

# Performing Arts Aerosol Study

Round one preliminary results

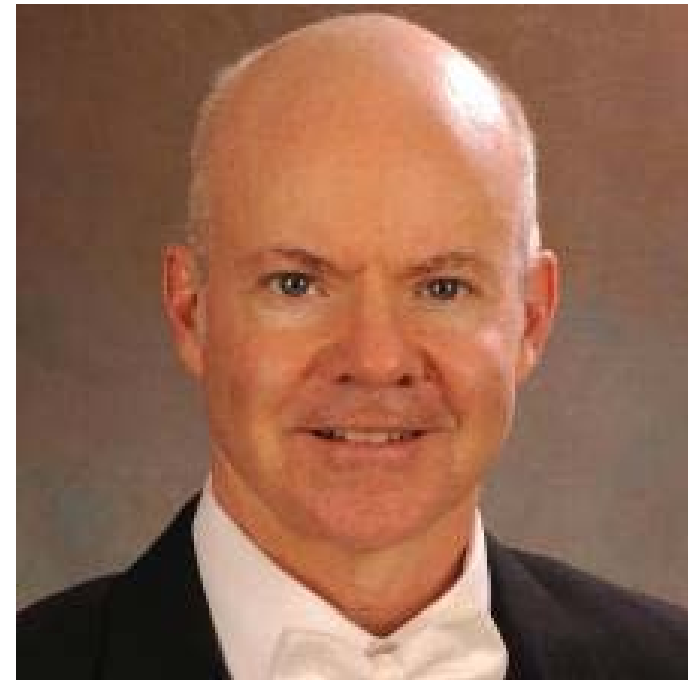
Clarinet, Flute, Horn, Soprano Singer, Trumpet

# Study Chairs

James Weaver - NFHS Director of  
Performing Arts and Sports



Mark Spede – CBDNA President,  
Director of Bands, Clemson University



# Lead Funders



# Contributing Organizations



# Contributing Collegiate Conference Band Associations and Universities



# Supporting Organizations

American School Band Directors Association (ASBDA)  
American String Teachers Association (ASTA)  
Arts Education in Maryland Schools (AEMS)  
Association Européenne des Conservatoires/Académies de  
Musique et Musikhochschulen (AEC)  
Buffet et Crampon  
Bundesverband der deutschen  
Musikinstrumentenhersteller e.V  
Chicago Children's Choir  
Children's Chorus of Washington  
Chorus America  
Confederation of European Music Industries (CAFIM)  
Drum Corps International (DCI)  
Educational Theatre Association (EdTA)  
European Choral Association - Europa Cantat  
HBCU National Band Directors' Consortium  
High School Directors National Association (HSBDNA)

International Conductors Guild  
International Society for Music Education  
League of American Orchestras  
Louisiana Music Educators Association  
(LMEA)  
MidWest Clinic  
Minority Band Directors National Association  
Music Industries Association  
Musical America Worldwide  
National Dance Education Organization  
(NDEO)  
National Flute Association (NFA)  
National Guild for Community Arts Education  
Percussive Arts Society (PAS)  
Save the Music Foundation  
United Sound  
WGI Sport of the Arts

# Lead Researchers

Dr. Shelly Miller  
University of Colorado Boulder



Dr. Jelena Srebric  
University of Maryland



# Lab Work

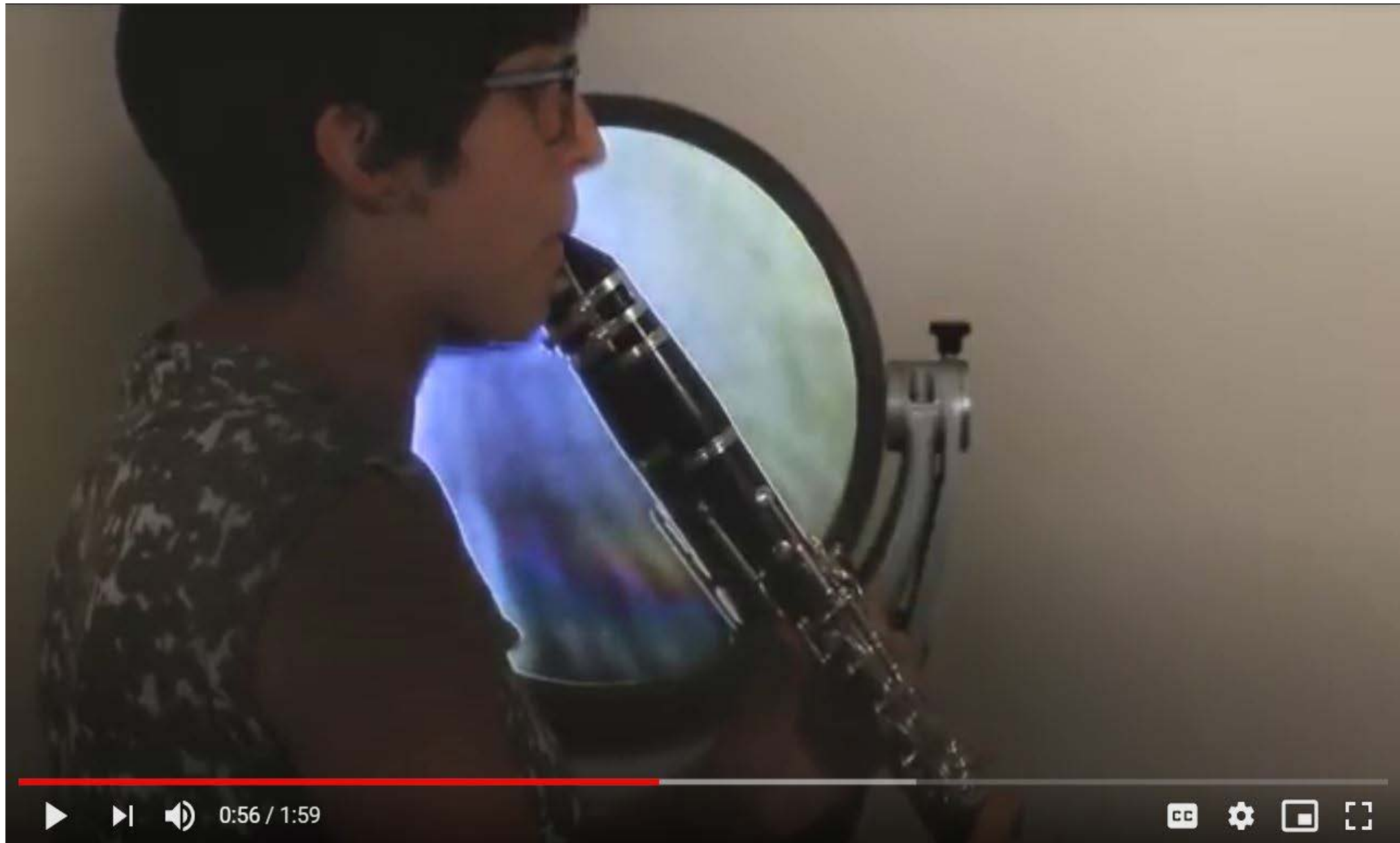
Exploratory measurements on some band instruments and singing completed

Tests conducted in controlled "clean room"

Goal was to identify flow and aerosol release pathways

Particle size and concentration measured near to the aerosol release

Next phase is to improve aerosol capture and estimate emission rates



0:56 / 1:59





# Schlieren Test

Goal was to identify flow pathways,  
which would carry emitted  
particles



Video  
Reciting Alphabet Schlieren Test

<https://youtu.be/0UXn3Zke1qA>

# Video Clarinet Schlieren Test

[https://youtu.be/r0-aZ-PQ\\_hI](https://youtu.be/r0-aZ-PQ_hI)

# Bagged Clarinet



# Video Trombone Schlieren Test

<https://youtu.be/0s5kAgBAhAk>

# Video Soprano Schlieren Test

[https://youtu.be/JCHZ\\_dKa59k](https://youtu.be/JCHZ_dKa59k)

# Preliminary Lab Results

CPC and APS Total  
Concentration Over  
Time

# Preliminary Results Disclaimer

- These preliminary results are from our 1st week of exploratory testing. They will be further defined as the study continues. We are providing these preliminary results to assist in the safe return to classrooms. (Normally we do not release data until they have been quality assessed and peer reviewed).
- This study focuses strictly on the distribution of respiratory aerosols that are released while playing wind and brass instruments, singing, acting, speaking, dancing, and during a simulated aerobic activity.
- This study did not use a live virus or infected participants and therefore cannot be used to determine specific infection rates. This study was designed to (1) identify performing arts activities that generate respiratory aerosols including volume, direction, density, (2) estimate the emission rates of respiratory aerosol, (3) model the dispersion of these aerosols, and (4) investigate mitigation strategies.

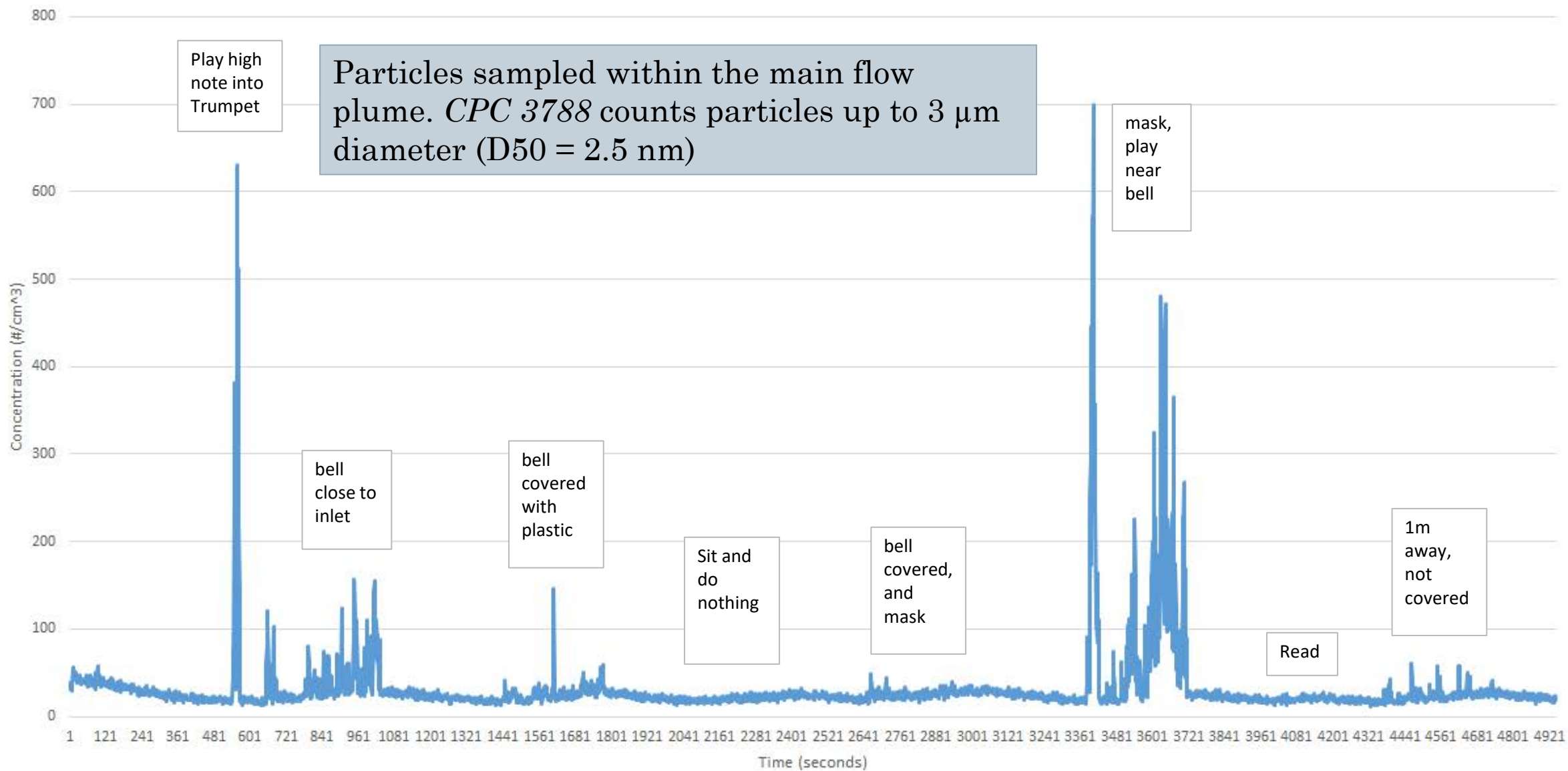
# Study Staggered Release

- Due to the size of this study the decision was made to explore winds and brass first as marching bands are currently rehearsing for the fall season.
- Additional information on vocal, theatrical, and aerobic tests will be ready by the end of July.
- The study will then enter another phase of deeper research and finalize results that will be added to the body of peer-reviewed science for our overall knowledge of respiratory safety in performing arts classrooms and performance venues.

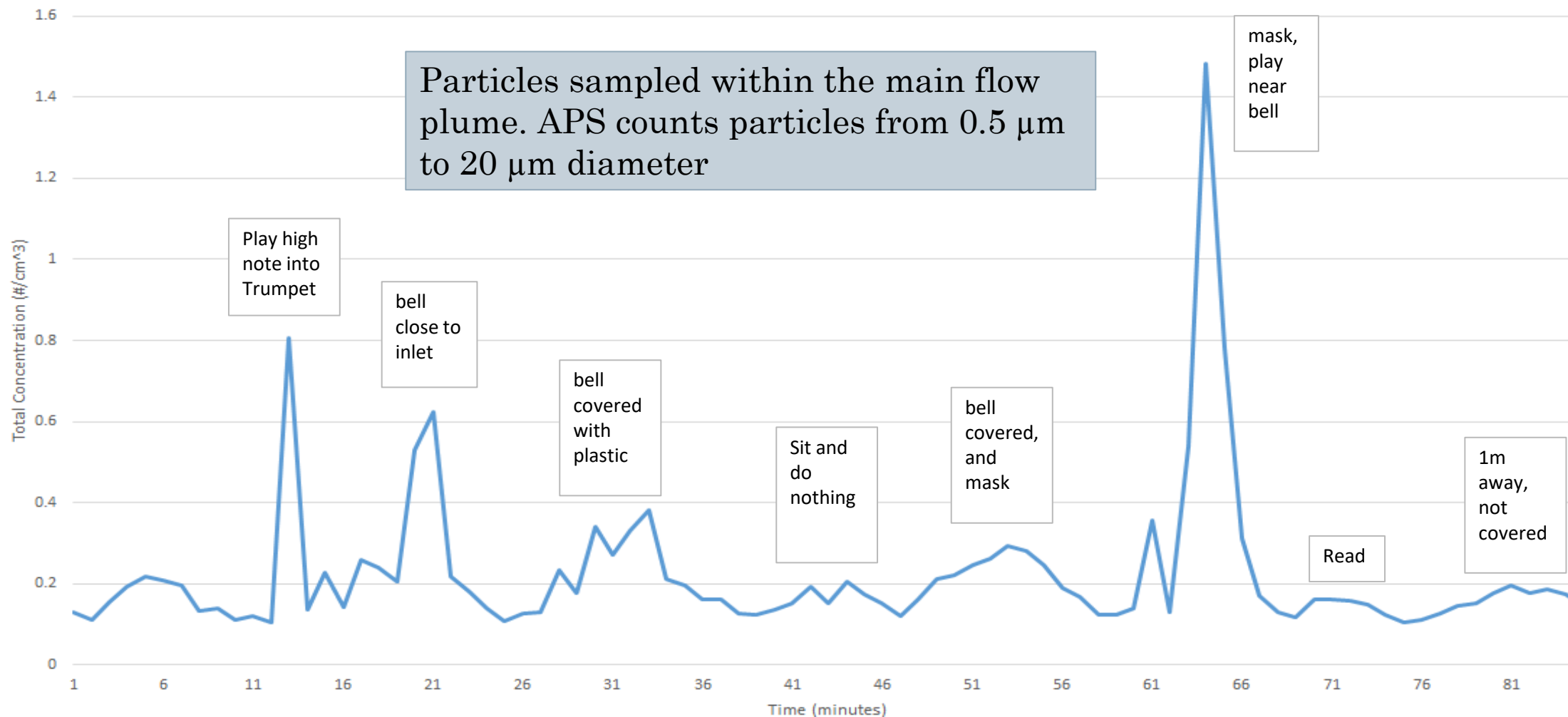
# Definitions

- Condensation particle counters (**CPC**) measure number concentration of airborne particles  $< 3 \mu\text{m}$  (microns).
- The Aerodynamic Particle Sizer spectrometer (**APS**) is based on the acceleration of **airborne** particles immersed in an air flow through a nozzle (measures 0.5-20  $\mu\text{m}$  particles).

### Trumpet CPC: Total Concentration over Time



Trumpet, APS: Total Concentration vs Time



Particles sampled within the main flow plume. APS counts particles from 0.5  $\mu\text{m}$  to 20  $\mu\text{m}$  diameter

Play high note into Trumpet

bell close to inlet

bell covered with plastic

Sit and do nothing

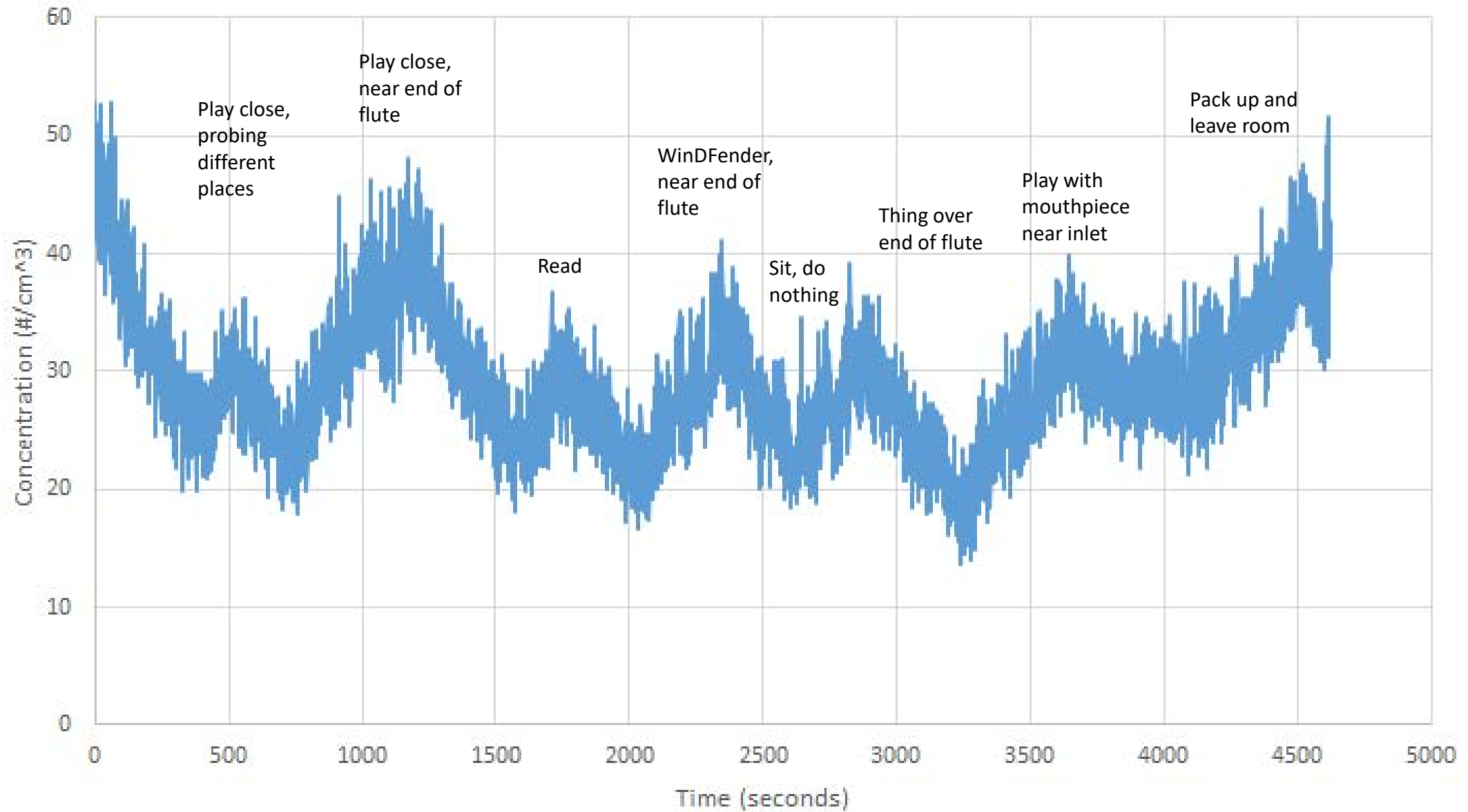
bell covered, and mask

mask, play near bell

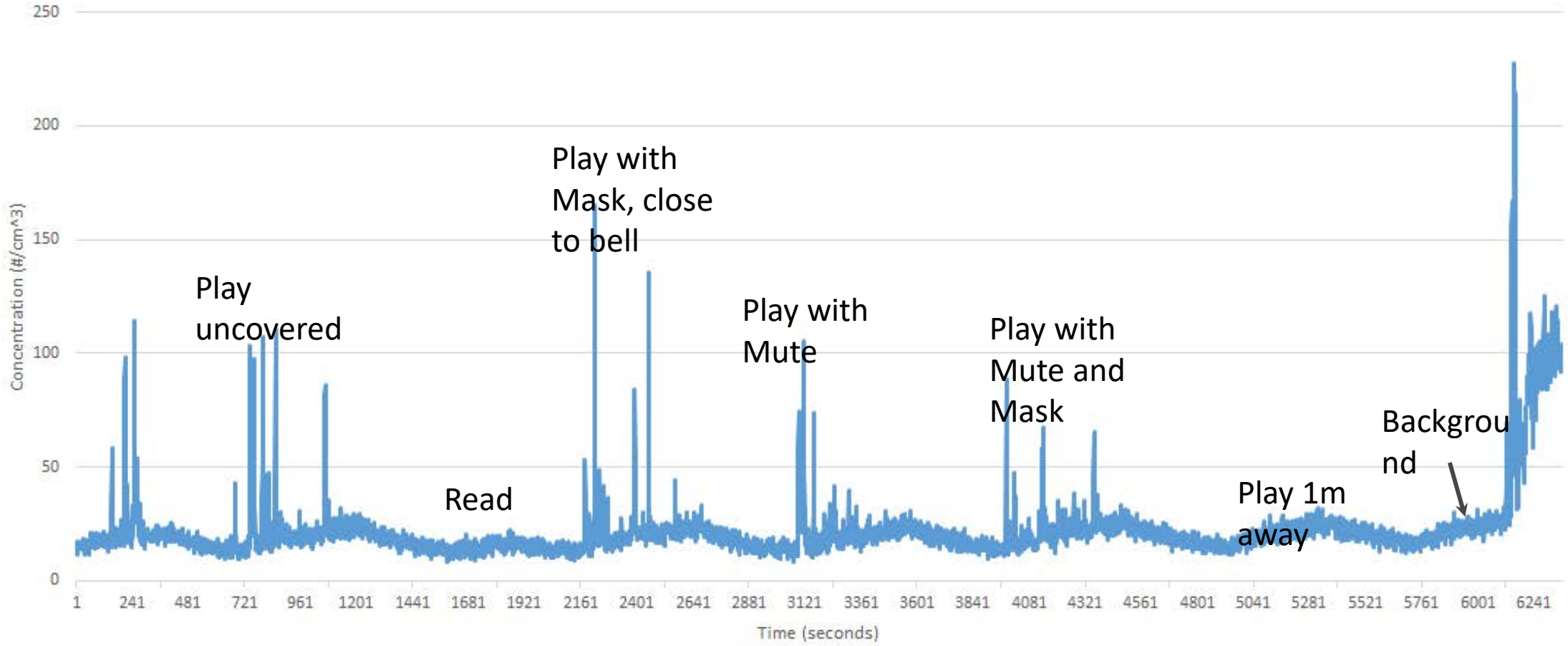
Read

1m away, not covered

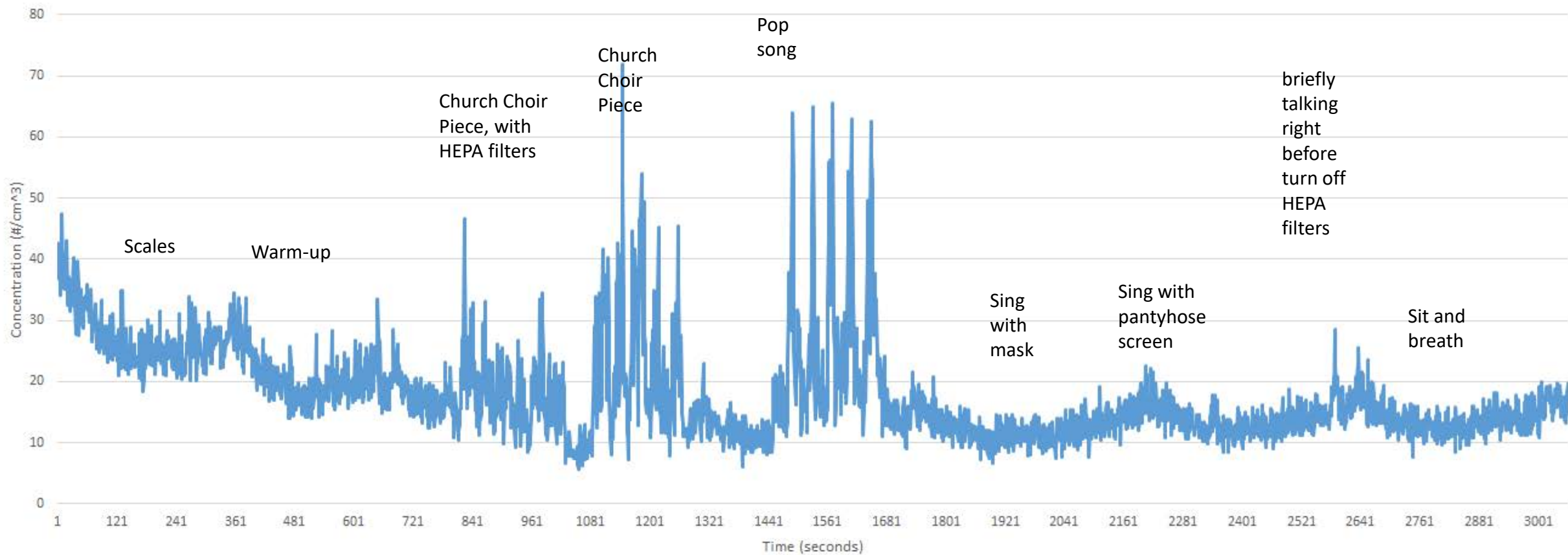
# Flute CPC: Total Concentration over Time



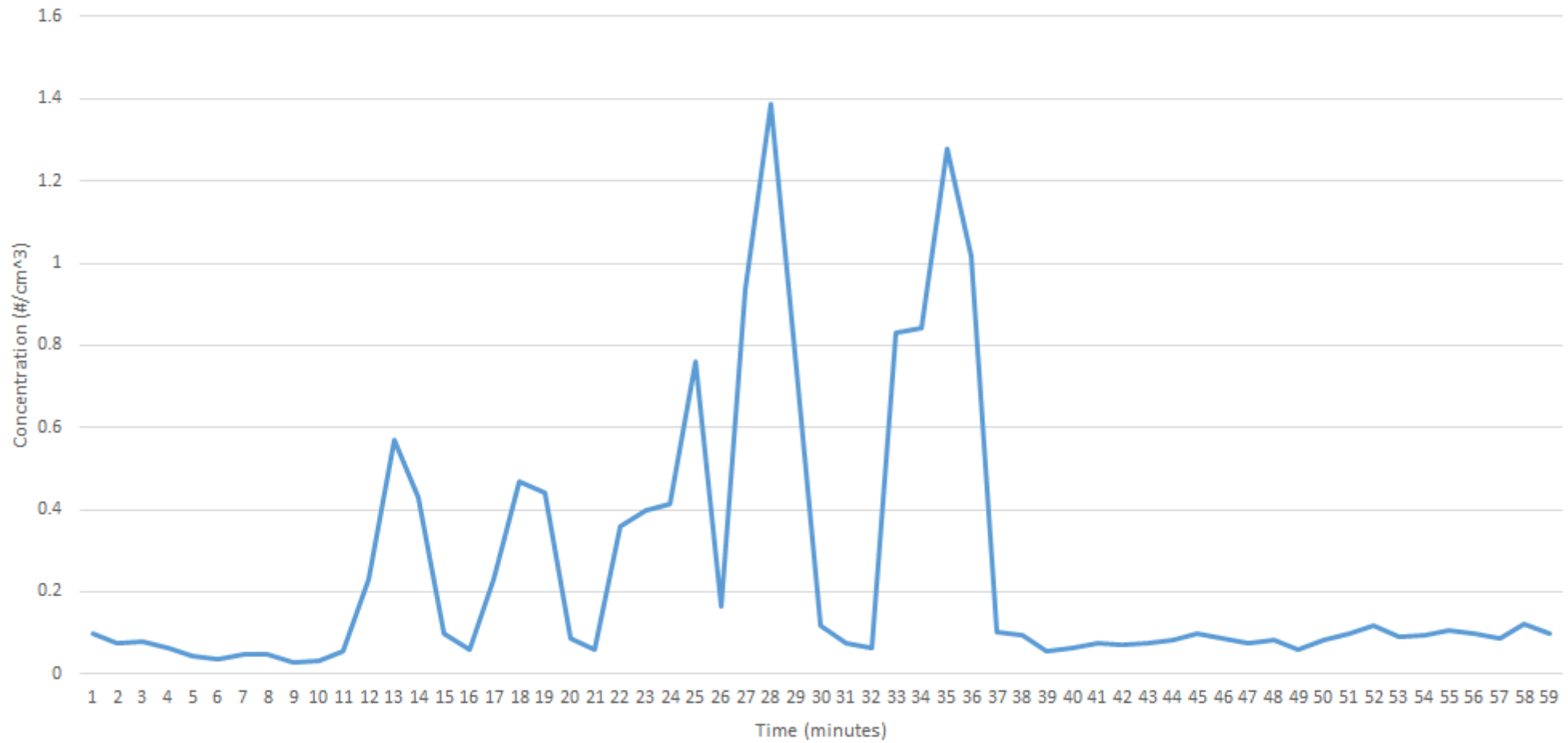
French Horn CPC: Total Concentration over Time



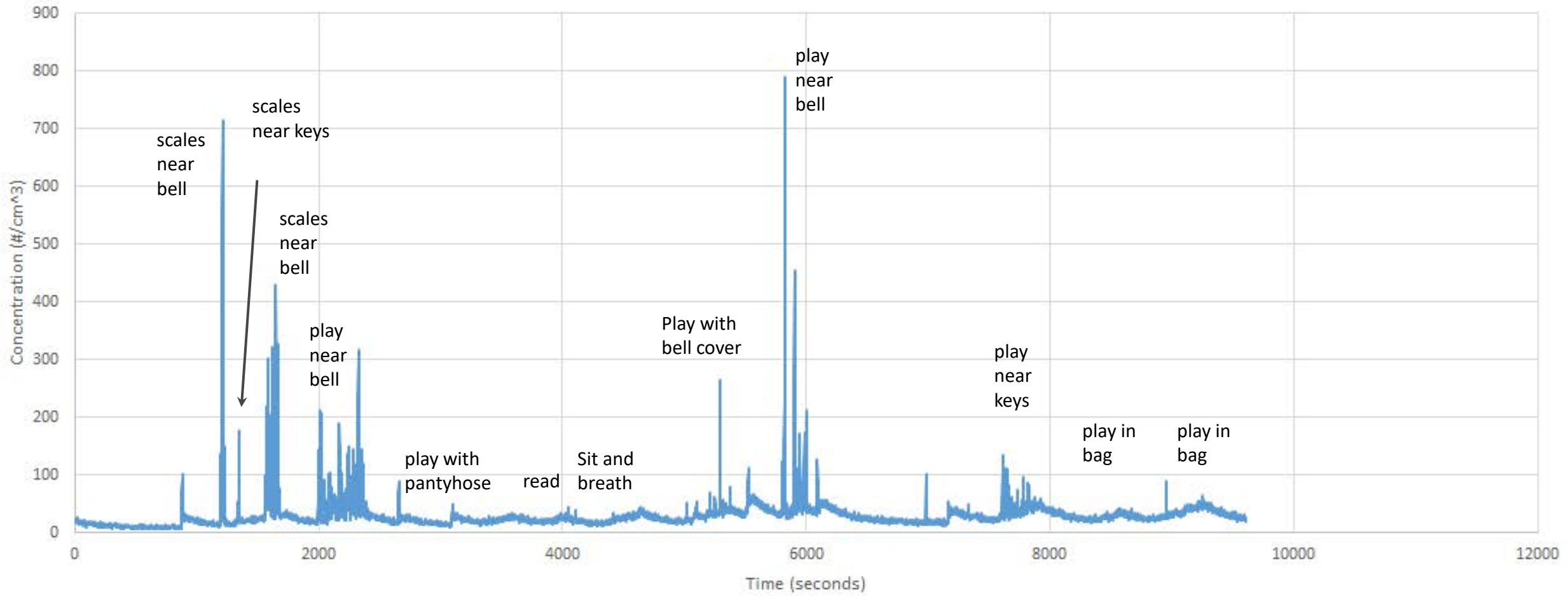
Soprano Singing, CPC: Concentration over Time



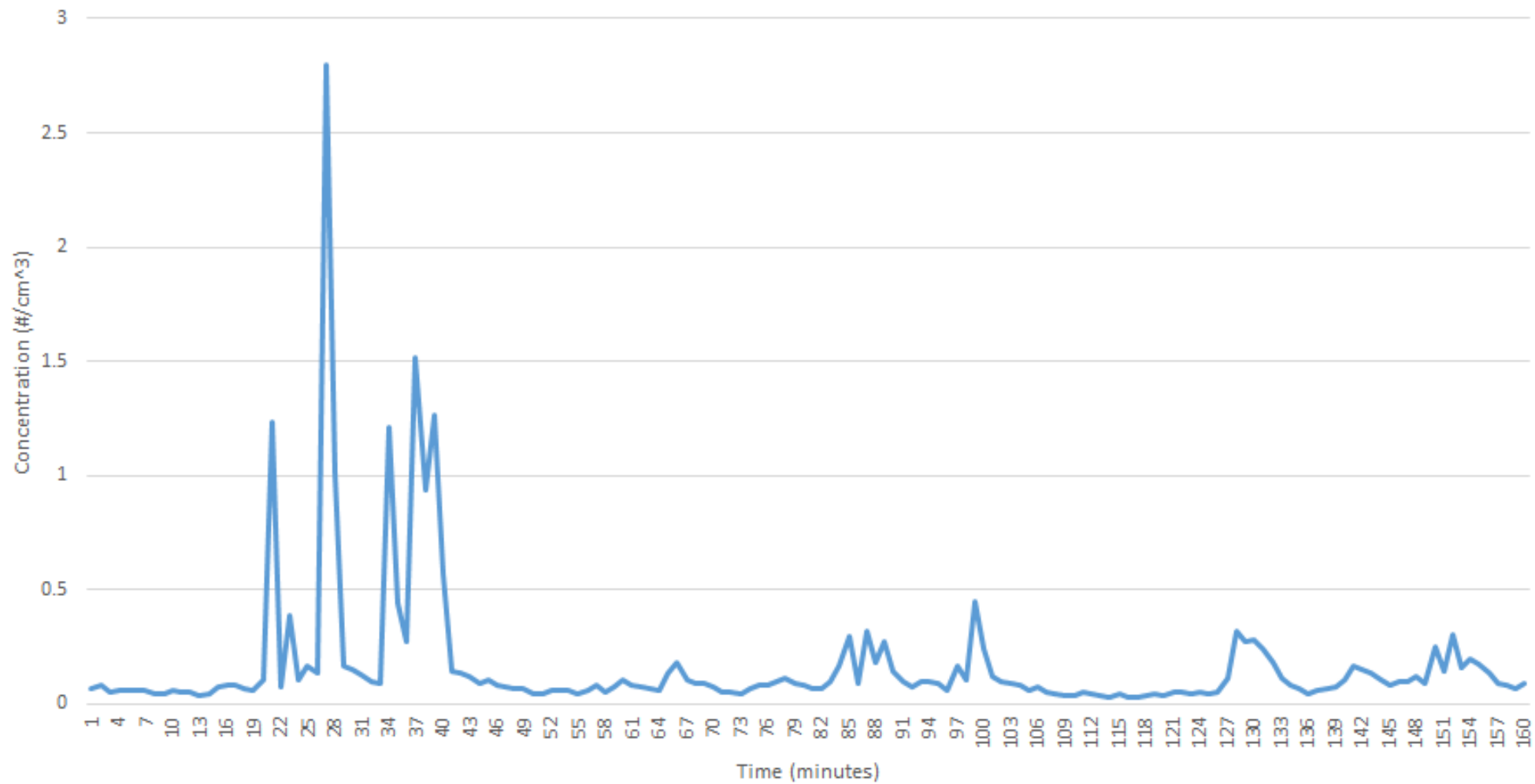
Soprano Singing, APS: Total Concentration over Time



Clarinet CPC: Concentration over Time



Clarinet APS: Total Concentration over Time



# Remarks based on Initial Exploratory Testing

- Exploratory results indicate the need to contain the aerosol emissions in a smaller sampling volume
- Sizing measurements show particles are typically  $< 10 \mu\text{m}$
- Concentrations were relatively higher for instruments that had straight shapes from mouthpiece to bell (trumpet, clarinet)
- Masks, nylon bell coverings all reduced particle concentrations

# Initial CFD Results of Aerosol Spread from a Singer without a Mask

Shengwei Zhu and Jelena Srebric

Center for Sustainability in the Built Environment (*City@UMD*)

University of Maryland

July 11, 2020



# CFD (Computational Fluid Dynamics) Modeling

Using computational fluid dynamics and the Wells-Riley equation, the City@UMD team has analyzed the concentration of airborne COVID-19 particles in **one outdoor and two indoor case studies**.

The **outdoor case study** represents a musician in a light wind field of 1m/s (2.2 mph) at 10 m (33ft) above ground, being roughly 0.2 m/s (0.5 mph) at a person's height. A simulation represents a single wind direction, so considering that a wind often changes its direction, the presented Covid-19 concentrations and infection risk will likely occur in a radius around a musician, rather than just behind a musician.

The **indoor case studies** represent a typical small rehearsal hall with a single musician. **Indoor Case 1** has both the supply and exhaust at the ceiling level, a typical ventilation system design. **Indoor Case 2** has the supply at the ceiling and the exhaust at the floor. Both cases are simulated with a musician breathing out Covid-19 in the center of the room. The two indoor cases differ solely in the placement of the space's HVAC supply and exhaust diffusers.

**Animations of Indoor cases  
can be found here:**

<https://city.umd.edu/covid-19>

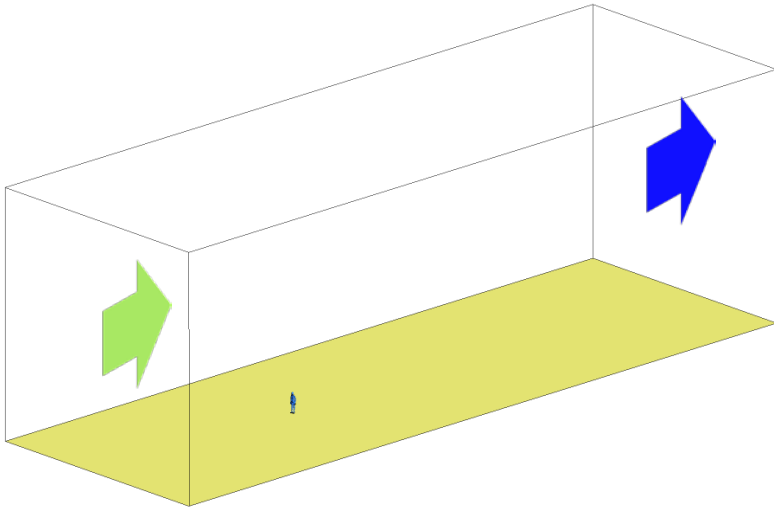
# CFD Case Study Setups

## Outdoor Case (20 m × 60 m × 20 m)

Inlet (green arrow):

Vel.: 1 m/s at elevation of 10 m

Temp.: 22°C at elevation of 1.5 m



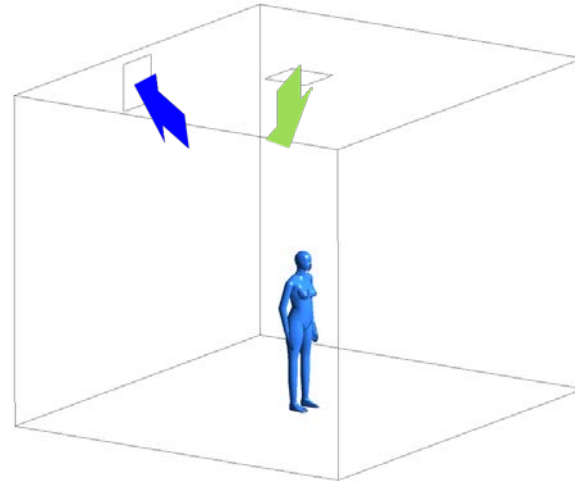
## Indoor Cases (4.5 m × 4.0 m × 3.5 m)

Inlet (green arrow):

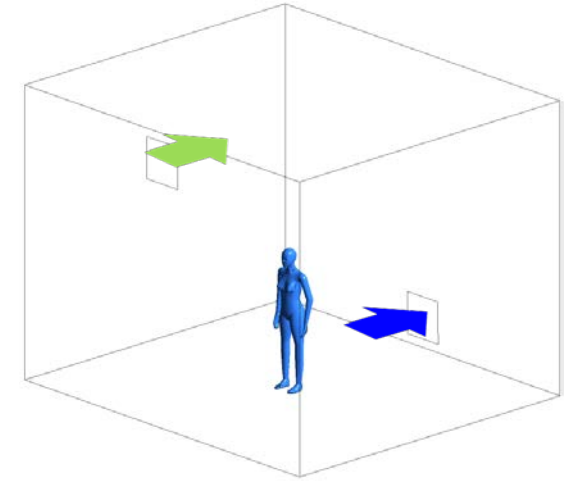
Size: 0.5 m × 0.5 m

Vel: 0.21 m/s (3 ACH)

Temp.: 22°C



Indoor Case 1



Indoor Case 2

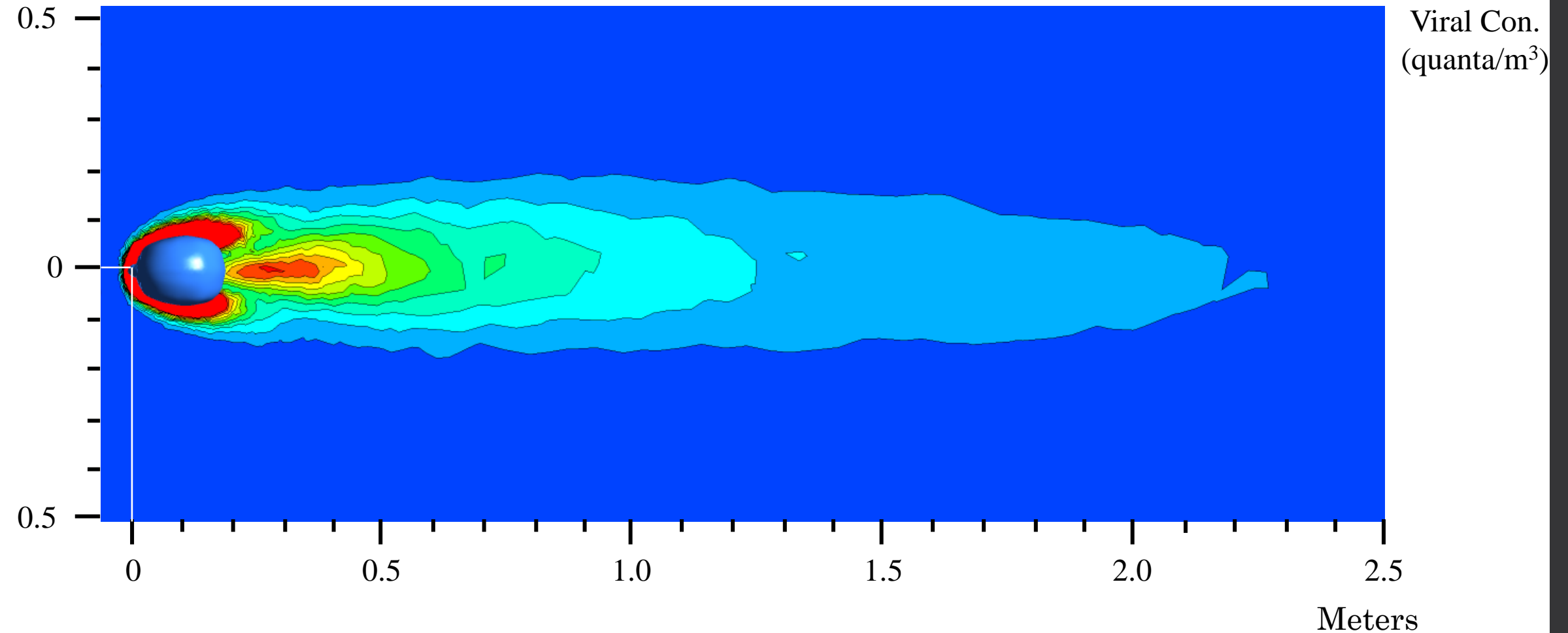
Human Body: Area of 1.47 m<sup>2</sup> and Heat flux of 23 W/m<sup>2</sup>

Mouth Opening: Area of 3.8 cm<sup>2</sup>, Velocity of 0.56 m/s, Temp. 32°C, and NO mask

Covid-19 generation rate: 48 quant/hr

# Outdoor Case: Virus Distribution after Roughly 90 Minutes

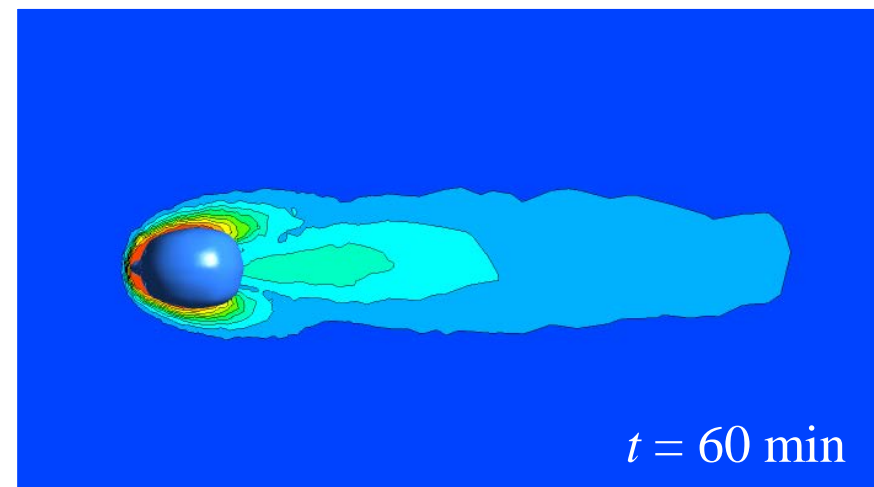
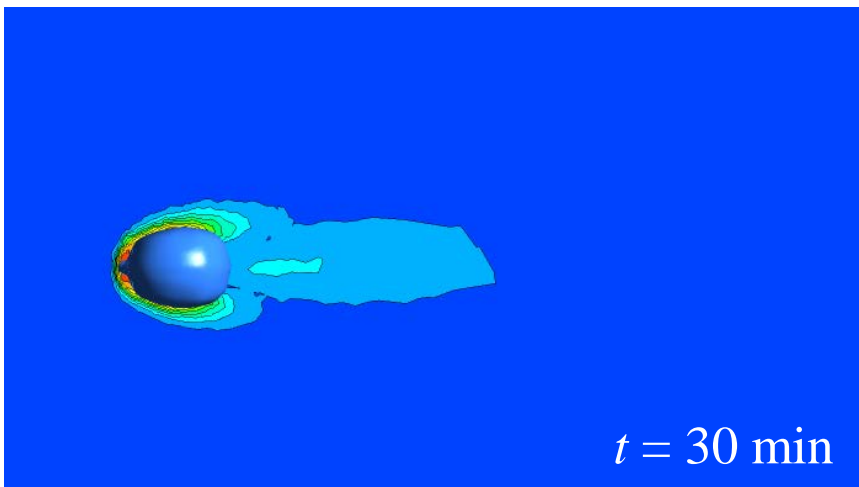
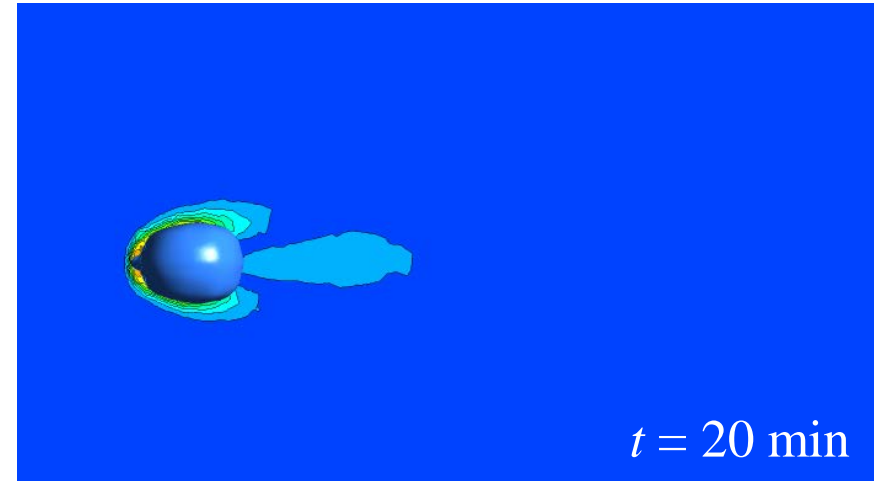
At the height of mouth opening



# Outdoor Case: Infection Risk at the Horizontal Cross Section

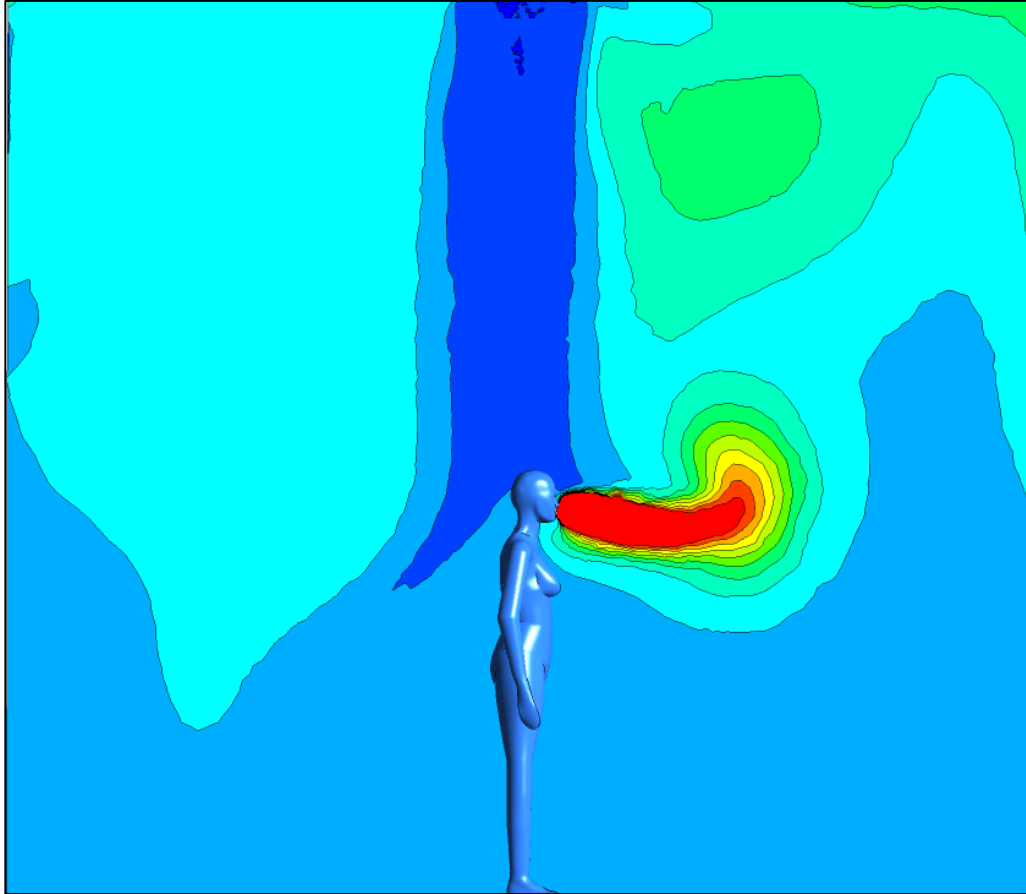
Infection risk  $r$  by the Wells-Riley equation:

At the height  
of mouth  
opening  
 $r$

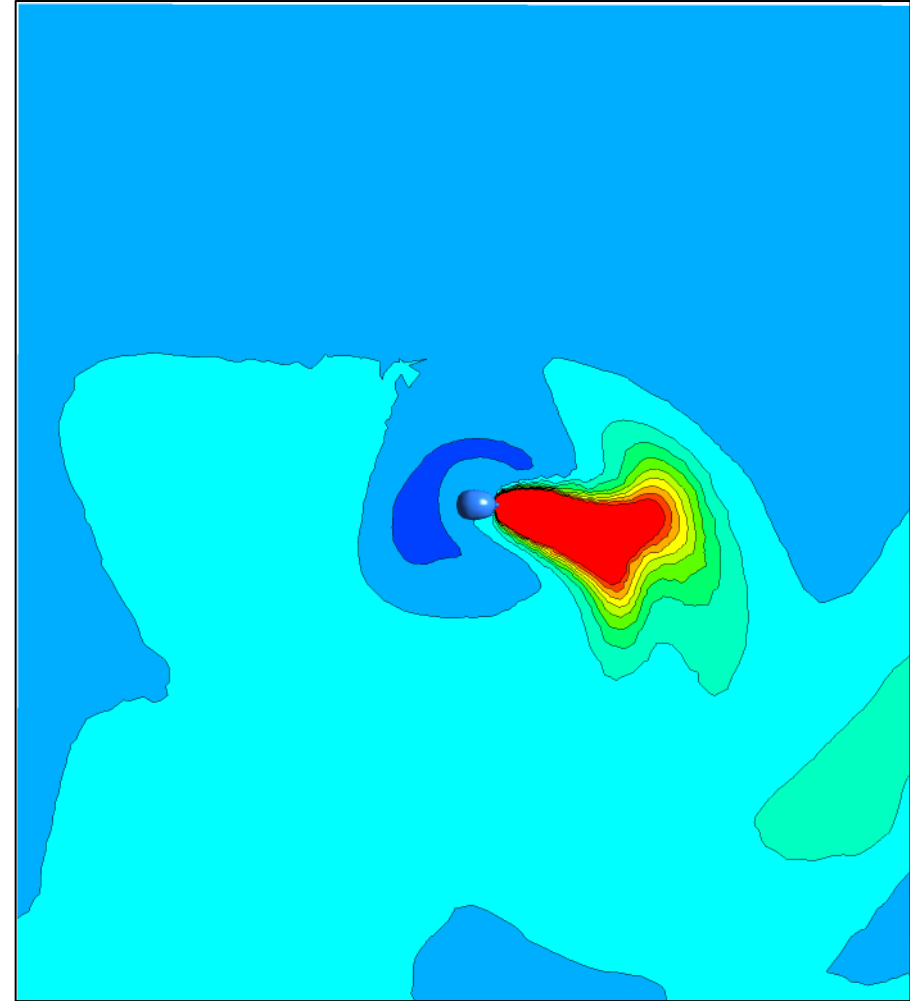


# Indoor Case 1: Virus Concentrations after Roughly 60 Minutes

Viral Con.  
(quanta/m<sup>3</sup>)  
)



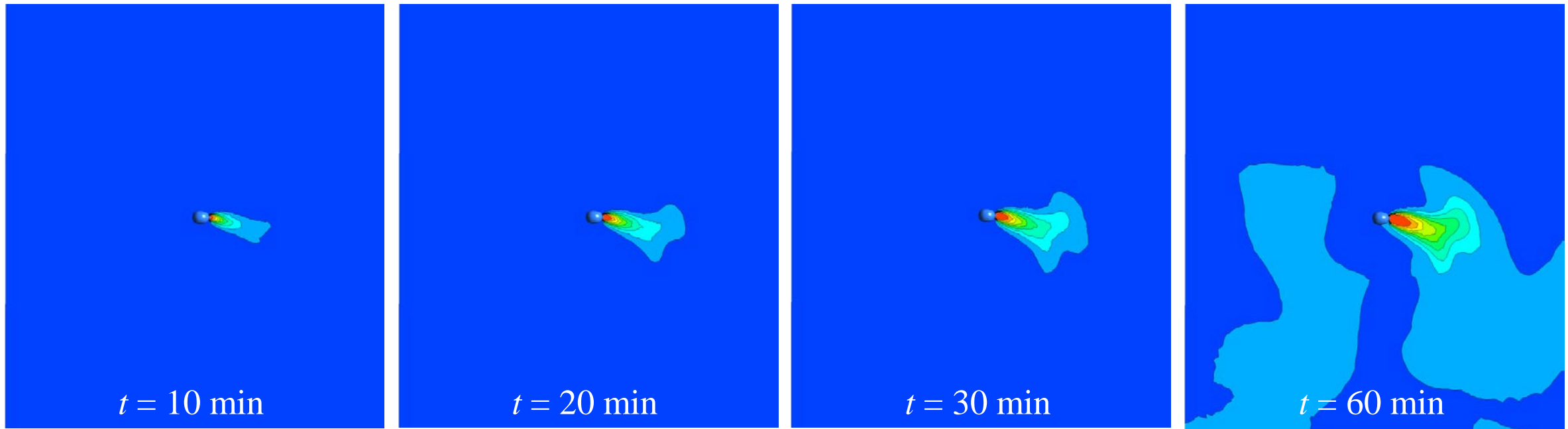
Vertical section  
cross the middle of human body



Horizontal section  
at the height of mouth opening

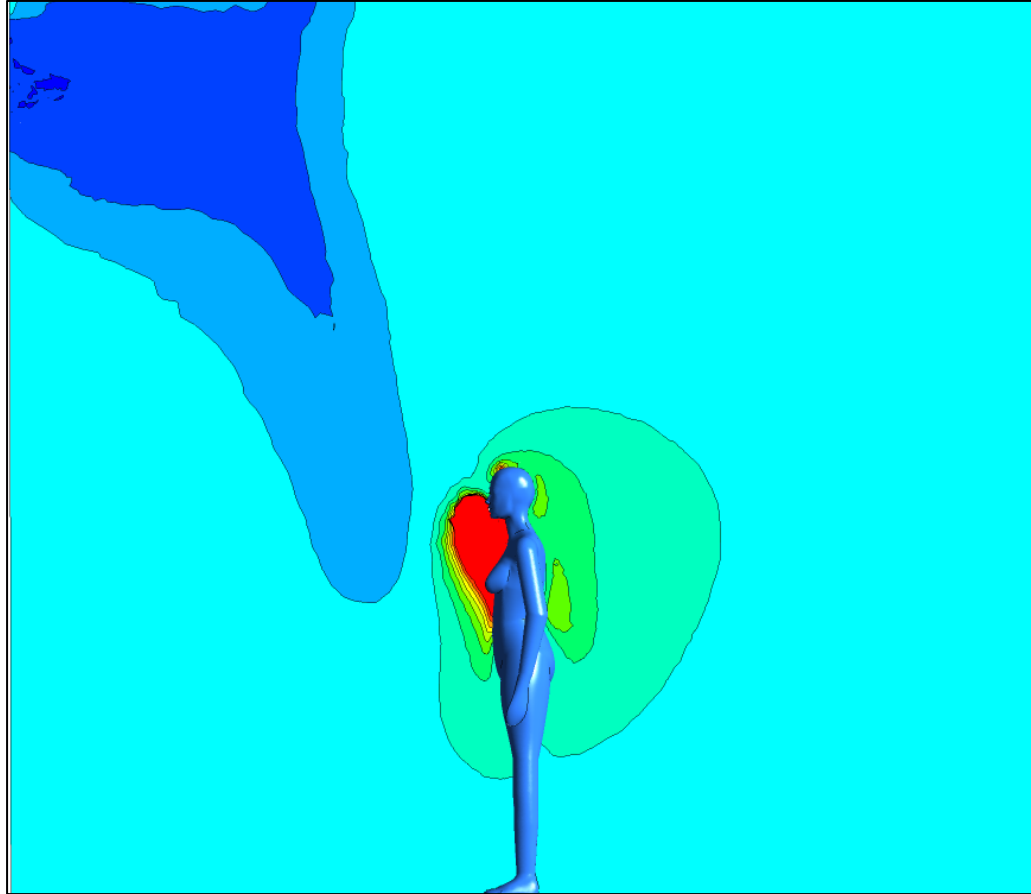
# Indoor Case 1: Infection Risk at the Horizontal Cross Section

Infection risk  $r$  at the height of mouth opening by the Wells-Riley equation:

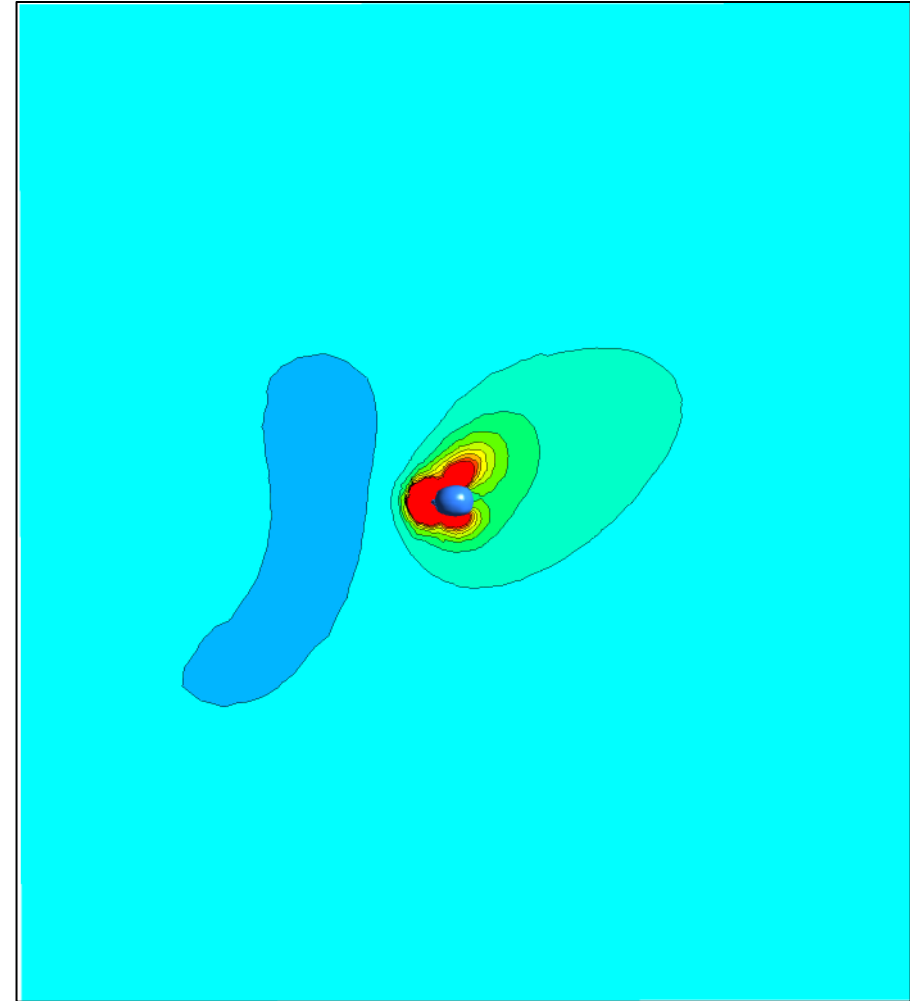


# Indoor Case 2: Virus Concentrations after Roughly 60 Minutes

Viral Con.  
(quanta/m<sup>3</sup>)



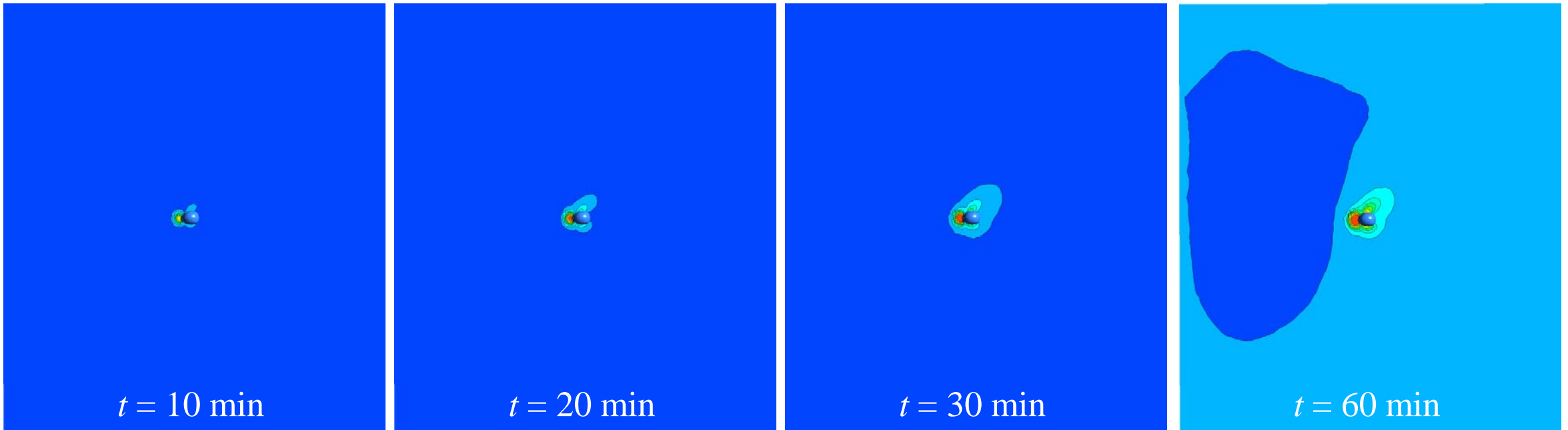
Vertical section  
cross the middle of human body



Horizontal section  
at the height of mouth opening

# Indoor Case 2: Infection Risk at the Horizontal Cross Section

Infection risk  $r$  at the height of mouth opening by the Wells-Riley equation:



# Remarks based on Initial CFD Simulations

**Initial CFD findings confirm the effectiveness of social distancing** directives to keep **2m/6ft** apart as this is the boundary of the region around an infected person in which the risk of infection begins to rise steeply, especially with an **exposure duration greater than 30 minutes**.

The simulations also show the variations in airborne particulate mixing due to different HVAC setups for the two indoor case studies. Indoor Case 1, a more **common layout of supply and exhaust air** in commercial buildings, is **less effective at removing COVID-19** particles yielding a larger and more persistent region of high COVID-19 infection risk.

Additional simulations will allow for multiple singers, multiple and varied instruments, and multiple infection risk mitigation strategies. All of these new cases will include measured data for the particle sources generated by musicians. City@UMD team will open for discussion future case studies as we have limited time to **answer most pressing questions** raised by our sponsors and colleagues.

# General Considerations

# General Considerations

- Masks should be worn by all students and staff prior to entering the performing arts room. Masks should continue to be worn until all students are seated and ready for instruction (example, long rests, sectional work, moving around the room, etc.)
- No talking should occur in the room without a mask being properly worn.
- When possible a mask with a small slit for mouthpiece access should be worn while playing.
- In instrument groups where a mask cannot physically be worn the mask should be worn over the chin and replaced during periods where the student is not playing. No talking without a mask.

# General Considerations

- Social distancing should occur as suggested by the CDC. Currently that distance is a 6x6 foot space around each student with the student sitting in the center. This may reduce the number of students that can fit in a performing arts classroom. Straight lines should be used as curved setups can affect the aerosol movement in a room.
- Students should sit all facing the same direction, back to front to minimize potential exposure.
- Trombones should have an additional three feet of distancing making their space 9x6. The player should be seated three feet in front of the back line, leaving an additional six feet in front of them due to the extended nature of the instrument and slide that can be in extended position.

# General Considerations

- Spit valves should not be emptied on the floor. Recommend using a puppy pad (or similar) to catch the contents of the spit valve and discard.
- Storage areas should be managed to limit the number of students at a time in the room. Anyone who enters the room should bring a 70% alcohol wipe to wipe all surfaces before and after touching. The wipe should be discarded properly upon leaving the storage area.
- Teachers should consider using a portable amplifier to keep their voices at a low conversational volume. Students should also ask questions in a low conversational volume with a mask.
- Teachers are assumed to talk the most and as a result should wear the most efficient mask possible that is readily available, which are surgical masks. (N95s are not recommended at this time due to supply chain issues.)

# General Considerations

- Existing HVAC systems should be fitted with HEPA filters if possible.
- There are HEPA air purifiers on the market to provide additional filtration appropriate to the size of the rehearsal space which will increase the air change rate from standard HVAC systems.
- Air change rate accounts for volume of the room.
- Air refresh rate per room to “clean” the room:
  - Air changes per hour (ACH),
  - $(1/\text{ACH}) \times 60 \text{ min/h} \times 3$
  - $3 \text{ ACH} = (1/3) \times 60 \times 3 = 60 \text{ minutes}$
- If volumetric flow rate (L/min) is available
  - divide by room volume to find the air change rate

# Outdoor, Open-sided Tents



- An option to indoor, poorly ventilated space might be an open-sided tent. This does not allow sunlight or vertical mixing effects but does reduce sun exposure to students.

# Marching Band

- See previous NFHS "Guidance for a Return to High School Marching Band"
- <https://www.nfhs.org/media/3812337/2020-nfhs-guidance-for-returning-to-high-school-marching-band-activities.pdf>
- Additionally, bell covers are highly recommended as "masks" for the instruments. Bell covers can be made of multi-layered high denier nylon material and provide a barrier for aerosols.
- Outdoor rehearsals are considered best practice; indoor rehearsals using CDC guidelines plus bell covers may be considered.

# Risk Estimator Tool

- The University of Colorado-Boulder has developed a risk assessment tool: <https://tinyurl.com/covid-estimator>
- NFHS is developing a web-based tool specifically for music applications. Projected roll-out of the tool to occur by the end of July.
- Data needed for tool:
  - Room volume (length x width x height)
  - HVAC outside air turnover rate, expressed by air "changes per hour" or "liters per second."
  - Add additional HEPA air purifier units to reach higher "changes per hour" or "liters per second."