UNIVERSITY OF BIRMINGHAM

EGO

News on the ET sensitivity curve

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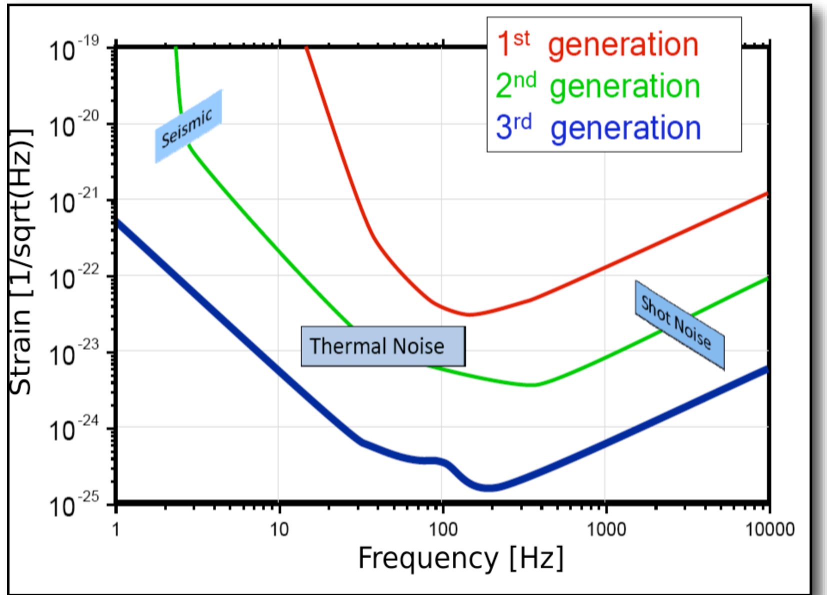
Overview

- These slides do not represent any coherent analysis and are only thought to provide an overview of various ongoing activities and ideas connected to the ET sensitivity.

- Topics of this talk:
  - Overview of available sensitivity curves.
  - Showing the weaknesses of the different curves.
  - Requests for various input from WP4 to sensitivity curve discussions.
  - Summary of what are the next steps towards a ‘really’ realistic sensitivity curve.

The ‘famous’ ET sensitivity (ET-A)

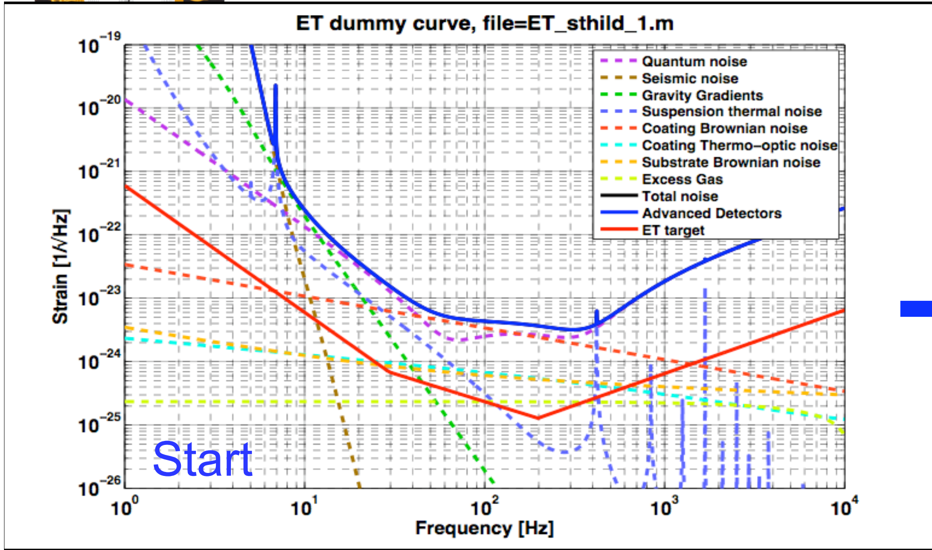
- Blue line = ‘famous’ curve from an old FP6 proposal 2004.
- To avoid complicated names I call this sensitivity ‘ET-A’.
- This curve is a good design target, however today we know that this curve is not necessarily realistic:
  - Curve entirely limited by quantum noise.
  - Gravity gradient noise not included.
  - Suspension thermal noise not included.
  - Not (well) documented.

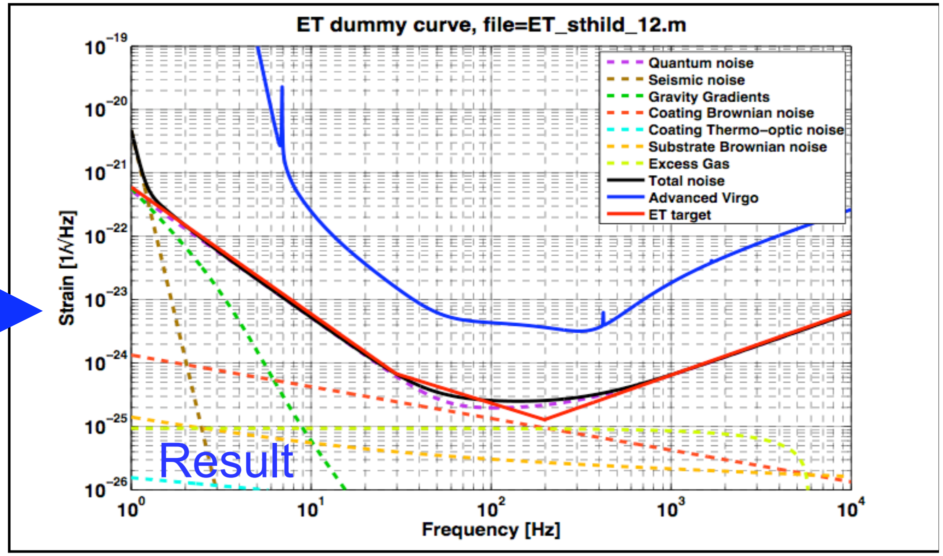


ET sensitivity from arXiv:0810.0604 (ET-B)

- Aiming for a more realistic noise budget for ET.
- Used approach:
  - Only using conventional technologies (either available or up-scaled).
  - Starting from a 2nd generation instrument.
  - Configuration: Michelson + Arm cavities + power and signal recycling.
  - Arm length 10km.
  - Cover the full frequency band with a single instrument.
- Documentation and details can be found in S.Hild et al: arXiv:0810.0604 or at http://www.sr.bham.ac.uk/~hild/presentations/ET_brute_force.ppt

ET-B





	advanced detector	potential ET design
Arm length	3 km	10 km
SR-phase	detuned (0.15)	tuned (0.0)
SR transmittance	11 %	10 %
Input power (after IMC)	125 W	500 W
Arm power	0.75 MW	3 MW
Quantum noise suppression	none	10 dB
Beam radius	6 cm	12 cm
Temperature	290 K	20 K
Suspension	Superattenuator	5 stages of each 10 m length
Seismic	$1 \cdot 10^{-7}\,\mathrm{m}/f^2$ for $f > 1\,\mathrm{Hz}$ (Cascina)	$5 \cdot 10^{-9}\,\mathrm{m}/f^2$ for $f > 1\,\mathrm{Hz}$ (Kamioka)
Gravity gradient reduction	none	factor 50 required (cave shaping)
Mirror masses	42 kg	120 kg
BNS range	150 Mpc	2650 Mpc
BBH range	800 Mpc	17700 Mpc

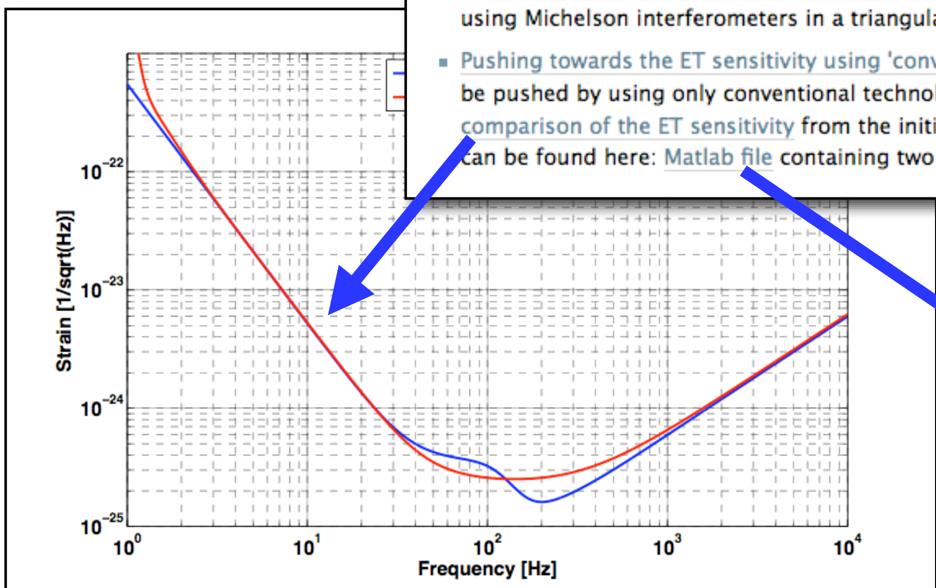
Availability of ET-B

- ET-B can be downloaded from the WG3 work area:

https://workarea.et-gw.eu/et/WG3-Topology

Science Documents

- An excerpt from the ET proposal: A general description of the ET design study as well as a summary description of the work covered by the WP3 group.
- Triple Michelson Interferometer for a Third-Generation Gravitational Wave Detector (arXiv): A review article on the idea of using Michelson interferometers in a triangular shape.
- Pushing towards the ET sensitivity using 'conventional' techniques: Analysis of how far the sensitivity of a 10km Michelson can be pushed by using only conventional technology (Also available at arXiv:0810.0604v1 [gr-qc]). This plot shows a comparison of the ET sensitivity from the initial proposal and this analysis. The data of the ET sensitivity from arxiv:0810.0604 can be found here: Matlab file containing two vectors for frequency and strain sensitivity (as amplitude spectral density).



Matlab file (*.mat):

- frequency vector
- sensitivity vector (ASD)

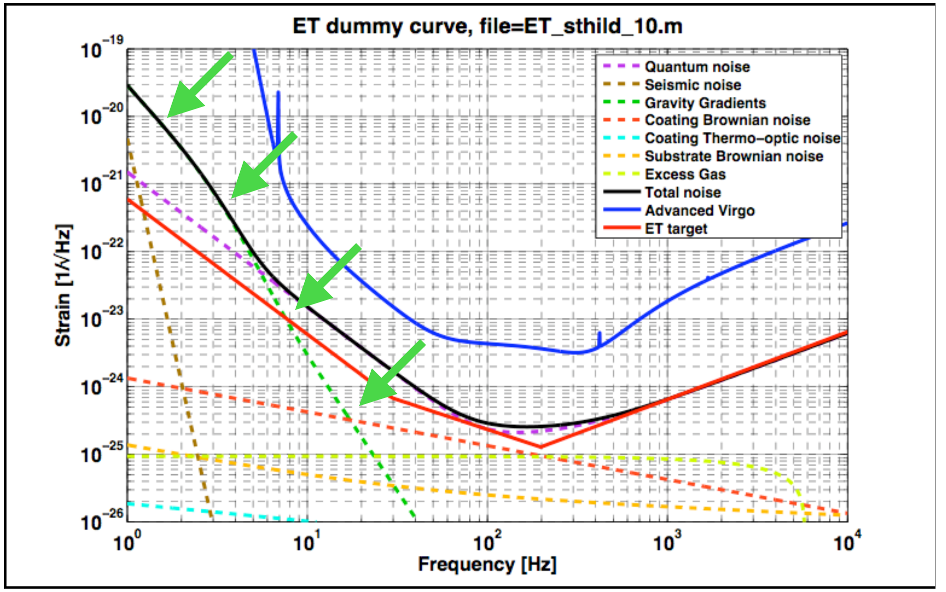
Major Weaknesses of ET-B

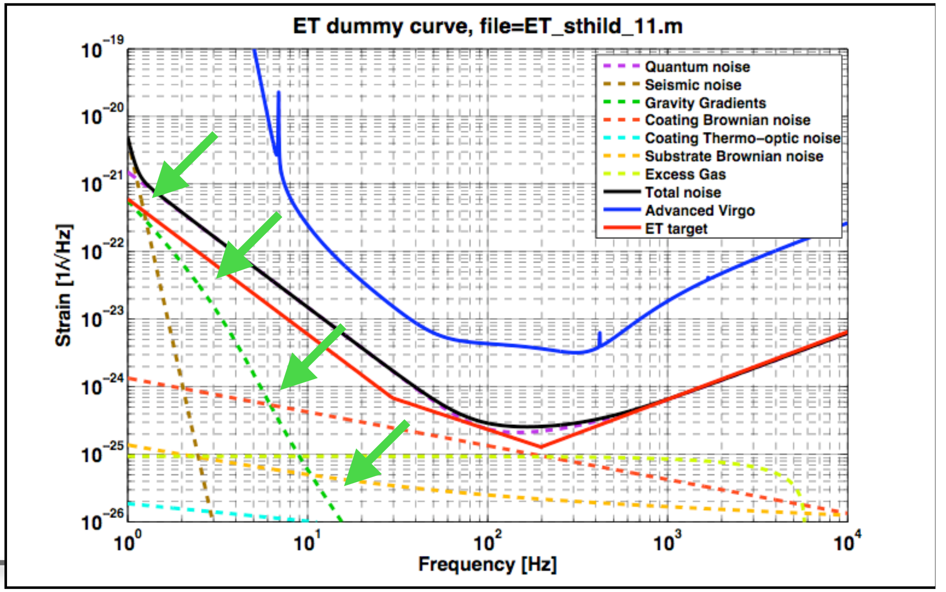
- Still no suspension thermal noise included.
- Gravity gradient noise for underground site so far only preliminary.
- Thermal noise of cryogenic temperatures need to be checked by experts.
- How can high optical power (several megawatts) go together with cryogenic mirrors (20K)?

Nevertheless, there is plenty to learn from ET-B …

Some remarks to ET-B

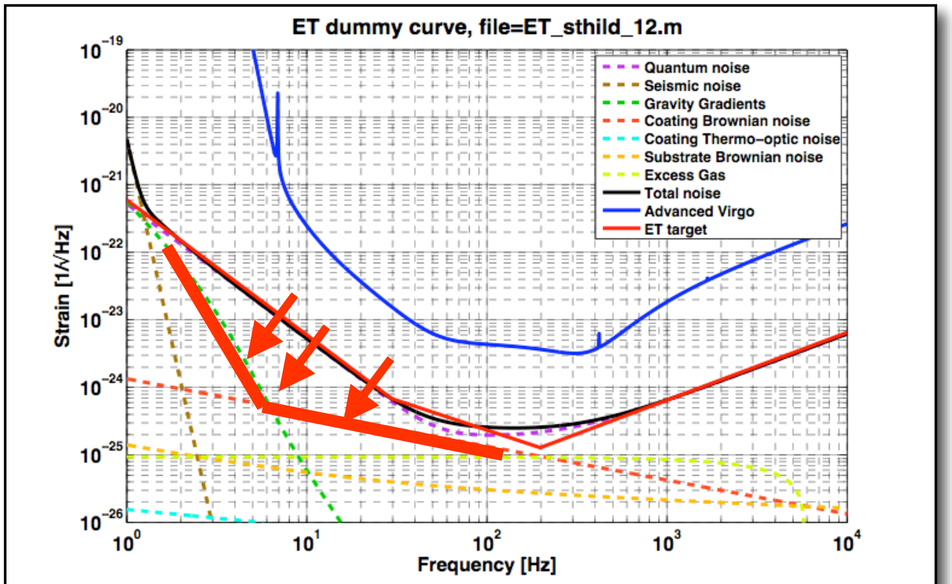
- Gravity Gradient noise will be extremely challenging!
- Even with a quiet underground site we are still missing a factor 50 reduction to achieve target at 1Hz sensitivity.
  - Clever Cave shaping?
  - Measuring seismic and coupling to allow subtraction?





Some remarks to ET-B

- However, if we would be able to deal with gravity gradient noise, then there might be a chance to get some 'easy and cheap' (heavier mirrors) increase of the sensitivity in the range between 3 and 30 Hz.

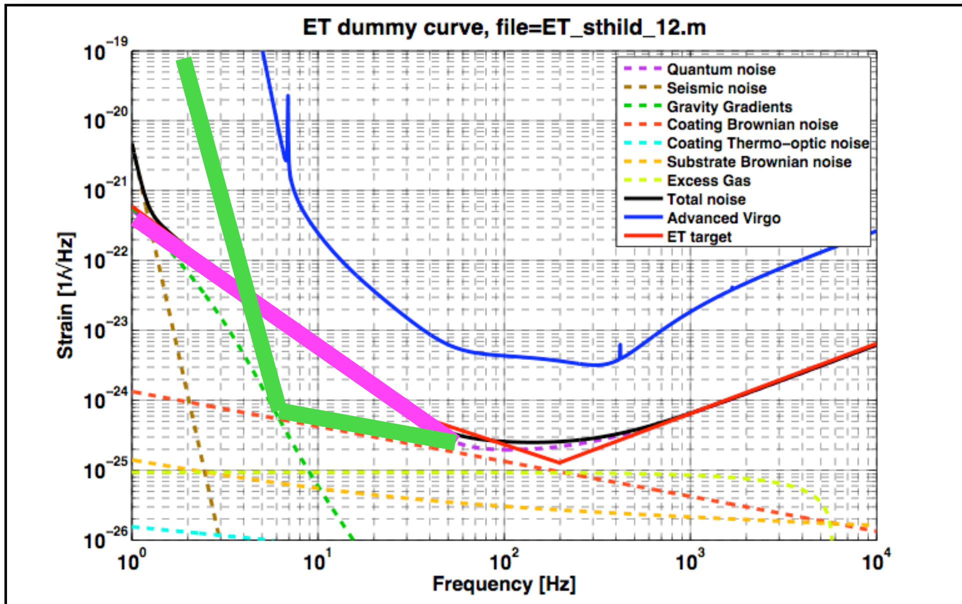


WP4 input for sensitivity trade-offs ?

- I guess for WP1-WP3 it would be interesting to get input from WP4 for sensitivity trade-offs:
  - To achieve ET-A around 1Hz will be experimentally very challenging/close to impossible.
  - However, as shown on the previous slide we might be able to do much better than ET-A around 10 Hz.

- Can we trade-off a poor sensitivity below 3 Hz, by improved sensitivity around 10 Hz?

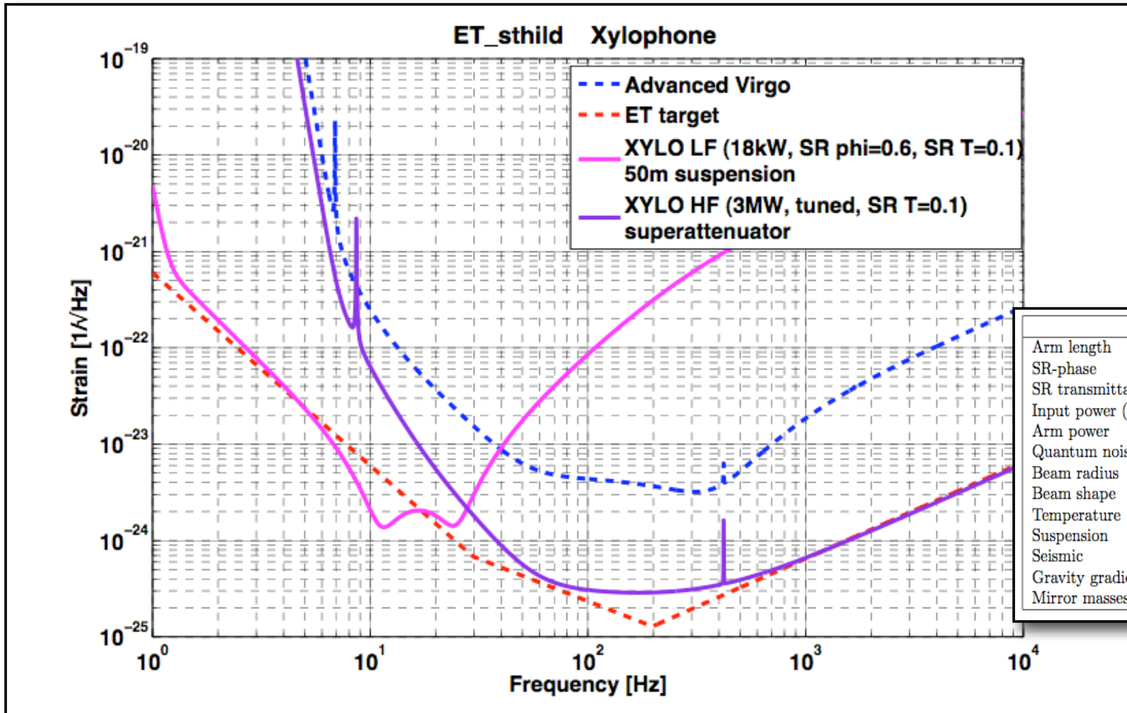
- How does the science we can do compare for the sensitivities displayed in **green** and **pink** ??



Xylophone options

- For various reasons (for instance high power vs low temperature conflict) it might be beneficial to split the detection band into several detectors:
  - Each detector covers only a part of the targeted detection band.
  - All detectors together will give the targeted sensitivity.
- Perhaps ET could be composed of at least 2, maybe 3 xylophone interferometers.
- Question for WP4: Are there any disadvantages connected to a xylophone ET compared to a single broad band detector?

Xylophone Example: ET-B-Xylo

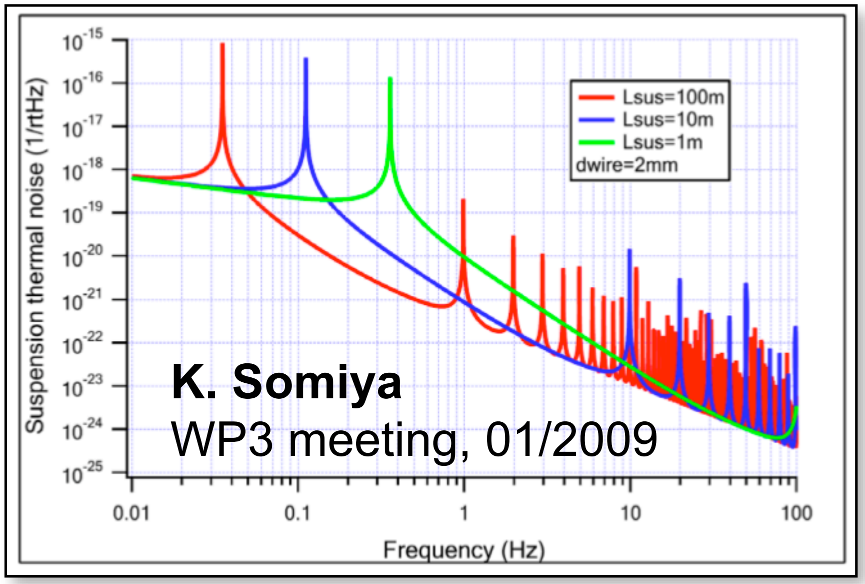


	ET high frequency	ET low frequency
Arm length	10 km	10 km
SR-phase	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	10 %
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Quantum noise suppression	10 dB	10 dB
Beam radius	12 cm	12 cm
Beam shape	LG_{33}	TEM_{00}
Temperature	290 K	currently 290 K, but need to gor cryogenic
Suspension	Superattenuator	5 stages of each 10 m length
Seismic	$1 \cdot 10^{-7}\,\mathrm{m}/f^2$ for $f > 1$ Hz (Cascina)	$5 \cdot 10^{-9}\,\mathrm{m}/f^2$ for $f > 1$ Hz (Kamioka)
Gravity gradient reduction	none	factor 50 required (Subtraction technique?)
Mirror masses	120 kg	120 kg

- HF detector: high power (3MW), room temperature, surface location, normal suspensions, LG33 mode, no gravity gradient noise subtraction…
- LF detector: low power (18kW), cryogenic, underground location, 50m suspensions, TEM00 mode, gravity gradient subtraction…

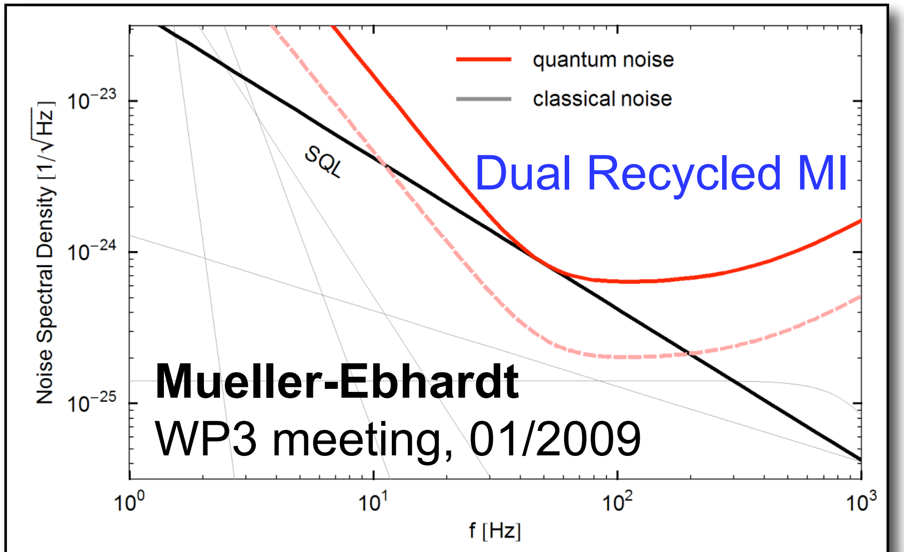
Next steps I: Suspension Thermal noise

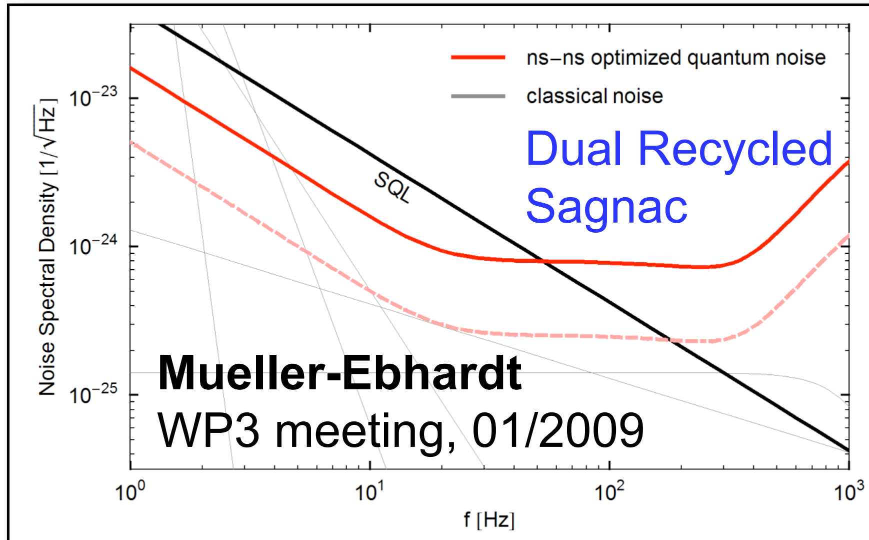
- We need to properly include suspension thermal noise into our models:
  - Recent investigations for Advanced Virgo showed that there are always surprises…
- Are violin modes a problem from WP4 point of view?
  - How much science do we loose when the sensitivity is spoiled with a 10Hz-comb of lines?
  - What is the closest separation of violin modes that are tolerable? (50 Hz, 10 Hz, 2 Hz?)



Next steps II: Advanced Configurations

- We want to use the dual-recycled MI from ET-B as reference for analyzing more advanced configurations:
  - Dual Recycled Sagnac with arm cavities
  - Optical Levers





- Hannover has already computed and optimised the quantum noise of various configurations. However, still need to implement all other noise contributions for these new configurations.

Summary

- ET-A is (and has never been) an official ET target.
- ET-B gives roughly the same sensitivity as ET-A, but is more realistic and better documented.
  - Data available on the web.
- **Input required from WP4:**
  - Can we trade-off worse sensitivity below 3 Hz for better sensitivity around 10 Hz?
  - Any problems if we go for xylophone configurations?
  - How critical are line forests (violin modes from tall suspensions) for data analysis?
- ET-A and ET-B will NOT be the final ET-sensitivity! People are working on this topic and there will be more realistic sensitivity curves (ET-C, ET-D etc) coming over the next months. => Stay tuned!
- Please keep in mind: Providing a comprehensive and realistic sensitivity curve for ET is one of the main OUTCOMES of the design study.

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