The Present Status of Reconstruction of Large-Multiplicity and Long-Staggered Pixel Run with EUTelescope

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on behalf of ATLAS-Japan silicon and ATLAS PPS collaborations

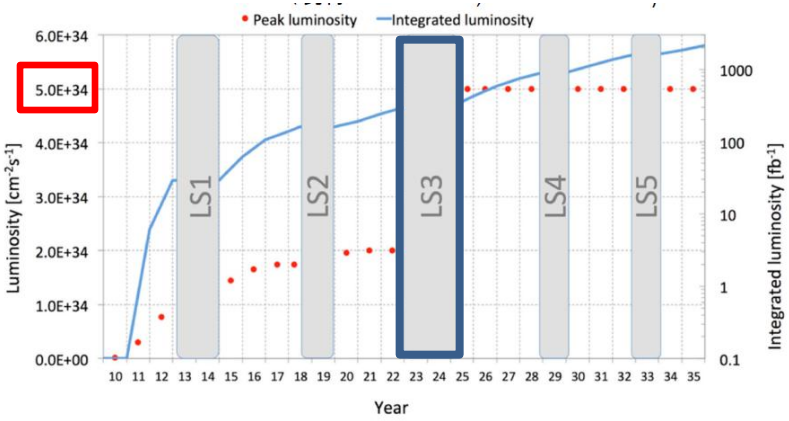
Outline

- HL-LHC, ATLAS ITk upgrade 2022-2025
- Testbeam and Analysis
- DESY Nov. 2013 Long-staggered Pixel
- SLAC May 2014 Large-multiplicity run
- Summary and Future Plan

HL-LHC, ATLAS ITk Upgrade

- 2022-2025
  - Center of Mass Energy : 14 TeV
  - Peak Luminosity -> 5 × 10^{34} cm^{-2} s^{-1}
  - Integrated Luminosity -> 3000 fb^{-1}

  All inner detectors will be replaced!!

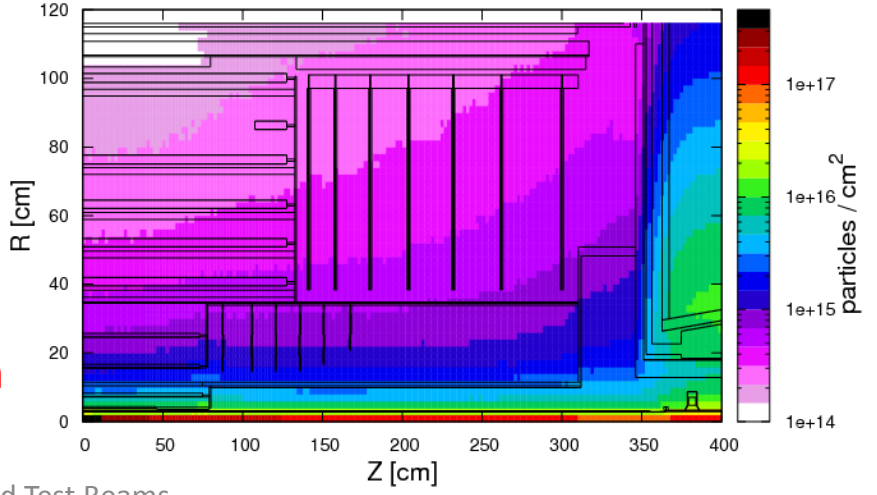


- Requirements for Inner Detectors (Outer 2 layers)
  - Higher granularity (smaller pixels) :

    50 × 400μm² -> 50 × 250 μm²
  - Faster data transfer : FE-I3 -> FE-I4
  - Higher radiation tolerance :

    ~ 10^{15} 1MeV n_{eq}/cm^2

  -> R&D of n^+-in-p planar pixel sensors with HPK is on-going to meet those needs



Testbeams

- Testing radiation hardness of sensors
- Telescopes
  - Mimosa26 telescopes: $18.4 \times 18.4\ \mu m^2$, 1152 columns × 576 rows ($2 \times 1 cm^2$)
- DUTs
  - Both irradiated and non-irradiated (reference)
- Recent testbeams (2013 - 2014)
  - Mar. 2013 @DESY
  - Aug. 2013 @DESY
  - Nov. 2013 @DESY
  - May 2014 @SLAC
  - Nov. 2014 @CERN

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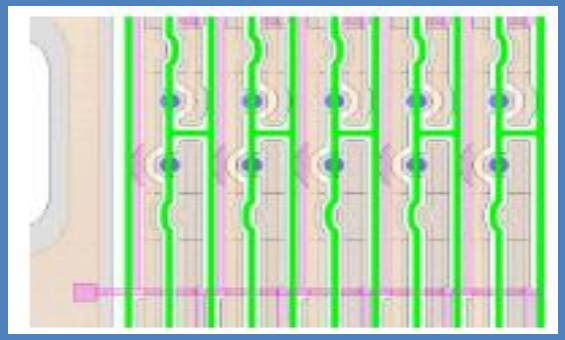
Topic: TB analysis of these testbeam data

Testbeams

Long-Staggered Pixel @ DESY



$25 \times 500\ \mu m^2$ pixel
(half-pitch pixel size)

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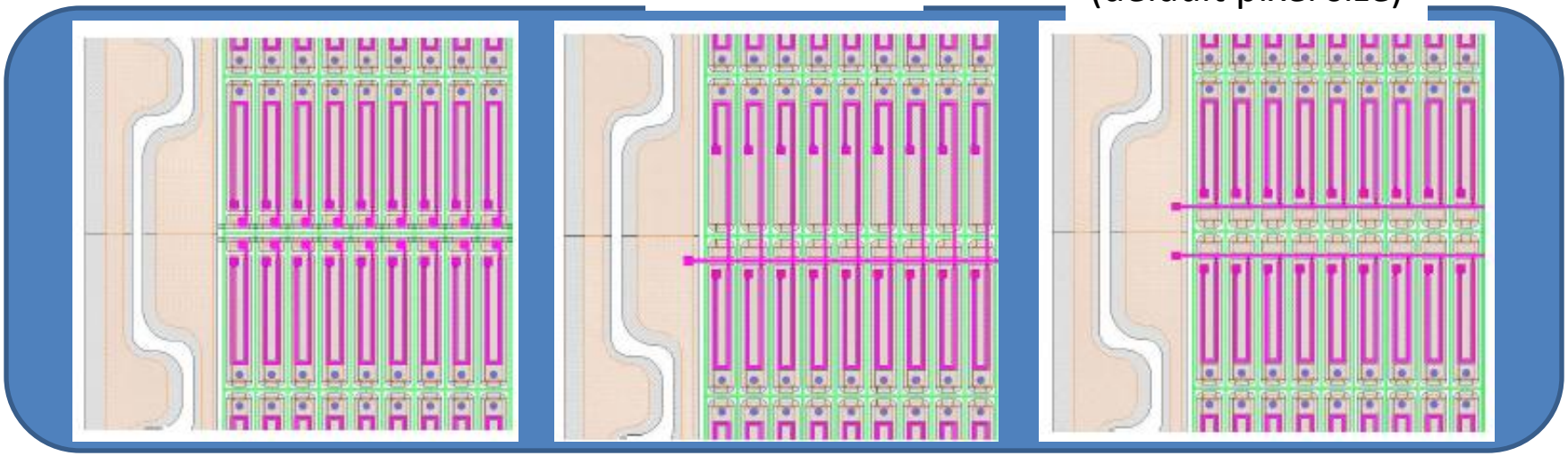
Testbeams



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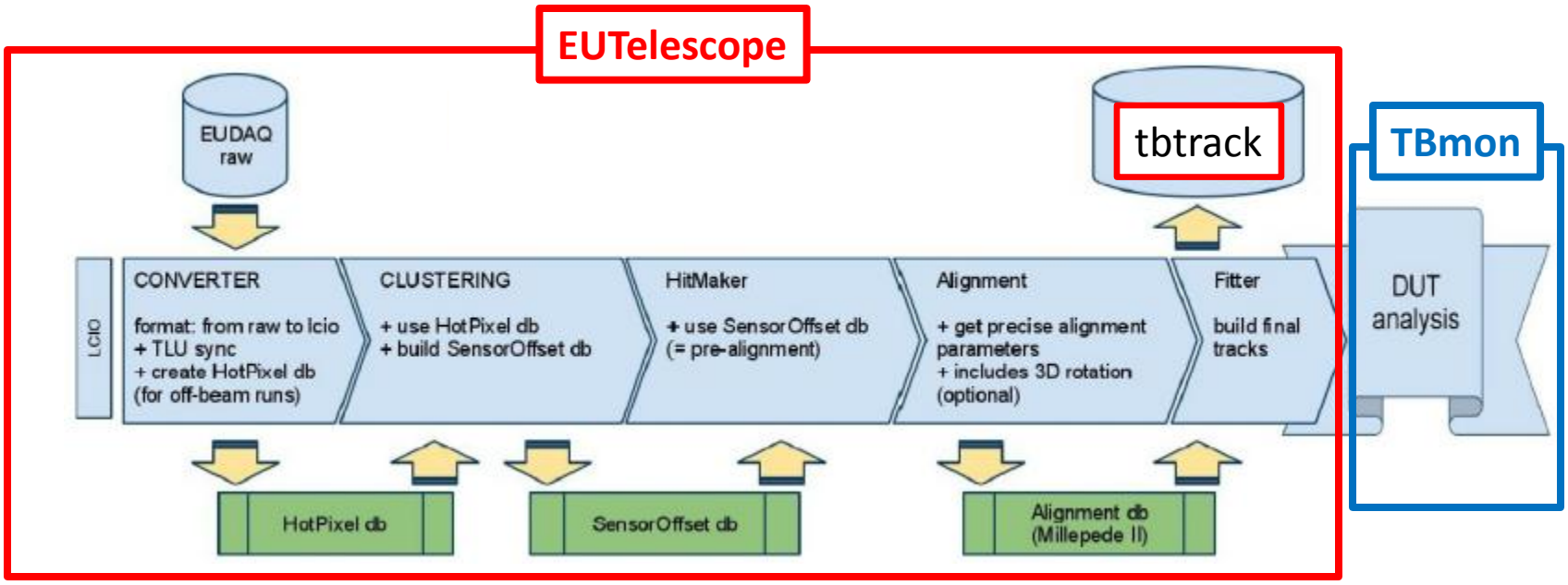
Topic: TB analysis of these testbeam data

Analysis

- EUTelescope
  - A software framework for track reconstruction
- TBmon
  - An offline analysis software framework
  - Load and analyze tbtrack data from EUTelescope



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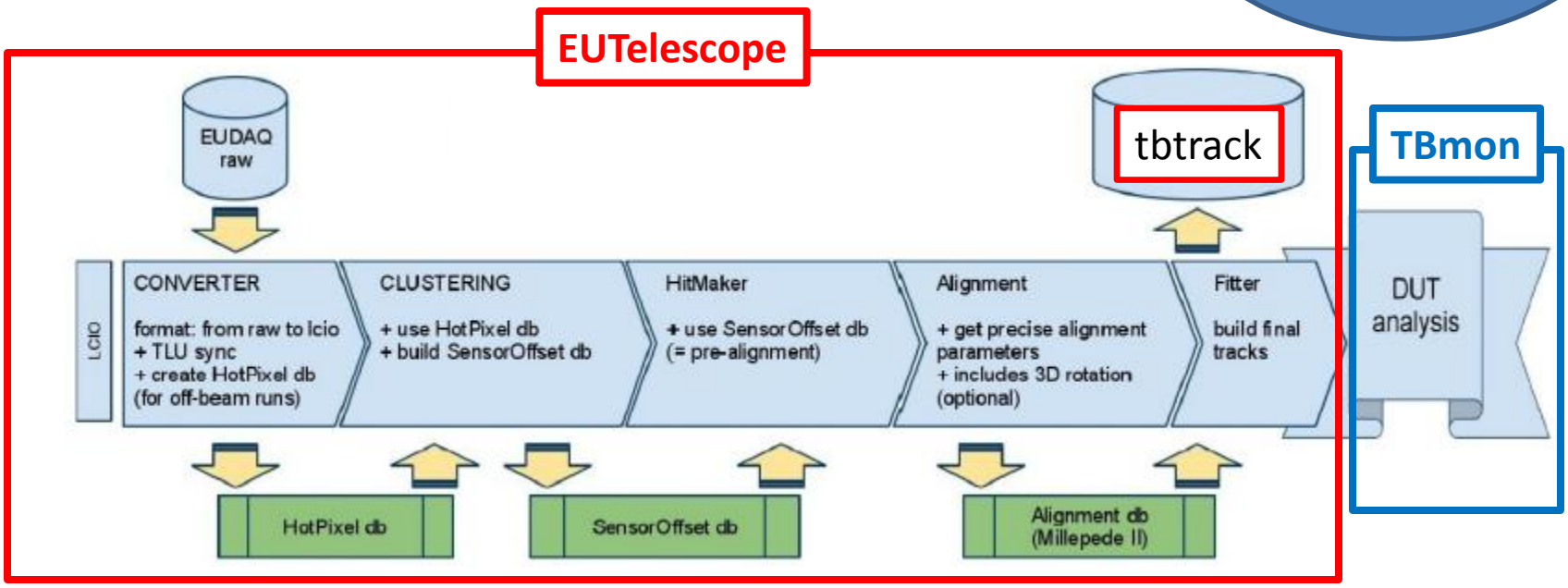
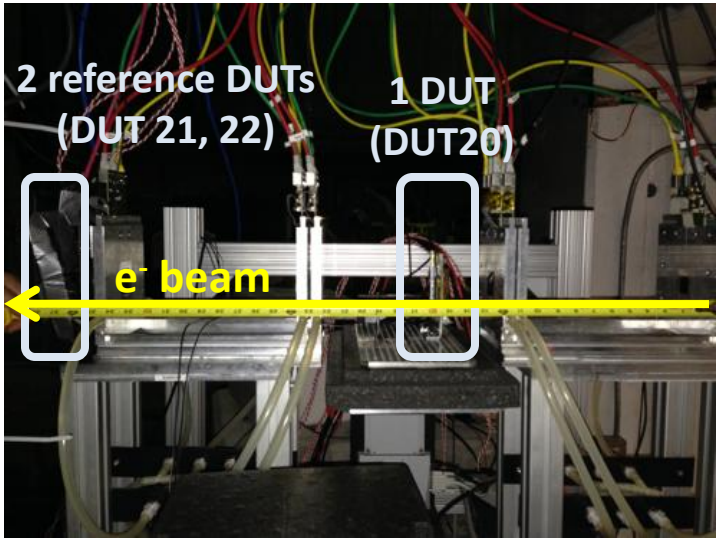
Today, the main focus is on reconstruction!

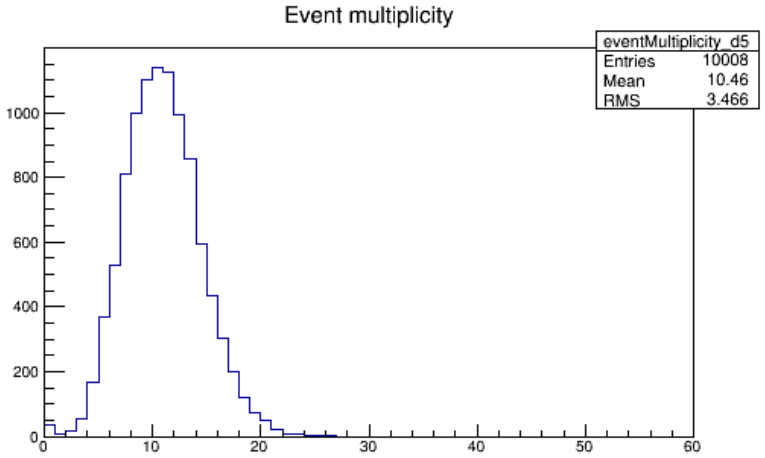


SLAC May 2014 Reconstruction

- 6 telescopes & 3 DUTs (non-irradiated)
  - Pixel size: 50 × 250 μm^2, Thickness: 150 μm
- Batch 5a run711 (2.5 GeV e$^-$ beam)
- Large multiple scattering effect
- Z position:

tel0	tel1	tel2	dut20	tel3	tel4	tel5	dut21	dut22
0.00	243.5	258.5	356.5	539.5	560.0	843.5	893.5	903.5



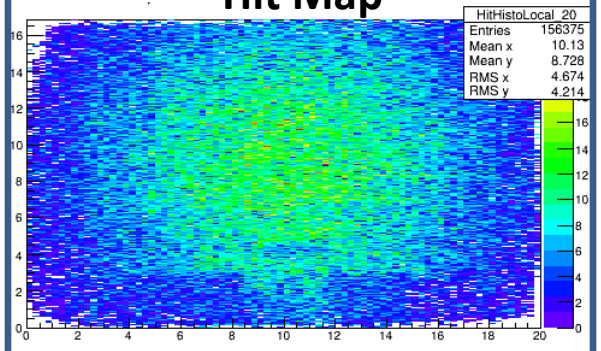


- ~10 particles/event
  (tuned by the multiplicity of the most downstream telescope)
- Attempt to analyze large multiplicity run with EUTelescope v00.09.03 and TBmon2

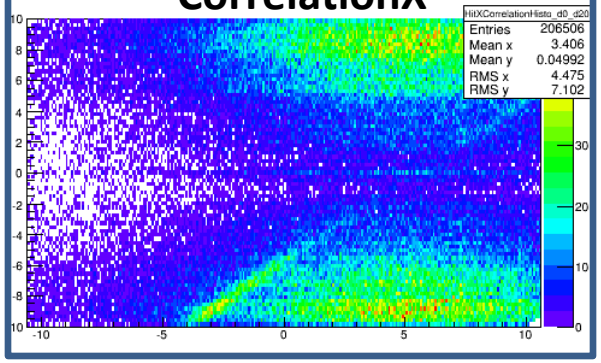
HitMaker

DUT20

Hit Map

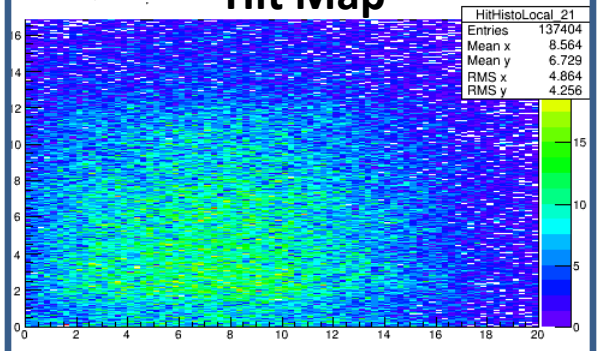


CorrelationX

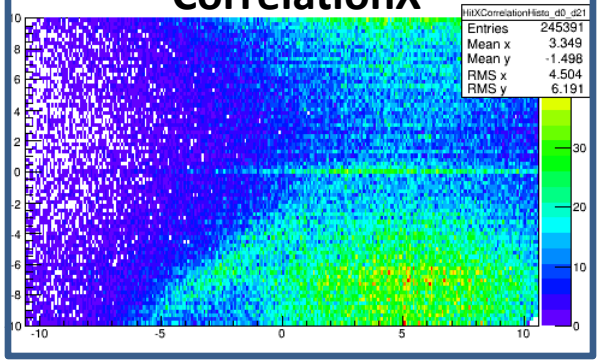


DUT21

Hit Map

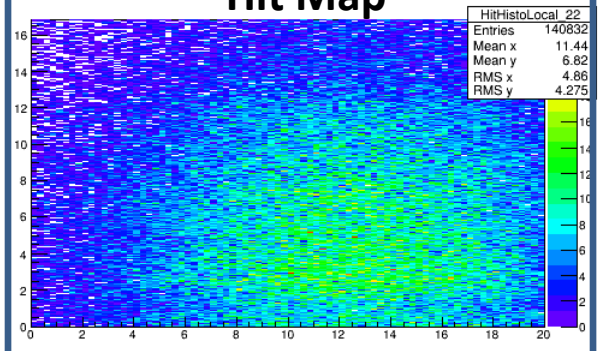


CorrelationX

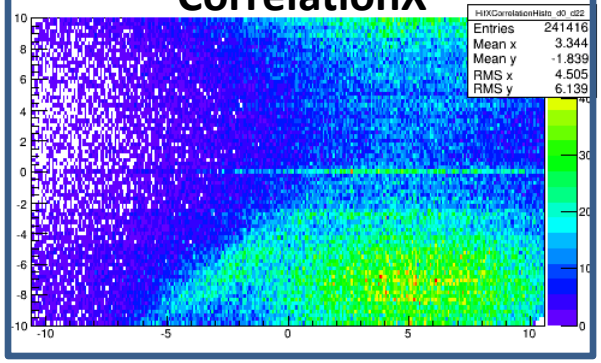


DUT22

Hit Map

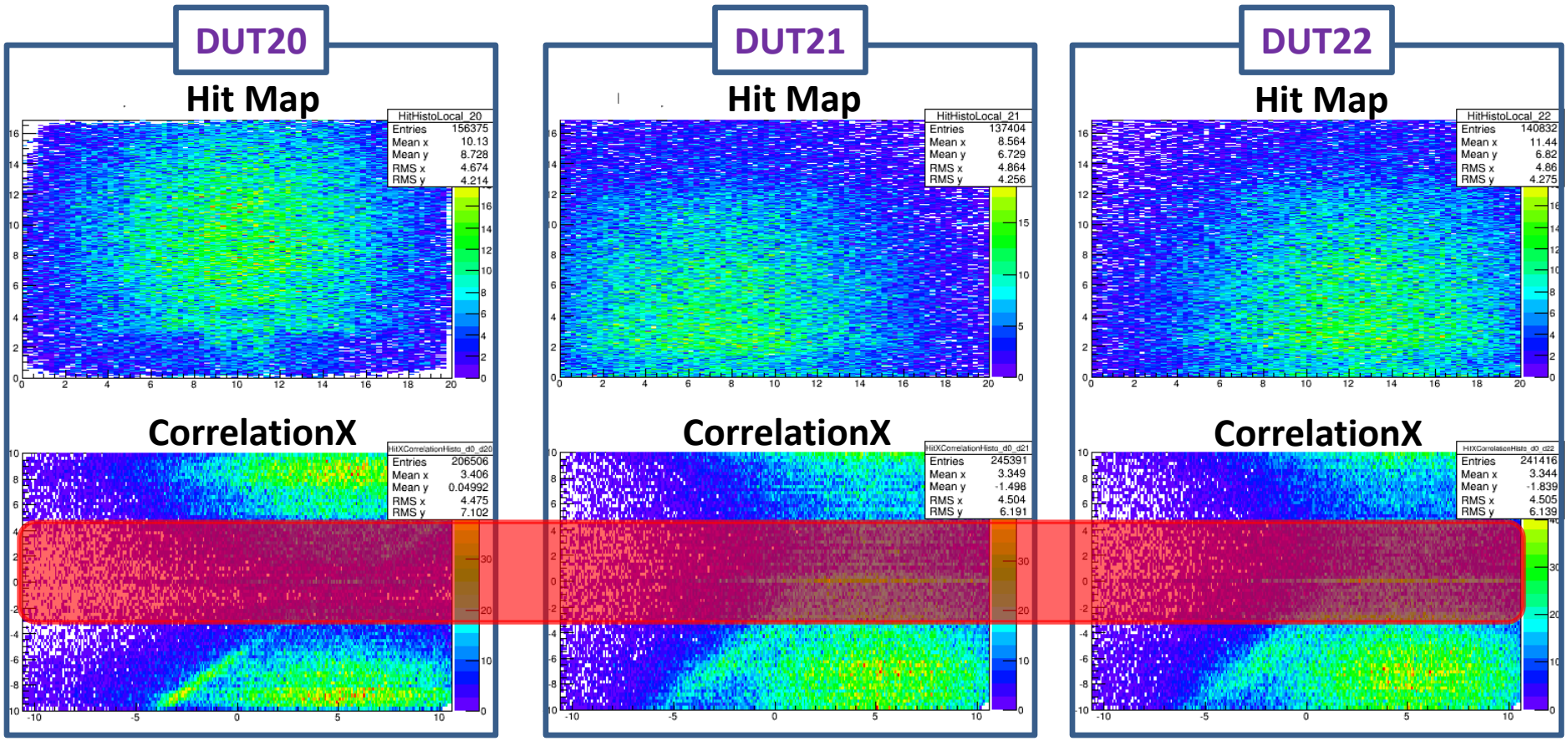


CorrelationX



Strange regions were observed in DUT correlation (tel0 vs DUTs) maps…

HitMaker



Strange regions were observed in DUT correlation (tel0 vs DUTs) maps…

SOLVED!

HotPixelKiller over-killed hits in the central region (shadowed region)

Hot Pixel Killer

- Max Firing Frequency (MFF): A parameter determines noise threshold
  - Defined as …

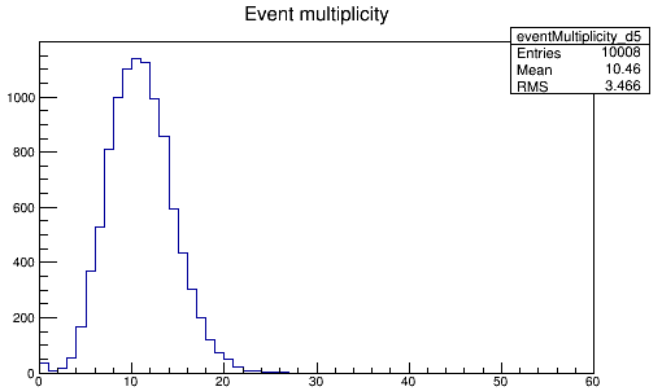
    (maximum allowed firing pixels per event) / (fiducial pixels per frame)

    i.e.

$$MFF = \frac{AllowedFiringPixel}{\sim 30000 Pixels}$$

  - Set 0.0005 as default for telescopes

    But, this default value did nothing wrong with mono-multiplicity testbeam analyses



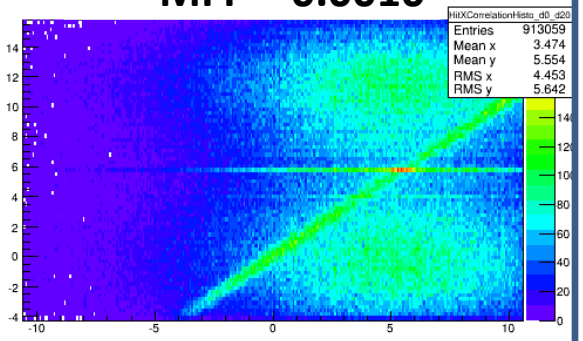
- To get the whole events, it is sufficient to set Allowed Firing Pixel～40
  - Approximately, the appropriate MFF is estimated to be around 1.3×10^{-3}

- Scanned MFF value, in order to confirm this estimation

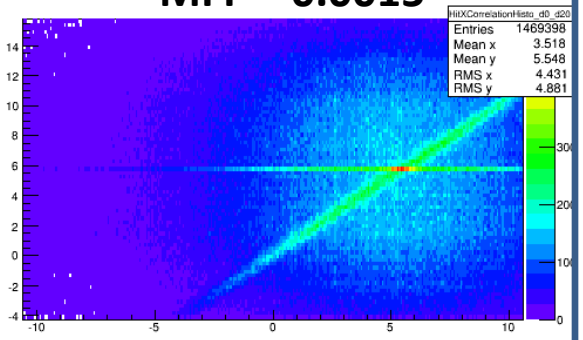
HitMaker after MFF Modification

DUT20

MFF = 0.0010

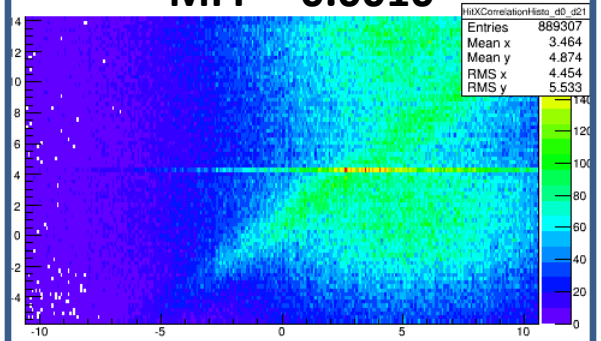


MFF = 0.0015



DUT21

MFF = 0.0010



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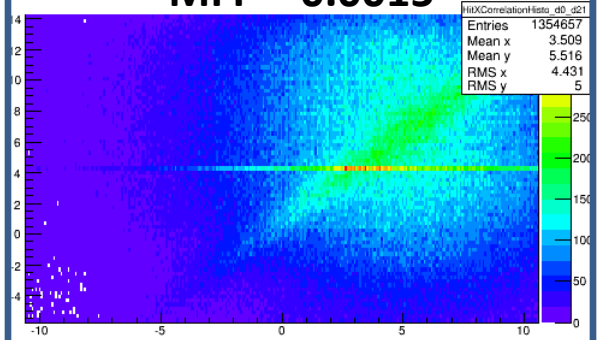
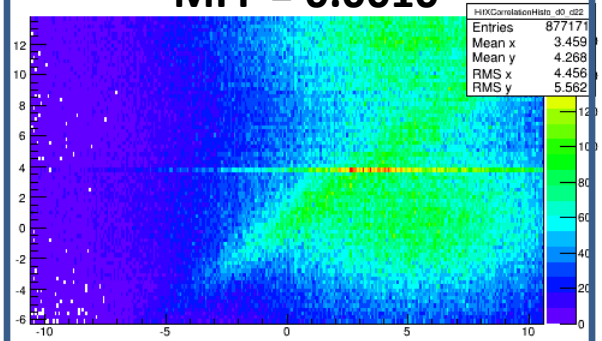


DUT22

MFF = 0.0010



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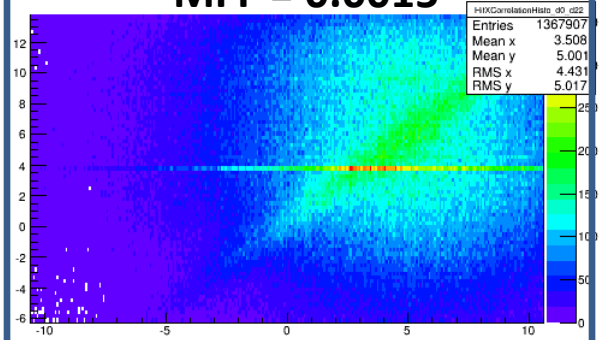


This indicates there are large number of events whose multiplicity is 30-50 (by the definition of Max Firing Frequency)

Multiplicity on the last telescope is not true? Must look at multiplicity on DUTs

Short Summary of SLAC Reco.

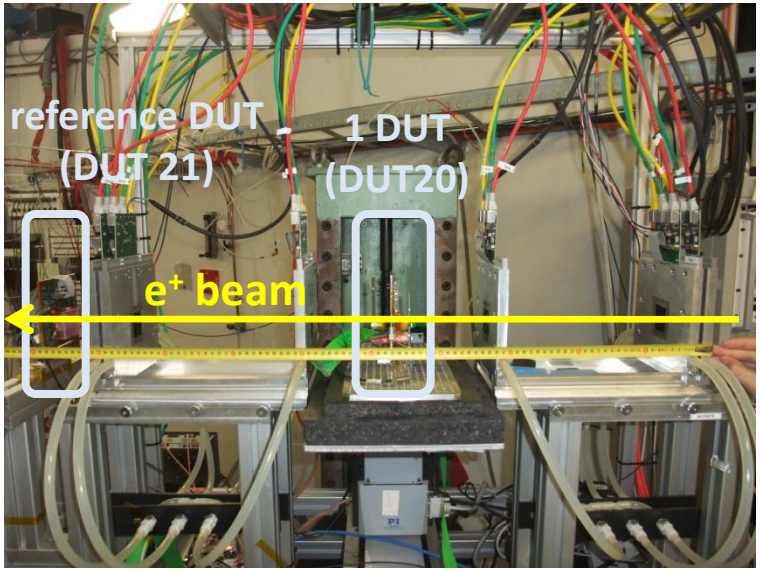
- An attempt to reconstruct large-multiplicity run
  - 10 particles per bunch (from the multiplicity histo of the most down-stream telescope)
- Reconstruct 2.5GeV e- run with EUTelescope v00.09.03
- Strange correlation plot is observed in HitMaker process
  - Due to Hot Pixel Killer process in Converter
  - Over-rejected the hits in the central part of DUTs
  - Since the beam includes 10 particles per bunch, MFF value was too small
- Scanned MFF value
  - By definition of MFF, it is likely that the appropriate multiplicity is 30-50
  - Investigating the multiplicity on each DUTs

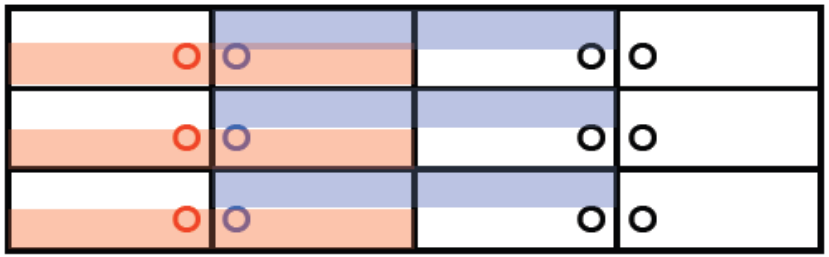
DESY Aug. 2013 Reconstruction

- 6 telescopes & 2 DUTs (non-irradiated)
- Batch 5f run2472 (4 GeV e^+ beam)
- Large multiple scattering effect
- Z position:

tel0	tel1	tel2	dut20	tel3	tel4	tel5	dut21
0.00	20.50	303.5	452.5	594.5	877.0	897.0	980.5

- DUT20 has long-staggered pixels
  - pixel size: 25 × 500 μm^2, Thickness: 150 μm





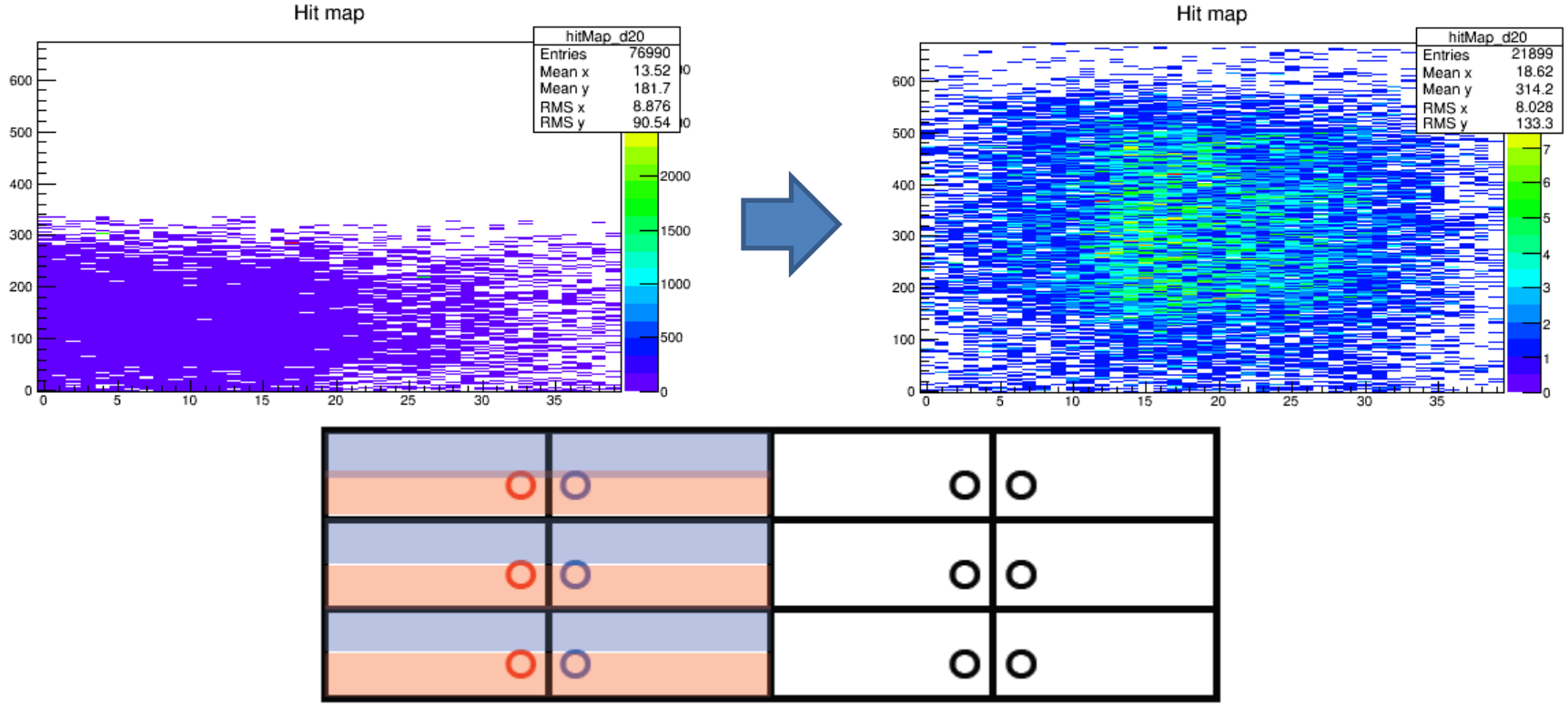
- The same y-pitch with the inner-most pixel layer
- Upsides of staggered geometry
  - Better x-resolution for cluster size 2
  - Less efficiency drop on pixel corners

  -> under investigation

EUTelescope v00.09.03

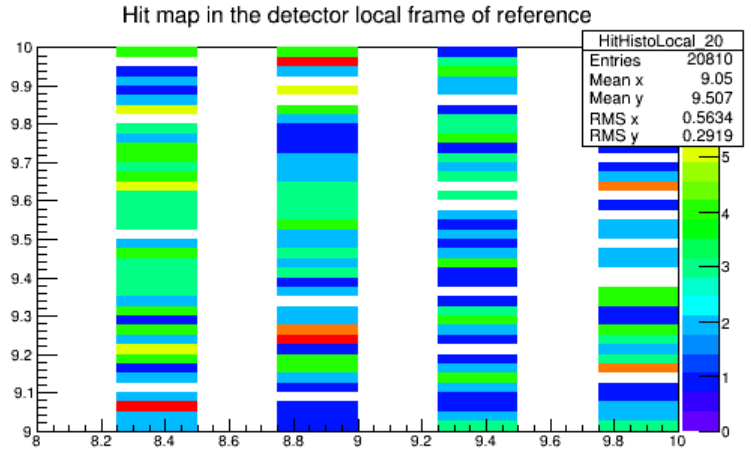
- Since the number of FE-I4 chips is 80 columns × 336 row, converter source file needs to be edited to make clustering hitmaps to 40 columns × 672 row

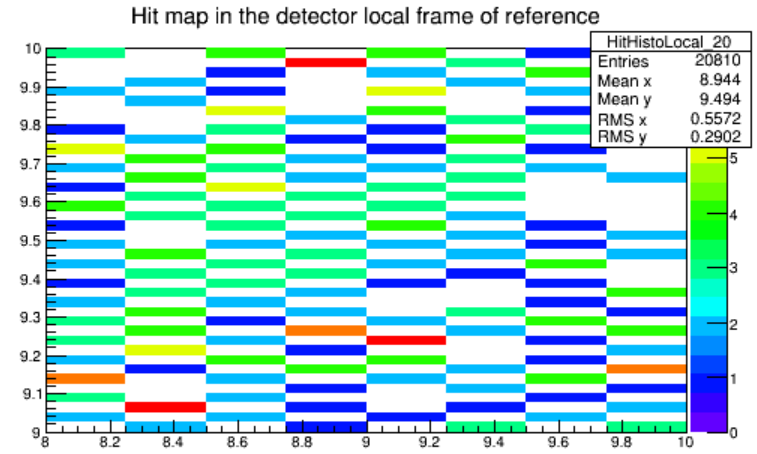
  (note that pixels are NOT STAGGERED in this procedure)

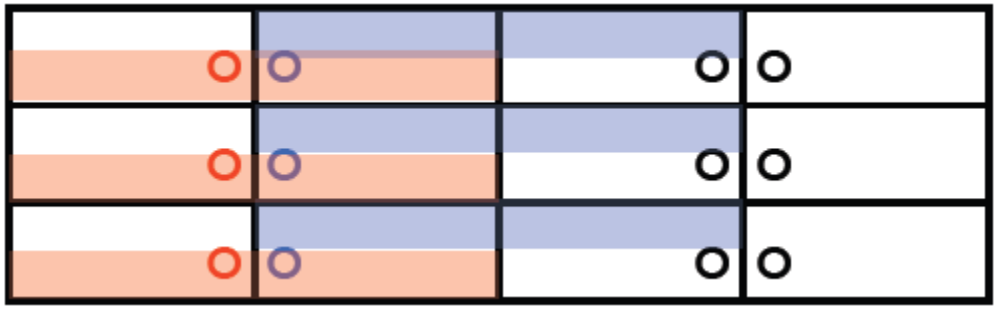


Making “Staggered” Map

- Edited hitmaker source file to shift every other row towards X (horizontal in the figures below) direction by 250µm (half pixel length)







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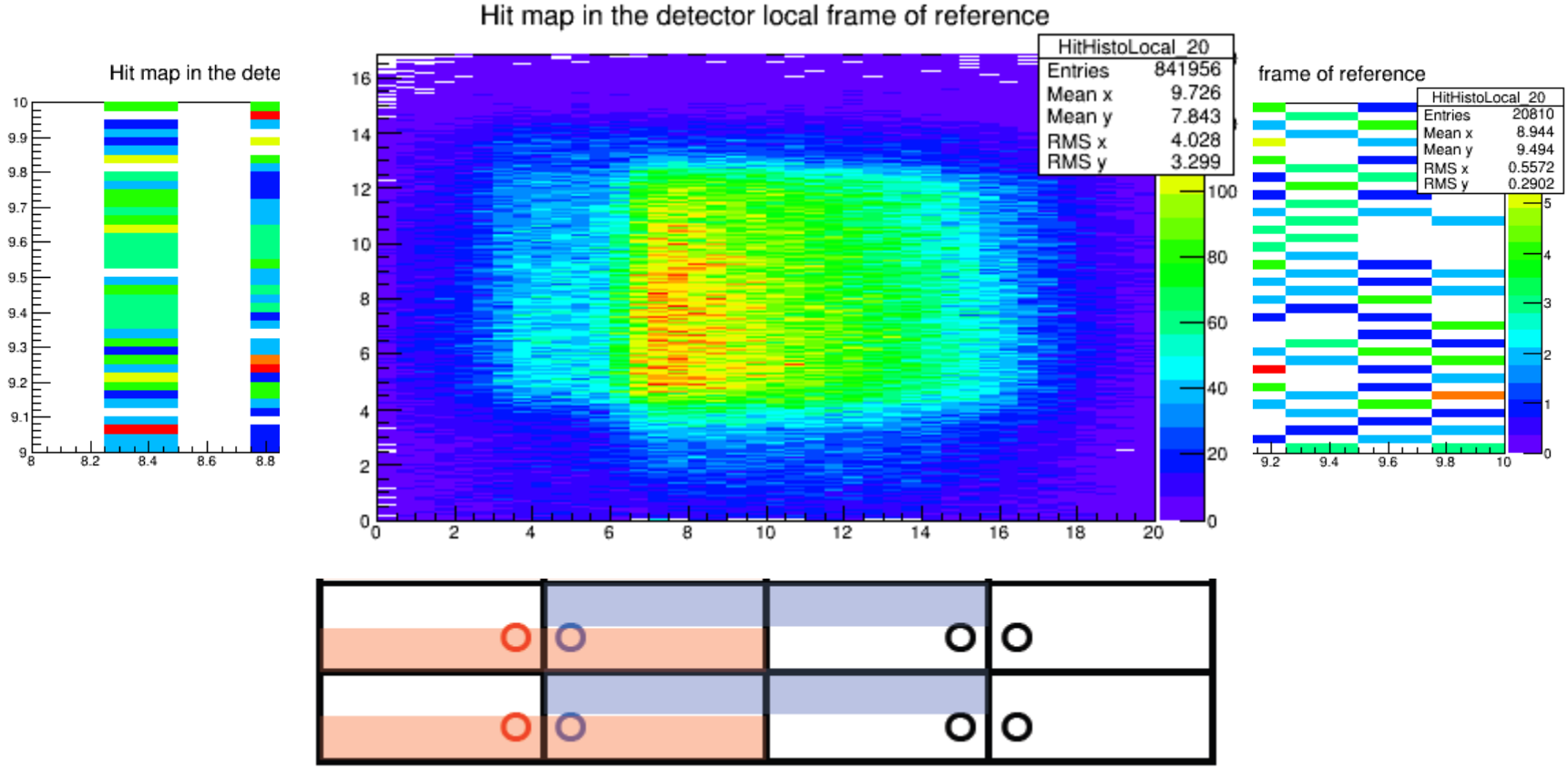
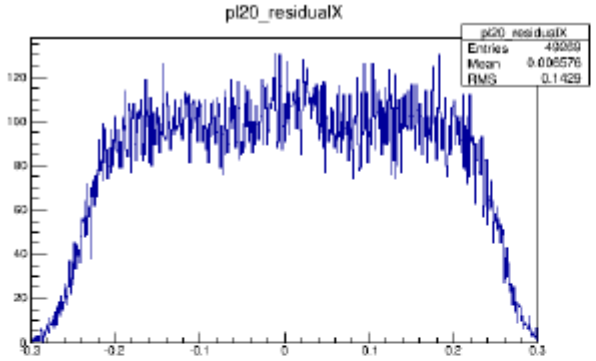
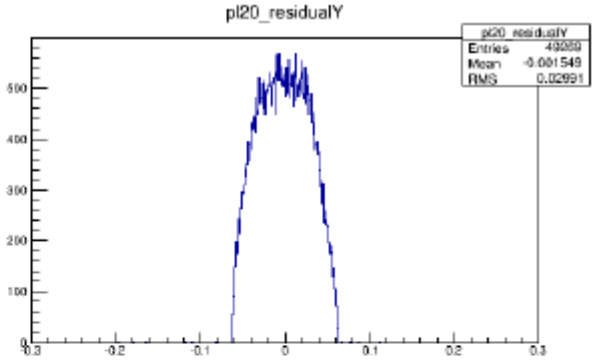
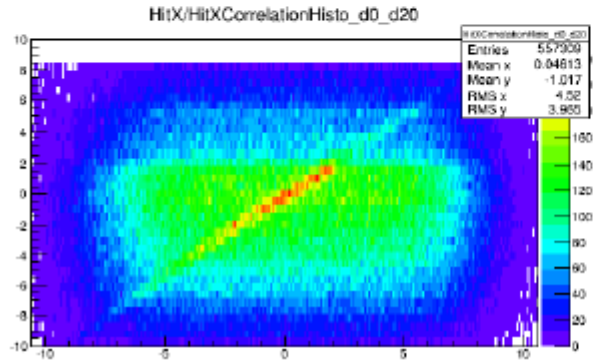


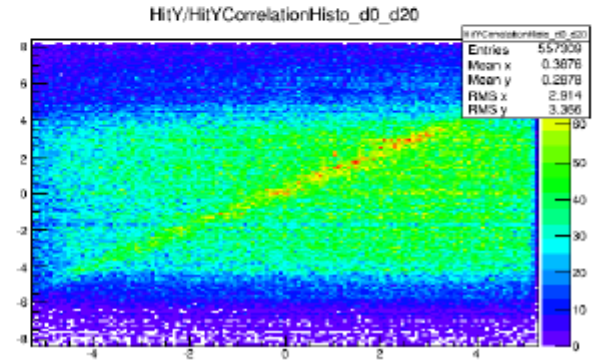
Alignment and Fitting

- Looks like aligned and correlated well.
- However, wider correlation is observed in residual Y distribution



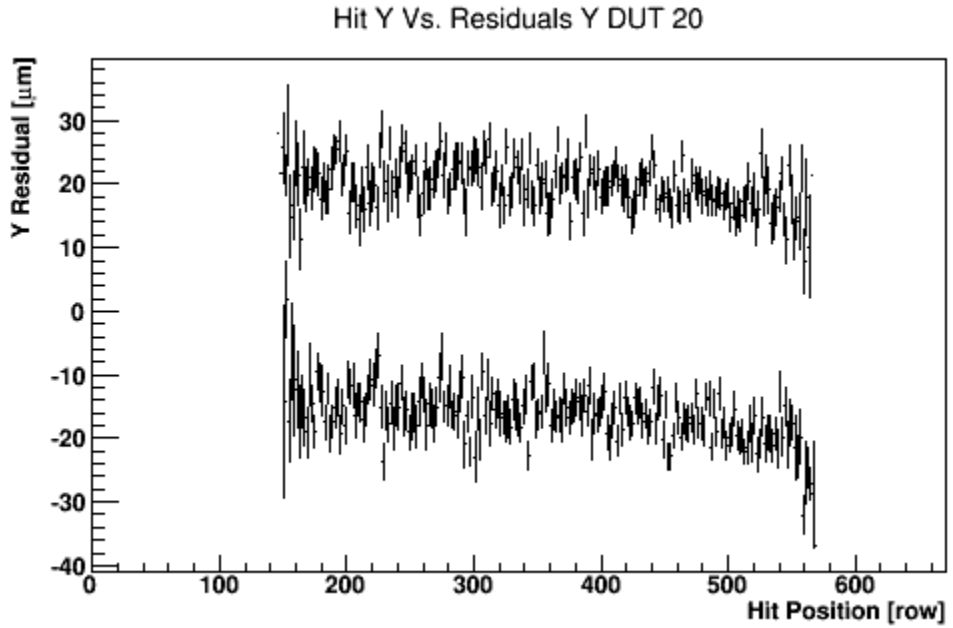






Residual Y in TBmon2

- Analyzed anyway with TBmon (ver.2.0), and got the Residual vs Hit Position plot below



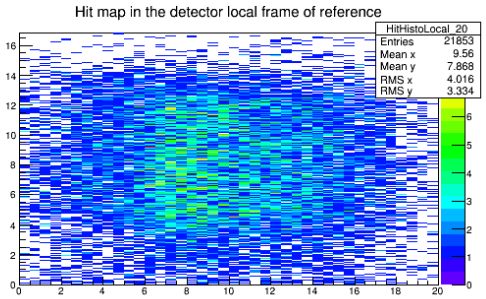
For each hit position, two residual values (~ ±15μm) exist…

-> It seems the wider residual distribution is attributed to overlap of these two residual distribution

EUTelescope v1.0.0-beta.1

- It seems that something's wrong with clustering process and cluster size 2 hits are accidentally regarded as those of cluster size 1
  - Must apply staggered geometry in the converter process?
  - Unfortunately, this is very difficult with EUTelescope v00.09.03

- In order to solve this problem, I decided to use the latest version of EUTelescope (v1.0.0-beta.1)
  - Enable us to apply pixel geometry (including staggered geometry) in converter
  - So far, converting hitmap is succeeded as shown in the v00.09.03 reconstruction
  - However, some problems occurred when applying pix geometry into converter process (Next page)



Problems

- Fail Applying Long-Staggered Structure

Info in <TGeoManager::CountLevels>: max level = 5, max placements = 1344
Info in <TGeoManager::CloseGeometry>: 4069892 nodes/ 24 volume UID's in v0.1

Error in <TGeoNavigator::cd>: Path
/volume_World_1/volume_SensorID:20_1/sensarea_fei4/fei4region2_96/fei4pixel2_13 not valid

- Probably, this comes from incorrect mapping of pixels.
  - Debagging is on-going

Summary and Future

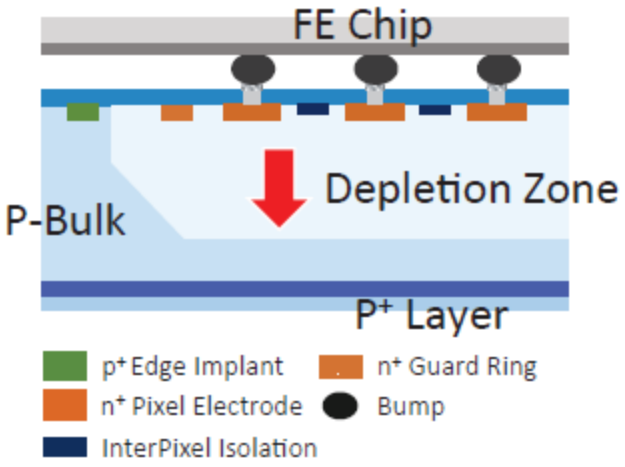
- ITk upgrade is geared toward the HL-LHC upgrade 2022-2025
  - Japan silicon group has been trying to develop high radiation-tolerant PPS
  - Tb analysis with two software frameworks: EUTelescope and TBmon
- SLAC large multiplicity run analysis
  - Reconstruction is on-going with EUTelescope v00.09.03
  - Problem in HitMaker, strange regions in correlation plot, was solved by changing MFF value
  - It seems that the REAL multiplicity value is 30-50? -> under investigation
  - Thinking of moving on to TBmon analysis, after the whole reconstruction is completed.
- DESY long-staggered pixel run analysis
  - Successfully obtained 40×672 pixel map both with EUTelescope v00.09.03 and v1.0.0-beta.1
  - Fail applying staggered geometry into process with EUTelescope v1.0.0-beta.1

    -> Debagging pixel mapping…

BACKUP

ATLAS Japan n^+-in-p PPS

- n^+-in-p planar pixel sensors
  - High radiation tolerance
    - Depleted zone is expended from read-out connector side
    - Less affected by n-to-p type inversion from radiation damage
  - Since e- is collected to FE-chip, charge collection speed is faster



Clustering SLAC 2014