TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Science Institute of Nuclear and Particle Physics

Photoluminescence measurements and their comparison to PTIS

GERDA collaboration meeting

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LNGS, 30.09.09

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Outline

- Motivation
- Photoluminescence (PL)
  - Comparison to PTIS
- Results from PL (and PTIS) measurements
- Summary

Motivation

- **GERDA** → ^{76}Ge candidate for neutrinoless double-beta decay

- Need of Ge detectors

→ Need of high purity Ge crystals (impurity conc. < 10^{11} cm^{-3})

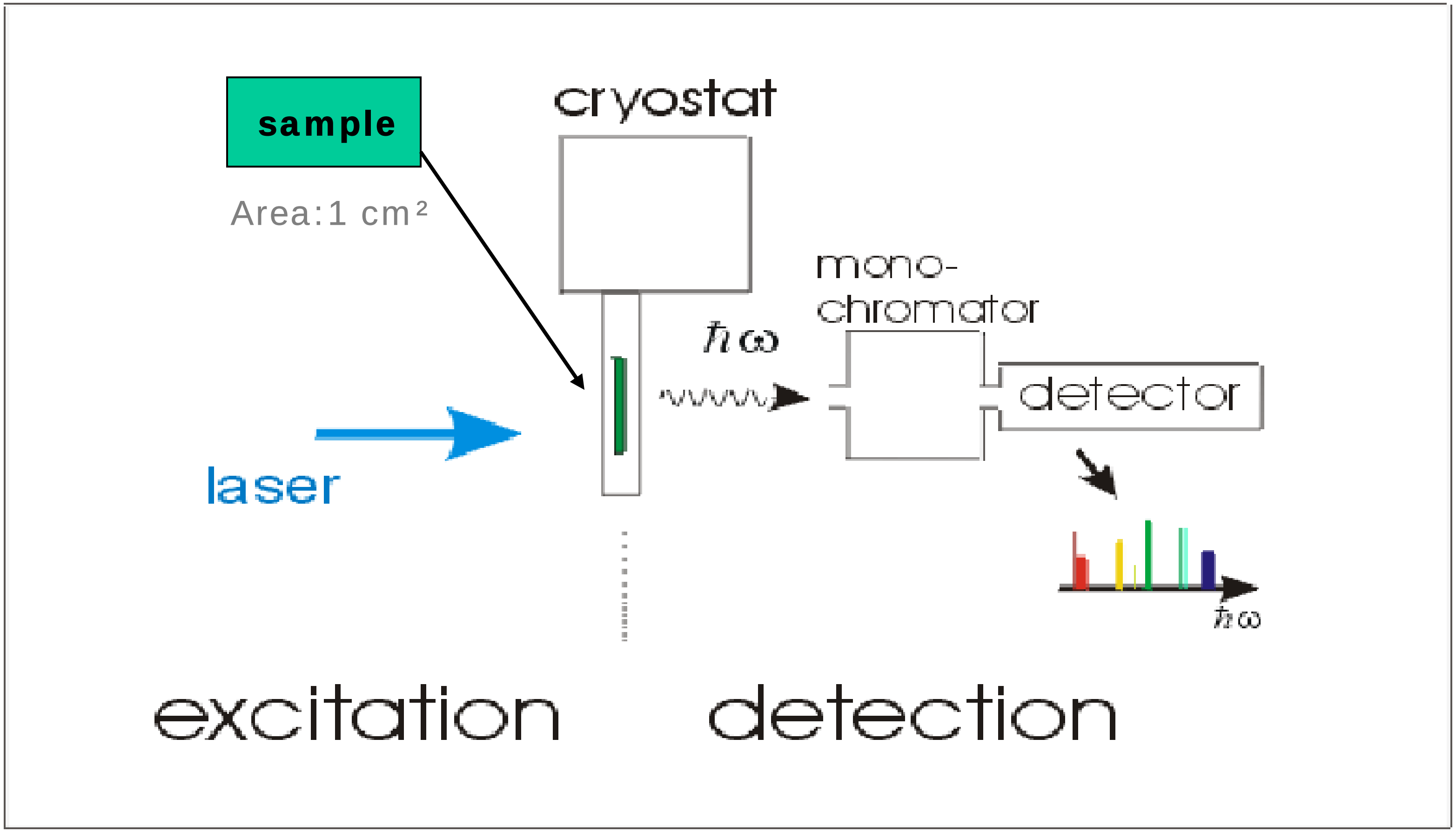
- Crystal growth at IKZ (Berlin) with Czochralski method

- Crystal characterization:

    - IKZ (Hall measurements, PTIS)

    - TU Dresden (**Photoluminescence**)

Photoluminescence



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Recombination processes

a) Electron hole pair generation

b)+c) Non-radiative recombination

d) Direct band-to-band transition

e) Free exciton (FE)

f) **Bound exciton (BE)**

g)+h) Impurity-band transition

i) Donor-acceptor transition

What is an exciton?

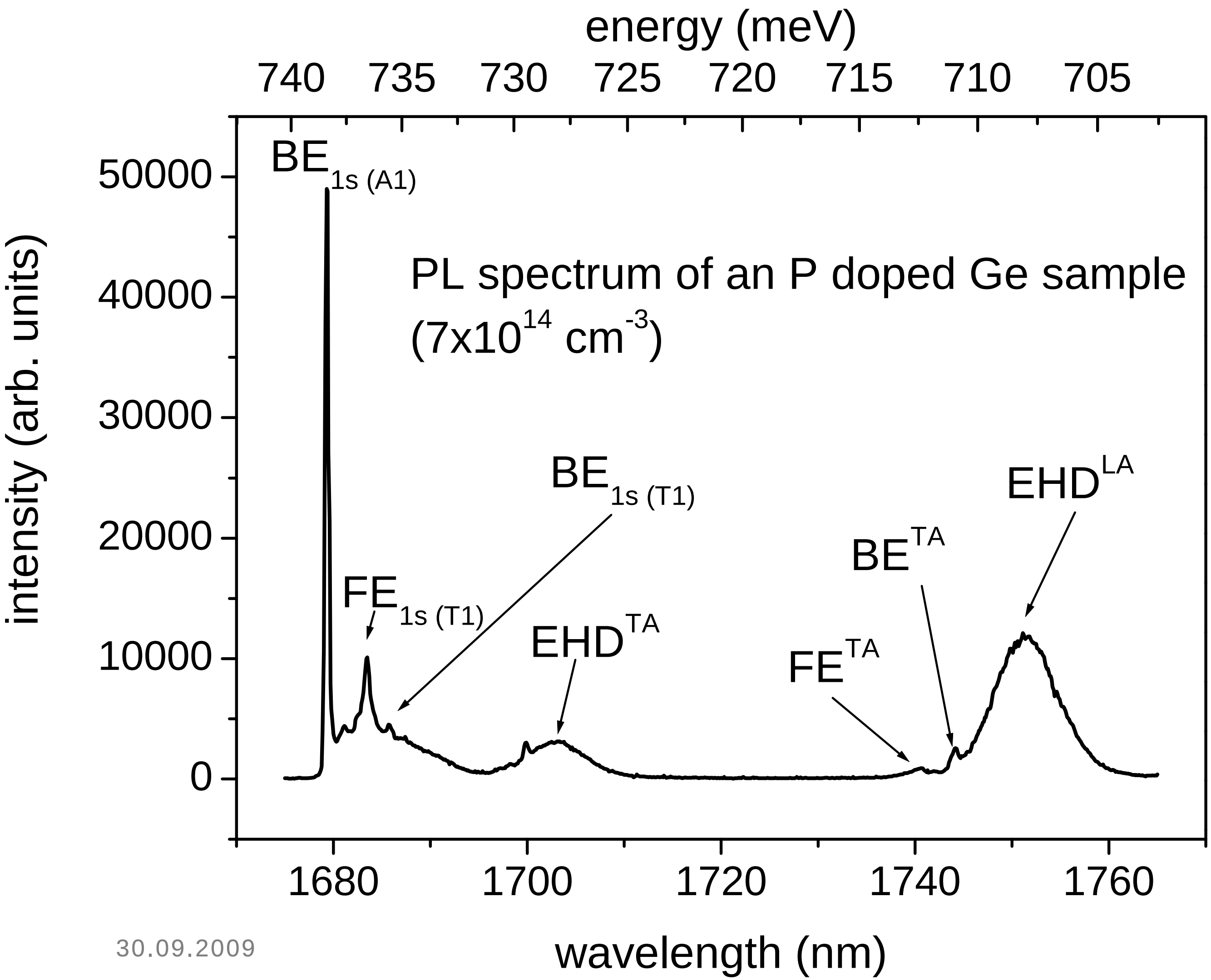
- Bound state of an electron hole pair caused by Coulomb interaction
- Localized to an impurity atom

→ Bound exciton

$$E_{Ph} = E_G - E_{BE}$$

→ Energy differs for each impurity

Photoluminescence



EDH – Electron hole droplet

FE – Free Exciton

BE – Bound Exciton

PTIS

- Photothermal ionization spectroscopy

→ Ionisation of the electric-active center in a two step process:

1. Transition of the bound electron (hole) from ground to excited state by absorption of a photon

2. Thermal activation (by a phonon) into the conduction (valence) band.

→ Measuring the generated current → PTIS spectra generated by varying the photon energy

→ Suitable for shallow donors (acceptors) in semiconductors

PL vs. PTIS

PL:

- Advantages:

- Detection of different impurities which form shallow donors/acceptors
- Concentrations detectable down to $10^{11}cm^{-3}$
- Spatial resolution, limited by excitation area

- Disadvantages:

- No saturation excitation

→No absolute impurity concentration measurable

- Aluminum seems not to be detectable

PTIS:

- Advantages:

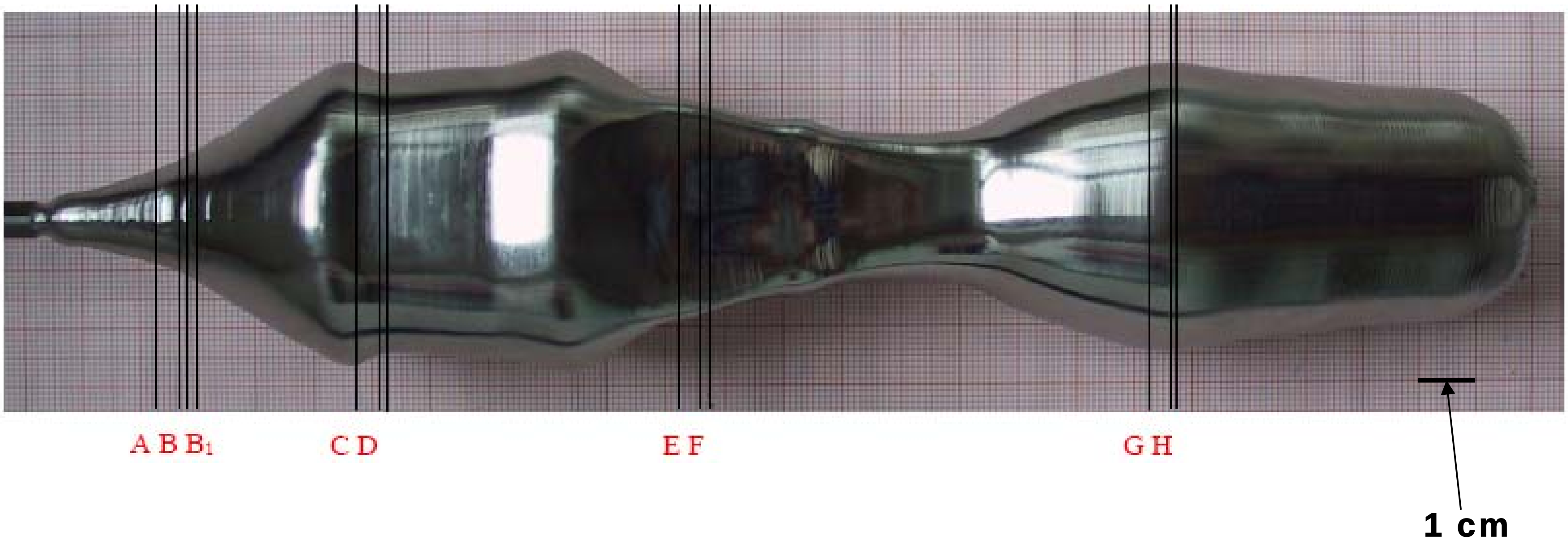
- Detection of different impurities which form shallow donors/acceptors
- Extreme low concentrations detectable below $10^{10}cm^{-3}$

- Disadvantages:

- Only relative impurity concentration
- No spatial resolution

PL results

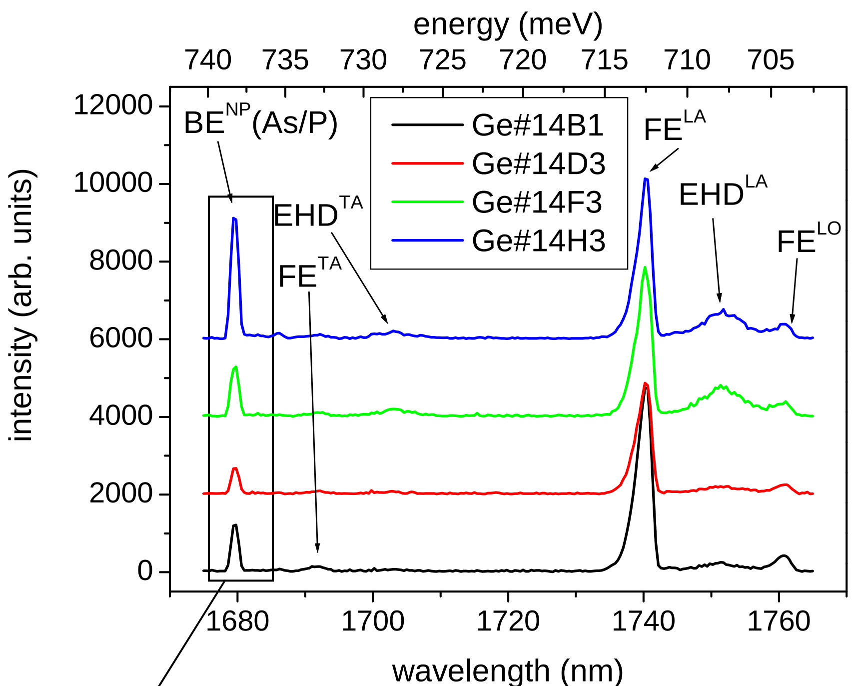
Crystal GeCz14, grown in july 2009 at IKZ

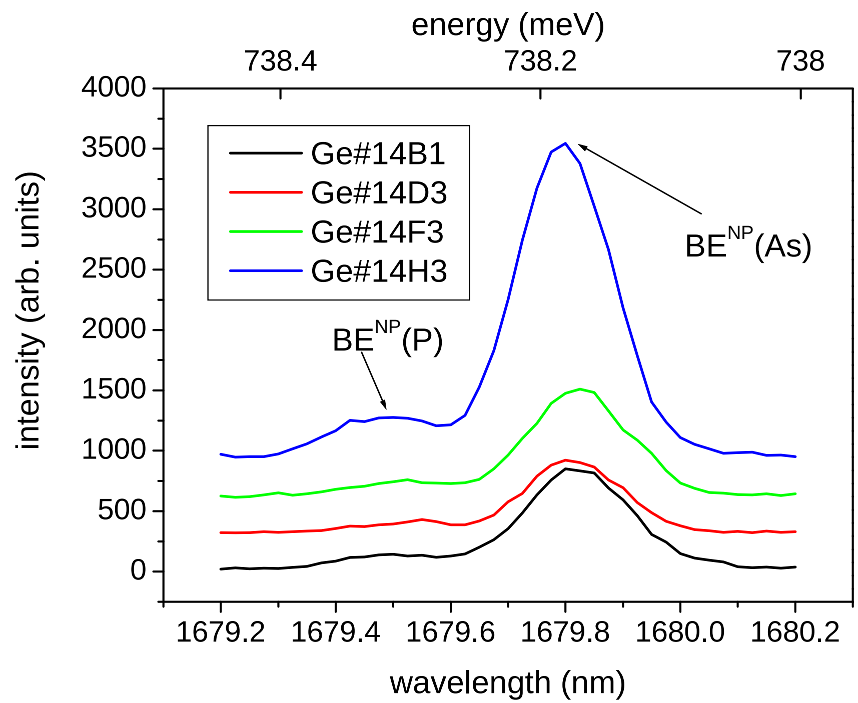


- investigated samples from positions B, D, F and H :

GeCz14B1 GeCz14D3 GeCz14F3 GeCz14H3

PL spectra of GeCz14 samples





Interesting range

→ **Impurity related luminescence**

- **arsenic** → main impurity, **phosphorus** also detectable

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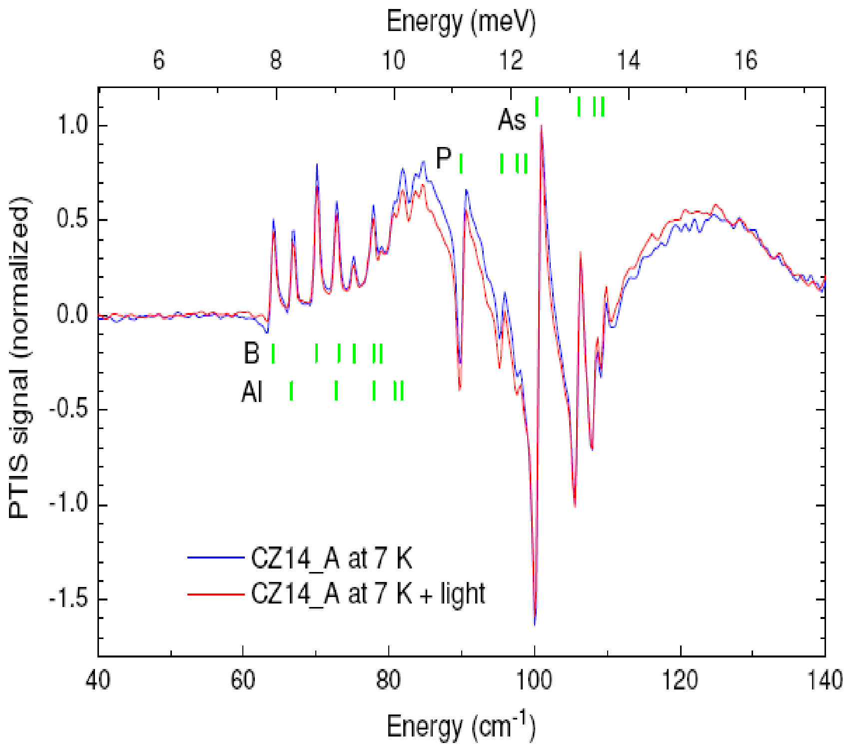
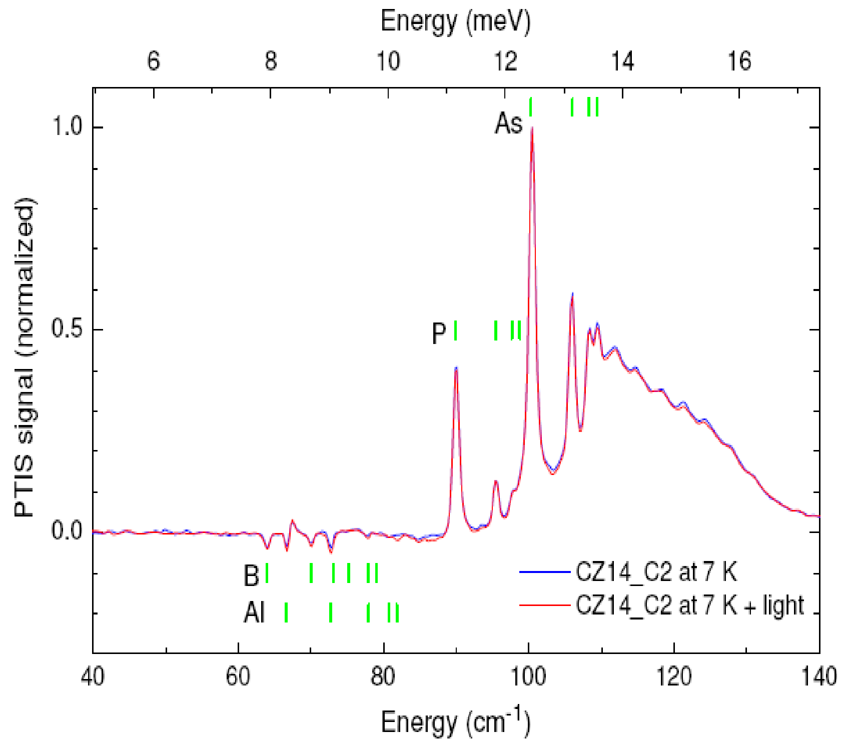
PTIS spectra of GeCz14





Hall effect measurements

	Resistvity (Ωcm)		carrier concentration (cm^{-3})		Mobility (cm^2/Vs)	
Temperature	RT	77 K	RT	77 K	RT	77 K
Ge-CZ14_B	43	5040	-9.9×10^{13}	$+1.1\times10^{11}$	1450	11200
Ge-CZ14_D2	40	78	-9.7×10^{13}	-2.1×10^{12}	1590	37200
Ge-CZ14_F2	29	26	-1.3×10^{14}	-6.5×10^{12}	1680	36700
Ge-CZ14_H2	27	12	-1.2×10^{14}	-1.4×10^{13}	2000	36700

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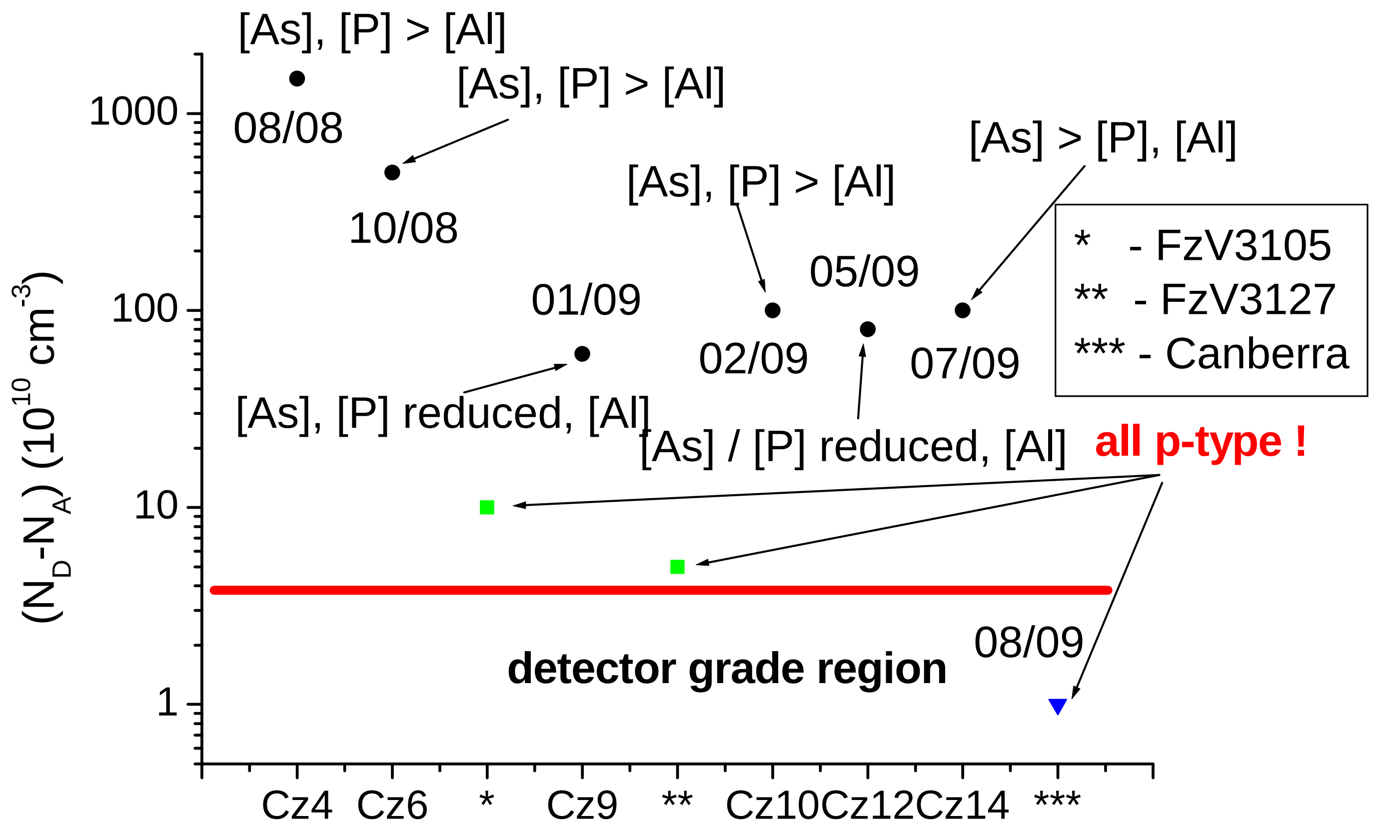
Previous crystals



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Summary

- Photoluminescence

→ Suitable experimental technique for characterizing impurities (As, P, Al; shallow donors/acceptors) in Ge

→ Impurity concentrations detectable down to 10^{11} cm^{-3}

→ Good agreement results received from PTIS

→ Plans to measure Al doped Ge samples (samples now available)

- Ge crystals:

→ Impurity concentrations in Cz crystals still too high

→ Float zone crystals have higher purity but crystal pulling with this technique difficult

(limited to a crystal diameter of 30 mm; goal for Cz pulling:80 mm)

Thank you for your attention!