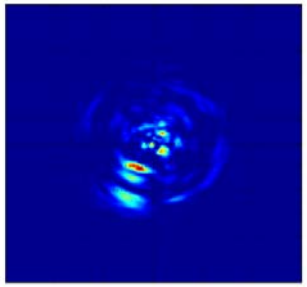
Simulation of sensitivity curves for dual recycled interferometers using DarkF



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Outline

- **Introduction**
- **Shot noise limited sensitivity curves**
  - ⇒ SR mirror transmission
  - ⇒ SR phase detuning
  - Influence of the mirror maps
  - ⇒ “Realistic” mirror maps
- **Summary**
- **More about DarkF**

Introduction

- DarkF: simulation → diffraction of an arbitrary optical beam.

  (Fortran90 by J.-Y. Vinet, M. Laval, M. Pichot in ARTEMIS)

  (former code developed by JYV and P. Hello in the 90's)

- Uses Fourier Transform to treat paraxial diffraction, and extensively exploits FFT's.

- Beams and mirrors are sampled on a grid (x,y) .

- DarkF resolution depends on the grid size and on the number of points (typically a size of 0.6m (larger than a mirror) with 128*128 points).

- Includes: mirror surface maps, thermal effects (thermal lens and coating deformation) and thermal compensation (TCS).

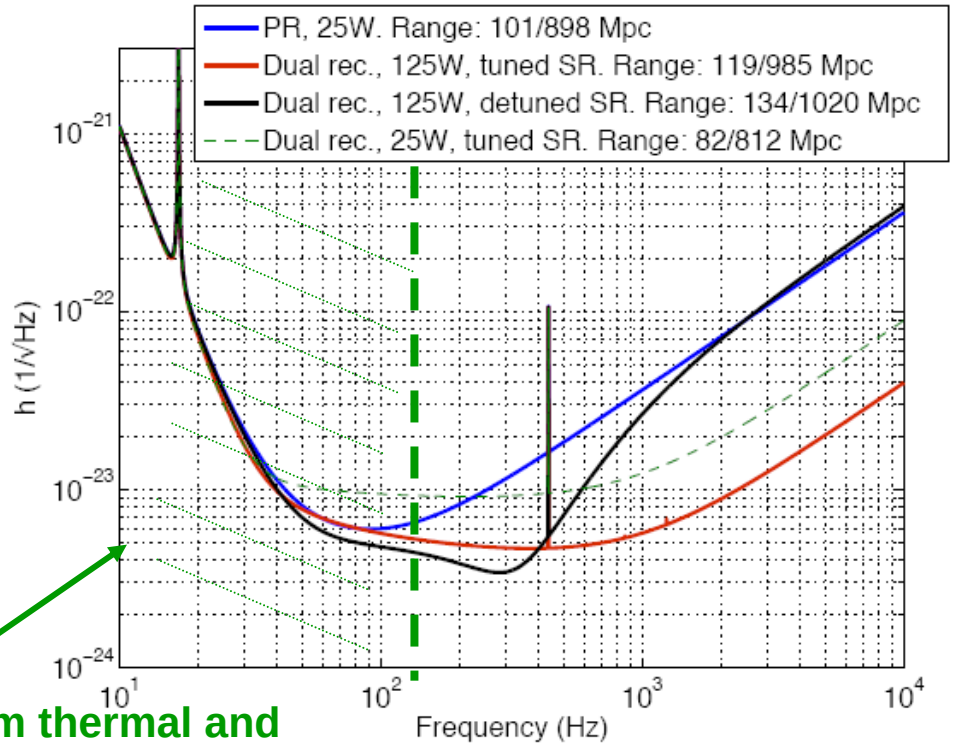
- Simulates: Fabry Perot cavities to Adv Virgo or aLIGO (for the carrier and for the sidebands).

Shot noise limited sensitivity curves

- Last upgrade => Implementation of the Audio Sidebands for the simulation of the interferometer with dual recycling.

=> plot the sensitivity curve

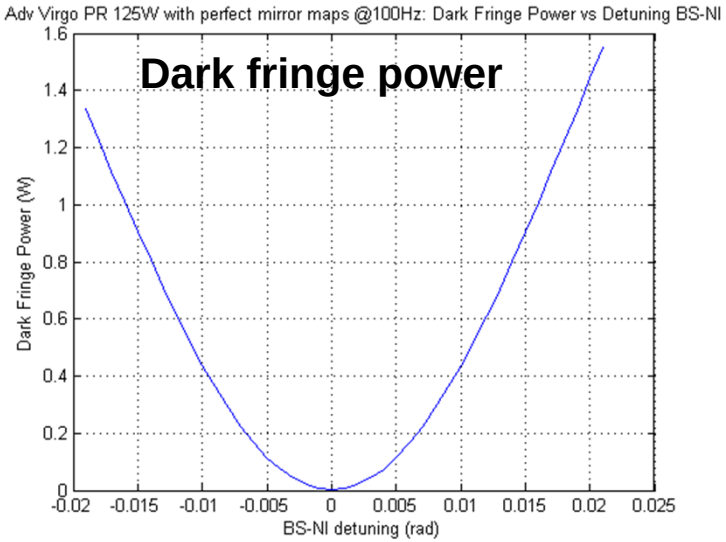
- Sensitivity curve limited by the Shot Noise.



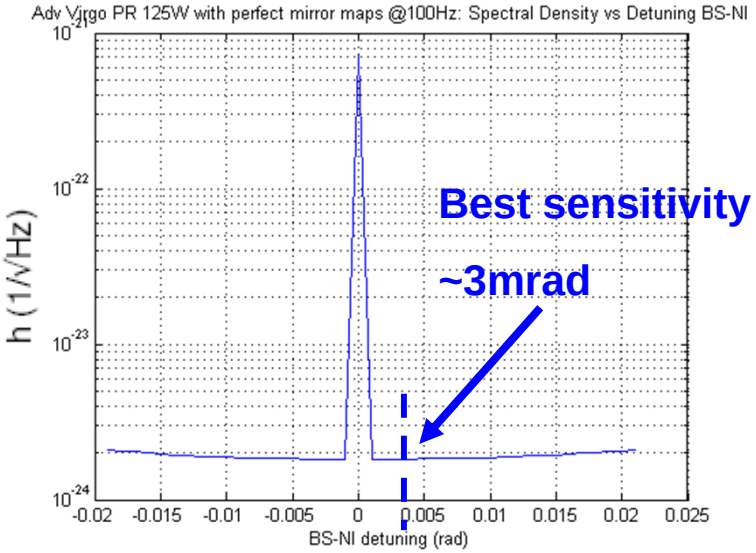
No contribution from thermal and suspension noise.

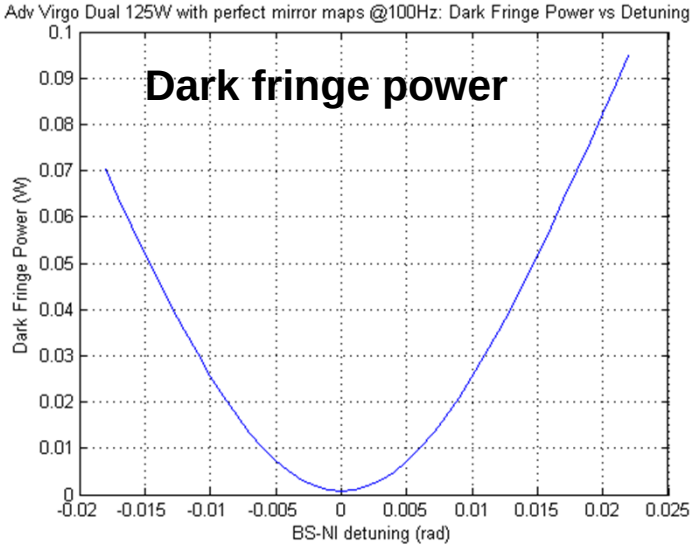
Simulation condition

- To calculate the optimal sensitivity -> detuning ITF arms (long or short).

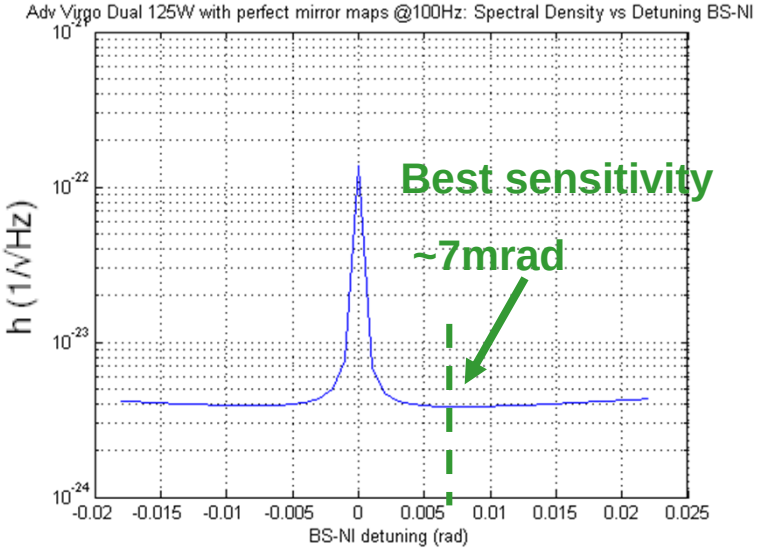


PR 125W @ 100Hz





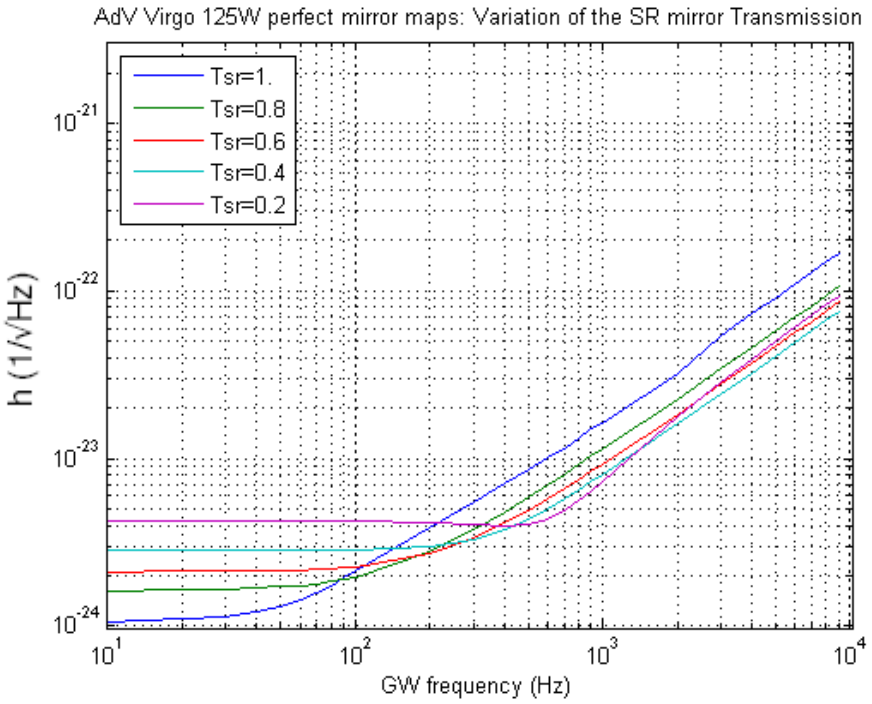
Dual 125W @ 100Hz



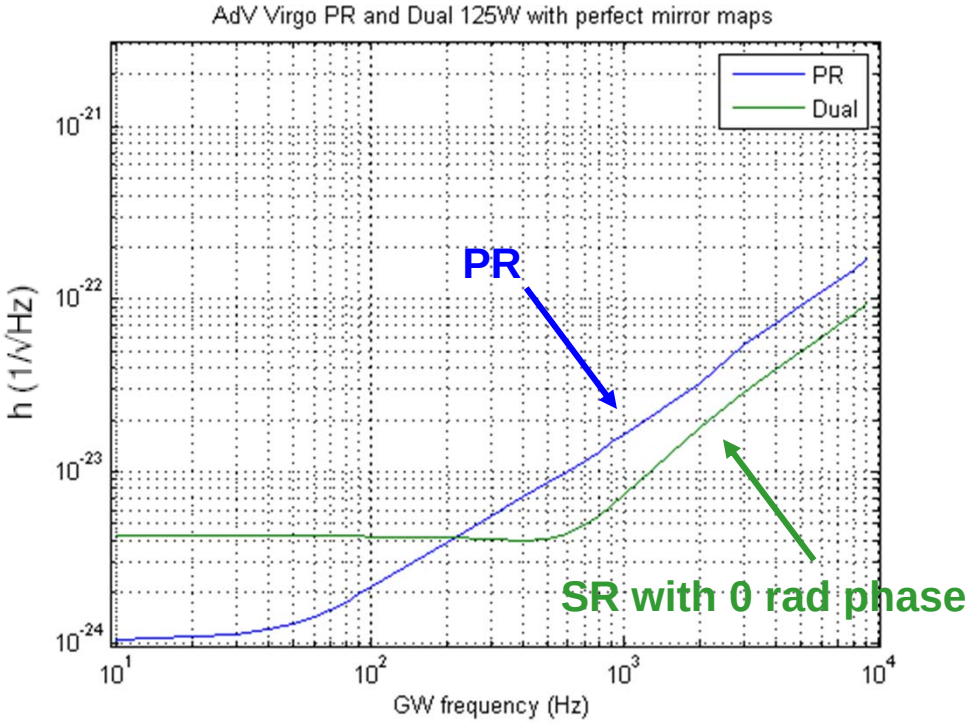
SR mirror transmission

- From a PR configuration with the SR mirror transmission (Tsr) = 1

=> To a dual configuration, with Tsr from 0.8 to 0.2



Ex: Sensitivity Curve vs SR mirror Transmission (125W input power)

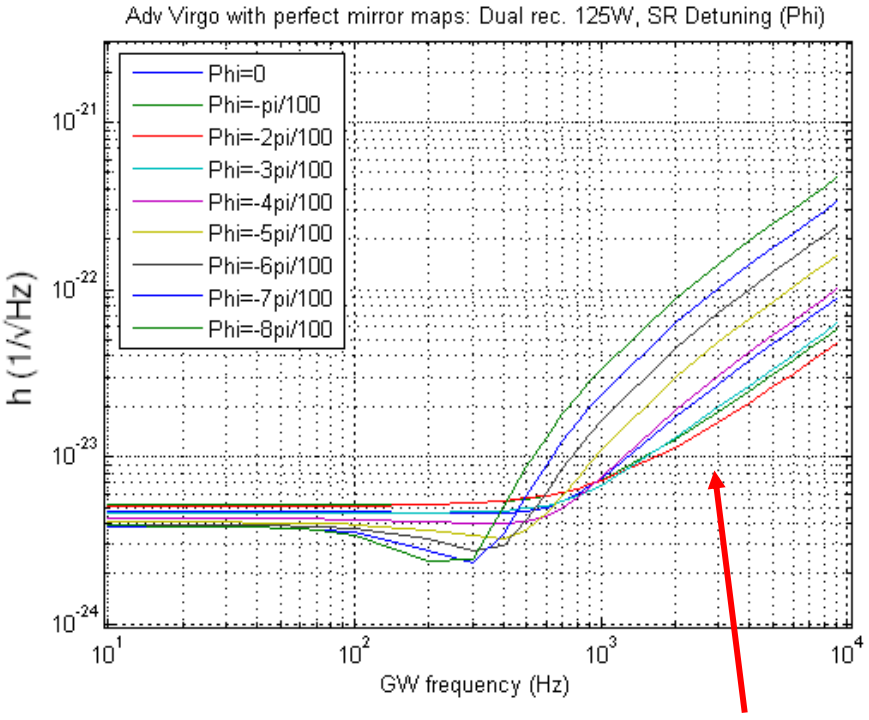


Ex: Adv Virgo Sensitivity Curve (PR 125W, Dual rec. 125W)

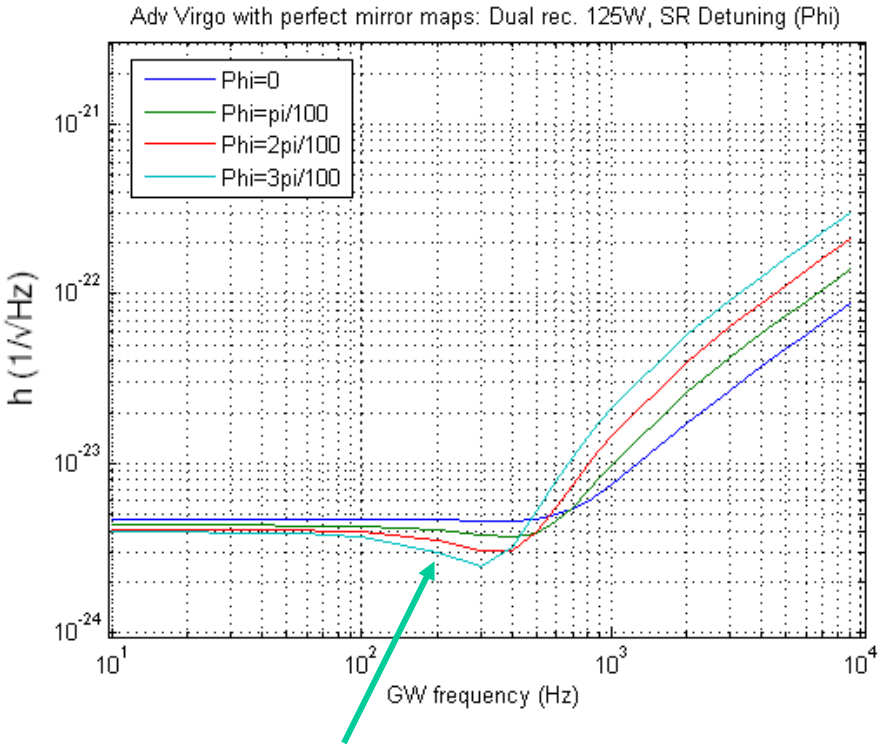
SR phase detuning

- The researched source range depends on the detuning phase.

- Various possibilities for sensitivity curves.

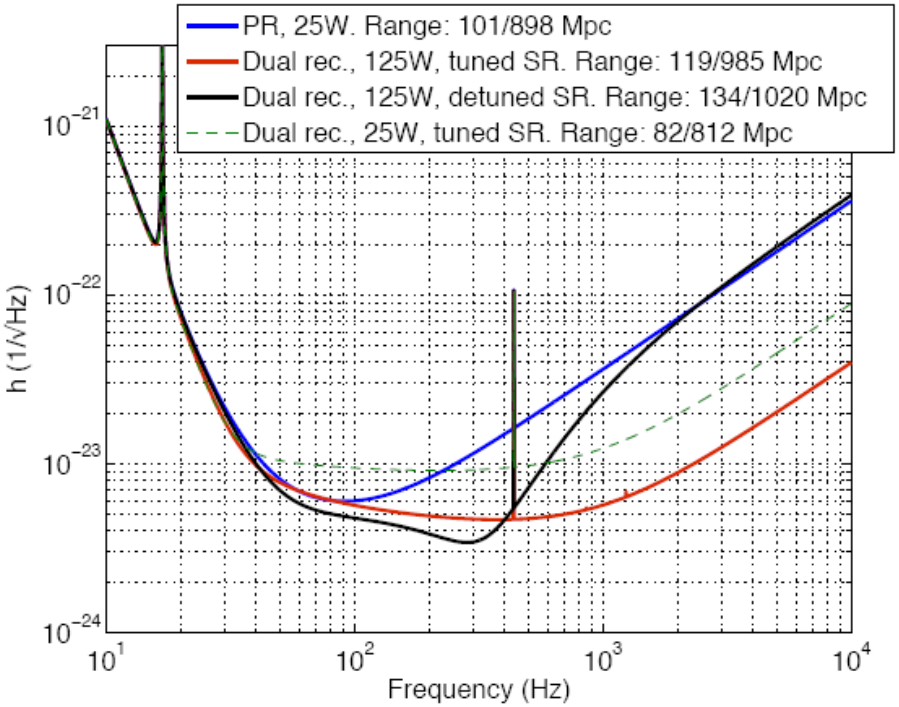


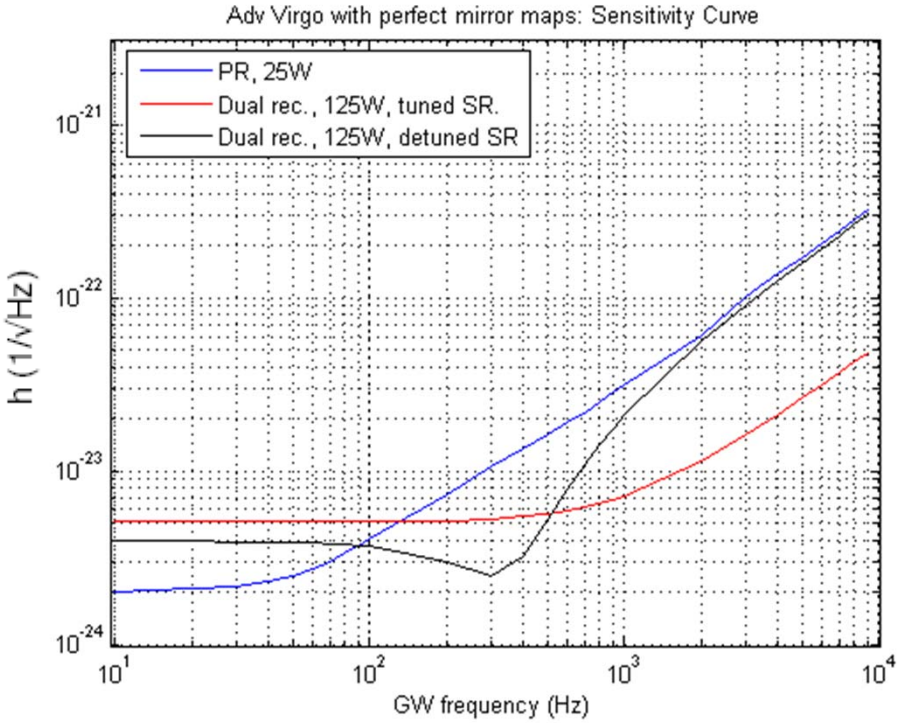
Corresponds to a range of 119/985 Mpc (BNS and BBH).



Corresponds to a range of 134/1020 Mpc (BNS and BBH).

Theory vs Simulation





=> Perfect mirror maps: each mirror has a perfect flatness and a real diameter.

Influence of the mirrors maps

The response of the ITF will be different taking into account the real mirrors characteristics => sensitivity curve as well.

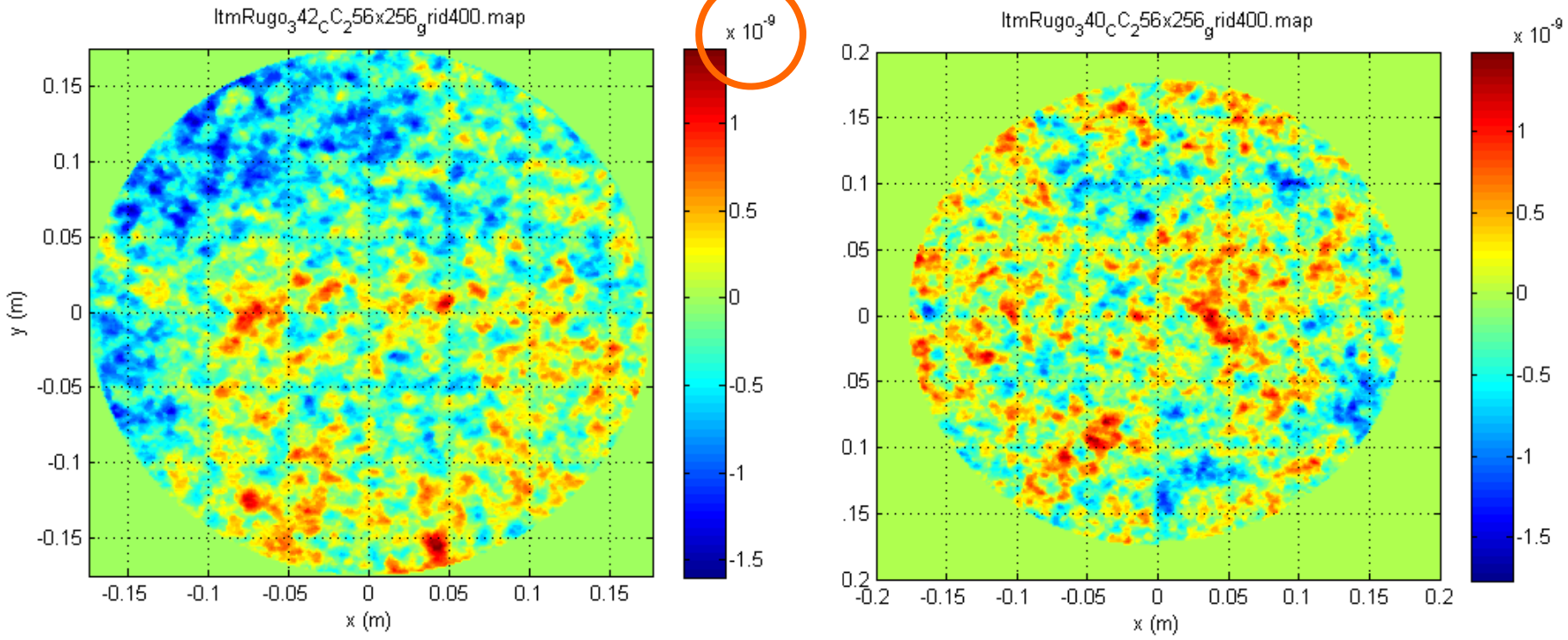
=> Simulations with « realistic » mirror maps.

“Realistic” mirror maps

- Mirror maps given by the LMA and based on the spectral density of the Virgo+ mirrors, after polishing (see R. Bonnand PhD thesis).

- RMS flatness around 0.5 nm.

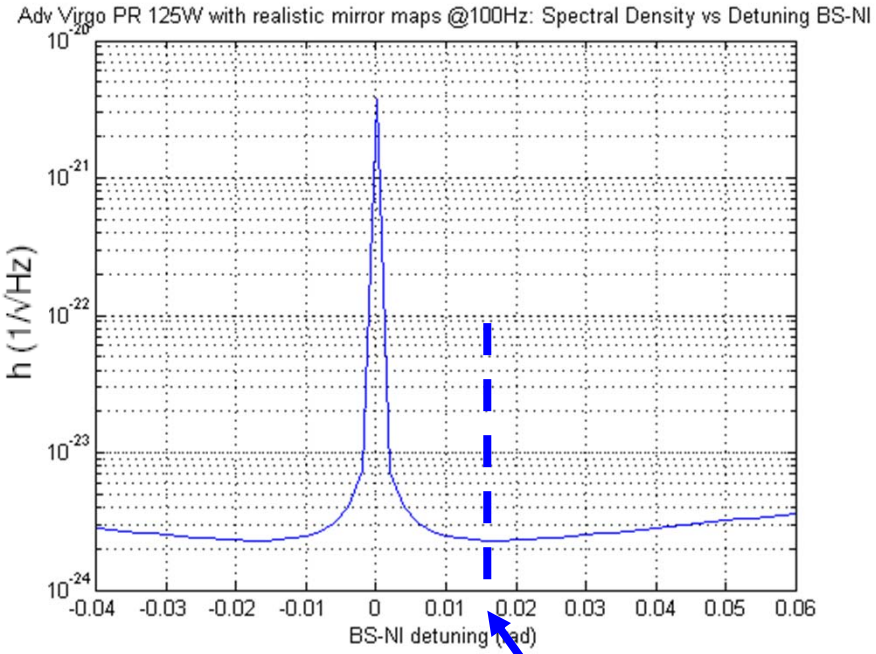
Surface amplitude



Simulation condition

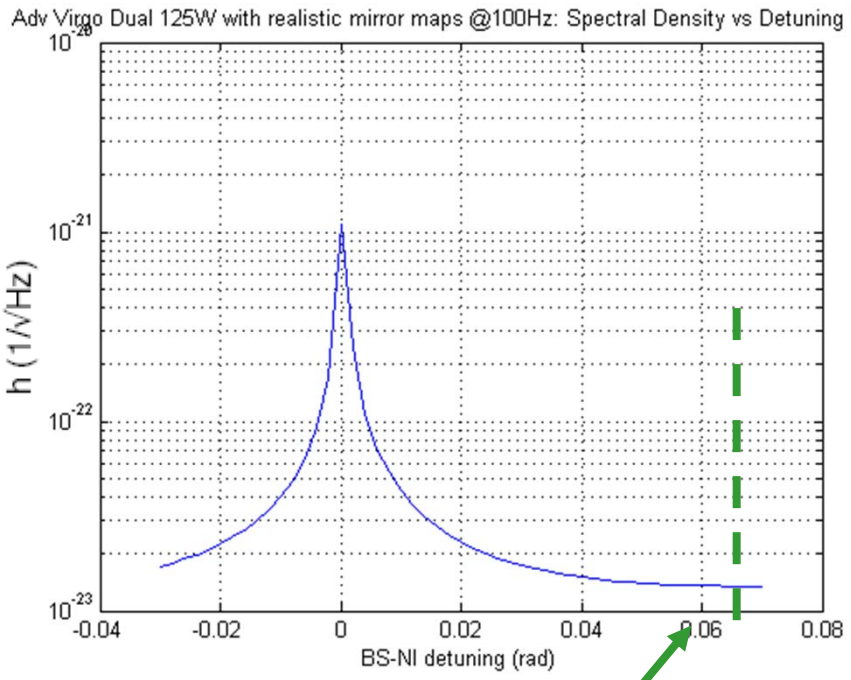
- Same thing as before: calculation of the optimal sensitivity -> detuning the ITF.

PR 125W @ 100Hz



Sensitivity Max ~15mrad

Dual 125W @ 100Hz

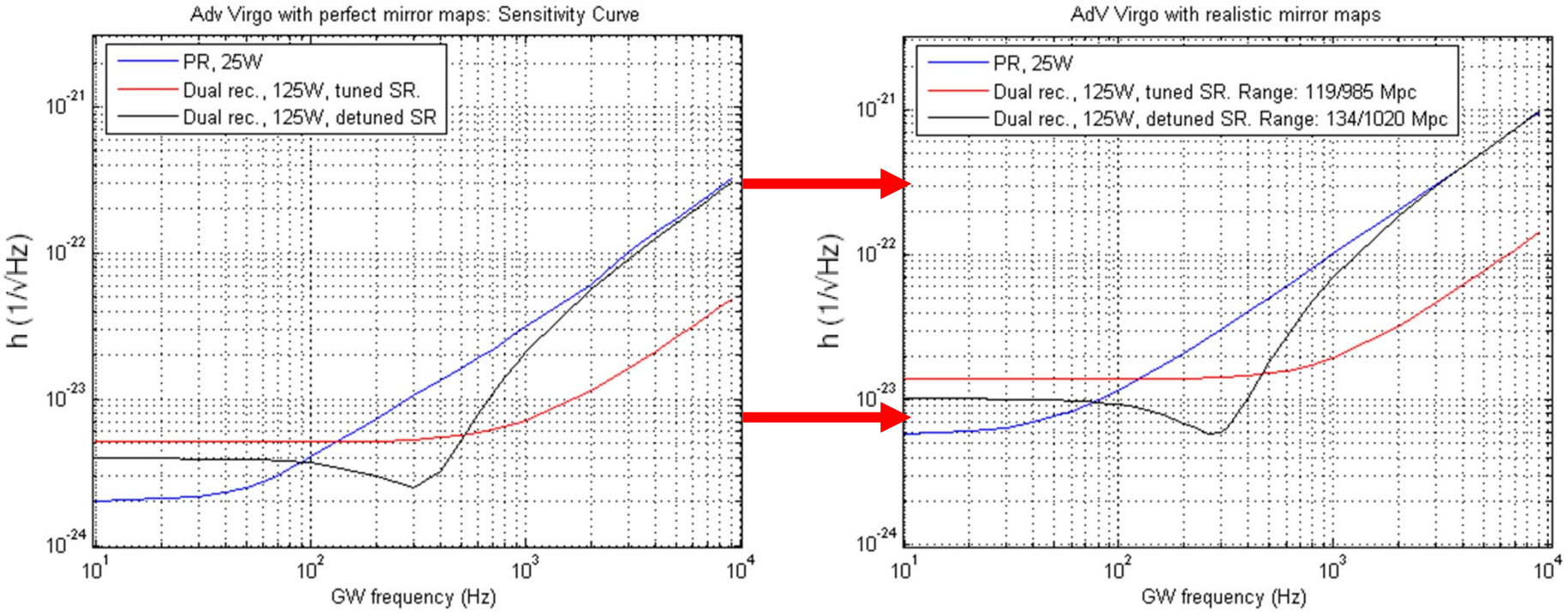


Sensitivity Max ~65mrad

=> Quite different from the perfect mirror case.

Simulation with “realistic” mirror maps

- Use of 4 mirror maps on the ITMs and ETMs.



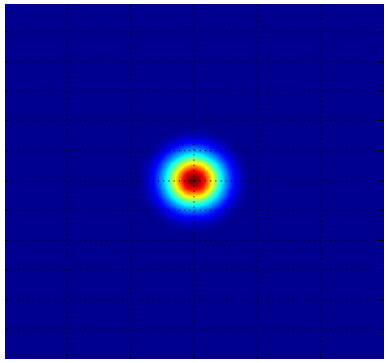
Adv Virgo Sensitivity Curve with perfect mirrors.

With « realistic » mirror maps: RMS flatness around 0.5nm

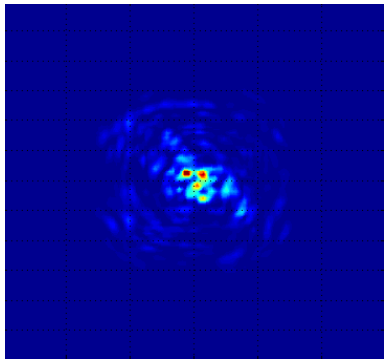
=>PRELIMINARY results

Hints

⇒ **Simulations without OMC (PR: after BS, Dual: after SRM).**



(ex: Dark fringe with perfect mirrors)



(ex: Dark fringe with "realistic" mirror maps)

⇒ **Study of the SNR: S ↘ or N ↗**

⇒ **Check with the aLIGO configuration (NDRC).**

Summary

• **The implementation of the Audio Sidebands has been completed, for a dual recycled interferometer.**

⇒ **Sensitivity curve in agreement with the theory (with perfect mirrors).**

• **Influence of the mirrors characteristics:**

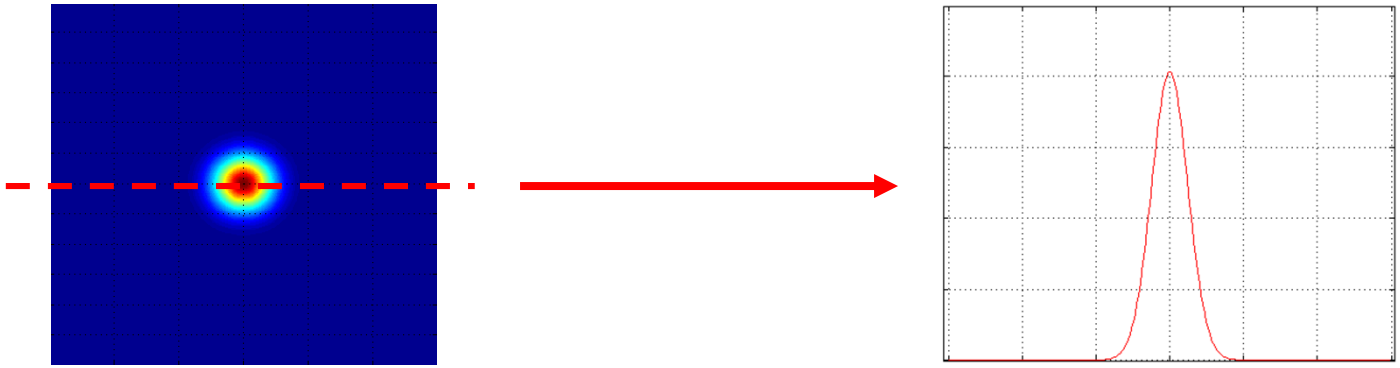
- The realistic mirror maps have some impact on the sensitivity.

⇒ **Investigation around this effect (OMC, signal, noise, …).**

⇒ **Look forward to test the real mirror maps with their own characteristics.**

More about DarkF

- **Simulation time for AdvITF (128x128 for the carrier): < 30s.**
- **Even faster with "1D" simulation (128x1):**



- **DarkF is available for different OS:**
  - **Unix**
  - **Mac**
  - **Windows**

Share code => Have comparison and get feedback.

Extra slide

- Try with different set of maps.