

Prudential Body Box Results

Kate Gushwa

Margot Phelps

Calum Torrie

Body Box



- Series of exercises performed inside an ISO Class 3 box.
- Particles collected at knee and sub floor levels.

Exercises

During each test:

- Stand still (1 min)
- Reach arms out then touch shoulders (5 min)
- Stand still (1 min)
- March and touch shoulders (5 min)
- Stand still (1 min)
- Bend knees (1 min)
- Stand still (1 min)

Constants

- Wore:
 - Bouffant cap
 - Booties
- Same activities performed during each test.
- Garb removed immediately after tests.
- Subjects were tested in the same order to allow a cool down period between tests.

Constants

- Short wait after each test while the particle count stabilized in the empty Body Box.
- Subjects had breakfast and drove to Prudential in scrubs to better simulate normal use.



Prudential Trips

Trip #1

- **Participants:** Calum, Margot, Kate
- **Tests:**
 1. 2010 garb w/ scrubs
 - LHO hood & new veils
 2. 2008 garb w/ scrubs
 - LHO hood disposable mask
 3. 2010 garb w/ street clothes
 - Calum: shorts
 - Margot: slacks
 - Kate: jeans

**Assume 15-17 washes per year*

Trip #2

- **Participants:** Calum, Margot, Kate, Betsy
- **Tests:**
 1. Brand new garb w/ scrubs
 - LHO hood (one size fits all)
 - New veils (Betsy in mask)
 2. Brand new garb w/ street clothes
 - Calum: shorts
 - Margot: slacks
 - Kate & Betsy: jeans

**Virgin garb washed 3x (customary before first use)*

2008 Garb

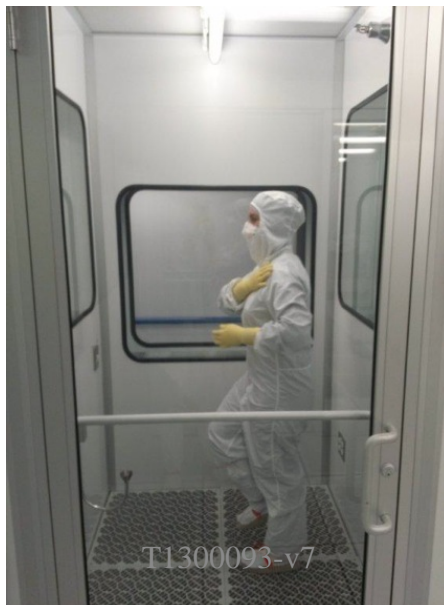


- Size of gaps between mask and hood varied between subjects.
- Was “best case” test of old garb because subjects had well-fitting hoods.
- Sometimes have to wear wrong size at observatories, resulting in bigger gaps.



2010 Garb

- Calum – hole in suit covered with tape.
- Kate – noticeable shedding and loose threads.



New Garb

- Never worn before test.
- Washed 3 times.
- One size fits all hood (adjustable).



Scrubs

- ESD Micro Denier polyester

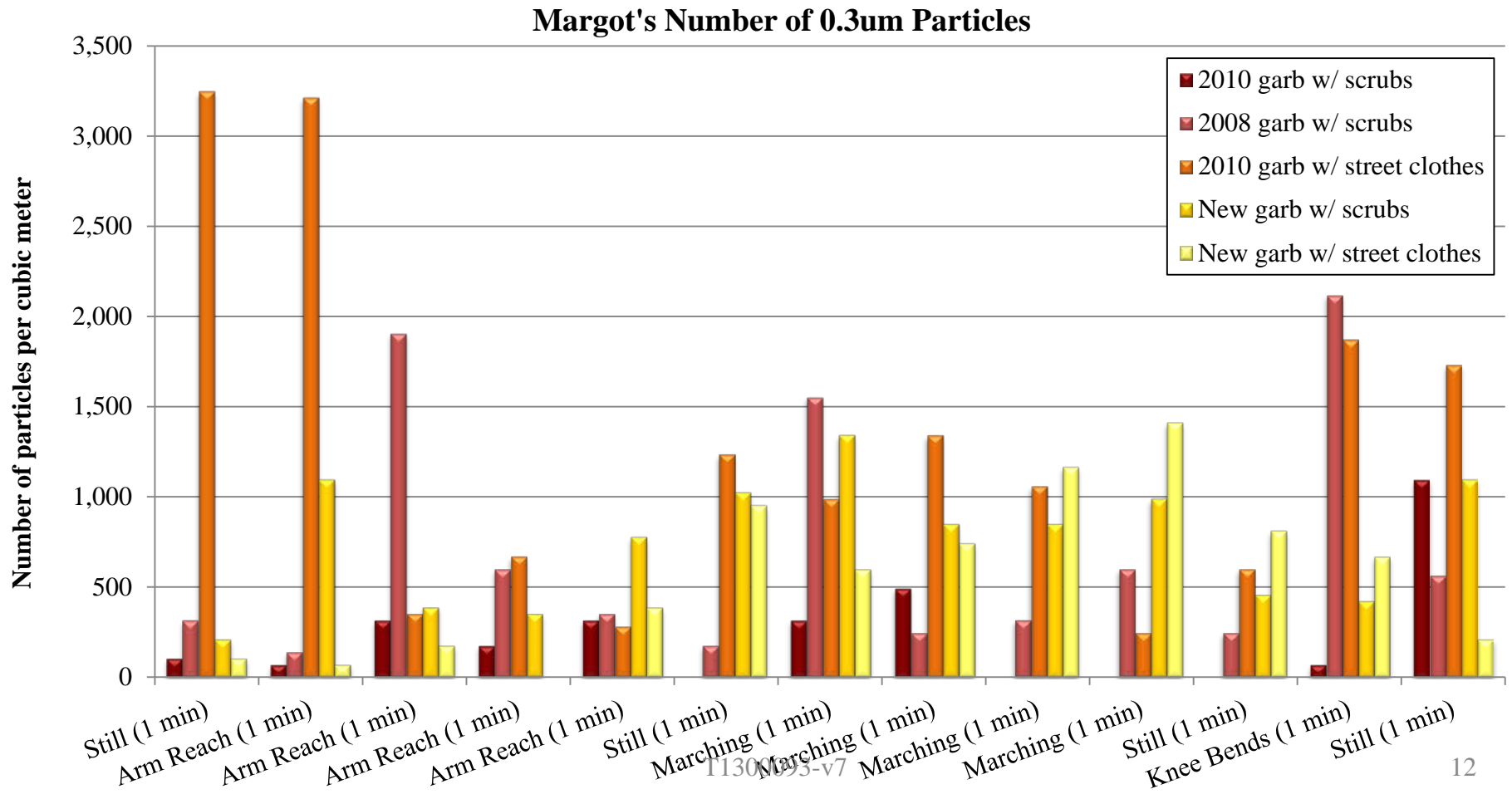


Important Notes

- “Adjusted” particle count:
 - Initial count (measured before subject entered) subtracted from counts for each activity.
- Negative counts:
 - In Margot’s 1st test & Kate’s 3rd test, the adjusted particle count for some of the activities was a negative number. The count was zeroed for these cases.
- Anomaly:
 - Calum was an anomaly. He shed more in 2010 garb (which had a hole) than 2008 garb.

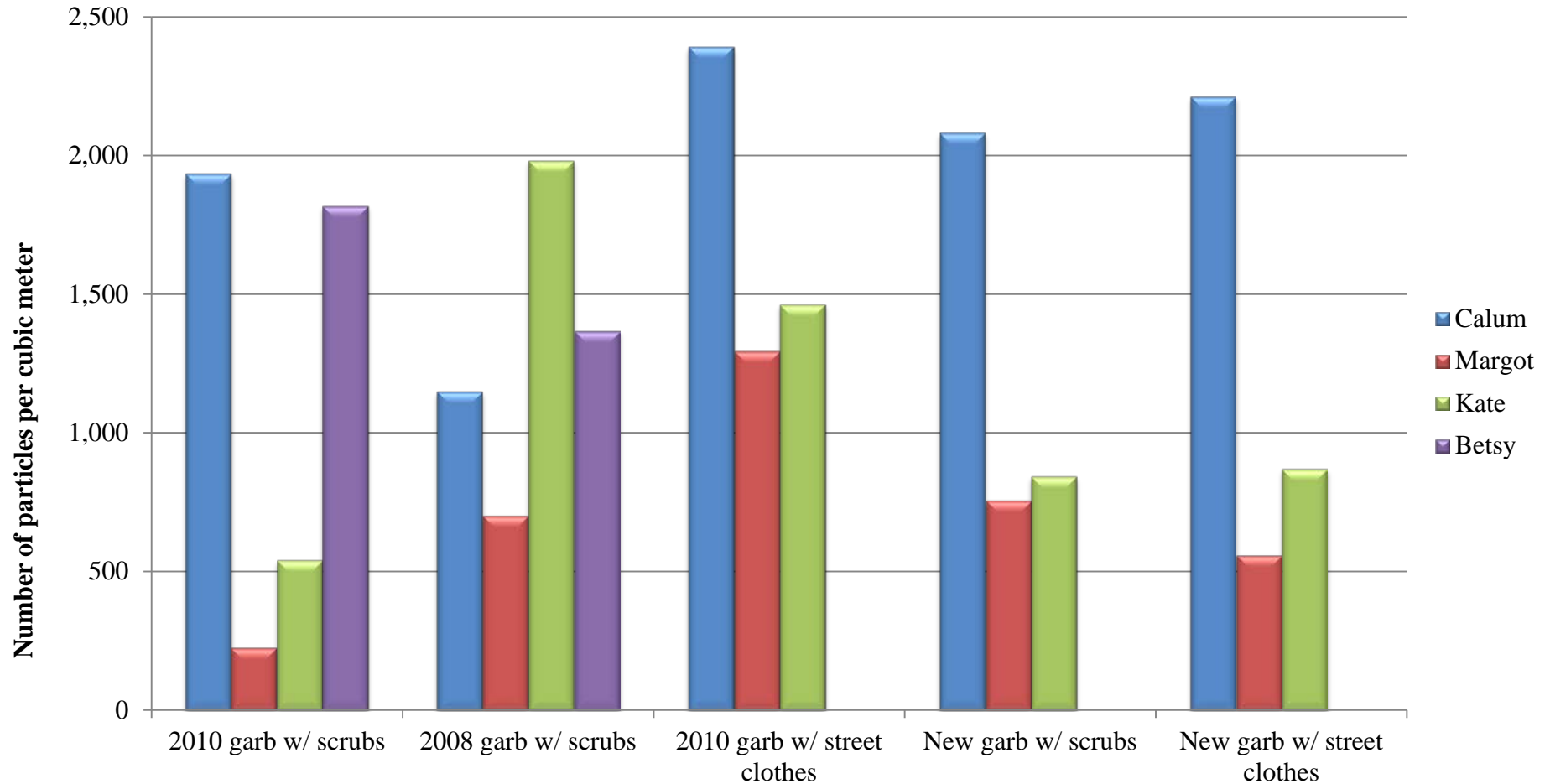
Interpreting Data

- Each subject's counts (like graph below) were averaged for comparison.



Body Box Averages

Average Number of 0.3um Particles



What we're looking for

		What is it?	What is learned?	How it's evaluated?
Garb	C3 Shedding	Particle generation by C3 garb	How LIGO's garb is holding up. Whether we need to purchase new garb.	New vs. 2010 vs. 2008 garb, constant = scrubs
	Shielding	Particle penetration through garb	How effectively LIGO's garb contains particles generated by clothes (linting) and people.	New garb vs. 2010 garb, constant = street clothes
Clothing	Scrubs?	Particle generation by clothes worn under garb	Whether implementing scrubs under garb will significantly reduce contamination.	Scrubs vs. street clothes, i) constant = new garb ii) constant = 2010 garb

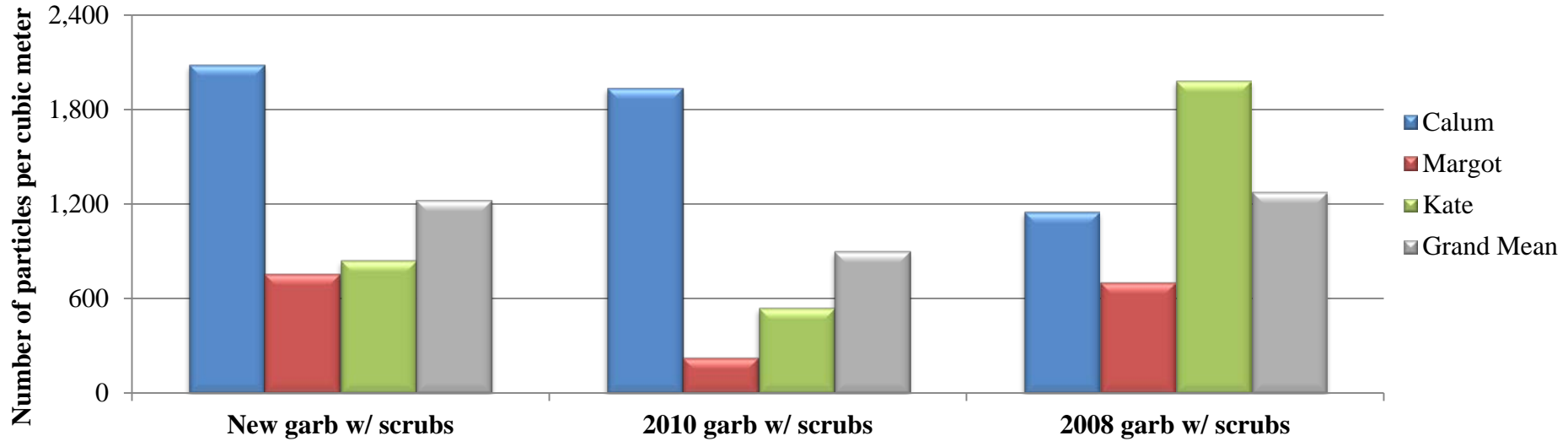
Note: Can never fully separate variables (ex: shedding, shielding). This is just our best attempt.

C3 Shedding

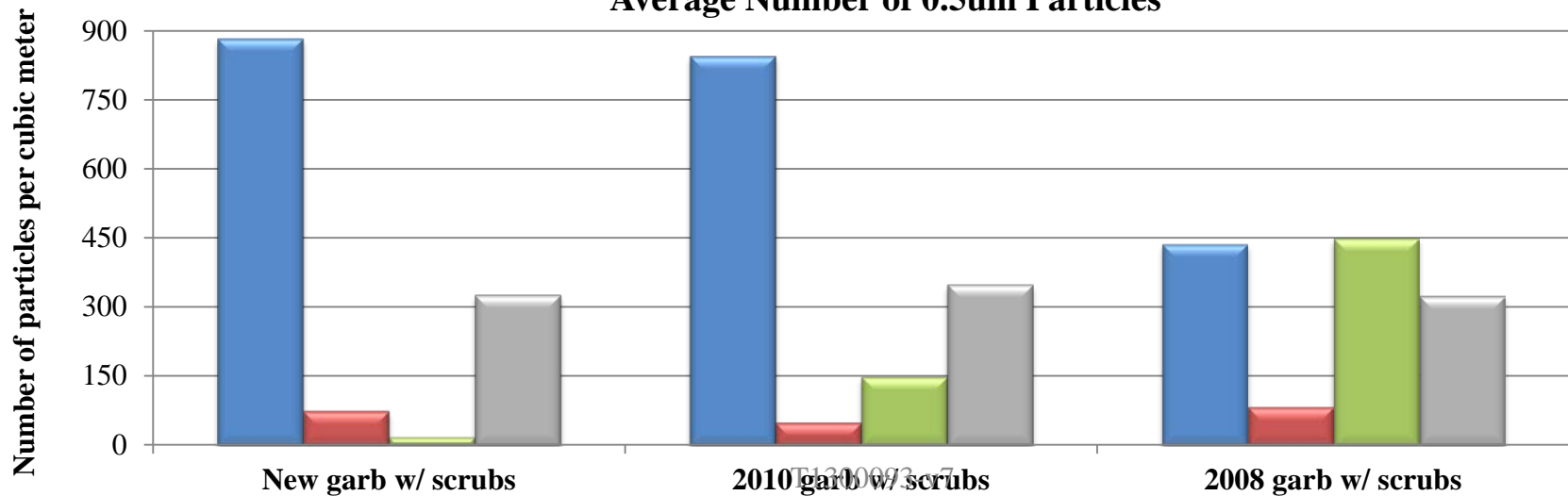
New vs. 2010 vs. 2008 garb
constant = scrubs

C3 Shedding

Average Number of 0.3um Particles

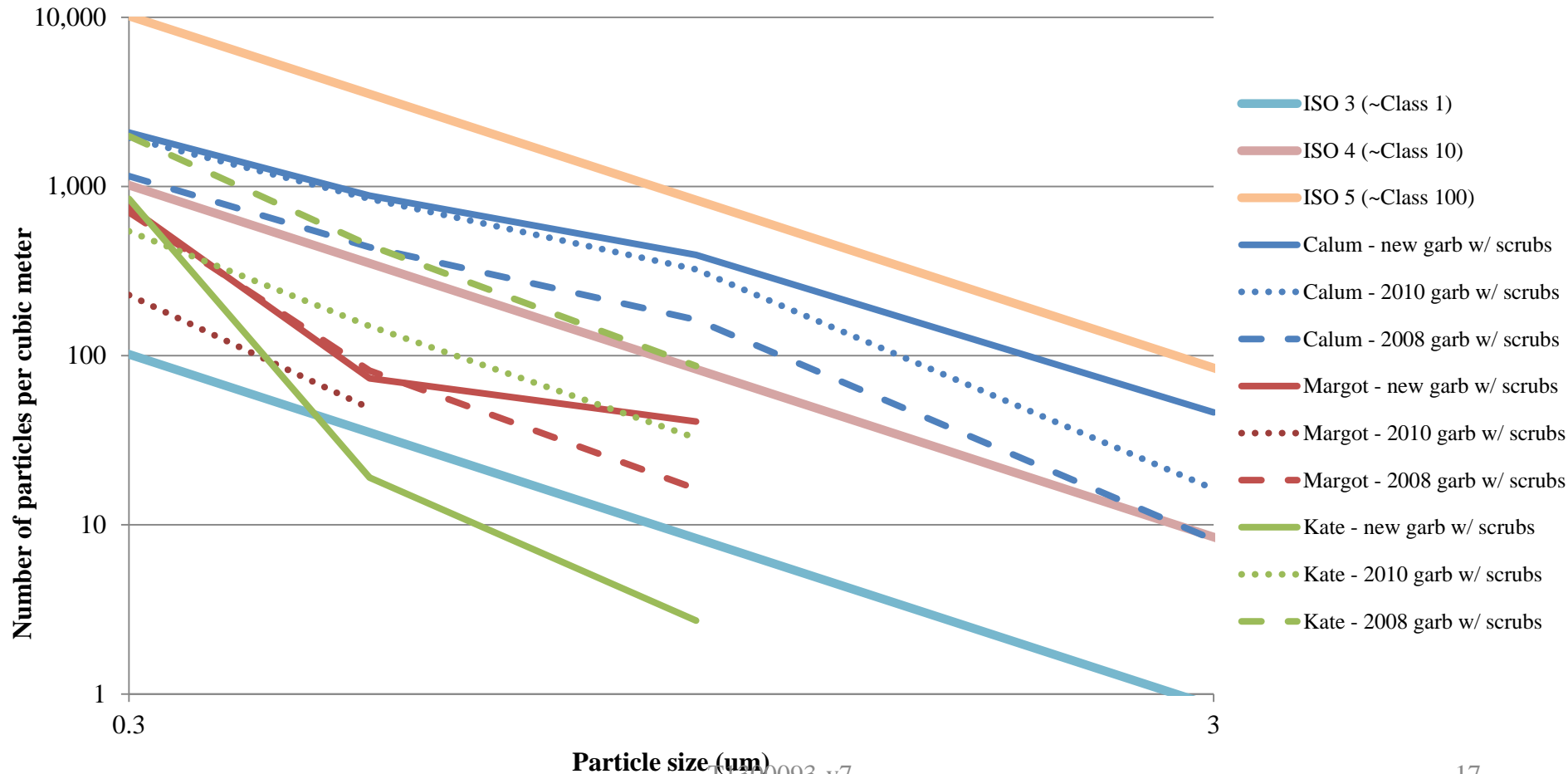


Average Number of 0.5um Particles



C3 Shedding

- Compare blue to blue, red to red, green to green.
- **In terms of shedding, our old garb is holding up well.**



C3 Shedding

CALUM:

	Avg # of Particles (um)			Total Particles	Highest Class
	0.3	0.5	0.1		
2008 garb w/ scrubs	1,152	437	163	22,884	4.8
2010 garb w/ scrubs	1,937	845	323	40,577	5.1
New garb w/ scrubs	2,084	883	394	44,285	5.8

MARGOT:

	Avg # of Particles			Total Particles	Highest Class
	0.3	0.5	1		
2008 garb w/ scrubs	704	81	16	10,418	4.3
2010 garb w/ scrubs	228	49	0	3,602	4.0
New garb w/ scrubs	758	73	41	11,336	4.4

KATE:

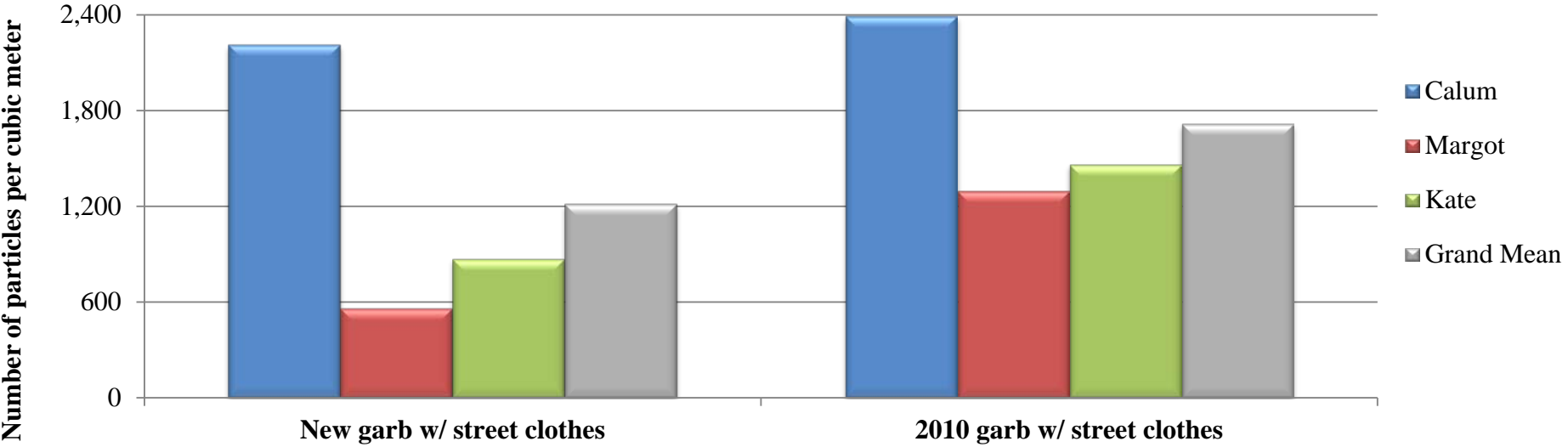
	Avg # of Particles			Total Particles	Highest Class
	0.3	0.5	1		
2008 garb w/ scrubs	1,983	448	87	32,737	4.6
2010 garb w/ scrubs	543	149	33	9,429	4.2
New garb w/ scrubs	845	19	3	11,265	4.5

Shielding

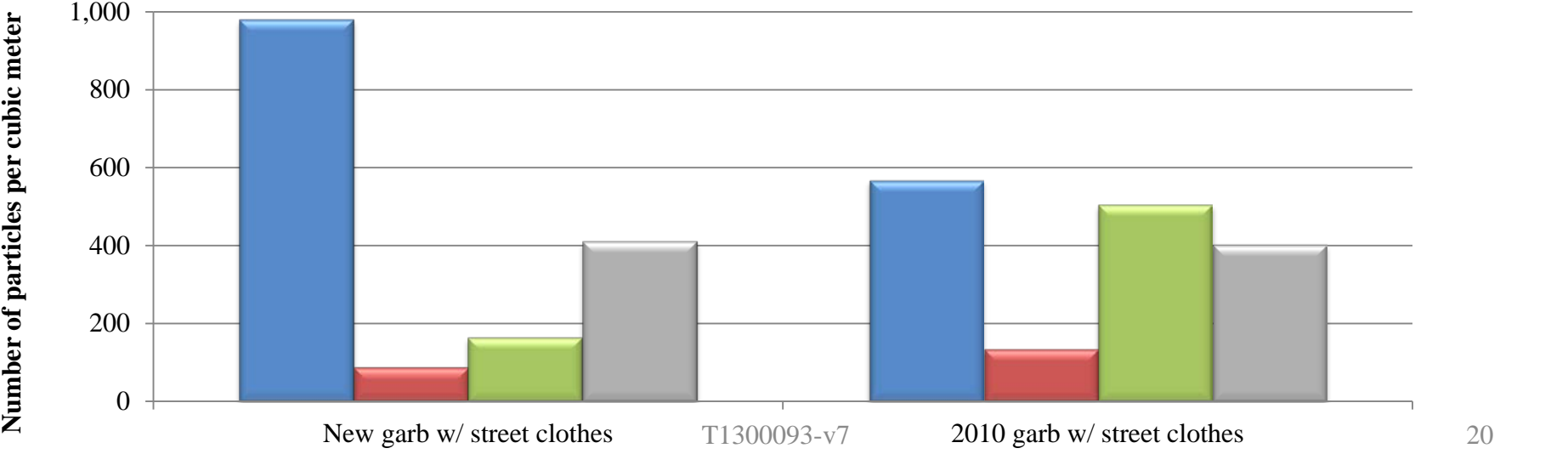
New garb vs. 2010 garb
constant = street clothes

Shielding

Average Number of 0.3um Particles

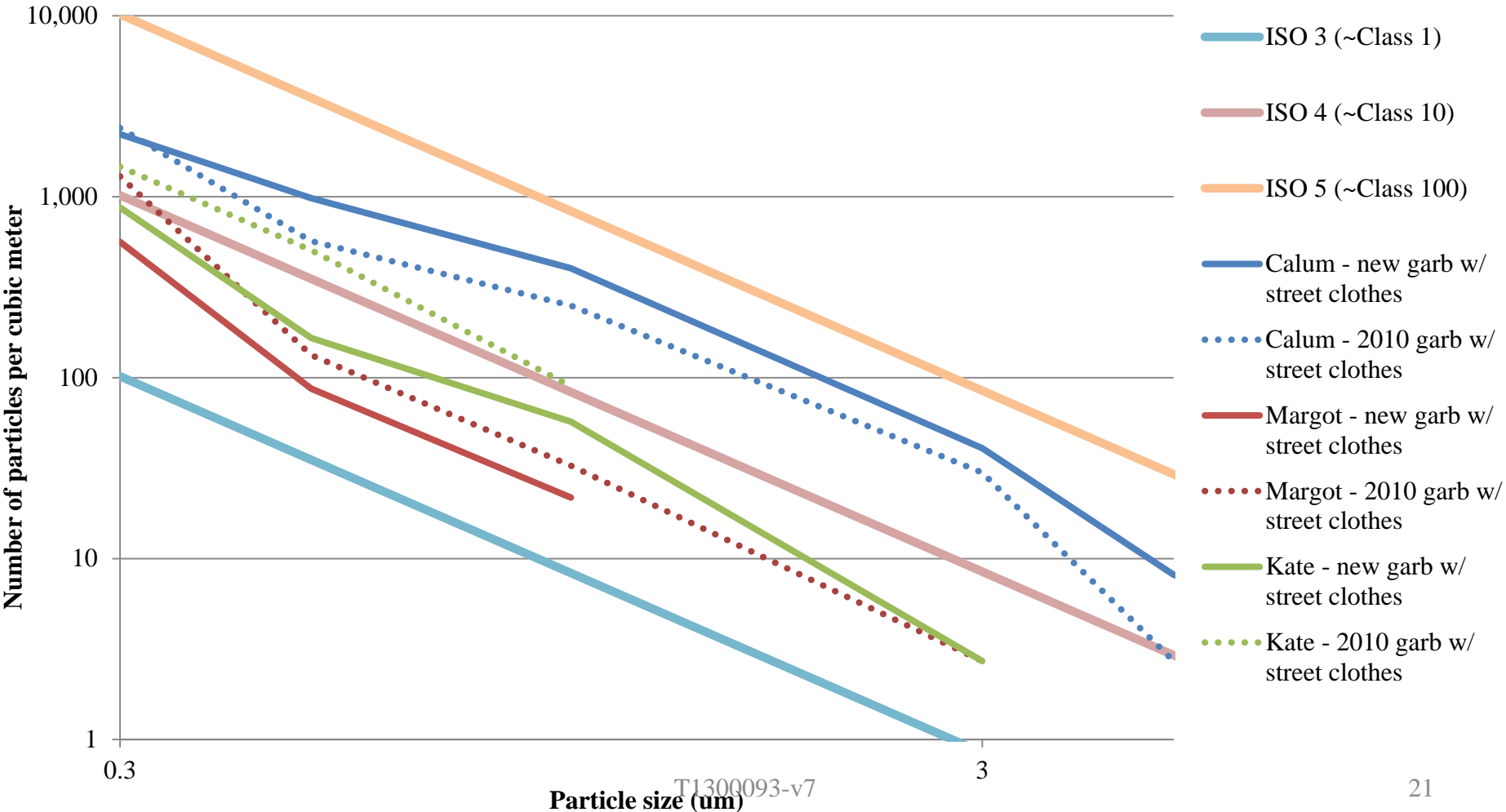


Average Number of 0.5um Particles



Shielding

- **Brand new garb is a better barrier.**
- *Did not test 2008 garb w/ street clothes, so had to use Calum's anomalous 2010 garb data.*



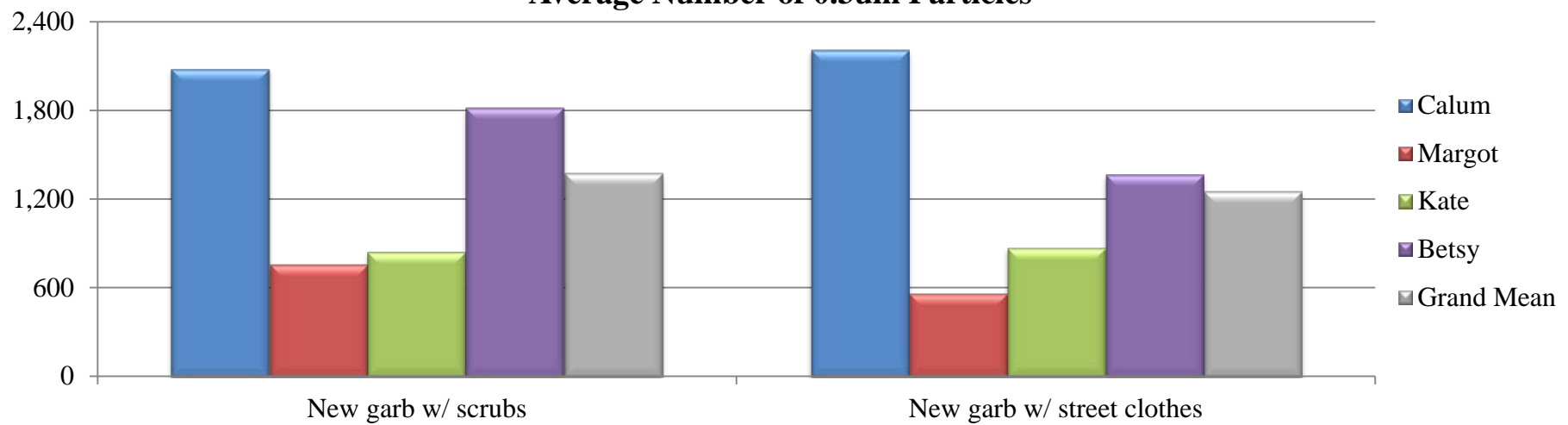
Scrubs?

Scrubs vs. street clothes

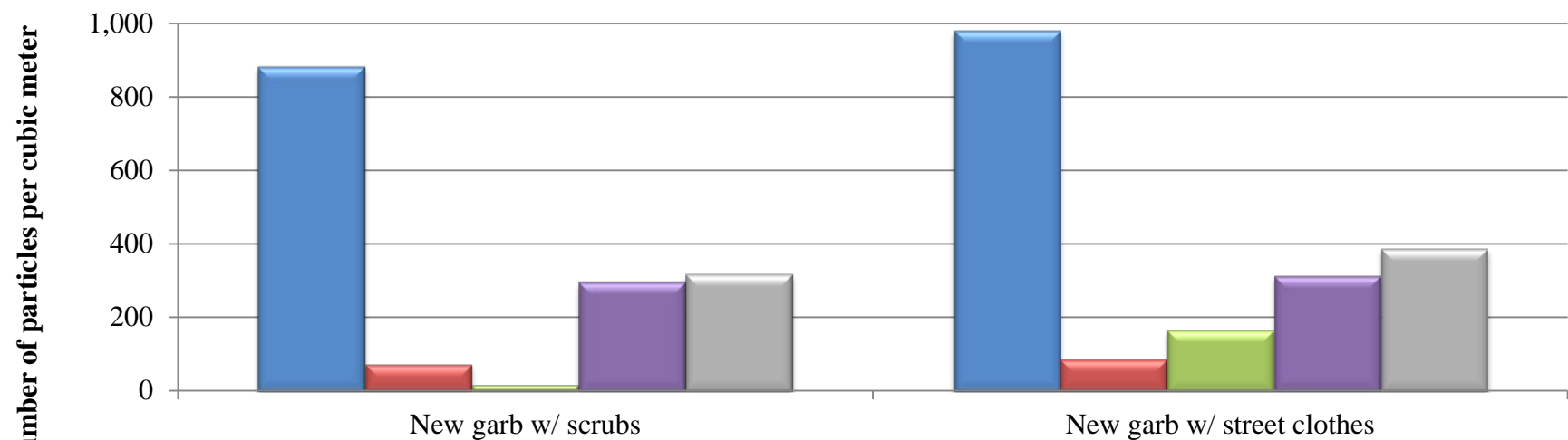
- i) constant = new garb
- ii) constant = 2010 garb

Scrubs vs. Street Clothes (New Garb)

Average Number of 0.3um Particles

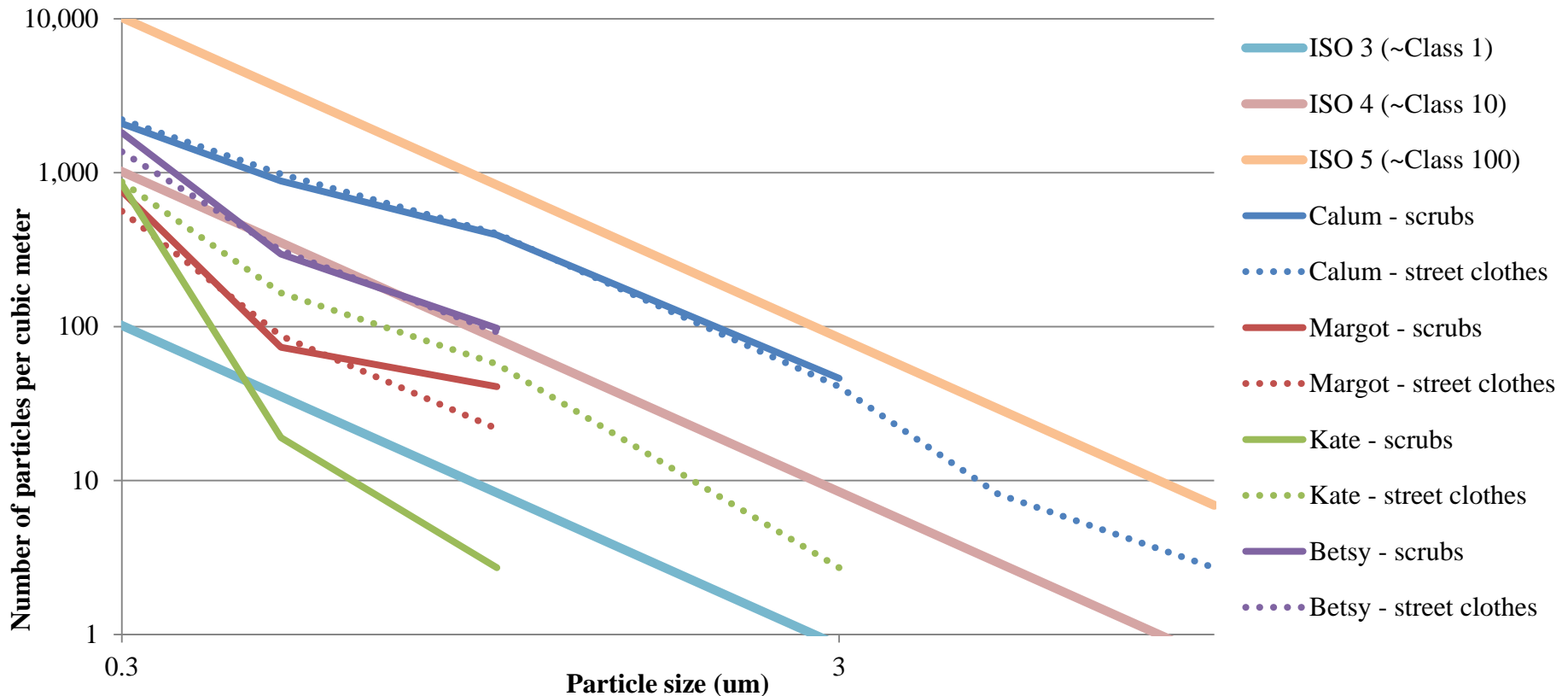


Average Number of 0.5um Particles



Scrubs vs. Street Clothes (New Garb)

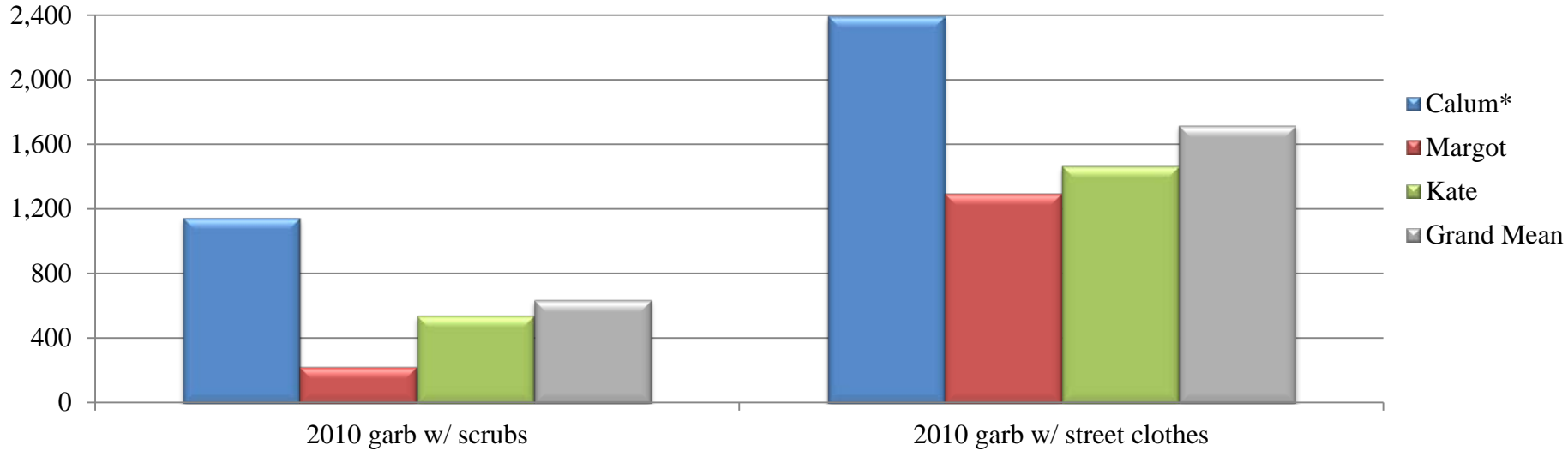
- Kate shed less in scrubs.
- Subtler difference for Calum, Margot, and Betsy.
- **New garb is better at shielding, and masks the contamination from people and clothes.**
OR new garb sheds more, and masks the benefits of scrubs.



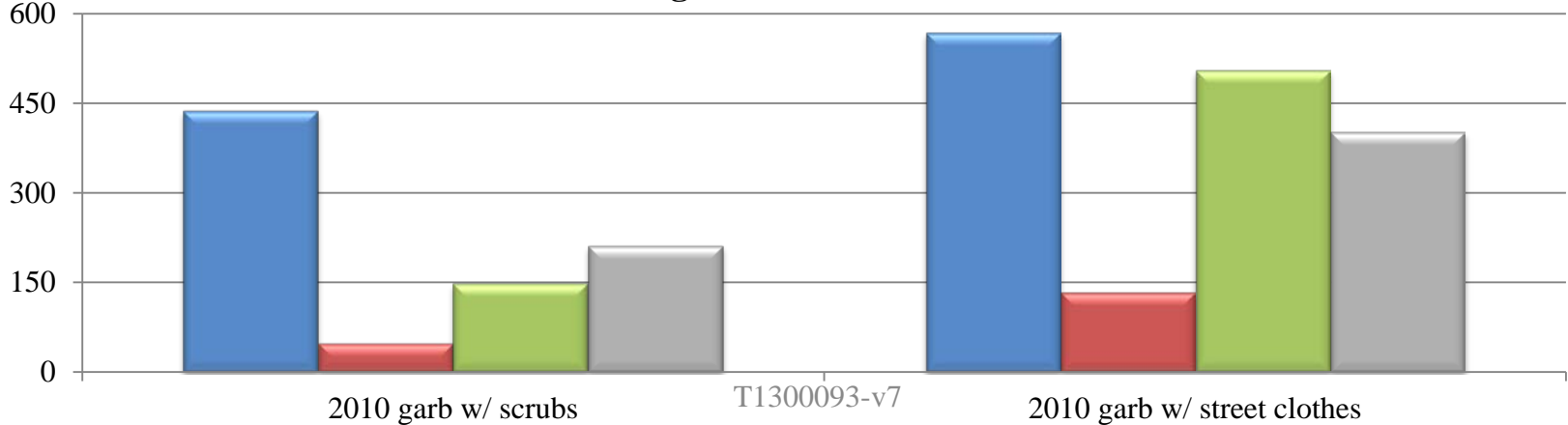
Scrubs vs. Street Clothes (2010 Garb)

* Used Calum's 2008 garb w/ scrubs data due to anomalous test with 2010 garb (had a hole).

Average Number of 0.3um Particles



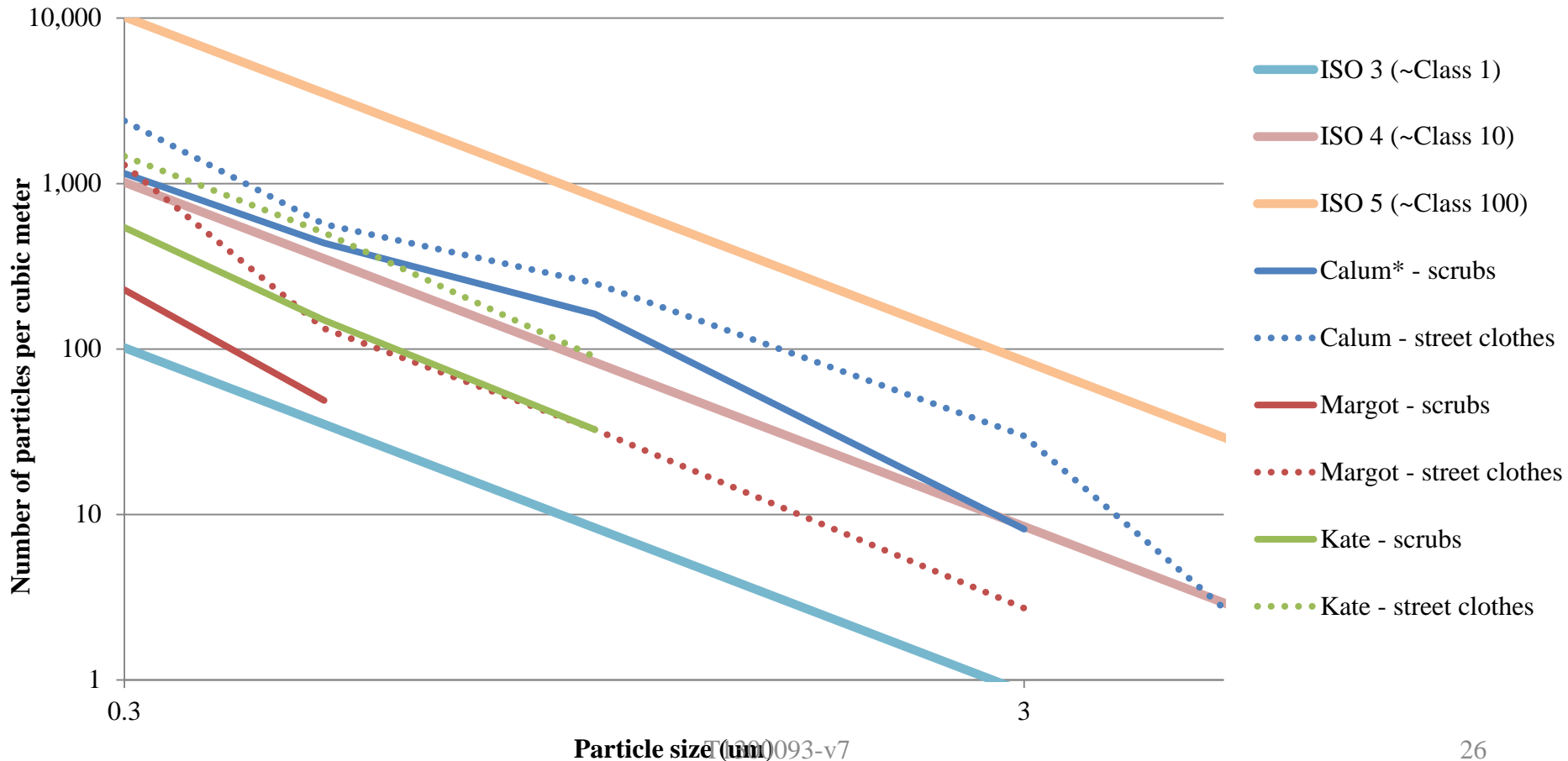
Average Number of 0.5um Particles



Scrubs vs. Street Clothes (2010 Garb)

- **Wearing scrubs made a difference in cleanroom class for Margot and Kate.**

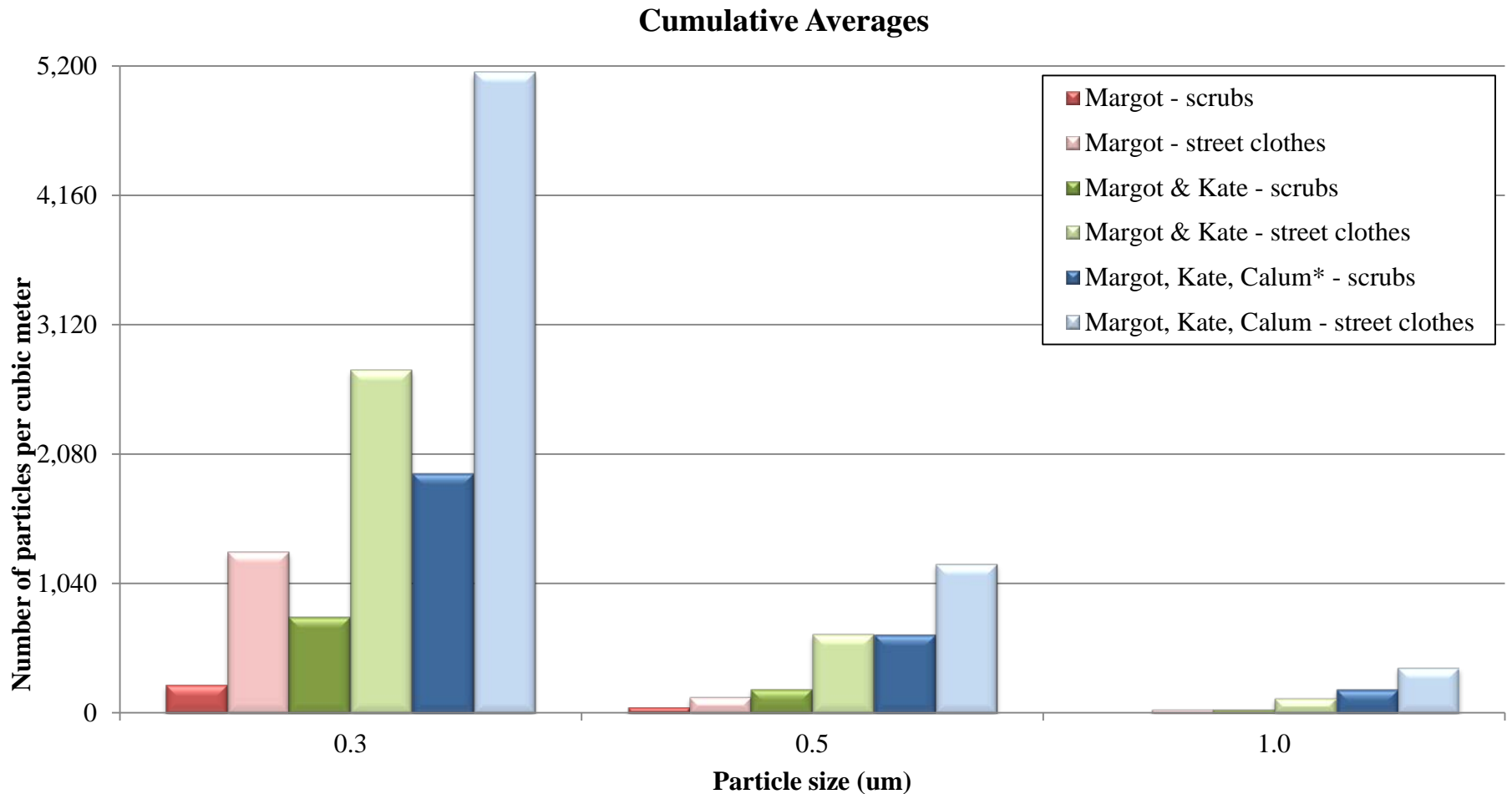
* *Used Calum's 2008 garb w/ scrubs data due to anomalous test with 2010 garb (had a hole).*



Scrubs vs Street Clothes (2010 Garb)

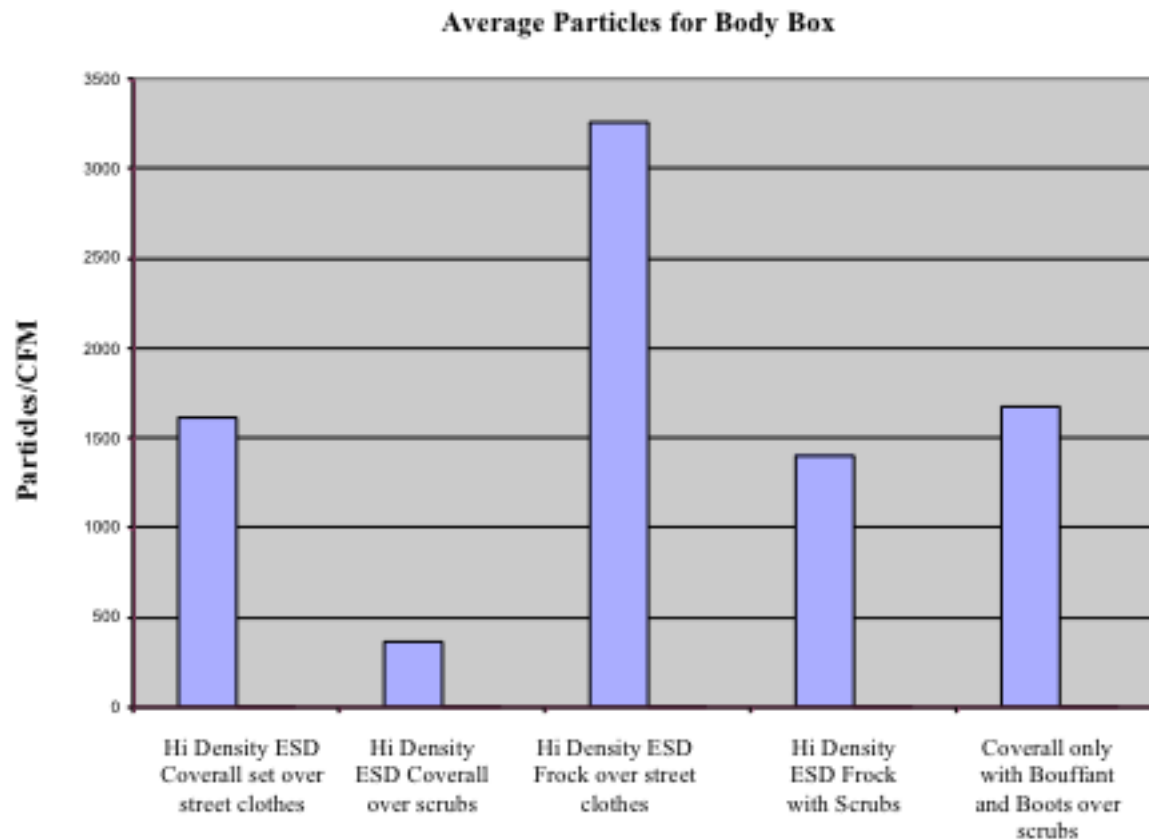
Cumulative Results

- Graph highlights benefits of scrubs for compounded contamination.



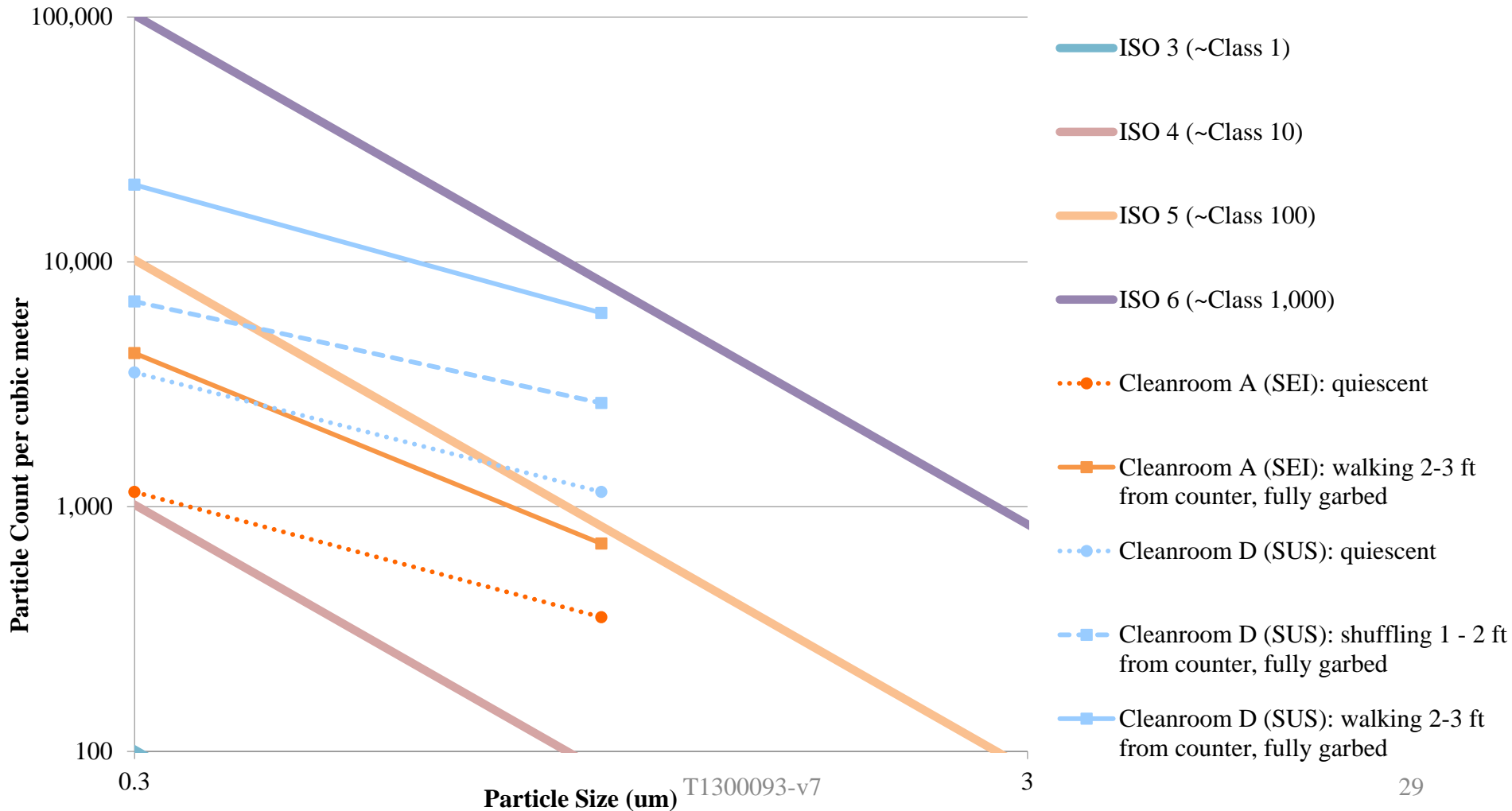
Further Evidence for Scrubs

- [Amarak](#) study showed coveralls over street clothes shed more than frocks over scrubs.



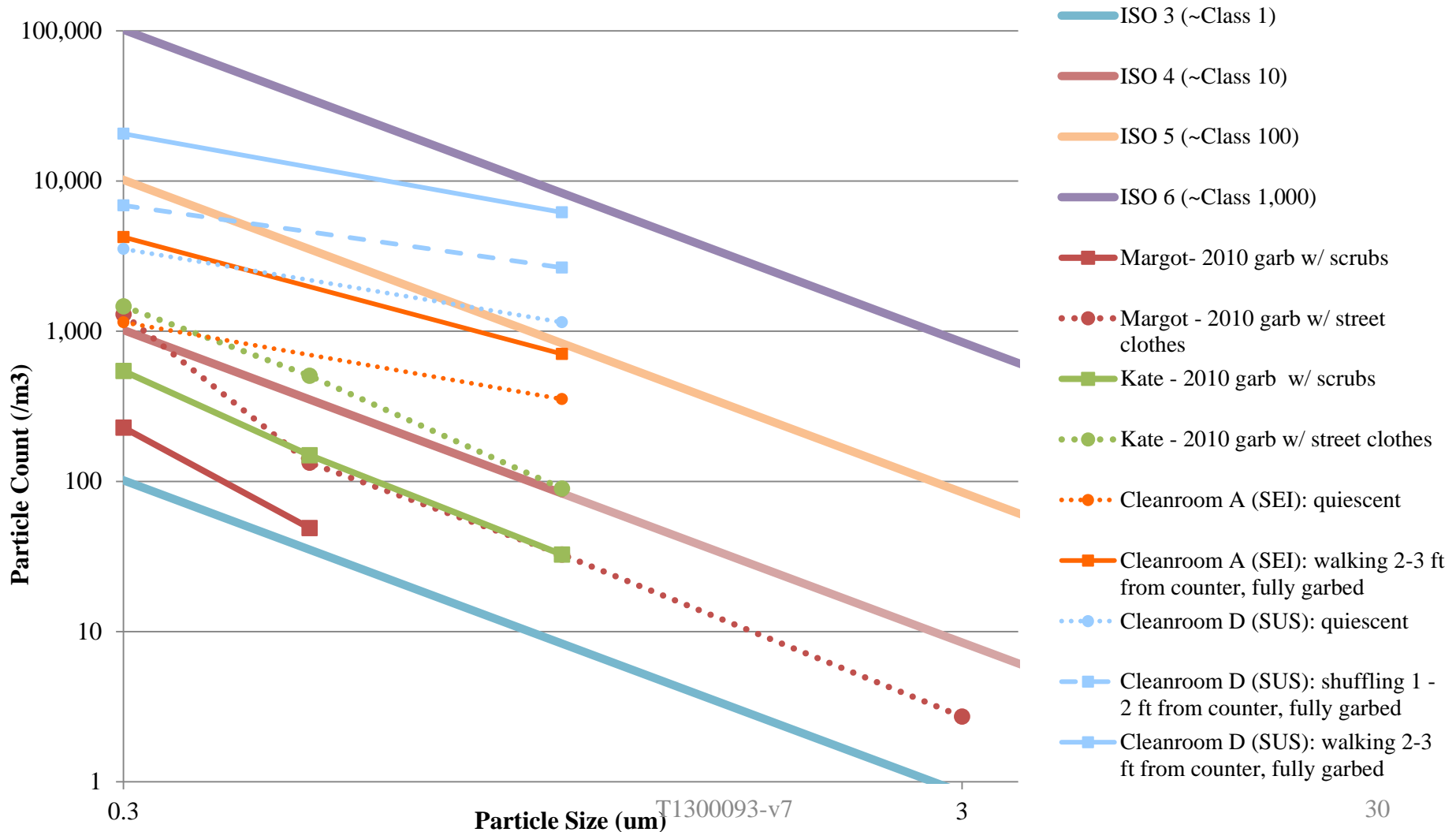
LLO High Bay Particle Count

- People are the largest source of contamination in a cleanroom.

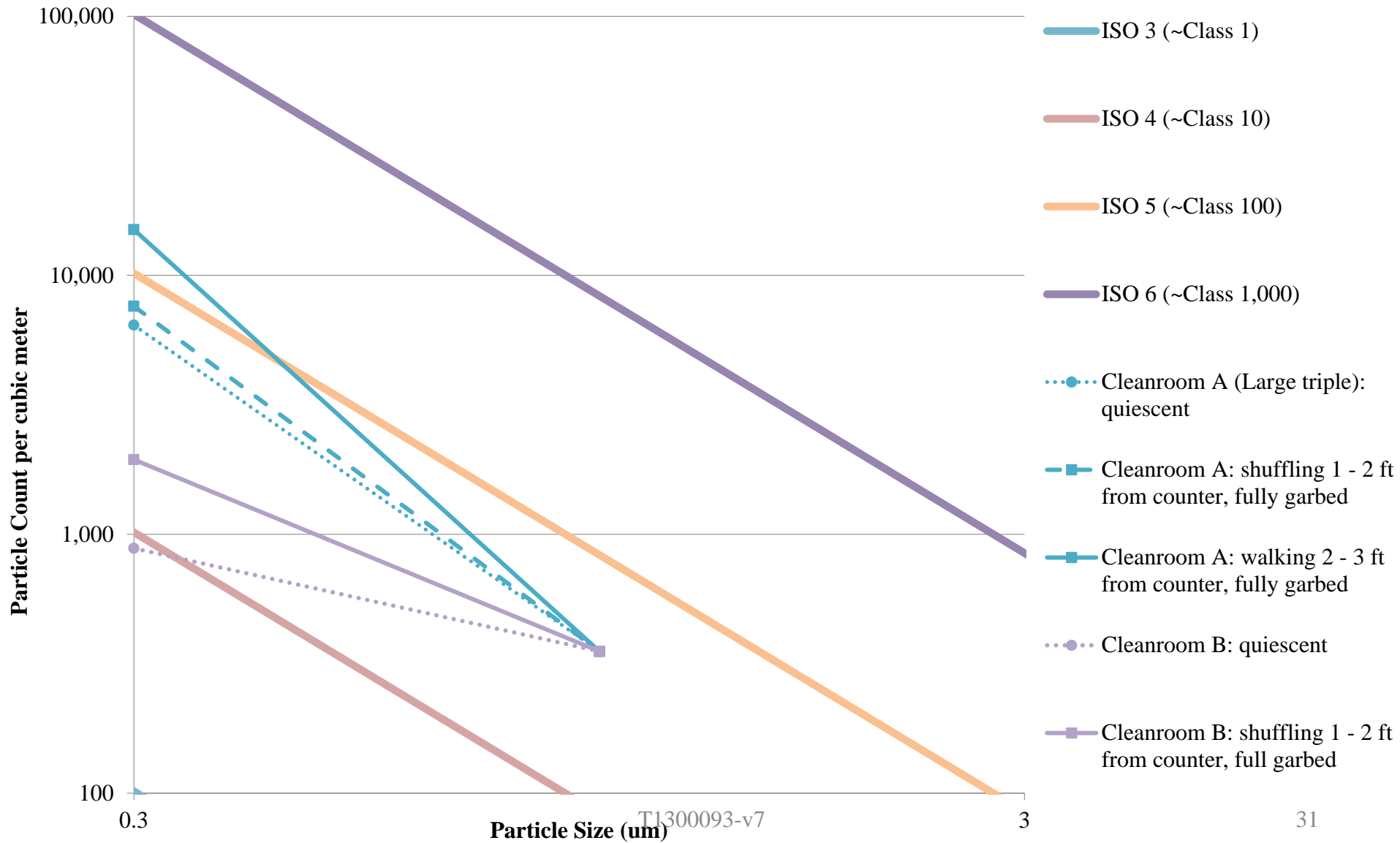


LLO High Bay vs Margot & Kate

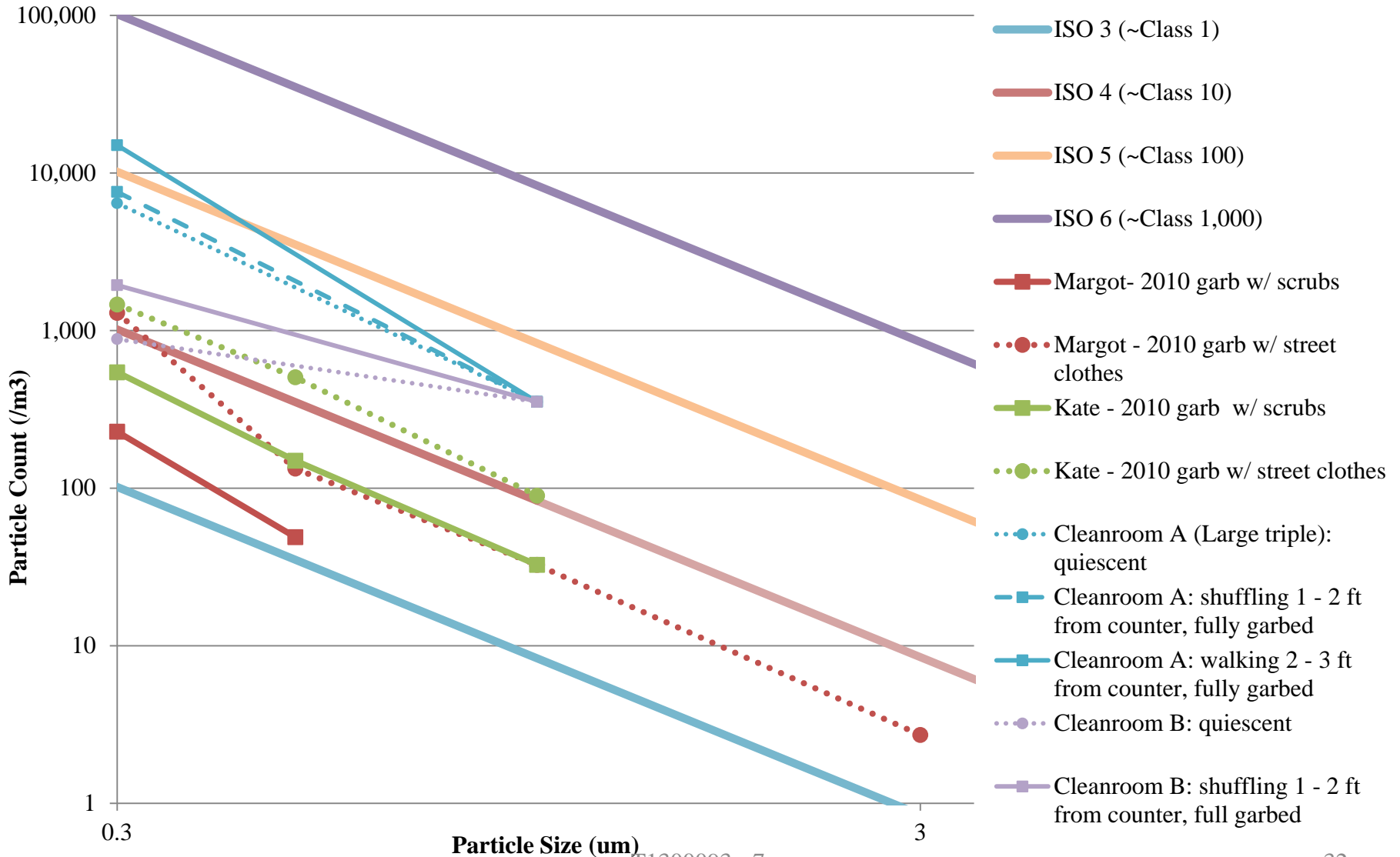
- Apples to oranges comparison, but gives idea of scale of improvement.



LLLO Banquet Room Particle Count



LLO Banquet Room vs Margot & Kate



Conclusions

Garb Shedding:

- Old LIGO garb holding up well.
- Additional washes may reduce shedding for brand new garb. (Discussing with Prudential)

Garb Shielding:

- 2010 garb shed 10,300 – 12,500 more particles than new garb (ignoring Calum's anomalous 2010 data).
- New garb is a better barrier.

Scrubs:

- Street clothes shed 15,400 – 19,300 more particles than scrubs.
- Made a difference in cleanroom class for Margot and Kate.

Input from Prudential

Garb Shedding:

- C3 sheds larger amounts of particles initially.
- 3 washes brings shedding down to an acceptable level.
- Garb sheds less and less up until 20-25 washes, then it sheds again, then it slows again.
- Waiting for additional input from test lab.

Garb Shielding:

- Fabric weave tightens over time, and there is less penetration between the fibers.
- Older garb is a much better barrier than newer garb until the fabric begins to breakdown somewhere above 150 cycles.

Recommendations

Ideal

1. Implement scrubs.
 - Should offer at least $\frac{1}{2}$ a cleanroom class improvement (log graph, factor of ~ 3 reduction in particles).
2. Plan upcoming purchase of new garb.
 - Investigating total number of washes before retirement.

Backup

1. Buy new garb now.



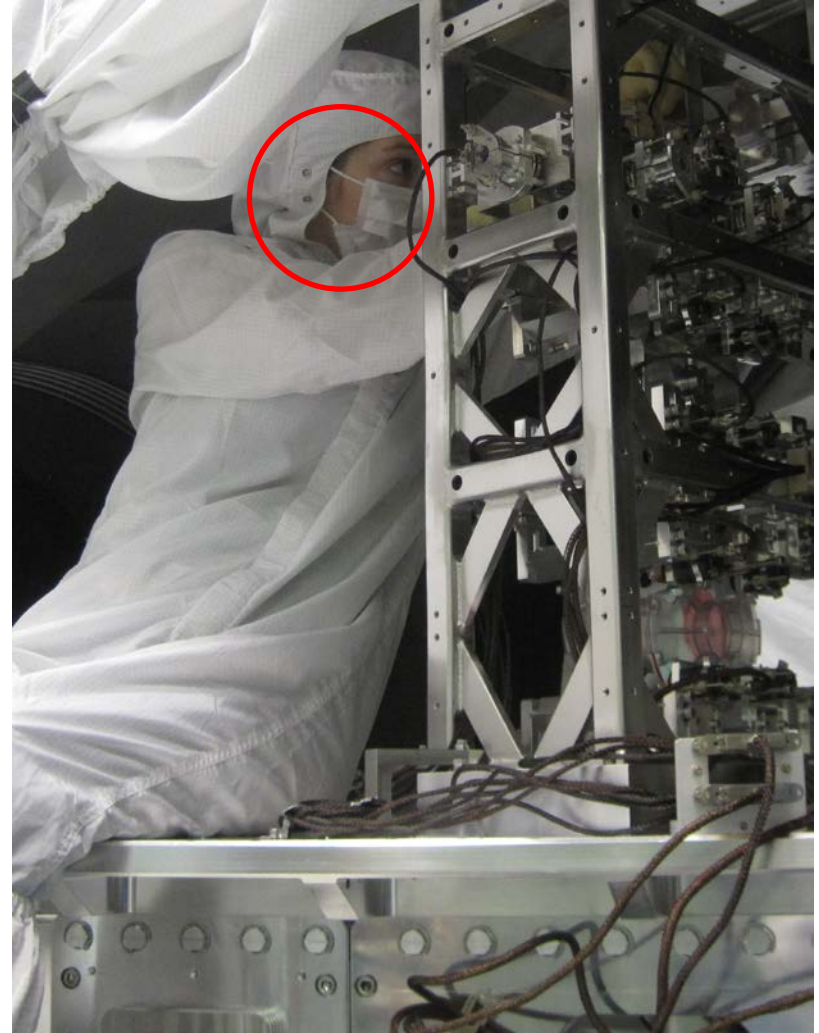
→ *Body Box selection tests or Helmke drum tests (material, type)*

Old Garb in Action at LHO

- Photos highlight effects of movement on garb.



Best case



Cheek & hair exposed, bouffant cap slipped

Old Garb in Action at LHO

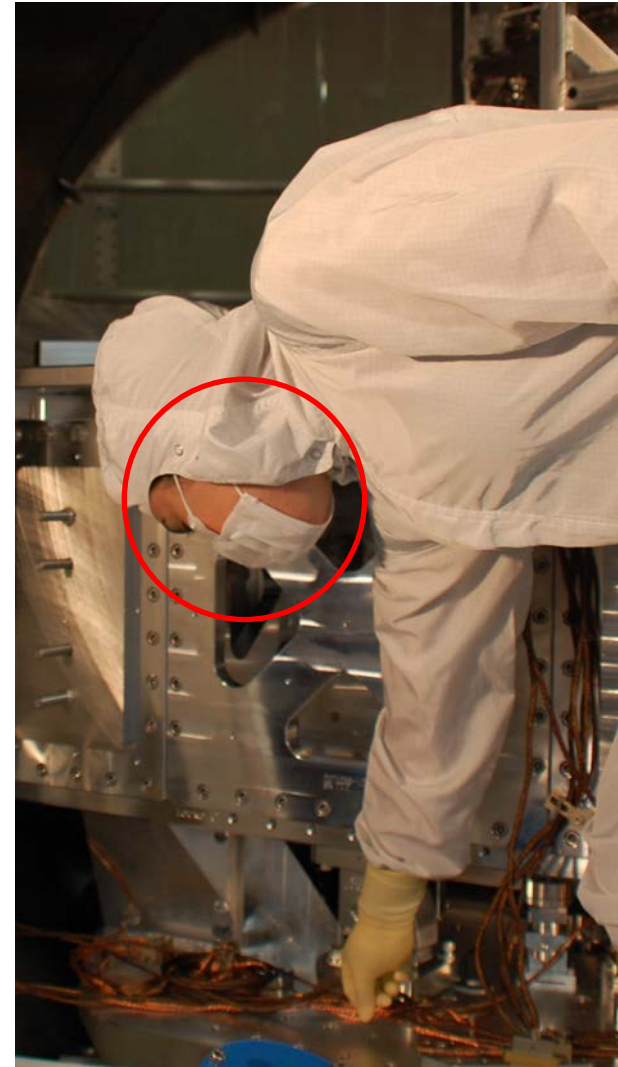
- Photos highlight effects of movement on garb.



Best case



T1300093-v7
Cheek and hair exposed



37
Cheek, hair, chin exposed