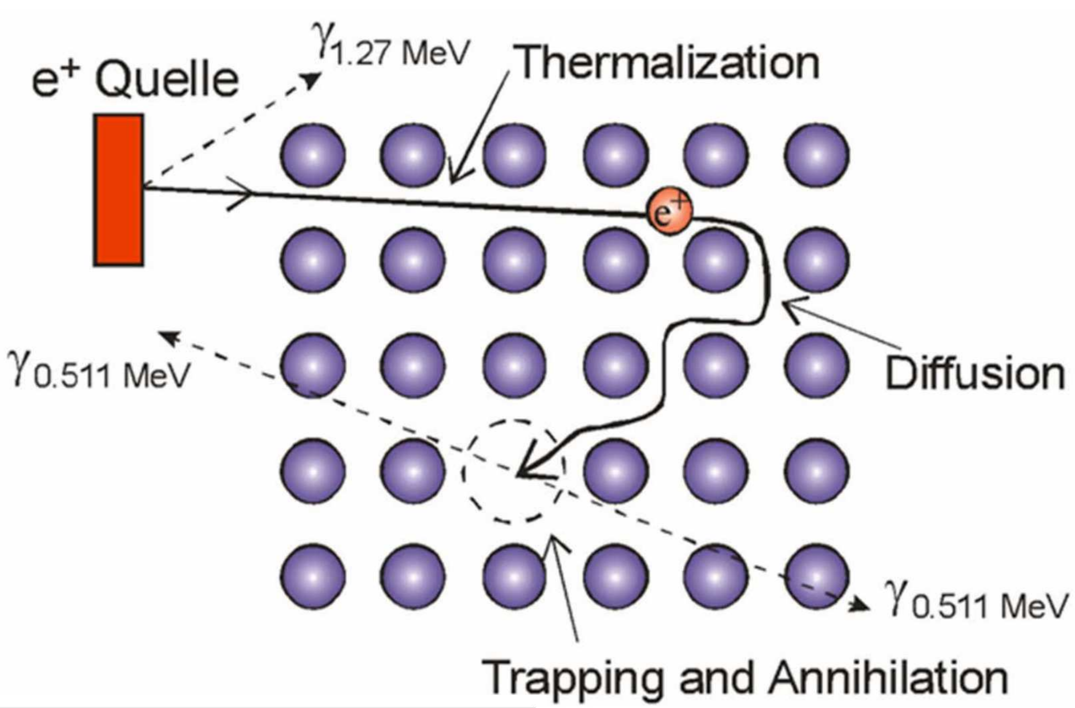
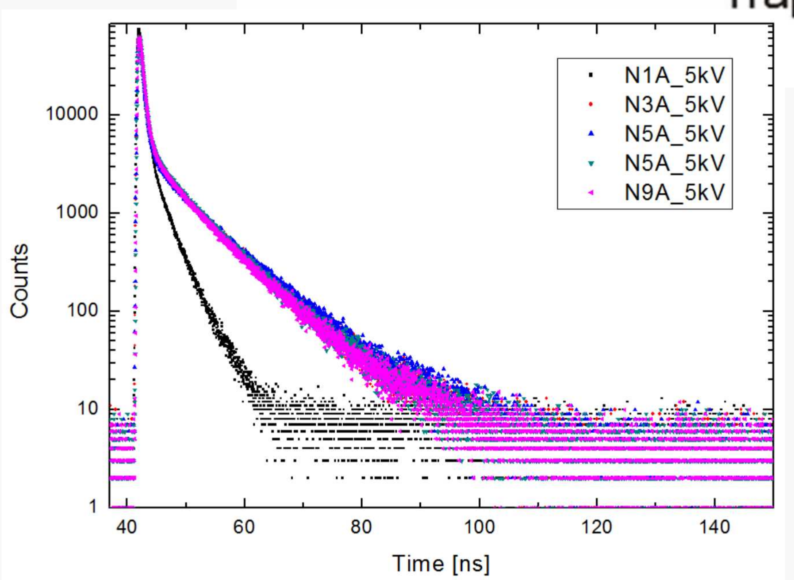
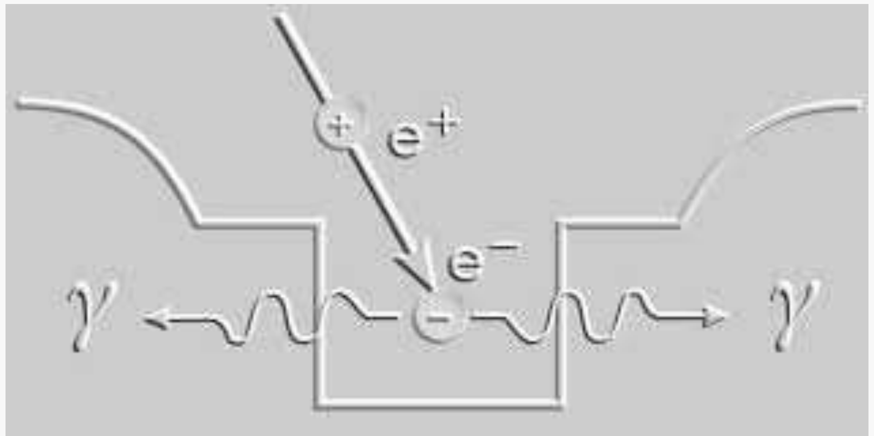
Do we have a competitive positron beam?

Probably NOT
but it does not cost much to consider it



- Positron wave-function is localized in the attractive defect potential
- Annihilation parameters change in the localized state
  - Positron lifetime increases in a vacancy
  - Doppler broadening decreases in the open volume defect
  - Coincidence spectrum depends on local chemistry





Positron to detect sub-micron defects

Quality assurance and innovation in manufacturing is underpinned by metrological methods and techniques that improve and drive forward the measurement infrastructure available to industry. Metrology is especially important in advanced manufacturing areas producing high-performance and high-value components that are made in and are required to perform under hostile environments. Heat and pressure treatments, new welding methods, radiation exposure, and impact damage are all examples of scenarios that can leave sub-micron defects in materials during advanced manufacturing or extreme performance use.

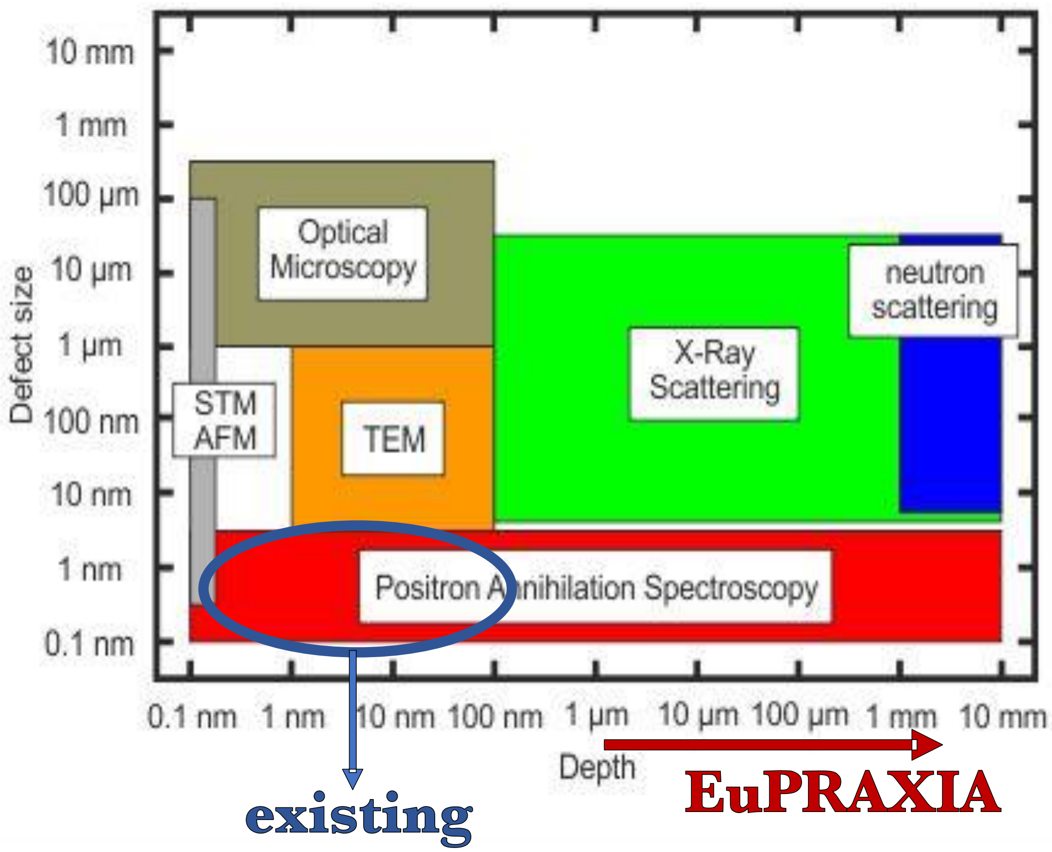
It is thus highly desirable for industry to be able to assess the uniformity and quality of materials over a wide range of thicknesses, sizes, and composition, ideally while being under significant stress. Moreover, it is vital that any inspection be carried out in a non-destructive manner. Generally speaking, non-destructive inspection can be easily performed at the surface of materials, but several difficulties are encountered when performing sub-surface, volumetric inspections. Several techniques have been developed, which can be classified depending on the particles used to probe the materials: neutron driven, X-ray driven, or positron driven.

Of them all, positron annihilation lifetime spectroscopy (PALS) is arguably the only one that can provide nanometre-scale resolution over a significant range of material thicknesses and detect defects and vacancies in materials down to a few parts per million (Fig. 2.15, left). When in a material, a positron enters a Bloch state, but it is rapidly localised in regions of missing matter; in other words, positrons get easily trapped at vacancy defects. In a timescale of the order of 100 ps,

http://www.eupraxia-project.eu/eupraxia-conceptual-design-report.html

EuPRAXIA
European Plasma Research Accelerator with eXcellence In Applications

Challenges & Opportunities



Reference
EuPRAXIA

Material	Bulk	Defect structure	V_A	V_B	V_O
$PbTiO_3$	161	Unrelaxed	292	204	165
		Relaxed	290	185	
$SrTiO_3$	152	Unrelaxed	280	195	161
		Relaxed	281	189	
$SrRuO_3$	150	Unrelaxed	288	200	161
$Sr_3Ru_2O_7$	180	Unrelaxed	301	207	187
$LaMnO_3$	145	Unrelaxed	282	196	158
$TbMnO_3$	152	Unrelaxed	259	199	161
$BiFeO_3$	154	Unrelaxed	290	198	161

Table 2.3: Calculated positron lifetimes (ps) for perfect lattice (bulk) and monovacancy defects in selected ABO_3 and related materials (adapted from [147]).

- Need 100 ps time resolution for entering positron
- Need good beam quality
- Apparently there are not many MeV positron beams

Existing accelerators

As an example, the ELBE Centre at Dresden-Russendorf provides positron bunches with a duration (FWHM) of 250 ps and an energy tuneable from 0.5 to 15 keV [143]. The SPONSOR area can instead reach up to 36 keV [144]. The maximum intensity achievable by the machine is 10^6 positrons per second. The NEPOMUC machine at the Technical University of Munich exploits neutron-induced positron production in ^{113}Cd and produces approximately 10^9 positrons per second with an energy of 1 keV [145]. The PLEPS line in Munich [146] instead provides a DC beam with approximately 5×10^4 particles per second. Four minutes are needed to get a full lifetime spectrum, whereas up to two hours are necessary to get a complete depth profiling, accumulating 25 spectra.

Despite the high performance of these machines and their wide use for industrial applications, it is difficult to produce high-quality positron beams with higher energy (up to a few MeV), able to penetrate deeper into the material under study. Also, the relatively long duration of the beams, comparable to the typical timescales of annihilation in materials (see Table 2.3, adapted from [147]), limits the resolution of the systems and makes data extraction rather complicated and prone to

Is a parasitic extraction of positrons possible?

- Introduce a weak dipole right after capture solenoid to extract 2 MeV positrons and pray that it is possible to ged rid of stray solenoidal fields. Pray also that we do not reduce too much the muon transport.
- Alternative: use a separator?
- Select only a small fraction (10^{-5}) of positrons to have good beam quality. To avoid problems maybe select at max one muon per RF cycle
- Develop a <100 ps entrance detector for positrons.
- Use RF as coincidence for entrance detector if needed
- Use RF—entrance-detector timing to improve determination of longitudinal momentum (penetration depth). Make a long beamline.