INTT Sensor Capacitance

RIKEN/RBRC

Itaru Nakagawa

Strip Capacitance

FVTX NIM

The strip length increases with radius on the sensor, and goes from 3.4 mm at the inner radius to 11.5 mm at the outer radius, with a pitch of 75 μm in the radial direction. Each sensor covers 7.5° in ϕ, and since the strips are perpendicular to the radius, they make an angle of 86.25° with respect to the centerline, as can be seen in Fig. 4.

The data words are output over two LVDS serial lines at up to 200 MHz clock rate. The total power consumption of the FPHX is ~390 μW per channel. The noise, when the chip was wire bonded to a sensor with strips ~2–11 mm in length (~1–2.5 pF), was simulated and measured to be below the design specification of 500 electrons.

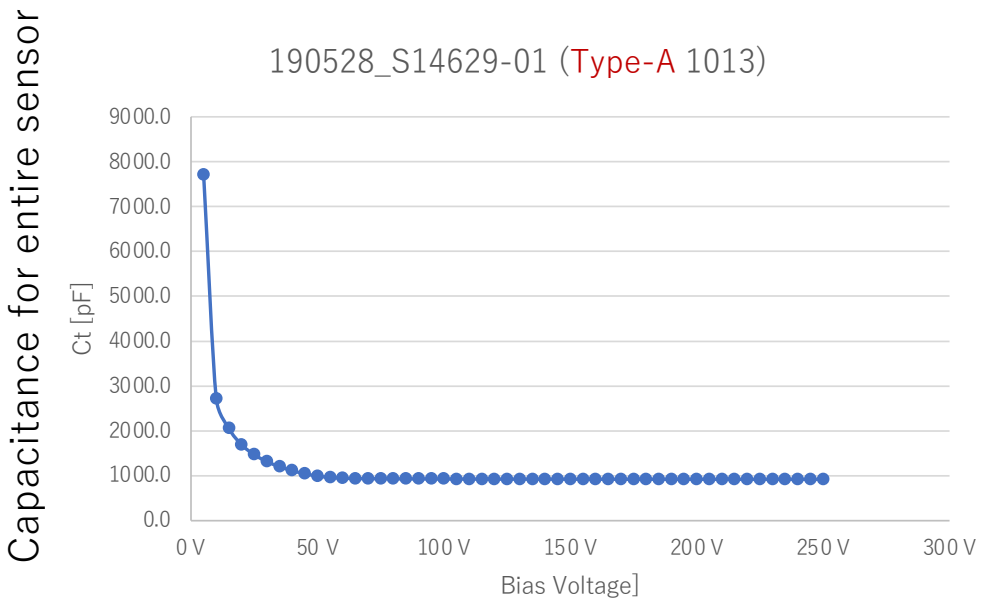
There are discrepancy between the actual measurement by Kaiyu, Hamamatsu, and expected value by simple scaling from FPHX by the length of the strip.

**later slide Hamamasu's measurement

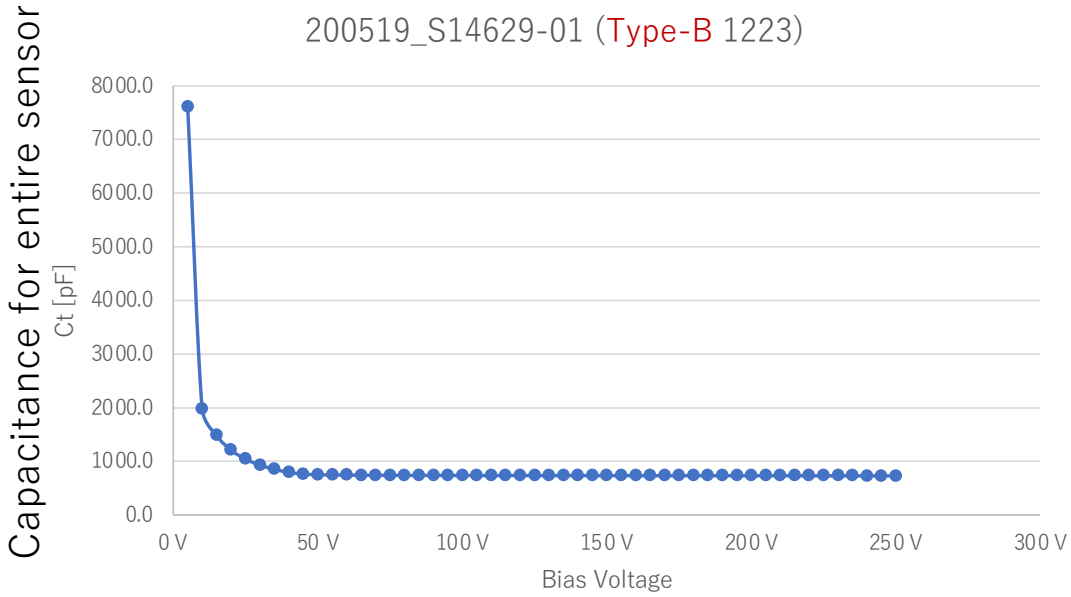
Strip	Thickness [μm]	Width [μm]	Length [mm]	Capacitance [pF]	Measurement (Kai-Yu)	Hamamatsu DC cap**
FVTX	320	78	2 ~ 11 mm	1 ~ 2.5		
INTT-Type-A			12mm	2.5*	~ 1 [pF]	0.45 [pF]
INTT-Type-B			18mm	3*		0.57 [pF]

*Simple scaling from FVTX

Hamamatsu's Measurement

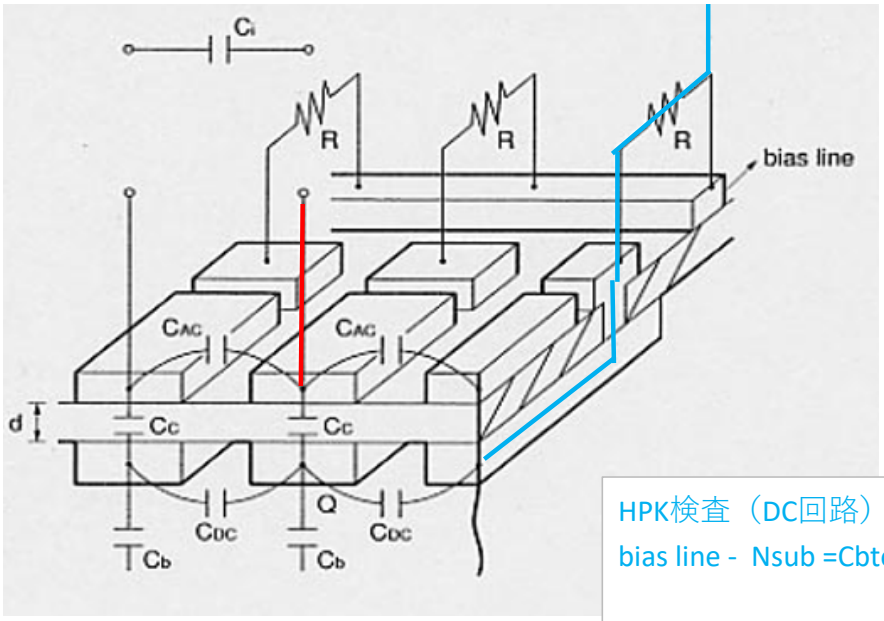


$$\frac{919\ [pF]total}{128\ [strip]\ 16\ [cell]} = 0.45\ [pF/strip]$$



$$\frac{730\ [pF]total}{128\ [strip]\ 10\ [cell]} = 0.57\ [pF/strip]$$

Hamamatsu's vs Kai-Yu's Measurement



CC : Coupling capacitance
Cb : Body capacitance
CDC : Capacitance between strip diffusions
CAC : Capacitance between AC electrodes
R : Bias resistance
Ci : Interstrip capacitance

HPK検査（DC回路）
bias line - Nsub =Cbtotal

論文の測定（AC回路）
CcやCiが加わる

On 2023/05/22 1:52, kaoshima@hq.hpk.co.jp wrote:

理化学研究所　中川様

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浜松ホトニクス株式会社　青嶋です。

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論文とは対象としている容量が異なると思います。

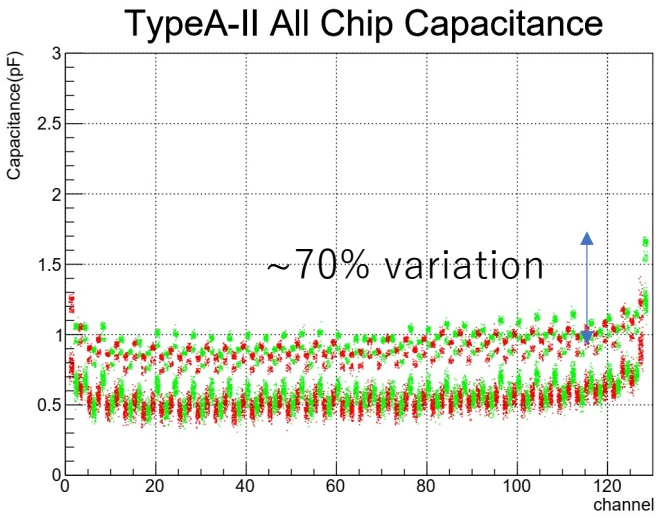
when the chip was wire bonded to a sensor with strips ~ 2–11 mm in length (~ 1–2.5 pF), was
simulated and measured to be below the design specification of 500 electrons.

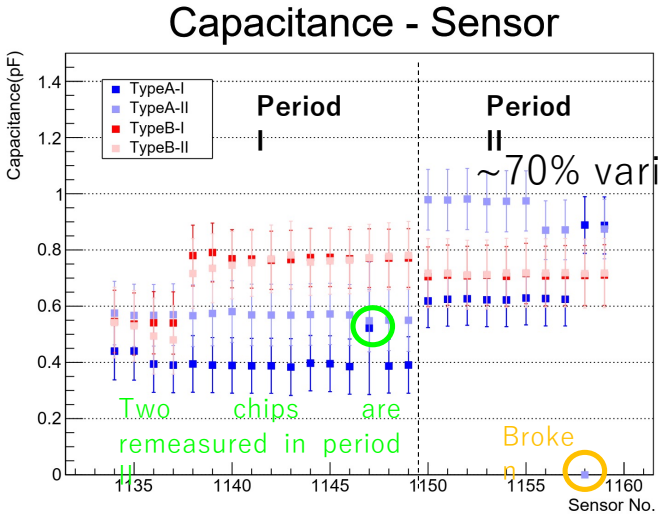
ですので、ACPADから見た際の容量(Load capacitance)になりますので、

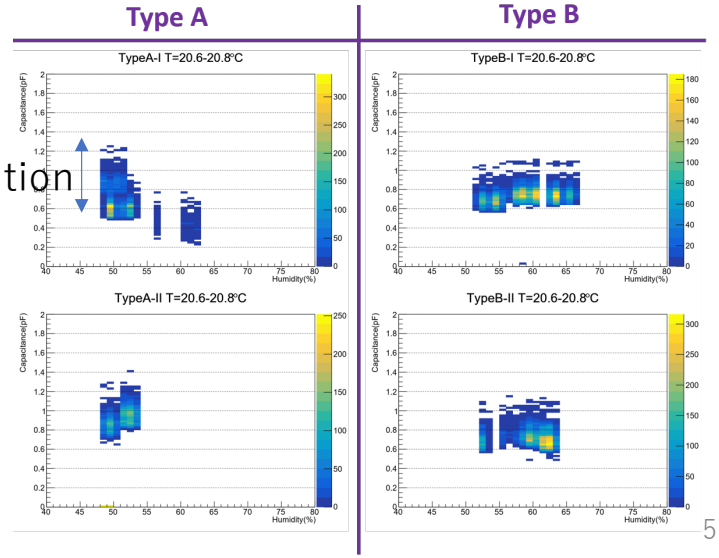
のモデル図になるかと思います。
HPKから提供しているデータは、Bias ring-Nsub間の総容量（Vfd算出のための測定データ）ですので、
このうちCbの全strip totalを測定しているものとなります。

The Measurement Result of INTT Sensor Testing

- Because the layout of sensor, each module is divided into four parts in the measurement. The left plot show one part result of sensor 1133-1159. All capacitance of channels are gaussian distribution, so we can identify the broken and functional channels from measurement. The left plot obviously show there are two different distributions. These differences could match to measuring period that be showed in middle plot.
- The capacitance of signal channel showed in left plots is about 0.5pF, so total capacitance is about 1000pF. Compared with total sensor from HAMAMATSU's inspection only has 7% difference. Therefore, this method could measure the capacitance of single channel.
- To check why capacitances are different in periods, we analyze the relation between environment and measurement. The right plots shows the variety of capacitance with humidity at same temperature. The result shows the measurement is not obviously affected by humidity, so maybe this effect come from the status of sensor or measure system.

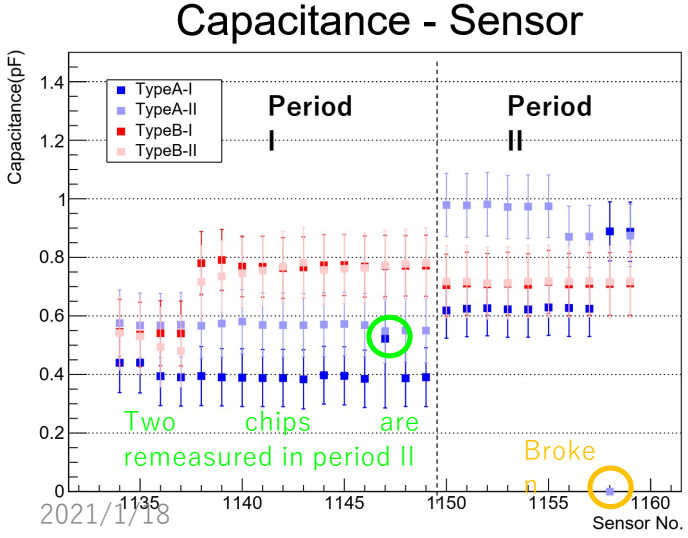


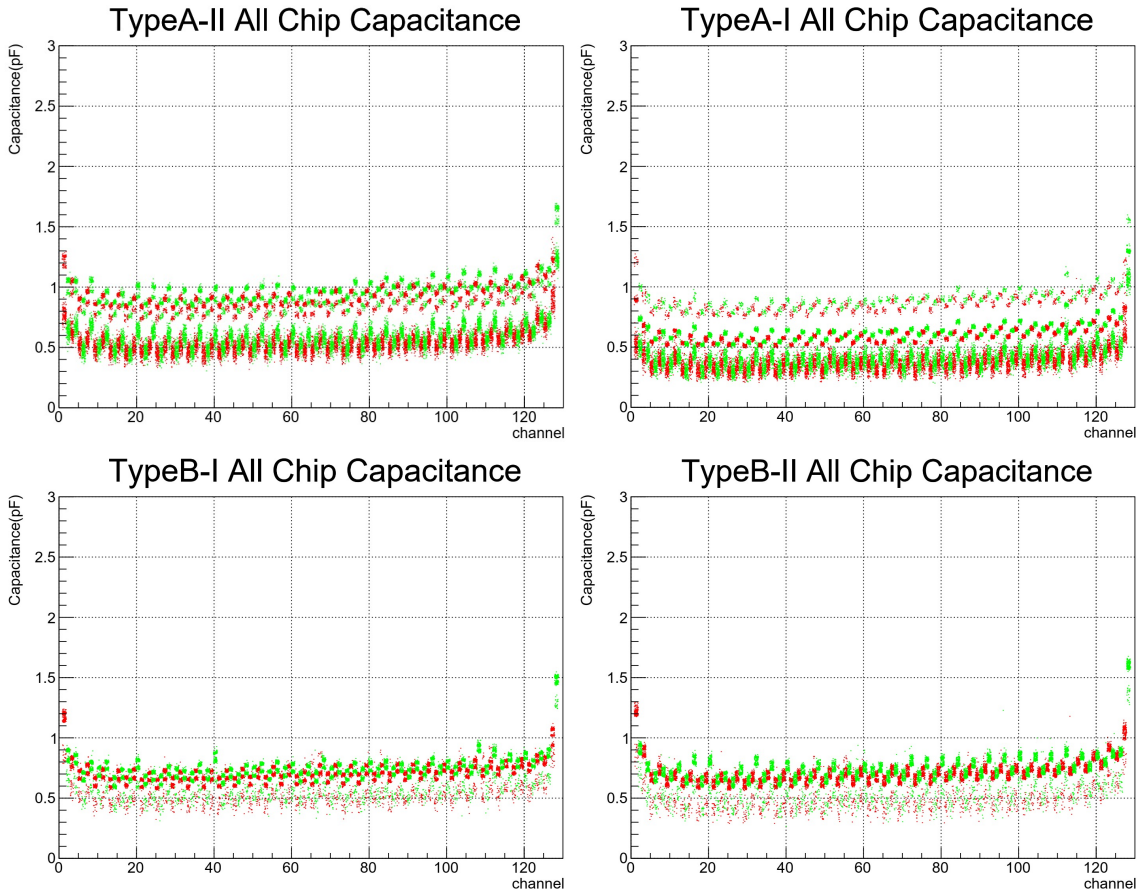




The Measurement Result of INTT Sensor Testing

- One set of sensor need use four probe cards to measure all chips. All sensor data shows in right four plots. These plots obviously show there are few different capacitance distributions. These differences could match to measuring period.
- The measurement was paused in the middle, so whole testing could be divided into two period. The bottom plot shows the values are different in these two periods.





HPK’s Response

- 送信者: "Itaru Nakagawa" <itaru@riken.jp>
  宛先: kaoshima@hq.hpk.co.jp
  日付: 2023/05/24 22:54
  件名: Re: シリコンストリップのCapacitance

浜松ホトニクス株式会社
青嶋様、
　ご返答ありがとうございます。御社の測定がDC回路の測定であること、承知しました。
AC-PADで我々の実測はType-Aのストリップ長で典型的に1 pF程度なのですが、FVTX(2-11 mm) よりもストリップが長いのに電気容量が小さいようです。厚みやストリップ幅が同じなので、単純に考えるとFVTXよりも長さが長い分だけけ我々のシリコンの方が電気容量が大きくなりそうな気がするのですが、何かを見落としているか、ご指摘いただければ幸甚に思います。

中川

230530_StripCapacitanceCalc.xlsx

On 2023/05/24 21:03, kaoshima@hq.hpk.co.jp wrote:

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  理由については、よくわからないです。
  そのため、こちらの持っている試算モデルで、ジオメトリーからの理論値を出してみました。
  論文の容量値のほうは少し大きく出ている気がします。

  FVTX：　pitch 75um
  　　P+ width 18um
  　　AL width 28um

  strip length 2mm　0.32pF/strip
  　　11mm　1.74pF/strip

  S14629-01：　pitch 78um
  　　P+ width 10um
  　　AL width 20um

  strip length 12mm　1.57pF/strip
  　　18mm　2.35pF/strip

  よろしくお願いします。

Strip Capacitance

Thickness:320 [μm]

Strip	Length [mm]	Pitch [mm]	p+ width [mm]	Al Width [mm]	Meas. [pF] (Kai-Yu)	HPK model [pF]	FVTX NIM
FVTX	2	75	18	28	N/A	0.32	1
FVTX	11				N/A	1.74	2.5
INTT-Type-A	12	78	10	20	0.5 ~ 1.5	1.57	
INTT-Type-B	18				0.4 ~ 1.5	2.35	

- Hamamatsu's a model calculation is consistent with given dimensions.
- The capacitance value found in FVTX NIM is larger than Hamamatsu's calc by factor of 2 to 3.
- Kaiyu's measurement is smaller than Hamamatsu's calc by > 1/3 or so.
- Problem what to be stated in the INTT paper.

Hamamatsu's Model Calculation

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Nuclear Instruments and Methods in Physics Research A 485 (2002) 343–361

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

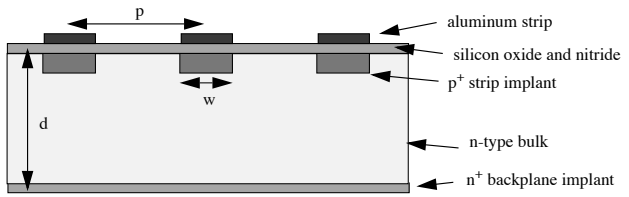

Fig. 1. Cross-section through an AC-coupled strip detector. Throughout the paper w will indicate the width of the p^+ implant, p the strip pitch and d the detector thickness.

Investigation of design parameters for radiation hard silicon microstrip detectors

S. Braibant[a], N. Demaria[b], L. Feld[c], A. Frey[a], A. Fürtjes[a], W. Glessing[a], R. Hammarström[a], A. Honma[a], M. Mannelli[a], C. Mariotti[a], P. Mättig[a], E. Migliore[a,*], S. Piperov[d], O. Runolfsson[a], B. Schmitt[e], A. Söldner-Rembold[a], B. Surrow[a]

[a] *CERN, CH-1211 Geneva 23, Switzerland*
[b] *INFN Sez. di Torino, I-10125 Turin, Italy*
[c] *Albert-Ludwigs-University, D-79104 Freiburg, Germany*
[d] *Humboldt University, D-10115 Berlin, Germany*
[e] *Paul Scherrer Institut, CH-5232 Villigen, Switzerland*

Received 14 May 2001; received in revised form 29 September 2001; accepted 18 October 2001

2.3. Total capacitance

The relevant parameter for the electronics noise figure is total strip capacitance C_{tot}. It has been calculated by an electrostatic simulation [6] solving a two-dimensional Poisson equation. For a given pitch p, it predicts a linear dependence on the strip width w. In the range $0.10 < w/p < 0.55$, for a detector thickness of 300 μm one obtains

$$C_{tot} = \left(0.8 + 1.6\frac{w}{p}\right)\text{pF/cm} \quad p = 100\ \mu\text{m}$$

$$C_{tot} = \left(0.9 + 1.4\frac{w}{p}\right)\text{pF/cm} \quad p = 50\ \mu\text{m}$$

$$C_{tot} = \left(0.9 + 1.6\frac{w}{p}\right)\text{pF/cm} \quad p = 25\ \mu\text{m}. \qquad (8)$$

Predictions from this model have been compared with measurements for pitches varying between 25 and 80 μm. Agreement of up to 15% is found in Ref. [6].

INTT:
w=10, p=78 [um]
w/p=0.13

	Type-A (12mm)	Type-B (18mm)
	1.21	1.81
	1.30	1.94

Hamamatsu Calc.
1.57 2.35
-> 20% larger than my calc

Nuclear Instruments and Methods in Physics Research A 485 (2002) 343–361

230530_StripCapacitanceCalc.xlsx

Reference [6]

Nuclear Instruments and Methods in Physics Research A310 (1991) 189-191
North-Holland

NUCLEAR
INSTRUMENTS
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IN PHYSICS
RESEARCH
Section A

Electrostatic simulations for the design of silicon strip detectors and front-end electronics

R. Sonnenblick, N. Cartiglia, B. Hubbard, J. Leslie, H.F.-W. Sadrozinski and T. Schalk
Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064, USA

We report the first results from a simulation of the electrostatic properties of silicon microstrip detectors. We extract the capacitance and pulse shapes and show their importance for the design of front-end electronics and strip detector geometries for HERA and the SSC.

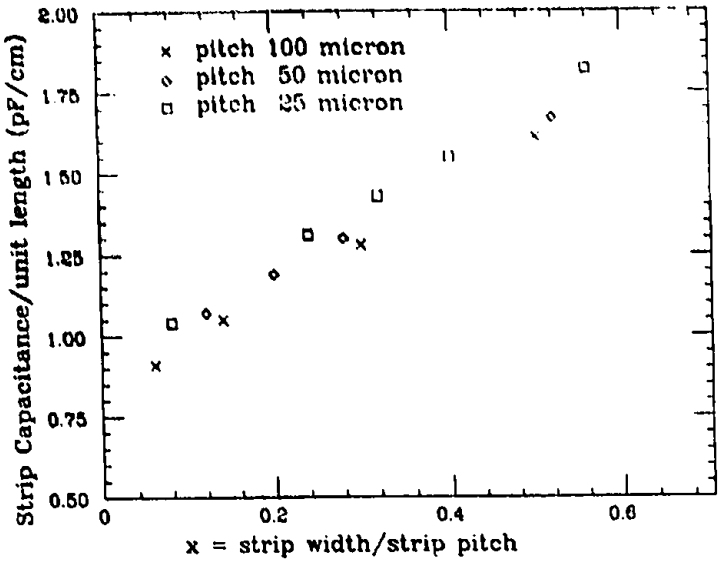

Fig. 1. Capacity per unit length for strip detectors of different pitch as function of the ratio x of implant width to strip pitch.

Conclusion

- The capacitance was measured by NCU group and varies by 70% or so. This variation is mainly driven by the strip-by-strip variation rather than silicon-by-silicon variation. The capacitance also varies by the different period (Unfortunately, these measurements cannot be stated in the publication.)
- Hamamatsu's model calculated capacitance is 50~100% larger than NCU's measurement.
- The capacitance value found in FVTX NIM is larger than Hamamatsu's calc by factor of 2 to 3.

Backup

Stripの電気容量

*FVTXの長さでスケールした予測値

Strip	Thickness [μm]	Width [μm]	Length [mm]	Capacitance [pF]	実測値	Hamamatsu DC cap**
FVTX	320	78	2 ~ 11 mm	1 ~ 2.5		
INTT-Type-A			12mm	2.5*	~ 1 [pF]	0.45 [pF]
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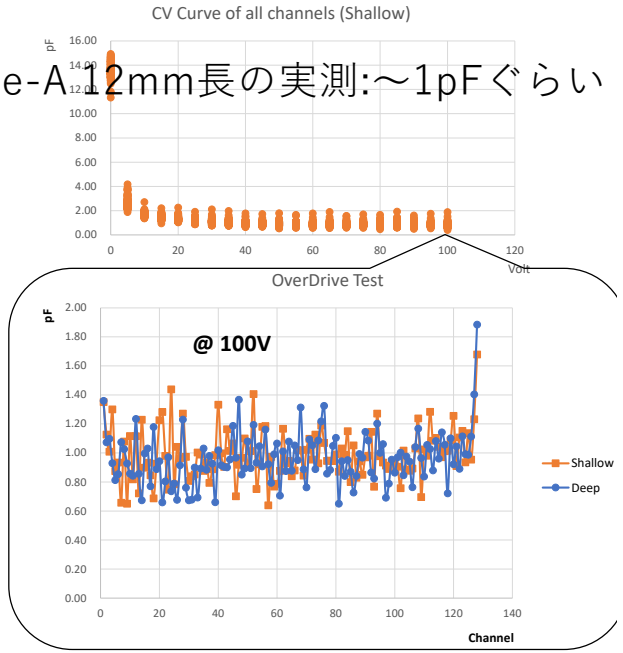
Type-A 12mm長の実測:~1pFぐらい



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  　　P+ width 10um
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  strip length 12mm 1.57pF/strip
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  よろしくお願いします。

＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊
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