Development of the Time Projection Chamber readout for heavy RI collision experiment

K. Fujiwara, T. Kobayashi (Tokyo Metropolitan IRI)
T. Isobe, A. Taketani (RIKEN)
H. Ando, T. Tamagawa (Tokyo Metropolitan CIT)
Y. Kawamo (Rikkyo Univ.), H. Miya (CNS, Univ, of Tokyo)

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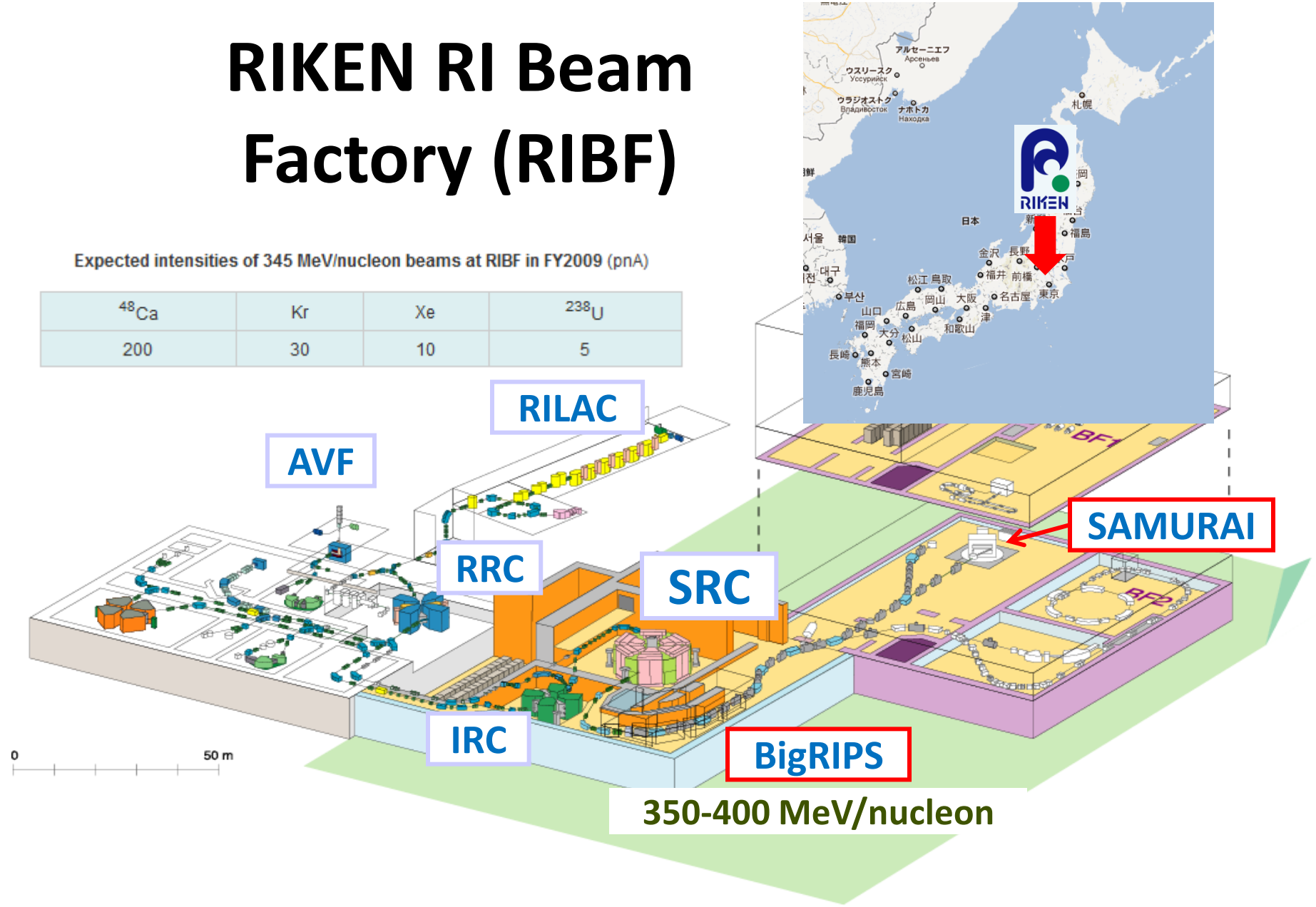
- Heavy RI collision experiment at RIKEN-RIBF
  - What is new challenge and difficulty.
- Designing of lower crosstalk transmission line and pattern for TPC readout pad.
- Status of MicroMEGAS study
- Summary

RIKEN RI Beam Factory (RIBF)

Expected intensities of 345 MeV/nucleon beams at RIBF in FY2009 (pnA)

^{48}Ca	Kr	Xe	^{238}U
200	30	10	5

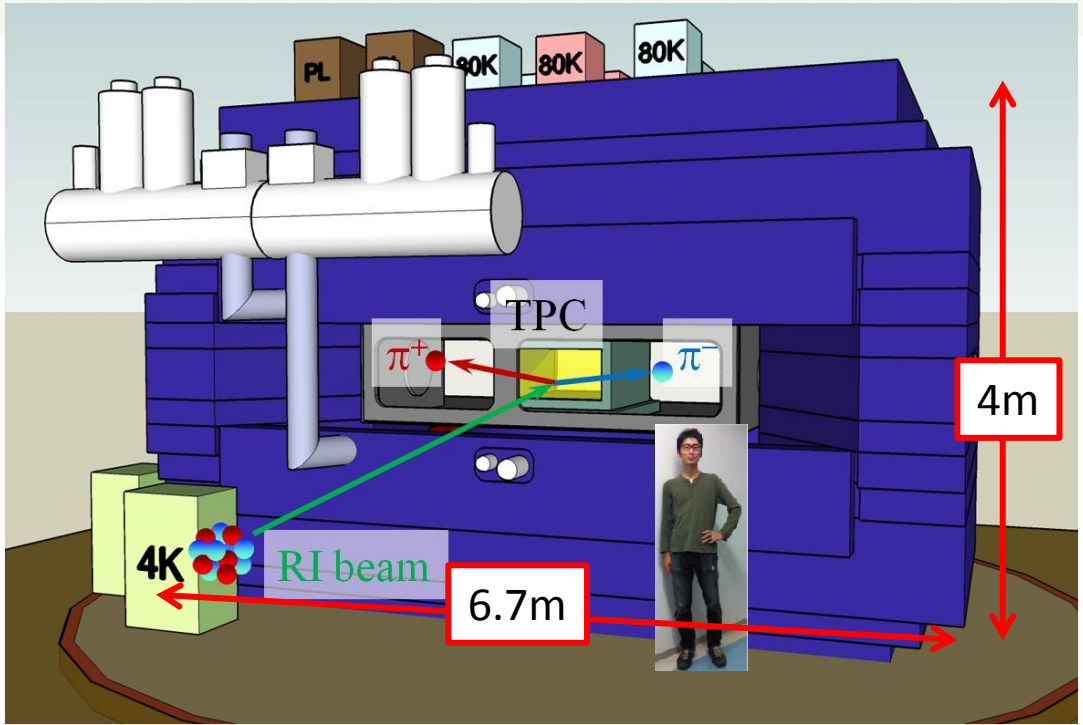


Intense (80 kW max.) H.I. beams (up to U) of 345AMeV at SRC
Fast RI beams by projectile fragmentation and U-fission at BigRIPS

SAMURAI Time Projection Chamber

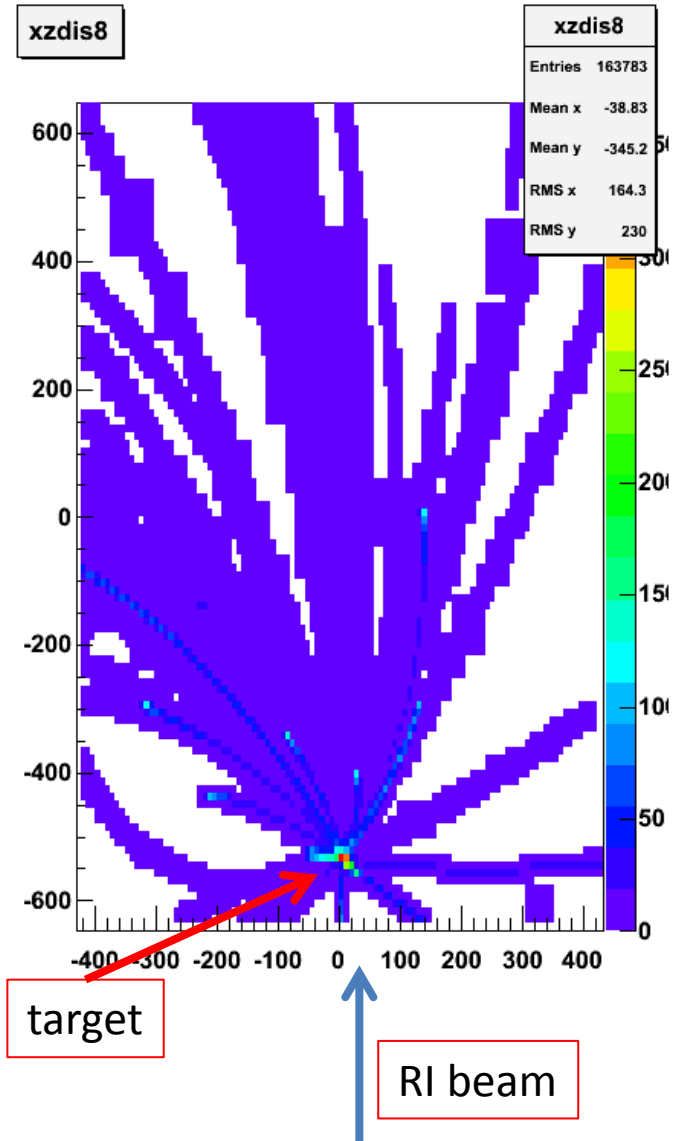
- Gaseous tracking detector which will be installed inside of the SAMURAI superconducting dipole magnet. (B<3.1T)
- Heavy Radioactive Isotope Collisions (HRIC) for study of EoS
  - Such as 124Sn + 132Sn, E=345AMeV
  - Simultaneous measurement of pion, proton, and ions.
- Collaborative work by by 8 Countries, 43 researchers.
  - http://groups.nscl.msu.edu/hira/sep.htm

3D tracking detector
MWDC type readout
12mm x 8mm pad
108 x 108 ch (12k in total)
~50cm drift length
B=0.5T for EoS experiments



Wide dynamic range on particle charge

- High multiplicity 10~100
- Particle charge “Z”: 1~50
  - Different from relativistic energy experiments.
- We want to measure the large Z particle (ions) as well as protons and pions.
- Limited by the dynamic range of readout.
  - $dE/dX \propto Z^2$.
  - $200 \sim 200*50^2 = 500{,}000$??
- Measurement up to Z~8.



Crosstalk study and readout pad design for Z=1 particle measurement

- Crosstalk from large Z particles may make fake track of Z=1.
- Crosstalk level of less than 0.5% is necessary for Z=1 particle tracking.

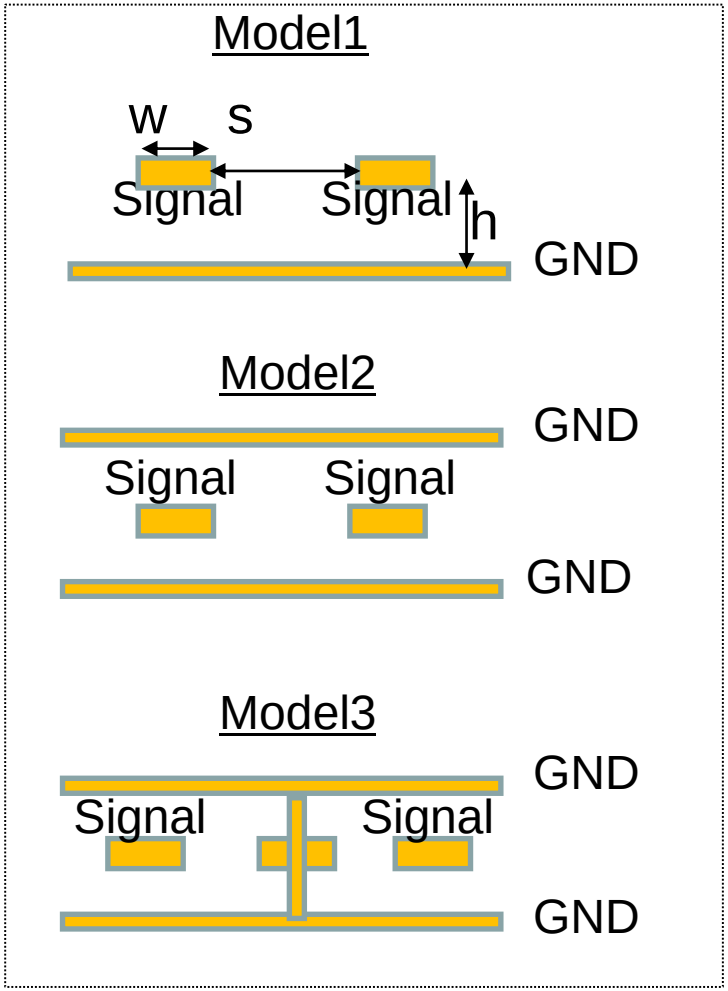
- <u>Design lower crosstalk transmission line and pattern for readout pad.</u>

1. Electromagnetic simulation
   - Dependence on Layer structure, physical parameters
2. Circuit Simulation for crosstalk
   - Calculate crosstalk level in an adjacent line
3. Making Test board for crosstalk evaluation
4. Design TPC pad

Models for crosstalk study

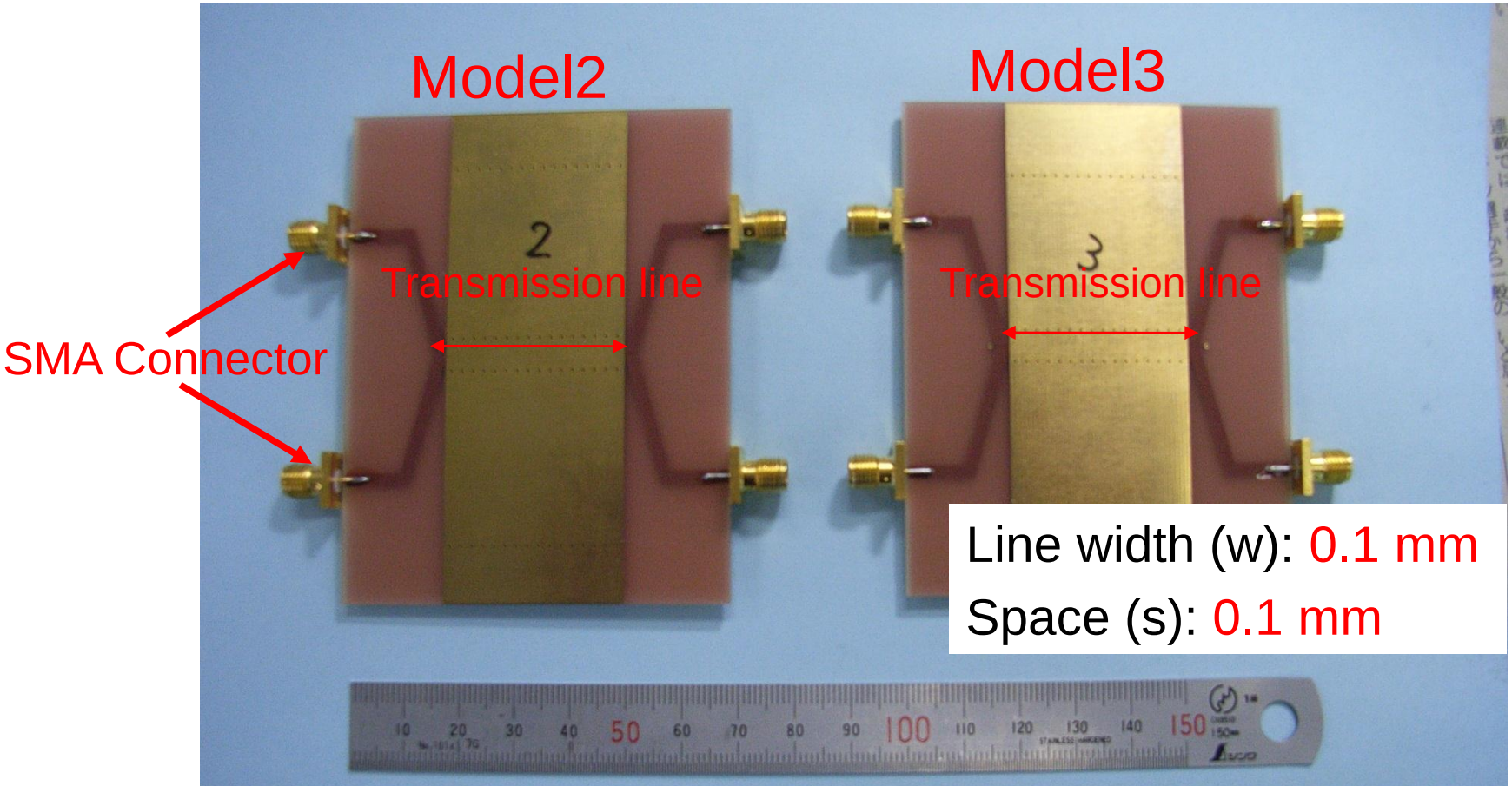
- 3 types of transmission line
- Line width (w): 0.1 mm
- Space (s): 0.1 mm
- Line length: 36 mm
- Thickness (h): 43 μm
- Substrate: FR-4 (er=4.2, tanδ=0.015)
- Conductivity: 5.8 x10^8 S/m

Simulation Models



Test boards for crosstalk study

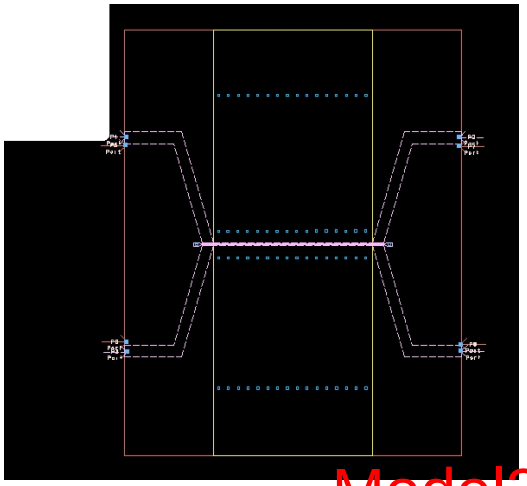
- To evaluate transmission line in Model2 and Model3.
- Measured cross talk level, impedance are compared with simulation result.



Result of electromagnetic simulation

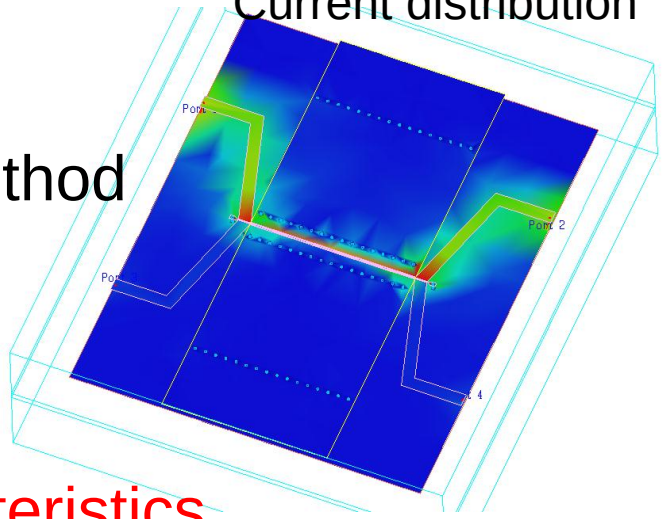
Calculating the S-parameters from 10 MHz to 2.5 GHz.

Electromagnetic simulation model

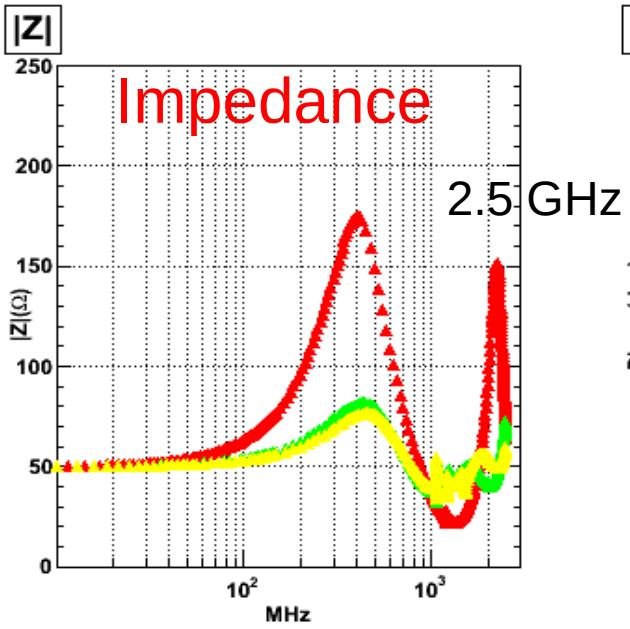


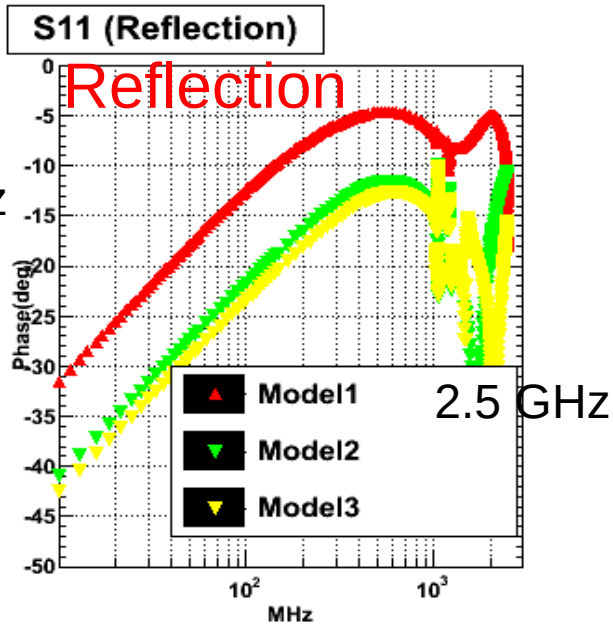
Momentum, BED Method
with ADS by Agilent

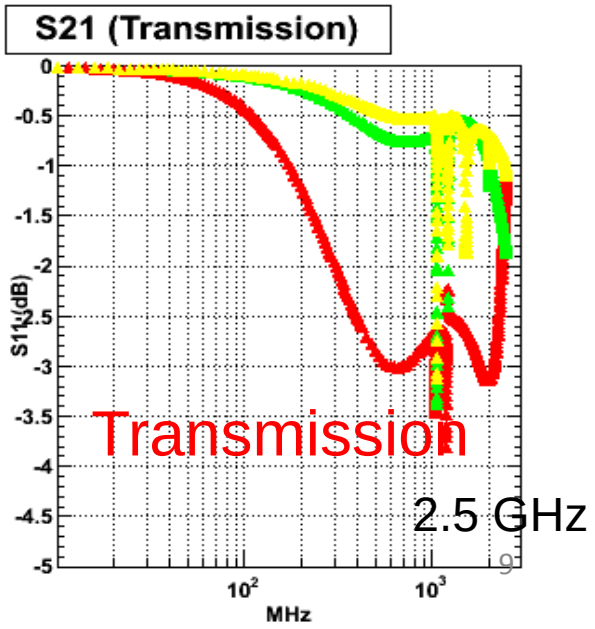
Current distribution



Model3 has the best characteristics.

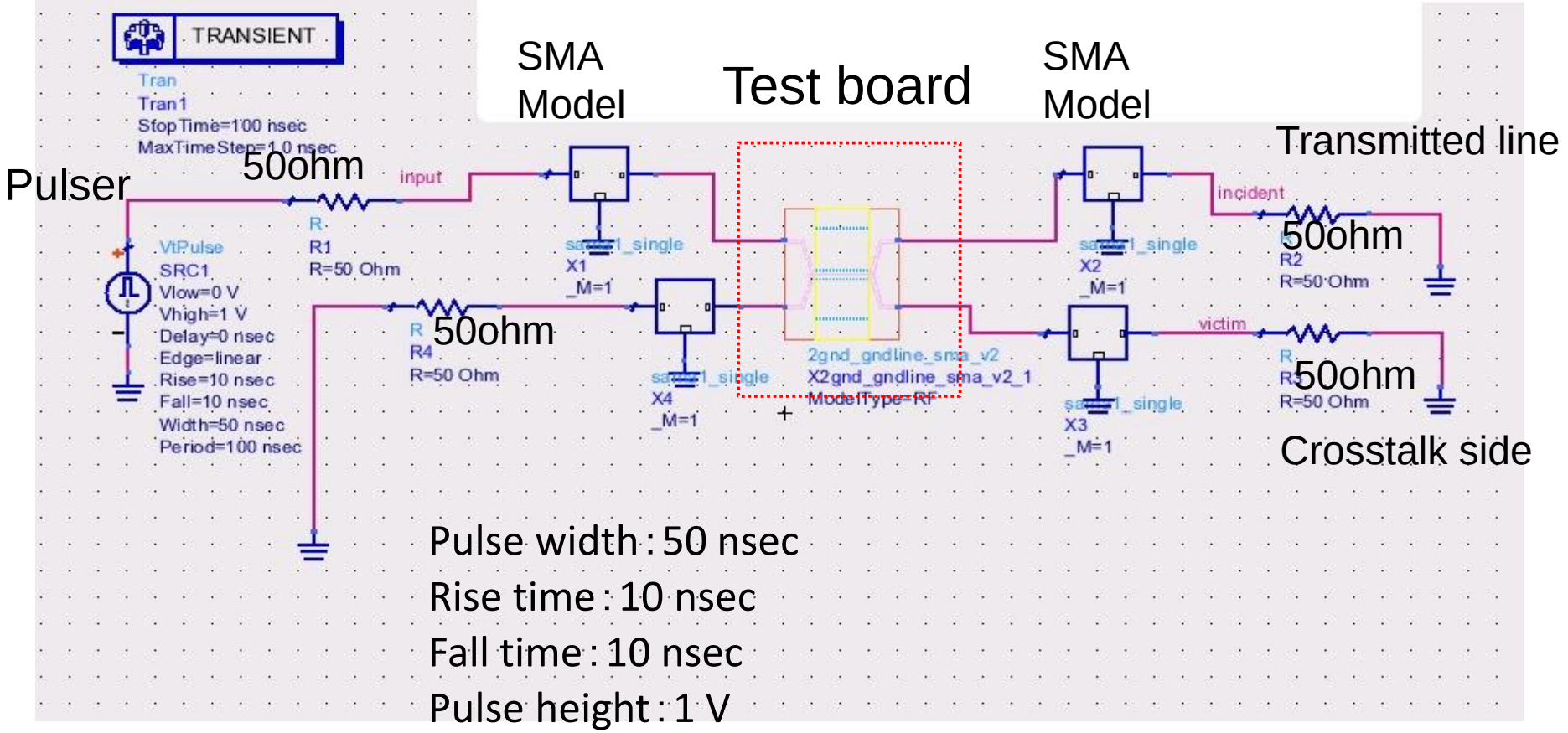






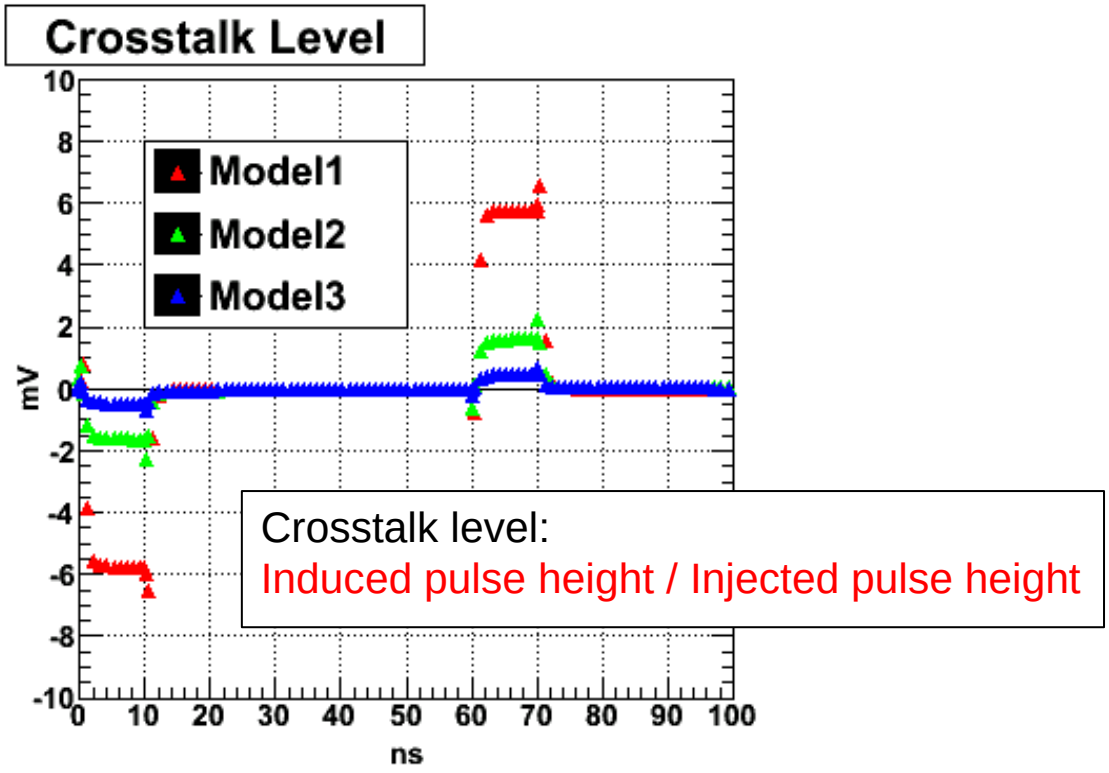
Simulation model for crosstalk evaluation

SMA connector model is included to make a realistic model.
Without connector model is also prepared.



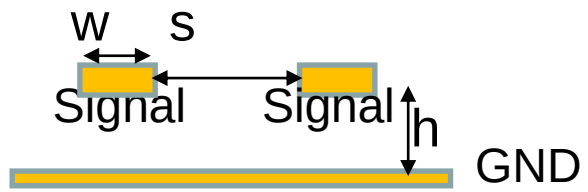
Pulse width : 50 nsec
Rise time : 10 nsec
Fall time : 10 nsec
Pulse height : 1 V

Simulated crosstalk level in each models

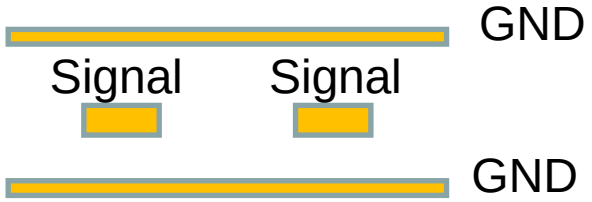


Crosstalk level:
Induced pulse height / Injected pulse height

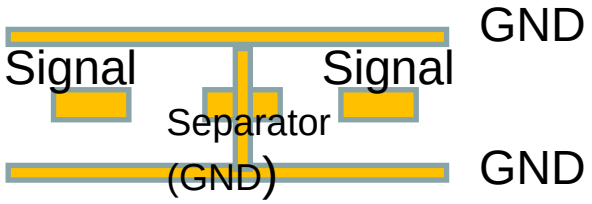
Model1



Model2



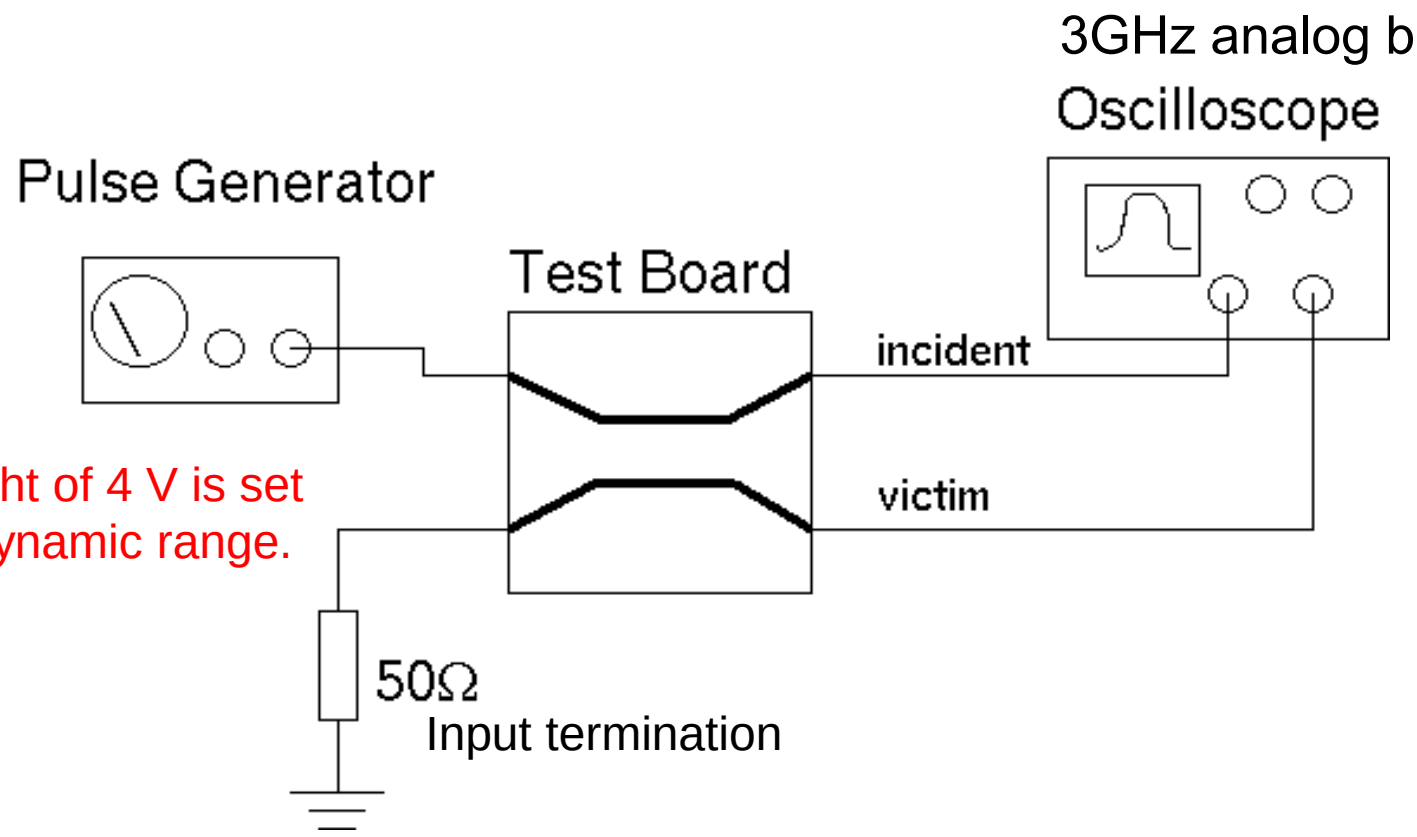
Model3



	Crosstalk Level (no SMA)	Crosstalk Level (with SMA)
Model1	1.67%	1.70%
Model2	0.31%	0.33%
Model3	0.08%	0.08%

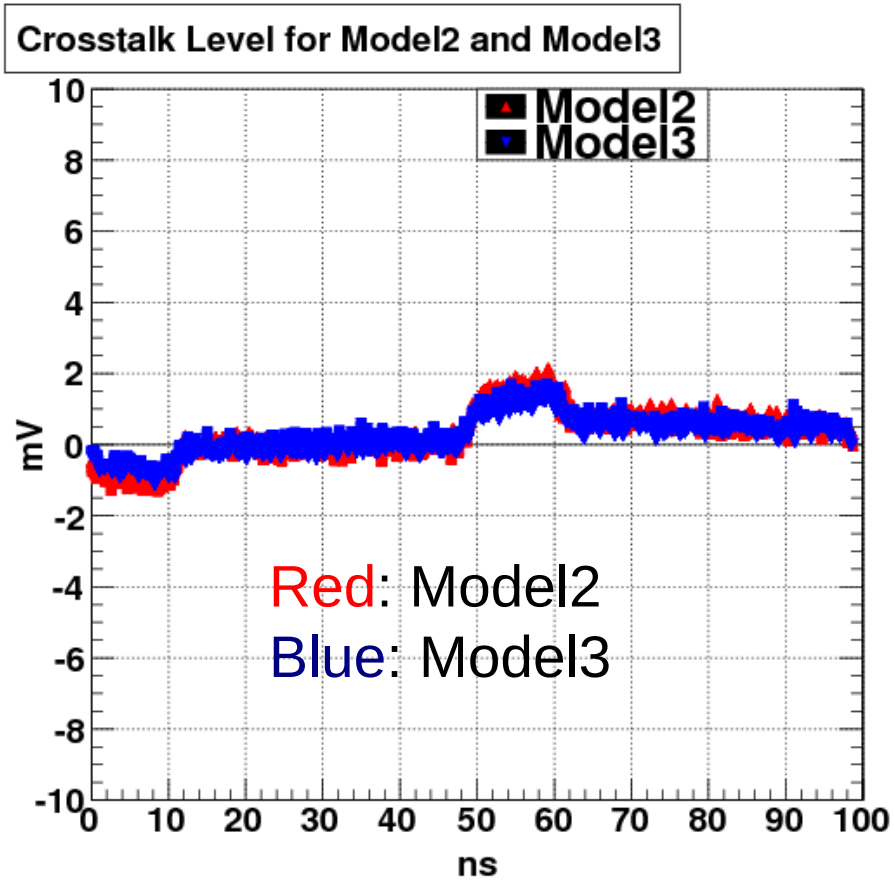
Model3 shows best performance.

Setup for crosstalk level measurement



Pulse Height of 4 V is set to obtain dynamic range.

Measurement of crosstalk level



	Simulation	Measured
Model2	0.33%	0.05%
Model3	0.08%	0.04%

Crosstalk level of Model3 is twice better than the simulation.

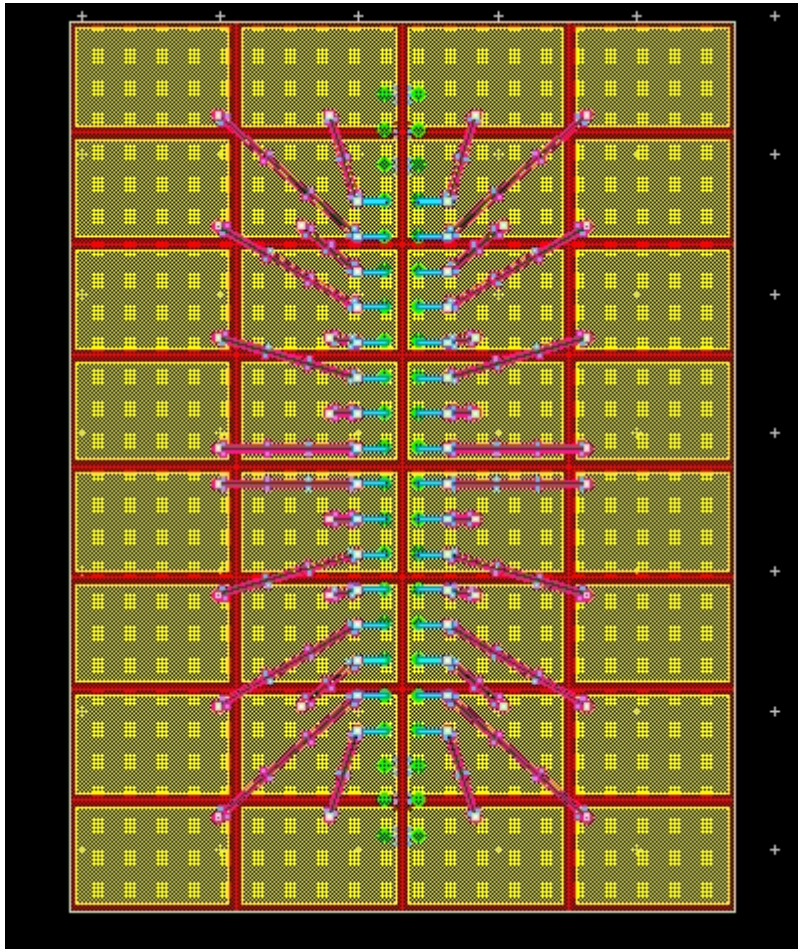
→ lack of understanding of SMA connector frequency characteristics?

Satisfy the requirement for TPC readout.

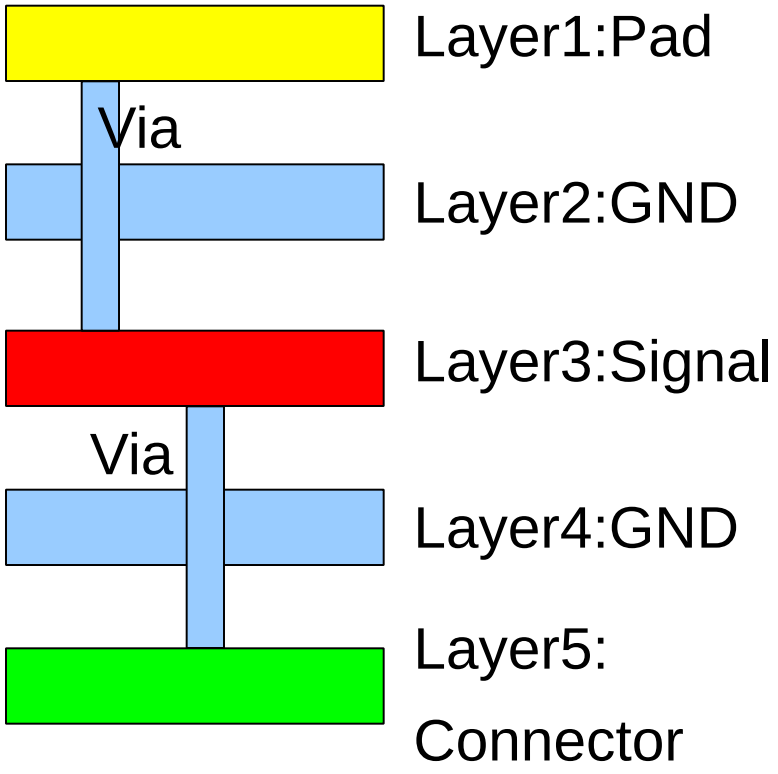
Designed TPC pad structure

5 Layers structure

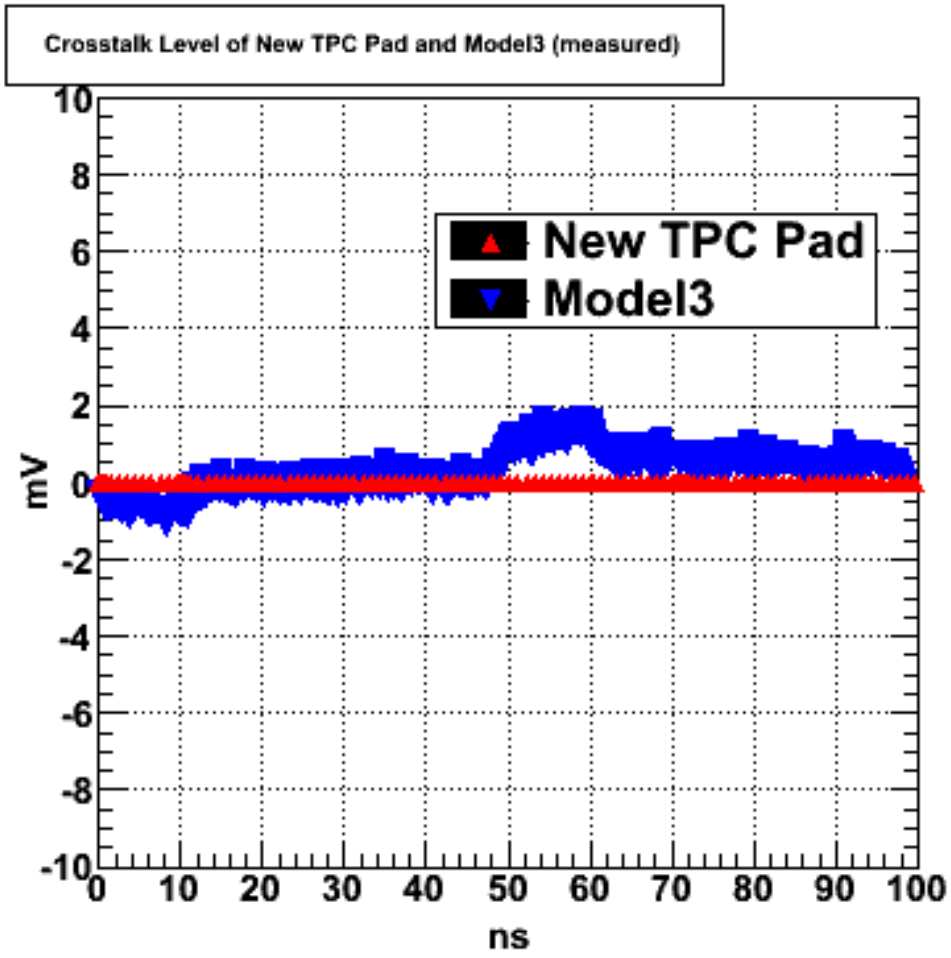
- 1 Pad area: 11 mm x 7 mm



Cross Section



Simulated crosstalk of TPC Pad



1.4% of Model3.

MicroMEGAS study in Japan

- MicroMEGAS readout is useful for high-multiplicity particle measurement.
  - Good 2 track separation capability with fine pitch pads.
  - 2D good resolution is useful for active target TPC experiment.
- Good crosstalk comparing with MWDC readout??
  - Larger coupling between anode readout pad and cathode wire.
- Started test with Saclay MicroMEGAS

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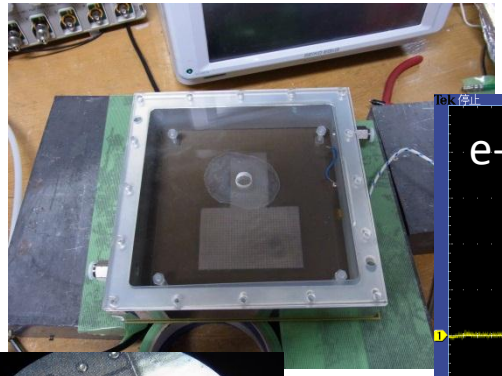
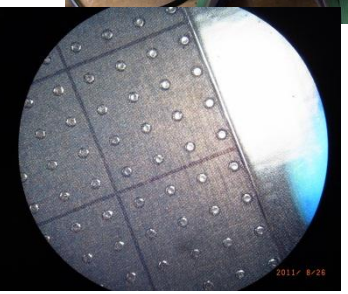
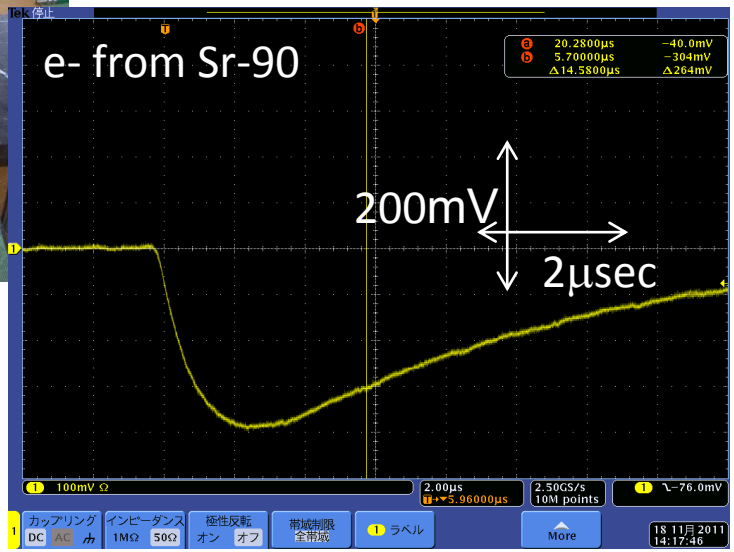
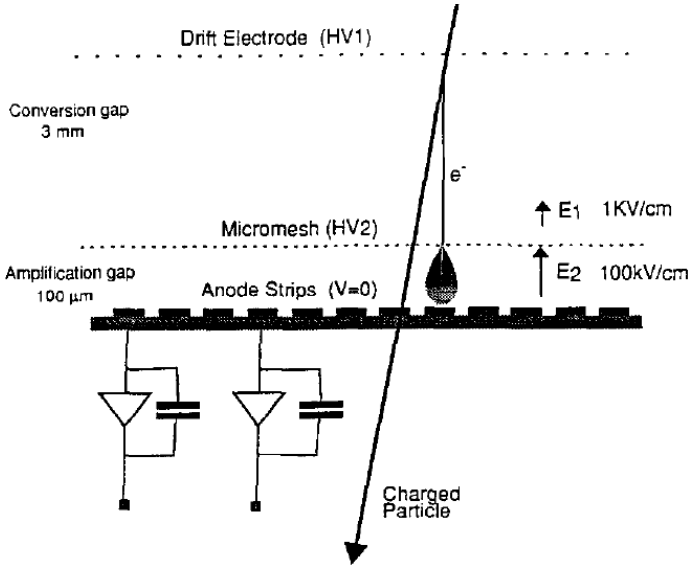








Summary

- SAMURAI-TPC international collaboration work has been performed for the study of nuclear EoS.
- Crosstalk study has been performed for simultaneous measurement of various kind of particles.
  - Important also for Z=1 particle measurement.
  - Crosstalk level by simulation: 0.08%
  - Crosstalk level by measurement: 0.04%
  - Requirement: <0.5%, it is satisfied.
- MicroMEGAS study for HRIC experiments was launched.
  - Ion beam test at next FY
- Wide dynamic range ADC and preamp is necessary for complete detection of particles in HRIC.

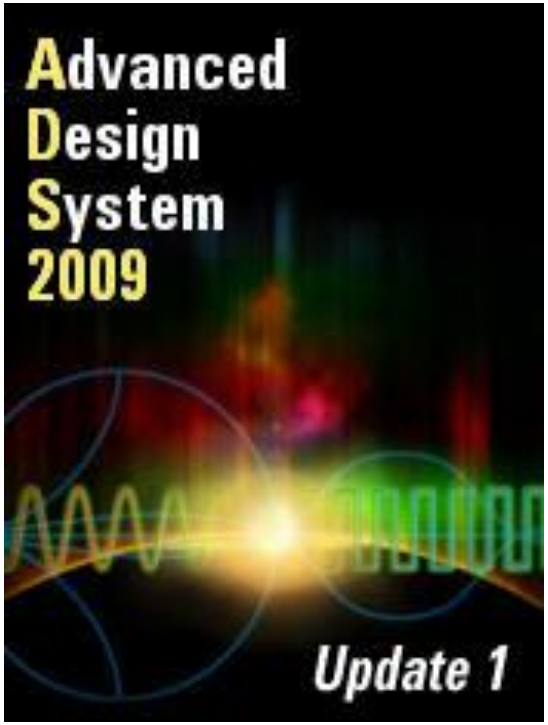
Thank you for your attention!

RIKEN-RIBF detector team

Backup

Development Software for the simulation

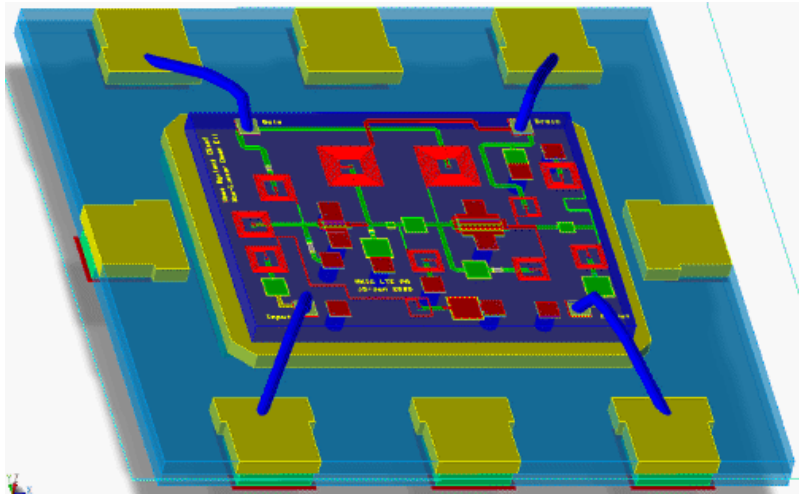
Agilent Technology: Advanced Design System (ADS)



Development of:

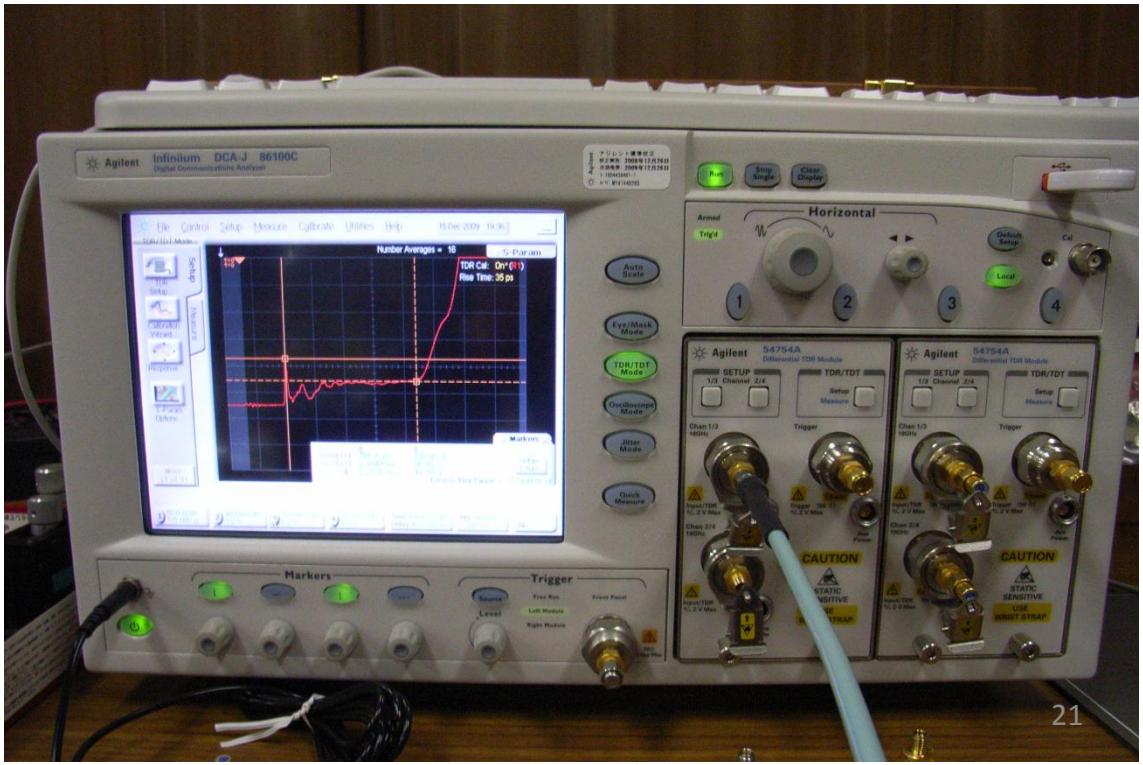
- RF circuit, High Speed RF circuit
- Monorisic Microwave IC (MMIC), RFIC
- Transmission Line, Antenna

Example of MMIC design



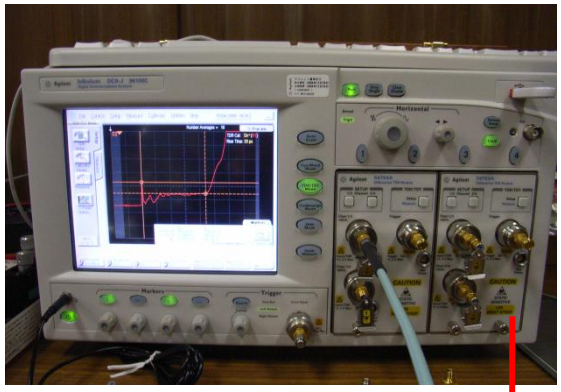
5. Impedance measurement

- Time Domain Reflectometry (TDR)
- Agilent 86100C
  - TDR Module 54754A x 2
- Minimum pulse rise time:10 ps
- To evaluate characteristic impedance in time domain.
  - Transmission lines
  - Finding failure point
    - Lines
    - Wire-bonding…



Impedance measurement setup

TDR (B.W=18 GHz)

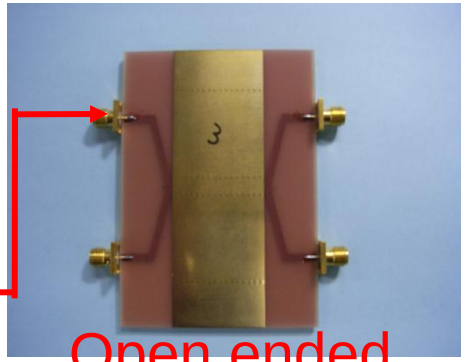


Oscilloscope
+
Pulser

35 ps Injection
step pulse

Reflected pulse

Test Board



Open ended

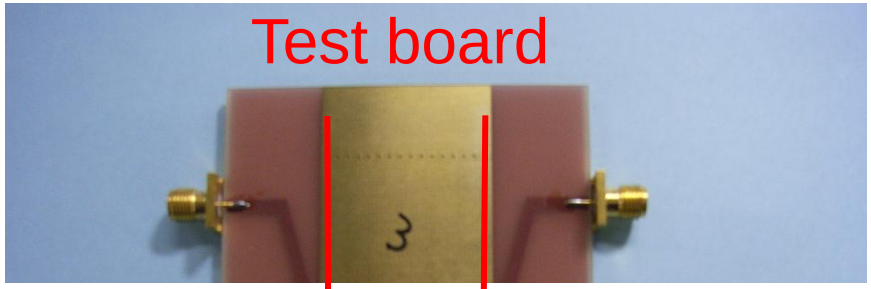
Composing

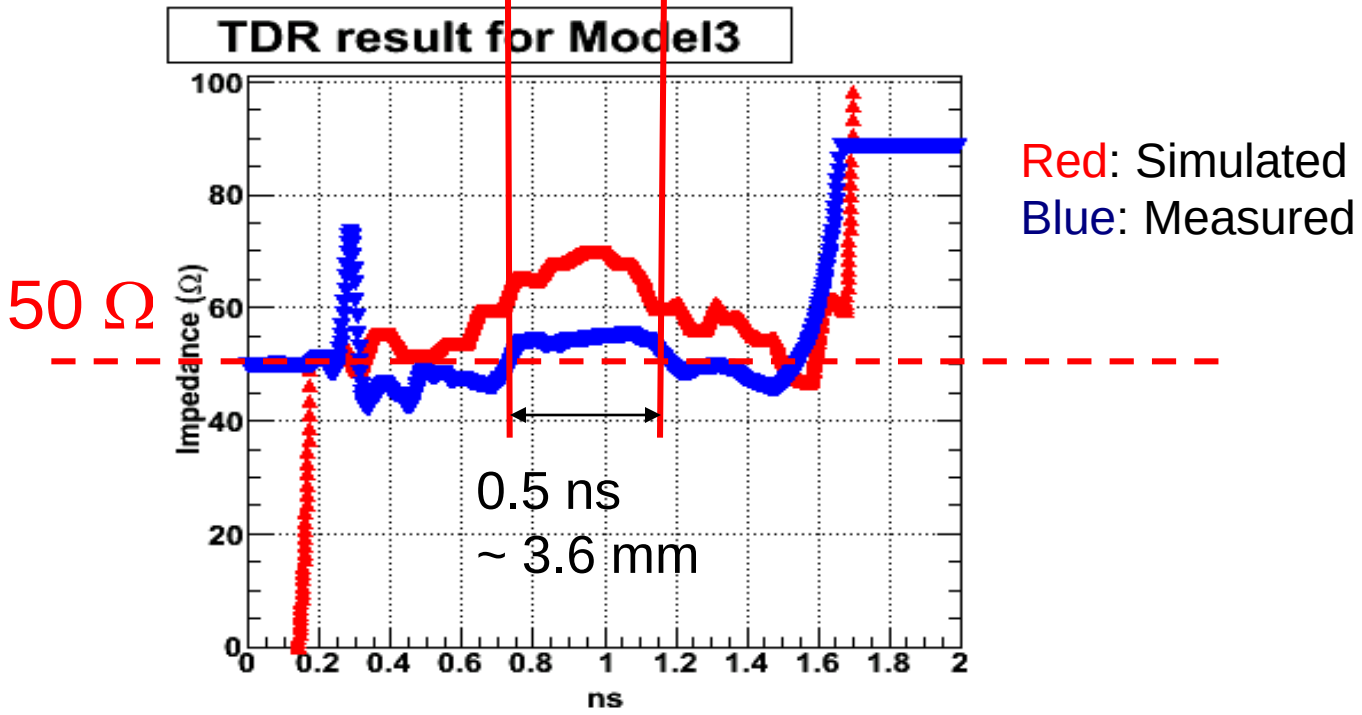
Injection + Reflection pulse

Impedance measurement result 1

Test board of Model3 has better impedance characteristics.

- Z ~ 55 Ω
- Line length by TDR measurement: ~ 36 mm
  - It is consistent with the real length.





Impedance measurement result 2

It seems Model3 has better impedance characteristics.

- Line impedance of transmission region in Model3 is flat than Model2.
- Good result by separator (GND line) in Model3

→ Electric force line can be shielded.