Quantum Radiation group

Max-Planck Institute for the Science of Light

TRANSVERSE ENTANGLEMENT OF BIPHOTONS

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european social fund in the czech republic

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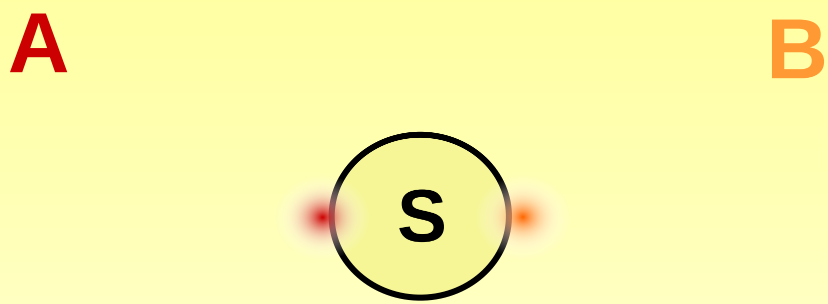
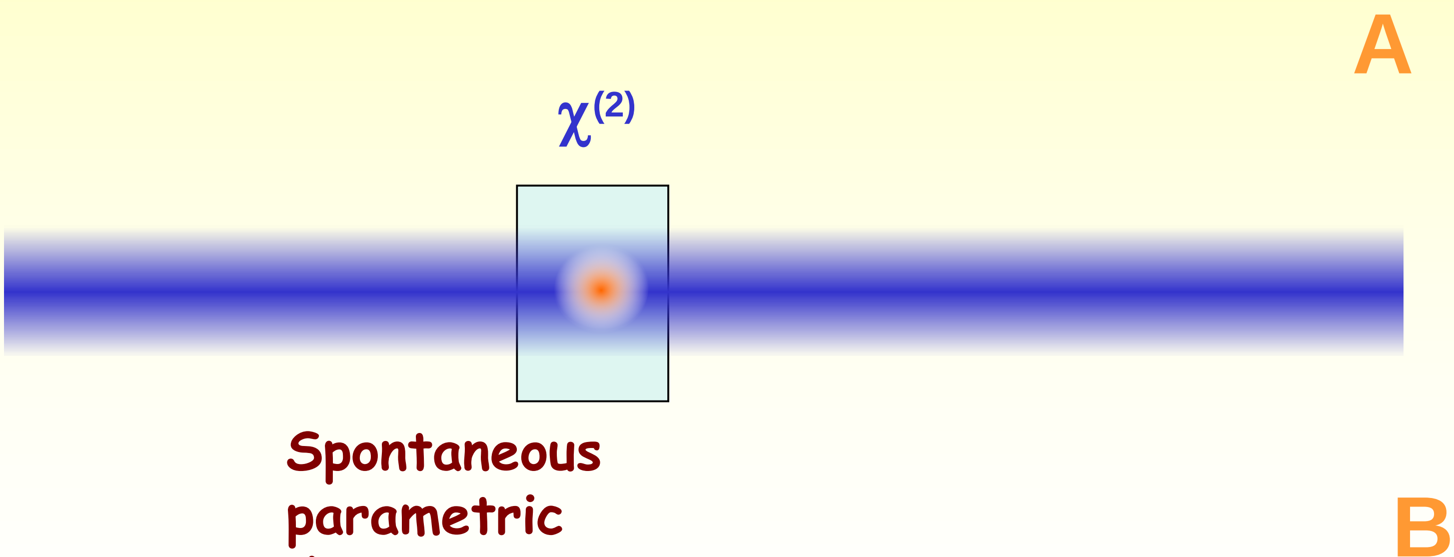
INVESTMENTS IN EDUCATION DEVELOPMENT


Felix Just
Andrea Cavanna

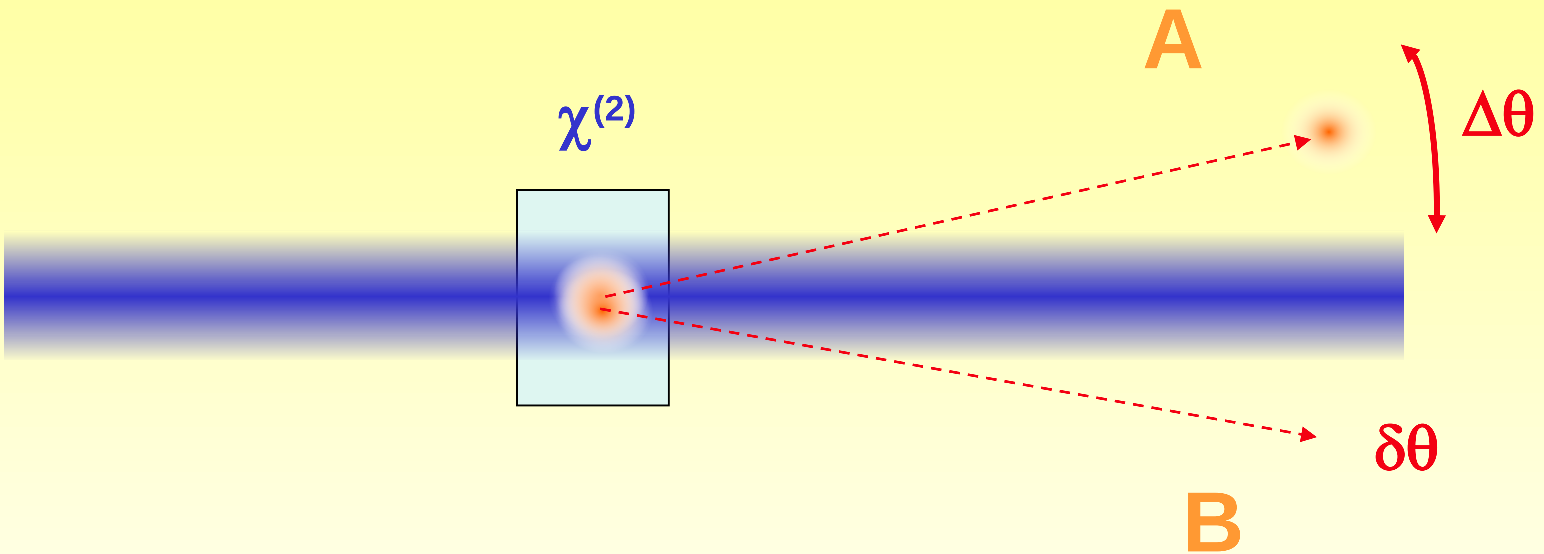
BIPHOTONS





Spontaneous
parametric
down-conversion

TRANSVERSE ENTANGLEMENT

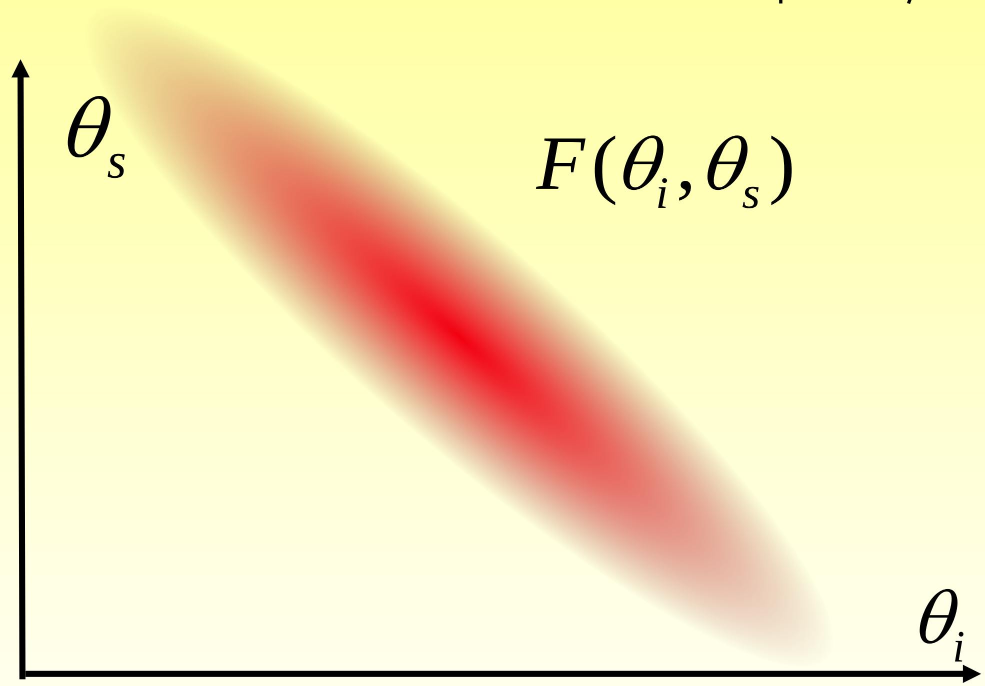


Entanglement: $\Delta\theta >> \delta\theta$

Uncertainty for one subsystem plus correlations between the two subsystems

TWO-PHOTON AMPLITUDE

$$|\Psi\rangle = \iint d\theta_i d\theta_s F(\theta_i,\theta_s) a^+(\theta_i) a^+(\theta_s) |\text{vac}\rangle$$

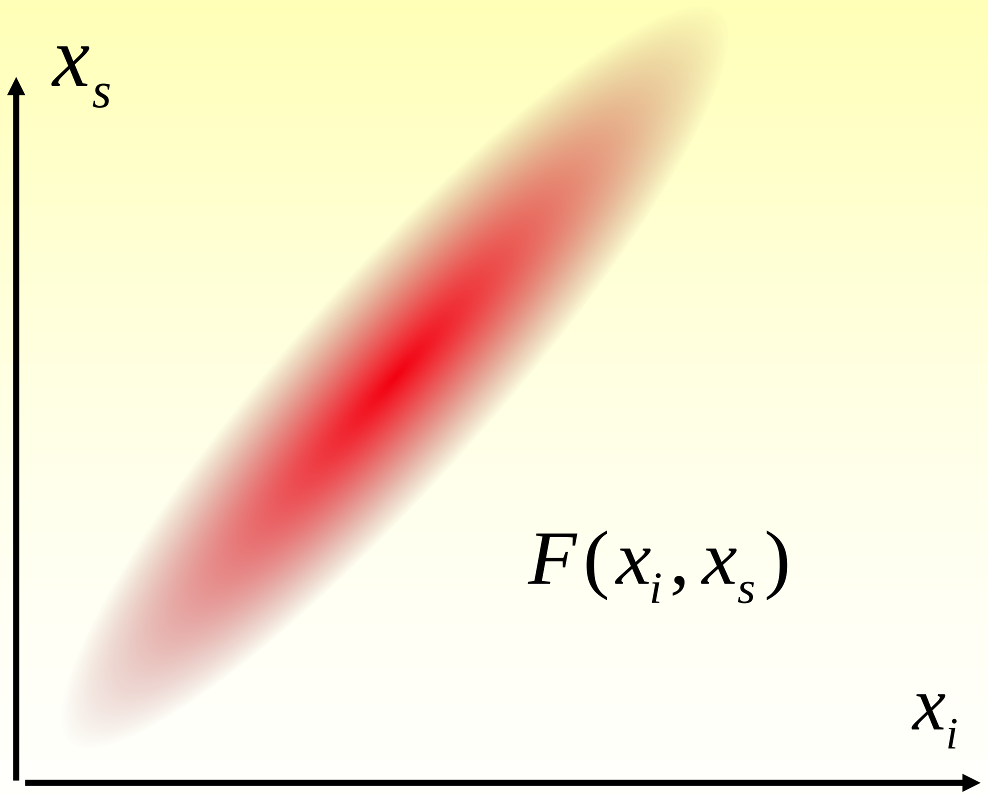


$$F(\theta_i,\theta_s) = \sum_n \sqrt{\lambda_n}\varphi_n(\theta_i)\chi_n(\theta_s), \ \sum_n \lambda_n = 1, \quad K = [\sum_n \lambda_n{}^2]^{-1}$$

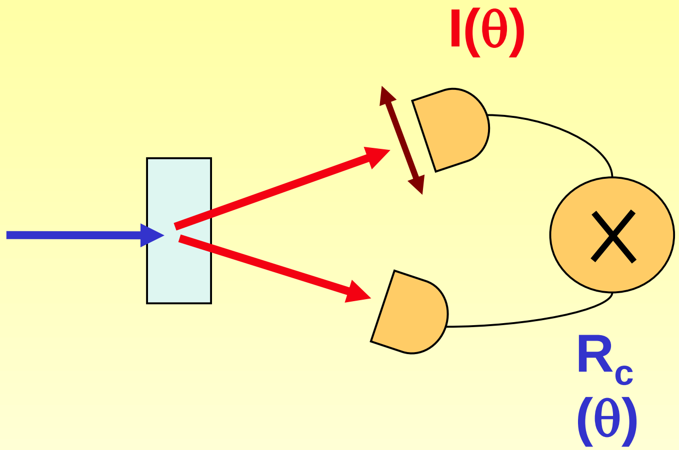
The Schmidt number

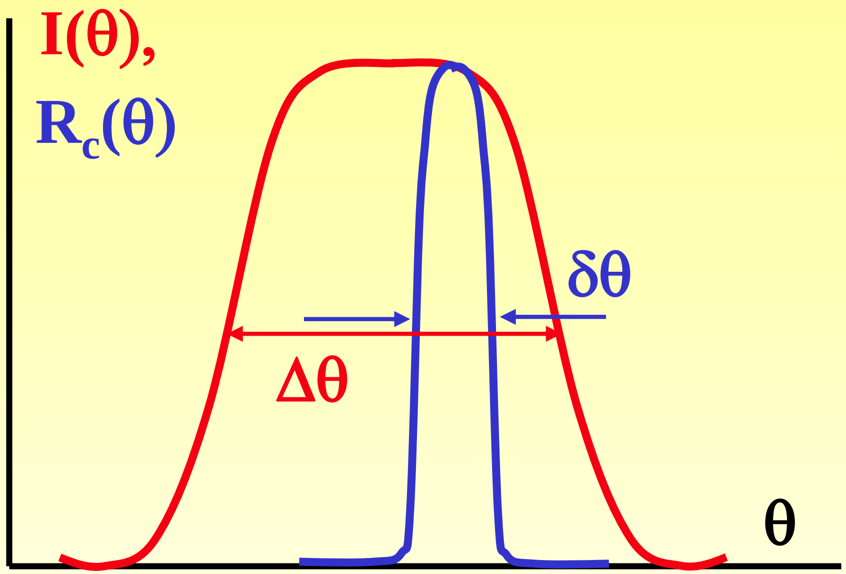
TWO-PHOTON AMPLITUDE: NEAR FIELD

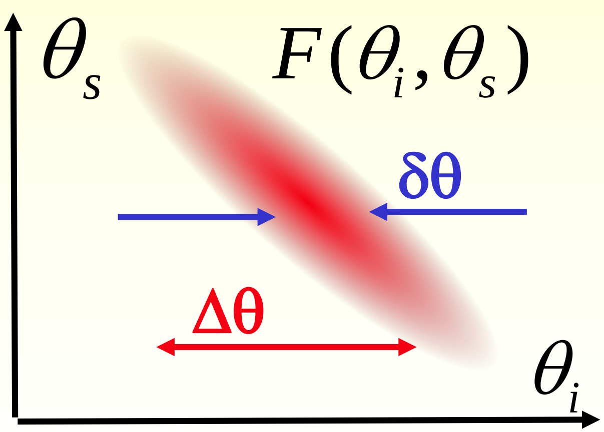
$$|\Psi\rangle = \iint dx_i dx_s F(x_i, x_s) a^+(x_i) a^+(x_s) |\text{vac}\rangle$$



FEDOROV RATIO





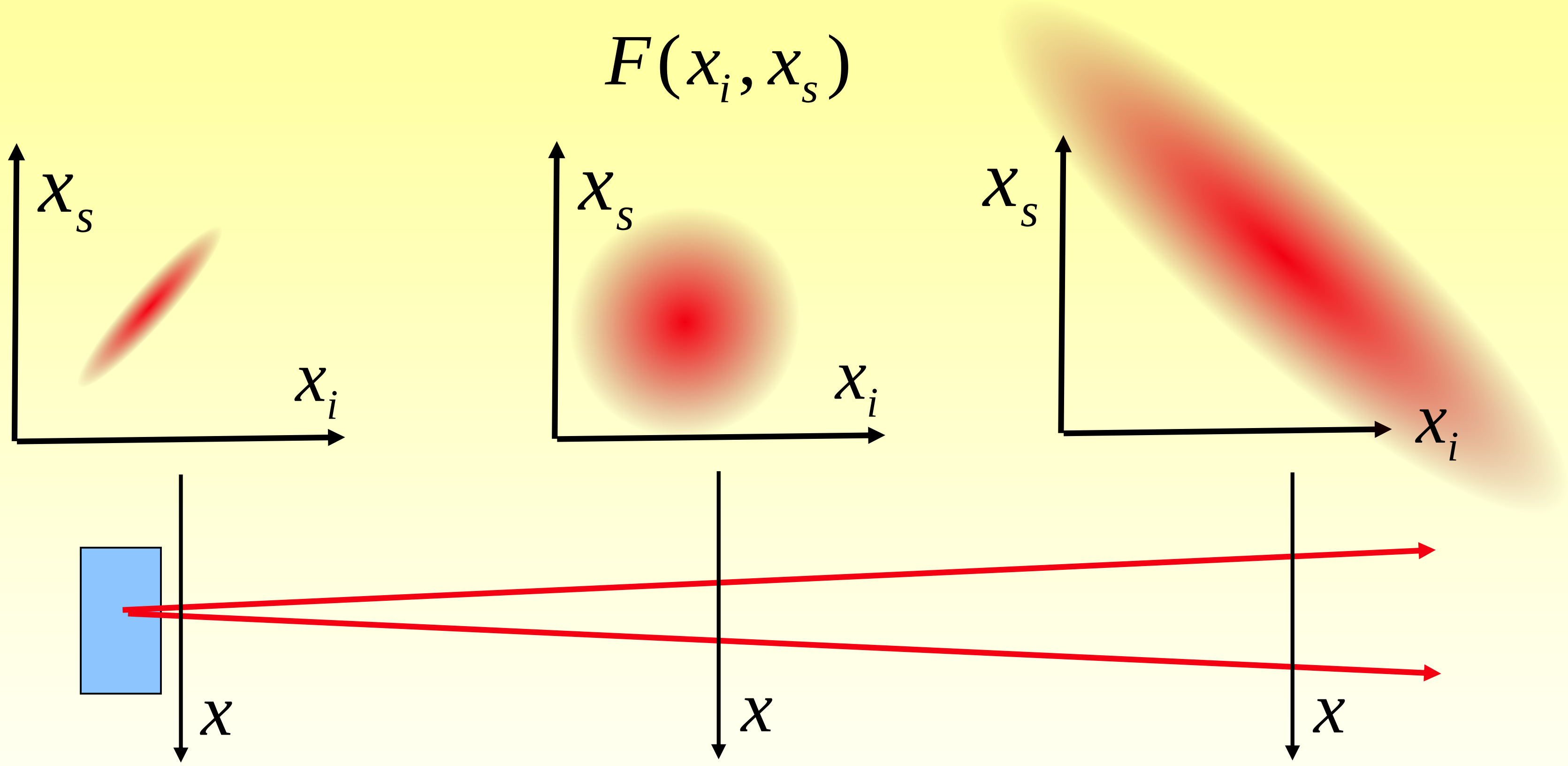


Fedorov ratio: $R = \Delta\theta / \delta\theta$

Valid only for pure states;
For Gaussian TPAs coincides with the Schmidt number

FROM NEAR TO FAR FIELD

$$F(x_i, x_s)$$

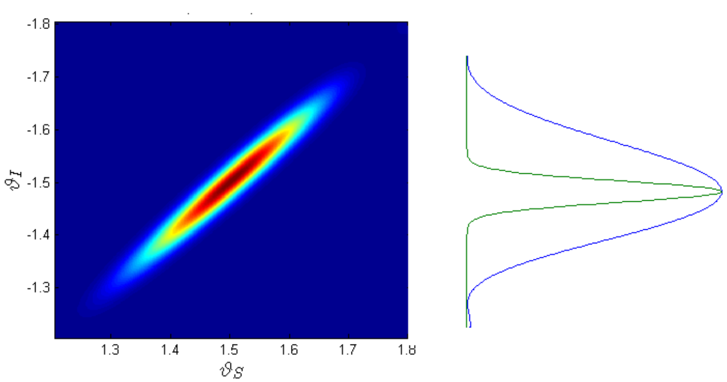


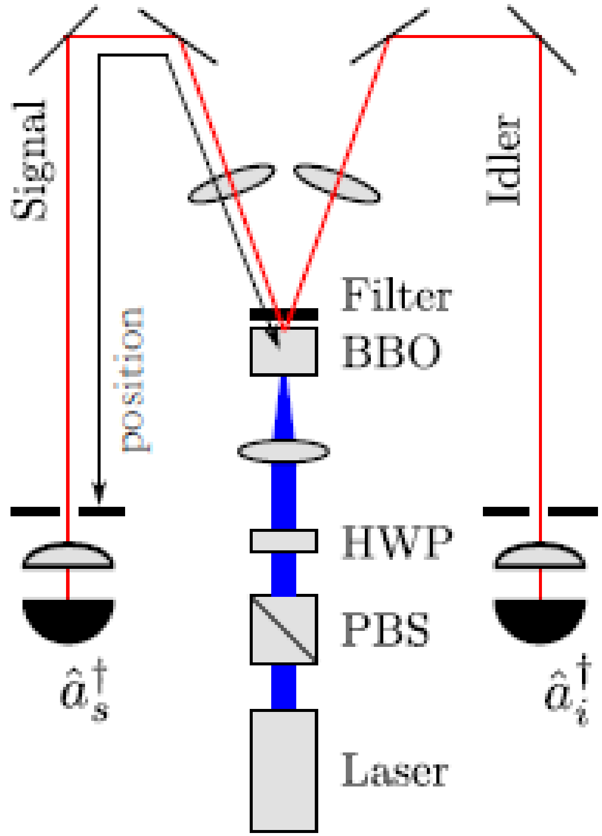
The Fedorov ratio becomes unity between near and far field. But entanglement cannot disappear!

K.W.Chan, J.P.Torres, and J.H.Eberly, PRA 75, 050101 (2007).

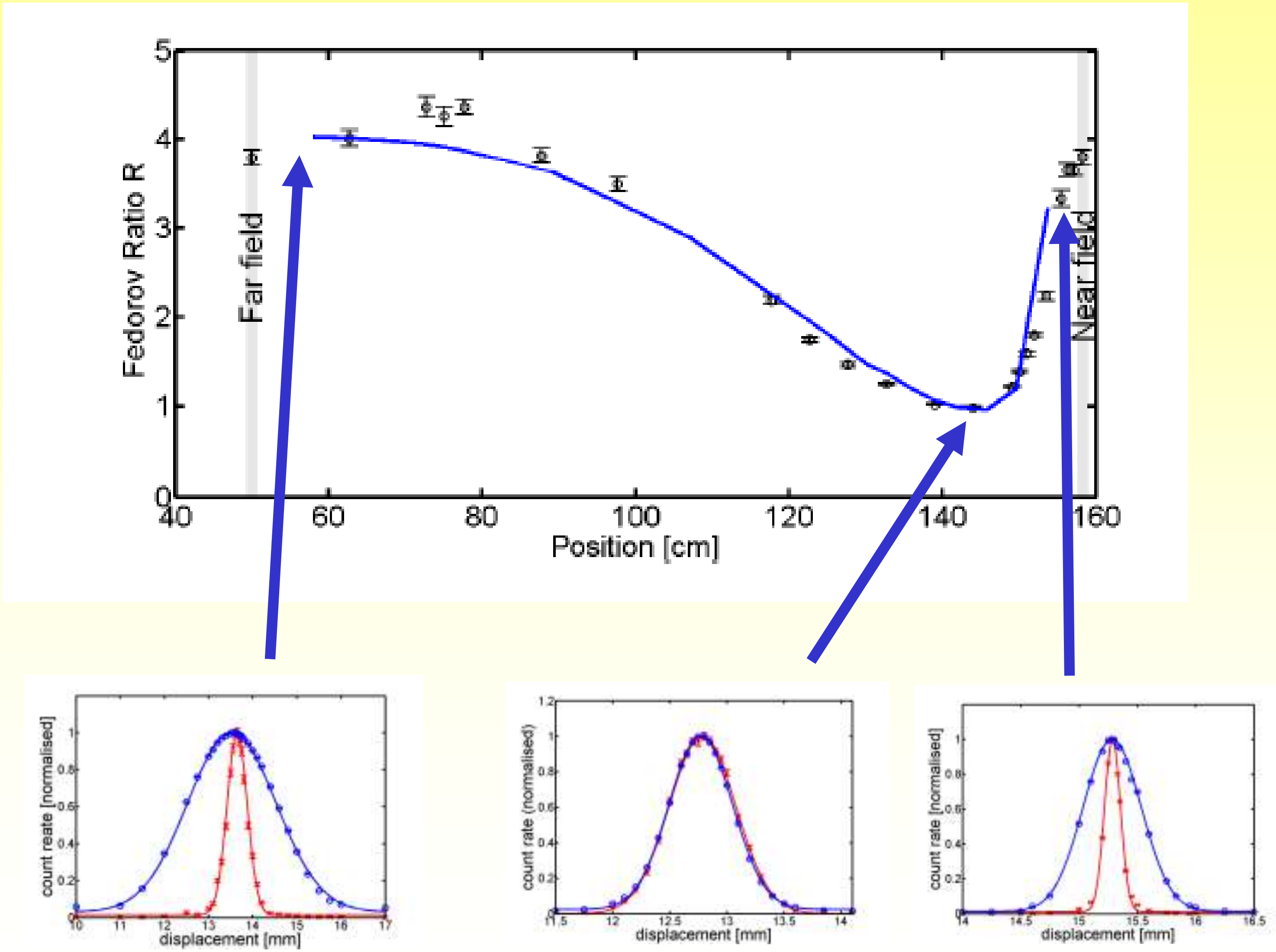
EXPERIMENT

We measure the Fedorov ratio at different distances from the crystal, passing from the far field to the near field



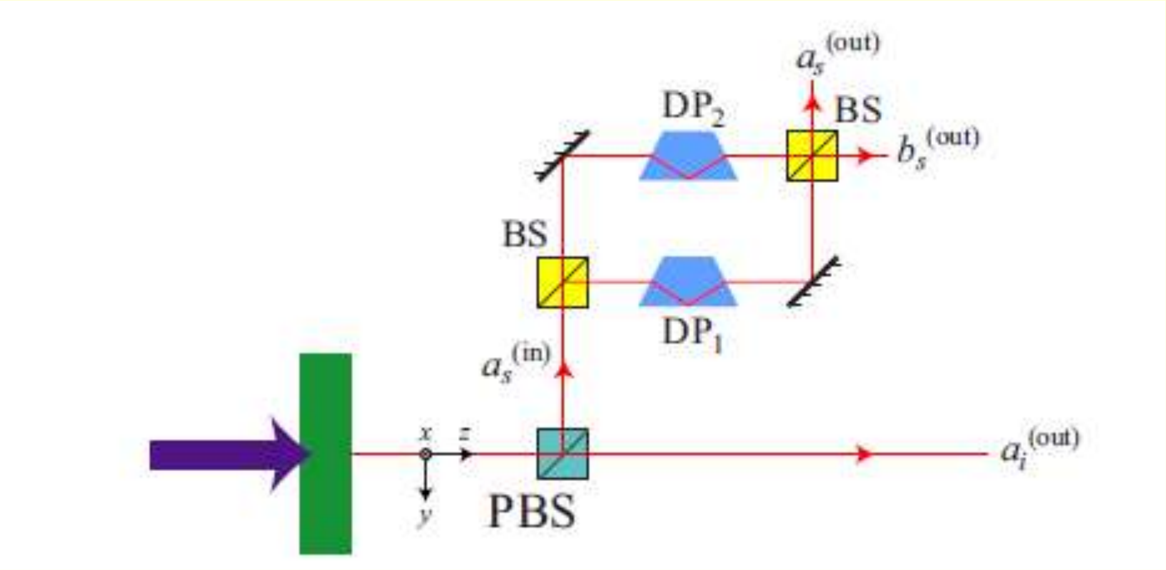


RESULTS: FEDOROV RATIO



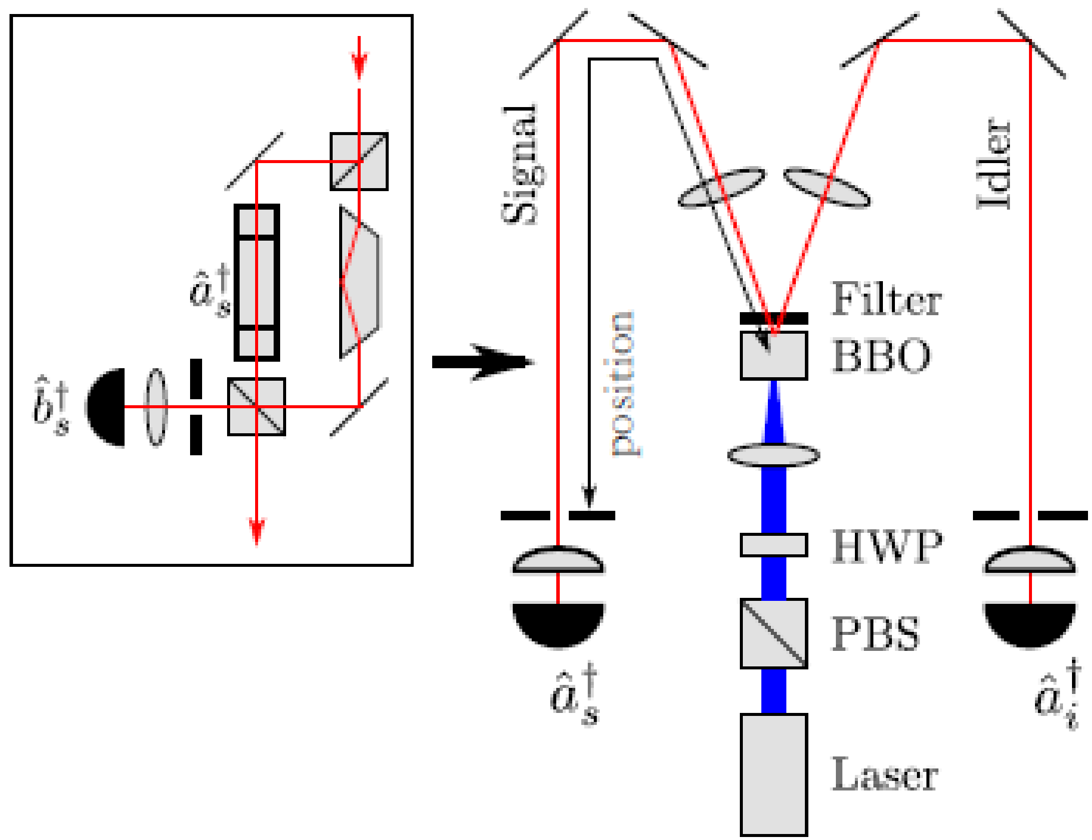
SCHMIDT NUMBER MEASUREMENT

The Schmidt number gives the number of transverse (spatial) modes. The more modes, the less the spatial coherence. Spatial coherence can be measured through interference.



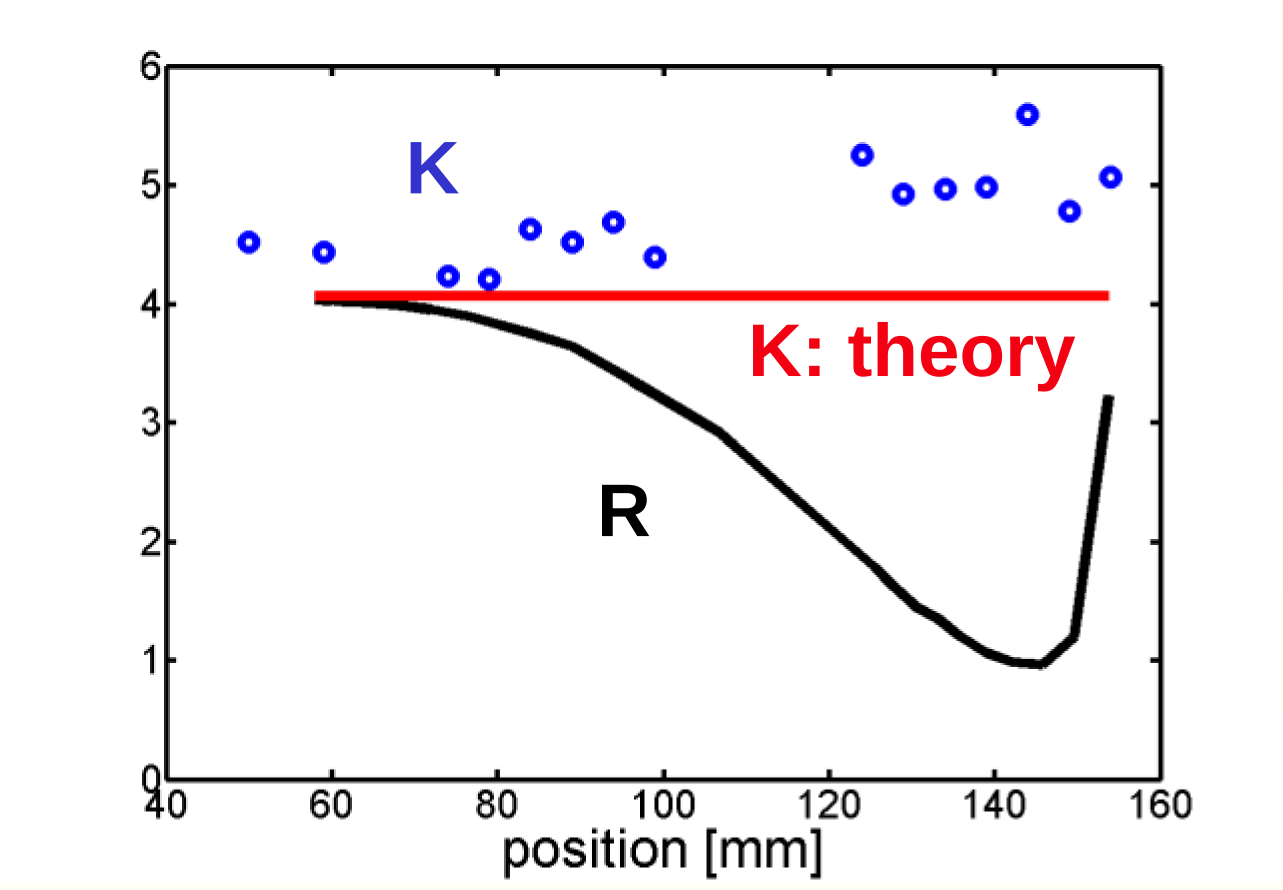
K.W.Chan, J.P.Torres, and J.H.Eberly, PRA 75, 050101 (2007)

EXPERIMENT


$\hat{a}_s^\dagger$
$\hat{b}_s^\dagger$
Signal
position
Idler
Filter
BBO
HWP
PBS
Laser
$\hat{a}_s^\dagger$
$\hat{a}_i^\dagger$

INTERFEROGRAMS

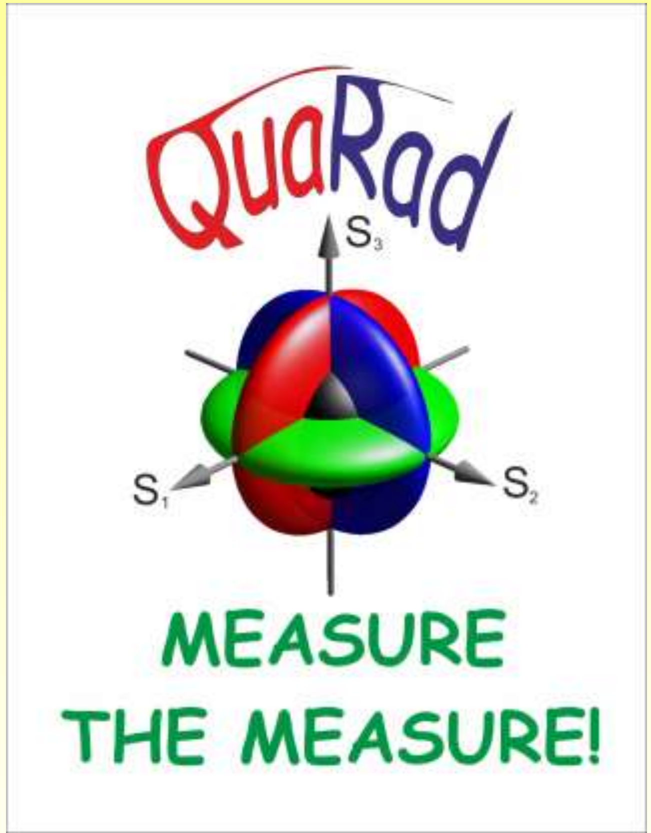
RESULTS: THE SCHMIDT NUMBER



CONCLUSIONS

1. The Fedorov ratio can be used as a measure of entanglement only in the near and far field zones.

2. As a universal measure of entanglement, the Schmidt number can be used. It can be measured as the inverse visibility of interference. And it does not change as the field propagates from near to far zones.



THANK YOU FOR YOUR ATTENTION!