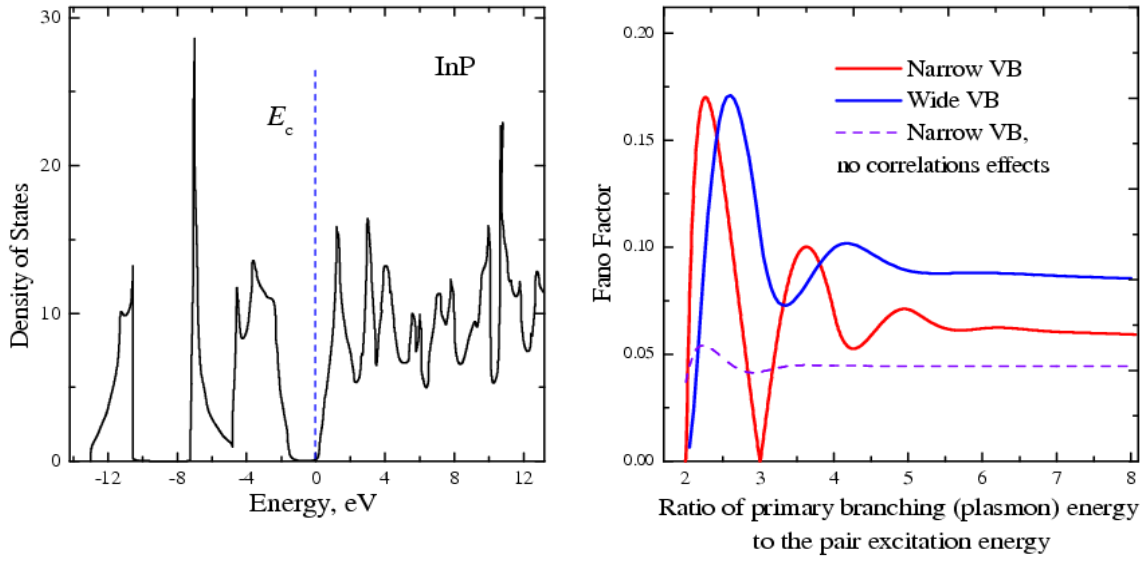
Semiconductor gamma detectors: Band structure effects in energy resolution

Arsen Subashiev and Serge Luryi
SUNY–Stony Brook, U.S.A.

Measurements of the γ-particle energy in gamma detectors rely on counting the number of electron-hole pairs produced by energy branching of the primary high-energy electron excited by the γ-photon from deep atomic shells. Limitations on the energy resolution arise from statistical fluctuations of the number N of pairs produced in the branching cascade by impact ionization. The deviation of pair statistics from Poissonian is characterized by the so-called Fano factor, $F = \mathrm{var}(N)/\langle N\rangle$. Due to restrictions imposed by the total energy conservation, F is generally less than unity in semiconductors.

We discuss an additional correlation due to the fact that plasmon emission is dominant energy branching channel in a large energy range. This makes the Fano factor sensitive to band structure effects, and in particular, to the width of the valence bands. The valence band density of states in A_3B_5 and A_2B_6 semiconductors (*e.g.*, GaAs, GaP, InP, CdTe) has 3 distinct peaks of width typically narrower than 4 eV (see left figure panel).



The plasmon energy can be considered the initial energy E_0 for the "final-stage" energy branching via impact ionization. We have developed a detailed model of the final-stage energy branching taking into account the main features of the valence band density of states and the effects of competition between impact ionization and phonon emission. When E_0 is close to triple the impact ionization threshold, $E_0 \approx 3E_{ii}$, one has a strong minimum in F (see the right panel), especially pronounced in the limit of narrow valence bands, when only electrons (and not holes) inherit kinetic energy in impact ionization events. The strong correlation at $E_0/E_{ii} = 3$ arises from the fact that the number of pairs produced by impact ionization is fixed (exactly two), irrespective of the carrier final state energies. Account of phonon emission shifts the minimum to higher energies.

One can anticipate that for optimally chosen A_3B_5 or A_2B_6 composite semiconductor one can achieve a substantially reduced Fano factor and hence improve the energy resolution.