Preventivi TIFPA 2024

LET lab

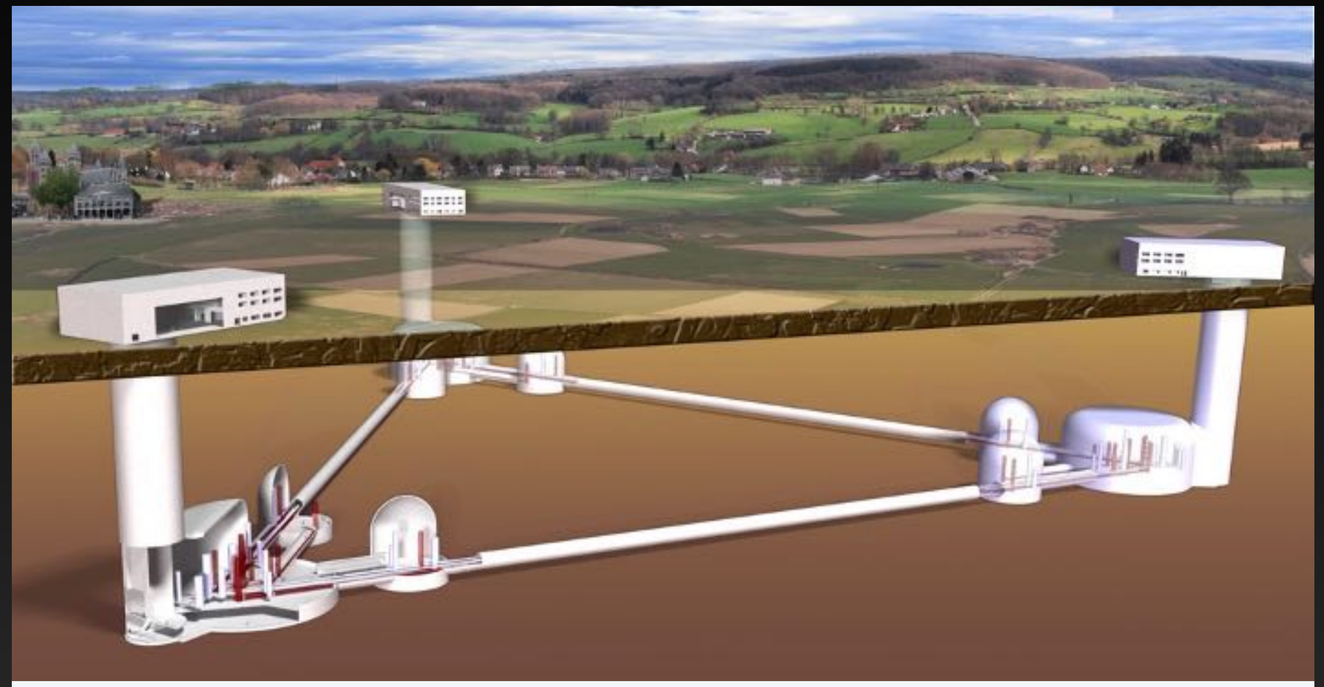
University of Trento

LIGO/Virgo/Kagra and ET group
TIFPA 2023

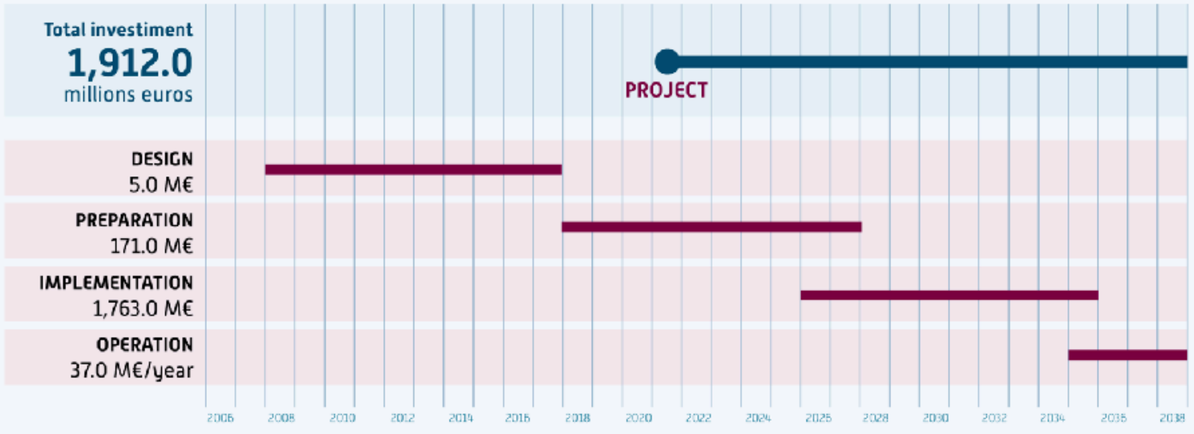
Trento, 29 June 2023

Einstein Telescope

The new collaboration



Timeline and investments



2025 - Start

The first implementation of the 3rd generation of gravitational wave detectors

- 10 times improvement in the detection sensitivity over the second generation
- Increase the number and extend the kinds of sources
- Performing Multimessenger Astronomy with neutrinos, electromagnetic and High Energy cosmic ray

Scientists from LIGO, Virgo and Kagra importing expertise

- All the technology has to be improved
- More than 1400 scientists, 23 Countries, 221 Institutes

Timing

- 2010 - Concept design
- 2020 - Design Update
- 2021 - in ESFRI
- 2022 - New collaboration

Einstein Telescope

News

Notizie

EINSTEIN TELESCOPE: IL GOVERNO UFFICIALIZZA LA CANDIDATURA ITALIANA PER L'INFRASTRUTTURA DI RICERCA INTERNAZIONALE

Giugno 9, 2023

Roma, 6 giugno 2023 – Riuscirà a osservare un volume di universo almeno mille volte maggiore...

ilsole24ore.com
https://www.ilsole24ore.com › art › einstein-telescope-og...

Einstein telescope, l'Italia lancia la candidatura per si candida ...

6 giu 2023 — «Volevo offrire con la mia presenza l'attenzione, la volontà, la dedizione che il **governo** italiano intende mettere sulla candidatura dell'Italia ...

www.governo.it
https://www.governo.it › articolo › presentazione-della...

Presentazione della candidatura italiana per Einstein Telescope

6 giu 2023 — Il Presidente del Consiglio, Giorgia Meloni, ha tenuto un intervento alla

repubblica.it
https://www.repubblica.it › 2023/06/06 › news › telescop...

L'Italia si candida per ospitare il telescopio Einstein in Sardegna

6 giu 2023 — Il **governo** promette 1,7 miliardi in 9 per realizzare lo strumento rilevatore di onde gravitazionali a Sos Enattos, a sud di Olbia.

Einstein Telescope
Current Status

Study of two possible locations
- Sos Enattos, Lula (Sardinia)
- Meuse-Rhine Euroregion (Belgium, Germany, Netherland)

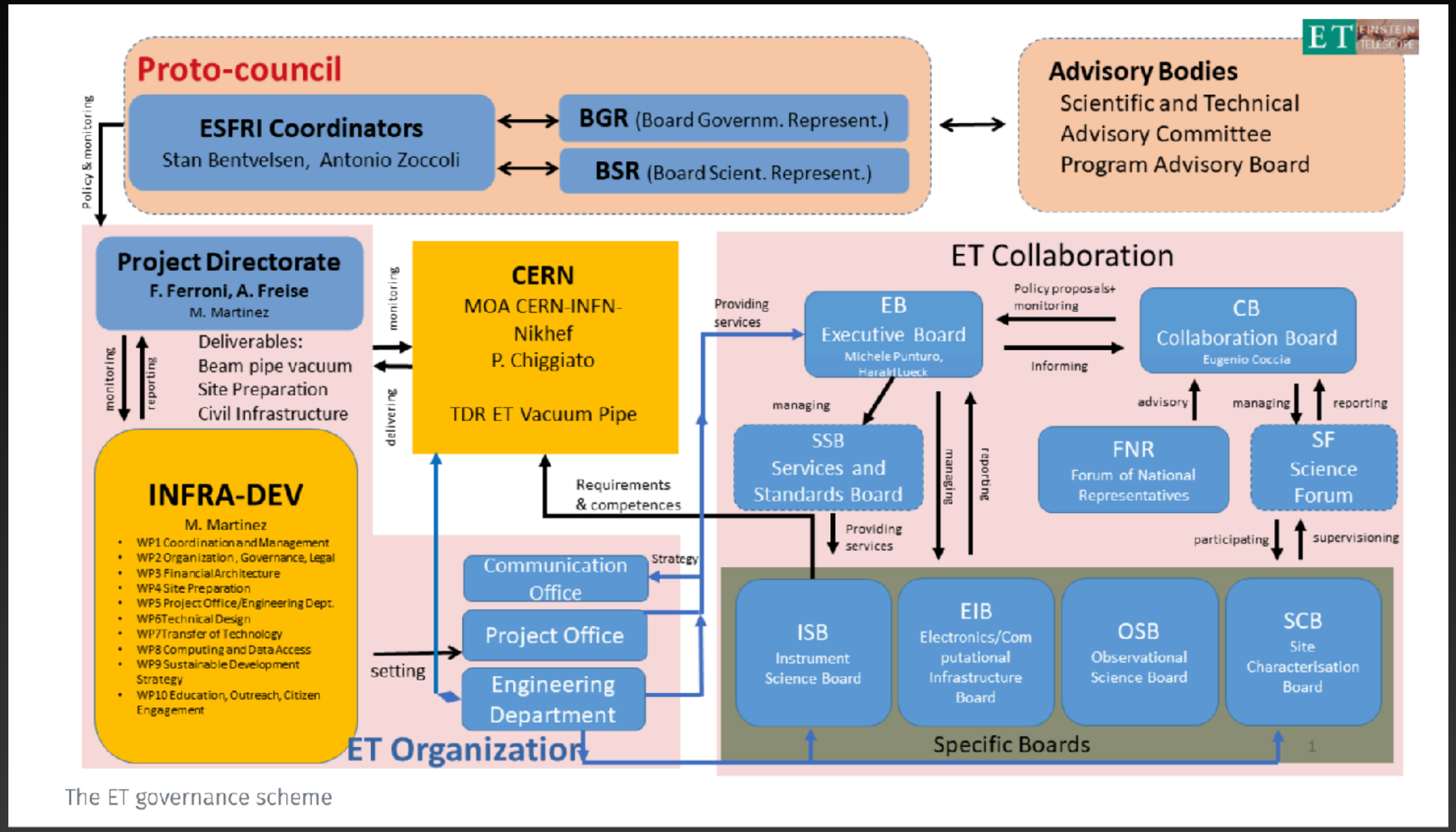
Technical Design Document
- Infrastructure design
- Systems and sub-systems
- Strategies (i.e. lock acquisition, controls, etc.,...)

R&D
- Coordinating national requests
- Research area are working synergistically
- Infrastructure working group started

2025 - Start

Einstein Telescope

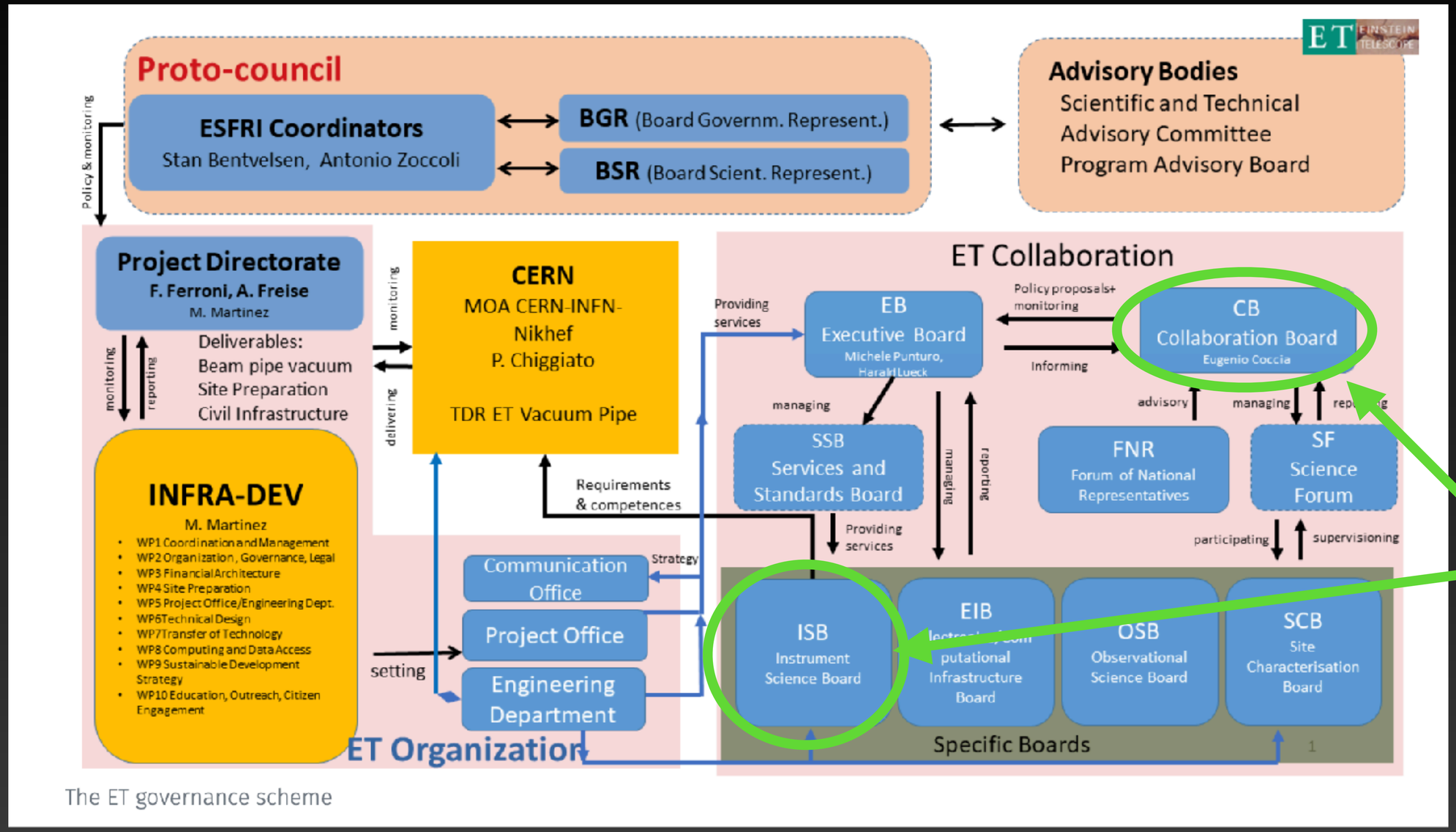
The Governance



The ET governance scheme

Einstein Telescope

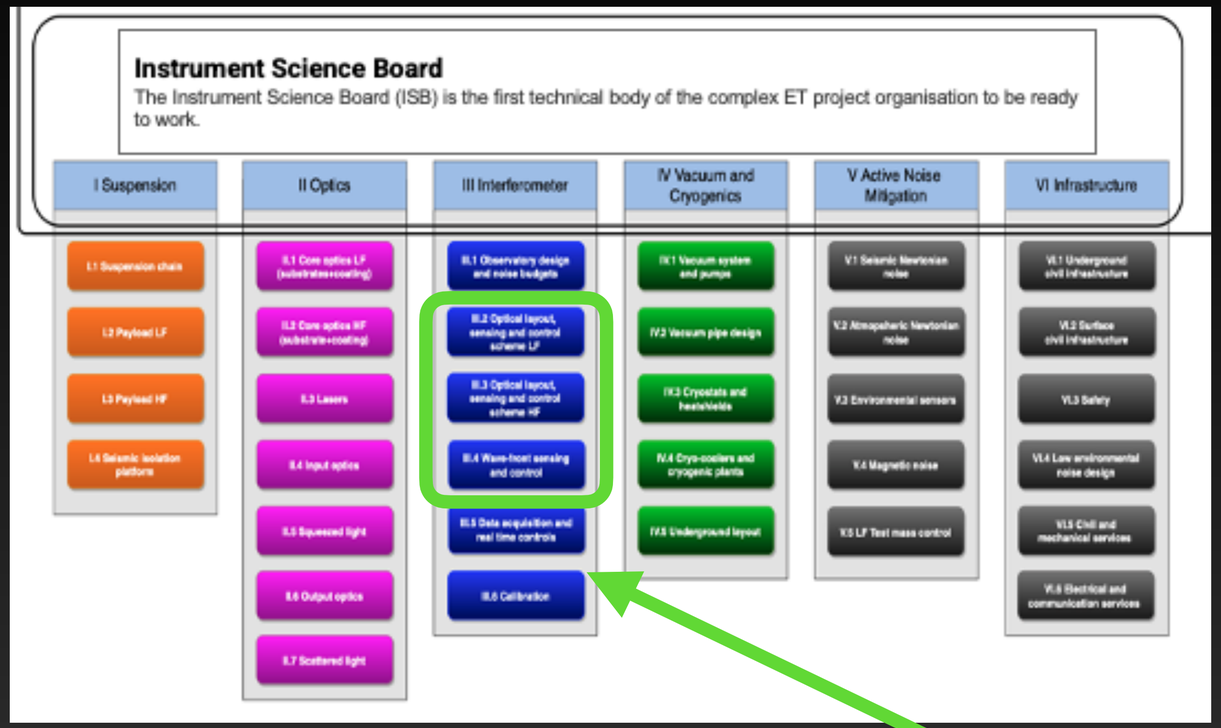
The Governance and Trento-ET

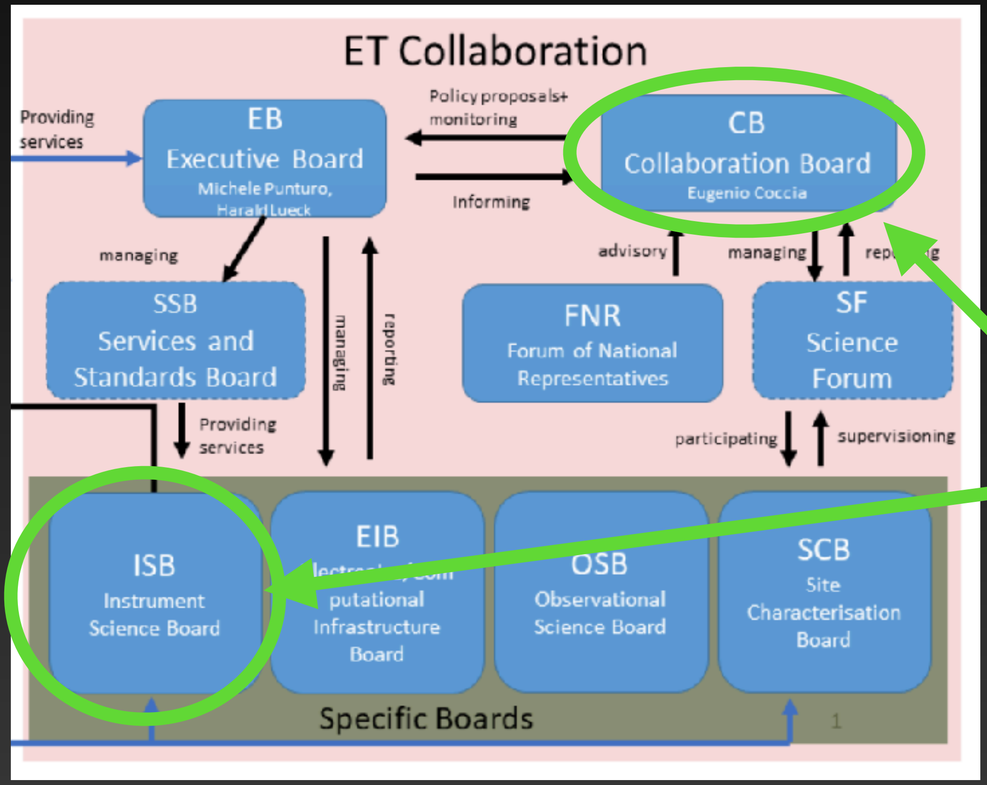


The ET governance scheme

Einstein Telescope

The Governance and Trento-ET





Trento-ET

What do we do?

- Mode matching/astigmatism analysis
- Sensing
- Control
- Commissioning (Virgo)

Einstein Telescope

Trento-ET and Virgo Group activities

Mode Matching (MM) and Astigmatism Sensing and correction @1550nm

Technology transfer of Trento expertise develop for Virgo standard wavelength (1064nm) to the ET one 1550nm.

Particular focus on:

- Mode Matching and Astigmatism sensing system
- Device for MM and Ast. correction (Actuator)

Experimental projects

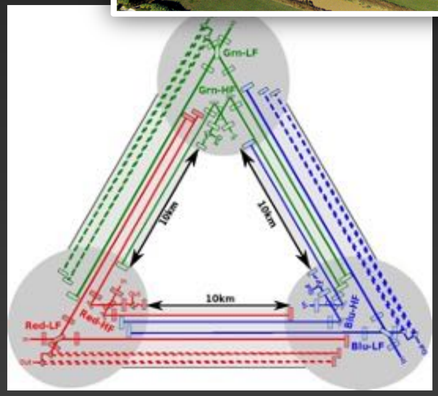
Sensing and corrections only for symmetric Mode Matching at 1064 nm

Virgo

- ET design project:
  - Wavefront sensing and correction
  - Signal Recycling design
  - Low Frequency lock acquisition and control
  - High frequency lock acquisition and control
  - Optical simulation for detector sensitivity in different Configuration

Data analysis: planned developments

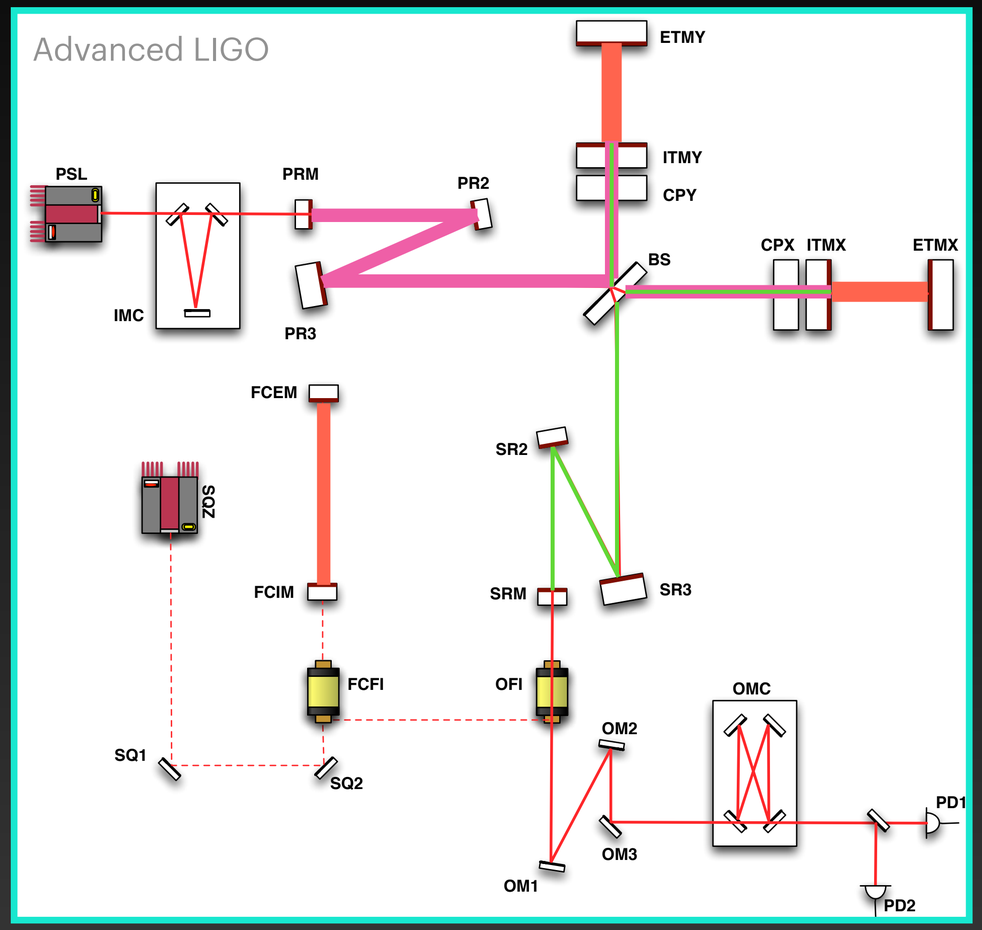
- Search for gravitational wave transients in an observatory including ET with expected pile-up of astrophysical signals
- Targeting post-merger signals from binary NS mergers and isolated NS emissions
- Neutron star formation and binary systems
- Multimessanger signals from nearby and cosmological distance source

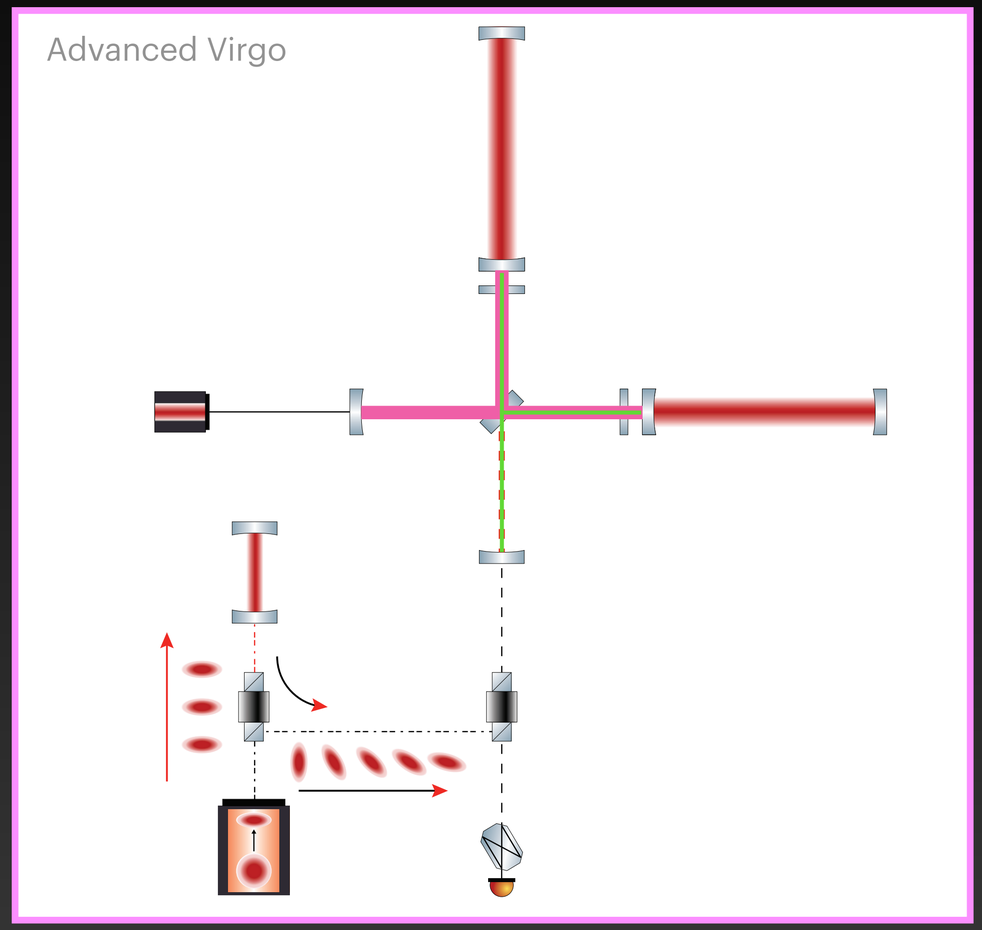


Why?

Advanced Gravitational Wave detectors

Layouts





Advanced Gravitational Wave detectors

- In a real interferometer the level of squeezing is limited by losses and quadrature fluctuations
- Losses mix squeezed vacuum state with the unsqueezed state
- **Sources of losses:**
  - Reflection from optics
  - Scattering
  - Quantum efficiency
  - Mode Matching

Oelker et al.,

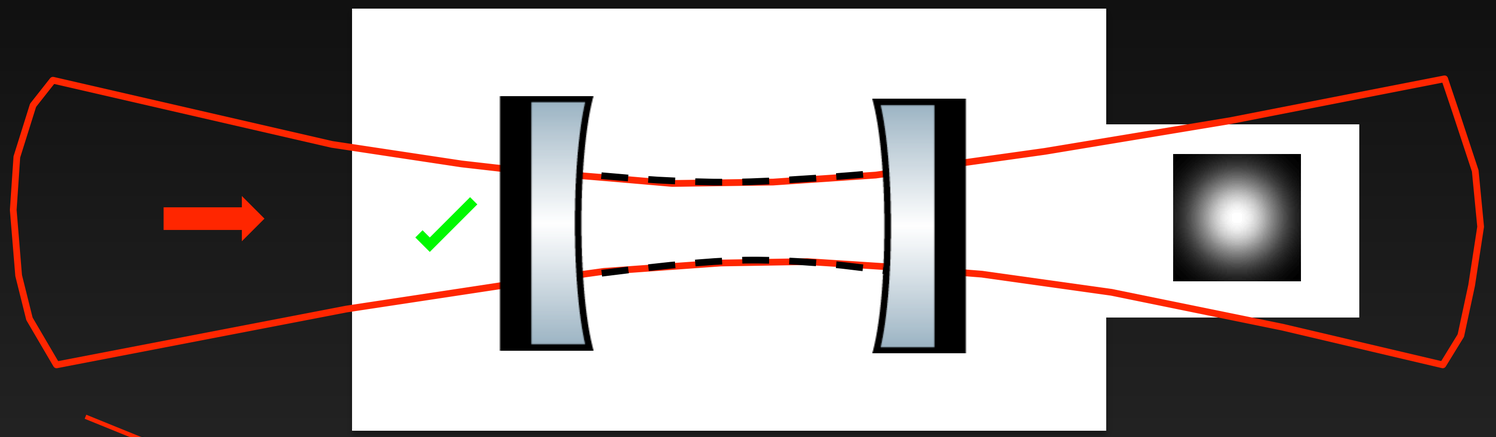
Optics Express Vol. 22, Issue 17, pp. 21106-21121 (2014) • https://doi.org/10.1364/OE.22.021106

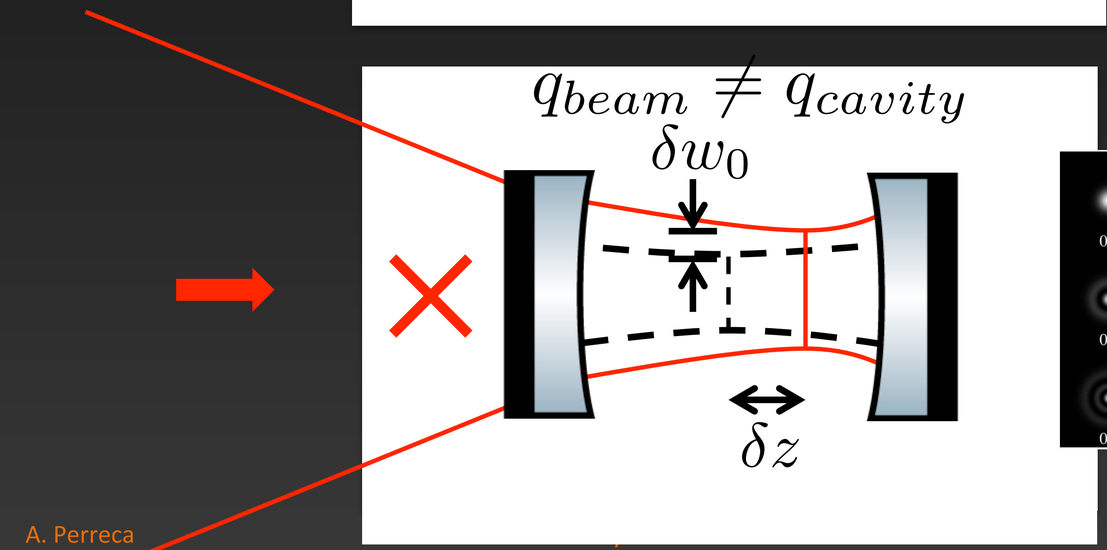
Total losses must be limited to ~10%-15%

Losses due to mode-matching must be ~1%

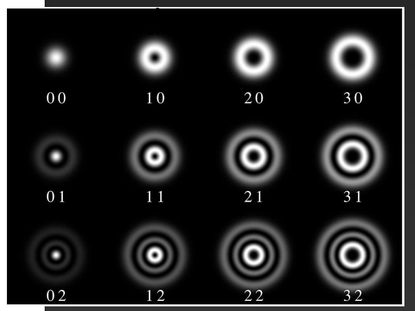
Advanced Gravitational Wave detectors

Mode Matching in a single cavity





Laguerre-Gaussian

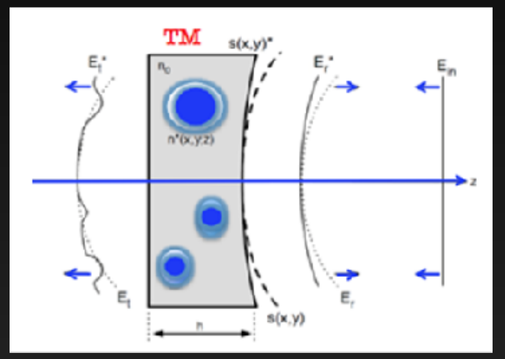


A. Perreca

Advanced Gravitational Wave detectors

Causes of Mode Mismatch

- Static
  - Mirror Aberrations
  - Radii of curvatures deviations from nominal values



VIR-0598A-18

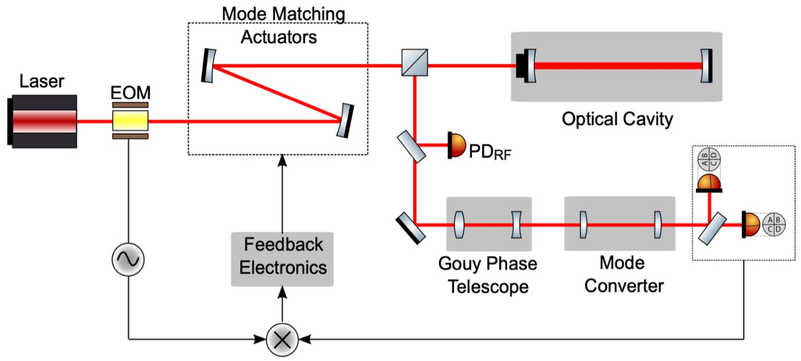
- Dynamic
  - Thermal Lensing
    - Thermo-elastic
    - Thermo-refractive

Wavefront Sensing

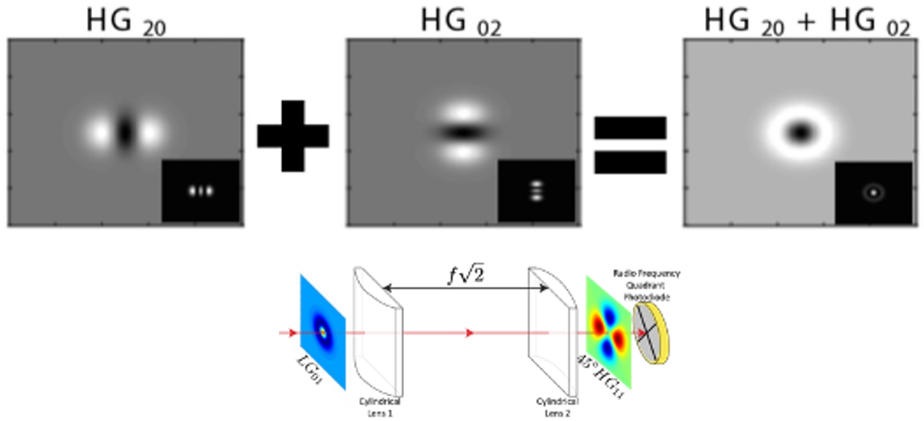
Virgo and ET wavefront sensing technique

Mode Converter Telescope

Simplified optical setup of the mode-matching sensing system. The Gouy phase telescope focuses the reflected light from the cavity in the middle of the two cylindrical lenses.



The mode converter telescope composed of two cylindrical lenses. The LG01 mode is transformed in a 45deg rotated HG11 mode and measured by a conventional quadrant photodiode.

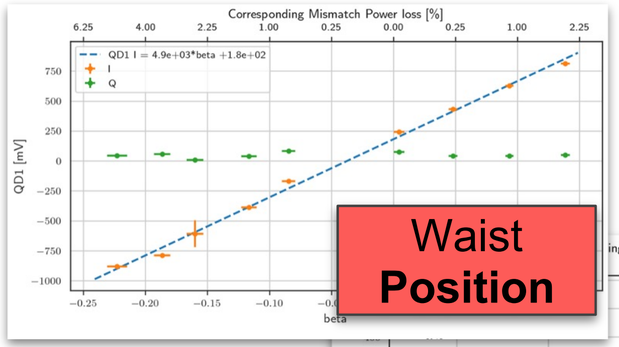


Virgo and ET wavefront sensing technique

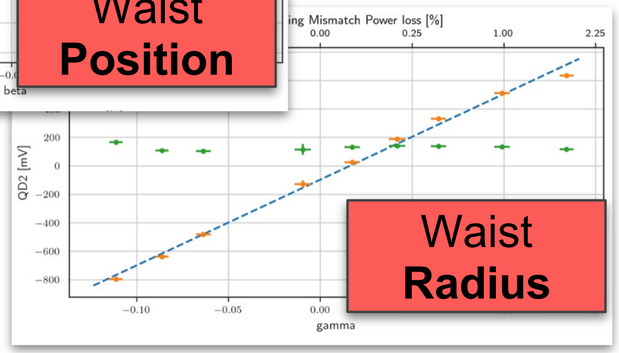
Results for Virgo; ET setup under construction

Test and validation of Mode Converter Technique:

- ✓ Measurement of linear error signal as function of Mode Matching parameters
- ✓ Installation of Mode Converter Telescope in Advance Virgo Plus
- ○ Commissioning of Mode Matching sensors in Avance Virgo Plus



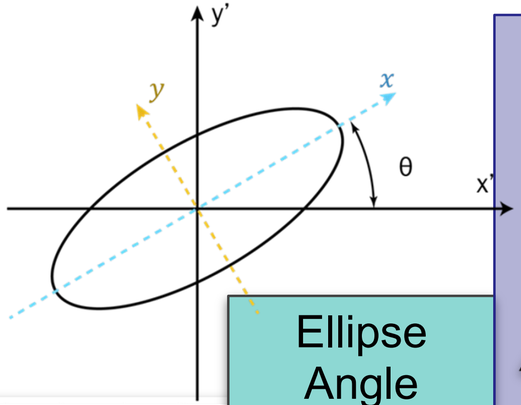
Waist **Position**



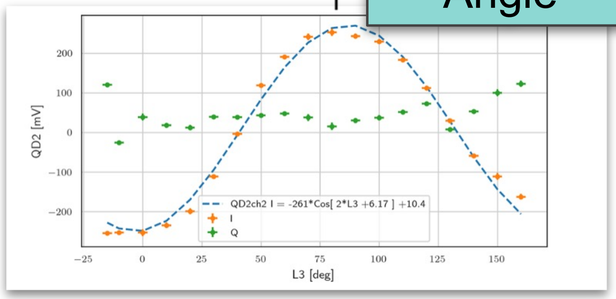
Waist **Radius**

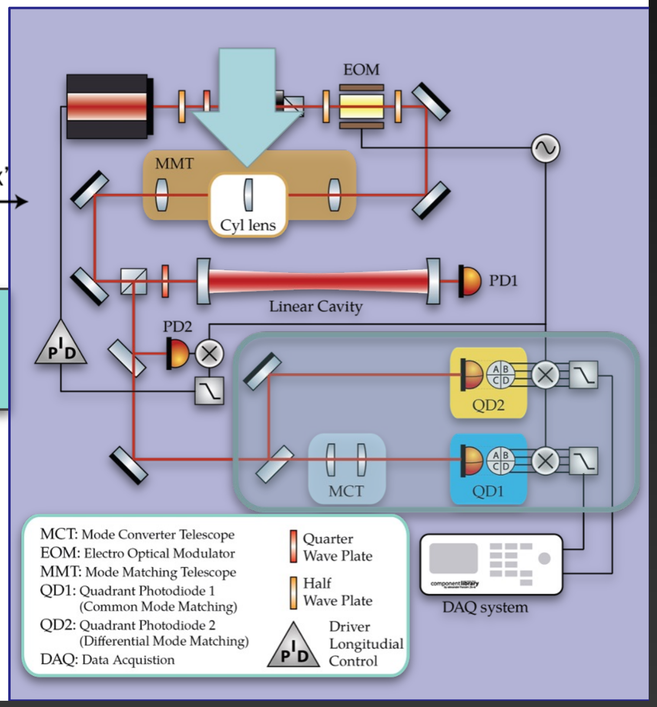
Astigmatic Mode Matching Sensing

- ✓ Development of theoretical model for Astigmatic Mode Matching Sensing
- ✓ Modification of Table Top Experiment to for validation
- ✓ Measurement of error signal as function of Ellipse Angle
- ○ Installation of other 4 Quadrant Photodiode for full setup



Ellipse Angle





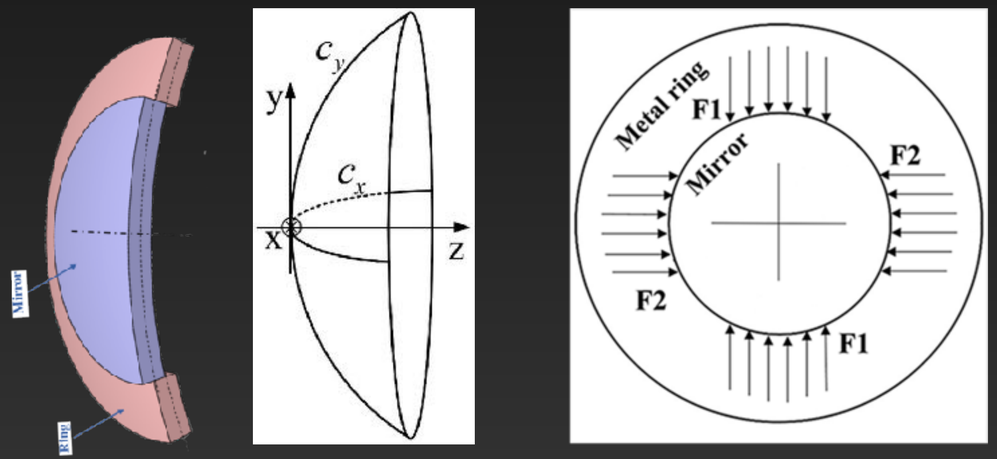
Wavefront Control

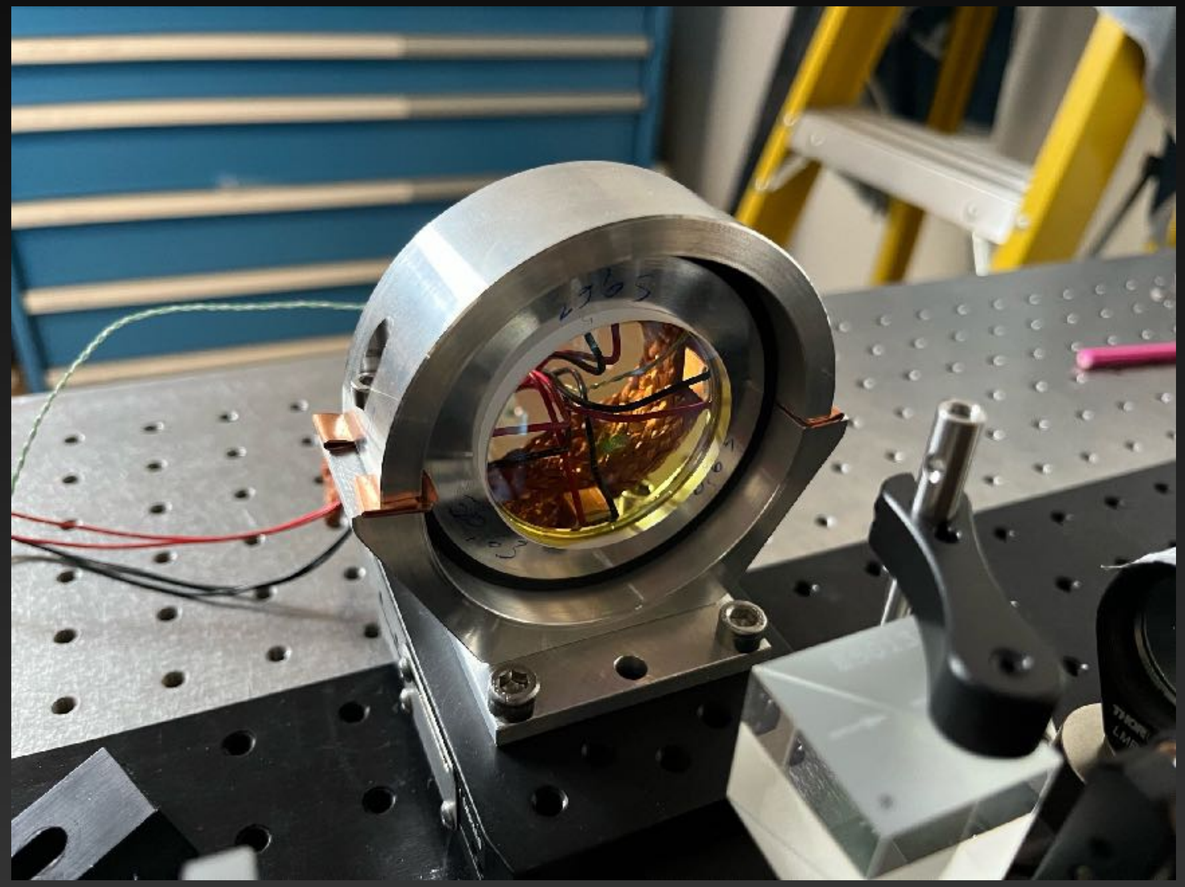
Virgo and ET wavefront control technique

Virgo (symmetric actuation) device under test

Idea

- Symmetric contact pressures, F1=F2, distributions will produce changes in curvature





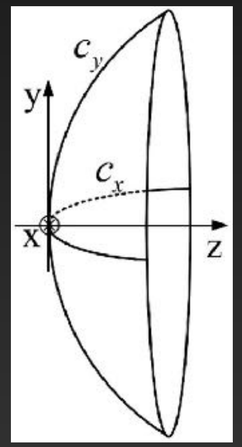
Virgo and ET wavefront control technique

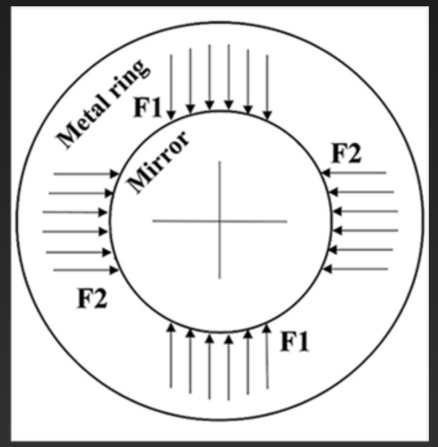
ET (asymmetric) setup under construction

Idea

•Different contact pressures distributions will produce differences in curvature

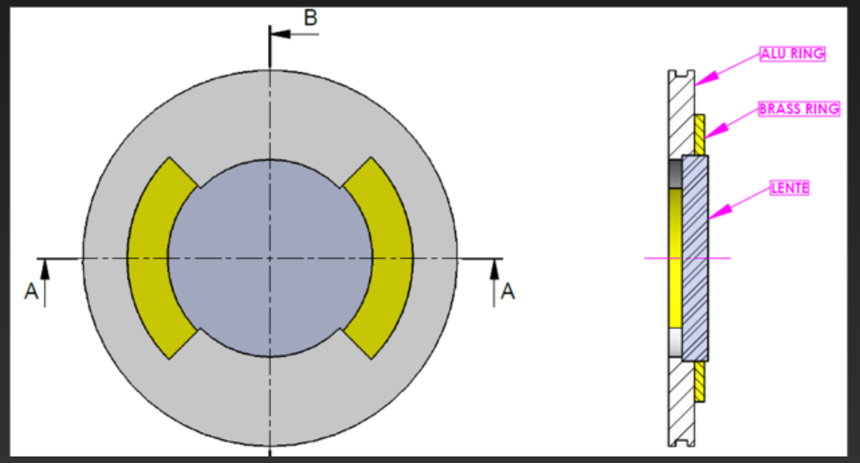
Two opportunely shaped ring made of materials with different coefficient of thermal expansion (CTE) will produce two orthogonal different contact pressure distributions





FEM results: PROMISING

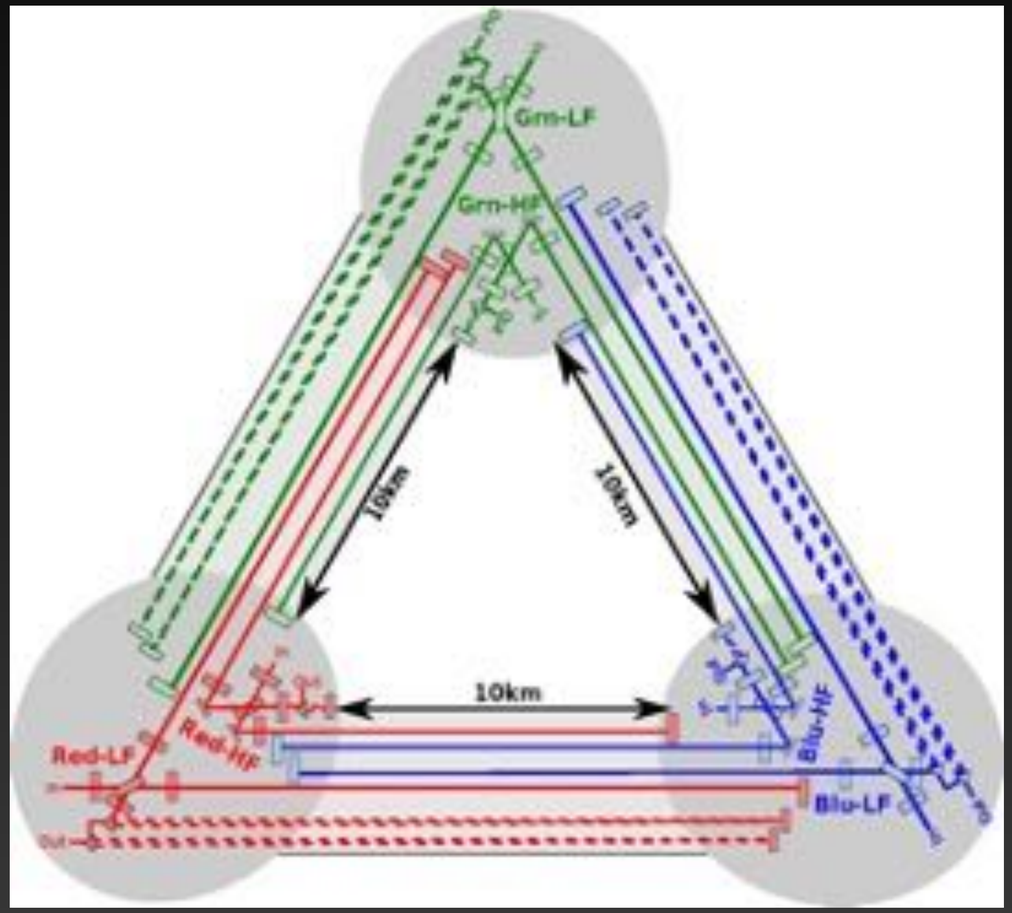
University of Trento



Collaboration with University of Napoli, Federico II: Alcide Bertocco, Matteo Bruno and Luca Esposito

Einstein Telescope
Preventivi TIFPA 2024

- In 2024 the work will be focused on mode-matching error-signal and astigmatic actuators
  - 40k Inventariabile
    - Vacuum chamber, and pumps
  - 10k Consumabile
    - Optics for actuators
  - 3.5k Travel



Virgo and ET experimental activities 2024

Sensing and Correction

Virgo

Miglioramento misure del sensing del mode matching e dell'astigmatismo

- Completo trasferimento da Padova a Trento

Test attuatori simmetrici per correggere perdite ottiche dovute al mode matching

ET

Implementazione del sistema di sensing su banco

- Locking della cavita'
- Prime misure di mismatch

Test attuatori Asimmetrici per correggere perdite ottiche dovute all'astigmatismo

Einstein Telescope

Squadra

Italy

Strutture INFN

- BO - Tommaso Chiarusi
- CA - Andrea Contu
- FE -
- FI - Filippo Martelli
- GE - Gianluca Gemme
- GSGC - Jan Harms
- LNF - Roberto Cimino
- LNGS - Stefano Pirro
- LNS - Domenico D'Urso
- NA - Rosario De Rosa
- PD - Jean Pierre Zendri
- PG - Michele Punturo
- PI - Alberto Gennai
- ROMA1 - Piero Rapagnani
- ROMA2 - Viviana Fafone
- ROMA3 - Wolfango Plastino
- SA - Veronica Granata
- TIFP - Antonio Perreca
- TO - Stefano Bagnasco

Sottoprogetti

- ET_ITALIA - Domenico D'Urso

Trento-ET Research Unit

fte-i_infn_tifp_csn2_et_italia

cognome	nome	note	struttura	modulo	contratto	profilo	stato	aff	perc
Avi	Damiano		TIFP	G3	Associato	Associazione Tecnica	Attivo	2	50%
Bini	Sophie		TIFP	G1	Associato	Scientifica Dottorandi	Attivo	2	20%
Ferrari	Gabriele		TIFP	G1	Associato	Scientifica Dipendenti altri enti	Attivo	2	20%
Lamporesi	Giacomo		TIFP	G1	Associato	Scientifica Dipendenti altri enti	Attivo	2	20%
Leonardi	Matteo		TIFP	G1	Associato	Incarico di Ricerca scientifica	Attivo	2	20%
Perego	Albino		TIFP	G1	Associato	Incarico di Ricerca scientifica	Attivo	4	10%
Perreca	Antonio		TIFP	G1	Associato	Incarico di Ricerca scientifica	Attivo	2	40%
Prodi	Giovanni Andrea		TIFP	G1	Associato	Incarico di Ricerca scientifica	Attivo	2	20%
Zenesini	Alessandro		TIFP	G1	Associato	Scientifica Dipendenti altri enti	Attivo	2	20%

Einstein Telescope

Partecipazioni a conferenze 2023

1. H*sinchu City*, Taiwan, 10th KAGRA International Workshop (KIW-10), Contributed talk: “Astigmatic Mode Mismatch Sensing for the Next Gravi- tational Wave detectors”.
2. Elba, Italy, Gravitational Wave Advanced Detector Workshop 2023 (GWADW2023), poster: “Astigmatic Mode Mismatch Sensing for the Next Gravi- tational Wave detectors”.

Articoli 2023

1. Nessuno

Einstein Telescope

Stato spese Giugno 2023

N.B. E' previsto l'azzeramento del conto con i prossimi due ordini previsti entro la fine di Luglio

- Ottiche e montaggi
- Sistema di piezo e HV amplifier for automatic alignment
  - Impegnati 16.5keuro
  - Disponibilita' di 45keuro

Stato missioni Giugno 2023

N.B. E' previsto l'utilizzo dei fondi entro fine anno per missioni stanziati per meeting interni ET

- Disponibilita' di 5keuro

...Thank you

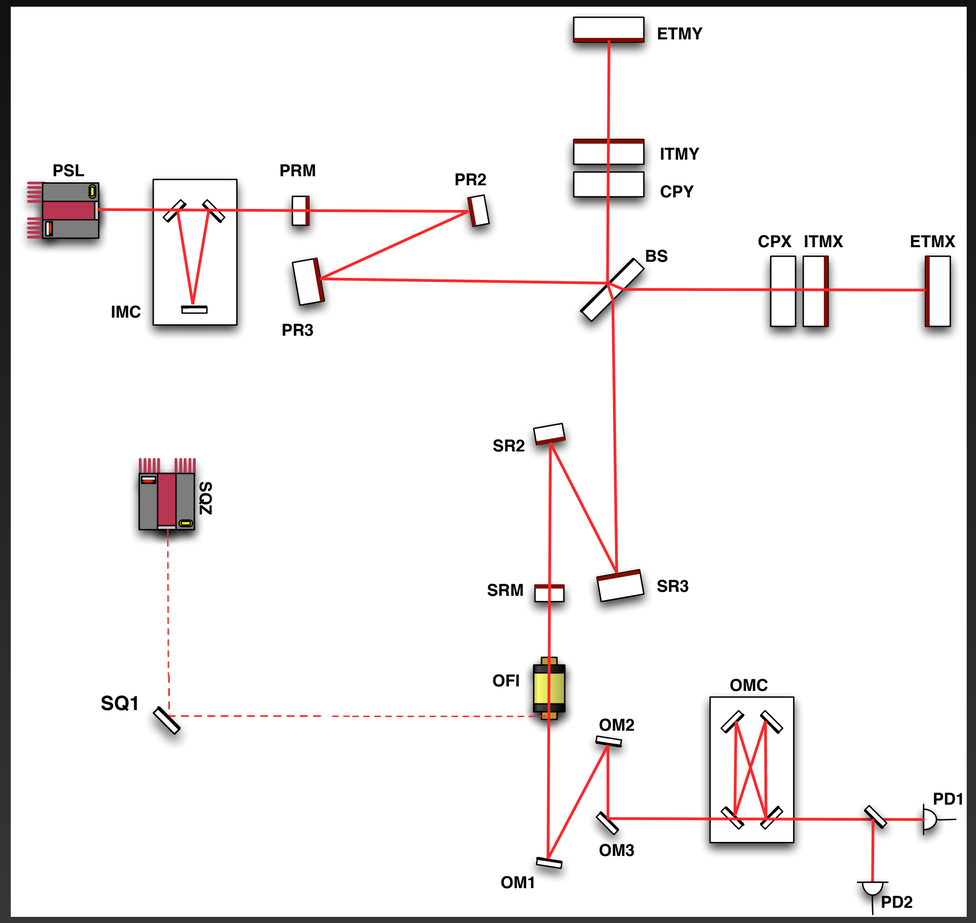
Advanced Gravitational Wave detectors

Frequency Dependent Squeezing

- Initially fluctuations of a vacuum state are uniformly distributed between Amplitude and Phase quadratures
  - Squeezing involves the preparation of a vacuum state
  - Frequency independent squeezing: High frequency quantum noise suppression
  - Frequency dependent squeezing: Low and High frequency quantum noise suppression

Advanced Gravitational Wave detectors

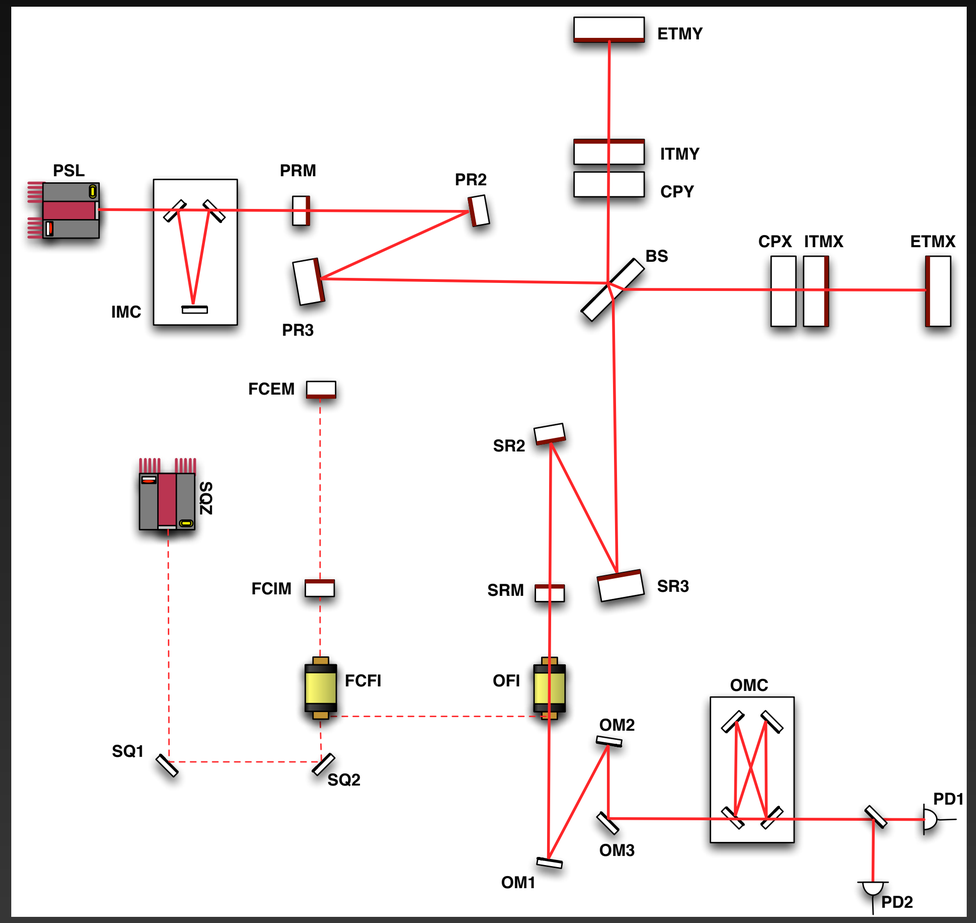
Frequency Independent Squeezing



- Initially fluctuations of a vacuum state are uniformly distributed between Amplitude and Phase quadratures
  - Squeezing involves the preparation of a vacuum state
  - Frequency independent squeezing: High frequency quantum noise suppression
  - Frequency dependent squeezing: Low and High frequency quantum noise suppression

Advanced Gravitational Wave detectors

Frequency Dependent Squeezing



- Initially fluctuations of a vacuum state are uniformly distributed between Amplitude and Phase quadratures
  - Squeezing involves the preparation of a vacuum state
  - Frequency independent squeezing: High frequency quantum noise suppression
  - Frequency dependent squeezing: Low and High frequency quantum noise suppression

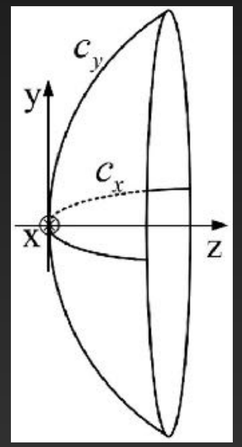
Wavefront control (05 - Post 05)

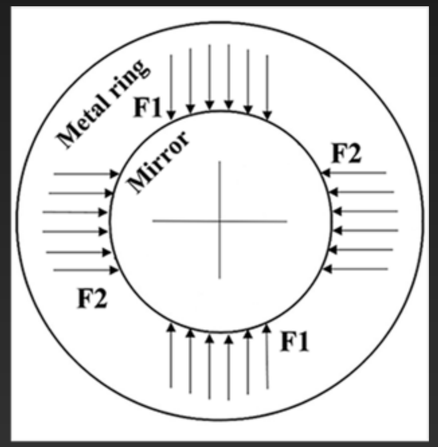
Astigmatism Corrections

Idea

•Different contact pressures distributions will produce differences in curvature

University of Trento

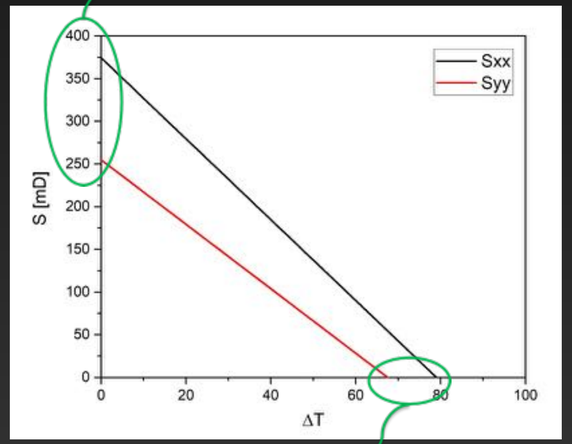




Collaboration with University of Napoli, Federico II:
Alcide Bertocco, Matteo Bruno and Luca Esposito

FEM results: PROMISING

Defocus on xx and yy axis can be modified changing the elastic material properties and the initial interference



Tuning on CTE and interference

Upgrade and commissioning of Advanced Virgo

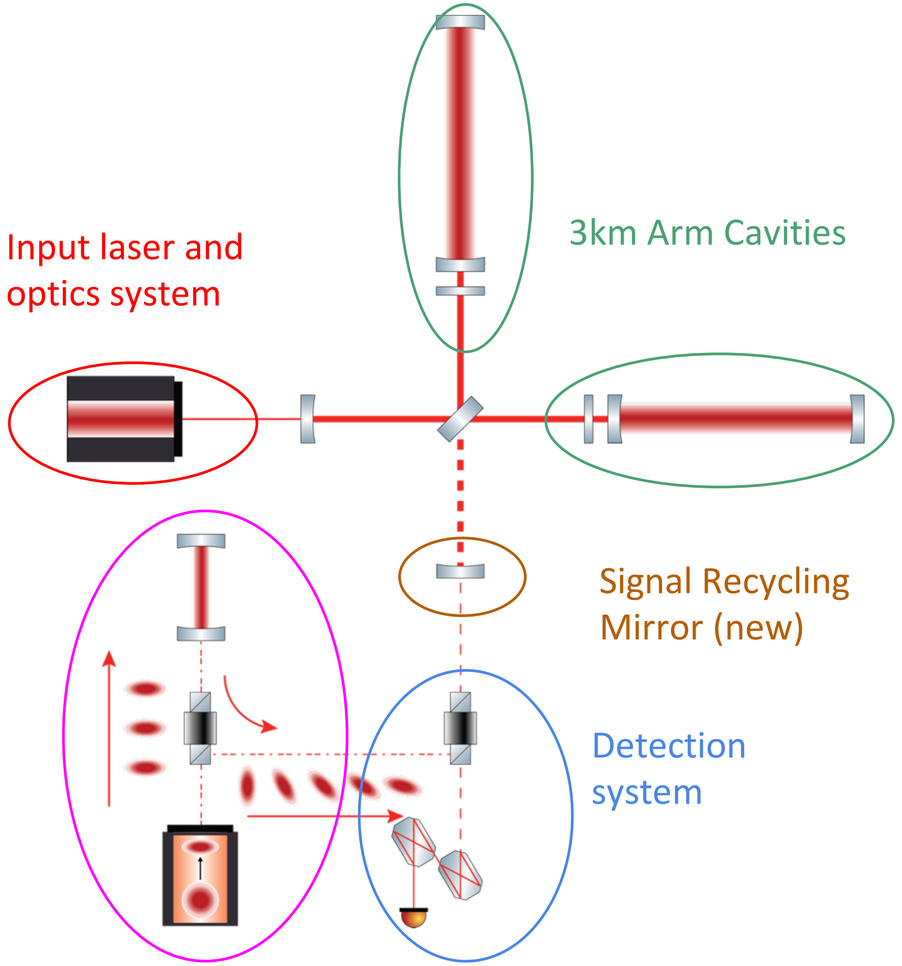
Deep involvement of our PhDs in these pre-commissioning and commissioning activities.

Valentini Michele: full-time on-site commissioning in Interferometer Sensing and Control:

- Young leader for the integration of the **Auxiliary Laser System** in the overall Interferometer Sensing and Control System.
- Commissioning of **Longitudinal Controls:** simulation and test of the new control strategy involving the lock of the Signal Recycling mirror.
- Step by step implementation and automation of the new **Lock Acquisition Procedure,** from scratch to the dark fringe state.

Grimaldi Andrea: part-time on-site commissioning in Frequency-Dependent Squeezing.

- Installation and Commissioning of wavefront sensor for **Mode Matching and Alignment**
- Commissioning of Filter Cavity and preparation activities for Frequency Dependent Squeezing Measurement



Optical Mode Matching in FDS

Next year activities

Delay from 2022 **Due to long delivery time we had to postpone most of the activity:**

- Auto-alignment on QD
- Analog pre-processing for the QD Signals
- Cavity mirror changes
- Installation of four extra QD sensors
- Complete the installation for Astigmatic Mode Matching Telescope

New Activity **Development of Astigmatic Actuator based on the PresFit Technology:**

- Upgrade Hartman setup with better sensor
- New Compression Ring designed by Napoli Collaborator