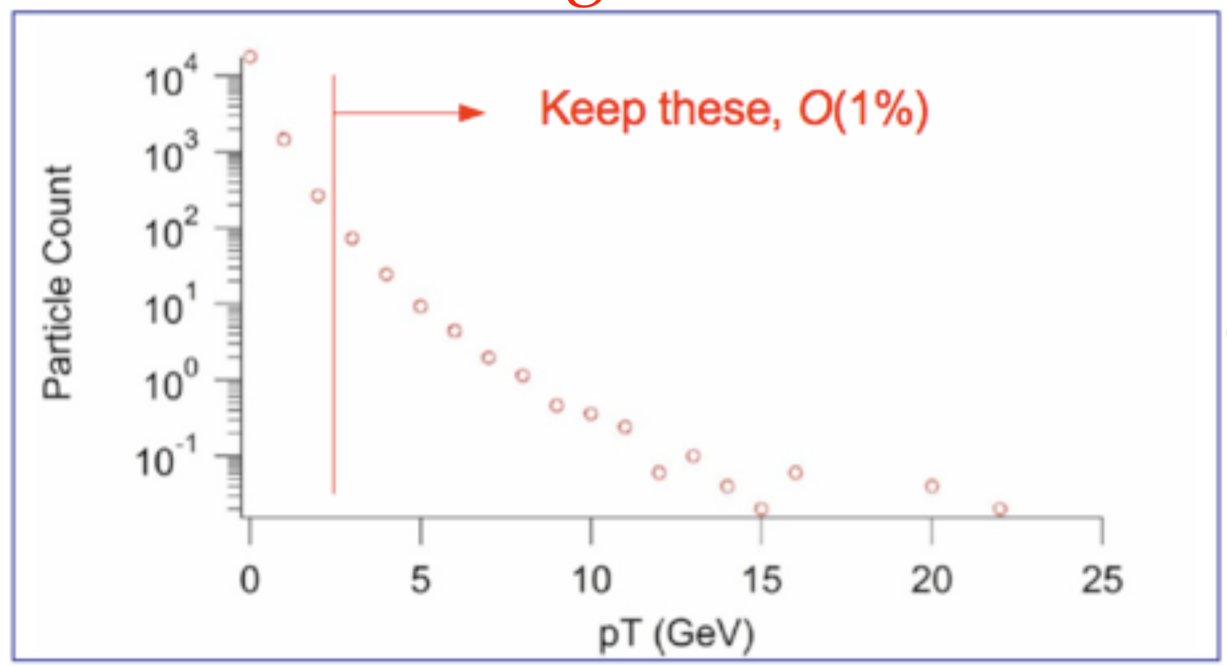
Data reduction

Fabrizio Palla

Select only hits from “high-p_T” tracks

- Select only tracks above a given p_T since they are few
- Send reduced data volume off detector for further logic



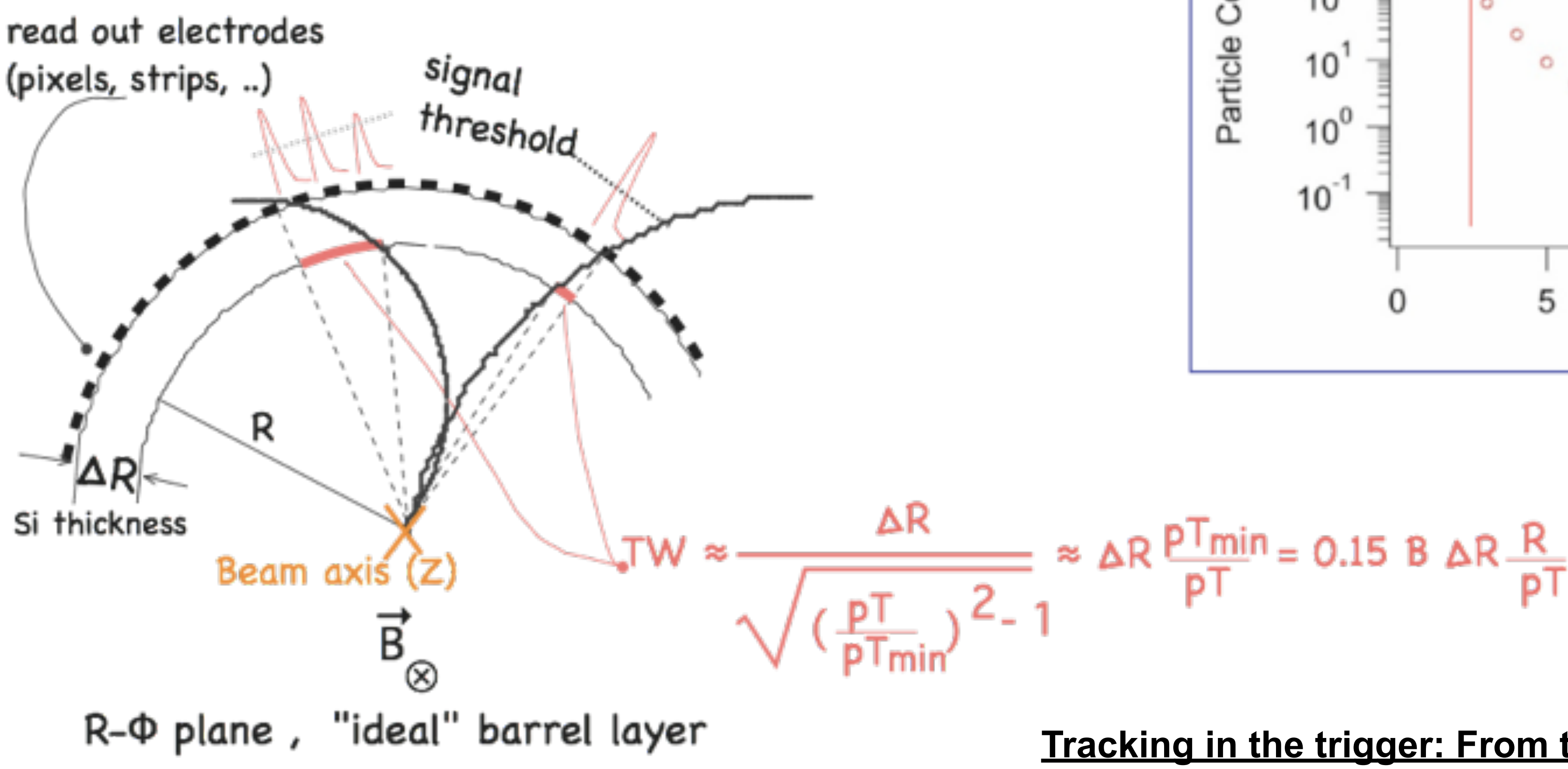


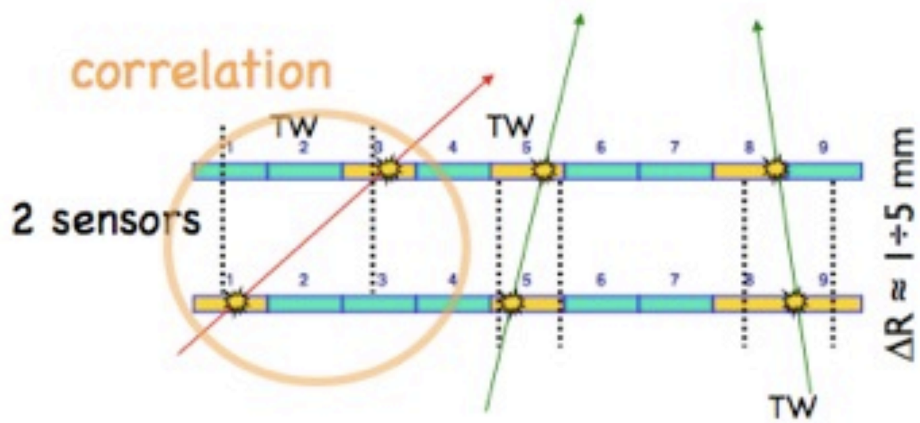
Figure of merit: Thickness/pitch

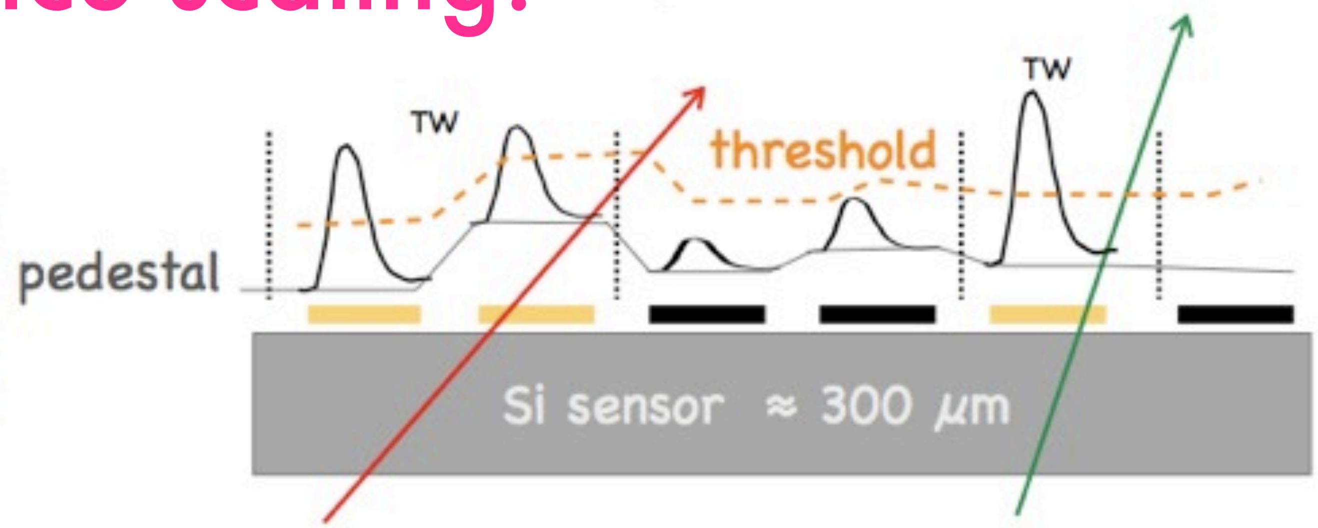
Tracking in the trigger: From the CDF experience to CMS upgrade.
Fabrizio Palla (INFN, Pisa), Giuliano Parrini (Florence U. & INFN, Florence). 2007. 14 pp.
Published in **PoS VERTEX2007 (2007) 034**

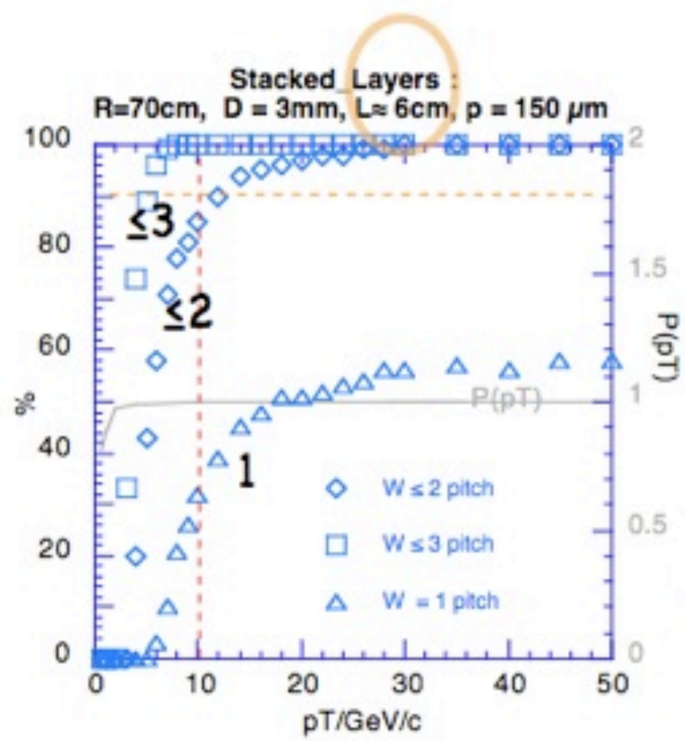
Track width measurements

Very similar

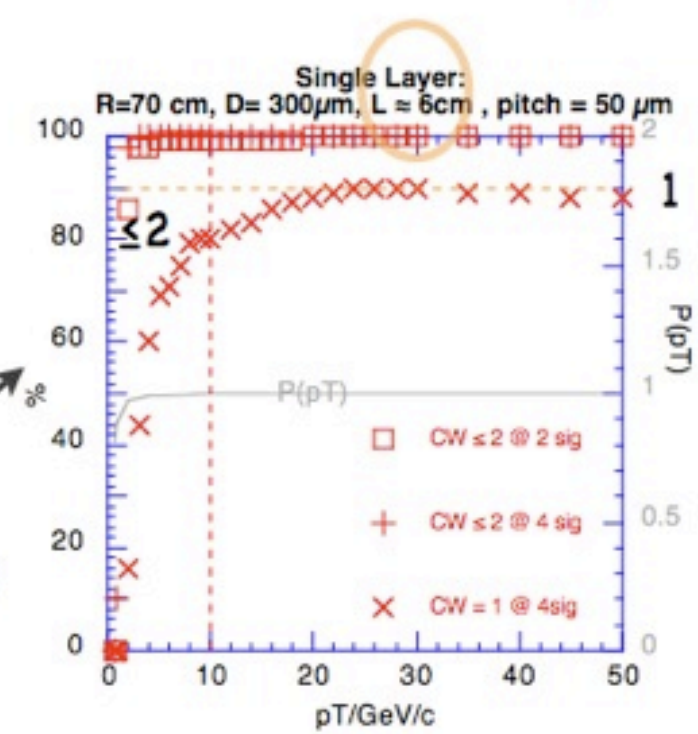
Stacked Layers notice scaling! Single Layer







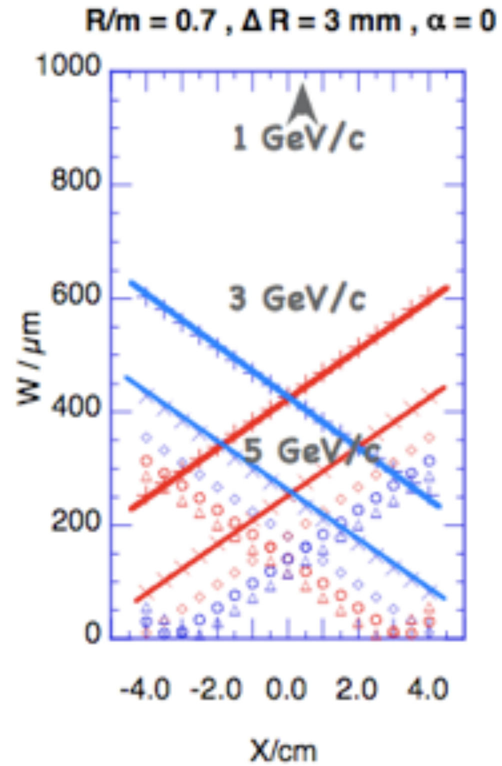
measurements give pT lower limits



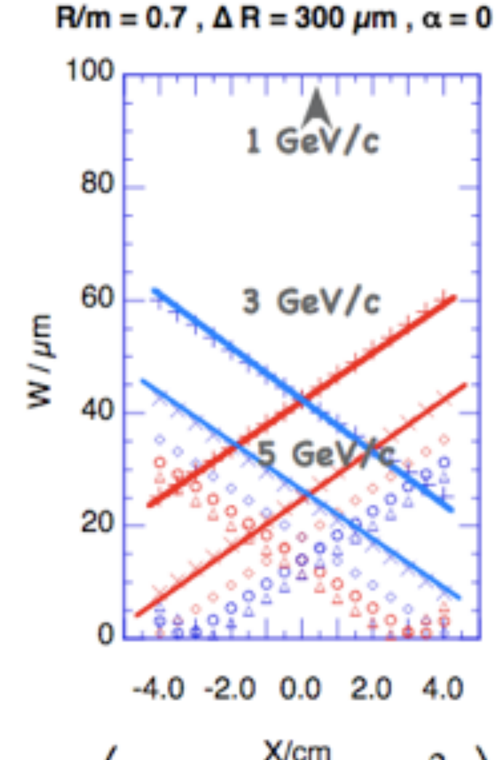
Complications

- Effects due to non-flatness and tilt

Stacked



Cluster width



$$TW \approx \Delta R \frac{pT_{\min}}{pT} \pm \Delta R \frac{x}{R}\left(1 + \left(\frac{pT_{\min}}{pT}\right)^2\right)$$

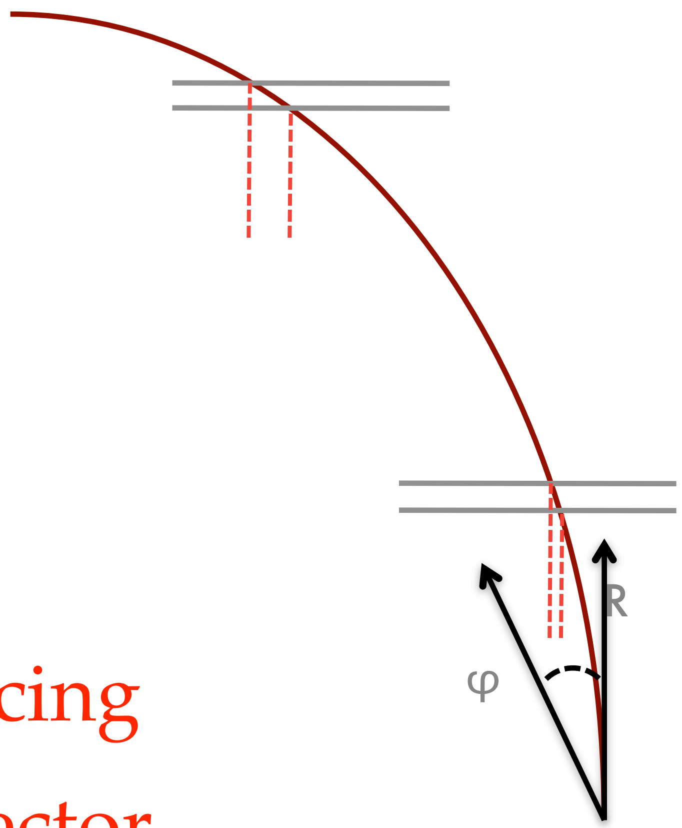
Tilt affects the two in a opposite way:

while for the track width goes to correctly compensate

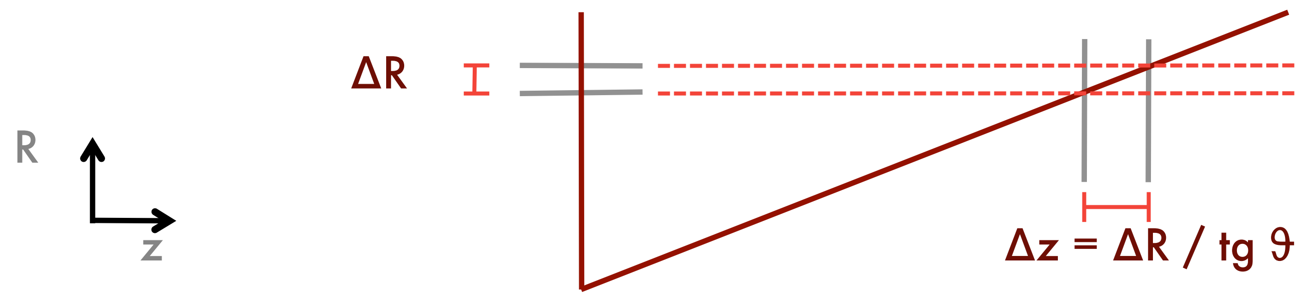
for the stacked introduces an offset that is different for +ve and -ve tracks, though some charge discrimination possible with complex logic

p_T modules in barrel and end-cap

- Sensitivity to p_T from measurement of $\Delta(R\phi)$ over a given ΔR
- For a given p_T, $\Delta(R\phi)$ increases with R
  - A same geometrical cut, corresponds to harder p_T cuts at large radii
  - At low radii, rejection power limited by pitch



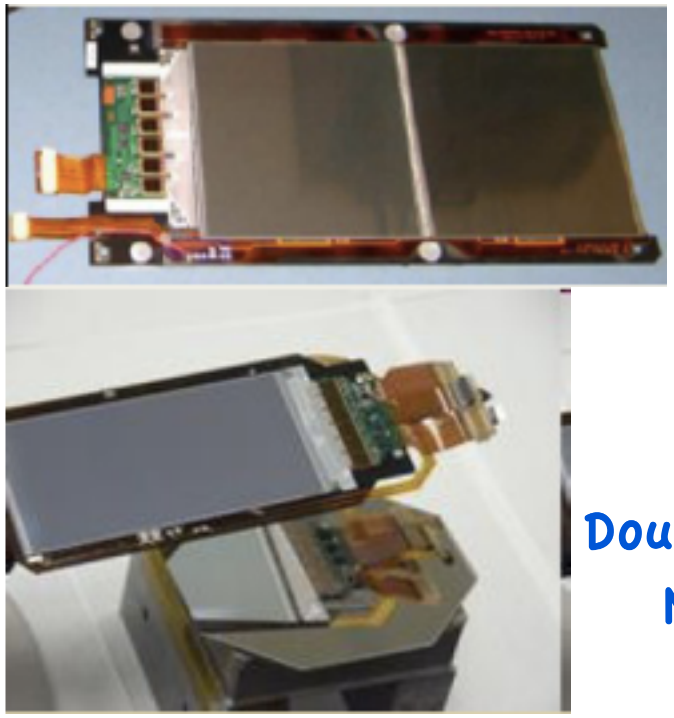
- In the barrel, ΔR is given directly by the sensors spacing
- In the end-cap, it depends on the location of the detector
  - End-cap configuration typically requires wider spacing



Method Validation using LHC collision data in CMS

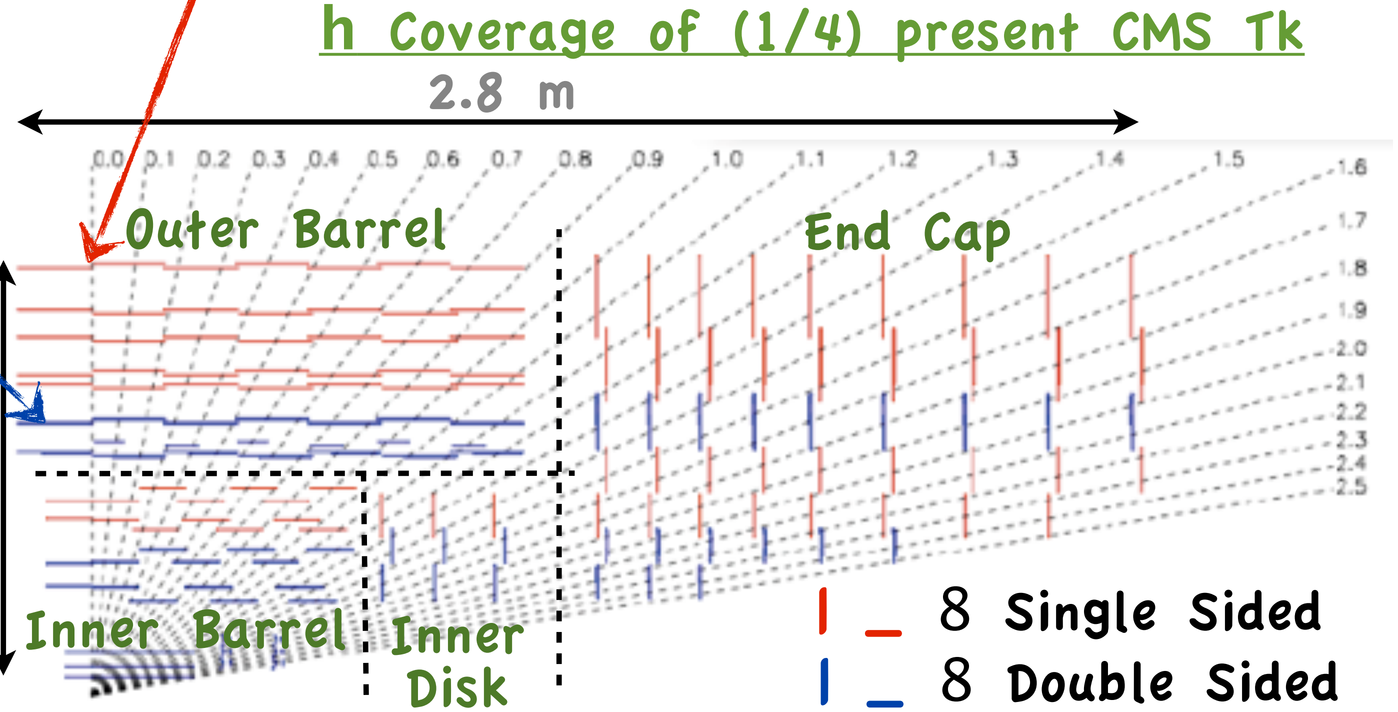
Double Sided (DS) modules
considered to mimic
the 2-in-1 stacked modules
>> TOB Layer 2
- R = 70 cm
- ToP = 21.9

Single Sided (SS) modules
TOB Layer 6
R = 108 cm
ToP = 4.2

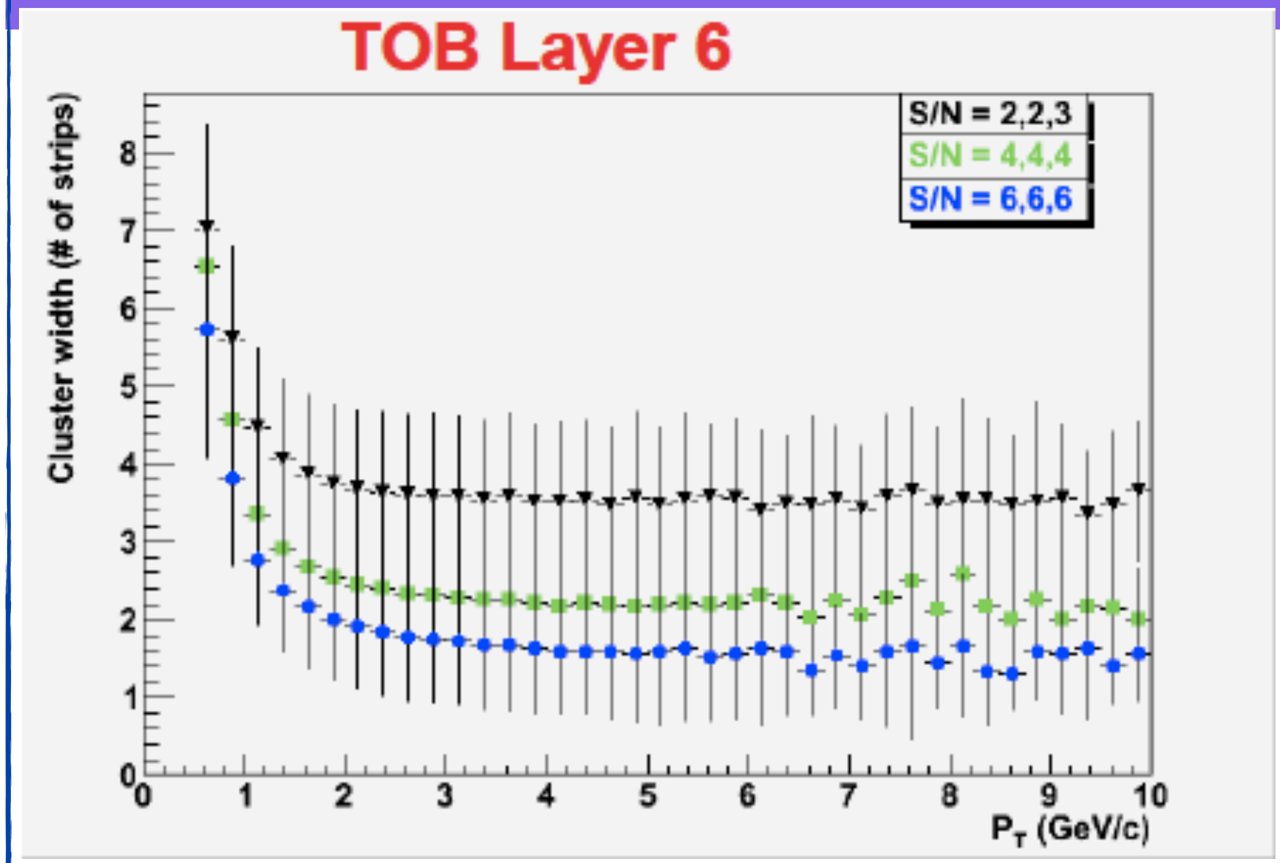


Single Sided Module

Double Sided Module



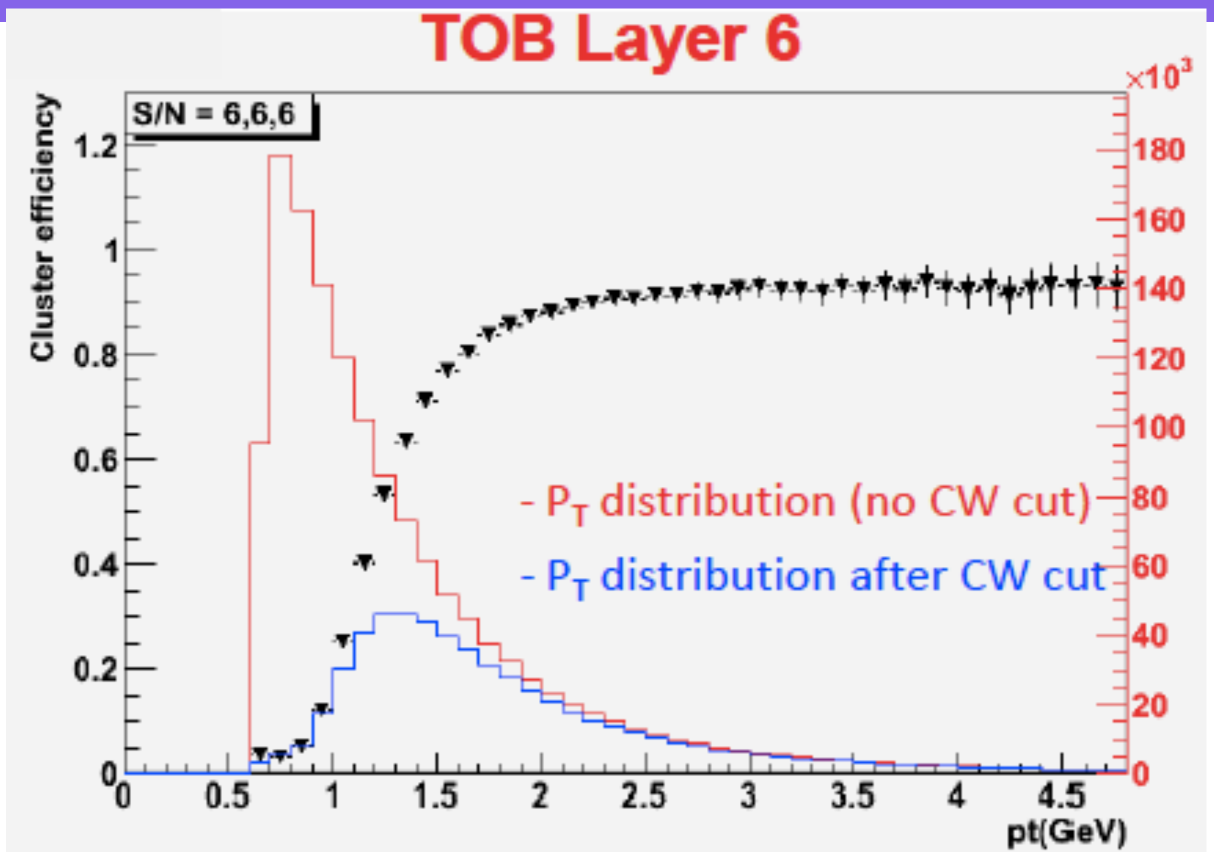
SS: Sensitivity to CW



Tracks CW correlated with reco p_T for various clustering thresholds

>> CW decreases with pT, as foreseen from theoretical model

>> Good pT sensitivity for higher clustering thresholds (S/N > 6) due to suppression of capacitive couplings effects on FE electronics generating false large clusters

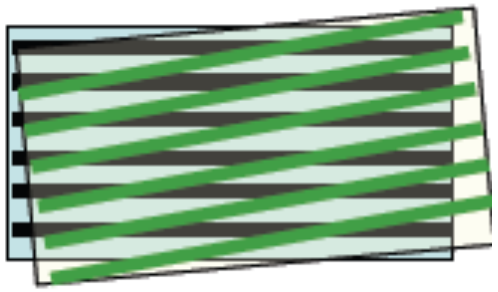


Tracks selected with CW < 3

>> Selection efficiency as a function of p_T superimposed to track p_T distributions

>> Efficiency > 90% yet from 2 GeV/c

Using glued detectors

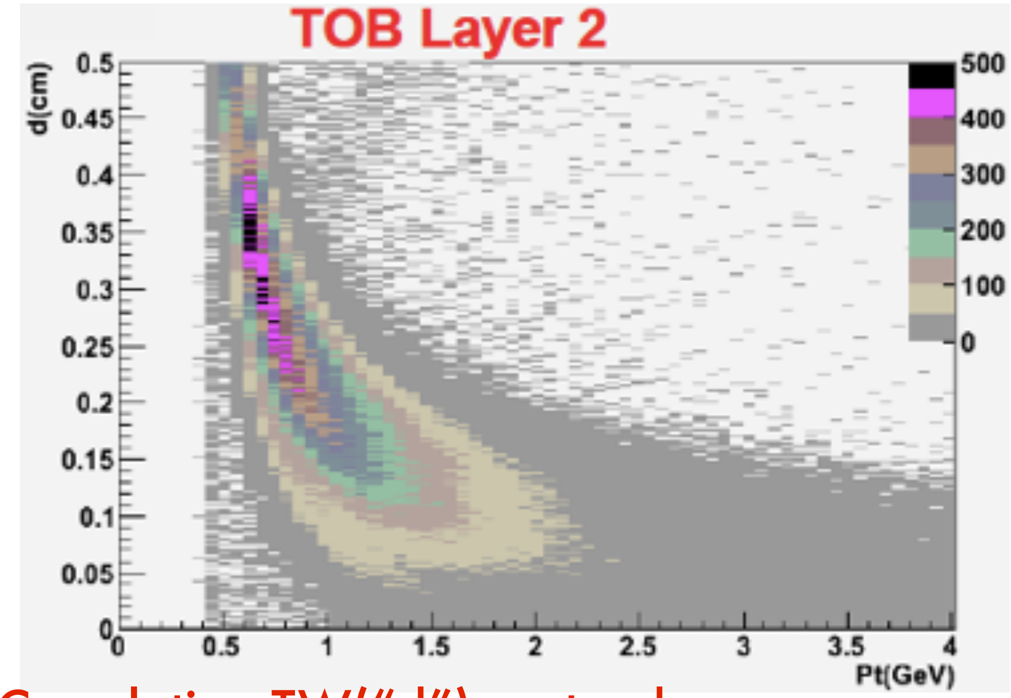


tilt angle: 100 mrad

Glued modules in CMS are used to get z info

>> 2 SS modules are in "stereo" configuration
i.e. rotated by 100 mrad, separated by ~2mm

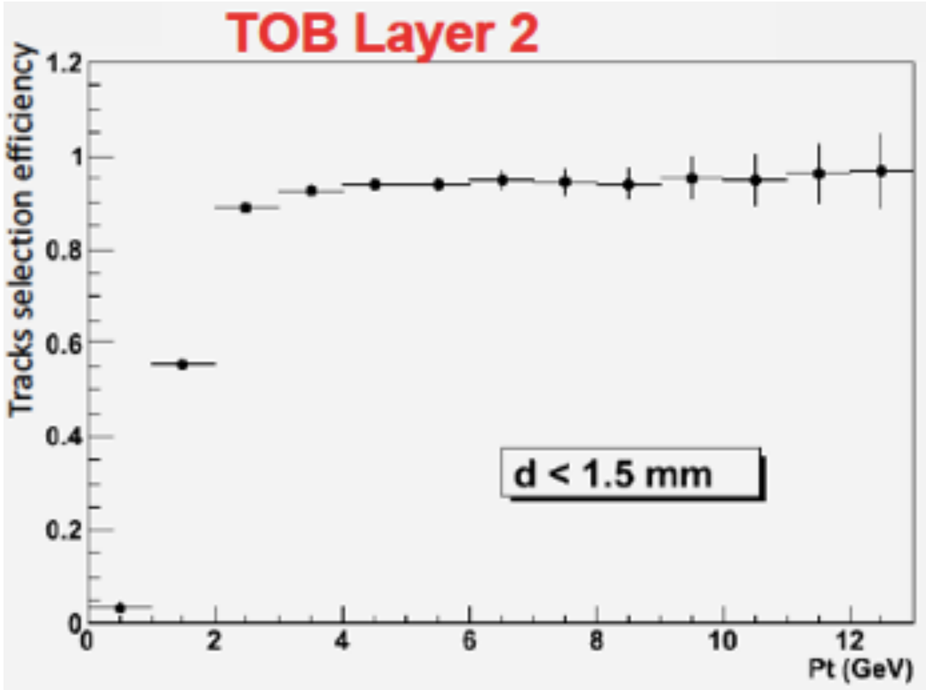
>> Correcting off-line for the stereo angle, we can
use these modules as double layer detectors



Correlation TW("d") vs. track p_T

>> High p_T (>2 GeV/c) tracks have clusters almost overlapping

>> Clusters for low p_T ones are far each other



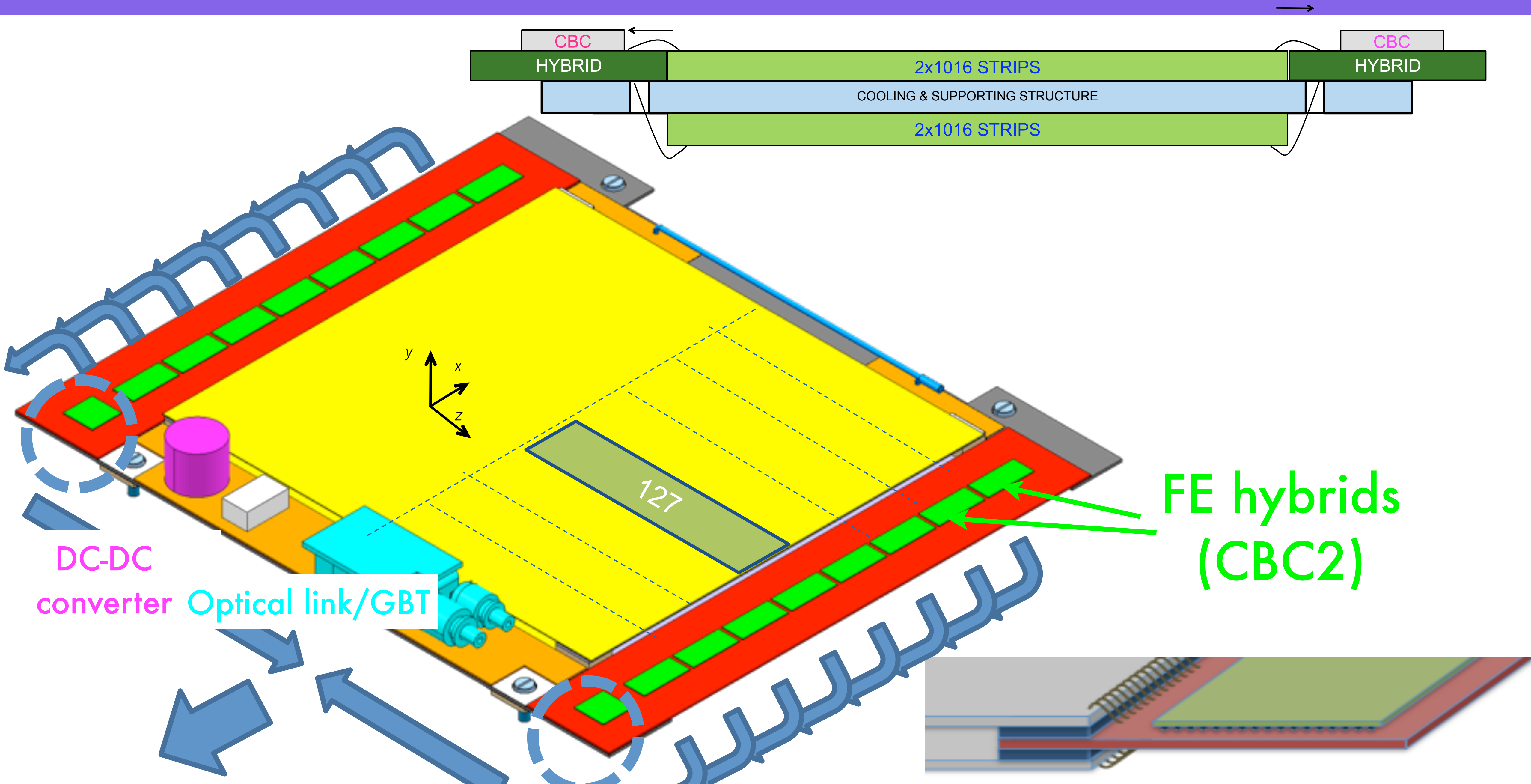
Tracks selected with TW("d") < 1.5 mm

>> Selection efficiency vs. track p_T

>> Efficient selection (~100%) for high (> 5 GeV/c) p_T tracks

Hardware designs

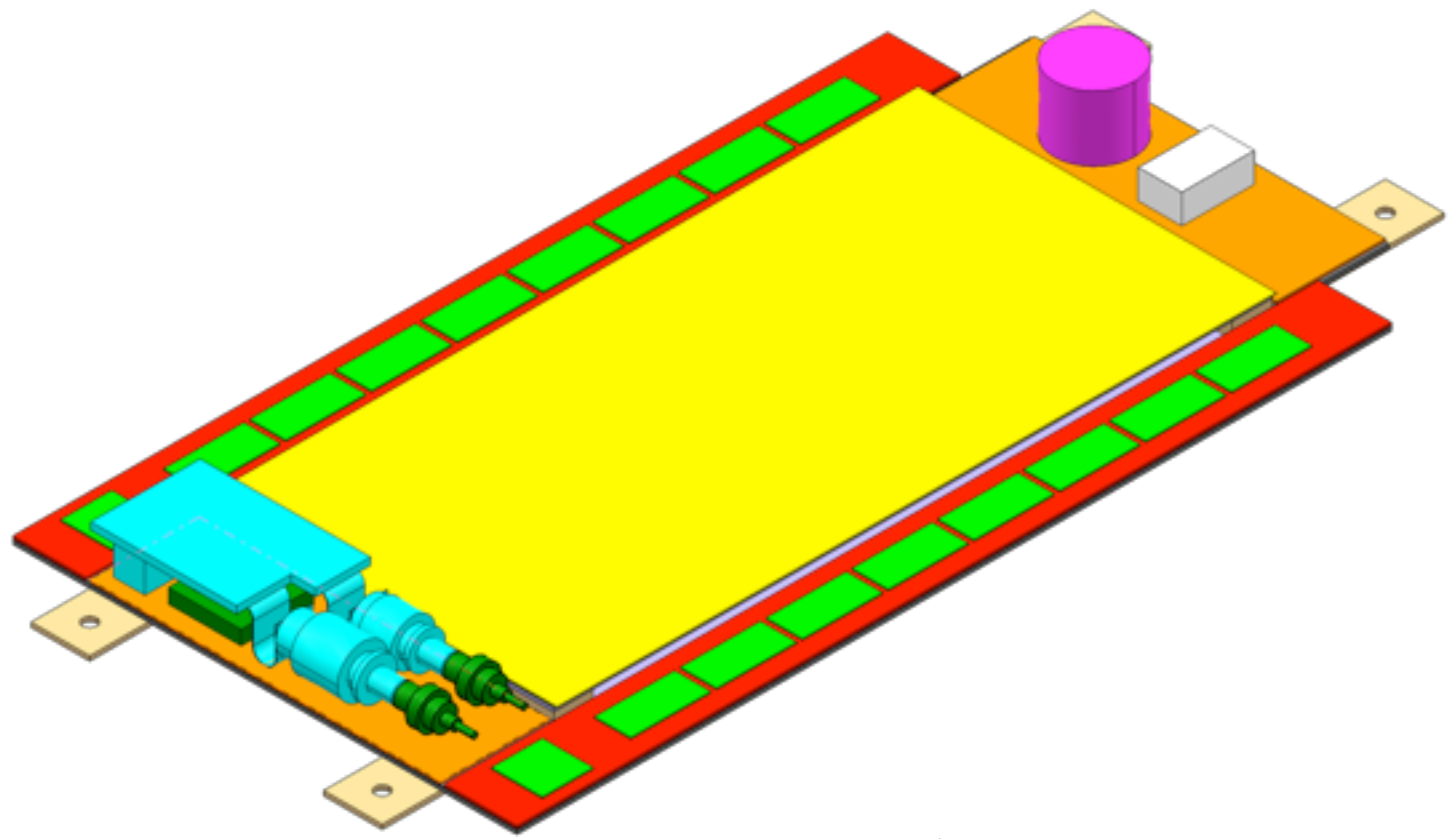
2S pT-modules

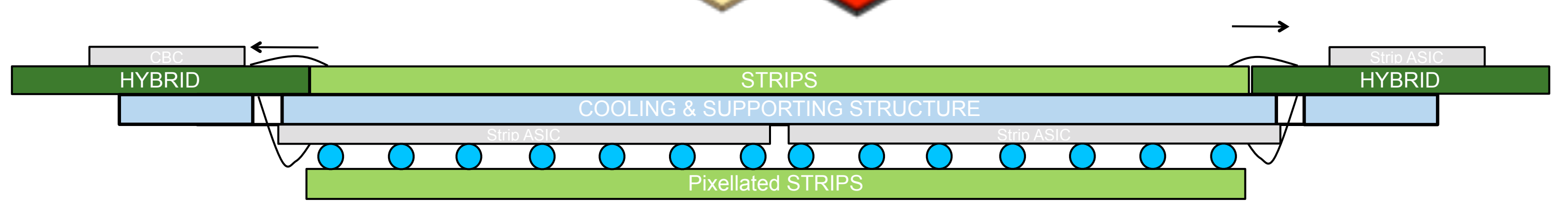


- ≈ 5 cm long strips, ≈ 90 µm pitch, ≈ 10x10 cm^2 overall sensor size
- Wirebonds from the sensors to the hybrid **on the two sides**
  - 2048 channels on each hybrid

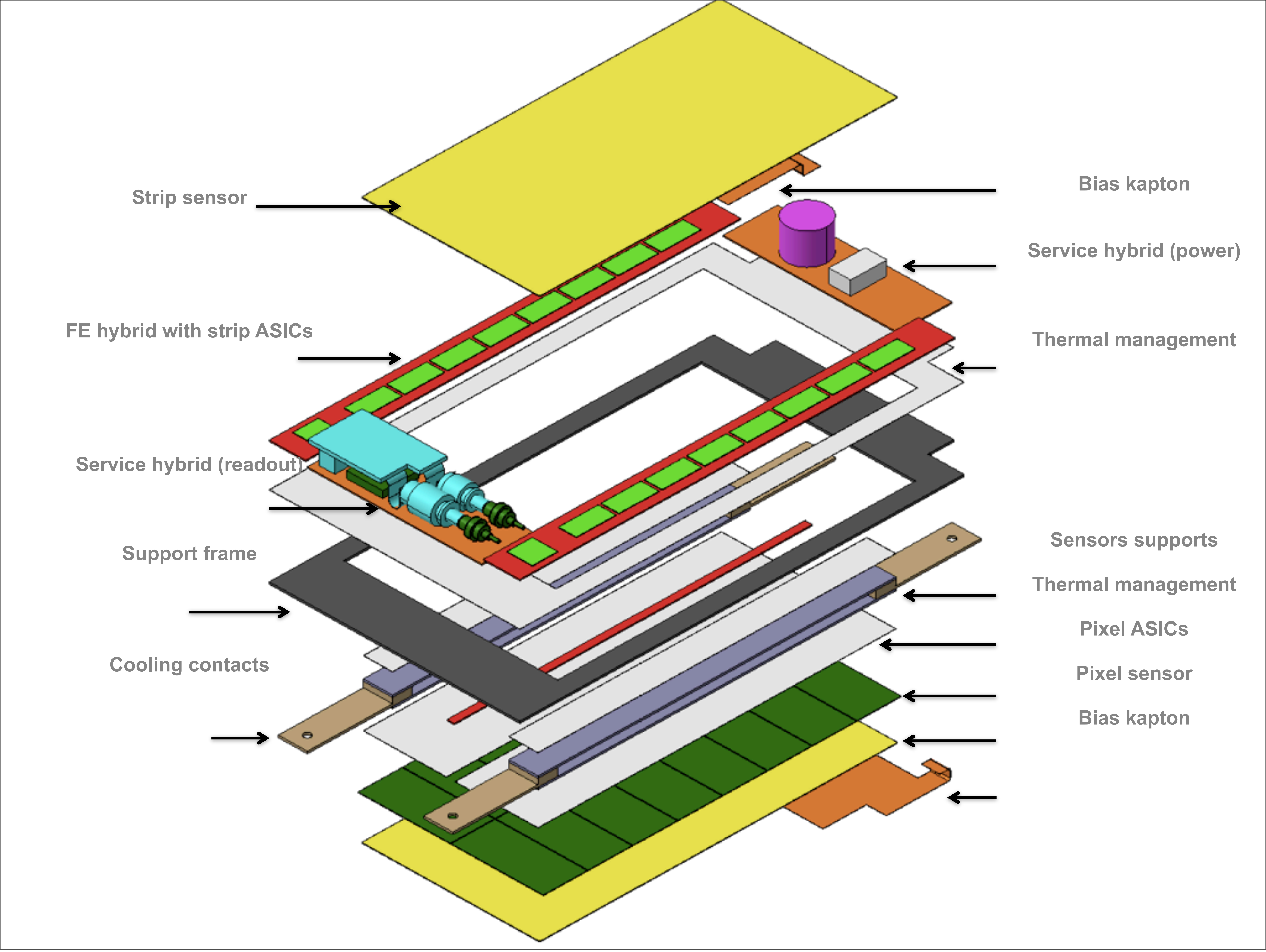
Pixels-Strips (PS) p_T-modules

- Sensors:
  - Top sensor: strips
    - 2×25 mm, 100 μm pitch
  - Bottom sensor: long pixels
    - 100 μm × 1500 μm
  - ≈ 5x10 cm^2 overall sensor size



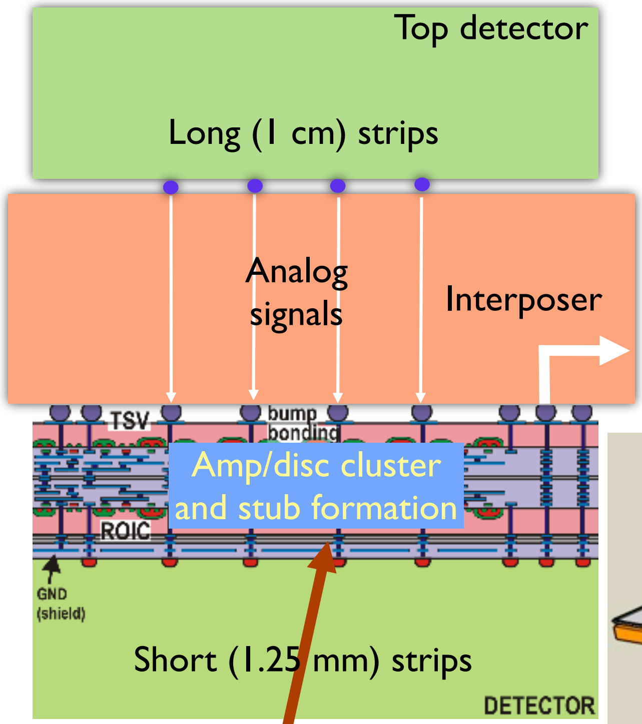


- Readout:
  - Top: wirebonds to "hybrid"
  - Bottom: pixel chips wirebonded to hybrid
  - Correlation logic in the pixel chips



Strip sensor
FE hybrid with strip ASICs
Service hybrid (readout)
Support frame
Cooling contacts
Bias kapton
Service hybrid (power)
Thermal management
Sensors supports
Thermal management
Pixel ASICs
Pixel sensor
Bias kapton

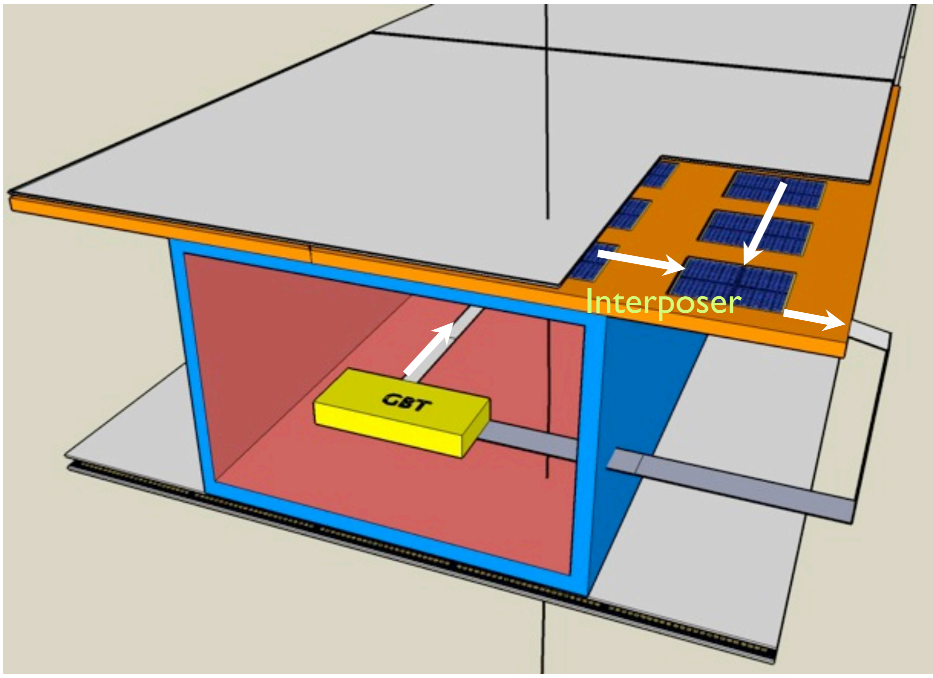
3D pT-modules

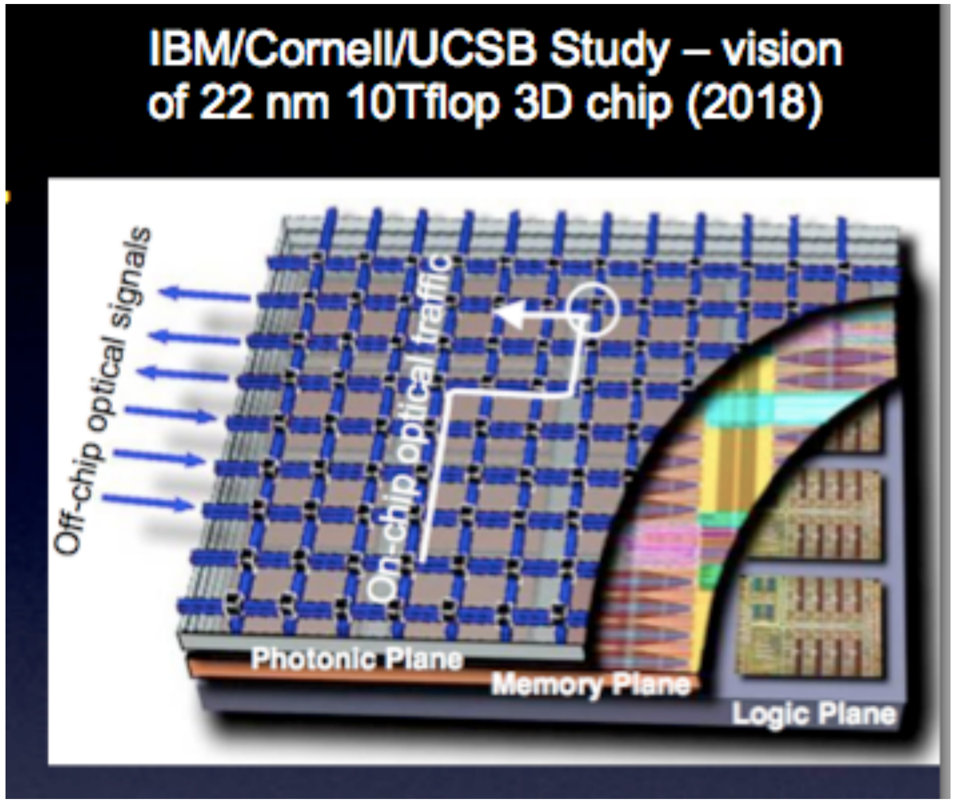


ROIC sees signals from top and bottom sensors all correlations local

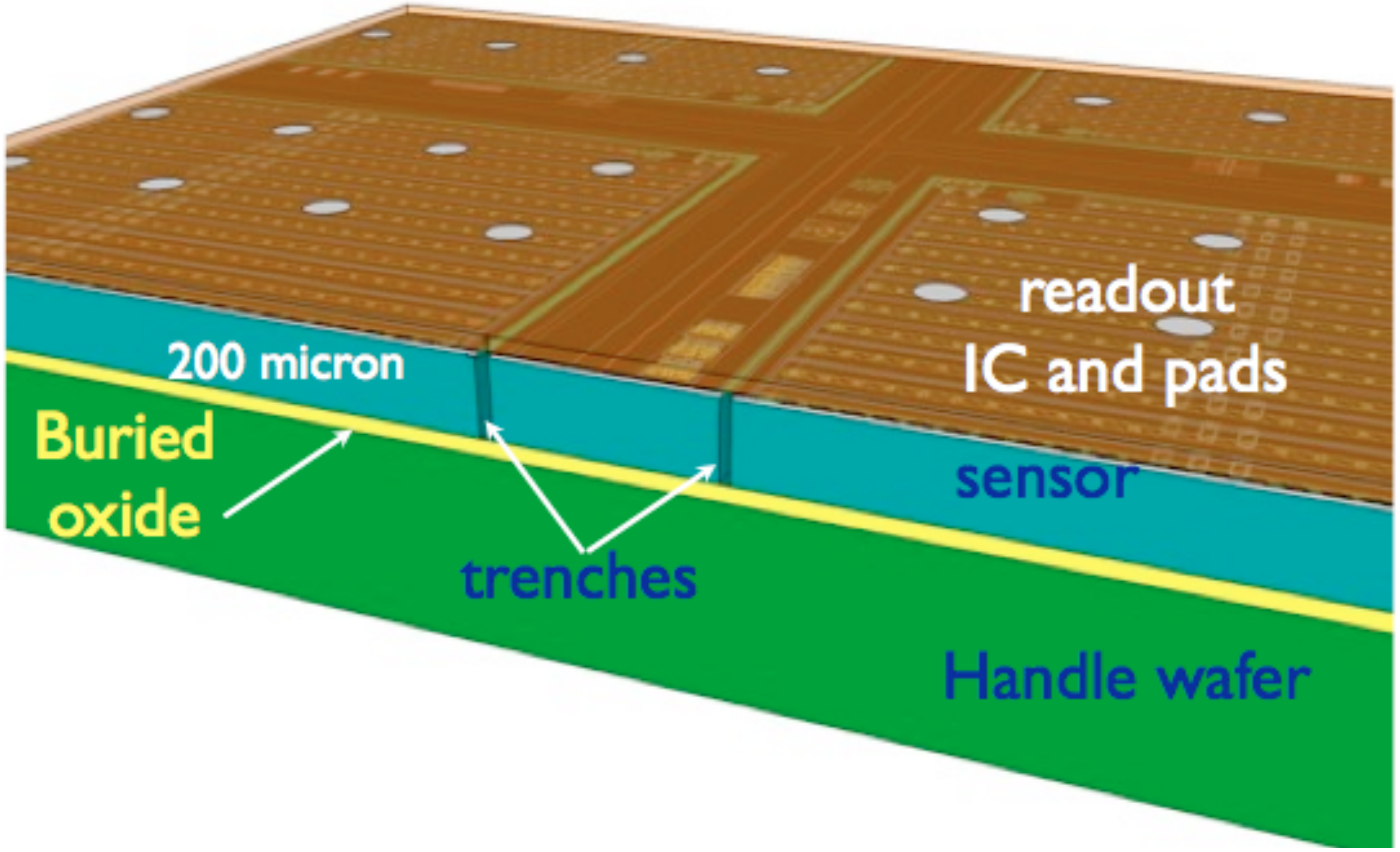
Data Flow

Top sensor analog information flows through interposer to IC mounted on bottom
Long strips on top provide r-phi minimize number of interposer connections
Short strips on the bottom provide Z resolution
ROIC amplifies and discriminates forms stubs and manages pipeline

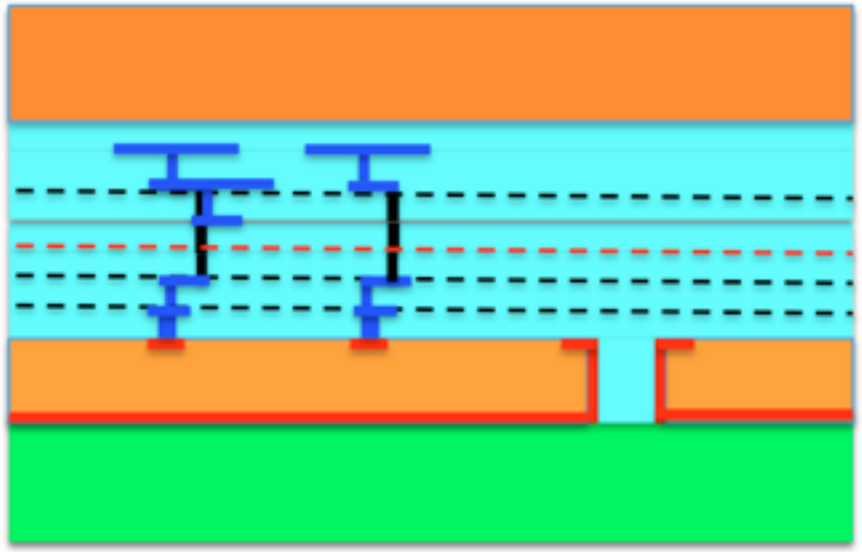




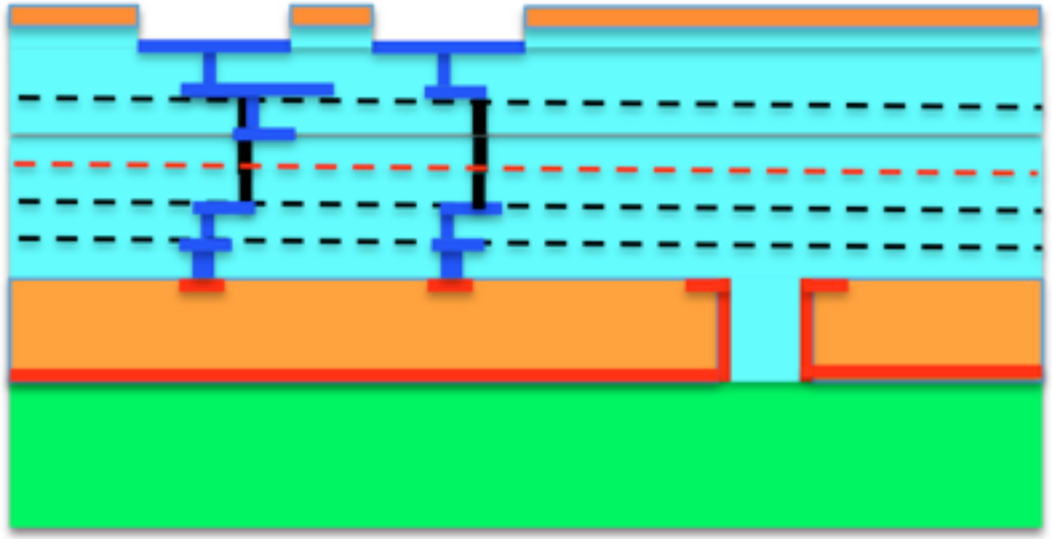
3D modules



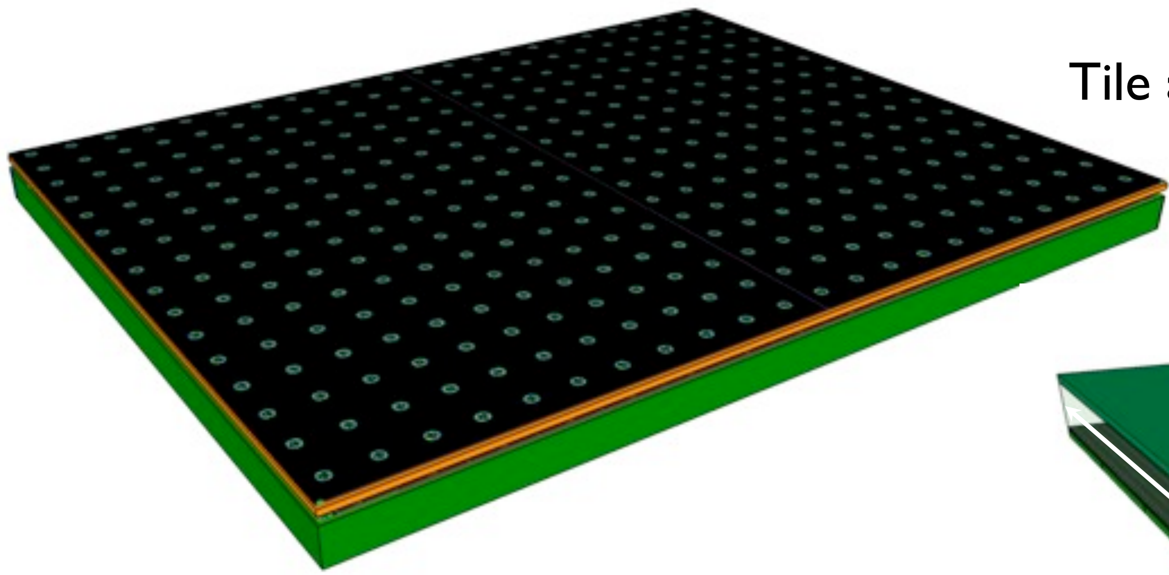
Wafer-wafer bond



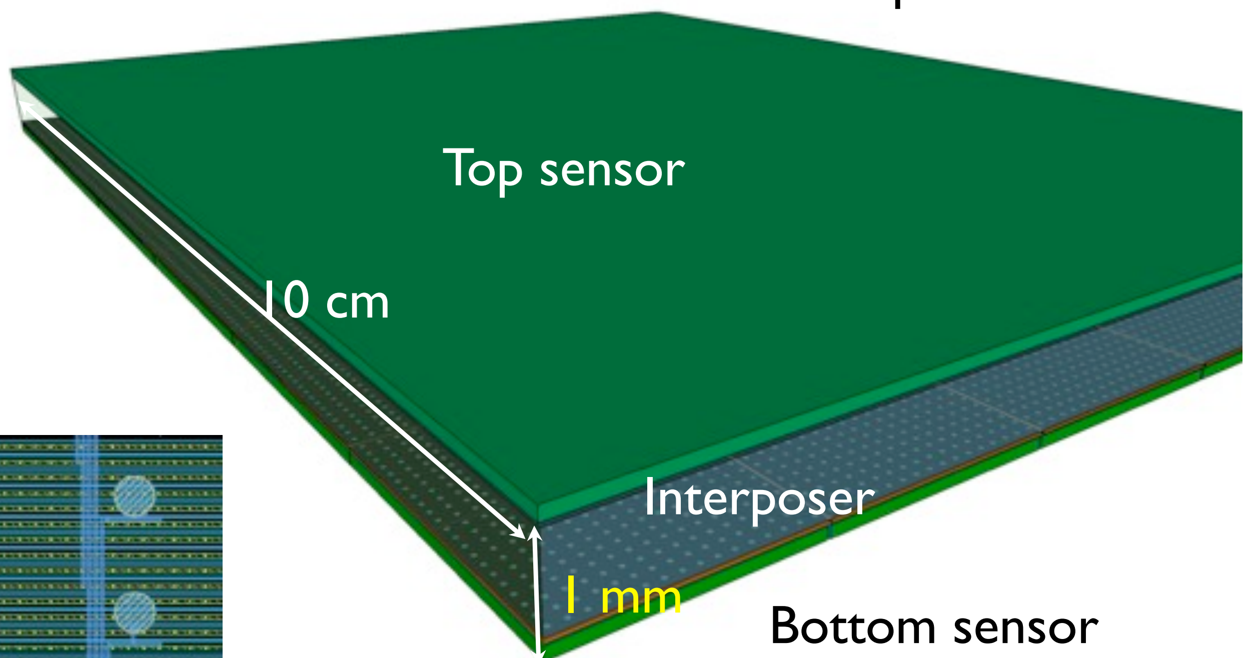
Backgrind, etch silicon and oxide



Tiled Active Edge Modules



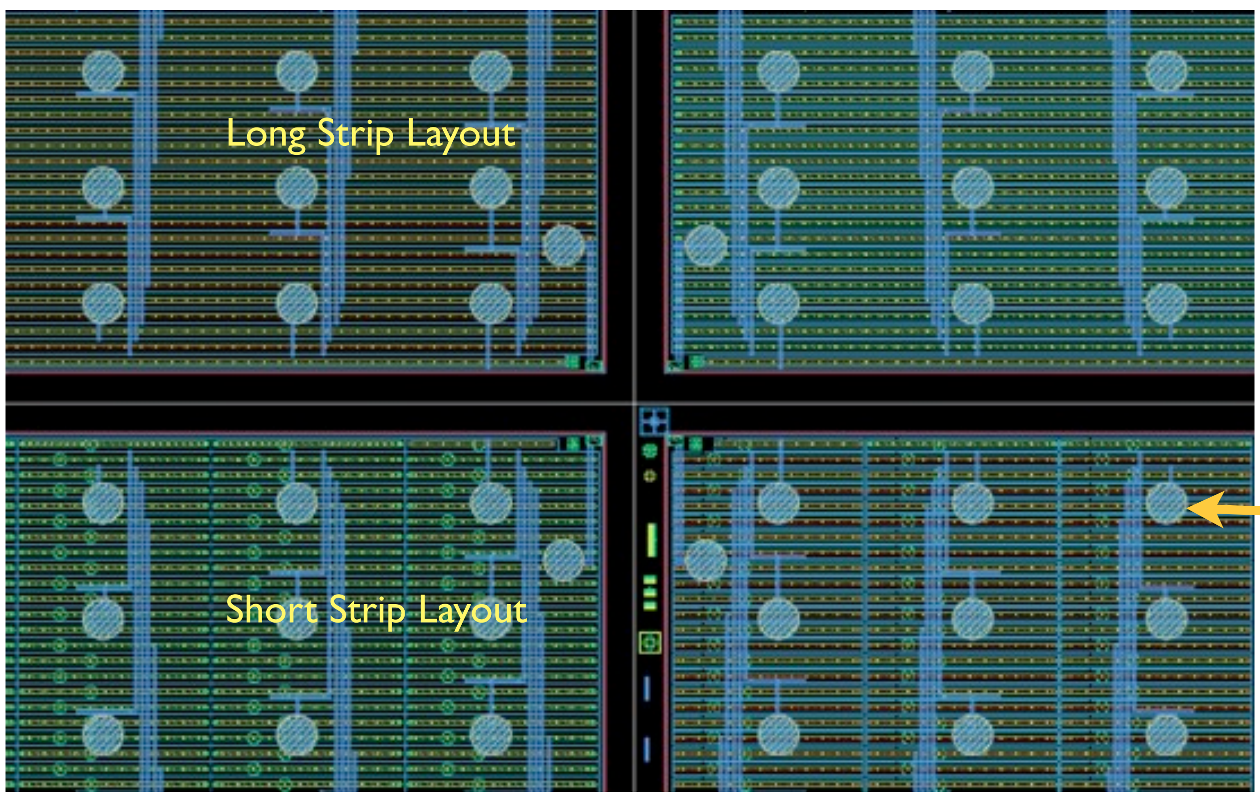
Tile after handle wafer removal and singulation



Full Module with interposer and top sensor

Bottom sensor

- Design of sensors is complete
- Design of dummy ROIC is complete

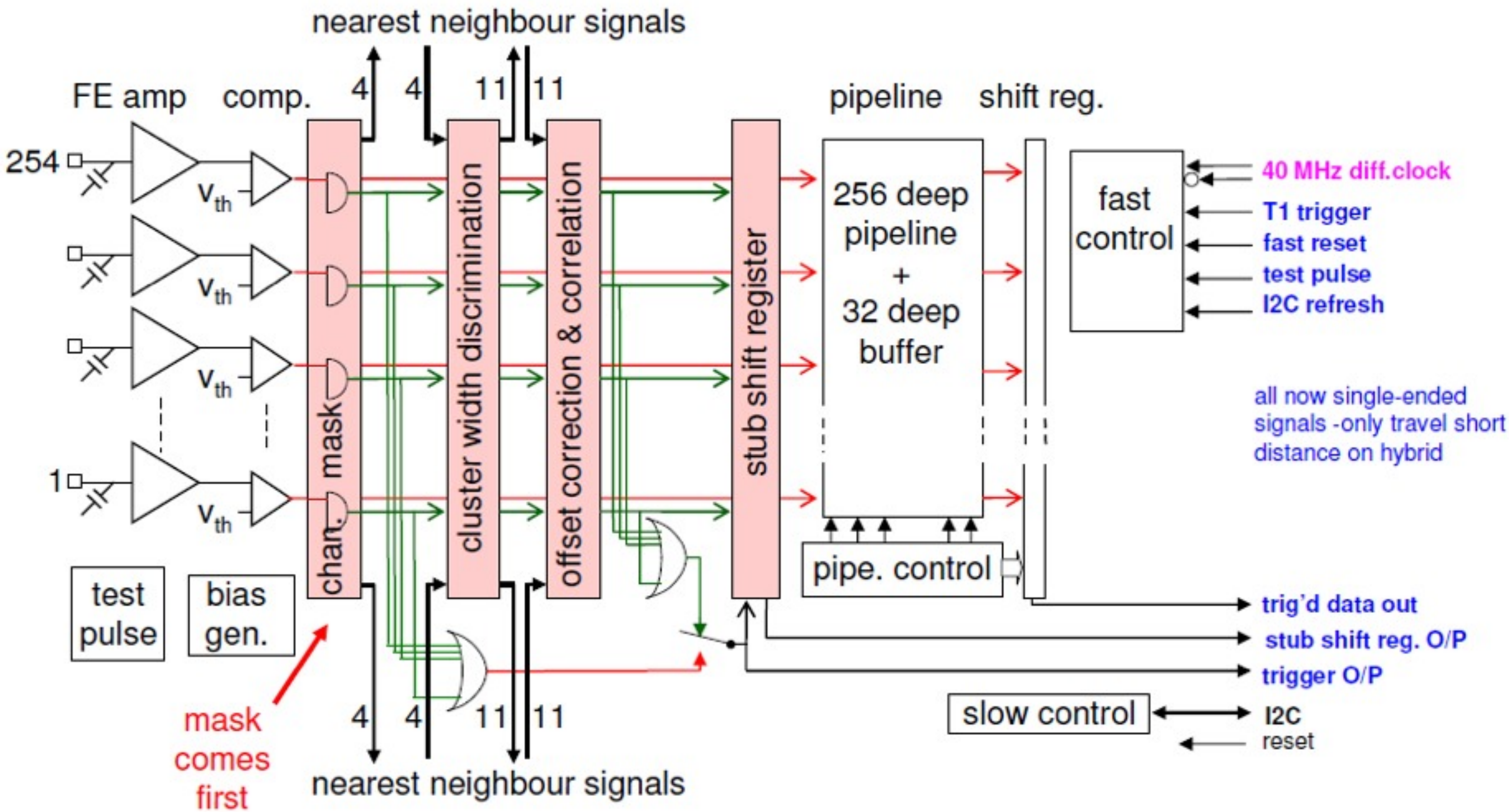


Trench

Bump bond pads

Correlation electronics

CBC2 Architecture



blocks associated with Pt stub generation

- **channel mask**: block noisy channels (but not from pipeline)
- **cluster width discrimination**: exclude wide clusters
- **offset correction and correlation**: correct for phi offset across module and correlate between layers
- **stub shift register**: test feature - shift out result of correlation operation at 40 MHz
- **fast OR at comp. O/P and correlation O/P**: - can select either to transmit off-chip
  for normal operation choose correlation O/P

neighbour chip signals - CWD O/Ps

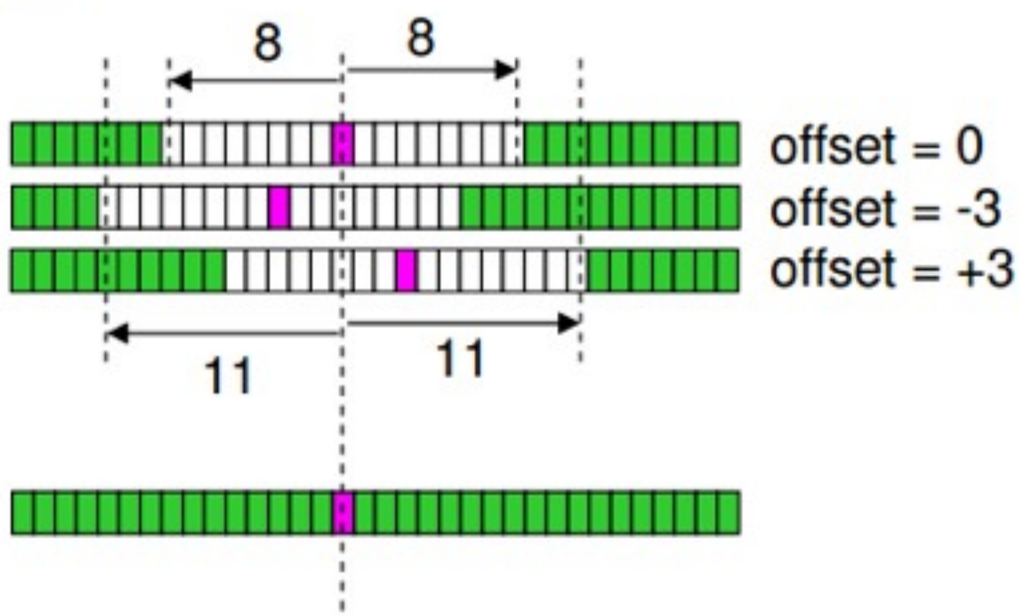
need programmability of **offset** and **window** width for upper layer channels to correlate with hit in inner layer

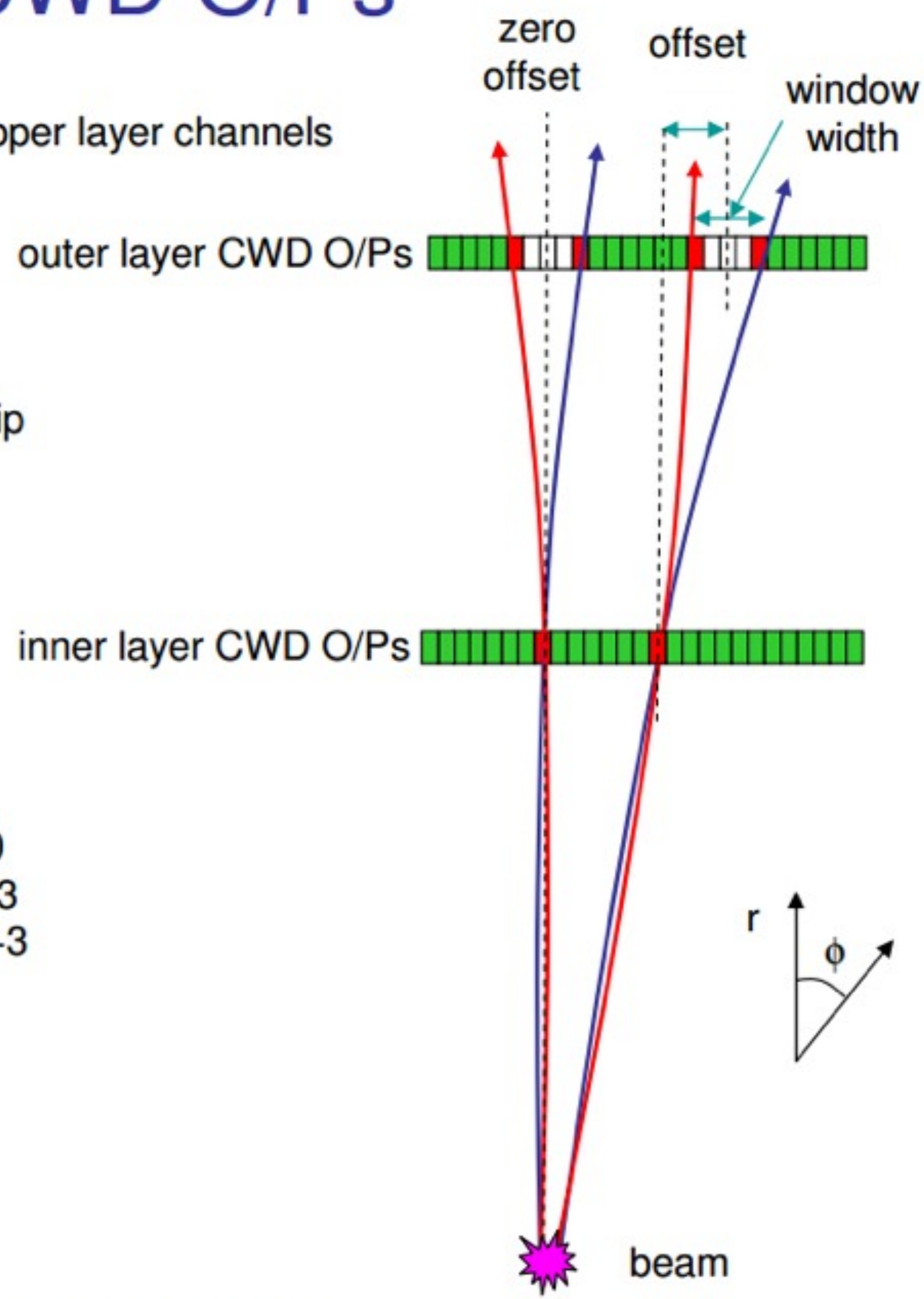
window defines Pt cut
  width programmable up to **+/- 8** channels

offset defines lateral displacement of window across chip
  programmable up to **+/- 3** channels

=> 11 signals to transmit to neighbouring chip
  11 to receive from neighbouring chip

  = 22 signals



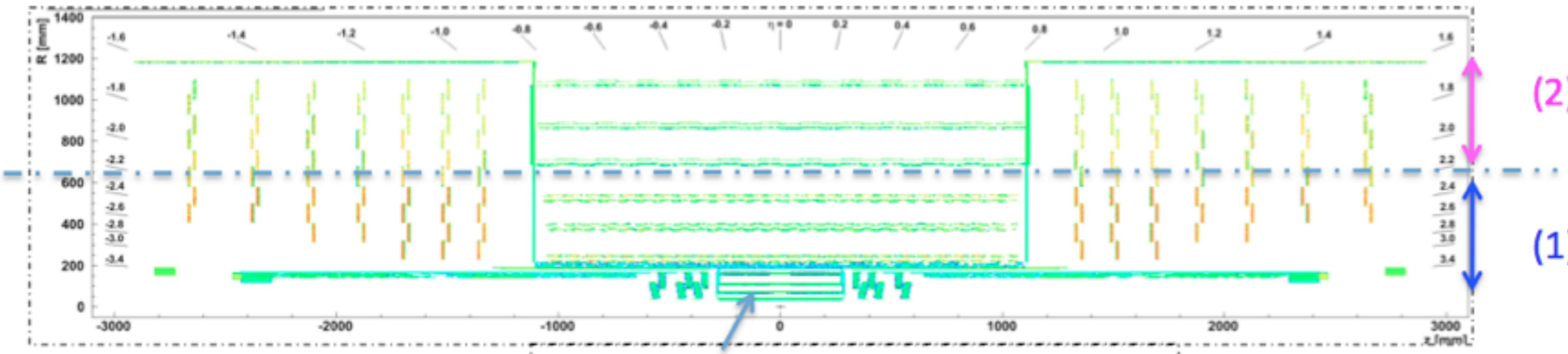


adding comp O/Ps -> 30 signals altogether, top and bottom of chip

Some simulation results

CMS - traditional geom.

The "Barrel-EndCap" design comprises 6 barrel layers and 7 endcap disks composed of rings.



Inner pixel Detector : 4 layers- 3disks

The inner part (1) is populated by Pixel-Strip stacked (PS) modules .

The outer part (2) is populated by Strip stacked (2S) modules.

The number of endcap disk is optimized for tracking performance.

Different spacings between the two sensors of the Pt modules:
0.8mm in the outer barrel (2S)
1.6 and 2.6mm in the inner barrel (PS)
4.0, 2.6 and 1.2mm in the outer end-cap (2S)
4.0mm in the inner end-cap (PS)

L1 tracking precision potential
- pT resolution 4% @ 10 GeV in forward

Tracking precision
- pT resolution 1.4% @ 10 GeV
- pT resolution 3% @ 100 GeV

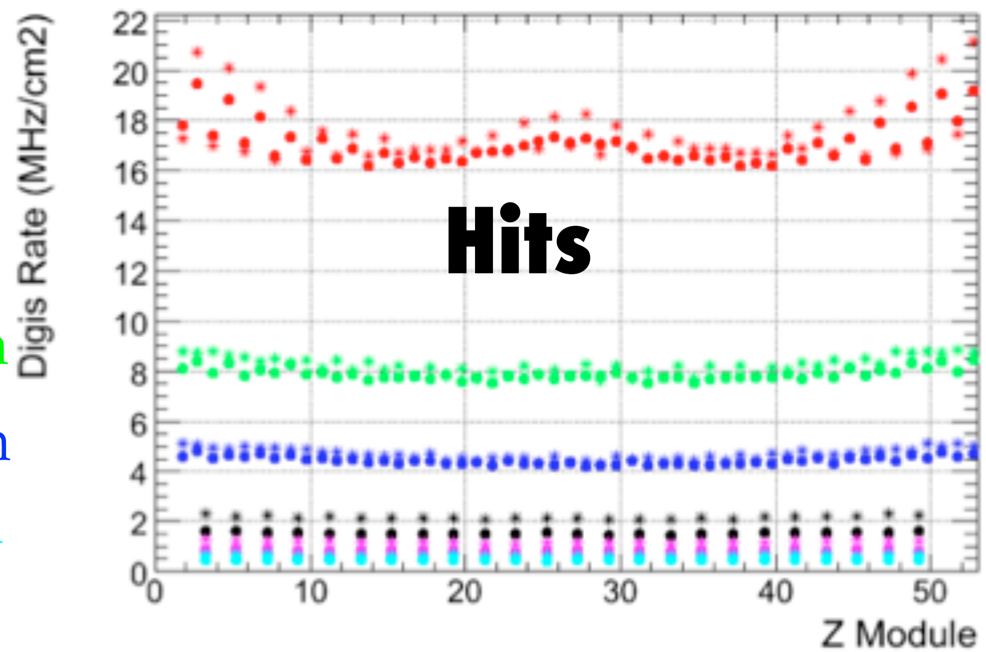
Data reduction

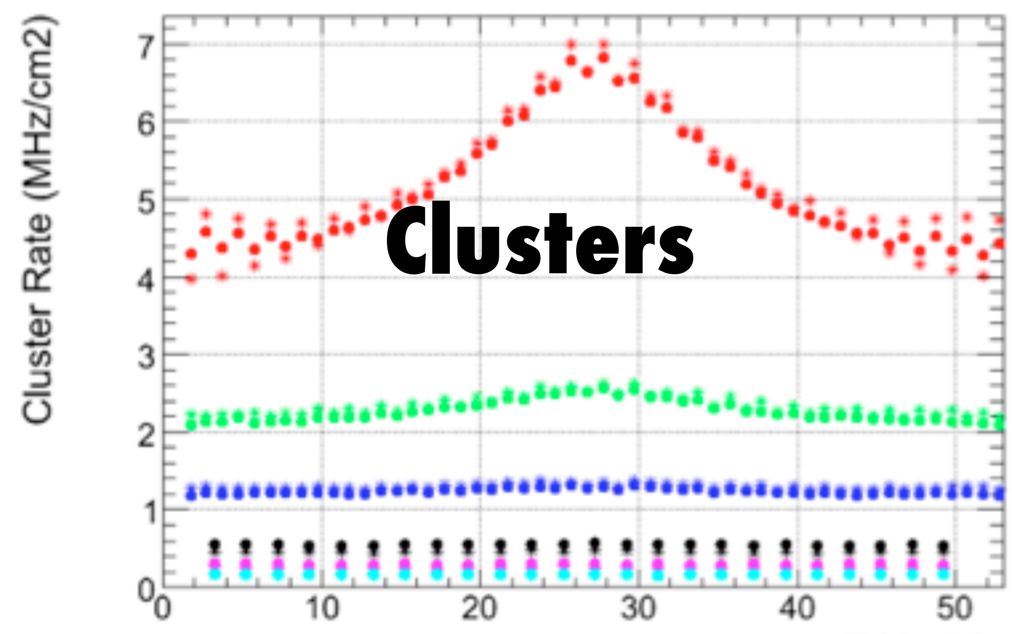
R=23 cm

R=38.2 cm

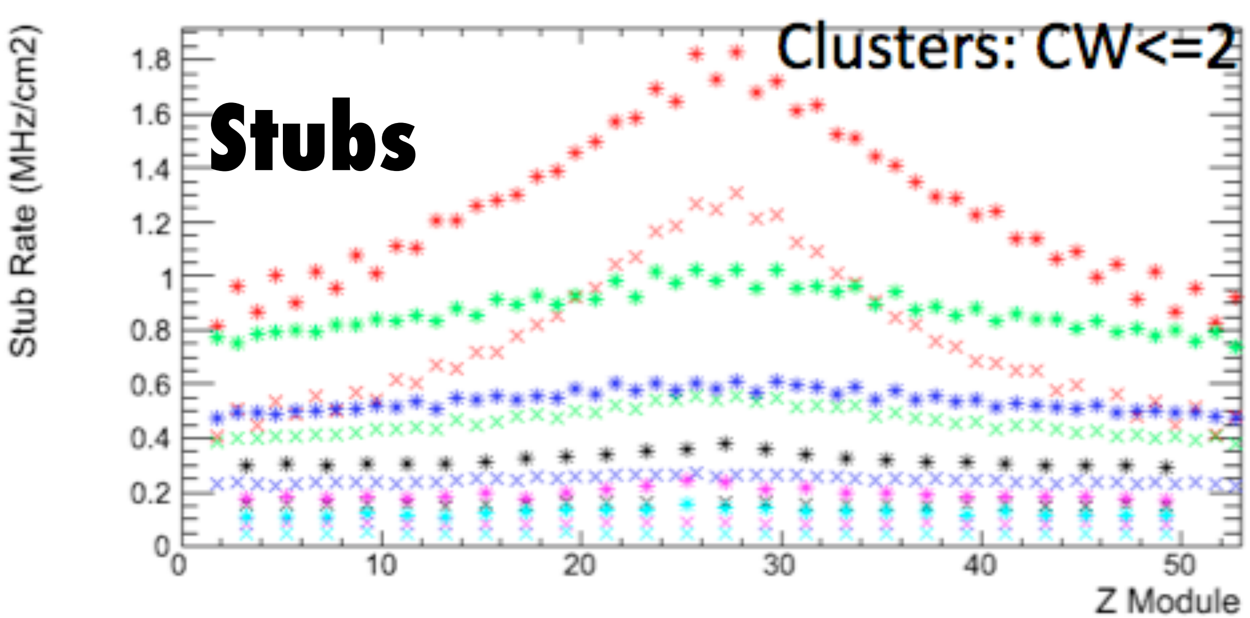
R=52.4 cm

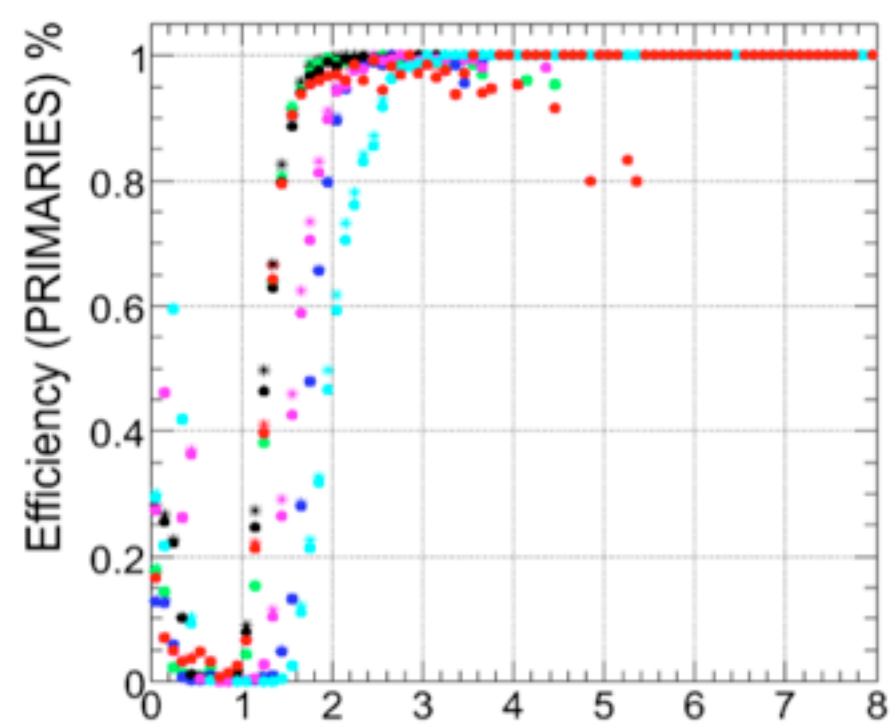
R=108 cm





CW<3 stri

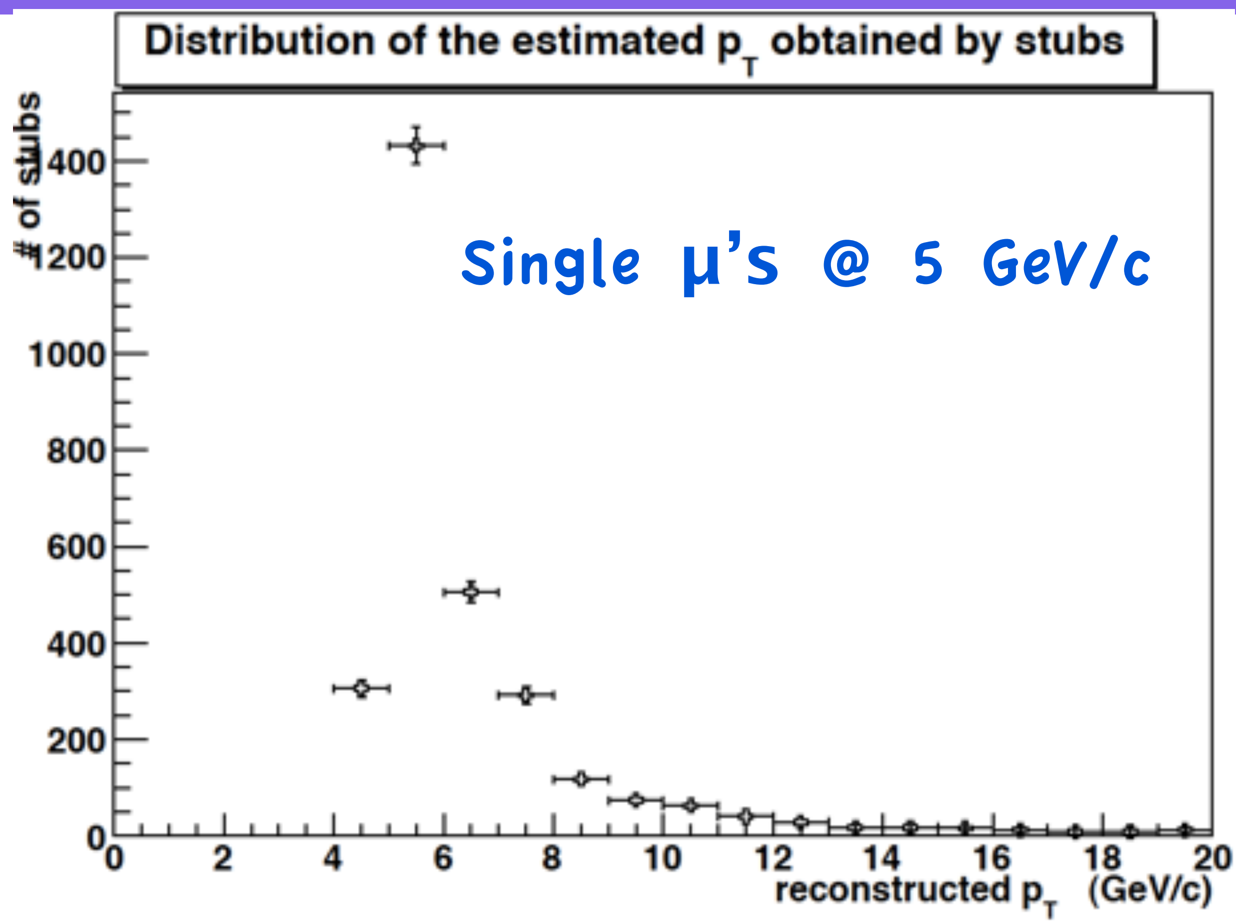


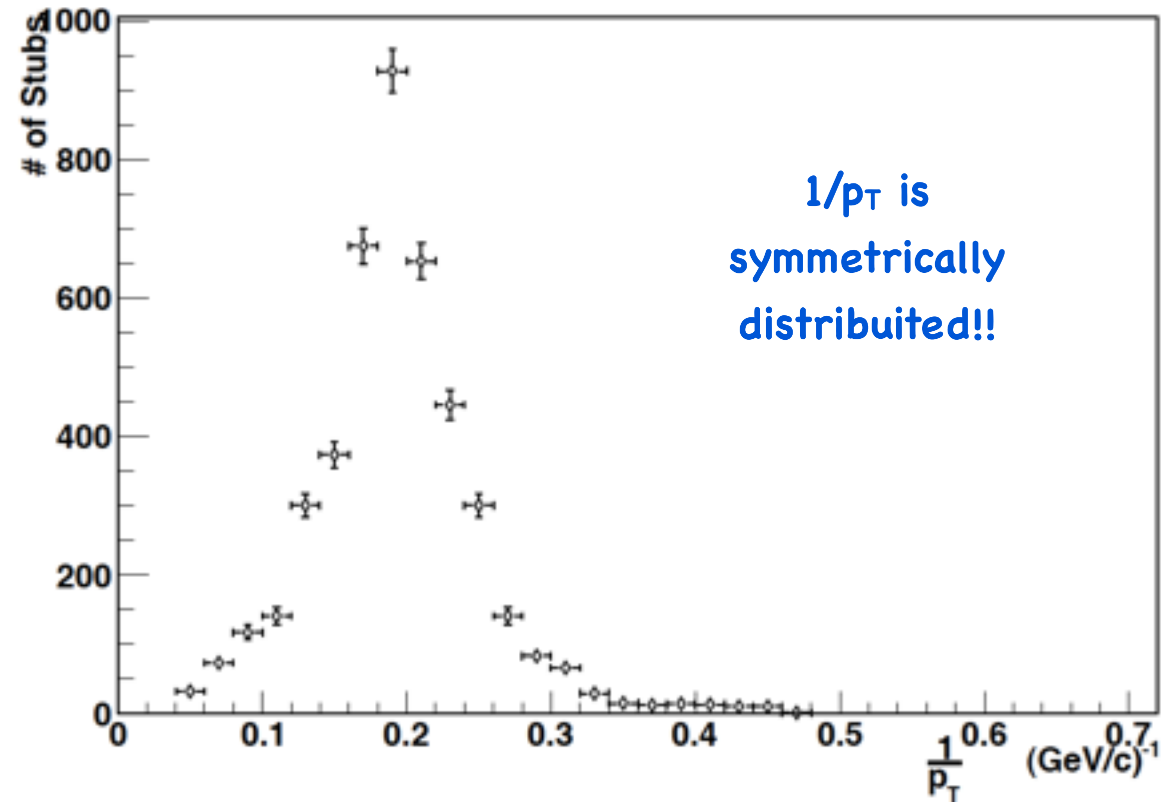


p_T (GeV)

Clusters: CW<=2

Stub p_T Measurement





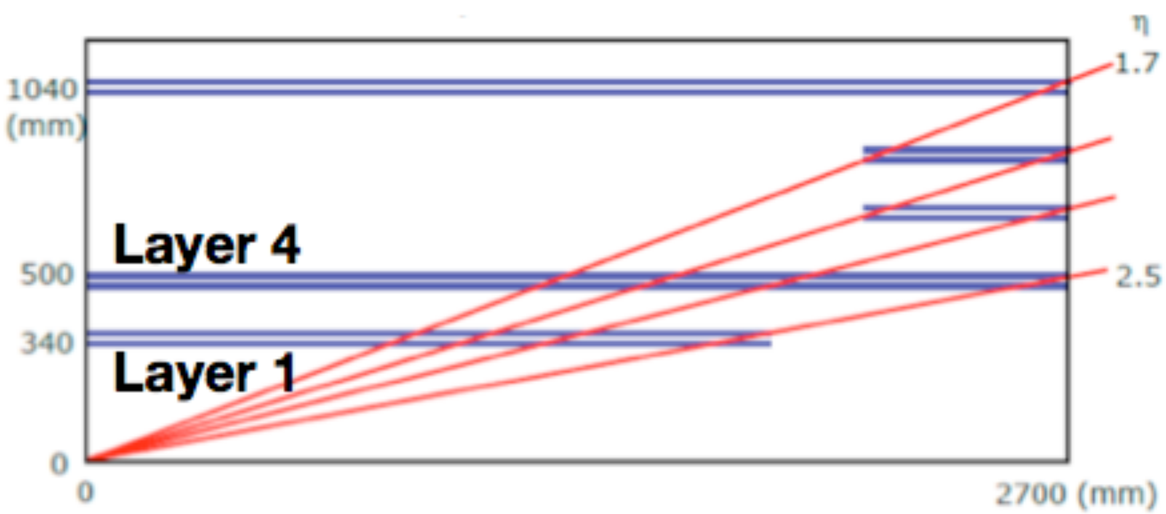
- μ-strip 98 μm pitch
- sensors separation ΔR=1 mm

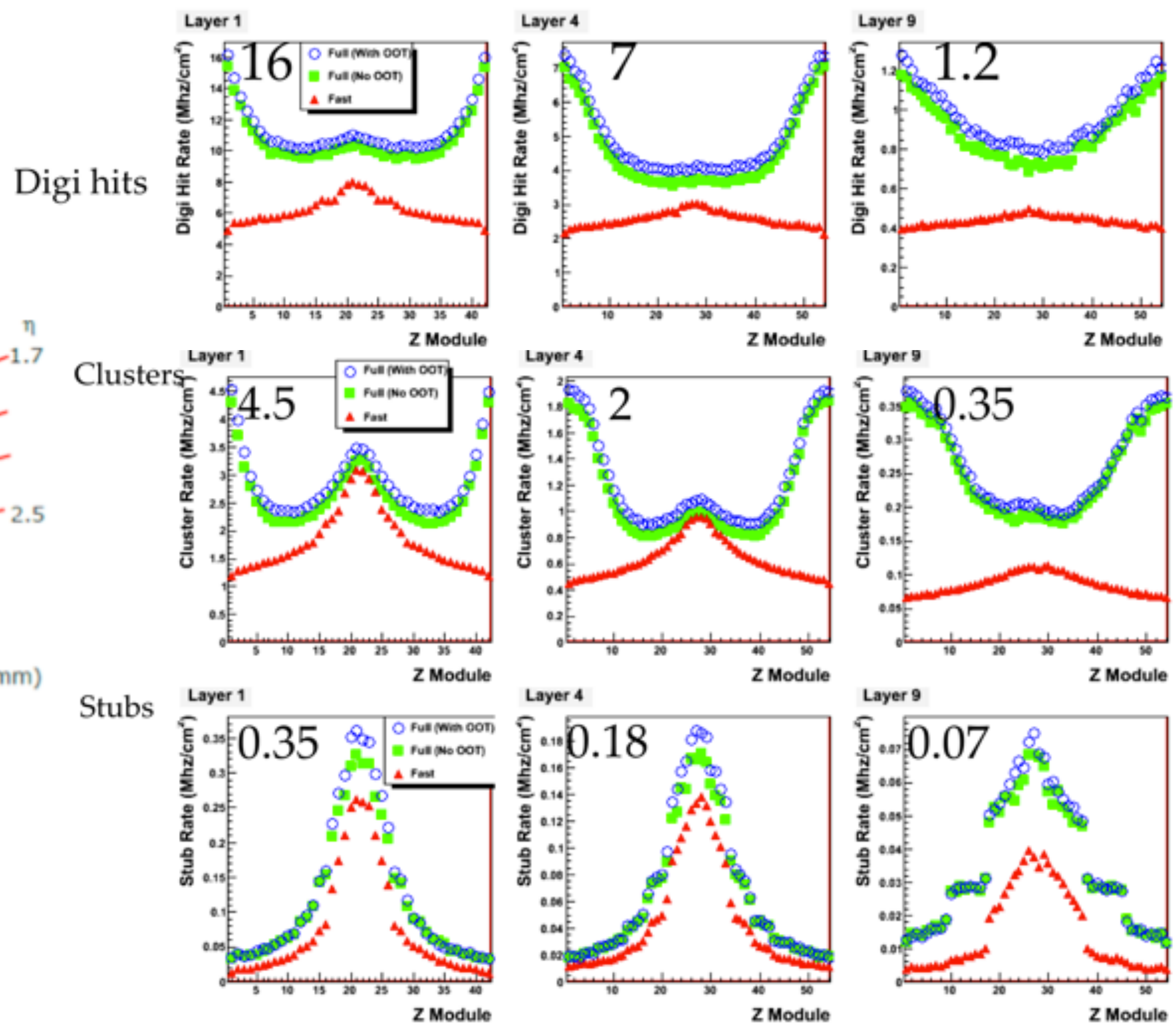
R 51 cm - mean $\sqrt{(1/p_T)}$: ~0.076

R 82 cm - mean $\sqrt{(1/p_T)}$: ~0.073

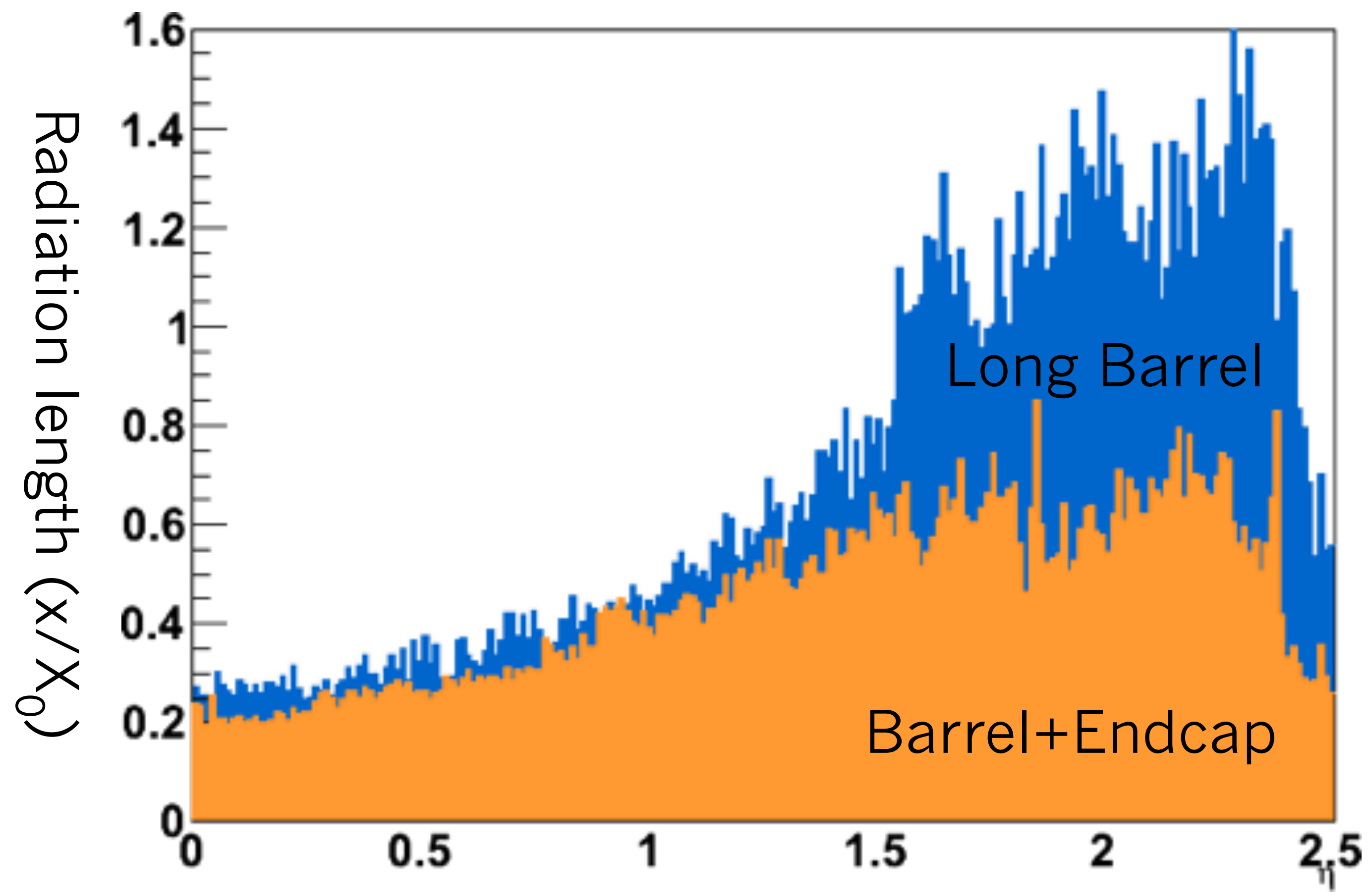
R 102 cm - mean $\sqrt{(1/p_T)}$: ~0.069

Long Barrel layout (CMS)





Geometry Comparison



Data Rates

Assumptions

- CMSSW full simulation MinBias Events
- Barrel EndCap Geometry (already presented in previous meetings..)
- Assuming 200 p-p interaction pile-up (20 MHz LHC clock)
- First estimation of data flow (trigger+data) with MinBias events
  - Zero suppression and asynchronous read-out of cluster (full data) and stubs (trigger data)
  - throughput of Concentrator, assuming one concentrator per ½ module

Stub Flow
Trigger

- Trigger Data (stub flow):
  - Stub data
    - Stub position: 7bits (max 128)
    - ½ strip precision : 1bit
    - Chip# :3 bits(1/2 module= 8 chips)
    - Bend : 3 bits
      - TOTAL: A1= 14 bits transfered for each stub at 20MHz
      - case of MixedPt Module: 4 additional bits for the position z: 18 bits in total
  - Header:
    - Time stamp: 12 bits
    - Number of Stubs: 4 bits (max 16)
    - Data or trigger id: 1 bit
    - Complete trame to allow a resynch in case of corrupted data: 8 bits (might be surevaluated)
      - Total B1= 25 bits transfered at 20 MHz per ½ module
- For a given ½ module flow := n_stubs* A1 +B1

Bandwith: Results from MB simulations (200PU-50ns)

	<clusters>/1/2 module/BX	<stubs>/1/2 module/BX	BW Mbs Trigger	BW Mbs Data
Layer4	3.4	0.37	237	6
Layer5	1.9	0.2	131	4
Layer6	1.1	0.1	77	2
Layer1 (Mixed pt module)	15	0.8	558	32

All clusters (no cut)
To be transmitted
In the data channel
@100kHz

StubsCW <=2, Ww size=6
To be transmitted
@20MHz

BW per concentrator
(1/2 module)