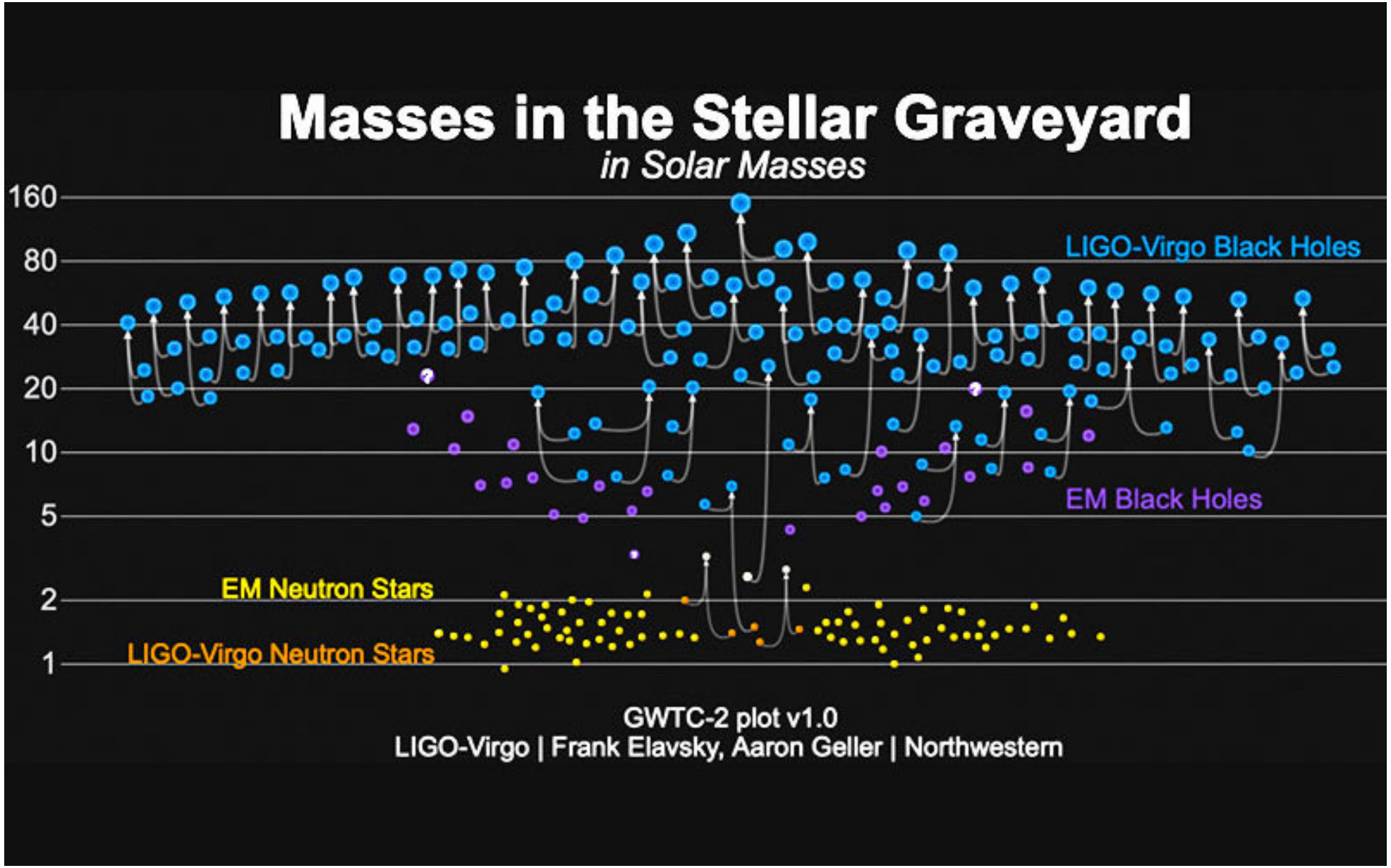
A new instrumented baffle for AdV+

Lluïsa-Maria Mir
for the Virgo Collaboration

GWADW2021 Gravitational Wave Advanced Detector Workshop

17-21 May

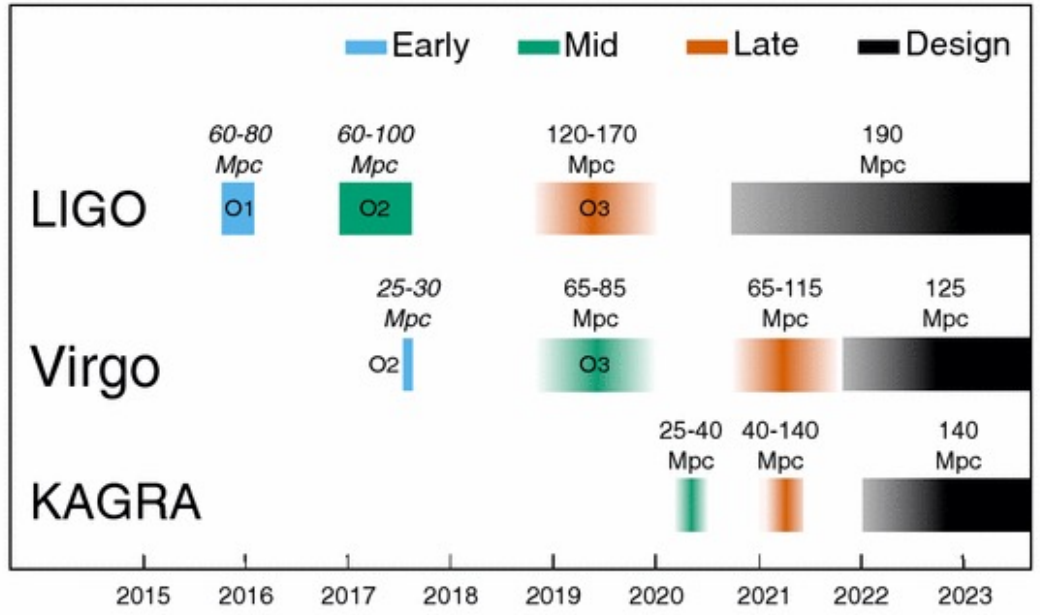
O1+O2+O3a events



GW detector sensitivities

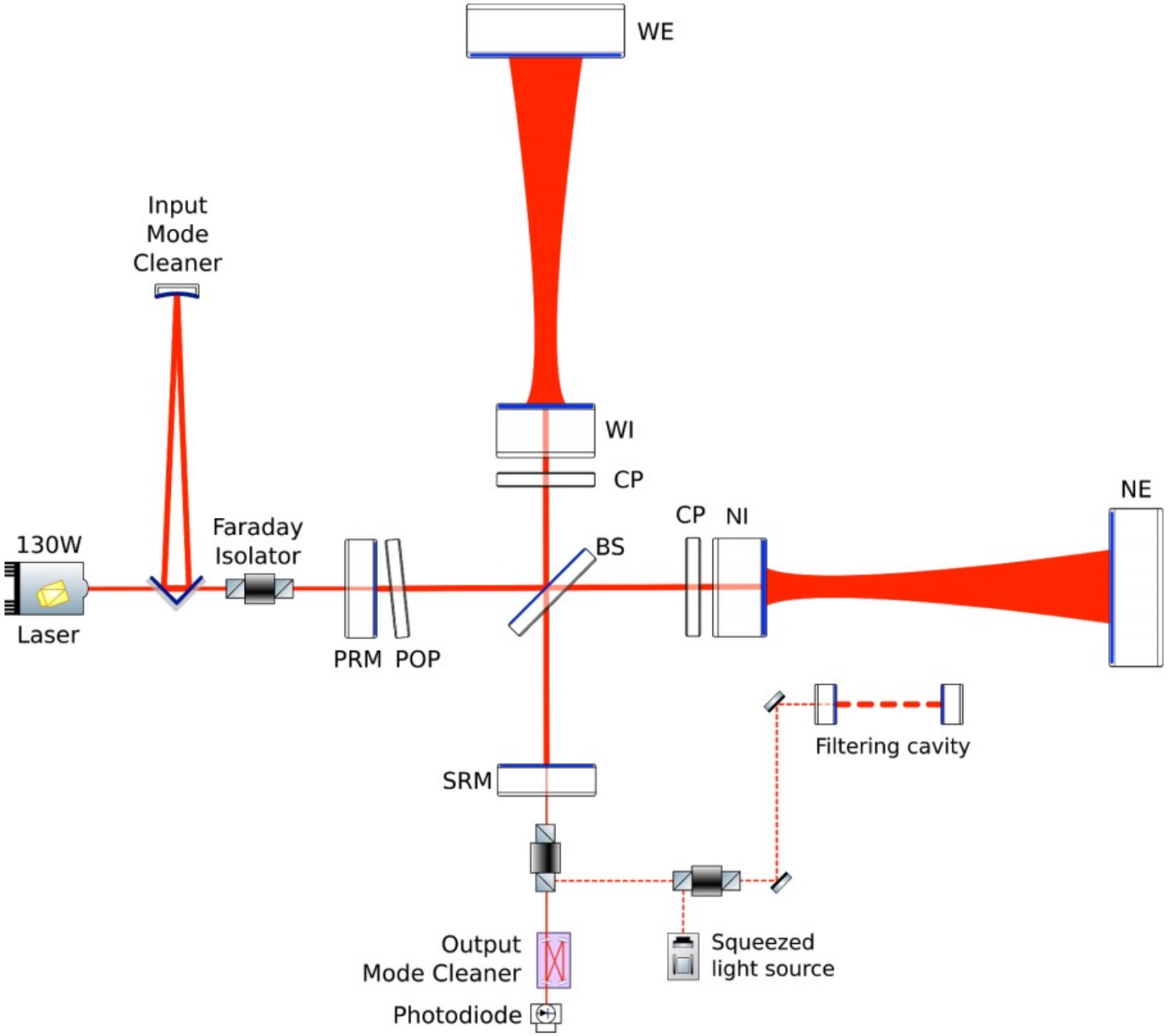
	LIGO		Virgo		KAGRA	
	BNS range/Mpc	BBH range/Mpc	BNS range/Mpc	BBH range/Mpc	BNS range/Mpc	BBH range/Mpc
Early	40–80	415–775	20–65	220–615	8–25	8–250
Mid	80–120	775–1110	65–85	615–790	25–40	250–405
Late	120–170	1110–1490	65–115	610–1030	40–140	405–1270
Design	190	1640	125	1130	140	1270

Ranges quoted for 1.4 M⊙+1.4 M⊙ BNS and 30 M⊙+30 M⊙ BBH systems



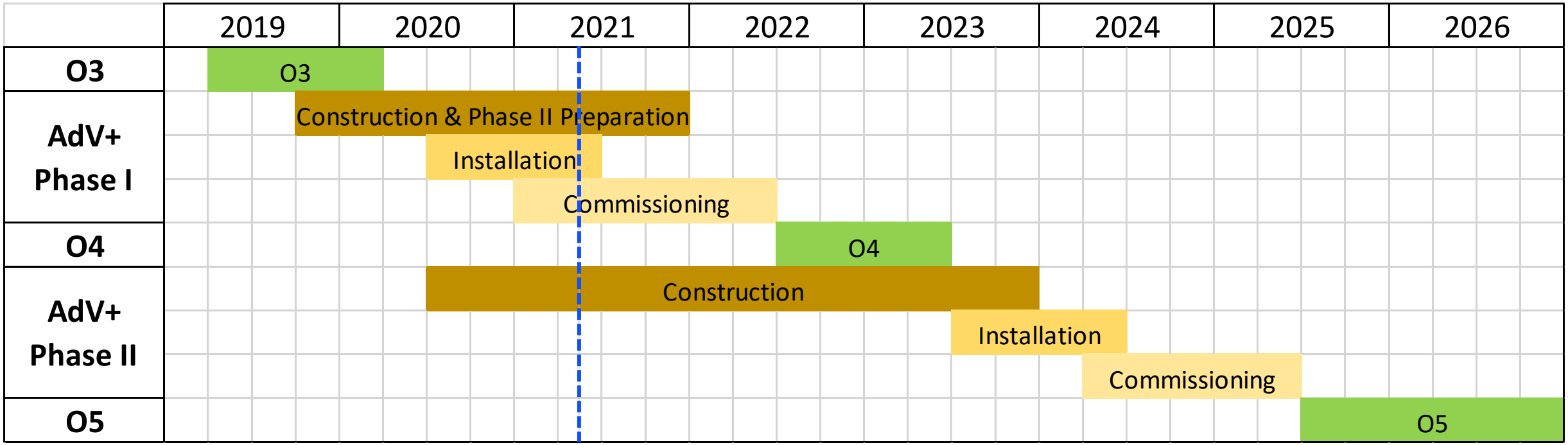
@ Living Rev Relativ (2018) 21:3
https://doi.org/10.1007/s41114-018-0012-9

AdV+: Advanced Virgo upgrade

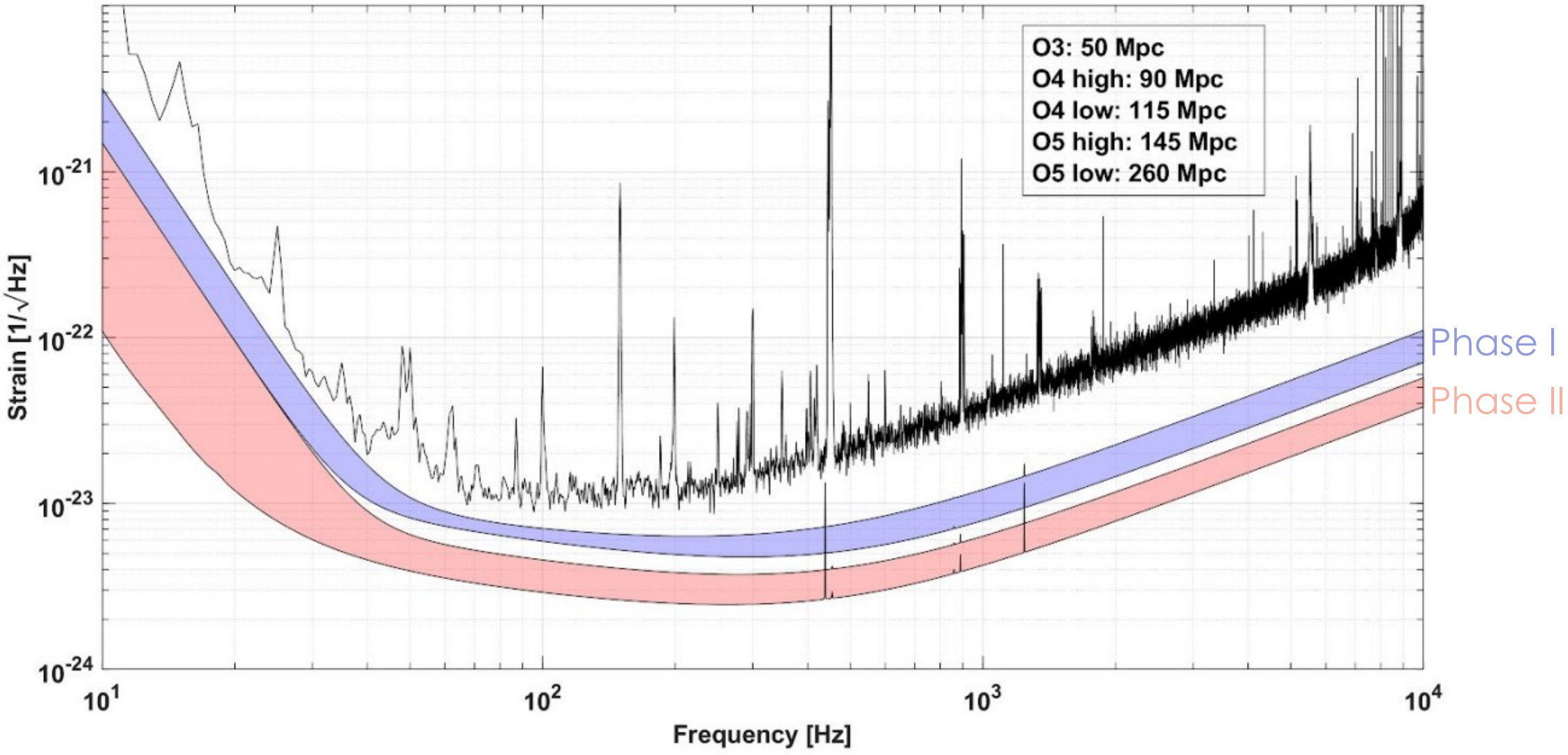


O4: Reduction of quantum noise
Signal recycling cavity
Frequency depending squeezing
Newtonian noise cancellation
100 W laser input power
40 W power into interferometer
O5: Reduction of thermal noise
Larger beam
Larger mirrors
Better coating
130 W laser input power
60 – 80 W power into interferometer

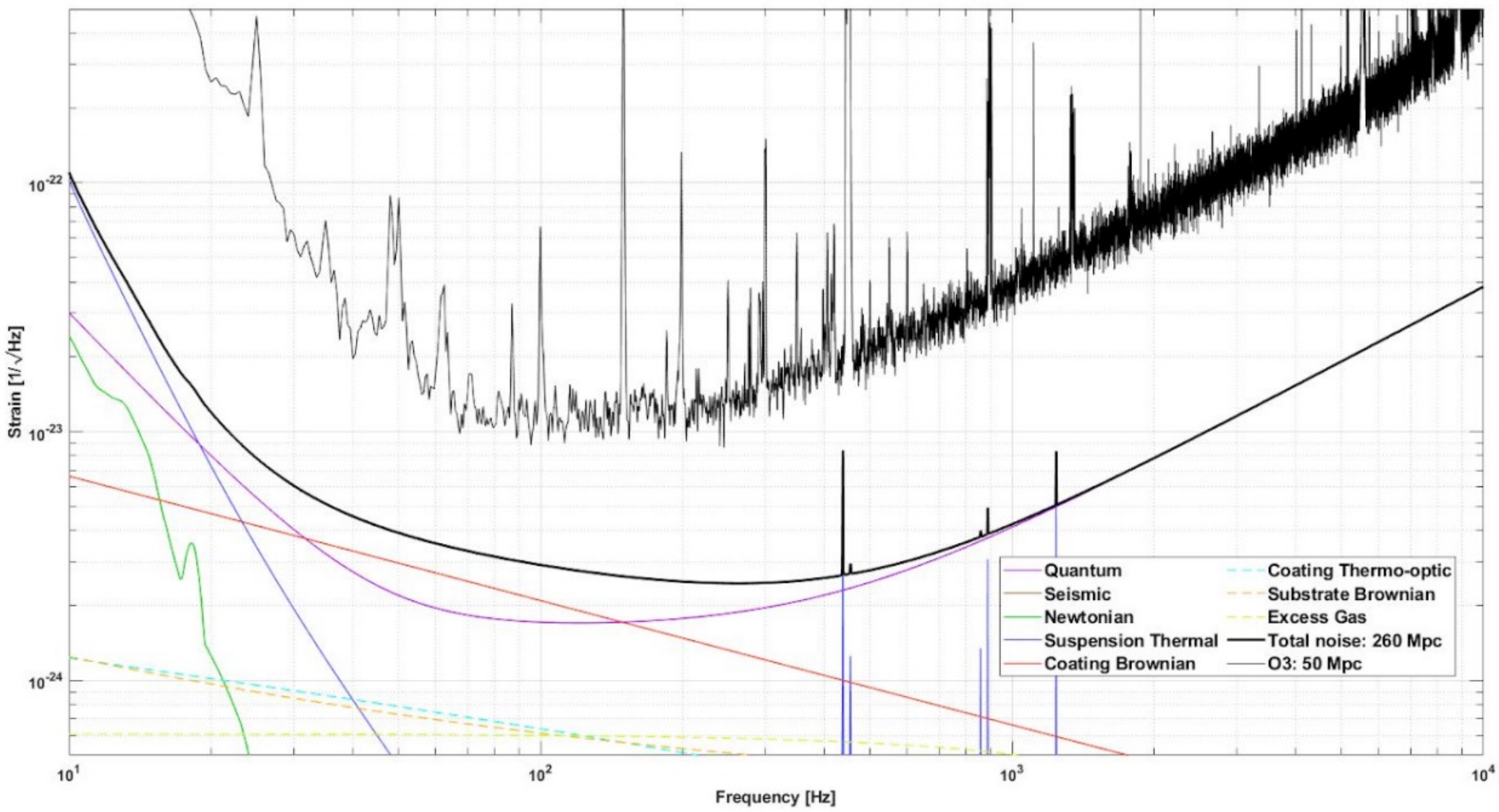
AdV+ upgrade schedule



Range of sensitivities for AdV+

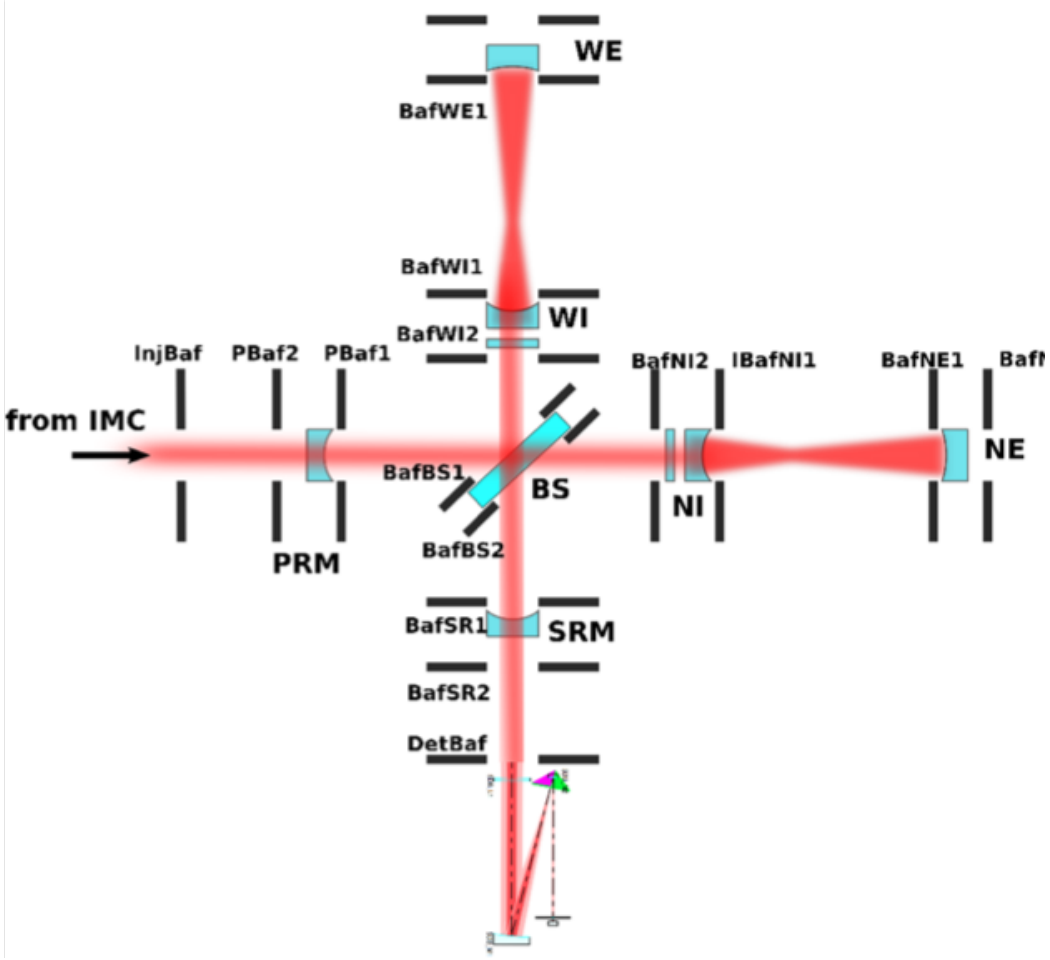


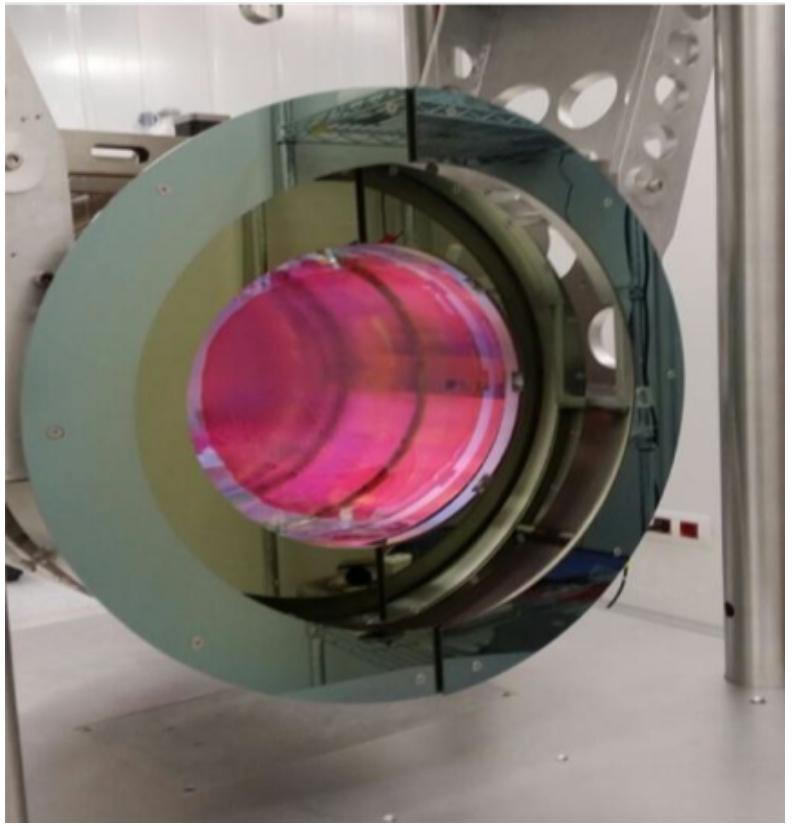
Best sensitivity curve for AdV+ phase II



Importance of stray light control

- Large fraction (70%) of light in interferometer lost in the form of stray light
- AdV is full of passive (AR coated) baffles to eliminate diffused light (99.5%)
- No real control/monitoring on where light goes



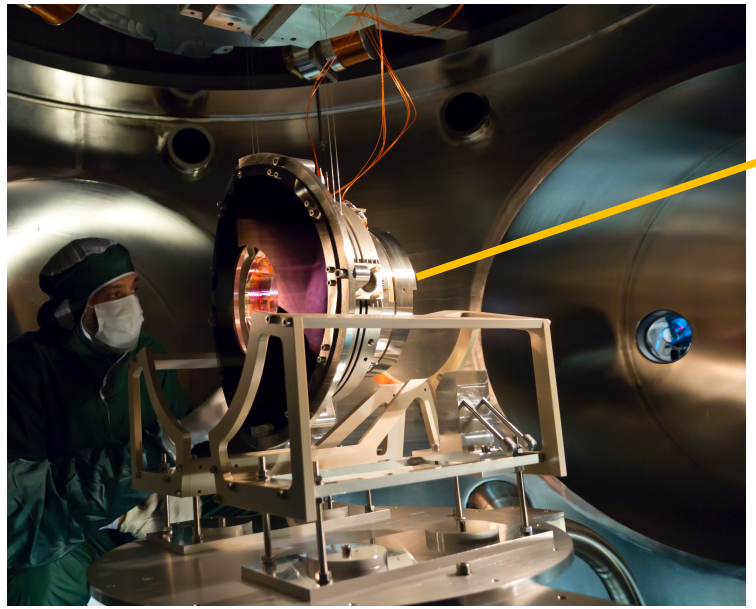


Instrumented baffles?

Problem
Beam not easy to localize during pre-alignment
Rough targets installed on baffles to visualize beam
Scattered light is monitored with cameras

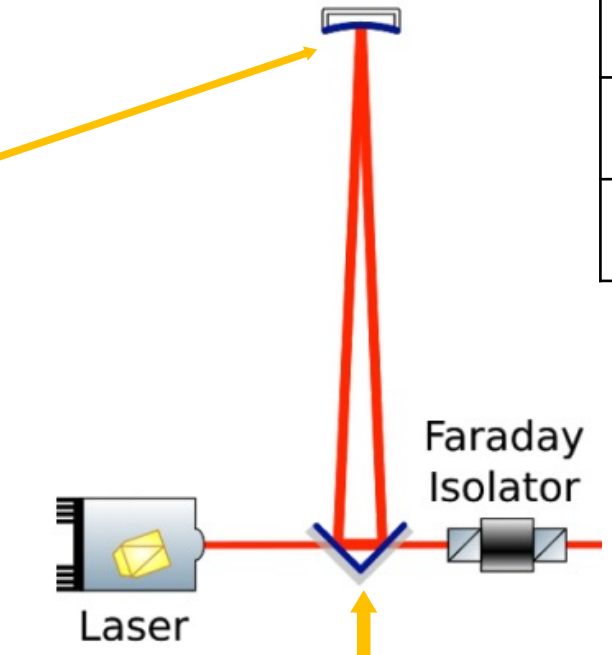
Solution
Sensors embedded in baffles allow monitoring of small-angle scattered light
Catch possible high order modes falling out the mirror
Discover possible ageing or contamination of mirror surfaces

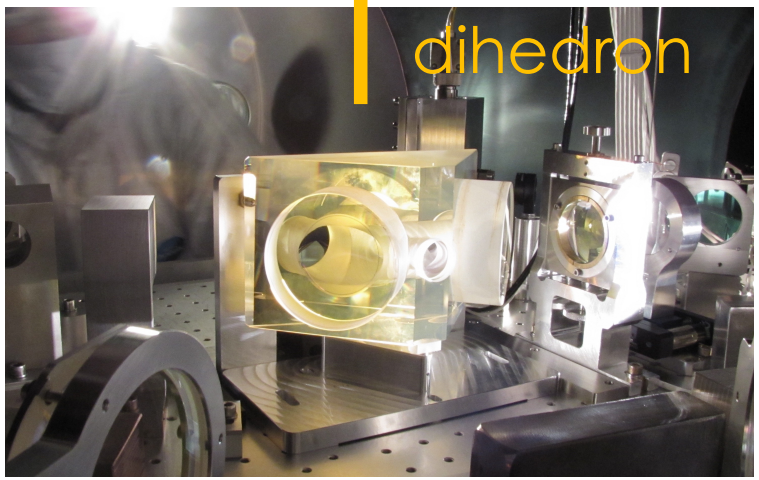
Input mode-cleaner



https://www.nikhef.nl/pub/departments/mt/projects/virgo/inputmodecleaner.html

End mirror	
Diameter	145 mm
Thickness	95 mm
Baffle	140 – 350 mm





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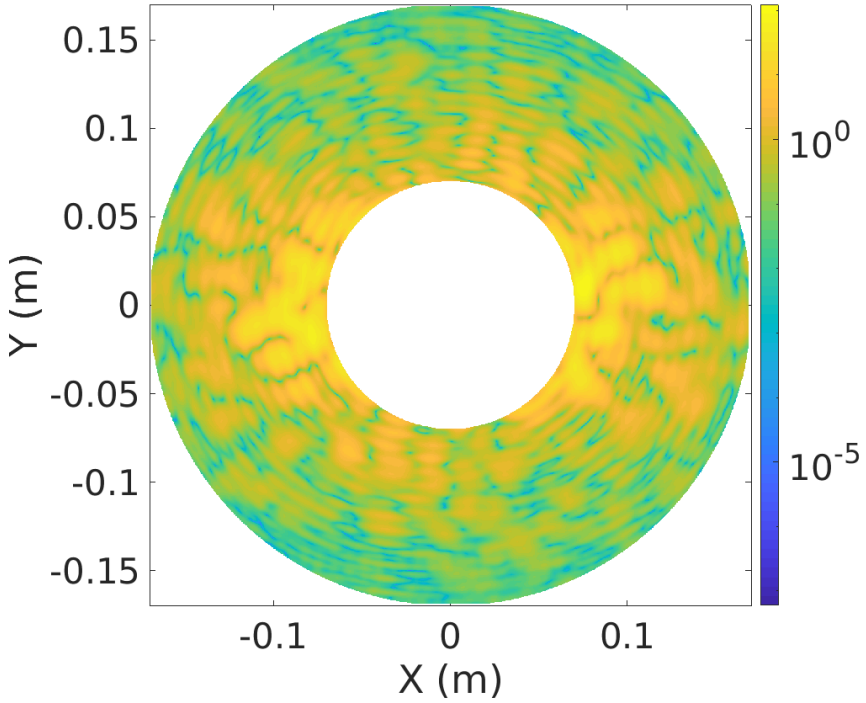
Triangular cavity	
Length	143 m
Finesse	1000

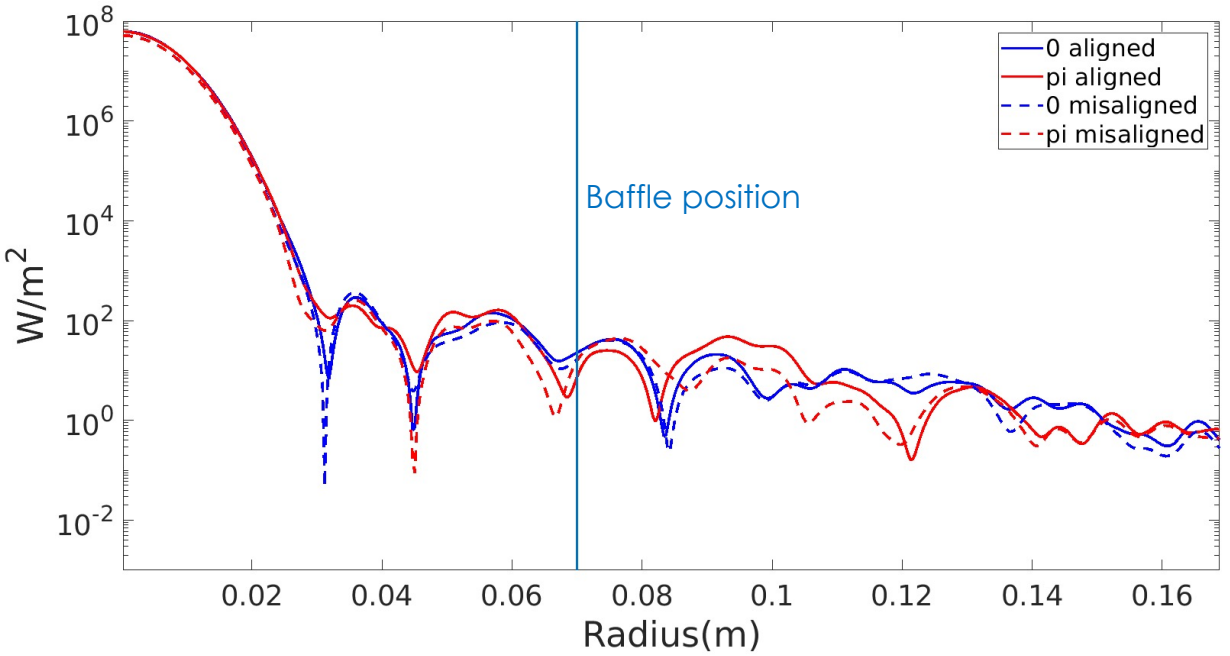
IMC tower

Credit: IFAE

IMC end mirror simulation

Most of the scattered light concentrates at low angles





Scenarios	Mirror + baffle	Baffle	Photodiode
Resonance	1.35 x 10^4 W	0.20 W	3.2 x 10^{-3} W
Misaligned (10 μrad)	1.19x 10^4 W	0.17 W	3.0 x 10^{-3} W
Extremely misaligned	-	-	2.1x 10^{-2} W
Mechanical drift	390 W	-	130 (for 10 ms)

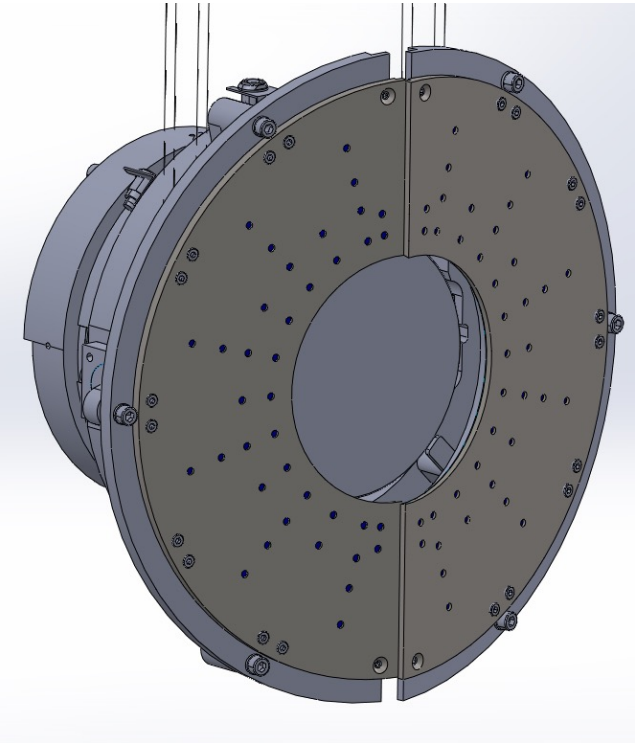
A. Romero-Rodríguez *et al*, 2021, *Class. Quantum Grav.* **38** 045002

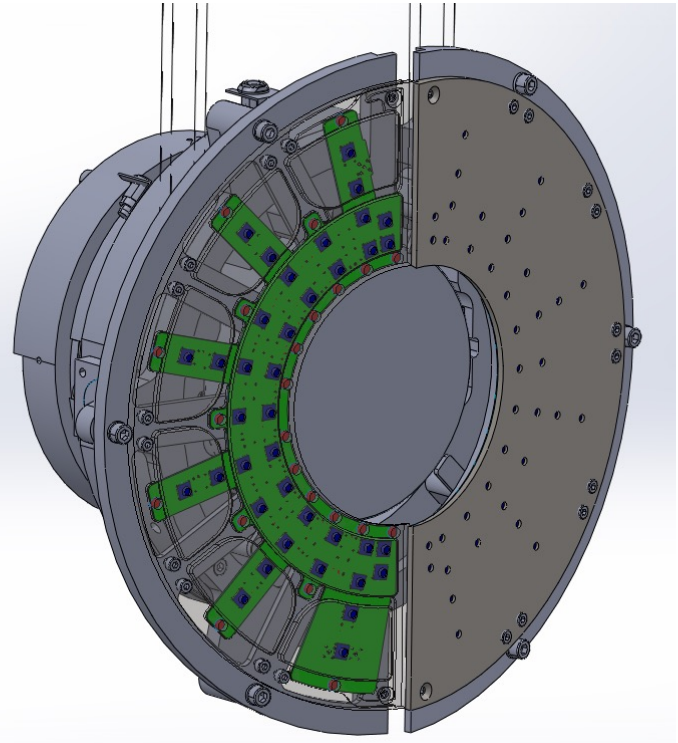
IMC instrumented baffle design

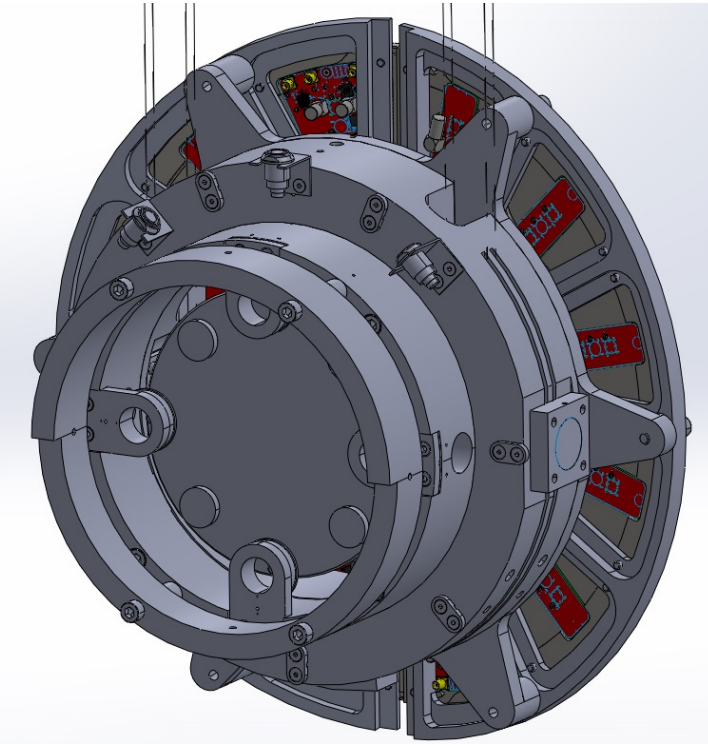
O3 (plain) baffle		**O4 (instrumented) baffle**	
Component	Weight (g)	Component	Weight (g)
Stainless steel	1887.47	Stainless steel	753.1 + 751.6
		Screws	0.17 x 46
		PCBs	95.77 + 98.03
		Antennae + interconnection	11.14
		Connectors	5 x 2
		Cables	0.56
Total	1887.47	Total	1728.02
Difference = 159.45 g			

New center of mass has moved away (-0.34, 0.82, 2.02) mm with respect to the non-instrumented current baffle

Instrumented baffle design

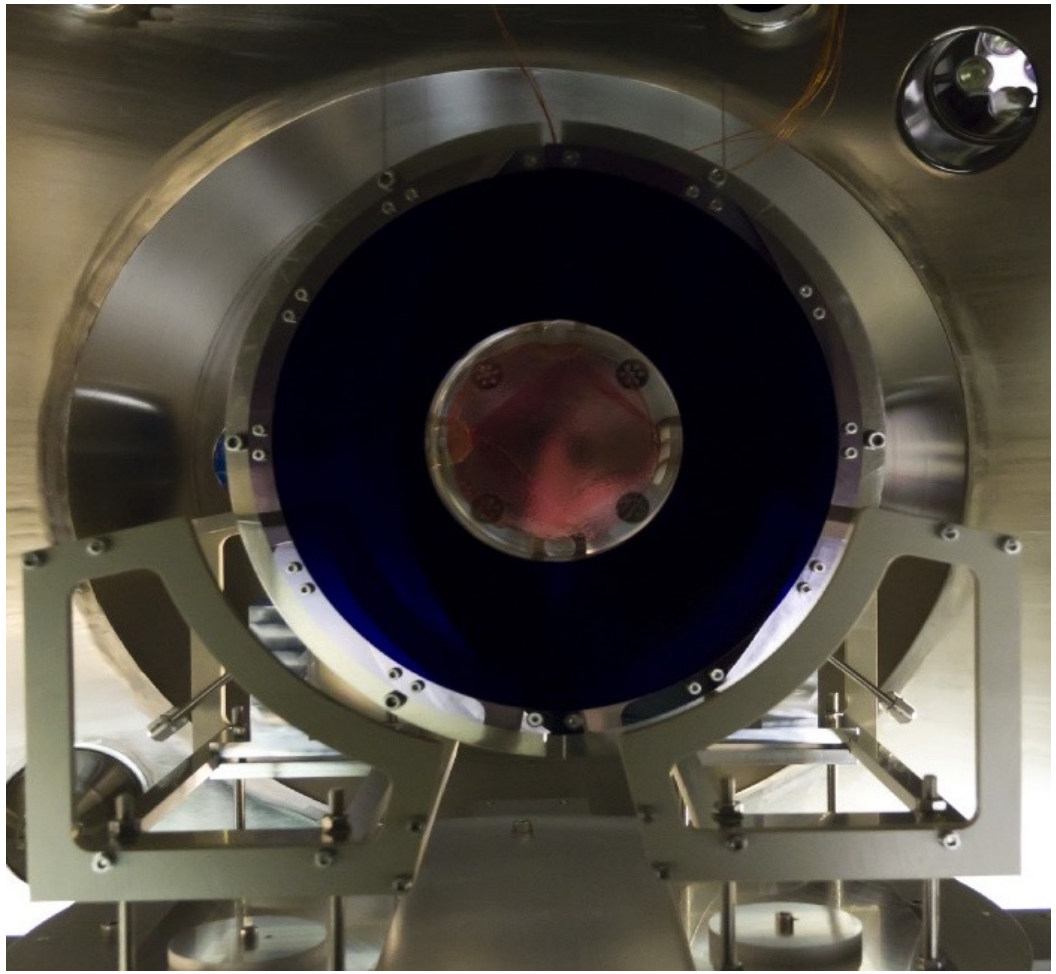






- 76 photosensors behind plate
- Sensors active area 0.49 cm^2
- Conical (12^o) holes of 4 mm of diameter (in the polished side)

Successful installation on April 28th



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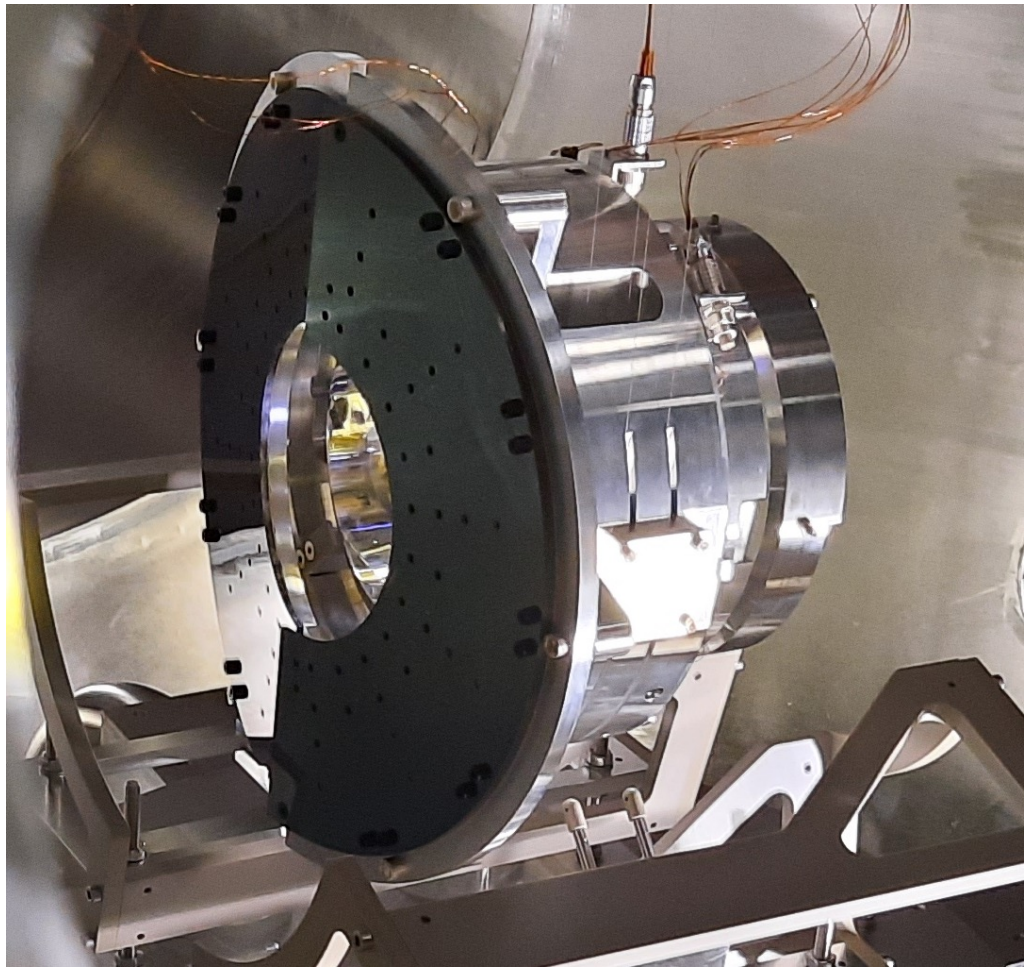
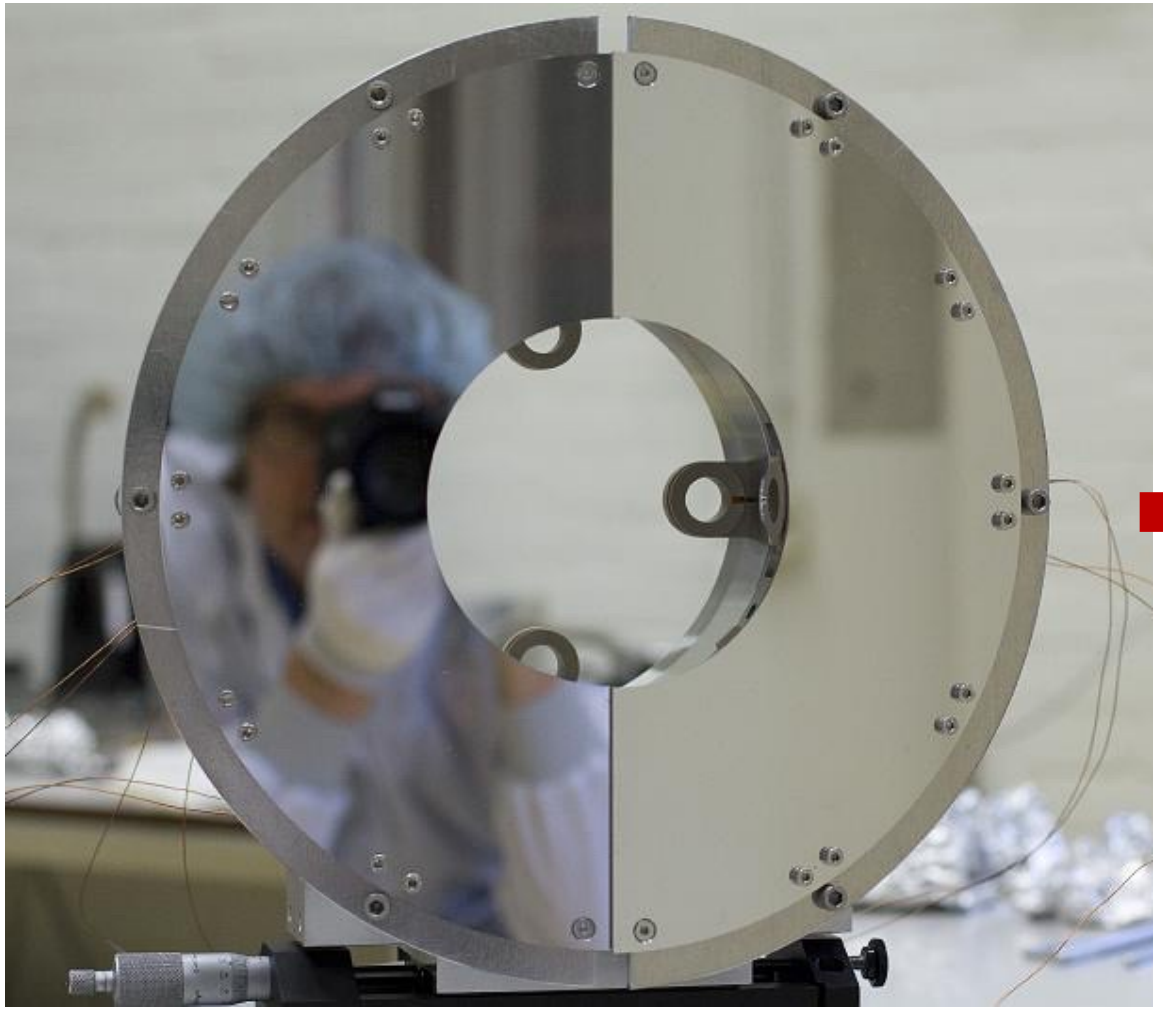


Credit: IFAE

Baffle mechanics



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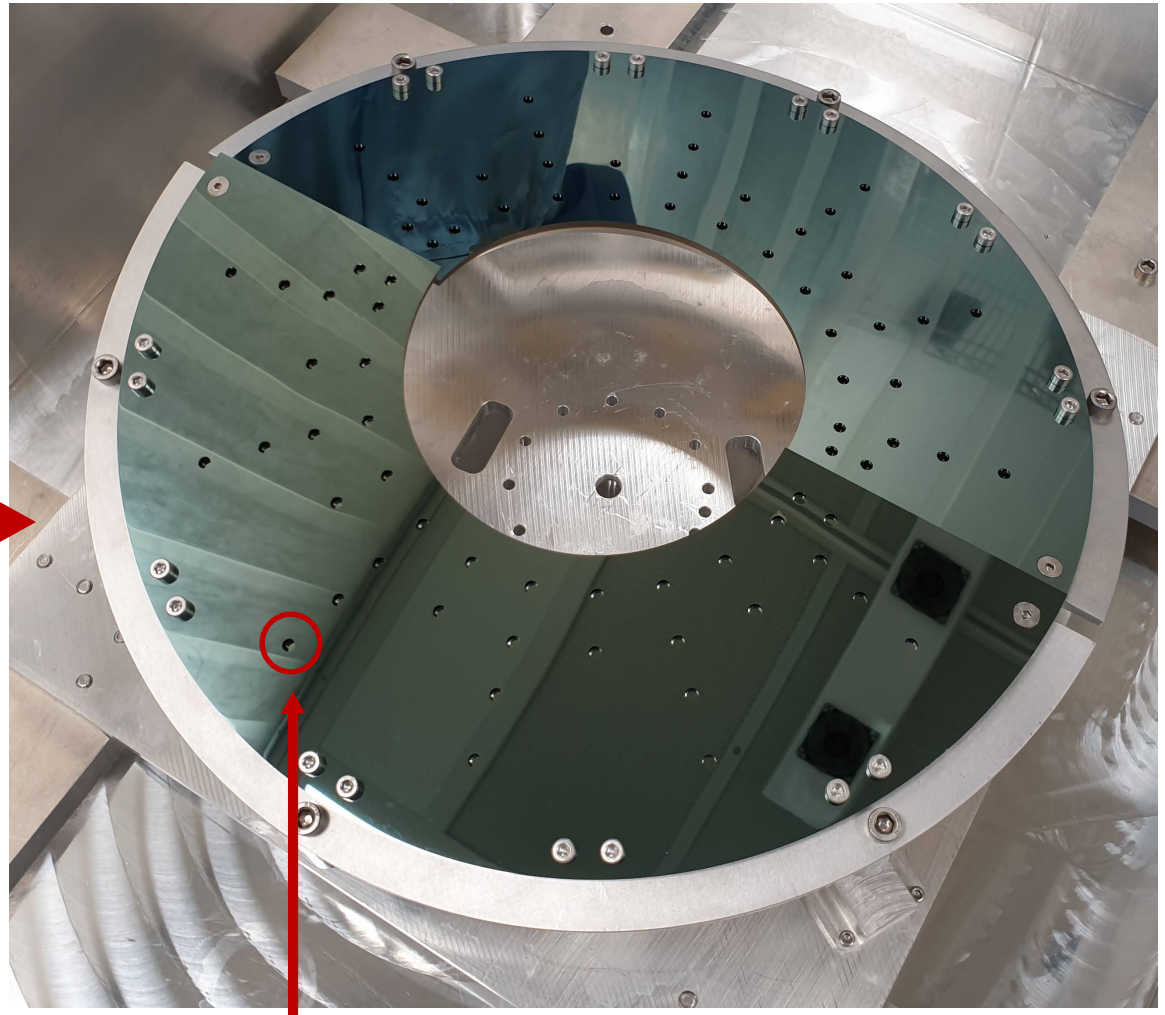
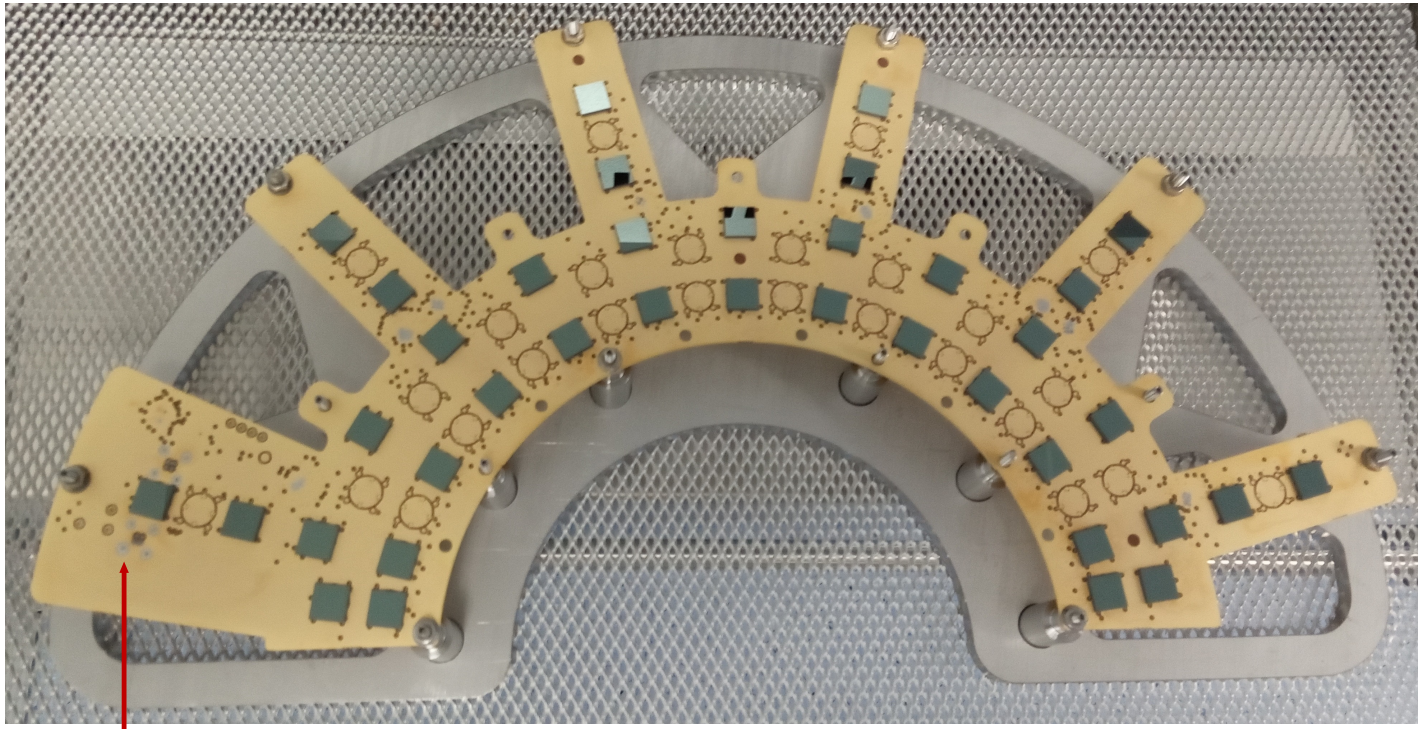


Credit: IFAE

76 holes (4 mm of diameter)

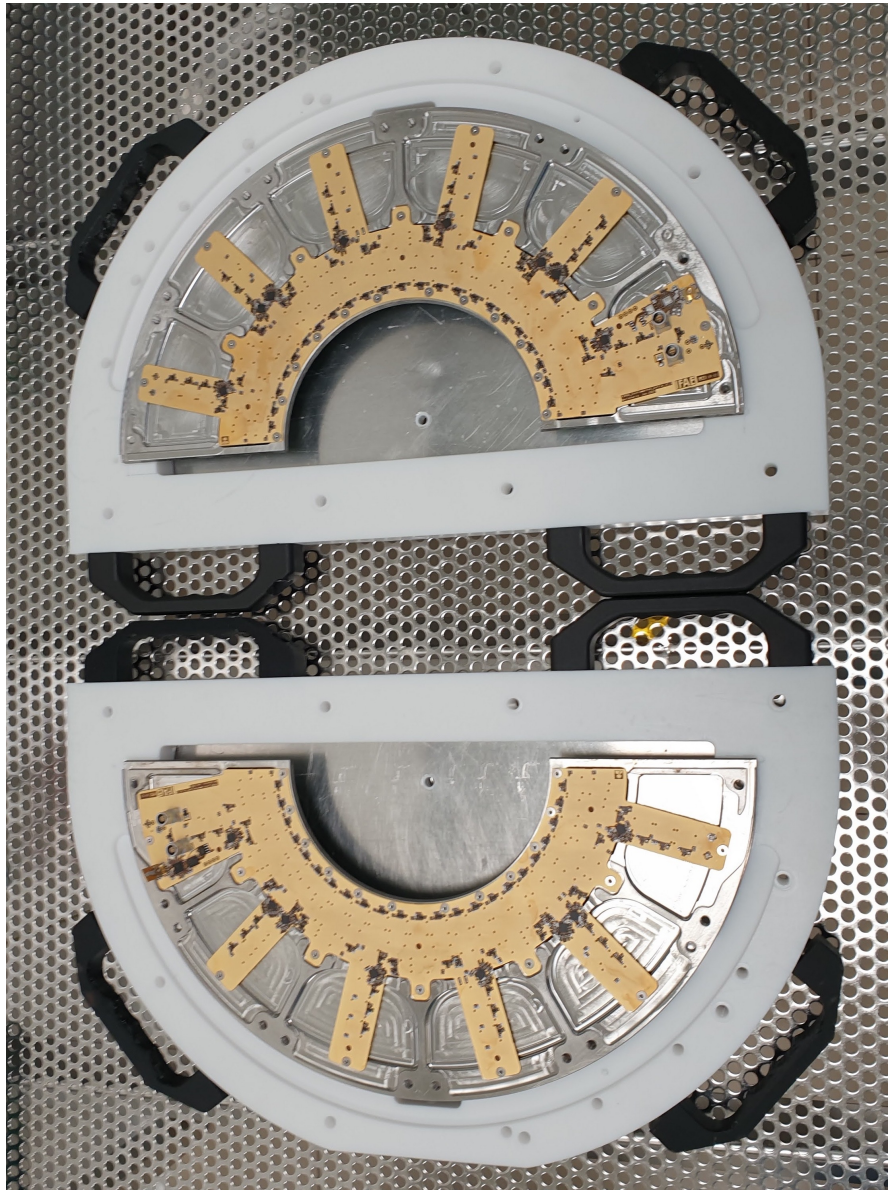
Baffle electronics



Credit: IFAE

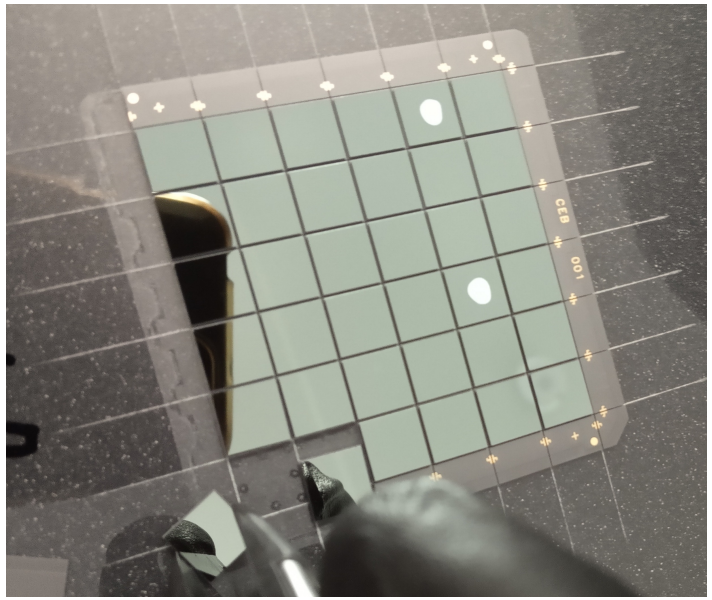
38 photodiodes

Gold plated to dissipate heat



Credit: IFAE

Photodiodes



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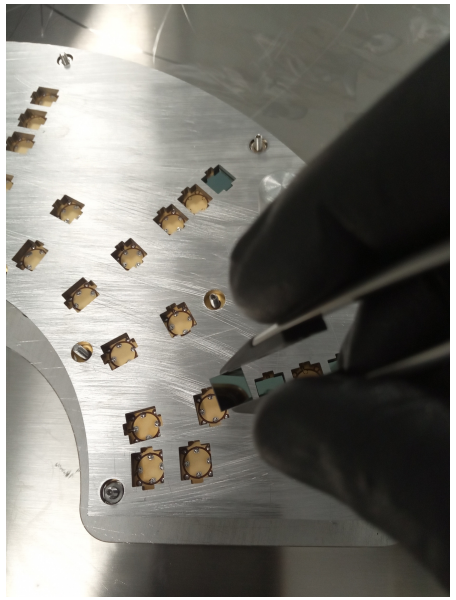

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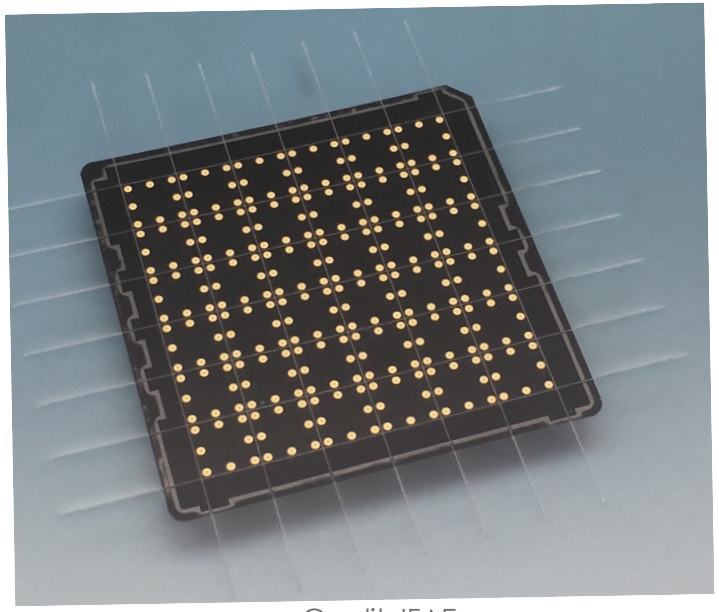
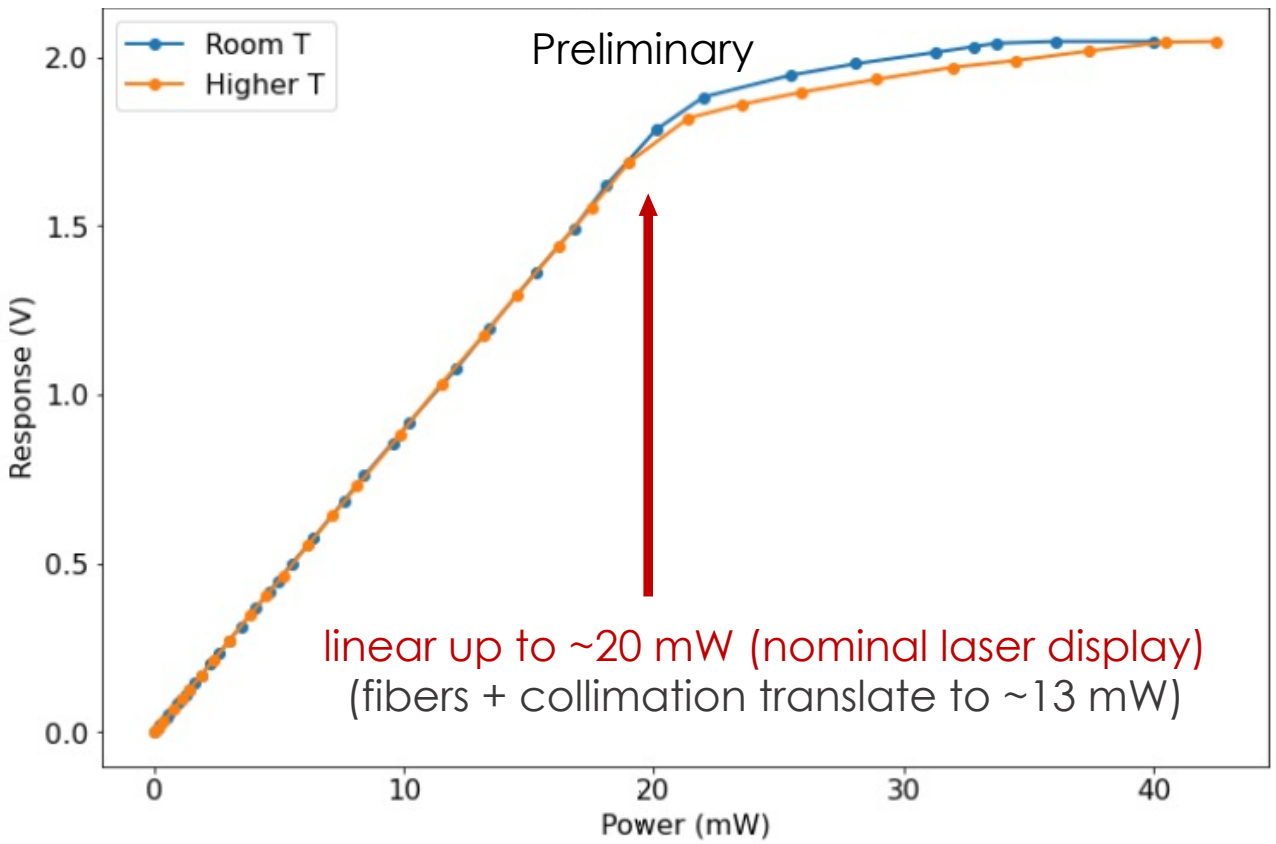


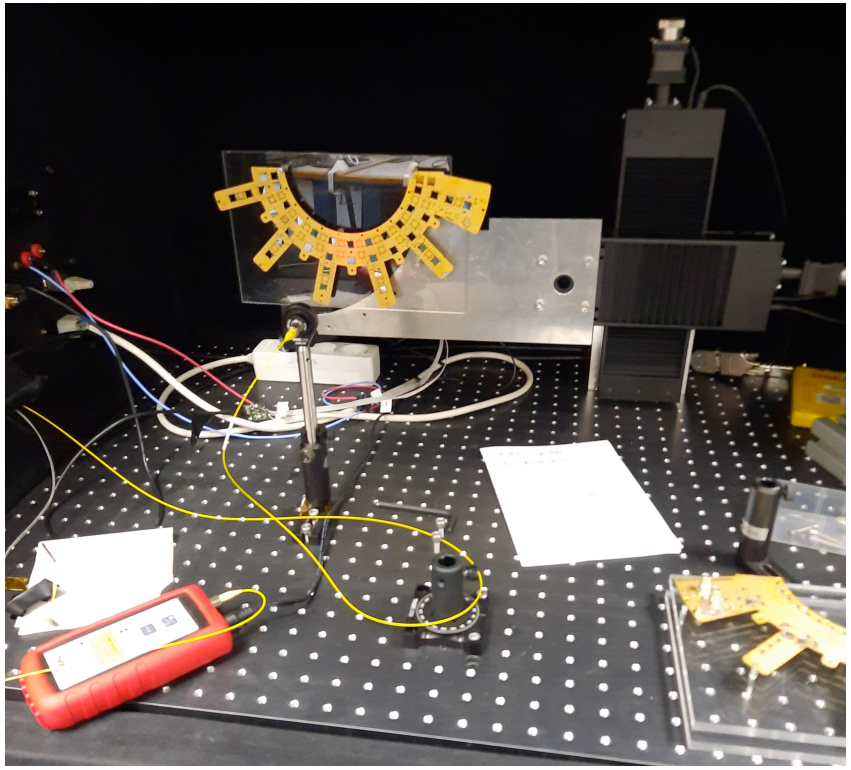
Credit: IFAE

HAMAMATSU
PHOTON IS OUR BUSINESS

Dimensions	7.37 x 7.37 mm^2
Sensitive area	6.97 x 6.97 mm^2
Operation temperature	-40 to 100 °C
Power dissipation	50 mW
Reflectivity	1.8%
Photosensitivity	660 mA/W

Photodiodes

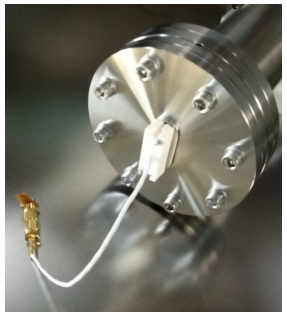




Credit: IFAE

- Photodiodes illuminated with a 1064 nm laser with increasing power
- Light collimated in a 1.38 mm diameter circular aperture in setup ➞ 54 mW would reach sensor through 4 mm diameter hole
- While in resonance 3.2 mW reach the sensor (according to simulation)

Baffle installation in IMC tower



Credit: IFAE

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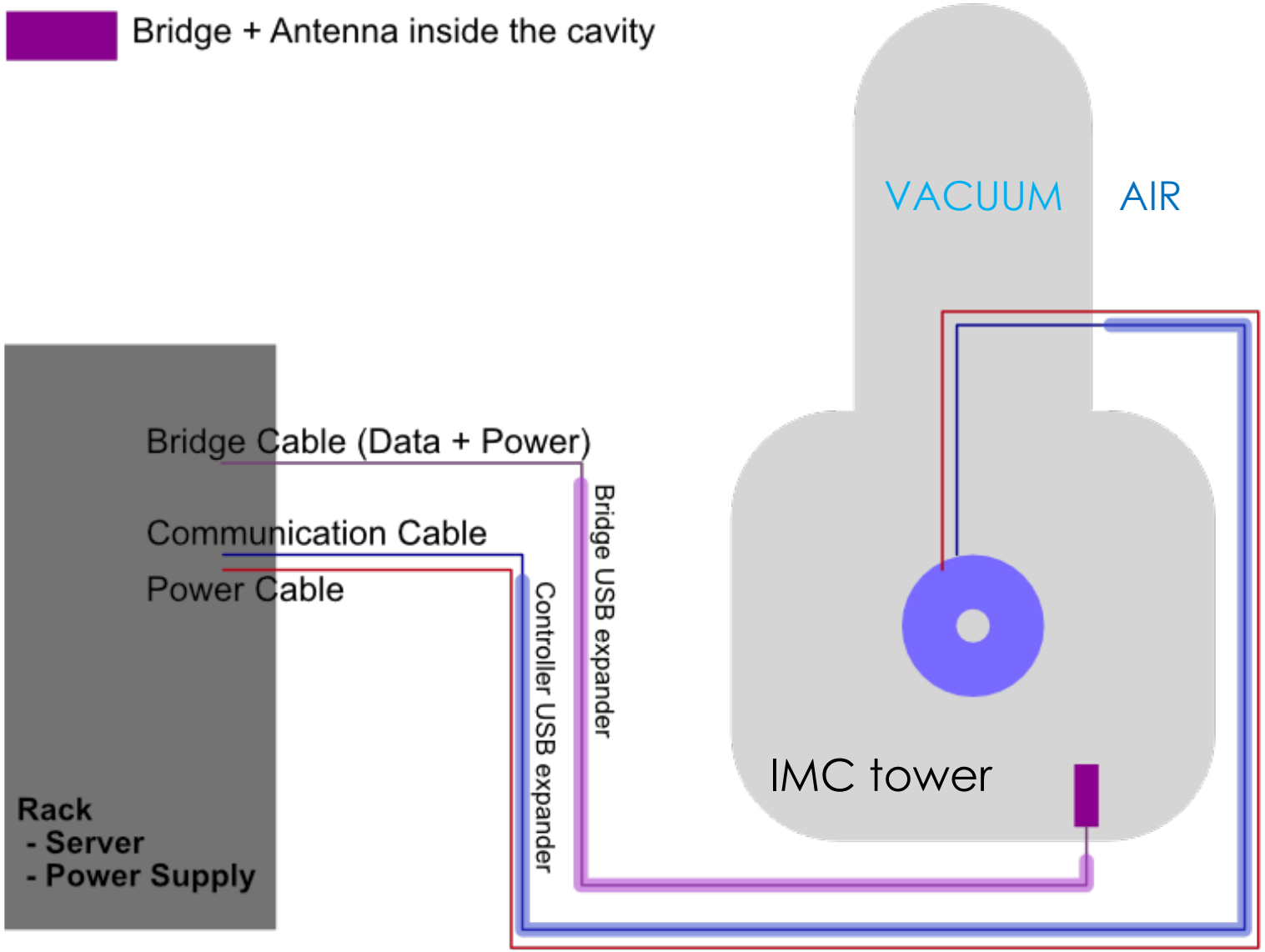


Data acquisition

Bridge

- Receives commands
- Forward commands to Controller
- Enables change of transmission mode
- Connects to server by UART

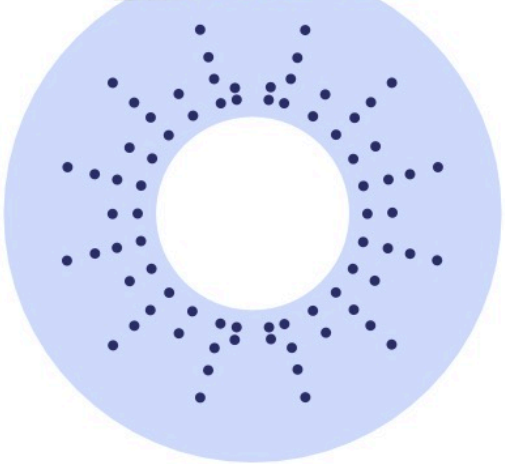
Serial

Server Machine (HW)

- Contains the Baffle DAQ Server
- Implements the Engineering Database (InfluxDB)
- Implements the main interfaces
  - Virgo fm
  - Web GUI

Bluetooth - WiFi

Bluetooth** - WiFi** - Serial ***



Controller

- Receives commands
- Send data
- ADC spi bus
  - Read ADC data
  - Read ADC temperatures
- Configure read out
  - Frequency
  - Sensors
- Configure transmission mode

Baffle DAQ Server (SW)

- Interface with Bridge
- Interface with clients
- Stores data into DB
- Logging

ØMQ

Virgo DAQ Client

- Interface to Baffle DAQ Server to integrate into Virgo infrastructure using fd framework

Engineering GUI

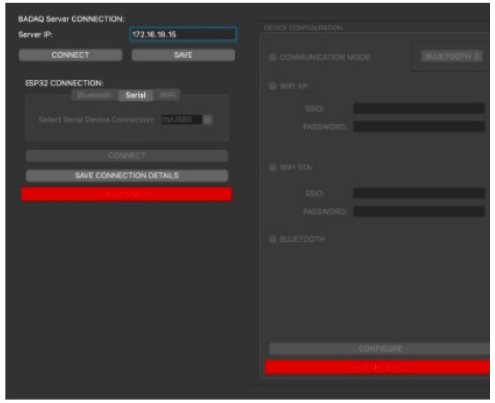
- Capacity to send commands
- Display of received data
- Display of aggregated data (1min, 5 min)
- Any other relevant statistic can be displayed
- Display system logs

Baffle GUI

Icon:	
Description:	Easy access to data reading from BaDAQ

1:	Connect to BaDAQ server and make BaDAQ server connect to device
2:	Start/Stop Sending Reports
3:	ADC Information: - Grey: not connected - Green: UP and Connected - Orange: Error in Reading. ADC was disabled - Red. Error in initialization. ADC disabled Any ADC maybe selected in order to show information
4:	Shortcut to show sensor values.TODO.

Icon:	
Description:	System Configuration

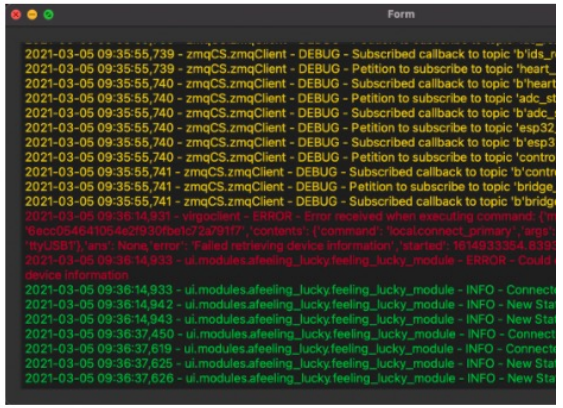


1:	Server and device Connection
2:	Device Configuration

Icon:	
Description:	ADC channels configuration

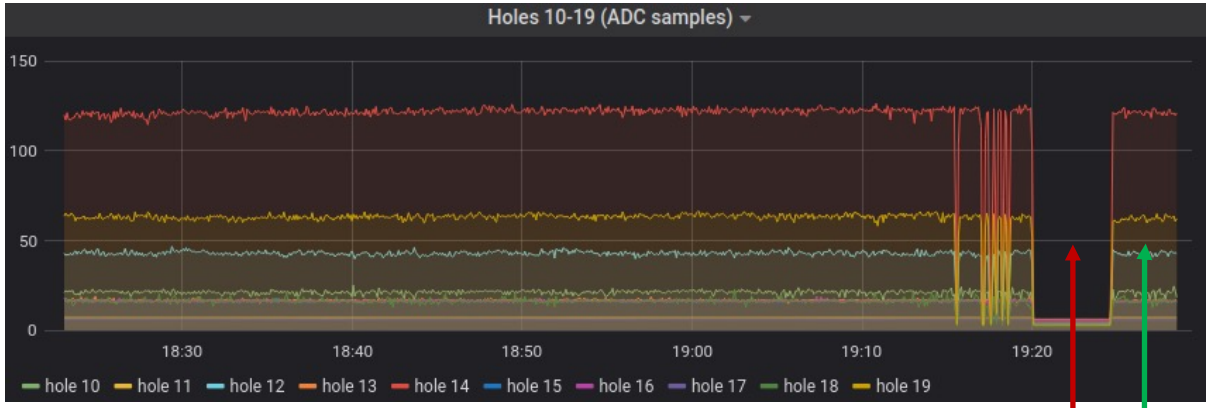
Enable/Disable any ADC
Enable/Disable any channel from any ADC
one tab for each baffle

Icon:	
Description:	Log information

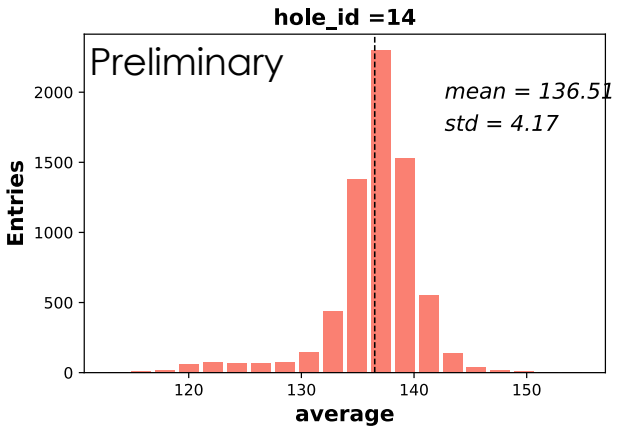


Line color is different for each Logging LEVEL

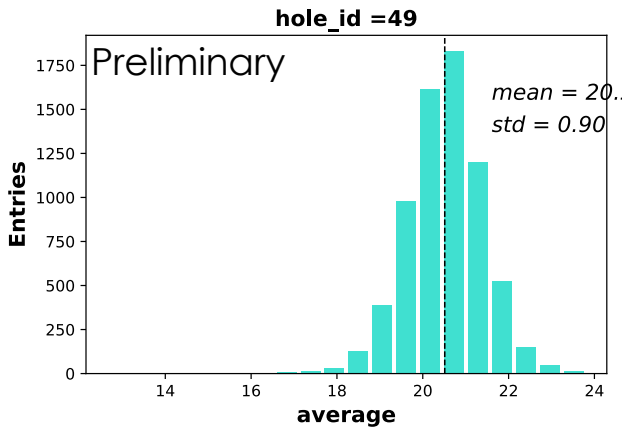
First data results



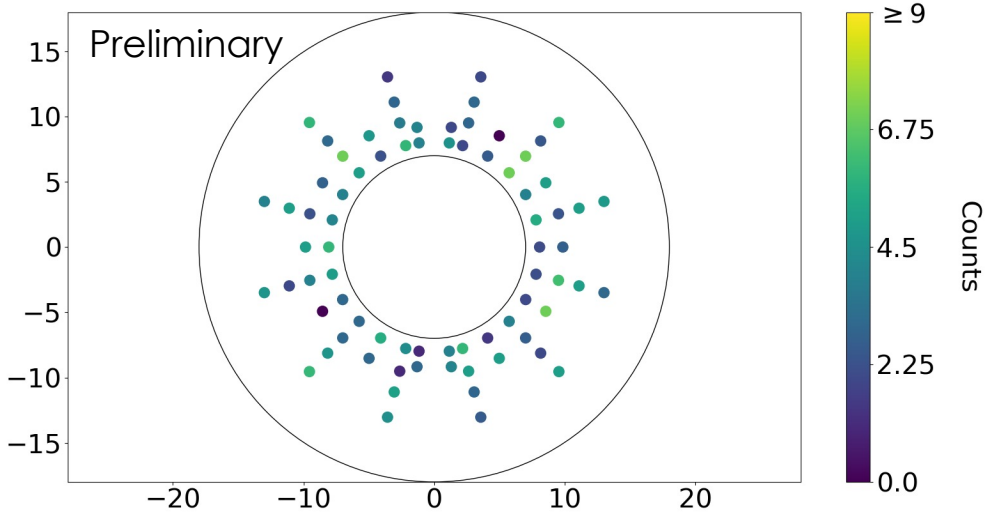
Inner row



Outer row



Laser off



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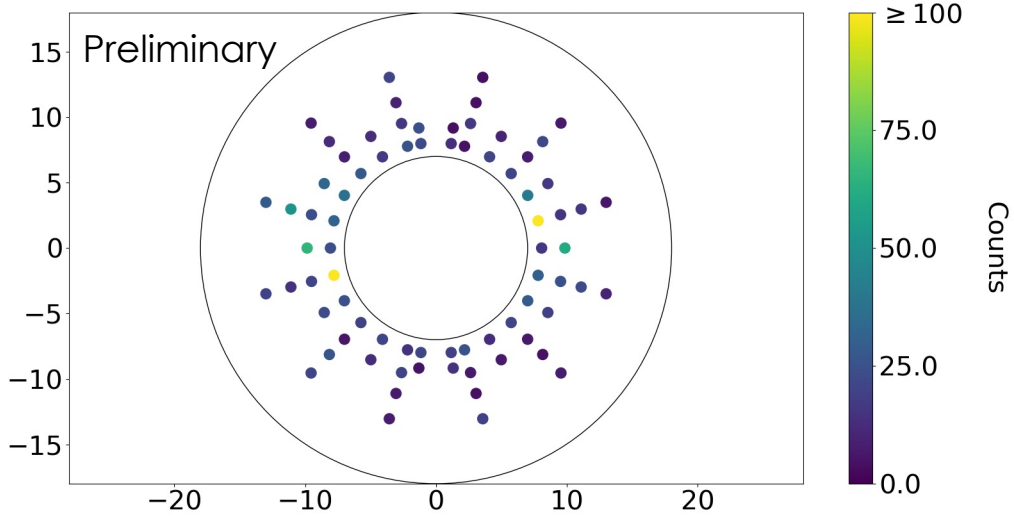
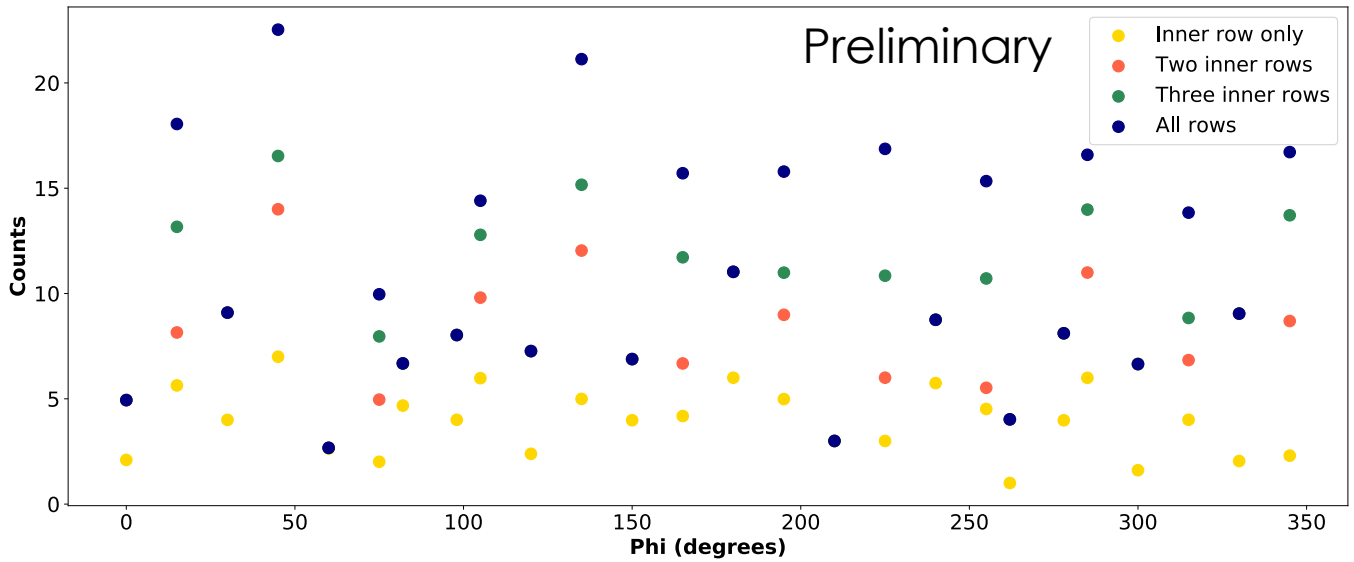


ADC counts (absolute calibration in progress)

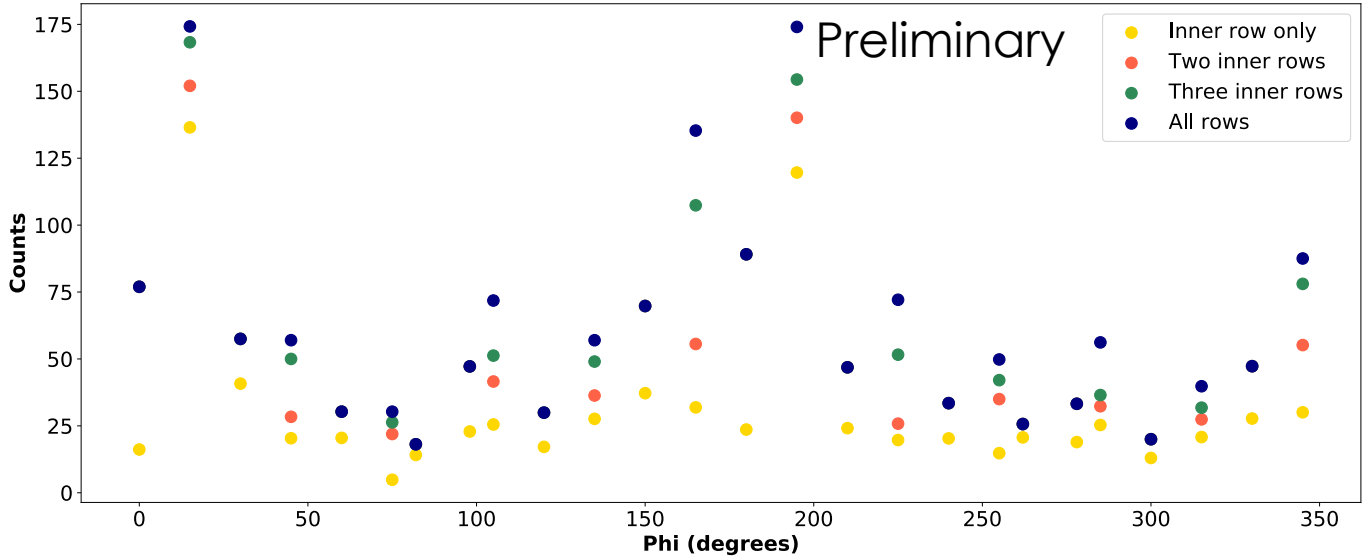
First data results

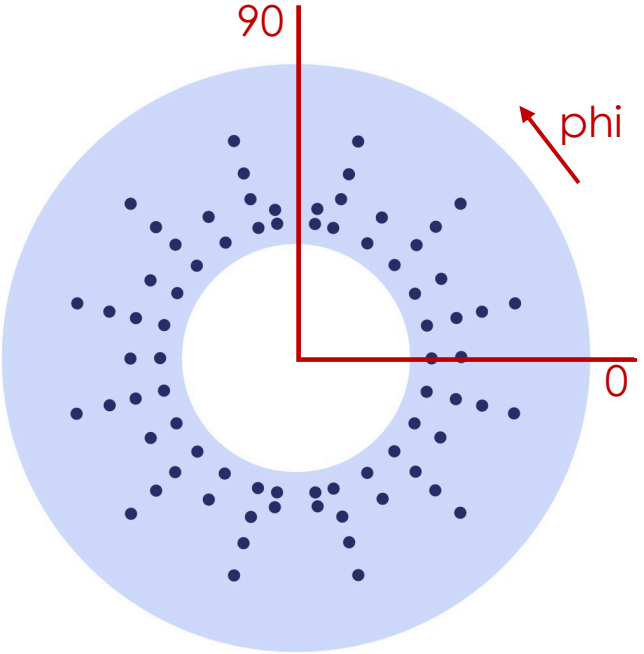
ADC counts (absolute calibration in progress)

Laser off



Laser on





First data results

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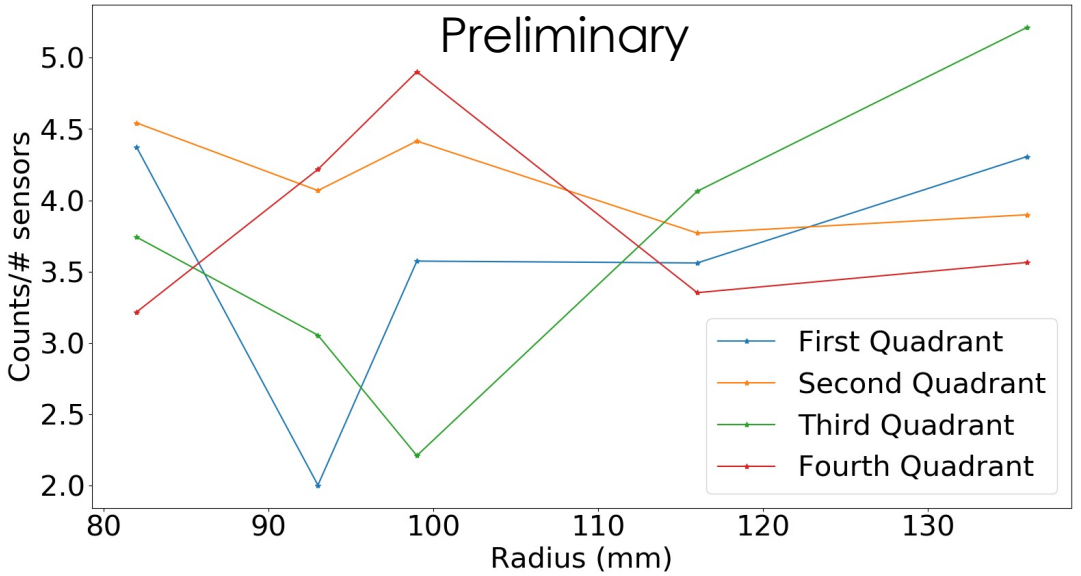
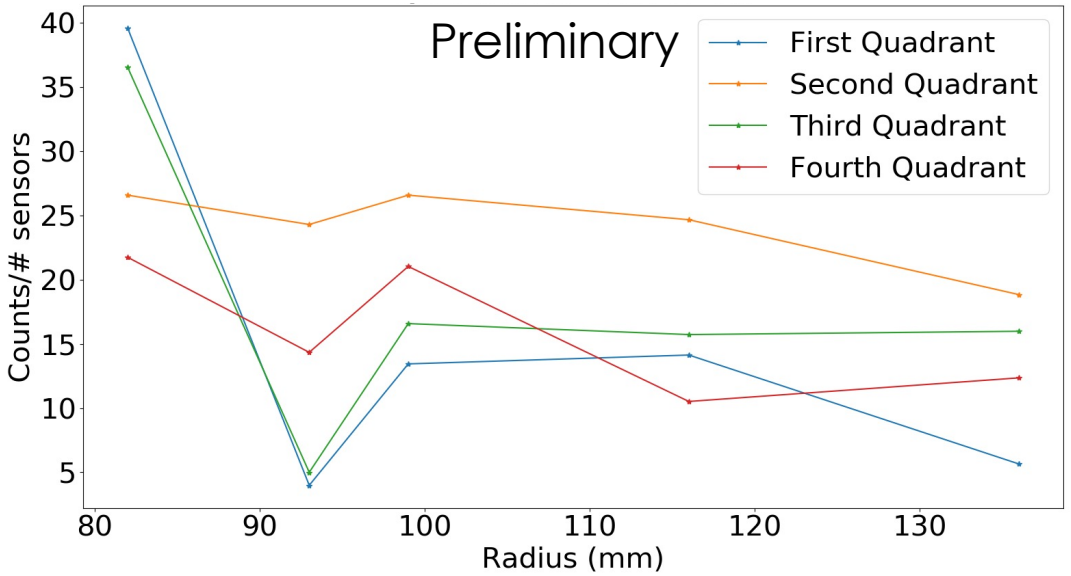
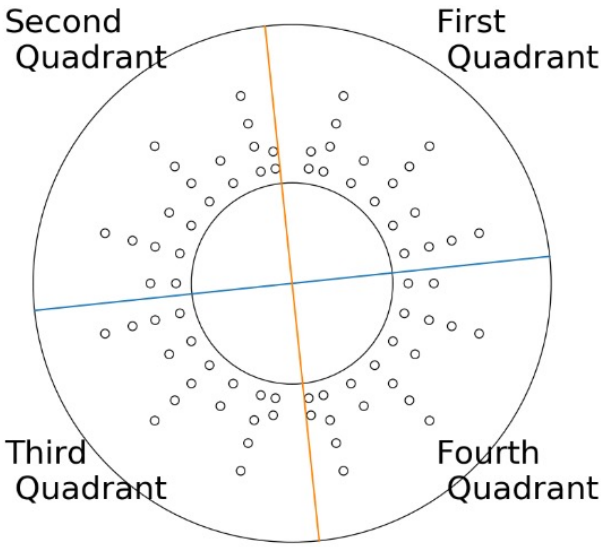


Laser on





Summary

- Stray light origin is hard to identify and its harmful effects difficult to mitigate
- IFAE has instrument the baffle in front of IMC end-mirror to allow fully monitoring of small-angle scattered light
- IMC cavity operational since beginning of May with no significant effect from the instrumented baffle
- Special tests to determine the sensitivity of the baffle to losses, alignment and mirror temperature
- First data being analyzed
- This baffle will be taking data from O4 on
- Experience gained will help in the design of instrumented baffles for test masses in time for O5