Silicon Sensor and Detector Developments for the CMS Tracker Upgrade

- sLHC requirements for the tracker
- Tracker Sensor RD program
- Tracker Trigger RD

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CMS Tracker Collaboration

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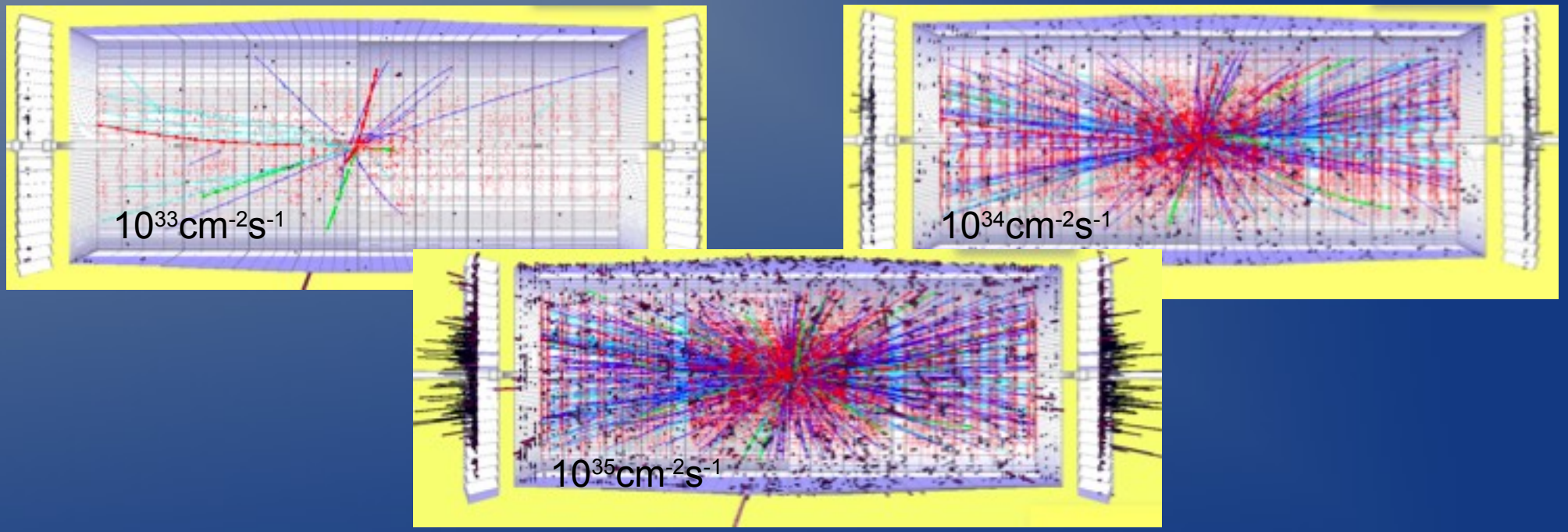
Requirements

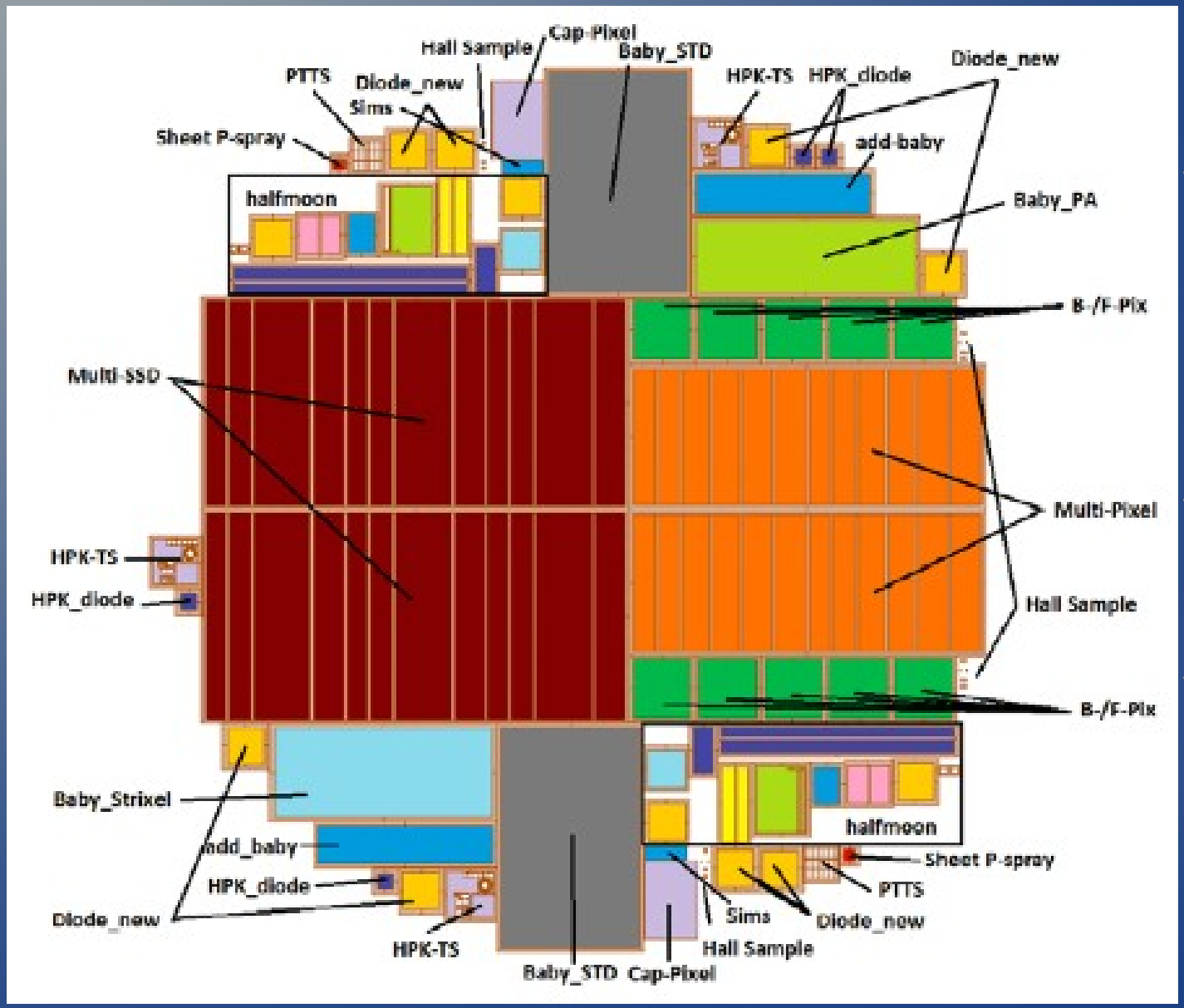
- The CMS tracker for sLHC needs to have:
  - higher radiation resistance, with respect to both instantaneous and integrated levels
  - higher readout granularity, to keep the channel occupancy at an adequate level
  - develop sensors able to give information about track p_T and direction for the trigger
- The Challenge: Build a replacement Tk for $L>10^{34}$ $cm^{-2}s^{-1}$ with L1 trigger capabilities

Requirements (2)

- Silicon sensors must survive accumulated dose levels 10 times higher than the current Tracker.
- Higher granularity and (perhaps) thinner sensors will be required made with different technologies.



HPK Wafer



Substrate types:

- FloatZone (FZ), Magnetic - Czochralski (MCZ), Epitaxial (Epi).

Implants:

- p-in-n (N-type) , n-in-p (p-stop) (P-type), n-in-p (p-spray) (Y-type)
- p-in-n (double metal), n-in-p (p-stop; double metal), n-in-p (p-spray; double metal)

RD objectives

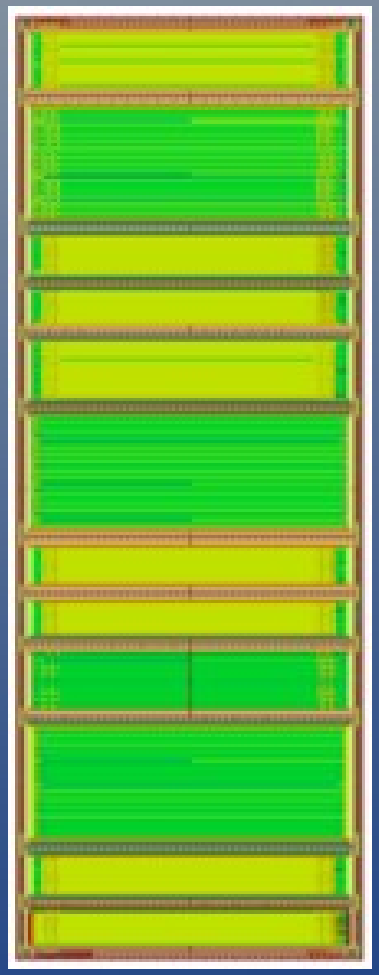
- Conduct tests, before and after irradiation, to determine the characteristics of single-sided silicon sensorsof various thicknesses and materials acquired from HPK in order to establish optimal material and strip/pixel features for the upgrade of the CMS Tracker.
- Collaboration wide effort. For example (this talk):
  - Efforts on Multi-Strip-Sliconstrip Detector (MSSD) sensors at:
    - Cern, Fermilab, Florence, KIT, Others

Many complicated and variegated scenarios

- Examples (just for beam tests) .....
  - Sensors for beam test in November?
    - MSSD (mostly irradiated, MCz non-irradiated, FZ320 as reference)
    - MPIX (MCz non-irradiated)
    - Baby_Strixel (maybe, if possible)
  - Sensors for beam test in October (HEPHY)
    - Baby_PA
    - Baby_Std_2nd_metal_layer
    - Baby_Add_2nd_metal_layer
  - Next year test beam with Baby_Std

MSSD sensor under study

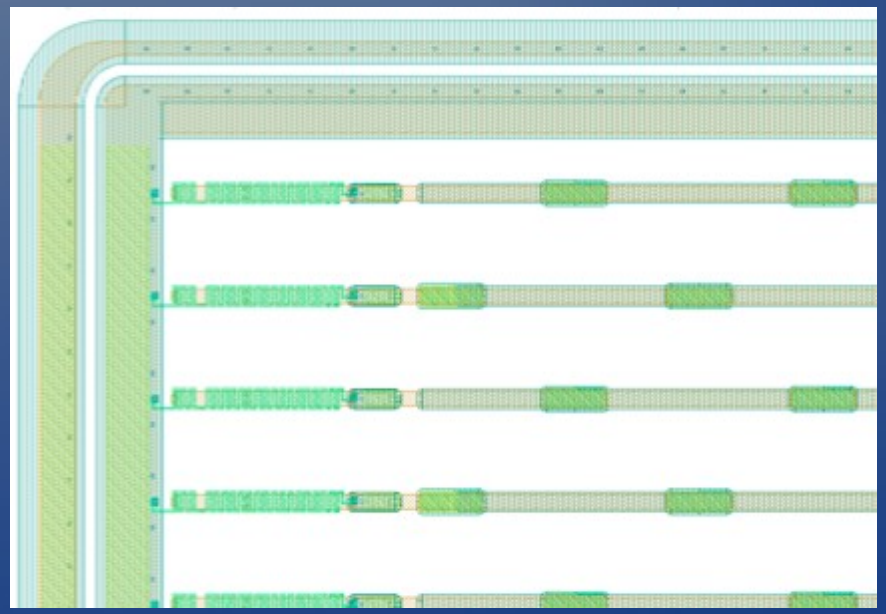
- 65744,25um x 32792um
- 12 regions – Different: pitch, width, ratios

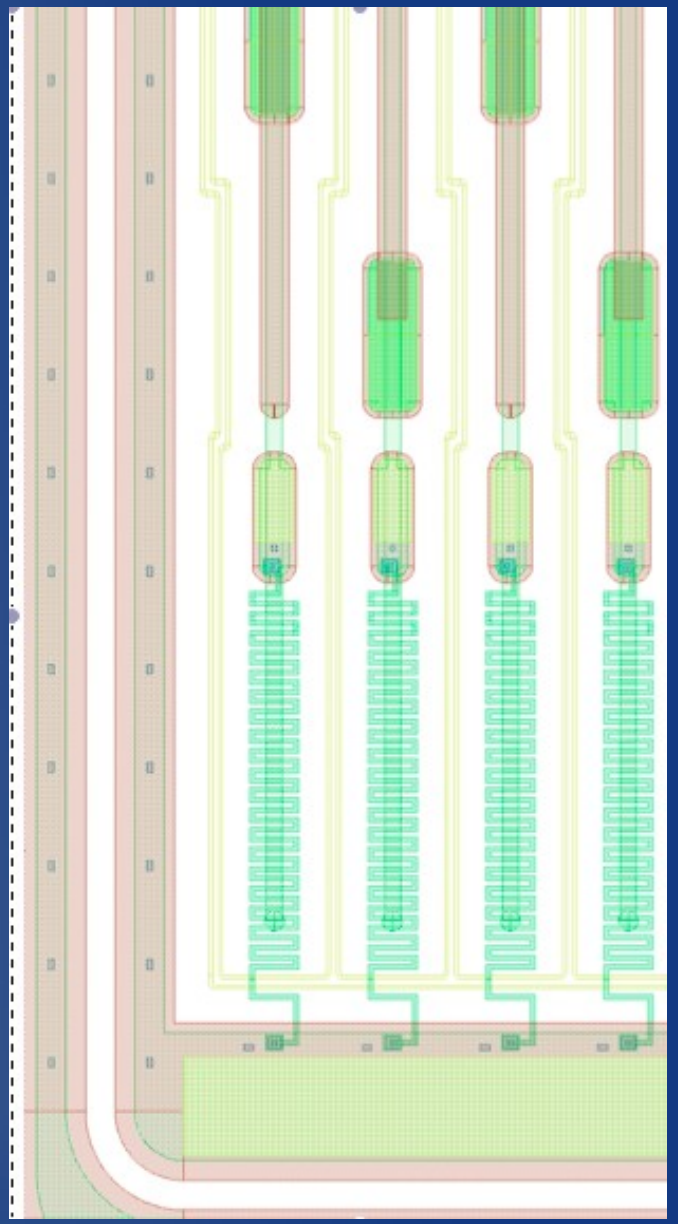


region	pitch	implant width	alu width	w/p	DC Padsize	AC Padsize
1-120	120	16	29	0.133	85x38	150x50
2-240	240	34	47	0.142	85x38	150x50
3-80	80	10	23	0.125	85x38	150x50
4-70	70	8,5	21,5	0.121	85x38	150x50
5-120	120	28	41	0.233	85x38	150x50
6-240	240	58	71	0.242	85x38	150x50
7-80	80	18	31	0.225	85x38	150x50
8-70	70	15,5	28,5	0.221	85x38	150x50
9-120	120	40	53	0.333	85x38	150x50
10-240	240	82	95	0.342	85x82	150x82
11-80	80	26	39	0.325	85x38	150x50
12-70	70	22,5	35,5	0.321	85x38	150x50

MSSD examples

- Multi-SSD, P-type:
  - Individual p-stops
  - 120um Pitch
  - 16um Implant
  - 29um Al
- Multi-SSD, N-type
- 240um Pitch
- 34um Implant
- 47um Al

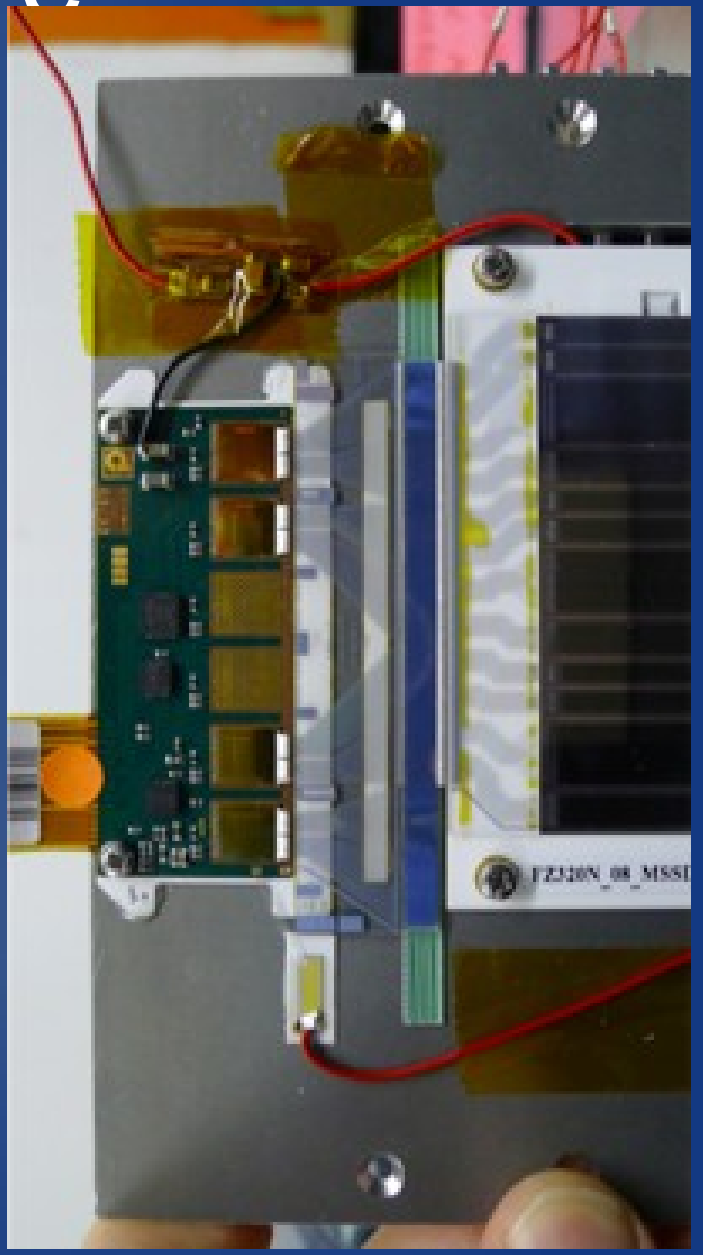




Reuse existing hardware

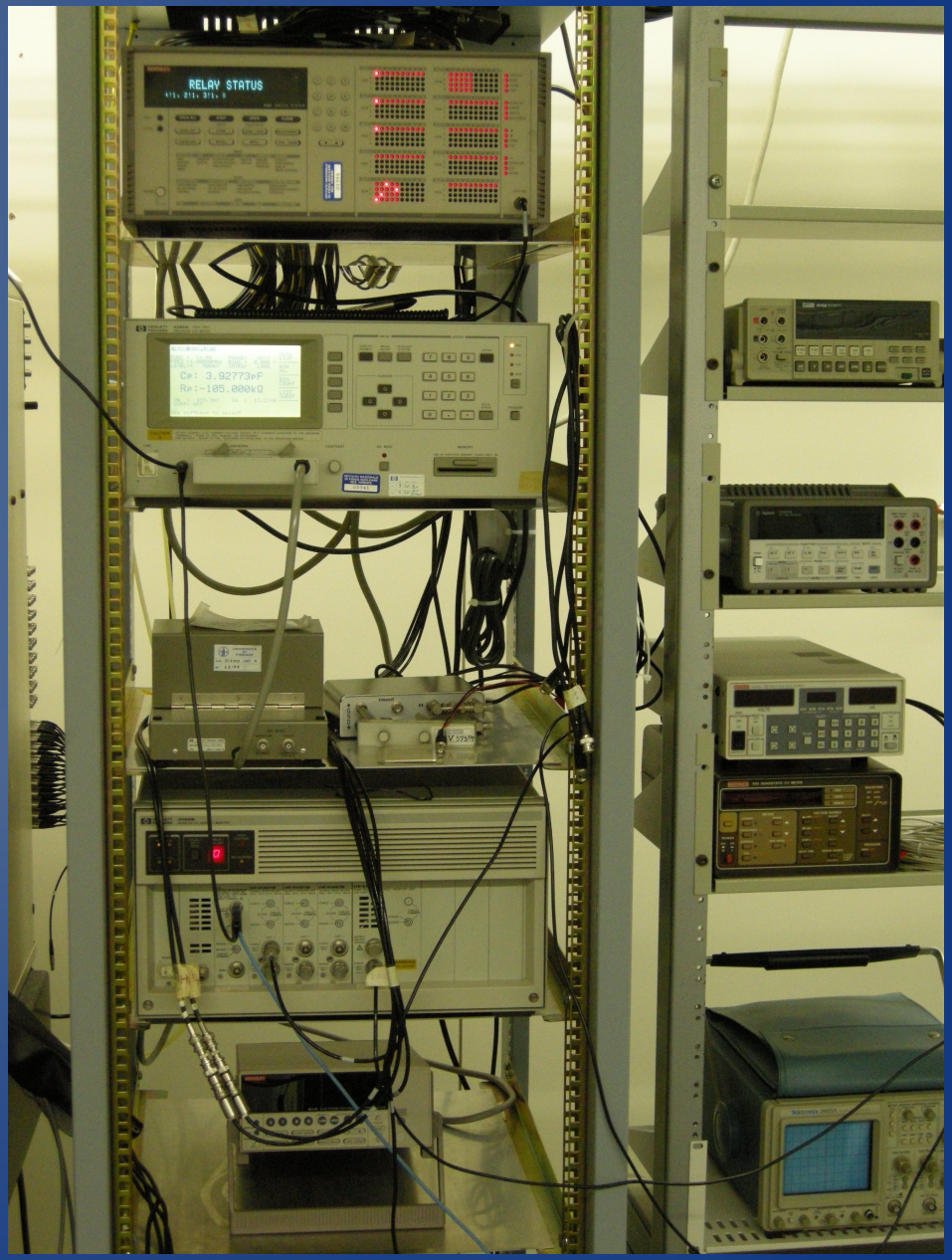
- We used TEC und TOBhybrids with 4 APV's
- Also produced many new pieces

  Pitch adapters for example:
  - TOB_hybrid_PA (44µm - 110µm)
  - TEC_hybrid_PA (44µm - 139µm)
  - 100 pieces TOB_hybrid_PA
  - TOB_Extension_PA (110µm)
  - TEC_Extension_PA (139µm)
  - MPIX_PA (multi-pixels - 110µm)
  - MSSD_PA (multi-strips - 139µm)



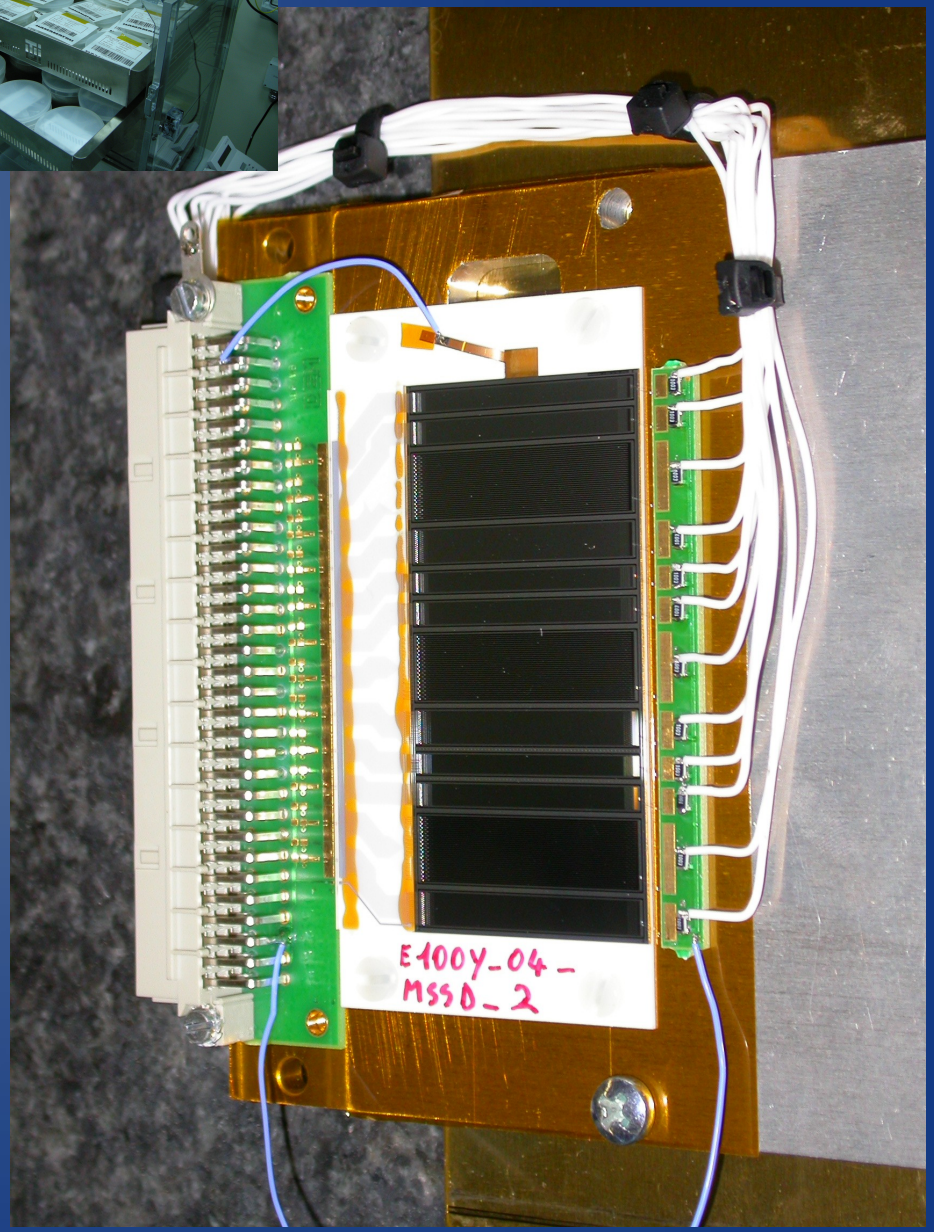
MSSD Test setup

- Firenze setup for static measurements



MSSD sensor mounting

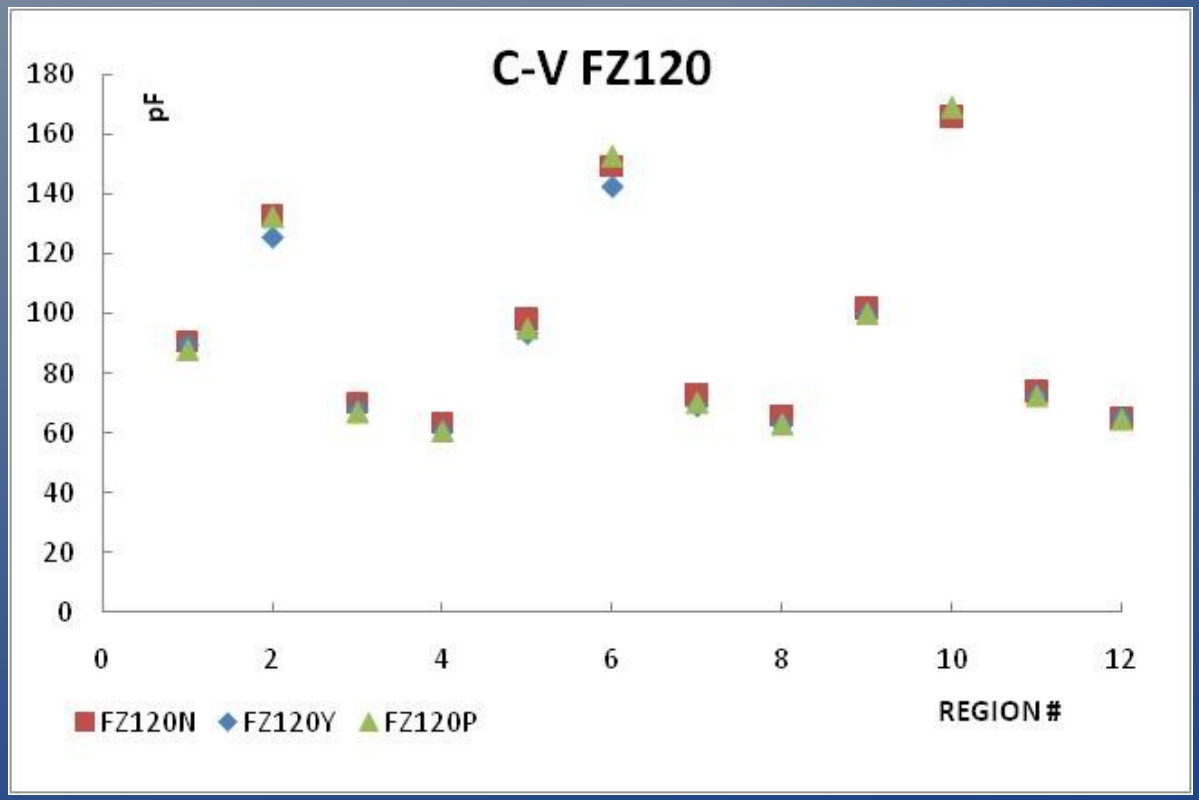
- The sensor and the pitch adapter are glued to a thin ceramic frame.
- Sensor and PA are then bonded.
- This is the basic assembly that is then shipped around the participating institutes.
- When measurements need to be done:
  - the assembly is placed on an aluminium support structure
  - bonds connect the sensor to two PCBs that route guard rings and strips to a connector

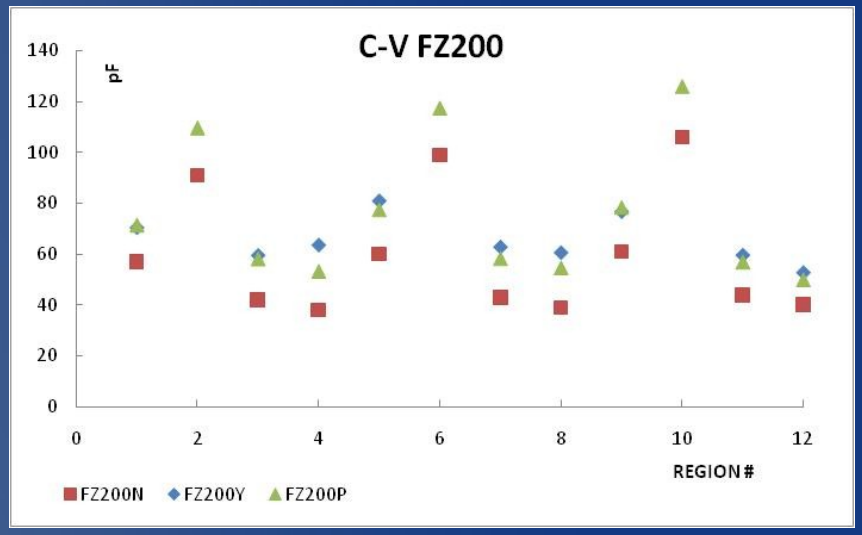


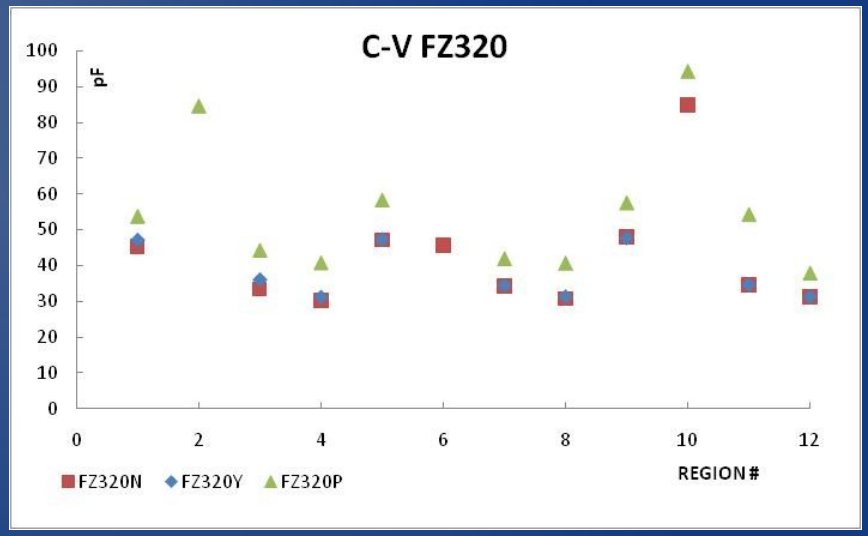
Float Zone sensors

- Three thicknesses: 320um, 200um, 120um.

C_back capacitance on all 12 regions on FZ thicknesses 120, 200 and 320um compared for N, P and Y

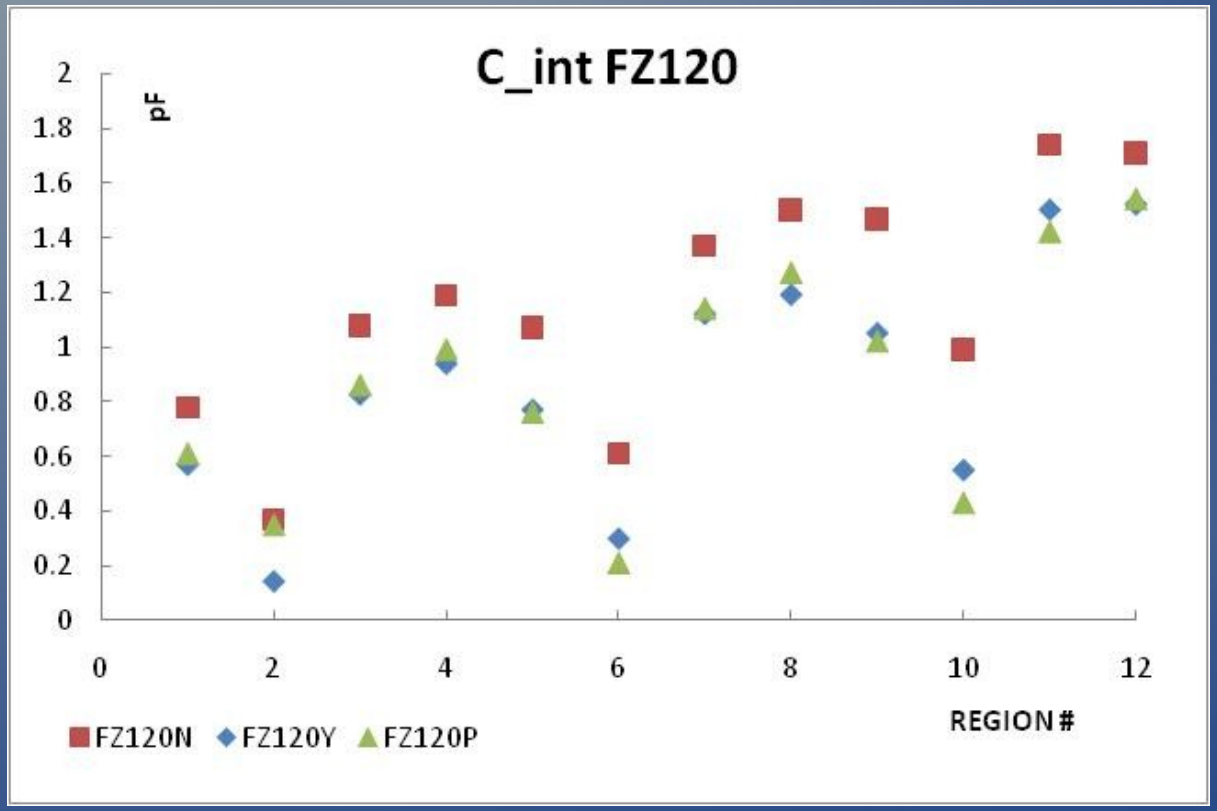


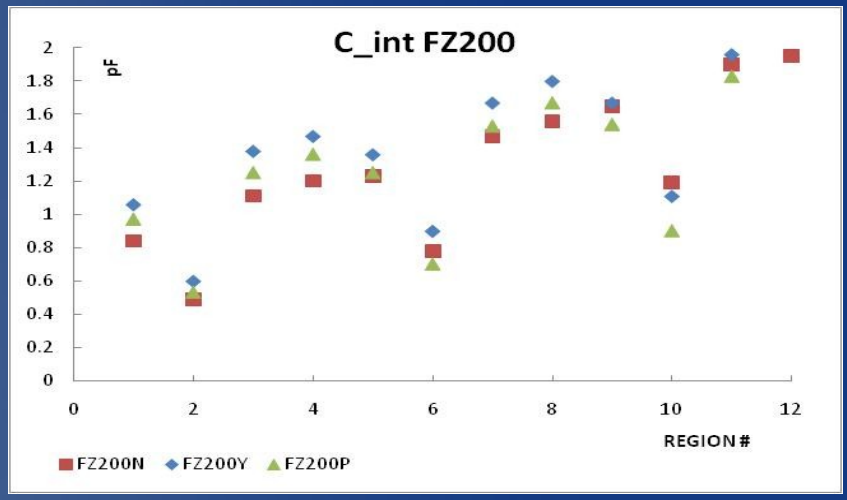


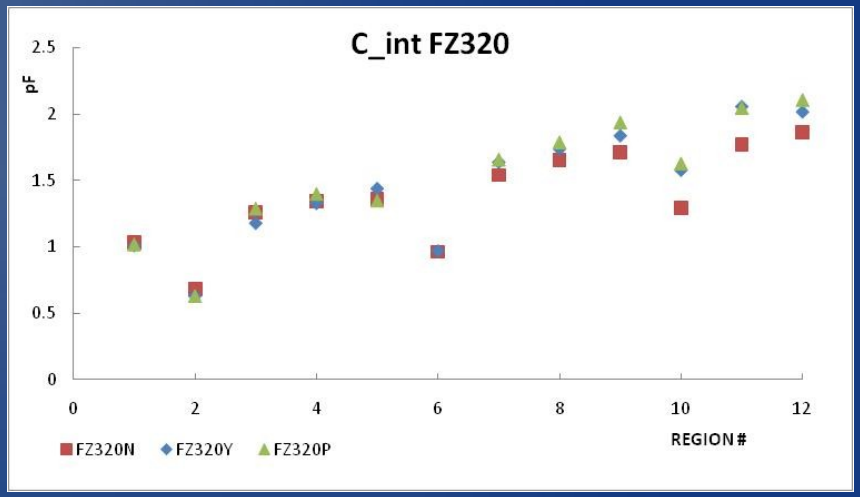


Float Zone sensors

Interstrip capacitance on all 12 regions on FZ thicknesses 120, 200 and 320um compared for N, P and Y

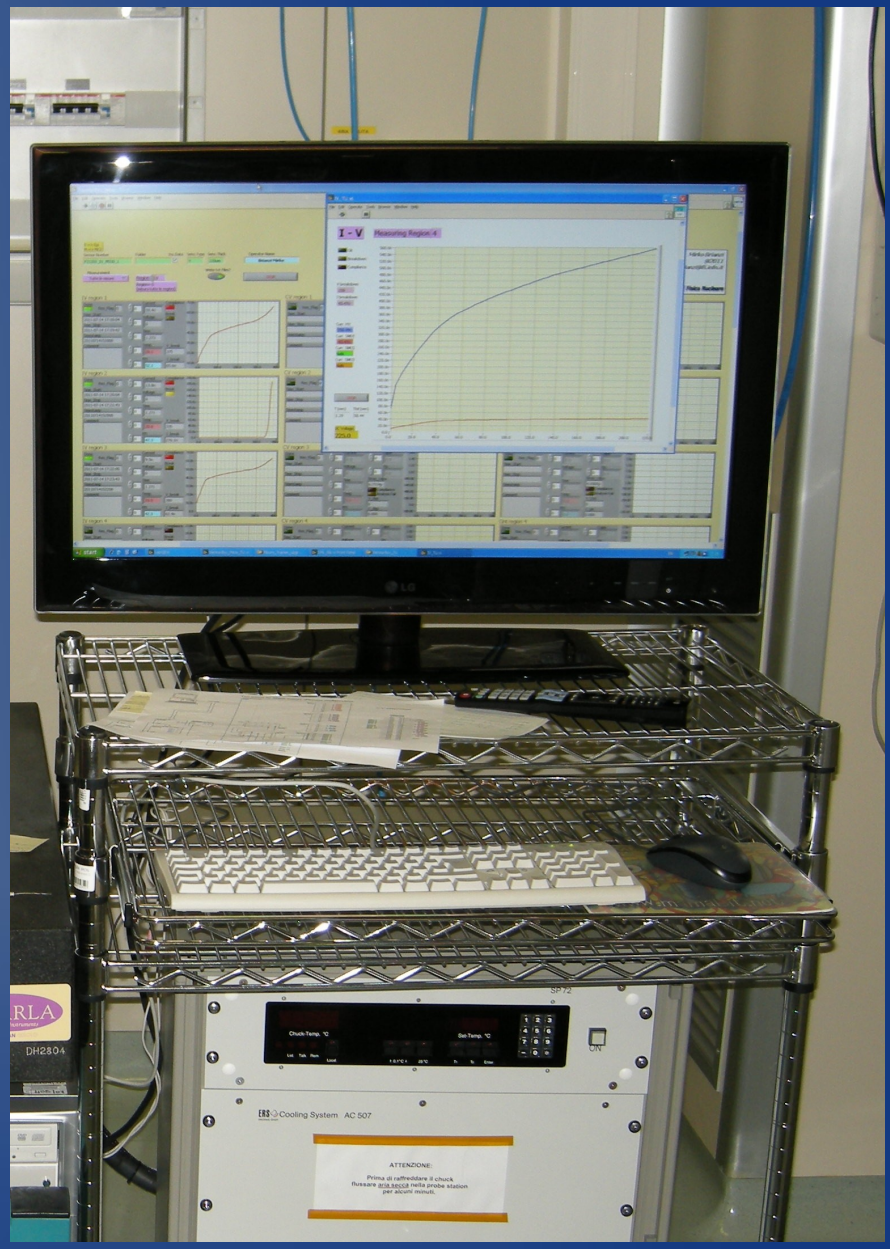






Measurements

- Campaign just started. First irradiated sensors not measured yet.
- Intercalibration between centres is still ongoing.
- Setups are now stable and we have converged to a common procedure and data format for the results.
- Results are stored as xml files on an SQL database.

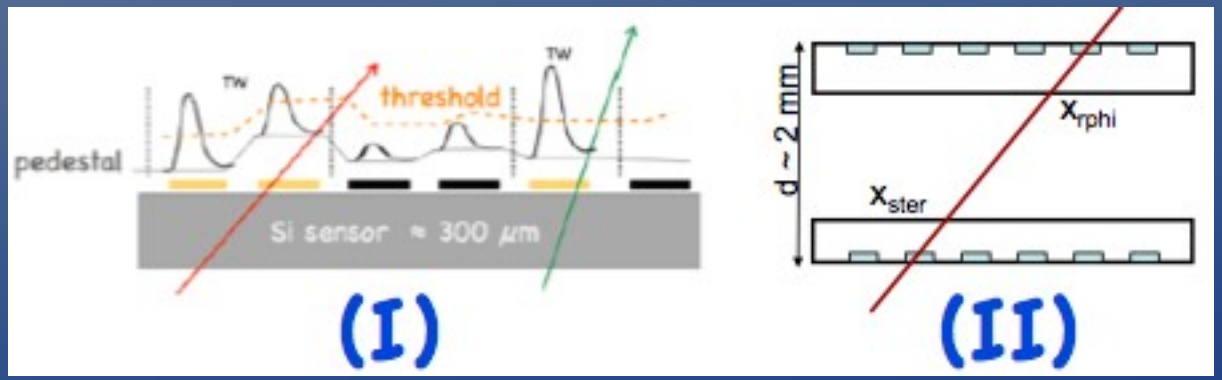


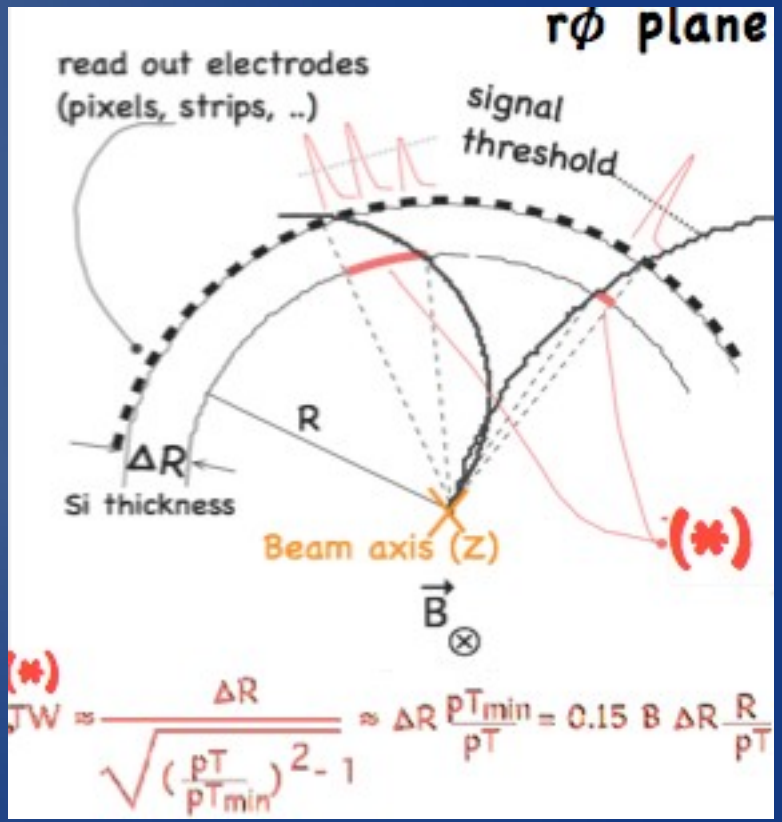
Trigger information

- Derive p_T information LOCALLY
- In a B field, ideal case of cylindrical layers with non-flat modules:

$$p_T^{meas}[GeV/c] = 0.15\, B[T]\, R[m] \frac{\Delta R[\mu m]}{TW[\mu m]}$$

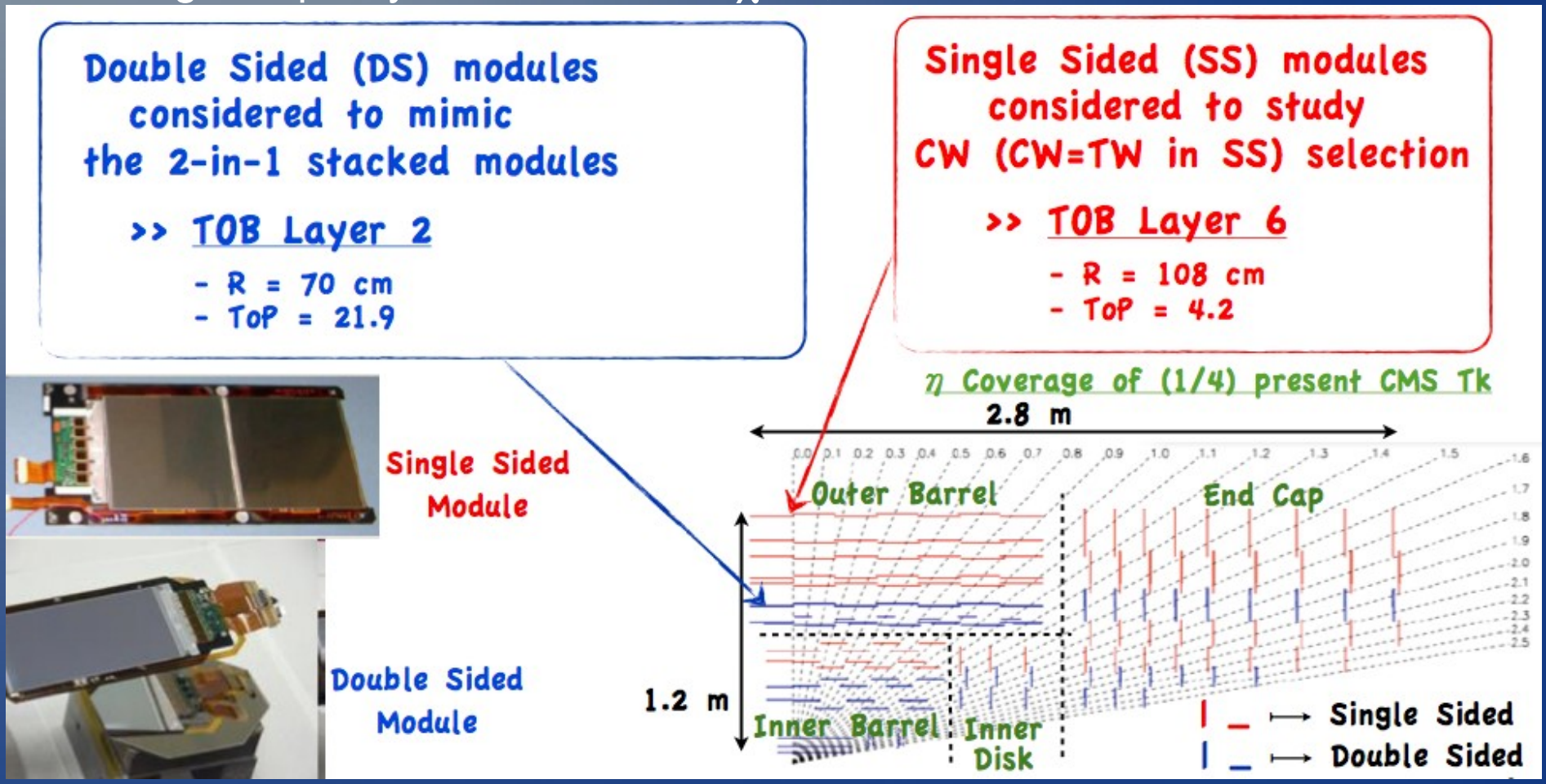
TW is the cluster size in terms of pitch





Studies from data

- Performance of “trigger” modules evaluated with CMS data (7 TeV p-p collisions)
  - Mainly MinBias/QCD events, π & μ tracks inside hadronic jets
  - good quality tracks selected: χ^2<2, #hits>11, etc.



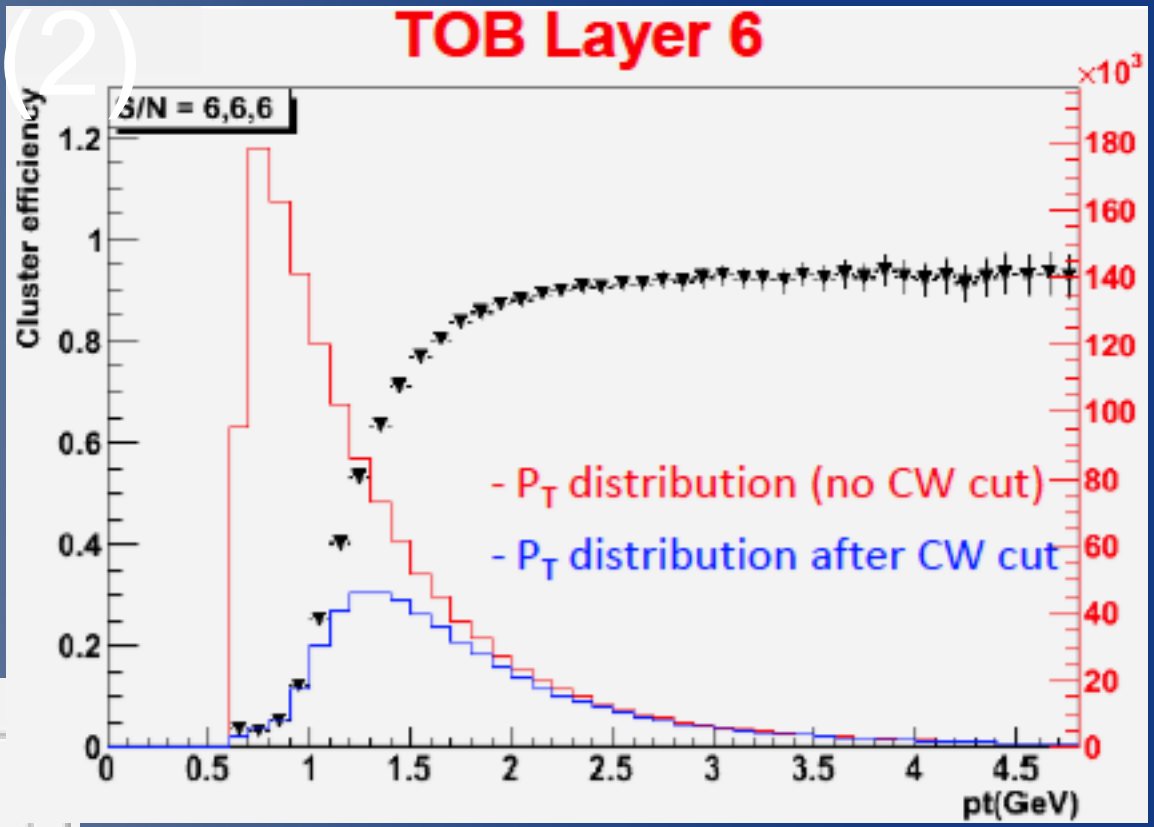
Studies from data (2)

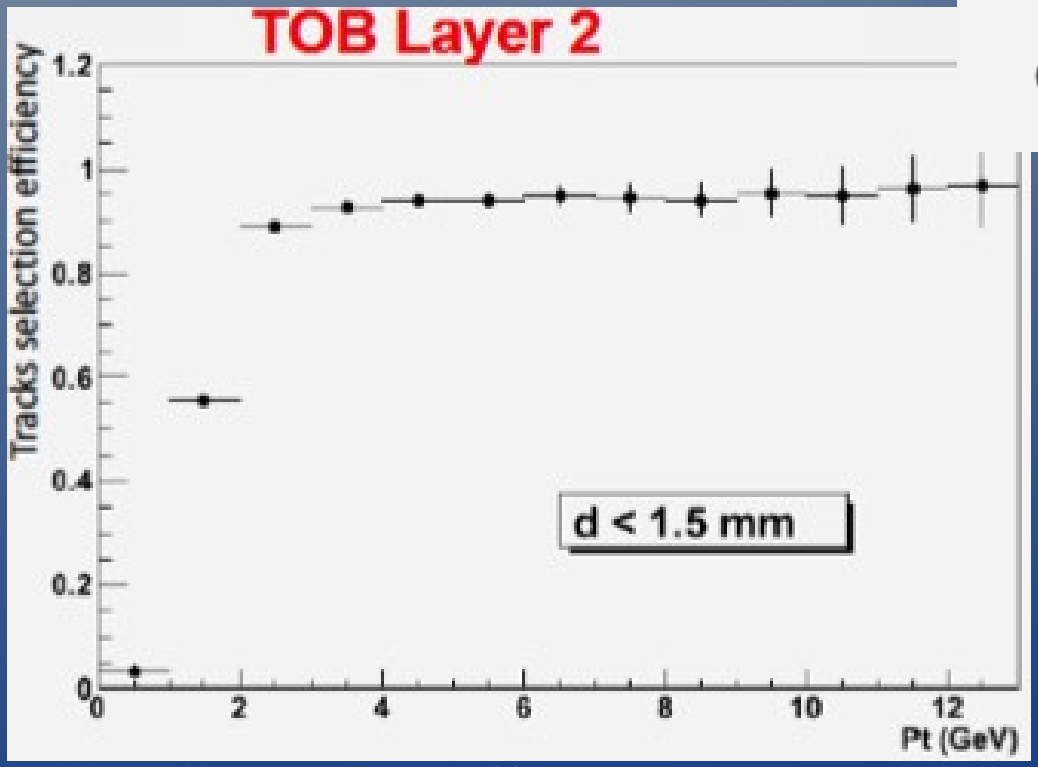
- SS: Sensitivity to CW

  Tracks selected with CW < 3

  Selection efficiency as a function of p_T

- Efficiency > 90% from 2 GeV/c onward.





DS:

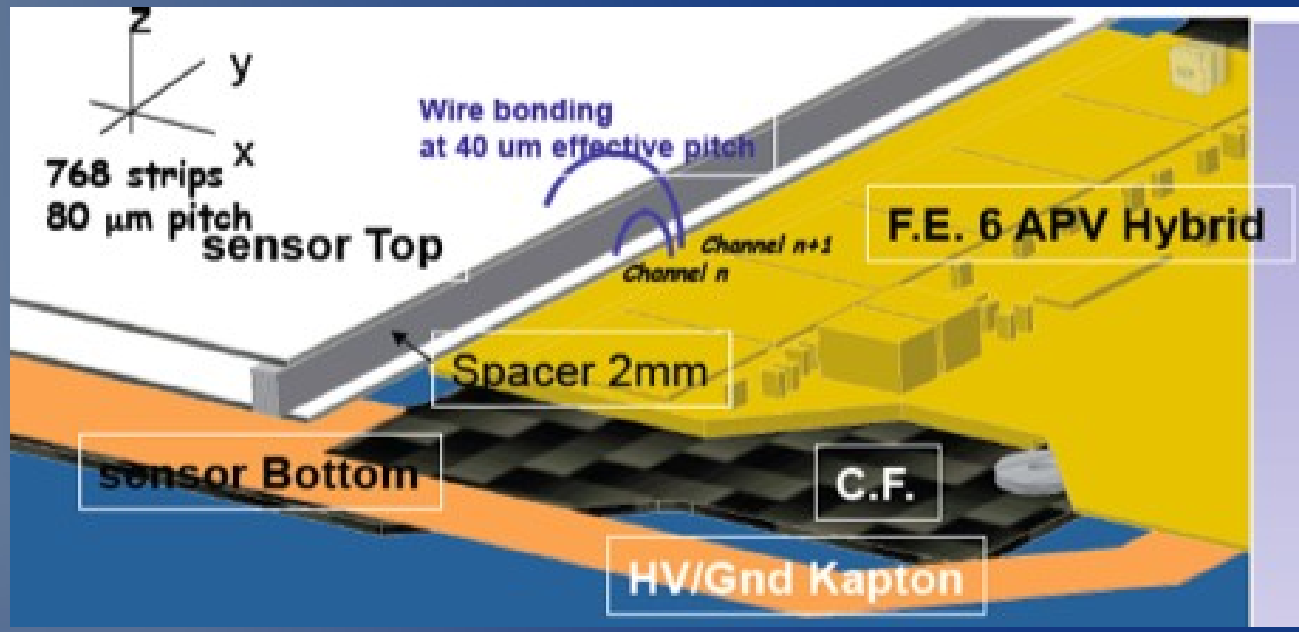
Tracks selected with TW("d") < 1.5 mm

Efficiency ~100%

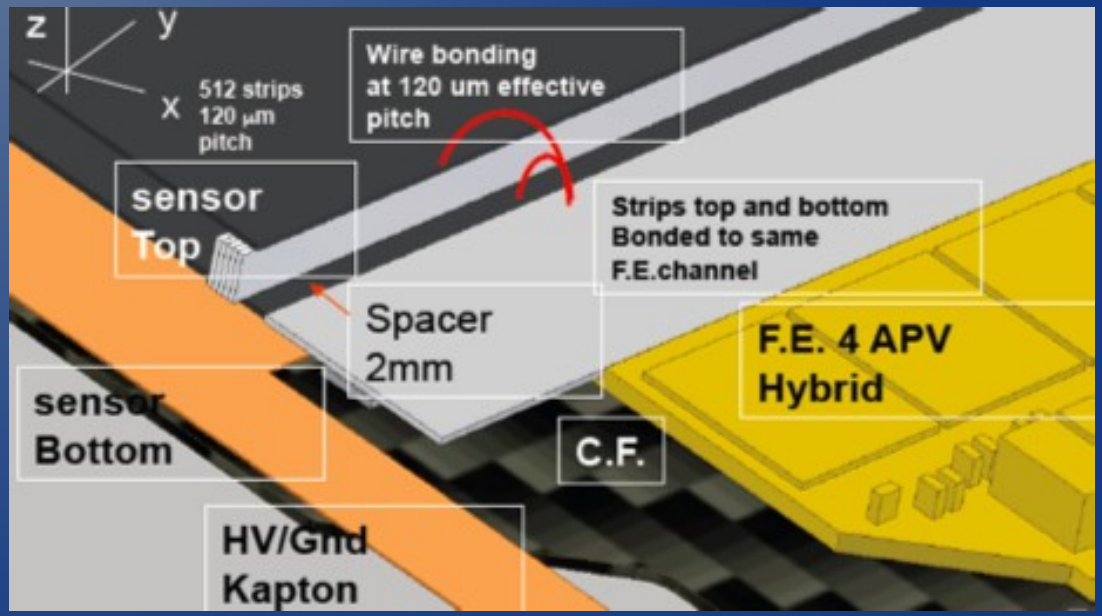
for high (> 5 GeV/c) p_T tracks

Stacked modules

- Pair of corresponding strips wire-bonded to a pair of neighboring readout channels
- Wire-bonding performed at ~40 μm effective pitch
- NO pitch adapter

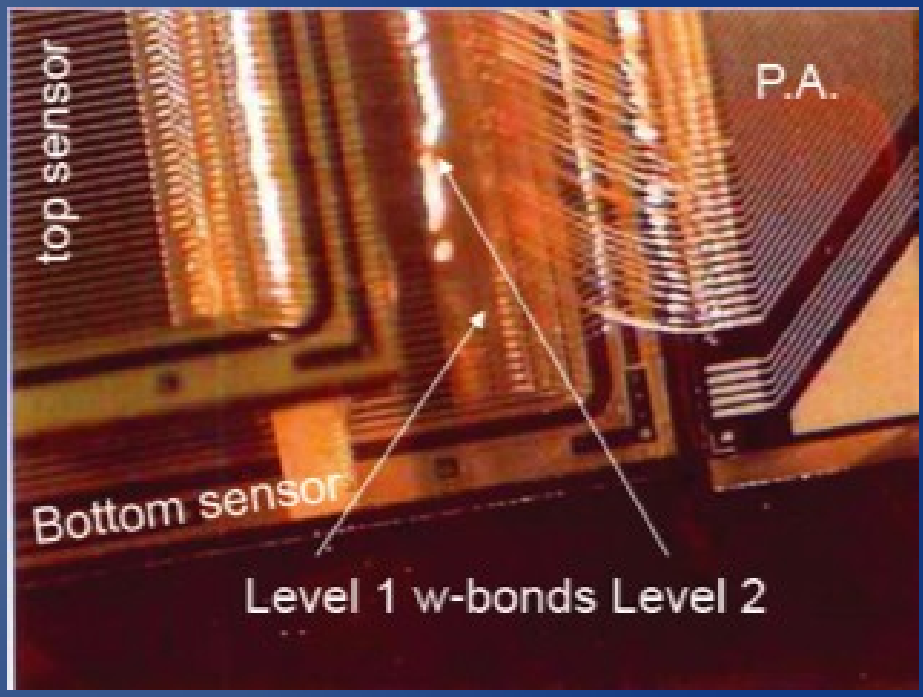


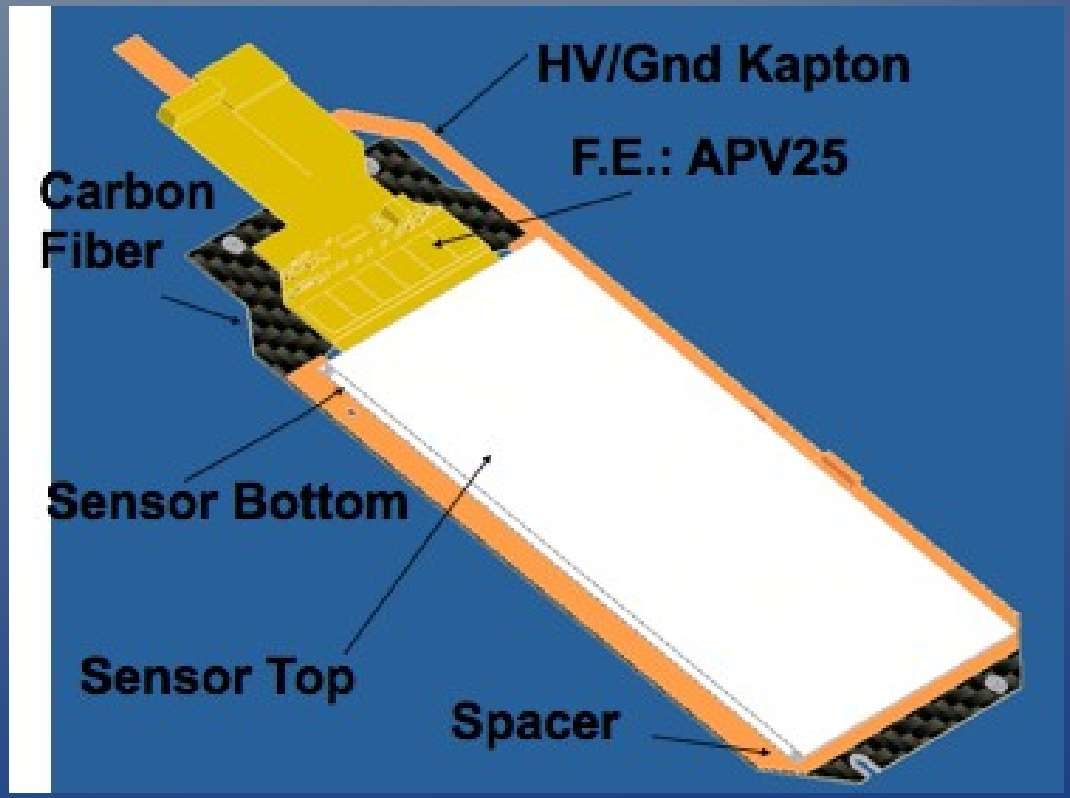
- Pair of corresponding strips wire-bonded to the same read-out channel
- Wire-bonding performed at ~ 80 μm and ~120 μm effective pitch (2 prototypes)
- through pitch adapter



Stacked modules

- Detectors assembled with spare modules from the current CMS tracker





Conclusions

- A systematic RD campaign for a new tracking system has begun.
- Many items (electronics, data links, sensors, triggering, cooling, mechanics, etc.)
- Sensor campaign well underway with the objective of having all relevant information in by the end of 2012.
- Trigger studies have already led to the production of stacked modules which could be the basis for a future trigger layer.

Strixels tests

Baby_Strixel Example

One Baby_Strixel is divided in
2 x 256 strips