Observation of vacancies during Zn diffusion in GaP

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1. Zn-diffusion experiments in GaP
2. The EPOS positron source at Research Center Rossendorf

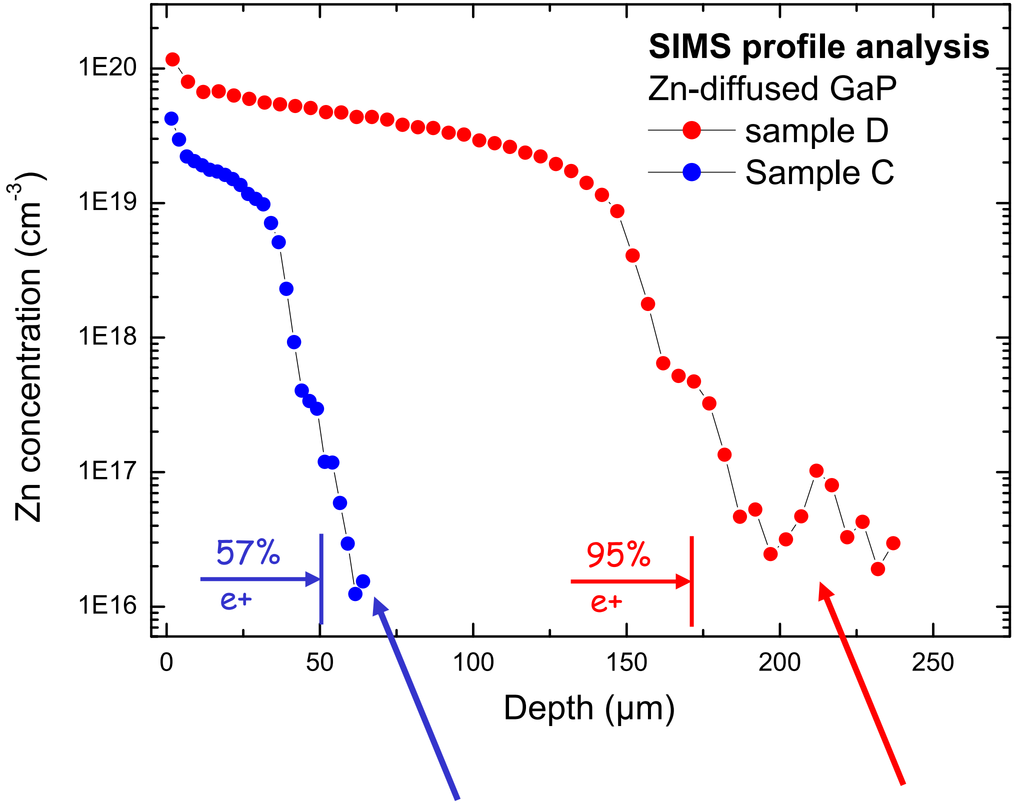
Sample conditions

Experiment	sample	treatment	remarks
Reference	A	as-grown GaP reference sample	negligible low dislocation density, no extended defects
	B	Reference annealing: 95.1 h at 907°C	defined P vapor pressure, but no Zn in ampoule
Diffusion experiments	C	Zn diffusion annealing: 95.1 h at 907°C	defined P vapor pressure, Zn vapor pressure obtained by adding GaP:Zn to the ampoule
	D	Zn Diffusion annealing: 95.1 h at 907°C	defined P vapor pressure, Zn was added as an elementary powder to the ampoule

- Samples were quenched to RT water during diffusion
- Main difference of diffusion experiments: Zn vapor pressure varies due to different Zn source
- Diffusion profiles are distinctly different

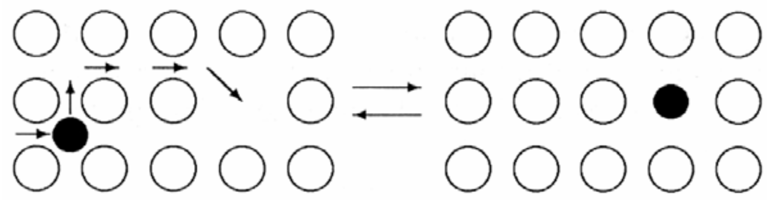
Zn diffusion profiles by SIMS

- Zn diffusion profiles obtained by SIMS at beveled samples (wedge angle 6°)



- expected diffusion model: interstitial-substitutional mechanism (Frank-Turnbull mechanism)
- I_{Ga} and V_{Ga} shall be involved

  (J. Poepping et.al, ICDS-21)
- $Zn_I + V_{Ga}$ <-> Zn_{Ga}

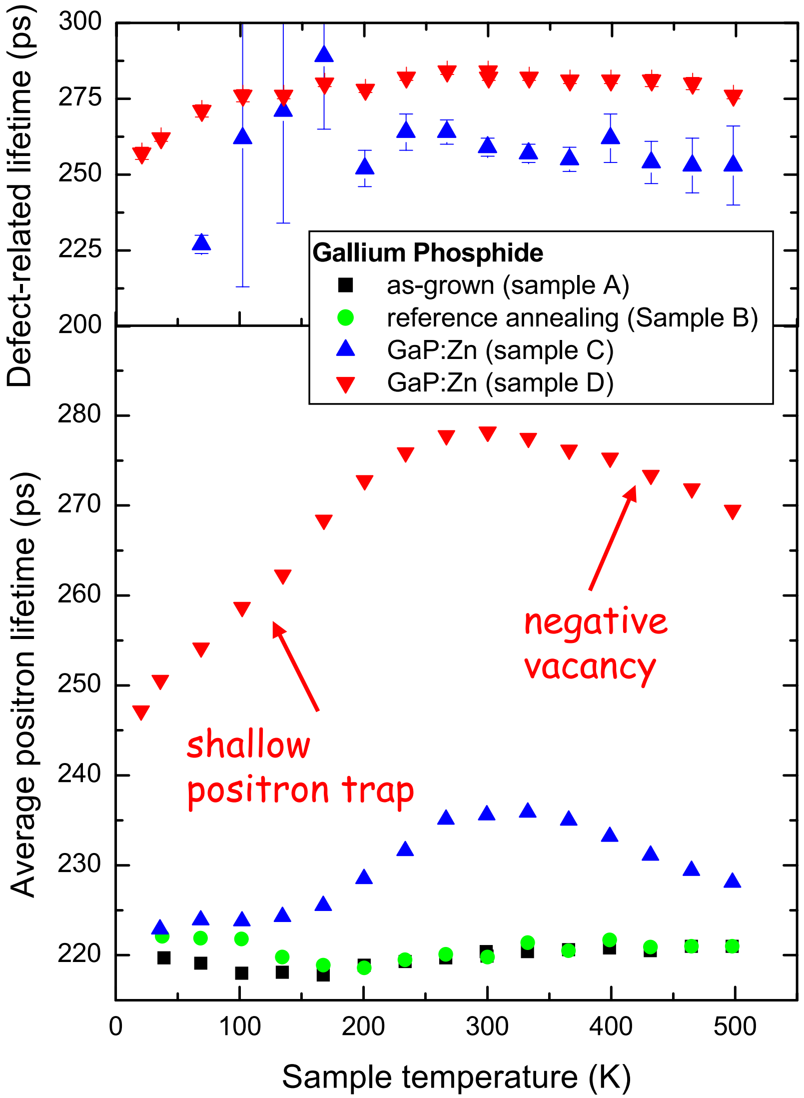


Interstitial-substitutional exchange mechanisms of foreign atom diffusion

Zn source: GaP:Zn sample Zn powder

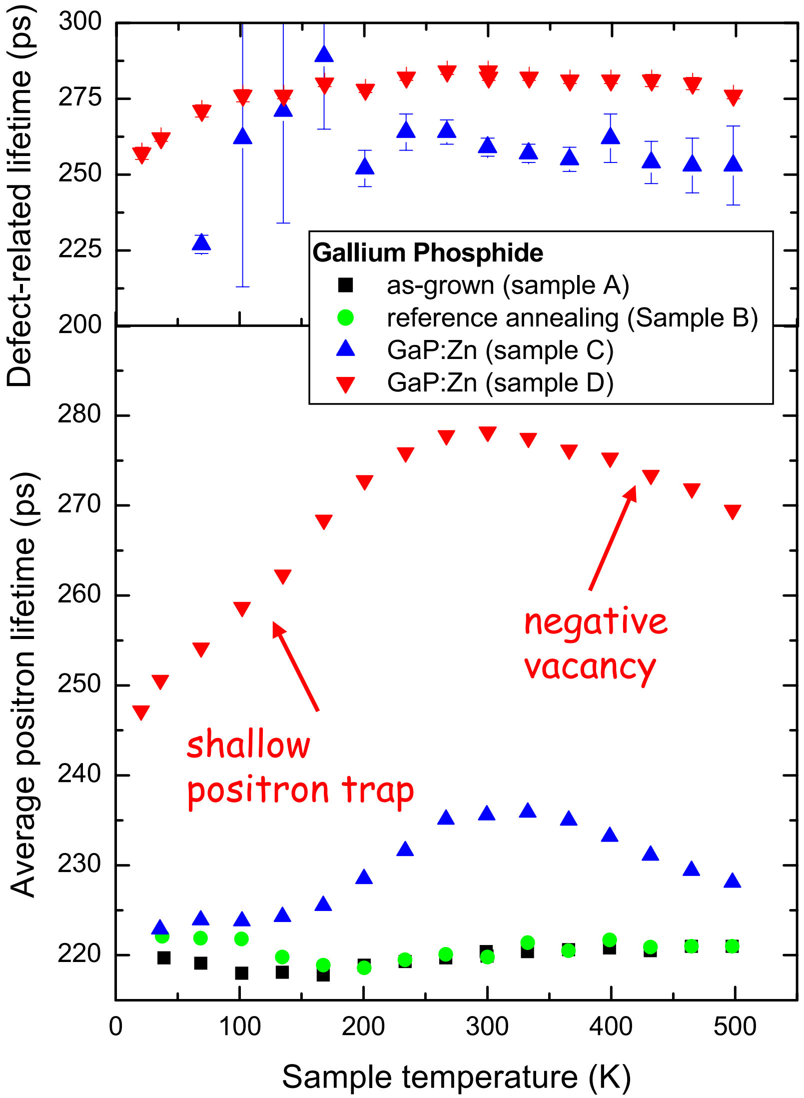
Diffusion annealing: 95h at 907°C in quartz ampoule

Positron lifetime results



- both reference samples: no trapping
- distinct vacancy signal only after Zn in-diffusion
- sample D: almost complete positron trapping at RT
- defect-related lifetime: $\tau_v = 282$ ps
- outward relaxation is expected for both vacancies:
- V_{Ga} -> 3.8% and V_P -> 6.1%
  (G. Schwarz et al., Phys. Rev. 1998)
- lifetimes were theoretically calculated taking into account the relaxation

Positron lifetime results



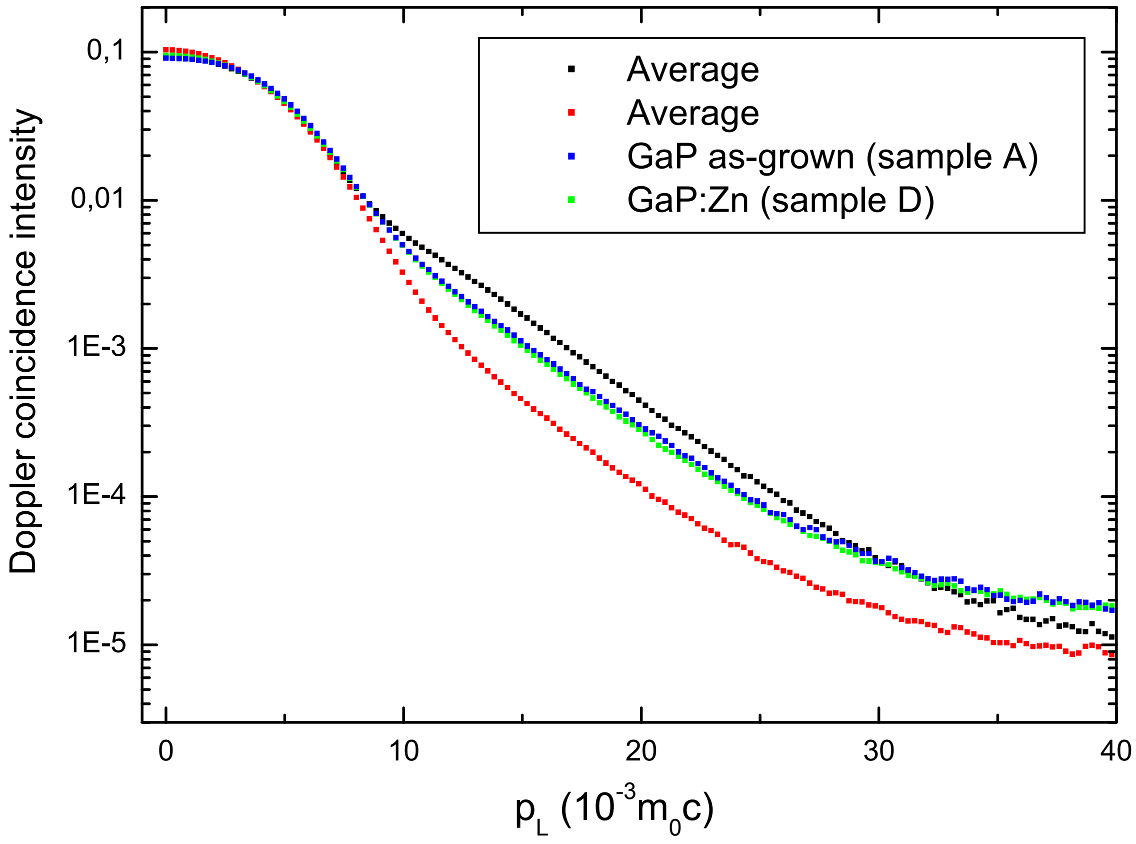
- defect-related lifetime: $\tau_v = 282$ ps

Defect	e^+ lifetime in ps	remarks
GaP bulk	220	
V_{Ga}	258	unrelaxed
	270	3.8% outward relaxation
V_P	244	unrelaxed
	271	6.1% outward relaxation
V_P-Zn_{Ga}	274	6.1% outward relaxation
V_P-V_{Ga}	307	unrelaxed

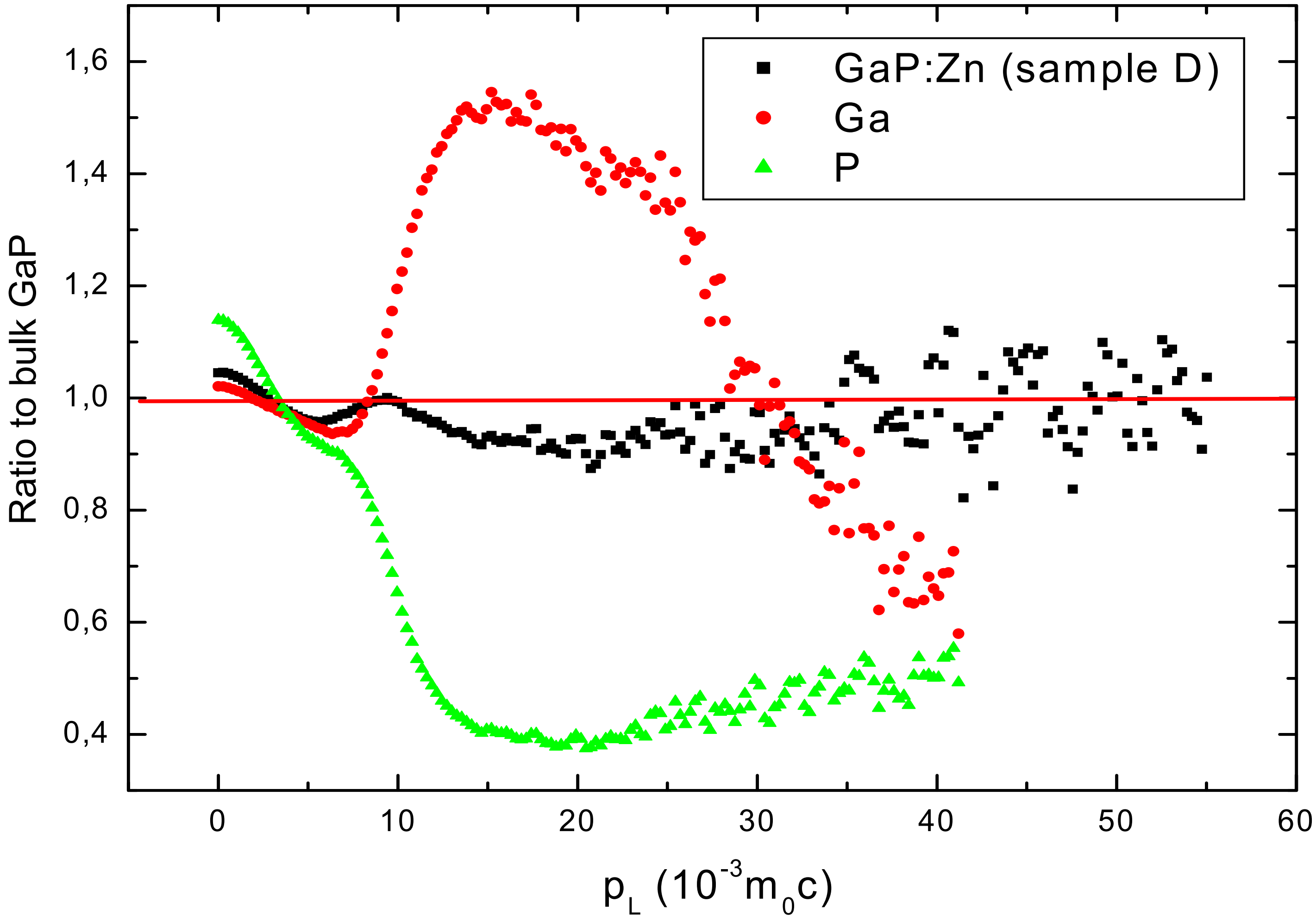
- from lifetime: no decision between V_{Ga} and V_P

Doppler Coincidence Experiments

- DBCS was used to study the chemical environment of the detected mono-vacancy
- surprise: although complete trapping -> high-momentum Doppler spectrum close to reference sample
- comparison with theoretically calculated spectra required

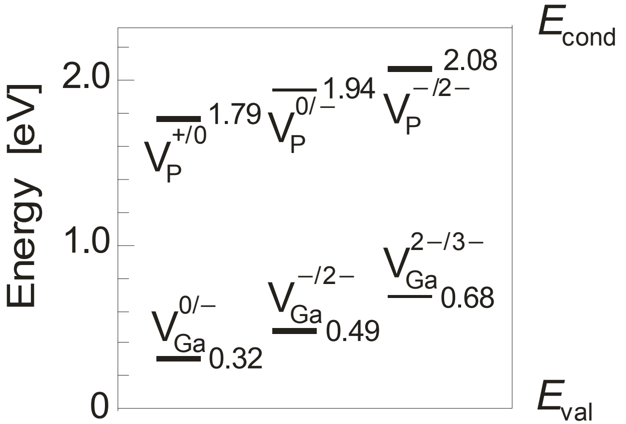


Doppler Coincidence Experiments



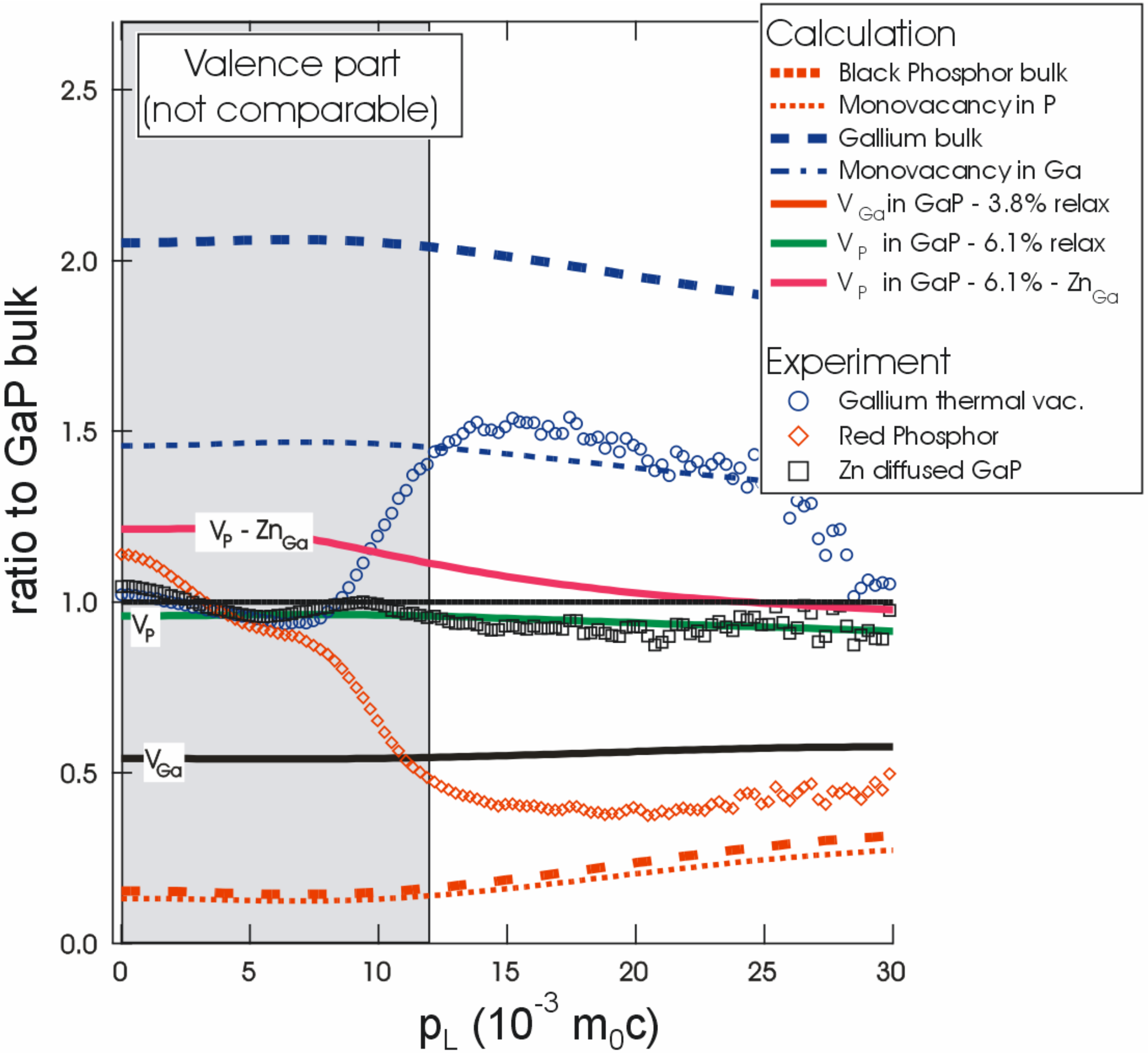
Doppler Coincidence Experiments

- calculations agree well for Ga and P
- V_{Ga} is close to P data, while V_P is very close to the bulk behavior
- conclusion: we detected V_P



(M. Puska, J. Phys. Cond. Mat. 1989)

- however: V_P should be positive in p-type GaP
- probably we detect V_P-Zn_{Ga}

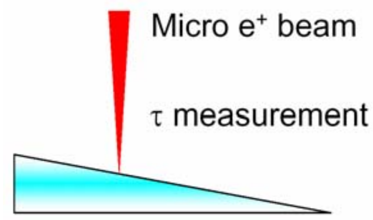


Conclusion

- During Zn in-diffusion: vacancies are formed
- concentration is much higher than thermal vacancies
- Vacancy is located in P sublattice
- V_p should be positive -> thus a defect complex is most probably observed
- best candidate: V_P-Zn_{Ga}

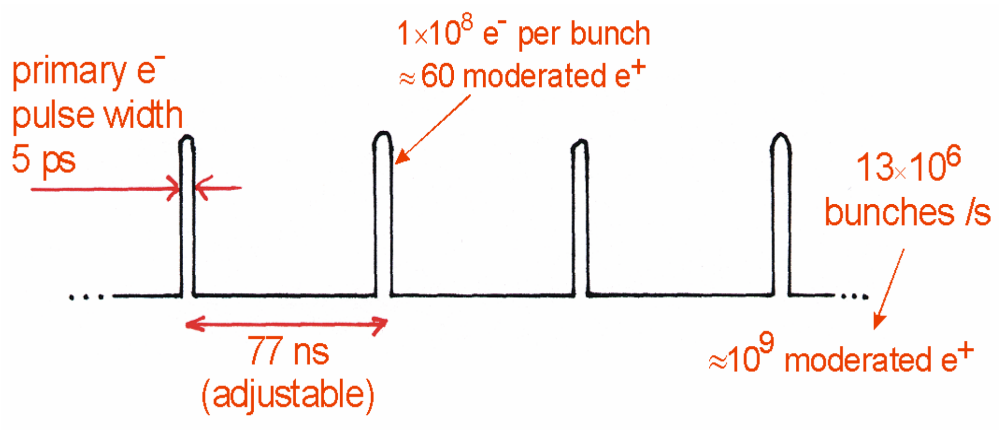
planned experiment:

- comparison of vacancy depth profile with Zn-diffusion profile
- we will use Munich Microbeam and the beveled SIMS samples



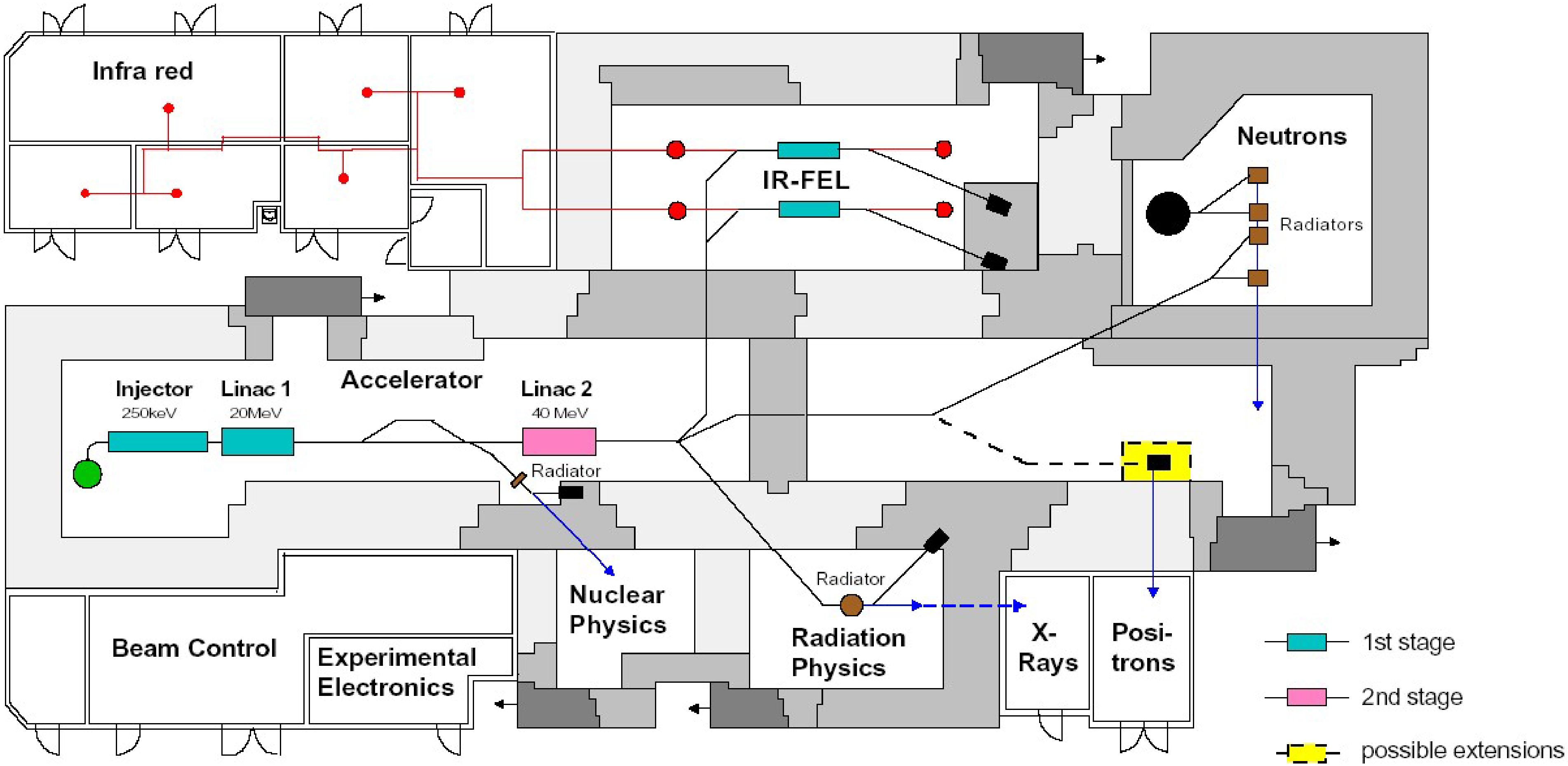
The EPOS positron source at Research Center Rossendorf

- main experiment: Radiation source ELBE (**E**lectron **L**inac with high **B**rilliance) and low **E**mittance
- primary electron beam (40 MeV x 1 mA = 40 kW) is already available
- main goal: IR Free-electron Laser
- very interesting time structure: cw-mode of short bunches



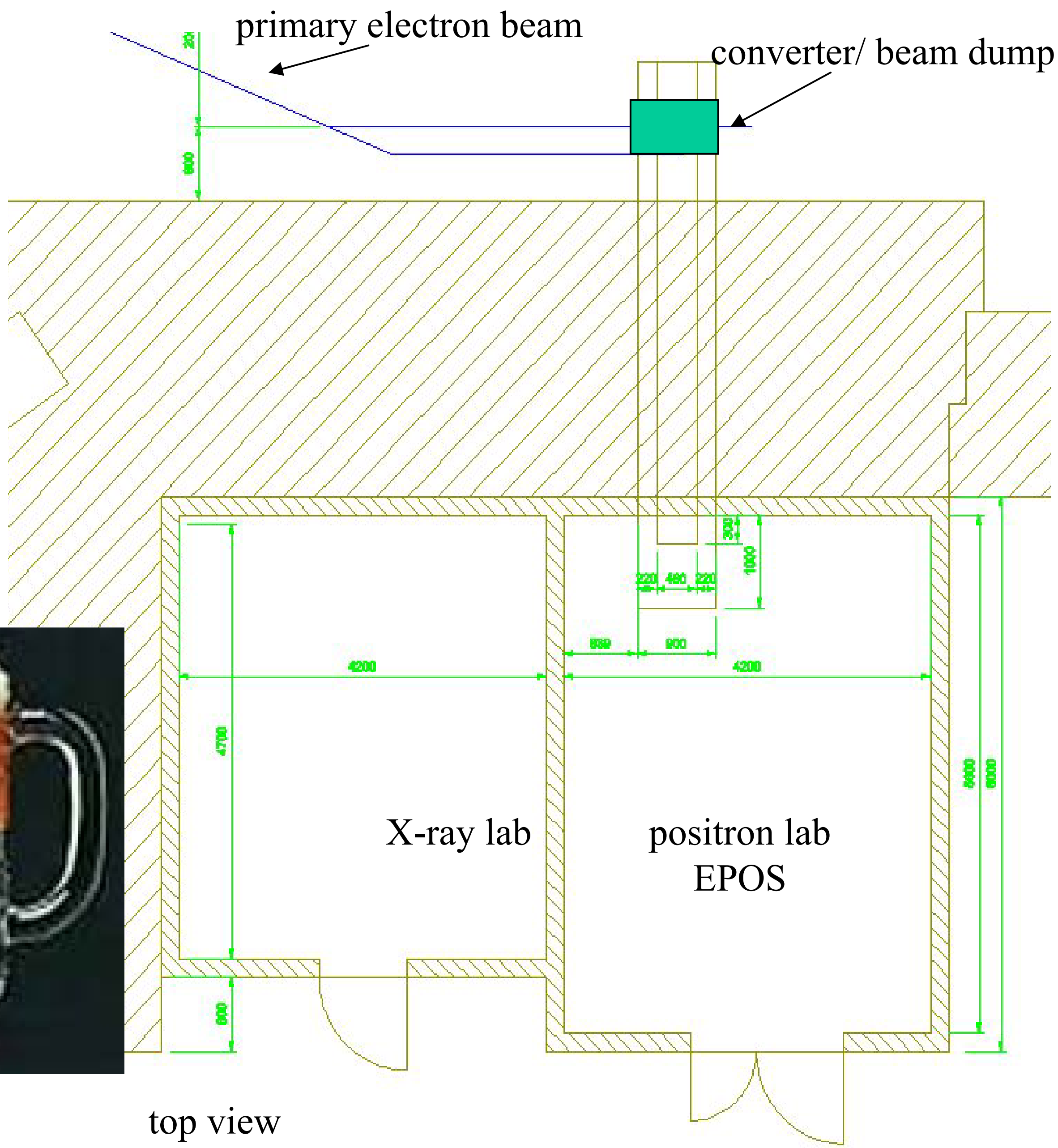
electron bunches

Ground plan of the ELBE hall



Ground plan of positron lab

- Construcion work started
- Financing ...



top view

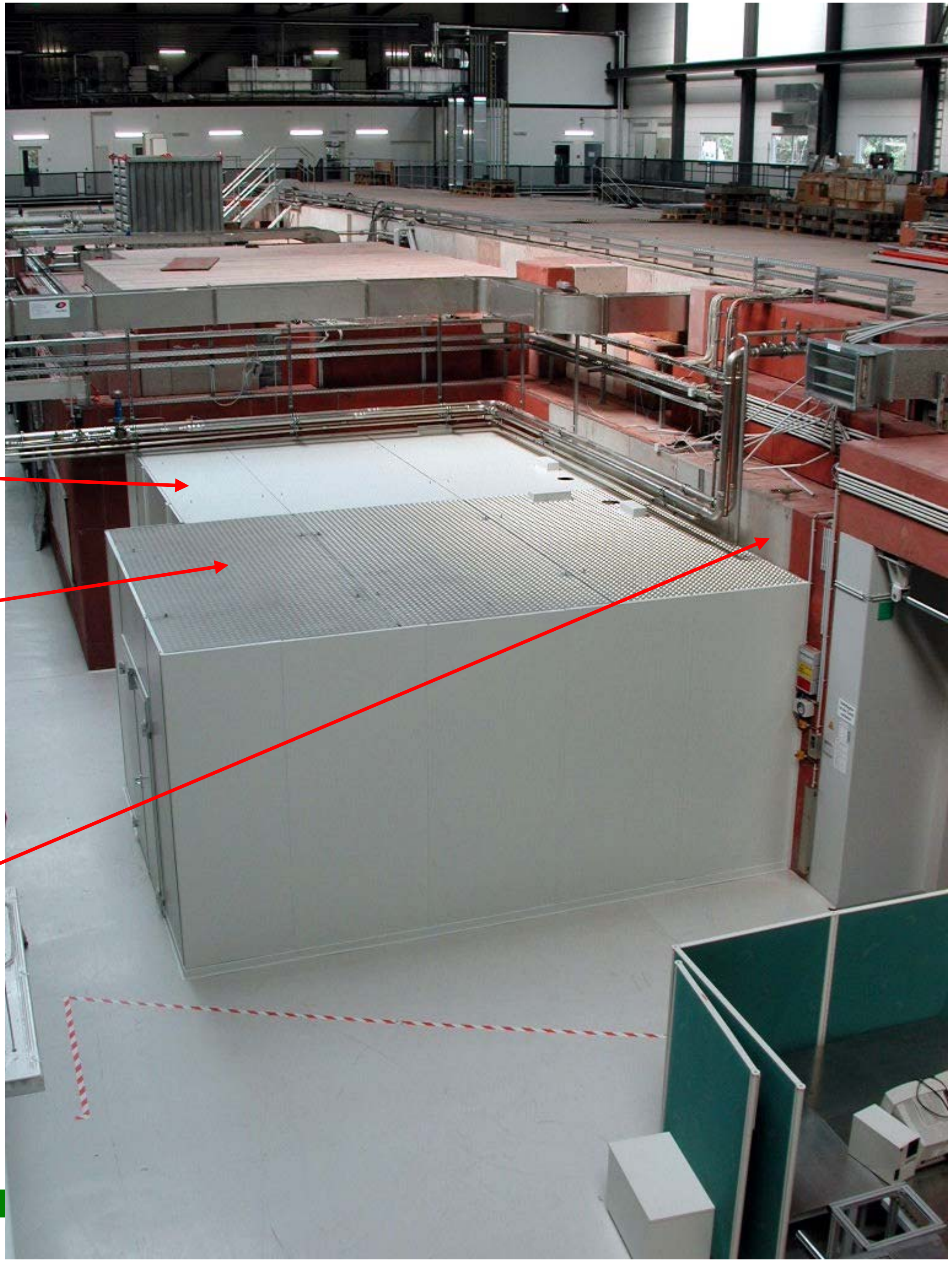
Positron Lab

- positron lab in ELBE hall already under construction

X-ray Lab

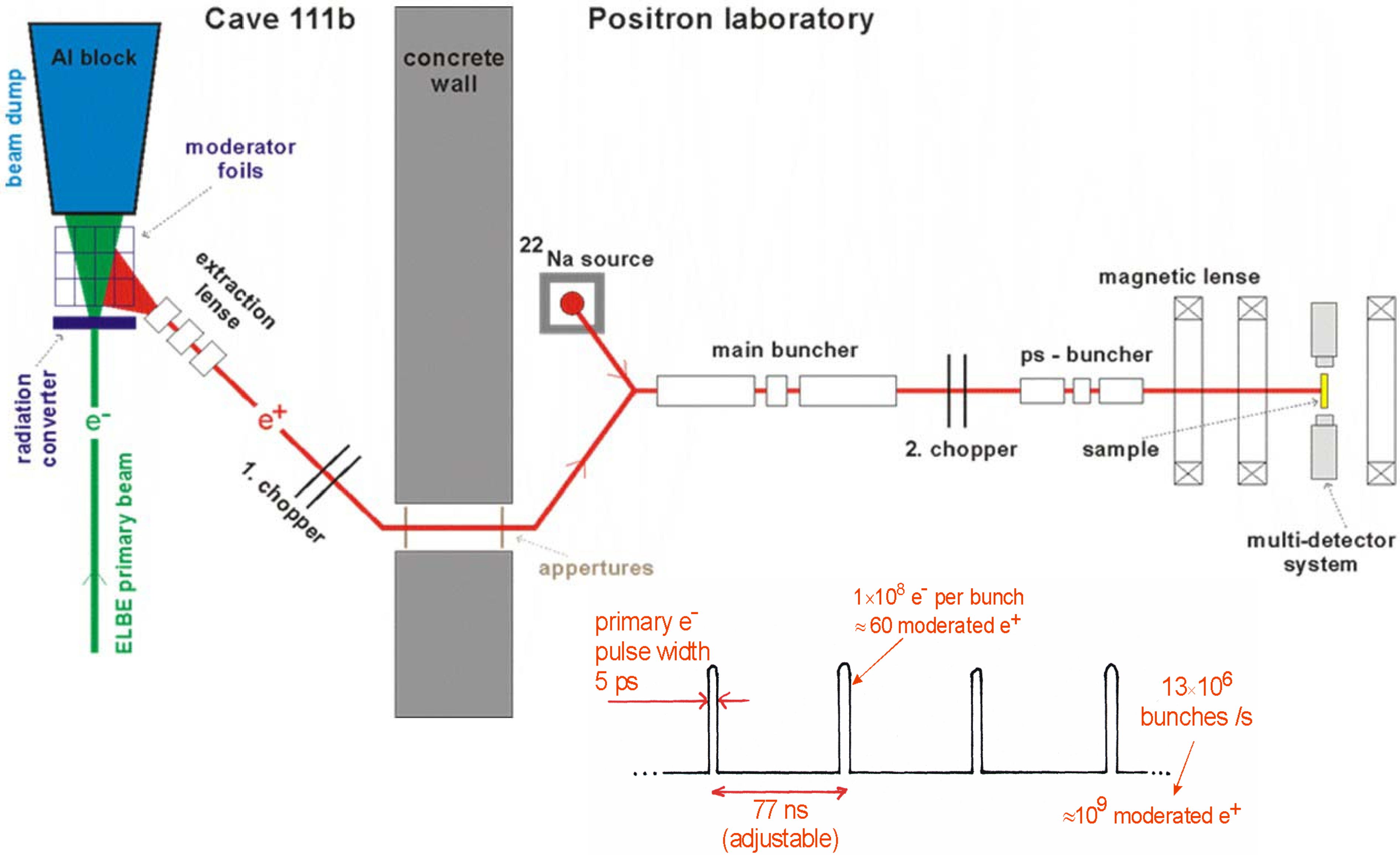
Positron Lab

concrete screening of Cave 111b (location of e^+ converter)



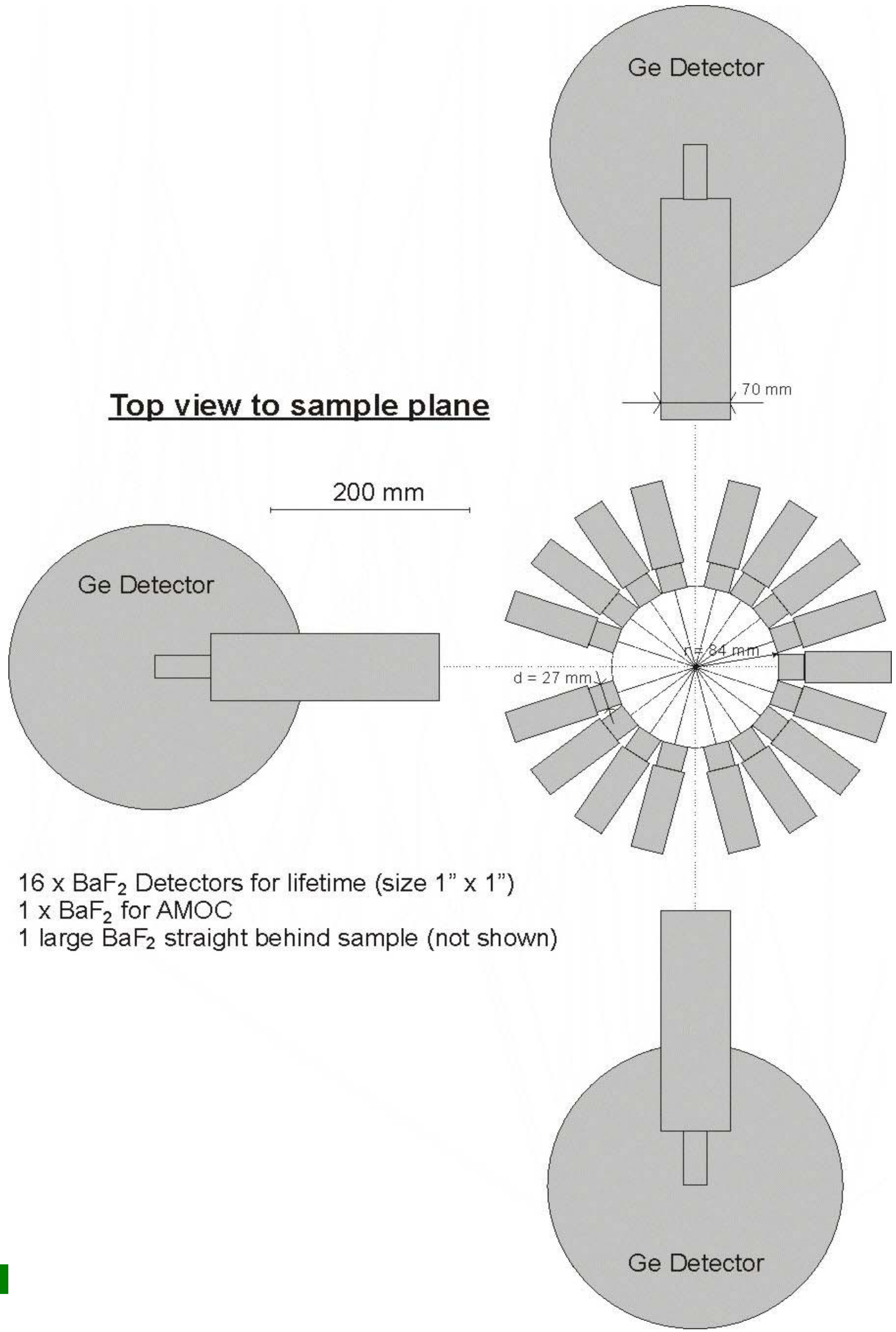

concrete screening of Cave 111b
cable tunnel to be used for e+ beamline

EPOS (ELBE Positron Source)



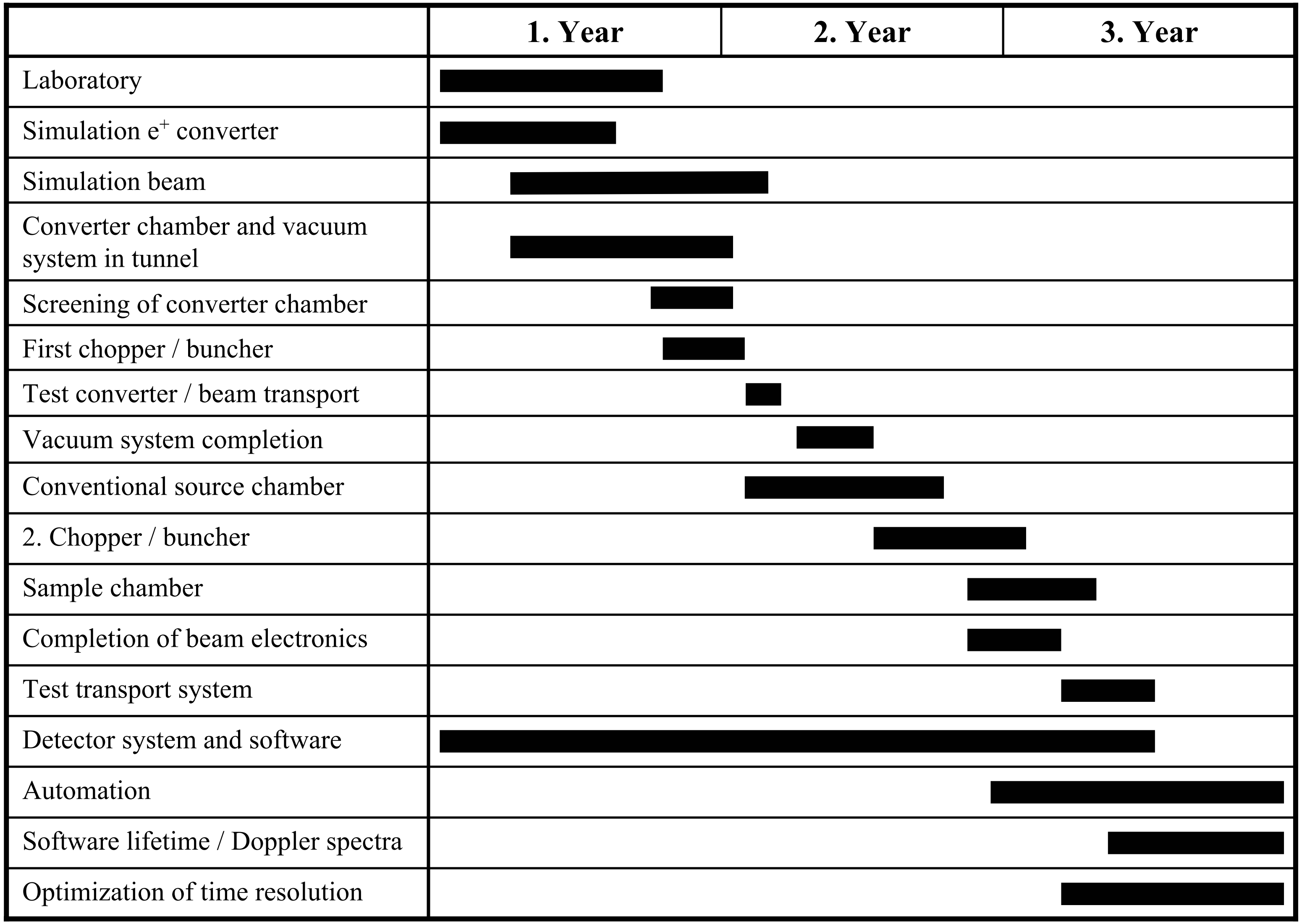
Detector system

- **3 experiments**: lifetime spectroscopy (16 BaF_2 detectors); Doppler coincidence (2 Ge detectors), and AMOC (1 Ge and 1 BaF_2 detector)
- **digital detection system**:
  - lifetime: almost nothing to adjust; time scale exactly the same for all detectors; easy realization of coincidence
  - Doppler: better energy resolution and pile-up rejection expected



16 x BaF_2 Detectors for lifetime (size 1" x 1")
1 x BaF_2 for AMOC
1 large BaF_2 straight behind sample (not shown)

Time Schedule



Thank you for your attention!

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