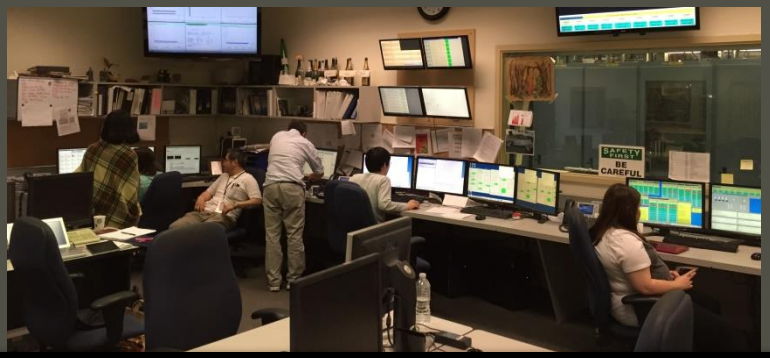
MRPC-TOF DEVELOPMENT

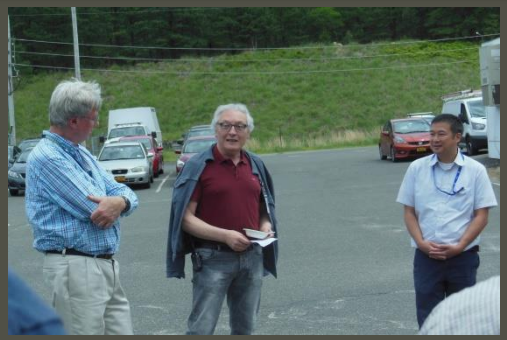
CiRfSE Workshop Jan. 24, 2017

Kazuki Sato

RHIC–PHENIX memorial year 2016

- June
  - RHIC-AGS meeting
  - End of Run16 and all experiment





Daniel and Mickey celebrate end of run16 and PHENIX

TOF on East arm

- October
  - Carry out TOF and super modules of RICH
  - Prepare for shipping back

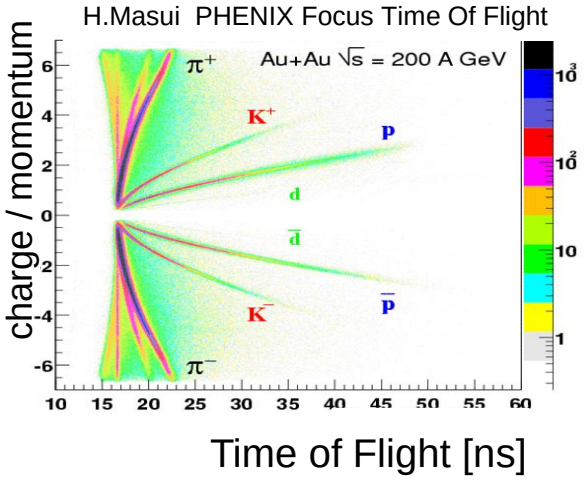
RICH

J-PARC HEAVY ION PROGRAM

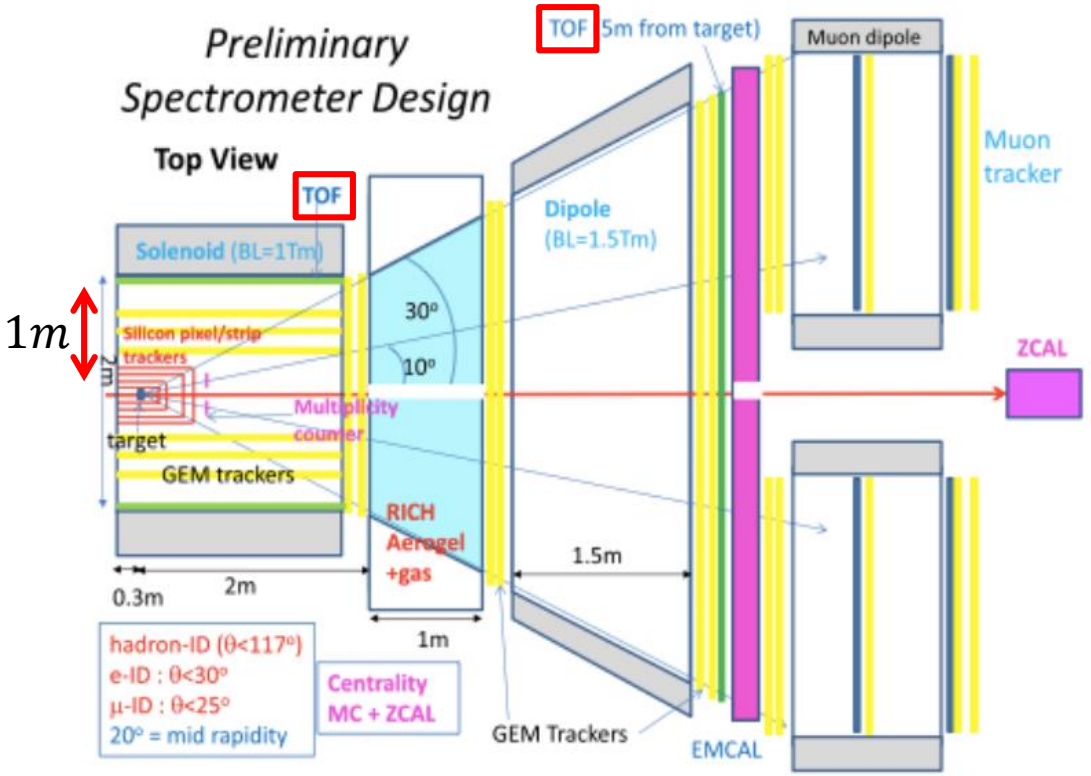
H. Sako et al.
White paper for a Future J-PARC Heavy-Ion Program (J-PARC-HI)

- Search low energy and high chemical potential area in QCD diagram by collisions with fixed target.

MULTI-GAP RESISTIVE PLATE CHAMBER × J-PARC



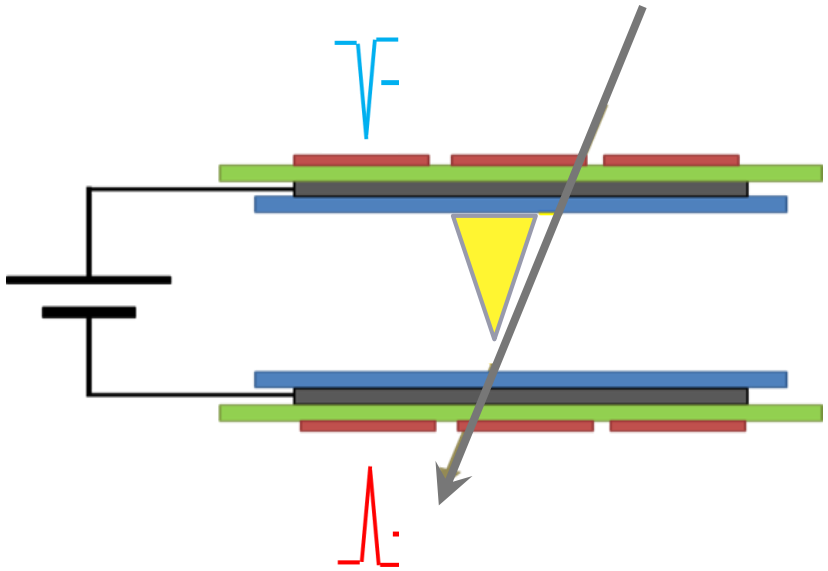
mass : $m = p\sqrt{\left(\frac{t}{L}\right)^2 - 1}$

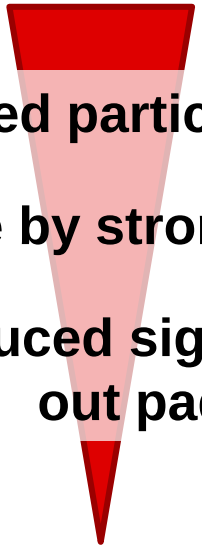


H.Sako et al.
Towards the heavy-ion program at J-PARC (2014)

- 60×60cm large and 30ps timing resolution is required at 1m far from collision point!!

HOW MRPC WORKS



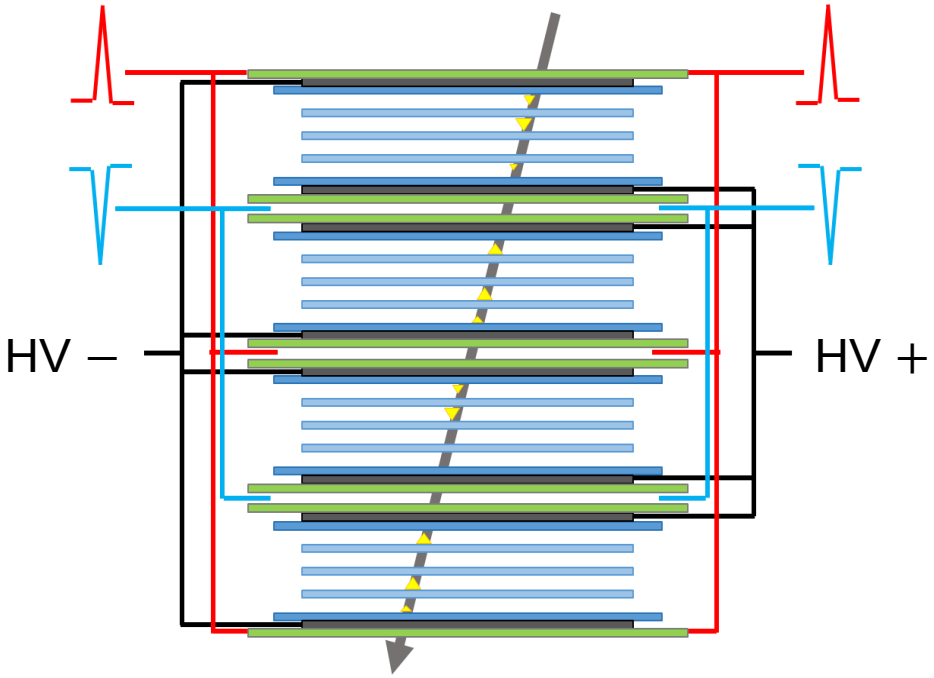


1. **Charged particle injection**
2. **Avalanche by strong electric field**
3. **Read induced signal from read-out pads**

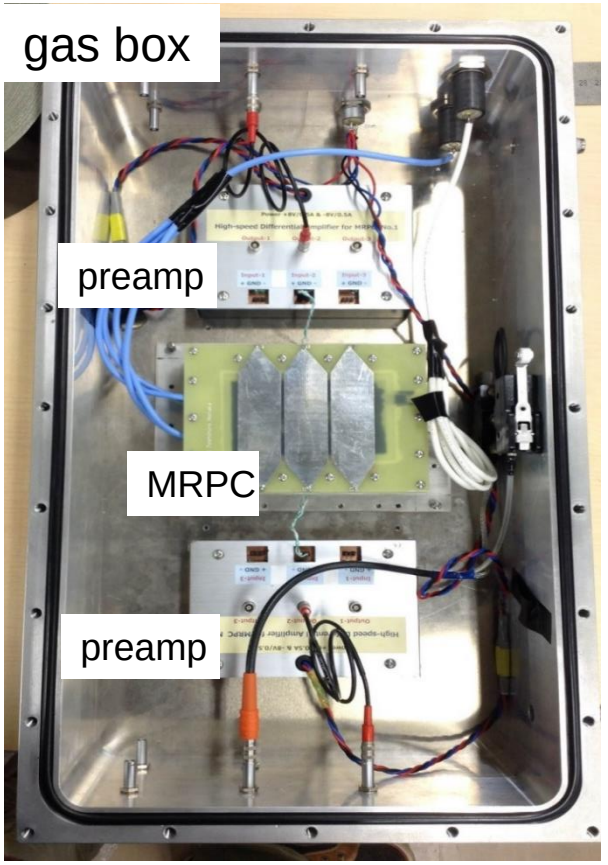
- ✓ Simple and reasonable materials.
- ✓ Easy to make larger one.
- ✓ Timing resolution can be improved by stacking more gaps.

➢ Match to requirements of Heavy-Ion program at J-PARC

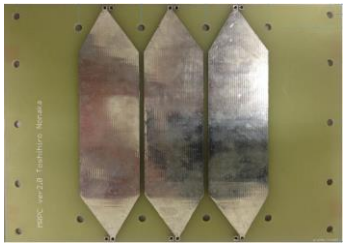
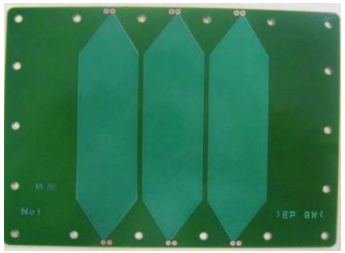
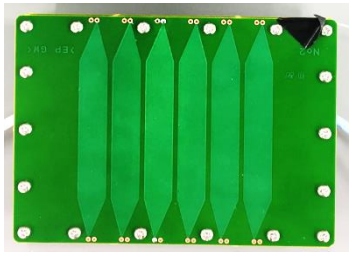
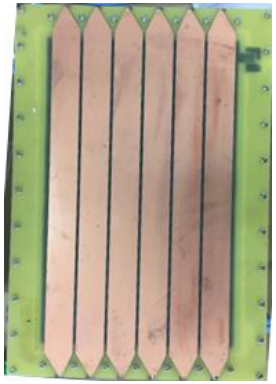
MRPC STRUCTURE AND TYPICAL SETUP



4 stuck MRPC structure



MRPC FAMILY

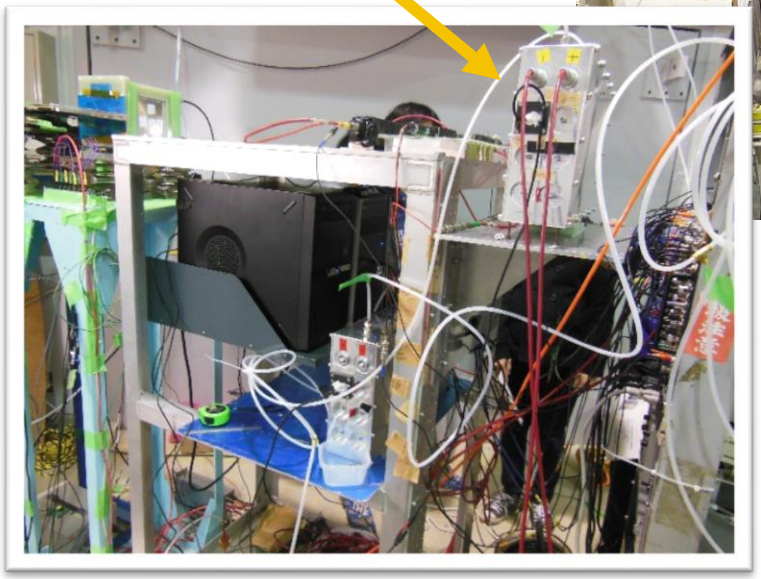
	small type	SONY type1 ※	SONY type2 ※	large type
Size: Read-pad width:	100×136 24	100×136 24	100×136 11	300×200 24
Gas gap width [μm] × number	165×6, 148×6, 128×7 104×9	260×5	260×5	165×6
Structure print board	4 stack FR-4	1 stack FR-4 + mylar film	1 stack FR-4 + mylar film	4 stack FR-4

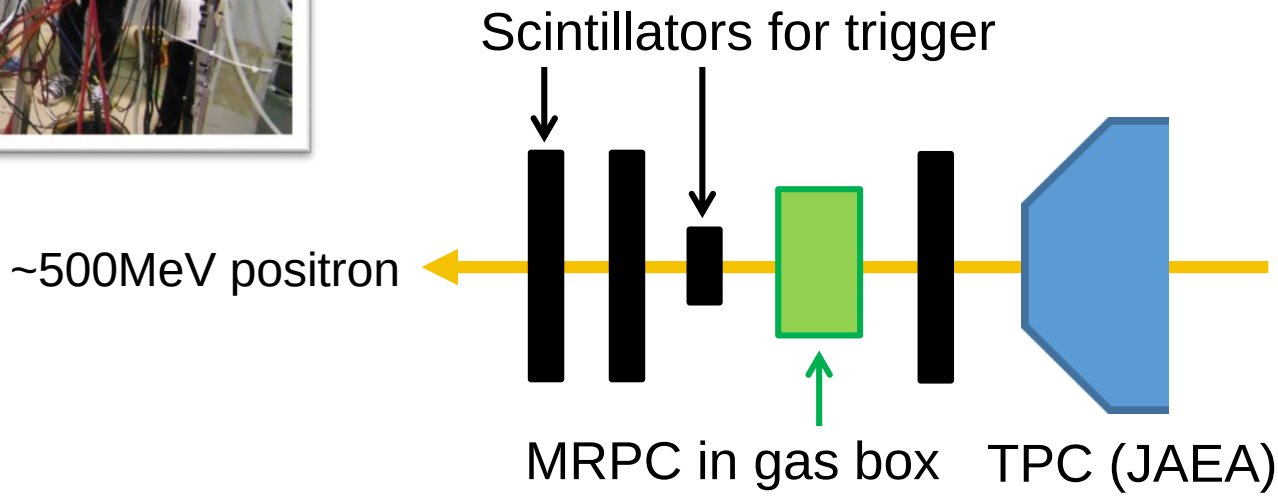
※ Designed by SONY GM & O corporation

POSITRON BEAM TEST AT ELPH IN TOHOKU UNIV.

Research Center for ELectron PHoton Science

MRPC inside

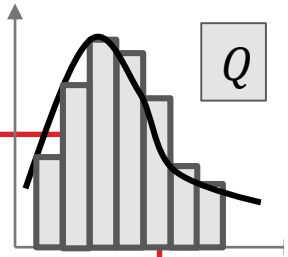




BASIC PERFORMANCE

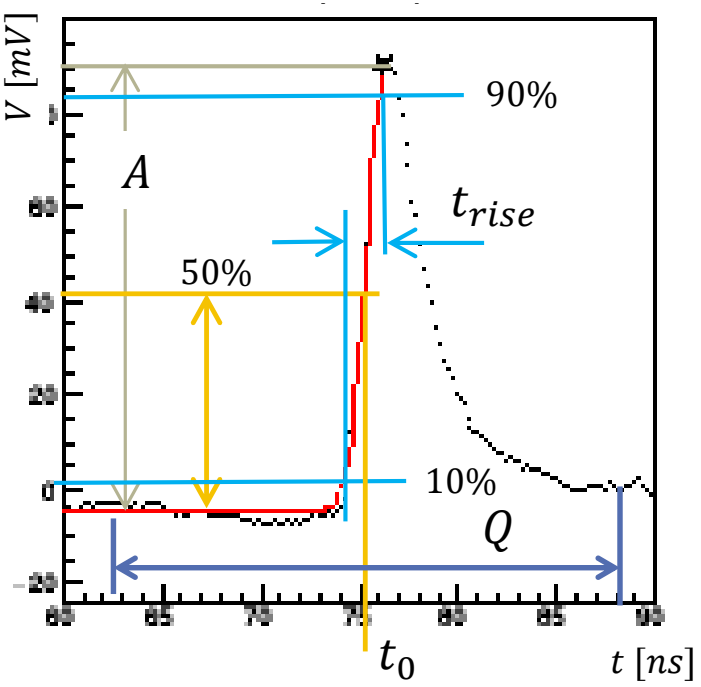
DATA EXTRACTION

Fit function: $f(x) = C_1 + \dfrac{C_2}{1 + \exp\left(\dfrac{x - C_3}{C_4}\right)}$



- A : Amplitude
- Q : Integrate around peak
- t_0 : Time that signal reached $A/2$
- t_{rise} : Time to rise up (10% to 90%)

Signal taken by DRS4 evaluation



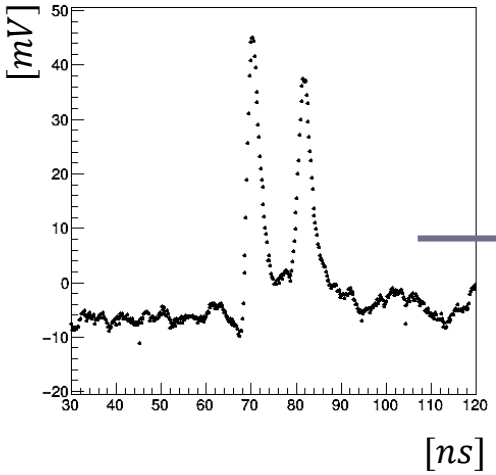
5GHz flash ADC

DRS4 Evaluation Board

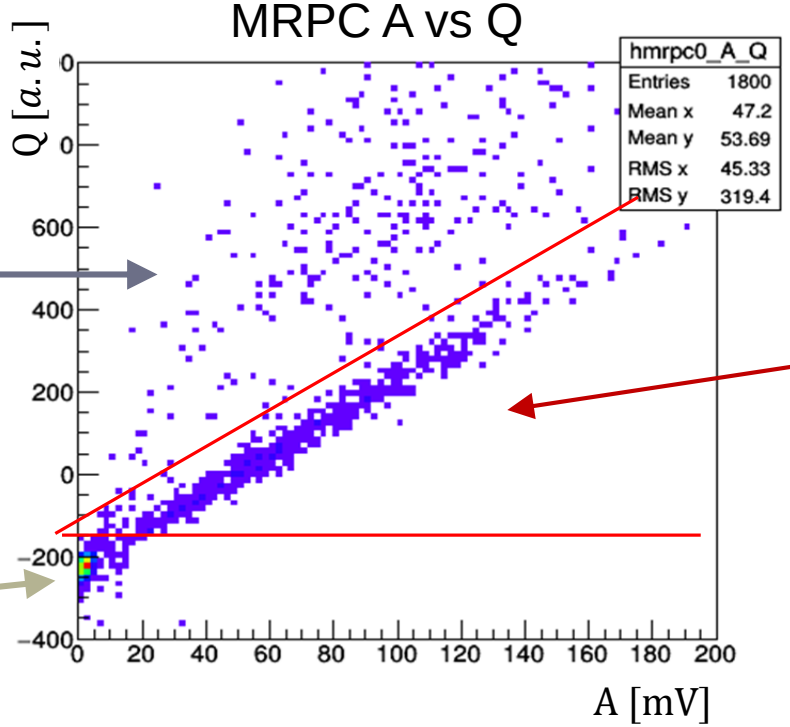
T. Nonaka master thesis (2015)

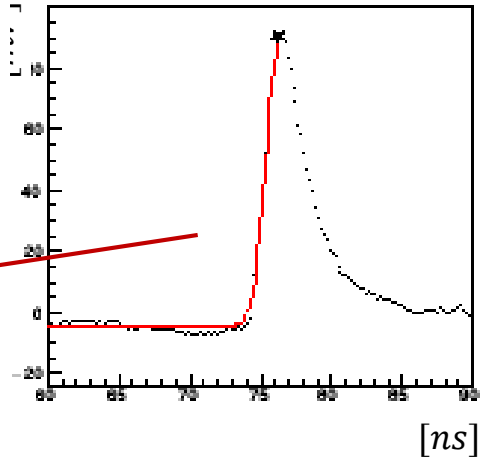
1. QUALITY OF SIGNAL

Streamer event



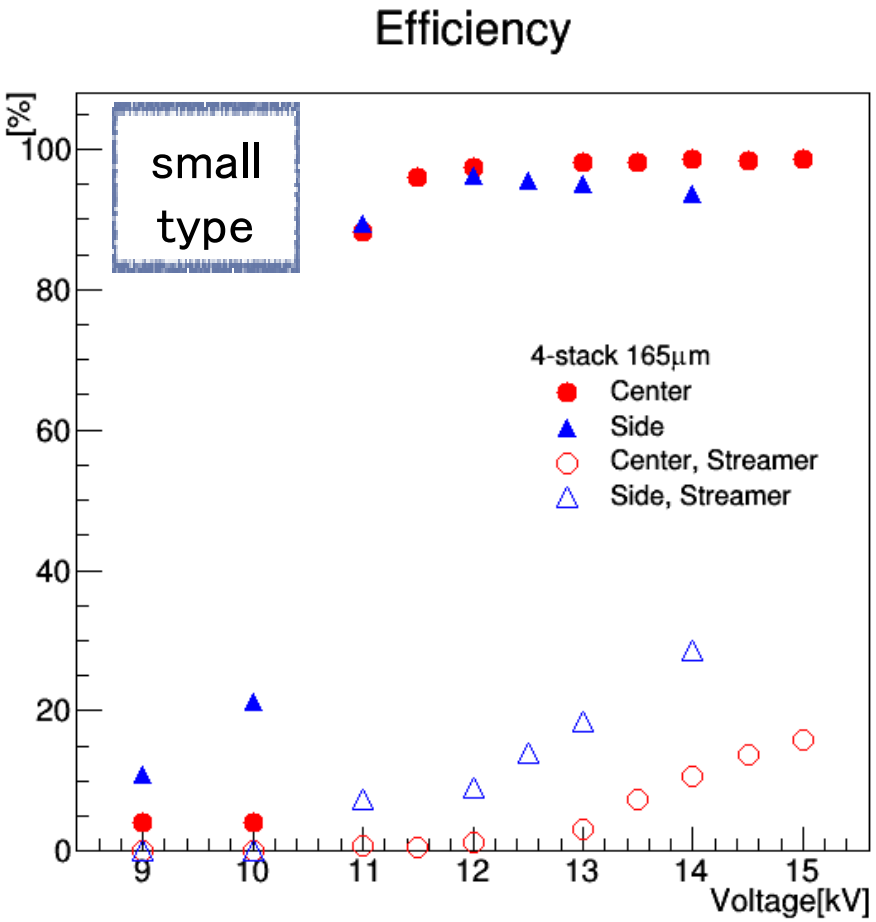
MRPC A vs Q

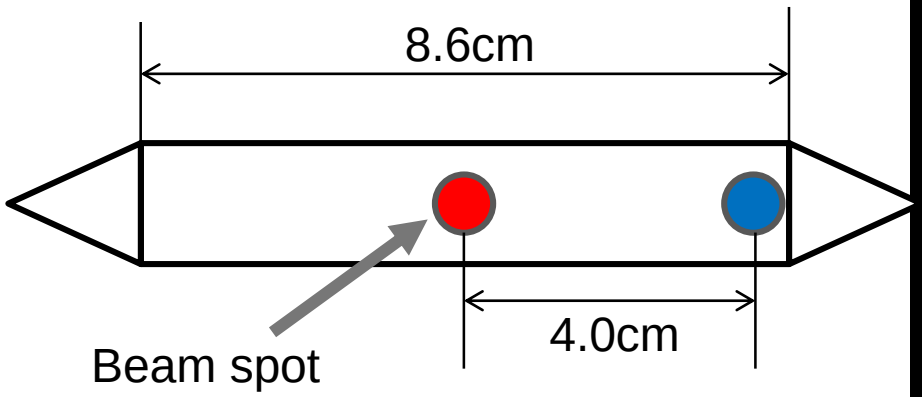




Inefficiency

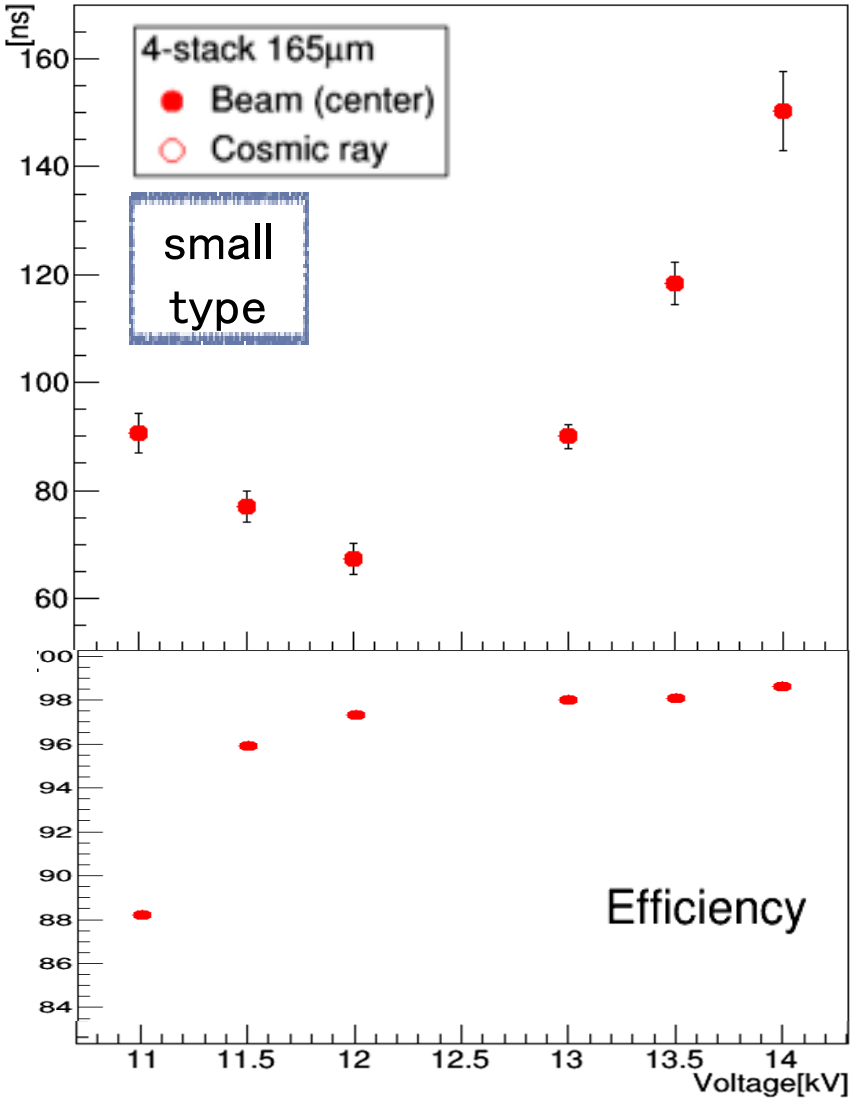
2. EFFICIENCY (BEAM)

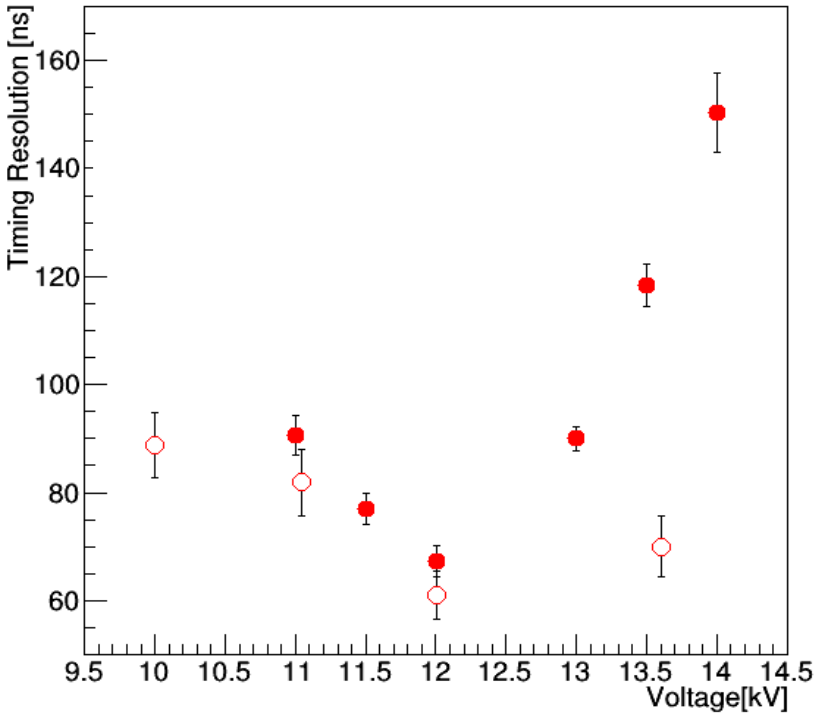




- ✓ $> 98\%$ the best (including streamer)
- ✓ Streamer gradually increases as voltage rises.

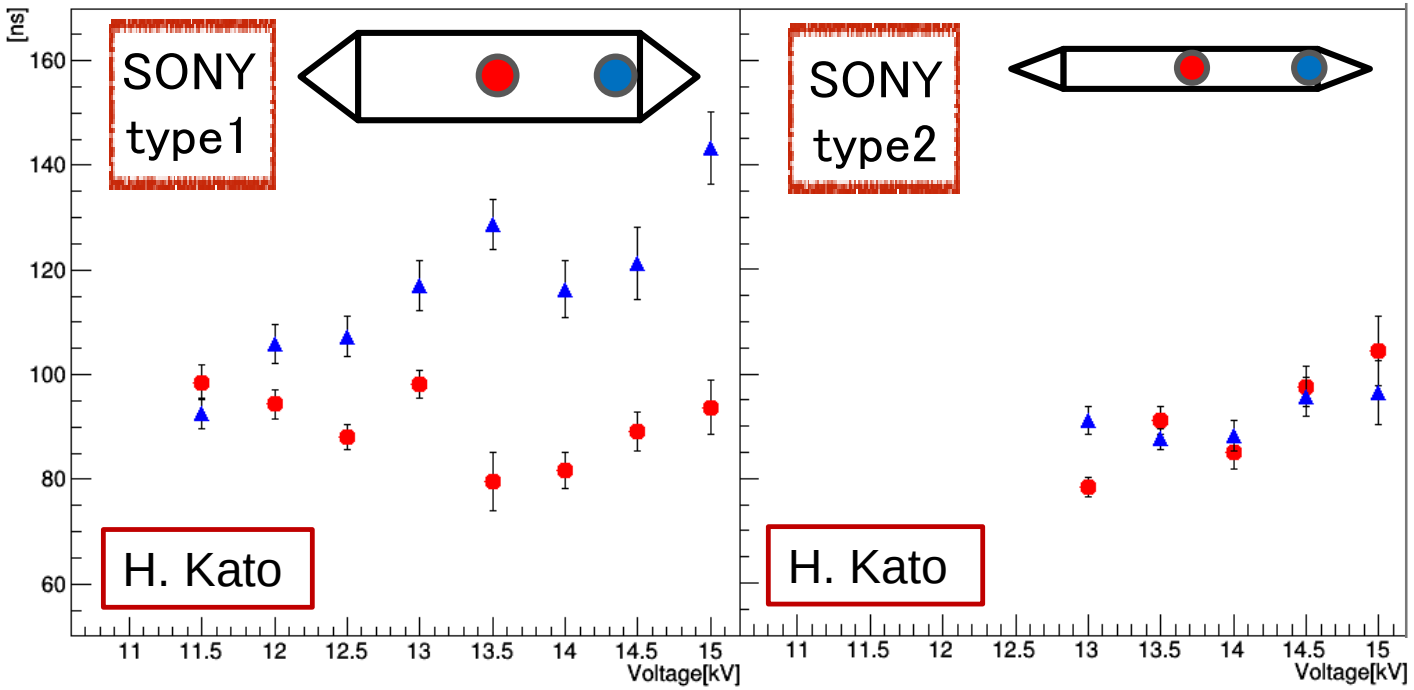
3. TIMING RESOLUTION (BEAM)





- ✓ Best timing resolution:
  67.4 ± 2.8 ps @ 12.0 kV
- ✓ Consistent to cosmic ray.

3. TIMING RESOLUTION (BEAM)

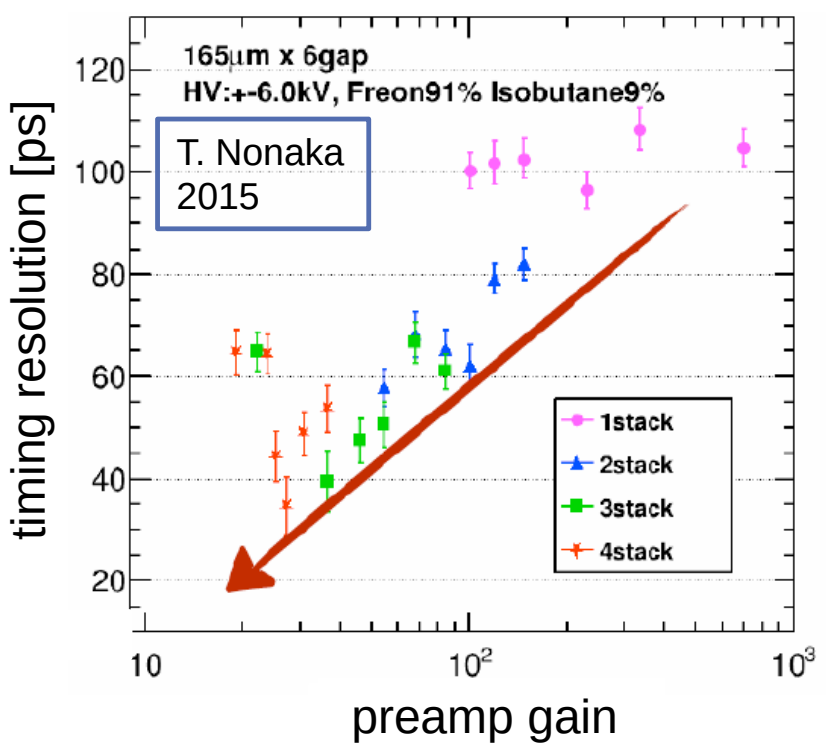


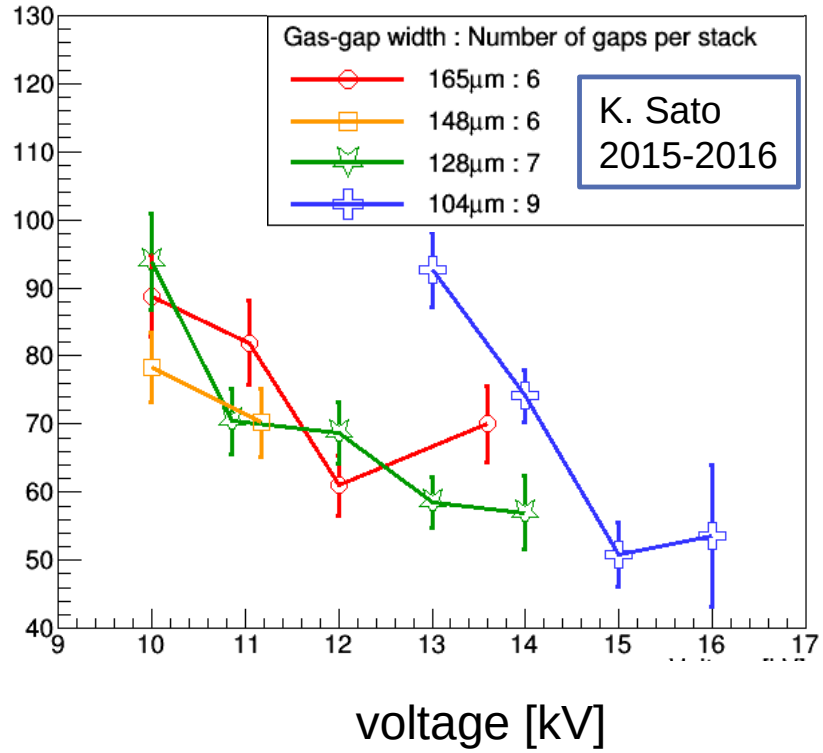
Best timing resolution

- type1: 85.4 ± 2.4ps
- type2: 78.9 ± 1.8ps thinner pad is better

4 stack with type2 can be 40ps??

4. TIMING RESOLUTION (COSMIC RAY)





small type

- ✓ 104 μm performed the best these days.
- ✓ The best timing resolution ~50ps marked by 165μm.

CONCLUSION

−Different type of MRPCs are designed and tested, with collaboration with SONY GM&O.

- Thinner read out pad has better timing resolution.

−The optimum operating voltage for small type is around 12kV as efficiency and timing resolution.

- The best timing resolution with beam is $67.4 \pm 2.8ps$.
- Efficiency over 98%.

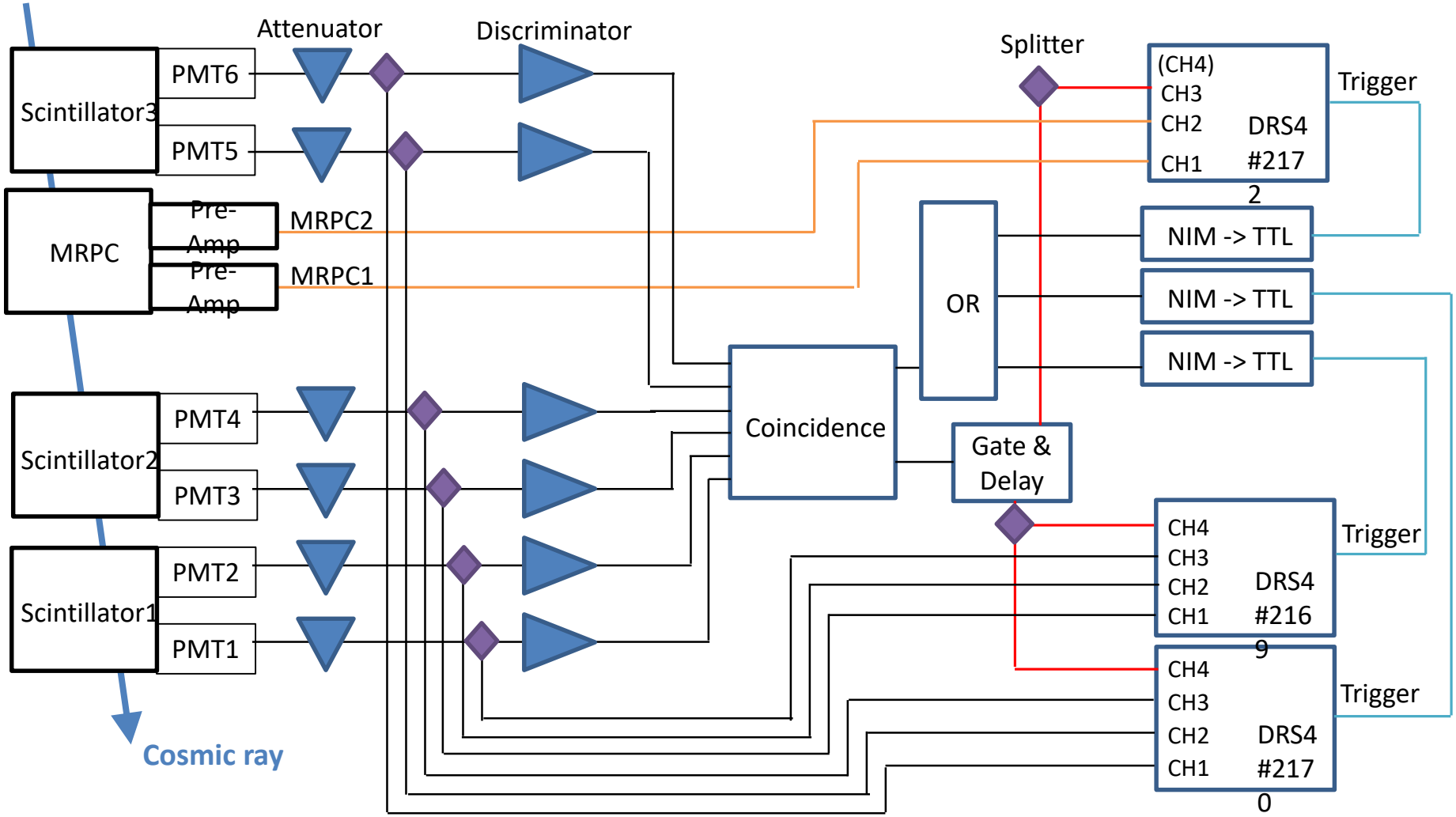
FUTURE WORKS

- **Design preamp that can preform well for high frequency signal.**
- **Match impedance of preamp for SONY and large type.**
- **Test 4 stacked SONY-type2 MRPC and 104-μm gap MRPC with beam.**

PICTURE BIBLIOGRAPHY

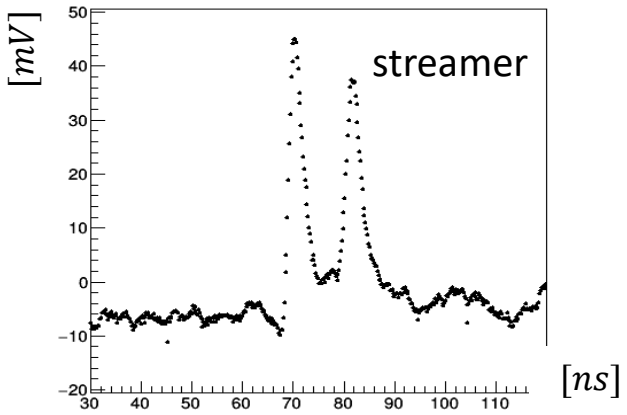
- PHENIX Focus Time Of Flight H.Masui
- White paper for a Future J-PARC Heavy-Ion Program (J-PARC-HI) May 27, 2016 H. Sako et al.
- J-PARC official web site http://j-parc.jp/
- ELPH–Tohoku University official web site http://hayabusa1.lns.tohoku.ac.jp/
- Towards the heavy-ion program at J-PARC Aug. 26th, 2014 H.Sako et al.

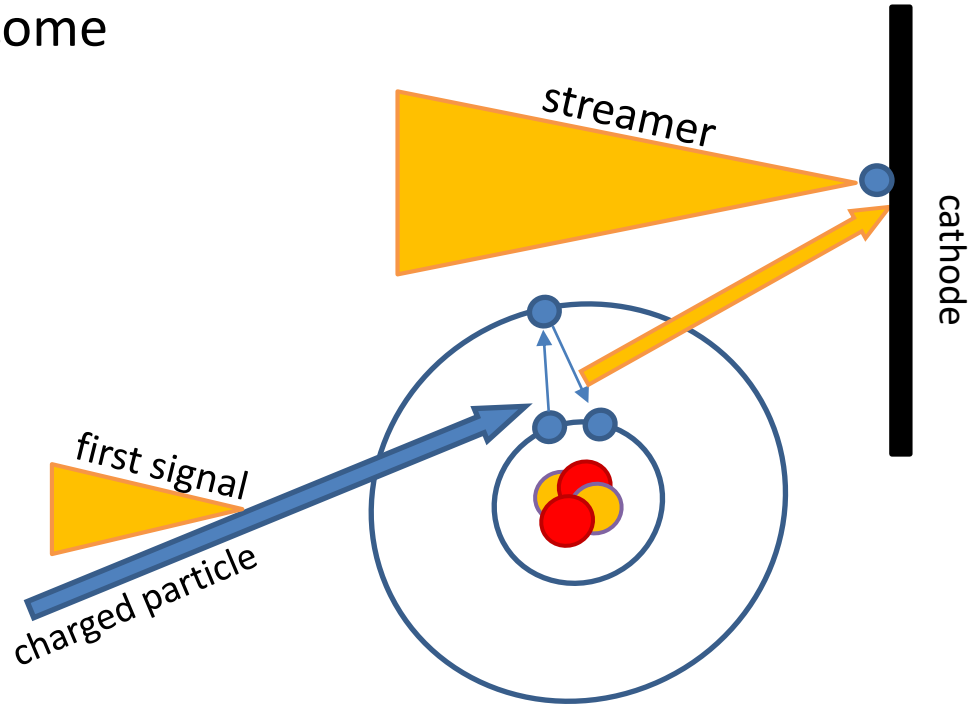
BACK UP


Attenuator
Discriminator
Splitter
Scintillator3
PMT6
PMT5
MRPC
Pre-Amp
MRPC2
Pre-Amp
MRPC1
Scintillator2
PMT4
PMT3
Scintillator1
PMT2
PMT1
Cosmic ray
Coincidence
OR
Gate & Delay
(CH4)
CH3
CH2
CH1
DRS4 #2172
Trigger
NIM -> TTL
NIM -> TTL
NIM -> TTL
CH4
CH3
CH2
CH1
DRS4 #2169
Trigger
CH4
CH3
CH2
CH1
DRS4 #2170
Trigger

Streamer

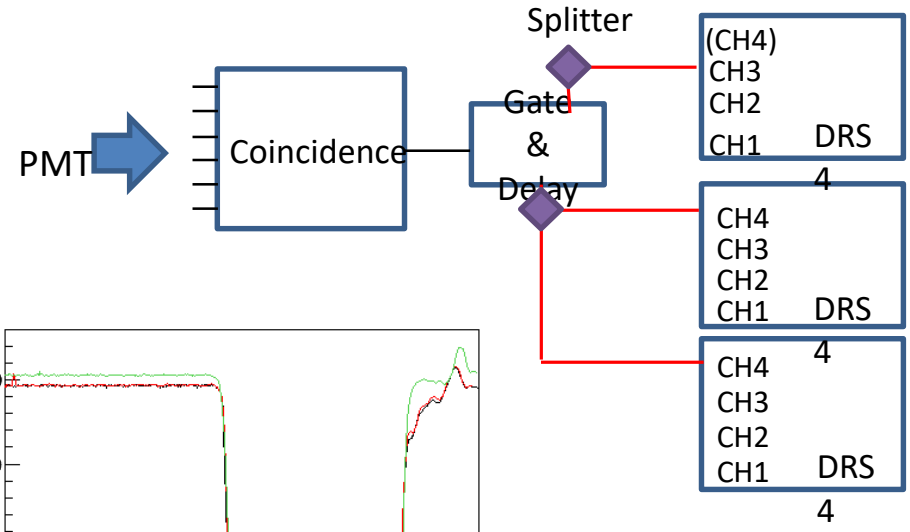
- Electron in atoms are excited
- Photon comes out when it come back to basic state
- Ionize cathode
- Delayed avalanche

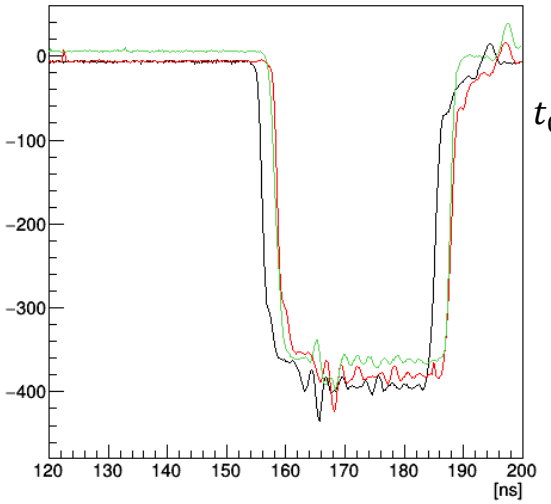




DRS4の時差補正

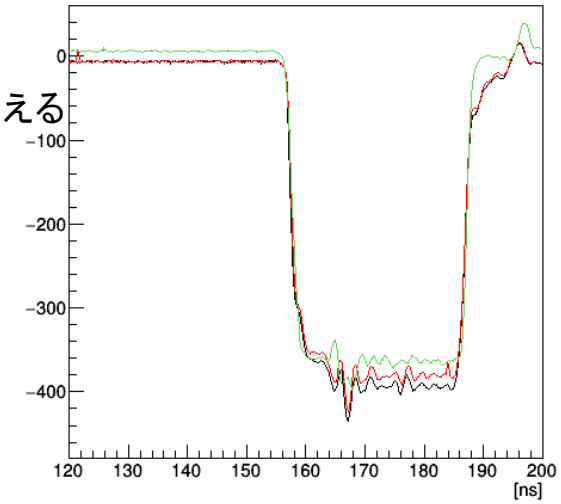
異なるDRS4に同じ矩形波を入力する





補正前

t_0の平均値にそろえる



補正後

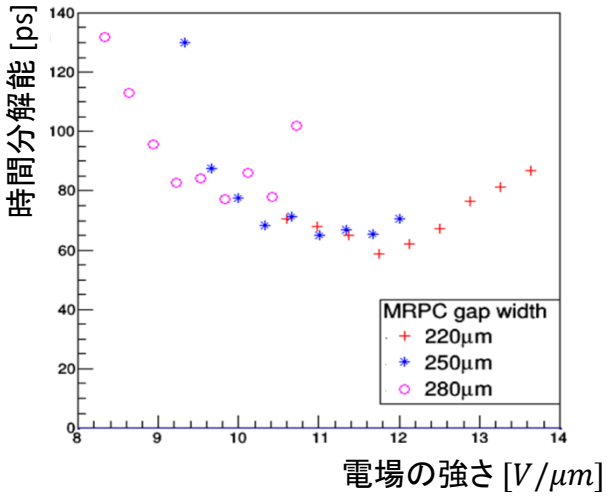
先行研究

- ４段型MRPC（ギャップ幅$165\mu m$）宇宙線を用いた実験で時間分解能$47.5 \pm 3.4\ ps$を達成。

（2015年、筑波大学グループ、野中俊宏氏修士論文）

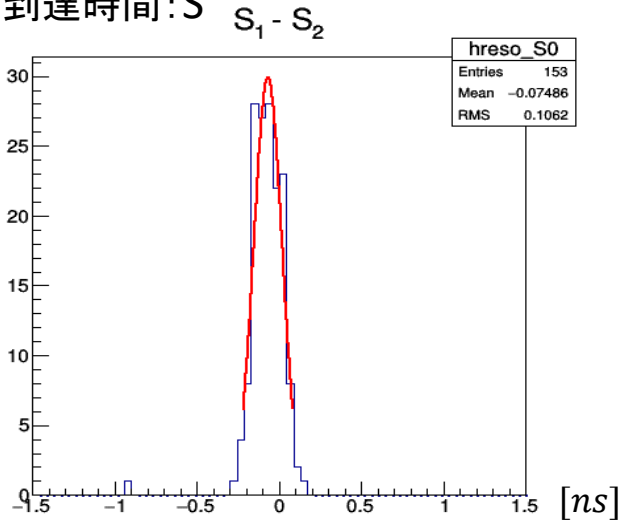
- １段型MRPCでガスギャップ幅が狭くなるほど時間分解能が向上する傾向。

（2002年、LHC-ALICE、Addendum to the TDR of the Time Of Flight System）



How to Estimate Timing Resolution

信号到達時間:S



$$S_1 = \frac{t_{0,PMT1} + t_{0,PMT2}}{2}$$

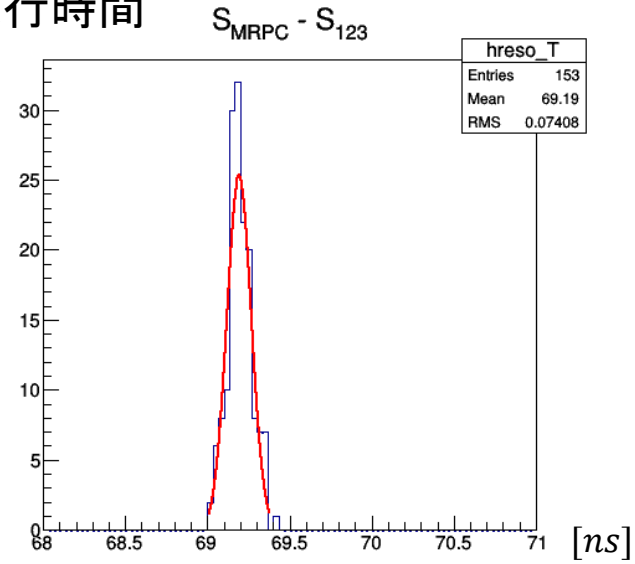
$$\sigma^2_{Si-Sj} = \sigma^2_{Si} - \sigma^2_{Sj}$$

$$\frac{1}{\sigma^2_{START}} = \frac{1}{\sigma^2_{S1}} + \frac{1}{\sigma^2_{S2}} + \frac{1}{\sigma^2_{S3}}$$

$\sigma_{Si} \sim 70ps$

$\sigma_{START} \sim 55ps$

飛行時間

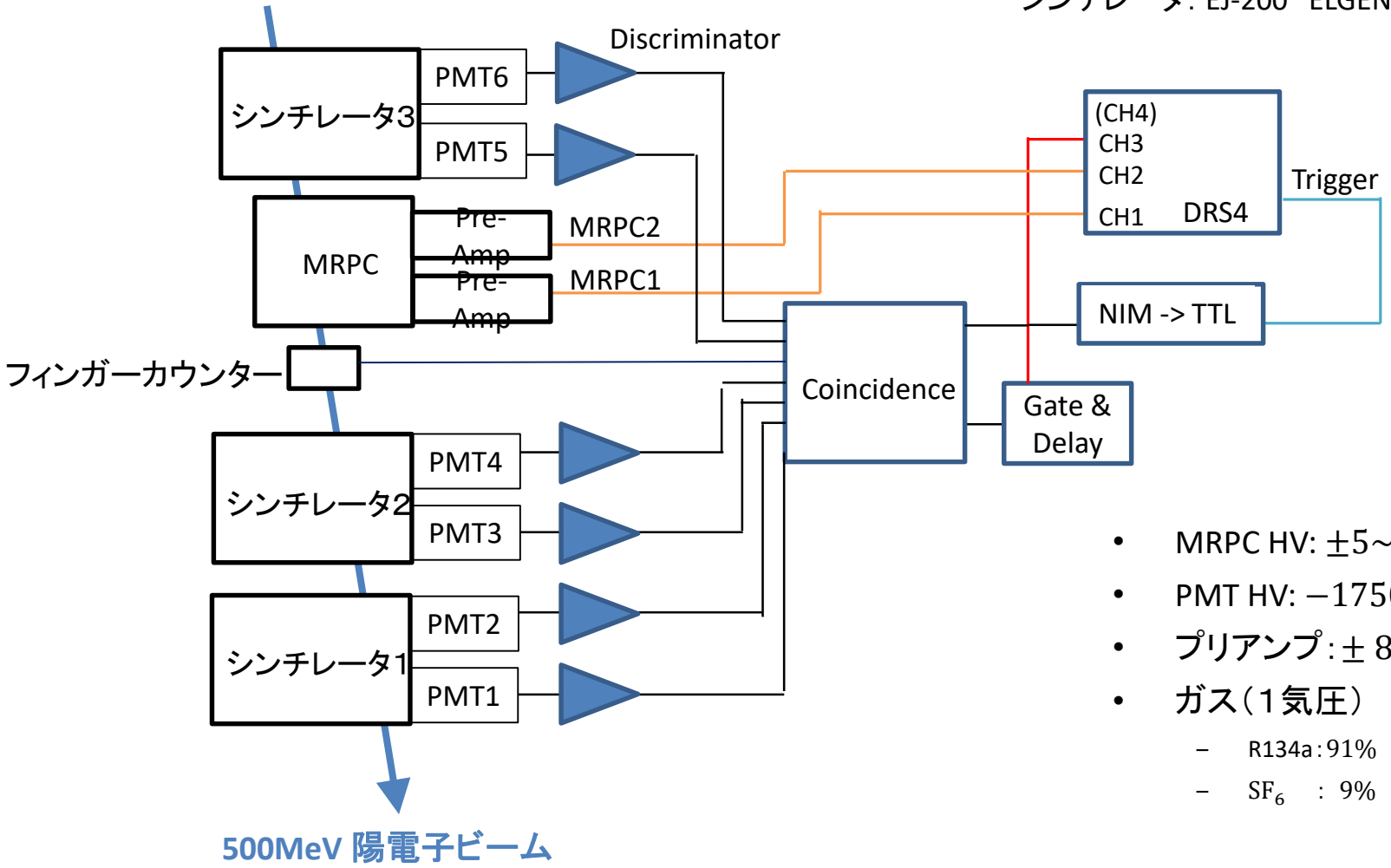


$$\sigma^2_{MRPC-S123} = \sigma^2_{S123} + \sigma^2_{MRPC}$$

MRPCの時間分解能 σ_{MRPC}

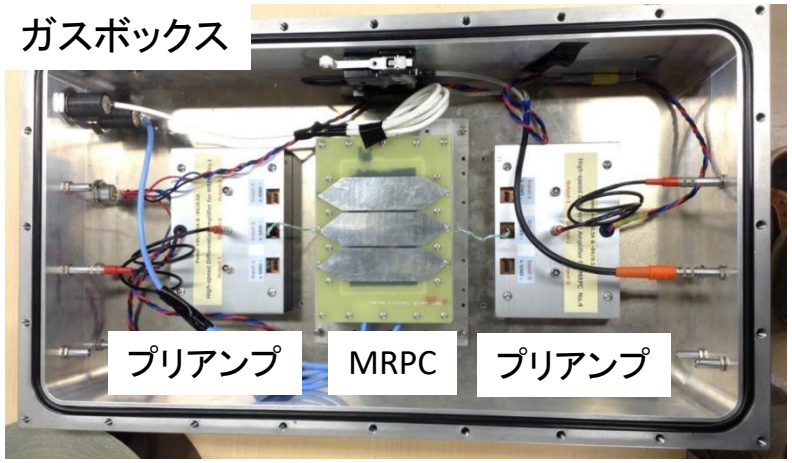
読出し回路とガス･電圧

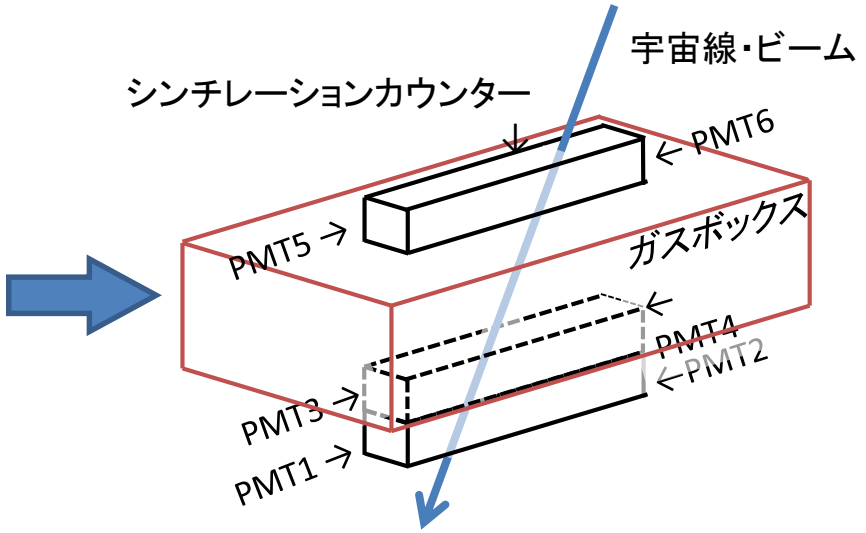
PMT: R3478 浜松ホトニクス
シンチレータ: EJ-200　ELGEN Technology



- MRPC HV: $\pm 5 \sim 8kV$
- PMT HV: $-1750V$
- プリアンプ: $\pm\ 8V$
- ガス（1気圧）
  - R134a: 91%
  - SF_6 : 9%

セットアップ





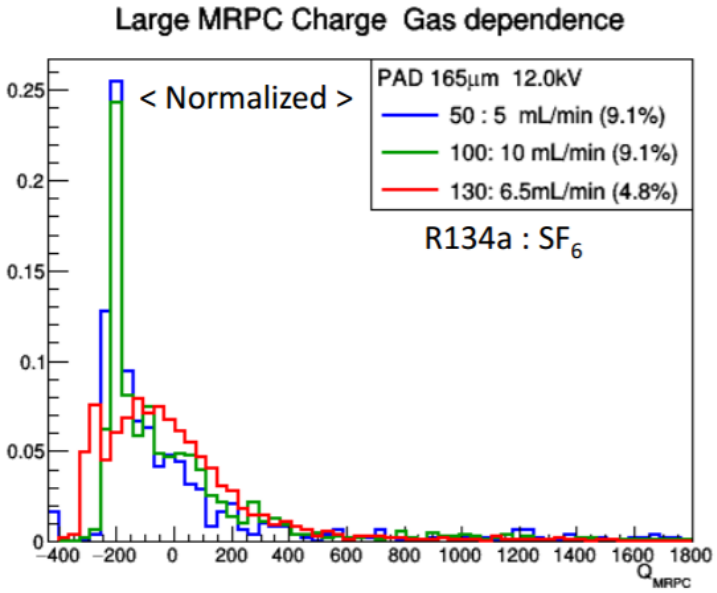
- データ記録：DRS4 Evaluation Board version 3.0
  - 200ps間隔でサンプリングする回路。
  - USB端子からデジタルデータとして送信する。

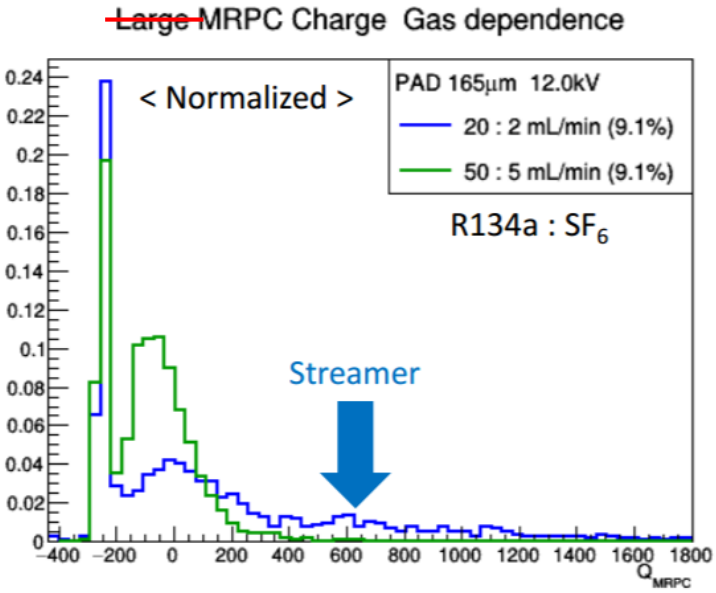
DRS4

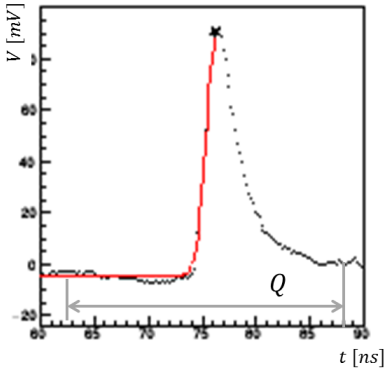
Gas mixture dependence

in order to reduce the ratio of streamer event

Small

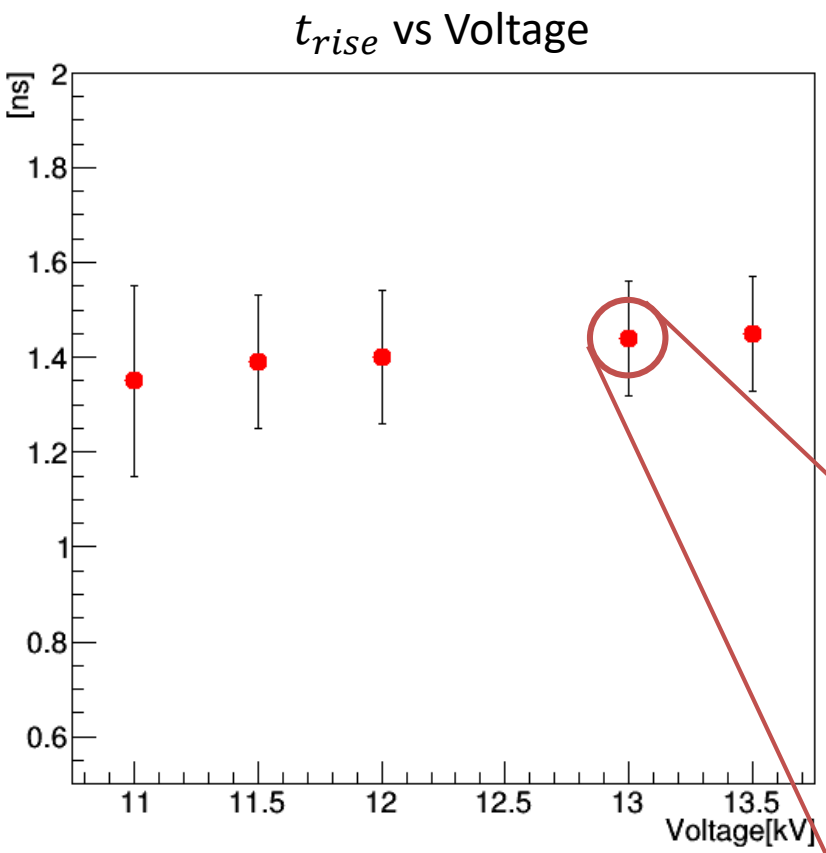




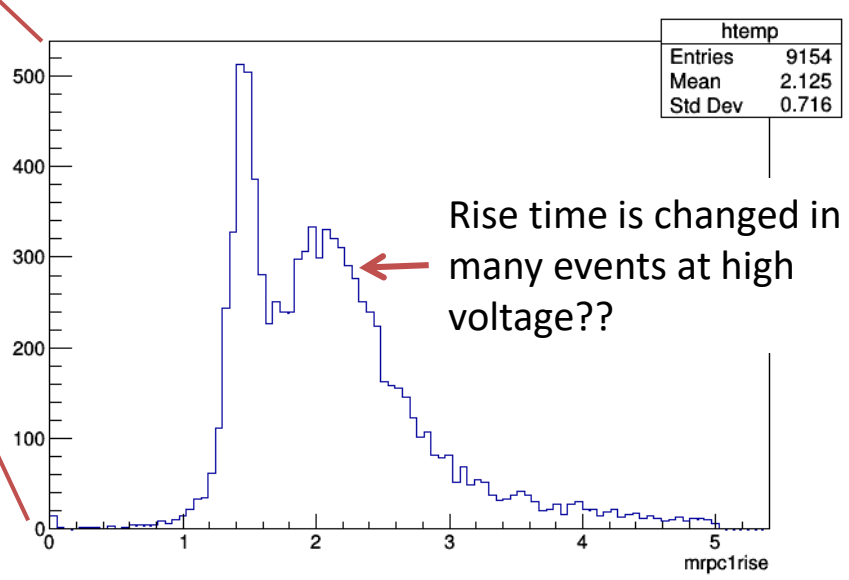


- Enough amount gas reduces streamer and quenching gas

2. Rise time

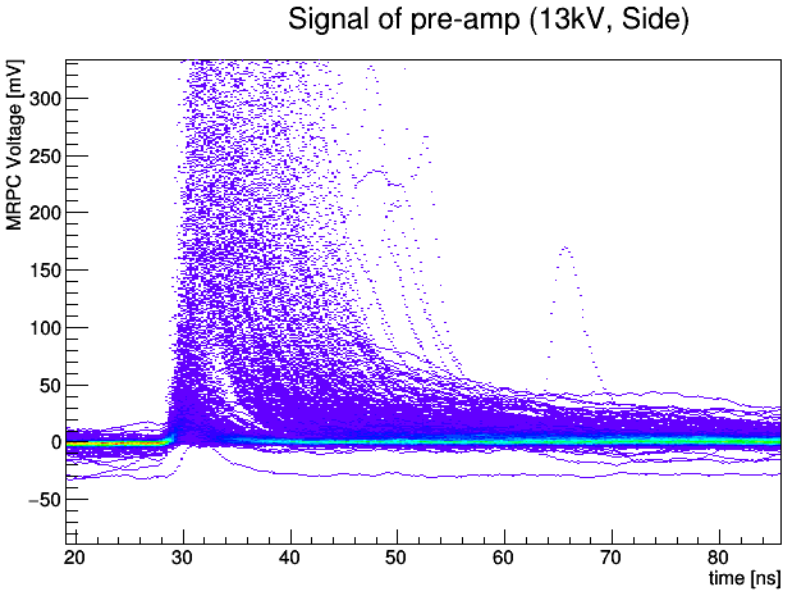


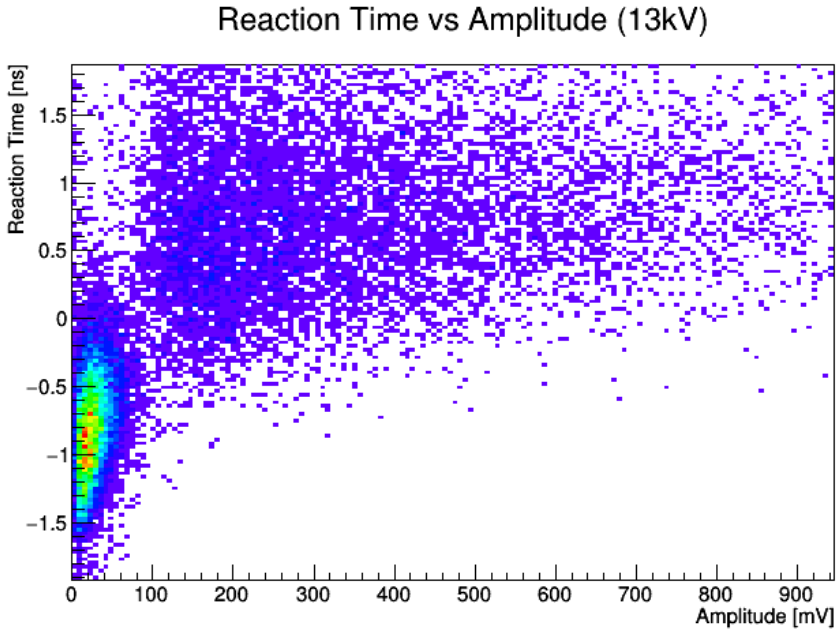
- Clear difference is not observed.
  - ≫ need to improve preamp?



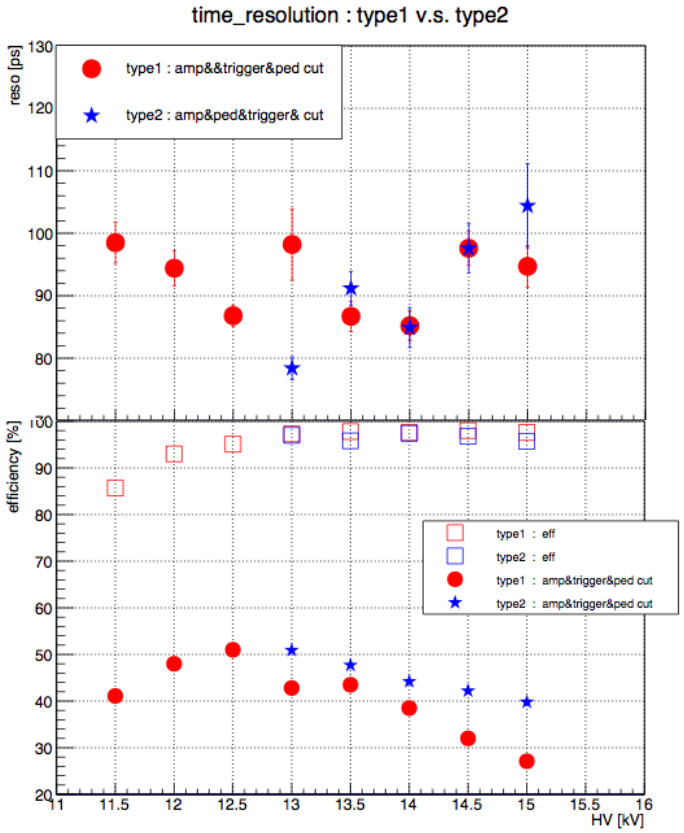
Rise time is changed in many events at high voltage??

Shape of Signal





Timing Resolution and Efficiency



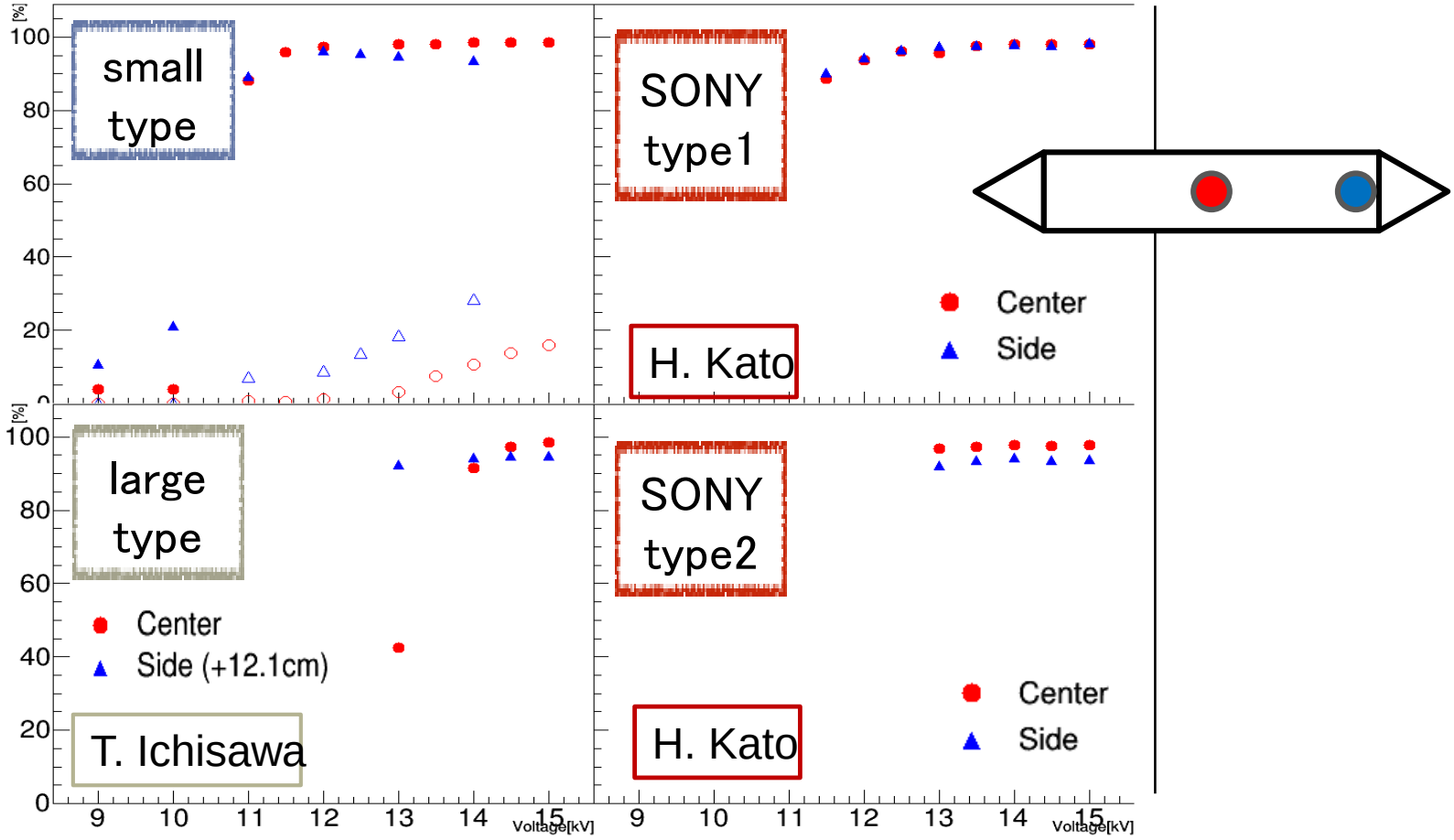
上図が時間分解能
下図がefficiency

左は波高とトリガーでのカットも載せてあります
どちらが使いやすいか分からなかったので両方のせました

白抜き四角が波高で閾値を決めたefficiency

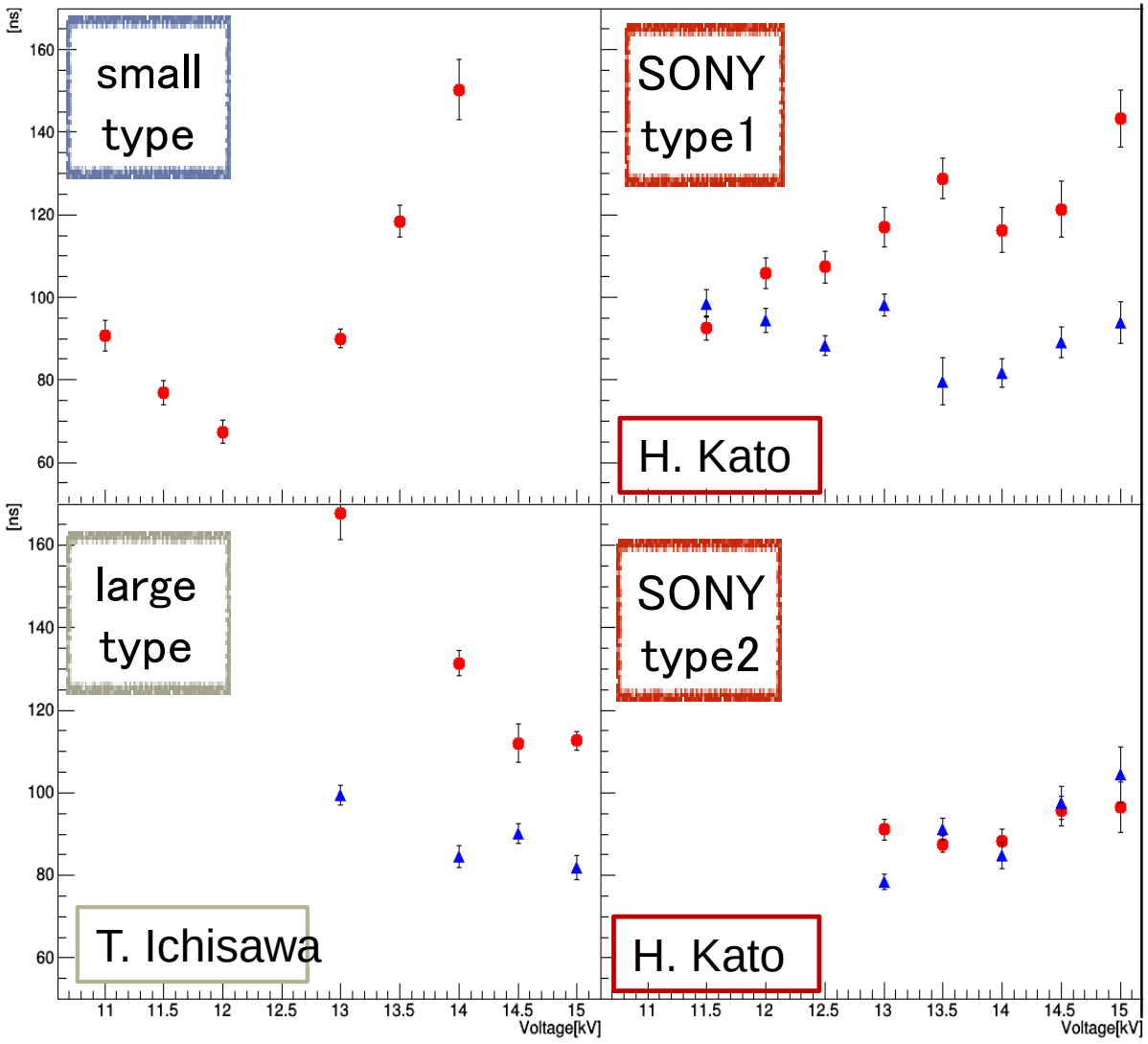
マーカーが対応している
例えば赤丸白抜きの分解能を出すためには赤丸白抜きのefficiencyになってしまう

2. EFFICIENCY (BEAM)



✓ The best efficiency of each MRPC is more than 95%

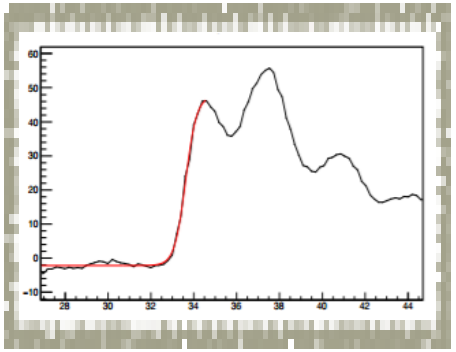
3. TIMING RESOLUTION (BEAM)



Best timing resolution
- type1: 85.4 ± 2.4ps
- type2: 78.9 ± 1.8ps

thinner pad is better

strong refection in large MRPC



NEED TO MATCH IMPEDANCE!!!