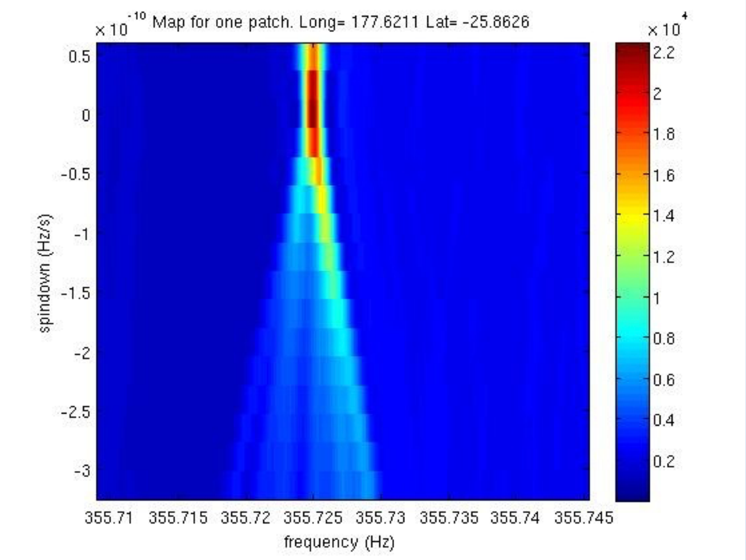
NEWS

H2020-MSCA-RISE-2016 – Grant Agreement N° 734303

European Commission

Summary of seconded activities WP2 (⇔WP3) and perspective

Andrew Laurence Miller
PhD in LIGO-Virgo CW data analysis group



- **Destination**: Japan, ICRR @Kashiwano-ha Campus
- **Theme**: Algorithms for Detection of Continuous Gravitational Wave, their extension
- **Why in Japan**: a very promising framework due to the scientific engagement in KAGRA, with both perspective detector networks and 3G
- **Activity goal**: to disseminate and further develop CW analysis methods

Applying a new estimator of significance to continuous wave searches

Andrew Miller, in collaboration with H. Yuzurihara, J. Suresh, and and H. Tagoshi at ICRR, Tokyo, Japan

Motivation

- Continuous wave (CW) searches are computationally demanding, typically all-sky, all frequency, trying to find a quasi-monochromatic signal buried deep within detector noise
- No signal has been found yet, but stringent upper limits have been placed
- However, in the event of a detection, it is not clear how to assign significance
  - We cannot do time-slides as in binary searches to determine background
  - p-values have been shown to not be the best indicator in binary searches
  - In CW searches, even very low p-values do not correspond to signals
    - Need better way of distinguishing: try new statistic: q-value

q-value

- Gives the probability of the false discovery rate, calculated based on p-values
- Interpreted as: expected probability of false discovery when rejecting the null hypothesis for a result that has a q-value equal to or less than the background's distribution
- Shown to be a better indicator of significance in binary searches

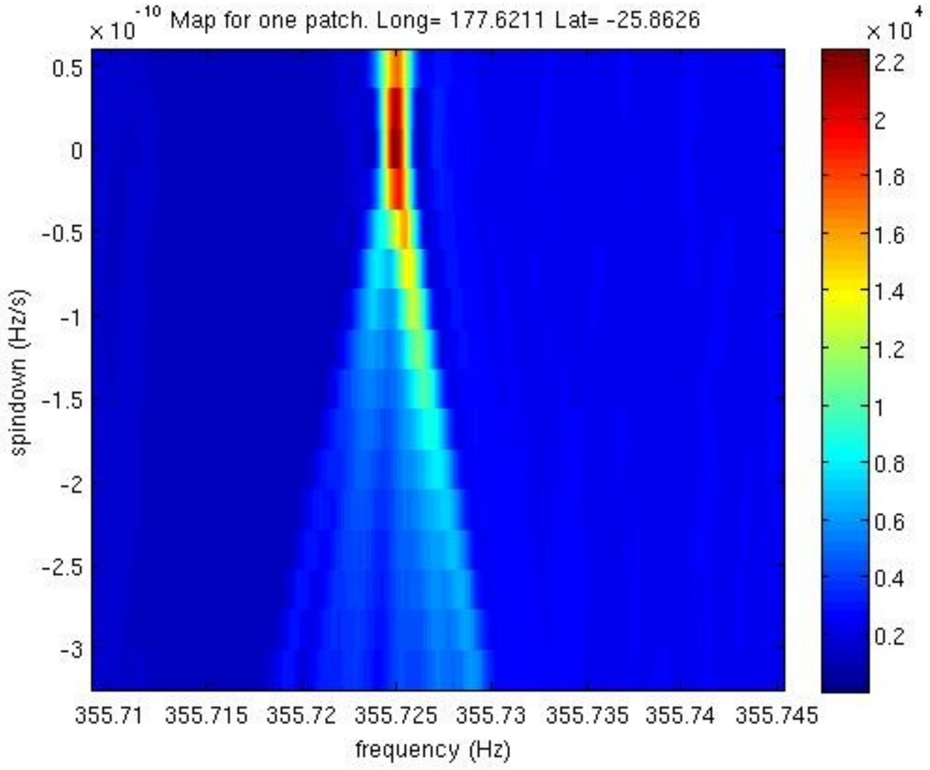
FrequencyHough

- Applying q-statistic to the output of the FrequencyHough transform, a method that maps points in the time/frequency plane of the detector to lines in the frequency/spindown plane of the source

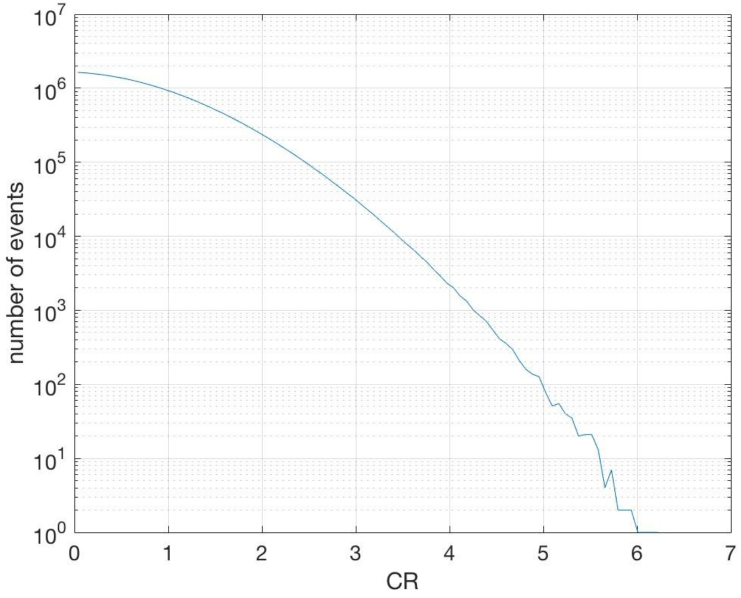
- Output: histogram number counts, and a detection statistic, called critical ratio (CR), is calculated:

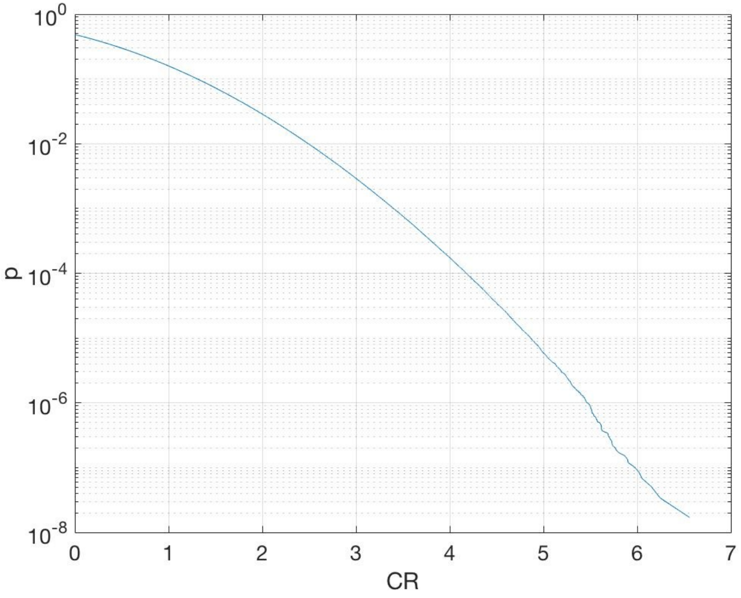
  - CR=(X-μ)/σ

  - Calculate for every frequency/spindown cell in this map to create background distribution, in one sky location



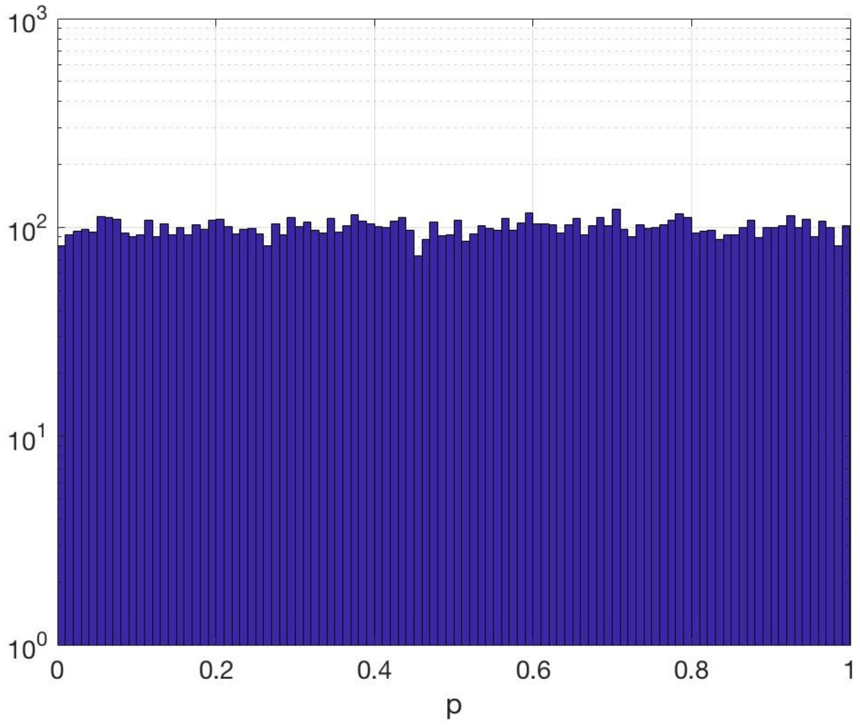
Background distribution





- One sky location, one frequency band (1 Hz)
- CR: critical ratio (detection statistic)
- p-val=sum(# candidates>CR)/tot # candidates

Check for uniform p-values



- Calculated p-values in different sky location, same frequency band using background distribution present on the previous slide

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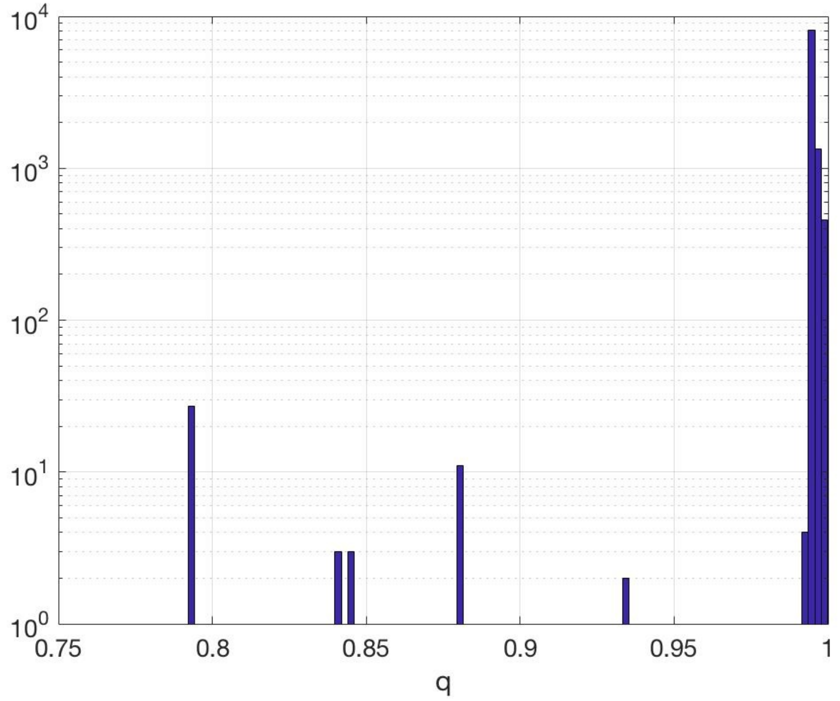
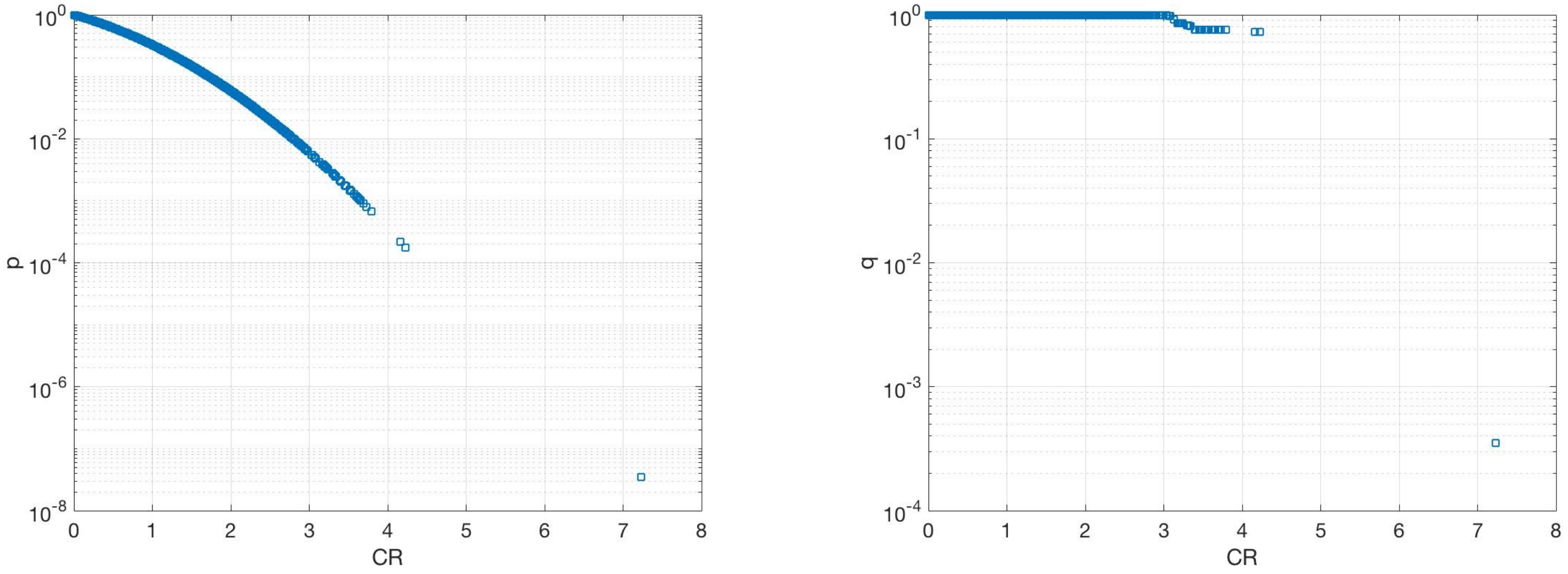
Corresponding q-values



- q-values large —> noise

q- and p- values for signal



- CR of signal chosen to be ~7, we see the difference in p/q values here
- However, it is not clear how much better q is than p. This is ongoing work.

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Ongoing work

- Compute p-values for many different sky locations, and different frequency bands, compare to background
- Inject real signals (with differing amplitudes), create real Hough maps, and calculate/compare p- and q-values

References

- Yuzurihara, Hirotaka, Shuhei Mano, and Hideyuki Tagoshi. "A nonparametric method to assess significance of events in search for gravitational waves with false discovery rate." arXiv preprint arXiv:1907.00379 (2019).
- Astone, Pia, et al. "Method for all-sky searches of continuous gravitational wave signals using the frequency-Hough transform." Physical Review D 90.4 (2014): 042002.

Ornella Juliana Piccinni

post-doc in LIGO-Virgo CW data analysis group

- **Destination**: Japan, ICRR @KAGRA site
- **Theme**: Algorithms for Detection of Continuous Gravitational Waves, Noise Frequency Event Miner (NoEMi)
- **Why in Japan**: a very promising framework due to the scientific engagement in KAGRA, with both perspective detector networks and 3G
- **Activity goal**: implementing SW tools for KAGRA, NoEMi in view of science runs

NoEMi, developed in Virgo community, is now installed in KAGRA

NoEMi

The Noise Frequency Event Miner (NoEMi) is a Virgo software tool dedicated to the monitoring and identification of spectral noise lines.

It uses codes for CW analysis to find and track spectral lines found in a given list of channels. It also looks for spectral features in coincidence between the "main channel" and the "auxiliary channels".

NoEMi documentation: https://apps.virgo-gw.eu/noemi/docs/index.html

This version, has 3 main components:

- the NoEMi events database (DB);
- the Line-Finder script (LF);
- the web user interface (WUI).

In addition to NoEMi the LinesDB will be installed soon.

Requirements

Staus

What's working

- The NoEMi events database is installed
- The Line finder scripts are installed
- The WUI output pages are not pubicly visible (coordination with Gary Hemming ongoing)
- Communication between the LF scripts and Condor BQS is working
- Communication between the LF scripts and the NoEMi events MySQL DB is working
- The main executable SFDB has been modified and is working (the detectors coordinates need to be updated, using virgo location for test)

What's missing

- Made the WUI page visible to users (we need to find the best authentication system, and choose the web page name)
- The last item will be the installation of the LineDB

NoEMi reconstructs false events produced by instrumental or environmental noise

Ornella Juliana Piccinni

Luca Naticchioni

researcher: Payload installation, 3G underground site selection, vibration measurements, R&D on new detection strategies

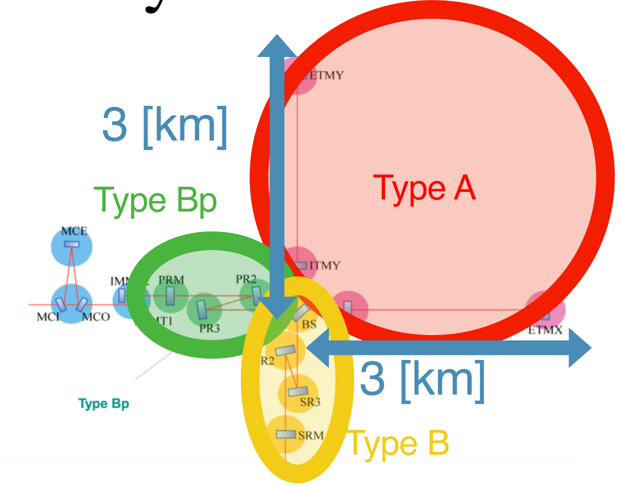
- **Destination**: Japan, ICRR @KAGRA site
- **Theme**: Assistance in commissioning shifts on seismic suspension tasks
- **Why in Japan**: towards 3G as KAGRA has a seismic suspension system inspired to Virgo, but a very different environment, being underground and cryogenic.
- **Activity goal**: Commissioning and Operation in underground

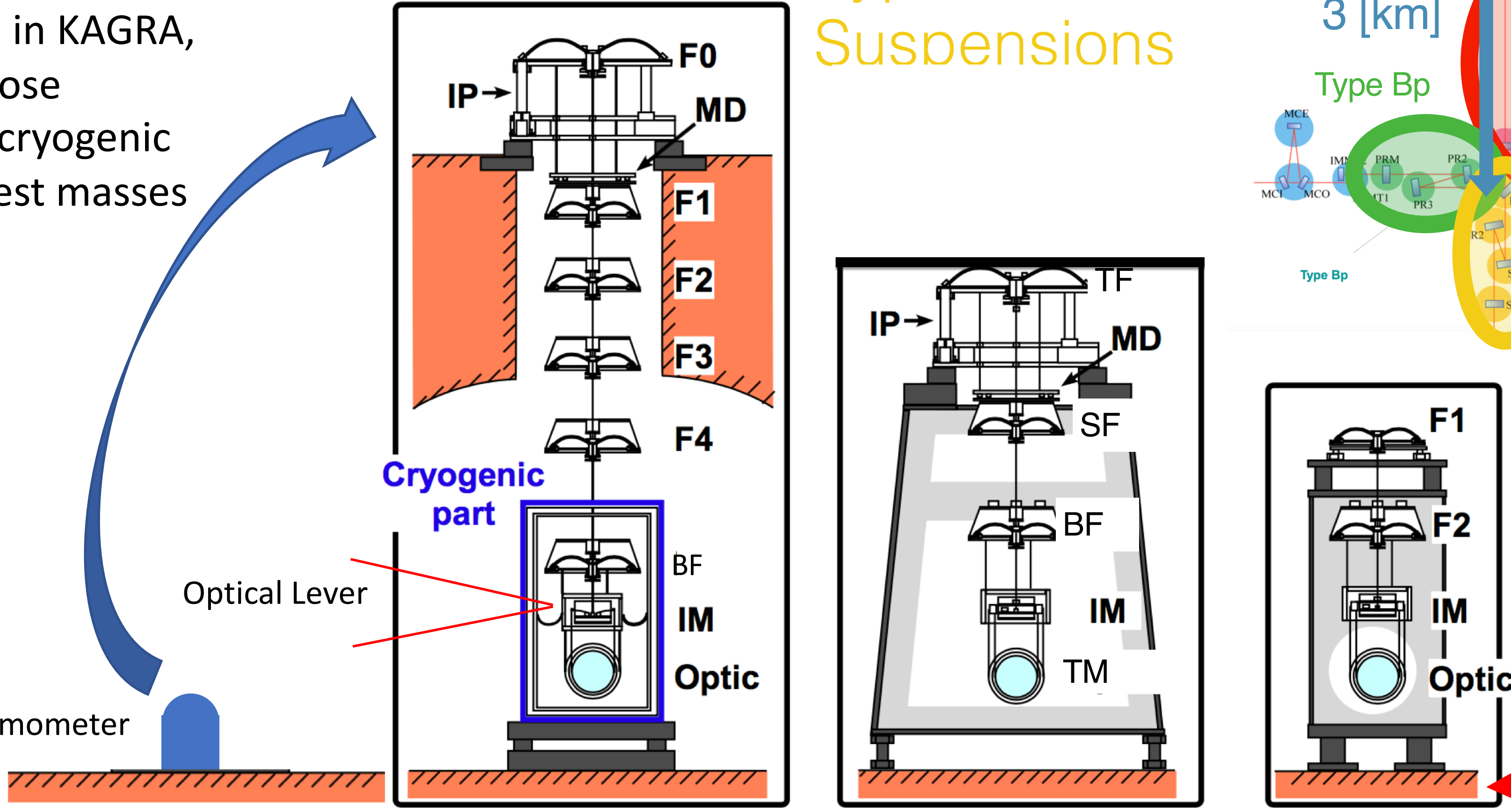
Luca Naticchioni: Mirror Suspension control with L. Trozzo (KAGRA staff)

VIS Suspension Systems

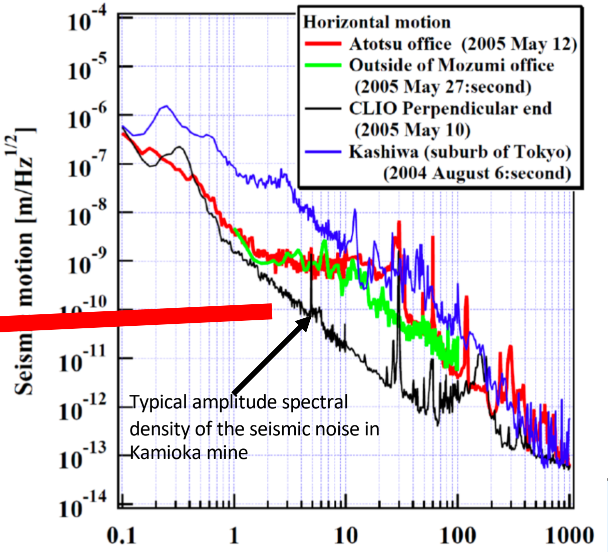
Type-B Suspensions

Several kind of suspension systems implemented in KAGRA, Type A are those dedicated to cryogenic payloads of test masses





Type-A Type-B Type-Bp



L.Trozzo, 22nd F2F KAGRA meeting, Kashiwa, 19-04-2019

Luca Naticchioni: Mirror Suspension control with L. Trozzo (KAGRA staff)

- Compliance of sensing devices actually installed in KAGRA with the suitable exploitation of low sesmicity provided by the site

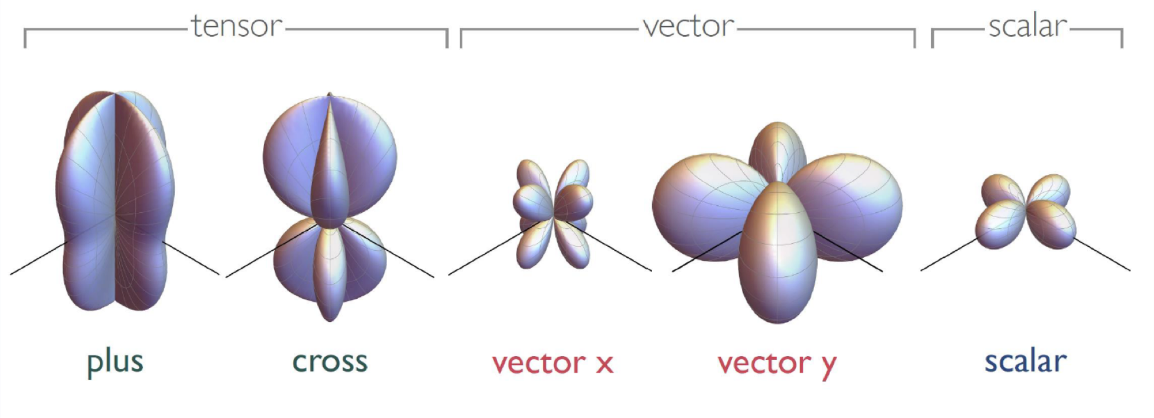
- Residual vibration impacting on test masses and Optical Lever use

- Sensing Diagonalization technicques KAGRA VS Virgo

- In Feb 2020 the will be followed also in 2020 during Observational Run O3

Giuseppe Intini

PhD in Virgo, GW theoretical physics/phenomenology



- **Destination**: US, CALTECH
- **Theme**: 5-vectors with non-GR polarizations models
- **Why in US**: Exchanges and Collaboration with Maximilian Isi
- **Activity goal**: Studying the potential of 5-vector algorithm

Non GR polarization: introduction

The GR has 4 more relations

$h_{\mu\nu}$:

16	**Components**
-6	**Symmetry**
-4	**Reference frame**
6	**Different Polarizations**

h_{ij}

SPIN $3 \otimes 3 = 5 \oplus 3 \oplus 1$

SPIN	Part of the matrix	Mode group
0	Trace	Scalar
~~1~~	~~Antisymmetric~~	~~Vectorial~~
2	Symmetric Traceless	Tensorial

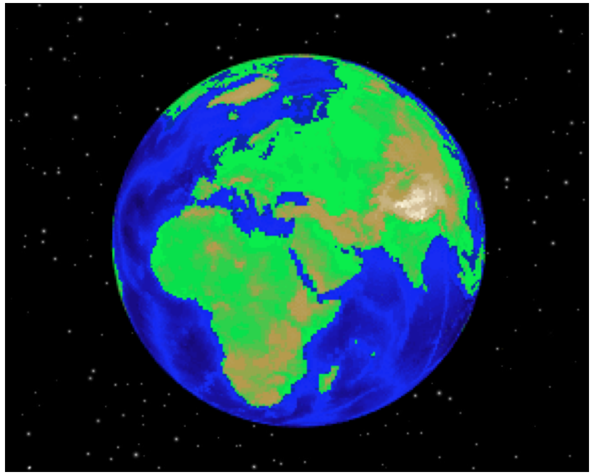
Symmetric Matrix

Giuseppe Intini

Scalar Polarization

$$\mathbb{e}_t = \frac{1}{3}\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

- It doesn’t transform under any rotation
  - It doesn’t have an actual antenna pattern for the 5 vectors
- It acts in the same way on all the directions
  - It is undetectable… at least by Virgo/LIGO interferometers



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Tensorial Polarizations

Polarization	Matrix	Transformation under rotations $\mathcal{R}$ along Z	SPIN
Plus	$\frac{1}{2}\begin{pmatrix}1 & 0 & 0\\ 0 & -1 & 0\\ 0 & 0 & 0\end{pmatrix}$	$\mathcal{R}_z(\psi)\mathbb{e}_+\mathcal{R}_z{}^T(\psi) = \mathbb{e}_+ \cos 2\psi + \mathbb{e}_\times \sin 2\psi$	$\alpha\lvert 2,+2\rangle \pm \beta\lvert 2,-2\rangle$
Cross	$\frac{1}{2}\begin{pmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 0\end{pmatrix}$	$\mathcal{R}_z(\psi)\mathbb{e}_\times\mathcal{R}_z{}^T(\psi) = \mathbb{e}_\times \cos 2\psi - \mathbb{e}_+ \sin 2\psi$	
x	$\frac{1}{2}\begin{pmatrix}0 & 0 & 1\\ 0 & 0 & 0\\ 1 & 0 & 0\end{pmatrix}$	$\mathcal{R}_z(\psi)\mathbb{e}_x\mathcal{R}_z{}^T(\psi) = \mathbb{e}_x \cos \psi + \mathbb{e}_y \sin \psi$	$\alpha\lvert 2,+1\rangle \pm \beta\lvert 2,-1\rangle$
y	$\frac{1}{2}\begin{pmatrix}0 & 0 & 0\\ 0 & 0 & 1\\ 0 & 1 & 0\end{pmatrix}$	$\mathcal{R}_z(\psi)\mathbb{e}_y\mathcal{R}_z{}^T(\psi) = \mathbb{e}_y \cos \psi - \mathbb{e}_x \sin \psi$	
Diagonal	$\frac{2}{3}\begin{pmatrix}½ & 0 & 0\\ 0 & ½ & 0\\ 0 & 0 & -1\end{pmatrix}$	$\mathcal{R}_z(\psi)\mathbb{e}_d\mathcal{R}_z{}^T(\psi) = \mathbb{e}_d$	$\lvert 2,0\rangle$

Difference with respect to Max Isi (2015, PRD 91)

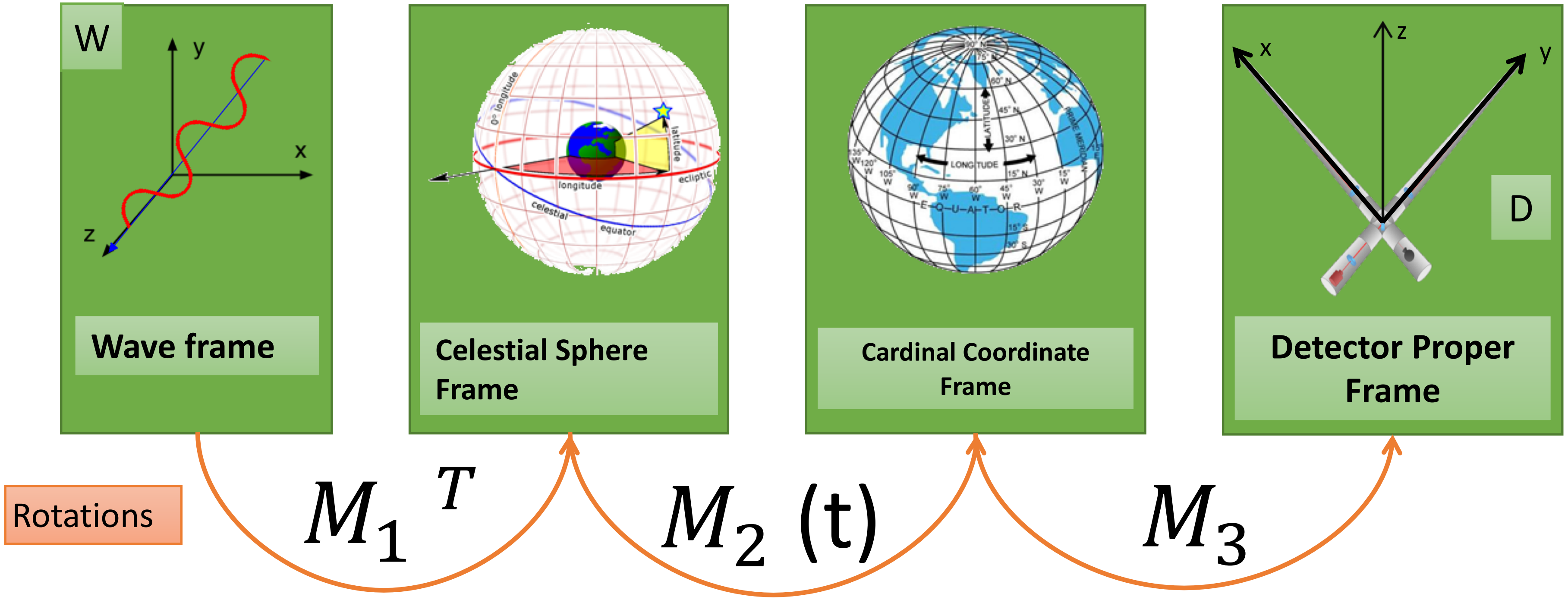
$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix} \textbf{Breathing: } \mathbb{e}_{\mathrm{b}} = 2\mathbb{e}_{\mathrm{t}} + \frac{2}{3}\mathbb{e}_{d}$$

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \textbf{Longitudinal: } \mathbb{e}_{\mathrm{l}} = \mathbb{e}_{\mathrm{t}} - \frac{2}{3}\mathbb{e}_{d}$$

- **In the (b,l) base:**
  - there are no undetectable polarizations
  - b and l are <u>degenerate</u> and <u>undistinguishable</u> (same antenna pattern)
  - we are <u>mixing</u> different spin particle
- **In the (d,t) base:**
  - there are no degenerate polarizations
  - t is undetectable in Virgo/LIGO but <u>may be detectable </u>in other interferometers

Antenna pattern computation

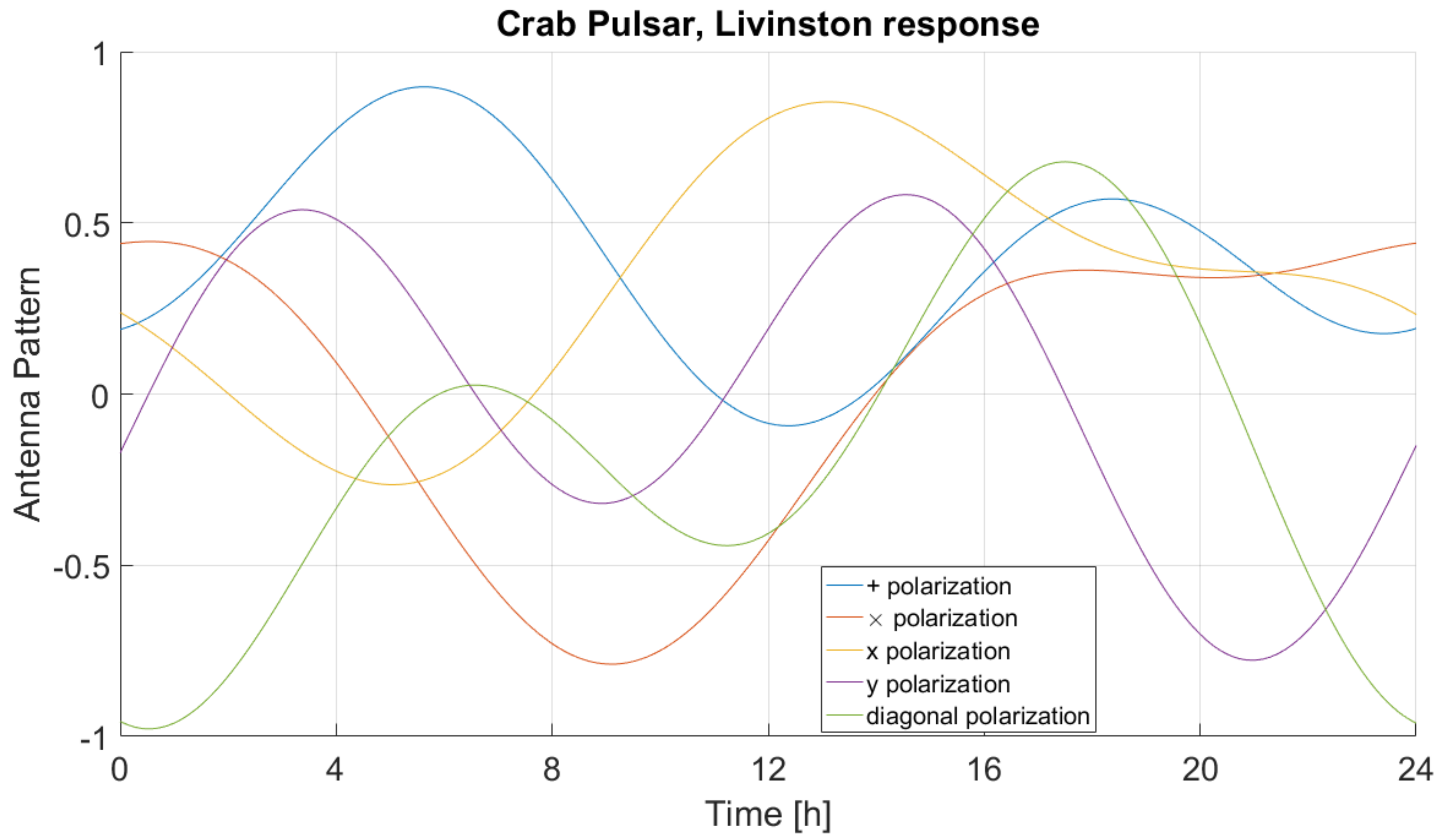
PRD 58.063001 (1998) - Jaranowski, Krolak, Schutz



$$\boldsymbol{h_D(t)} = \hat{x}^T M_3 M_2 M_1{}^T \boldsymbol{h_w(t)} M_1 M_2{}^T M_3{}^T \hat{x} - \hat{y}^T M_3 M_2 M_1{}^T \boldsymbol{h_w(t)} M_1 M_2{}^T M_3{}^T \hat{y}$$

Antenna pattern

The 5 Vectors functional form



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New elliptic Polarization

- $\mathbb{C}^5$ dimension polarization ellipse

$$h(t) = e^{-i\omega t} \sum_{p \in \{+,\times,x,y,d\}} h_p e^{-j\gamma_p} \mathbb{e}_p$$

- Consider separately
  - The |spin z| = 2 components (GR components)
  - The |spin z| = 1
  - The |spin z| = 0

$\boldsymbol{h'}_{0,1,2}$ is not a time derivative

$$\boldsymbol{h(t) = (h'_2(H_+\mathbb{e}_+ + H_\times\mathbb{e}_\times) + h'_1(H_x\mathbb{e}_x + H_y\mathbb{e}_y)e^{\cdots} + h'_0\,\mathbb{e}_d e^{-i\epsilon_0})e^{-i\omega t+\gamma}}$$

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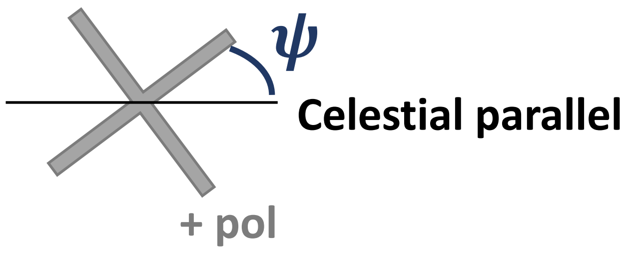
|spin z| = 2

Classic GR part (as actual definition)

$$\boldsymbol{h'_2(H_+ \mathbb{e}_+ + H_\times \mathbb{e}_\times)}$$

- $H_+ = \dfrac{\cos 2\psi - j\eta \sin 2\psi}{\sqrt{1+\eta^2}}$
- $H_\times = \dfrac{\sin 2\psi + j\eta \cos 2\psi}{\sqrt{1+\eta^2}}$



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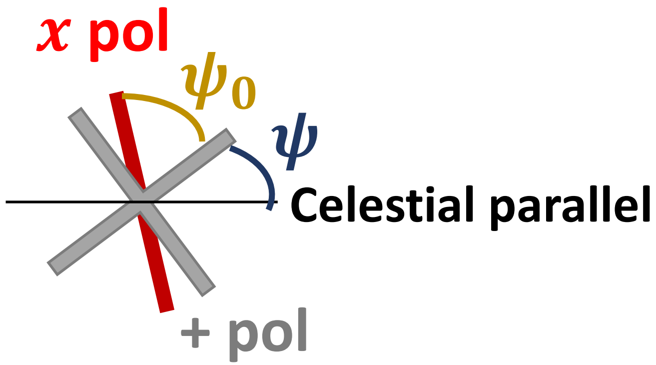
|spin z| = 1

We extend the definition as

$$h'_1\left(H_x \mathbb{e}_x + H_y \mathbb{e}_y\right)e^{-i\varepsilon_1}$$

- $H_x = \dfrac{\cos(\psi+\psi_0) - j\zeta\,\sin(\psi+\psi_0)}{\sqrt{1+\zeta^2}}$
- $H_y = \dfrac{\sin(\psi+\psi_0) + j\zeta\,\cos(\psi+\psi_0)}{\sqrt{1+\zeta^2}}$



ζ is the polarization ratio for the x-y polarizations.

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Overall amplitude and GR deviation angles

$$\boldsymbol{h}(\boldsymbol{t}) = [\boldsymbol{h'}_{\boldsymbol{2}}(\boldsymbol{H}_{+}\mathbb{e}_{+} + \boldsymbol{H}_{\times}\mathbb{e}_{\times}) + \boldsymbol{h'}_{\boldsymbol{1}}(\boldsymbol{H}_{\boldsymbol{x}}\mathbb{e}_{\boldsymbol{x}} + \boldsymbol{H}_{\boldsymbol{y}}\mathbb{e}_{\boldsymbol{y}})\boldsymbol{e}^{-\boldsymbol{i}\boldsymbol{\varepsilon}_{\boldsymbol{1}}} + \boldsymbol{h'}_{\boldsymbol{0}}\mathbb{e}_{\boldsymbol{d}}\boldsymbol{e}^{-\boldsymbol{i}\boldsymbol{\varepsilon}_{\boldsymbol{0}}}]\boldsymbol{e}^{-\boldsymbol{i}\boldsymbol{\omega}\boldsymbol{t}+\boldsymbol{\gamma}}$$

Collect the overall amplitude $\boldsymbol{h}_{\boldsymbol{0}} = \sqrt{\boldsymbol{h'}_{\boldsymbol{2}}^{\,2} + \boldsymbol{h'}_{\boldsymbol{1}}^{\,2} + \boldsymbol{h'}_{\boldsymbol{0}}^{\,2}}$

$$\boldsymbol{h'}_{\boldsymbol{2}} = h_0 \cos s_1 \cos s_0$$
$$\boldsymbol{h'}_{\boldsymbol{1}} = h_0 \sin s_1 \cos s_0$$
$$\boldsymbol{h'}_{\boldsymbol{0}} = h_0 \sin s_0$$

$(s_0, s_1) = (0{,}0)$ GR case

$$\boldsymbol{h}(\boldsymbol{t}) = \boldsymbol{h}_{\boldsymbol{0}}[\cos s_1 \cos s_0\, (\boldsymbol{H}_{+}\mathbb{e}_{+} + \boldsymbol{H}_{\times}\mathbb{e}_{\times}) +$$
$$+ \sin s_1 \cos s_0\, (\boldsymbol{H}_{\boldsymbol{x}}\mathbb{e}_{\boldsymbol{x}} + \boldsymbol{H}_{\boldsymbol{y}}\mathbb{e}_{\boldsymbol{y}})\boldsymbol{e}^{-\boldsymbol{i}\boldsymbol{\varepsilon}_{\boldsymbol{1}}} +$$
$$+ \sin s_0\, \mathbb{e}_{\boldsymbol{d}}\boldsymbol{e}^{-\boldsymbol{i}\boldsymbol{\varepsilon}_{\boldsymbol{0}}}]\boldsymbol{e}^{-\boldsymbol{i}\boldsymbol{\omega}\boldsymbol{t}+\boldsymbol{\gamma}}$$

Ongoing

- Generalize the injection codes
- Test the actual targeted search pipeline with non GR signals
- Generalize the targeted search to non GR signals
  - Given A_p the 5 vector response for each polarization, study the orthogonality (cross-correlation matrix)
    - 5 vettori -> 5 componenti. Rimane qualcosa per il rumore?
  - Study the detection statistic and the coherence for the generalized pipeline

Sibilla Di Pace

post-doc in Virgo, experienced in experimental optics, R&D on advanced detection strategies

- **Destination**: US,MIT
- **Theme**: Coating thermal noise measurement devices
- **Why in US**: a very effective apparatus meant to perform wide-band measurements of the coating thermal noise has been developed at MIT by E. Gras et al.. Both, Advanced detectors and 3G optics, will benefit of it.
- **Activity goal**: studying the device developed at MIT

COATING THERMAL NOISE FACILITY AT MIT

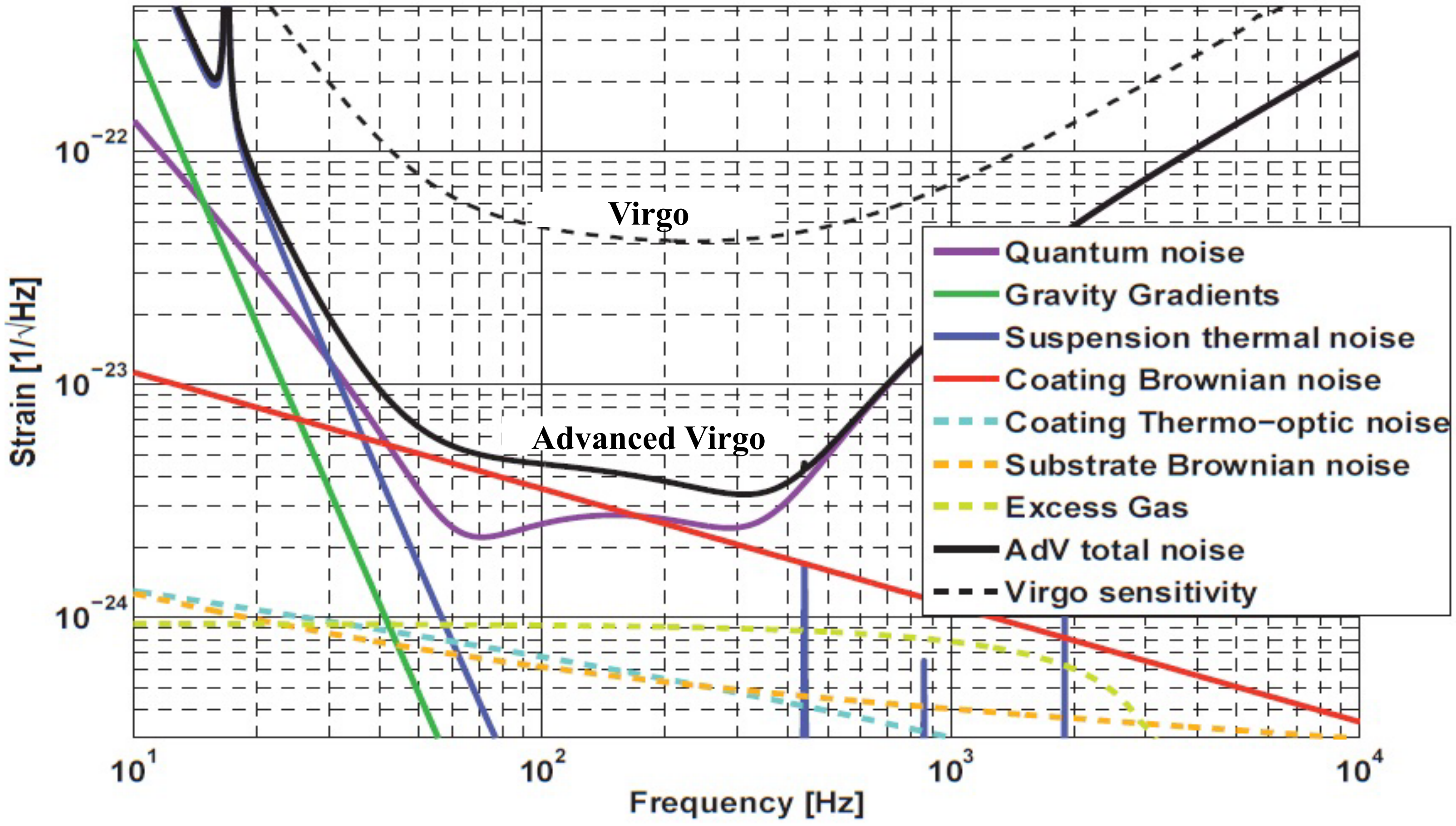
The goal of my visit at MIT LIGO lab is to study the Coating Thermal Noise (CTN) facility for the direct measurement of the coating thermal noise, which already gave important results concerning Advanced LIGO test mirrors, in order to define all the specifications required to realise in Rome an enhanced version of CTN experiment for the third generation of gravitational wave GW detectors

- DESCRIPTION OF THE CTN EXPERIMENT AT MIT
- EXPERIMENTAL RESULTS
- ESTIMATION OF CTN OF aLIGO END TEST MASS
- CONCLUSIONS and PERSPECTIVES

COATING THERMAL NOISE ISSUE

With the increasing sensitivity of ground based GW detectors, the **thermal noise of the coatings** of the main optics is becoming a limiting source of noise in the achievable sensitivity.
This issue gets even more critical for the future 3 rd generation of GW detectors, such as the European project called ET (Einstein Telescope)

Advanced Virgo Noise Curve expected for input Pin=125W



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COATING THERMAL NOISE MEASUREMENTS

Coating Thermal Noise (CTN) measurements:

Extrapolation from mechanical quality factors (Q), Poisson ratio, Young's modulus

LIMITATION:

- Uncertainty on the multilayer parameters
- Extrapolate from the mechanical Q (or loss angle) values

Direct measurements with Fabry Pérot Cavities

Suspended cavities
LIMITATION below 100Hz due to seismic motion

Fabry Pérot fixed
LIMITATION on the reflectivity of the measured sample due to readout in transmission

SOLUTION: FOLDED CAVITY
and probe with High Order Modes (HOM)

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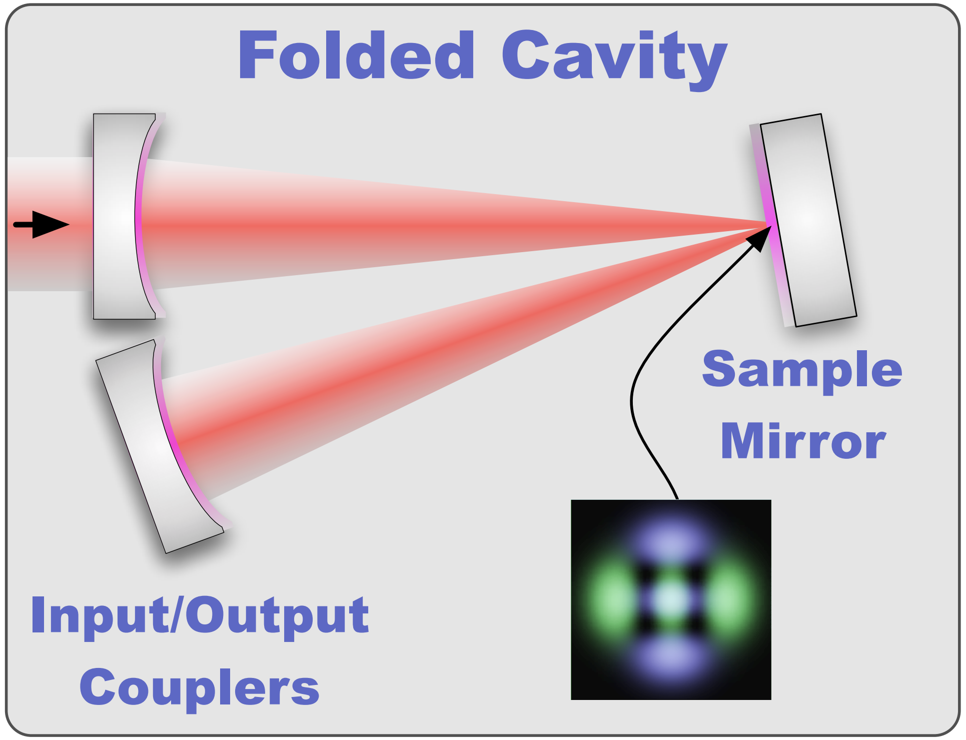
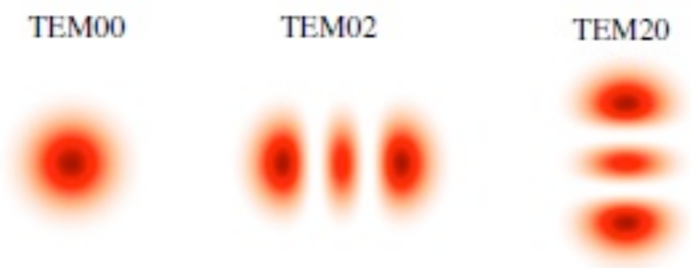
DESCRIPTION OF THE CTN FACILITY AT MIT

- One free-space Fabry Pérot cavity
- Cavity mounted on a vibrationally isolated platform in a vacuum chamber
- No upper limit on the sample reflectivity
- TEM modes 00, 02, 20 co-resonate: orthogonal spatial profiles probe different areas of the sample coating
- other displacement noises of the cavity are common to all resonating modes
- ***CTN is extracted from the frequency difference between the 2 higher order modes (TEM02, TEM20) measured in transmission***



S.Gras, M. Evans et al, 2016

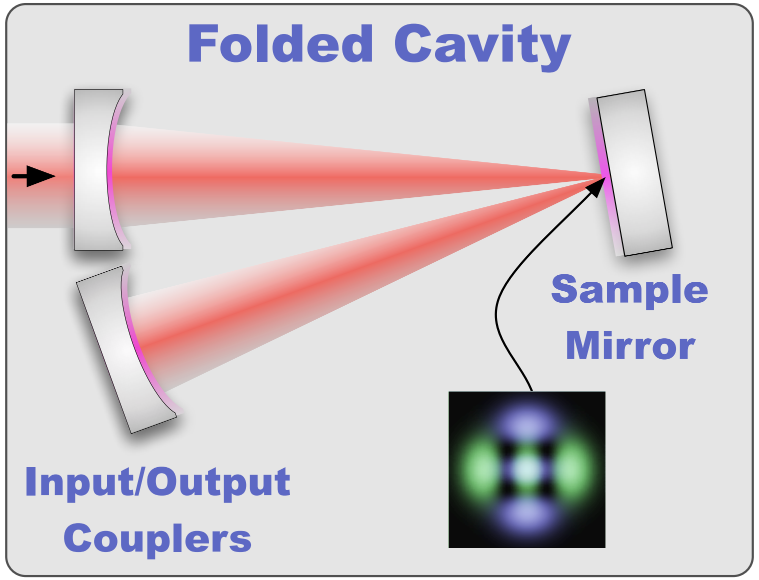


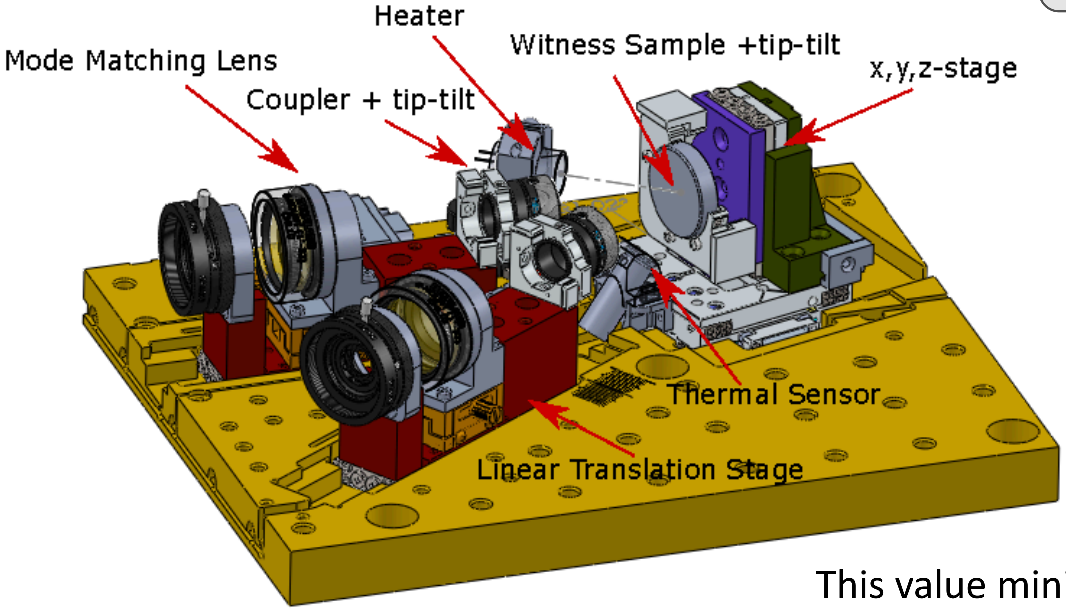
Since this experiment measures the difference between the resonance frequency of TEM20 and TEM02, ideally all cavity length noises cancel leaving only the desired CTN

DESCRIPTION OF THE CTN FACILITY AT MIT

Some other characteristics of the cavity:

- L=99.5mm, cavity length
- RoC=$R_{in\ c/out\ c}$=50.7mm, Couplers RoC
- w_0=49um, beam waist
- Transverse mode spacing 133MHz
- Nominal frequency difference between TEM00 and TEM02 and TEM20 is 266MHz
- Folding mirror= Sample mirror (high reflectivity flat mirror)
- High finesse 15000





In pratice, horizontal and vertical RoC are slightly different, so TEM20 and TEM02 experience different frequency shifts

This can be tuned by rotating the input coupler mirror wrt the output coupler

The **frequency difference of the 2 modes** defines the **BEAT NOTE frequency used for the main readout**

$$\Delta f_{20/02} = 4.5MHz$$

This value minimizes the laser frequency noise coupling and other technical noises

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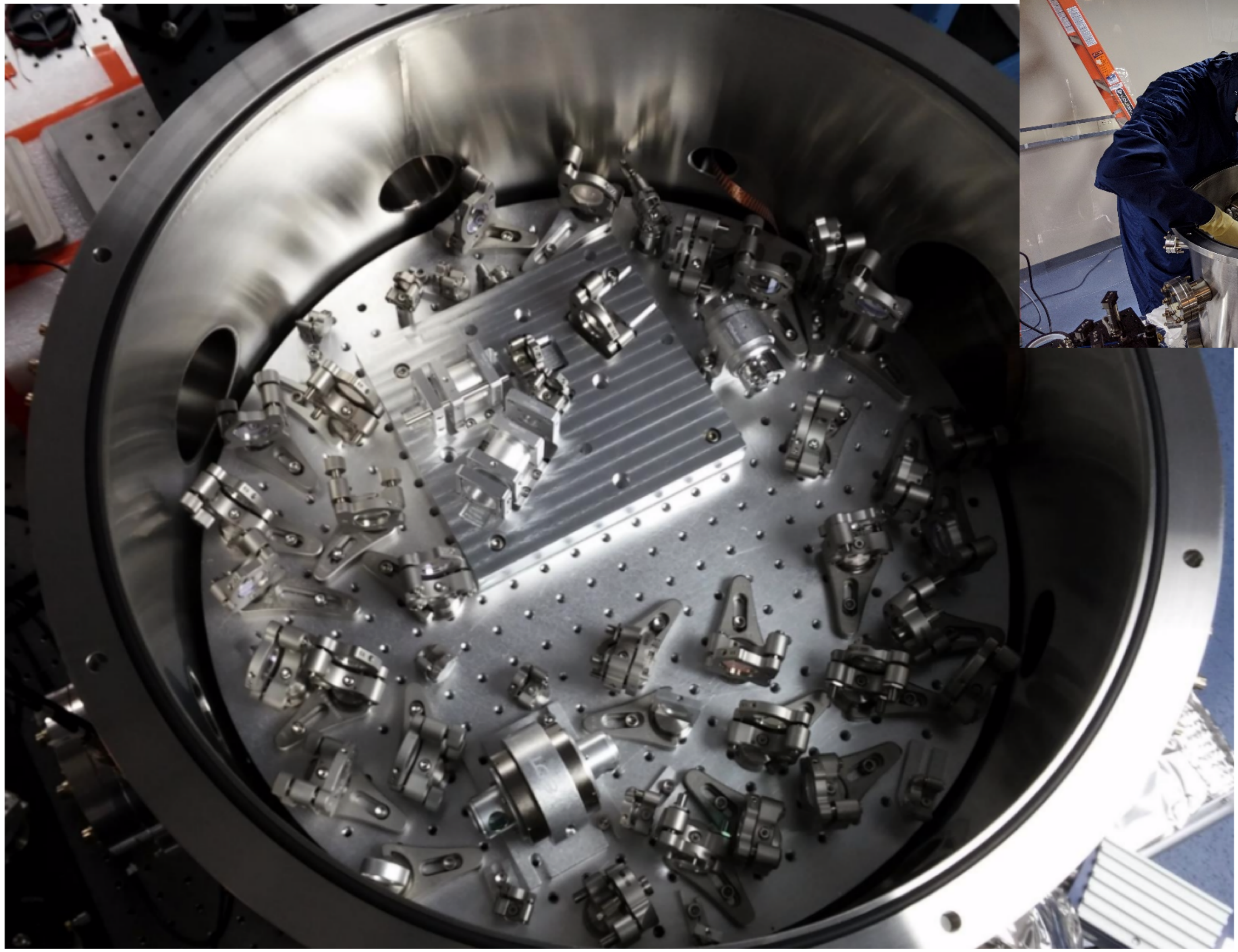
FOLDED CAVITY + OTHER OPTICS IN VACUUM TANK

- Cavity in vacuum
  10^{-5}Torr =1.33 10^{-5} mbar



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COATING THERMAL NOISE FACILITY AT MIT: CONCLUSION and PERSPECTIVE

- Novel experimet for broadband direct CTN measurement
- Achieved sensitivity $10^{-17} \frac{m}{\sqrt{Hz}}$ in the frequency band (30Hz-2kHz)
- Thanks to high finesse FOLDED CAVITY with TEM00, TEM20, TEM02 co-resonating
- Folded mirror is the sample mirror (flat high reflective mirror)
- Rapid testing of new coatings for future generation of GW detectors

- CTN facility already gave important results on coating thermal noise direct measurements
- An upgraded setup will allow to investigate and identify suitable coating materials for test mass mirrors for the third generation of GW detectors
- The realisation of an enhanced CTN setup in Rome is of great interest for all the GW scientific community, and it will gave to the group a dominant role in this domain

Sibilla Di Pace

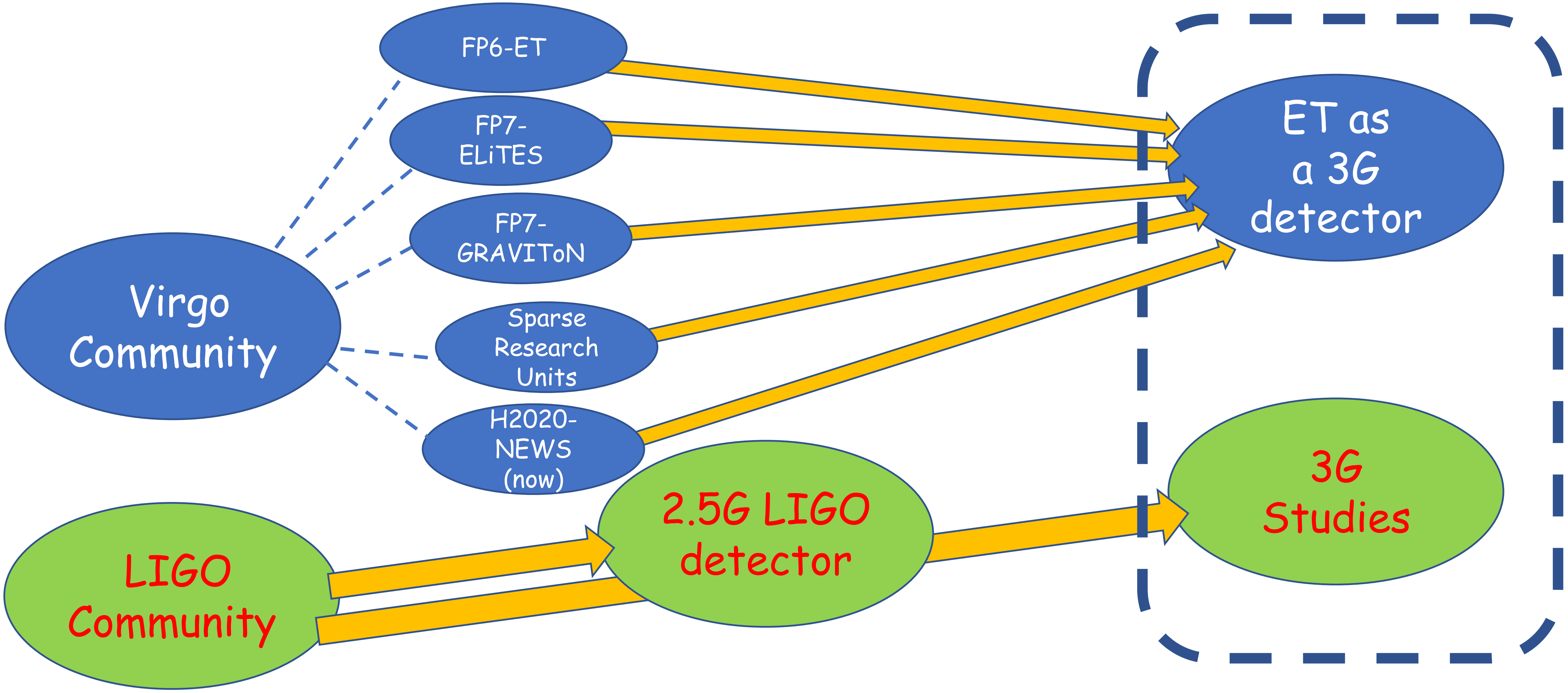
Ettore Majorana

Lead researcher, GW detectors

- **Destination**: Japan, ICRR
- **Theme**: KAGRA experience in Underground/Cryogenics
- **Why in Japan**: integrating a pre-existent fruitful collaboration in RISE-NEWS in the 3G perspective
- **Activity goal**: Installation of cryogenic payloads and further developments

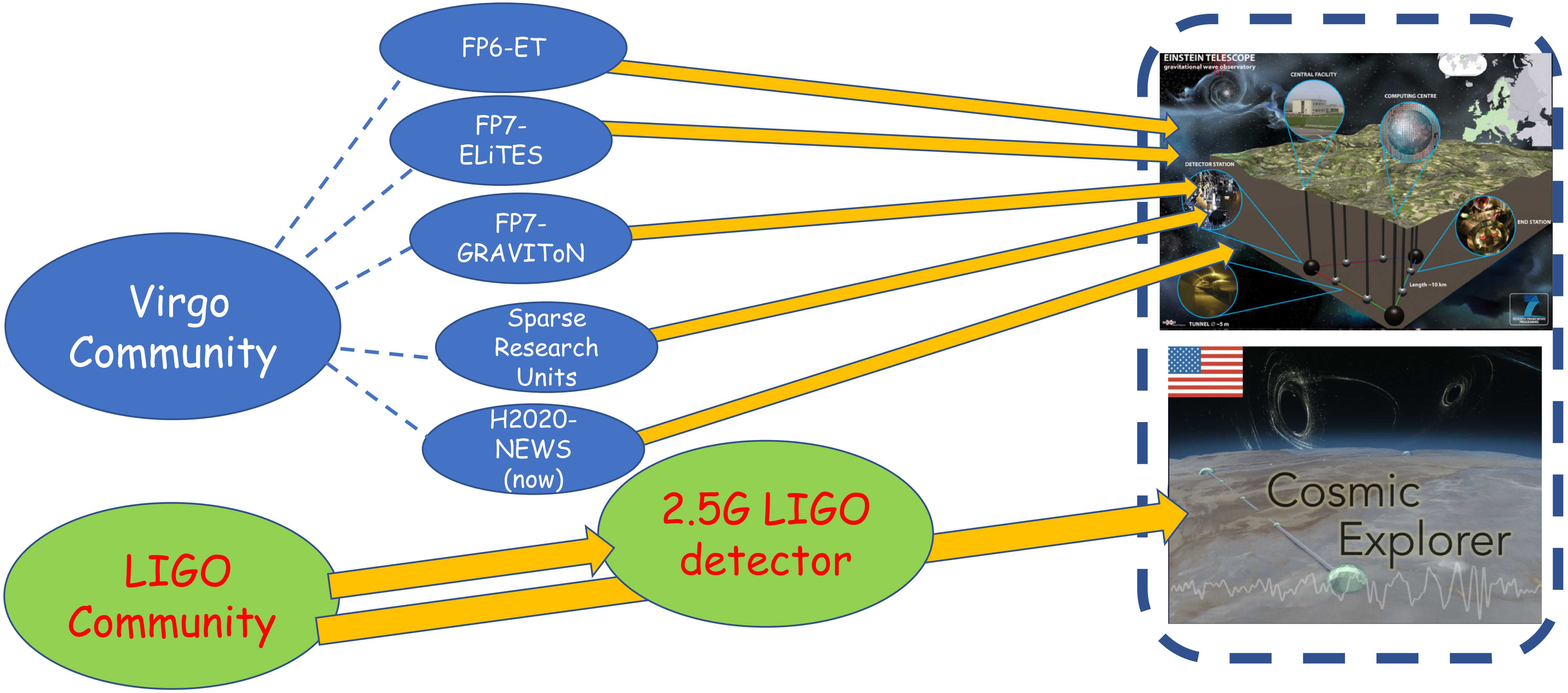
A glance: the development of 3G ideas

2nd generation detectors evolution and 3G roadmap: different scenarios in US vs Europe in the last decade

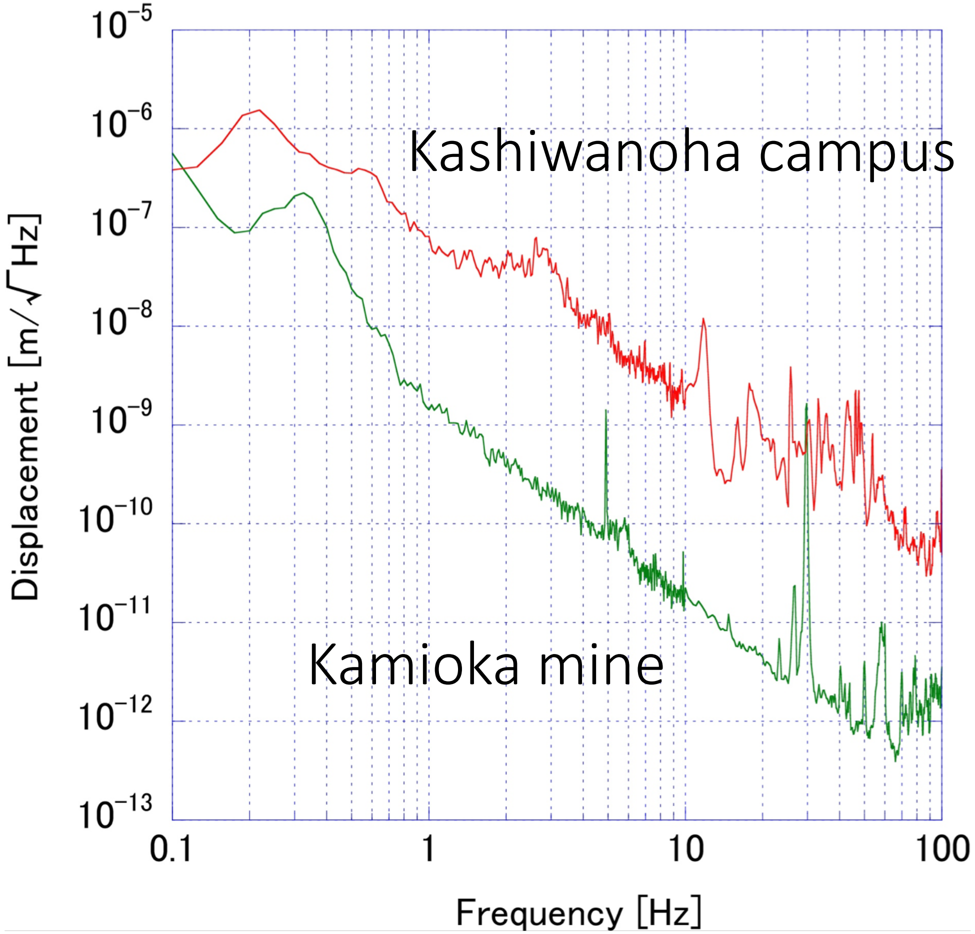


A glance: the development of 3G ideas

2nd generation detectors evolution and 3G roadmap: different scenarios in US vs Europe in the last decade



KAGRA a glance



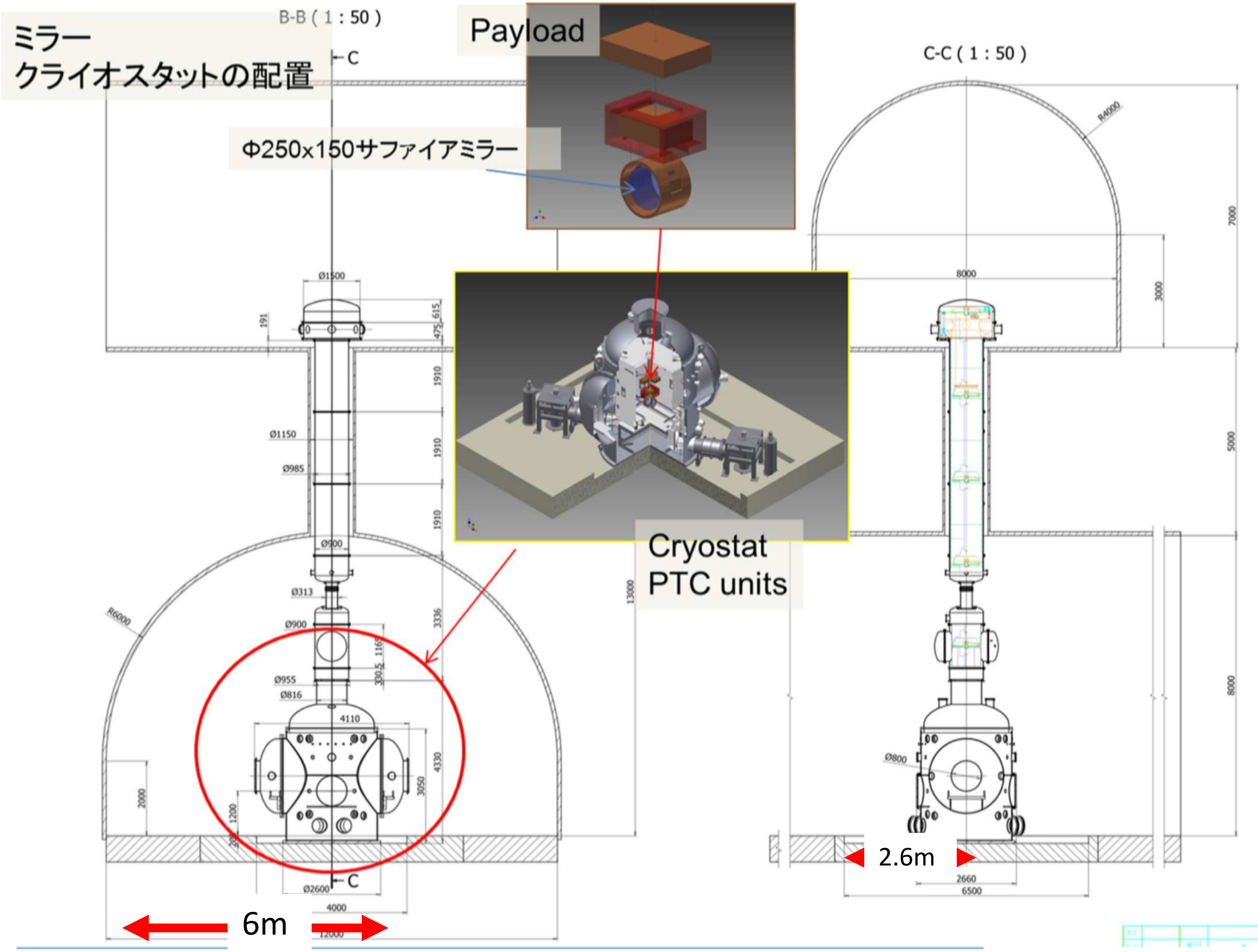
Cryogenics
(low thermal noise)
Pretested at Toshiba
Keihin Product

Underground
installation
(low seismic noise)

KAGRA many issues but…major experience in this field

- No scaffolding to mount the suspension
- More complex, but smaller volume excavated
- Compact cryostats …

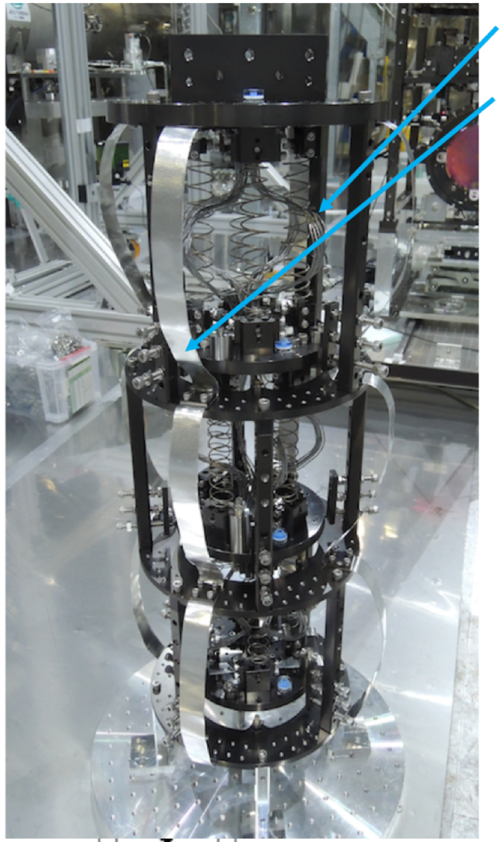
cryostat and sesimic isolation designs are strongly connected to the site characteristics and infrastructure



KAGRA Cryostats: mechanical characterization

Vibration measurement on cryostats is the last session. What else ?

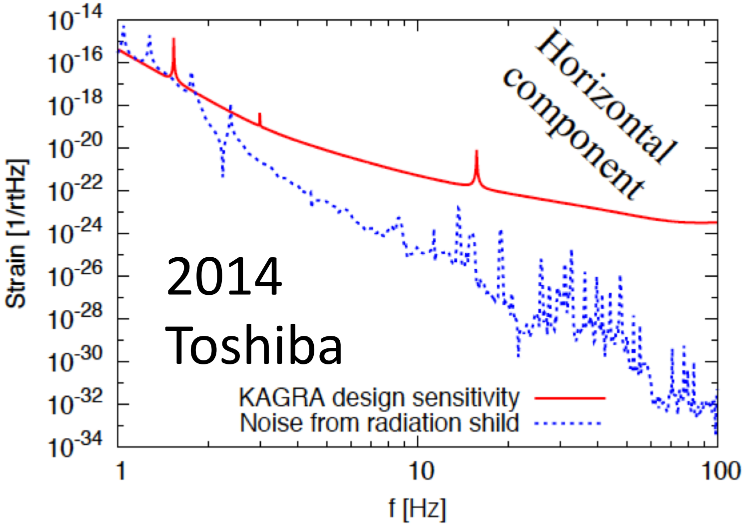
- ✓ Cooling issues (Thermal conductivity)
- ✓ Payload design and component characterization
- ✓ Seismic attenuation system
- ✓ Payload control
- ✓ Mechanical disspation & thermal noise

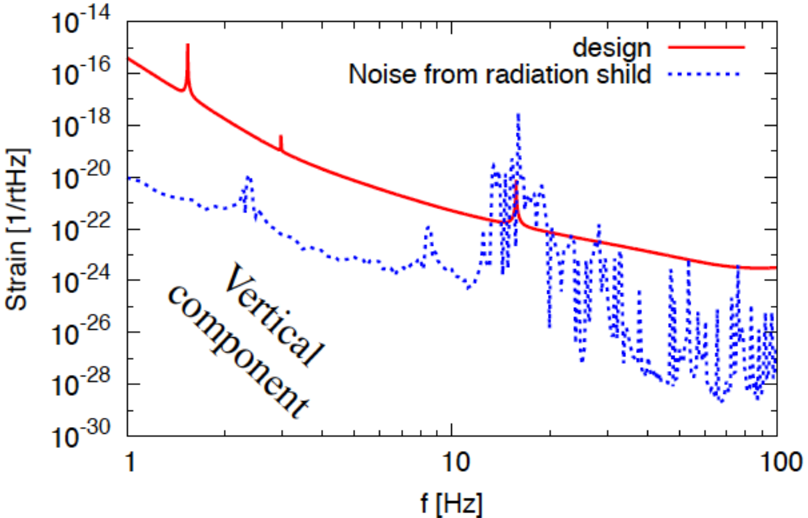


Heat-links

6N Aluminum thin band

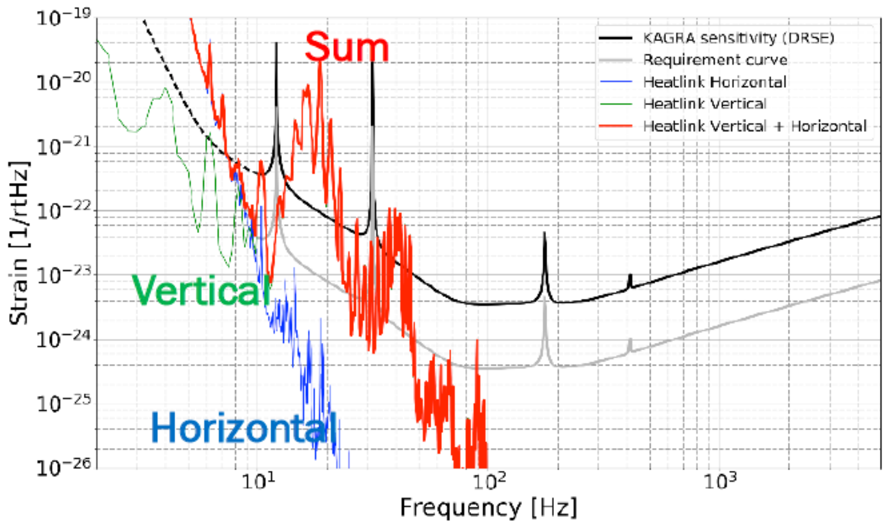
All the HLVISs in total have been installed into each cryostat.



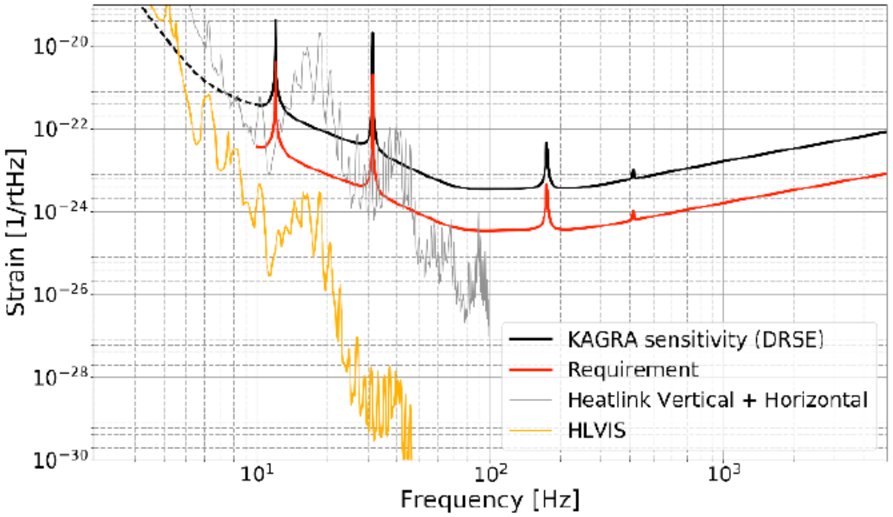


2018 at Kamioka

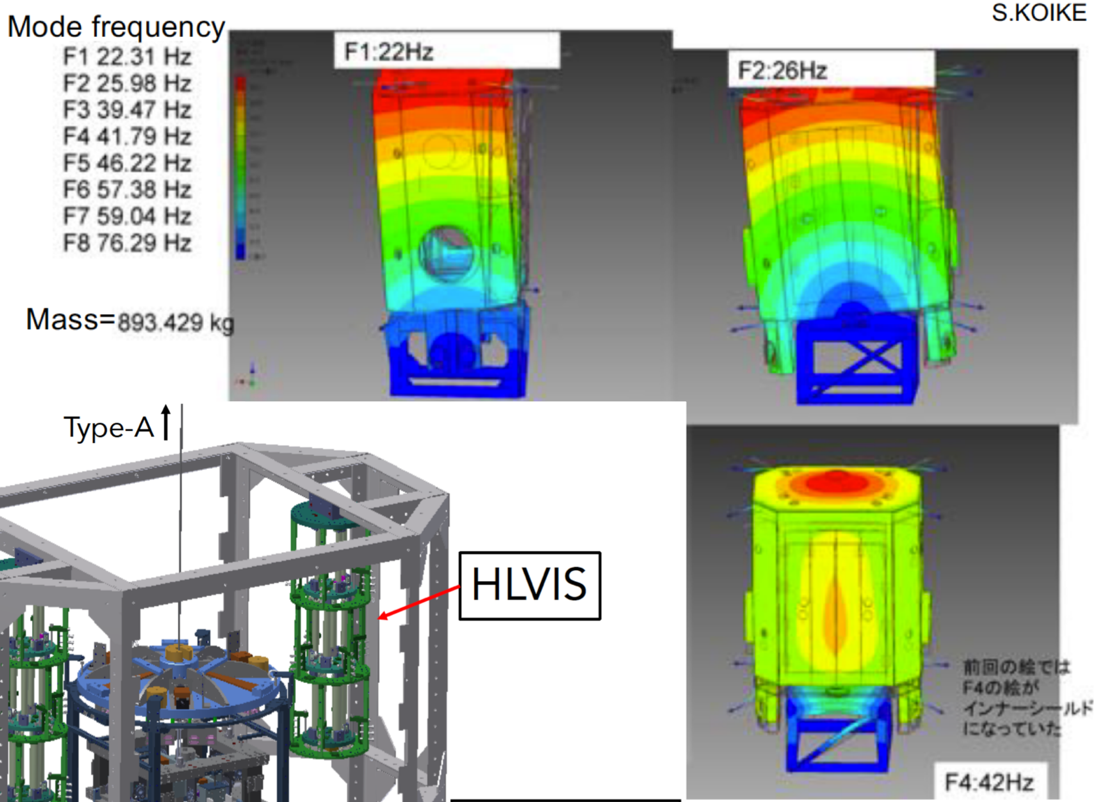
KAGRA ACCURATE CRYOSTAT DESIGN CRUCIAL GUARANTEE UNDERGROUND LOW SEISMICITY !

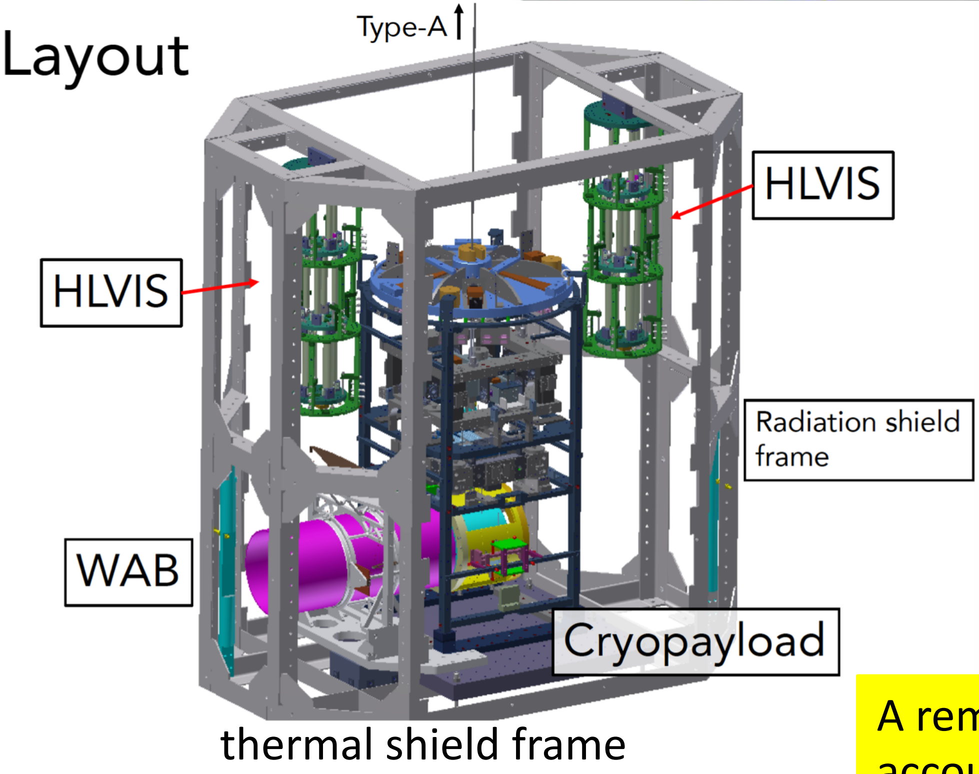


Improved by HLVIS



S.KOIKE





A remark: KAGRA had accounted all of that

KAGRA Cryogenic payload Sapphire, material selection and characterization

We will use **sapphire fibers** (φ 1.6 mm) to suspend cooled sapphire mirrors(20K).

High thermal conductivity → lower cooling time

High Q value → lower thermal noise

Requirements

Thermal conductivity: 5000 W/m/K

Q value: 5×10^6 etc...

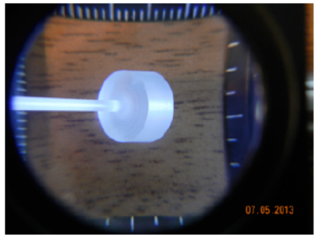
In Rome we tested two samples with good thermal conductivity.

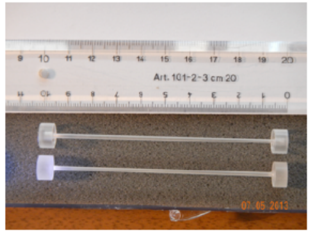
Fiber 1: 5000 W/m/K @20K

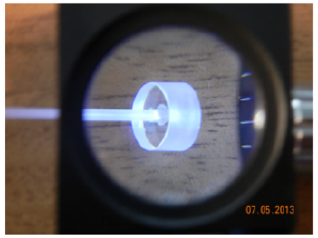
Fiber 2: 9000 W/m/K @20K

Our purpose is measuring the Q value of these fibers @ 20K

2.Sapphire fiber at Rome







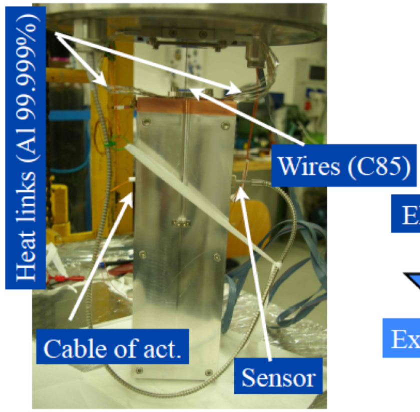
Fiber 1

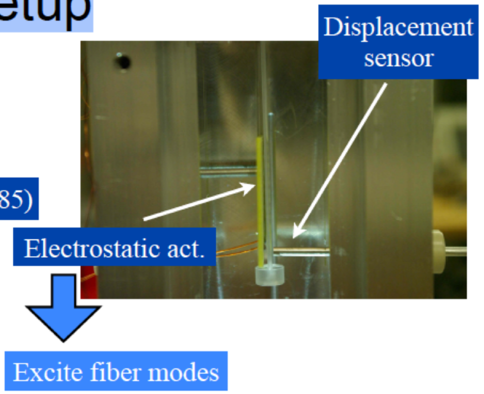
- 5000 W/m/K @20K
- Monolithic

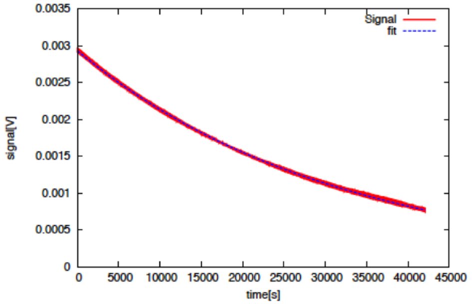
Fiber 2

- 9000 W/m/K @20K
- Non-monolithic
- Brazed through alumina
- HEM quality
- Thermopolishing

3.Measurement setup

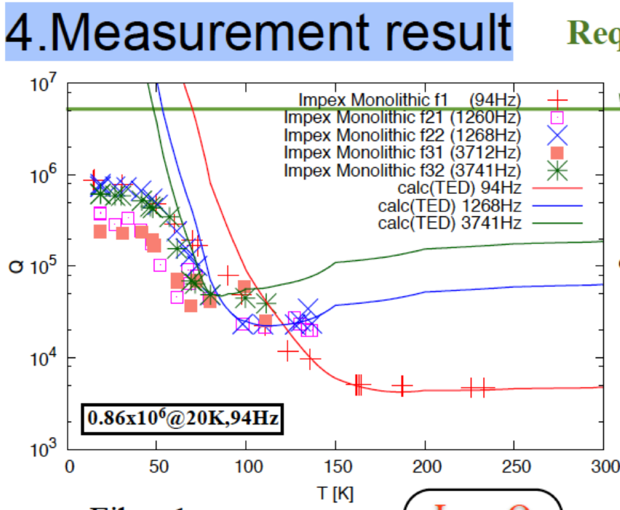




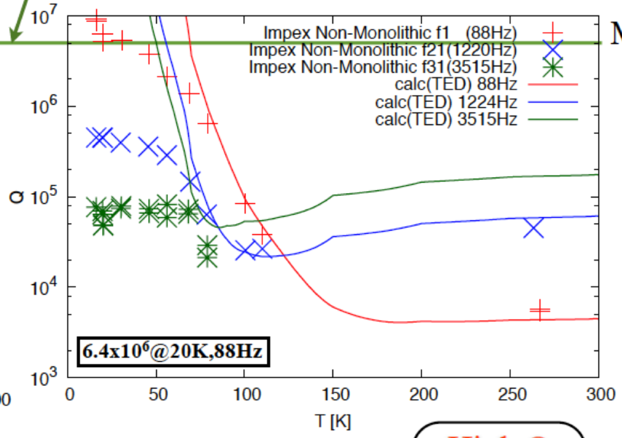


We calculated Q from the ring dawn signal.

4.Measurement result

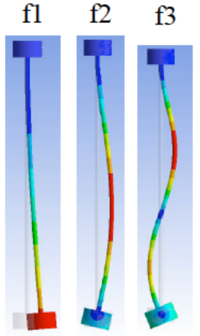


Fiber 1 Low Q



Fiber 2 High Q

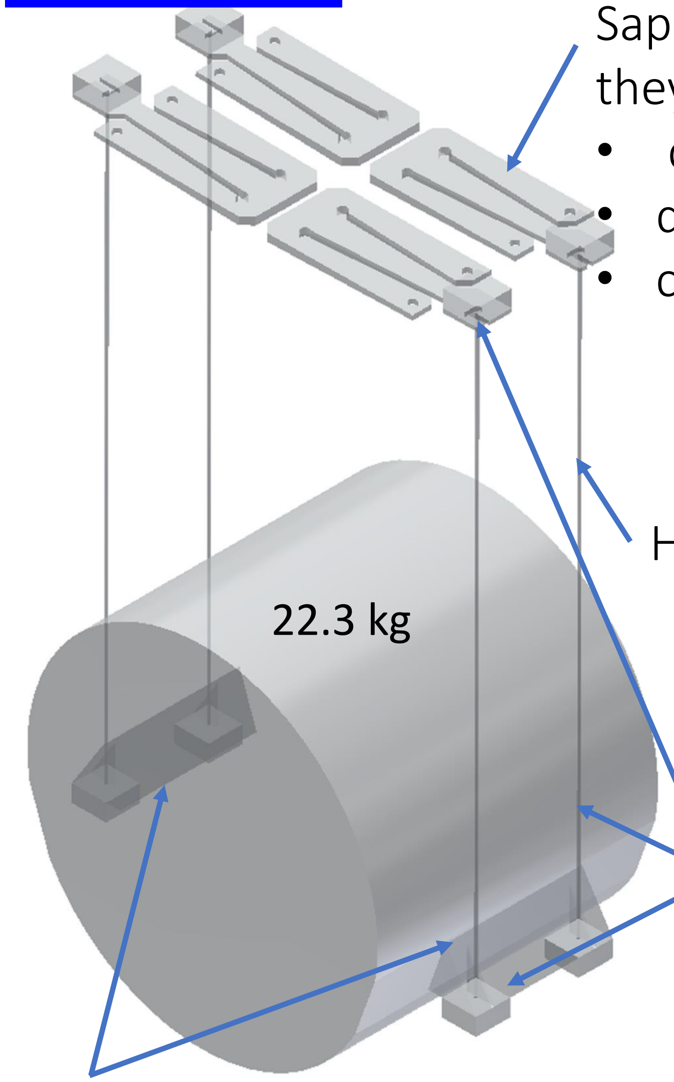
Modal simulation



We measured Q values of two kinds of sapphire fiber whose thermal conductivity is higher than the requirement value. **One of them (fiber 2) has high Q which is higher than requirement value.** This means even non-monolithic fiber can have high Q. HEM quality and thermopolishing might improve Q value.

KAGRA

Cryogenic payload Sapphire, material selection and characterization



Sapphire Blade springs, needed to distribute the stress due to length difference, they must be:

- compact
- detachable to substitute the suspension ➔ Interface layer of thin material
- contacted to the fiber heads without spoiling

thermal conductivity ➔ TESTS/selection/design

quality factor ➔ TESTS/selection/design

High thermal conductivity needed ➔ Sapphire, 20 K ➔ fibre diameter 1.6 mm

Monolithic machining of Sapphire fibers two heads non-trivial, several test
350 mm-long still a challenge (monolithic 100 mm-long max)

A great advancement in 2014 (Glasgow):
HCB of Sapphire surfaces (mirror ears) possible thanks to the KAGRA development context !

<table><tr><td>KAGRA</td><td>Comparative tests in Rome
(just an example…)</td></tr></table>

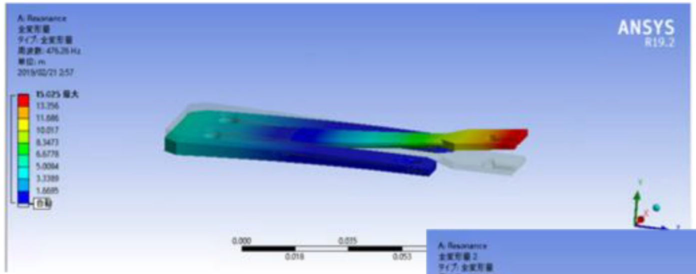
RISE-NEWS well integrated in 3G perspective

Japanese ESR and SR supported by JSPS visit GW community and local facilities

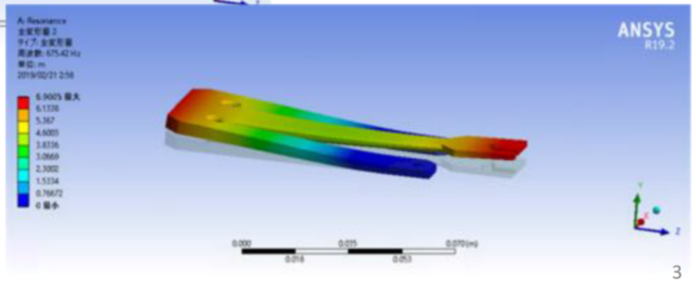
- Development in local facilities
- Virgo (for payload installation, control …)
- Collaborative effort figuring out present and future engagement in GW physics accessed by Detectors

KAGRA blade measurement(1st mode)

- Maximum measured Q: 1.3×10^{5} in 1st mode
  ⟷ 2.8×10^{4}@ KASHIWA
  (Requirement: 1.6×10^{6})
- ANSYS mode analysis



1st mode: 476 Hz



2nd mode: 675 Hz

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