A personal perspective on past silicon detector R&D efforts in Korea

J. Lee
Center for High Energy Physics
Kyungpook National University

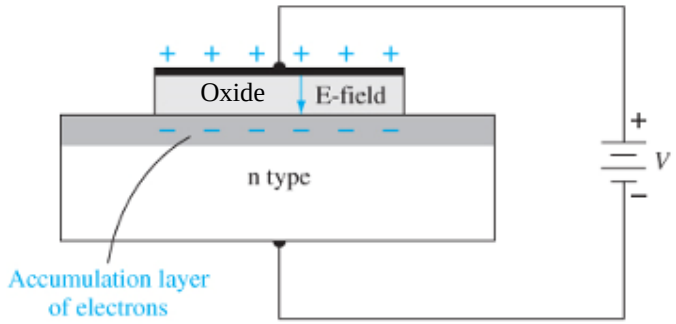
Particle Detector Workshop 2026 @ IBS

Feb 6, 2026

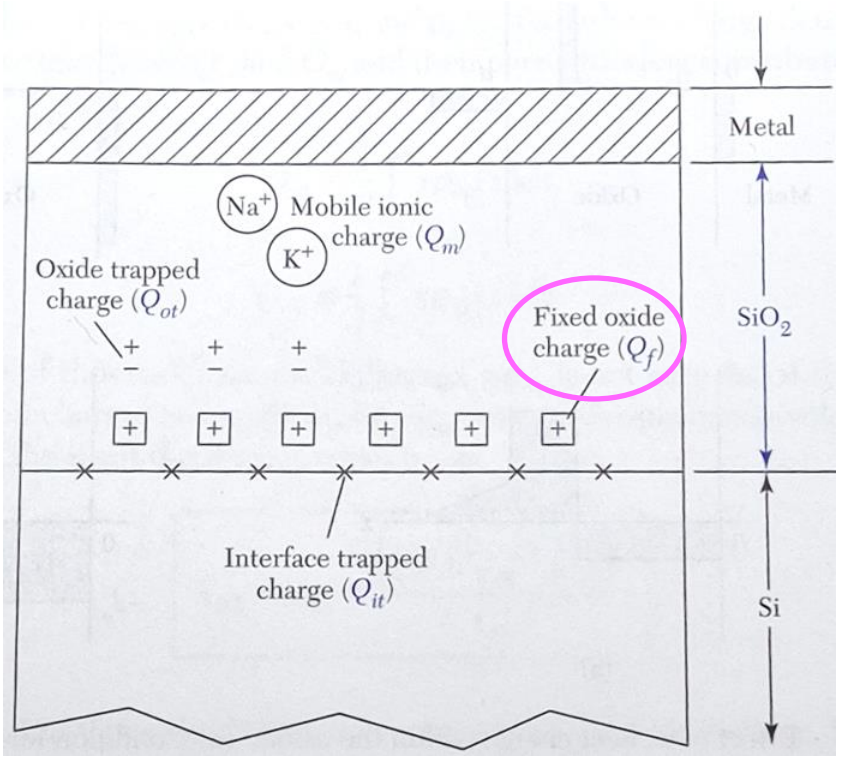
Outline

1. Introduction
   - How my work on Silicon Detectors began
2. Legacy & Lineage in Korean Silicon Detector R&D
3. Individual Lab vs Common Lab
4. Open Question
5. Conclusion

Question that led me to Silicon work

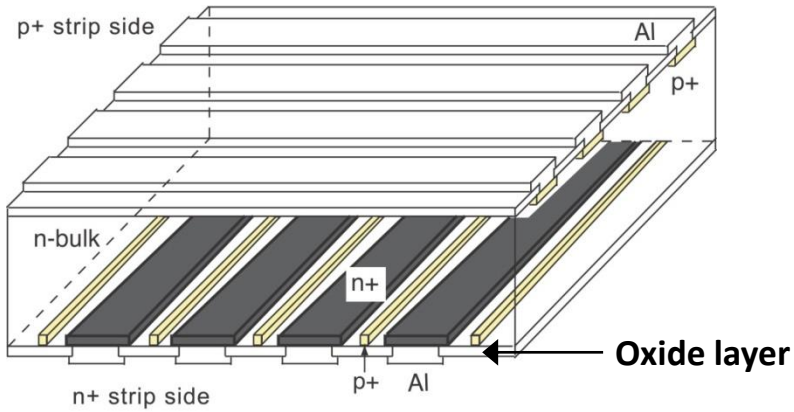


Much Later I found a clue in "Semiconductor Devices Physics and Technology Second Edition", S.M. Sze



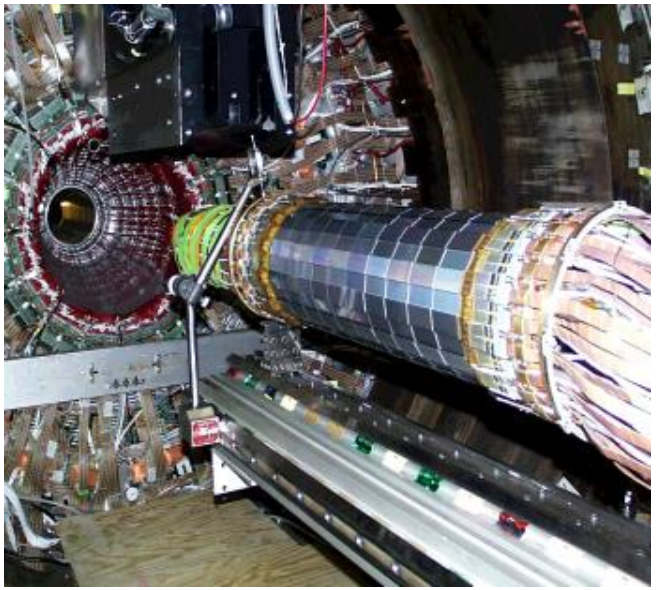
Electron accumulation layer can exist even with V = 0! Why?

Double-sided strip sensor for Si3 detector



Electron accumulation layer can exist in n-bulk due to positive fixed oxide charge.

Si3(4-layer) Vertex Detector Development



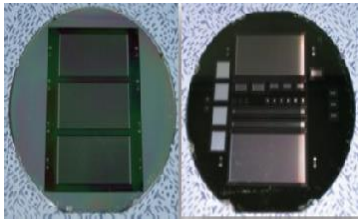
Strip/Photo Sensor Development @ KNU

From H. Park @ KNU

Total 15 types: Strip sensors were developed for International Linear Collider

2002 — **H. Park, J. Lee & H.J. Kim began discussions on silicon strip sensor development.**

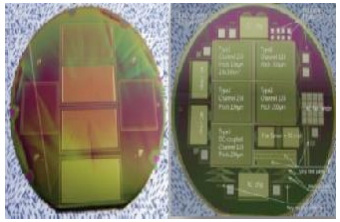
2003



DC-coupled Single-/Double-sided strip sensor

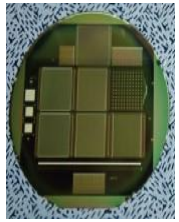
2005

2007



DC/AC-coupled strip sensor for tracker used by University of Maryland

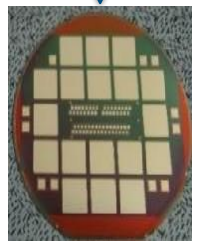
2009



AC-coupled Single-/Double-sided strip sensor

2011

2012



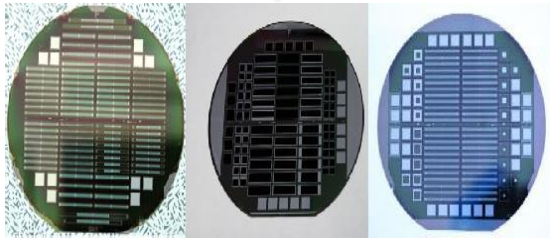
Large are photodiode for ISS-CREAM experiment

TCD & BCD

2014

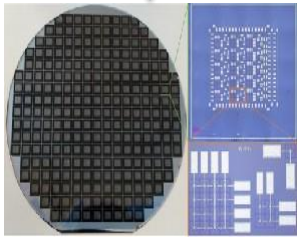
AC-coupled Single-sided strip sensor

2015



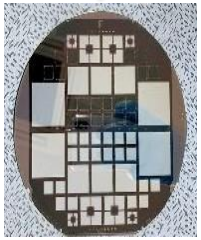
DC/AC-coupled Single-/Double-sided photo sensor

2017



JFET Pixel Array Sensor for Imaging

2019

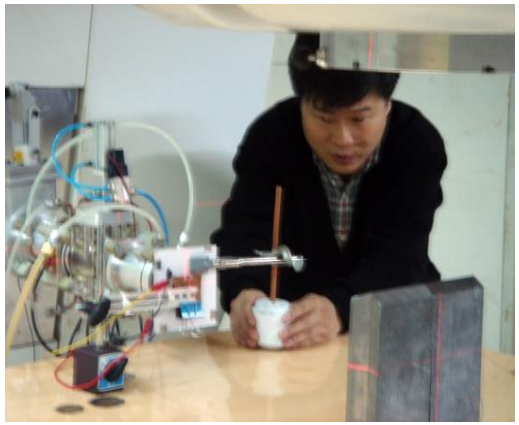


PIN photodiode sensor for X-ray detection

H. Park's KNU group: Legacy & Lineage

- H. Park served as one of Tracking and Vertexing Working Group Conveners for International Linear Collider
  - J. Lee presented "Silicon Strip Sensor R&D Activity in Korea" for Korean Working Group (12 members) @ LCWS 04 (https://llr.in2p3.fr/sites/lcws2004/) The site still exists !
- "Radiation Hardness Study for Silicon Strip Sensors Using the 35-MeV Proton Beam from the MC-50 Cyclotron at the KIRAMS", J. Lee et al, JKPS, **48**, 4(2006) -> First Paper from Strip R&D
- Silicon Sensor R&D SCI Journal Publications : ~50
- Vital contributions to Belle-II SVD R&D -> many Belle-II physics papers
- Lineage in Detector R&D
  - H.J. Hyun, K.H. Kang, H.B. Jeon, S.C. Lee, and many more
  - H.J. Hyun & S.C. Lee @ Pohang Accelerator Laboratory is developing LGAD for X-Ray Detection
  - K.H. Kang -> Next talk

KNU group




IPMU clean room
Seungcheol Lee
Hwanbae Park
Kookhyun Kang
L4 members
Hyebin Jeon

Silicon Charge Detector Development @ Ewha/SKKU

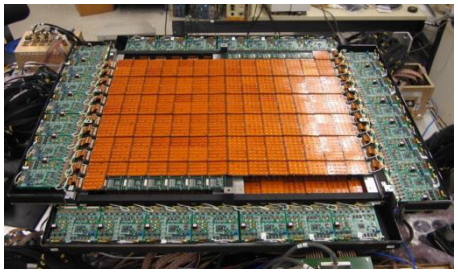
2002 2003 2004 | 2005 | 2006 | 2007 2008 | 2009 | 2010 | 2011

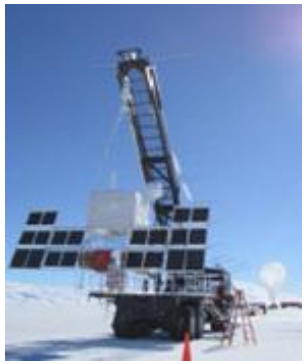
CREAM SCD
DC-coupled 4x4 pad sensor
5 inch 380 μm

CREAM-I Flight (SCD-1)

CREAM-II Flight (SCD-2)

CREAM-III Flight (SCD-2)





CREAM-IV Flight (SCD-2)

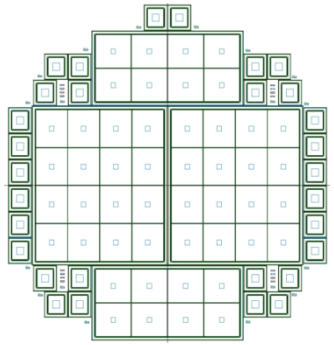
CREAM-V Flight (SCD-2)

CREAM-VI Flight (SCD-2)

2010 2011 2012 2013 2014 2015 2016 2017 | 2018 2019

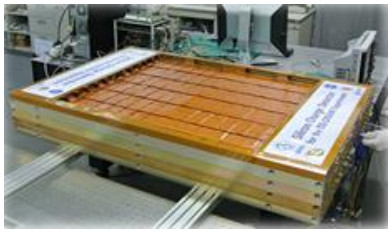
SCD-3 & SCD-L Built

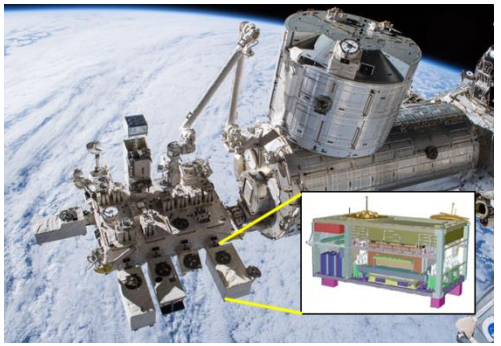
ISS-CREAM Launch on 20170814



6 inch 525 μm

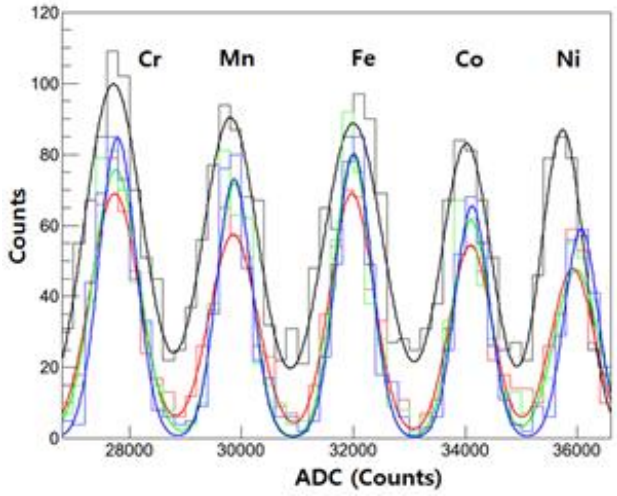
SCD-3 & SCD-L & More Sensors Converted To ISS-CREAM 4-Layer SCD

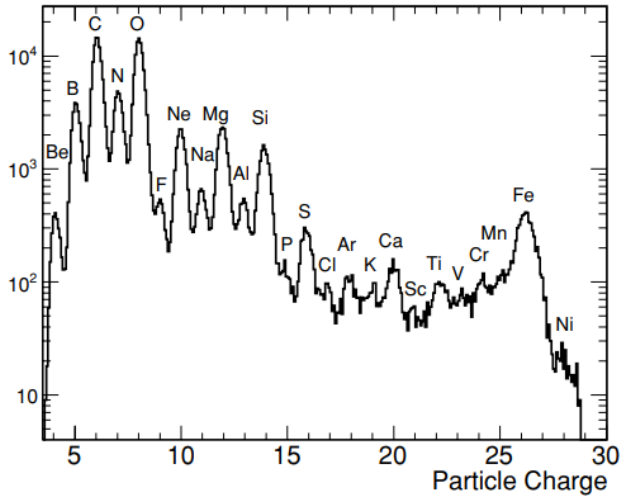


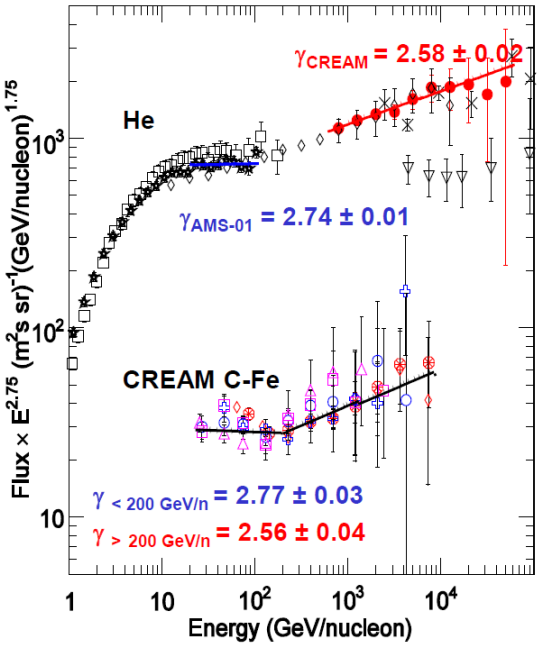


"I would like to thanks a lot for the beautiful instrument." M.H. Lee

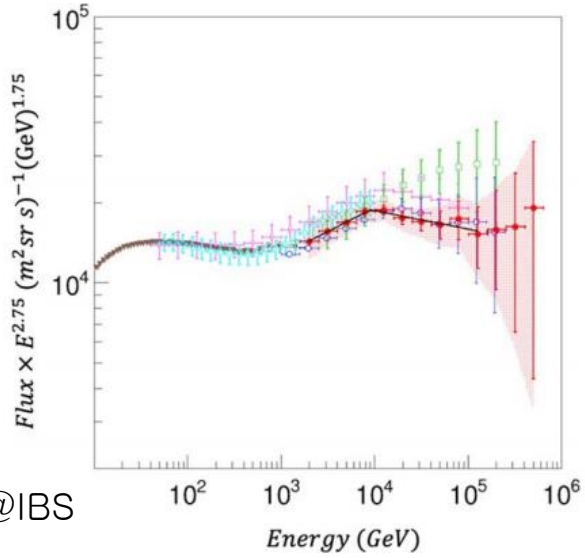
Impact of Detector on Physics







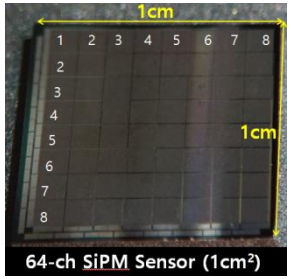
Discrepant Hardening in Energy Spectra (Ahn et al., ApJ 714 L89, 2010)

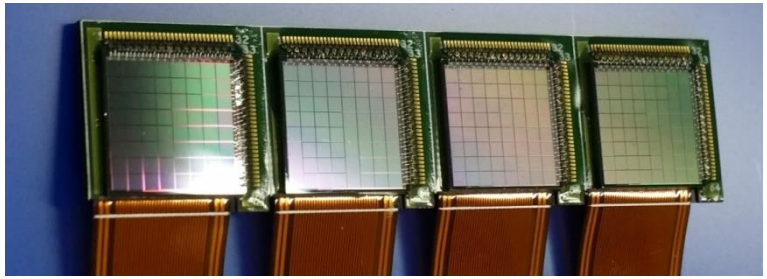


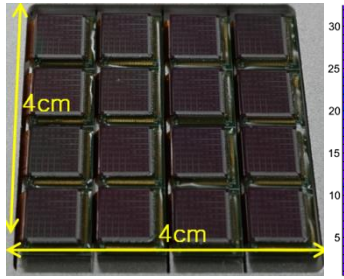
Measurement of High-energy Cosmic-Ray Proton Spectrum from the ISS-CREAM Experiment (G. H. Choi et al., ApJ 940 107, 2022)

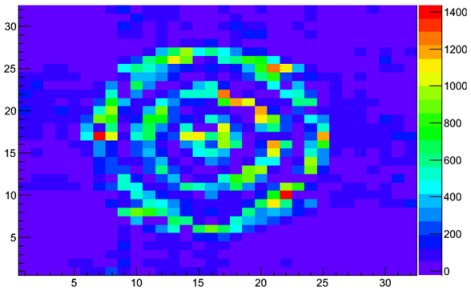
I.H. Park's SCD Group: Legacy & Lineage

- I.H. Park was the leader of Ewha/SKKU group who successfully developed the silicon pad sensor first ever in Korea
- Silicon Detector R&D Journal Publications: ~15 and more
- Vital contribution to CREAM/ISS-CREAM experiments -> many CREAM/ISS-CREAM physics papers
- J. Lee was in charge of SCD-3, SCD-L, ISS-CREAM-SCD production
- J. Lee was PI for 1024-ch SiPM camera development (I.H. Park, H.Y. Lee, J. A. Jeon)



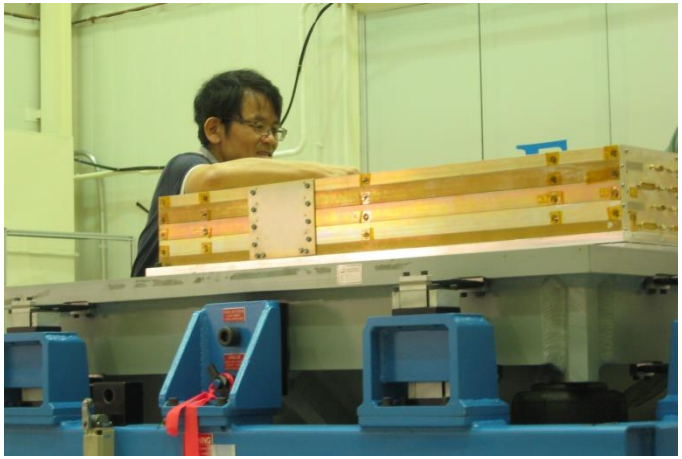




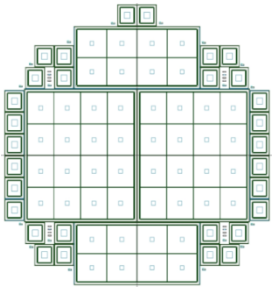
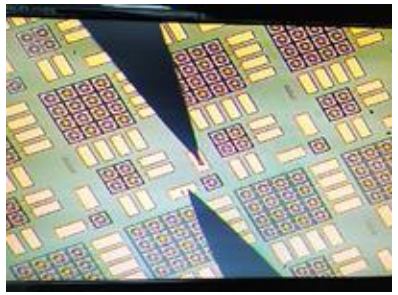


- Lineage in Detector R&D
  - H.Y. Lee, J.A. Jeon, M.B. Kim, G.H. Hong and many more
  - J.A. Jeon and M.B. Kim are with AMoRE
  - H.Y. Lee -> First talk in the 2nd session

SCD group

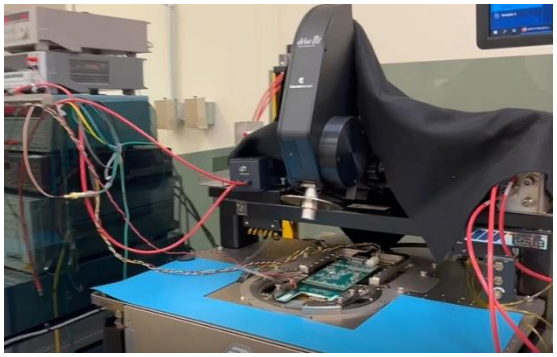


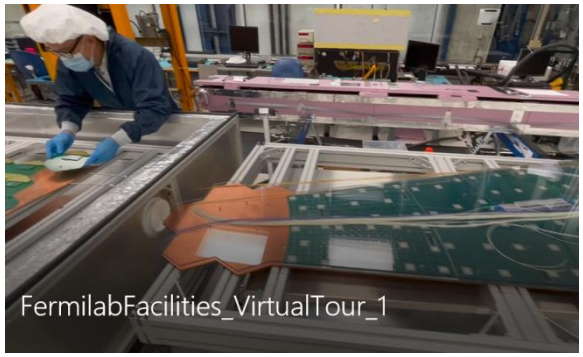
Individual vs Common Lab

	Design	Fab/Foundry	Post Fab	Characterization
Pro	Design & Simulation	Photolithography w/ mask, Oxidation, Implant, Deposition, Metallization, Etching, Polishing	Dicing Bonding(wire, bump) Encapsulation Packaging	Electrical, Optical, Low temperature Tests Radiation Test w/ Electronics
Con				
Individual Lab **Focused, Quick;** **Project-based,** **Short-lived**	Own/External Software	External Facilities/Equipment	Own/External equipment, No support	Own/External equipment, No support
Common Lab **Diverse, Slow;** **Last longer**	Common /External Software	Common Facilities/Equipment? → **Long shot !**	Common equipment, Eng/Tech support	Common equipment, Eng/Tech support

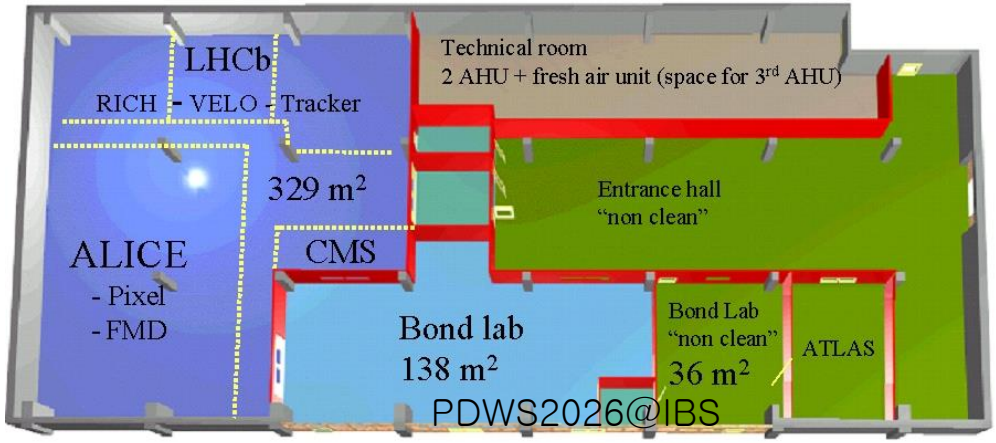
Common Lab Examples: SiDet & CERN Lab

- Fermilab's Silicon Detector Facility(SiDet)
  - https://detectors.fnal.gov/test-areas/
  - 5,000 square feet of cleanroom space





- PH Department Silicon Facility (DSF) at CERN
  - https://ssd-rd.web.cern.ch/dsf/default.htm

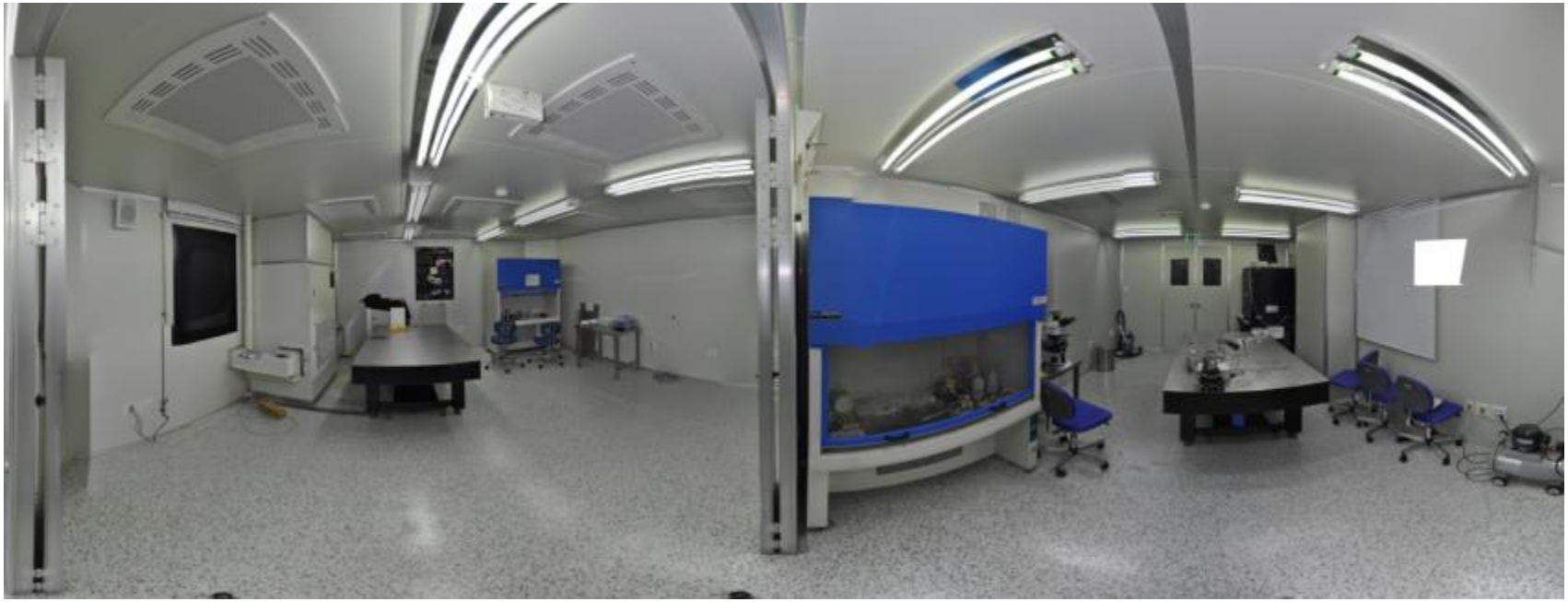


Examples of Engineering/Tech Support

- SiDet Wirebonding
  - Fermi News 2000. 12. 01 **SiDet Adds Precision** https://www.fnal.gov/pub/ferminews/ferminews00-12-01/p1.html
- Department Silicon Facility (DSF) wirebonding
  - https://ssd-rd.web.cern.ch/bondlab/

Shouldn't have happened

- A famous physicist (invited to Korea by a Korean funding program) started a kind of clean room, and then stopped and left.
- Such a situation will not occur with the establishment and use of the Common Lab.

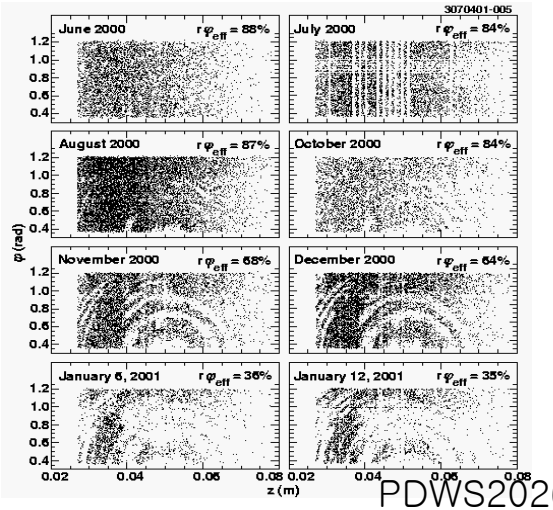


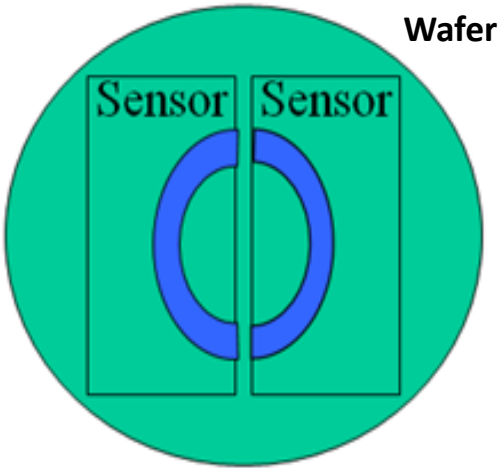
Buy vs Fab. : Open Question

- Buying commercial/customized silicon sensors?
  - Not a bad option if price is acceptable
  - Even some people think it is the best option.
  - However, this leads to dependence on manufacturers, which can be problematic—especially when they are based overseas.
  - In the very long term, owning a fabrication facility is beneficial.

- An example where buying does not always work

Efficiency of N-side Layer-2 over time





Silicon Sensor Manufacturers

- Hamamatsu
- FBK
- Micron Technology
- SensL -> On semi
- Ketek
- & more …

- What about Korean Companies?
  - Big companies are generally not interested in silicon sensor manufacturing because the market is small.
  - A venture company which manufactured silicon pad sensors was not able to survive long
  - We need companies that are willing to work closely with detector experts through iterative development (such as Hamamatsu).

Conclusion

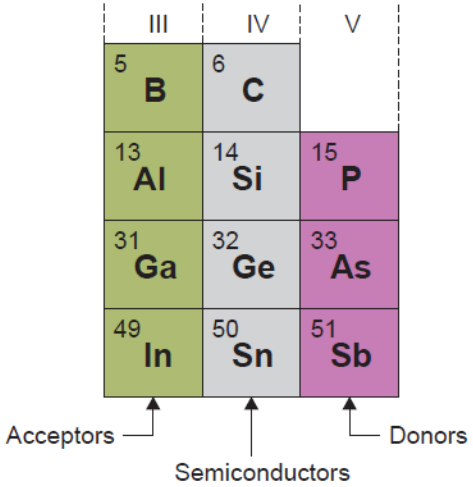
- Many ongoing/upcoming excellent experiments in Korea
  - CMS, Alice, EIC, DUNE, RENE, HK, KNO, etc.
- Each experiment can run its Own Lab independently -> However better with a Common Lab

- # of Silicon Particle Detector R&D groups in Korea
  - 2 in early 2000
  - 6 (counting today's speakers) + many more in 2026
  - The lineage will continue to expand.
- The impact of R&D will be more apparent in smaller experiments (for example, small- or mid-scale space missions).

- Final Remark
  - Take many photos while at work (possibly in a Common Silicon Lab) and save them in an organized way.

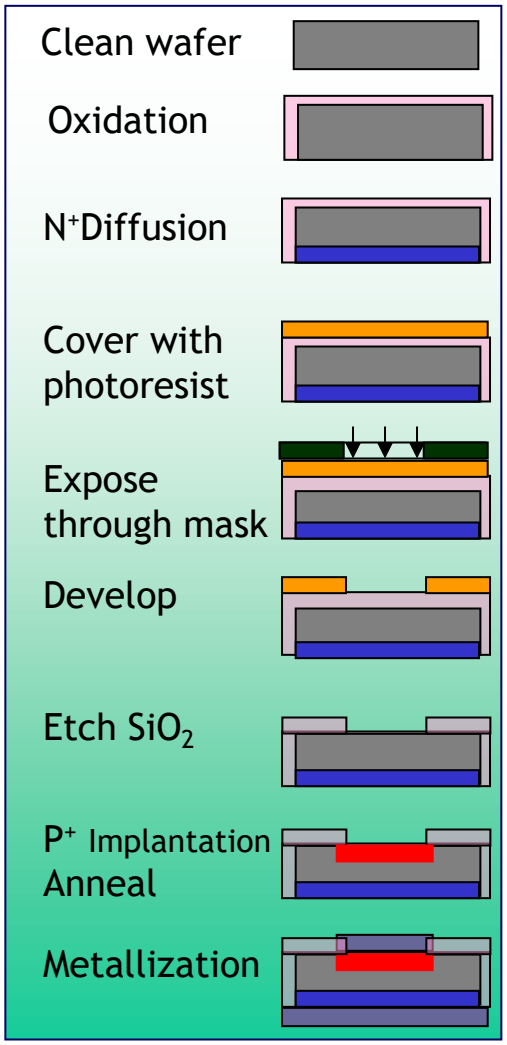
Back-up slides

Why Silicon?

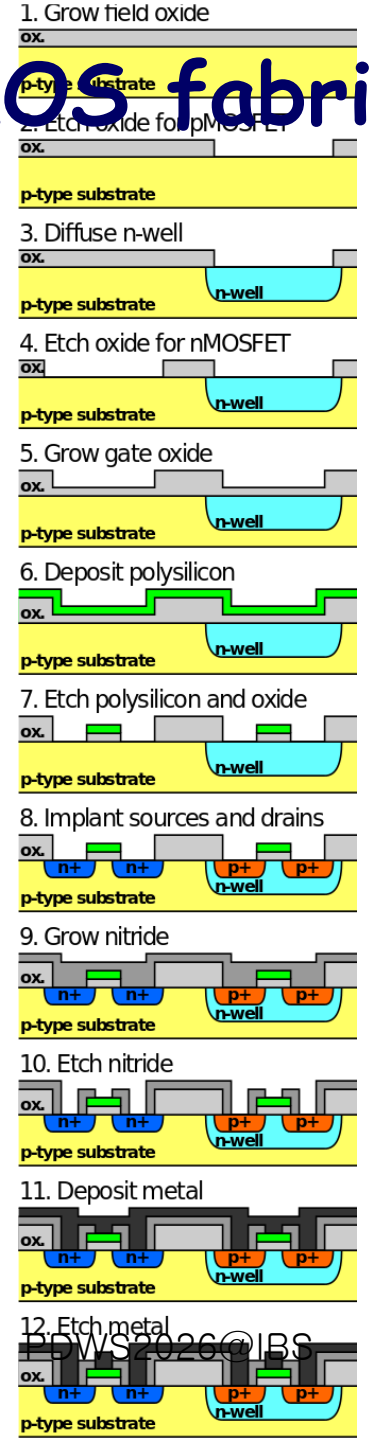


- abundant --> cheap
- Lighter
- SiO_2 layer
  - Naturally or inexpensively formed
  - chemically and mechanically very stable
  - effectively passivates the surface states of the underlying silicon
  - forms an effective diffusion barrier for the commonly used dopant species
  - easily preferentially etched from the silicon, and vice versa, with high selectivity
  - By contrast, GeO_2 is a chemically unstable, poor electrical insulator that is 33 times more soluble in water than SiO_2, making it less suited to the photolithographic and wet chemical processes used to fabricate integrated circuits.

Recipe for fabrication process



Example of CMOS fabrication process

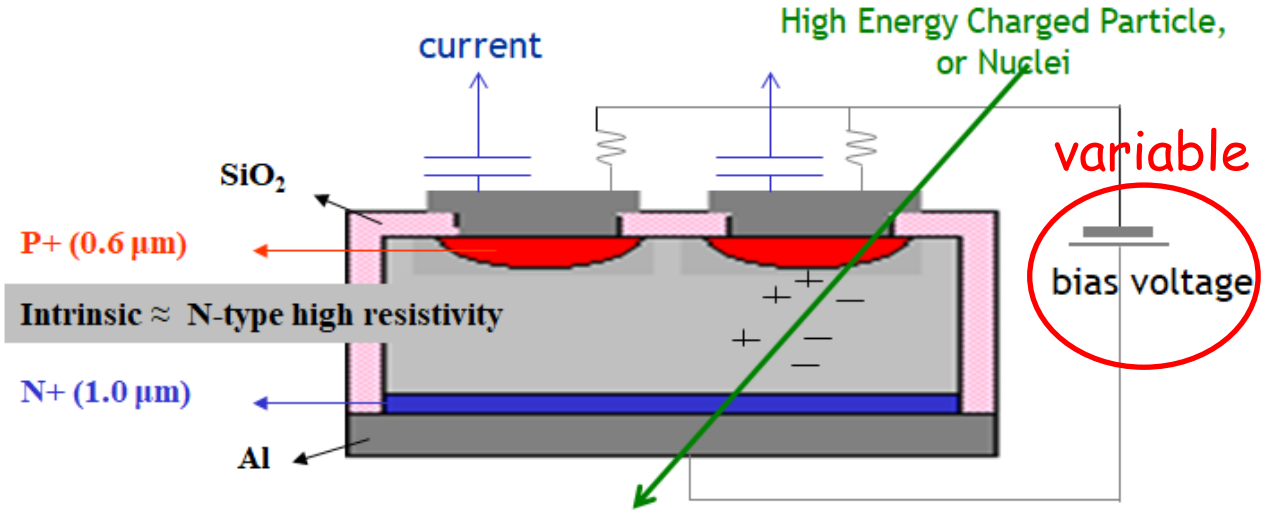


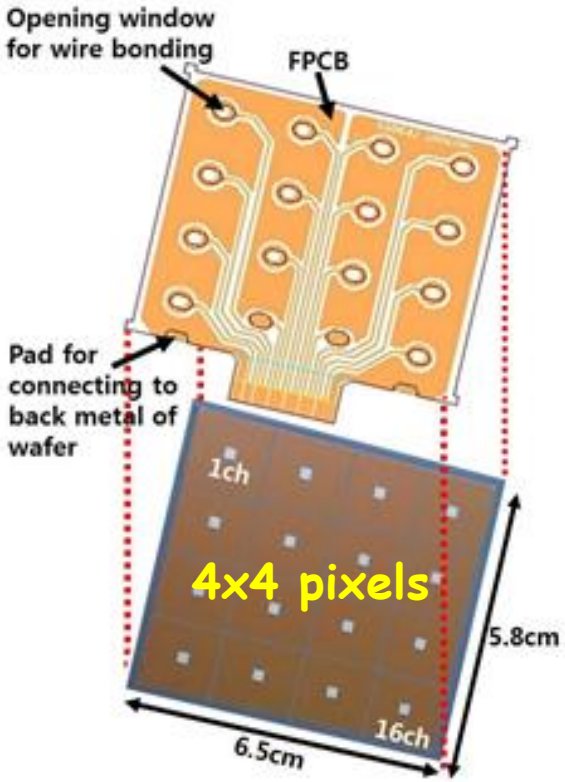
From
https://en.wikipedia.org/wiki/CMOS

Silicon pixel sensor

- PIN diode, DC type
- Wafer: 5 inch, 525 μm in thickness, double polished side, N-type high resistivity (>5 kΩ-cm), (111) orientation

pixel size = 1.55 cm x 1.38 cm





- The heavily-doped pieces are called n^+-type or p^+-type; the lightly-doped pieces, simply n-type or p-type.