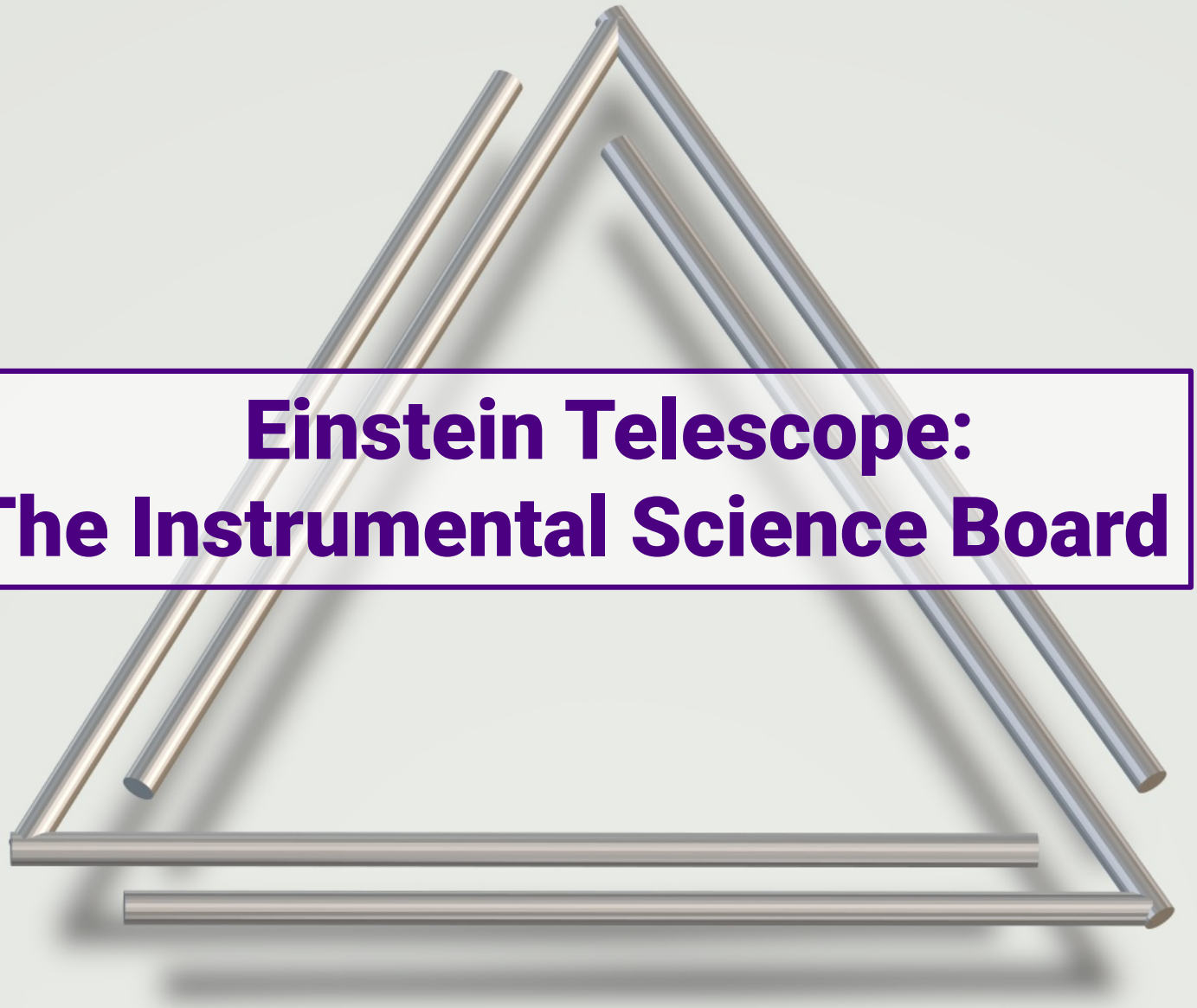


Einstein Telescope: The Instrumental Science Board

J. Degallaix

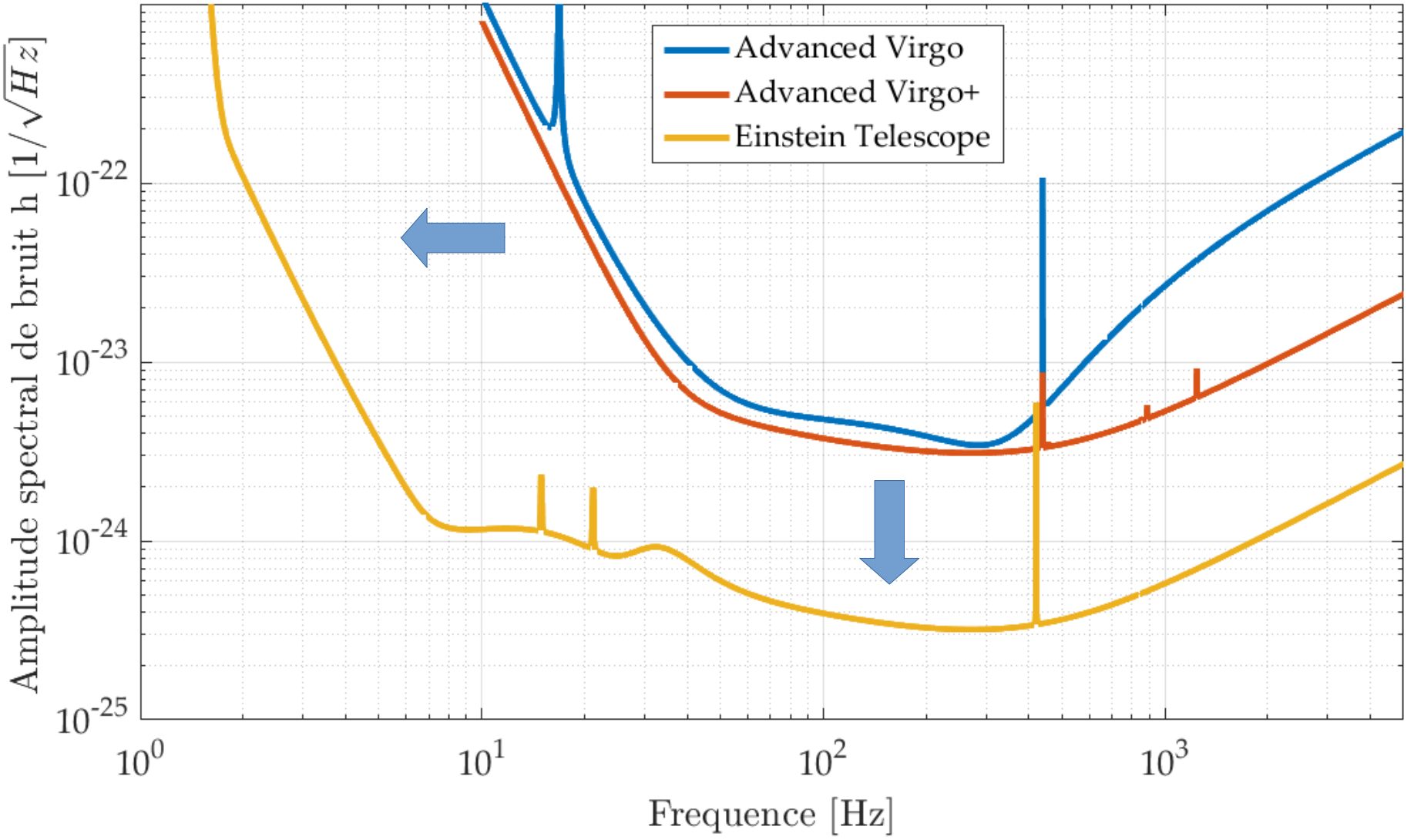
ET EINSTEIN TELESCOPE

IP2I – Juillet 2022

I
Einstein Telescope - l’instrument

But de ET: être 10 fois plus sensible

que la seconde génération de LIGO-Virgo (Advanced Virgo/LIGO)



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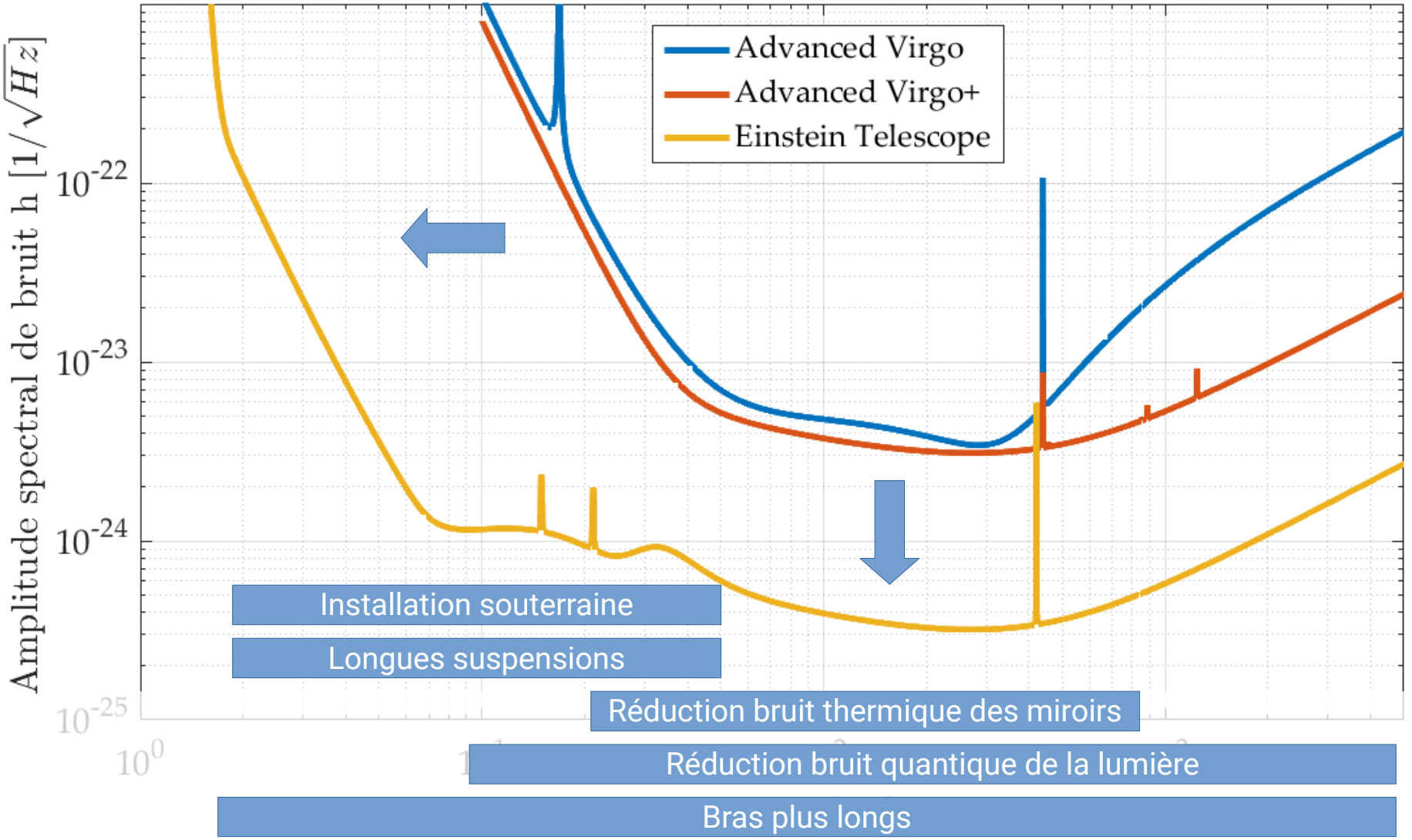
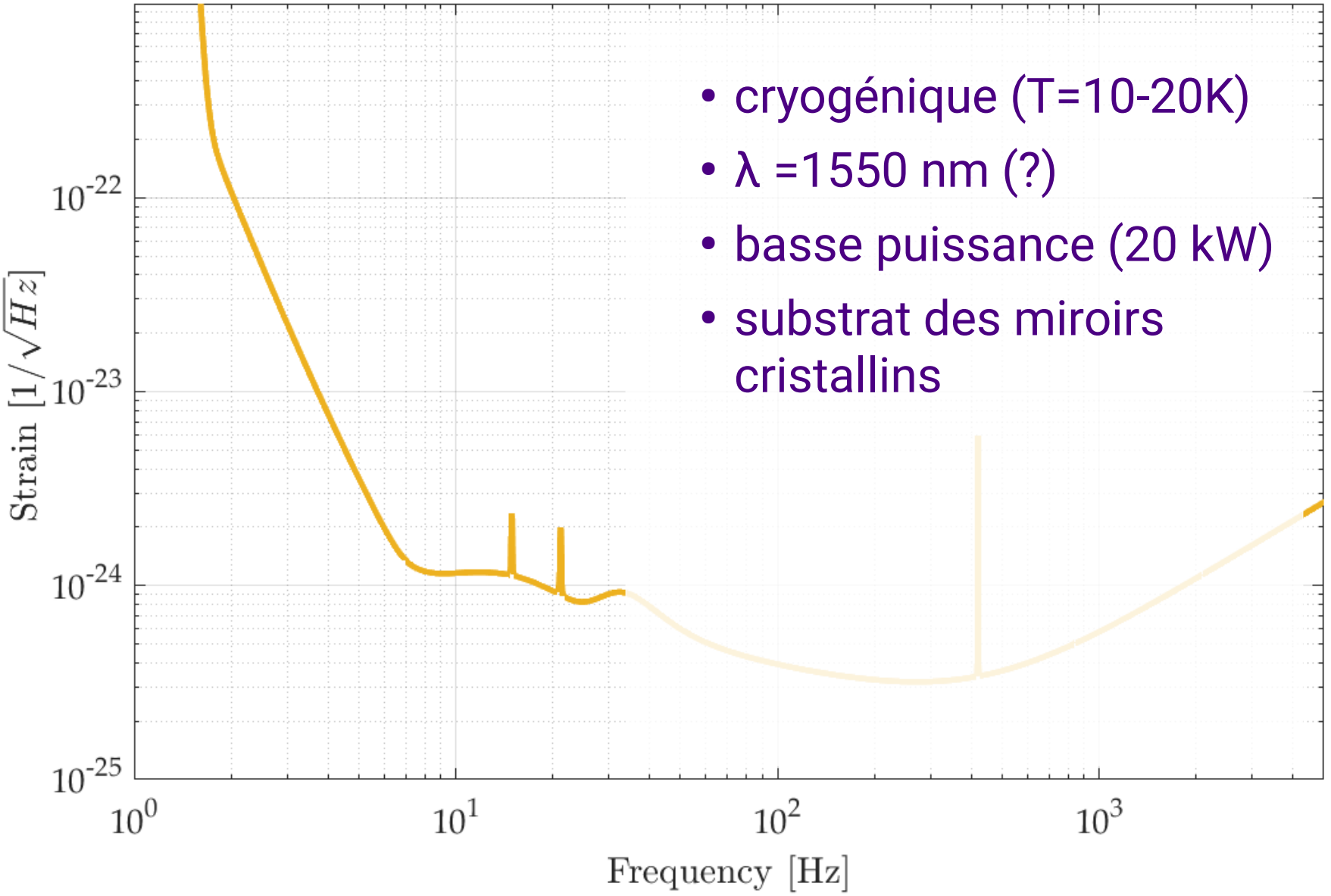


La courbe de sensibilité reconstituée

Le détecteur basse fréquence (ET-LF)

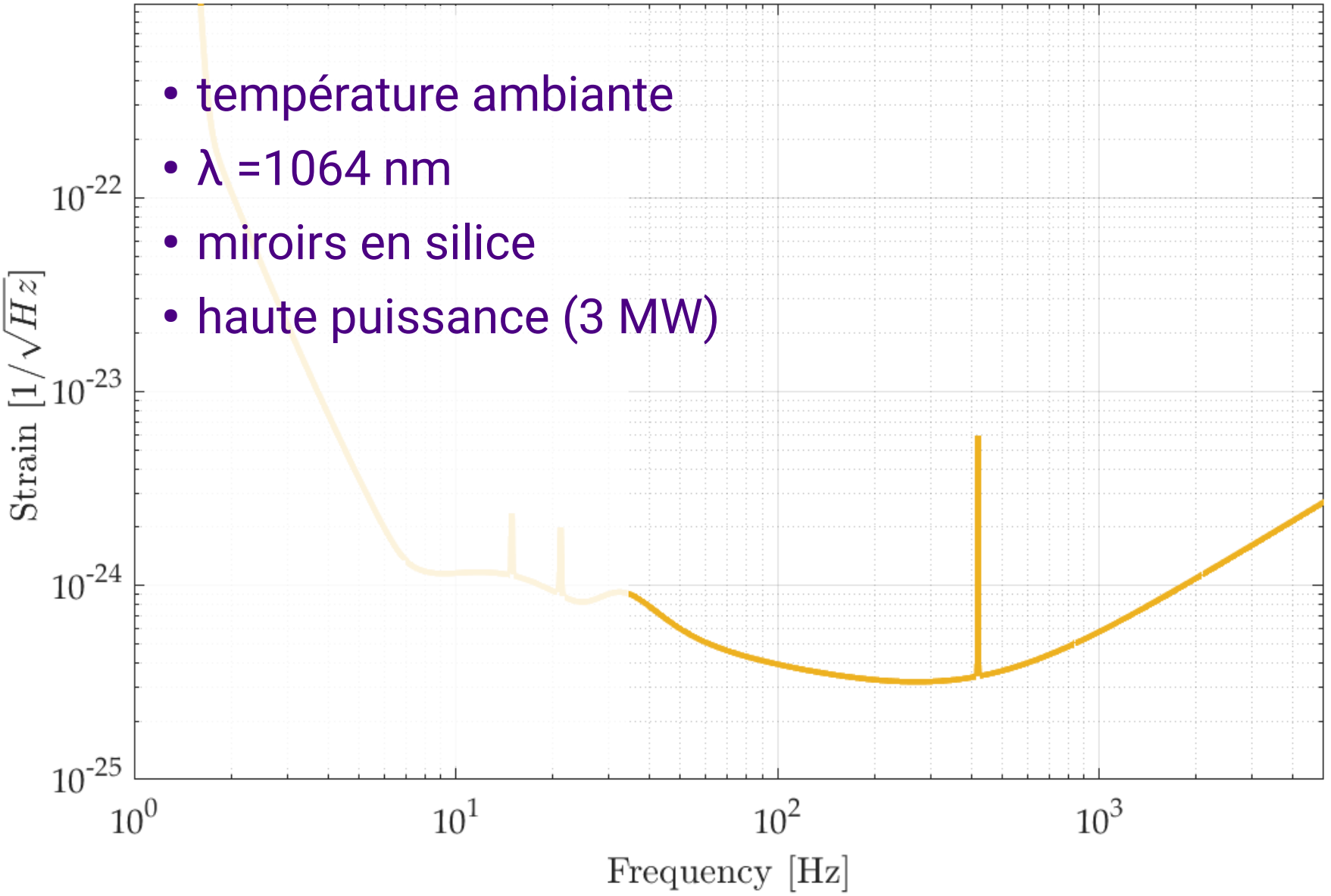


- cryogénique (T=10-20K)
- λ =1550 nm (?)
- basse puissance (20 kW)
- substrat des miroirs cristallins

La courbe de sensibilité reconstituée

Le détecteur haute fréquence (ET-HF)

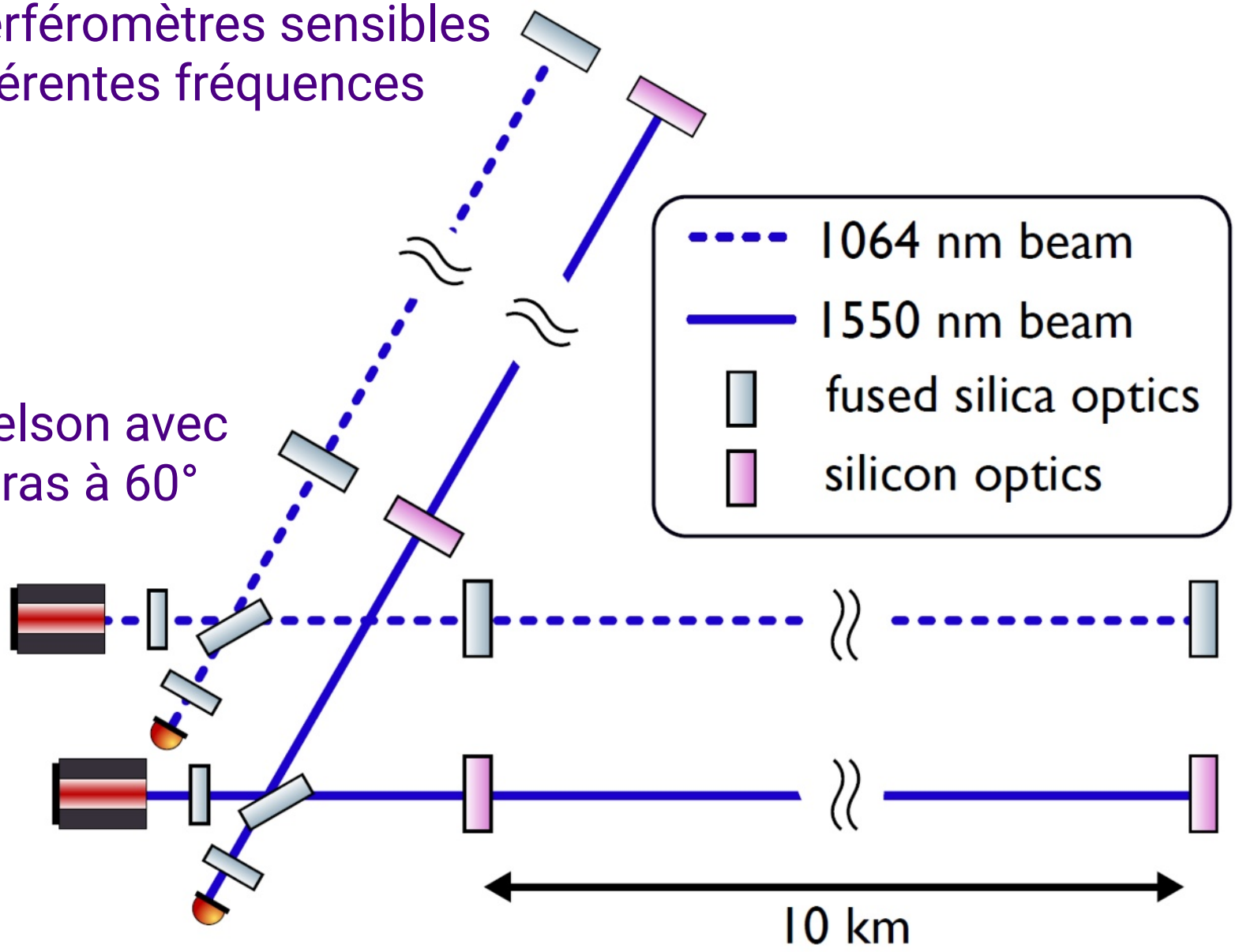
- température ambiante
- λ =1064 nm
- miroirs en silice
- haute puissance (3 MW)



1 détecteur = 2 interféromètres

2 interféromètres sensibles
à différentes fréquences

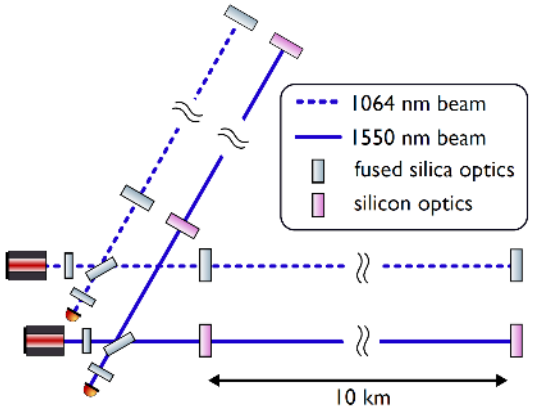
Michelson avec
des bras à 60°

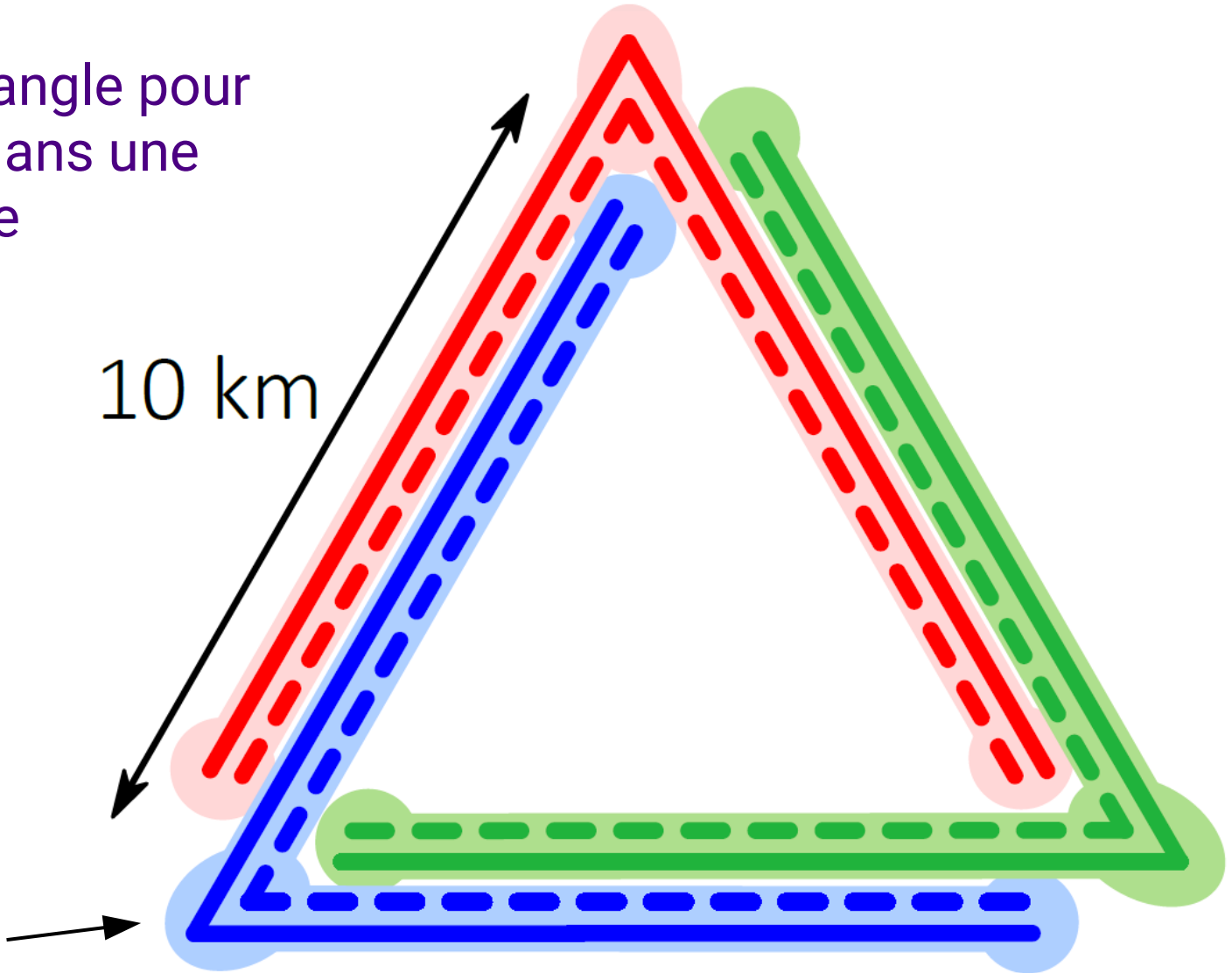


https://apps.et-gw.eu/tds/ql/?c=15707

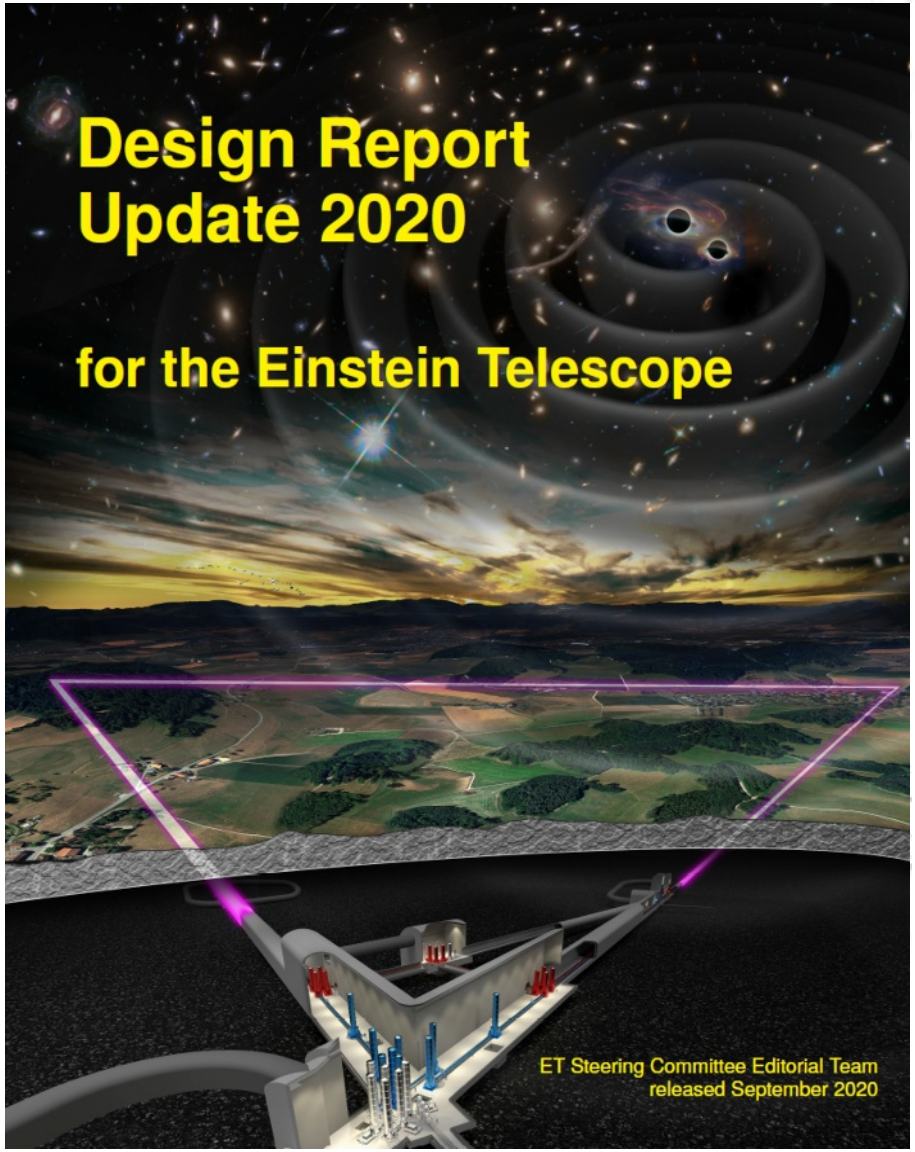
Pas 1, mais 3 détecteurs

Configuration en triangle pour avoir 3 détecteurs dans une même infrastructure





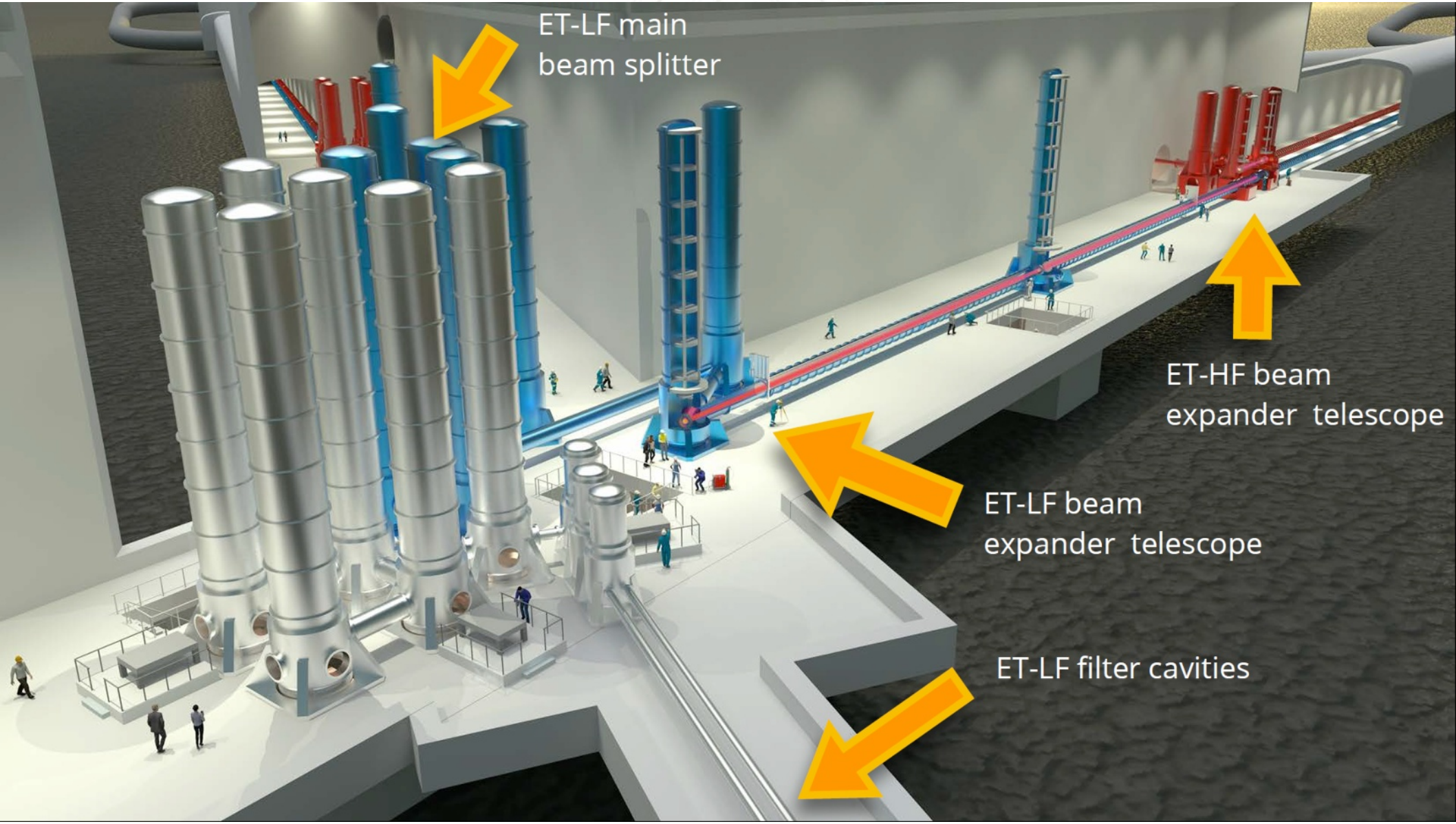
Pour en savoir plus...



Parameter	ET-HF	ET-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10-20 K
Mirror material	fused silica	silicon
Mirror diameter / thickness	62 cm / 30 cm	45 cm/ 57 cm
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase (rad)	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×300 m	2×1.0 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	TEM_{00}	TEM_{00}
Beam radius	12.0 cm	9 cm
Scatter loss per surface	37 ppm	37 ppm
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10}\,\mathrm{m}/f^2$	$5 \cdot 10^{-10}\,\mathrm{m}/f^2$
Gravity gradient subtraction	none	factor of a few

https://apps.et-gw.eu/tds/ql/?c=15418

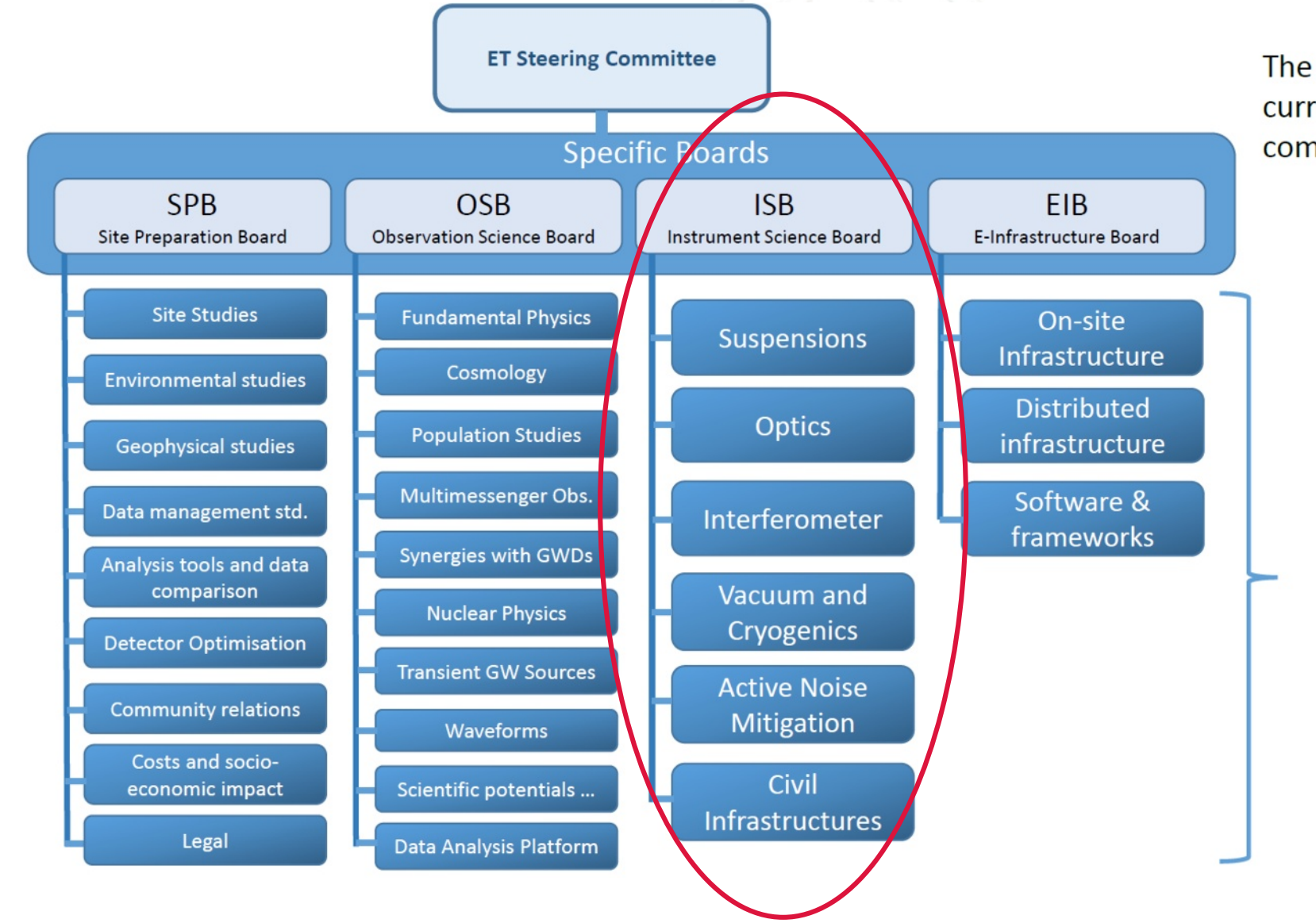
Vue de la caverne centrale ET-LF



https://apps.et-gw.eu/tds/ql/?c=15707

II.
The Instrument Science Board (ISB)

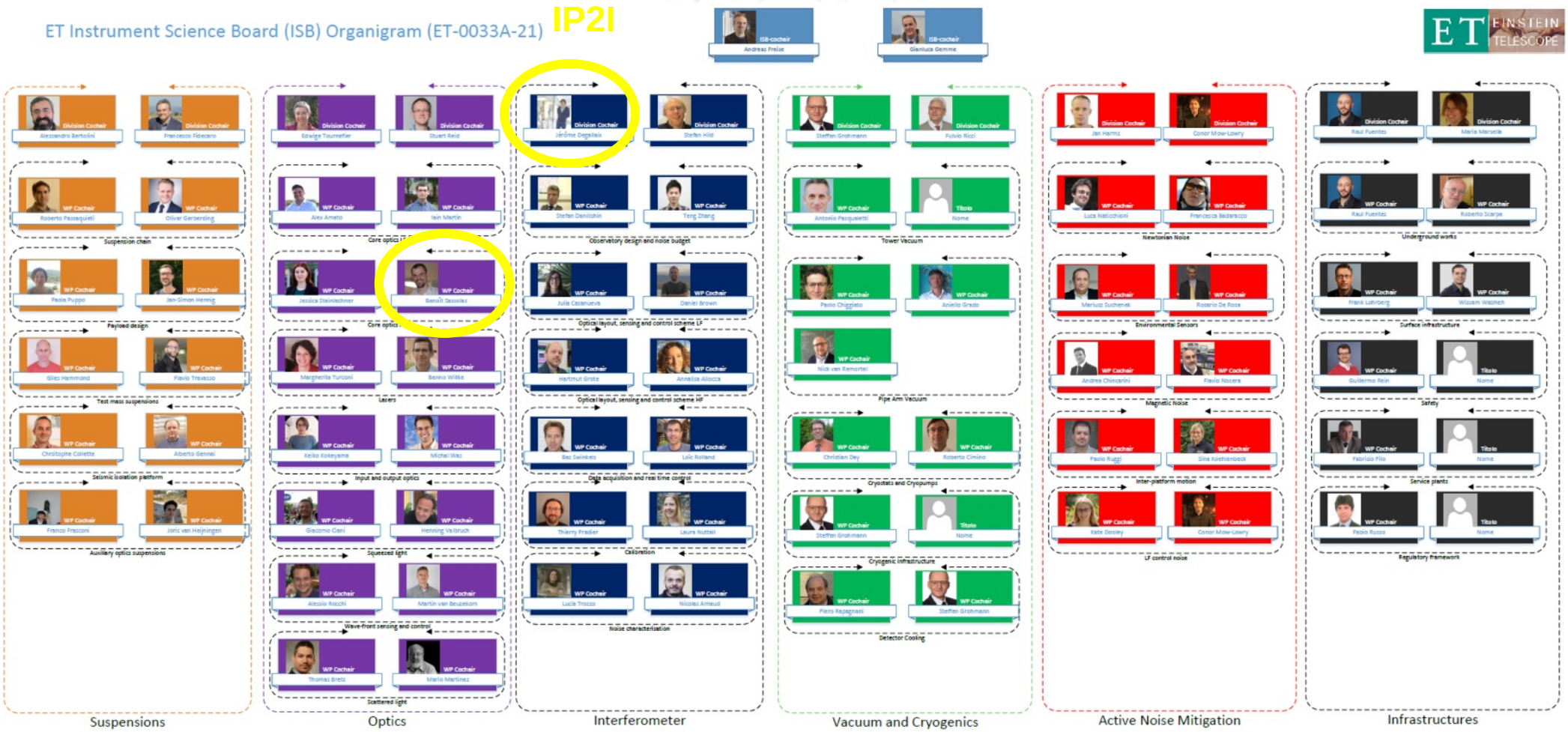
L'organisation



The proto-collaboration is currently the most organised component of the ET project

5

L'Instrument Science Board (ISB)



6 divisions, 32 Work Packages (WP)

Pour les gens de Virgo

Le mandat de l'ISB

EXCERPTS FROM THE ISB MANDATE
(ET-0085A-20, DEC 2020)

- The first objective of the team is to deliver the **ET Technical Design Report (ET-TDR)** of the infrastructure and of the detectors [...] in an iterative process. [...]:
  - **By the end of 2022** (including costs evaluations) initial report:
    The level of detail of the design must be sufficient to allow the customization of the design for the two different sites, in order to prepare the site bids.
  - **By end of 2025** (including costs evaluation) for the Research Infrastructure:
    This activity will probably be transferred to (or shared with) an external company
  - **By the end of 2025** (including costs evaluations) for the detector

- **The timing is outdated. We are currently discussing an update of the timing and deliverables**

[...] If the technical solution is missing, they have to **highlight the need for R&D activity in this sector**. They are to coordinate the decision-making process to select between alternative design options that affect several work packages across divisions [...]

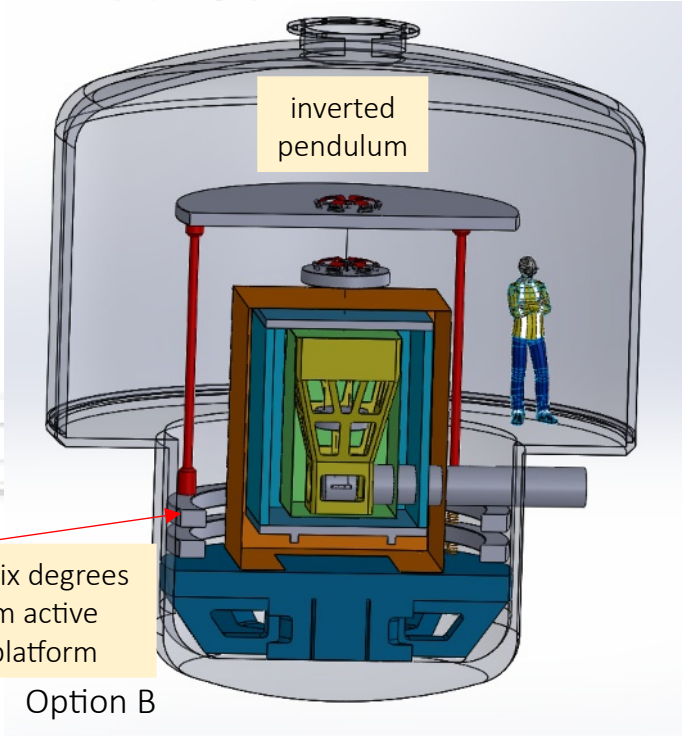
III.
Les divisions

Plus de détails dans le dernier Einstein Symposium (link)

Suspension

- le défi de l'isolation à basse fréquence !
- grande expérience sur les détecteurs actuels
- R&D sur les sismomètres multi-axes, suspensions bas bruit

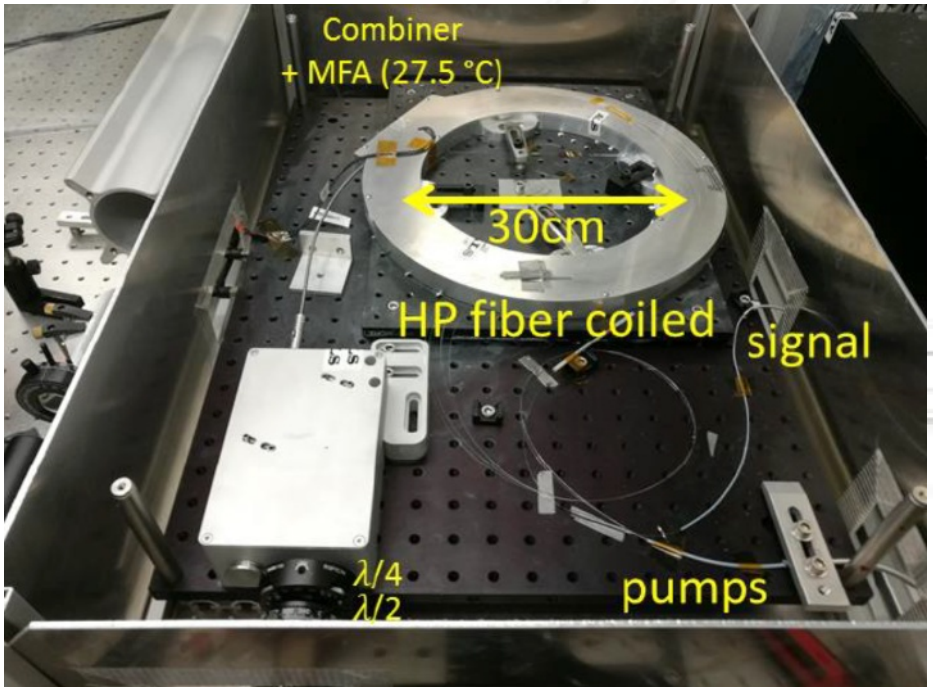
6-D interferometric readout inertial sensor
Credit: Conor Mow-Lowry, VU Amsterdam



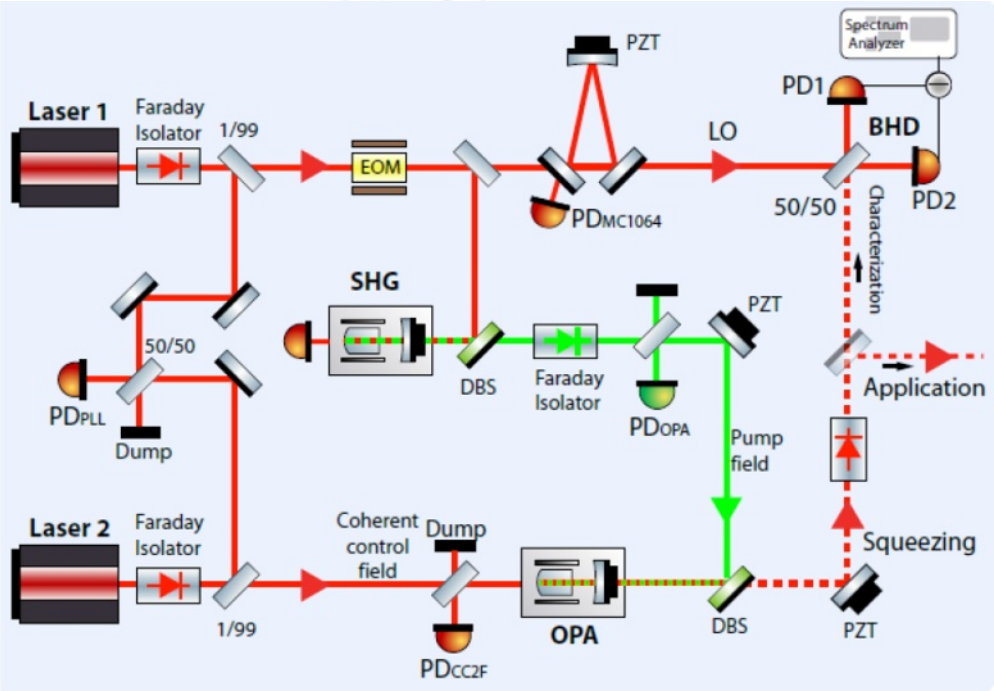
Option B

Optique

- fournir les grands miroirs
- responsable pour le laser, injection, détection, lumière diffusée, contrôle des aberrations et la réduction du bruit quantique
- bonne implication française (LMA, LAPP, IJCLAB, APC, Artemis)



Laser fibré



Génération de ‘’squeezed light’’

Interféromètre

- calcul de la sensibilité (noise budget)
- réalisation du schéma optique, stratégie de contrôle
- calibrations, DAQs, électronique de contrôle
- participants tricolores : LMA, LAPP

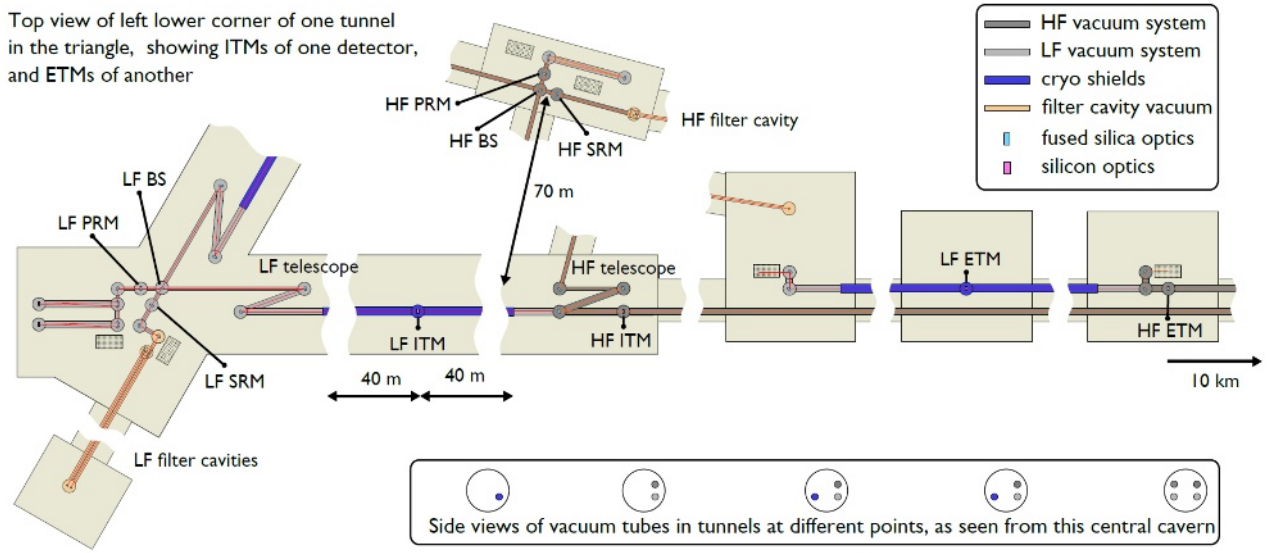
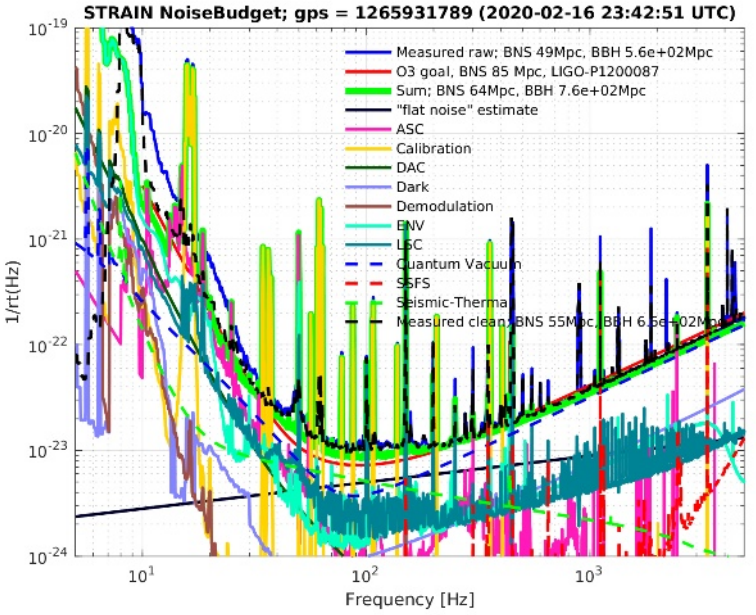


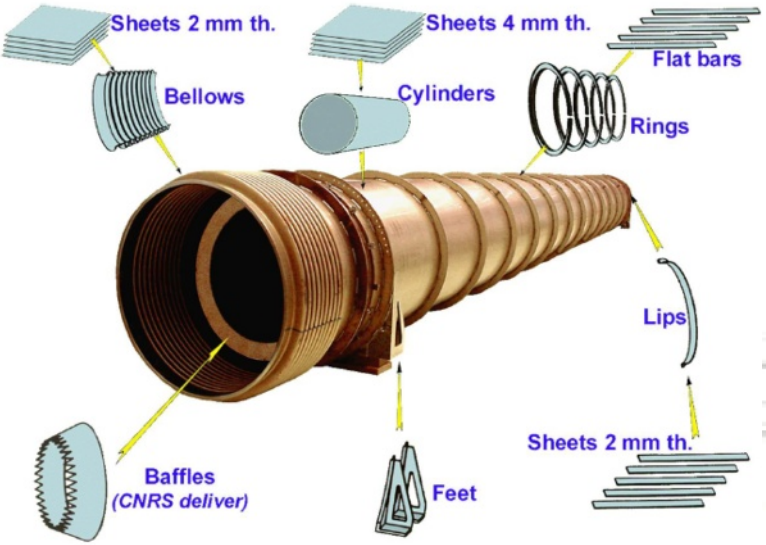
Schéma de la partie centrale



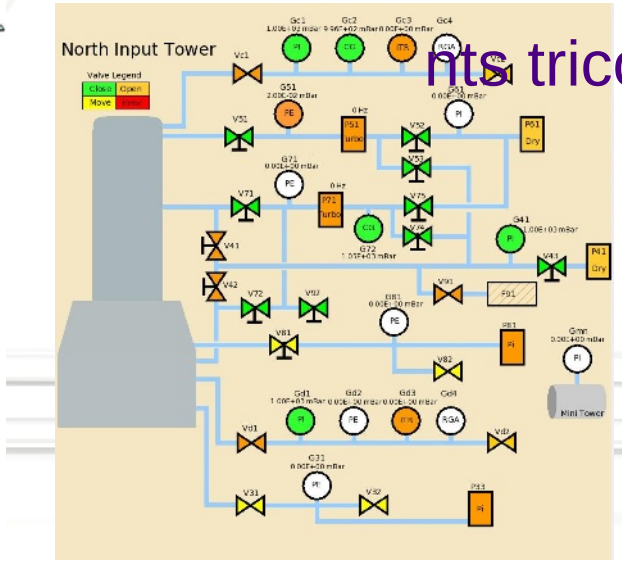
Aussi prévoir le noise budget pendant le commissioning

Vide et cryogénie

- 120 km de tube UHV, pression de 10^{-10} mbar
- des dizaines de tours à vide
- cryostat bas bruit
- R&D et conception sur :

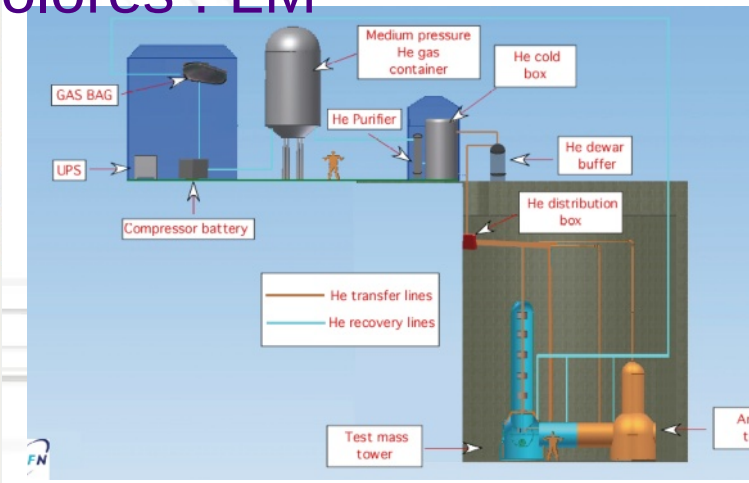


Design du tube à vide



Stratégie de pompage

nts tricolores : LM



Système de refroidissement

Avec la participation du LAPP et IJCLab sur le vide, chapeauté par le CERN

Réduction de bruit active

- basée sur l'expérience des détecteurs 2G
- défi pour les basses fréquences (10^6 mieux que 2G en déplacement)
- réduction bruit environnemental

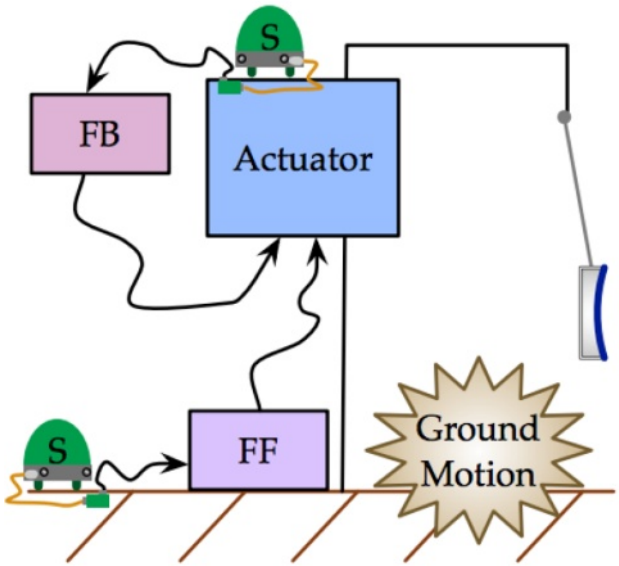
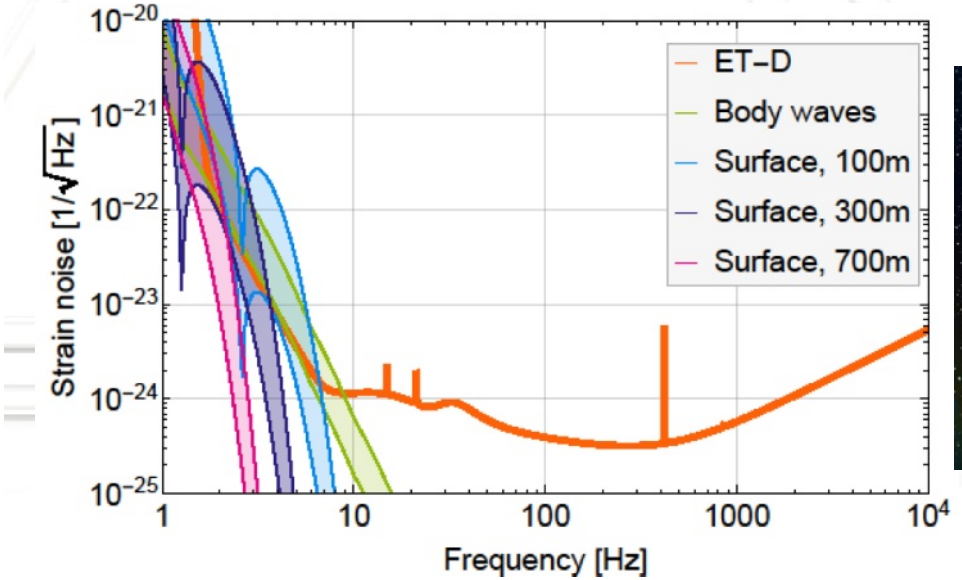


Schéma de suspension active

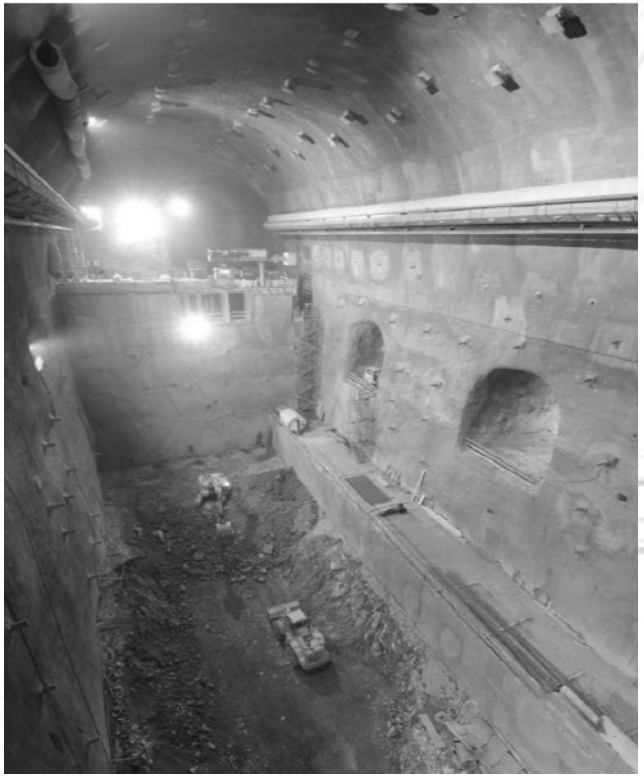


Estimation du bruit Newtonien

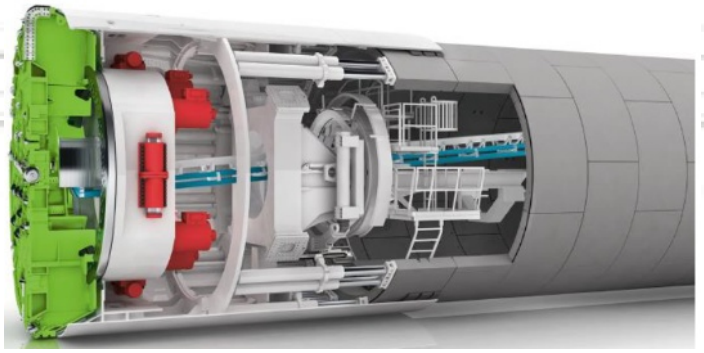
Bruit magnétique

Infrastructure

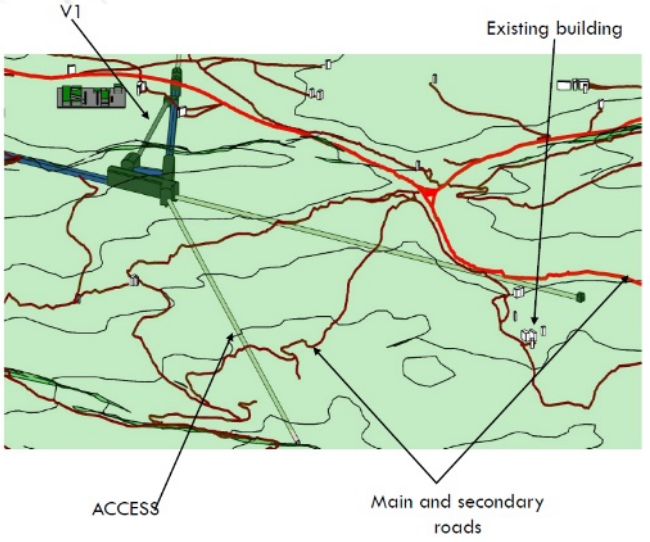
- stratégie pour la construction des tunnels et cavernes
- gestion infrastructure souterraine
- intégration dans l'environnement local



Taille, forme des cavernes ?



Méthode d'excavation ?



Installations existantes ?

IV.
La R&D

Organisation de la R&D

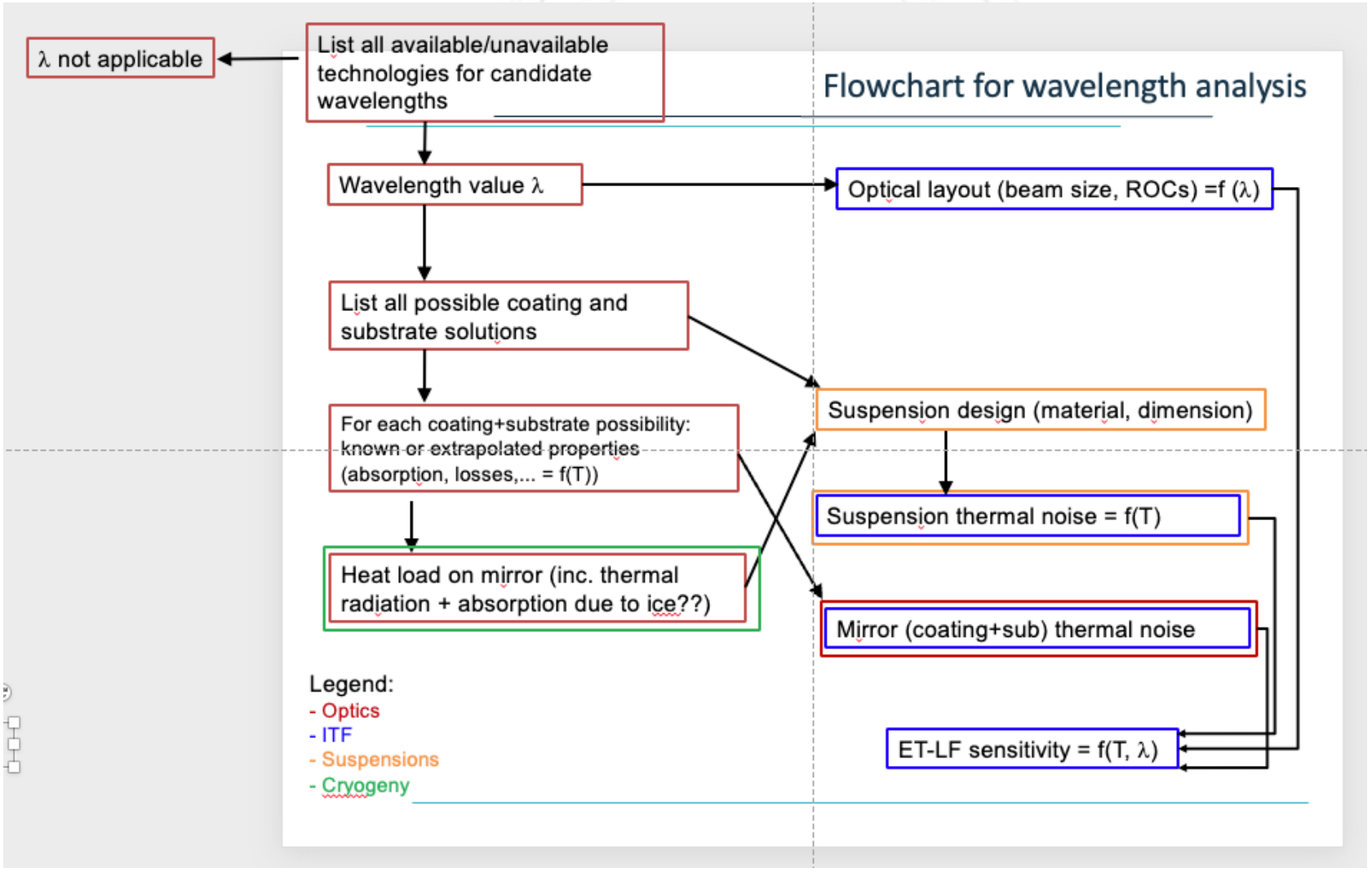
- nous ne maîtrisons encore pas toutes les technologies pour ET
- besoin de coordonner les efforts de R&D (avec de la redondance)
- production d'un livre blanc pour répondre à des appels d'offres

	List of all tasks (use "data->filter views" to view only one division)					
Number (automatic)	**Task description (a few sentences to give a clear and unique description pf the task)**	**Divsion**	**ET LF**	**ET HF**	**Keywords**	**Milestones, outcomes (a list of specific outcomes of the task)**
1	Laser amplifier 1550nm, ...	OPT	☑	☐	laser, optics, 1550	
2	Seismic platform requirements	ANM	☑	☐	suspension, seismic isolation, control	Determination of maximum acceptable motion down to ~50mHz before controls noise performance is compromised. Systems-level understanding of dependent subsystems, including volume and mass needed by eg baffles and sensors.
3	AlGaAs coating at full mirror size (1064nm), ...	OPT	☐	☑	1064, coating	
4	ET LF length sensing and control for detuned SR	INF	☑	☐	simulation, control	Find robust error signals
5	Control of dust particles in vacuum chambers	VAC	☑	☑	simulation, design	Methods and diagnostics to keep under control the concentration of dust particles on the walls of vacuum chambers Solutions are needed during both fabrication process and service phase: special indications will be included within the 3G vacuum chambers specifications
6	Structural materials for ET arm pipes	VAC	☑	☑		Affordable structural materials for the vacuum vessel of the ET's arms Surface modifications to reduce water vapour outgassing and possibly avoid bakeout Participation of industrial partners
7	Thermal link design of ET-LF optics and inner shields	VAC	☑	☐	simulation, design	Development of ultra-low noise cooling methods
8	Thermal and particle load reduction	VAC	☑	☑	simulation, design	Surface emissivity and temperature control of inner shields (ET-LF) and arm pipe cryotraps (ET-LF & ET-HF) Vacuum-compliant ‚black materials' Active (pumping) and passive (conductance) measures to reduce particle loads on the mirror
9	Vacuum contaminants on cryogenic mirror surfaces	VAC	☑	☐	simulation, design	Source quantification and contamination control is a critical and general task throughout the ET project Few nm thick frost layers yield risk of significant energy absorption and thermal drift, requiring a removal strategy ET-LF and ET-HF: Mitigation and and removal of electrostatic charge from mirrors
						Use topographic and geological information of a site and observed seismic

Compilation des idées

Le choix de la longueur d'onde pour ET-LF

- activité transverse, multi-division
- workshop sur 2 jours (lien 1, lien 2)
- comparer 1064 nm, 1550 nm et 2 µm



Idée de R&D

- développement de simulations optiques
  - incluant la polarisation
  - en 3 dimensions
  - pour la lumière diffusée

- algorithme pour réduire le bruit Newtonien (avec quels capteurs ?)
- matériaux pour les tubes à vide
- contrôler les particules dans les enceintes à vide
- comment bien refroidir les miroirs ?
- ...

Conclusion

- ET = future grande infrastructure pour la science de demain
- possibilités de contribuer aux travaux des divisions
- plus d’info : ISB welcome page
- certains choix techniques pourront être validés à Virgo (post O5)
- point de contact : les responsables de division et le groupe ET-IP2I