R&D of QPIX

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Introduction
motivation

QPIX

setup

beam test

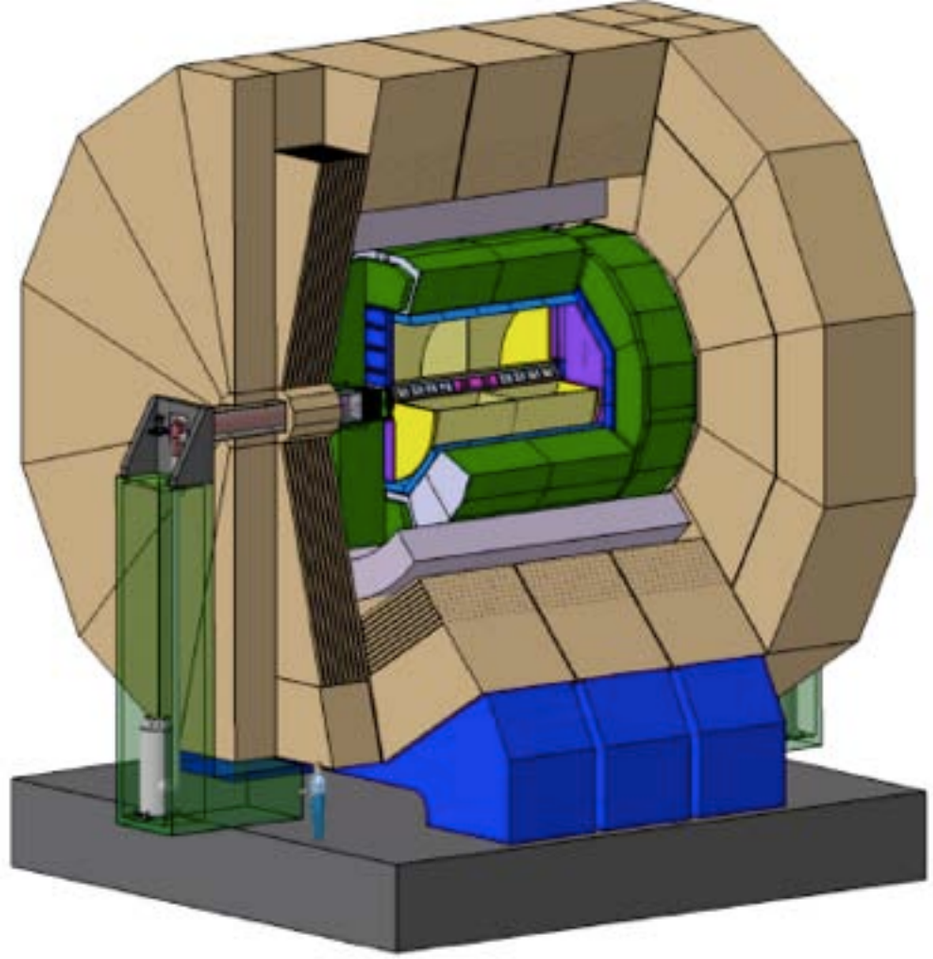
further work

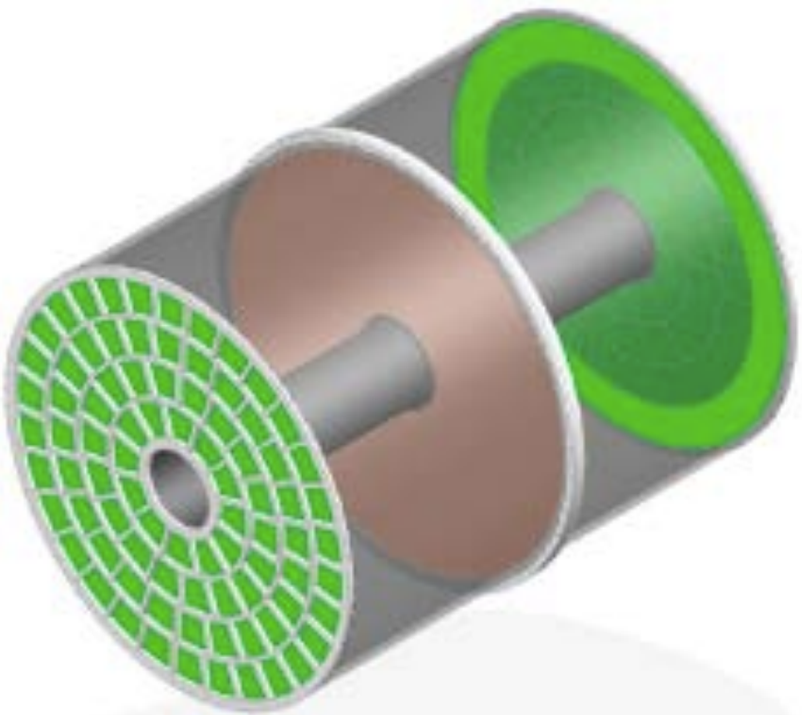
LC-TPC

ILD concept group choose gaseous tracker(TPC)
as a main tracker for LC detector

A) good momentum resolution
for Z recoil missing mass res.

B) good tracking efficiency
for Particle Flow Algorithm
(jet energy resolution)





1) good resolution w/ high B field(3.5T)
using high $\omega\tau$ gas ($ArCF_4isoC_4H_{10}$)
100um @ 2m drift
2) good hit efficiency and 2 track separation
eff. >99% (Pt>1GeV/c) differentiate 2mm sep.
3) low material budget
in order not to deteriorate Cal res.
15% X_0@endplate
4) large area coverage
3.6m in diameter, 4.6 m long in z

How spatial resolution behave in gas detector

naive expectation of local resolution

$$\sigma_r = \sqrt{\sigma_0^2 + \frac{C_D^2 \cdot z}{N}}$$

this term dominate @ long drift

low diffusion gas @ B field

Contribution from ion statistics

$N_{eff} \neq \langle N \rangle$ **Landau fluctuation**

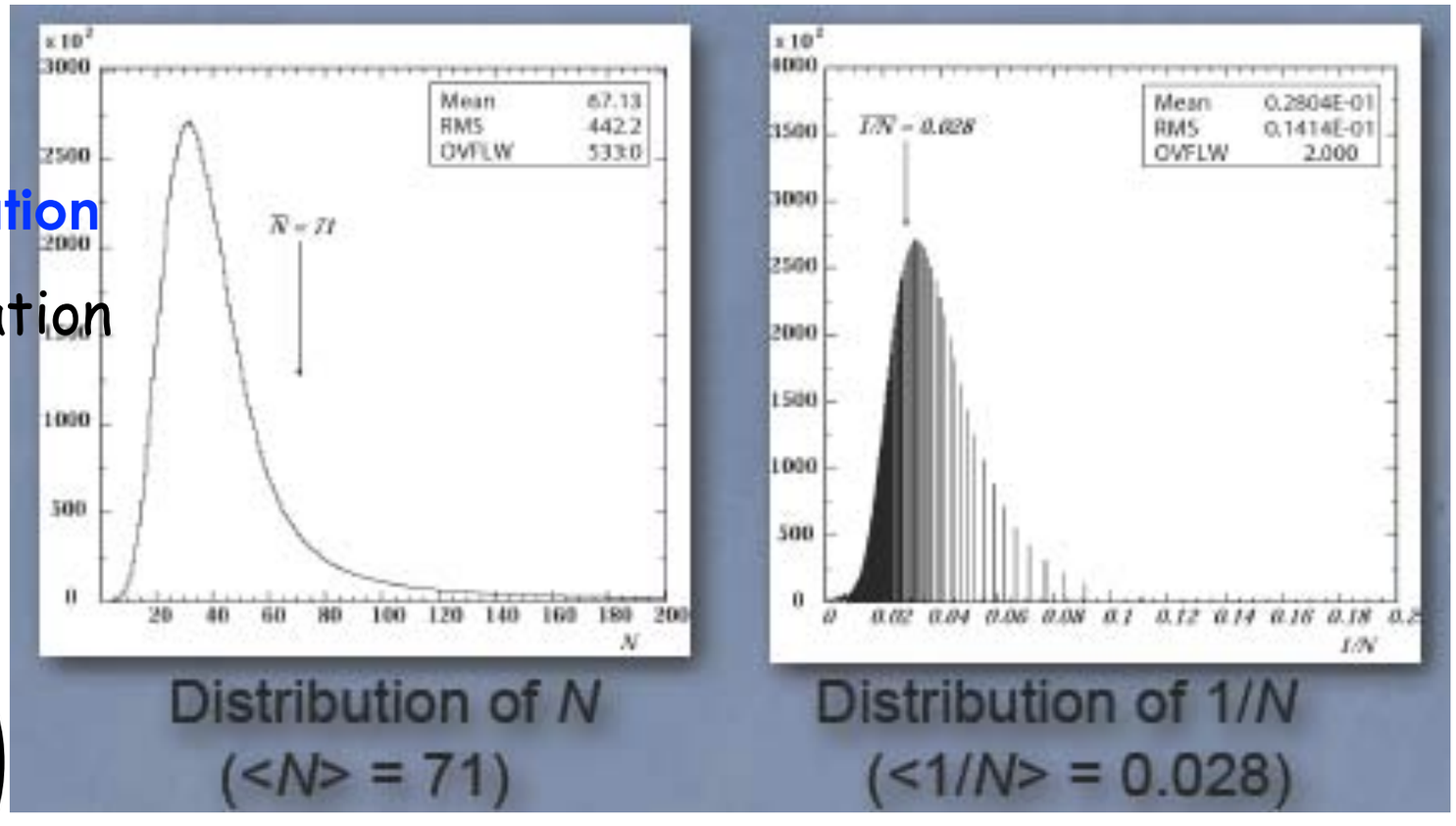
$N_{eff} \sim 1/\langle 1/N \rangle$ + Gain fluctuation

$N_{eff} \sim 0.5\text{-}0.6\langle N \rangle$

Effect of read-out pitch

$$\sigma_x^2 \sim \frac{1}{N_{eff}} \left(\frac{w^2}{12} + C_d^2 z \right)$$

PRF << pad-pitch(w)



PRF: Pad response function determined by diffusion@gas amplification

pad pitch <~ 3*PRF (3~400um@GEM; 20um@MM)

GEM TPC can go with 1mm pitch pad

not for MM

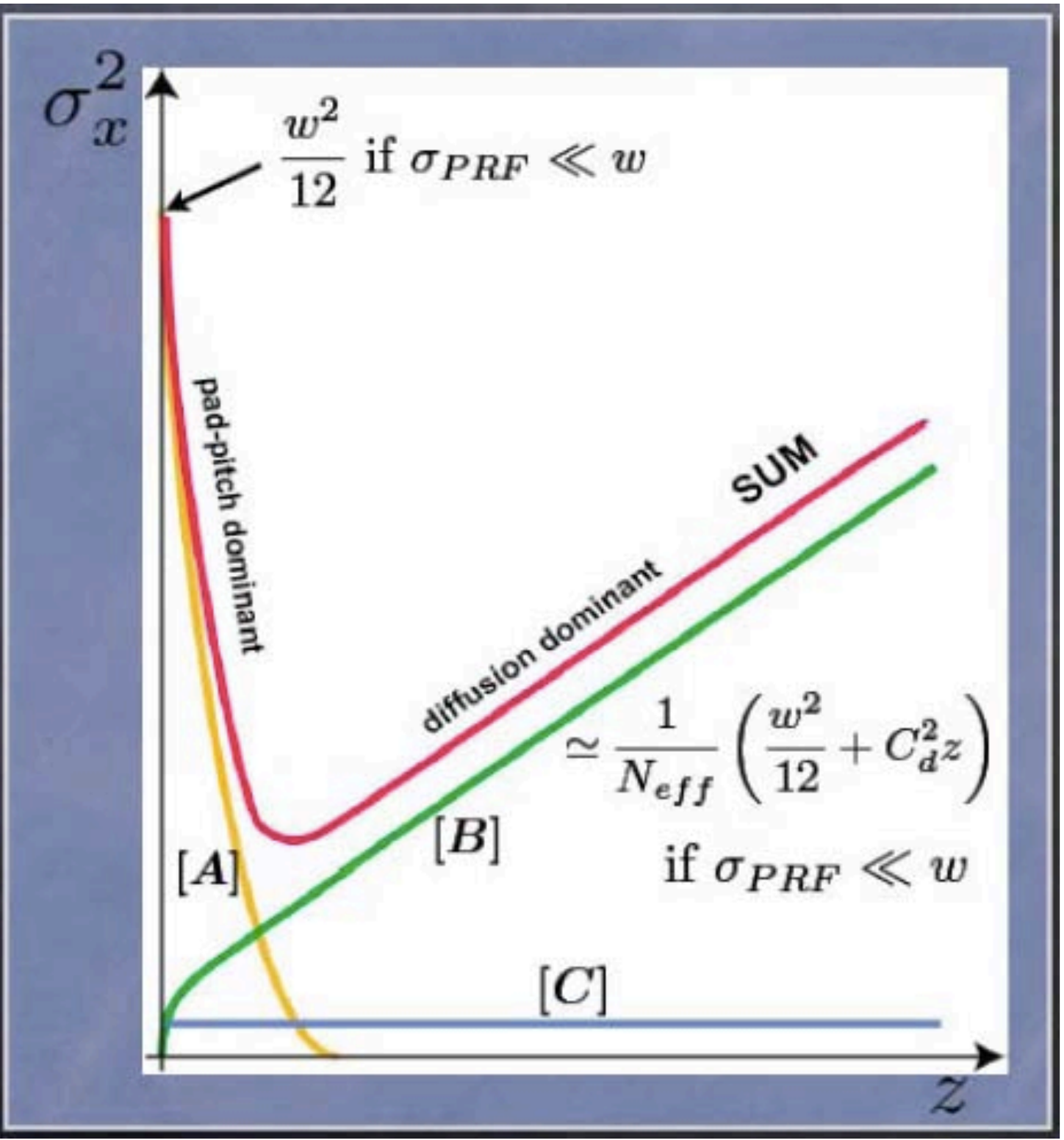
MM needs charge broadening mech.

like registive anode

How spatial resolution behave in gas detector

PRF: Pad response function - depend on gas amplifier and gas itself

~300um for typical 3 GEM ~10um for Micromegas



[A] purely geometric

pad-pitch(w) >> PRF + diffusion

-> hode-scope effect

[B] diffusion dominant

pad-pitch contribute

$$\sigma_x^2 \sim \frac{1}{N_{eff}}\left(\frac{w^2}{12} + C_d^2 z\right)$$

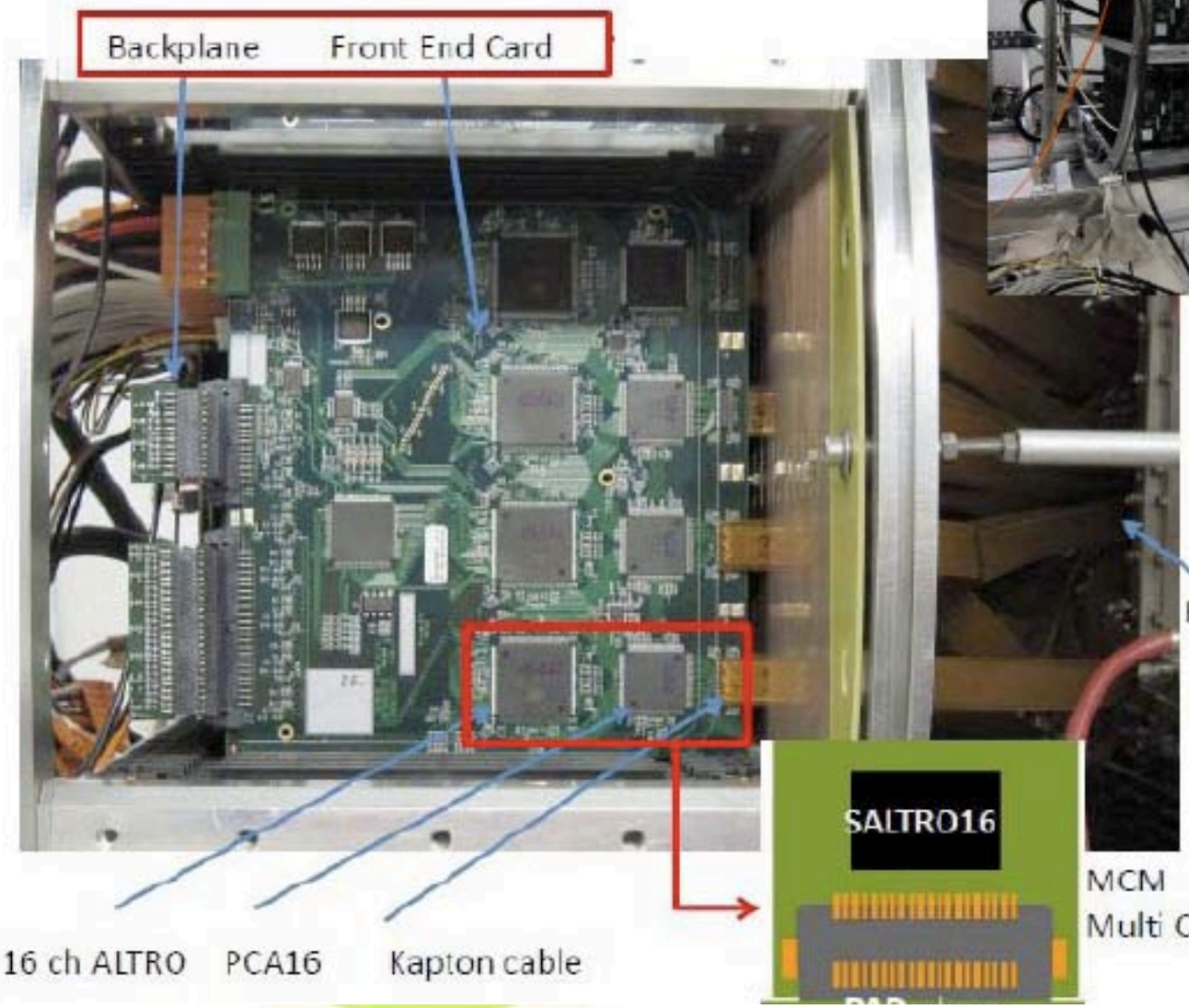
PRF << pad-pitch(w)

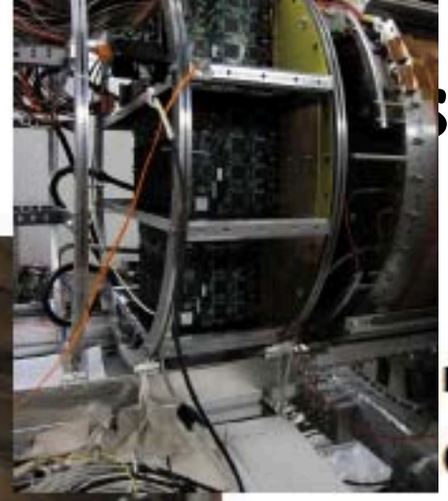
[C] noise

pad-pitch be less than 3*PRF

vanced Endplate

Present front end electronics

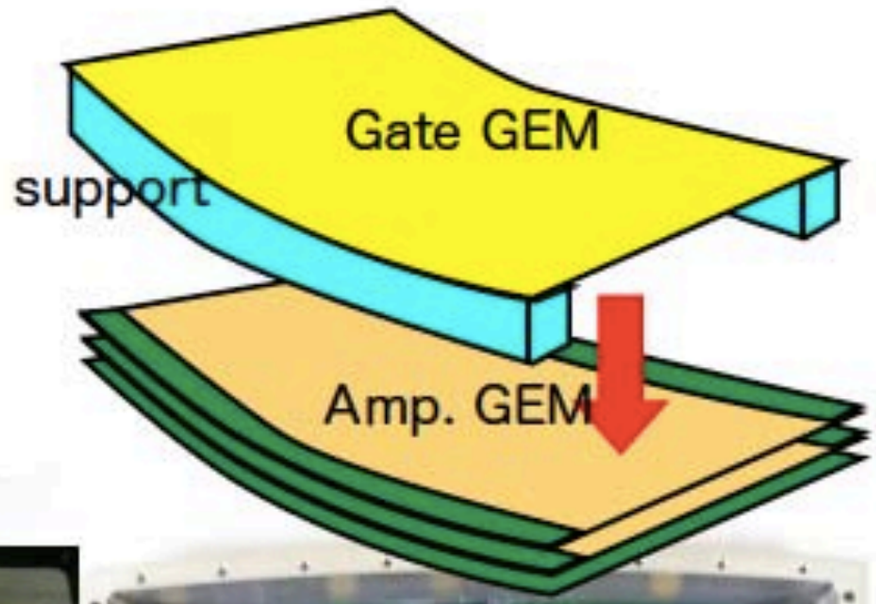




detector?

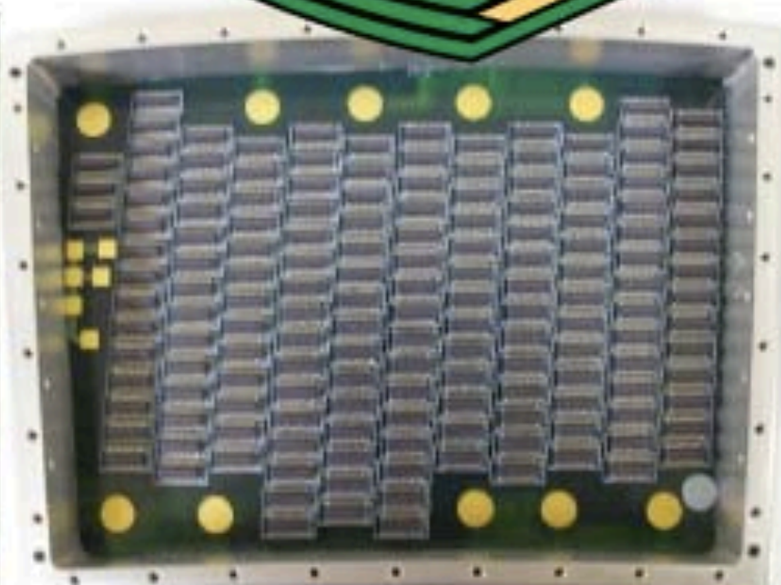
rφ方向の不感領域低減

GEMの構造簡素化



Direc

Time
f
5



What is QPiX

Maximize information from ionized electrons

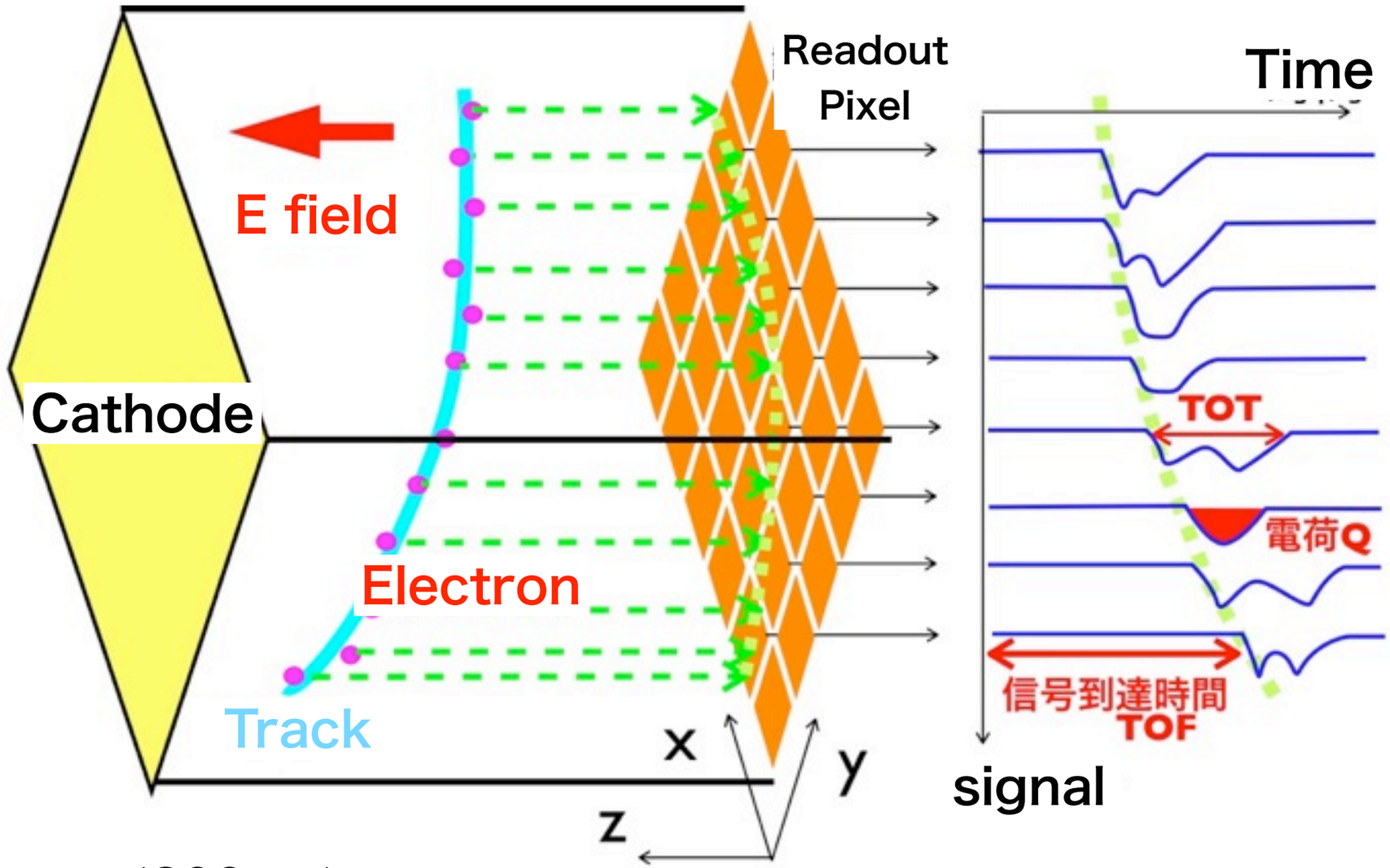
Charge info. on each fine 3D Volume cell (Voxcel) is ideal
but not possible yet

TOF : Time of Flight	drift time	→ z coordinate
TOT : Time over Threshold	signal width	→ electron distribution on z
ADC : SAR ADC	fast ADC	→ charge
pixel position		→ x-y coordinate

Quad information

Quasi-3D **Pix**el

Q(charge) **Pix**el

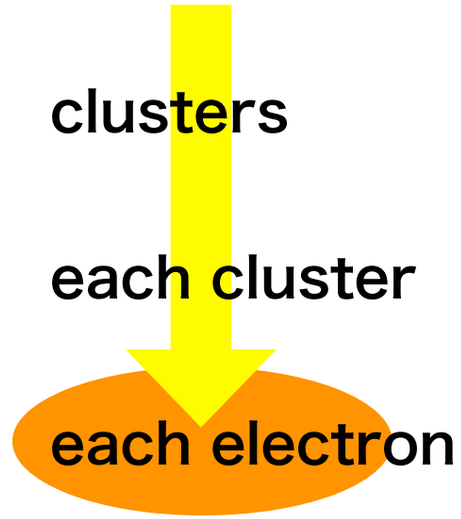


Pixel size became larger (200um)

How do we use pixel readout

what do we read?

clusters, cluster or electron



究極のガス検出器
電子霧箱
デジタル霧箱

1mm pad

O(200um)

TimePix/
MediPix
O(50um)

conclusion from LCTPC

PRF should be ～ pixel size /3

PRF
MPGD
pixel size

300um
(Triple GEM)
1mm pad

20um
(Micromegas)
60um pixel

MPGD choose
optimal pixel size

QPiX pixel size is 200um ~ 400um

PRF ~100um
Which MPGD

single GEM, short stack GEM,
GEM +MM

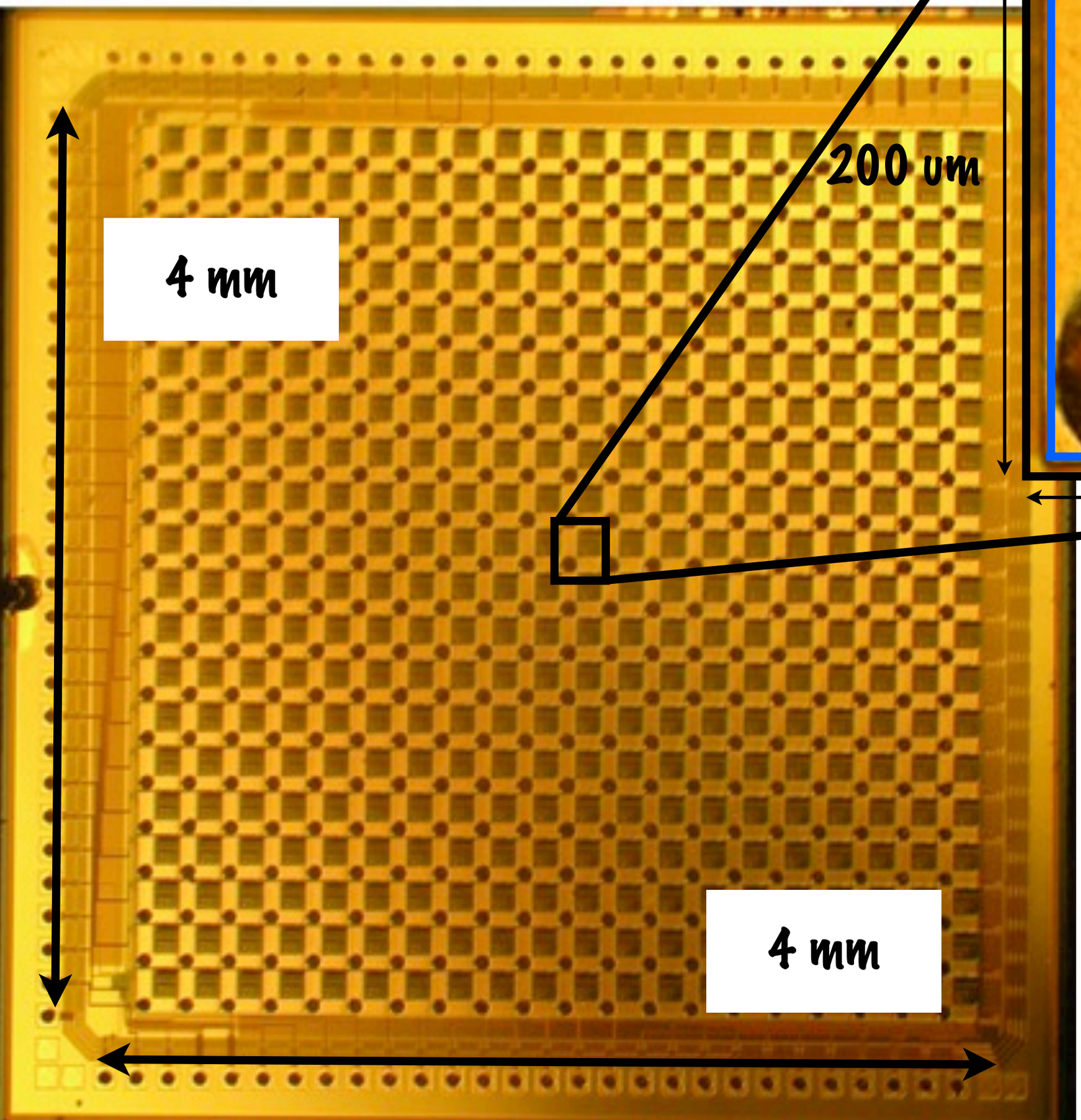
Multi hit capability is necessary for ILC
but is not implemented yet

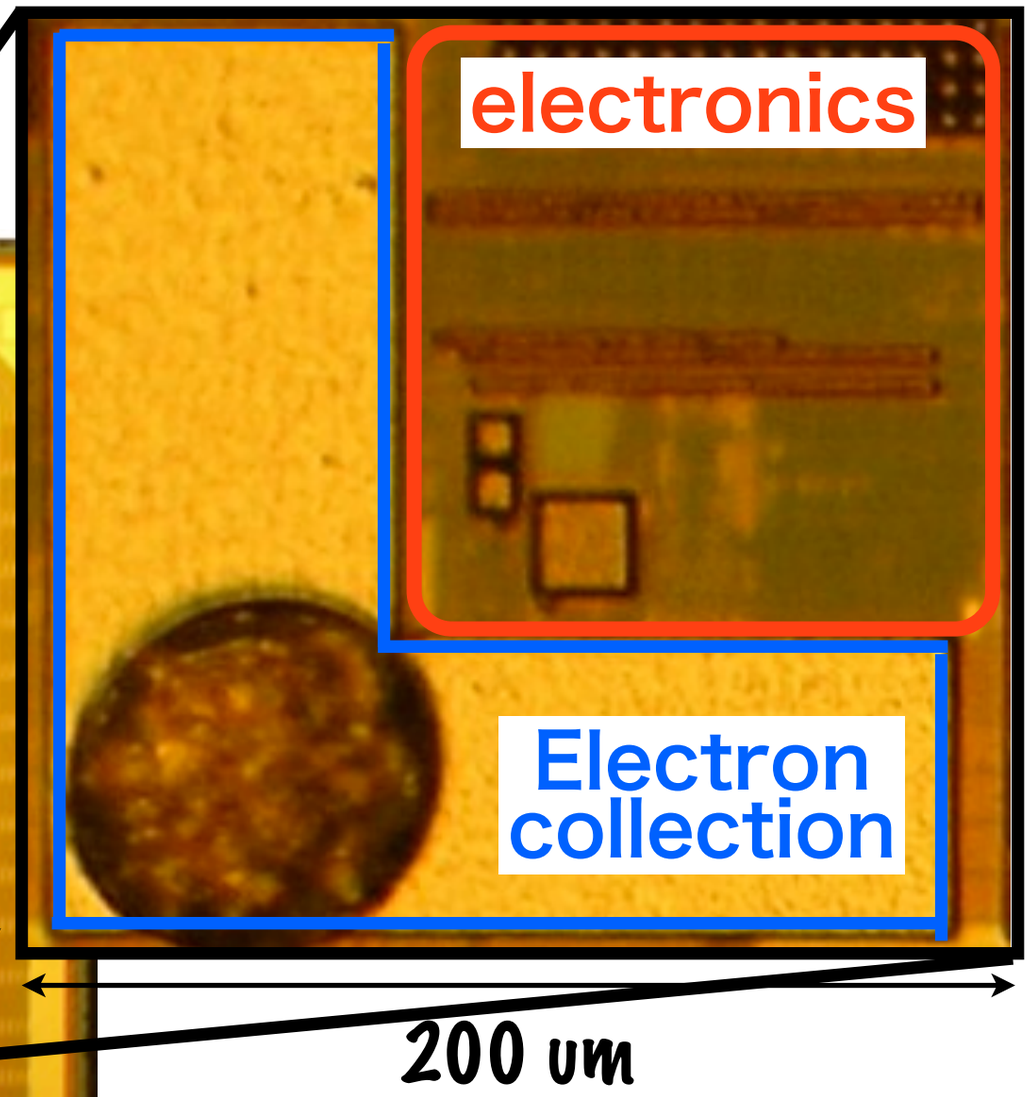
Dark matter detection is better application for QPiX
due to low signal rate

QPiX R&D for Dark matter is more realistic

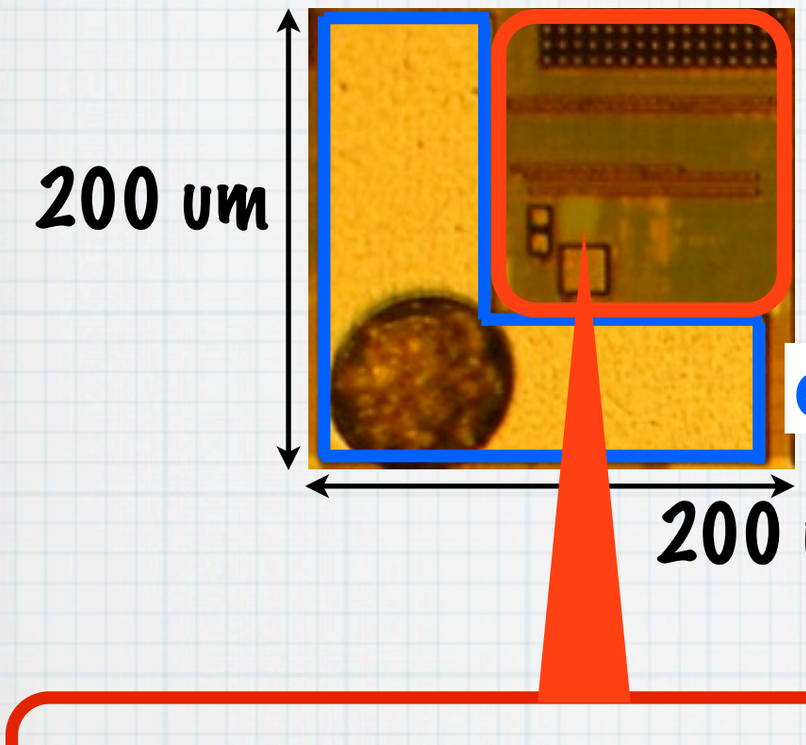
may reach to ILC upgrade later

QPIX ver 1.

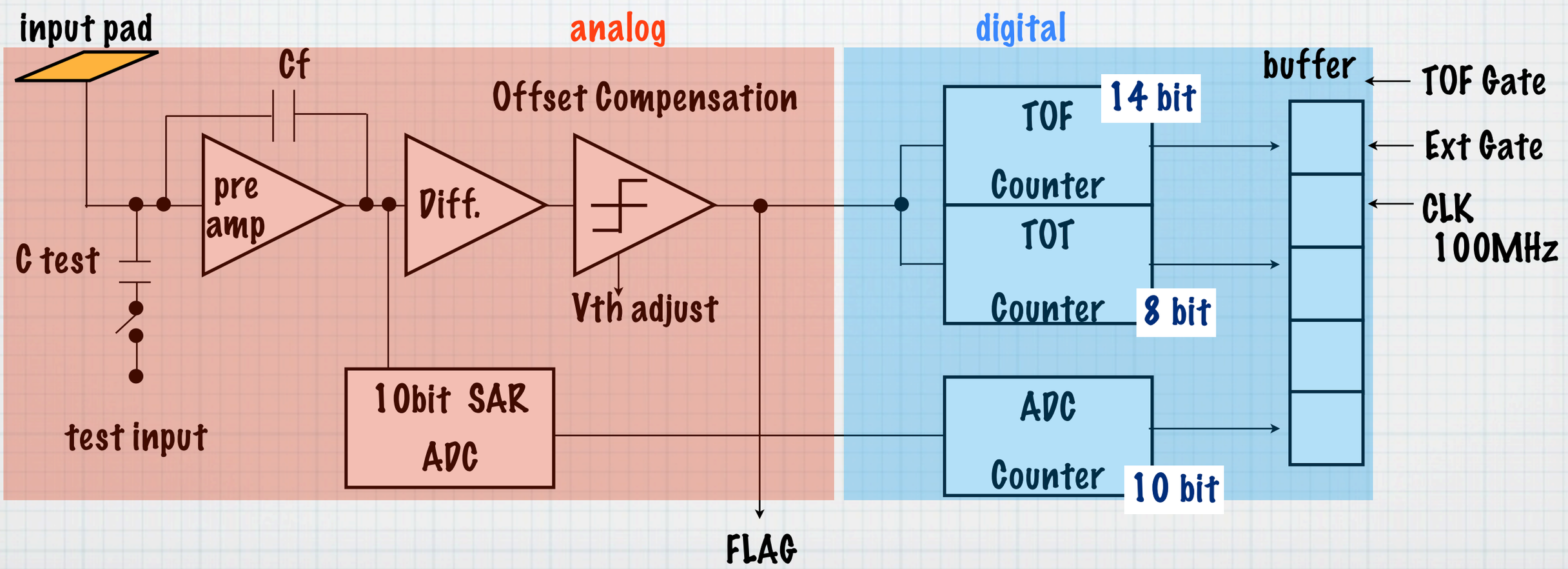




QPIX ver 1.



	QPIX.v.1
Dimensions	200 x 200μm²
Preamp Gain	0.43 mV/fC
Comparator threshold	35 fC
ADC LSB/MSB	1.6 fC/1.6 pC
Readout information	TOF: 14 bits
	TOT: 8 bits
	ADC: 10 bits, 10Msps
Power	150 μW
Read out	Serial/Parallel



Function test by test pulse

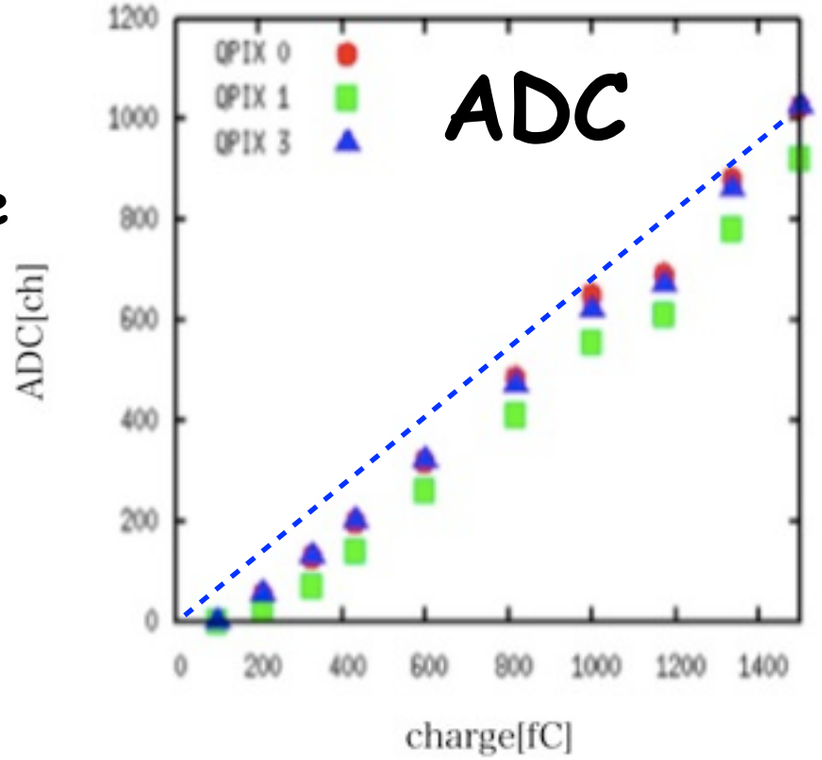
test input has unknown stray capacitor

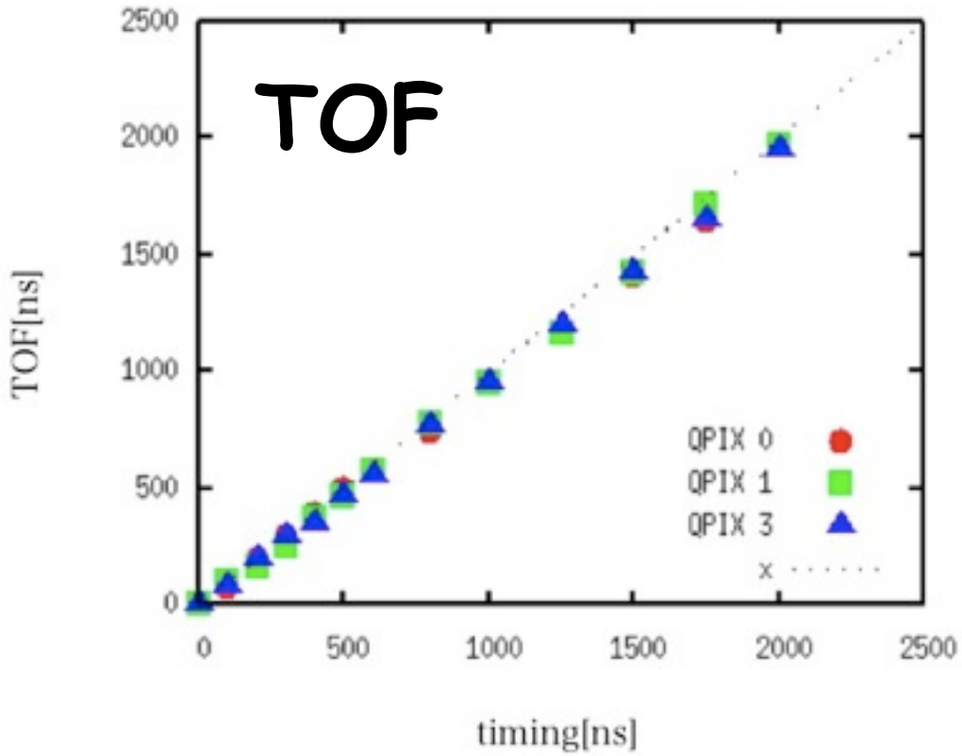
All function works well
but....

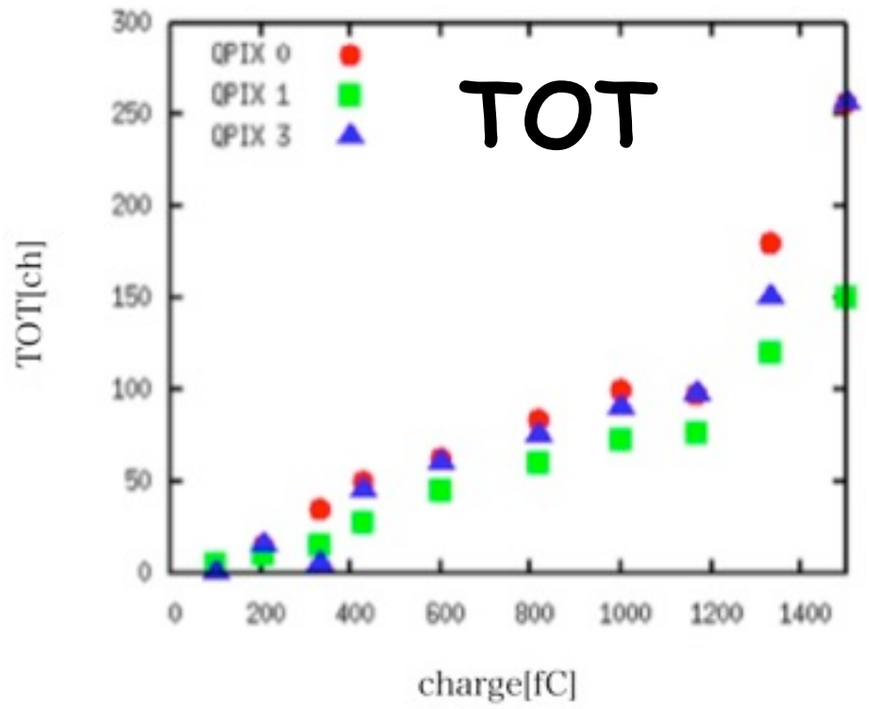
Sensitivity seems to be OK
but OFFset
(70~100 fC)
due to A-D x-talk

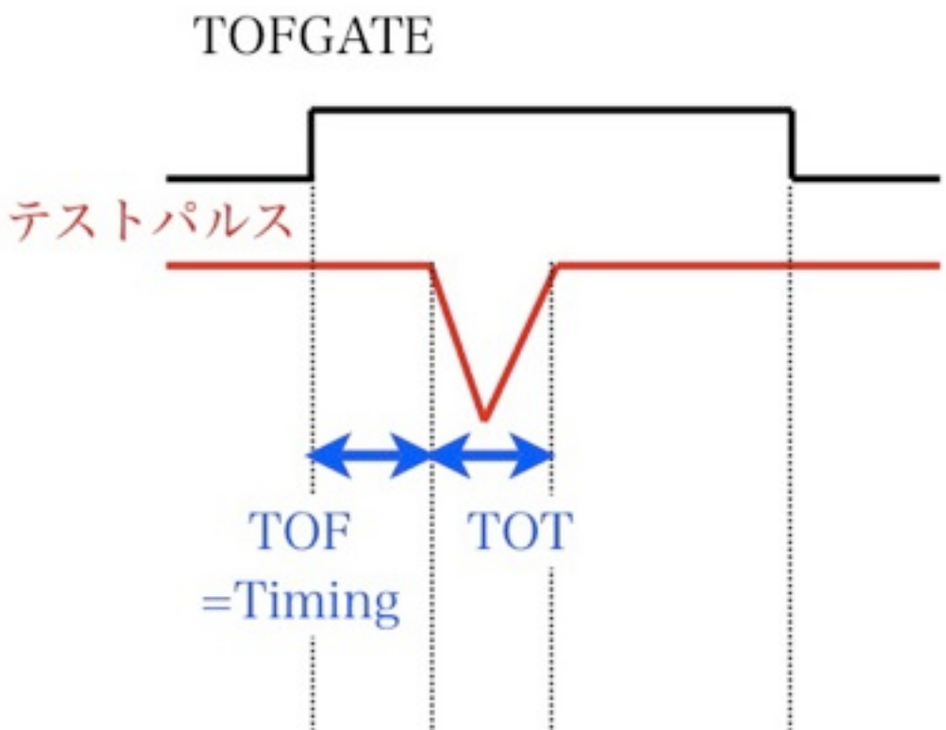
Input impedance is not clear
real capability is ??

We had tried to detect signal using Cf, alpha source without success

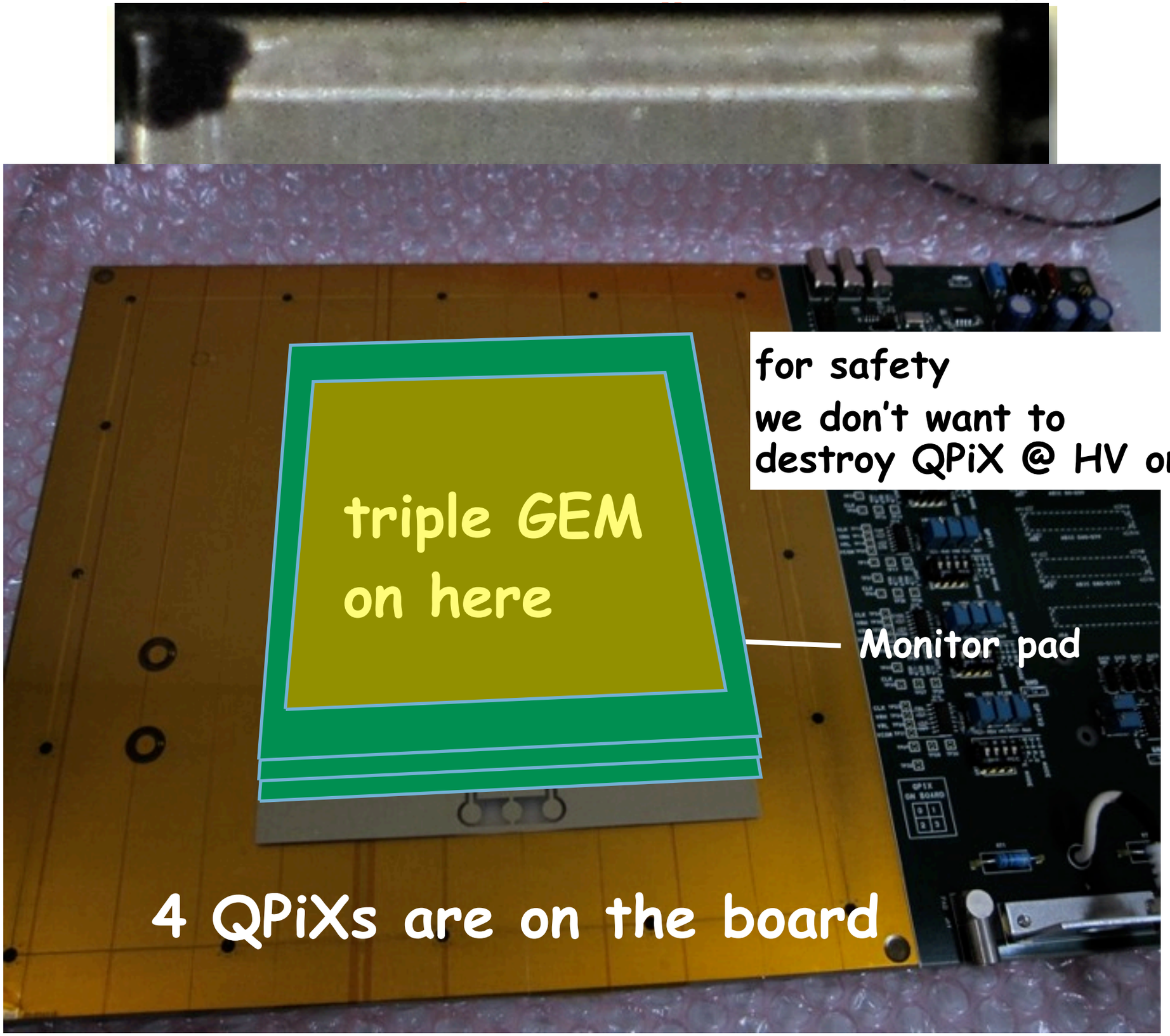








Wire bonding to base plate/
metal cover for field shaping

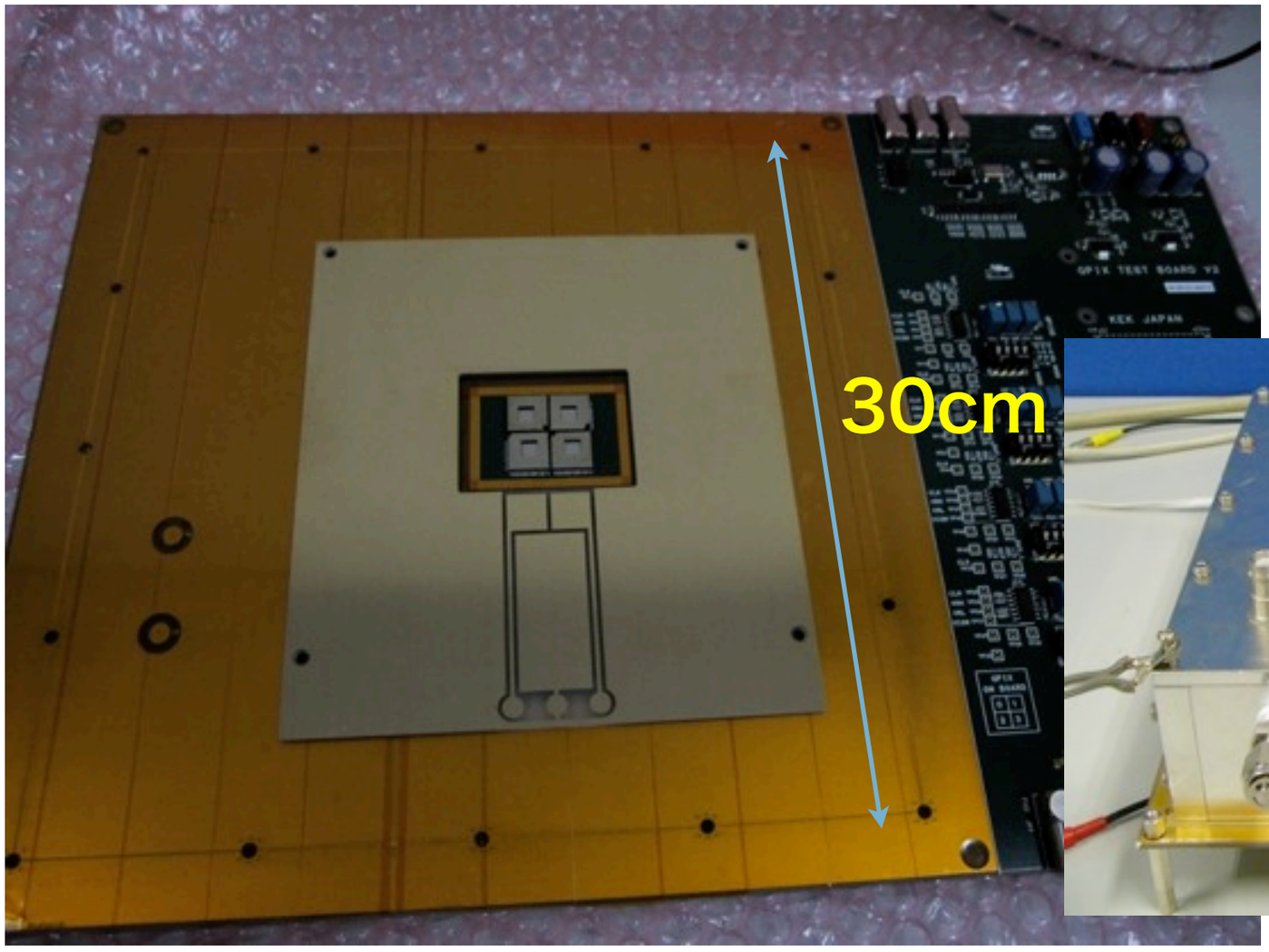


Ion (Ne) beam test

range in Ar
= size of chamber

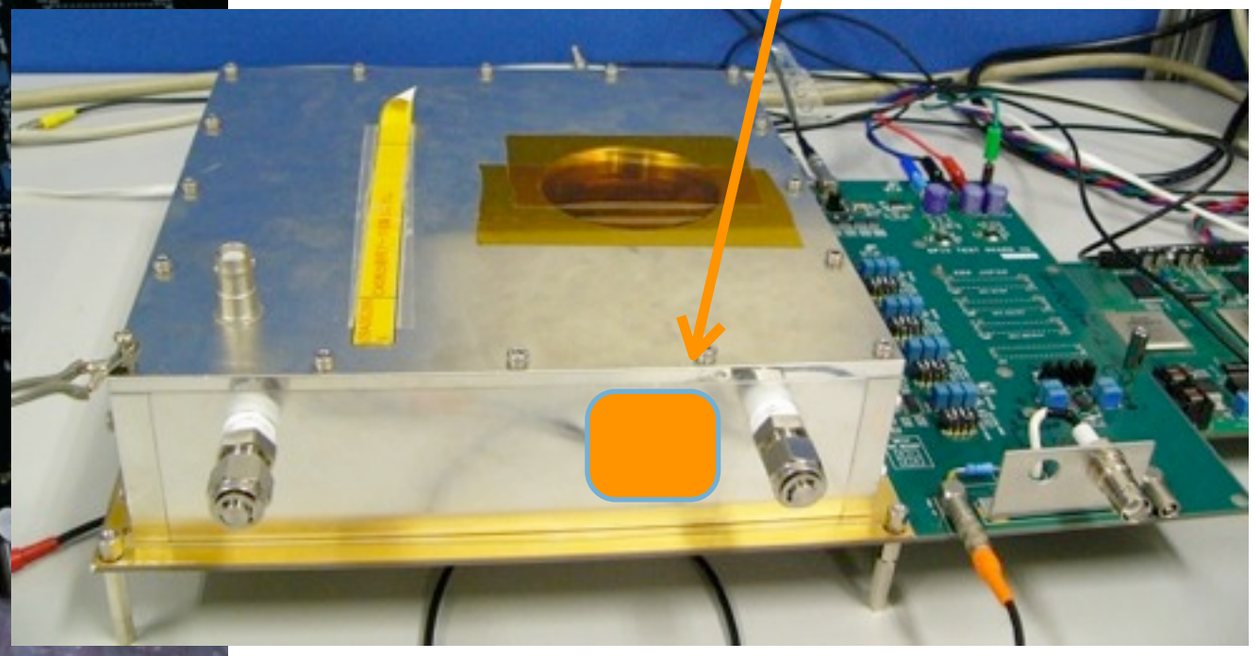
粒子	energy[MeV]	飛程 (空気1気圧)	飛程 (Al)	飛程 (Be)	飛程 (Ar 1 気圧)	dE/dx [MeV/mm] (Ar 1 気圧)
Ne^{7+}	250	360mm	200μm	270μm	360mm	0.44
p	1				9mm	0.04

252Cfでの実験値



+ trigger counter
behind chamber

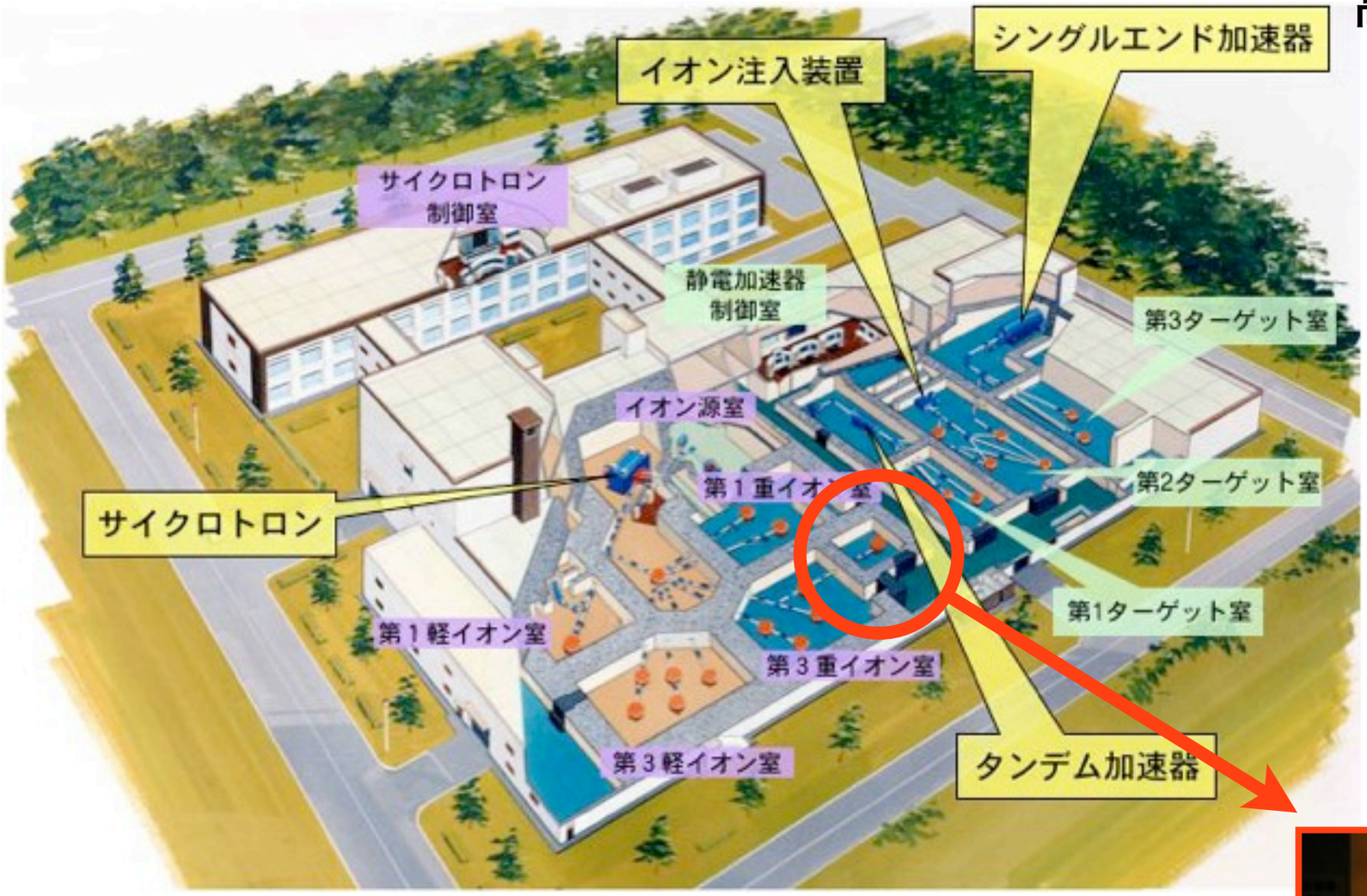
we have mylar window



TIARA イオン照射研究施設

日本原子力研究開発機構(JAEA)
Japan Atomic Energy Agency
高崎量子応用研究所

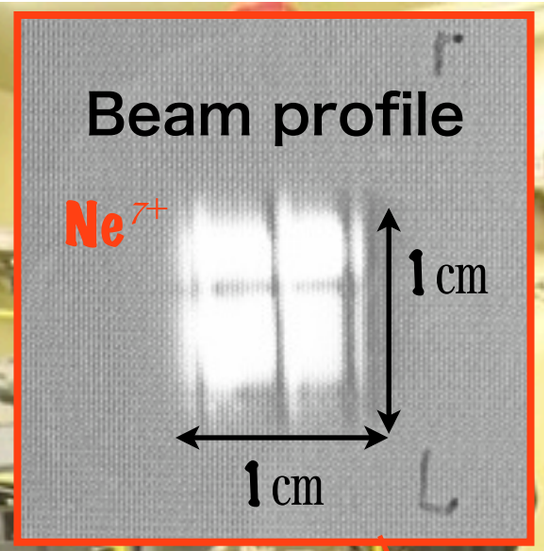
TAKASAKI ION ACCELERATORS for ADVANCED RADIATION APPLICATION



カクテルビーム

collabo. with：
T.Ohshima, S.Onoda

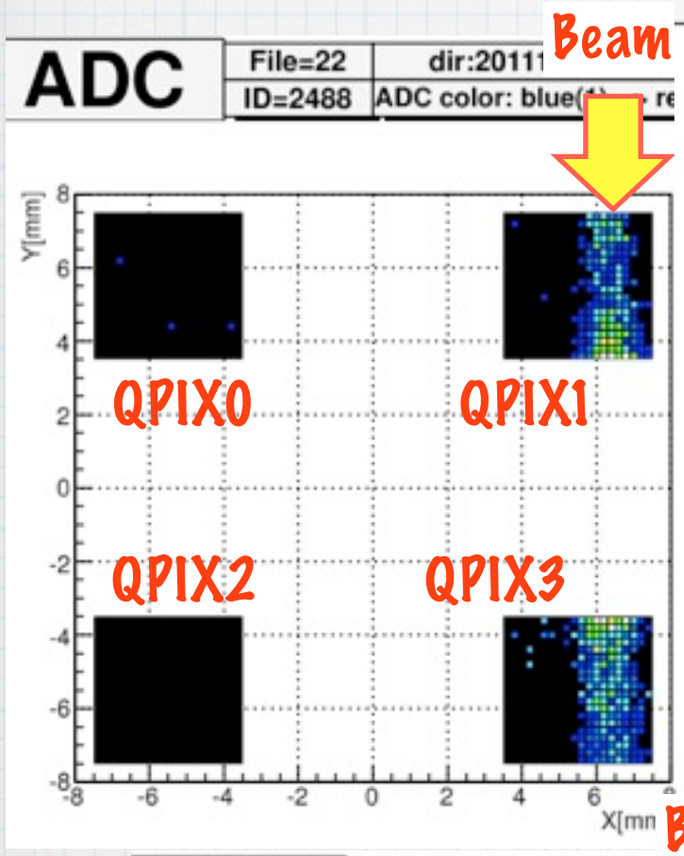
照射室

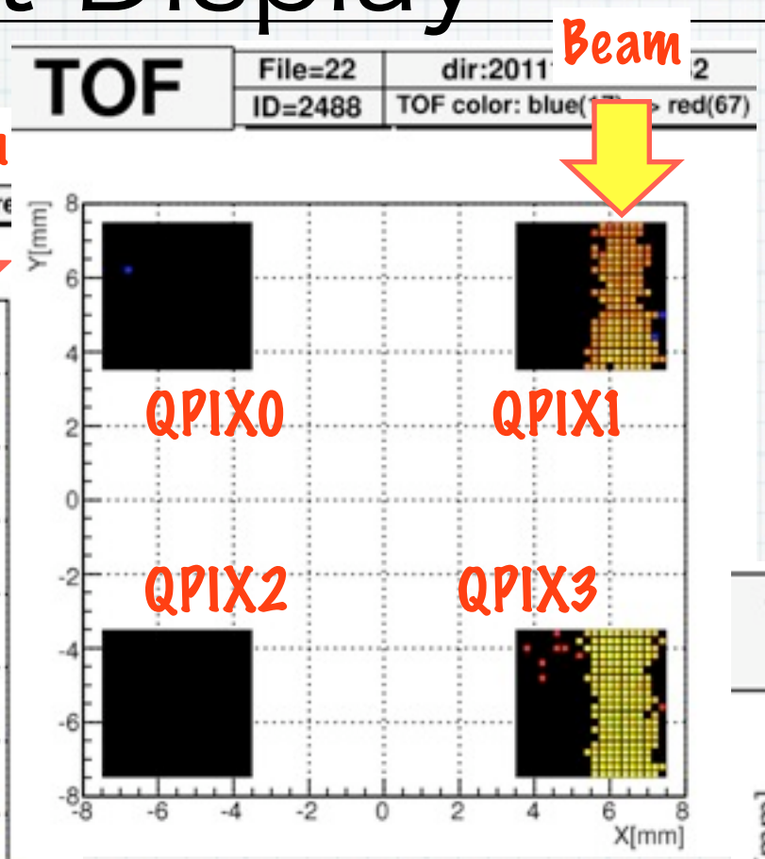


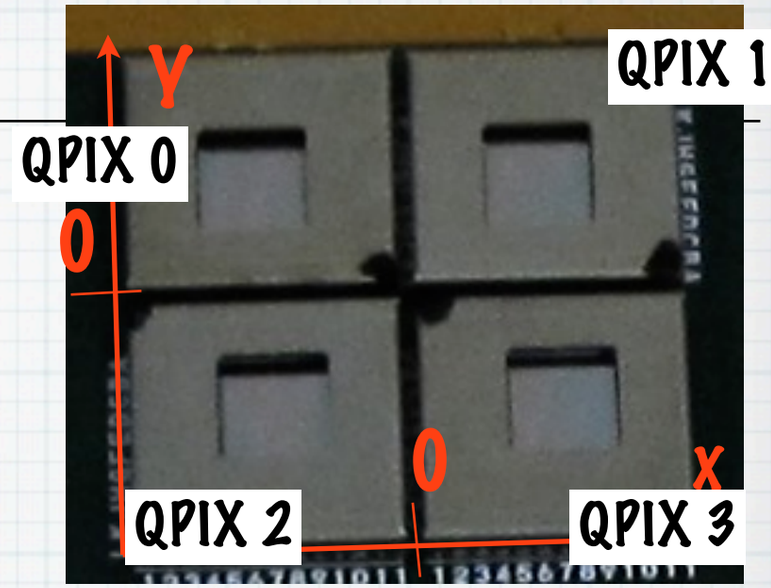
Detector

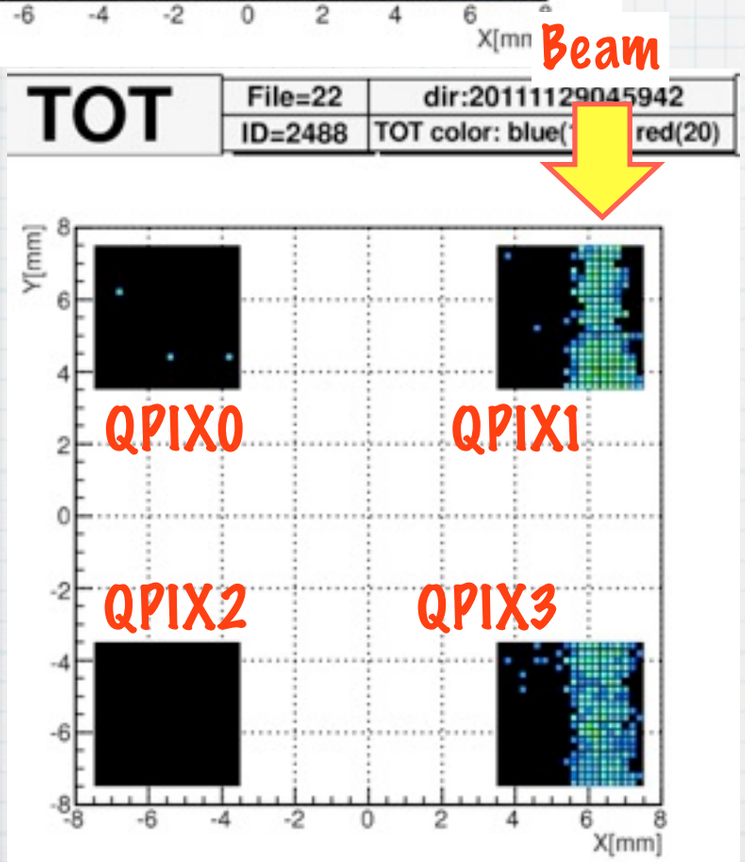
trigger counter

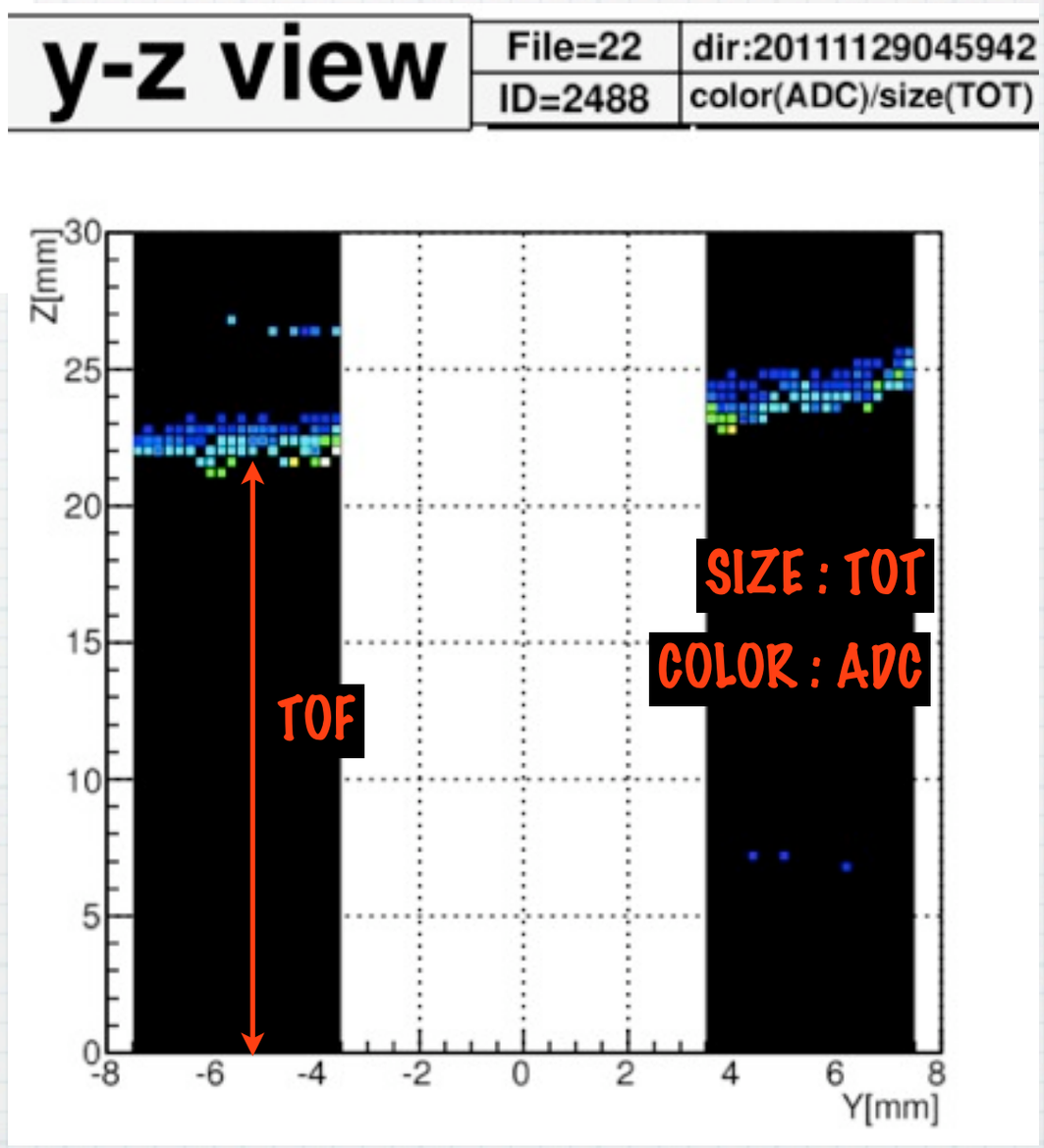
Event Display







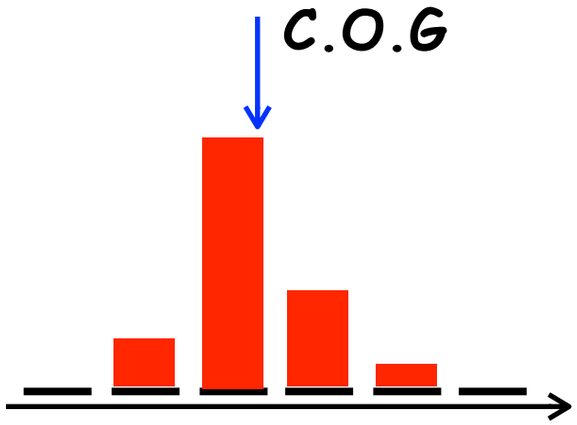




Tracking & Position resolution

Method 1: conventional 1D tracking

Charge distribution @x-row -> Center of Gravitiy for x



linear fit (minimize $\chi^2 = \Sigma(x_{track}-x_i)^2/\sigma_i^2$)

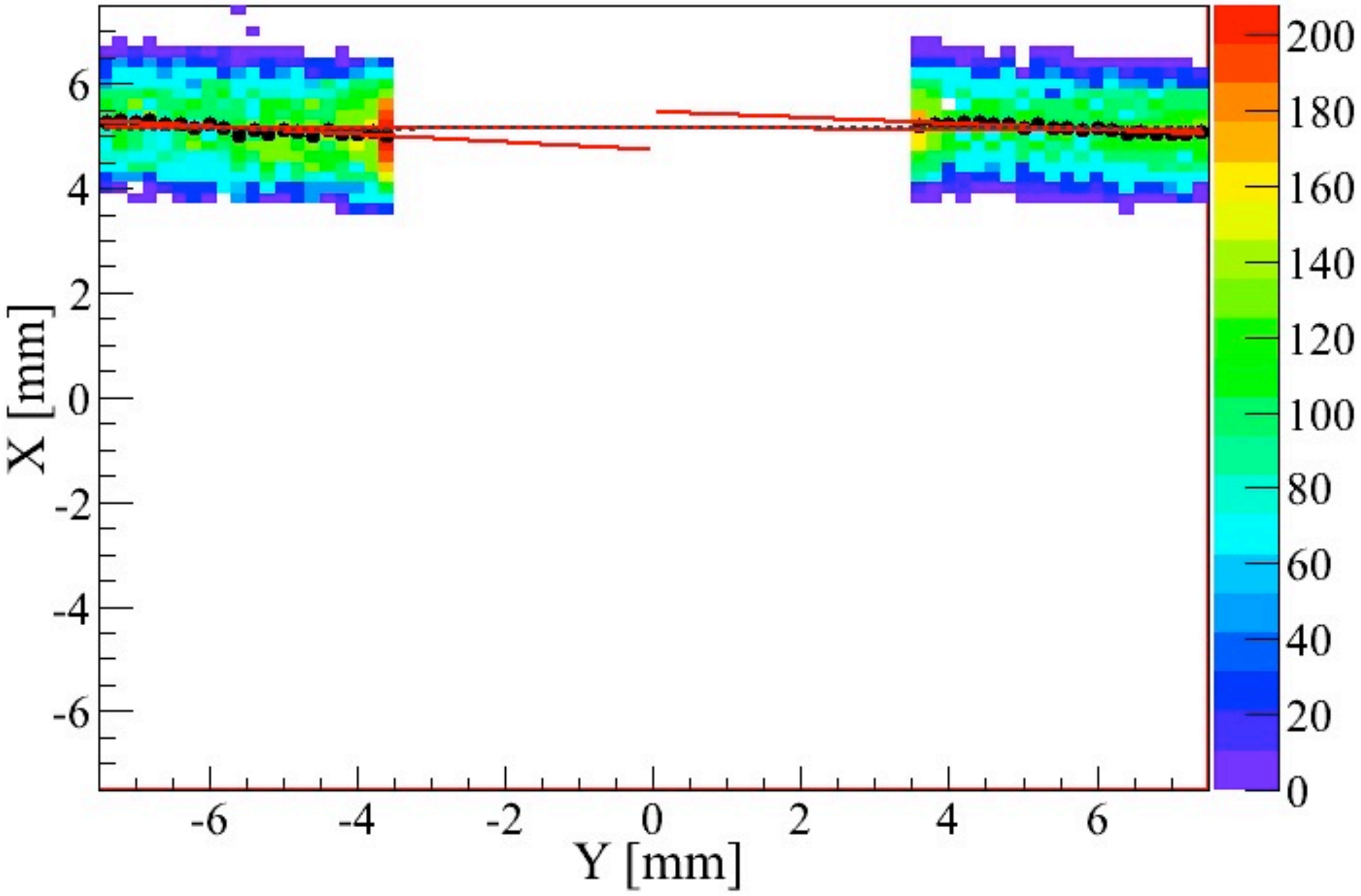
using c.o.g. along y axis

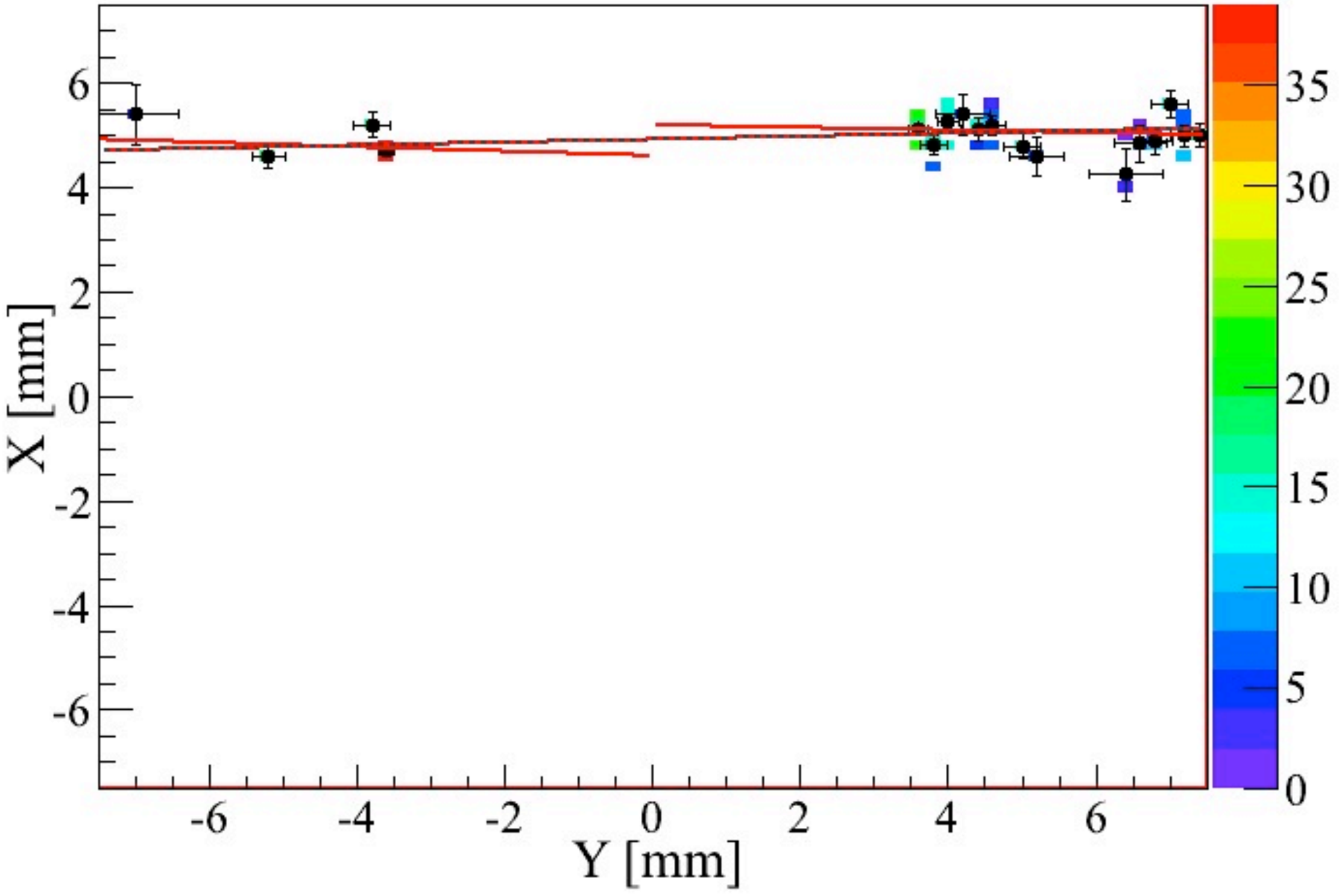
Method 2: 2D clustering

more general for pixel detector

Linear fit using c.o.g.

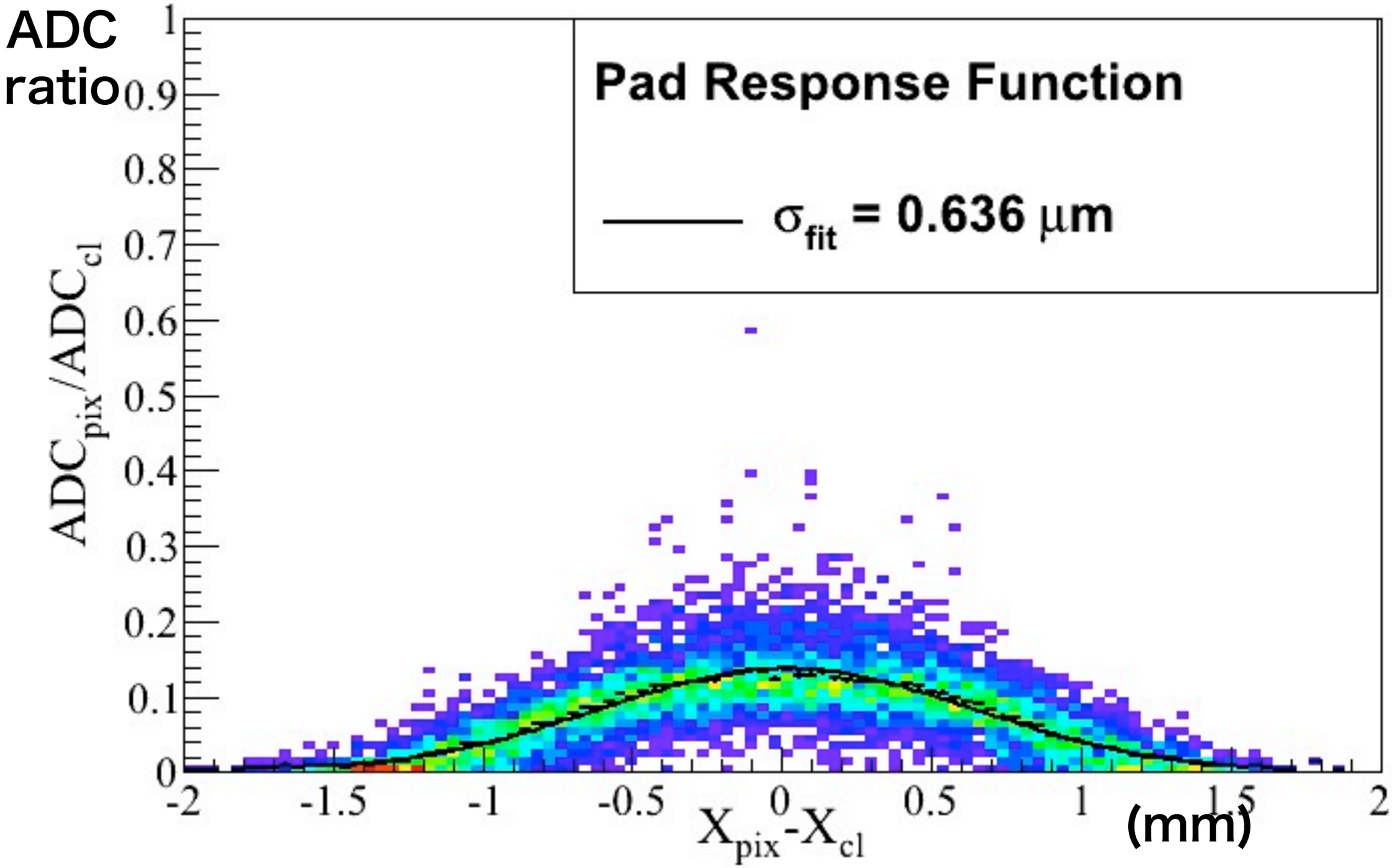
alignment of chip ? or field distortion ?




X [mm]
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6
Y [mm]
35
30
25
20
15
10
5
0

Charge distribution

Charge spread is mainly coming from diffusion
of electron @ drift and gas amplification

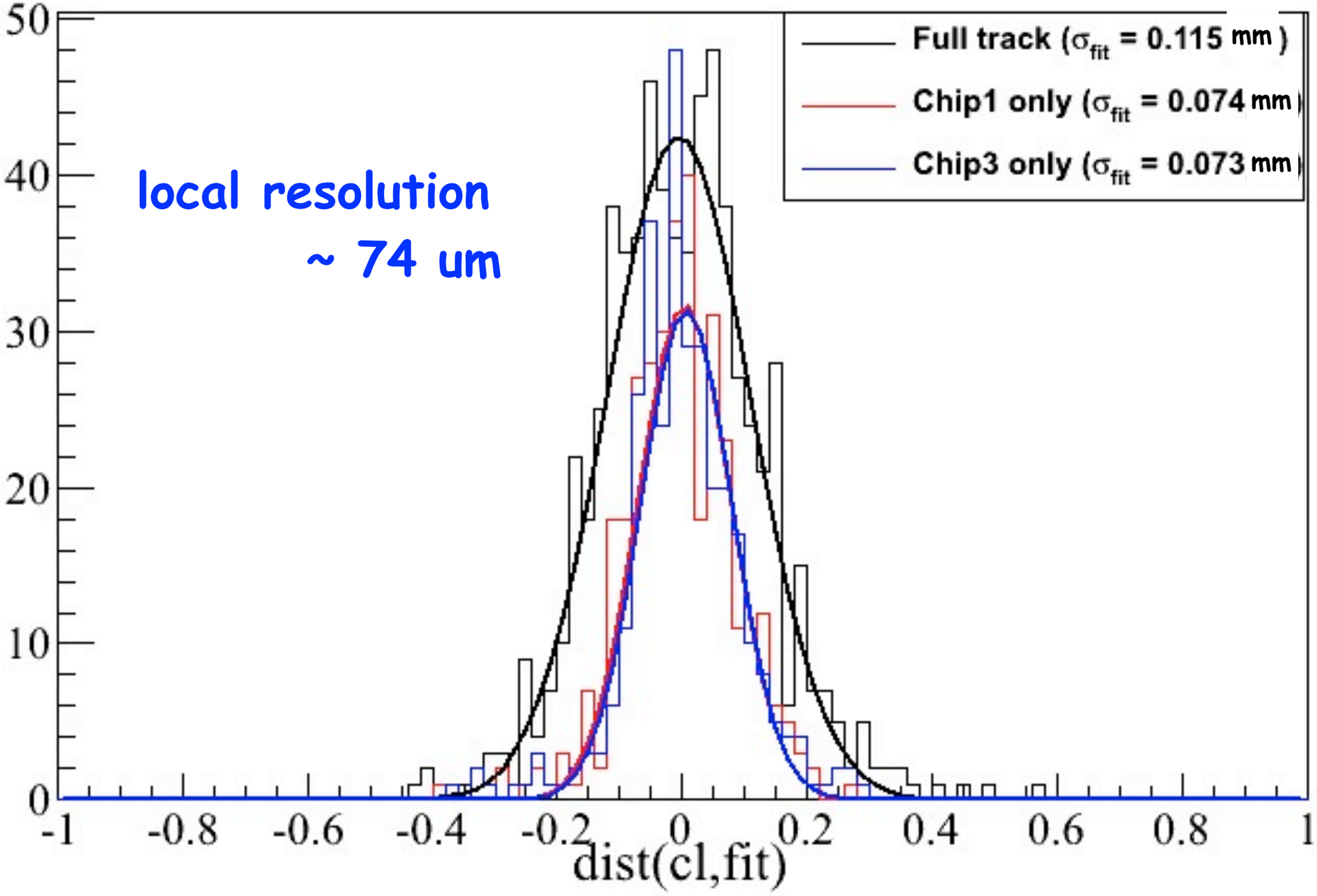


center of pixel — X track

Residual

= difference between (expected) track and C.O.G

~= position resolution



Charge calibration

we could see tracks under ions irradiation
But not sure what we detect
as ADC contain offset and we cannot say how much dE/dx it has

real threshold
charge collection efficiency

We may need source of calibration
we've tried different ion (O) but .....

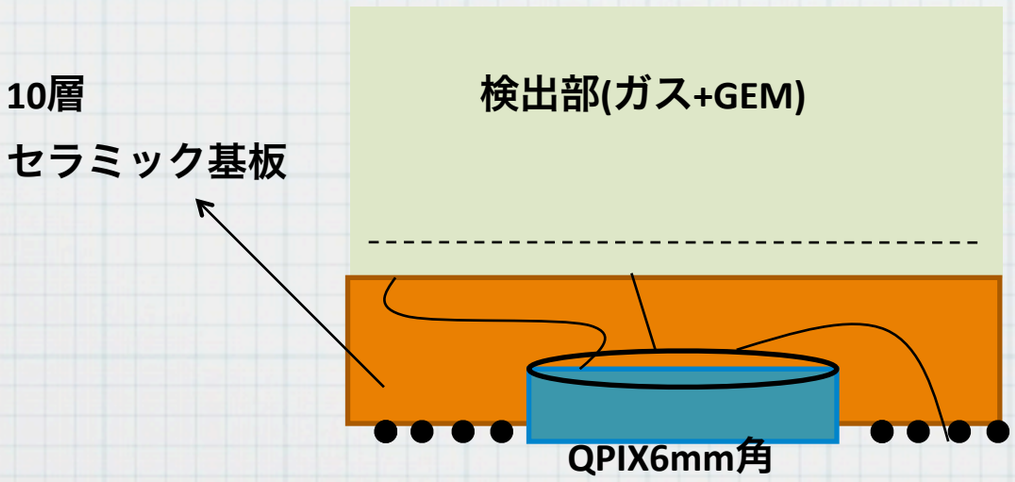
planning to use Laser system this summer as well as ion beam
chamber is under modification for quartz window

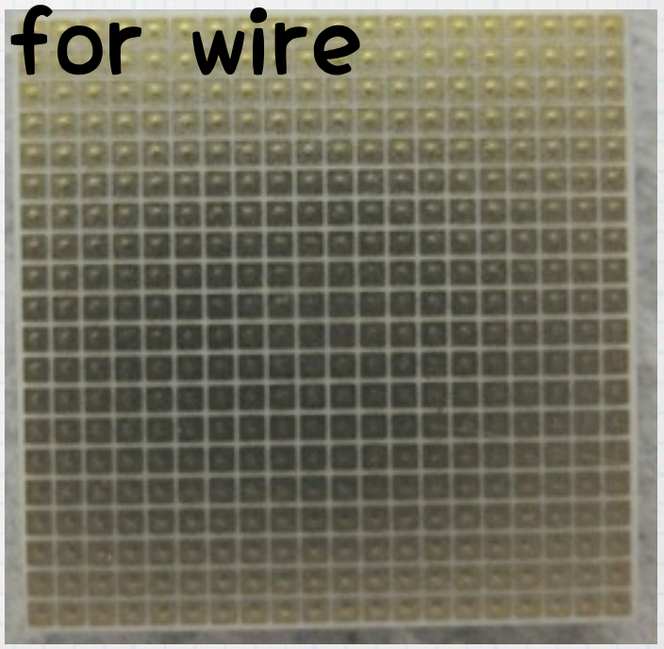
Mount technique of chip

- wire bonding
  - conventional technique
  - but
  - inevitable dead space for wire

- flip chip + LTCC　　200um pixel -> 400um pixel

New pad board by LTCC
(Low Temperature co-fired ceramics)
bump bonding
in order to remove dead space for wire





Future plan

QPiX

current version

test using laser system this summer

ion beam test again this summer

next version

single channel TEG tested

20x20 channel will be within this year

operation test @ next year

up to manpower & money

Fabrication

LTCC + simple chip

sample is ready to be test

Summary

QPiX : has observed heavy ion charged tracks

all function is working well

except for high threshold

due to A - D X-talk

version 2 is coming soon

LTCC : dead spaceless fabrication is under study