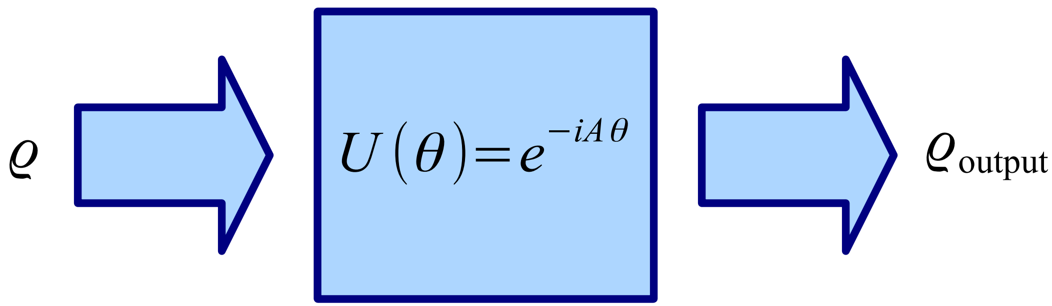
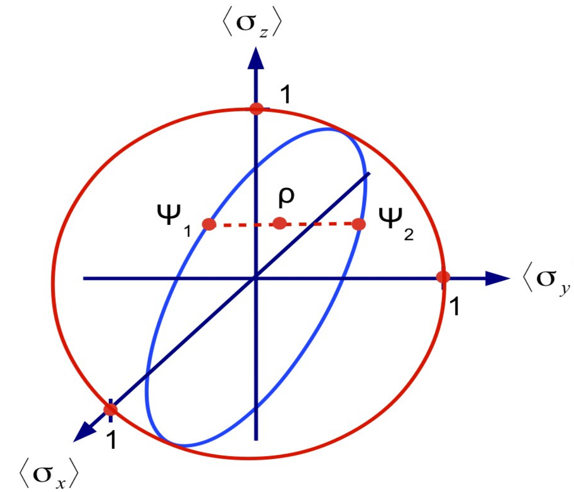
Fundamental properties of the quantum Fisher information

QFI determines a lower bound on estimating Θ:

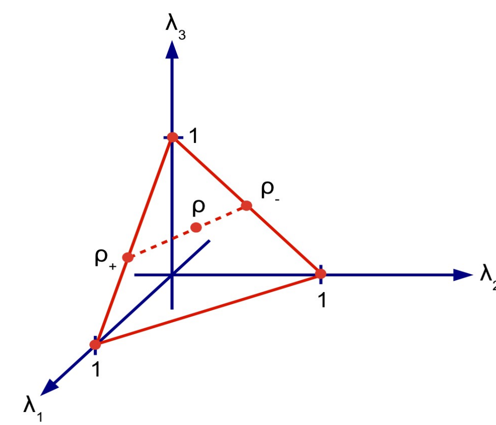




We have shown that it is its own convex roof and fulfills

$$(\Delta A)^2_\varrho \geq \sum_k p_k (\Delta A)^2_k \geq \frac{1}{4} F_Q[\varrho, A]$$

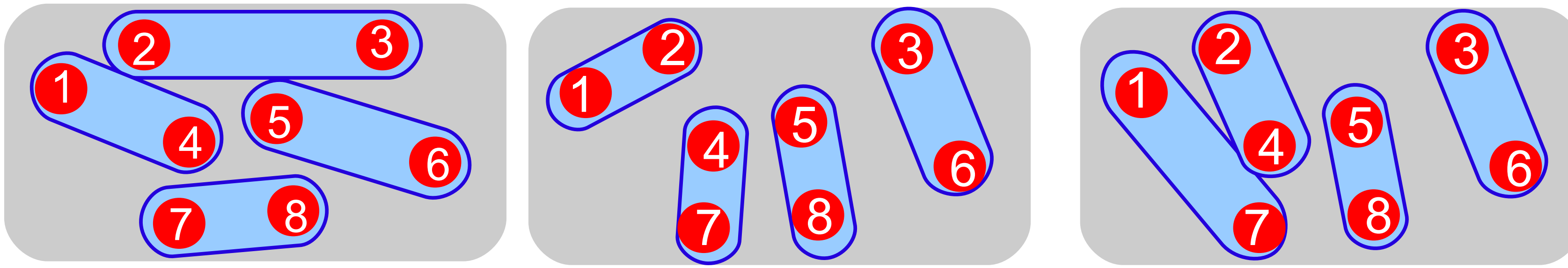
The the two bounds are tight.



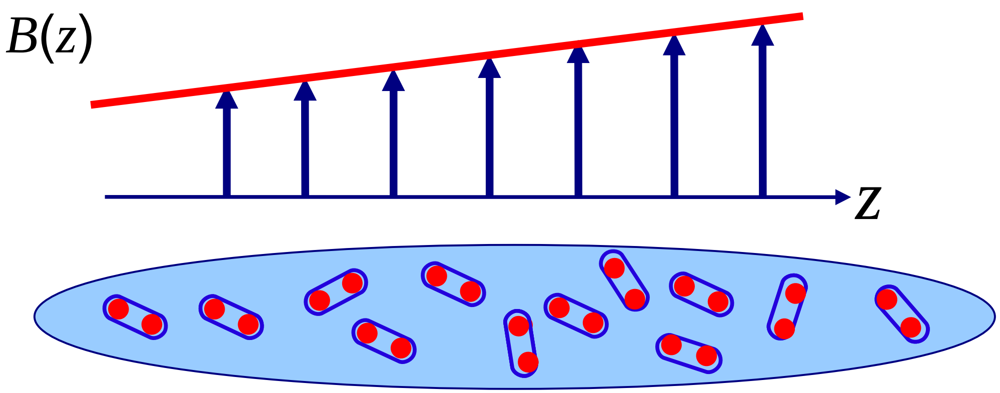
G. Tóth and D. Petz, Phys. Rev. A (2013).

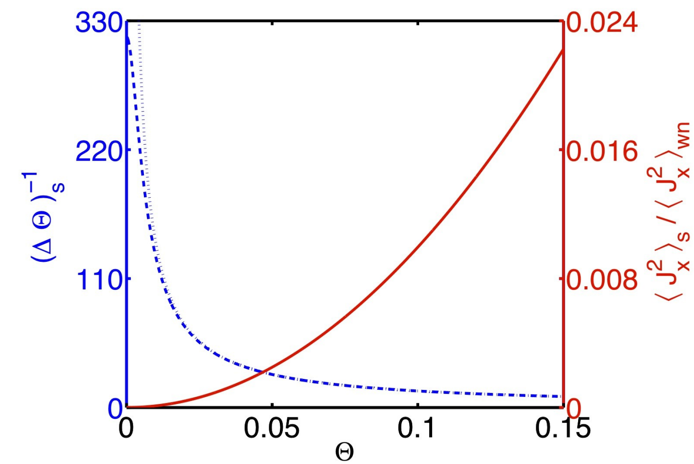
Metrology with macroscopic entangled states

A singlet state of 10^6-10^9 particles is created by spin squeezing (NJP 2010).



Singlets are sensitive to the gradient of the magnetic field.





The gradient is estimated based on measuring the

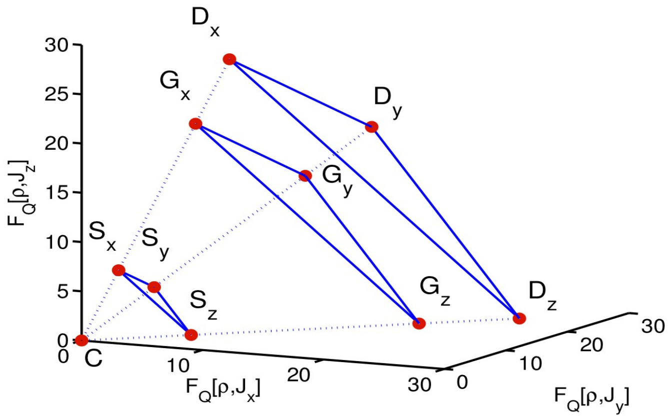
Ongoing cold gas experiment at ICFO (M.W. Mitchell)

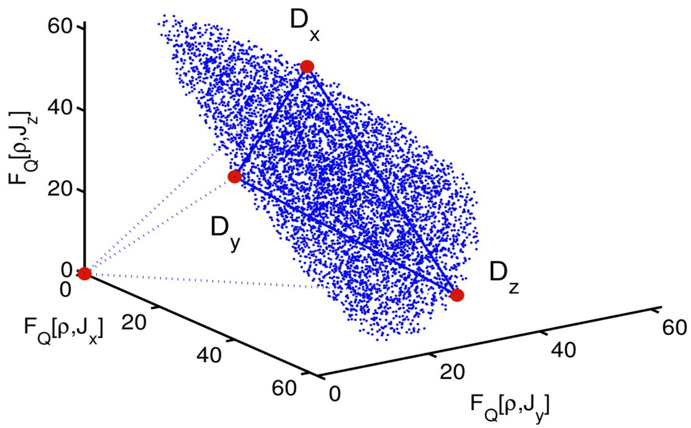
I. Urizar-Lanz, P. Hyllus, I.L Egusquiza, M.W. Mitchell and G. Tóth, arxiv:1203.3797; Tóth and Mitchell, NJP 2010.

Multipartite entanglement and high precision metrology

Multipartite entanglement is the main goal in many quantum experiments..

We show that such entanglement is necessary to achieve maximal sensitivity in metrology.





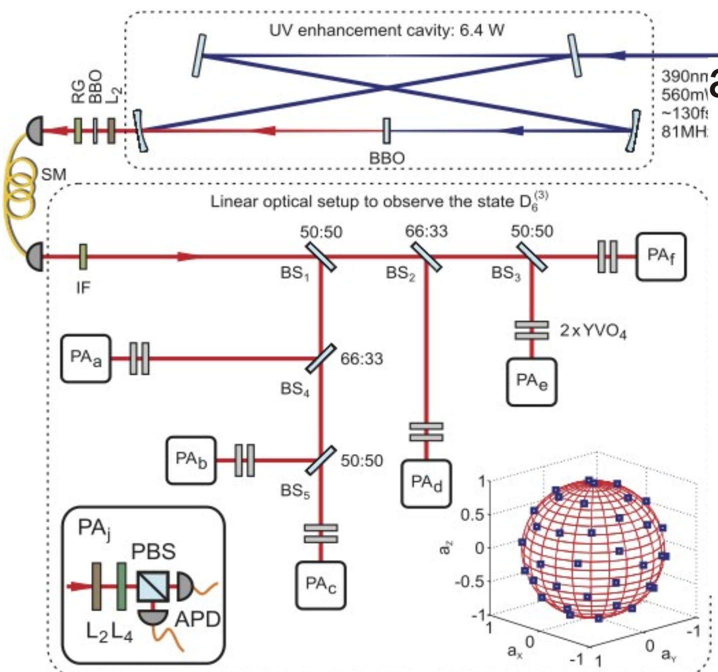
The space above *Gx*-*Gy*-*Gz* is accessible only for states with genuine multipartite entanglement. (Example for $N=6$ qubits.)

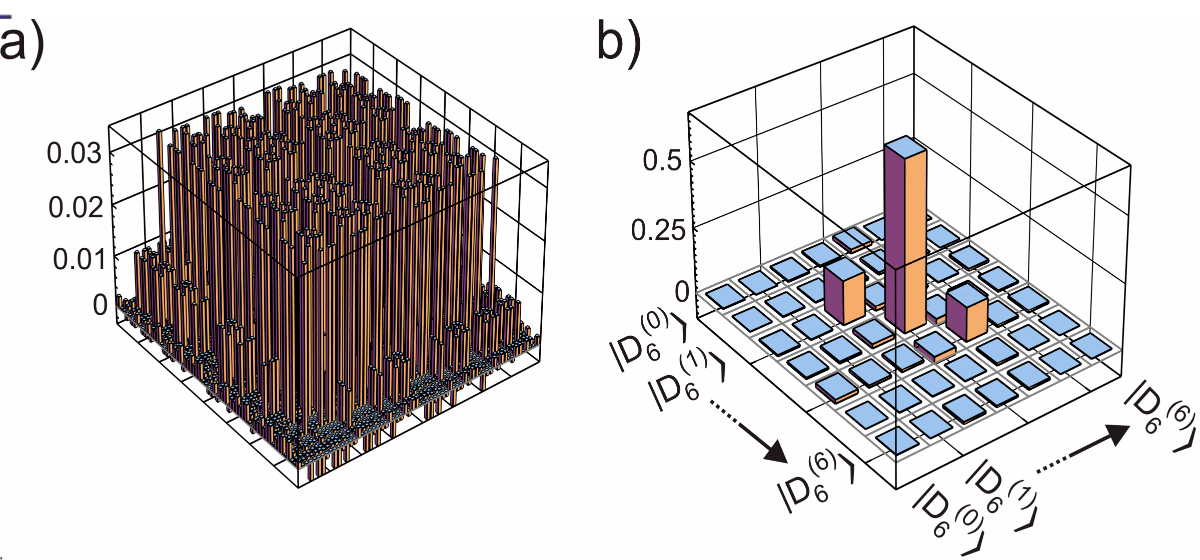
Without multipartite entanglement	Quantum maximum
$F_Q[\varrho, J_l] \leqslant (N-1)^2 + 1,$	$N(N+2)$
$\sum_{l=x,y,z} F_Q[\varrho, J_l] \leqslant N^2 + 1.$	N^2

G. Tóth, Phys. Rev. A **85**, 022322 (2012); P. Hyllus et al., Phys. Rev A **85**, 022321 (2012)

Permutationally invariant tomography

- Full state tomography is not feasible even for modest size systems.
- PI tomography is a scaleable alternative (PRL 2010).
- We developed a scaleable method for fitting a physical density matrix on the measured data (before: bootle neck of state reconstruction)



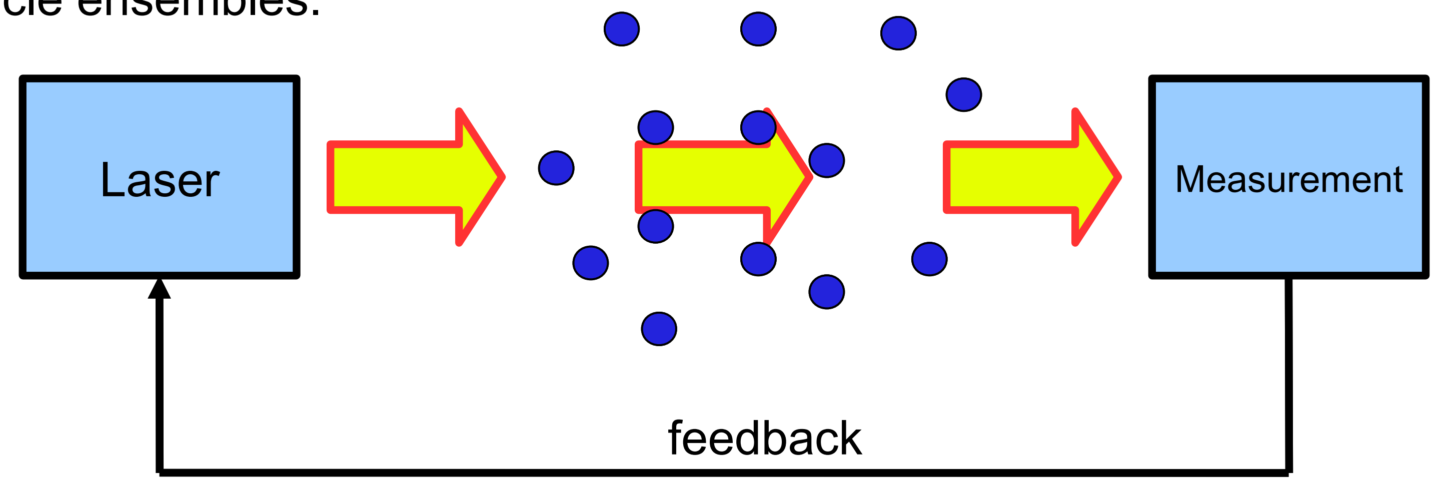


Ongoing experiment at the Max Planck Institute for Quantum Optics, München.

T. Moroder et al., New J. Phys **14**, 105001 (2012); G. Tóth et al., PRL 2010.

Spin squeezing inequalities for a fluctuating particle number

Spin squeezing entanglement criteria are used for entanglement detection in large particle ensembles.



- They are typically for a fixed particle number.
- We developed criteria that can tolerate particle number variance.

$$(\Delta \hat{J}_{\perp})^2 \geqslant \langle \hat{N} \rangle j \; F_{kj}\left(\frac{\langle \hat{J}_{\mathbf{n}} \rangle}{\langle \hat{N} \rangle j}\right)$$

For fixed N: Sørensen and Mølmer, Phys. Rev. Lett. (2001)

$$(\Delta \hat{J}_{\mathbf{l}})^2 \geqslant \left\langle (\hat{N}-1)^{-1} \hat{J}_{\mathbf{i}}^2 \right\rangle + \left\langle (\hat{N}-1)^{-1} \hat{J}_{\mathbf{j}}^2 \right\rangle - \langle (\hat{N}-1)^{-1} \hat{N} \rangle / 2$$

P. Hyllus, L. Pezzé, A. Smerzi, and G. Tóth, Phys. Rev. A **86**, 012337 (2012)