

# Possibility of realizing Bussey's thought experiment on collapse of the wave function at the microscopic level

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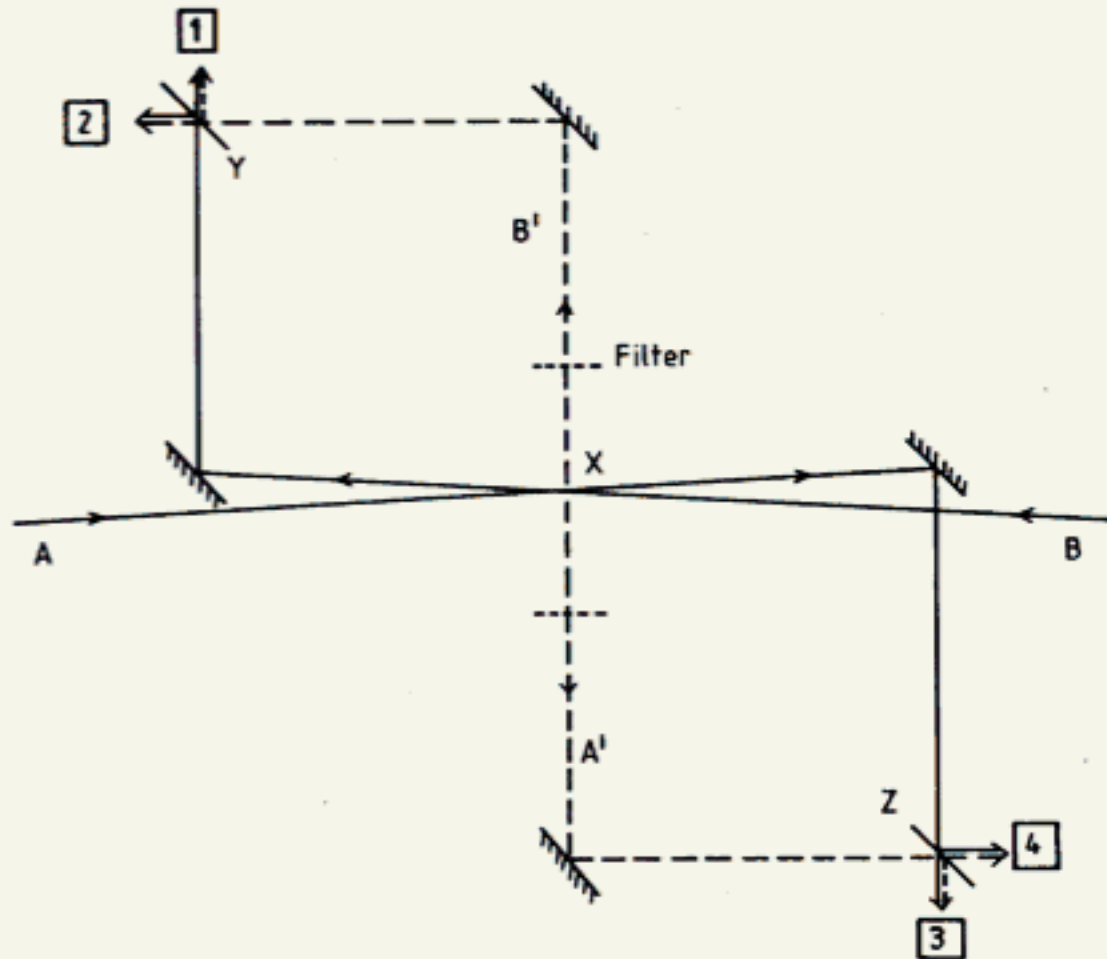
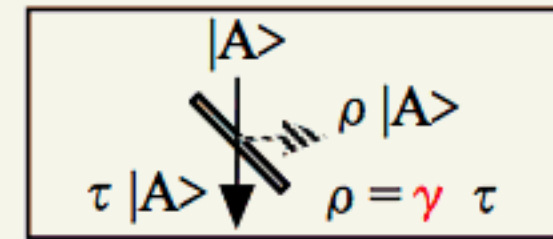


Fig. 1. The double interferometer. The filters remove scattered particles of type A' from the B' arm, and vice versa.

[1] P.J. Bussey, Phys. Lett. 106A(1984) 407

Parameters  $\tau, \rho, \gamma$   
of the beam splitter  
(symbols 'Y' and 'Z' in figs.)



if  $|\Psi\rangle = \alpha|A\rangle|B\rangle + \beta|A'\rangle|B'\rangle$  (non-collapse)

$$C_{13} = |\tau|^4 |\alpha - \beta|^2, \quad C_{14} = |\tau|^4 |\alpha + \beta|^2 \quad \text{for } \gamma = e^{i\pi/2}$$

[for general  $\gamma$ :  $C_{13} = |\tau|^4 |\alpha + \gamma^2 \beta|^2$ ,  $C_{14} = |\gamma|^2 |\tau|^4 |\alpha + \beta|^2$ ]

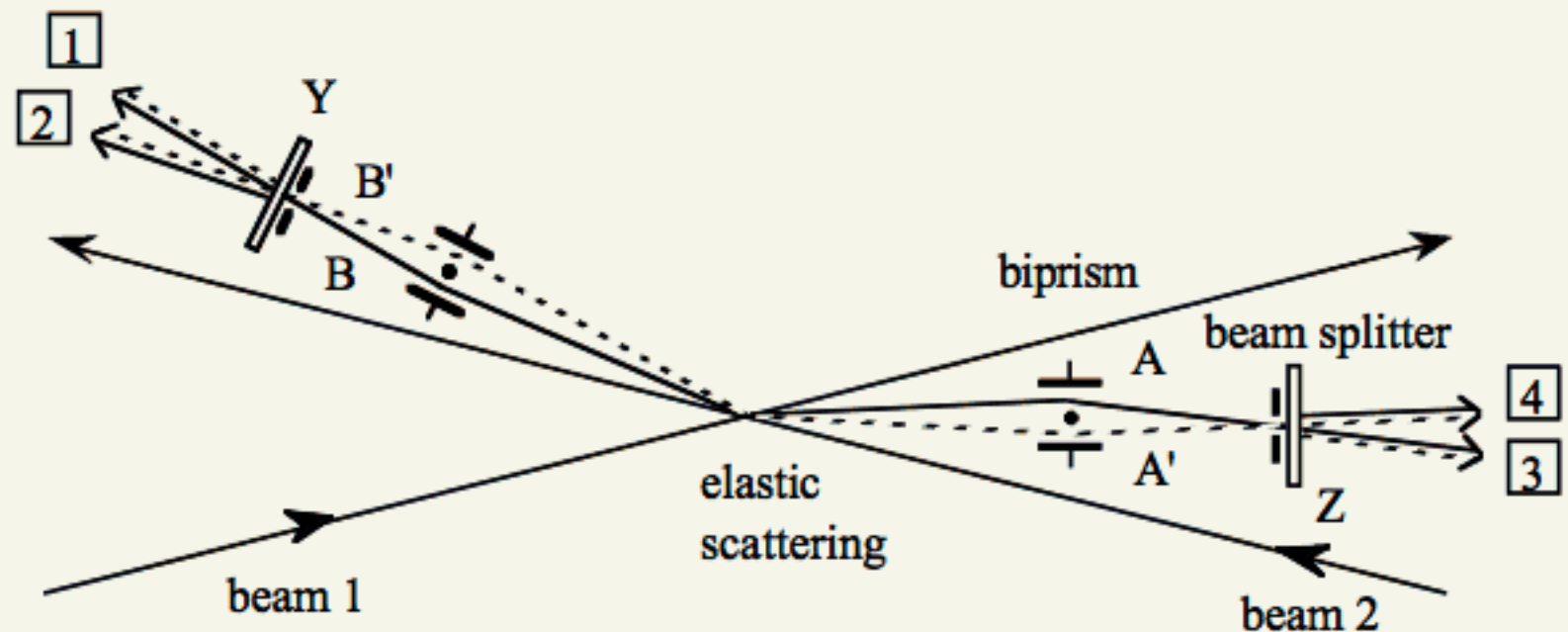
if  $|\Psi\rangle = |A\rangle|B\rangle$  or  $|A'\rangle|B'\rangle$  with weights  $|\alpha|^2$  and  $|\beta|^2$   
(collapse)

$$C_{13} = C_{14} = |\tau|^4 (|\alpha|^2 + |\beta|^2) \quad \text{for } \gamma = e^{i\pi/2}$$

[for general  $\gamma$ :  $C_{13} = |\tau|^4 (|\alpha|^2 + |\gamma|^4 |\beta|^2)$ ,

$$C_{14} = |\gamma|^2 |\tau|^4 (|\alpha|^2 + |\beta|^2) ]$$

'C<sub>13</sub>' denotes the coincidence rate between counters '1' and '3', etc.



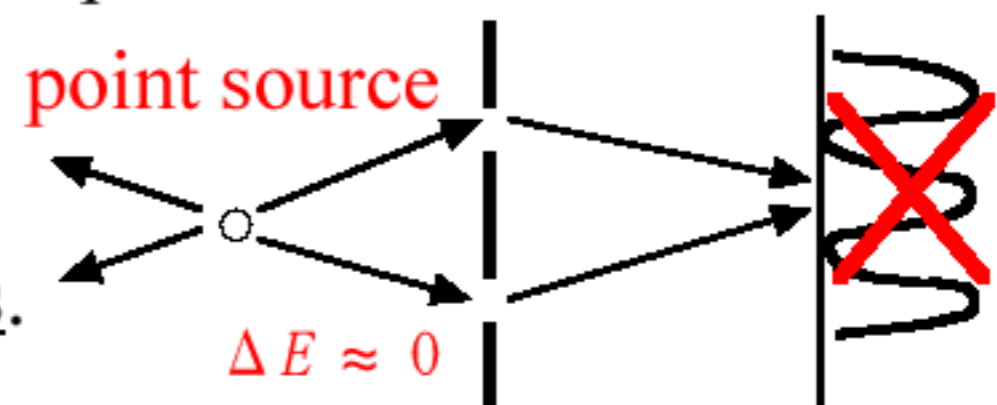
If we observe only the particle A, we must calculate  $|\langle r_1 | \Psi \rangle|^2$  by integrating over the position of the particle B.

$$|\langle r_1 | \Psi \rangle|^2 = |\alpha|^2 |\phi_A(r_1)|^2 \langle B|B \rangle + |\beta|^2 |\phi_{A'}(r_1)|^2 \langle B'|B' \rangle + 2\text{Re}[\alpha^* \beta \phi_A^*(r_1) \phi_{A'}(r_1) \langle B|B' \rangle]$$

Assuming the orthonormality of the wavefunction of the particle 2, interference term vanishes because  $\langle B|B' \rangle = 0$ .

Then no interference fringe appears however small the source (collision region) size is, and however monochromatic the particle beam is. **no fringe!**

This is not because the w.f. collapsed, but just **because of the entanglement of two particles.**



With low-energy electron collision and electron biprisms, we can prepare to confirm the disappearance of the fringe[2].

[2] K. Toyoshima et al., Czech. J. Phys. Vol.56 (2006) 1361.

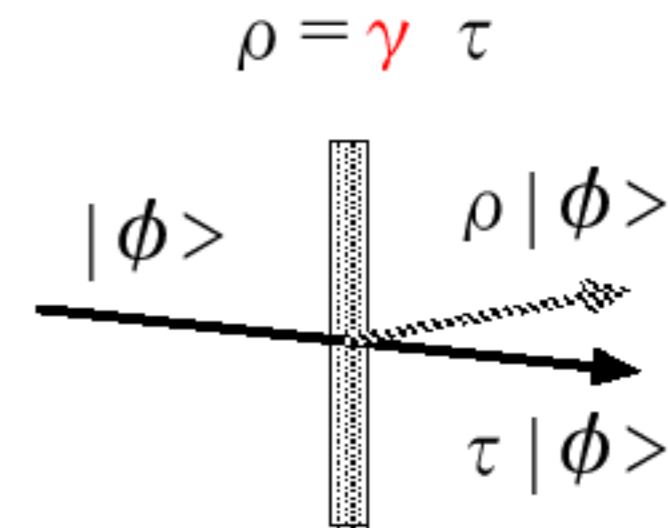
Thin crystal film as a beam splitter.

10-nm thick self-supporting Si crystal is reported[3].

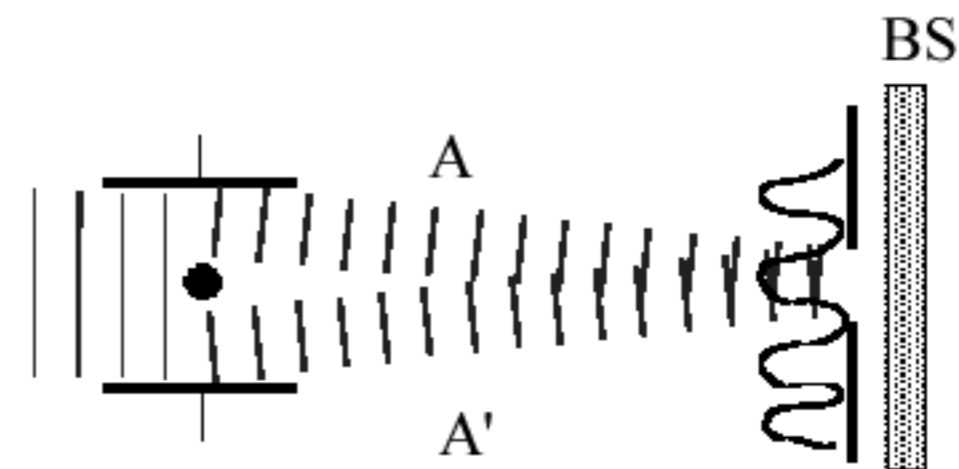
mean free path is 3.2nm for 2.5keV electron.

(attenuation to 4.4% after 10nm film)

- smallest Bragg diffraction angle:  $2\theta = 4.49^\circ$
- relative phase ( $\gamma$ ): no data available, but supposed to differ from zero significantly[4].



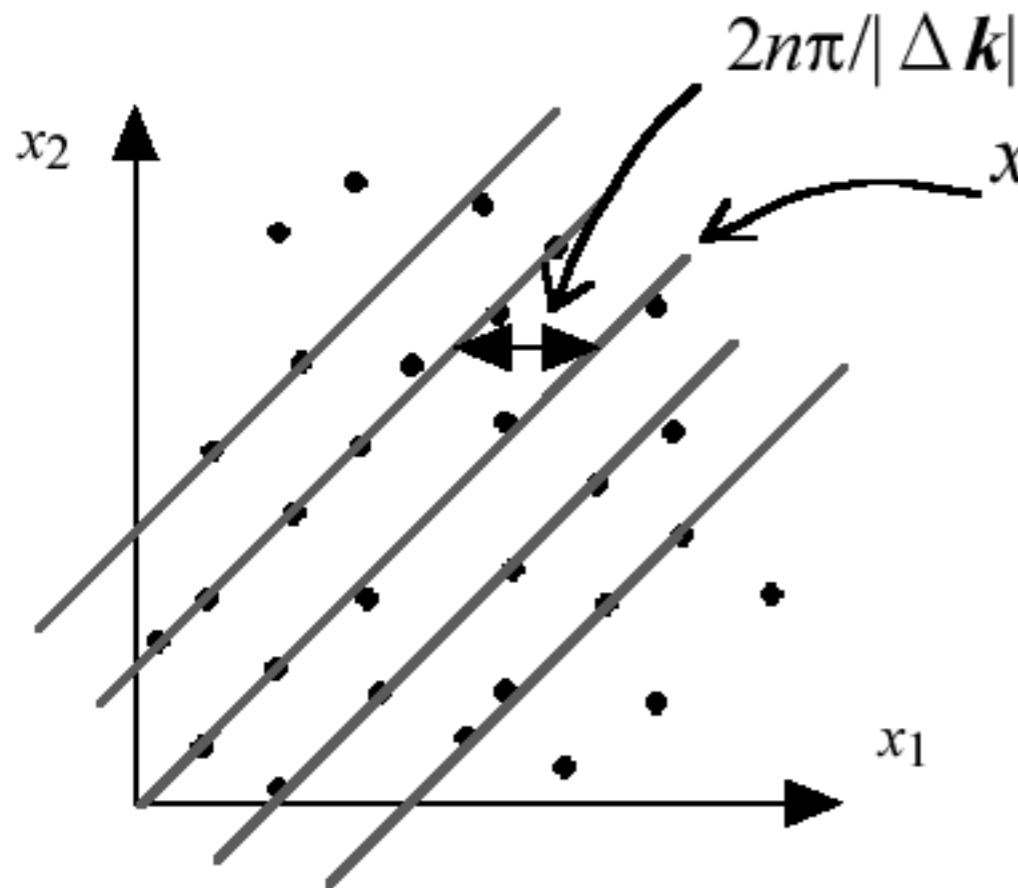
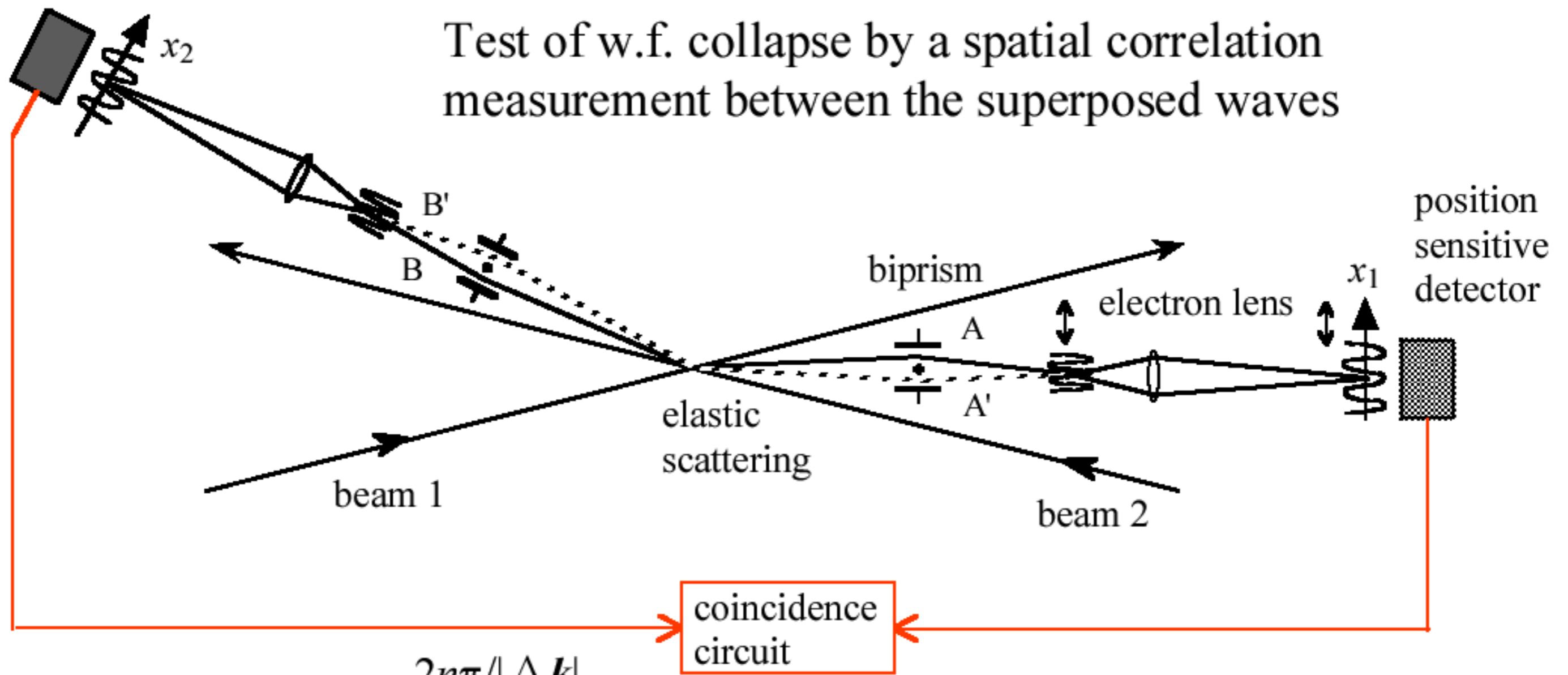
Fatal demerit: only single fringe line should be selected to hit the beam splitter.  $\rightarrow$  too small intensity.



[3] S. J. Utteridge et al., Applied Surface Science, Vols 162-163, 1 Aug. 2000, P. 359-367

[4] Phase shift values for Si single atom at  $E_e=10\text{keV}$  are tabulated in "International Tables for X-ray Crystallography, vol. IV.

# Test of w.f. collapse by a spatial correlation measurement between the superposed waves



(for simplicity,  
 $\alpha = \beta = 1$  is assumed)

$$\begin{aligned}
 & |\langle \mathbf{r}_1, \mathbf{r}_2 | \Psi \rangle|^2 \\
 &= |\phi_A(\mathbf{r}_1)|^2 |\phi_B(\mathbf{r}_2)|^2 + |\phi_{A'}(\mathbf{r}_1)|^2 |\phi_{B'}(\mathbf{r}_2)|^2 \\
 &+ 2 \cos[|\Delta \mathbf{k}| (x_1 - x_2)]
 \end{aligned}$$