Overview of suspension activities for current and future GW detectors

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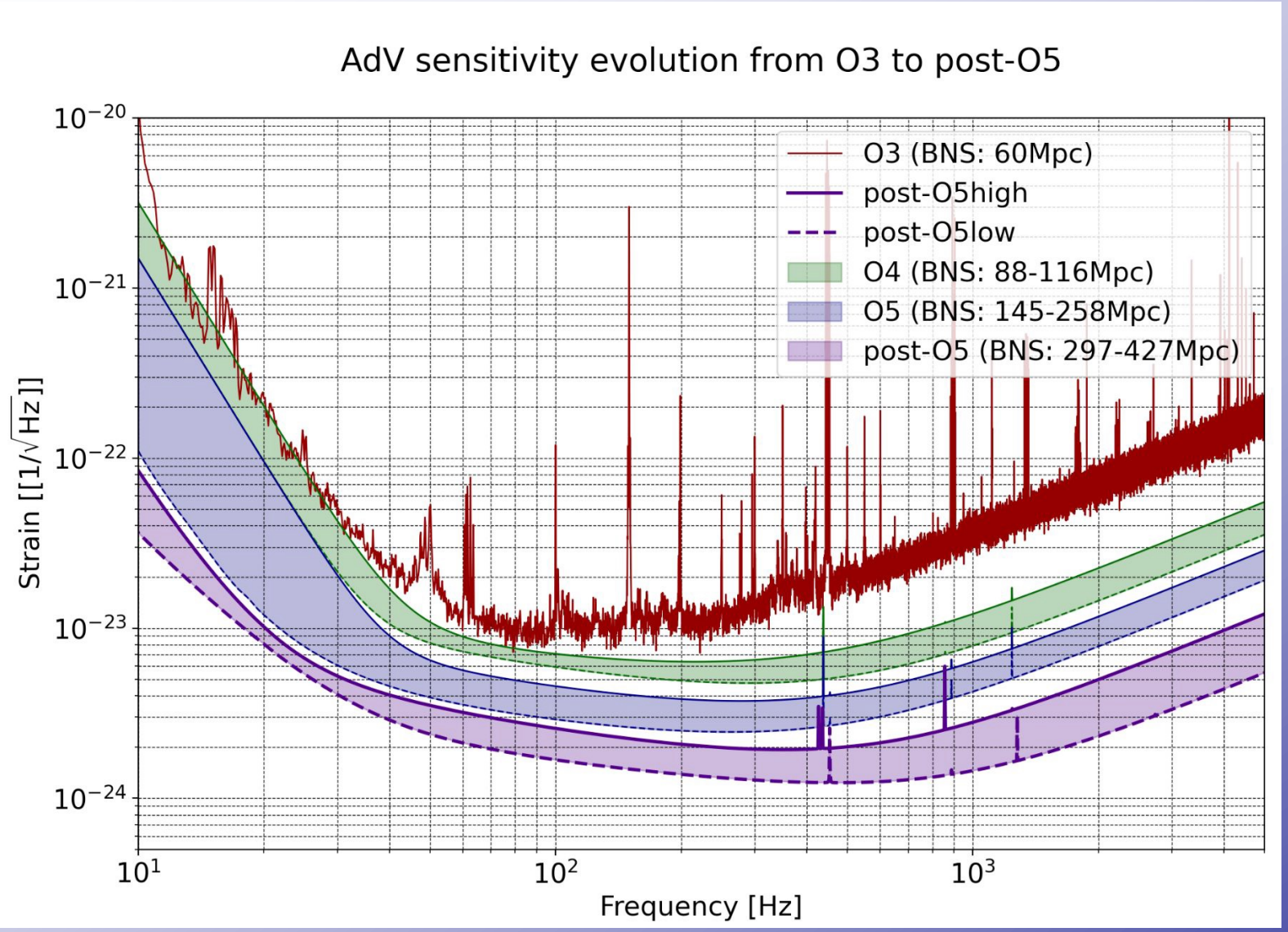
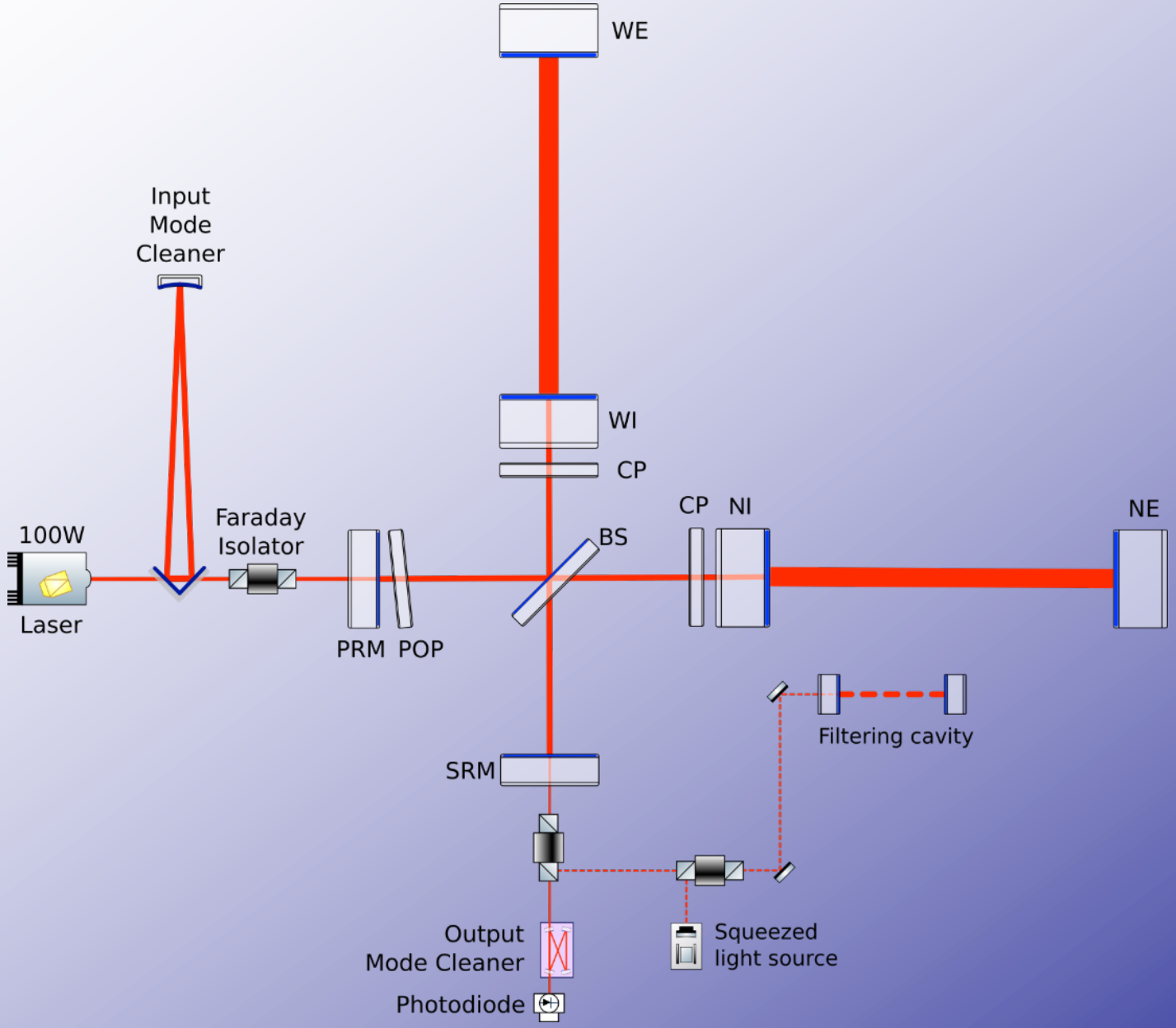
Sensitivity scenarios



Optical Design

AdVirgo+ Phase I Baseline



Introduction
Control system setup

On long superattenuators (BS, NI, NE, WI, WE, PR, SR) are installed:

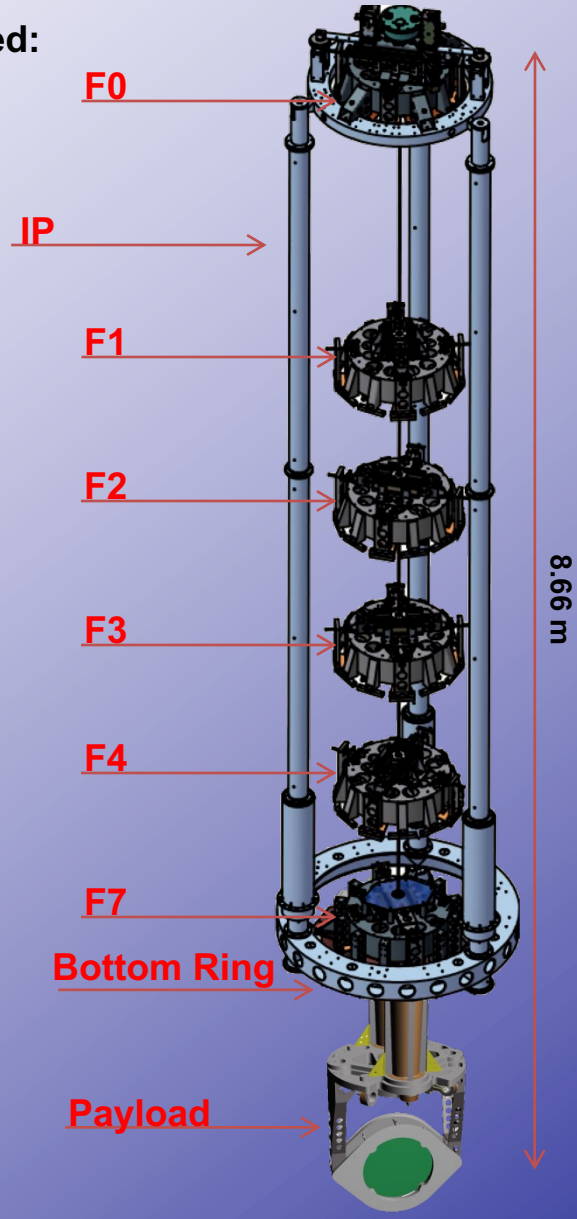
- **18 LVDTs** of 3 different types
  - 9 Vertical LVDTs (F0 – F7 Crossbar, Bottom Ring)
  - 3 F0 Horizontal LVDT
  - 6 F7 LVDTs

- **5 Accelerometers** of 2 different types installed on F0:
  - 3 Horizontal Accs
  - 2 Vertical Accs

- **23 Coils** of 4 different types
  - 5 F0 Coils
  - 6 F7 Coils
  - 8 Marionette coils
  - 4 Mirror coils

- **3 Piezos** on bottom ring (**Not used yet**)

- **21 Motors**
  - 1 Top screw F0 vertical motor
  - 3 F0 trolley motors
  - 6 Fishing rod motors
  - 2 Marionette motors
  - 4 F7 motors
  - 5 Accelerometer motors



Introduction
Control system setup

On IB superattenuator are installed:

- **9 LVDTs** of 2 different types
  - 6 Vertical LVDTs (F0, F4, F7 Crossbar, Bottom Ring)
  - 3 F0 Horizontal LVDT

- **5 Accelerometers** of 2 different types installed on F0:
  - 3 Horizontal Accs
  - 2 Vertical Accs

- **13 Coils** of 2 different types
  - 5 F0 Coils
  - 8 Marionette coils

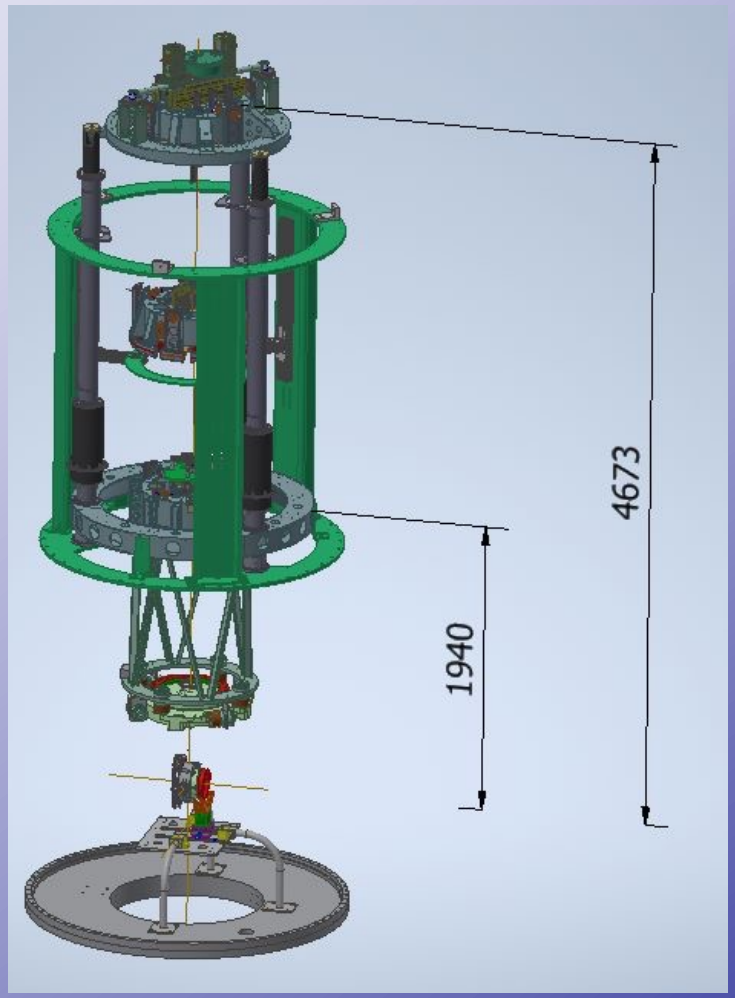
- **3 Piezos** on bottom ring (**Not used yet**)

- **18 Motors**
  - 1 Top screw F0 vertical motor
  - 3 F0 trolley motors
  - 3 Fishing rod motors
  - 2 Marionette motors
  - 4 F7 motors
  - 5 Accelerometer motors

Introduction
Control system setup

On MC superattenuator are installed:

- **9 LVDTs** of 2 different types
  - 6 Vertical LVDTs (F0, F4, F7 Crossbar, Bottom Ring)
  - 3 F0 Horizontal LVDT
- **5 Accelerometers** of 2 different types installed on F0:
  - 3 Horizontal Accs
  - 2 Vertical Accs
- **17 Coils** of 3 different types
  - 5 F0 Coils
  - 8 Marionette Coils
  - 4 Mirror Coils
- **3 Piezos** on bottom ring (**Not used yet**)
- **19 Motors**
  - 1 Top screw F0 vertical motor
  - 3 F0 trolley motors
  - 4 Fishing rod motors
  - 2 Marionette motors
  - 4 F7 motors
  - 5 Accelerometer motors



Introduction
Control system setup

On detection superattenuator (OB) are installed:

- **9 LVDTs** of 3 different types
  - 6 Vertical LVDTs (F0, F4, F7 Crossbar, Bottom Ring)
  - 3 F0 Horizontal LVDT

- **5 Accelerometers** of 2 different types installed on F0:
  - 3 Horizontal Accs
  - 2 Vertical Accs

- **5 F0 Coils**

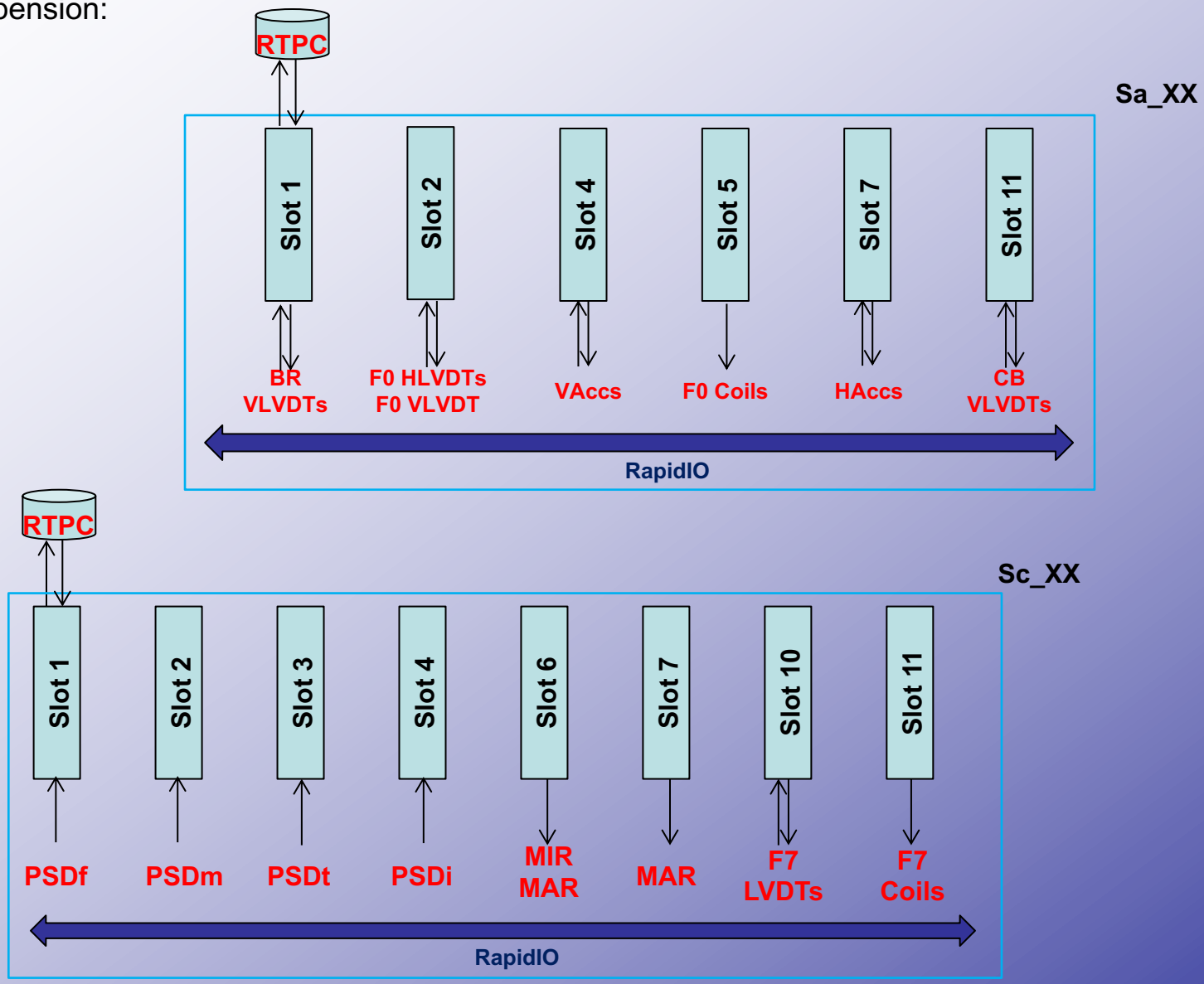
- **3 Piezos** on bottom ring (**Not used yet**)

- **18 Motors**
  - 1 Top screw F0 vertical motor
  - 3 F0 trolley motors
  - 3 Fishing rod motors
  - 2 Marionette motors
  - 4 F7 motors
  - 5 Accelerometer motors

AdVirgo Superattenuator

Control system hardware

• A total of 14 boards, each one equipped with an 8-core TMS320C6678 DSP, are connected to each long suspension:



AdVirgo Superattenuator
Control system software

SA control is an extremely complex system:

- **131** DSP boards are installed on BPC, BS, IB, MC, PR, NI, NE, WI, WE, SR, OB
- **185** control code files are running at the same time on the DSP cores at 10 kHz (IP, F7, LC controls), 40 kHz (Global signals oversampling) and 320 kHz (Digital demodulation of sensors)

- All the DSP software (code, generated assembler and binaries) is archived in an SVN repo that can be browsed:
  https://svn.ego-gw.it/svn/satsw/DSPCode_Adv/

O2 SOFTWARE MAP

SA	BOARD IP	CONNECTED DEVICES	SOFTWARE RUNNING (Core4, 10 kHz)	SOFTWARE RUNNING (Core1, 320 kHz)
BPC	172.16.2.104	PSD	/virgoDev/Sa/DSPCode_Adv/BPC/BPC_PSD	
BPC	172.16.2.141	PIEZO	/virgoDev/Sa/DSPCode_Adv/BPC/BPC_CD	
Sa_BS	172.16.2.62	BR LVDTs	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_MASTER	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_BR_LVDT_Demod
Sa_BS	172.16.2.53	F0 LVDTs	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_LVDT_HG_SRIO	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_LVDT_HG2
Sa_BS	172.16.2.32	F0 VAccs	/virgoDev/Sa/DSPCode_Adv/BS/Accs/BS_vAcc_LQG	/virgoDev/Sa/DSPCode_Adv/BS/Accs/BS_vAcc_Demod
Sa_BS	172.16.2.33	F0 Coils	/virgoDev/Sa/DSPCode_Adv/BS/InertialDamping/BS_ID_Diag	
Sa_BS	172.16.2.133	F0 HAccs	/virgoDev/Sa/DSPCode_Adv/BS/Accs/BS_Acc_LQG	/virgoDev/Sa/DSPCode_Adv/BS/Accs/BS_Acc_Demod
Sa_BS	172.16.2.52	F1-F7 VLVDTs	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_VLVDT_SRIO	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_VLVDT
Sc_BS	172.16.2.80	PSD	/virgoDev/Sa/DSPCode_Adv/BS/LC/BS_PSDf	
Sc_BS	172.16.2.108	PSD	/virgoDev/Sa/DSPCode_Adv/BS/LC/BS_PSDm	
Sc_BS	172.16.2.110	PSD	/virgoDev/Sa/DSPCode_Adv/BS/LC/BS_PSDt	
Sc_BS	172.16.2.84	PSD	/virgoDev/Sa/DSPCode_Adv/BS/LC/BS_PSDi	
Sc_BS	172.16.2.181	MIR, MAR Coils	/virgoDev/Sa/DSPCode_Adv/BS/LC/BS_Mir	
Sc_BS	172.16.2.179	MAR Coils	/virgoDev/Sa/DSPCode_Adv/BS/LC/BS_Mar	
Sc_BS	172.16.2.139	F7 LVDT	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_F7_LVDT	/virgoDev/Sa/DSPCode_Adv/BS/LVDT/BS_F7_LVDT_Demod
Sc_BS	172.16.2.120	F7 Coils	/virgoDev/Sa/DSPCode_Adv/BS/F7/BS_F7_CD	
Sa_IB	172.16.2.28	BR LVDTs	/virgoDev/Sa/DSPCode_Adv/IB/LVDT/IB_MASTER	/virgoDev/Sa/DSPCode_Adv/IB/LVDT/IB_BR_LVDT_Demod
Sa_IB	172.16.2.130	F0, F4, F7 LVDTs	/virgoDev/Sa/DSPCode_Adv/IB/LVDT/IB_LVDT	/virgoDev/Sa/DSPCode_Adv/IB/LVDT/IB_LVDT_Demod
Sa_IB	172.16.2.9	F0 VAccs	/virgoDev/Sa/DSPCode_Adv/IB/Accs/IB_vAcc_LQG	/virgoDev/Sa/DSPCode_Adv/IB/Accs/IB_vAcc_Demod
Sa_IB	172.16.2.121	F0 Coils	/virgoDev/Sa/DSPCode_Adv/IB/InertialDamping/IB_ID_Diag	
Sa_IB	172.16.2.23	F0 HAccs	/virgoDev/Sa/DSPCode_Adv/IB/Accs/IB_Acc_LQG	/virgoDev/Sa/DSPCode_Adv/IB/Accs/IB_Acc_Demod
Sc_IB	172.16.2.118	PSD	/virgoDev/Sa/DSPCode_Adv/IB/LC/IB_PSDf	
Sc_IB	172.16.2.86	PSD	/virgoDev/Sa/DSPCode_Adv/IB/LC/IB_PSDi	
Sc_IB	172.16.2.107	PSD	/virgoDev/Sa/DSPCode_Adv/IB/LC/IB_PSDt	
Sc_IB	172.16.2.173	MAR Coils	/virgoDev/Sa/DSPCode_Adv/IB/LC/IB_Mar1	
Sc_IB	172.16.2.174	MAR Coils	/virgoDev/Sa/DSPCode_Adv/IB/LC/IB_Mar2	
Sa_MC	172.16.2.128	BR LVDTs	/virgoDev/Sa/DSPCode_Adv/MC/LVDT/MC_MASTER	/virgoDev/Sa/DSPCode_Adv/MC/LVDT/MC_BR_LVDT_Demod
Sa_MC	172.16.2.51	F0, F4, F7 LVDTs	/virgoDev/Sa/DSPCode_Adv/MC/LVDT/MC_LVDT	/virgoDev/Sa/DSPCode_Adv/MC/LVDT/MC_LVDT_Demod
Sa_MC	172.16.2.158	F0 VAccs	/virgoDev/Sa/DSPCode_Adv/MC/Accs/MC_vAcc_LQG	/virgoDev/Sa/DSPCode_Adv/MC/Accs/MC_vAcc_Demod
Sa_MC	172.16.2.103	F0 Coils	/virgoDev/Sa/DSPCode_Adv/MC/InertialDamping/MC_ID_Diag	
Sa_MC	172.16.2.14	F0 HAccs	/virgoDev/Sa/DSPCode_Adv/MC/Accs/MC_Acc_LQG	/virgoDev/Sa/DSPCode_Adv/MC/Accs/MC_Acc_Demod
Sa_MC	172.16.2.150	PIEZO	/virgoDev/Sa/DSPCode_Adv/MC/Tilt/Piezo_Test	
Sc_MC	172.16.2.101	PSD	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_PSDf	
Sc_MC	172.16.2.168	PSD	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_PSDi	
Sc_MC	172.16.2.88	PSD	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_PSDTf	
Sc_MC	172.16.2.109	PSD	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_PSDTi	
Sc_MC	172.16.2.171	MAR Coils	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_Mar1	
Sc_MC	172.16.2.172	MAR Coils	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_Mar2	
Sc_MC	172.16.2.176	MIR Coils	/virgoDev/Sa/DSPCode_Adv/MC/LC/MC_Mir	
Sa_NE	172.16.2.37	BR LVDTs	/virgoDev/Sa/DSPCode_Adv/NE/LVDT/NE_MASTER	/virgoDev/Sa/DSPCode_Adv/NE/LVDT/NE_BR_LVDT_Demod
Sa_NE	172.16.2.40	F0 LVDTs	/virgoDev/Sa/DSPCode_Adv/NE/LVDT/NE_LVDT	/virgoDev/Sa/DSPCode_Adv/NE/LVDT/NE_LVDT_Demod

Summary of O4 activities

Here is a summary of O4 activities in charge of Virgo Pisa:

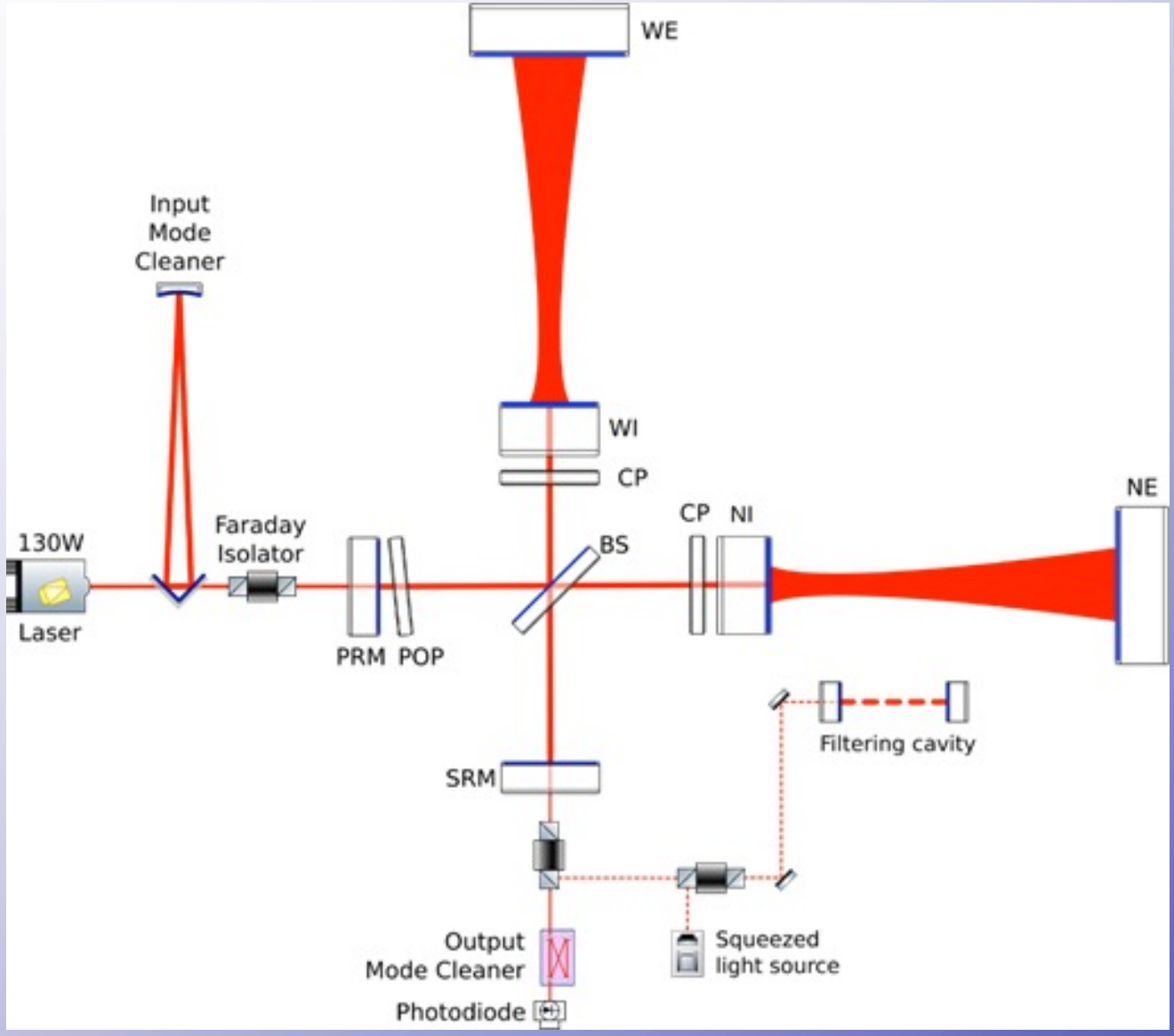
- **Monitoring of system mechanical components:**
  - Overall monitoring of all signals generated by the entire suspension system (> **500 channels**).
  - People currently involved: Boschi, Majorana (Roma1), Ruggi (EGO)

- **Maintenance of control system hardware:**
  - Troubleshooting of all sensors (**153 LVDTs, 50 Accelerometers**), actuators (**196 coils**, **201 motors**), and signal processing devices (**131 DSPs, 19 MCHs**), timing and DAQ systems links.
  - People currently involved: Boschi, Gennai, Piendibene, Ruggi (EGO)

- **Maintenance and development of control system software:**
  - Troubleshooting and development of all software currently running on DSPs (**185 control files**).
  - Troubleshooting and development of all software currently interacting with the automation system (supervisor).
  - Troubleshooting of DAQ and Global Control communication.
  - People currently involved: Boschi, Gkaitzis, Ruggi (EGO)

- **On call during both commissioning and science run:**
  - Rapid response diagnose and intervention (24/7 during run) in all cases operators are unable to solve the issue.
  - People currently involved: Boschi, Majorana (Roma1), Ruggi (EGO),

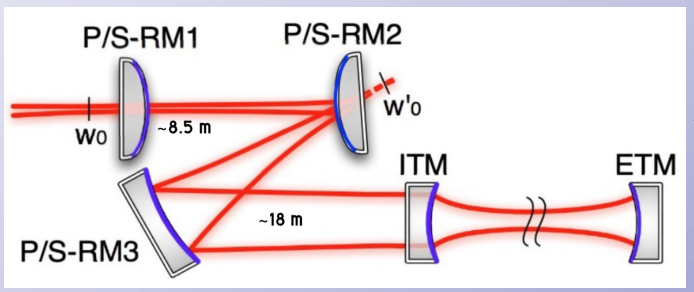
Optical Design
AdVirgo+ Phase II LMs

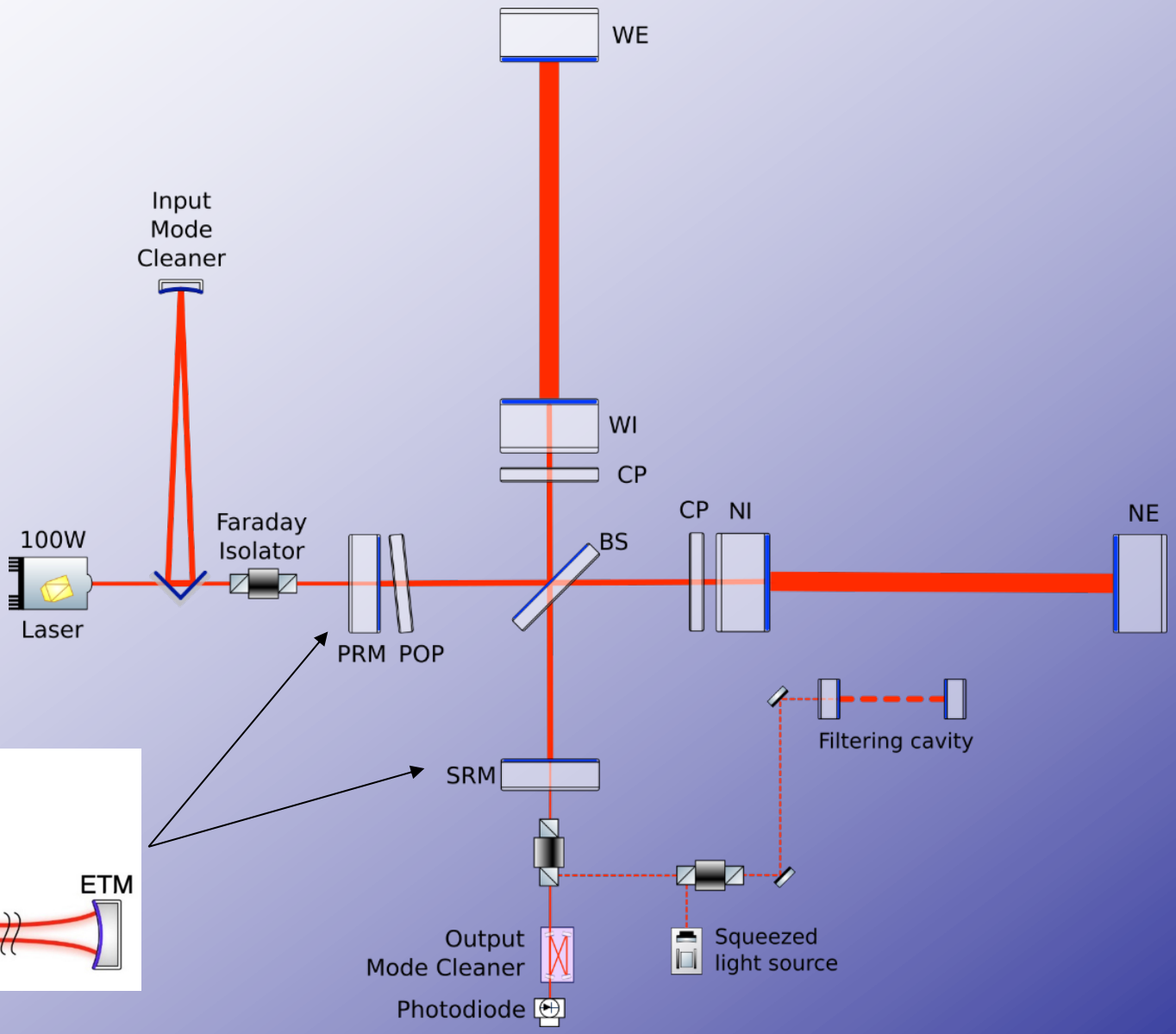


Optical Design
AdVirgo+ Phase II SRCs

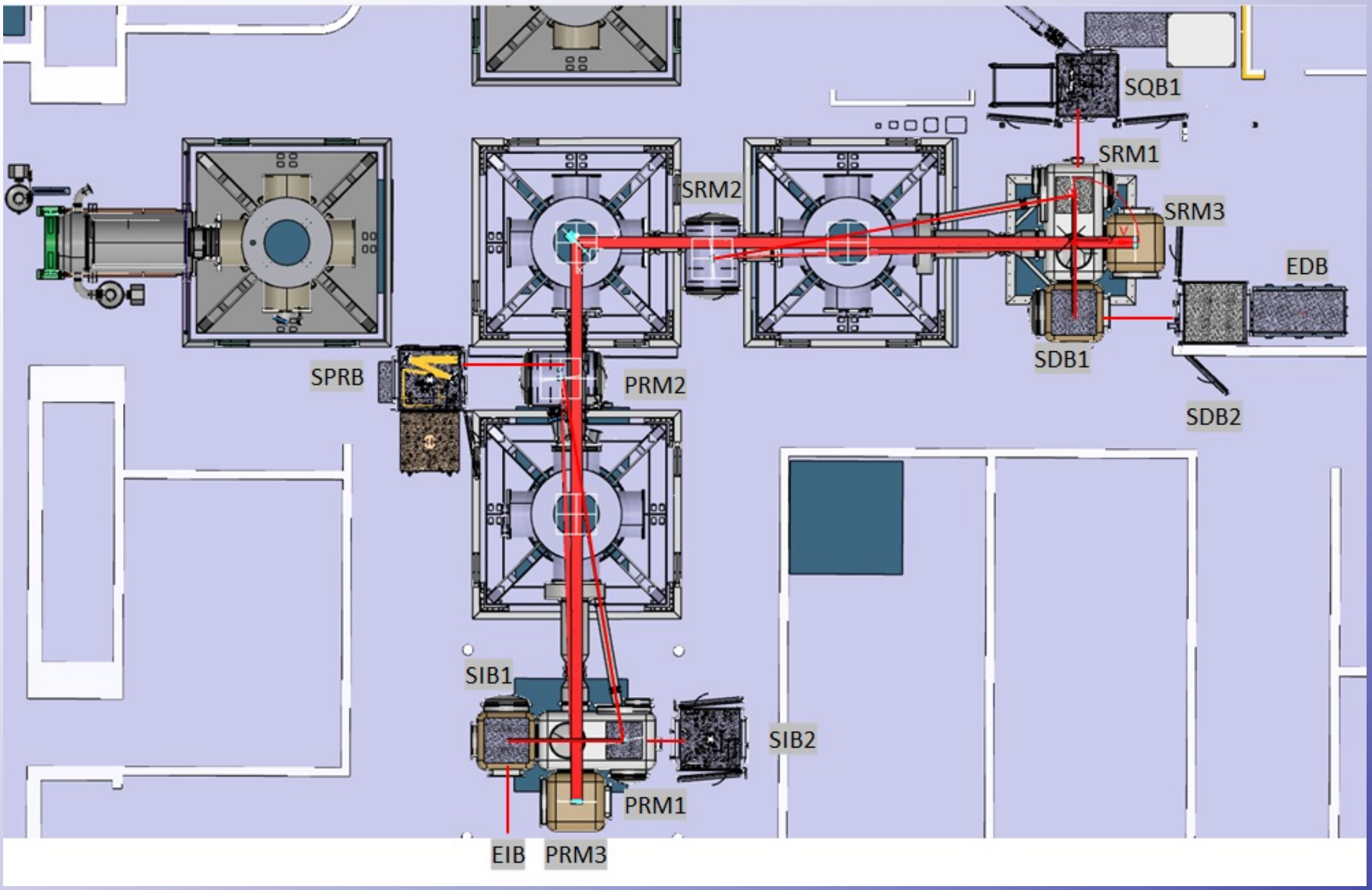
3 Mirrors will have to be used for each new cavity:

- 2 x 3 kg
- 1 x 20 kg





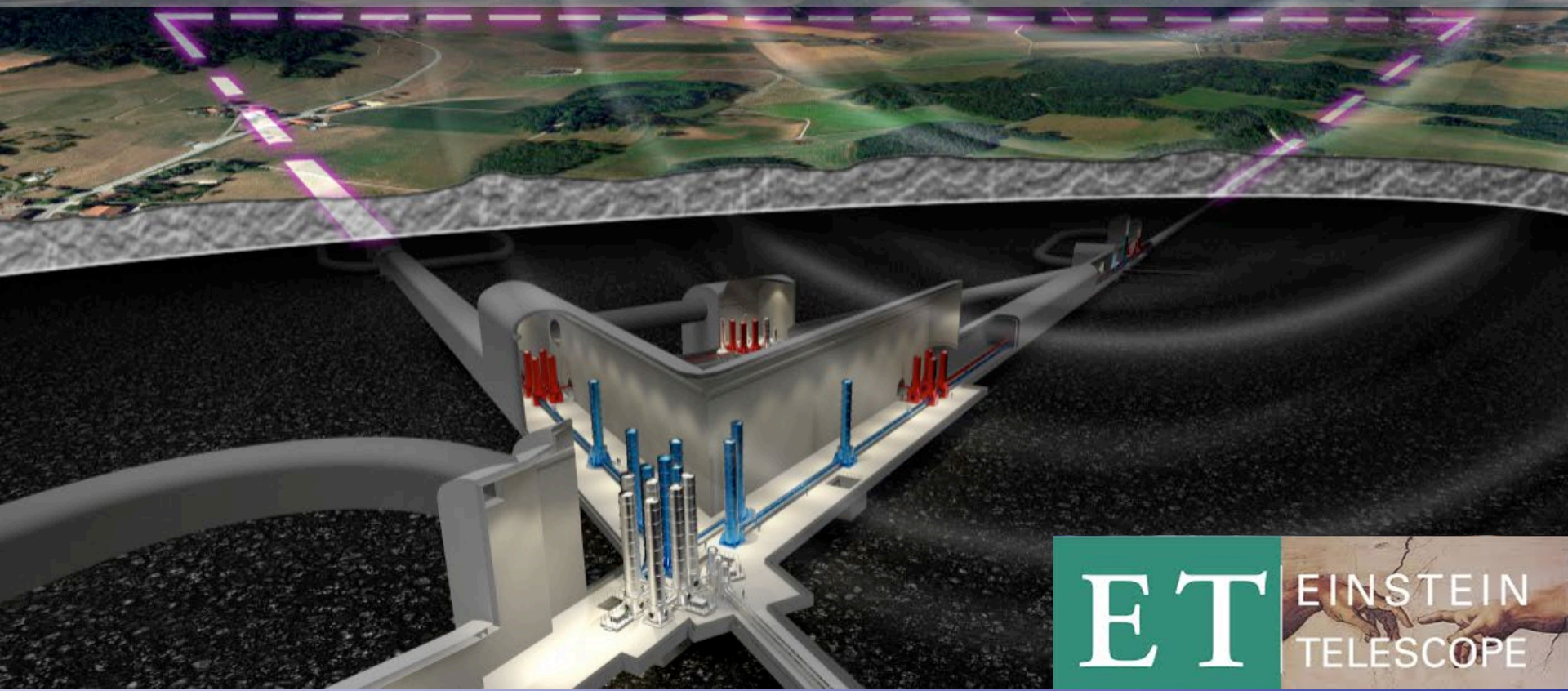
Optical Design
AdVirgo+ Phase II SRCs



The future of gravitational wave astronomy

Einstein Telescope

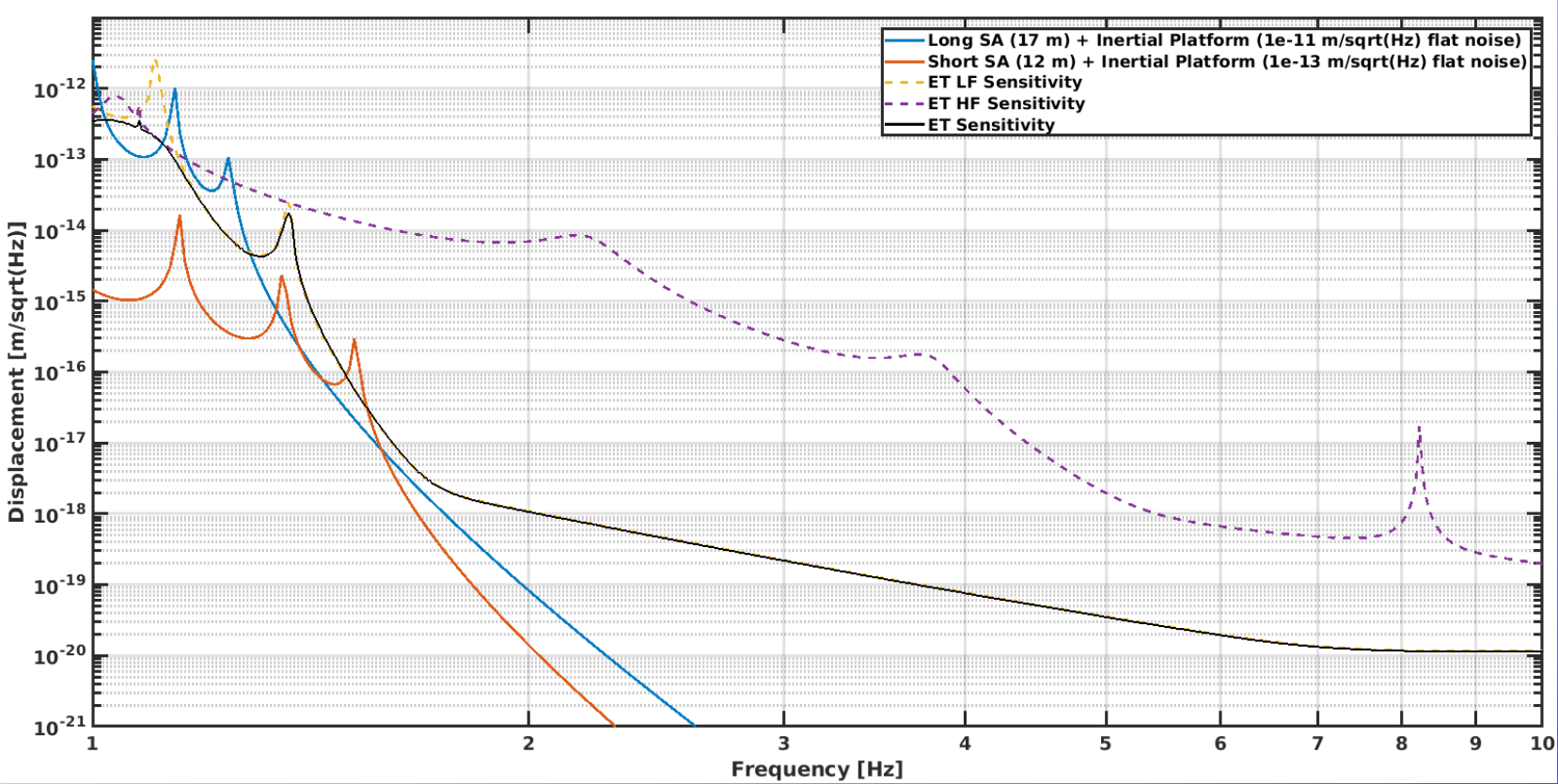
- Einstein Telescope (ET) is expected to have a triangular configuration, with 10 km of length for each side, in order to host two detectors with different bandwidths, and, to drastically reduce the effects of ground motion, will be built underground, making the needed infrastructural works very complex and expensive.
- In Europe three candidate sites have been identified for ET: an area in the Nuoro province, in Sardinia, Italy, the Meuse-Rhine euroregion at the border between Netherlands, Belgium and Germany, and a location in Saxony, Germany.



Einstein Telescope
Seismic isolation

- The gravitational-wave interferometers of next generation, Einstein and Cosmic Explorer, aim at gaining a factor of 10 in noise level, respect to Virgo and LIGO, but also extending at low frequency their detection band.

- Even in a site with very low seismicity, the sensitivity increase in the low frequency region will put challenging constraints on the suppression of seismic noise: **new designs should be studied**.



ET Design Update (ET-0007B-20)

Laser Interferometer Lunar Antenna

https://www.vanderbilt.edu/lunarlabs/lila/