

Discussion on Interferometer Configuration for O4

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Executive Summary

- We are not sure yet if DRFPMI is feasible or not, and if polarizers in PRC/SRC will improve the situation (both sensitivity wise and stability wise)
- We are also not sure yet if inhomogeneous ITM transmission map is limiting our frequency noise and intensity noise coupling
- Therefore, we cannot conclude at this point
- **Measurements** (especially DRFPMI characterization and frequency/intensity noise coupling) before the vent for O4 is necessary to investigate the necessity of polarizers and ITM re-polishing
- Measurements will require at least ~2 weeks

List of Considerations for O4

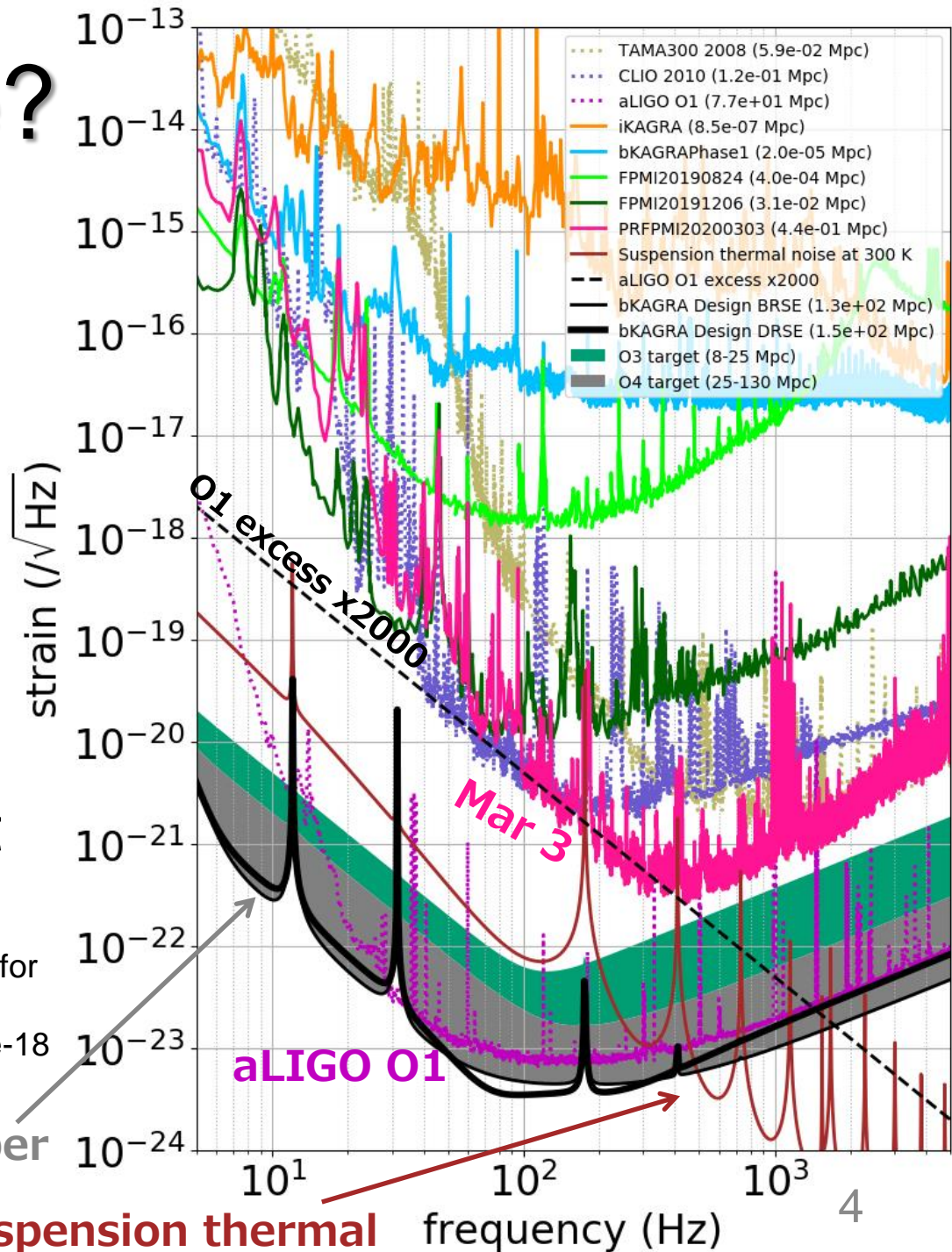
- **Cryogenic** temperature necessary?
 - Depends on sensitivity necessary
- Which **SRM reflectivity**?
 - 0 % or 70 % or 85 % (compound or monolithic)
 - Depends on feasibility of DR locking
- **Polarizers** in PRC and SRC necessary?
 - Depends on birefringence effect to sidebands
 - See [JGW-T1910396](#) for proposal
- **ITM re-polishing and re-coating** necessary?
 - Depends on the effect of transmission asymmetry and TWE to CMRR of frequency/intensity noise

Where Are We?

- 400-500 kpc
- PRFPMI with 70% SRM tilted, 3-5 W to PRM, ~240 K, DC readout
- O1 excess x2000 !
- Pretty close to shot noise ([klog #13144](#))?

([klog #12772](#) gives $6\text{e-}18$ m/rHz @ 1 kHz for 1.4 W input, 3.4 mW at OMC PDA. 4.5 W input, 8 mW at OMC PDA should give $\sim 2\text{e-}18$ m/rHz for current setup.)

O4 target on Obs. Scenario Paper
25-130 Mpc by ~2021



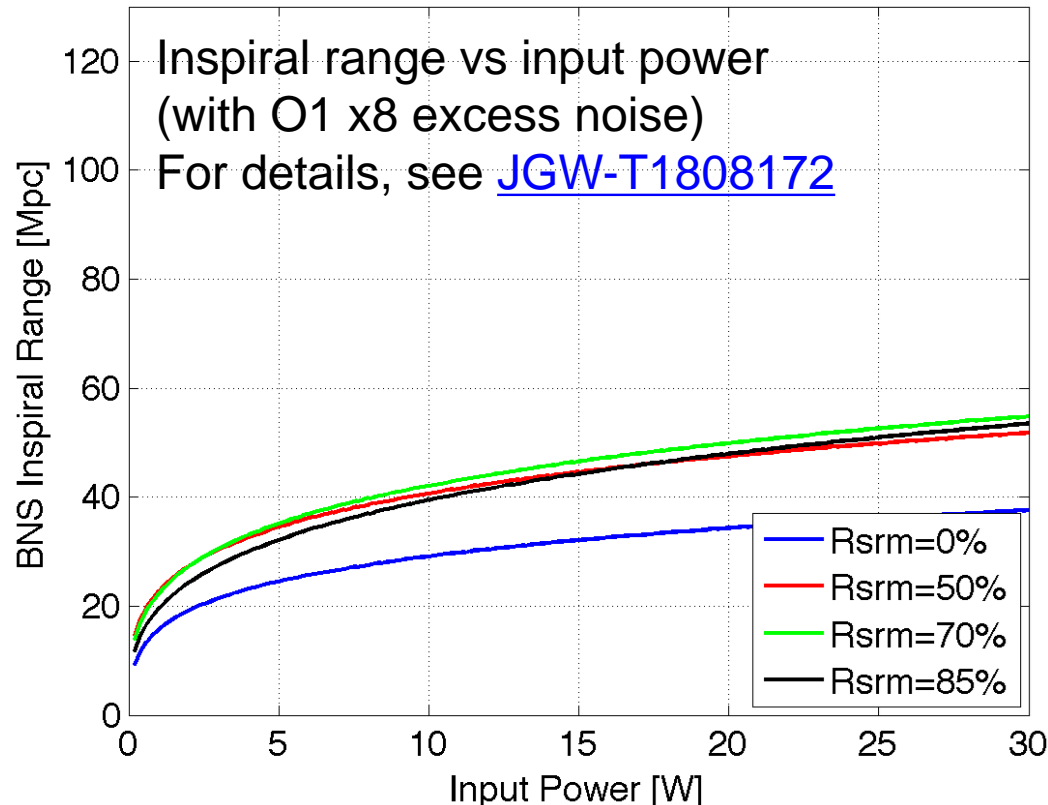
Current Status and O4 Target

- Cryogenic necessary for sure

	Mirror temp.	Power at BS	SRM reflectivity	Detuning angle	Homodyne angle	Excess noise
NOW	~240 K	30-50 W	70% tilted	~90 deg (PRFPMI)	~90 deg (conventional)	O1 x 2000
O3 low	22 K	10 W	0 %	90 deg (PRFPMI)	90 deg (conventional)	O1 x 20
O3-15Mpc	22 K	10 W	70 %	90 deg	90 deg	O1 x12
O3 high / O4 low	22 K	33 W	70 %	90 deg (BRSE)	90 deg (conventional)	O1 x 8
O4 80Mpc	22 K	404 W	85 %	90 deg	90 deg	O1 x 2
O4 high	22 K	673 W	85 %	90 deg (BRSE)	90 deg (conventional)	no excess
Design	22 K	673 W	85 %	86.5 deg	135.1 deg	no excess

DR Necessary?

- **DR is better and almost necessary** (especially better when low frequency excess noise is too much)
- Still, **70% SRM seems good** for O4 (we don't have much confidence on higher power)



Feasibility of Locking DR

- According to Nakano-kun
 - DRMI on 1f is fine. Lasts 30 min or so
 - DRMI on 3f lasts 5 min or so [klog #12535](#)
- Needs more time (~ a week?) to assess if DRFPMI is feasible or not with current ITMs
- If not feasible, our choice for O4 will be
 - Go with PRFPMI, install 0% SRM
 - Evaluate if polarizers in PRC and SRC will help locking DRFPMI

Compound or Monolithic SRM

- Only monolithic SRM we have is 85%
- If compound SRM is not OK for O4, and 70% or 0% SRM is necessary, we have to make a monolithic SRM
 - cf. aLIGO O1 was done with compound SRM
 - KAGRA might have more HOMs at AS which give more scattered light due to compound SRM
- If compound SRM is giving a nasty effect, may be we should use 85 % monolithic SRM
- Need to estimate the effect of compound SRM if we could lock DRFPMI

Effect of T_ITM asymmetry

- See [JGW-T1910352](#)
- Considering frequency noise and intensity noise coupling, achieving the designed sensitivity is not feasible, but achieving O4 target (25-130 Mpc) should be possible with current ITM transmission asymmetry (if inhomogeneity effect is not considered)
- **Just re-coating is not necessary for O4** (the problem is TWE map and birefringence)

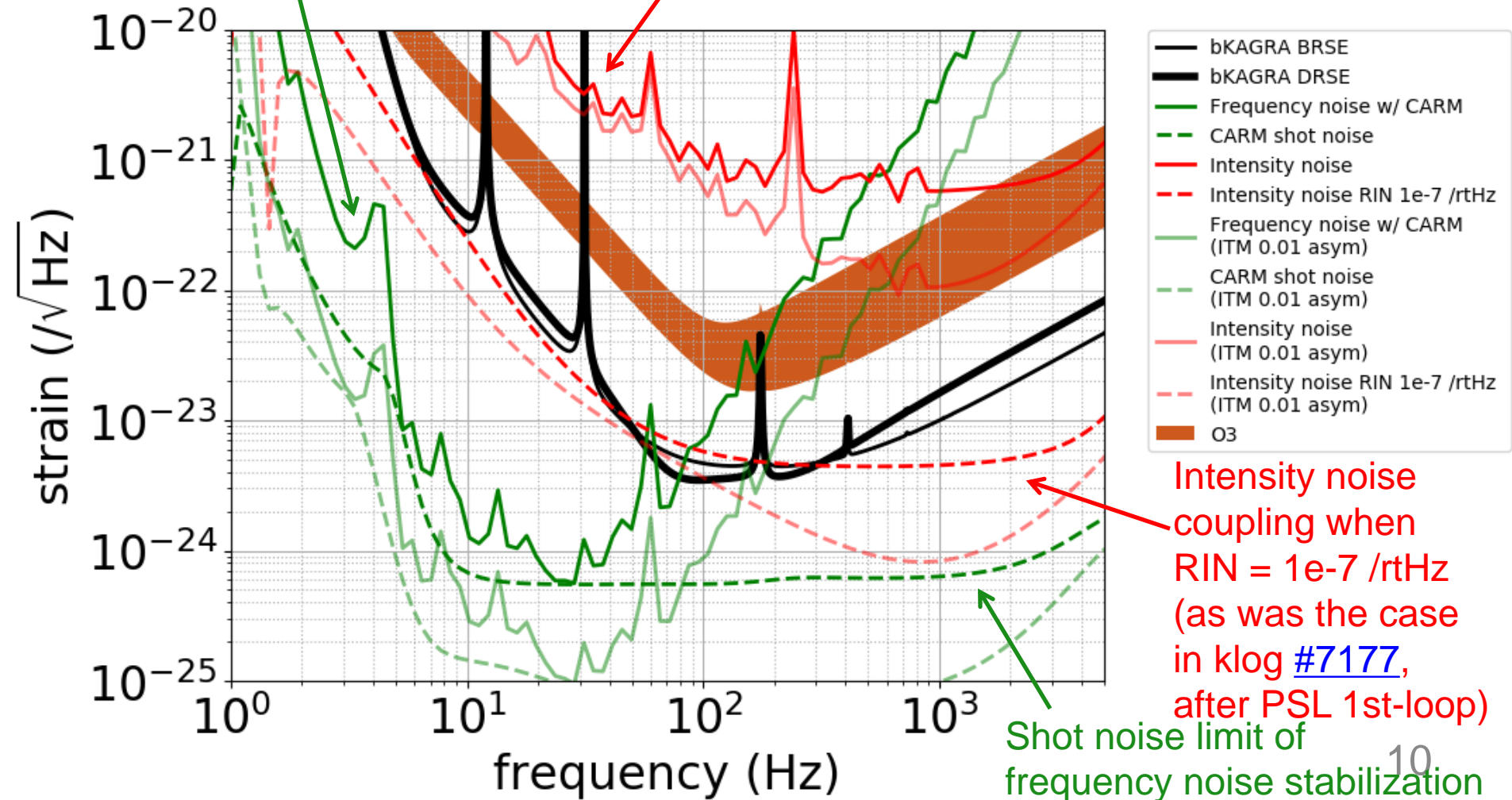
Frequency noise coupling estimated with current measured frequency noise; CARM loop turned on (could be limited by measurement noise at high frequencies)

Result

Copied from
[JGW-T1910352](#)

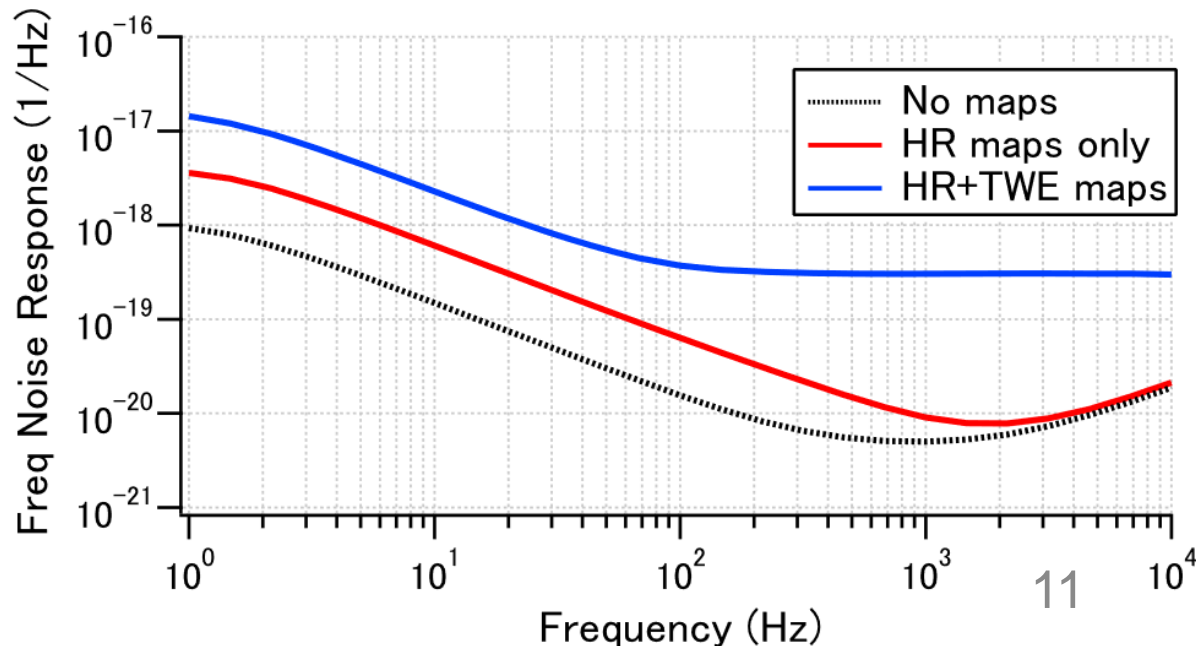
Dim lines represent same curves when ITM transmission asymmetry was 0.01

Intensity noise coupling estimated with current measured intensity noise (stabilization servo not on yet)



Effect of ITM TWE

- See [Phys. Rev. D **100**, 082005 \(2019\)](#)
- According to Somiya-san's simulation, ITM TWE gives x8 frequency noise coupling @ 100 Hz
- Intensity noise coupling not yet simulated
- Needs to assess the effect both with simulation and measurement
- If the effect of birefringence is bigger, TWE correction is not effective



Conclusions So Far

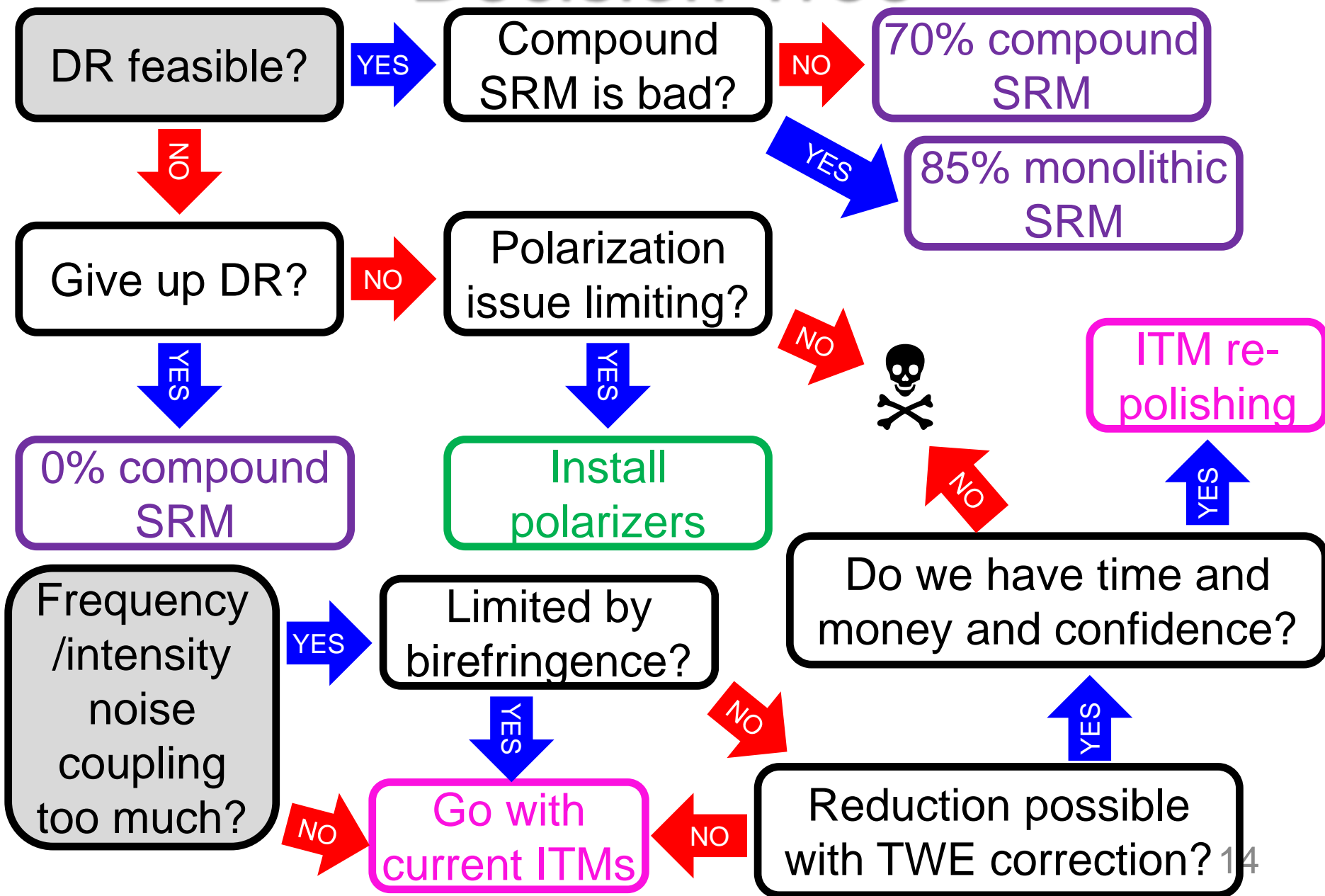
- **Cryogenic** temperature necessary?
 - Necessary to achieve O4 target (25-130 Mpc)
- Which **SRM reflectivity**?
 - DR is better but we have to assess if DR locking is feasible or not
 - If DR is feasible, 70% SRM is good
 - If compound SRM is not good, use 85% monolithic SRM
- **Polarizers** in PRC and SRC necessary?
 - We need to assess if DR locking is feasible without polarizers
- **ITM re-polishing and re-coating** necessary?
 - Recoating is not necessary but we should estimate the effect of inhomogeneity to see if re-polishing is necessary to compensate TWE

List of Measurements to be Done

- Feasibility of locking DRFPMI (~ 1 week)
- Shot noise calculation (~ 0.5 day)
- Power recycling gain for sidebands (~ 0.5 day)
- LSC and ASC sensing matrix (~ 2 days)
- MICH/PRCL/SRCL to DARM coupling (~ 1 day)
- Frequency and intensity noise coupling (~ 1 day)
- MICH contrast defect with MICH locked and FPMI locked (~ 1 day)
- Mode content of AS (OMC cavity scan) (~ 0.5 day)
- The effect of compound SRM for sensitivity (~ 0.5 day)
- Scattered light investigations (~ 1 week)
- Compare measurements with Optickle/FINESSE simulations

See, also
[Minutes20200309](#)

Decision Tree



Yuta's Personal Opinion

- **Cryogenic** temperature necessary?
 - Necessary to achieve O4 target (25-130 Mpc)
- Which **SRM reflectivity**?
 - Use 70% compound SRM. I just assume compound SRM is OK.
- **Polarizers** in PRC and SRC necessary?
 - No. It is likely that we can lock DR without them.
- **ITM re-polishing and re-coating** necessary?
 - No. We should concentrate on making ITMs without birefringence. Frequency and intensity noise can be subtracted.