Status of the Barrel Strip Sensors
Choice of Technology and Qualification

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HIC for FAIR
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JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

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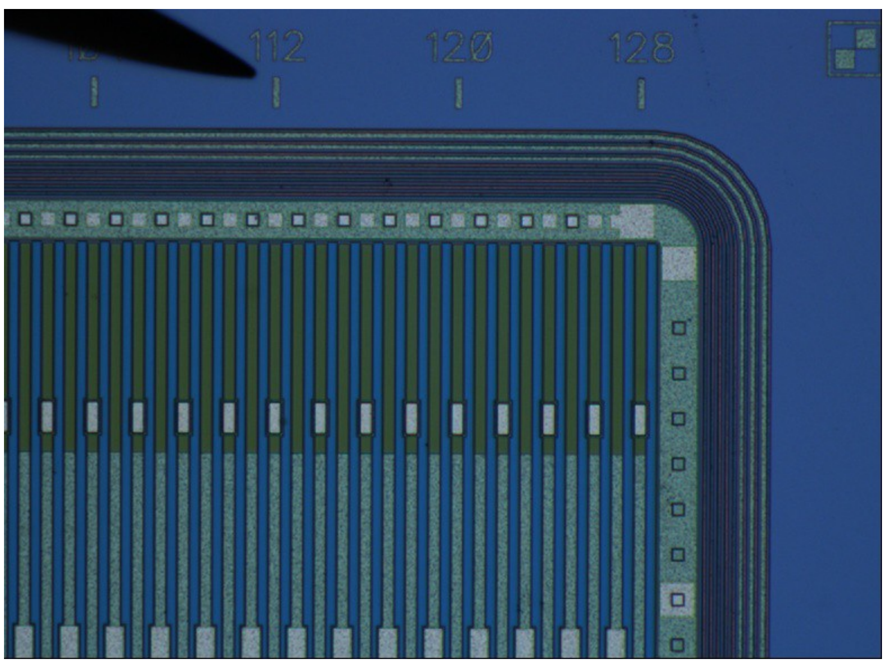
Prototype Sensors

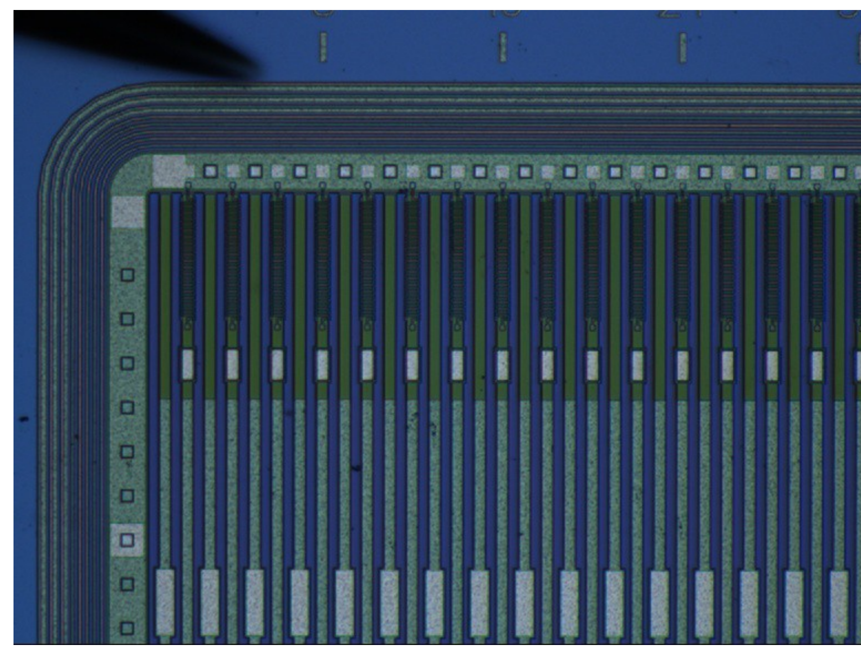
Prototyping Runs

Run	Year	Biasing	Resistivity	Vdep	Thickn.
CIS 01	2010	punch-through	5.2 kΩ cm	50	285+-10
CIS 02	2013	poly-Si	2.8 kΩ cm	100	285+-10

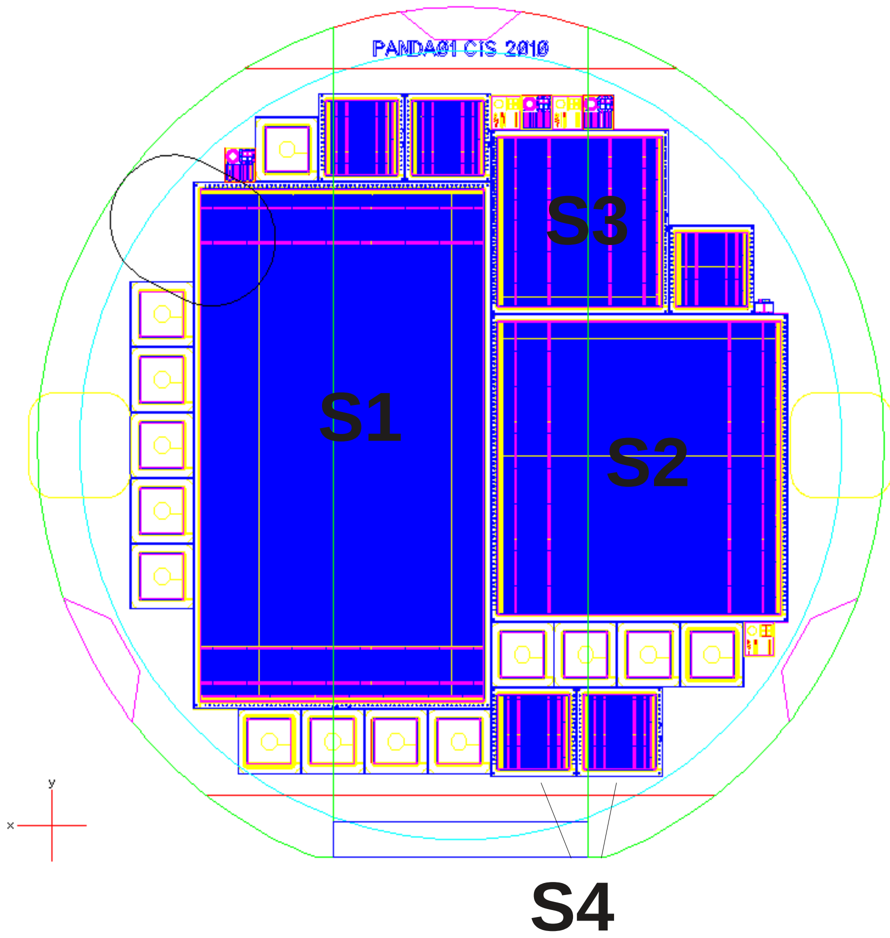
CIS01

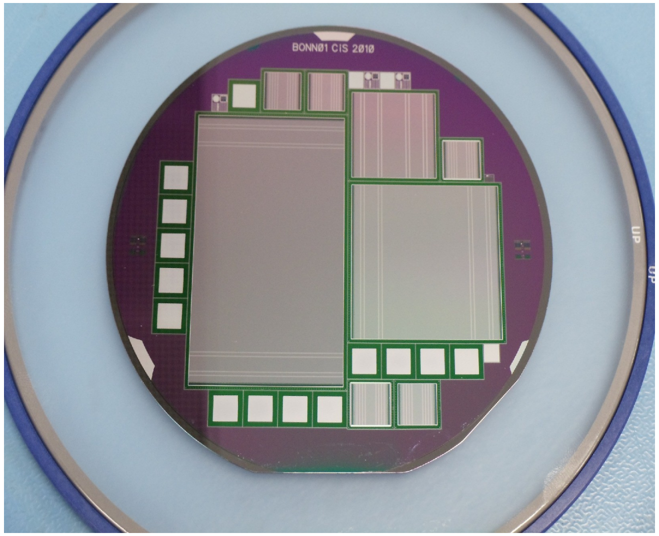


CIS02



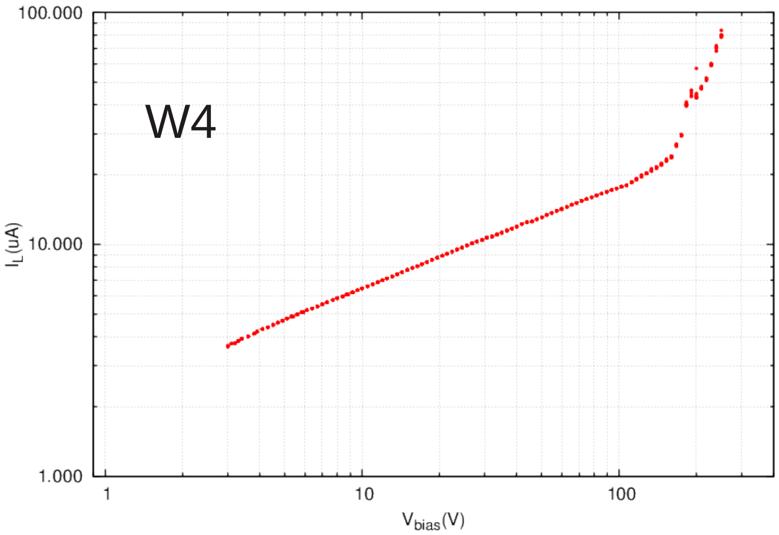
Prototype Sensors

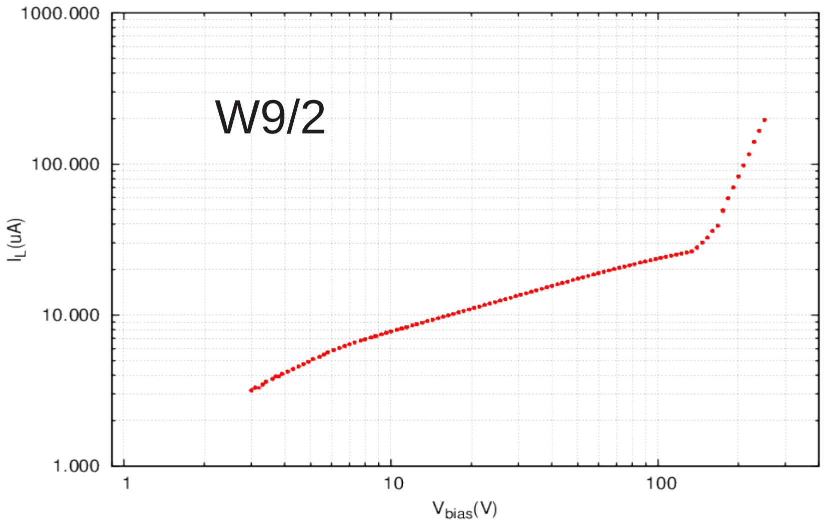


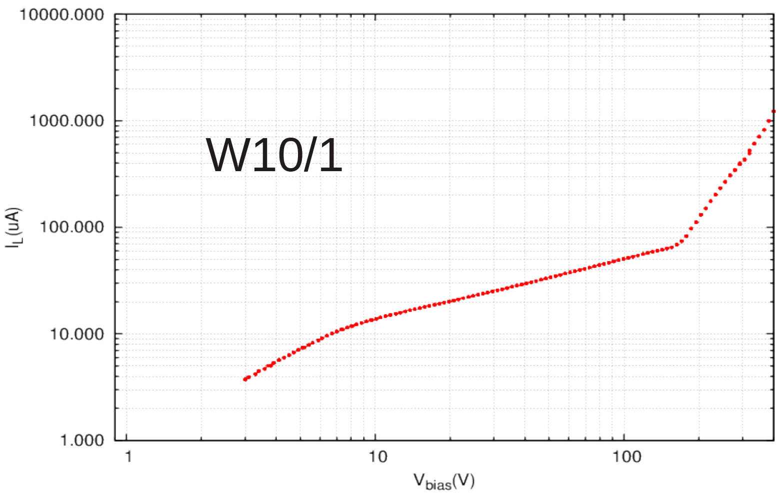


S1			
	p-side/n-side strips	896/512	
	pitch/width	65/30	µm
	active area	58.275×33.315	mm^2
S2			
	p-side/n-side strips	512/512	
	pitch/width	65/30	µm
	active area	33.315×33.315	mm^2
S3			
	p-side/n-side strips	384/384	
	pitch/width	50/20	µm
	active area	19.230×19.230	mm^2
S4			
	p-side/n-side strips	128/128	
	pitch/width	65/30	µm
	active area	8.355×8.355	mm^2

Prototype Sensors







Problem with CIS 01 Sensors:
Early Breakdown

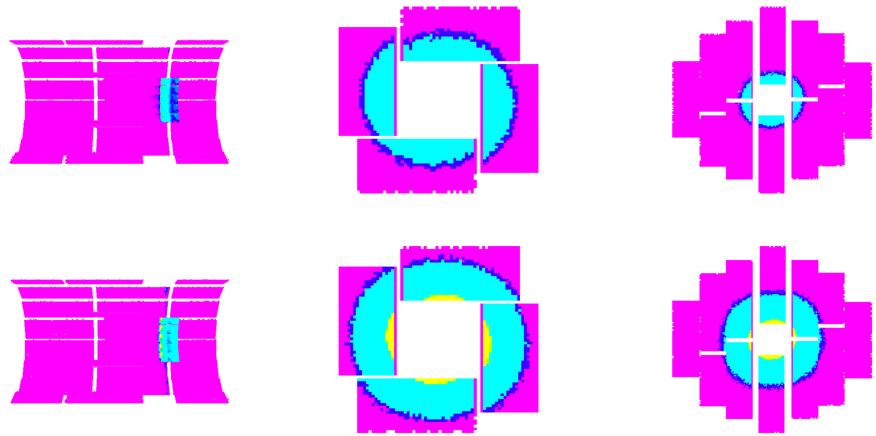
- Many sensors show breakdown at <250V
- Depletion behavior at higher irradiation doses not accessible → no QA
- CIS 02: Breakdown > 460V → ok

Radiation Hardness

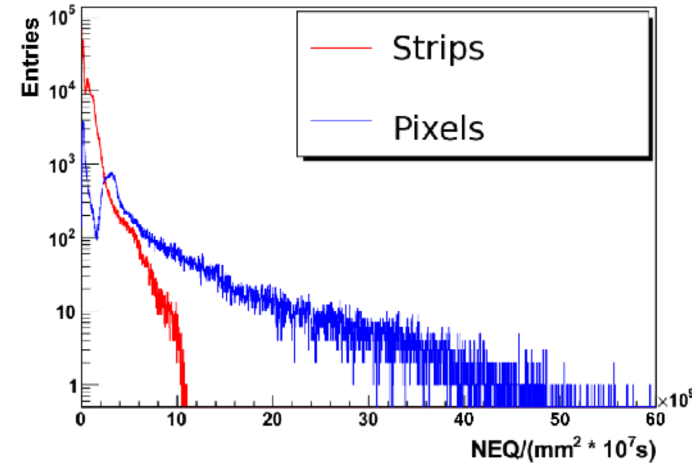
Pixel barrel/disks

2GeV

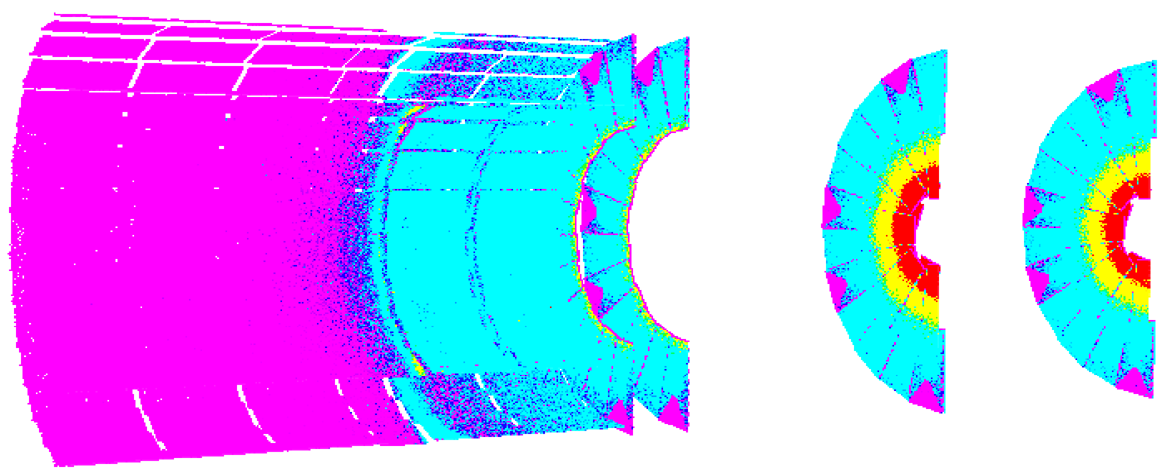
15GeV



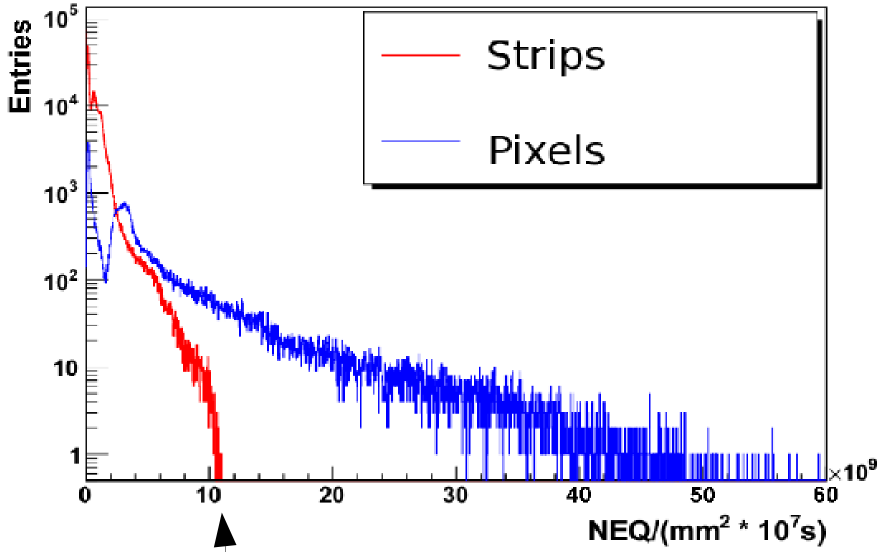
$\bar{p}p$ DPM calculations
(Tobias)



Strip barrels/disks
@ 15GeV



Radiation Hardness



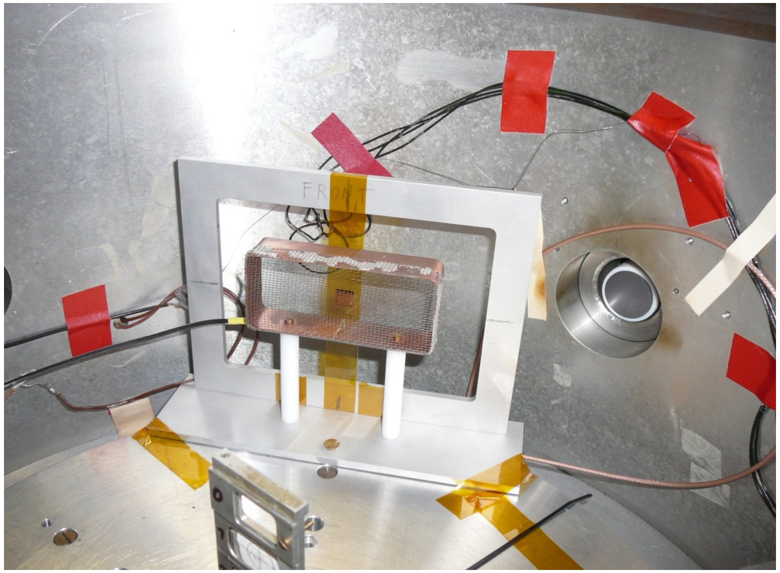
~1.1 10^{10} neq/(mm² 10^{7}s)

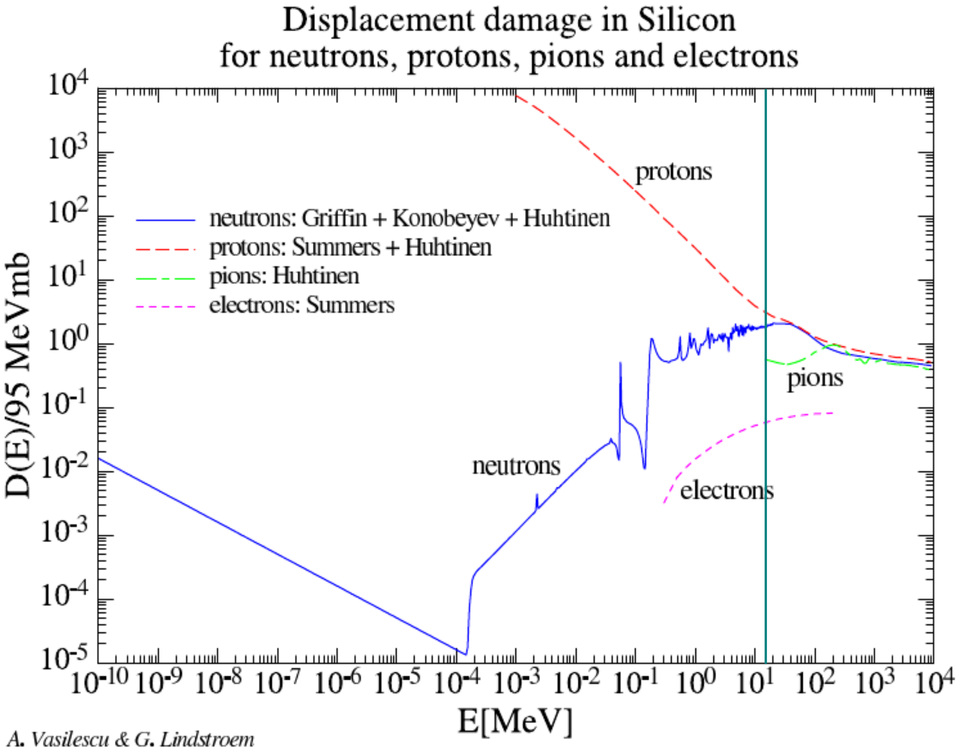
corresponds to ~3.5 10^{13} neq

- for 10 years operation
- 100% duty cycle

Sensor Irradiation

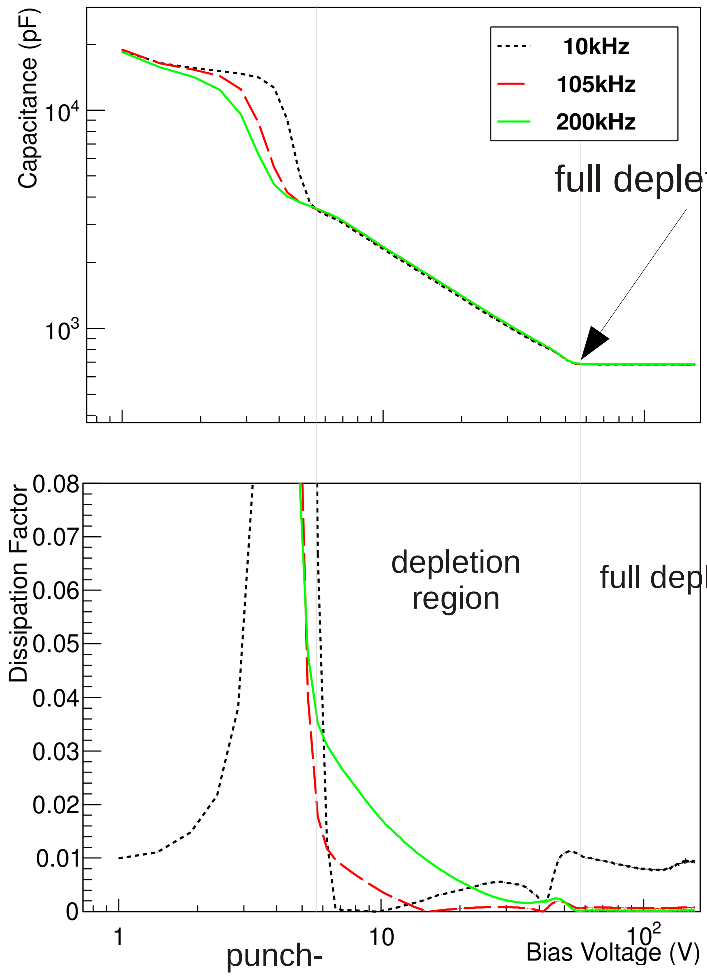
Proton irradiation at Bonn isochrone cyclotron, T=14 MeV

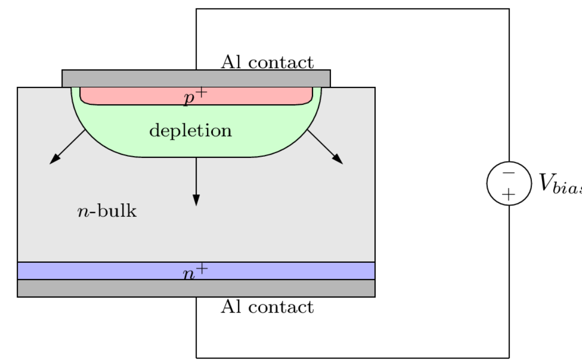


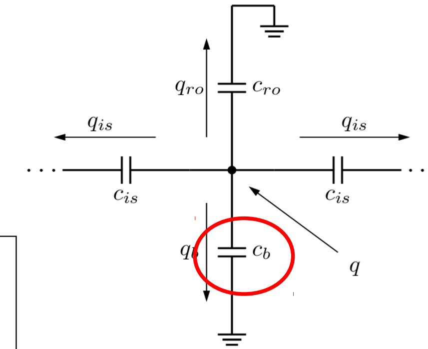


14 MeV protons: D ≈ 3

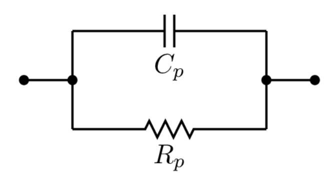
back side capacitance







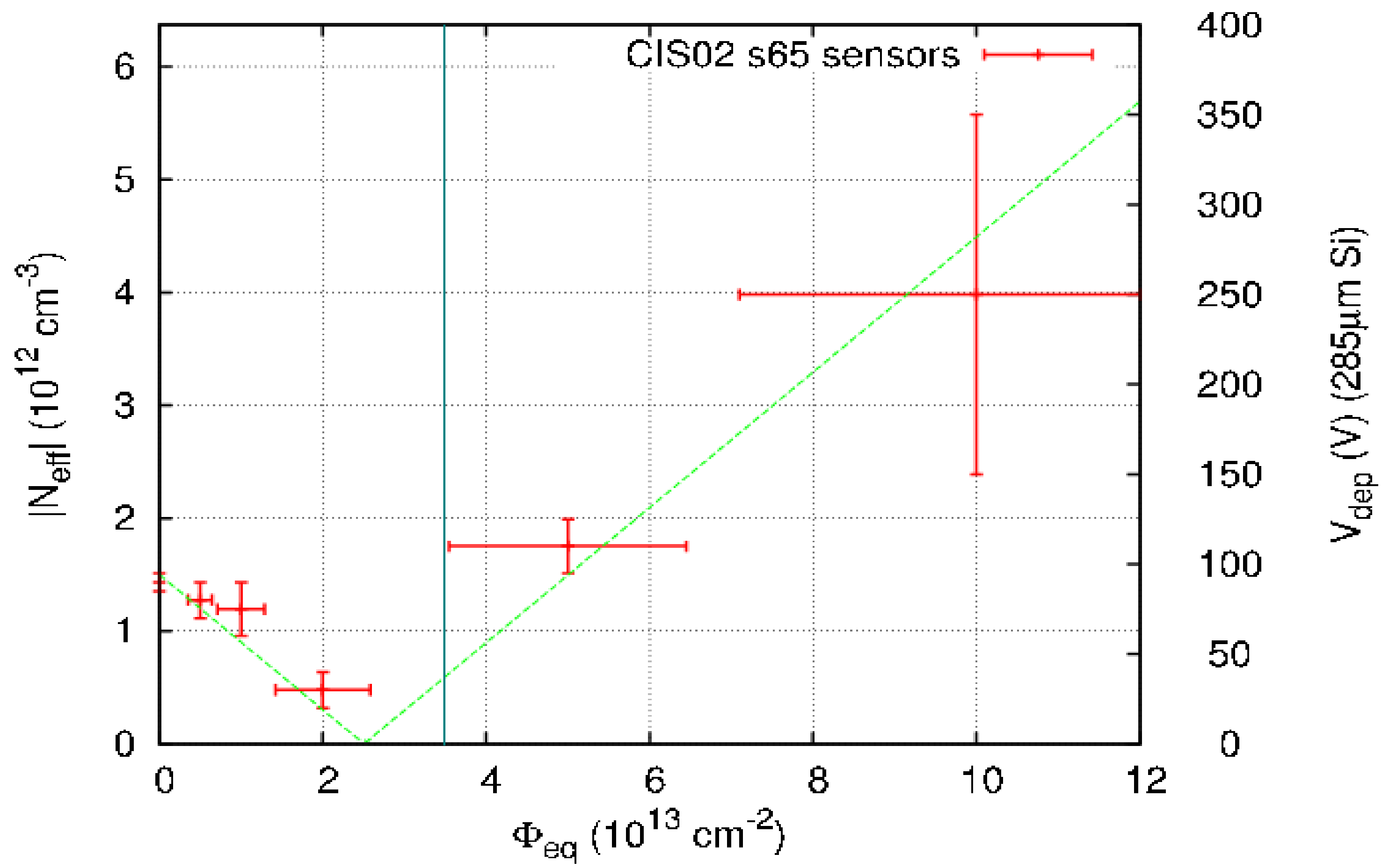
complex impedance Z



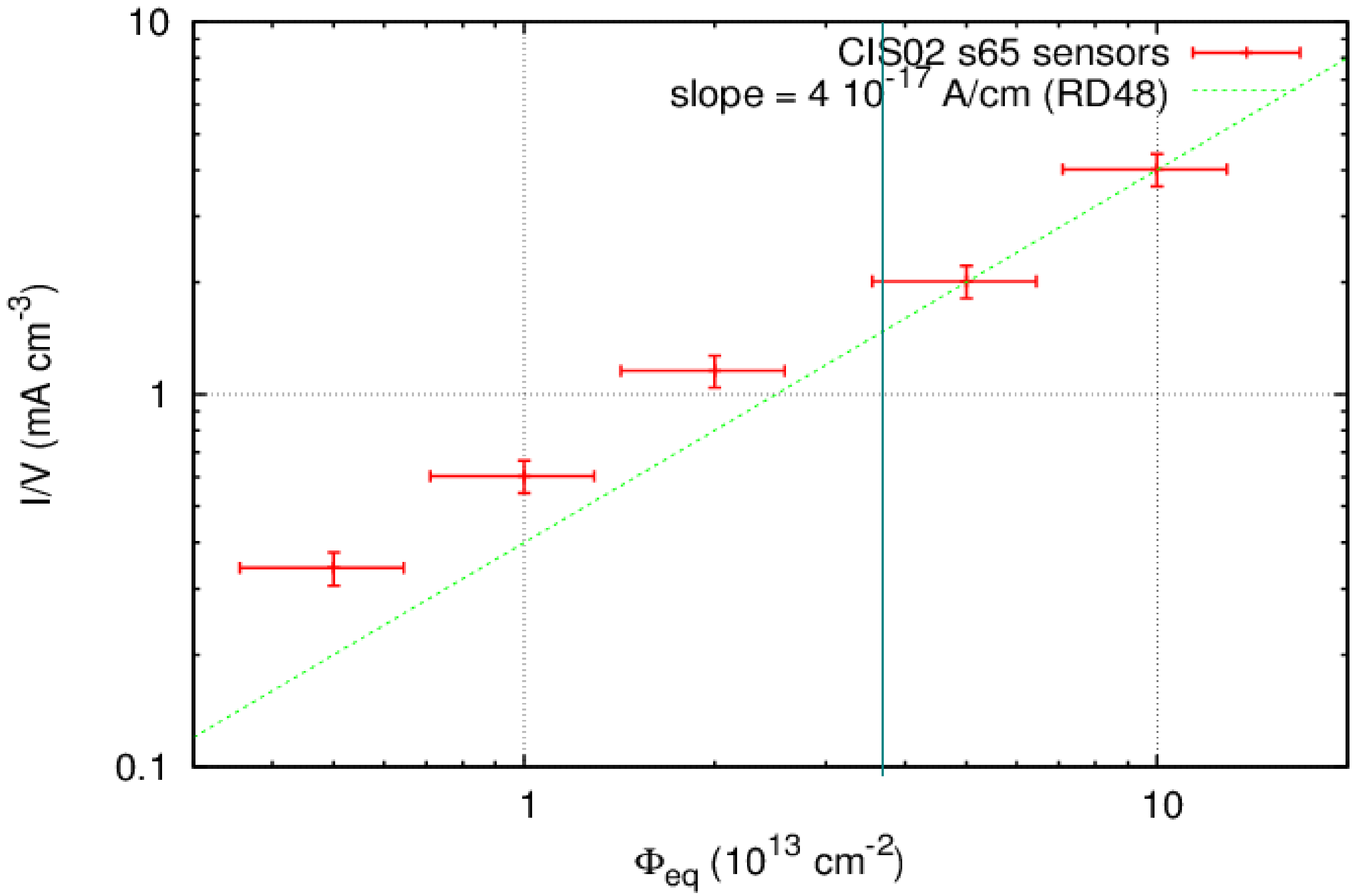
$$D = \tan\delta = \frac{\mathrm{Re}\, Z}{\mathrm{Im}\, Z} = \frac{1}{\omega C_p R_p}$$

Handle on depletion behavior of sensors

Radiation Hardness

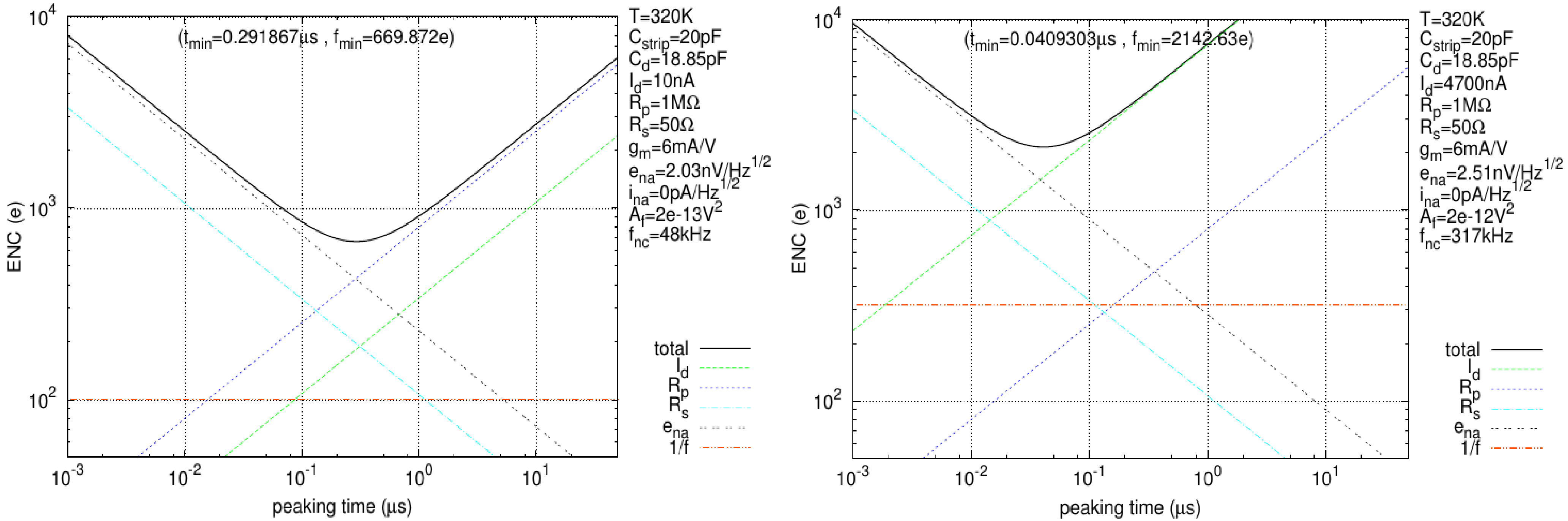


Radiation Hardness



Radiation Hardness

Total Noise: $$q_n^2 = \sum_i q_{n,i}^2$$



$$q_{n_{I_L}}^2 = A \cdot 2eI_L \cdot \tau$$

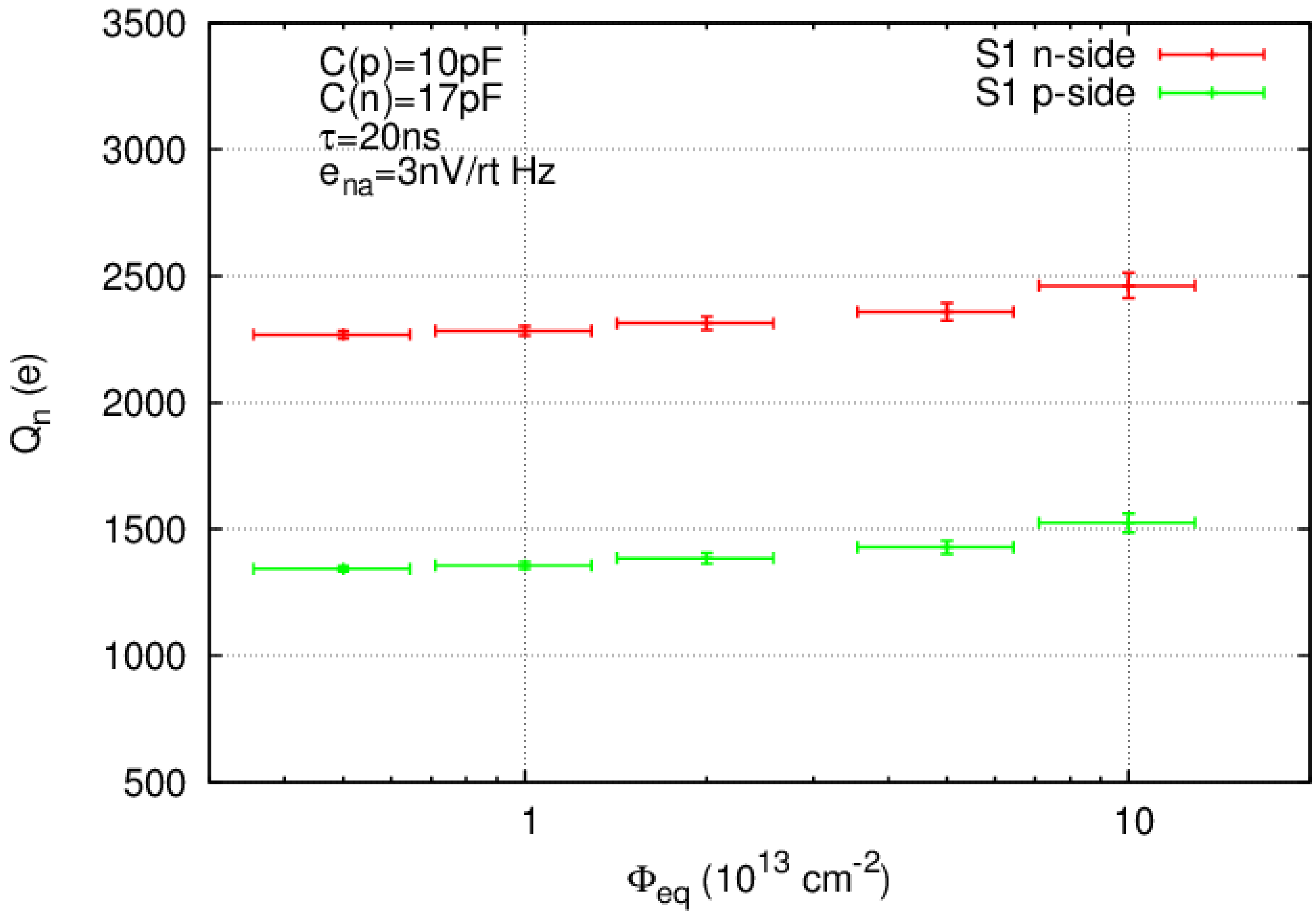
$$A \approx 1$$ (Shaper Constant)

$$q_{n_A}^2 = A \cdot e_{na}^2 \cdot \frac{C_{strip}^2}{\tau}$$

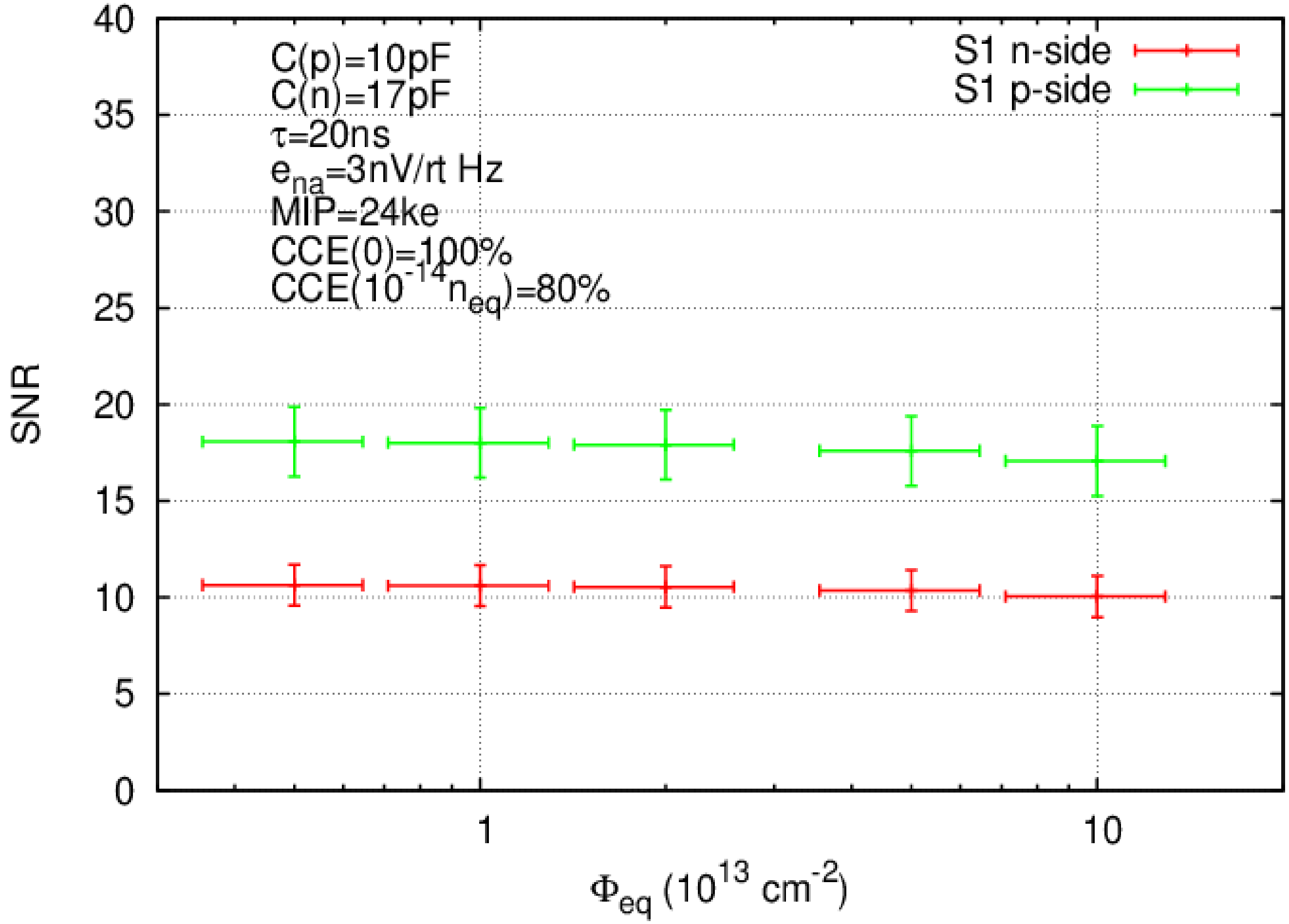
Radiation Hardness

PASTA FE ASIC:

- 20ns shaping in analog stage
- Baseline noise determines overall noise figure (ToT time jitter negligible)

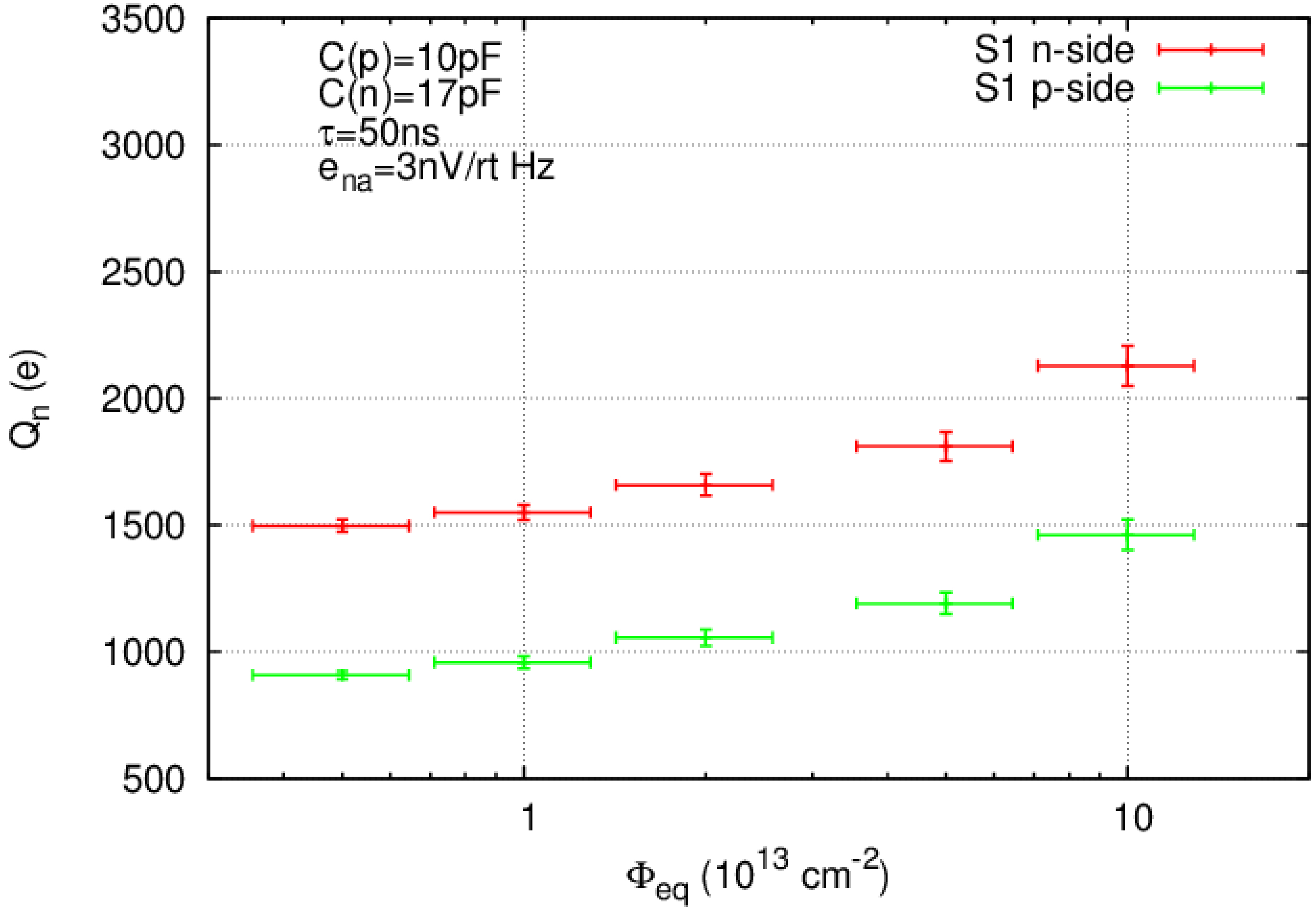


Radiation Hardness

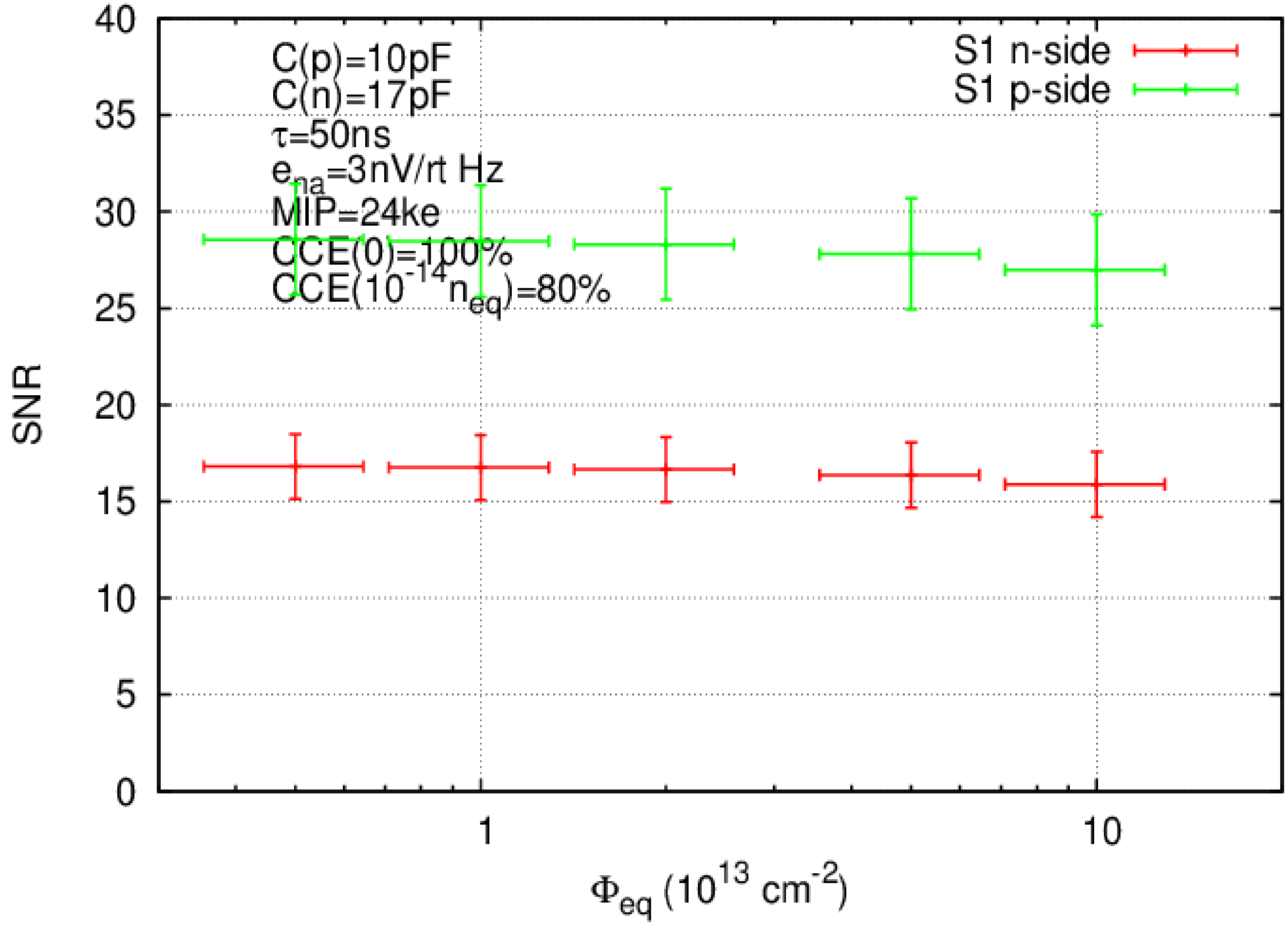


Radiation Hardness

If analog shaping time constant was 50ns



Radiation Hardness

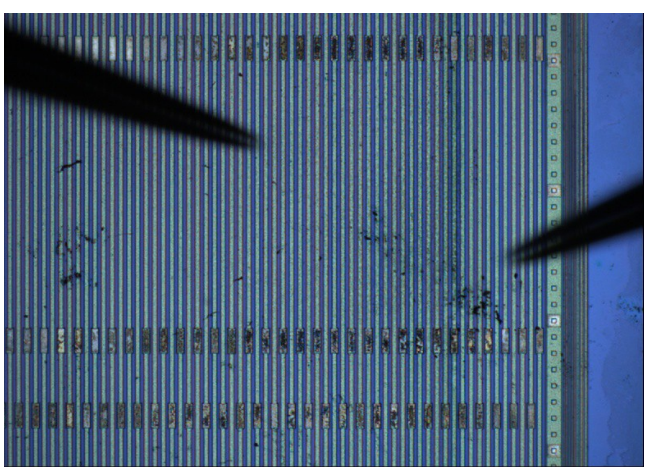


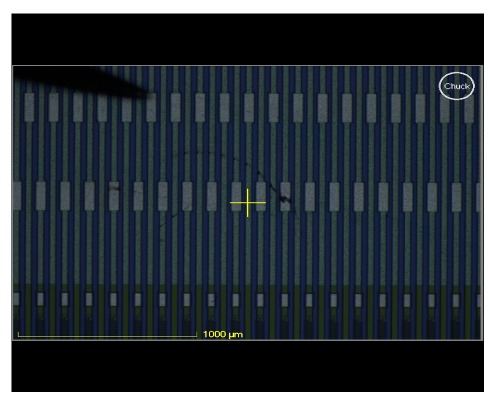
Spatial Resolution

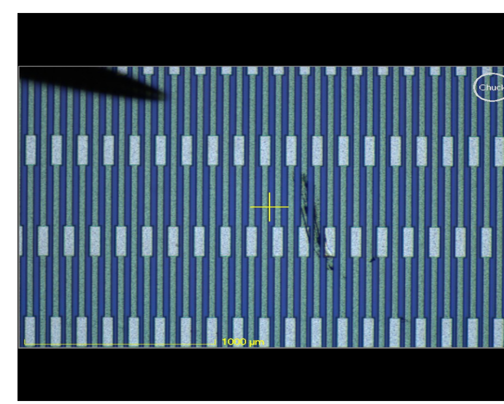
r/o pitch (µm)	worst RMS resolution $\frac{p}{\sqrt{12}}$(µm)	nr. of intermediate strips	SNR	spacial resolution RMS (µm)
65	18.8	0	10	16.09 ± 0.02
			16	13.08 ± 0.02
			25	10.63 ± 0.01
130	37.5	0	10	34.70 ± 0.05
			16	31.64 ± 0.04
			25	29.28 ± 0.04
130	37.5	1	10	24.92 ± 0.03
			16	16.13 ± 0.02
			25	12.11 ± 0.02
195	56.3	2	10	44.52 ± 0.06
			16	26.68 ± 0.03
			25	13.84 ± 0.02
260	75.1	3	10	54.62 ± 0.07
			16	35.92 ± 0.05
			25	18.11 ± 0.02

Next Steps

- Work out target specifications for sensor qualification with CIS (yield: >75% at 10 batch prod. run, on-site probing)
- Define set of additional (complementary) full sensor / wafer tests to be done in Giessen
- Set up optical inspection system with pattern recognition algorithms
- Set up QA database for sensor parameters, measurements and histories

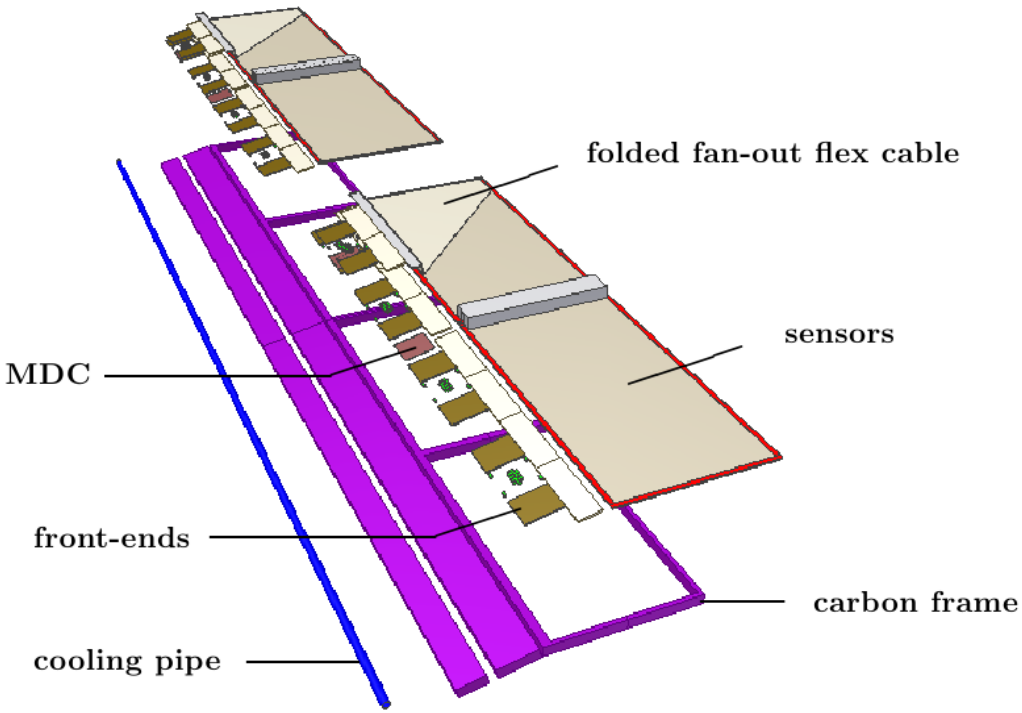


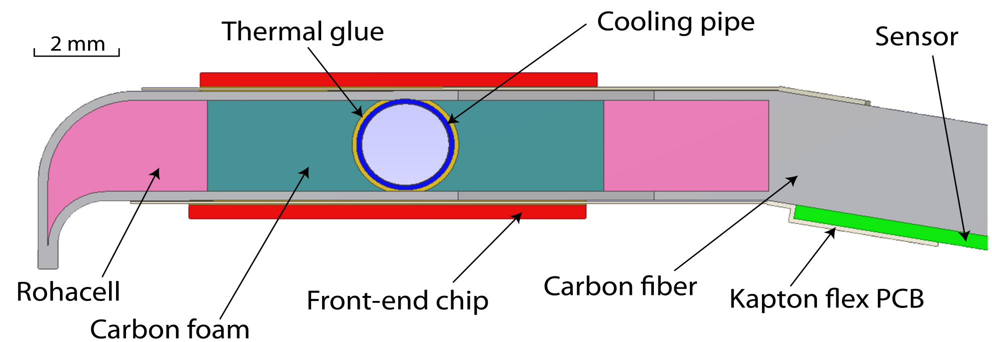


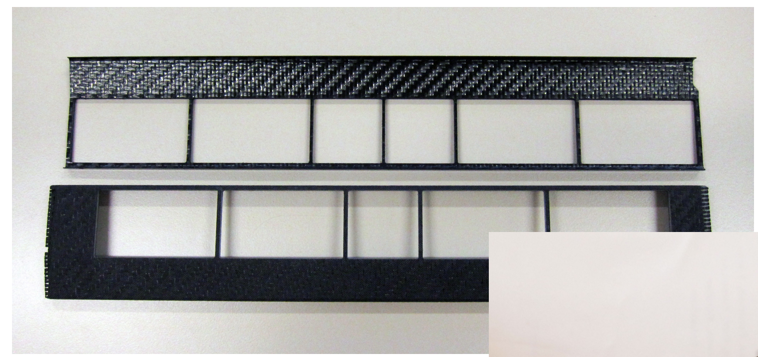


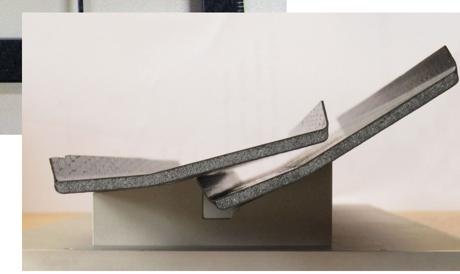
Backup Slides

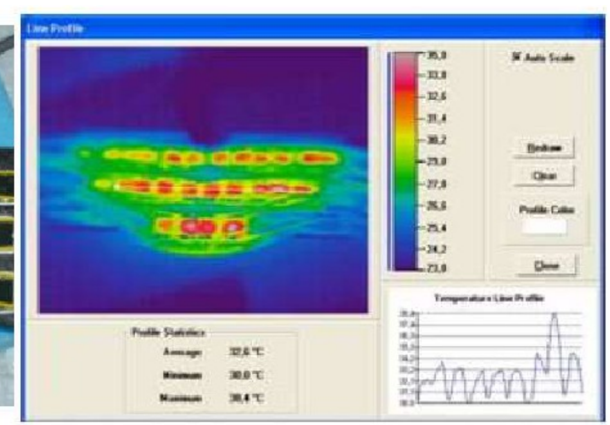
Strip Sensor Staves

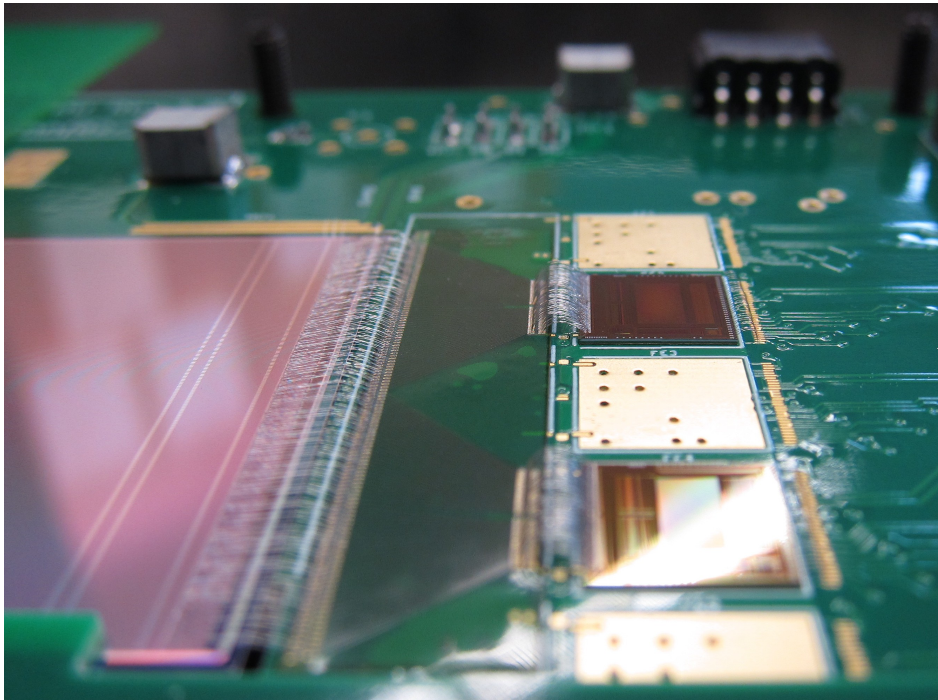




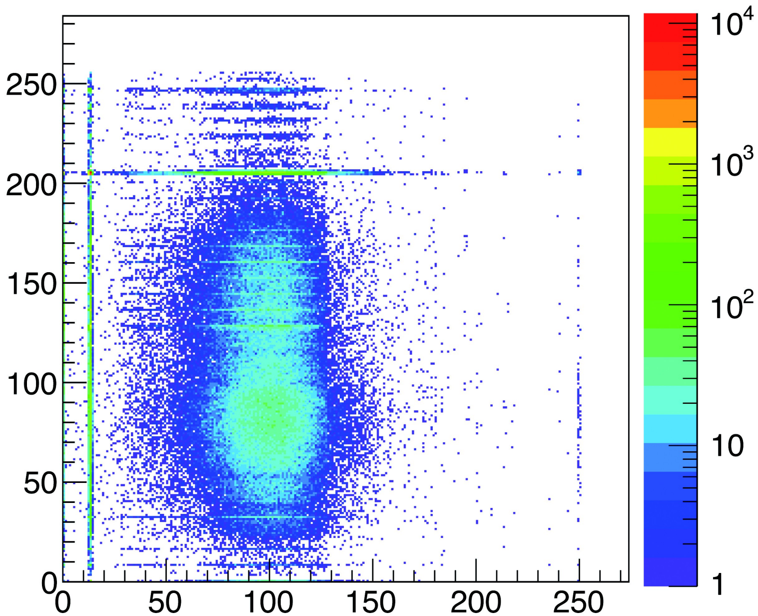


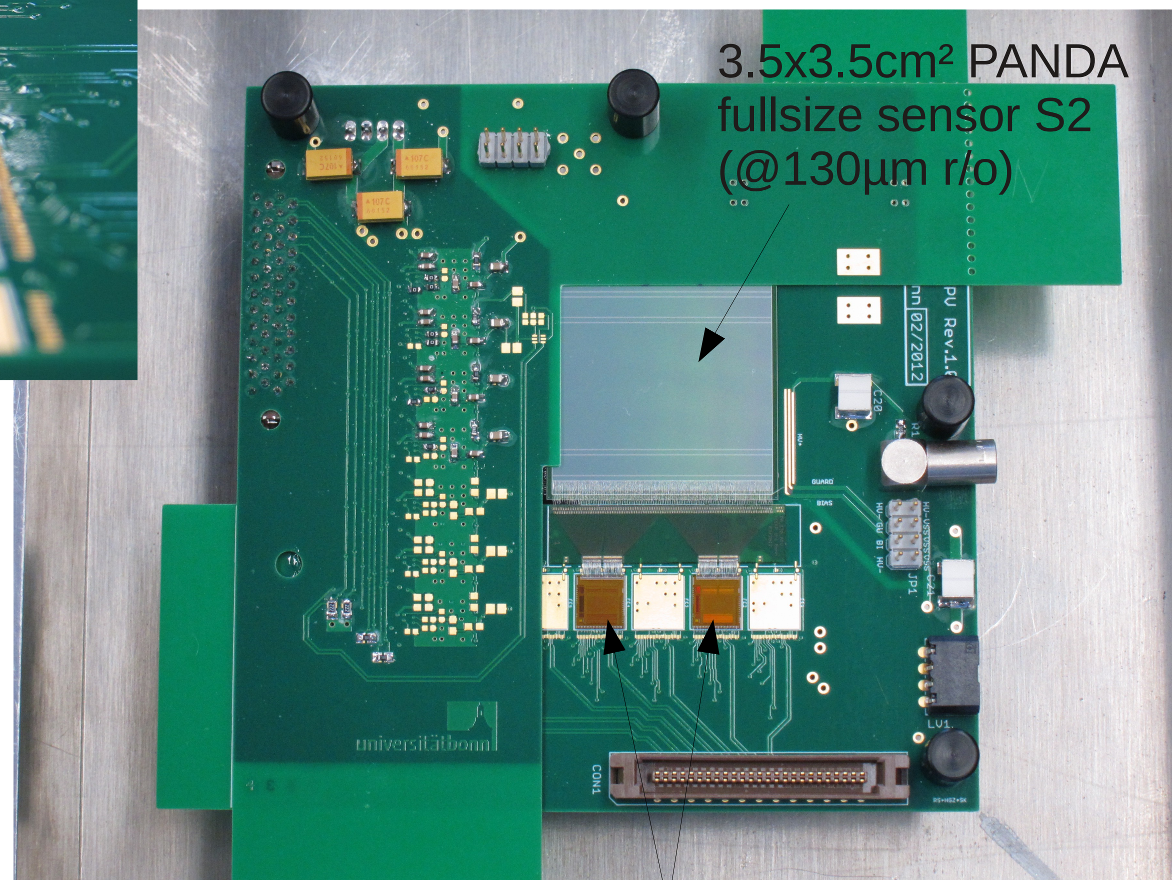






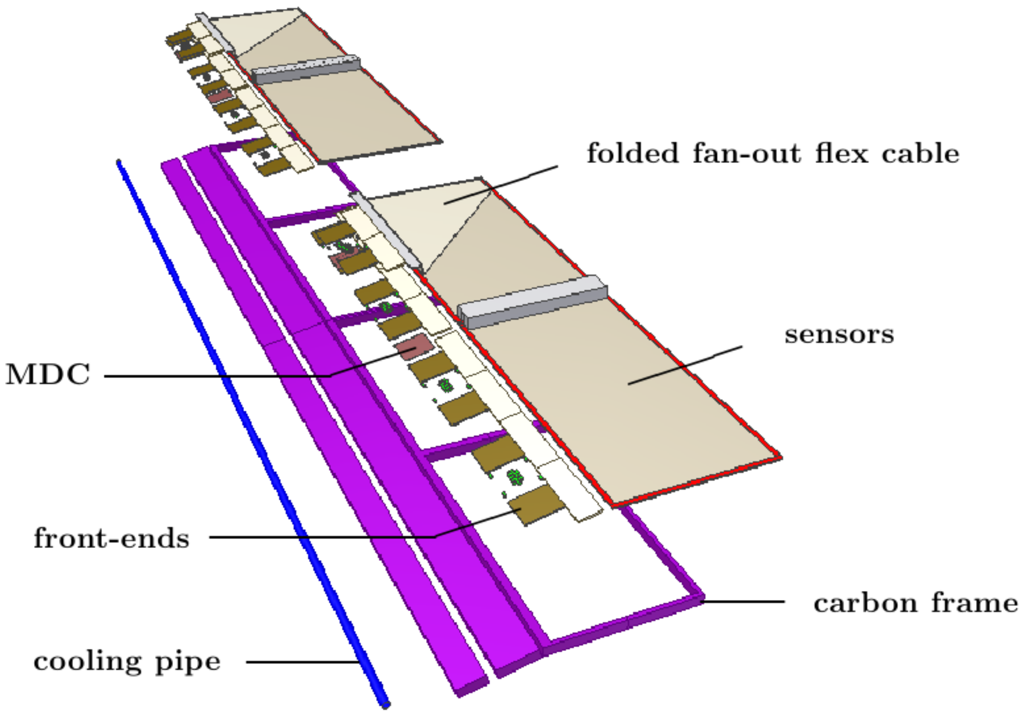
Flex-PA and squared sensor assembled on a test board and successfully tested at SPS, CERN (September 2012)

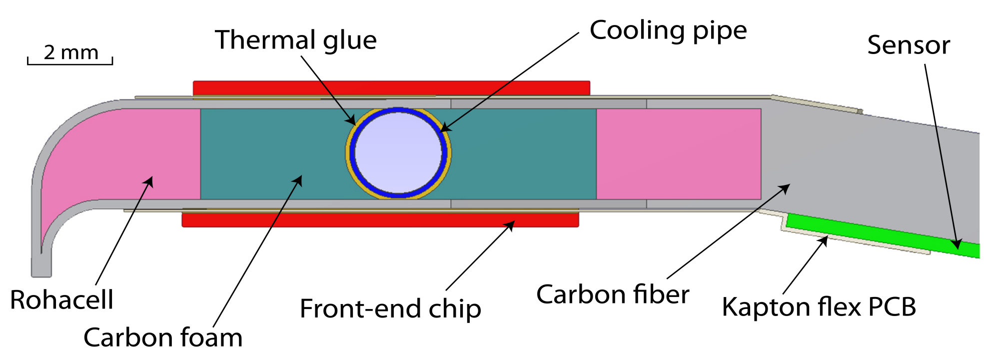




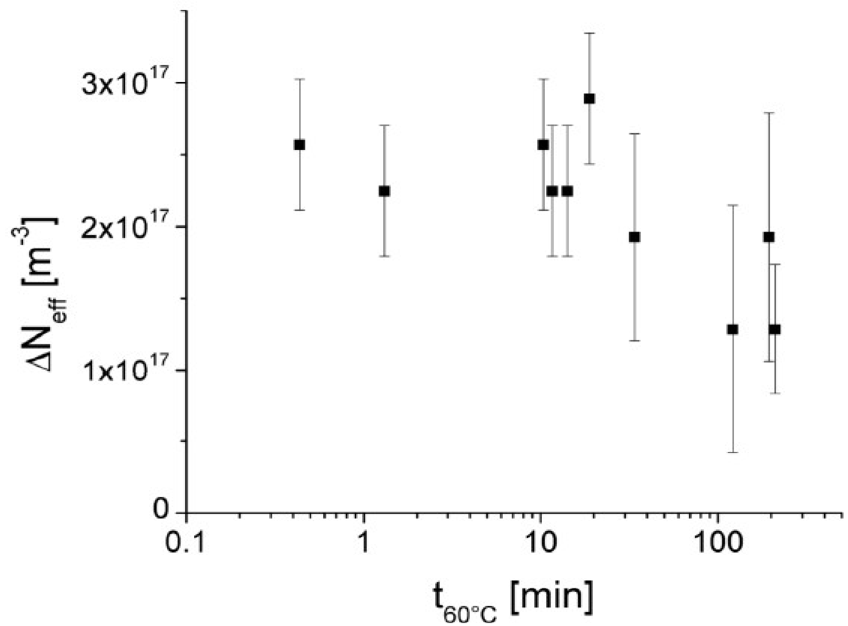
APV25 Front-ends

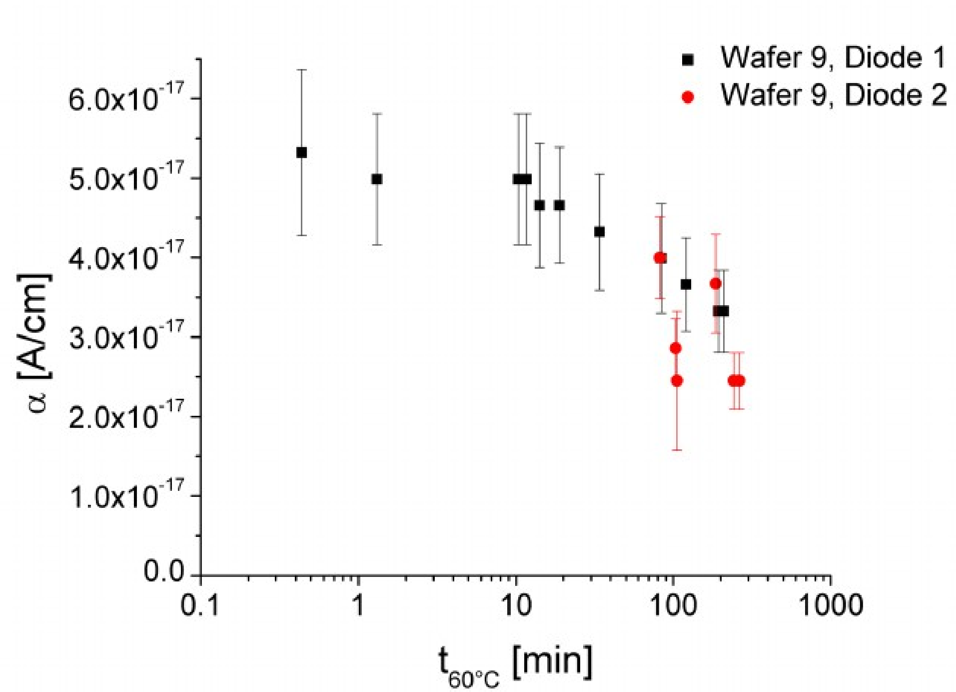
Grounding of Carbon Staves





Thermal Annealing





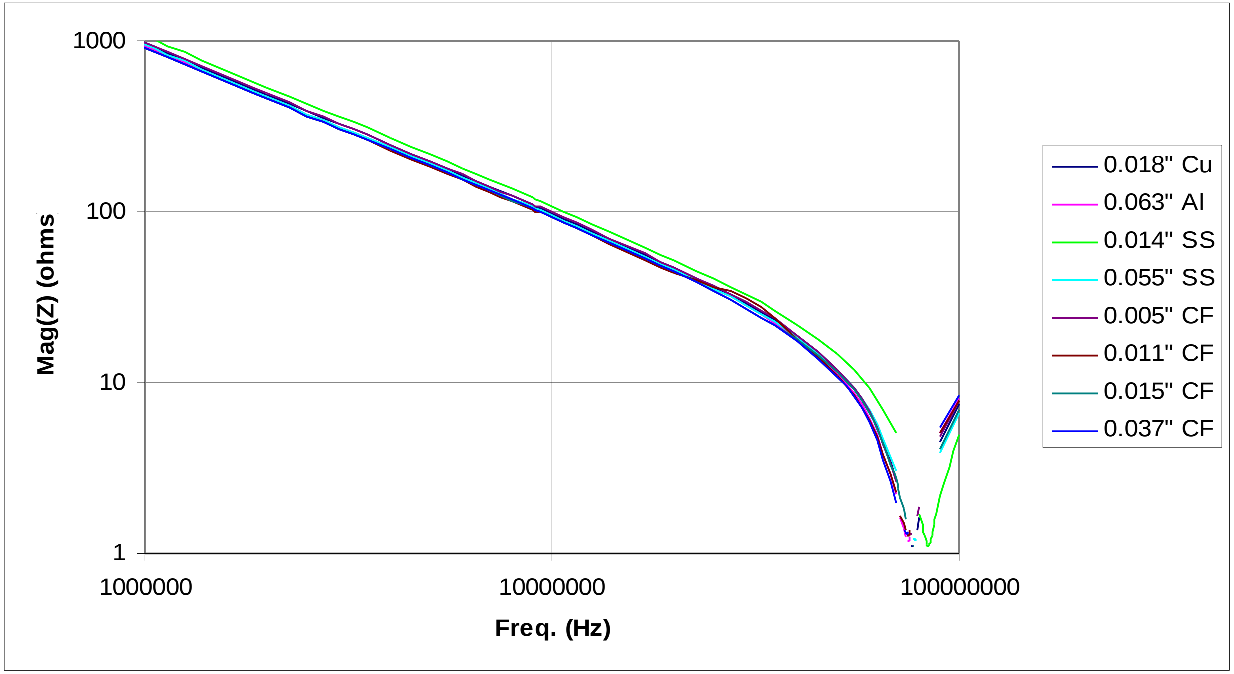
Partial recovery of properties through thermal ordering effects = Annealing

Grounding of Carbon Staves

- Current pitch fabrication techniques that produce carbon fiber with ultra-high modulus (~1000 GPa) also yield
  very low resistivity (~100 μΩ•cm)

- Floating conductors tend to strongly couple to silicon sensors

- Very nasty source of noise, esp. in densely packed structures of high impedance and highly sensitive sensors (lose coupling)

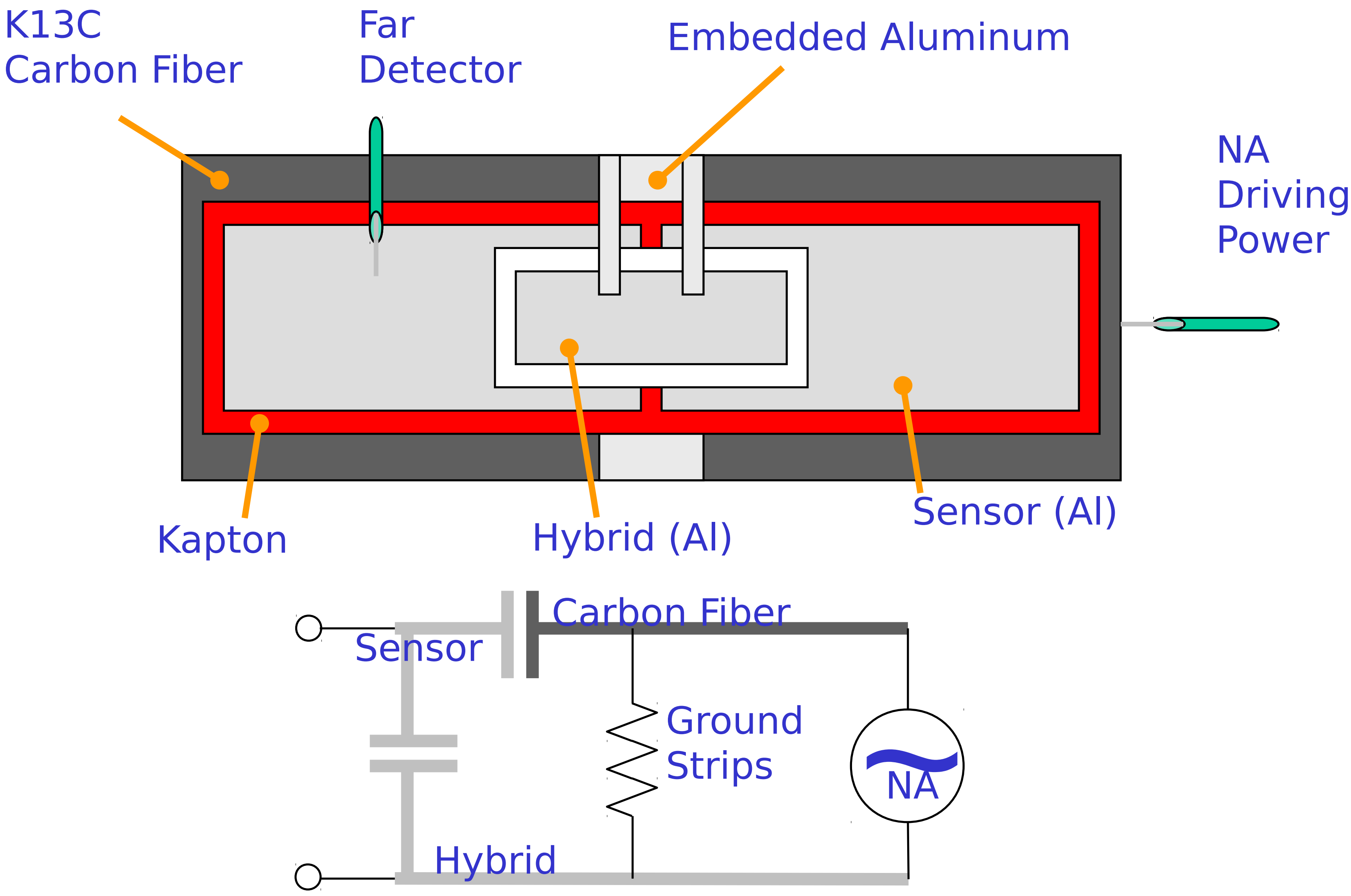


Strip Sensor Staves

D0:

- Electrical coupling of reference ground conductor to carbon stave is **crucial**
- Embed Al foils into carbon structure
- Al foil coverage of 20...25% of the carbon stave
- Oxidation and fragility of Al foil are critical

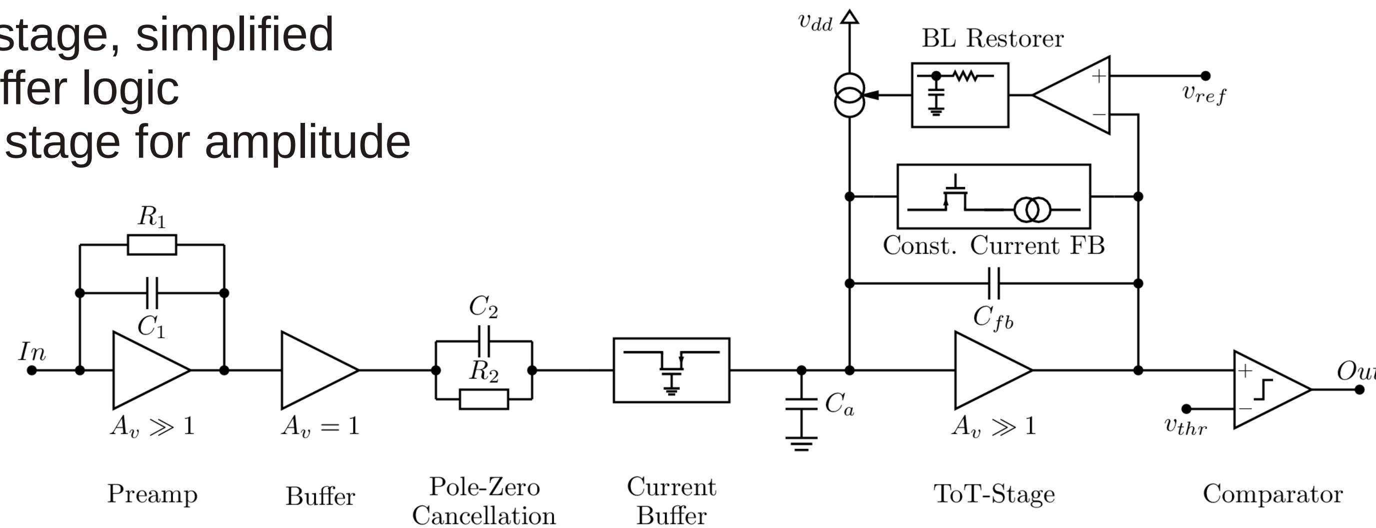
D0 L0/L1 Mock-up



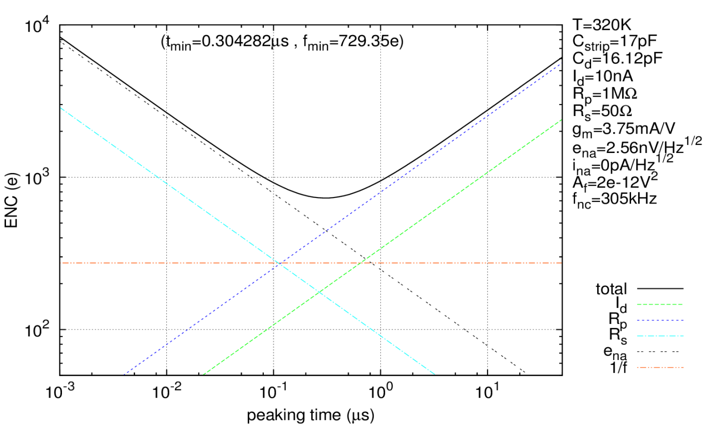
Strip Front-end

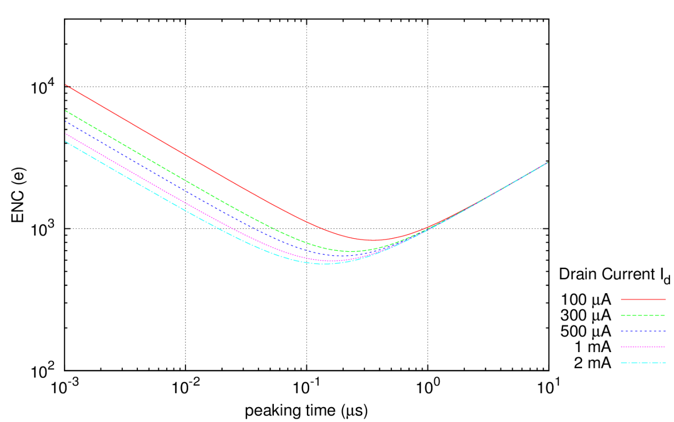
- design of new selftriggered FE based on ToPIX pixel FE started in 2012
- modified analog stage, simplified single column buffer logic
- ToT+HiRes TDC stage for amplitude measurement

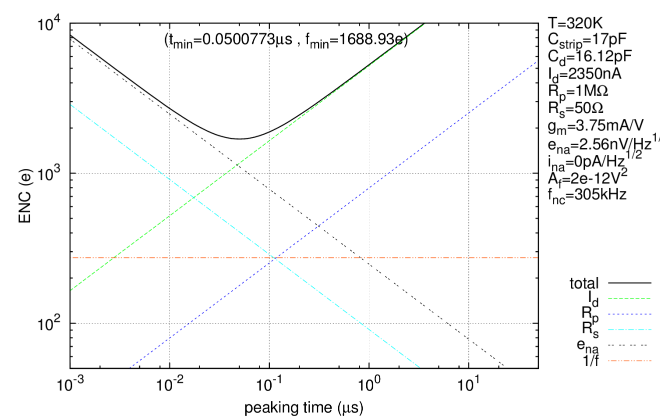
INFN Torino, JLU Giessen, IKP Jülich



Preamp. Noise:







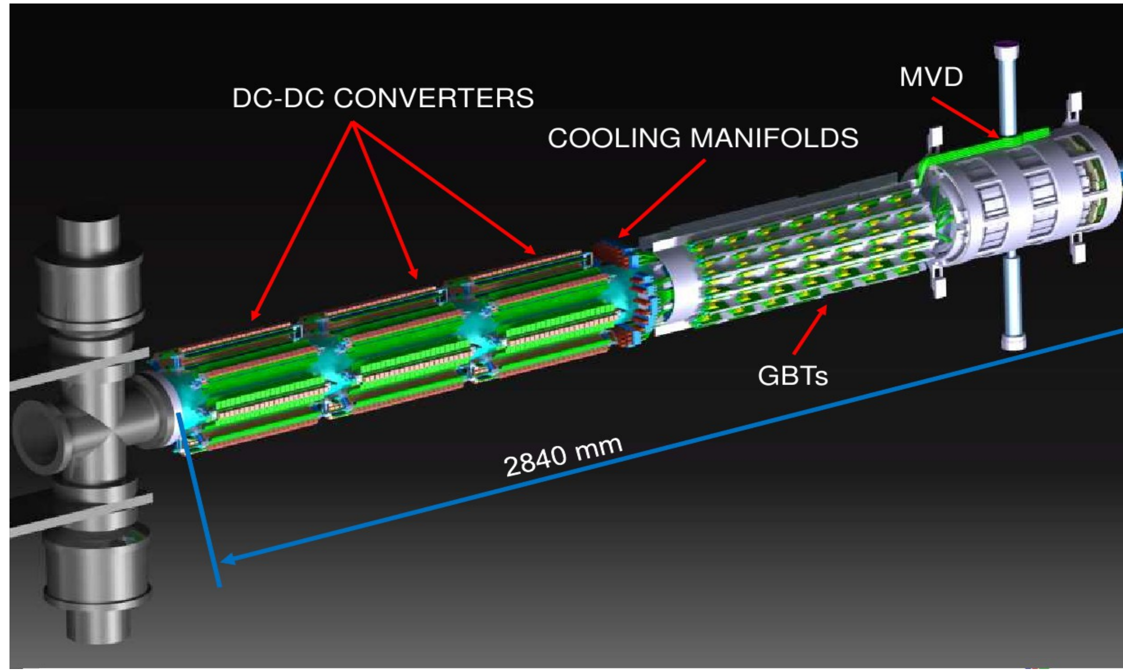
unirradiated

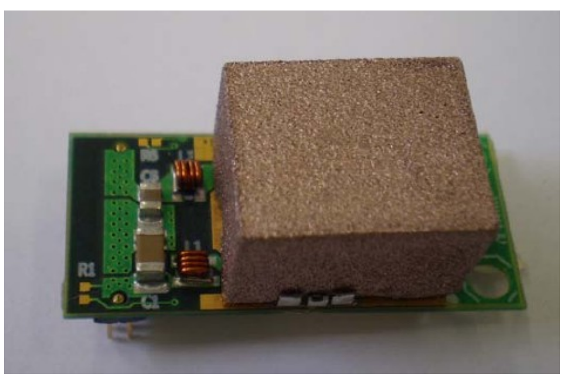
5e13 n. eq.

Powering

DC-DC powering concept

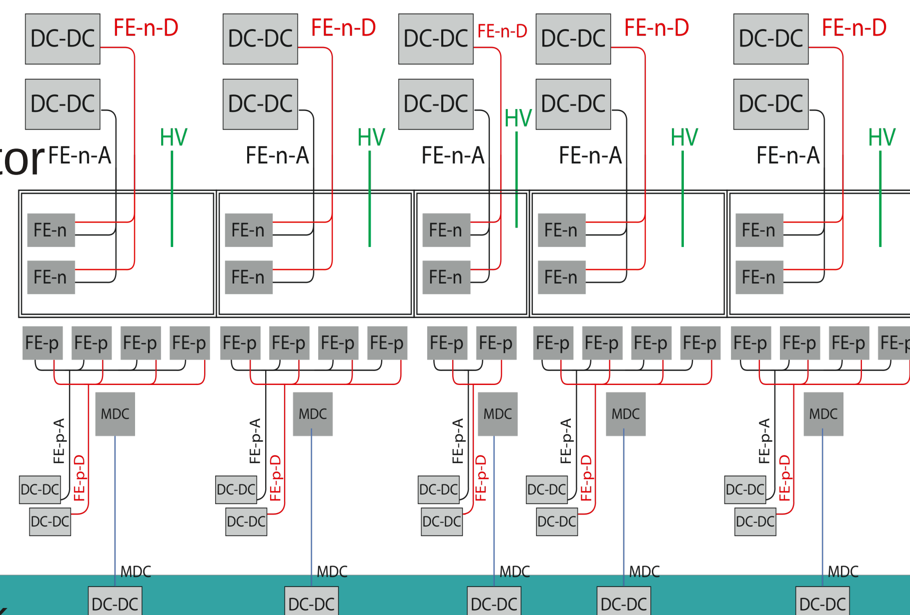
- Air-coil converters operate inside strong magnetic fields
- 80% efficiency
- Converter developed at CERN for LHC upgrade



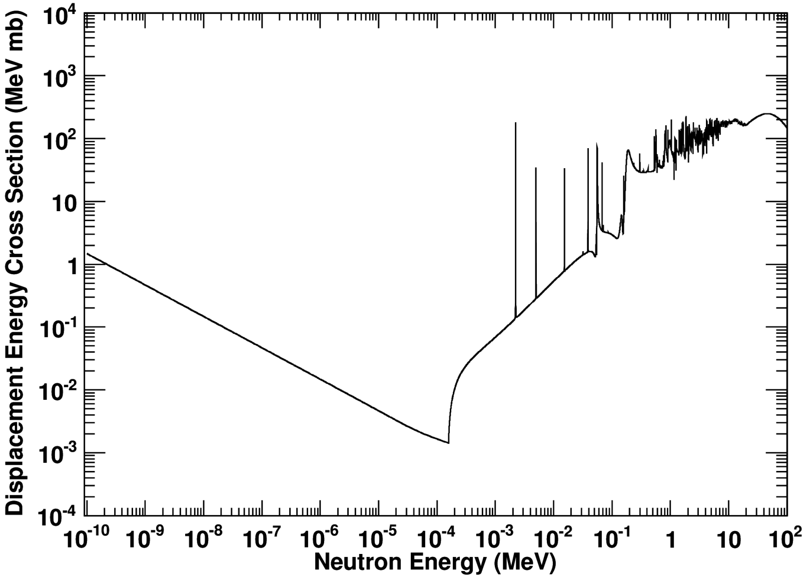


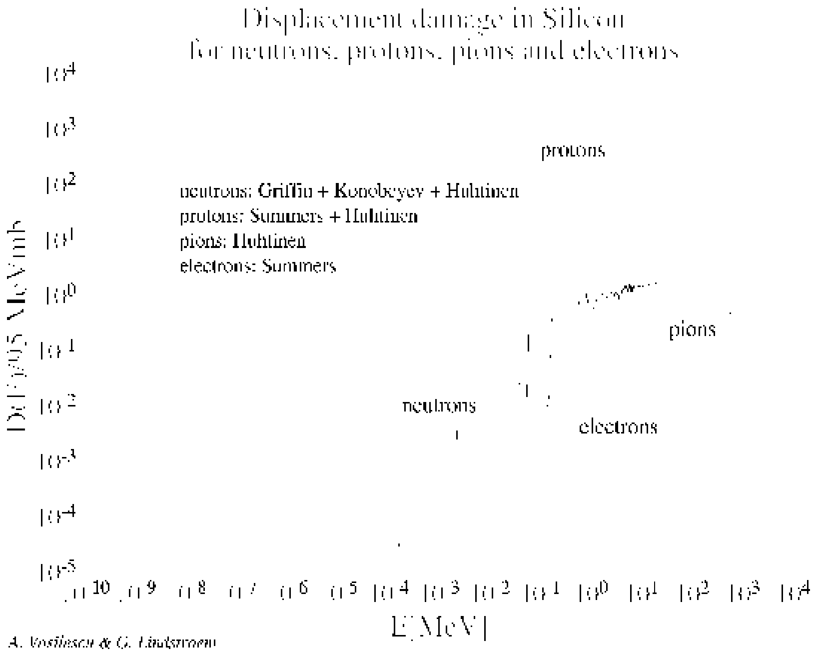
SM01C DC/DC converter

Strip subdetector powering

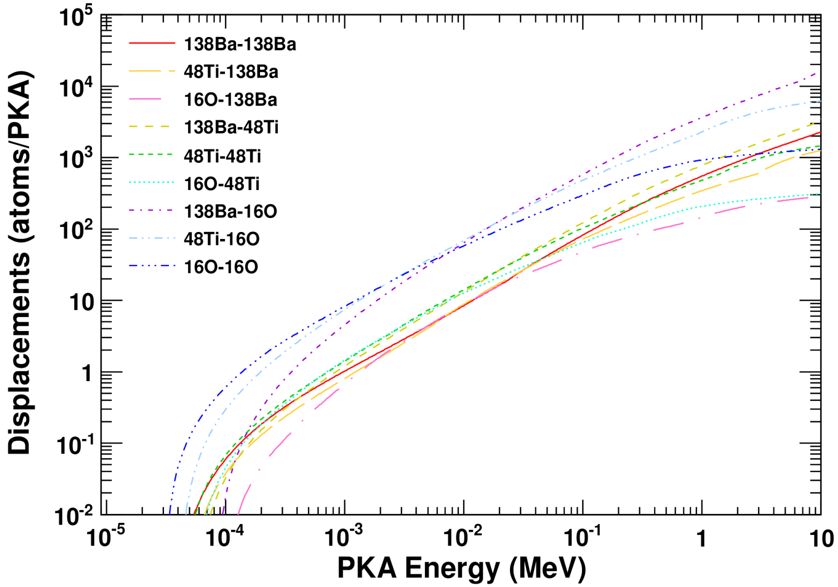


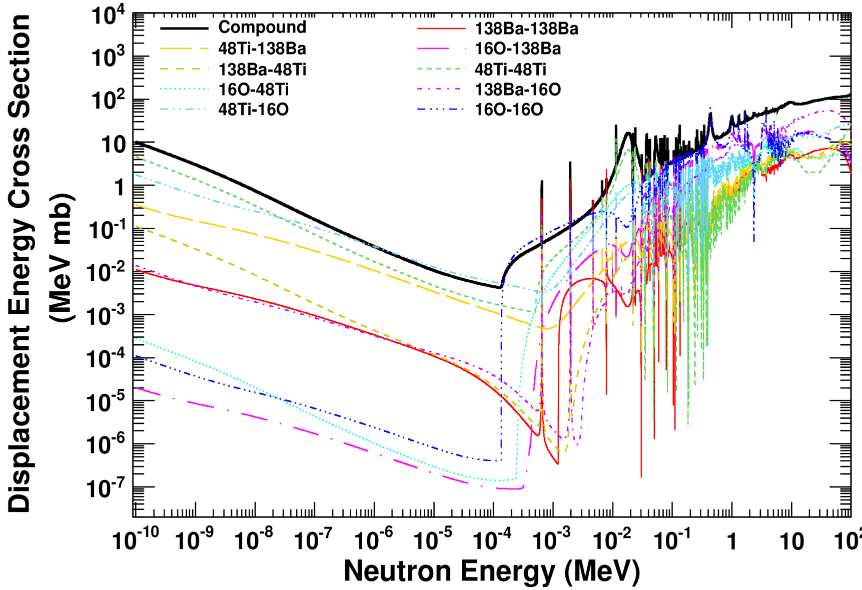
Si - compound

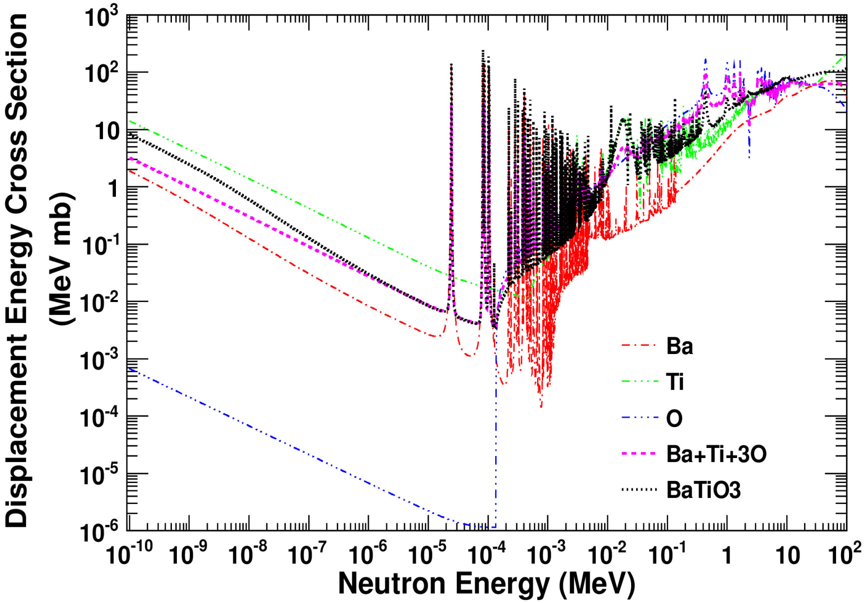

Displacement Energy Cross Section (MeV mb)
Neutron Energy (MeV)

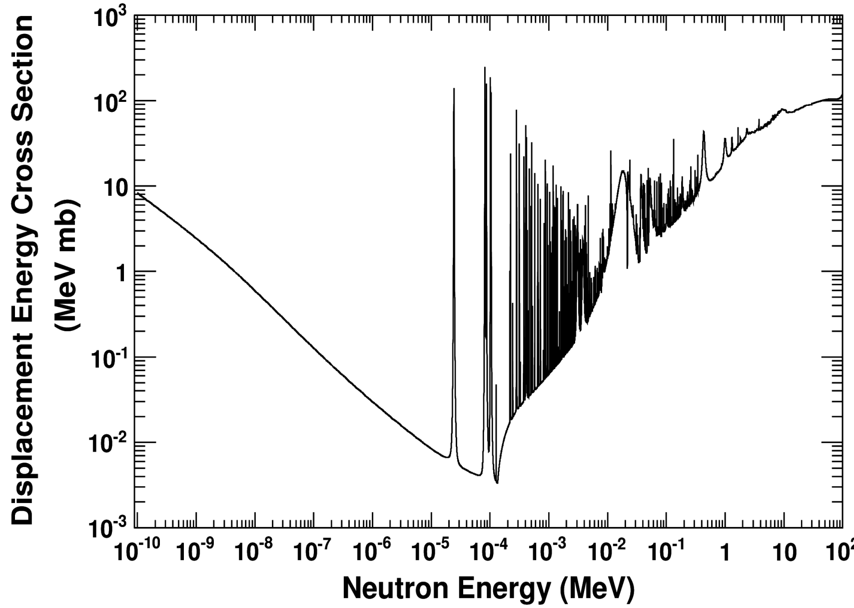

Displacement damage in Silicon
for neutrons, protons, pions and electrons
protons
neutrons: Griffin + Konobeyev + Huhtinen
protons: Summers + Huhtinen
pions: Huhtinen
electrons: Summers
pions
neutrons
electrons

$BaTiO_3$ - compound

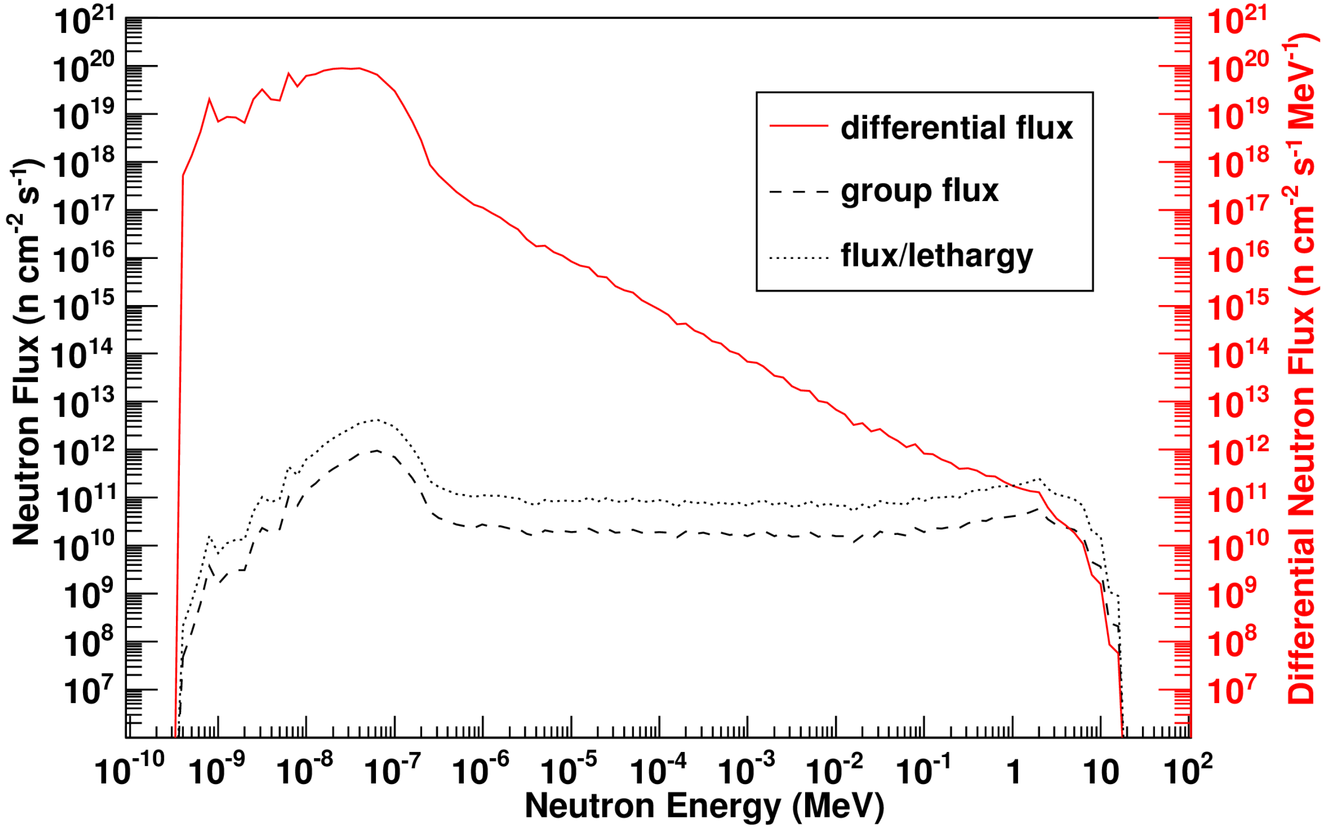




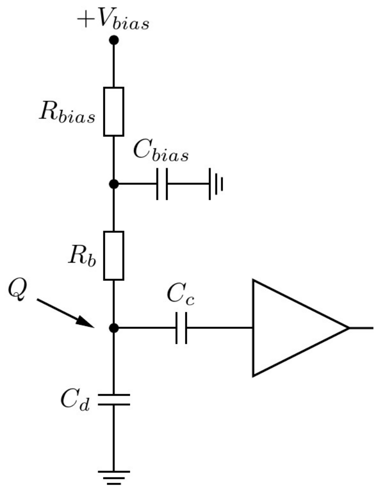


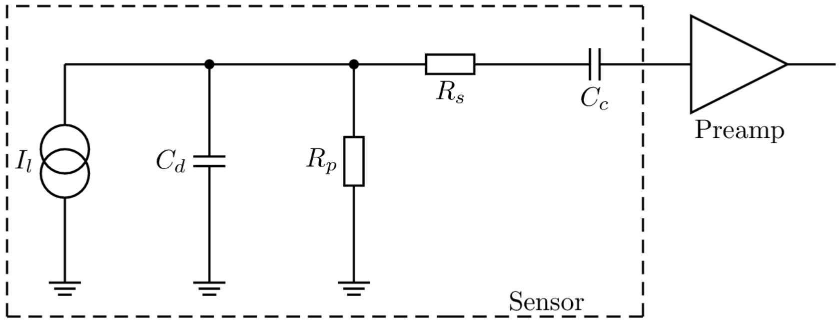


Radiation Damage



Strip Subdetector





Strip Sensors