



EINSTEIN TELESCOPE

STATUS/PROGRESS/OUTLOOK

Prof Sheila Rowan
Institute for Gravitational Research, Glasgow, UK

Shanghai Forum, 13/10/2014

LIGO-G1401206.

GW Timelines - Global Roadmap



You are here
↓

| | '06 | '07 | '08 | '09 | '10 | '11 | '12 | '13 | '14 | '15 | '16 | '17 | '18 | '19 | '20 | '21 | '22 | '23 | '24 | '25 | '26 | '27 | |
|-------------------|-----|-----|-----|--------|-----|---------|----------------|-----|-----|-----|-----|-----|-----|---------------|--------------|-------|-----|-----|-----|-----|-----|-----|------|
| Virgo | | | | Virgo+ | | | Advanced Virgo | | | | | | | | | | | | | | | | |
| GEO | | | | | | GEO 600 | | | | | | | | | | | | | | | | | |
| LIGO | | | | | | | | | | | | | | | | | | | | | | | |
| Hanford | | | | | | | | | | | | | | | | | | | | | | | |
| Livingston | | | | | | | | | | | | | | | | | | | | | | | |
| India | | | | | | | | | | | | | | | | | | | | | | | |
| LIGO 3G? | | | | | | | | | | | | | | | | | | | | | | | |
| KAGRA | | | | | | | | | | | | | | | | | | | | | | | |
| E.T. | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | DS | | | | | | | | | | Site Prep. | Construction | Comm. | | | | | | | data |

1st Generation

2nd Generation

3rd Generation

GEO 600



German/UK
detector

Near Ruthe,
Germany



Universitat de les
Illes Balears

Dual purpose instrument – GW searches/testing new technologies

Virgo



Italian/French
detector,
(with the
Netherlands,
Hungary)

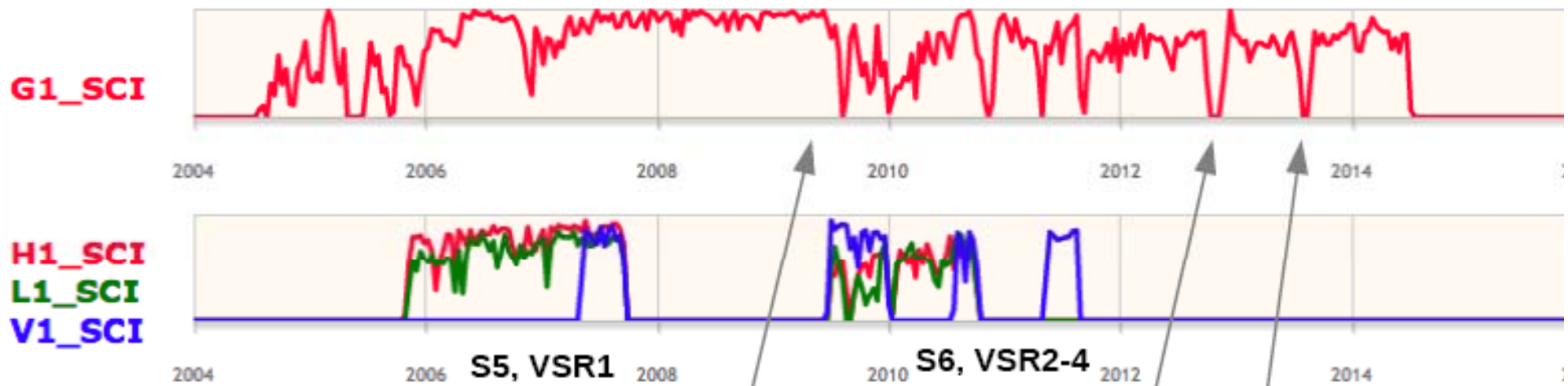
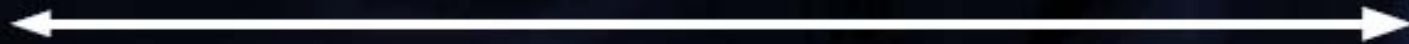
Near Cascina,
Italy)

3km arms

Sophisticated
low-frequency
vibration
isolation

Data Taking in the (L/V) Collaboration

10 years of data taking with GEO



R. Williams

Start of
GEO-HF
Upgrade
program

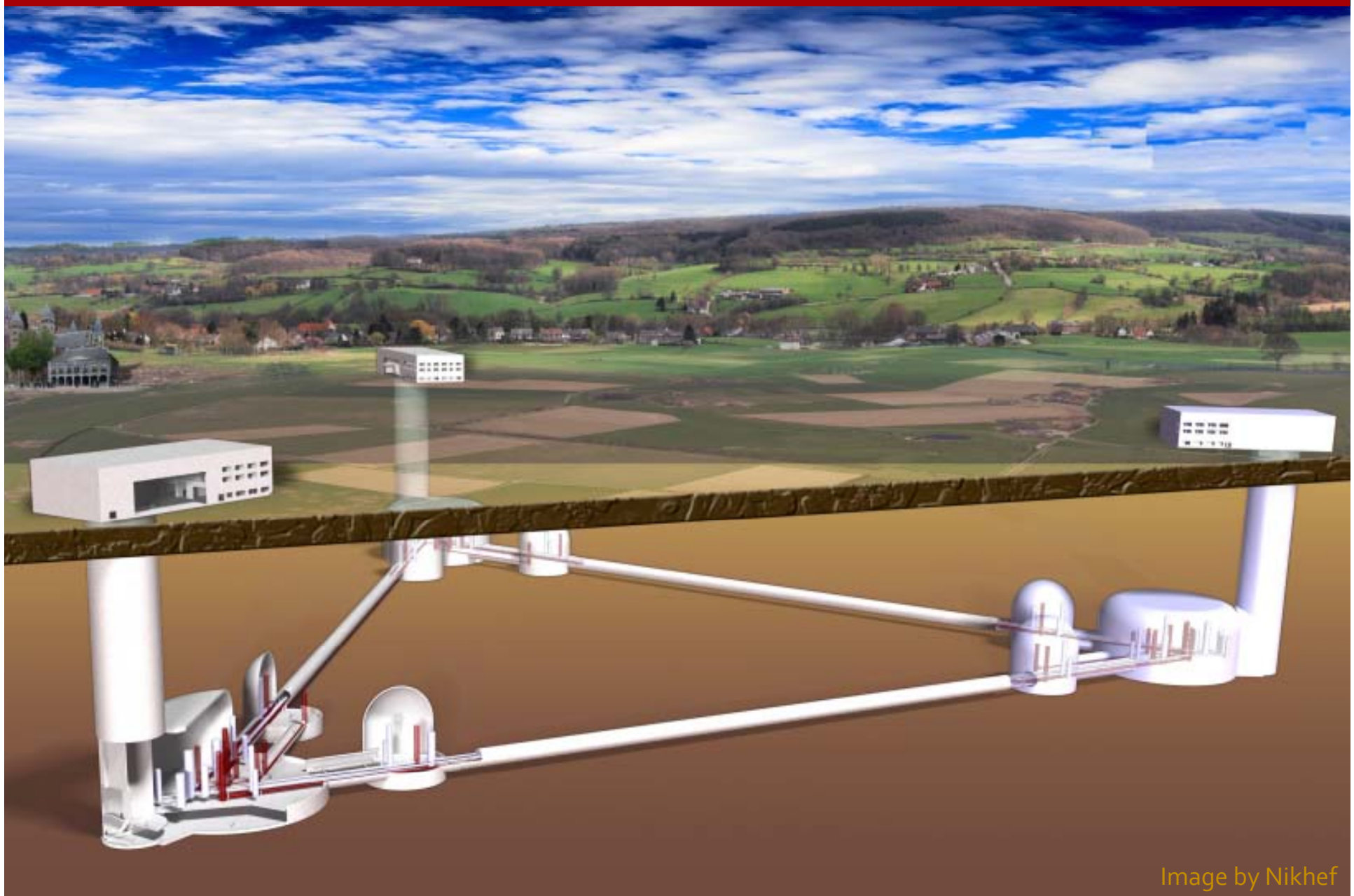
Input
Optics
Upgrade,
Baffle
Install.

TCS
upgrades,
Baffle
Install.

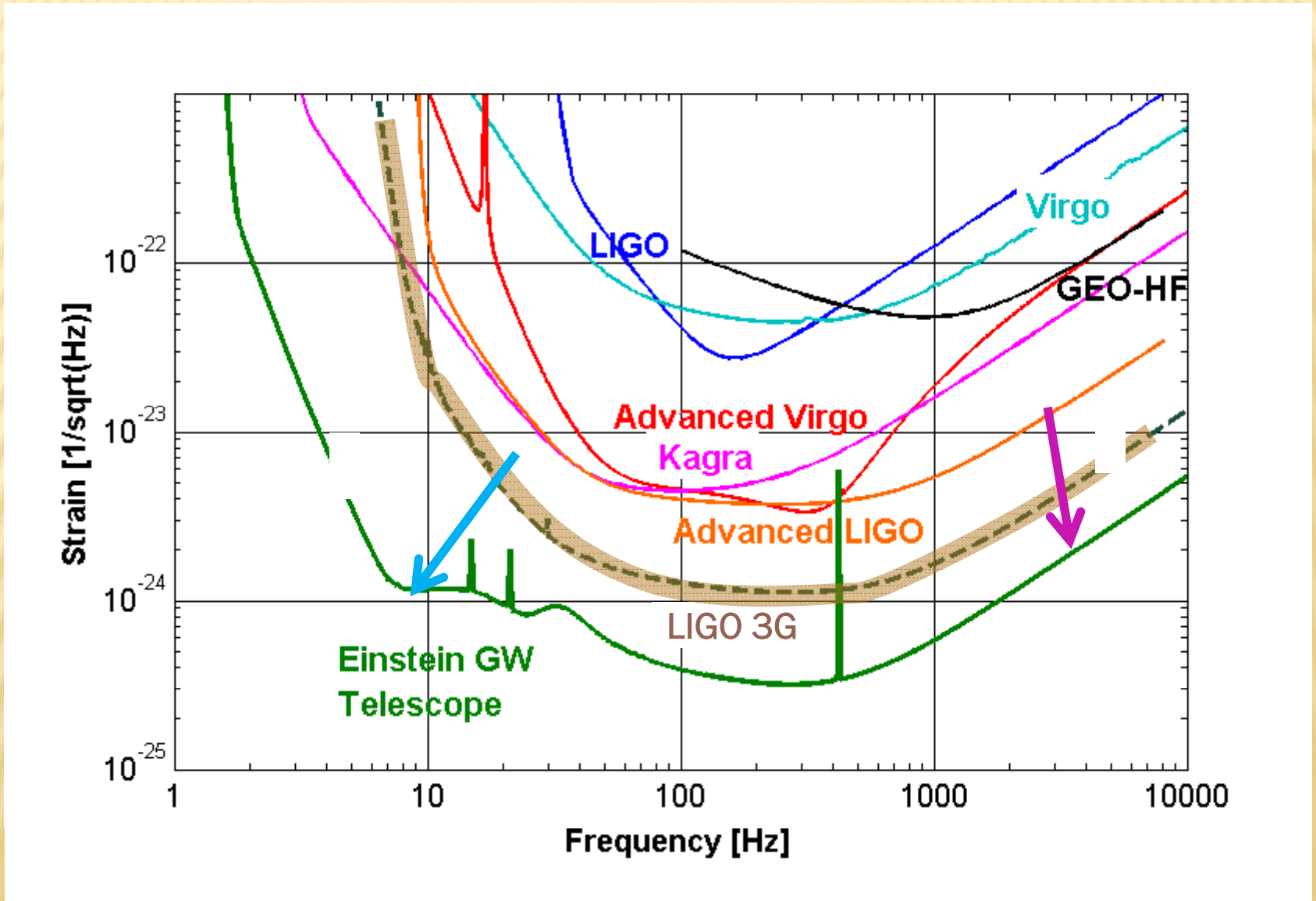
Geo-HF and Advanced Virgo

- Current status of GEO
 - Upgraded to include the use of 'squeezed light)
 - Currently operating in 'Astrowatch' mode
- Current status of (Advanced) Virgo
 - Hardware upgrades (laser, optics) well underway to form an 'Advanced Virgo' detector
- GW field across Europe working together with a vision for future generations of European Gravitational Wave interferometers

Einstein Telescope



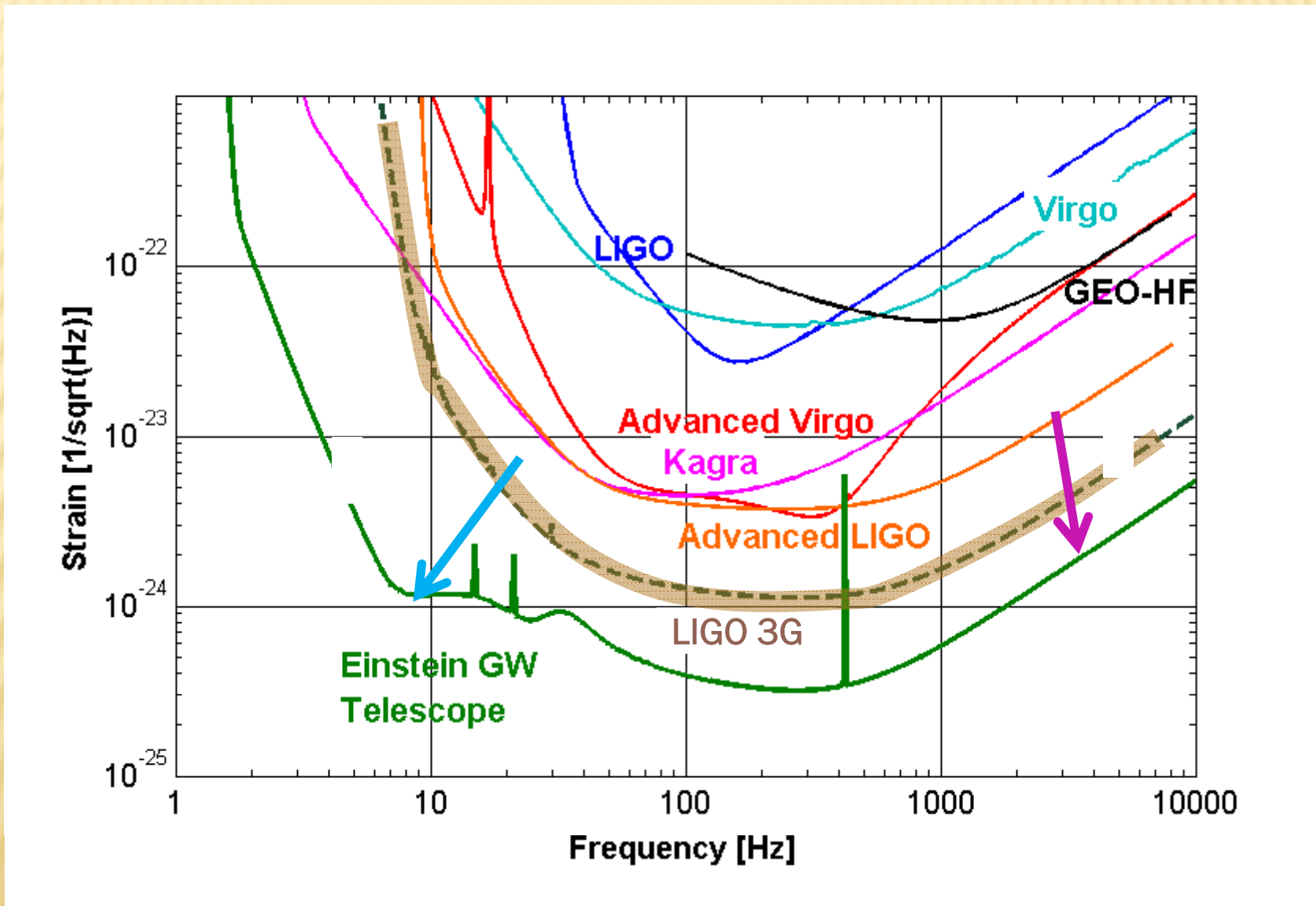
1ST, 2ND 2+, AND 3RD GENERATION



EINSTEIN TELESCOPE – CONCEPTION AND DESIGN

- ✘ Conceptual Design Study for a future GW interferometer in Europe supported by the European Commission under the Framework Programme 7(2008-11)
- ✘ Proposed by 8 European research institutes involved in experimental gravitational wave research.
- ✘ European Gravitational Observatory
- ✘ Istituto Nazionale di Fisica Nucleare
- ✘ Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V., acting through Max-Planck-Institut für Gravitationsphysik
- ✘ Centre National de la Recherche Scientifique
- ✘ University of Birmingham
- ✘ University of Glasgow
- ✘ NIKHEF
- ✘ Cardiff University

1ST, 2ND 2+, AND 3RD GENERATION



CONFLICT OF INTERESTS

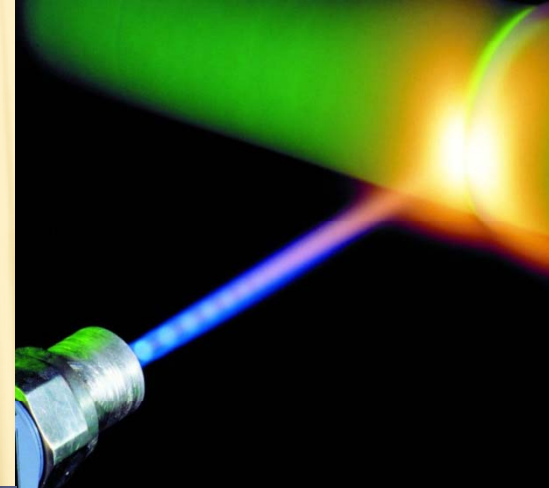
Need Cryogenics for
low Thermal Noise: 10K



www.miami.com



High Power for low
Shot Noise: 3MW



jgindo.wordpress.com



<http://s658.photobucket.com>

ET XYLOPHONE STRATEGY



Split detector into two interferometers optimised for

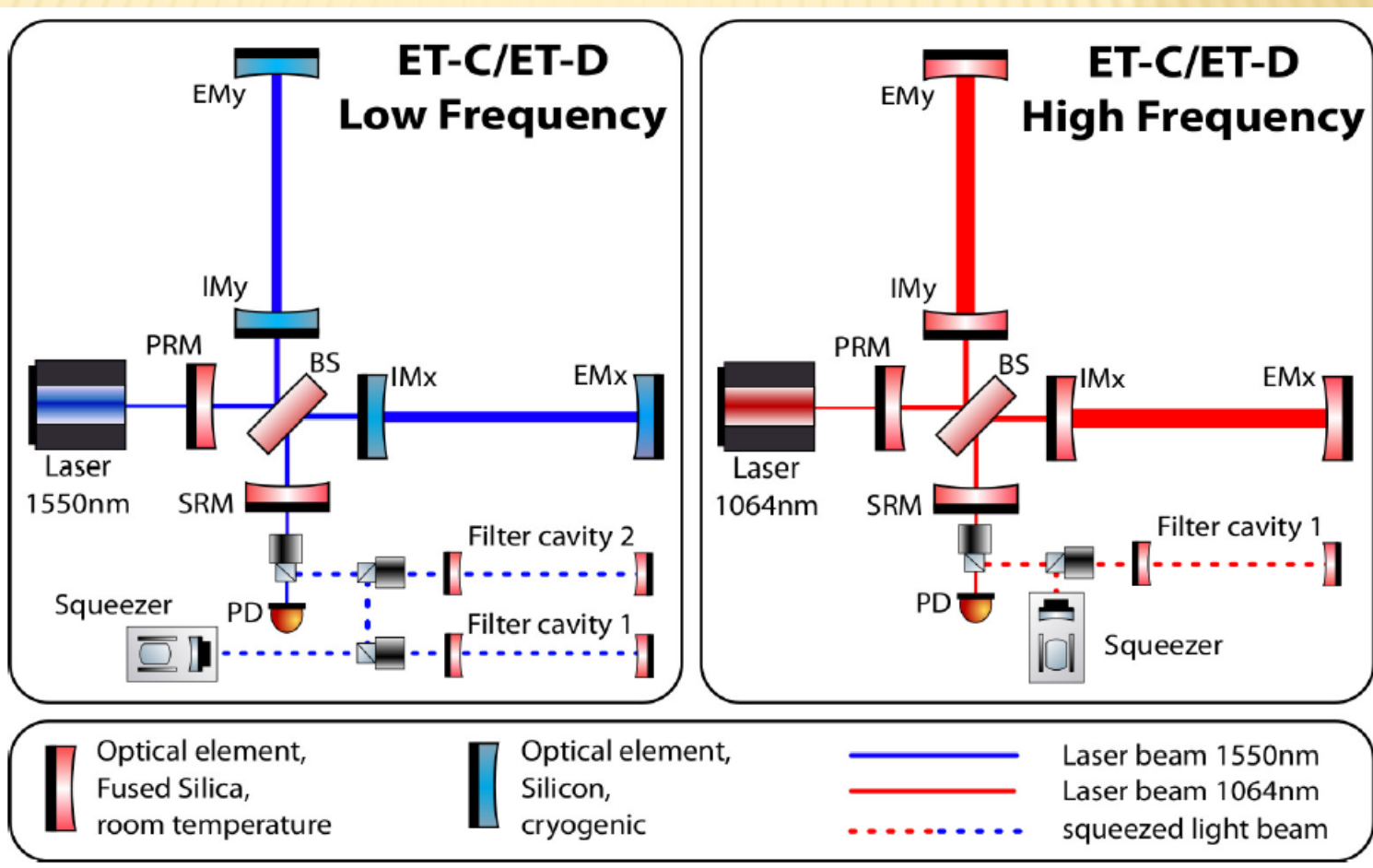
Low Frequencies

and

High Frequencies

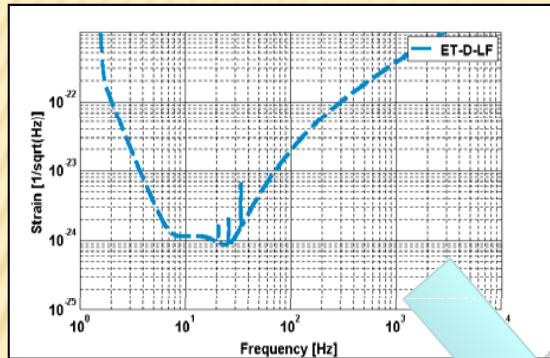
10K, 18kW, 1550nm

300K, 3MW, 1064nm

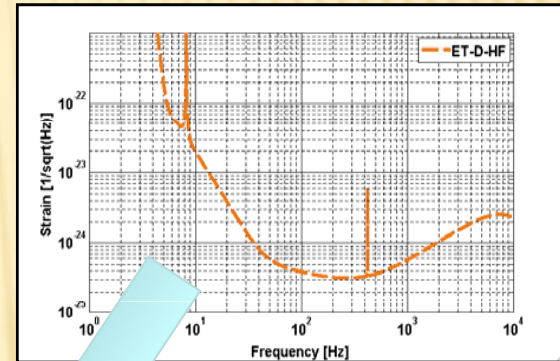


ET-D XYLOPHONE SENSITIVITY

Slide: Christian Gräf, 2013, modified

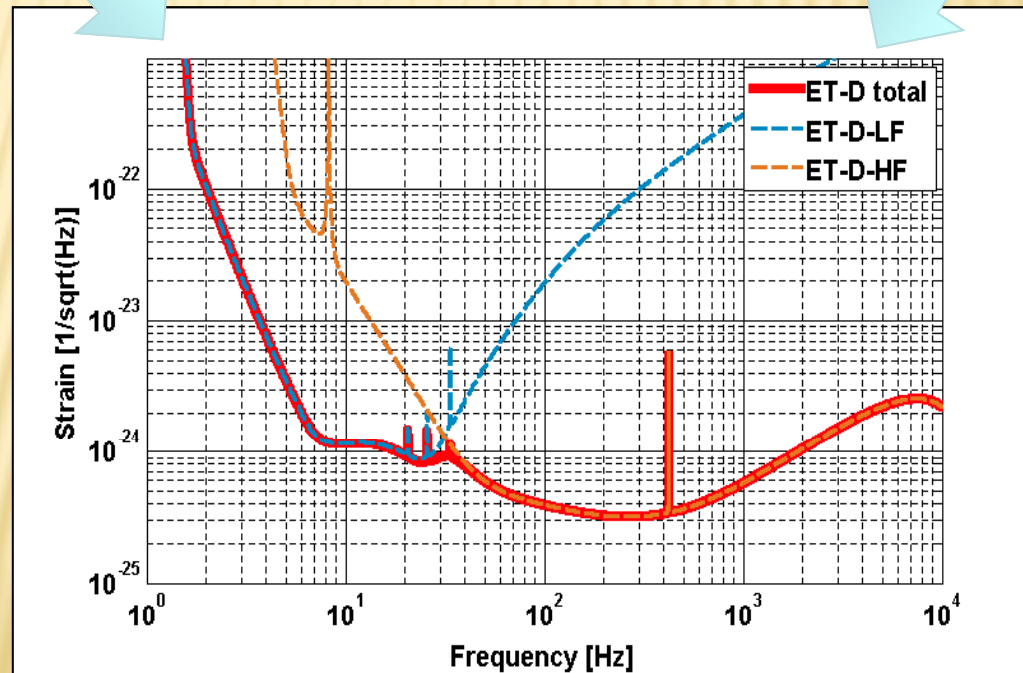


Combining the two interferometers

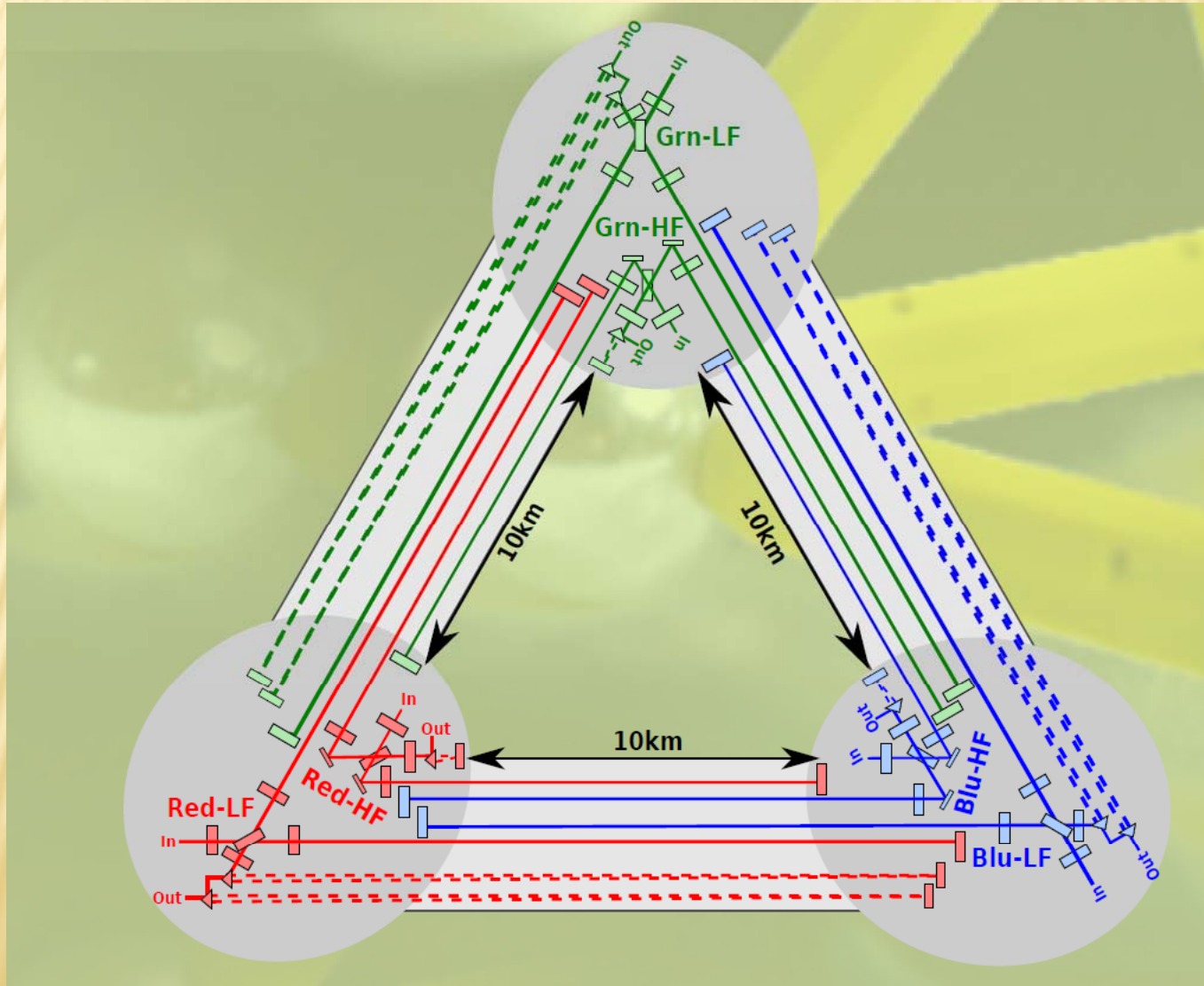


ET-D-LF

ET-D-HF



TRIANGULAR CONFIGURATION SIX INTERFEROMETERS IN TOTAL



The logo for the Einstein Telescope, consisting of the letters 'E' and 'T' in a white serif font on a green background.A small image showing a close-up of hands holding a small object, with the text 'EINSTEIN TELESCOPE' overlaid in white.

EINSTEIN TELESCOPE



WHAT NEW TECHNOLOGIES DOES IT NEED?

- ET is based mostly on „advanced“ technology
 - Longer arms („1.5“x10km) & underground
 - Higher power than advanced detectors (3 MW)
 - Cryogenic optics for low thermal noise
 - Split into two (Xylophone) to make Cryo and MW compatible
 - Larger, heavier optics; HOM (LG33) beams;
 - Laser Wavelength (Silicon:1550nm; fused Silica: 1064nm)
 - Frequency dependent 10 dB squeezing
 - No new coatings in baseline concept, but will be used as state of the art allows

ONGOING PROJECTS ([HTTP://WWW.ET-GW.EU/](http://www.et-gw.eu/))

- ✘ **ELiTES** (FP7-PEOPLE-IRSES)

3/2012 – 2/2016

+ common ET / KAGRA aspects



- ✘ **ET R&D**, (ASPERA 3rd common call)

5/2013 – 4/2016

+ addresses long term R&D needs

- ✘ **GraWIToN** (FP7-PEOPLE-2013-ITN, Marie Curie Actions)

2/2014 – 1/2017 13 PhDs

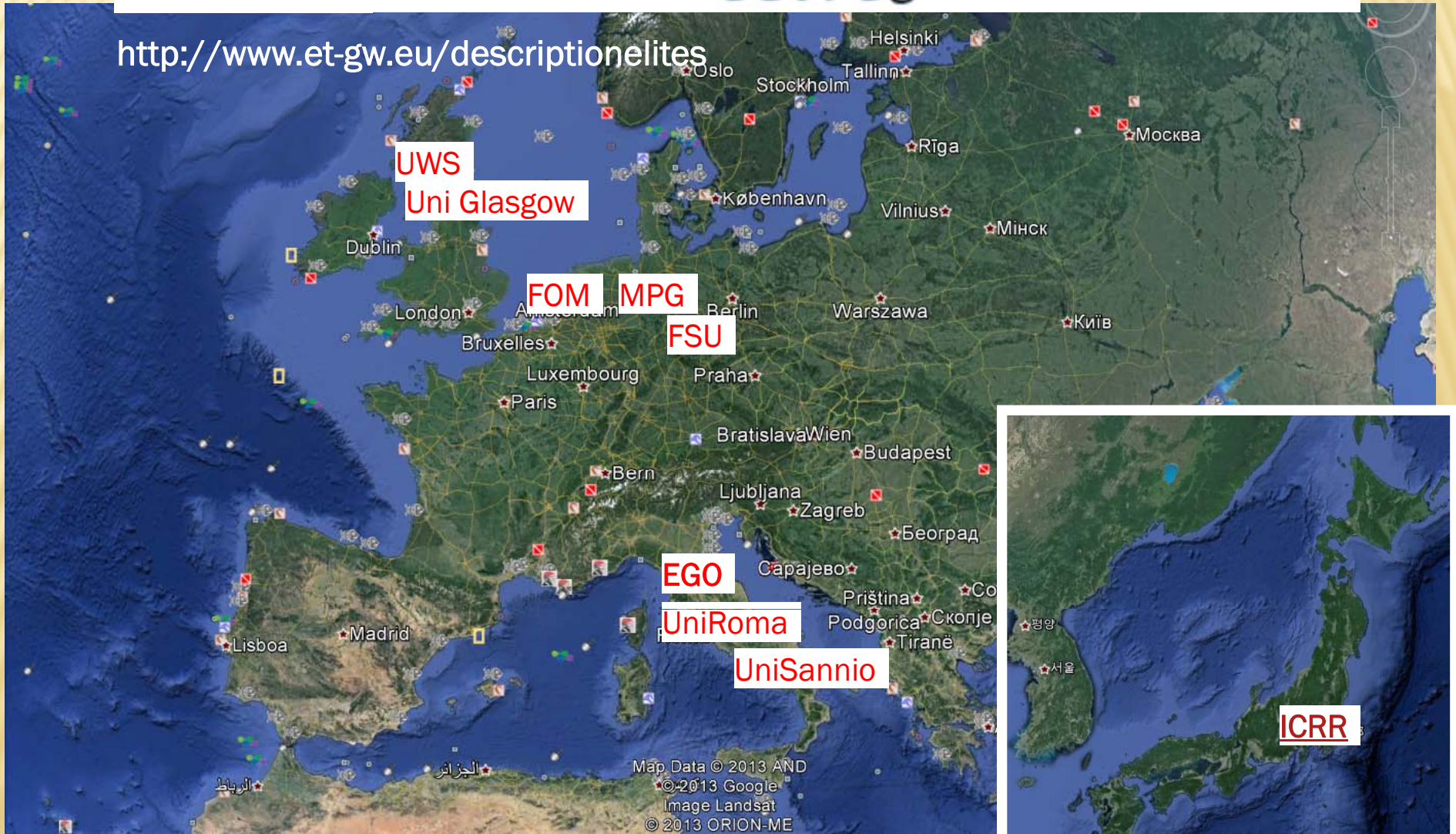
+ Optics, Simulation, High power lasers, Data Analysis



ELITES



<http://www.et-gw.eu/descriptionelites>





3/2012 - 2/2016

- **WP1, "Cryogenics and suspensions",**
 - Measure of the performance of designed cryogenic suspension system in a practical interferometer from the point of seismic and vibration isolation
 - Design and test of auxiliary attenuation system for thermal link
- **WP2, "Mirror thermal noise and cryogenics"**
 - Investigation of the mechanical loss in both silicon and sapphire bulk materials;
 - Performance of suitable optical coatings on sapphire substrates for the development of the mirrors for LCGT and to share the complimentary expertise contained within the LCGT and ET groups (e.g. Japanese expertise in studying low temperature properties of sapphire, European expertise in studying low temperature coatings)
 - Assessment of the properties and suitability of silicate bonding for bonding sapphire, and comparison with the properties of bonded silicon, to develop techniques for constructing sapphire suspensions for use in LCGT and as a possible alternate suspension material for use in ET
 - Characterisation of the thermal and mechanical properties of suspension elements (fibres, bond areas, etc.)
- **WP3, "Large-scale cryogenic infrastructure for LCGT and ET"**
 - Specifying noise sources arising from cooling system quantitatively and qualitatively
 - Optimum design of radiation shield
 - Prevention of possible contamination of clean surface of mirrors

ET R&D



5/2013 - 4/2016

- ✘ 3rd 'ASPERA' common call
- ✘ essential R&D tasks in preparation for a more technical design phase

ET

EINSTEIN
TELESCOPE

ET R&D PROJECT



<http://www.et-gw.eu/etrddescription>





Four Working Projects

- **WP1, "ET's scientific potential"**
 - Mock ET data and science challenges of increasing complexity
 - Explore how well astrophysical models of GW sources could be tested with ET
 - Investigate possible strong field tests of GR with ET
 - Probe ET's potential for understanding the geometry and dynamics of the Universe
- **WP2, "Long term seismic and GGN studies of selected sites"**
 - Studies at candidate sites
 - Sensor and network development
 - Modeling of seismic and GGN noise
- **WP3, "Optical properties of silicon at cryogenic temperatures"**
 - Stress induced birefringence of silicon-based optic
 - Homogeneity of optical properties within larger samples
 - Investigation of Whispering Gallery Mode Oscillators made of silicon to probe absorption and scattering
- **WP4, "ET Control systems"**
 - Mitigation scheme for radiation pressure effects for the ET-HF interferometer.
 - Control scheme for the injection of frequency dependent squeezed light.
 - Low-frequency control scheme for the ET-LF interferometer.
 - Mitigation scheme for correlated noise in co-located interferometers.
 - Contamination of potential null stream signals by technical noises.

- ✦ Sathyaprakash (Cardiff University, UK)
 - + Carry out a series of mock ET data and science challenges of increasing complexity
 - + Explore how well astrophysical models of GW sources could be tested with ET
 - + Investigate possible strong field tests of GR with ET
 - + Probe ET's potential for understanding the geometry and dynamics of the Universe

WP2: LONG TERM SEISMIC AND GGN STUDIES OF SELECTED SITES

- ✘ Jo v.d. Brand (Nikhef, NL)
 - + Studies at candidate sites
 - + Sensor and network development
 - + Modeling of seismic and GGN noise

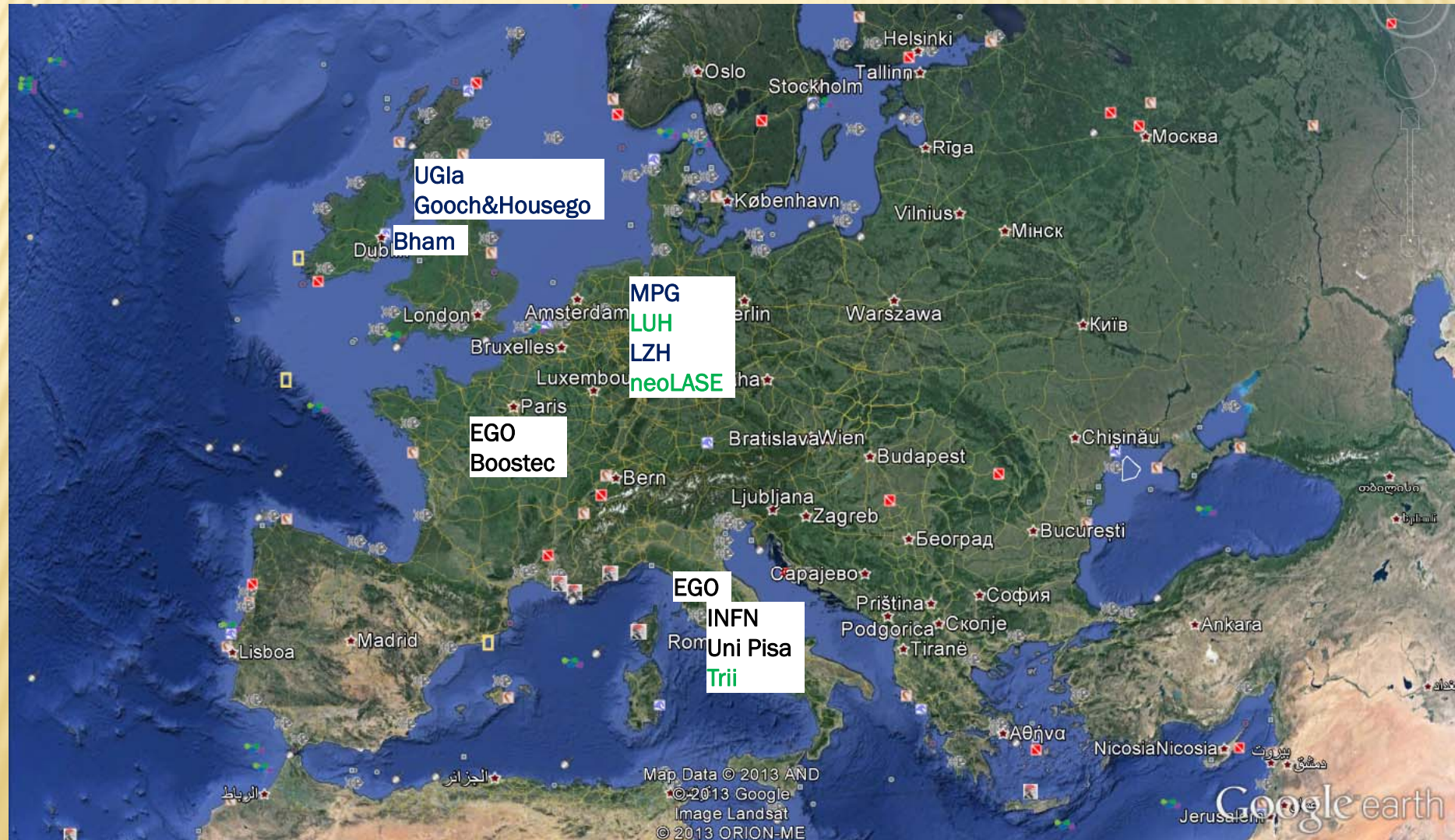
WP3: OPTICAL PROPERTIES OF SILICON AT CRYOGENIC TEMPERATURES

- ✘ Ronny Nawrodt (FSU Jena, DE)
 - + Stress induced birefringence of silicon-based optic
 - + Homogeneity of optical properties within larger samples
 - + Homogeneity of optical properties within larger samples
 - + Investigation of Whispering Gallery Mode Oscillators made of silicon to probe absorption and scattering

- ✘ Andreas Freise (Birmingham University, UK)
 - + Mitigation scheme for radiation pressure effects for the ET-HF interferometer.
 - + Control scheme for the injection of frequency dependent squeezed light.
 - + Low-frequency control scheme for the ET-LF interferometer.
 - + Mitigation scheme for correlated noise in co-located interferometers.
 - + Contamination of potential null stream signals by technical noises.

Optics, Simulation, High power lasers, Data Analysis

<http://www.grawiton-gw.eu/index.php/jobopportunities> for 13 ESRs



CURRENTLY...



- ✘ Proposal submitted 902/09/2014)for the Horizon 2020 call:
EGWII
INFRAIA-1-2014/2015:
Integrating and opening existing national and regional research infrastructures of European interest



THE CALL:



- **Integrating gravitational wave research.** This activity aims at integrating the communities of researchers studying gravitational waves and their astrophysical sources: both laser and atom interferometers with their extreme technological requirements; observations of gravitational-wave sources through electromagnetic waves and high-energy particles; numerical/theoretical studies of such sources. It should address also the computing and data handling needs of these communities.

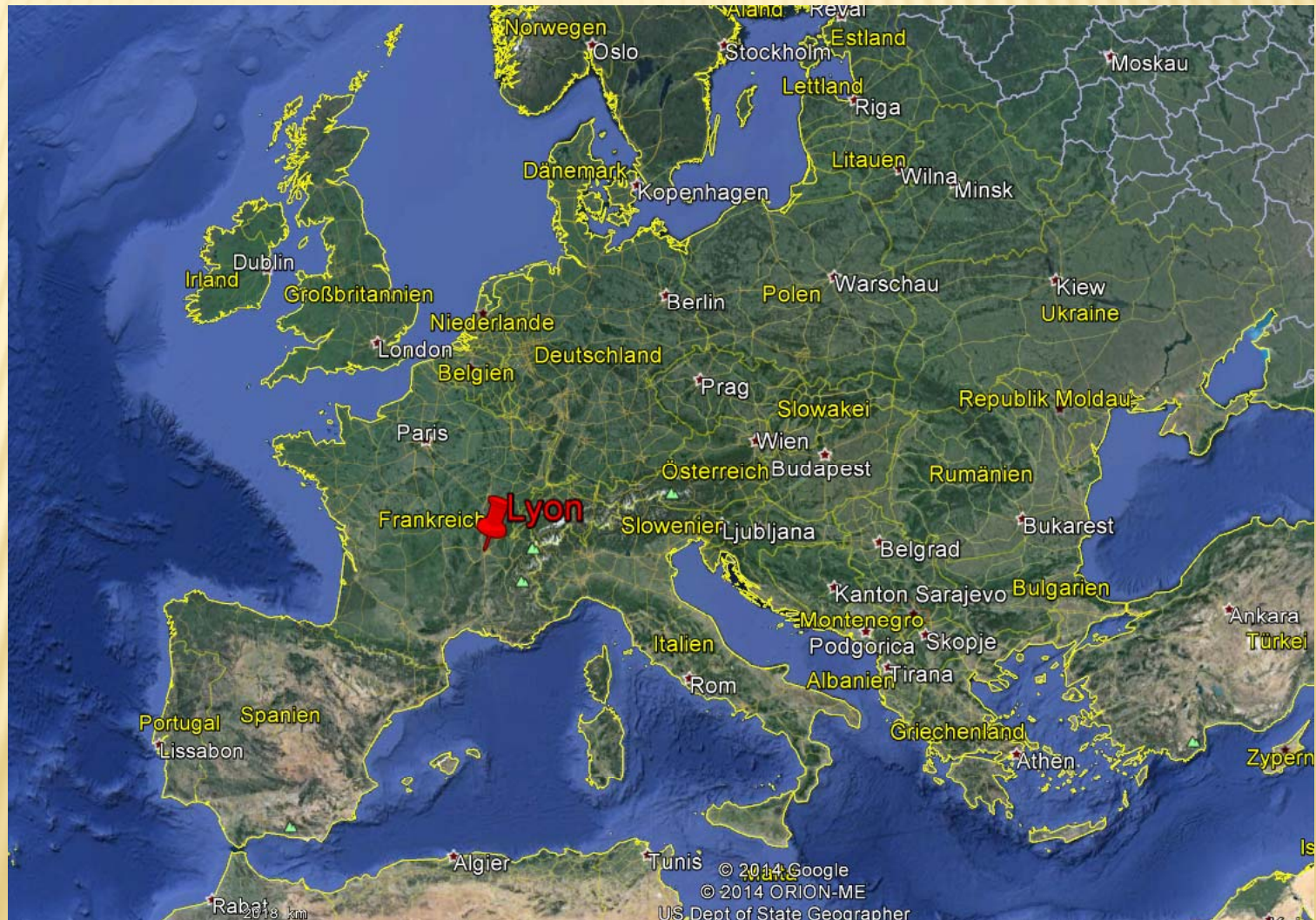
- Involves almost all institutions involved in GW in Europe
- Start: Spring 2015; Duration 4 years
- Will consist of
 - Networking activities
 - Transnational access to the research Infrastructures
 - Joint research activities
 - Outreach & management

NEXT ET GENERAL MEETING



✘ 19th/20th of November 2014

✘ LMA
→ Lyon

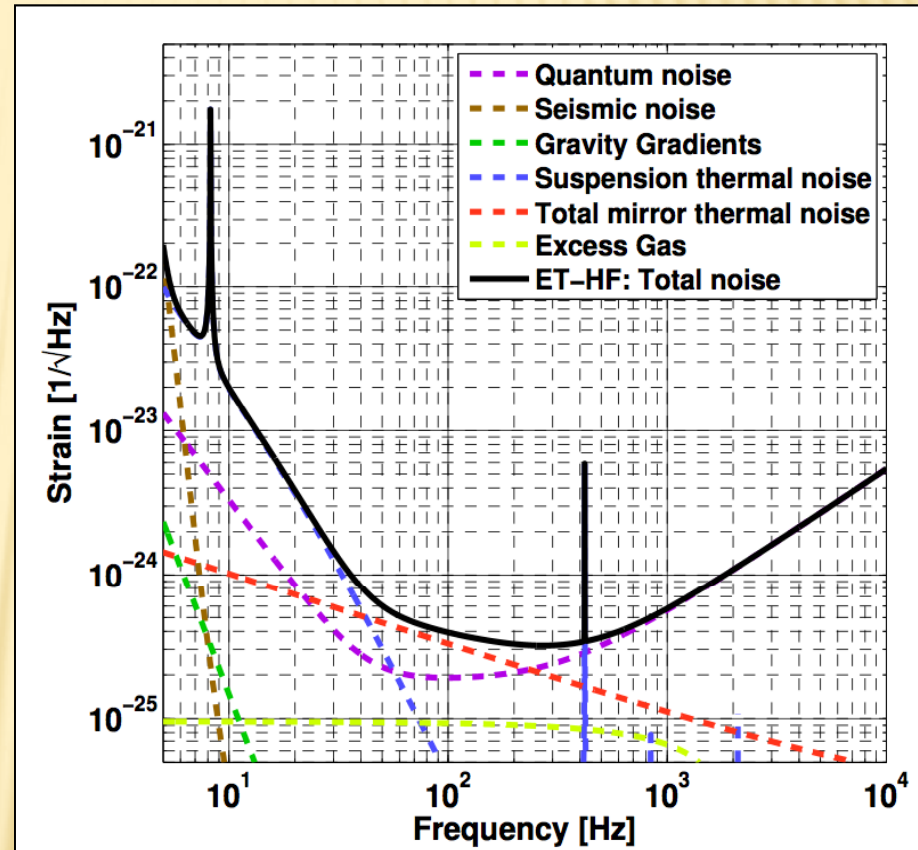
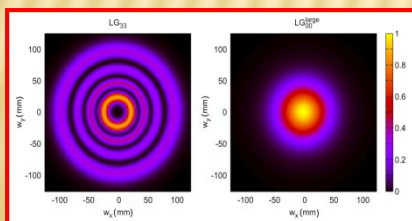




ET-D HIGH FREQUENCY DETECTOR

Slide: Christian Gräf, ET Symp., 2013, modified

- **Quantum noise:** 3MW, tuned Signal-Recycling, 10dB Squeezing, 200kg fused silica mirrors.
- **Suspension Thermal and Seismic:** Superattenuator (standard Virgo)
- **Gravity gradient:** No Subtraction needed
- **Thermal noise:** 290K, 12cm beam radius, fused Silica, LG33 (reduction factor of 1.6 compared to TEM00).



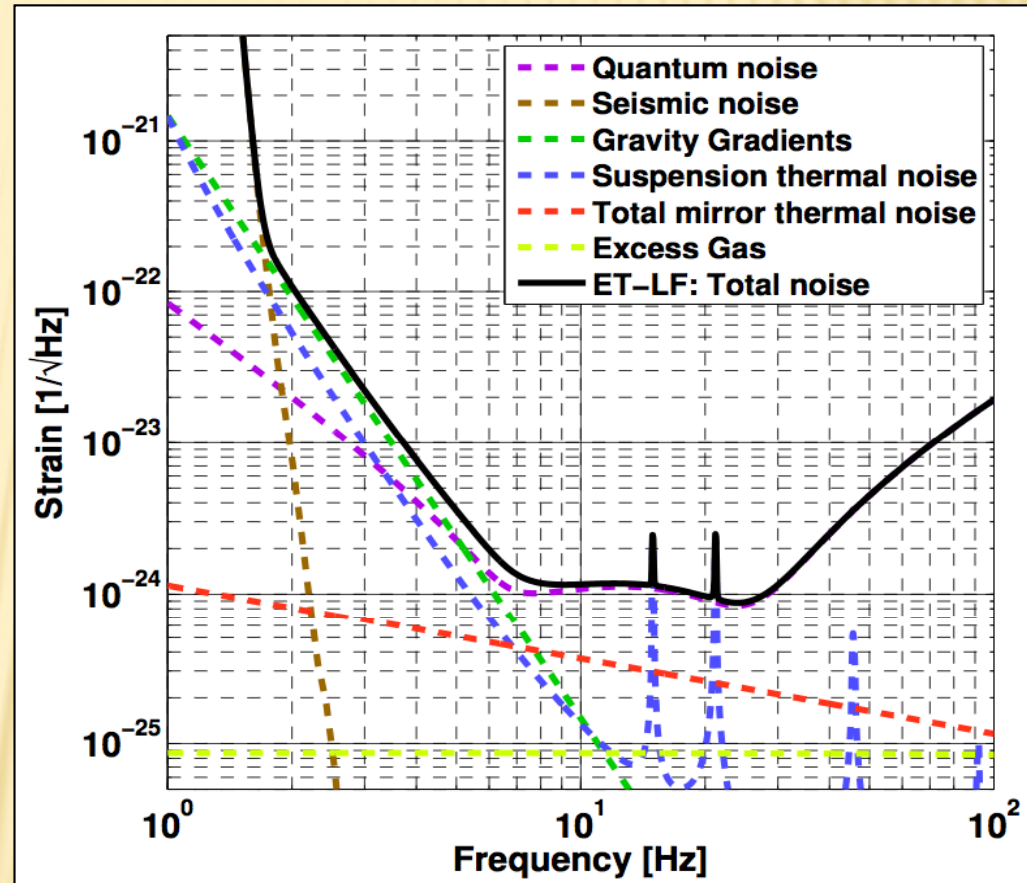
Coating Brownian reduction factors (compared to 2G):
3.3 (arm length), 2 (beam size) and 1.6 (LG33) = 10.5

Shot Noise reduction factors (compared to 2G):

1.6 (arm length), 1.9 (power), 3.2 (squeezing (10dB)) = 9.7

ET-D LOW FREQUENCY DETECTOR

- **Quantum noise:** 18kW, detuned Signal-Recycling, 10 dB frequency dependent Squeezing, 211kg mirrors.
- **Seismic:** extended Superattenuator, 17m tall
- **Gravity gradient:** no subtraction assumed in noise curve
- **Mirror thermal :** 10K, Silicon, 12cm beam radius, TEM00.
- **Suspension Thermal:** penultimate mass@2K, 3mm diameter silicon fibres, 2m long; limiting noise contribution from 1Hz-10Hz



As mirror TN is no longer limiting, one could relax the assumptions on the material parameters and the beam size...



450 mm

300 mm

Source:

http://www.iisb.fraunhofer.de/content/dam/iisb/de/images/geschaeftsfeilder/halbleiterfertigungsgeraete_und_methoden/gadest_2011/

Large Silicon Substrates are available but only in CZ grown Crystals. Whether the purity reachable is sufficient is currently being tested



Source: <http://www.quora.com/Semiconductors/How-do-silicon-boules-not-break-off-during-semiconductor-fabrication>

HEAVY SILICON BOULES

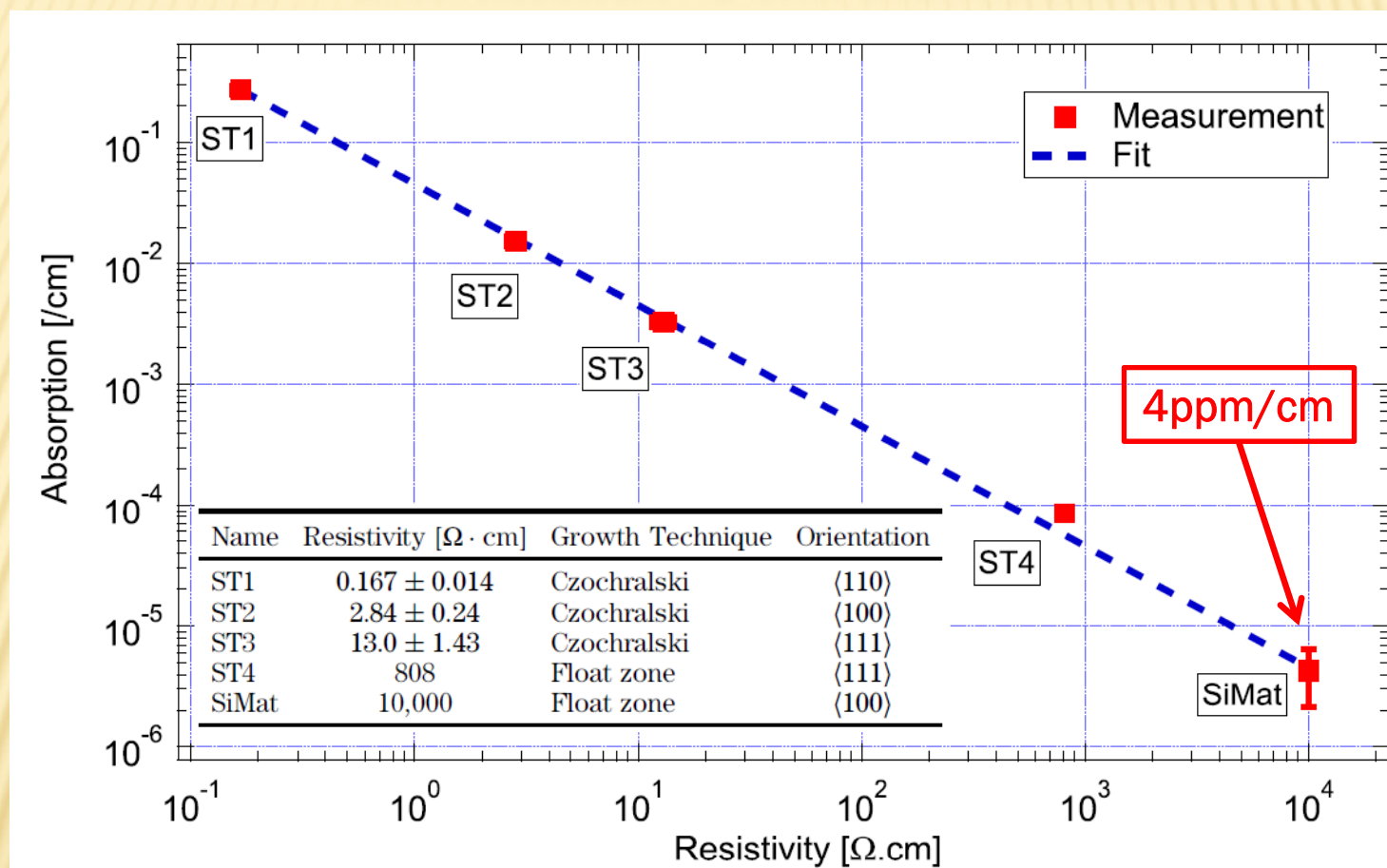


Silicon Boules can be grown to a weight of 450kg



Source: www.pvatepla.com

SILICON ABSORPTION



- ✘ Requires pure (float zone) material
- ✘ Inconsistent measurements across groups
- ✘ Indications for enhanced absorption close to surfaces
- ✘ Under investigation

ET PARAMETERS



| Parameter | ET-D-HF | ET-D-LF |
|------------------------------|-----------------------------|-----------------------------|
| Arm length | 10 km | 10 km |
| Input power (after IMC) | 500 W | 3 W |
| Arm power | 3 MW | 18 kW |
| Temperature | 290 K | 10 K |
| Mirror material | fused silica | silicon |
| Mirror diameter / thickness | 62 cm / 30 cm | min 45 cm / T |
| Mirror masses | 200 kg | 211 kg |
| Laser wavelength | 1064 nm | 1550 nm |
| SR-phase | tuned (0.0) | detuned (0.6) |
| SR transmittance | 10 % | 20 % |
| Quantum noise suppression | freq. dep. squeez. | freq. dep. squeez. |
| Filter cavities | 1×10 km | 2×10 km |
| Squeezing level | 10 dB (effective) | 10 dB (effective) |
| Beam shape | LG ₃₃ | TEM ₀₀ |
| Beam radius | 7.25 cm | 9 cm |
| Scatter loss per surface | 37.5 ppm | 37.5 ppm |
| Seismic isolation | SA, 8 m tall | mod SA, 17 m tall |
| Seismic (for $f > 1$ Hz) | $5 \cdot 10^{-10}$ m/ f^2 | $5 \cdot 10^{-10}$ m/ f^2 |
| Gravity gradient subtraction | none | none |