PHENIX Silicon Pixel Detector Construction, Operation, and the first Results

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Outline

1. Detector Hardware
2. Installation and Peripheral
3. Operation and Physics result
4. Issue and repair work
5. Summary

History

2004.8 First proposal

2007.6 Start Construction

2008.8 Beam test at FERMILAB

2010.10 Barrel assembly start

2010.12 Installed and operation start

Detector and Hardware

Requirements for Vertex Tracker

Heavy Ion collision and polarized proton-proton

Physics side

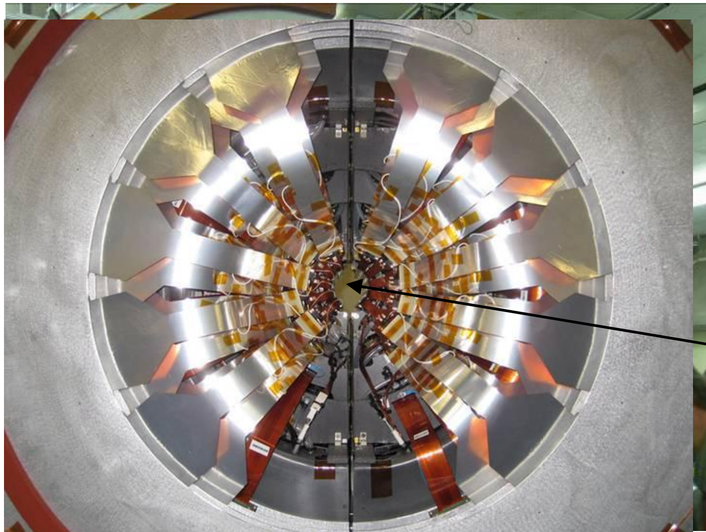
up to CMS 200 / 500GeV

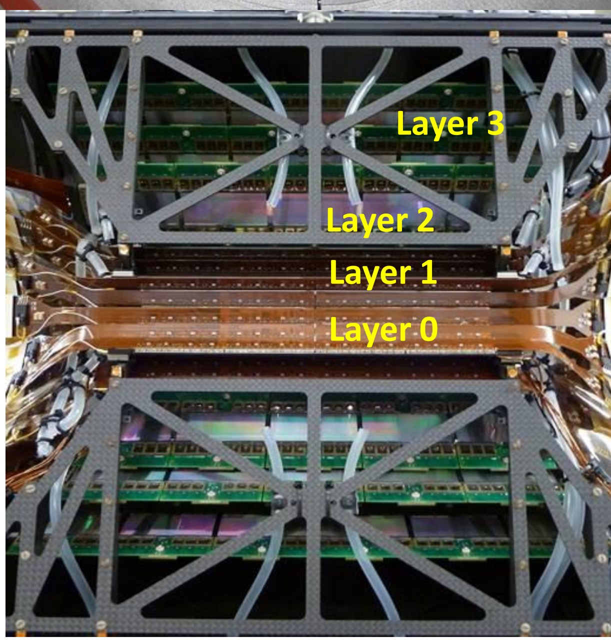
- High precision tracking for displaced vertex measurement.
  - $c\tau$ ~ 100μm(D), ~400μm(B)
- Large coverage tracking capability with momentum resolution (|η|<1.2 , and full azimuthally with σ/P ~ 5%P)

Environment side

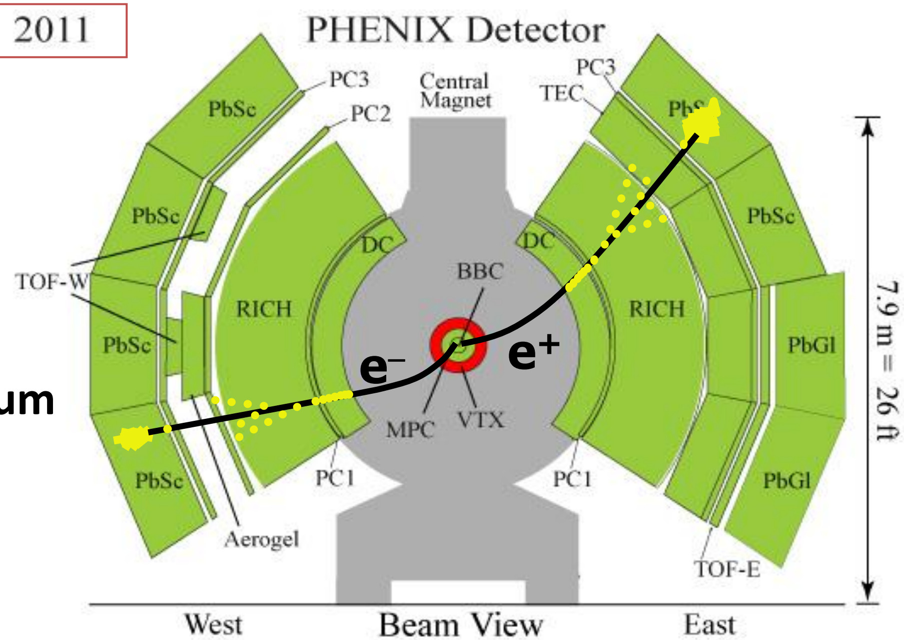
- High charged particle density 'dN/dη' ~ 700 @η=0 ~ 2000 Tracks
- High Radiation Dose ~100KRad@10Years
- High Luminosity $2*10^{32}$ cm^{-2} s^{-1}@PP -> High rate readout
- *Low Material Budget <- avoid multiple scattering and photon conversion for electron measurement by outer detectors.*

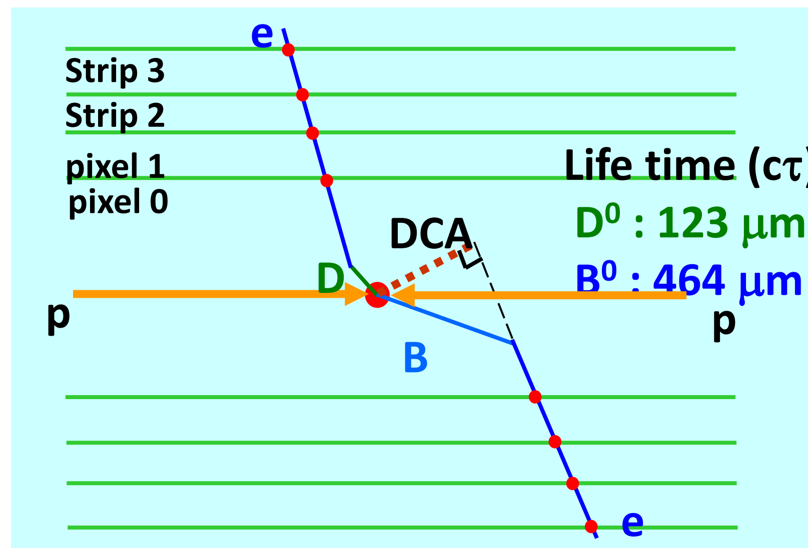
VTX: Silicon Barrels ~ 2π





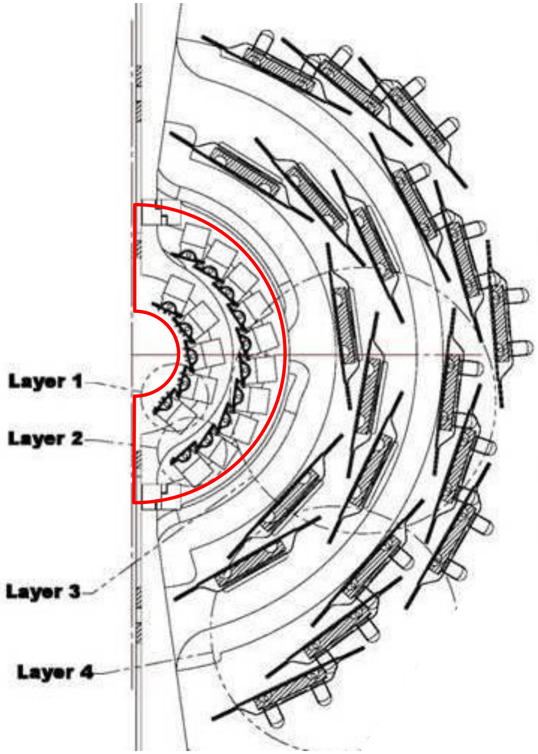
2011

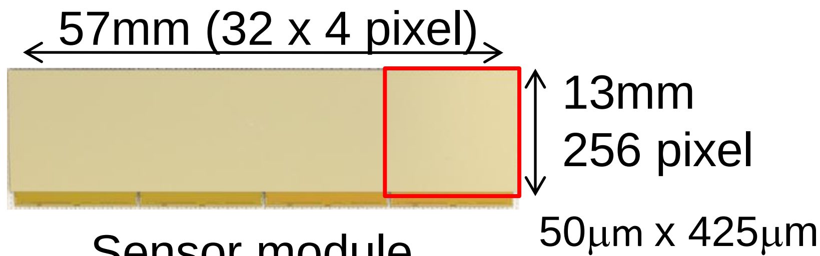




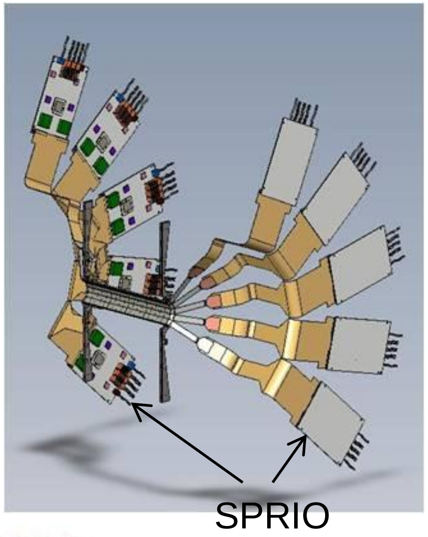
Pixel : inner 2 layers and Stripixel: outer 2 layers

Pixel Detector





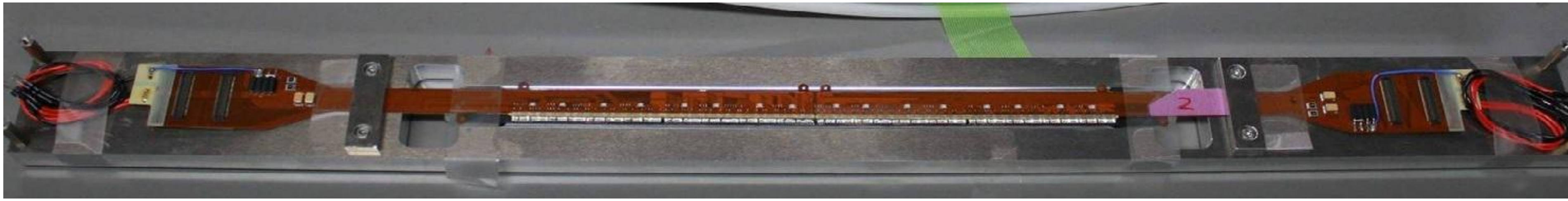
Sensor module



Pixel bus

Pixel sensor modules

Pixel stave (with cooling)

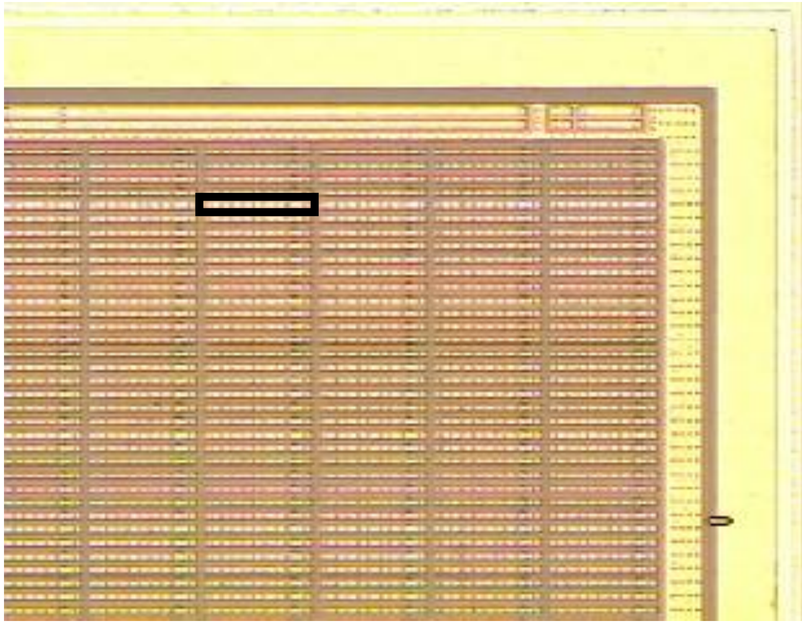


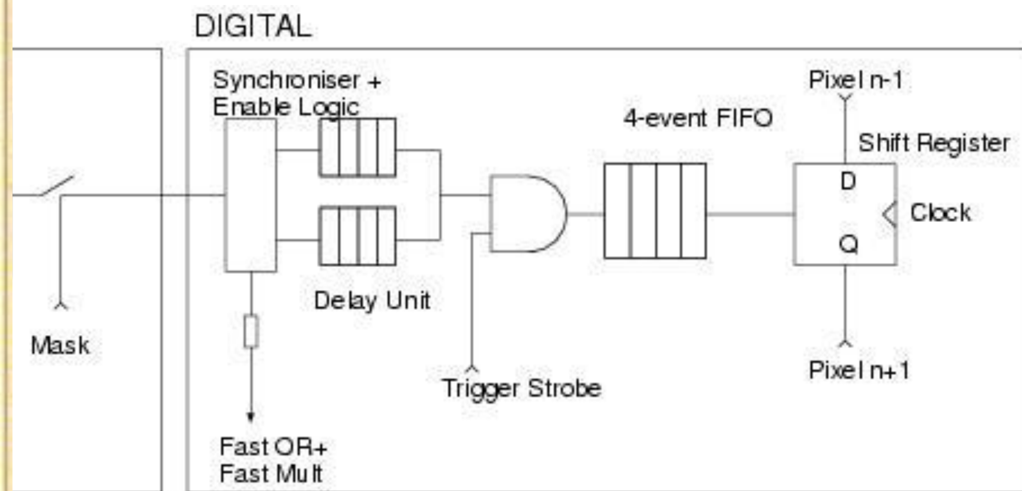
Pixel detector = inner 2 layers of VTX

1st layer: 10 full pixel ladders = 20 half ladders = 40 sensor modules

2nd layer: 20 full pixel ladders = 40 half ladders = 80 sensor modules

PIXEL (Sensor and Readout, bump bonded)





Pixel size(Φ x z) 50 μm x 425 μm
Sensor Thickness 200μm
$\Delta r\Phi = 1.28$cm, $\Delta z = 1.36$ cm (Active area)
256 x 32 = 8192 channel / sensor
4 chip / sensor
4 sensor / stave

Total 4M Pixel

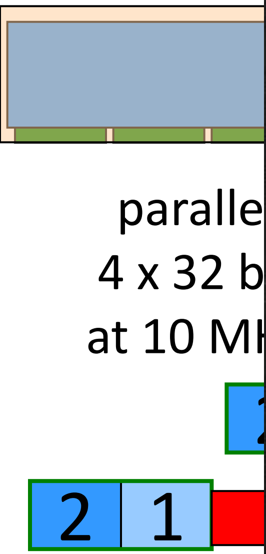
Readout by ALICE_LHCB1 chip

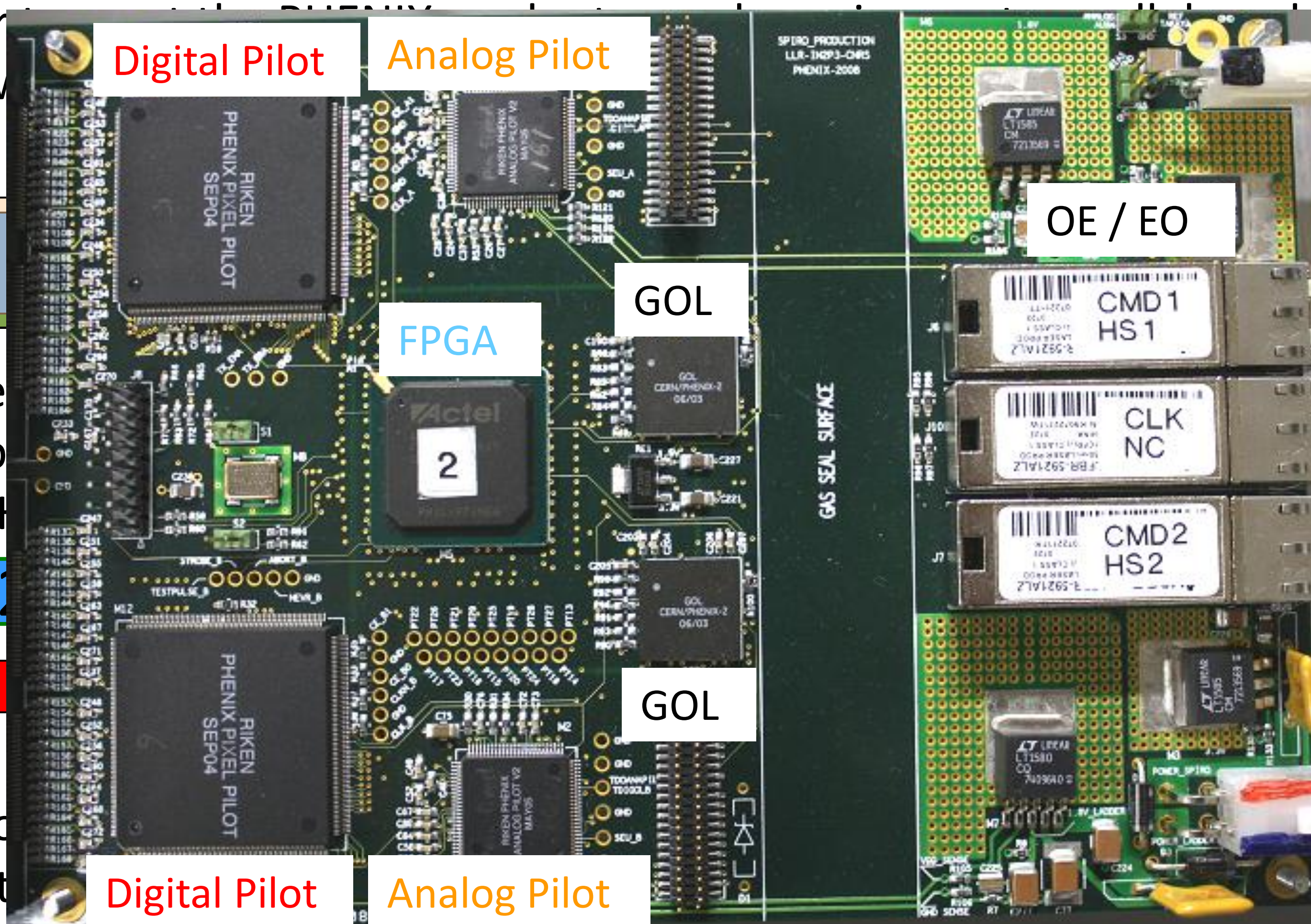
- Amp + Discriminator / channel
- Bump bonded to each pixel
- Running 10MHz clock (RHIC 106nsec)
- Digital buffer for each channel > 4μsec depth
- Trigger capability > FAST OR logic for each crossing
- 4 event buffer after L1 trigger

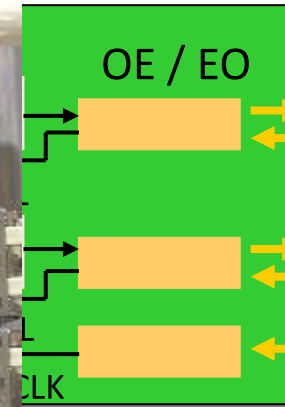
Reaout overview

Readout scheme

In order t ... ut (4 x 32 bit) v







paralle
4 x 32 b
at 10 M

• Number c
• Readout t
= 51.2 μs

e

a from R/O

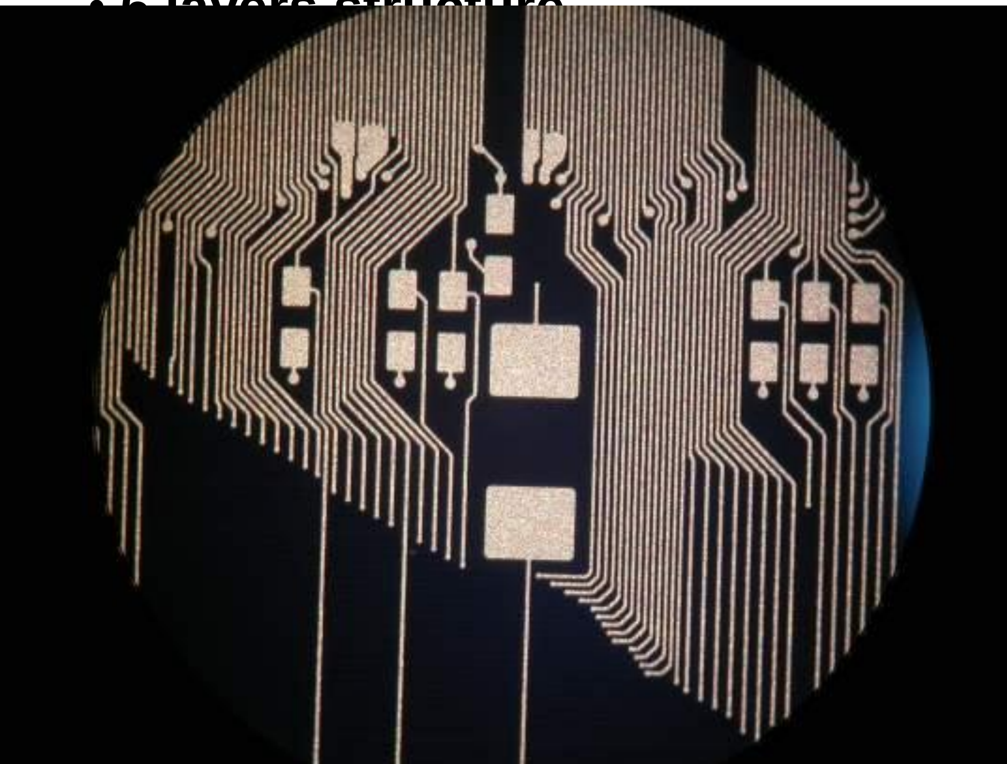
tage for R/O chips.

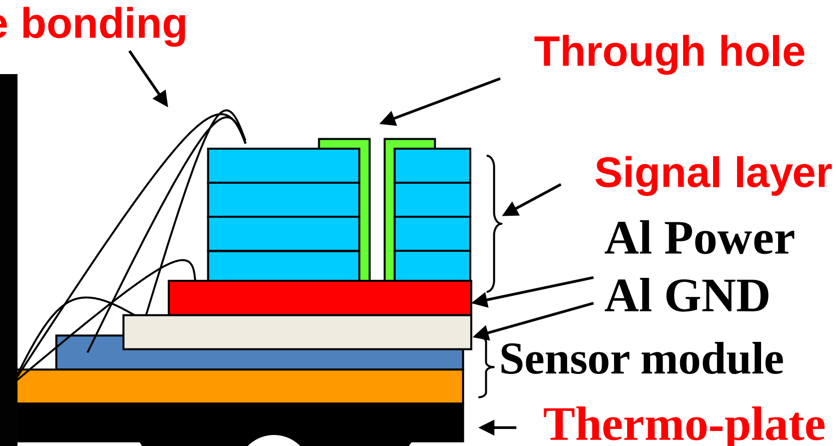
• Monitoring supply, bias voltage and temperature on the detector.

• GOL : Transmit data with 1.6 Gbps

Bus structure

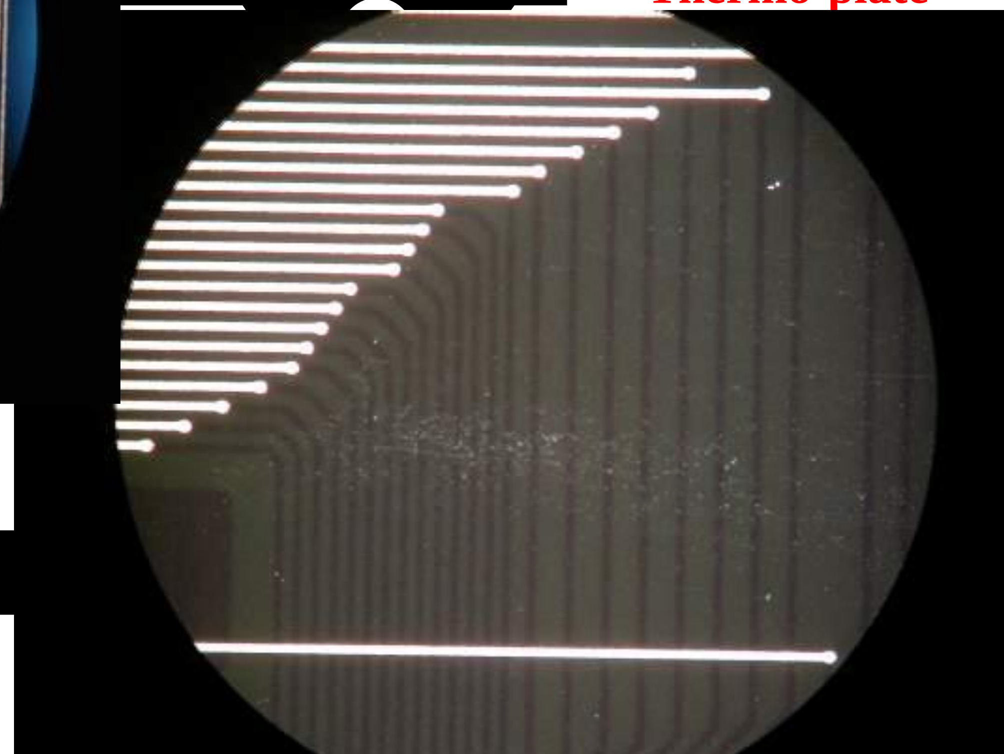
- 6 layers structure





Power 50 µm Al

GND 50 µm Al



Signal lines; 60 µm pitch

Material Budget; Total ~ 0.26 %

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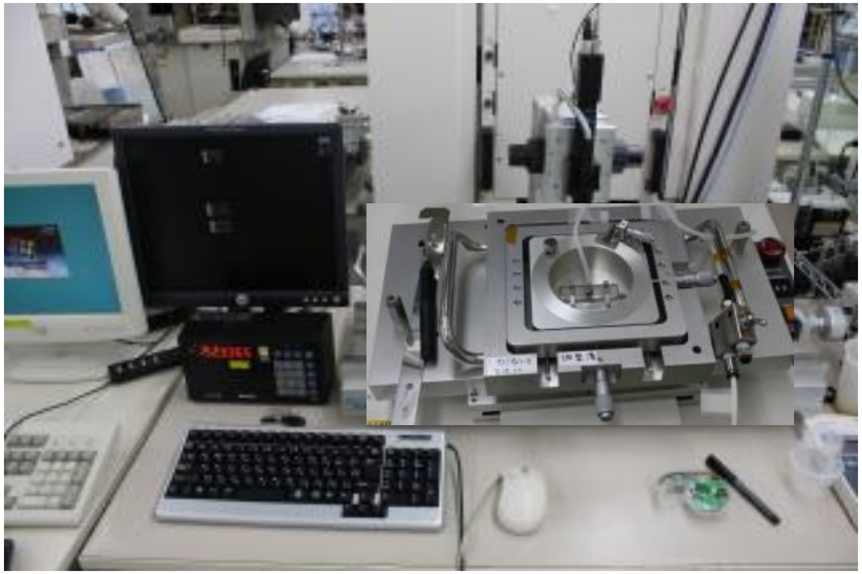
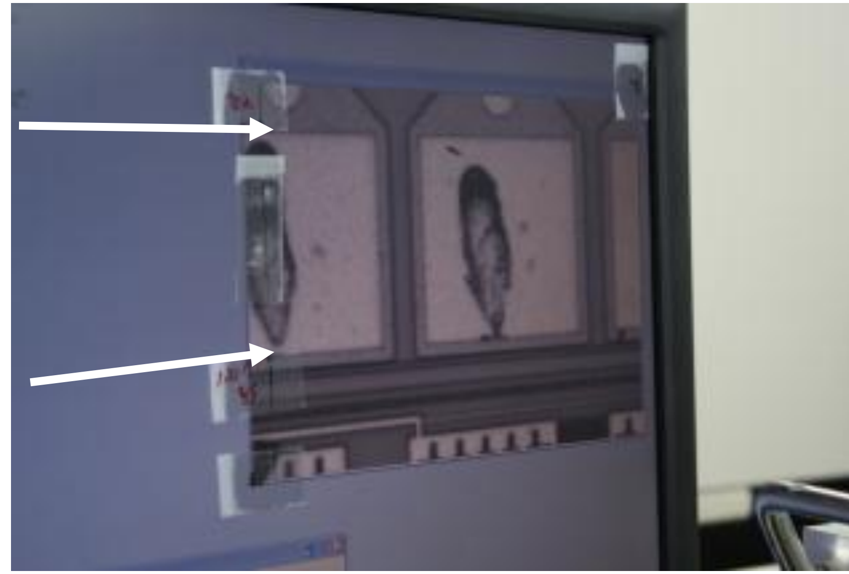
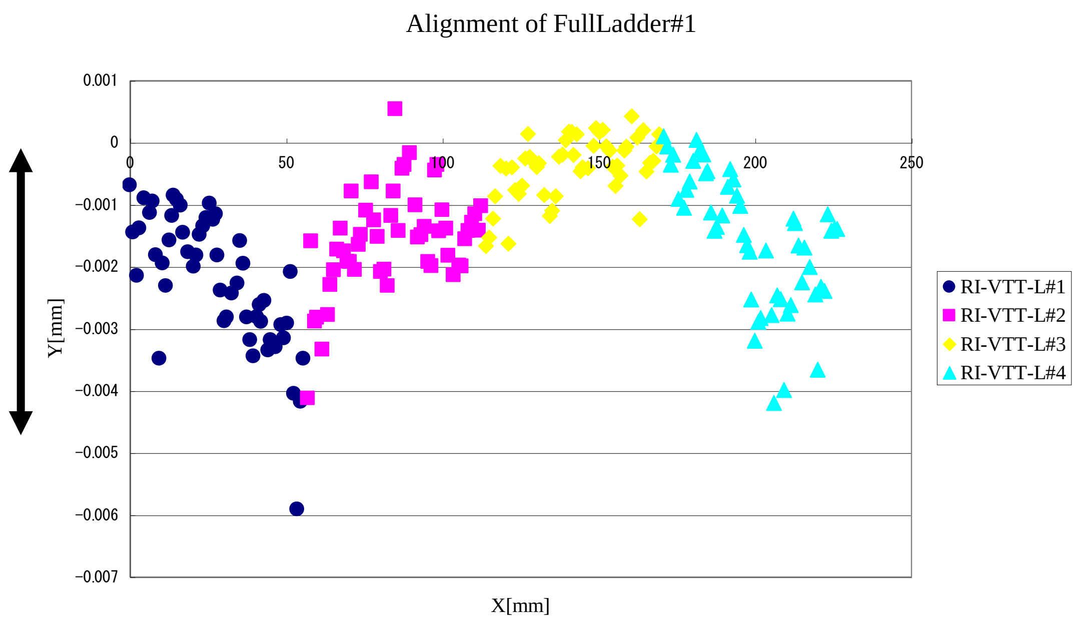
Procedure 3

3. Align each sensor module



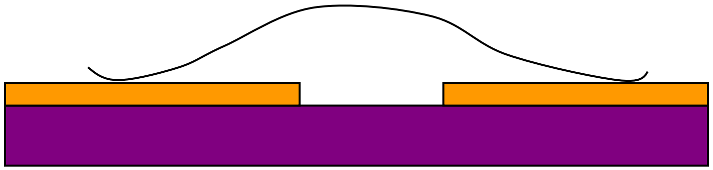


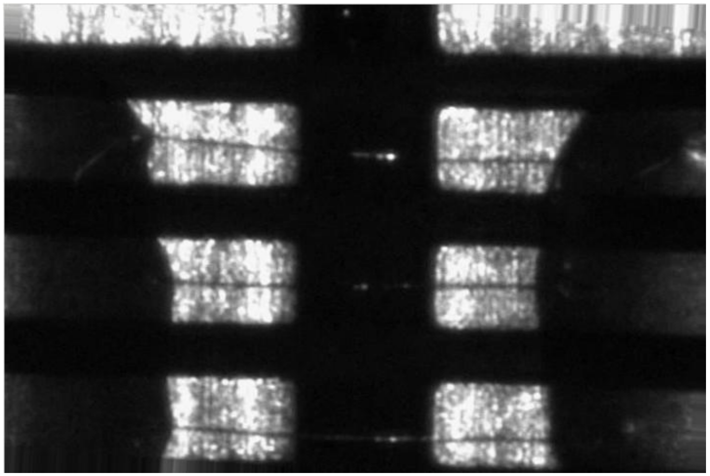
5µm



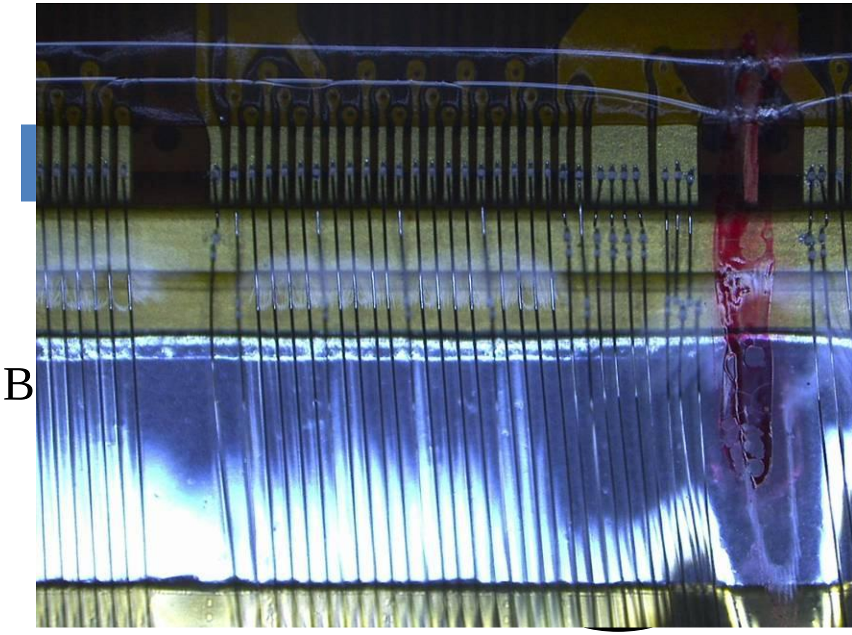
Encapsulation of wire

Side view of bonding wire



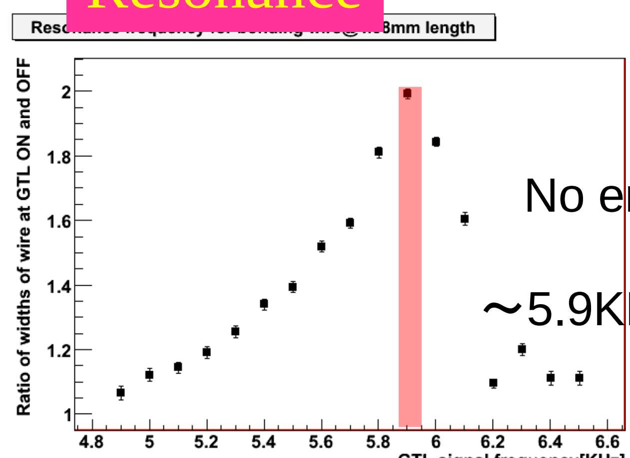


B



Cross section

Resonance



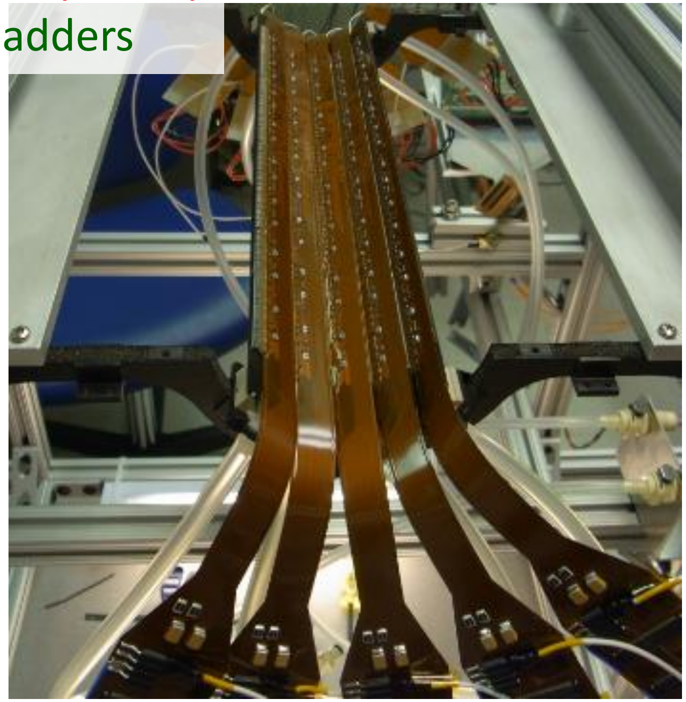
No encap

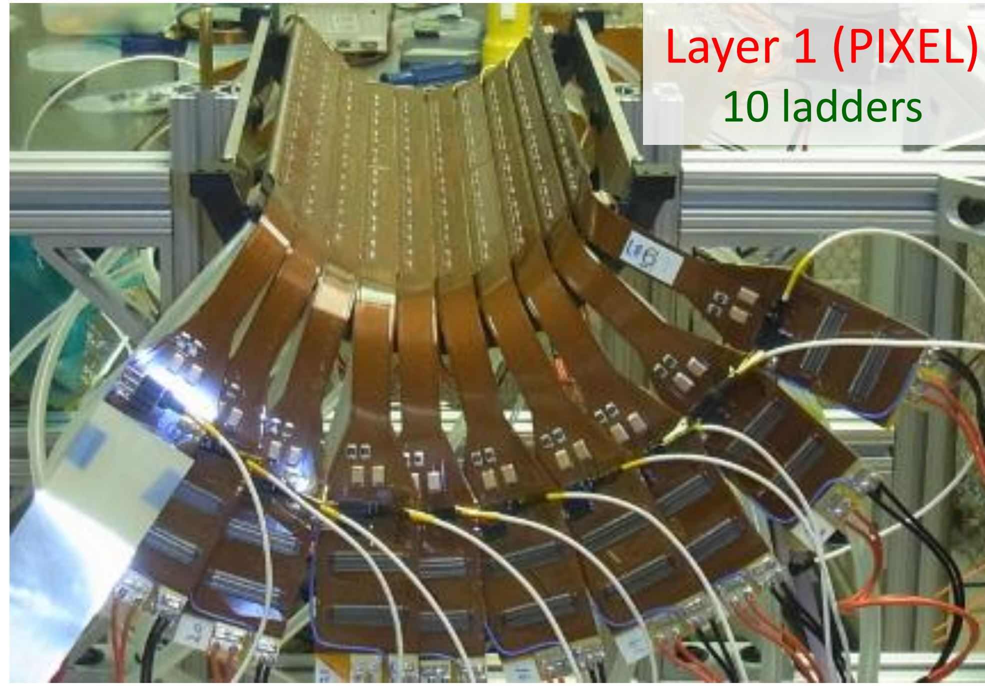
～5.9KHz

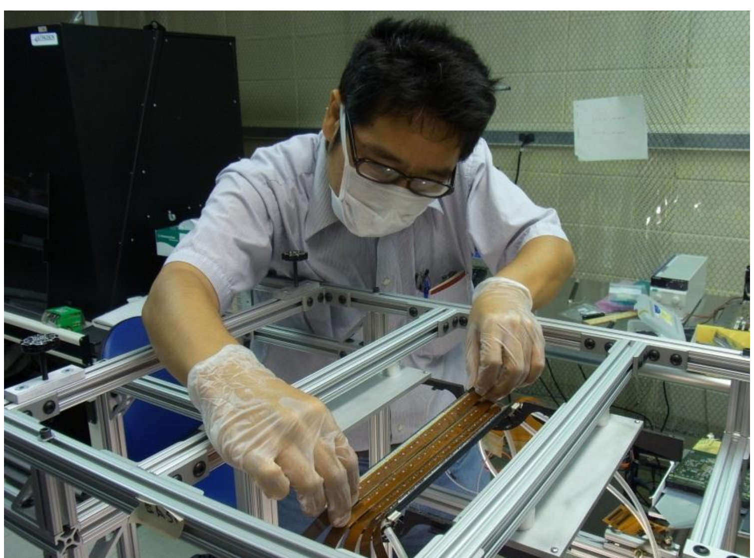
- Wire has intermittent current due to readout synchronized the level 1 trigger.
- Wire vibrates in magnetic field and may break

Installation and Peripheral

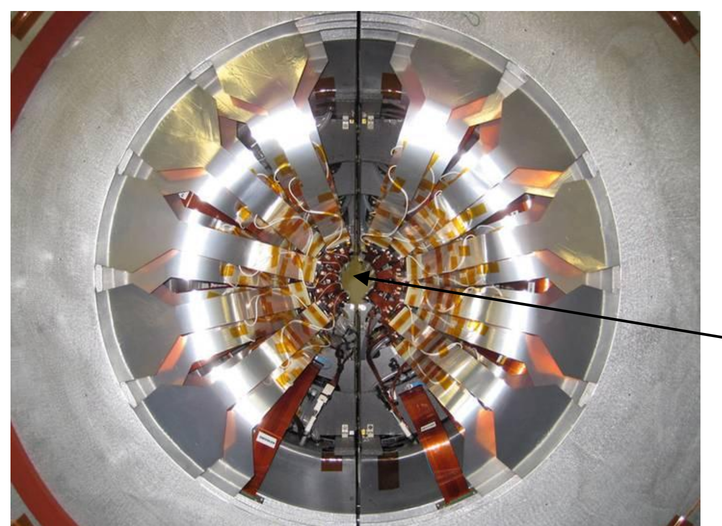
Layer 0 (PIXEL)
5 ladders





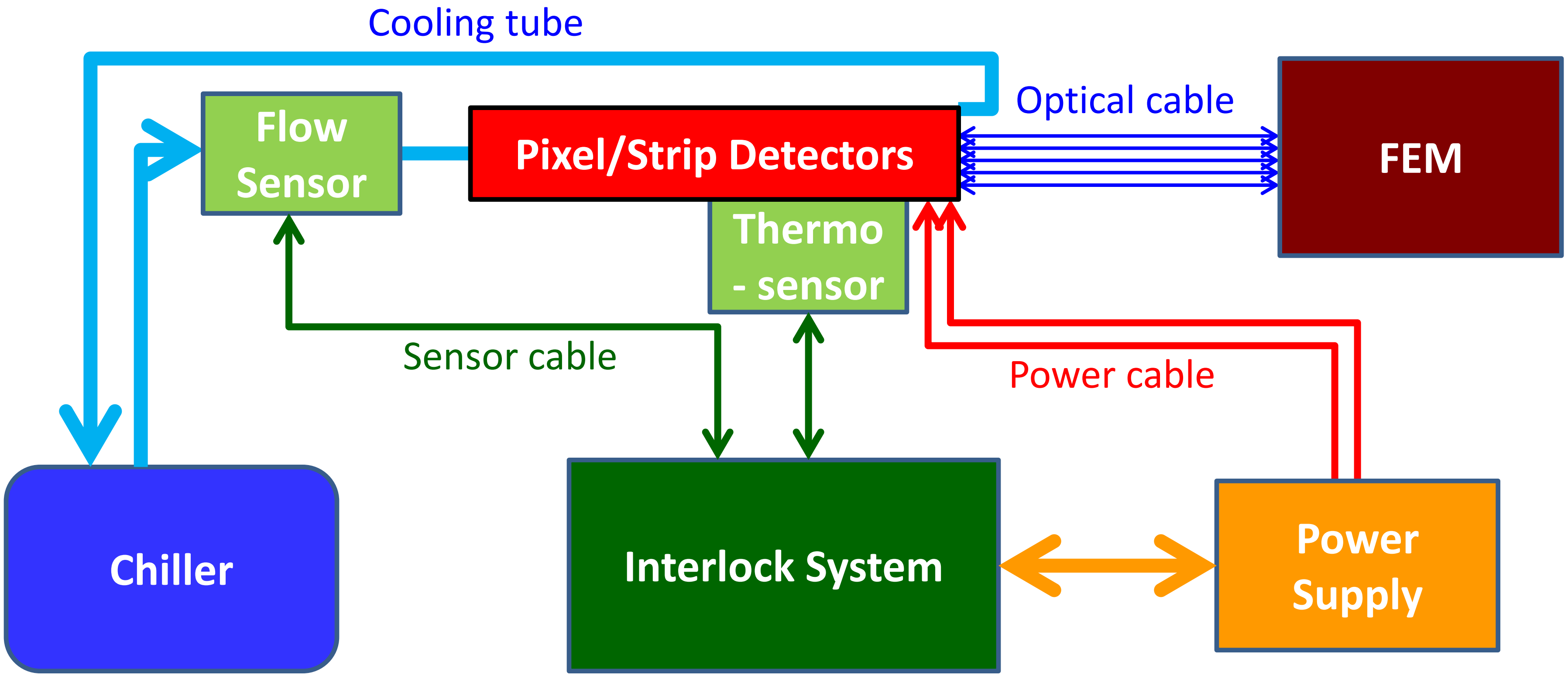


Completed and installed on 2011.12



Berylium beam pipe

VTX System



- To remove power dissipation 1560W/VTX, need to cool down pixel/strip detectors.
- To avoid detector destruction by heating, need safety interlock system
  - Interlock trips off power supply by temperature and flow of coolant.

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Operation and Physics result

Pixel ladder as of 2011 January 15

Q/A test by Asano and Akimoto

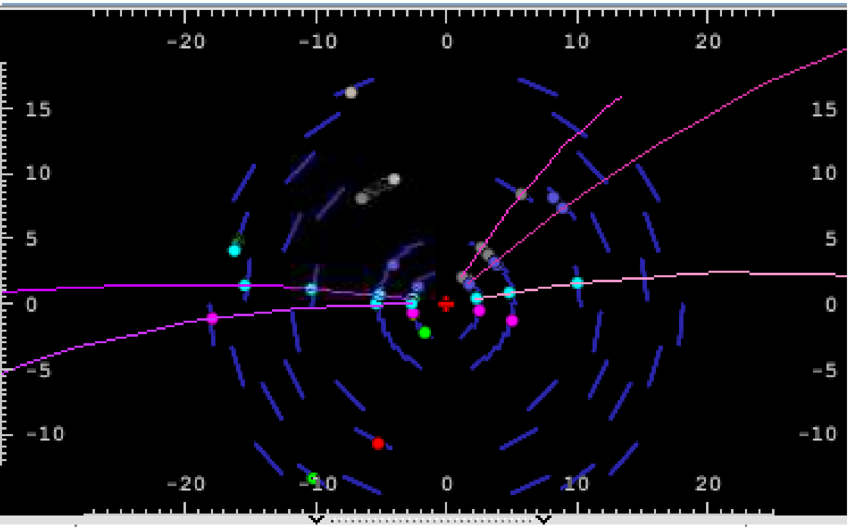
	EE	EF	EG	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ	ER	ES	ET
	Pulse Test@IR 2															
le	R								L							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
West L0	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	X	=	=	50	=	=	=	=	=
West L1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
East L0	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	X	=	=	=	=	=	=	=	=	=
	=	=	=	50	=	=	=	50	=	=	=	=	=	=	=	=
	=	=	=	=	50	X	=	50	50	X	L	50	50	X	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
East L1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	X	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	L	=	=	=	=	X	=	=	=	=	=	=	=	=
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
	=	=	=	25	=	=	=	=	=	=	=	=	=	=	=	=
	=	X	X	X	50	=	=	=	=	=	=	=	=	=	=	=

Date:Jan,15th, 2011

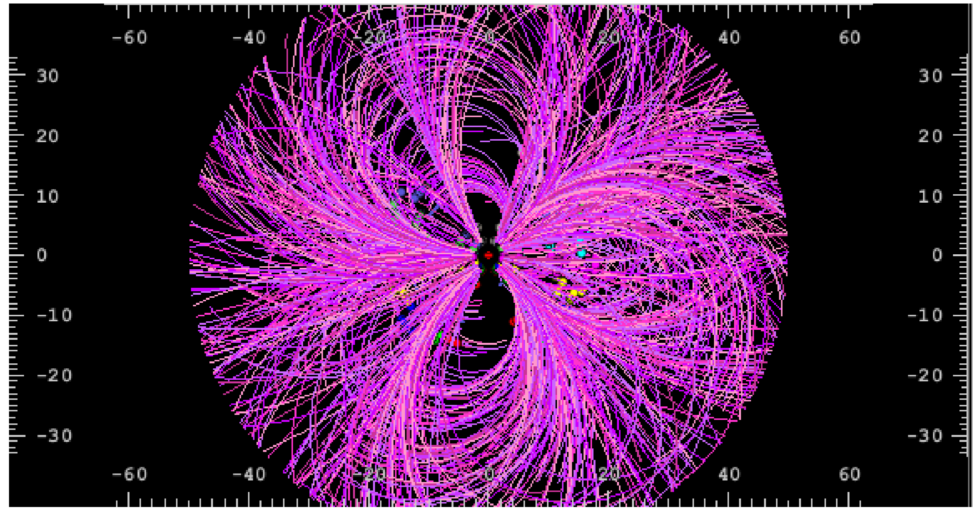
West bottom
Central Arm
West top
West bottom
Central Arm Acceptance
West top
East top
Central Arm
East bottom
East top
Central Arm Acceptance
East bottom

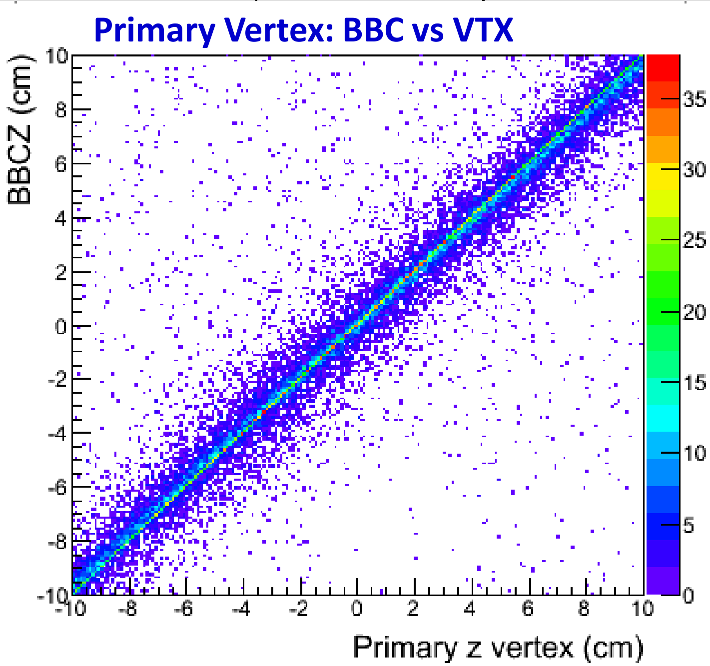
Compiled by H. Asano

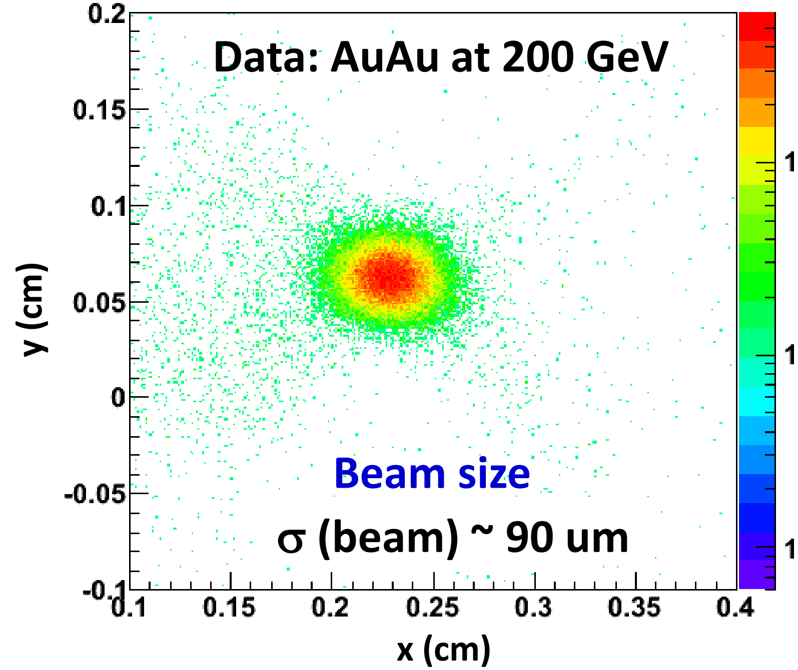
VTX in Run 2012: p+p at 200 GeV



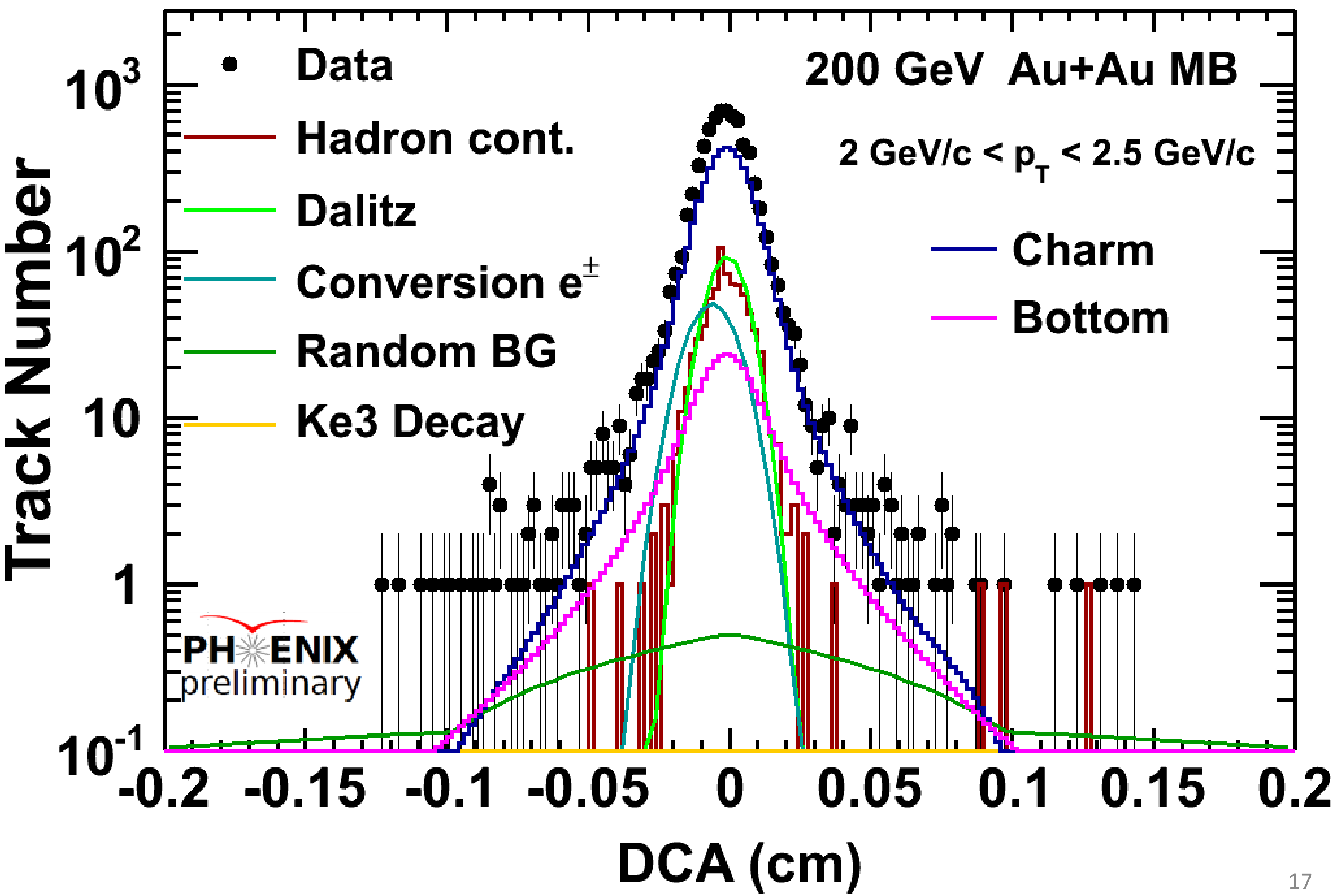
VTX in Run 2011: Au+Au at 200 GeV







Electron



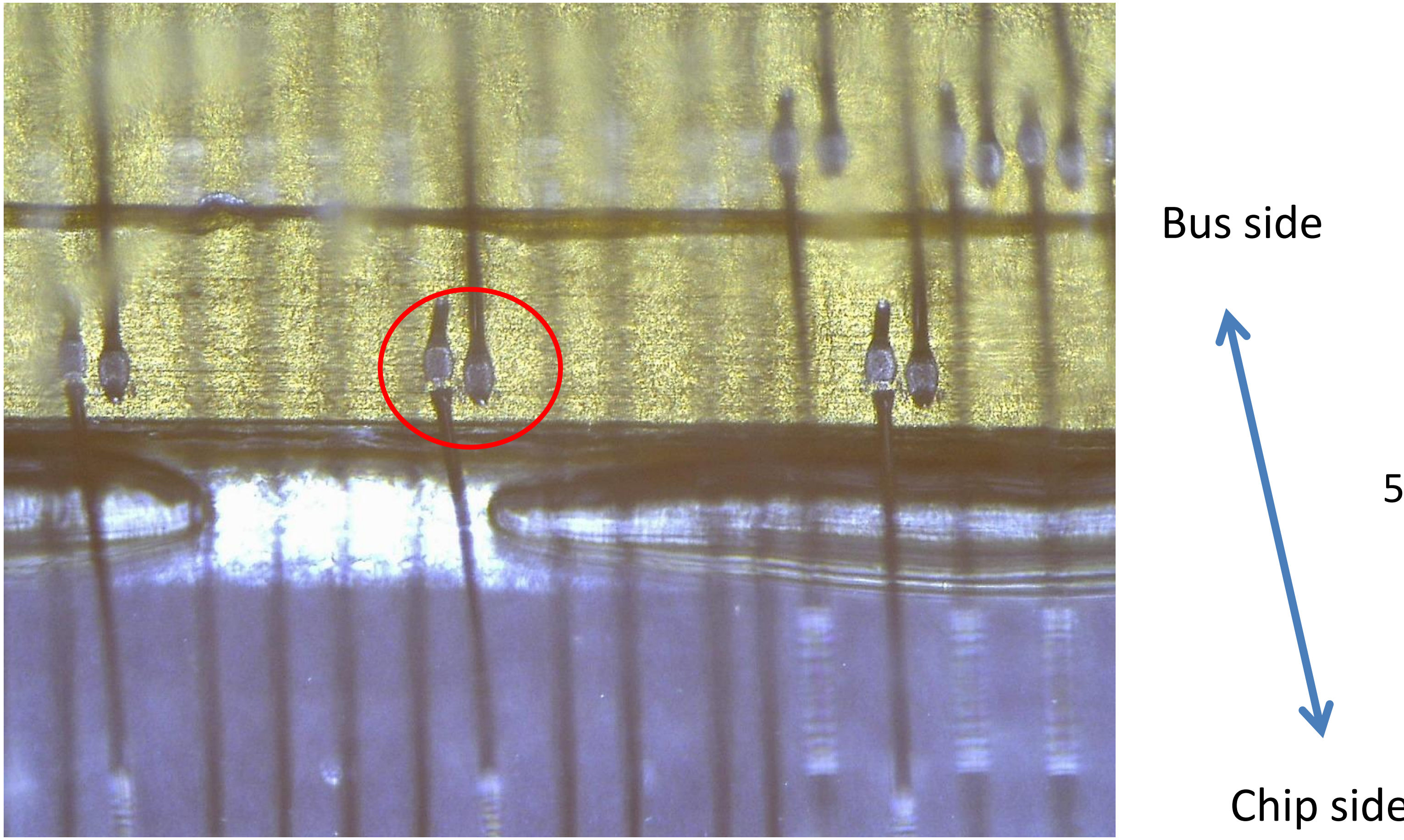
Data
Hadron cont.
Dalitz
Conversion e±
Random BG
Ke3 Decay
200 GeV Au+Au MB
2 GeV/c < p_T < 2.5 GeV/c
Charm
Bottom
PHENIX
preliminary
Track Number
DCA (cm)
10^3
10^2
10
1
10^-1
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2

Pixel at PHENIX VTX completed

- Since 2011.12, Operation started.
- We archived
  - ✓Large acceptance → $|\eta| < 1.2$, $\Delta\phi \sim 2\pi$
  - ✓Primary vertex resolution(DCA) → $\sigma \sim 77\mu m$
  - ✓b->e and c->e separation

- Issues: Damage to wires of pixel detectors during 1st run

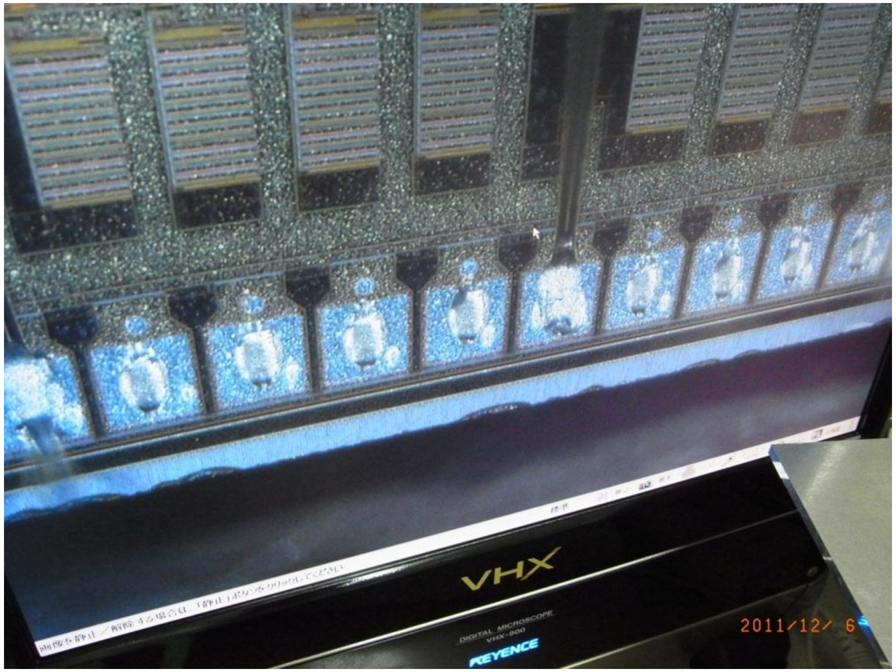
Issue and repair work



Large temperature excursion due to the cooling interlock broke wires.

- Wire breaks at neck. -> not problem on wire bonding, problems on extra tensions
- 5-10deg -> -5deg for a few minibus, by turning off power ~ 1W/cm^2, but running cooling system
- Expansion coefficient Encapusulant ~ 300ppm/deg (Sylgard 184 and 186)
  Other material (Myler, Si, Al, Cu Carbon) 20~30ppm/deg

Reapir



1. Removing encapulant
2. Clean up pad

- But fear to damage pad
- Decide wire on bond mark.

- After re-wire bonding, pull tests were performed.
- Always neck breaks with 6-8g tension.

Actions and Repairing work

- Fix interlock system, minimize unnecessary LV off.
- Operate 15-20deg, to decrease thermal shock.
  - No additional broken wire.
- Repair work
  1. Remove encapsulant
  2. Clean up bonding pad
  3. Re-wire bonding
  4. encapsulation

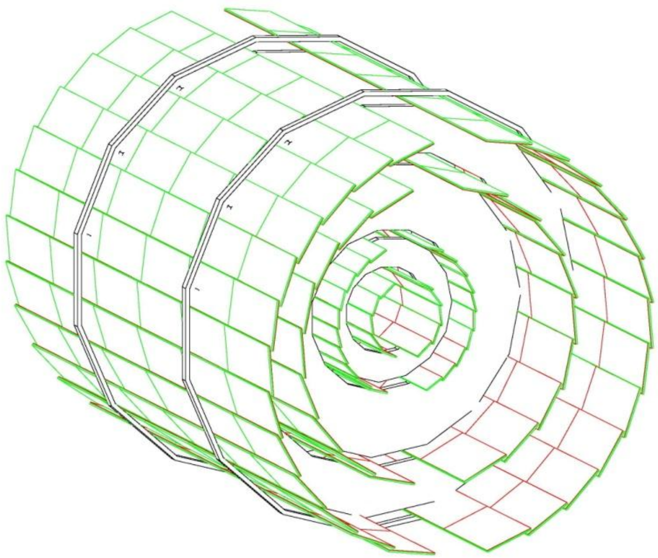
- Encapsulant
  - Available encapsulation material 300ppm/deg
  - Use soft material to minimize extra tension.
    - Penetration 65 (JIS K2207)
- Survive Heat shock test (0<->40deg 1min 50 times)

Summary

- We constructed Si Pixel detector for heavy ion collision experiments.
- It works and performs well for physics
  - Vertex resolution 77μm.
- Some of pixel ladders were damaged in the first run. Repair work is underway

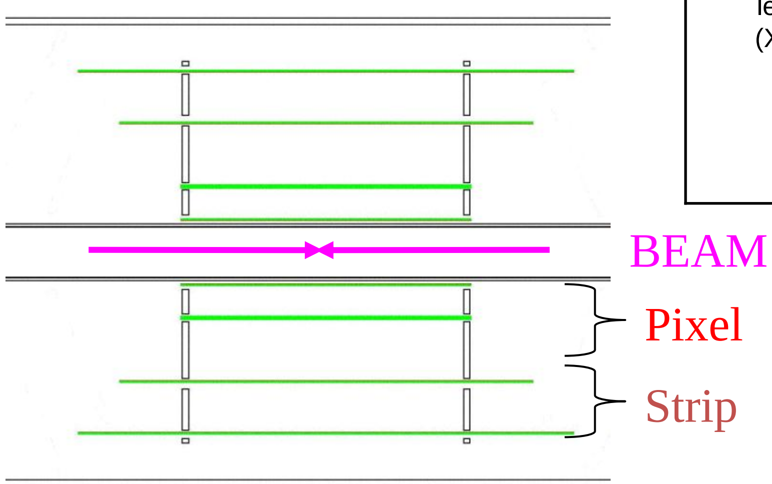
Backup

VTX parameters (in proposal)



Pixel detector Strip detector

VTX	Layer	R1	R2	R3	R4
Geometrical dimensions	R (cm)	2.5	5	10	14
	Δz (cm)	21.8	21.8	31.8	38.2
	Area (cm^2)	280	560	1960	3400
Channel count	Sensor size R × z (cm^2)	1.28 × 1.36 (256 × 32 pixels)		3.43 × 6.36 (384 × 2 strips)	
	Channel size	50 × 425 μm^2		80 μm × 3 cm (effective 80 × 1000 μm^2)	
	Sensors/ladder	4 × 4		5	6
	Ladders	10	20	18	26
	Sensors	160	320	90	156
	Readout chips	160	320	1080	1872
	Readout channels	1,310,720	2,621,440	138,240	239,616
Radiation length (X/X0)	Sensor	0.22%		0.67 %	
	Readout	0.16%		0.64 %	
	Bus	0.28%			
	Ladder & cooling	0.78%		0.78 %	
	Total	1.44%		2.1 %	



Layer	radius	Detector	Occupancy in Au+Au collision	
Layer 1	2.5 cm	Pixel	0.53 %	
Layer 2	5.0 cm	Pixel	0.16%	
Layer 3	10.0 cm	Strip	4.5 % (x-strip)	4.7 % (u-strip)
Layer 4	14.0 cm	Strip	2.5 % (x-strip)	2.7 % (u-strip)