R&D Status and plan for FPCCD VTX

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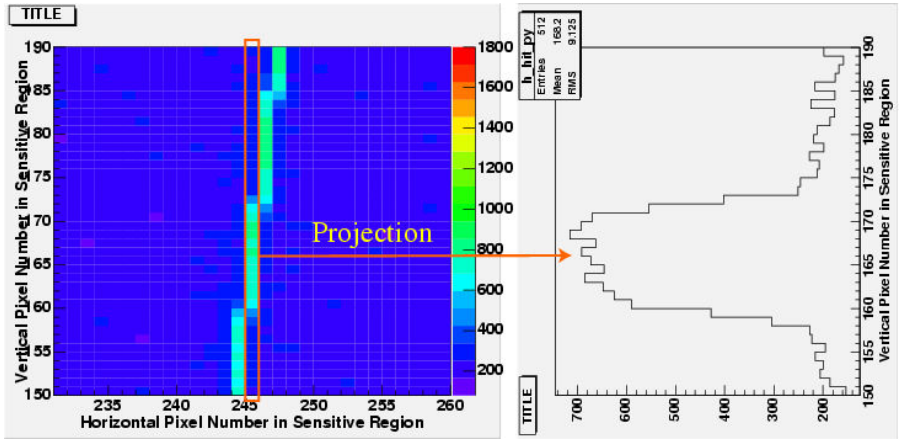
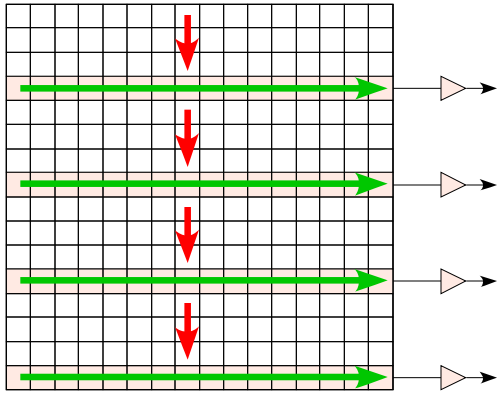
R&D Issues

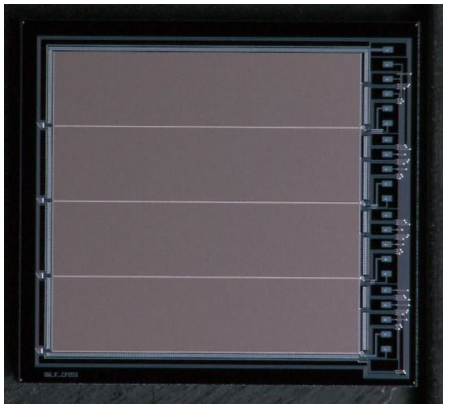
- FPCCD Sensor
- Readout **ASIC**
- Peripheral electronics
- Wafer thinning and low mass ladder
- Cooling system
- Simulation of background rejection

Sensor R&D

- 2007: Fully depleted CCD
  - Pixel size: 24μm
  - High resistive epi, 15μm thick
- 2008: FPCCD#1
  - Pixel size: 12μm
  - Chip size: 6.1mm
  - 4ch/chip
  - Horizontal register in the image area
- 2009: FPCCD#2
  - Pixel size: 12μm
  - Improvements from 2008 model
- 2010: FPCCD#3
  - Pixel size: 12~6μm
  - To be delivered in few days

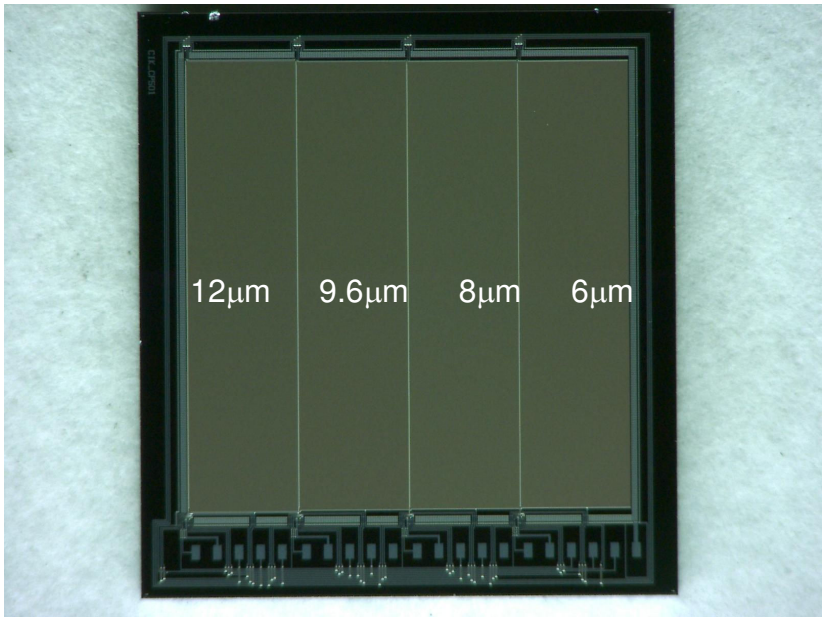


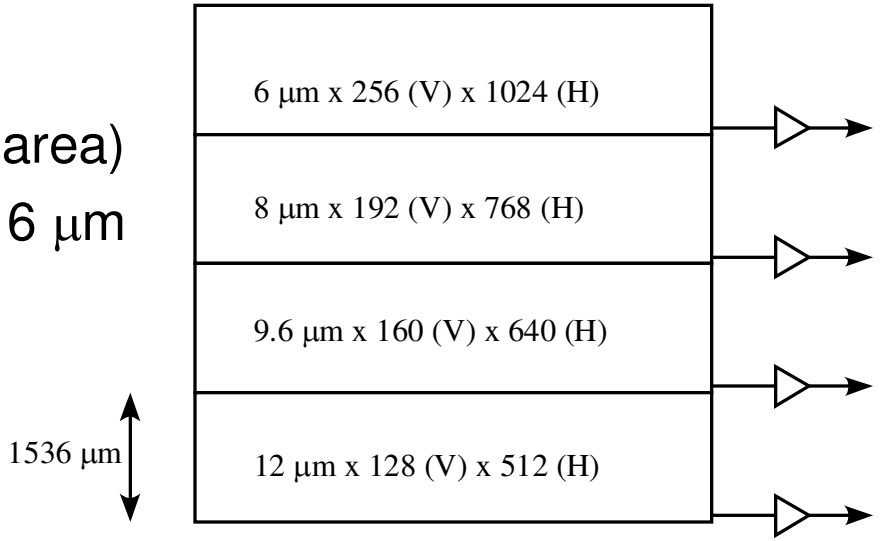


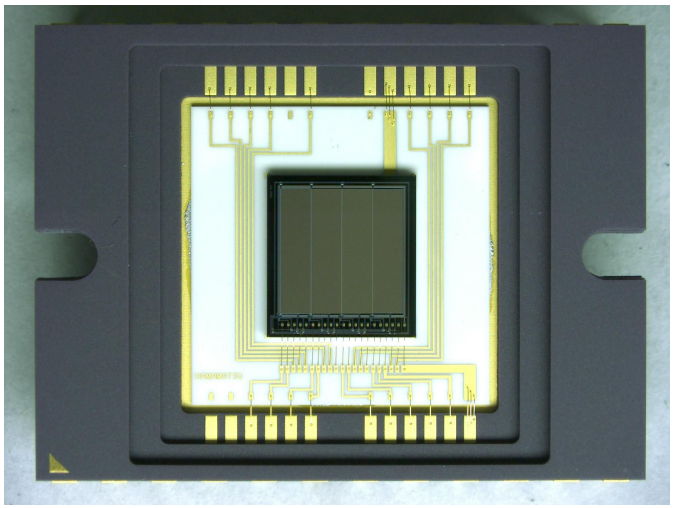


Sensor R&D

- FPCCD in 2010
  - Chip size: 6.1mm (image area)
  - Pixel size: 12, 9.6, 8, and 6 μm
  - Reduced CR of Al line for horizontal register gate







Sensor R&D

- Study plan of FPCCD in FY2010-2011
  - S/N ratio
  - Incident angle measurement using cluster shape
  - Spatial resolution
  - Two-track separation
  - Radiation immunity

Cooling system

- Cooling of FPCCD VTX
  - Power consumption ~ 80W (sensor + FE ASIC) + additional power consumption (clock driver, etc.) outside VTX cryostat
  - Operation at ~−40℃ inside the cryostat
- Possible cooling system
  - Cool nitrogen gas
    - For ΔT=20℃, gas flow of ~3 ℓ/s is necessary
    - If pipe diameter is 1cm, v=40 m/s
  - 2-phase CO2
    - FPCCD VTX has heat source at the ladder ends
    - Cooling with liquid coolant can be a solution

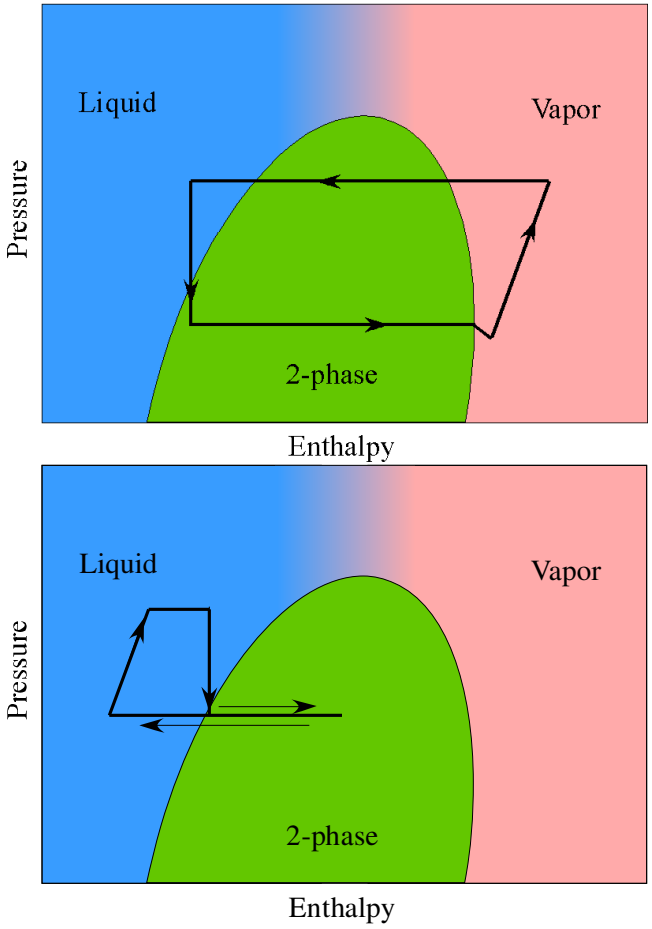
2-phase CO2 cooling

- Cooling by latent heat of evaporative CO2
- Compared to other (C_nF_{2n+2}) 2-phase coolant
  - Larger latent heat
  - Lower viscosity
  - ➔Thinner pipe
  - High pressure: 1 MPa (@ −40℃) – 5 MPa (@ 15℃)
- NIKHEF group is proposing this system for ILD TPC cooling
- Used/planned for
  - AMS
  - LHCb-VELO
  - SLHC detector upgrade
  - ILD TPC

	CO2	C2F6	C3F8
Latent heat@ −40℃	321 J/g	~100 J/g	~110 J/g
Triple point	−56.4℃	−97.2℃	−160℃
Critical point	31.1℃	19.7 ℃	71.9 ℃
GWP	1	9200	7000

2-phase CO2 cooling

- Two options of cooling principle
  - With CO2 compressor
    - Conventional method
    - Warm transfer between cooling plant and detector
    - J-T expansion near detector
  - Without CO2 compressor
    - Liquid CO2 is circulated using liquid pump
    - Cold transfer between cooling plant and detector
    - For TPC cooling (~room temp.) CO2 can be condensed using cool water
    - For low temp. cooling, additional cooling cycle is necessary to condense CO2
- R&D collaboration in Japan
  - ILD TPC, FPCCD VTX, Belle-II VTX, and KEK cryogenic group
  - We will request budget from KEK in FY2010



Summary

- We have developed fully depleted CCDs with standard (24μm), medium (12μm), and finally fine (6μm) pixel size
- Detailed study on the FPCCD will be done in FY2010-2011
- Cooling system using 2-phase CO2 is an interesting option for FPCCD VTX because FPCCD VTX has main heat source only at the ladder ends
- We will start R&D on 2-phase CO2 cooling collaborating with TPC group, Belle-II VTX group, and KEK cryogenic group

backup

p-h diagram of CO2