ET recycling cavities design

(a work in progress)

J. Degallaix for the ET team

Introduction for the current ET work

- main focus on the recycling cavities design
- as the infrastructure TDR will come before the instrument TDR
- based on the arm cavity design previously published
  (Design Report Update 2020)

The starting point: the arm cavities

One given parameter : the cavity length (10 km)

- ET - HF: set a g-factor (0.95) → derived the beam radius, mirror diameter
- ET- LF set a substrate size (Ø 450 mm) → derived the beam radius, g-factor

The starting point: the arm cavities

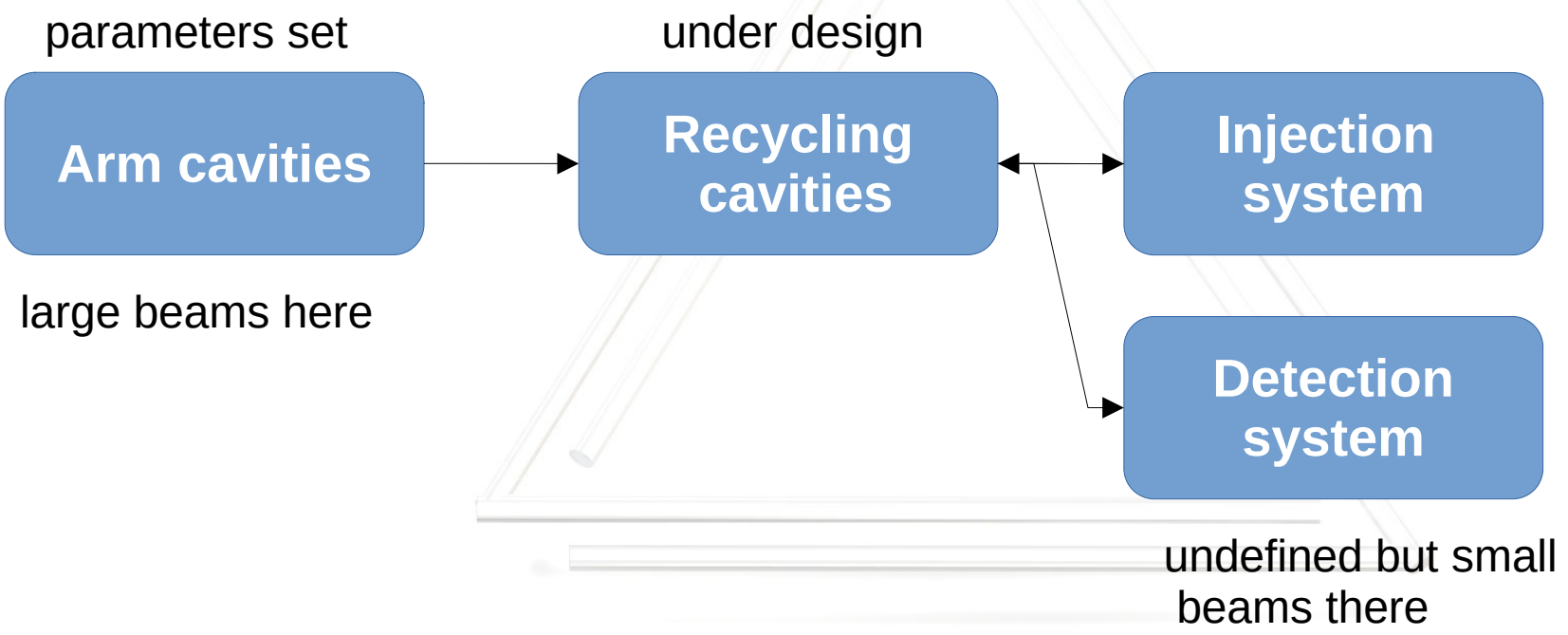
	λ [nm]	Cavity length [km]	Mirror Ø [cm]	Beam radius IM / EM [cm]	g-factor
ET - HF	1064	10	62	12	0.95
ET - LF	1550		45	9	0.63

The starting point: the arm cavities

Initial design to be fined tuned after more advanced simulations (with realistic mirror profiles, check parametric instabilities...)

	λ [nm]	Cavity length [km]	Mirror Ø [cm]	Beam radius IM / EM [cm]	g-factor
ET - HF	1064	10	62	12	0.95
ET - LF	1550		45	9	0.63

The recycling cavity: at the heat of the interferometer



The recycling cavity: at the heat of the interferometer

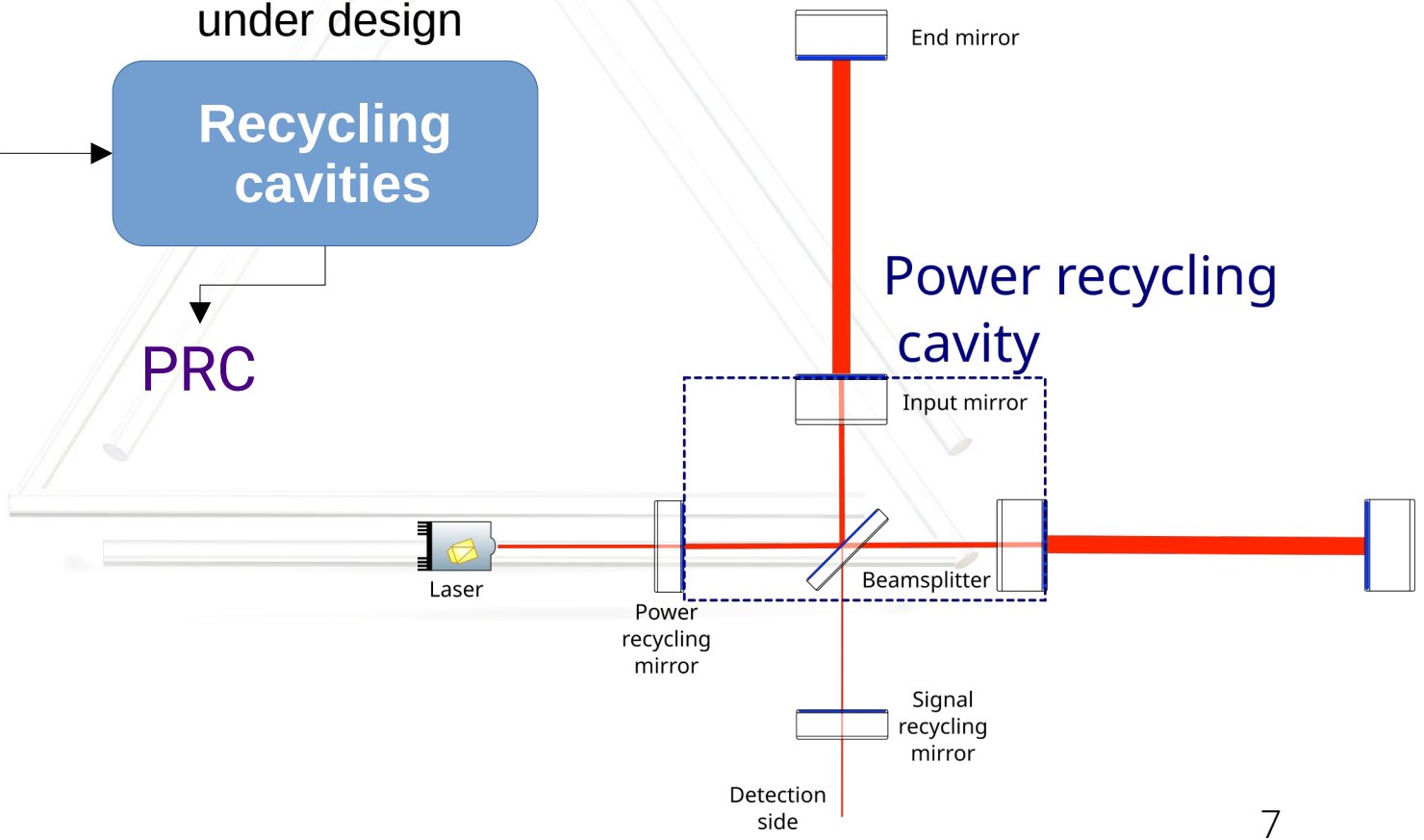
parameters set

under design

Arm cavities

Recycling cavities

PRC



The recycling cavity: at the heat of the interferometer

parameters set

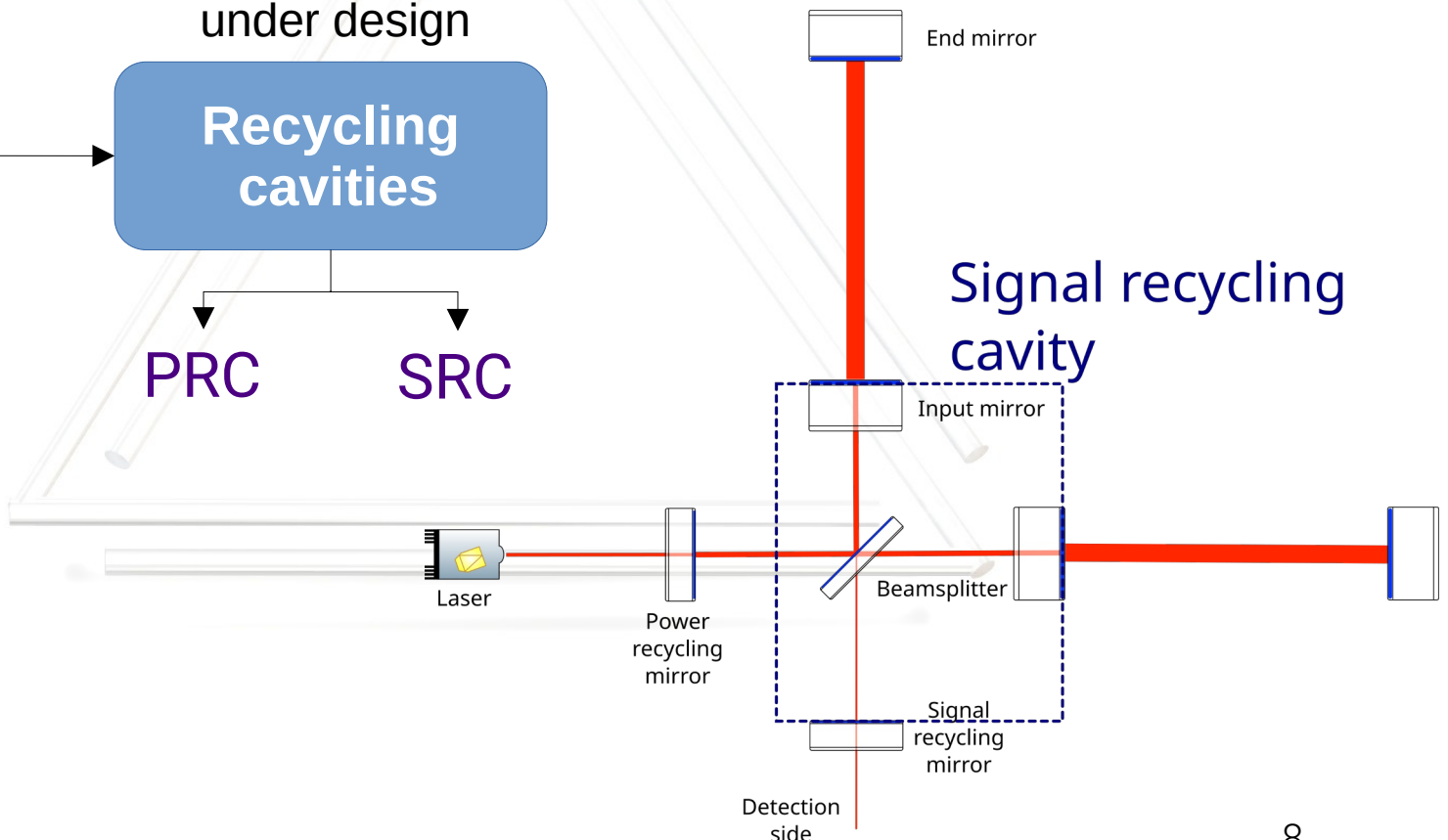
under design

Arm cavities

Recycling cavities

PRC

SRC



First constraint on the recycling cavities

Design based on the experience from the current generation of instruments:

- non-degenerated (stable) cavities
- one-way Gouy phase > 20º
- decrease the beam size
- not too long ~100m, +/- 20 m (constraint for the SR cavity)
- first thoughts: PRC and SRC similar, BS at 45º

Some additional constraints for ET-HF

- ET-HF room temperature interferometer, with huge circulating power in the PRC (~20 kW)
- For ET-HF, managing thermal effects:
  - large beam radius at BS (> 26 mm)[1]
  - large beam radius on PRM (> 10 mm)[2]

[1] ET TDS
[2] To achieve same power density as on the ITM

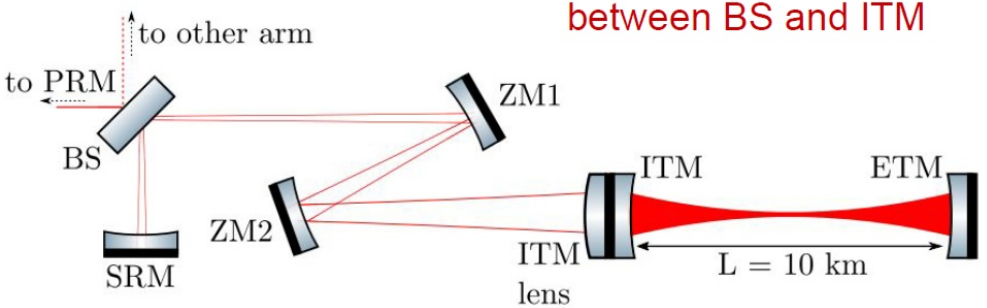
The design for ET - LF

Already published[1] and compatible.

Need some refinement to estimate the optical losses and astigmatism

Waist at the BS

Steering mirrors between BS and ITM

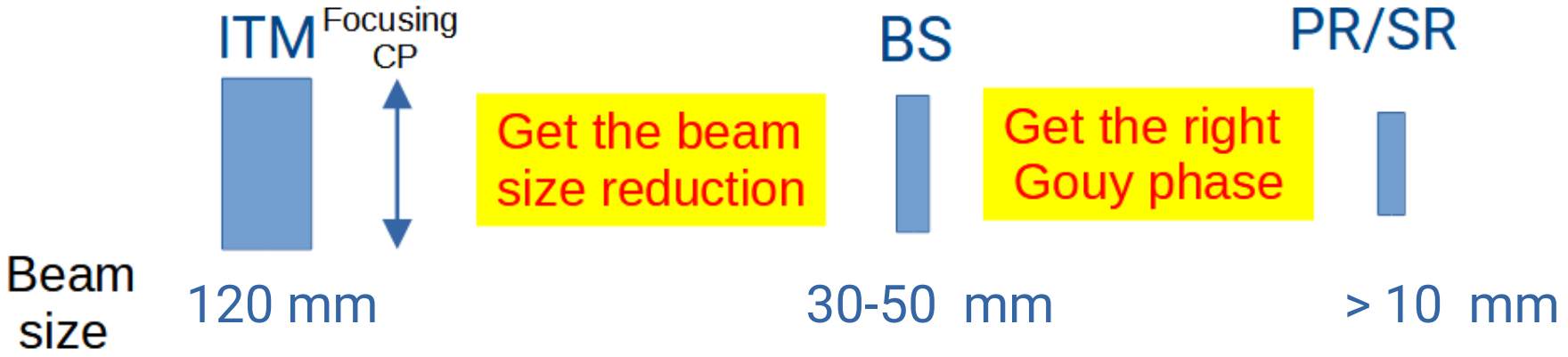


Compensation plate shaped like a lens

Optic		SRM	BS	ZM1	ZM2		
ROC [m]	LF	−9410	inf	−50	−82.5		
	HF	−630			−63.2		
Beam radius [mm]	LF	6.1	6.2	8.9	30		
	HF	6.3	6.4	8.3	38		
Space		SRM-BS	BS-ZM1	ZM1-ZM2	ZM2-1TM		
Length [m]	LF	10	70	50	52.5		
	HF			80			
Gouy phase [deg]	LF	7.5	39	5.3	0.6	Total accumulated	52
	HF	4.8	26	4.9	0.2	Gouy phase [deg]	36

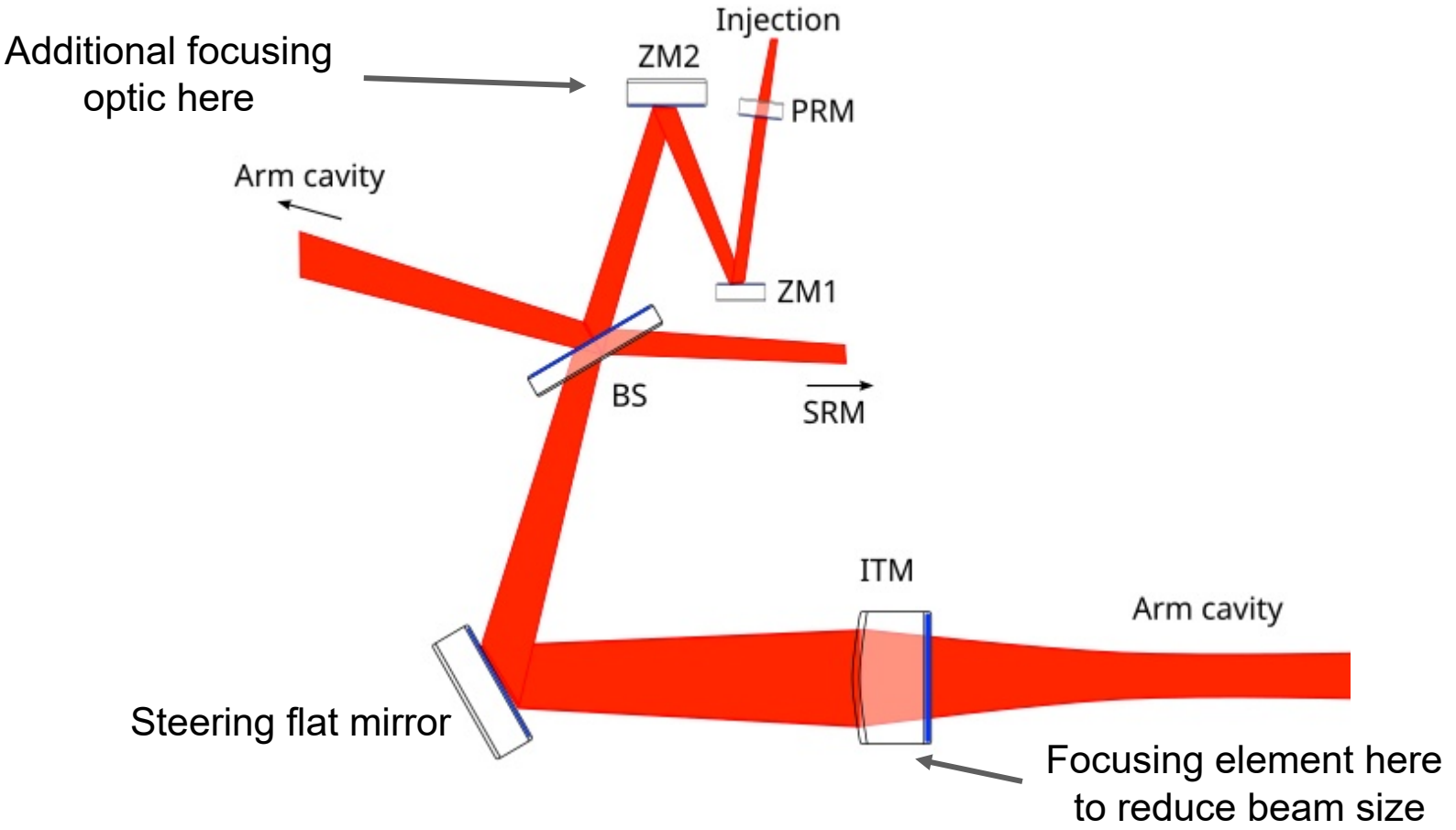
[1] doi

The approach for ET - HF



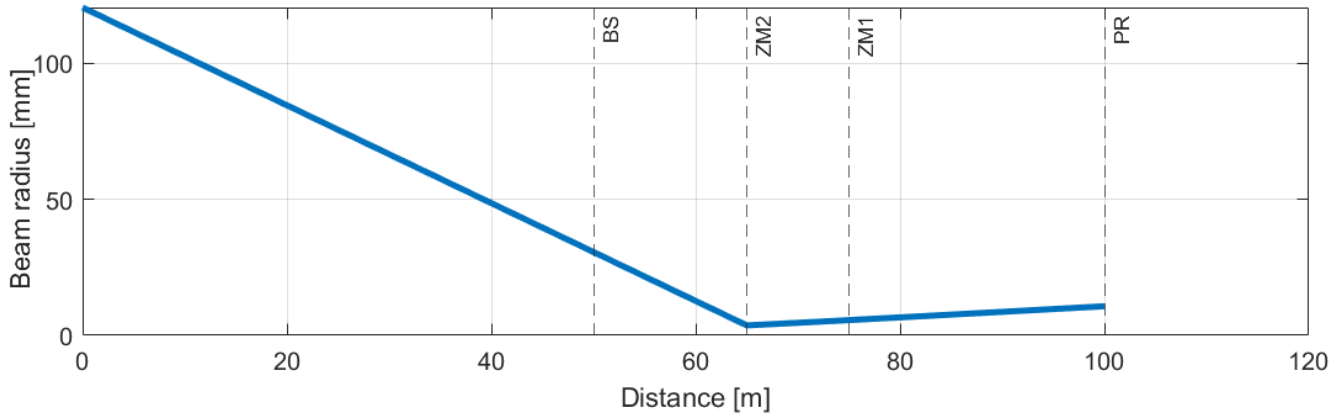
Typical difficulty: increasing the Gouy phase will decrease the beam size

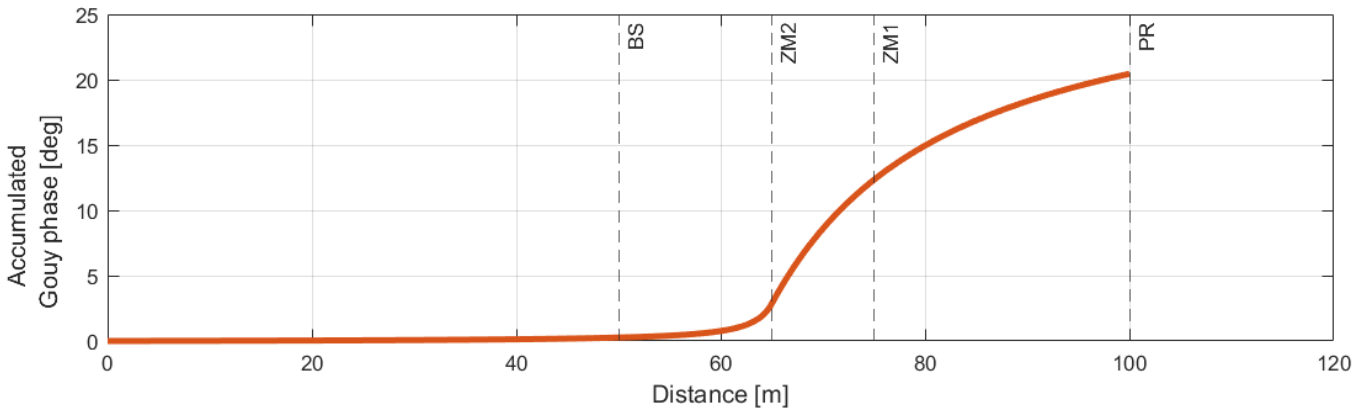
The approach for ET – HF, how it may look like



Beam evolution (ET-HF)

ITM





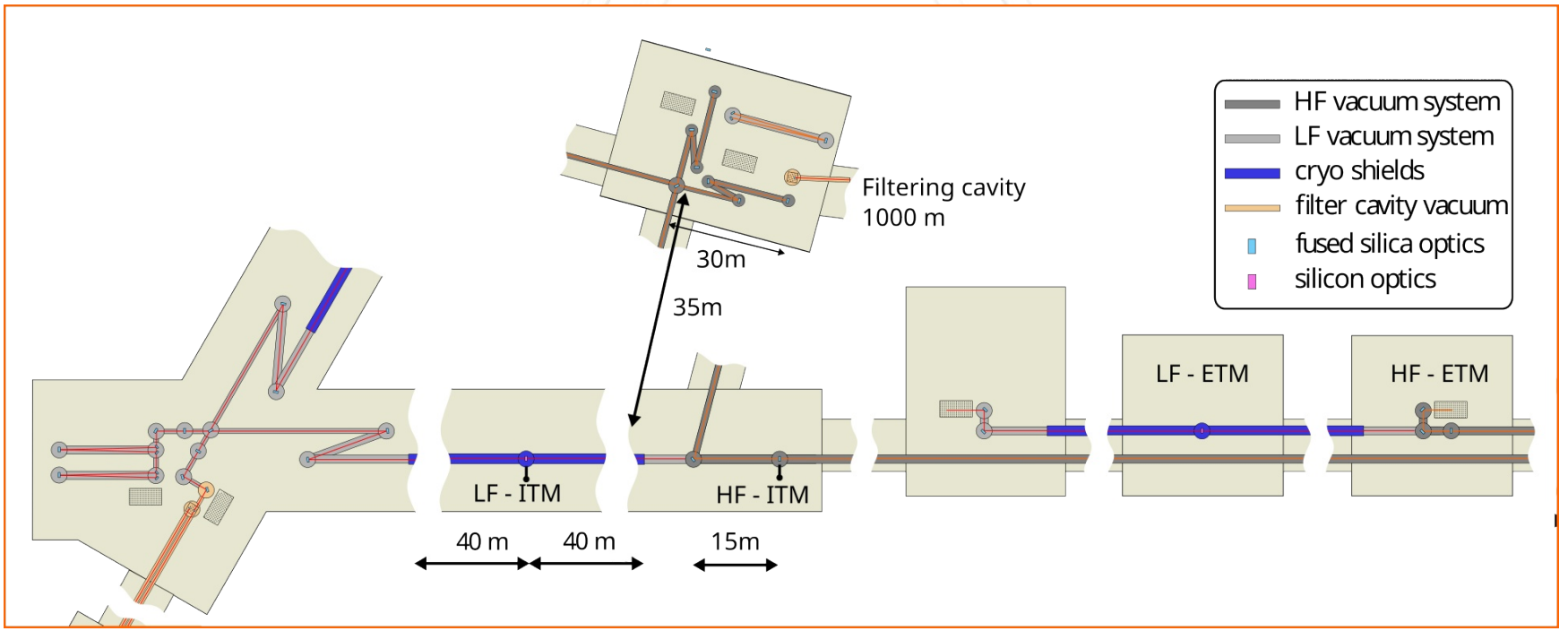
RoC_{ITM_AR} = 29.6 m

RoC_{ZM2} = -3.7 m

AoI_{ZM2} = 2.8°

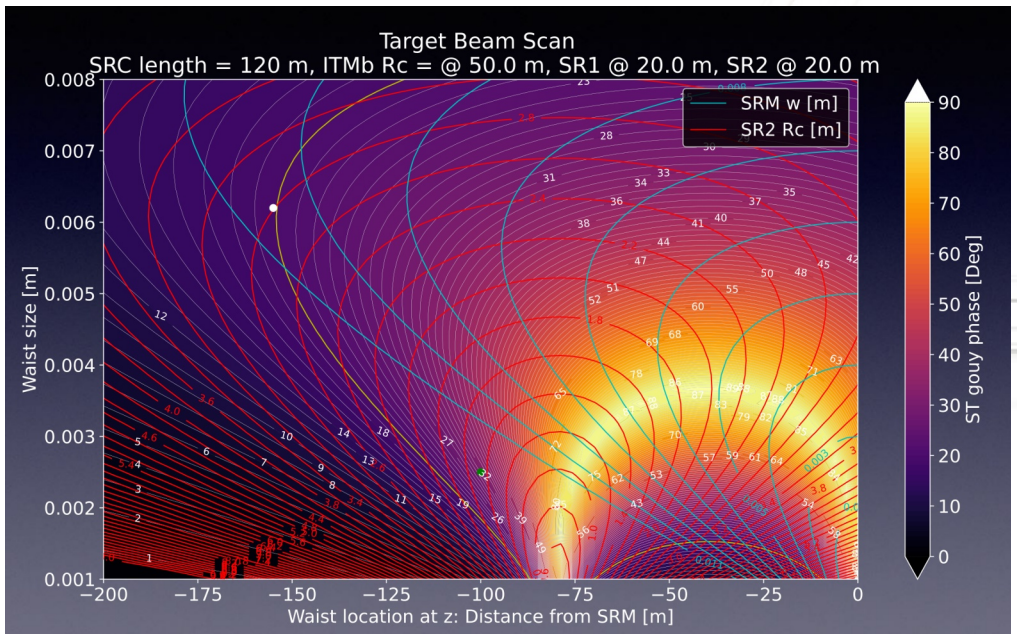
The updated proposed layout

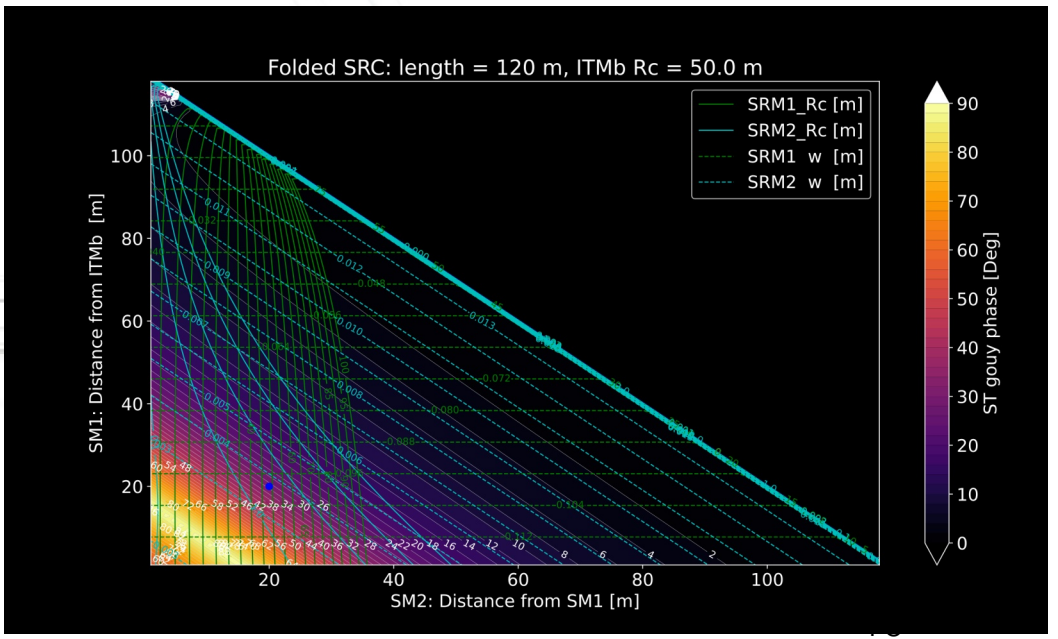
Design of the recycling cavities critical for the infrastructure and must include a long term vision (compatible with Advanced ET+)



Status of the design

- so far design only with the ABCD matrix, simple parameter scans
- currently: more systematic approach with 1-2 or 3 focusing elements:





The short term work: consolidate the design

- compared configurations, looking for the best robustness
- more advanced simulations with aberration (FFT, modal expansion), how to compensate cold and hot distortions ?
- work on the control scheme (impact of longer arms, higher finesse)
- confirmed PyGWinc quantum noise level with realistic losses, imperfections
- check for pick-off beams (in 3D), ghost beams