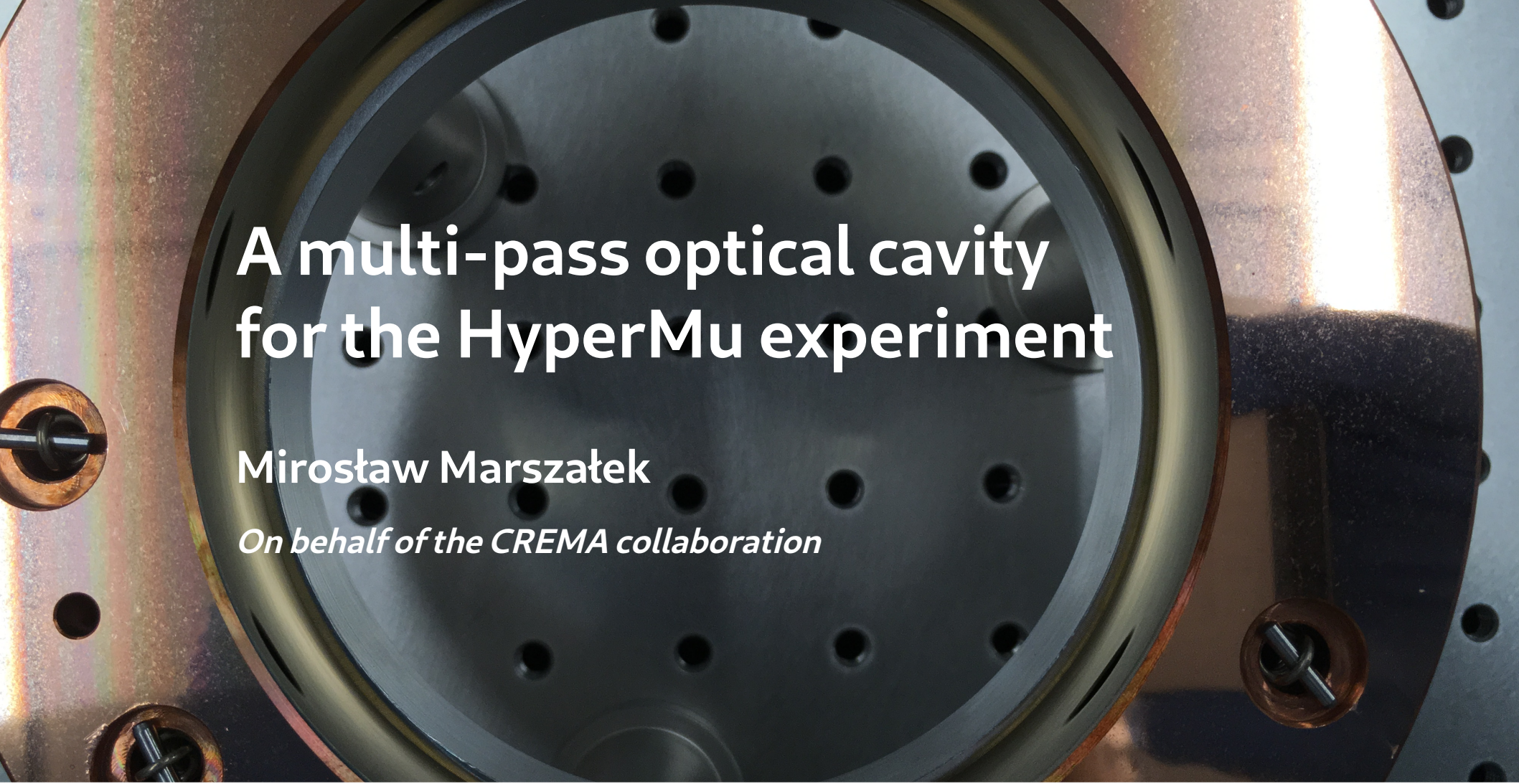


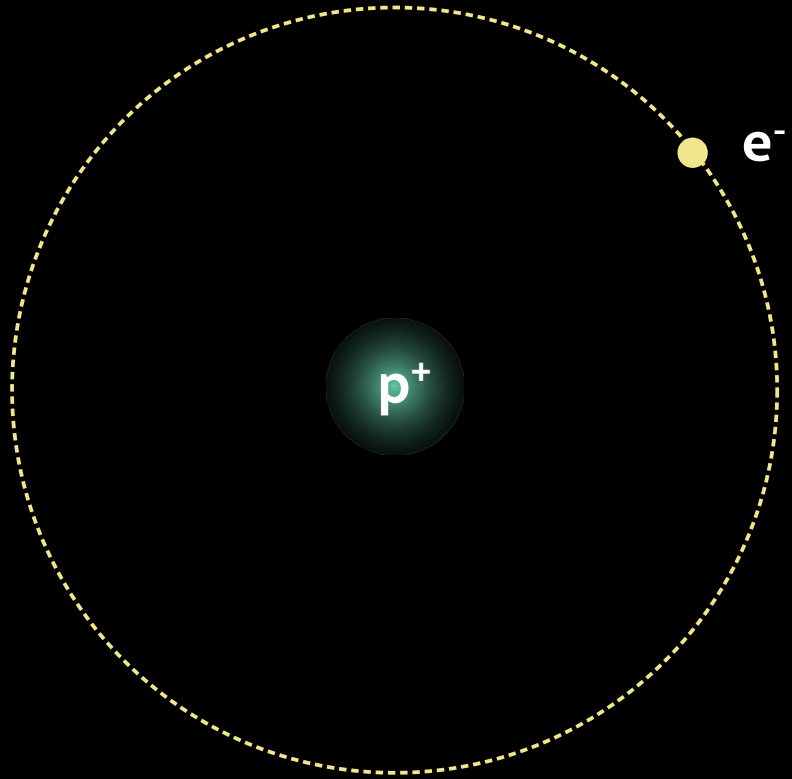
A multi-pass optical cavity for the HyperMu experiment

Mirosław Marszałek

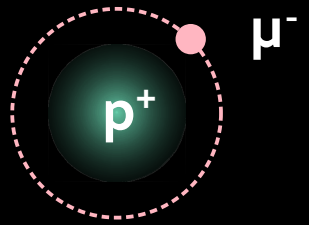
On behalf of the CREMA collaboration

10 Oct 2019, Zurich PhD Seminar 2019

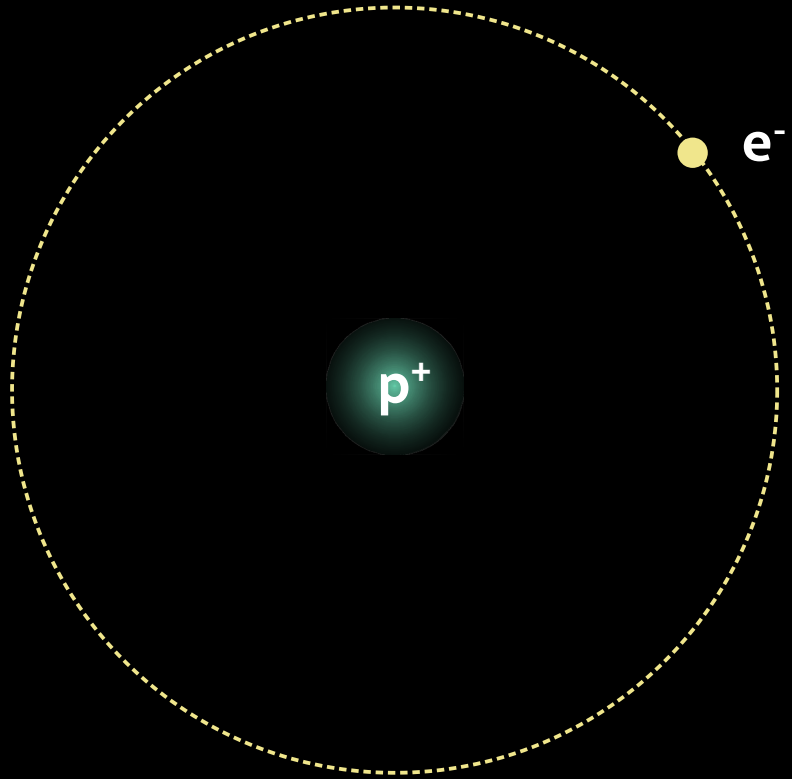
Electronic hydrogen



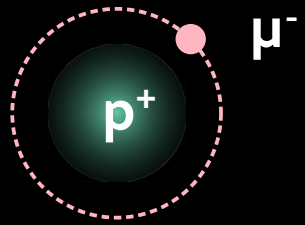
Muonic hydrogen



Electronic hydrogen



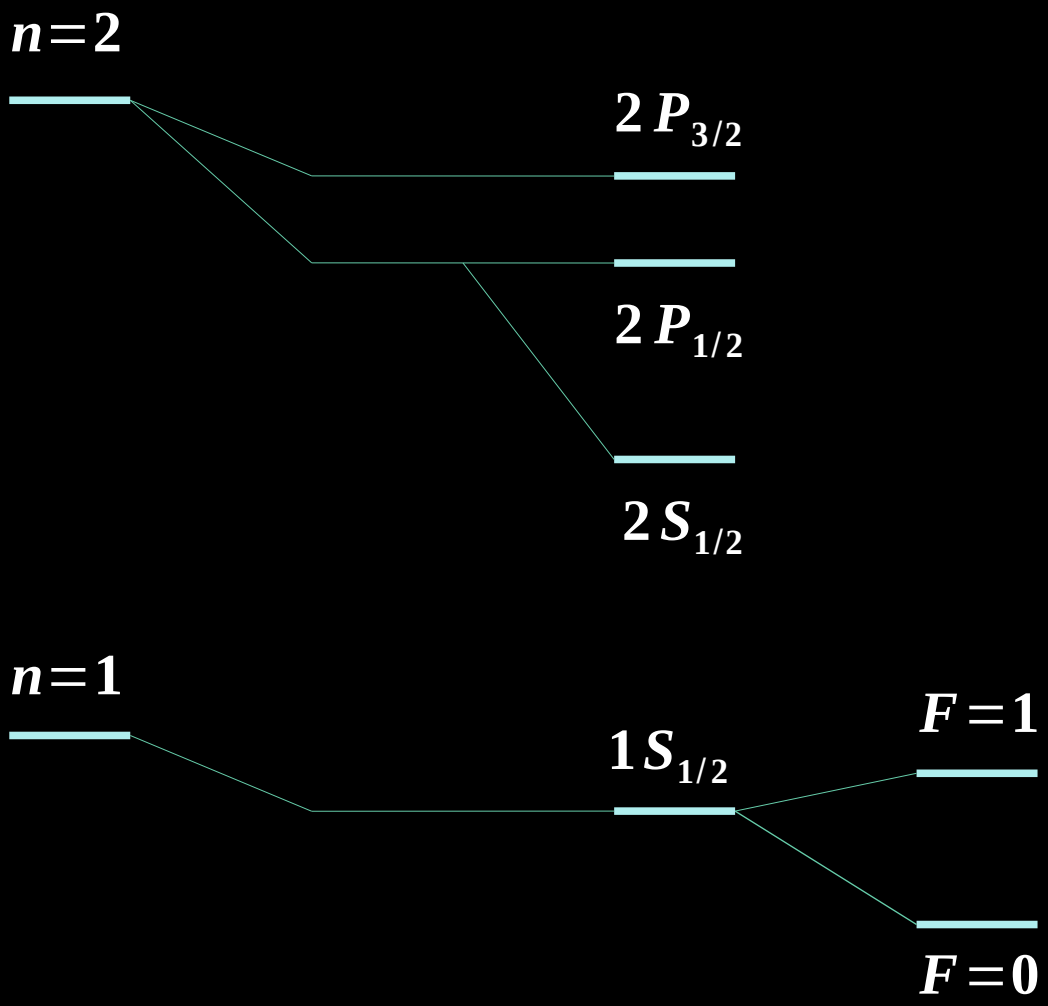
Muonic hydrogen

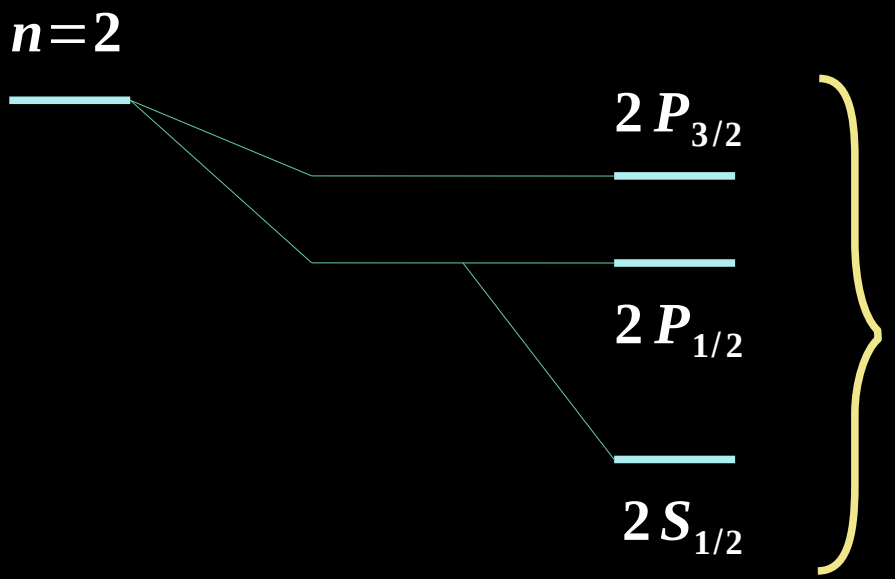


$$\Delta E \propto \left|\Psi(0)\right|^2 \propto m_r^3$$

$$m_\mu \approx 200\, m_e$$

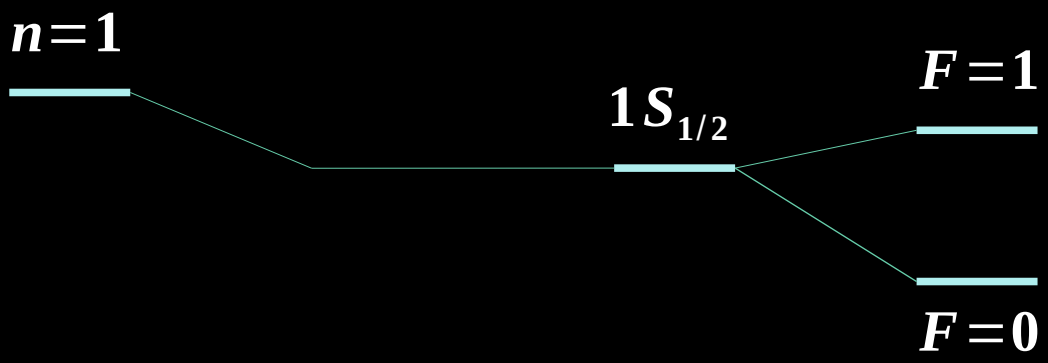
$$\Delta E_\mu \sim 10^7 \Delta E_e$$

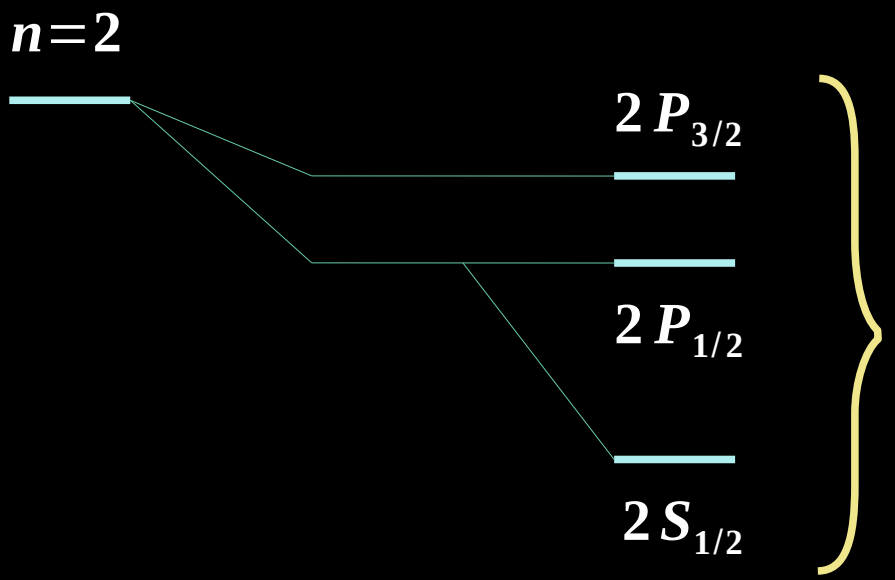

$n=2$
$2P_{3/2}$
$2P_{1/2}$
$2S_{1/2}$
$n=1$
$1S_{1/2}$
$F=1$
$F=0$



Lamb shift → charge radius

Pohl et al., Nature 466, 213 (2010)
Antognini et al., Science 339, 417 (2013)





Lamb shift → charge radius

Pohl et al., Nature 466, 213 (2010)
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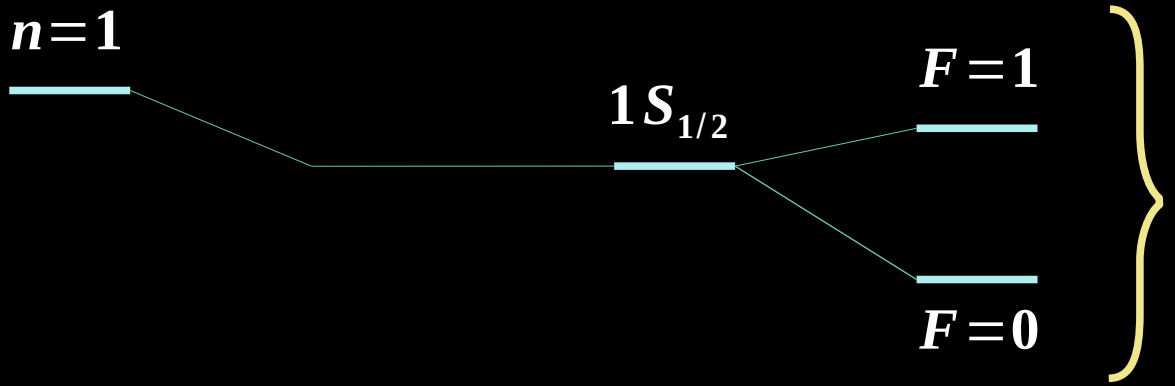
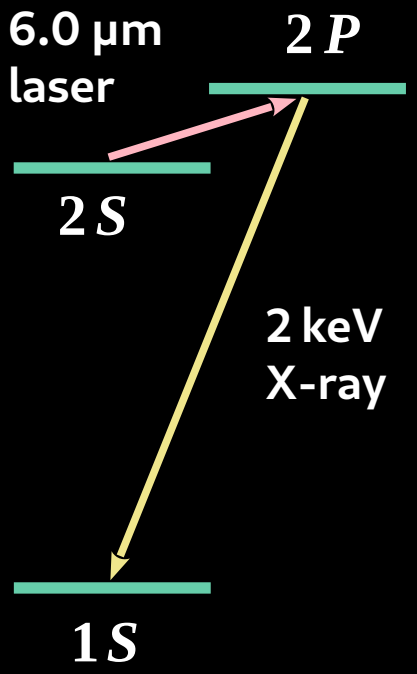


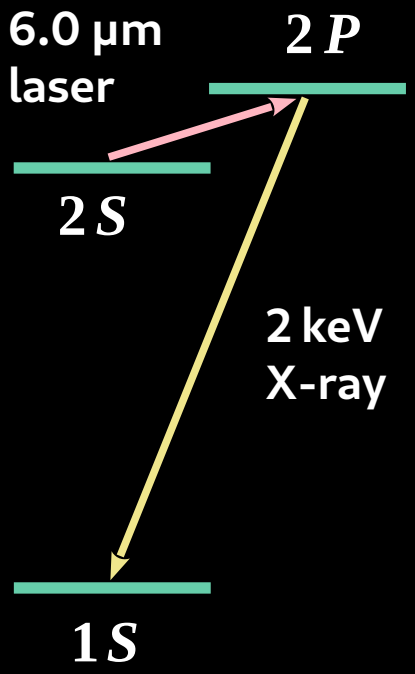
HFS → Zemach radius

In progress!

Lamb shift

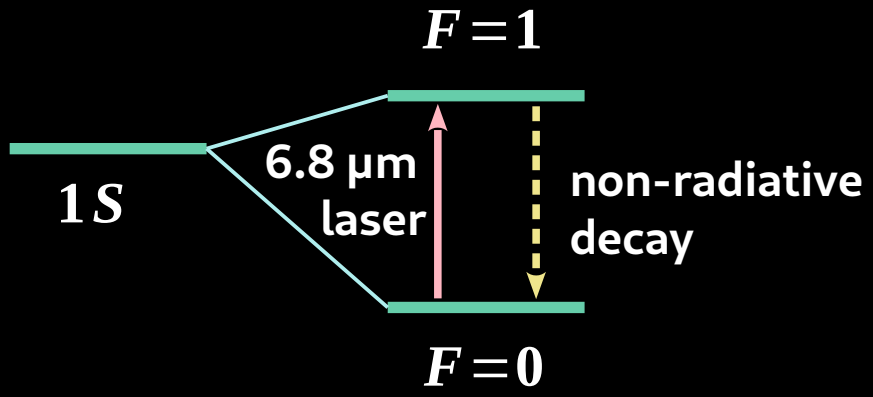


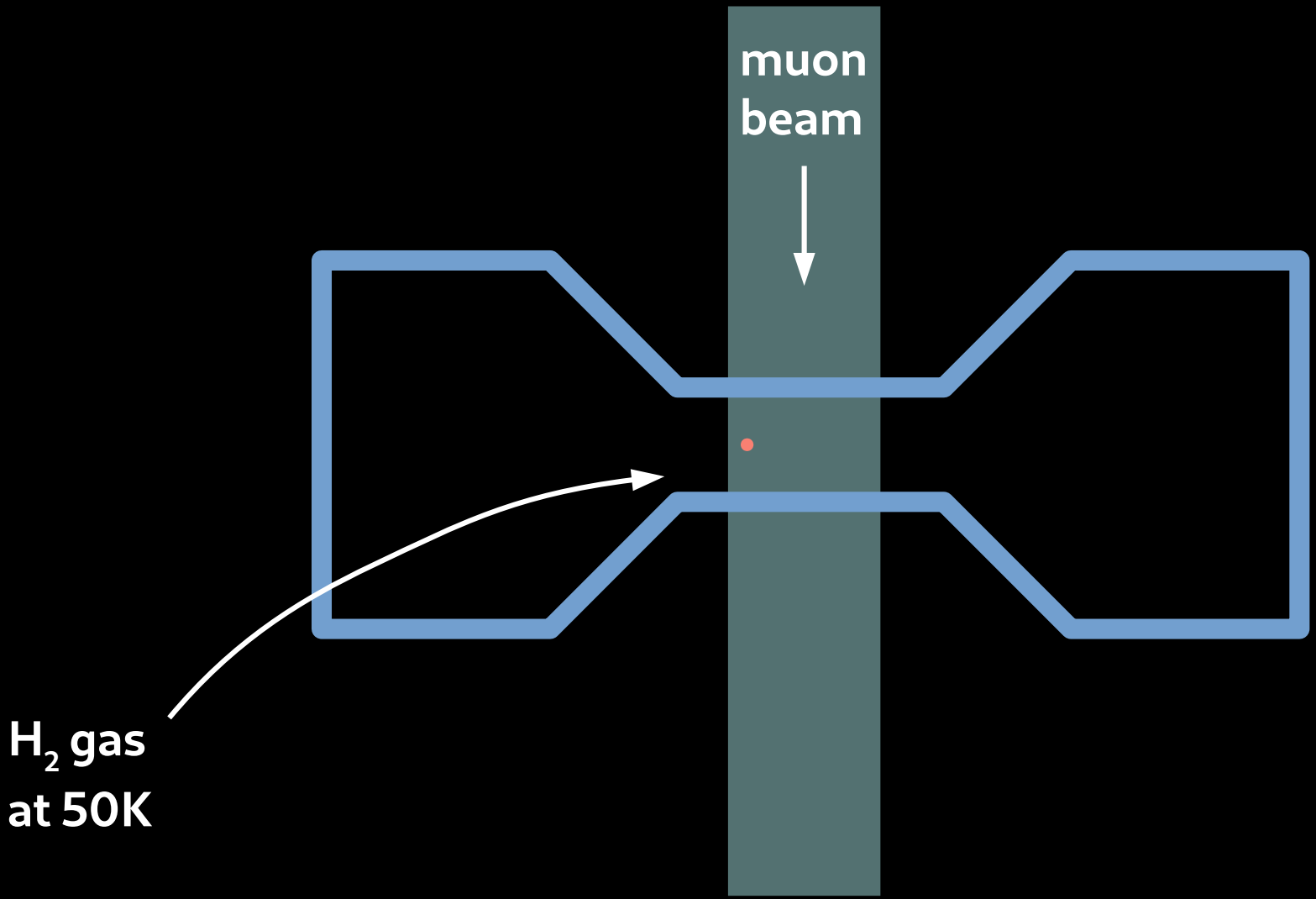
Lamb shift

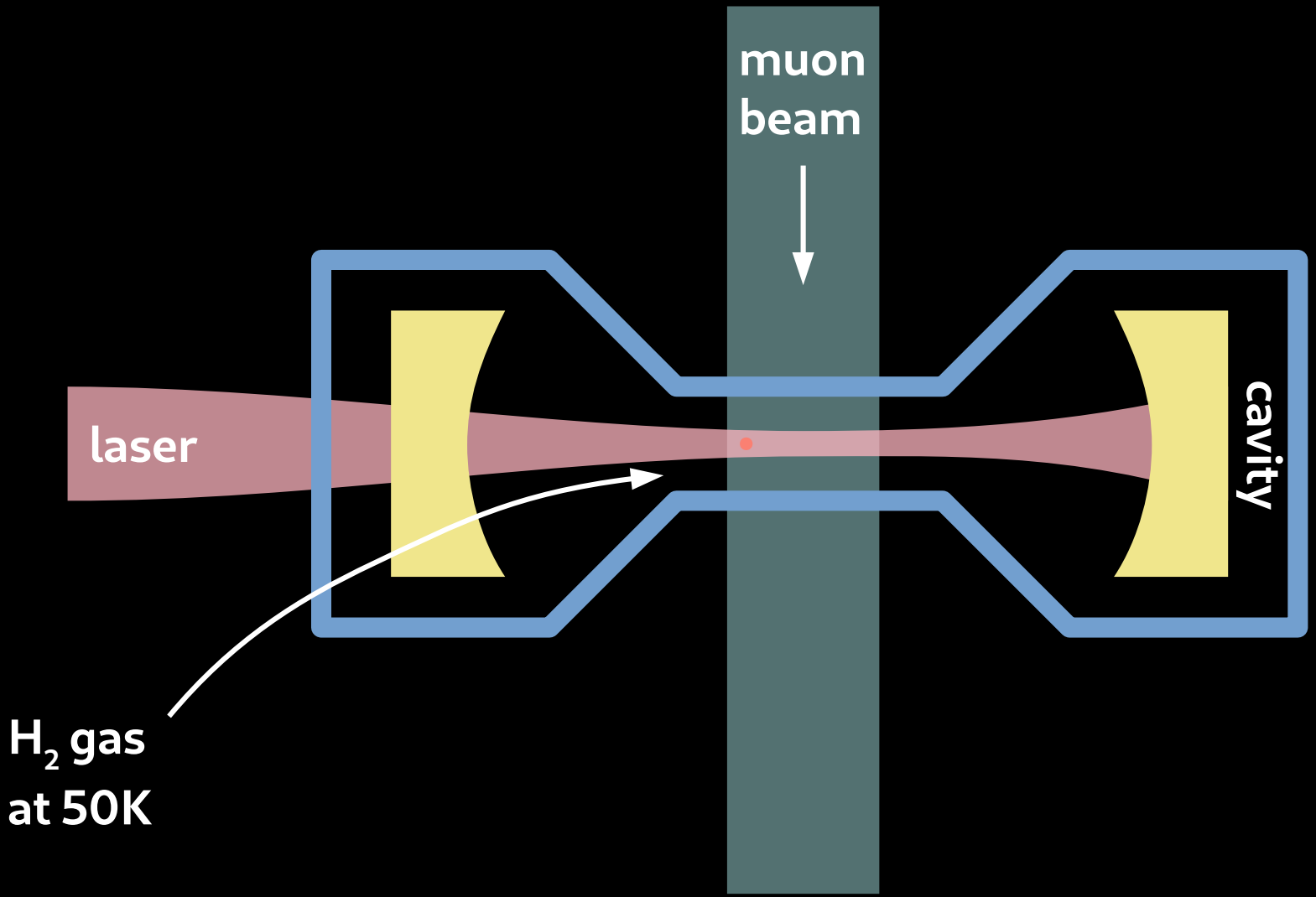


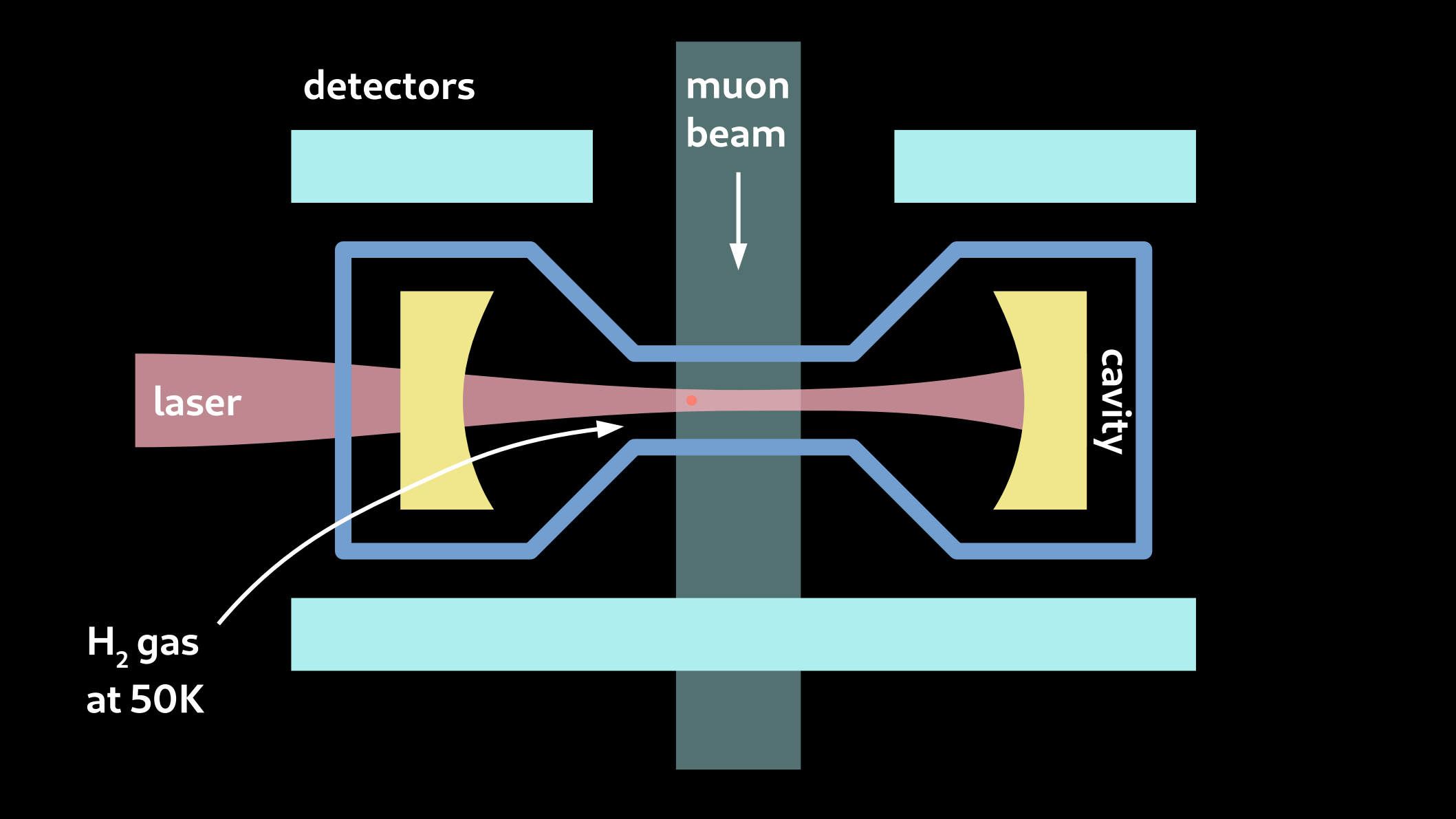
Hyperfine splitting

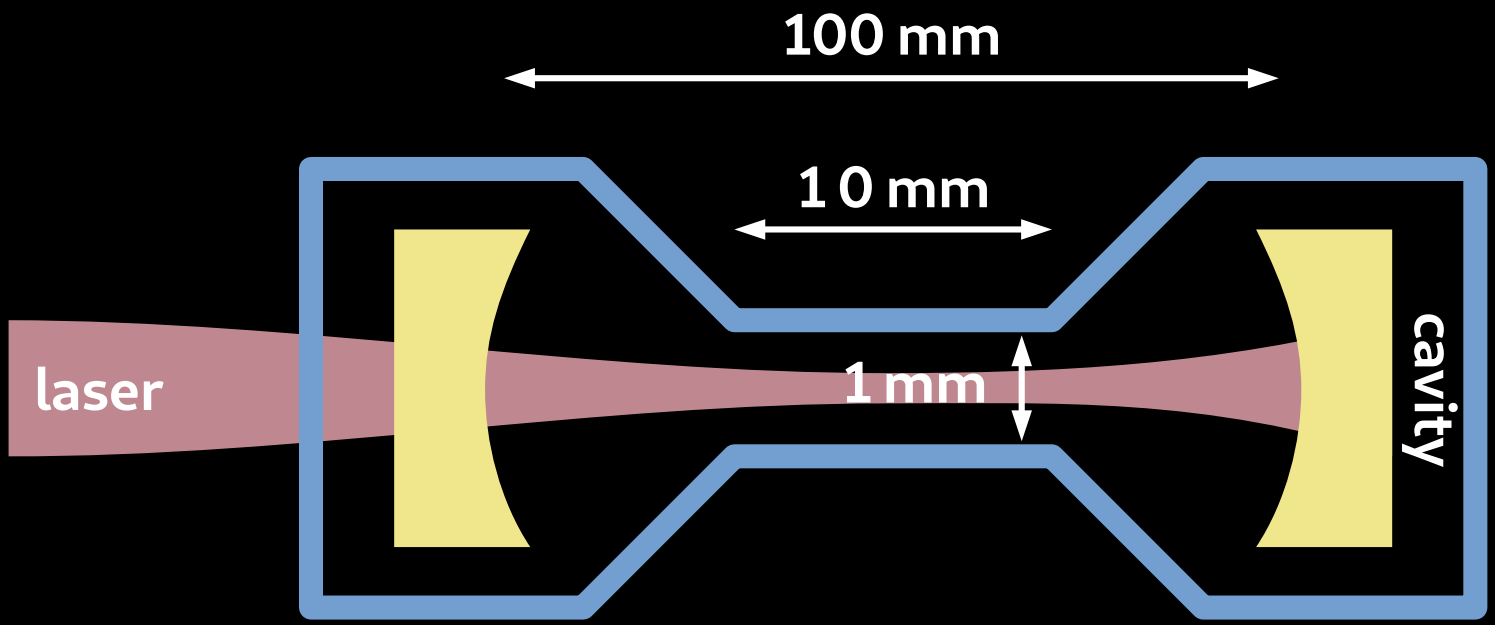
- Magnetic dipole transition
- No emitted photon




muon
beam
H_2 gas
at 50K

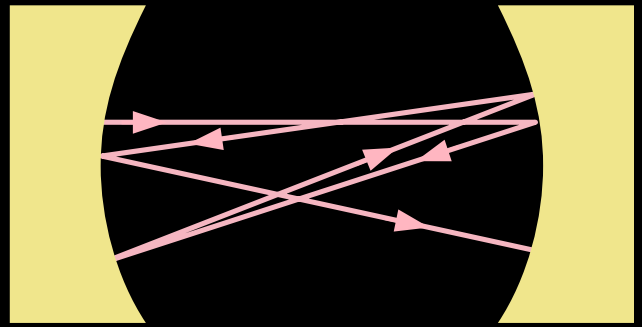

muon
beam
laser
cavity
H_2 gas
at 50K


detectors
muon beam
laser
cavity
H_2 gas at 50K

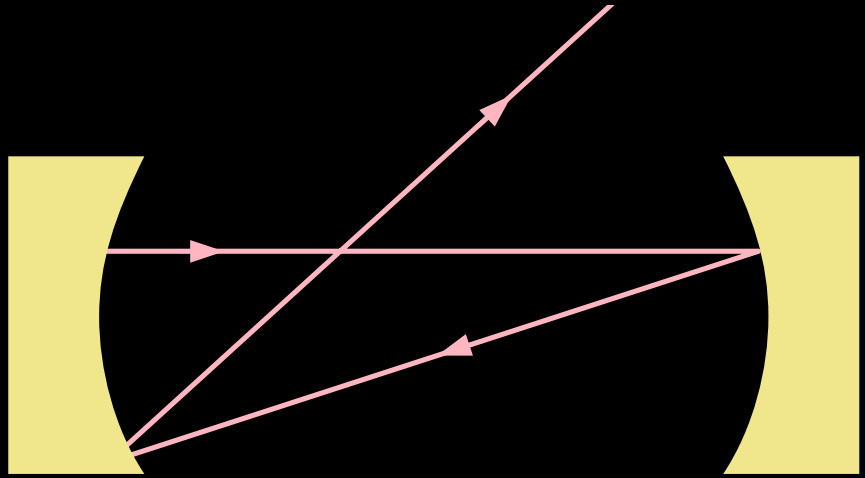


- Operation at 50 K
- Large illuminated volume
- Large laser fluence required (2 J/cm^2)
- ~500 reflections through a 1 mm gap

Stable vs. Unstable

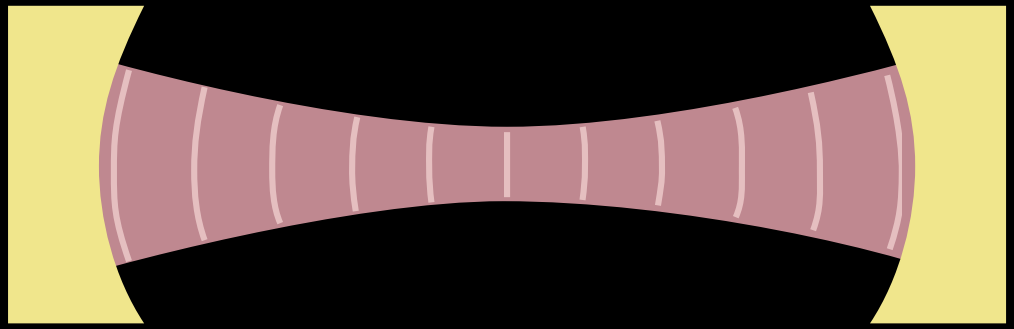


$L < 2R$



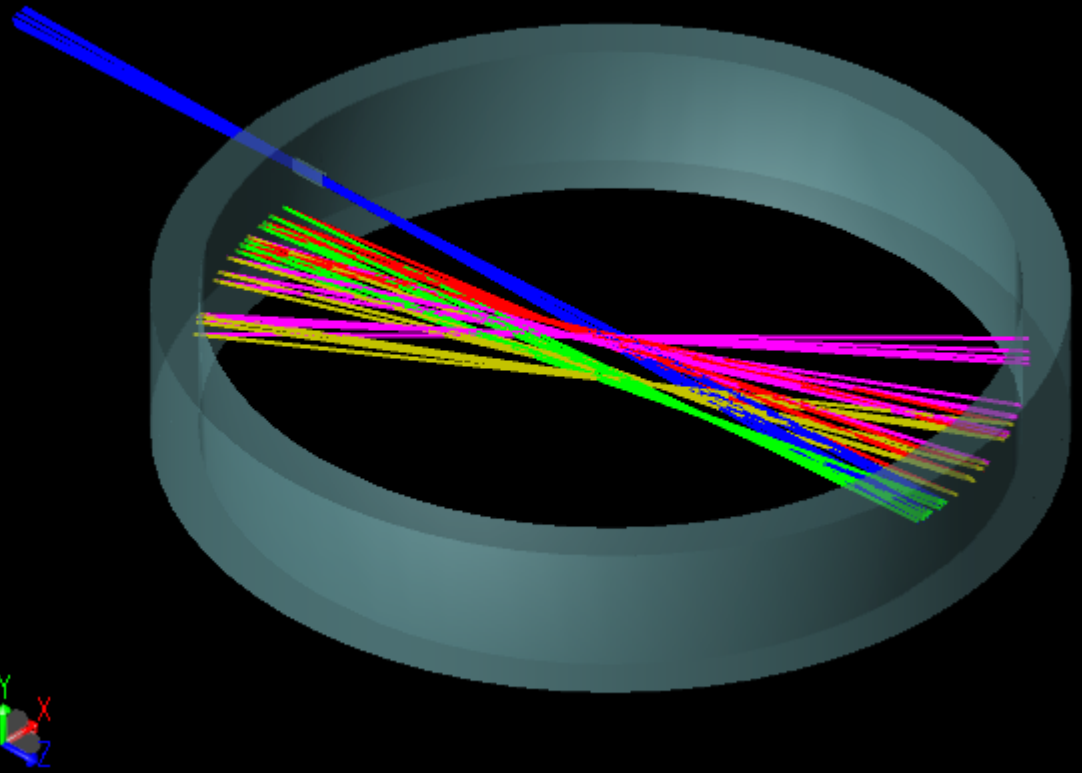
$L \geqslant 2R$

Resonant

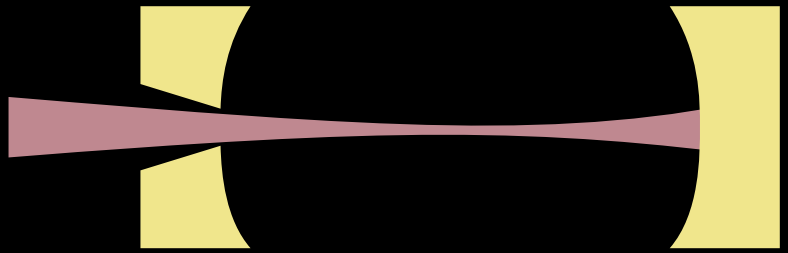


$$R = \frac{L}{2}\left[1 + \left(\frac{\frac{\pi w_0^2}{\lambda}}{L/2}\right)^2\right]$$

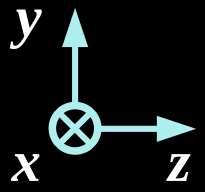
Design No. 1.

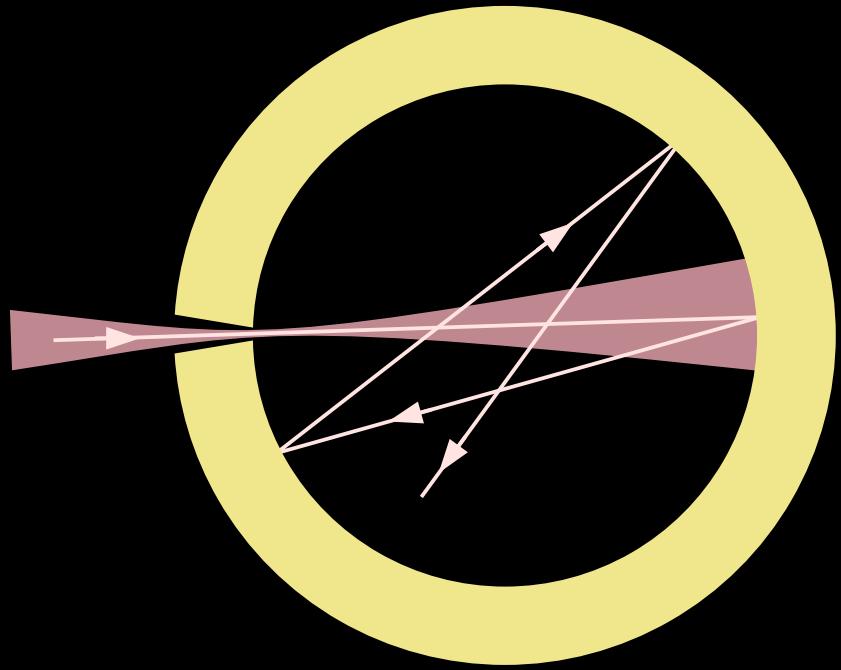


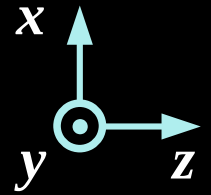
Design No. 1.



$L < 2\,R_y$

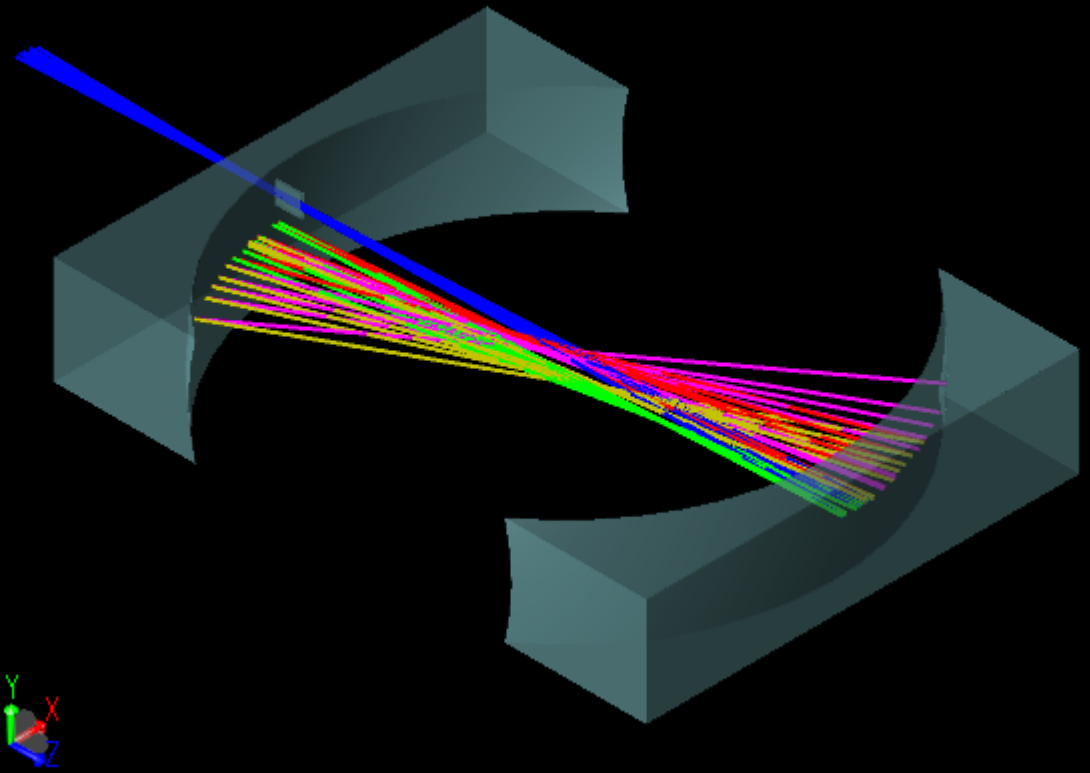




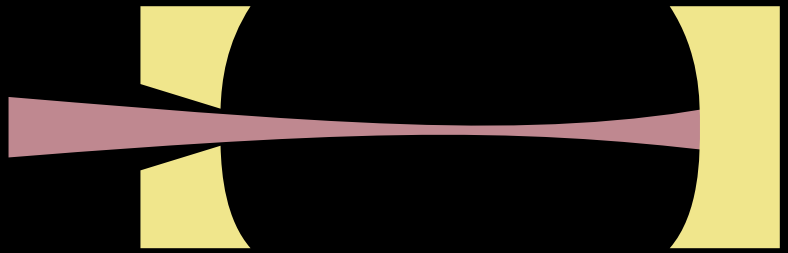


$L = 2\,R_x$

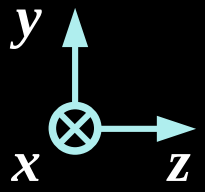
Design No. 2.

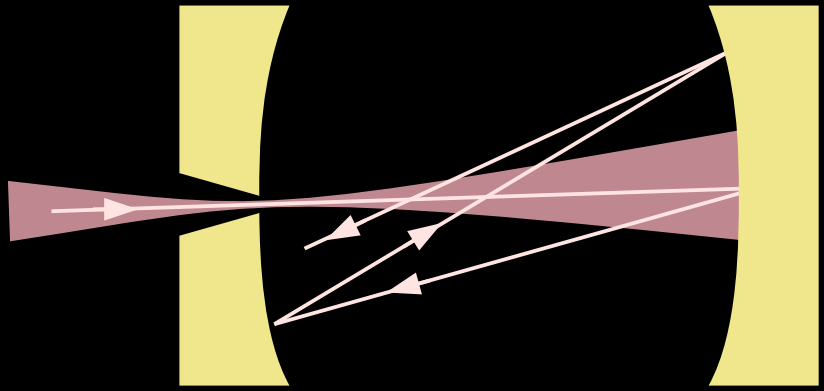


Design No. 2.

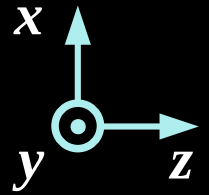


$L < 2\,R_y$

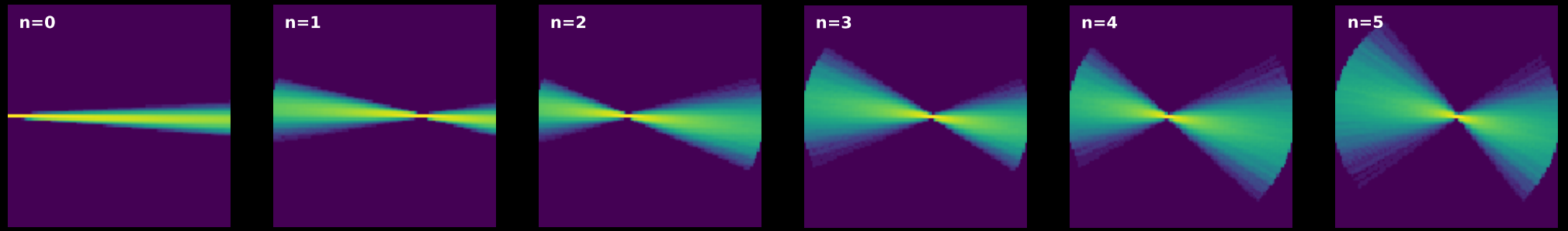




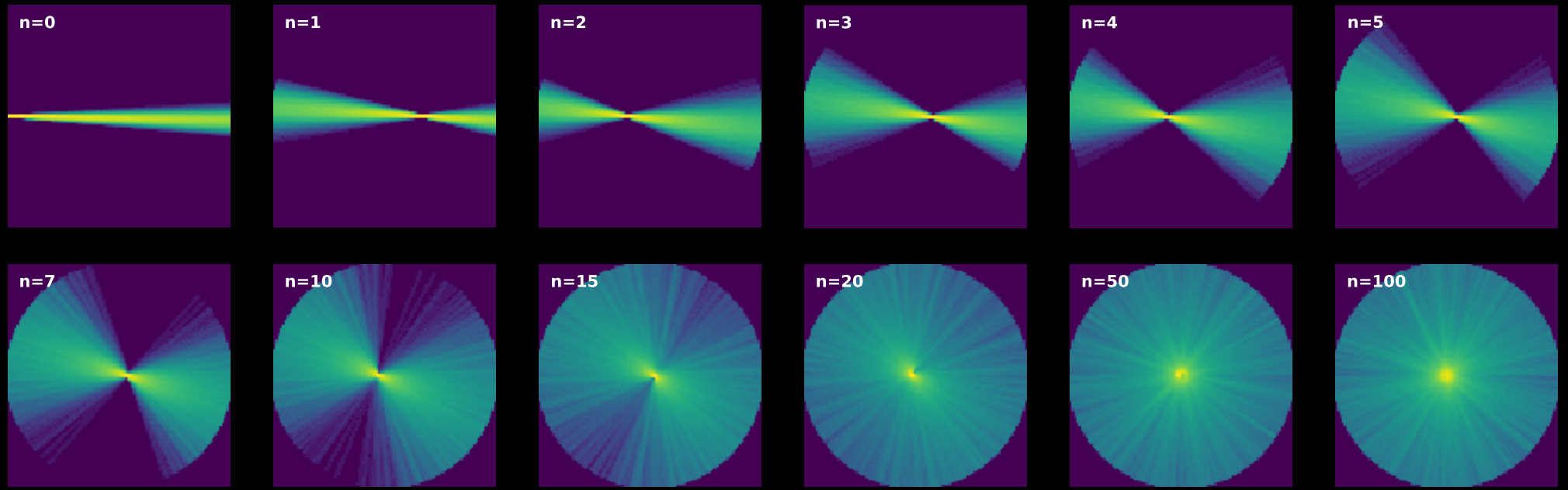
$L < 2\,R_x$

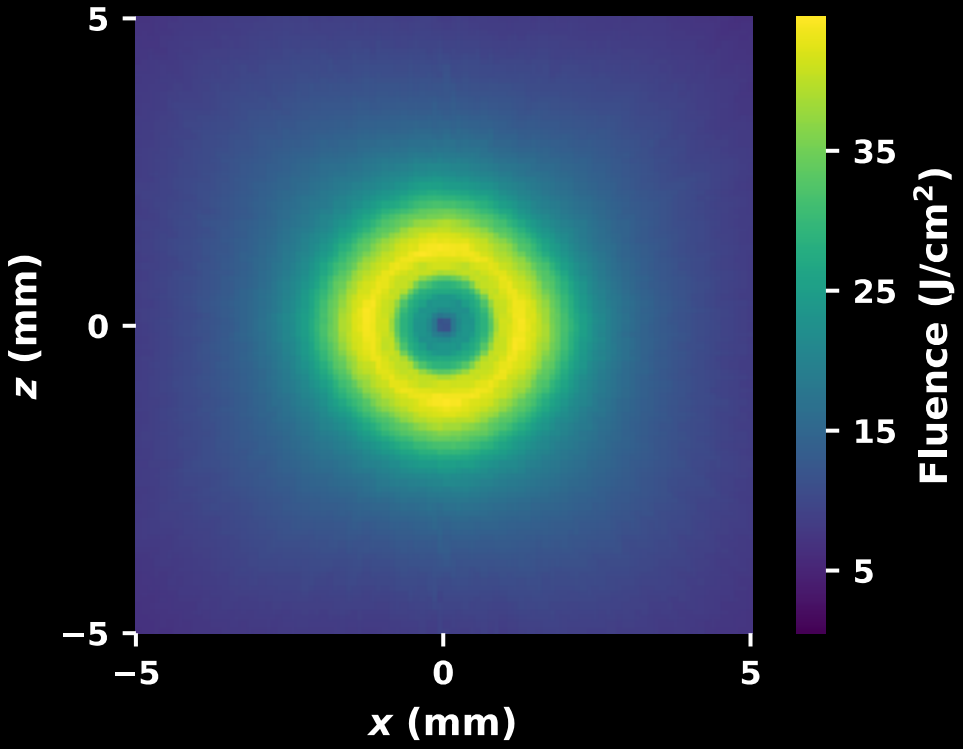


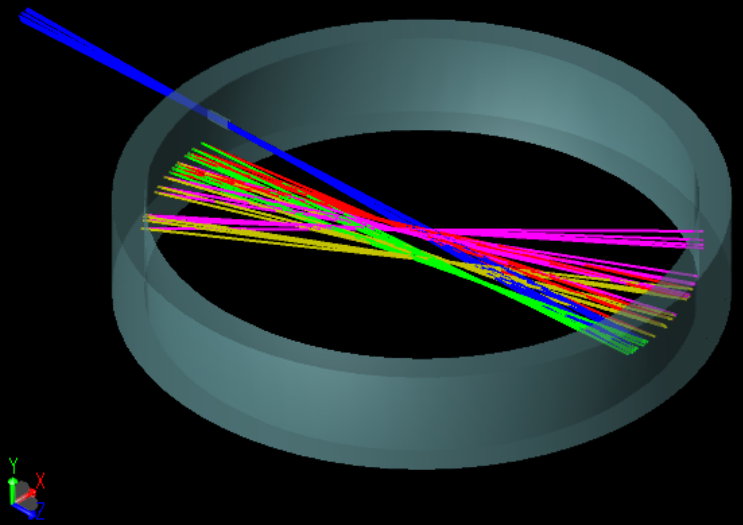
Ray tracing

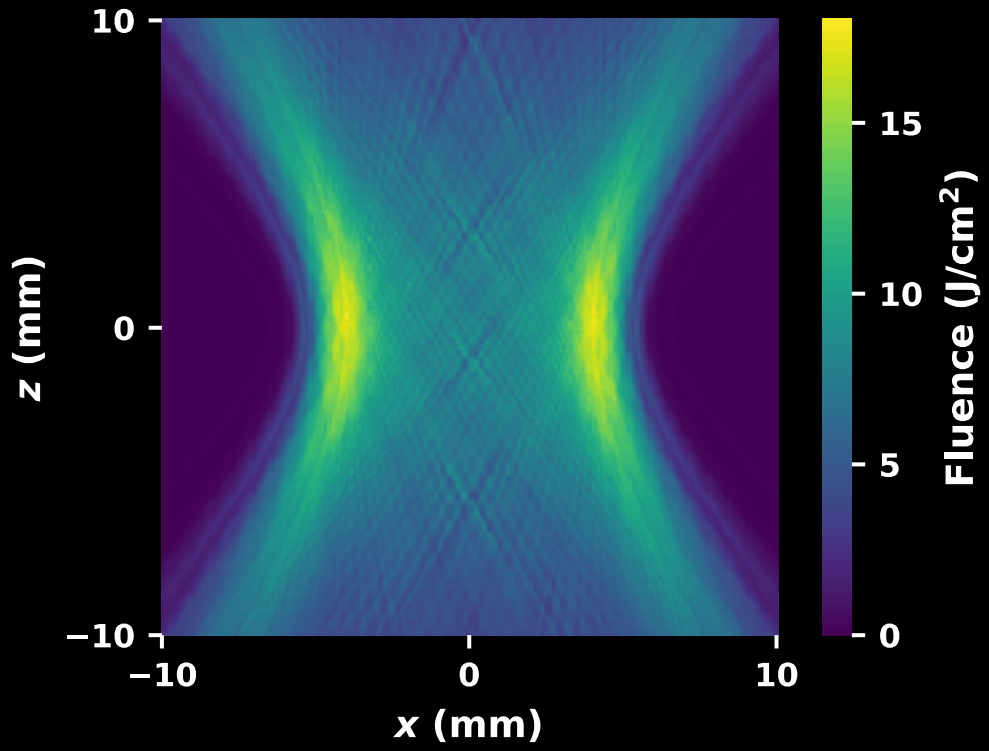


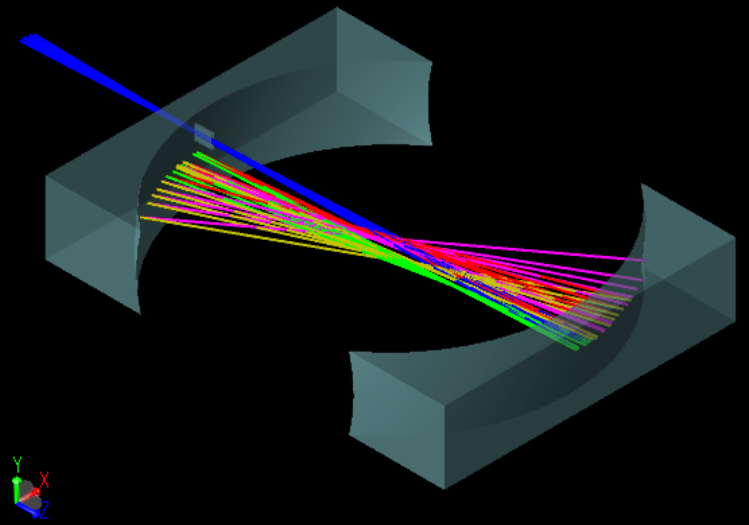
Ray tracing

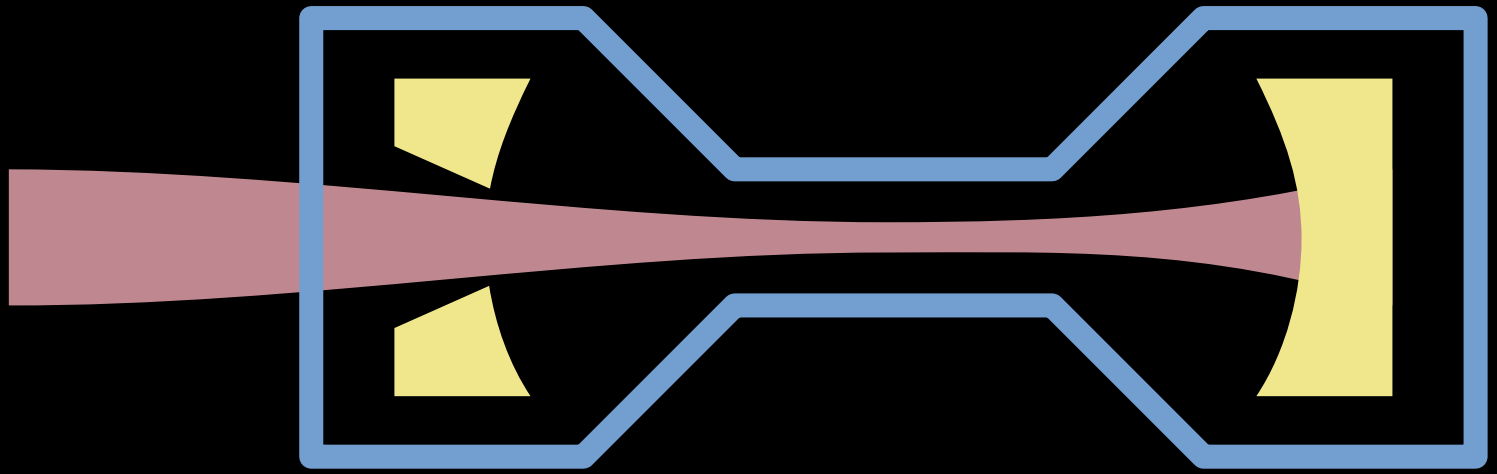


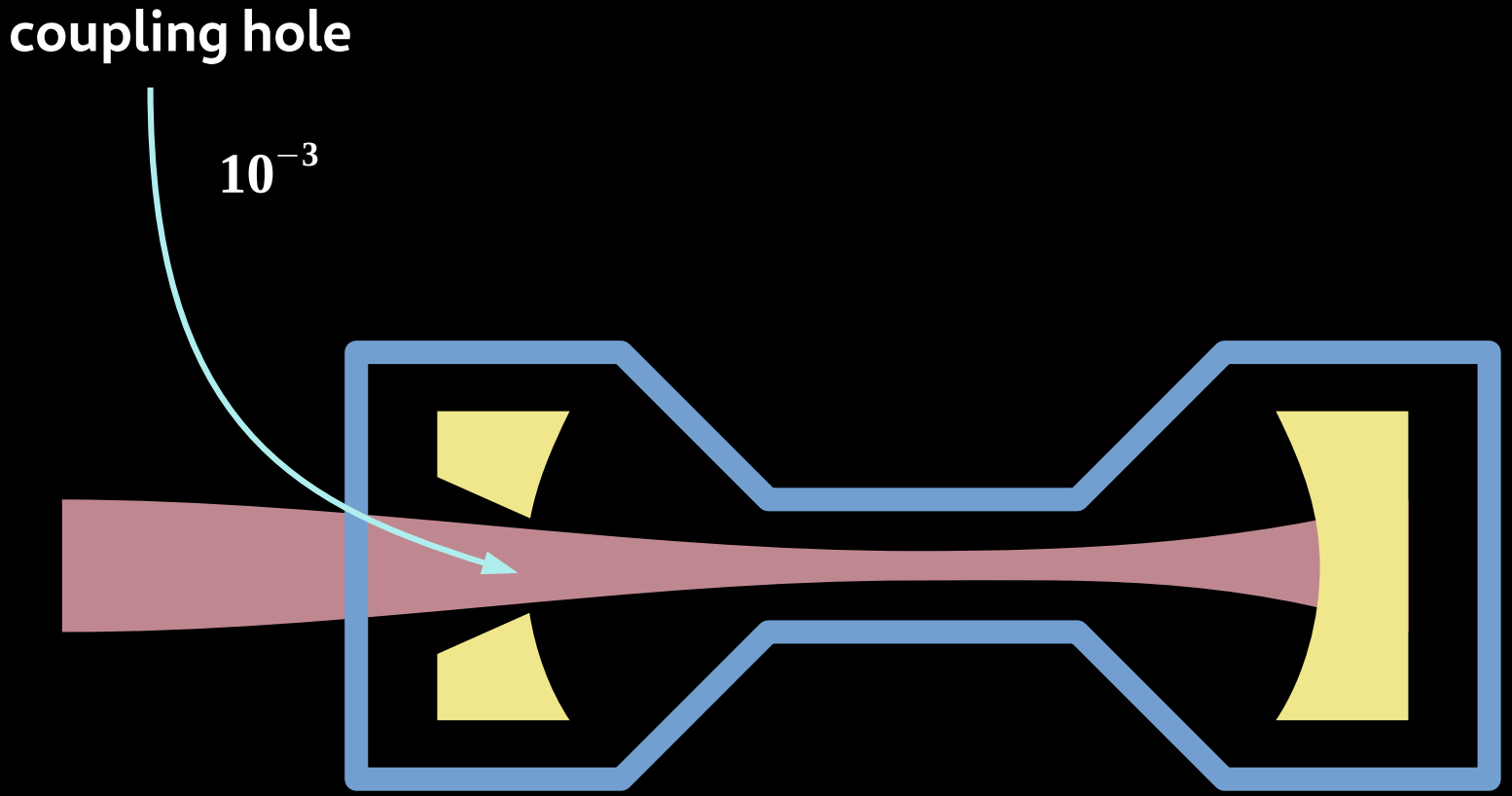

5
0
−5
z (mm)
−5
0
5
x (mm)
35
25
15
5
Fluence (J/cm²)

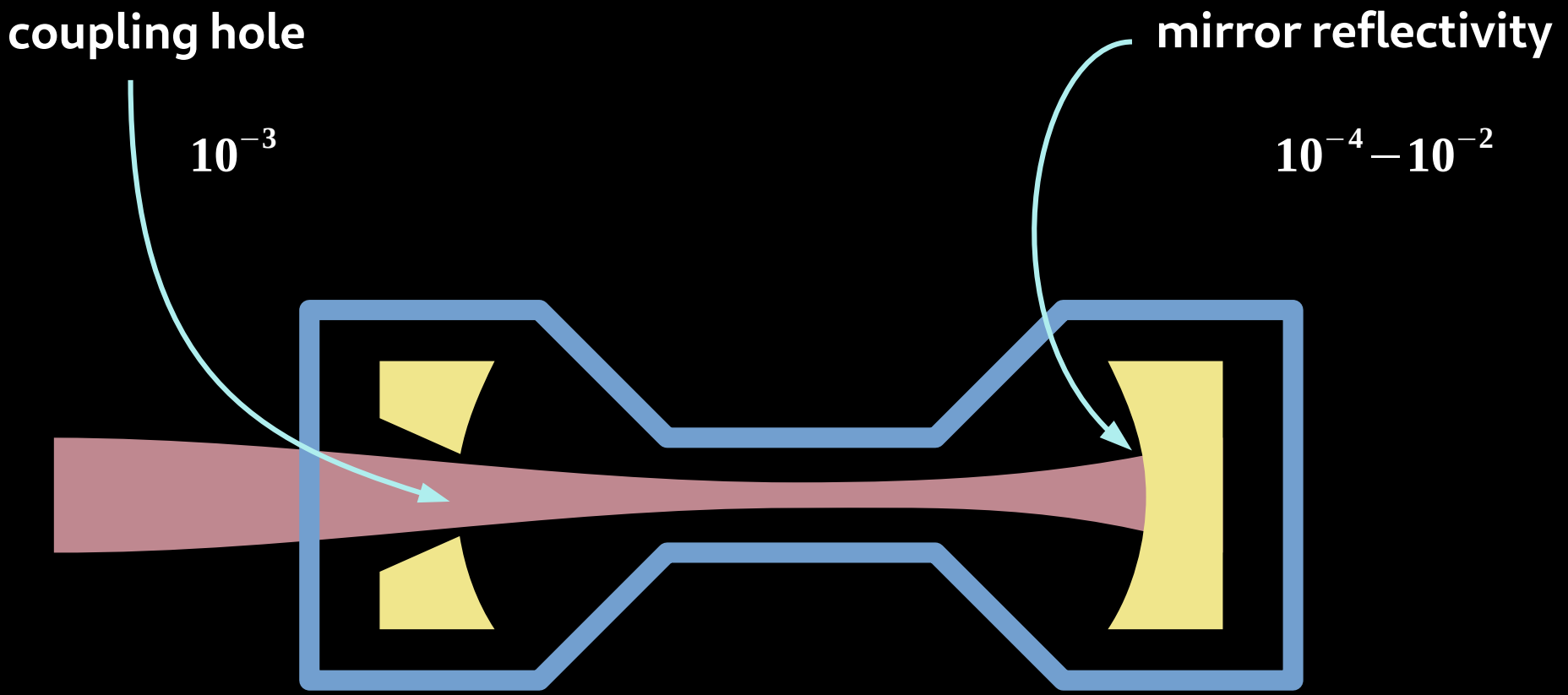

Y
X
Z

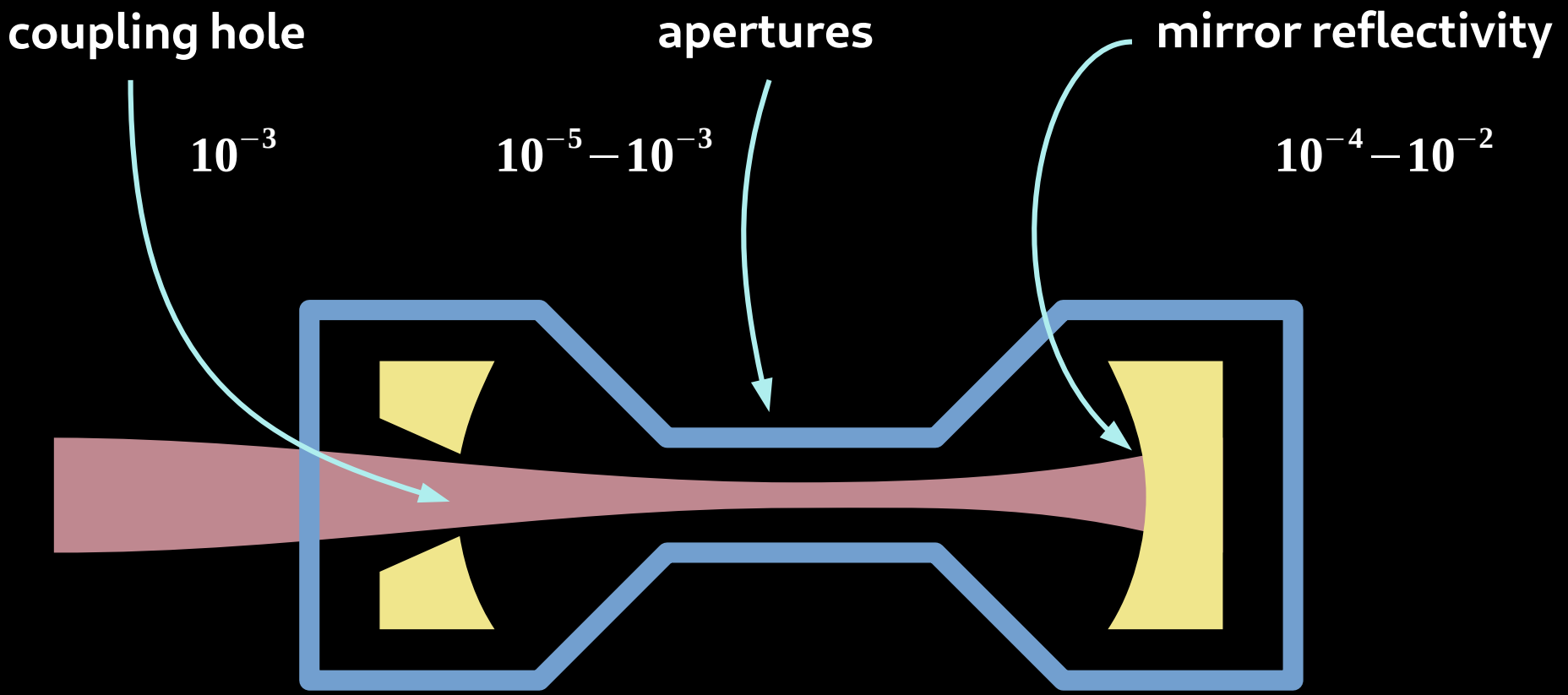

10
0
−10
z (mm)
−10
0
10
x (mm)
15
10
5
0
Fluence (J/cm²)

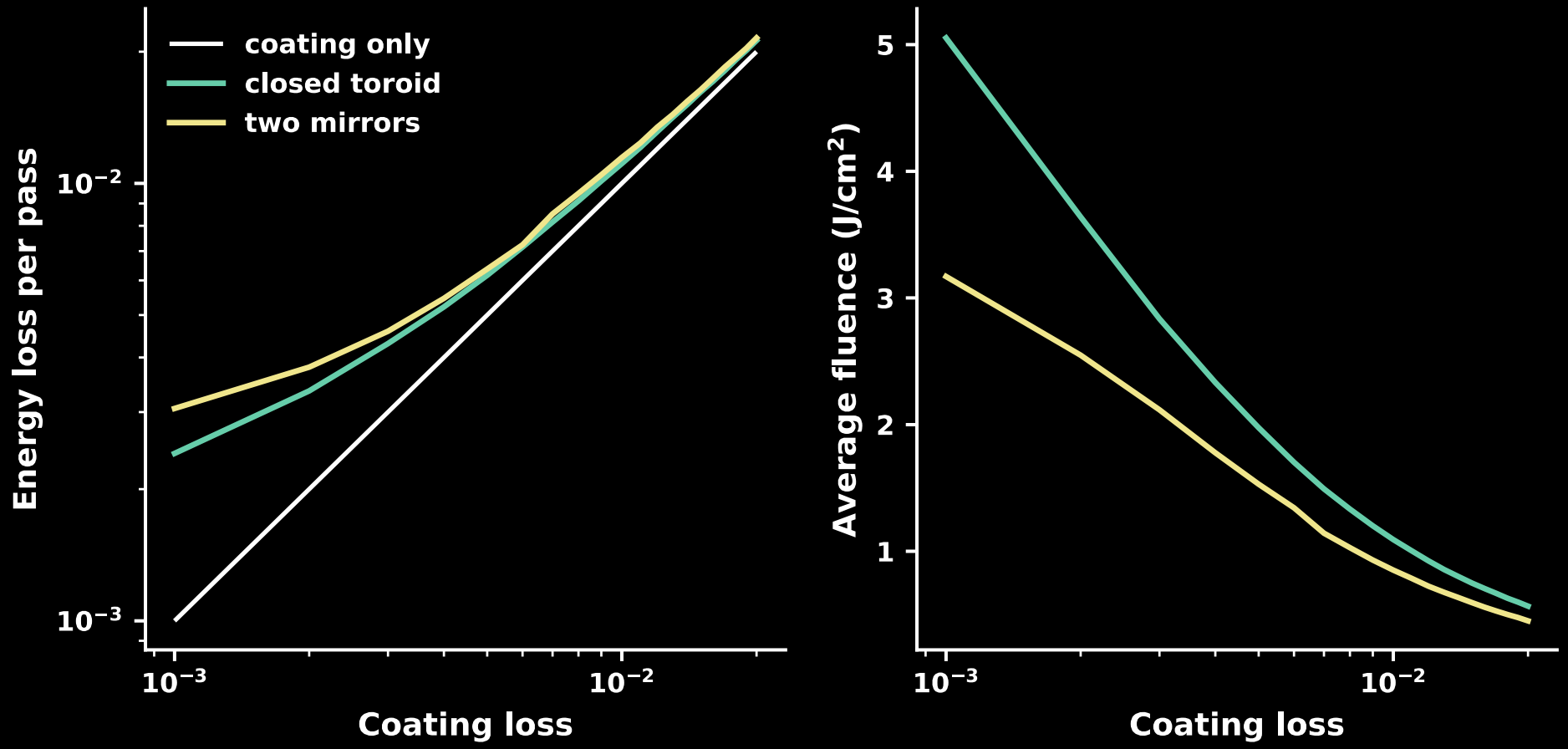

Y
X
Z

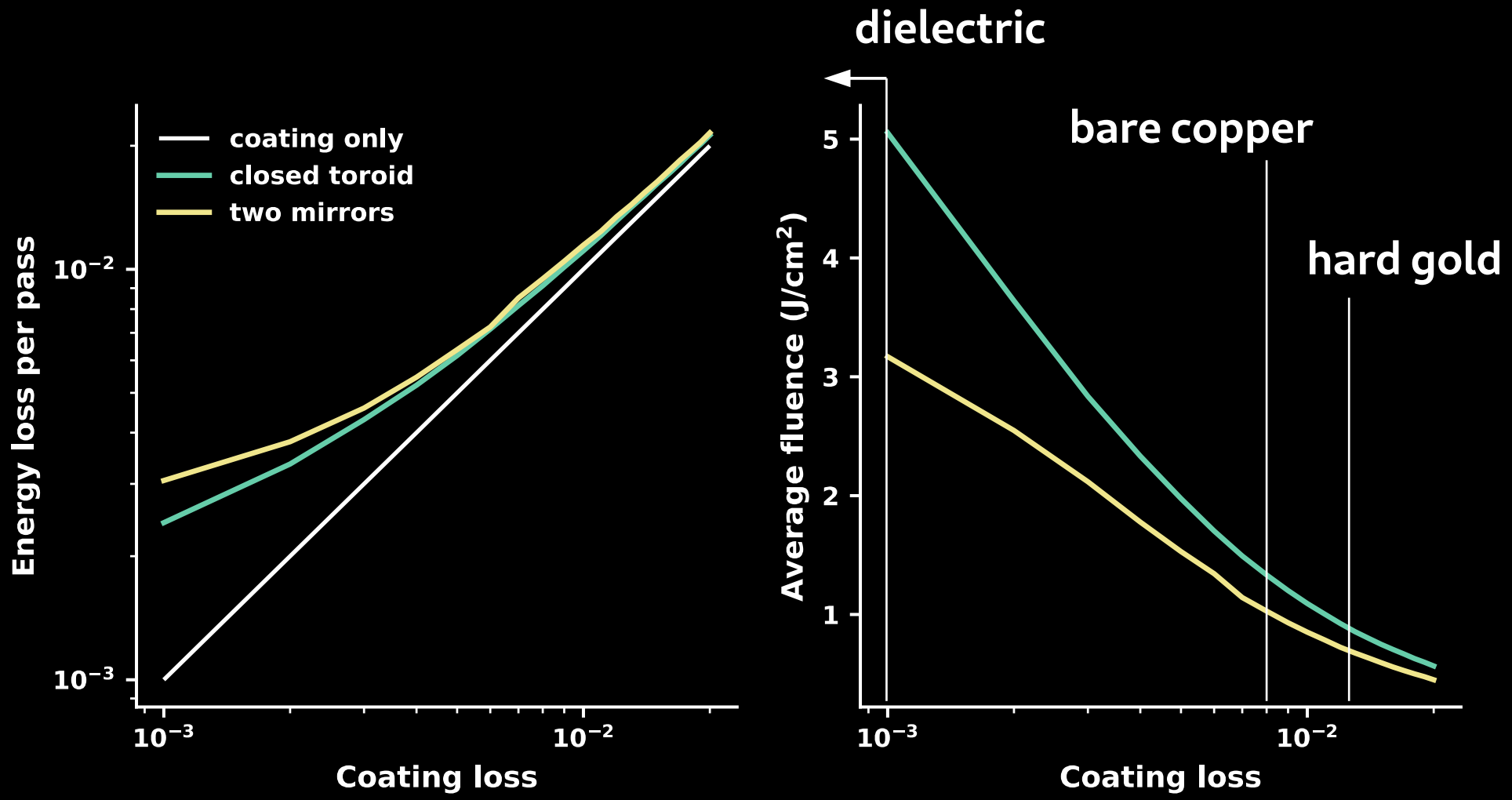


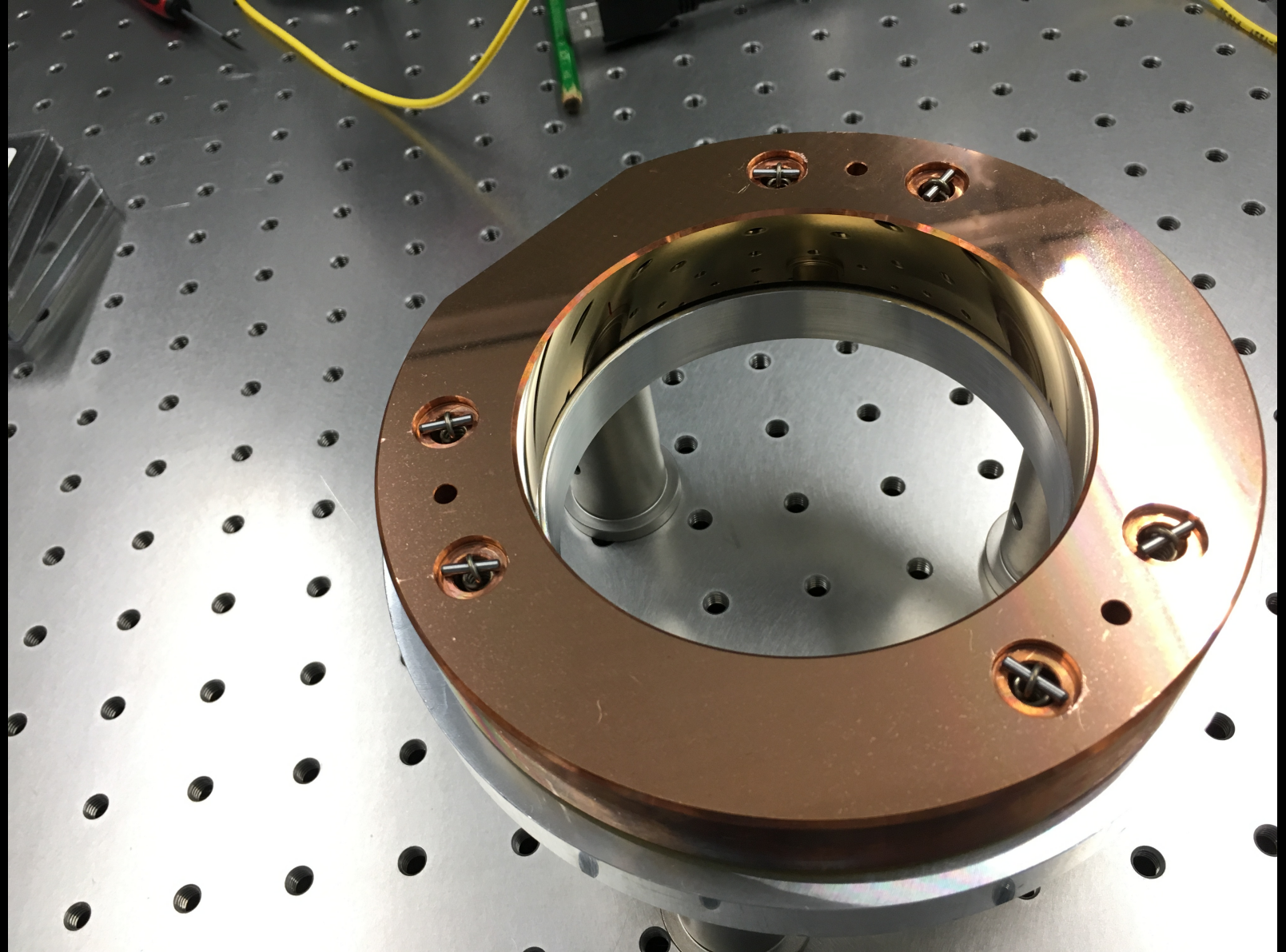

coupling hole
10^{-3}

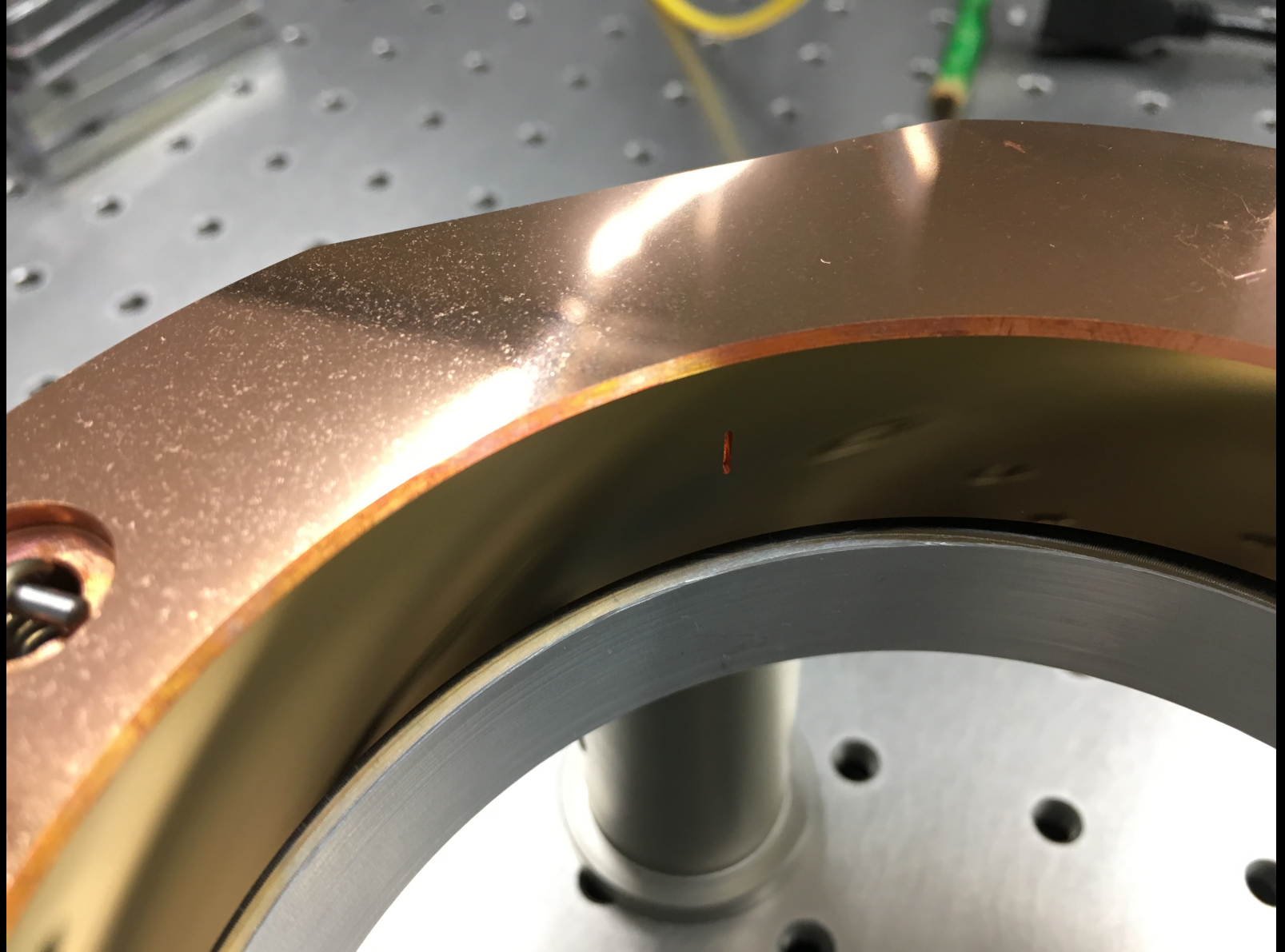

coupling hole
10^{-3}
mirror reflectivity
$10^{-4} - 10^{-2}$

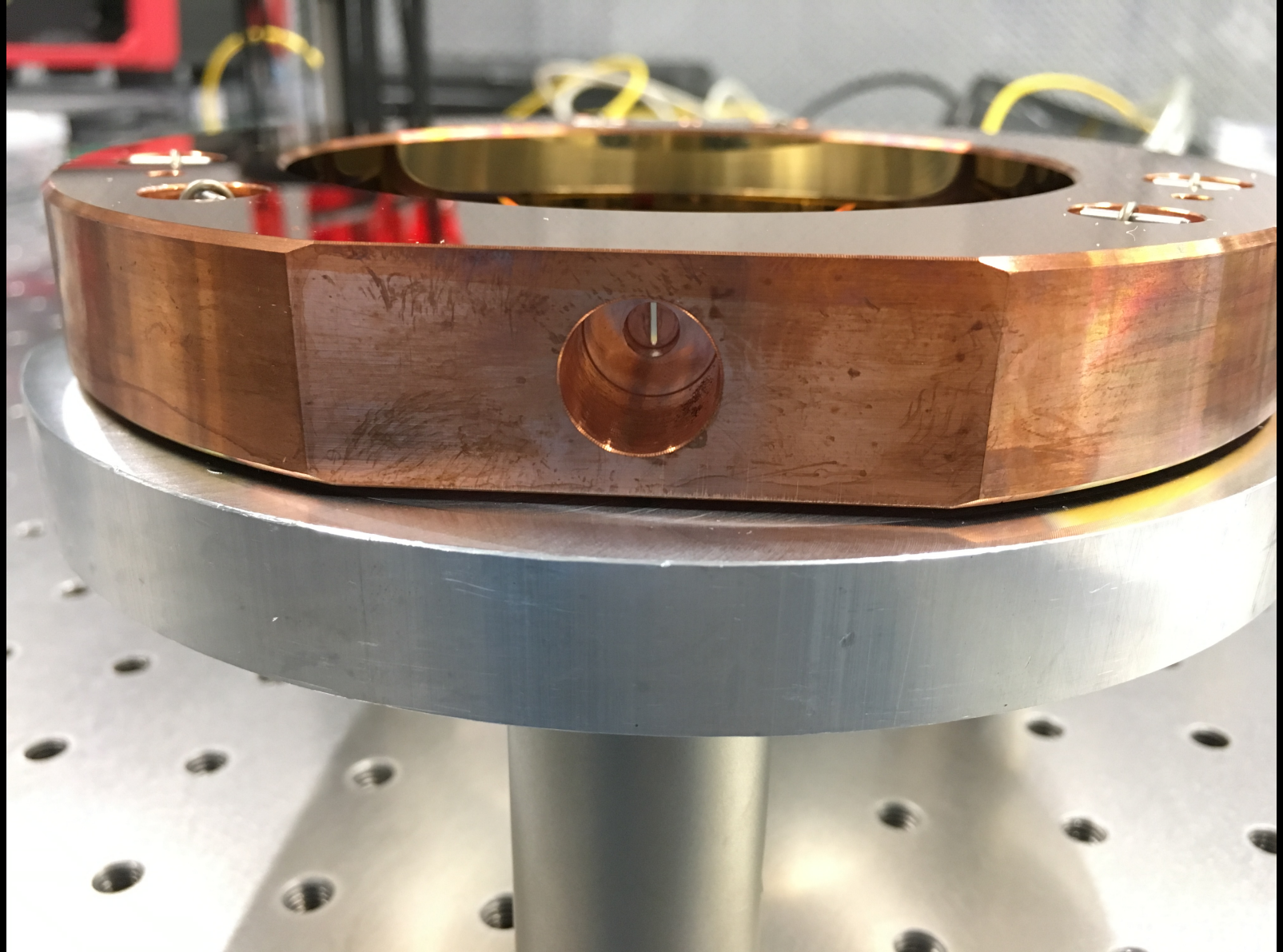

coupling hole
10^{-3}
apertures
$10^{-5} - 10^{-3}$
mirror reflectivity
$10^{-4} - 10^{-2}$

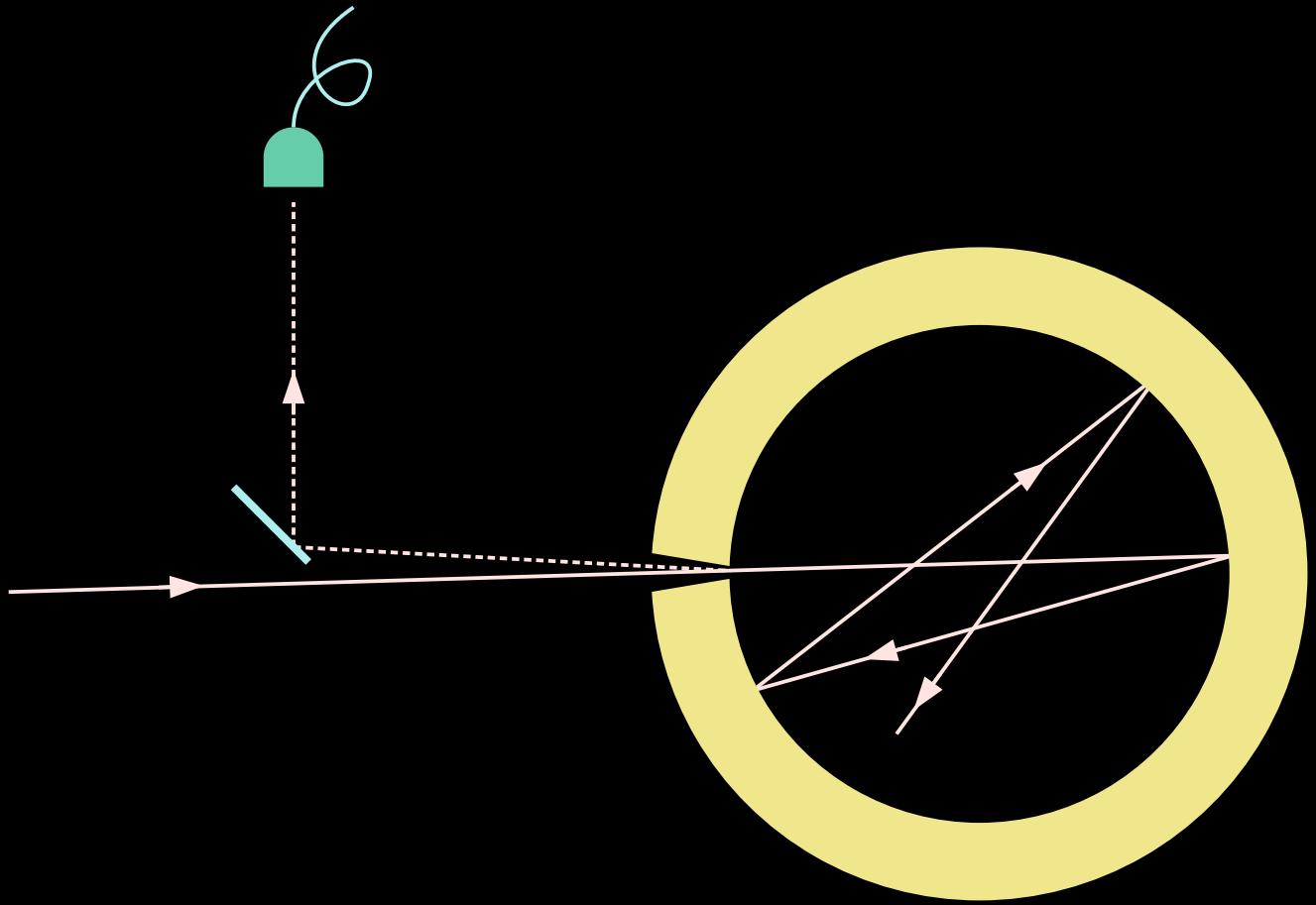

coating only
closed toroid
two mirrors
Energy loss per pass
10^{-2}
10^{-3}
10^{-3}
10^{-2}
Coating loss
Average fluence (J/cm^2)
5
4
3
2
1
10^{-3}
10^{-2}
Coating loss

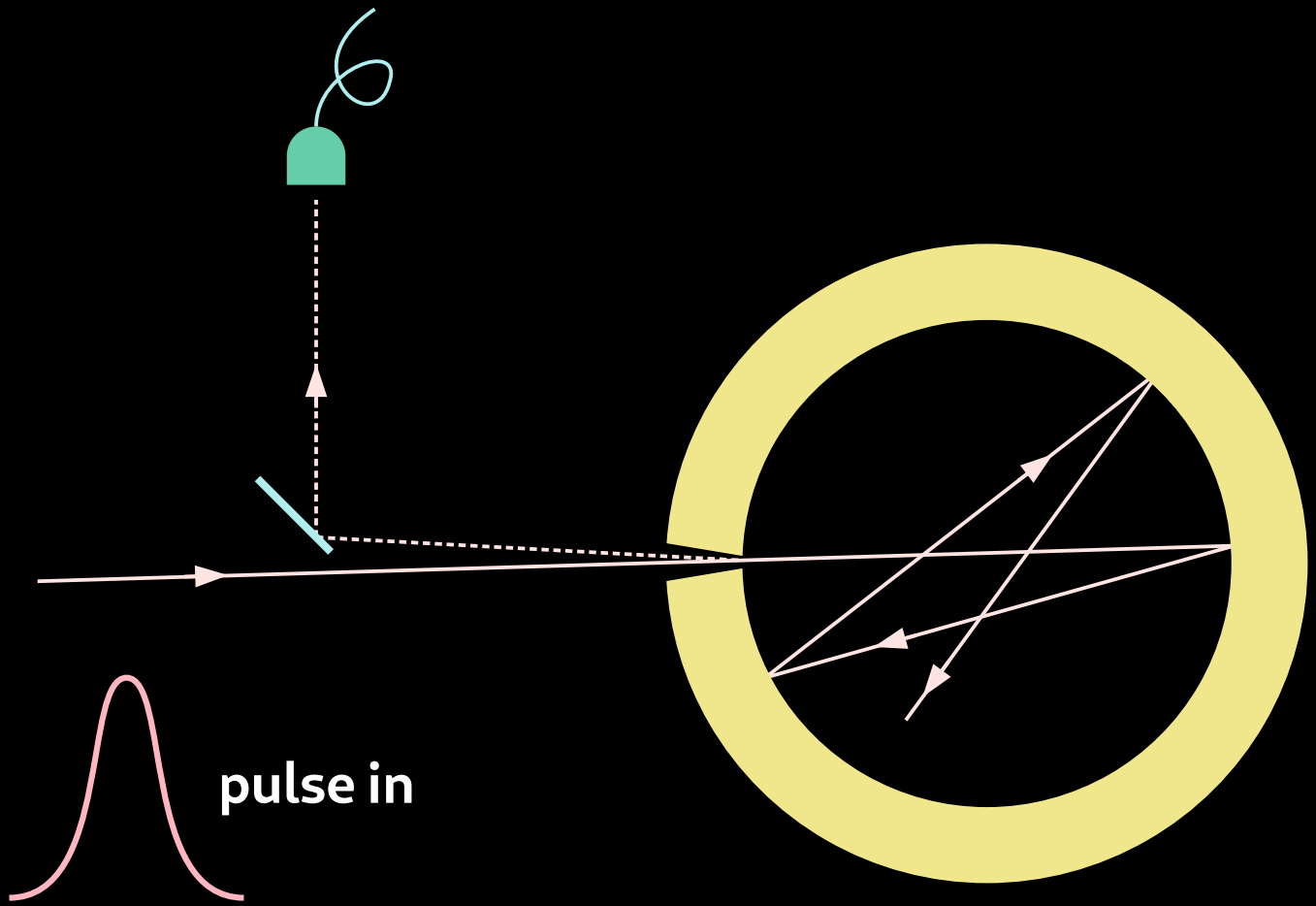

coating only
closed toroid
two mirrors
Energy loss per pass
10^{-2}
10^{-3}
10^{-3}
10^{-2}
Coating loss
dielectric
bare copper
hard gold
Average fluence (J/cm^2)
5
4
3
2
1
10^{-3}
10^{-2}
Coating loss

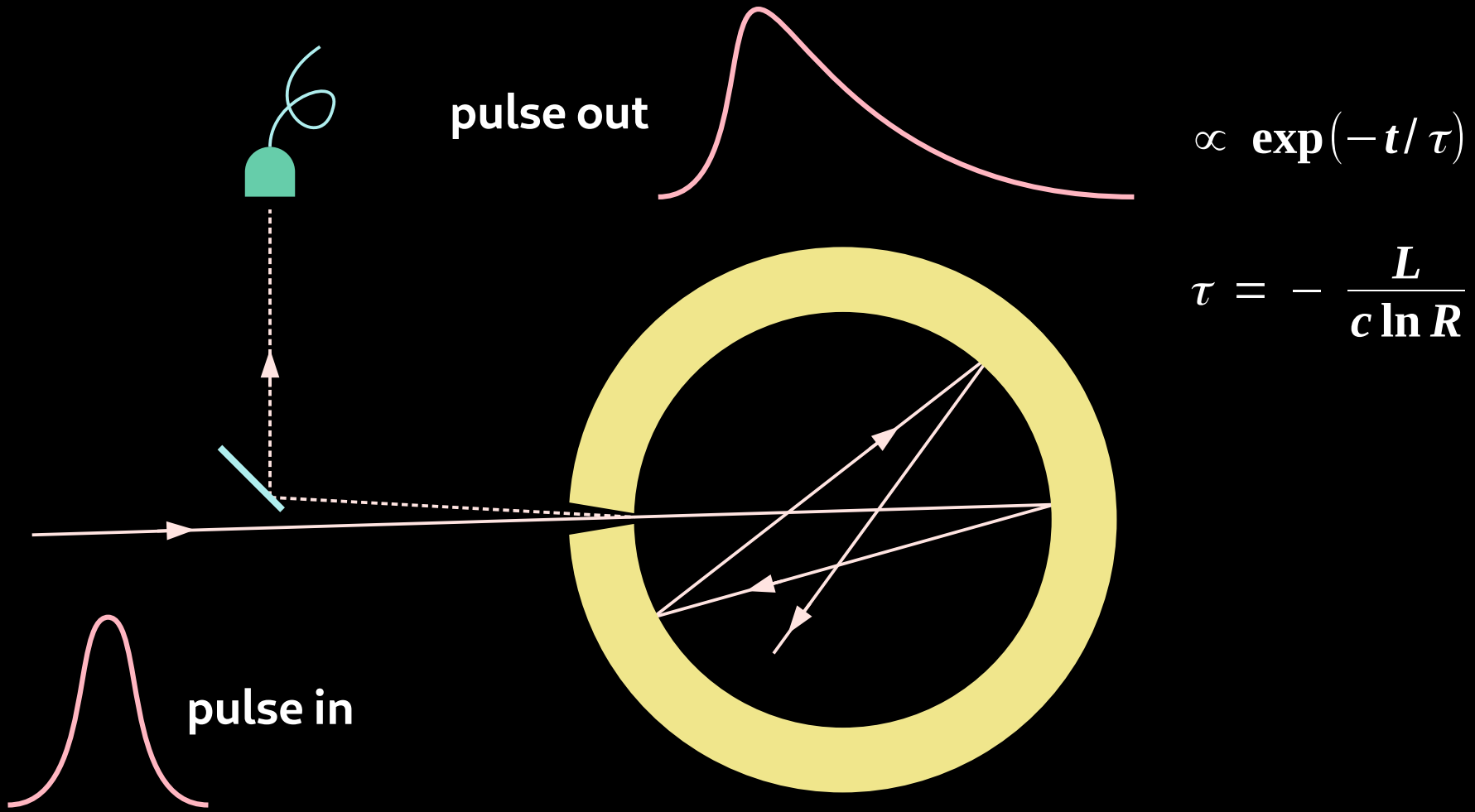






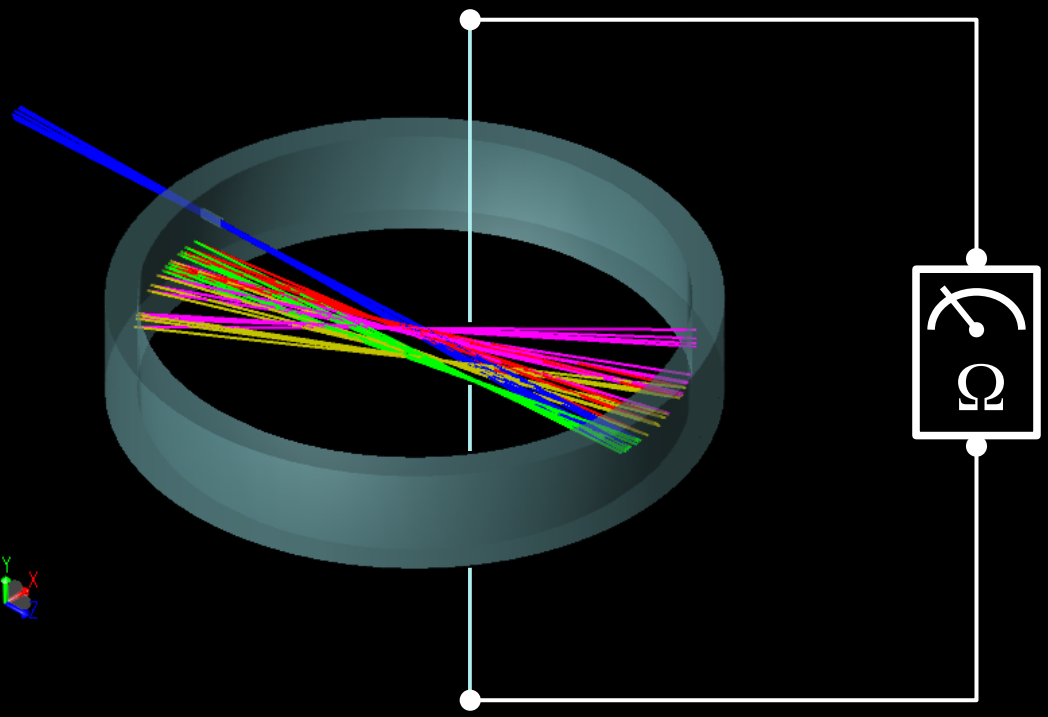


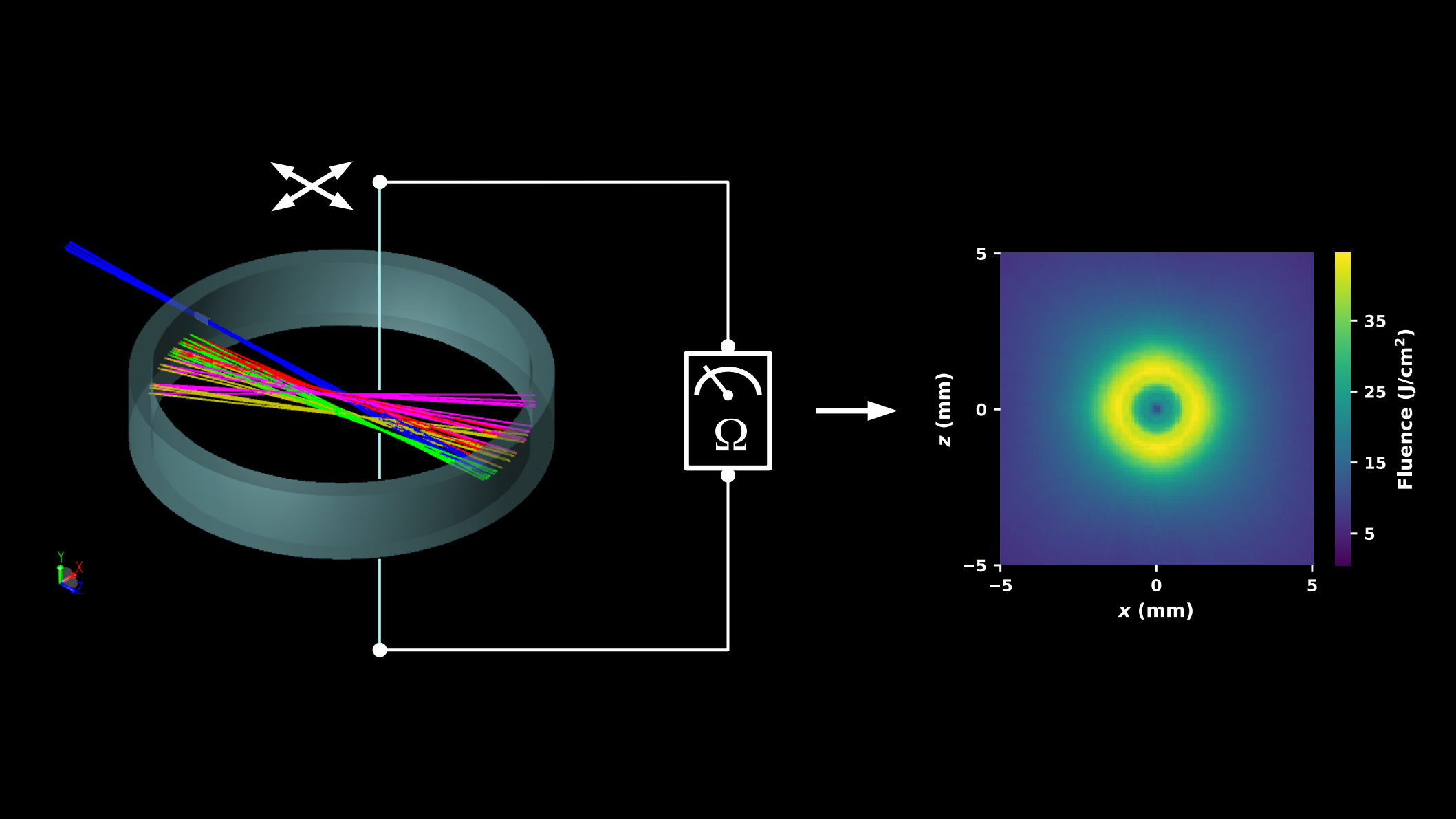

pulse in



$$\propto \exp\left(-t/\tau\right)$$

$$\tau = -\frac{L}{c \ln R}$$


Y
X
Z
Ω


Ω
5
0
−5
z (mm)
−5
0
5
x (mm)
35
25
15
5
Fluence (J/cm²)

Summary

- 2 possible designs of the cavity
- First prototypes have arrived
- Preparing for tests

Summary

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- First prototypes have arrived
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Thank you for your attention!