Silicon Strip Detector: From Construction to Operation of the Belle II SVD

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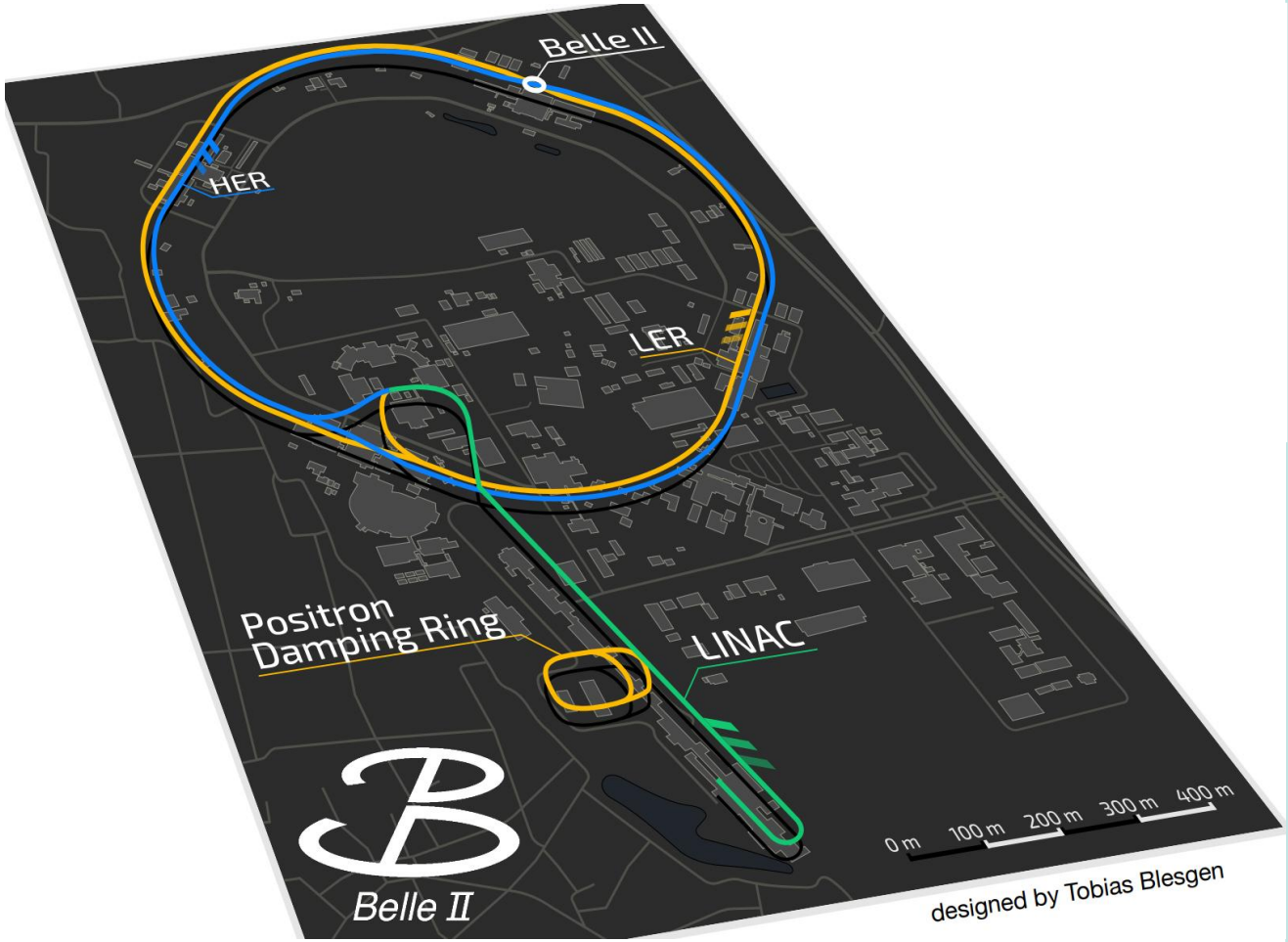
2026.02.06 Particle Detector Workshop 2026

Outline

- Silicon Vertex Detector (SVD) for Belle II experiment
- Design & Construction
- ~~Operation & Performance~~
- Summary

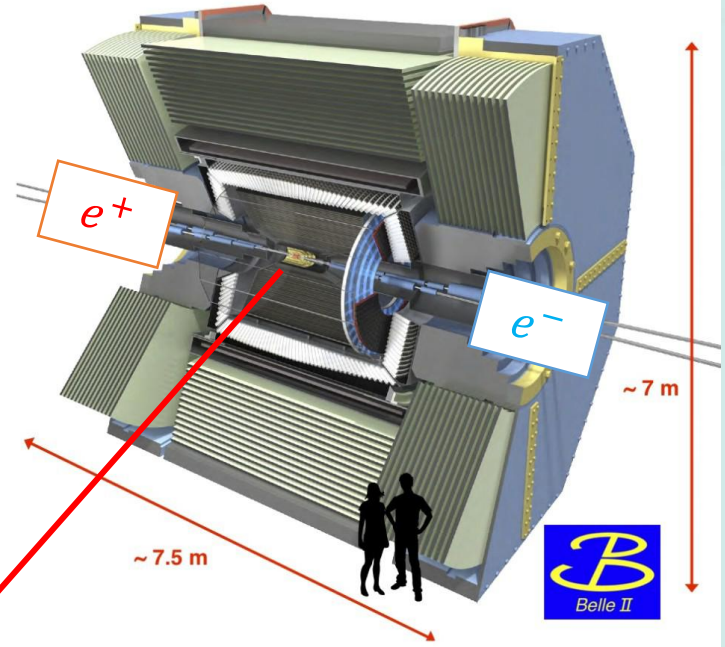
SuperKEKB and Belle II

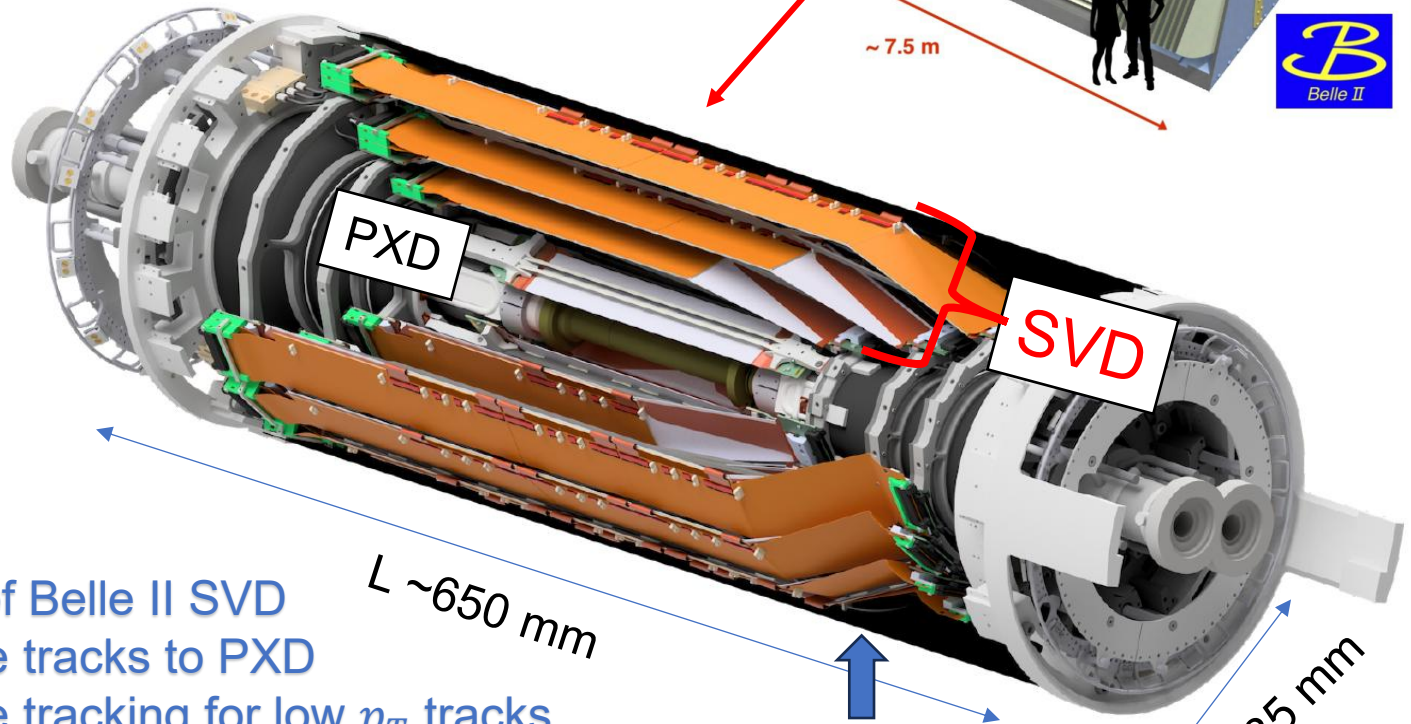
- SuperKEKB collider (KEK, Japan)
  - Asymmetric energy ($4\ GeV\ e^+$ & $7\ GeV\ e^-$)
  - CM energy: 10.58 GeV for $\Upsilon(4S)$
  - Nano beam scheme
  - Target luminosity: $6 \times 10^{35}\ cm^{-2}s^{-1}$
  - Target Integrated L: $50\ ab^{-1}$
- B factory at luminosity frontier <-> LHC
  - Search for new physics with B, charm, and τ rare decays
- So far ~ $599/fb^{-1}$ are collected since March 2019
  - ~ $5.1 \times 10^{34} cm^{-2}s^{-1}$, the new world record luminosity more than twice of KEK



Belle II Silicon vertex detector

- Vertex detector (VXD)
  - 2 layers pixel detector (PXD)
  - 4 layers silicon vertex detector (SVD)
- Double-sided Silicon Strip Detector
- Ladders
- Material budget
- Cooling
- Construction
  - Wire boding & Gluing
- Re-installation @ LS1





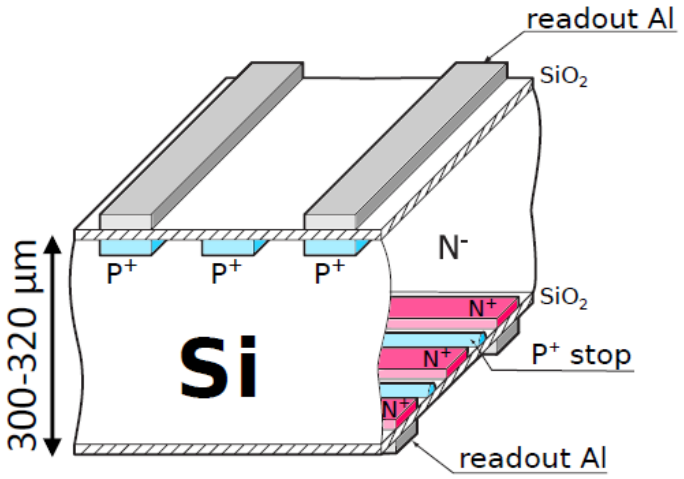
Main features of Belle II SVD

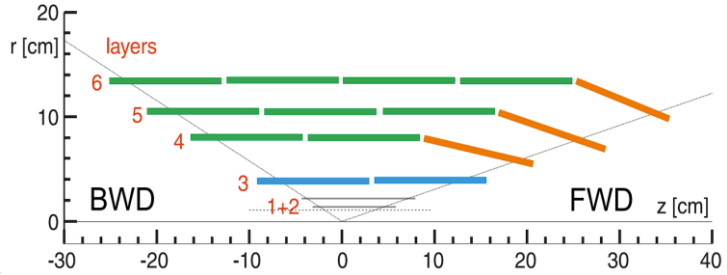
- Extrapolate tracks to PXD
- Standalone tracking for low p_T tracks
- Precise vertexing of K_S
- Particle identification via dE/dx

Asymmetric energy

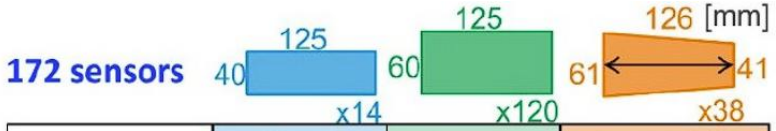
Design and Construction

- Vertex detector (VXD)
  - 2 PXD
  - 4 layers SVD
- **Double-sided Silicon Strip Detector** ➡️
- Ladders
- Material budget
- Cooling
- Construction
  - Wire boding & Gluing
- Re-installation @ LS1





- Double-sided Silicon Strip Detector (DSSD)
  - AC coupled strips
  - Depletion Voltage: 20-60 V
  - Operation Voltage: 100 V



	Small	Large	Trapezoidal
# of p-strips*	768	768	768
p-strip pitch*	50 µm	75 µm	50-75 µm
# of n-strips*	768	512	512
n-strip pitch*	160 µm	240 µm	240 µm
thickness	320 µm	320 µm	300 µm
manufacturer	HPK		Micron

*readout strips – one floating strip on both sides

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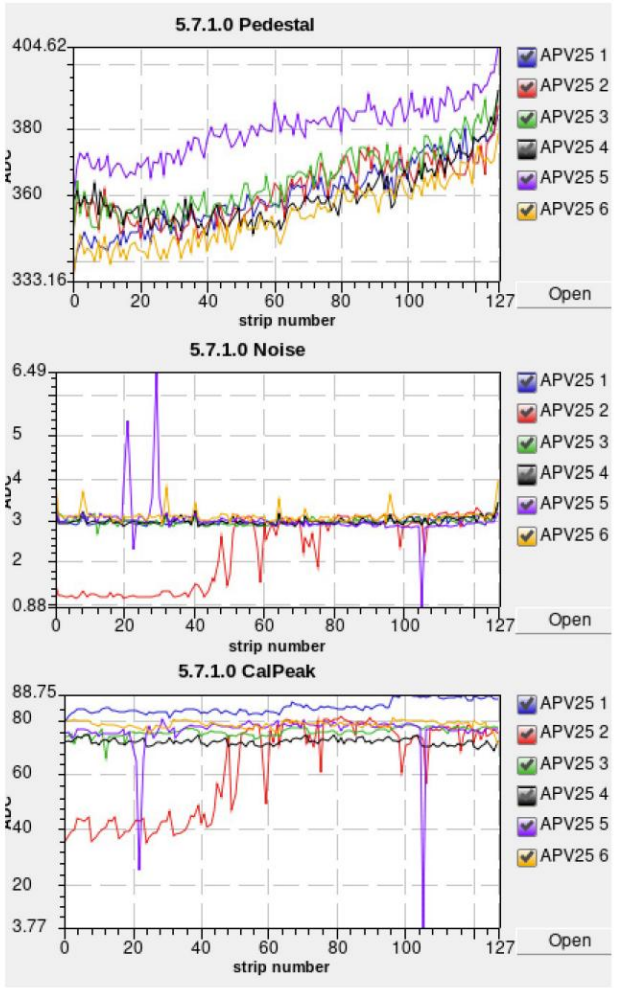
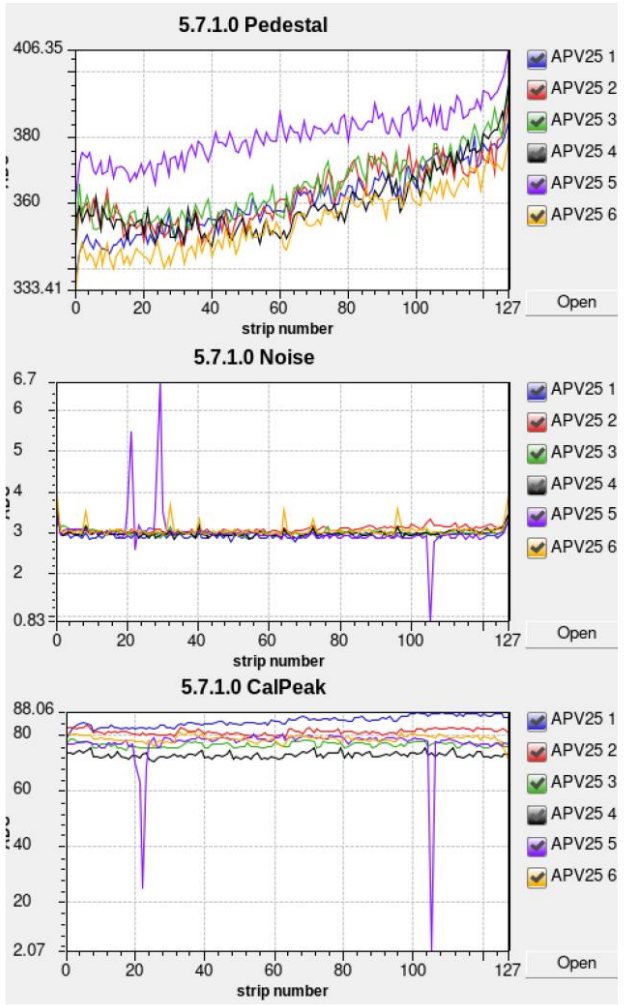
- Re-installation @ LS1

Aug. 27th, nominal HV, Vsep



Aug. 29th, nominal HV, Vsep, N2 on.



Humidity sensitivity of Micron sensors was causing the shorts

Design and Construction

- Vertex detector (VXD)
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  - 4 layers SVD
- Double-sided Silicon Strip Detector
- **Ladders** ➡️
- Material budget
- Cooling
- Construction
  - Wire boding & Gluing
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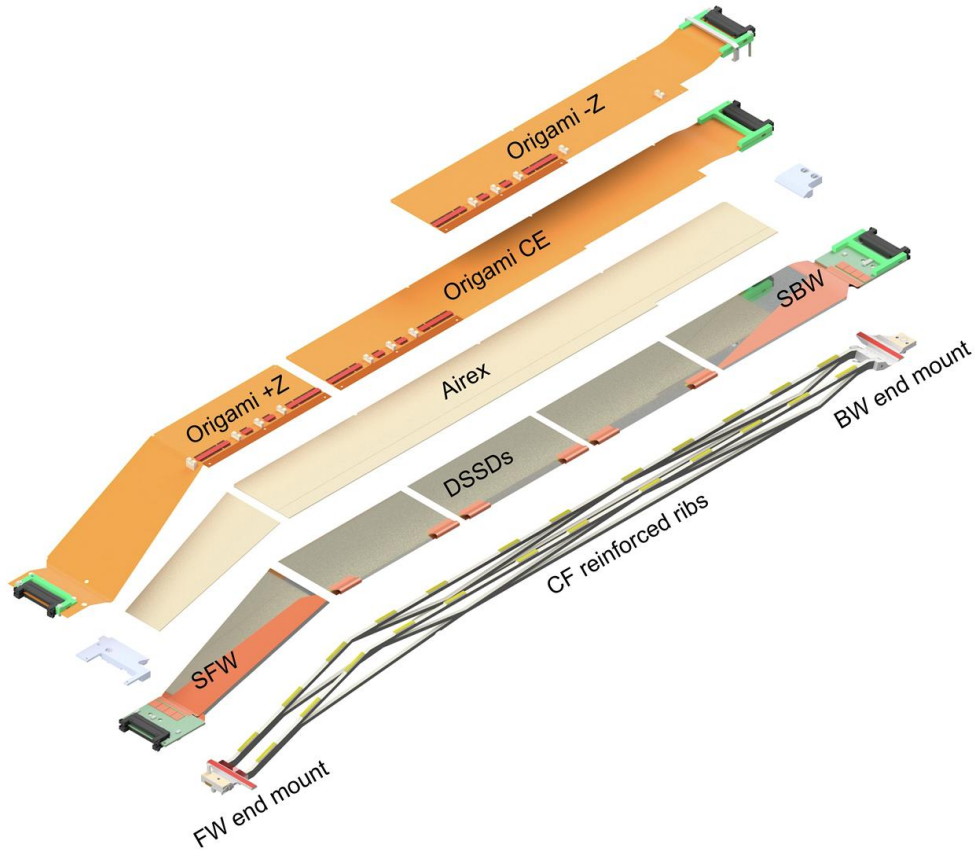

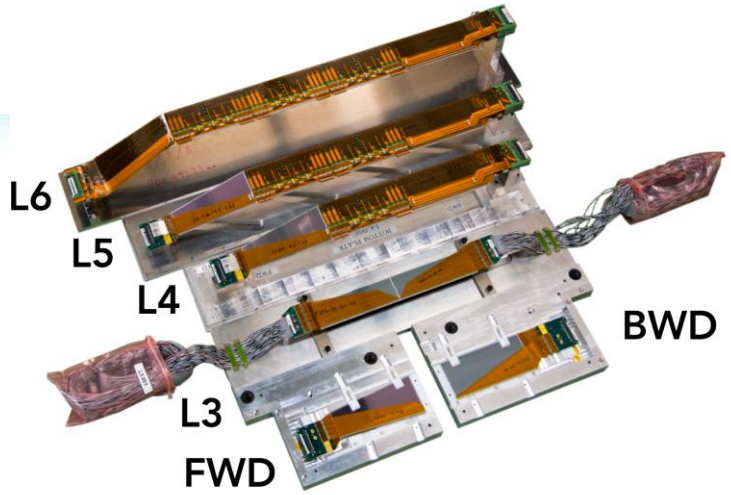

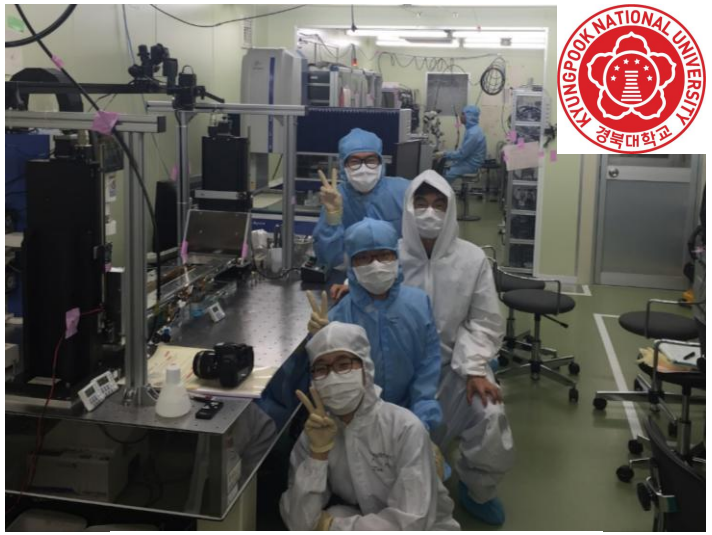

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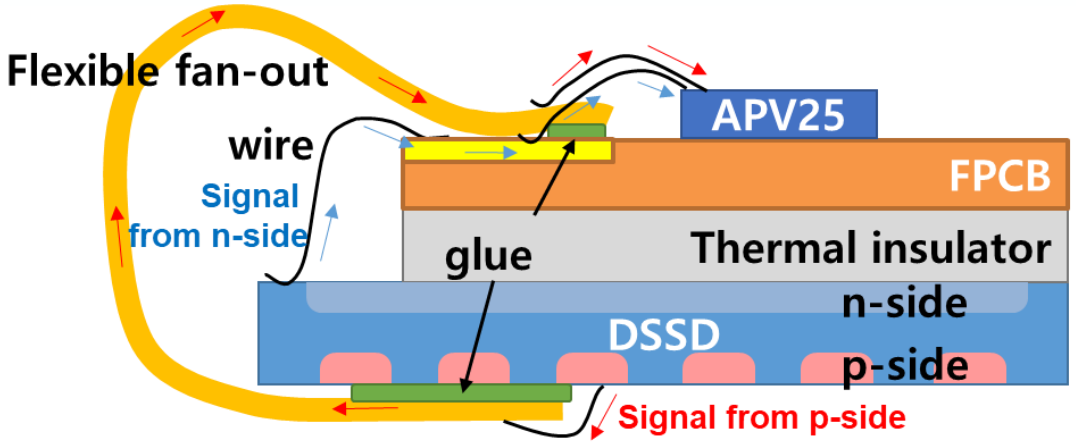
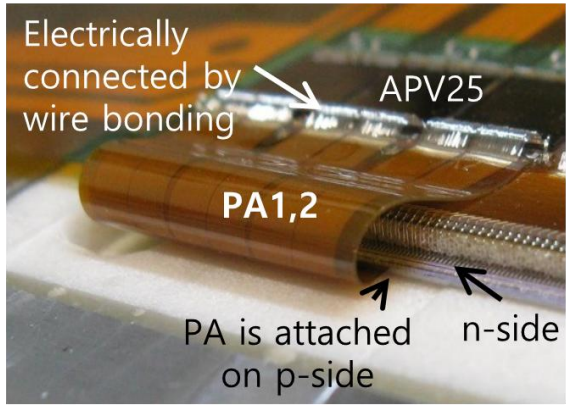
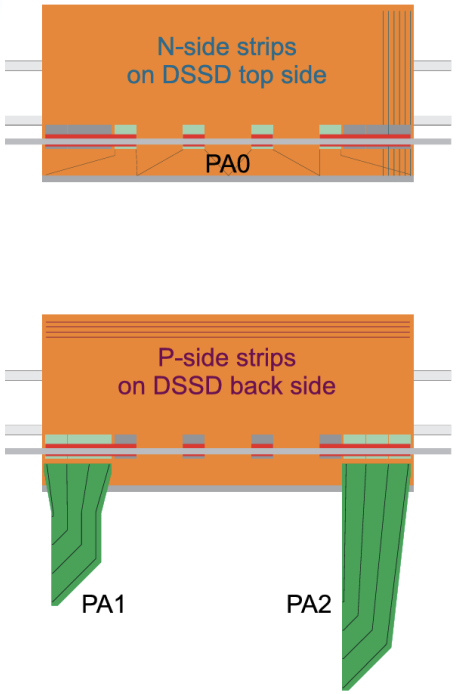
Design and Construction

- Vertex detector (VXD)
  - 2 PXD
  - 4 layers SVD
- Double-sided Silicon Strip Detector
- Ladders
- **Material budget**
  ➡ "Origami"
- Cooling
- Construction
  - Wire boding & Gluing
- Re-installation @ LS1

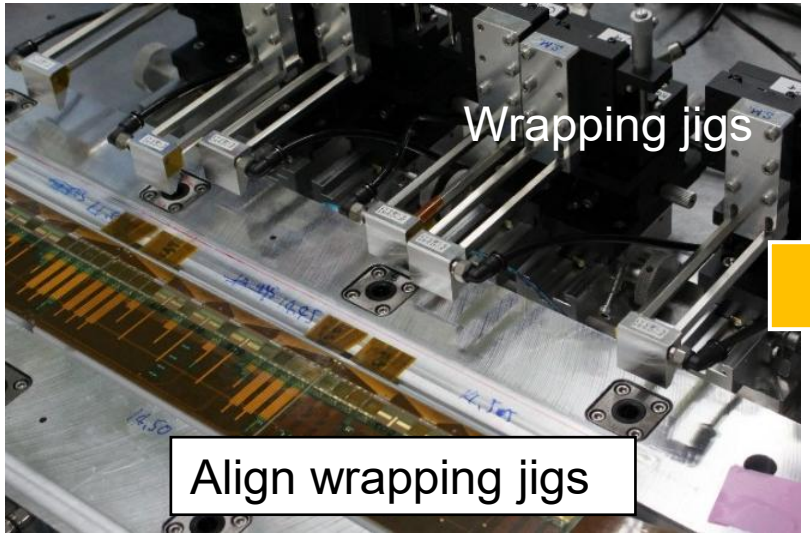


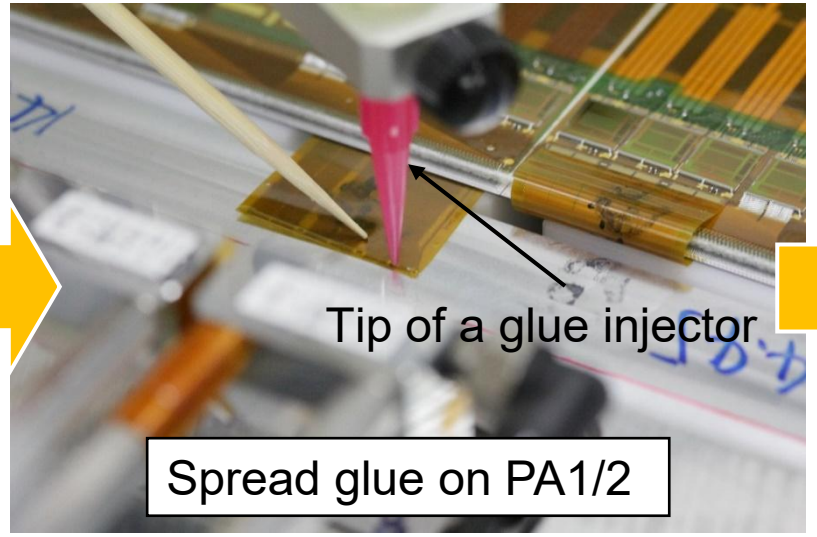


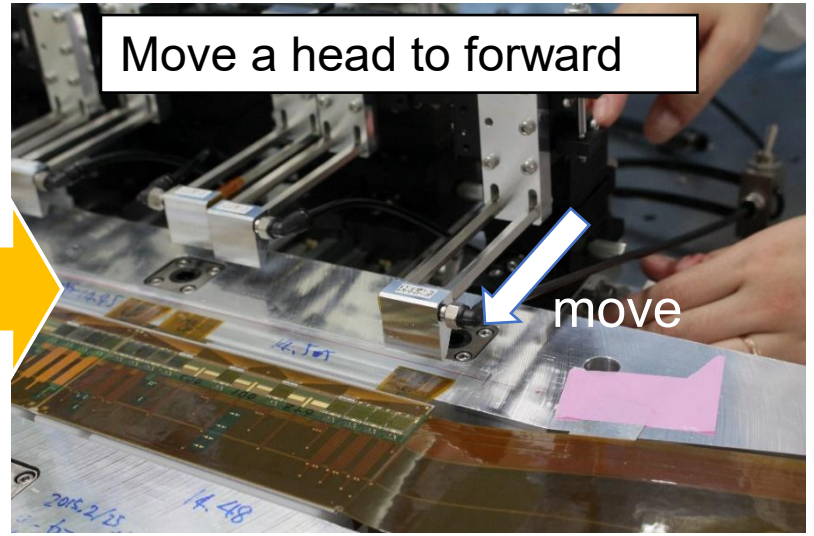


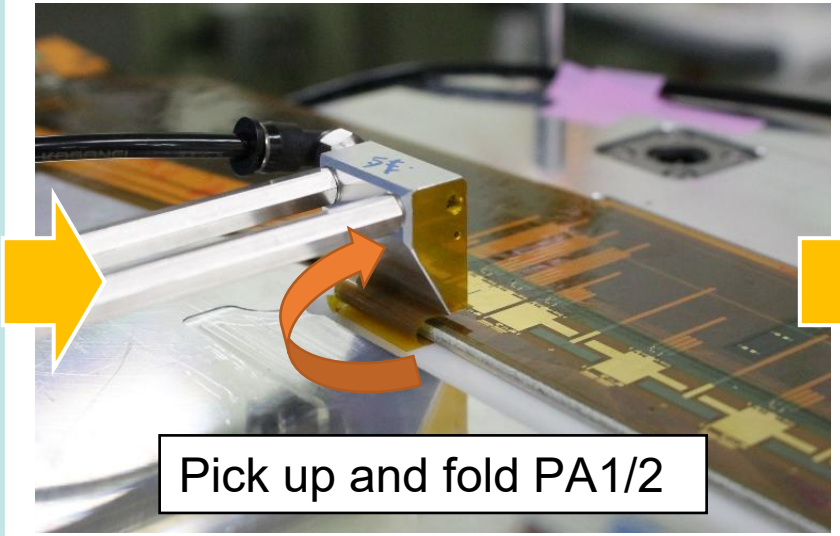
Low material budget: 0.7%X_0 per layer
Low noise due to the short sensor–APV25 connection length

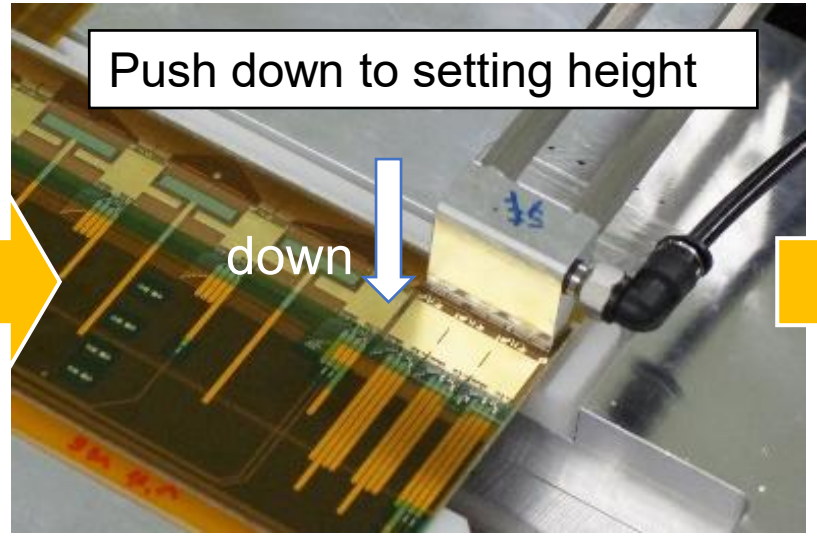
Wrapping Procedure

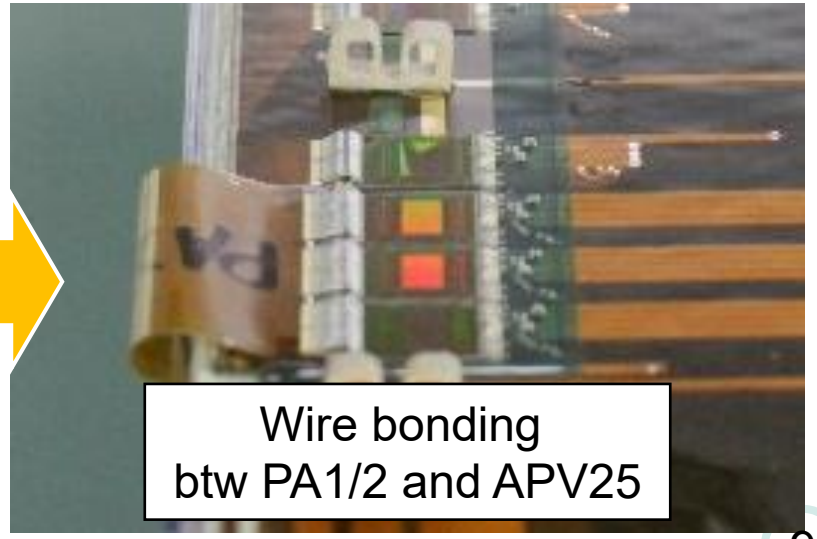












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  - 2 PXD
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- Double-sided Silicon Strip Detector
- Ladders
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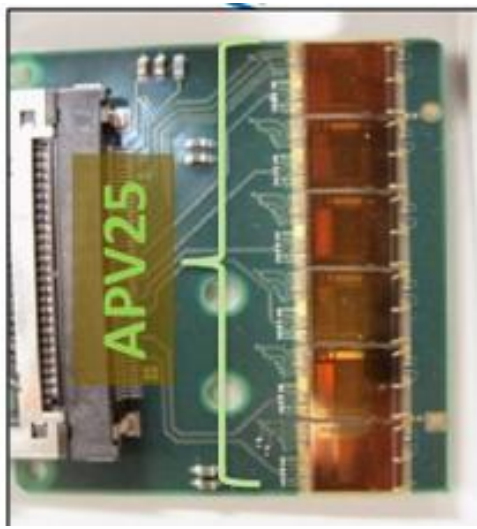
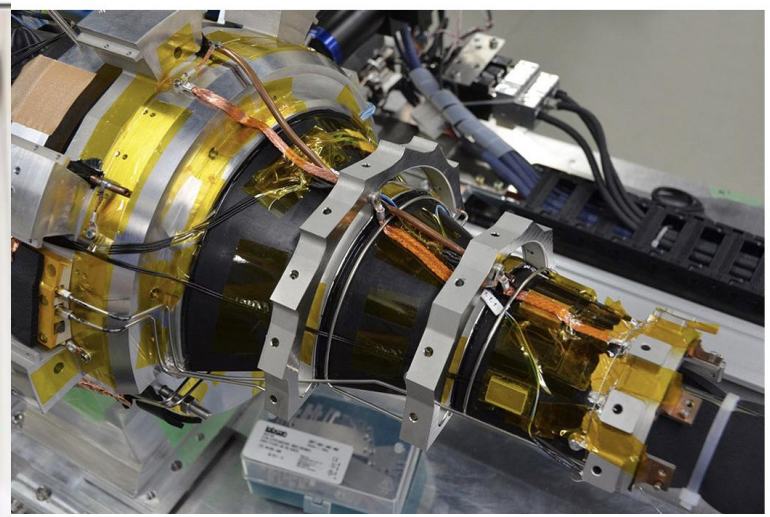
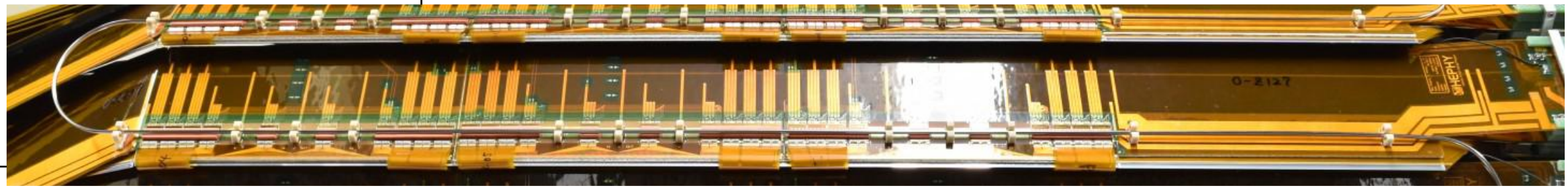
- **Cooling** ➡️
- Construction
  - Wire boding & Gluing
- Re-installation @ LS1



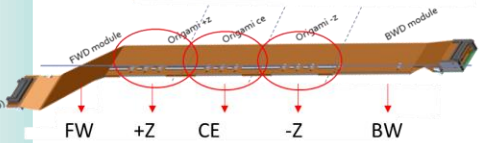


CO2 dual phase cooling -25 degC → APV25 temp. = ~10-20
Also thanks to Origami structure → safe & reduced pile line

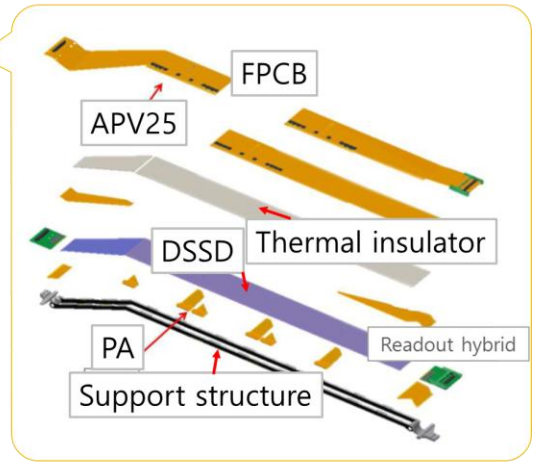


SVD – construction

Components of the L6 ladder



- 5 DSSD modules on L6
- Components
  - Hybrid board (2)
  - FPCB (3)
  - Flexible pitch adapter (PA)
  - DSSD (5)
  - Support structure (2)
  - etc.



Assembly Procedure

Repeat

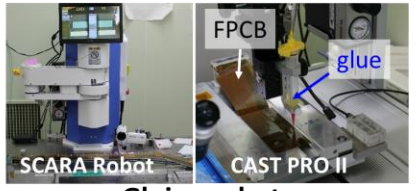
Sensor Alignment

- Jig with O(20 μm) tolerance
- Precision is measured by a CMM (Coordinate measuring machine).

CMM

Gluing

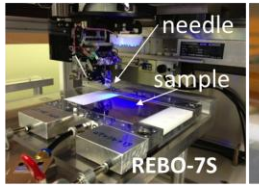
- Adhesive: epoxy (Araldite 2011)
- Glue is spread by gluing robots.



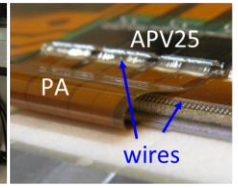
Gluing robots

Electrical connection*

- Wire-bonding
- Al (Si 1%) wire with Φ=25 μm

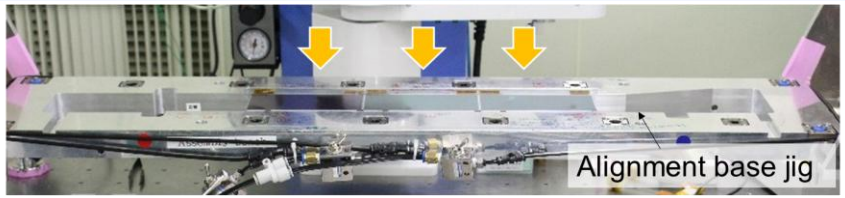


Wire-bonder

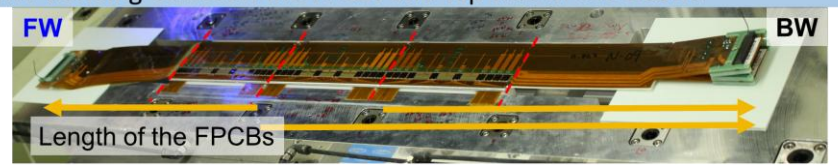


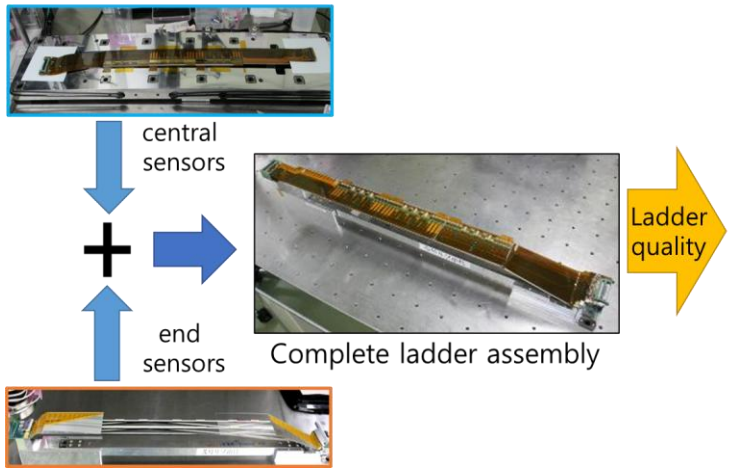
Bonded wires

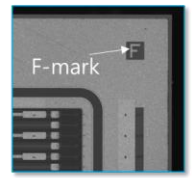
Align the DSSDs on the alignment base jig.



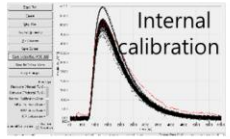
Attach the thermal insulator and the Origami FPCBs, and then perform wire-bonding between the FPCBs and top side of the DSSDs.

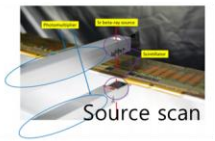






- **Mechanical** quality is verified by F-mark positions on the sensor using the CMM.





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- Construction ➡
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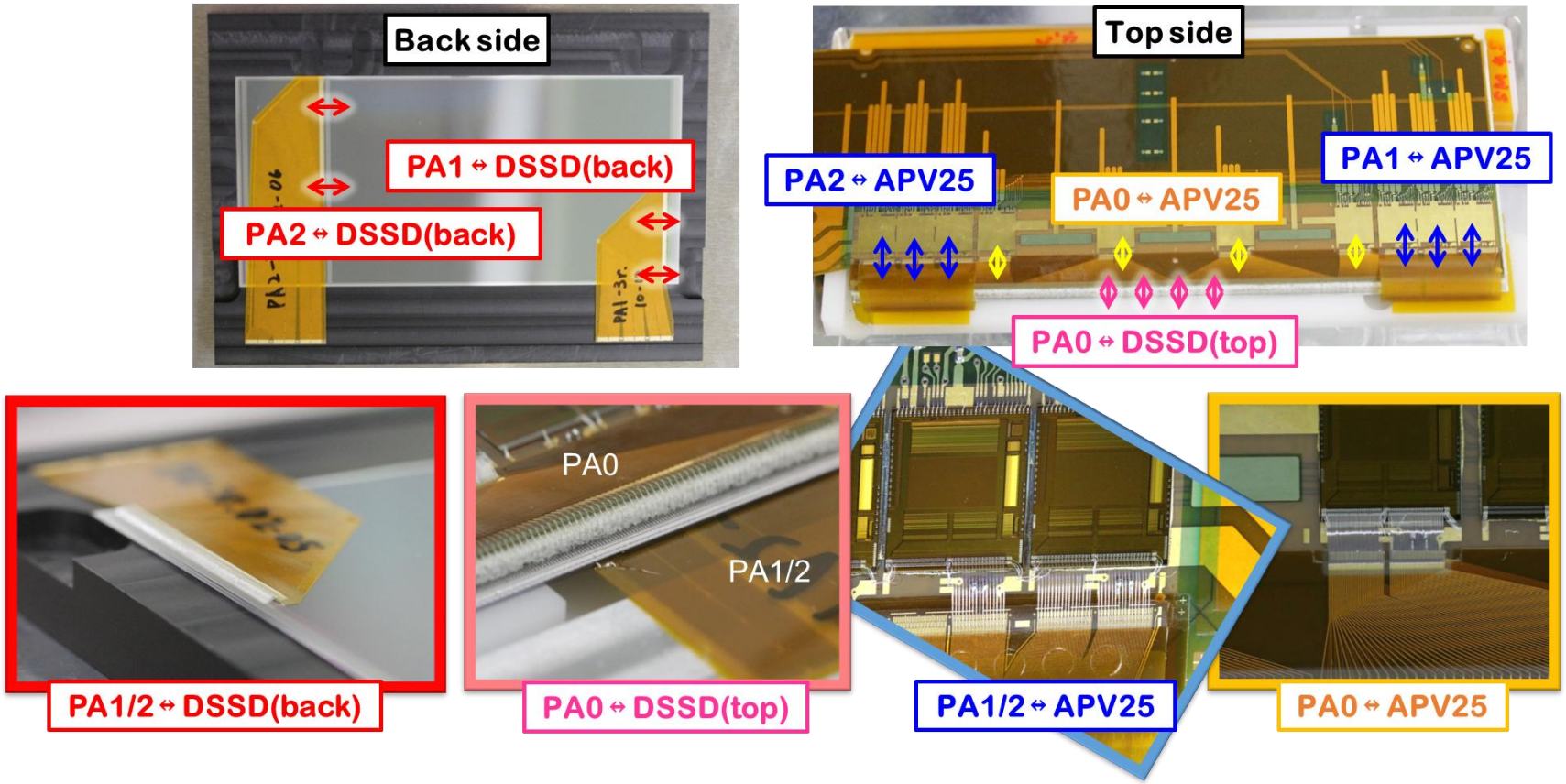
- Re-installation @ LS1



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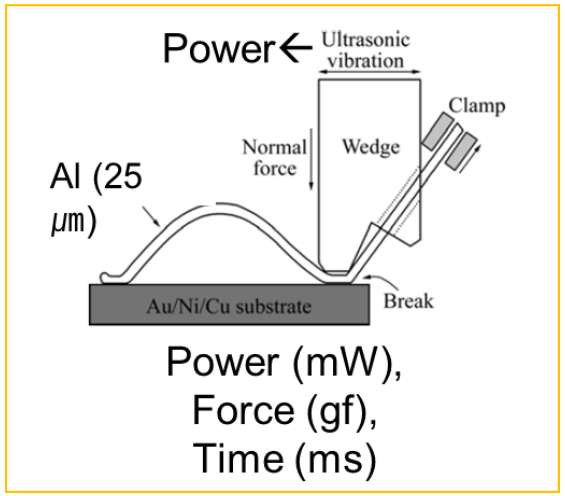
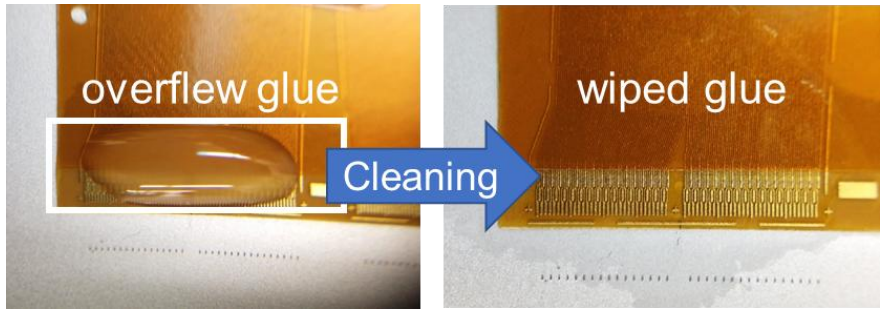
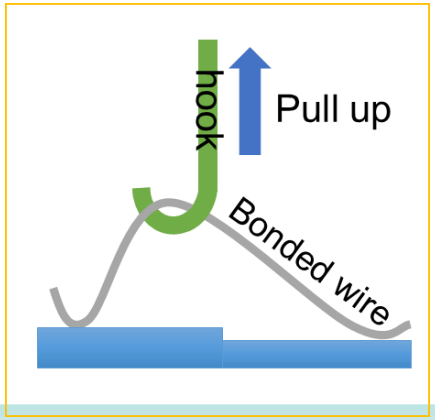
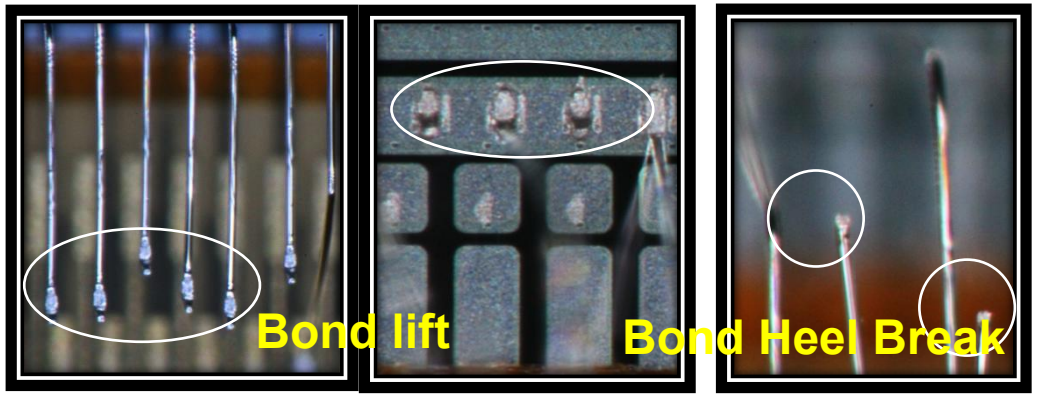




Optimized bonding parameters and gluing quality led to a 99% bonding efficiency - validated by pull-force measurements and bond pad inspections.





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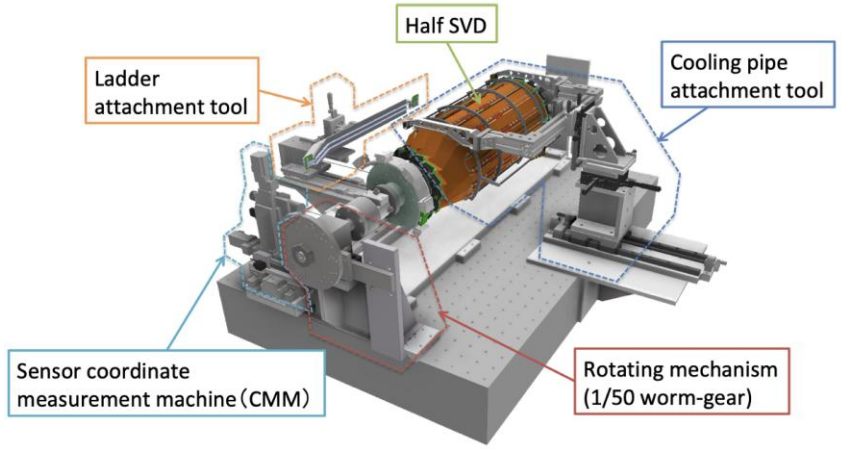

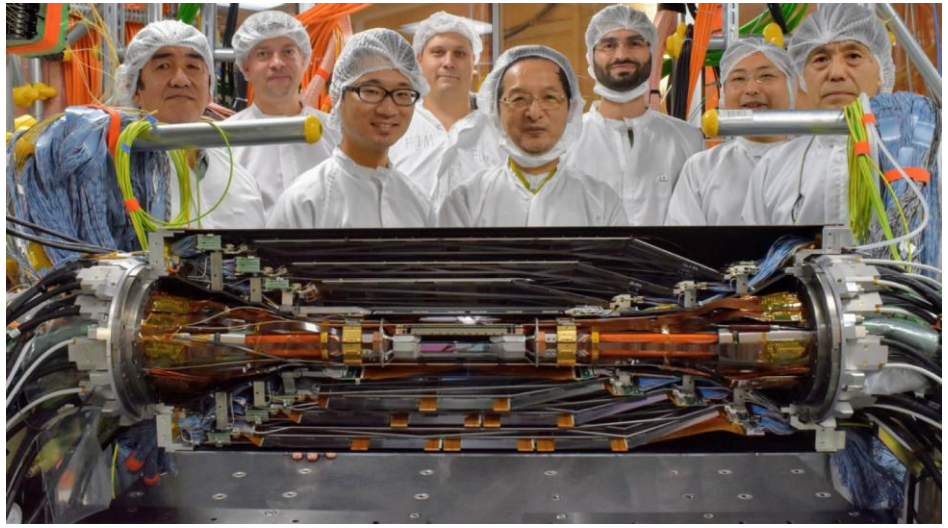

- **2008**: first Origami chip-on senor concept
- **2010**: Belle II Technical design report
- **2012**: ladder R&D
- **2016**: ladder mass production
- **2018:** 1st/2nd SVD half-shell assembled & installed in Belle II
- **2019**: first beam collision with complete detector

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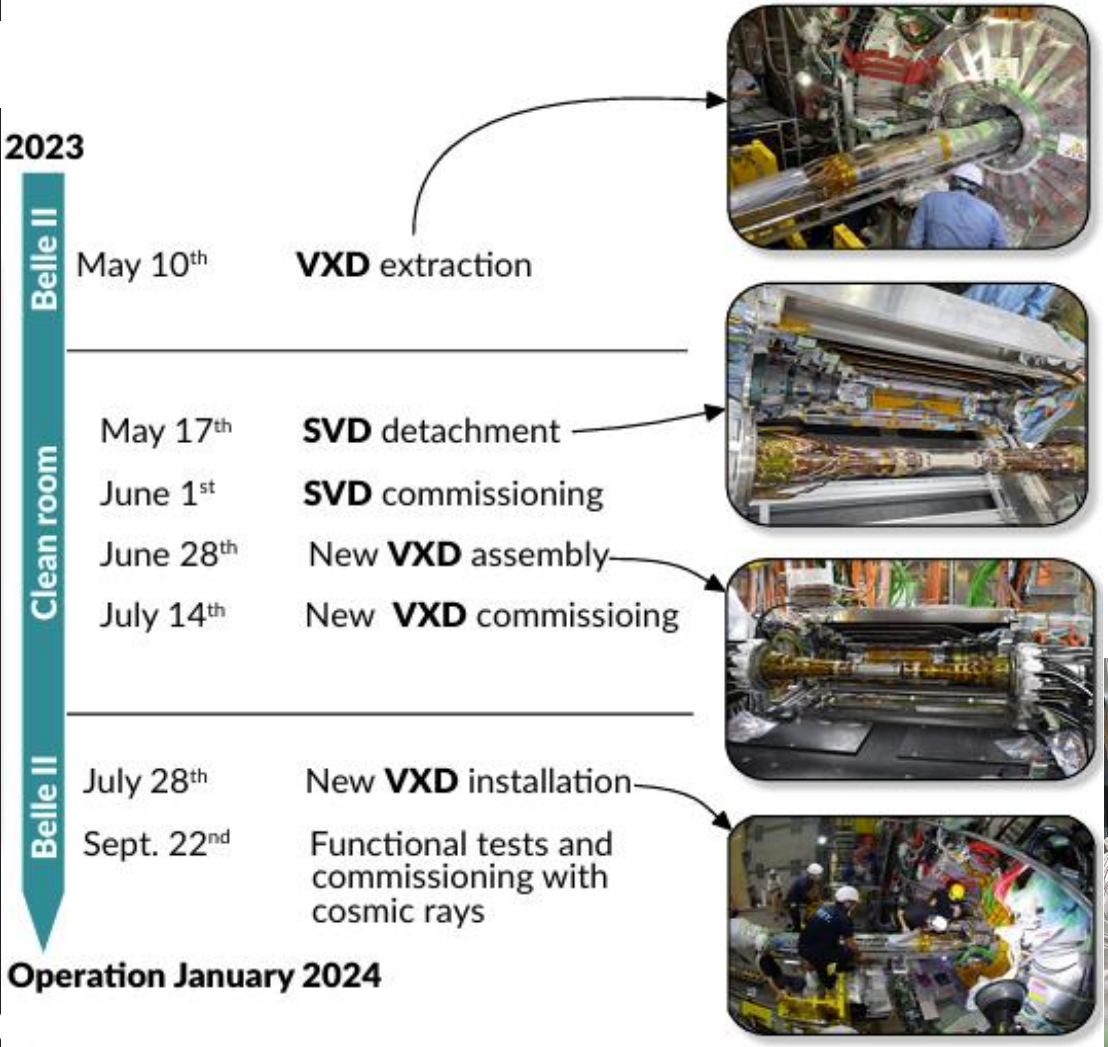


Upgrade VXD with a new PXD

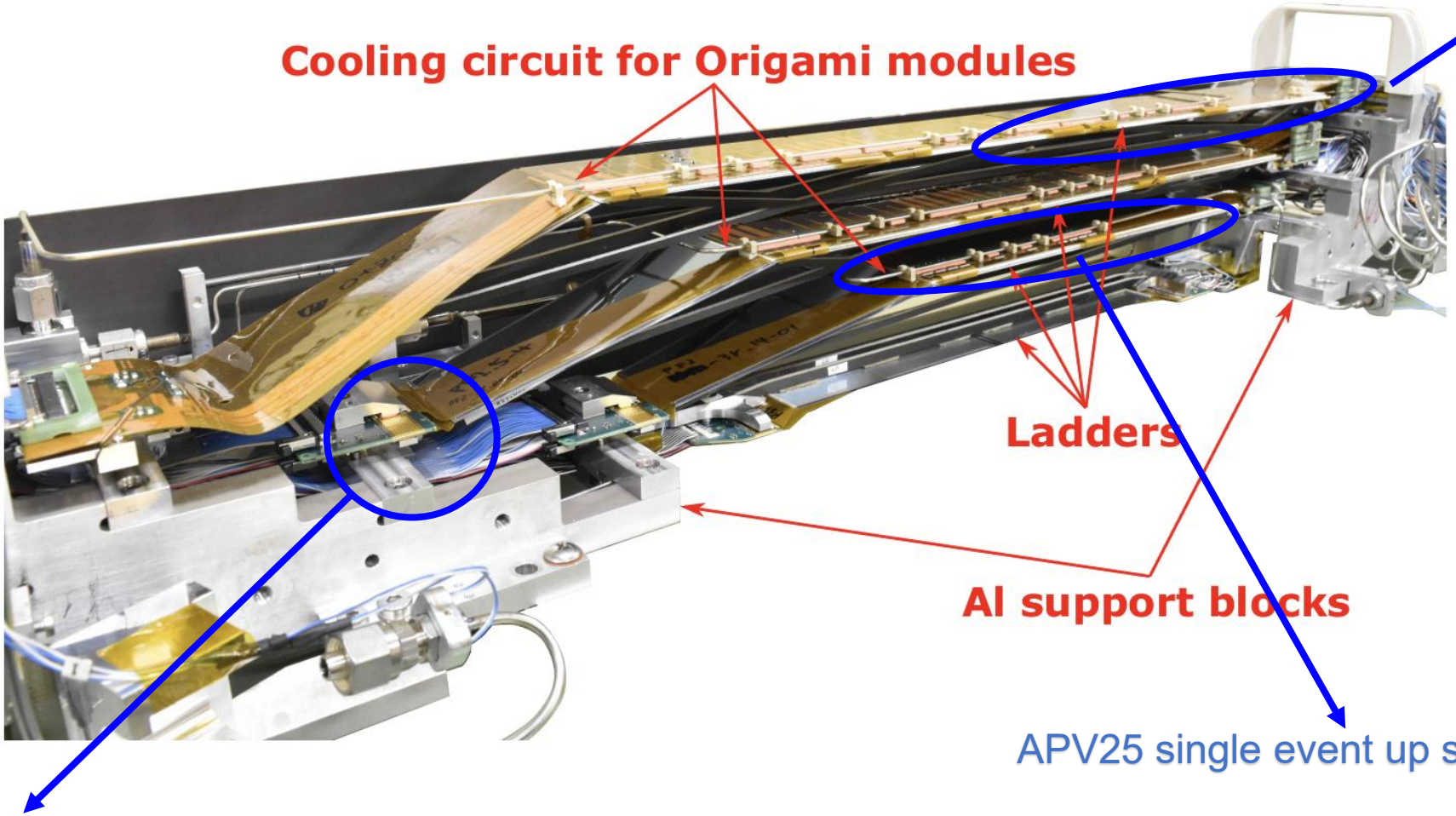
First time performing de-installation of VXD

Several SVD test campaigns to promptly **spot problems** and **sanity check**

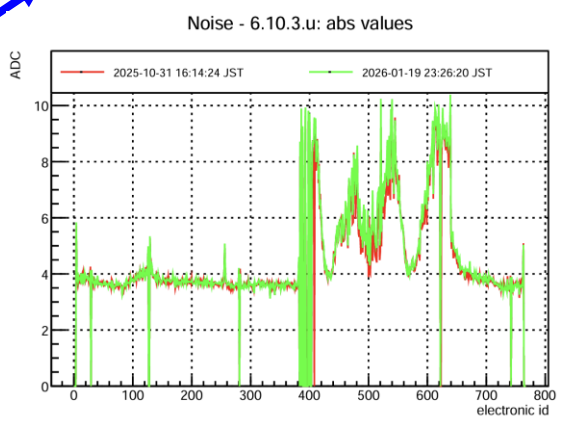
The reinstalled detector

→ **demonstrated good performance**

Design and Construction - issues

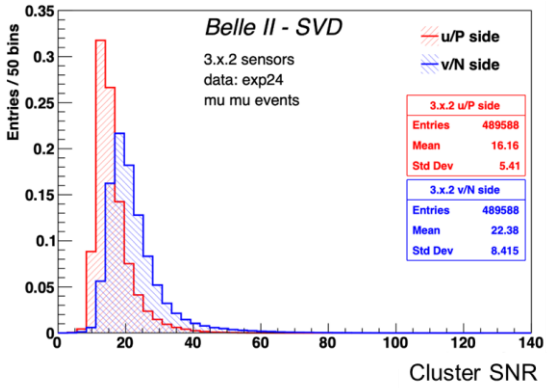


Crosstalk issue



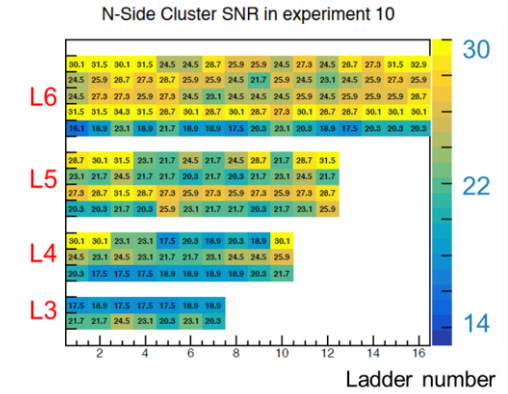
APV25 single event up set (SEU)

FWD PA peel off issue



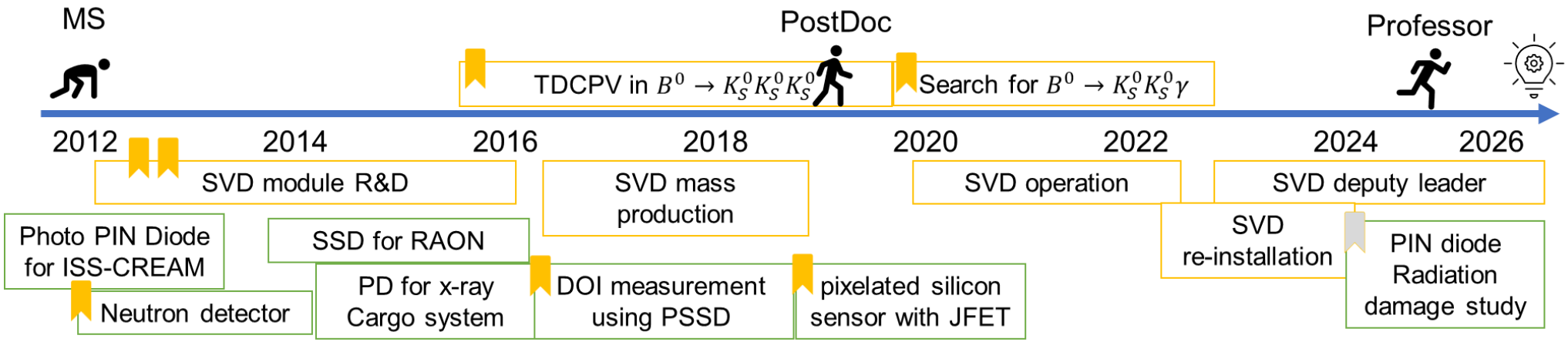
SVD operation & performance

to be presented next Particle Detector Workshop 2026



Summary

- The **SVD plays a crucial role** in Belle II and has been one of the most stable and best-performing detector.
  - Essential contributions of electronics and mechanical engineers and technicians.
- Radiation effects observed so far remain moderate, and the SVD performance is expected to be maintained up to the **VTX upgrade @2032**
- Over more than 10 years of involvement in the SVD, we (I) have accumulated extensive experience in design, construction, operation, and performance.
  - The SVD technical paper published in JINST (JINST 17 P11041 2022)



Belle II – SVD
& VTX upgrade
EIC – BIC
LGAD for x-ray
+ ???

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