FPCCD VTX R&D Plan in next 5 years

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@ILC detector seasonal meeting

Timeline

- Vertex detector is the last sub-detector to be installed into ILD (~9 years from the ILC ground breaking)
- We don’t have to complete all of the R&D items to get construction-ready design (sub-detector TDR) in the preparation phase
- But we have to achieve R&D goals required at each phase: LOI, technical proposal, etc.

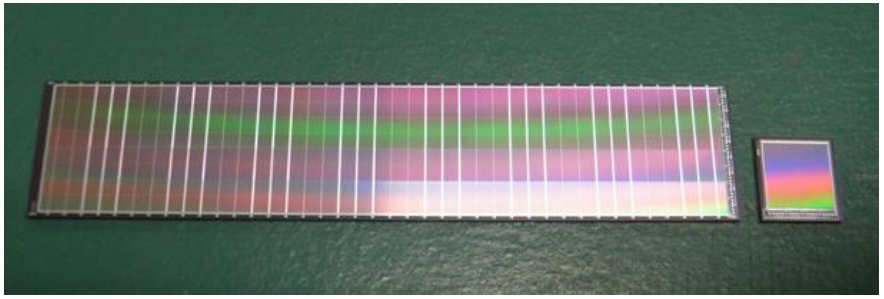
R&D Items

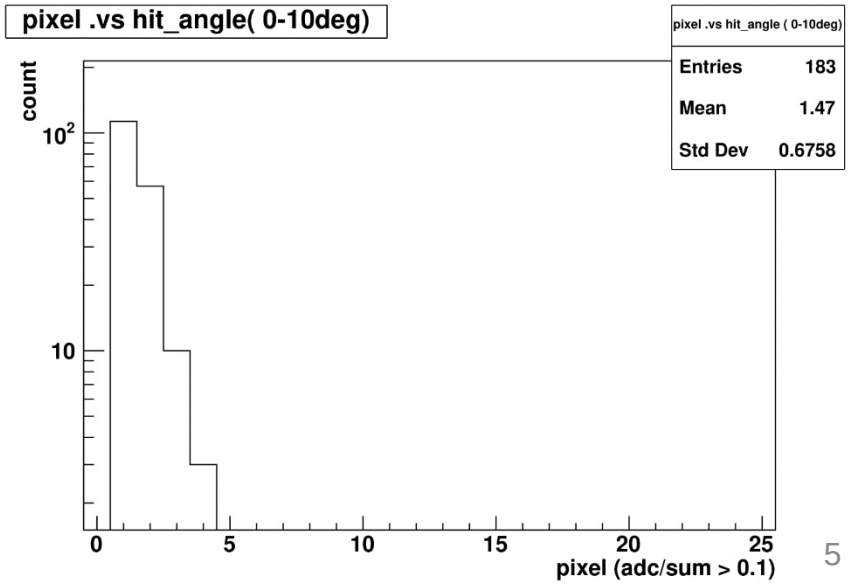
- Sensor R&D
  - Small prototypes with improved radiation immunity
  - Large prototypes with smaller dead area
- Readout electronics
  - ASIC
  - Peripheral circuits (Driver, Serializer, etc.)
- CFRP Ladder
  - Assembly procedure
  - Engineering prototype
- Cooling system
  - Remote operation
  - Automatic operation

SENSOR R&D

Present status

- Small prototypes and large prototypes have been developed
  - Pixel size: 6um
  - Sensor size: 6mm square (SP) / 12.3x62.4mm^2 (LP)
  - Thin wafer: ~50um
- Excellent two-track separation capability has been demonstrated
- More radiation immunity is desirable





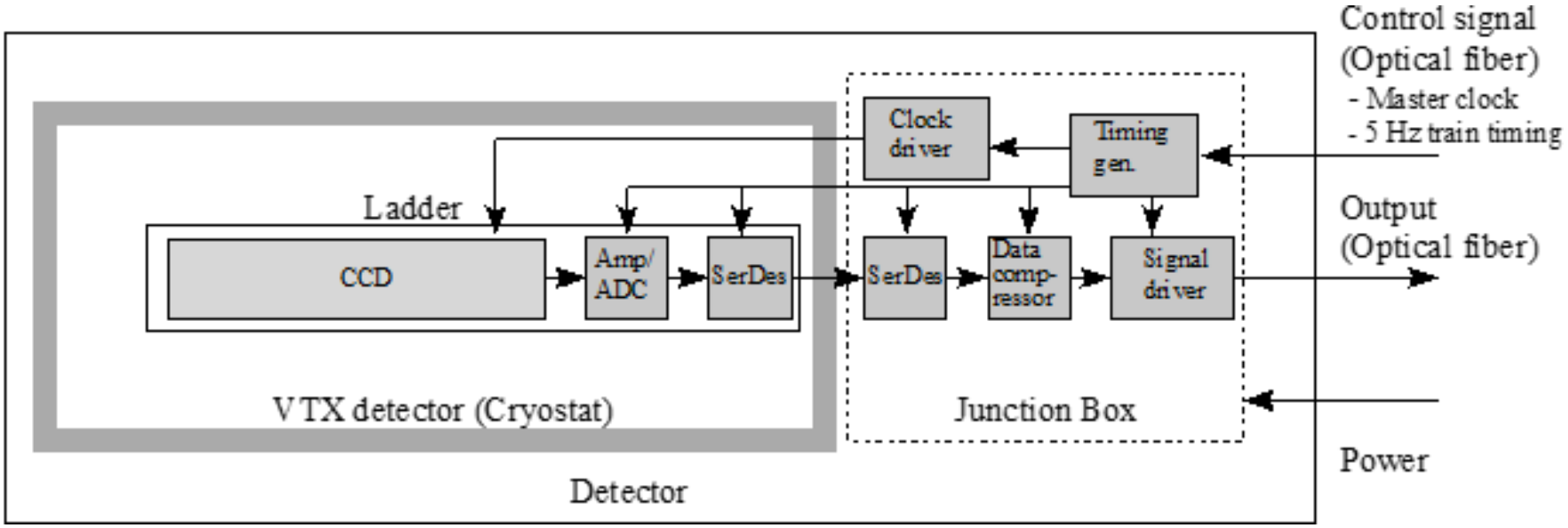
R&D plan

- Radiation immunity test with prototype sensors on hand
  - Electron irradiation at ATF linac (FY2021~)
  - Detailed plan → see the previous seasonal meeting
- Study of spatial resolution
  - At new test beam of ~5 GeV electron at KEK (FY2022~)
- Development of small prototypes with improved radiation immunity
  - Charge injection mechanism
  - Notch channel
- Development of large prototypes with less dead area

READOUT ELECTRONICS

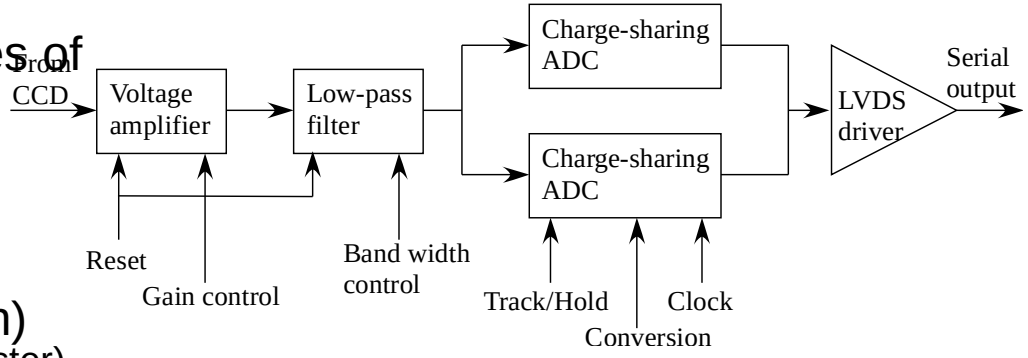
Global design

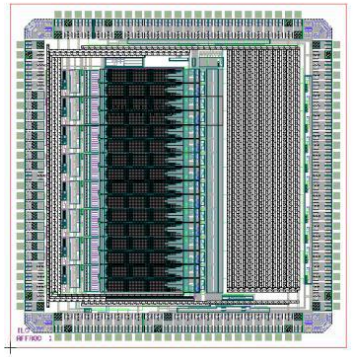
- Sensors, FE-ASIC (Amp+ADC), serializer on ladders inside cryostat
- Kapton FPC cables extracted from the cryostat to junction box
- De-serializer, DSP for data compression, signal driver for optical fiber, timing generator, and clock drivers in the junction box near the cryostat

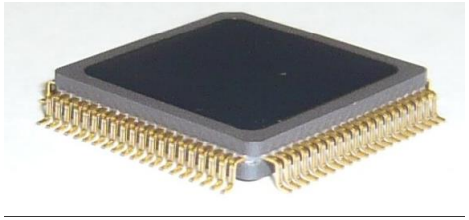


FE ASIC

- Achievement so far
  - We have developed prototypes of ASIC
  - 8ch/chip
  - 0.25um TSMS process
  - Amp, LPF, CDS, 8-bit charge-sharing SAR-ADC (2 ADCs/ch)
    (SAR:Successive Approximation Register)
- Known problems
  - Gain drop at high speed readout
  - Linearity
  - Asymmetry in even/odd pixels
- We would like to design and fabricate a new prototype of the FE ASIC







AFFROC01 layout
(Asic For Fpccd ReadOut Chip)

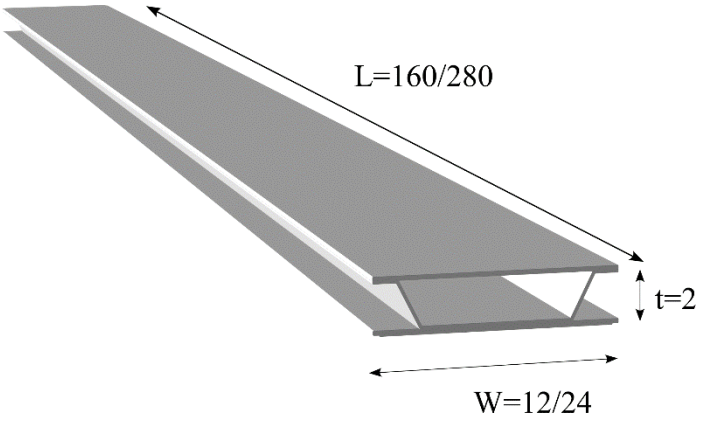
Peripheral circuits

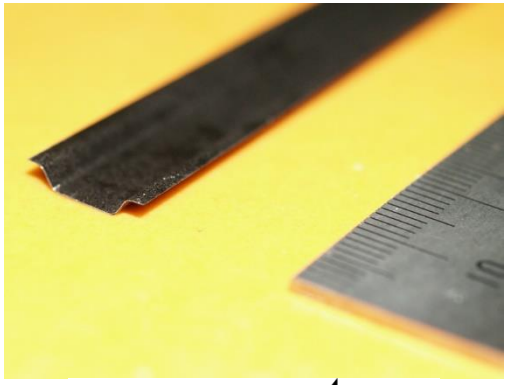
- Design of peripheral circuits (serializer, de-serializer, data compressor, etc.) has been almost untouched
- R&D of the peripheral circuit has to be done after ASIC development

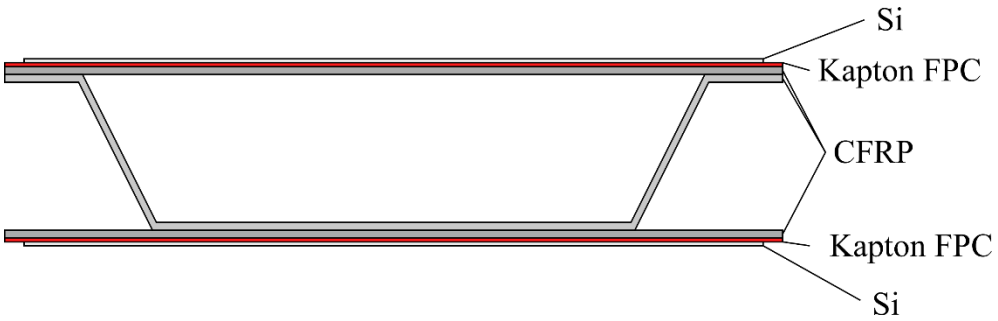
CFRP LADDER

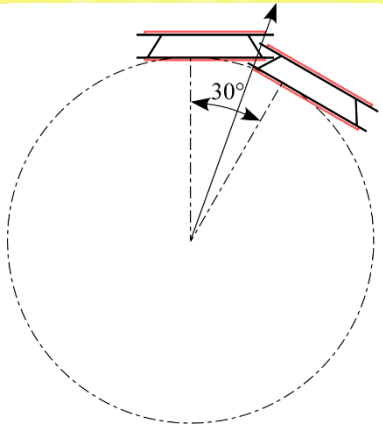
Conceptual design

- Double-sided ladder: 2 layers are ~2mm apart
- Main support structure is made of CFRP: 2 flat plate and a Ω-shape spacer
- Vacant space at the edge to allow minimum dead space









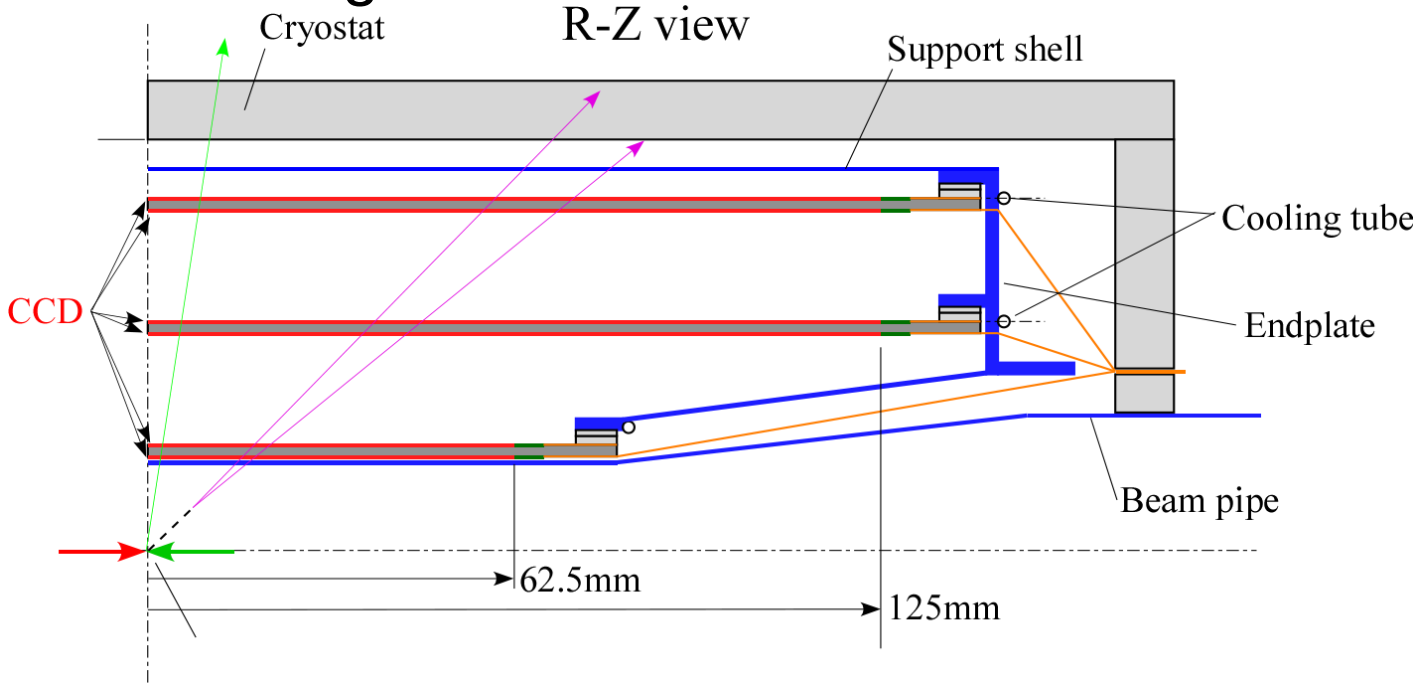
R&D issues

- Ladder assembly procedure is not clear → We have to establish the assembly procedure using dummy Si wafers instead of FPCCD sensors
- Construct a engineering prototype of VTX (dummy ladders, end plates, cryostat) and study the mechanical and thermal properties

COOLING SYSTEM

FPCCD VTX cooling

- FPCCD sensors are operated at ~-40 degrees in order to improve radiation immunity
- Most of the power is dissipated at the both ends of the ladder (ASICs)
- Ladders are cooled from both ends through endplates on which cooling tubes are attached



Support shell, end plate, cooling tube

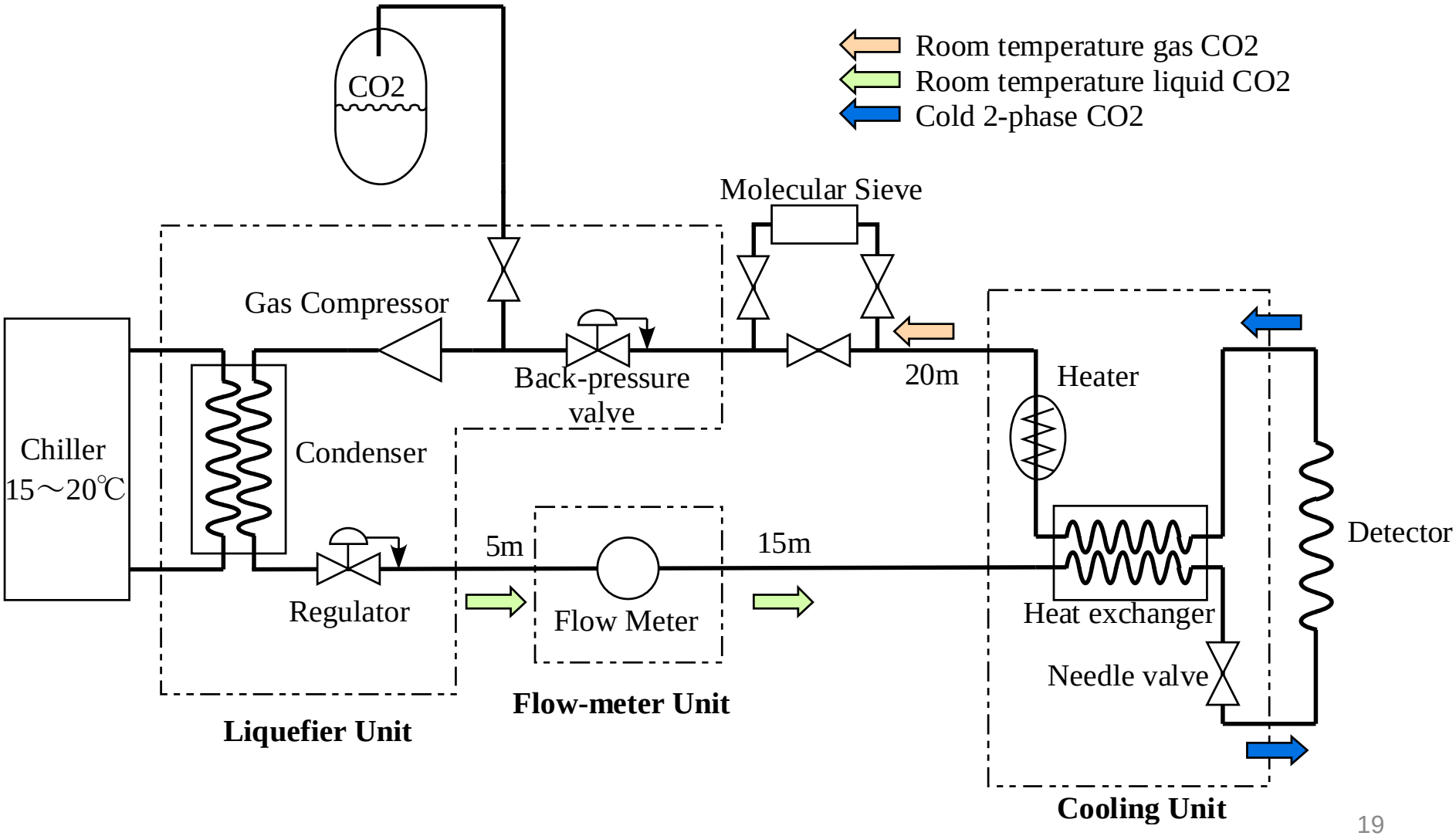
2-phase CO2 cooling

- 2-phase CO2 cooling system will be used for FPCCD VTX
- 2-phase CO2 cooling system is suitable for detector cooling between ~−50℃ (triple point: −56.6℃) and near room temperature
- Cooling temperature is fixed by the pressure of CO2, and constant along the cooling tube, unless it evaporates completely

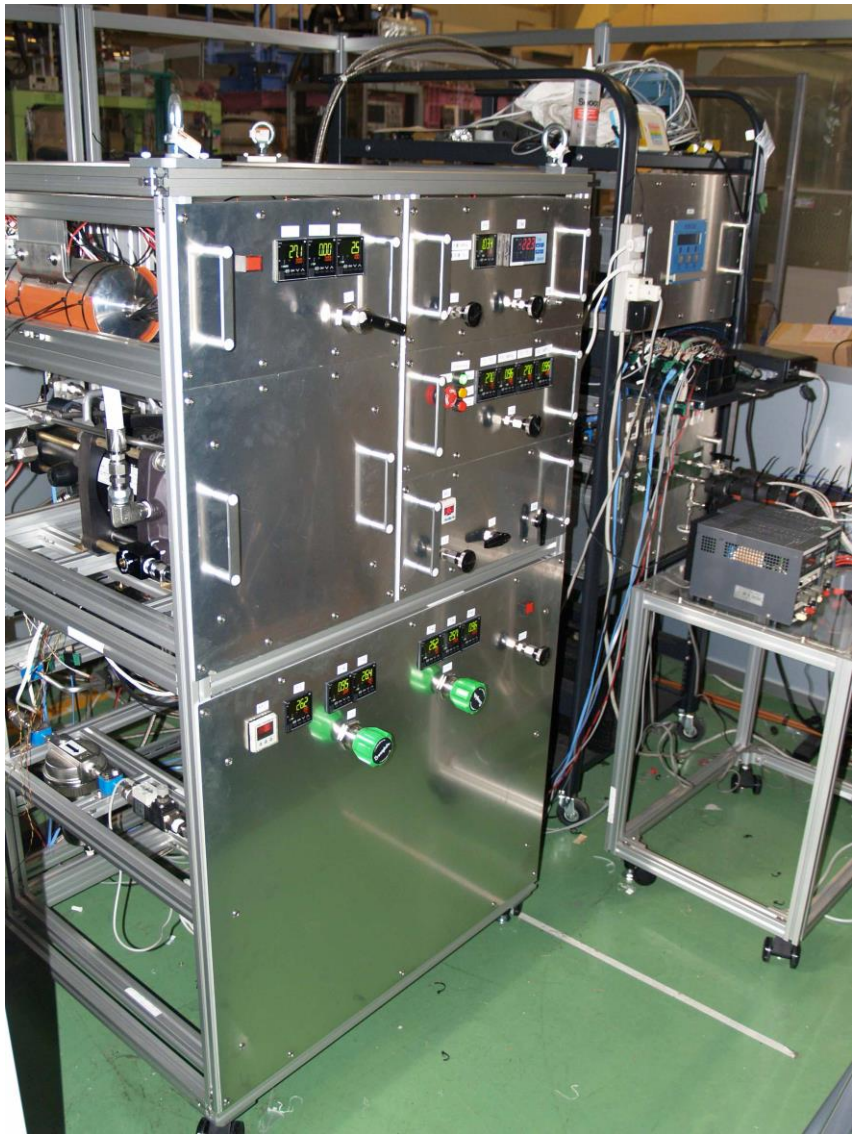
Our design of 2-phase CO_2 cooling system

- Gas compressor is used for circulation of the coolant (Other groups use liquid pumps)
- Room temperature liquid CO_2 is transferred between liquefier plant and the detector
- Liquid CO_2 is decompressed and cooled down near/inside the detector
- Tight thermal insulation for the long transfer tube is not necessary, and standard flexible tube can be used → suitable for push-pull operation

Schematics of the prototype



Liquefier Unit



R&D issues

- Light weight heat exchanger
  - The heat exchanger will be placed inside the detector
  - It should have low material budget
- Remote operation / automated operation
  - The prototype at present has many manual nobs
  - These should be controlled remotely, and automatically

SUMMARY

Summary

- We have a lot of things to do for the FPCCD vertex detector
- In addition to sensor R&D, mechanical R&D is indispensable to get a complete design of the vertex detector
- We need resources: Manpower & \