The CMS HPK campaign - An overview

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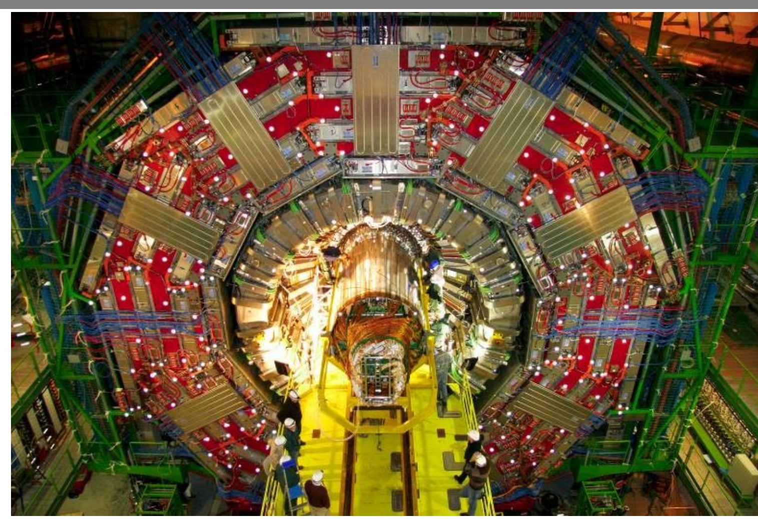

CMS Strategy

- Most of the volume of a future Tracker will be equipped with planar silicon sensors
  - We have started a survey of available silicon materials to probe their individual limits
  - One wafer layout has been developed and the various materials are processed with this mask by the same producer, which allows well defined comparisons
  - We investigate the properties of several layout options for strip, strixel and pixel sensors
  - A well defined measurement plan has been worked out and participating institutes have been inter-calibrated to guarantee comparable measurements
  - For the test wafers a producer was chosen, that can provide the large quantity and high quality we need → "**HPK campaign**"
  - Measurements are complemented by device simulations
- In parallel, there are R&D projects on potential additional candidates for the most inner layer(s)
  - 3D silicon sensors (production with Sintef, FBK, CNM)
  - Diamond sensors

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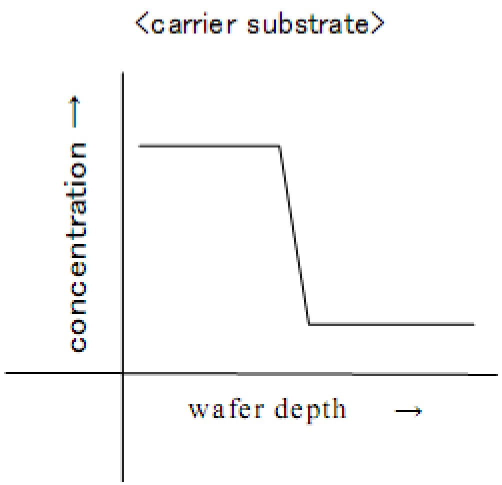
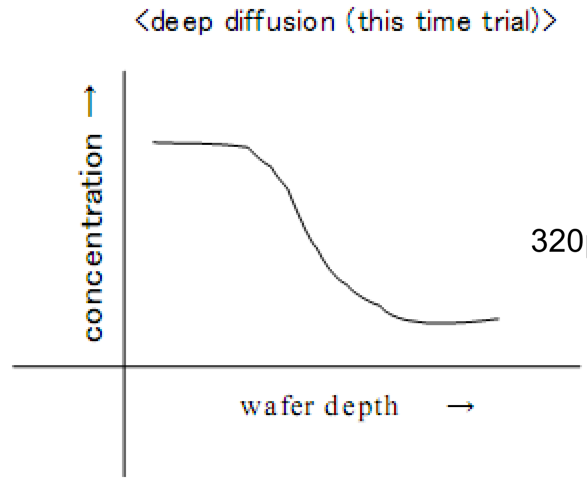
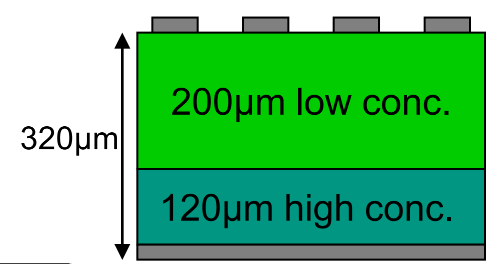
HPK campaign – Materials

- Initially ordered production of 126 wafers delivered completely
- Part of thin FZ wafers came “deep diffused” showing some features, which makes a comparison with physical MCz difficult
- “Deep diffused” wafers are about 20% cheaper than 200µm thin wafers! We will investigate this option…
- Additional material ordered lately and expected Sept./Nov.

	n-type	p-type (p-stop)	p-type (p-spray)
FZ320	6 / 6	6 / 6	6 / 6
FZ200 deep diff.	6 / 6	6 / 6	6 / 6
FZ120 deep diff.	6 / 6	6 / 6	6 / 6
MCz200 physical	6 / 6	6 / 6	6 / 6
Epi100	2 / 6	6 / 6	6 / 6
Epi70	4 / 0	-	-
Epi50	6 / 6	6 / 6	6 / 6
FZ200 deep diff. & 2.metal	6 / 6	6 / 6	6 / 6
FZ200 physical	0 / 6	0 / 6	0 / 4
FZ120 on carrier	0 / 6	0 / 6	0 / 4



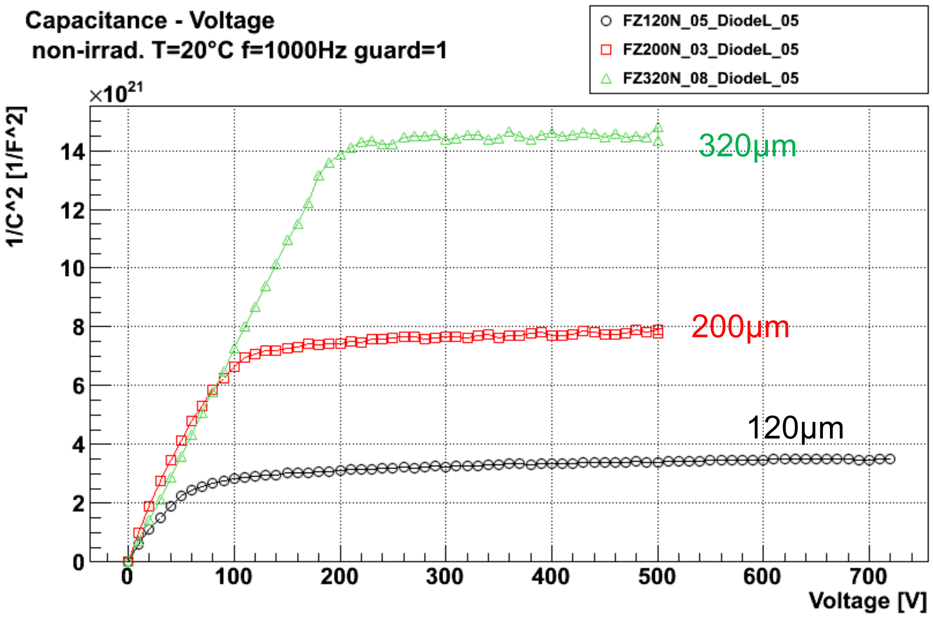


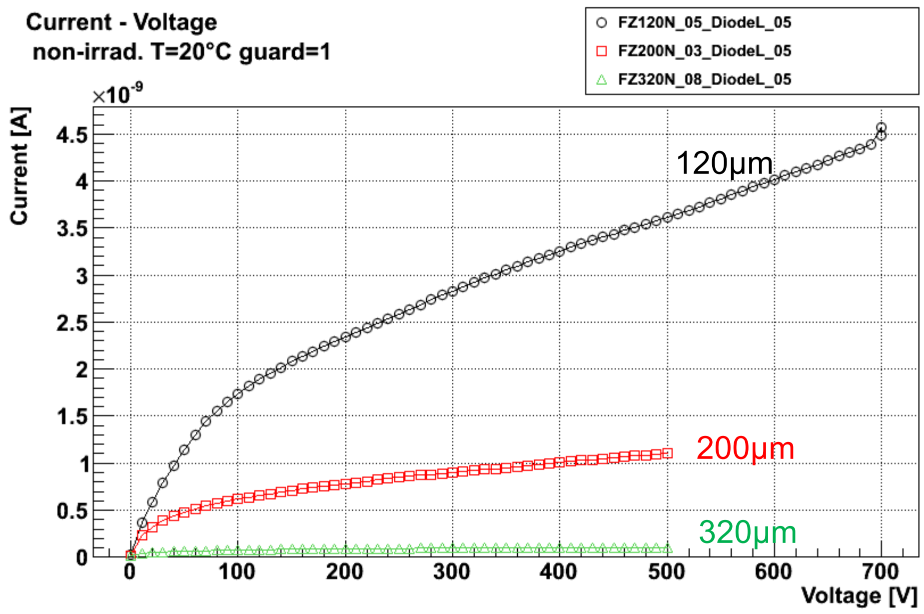


FZ200 deep diff.

Investigation of “deep diffused” material

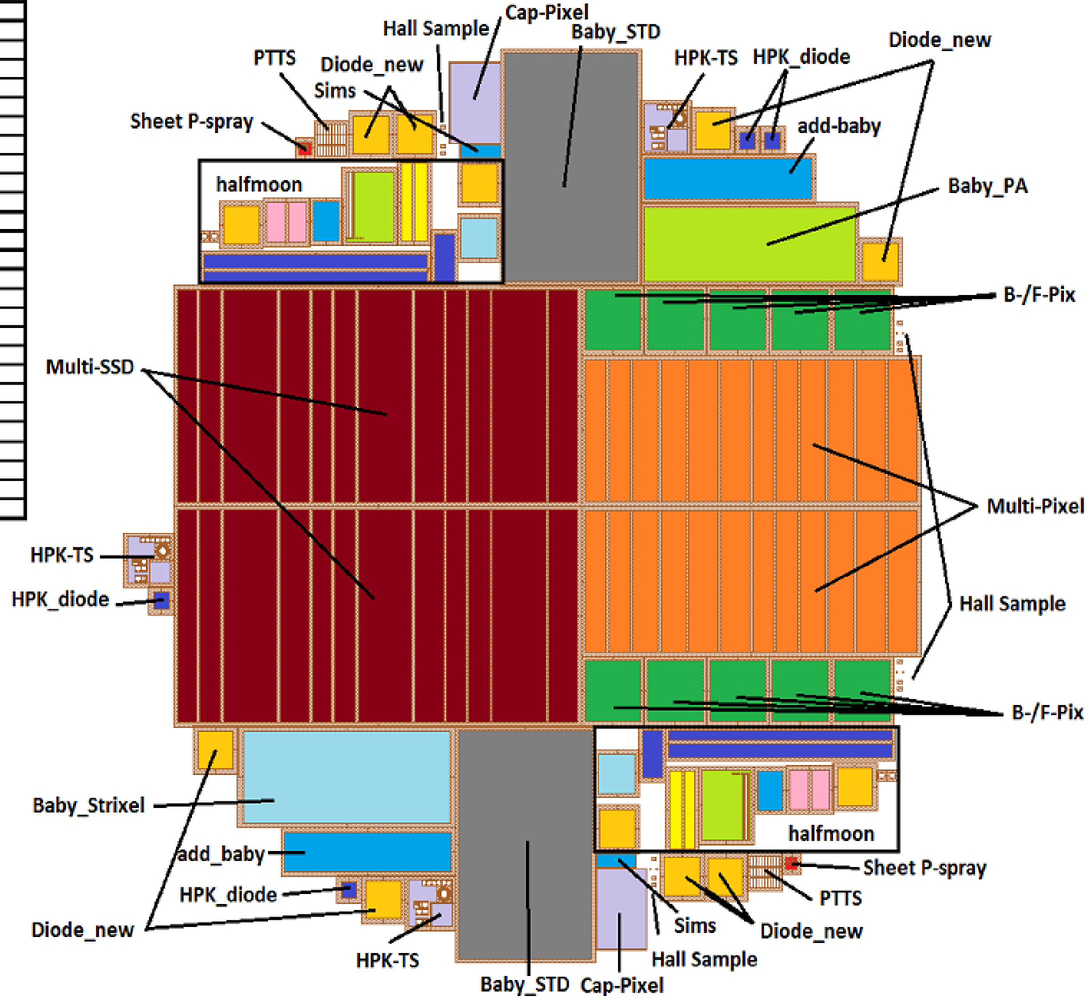
- Unusual behaviour of thin “deep diffused” material
- Well seen in IV and CV of diodes
- Thin diodes show non-abrupt depletion behaviour
- Volume generated currents are higher than in thick diodes
  - But currents are still very low (<1.5µA/cm³ @ 500V)!





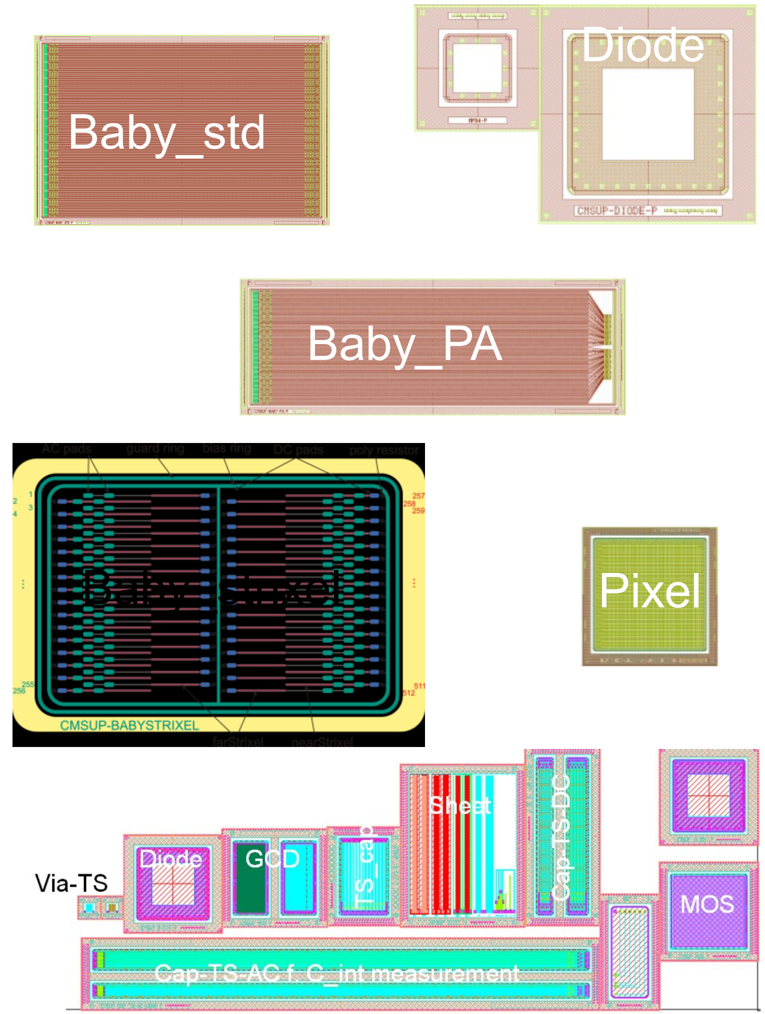
HPK wafer layout

	name	pcs/wafer
1	Multi-Geometry-SSD	2
2	Multi-Geometry-PIXEL	2
3	BPIX-A	1
4	BPIX-B	2
5	BPIX-C	1
6	BPIX-D	2
7	FPIX-E	2
8	FPIX-F	2
9	TS-cap	2
10	Cap-TS-DC	2
11	MOS	2
12	Sheet new	2
13	GCD new	2
14	Cap TS AC long (CCP)	2
15	Diode new	12
16	Via1	2
17	Via2	2
18	SIMS	2
19	TS_Sheet_Pspray	2
20	Cap-Pixel	2
21	BabySensor std	2
22	BabySensor PA	1
23	BabyStrixel	1
24	Add Baby	2
25	Hall Sample	4
26	Pucnh Through TS	2
27	HPK Test Structure	3
28	HPK Diode	4



Structures and goals

- Diodes
  - Material characterization and add. annealing studies
  - Measure IV, CV, CCE, TCT, DLTS, TSC, photo cond., …
- Mini sensor I (Baby_std)
  - Material characterization, charge collection
  - Measure IV, CV, strip para., CCE, e-TCT
- Mini sensor II (Add_Baby)
  - Material characterization using different radiation sources
  - Measure IV, CV, Lorentz angle
- Sensor with integrated PA (Baby_PA)
  - Layout study: spare glass PA
  - Measure strip capacitances, CC, signal coupling
- Sensor with short strips and edge read-out (Baby_strixel)
  - Layout study: read-out lines from inner strip to outer edge
  - Measure strip capacitances, CC, signal coupling
- Test structure field (TS)
  - Process qualification
  - Measure many things incl. SIMS, SRP, SEM, …
- Pixel
  - Real size pixel sensor for CMS ROC footprint
  - Measure IV, efficiency, σ
- Multi-geometry strip (30mm) sensor (MSSD)
  - Layout study: strip width and pitch variations
  - Measure CV, IV, Cint, S/N, σ
- Multi-geometry pixel (1.25mm/2.5mm) sensor (MPix)
  - Layout study: pixel length and pitch variations
  - Measure CV, IV, Cint, R_{poly}/R_{PT}, S/N, σ



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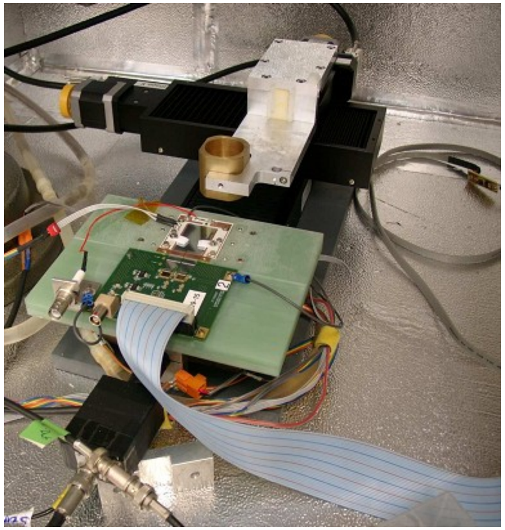
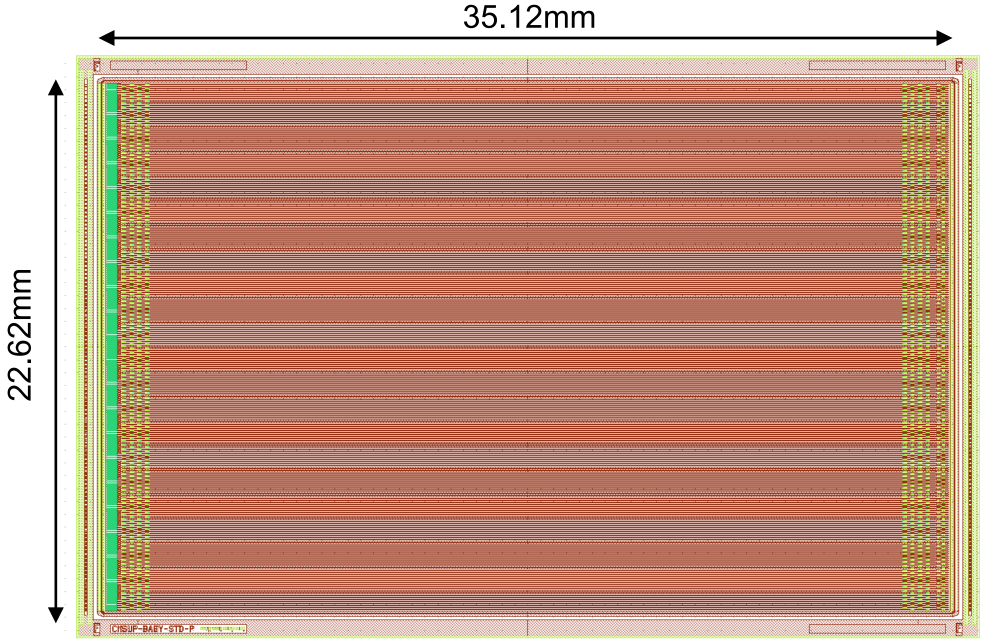
Baby_std

- A “standard” mini strip sensor with 256 strips and 80µm pitch
- Evaluation of all electrical parameters
- Measurement of charge collection with beta-source and LHC-like read-out system
- Edge-TCT can provide E-field and charge collection vs. thickness profile on sub-set

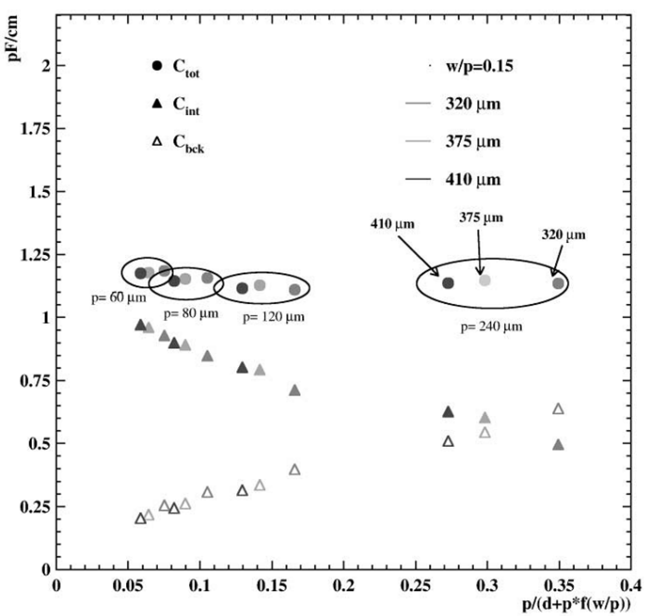


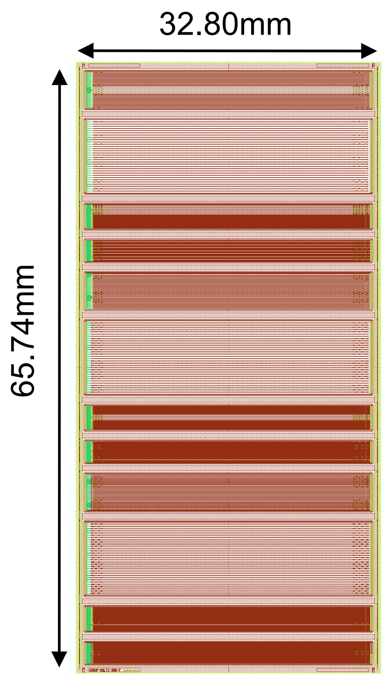
ALiBaVa setup at KIT



Multi-SSD

- Contains 12 regions with different strip sensor layouts
- This is a replica of the famous test-structure, which brought us the conclusion that the total strip capacitance is a function of w/p only (demonstrated for 0.2<p/d<0.8 and 0.1<w/p<0.6) [CMS Note 2000/011]
- This time we check thinner material (0.2<p/d<**2.0**) and higher irradiation!





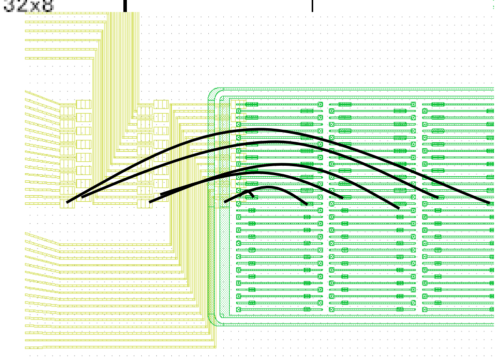
REGION No.-PITCH	P	WP	WAL	D	E	L
1-120	120	18	26	60	60	3820
2-240	240	36	44	120	60	7660
5-120	120	24	32	60	60	3820
6-240	240	48	56	120	60	7660
9-120	120	36	44	60	60	3820
10-240	240	72	80	120	60	7660

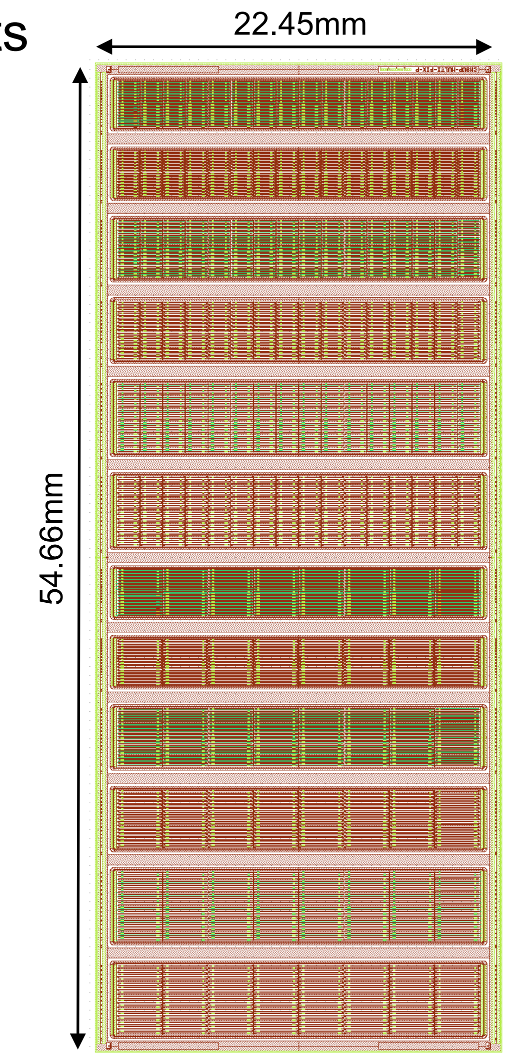
REGION No.-PITCH	P	WP	WAL	D	E	L
3-80	80	12	20	60	60	2580
4-60	60	9	17	50	50	1940
7-80	80	16	24	60	60	2580
8-60	60	12	20	50	50	1940
11-80	80	24	32	60	60	2580
12-60	60	18	26	50	50	1940

Multi-Pixel

- Contains 12 regions with different pixel/strixel layouts
- Pixel size in the regime of pixellated p_T layers
- Study inter-pixel capacitances and different biasing schemes
- Special PA to read-out with APV25 in beam test

	PIXEL Length	Pitch	bias type	No. of pixels	Pixel size (um)	Lateral P-P gap
1	1250	80	Poly	32x16	20x1160	60
2			PT	32x16		
3		100	Poly	32x16	25x1160	75
4			PT	32x16		
5		120	Poly	32x16	30x1160	90
6			PT	32x16		
7	2500	80	Poly	32x8	20x2410	60
8			PT	32x8		
9		100	Poly	32x8	25x2410	75
10			PT	32x8		
11		120	Poly	32x8	30x2410	90
12			PT	32x8		



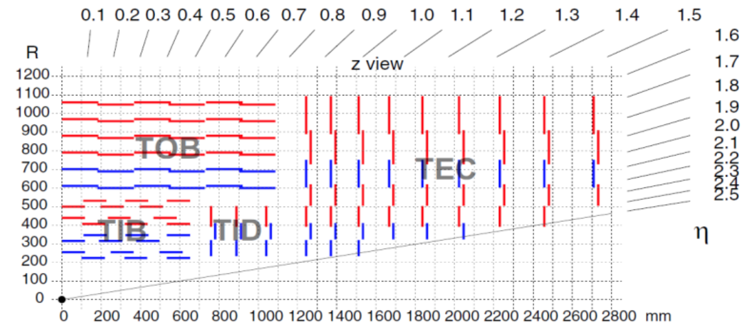


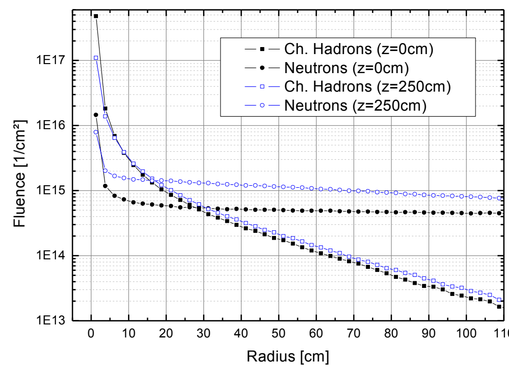
Irradiation fluences

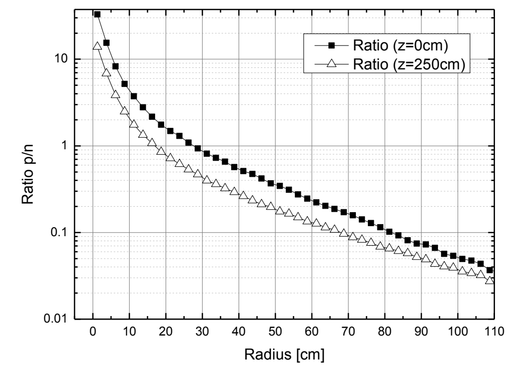
- Need to understand damage by neutron, charged hadron and mixed particle irradiation
- Fluences chosen for conditions at various radii
- Neutron fluence slightly adapted to get info on increasing neutron fluence
- Annealing steps chosen to cover initial short term and long term annealing:

Step	1	2	3	4	5	6	7
Temp. / ° C	60	60	60	60	80	80	80
Time / min	20	20	40	76	15	30	60
∑t@60° C / min	20	40	80	156*	312	624	1248
∑t@20° C / d	4.5	8.1	15.6	31.8	92.8	243	496

* 156min at 60°C ~ 15min at 80°C





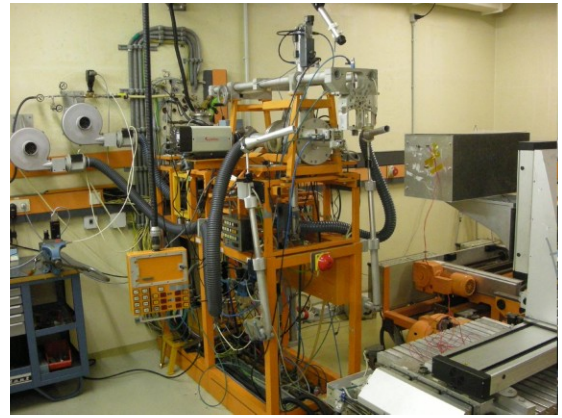


	z=0cm			z=250cm		
Radius	Ch. Hadrons	Neutrons	Ratio	Ch. Hadrons	Neutrons	Ratio
40cm	2,8	5,2	0,54	3,4	12,2	0,28
20cm	9,5	5,9	1,61	11,1	14,2	0,78
15cm	15,4	6,2	2,48	17,4	14,4	1,21
10cm	31,0	7,0	4,43	32,5	15,2	2,14
5cm	125,7	10,0	12,57	101,4	18,5	5,48

Radius	Protons	Neutrons	Ratio p/n	Total	Material
40cm	2,5	4	0,63	6,5	≥ 200µm
20cm	10	5	2,00	15,0	all
15cm	15	6	2,50	21,0	all
10cm	30	8	3,75	38,0	all
5cm	130	12	10,83	142,0	< 200µm

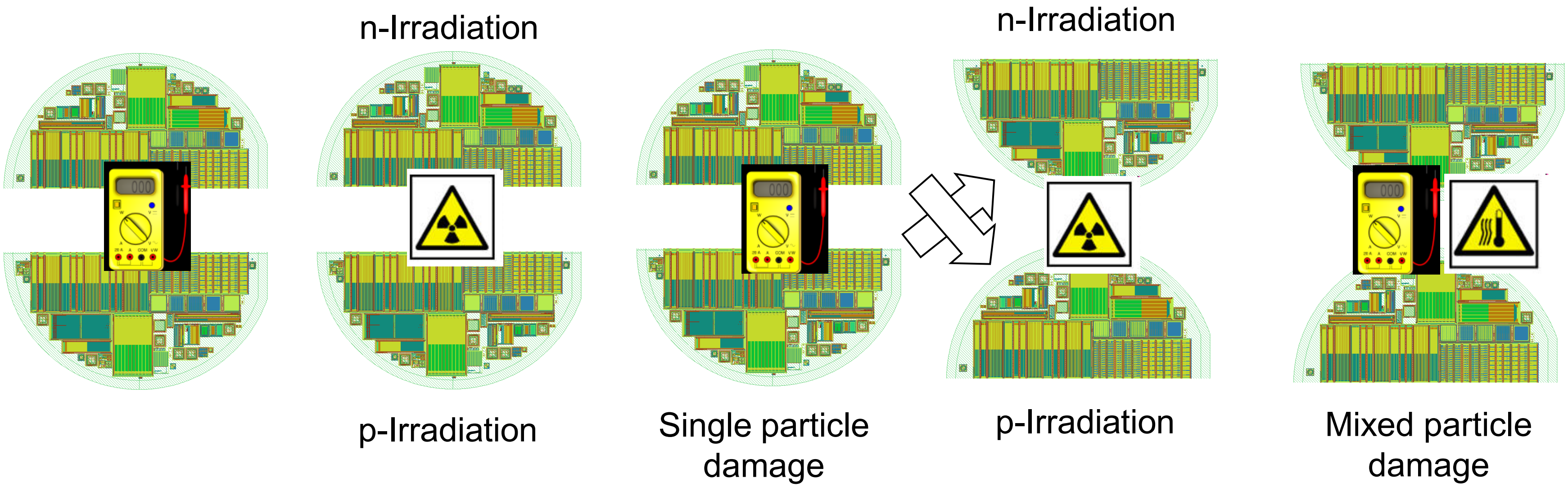
Irradiation sequence

- Initial measurements of all parts
- Irradiation with n/p
- Short annealing 10min @ 60°C
- Measurement of devices
- Irradiation with p/n
- Short annealing 10min @ 60°C
- Measurement of devices for several annealing steps

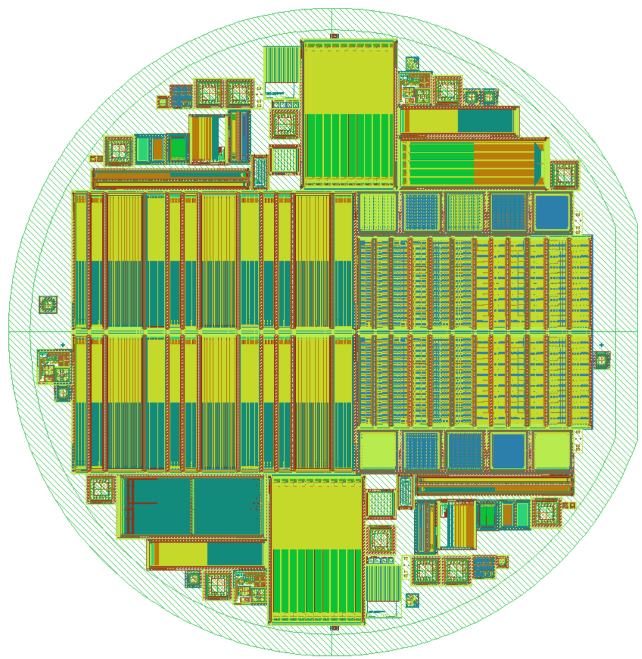


Proton cyclotron, KIT

TRIGA reactor, Ljuljana



17 institutes currently involved in HPK campaign



Size of logos has **no** meaning!!!

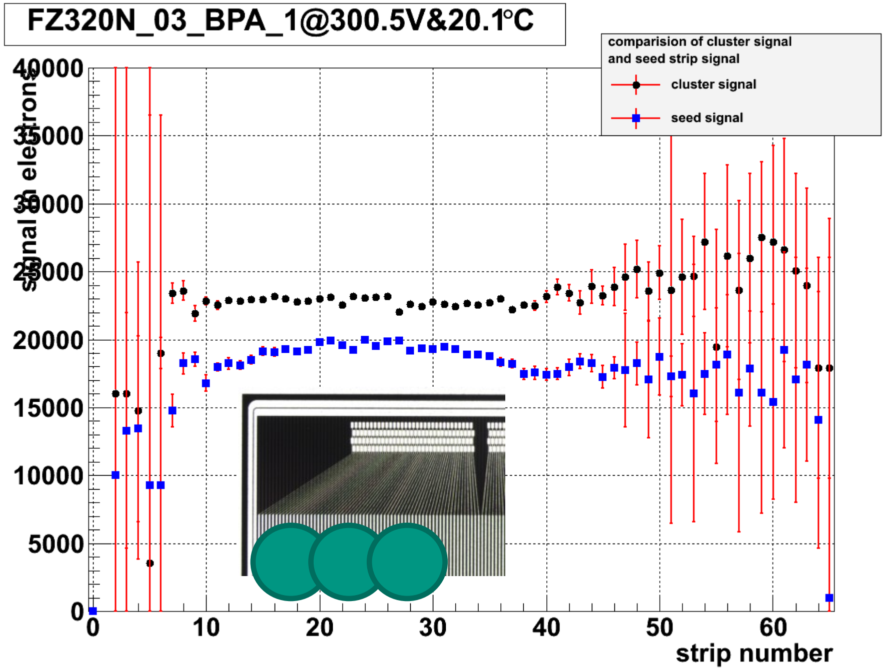
Latest activities

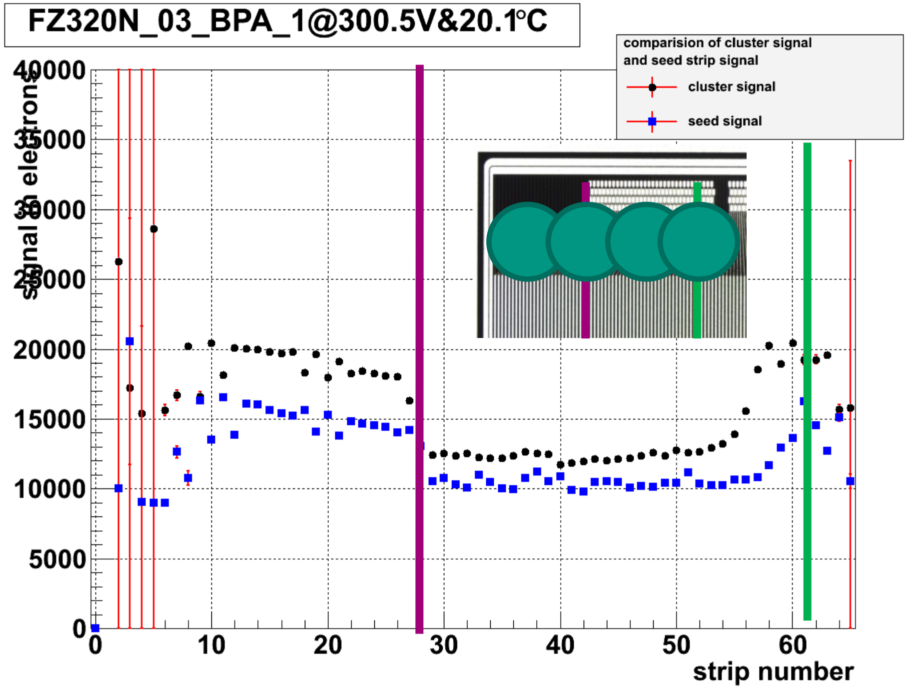
- Initial qualification of structures and materials ongoing
  - Most participating institutes perform measurements routinely
  - Measurement results are being uploaded to a dedicated database (essential for more than 5000 pieces!)
- Deep diffusion material investigated on diodes before and after irradiation (protons and neutrons each $1e14n_{eq}/cm^2$)
  - → Next talks by Joachim Erfle (UHH) and Robert Eber (KIT)
  - → Talk from Alexandra Junkes (UHH) yesterday
- Complete mixed irradiation scenario exercised on FZ part of Add_Baby, which will be used for dedicated Lorentz angle studies
  - → Talk by Andreas Nürnberg (KIT) at 15:00
- First beam test with MSSD and MPix structures successfully performed at FNAL
  - → Talk by Panja Luukka (HIP) at 14:40
- Special strixel read-out and PA on sensor being investigated (coupling of routing lines and PA layouts will also be studied on 2. metal wafers)

BACKUP

Baby_PA

- Signal almost homogeneous when charge is generated (by Sr90 source) on normal region
- Strong signal drop (~30%) when charge is generated in PA region (~2.5mm), where signal is lost to other channels due to the crossing read-out metallization





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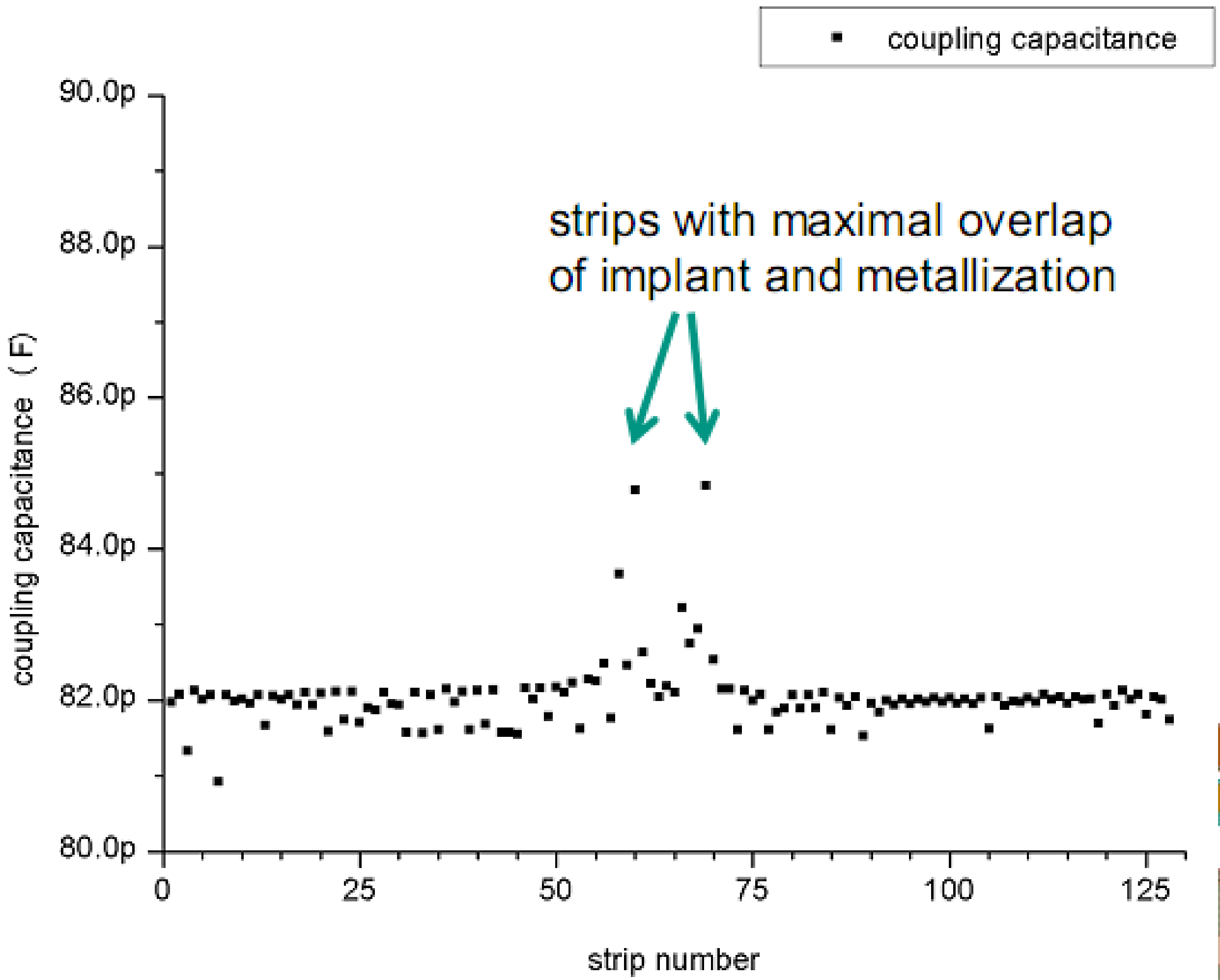
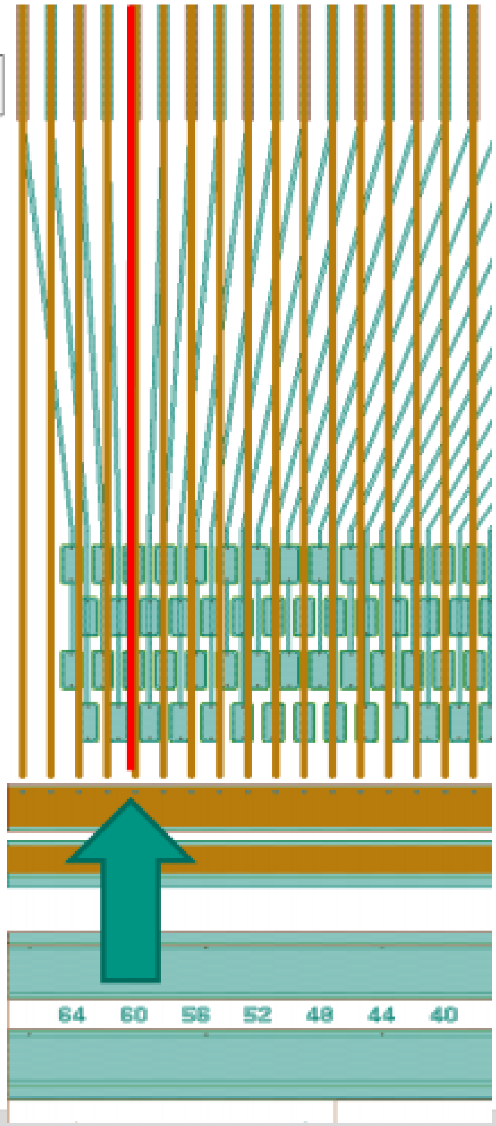
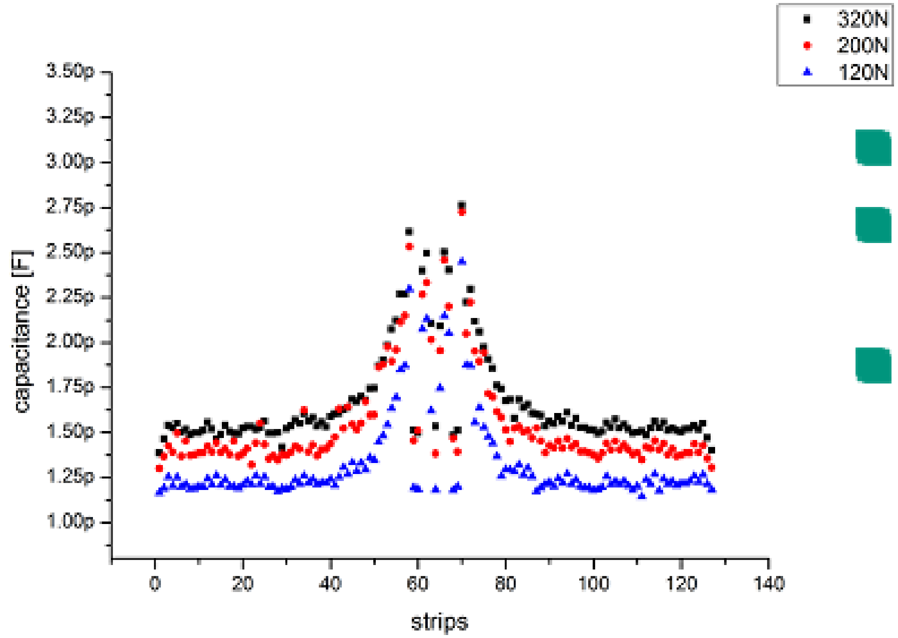
Coupling capacitance

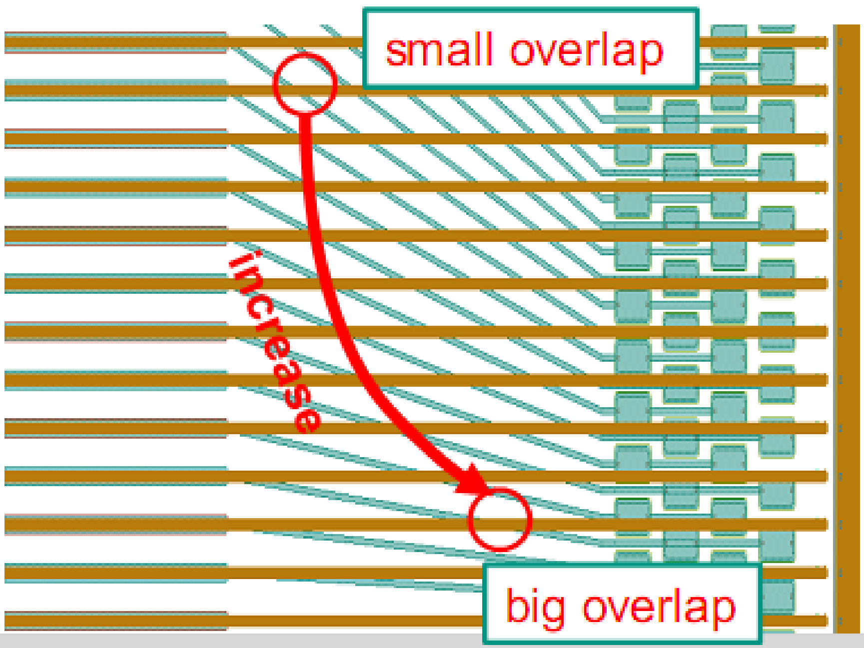




Interstrip capacitance



- Pictured: n-type sensors
- Other types (p/y) show the same behavior
- C_int increases with thickness

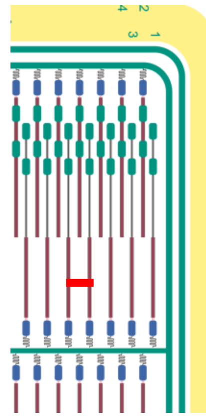
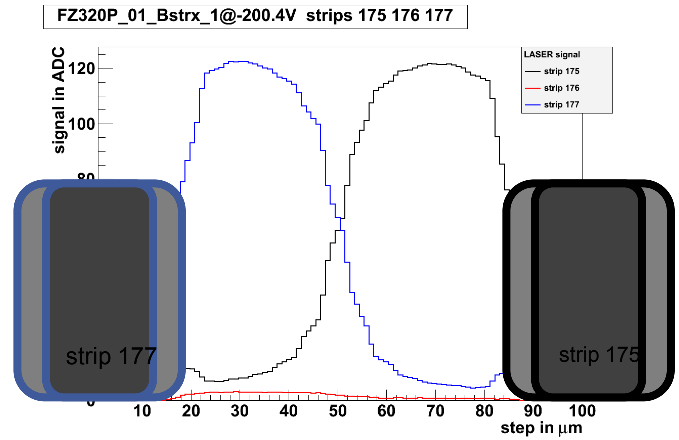


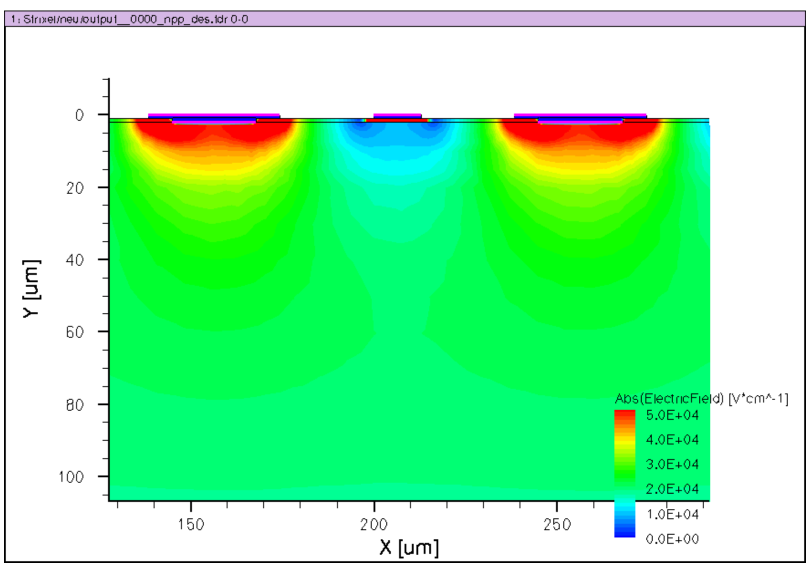
Possible explanation:

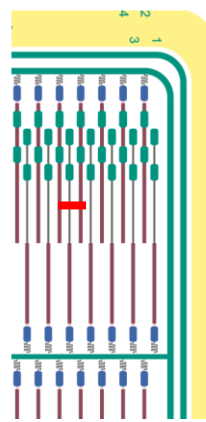
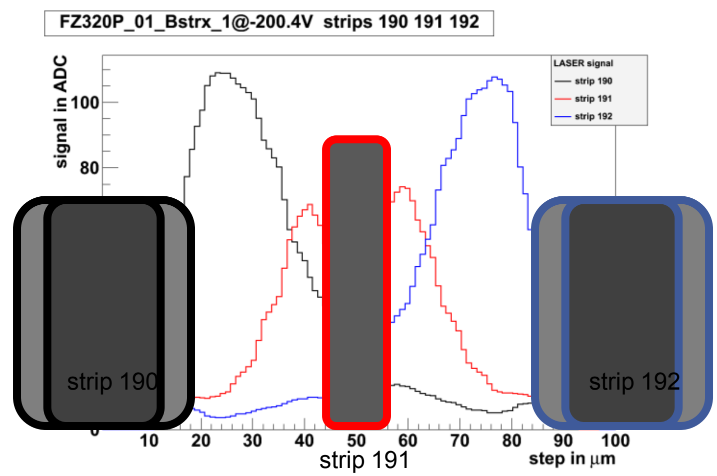
- additionally a parasitic capacitance over the coupling oxide is measured
- with increasing overlap of routing and implantation of adjacent strips the measured coupling capacitance increases

Baby_strixel

- Scan with IR laser between two strips
- Scan in far region shows no induced charge on near implantation
- Scan in near region shows a strong induced charge on read-out metal running between near implantation
- Signal is high enough to mimic charge generation in far region → more advanced cluster algorithm needed!



MSSD testing

- IV, CV and Cint on all 12 regions of sensor automatized by switching matrix and ready for cold measurements in insulated box
- Additional beta setups are being setup to measure S/N and charge sharing
- Available at Florence and CERN; FNAL setting up