

# Qpix v.1: A High Speed 400-pixels Readout LSI with 10-bit 10MSps Pixel ADCs

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**on behalf of the QPIX Collaboration**

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- **Prototype Chip : Qpix v.0**
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# Qpix Development in Japan

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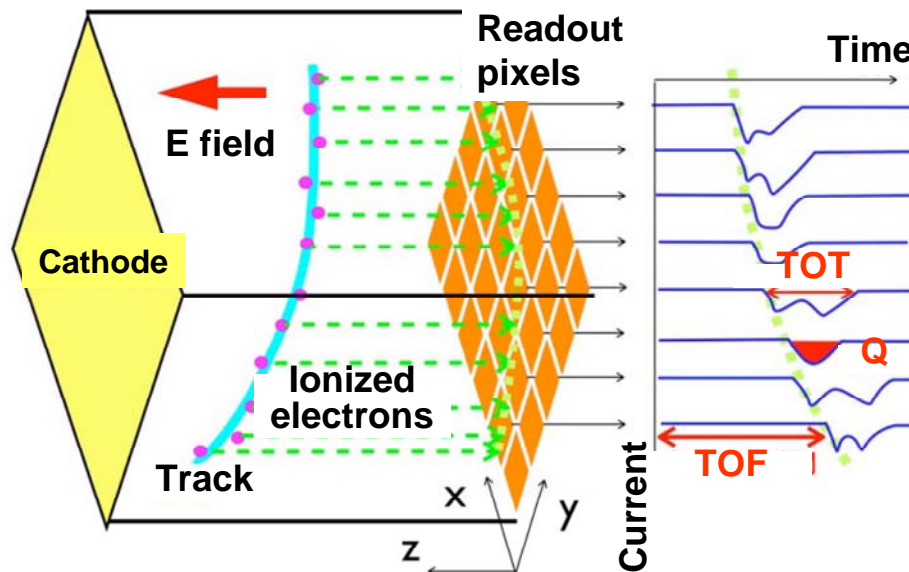
- **Q**uad information / **Q**uasi-3D / **Q** (Charge) information provided **pixel** → **Qpix**

TOF ( Drift time ) → z-axis information

TOT ( Signal width ) → Density of electron in z direction

**Q : (SAR ADC ) → the energy of the particle**

Pixel position → x-y-axis information



TOF : Time of Flight

TOT : Time over Threshold

**Q : total charge**

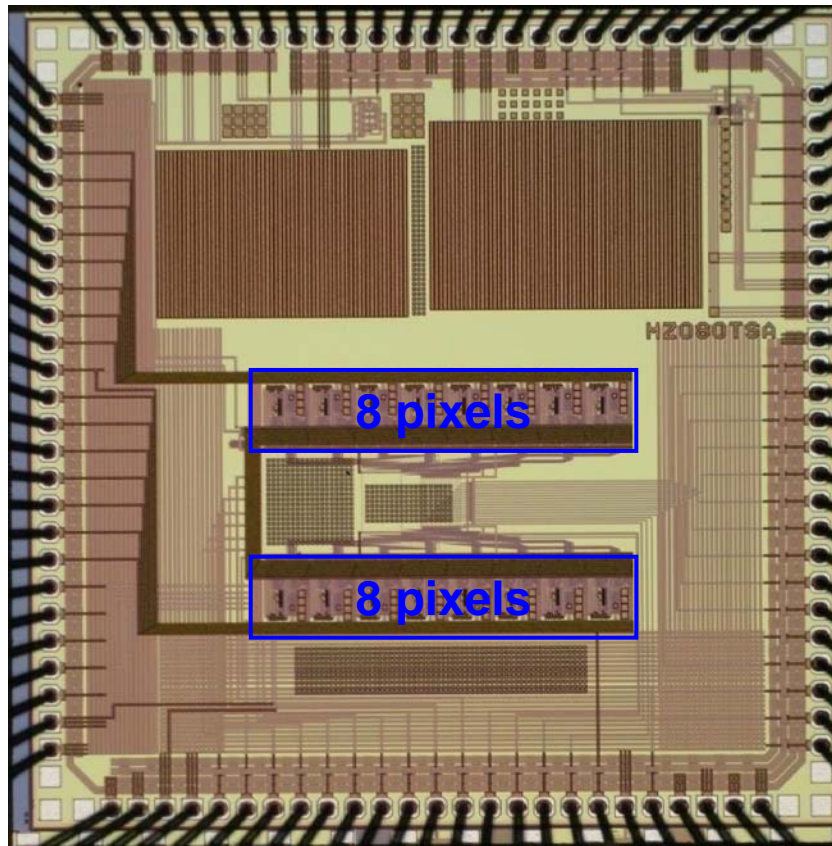
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# The Prototype Chip: Qpix v.0

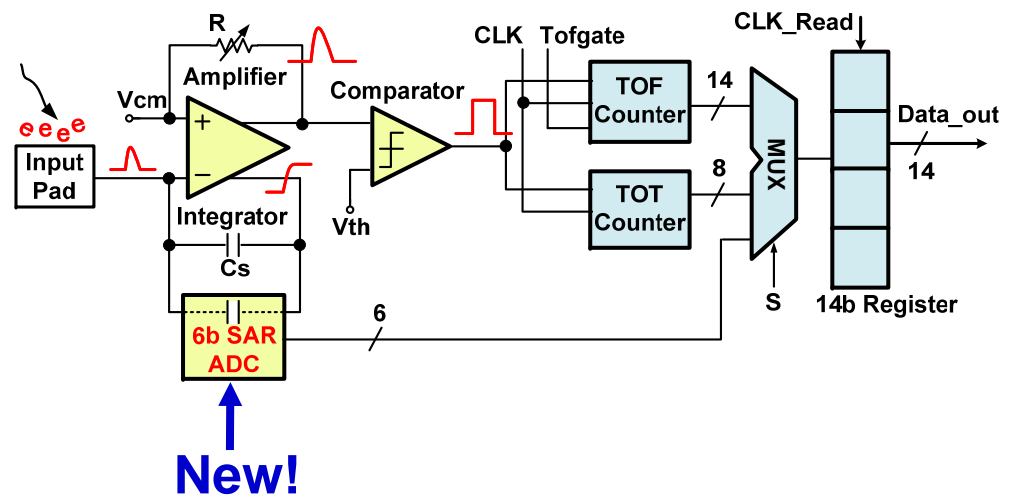
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Qpix v.0 was implemented to validate the basic function, having a pixel size of  $140\ \mu\text{m} \times 200\ \mu\text{m}$ .

## QPIX v.0 Chip



## Pixel Circuit

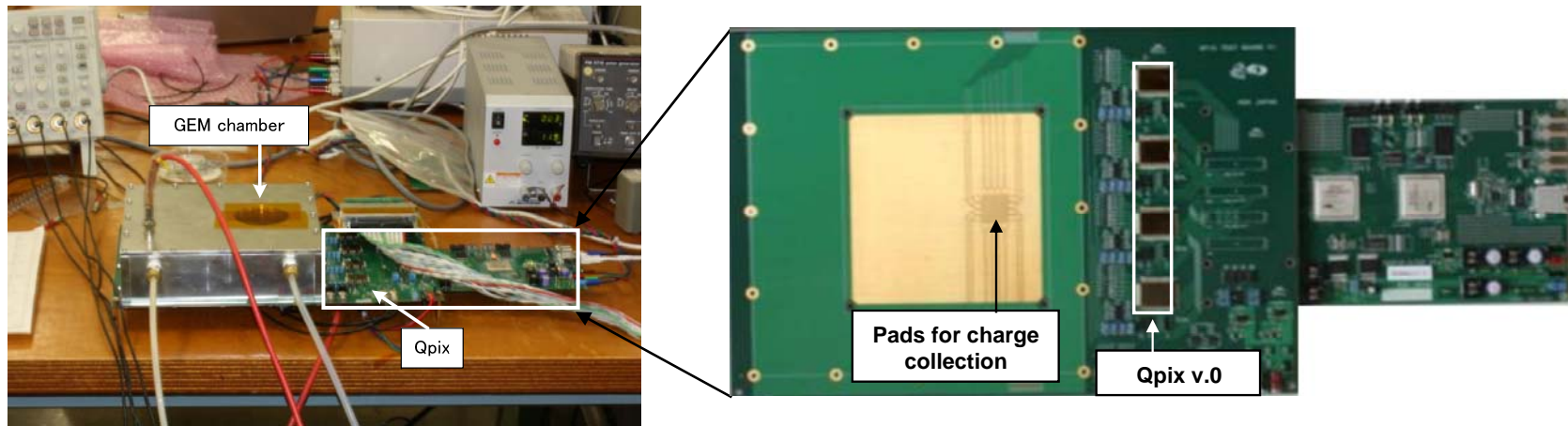


# Qpix v.0/GEM Experiments

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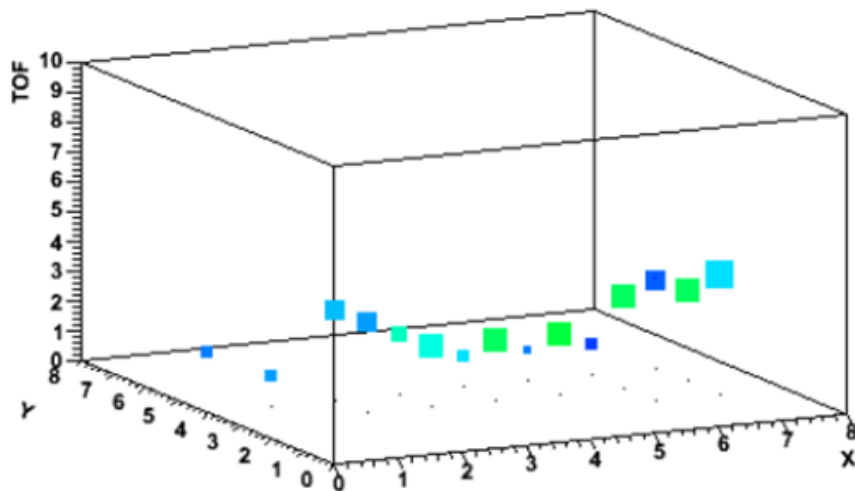
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## Demonstrated its ability in 3-D tracking detector



## A sample 3D track by Qpix

( $V_{GEM} = 330V$ , 5 Mev  $\alpha$ -ray source)



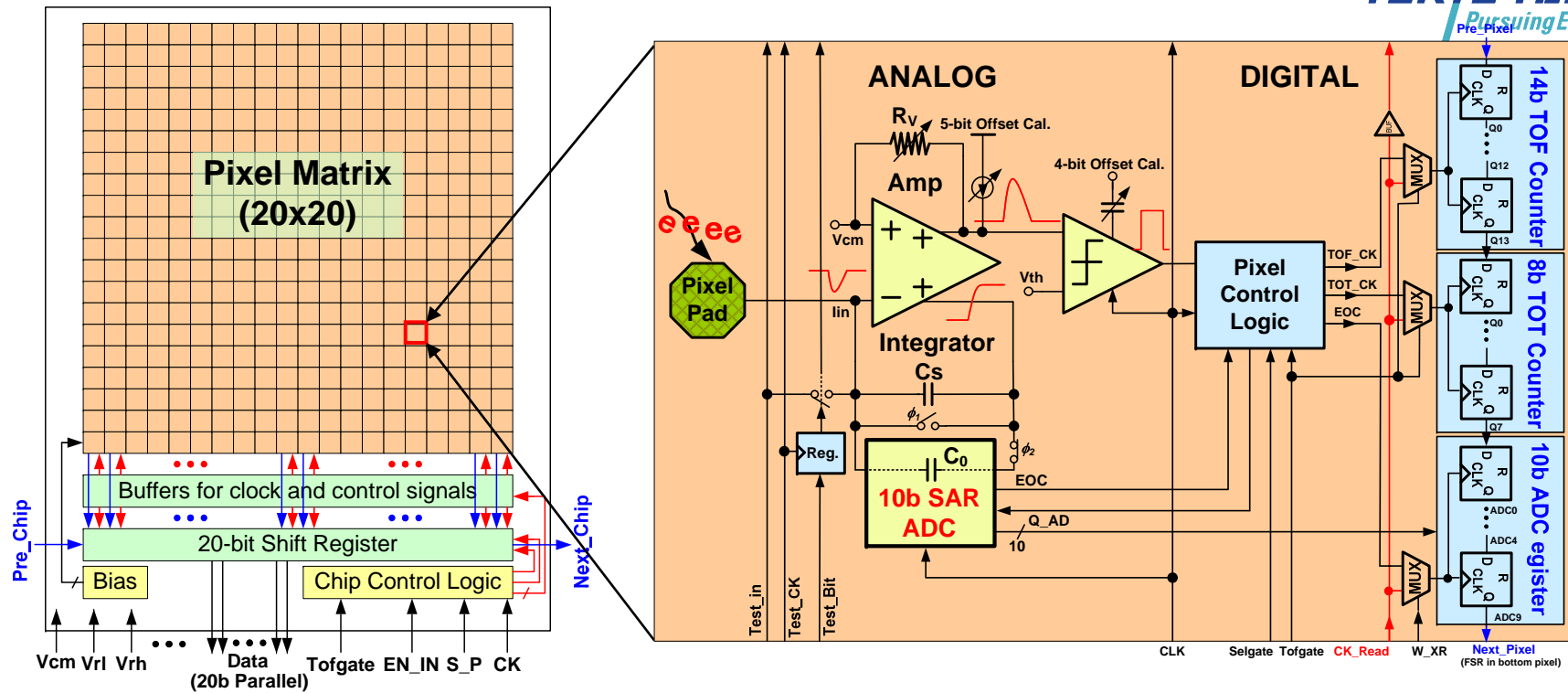
## Some limitations :

- no pixel pad
- readout scheme is too simple
- binary counter
- offset in amp and comparator

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# Qpix v.1

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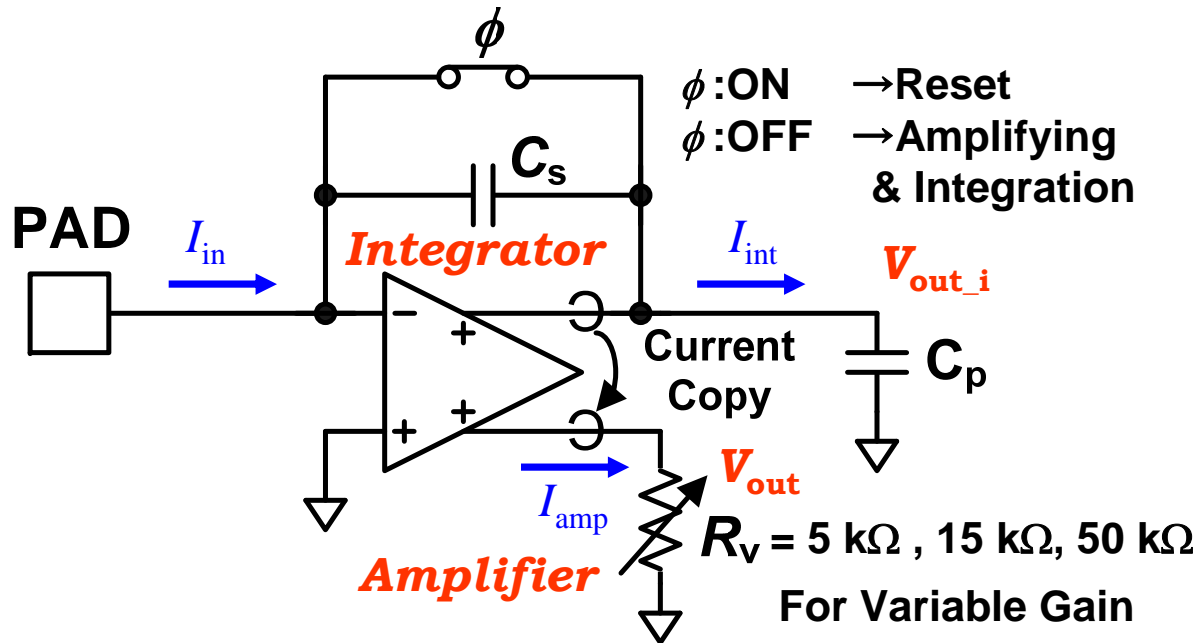


- Linear Feedback Shift Register
- Full custom designed DFF
- Amp with offset calibration
- Comparator with Capacitance Calibration
- 10-bit SAR ADC
- Pixel pad



# Charge Amplifier and Integrator

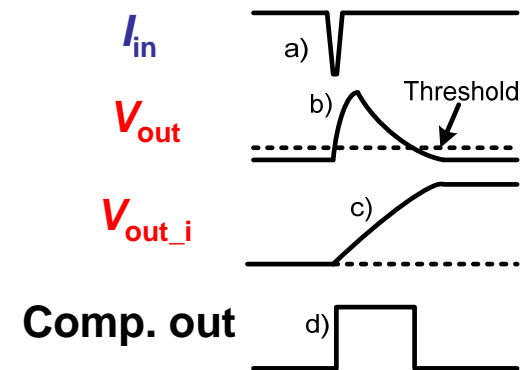
Both charge amplifier and integrator are realized with only one operational amplifier.



$$I_{in} \approx I_{int} \approx I_{amp}$$

$$V_{out\_i} = \frac{1}{C_s} \int I_{in} dt$$

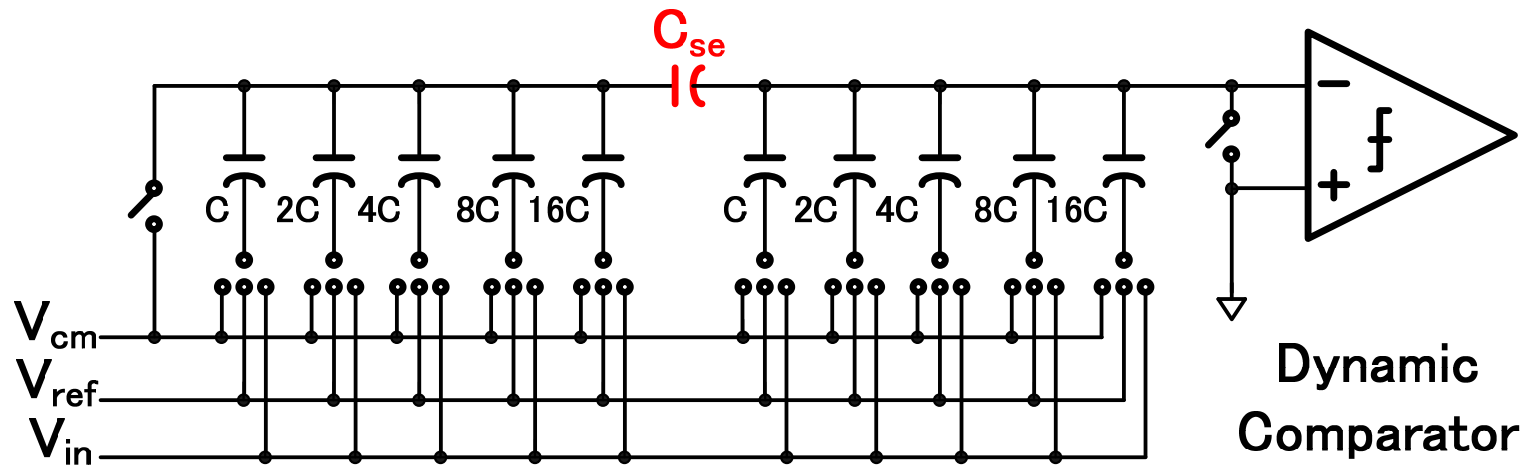
$$V_{out} = R_v I_{amp}$$



# SAR ADC

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## SAR (Successive Approximation Register) ADC is the optimal candidate for Qpix

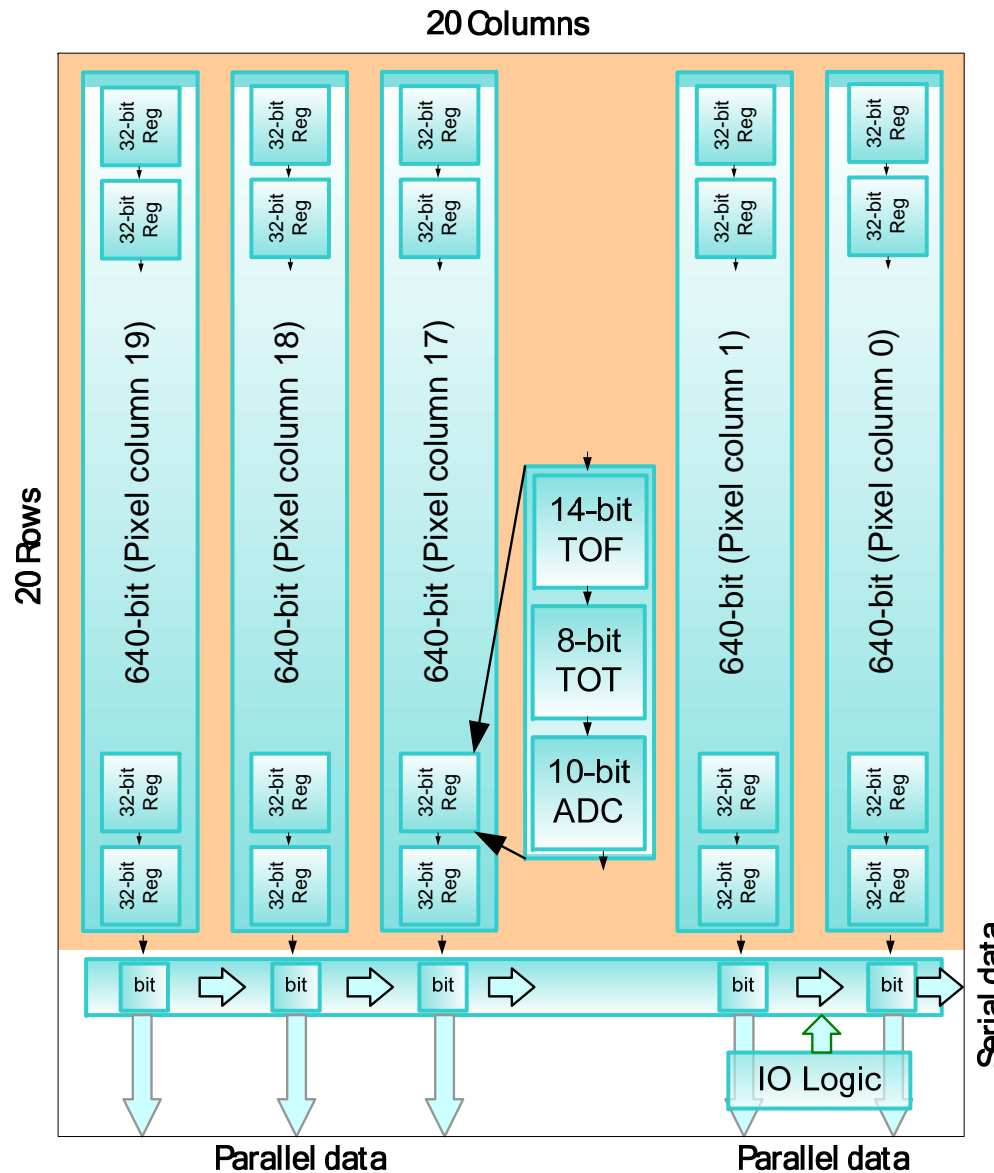


- ☺ Low power (no static current)
- ☺ Compact (2 stage weighted capacitance DAC)
- ☹ Low speed (but we need only 6.7 MSps)

### Specification

Process	0.18 $\mu\text{m}$ CMOS
Resolution	10 bit (ENOB : 8.4)
Speed	8.3 Msps
Power	460 $\mu\text{W}$
Area	70 $\mu\text{m}$ x 140 $\mu\text{m}$

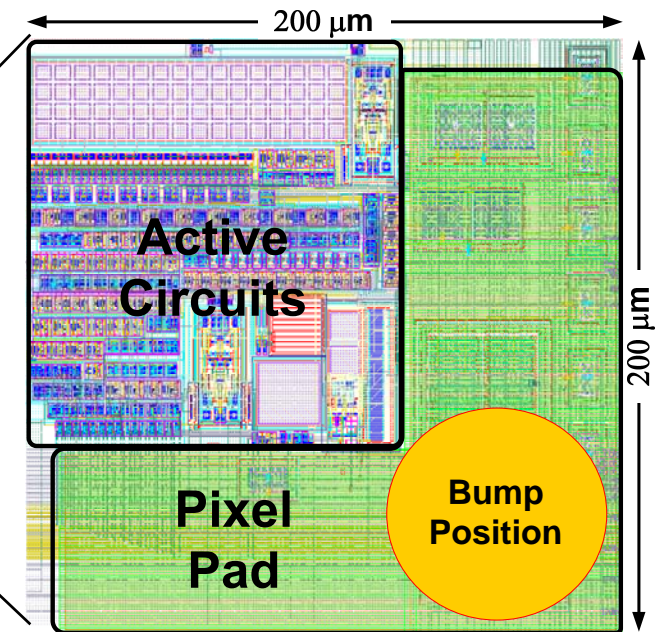
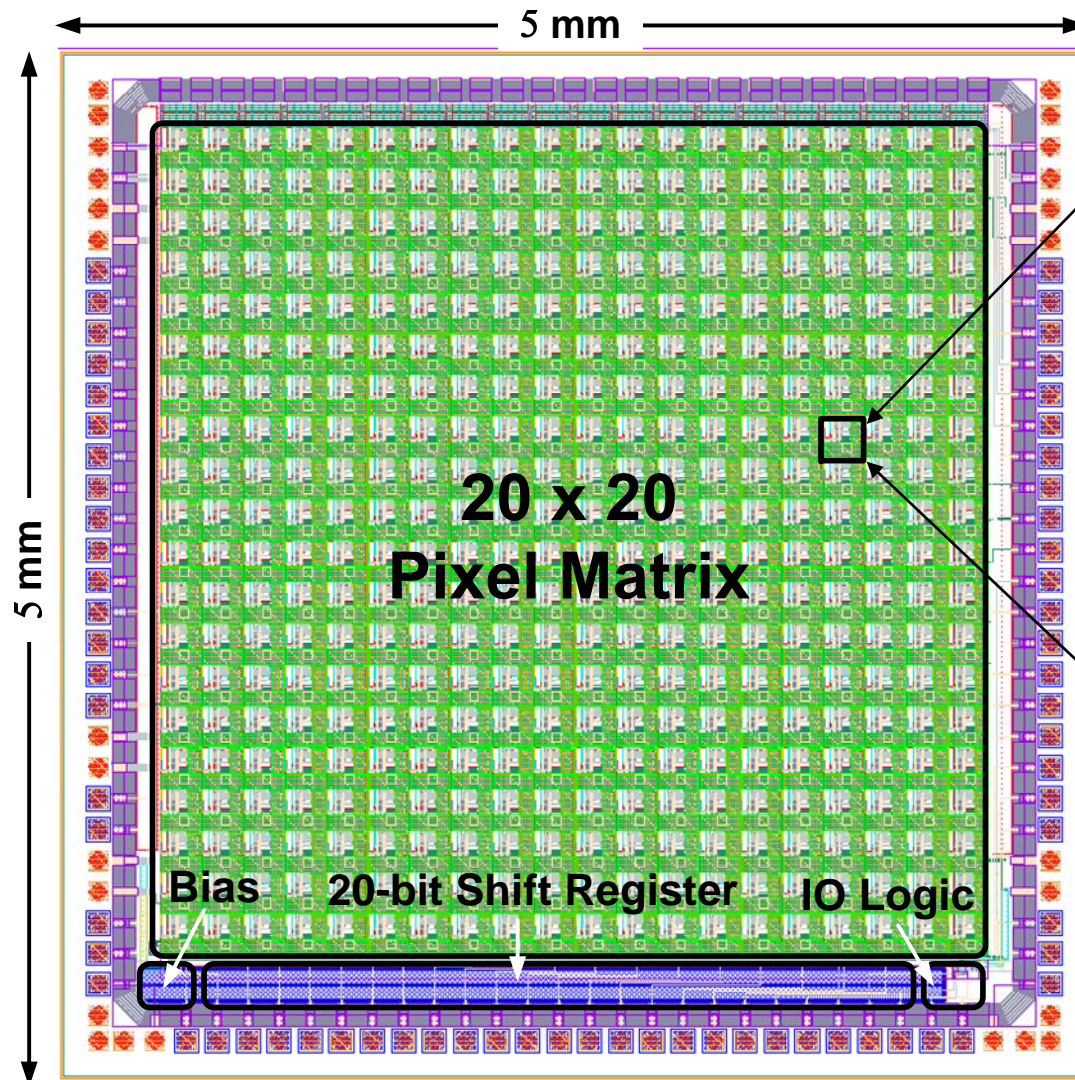
# Data Readout Scheme



- **Serial / parallel readout mode**
- **240 Mbps readout speed is achievable. (limited by measurement environments)**
- **Readout time:  
2.6  $\mu$ s @ parallel mode /  
54  $\mu$ s @ serial mode**

# Chip Layout

Designed for large area applications



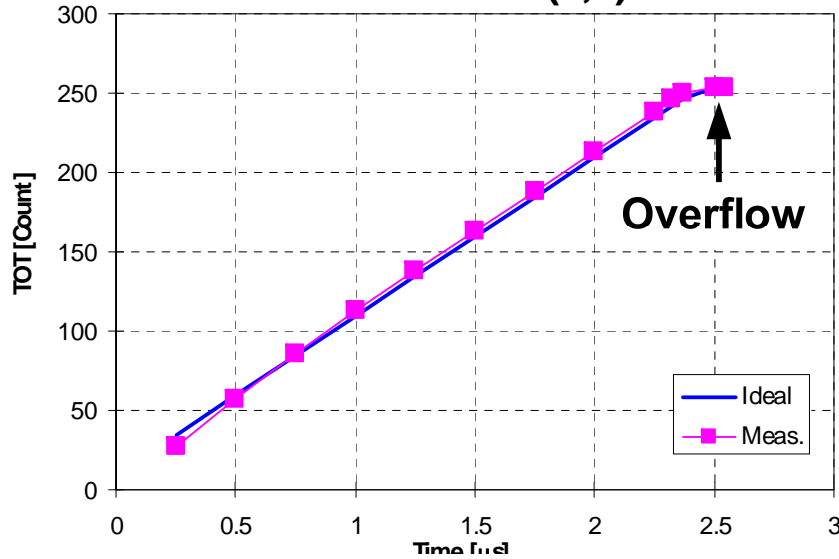
- Pixel pad area is 48.9% of the total pixel area

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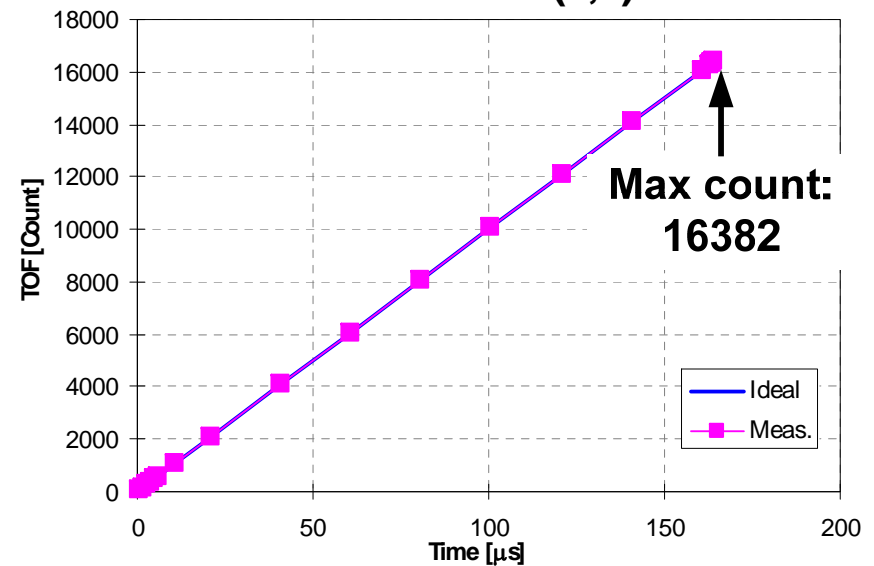
# Preliminary Electrical Experiment

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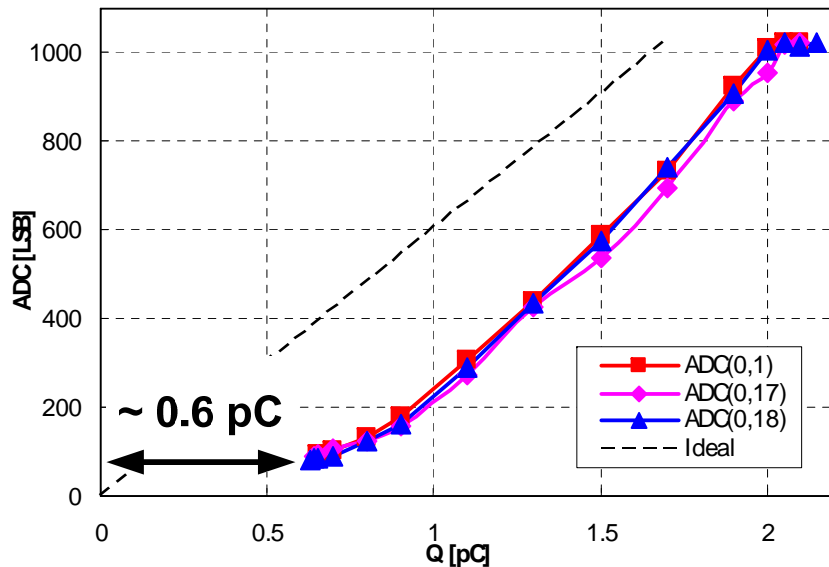
### TOT of Pixel (0,0)



### TOF of Pixel (0,0)



### ADC of Selected Pixels



- TOT and TOF : 10ns accuracy
- ADC codes show that the monotonicity can be kept
- Power consumption:  
**187.5 μW/pixel**

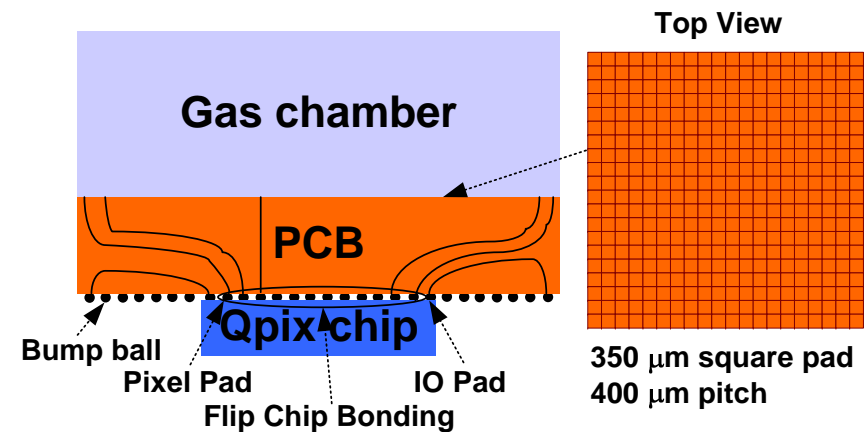
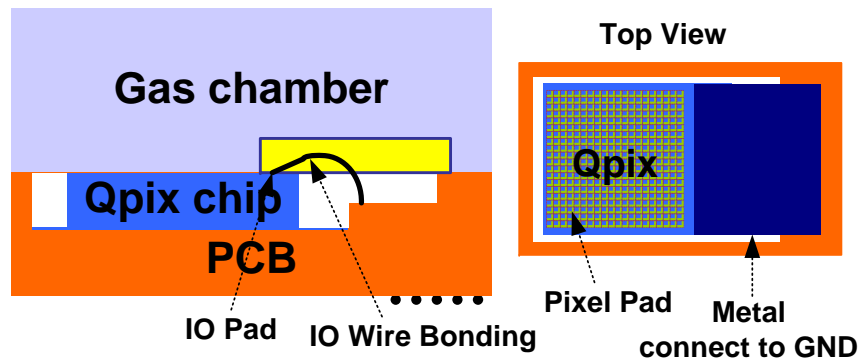
Offset charge is caused by large paracitic capacitance in measurement system.



# Qpix v.1/GEM Experiments

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## Two proposals are under way



- ☺ Only wire bonding
- ☹ Protection for Qpix chip and bonding wires (materials and methods for discharge)

- ☺ Qpix chip is isolated from particles by PCB
- ☹ Difficulties during the flip-chip bumping (curving surface of the PCB)

Data will be available at the end of Sep.

# Performance Summary

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	Qpix v.1	Qpix v.0	Timepix
Number of Pixels	<b>20 x 20</b>	2 x 8	256 x 256
Pixel dimensions	200 x 200 $\mu\text{m}^2$ (Pixel pad included)	140 x 200 $\mu\text{m}^2$ (No pixel pad)	50 x 50 $\mu\text{m}^2$
Dynamic range	<b>10 fC ~ 1.5 pC</b>	100 fC ~ 1.0 pC	0.1 fC ~ 12 fC
Preamp gain	0.43 mV/fC	0.4 mV/fC	100 mV/fC
Comp. threshold	35 fC	245 fC	0.1 fC
ADC LSB/MSB	1.5 fC/1.5 pC	15 fC/ 1.0 pC	-
Readout information	TOF: 14 bits, 10 ns	TOF: 14 bits, 10 ns	14 bits, 10 ns (TOF or TOT or Photon counter)
	TOT: 8 bits, 10 ns	TOT: 8 bits, 10 ns	
	<b>ADC: 10 bits, 10MSps</b>	ADC: 6 bits, 10MSps	None
Power/channel	<b>150 <math>\mu\text{W}</math></b>	350 $\mu\text{W}$	6.5 $\mu\text{W}$ + 7 $\mu\text{W}$
Readout mode	<b>Serial/Parallel</b>	Switched parallel	Serial/Parallel



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# Conclusion

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- Qpix aims at the future 3-D gas detectors
- Qpix v.0 chip demonstrated the ability for 3-D particle tracking
- Qpix v.1 is designed for large area applications and to increase the basic performance
- Qpix v.1/GEM experiments are under way

**Acknowledgments to all the contributors to the Qpix project, in particular Dr. S. Tanaka, Dr. Y. Arai, Dr. J. Haba, in KEK, A. Sugiyama, T. Azuma in Saga Univ., and Dr. K. Miuchi in Kyoto Univ..**

**Thank you  
for your interest!**

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