

# Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safer Return from COVID19

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@Smogdr

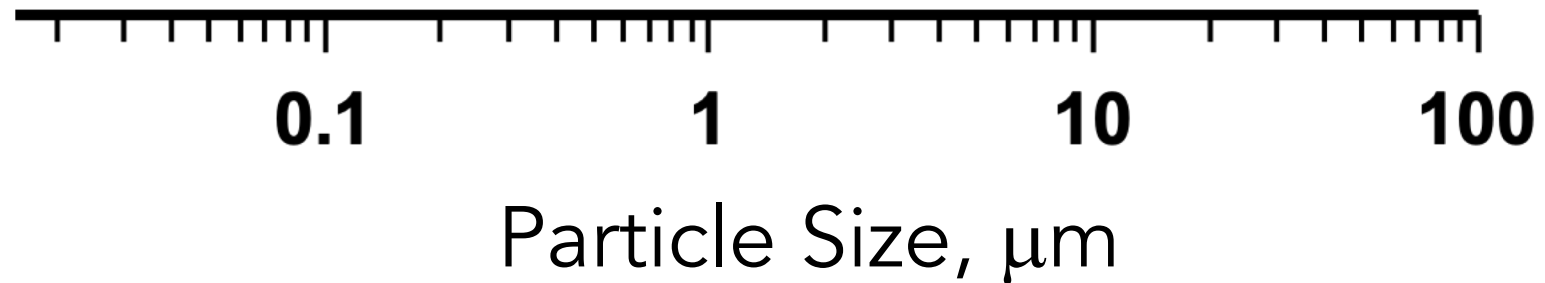
Why don't  
we have  
more  
answers  
here?

- For every 1,000 doctors that graduate from US medical schools, we see ~1 new PhD granted in aerosol science
- There are probably fewer than 5,000 *aerosol* PhDs actively working in the U.S.
- 80% of those PhDs work outside of academia
- Probably less than 5% study *bioaerosols* and *public health*
- *Not everything you read on the internet is true...*

# Questions we hope to answer

1. What is the rate (and size) of bioaerosol emitted by performers of varying age and gender when engaging in music, voice, and dance?
2. How effective are active and passive control measures at reducing bioaerosol emissions and exposures?
  - isolation and distancing
  - room ventilation and filtration
  - use of homemade masks, respirators, shields or other barriers
3. Can the risks of co-exposure be reduced to “acceptable levels” using these active and passive controls?

# Some Sizes and Sources of Airborne Particles



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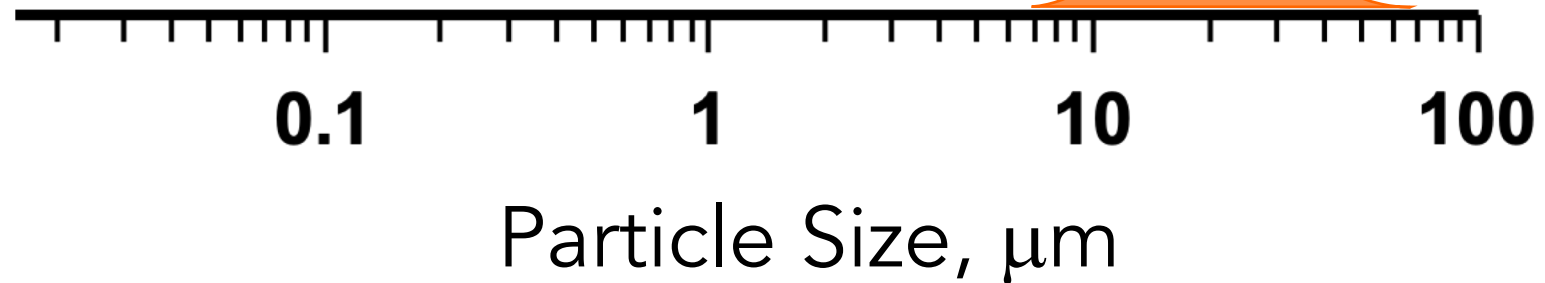
Flour Dust



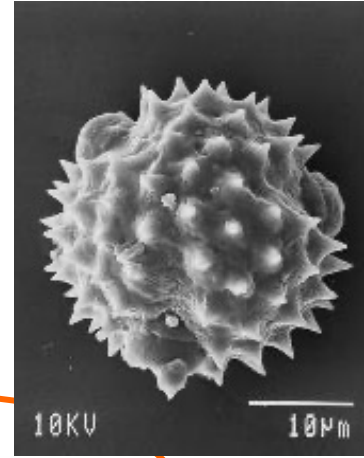
# Some Sizes and Sources of Airborne Particles



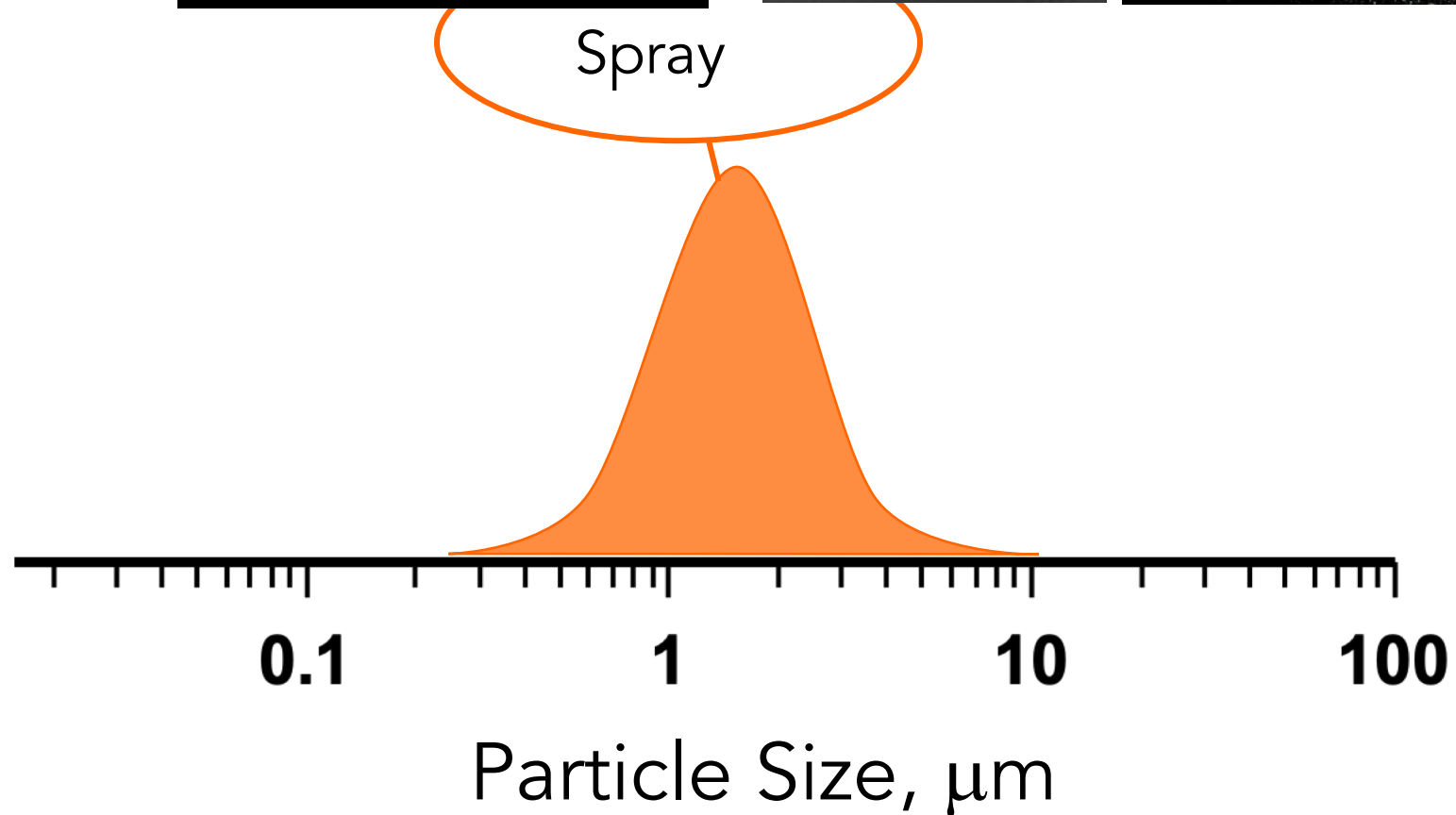
Pollen



# Some Sizes and Sources of Airborne Particles



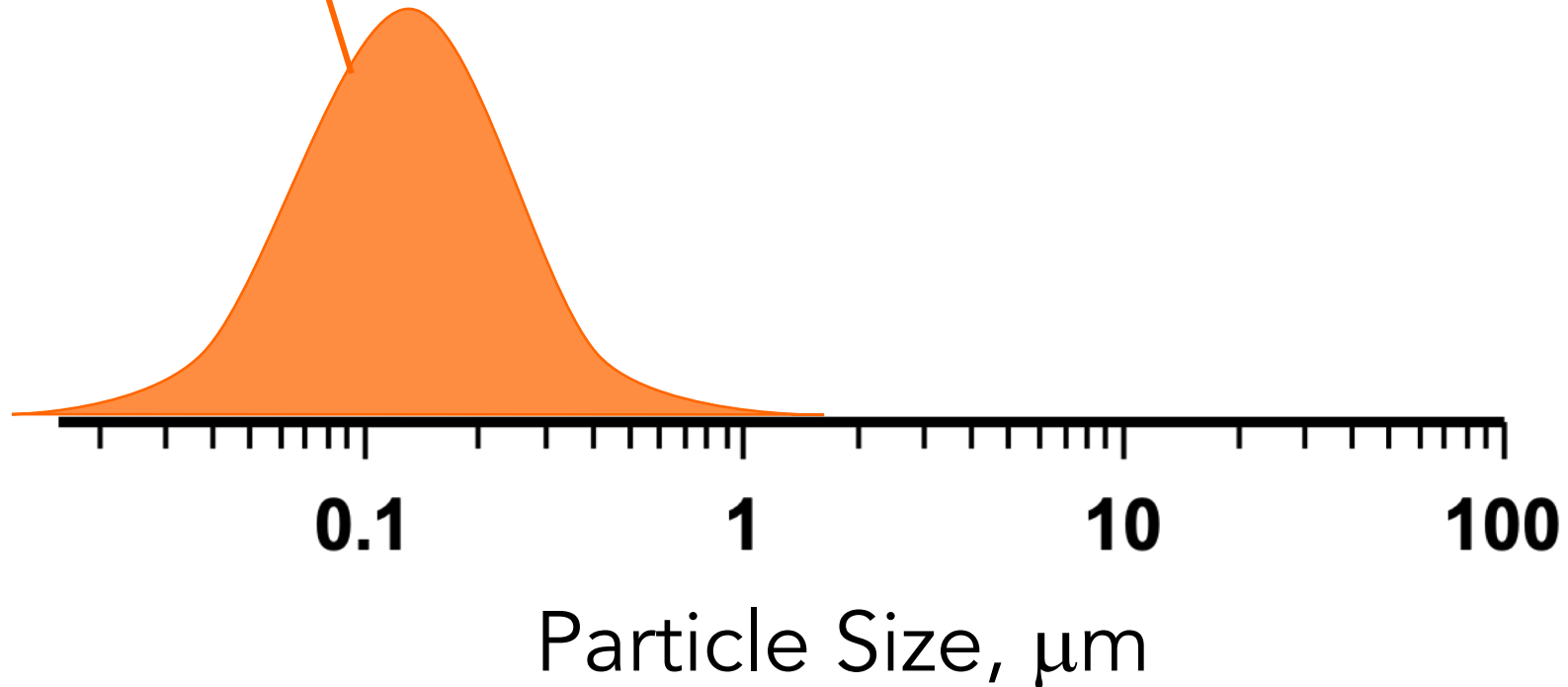
Spray



# Some Sizes and Sources of Airborne Particles

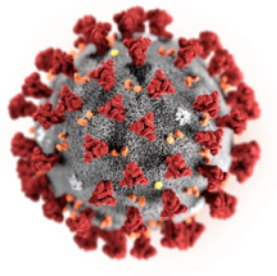
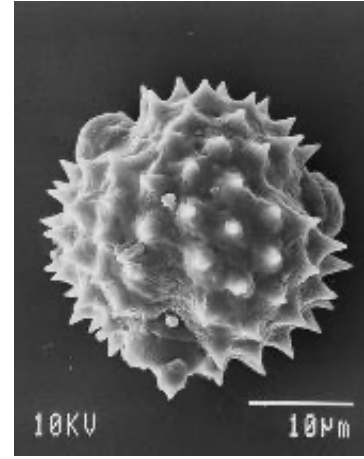


Smoke





# Some Sizes and Sources of Airborne Particles



0.1

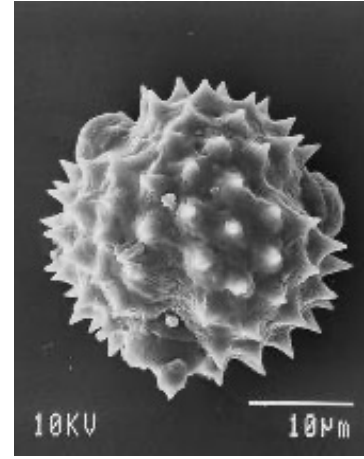
1

10

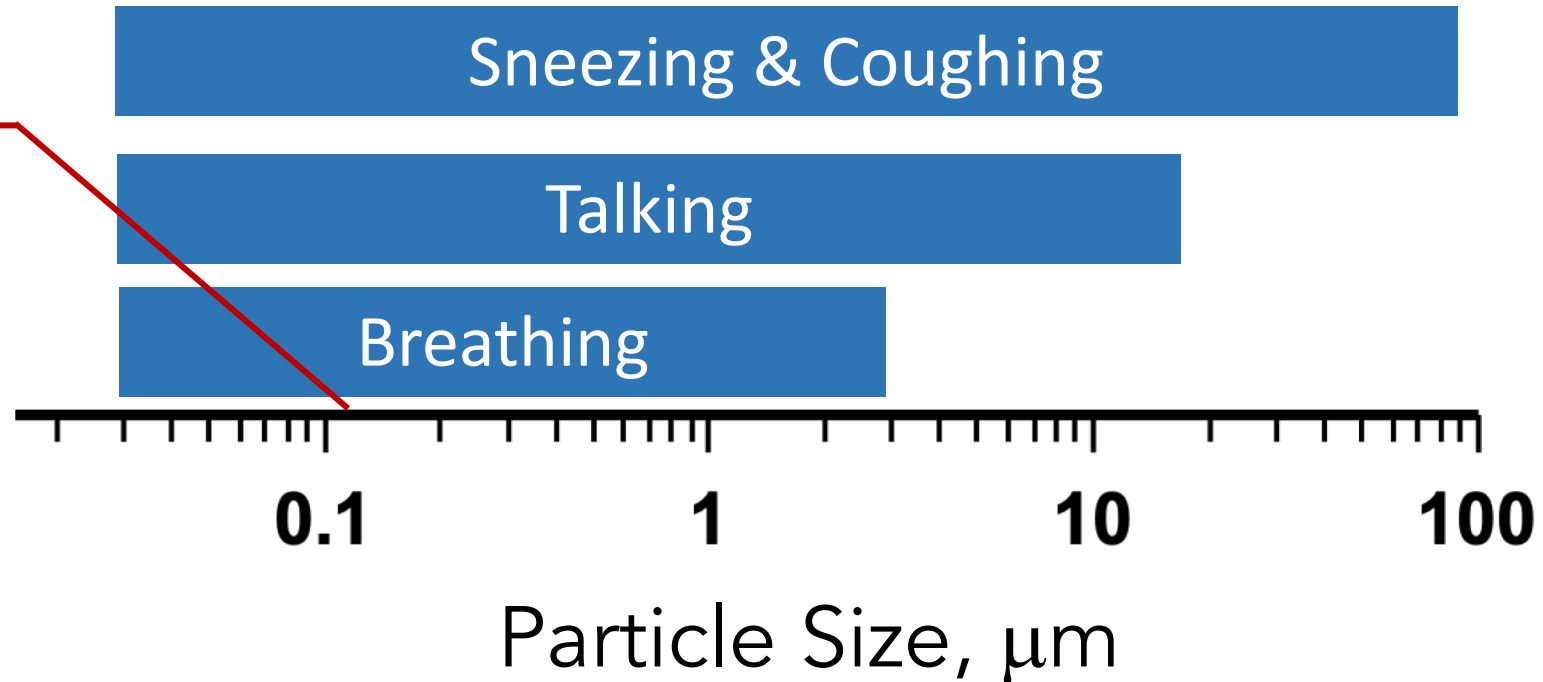
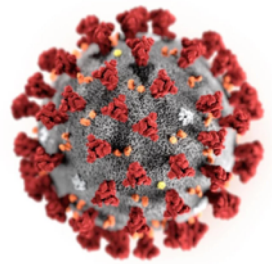
100

Particle Size,  $\mu\text{m}$

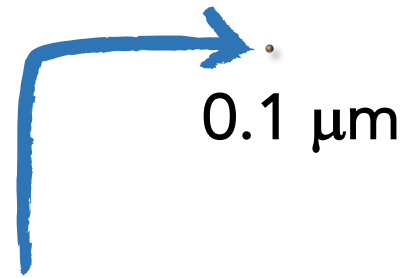
# Some Sizes and Sources of Airborne Particles



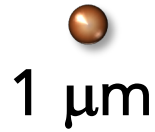
Musical and Vocal Arts?



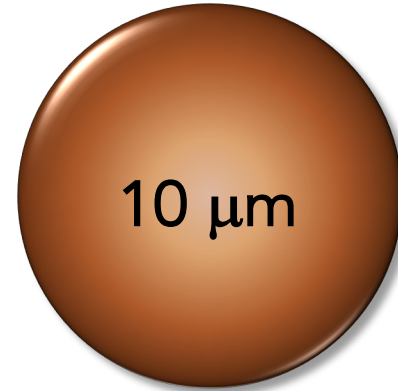
# Human bioaerosol spans a huge size range (and not all particles behave the same)



0.1  $\mu\text{m}$



1  $\mu\text{m}$



10  $\mu\text{m}$

100  $\mu\text{m}$

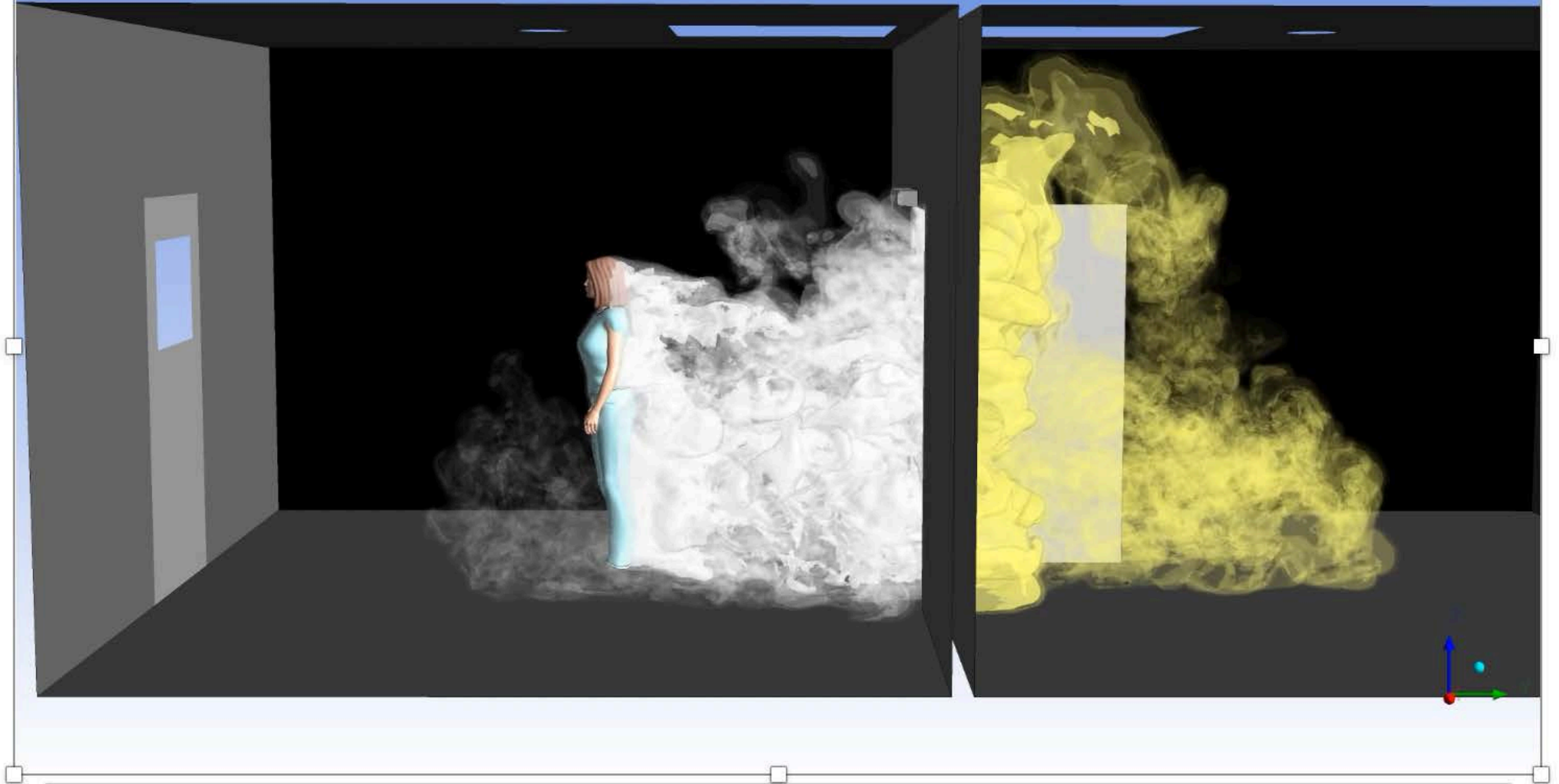
If this particle were  
the size of a baseball

Then this particle would be  
the size of a baseball stadium



time [s]: 10.4

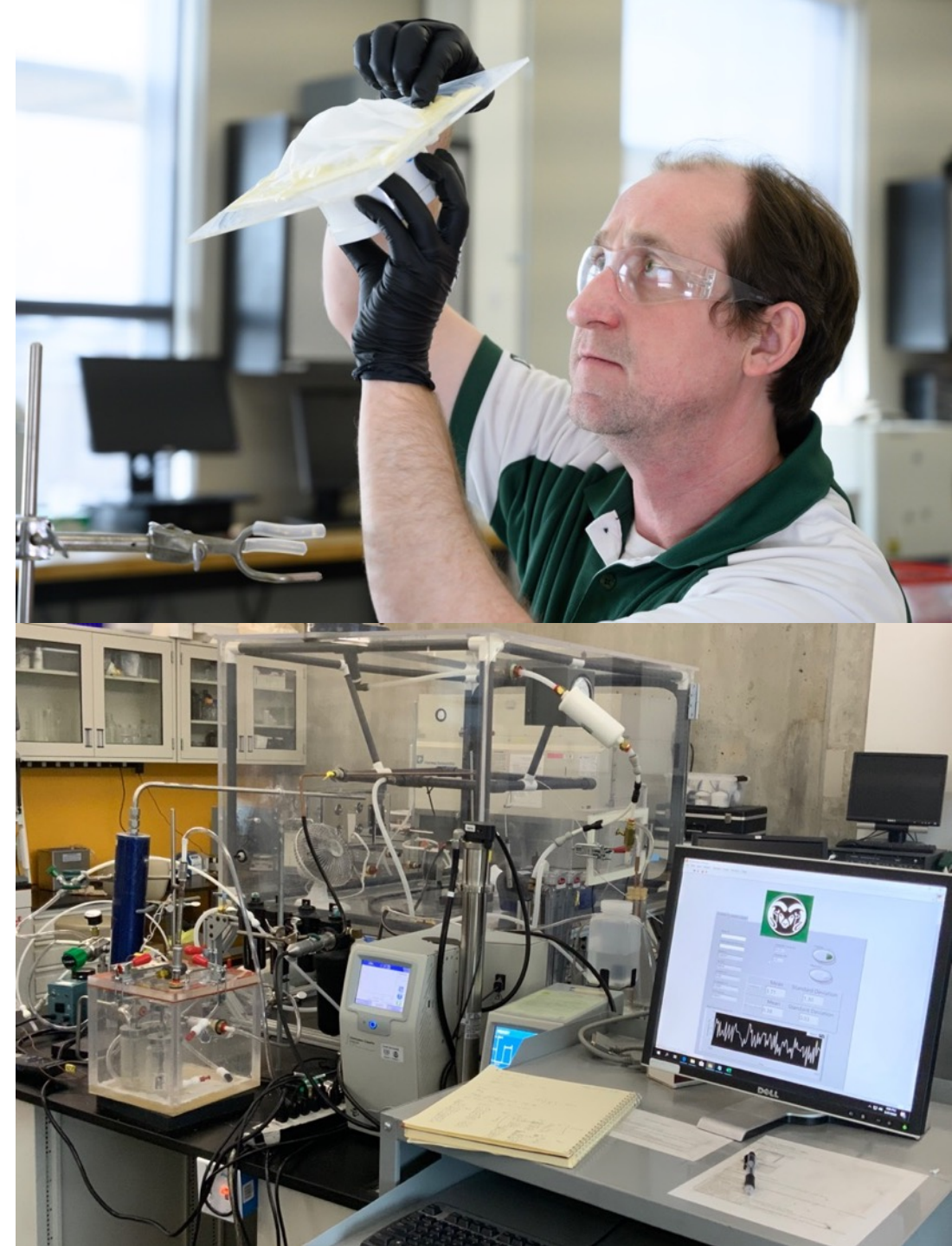
ANSYS  
R15.0



# CSU Mask and Respirator Testing Program

- Shortage of N95 respirators for healthcare workers across Colorado
- Supply of domestic and international respirators of unknown quality / performance
- On March 25<sup>th</sup>, Colorado Governor Jared Polis asked our lab to provide respirator testing & performance verification for State of Colorado COVID-19 Task Force

*Over 200 different mask designs tested as of 20 Aug 20*



N95 means 95% removal efficiency for particles that flow into the mask

CSU testing program follows modified\* NIOSH protocol for particle collection and "breathability"

"Looks" can be deceiving!



Only CDC/NIOSH can certify masks to bear the "N95" label



\* <https://www.cdc.gov/niosh/npptl/respirators/testing/default.html>

# Anonymous Donor:

*"Please test these 24 different masks, each made with popular mask material, and make the data publicly available"*



*Most N95 masks remove ~99% of all particle sizes*



Fraction Collected by Mask

1.00  
0.90  
0.75  
0.50  
0.25  
0.10

mask

— N95

1

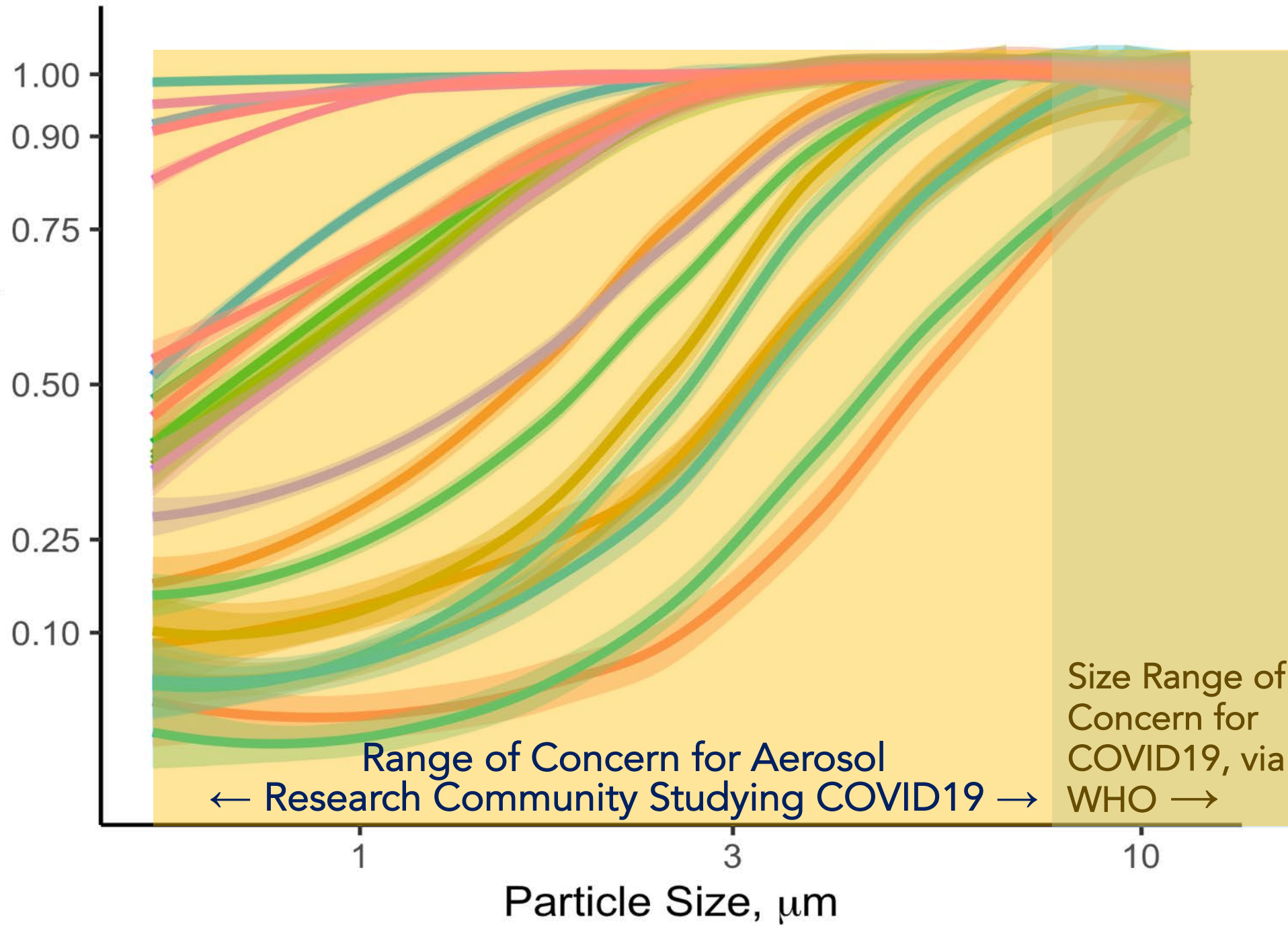
3

10

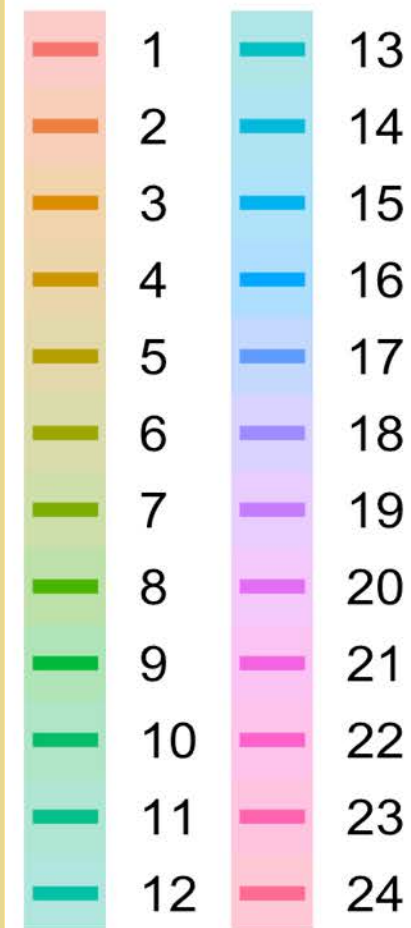
Particle Size,  $\mu\text{m}$

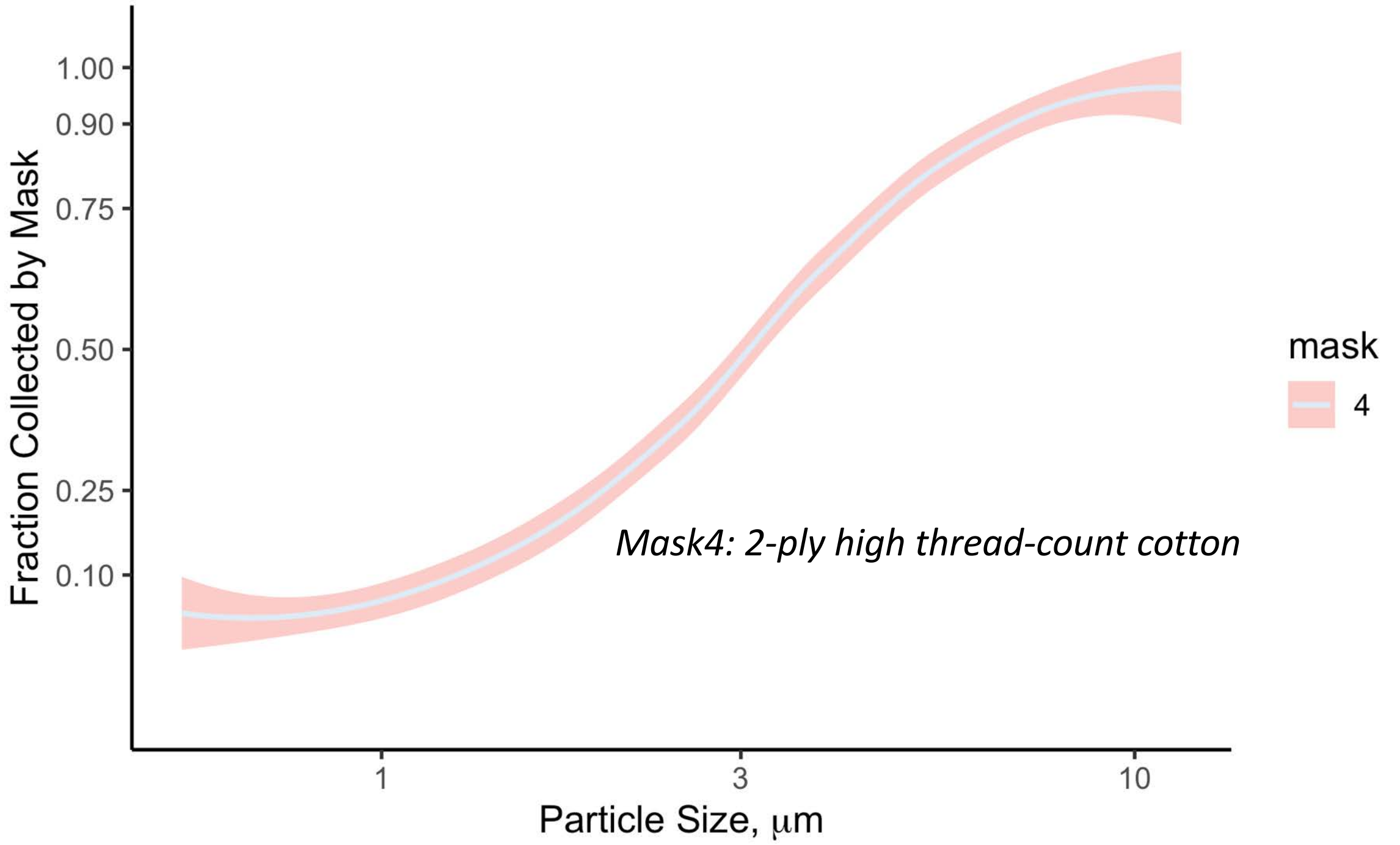


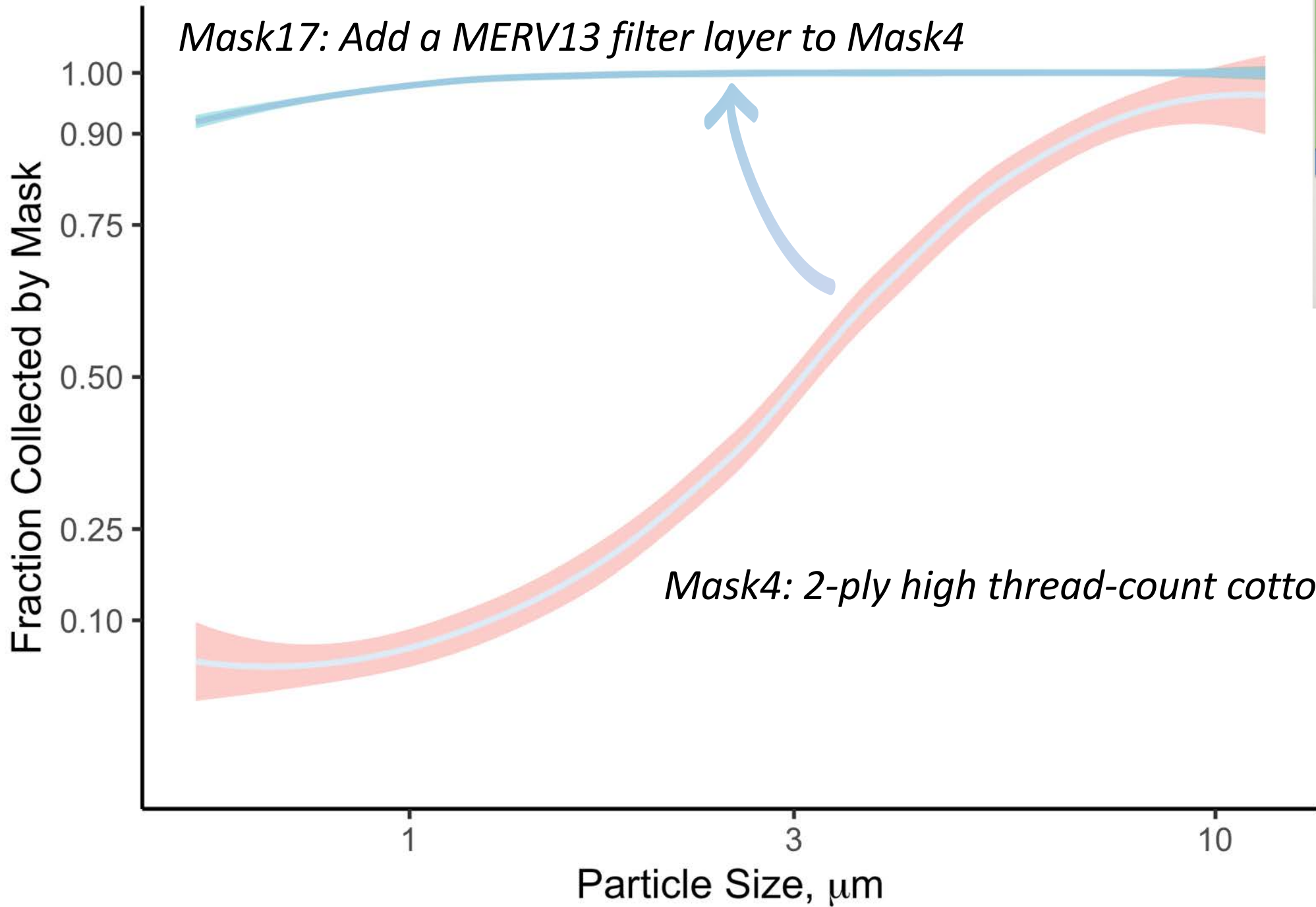
Fraction Collected by Mask



mask

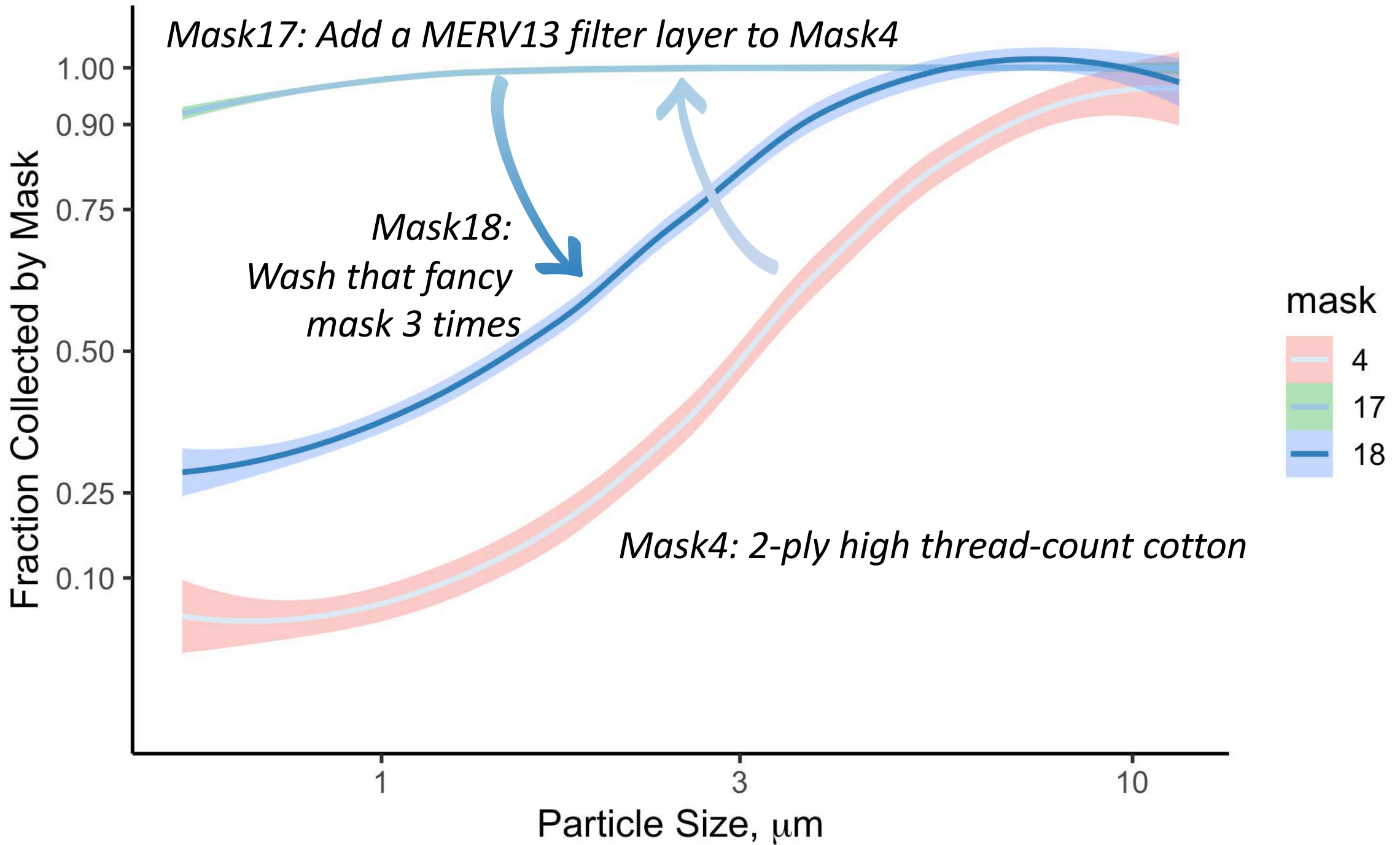






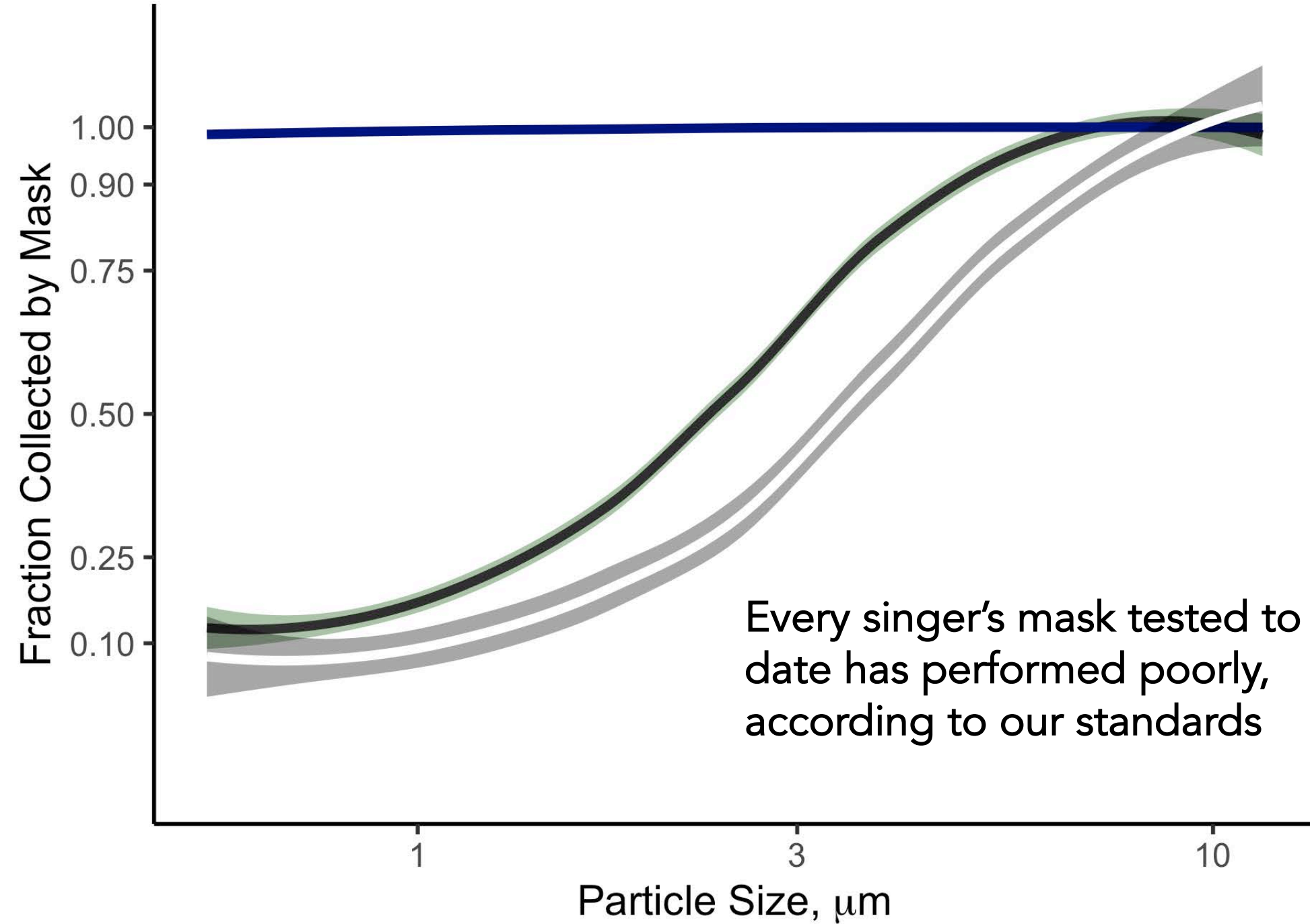
mask

- 4
- 17



What about "Singer's Masks"?





Every singer's mask tested to date has performed poorly, according to our standards

mask

- black
- N95
- white



<https://smt.d.colostate.edu/>



ABOUT

ADMISSIONS

NEWS AND EVENTS

FACILITY

GIVING

CONNECT



# CSU Aerosol Emissions Study

**Reducing Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safer Return from COVID19**

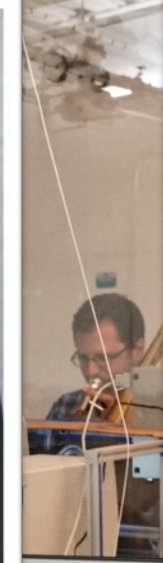
# Experimental Design

- 100 volunteers over 3 months (~2/day)
  - Open to ages 12 and up; all genders
  - ~28 singers, actors, dancers
  - ~72 instrumentalists: bassoon, clarinet, euphonium, flute, French horn, trumpet, trombone, saxophone, and possibly others
- Everybody speaks, sings and “does their thing”
  - With and without control technologies in place
    - Masks, bell covers, and screens to be tested
    - “BYOM” approach to testing
- Particle sizes from 0.01 to 100 micrometers



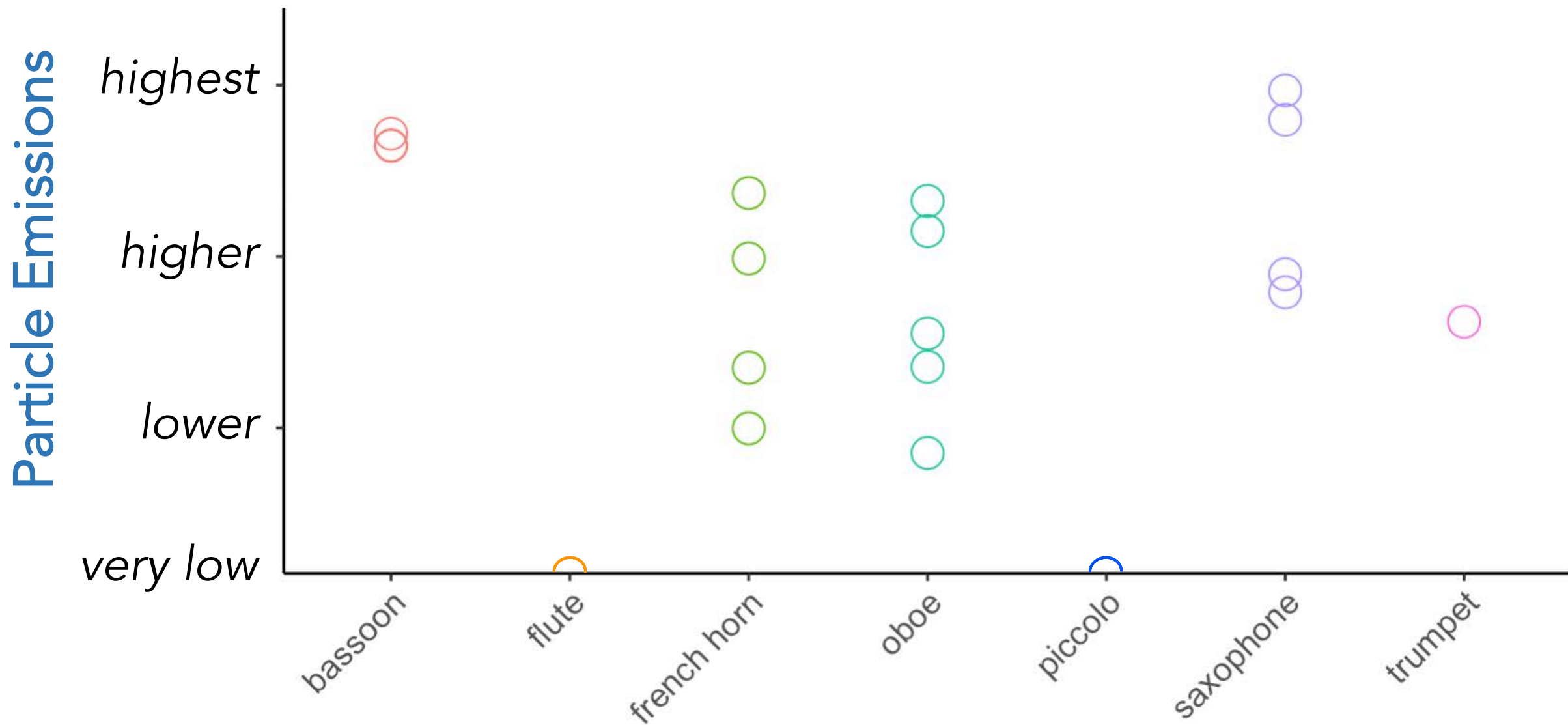


SET Facility: A Musical Class 100 Cleanroom



SET Facility: A Musical Class 100 Cleanroom

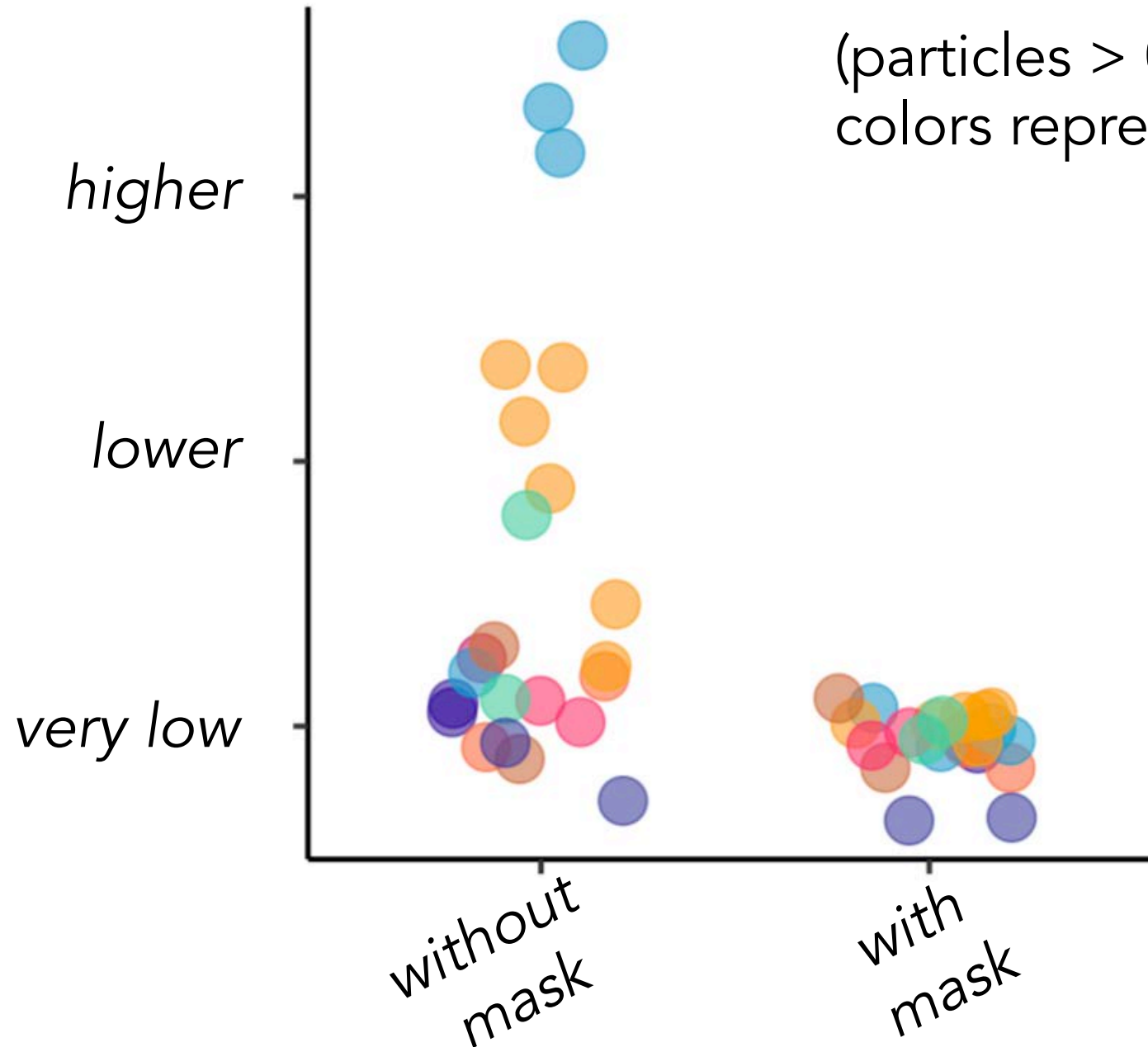
# Preliminary Instrument Results (particles > 0.3 μm)



# Preliminary Vocal Results

(particles > 0.3  $\mu\text{m}$ ; n = 9 participants;  
colors represent different individuals)

Particle Emissions



# Preliminary Findings (less than 1/5<sup>th</sup> of the way there)

1. Wind instruments produce aerosol of varied concentration and size

*higher levels*  *intermediate*  *very low*  
Trumpet, saxophone, bassoon > French horn, oboe, voice > flute, piccolo

2. Masks reduce vocal emissions by 90% or more

3. Variability from one person to the next is IMPORTANT.

# Thank you to those who made this work possible!

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**Yamaha Corporation**

**United States Institute for Theatre Technology (USITT)**

## Lead Supporters:

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**American Choral Directors Association**

**American Guild of Musical Artists (AGMA)**

**Auburn University**

**Big Ten Band Directors Foundation**

**CSU School of Music, Theatre, and Dance**

**Mill City Church**

**National Band Association**

**University of Kentucky**

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