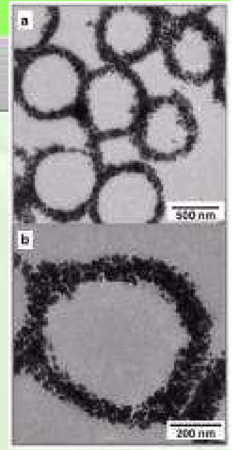
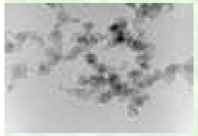
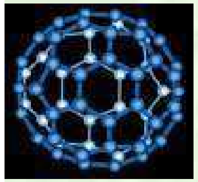
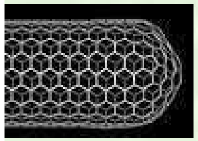
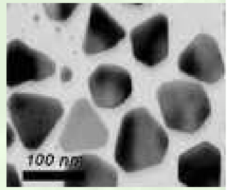


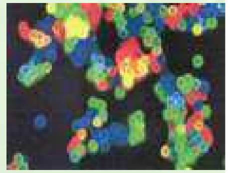
Experimental evaluation of personal protective equipments against carbon nano aerosols > 10 nm











Fibrous filter, respirators, protective clothing and gloves

CEA-Grenoble Liten, France
F. Tardif, L. Golanski, F. Rouillon, A. Guiot, S. Bernard

Work funded by EC 6th PCRD programs : Nanosafe2 project

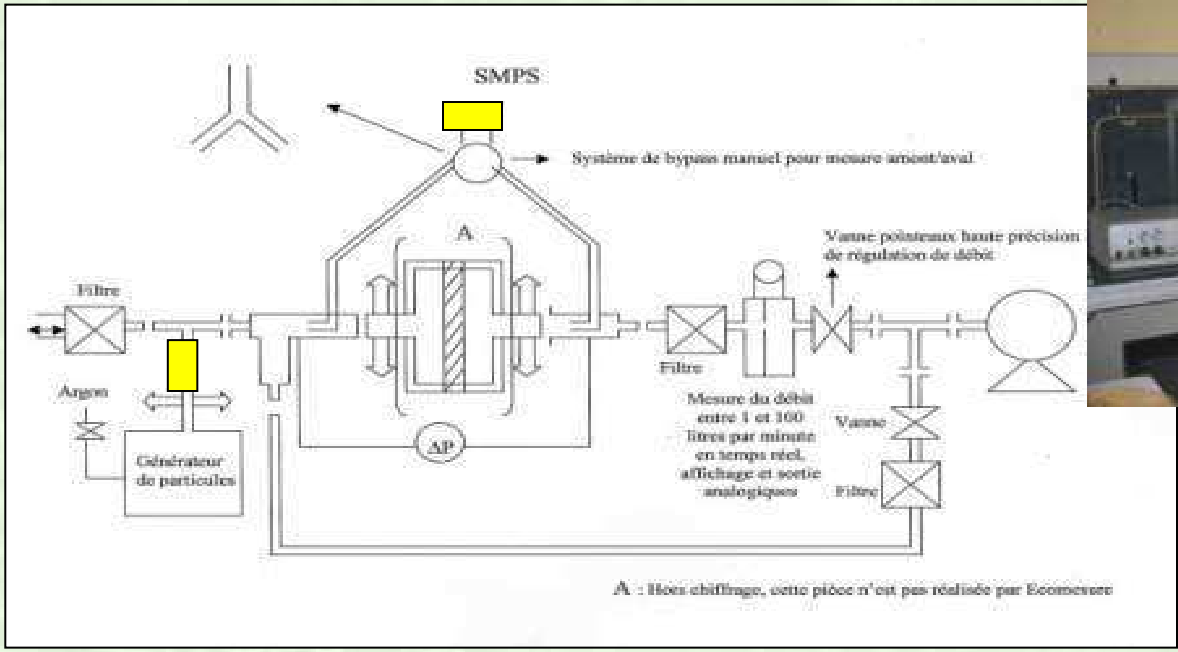
Without specific standards for nanoparticles, each industrial company and lab have their own practices to protect workers against nanoparticles

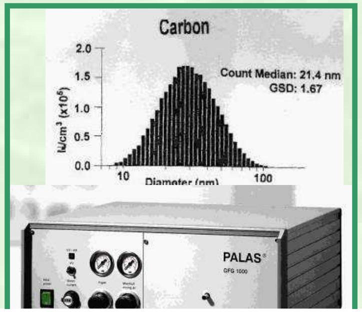
Are conventional protection equipments still efficient for particles < 100 nm?

SUMMARY

- ✓ Test procedures
- ✓ Fibrous filter efficiency
- ✓ Respirator efficiency
- ✓ Protective clothing efficiency
- ✓ Glove efficiency
- ✓ Conclusion

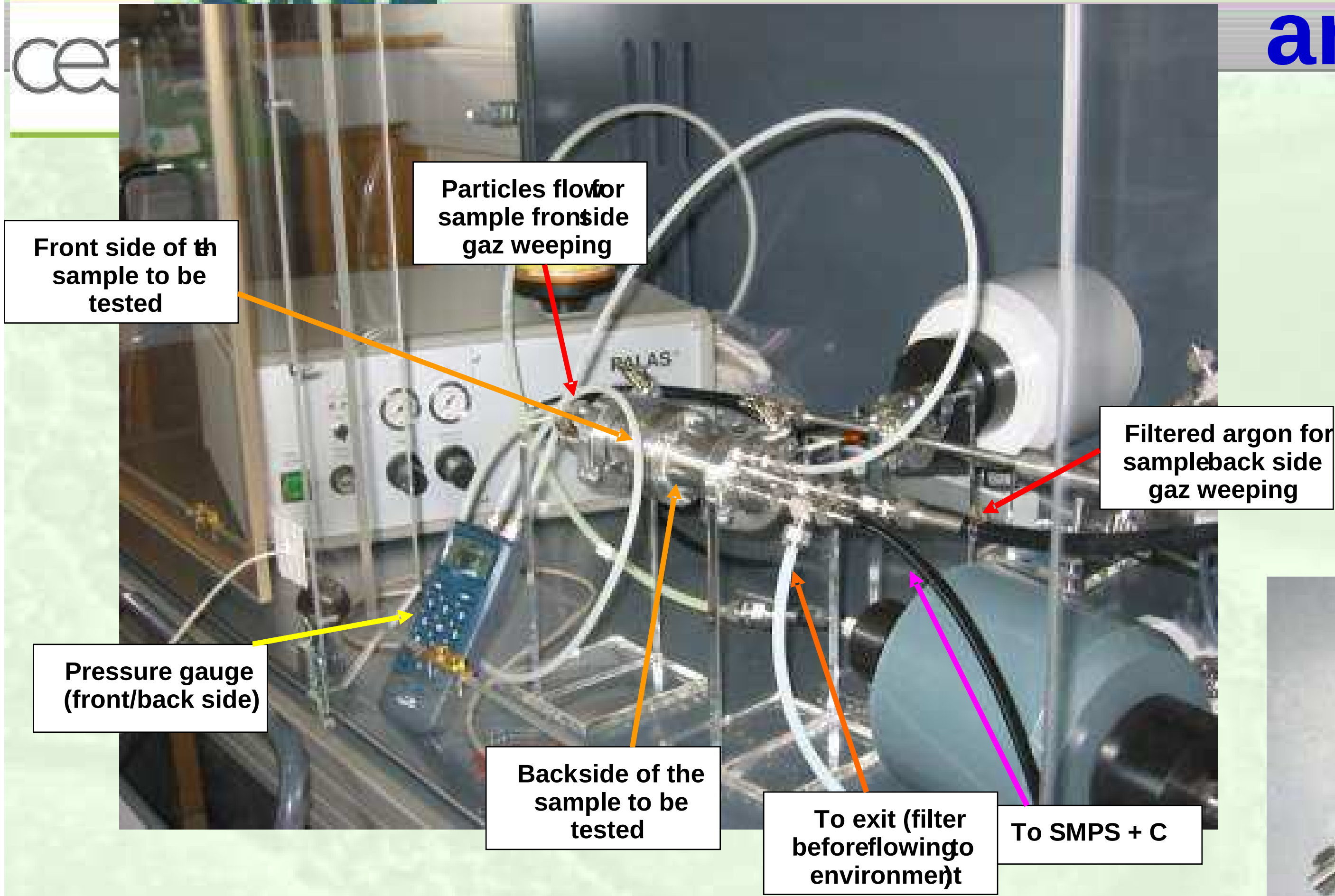
Secured installation for filter and mask testing

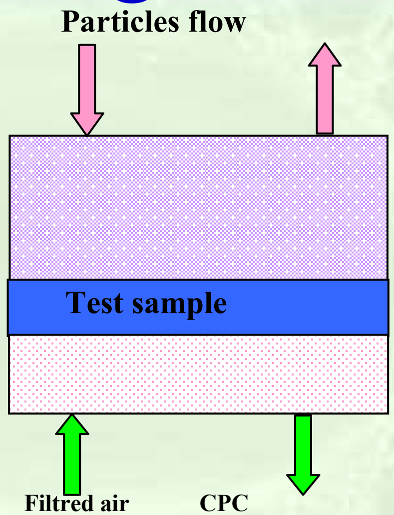




- ➢ **Challenge particles:** **polydispersed graphite nanoparticles generated by electrical plasma (Japuntich et al 2007 ➔ polydispersed equivalent to mono)**
- ➢ **Air flow:** **generated by depression in the media 1 to 110 L/min (identical to use conditions)**
- ➢ **Measurements:** **Scanning Mobility Particle Sizer**

Test devices for protective clothing and gloves





- Concentration of graphite particles in upper cell maintained constant
- A 20 g/cm² differential pressure mimics a slight contact
- CNC measurement are performed in the down stream part of the cell for 2 particle size challenges: 30 and 60 nm.
- Derivated from "Through-diffusion" method standards NF EN 374 and NF EN ISO 6529).

SUMMARY

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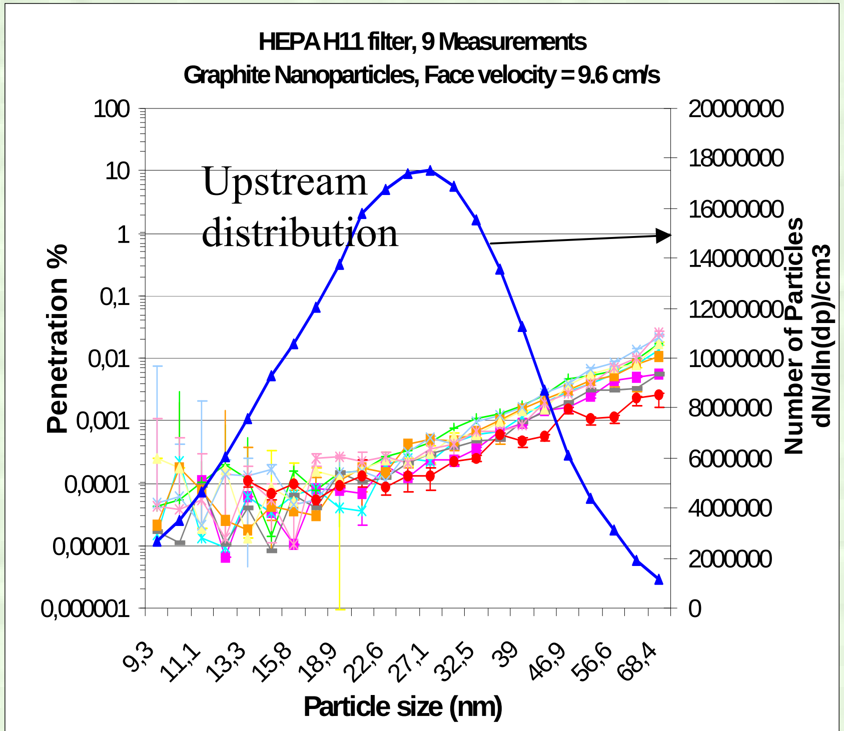
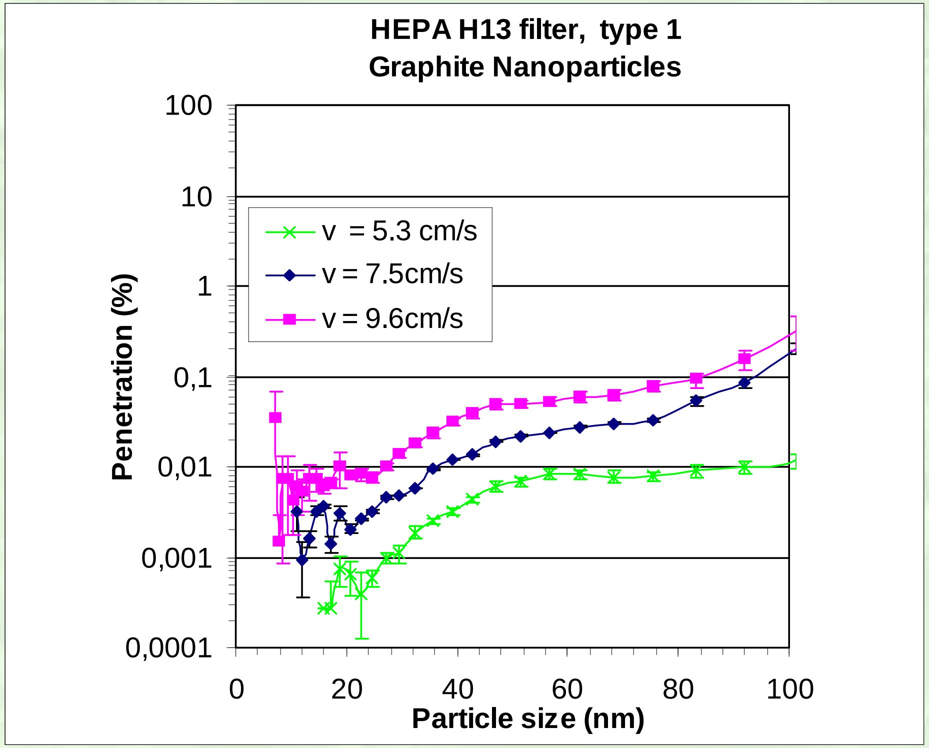
Validation of the method

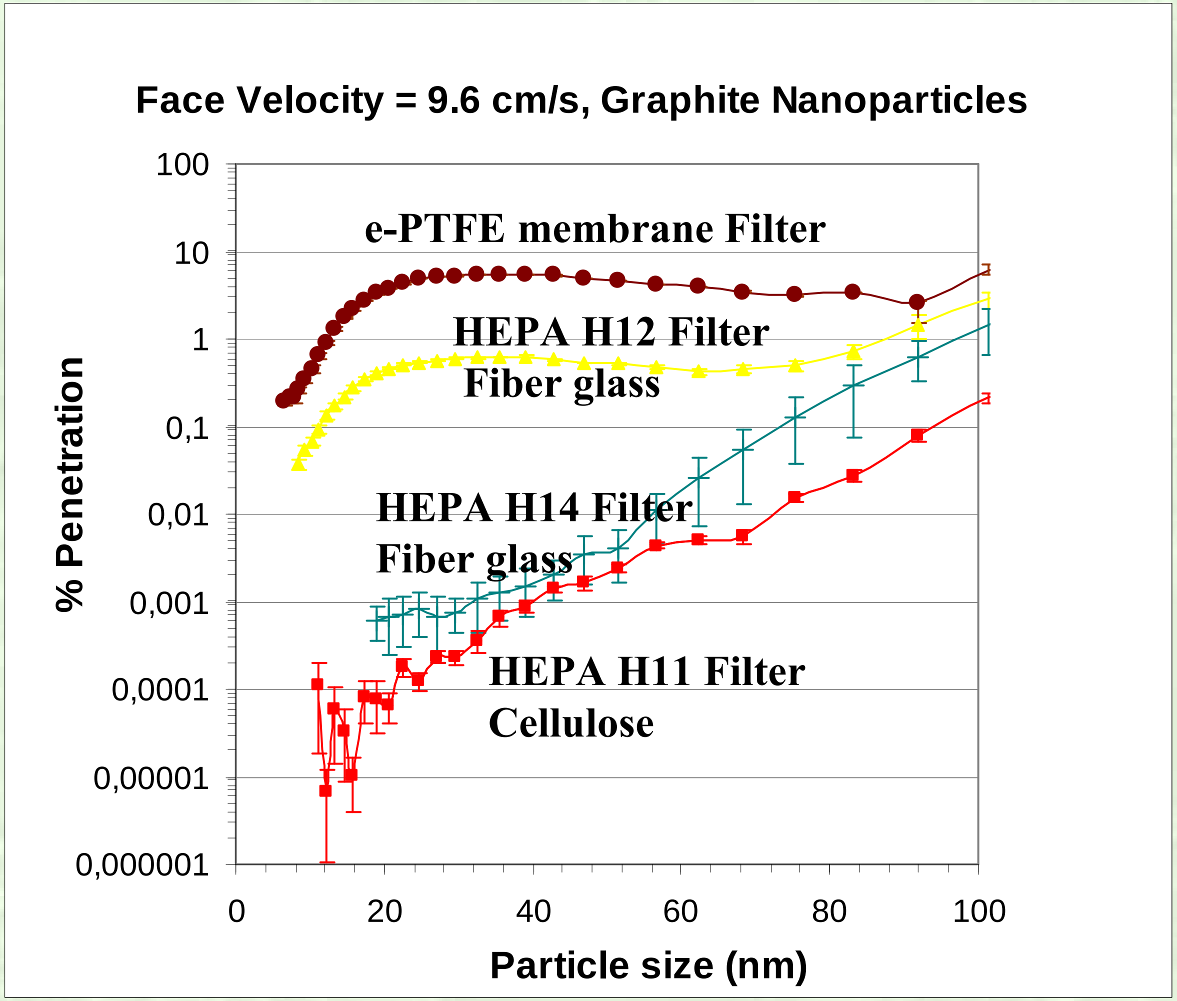




❖ Good reproducibility on a H11 filter, accuracy limit around 10 nm (too low downstream concentration)

❖ Verification: the higher the flow rate, the higher the penetration

Results obtained on filter media with C particles



❖ Results from different filter media against C particles

Conclusion :

. As expected: better efficiency for particles < 150 nm (MPPS)

. No thermal bounce detected with graphite nanoparticle > 10 nm

Filtration theory in fibrous media

Thermal bounce or not thermal bounce that is the question …

Looking for Wang &Kasper (91) prediction without success :

Authors	Detection of thermal bounce	Size range of nanoparticles	Nanoparticle type
Ichitsubo and al. (1996)	No	2-7nm	Ag and NaCl particles
Alonso and al. (1997)	No	2-7nm	Ag and NaCl particles
Balazy and al., (2004)	Yes	At D = 20nm	DEHS liquid aerosol
Heim and al., (2005)	No	2.5-20nm	NaCl particles
Kim and al., (2007)	No	3-20nm	Ag particles
This work	No	> 10nm	Graphite particles

Finally, it is more and more accepted that thermal bounce is not an issue upper 2-3 nm at ordinary temperature (D. Pui et al. 2007).

SUMMARY

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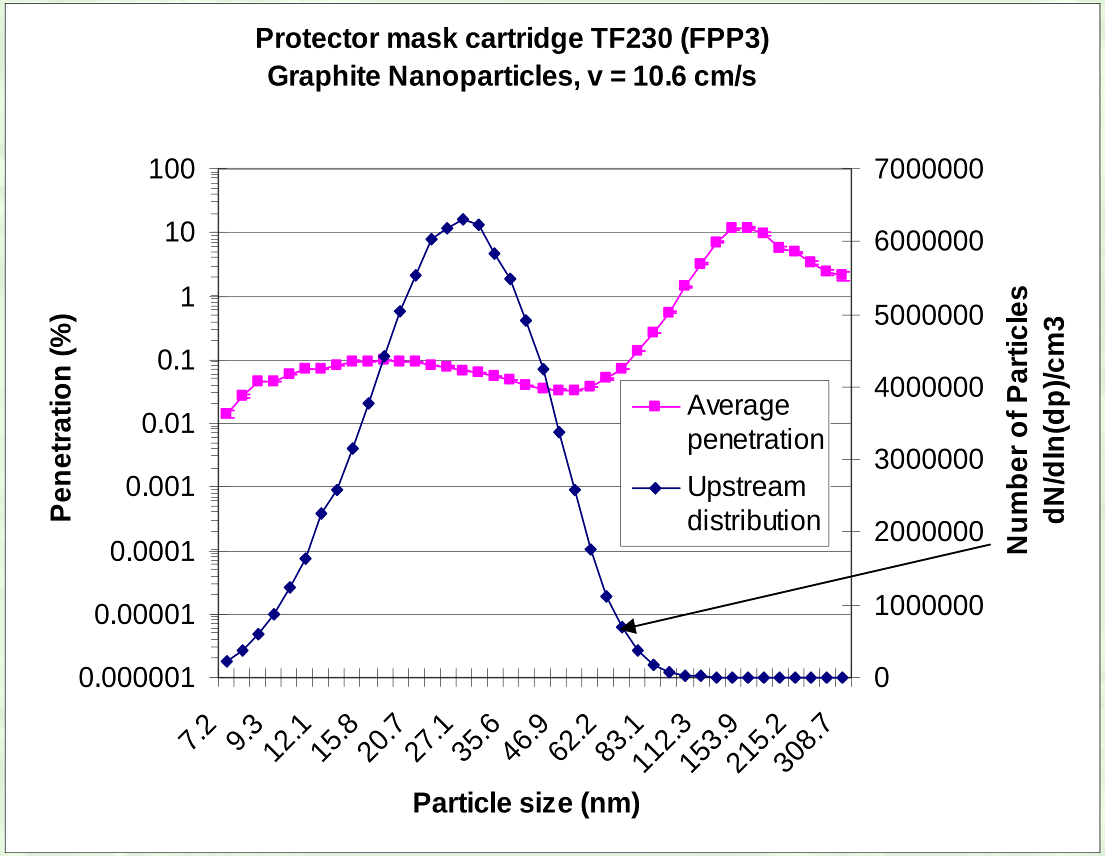
MASK CARTRIDGE EFFICIENCY



Filtration efficiency of respirator filters against carbon nanoparticles

❖ **For D < 20nm : penetration ≤ 0.1%**

SUMMARY

- ✓ Test procedures
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Test efficiency of protective clothing measured like a filter

Measured at quite high velocity with NaCl challenge particles

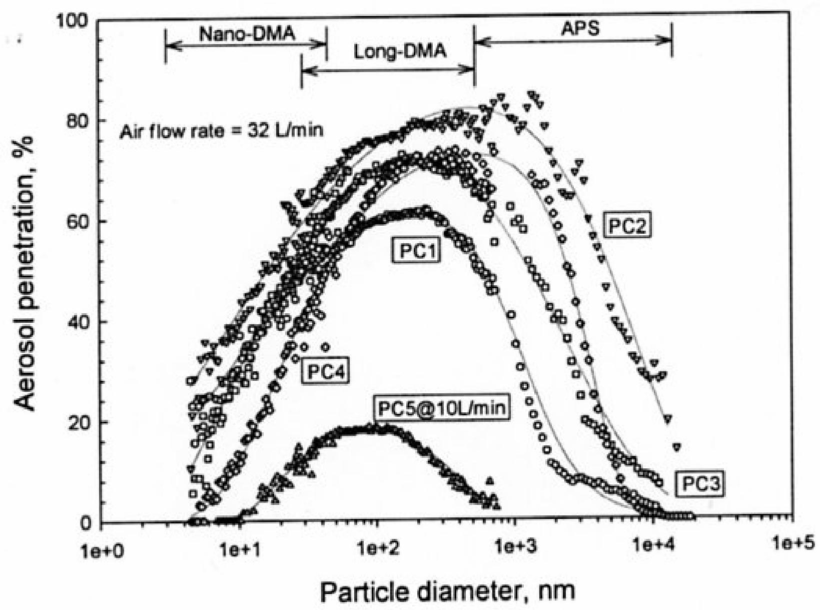
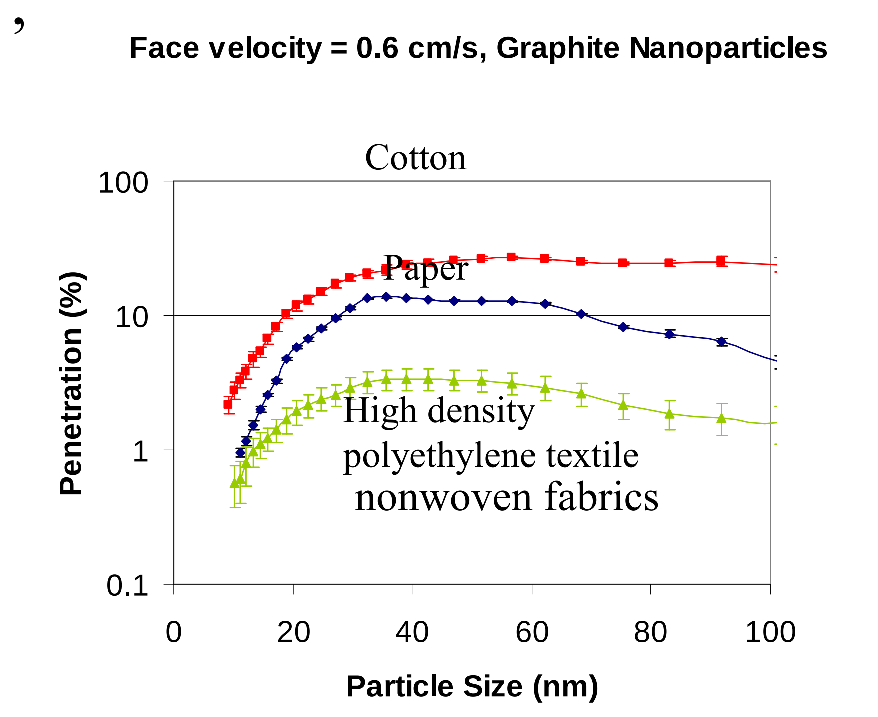


Fig. 1. Aerosol penetrations of protective clothing media.

Measured at very low face velocity with carbon particles



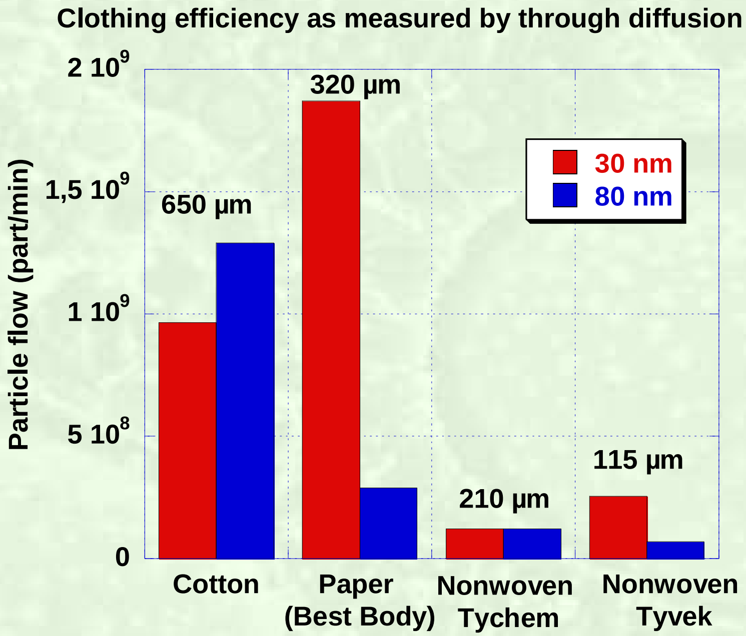
- ❖ S.H. Huang et al 2007: almost same behavior as filters
- ❖ This work: same behavior

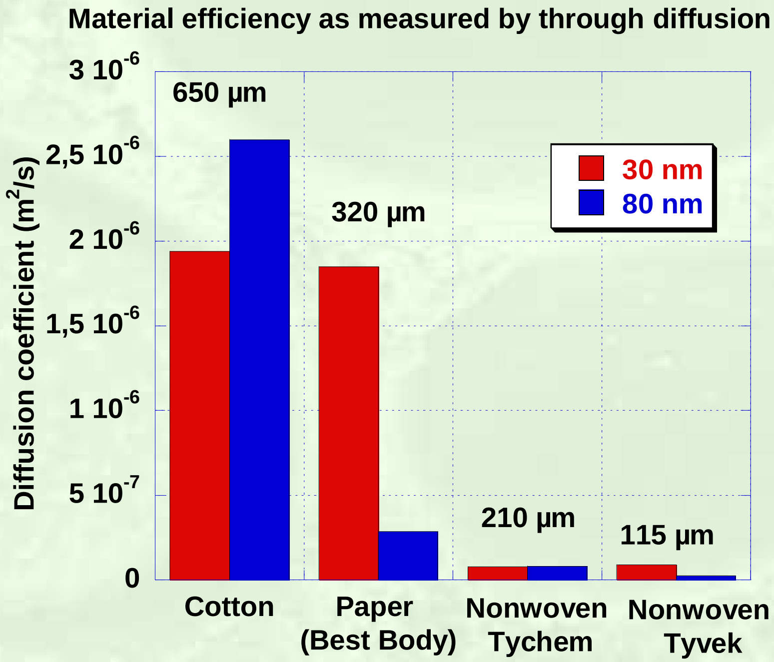
High density polyethylene textile (Tyvek type) better than cotton and paper

Test efficiency of protective clothing as measured by through diffusion method

Clothing efficiency: Particle flow per minute

Fabric efficiency: Diffusion coefficient





Conclusion: best results obtained with nonwoven fabrics
Same trend for the 2 approaches: flow and through diffusion!

SUMMARY

- ✓ Test procedures
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- ✓ Respirator efficiency
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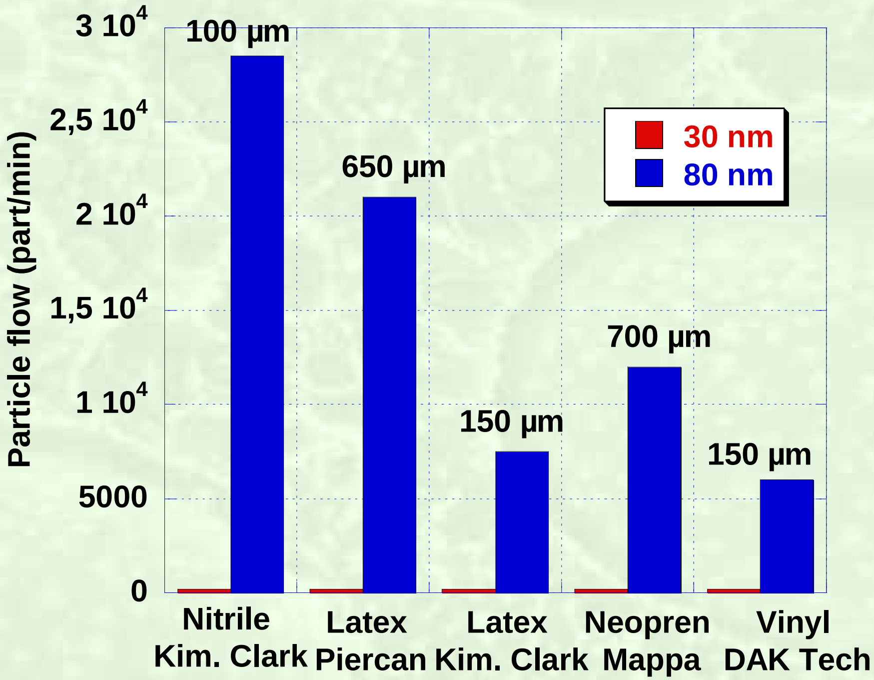
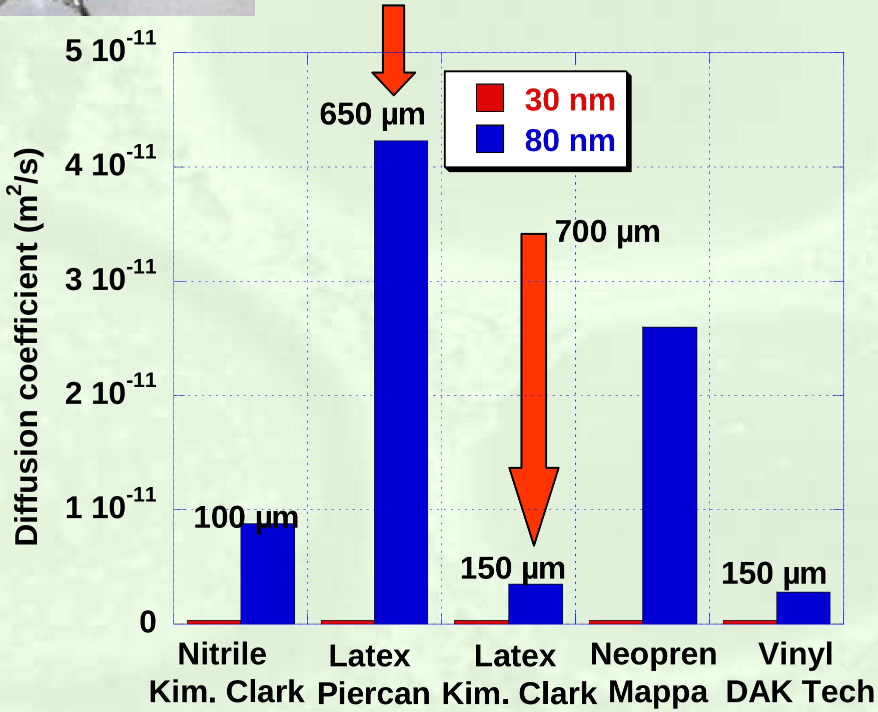
Test efficiency of gloves as measured by through diffusion method

Glove efficiency:
Particle flow per minute

Material efficiency:
Diffusion coefficient





- ✓ Best results obtained here with vinyl gloves
- ✓ Efficiency depending on material and thickness and process manufacturing (≠ latex)

General conclusion

➢ Fibrous filter, respirator cartridges:

In accordance with the conventional filtration theory fibrous filters (paper, glass fibre, etc.) are more efficient for nanoparticles down to MPPS.
Results with graphite particles are consistent with other particles described in the litterature DOP, Ag, NaCl : no thermal bounce is observed until 10 nm.

➢ Protective clothing:

Important efficiency differences observed: better not to use cotton fabrics, nonwoven fabrics seems much more efficient (air tight materials) Tyvek type.

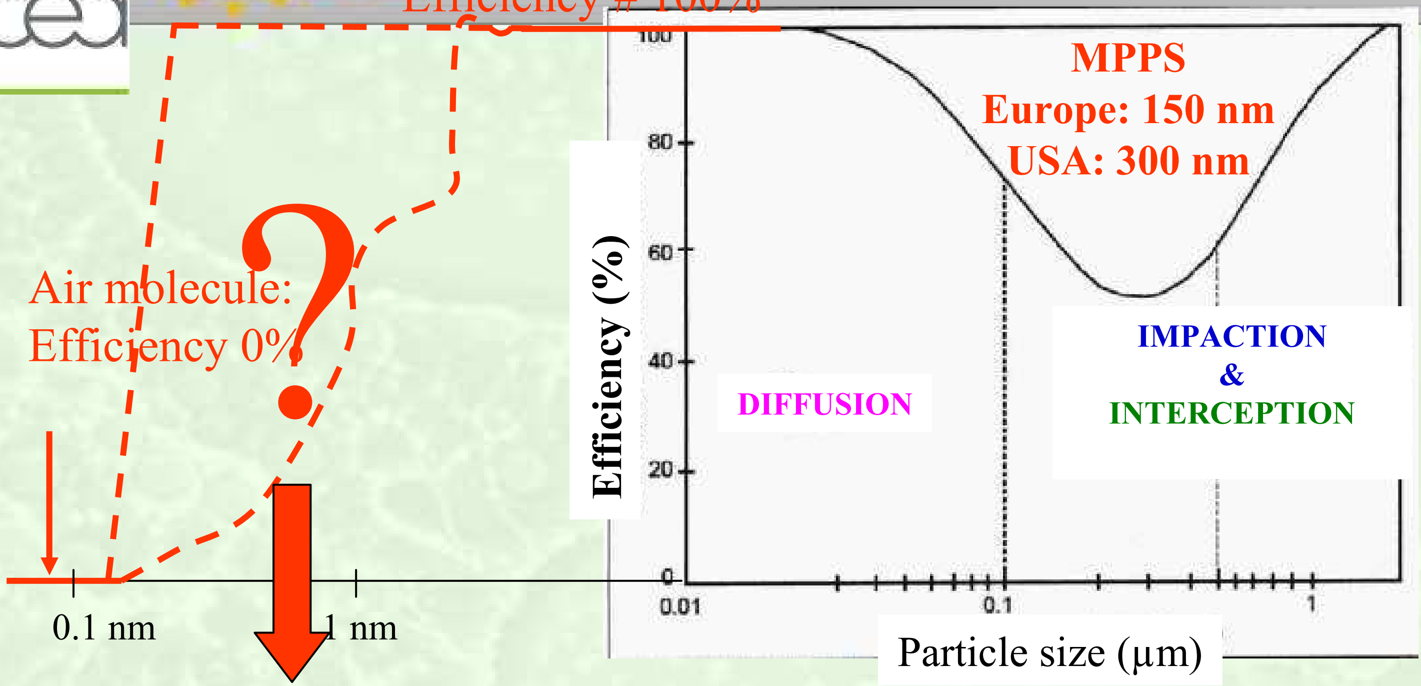
➢ Gloves:

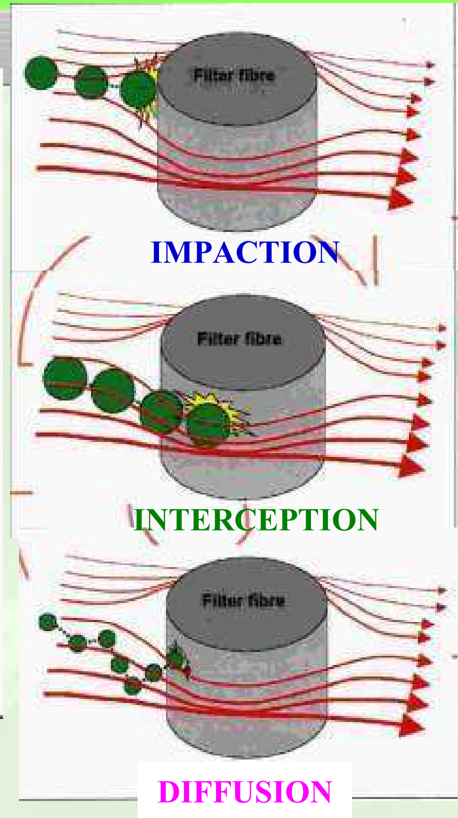
80 nm nanoparticles diffuse through gloves materials!
Best gloves tested are made with vinyl polymers.

One of the 2008 rendez-vous

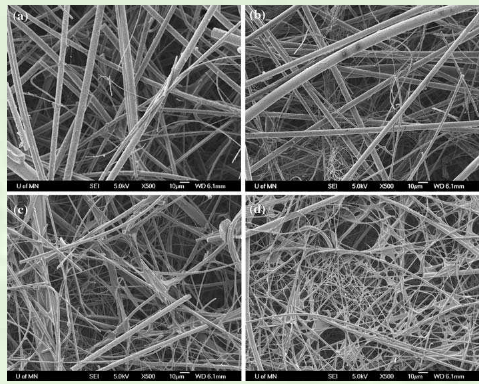
Nanosafe International conference Novembre 2008

Filtration theory in fibrous media





Thermal bounce
or not thermal bounce
that is the question …



Wang and Kasper, 1991: Bounce effect would occur in the region of 10 nm and below due to non favorable balance between Brownian kinetic energy and vdW energy!

Depending on : size, fiber/particle affinity, particle deformation, temperature, etc.

Test efficiency of protective clothing as measured by through diffusion method

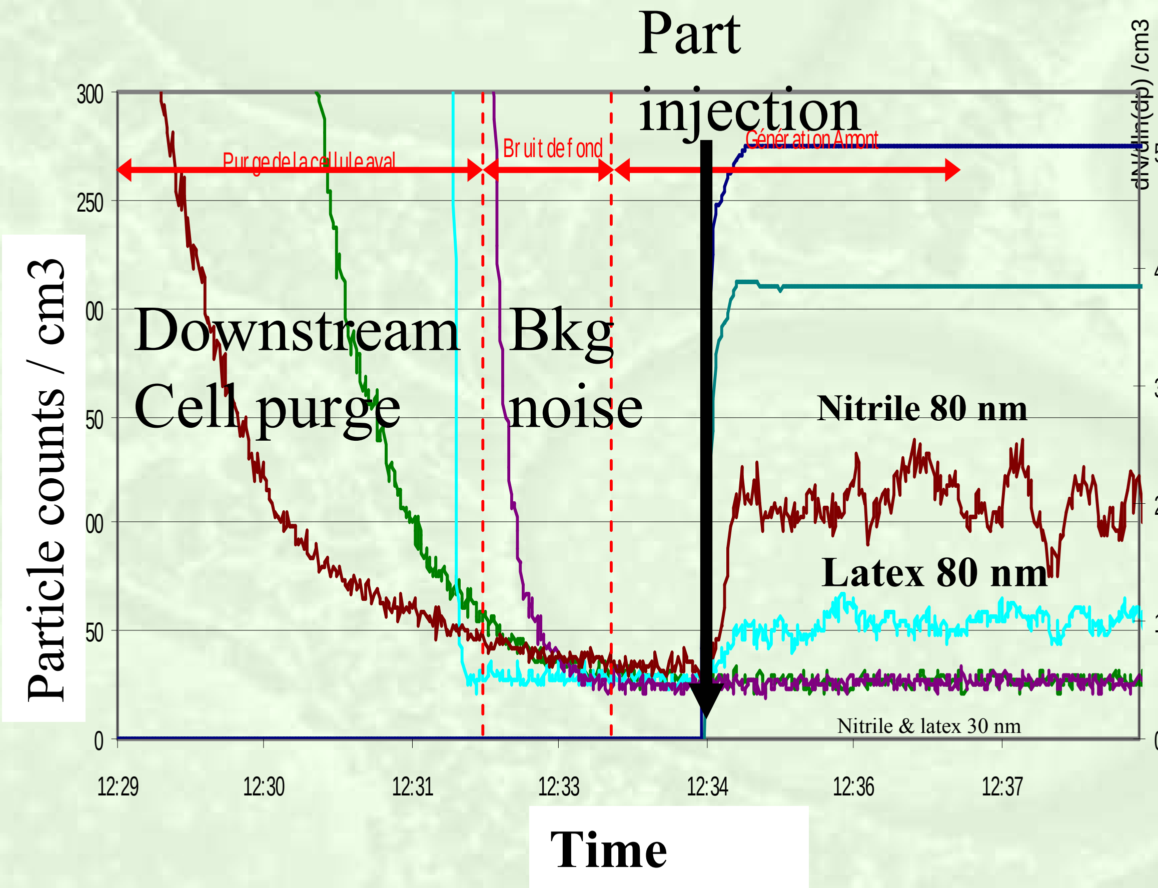
Clothing efficiency — Material efficiency

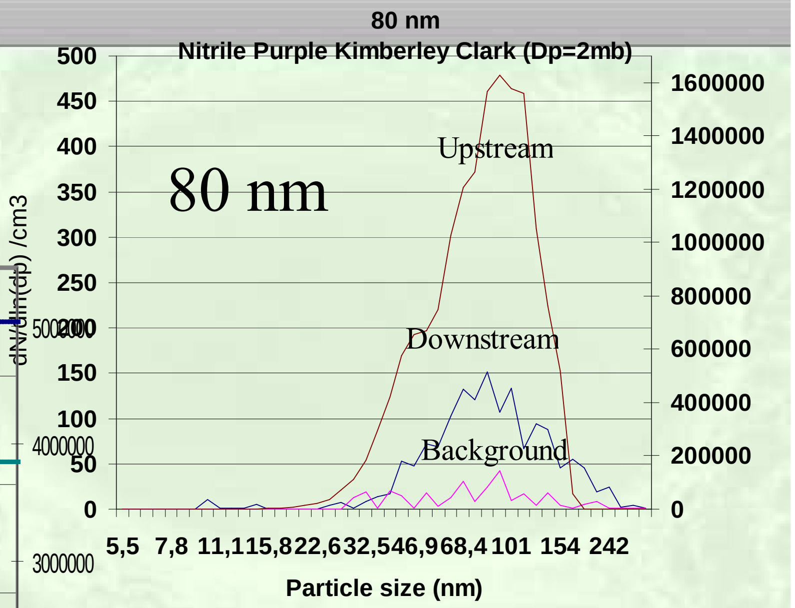
	Thickness (µm)	30 nm particle flow (Part/min)	30 nm Diffusion Coefficient (m^2/s)	80 nm particle flow (Part/min)	80 nm Diffusion Coefficient (m^2/s)
Cotton suit	650	9.6e+08	1.9e-6	1.3e+09	2.6e-6
Synthetic suit (best body)	320	1.9e+09	1,8e-6	2.9e+08	2.9e-7
Nonwoven fabric Tychem	210	1.2e+08	7.9e-8	1.2+08	7.9e-8
Nonwoven fabric Tyvek	115	2.5+08	9.1e-8	6.9e+07	2.5e-8

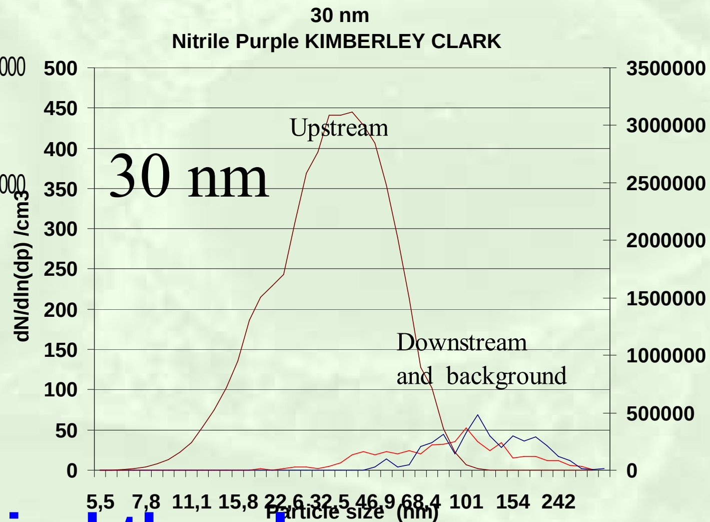
Conclusion: best results obtained with nonwoven fabrics (worse: cotton)
Same trend for the 2 approaches: flow and through diffusion!

Test efficiency of gloves as measured by through diffusion method

- ❖ **Example of results @ 80 nm**







- ❖ **@ 30 nm: no measurable level behind the glove**

More efficient for smaller particle: same behaviour as filters

Test efficiency of gloves as measured by through diffusion method

Results @ 80 nm

Material	Thickness	Particle flow (part/min)	Diffusion coefficient (m^2/s)
Nitrile Purple Kimberley Clark	100 µm	28 500	8.8e-12
Latex BAG Piercan	650 µm	21 000	4.2e-11
Latex PFE Kimberley Clark	150 µm	7 500	3.5e-12
Neopren 420 Mappa	700 µm	12 000	2.6e-11
Vinyl DAK Technical	150 µm	6 000	2.8e-12

- ✓ Best results obtained with vinyl gloves
- ✓ Efficiency depending on material and thickness and process manufacturing (≠ latex)