POSITRON ANNIHILATION

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Outline

- making positrons
- positron-solid interactions
- observables
- how we analyze data
- applications

Making positrons

- Radioisotope source, usually Na-22
- (convenient, but low intensity – beam flux 10^5 – 10^6 per second)

- Positrons require moderation, usually tungsten foil or mesh, to make a monoenergetic beam

- Reactor or LINAC-based, using pair production
- (high intensity – 10^8 per second)

4 fates…

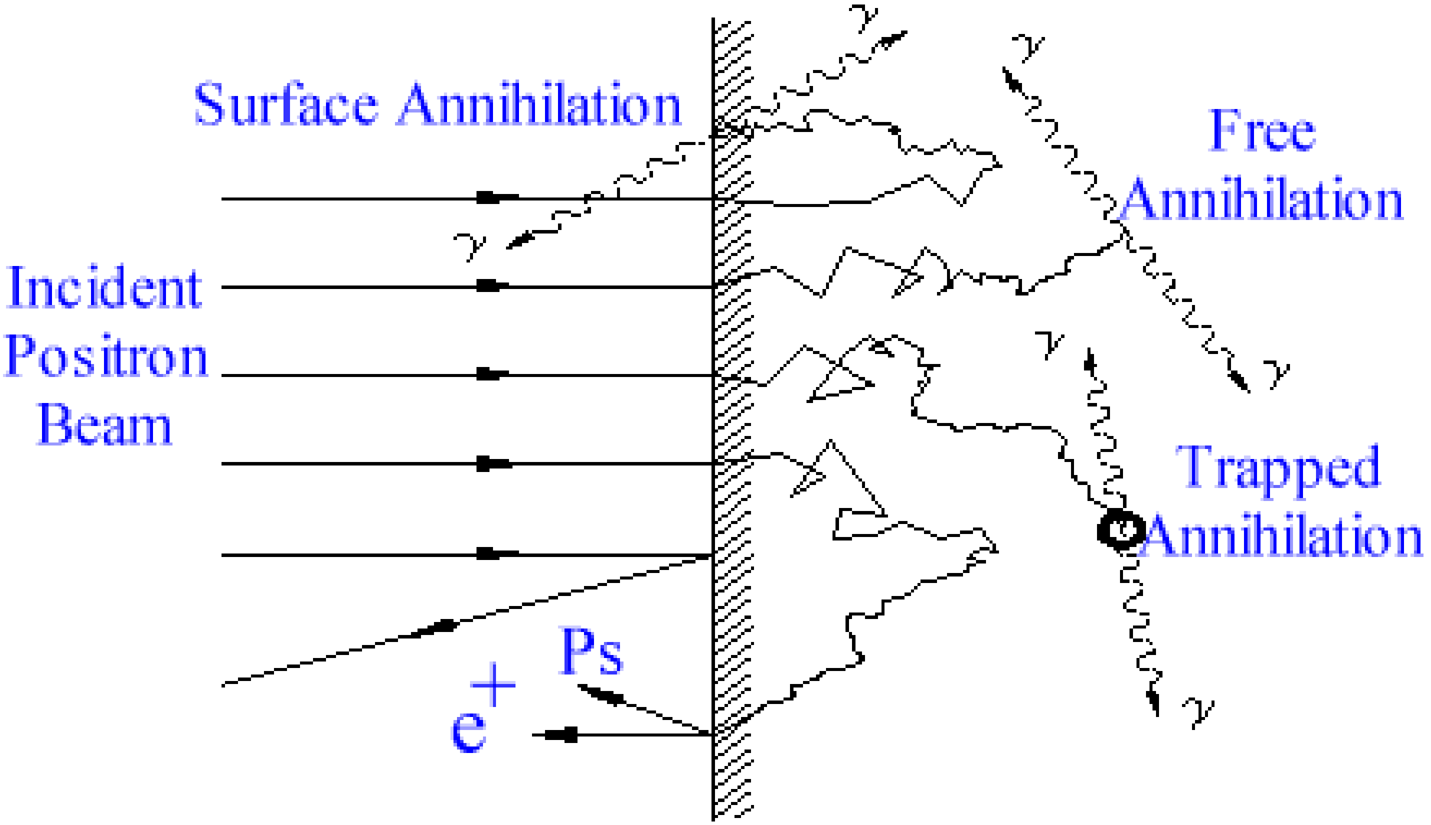
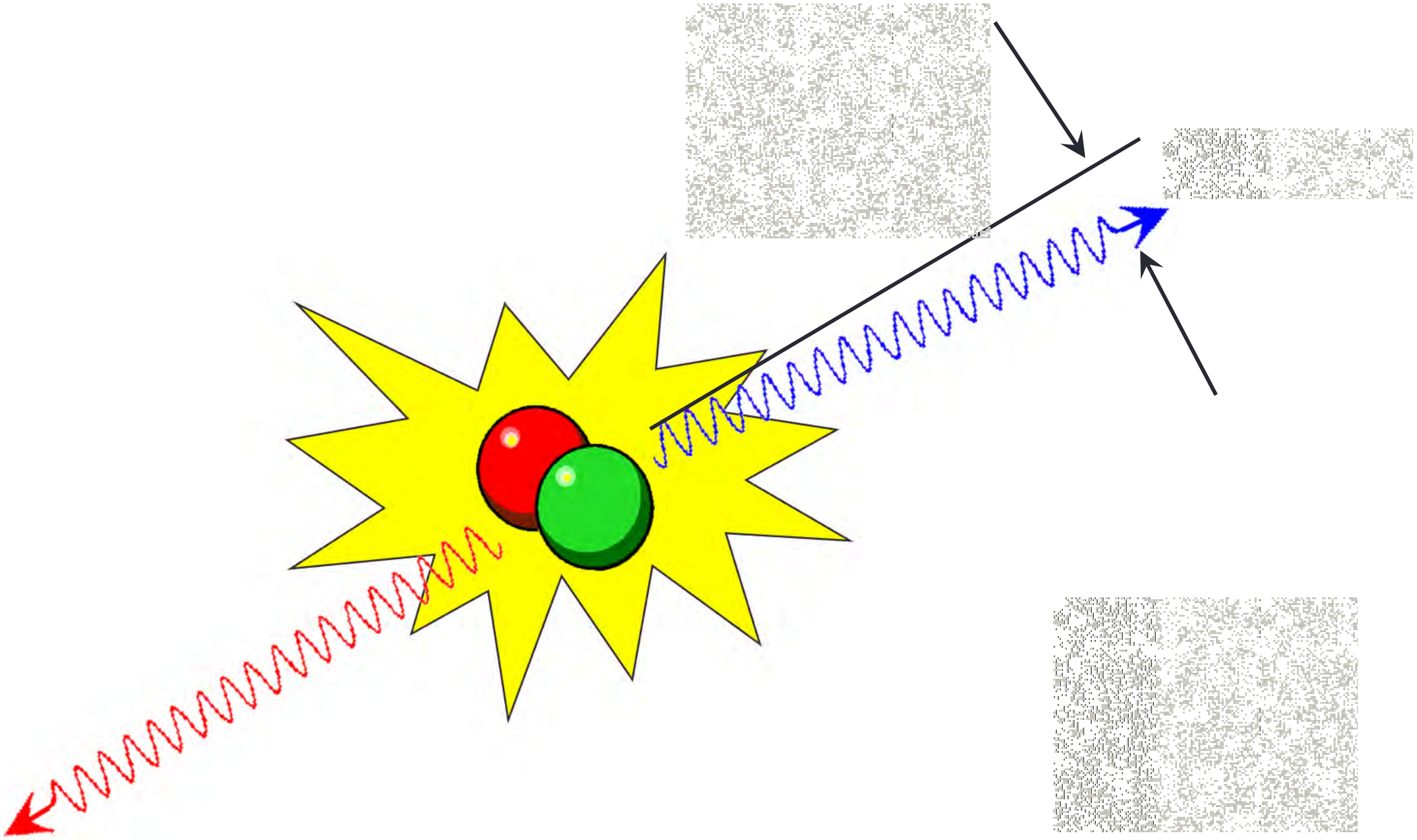


Figure from D.W. Gidley

Positron Annihilation



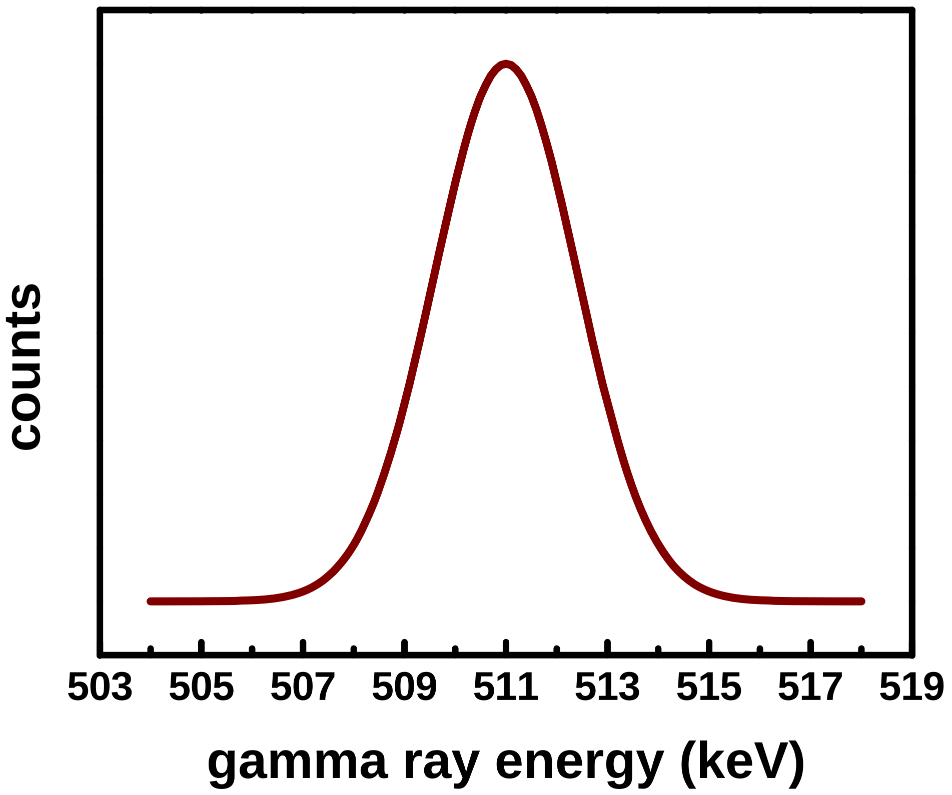
Observables

- We can measure:

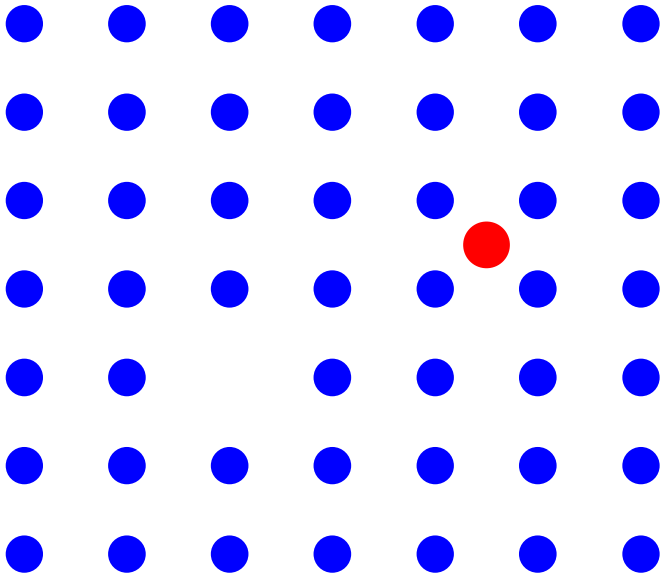
- **Positron lifetime**
- **Angular correlation**
- **Doppler broadening**

- All have their advantages, but we use **Doppler broadening** because it is the easiest method to apply with *monoenergetic* positrons, which we need to use to study thin layers

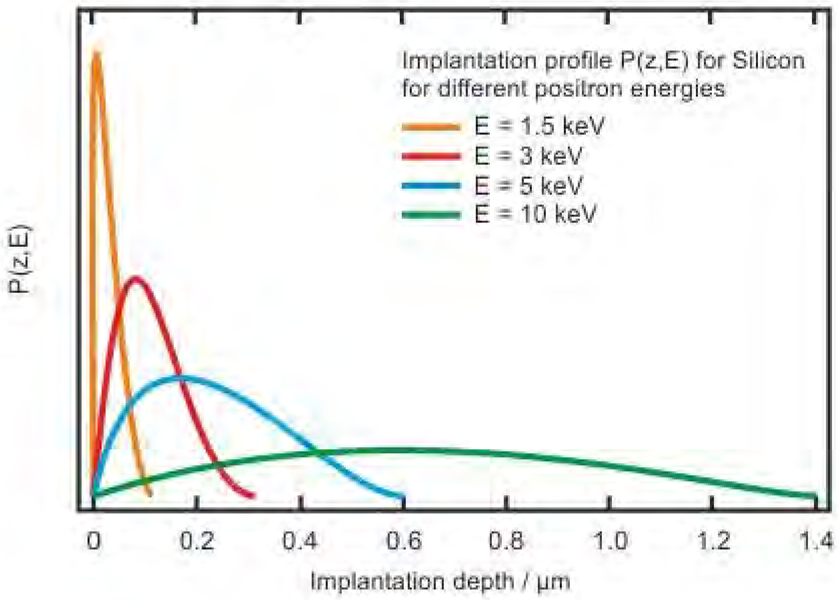
Gamma ray spectrum



Positrons are trapped by defects



“S”harpness parameter



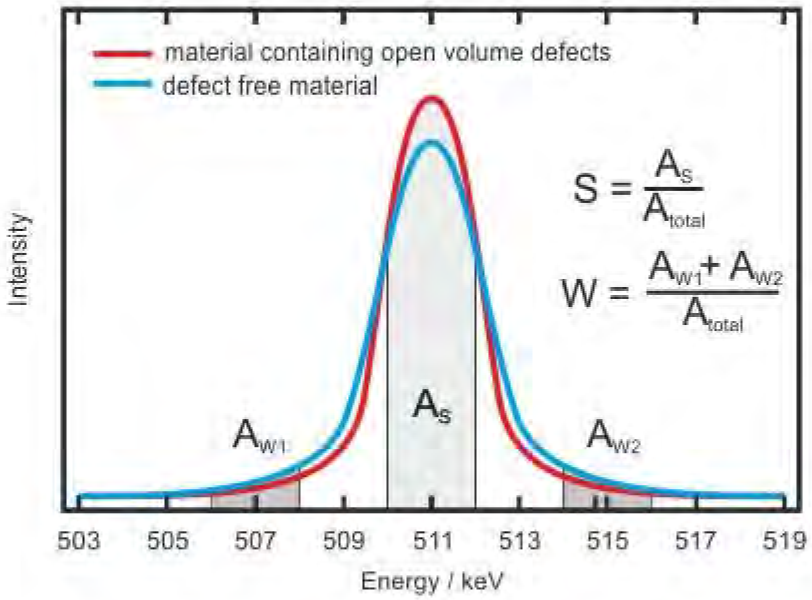


Figure by Maik Butterling

Positron trapping

TRAPPED FRACTION F

$$F = \frac{\nu C}{\lambda + \nu C}$$

ν = DEFECT SPECIFIC TRAPPING RATE
(TYPICALLY $\sim 10^{15}$ s^{-1})

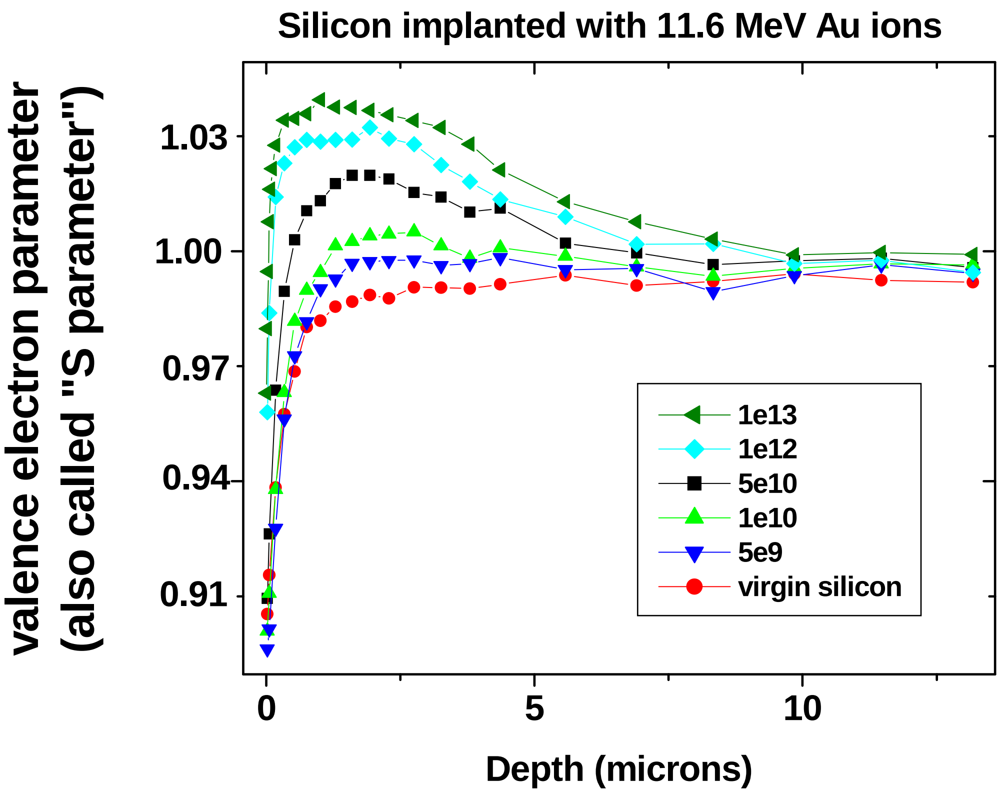
C = CONCENTRATION
(RANGE OF SENSITIVITY FROM
$\sim 10^{-6}$ to 10^{-2}
ie. 10^{16} to 10^{19} cm^{-3})

λ = FREE ANNIHILATION RATE
(4.55×10^{9} s^{-1} IN SILICON)

S parameter is a weighted average…

$$S = F_{free}S_{free} + F_{defect}S_{defect} + F_{surface}S_{surface}$$

Example: ion-implanted silicon



Modelling with POSTRAP

- user supplies a model defect profile, in layers

Then for each positron energy:

- model the positron implantation profile
- model the positron diffusion (which is defect dependent)
- calculate the trapped fraction in each layer
- assign S parameters to each ‘state’ (i.e. surface, free, defects)
- calculate S for each energy
- adjust model and iterate

Applications

- Irradiation
- Aging
- Fatigue
- Thermal history
- Thin film growth
- Porosity

- Semiconductors
- Metals
- Polymers
- Ceramics