ILC vertex detector:
- Requirements:
  - Position resolution: < 3 um
  - Material budget: 100 um/layer
  - Power consumption: 50 mW/cm²
  - Radiation hardness: TID < 100 krad/year
  - Beam bunch (54 ns) identification is preferred to reduce occupancy

Hit time is stored and read out in between trains → Developing SOFIST that can measure space and time

SOFIST (Silicon On Insulator):
- Technology to implement MOSFETs on oxide layer (SOI)
- Advantages:
  - Monolithic:
    - Reduction of stray capacitance
    - Low power consumption
    - Low material, Radiation hardness

SOFIST3: Evaluation by using 120 GeV proton beam
- Each pixel is implemented 3 timestamp memories to hold time information and 3 analog signal memories to hold charge information.

Design value of SOFIST3
- Parameter:
  - Wafer Thickness: 300 um, 75um
  - Chip size: 6.0 × 6.0 mm²
  - Pixel array: 128 × 128
  - Wafer resistance: 4.25–6.73 kΩ/cm
  - Wafer: Double-SOI P-Type

BeamTest® FermiLab:
- Period: February 17 to March 8, 2019
- Beam: 120 GeV proton beam
- Spill structure (4 seconds per minute)
- Purpose:
  - Evaluation of time resolution
  - Evaluation of position resolution

Simultaneity of hits in shared clusters:
- In order to check the intrinsic time resolution, time difference of 2 pixels in the 2-hit clusters was studied.

From the histograms, the intrinsic time resolution within one sensor is
- IP11: 1.90√2 = 1.34 us
- IP15: 2.19√2 = 1.55 us

Time resolution:
- After alignment, plot the time difference between the two sensors that the beam passed through is √2:
  - IP11_IP15: 2.67√2 = 1.87 us

(< In SOFIST ver2, the time resolution was 1.55 us)

Conclusion:
- SOFIST3:
  - From the analysis in the beam test, the time resolution was estimated to be 1.87 us (including calibration error). Intrinsic is 1.34 us ~ 1.55 us.
  - Multi memory read-out, first in SOFIST3, was evaluated successfully.
- SOFIST4:
  - Beta rays imaged as a 3D stacked sensor.
  - The connection yield of micro bumps was 99.9%.

Plans:
- Evaluate position resolution of SOFIST3.
- Performance evaluation in beam test of SOFIST4.

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