Si Micro Pixel Detector

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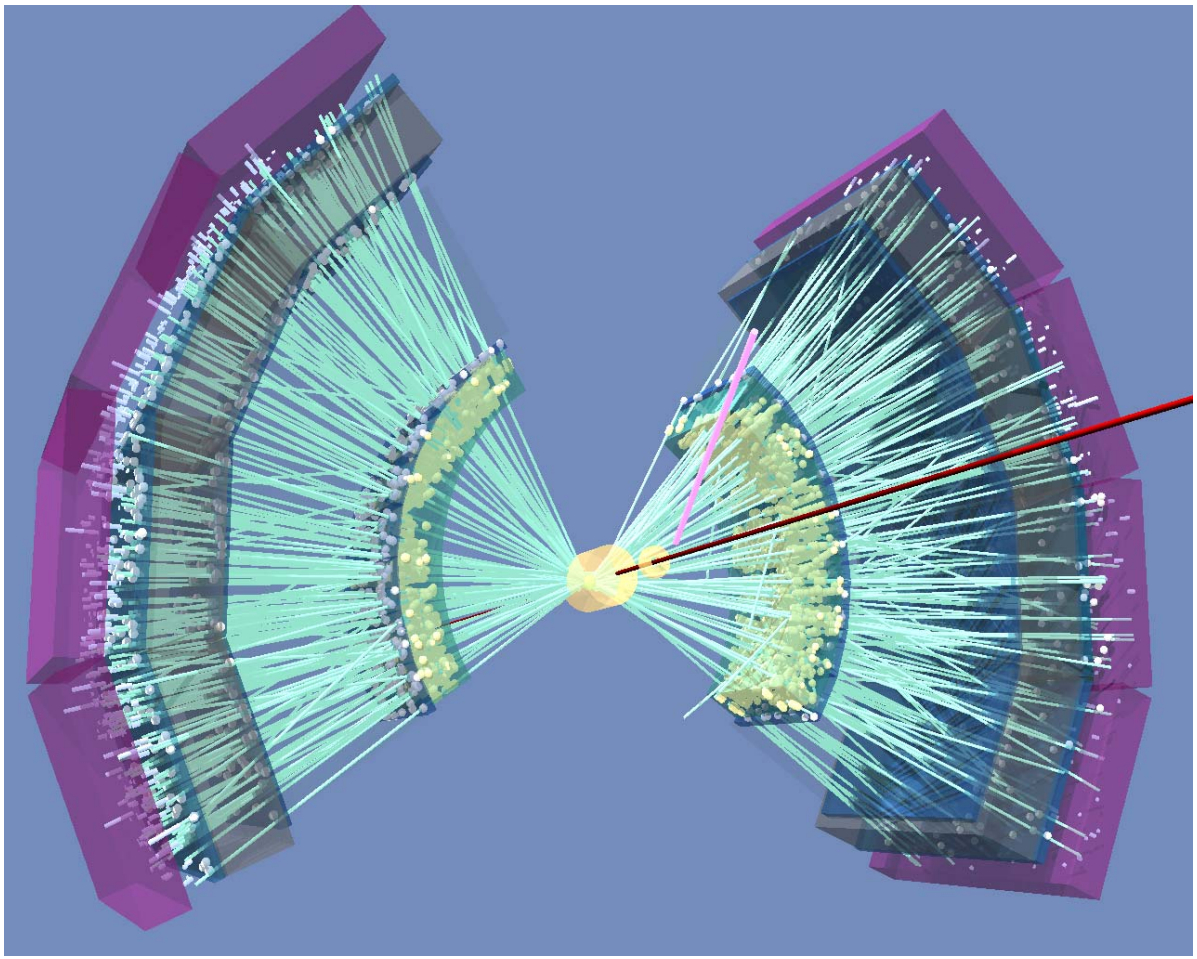
1. Pixel Detector at RHIC experiment
2. Pixel Detector for RIBF experiment

RHICでの物理からの要求



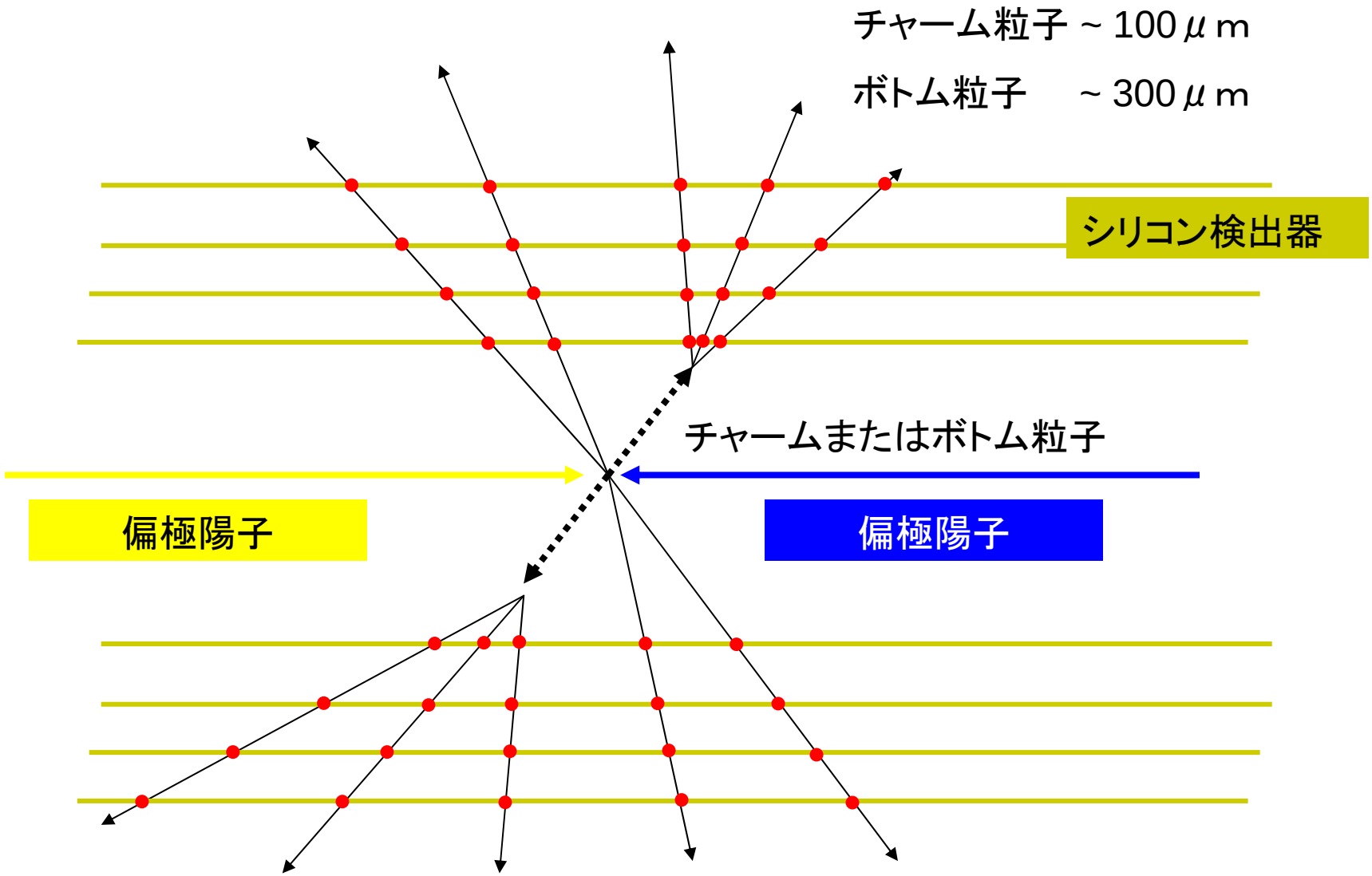
荷電粒子総数　~ 2000

この中から

Charm　quark

bottom quark　を見つける。

長寿命の粒子をみつける



Feature of Silicon Detector

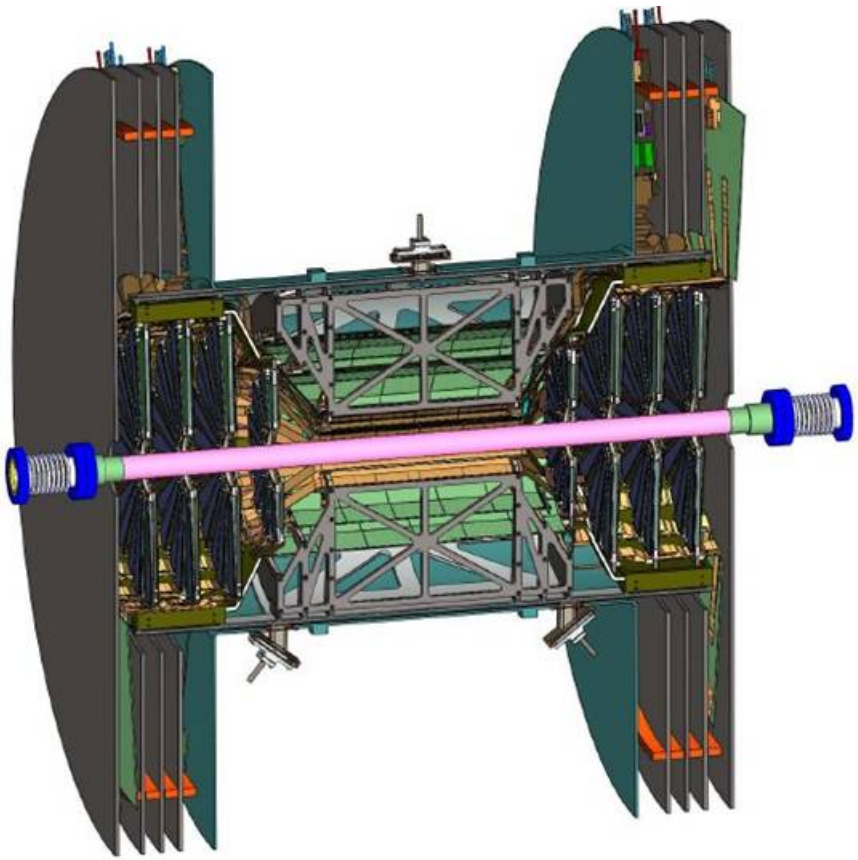
- High dE/dx (~ 2MeV /(g/cm^2))
  - Solid state detector comparing to gas chamber -> thin detector
- Low e-h pair creation energy
  - 3.6 eV instead of 13.6 eV for gas chamber
- Available Technology
  - Small and precise
  - Huge number of read out channel
- But no intrinsic amplification
  - Required low noise electronics

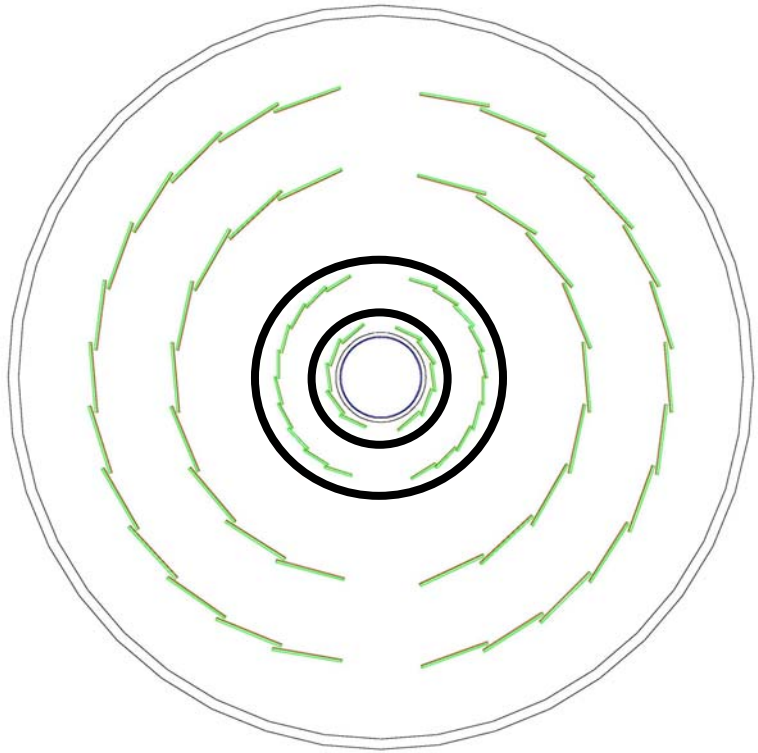
Required Specification

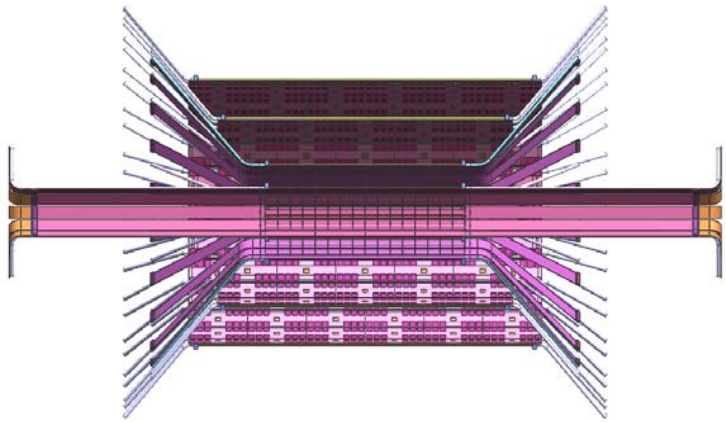
- Collision Rate ~ 10MHz
  -> Timing Resolution < 100nsec
- Trigger Rate 5KHz ~ 10KHz
- Occupancy < 1% for pixel detector
- Pixel size 50 * 425 micron
- Tracking Resolution 50micron for displacement
- High precision at mechanical construction
  ~ 25 micron for internal
- Material Budget ~ 1% of radiation length
  荷電粒子の多重散乱、ガンマ線による電子ー陽電子対発生をふせぐ

Full detector shape

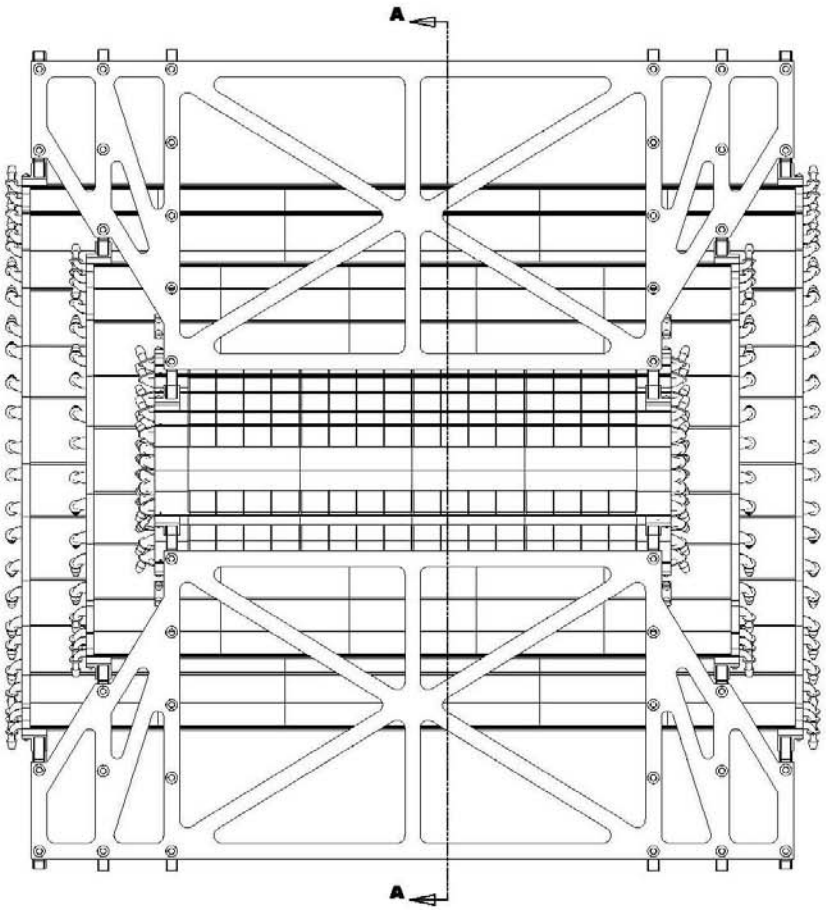
- Inner 2 barrel will be equipped with silicon Pixel detector

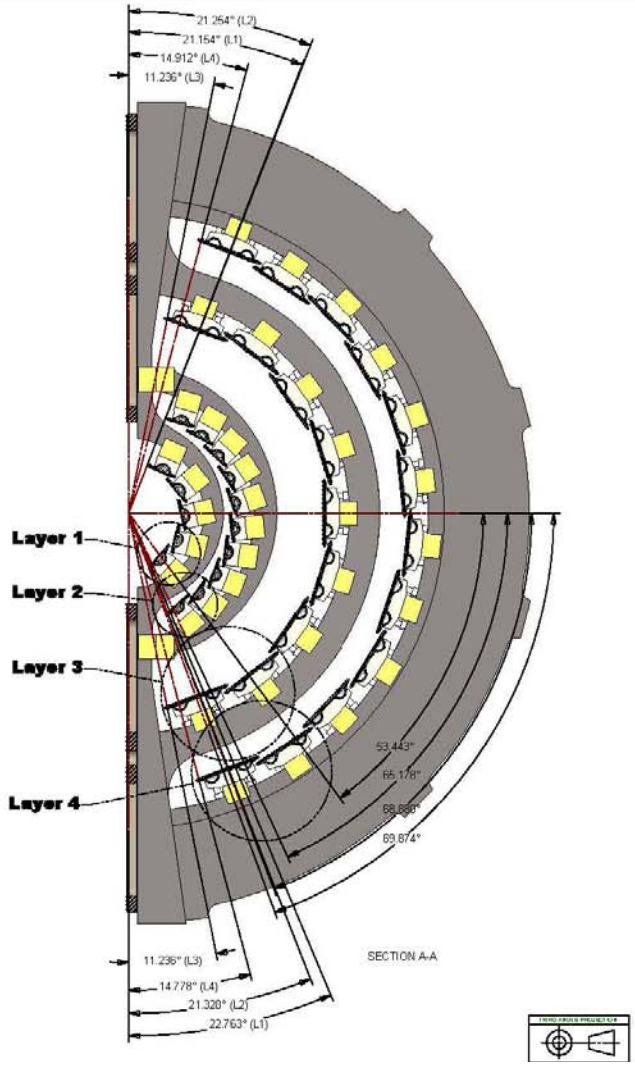






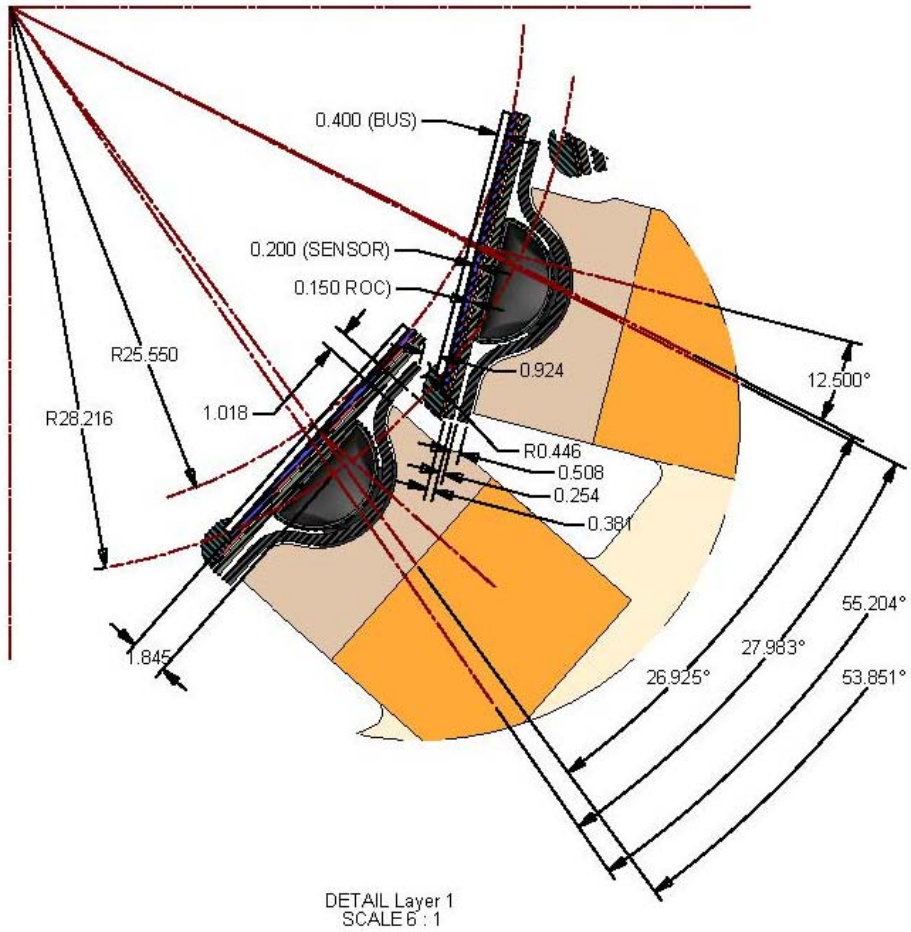
Current baseline for layer 1&2 position -





Current pixel ladder baseline -

Current CAD model has sensors in neighboring ladders aligned to their ideal edge location – no allowance for positioning error. Currently RIKEN proposes 10. micron sensor positioning tolerance, HYTEC proposes 25. – 50. microns positioning tolerance ladder to ladder.



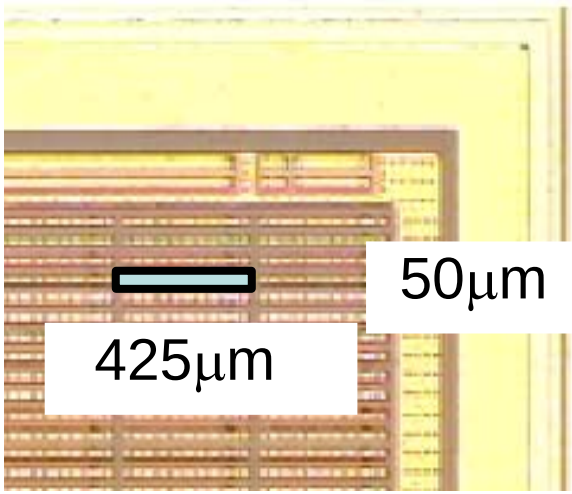
Specification

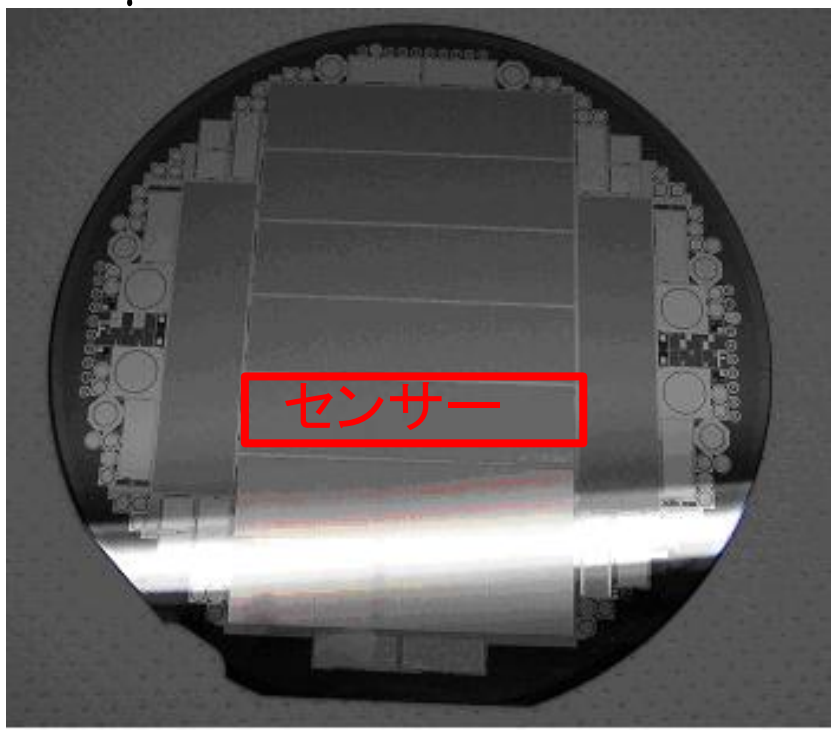
VTX	Layer	R1	R2	R3	R4
Geometrical dimensions	R (cm)	2.5	5	10	14
	Δz (cm)	21.8	21.8	31.8	38.2
	Area (cm^2)	280	560	1240	1600
Channel count	Sensor size $R \times z$ (cm^2)	1.28×1.36 (256×32 pixels)		3.43×6.36 (384×2 strips)	
	Channel size	50×425 μm^2		80 μm $\times$ 3 cm (effective 80×1000 μm^2)	
	Sensors/ladder	2×8		5	6
	Ladders	10	20	18	26
	Sensors	160	320	90	144
	Readout chips	160	320	1080	1728
	Readout channels	1,310,720	2,621,440	138,240	221,184
Radiation length (X/X0)	Sensor	0.2%		0.5 %	
	Readout	0.16%		0.8 %	
	Bus	0.14%			
	Ladder & cooling	0.7%		0.7 %	
	Total	1.2%		2.0 %	

ピクセルセンサー

- p-in-n シリコンピクセルセンサー
- 厚さ200μm (最小電離粒子:15000e^-)
- 32 x 256 (x4) ピクセル
- ピクセルの大きさ
  - 50 x 425μm^2
  - Intrinsic Resolution = 50 / √12 = 14μm
  - Diffusion + 多重散乱　~ 10μm
- 有感面積 12.8 x 13.6mm^2
- 空乏化電圧 ～8V

ピクセルセンサー

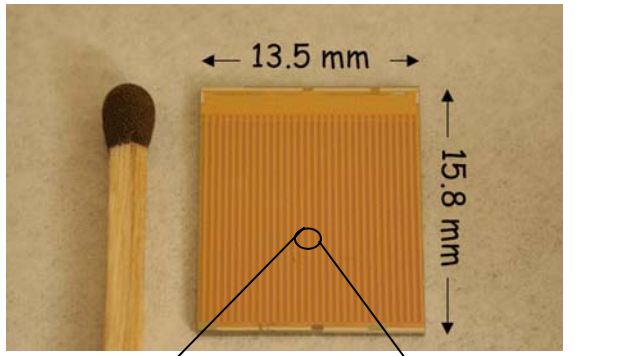


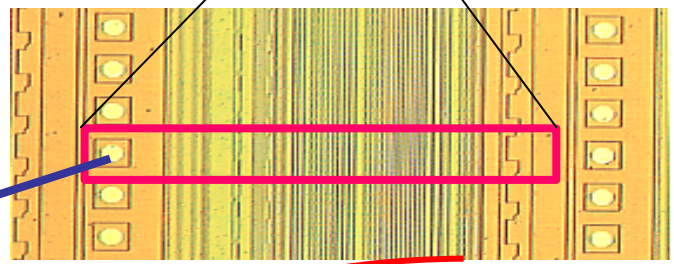


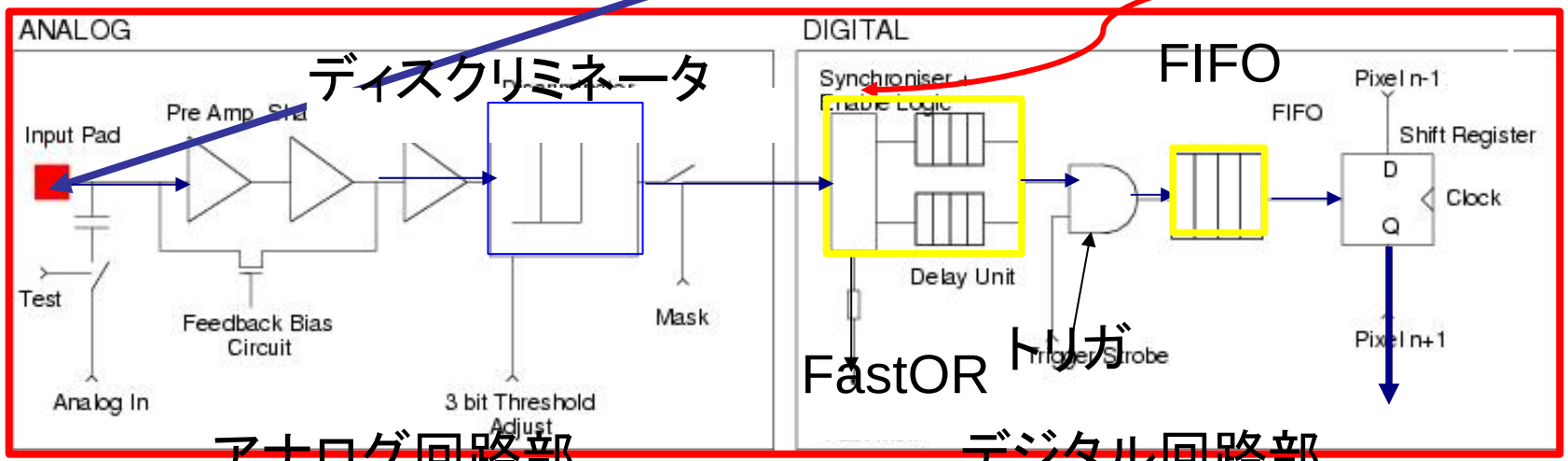
5インチウエファー

読み出しチップ

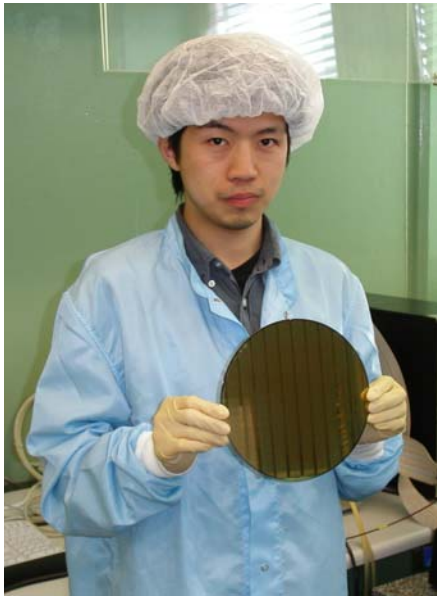
- **ALICE1LHCB読み出しチップ**
  - 8192チャンネル (32 x 256)
  - 大きさ:13.5mm x 15.8mm x 150❍m
    - CMOS 0.25❍m放射線耐性プロセス
  - 8ビット(+3ビット)で閾値を設定
  - パイプライン
  - 4イベントFIFO　デットタイム無し
  - 読み出し速度25.6❍秒@10MHzクロック
  - 放射線耐性 ～30Mrad
  - 消費電力 ～1W/chip

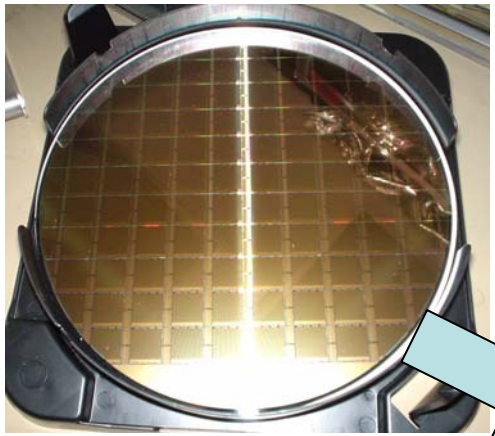






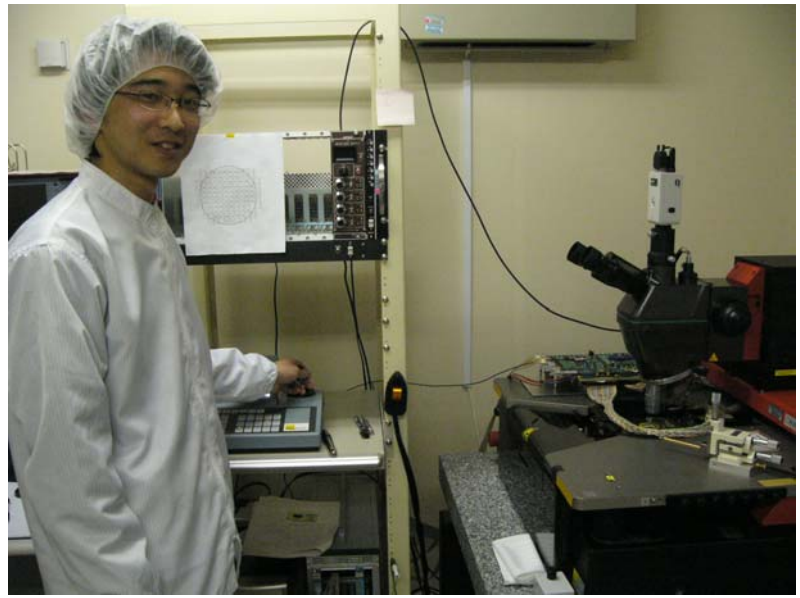
Readout chip probing

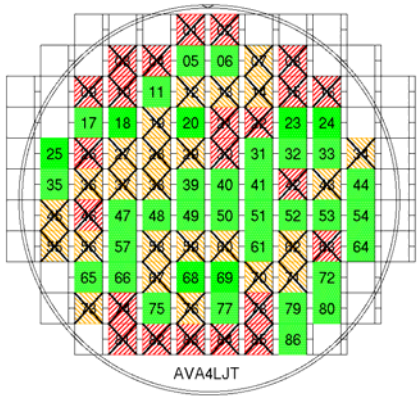




86 chips are on 8” wafer

Probe station setup at RIKEN



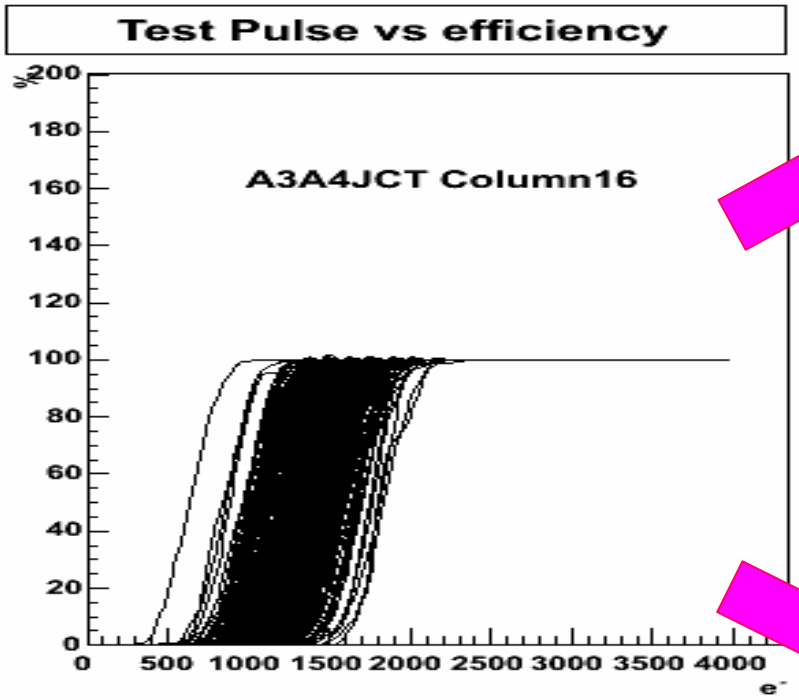


Typical results

- 21 wafers have been probed

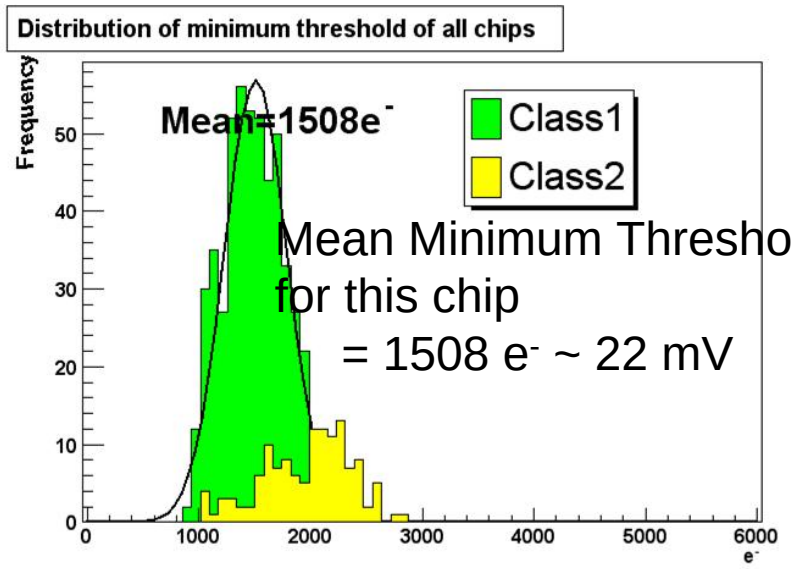
Class I	All functions are OK, defect pixels <= 1%
Class II	All functions are OK, but defect pixels > 1%
Class III	Not working with function

Typical test result

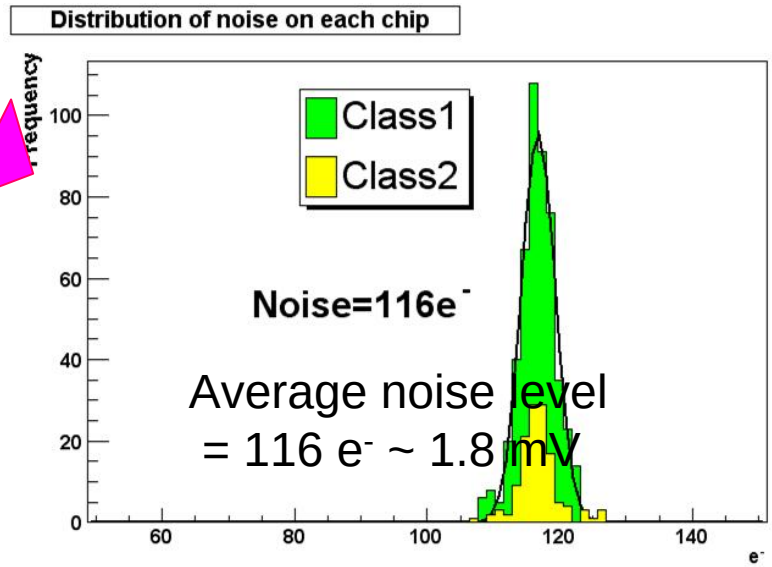


Results of threshold scan for all individual pixel on column (256 curves are superimposed)

MIP signal in 200 μm sensor ~ 14,000 e-

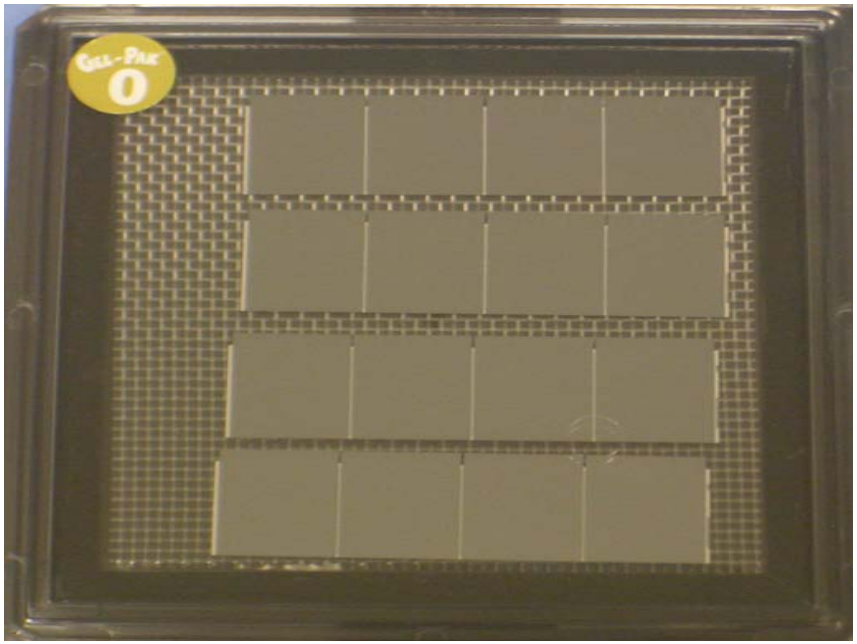


Mean Minimum Threshold for this chip = 1508 e- ~ 22 mV

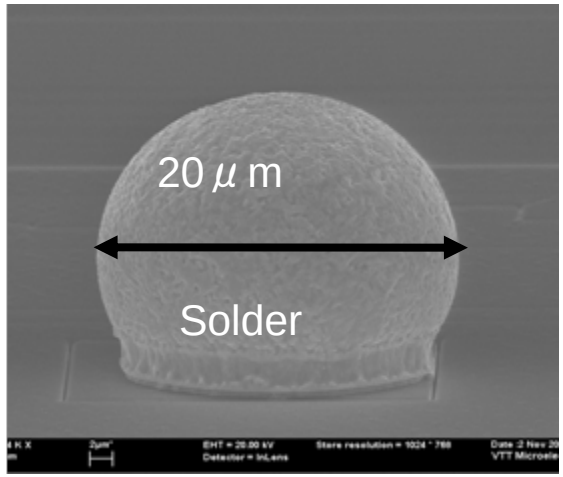


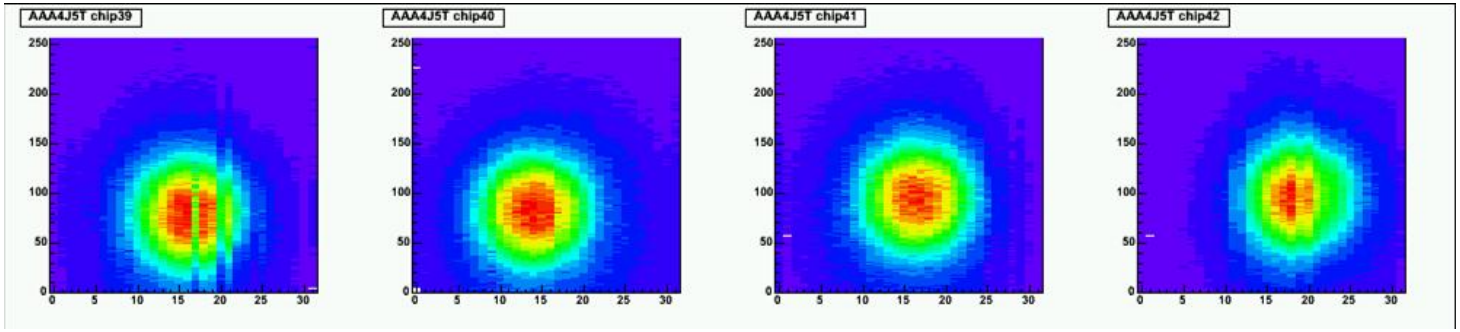
Average noise level = 116 e- ~ 1.8 mV

Bump bonding



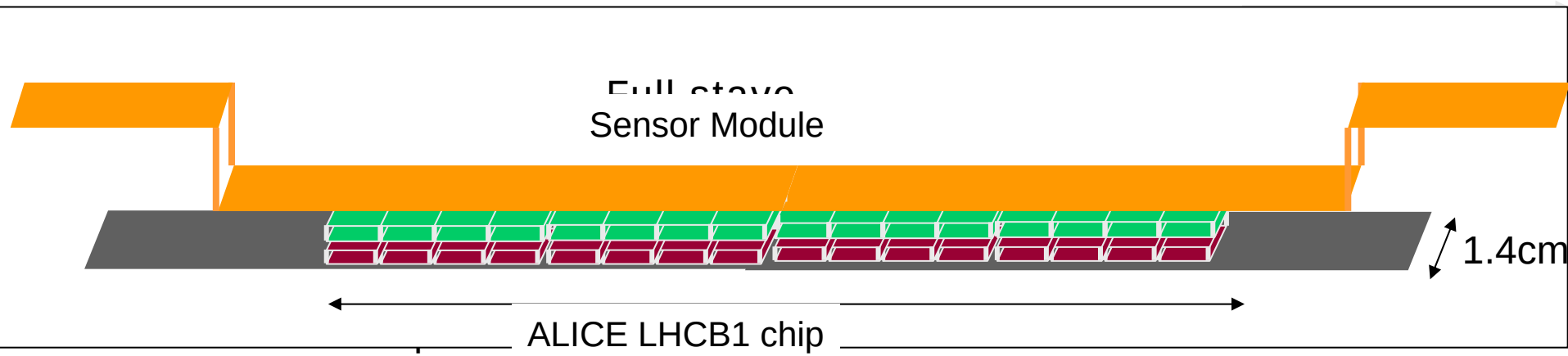
Bump bond to
silicon pixel sensor





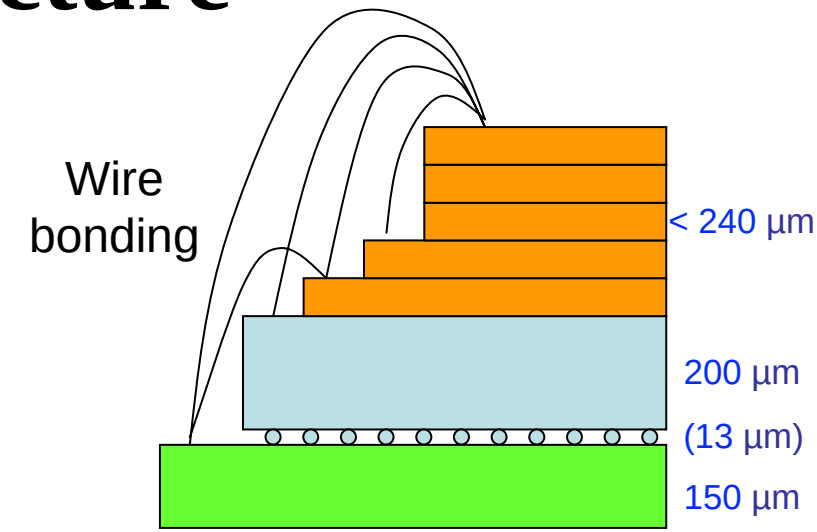
Pixel detector module

- Sensor module consists of 4 ALICE Pixel readout chips Bump-bonded to silicon sensor
- One readout unit, half stave, made from two sensor modules
- Half stave is mounted on the support structure
- Pixel BUS to bring data out and send control signal in to the readout chip is mounted on the half stave
- Each detector module is built of two half staves, read out on the barrel ends

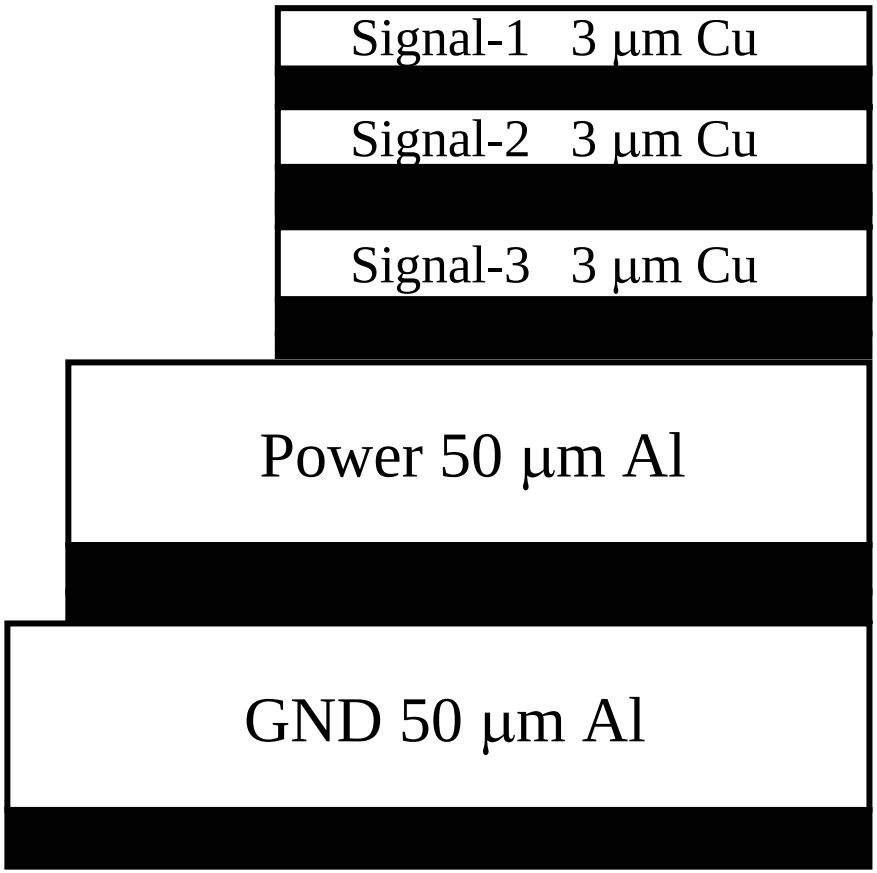


Bus structure

- **5 layers structure**
- **GND, Power and 3 signal lines**



Final configuration



Signal 1; (for Surface Mount Device)

Signal-1, Signal-2, and signal-3 are connected with through hole

Signal 2; (Vertical line)

line connected with pixel chip with wire bonding

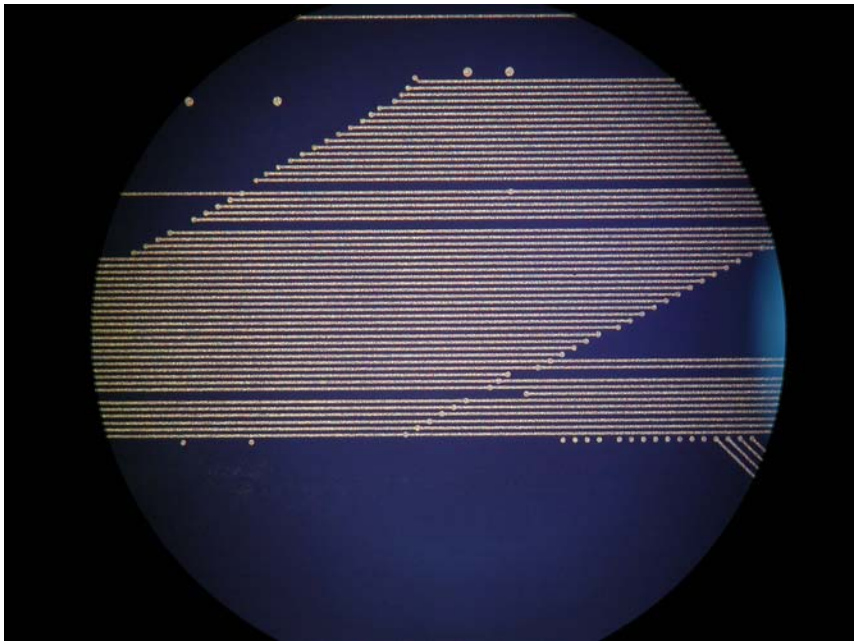
Signal 3; (Horizontal line)

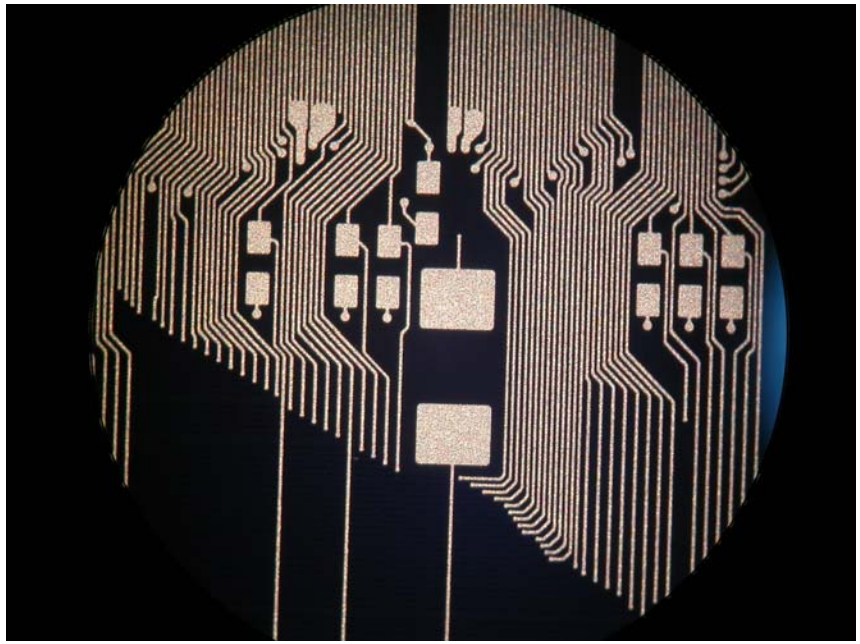
send signal to Pilot Module connected with vertical line with through hole

Signal lines; 60 μm pitch

Material Budget; Total ~ 0.26 %

Bus





Using 3 micron thick Cu as signal patterns and 50 micron Al for GND/Power line.

Cu Pattern and through hole are manufactured industry standard technology. ->

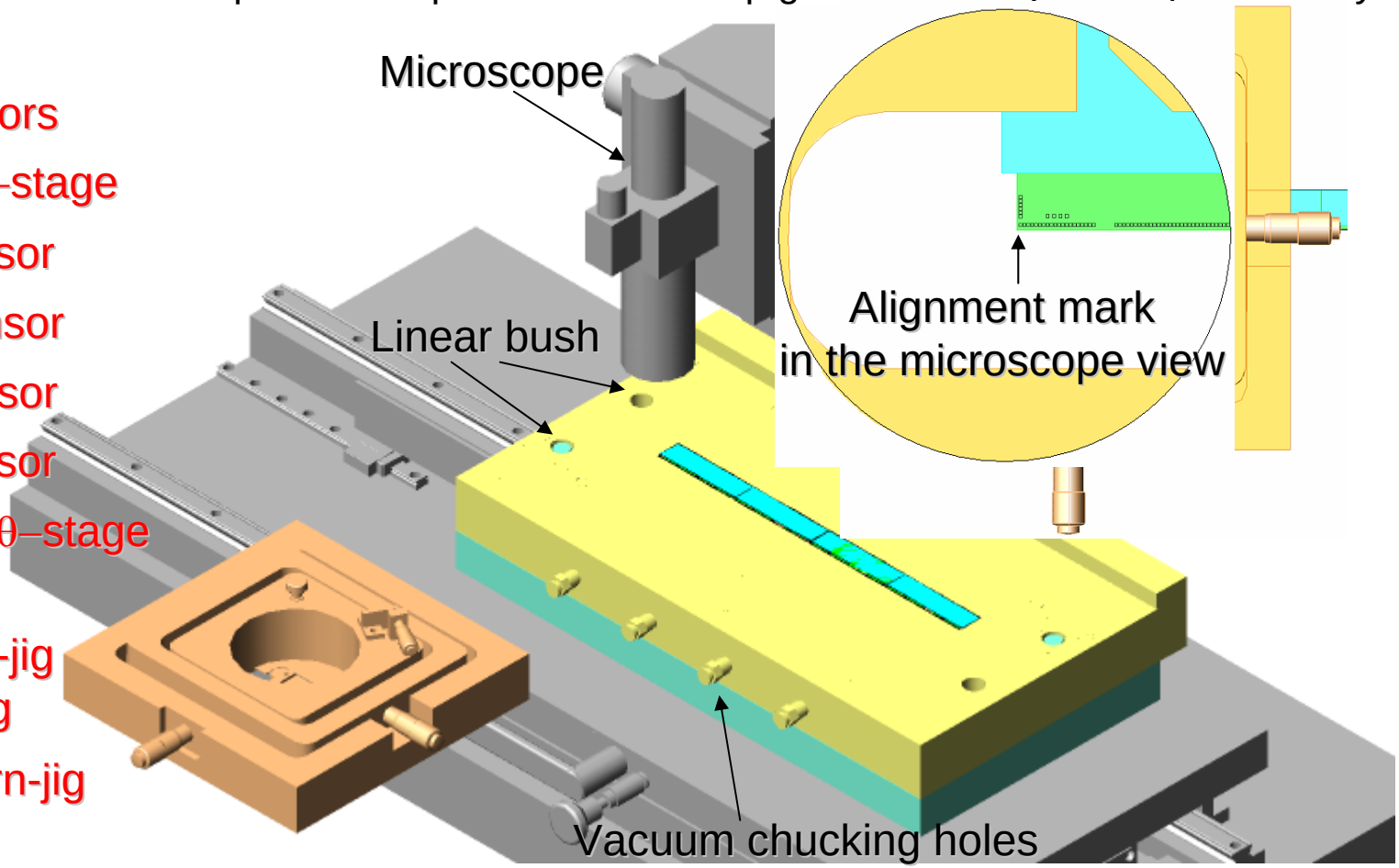
Alignment

Linear bush:

Linear ball bearing inside in the shell structure

- Relative position between jigs is determined by linear bush and pin at <5μm accuracy in order to assemble stave at <25μm precision.
- Jigs have a flexibility for modification of the component.
- Detailed and quantitative procedures to keep good uniformity and reproducibility

1. Set the sensors
2. Set the XYθ–stage
3. Align 1st sensor
4. Align 2nd sensor
5. Align 3rd sensor
6. Align 4th sensor
7. Take out XYθ–stage and slide
8. Set the Turn-jig and chucking
9. Take out Turn-jig



Gluing

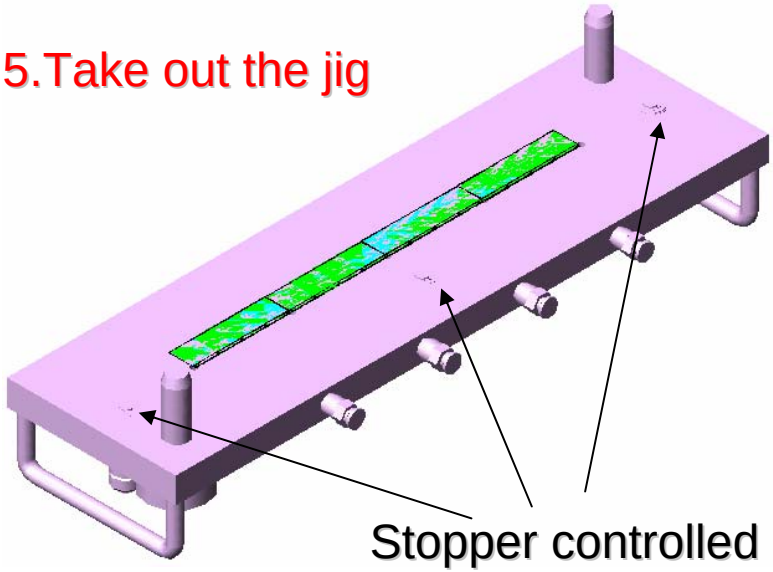
1.Set the jig on the glue dispenser robot

2.Set the C/C support and on the jig

3.Dispense the glue on the support

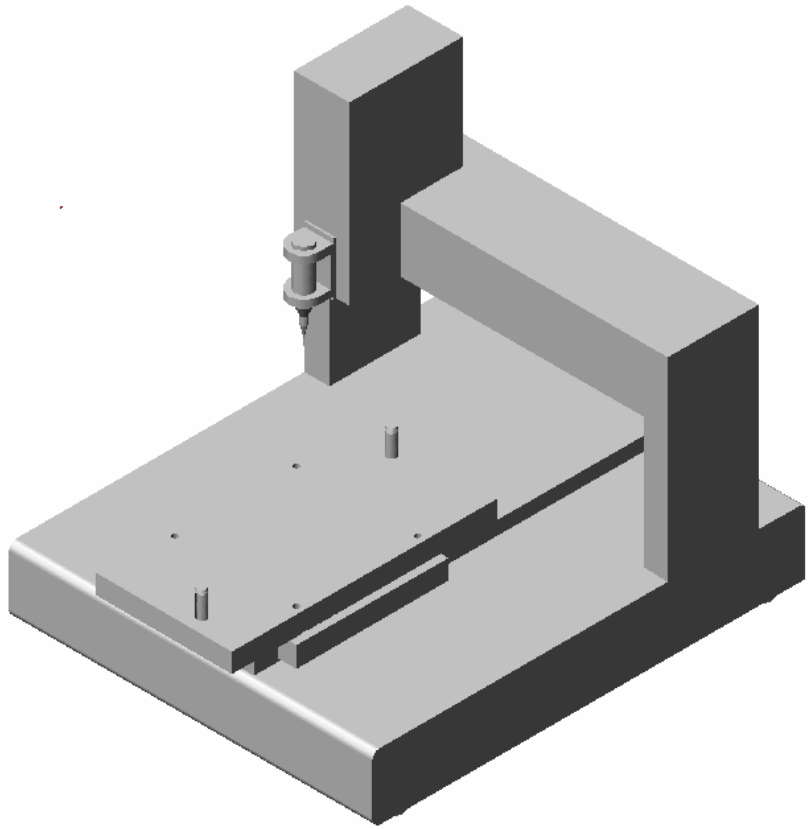
4.Glue the sensor and support with micrometer to control the thickness of glue

5.Take out the jig



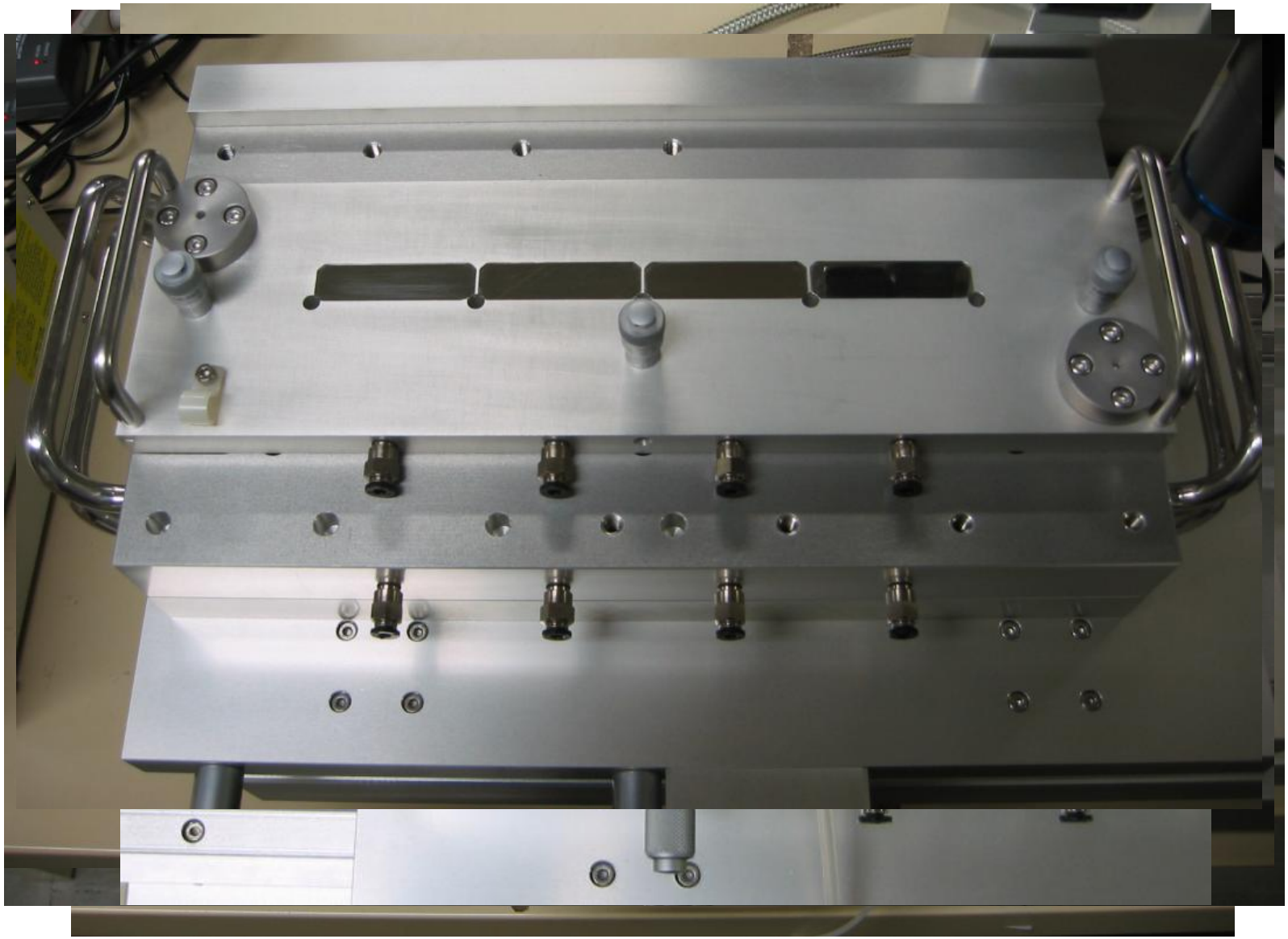
Stopper controlled by micrometer

Dispenser robot

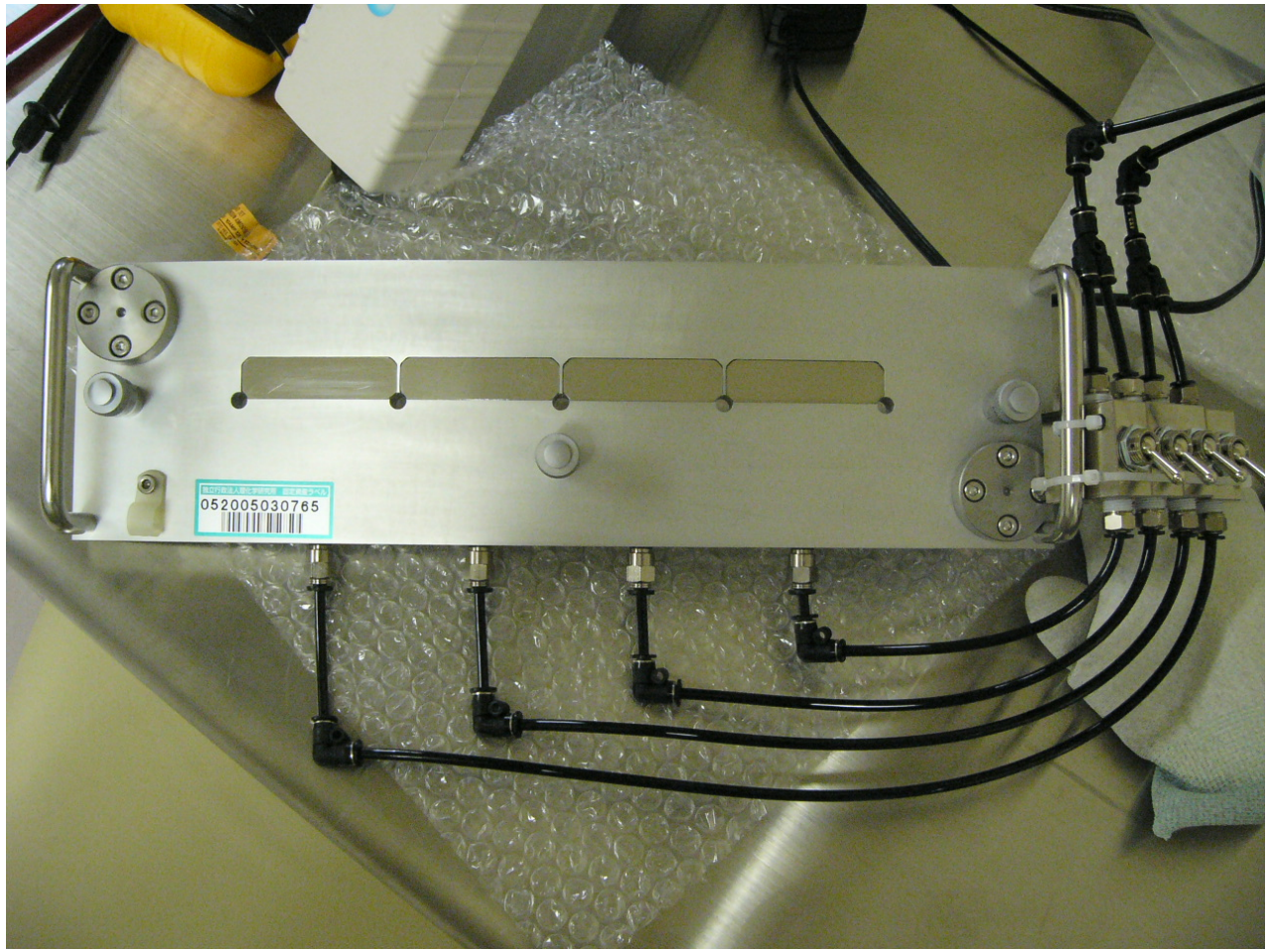


Sensors have been chucking to fix until glue is cured.
Also, assembly procedure for bus is as same as the procedure for sensor.

Jigs have been delivered on 24 March

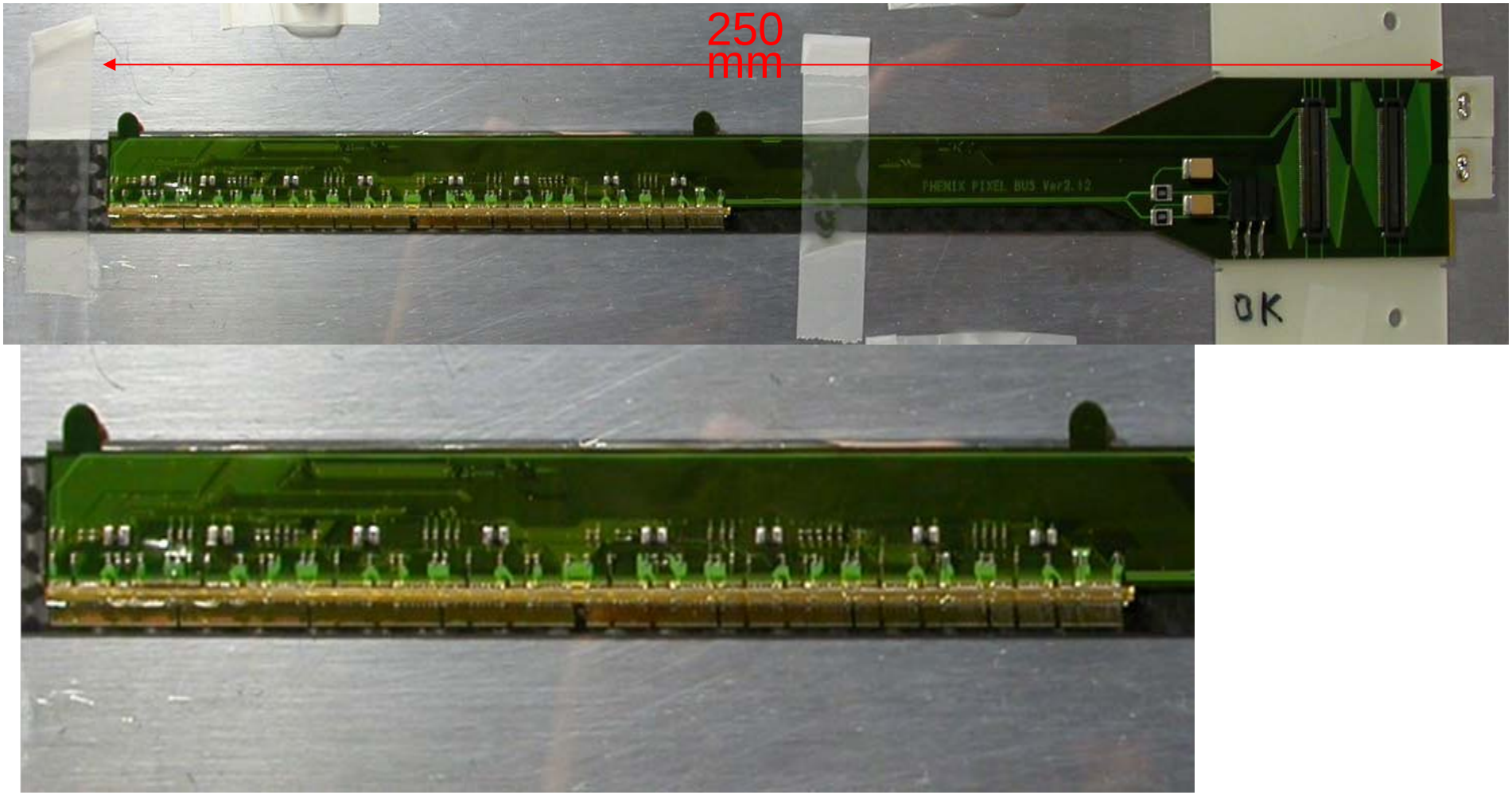


Assembling

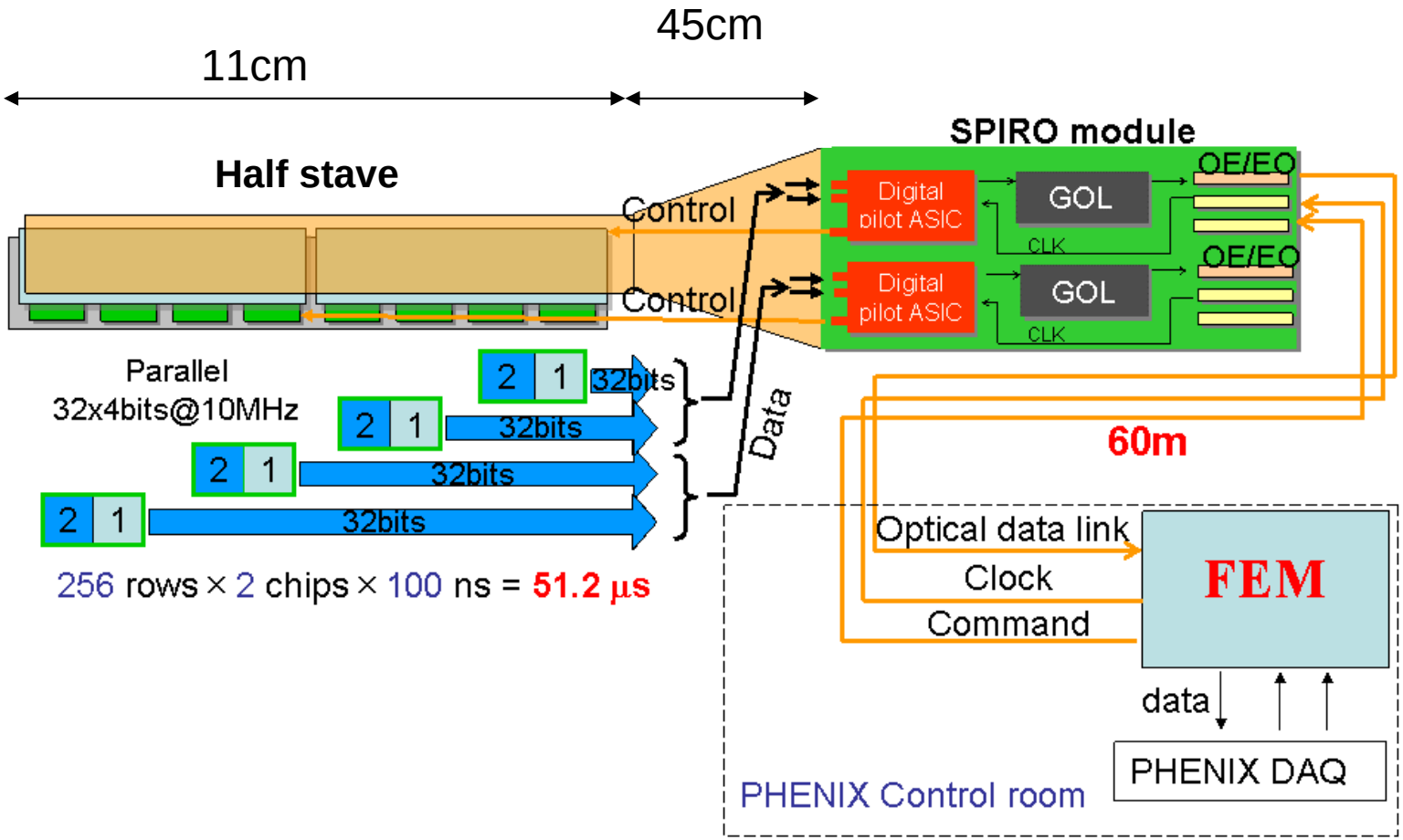


1.5cmハーフラダー

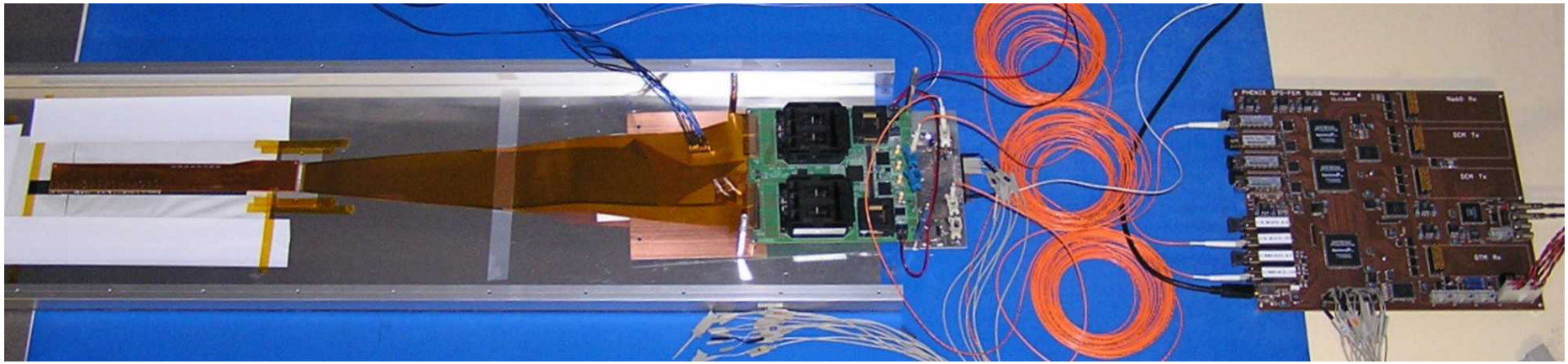
- 1.5cmハーフラダーが完成した。



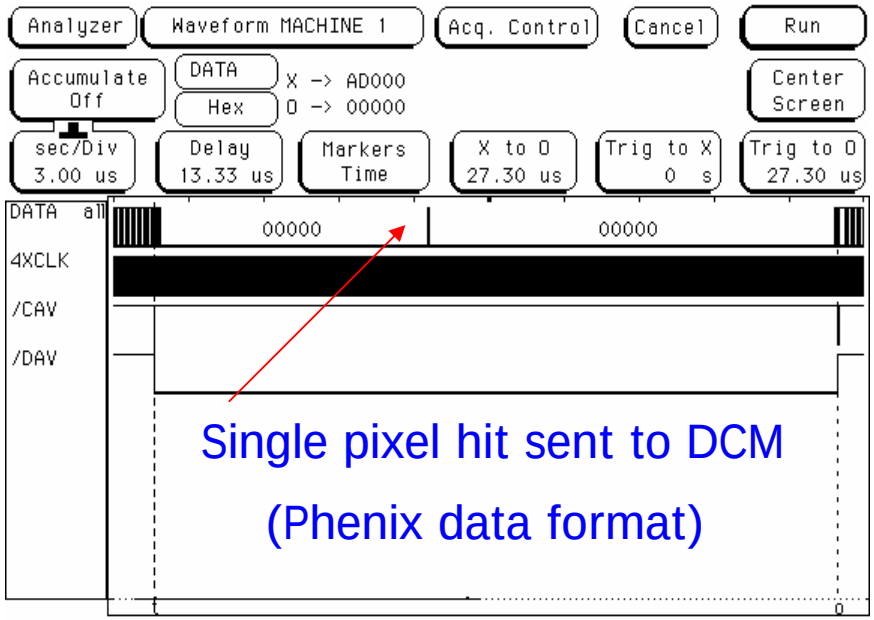
Pixel Readout Overview

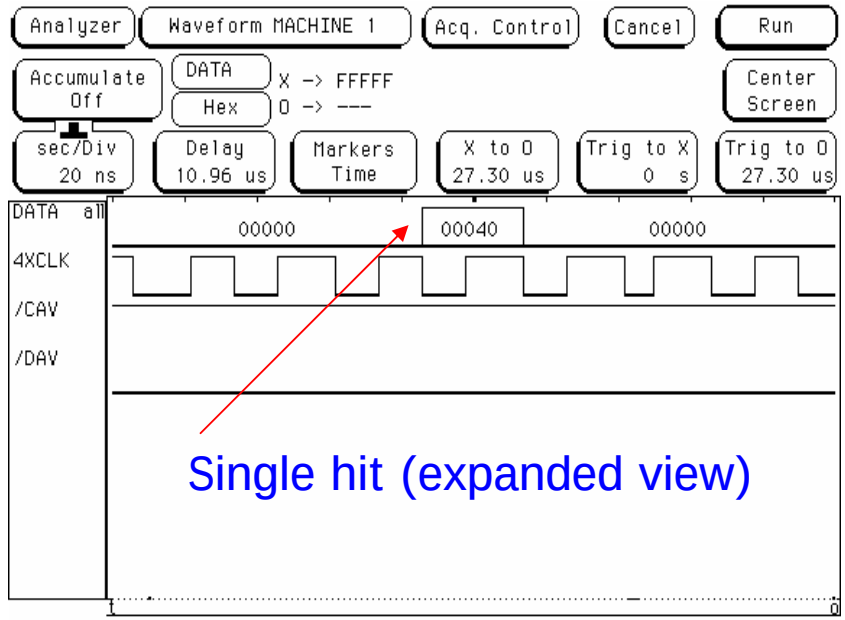


Chain Test at Stony Brook in this week

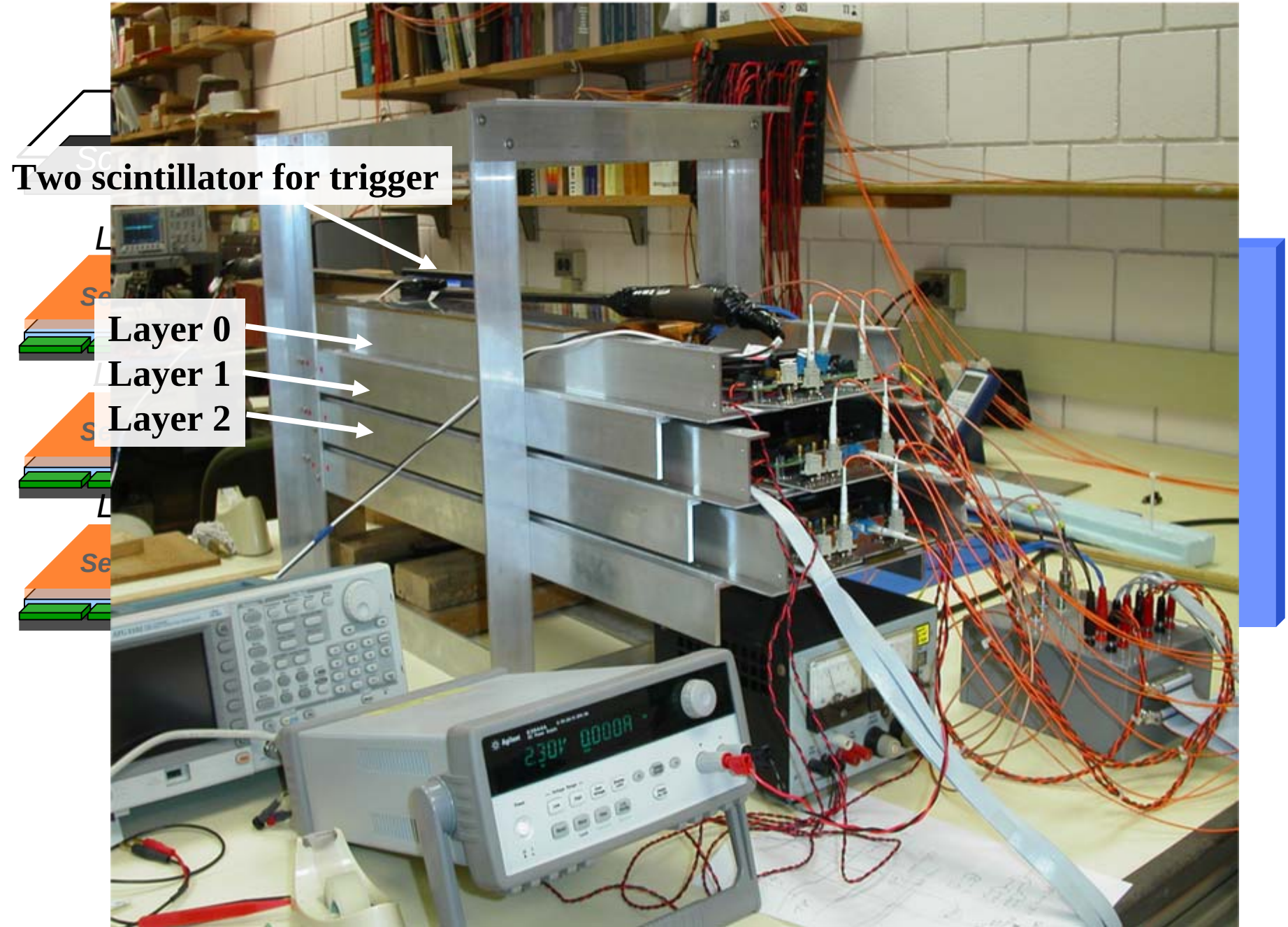


Pixel Ladder SPIRO FEM





2. Cosmic-ray Experiment



Test Results

- **DAQ system was operated successfully.**
- **Clear track of cosmic-ray was detected for 50 events.**

Layer 0

Layer 1

Layer 2

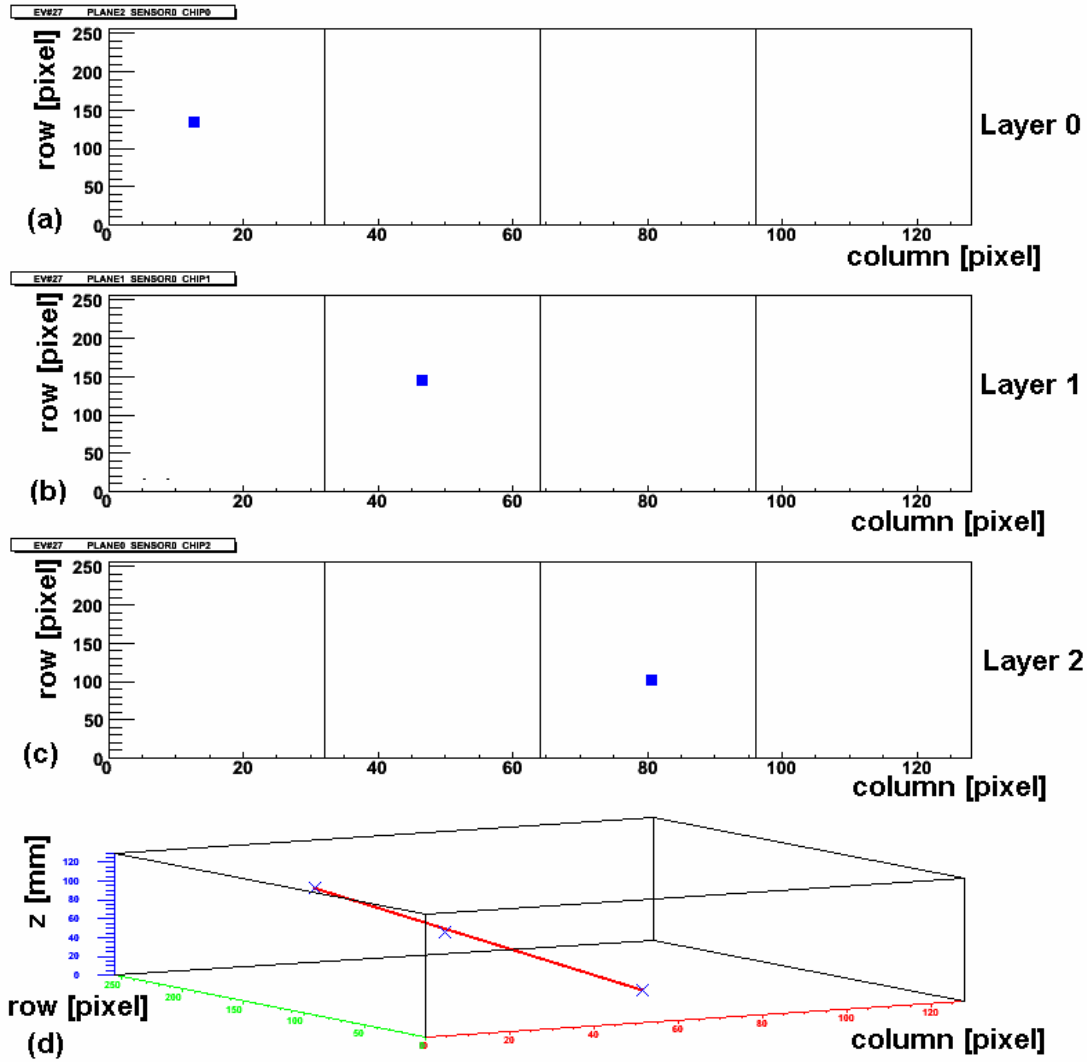


Fig2. Event display.

Plan

- Finalized pre-production version of ladder soon
- Start production ladder in late spring/ early summer 2008
- Production ladder finish : fall
- Start to assembly into whole structure : fall
- Install into PHENIX : Summer 2008
- Start experiment with pixel part : Winter 2008

RIBF Experiment

- 大津さんの話とこのWork Shopでの話し

- Rate 10^6 Hz/cm^2
- Dynamic Range 2500
- Low material t/RL = 10^{-4}

Rate

Shaping time ~ 30nsec -> 10MHz / pixel

Trigger rate ~ 20KHz

-> Optimize pixel size

50*500 μm^2 is too small for rate

Larger pixel size ->

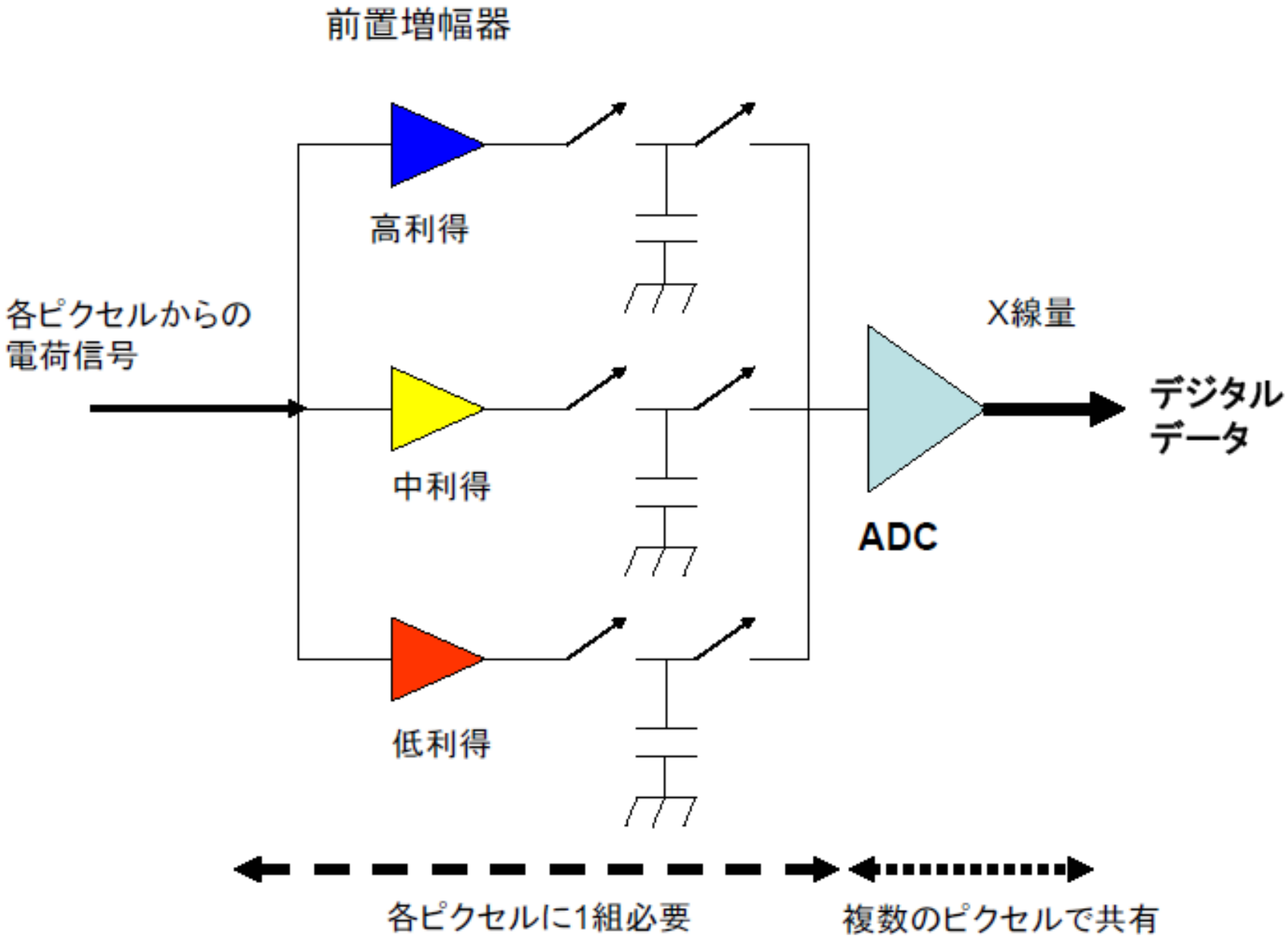
Easy to develop readout

Minimize total number of readout channel

Dynamic range > 2500

- Current pixel detector is threshold type readout.
- Noise may be small problem at preamp.

  -> Increase noise by detector Capacitance $\propto$ pixel area
- ADC readout ??
  - There are some development on going
  - How much resolution in highest range?


前置増幅器
高利得
各ピクセルからの
電荷信号
中利得
低利得
X線量
ADC
デジタル
データ
各ピクセルに1組必要
複数のピクセルで共有

Material budget

- Si can be thinner, but manufacture can not handle such thin sliced silicon.
- Readout electronics has some thickness.
- 100-200 μm may be OK.
- But not t/RL ~ 10^{-4}

Summary

- Radiation-lab group has been developed Si pixel sensor for high position resolution MIP detection.
- This can be used for RIBF experiments?
- If you need position resolution and high rate capability, Si pixel /Strip may be best solution.