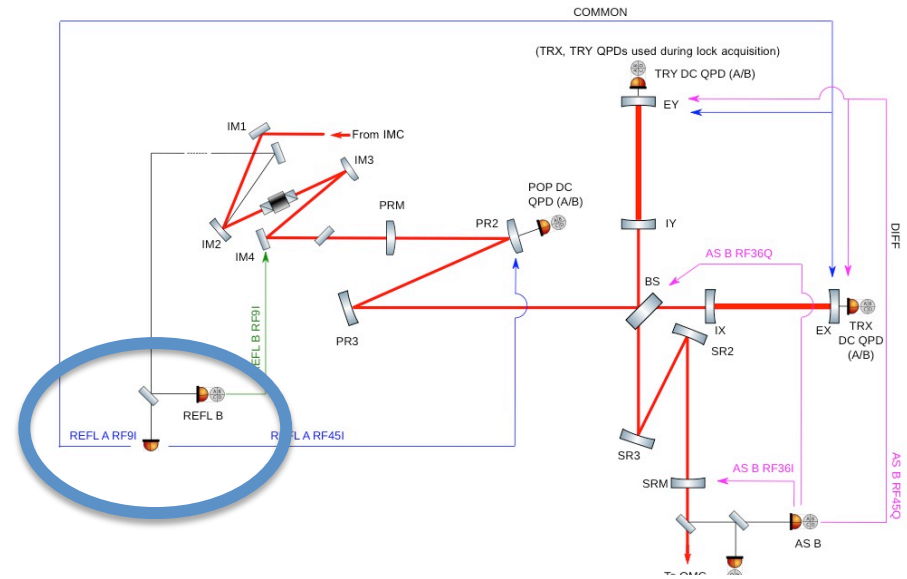# ASC Sensing Matrix
with losses in the arms
- PRC2 signal -

Marie Kasprzack

Koji Arai, Lisa Barsotti

(previous presentation G1500519-v1)

Motivation

- REFL port is used
 for the control of 3 ASC DOFs:
  CHARD, PRC2, IM4

- H1 and L1 have different ASC sensing schemes:

| DOF	Drive	Sensor
CHARD	(EX − IX) + r(EY - IY) or actual: EX + EY	H1: REFL A 9I + REFL B 9I L1: REFLA 9MHz + REFLB 9MHz + REFLA 45 MHz
PRC2	PR2	H1: - REFL_A 9I - REFL_A 45I - REFL_B 9I - REFL_B 45I L1: -10 REFL_A 9I + 15 REFL_A 45I
IM4	INP2	H1: REFL_A 9I - REFL_B 9I L1:-1.25 REFL_A 9I + 1.25 REFL_B 9I

Motivation

- The DRFPMI is equivalent to a Fabry-Perot cavity
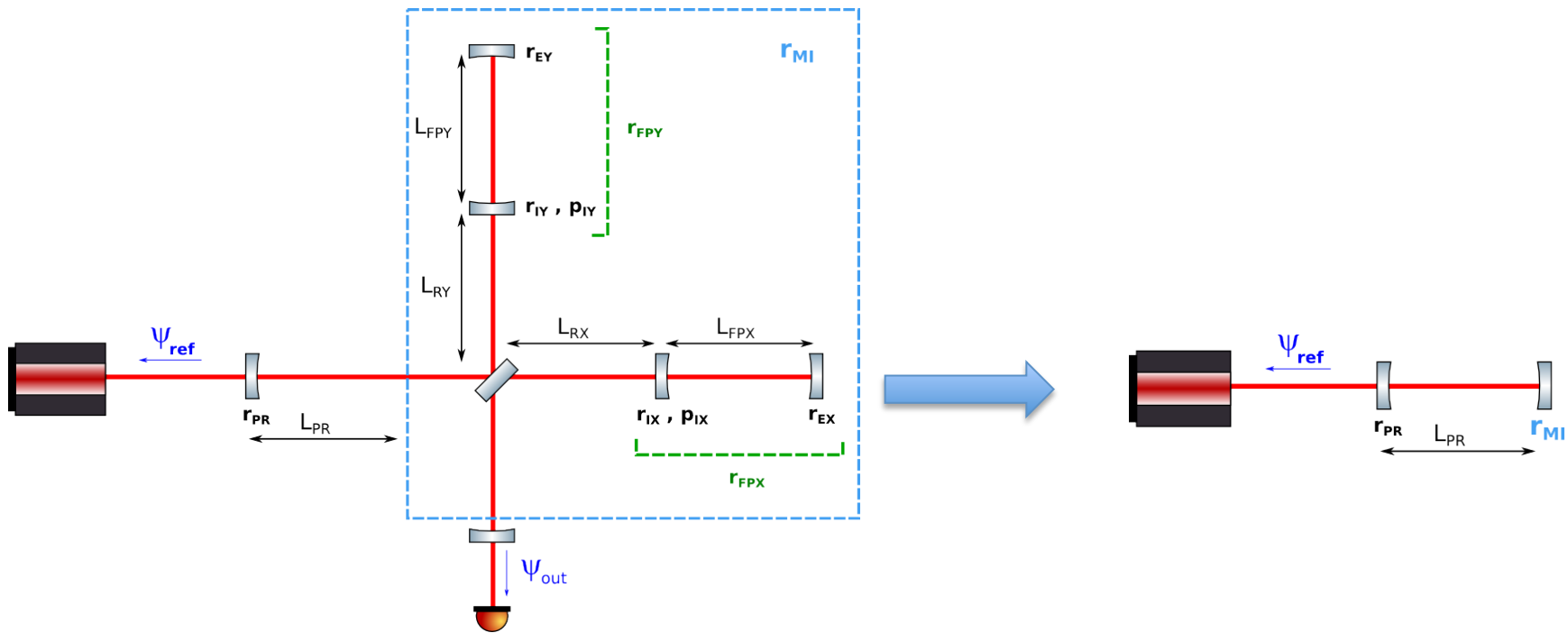
- For a specific value of reflectivity r_{MI} the IFO becomes **critically coupled:**

  the carrier power reflected $P_{ref} = |\psi_{ref}|^2$ drops.

→ **Where (at which loss/recycling gain) does this happen?**

ASC Optickle simulation
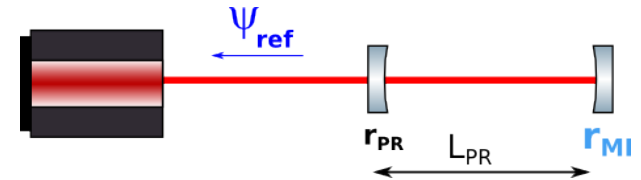
- **Critical point**
  - That can happen for specific values of losses in the arms:
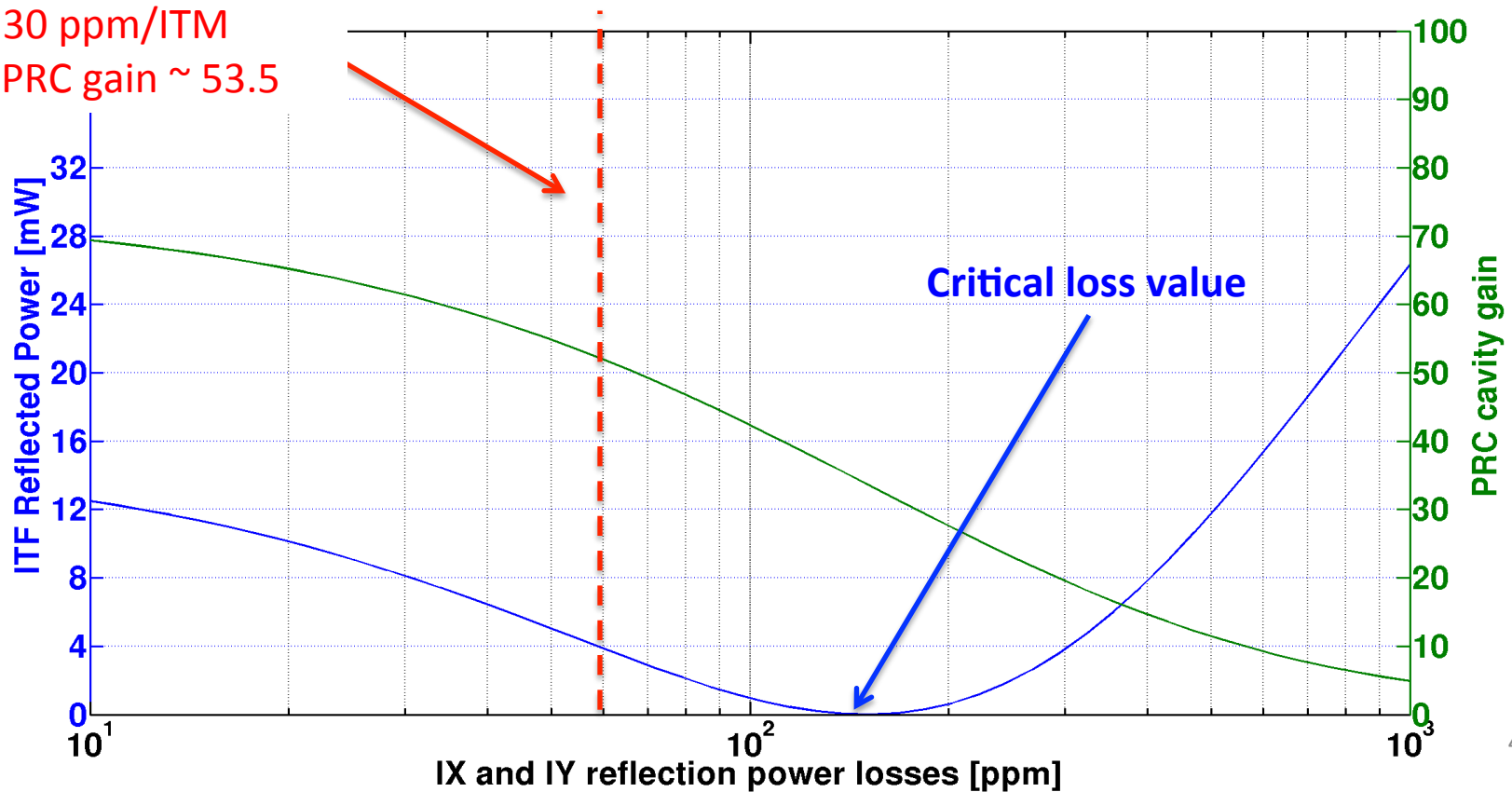
    $p_{IX} + p_{IY}$ about 155 ppm

  - That is a specific cavity gain:

PRC gain about 33.5
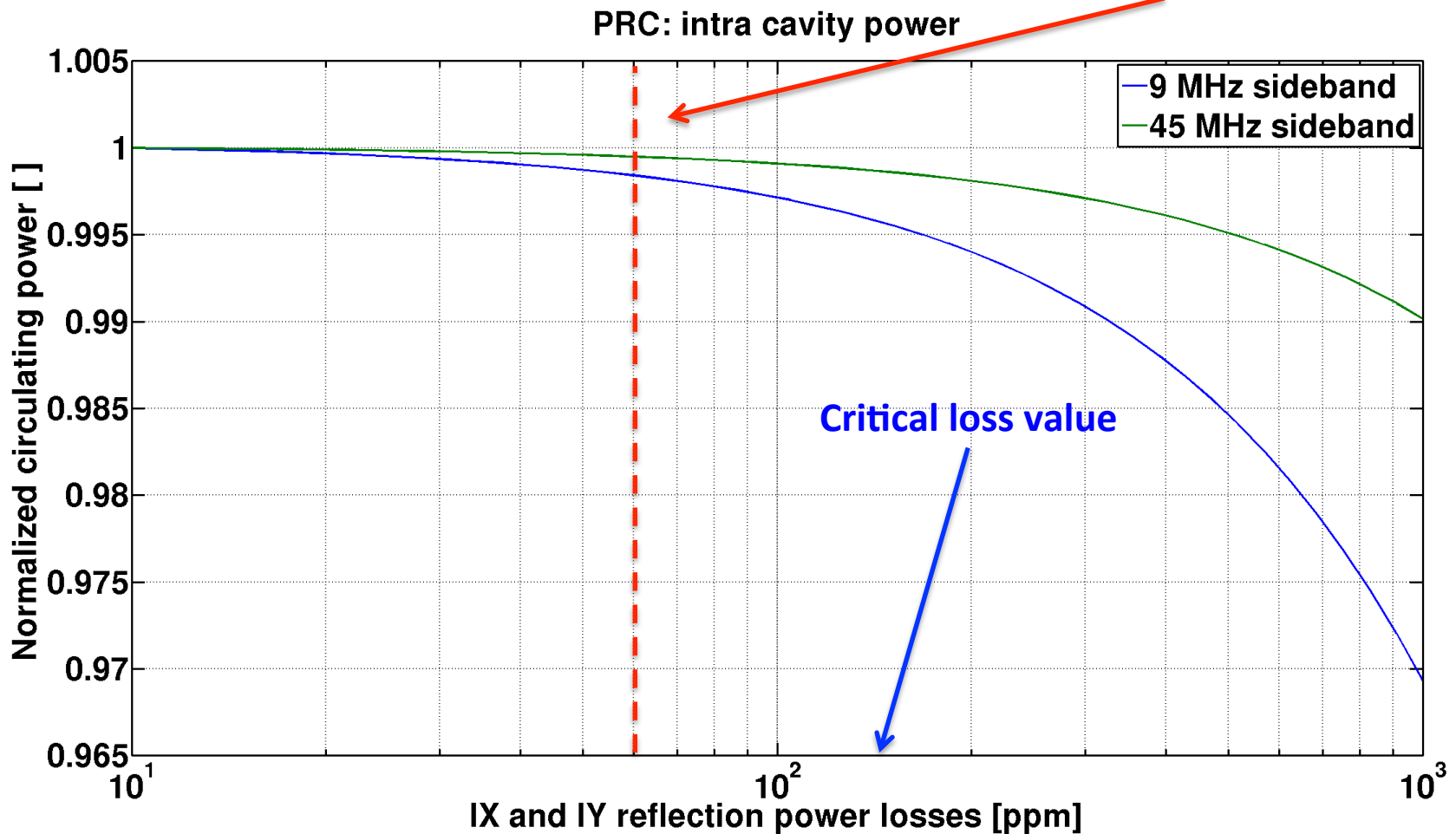
Design losses:
30 ppm/ITM
or PRC gain ~ 53.5

Critical loss value

ASC Optickle simulation

- Effect of power losses on sidebands inside PRC

Design losses:
30 ppm/ITM
or PRC gain ~ 53.5

PRC: intra cavity power

Legend:
- 9 MHz sideband
- 45 MHz sideband

Y-axis: Normalized circulating power [ ]

X-axis: IX and IY reflection power losses [ppm]

Critical loss value

ASC Optickle simulation

Simulation parameters

Optics N	Transmission (t_N^2)	Losses (p_N) [ppm]
IX	0.0148	30
IY	0.0148	30
EX	5.10^{-6}	30
EY	5.10^{-6}	30
BS	0.5	37.5
PRM	0.03	37.5

- **Losses equally split** into the ITMs : $p_{ITM} = p_{IX} = p_{IY}$ and $r_i^2 = 1 - t_i^2 - p_{ITM}$

- **CHARD configuration:**
  The signals have the same behavior in PITCH and YAW
  with the DOF definition

$$\text{PITCH}$$
$$\text{CHARD} = (EX - IX) + r(EY - IY)$$

$$\text{YAW}$$
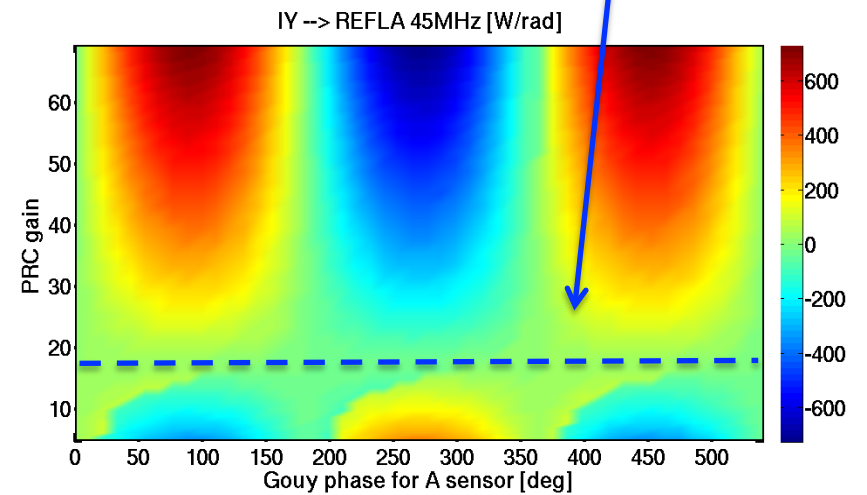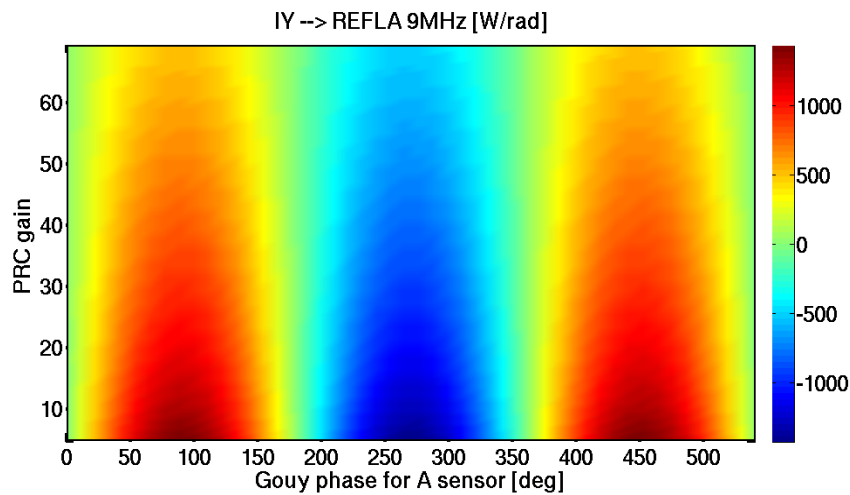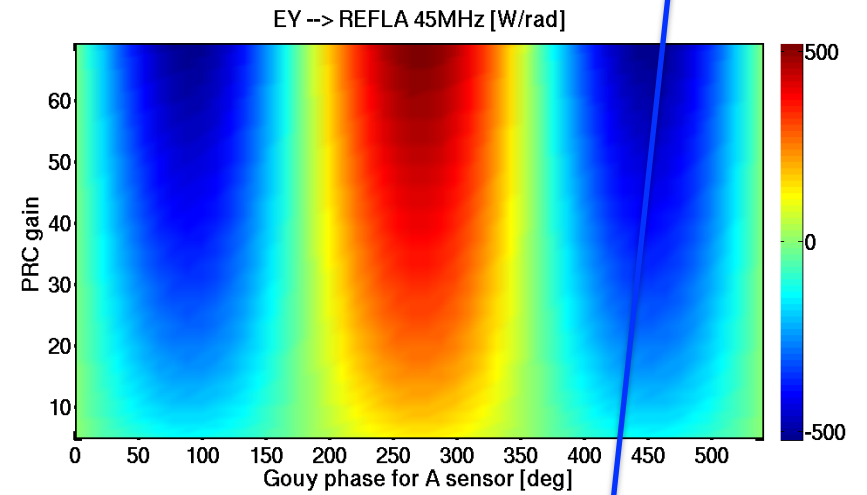$$\text{CHARD} = (EX + IX) - r(EY + IY)$$

ASC Optickle simulation: DOFs

TMs angular motion sensing

EY --> REFLA 9MHz [W/rad]

EY --> REFLA 45MHz [W/rad]

IY --> REFLA 9MHz [W/rad]

IY --> REFLA 45MHz [W/rad]
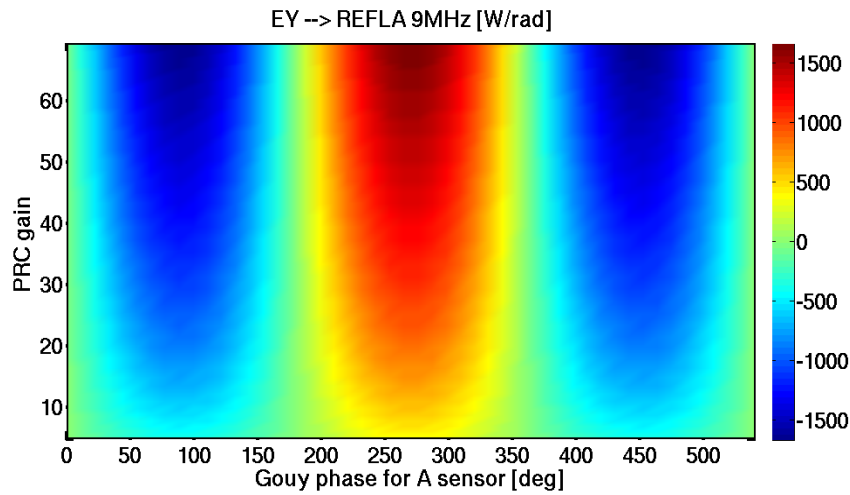
ASC Optickle simulation: DOFs

Livingston

CHARD

CHARD theoretical [W/rad]

CHARD simple [W/rad]
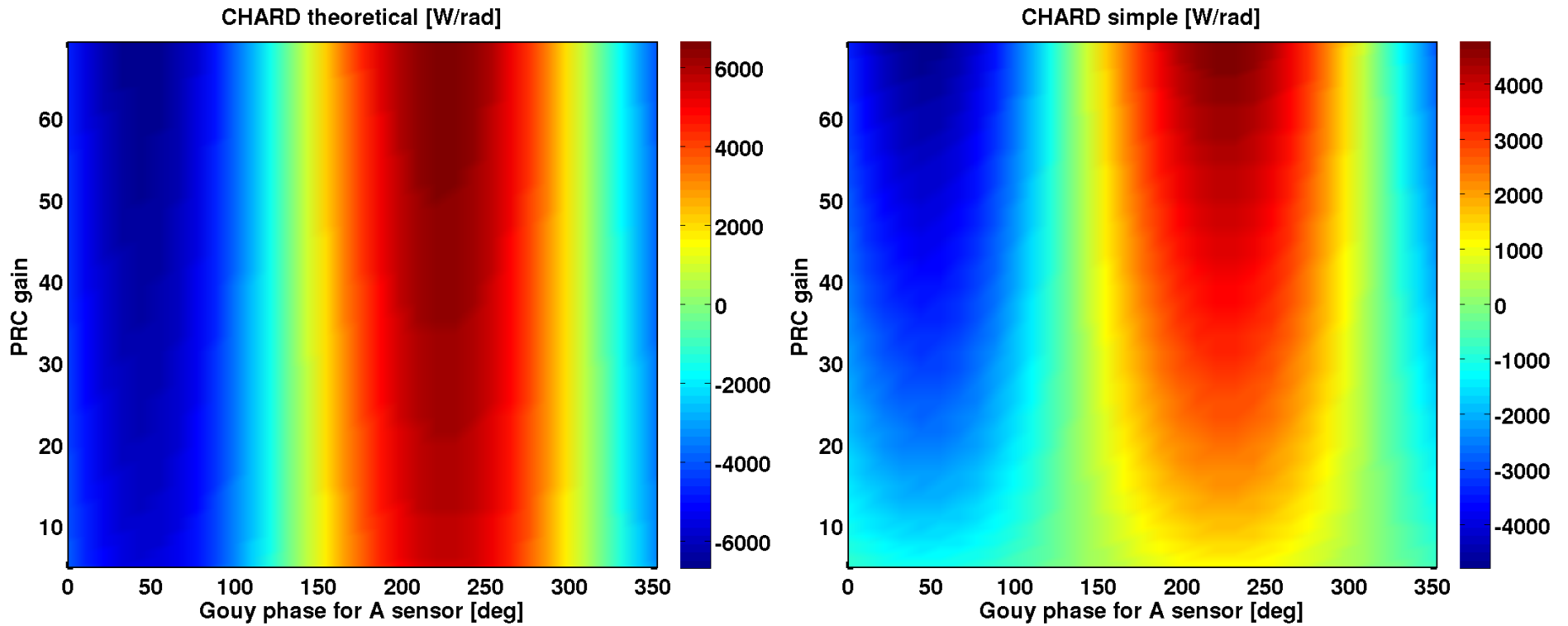
→ **CHARD sensing is free of singularities**

ASC Optickle simulation: DOFs

Livingston

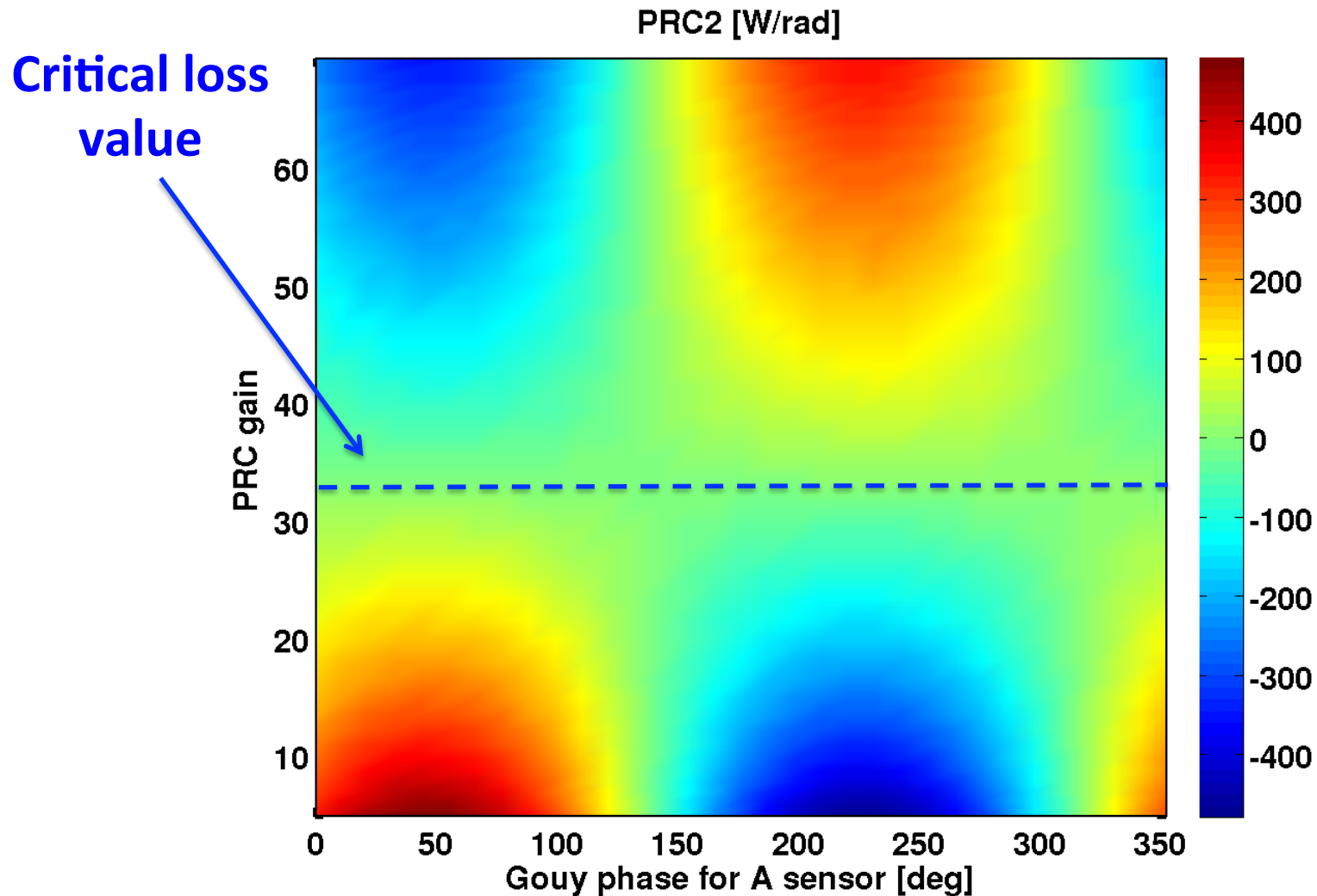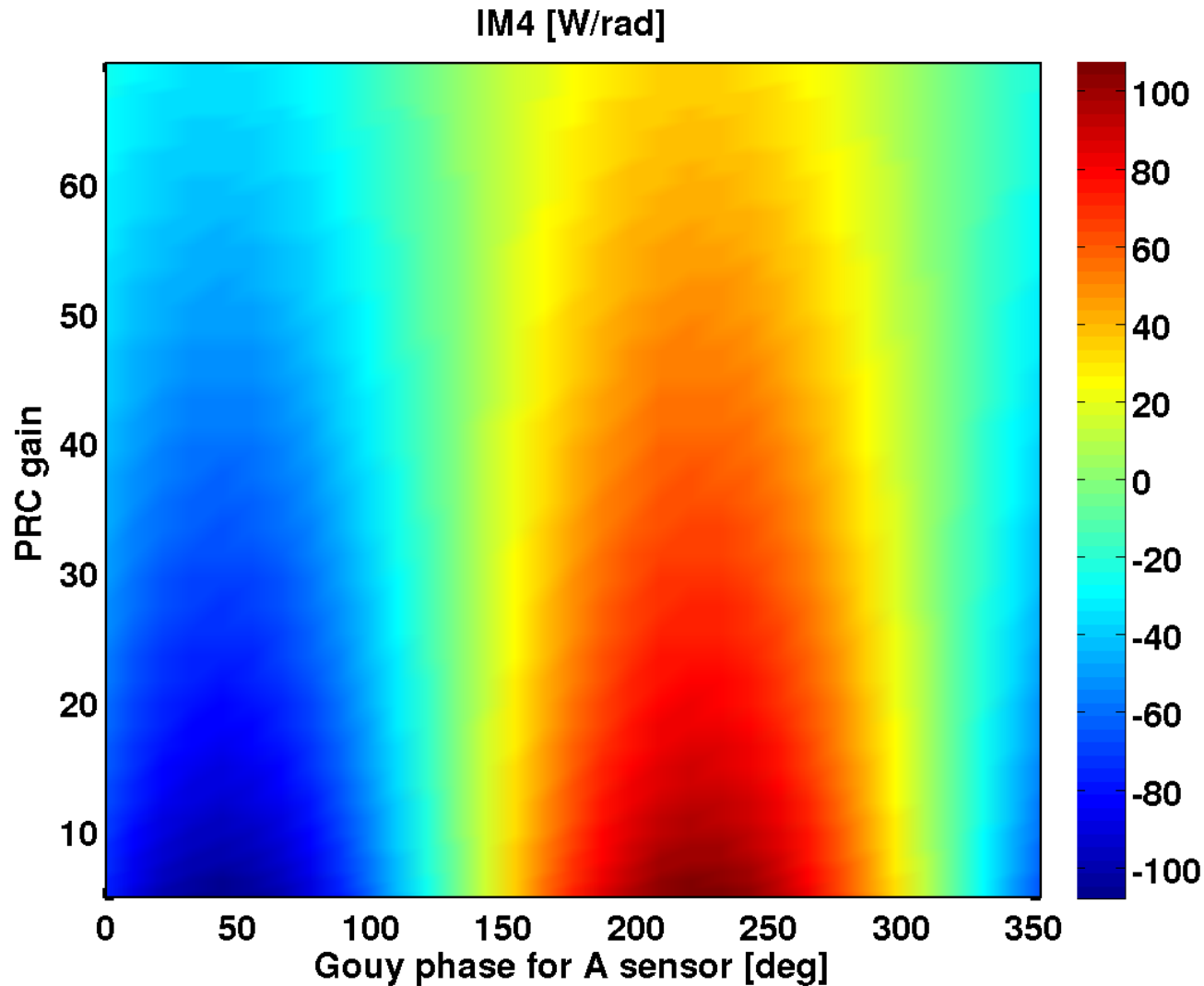→ **PRC2 is affected by the critical coupling around 33.5 PRC gain at all Gouy phases**

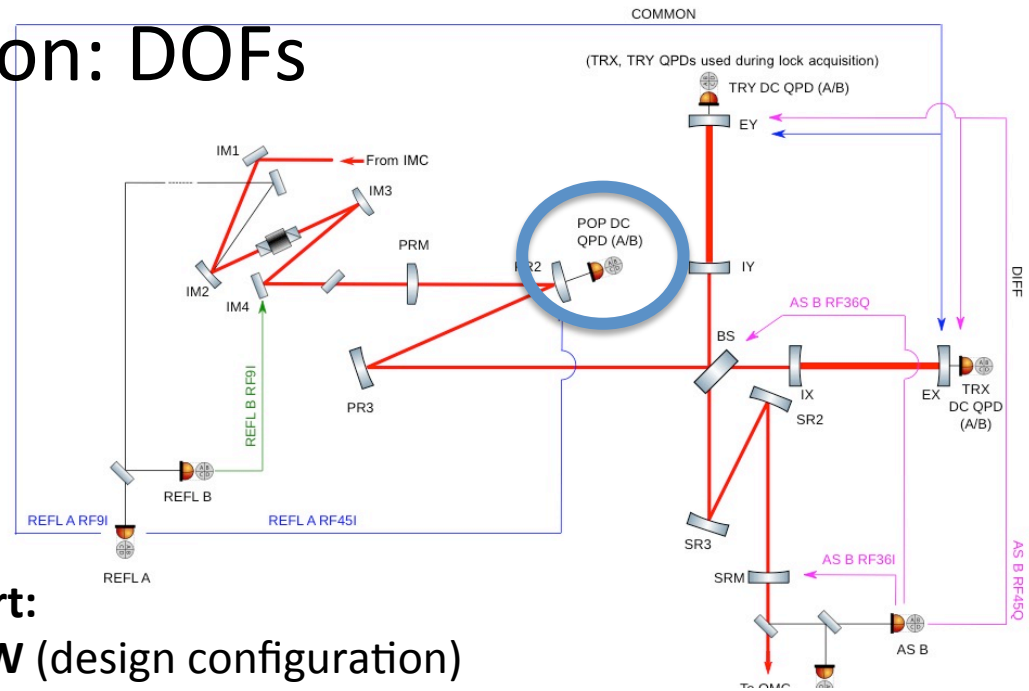# ASC Optickle simulation: DOFs

Livingston

IM4 [W/rad]

→ **IM4 sensing is free of singularities**

ASC Optickle simulation: DOFs

Possible solution :   POP signal
(LLO configuration)

- **Amplitude relative to the REFL port:**
  - **REFL port DC power = 665 mW** (design configuration)
  - REFL pick-off = 0.5%
  - 3 Beam splitters at 50%
  - Power on the WFS = 3.85 mW

  - **POP port DC power = 616 mW** (design configuration)
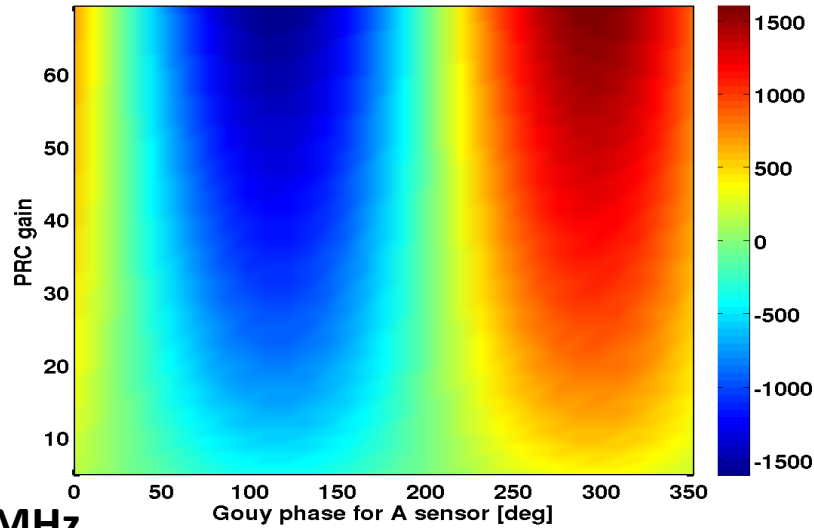 - POP pick-off = 250 ppm
  - Power on the WFS = 128 uW

POP DC signal is about 30 times lower than REFL DC
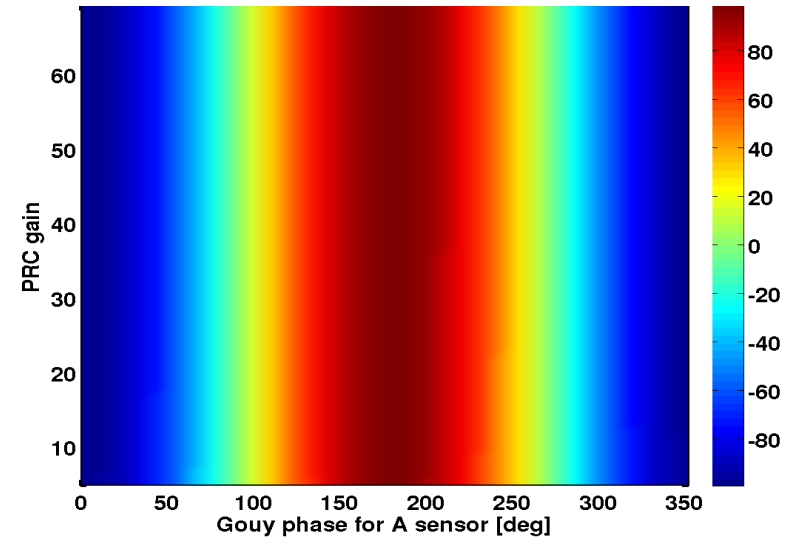
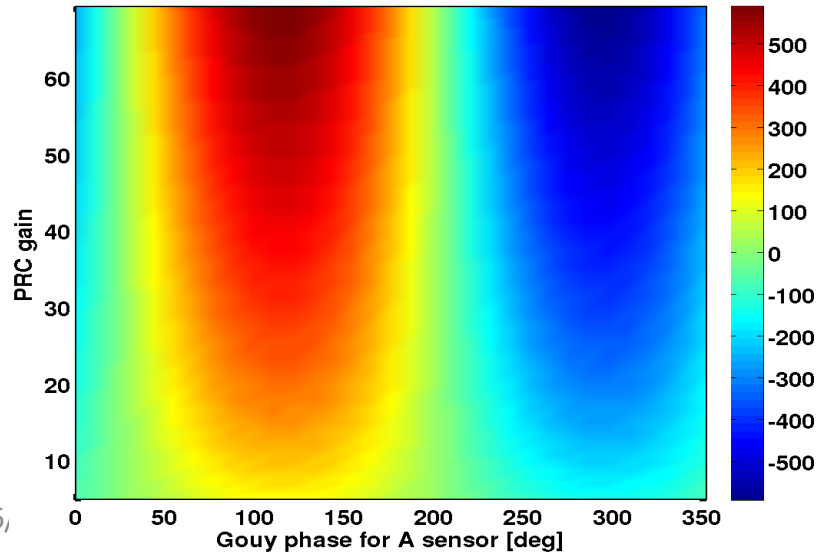# ASC Optickle simulation: DOFs

PRC2 signal at the POP output
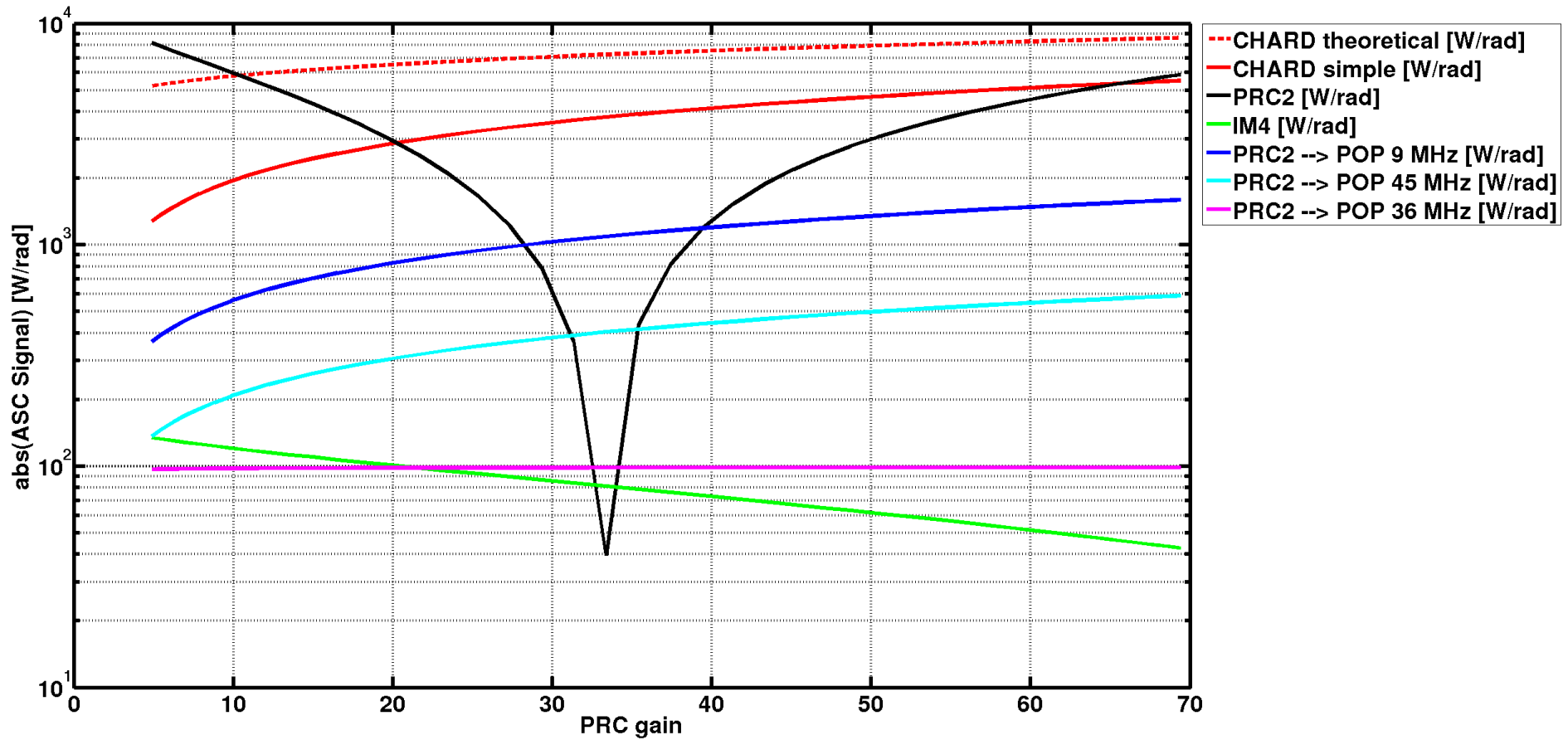
9 MHz

36 MHz

45 MHz

→ **POP sensing for PRC2 experiences no singularities**

ASC Optickle simulation: DOFs

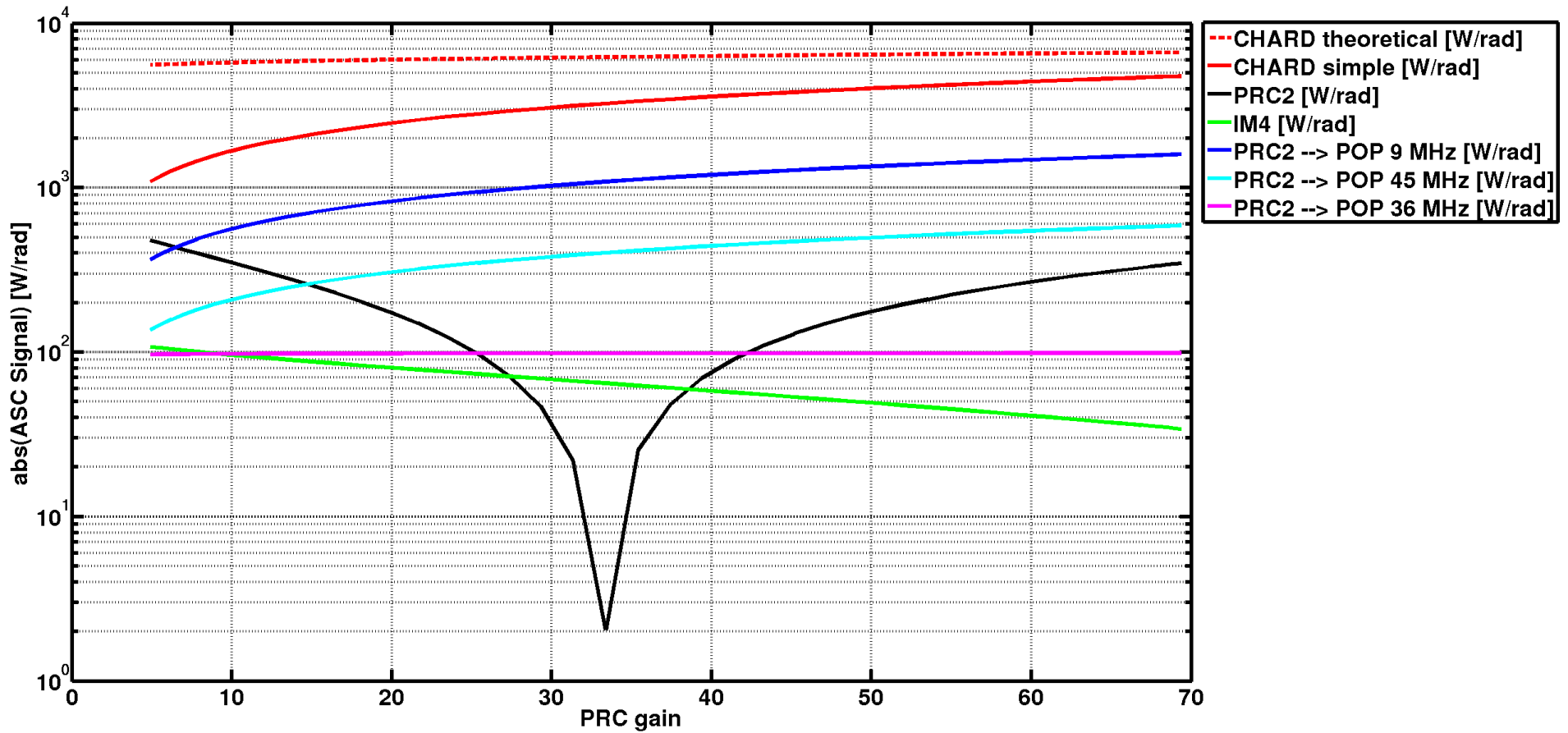**Abs value at the best Gouy phase**   **LIVINGSTON**

ASC Optickle simulation: DOFs

Abs value at the best Gouy phase   **HANFORD**

Conclusion

- **To answer questions from Koji:** **(LIGO-G1500745)**

Where (at which loss/recycling gain) does the singularity happen?

- The critical point is expected for p_{IX} + p_{IY} about 155 ppm
  or **PRC gain about 33.5**

- The impact of the losses in the sensing matrix is relative to the DOFs:
  - **CHARD** : the signal is not significantly affected by the losses
  - **IM4** : the signal is not significantly affected by the losses
  - **PRC2 : a critical point is observed around 155 ppm at all Gouy phases**

For PRC2, which signal should we use? (POP9, 45, or 36?)
Is the noise level good enough for the low noise operation?

- **POP 9, 36 or 45 MHz do not experience the drop in the signal**
- POP 9 MHz has the highest amplitude