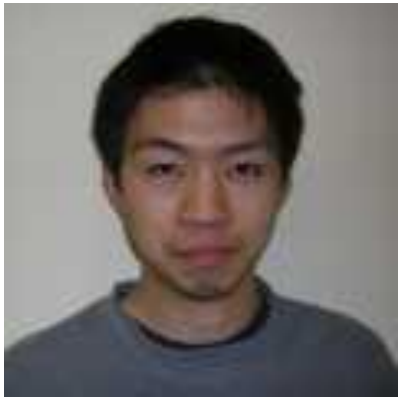
TPC pad simulation for wide dynamic range application

RD51 meeting at Kobe 2011 Sep 2nd



Thesis: Fine pitch FPC(30μ/30μ L/S) for PHENIX Si Pixel detector

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Outline

1. Development motivation from Nuclear Physics
2. Development steps of a TPC pad
3. Crosstalk measurement
4. Impedance measurement
5. New TPC pad development
6. Summary

2. Development motivation

- Heavy Ion 400MeV/A , measuring interaction products by TPC.
- Pulse height induced in a detector $\propto Z^2$
- Target range of Z is Z~10.
- MIP should be detected near by Z=10

↓

- Dynamic range > 100
- In order to obtain the detection dynamic range, the crosstalk level should be less than 0.5%.

3. Development steps of a TPC pad

We are developing a new TPC pad with RIKEN.

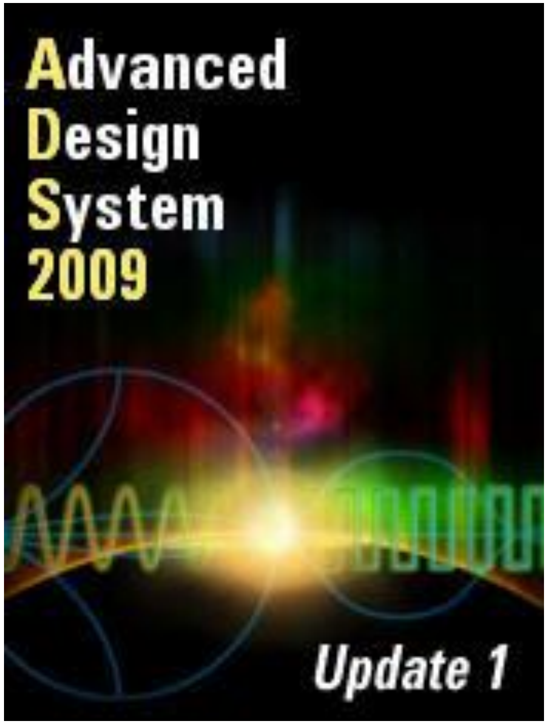
1. Electromagnetic simulation
   - Design lower crosstalk transmission line and pattern.
   - Layer structure, physical parameters
   - Current distribution, S-parameter calculation
2. Circuit Simulation for crosstalk

   Calculate crosstalk level in an adjacent line

   -> Required crosstalk level is less than 0.5%.
3. Making Test board for crosstalk evaluation
4. Design TPC pad

Development Software for the simulation

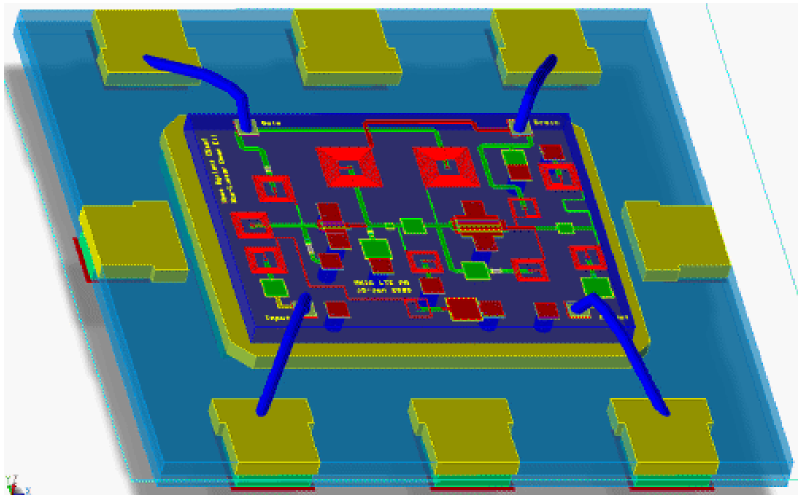
Agilent Technology: Advanced Design System (ADS)



Development of:

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

Example of MMIC design

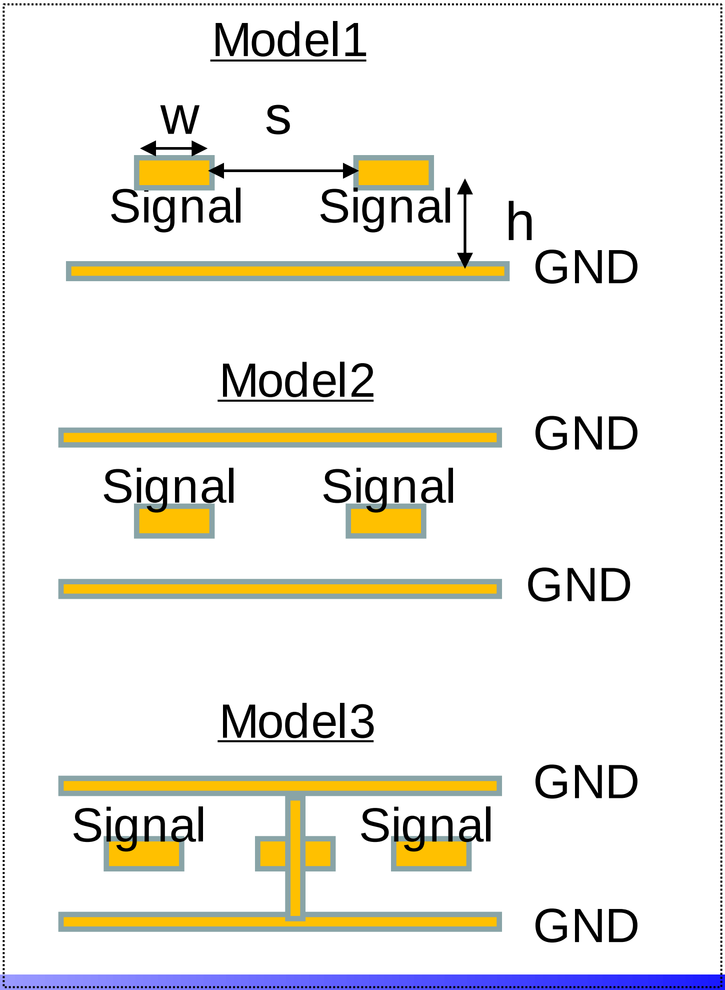


Electromagnetic simulation models

First, development of low crosstalk transmission line in TPC pad

- 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

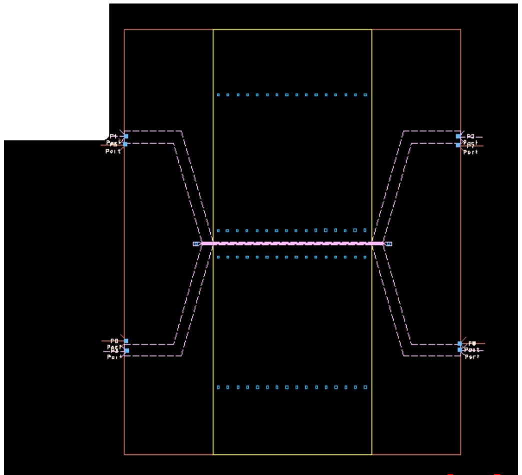
Simulation Models



Result of electromagnetic simulation

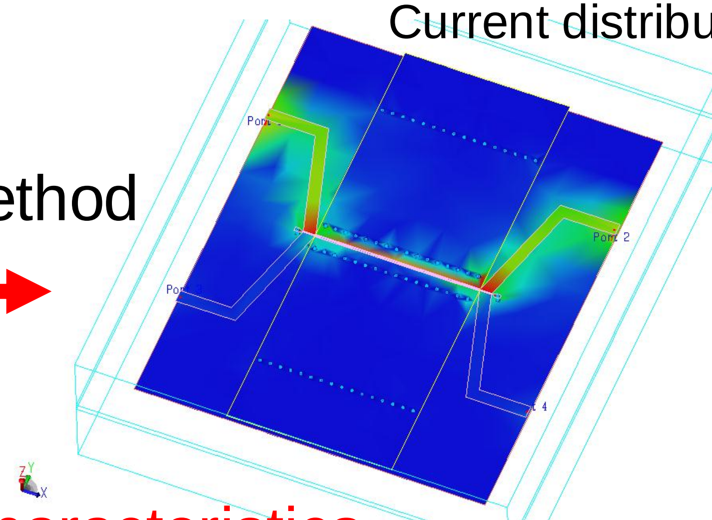
Calculating the S-parameters from 10 MHz to 2.5 GHz.

Electromagnetic simulation model

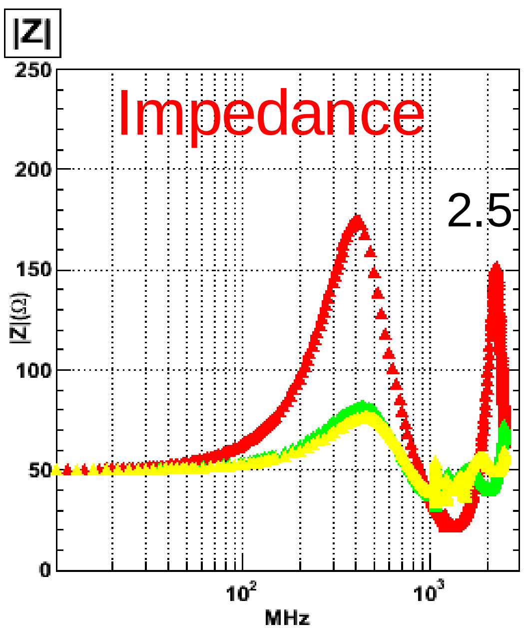


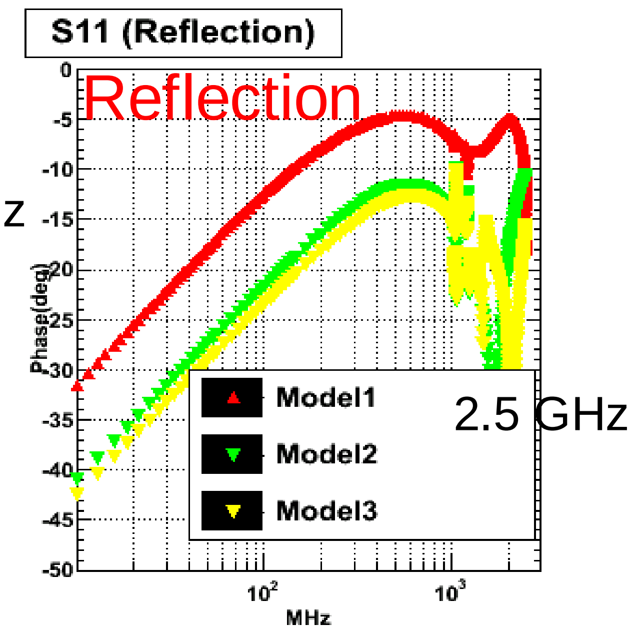
Momentum Method

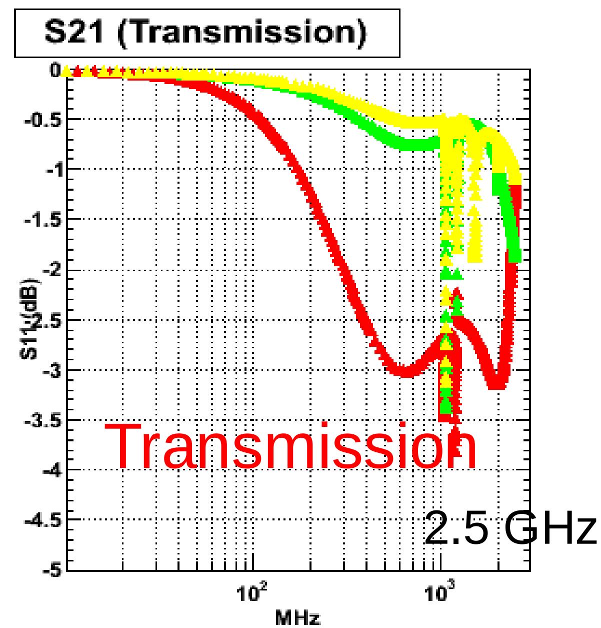
Current distribution



Model3 has the best characteristics.



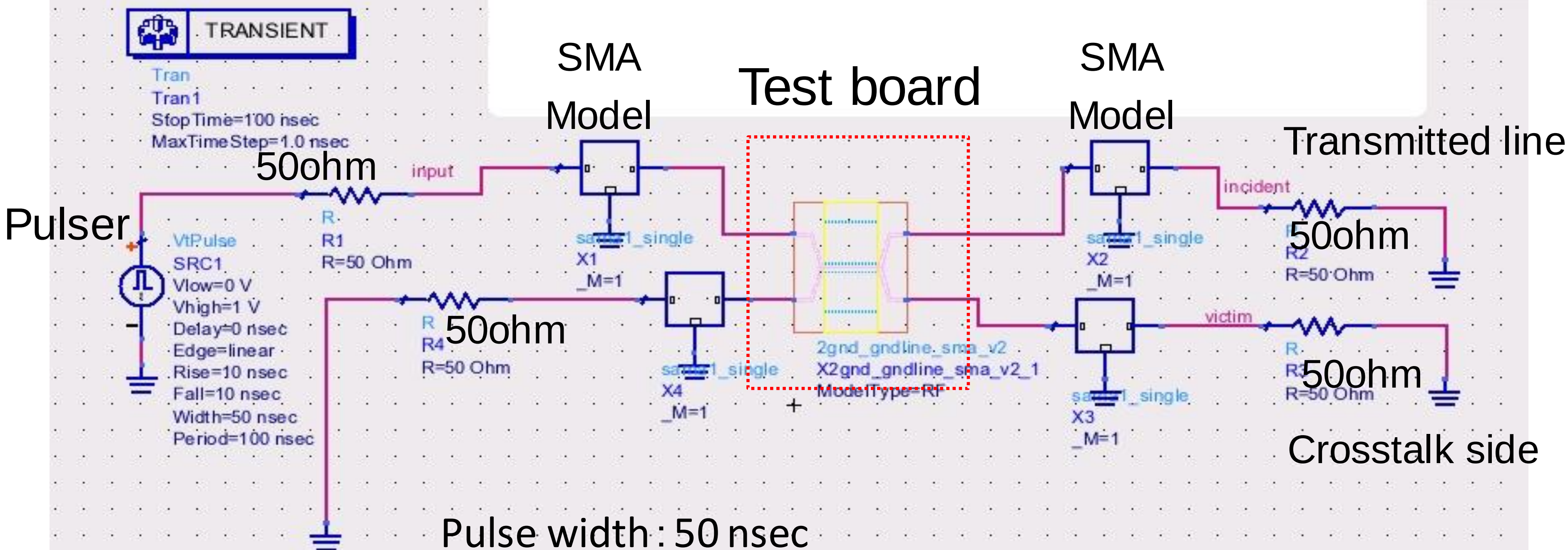




Calculation model for crosstalk evaluation

SMA connector model is included to make a realistic model.

Without connector model is also prepared.



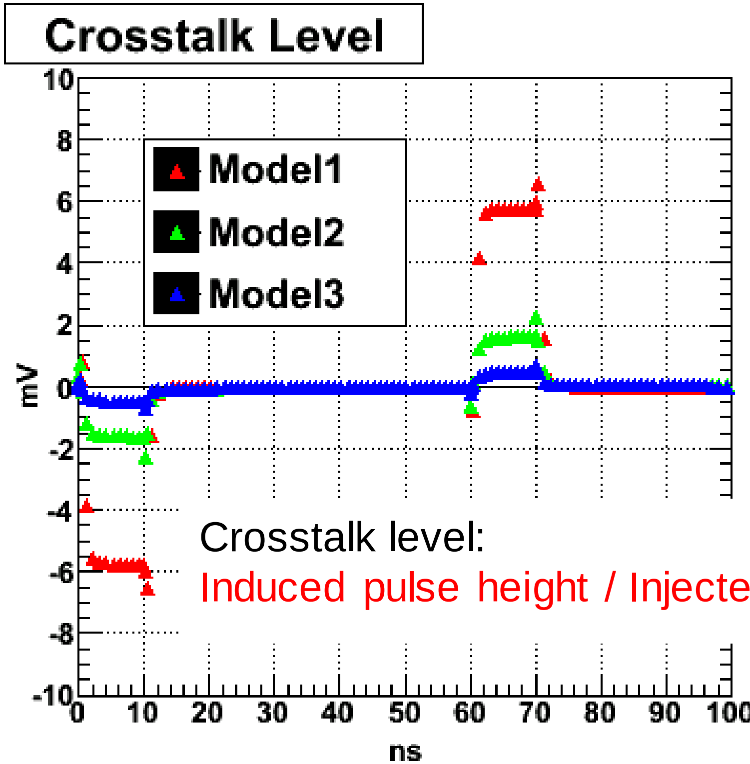
Pulse width : 50 nsec

Rise time : 10 nsec

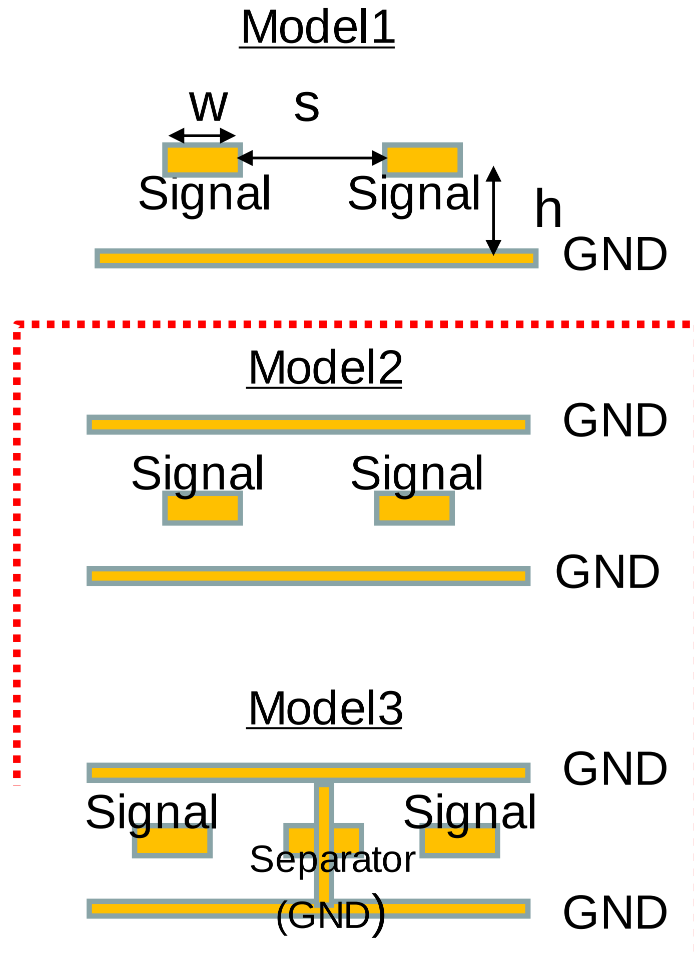
Fall time : 10 nsec

Pulse height : 1 V

Crosstalk level in each models



Crosstalk level:
Induced pulse height / Injected pulse height

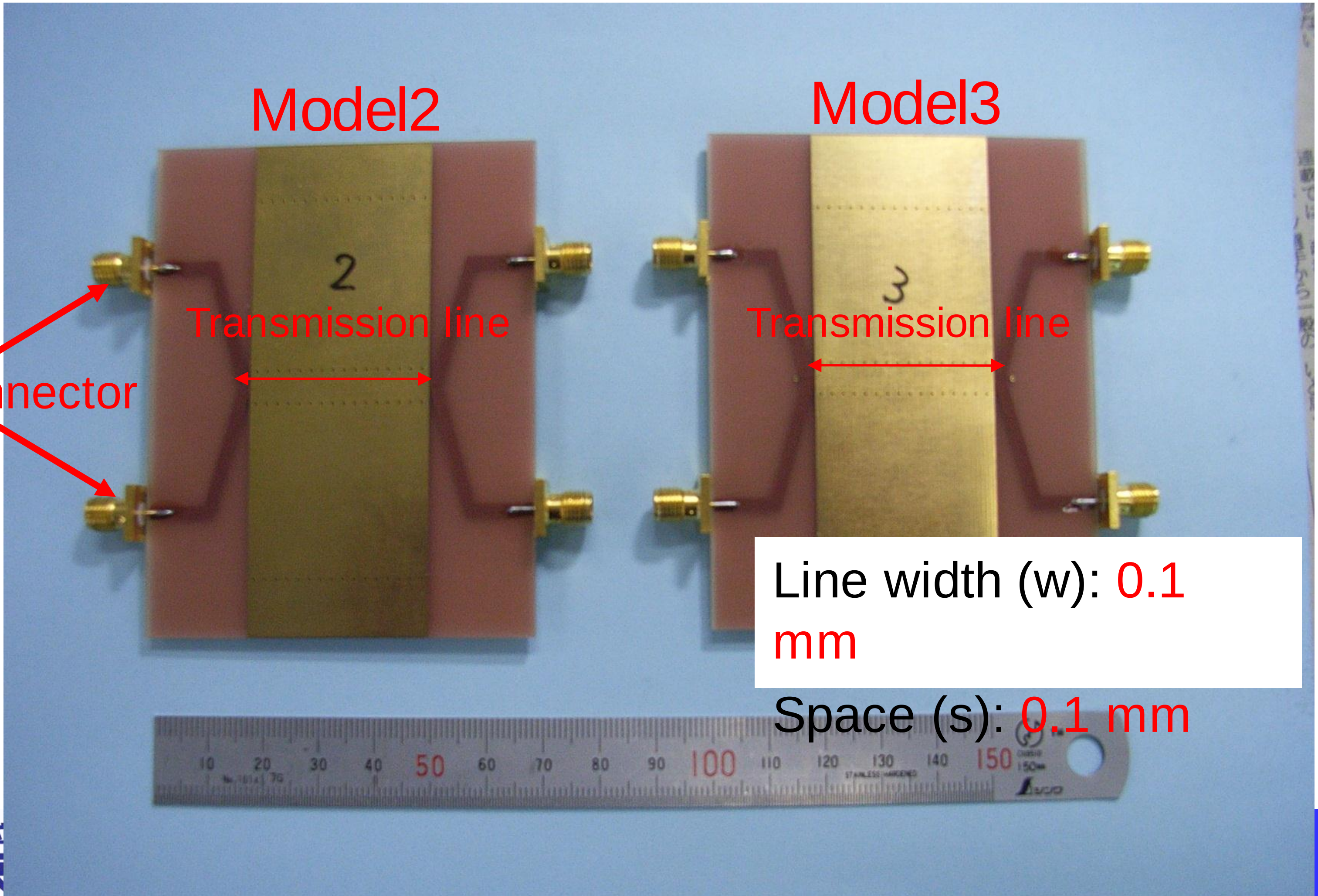


	Crosstalk Level (no SMA)	Crosstalk Level (with SMA)
Model1	1.67%	1.70%
Model2	0.31%	0.33%
Model3	0.08%	0.08%

Crosstalk level of Model3 is also the best in the measurement.

Test boards

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

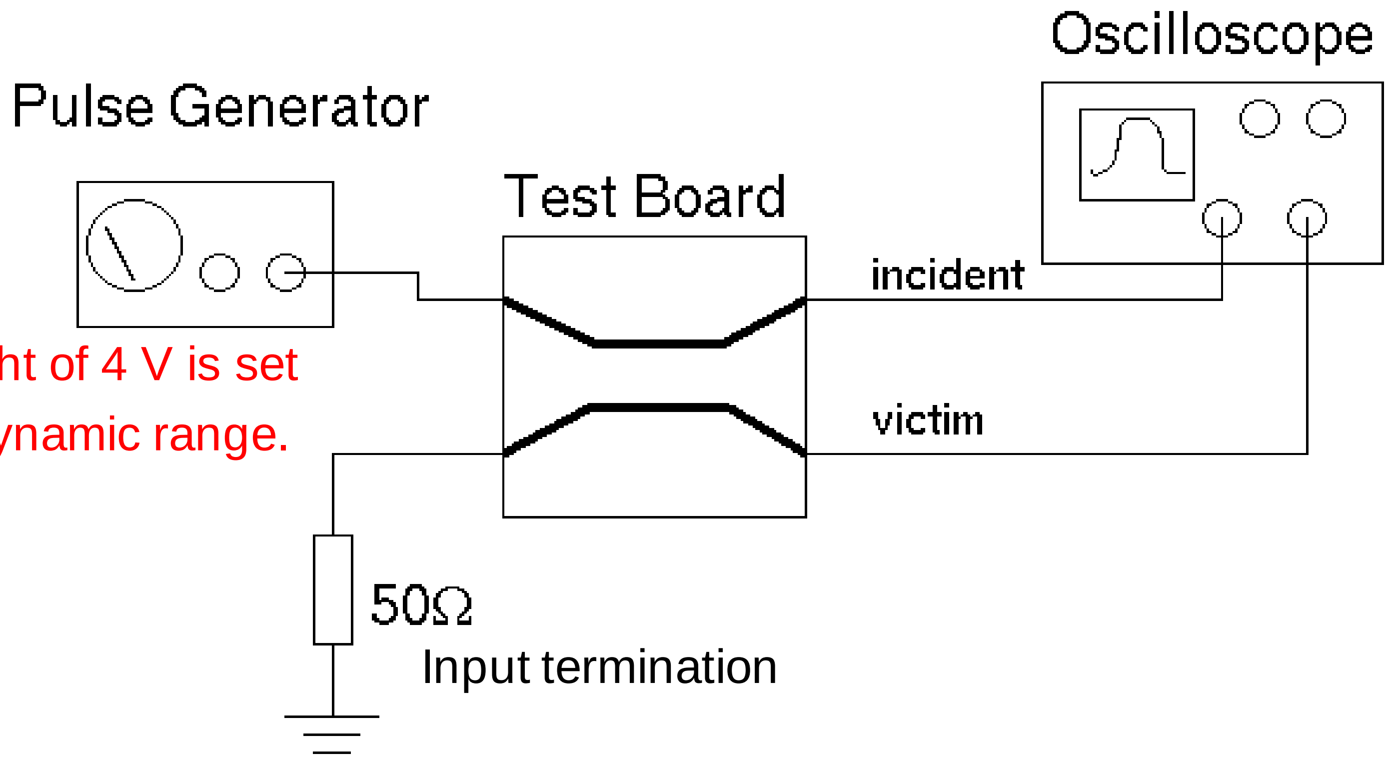


Line width (w): 0.1 mm

Space (s): 0.1 mm

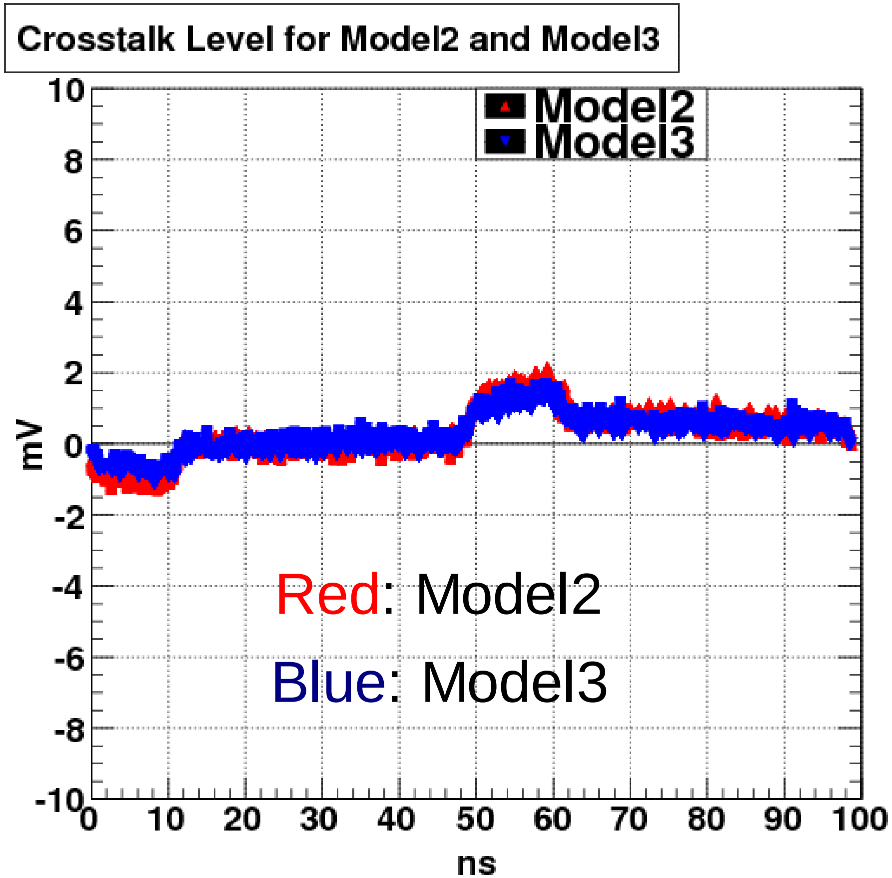
4. Crosstalk level measurement

- Crosstalk measurement setup
  - 3 GHz analog bandwidth oscilloscope
  - Pulse Generator (Pulse height=4 V)



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

Crosstalk level measurement result



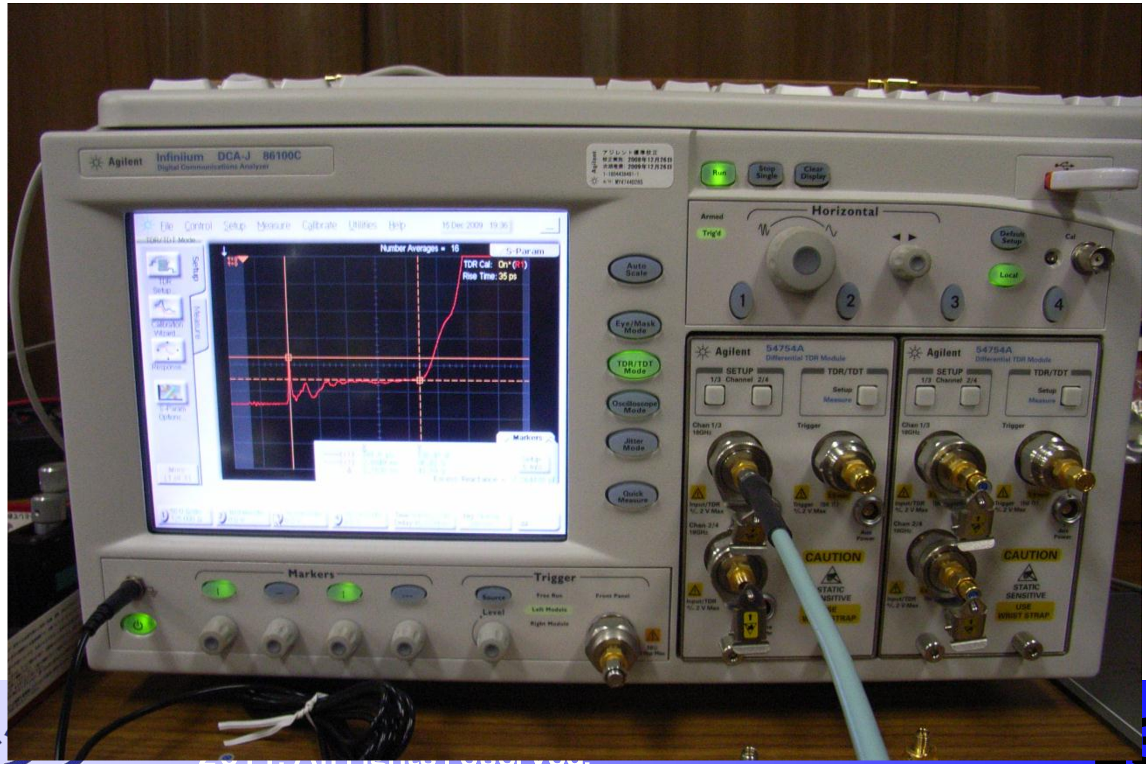
	Crosstalk Level (Simulated)	Crosstalk Level (Measured)
Model2	0.33%	0.05%
Model3	0.08%	0.04%

Crosstalk level in Model3 is improved than the simulation.

→ It might be reason of SMA connector frequency characteristics.

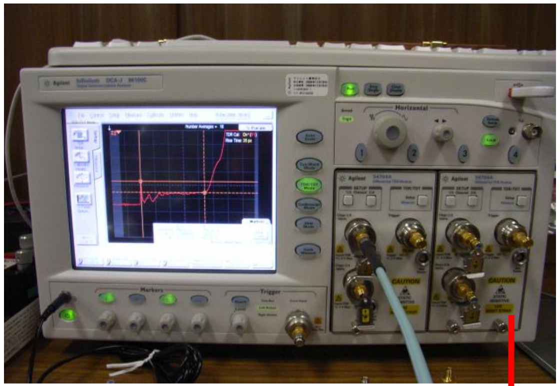
5. Impedance measurement

- 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)

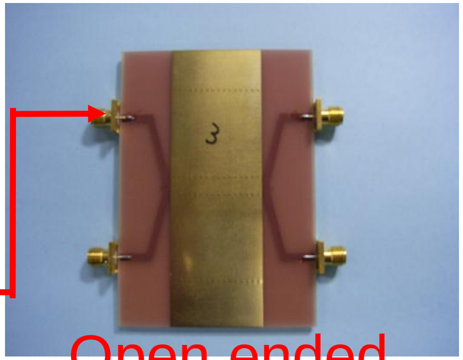


Oscilloscope
+
Pulser

35 ps Injection step pulse

Reflected pulse

Test Board



Open ended

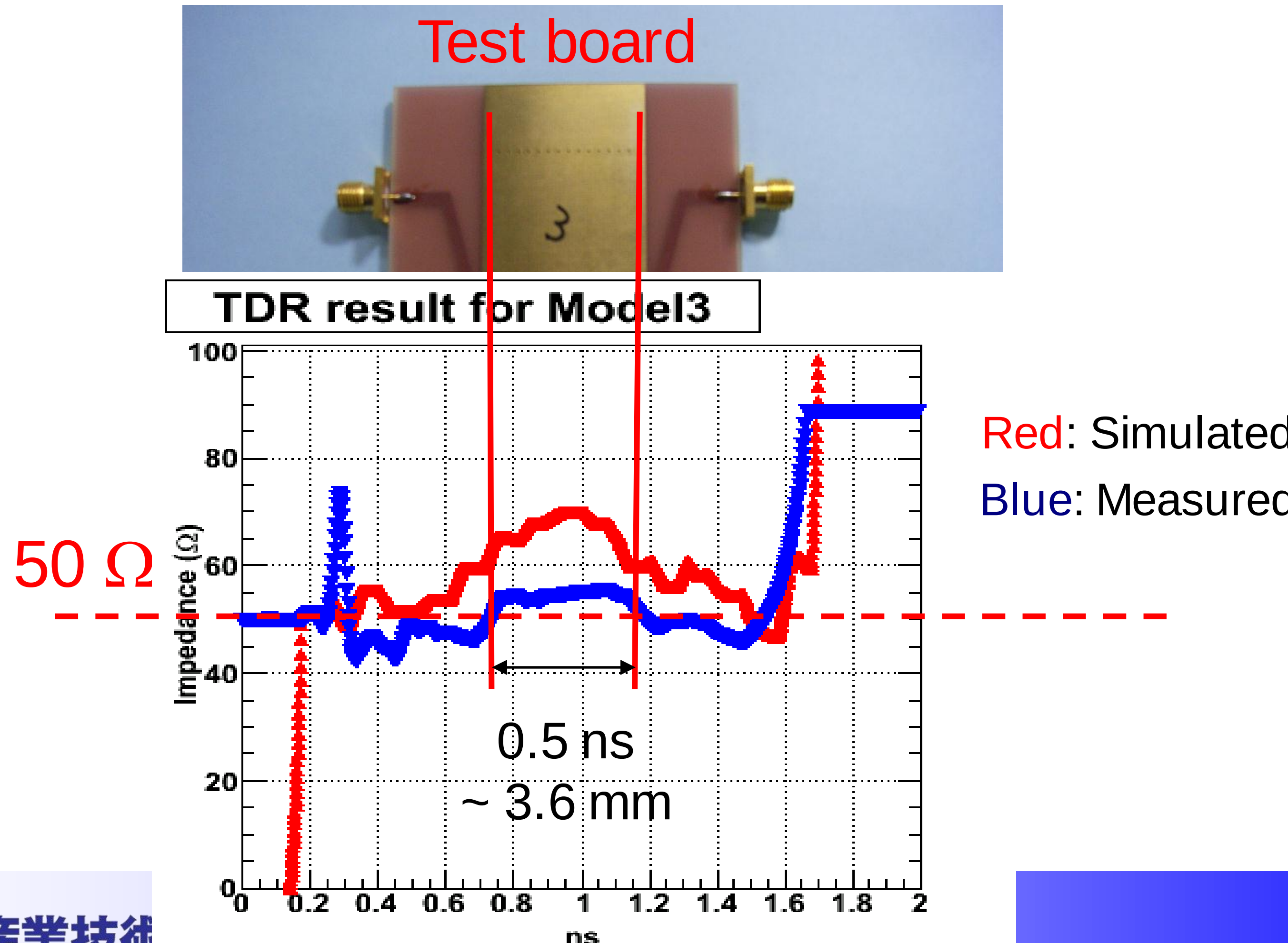
Composing

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.

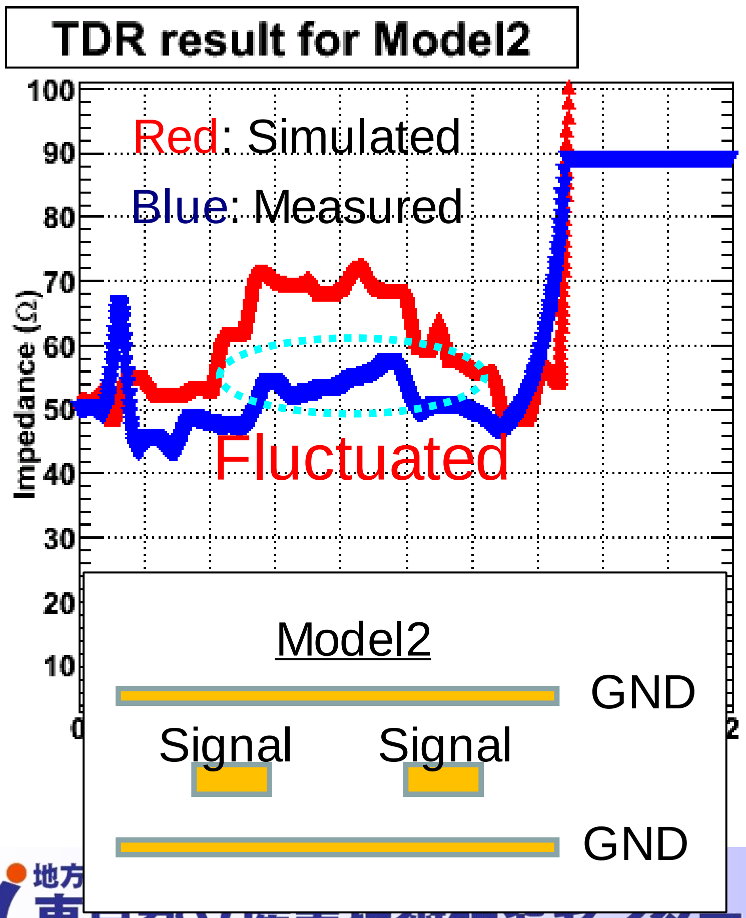


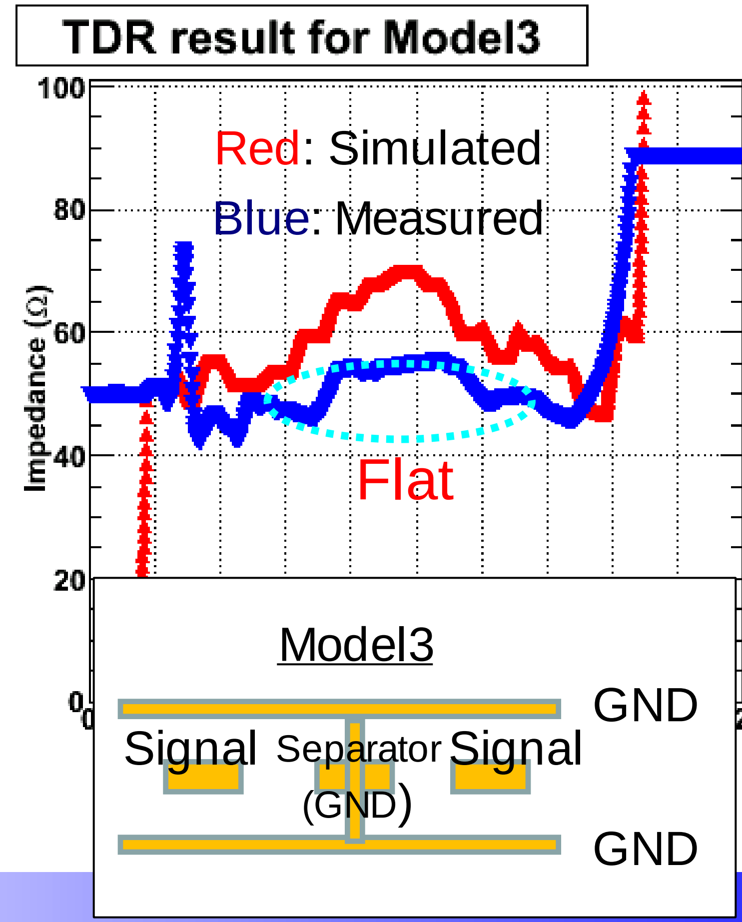
Impedance measurement result 2

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.

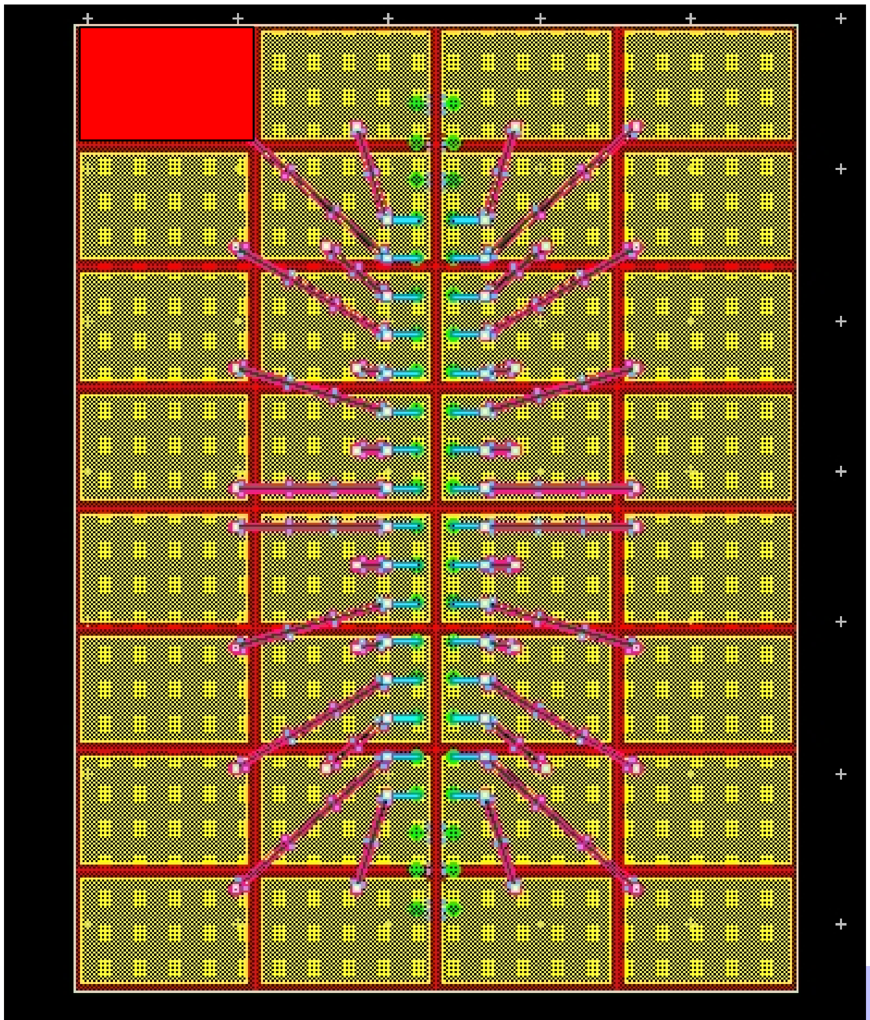




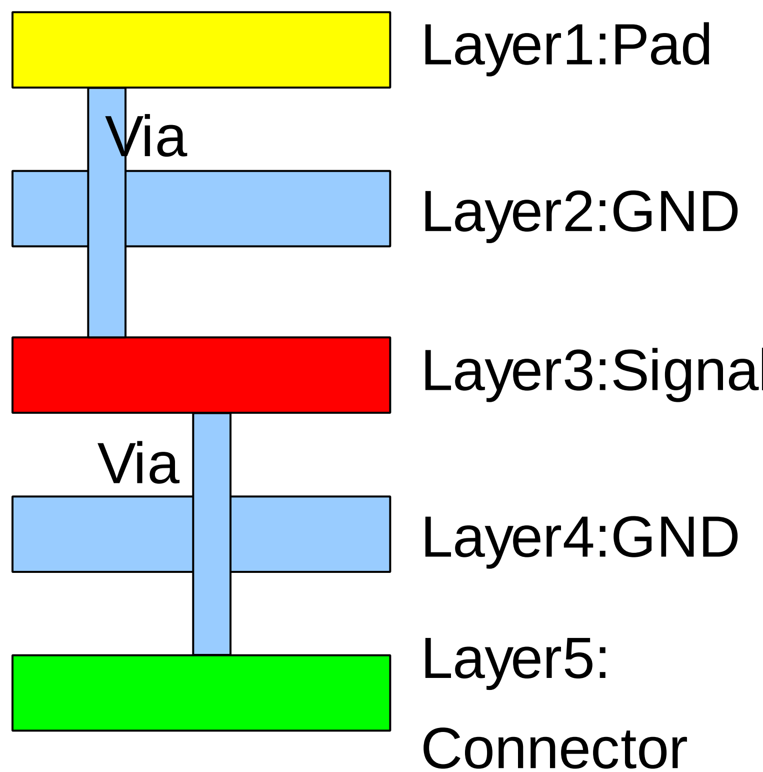
6. New TPC pad

5 Layers structure

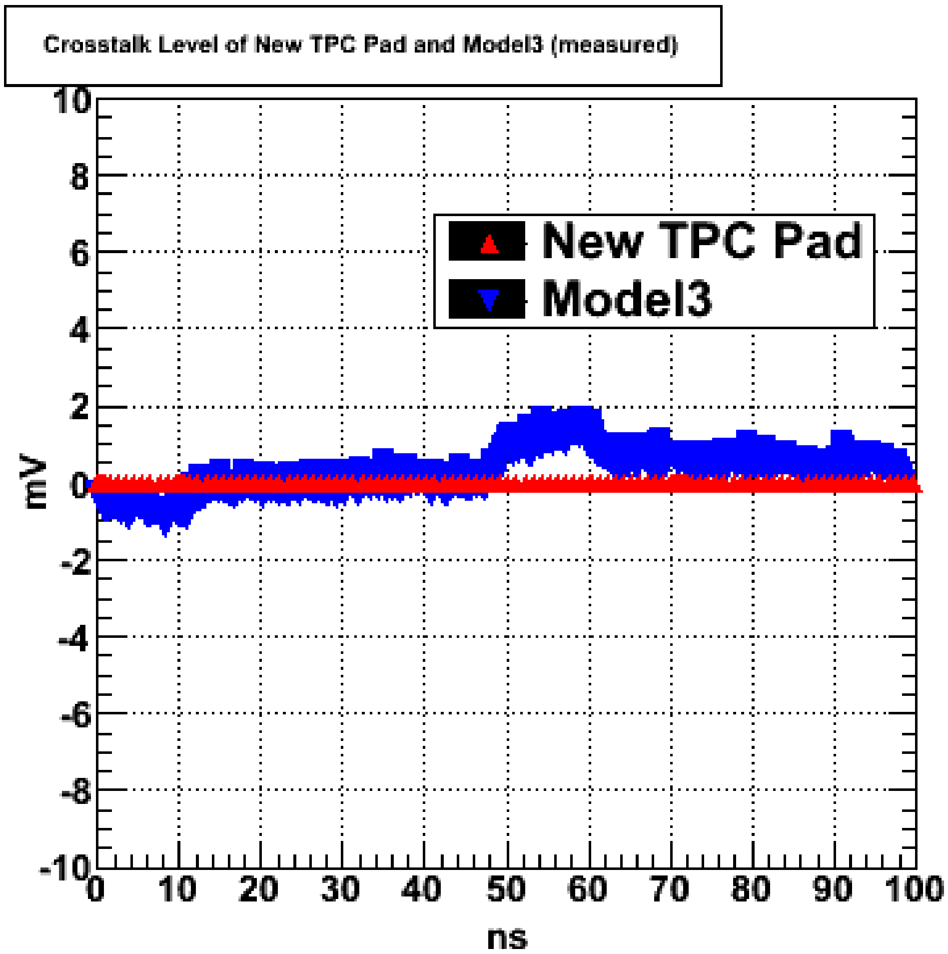
- 1 Pad area: 11 mm x 7 mm



Cross Section



Simulation with Pad



-98.6% than Model3.

7. Summary

- We are developing lower crosstalk TPC pad including transmission line.
  - Crosstalk level by simulation: 0.08%
  - Crosstalk level by measurement: 0.04%
  - Requirement: <0.5%, it is satisfied.
- Line impedance stability is confirmed by TDR.
  - Model3 has has good stability.
- Starting new TPC pad simulation and design.
  - 1 Pad area: 11 mm x 7 mm.
  - 5 Layers structure
- Do simulation including TPC capacitance (~10 pF) including transmission line. Seems fine.

Future Plan

Building with MICROMEGAS

Look at cross talk at readout electronics

Need wide dynamic preamp and ADC