# Mode matching investigations @ LLO

Chris, Lisa

LLO Team, Peter, Hiro

# Measurements - I

✧Mode matching to the OMC (1W):

Bright Michelson: 74%

Single Bounce X arm: 79%

Single Bounce Y arm: 71%

➔The matching is bad

➔X and Y Michelson arms are different

https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=8559

# Measurements - II

- Direct measurement of the beam profile at the AS port, right after SRM (before OMC):
  - Indeed X/Y are different
  - Propagation of this beam to the OMC "explains" mode mismatch

https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=8182

# Confusion…

Isn't T0900043 telling us that we don't need TCS up to 25W?

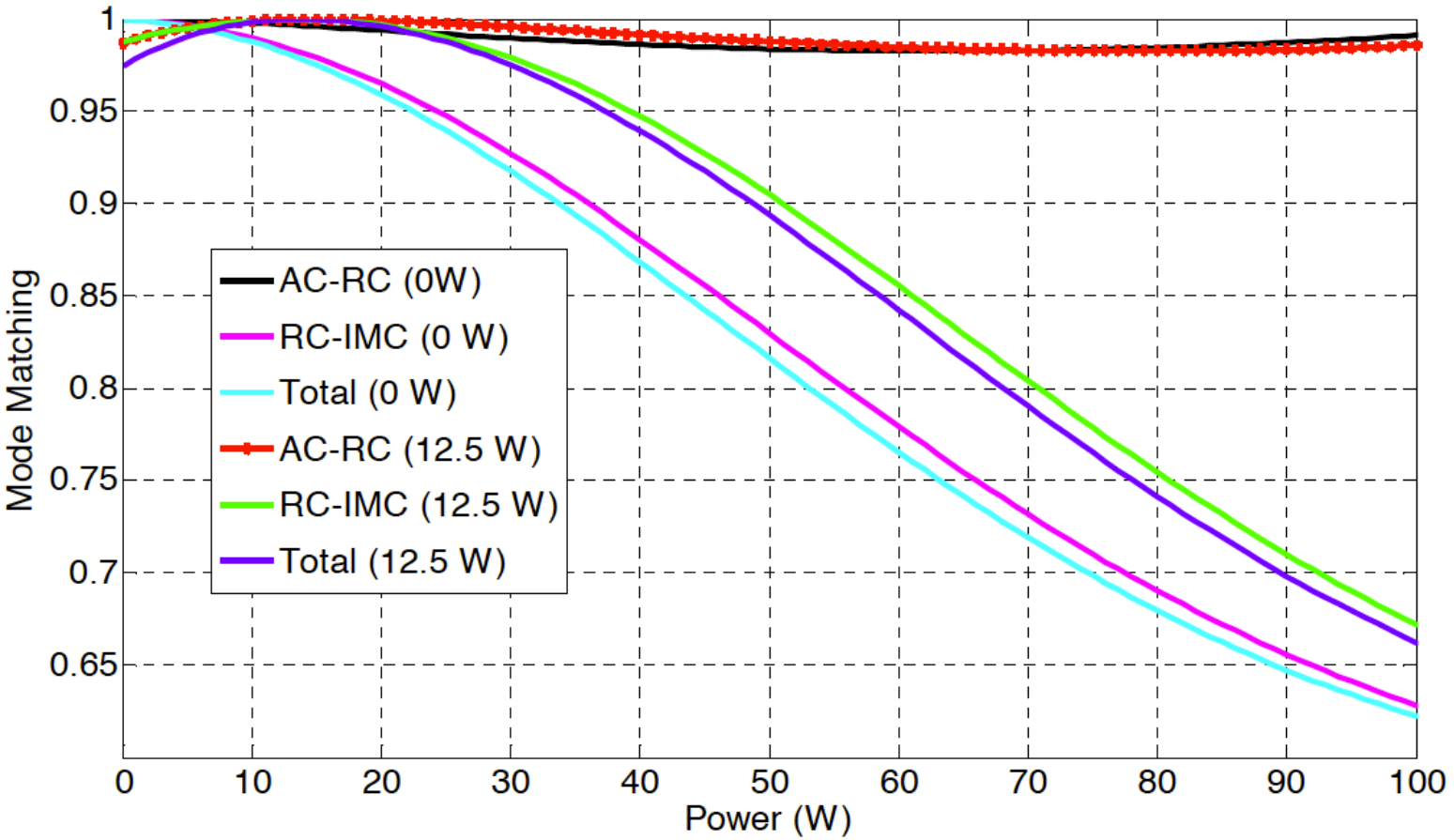



Fig. 3: Coupling between various modes for the carrier. Here RC-AC represents the coupling between the arm cavity mode and the recycling cavity mode. Total represents the product of coupling between AC-RC and IMC-RC.

# Model of recycling cavities with as built parameters (optimized for 12.5W, 50 km lens in ITMs)

- ✧ Predicted mode matching Single Bounce X: 90%
- ✧ Predicted mode matching Single Bounce Y: 85%

Asymmetry understood!
It is due to ~ 27 meters difference between ITMs:

R_ITMX = 1934 + 5.86 m
R_ITMY = 1934 - 21.2 m

**…but still, we are looking for X 79%, Y 71%**

# With optimal parameters for cold state, difference in ITMX/ITMY ROCs is negligible

- ✧Because the optimal state for 12.5W is not optimal for cold state, **sensitivity to ROCs/ lengths of recycling cavities is much higher**
- ✧ Measured DRMI lengths ➔ no serious error analysis, but we believe they are right ("not very wrong")
- ✧ROCs of PR3/SR3 becomes critical (ROC~36m), sensitivity at the ~cm level

# Tolerances on measured ROCs

| Optic Installed | Measured ROC (m) | ROC Tolerances | Design ROC (m) | Design Tolerance (m) |
|---|---|---|---|---|
| PRM-02 | -11.0086 | +15.9 mm, -15.2 mm | -11.00 | 0.11 |
| PR2-02 | -4.5443 | +/- 4.2 mm | -4.56 | |
| SRM-08 | -5.677 | +6.1 mm, -5.9 mm | -5.69 | 0.06 |
| SR2-04 | -6.4057 | +5.6 mm, -5.9 mm | -6.43 | 0.03 |
| PR3 | +36.0276 | +-15 mm ? | +36.00 | 0.18 |
| SR3 | +39.973 (v) | +-15 mm ? | +36.00 | 0.18 |

Rodica, GariLynn

# Caveat

✧ My model and Chris's model agree for the "as built" parameters, but they don't predict the same sensitivity to the ROCs/Lengths

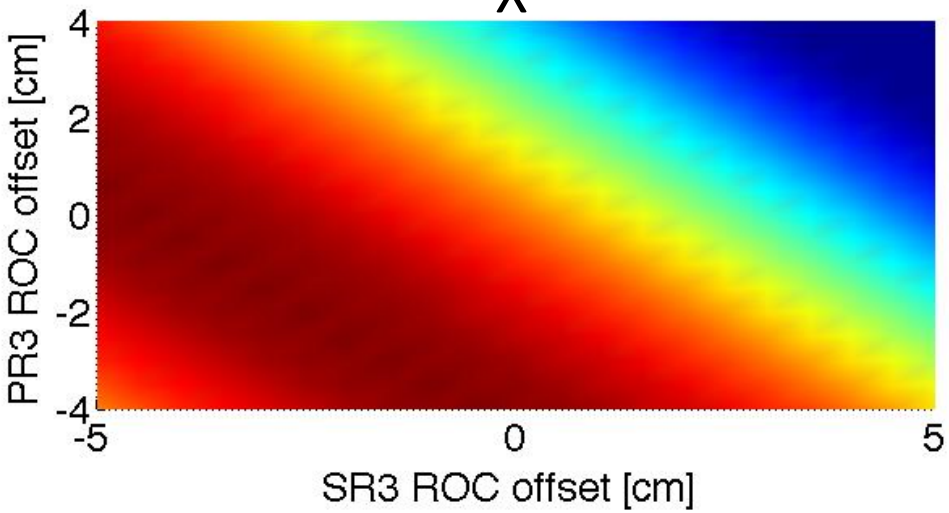
➔I guess this is a proof that we are very sensitive!?

The message of the following slides is correct, but the actual numbers might be slightly different

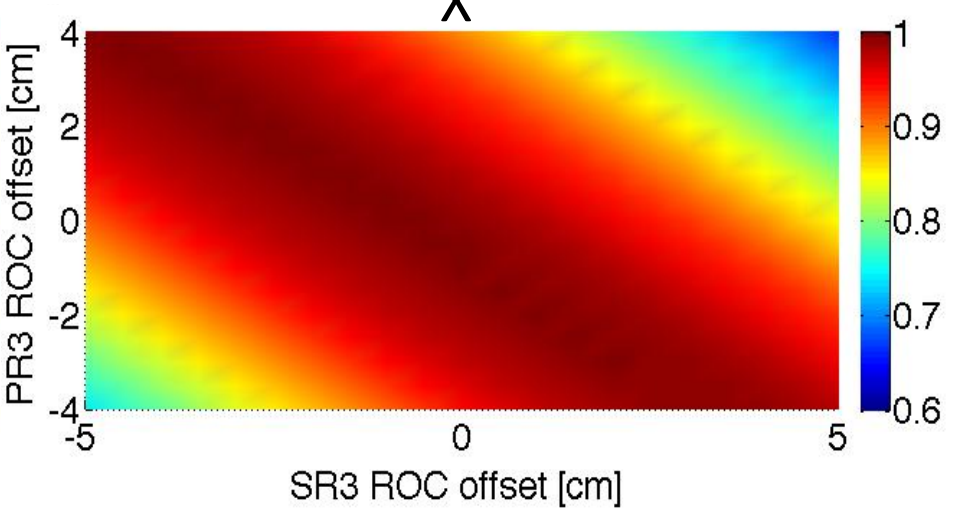
As built parameters
Cold state, with optimal at 12.5W

Optimal parameters for cold state

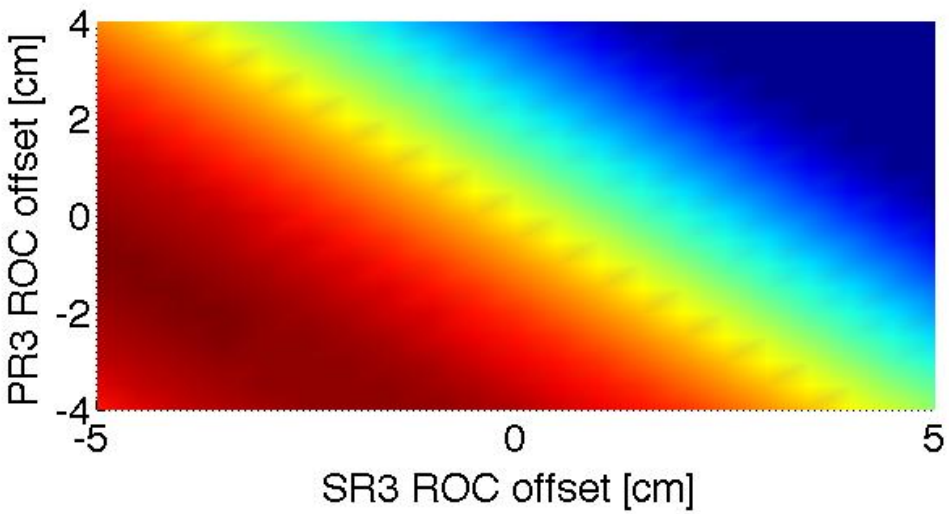
X



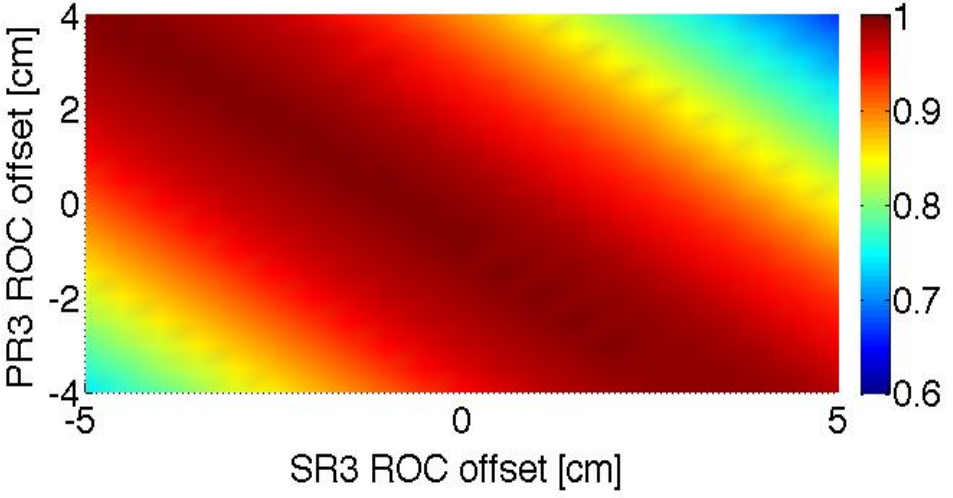

X



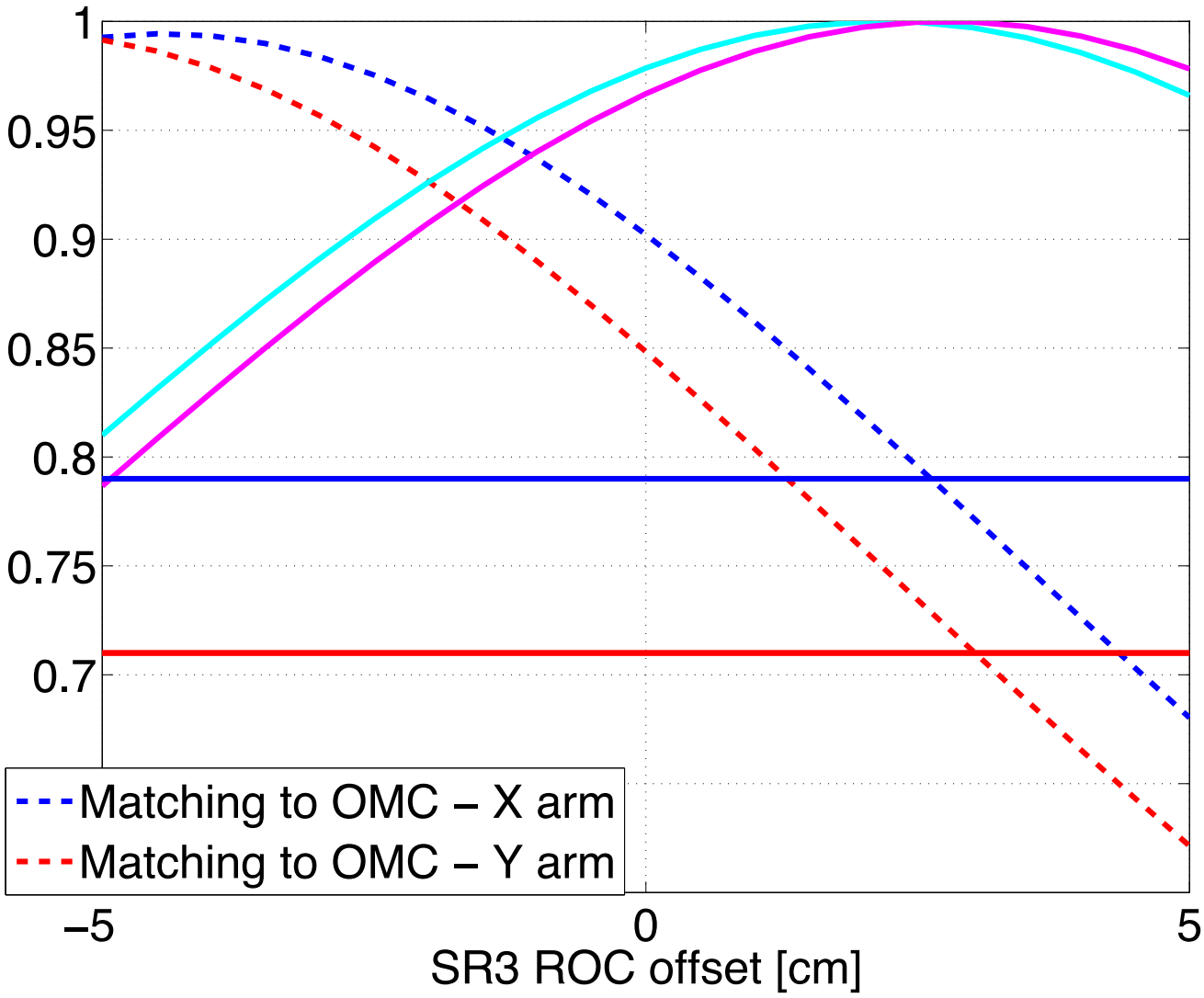

Y




Y



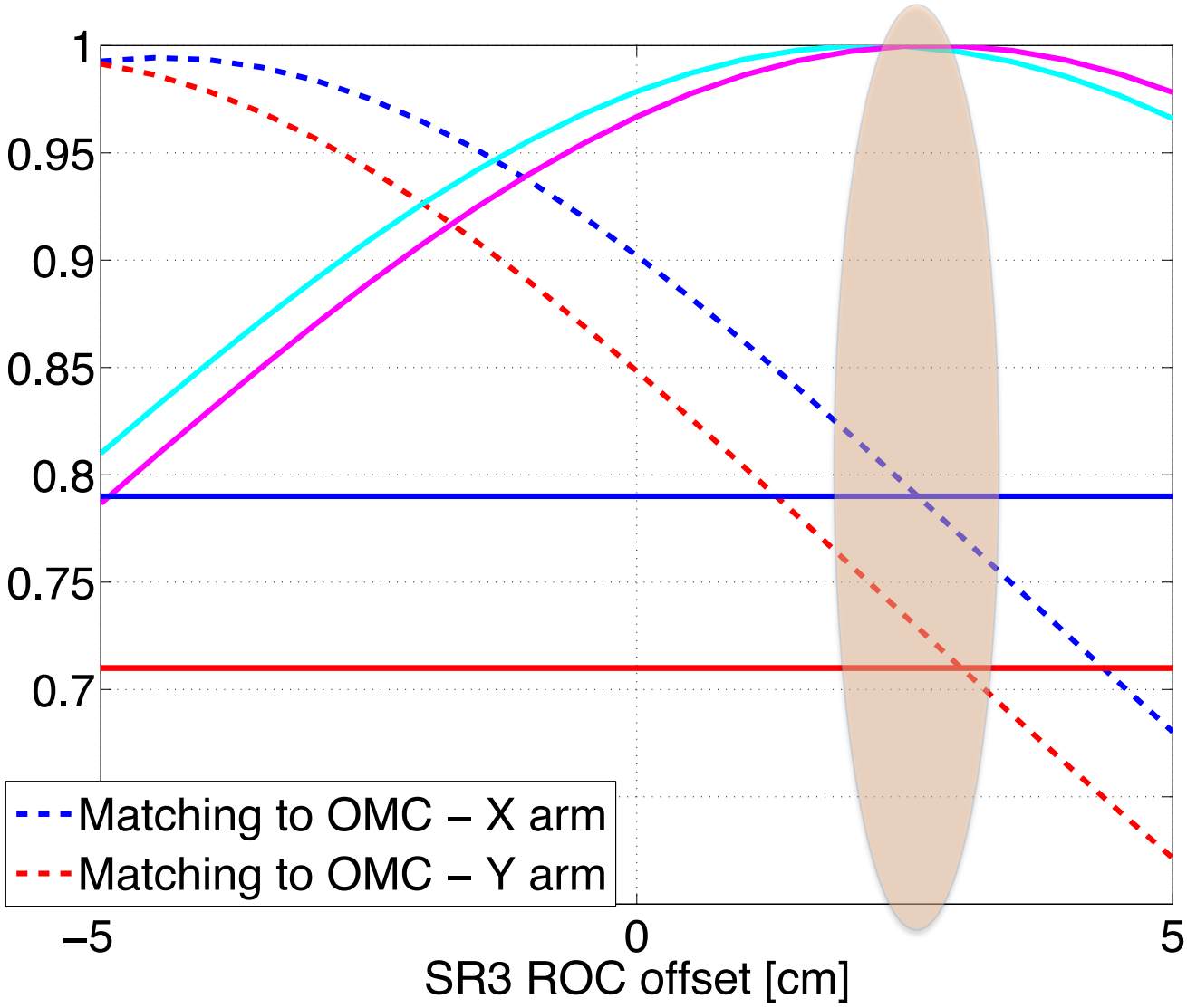
# Where are we?




Overlap with measured beam profile after SRM

Measured mode matching with OMC

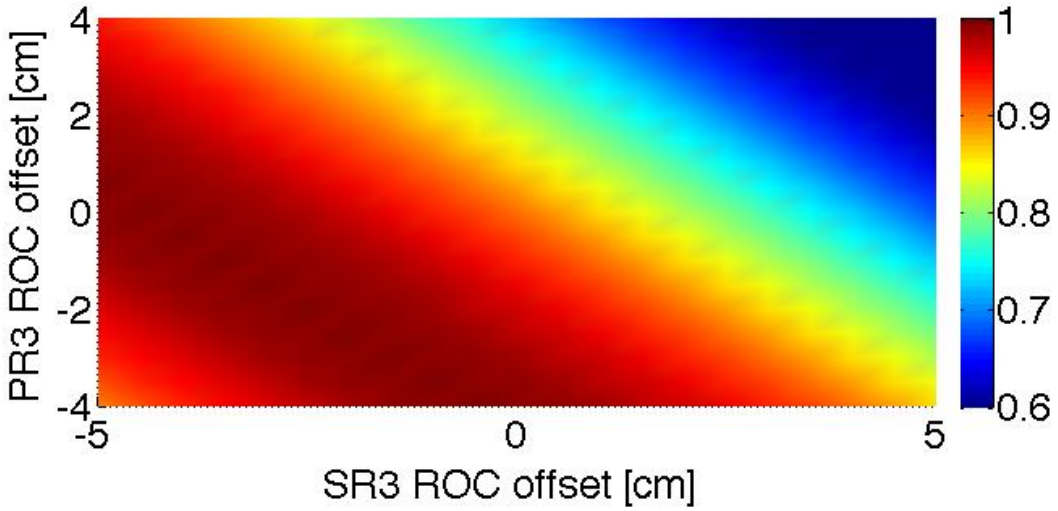
# Where are we?(PR3 ROC as built)

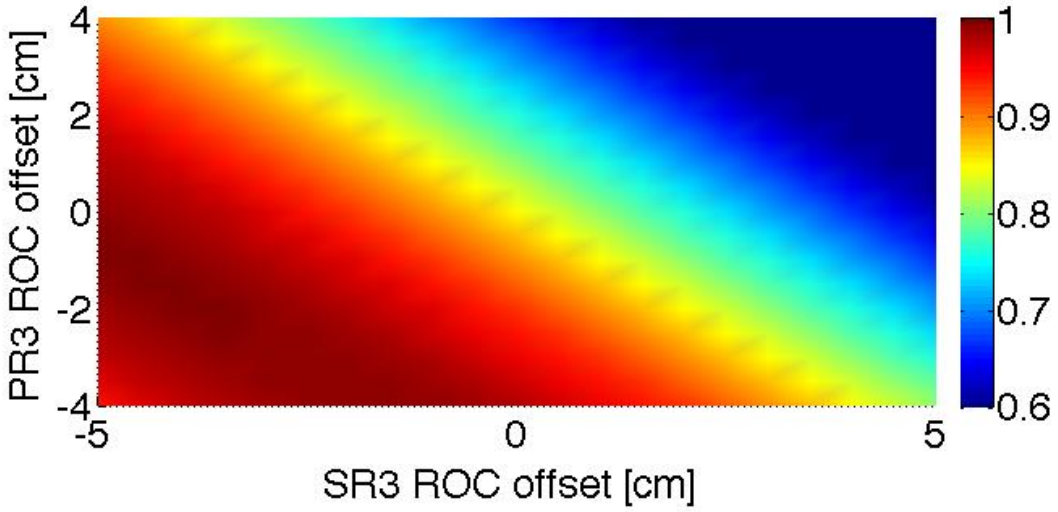



Overlap with measured beam profile after SRM

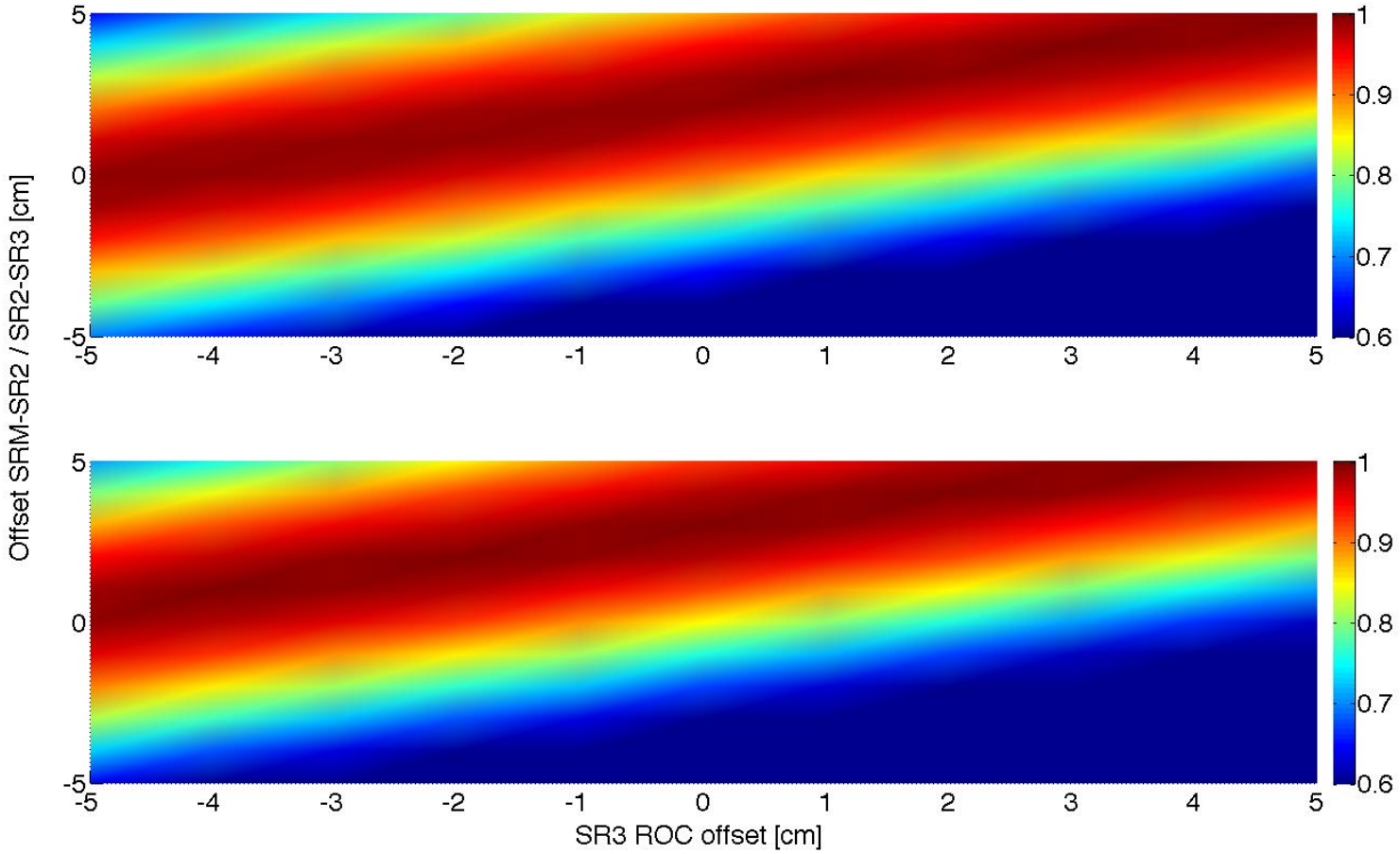
Measured mode matching with OMC

# On the wrong side!



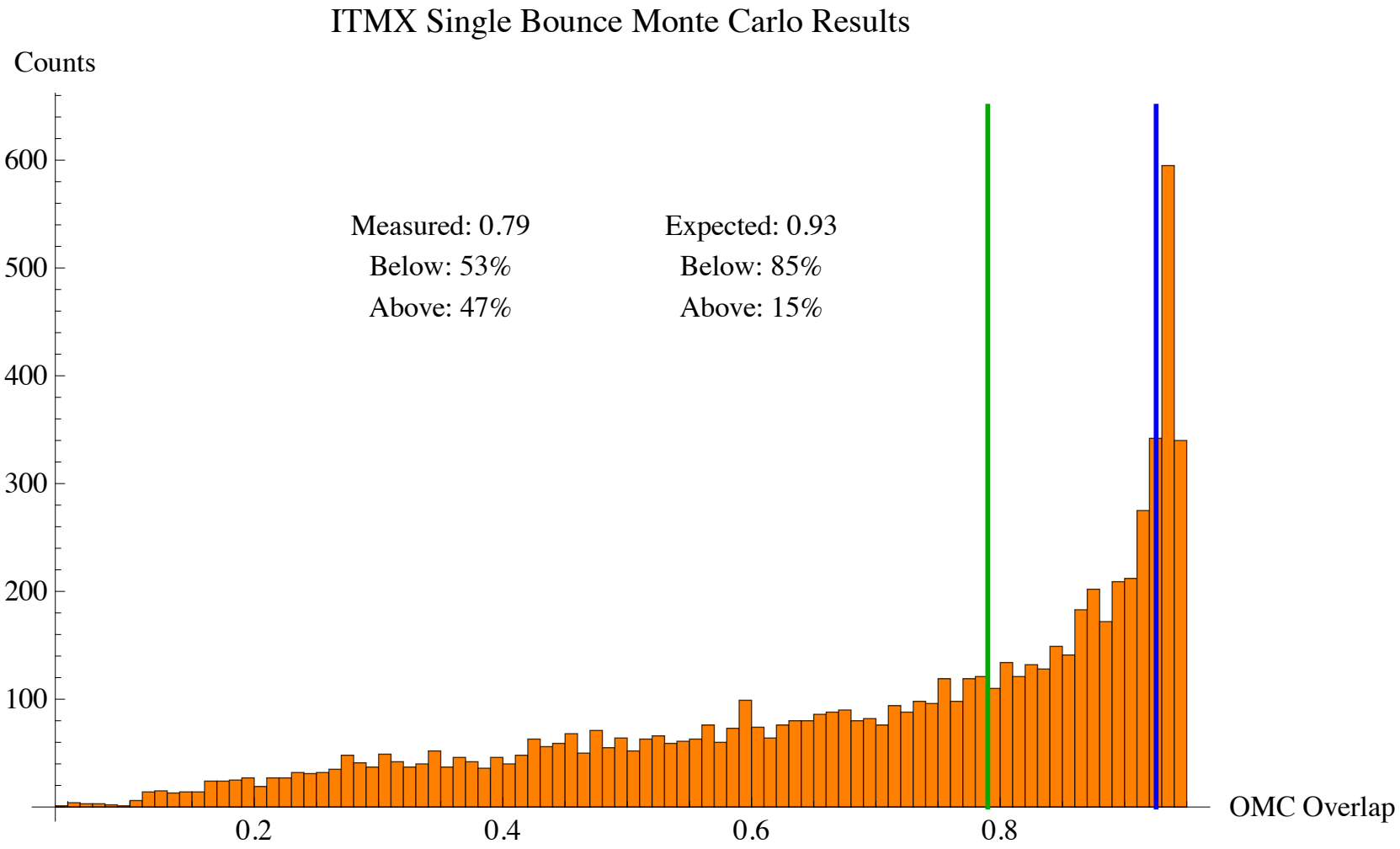



# With our tolerances we can't predict correct lengths

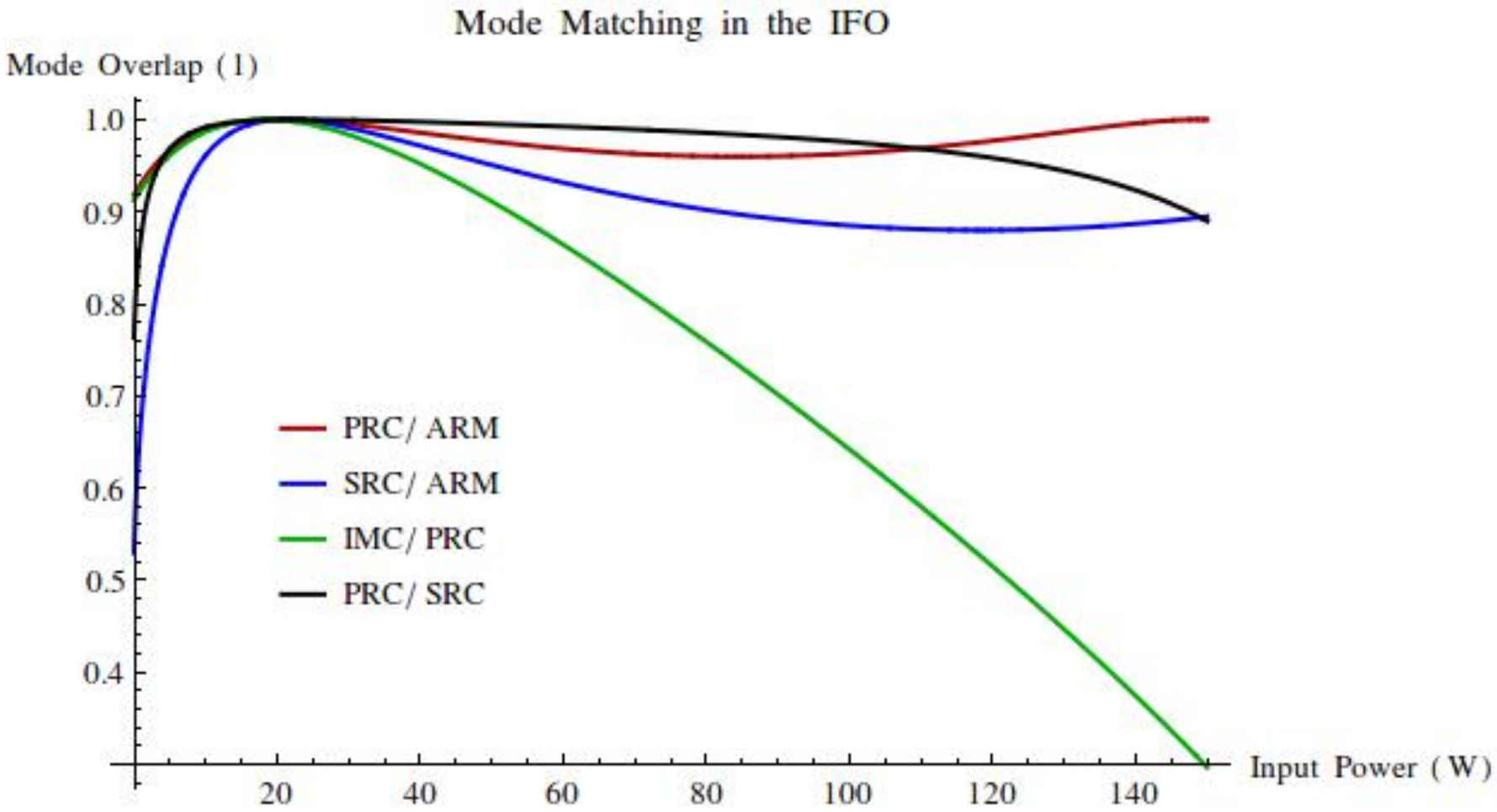



But "correct lengths" do exist! For instance, we can change relative distances SRM-SR2/ SR2-SR3 (total SRC remain the same)

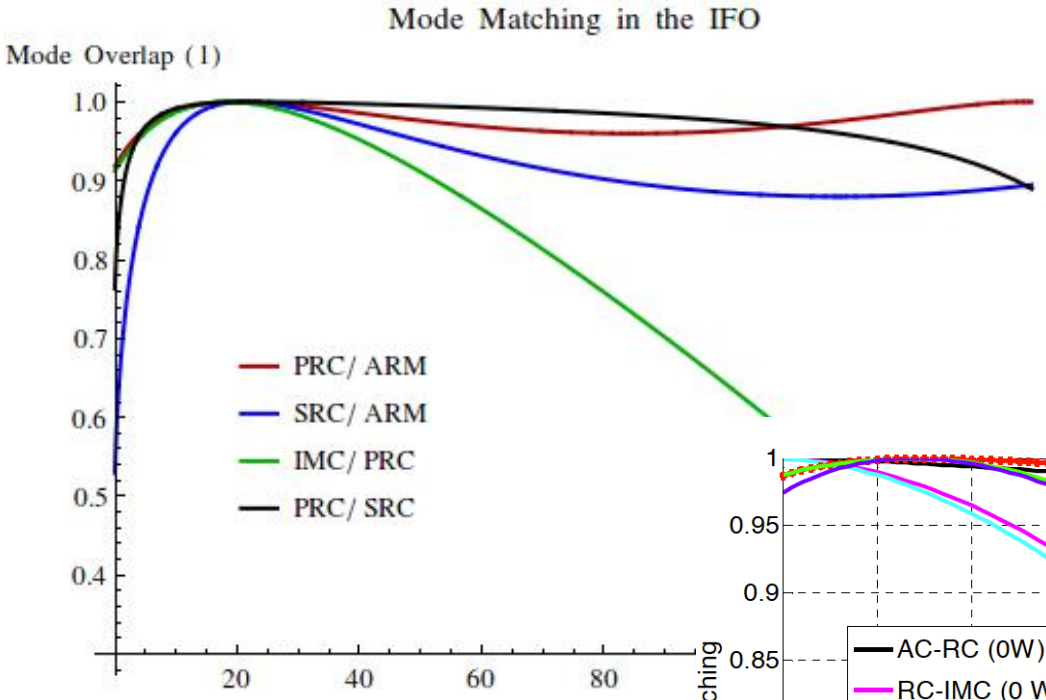
# Unlucky? Not particularly, 50% chance

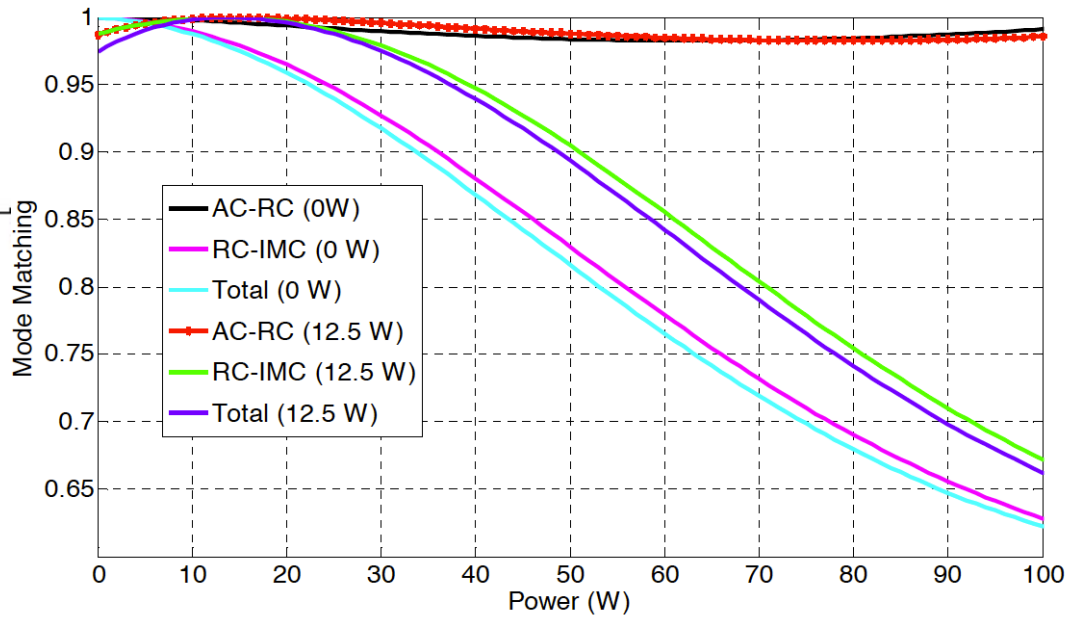


# The current parameters are not optimal for 12.5W, but for higher power



# Slope in cold state is much steeper



# Message

- ✧Our recycling cavities are not what we thought we had..
- ✧They have been (not intentionally) tuned for being optimally matched at higher power
- ✧They are much more sensitive to changes of the optical parameters in the cold state