

# Simulation on Pixel Vertex Detector

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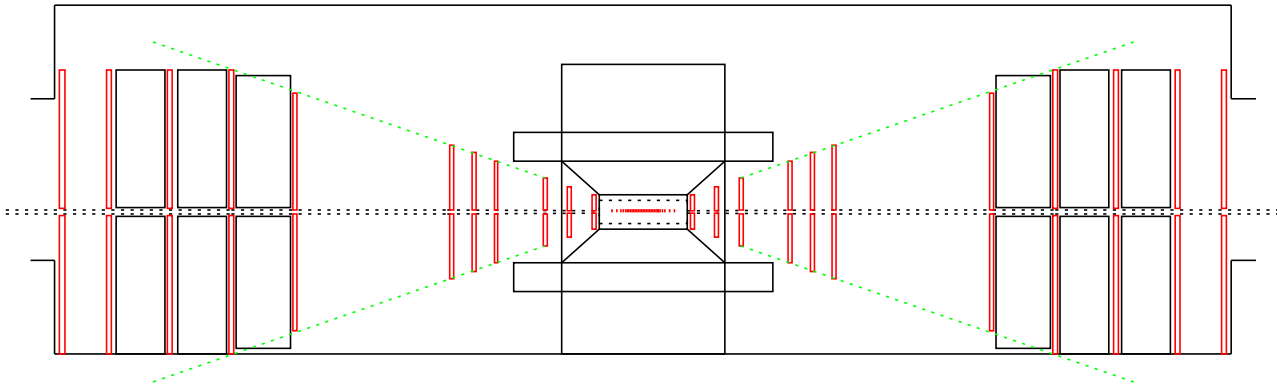
Syracuse University

BTeV meeting, Dec 7, 1997

- Signal simulation
- Impact point reconstruction
- Some interesting results
  - Resolution dependence on threshold
  - Resolution dependence on track angle
  - how bit number affect resolution
  - Pixel size
- Summary

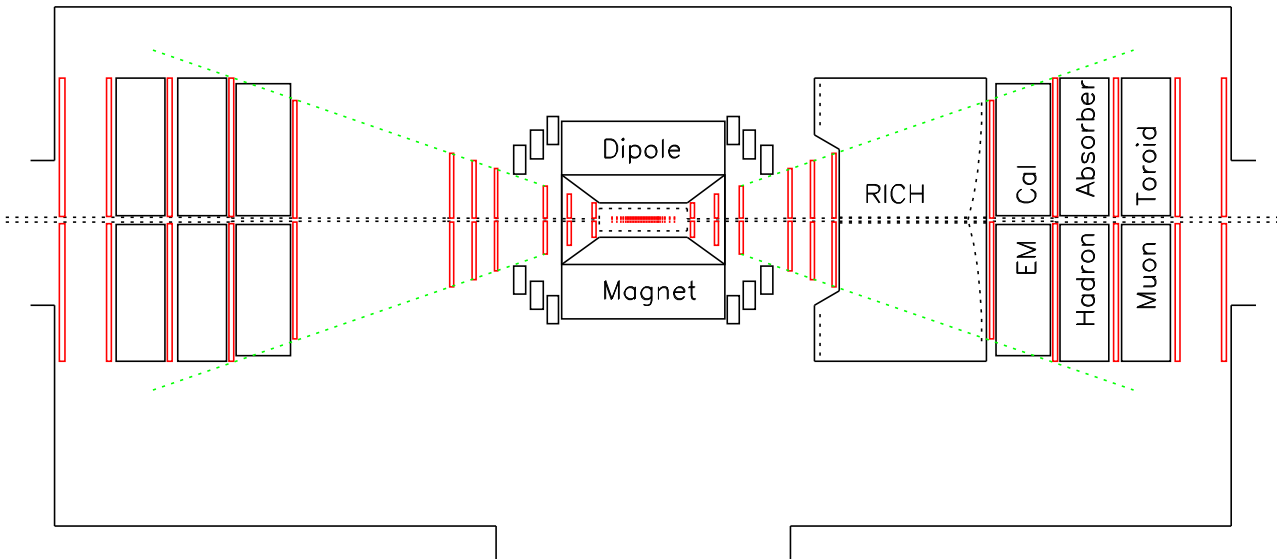
# BTeV/C0 Spectrometer

Elevation View



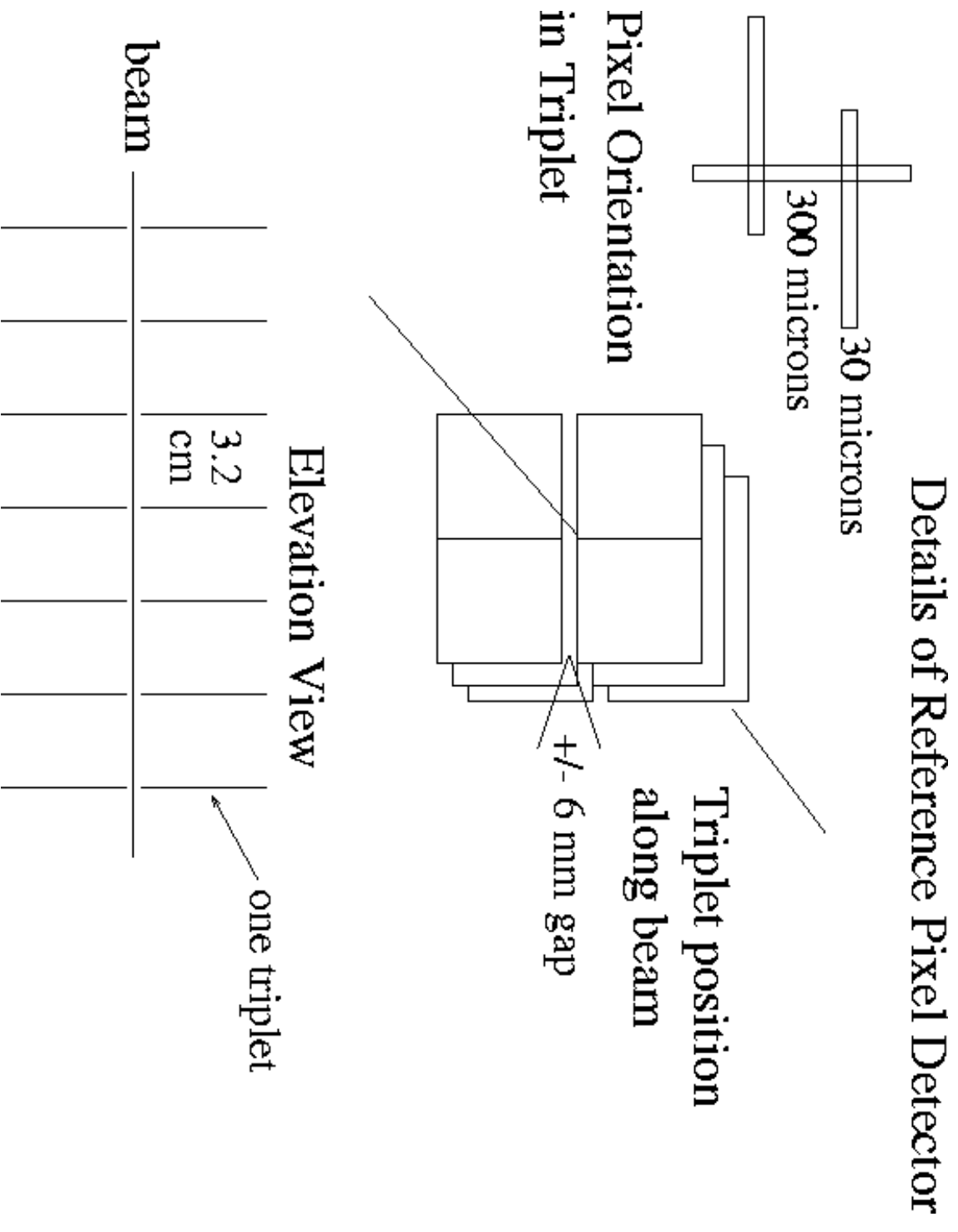
Plan View

0 12 m



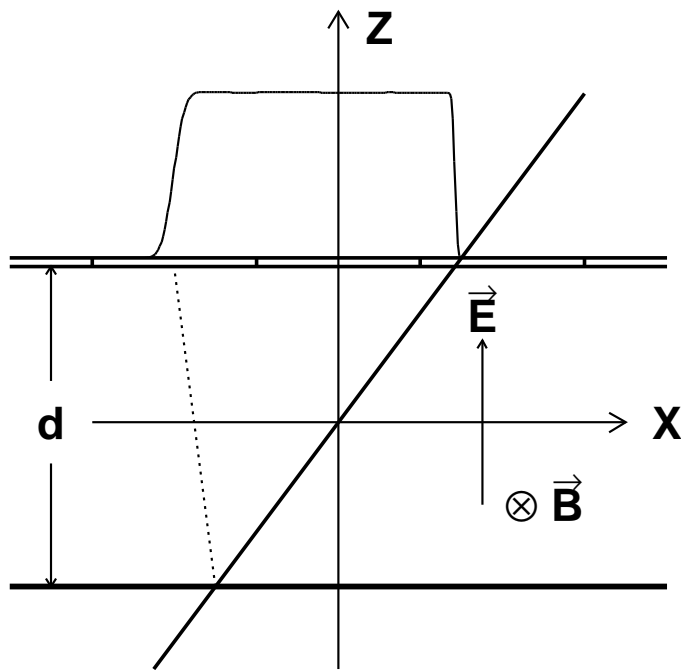
# Pixel Vertex Detector

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# Signal Simulation

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$$d = 300 \mu\text{m}$$

$$U_D = 120 \text{ V}$$

$$(3 \text{ k}\Omega \text{ cm})$$

$$U = 200 \text{ V}$$

$$E_z = \frac{U - U_D}{d} + \frac{2U_D Z}{d^2}$$

$$B_y = 1.6 \text{ Tesla}$$

X – bending direction ♡

Total Charge: Landau distribution

$$Q_{\text{most\_prob}} = 24,000 \text{ e} \quad \text{FWHM} = 8,100 \text{ e}$$

Charge Drifting:  $\vec{v} = \mu \vec{E}$

$$\text{for electron } \mu = 1450 \text{ cm/Vs} \quad t(d) \approx 3.6 \text{ ns}$$

$$\text{for hole } \mu = 400 \text{ cm/Vs} \quad t(d) \approx 13 \text{ ns}$$

Lorentz angle:  $\tan \theta_L = \mu_H H$

$$\text{for electron } \mu_H = 1.15\mu \quad \theta_L \approx 260 \text{ mrad}$$

$$\text{for hole } \mu_H = 0.72\mu \quad \theta_L \approx 50 \text{ mrad}$$

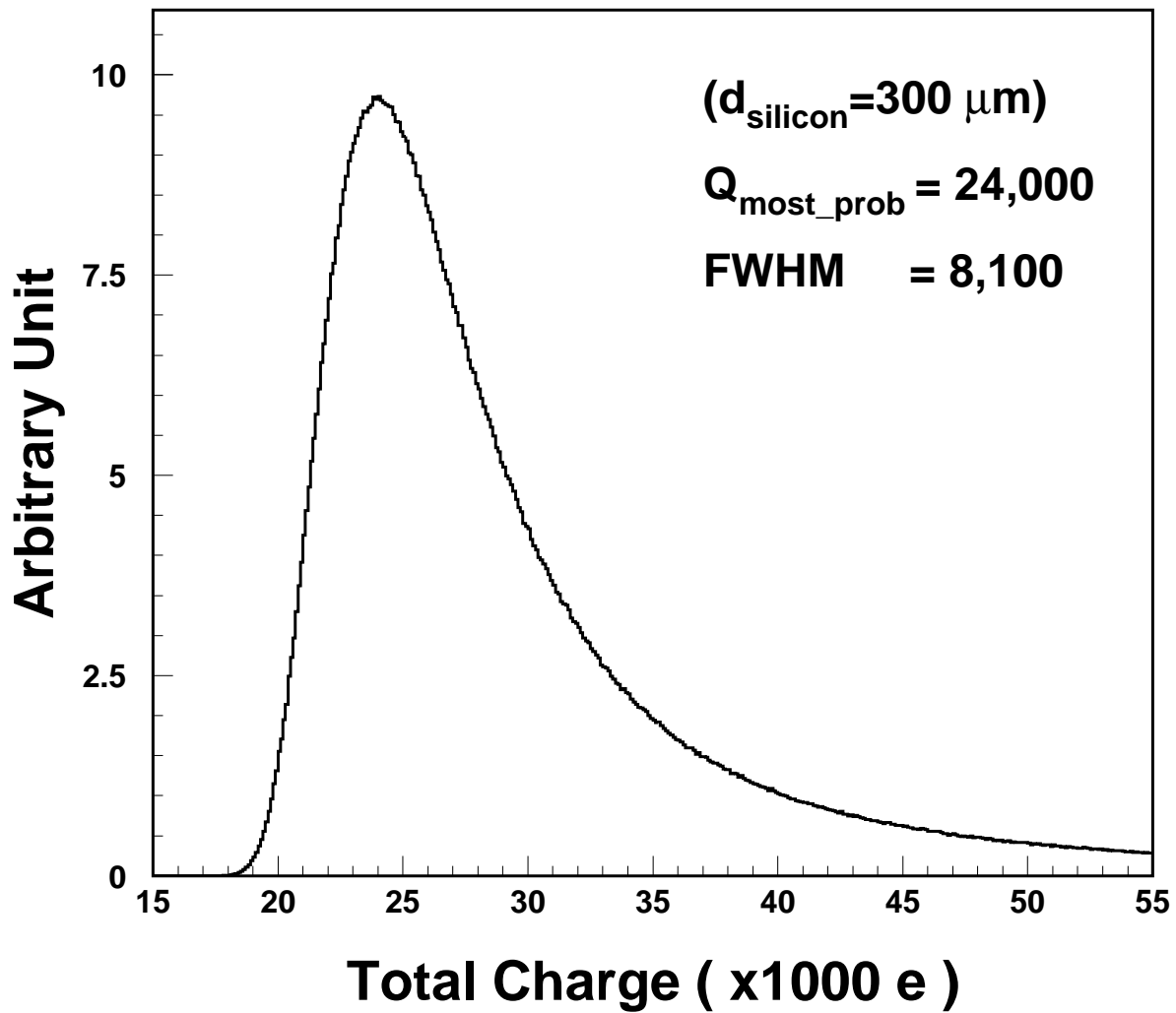
Diffusion:

$$\text{for electron } D = 35 \text{ cm}^2/\text{s}$$

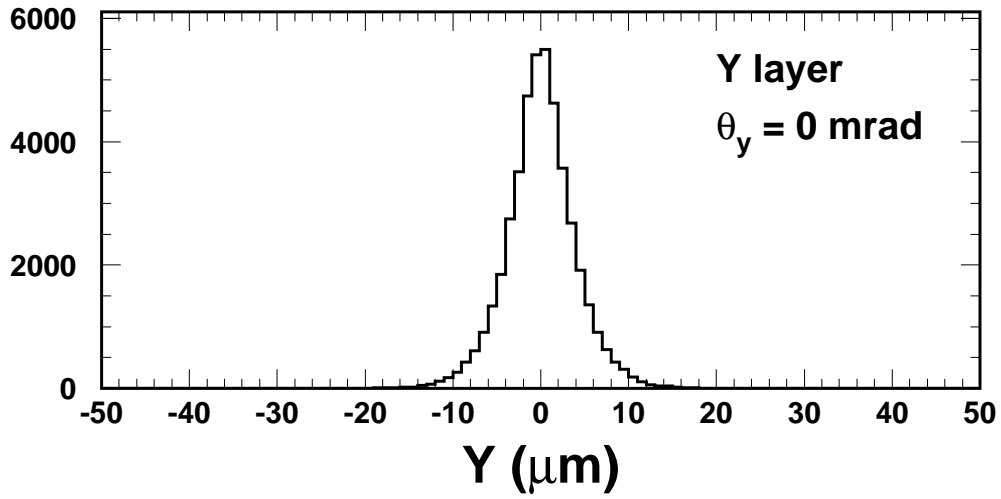
$$\text{for hole } D = 12 \text{ cm}^2/\text{s}$$


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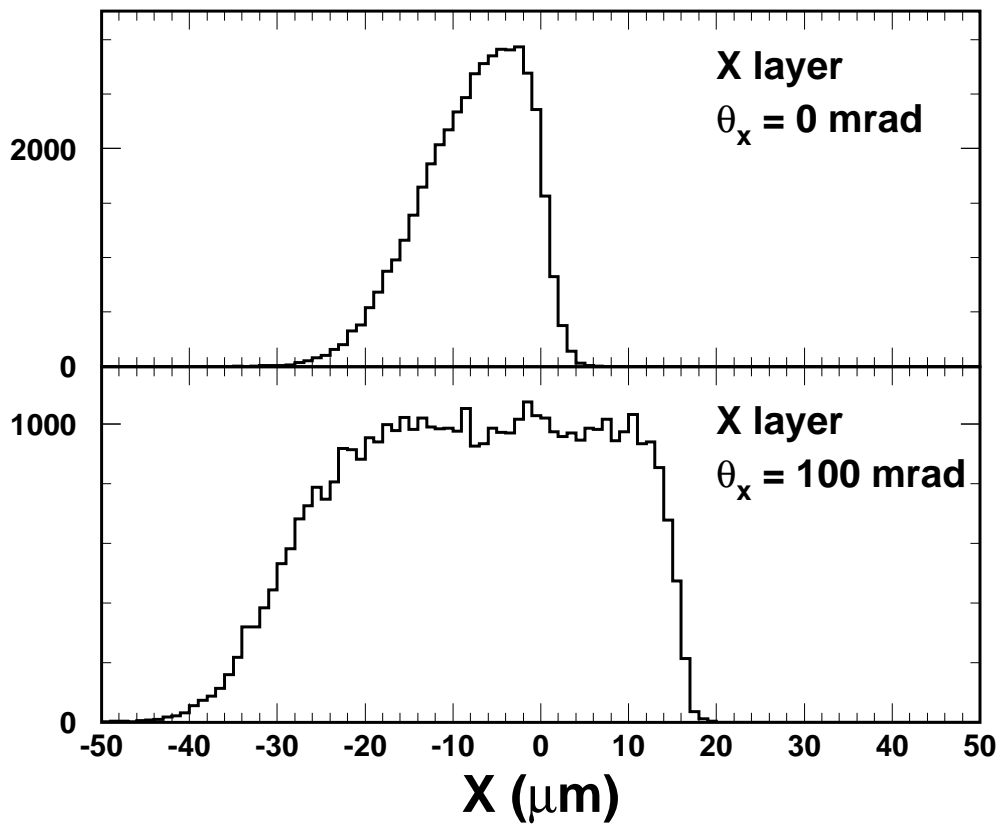
# Landau Distribution



# Charge Distribution



Charge /  $\mu\text{m}$



# Signal Simulation

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- Noise simulation:  $\sigma = 150 e$

- Gain uncertainty:  $\pm 20\%$

use uniform distribution between 0.8 and 1.2  
 $\pm 20\%$  might be too conservative

- ADC:

$$\text{ADC}_i = \frac{Q_i - Q_{\text{threshold}}}{Q_{\text{step}}}$$

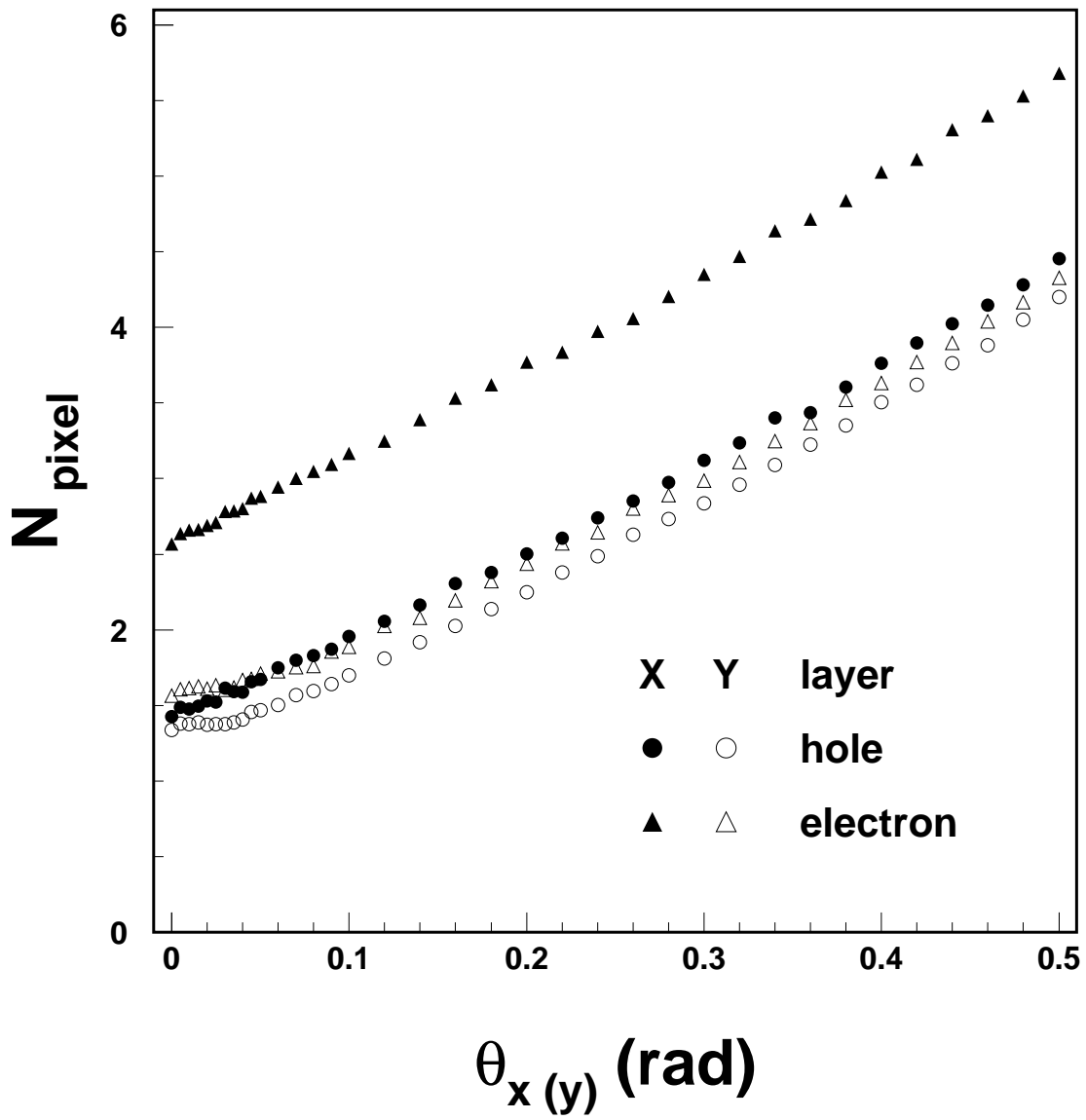
$$Q_{\text{threshold}} = 1000 e$$

$Q_{\text{step}} =$	3,200 e	4-bit
	1,600 e	5-bit
	800 e	6-bit

Covers up to  $2 Q_{\text{most\_prob}}$

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<b>Pixel size</b>	<b>50 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>



# Reconstruction Method

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- Digital Reconstruction:
  - No Pulse Height read out
  - form cluster

$$X_{\text{dig}} = \frac{\sum_i X_i}{\sum_i 1}$$

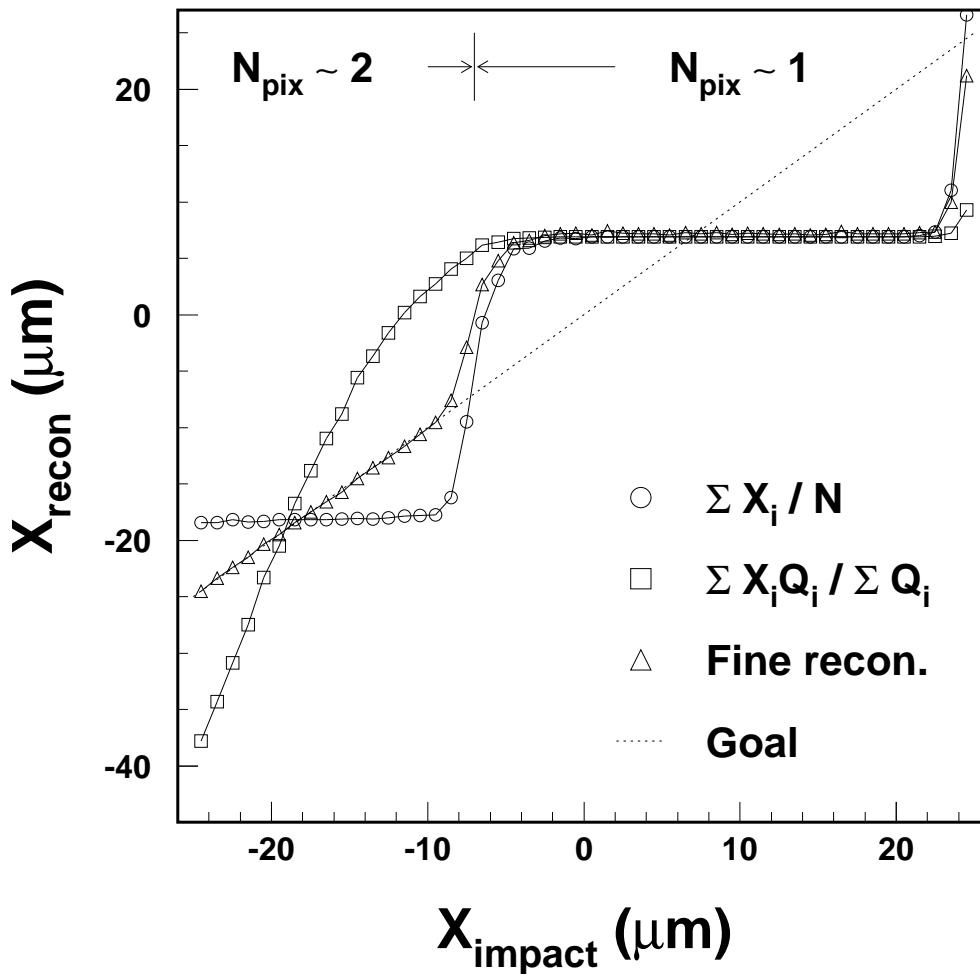
- Simple Analog Reconstruction: Pulse Height read out

$$X_{\text{sim}} = \frac{\sum_i X_i Q_i}{\sum_i Q_i}$$

- Refined Analog Reconstruction:
  - Track angle reconstructed from above
  - Angular-dependent correction to  $X_{\text{sim}}$

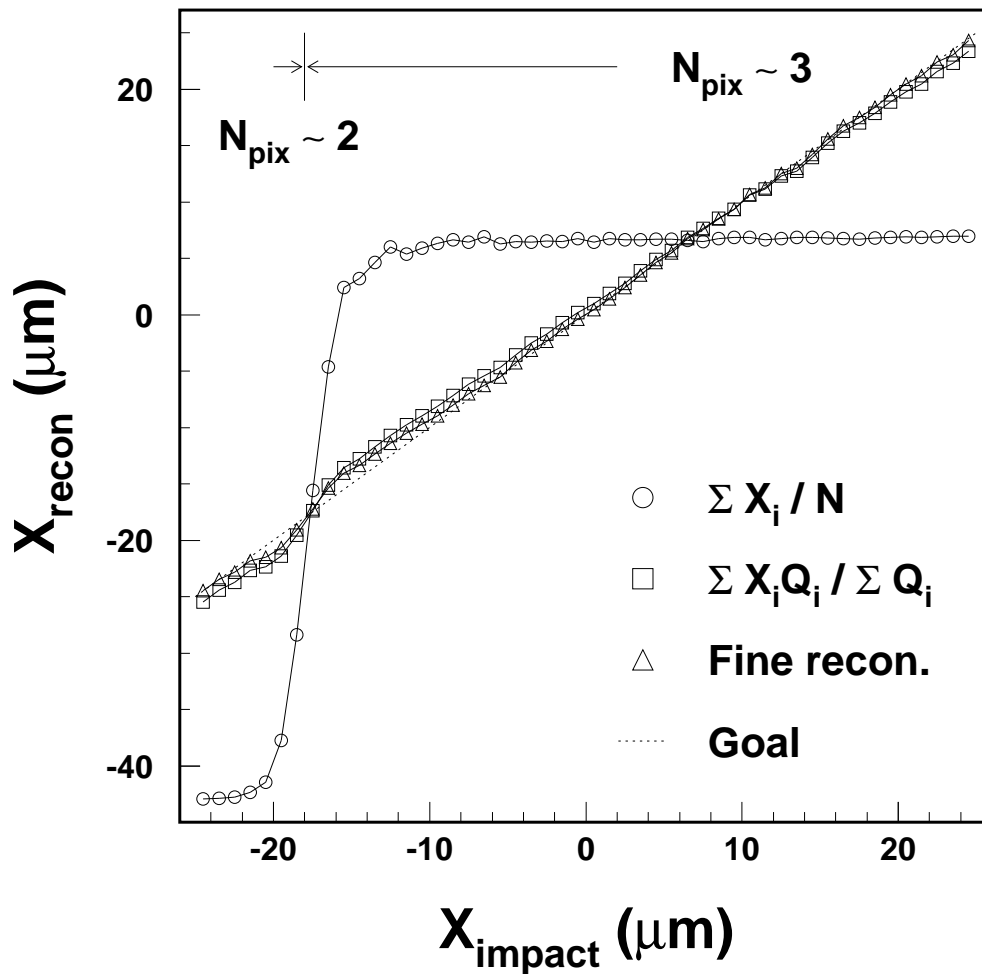
# Reconstruction Method

Pixel size	50 X 300 $\mu\text{m}^2$
$\theta_x$	0 rad
Threshold	1000 e
Noise	150 e
Gain uncert	$\pm 20\%$
ADC	6-bit

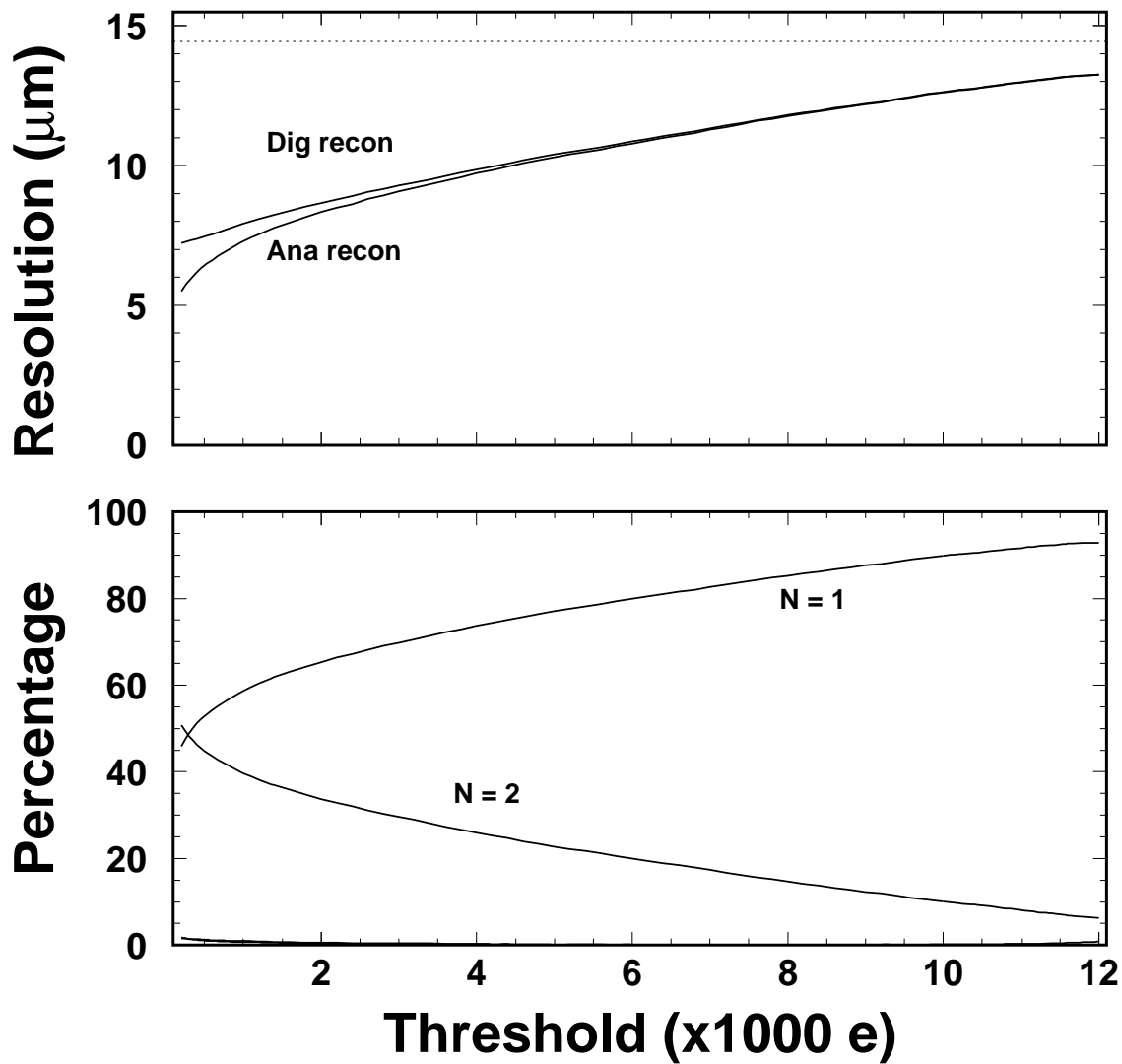


# Reconstruction Method

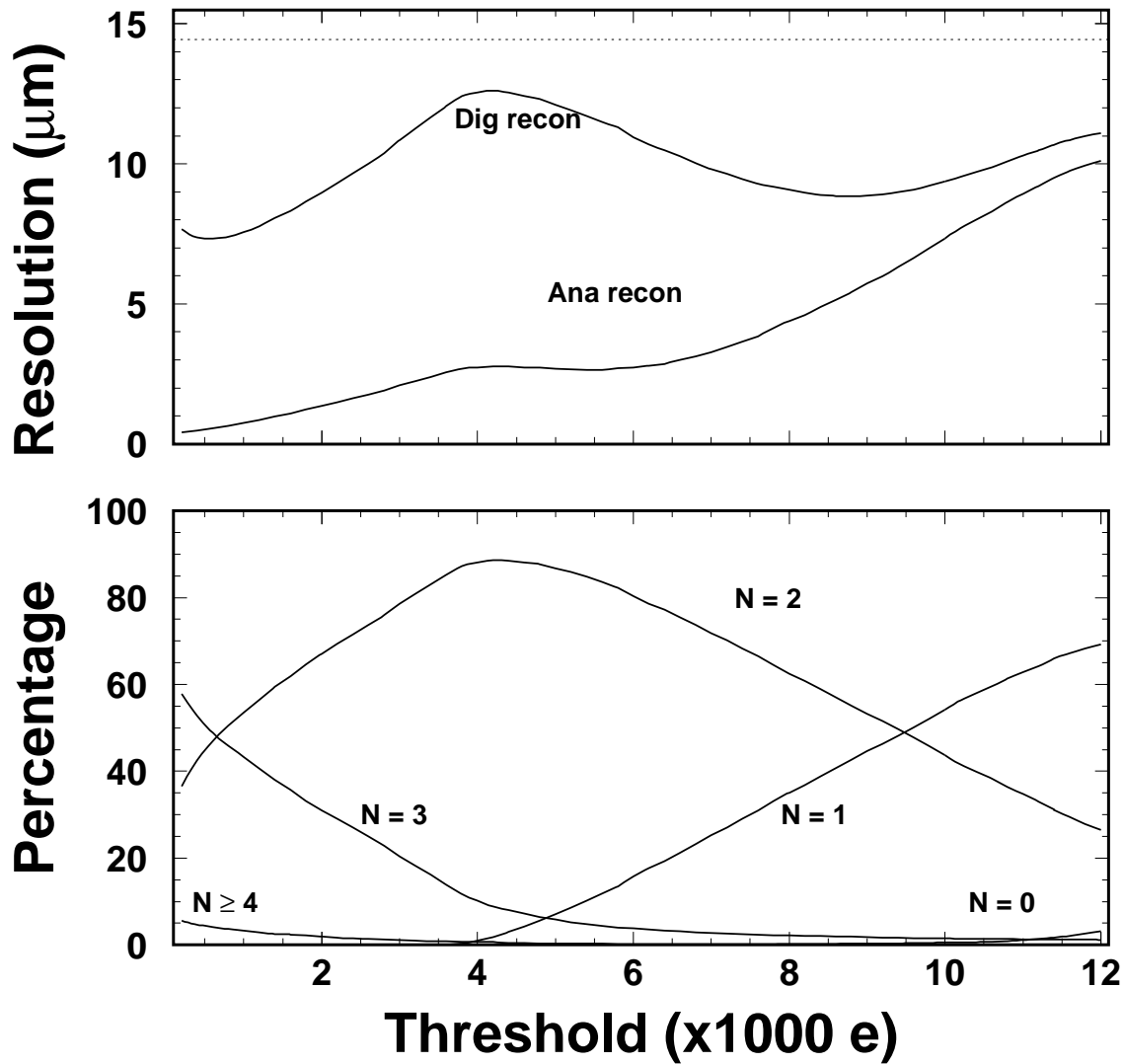
Pixel size	50 X 300 $\mu\text{m}^2$
$\theta_x$	300 mrad
Threshold	1000 e
Noise	150 e
Gain uncert	$\pm 20\%$
ADC	6-bit



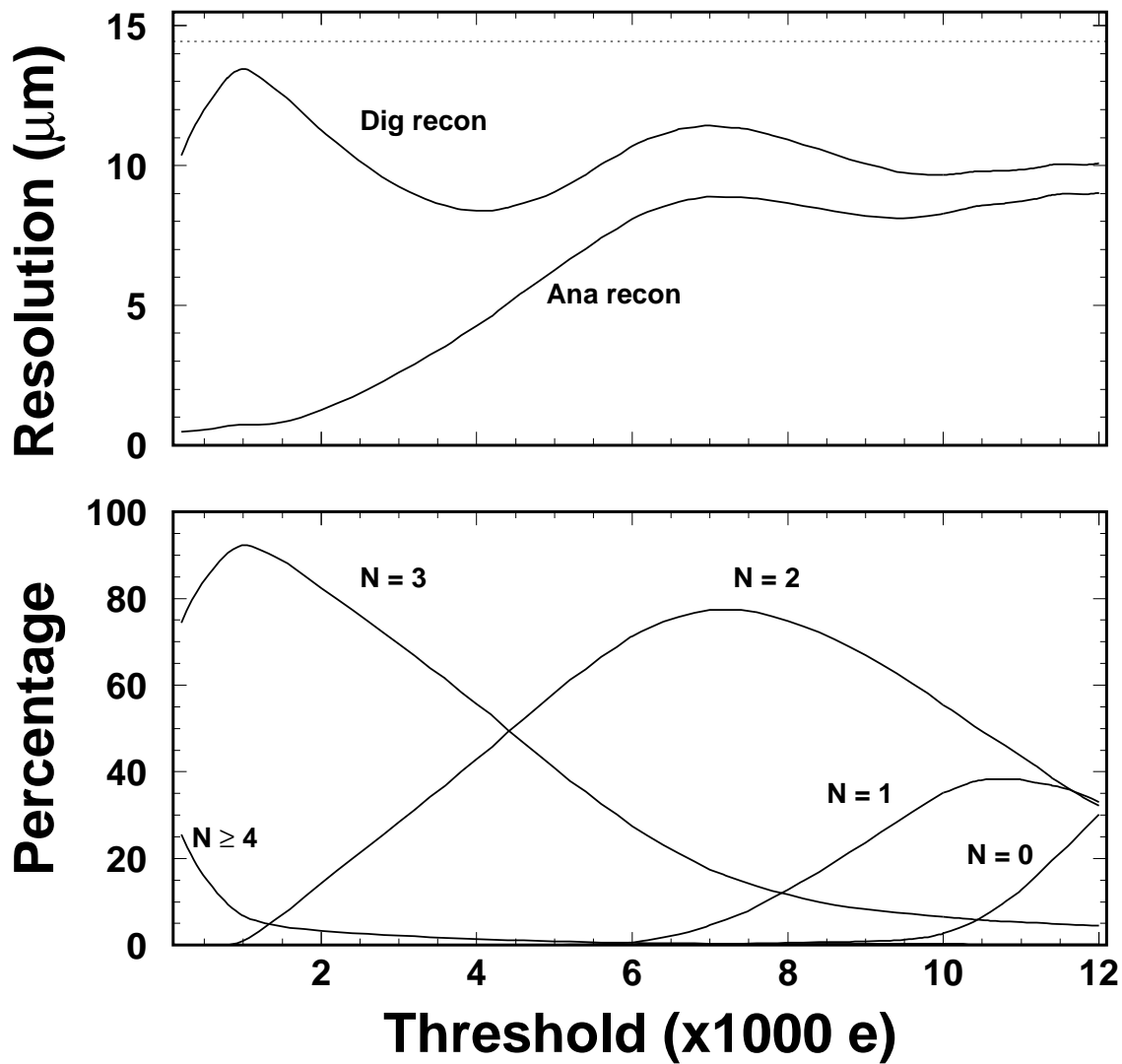
**50 x 300  $\mu\text{m}^2$  Pixel**  
**Normal incident Track**  
**No noise, perfect gain**



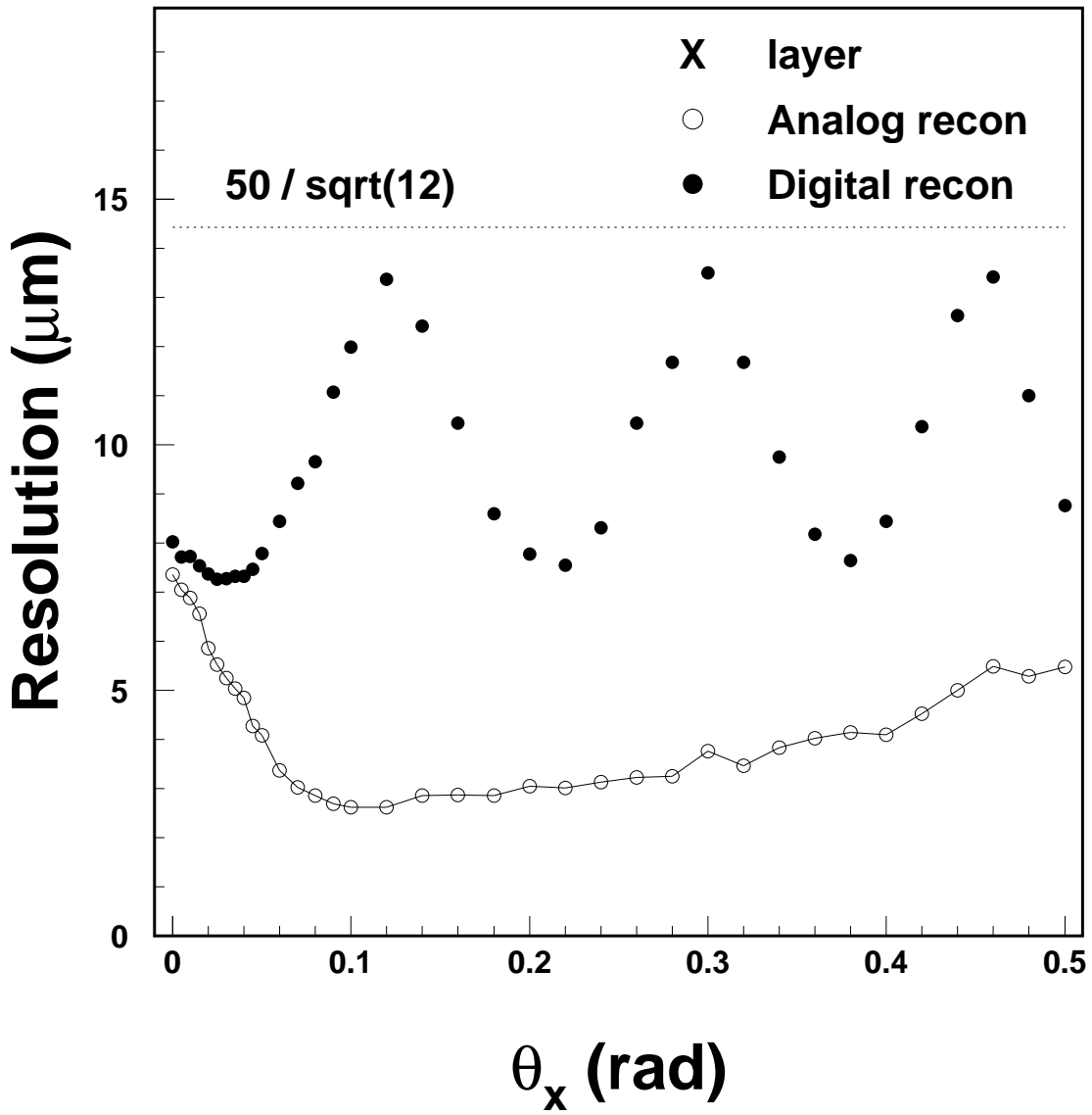
**50 x 300  $\mu\text{m}^2$  Pixel**  
 **$\theta_x = 200$  mrad Track**  
**No noise, perfect gain**



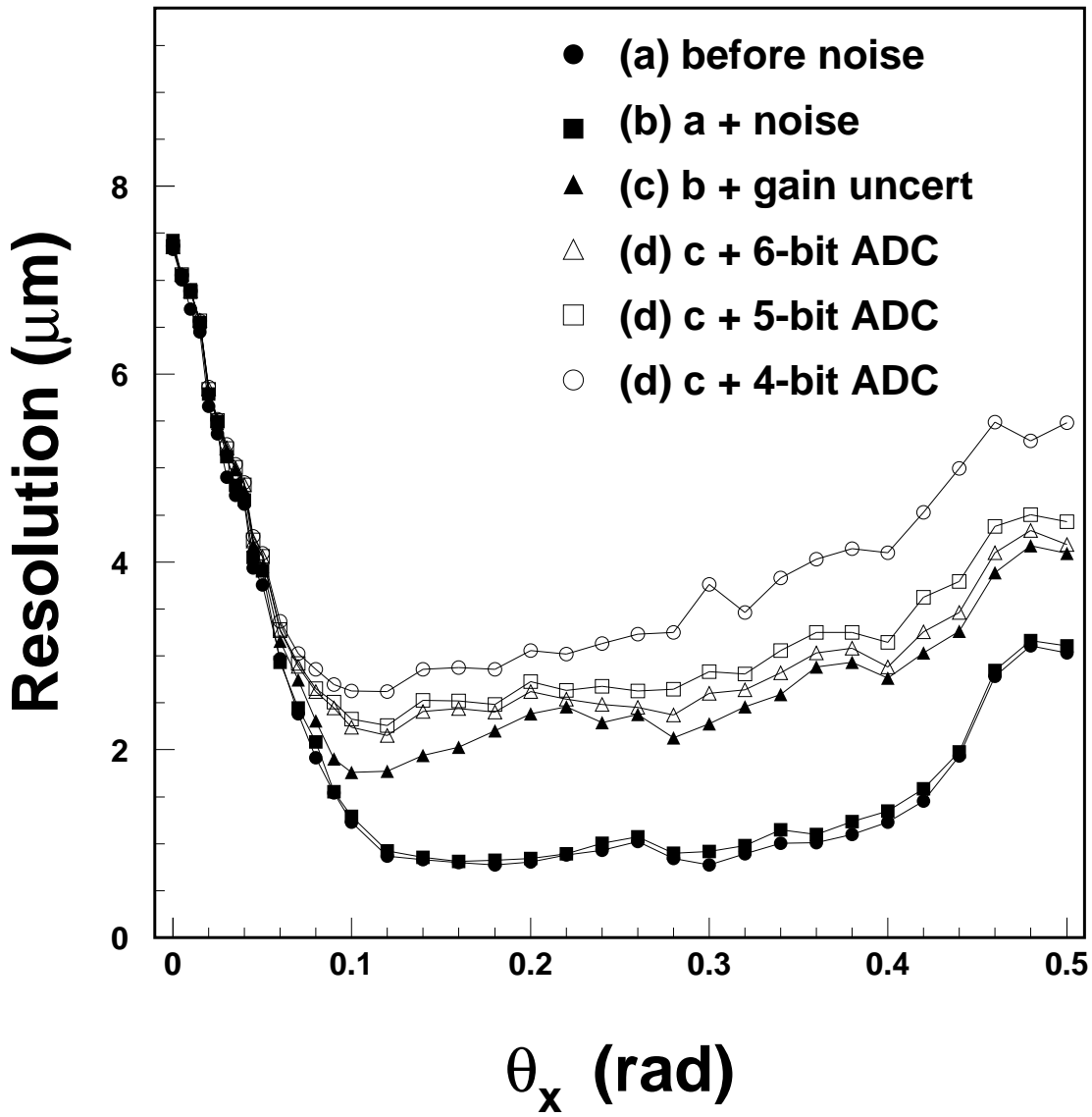
**50 x 300  $\mu\text{m}^2$  Pixel**  
 **$\theta_x = 300$  mrad Track**  
**No noise, perfect gain**



<b>Pixel size</b>	<b>50 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>hole</b>

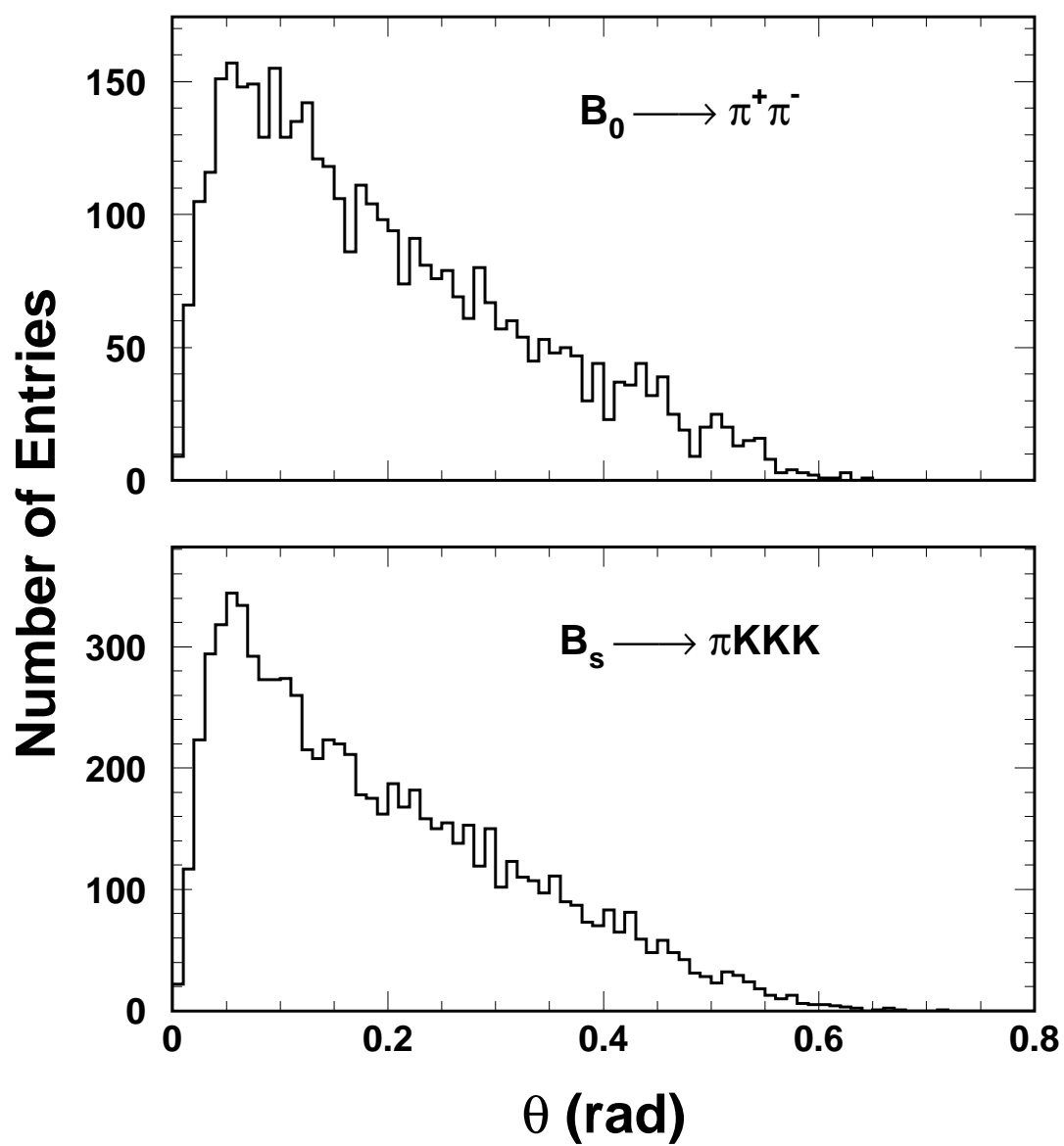


<b>Pixel size</b>	<b>50 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>hole</b>



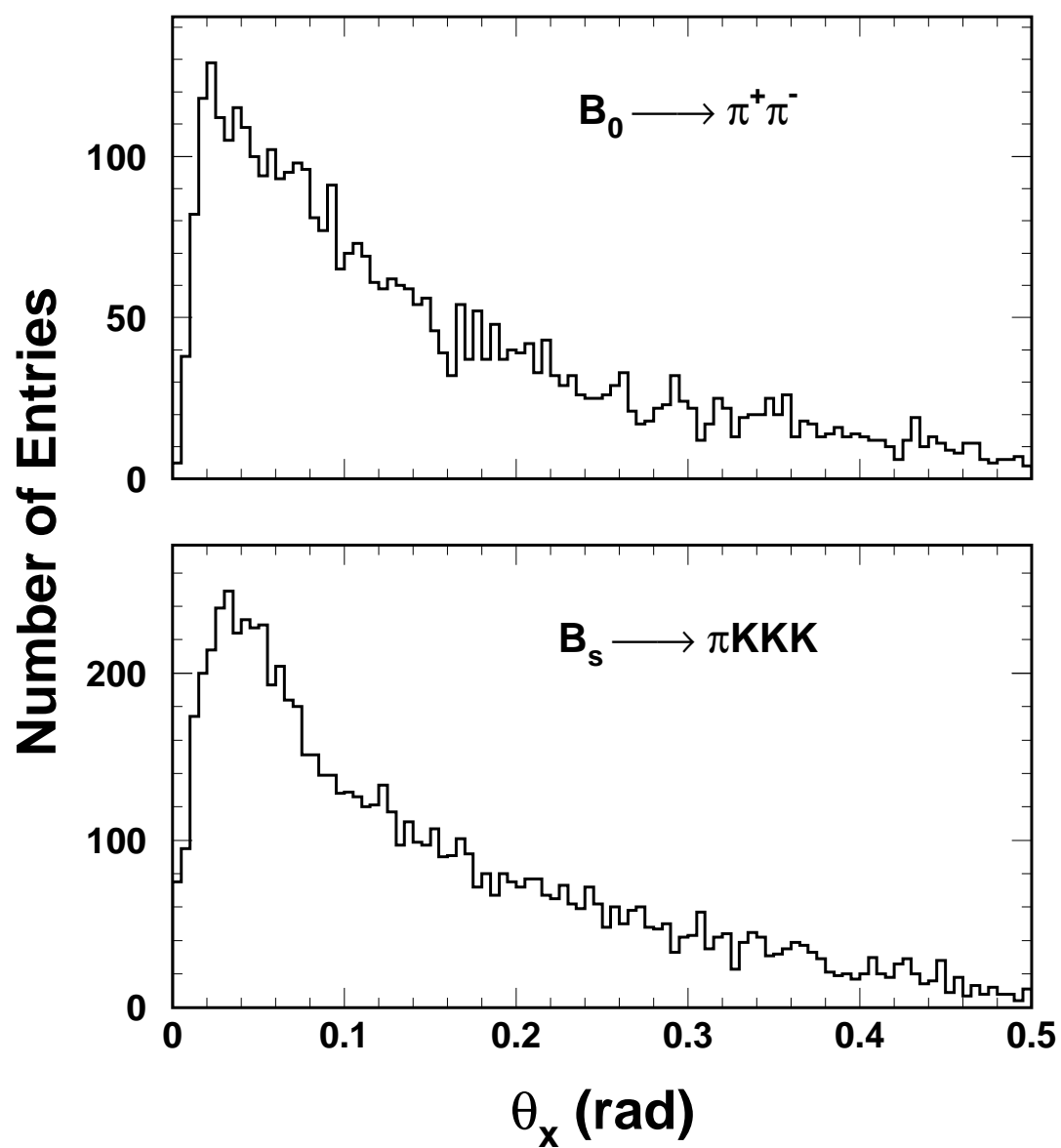
# Track angle Distribution

$N_{\text{hits}} \geq 9$



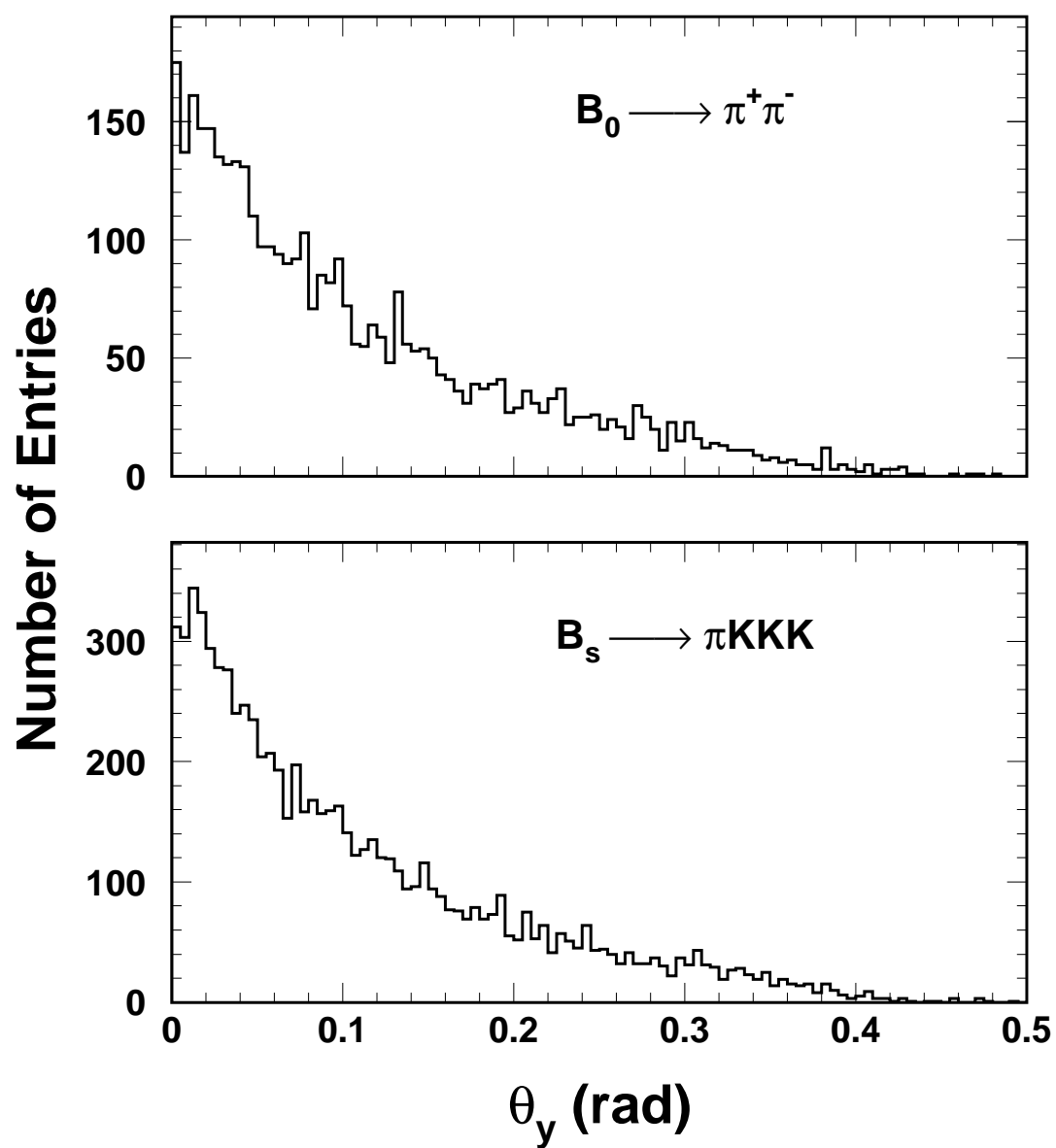
# Track angle Distribution

$N_{\text{hits}} \geq 9$

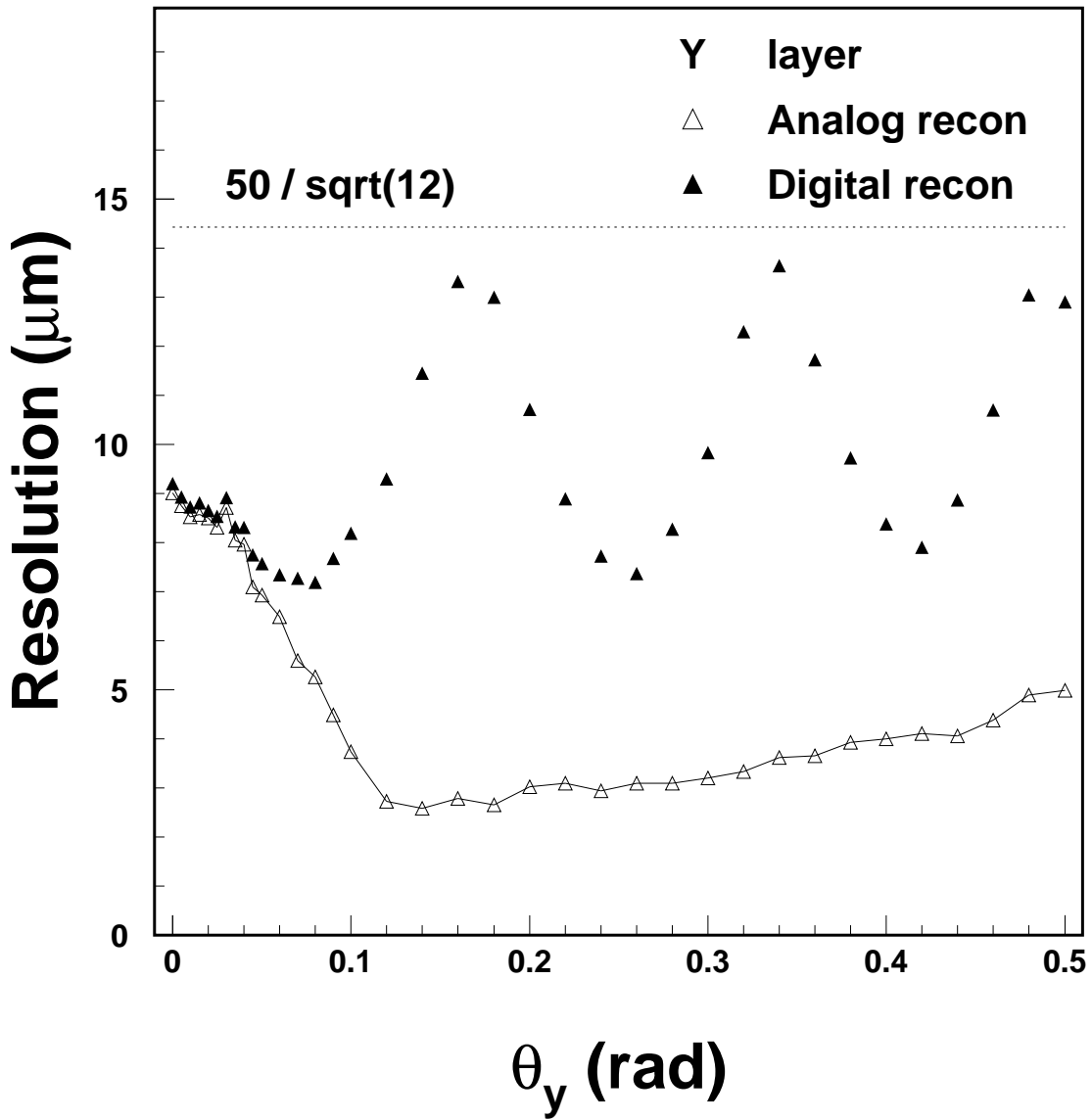


# Track angle Distribution

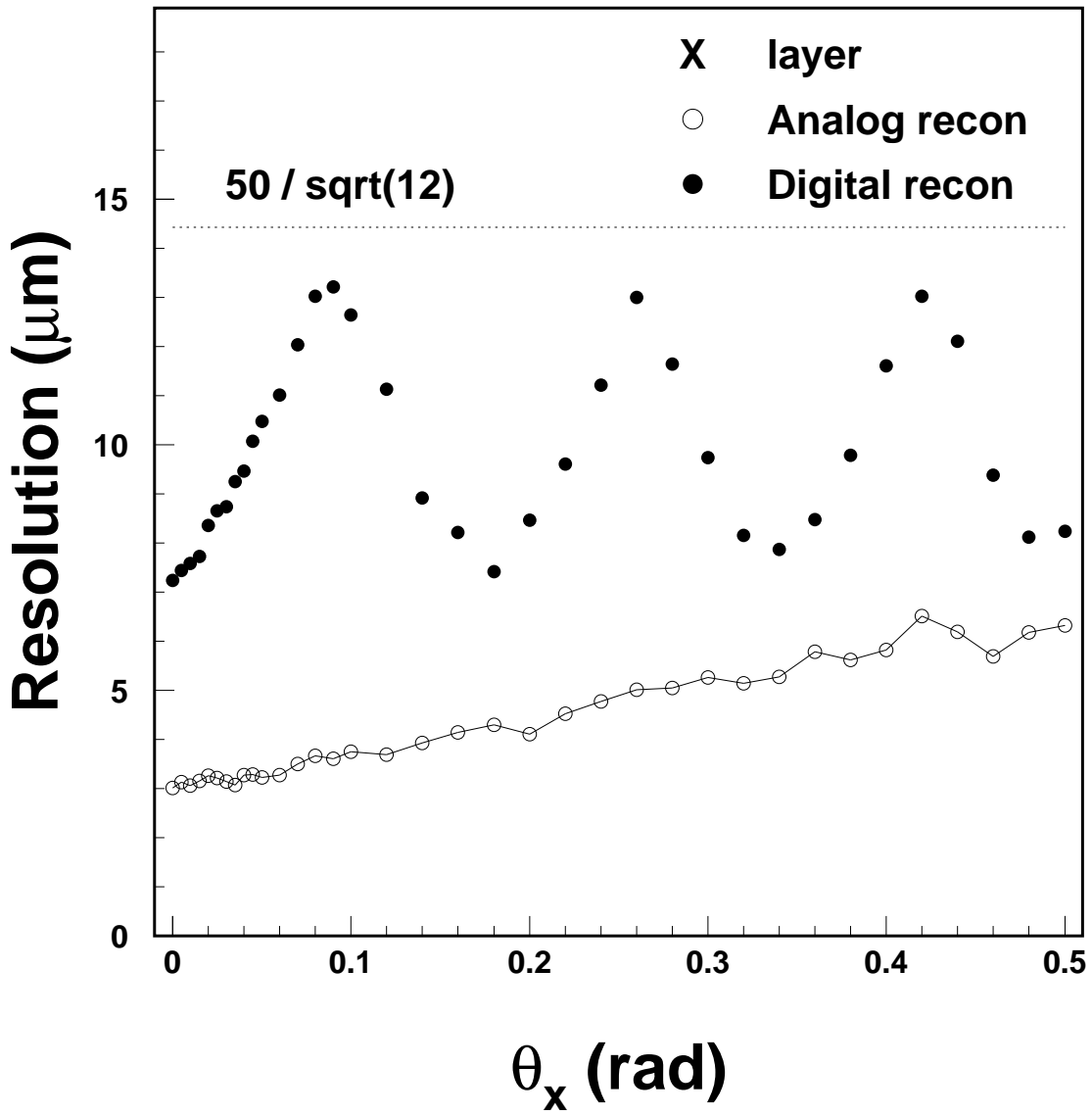
$N_{\text{hits}} \geq 9$



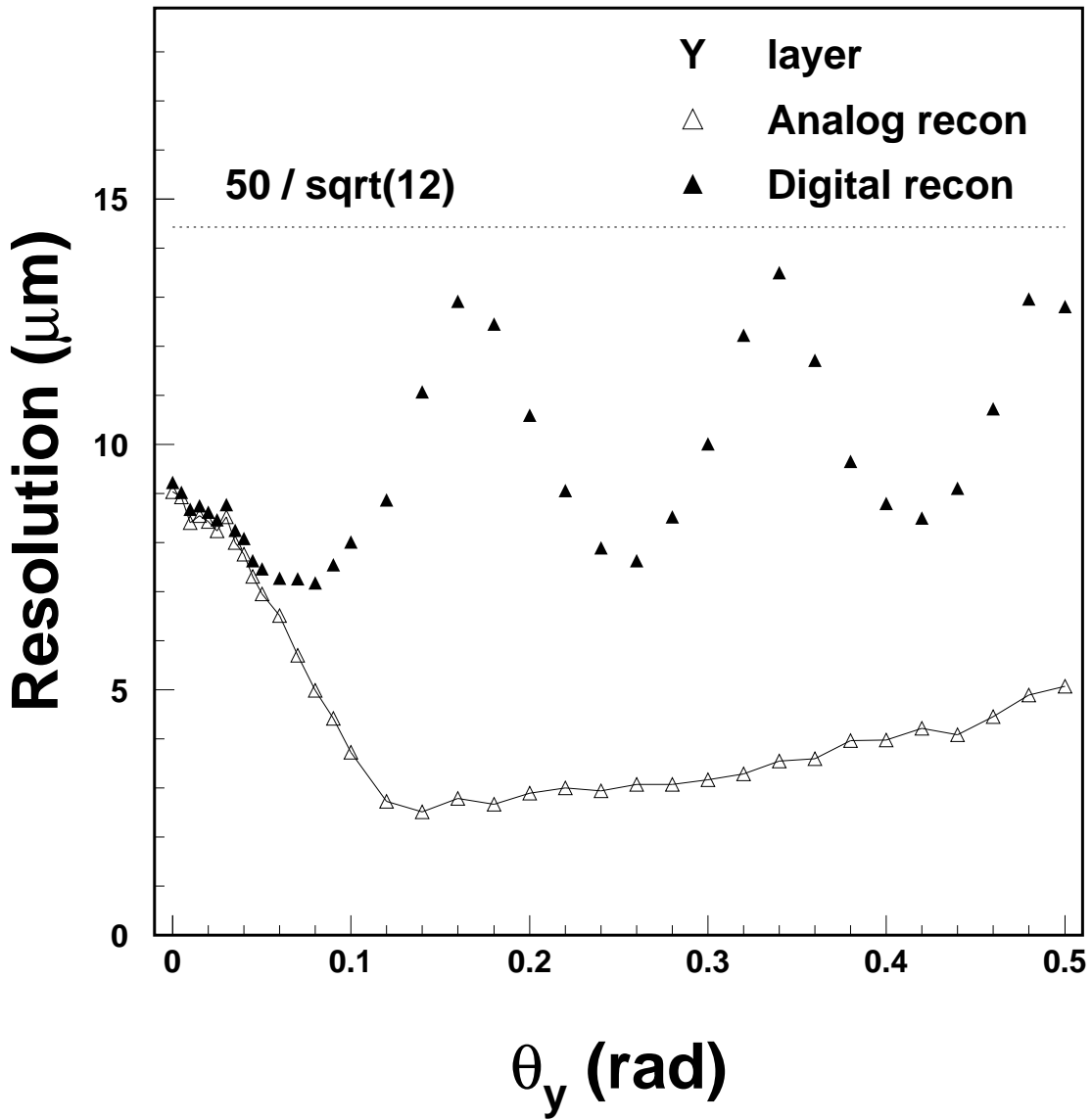
<b>Pixel size</b>	<b>50 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>hole</b>



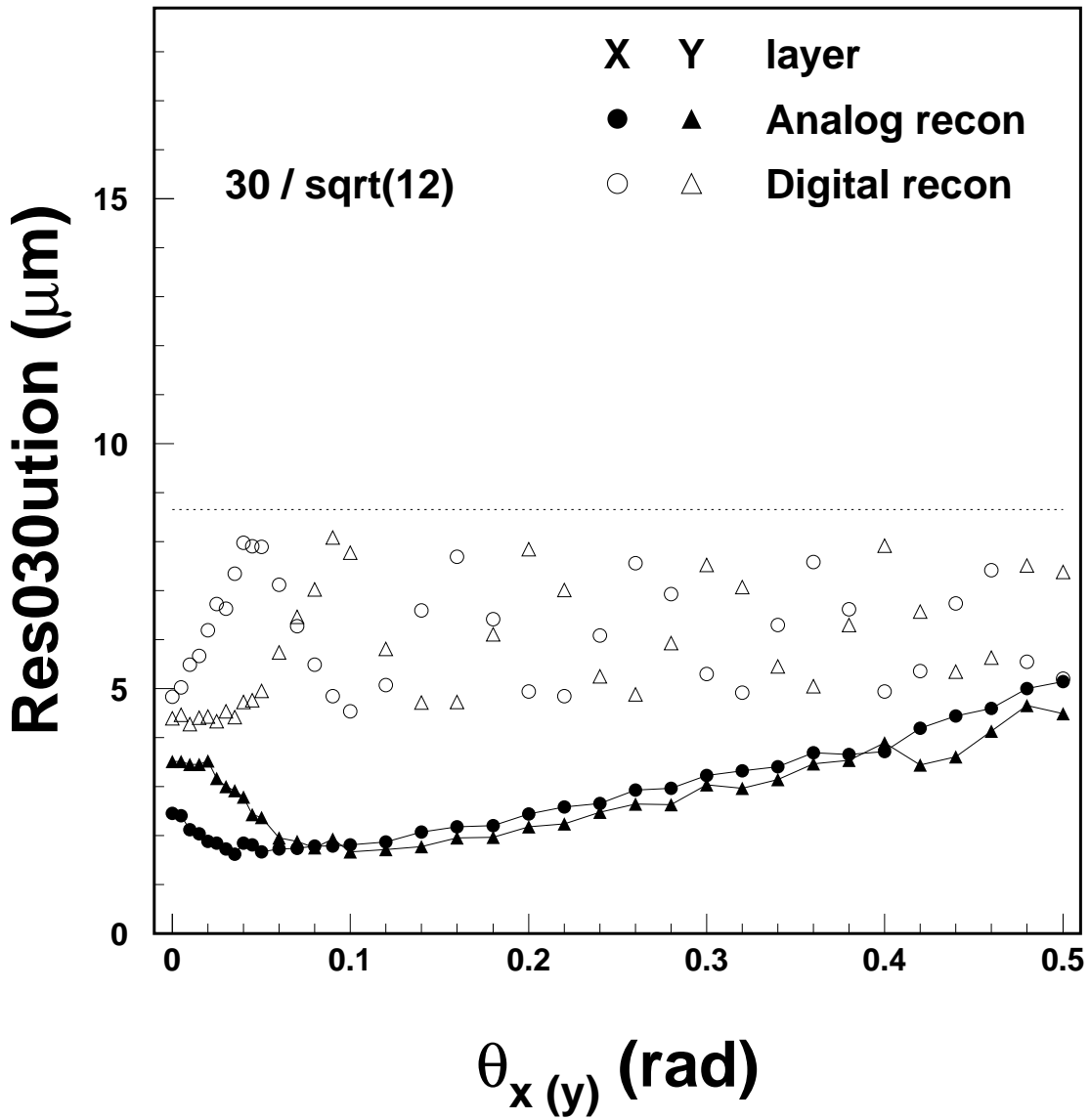
<b>Pixel size</b>	<b>50 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>electron</b>



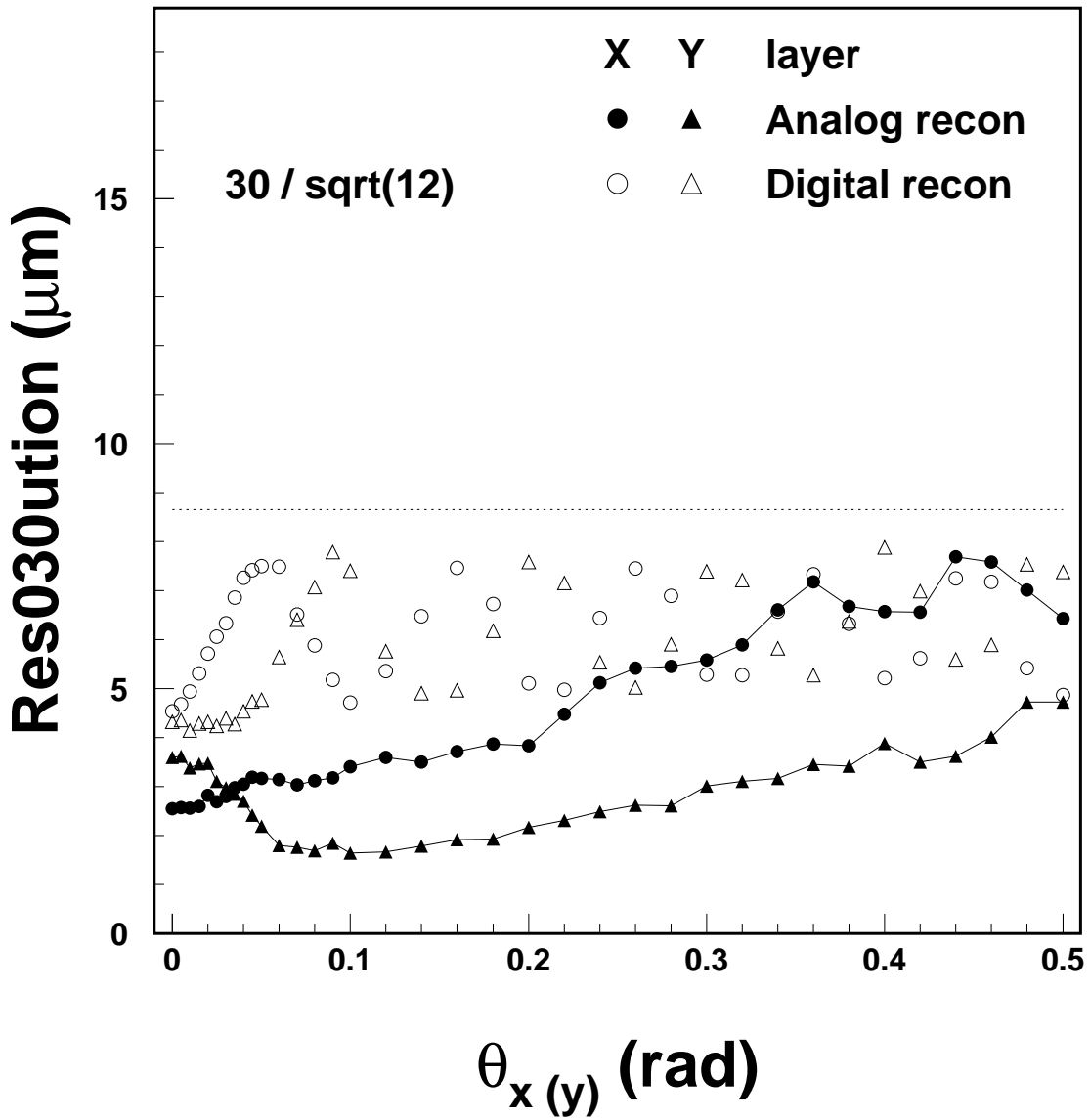
<b>Pixel size</b>	<b>50 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>electron</b>



<b>Pixel size</b>	<b>30 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>hole</b>



<b>Pixel size</b>	<b>30 x 300 <math>\mu\text{m}^2</math></b>
<b>Threshold</b>	<b>1000 e</b>
<b>Noise</b>	<b>150 e</b>
<b>Gain uncertainty</b>	<b><math>\pm 20\%</math></b>
<b>ADC</b>	<b>4-bit</b>
<b>Charge carrier</b>	<b>electron</b>



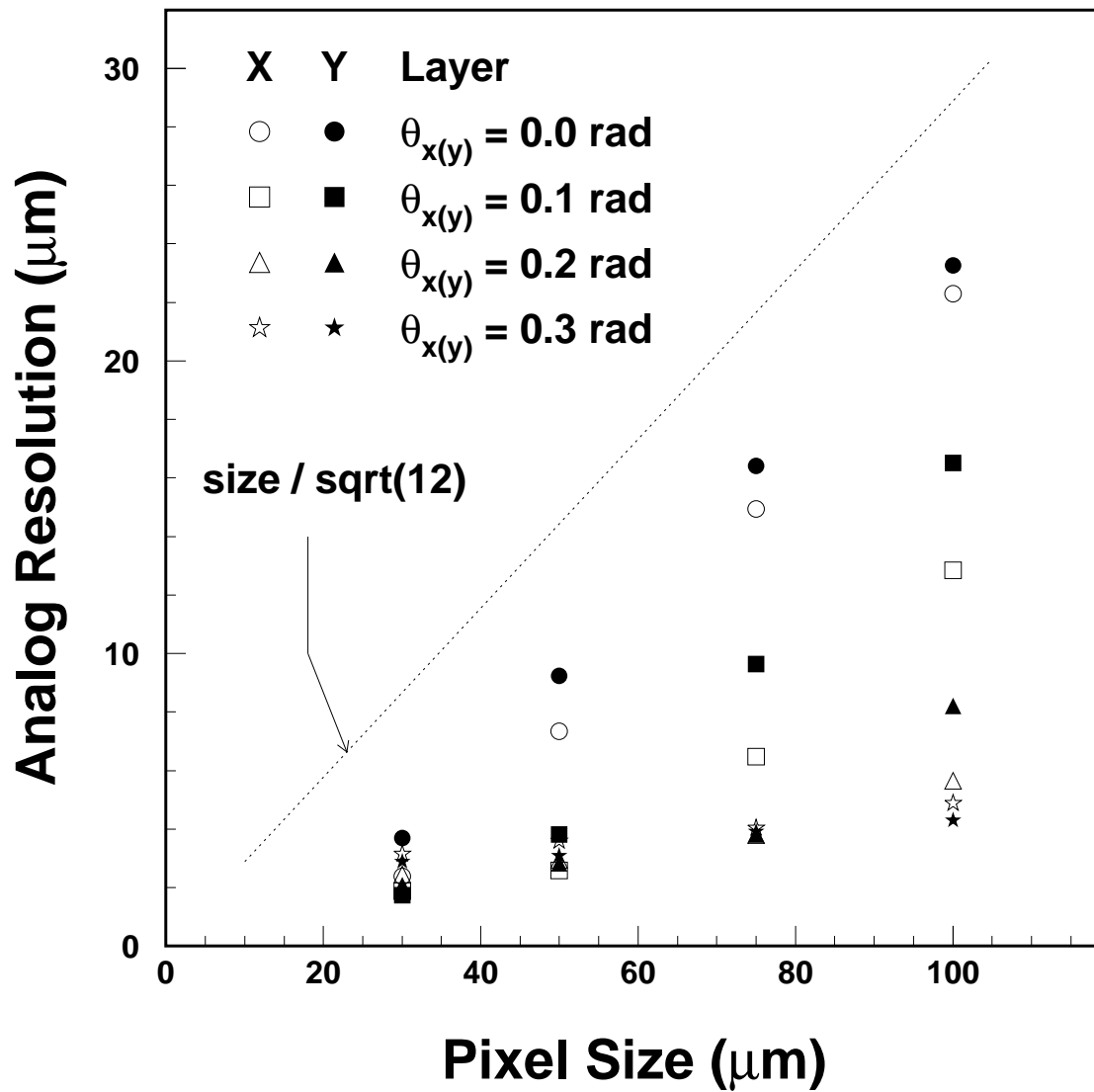
# Position Resolution

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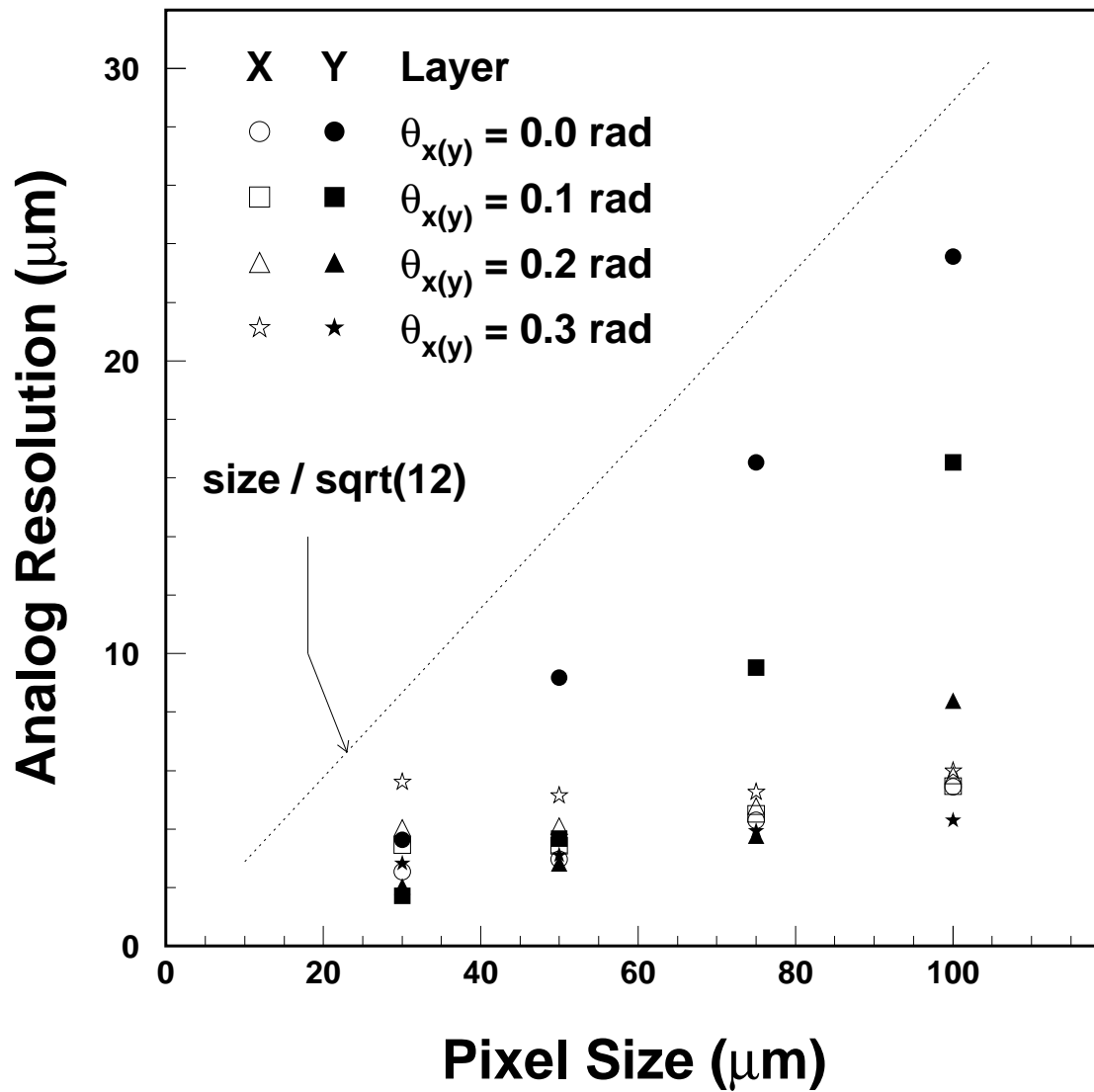
$\theta_{x,y}$ mrad	$30 \times 300 \mu m^2$				$50 \times 300 \mu m^2$				
	hole		electron		hole		electron		
	x	y	x	y	x	y	x	y	$y^*$
0	2.5	3.5	2.5	3.6	7.4	9.0	3.0	9.0	3.7
50	1.8	2.4	3.2	2.2	4.1	6.9	3.2	7.0	2.7
100	1.8	1.8	3.4	1.6	2.6	3.7	3.8	3.7	2.9
200	2.4	2.2	3.8	2.2	3.1	3.0	4.1	2.9	3.2
300	3.2	3.0	5.6	3.0	3.8	3.2	5.3	3.2	4.0

- $y^*$  is with Y-layer tilted 100 mrad
  - alignment error not considered
  - EOI baseline 5 – 9  $\mu m$
-

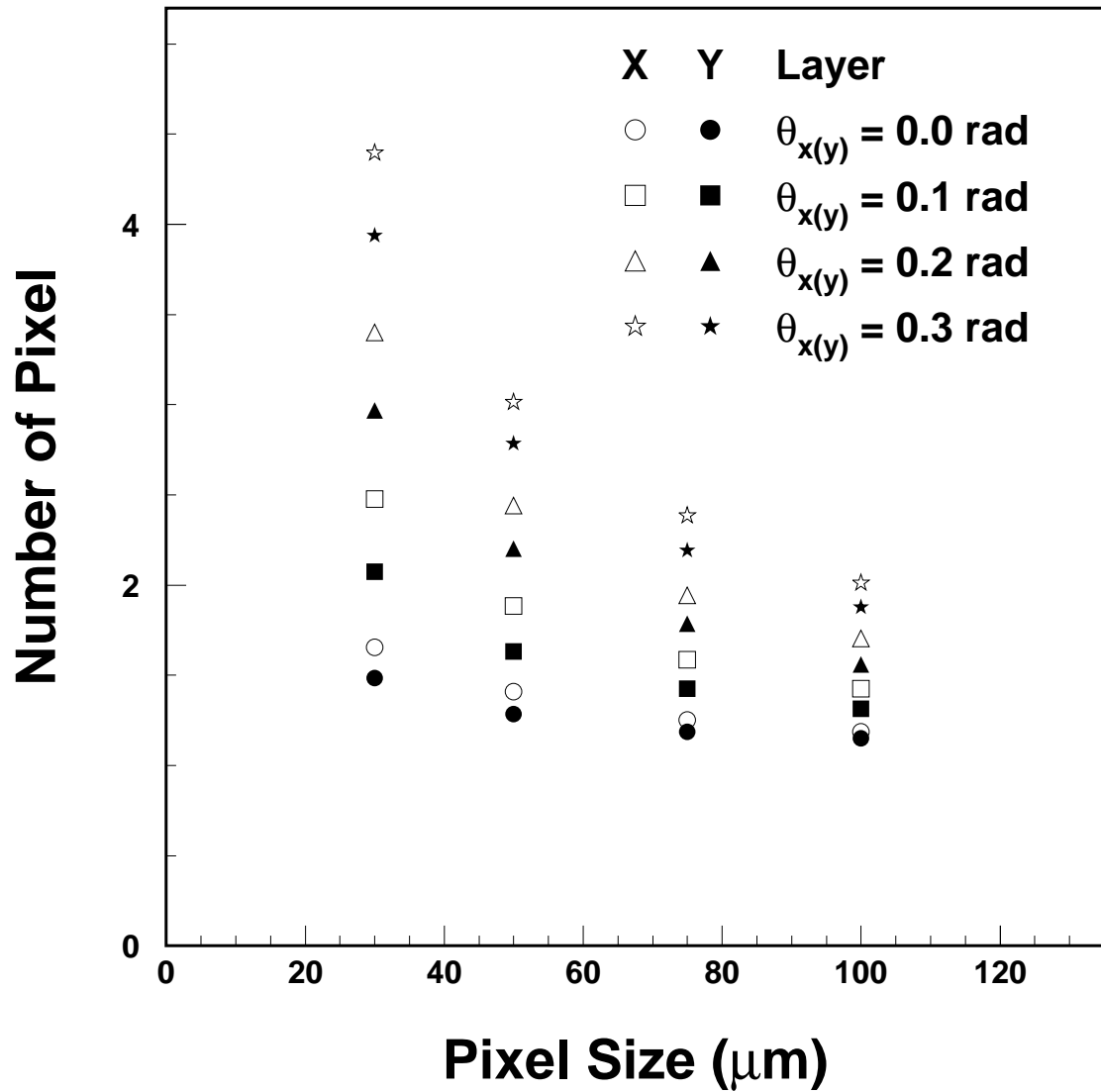
# Hole as Charge carrier



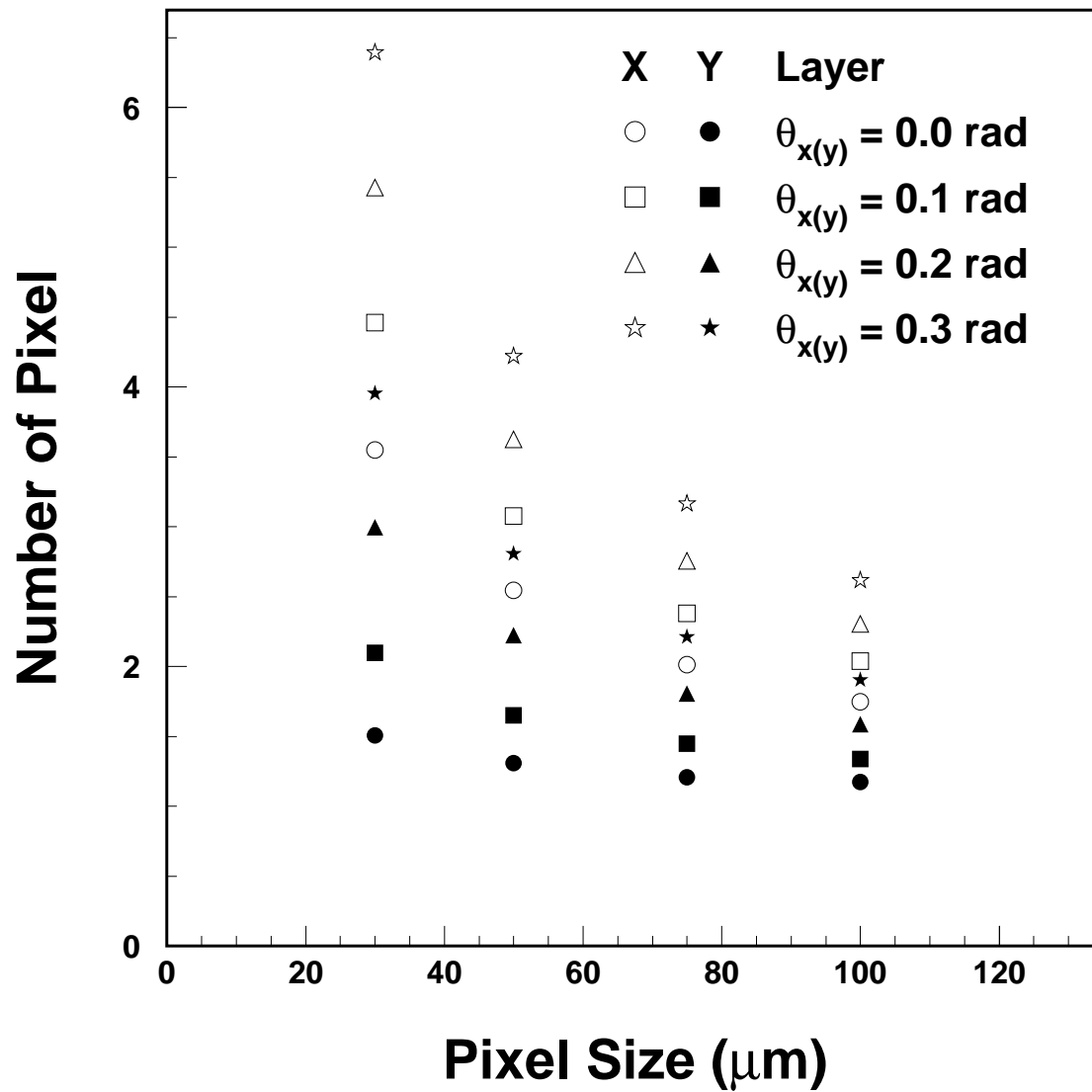
# Electron as Charge carrier



# Hole as Charge carrier



# Electron as Charge carrier



# Summary

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- Electron as charge carrier is better than hole
  - Tilting y-layer will improve Y resolution for small angle track
  - With  $50 \times 300 \mu\text{m}^2$  pixel, electron as carrier, and tilting 100 mrad in Y direction, the resolution is better than EOI baseline
-