Vertex Detector for the Super KEK B factory

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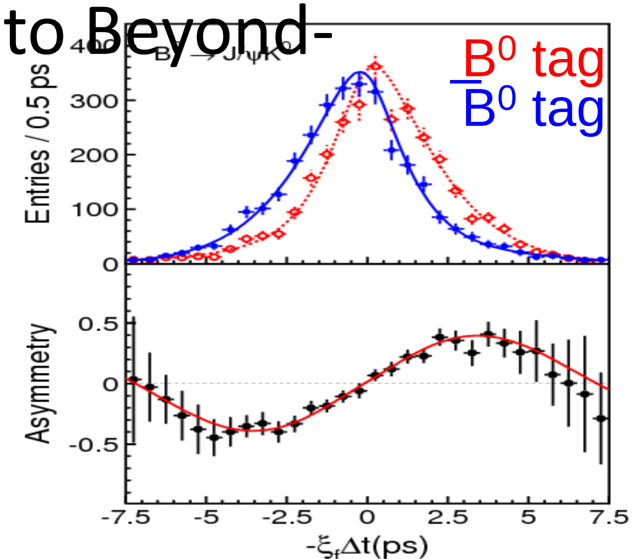
Status of Super KEKB

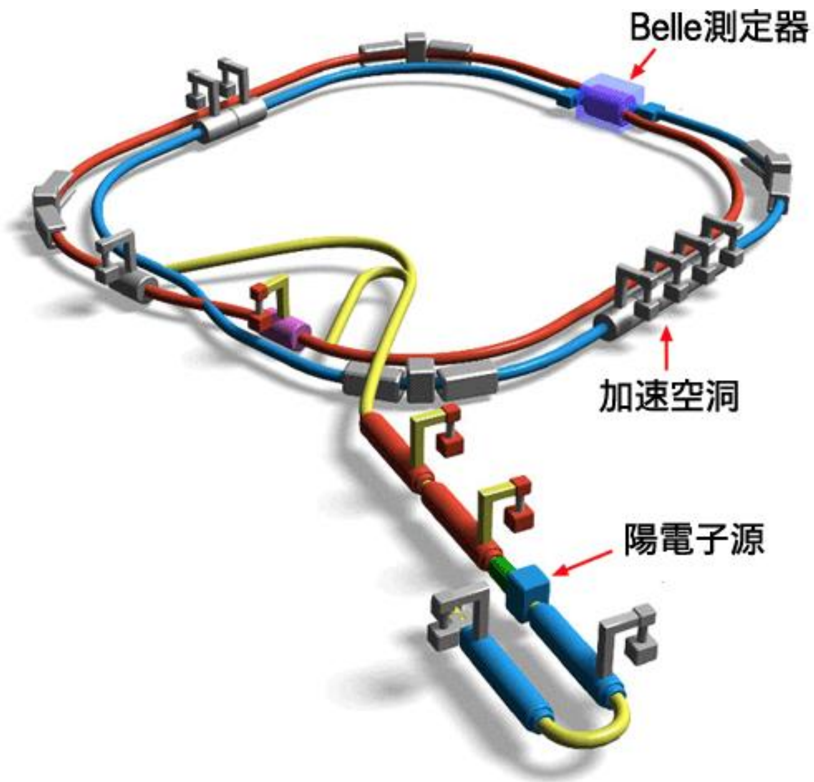
- Super KEKB aims to explore the beyond-standard-model physics.
- KEKB & Babar established the standard model by observing the CP violation decays of B^0 meson.
  - Luminosity ~ 2×10^{34}/cm2/sec
  - Integrated luminosity ~2 ab^{-1} or 2billion B-B events

- Super KEKB extends the physics reach to Beyond-standard-model physics
  - Luminosity ~ 80×10^{34}/cm2/sec
  - Integrated luminosity >50 ab^{-1}.

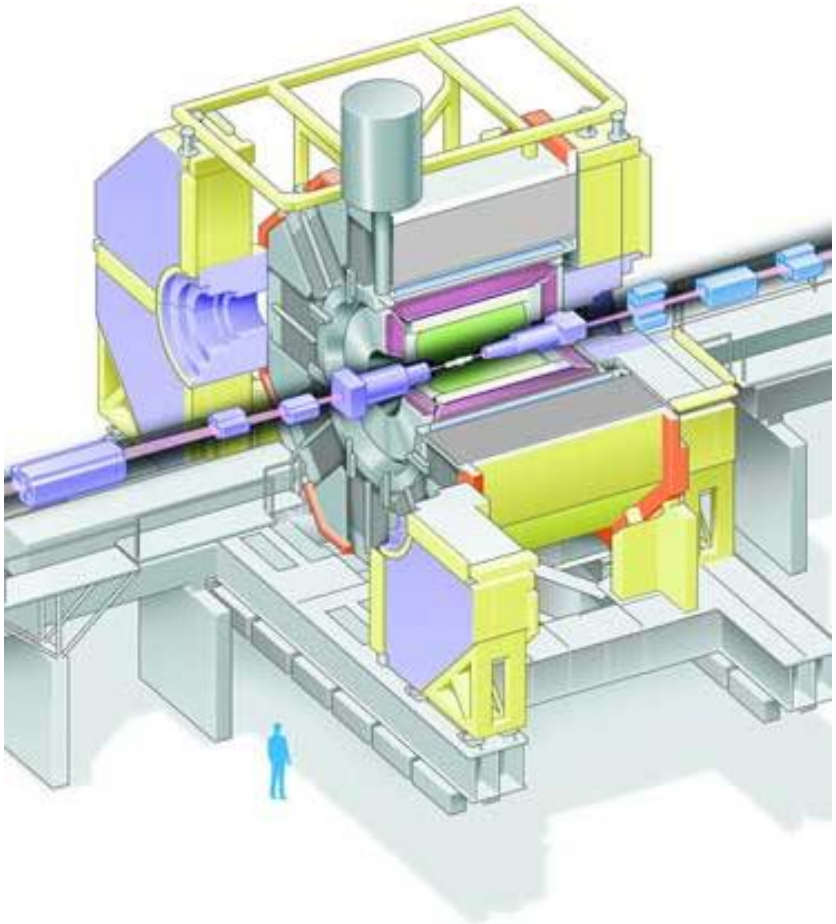


KEKB Experiment

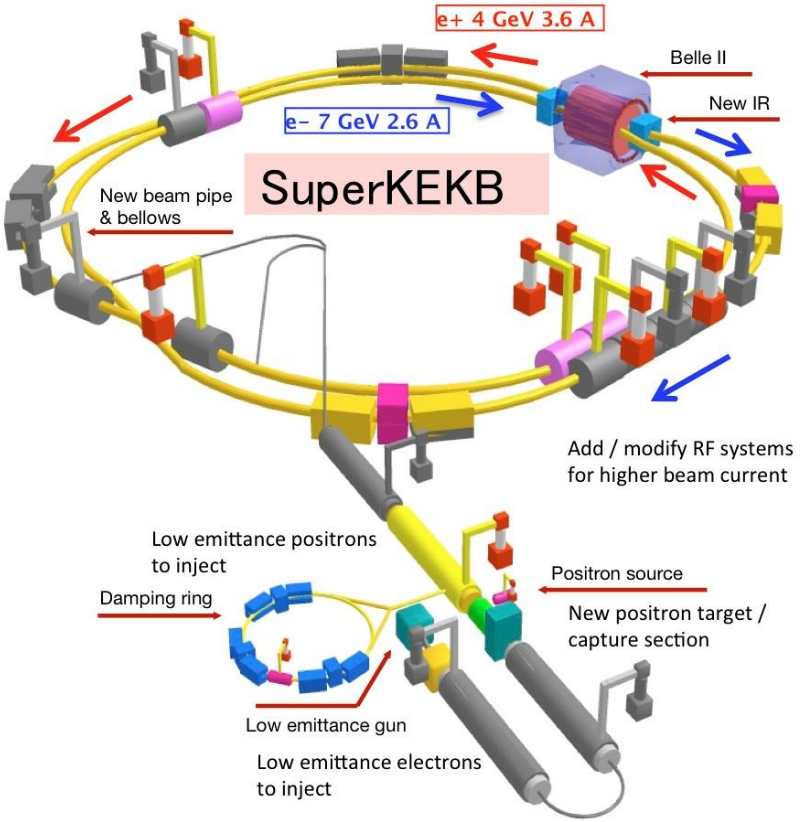
- KEKB Accelerator

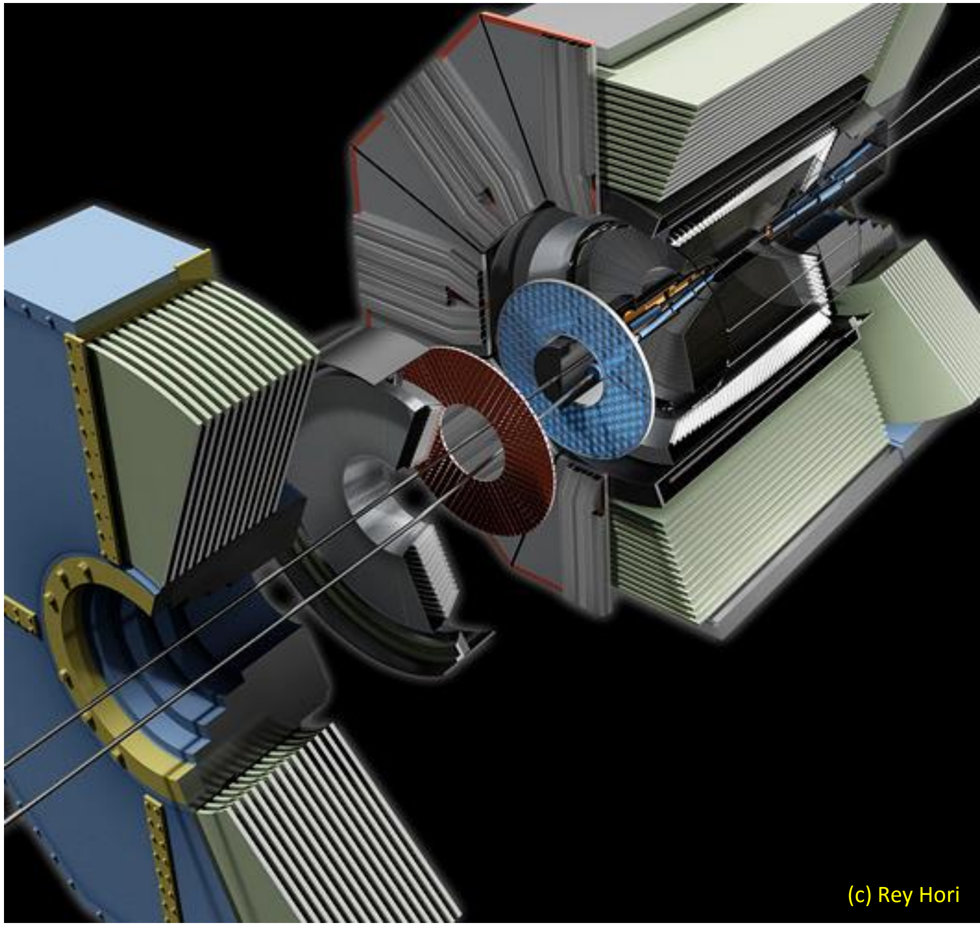


- Belle



Super KEKB


e+ 4 GeV 3.6 A
Belle II
New IR
e− 7 GeV 2.6 A
SuperKEKB
New beam pipe
& bellows
Add / modify RF systems
for higher beam current
Low emittance positrons
to inject
Positron source
Damping ring
New positron target /
capture section
Low emittance gun
Low emittance electrons
to inject


(c) Rey Hori

Comparison of accelerator

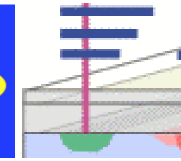
	KEKB (achived)	Super KEKB (goal)
Accelerator	3km tunnel circumfarence, 508 MHz RF system	
Beam Energy	8 GeV e^- 3.5 GeV e^+	7 GeV e^- 4 GeV e^+ (*)
Beam Current	1.2 A e^- 1.6 A e^+	2.6 A e^- 3.6A e^+
Luminosity	$2 \times 10^{34}/cm^2/s$ (20/nb/sec)	$8 \times 10^{35}/cm^2/s$ (0.8/fb/sec)
Beam size	1 μm x 150 μm	0.1 μm x 10 μm
Injection	Top up (trickle)	To up (trickle)
Collision rate	6 nsec (max)	4 nsec (max)

(*) CM Energy can be adjusted up to Υ(6S)

Improvement of detector

- The physics target is same, the requirements to the detector do not change.
  - Detector size: Can not be larger/smaller
  - Full reconstruction capability
    - Thin material and large acceptance
    - Efficient high-resolution tracker and calorimeter
    - Particle Identification: Identify K+/K- from pions
  - Measurement of time evolution of B mesons
    - Precise and efficient Vertex mesaurement
- Requirements from to higher luminosity & backgrounds
    - Data acquisition rate 100 Hz → 5 kHz
    - Immunity to radiation effects
    - A higher detector segmentation
    - A better time resolution.

Comparison of detectors

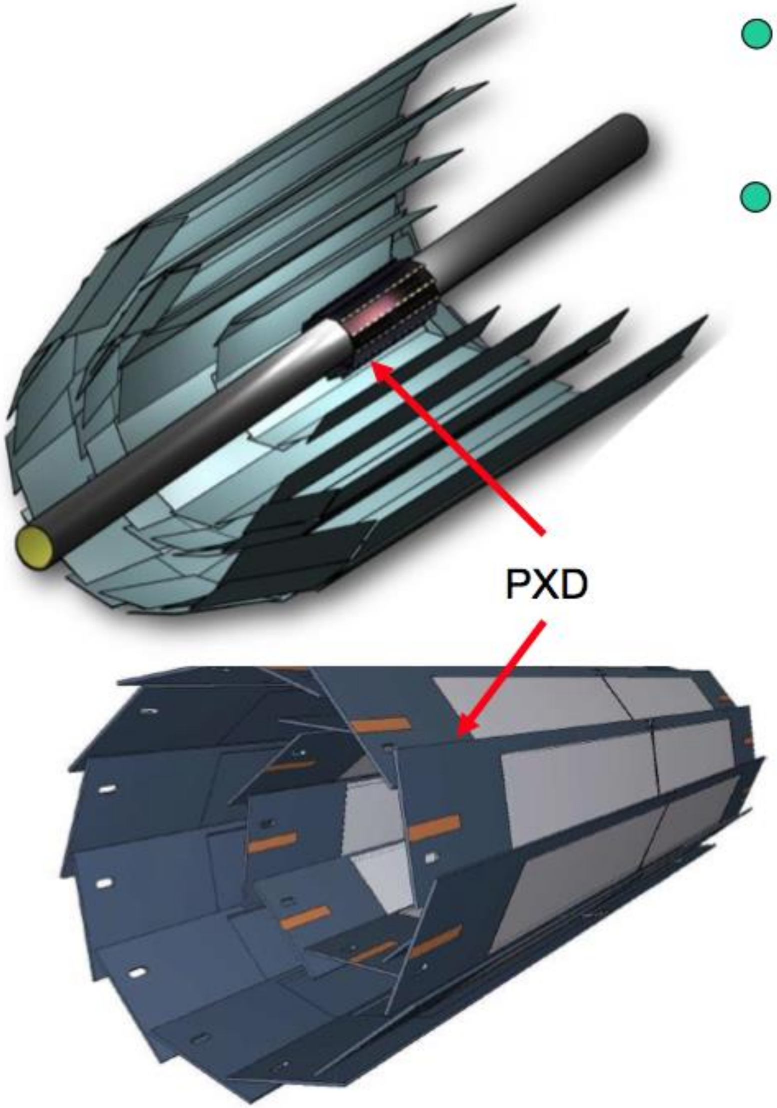


	KEKB (achived)	**Super KEKB (goal)**
Beam pipe	R=1.5cm	R=1.0 cm
Vertex detector	4layer silicon strip 2.5-10 cm	2layer pixel 1.8-2.3 cm 4layer Silicon strip 4 cm-16 cm
Central tracker	Small cell drift chamber 0.12-1 m	Small cell drift chamber 0.2-1.2 m
Particle ID Barrel	Aerogel Cerenkov counter (threshold)	TOP (ring image cerenkov counter projected to time infortmation)
Endcap		Aerogel Rich counter
Calorimeter	CsI (Tl) charge integration	Csi(Tl) digital filtering
K-long/Muon	RPC in Iron yoke	Scintillator & RPC in Iron yoke
Magnetic Field	1.5 T (Super conducting Solenoidal magnet)	
DAQ	Max trigger rate 150 Hz	Trigger rate 5kHz
Computing	Managable in KEK	Worldwide with Grid and Cloud

Vertex detector

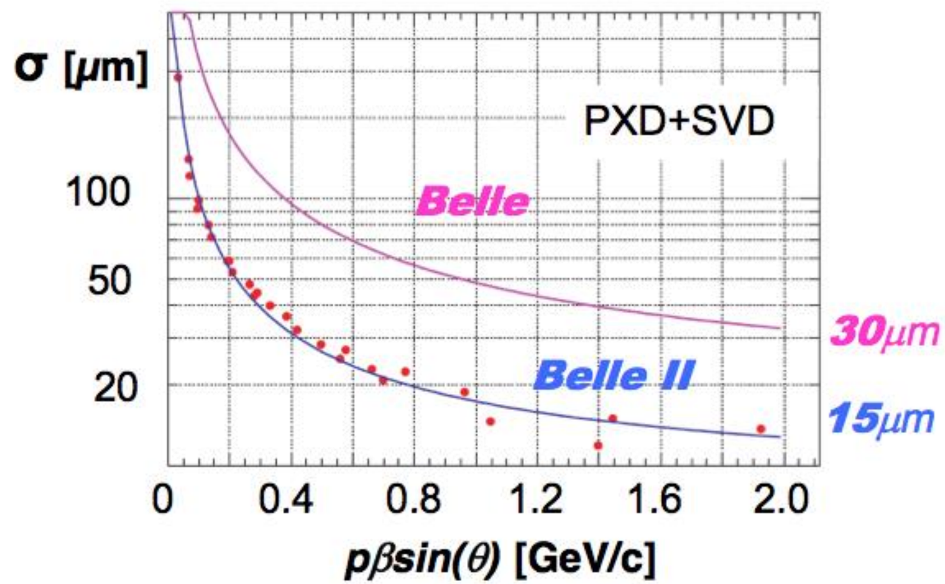
	KEKB SVD (achieved)	**Super KEKB (goal)**
Strip detector (SVD)	4-layer silicon strip 2.5-10 cm	4-layer Silicon strip 4 cm-16 cm
Sensor size	79mmx28	125mmx60mm
Total sensor area	0.6 m^2	1.2 m^2
Readout chip	VA1TA(Viking variant)	APV25 (developped for CMS)
Readout method (ganging)	1-3 sensors are read by one chip (ghost hits exist)	1 chip read out 1 sensor (no ghost hits)
Shaping time	800 nsec.	50 nsec
Pipeline	No	192 stage
Material thickness	0.4 % X_0/layer: silicon 300 μm	0.6 % X_0/layer: sensor+readout flex
Pixel detector (PXD)		2 layer DEPFET sensors R=1.4 2.2 cm
Thickness		0.1 % X_0 (silicon 75 μm)/layer 0.2 % X_0/layer including peripherals
Readout		Rolling shutter (with injection veto)

Expected performance



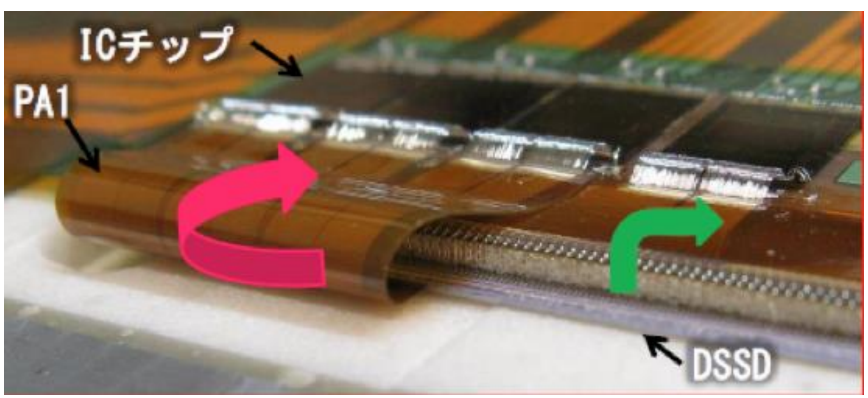
- SVD: 4 layer Si strip detector (DSSD)
  (R = 3.8, 8.0, 11.5, 14.0 cm)
- PXD: 2 layer Si pixel detector (DEPFET technology)
  (R = 1.4, 2.2 cm)
  monolithic sensor
  thickness 75 µm (!),
  pixel size 50 x 55 µm² to 50 x 85µm² (depending on layer and z)

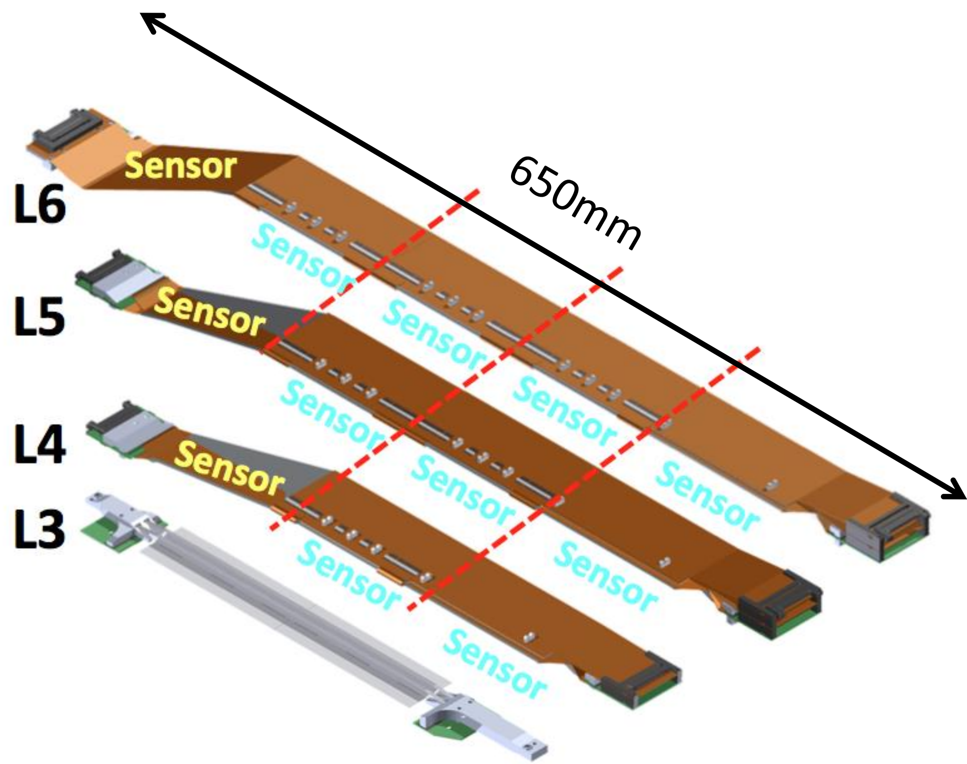
Significant improvement in z-vertex resolution



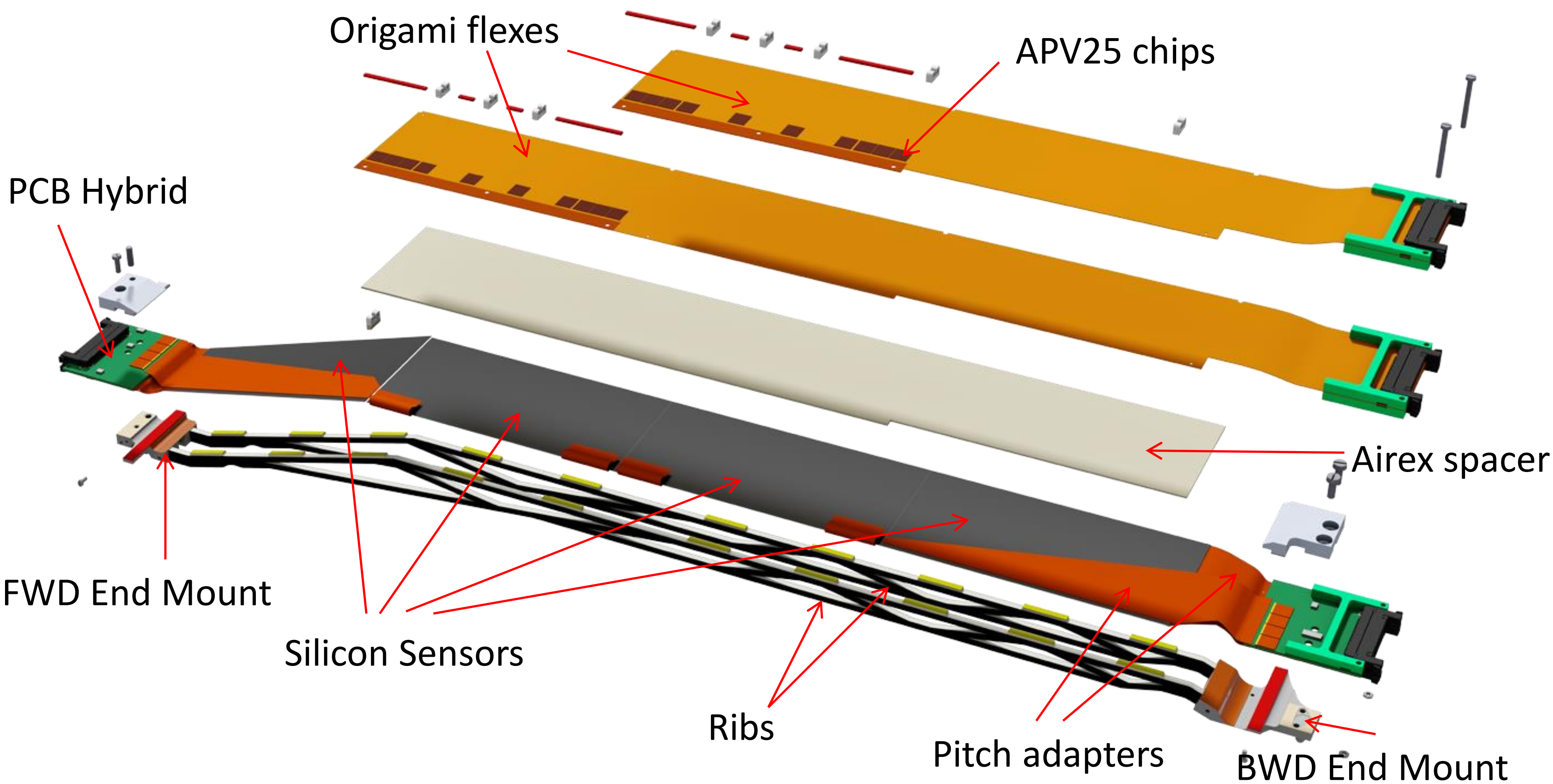
SVD (Silicon Strip detector)

- 2-5 sensors are glued together to form "ladders"
- Forward region is covered with a slant sensor in order to reduce length and cost.
- Readout with APV25 developped for CMS
- APV25 is mouted on DSSD
- Data in the bottom side is brought to top side using flex circuits.





Exploded view

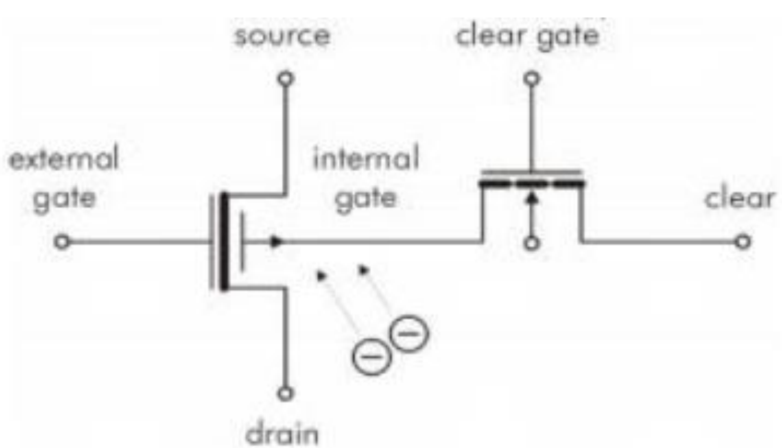


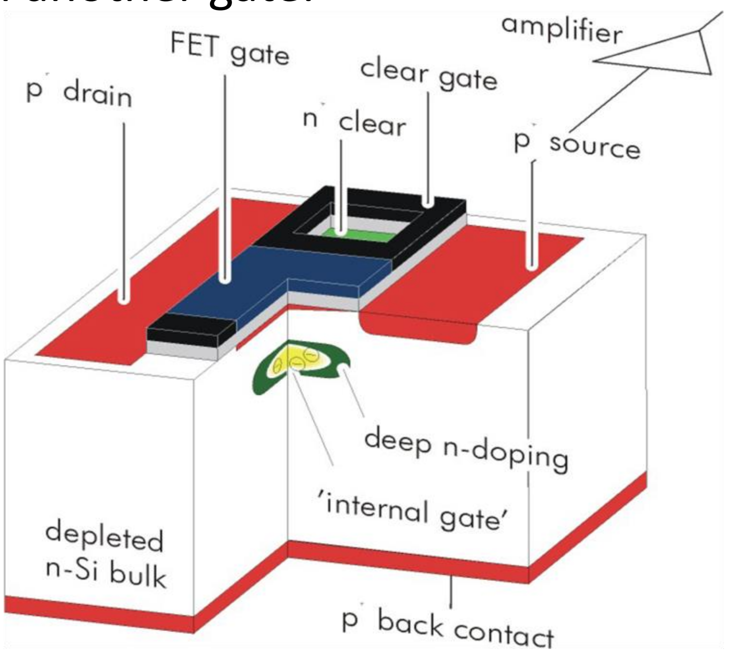
DEPFET pixel detector

- DEPFET group joined to Belle group in 2009.
- The only available proved monolithic detector with fully depleted silicon sensors.
- Detector can be thinned to 50-75 μm.
- Can be operated in room temperature.
- Max Planck institute fur Physik in Munich works with Siemens and they can only perform this special semiconductor process.

DEPFET pixel detector

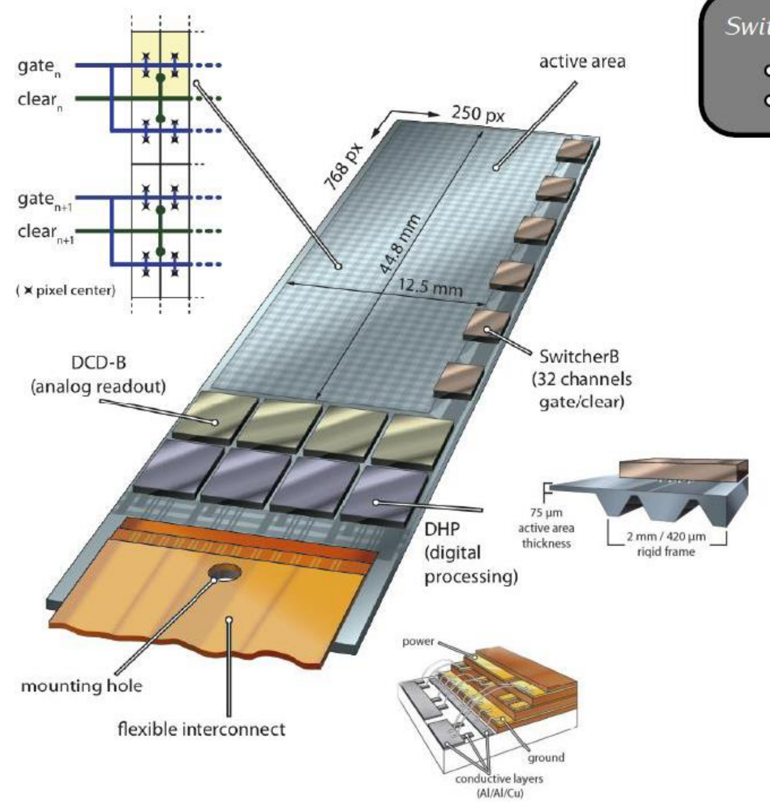
- DEPFET group joined to Belle group in 2009.
- The only available proved monolithic detector with fully depleted silicon sensors.
- Detector can be thinned to 50-75 μm.
- MOSFET is produece at center of pixel.
- The charge induced in wafer is collected by the internal gate.
- The drain current is of MOSFET moduleted by the potential of the internal gate.
- Pixels can be read out with scanning the source current and readout gate.
- The chage in the internal gate can be cleared with another gate.
- Rolling shutter readout.
- 20 μsec frame rate for Super KEKB.



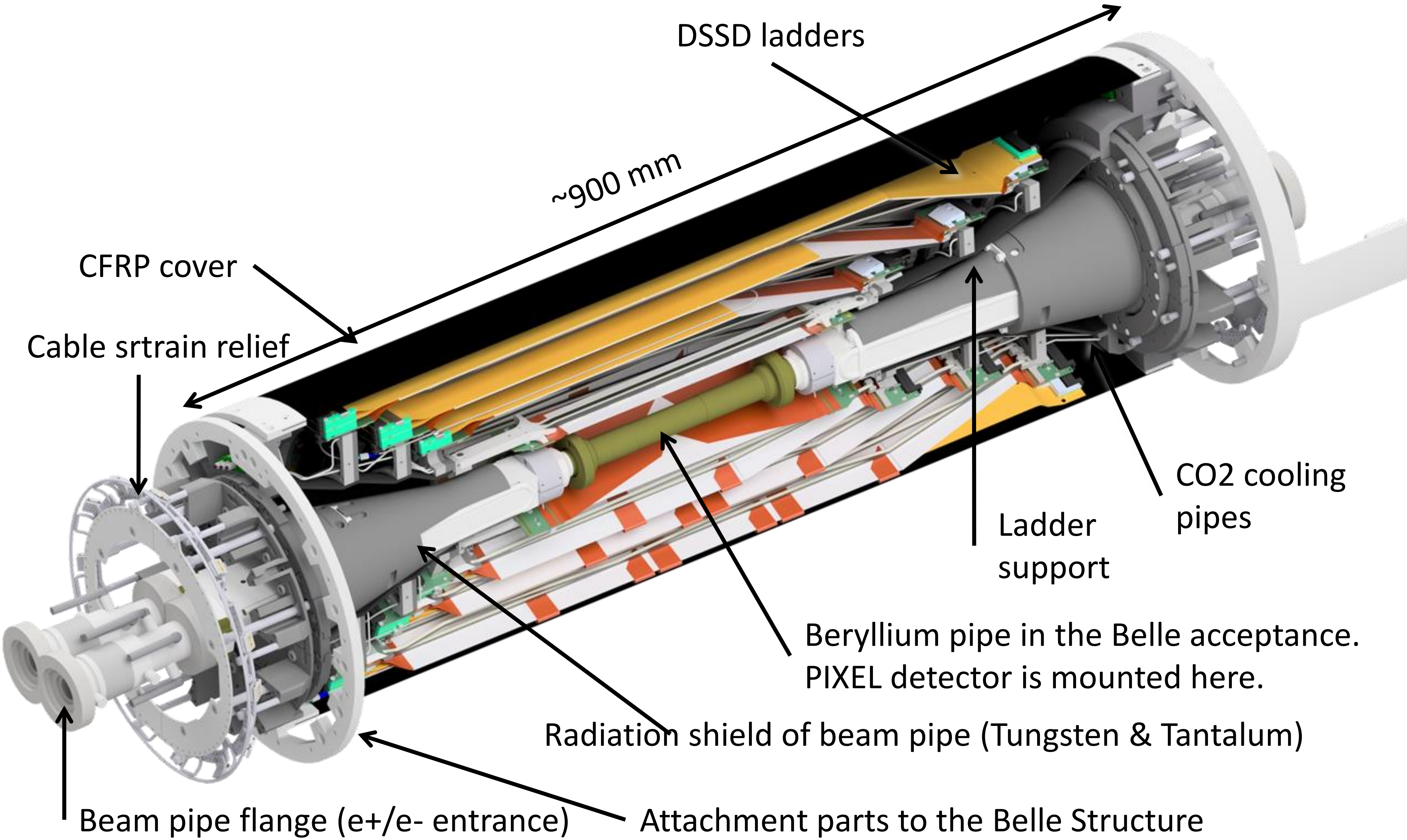


Readout chain of DEPFET

- The drain current from pixels are digitized with DCD chips and "base line subtraction and hit pixe selection" is done on DHP chips on the same DEPFET wafer.
- The pixel scanning (and resetting) is mediated by switcher chips also on the DEPFET wafer.
- The output from DHP is sent to offline data acquisition system through the kapton flex circuit.
- Huge number of flip-chip bonding is also a challenge.

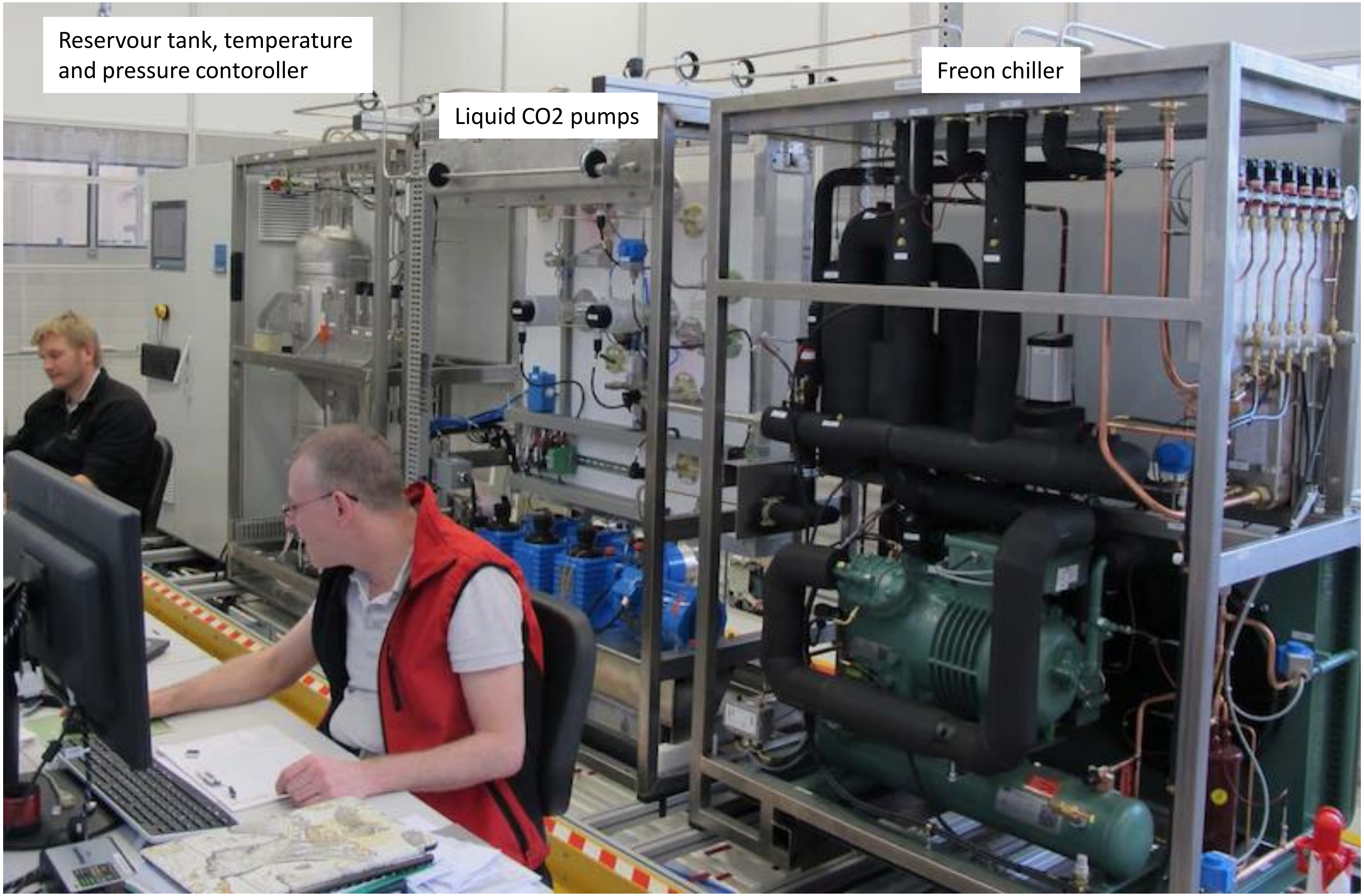


SVD support mechanics



The CO_2 cooling plant

- IbBelle



2-phase CO_2 cooling

- CO_2 can be liquefied at T < 30°C & P>20 MPa.
- Gas and liquid phases can co-exist conditions met.
- We chose 2MPa and -20°C for SVD/PXD cooling
- If 1 g, -20°C liquid CO_2 evaporates to gas, it absorbs 300 Joule.
- By evapolating 3g/sec, we can remove 1kW heat.
- Stanless steel pipes 0.1 mm wall thick and 1.5 mm inner diameter can hold 20 MPa pressure, in theory.
- Belle SVD/PXD adopted CO_2 cooling.
- The design of CO_2 plant for Atlas IBL pixel detector cooling is modified and construction finished this summer and shipped to KEK soon.

Present status and Schedule

- 2016
  - Super KEKB completed the initial operation.
  - Beam current 1 A was stored to electron and positron rings (no collisions).
  - We are producing ladders (SVD) final sensors (DEPFET)
  - Mechanical discussions are near completion. Final mechanics production will be done.
- 2017:
  - SVD ladders will be mounted to the SVD support.
  - DEPFET detector will be prepared and tested in MPI Munich.
  - Super KEKB operation with Belle-2. Background and luminosity tuning starts.
- 2018
  - SVD and DEPFET will be combined and final commisioning is performed.
  - Super KEKB should achieve reasonable luminosity (> $2 \times 10^{34}/cm^2/s$) and low beam background condition so VXD are not damaged.
  - Then, the vertex detector is installed and real physics operation will start.

DEPFET collaboration

- Germany, Czech, Spain…

SVD collaboration

- Japan, Australia, Austria, Czech, India, Italy, Korea, Poland

- I apologize if some country/institution is missing.