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Reducing quantum noise for Advanced Virgo gravitational-wave detector by using frequency-dependent squeezing technique with Einstein-Podolsky-Rosen (EPR) entanglement

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In order to increase the science reach of GW detectors, it is fundamental to reduce the quantum noise, composed of radiation pressure noise (RPN) at low frequencies (roughly < 100 Hz) and shot noise (SN) at high frequencies (roughly >100 Hz). Since the *quantum noise* is generated by vacuum fluctuations entering the interferometer, the injection of phase-squeezed vacuum states reduces the SN and increases the RPN. Frequency-independent squeezing (FIS) has been implemented in the Advanced Virgo for the current LIGO-Virgo observation run O3. As RPN does not limit the current sensitivity of Advanced Virgo, the increasing of RPN due to FIS is not a problem. However, for the next detector upgrade (Advanced Virgo+), RPN will limit the sensitivity at low frequencies. In order to reduce simultaneously SN and RPN, the injection of frequency-dependent squeezing (FDS) is needed. This can be obtained inserting an *external filter cavity* between the squeezing source and the interferometer, before the injection of the squeezed vacuum in the interferometer.
Alternatively, it has been recently proposed that a broadband reduction of quantum noise in gravitational-wave detectors can also be achieved using a pair of squeezed EPR-entangled beams. A frequency-dependent optimization of the injected squeezed light fields is possible with this technique, without the need of an external filter cavity.
After an introduction about the squeezing techniques in the context of GW detectors, we will introduce the EPR squeezing and we will describe the R&D on-going effort in Virgo about this technique.

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