

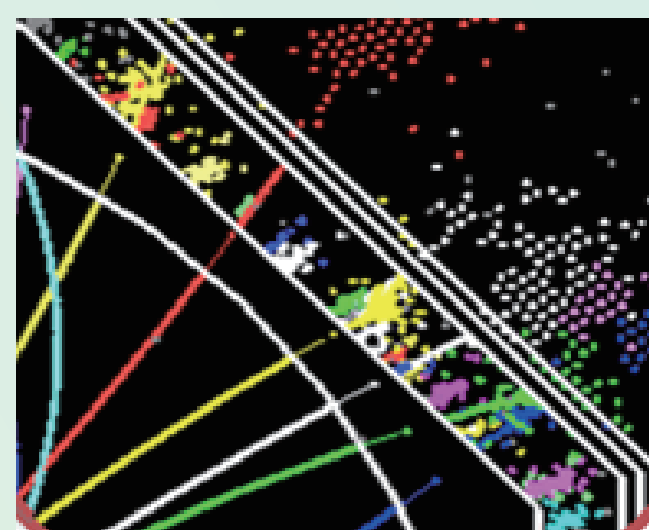
Development of Position-Sensitive Silicon Detector for ILC calorimeters

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Motivations and Principles

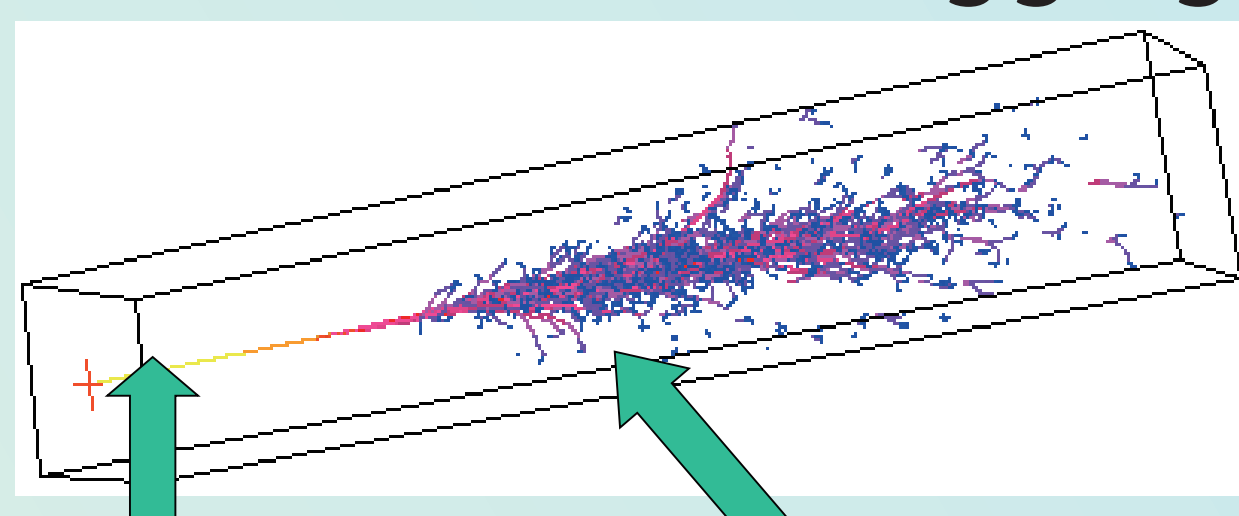
Silicon-Tungsten ECAL

Suitable for Particle flow calorimetry separating particle inside jets
Extremely highly-granular EM calorimeter with 5x5 mm cells, 30 layers, 10⁸ channels in total



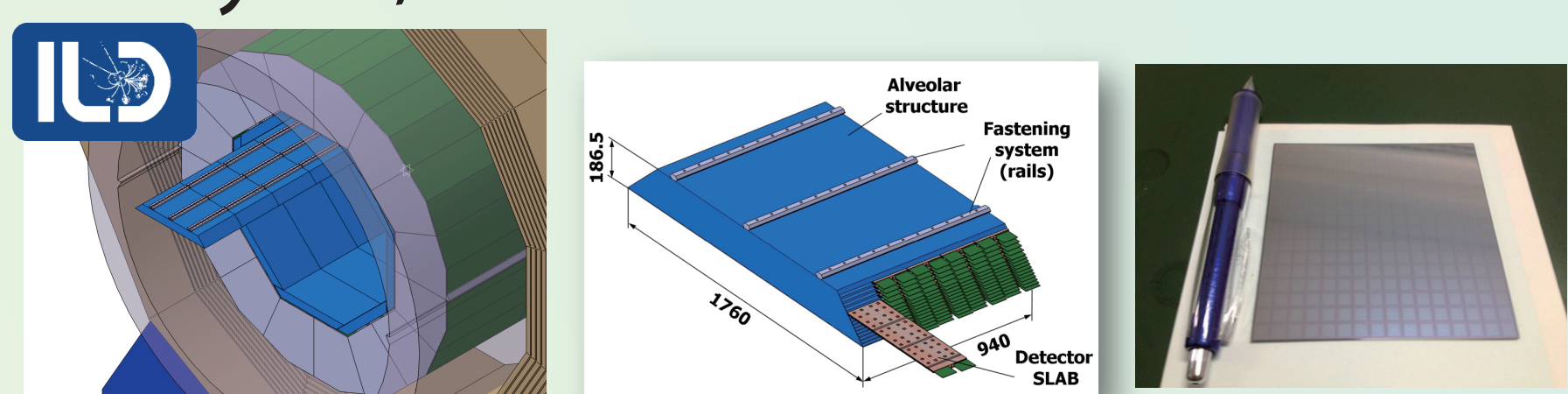
Motivation for position resolution

Position and direction of photons are important to find displaced photons (new physics search, flavor tagging etc.)



Inner layers
single-point resolution is more important

At shower-max
position resolution of center mainly determined by Moliere radius



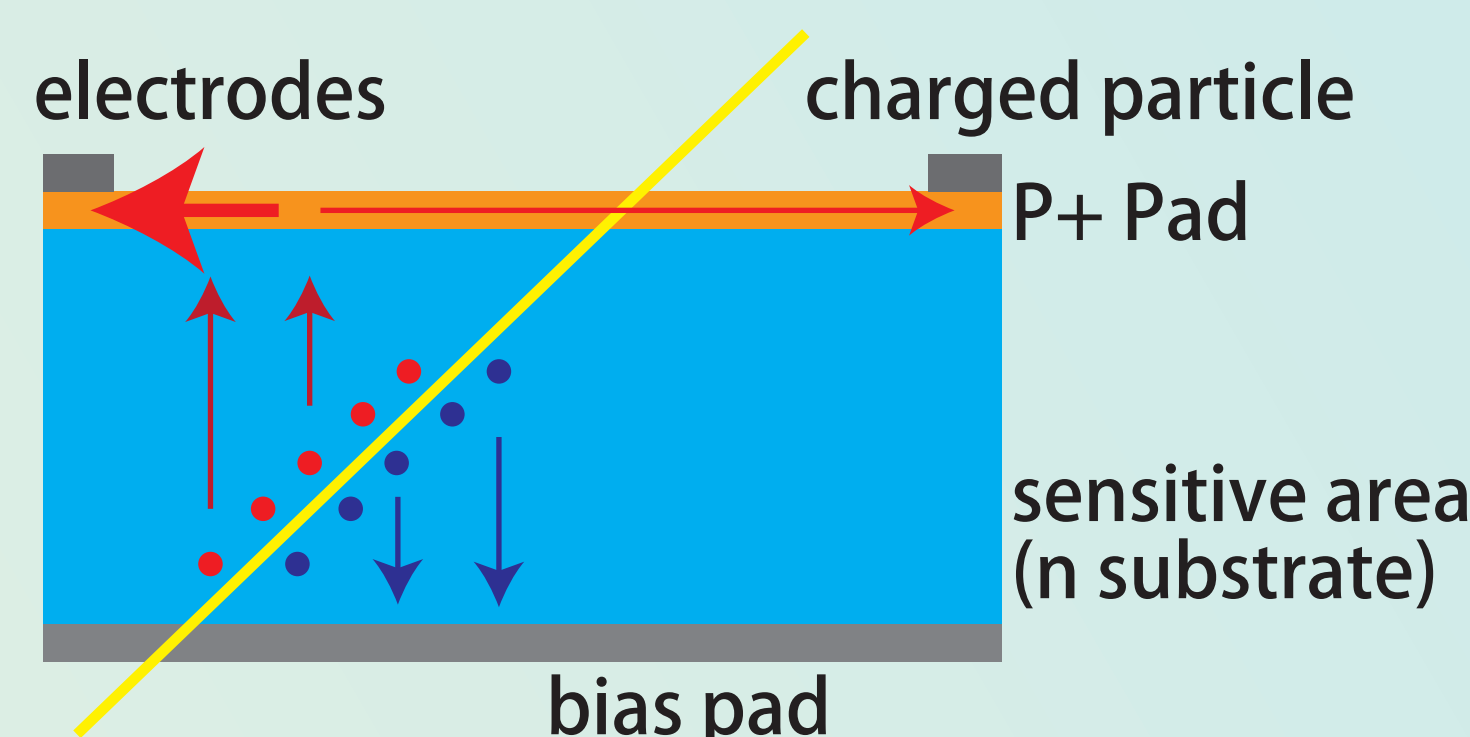
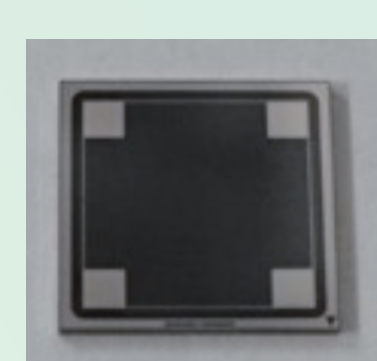
Principles of Position-Sensitive Detectors (PSDs)

Resistive surface and multiple electrodes in one cell (4 electrodes /cell)

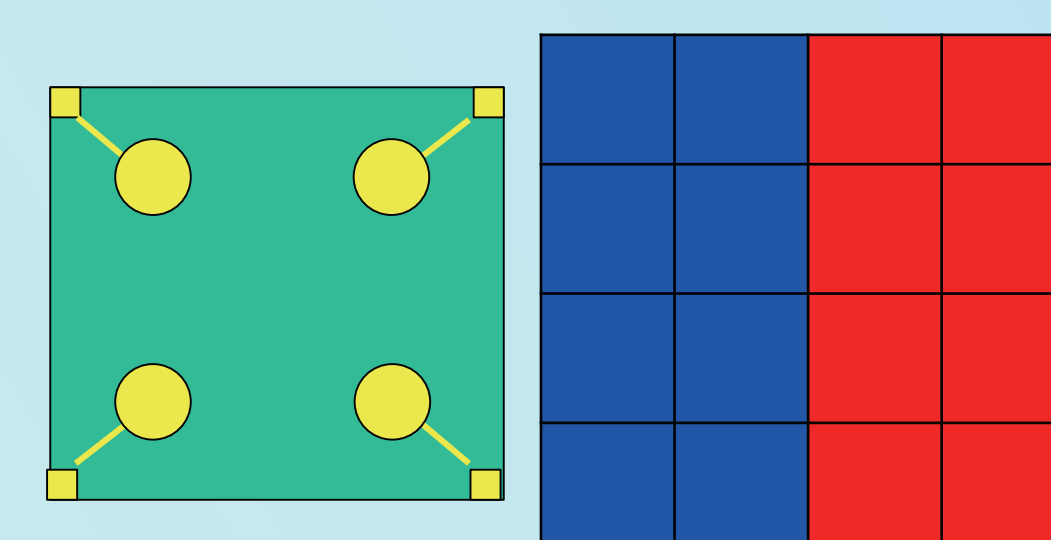
charges are split into electrodes by resistive division

Position resolution affected by S/N ratio of the charge measurement

Common device in optics / nuclear physics

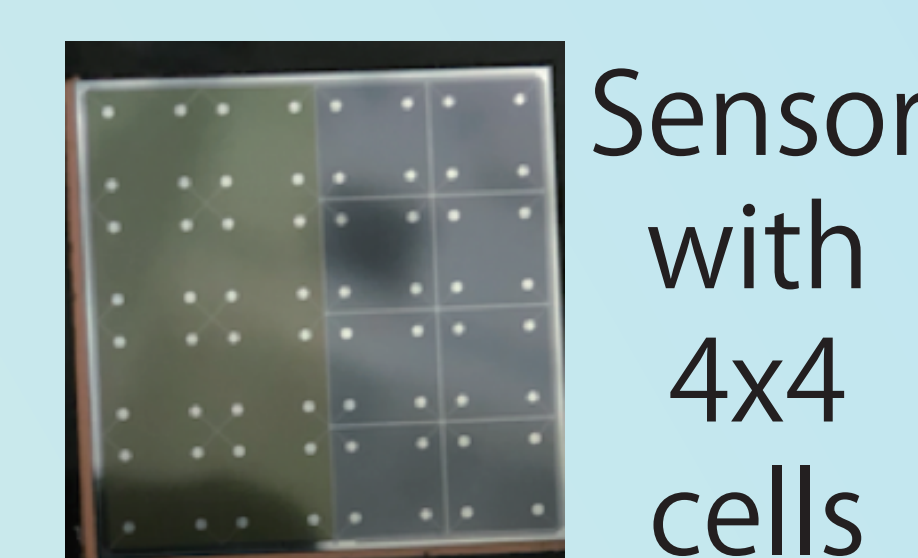


Samples



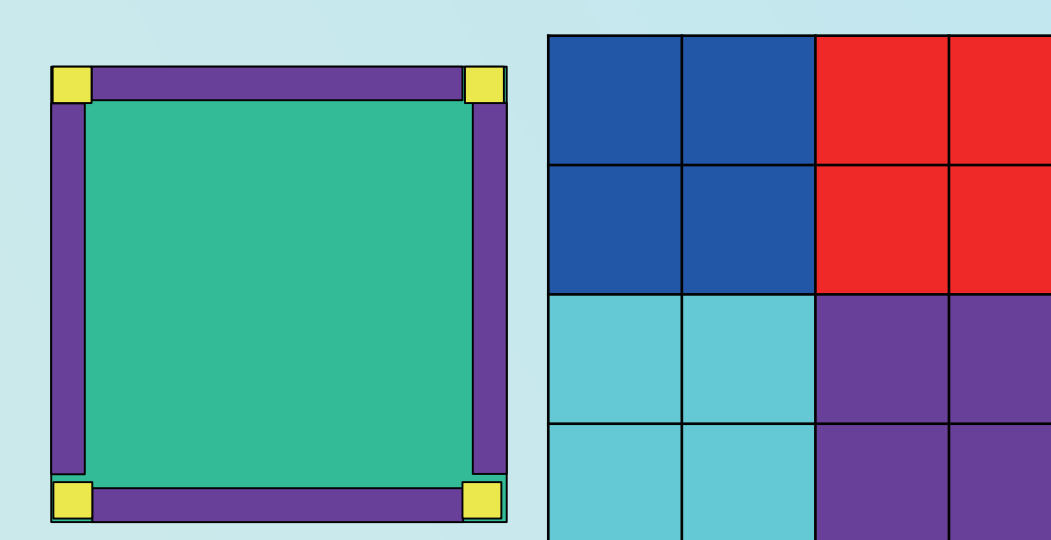
Type A: normal type

Flat resistance over surface with 4 electrodes on corners.



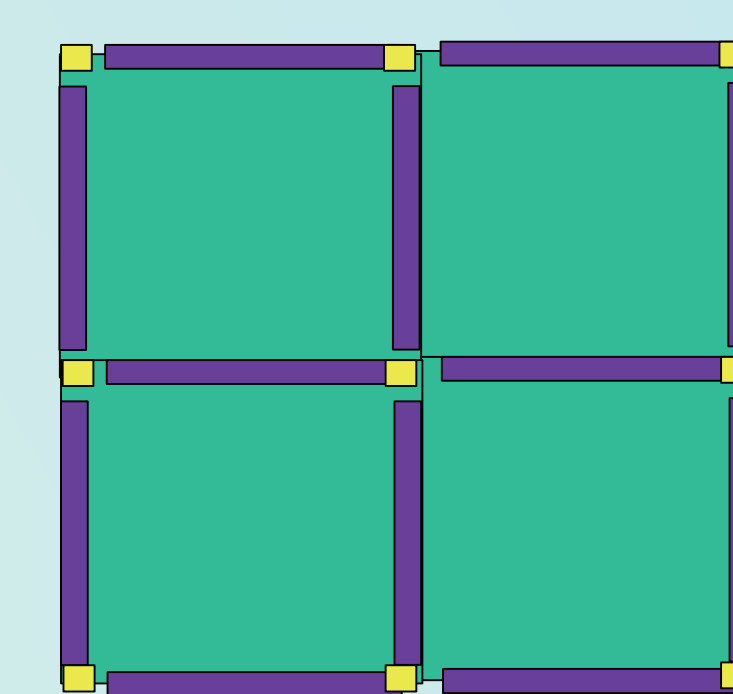
Sensor with 4x4 cells

Low (blue) and high (red) surface resistance



Type B: low-R edge

Lower resistance on edge lines to reduce position distortion. 4 configurations on surface resistance and low-high ratio

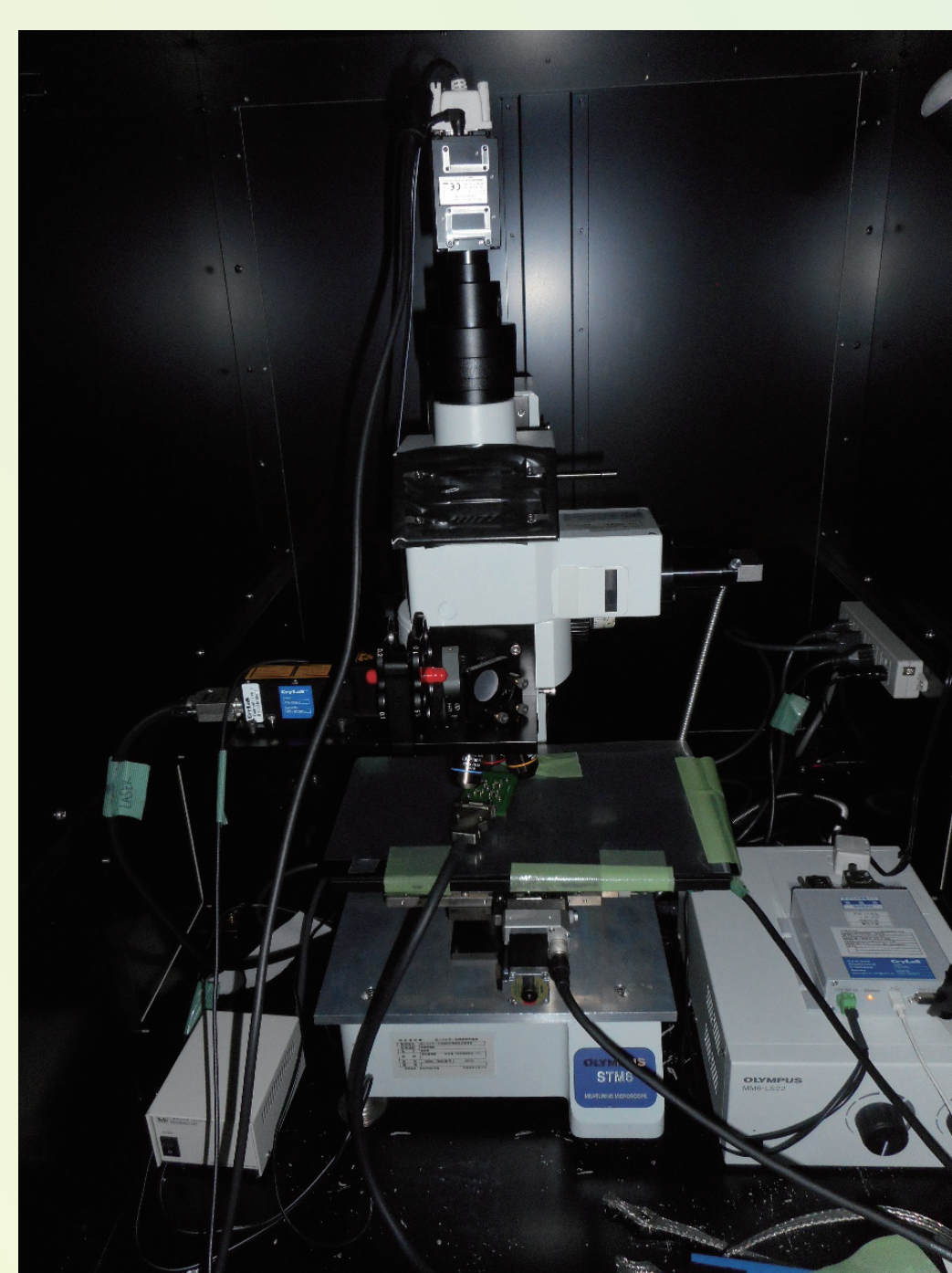


Type C: Shared pads

Electrodes are shared with neighbor cells to reduce number of readout channels. Resistance configuration as same as Type B

Test results

Laser irradiation (single cell, low surface R)

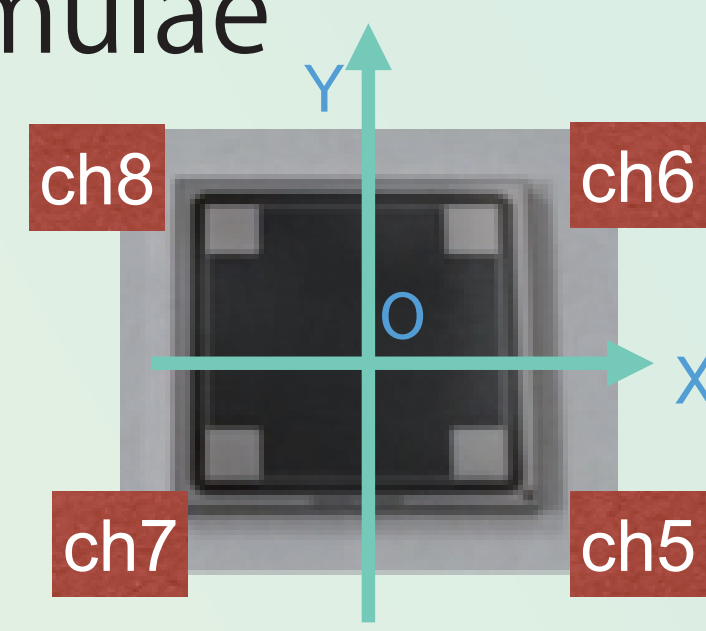


Pulsed infrared laser (Nd:YAG, 1064 nm)
~1 kHz repetition rate
a few ns pulse length
~50 MIP equivalent signal strength
~20 μm spot size (focused)

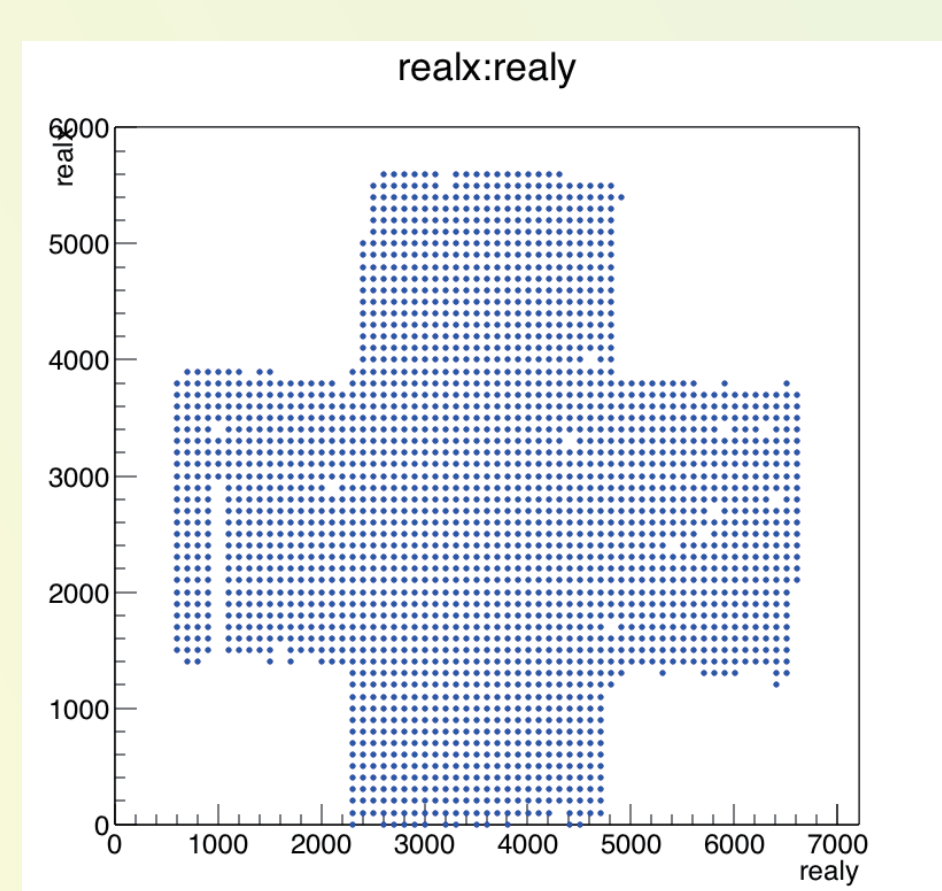
Position reconstruction formulae

$$X_{rec} = \frac{(ch5 + ch6) - (ch7 + ch8)}{ch5 + ch6 + ch7 + ch8}$$

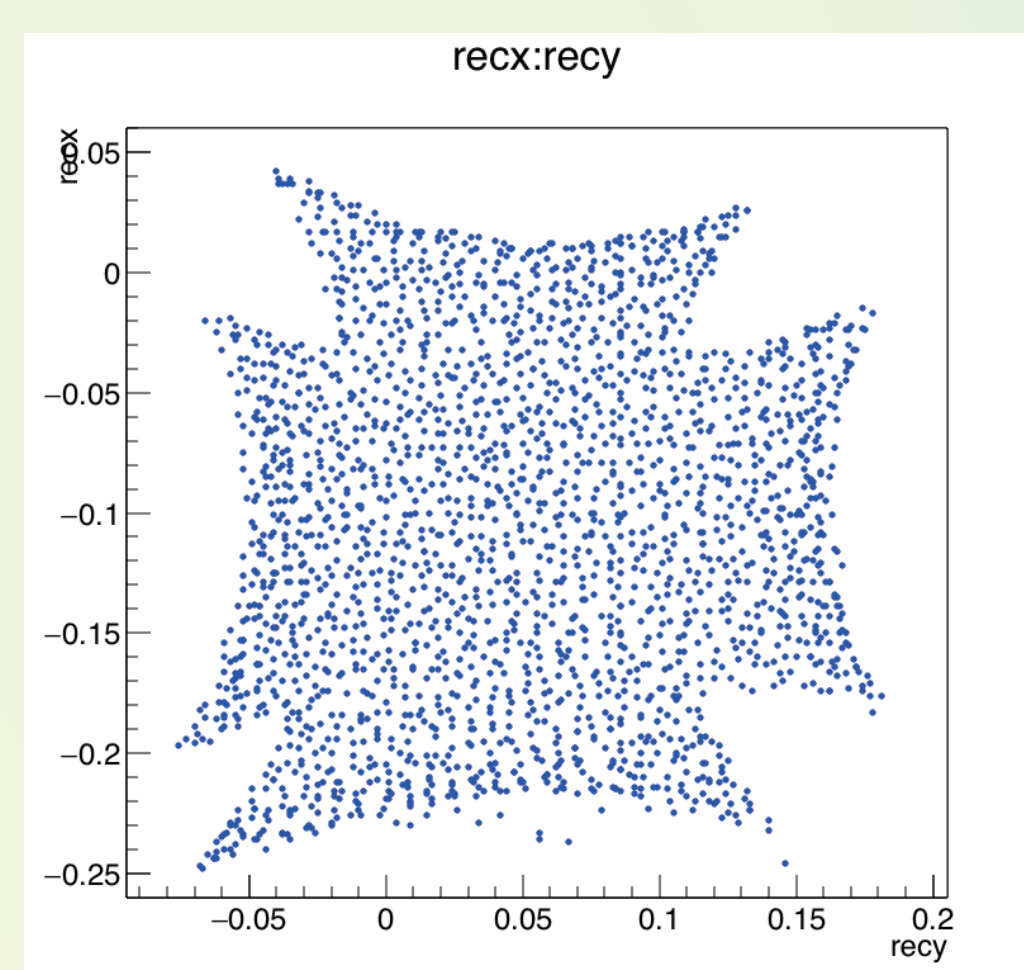
$$Y_{rec} = \frac{(ch6 + ch8) - (ch5 + ch7)}{ch5 + ch6 + ch7 + ch8}$$



Infrared laser system



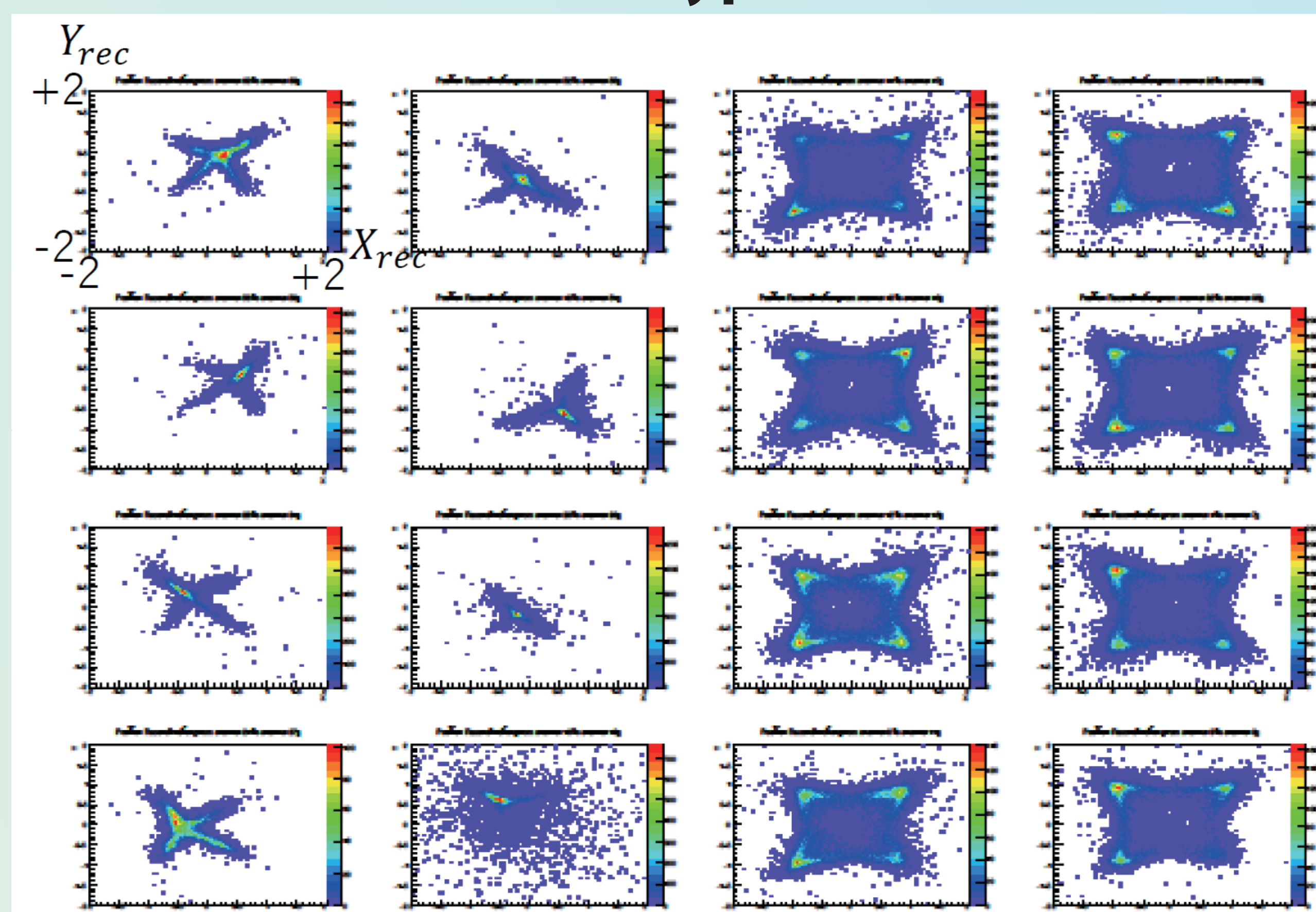
Actual position



Calculated position

Position reconstruction is possible, but some distortion seen. Dynamic range of the calculated position is not enough, suffered from low surface resistance.

Beta (⁹⁰Sr) irradiation (Type B)



Low surface R

High (x10) surface R

Good dynamic range seen with high surface R. (Poor dynamic range with low surface R.) Concentration on corners are due to high trigger threshold on each channel due to electronics problems.

Summary and plans

- ✔ PSDs can be used as a substitute to silicon pads to have better position resolution in inner ECAL layers.
- ✔ Low-resistance edge and high surface resistance can achieve enough dynamic range with radiation.
- ✔ Position resolution is limited by S/N ratio. Avalanche gain can improve it. LGAD-type PSDs will be studied.
- ✔ Trigger with sum of electrodes is desired.