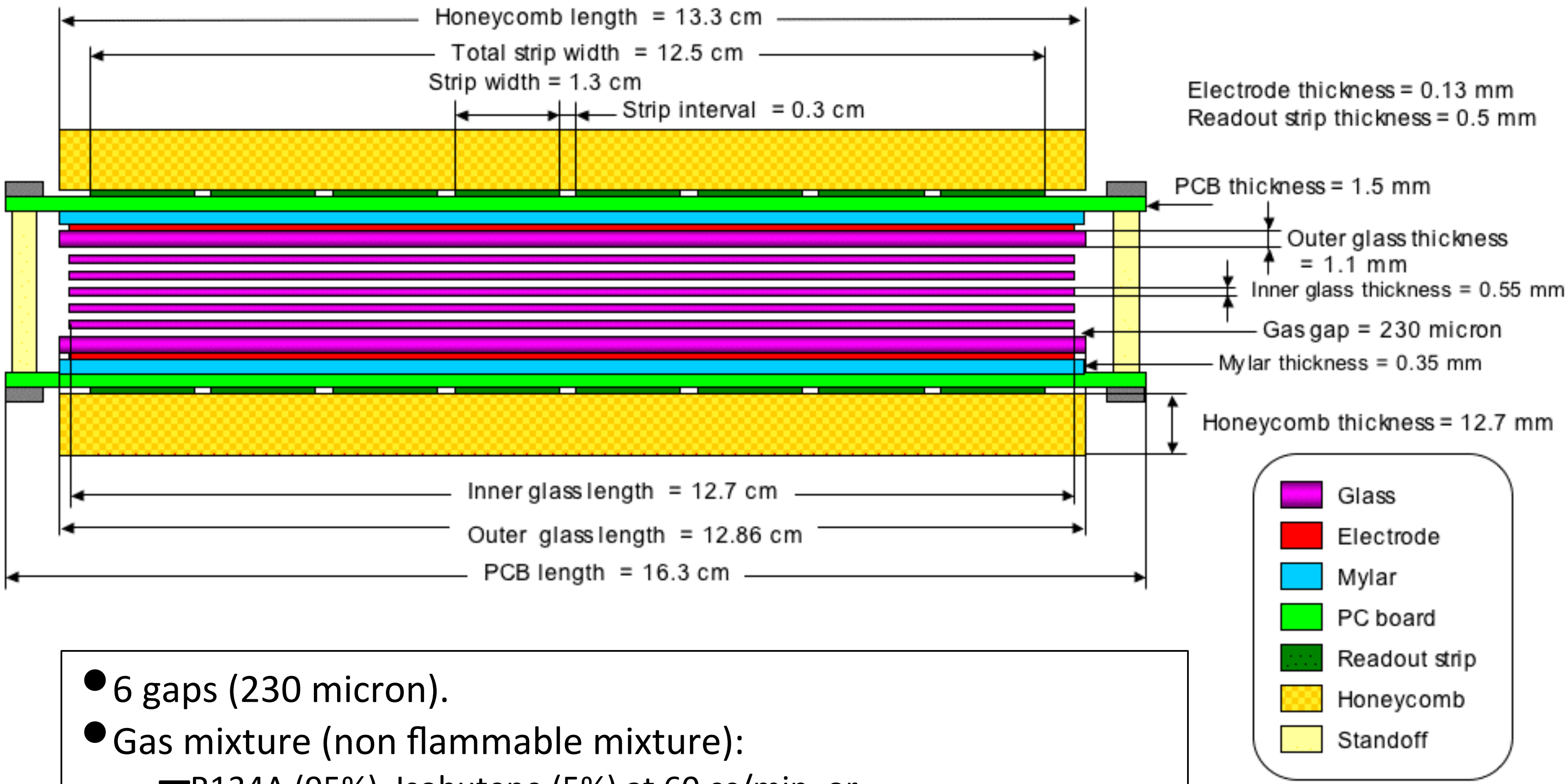
MRPC TOF (PHENIX)





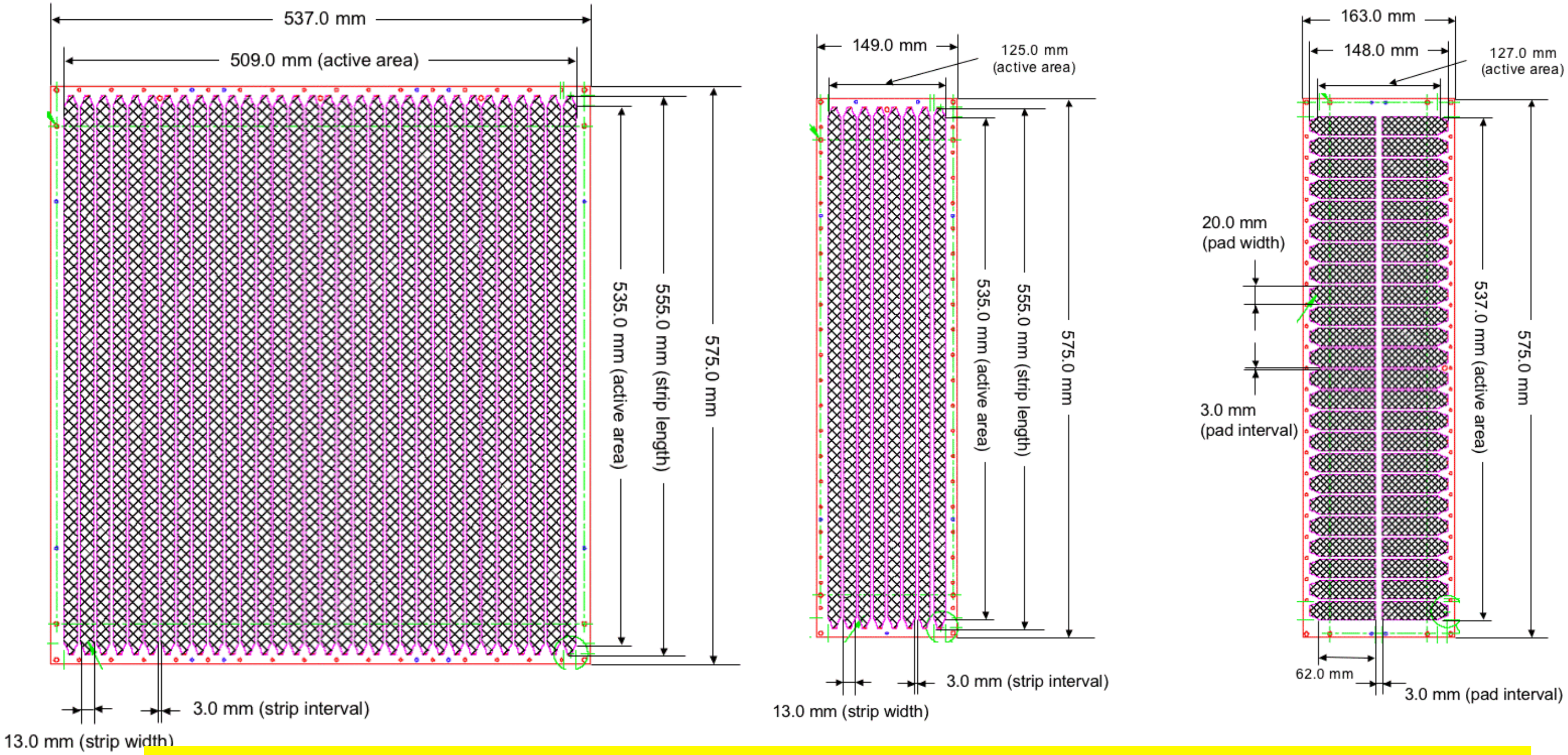
PHENIX-MRPC



- 6 gaps (230 micron).
- Gas mixture (non flammable mixture):
  - R134A (95%), Isobutene (5%) at 60 cc/min. or
  - R134A (90%), Isobutene (5%), SF6 (5%) at 60 cc/min.
- Operating HV: ±7.0 ~ 7.5 kV

3 Prototypes

PH1 PH2 PH3

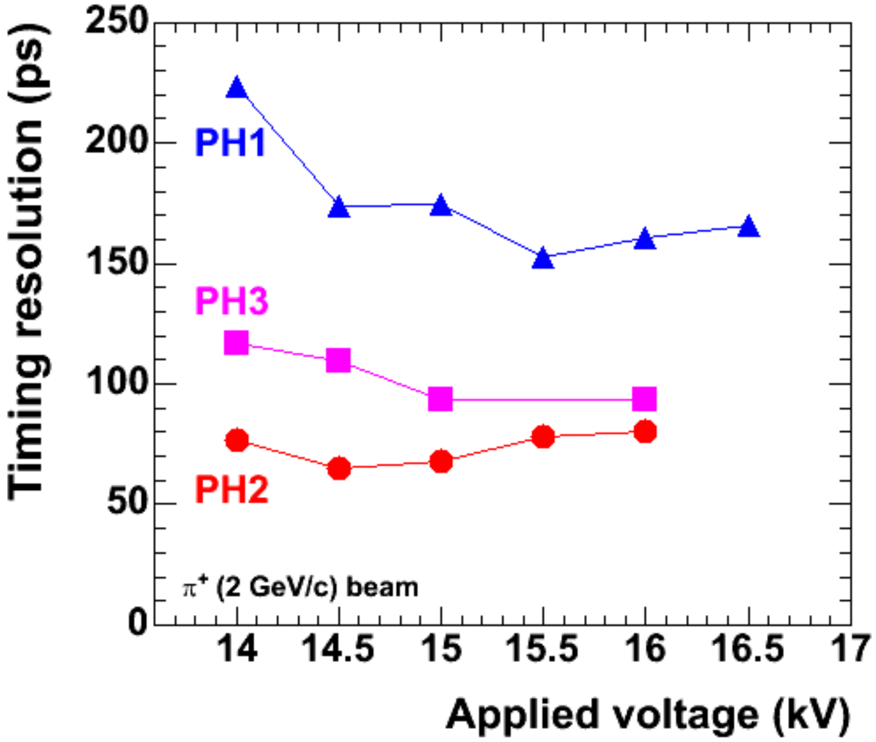


Different pad/strip design, same structure inside

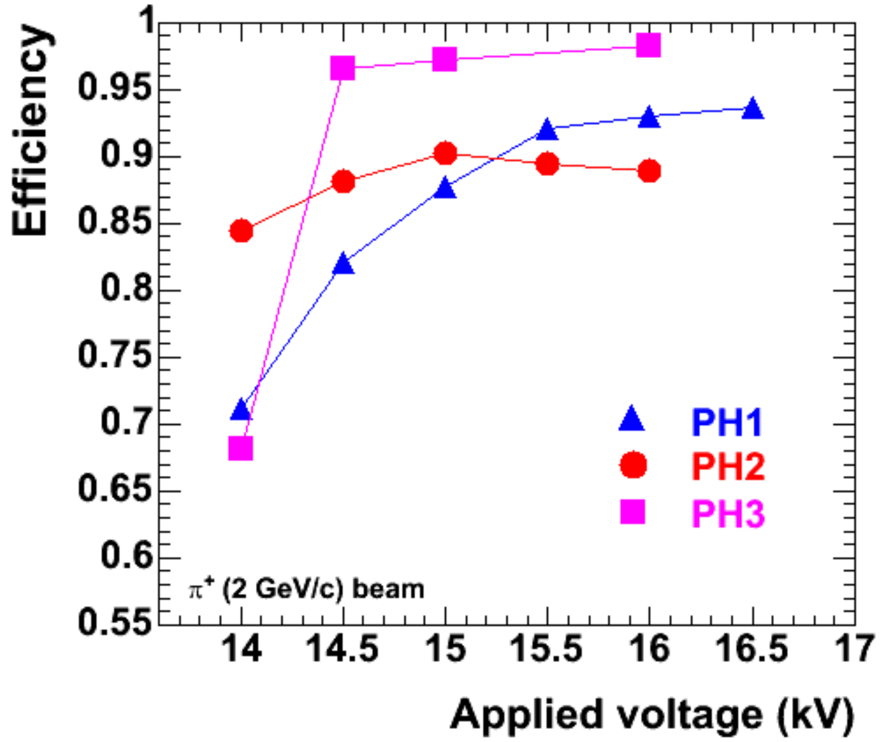
- PH1: 50.9 x 53.5 cm^2, 32 strips, readout at both ends.
- PH2: 12.5 x 53.5 cm^2, 8 strips, readout at both ends.
- PH3: 12.7 x 53.7 cm^2, 48 pads (6x2 cm^2), similar to STAR MRPC.

PHENIX MRPC TOF prototypes (results, 2004)

Time Resolution



Efficiency



- PH1: worse timing resolution (>150 ps), same efficency as PH2. Problem on uniformity of performance across the chamber. Difficulties in mechanical assembly.
- PH2: **68ps timing resolution** at optimal condition, but 90% efficiency. Solution → increase strip width.
- PH3: comparable timing resolution with PH2 (best value: 67ps), 98% efficiency.

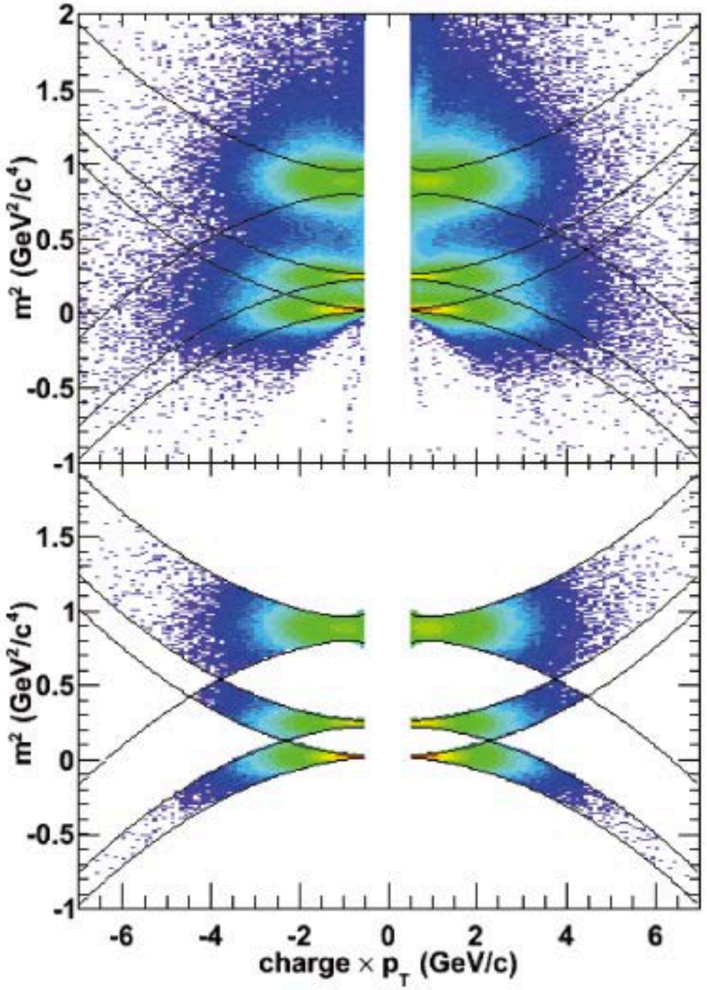


FIG. 2. (Color online) The particle identification method, m^2 vs charge × p_T for 2007 Au + Au data; the 2008 d + Au data are very similar. The solid black lines indicate the two-standard-deviation PID bands used for the cuts. The top panel shows the bands superimposed on the entire m^2 distribution; the bottom panel shows the distribution after the cuts have been applied.

PHYSICAL REVIEW C 88, 024906 (2013)

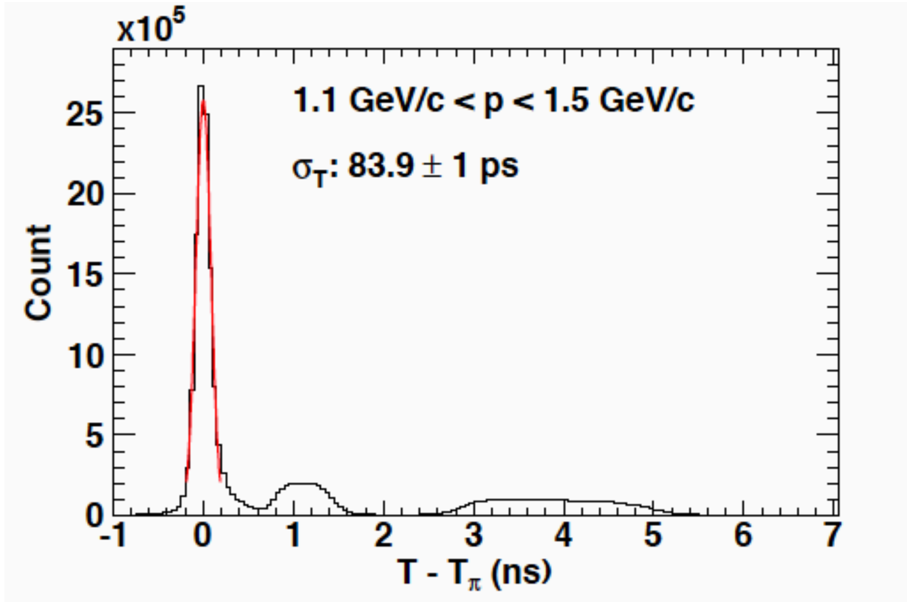


FIG. 2: (color online) Timing difference $T - T_\pi$, the difference between the measured time in the TOFw and the time calculated assuming each candidate track is a pion.

Phys. Rev. C **85**, 064914 (2012)

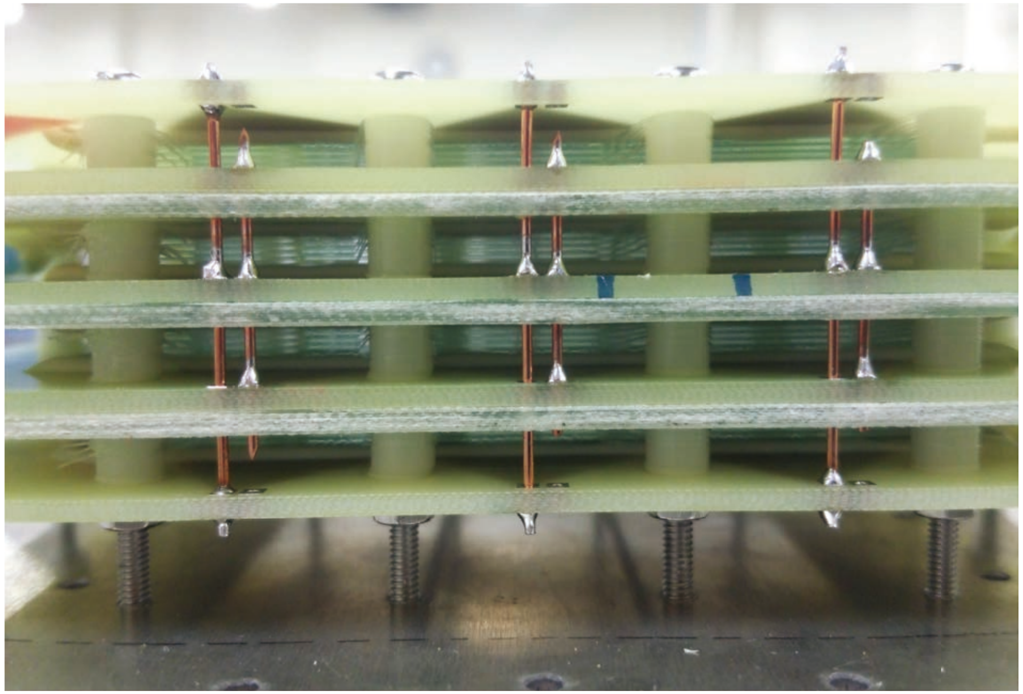
PHENIX TOF-W:

a total of 128 MRPCs, 512 strips, and 1024 readouts.
Timing resolution is **84 ps in Au + Au.**
(includes the uncertainty in the start time BBC)

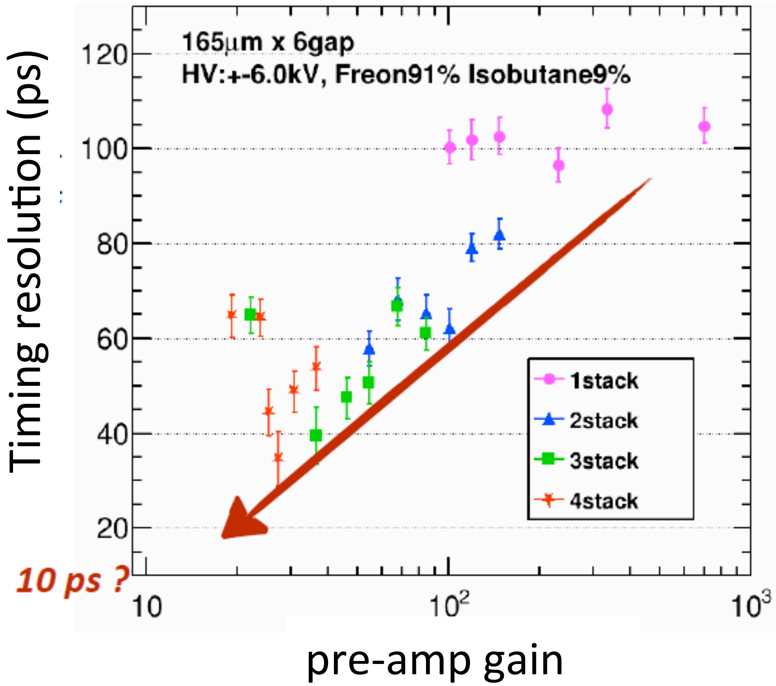
2. 4 Stuck MRPCs R&D w/ cosmic rays @ Tsukuba

1. Reproduce a good timing resolution 20-40 ps by 4 stuck MRPCs.
2. Optimize the parameters (# of gas gaps, gas gap width, etc.)
3. R&D for the J-PARC Heavy Ion project (30 ps TOF for hadron and muon ID) & potential use for J-PARC E16.
4. Extensive study with cosmic rays.

4 stacks MRPC in Tsukuba (2014-)



4 stacks MRPC (6 gaps x 4)
T. Nonaka (U. Tsukuba, 2015, master thesis)



T. Nonaka

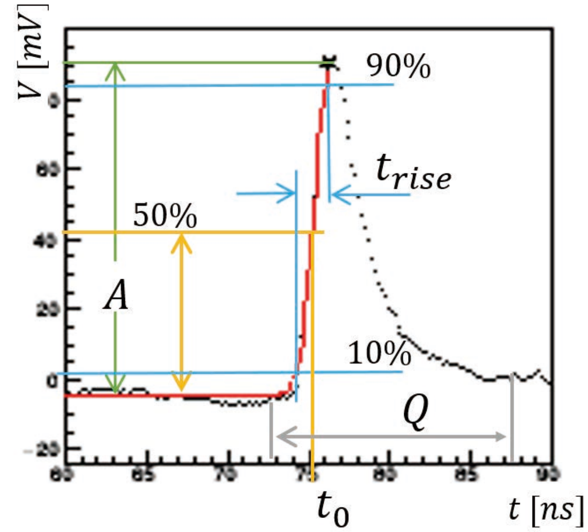
Approaching to 30 ps timing resolution, importance of pre-amp gain tuning.
read out system: DRS4 evaluation board (ver. 4)
Current best & reliable value of timing resolution of this type: **47.5 ps (cosmic ray)**

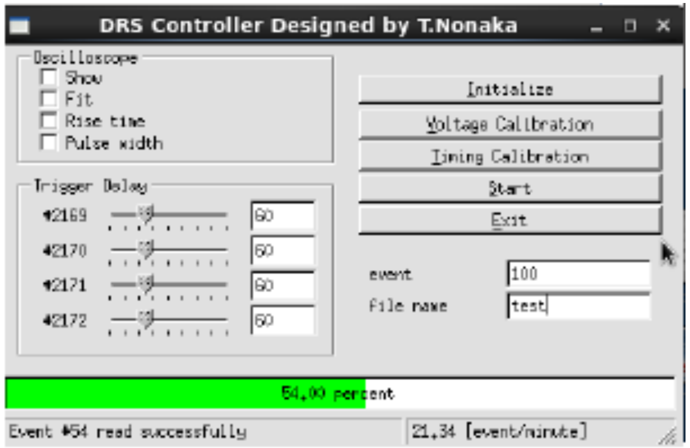
Readout system (DRS4 ver.3)

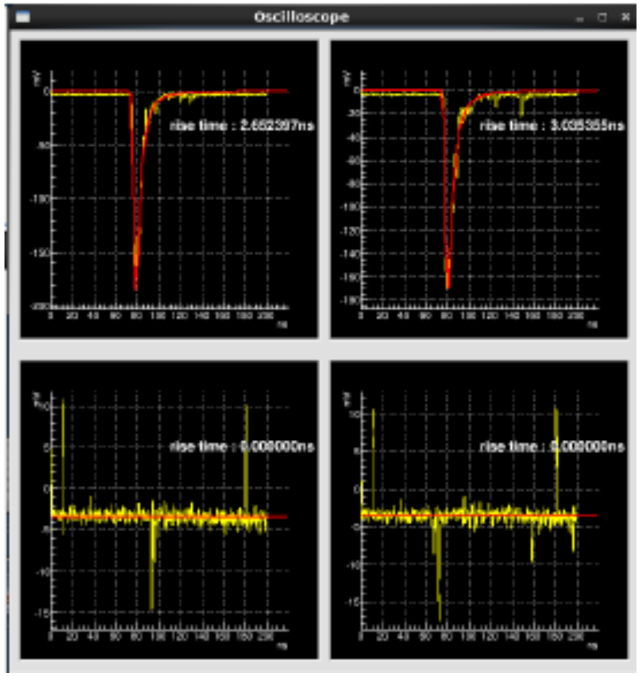
T. Nonaka, Master thesis (2015, Mar.)

DRS4 evaluation board
(4ch x 3, 5 Gsa (200 ps sampling), switched capacitor array, PSI).

MRPC pulse measured by DRS4



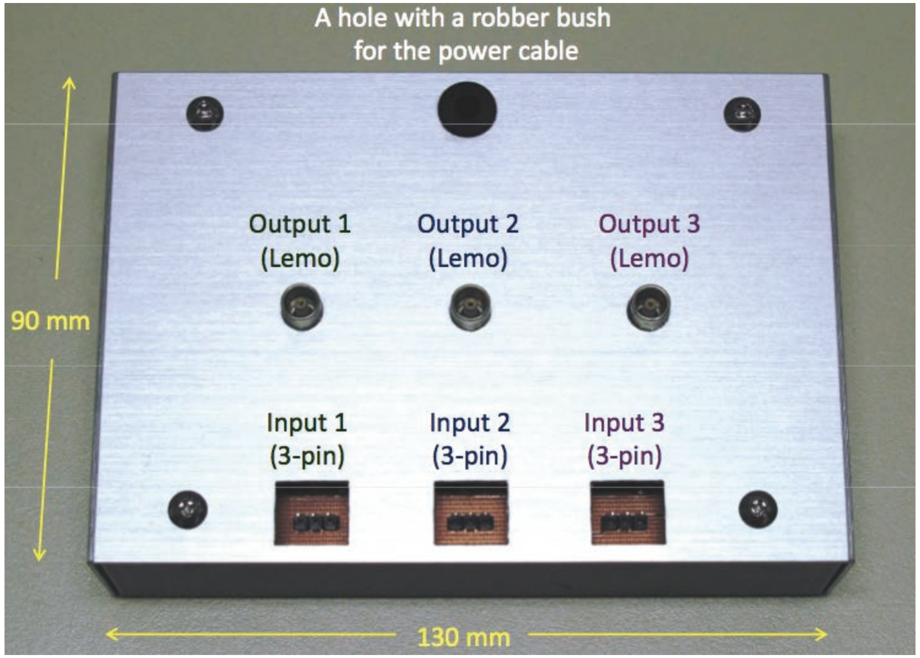


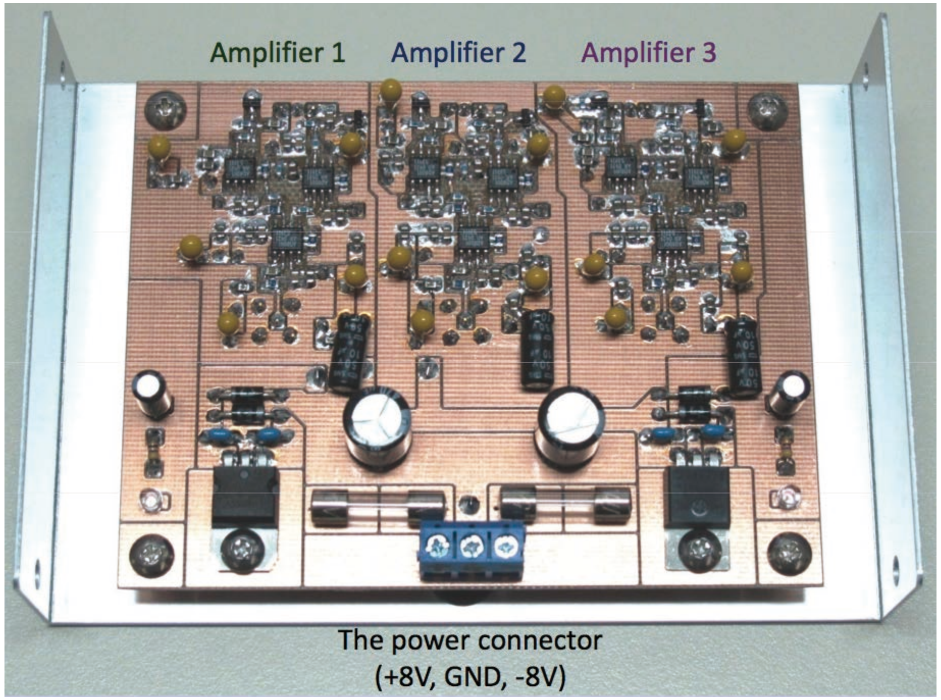


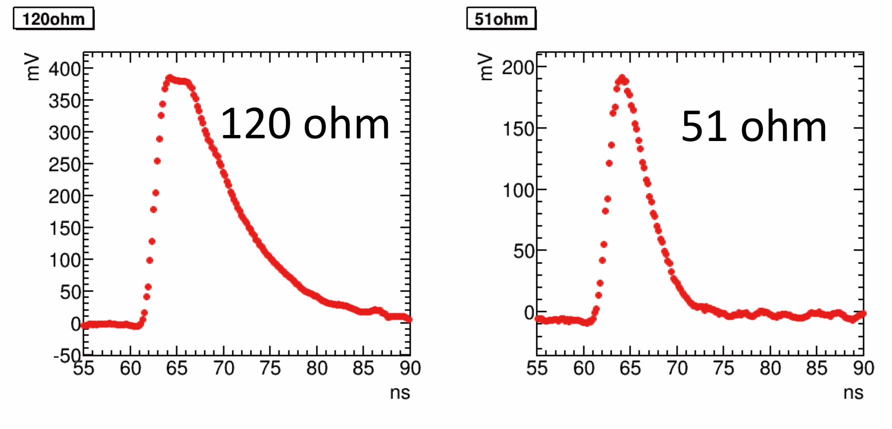
DAQ GUI for DRS4 (T. Nonaka)

Preamplifier (M. Inaba)

Used +/- differential amplifier
- Importance of optimization of gain and impedance matching

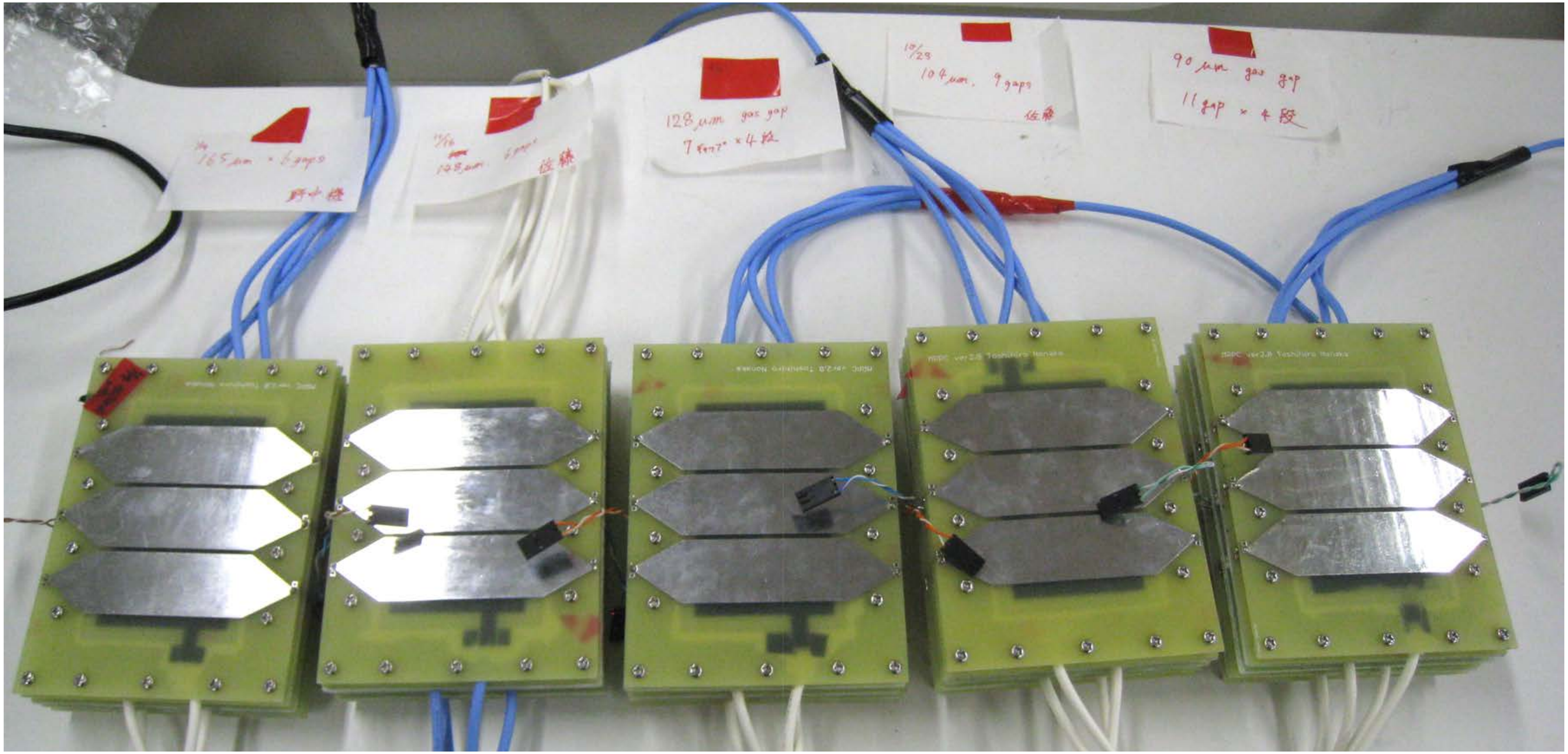






← impedance matching dep. on pulse shape

New 4 stack prototypes in Tsukuba for ELPH test beam (K. Sato, R. Koyama, T. Nonaka, R. Aoyama, T. Sugiura, H. Kato: 2015-2016)



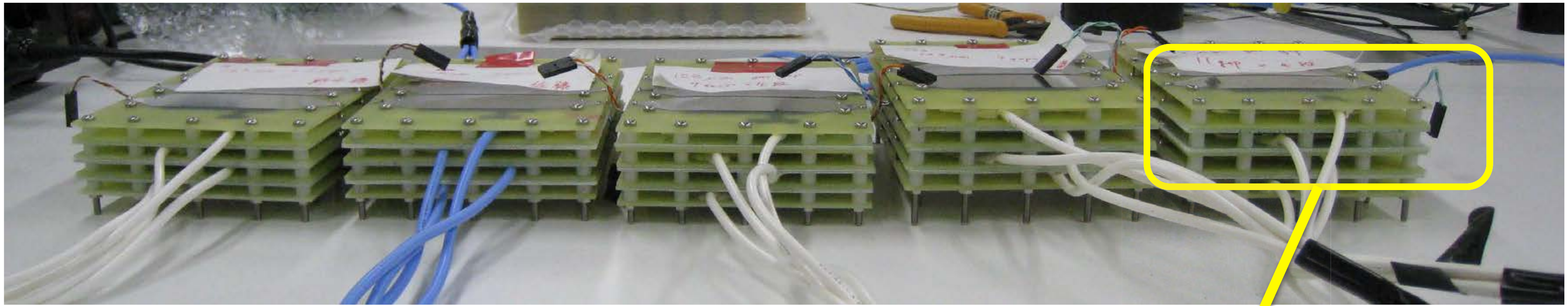
165 micron,
6 gaps

148 micron,
6 gaps

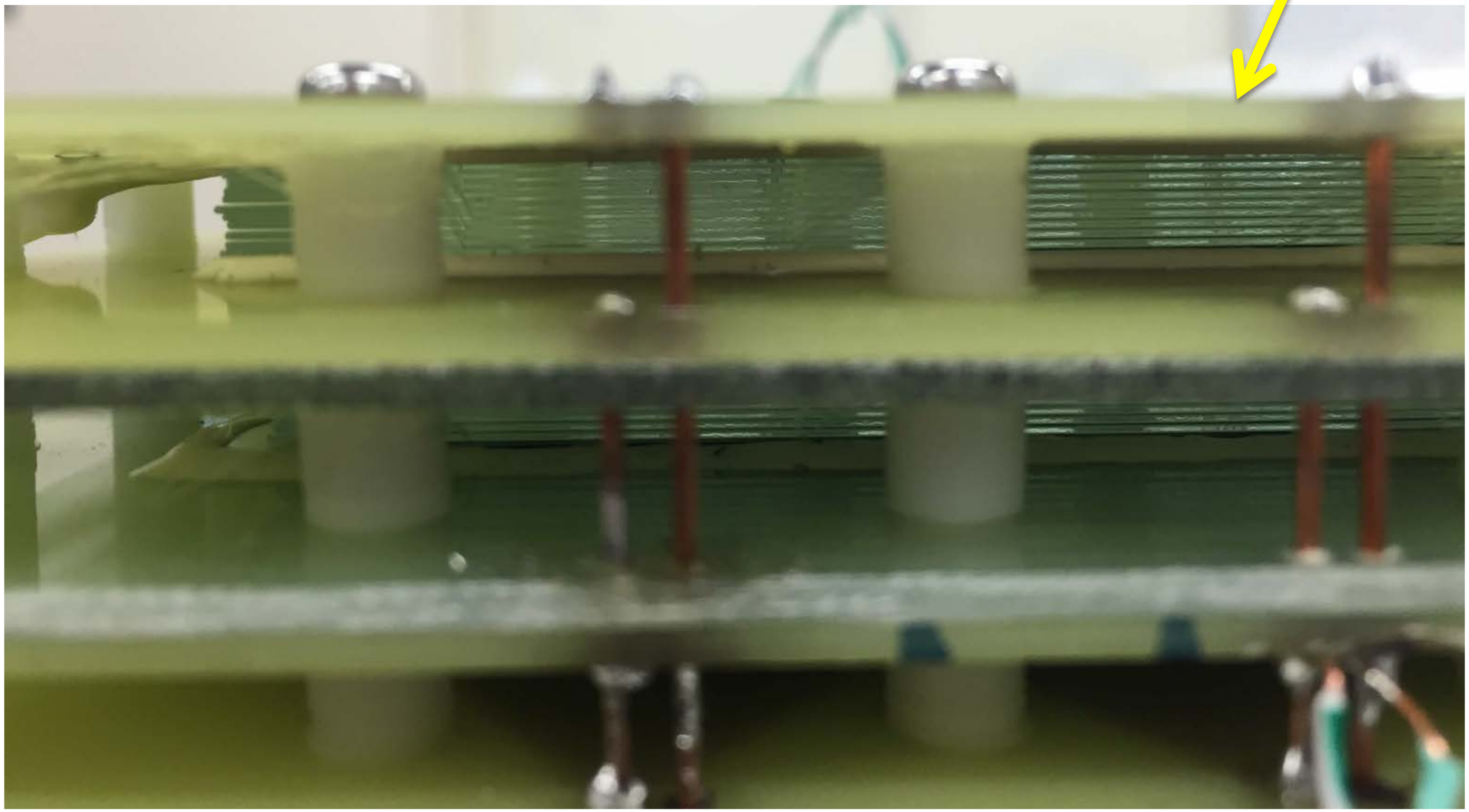
128 micron,
7 gaps

104 micron,
9 gaps

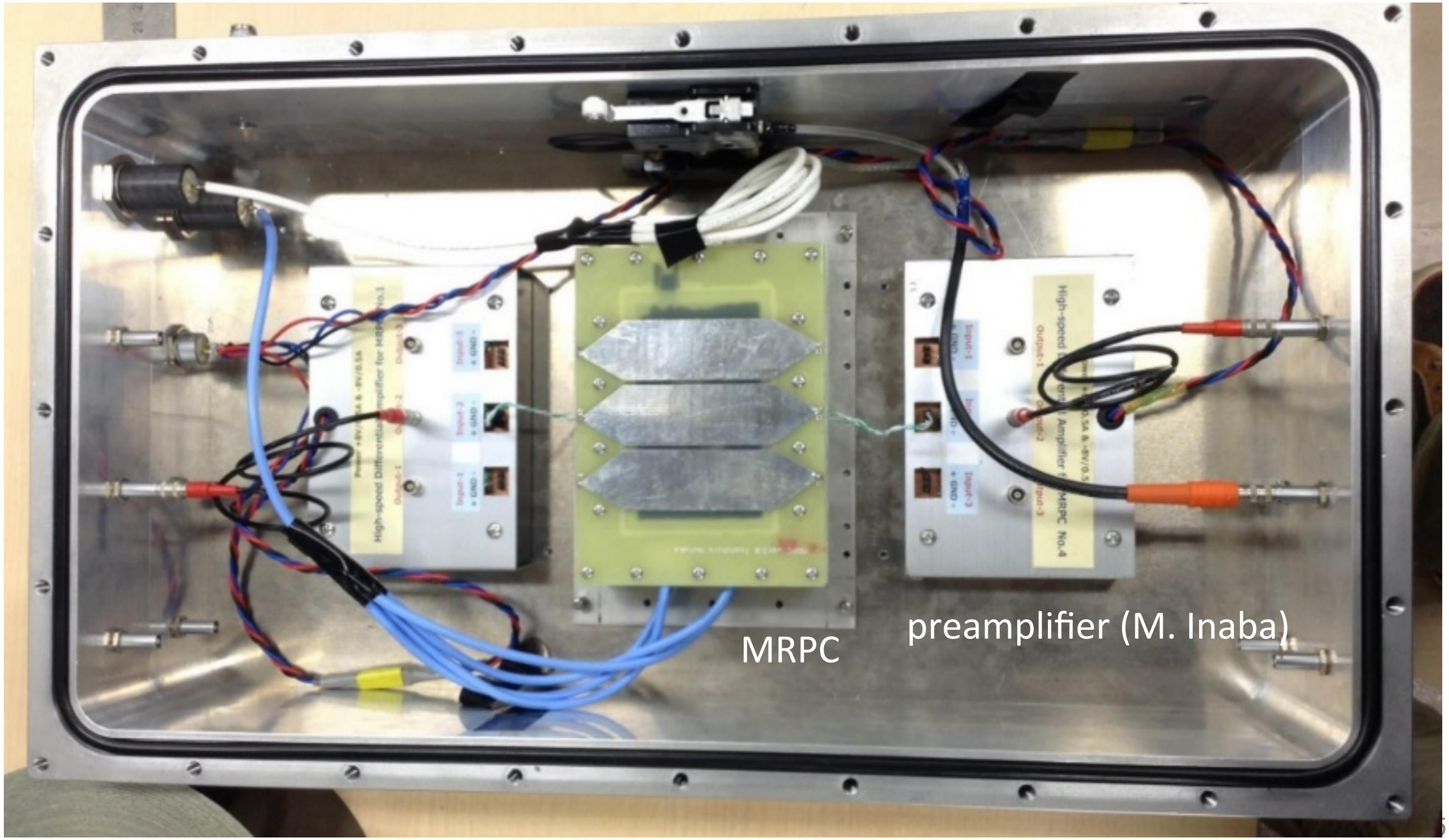
90 micron,
11 gaps



90 micron,
11 gaps



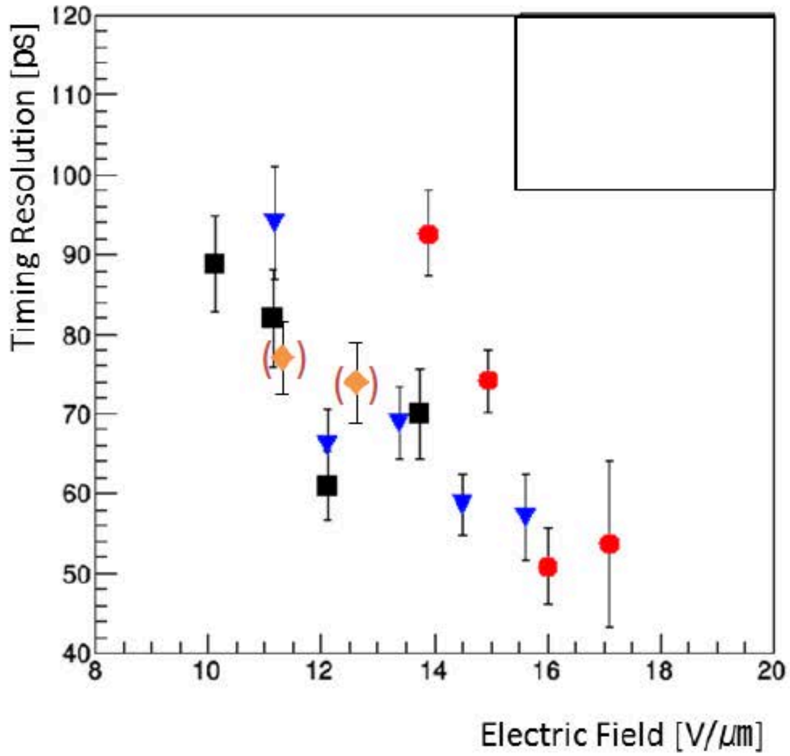
Typical setup for MRPC



4 stuck MRPC results by cosmic rays

K. Sato

Shown @ JPS2016 spring meeting (K. Sato)



Gas gap width

165μm

128μm

104μm

R134a : SF_6 = 20 : 2 mL

Good signal : Streamer = 1 : 1 at the best timing resolution

148μm

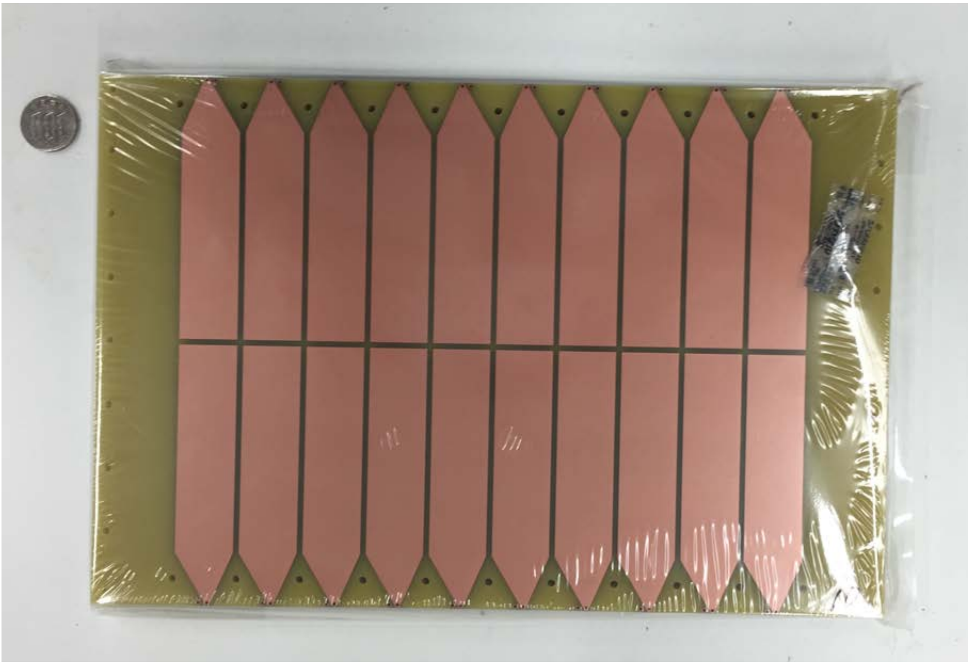
(July 19, 2016)

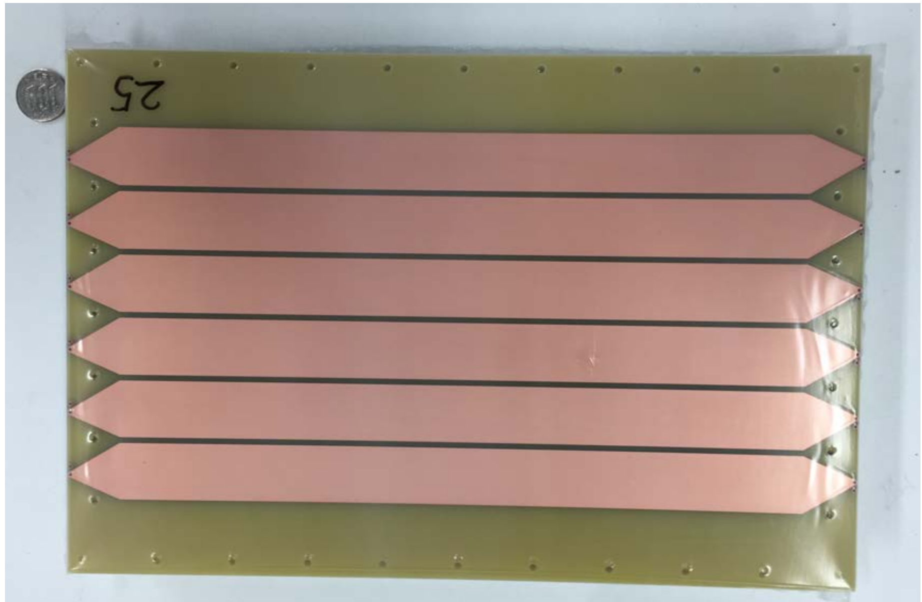
R134a : SF_6 = 50 : 5 mL

Good signal : Streamer = 97 : 1%

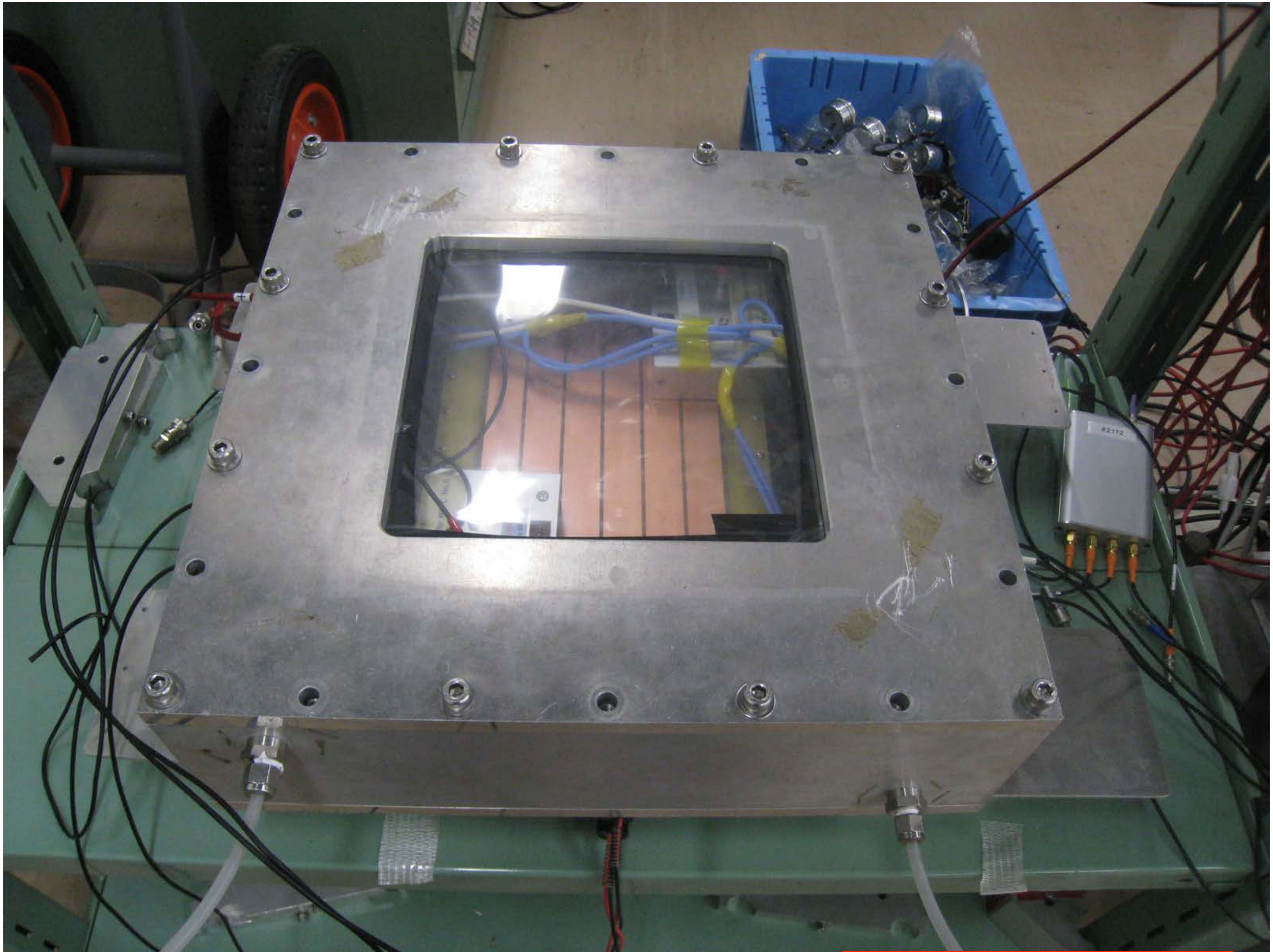
* 165 um MRPC: tested with beam at ELPH (2016)

Medium area MRPC prototypes





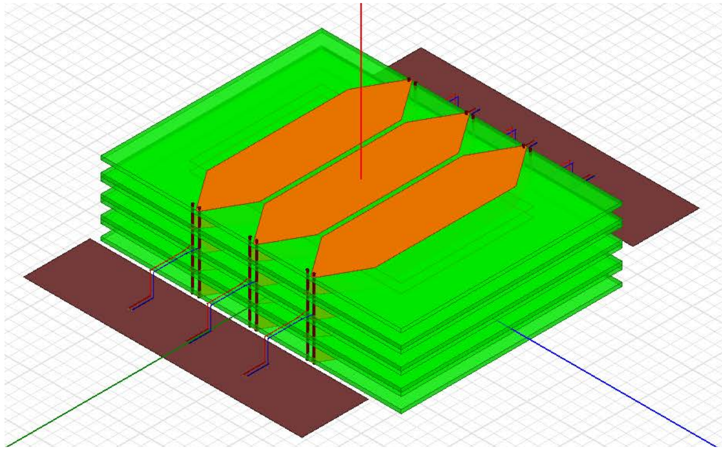
- Two types (pad and slat) PCB have been made.
- 20 cm x 30 cm PCB size
- built **4 stack MRPCs** for each time, under the test with cosmic rays.
- to be tested at ELPH.
- It could be a prototype for E-16.



@ U. Tsukuba lab.

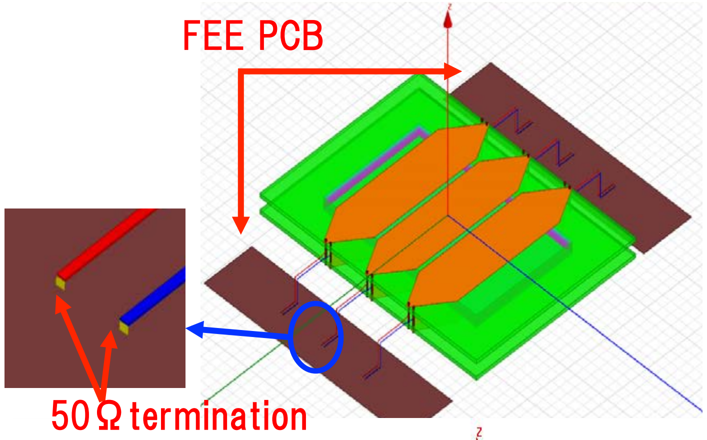
3. Signal properties (collaboration w/ SONY)

- SONY Global Manufacturing & Operations Co. (SONY GM&O)
- Modeling MRPC detector
  - Electromagnetic field cal. by solving Maxwell eq. numerically.
  - Consulting of fast signal propagation in electrodes, cables, impedance matching, and actual test.

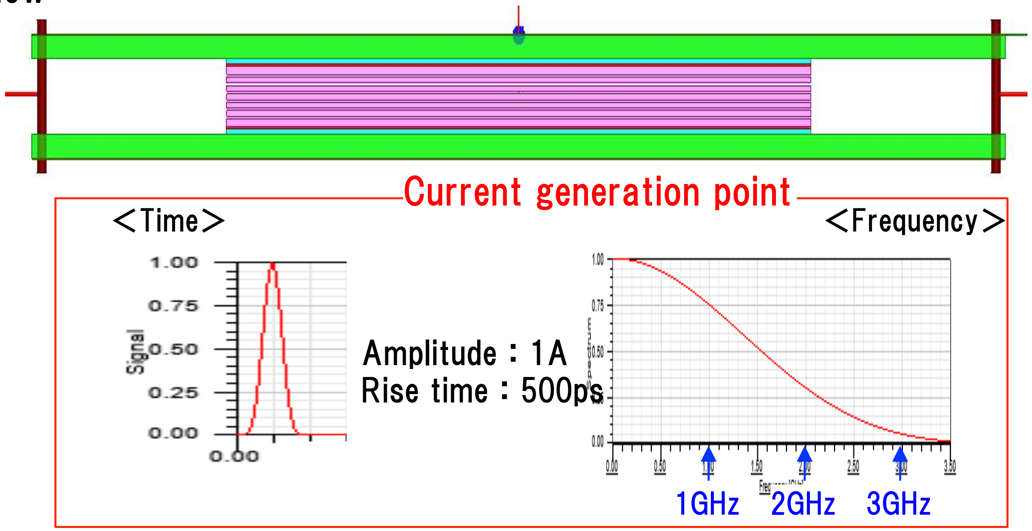


Electromagnetic field cal. Model (SONY)

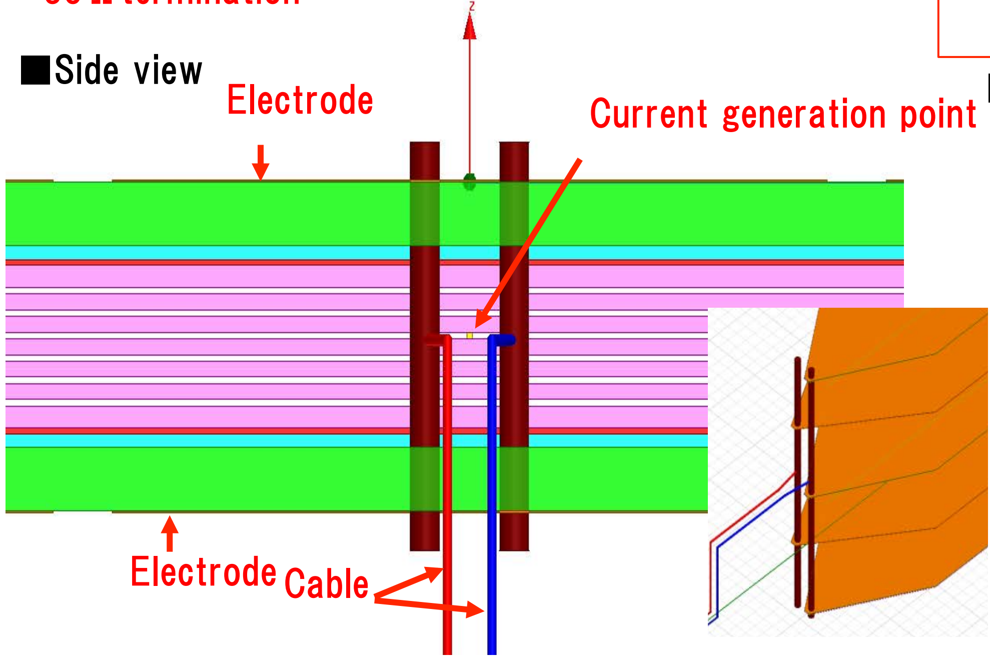
HFSS analysis, MRPC-3D model



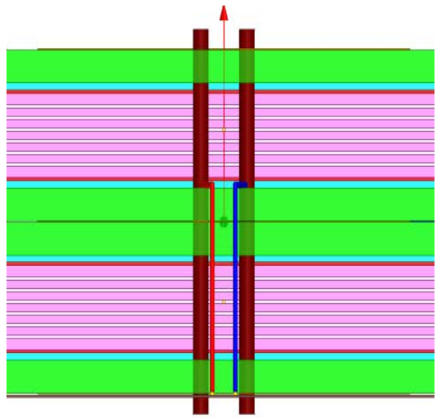
■Side view

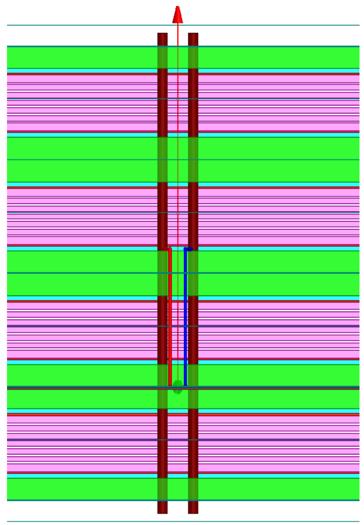


■Side view



■Side view (2stack,4stack)

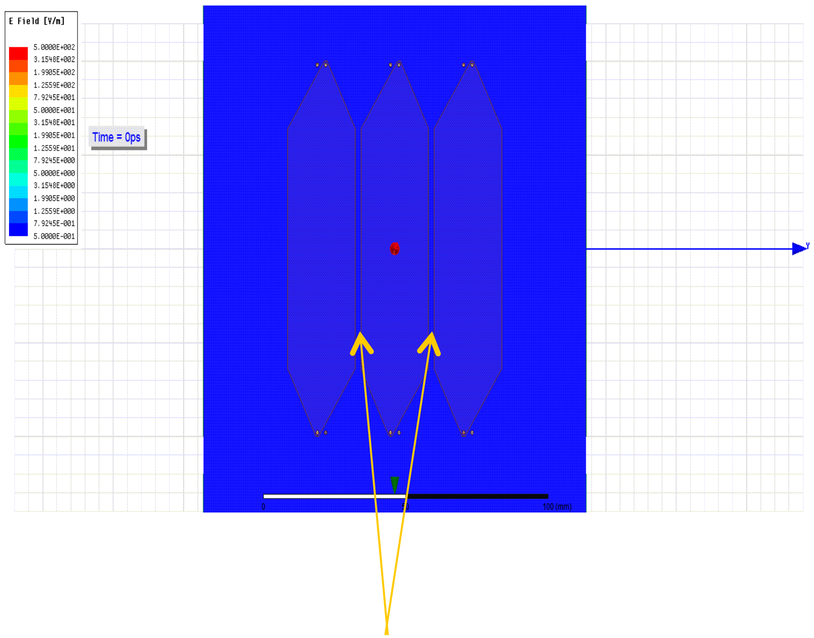




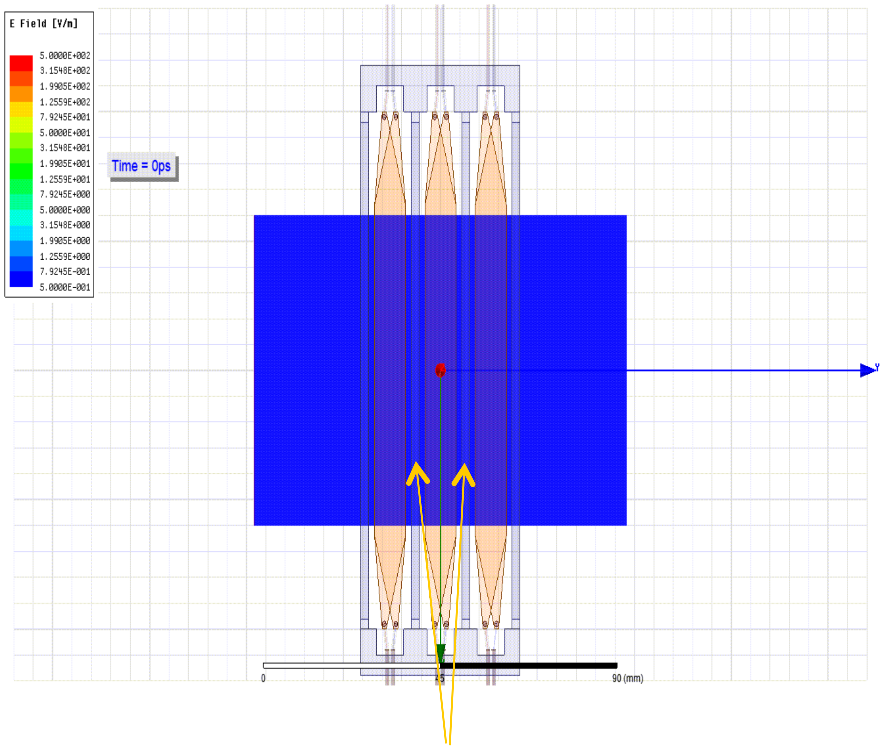
An example: proposed modifications (SONY)

Electric filed near electrodes （as a function of time）

Default



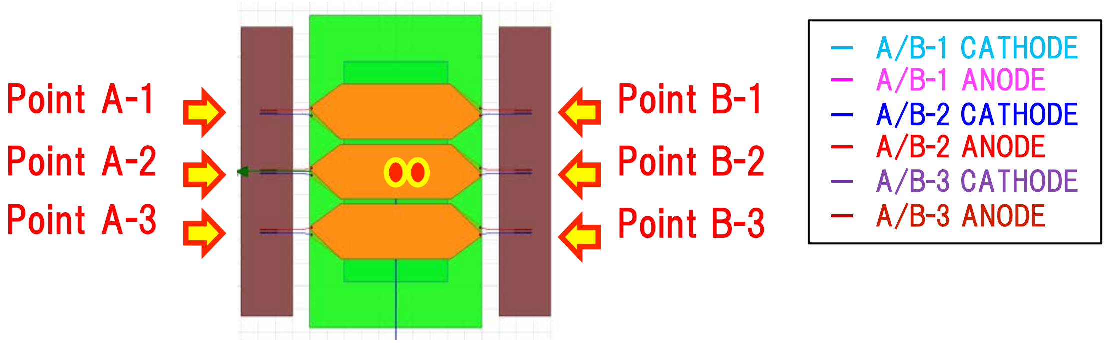
Modified (Ref. conductor)

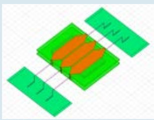
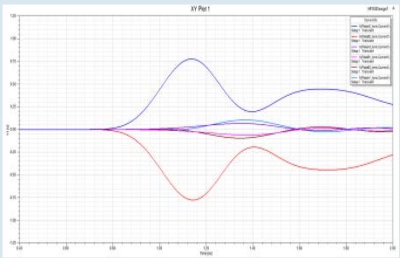
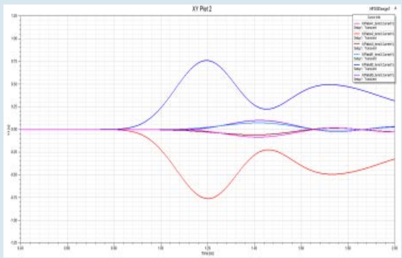
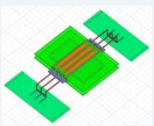
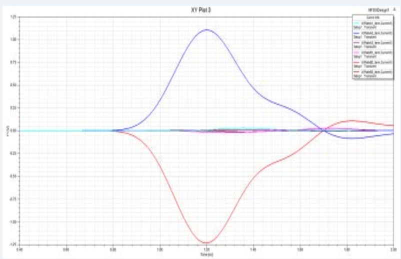
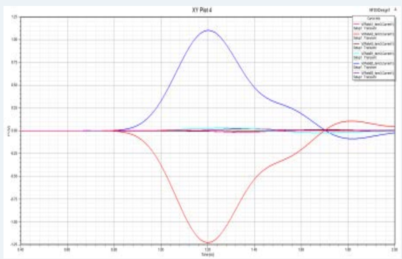


high density of electric field on the edges of electrodes
⇒interference

Ref conductor, reduce the dispersion of electric filed⇒small interference

Example: Pulse response



	A side	B side
Default 		
Modified ① 		

Merit

・Lager amplitude
・Reduction of reflection
・Reduction of interference between adjacent electrondes

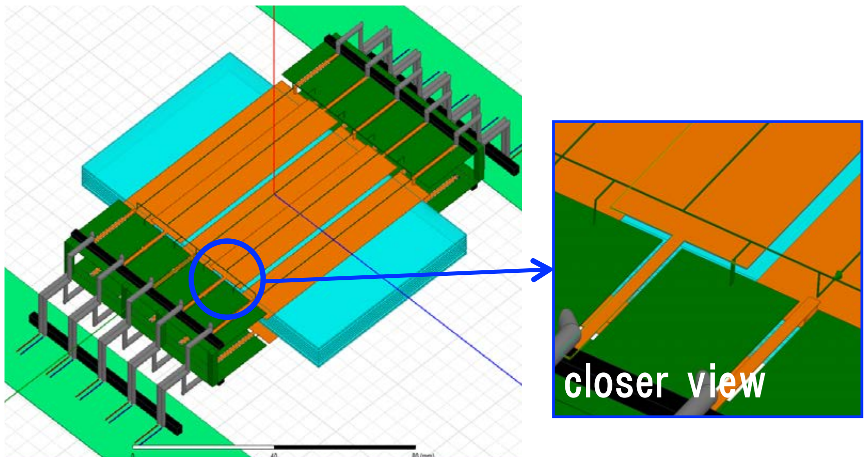
Demerit

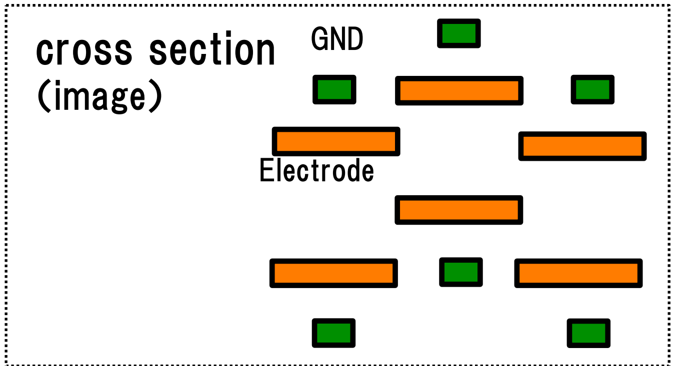
・Reduce electrode area
※ width 24mm⇒8mm
➔ reduction of efficiency.

Proposed modification（Dec. 2015）

Plan ①: Multi layer PCB

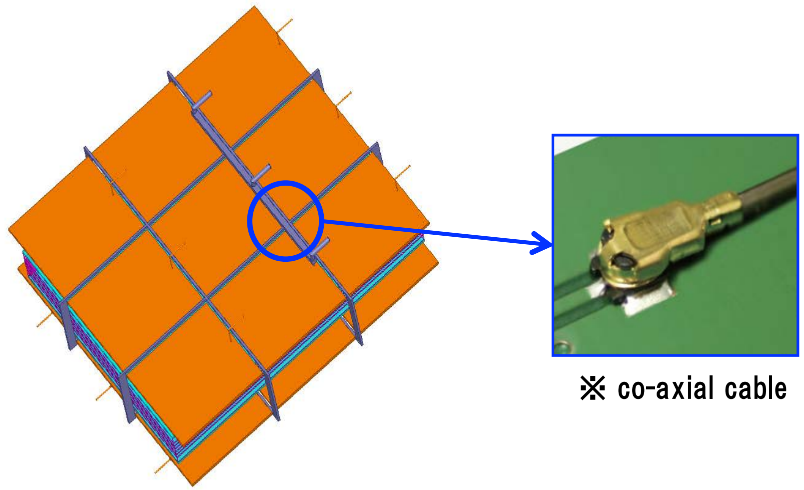
- Electrodes in the different layer of PCB
- GND above electrodes
- Add current on near-by electrodes (by a different circuit)



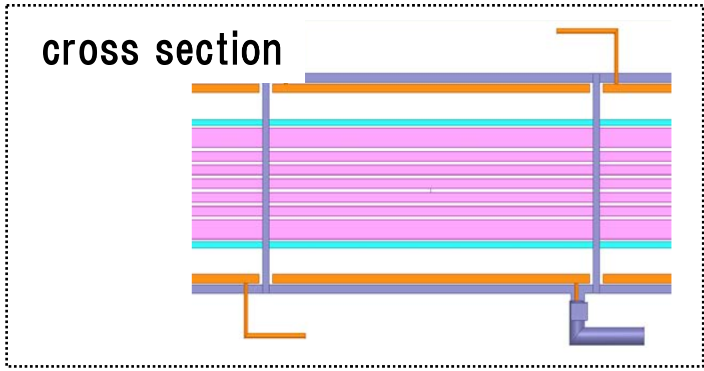


Plan ②: Patch structure

- electrode pad: 24mm×24mm
- put co-axial connector and cables on each pad



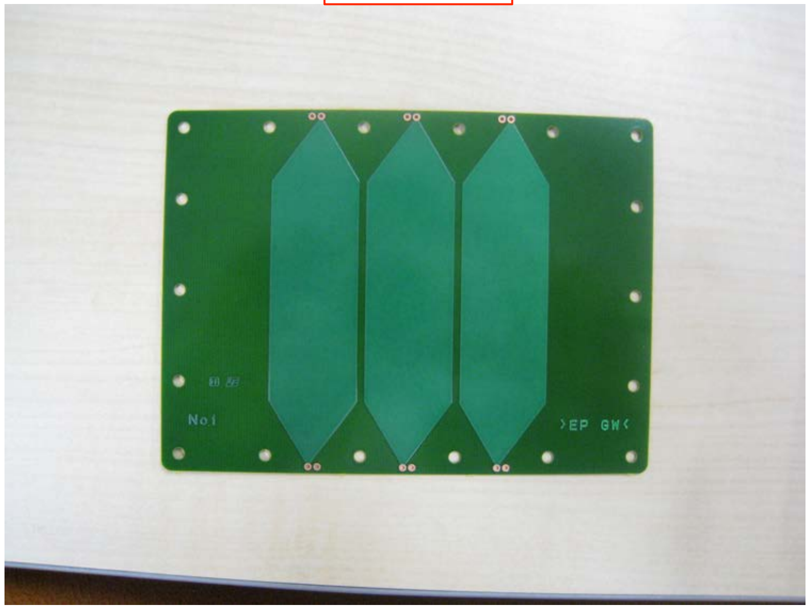
※ co-axial cable



Design considerations

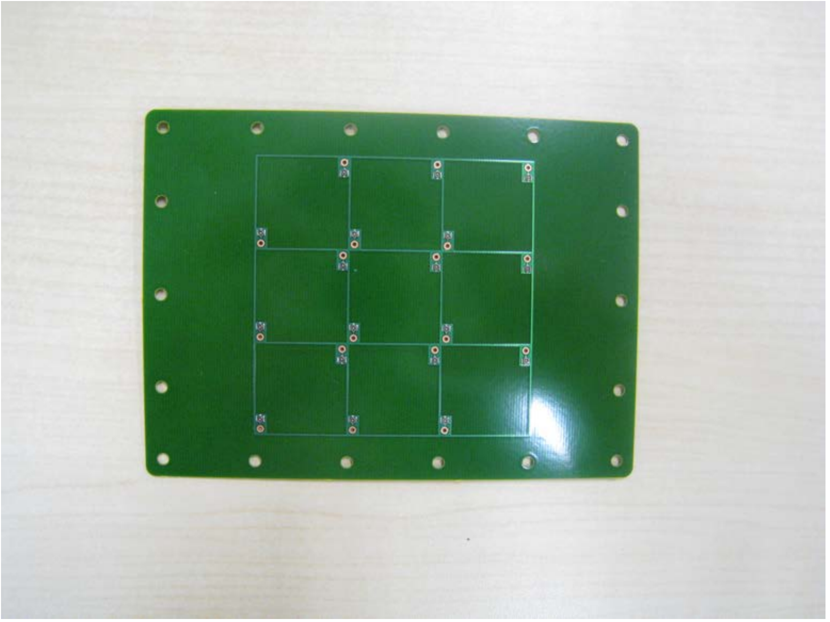
- Grounding, signal reflection, impedance matching, preamp design.
- Two prototypes has been tested at ELPH beam test in Nov. 2016, together with the planed MRPC prototypes (small and medium sizes).

Default

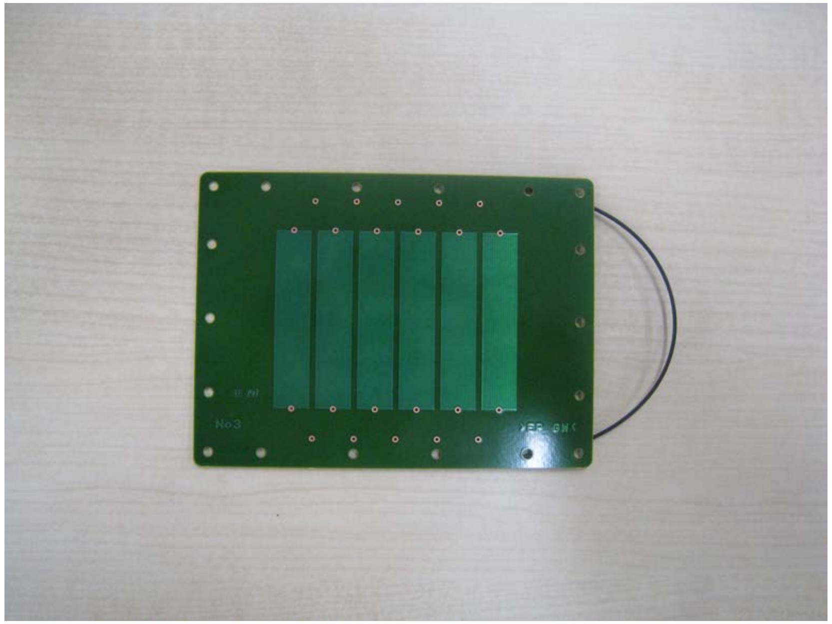


Small slat

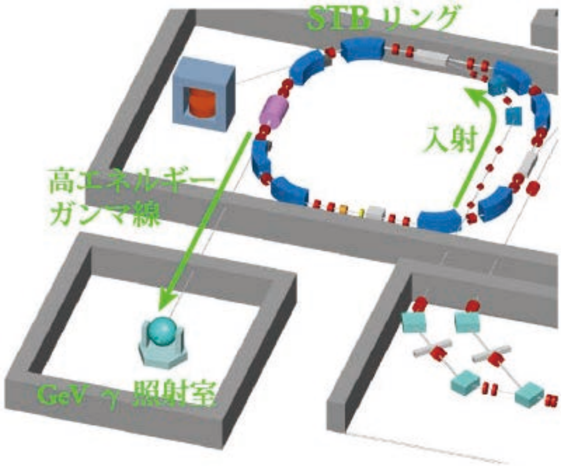
Patch

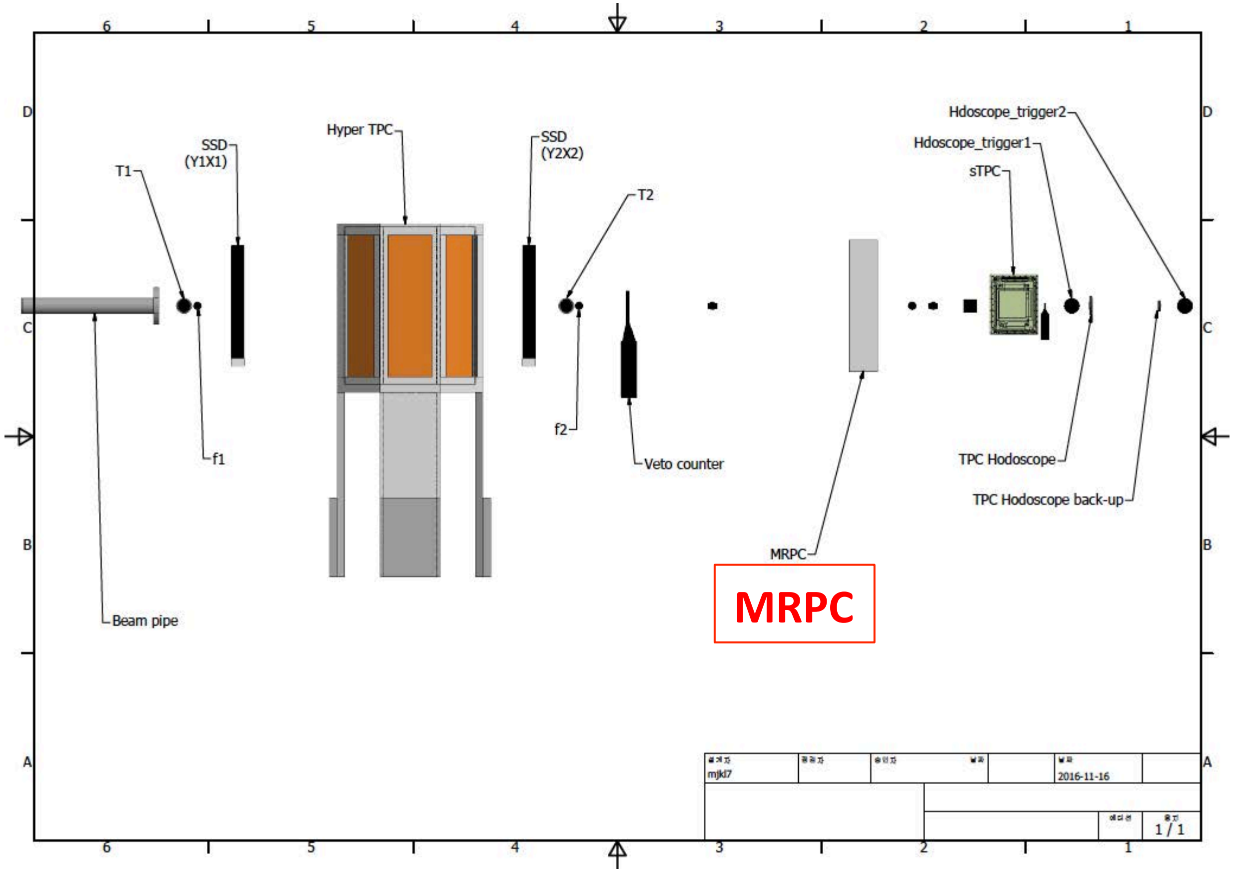


Multi-layer w/ GND (for current sum)



4. Test beam experiment in 2016 @ ELPH



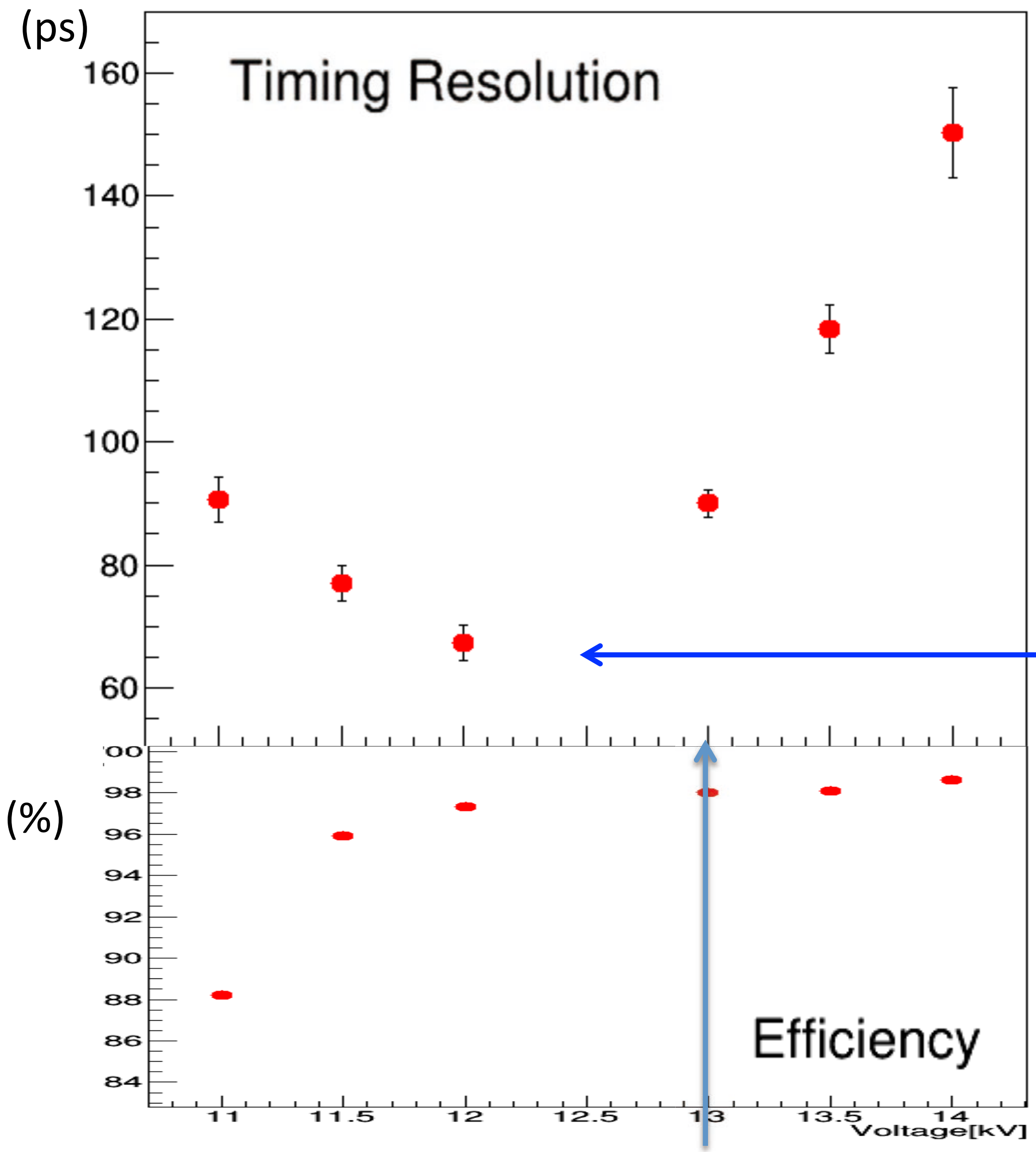


GeV γ beam line @ ELPH (U. of Tohoku)

- positron beam @ 0.9 GeV
- Tested on Nov. 7-9, 2016, w/ JAEA group (GEM TPC)

4 stuck (165 um) MRPC with beams

K. Sato



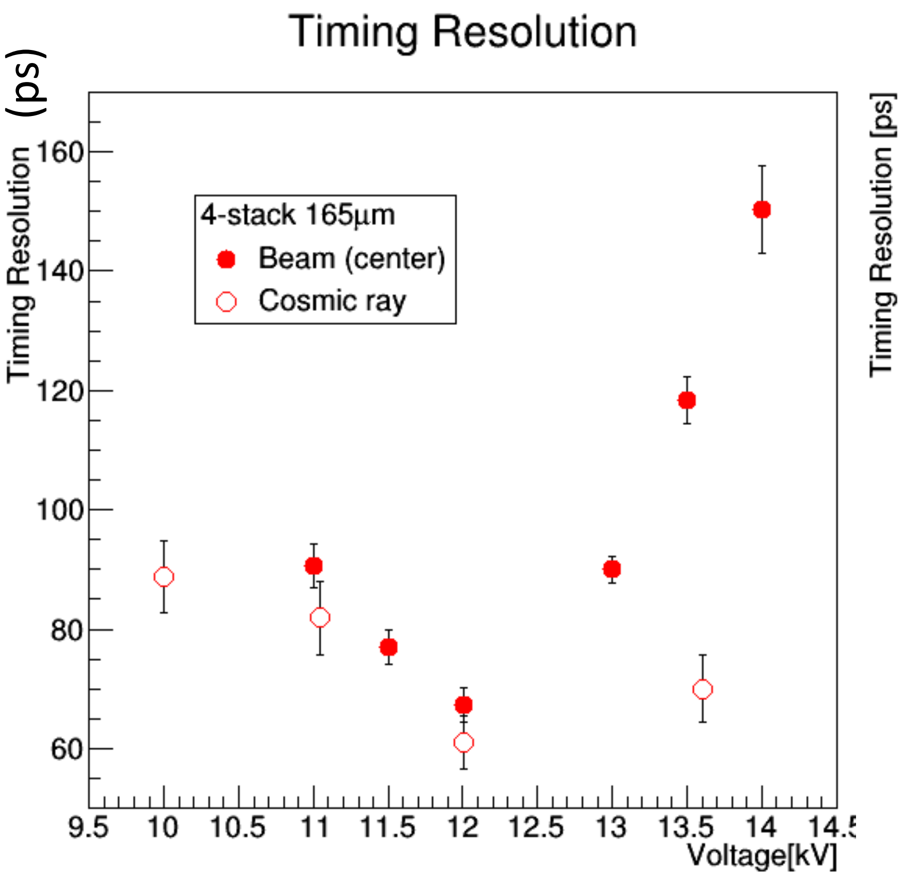
Gas mixture and flow:
- R134a 50 ml/min
- SF6 5 ml/min (9.1%)

Best timing resolution:
- 67.4 ± 2.8 ps @ 12.0 kV

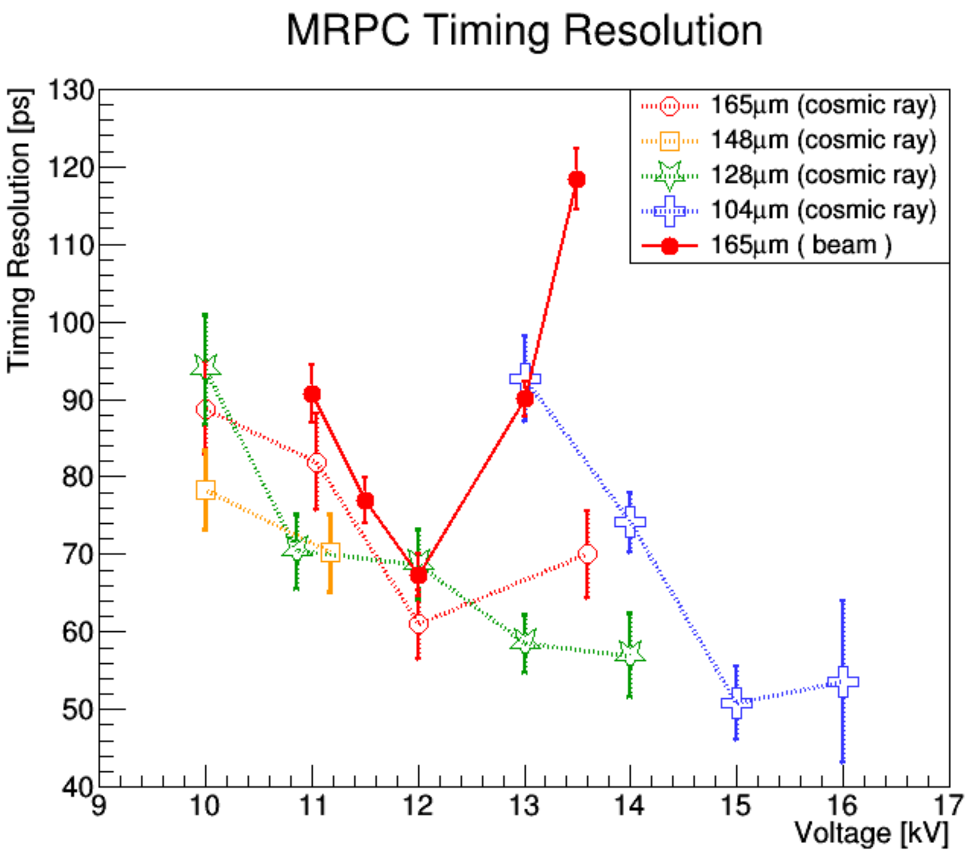
affected by streamers >13 kV

4 stuck (165 um) MRPC with beams

K. Sato



a) Comparison w/ cosmic ray measurements



b) Comparison w/ other types (cosmic)

- Consistent with the results with cosmic

- Try 104 micron with beams (next step)

T. Ichisawa

Medium scale MRPC: 4 stuck (165 um) MRPC with beams

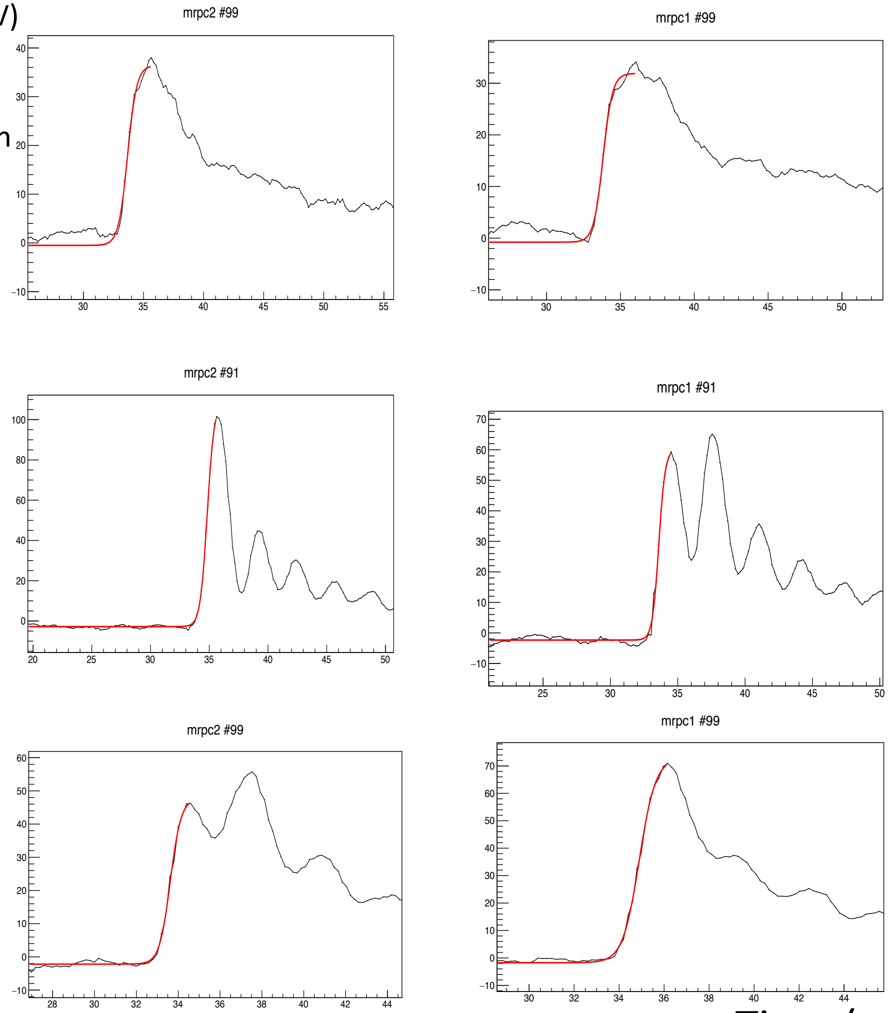
Pulse shape, beam position dep.

Readout (L) Readout (R)

(mV)

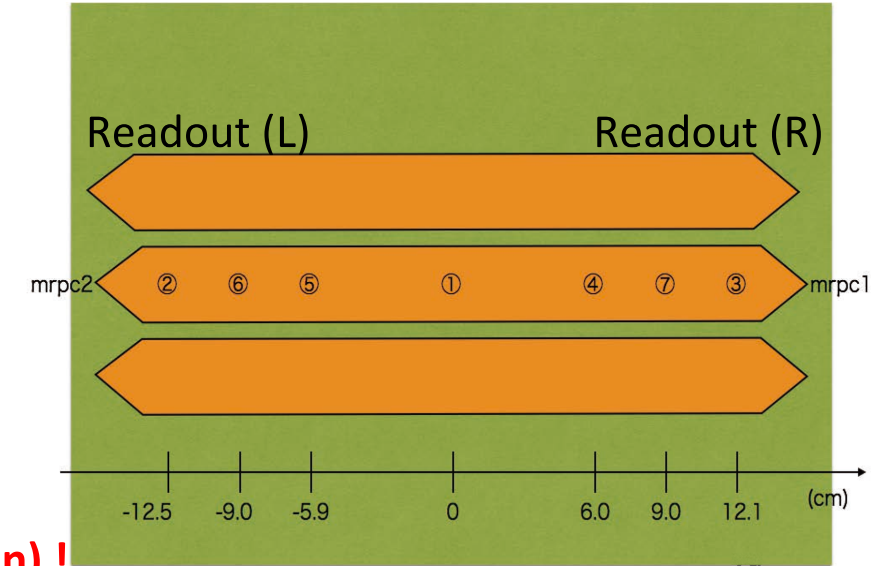
Beam Position

① ③ ⑤



Time (ns)

20 cm x 30 cm PCB size
4 stuck 165 micron gap width, 6 gaps/stuck
Preamp gain: 27, preamp impedance: 62 Ohm

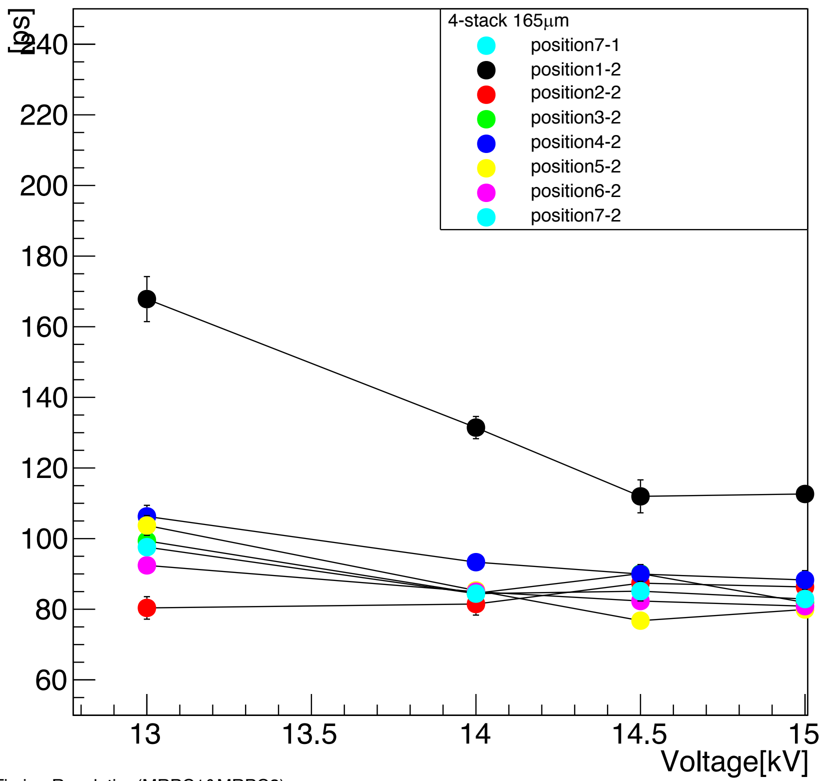


Strongly affected by the refection (and attenuation) !

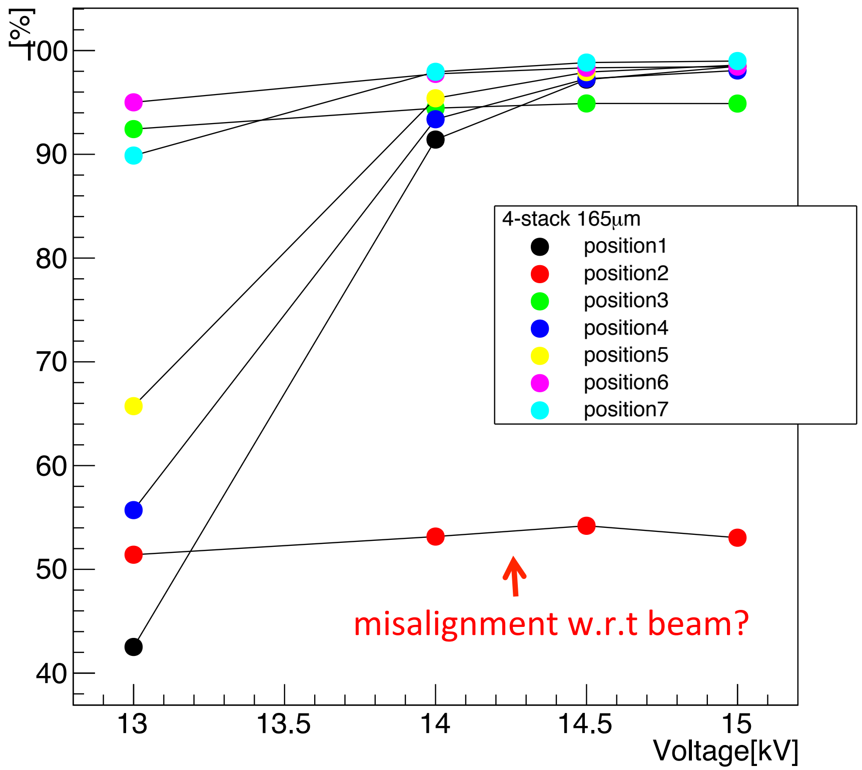
T. Ichisawa

Medium scale MRPC: 4 stuck (165 um) MRPC with beams

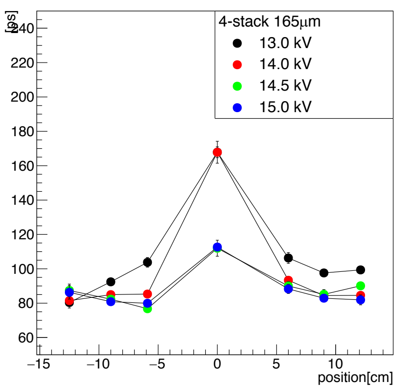
Timing Resolution(MRPC1&MRPC2)



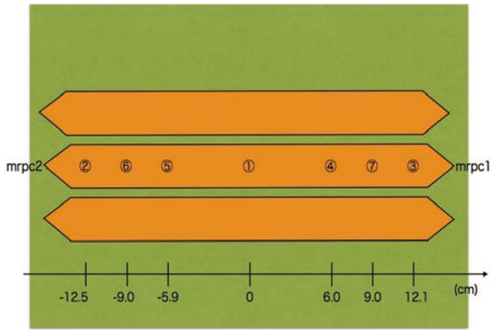
Efficiency



Timing Resolution(MRPC1&MRPC2)

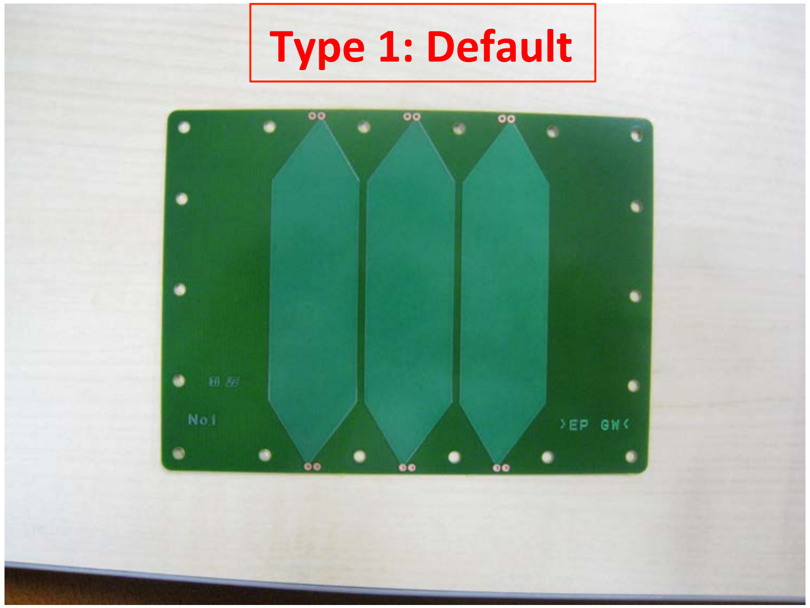


- Best resolution: **76.7 ps @ 14 kV** at position "5"
- Worse resolution at the middle position "3", due to the reflection on both ends.



1 stuck (165 um) MRPC, pad size dep. with beams

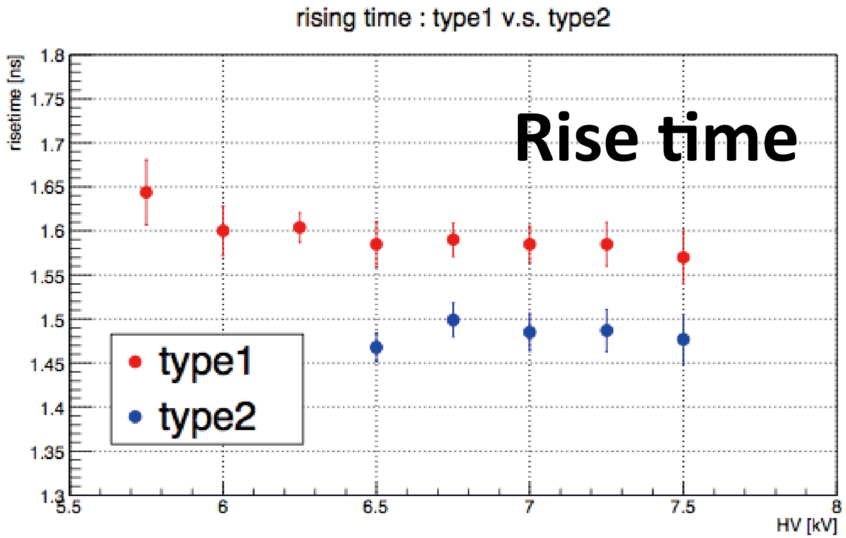
H. Kato

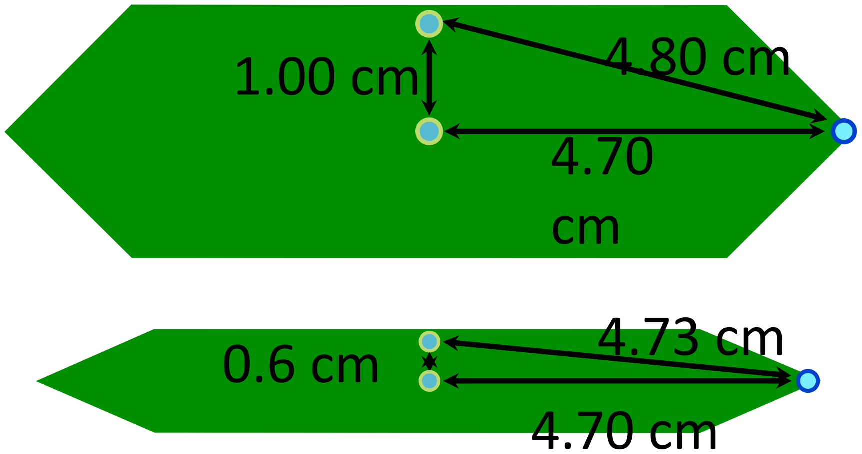


- Expected timing resolution is 80-100 ps, but we focused on the signal shape change due to the pad shape.
- Collaboration with SONY.

1 stuck (165 um) MRPC, pad size dep. with beams

H. Kato



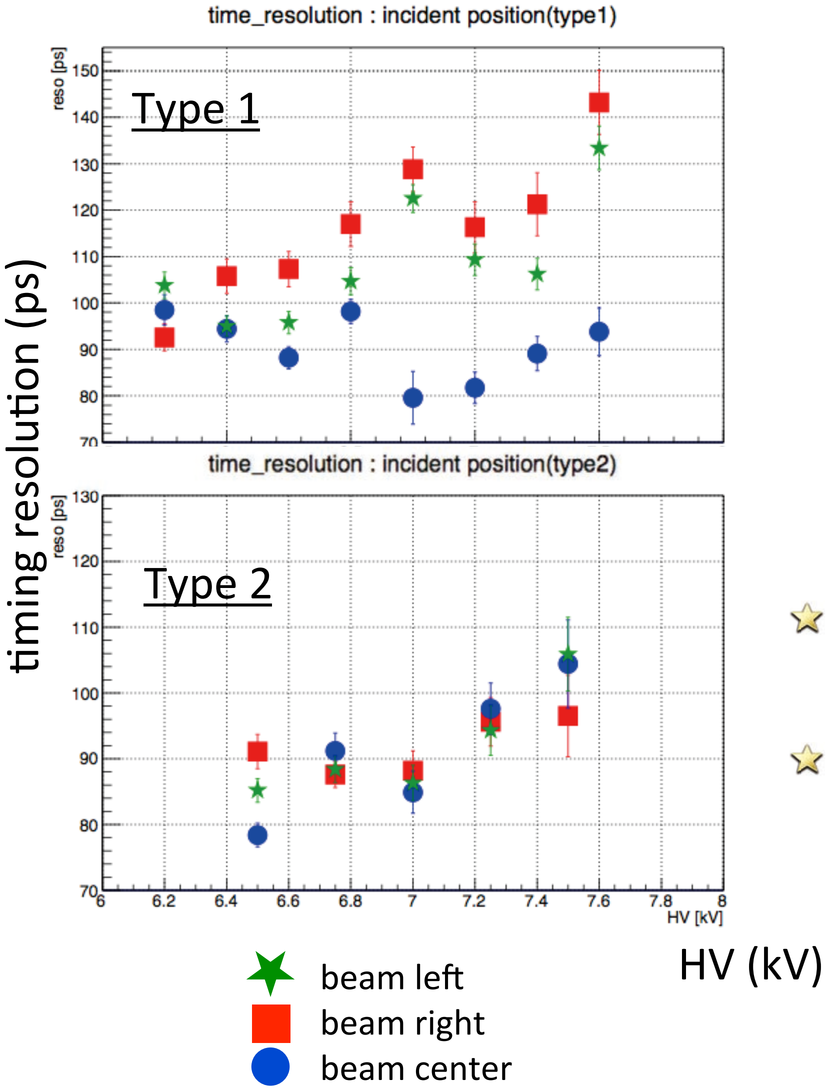


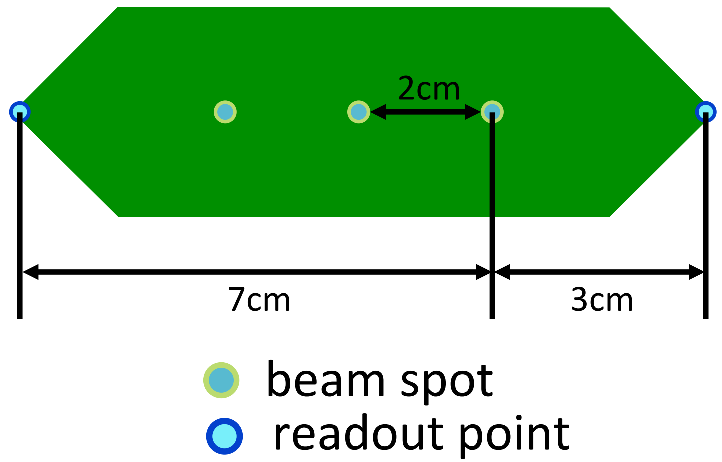
- Rise time of type2 is faster.
- The area of trigger is larger than width of type2.
- The distance to which signal run are different.
- any other reasons..?

1 stuck (165 um) MRPC, pad size dep. with beams

H. Kato

Timing resolution (beam spot dep.)





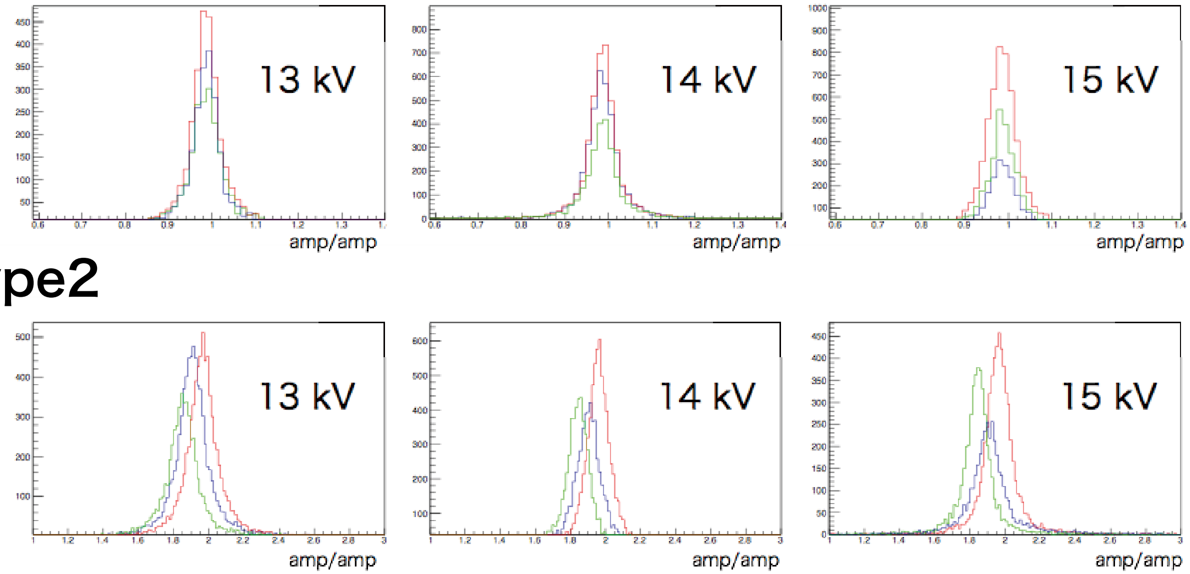
- Type2 was no obvious beam position dep.
- Different trend in type1. (affected by the refection)

1 stuck (165 um) MRPC, pad size dep. with beams

H. Kato

type1

type2



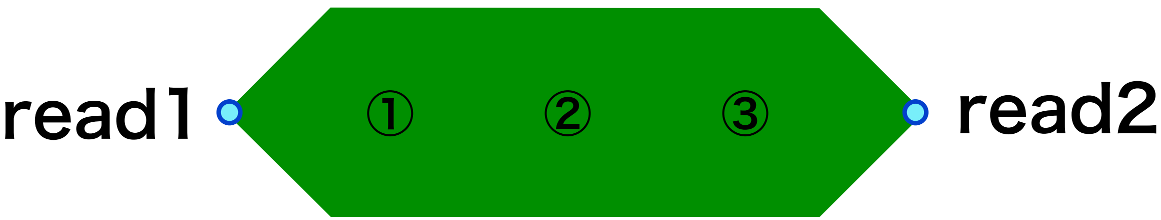
- ①
- ②
- ③

- Amp. for type1 are uncorrelated to the beam position.
- Near the reading position, amp. is higher than that for far reading position in type2.

→ Opposite to the medium scale MRPC (refection)

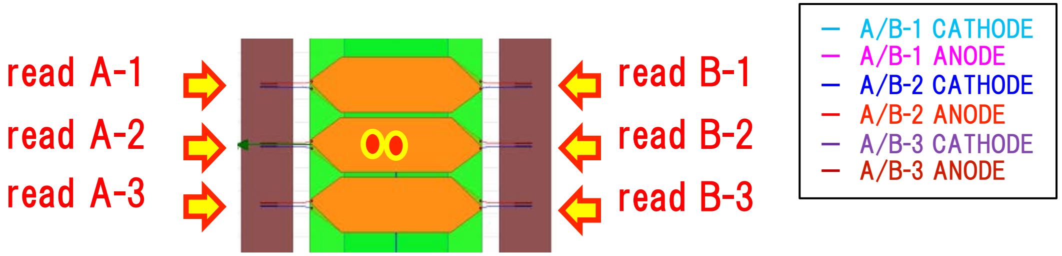
→ Due to the expected signal attenuation & less reflection?

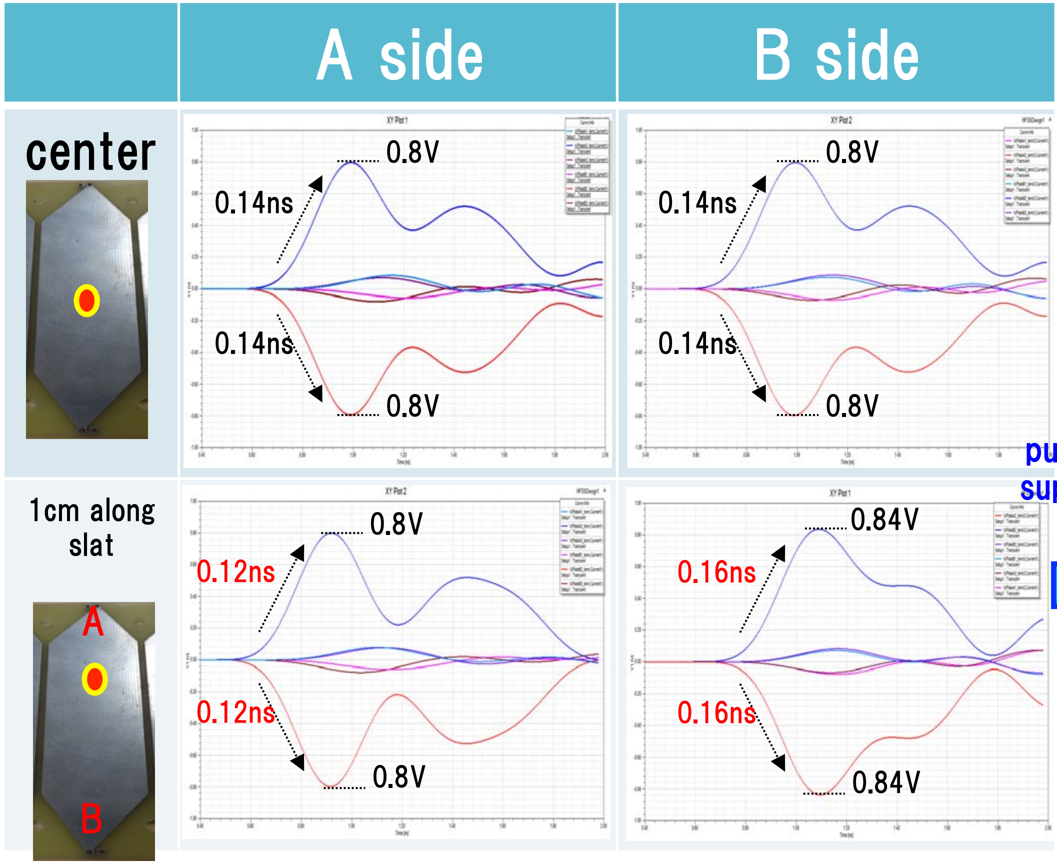
$$\text{Xaxis} = \frac{\text{amp for read1}}{\text{amp for read2}}$$



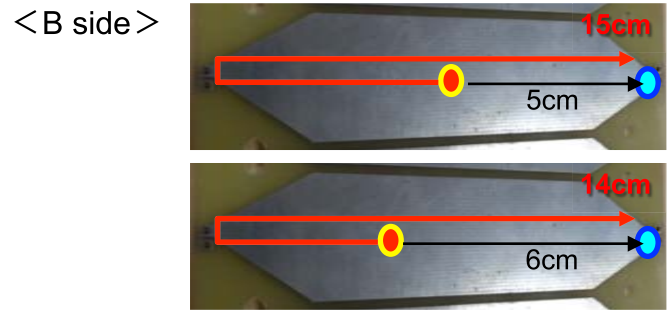
Simulation by SONY

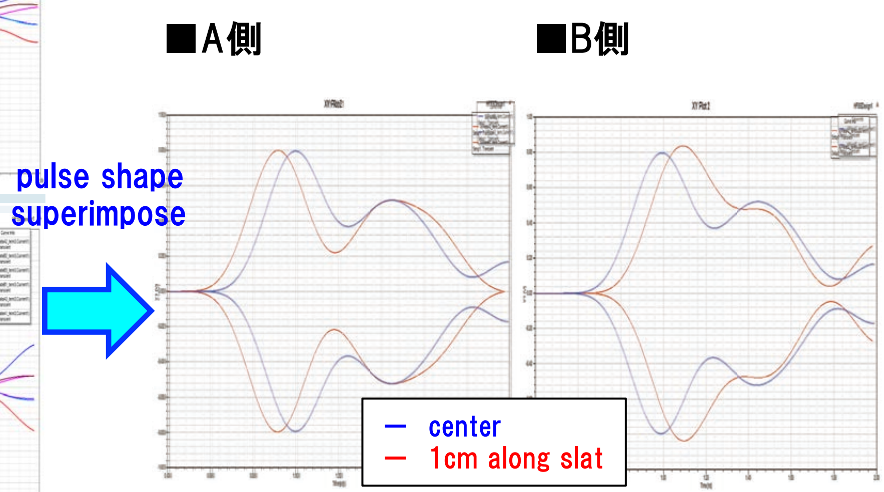
beam position dep.



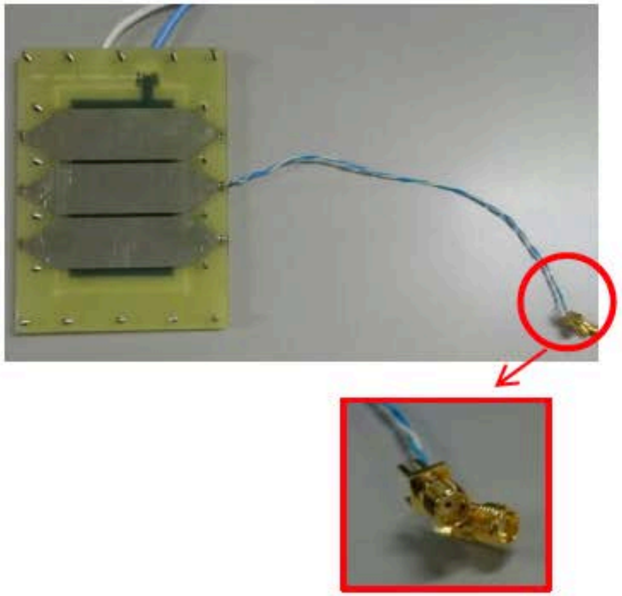


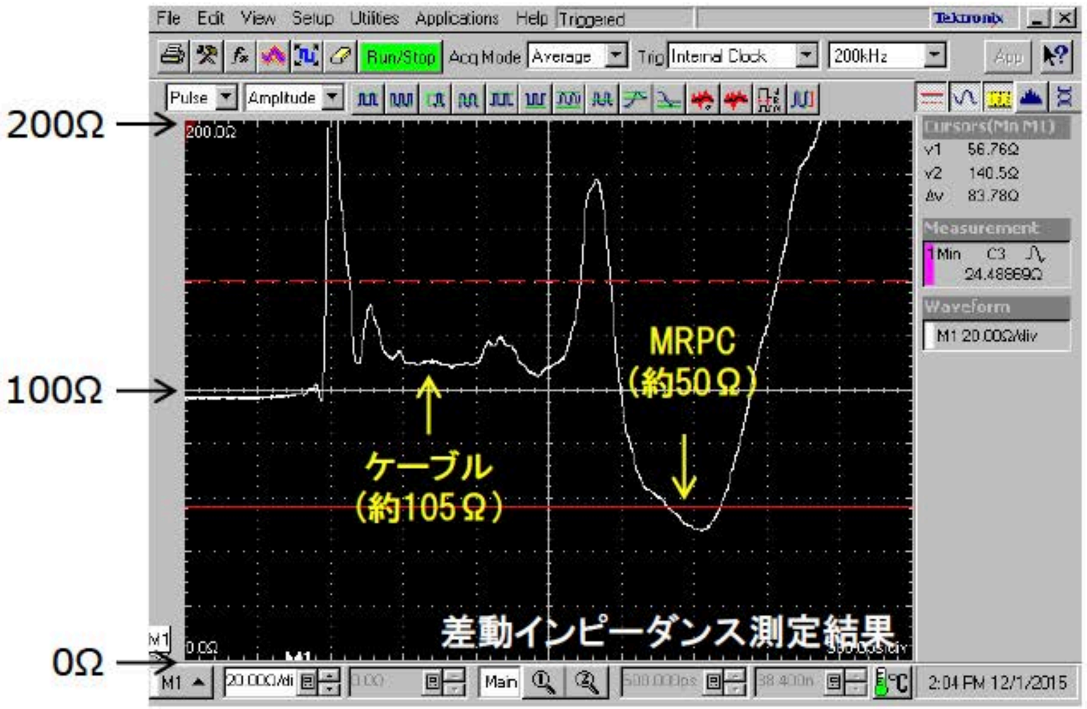
Signal arrival times are different for A and B, when beams are off center. PH are also different, due to the reflection.





Impedance measurements @ SONY





Connected signal cables and MRPC, TDR (differential impedance) measurement for the real prototype:

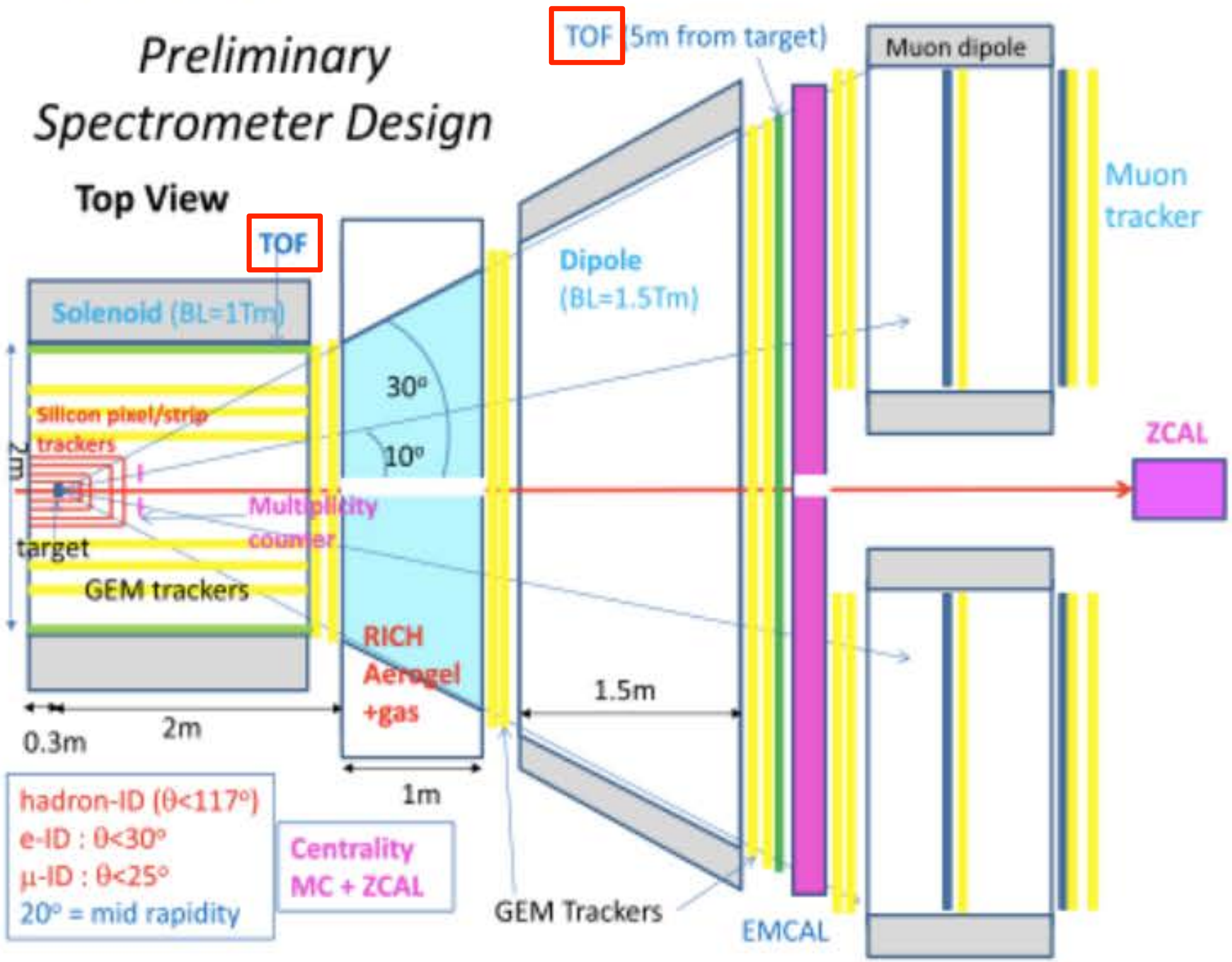
- Cable's differential impedance: ~100 Ohm
- MRPC's differential impedance: ~50 Ohm

→ Needed to be match !

5. Summary and future plans

- Different type of MRPCs have been built and tested with cosmic and test beam at ELPH, with the collaboration with SONY.
  - Importance of impedance matching and gain optimization for each type of MRPC (measurement).
  - For 4 stuck 165 um (104 um) MPRCs (small type): best value ~47 ps with cosmic ray, and 67 ps with beams (ELPH).
  - Need more optimization for medium scale MRPC (reflection)
  - Narrower pad (~ 1.2 cm width) has a better properties on signal shape and timing.
- **Plan in 2017:**
  - Try 104 and 90 um gap size, with **"on board"** differential amp for each stuck first, and then summing (SONY, M. Inaba).
  - Test on patch type, and further study on larger area MRPC.
  - ELPH test beam in late 2017.
  - Collaboration with M. Chiu (BNL) for sPHENIX fast TOF (achieved 18 ps timing resolution)
  - Garfield++ simulation?
  - Readout electronics R&D using DRS4 and prototyping.

BACKUP


Preliminary
Spectrometer Design
Top View
TOF
TOF (5m from target)
Muon dipole
Muon
tracker
Dipole
(BL=1.5Tm)
Solenoid (BL=1Tm)
30°
10°
Silicon pixel/strip
trackers
2m
target
Multiplicity
counter
GEM trackers
ZCAL
RICH
Aerogel
+gas
1.5m
0.3m
2m
1m
hadron-ID (θ<117°)
e-ID : θ<30°
μ-ID : θ<25°
20° = mid rapidity
Centrality
MC + ZCAL
GEM Trackers
EMCAL