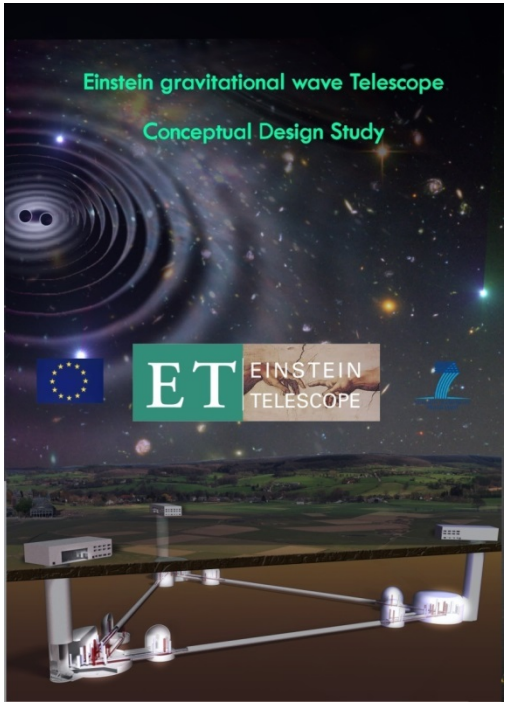
Défis expérimentaux pour Advanced Virgo et au-delà

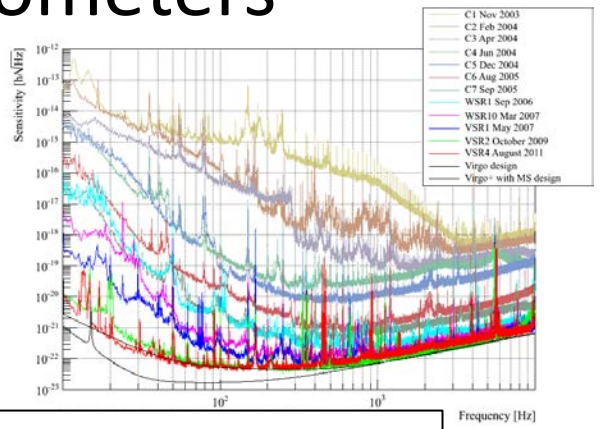
Romain Gouaty pour le groupe Virgo



Ground-based interferometers

- 1st generation interferometric detectors
  - Initial LIGO, Virgo, GEO600

    (Commissioning started in 2003 – 1st science run in 2007)
  - Enhanced LIGO, Virgo+ (2008 - 2011)



Validation of technologies for ground-based interferometers

- 2nd generation detectors
  - Advanced LIGO, Advanced Virgo, GEO-HF, KAGRA

x 10 in sensitivity
→ new technical challenges

Planning Advanced Virgo:

Construction: 2011-2014
Commissioning starts in 2015
First science run in 2016 ?

  - 2.5 generation

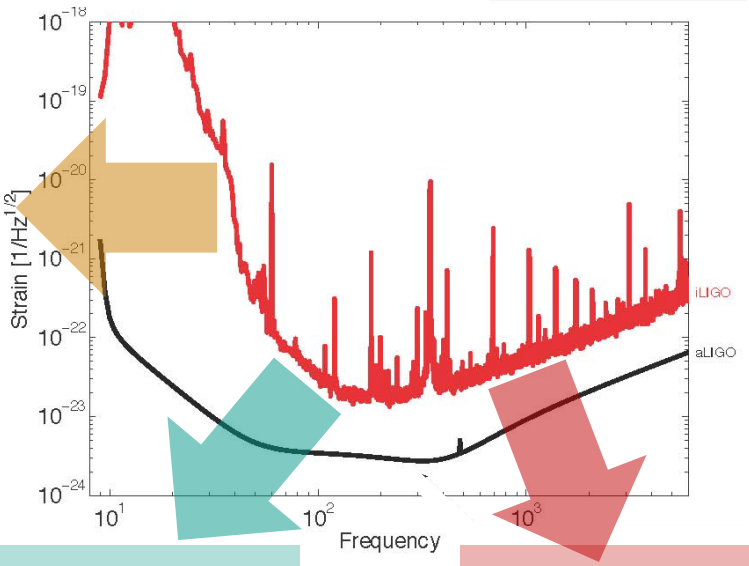
Keep same infrastructures
R&D effort needed

- 3rd generation detectors
  - Einstein Telescope, US counterpart to ET

2nd generation

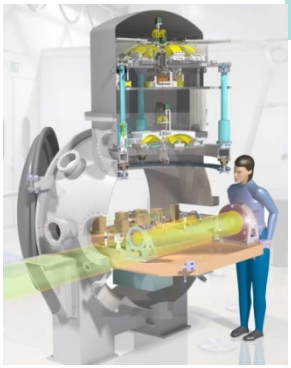
Seismic noise
Improved seismic isolation
(already OK for Virgo)

More about LAPP contributions later…



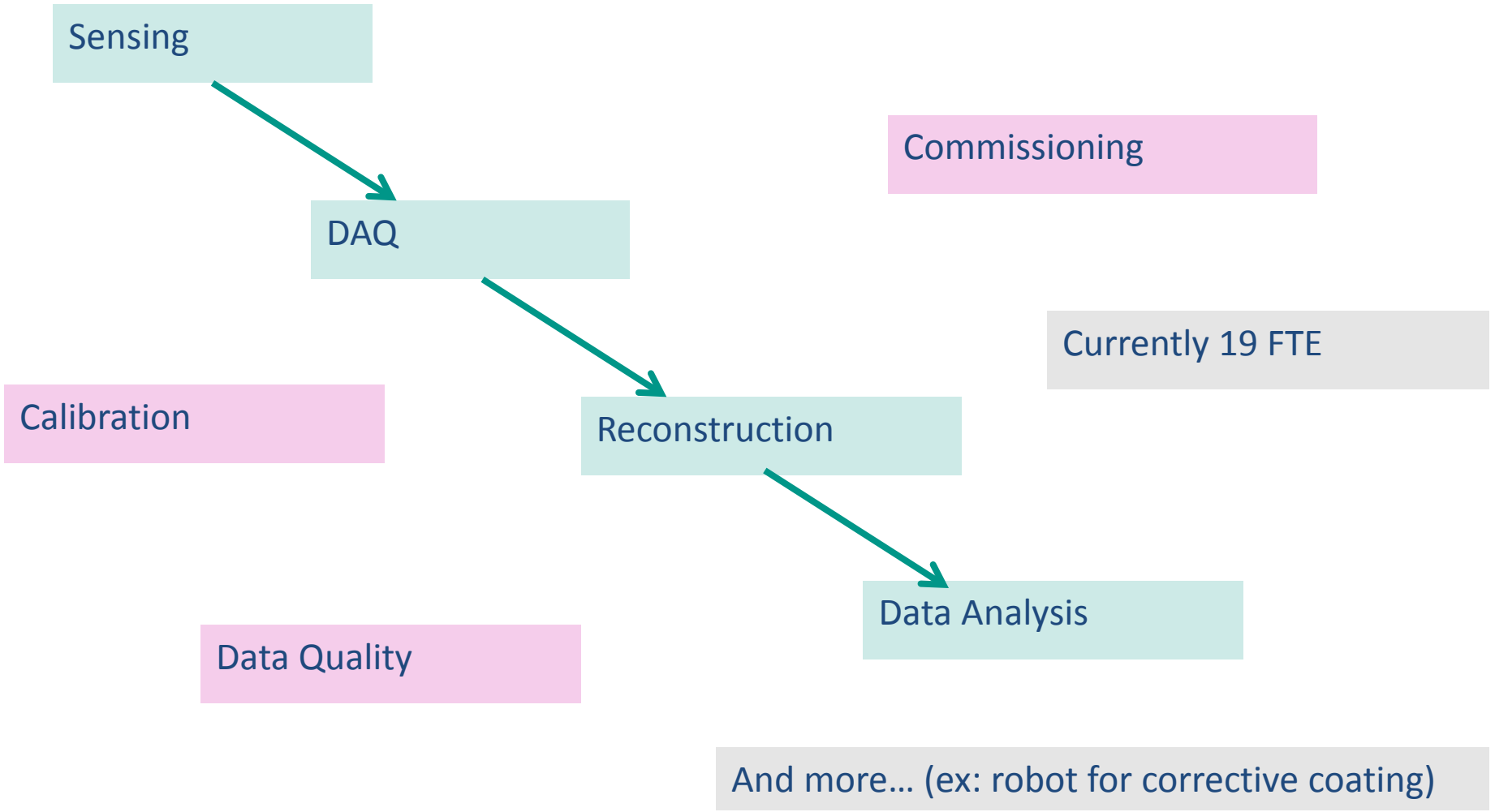
Thermal noise
Monolithic suspensions
Improved mirror coatings
Larger beam size

Quantum noise
Higher laser power
Higher finesse of the arm cavities
Thermal compensation
Signal recycling
DC detection

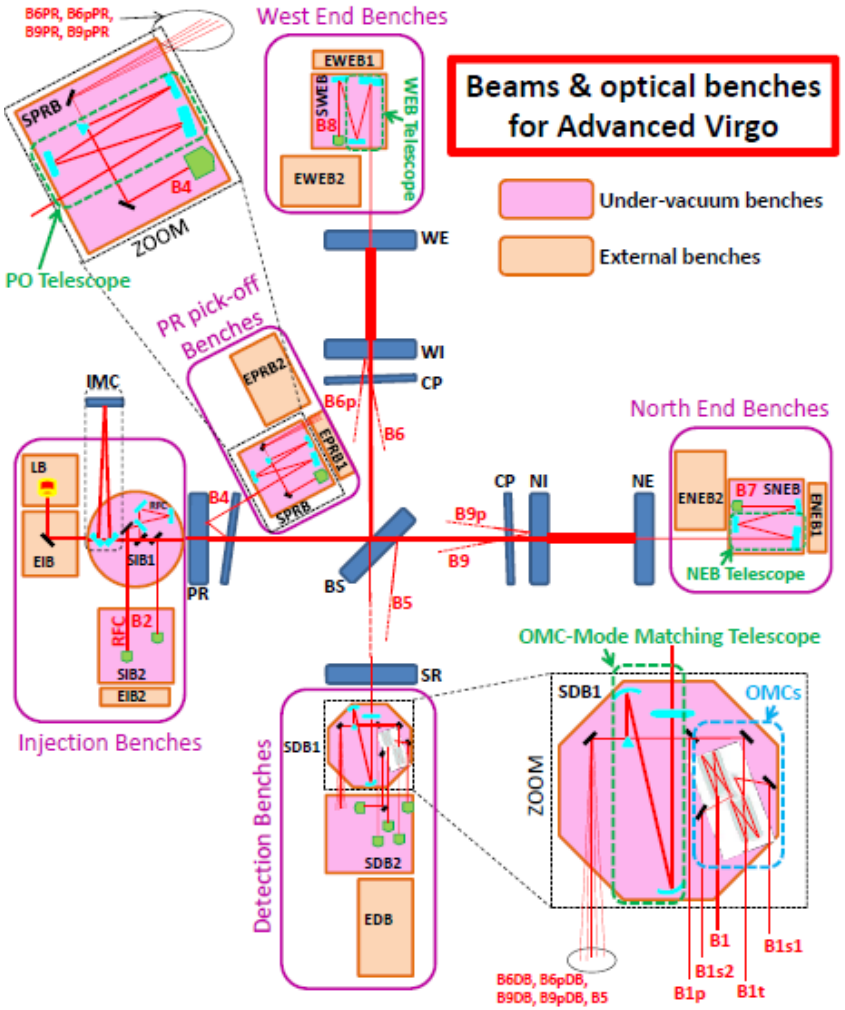


Improve interferometer immunity against environmental noises:
Photodiodes on suspended benches under vacuum

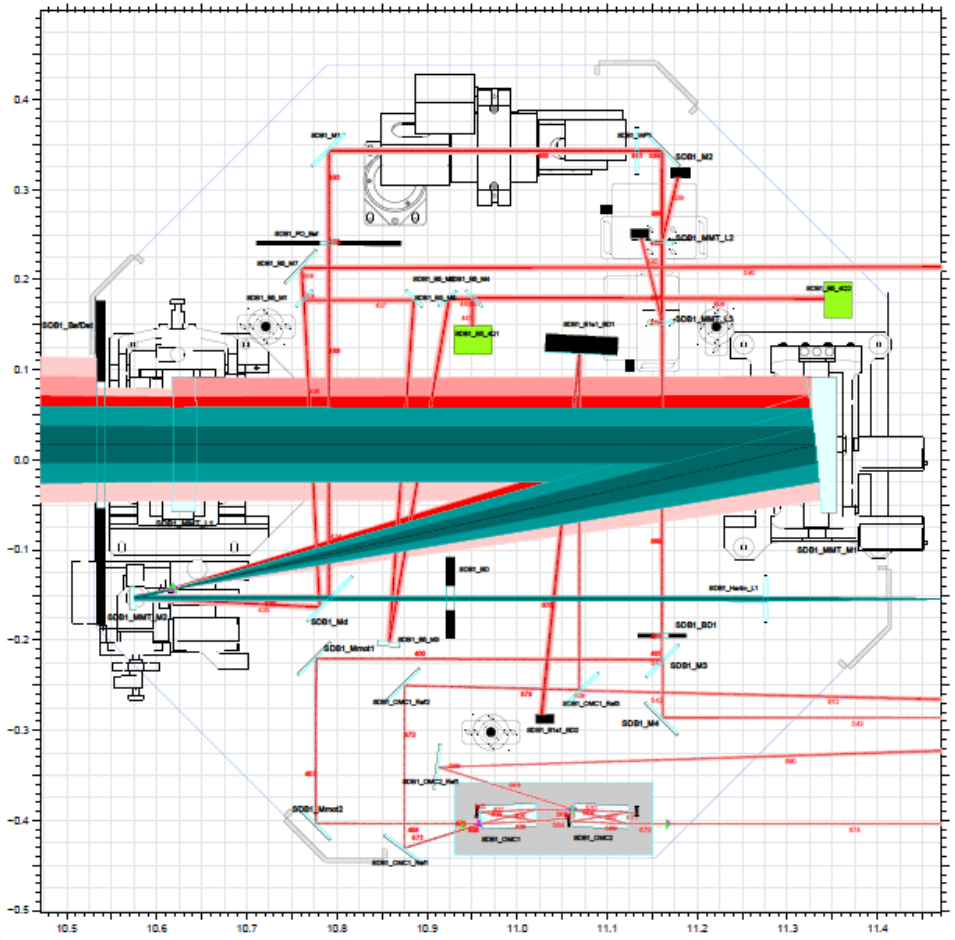
Advanced Virgo @ LAPP



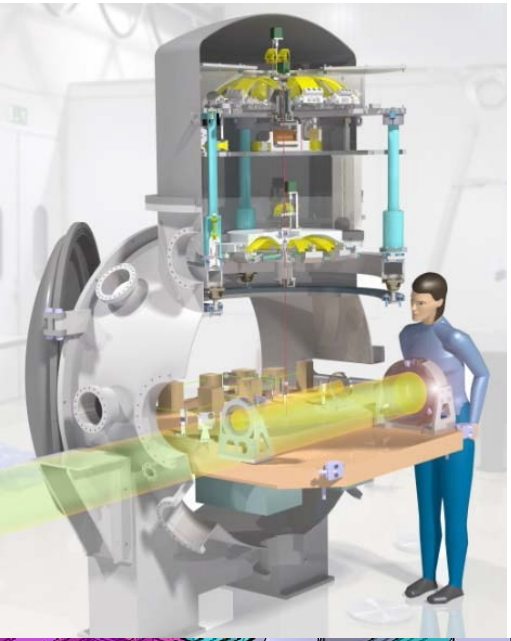
AdV @ LAPP: Detection system (I)



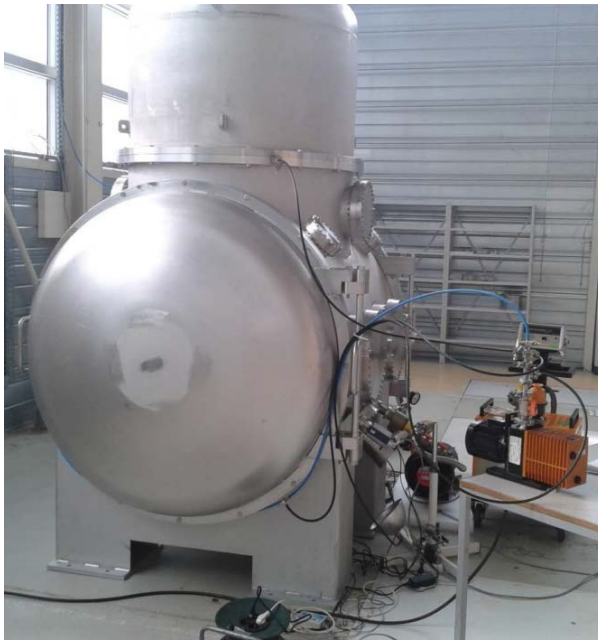
- More benches suspended in vacuum for AdV
- Optics is only one angle of the project



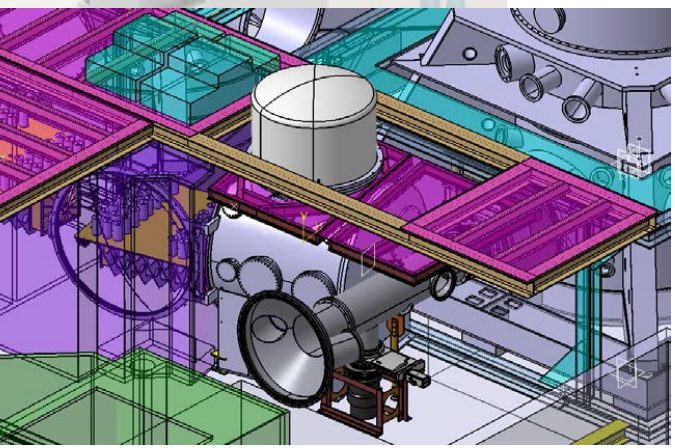
AdV @ LAPP: Detection system (II)



- Vacuum chambers designed @ LAPP
  - First two delivered early 2013 at LAPP & NIKHEF
  - Three more to come
- On-going study for on site integration



- Optical benches holding containers for electronics

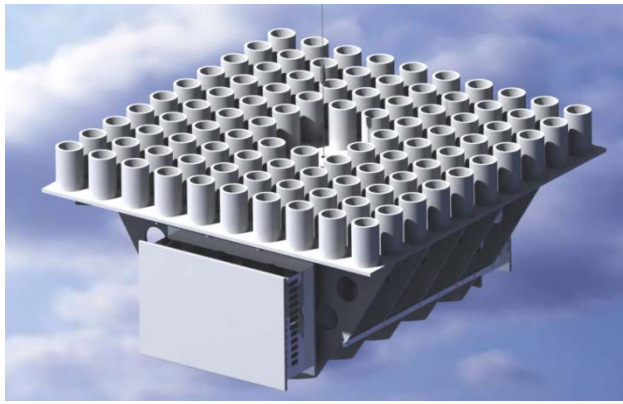


➢ **Thermal dissipation in vacuum is an issue**

→ may require bench anodization, sand-blasting of the chamber,…

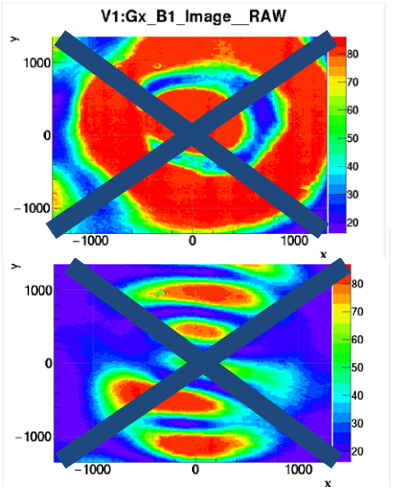
➢ **Local controls**

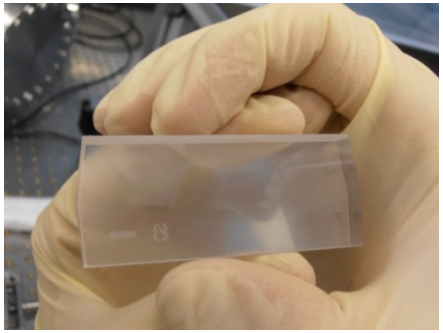
Design on going, full scale tests under preparation

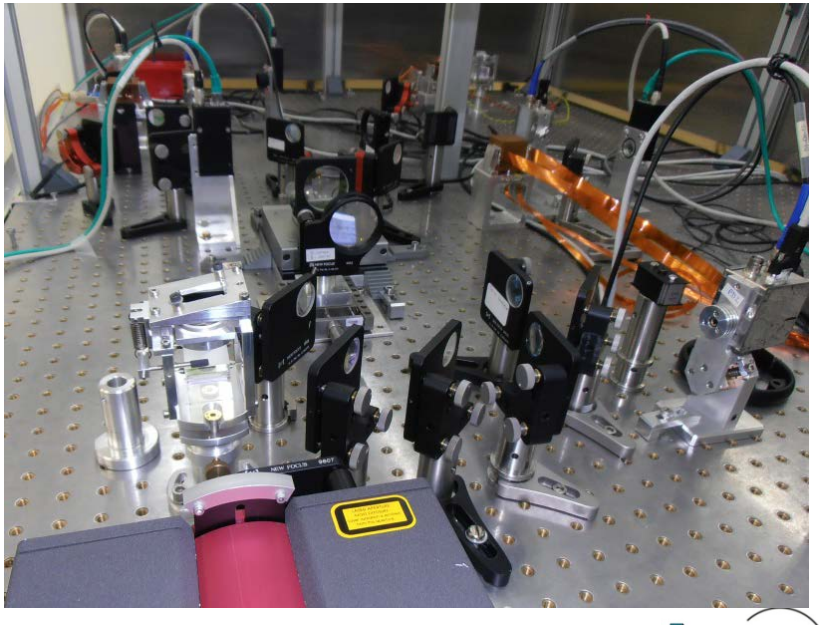


AdV @ LAPP: Detection system (III)

- Output mode-cleaner is a crucial element for sensitivity (shot noise)
  - Filter high order modes generated by beam mismatch, misalignments and astigmatism
  - New for AdV : filter RF side-bands for DC detection
- Final prototype being characterized and hopefully validated







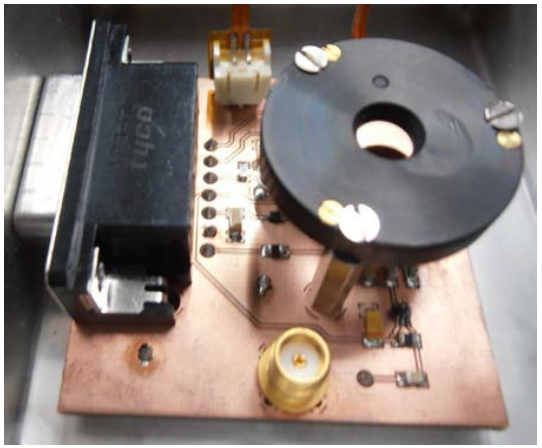
- Cavity kept on resonance with thermal control

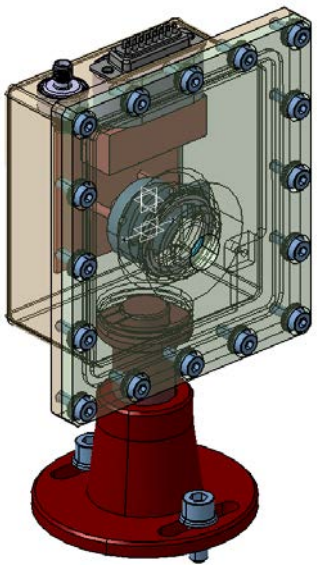
→ Accuracy crucial to keep thermo-refractive noise low

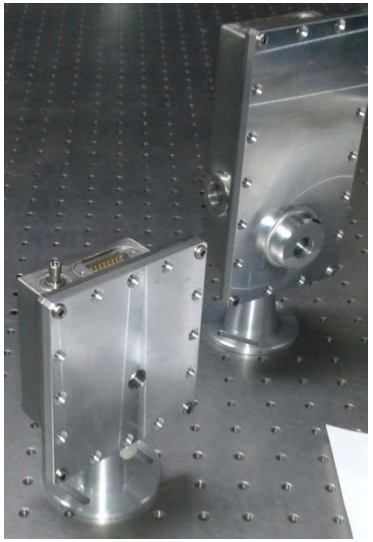
- Not the only sensitive part of detection system : scattered light, electronics…

AdV @ LAPP: Detection system (IV)

- **Photodiodes**
  - Main beam & auxiliary beams
  - For detection & controls
- **Readout and demodulation electronics**
  - Low noise, large dynamics

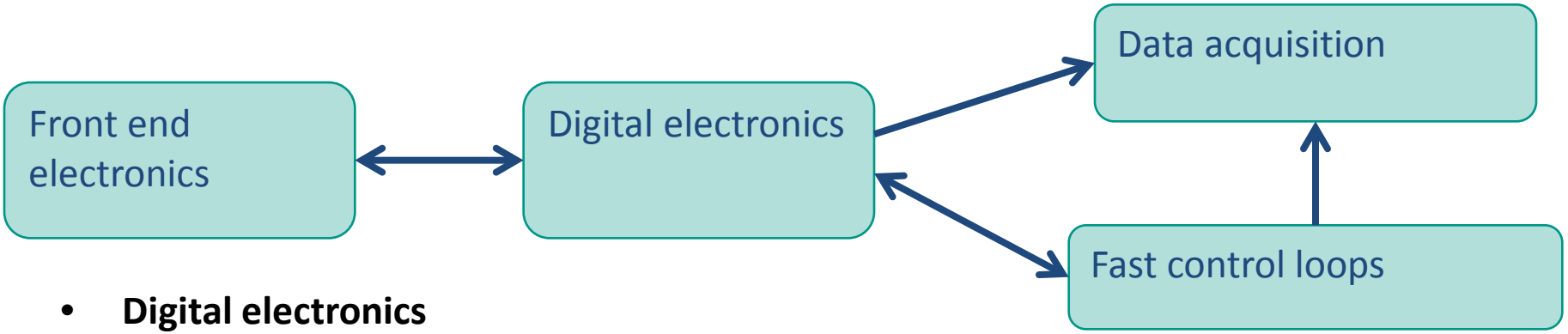






- Photodiodes in air in sealed boxes on benches in vacuum

AdV @ LAPP: Data Acquisition (I)



- **Digital electronics**
  - ADCs
  - DACs
  - Video
  - Digital demodulation
  - Photodiode control

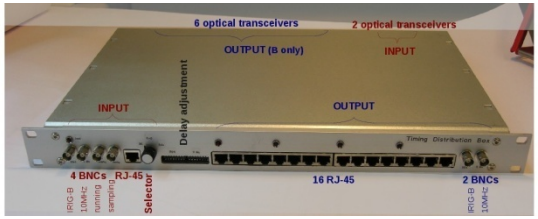
- Network for data exchange and fast controls
  - Optical fibers
  - Timing
  - Multiplexing
  - Real time PCs

- Calibration

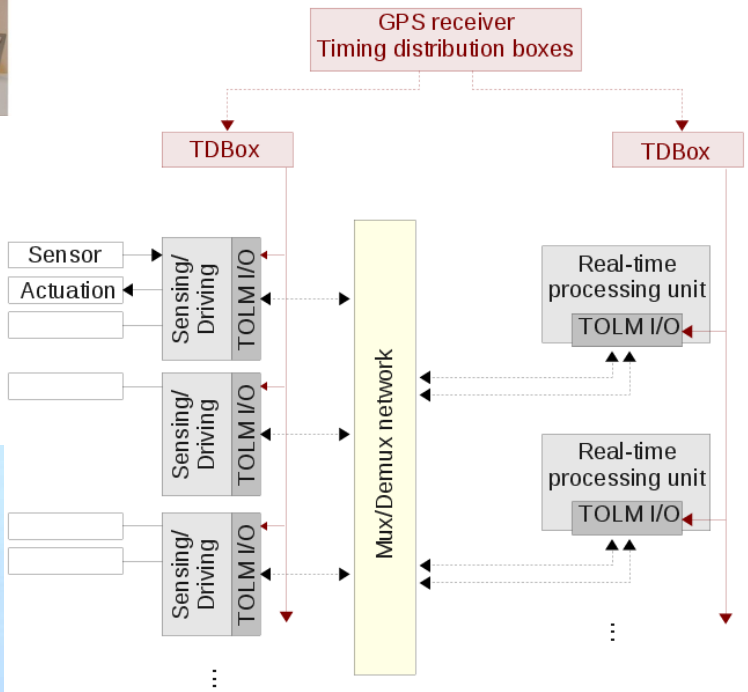
- Major upgrade for Virgo+, follow-up developments for AdV

AdV @ LAPP: Data Acquisition (II)

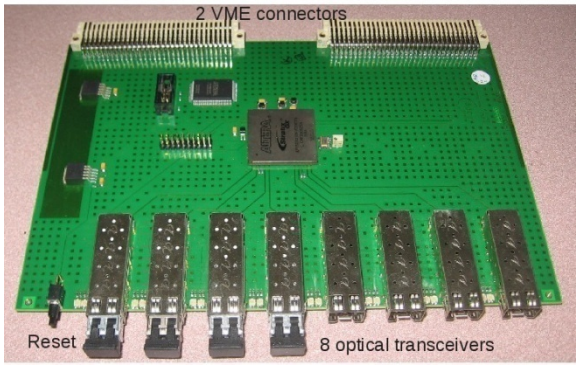
Timing distribution box



Clocks synchronised within less than 50 ns for the whole interferometer



Mux/demux boards



TOLM with PCIe interface (prototype)

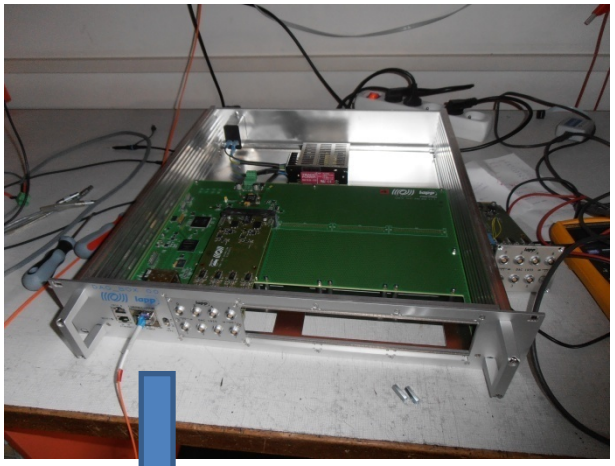
New real time PCs

AdV @ LAPP: Data Acquisition (III)

DAQ-box *(to be hosted inside bench air container)*

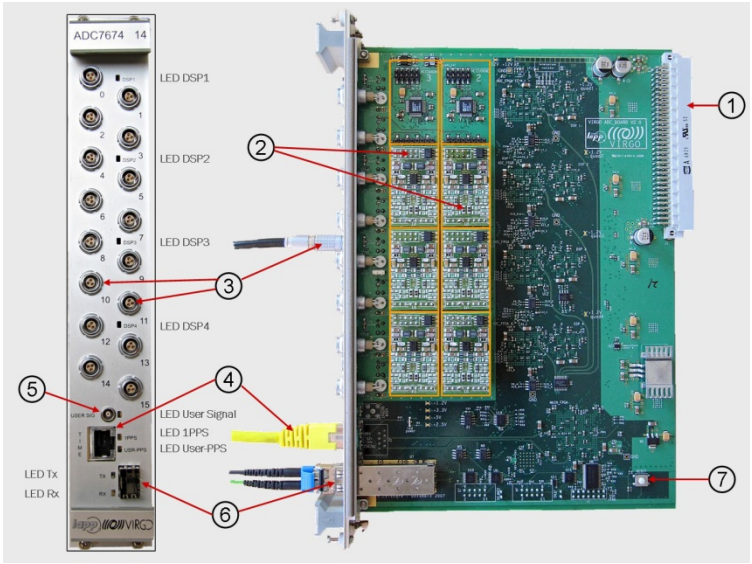
Generic mother board hosting several functional mezzanines

→ ADC, DAC, demodulation, photodiode control, camera control



DAC mezzanine

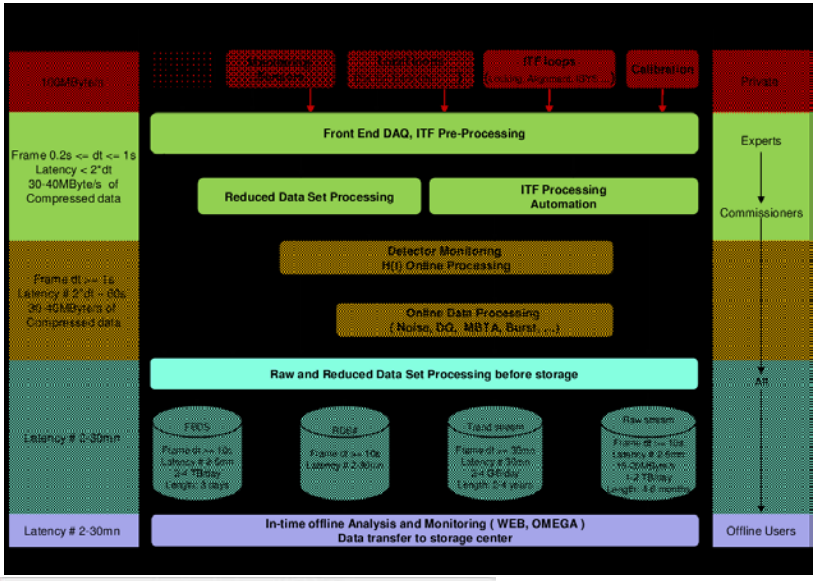
Virgo+ ADC board ➔ ADC mezzanine for AdV



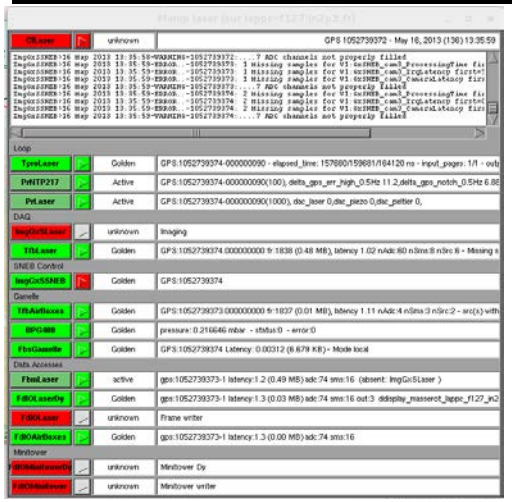
Virgo+ camera box

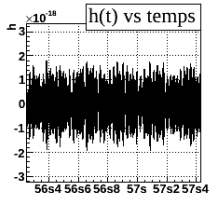
➔ camera mezzanine for AdV

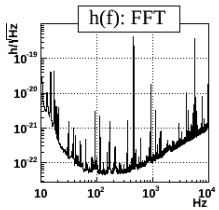
AdV @ LAPP: Data Acquisition (IV)

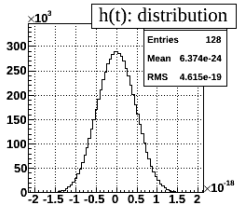


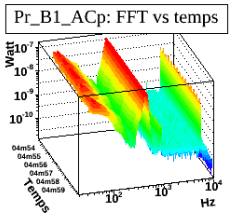
- DAQ software
- Online processes control GUI
- Data display
- Monitoring web pages

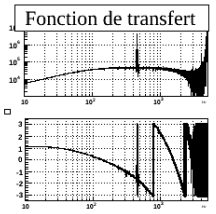


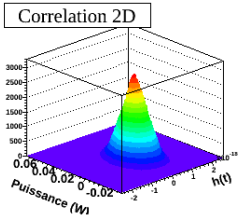


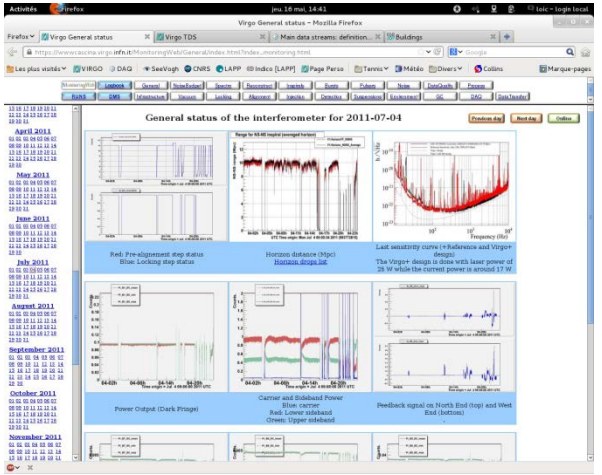












From commissioning to data analysis

- Assembling ➔ Commissioning ➔ Data taking

  Requires careful preparation: ***Be ready to face the unpredictable***

- **LAPP contribution to commissioning:**

  - Commissioning of the detection system and data acquisition
  - Understand how our sub-systems may affect the performances of the whole interferometer
  - Noise hunting
  - Control optimization
  - Keep upgrading the sub-systems to improve the interferometer sensitivity

  → **Need to maintain a technical R&D effort**

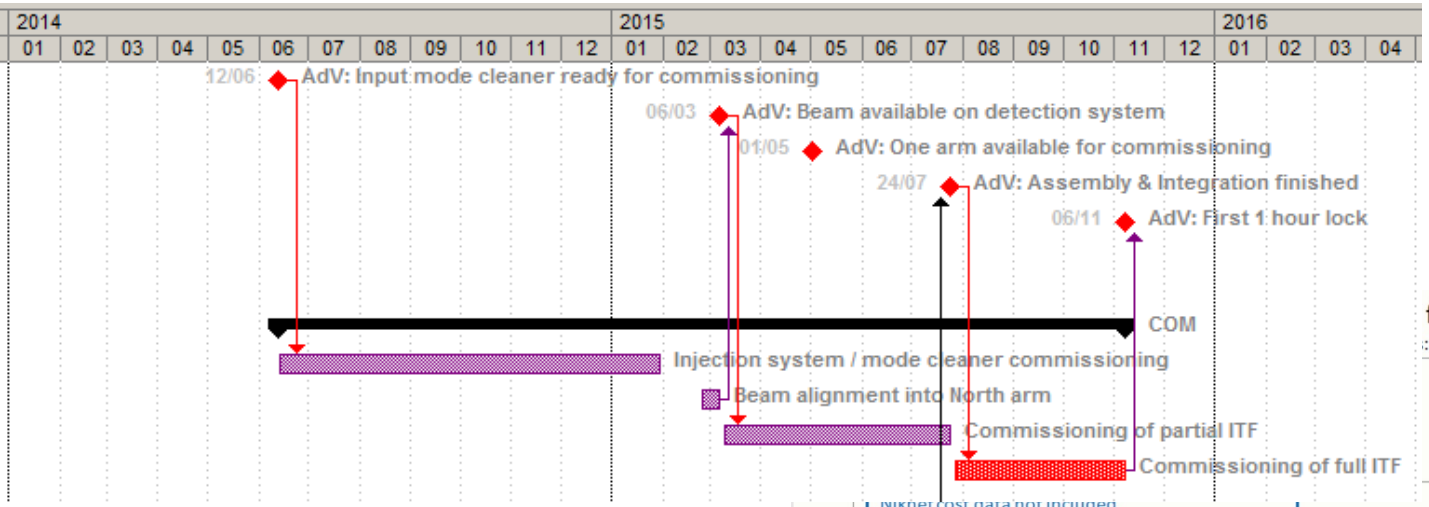
  → **Pursue tests on optical bench** (ex: upgrade of mode cleaner cavity)

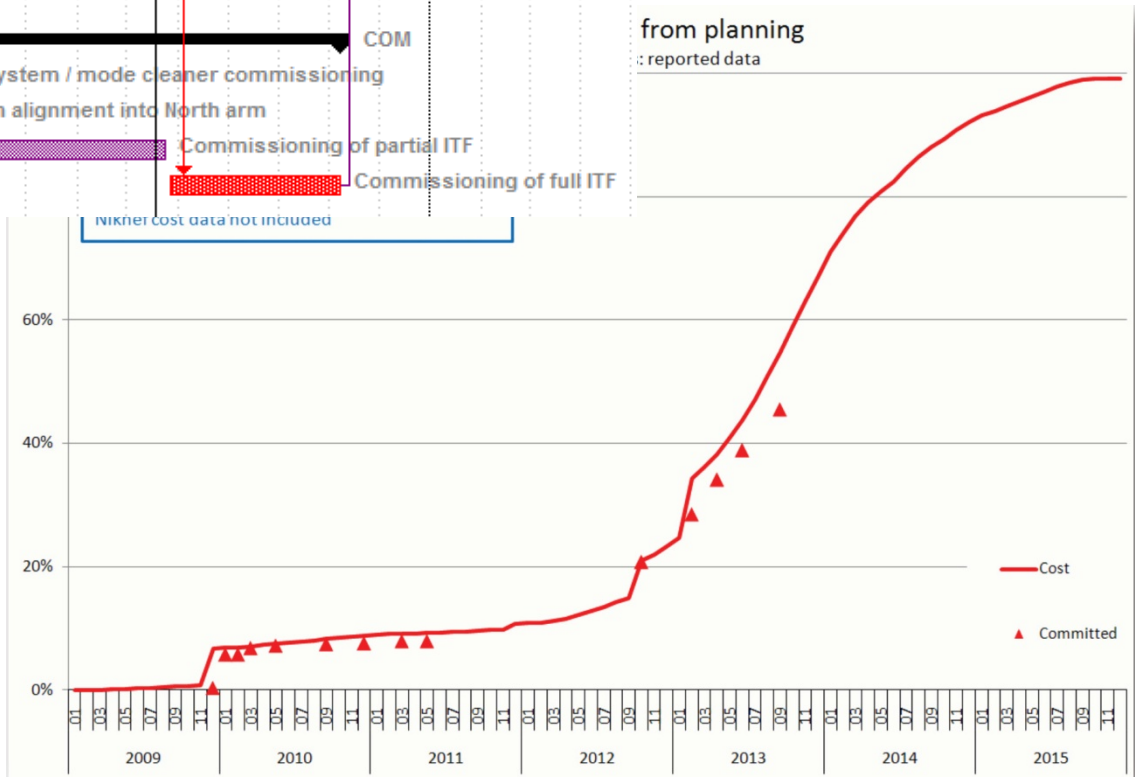
- **Calibration and h(t) reconstruction:**

  - Develop the calibration & reconstruction procedure for a more complex instrument (dual recycling, radiation pressure effects)
  - Upgrade of the photon calibrator for an independent cross-check → **Testing at LAPP**

- Virgo data quality
  - Detector characterization, online veto production
- Online search for compact binary

AdV planning & progress

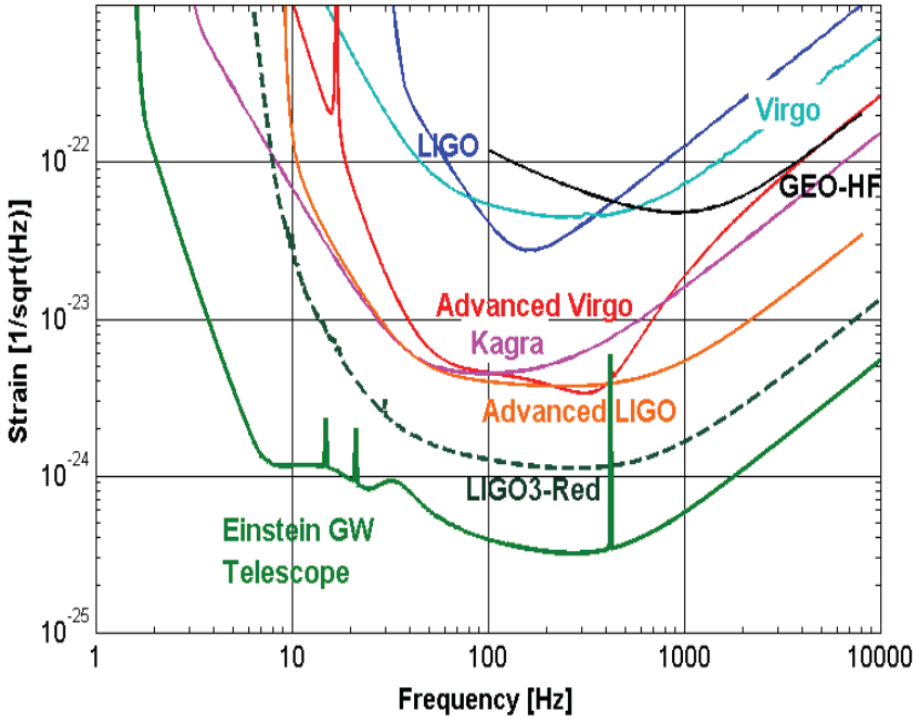




- Infrastructure works mostly done
- Detector installation on site will start in November

AdV+

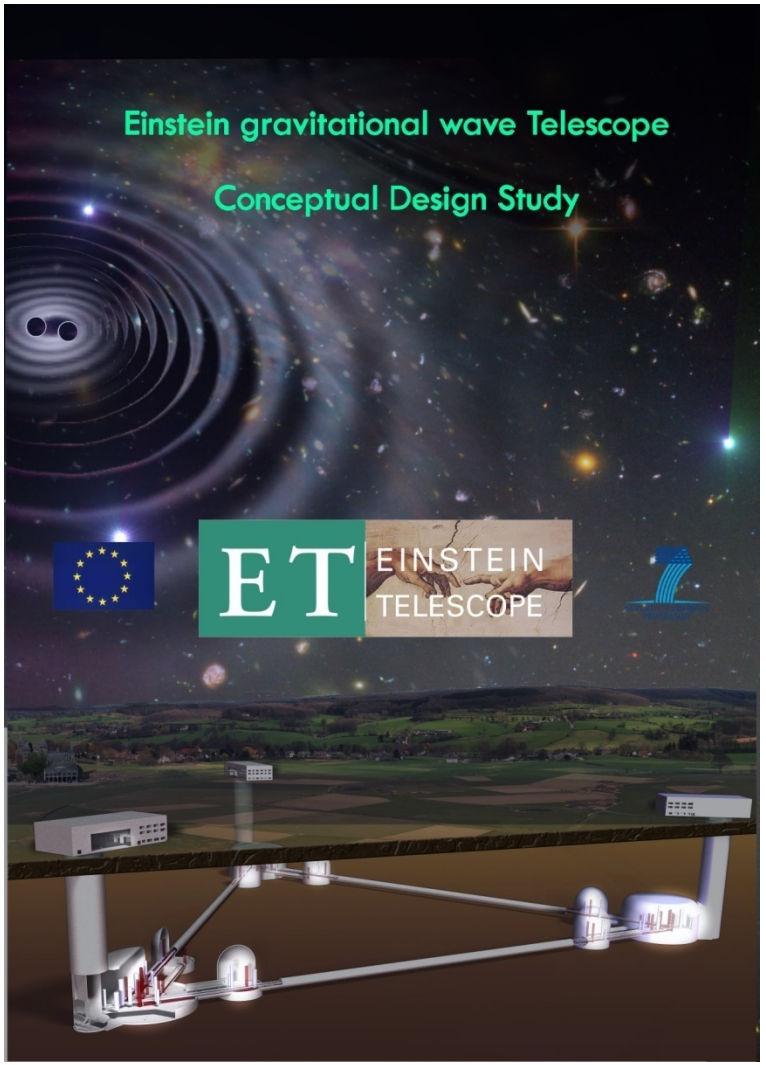
- Room for improvement within infrastructure
- Examples:
  - Subtract gravity gradient noise
  - Increase mirror weight
  - Increase length of final pendulum stage
  - Improve fiber geometry
  - Improve coating materials
  - Larger beam size
    - » Larger mirrors, different beam shape
  - More powerful laser
    - » Change wavelength
  - Squeezing
  - Cryogenics
  - …



- Need to fight fundamental noises but also technical noises
- Brainstorming started in LIGO two years ago: LIGO-3G
  - Broadband sensitivity improvement by a factor of 3-5 ➔ event rate x 25-100
- **Need for sustained technical effort after AdV is installed**

3rd generation

- **Sensitivity**
  - 10x better than 2nd generation
  - Bandwidth starting at 1 Hz
  - BNS / BBH to z ~ 4 / 10
- **Configuration**
  - Several large interferometers (30km?)
  - Underground
- **Improved technologies**
  - Cryogenic, mirrors, laser, squeezing…
- **Status**
  - ASPERA roadmap
  - FP7 Design Study
    - 2008-2011
  - Construction?
    - Probably not before 1st detection



Conclusions

- Strong involvement of LAPP in the construction/installation of Advanced Virgo:
  - detection system and new vacuum chambers
  - data acquisition
  → period of intense activity for the group

- Installation of AdV is not the end of the story:
  - commissioning / noise hunting / calibration / technical upgrades
    → **technical support needed**
    → **pursue autonomous testing at LAPP**
  - data quality studies, preparation of data analysis

- AdV+ brings new technical challenges: R&D effort must start now!

- **Be ready for the first detection!**