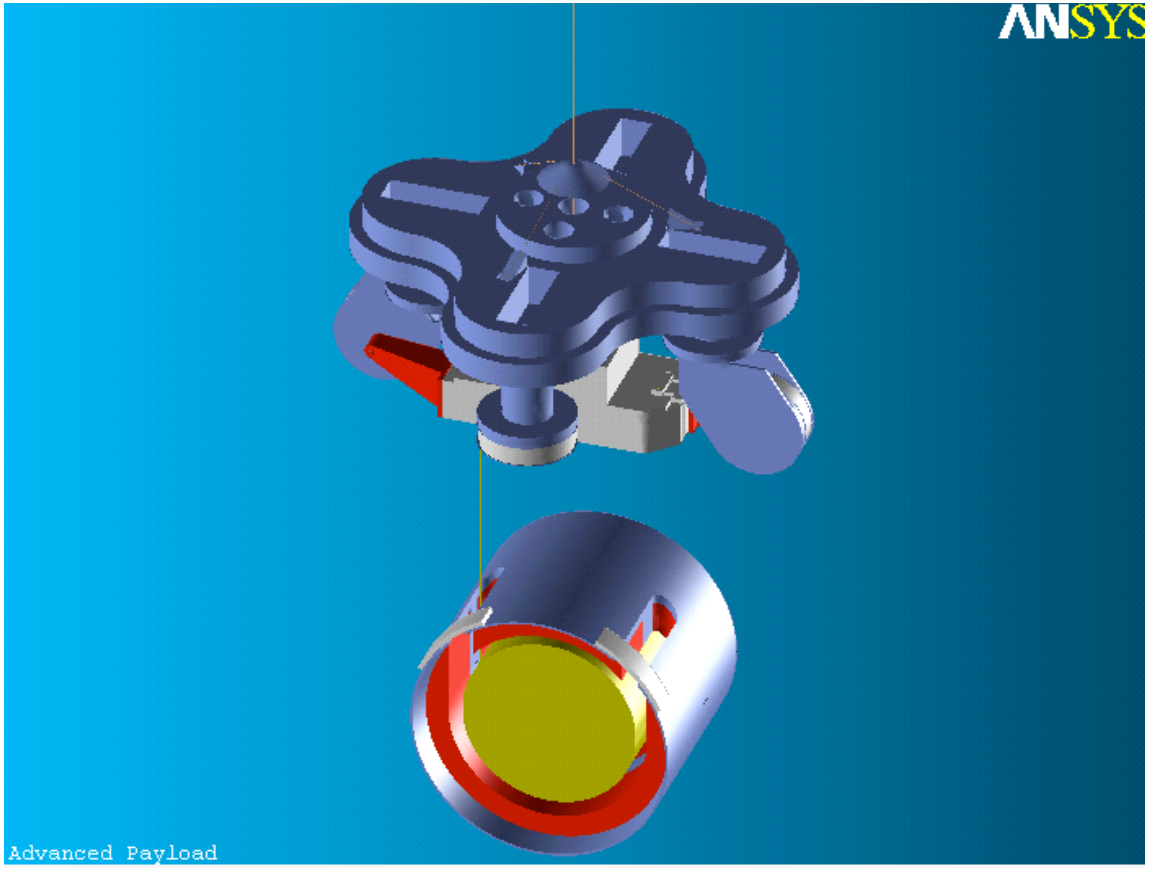
PAY Review

27/4/2009

P. Rapagnani with contributions by the PAY Team



PAY Deliverables

- Payload for the North Input Mirror
- Payload for the West Input Mirror
- Payload for the North End Mirror
- Payload for the West End Mirror
- Payload for the Beam Splitter
- Payload for the Power Recycling Mirror PRM1
- Payload for the Power Recycling Mirror PRM2
- Payload for the Power Recycling Mirror PRM3
- Payload for the Signal Recycling Mirror SRM1
- Payload for the Signal Recycling Mirror SRM2
- Payload for the Signal Recycling Mirror SRM3
- Payload for Input Mode Cleaner
- Marionette for Detection Bench
- Marionette for Input Bench

PAY Interfaces:
SAT
OSD
ISC
INJ
DET
VAC

PAY must provide:
- Local Control
- Actuation range and noise
- Alignment range
- Thermal noise

according to the requirements of others SS's and of AdV sensitivity

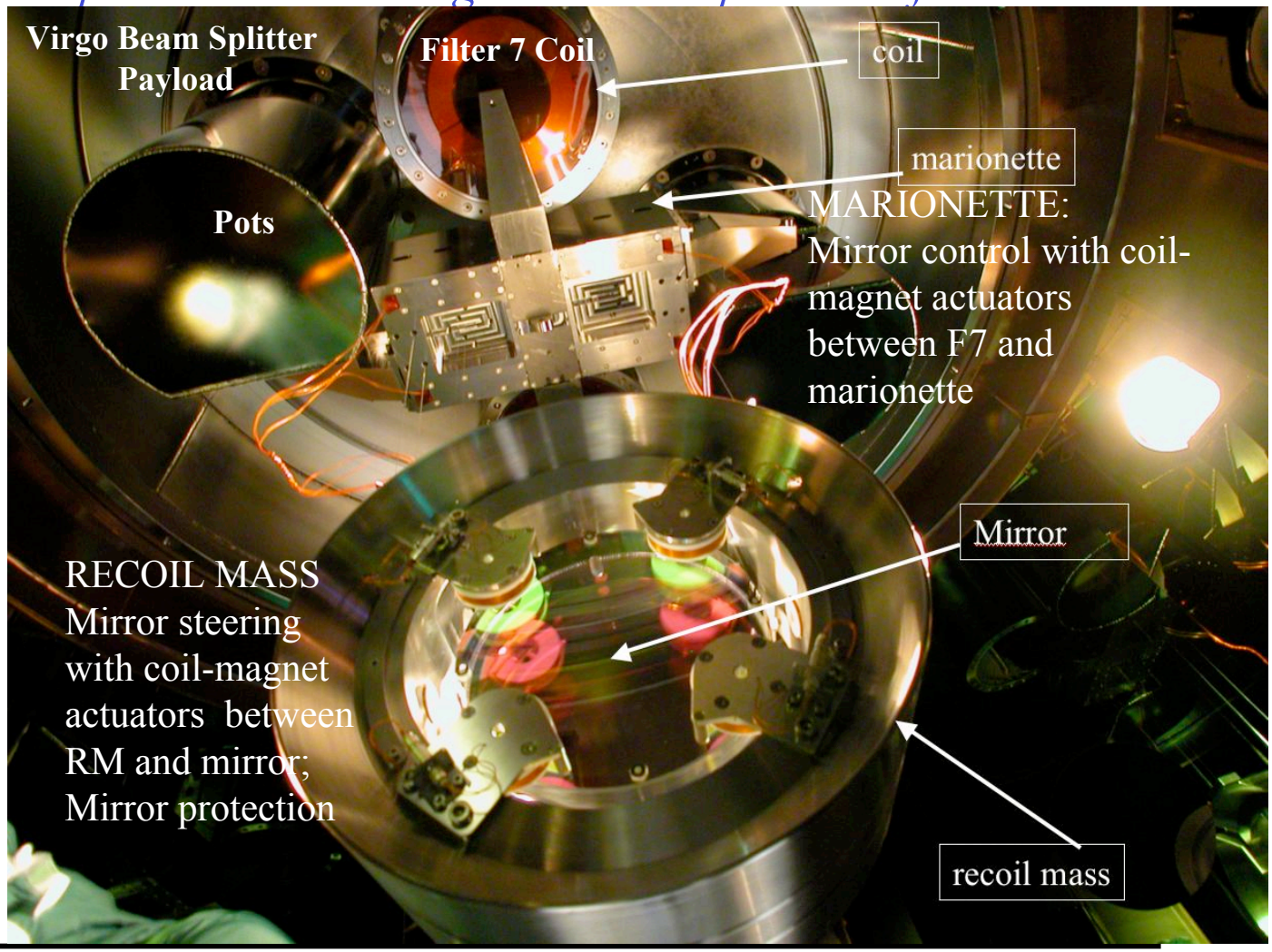
Payload

▪*The* **role of the Last Stage Suspension** *is to compensate the residual seismic noise and to steer the optical components maintaining the relative position of the interferometer mirrors.*

Requirements:

Materials:
•UHV compatible;
•Amagnetic;
•No electrostatic charges;
•Internal Frequencies above Virgo bandwidth;
•Low frequencies of the system below Virgo bandwidth;

▪**Compatibility with SuperAttenuator and lower part of the tower:**
- ▪Weights
- ▪Shape



Virgo payload design criteria:

- geometrical constraints given by SA, IVC, Pots
- measurement of payload modes
  (not checked by modelling the overall suspension system)
- measurement of bulk lowest frequency modes (RM, marionette…)
- DC tilt adjustment (motors)
- actuators (available space, needed force, coil aspect ratio, heating)
- Eddy currents
- Local controls (to allow Locking and Automatic Alignment activation)

Virgo payload improvement during Virgo experience (since Central ITF):

- mechanics: **no multi-piece-bodies along the main beam** ($f_i > 1$ kHz)
- Eddy Currents and magnetization control.
- Local controls (more efficient from marionette, but then coupling with roll must be considered)
- Transversal pendulum noise improved by unplugging the related actuators (actuation efficiency of actual solution depends on the coupling).
- Reaction mass: using 0.6 Hz for locking is easy, successful driving noise reduction through reallocation attained, but with some work.

VIRGO EXPERIENCE - 2

By Ettore Majorana

GENERAL LESSONS:

- careful choice of marionette **materials**
- simple and **compact shapes**
- as far as possible, **no multi-pieces** mechanics
- BS payload site critical for **diffused light**
- **BS control reallocation to marionette needed**, but only to a limited extent (reasonably avoidable in the future)
- **PR reallocation not needed**.
- **Local Control basically OK**, with some patch needed (e.g. x sensing, roll coupling)
- **It is very important to model** the overall mechanical system
- **Local Controls must be over-performing** until automatic control signals (lock and angular) aren't fully understood.

MONOLITHIC PAYLOAD EXPERIMENTAL STUDY → **Design of monolithic suspension done on this base**

PAY vs ISC requirements (by Maddalena Mantovani)

Advanced Ligo requirements (LIGO-T070247-01-I)

Test masses = 10^{-18} rad/√Hz

For the recycling mirrors and the BS the requirements are softer
BS 10^{-15} rad/√Hz
Recycling mirrors 10^{-14} rad/√Hz
Decentering < 1mm

DC Alignment Dynamics depends on:

- **the linearity range of the error signals**
- **performances of the PAY**

$\theta << \theta_{div} = \lambda/\pi w_0 = 1064 \cdot 10^{-9}/\pi 8 \cdot 10^{-3}$

~$4 \cdot 10^{-5}$ rad

Only a factor ~3 smaller than the present requirements

Accuracy requested from PAY

~ 10^{-7} rad => Feasible

Advanced Virgo Requirements: extrapolation @ 10 Hz

Virgo Test Masses performances:

$9 \div 3\ 10^{-15}$ rad/√Hz

For Advanced Virgo:

$\theta_{10Hz} = S\ h_{10Hz}\ L / d \sim 6\ 10^{-17}$

Safety factor ~ 1/10 **3km** **Decentering ~ 1mm**

Radiation Pressure Effects depend on:

- **Optical parameters**
  - –Radii of curvature, stability parameters, circulating powers…
- **Mechanical parameters**
  - –Mirror masses, mirror momentum of inertia, suspension parameters

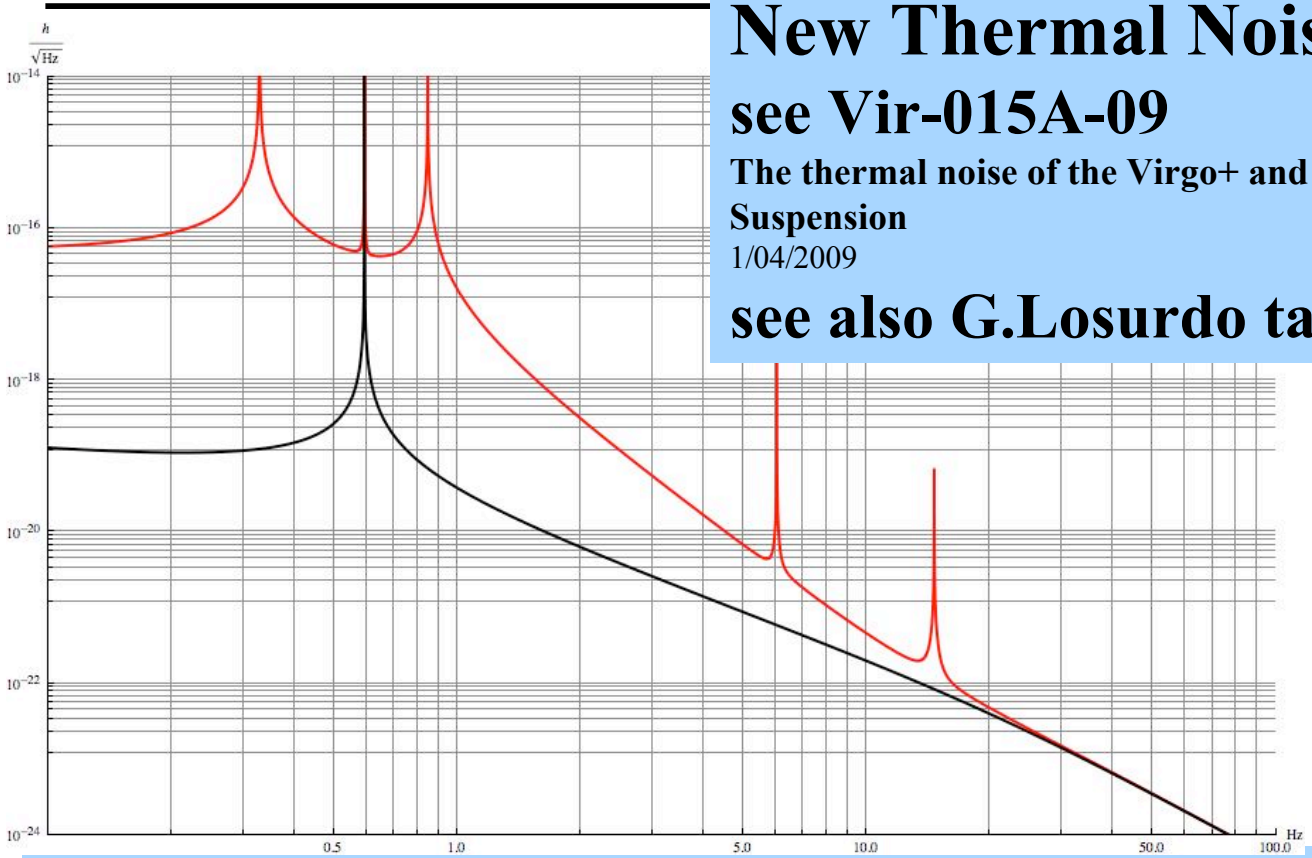
To be simulated

New Thermal Noise Predictions:

see Vir-015A-09

The thermal noise of the Virgo+ and Virgo Advanced Last Stage Suspension
1/04/2009

see also G.Losurdo talk



• *From the results of the new calculation on the thermal noise of the last stage suspension,* ***it turns out that the effect of the losses of the marionettes are very important:***

In AdV, the use of the MRM as an intermediate mass can be helpful to decrease the losses of the marionette, decoupling it from the upper suspension.

Test Masses Payloads - 1

NE and WE Payloads:

•Marionette for monolithic suspension:

Same design as in Virgo+MS payloads.

*If we keep the same distance between the suspension wires (**5 cm**), we could use the same pieces.*

•Reference Mass for monolithic suspension

Same basic design as in Virgo+MS payloads. Some *expensive* parts of the Virgo+MS could be re-used.

•Use of Marionette Recoil Mass could be essential to meet thermal noise requirements

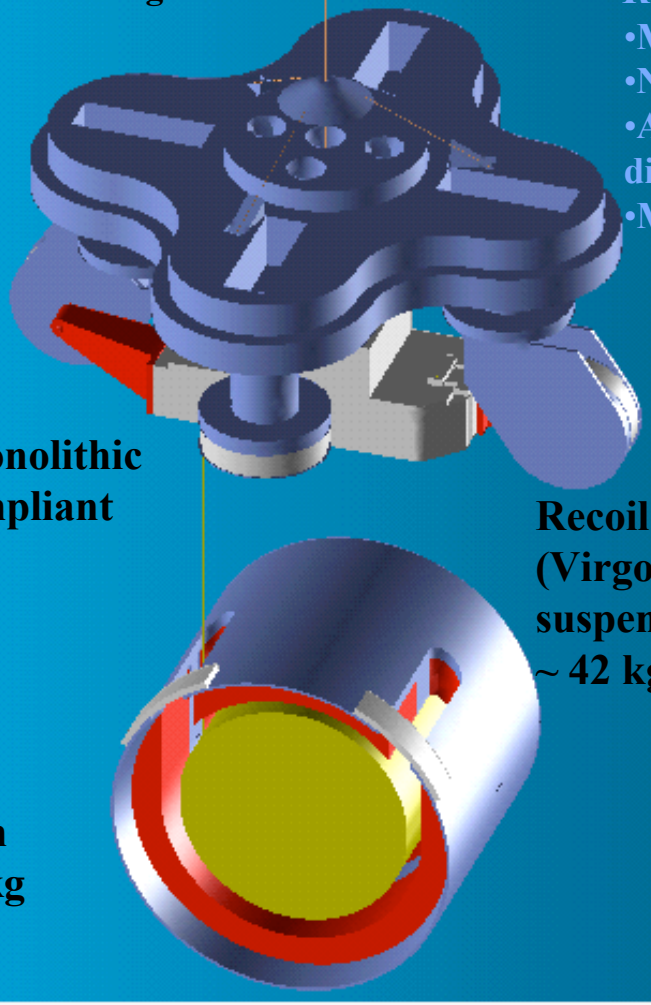
Local Control and Actuation:

Same reference solution as used in Virgo and Virgo+

Changes eventually to be asked by the ISC group

Advanced Virgo Payload

Total Payload Mass ~ 180 kg



Marionette Recoil Mass (MRM): R&D

- **Marionette steering**
- **No coil pots and filter 7 legs**
- **Allows to suspend mirrors with diameter > 370 mm**
- **Mass ~ 85 kg (filter 7 legs)**

Marionette (Virgo+ like, monolithic suspensions compliant ~ 100 kg mass)

Recoil Mass (Virgo+ like, monolithic suspensions compliant, ~ 42 kg mass)

Mirror: 350 mm ø, 200 mm thickness, 42 kg

Test Masses Payloads - 2

NI and WI Payloads:

•Marionette for monolithic suspension (NI, WI)

Same design as in Virgo+ MS payloads. *If we keep the same distance between the suspension wires (**5 cm**), we could use the same pieces.*

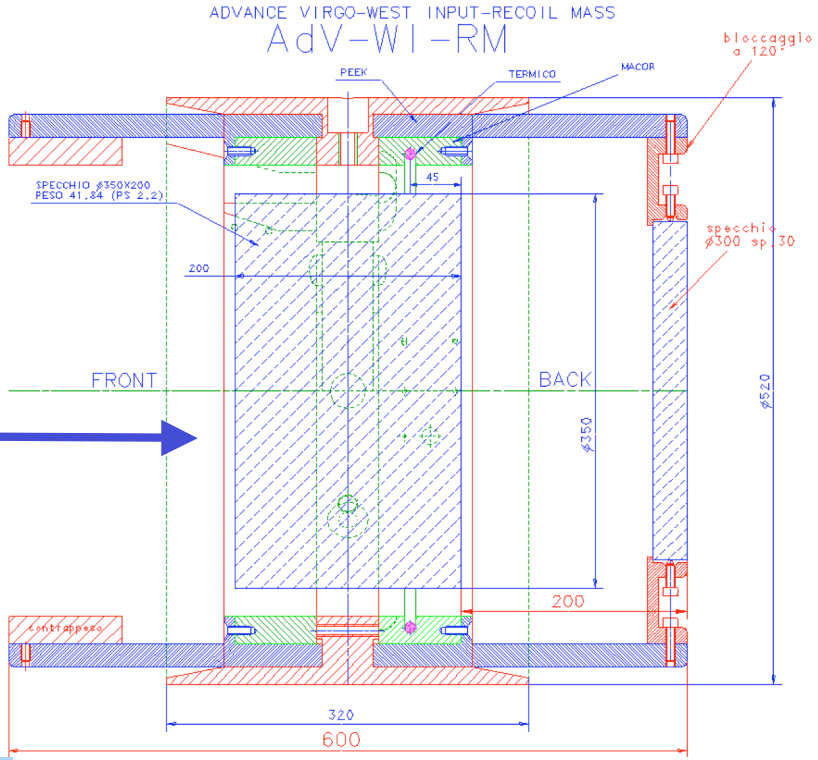
Even if an auxiliary mirror should be put in the NI and WI towers, it would be important to keep the same marionetta design.

•Reference Mass for monolithic suspension with compensation plate and heating ring (NE, WE)

Same basic design as in Virgo+ MS payloads, with some modifications to include the CP and Heating Ring from TCS. **Design is starting**

•Recoil Mass for monolithic suspension Marionette (NI, WI, NE, WE)

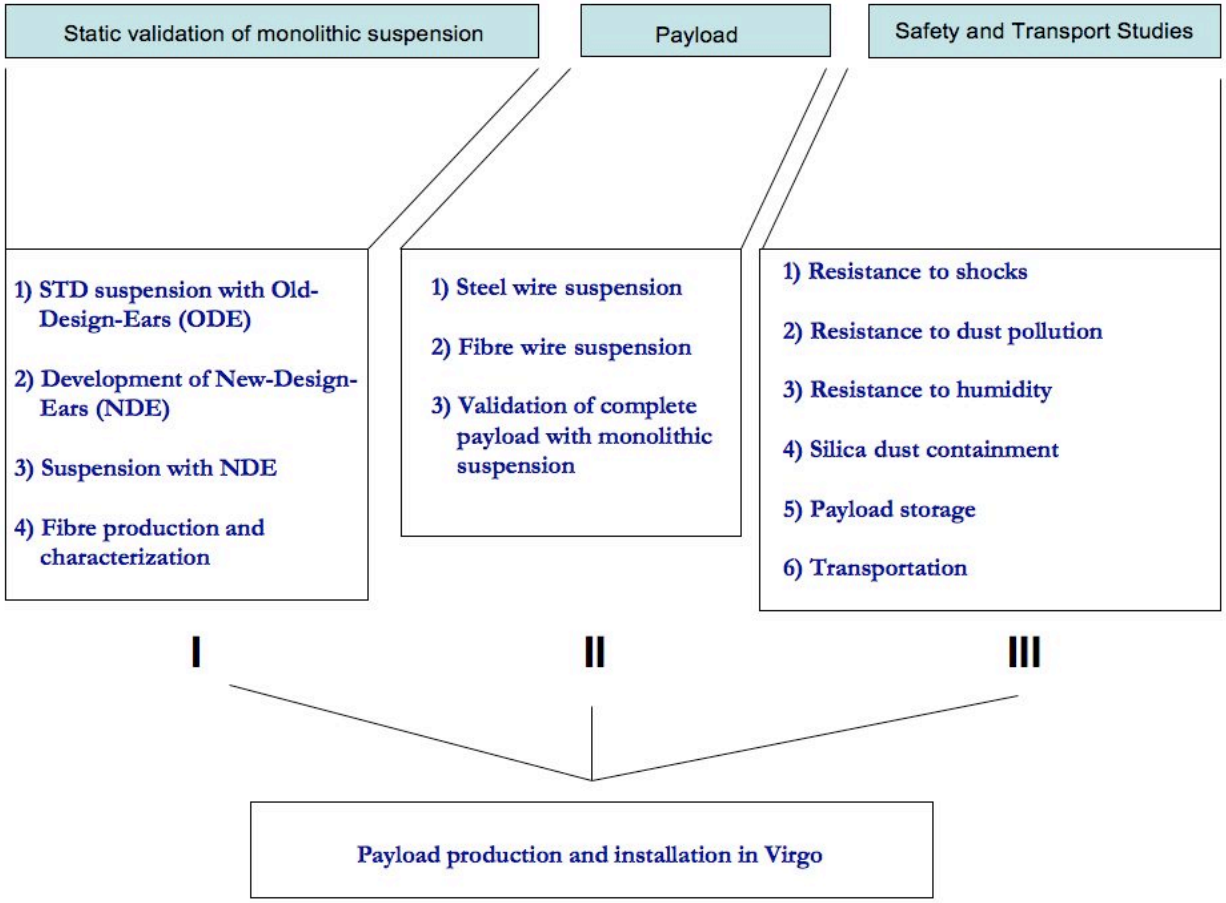
Same basic design of the Prototype Cryogenic Payload, suspended in series between Filter7 and marionette to improve the Thermal Noise



Monolithic Suspensions

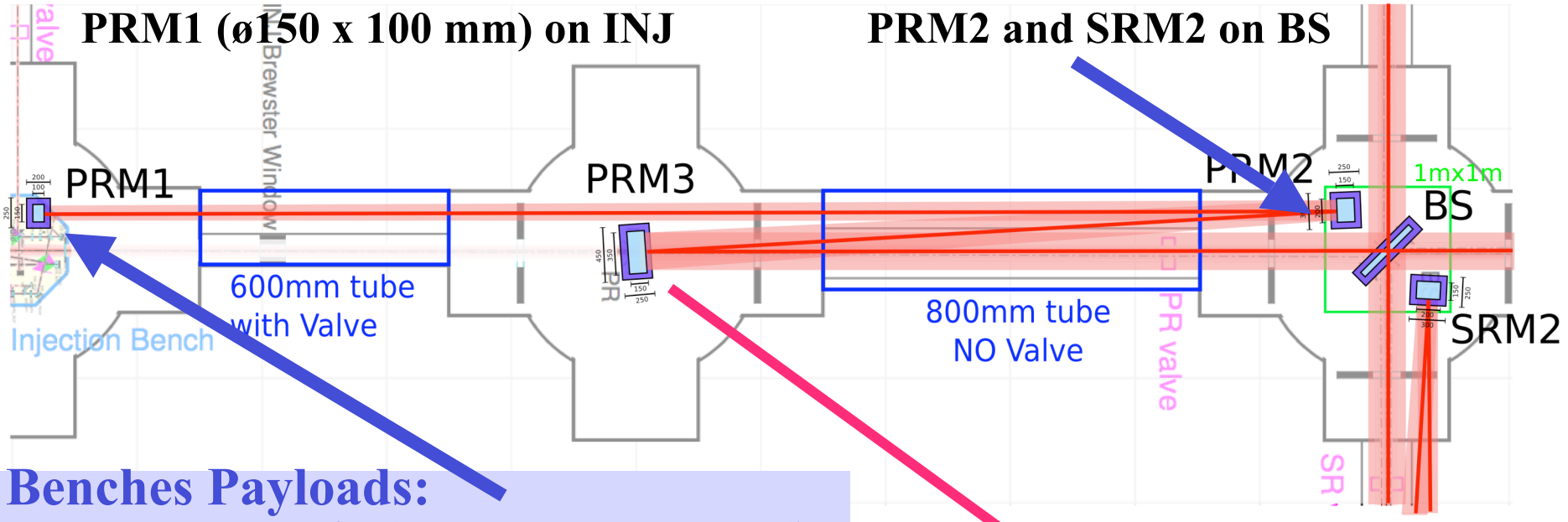
The Monolithic Suspension technology is now mature to be tested on Virgo+:

Four test masses with monolithic suspensions will be mounted in Virgo + in 2010



A summary of the main features of the monolithic suspensions is in the extended version of this presentation

Proposed Optical Schemes - Scenario 2



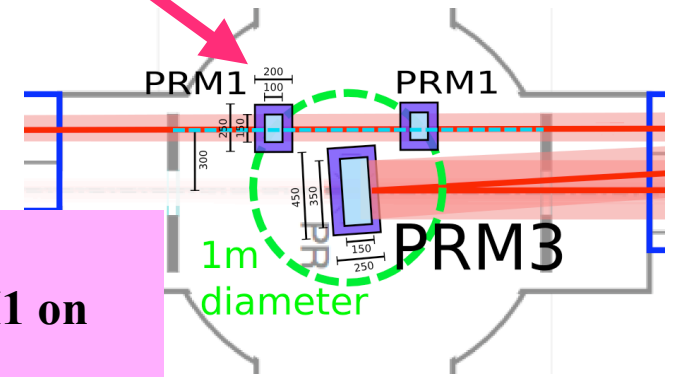
Benches Payloads:

Marionette for IB ***(with suspensions for PRM1)***

Marionette for DB ***(with suspensions for SRM1)***

IMC Payload

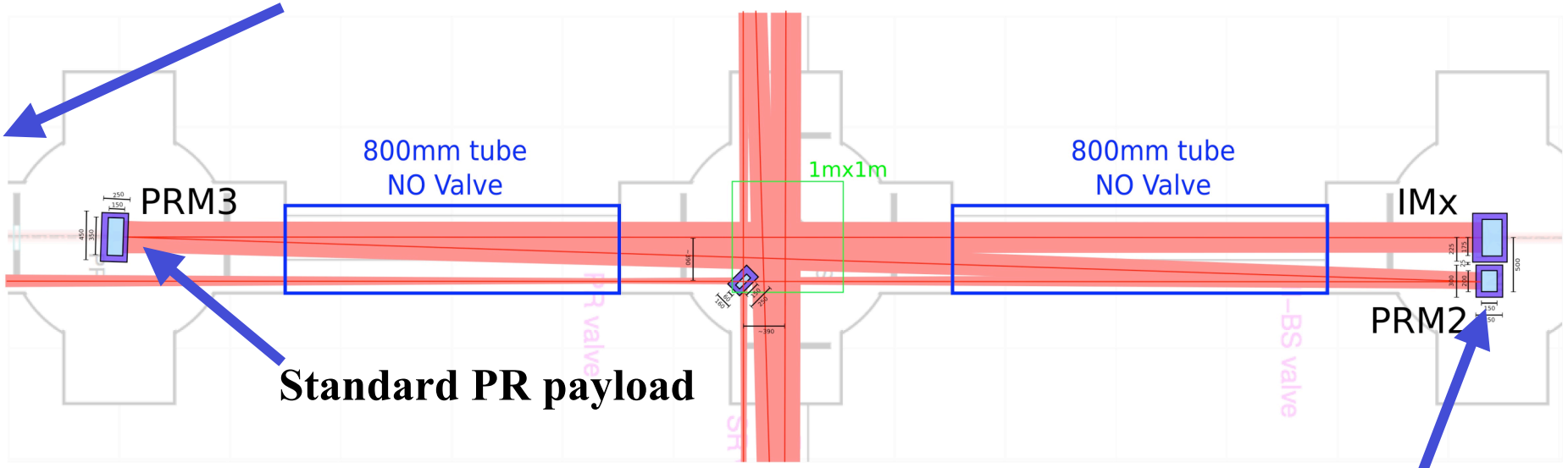
- Recoil Mass
- Marionette



Scenario 2a: further proposal to avoid PRM1 on the injection bench:

Porposed Optical Schemes - Scenario 4

PRM1 (ø150 x 100 mm) on INJ



Benches Payloads:

Marionette for IB ***(with suspensions for PRM1)***
Marionette for DB ***(with suspensions for SRM1)***
IMC Payload
- Recoil Mass
- Marionette

PRM2 and SRM2 on Input Mirrors: heavy redesign of Monolithic Payloads for Input Mirrors required

Central Area Payloads Design Driving Issues - 1

1 - Compatibility with Monolithic Suspensions:
Essential to preserve/use as much as possible the experience gained in Virgo+
OSD 4: secondary mirror suspended by Input Mirrors could be critical for:
•Alignment control
•Fabry Perot <=> NDRC alignment noise coupling.
•Thermal noise control

2 - OSD2 and OSD 4 simpler if no re-allocation on marionette is needed for BS/PR

3 - Diffused light:
constraints about clearance among beams around mirrors should come from optical tracing, their fulfillment will be checked according to mechanical possible drawings for OSD2/OSD4.

4 - Electromagnetic crosstalk:
to be carefully minimized for complex multiple payloads. minimal (or reasonable) distance among actuators

Central Area Payloads Design Driving Issues - 2

5 - both OSD2/OSD4 require:
- **different marionettes with 3 tilts controlled.**
- **DC counterbalance along transversal (x)**
- **z control through Recoil Masses for PRM3, BS**

5bis - differential radiation pressure at the BS (OSD2) requires torque compensation (apparently also elsewhere even if to a minor extent) => Further complication (e.g. an intermediate controlled mass might be necessary)

6 - Local Control design not easy given the limited number of optical ports: perhaps OSD4 a bit easier

7 - Criticality of beam centering/control noise for telescope mirrors PRM1,PRM2,SRM2

BASIC QUESTIONS:
At present ONLY Input Mirrors are under Local Control + driftControl: What will happen with NDRC?
Should NDRC telescope mirrors also be controlled via autoalignment (using which viewports?)?

Summary of the difficulty
to realize the new payloads in different NDRC scenarios:

	OSD 2	OSD 2a	OSD 4
WE	*Standard MS*	*Standard MS*	*Standard MS*
NE	*Standard MS*	*Standard MS*	*Standard MS*
WI	Standard MS + CP	Standard MS + CP	Standard MS + PRM2
NI	Standard MS + CP	Standard MS + CP	Standard MS + SRM2
BS	ø 50 cm + PRM2 + SRM2	ø 50 cm + PRM2 + SR	ø 50 cm
PR	PRM3	PRM3 + PRM1	PRM3
SR	SRM3	SRM3 + SRM1	SRM3
DET	DET + SRM1	Standard	DET + SRM1
INJ	INJ + PRM1	Standard	INJ + PRM1
IMC	Standard	Standard	Standard

Difficult:
Complete Redesign of Payload -
Control and Alignment Strategy to be identified
SAT to be heavily modified for heavier loads
Separating roof to be implementd in bench towers

Very Difficult:
Complete Redesign of Monolithic Payload -
Control and Alignment Strategy to be identified
SAT to be heavily modified for heavier loads

Important Changes:
Redesign of standard parts, with no major change in strategy

Standard Monolithic Suspension:
Standard (after Virgo+MS experience) monolithic suspension technology

Standard Virgo Technology

Final Remarks

What we have:

- **Consolidated experience with Virgo payloads**
- **Promising design of Virgo+ Monolithic Payloads**
- **Well estalished Local Control and Alignment Techniques**
- **2 yrs to make study, design, prototyping of new payloads**

What we need:

- **Continue and increase the interaction with OSD, ISC, SAT, VAC, INJ, DET to find the best tradeoff between different optical configurations**
- **Increase a comprehensive simulation activity**

Conclusions

-The design of the Payload for Advanced Virgo is greatly based on the experience on Virgo and Virgo+

- Marionetta will be almost the same as in Virgo+

- Recoil Mass design for Virgo+ can be adapted to different mirrors lengths and to accomodate TCS Compensation Plate (CP)

- A Marionetta Recoil Mass is being developed:
facilitates installation and operation for 350 mm diameter mirrors, could improve thermal noise matching for Test Mass Mirrors, *it is necessary for larger mirrors (i.e. the BS)*

- Monolithic suspensions currently being tested for 21 kg mirrors in Virgo+.
Technology should be easily portable to the AdV case for 42 kg mirrors

It is essential to use this experience as much as possible in AdV

- Intense interaction with OSD, ISC, INJ and SAT to freeze Optical Scheme underway

-Extensive simulation and prototyping of new payloads in progress