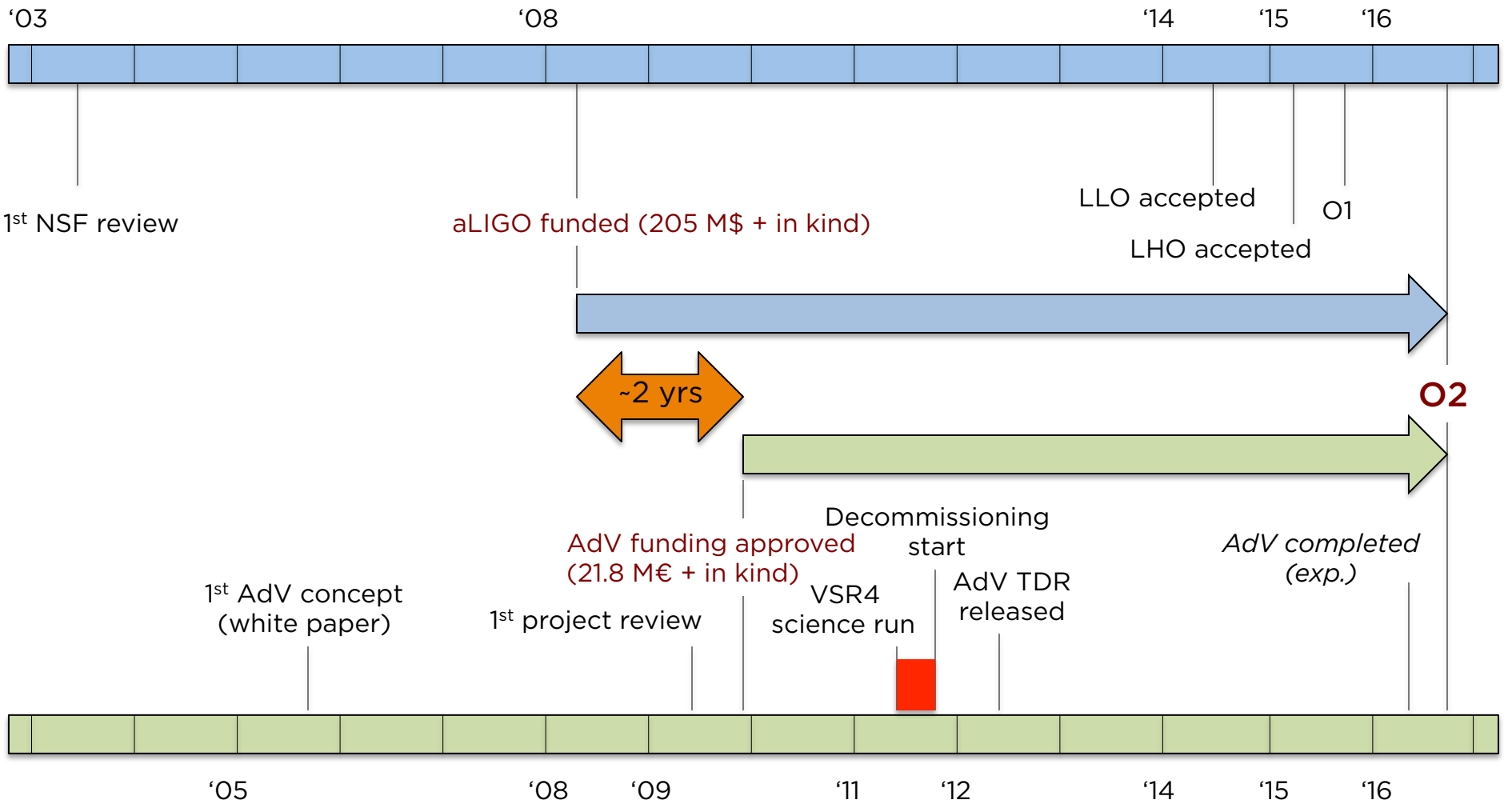
ADVANCED VIRGO

Giovanni Losurdo – INFN Firenze & EGO
Advanced Virgo Project Leader

for the Virgo Collaboration and EGO

2G DETECTORS TIMELINE



ADVANCED VIRGO

- Advanced Virgo (AdV): 2G upgrade of the Virgo interferometric detector
- Participated by France and Italy (former founders of Virgo), The Netherlands, Poland and Hungary
- Funding approved in Dec 2009 (21.8 ME + Nikhef in kind contribution)
- Part of the international network (MoU with LSC)
- Construction in progress. End of installation (phase 1): spring 2016
- Short term goal: join LIGO in the O2 run

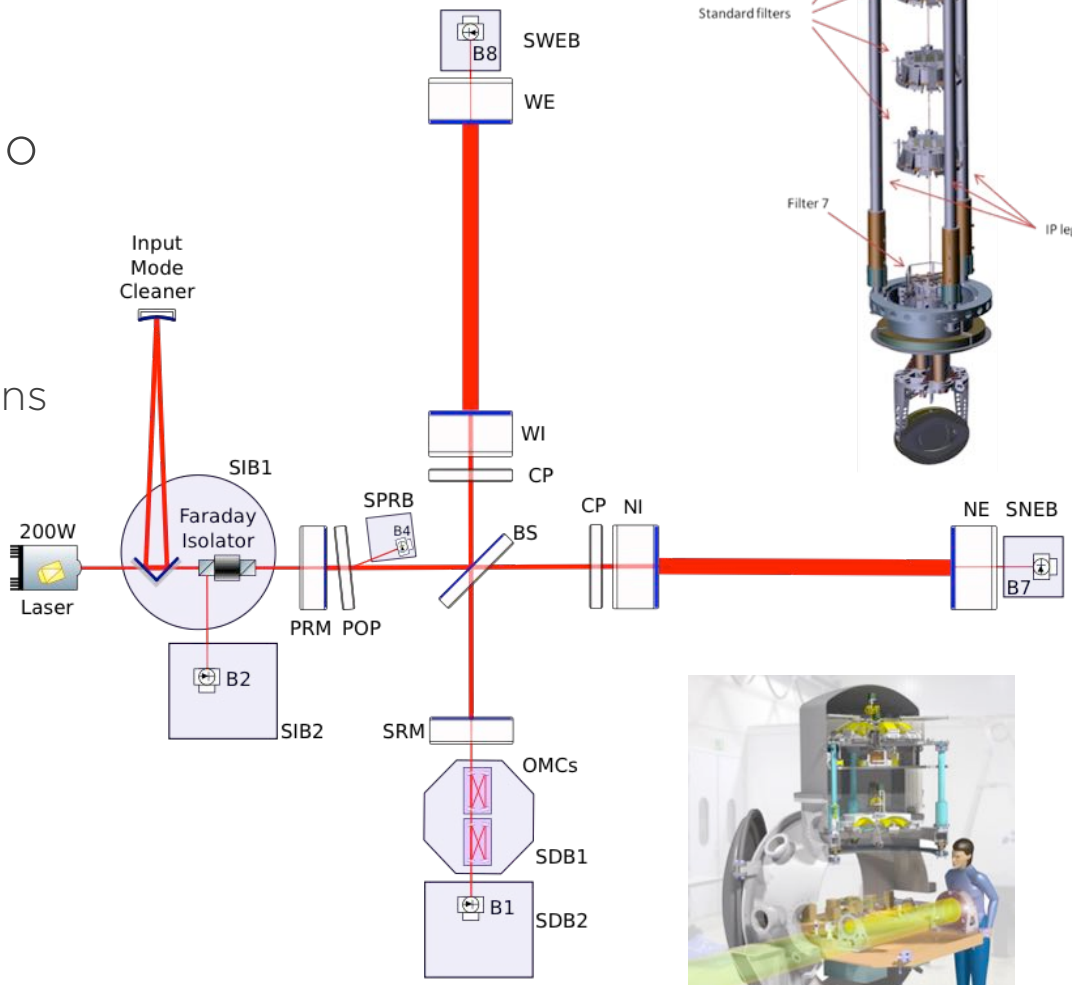
5 European countries
20 labs, ~250 authors

APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Padova
INFN TIFPA
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW(Poland)
RADBOUD Uni. Nijmegen
RMKI Budapest

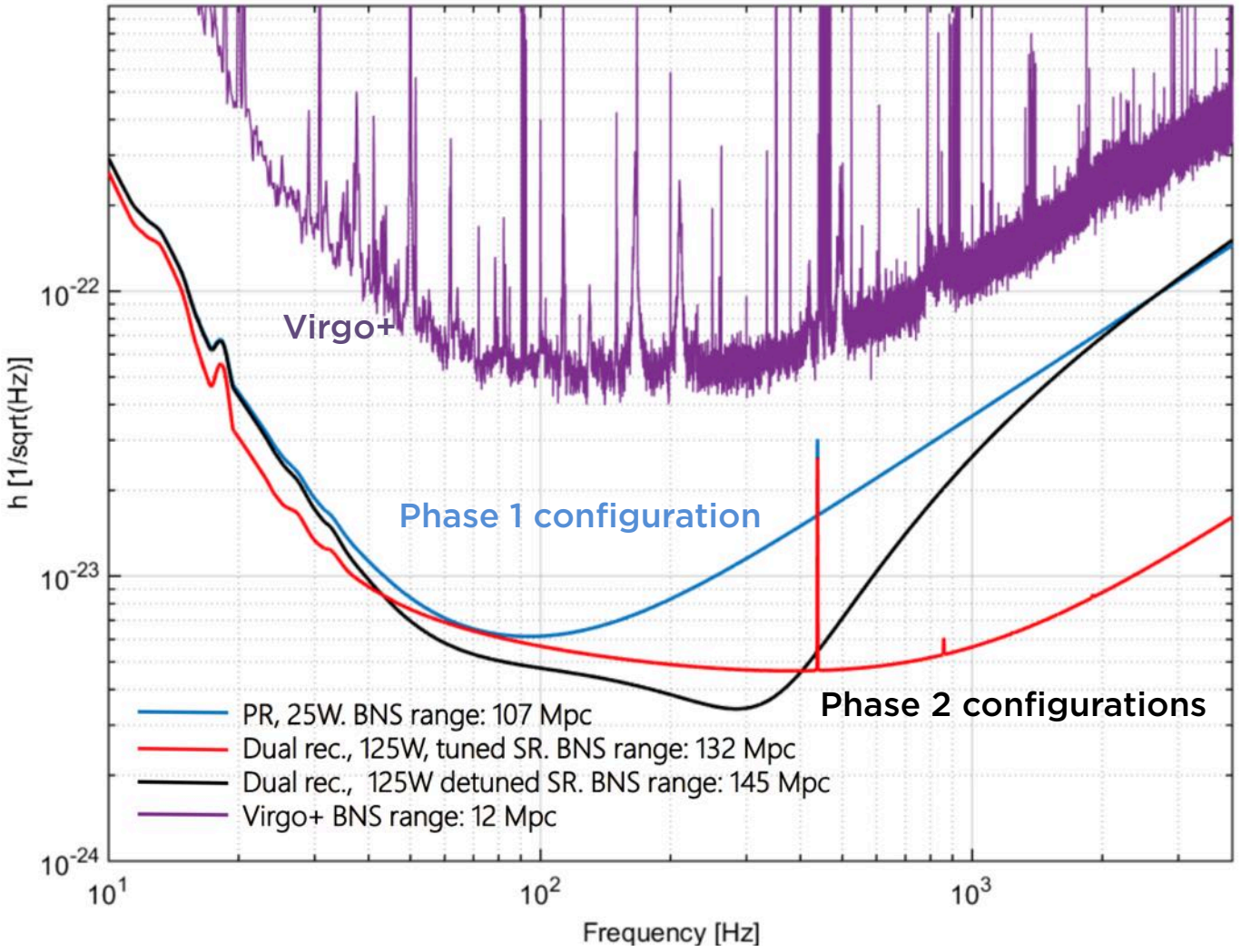
ADV DETECTOR DESIGN

- TDR released in 2012
- MAIN CHANGES wrt Virgo
  - larger beam
  - heavier mirrors
  - higher quality optics
  - thermal control of aberrations
  - stray light control
  - *200W laser*
  - *signal recycling*

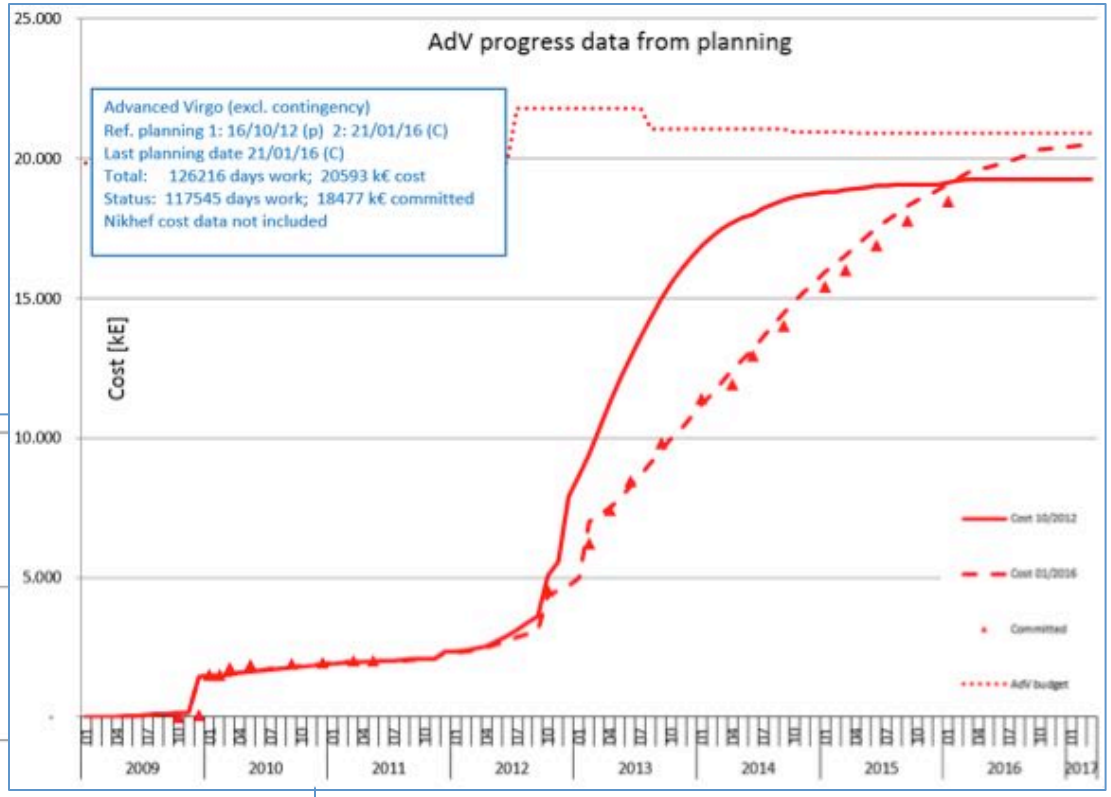
2017/18

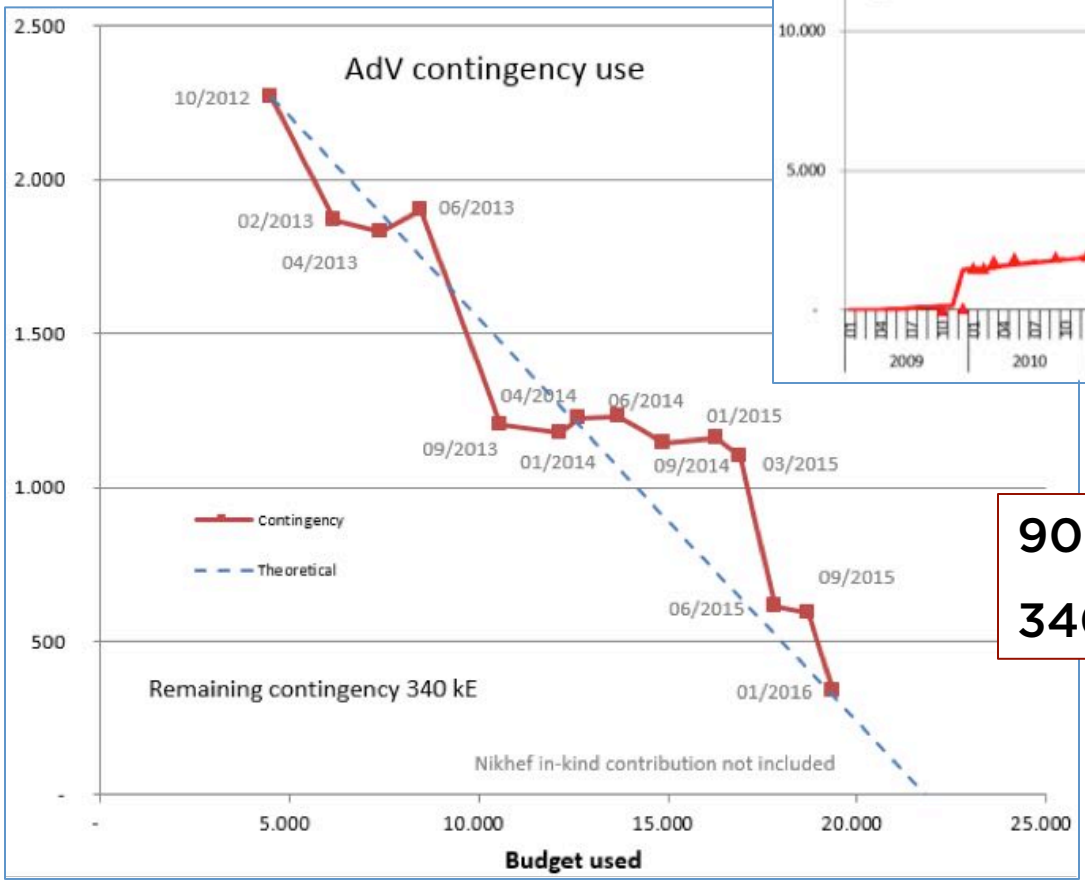


SENSITIVITY TARGETS



BUDGET





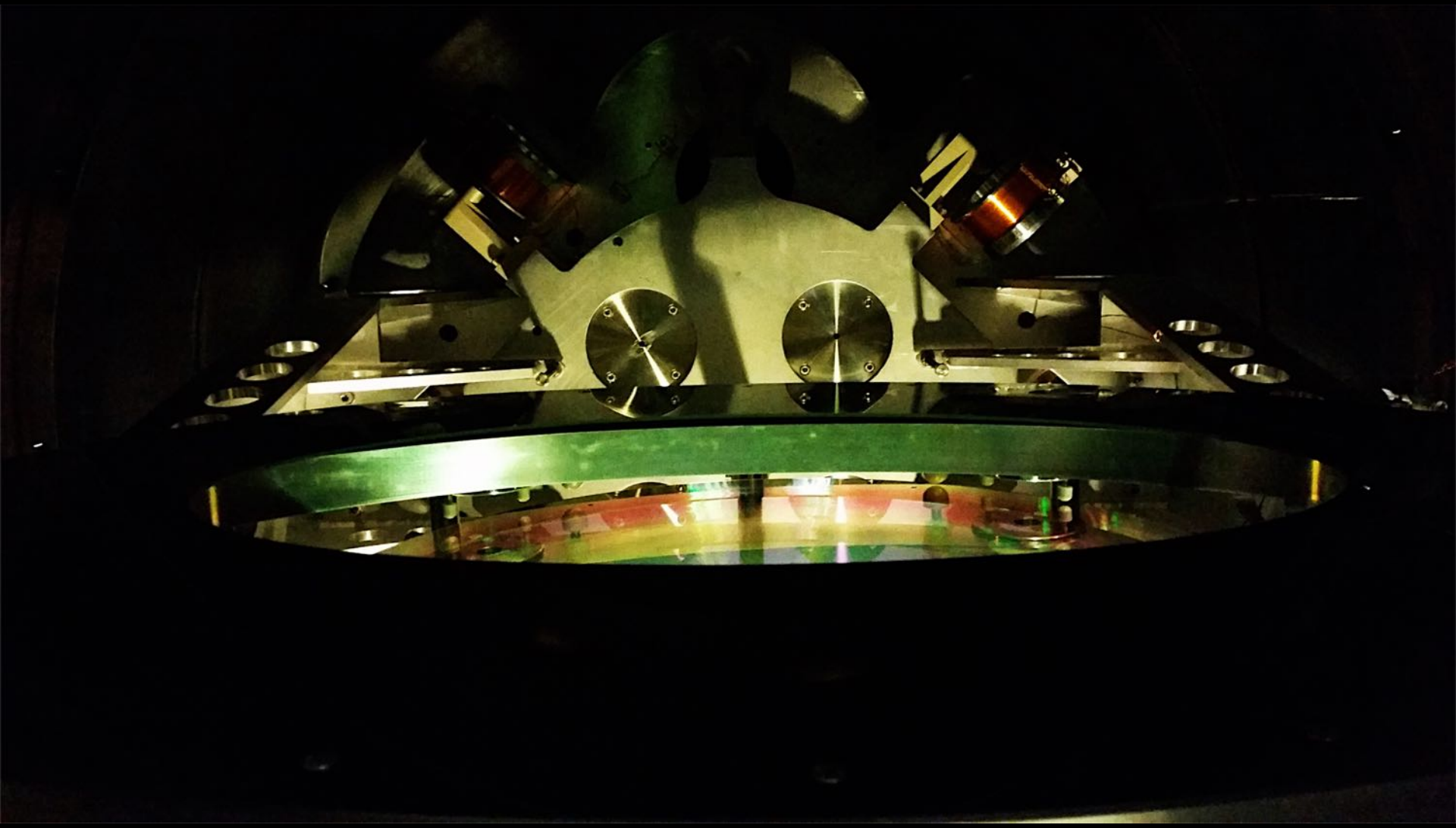
90% of project cost committed

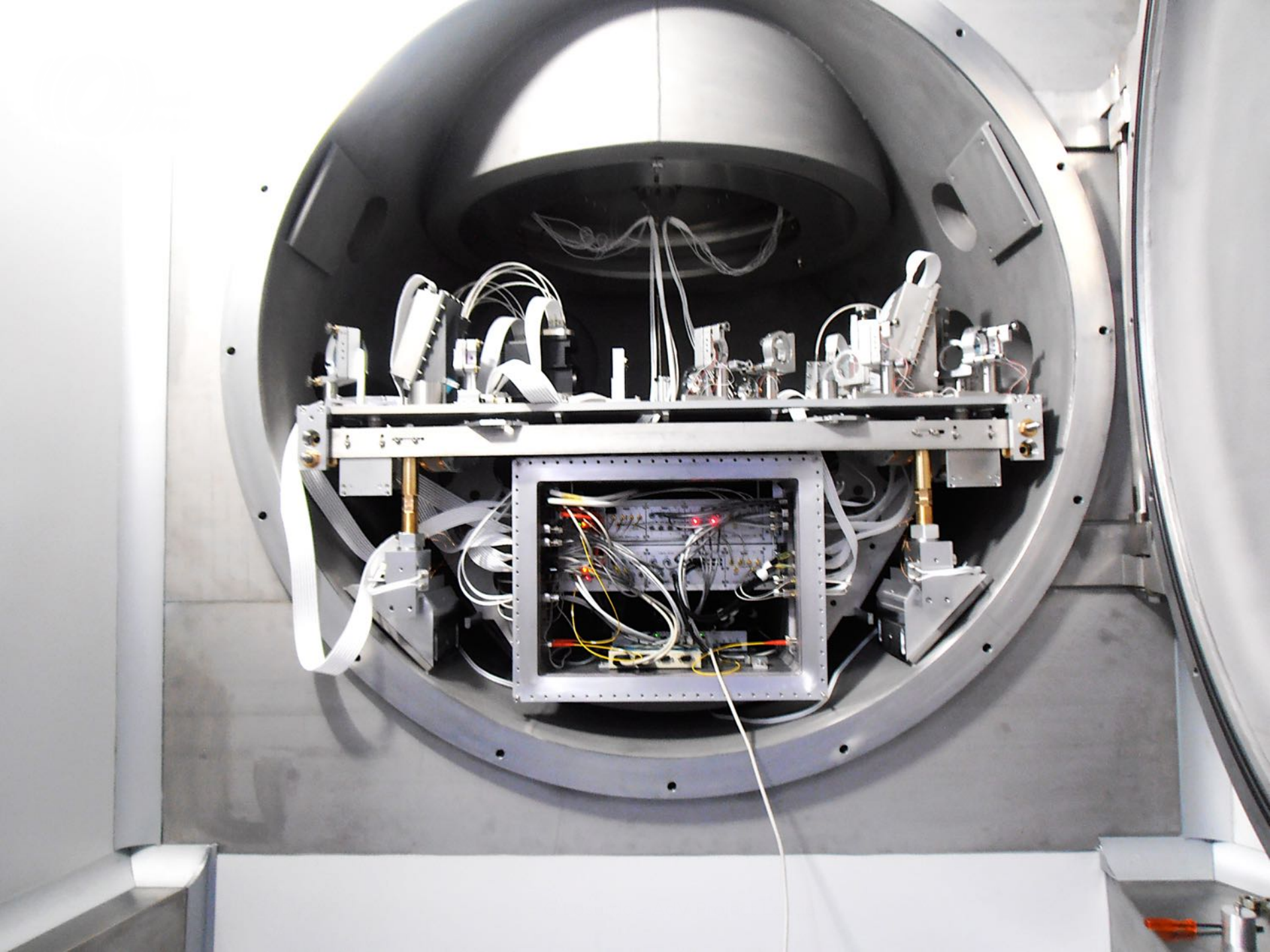
340 kE of contingency available

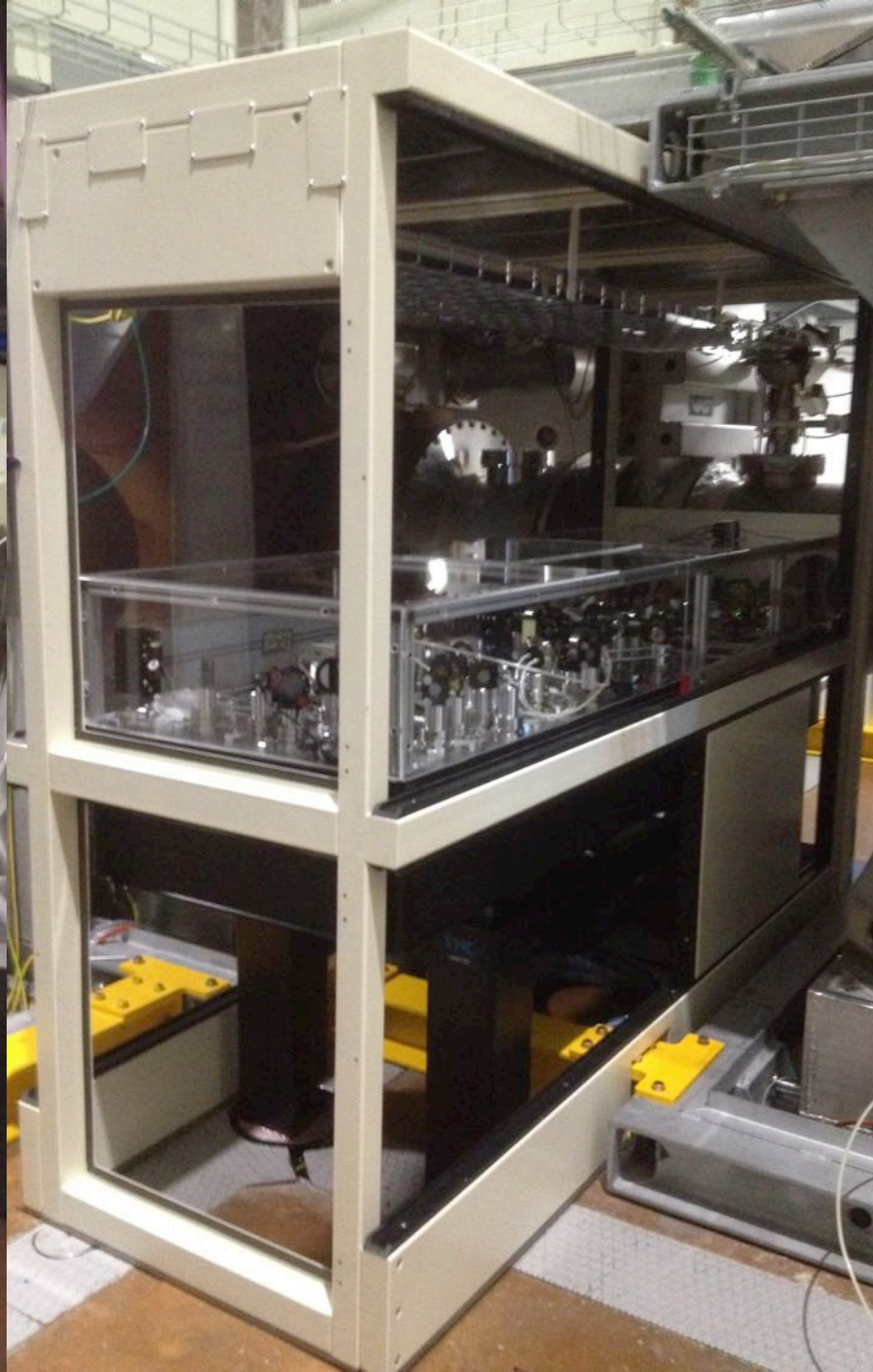
Virgo central hall
MARCH 2013

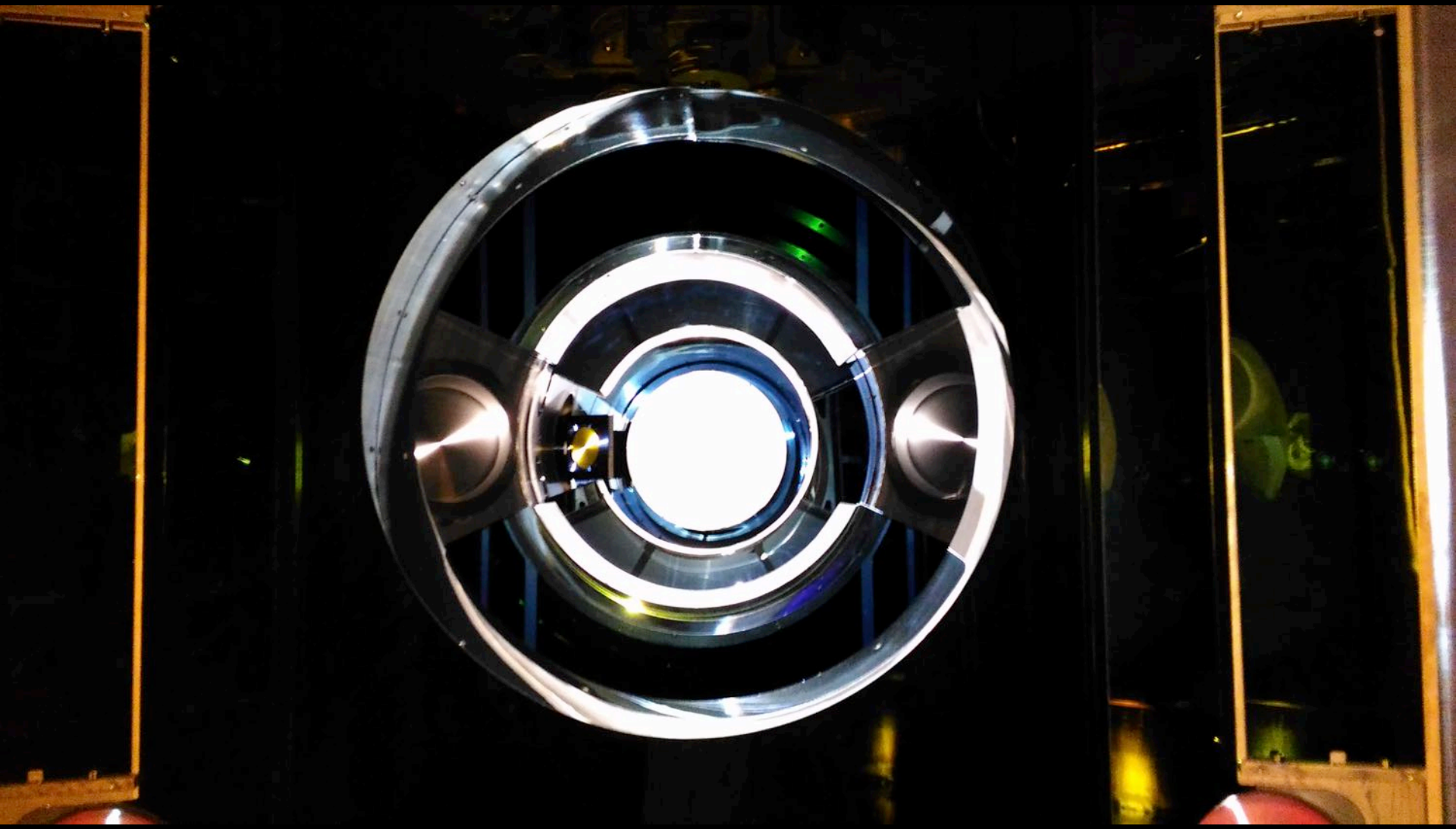

Virgo central hall
NOVEMBER 2014

Virgo central hall
APRIL 2016







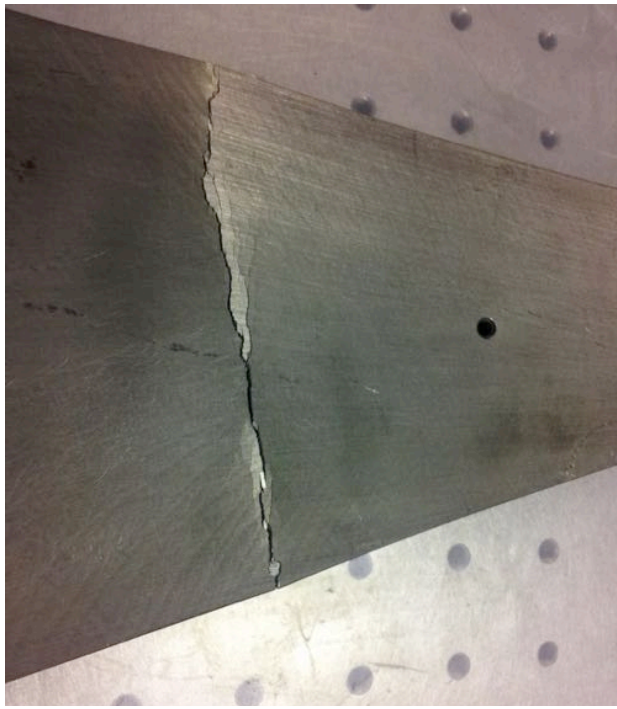


SCHEDULE

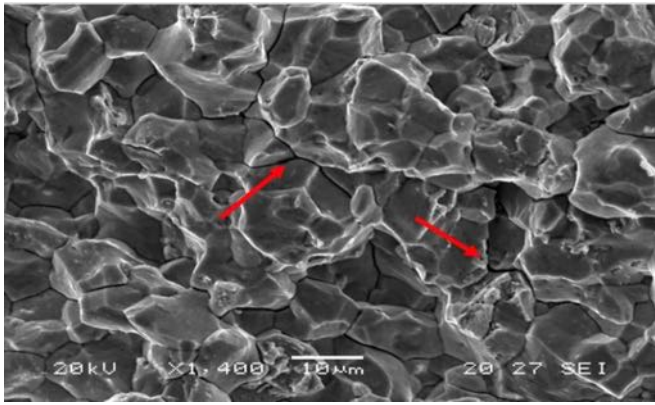
- Integration due to be completed by the end of 2015
  - A few months of delay taken mainly due to two important technical issues (see later)
- The main goal remains to join LIGO in the O2 run (end 2016)

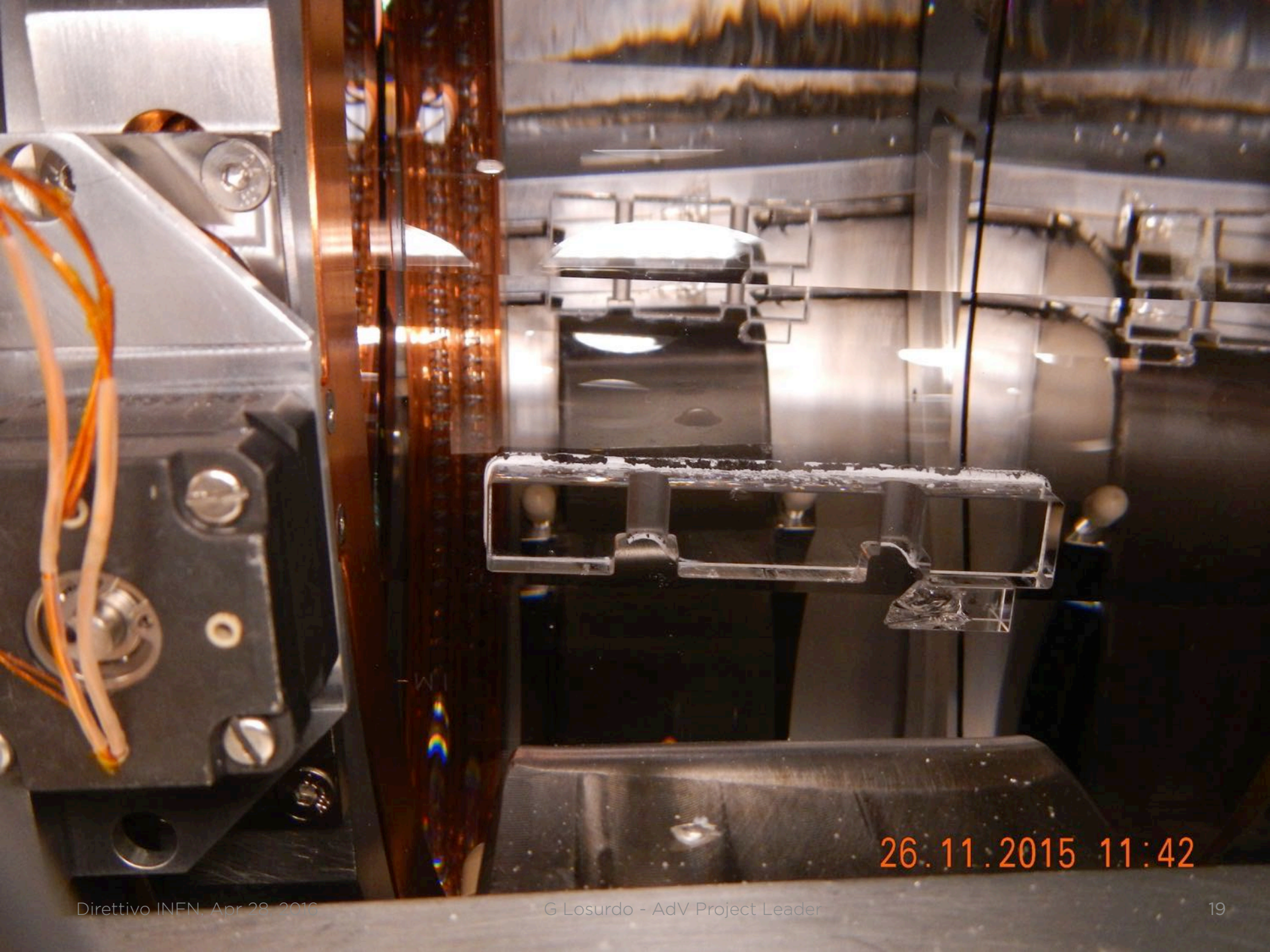
ISSUES

BLADES



- ISSUE: 13 superattenuator maraging blades found broken
  - Plus one on the Nikhef compact isolator
- CAUSE: Hydrogen embrittlement
- ACTIONS:
  - Extensive survey
  - Massive production of new blades and replacement of “risky” ones (120, 40% of the total)
- IMPACT: a few months of delay on the superattenuators completion
- PENDING RISKS:
  - Replacement decided upon outcomes of eddy current scan (qualitative method)
  - BS and short towers not scanned
- Risk mitigation: produce spares and define procedure for fast in situ replacement

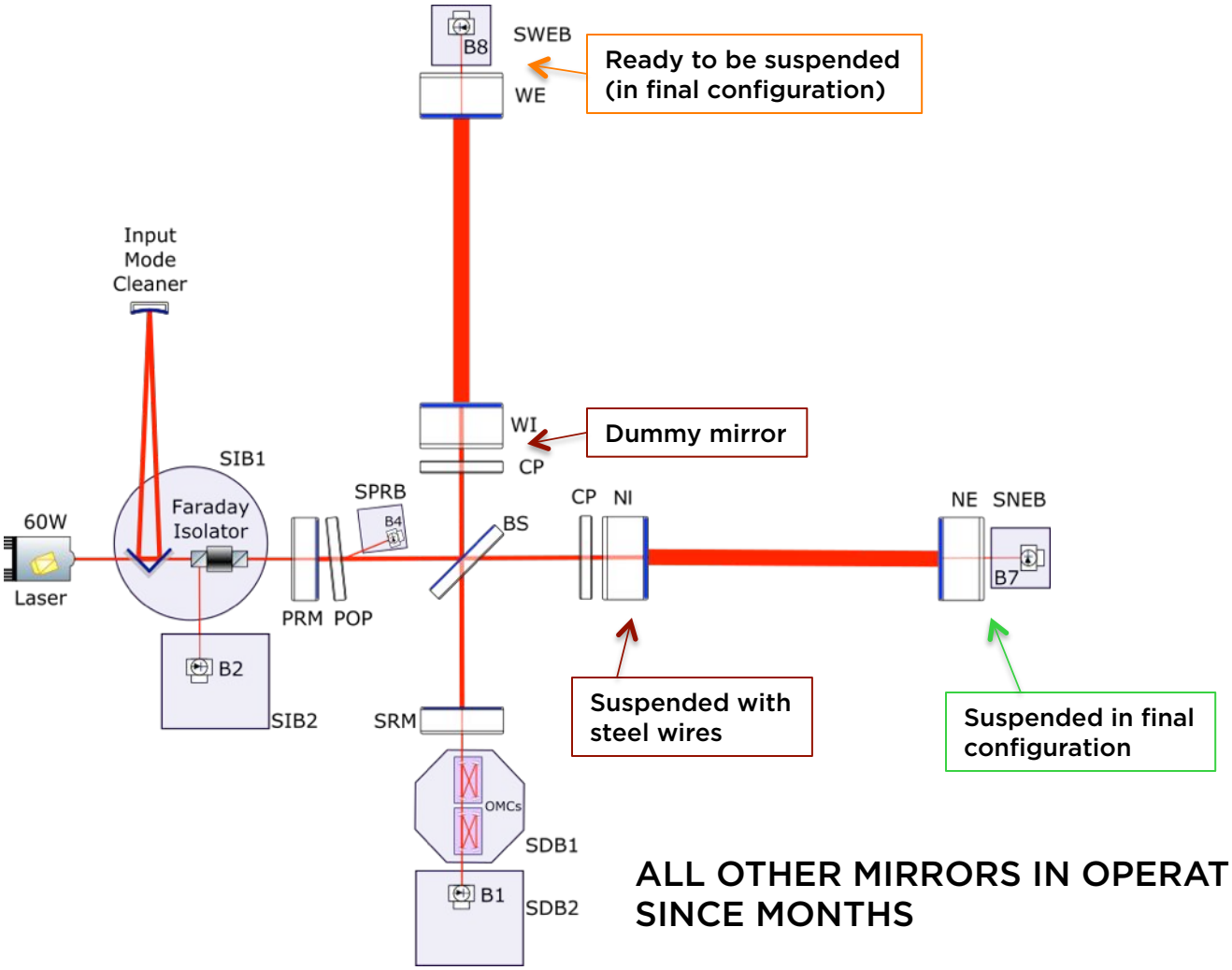



26.11.2015 11:42

MON. SUSP. FAILURE

- ISSUE: three failures of the monolithic suspension of the input test masses (WI + NI twice)
  - These mirrors had been suspended in air for months
  - The breakings happened after a few days in vacuum
- CAUSE
  - Main suspect: production defects in a bunch of silica anchors. Role of vacuum still to be understood
- ACTIONS
  - Extensive test plans on standalone fibers/anchors in lab
  - Payload with dummy mirror suspended in the Virgo chamber for tests
  - Anchors design modified to be more robust
  - Two-step evacuation procedure adopted
- IMPACT: completion of mirror integration delayed by a few months
- CURRENT SITUATION:
  - One monolithic payload (NE) in vacuum since one month
  - NI mirror suspended with steel wires to allow commissioning progress
  - WE mirror (equipped with safer anchors, like NE), ready for integration

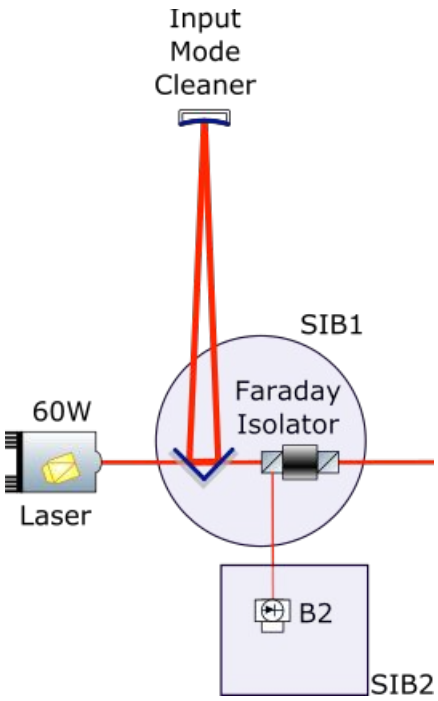
WHAT'S MISSING

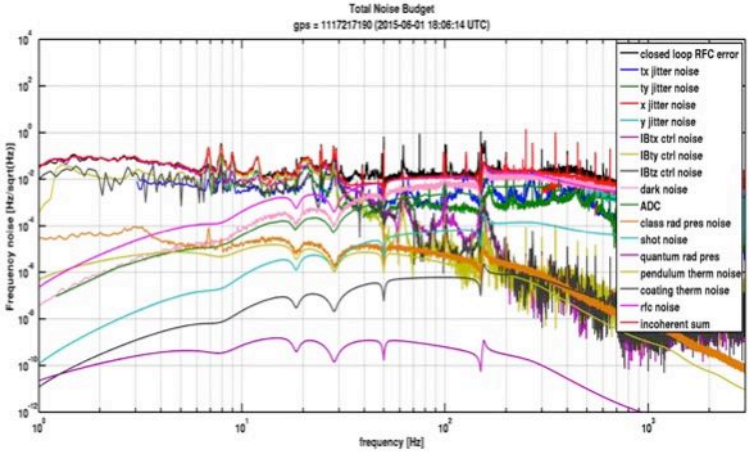


COMMISSIONING

SO FAR

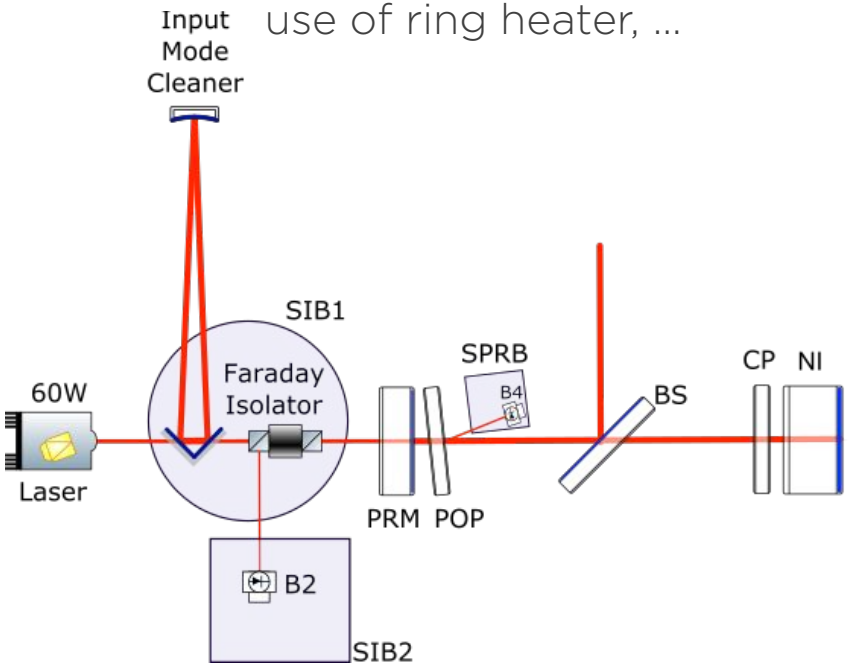
- Commissioning of INJ completed
  - Frequency noise within specs
  - Noise budget available, noises mostly understood

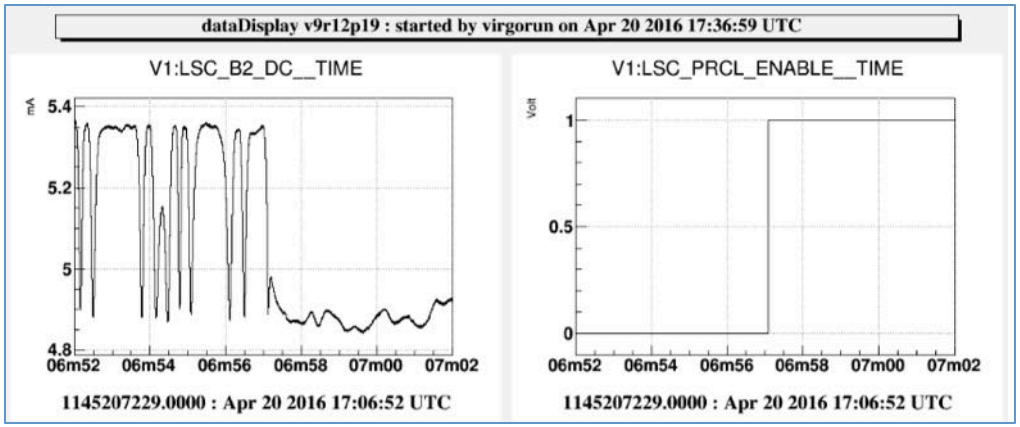




PR-NI

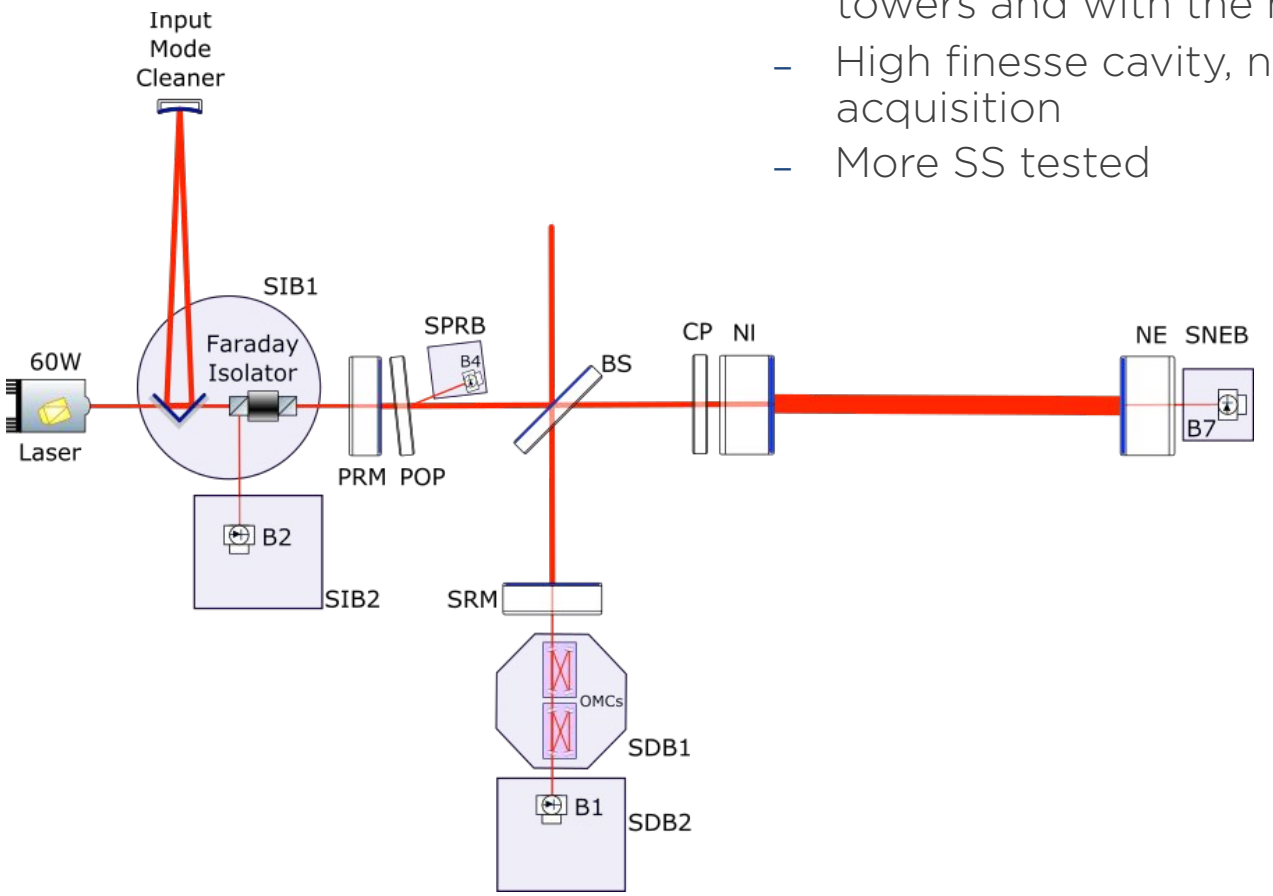
- Good integrated test for software, payloads, photodiodes, ring heater, …
- Cavity locked…
  - …with upgraded superattenuators, new payload design, new control electronics, digital demodulation, new acquisition/locking software, use of ring heater, …





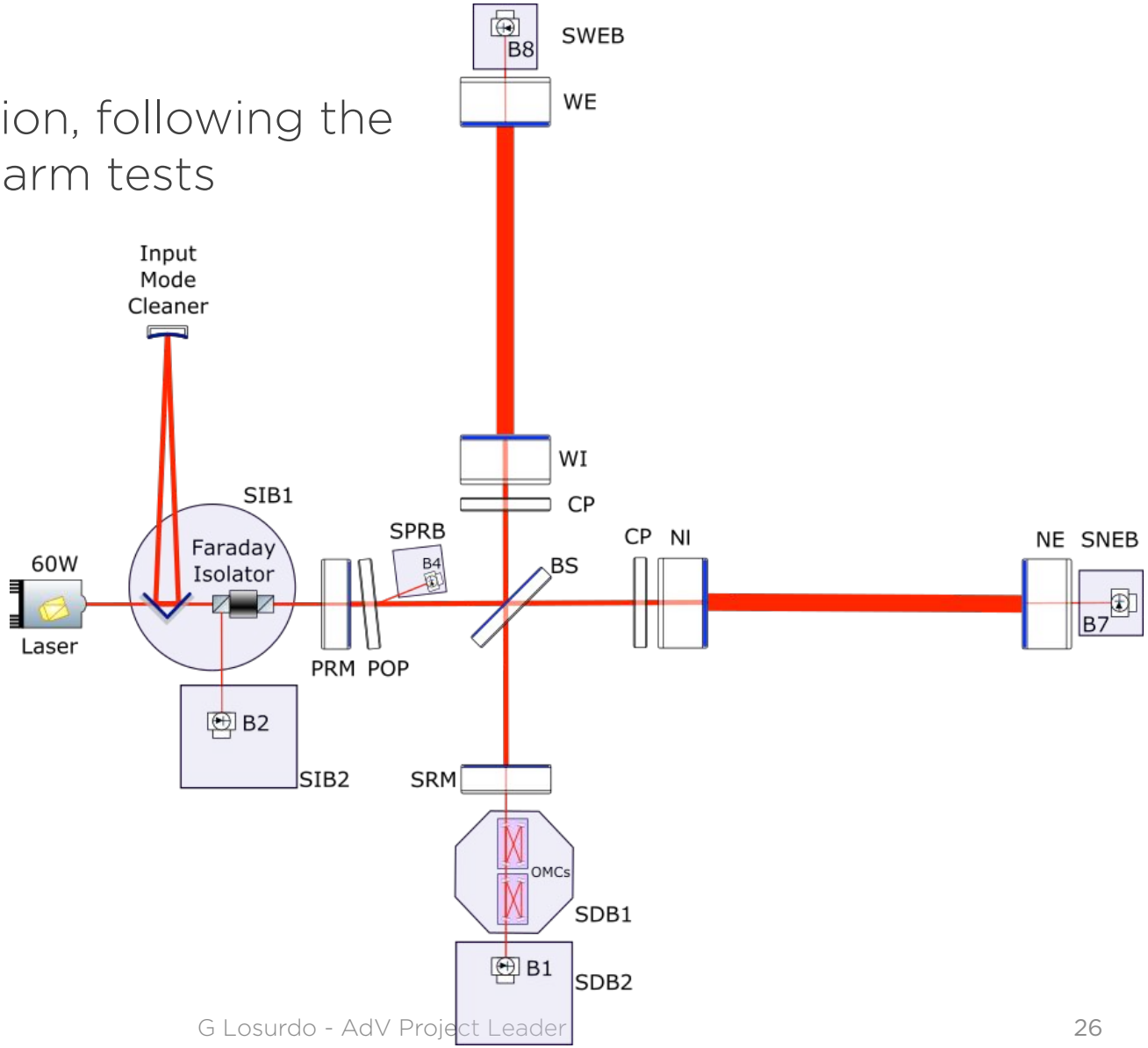
3 km NORTH ARM

- 3km cavity
  - Starting soon, after long pumping in the towers and with the new cryotraps
  - High finesse cavity, non trivial lock-acquisition
  - More SS tested



FULL ITF

- Final configuration, following the PR-NI and long arm tests

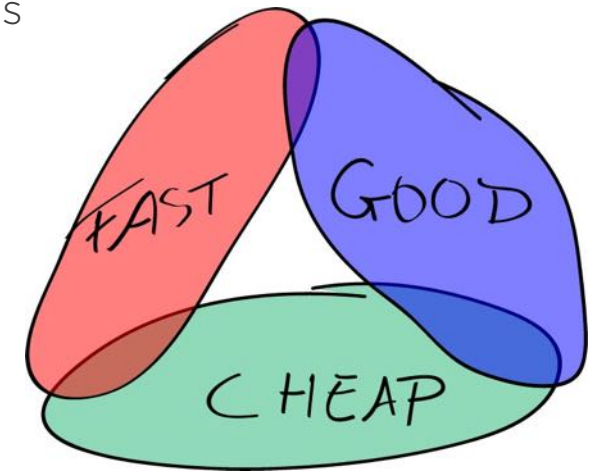


DA and COMPUTING

- Several search pipelines with crucial contribution from Virgo to the discovery of gravitational waves
  - BURST: cWB, oLIB, STAMP (long duration transients), GRB-triggered search, Cosmic Strings
  - EM FOLLOW-UP: low-latency searches, SkyMaps, GW alert production and transmission
  - CBC: MBTA (low latency searches, sky localization), TIGER (test of strong-field dynamics of GR)
  - CW: NoEMI (noise line identification), All-sky searches (time domain F-stat, Frequency Hough, polynomial search), targeted and directed searches (time domain F-stat, 5-vector)
  - SGWB: Isotropic and directional searches (Schumann resonances, polarization states)
- Computing effort in preparation of O2
  - Setting up in time data transfer from Virgo and LIGO detectors toward Virgo repositories: CNAF and Lyon
  - Increasing the level of compatibility between the LVC data analysis pipelines and the European GRID-based computing centers, in order to have CNAF within the LVC analysis resource network.
  - Great interaction with CNAF staff

CONCLUSIVE REMARKS

- Virgo was a success:
  - Achieved design sensitivity and 80% duty cycle
  - For years the most sensitive detectors at low frequency
  - Established the international network
- Huge work done to design, build, integrate Advanced Virgo.
- Integration almost complete
  - Main leftover: integration of 3 test masses
  - Pending issue: monolithic suspensions failures
- Project being completed on budget



CONCLUSIVE REMARKS

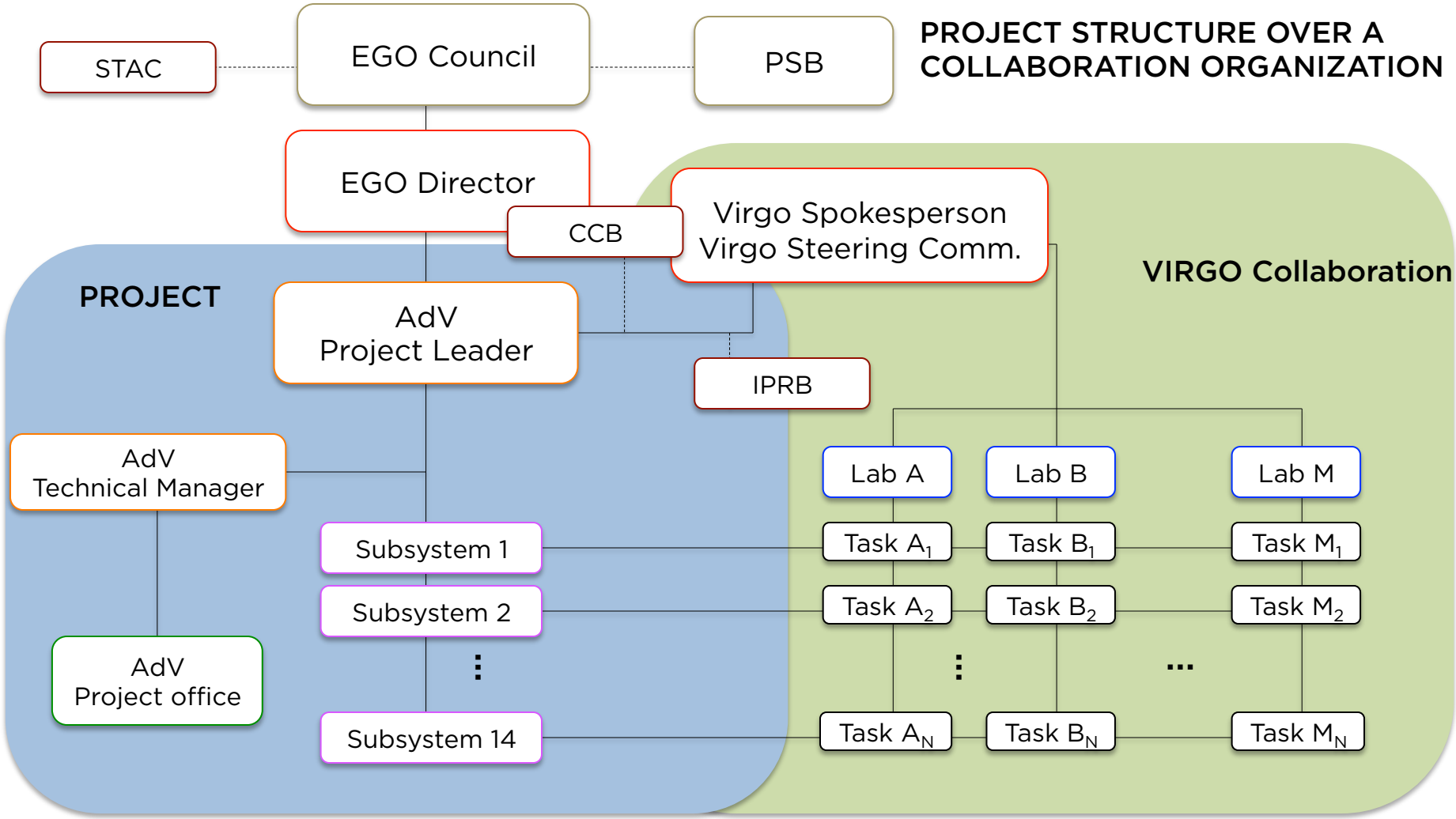
- The main goal: join O2 at the end of 2016
- Focus on commissioning
- Need restart of R&D to keep the pace with the LIGO upgrades and remain relevant in the network
  - Significant investments might be needed
  - Working at a coordinated strategy within the GW community (IGRAINE H2020 and PIRE NSF-INFN bilateral agreement open the way to coordinated and co-funded R&D)
- The human factor is essential: need to maintain the competences, renew and expand the INFN community in the GW field

SPARE SLIDES

AdV FELLOWSHIPS

LAB	SS	TYPE	Co-funded	Yrs	COST (ass.)	Notes
PISA	SAT	Electronic ENG		2	70	Hired
ROMA	PAY	Mechanical ENG		2	70	Hired
NICE	PSL	Laser ENG	yes	1.5	45	Renewal
APC	INJ/DET	Optical ENG		2	110	Renewal
FI/UR	PAY	Electronic ENG	yes	1	32	Renewal
PERUGIA	PAY	Post doc (PHYS)		2	50	Renewal
LAPP	DET	Post doc (PHYS)		2	109	Renewal
TOV	TCS	Post doc (PHYS)		2	53	Renewal
TOV	TCS	Post doc (PHYS)		1	27	Renewal
ROMA	PAY	Post doc (PHYS)	yes	2	30	Renewal
LAPP	DET	PhD (PHYS)	yes	3	49	Hired
NIKHEF	DET	PhD (PHYS)	yes	4	100	Hired
APC	INJ/DET	PhD (PHYS)	yes	3	50	Hired
LAL	ISC	PhD (PHYS)	yes	3	51	Hired
PERUGIA	PAY	Mechanical TECH		2	26	Hired
EGO	VAC	Technician		1	26	Hired
TOTAL					**898**	

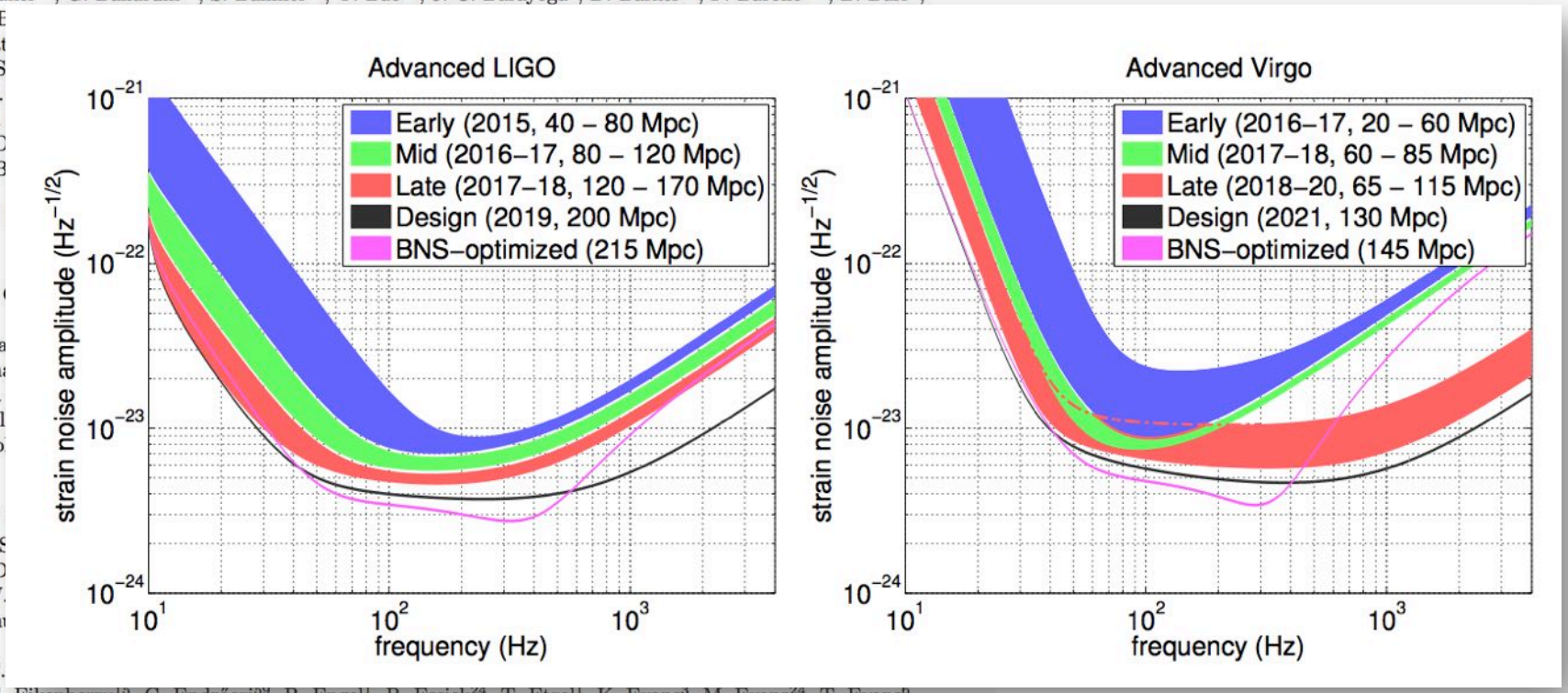
MANAGEMENT


PROJECT STRUCTURE OVER A COLLABORATION ORGANIZATION
STAC
EGO Council
PSB
EGO Director
CCB
Virgo Spokesperson
Virgo Steering Comm.
VIRGO Collaboration
PROJECT
AdV
Project Leader
IPRB
AdV
Technical Manager
Lab A
Lab B
Lab M
Subsystem 1
Subsystem 2
Subsystem 14
Task A1
Task B1
Task M1
Task A2
Task B2
Task M2
Task AN
Task BN
Task MN
AdV
Project office

SENSITIVITY EVOLUTION

Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories

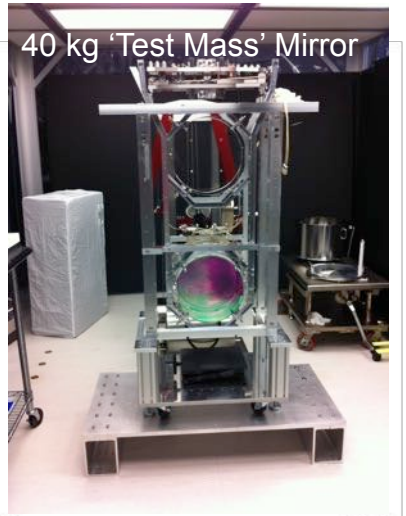
J. Aasi[1], J. Abadie[1], B. P. Abbott[1], R. Abbott[1], T. D. Abbott[2], M. Abernathy[3], T. Accadia[4], F. Acernese[5ac], C. Adams[6], T. Adams[7], P. Addesso[8], R. X. Adhikari[1], C. Affeldt[9,10], M. Agathos[11a], O. D. Aguiar[12], P. Ajith[1], B. Allen[9,13,10], A. Allocca[14ac], E. Amador Ceron[13], D. Amariutei[15], S. B. Anderson[1], W. G. Anderson[13], K. Arai[1], M. C. Araya[1], C. Arceneaux[16], S. Ast[9,10], S. M. Aston[6], P. Astone[17a], D. Atkinson[18], P. Aufmuth[10,9], C. Aulbert[9,10], L. Austin[1], B. E. Aylott[19], S. Babak[20], P. Baker[21], G. Ballardin[22], S. Ballmer[23], Y. Bao[15], J. C. Barayoga[1], D. Barker[18], F. Barone[5ac], B. Barr[3],

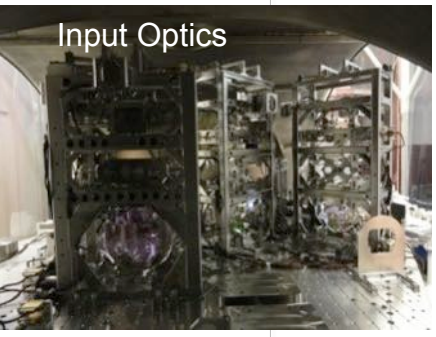


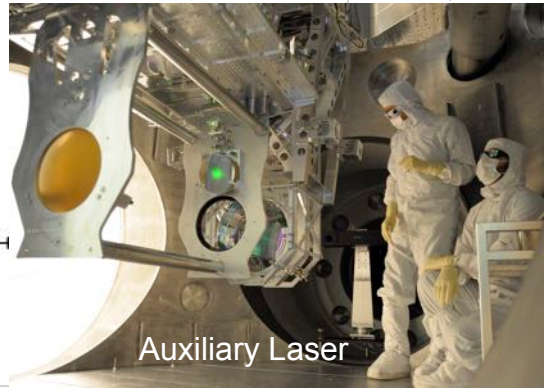
ADVANCED LIGO

- Proposal to NSF: 2003. Project start: April 2008
- Funding: $205 M$ from NSF, in-kind contribution from D/UK/AUS
- Two detectors installed, third interferometer to be shipped to India
- Construction completed: Jul 2014.
- First science run completed, DISCOVERY achieved

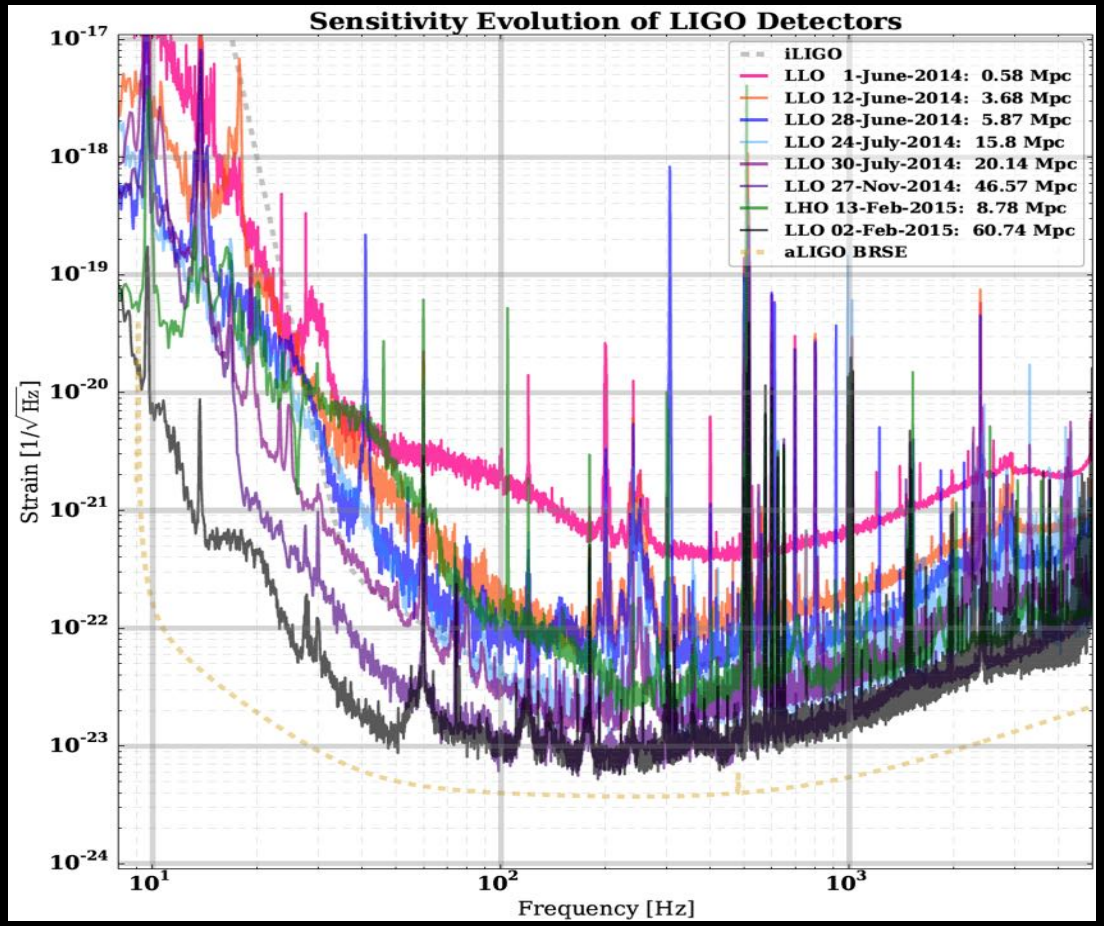
Advanced LIGO







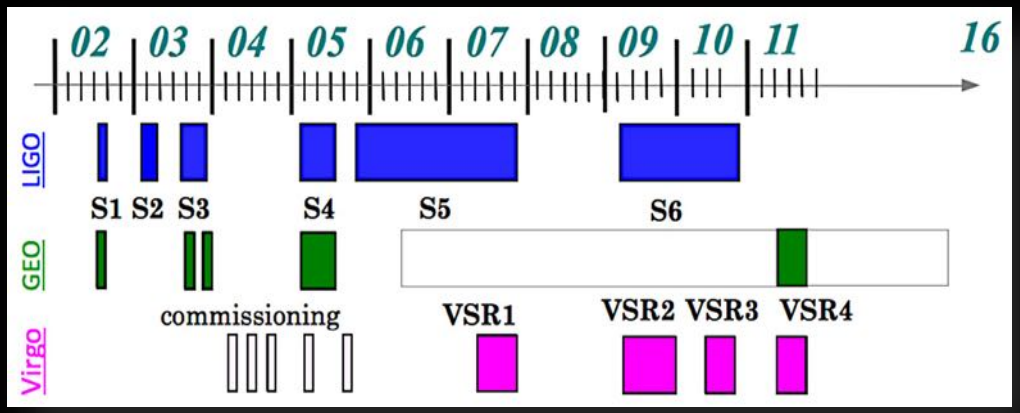
aLIGO COMMISSIONING



FROM 0 TO 60 Mpc
(BNS range)
IN 8 MONTHS

1st GENERATION DETECTORS

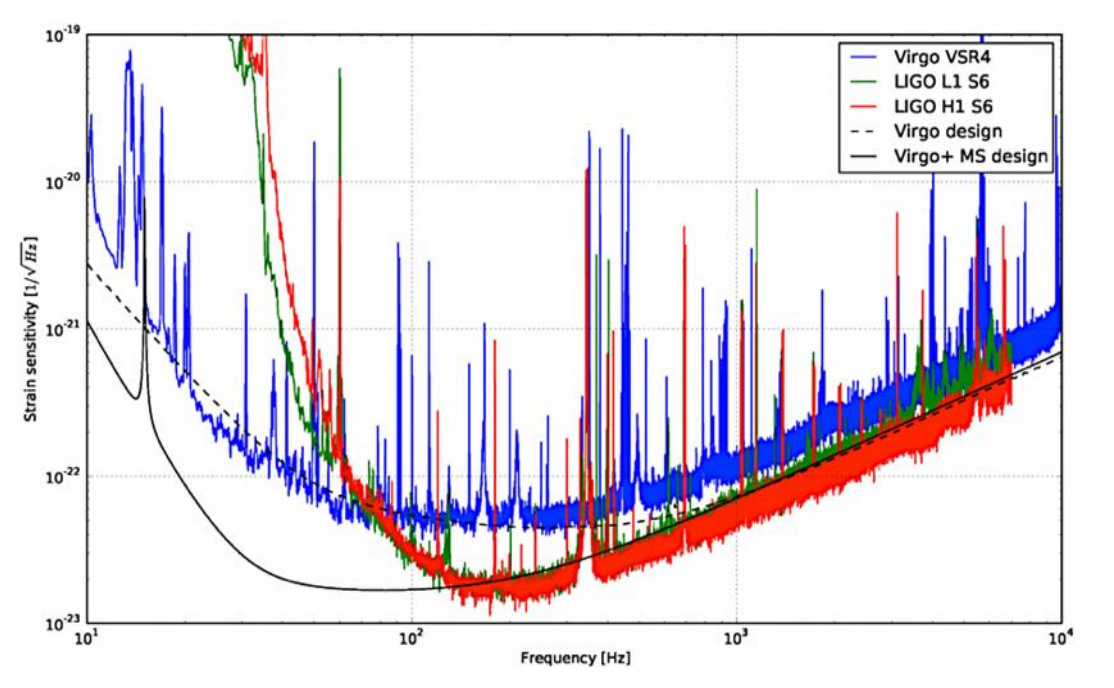
- The interferometers of the 1t generation (LIGO, Virgo, GEO600) have run in the 1st decade of 2000's



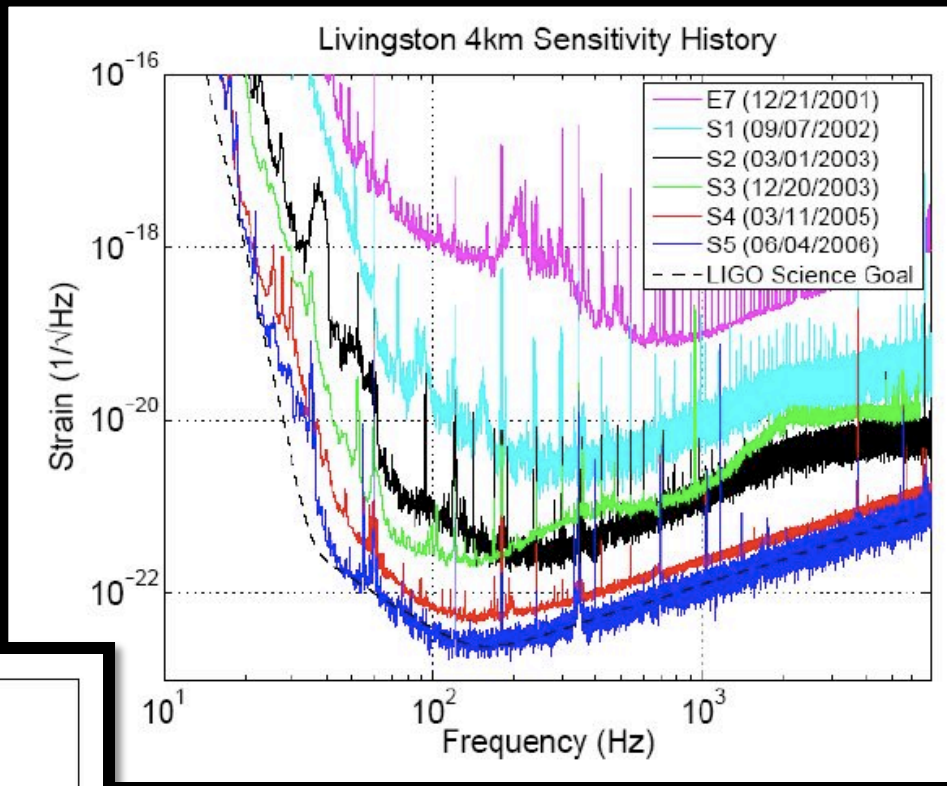
- The sensitivity finally achieved was enough to detect a coalescing BNS in ~100 galaxies…
  - …but such events happen ~1/10000 yr per galaxy…
- No detection done but a rich legacy left, invested on 2nd generation detectors

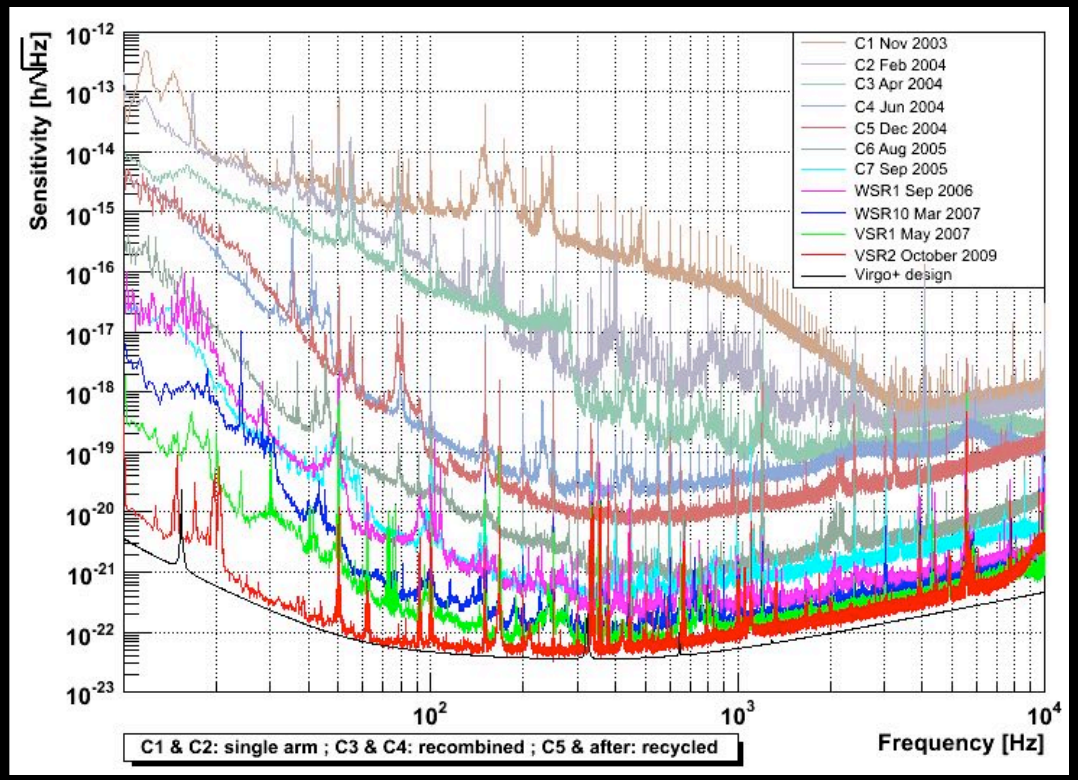
1st GENERATION DETECTORS

- The noise has been mostly understood
- The 1st generation design sensitivities have been approached closely (and somewhere exceeded upon detector upgrades)
- Excellent duty cycle (~80%): reliable instruments!



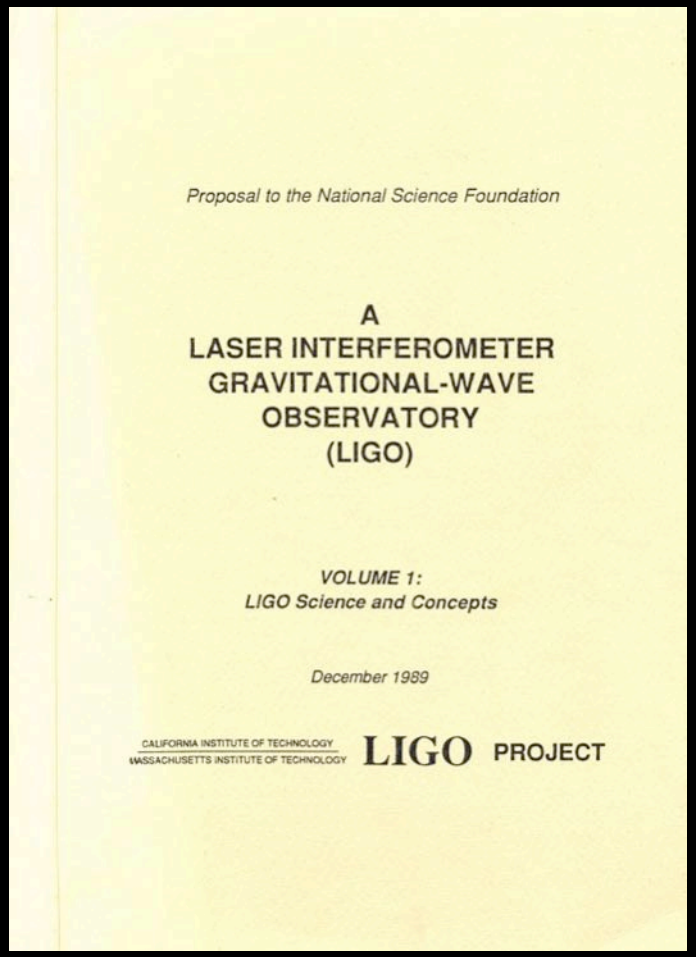
LIGO/VIRGO COMMISSIONING





5-6 YRS TO REACH THE TARGET SENSITIVITIES (INCLUDING DATA TAKING)

1989



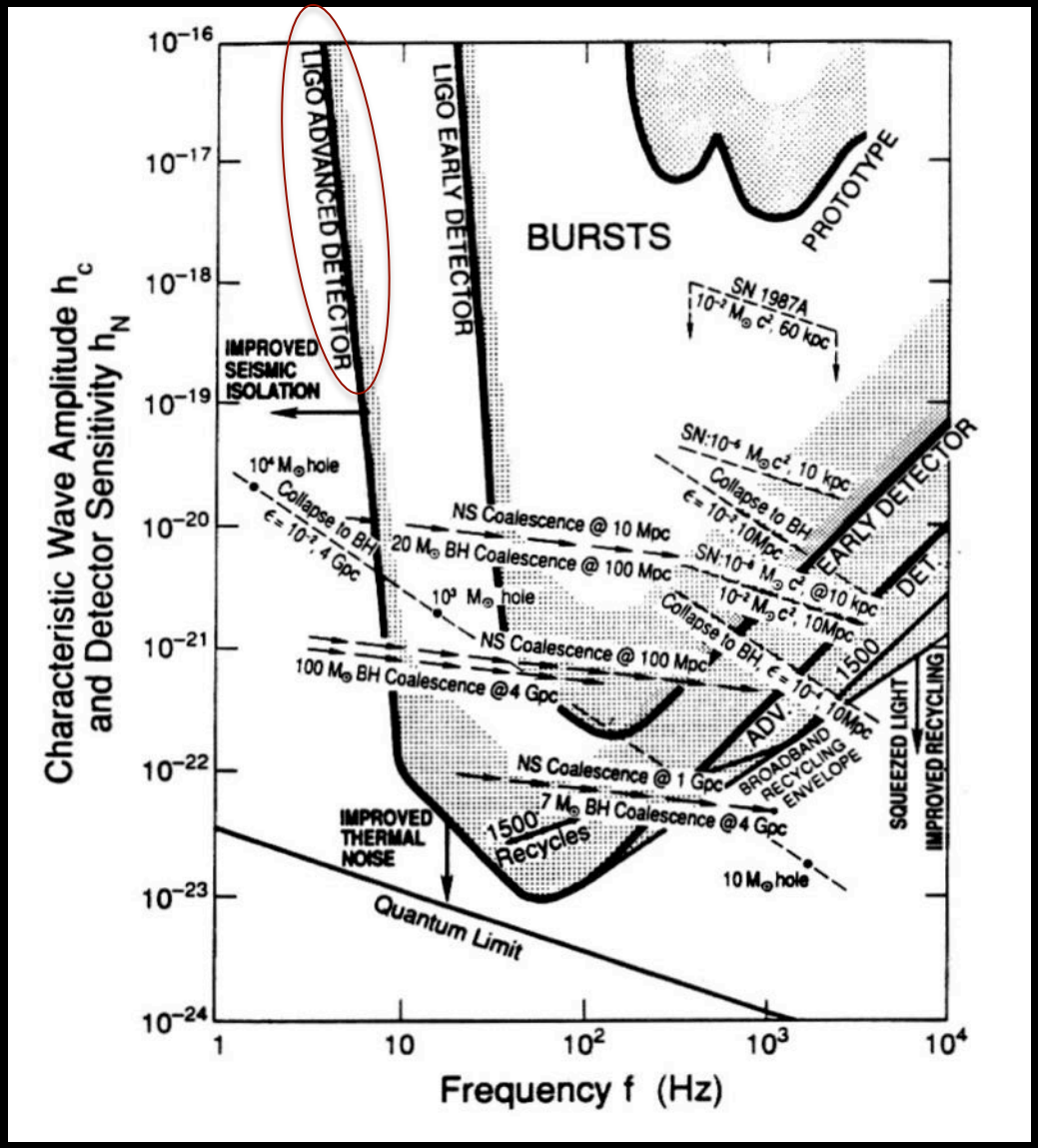
Proposal to the National Science Foundation

A
LASER INTERFEROMETER
GRAVITATIONAL-WAVE
OBSERVATORY
(LIGO)

VOLUME 1:
LIGO Science and Concepts

December 1989

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT



THE CONCEPT OF AN "ADVANCED" DETECTOR IS ALREADY IN THE LIGO PROPOSAL TO NSF

A WIDER COMPARISON

	Advanced LIGO	Advanced Virgo
# DETECTORS	2+1	1
MAX CBC RANGE	200 Mpc	140 Mpc
BUDGET	205(A) M$ + 16(B) (D/UK/AUS)	21.8(C) M€ + 2(B) (NL)
FUNDING APPROVED	Apr 2008	Dec 2009
CONSTRUCTION END(D)	Jul 2014	May 2016
1st PROJECT REVIEW	2003	2008
MEMBERS	~900	~200
COUNTRIES	17	5
LABS	82	19
R&D INVESTMENTS	~60(E) M$	~2(F)+1.5(G) M€

(A) Includes money for people ("half stuff, half staff")
(B) In kind contribution
(C) Only for investments
(D) Expected according to the latest planning
(E) Personal communication from D Shoemaker. LIGO lab R&D (+2-3 M$/yr in other labs)
(F) EGO R&D calls 2003 and 2007
(G) CSN2 funding 2005-2010 (data from Fulvio Ricci)

THE NEXT ACTIONS

From the Dawn Workshop final document P1500047

To improve GW detector network coordination, we recommend multi-month exchange visitor programs; international meetings regarding near- and long-term planning; and joint instrument science and engineering working groups developing common technical solutions. To establish a model for such collaboration, we advocate forming a joint working group involving experts from each of the gravitational wave detectors, to target initially just one near-term instrument refinement, and then beginning a joint engineering effort among the major GW detectors. These programs may require moderate investments at the level of collaborative multiple investigator funding.

We propose assembling a joint design program for GW detector improvements, distributing costs for development and production. This will be very important, since implementing detector upgrades may need significant resources, on the level of funding for mid-scale innovation projects. The current collaborations and other interested research groups should establish milestones for planning future detectors, and subsequently oversee activities to ensure that the milestones are achieved. We recommend a closer link among the global funding agencies to coordinate medium- and long-term planning, looking for synergy between the agency capabilities to most effectively stimulate the international field of gravitational wave physics and astrophysics.

CAN WE WALK A STEP FORWARD IN THIS DIRECTION?