



Report of the Internal Review Board for the choice of a baseline configuration for the stable recycling cavities of Advanced Virgo+

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Internal Review Board:

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A recap on the charge of the internal committee

Charge limits well defined: the committee paid attention to stay well focused on the assigned charge:

Gemme G.: Mandate of the internal review committee and timeline for decision on stable cavities.

<https://tds.virgo-gw.eu/?content=3&r=22807>, 2024. VIR-1162A-23.

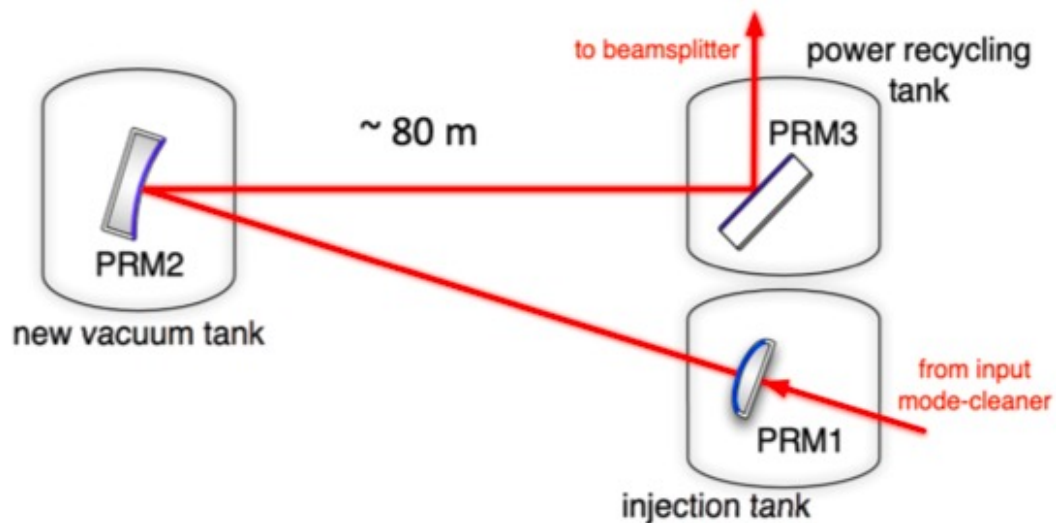
Here I highlight just two crucial points stated in this document:

1. **Review the document** delivered by the project management **with the risk assessment and proposal of a baseline configuration for stable cavities**, the methods used, the results obtained, and the conclusions drawn. Highlight any gaps in the risk assessment or aspects that require further investigation and could lead to a different conclusion.
2. **Write a report** that summarizes the main points of the document, **highlights its strengths and weaknesses**, and **provides constructive criticism and recommendations**.



Two main solution discussed: one proposed

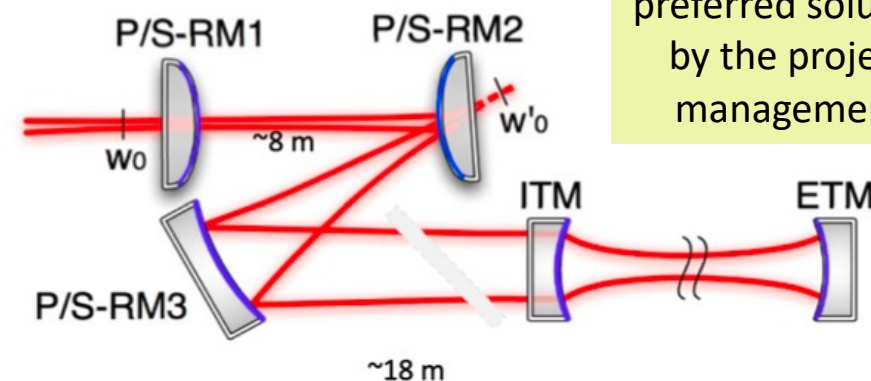
Long cavity layout



It requires the construction of additional external building + tunnels for the vacuum tubes

Limited activity in the central building

Short cavity layout



Proposed as preferred solution by the project management

It is conceived to keep all the recycling mirrors in the central building

Impact on the infrastructures and vacuum elements present in the central building

No significant activity outside of the present infrastructures



Chronology of the Internal Review Board Activity

- VSC appointed the committee on **December 21, 2023** asking to deliver the report on **January 31, 2024**
- The committee received the main document (VIR-0026a-2024) where the studies of the two solution are analysed on **January 15**. (*Risk register and proposed choice were not ready*).
- We started almost immediately to collect a series of questions and answer (Q&A Google doc)
- **On January 25** the management transmitted us a frozen version of the risk register **and they stated orally that the preferred solution is the short one**.
- We frozen the Q&A document and we started the editing of a report on the base of the management statement
- **On January 25** the management transmitted us a frozen version of the risk register **and they stated that the preferred solution is the short one**.
- **On January 30**, during the SubSystem Meeting it was shown that the *residual motion of the short cavity mirrors seems to ask for a resolution difficult to be achieve*. Further studies are needed to confirm the choice: << *the misalignment RMS is about 10 times smaller than what an alignment control could reasonably provide for the recycling cavities, assuming similar performance to the Advanced Virgo+ control loops* >> .
- **On March** , *new results on this item where available*. The committee asked for a summary report of the extra study carried on the SRC residual motion, that it was released on **March 29**.
- **March 31, 2024**: our final report was uploaded on VIRGO TDS



March 7th, 2024:

the statement of the AdV+ Upgrade coordinator *:

<< Following the activity on the mirror's residual motion requirements evaluation (which you can find summarized on the Wiki:

<https://wiki.virgo-gw.eu/AdvancedVirgoPlus/RecCavResidMotion>,

I can re-confirm that the preferred option is the short solution for the stable cavities configuration, as stated in VIR-0063B-24. >>

** This statement was the short content of a message sent to the internal board , after our request to get a detailed justification for the choice*



March 31th, 2024

the statement of the Internal Review Board

<<The internal review committee endorses the project management choice to favor the short cavity solution.

At present, the project is at a conceptual level. Several chapters of the design look really preliminary and need to evolve rapidly. In addition, a number of extra technical and management challenges have to be tackled, some of which are listed in the following sections, along with a list of concerns and recommendations.

The realization of the stable cavities will require a strong commitment and focus by the Collaboration. We believe this is a crucial step toward realizing an ambitious detector capable of producing science until the advent of the Einstein Telescope.

>>



Main reasons to endorse (unanimously) the choice

- the technical risks of the two options, identified up to now, are almost at same level and no show-stoppers have been found;
- the short cavity solution requires a considerably lower budget and one year less for the implementation;
- the LIGO successful experience is made with an optical configuration *similar* to the short cavity solution;



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List of recommendations – I – Optical Layout

Optical layout

The design effort presented here is mainly based on the assumption to run at 40 W of input power. **We recommend to extend the simulation at higher input power values.**

- **Requirements on the residual motion of the S(P)R mirrors**

Actions have to be taken to improve the organization and the coordination of the simulation activities.

A detailed study should continue increasing the complexity of the simulation.

- Scattered light

a) We recommend performing an extensive ray-tracing study to foresee solutions to dump them adequately as well as to check that auxiliary beams are not clipped: this serves also as an input for the vacuum pipe clear apertures.

b) The present version of the short cavity configuration assumes to have more than one optical bench in the same vacuum chamber, mitigation strategies should be developed to avoid that the light diffused in a bench affects the performances of the others.



List of recommendations – II – Mirrors and Suspensions

- **Mirrors**

An integrated production schedule for all the mirrors, based on information from the potential vendors (substrate production and polishing) is needed as soon as possible.

- **Suspensions**

a) We strongly advocate to immediately set up a coordinated working group of experts from different labs, working together to discuss and finalize the design and organize the prototyping activities.

b) We encourage the working group to pursue a thorough review of the proposed scheme, understand if and how it can improve and to produce an engineering design.

c) We encourage to pursue an adequate simulation effort and investigate further the alternative concept on the suspension for S(P)RM1 presented in figure 84 of Ref.[2].

d) The S(P)RM2-3 isolators, as proposed, are “tailored” to the mirror size. While we understand the reasons and advantages of this choice, we recommend to investigate further whether it can limit the flexibility for future upgrades.

e) We recommend to review the control system and present a plan including its implementation.



List of recommendations -III – Sensing-control and Vacuum

- **Interferometer sensing and controls**

We recommend to review in detail the locking procedure, in order to double check that the stable cavities do not introduce any major difference.

- **Vacuum**

a) We recommend to review attentively the production cost and include a large contingency, given the fluctuations in the material price that we are experiencing in this historical time.

b) Since vacuum pumps are sources of acoustic and vibration noise, it is recommended to plan, if possible, an installation away from sensitive elements such as view-ports and optical benches, or to isolate these noisy devices.

c) We recommend to study solutions ensuring the maximum flexibility of the experimental apparatus: flexibility is a great value which will play a crucial role in the commissioning speed up and in the future evolution of the detector.

d) We recommend that the vacuum is designed so that it satisfies the requirements set by the optical design; this includes also the propagation of ghost/auxiliary beams.



List of recommendations -IV- Infrastructures and Planning

- **Infrastructures**

Mechanical simulations (static, modal and thermo-mechanic) should be performed to guide the choice between filling the hole with concrete and the metallic frame.

- Cleanliness

We recommend that a well defined procedure is developed in advance to be ready to act in case contamination starts to accumulate.

- **Planning and person power**

A person power plan is missing. We recommend to pursue the preparation of such plan along with the TDR for the construction of the short SRC. In addition, we recommend to explore the possibility of an extended use of external person power, supervised by the experts of the collaboration. It will be a way to speed up the installation phase even in the case of systems traditionally assembled by Virgo internal experts.



Risk Register – An example: Most Severe Phase II Risks

<https://docs.google.com/spreadsheets/d/1ITpza81YfKm9eI3cKLpE3bMG8C29MxDyaZ-jFjf5TIU/edit - gid=954120015>

A1 | Most Severe Phase II Risks

Level	Probability										
	5	Extremely Likely – 90% probability of occurrence over the project life									
4	Highly Likely – 70% probability of occurrence over the project life										
3	Moderately Likely – 50% probability of occurrence over the project life										
2	Unlikely – 30 % probability of occurrence over the project life										
1	Highly Unlikely – 10% probability of occurrence over the project life										
Risk ID	Risk manager	Name	SS / Deliverable	Phase	Probability	Impact	Severity	Action Date (check)	Proposed Mitigation Actions	Status	Comments
MIR005	L. Pinard	End mirrors: Delivery delay	MIR.01	II	2	4	Med		Risk mitigation polishing schedule: share the load between companies (polishing of several lots in parallel), if the global cost is compatible with the MIR budget	Controlled	polishing companies have a lot of work, so delay are increasing in this period. The polishing schedule is followed even if it slightly shifted since the beginning. It is compatible with overall Adv+ planning even more as O4 duration has increased.
MIR006	L. Pinard	End mirrors: Polishing cost of substrate	MIR.01	II	4	5	High		price estimation made with a big margin	Closed	incertitude because first time such a large substrate polished with the required specifications. After the call for tender, the budget necessary for the EM polishing task was available despite the cost larger than foreseen (MIR budget reduction for some deliverables + contingencies)
MIR08	L. Pinard	Input mirrors: Delivery delay	MIR.02	II	2	4	Med		Risk mitigation polishing schedule: share the load between companies (polishing of several lots in parallel), if the global cost is compatible with the MIR budget	Controlled	polishing companies have a lot of work, so delay are increasing in this period. The polishing schedule is followed even if it slightly shifted since the beginning. It is compatible with overall Adv+ planning even more as O4 duration has increased.
MIR009	L. Pinard	Input mirrors: Polishing cost of substrate	MIR.02	II	4	5	High		price estimation made with a big margin	Closed	incertitude because first time such a large substrate polished with the required specifications. After the call for tender, the budget necessary for the IM polishing task was available despite the cost larger than foreseen (MIR budget reduction for some deliverables + contingencies)
MIR011	L. Pinard	Recycling mirrors: Delivery delay	MIR.03	II	2	4	Med		Risk mitigation polishing schedule: share the load between companies (polishing of several lots in parallel), if the global cost is compatible with the MIR budget	Controlled	polishing companies have a lot of work, so delay are increasing in this period. The polishing schedule is followed even if it slightly shifted since the beginning. It is compatible with overall Adv+ planning even more as O4 duration has increased.
MIR014	L. Pinard	Reference sphere: Delivery delay	MIR.09	II	2	4	Med			Controlled	polishing companies have a lot of work, so delay are increasing in this period. The polishing schedule is followed even if it slightly shifted since the beginning. It is compatible with overall Adv+ planning even more as O4 duration has increased.
SAT002	V. Boschi	Control electronics obsolescence	SAT.01, SAT.02	II	3	4	High		New spare DSP boards will be prepared	Controlled	A draft document summarizing the plans and the tests that will be performed on the board has been written.
SAT003	V. Boschi	Manpower	SAT.01, SAT.02	II	2	4	Med		Other Virgo groups are being involved (Napoli, Amsterdam)	Controlled	One technician and 2 engineers have been hired
TCS01	A. Rocchi	Breaking of glass rings during assembly	TCS.01	II	3	4	High		Procure enough spares	Identified	
TCS11	A. Rocchi	Power control system with half-wave plate and thin film polarizer not possible due to difficulty in procurement of optical components and high fluctuation in production prices	TCS.05	II	3	4	High		Alternative solution with prism or rhomb (to be tested)	Identified	
DAQ001	N. Letendre	Timing distribution upgrade: Components shortage delay	DAQ.01	II	3	4	High		Survive with TDBox_V1	Assessed	
PSL005	J-P Coulon	Effect of the line driver noise on Pstab	PSL	II	3	4	High		study of homemade systems	Assessed	
PSL006	W. Chaibi	unwelding the "old table" legs	PSL	II	3	5	High		Keep the old table with its extension (issue with the table active suspension system ; not confirmed)	Assessed	Solution already proposed by F. Carbognani on the unwelding technique ; Possibility to add protection around the table

Add

1000

more rows at the bottom



The Risk Scale

Comment:

The project management has set a *standard procedure to quantify the risk*. They define five levels of risk with different probability of event occurrence:

1 - green - Highly Unlikely - 10 %

2 - light green - Unlikely - 30 %

3 - yellow - Moderately Likely - 50 %

4 - orange - Likely - 70 %

5 - red - Extremely Likely - 90 %

Similar scale used to assess the

- severity

- the impact of the event on the project



Risk Register - Recommendation

- Each system is analysed independently and it has associated a corresponding Excel table with detailed description of the risk, comments devoted to the incertitude in the evaluation of the risk level and/or on action to mitigate the risk.

Recommendation:

- At present *the* risk register is detailed and ***we recommend to review and even to increase the number of details during the preparation of the technical design report of the project.***

- ***A risk evaluation concerning the availability of person power is missing.***

We have not received any person-power plan.

(In principle such a plan should be prepared even specifying if, for a given item, person power internal or external to the collaboration is needed)



Final remarks

- Our review was based on the rich documentation produced by the **Collaboration in a short time**.
- This material, resulting from **the impressive effort of the project management and the Collaboration**, contains original ideas, plans and risk assessment for the recycling cavity configuration.
- The project management started this work in a sort of “emergency mode”. *The reference document that we received did not report neither a detailed bibliography and/or a plain theoretical treatment on the subject nor extended references to LIGO and KAGRA experimental results (LIGO is taking data with SRCs since 10 years at least).*
- The need to study deeper some specific issue changed this modality. At present the approach is more rigorous and transparent, a crucial change to end up with a robust Technical Design of this important change of the Virgo experimental configuration.



Disclaimer and Acknowledgements

The internal review was focused on the assigned charges set by the VSC.

We are conscious that the detector can be affected by other limitations independent of the SRC issue.

However the analysis of these other aspects were out of our charge and we are confident that AdV+ upgrade management will identify and tackle independently of the SRC issue.

A huge effort has been done to elaborate and support this proposal by the whole Virgo collaboration and in particular by all the members of the various sub-systems. This effort will continue in the context of the preparation of a TDR for the future of Virgo postO4.

Finally, I wish to thank the members of the internal board: it was a pleasure for me to work with all of them: *Matteo Barsuglia, Livia Conti, Giovanni Losurdo, Cristophe Michel, Lluïsa-M. Mir, Maria . C. Tringali and Bas Swinkel.*