Budker Institute of Nuclear Physics

The development of digital X-ray detector for osteodensitometry

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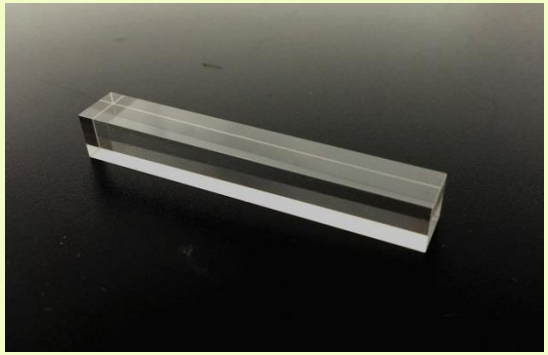
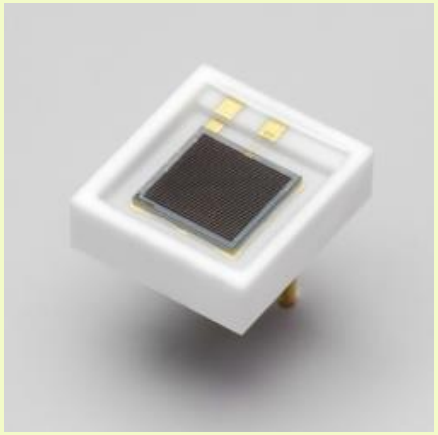
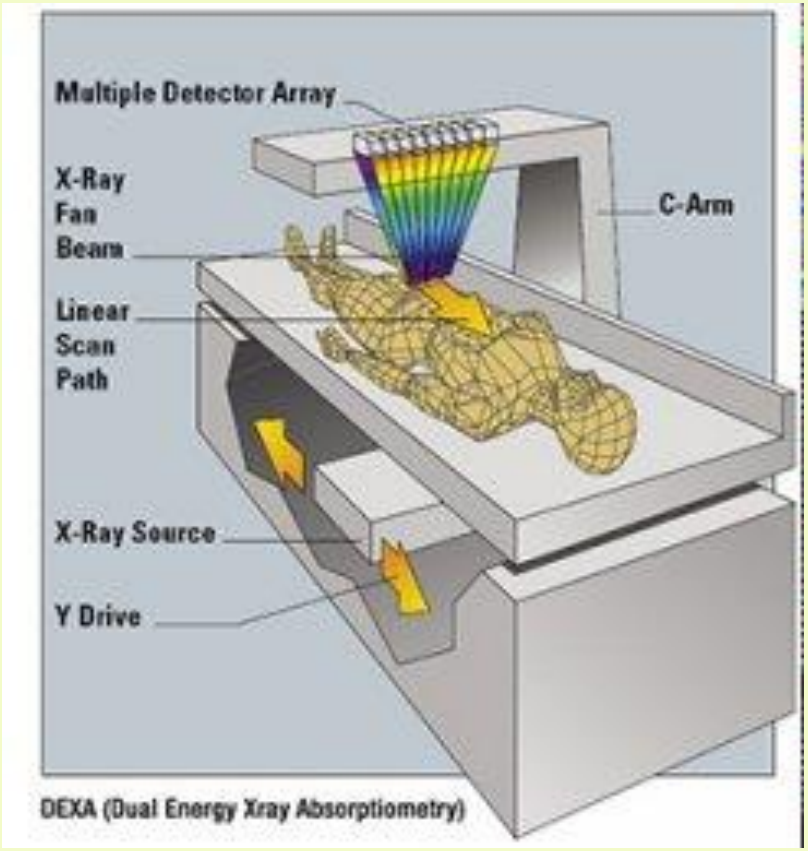
The main aim





detector



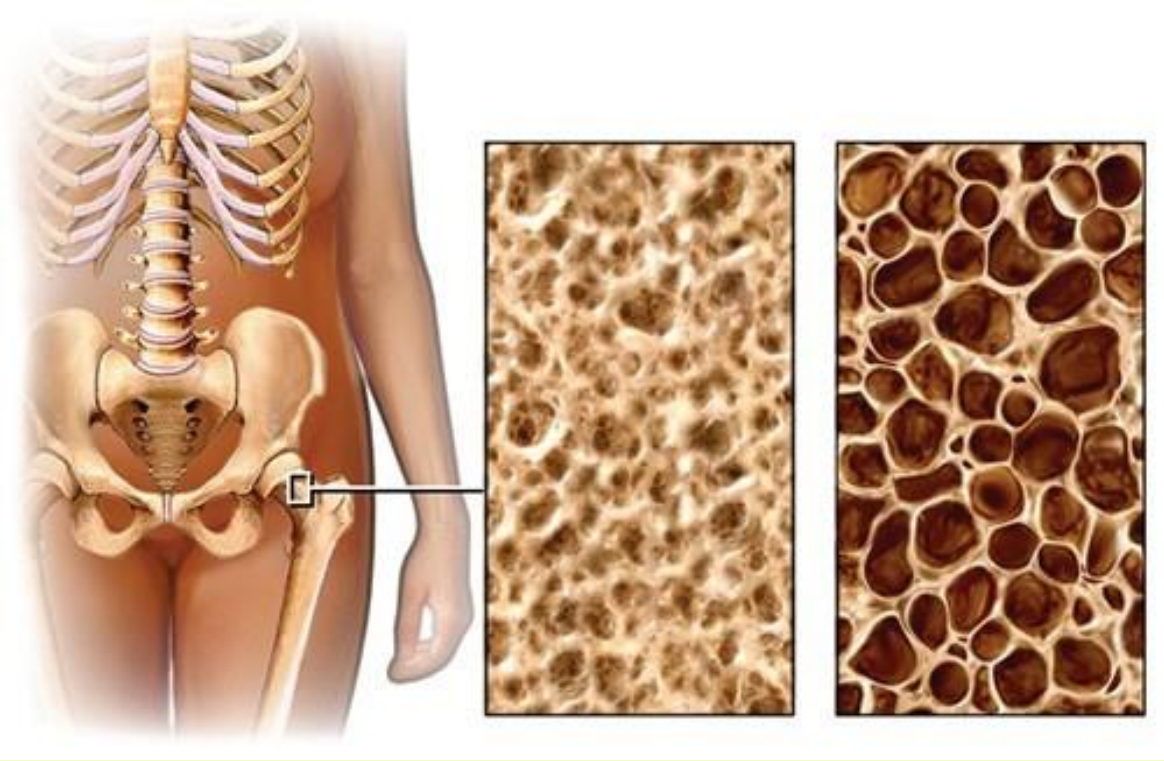
osteodensitometr

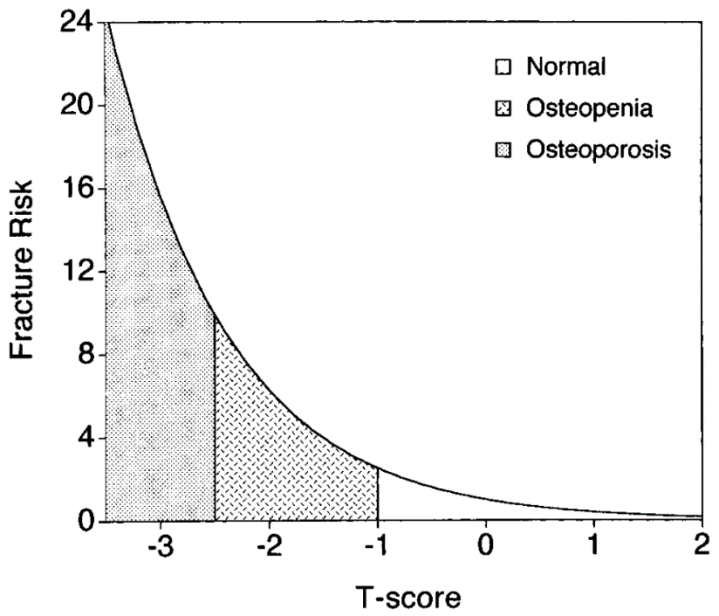
At present, densitometers are not produced in Russia

Place of Origin: South Korea

Place of Origin: France

Densitometer is a device that allows to determine bone mineral density





There are three main ways of collecting information from the detector

1) integrating mode (signal is proportional to the number of detected photons)

$$S = \sum_{i=0}^{N} Q_i \qquad Var[S] = Var[N] * E[Q]^2 + Var[Q] * E[N]^2$$

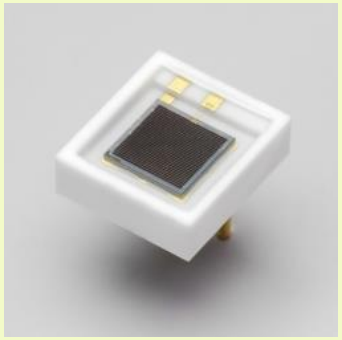
2) counting mode (allows to distinguish each individual X-ray photon)

$$S = Q_i \qquad Var[S] = Var[Q]$$

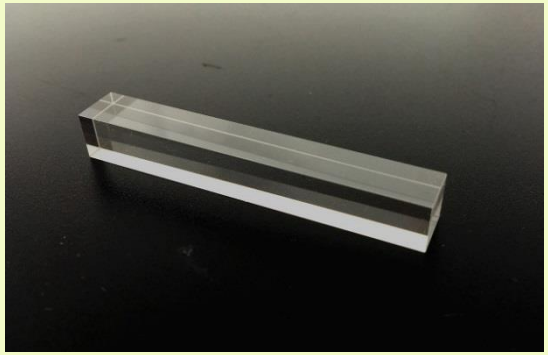
3) spectrometric mode (we not only separates each individual photon, but also register its energy)

$$S = Q_i \qquad Var[S] = Var[Q]$$

The detector



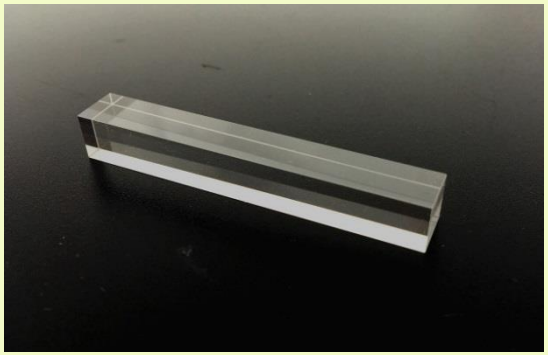
SiPM



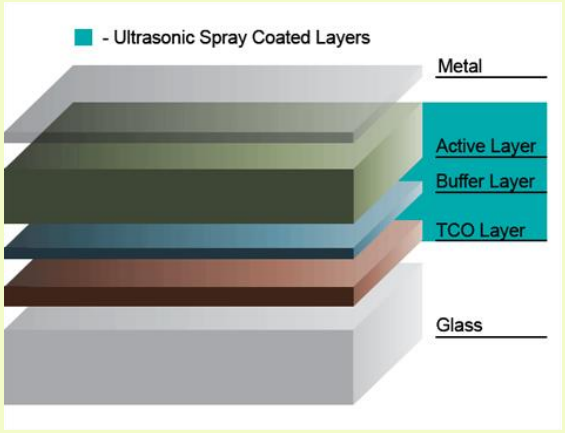
Scintillator

- non-hygroscopic
- bright
- fast
- high density and atomic number
- high energy resolution

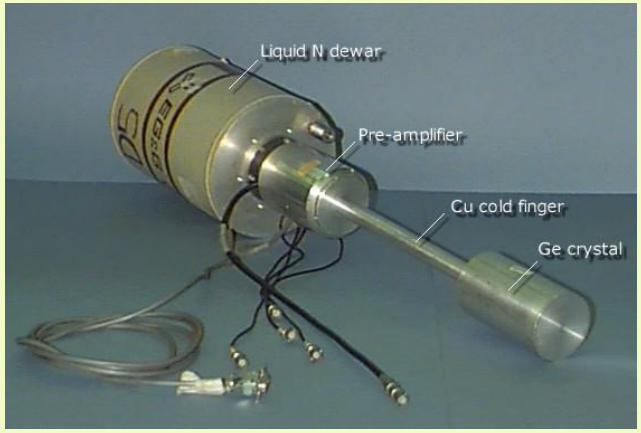
Two scintillators



YAP:Ce or LuYAG:Pr



CdTe is not technologically and requires special electronics

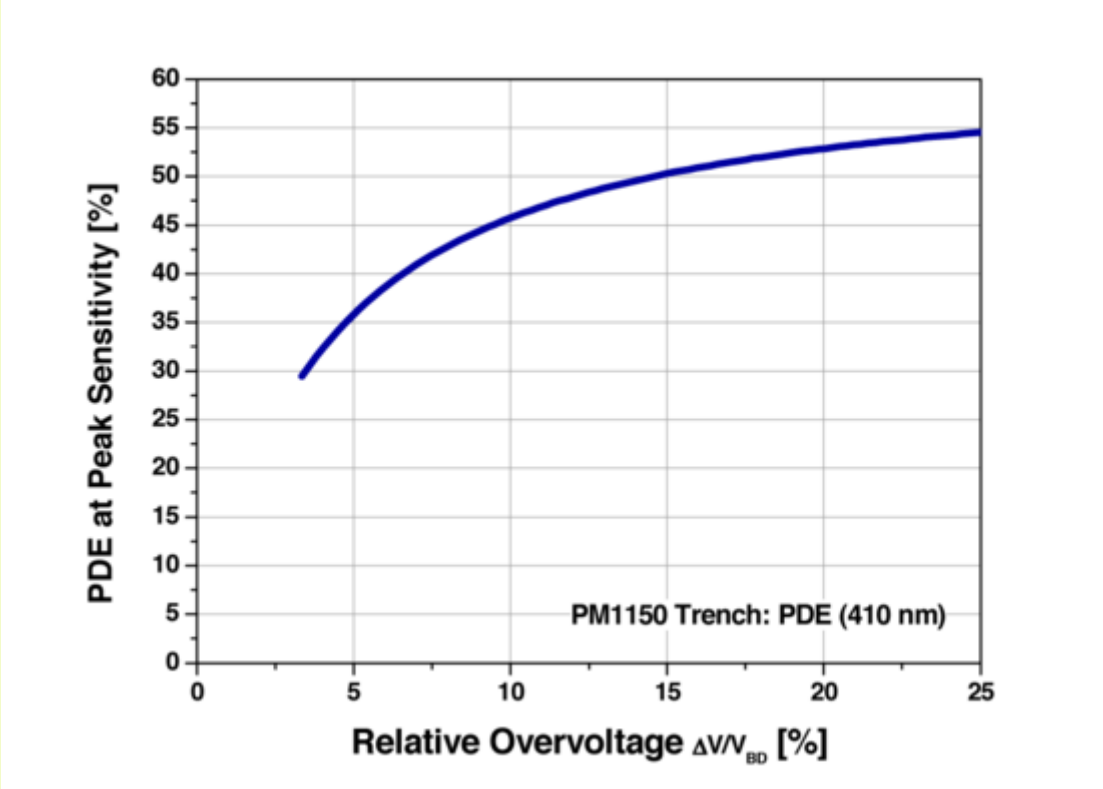


HPGe is too expensive for everyday use, because it requires cooling

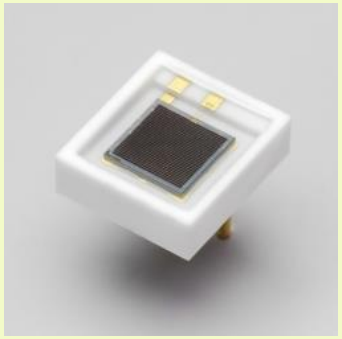
Selection of SiPM

The main characteristic significantly affecting the energy resolution is quantum efficiency

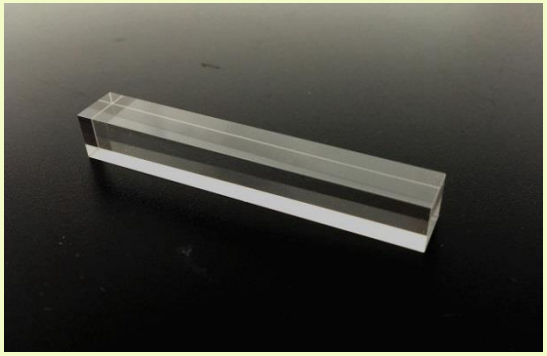
○ KETEC



What is necessary energy resolution of the detector?



SiPM KETEC



YAP:Ce

17% energy resolution at the energy of 59.5 keV

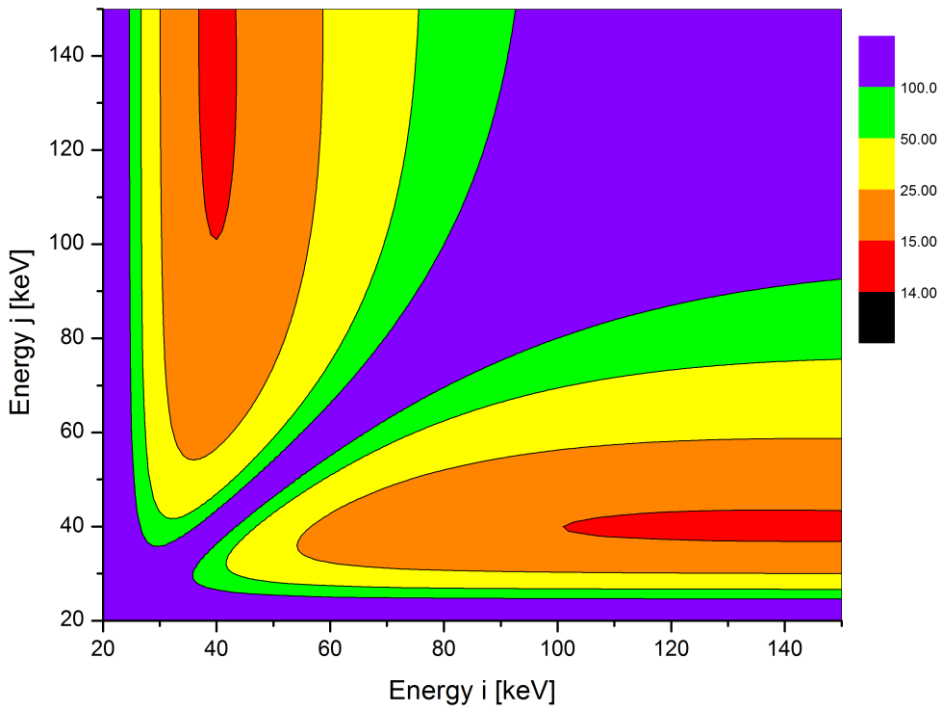
20% (FWHM at an energy of 40 keV (estimation)

Self-consistent model

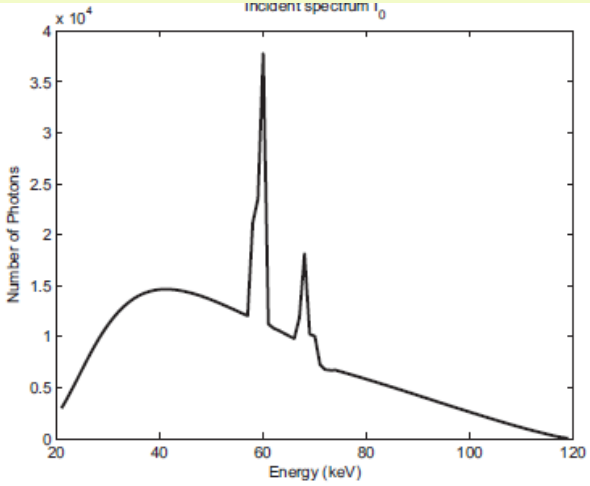
- the response of the detector
- the incident X-ray spectrum
- the number of particles in it

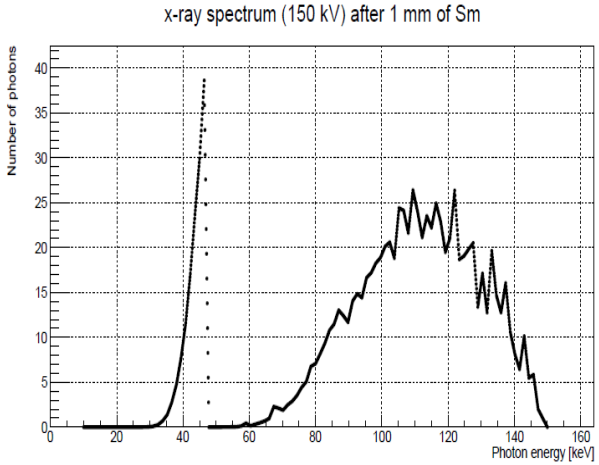
- the error of determining bone density

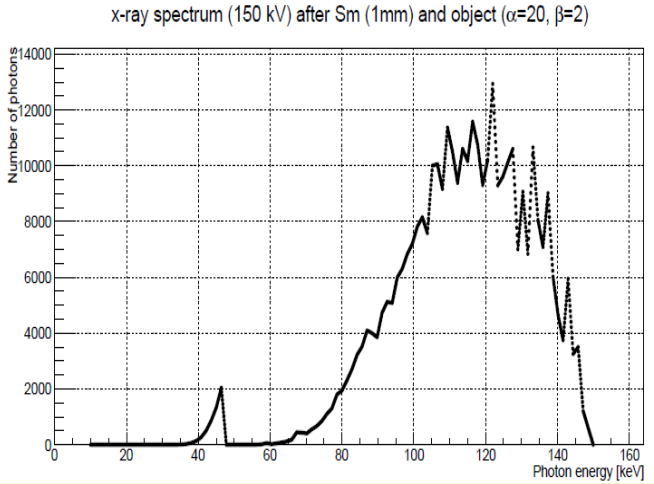
The case of two monoenergetic sources



At present







$$\mathcal{L}_P^*(t) = \log f(d \mid t) = \sum_i \left(-\gamma_i + d_i \log \gamma_i - \log d_i!\right).$$

$$\operatorname{Cov}\left(\hat{t}_i, \hat{t}_j\right) \approx \sum_k \sum_l \left(\frac{\partial \hat{t}_i}{\partial d_k}\right) \left(\frac{\partial \hat{t}_j}{\partial d_l}\right) \operatorname{Cov}\left(d_k, d_l\right)$$

a more precise and complex model

Conslusions

- one produced detector based on the combination of SiPM - scintillator allowing to achieve 17% energy resolution at the energy of 59.5 keV with high counting rate

- The model of the two monoenergetic sources allowing in the first approximation to estimate the error of determining bone density was considered

Thank you for your attention!