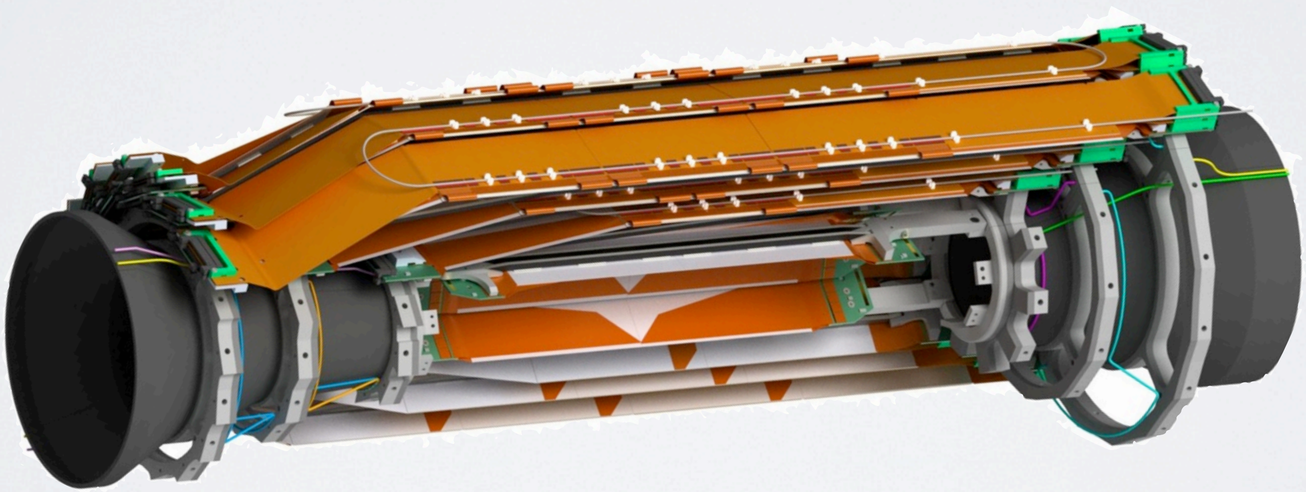
Belle II

SVD

INFN Istituto Nazionale di Fisica Nucleare SEZIONE DI PISA

The BelleII SVD Origami modules



Antonio Paladino on behalf of the BelleII SVD group - 22/02/2016

LPNHE, Paris - 11th Trento Workshop

OUTLINE

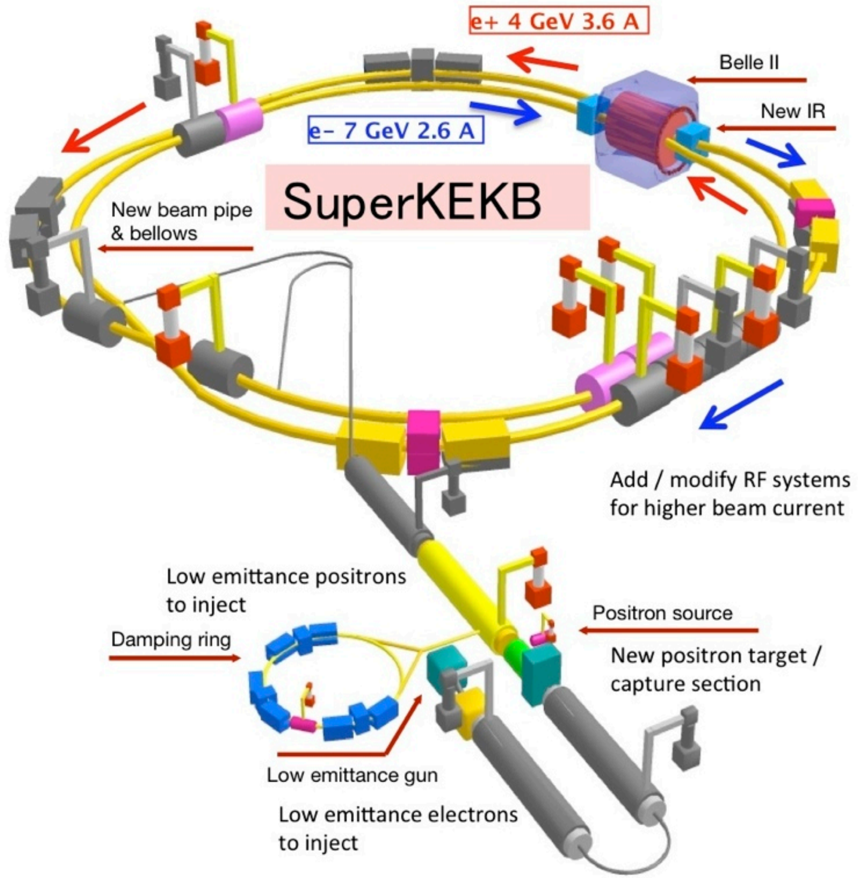
- BelleII at SuperKEKB
- The BelleII SVD
- Ladder overview and the Origami concept
- Challenges in ladder assembly process
- Mechanical measurements and performance

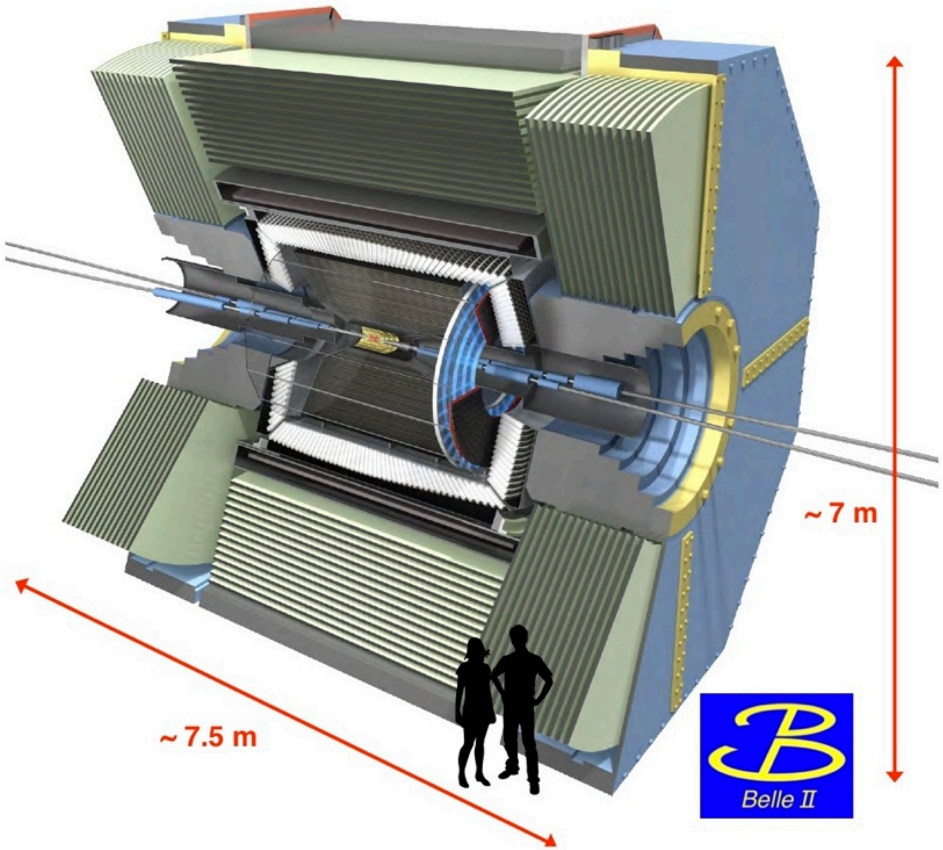
The BelleII experiment at SuperKEKB

The BelleII detector will operate at the asymmetric e^+e^- collider SuperKEKB (Tsukuba, Japan) based on the "Nano-Beam" scheme through which a target luminosity of $L=8.0 \times 10^{35}$ cm^{-2} s^{-1} will be achieved.

New Physics beyond the SM

CP-violating parameters in different B-decay modes will isolate a New Physics model out of several actual hypotheses.



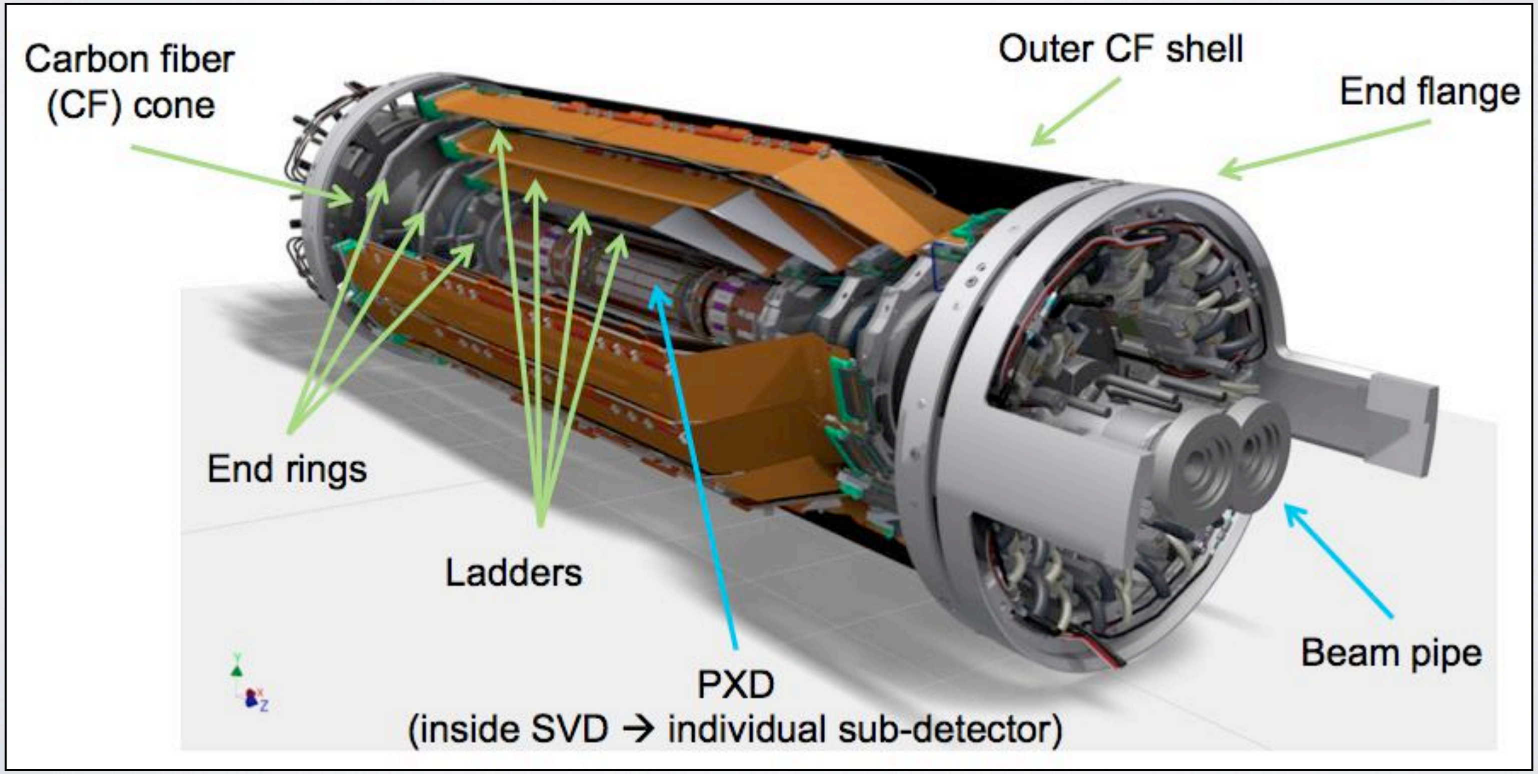


The BelleII VerteX Detector

Compared to KEK/BELLE: reduced boost by 2/3 & higher luminosity/ background → thin pixel detector at small radius & silicon strip detector with fast readout.

The whole VerteX Detector **(VXD)** is now composed by:

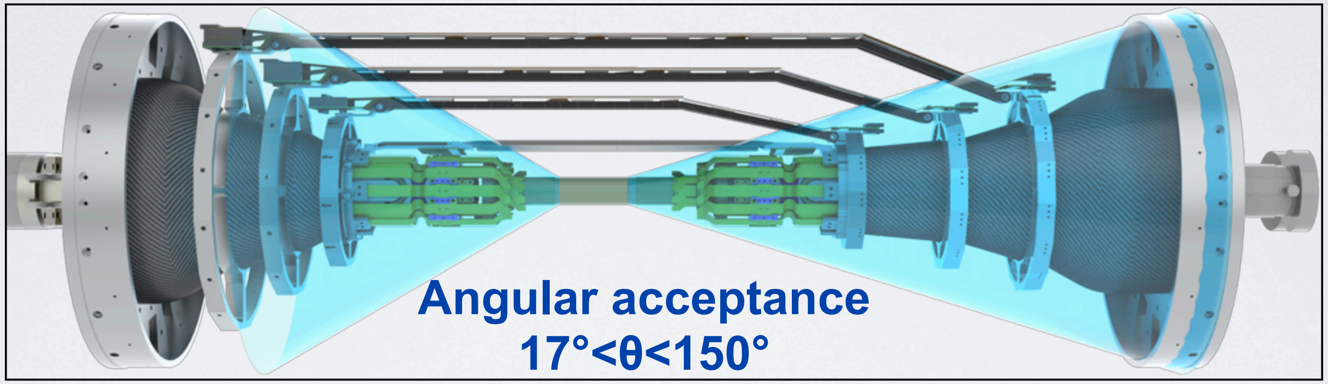
- **PiXel Detector (PXD)**, the innermost detector consisting of two layers of DEPFET pixels.
- **Silicon Vertex Detector (SVD)**, made by four layers of Double-Sided Silicon Strip Detectors (DSSD).



The BelleII SVD feautures

Vertex Detector has been optimized for the precision vertex reconstruction of the short-lived B meson decays. For this reason acceptance was extended w.r.t. Belle SVD:

- in radius, that means longer ladders (outer radius of 140 mm);
- in forward region, adding slanted sensors.



- Low momentum track reconstruction requires reduction of the multiple scattering, that leads to low material budget on the sensible volume.
- read-out of single sensor (no ganging) essentially due to:
  - reduce capacitive load on a fast read-out electronics;
  - reduce occupancy (shorter strips).

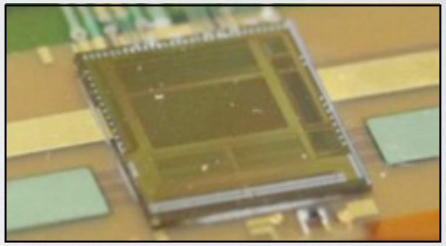
Single sensor read-out would require electronics placed on active area.

Read-out electronics and chip-on-sensor

To cope with BelleII's high luminosity background, the read-out chip should:
- have a short signal shaping time to minimize the occupancy.
- be radiation hard.

We have chosen the APV25 chip, originally developed for CMS:
- Shaping time = 50 ns
- Radiation hardness > 1MGy
- input channels = 128 per chip
- 192-deep analog pipeline for dead time reduction
- thinned to **100 μm** to reduce material

APV25 chip



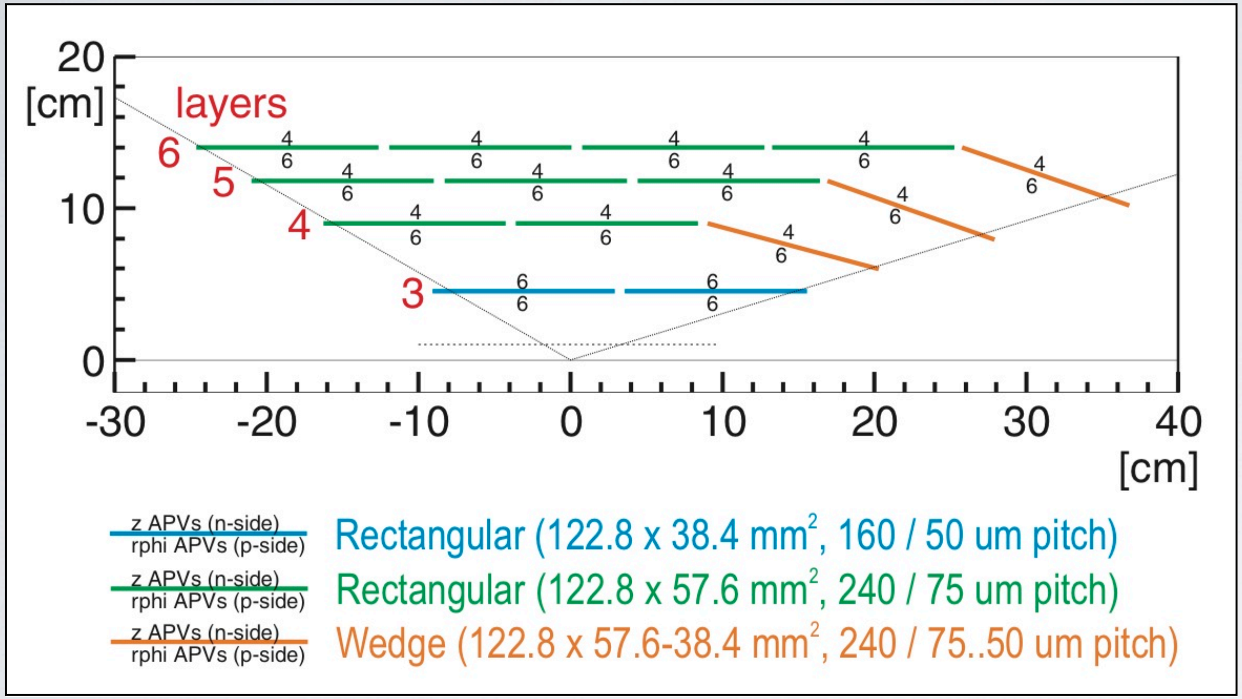
Read-out electronics inside active area	APV25 characteristics

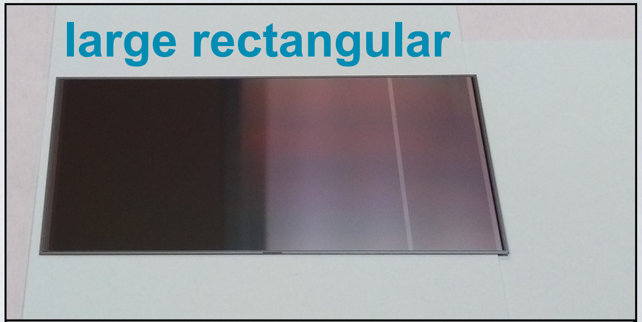
↓

Development of the chip-on-sensor concept, placing the APV25 chips in the active area of the SVD.
Origami ladder concept has been designed to fulfill this idea with minimum material.

SVD Silicon sensors

Double Sided silicon Strip Detectors of 300 μm thickness





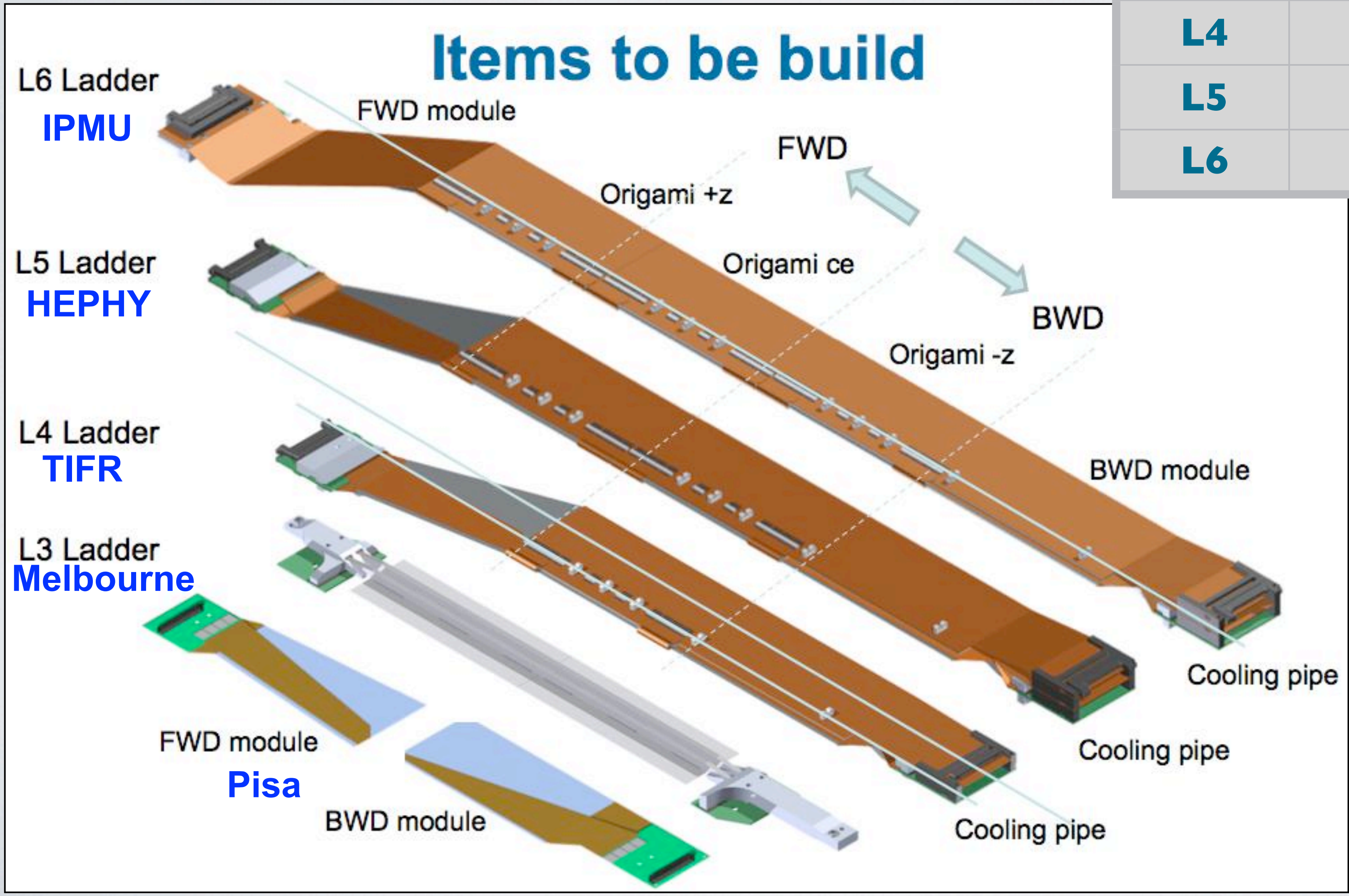
Rectangular sensors provided by HPK
Wedge sensors provided by Micron

HPK sensors	Large sensor	Small sensor
# strips p-side	768	768
# strips n-side	512	768
# intermediate strips p-side	767	767
# intermediate strips n-side	511	767
Pitch p-side	75 μm	50 μm
Pitch n-side	240 μm	160 μm
Area (total)	7442.85 mm^2	5048.90 mm^2
Area (active)	7029.88 mm^2 (94.5%)	4737.80 mm^2 (93.8%)

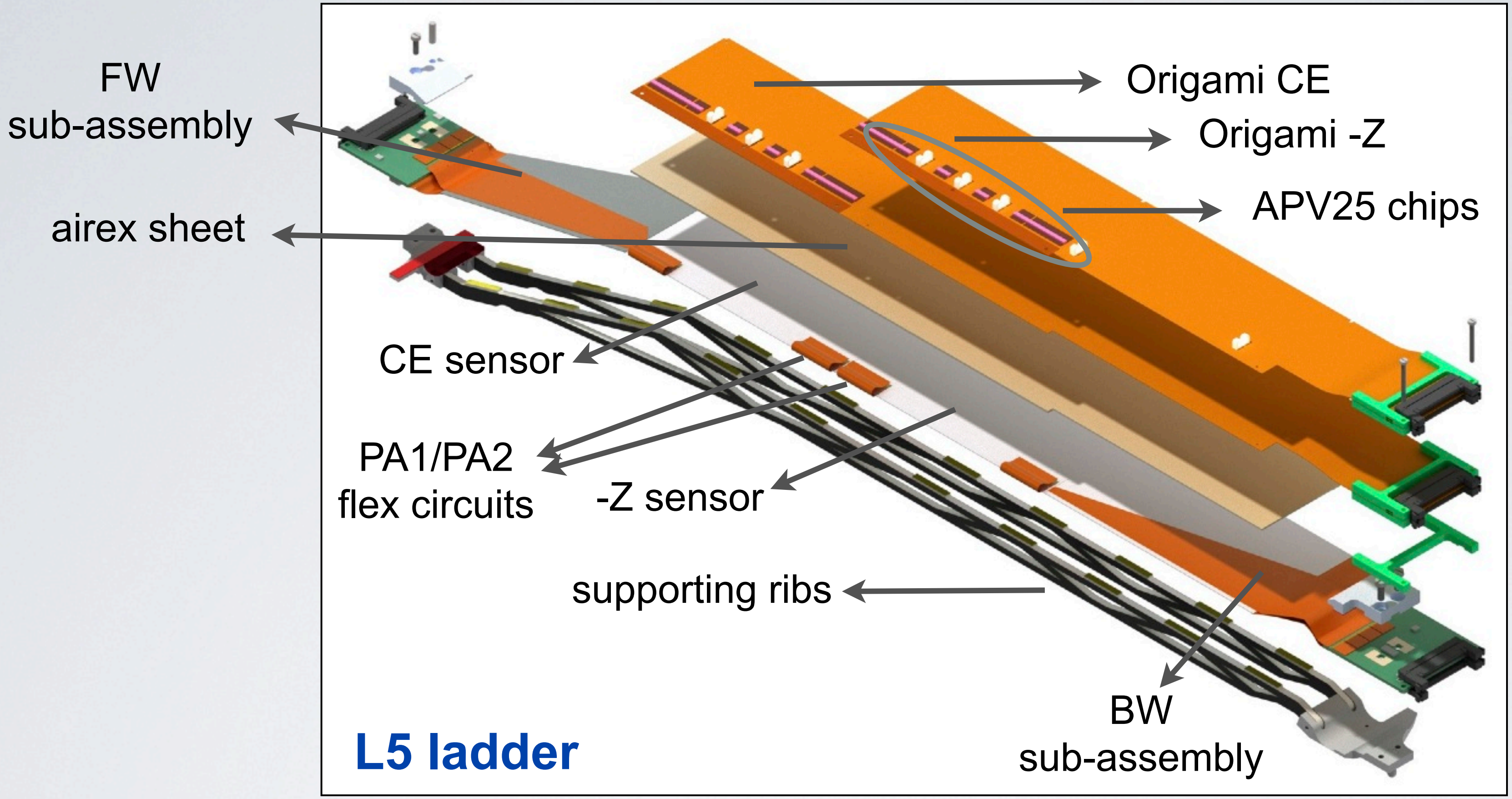
Micron sensors	Value
# strips p-side	768
# strips n-side	512
# intermediate strips p-side	767
# intermediate strips n-side	511
Pitch p-side	$75 \ldots 50\,\mu m$
Pitch n-side	$240\mu m$
Area (total)	6382.6 mm^2
Area (active)	5890 mm^2 (92.3%)
Slant angles	Layer 6: 21.1° Layer 5: 17.2° Layer 4: 11.9°

The SVD ladders overview

Layer	# of ladders	radius (mm)
L3	7	39
L4	10	80
L5	12	115
L6	16	140

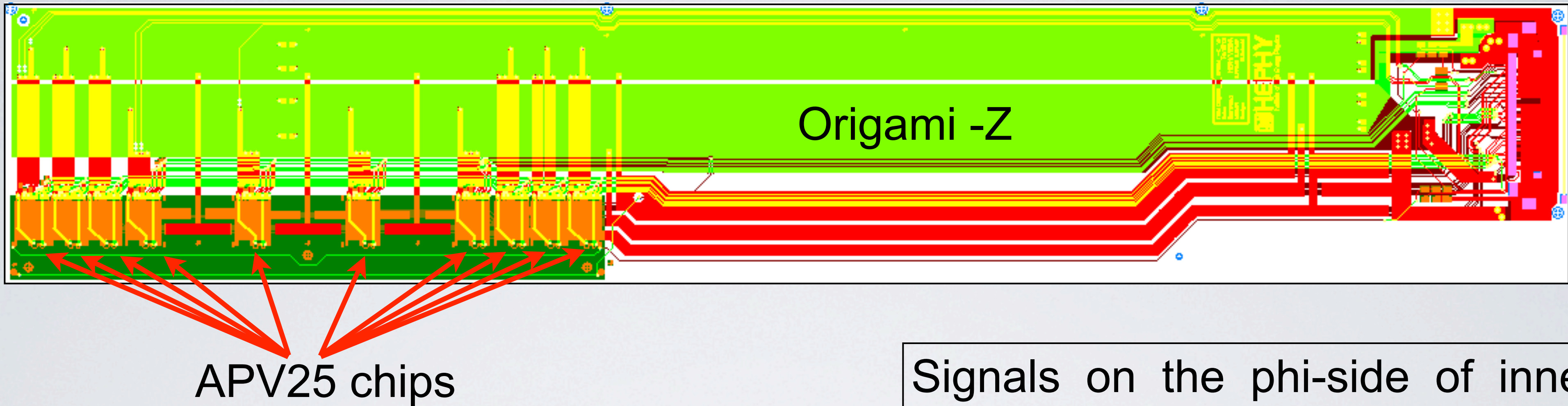


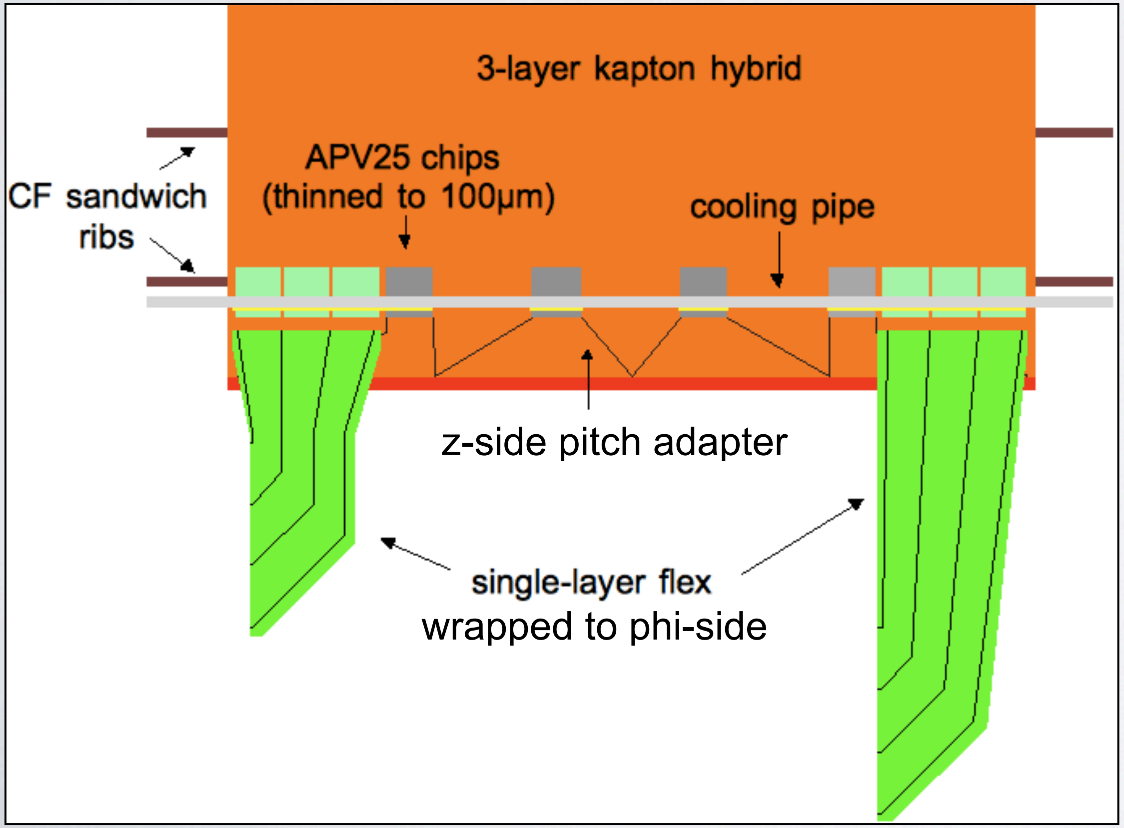
The SVD ladder design



FW and BW parts of ladders are read out by APV25 chips on hybrid boards placed outside of sensible volume of SVD.
For inner sensors APV25 chips are placed on a 3-layer kapton hybrid circuits called Origami, which are glued onto the sensors.

The Origami concept

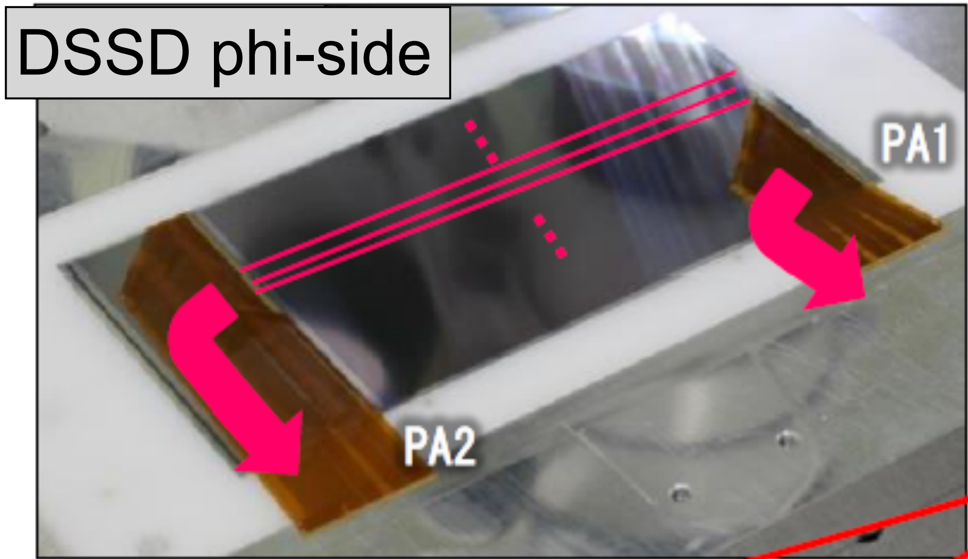


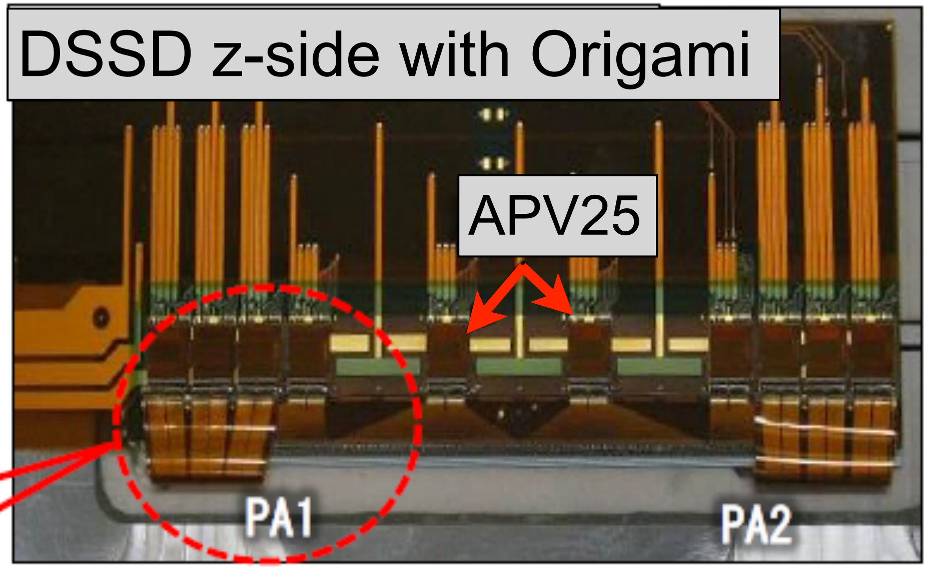


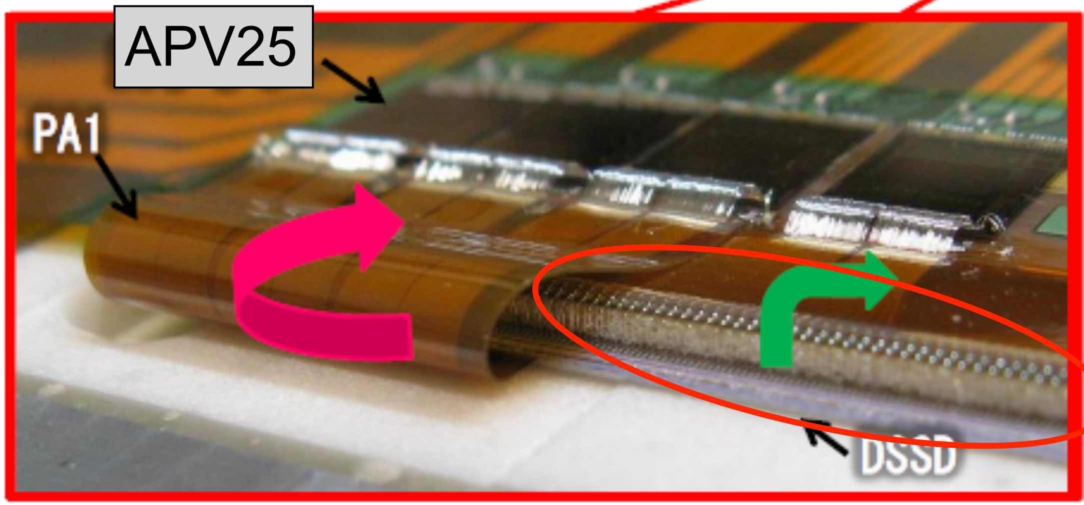
Signals on the phi-side of inner sensors are transferred to the z-side by flex circuits, so that all APV25 chips can be mounted on z-side.
In this way, placing read-out chips on the same line, only one cooling channel is required to chill them, thus keeping low the material budget.

Actual average material budget for the ladder:
x/X_0 = 0.6%

The Origami concept







PA1/PA2 flex circuits are wrapped to bring signals from phi-side to z-side of the DSSD and are glued above the micro bondings of the z-side.

Wire bondings DSSD ↔ PA0

Ladder assembly process and challenges

Assembly process summary

- FW/BW sub-assemblies gluing on the ribs.
- PA1/PA2 gluing and wire bonding on sensor phi-side.
- Airex and Origami gluing on sensor z-side.
- wire bonding DSSD ↔ PA0 ↔ APV25.
- PA1/PA2 wrapping.
- wire bonding PA1/PA2 ↔ APV25.

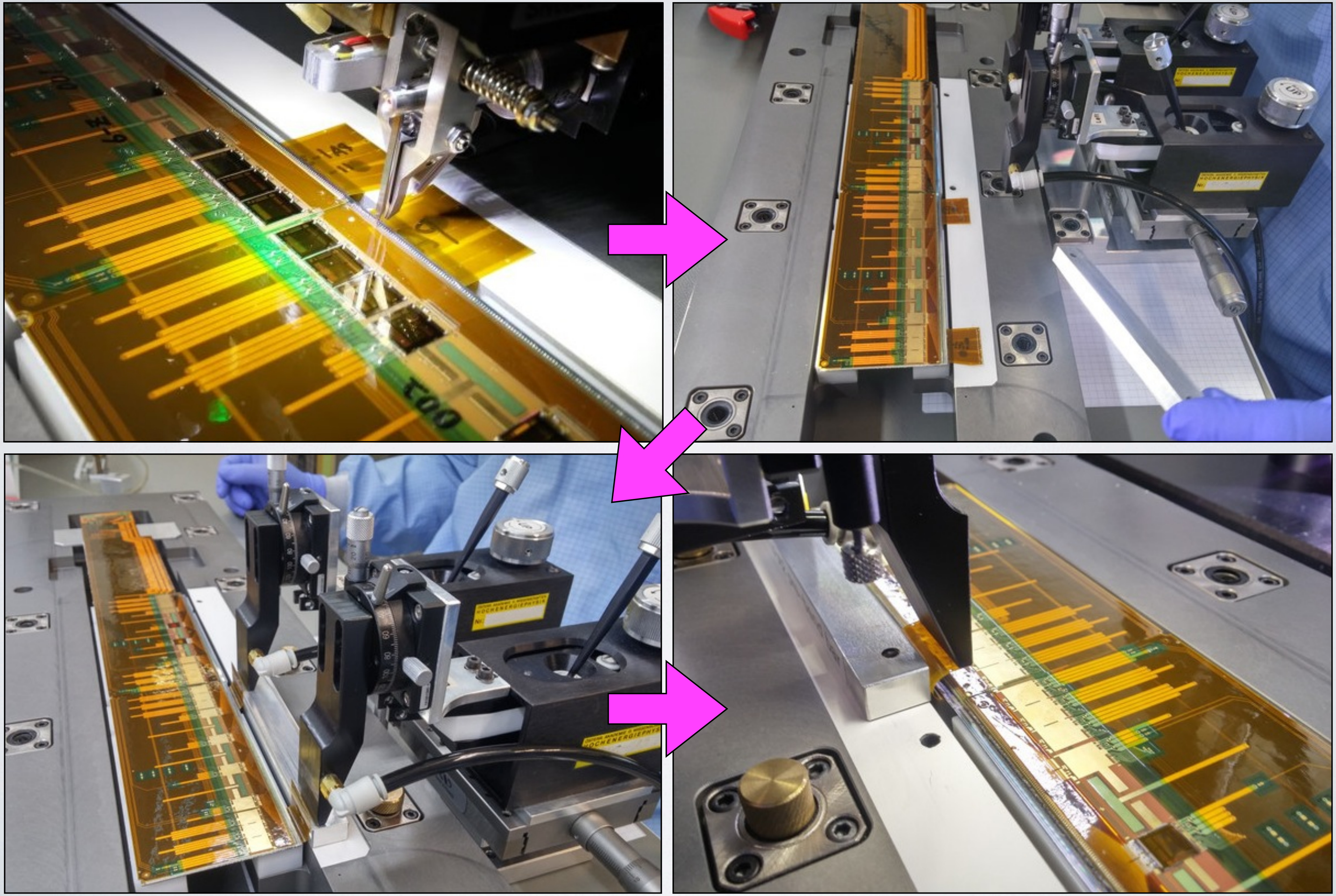
wrapping jigs

The whole ladder assembly takes up to three weeks, dominated by glue curing in several steps.

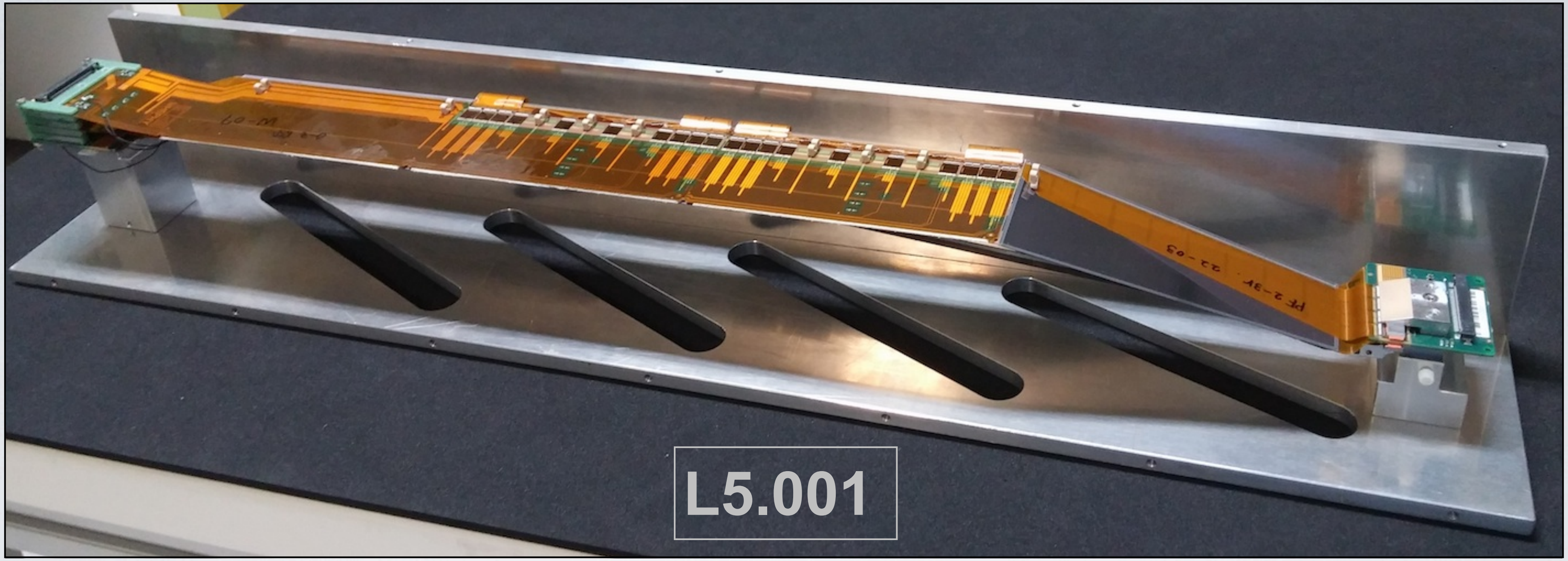
Moreover:

- Alignment of O(100 μm) between all ladder components should be achieved and kept during all the complex assembly steps.
- The wrapping needed the design of a sophisticated dedicated jig.
- Wrapping phase is critical because of the already existing wire bondings, over which the PA1/PA2 must be wrapped without any damage, and for the glue spread, which could cover bonding pads of PA1/PA2.
- All procedures require a high quality of all the jigs used, whose precision falls within design limits.

PA1/PA2 wrapping process



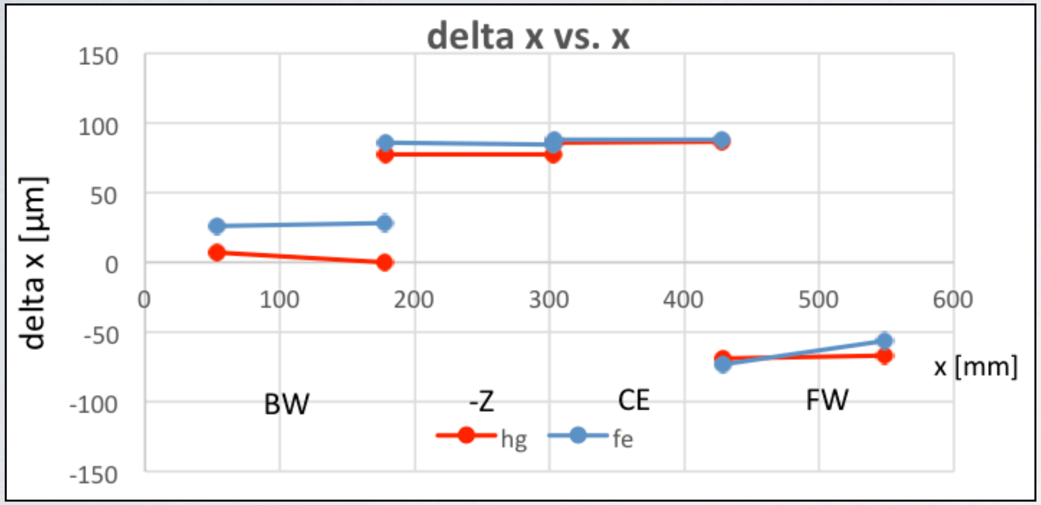
Ladder production status

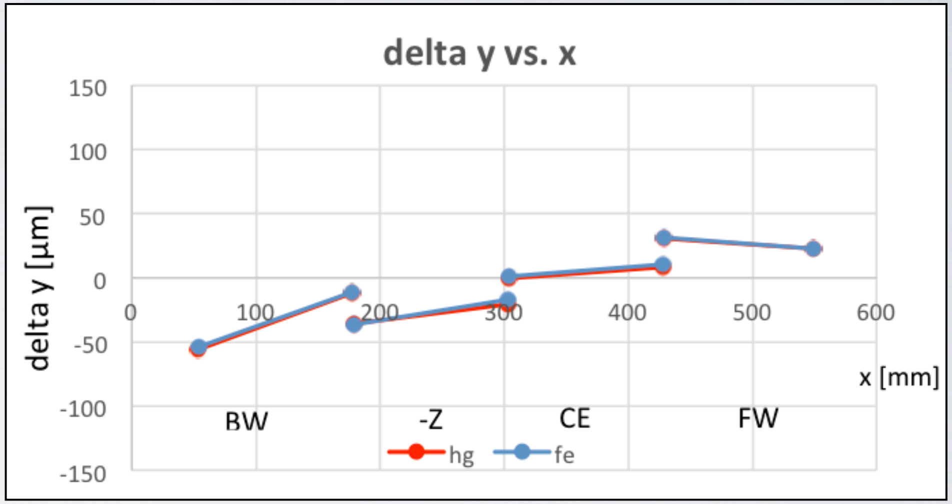


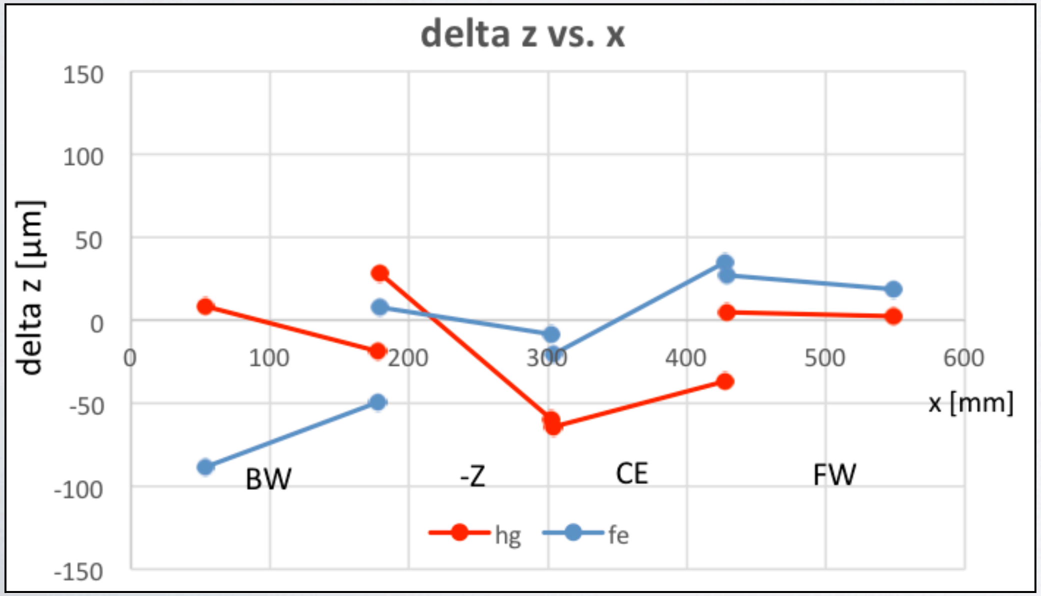
Every production site has proven its capability of building ladders with required precision.
Pisa started with mass production of FW/BW sub-assemblies on July 2015.
HEPHY started mass production in January 2016.
All other sites (Melbourne, TIFR, IPMU) have already produced electrically working ladders and will start mass production in the next months.
Start of ladder mount on support structure is foreseen in February 2017.

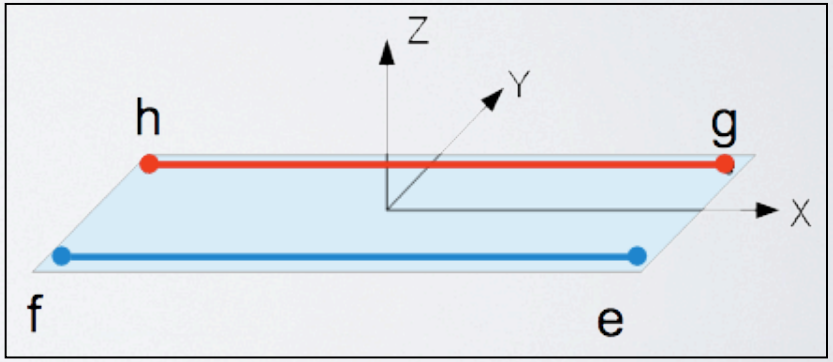
Measurements

The following plots show displacement of every sensor corner w.r.t. nominal positions for a L5 ladder (average over 4 different measurements).
Better than ±100 μm in all directions.



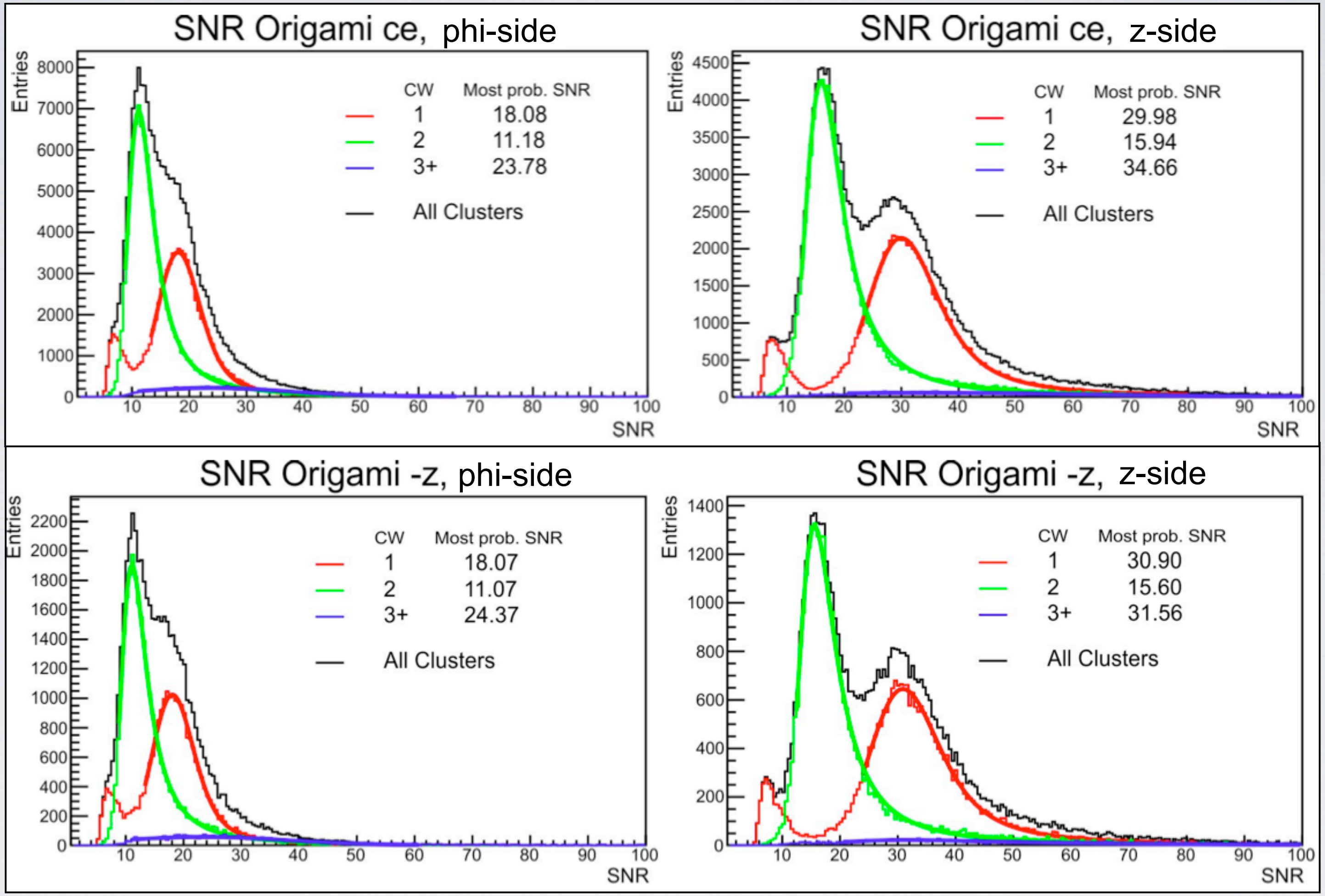






CERN beam test results - SNR

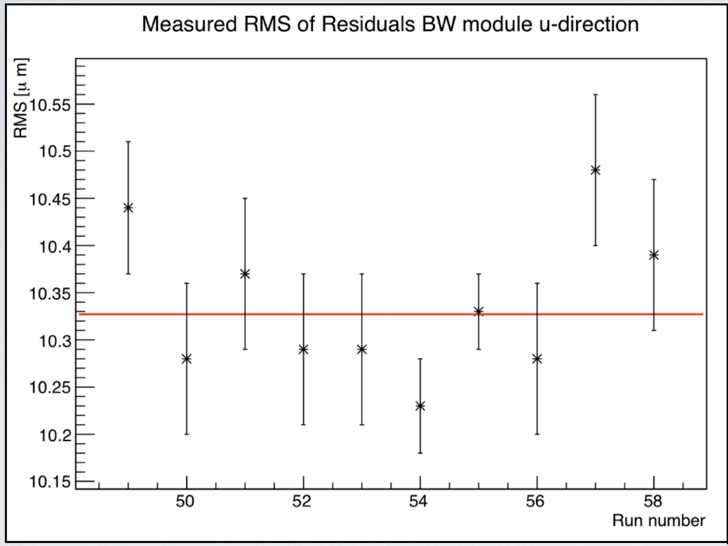
Signal to Noise Ratio evaluated for a L5 ladder for different cluster widths.

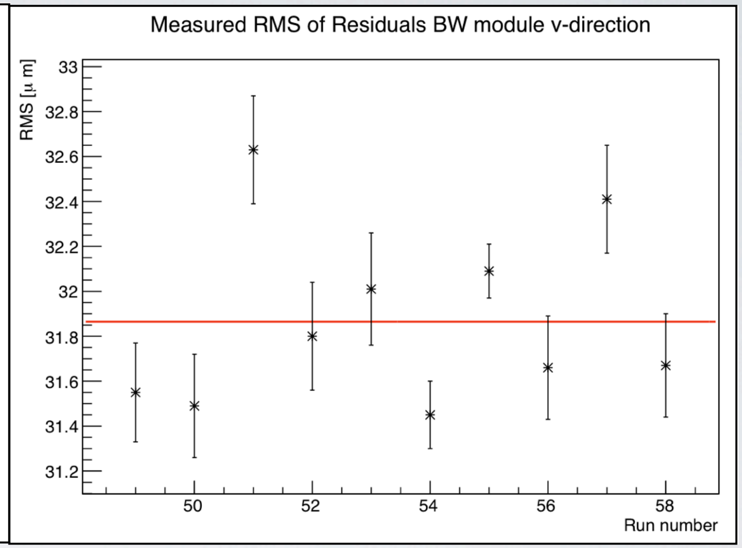


For cluster width = 1
$SNR_{phi\text{-}side}$ = 18
$SNR_{z\text{-}side}$ = 30
Similar results for FW/BW.

CW=2	without cooling	CO_2 cooling at -20°C
n-side	14	15
p-side	12	12.5

FW/BW sub-assemblies resolution





Analysis of CERN Beam Test data reveals that resolution for FW and BW sub-assemblies, evaluated for different beam positions, is better than digital resolution.

Digital resolution

Measured residuals Forward module (wedge)

side	pitch	pitch/$2\sqrt{12}$	measured residuals
n-side	240 μm	34.6 μm	31.6 - 34.8 μm
p-side	50 - 75 μm	7.2 - 10.8 μm	8.0 - 10.8 μm

Measured residuals Backward module (rectangular)

side	pitch	pitch/$2\sqrt{12}$	measured residuals
n-side	240 μm	34.6 μm	31.5 - 32.4 μm
p-side	75 μm	10.8 μm	10.2 - 10.5 μm

Summary and remarks

- Precision B-decay vertex detection is a crucial issue to access physics beyond the Standard Model.
- Chip-on-sensor idea was realized with Origami concept.
- All sites have proven their capability of producing ladders with the required precision.
- Good performance has been confirmed by electrical measurements and beam tests.
- Ladder mass production already started.
- SVD ladder mount scheduled in February 2017.
- SVD commissioning in October 2017.
- BelleII first physics run foreseen in fall 2018.

THANKS

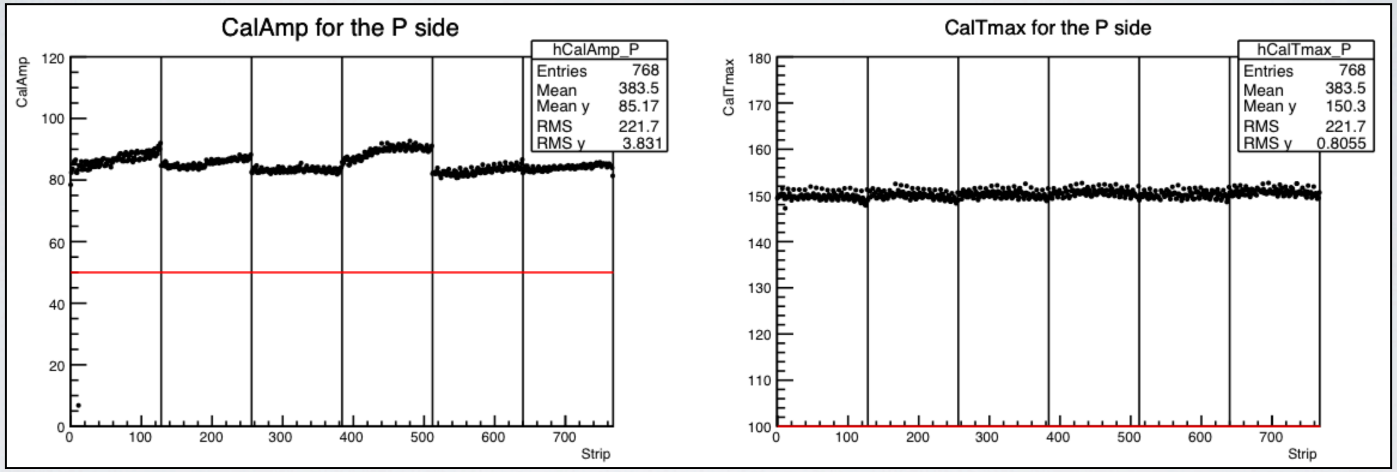
Belle II

SVD

INFN Istituto Nazionale di Fisica Nucleare
SEZIONE DI PISA

BACKUP SLIDES

FW/BW sub-assemblies defects



Electrical tests are performed on each sub-assembly to assess its quality. An automatic program called aDefectFinder was developed to analyse data from electrical tests and spot defects.

In Pisa, where FW/BW sub-assemblies are built, a comparison between DSSD and sub-assembly defects shows that introduced defects during the assembly process are less than 0.1%.

P-Side	2 (0.26%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.13%)	1 (0.13%)
15 (1.95%)	16 (2.08%)	p_Noisy	p_Open	p_Short	p_Pinhole	p_Particle_Resp
12 (1.56%)	P_Implant_open	0	0	0	0	0
1 (0.13%)	P_Pinhole	0	0	0	1	0
2 (0.26%)	P_Bad_Isolation	0	0	0	0	0

N-Side	4 (0.78%)	2 (0.39%)	0 (0.00%)	2 (0.39%)	0 (0.00%)	0 (0.00%)
	4 (0.78%)	n_Noisy	n_Open	n_Short	n_Pinhole	n_Particle_Resp