CMS tracker upgrade test beam activities

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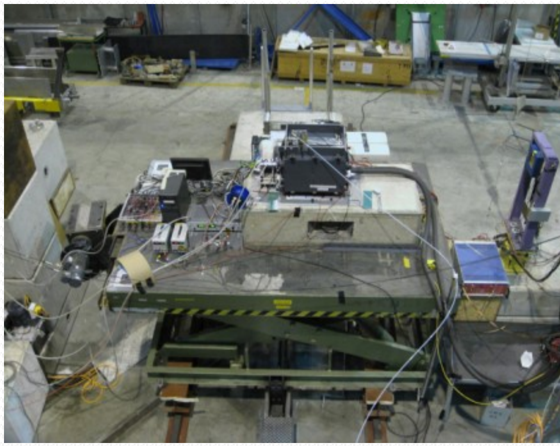
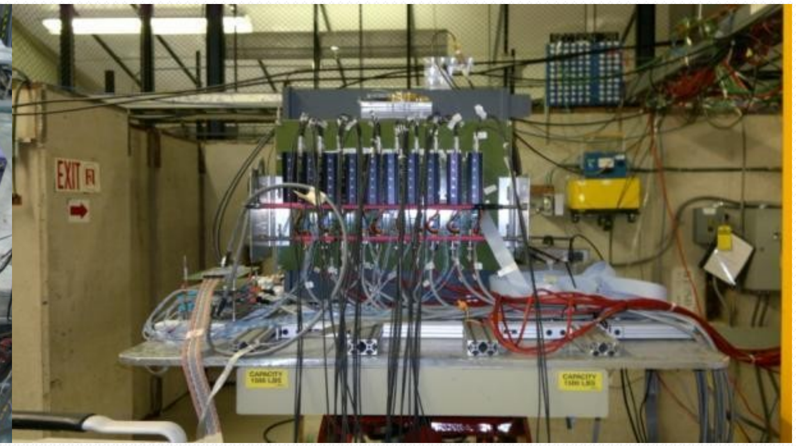
Silicon Beam Telescope (SiBT) Group

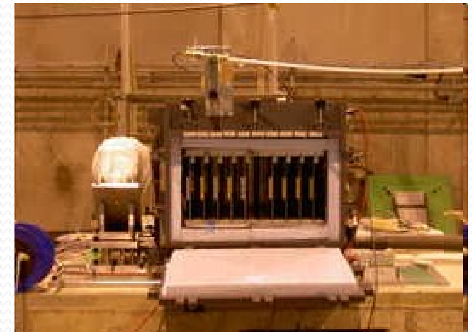



- Since 2007 a collaboration of several CMS institutes has been operating a silicon micro-strip beam telescope based on the CMS Tracker readout.
- So far there have been 6 test beam campaigns, the latest one including 14 FZ and 4 Epi-Si sensors from the official CMS R&D processing run from Hamamatsu.
- Original focus was to explore Magnetic Czochralski silicon as a radiation hard option for S-LHC strip tracker regions. Now the SiBT setup has become an integral part of the CMS phase II upgrade R&D program.

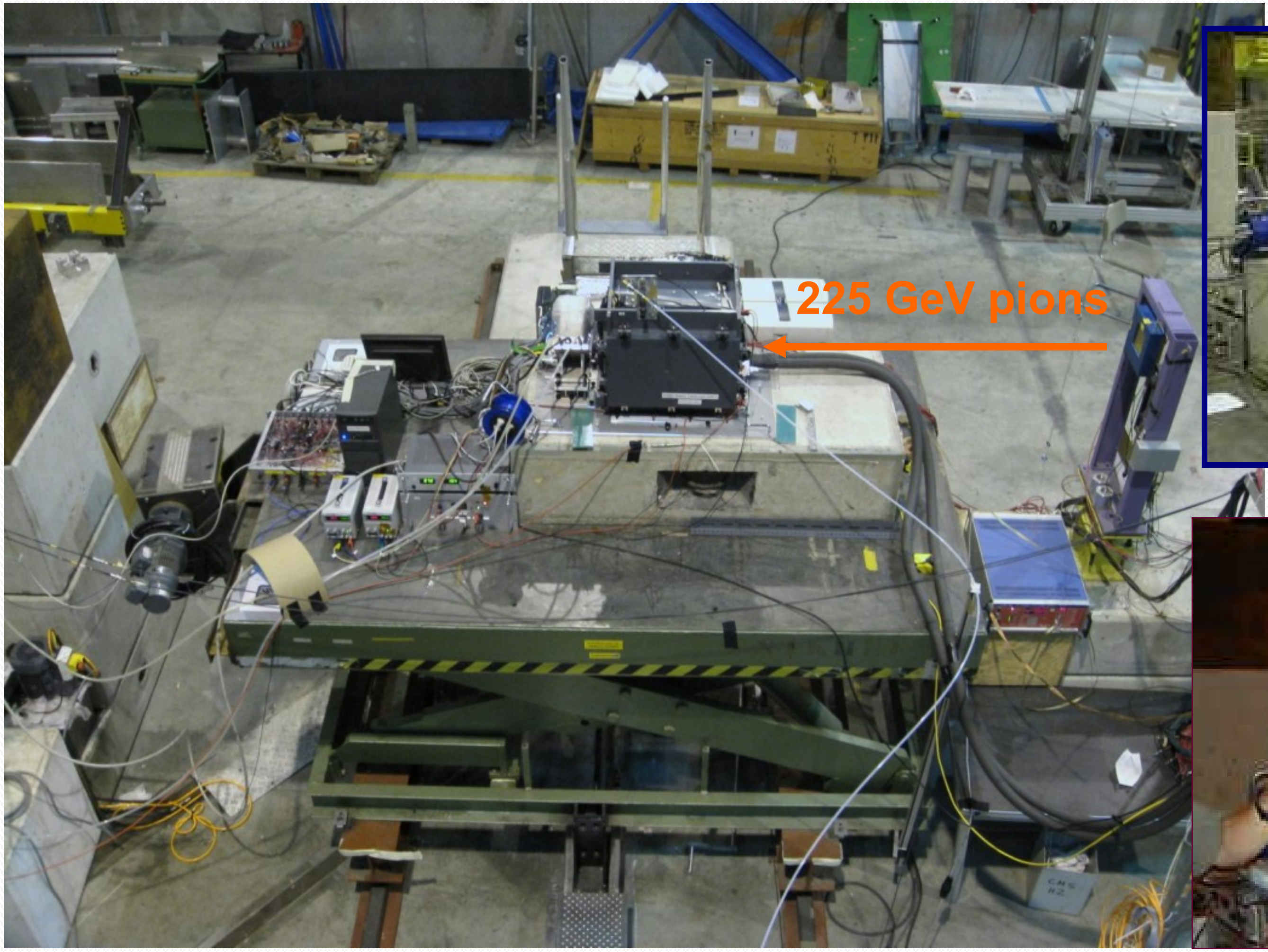
  http://www.hip.fi/research/cms/tracker/SiBT/php/home.php

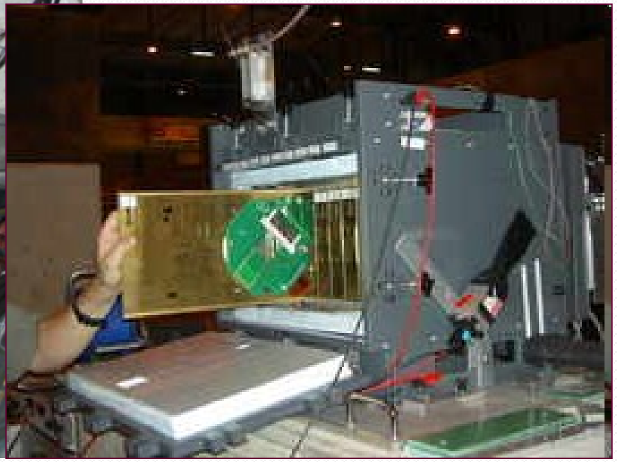
SiBT setup

- The telescope reference planes + detectors under test are housed inside a cold chamber that can be cooled down to -30°C.
- Reference planes are installed to ±45 degrees (due to the height limitation)
- Reference detectors are D0 Run IIb HPK sensors with:
  - 60 micron pitch and intermediate strips
  - size 4 cm x 9 cm
  - 639 channels
- Telescope active area: 3.8 cm x 3.8 cm.
- Readout electronics: CMS APV25.
- DAQ software: a modified version of the CMS Tracker data acquisition software (XDAQ).



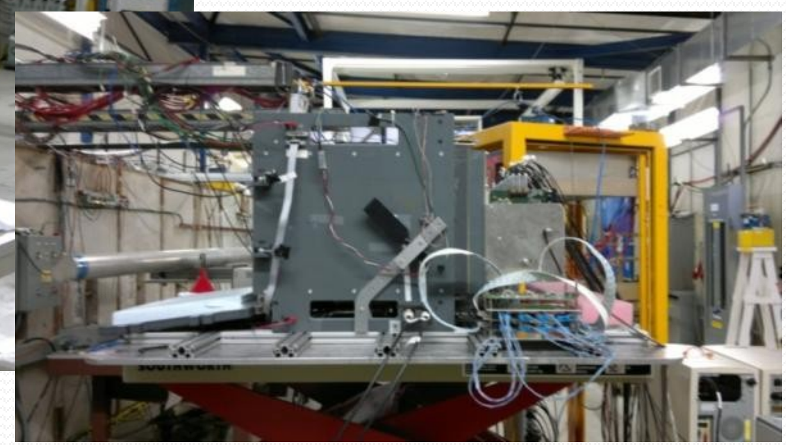
SiBT setup on the H2 beam line



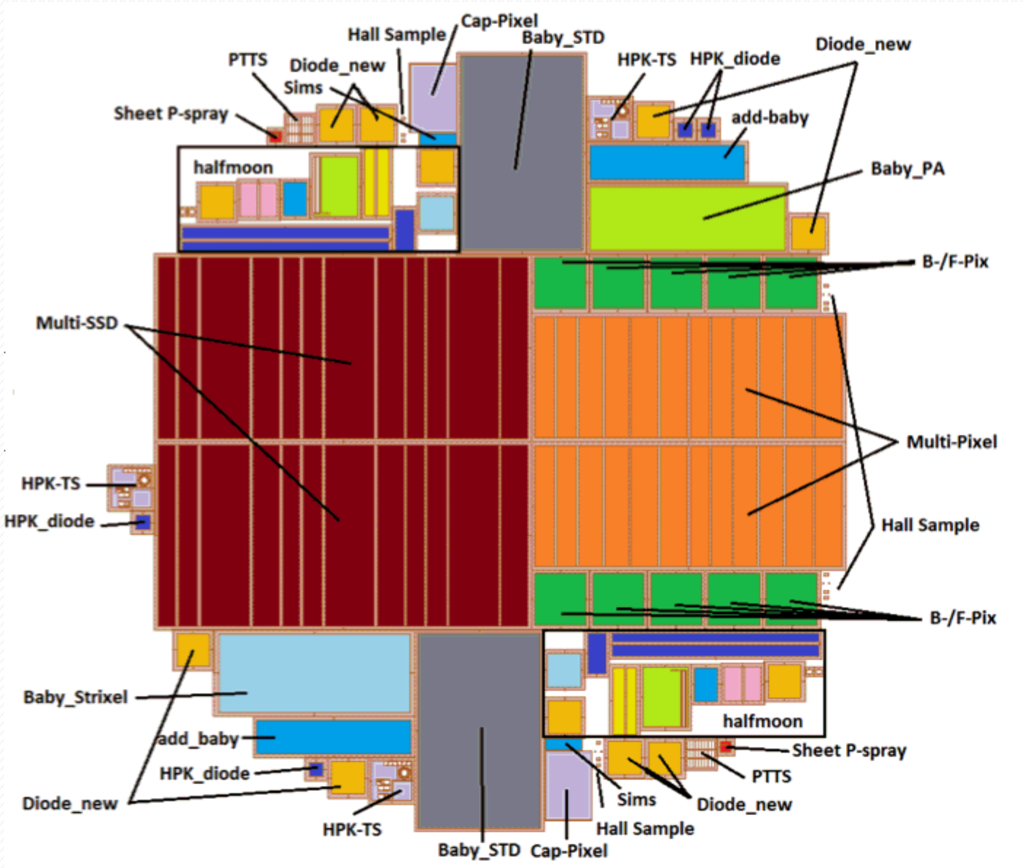


SiBT setup at Fermilab

The setup is relatively compact and can be transported by air cargo between the continents.

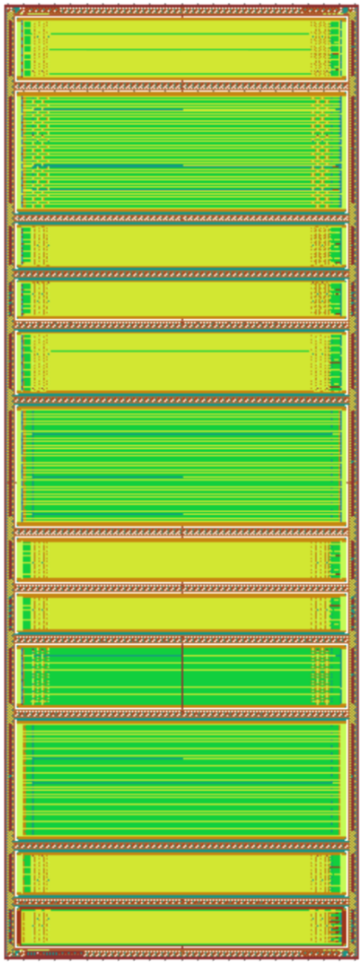


CMS "HPK Campaign"



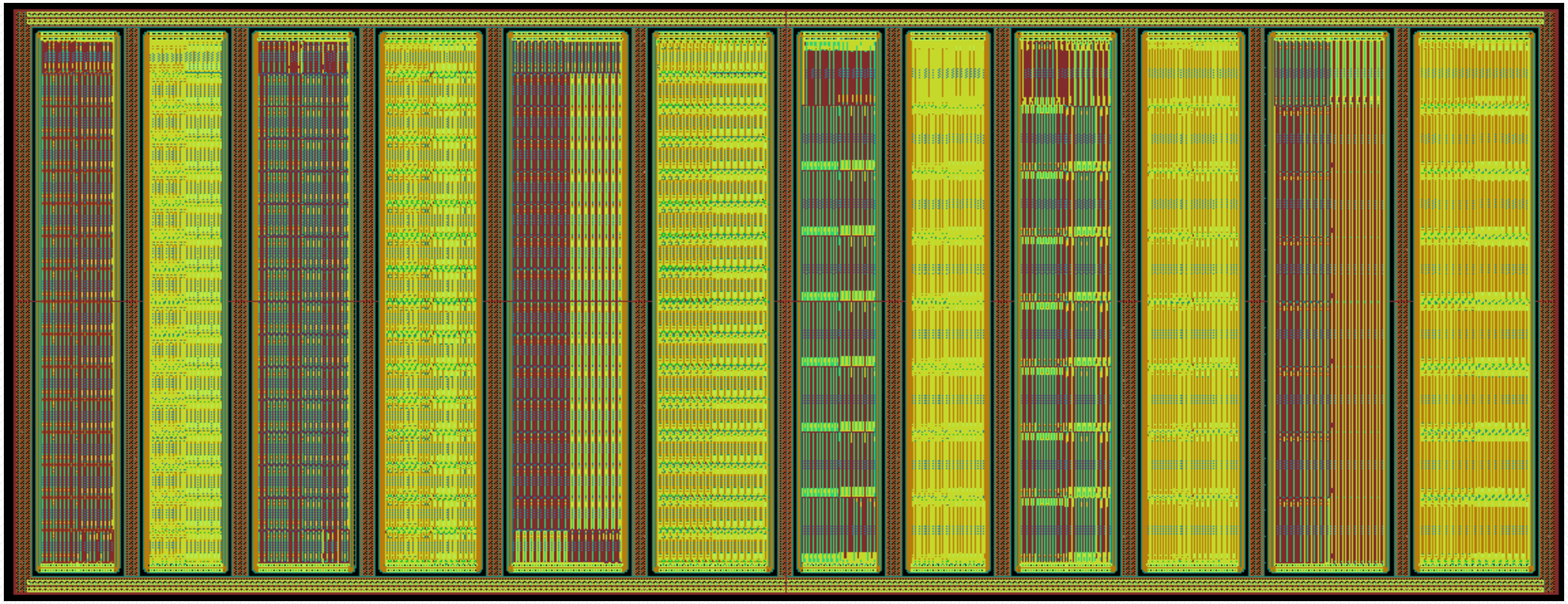
Over 100 6 inch wafers (Float Zone, Magnetic Czochralski, Epitaxial)
Bulk : n-type and p-type (p-stop, p-spray)

MSSD sensor



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

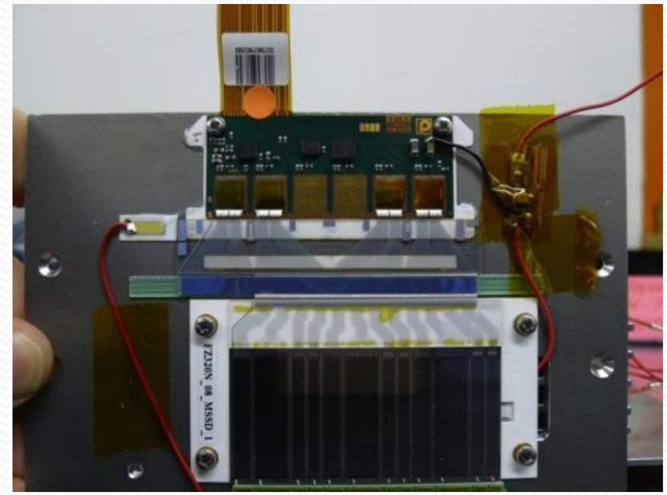
Mpix sensor

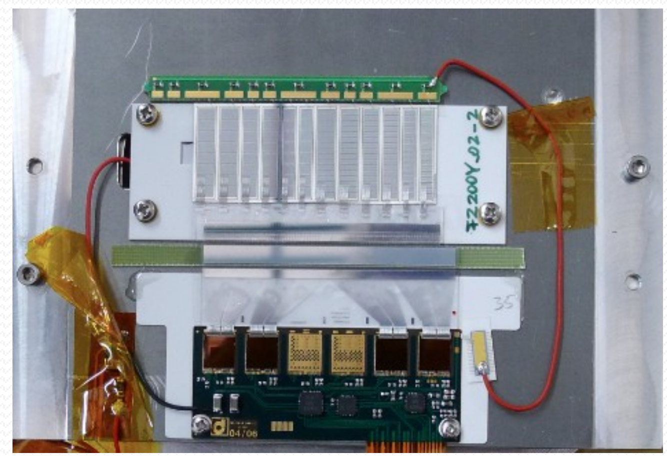


region	12	11	10	9	8	7	6	5	4	3	2	1
p+/n+ [µm]	18	18	23	23	28	28	18	18	23	23	28	28
alu [µm]	31	31	36	36	41	41	31	31	36	36	41	41
length [µm]	1171	1171	1171	1171	1171	1171	2421	2421	2421	2421	2421	2421
Pitch [µm]	80	80	100	100	120	120	80	80	100	100	120	120

MSSD and Mpix modules

- Both the MSSD and Mpix sensors were bonded to a CMS APV hybrid.
  - This seems to work well even for the Mpix sensor, even though the bonding was a bit more difficult than for a strip sensor.
- In order to allow the same sensor to be irradiated and tested again in a test beam, the sensor was bonded to the hybrid through several pitch adapters that each have several bonding pads.
  - The effect of several PAs on the noise has naturally to be taken into account while analyzing the resuls.



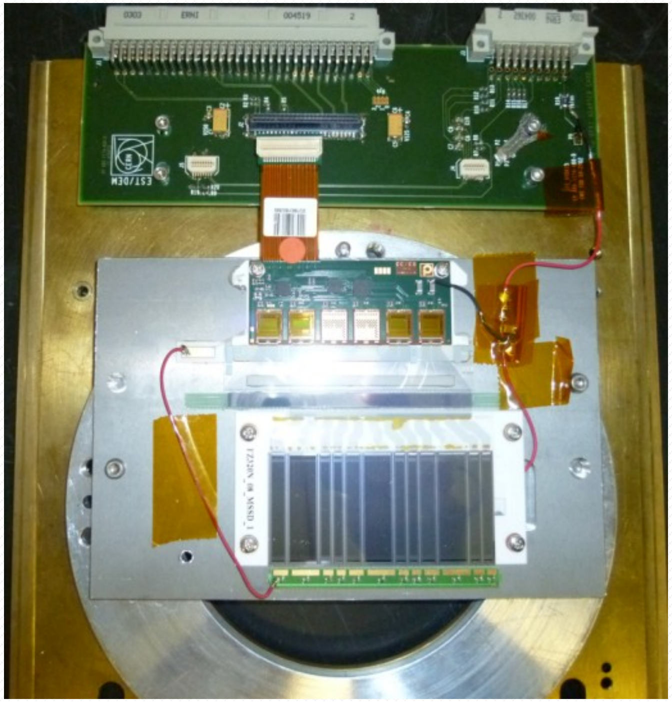


Tested MSSD and Mpixel modules at FNAL

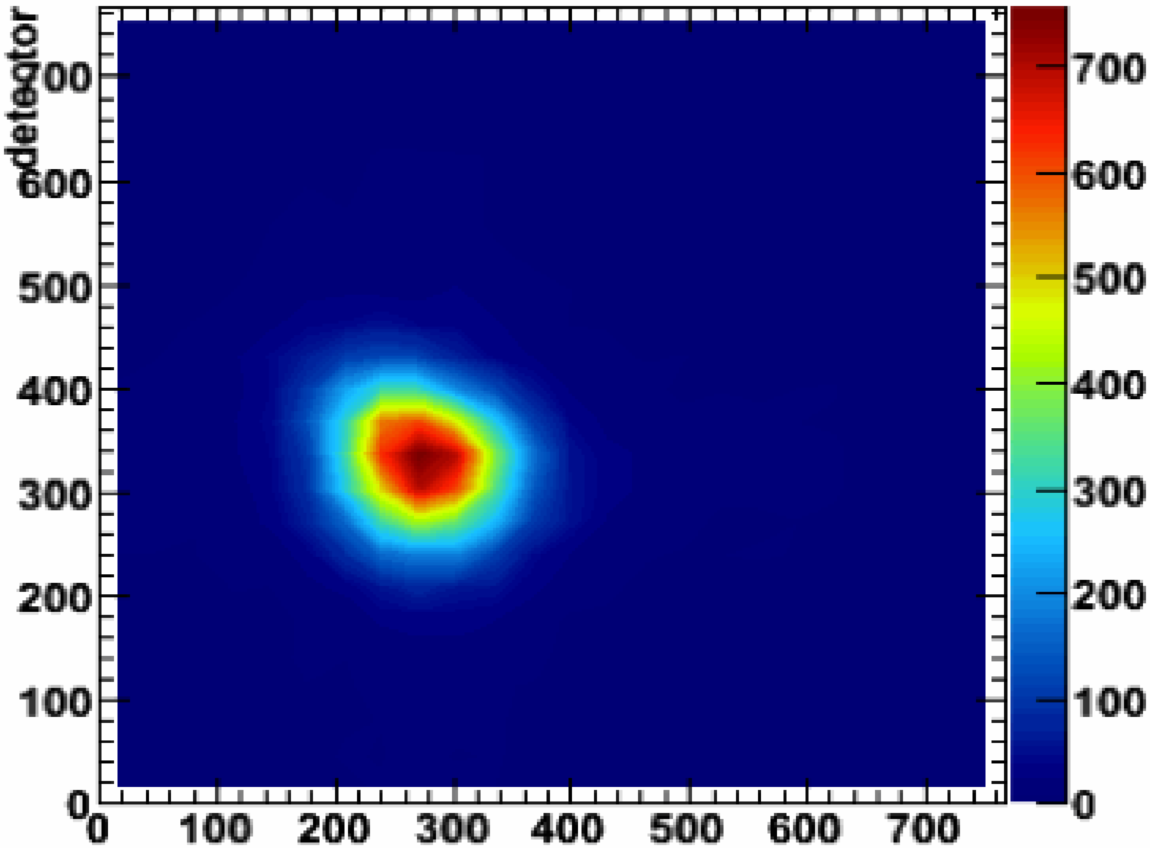
Devices: 18 strip and pixel detectors
Materials: FZ and Epi-Si with different thicknesses
N- and p-type bulk (p-spray and p-stop)

1) FZ320N_08_MSSD_1
2) FZ320P_01_MSSD_1
3) FZ200N_01_MSSD_1
4) FZ120N_02_MSSD_2
5) FZ320Y_04_MSSD_2
6) FZ200P_04_MSSD_1
7) FZ200Y_02_MSSD_2
8) E100N_02_MSSD_1
9) E50N_02_MSSD_1

FZ200N_06_Mpix_1
FZ320N_01_Mpix_1
FZ320P_04_Mpix_1
FZ120N_06_Mpix_1
FZ320Y_05_Mpix_2
FZ200P_01_Mpix_2
FZ220Y_02_Mpix_2
E100N_02_Mpix_1
E50N_02_Mpix_1

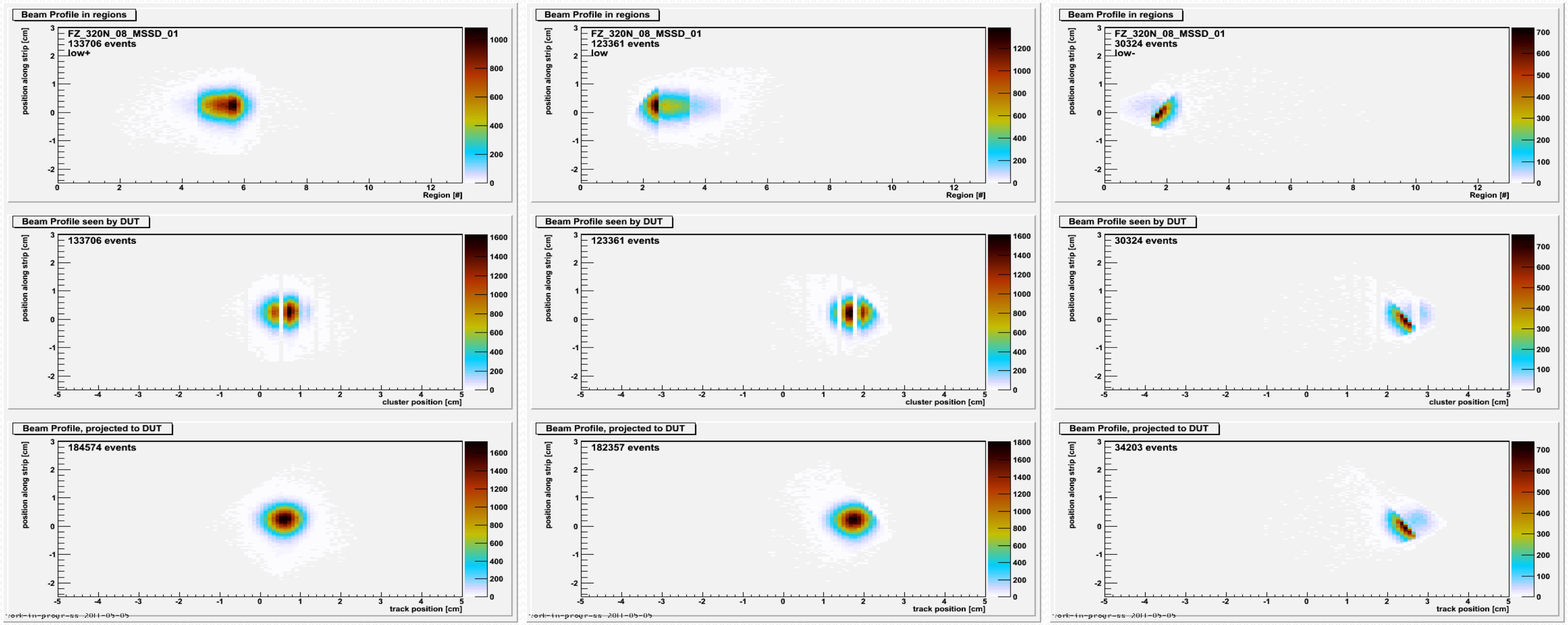


Online Beam Profile



- ~1 cm^2 beam spot, (preferred by the primary user) required 7 table positions per voltage setting to cover 12 distinct regions per MSSD/Mpixel module.
- Fermilab was able to respond to our request to double the spills per cycle due to the rare occasion of Tevatron being down and this allowed us to scan all the „baseline“ modules (Fz) + additional bonus modules (Epi-Si).

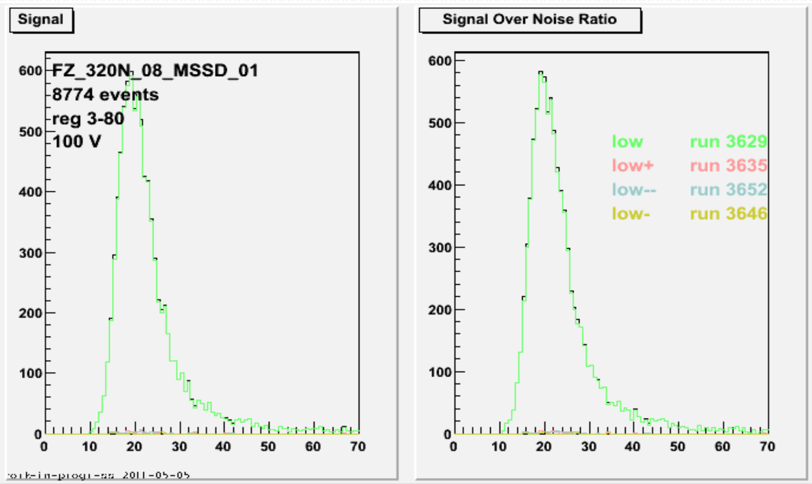
Preliminary results: beam profile for FZ_320N_08_MSSD_01 (3 “low” positions)

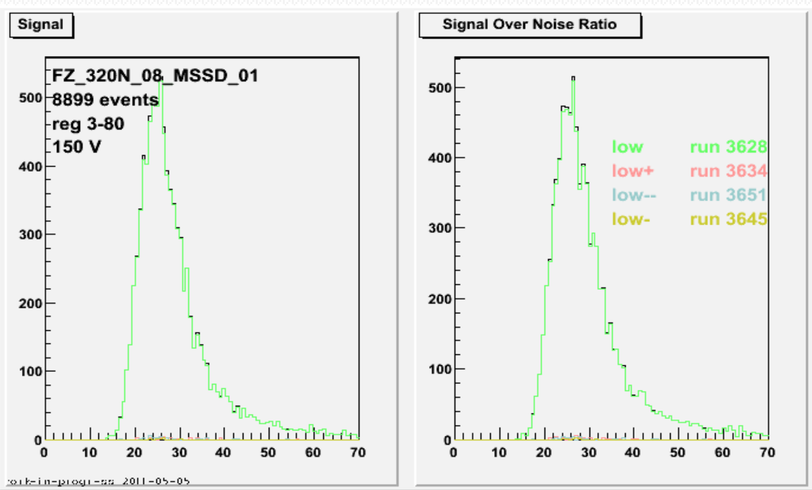


2: pitch 240 µm | 3: pitch 80 µm | 4: pitch 70 µm

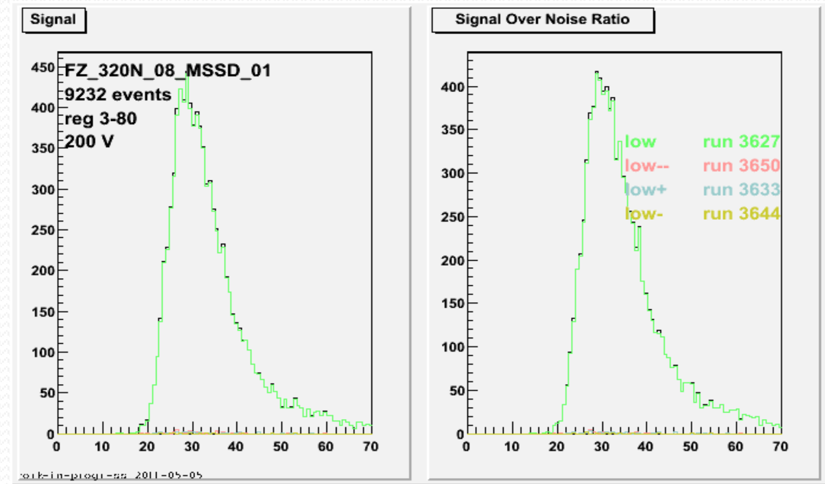
- The beam hits the MSSD in regions 2, 3 and 4 in these plots.

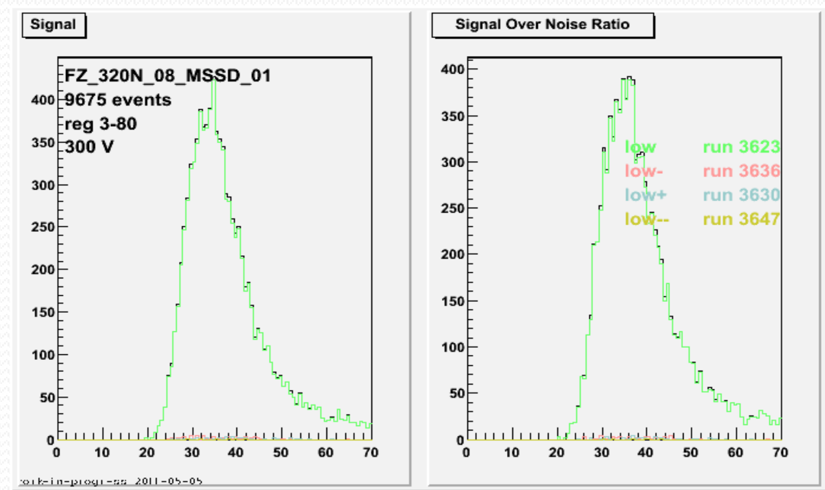
- Preliminary results: S/N of MSSD region 3 (pitch 80 µm).
- The effect of several pitch adapters hasn‘t been taken into account yet!





- @100V
- S/N: 20
- @150V
- S/N: 24
- @200V
- S/N: 28
- @300V
- S/N: 32





Conclusions

- The CMS beam telescope (SiBT) functions very well. It has been used in 6 test beam campaigns so far and it can be used both at CERN and at Fermilab due to its relatively compact size.
- We have obtained the first test beam results from the CMS HPK campaign.
- The analysis of the results has just started in several insitutes and we hope to have the baseline to which we can compare all the future test beam results ready in this summer.
- The next step is to irradiate the Fz and Epi-Si detectors and test them in the next test beam at CERN in September.
- In addition, we have a long-term plan of upgrading the telescope hardware to the CMS optical readout in order to accommodate more detectors under test and also to modernize the DAQ software and hardware.