Pixel Beam Profile Monitor for Linear Collider
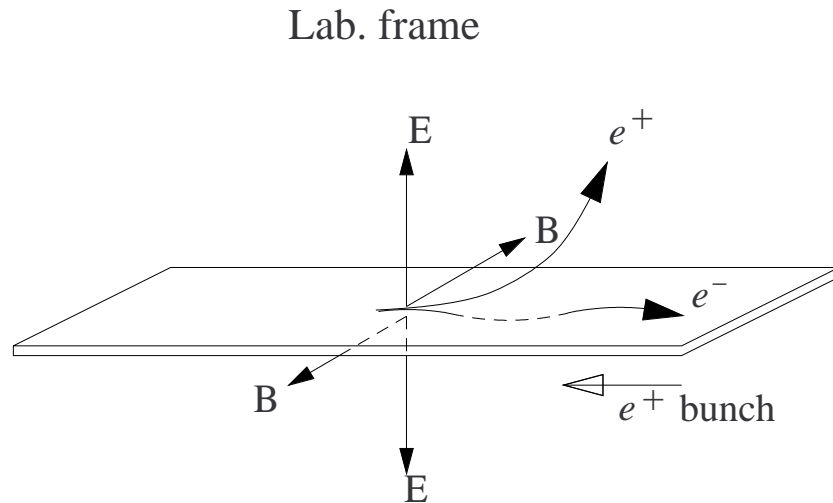
Hitoshi Yamamoto
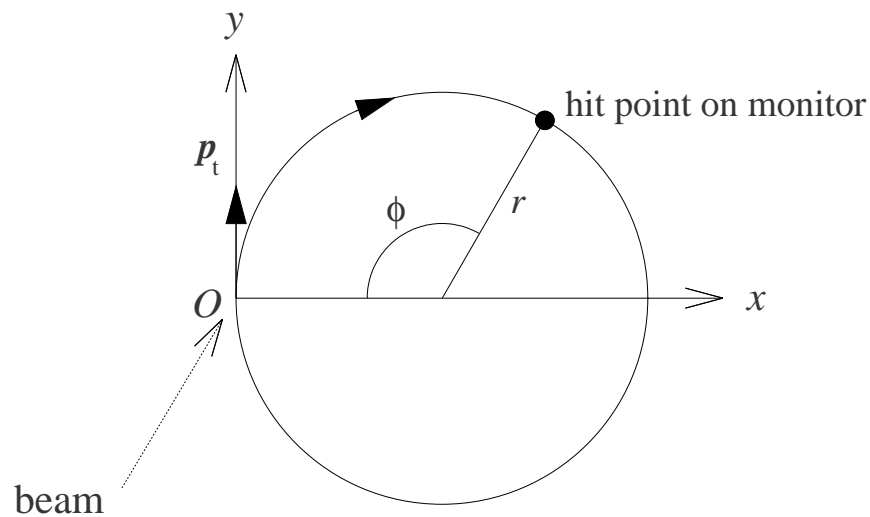
Berkeley, March, 2000

Kinematic Configuration of Pair 'Background'

Lab. frame

- $|E| = |B|$
  $\rightarrow$ no force from the co-moving bunch.
- $E(dyne/esu) = B(gauss) \sim 4 \times 10^7$
  $\rightarrow r \sim 170\mu$m for $p = 300$ MeV/c.
  $(\sigma_z \sim 80\mu$m$)$
- For an incoming e^+ bunch,
  e^- oscillates around the beam plane.
  e^+ acquires a large p_t kick (vertical).
- Round beam $\rightarrow$ no ϕ dependence,
  ϕ dependence $\rightarrow \sigma_y/\sigma_x$ ratio.

Hit Location on the Pair Monitor

$$\rho(\text{cm}) = \frac{p_t(\text{MeV}/c)}{3B_0(\text{Tesla})}, \qquad \phi = \frac{3B_0(\text{Tesla})L(\text{cm})}{p_z(\text{MeV}/c)}$$

L : distance to IP

- ρ measures p_t and ϕ measures p_z.
- For $\sqrt{s} = 500$ GeV, $N_{\text{bunch}} \sim 10^{10}$
  and $\sigma_{x/y/z} = 260\mu\text{m}/3\text{nm}/80\text{nm}$,

  $p_{t\text{max}} \sim 20\text{MeV}/c \rightarrow r = 3.3\text{cm}$ (2Tesla)

- For $L = 176$ cm, $p_z \sim 350$ MeV/$c \rightarrow \phi \sim \pi$.
- Look at ϕ distribution for $r = 5 \sim 7$ cm.

Requirements for the Pair Monitor

- Detect a few 100 MeV electrons.
- 30 hits/mm^2/train.
- $\sim$ 50 kRad/year.
- $\sim$ 70 keV threshold to reject X-rays.
- Identification of bunch in a train.
- Cover a circular area.

- Rate too high for a Si strip detector.
- CCD does not have TDC for each pixel.
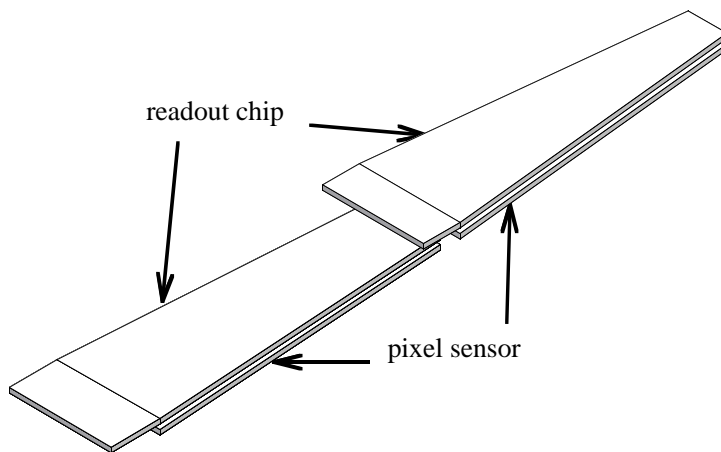- $\rightarrow$ active pixel sensor.

Use $100 \times 100\mu$m^2 pixel.
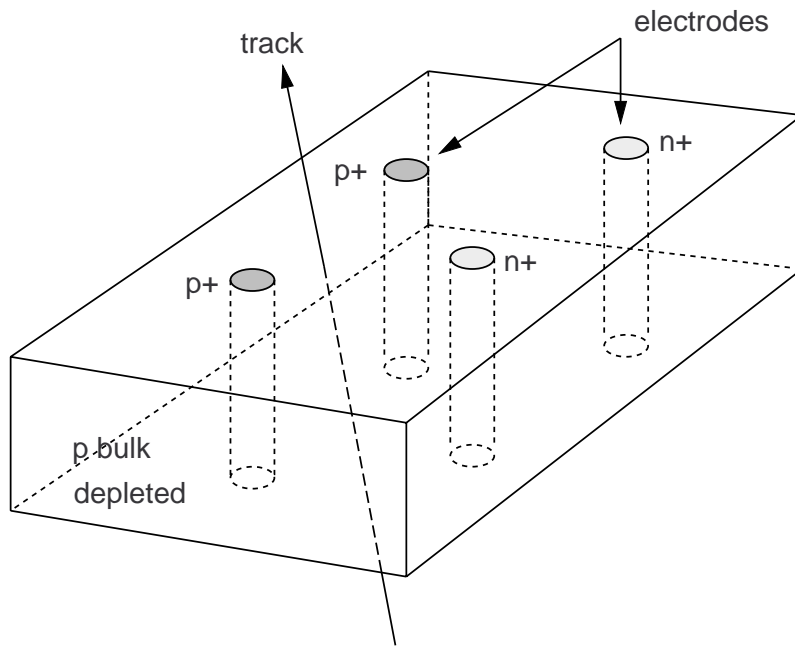TDC on each pixel.
Gating to reduce occupancy.

Pixel sensor arrangement for one disk

One stave

readout chip
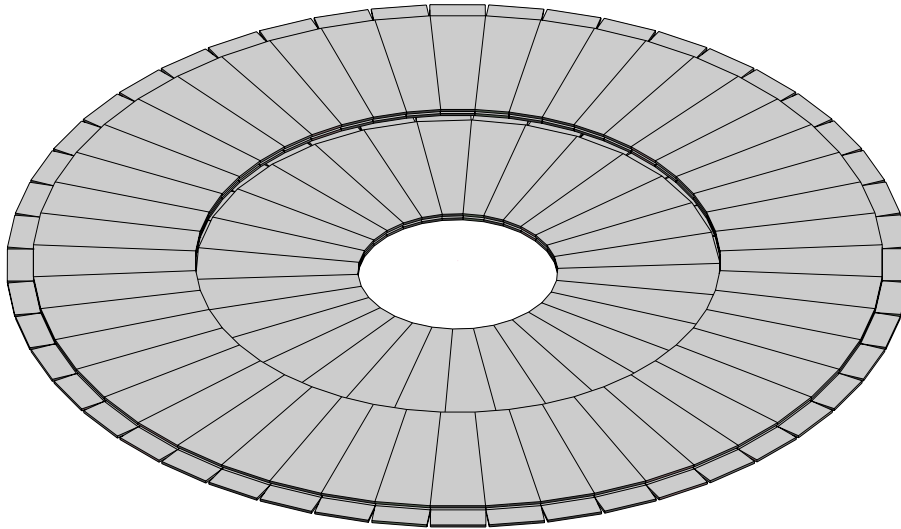
pixel sensor

3D Pixel Sensor

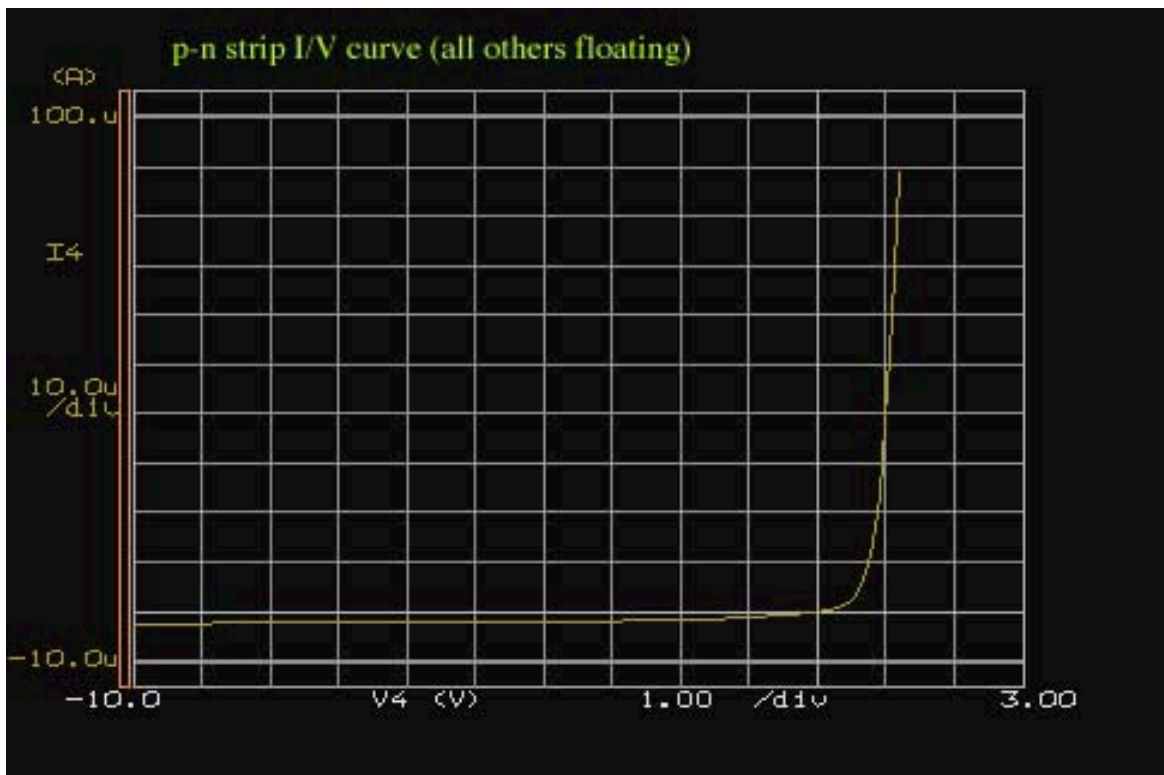Drift field parallel to the plane of sensor.

- Signal pulse is about $\times 10$ faster than typical pixel.
- $V_{\text{depletion}} \sim 5V$. Radhard.
- Flexible geometry (e.g. trapezoid).
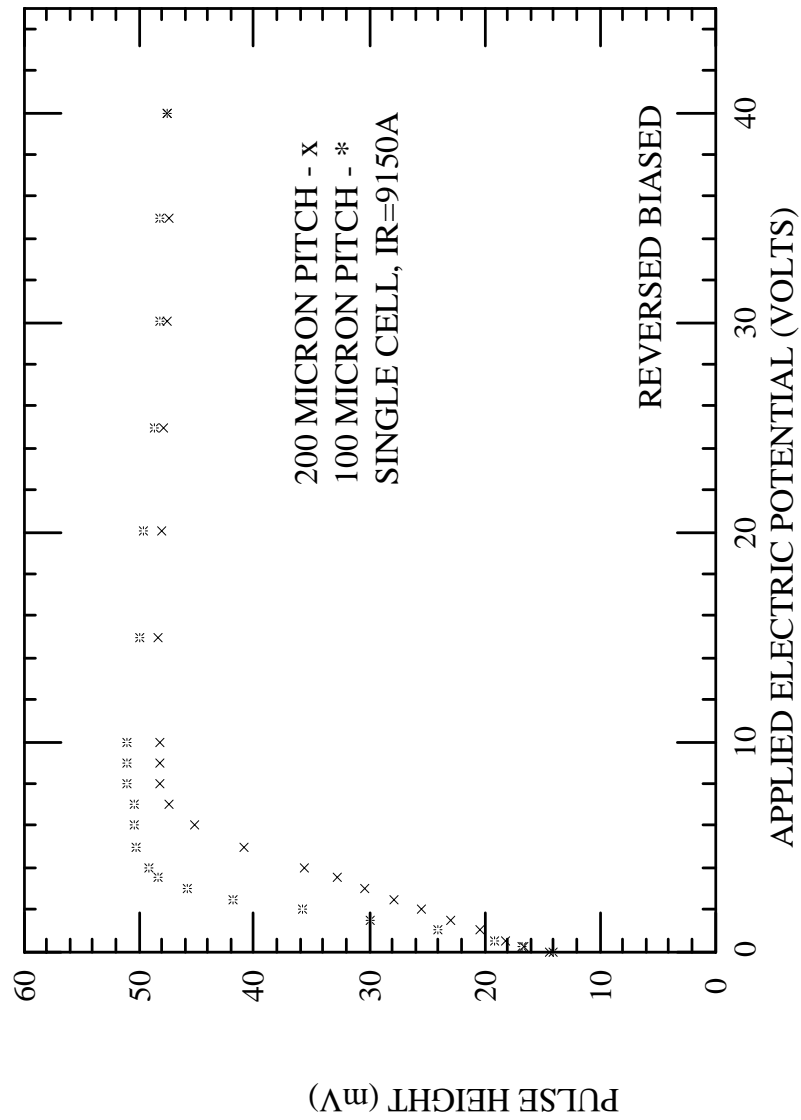- Active all the way to the edge (no guard ring).

3D Pixel Sensor Test Results

Prototype:

- 120μm thick
- Electrode diameter $\sim$20μm.
- Pitch: 100 or 200μm.
- 14 by 28 array.

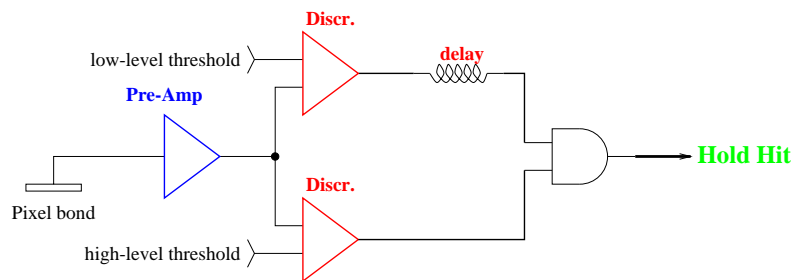100μm pitch version

3D Pixel Sensor IR Laser Test

200 MICRON PITCH - x
100 MICRON PITCH - *
SINGLE CELL, IR=9150A

REVERSED BIASED

APPLIED ELECTRIC POTENTIAL (VOLTS)

PULSE HEIGHT (mV)

Possible Timing Circuit

- Timing is defined by a low-threshold discriminator.
  Hit is defined by the high-threshold.
- Latch a couting gray code bus.
- TDC value stored on each pixel ($\sim$8 bits)
- Read-out time $\sim$ 3.5 ms.

Alternative: V_{ramp} stored on a capacitor in each pixel.