High Resolution RBS measurements – GePb/Ge, HfO_2/Ge

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8th International Workshop on High-Resolution Depth Profiling (HRDP8)

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Outline

- CIBA at a glance
  - *Beamlines, their uses*

- Germanium-Lead on Ge
  - *PLA, capping layers*
  - *RBS, HR-RBS results*

- Hafnium oxide on Ge
  - *HR-RBS*
  - *Ge damage*
  - *Damage correction*

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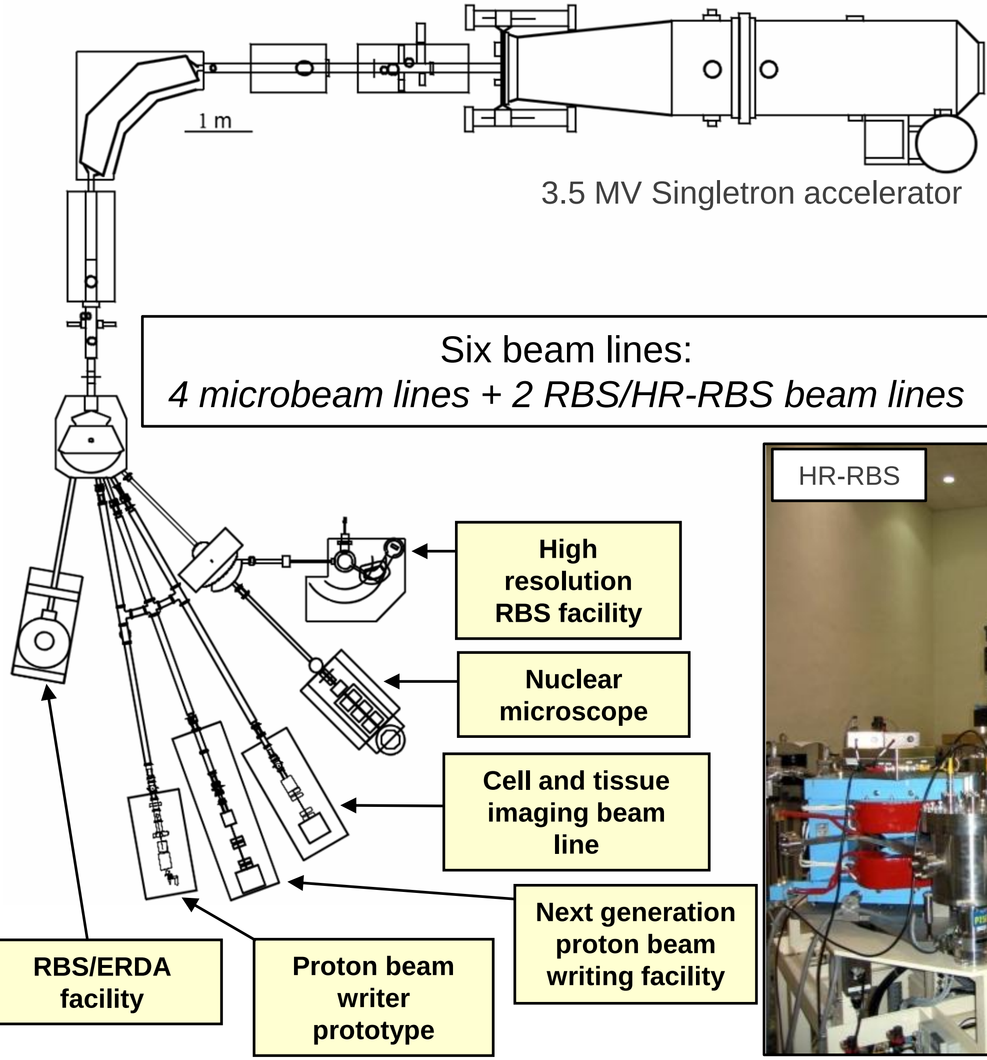

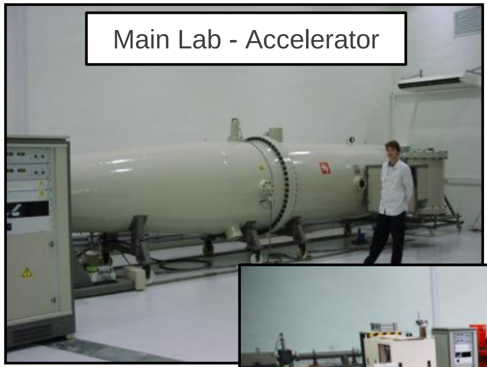

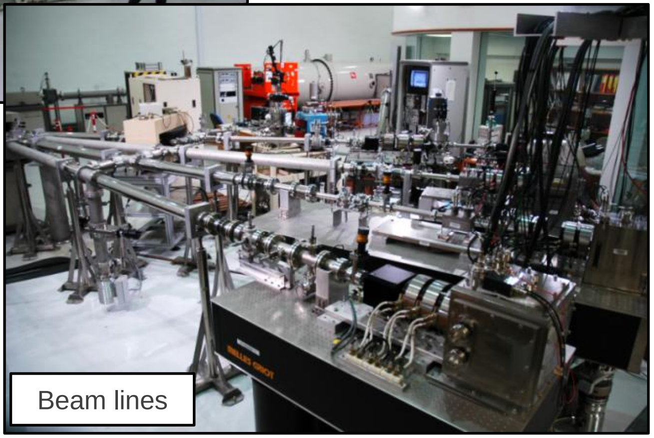

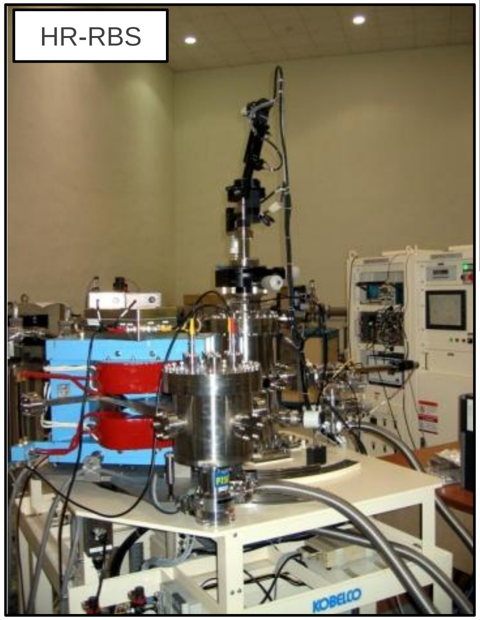

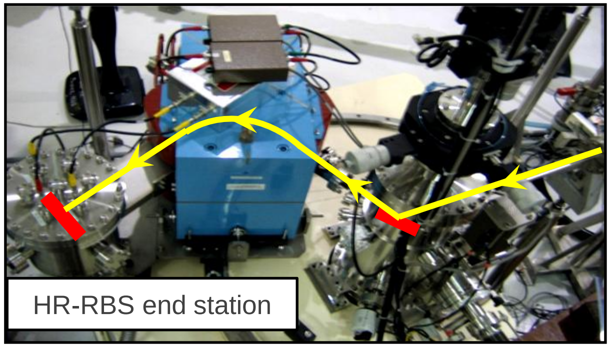

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Research at CIBA

Primary research thrusts at CIBA, in six groups

Andrew Bettiol:

Micro and Nano photonics

Metamaterials, proton beam modification of materials and bioimaging.

Thomas Osipowicz:

Materials Characterization:

Microbeam RBS/PIXE, High Res RBS/ERDA, Single Ion Applications (IBIC, STIM)

Mark Breese:

Proton modification of silicon:

Silicon microstructure fabrication and silicon photonics:

Jeroen van Kan:

Proton beam writing:

Development, molds and stamps for Biochips.

Frank Watt (Visiting):

Proton microscopy in biomedicine:

Trace elements in Alzheimers disease, Parkinsons disease, Atherosclerosis, and whole cell imaging.

Chammika Udalagama:

Fundamental studies:

Ion beam/material interactions. Data acquisition systems.

Why Germanium?

- Scaling down of transistors
  - large interest in alternative materials to replace Si
- Higher carrier mobilities than Si
- Easy integration with Si
- Direct band-gap compounds - Pb, Sn

GePb – Laser Induced Epitaxy

Motivation

- Need for crystalline GePb films
- Explore pulsed laser anneal (PLA) as a non-equilibrium process for dopant activation
- Study the effect of different capping layers on the behavior of Pb after PLA

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GePb thin film process flow

Starting substrate
n-type lightly doped Ge(100)

Pre-deposition clean using HF:H_2O

Sputter deposition of GePb

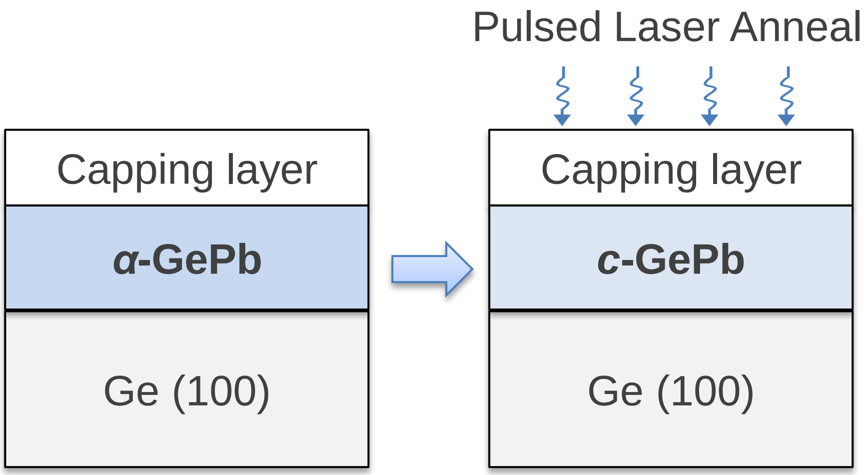
DC power on GePb target: 30 W
RF power on substrate: 12 W
Chamber pressure: 3 mTorr

Capping layer deposition

SiO_2, Si_3N_4, or Al_2O_3

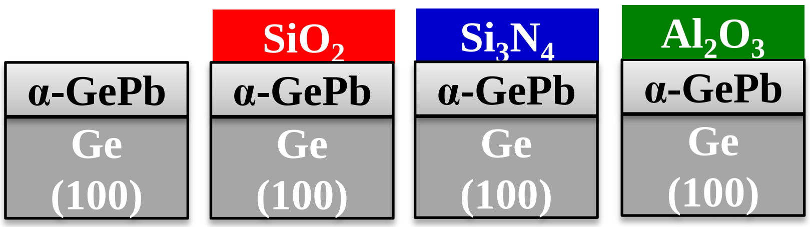
Pulsed laser anneal

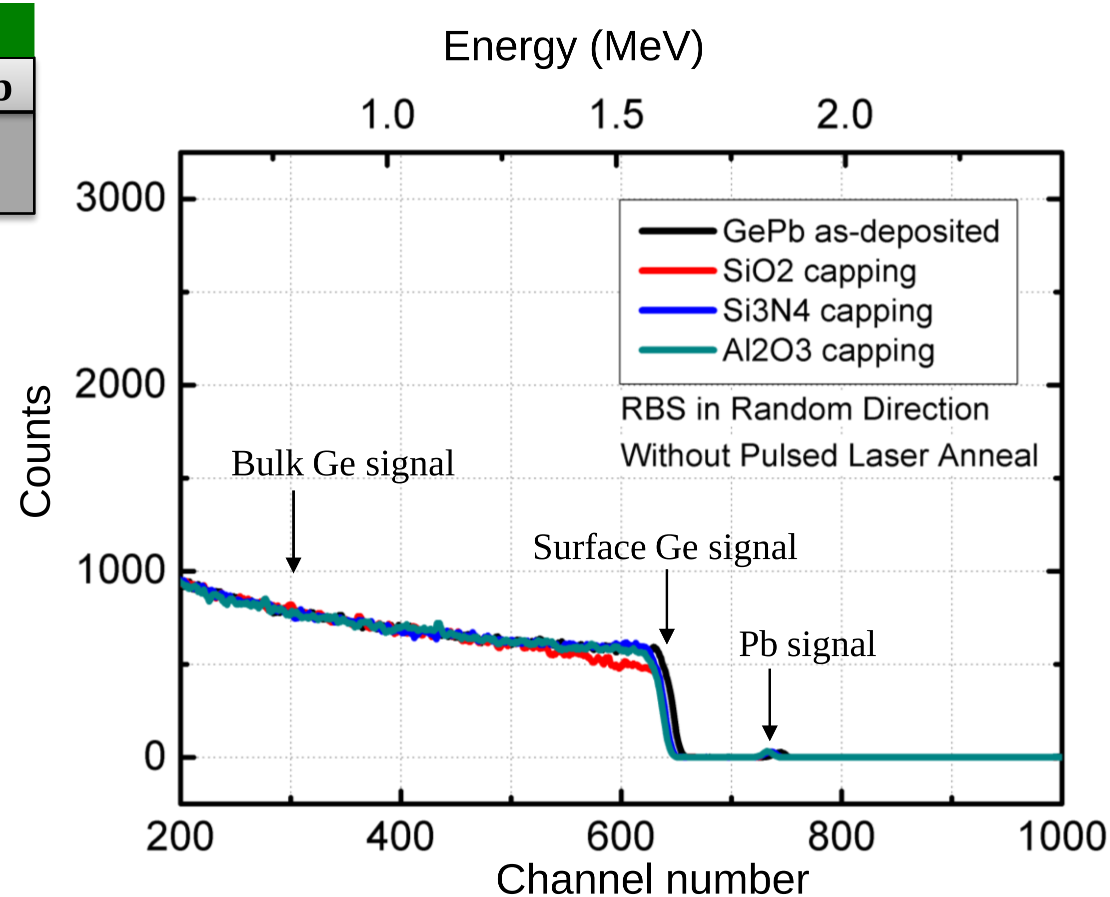
Laser wavelength: 248 nm
Fluence: 300, 350, 400, 450, or 500 mJ/cm^2
5 pulses (pulse duration: 23 ns)



Conventional RBS - GePb

Before pulsed laser anneal - With capping layers





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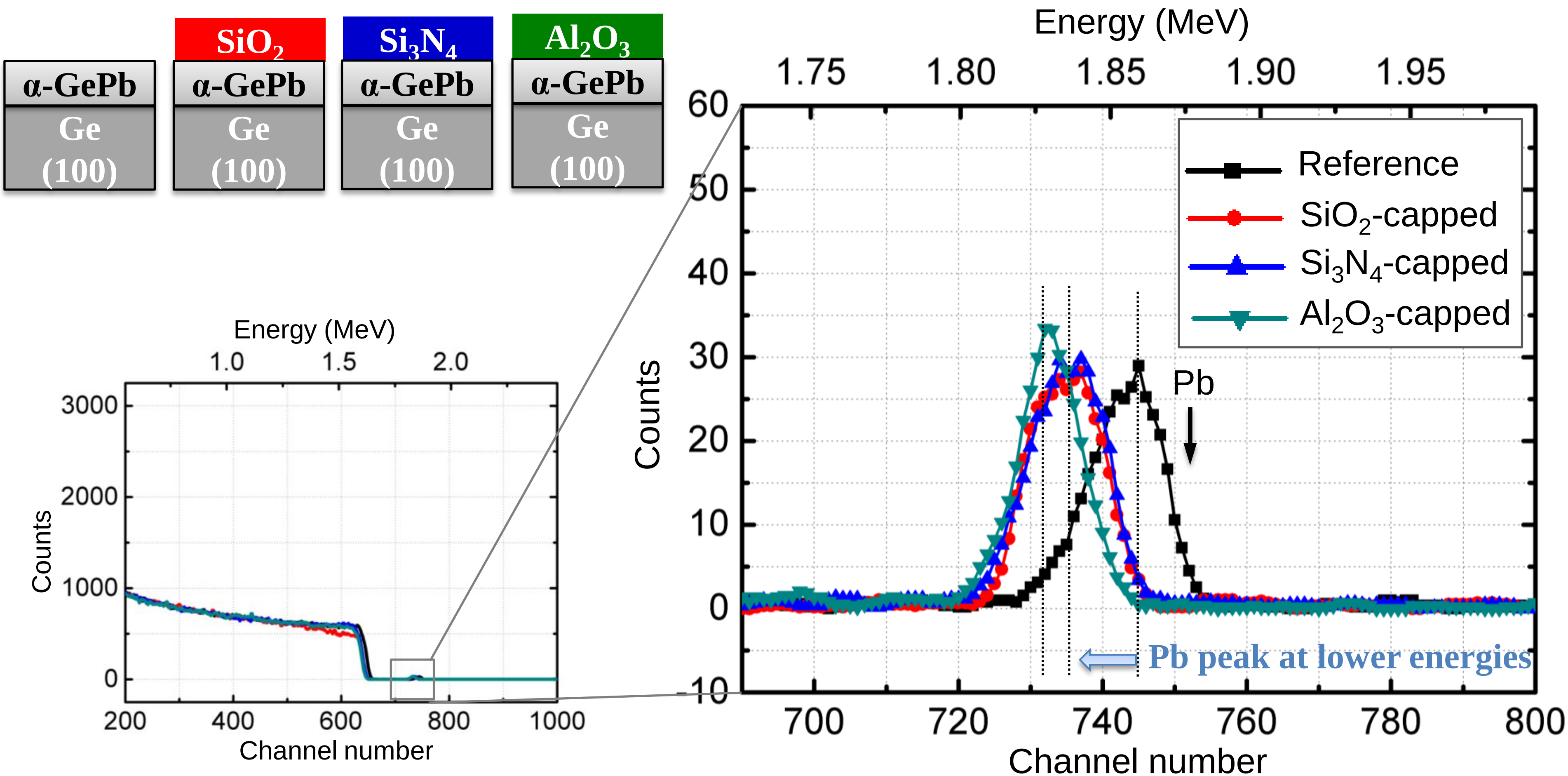

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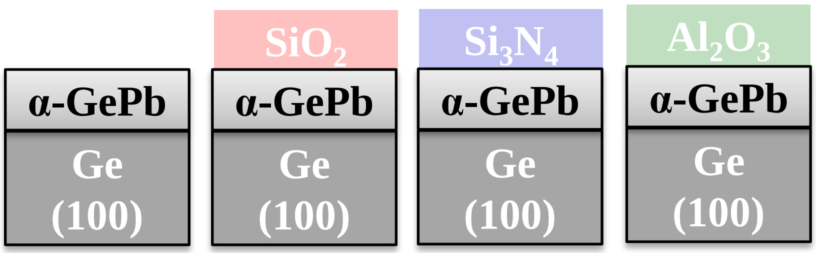
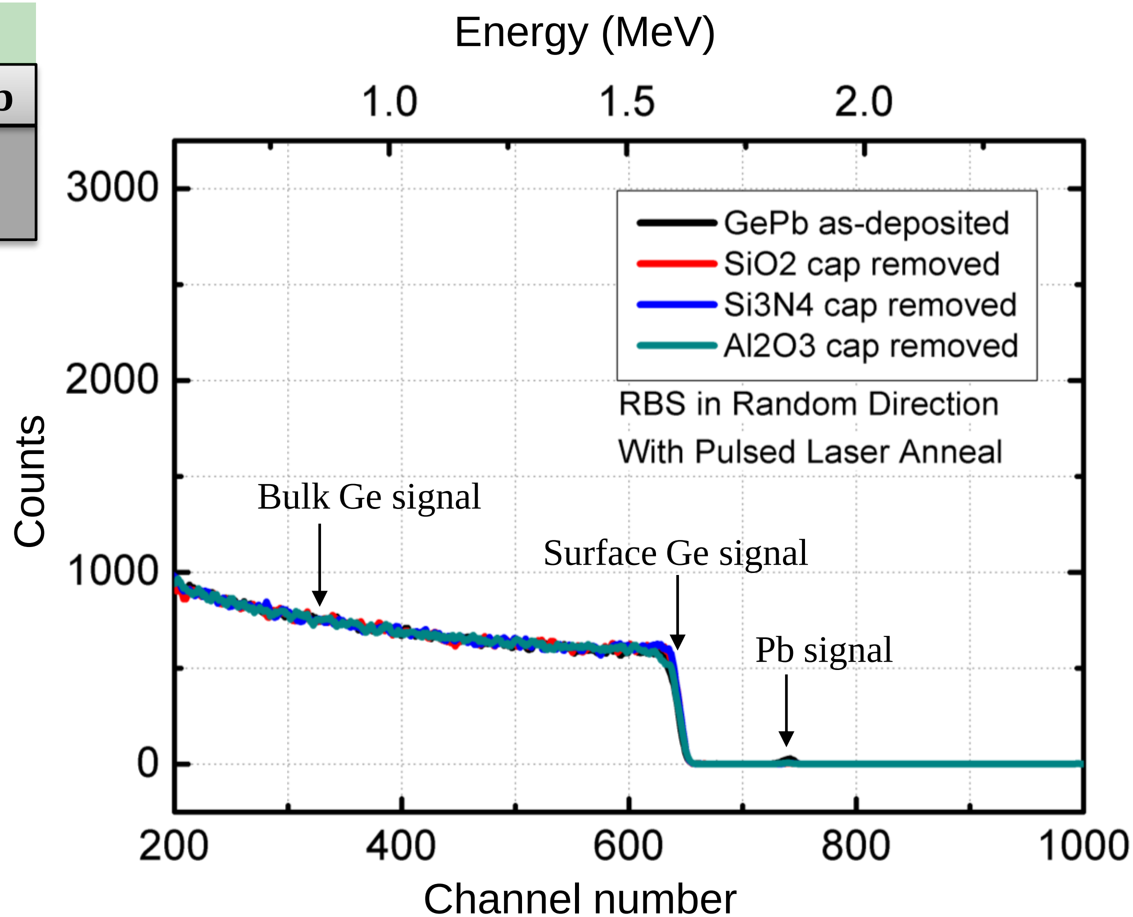
Conventional RBS - GePb

After pulsed laser anneal - Without capping layers





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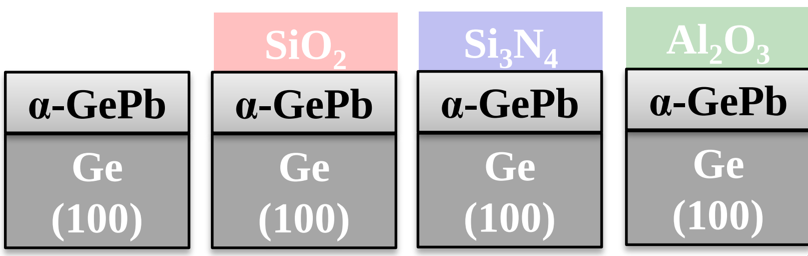
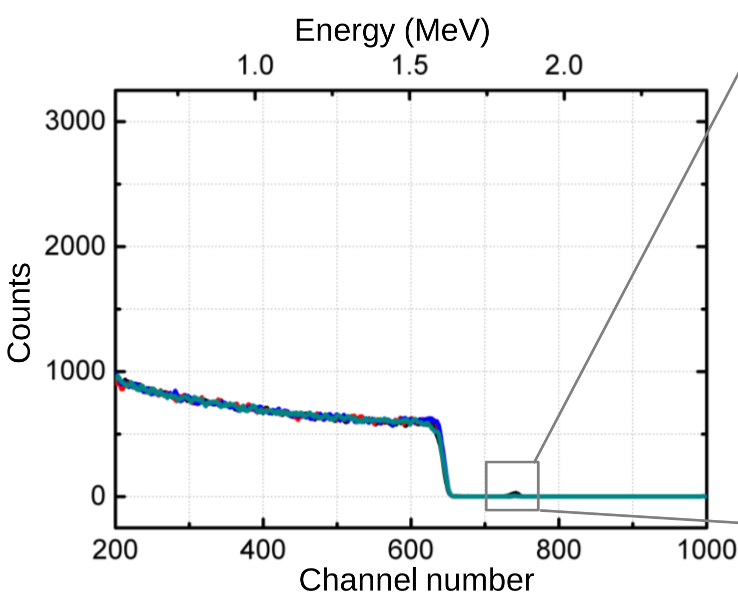
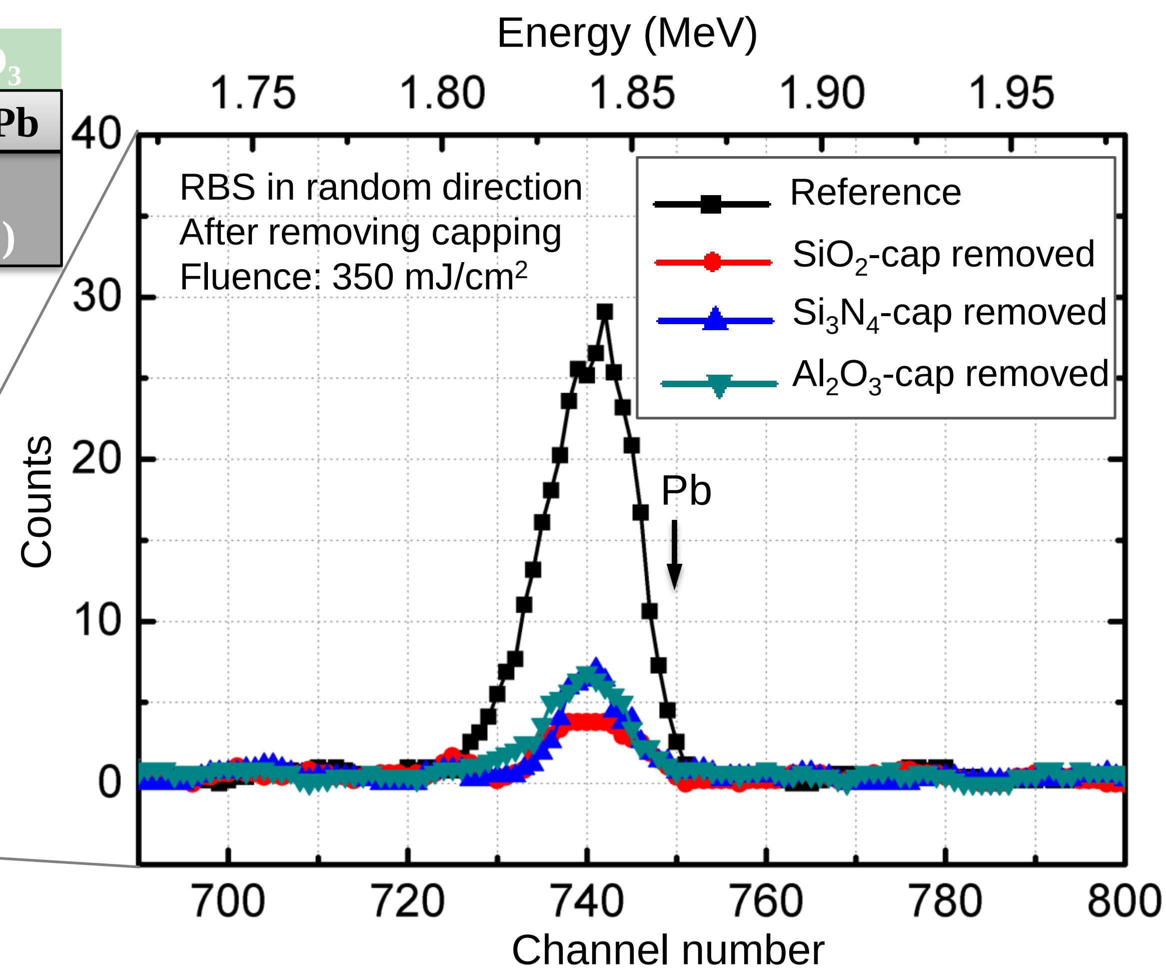
Conventional RBS - GePb

After pulsed laser anneal - Without capping layers







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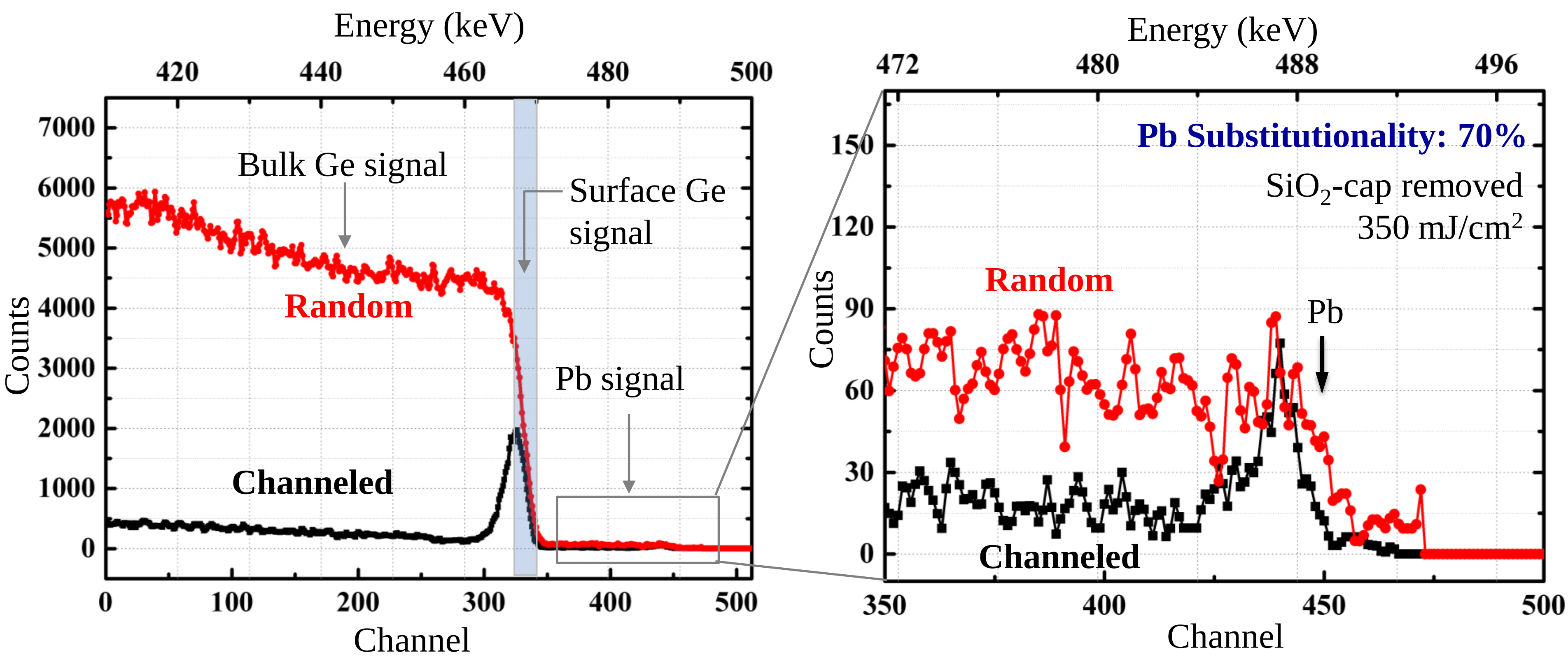
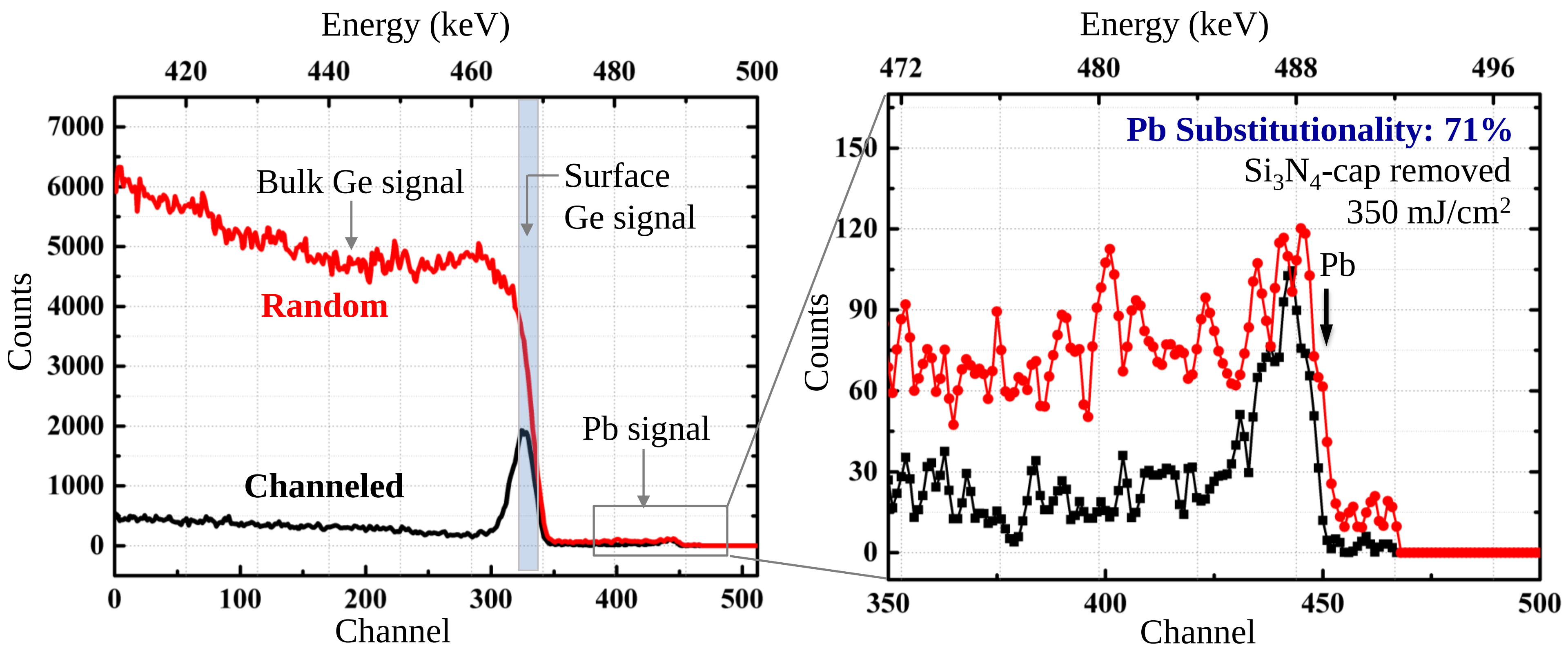
HR-RBS – GePb

SiO$_2$ cap removed



HR-RBS – GePb

Si_3N_4 cap removed



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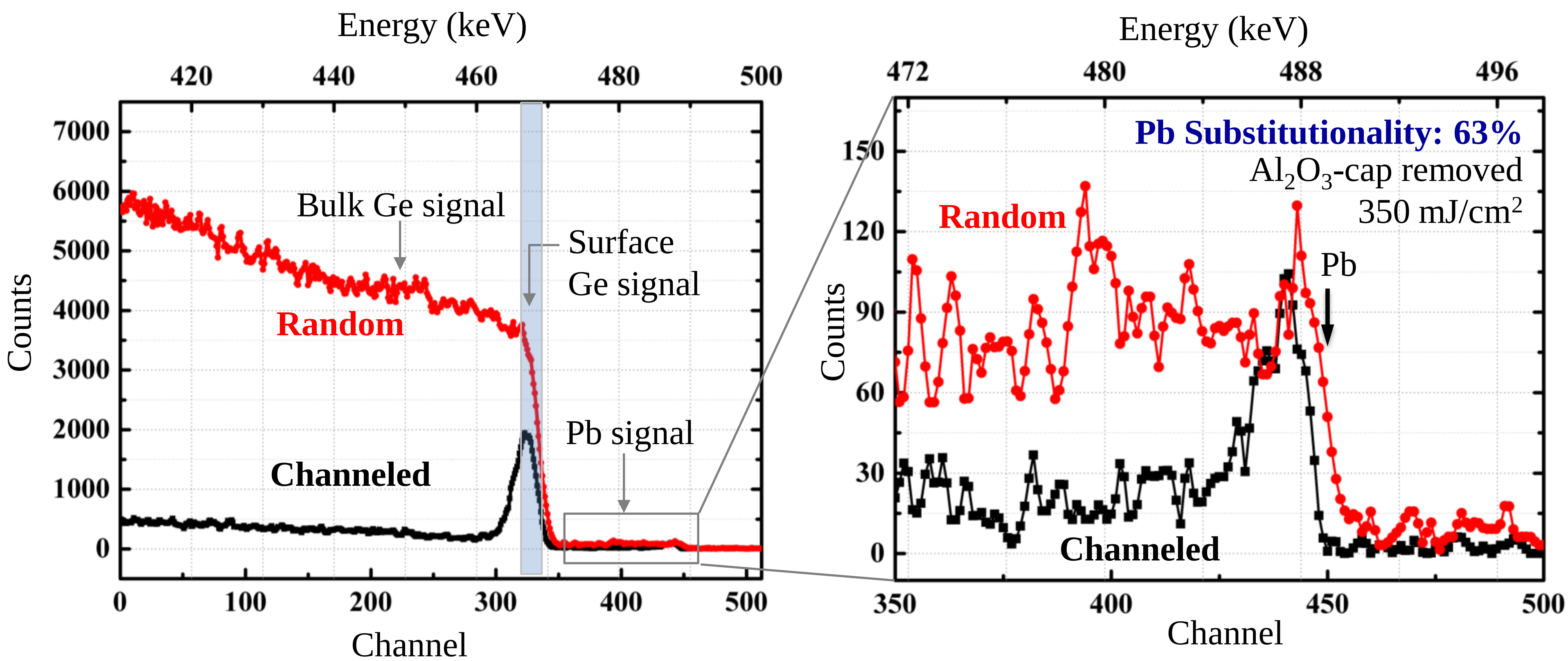
HR-RBS – GePb

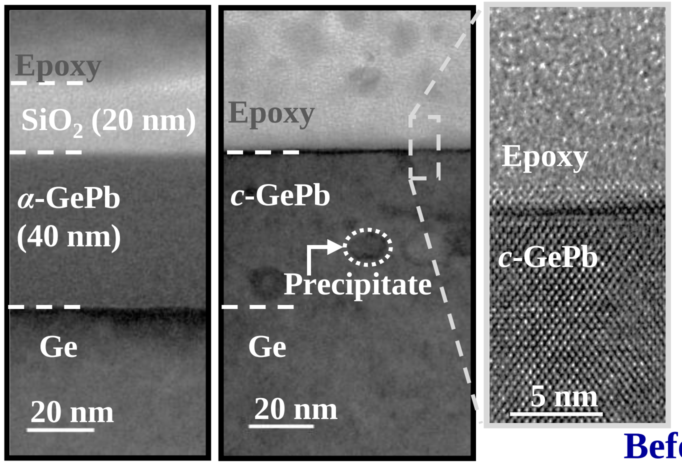
Al_2O_3 cap removed



TEM

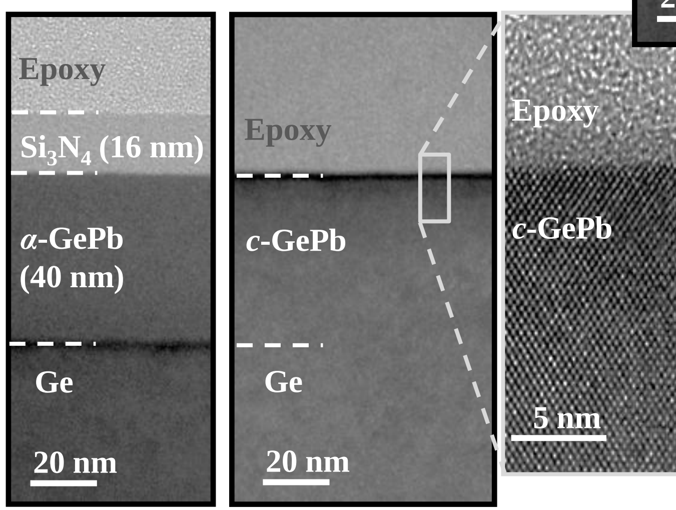
SiO_2-capped

Before PLA **After PLA**



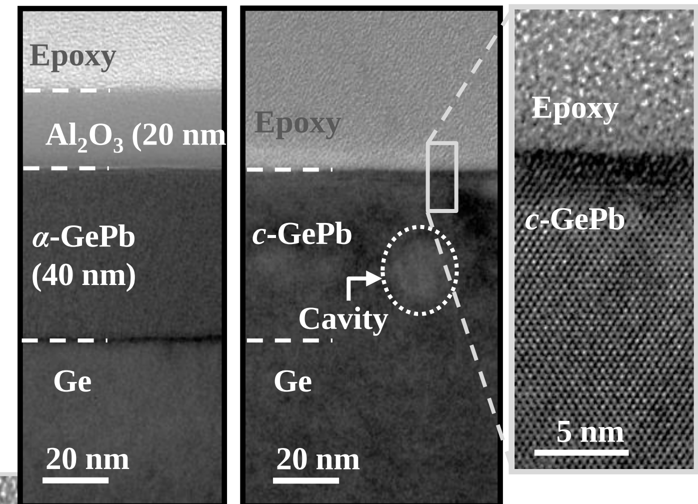
Si_3N_4-capped

Before PLA **After PLA**



Al_2O_3-capped

Before PLA **After PLA**



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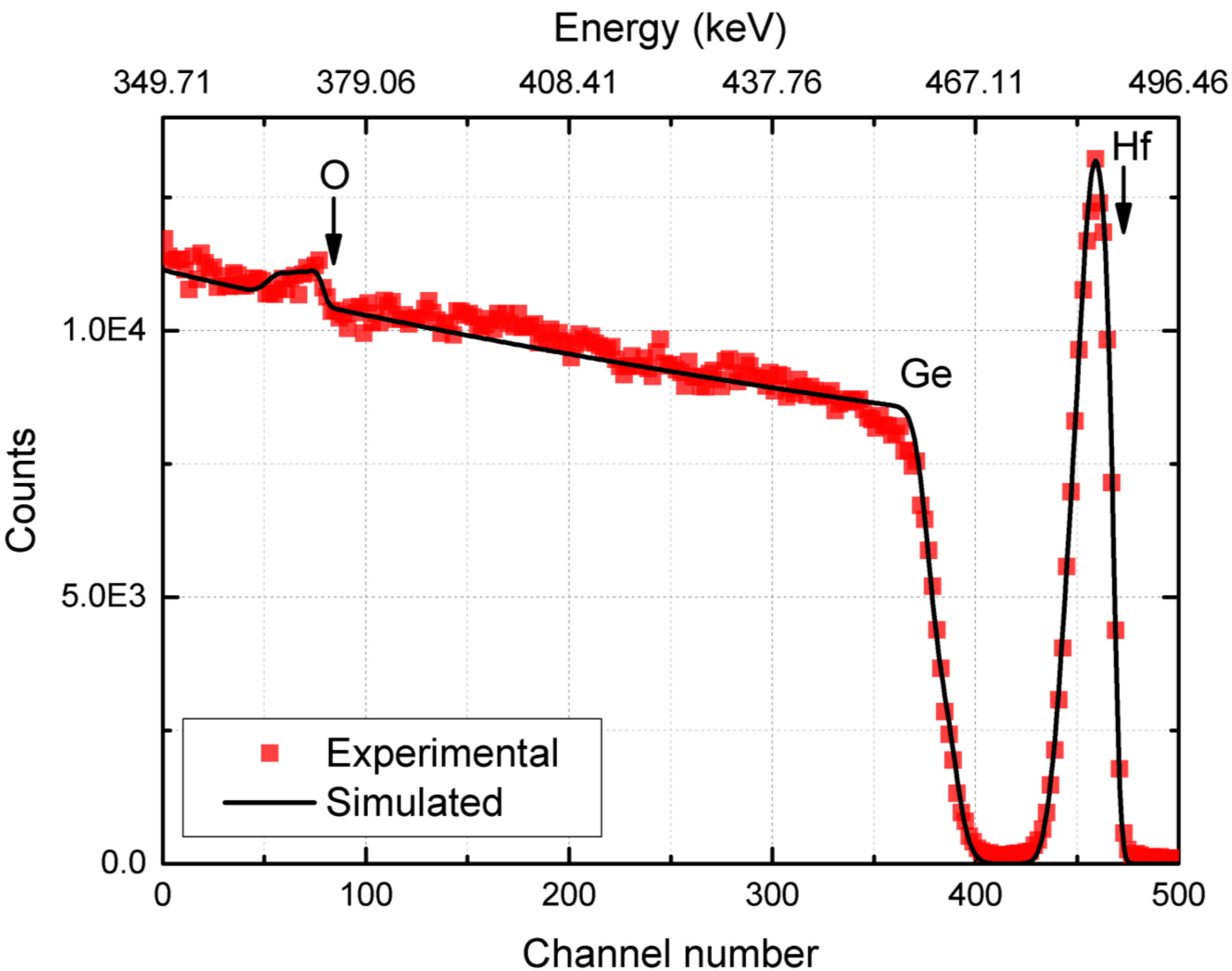
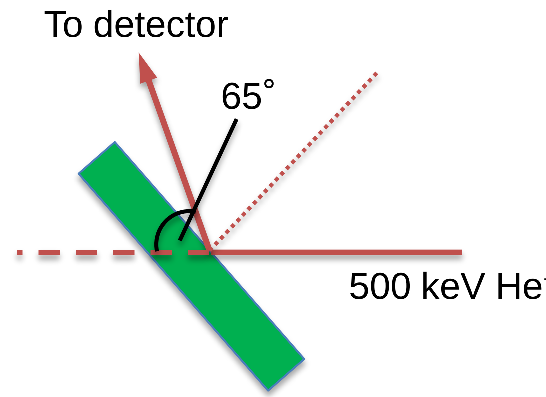
HfO_2 on Ge

Motivation

- Transistor scale down
- Explore the HfO_2/Ge interface using HR-RBS

HR-RBS

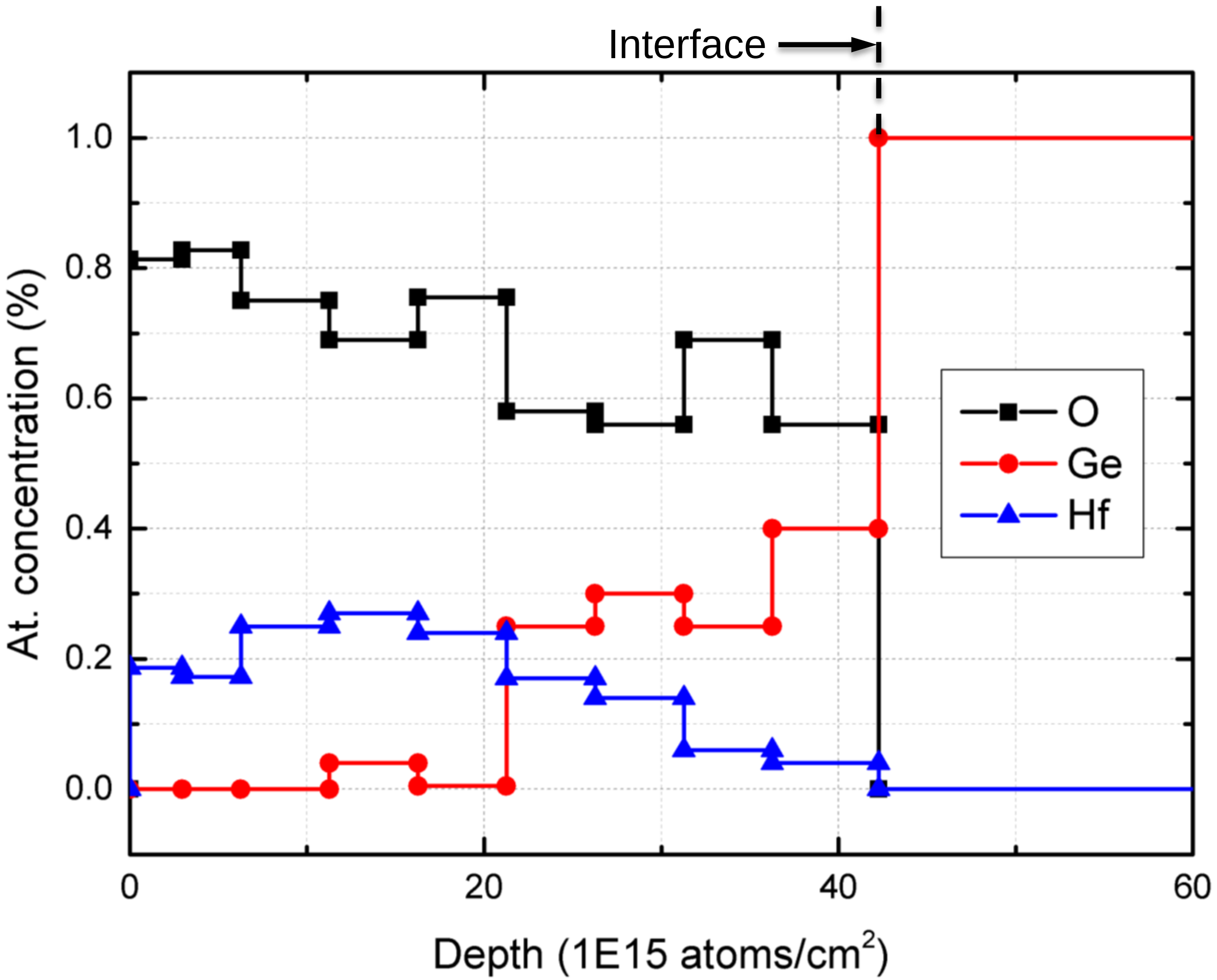




ALD hafnium oxide on (100) Ge

$Hf_{(1-x)}O_x$ ~ 2.5nm
HfGeO ~ 7nm
Ge substrate

Depth profile



Depth resolution in Ge at interface
~ 2.3 nm

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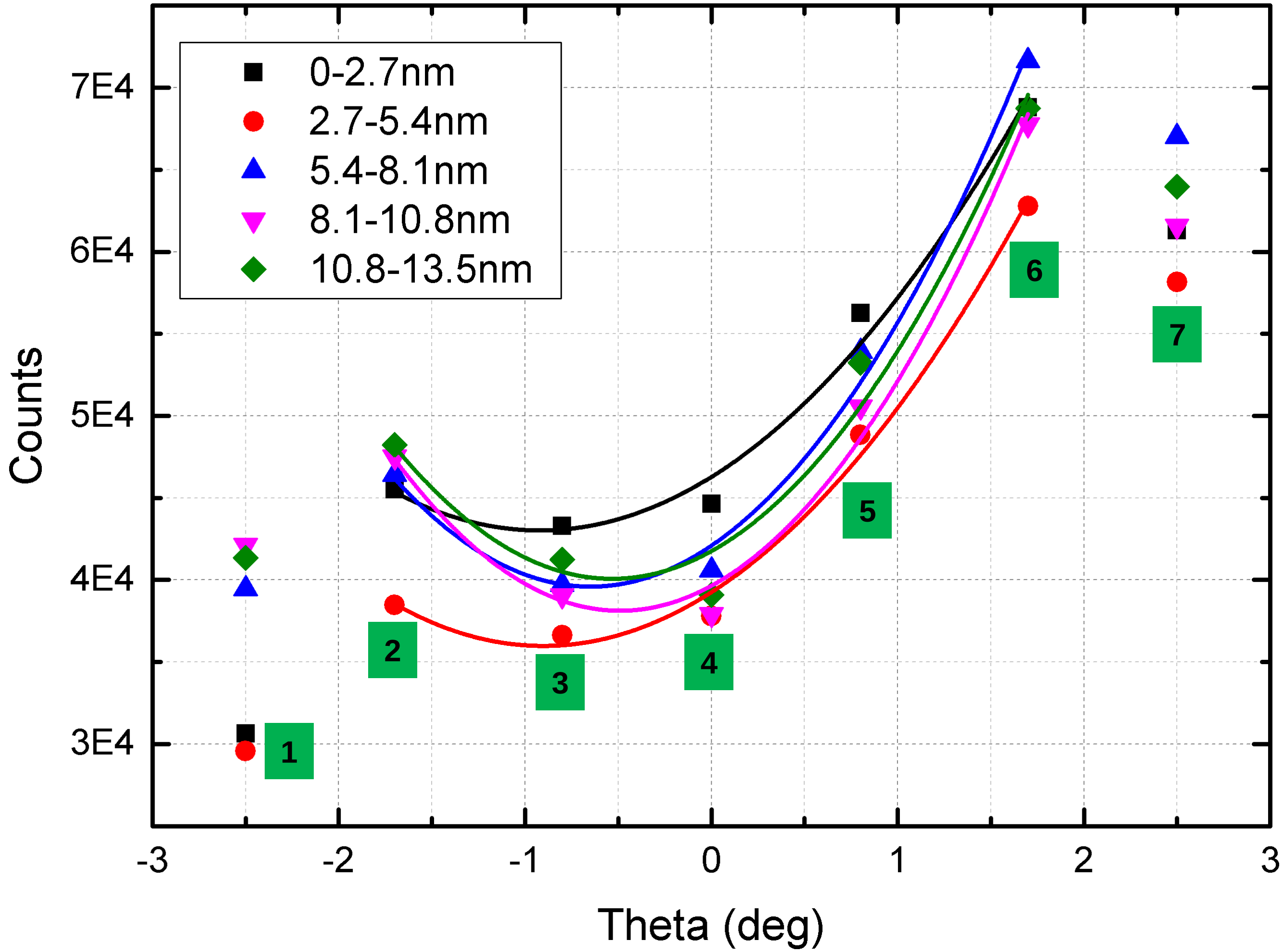
Angular scans about <111>



Order of measurement	Accumulated charge (uC)
1	5
2	10
3	15
4	20
5	25
6	30
7	35

Asymmetric curves

⇩

Ge damage

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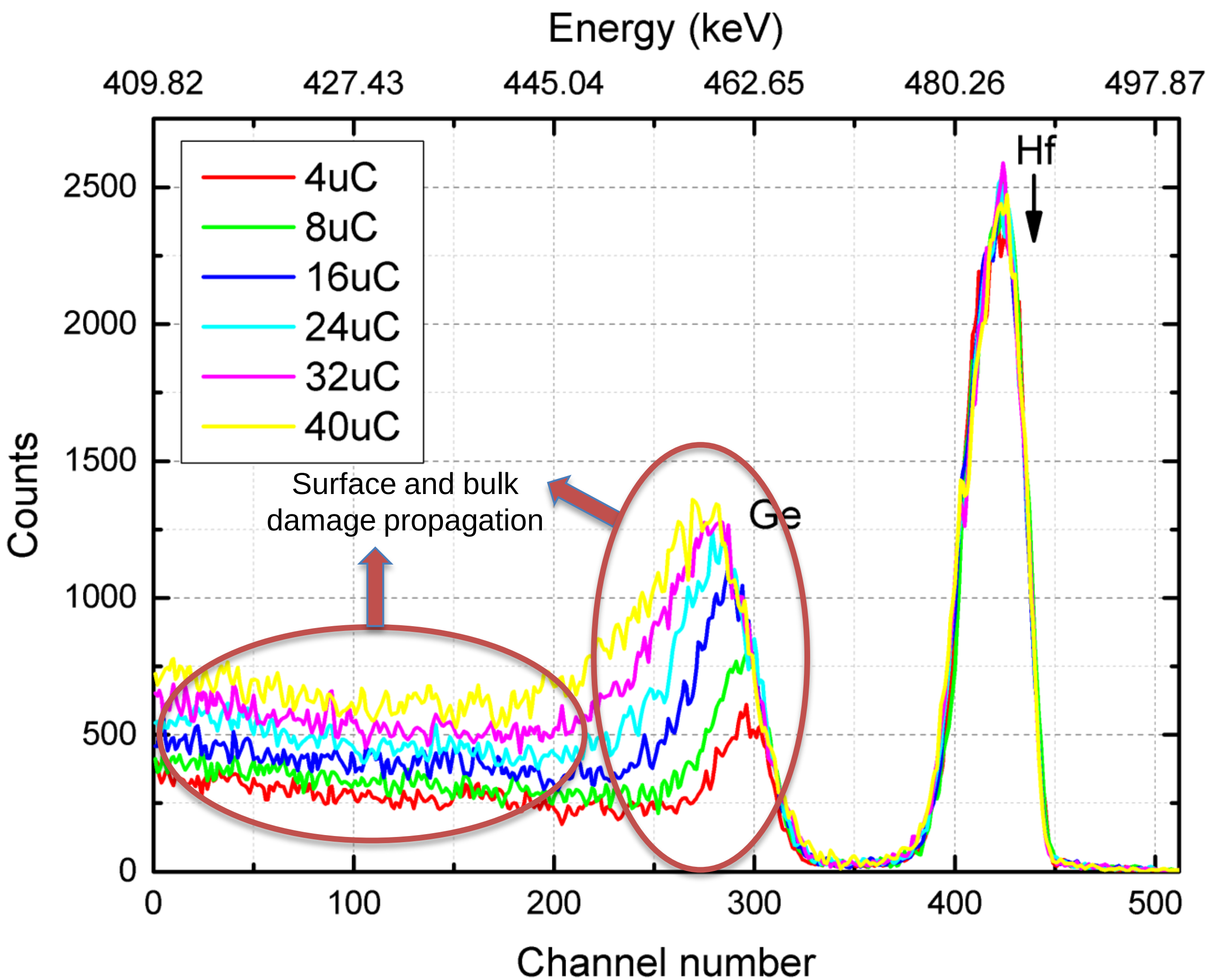
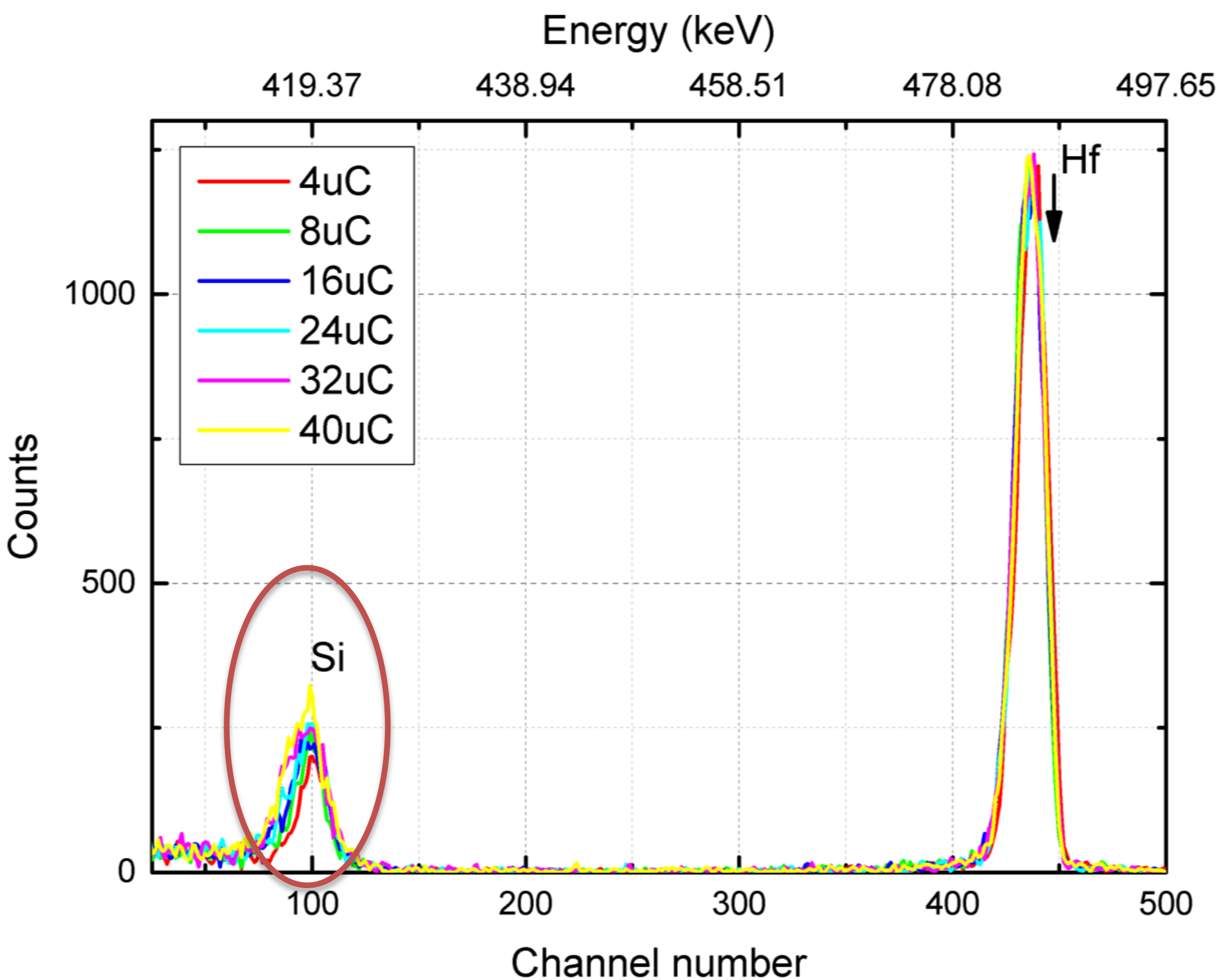
Ge substrate damage



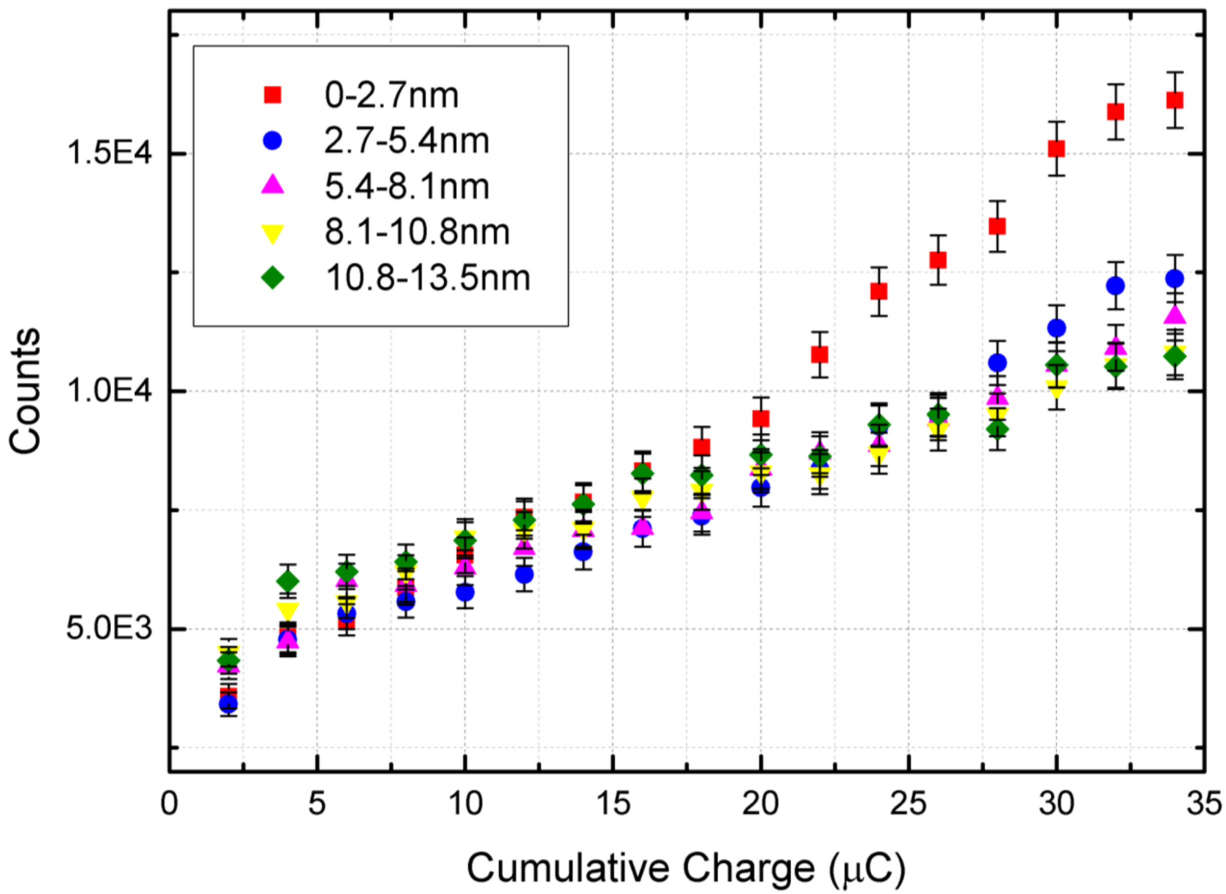
Each spectrum measured up to a charge of 2 μC and in the aligned orientation

Si substrate damage



Each spectrum measured up to a charge of 2 μC and in the aligned orientation

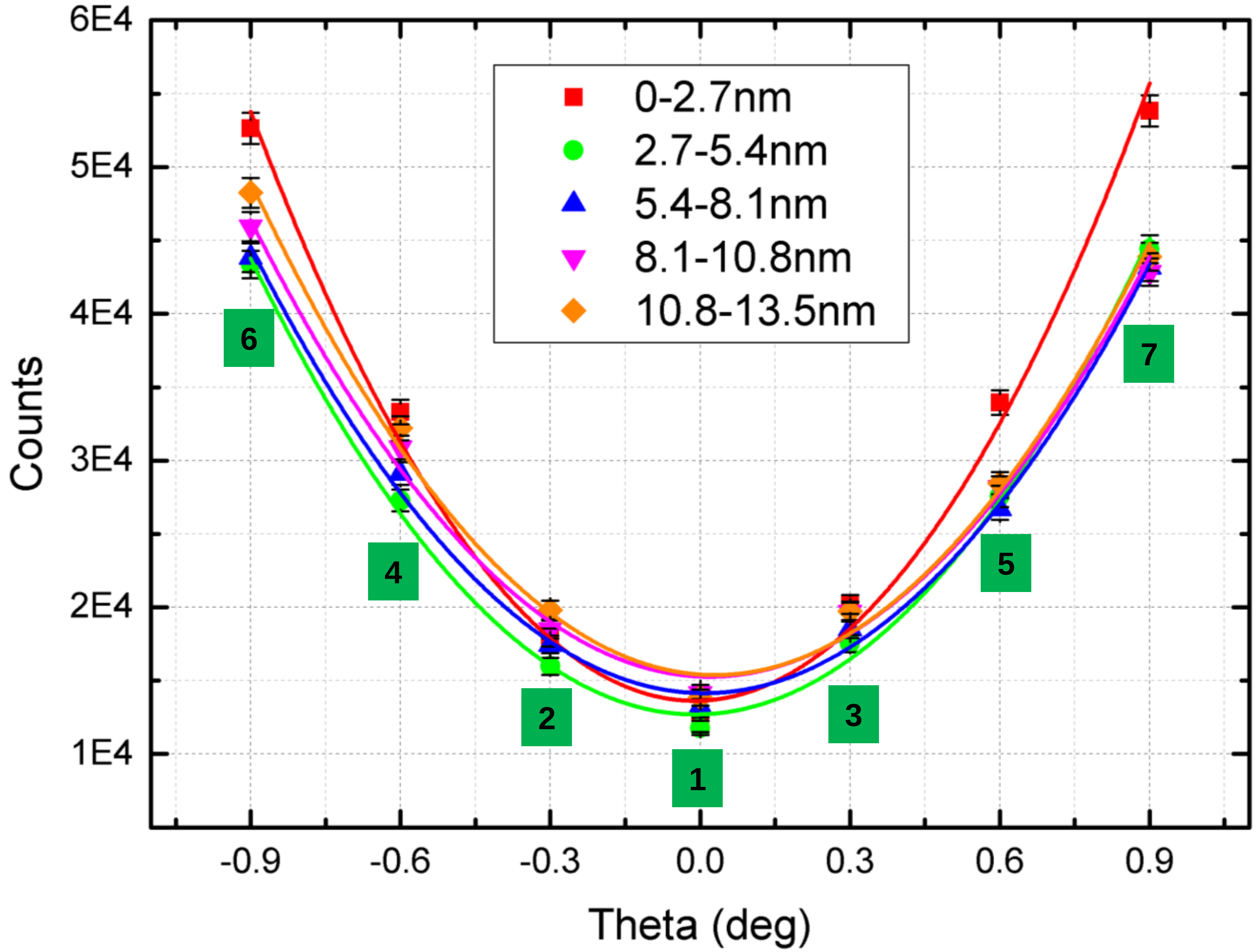
Ge damage evolution with depth



- First level of correction factors
- Taken in aligned orientation
- Correct for an increase in counts with depth

Angular scans about <111>

Before correction



Order of measurement	Accumulated charge (uC)
1	5
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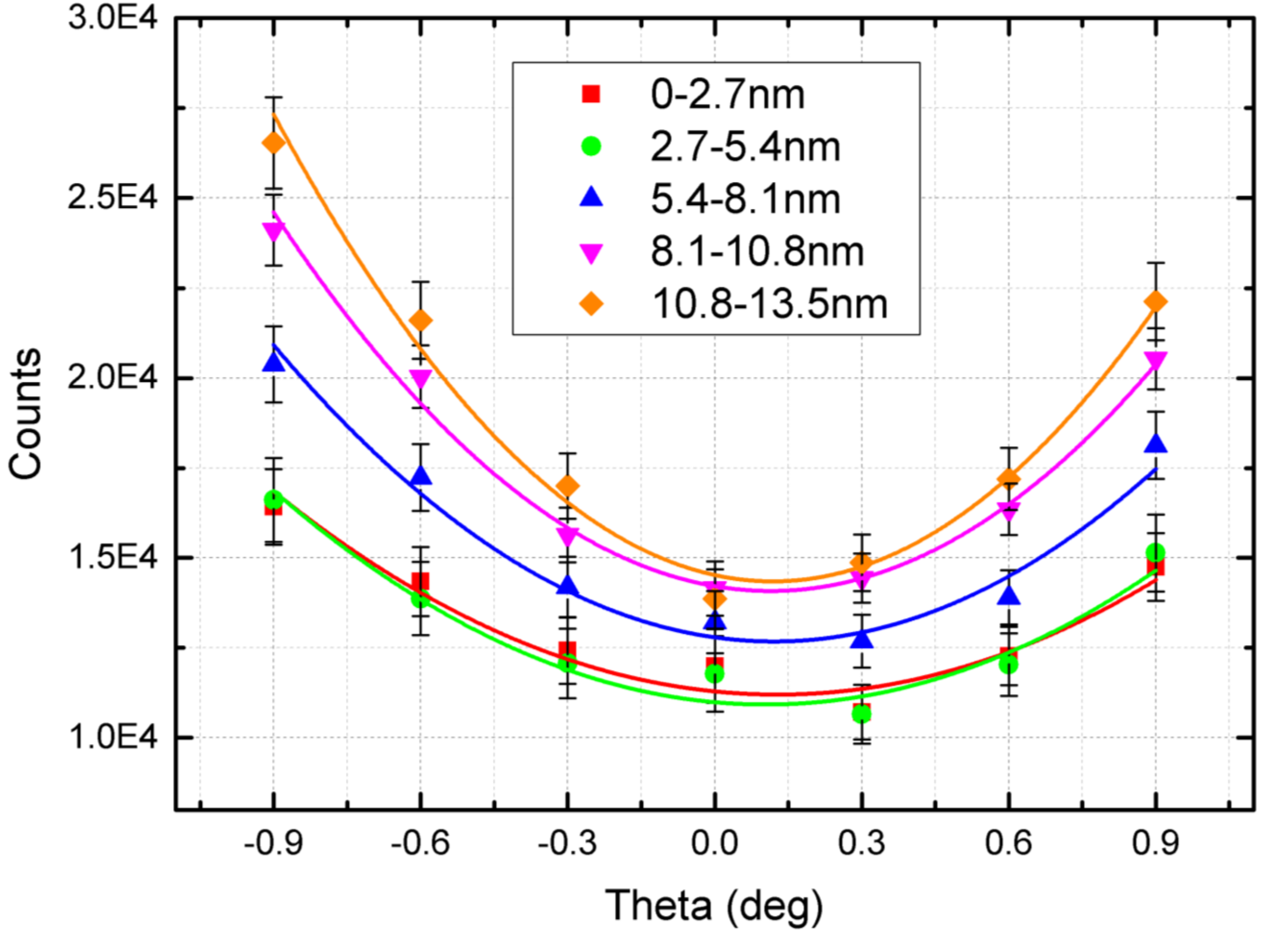
Order of measurement

⇩

Symmetric angular scans

Angular scan about <111>

After correction



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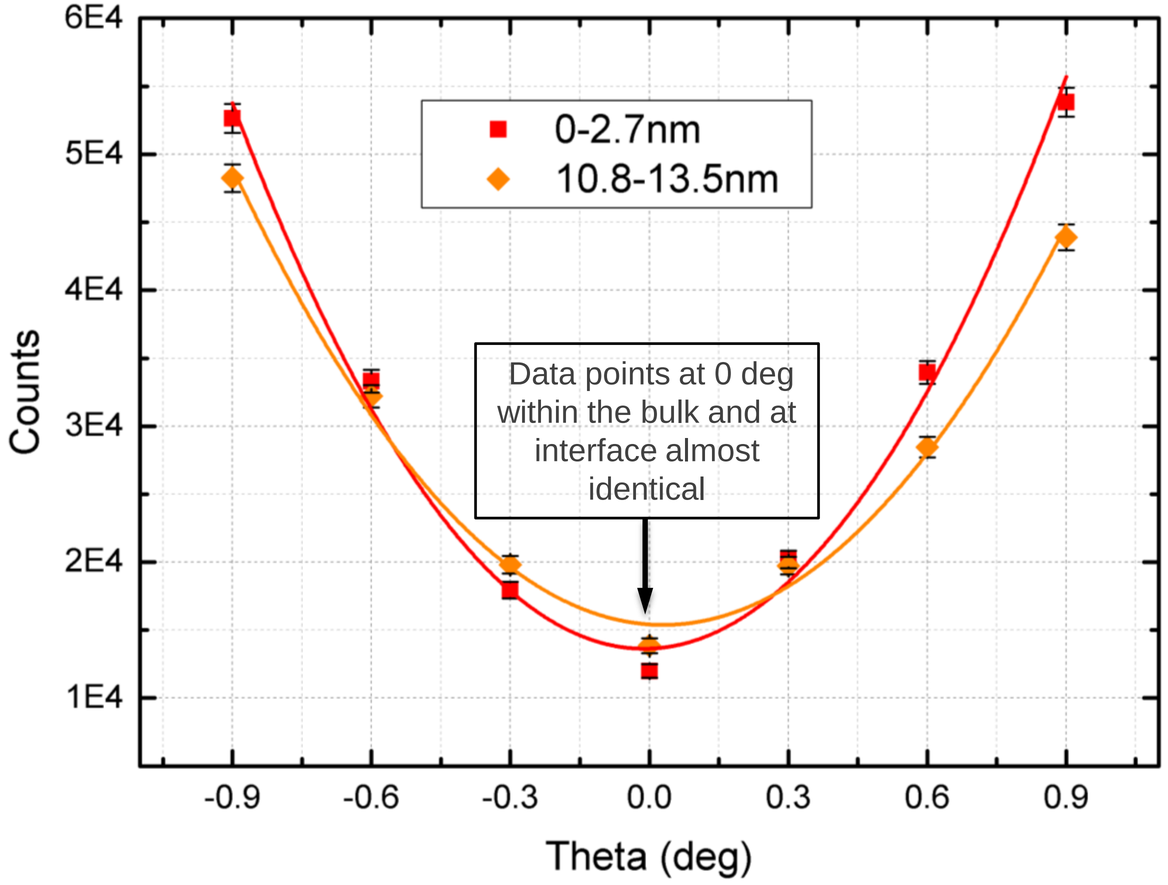
Angular scan about <111>

Before correction – Bulk/Interface



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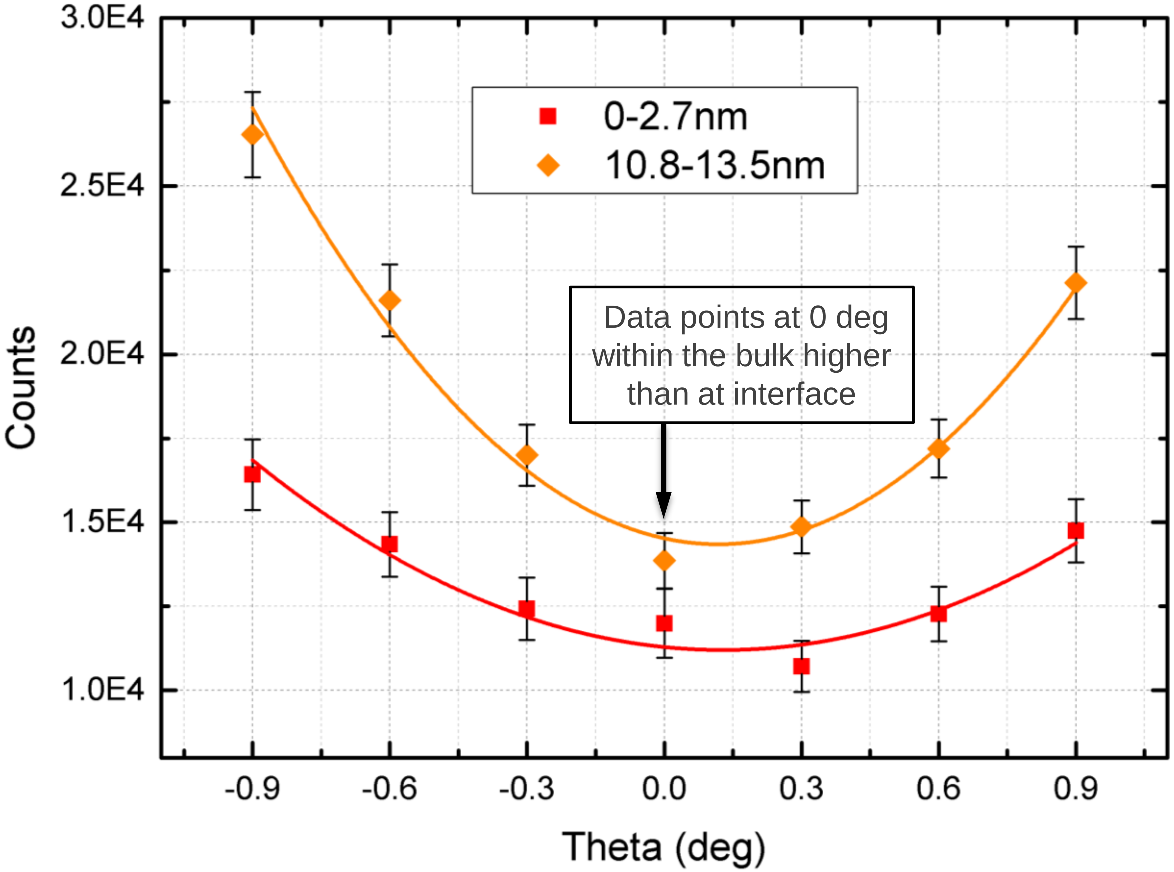
Angular scan about <111>

After correction - Bulk/Interface



- De-channeling effects
- Additional correction
- Preliminary interface strain
  - ~ 0.02% …?
  - close to the detection limit

Future directions

Hafnium oxide on Ge

- Explore Ge damage further
- Additional correction in place - quantify interface strain
- Cross-sectional TEM – interface layer
- Interface strain with GePb, GeSn as substrates

Acknowledgements

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Thank you!

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