# Radiation Damage Calculations and Thoughts about Stave Grounding

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PANDA Coll. Meeting
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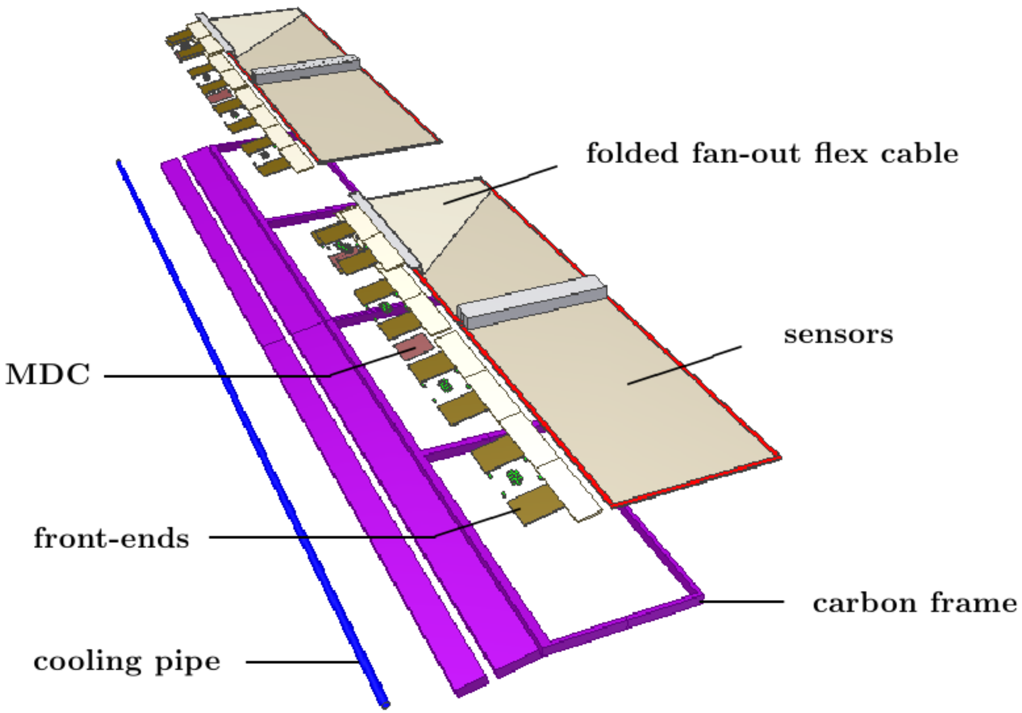
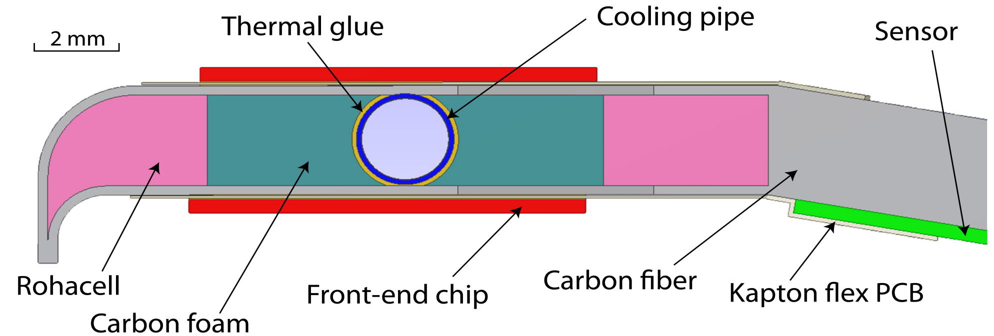
HIC for FAIR Helmholtz International Center

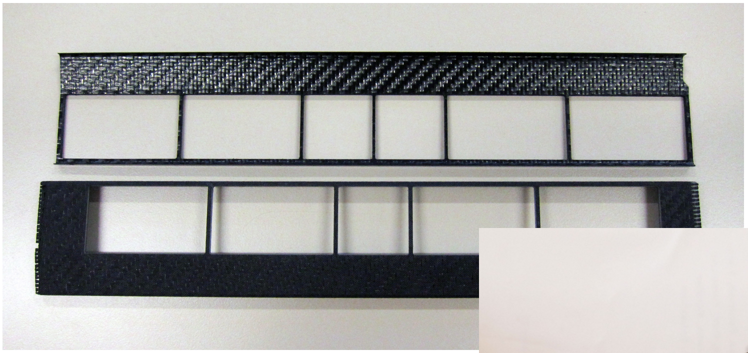
II. Physikalisches Institut

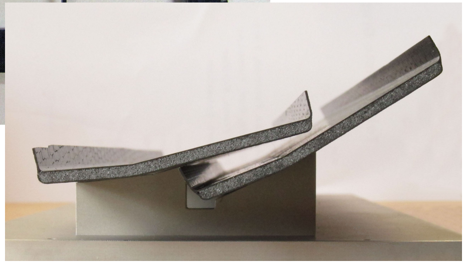
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

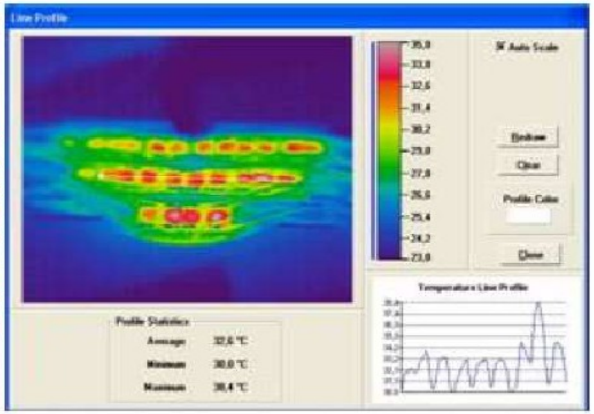
# Strip Sensor Staves





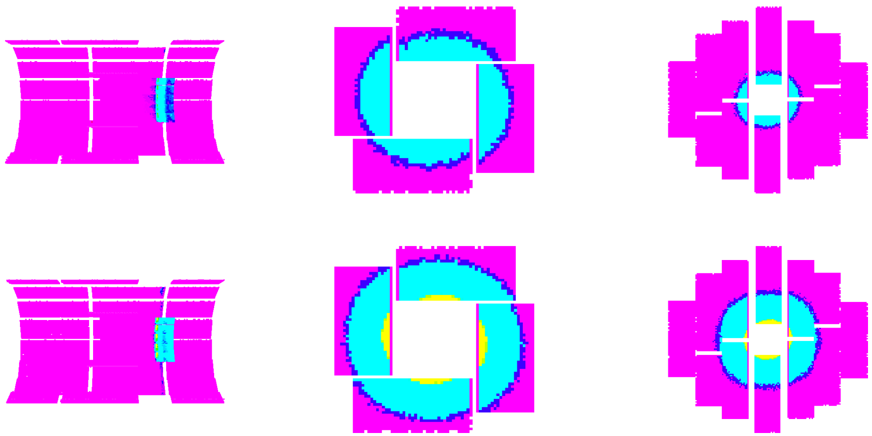


# Radiation Damage

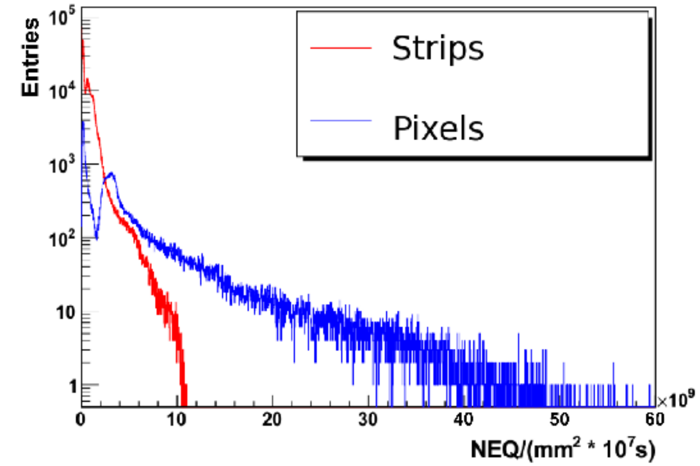
**Pixel barrels/disks**

2GeV

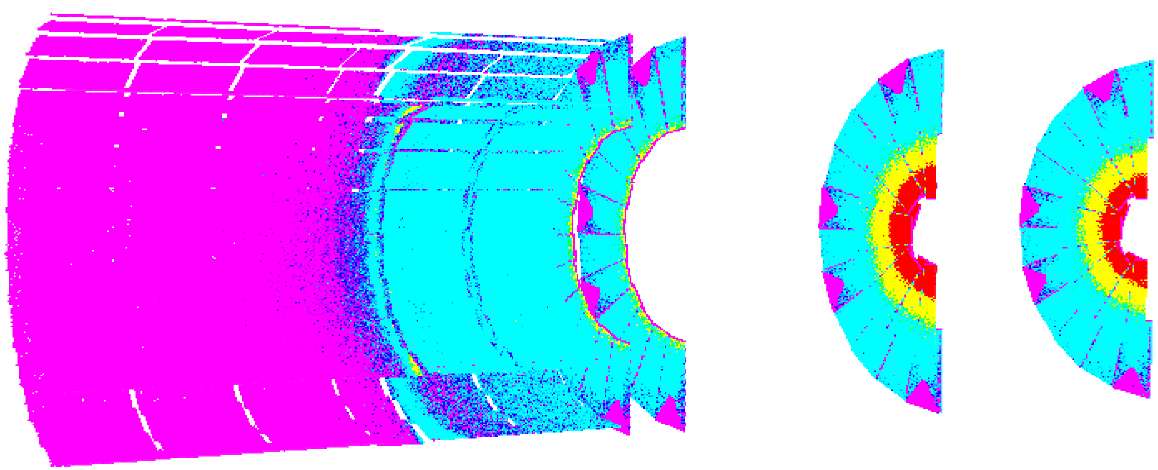
15GeV



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




**Strip barrels/disks**
@ 15GeV



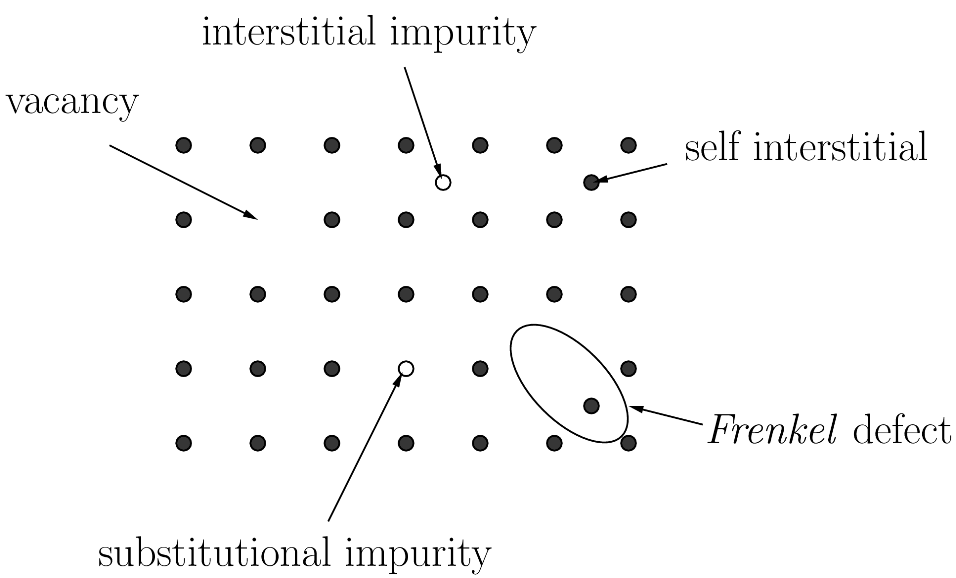
# Radiation Damage

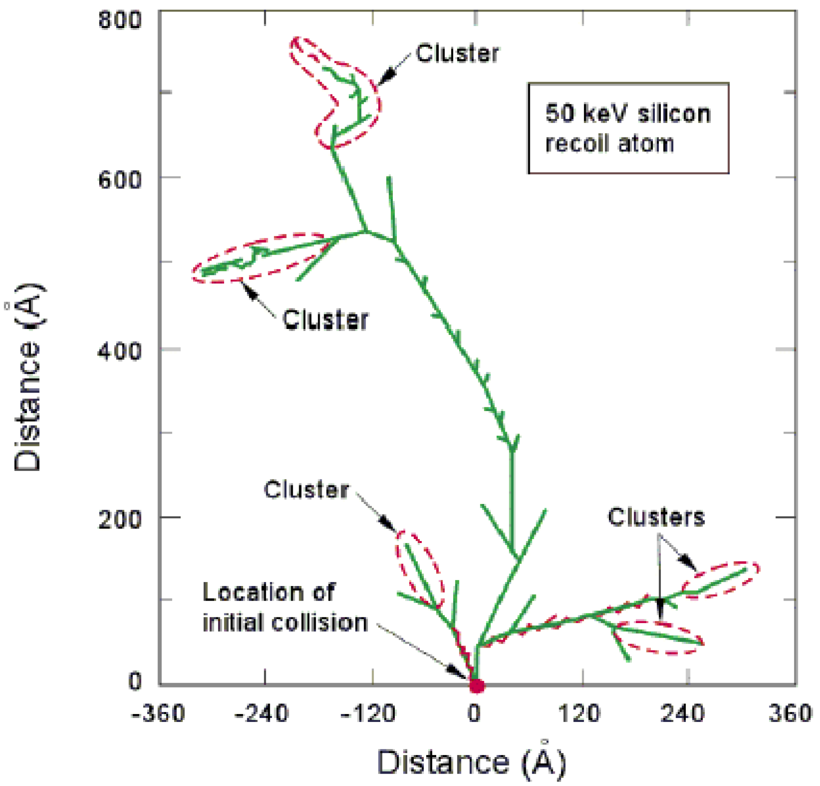
For Sensors and passive materials relevant:

**Non-ionizing effects**

- Atomic displacements
- Change of lattice-order in crystals
- Point-defects, cluster defects, amorphous
- Quantity of Interest: NIEL, KERMA, dpa …

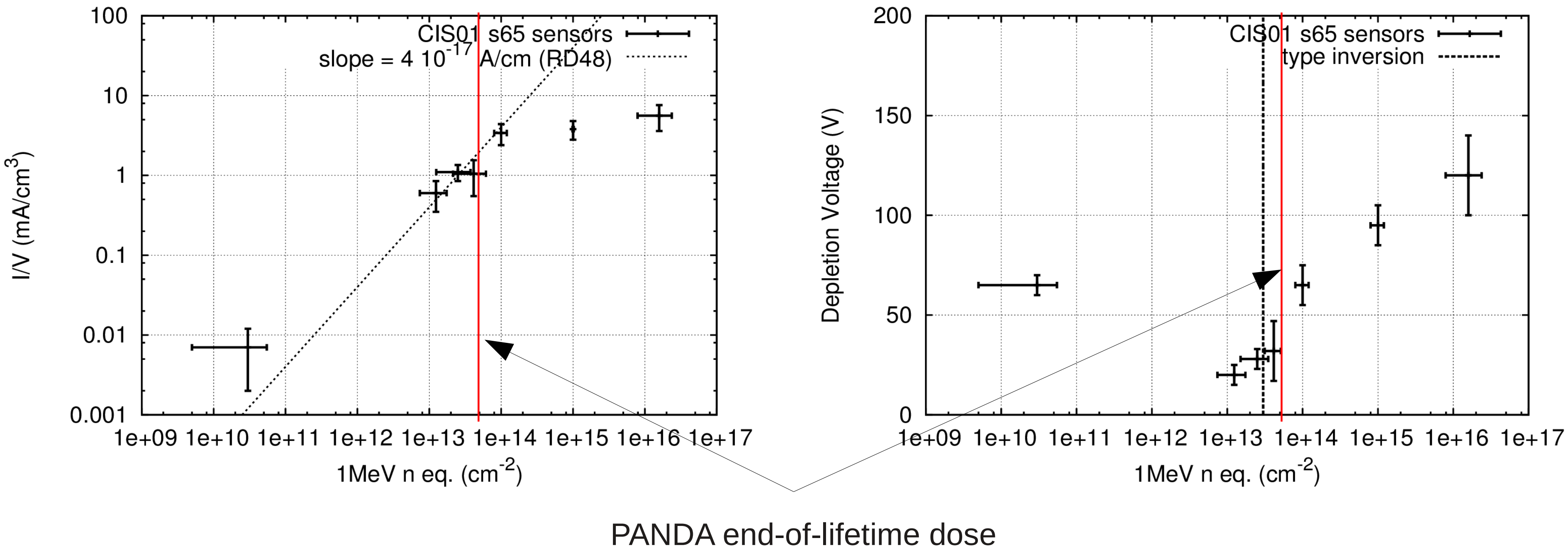
# Radiation Damage



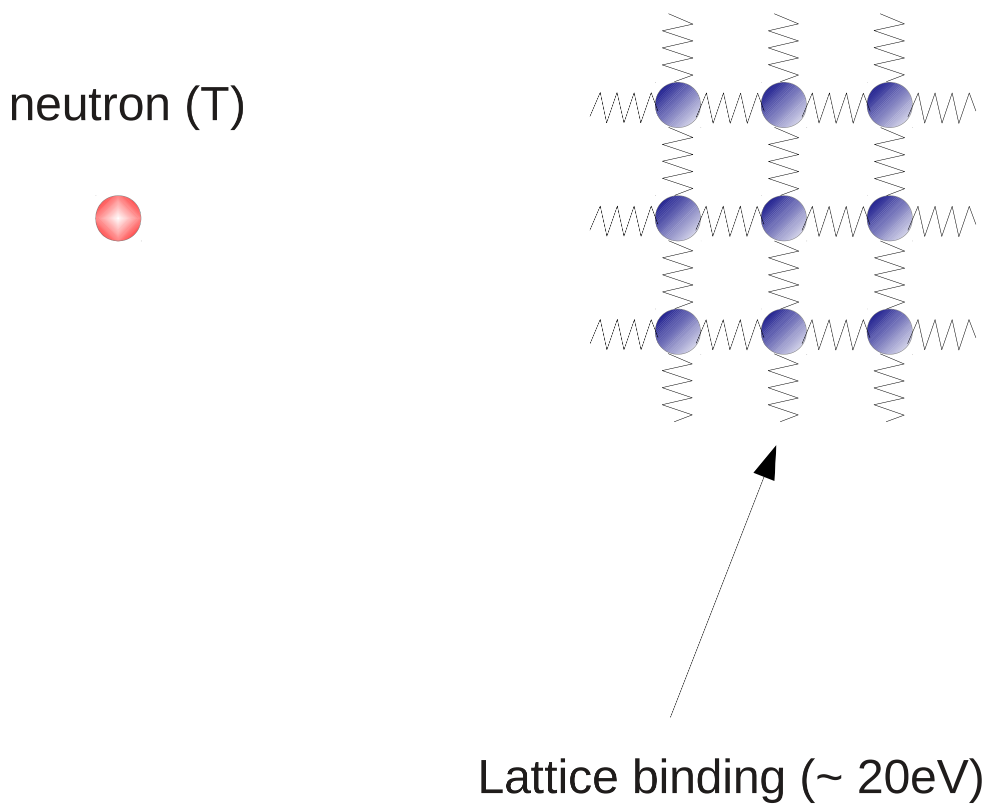
# Sensor Irradiation

Proton irradiation at Bonn isochrone cyclotron, T=14 MeV




Change of doping concentration
= change of full depletion voltage

# Displacement Damage



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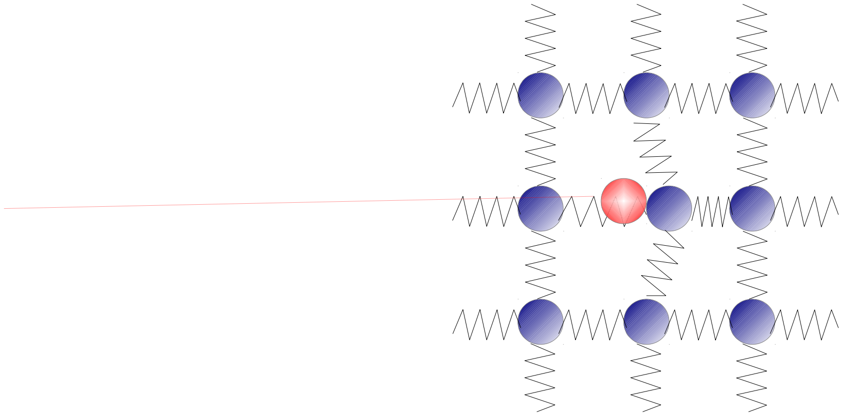

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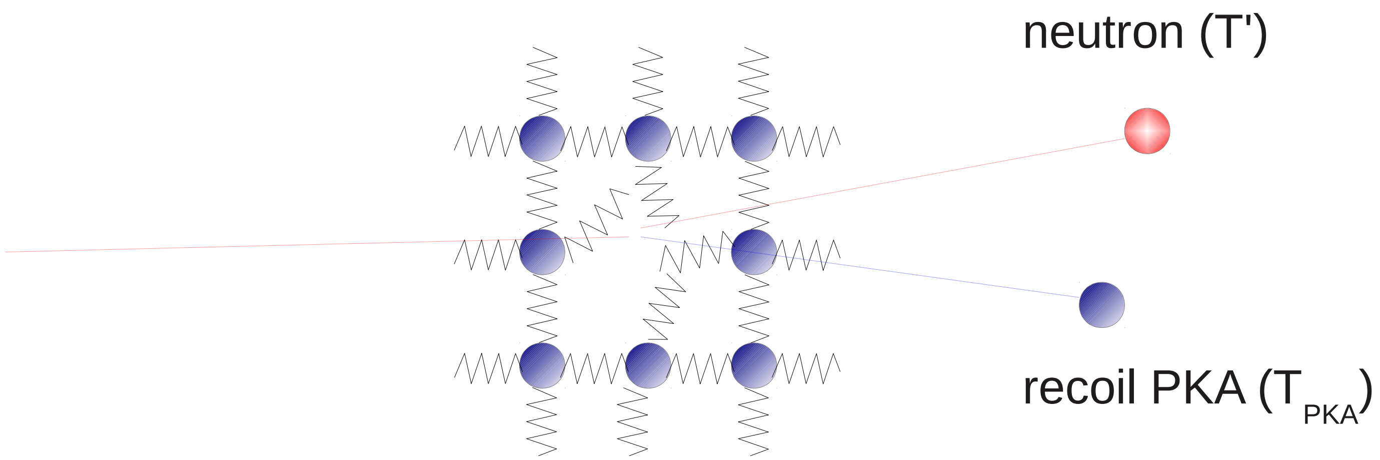

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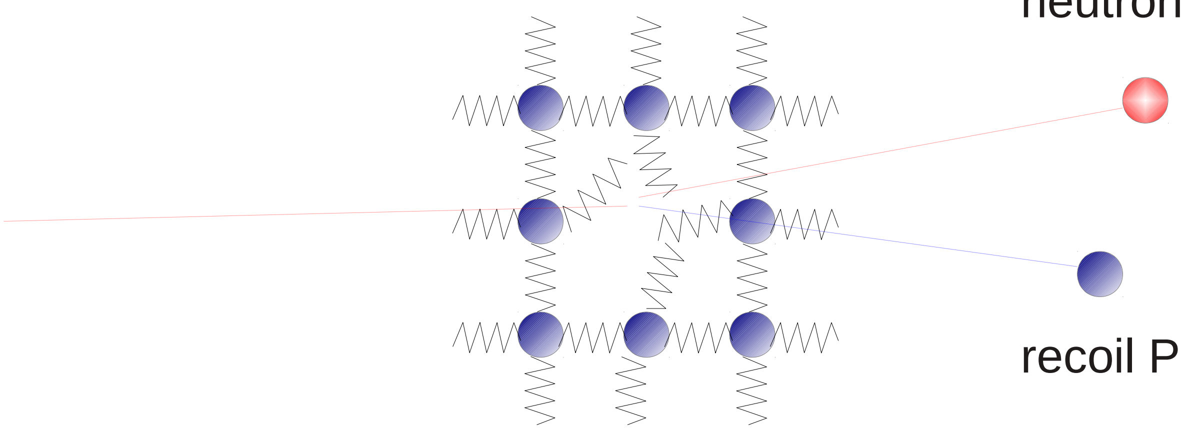
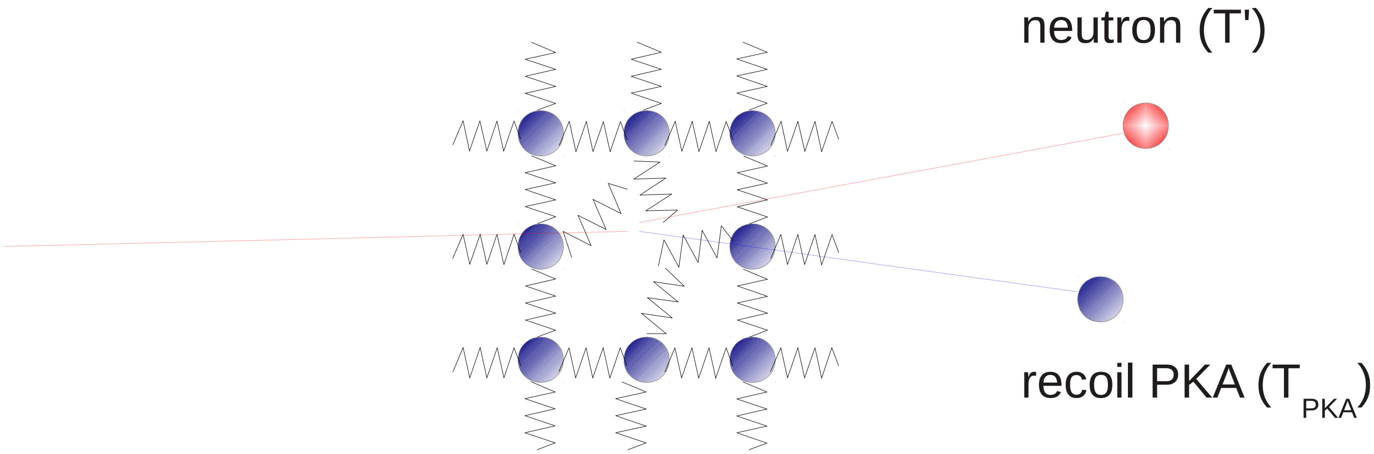



$$T = T' + T_{PKA} + E_{lattice}$$

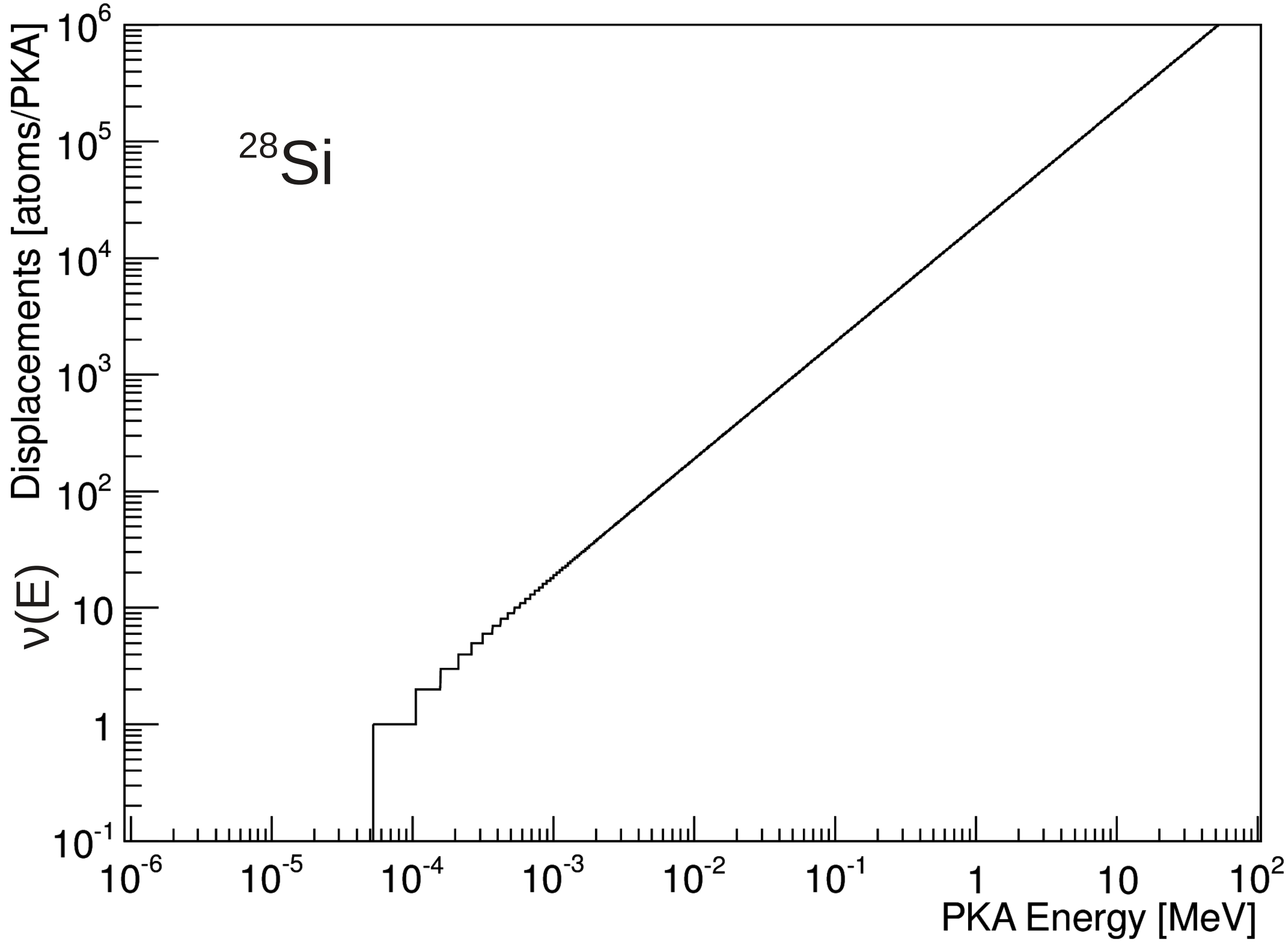
# Displacement Damage




at higher energies **ionization** comes into play

$$T = T' + T_{PKA} + E_{lattice} + E_{ionization}$$

# Collision Cascade Model

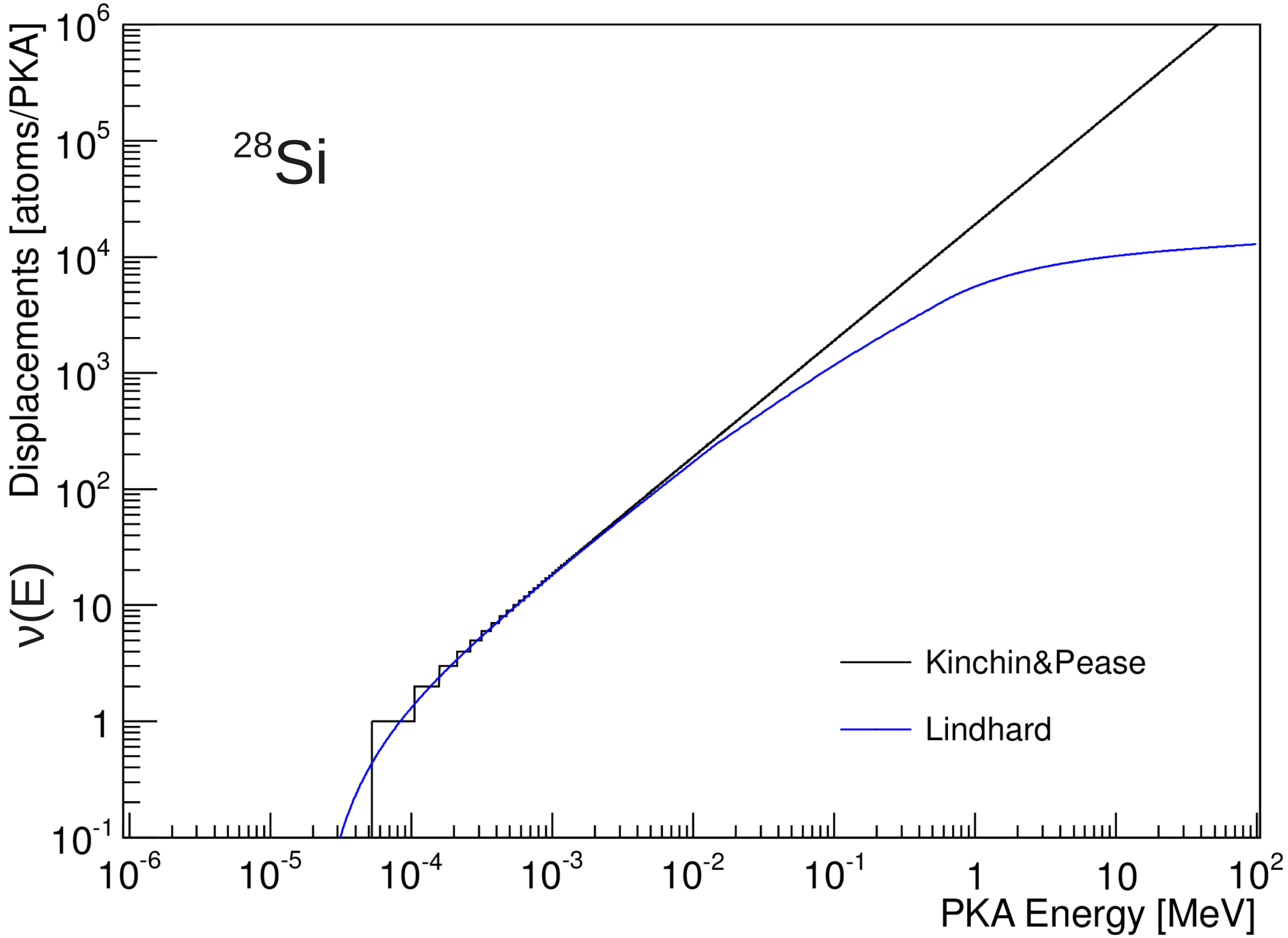



Kinchin and Pease: Nr. of displacements: $\nu = 0.8 \dfrac{T}{2E_{thr}}$

**[Rep. Prog. Phys. 18 (1955) 1]**

# Collision Cascade Model

Lindhard et al.: Consideration of ionization at higher energies




Numerical calculation of damage functions through solving coupled integro-diff. conservation equations in ν

**[Phys. Rev. 124 (1961) 128]**

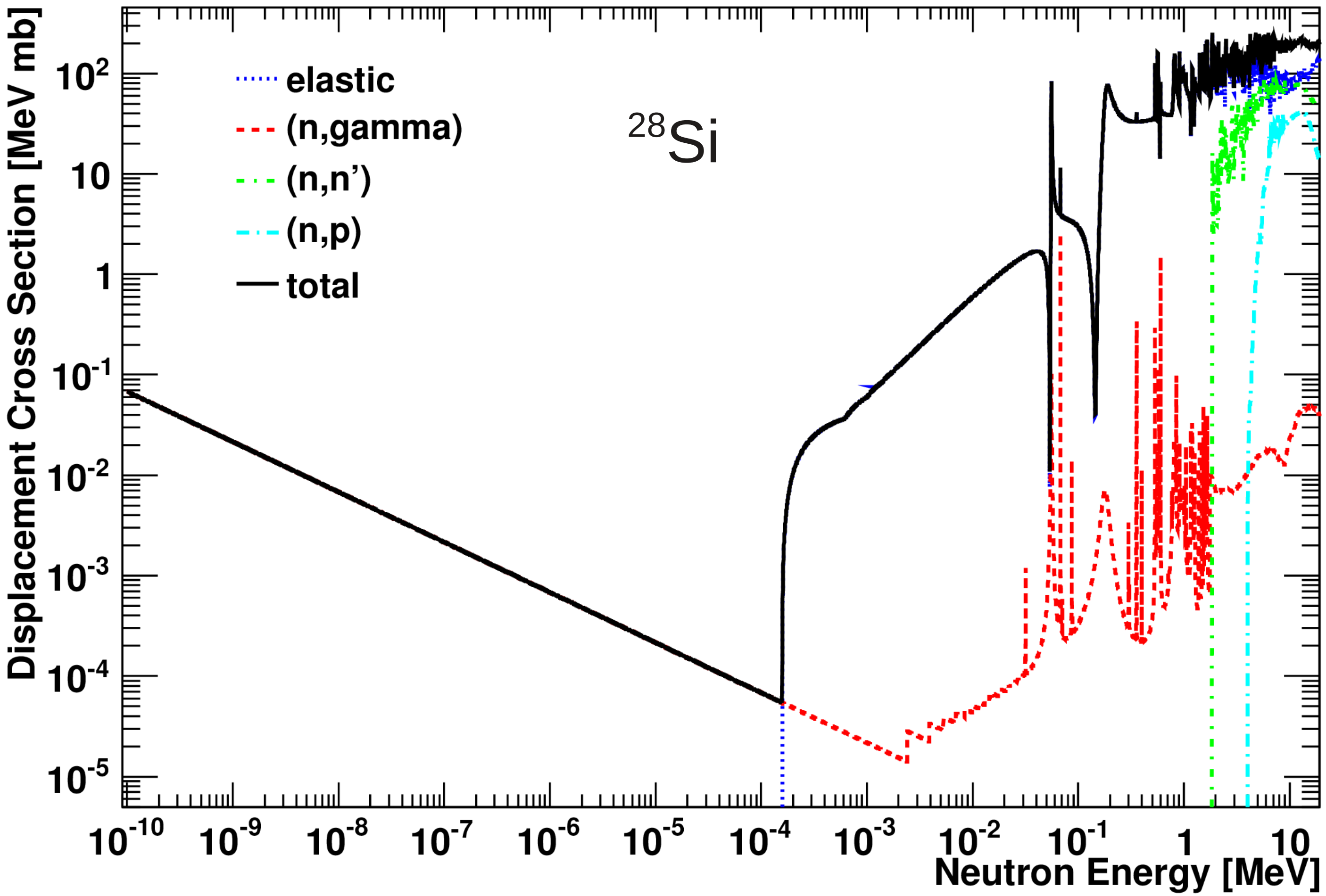
**[Mat. Fys. Medd. Dan. Vid. Selsk. 37 (1970) 1]**

**[J. Nucl. Mat. 199 (1993) 221]**

# Collision Cascade Model

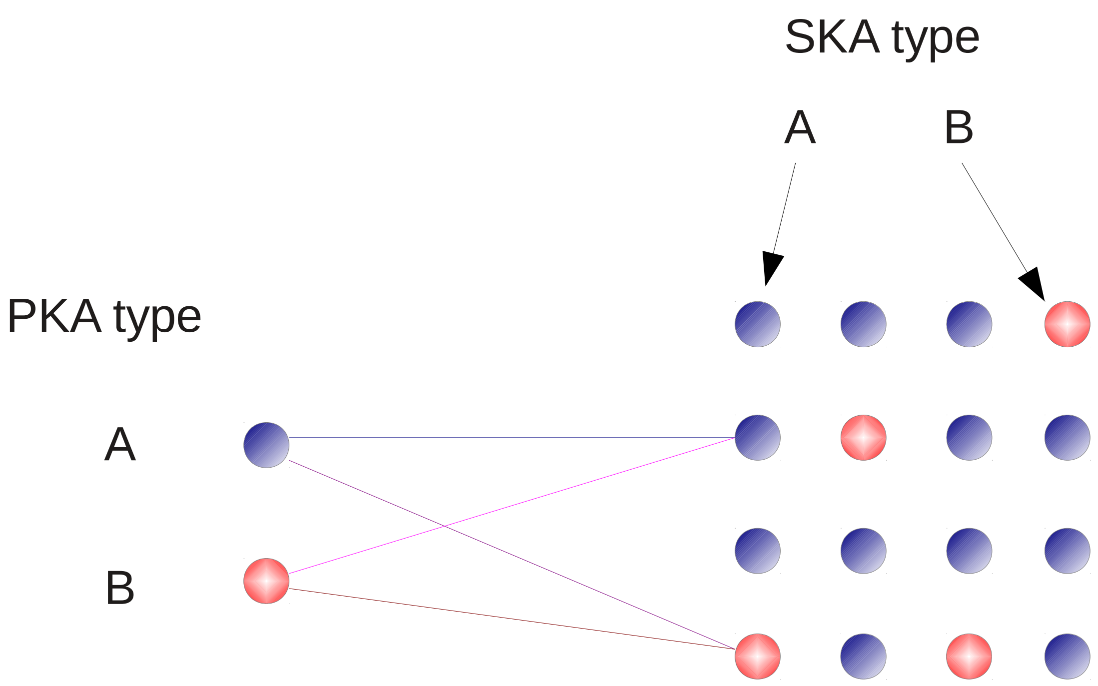
Folding of PKA-displacement spectra with neutron capture cross sections (ENDF library)

**[Chadwick,Herman,Oblozhinsky et.al. "ENDF/B-VII.1 Nuclear Data Library (2011) ]**



# Collision Cascade Model

Compound materials more difficult to describe




- Different damage spectra depending on PKA-SKA combination
- Different lattice binding energies
- Different kin. energy transfer efficiencies $\Lambda_{12} = \dfrac{4M_1M_2}{(M_1+M_2)^2}$

# Damage Functions

Example: $BaTiO_3$ dielectric material for ceramic capacitors

Considered nuclides with elemental abundances

**$_{56}$Ba:**

$^{138}$Ba 92.2%

$^{137}$Ba 11.2%

$^{136}$Ba 7.9%

$^{135}$Ba 6.6%

$^{134}$Ba 2.4%

**$_{22}$Ti:**

$^{48}$Ti 73.8%

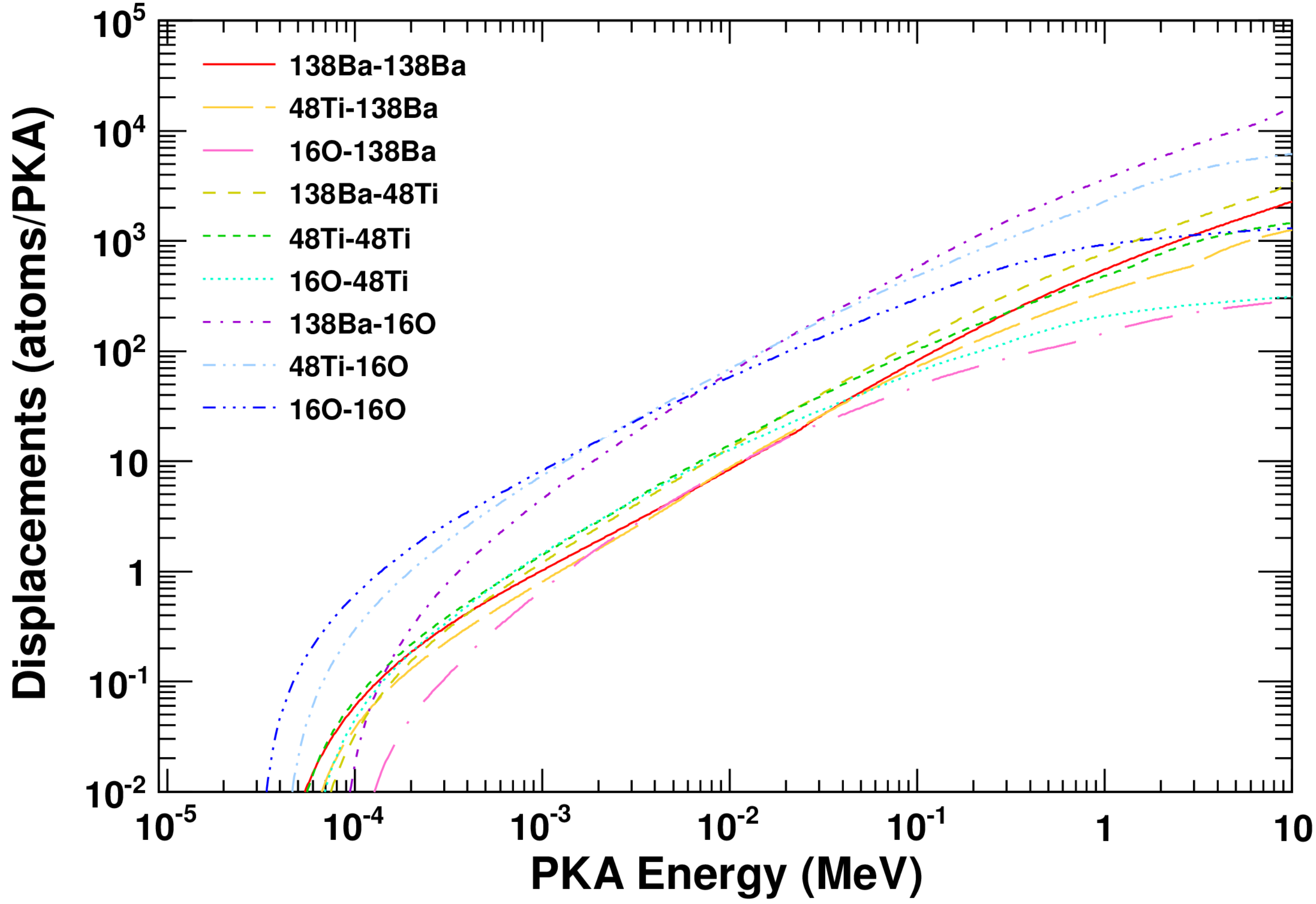
$^{46}$Ti 8.0%

$^{47}$Ti 7.3%

$^{49}$Ti 5.5%

$^{50}$Ti 5.4%

**$^{16}_{8}$O** ~100%



# Damage Functions

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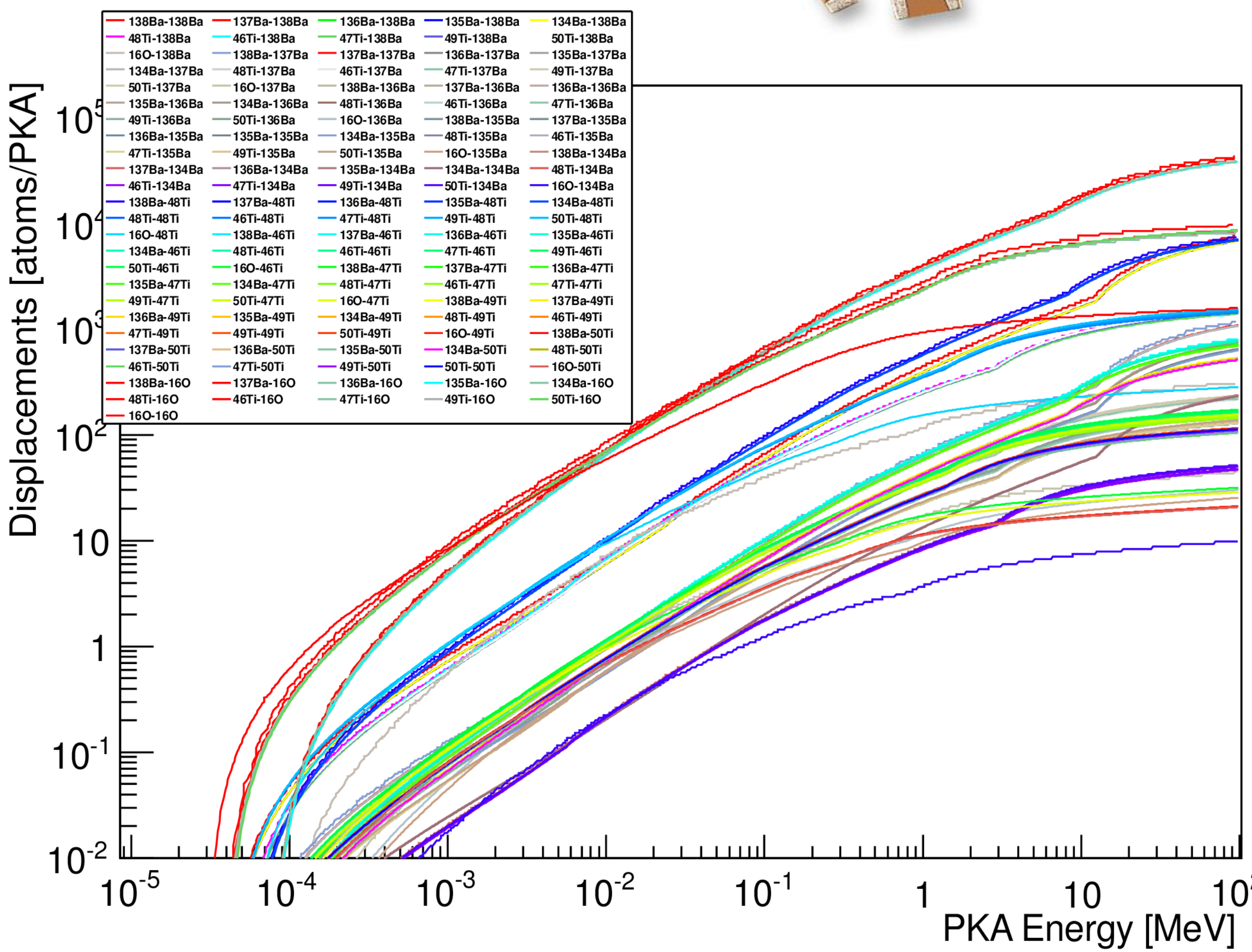
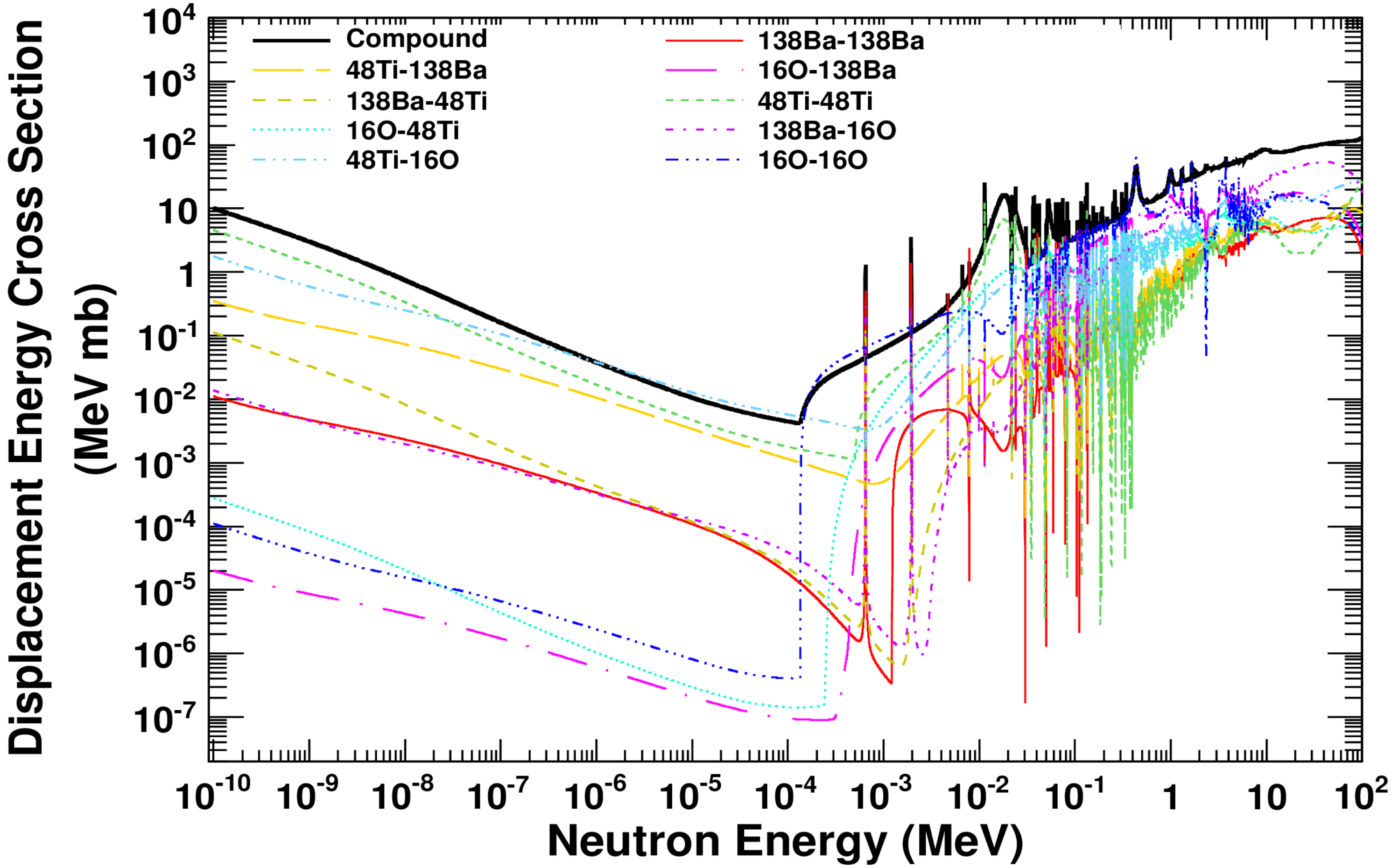


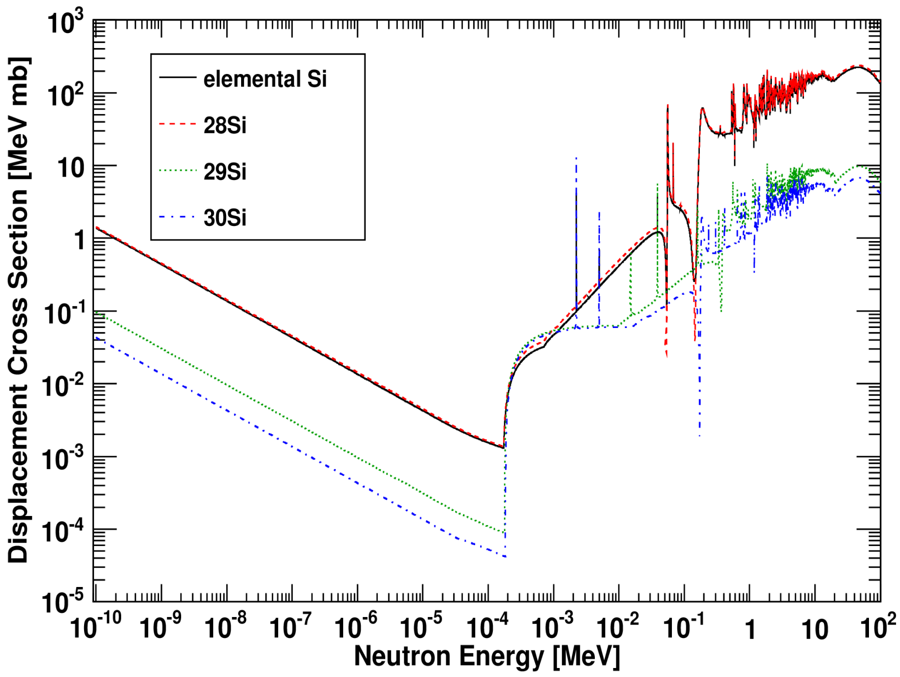
# Damage Cross Section

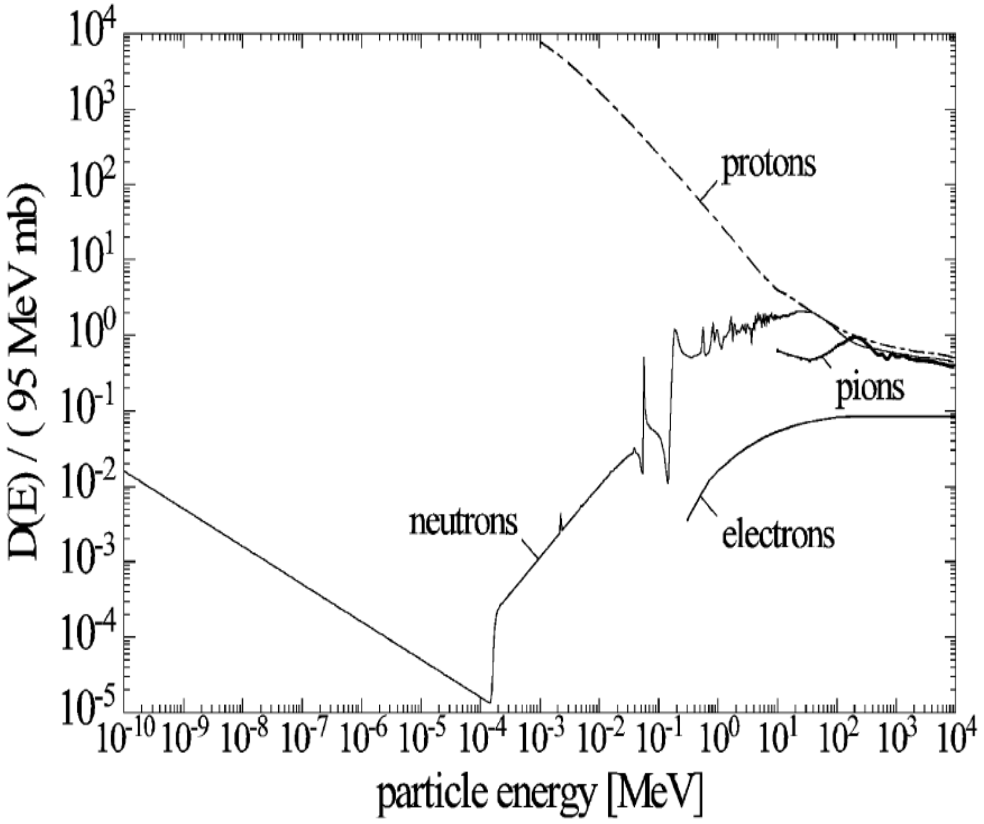
Example: $BaTiO_3$ dielectric material for ceramic capacitors




- Combine weighted partial cross sections according to atomic density of constituents

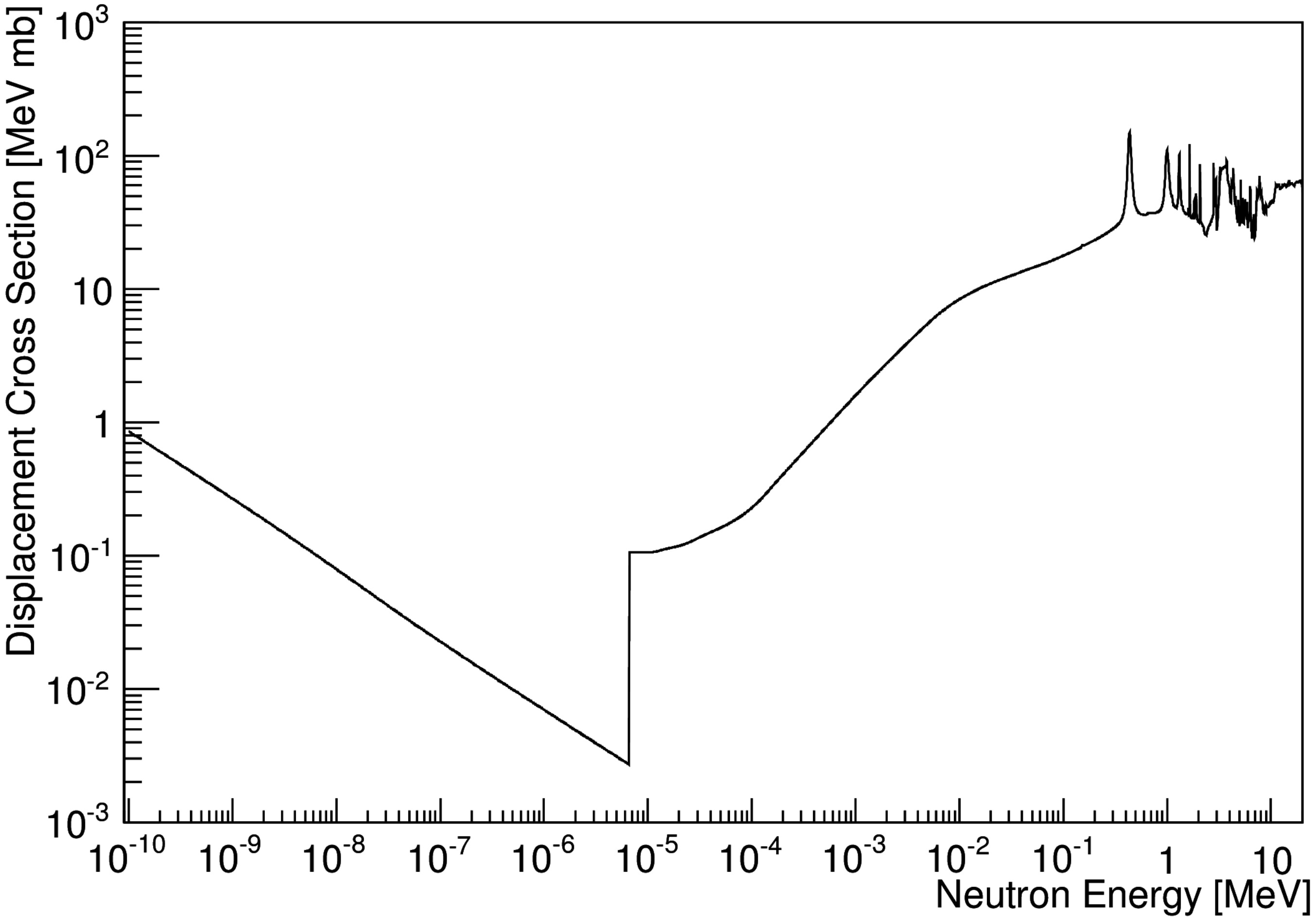
## Silicon

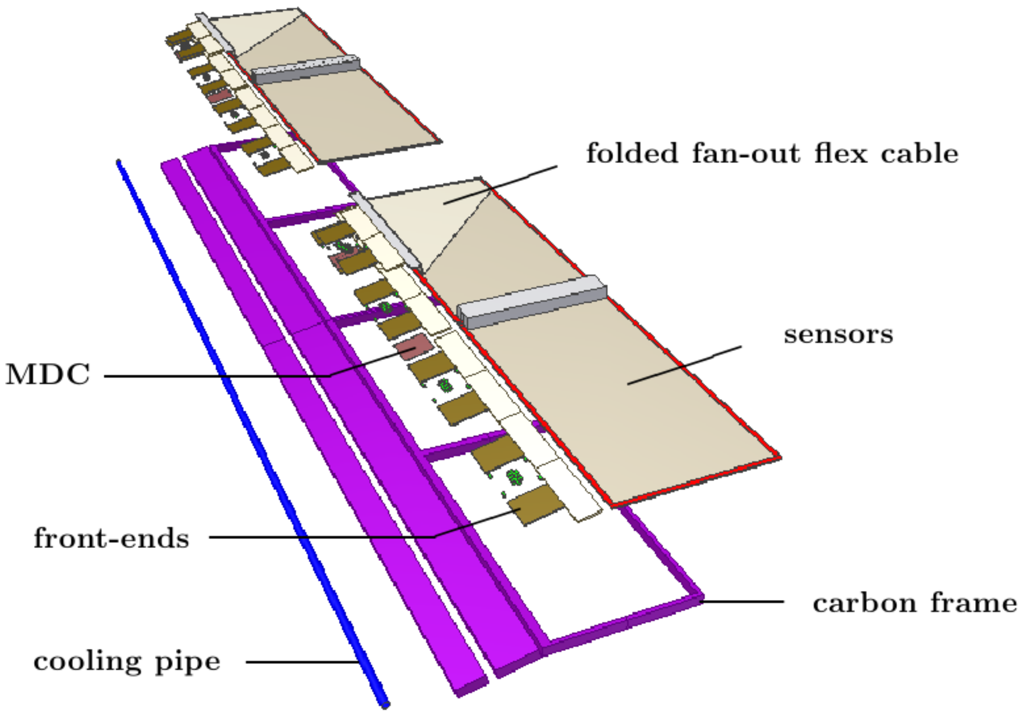

Displacement Cross Section [MeV mb]
Neutron Energy [MeV]
elemental Si
28Si
29Si
30Si

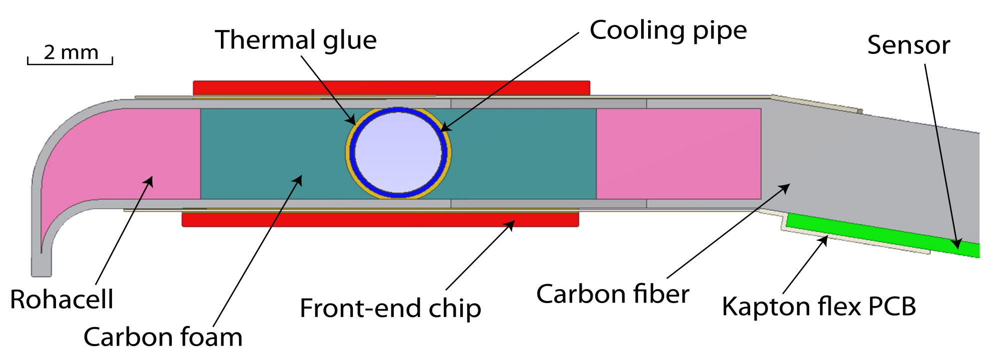

D(E) / ( 95 MeV mb)
particle energy [MeV]
protons
pions
neutrons
electrons

# Damage Cross Section

ROHACELL 51A compound, polymethacrylic-imide
$C_{14}H_{10}N_2O_6$

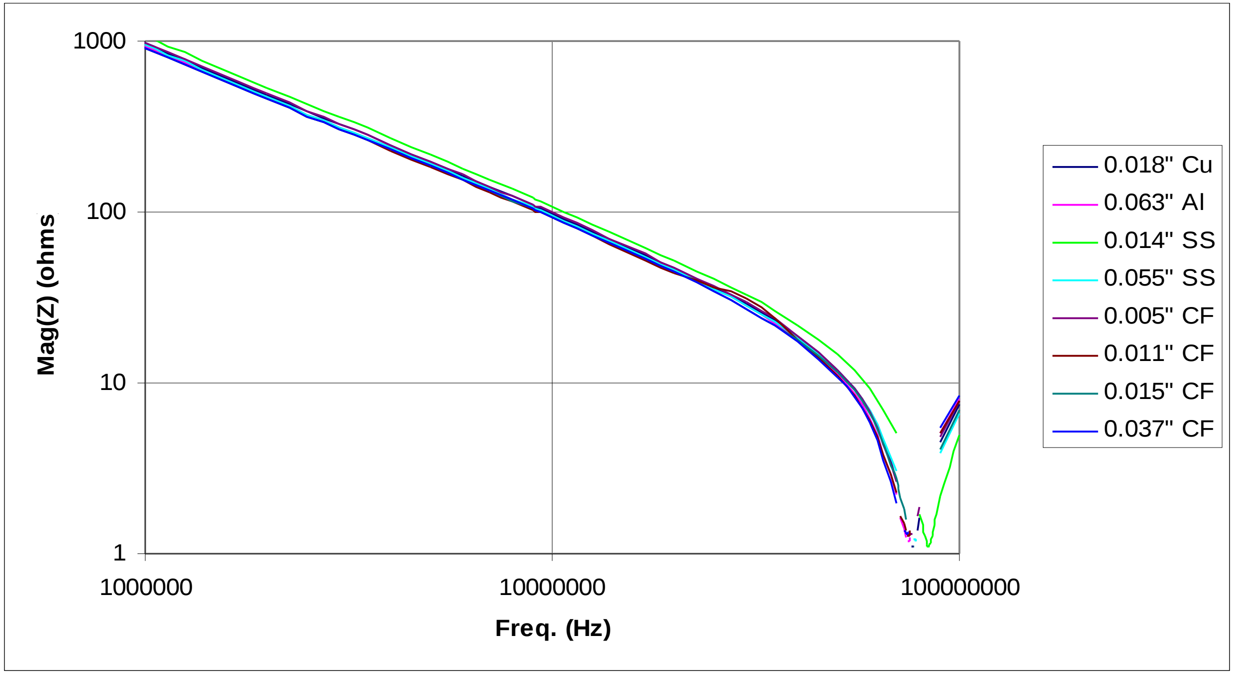



folded fan-out flex cable
sensors
MDC
front-ends
carbon frame
cooling pipe


2 mm
Thermal glue
Cooling pipe
Sensor
Rohacell
Carbon foam
Front-end chip
Carbon fiber
Kapton flex PCB

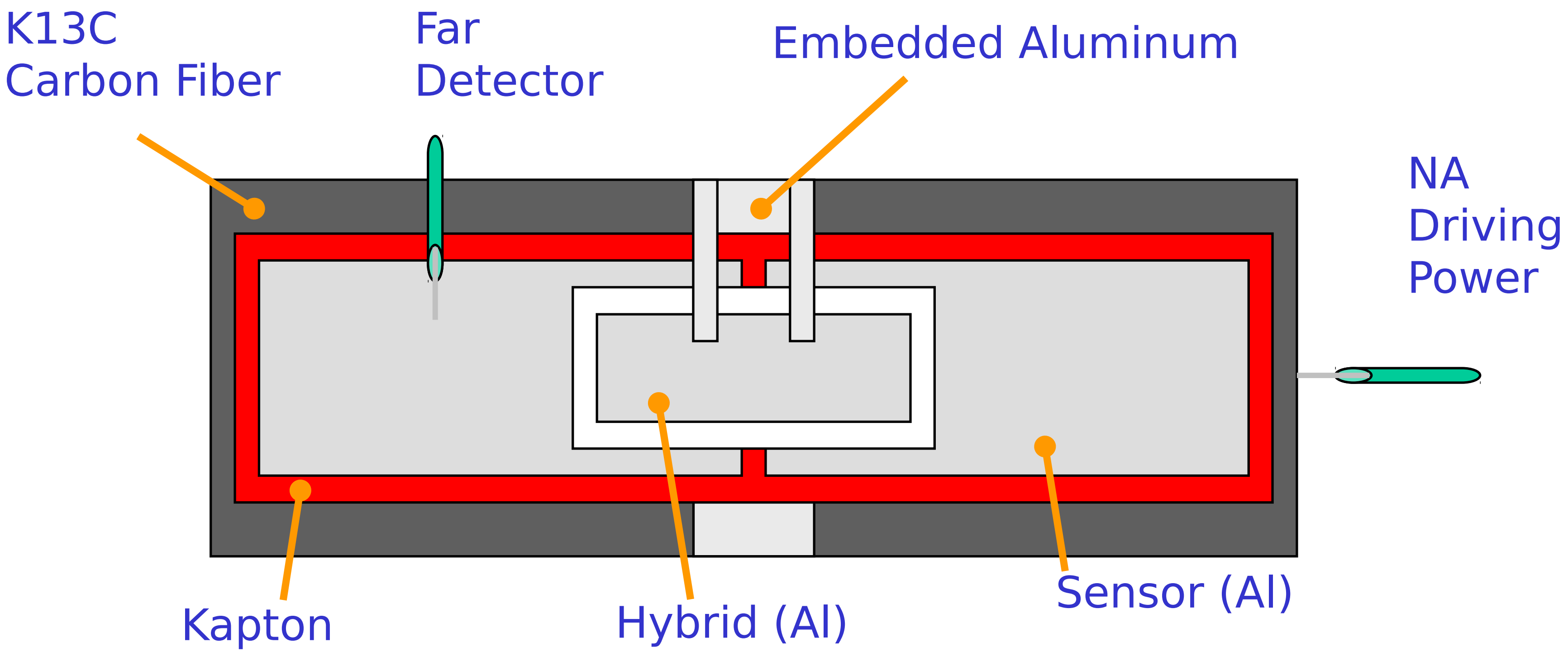
# Grounding of Carbon Staves

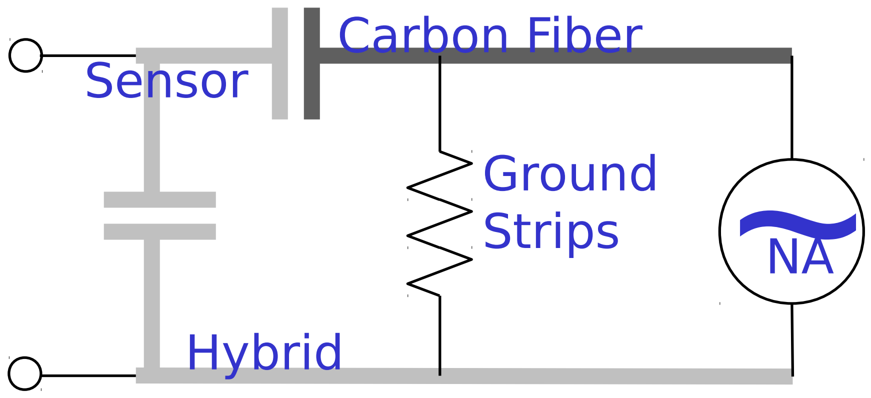
- Current pitch fabrication techniques that produce carbon fiber with ultra-high modulus (~1000 GPa) also yield very low resistivity (~100 μΩ•cm)
- Floating conductors tend to strongly couple to silicon sensors
- Very nasty source of noise, esp. in densely packed structures of high impedance and highly sensitive sensors (lose coupling)



# Grounding of Carbon Staves

## D0 L0/L1 Mock-up



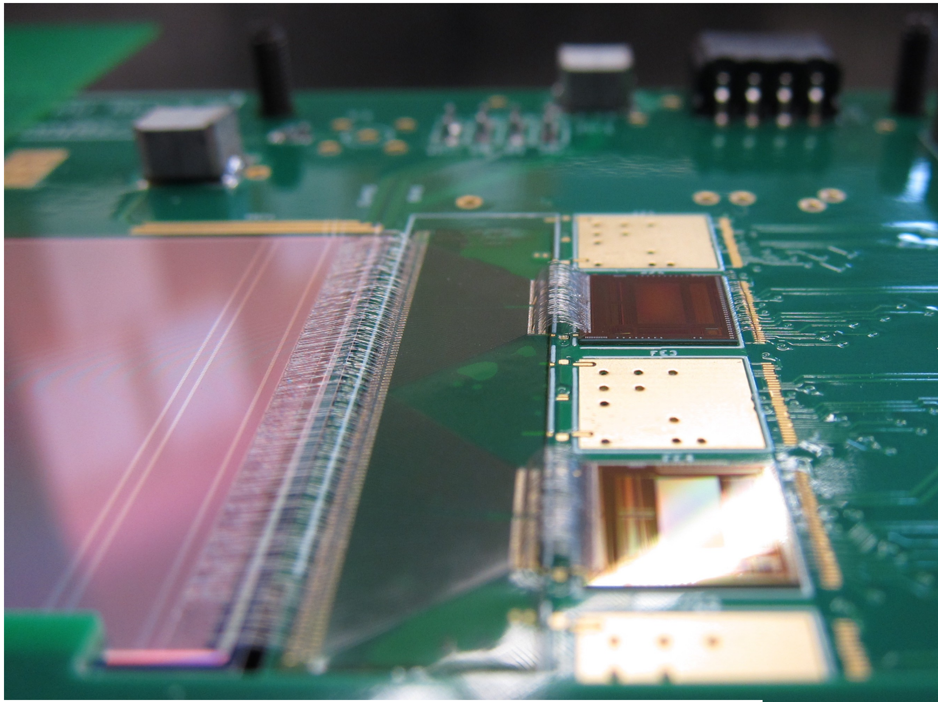
# Strip Sensor Staves

**D0:**

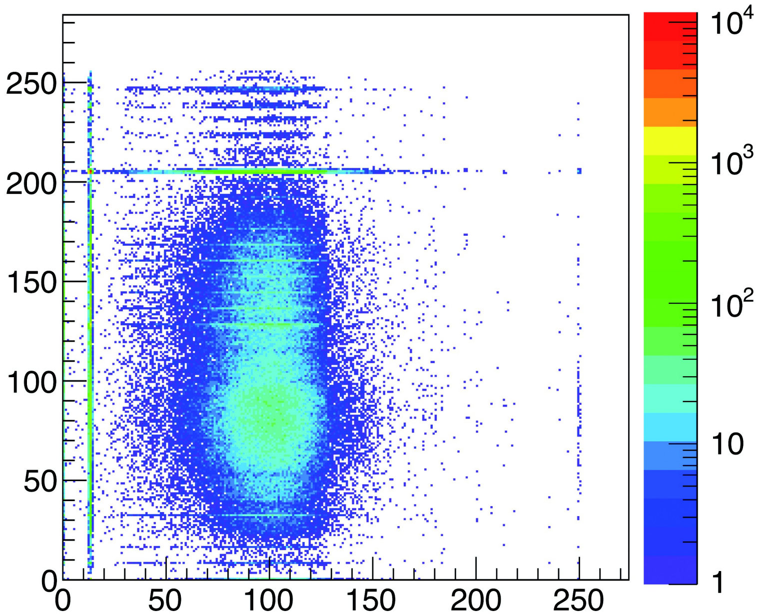
- Electrical coupling of reference ground conductor to carbon stave is **crucial**
- Embed Al foils into carbon structure
- Al foil coverage of 20...25% of the carbon stave
- Oxidation and fragility of Al foil are critical
- Alternative: bond flex and carbon by embedded Cu mesh

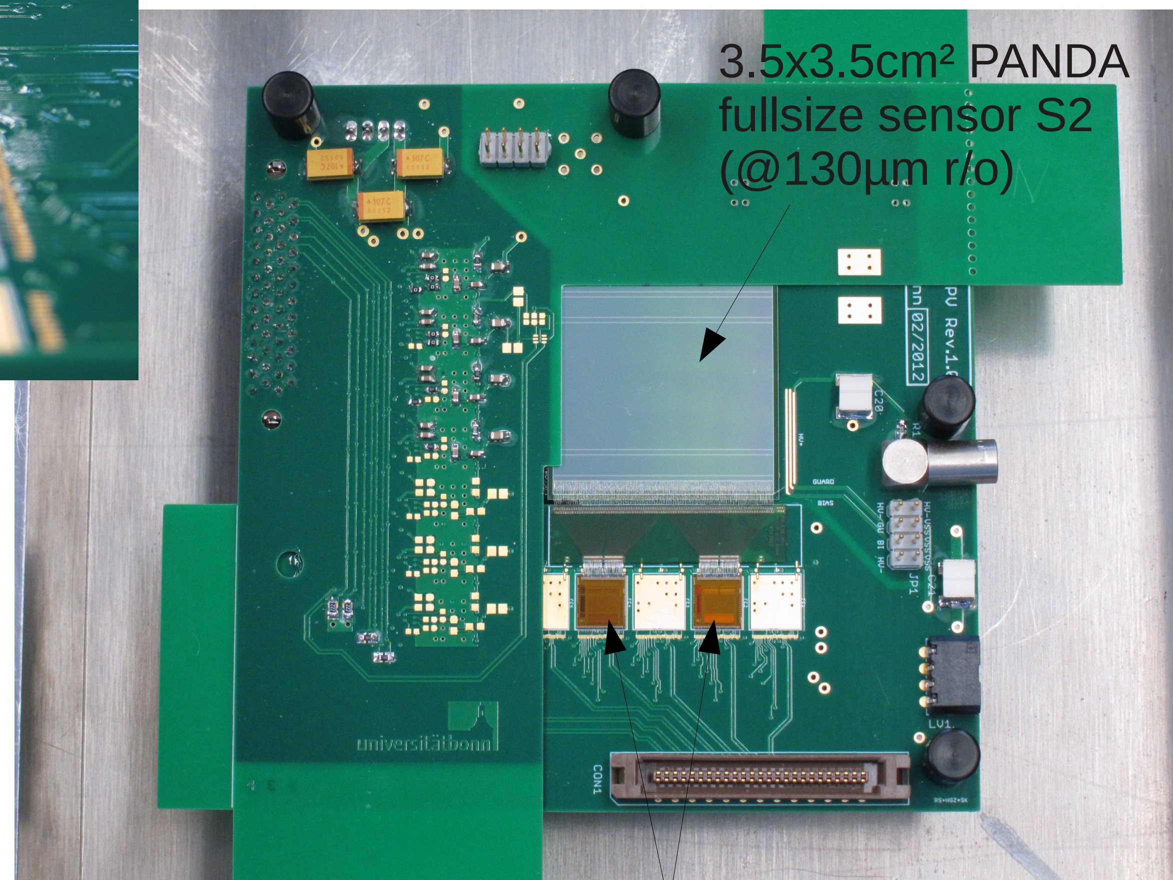
# Backup Slides

# Strip Sensors



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



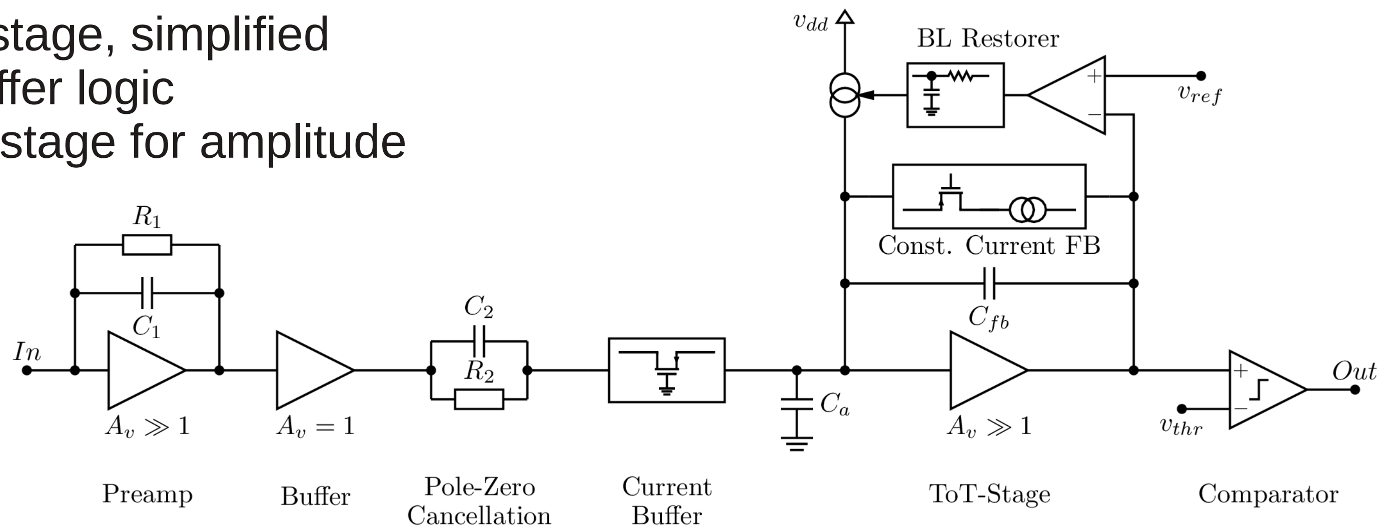




APV25 Front-ends

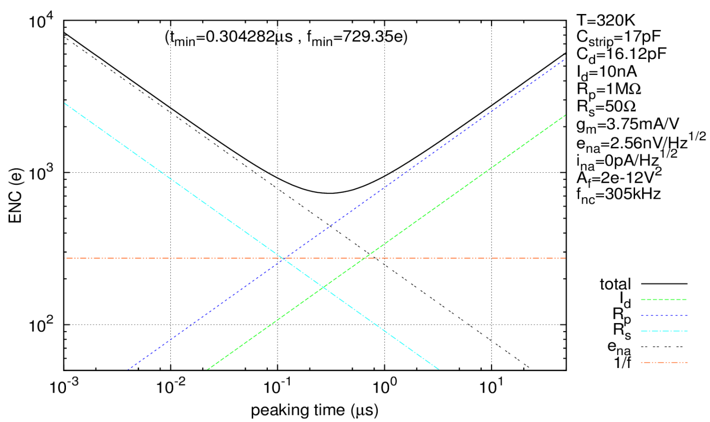
# Strip Front-end

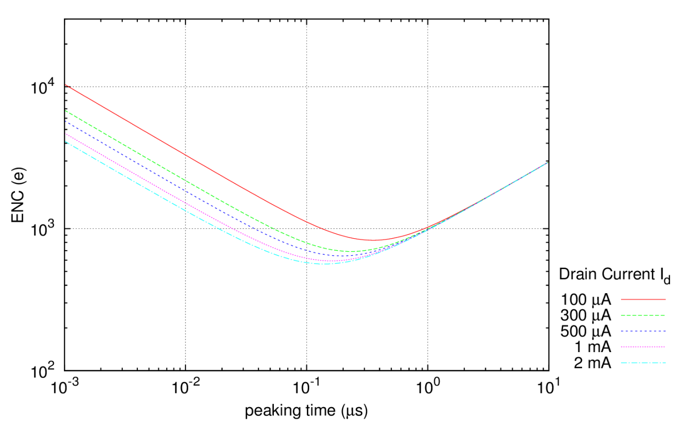
- design of new selftriggered FE based on ToPIX pixel FE started in 2012
- modified analog stage, simplified single column buffer logic
- ToT+HiRes TDC stage for amplitude measurement

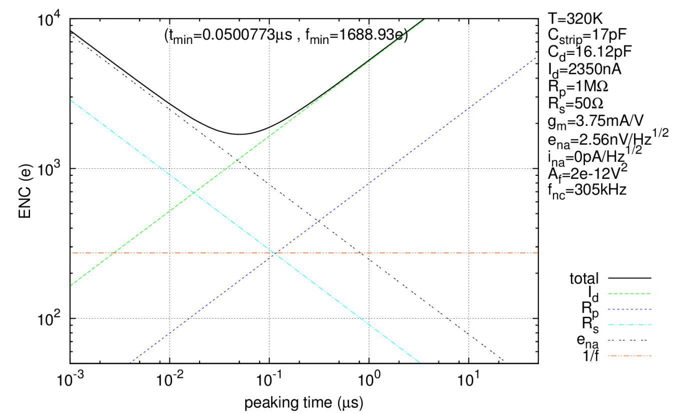
**INFN Torino, JLU Giessen, IKP Jülich**




Preamp. Noise:



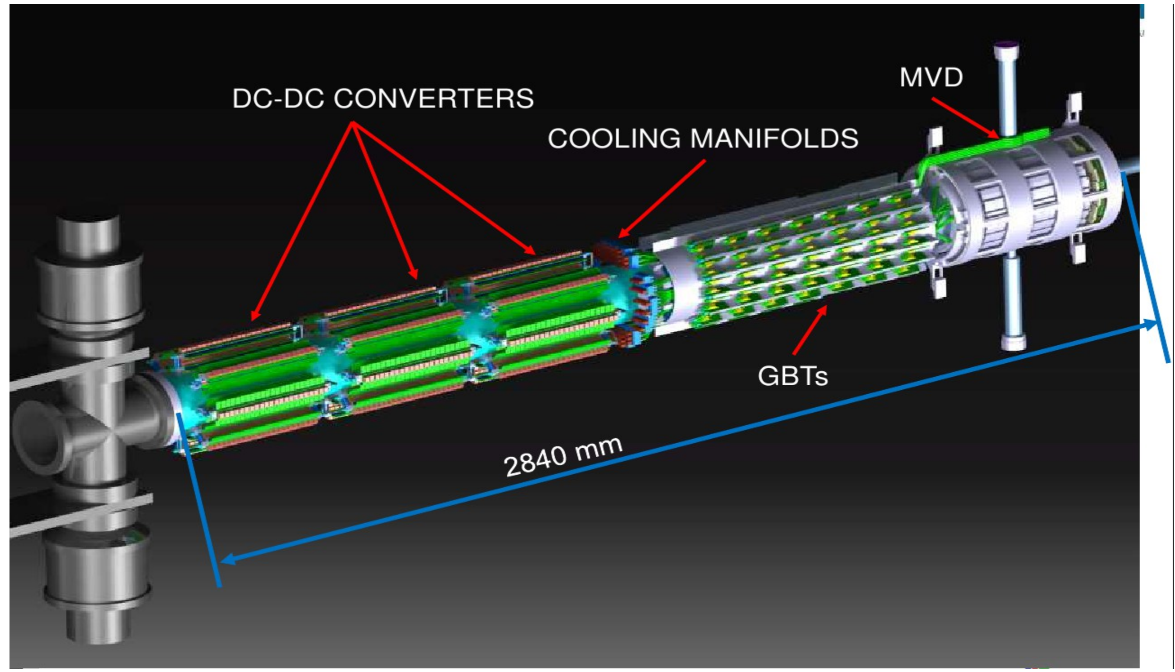

unirradiated

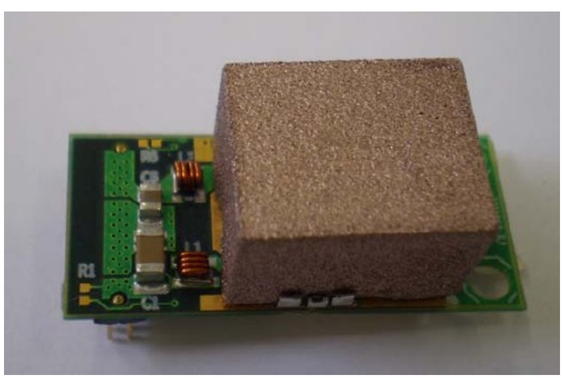
5e13 n. eq.

# Powering

DC-DC powering concept

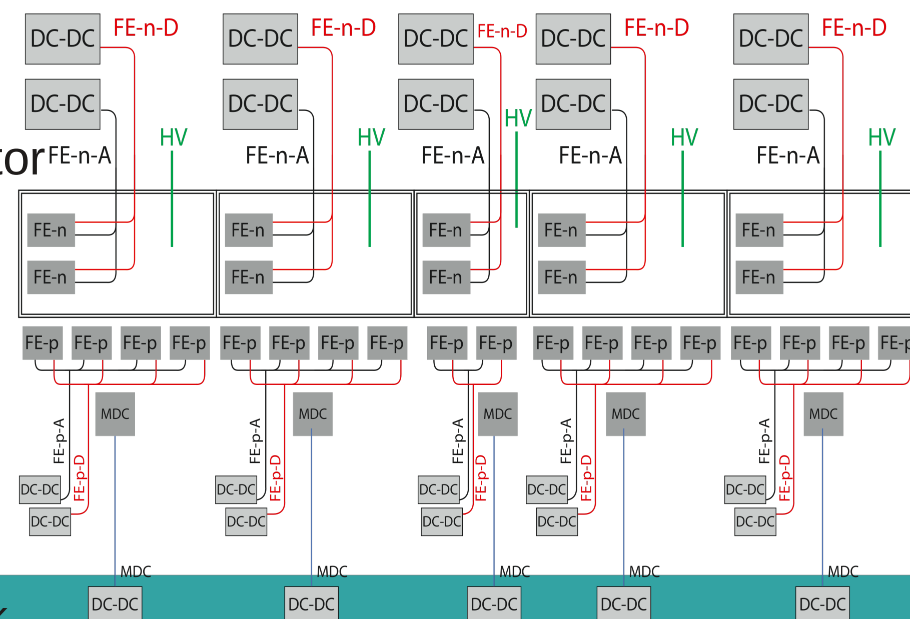
- Air-coil converters operate inside strong magnetic fields
- 80% efficiency
- Converter developed at CERN for LHC upgrade



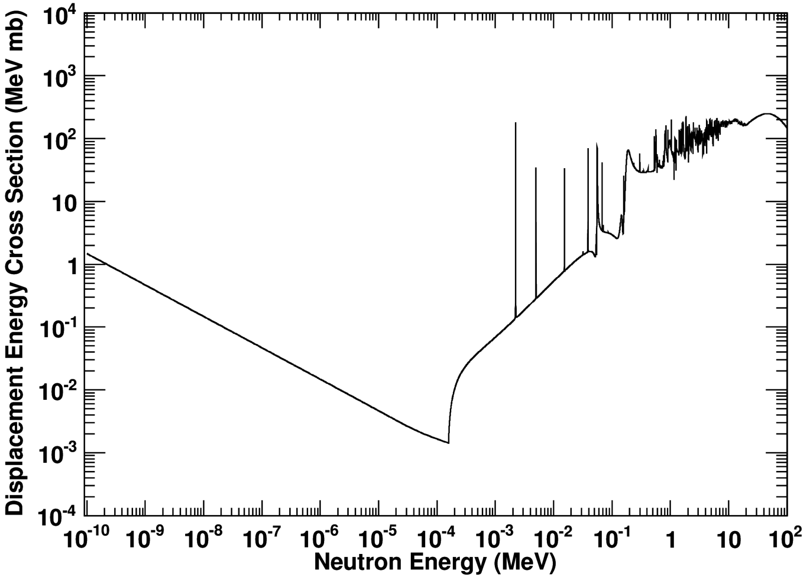



SM01C DC/DC converter

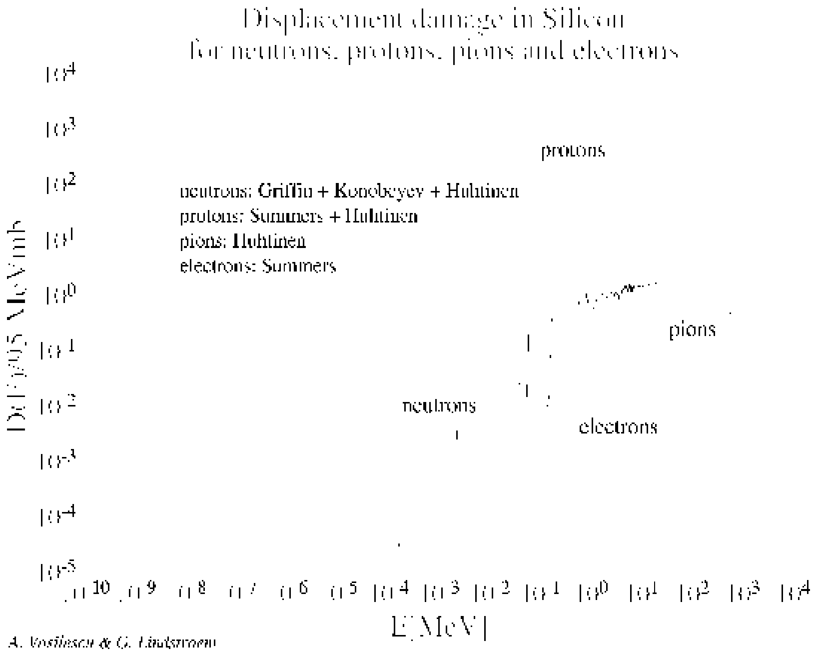
Strip subdetector powering



Si - compound



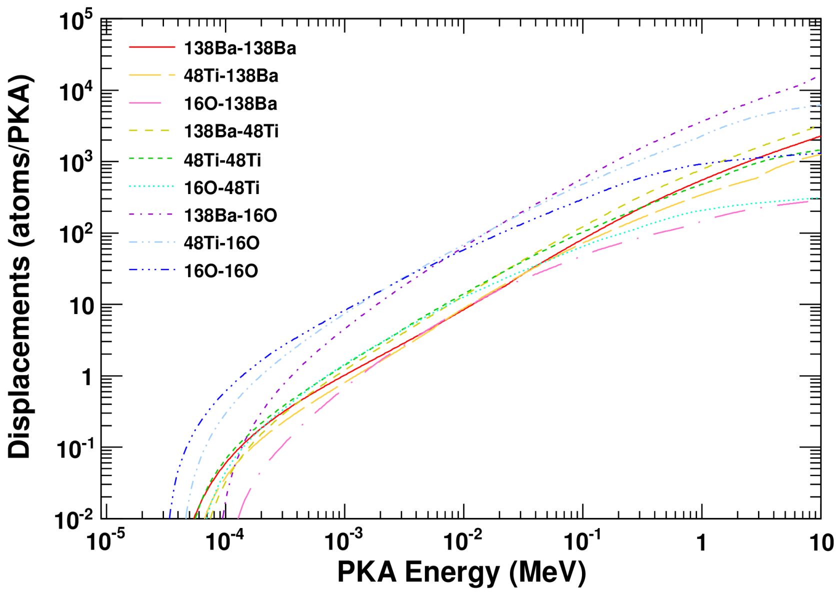
Displacement Energy Cross Section (MeV mb)
Neutron Energy (MeV)

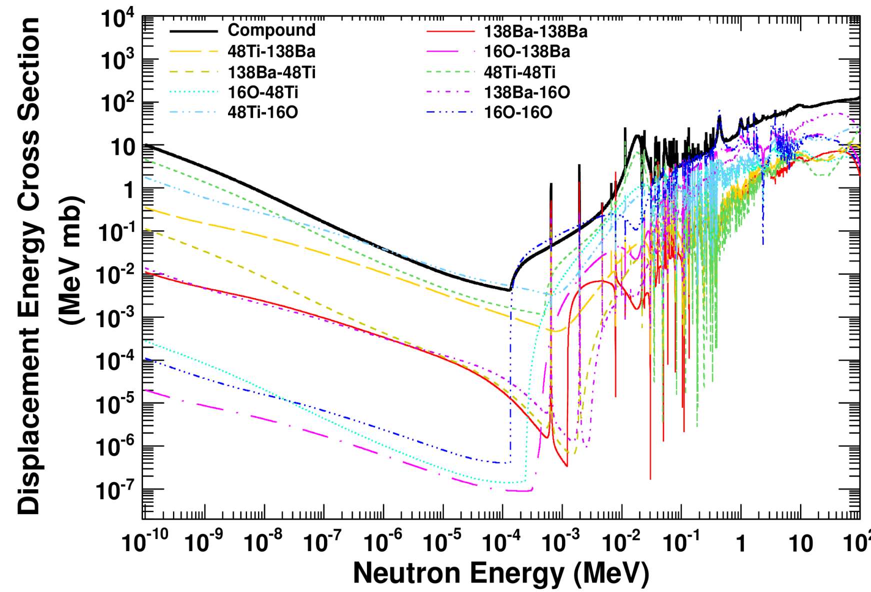



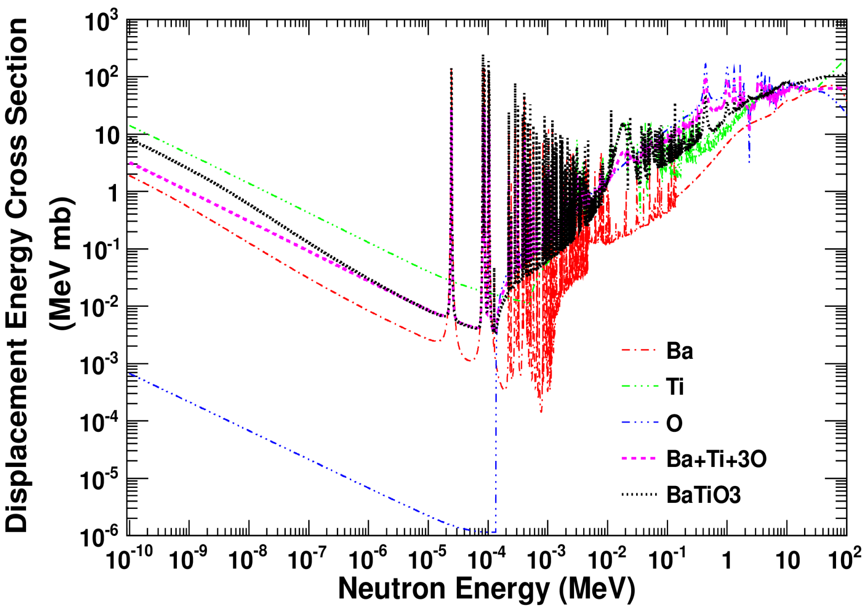
Displacement damage in Silicon
for neutrons, protons, pions and electrons
protons
neutrons: Griffin + Konobeyev + Huhtinen
protons: Summers + Huhtinen
pions: Huhtinen
electrons: Summers
pions
neutrons
electrons
A. Vasilescu & G. Lindstroem

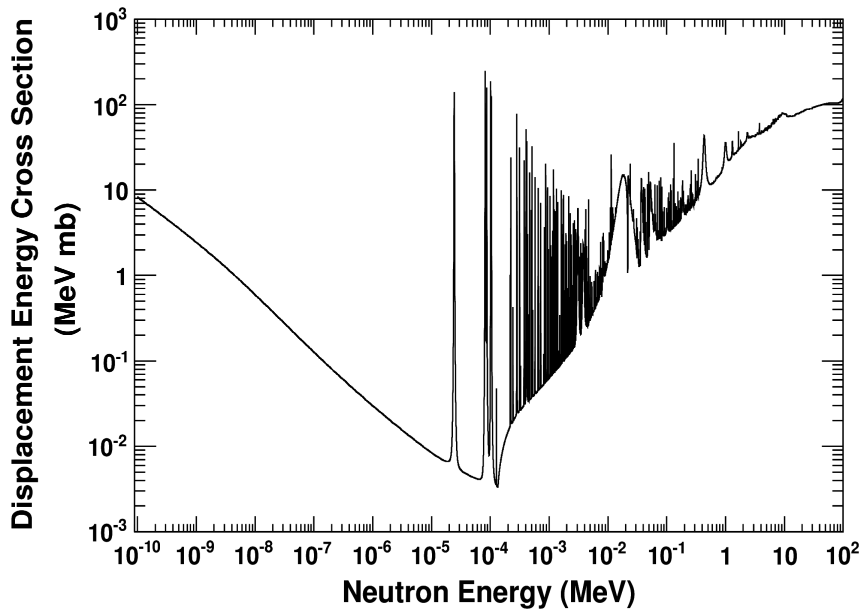
# Radiation Damage

BaTiO$_3$ - compound

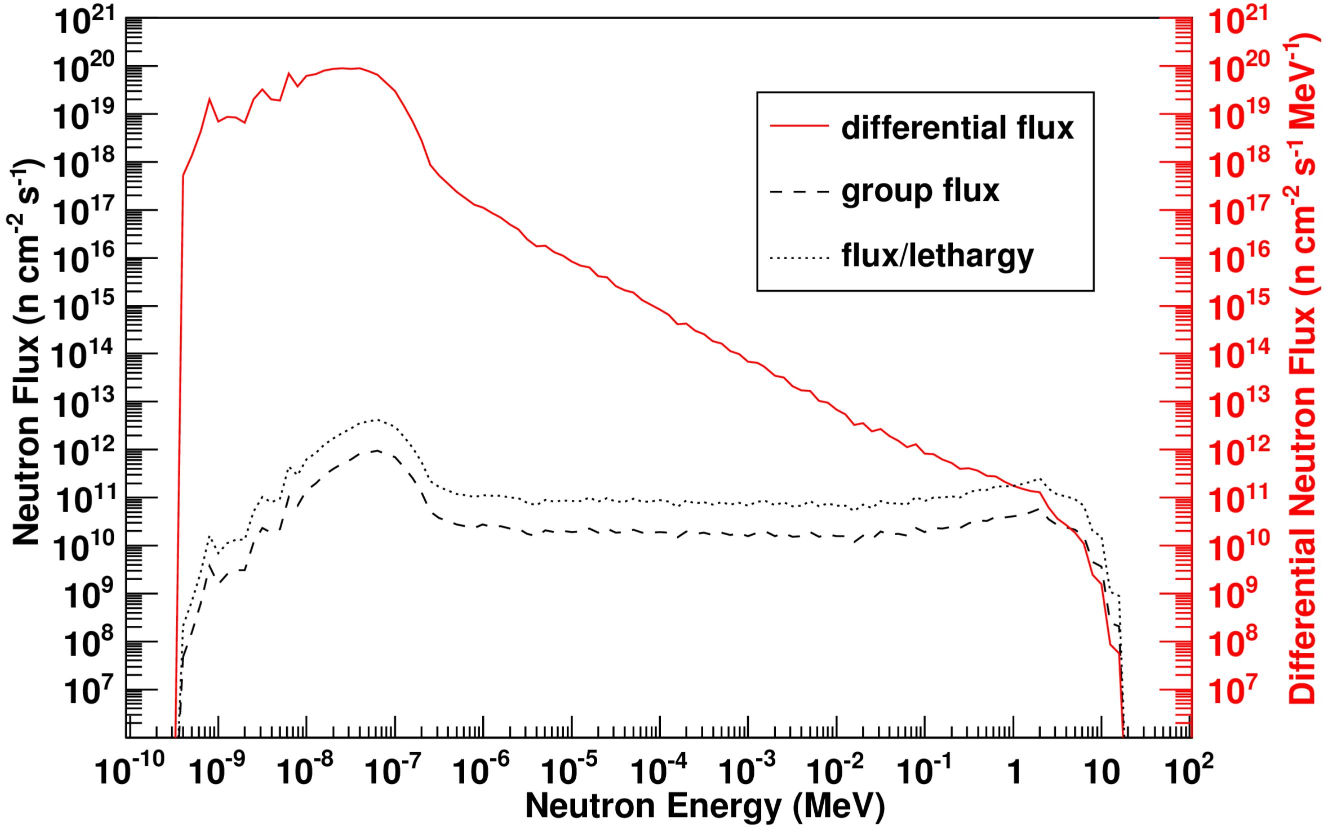


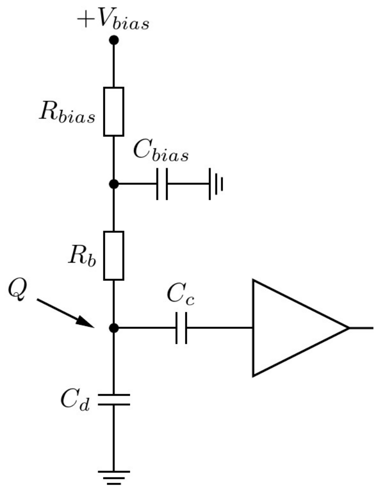



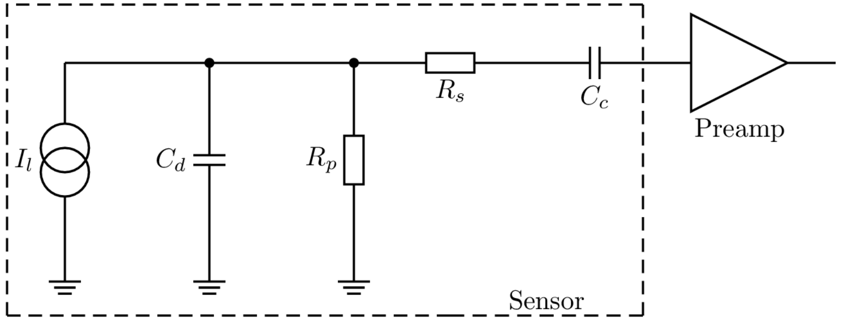



# Radiation Damage



# Strip Subdetector



# Strip Sensors