Advanced Virgo

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Maastricht University

Nikhef

Advanced Virgo

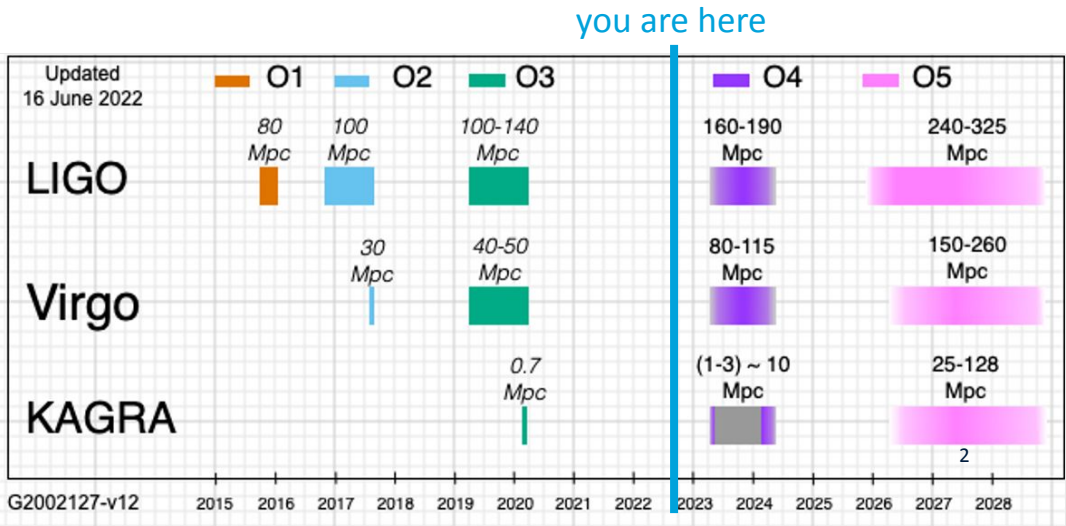
Virgo in a nutshell

What?
Interferometric gravitational-wave detector operating since 2007

Where?
Cascina, near Pisa, Italy

Who?
European Gravitational Observatory (EGO): INFN, CNRS, Nikhef; hosts Advanced Virgo
many institutions contribute to Virgo,
18 from NL-BE

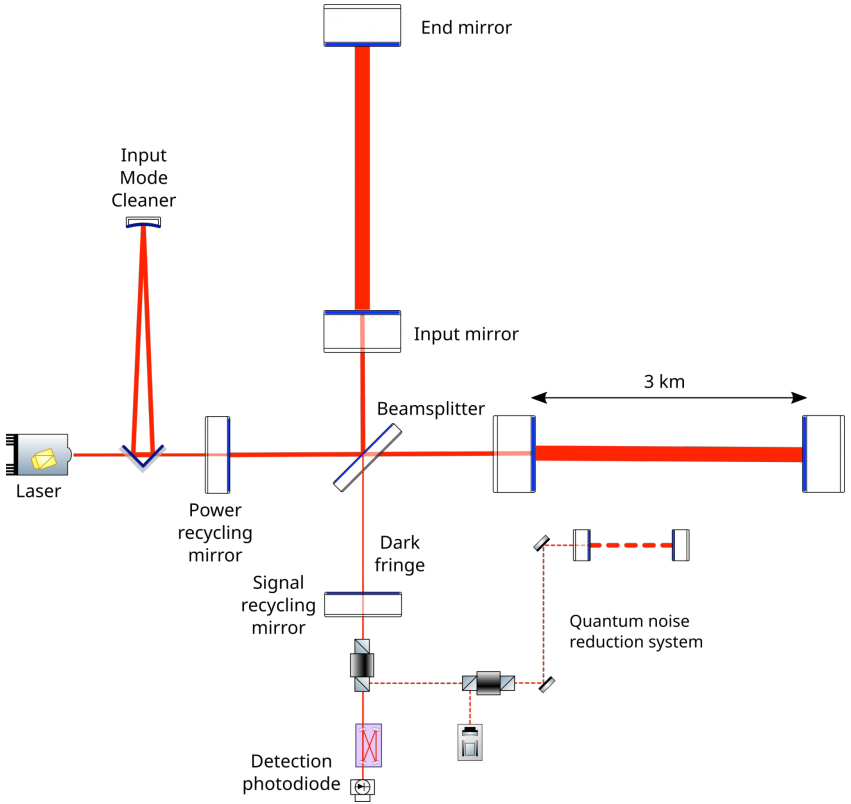
When?
currently upgrading from Advanced Virgo to Advanced Virgo+,
joining O4 observation run in spring 2023



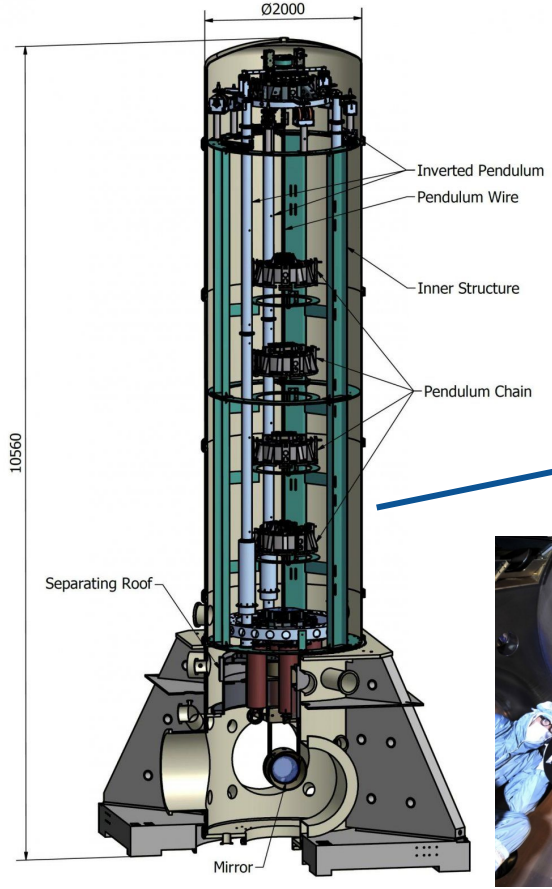
Optical layout of Advanced Virgo(+)

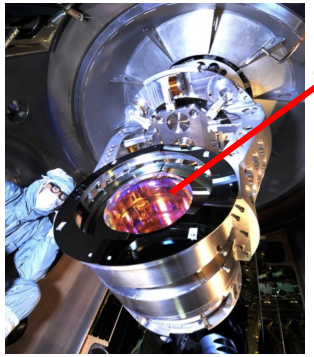
AdV+ is a “dual-recycled Michelson interferometer with Fabry-Perot arm cavities and frequency-dependent squeezing”

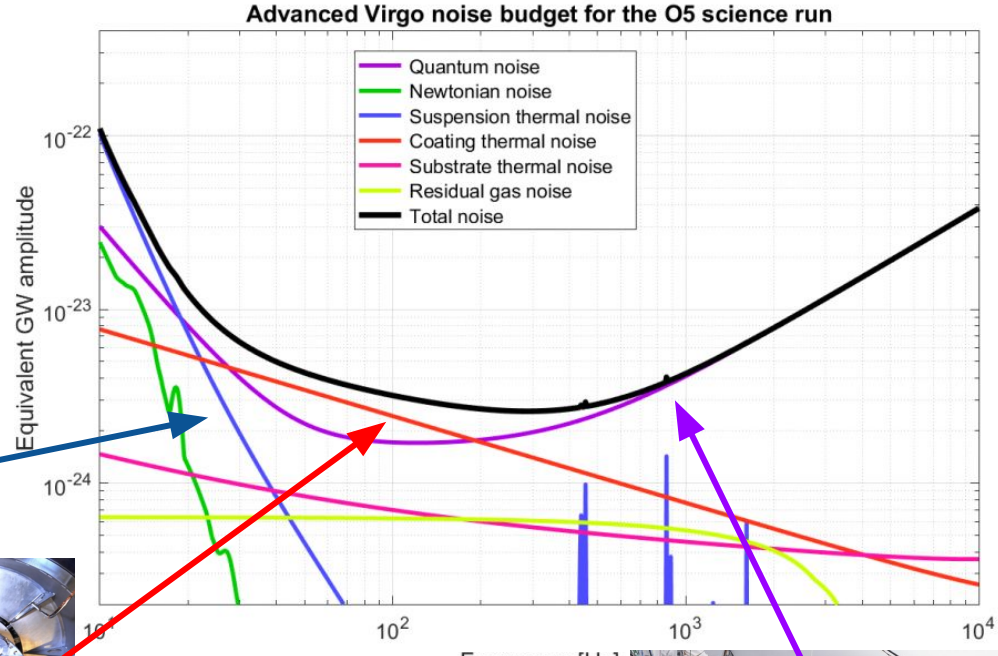
- Measures differential length change of two orthogonal arms, each 3km long
- Laser power is enhanced with resonators in the arms, and power recycling mirror
- (almost) perfect destructive interference at the output is disturbed by passing gravitational waves -> science signal
- “Squeezed light” technique reduces shot noise of laser light
- New: frequency-dependent squeezing
- New: signal-recycling mirror optimises detection bandwidth



Sensitivity of Advanced Virgo+







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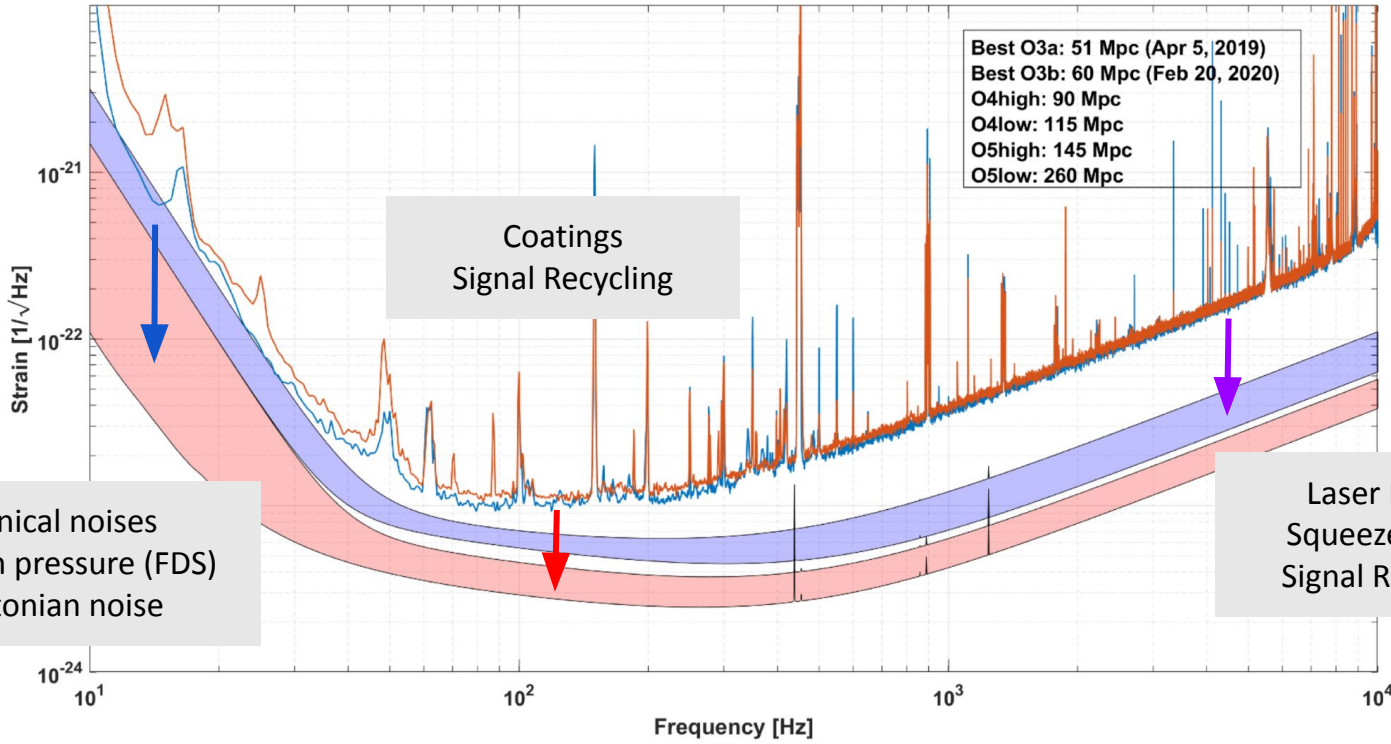
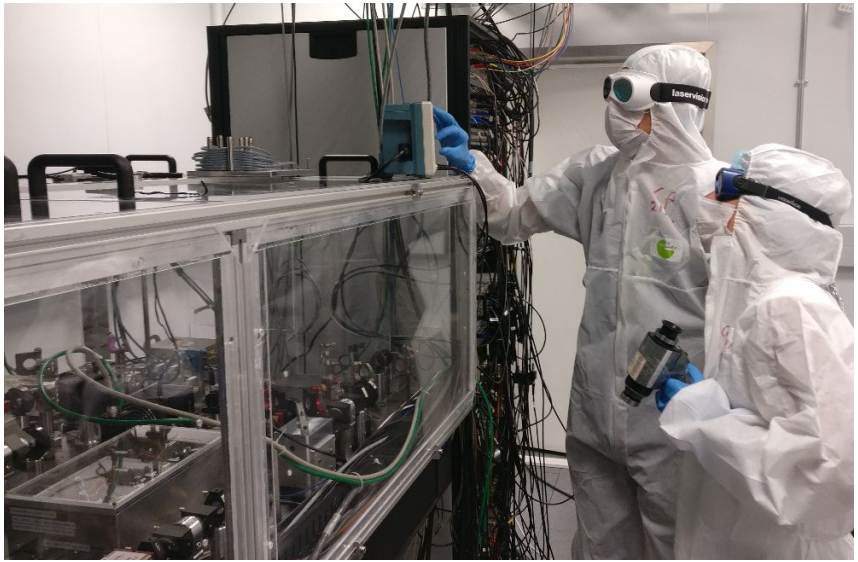


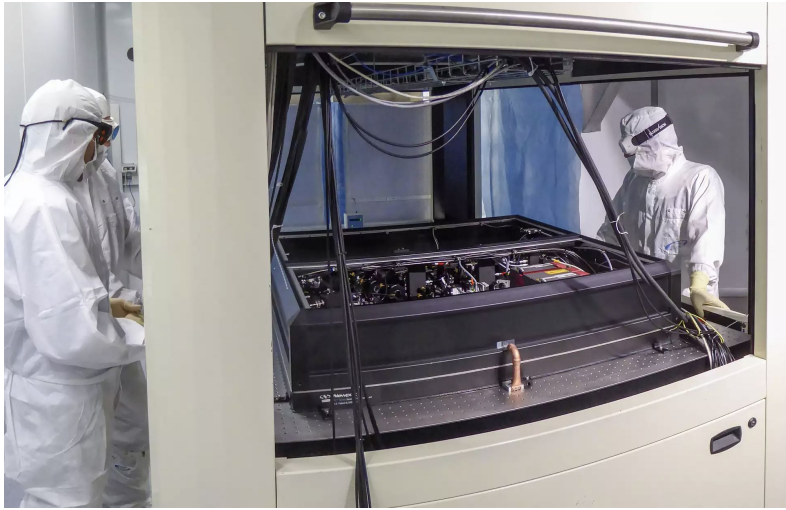
Current Upgrades: Laser

- Increase of laser power in interferometer directly leads to more signal, in principle
- In reality, higher laser power comes with increased thermal load on mirrors and sensors
  - Challenging to control interferometer in “cold state” and “hot state”
  - Generally small steps necessary to understand behaviour of system
- Increased radiation pressure forces on free-hanging mirrors
  - Optical springs make control challenging
- Currently upgraded laser power from 25W to 33W, ideally up to 40W



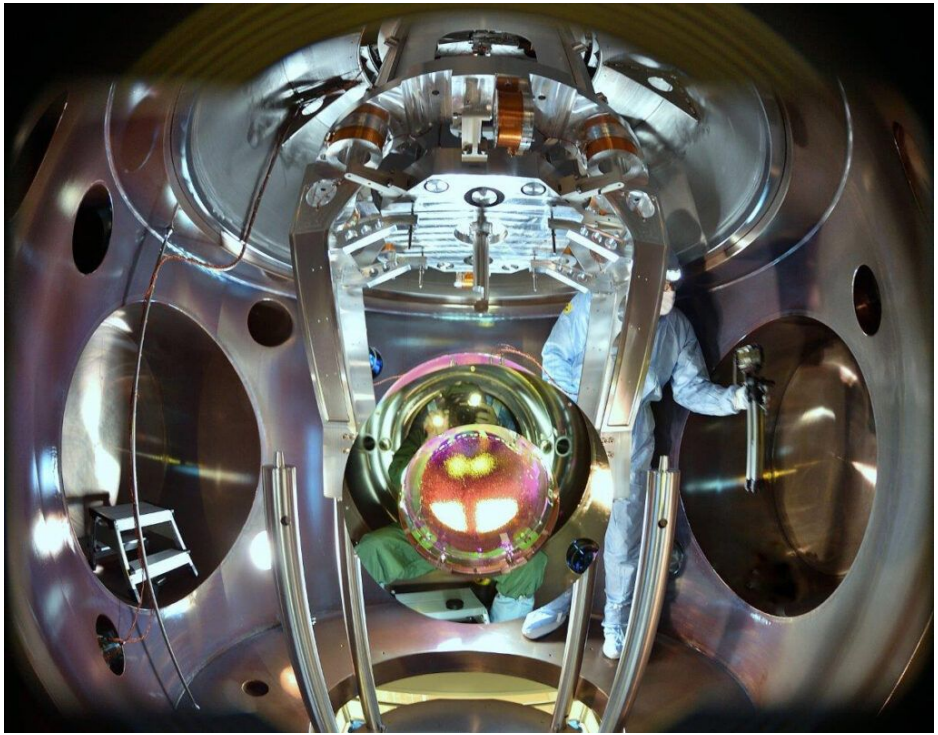
Current Upgrades: Squeezing

- Two kinds of noise in laser light: amplitude noise and phase noise
- These two are coupled via uncertainty relation, can't be made arbitratily small, but can make one smaller at expense of making other -> squeezed light
- Looks like increased laser power (factors of 5-10x within reach) but without the additional thermal load
- Need frequency-dependent shaping of the uncertainty relation for best effect
  -> filter cavity successfully installed
- See Yuefan Guo's talk tomorrow morning



Current Upgrades: signal recycling

- Signal recycling helps to shape the detector sensitivity “bucket” optimally
- Introduces another degree of freedom that has to be controlled
  - Installation of auxiliary locking system using green light to pre-stabilise the interferometer
  - Implementation of a new locking strategy
  - Adds strong optical spring depending on microscopic position
- Stray-light baffles to be installed in SR tower (Maastricht/Nikhef)

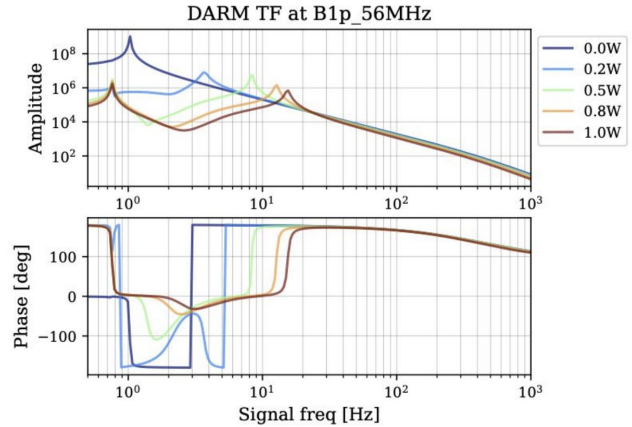


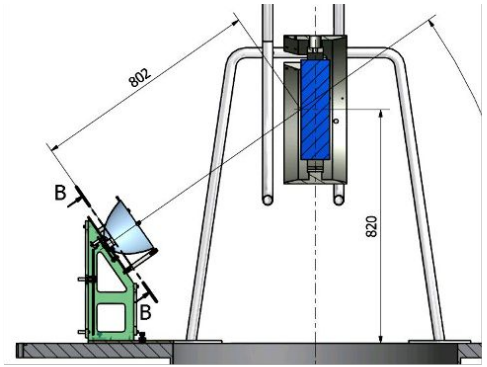
Current challenges

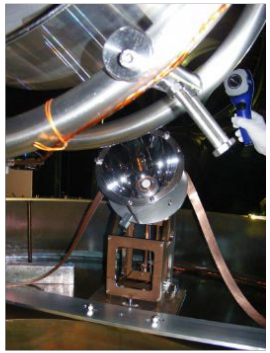
- While control of all degrees of freedom was achieved already last winter, it was not stable and repeatable enough
- Power and signal recycling cavity are close to instability, meaning that small deviations from perfect mirror shape have large effects on controllability
- Additional tuning via thermal radiation recently installed, so far with promising results

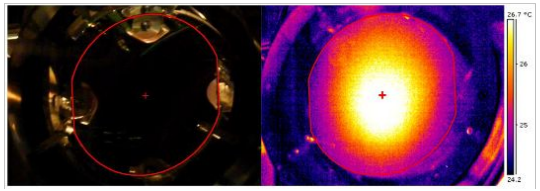
- Search for optimal working point of interferometer continues
  - … then starting noise hunting
  - … and injection of frequency-dependent squeezing

A. Green et al.







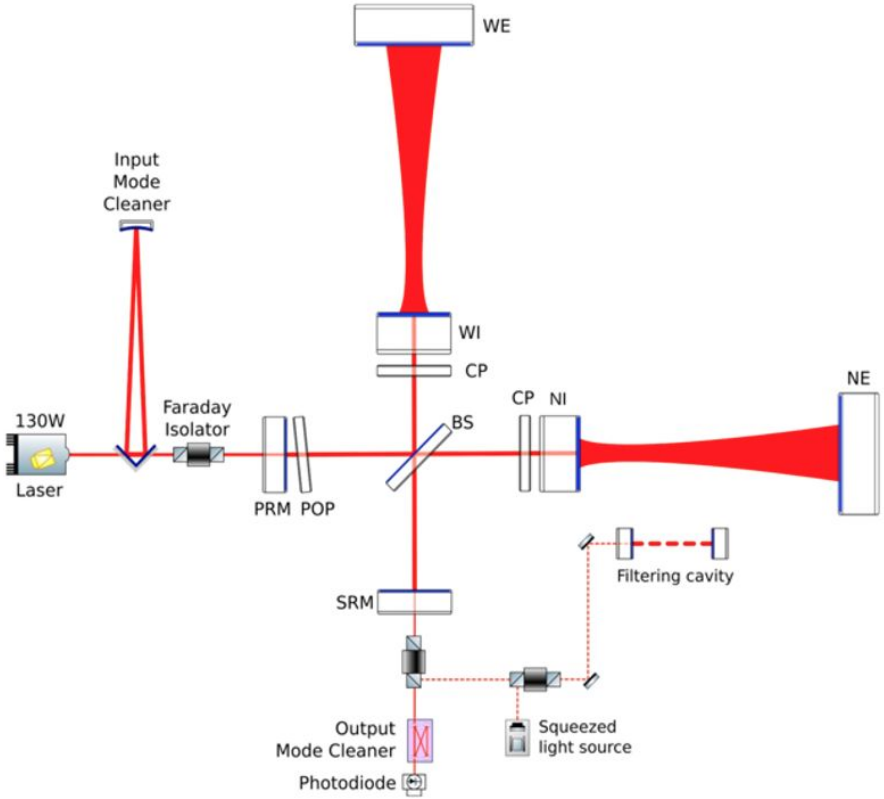


A. Chiummo, A. Rossi

After O4 comes O5: Advanced Virgo Phase II

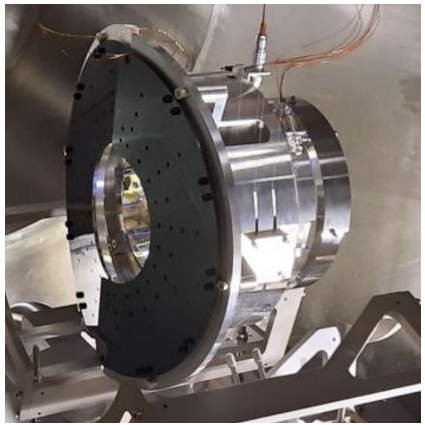
- increase beam size on EM to reduce coating thermal noise, roughly same spot size on IM
  - New, larger end mirrors
  - Change of all core optics except BS
  - New suspension for the heavier end mirrors
- new coating materials to further reduce CTN
- further increase in laser power
- adding more stray-light monitoring (instrumented baffles)

	Phase I	Phase II
EM diameter	350mm	550mm
EM RoC	1683m	1969m
IM RoC	1420m	1067m
PR/SR RoC	1475m	1075m
beam radius @ EM	58mm	91mm
beam radius @ IM	49mm	



Preparations for Phase II

- A working group on new coating designs has been established and Ti:Ge/SiO2 coatings are now developed and tested on large scale
- New mirror substrates have been procured and are being polished
- New super attenuators for large masses are being developed
- Payload stage with dummy mass of 100kg sucessfully tested
- Upgrade to laser system underway
- Upgrades to vacuum infrastructure planned



Virgo Collaboration

~760 members, ~450 authors,
128 institutions
from 15 countries

9 countries represented in the VSC Virgo