

# PPE does not sufficiently protect against virus aerosol unless combined with air purification

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## Introduction:

- Infectious SARS-CoV-2 laden aerosols can remain suspended in the air for prolonged periods of time & travel large distances.
- Individual airborne protective measures may be inadequate in isolation.

## Aims:

1. To quantify the degree of protection provided by masks (surgical, N95, fit-tested N95) and personal protective equipment (PPE).
2. To determine if a portable high efficiency particulate air (HEPA) filter can enhance the protective effect of PPE against virus aerosol.

## Methods:

- Simulated virus aerosol exposure experiments using a marker virus (bacteriophage PhiX174).
- A HCW wearing PPE was exposed to nebulized viruses (10ml of 10<sup>8</sup> PFU/mL) for 45mins.
- Virus exposure quantified by skin swabs applied to the face (under the mask) and inside nostrils of the exposed HCW, as well as via settle plates (data not shown here).
- The HCW showered & a HEPA filter (set to CADR=470m<sup>3</sup>/hr; ~13 air filtrations/hr) was used to purge the room of aerosol between conditions.
- To control for between-day variations in bacteriophage titre, all mask conditions were completed on the same day (randomized order) and replicated on subsequent days.

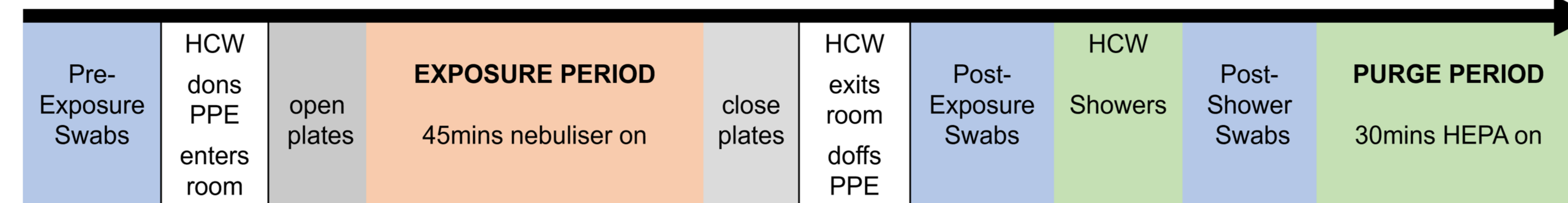


Figure 1. Timed protocol for simulated virus exposure experiments

**Experiment 1:** To assess the efficacy of PPE to protect against virus aerosol exposure, the HCW was seated at the bedside (0.85m from aerosol source) during nebulization. Conditions:

- 1) a no-PPE condition served as a control.
- 2) surgical mask.
- 3) poor-fitting N95 mask (fit factor < 100; BYD N95 Particulate Respirator, NIOSH Approval #84A-9279).
- 4) fit-tested N95 mask (fit factor = 194; 3M Aura 1870A+, NIOSH Approval #84A-5726).

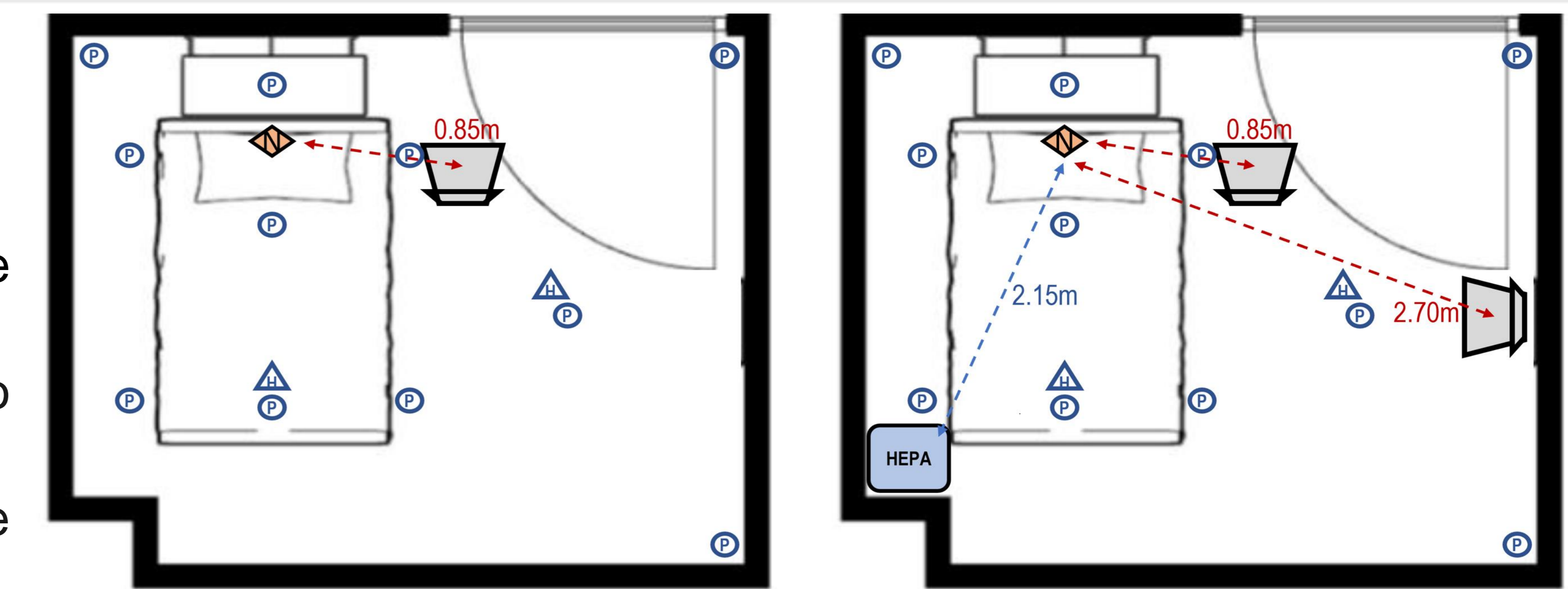


Figure 2. Sealed clinical room layout for experiments 1 (LEFT) and 2 (RIGHT). Room dimensions = 4.0 × 3.25 × 2.7 m (volume = 35.1 m<sup>3</sup>). Settle plates (circles & triangles) were placed around the room to quantify environmental contamination. The nebulizer (orange diamond) was positioned at the head of the bed, with the exit point facing vertically.

**Experiment 2:** To assess the efficacy of combining multiple control measures, the same design was used with constant HEPA filtration (CADR = 470m<sup>3</sup>/hr). Conditions:

- 1) surgical mask @ bedside (0.85m from aerosol source).
- 2) surgical mask @ distanced location (2.70m from source).
- 3) fit-tested N95 mask @ bedside (0.85m from aerosol source).
- 4) fit-tested N95 mask @ distanced location (2.70m from source).

## Results

### Experiment 1:

- Significant virus counts were detected on the face underneath surgical & N95 masks.
- Only the fit-tested N95 resulted in lower virus counts compared to the no-PPE control (p=0.027).
- Nasal swabs demonstrated consistently high virus exposure, which was not mitigated by the surgical/N95 masks.
- There was a trend for fit-tested N95 mask to reduce nasal virus counts (p=0.058).

### Experiment 2:

- HEPA filtration substantially attenuated but did not eliminate virus settling on surfaces (plate data not shown here).
- Higher virus counts were again observed in the nostril compared to under the mask
- Surgical masks combined with distance & HEPA filtration did not substantially reduce nasal virus counts.
- HEPA filtration combined with a fit-tested N95 reduced virus counts in the nostril to near zero levels.

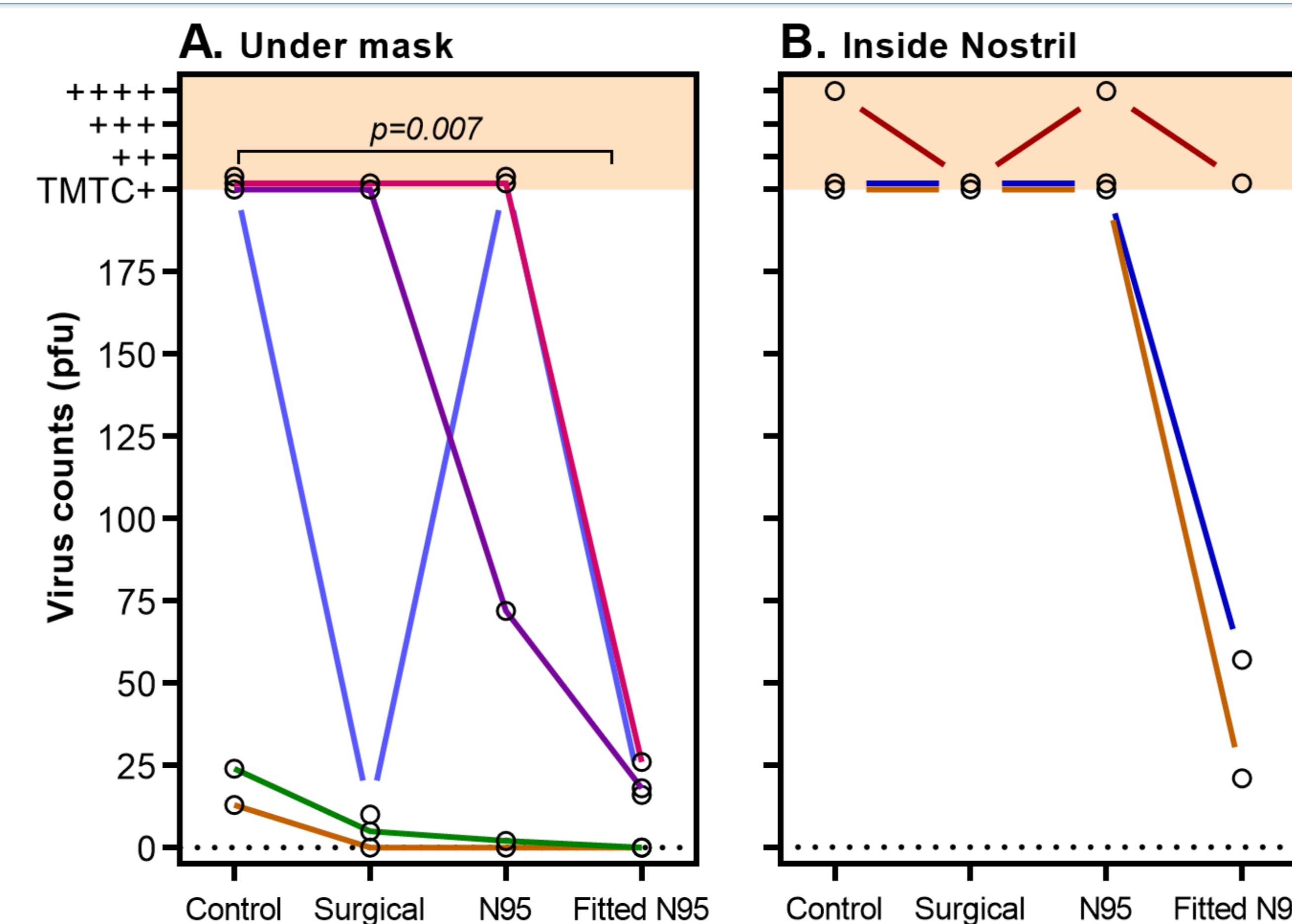


Figure 3 – The effect of PPE on Virus counts: **A) around mouth/nose underneath mask, B) Inside the nostril.** Colored lines represent data collected on same day (i.e. same bacteriophage titre). Despite inter-day variability in total virus counts, the Fitted N95 mask remained superior to all other conditions.

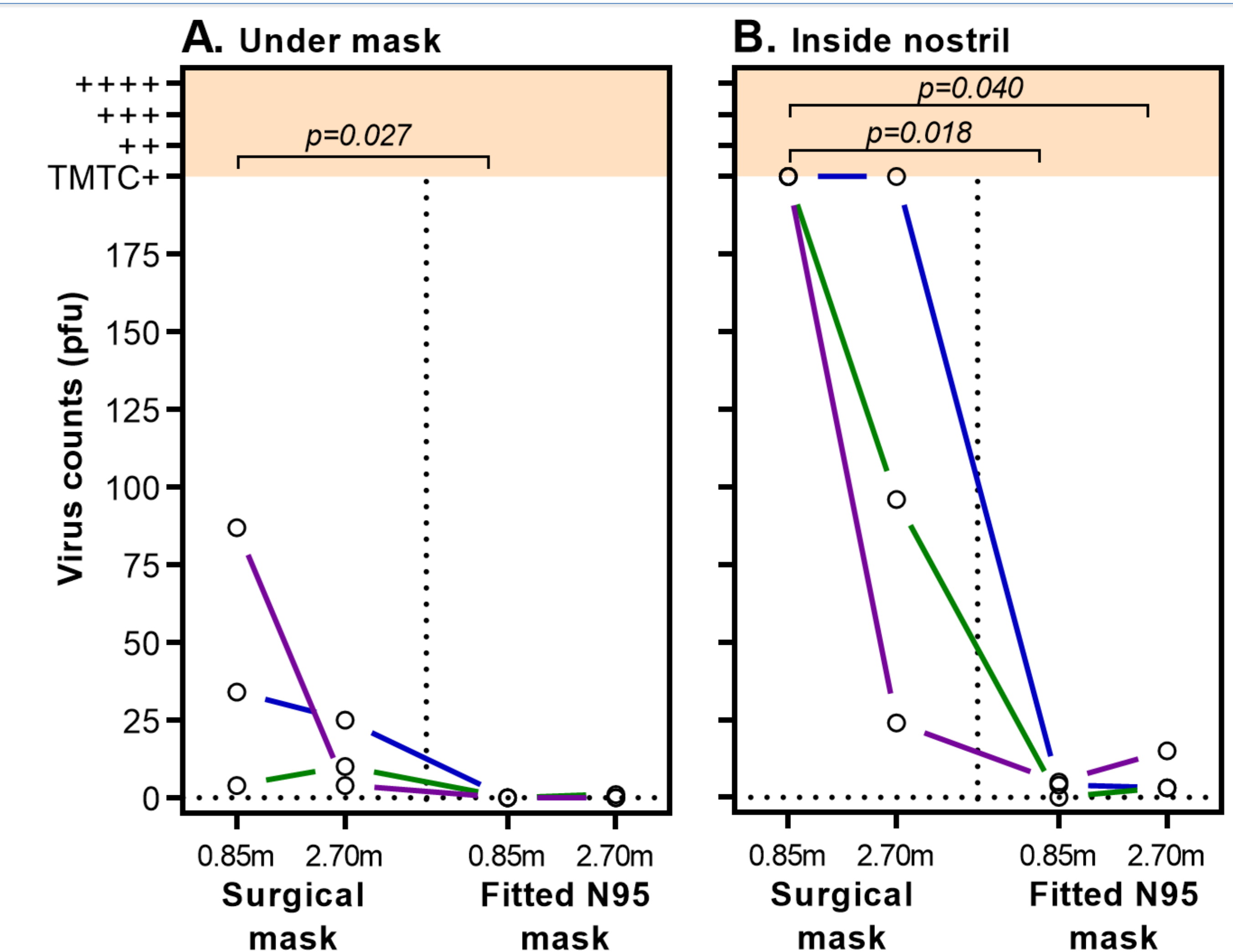


Figure 4 – The effect of HEPA filtration combined with PPE & distance on virus counts. **A) around mouth/nose underneath mask. B) Inside the nostril.** HEPA @ 470m<sup>3</sup>/hr ~ 13 air exchange/hr.

## Discussion:

Our study is the first to conduct live virus aerosol experiments to systematically examine HCW virus contamination and the interaction between virus aerosol, PPE and air filtration using a portable HEPA filter. Importantly, we found that the combination of a **quantitatively fit-tested N95 mask** and **portable HEPA filter** provided near complete protection against high virus aerosol loads at close range for prolonged periods of time. Critically, surgical masks provided inadequate protection against skin and upper airway contamination, even when combined with HEPA filtration and at distances of 2.70m.