ATLAS Japan ITk

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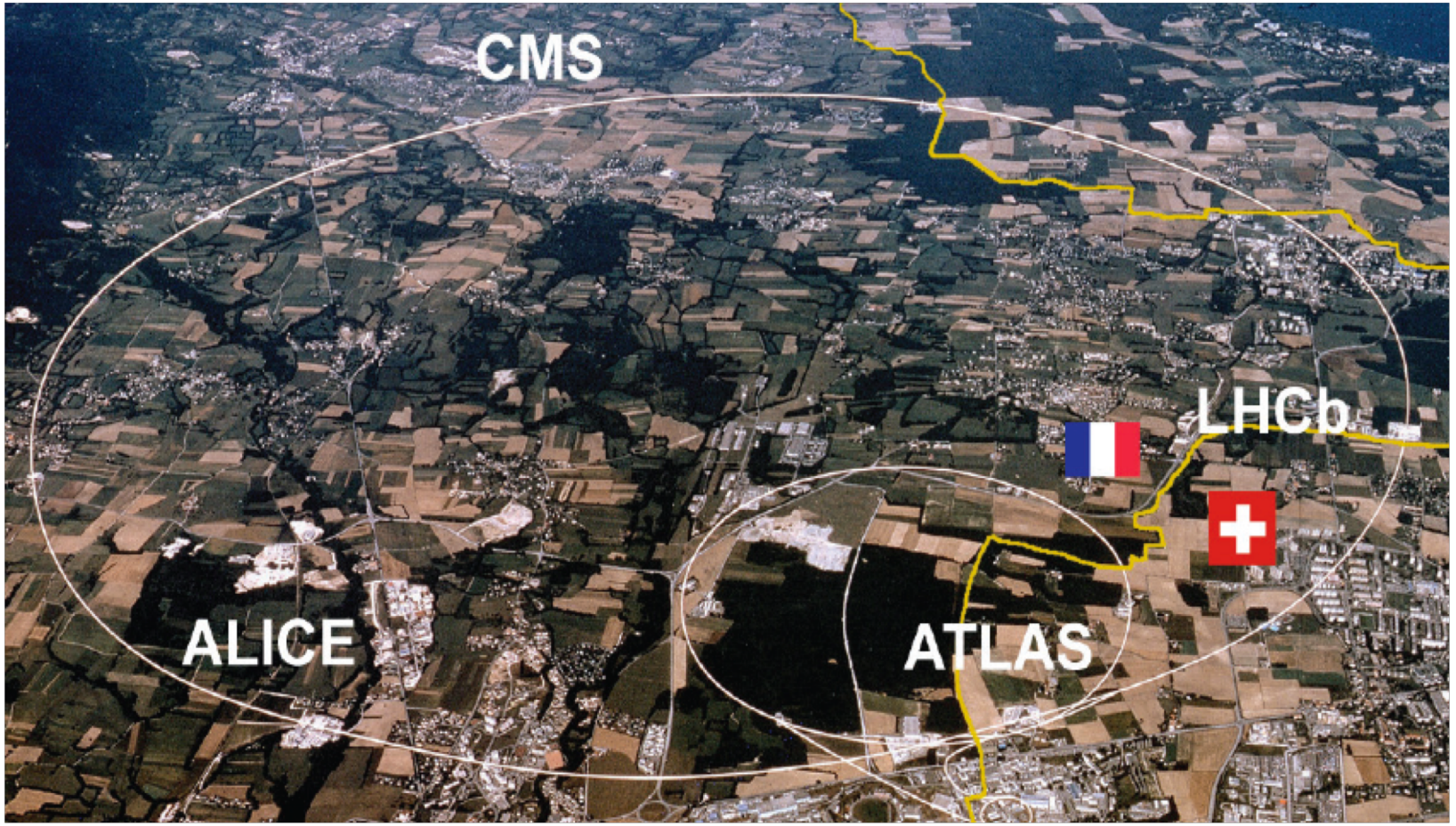
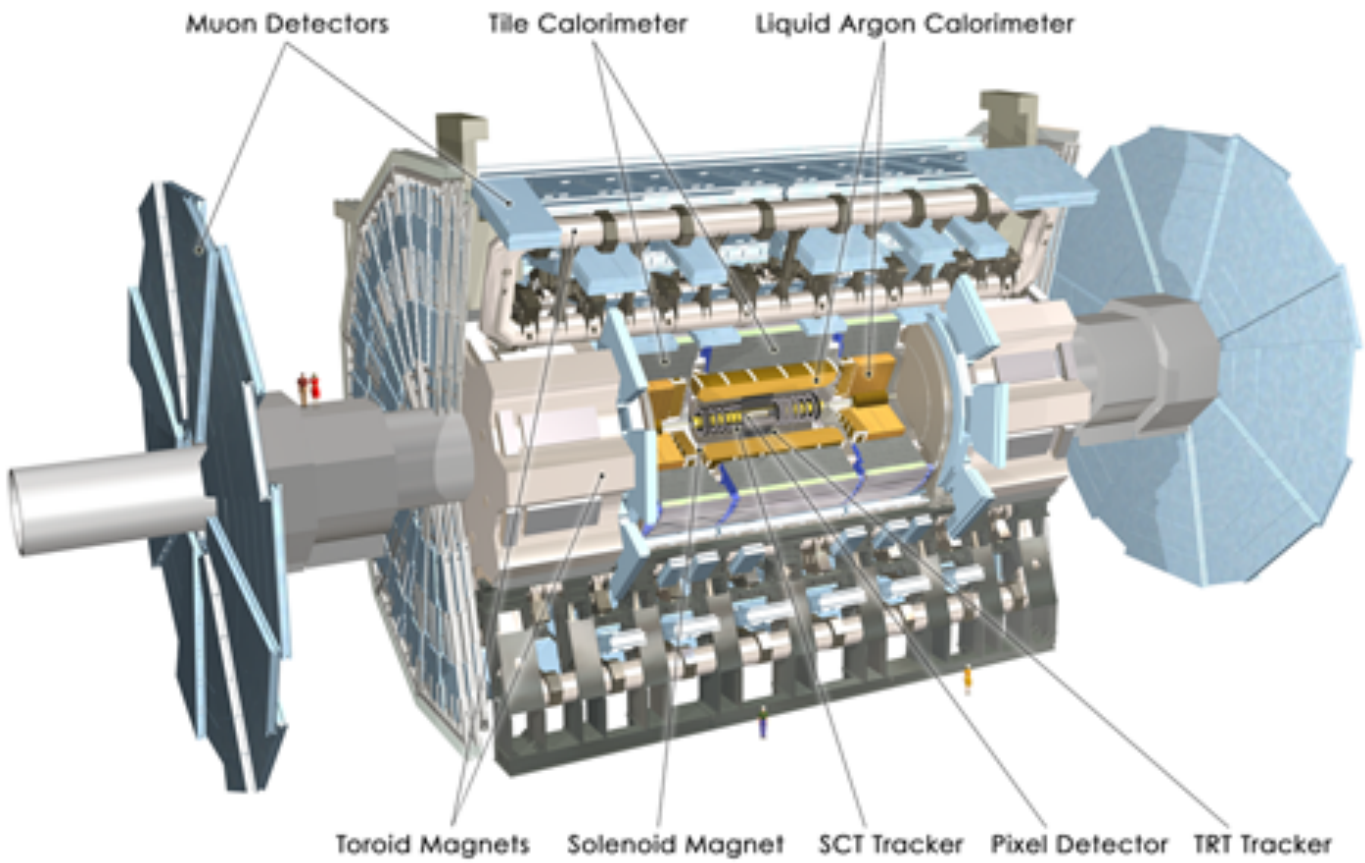
LHC



- The largest (27km) pp hadron collider in the world.
- 13 TeV Center of Mass energy
- 4 collision position (ATLAS, CMS, ALICE, LHCb)

ATLAS



height 25m, length 44m weight 7000t

three type sensors

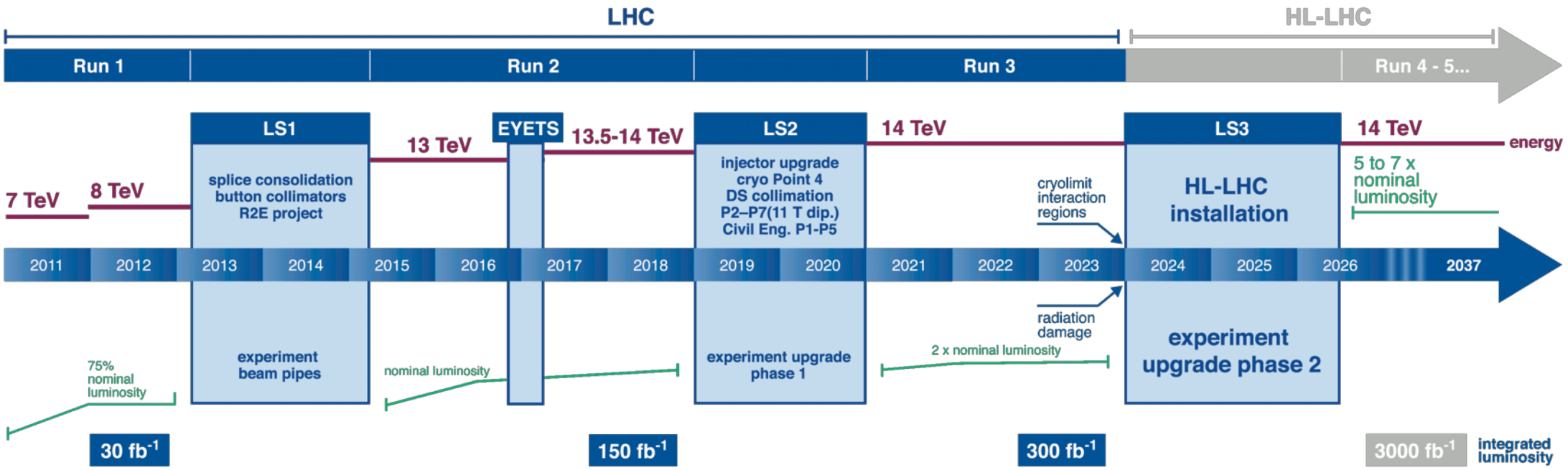
- Inner detector <- our group
  first part of ATLAS to see the decay products of the collisions
  very compact and highly sensitive

- Calorimeters
  measure the energy a particle loses as it passes through the detector

- Muon detectors
  detect muon using muon chambers

HL-LHC

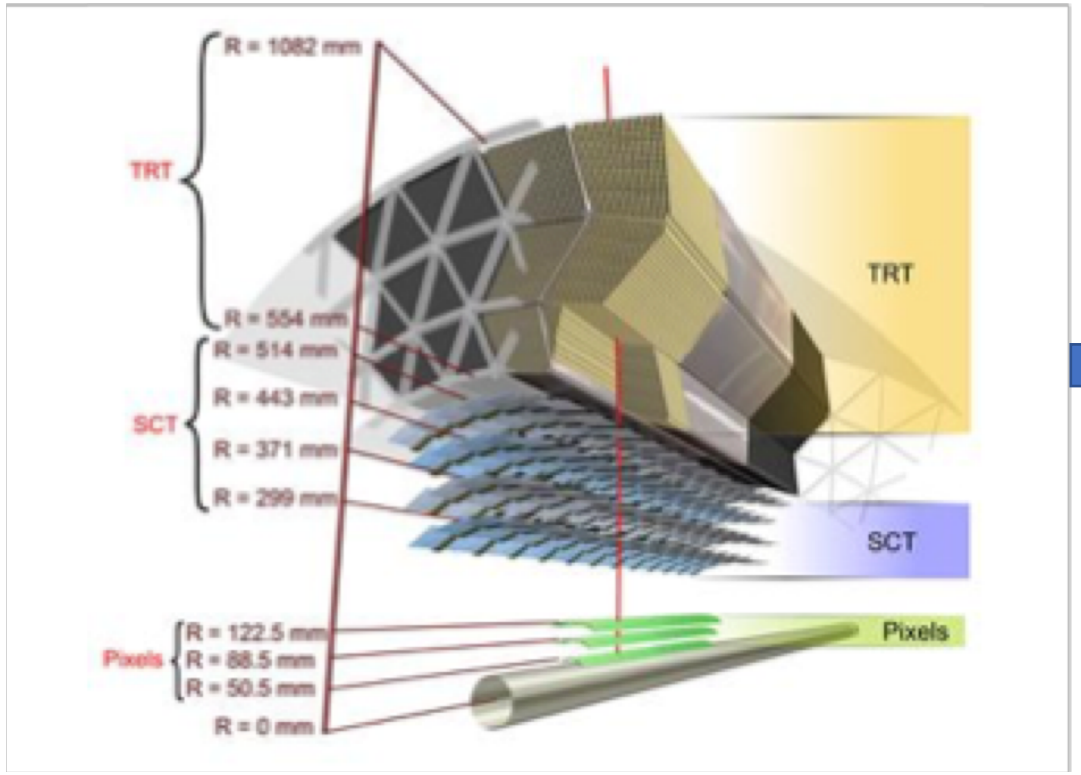
The LHC will become High-Luminosity-LHC(HL-LHC) at 2026.
The benefits are measurements and studies of rare processes.
Peak luminosity: 5-7 x 10^{34} cm^{-2} s^{-1} ~ x 5-7
Average pile-up: up to ~200 ~ x 5
Integrated luminosity: 3000 fb^{-1} ~ x 10



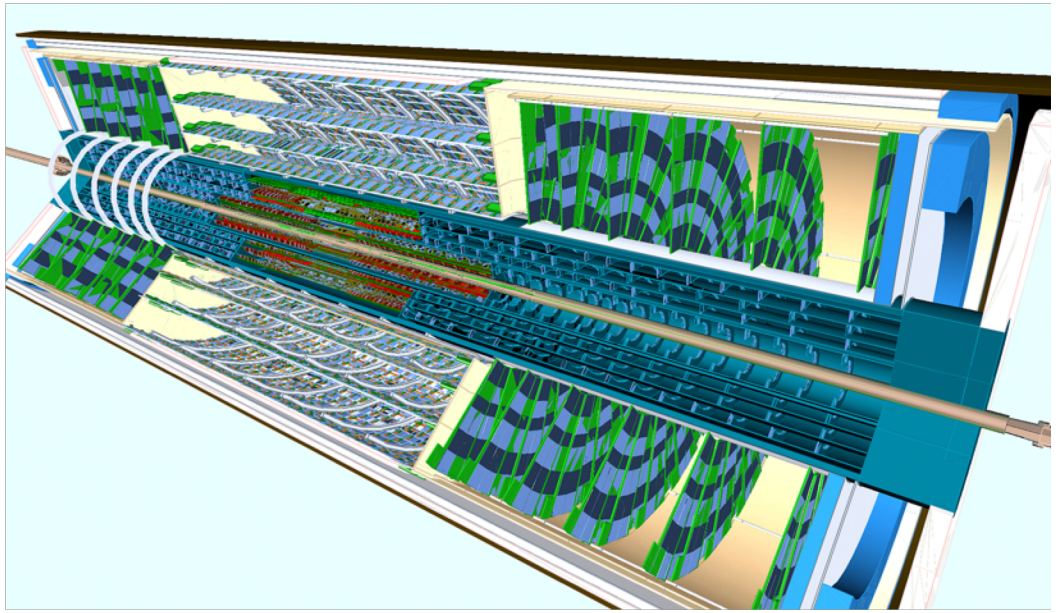
ITk

for HL-LHC ATLAS detector will upgrade.

- replace all silicon sensor strip/pixel detector
- cover large area (η =4.0)
- to reduce hit occupancy small pixel/strip size
- high radiation resistivity



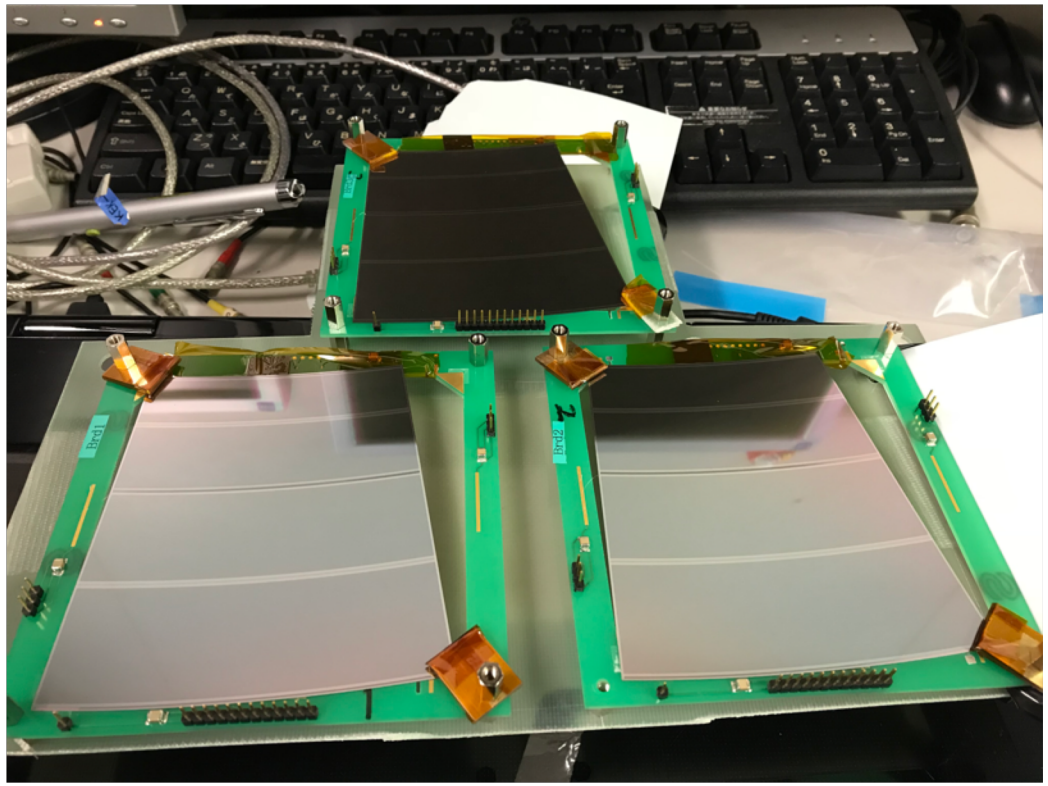
present Inner detector

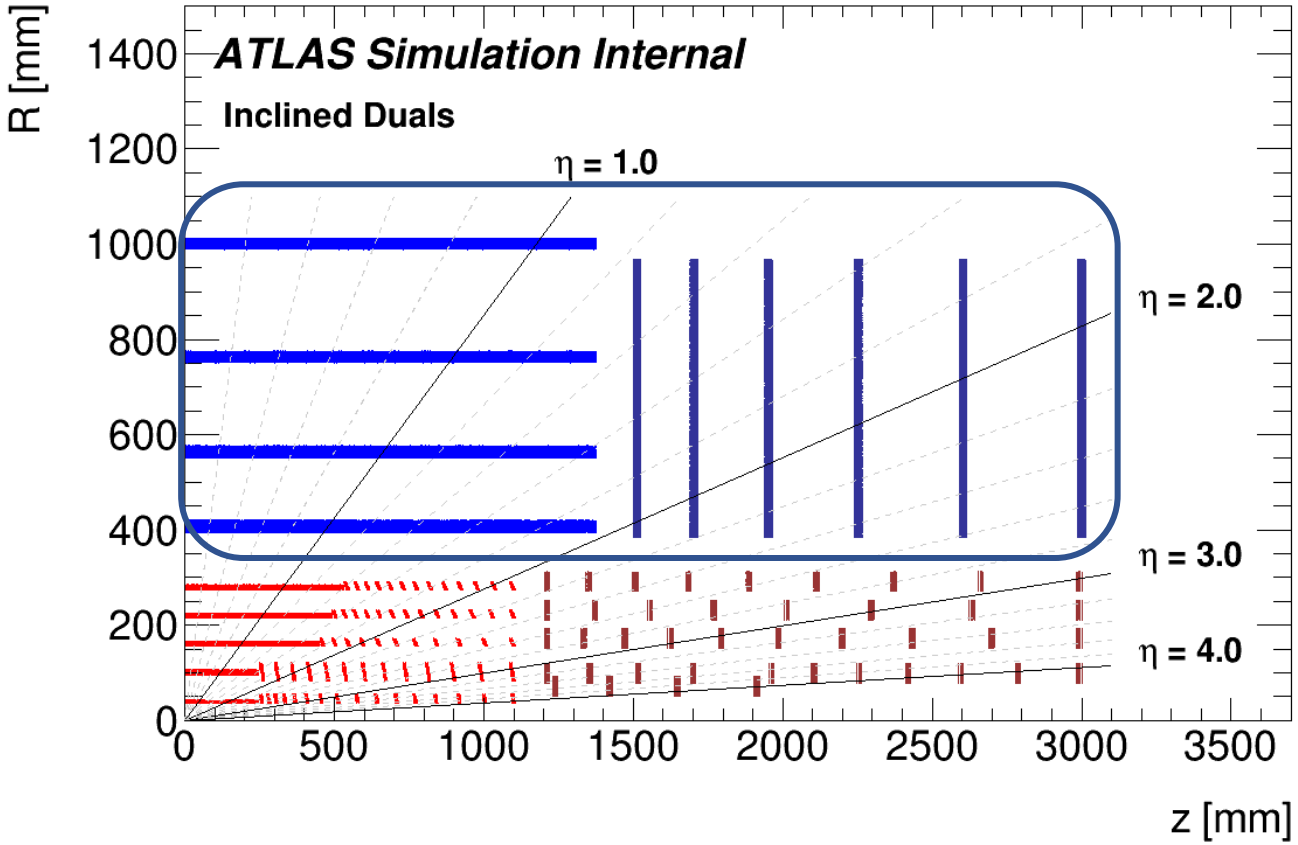


HL-LHC Inner detector (ITk)

strip detector

large area of ITk are strip detector.
strip sensors have already been under pre-production
Japan group QC/QA





Japanese QA/QC overview

Japan takes responsibility on ½ barrel sensor (~6,000) production and associated QC/QA

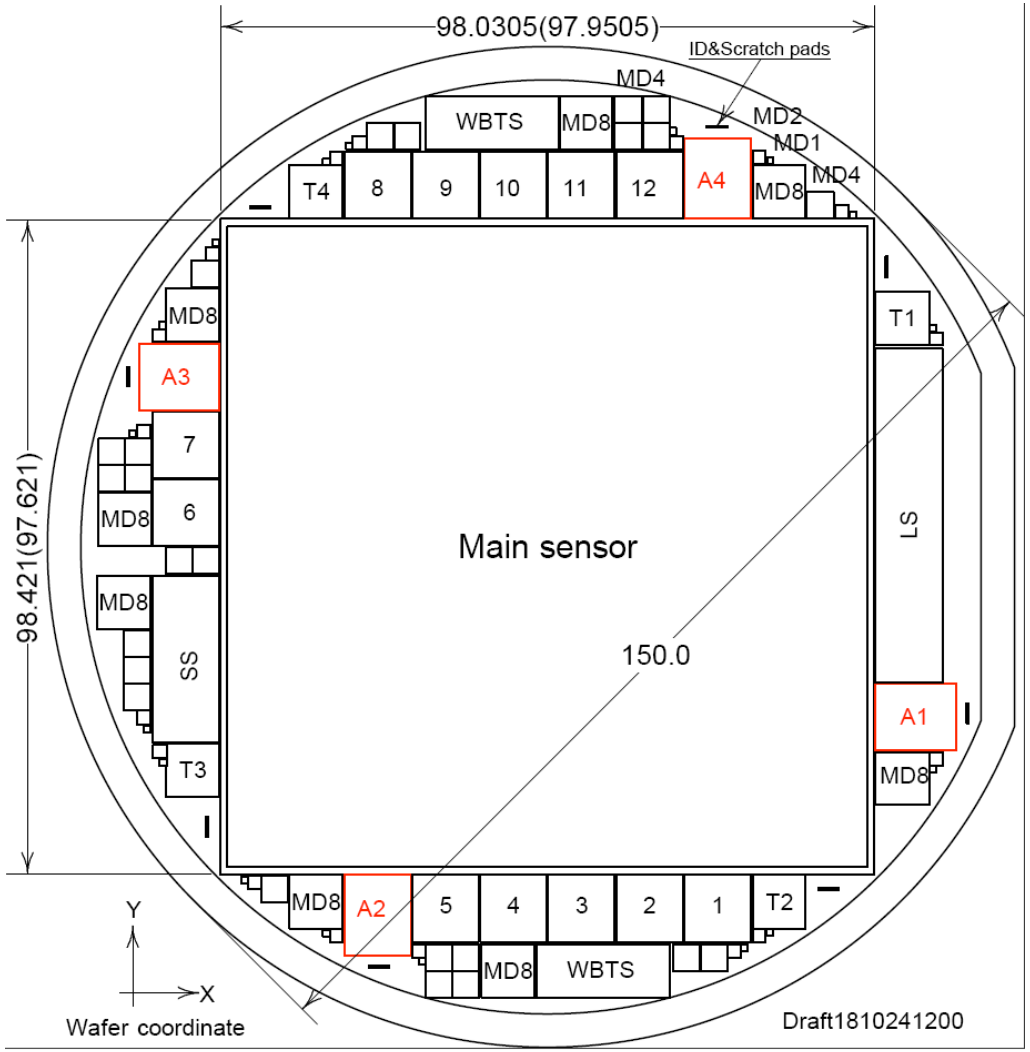
QC: everything at HPK
- ❖ IV+CV …. as HPK provides
- ❖ AC probing — 3 half moon's per batch (~50)
- ❖ DC probing — ~10 batches/month

Image capture/warp meas.
~~24h stability~~

QA: Tsukuba
mini CCE/IV/CV
MD8 IV/CV
~~TS surface properties~~

CYRIC irradiation (twice/year) as cross-check of monthly Birmingham irradiation
mini/MD8~~/TS~~

production

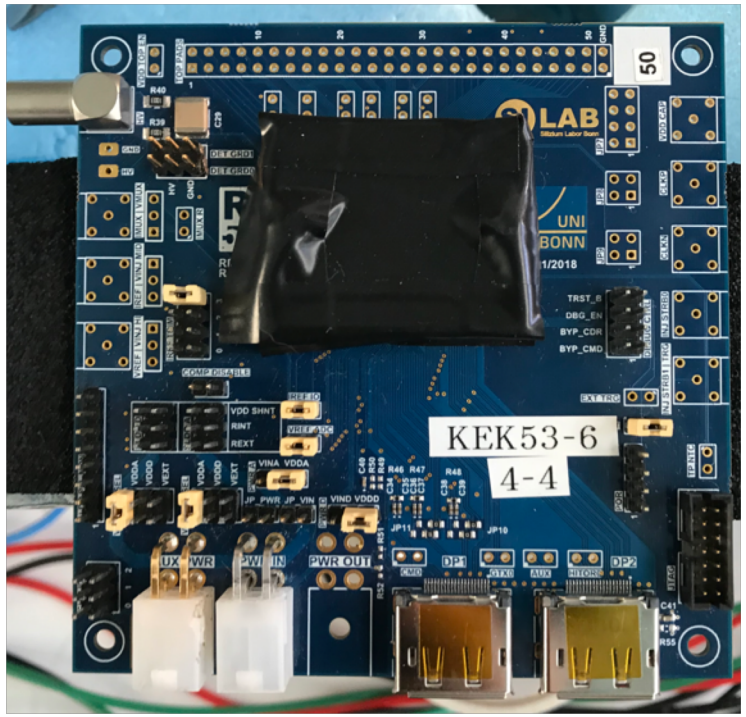


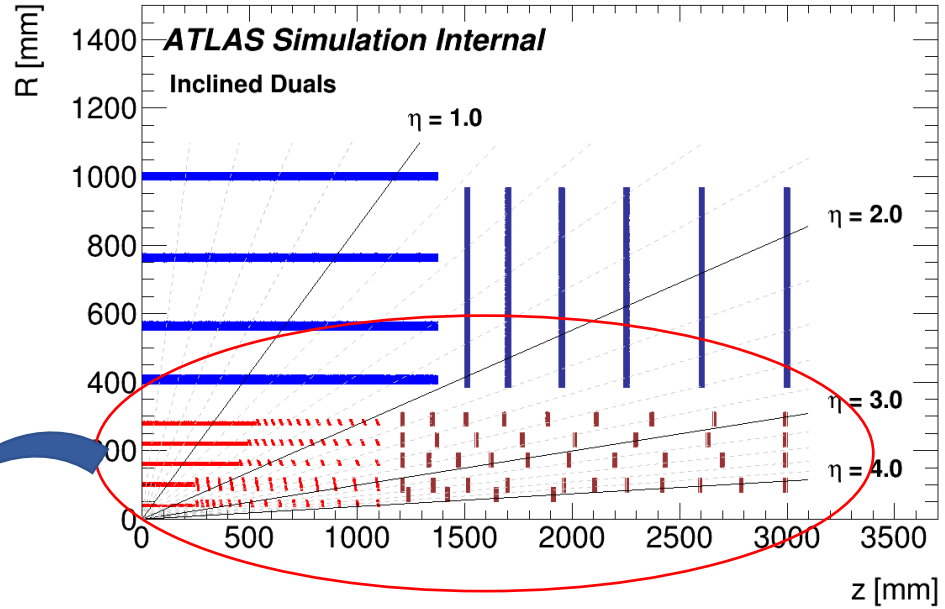
- All the Monitor test structures (except 8x8 and 4x4 diodes) can be inserted in one single test chip.
- Monitor diodes an minis placed close to test chip to form a “test Si piece”
- Four instances across the wafer
- In discussions with HPK it was agreed that in production they could cut:
  - Piece 1: 1 test chip + diodes
  - Piece 2: 1 mini sensor

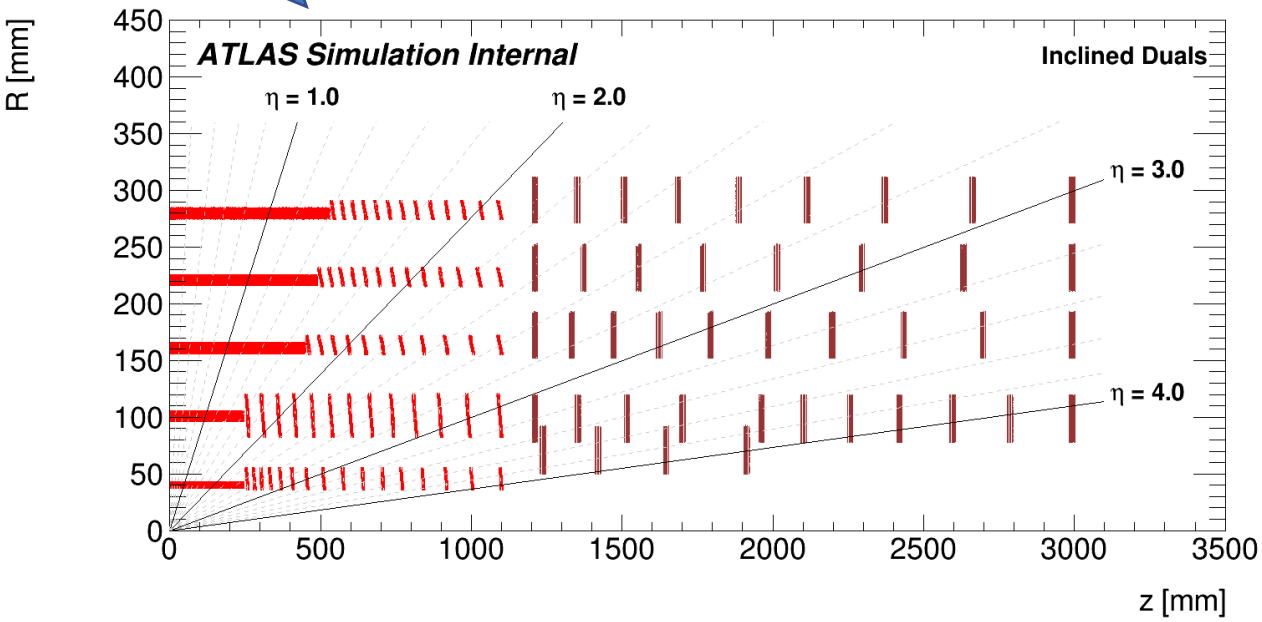
  In 2-3 wafers per batch (40-50)

pixel detector

pixel detector is innermost sensorin ITk.
1st layer is 3D sensor and 2nd to 5th layers are n+ in p
50×50um or 25×100um(1/5 size of present sensor)
Japan group develop 3rd to 5th sensor
these area fluence is 3.0×10^{15}



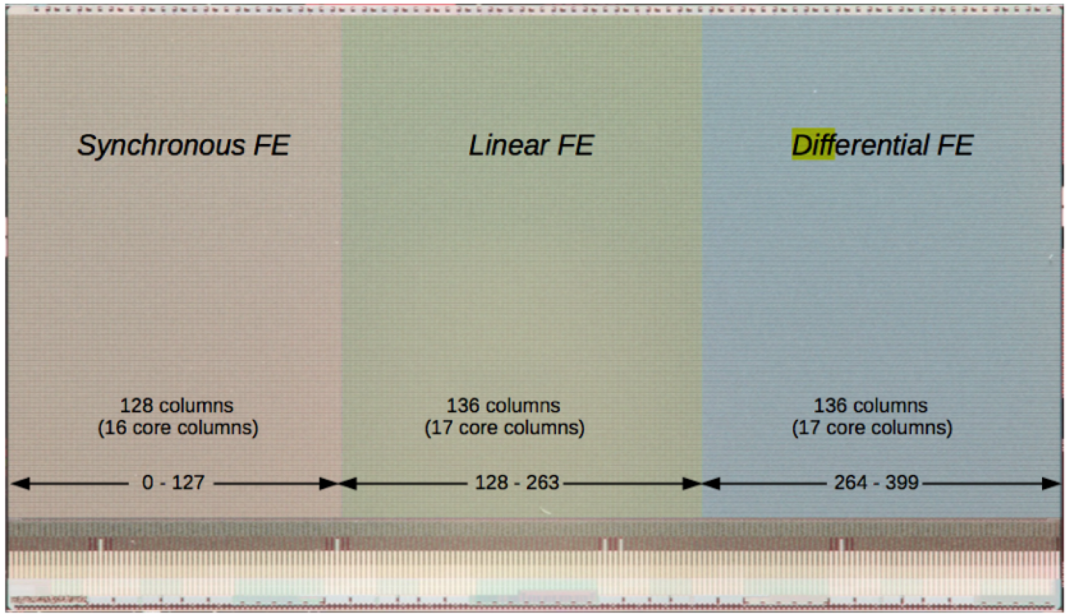


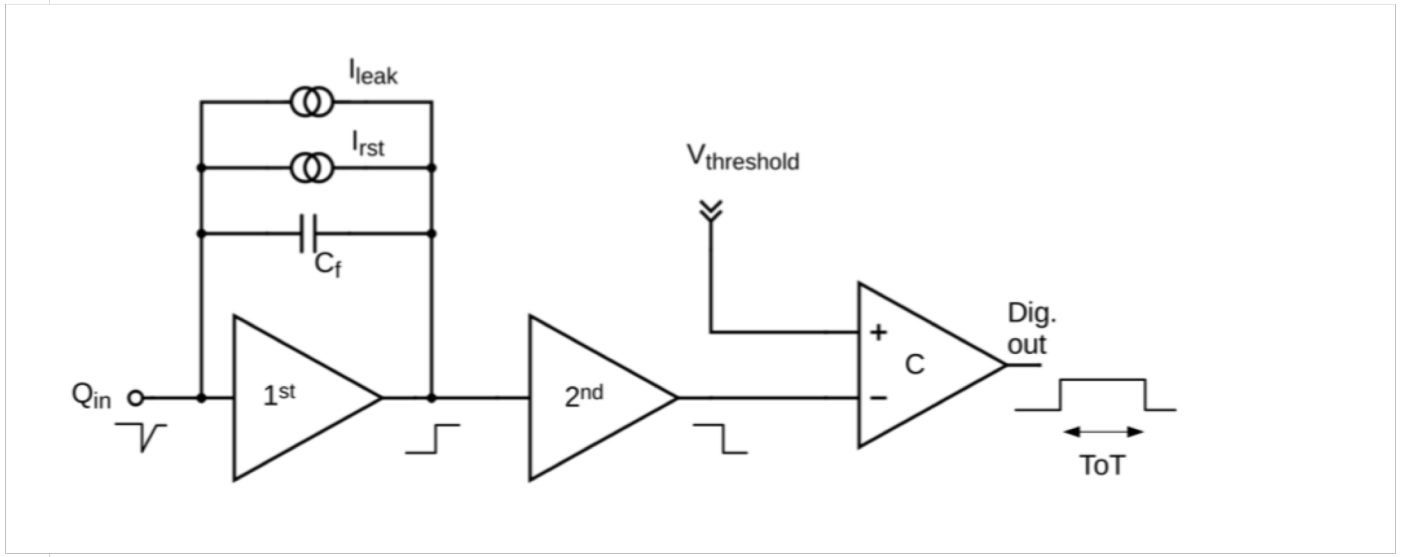


RD53A readout ASIC

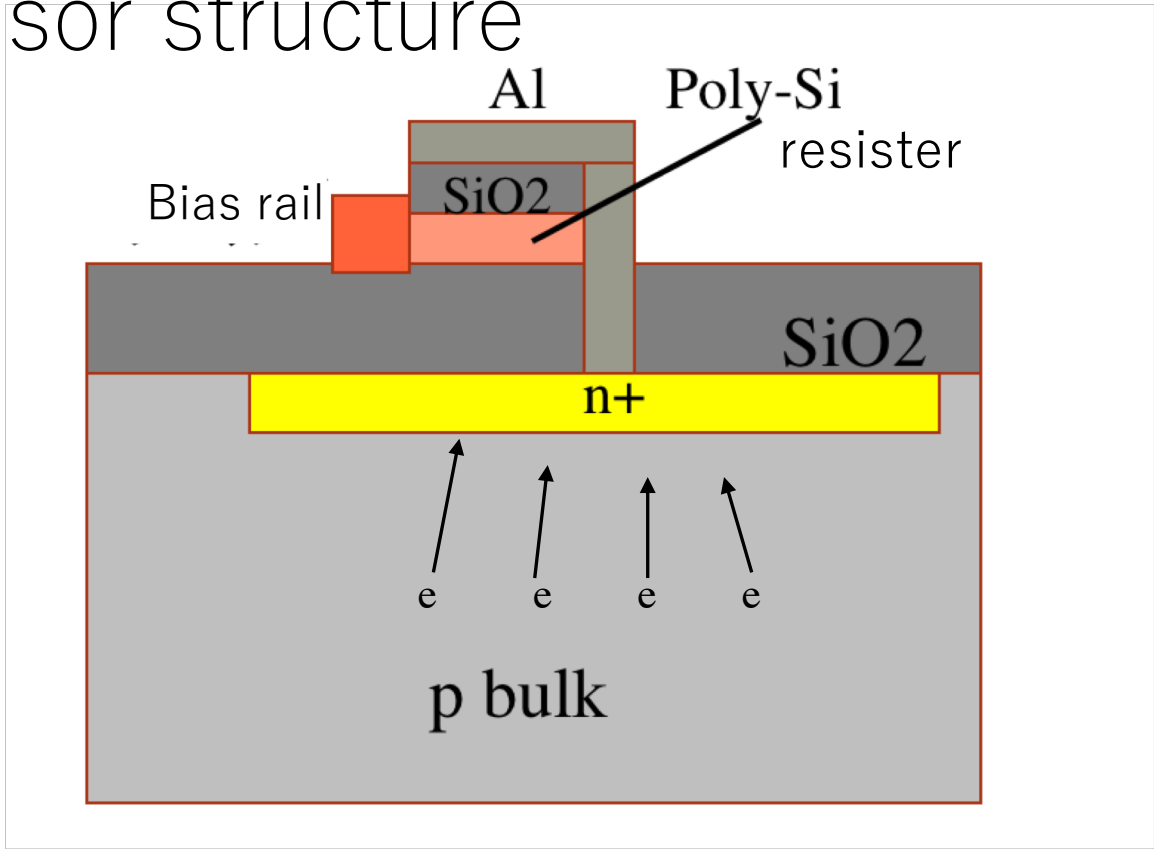
RD53A is new readout ASIC for test
bump pitch is 50x50 um
to improve radiation resistivity,
65um process
3 front end type by region

Feature	RD53A	Prod. spec.	Comment
Input pitch	50 μm × 50 μm	50 μm × 50 μm	aspect ratio defined by sensor
Bump columns × rows	400 × 192	400 × **384**	
Input polarity	Negative	Negative	
Min. stable threshold	600 e^-	600 e^-	with 50 fF load, 4μA/pixel analog.
In-time threshold	< (thresh.+600 e^-)	< (thresh.+600 e^-)	varies w/ front end
Hit loss to in-pixel pileup	$\leq$1%	$\leq$1%	at 75 kHz avg. hit rate
Single pixel noise (ENC)	<100 e^-	<100 e^-	with 50 fF load; varies w/front end
Trigger latency	<12.8 μs	**<35 μs**	
Trigger mode	single level	two level	
Current/pixel, analog	3-4 μA	<4 μA	varies w/ front end
Current/pixel, digital	4 μA	4 μA	@ 75 kHz/pixel and 1 MHz trigger
Current, periphery	<150 mA	**<200 mA**	4 enabled output drivers
Command & control	serial 160 Mbps	serial 160 Mbps	DC-balanced, no separate clock
Output	4 × 1.28 Gbps	4 × 1.28 Gbps	
Output protocol	Aurora 64b/66b	Aurora 64b/66b	can use 1 to 4 lanes
Data aggregator output	none	bf 5.12 Gbps	





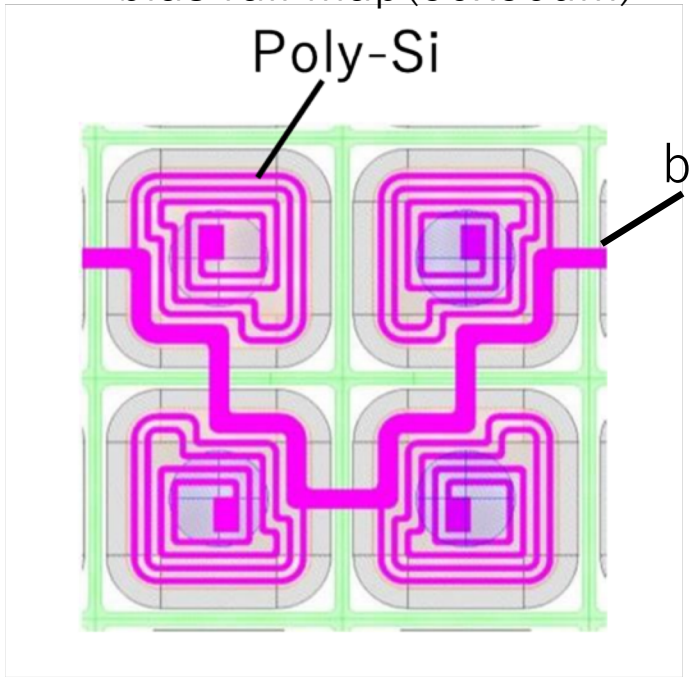
sensor structure



n+ in p bulk structure
No need to be full depletion to collect signal

Japan group introduce bias rail structure for HV test without ASIC when production.
bias rail connect all pixel, and drop ground level.

bias rail map(50x50um)



bias rail sensor is large noise and low efficiency compare to w/o bias rail sensor.
to solve these issue,
low noise sensor w/ bias rail

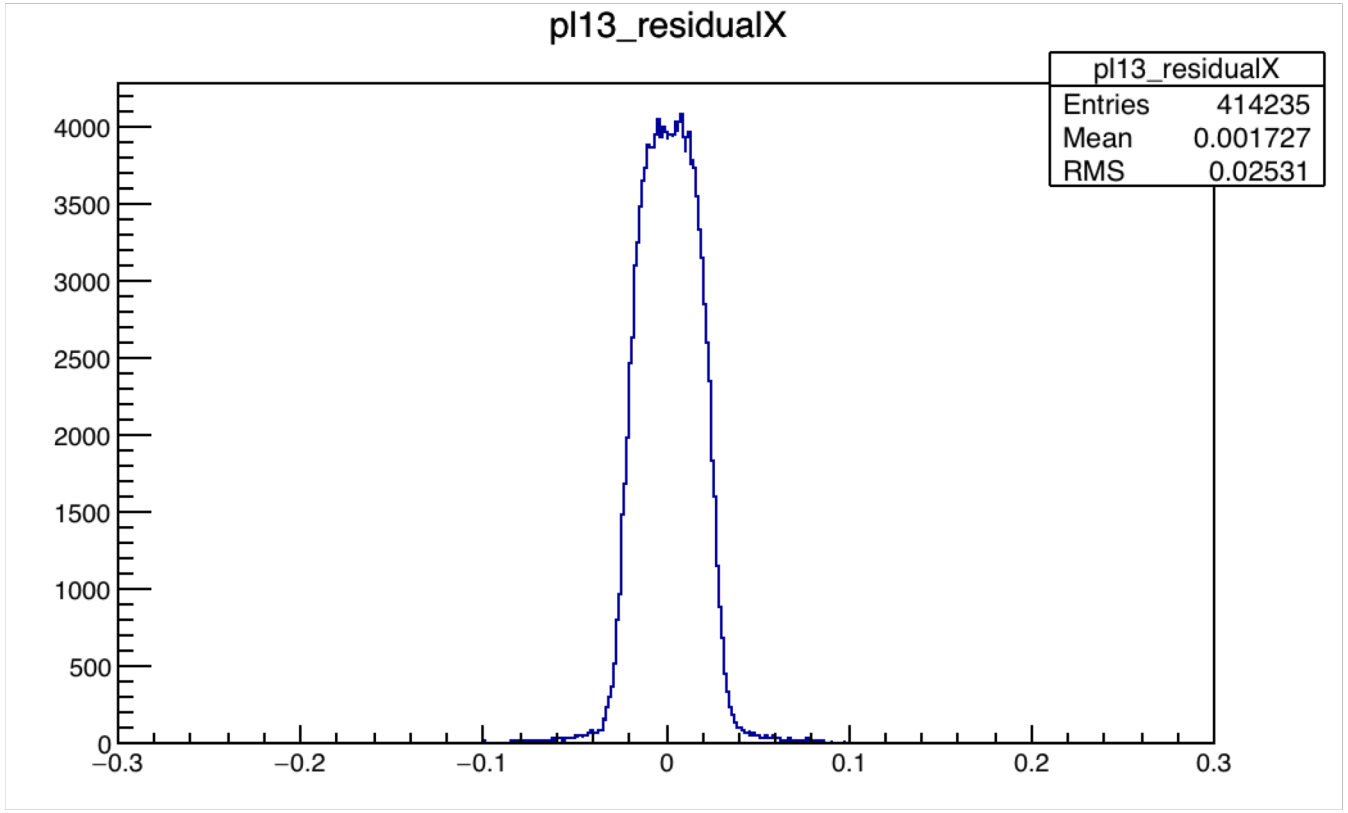
- large poly-Si resister
- small Al size

for high efficiency w/ bias rail

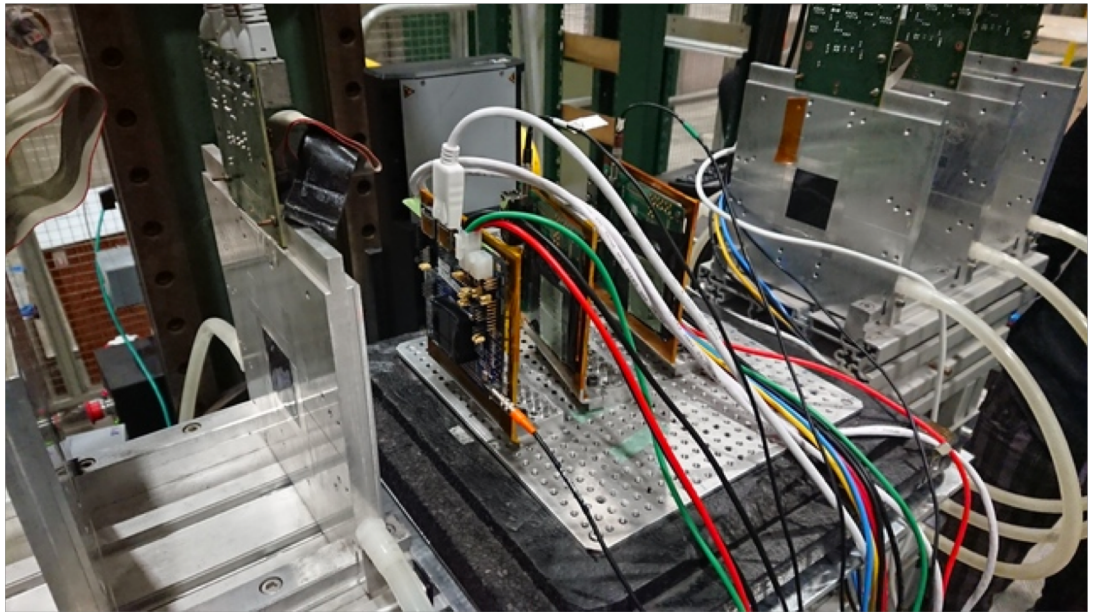
- large n+ pad

position resolution

test beam @CERN SPS

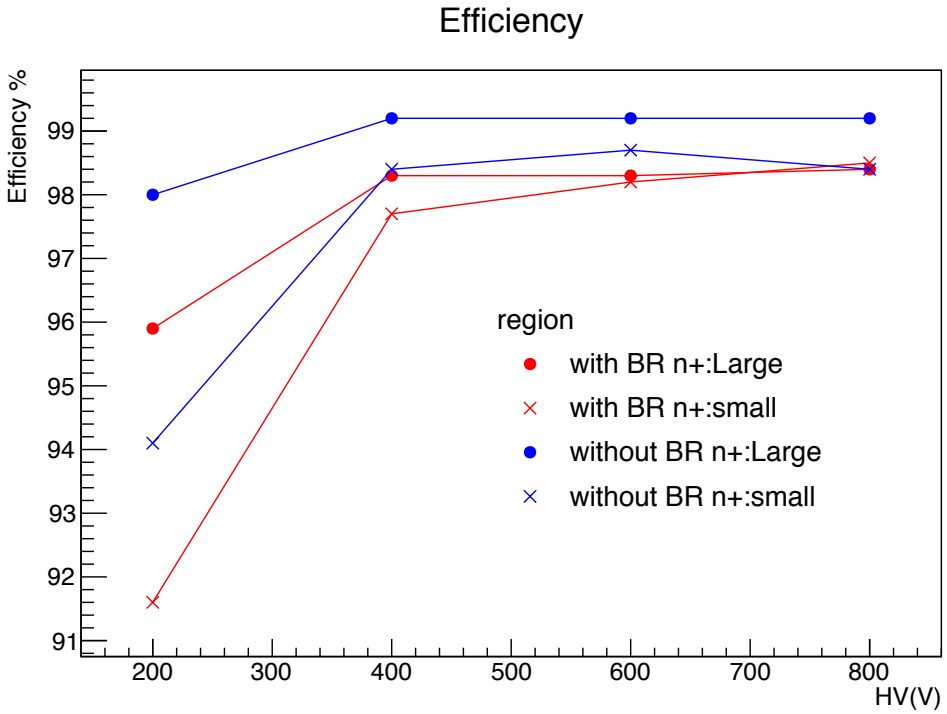


pixel size 50x50um sensor

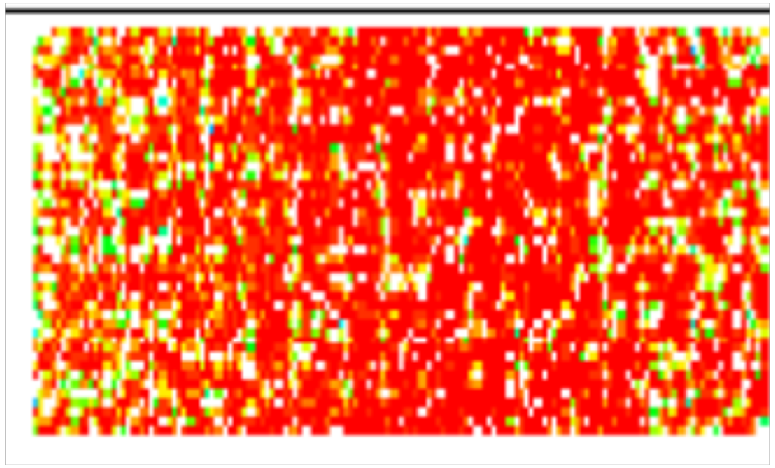


Radiation resistant

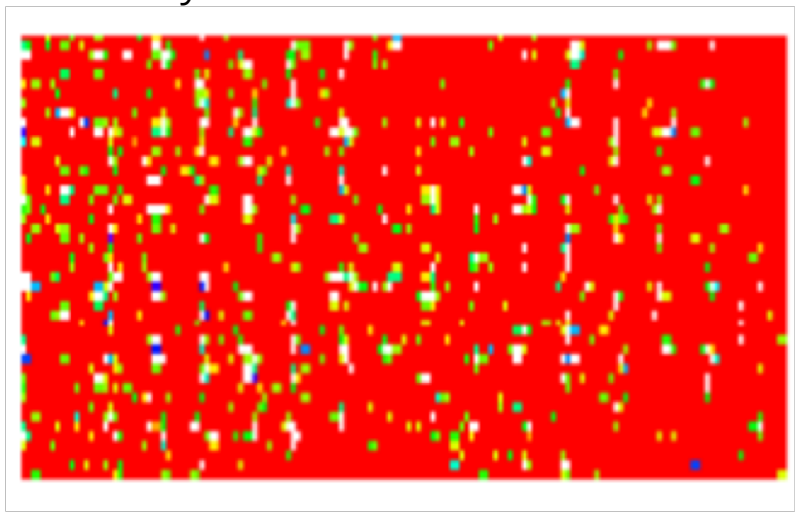
3^{rd} sensor's fluence is 3.0×10^{15} 1MeV n_{eq} during 10 years.
ATLAS request: Efficiency is >97% after radiation damage.
proton irradiation at CYRIC Tohoku University
result of testbeam, w/ bias rail sensor efficiency is over 97% when 400V bias voltage



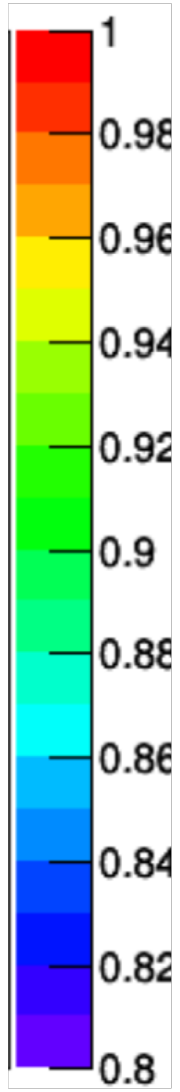
600V



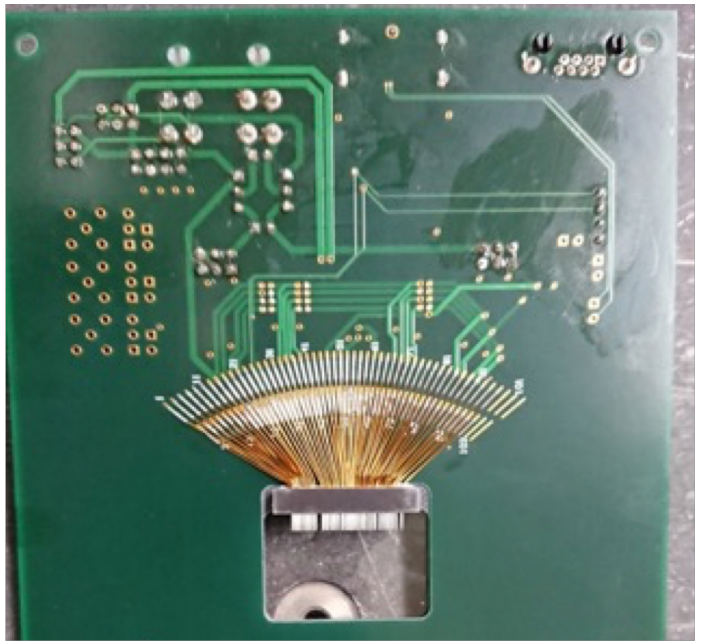
w/ bias rail structure large n+
efficiency98.33 ± 0.02



w/o bias rail structure large n+
efficiency99.23 ± 0.01



other test



- RD53A ASIC probe test
  before flip chip, RD53A operation check using probe card
  remove broken RD53A before flip chip, because flip chip is high cost.

- Threshold tuning test
  FEI4 pixel detector set in current ATLAS tracker has problem about tuning threshold.
  check about RD53A.