Impact of quick incident detection on safety in terms of ventilation response

P. J. Sturm[1)]; C. Forster[2)]; B. Kohl[2)]; M. Bacher[1)]

1) Institute for Internal Combustion Engines and Thermodynamics
Graz University of Technology, Austria
2) ILF-Consulting Engineers, Linz Austria

Problem

In case of an incident in a tunnel the time period between the event and its detection is a very important parameter.

The earlier an incident is detected, the smaller the consequences might be.

This concerns mainly incidents which happen in tunnels

- with bidirectional traffic
- tunnels with unidirectional traffic and an incident location within a queue

Problem

Design guidelines are often based on assumptions about time intervals for certain processes.

Quite important for the design of safety systems are time dependent development curves for fires (e.g. heat release), detection systems and start-up procedures for important system parts like ventilation.

Quick detection of incidents like fire allow for a quick reaction of the safety systems and hence reduce the risk for tunnel users.

Detection / reaction times

Fire detection

Incident detection is based on sensor information. Dependent on the type of incident and kind of sensor detection time might vary between seconds and minutes.

System (ventilation) start up

After incident detection a system reaction is expected. In terms of ventilation this could be quick in case of jet fans (no long start up phase) or much longer in case of big axial fans.

Detection / reaction times

System reaction

After incident detection and fan start up it will take some time until the expected ventilation goal is reached.

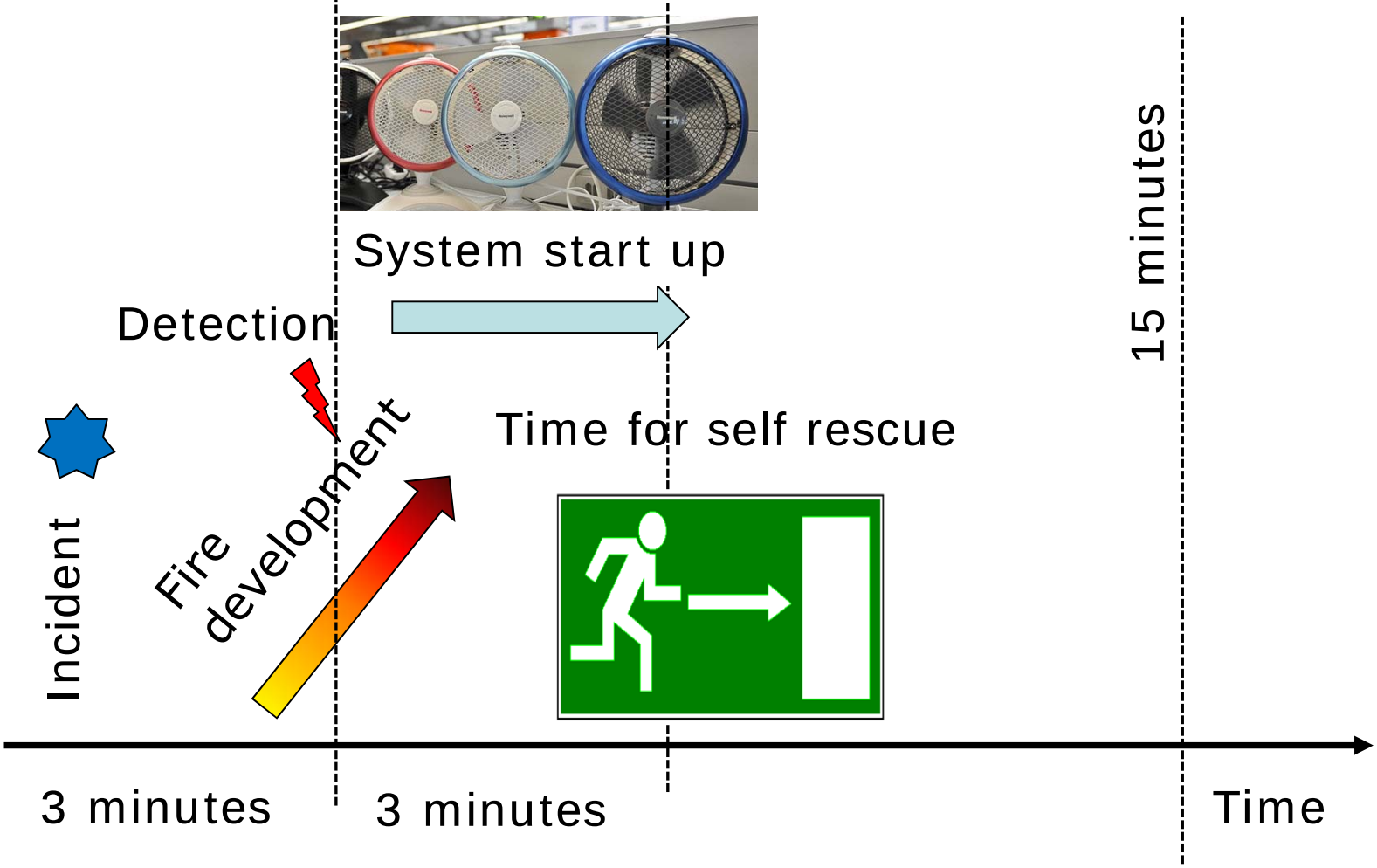
Typical time frames:

Detection by a linear heat detector: 1 to 3 Minutes (small fires much longer)

System start up jet fans: 15 to 30 s until full power
axial fans: 1 to 3 min

System reaction (stable incident mode):
longitudinal ventilation 2 to 3 min
transverse ventilation > 5 min

Detection / reaction times



Detection systems

Linear heat detectors:

- widely used and reliable systems
- give exact location of fire
- might be slow in case of fires with a low heat release rate (smouldering fires)

Smoke detectors:

- allow for a quick detection
- determination of location of fire is not easy as smoke moves with the air (important for transverse ventilated tunnels)

Video systems:

- having still a considerable failure rate
- determination of location dependent on distance between cameras (important for transverse ventilated tunnels)

Influence of detection / reaction time

The chances for self rescue are determined by the time needed for each involved person to reach a tenable environment.

This is dependent on:

- Velocity of smoke propagation
- Range of smoke-filled zone within the tunnel
- Distance to the next egress way
- Activation of fixed fire fighting systems (FFFS) if available

Velocity of smoke propagation

Longitudinal ventilation:

Very often the design is made for reaching critical velocity in order to avoid backlayering, i.e. velocity ranges between 2.5 and 3.5 m/s (upstream the fire)

Assuming a typical 30 MW fire (one truck) the downstream velocity increases to 4 – 5.5 m/s in average

Velocity of an escaping person in smoke 0.5 m/s to 1.5 m/s
(PIARC report, fire and smoke control 05.05.B 1999)

No problem for incidents on top of a queue, but big problem for incidents within a queue or in tunnels with bi-directional traffic

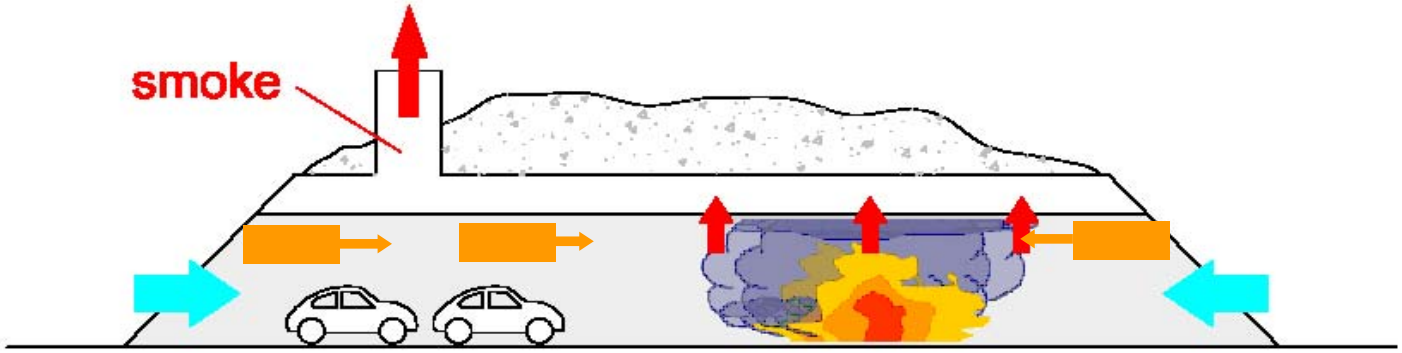
Velocity of smoke propagation

Transverse ventilation:

Velocity of smoke movement is dependent on extraction capacity at the open damper(s)

Typical values at location of dampers ~ 120 to 160 m^3/s (smoke temperature ~ 150- 200 °C for 30 MW fire)

Smoke is confined within the zone between fire location and open damper(s) – but only when system is in full operation



Velocity of smoke propagation

Transverse ventilation:

Smoke is confined within the zone between fire location and open damper(s) – but only when system is in full operation

During detection and start-up the system behaves like longitudinal ventilation – with longer time frames for achieving full operation

Problem for incidents within a queue or for tunnels with bi-directional traffic

Frequency of incidents

	RVS 09.03.11
Breakdown rate (tunnel)	2.372 breakdowns per 1 million veh-km

Numbers below represent accidents causing personal injury per 1 million vehicle-km

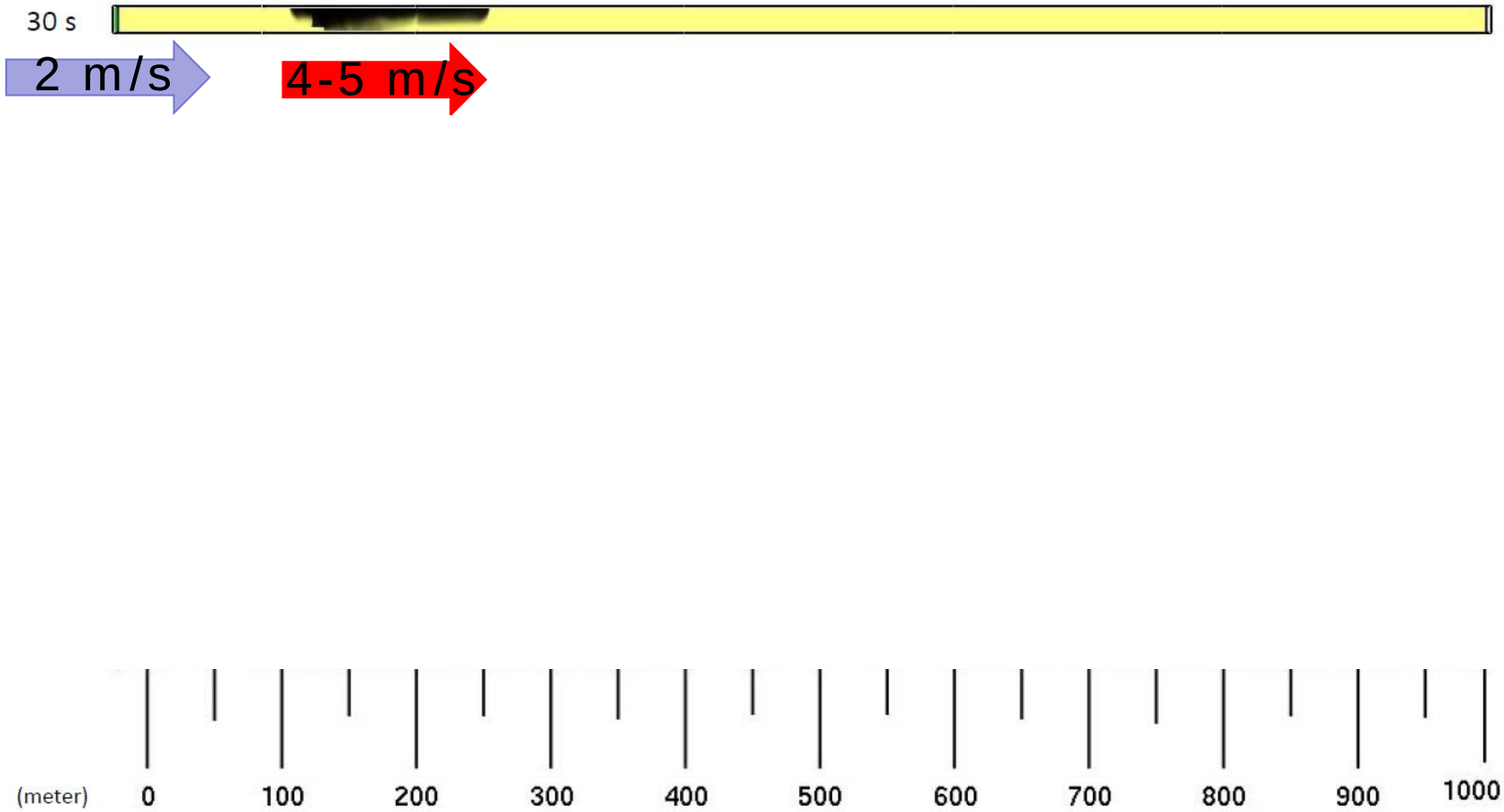
	Bidirectional		Unidirectional
No.of accidents	Rural roads	Highways	
	0.082	0.057	0.077

Frequency of incidents with fires

Fires following an accident	RVS 09.03.11
Single vehicle involvement	2.3%
Multiple vehicles in unidirectional tunnels	0.5%
Multiple vehicles in bi-directional tunnels	2.9%

The probability of an accident as well as of a subsequent fire is quite low.
However the extent of an incident (damage/injury) is maximum for accidents with multiple vehicles within a queue or within tunnels with bi-directional traffic.
The extent can only be minimised by reduction of time frames for detection and system reaction.

Smoke propagation in a longitudinal ventilated tunnel



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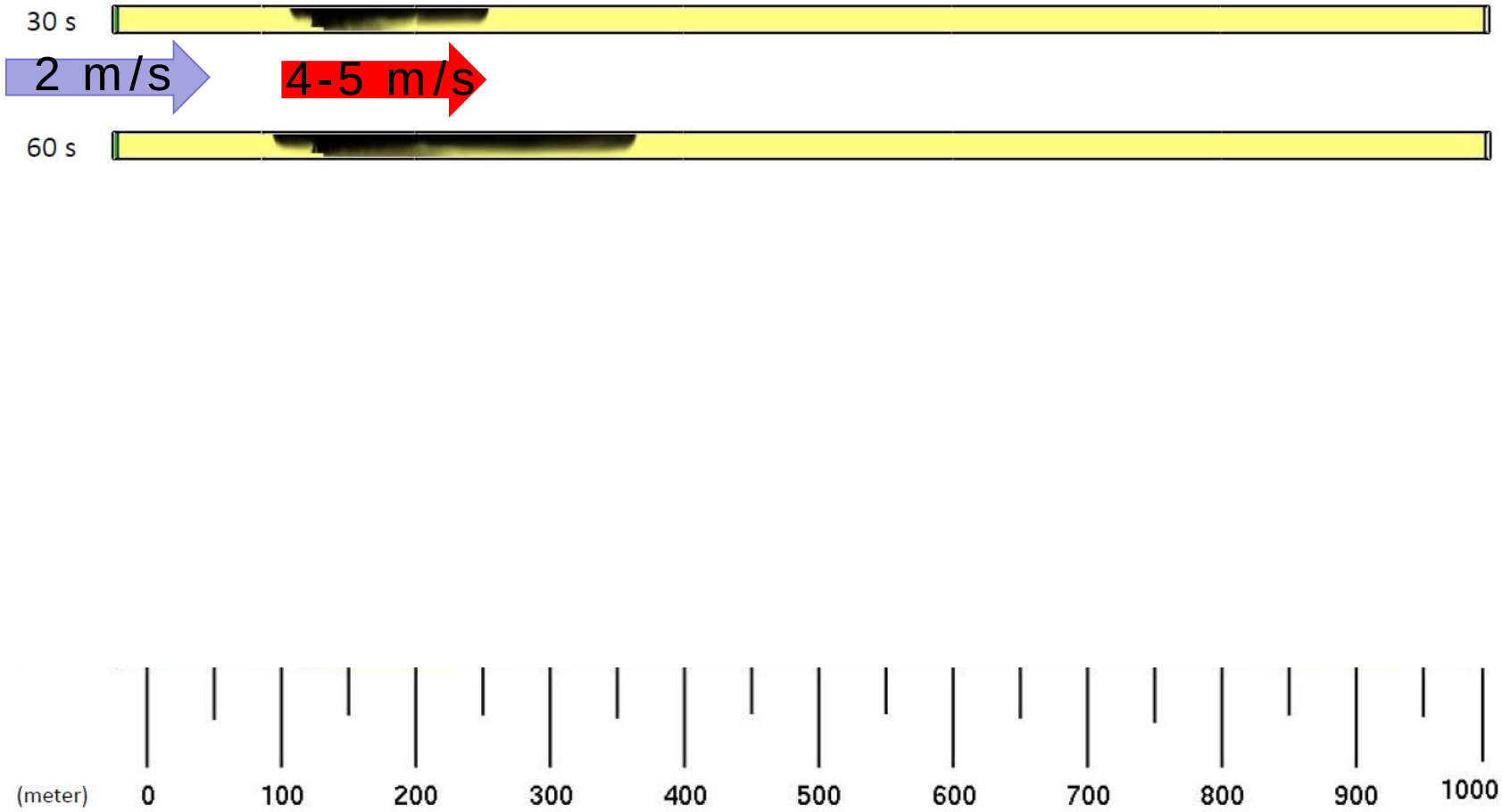

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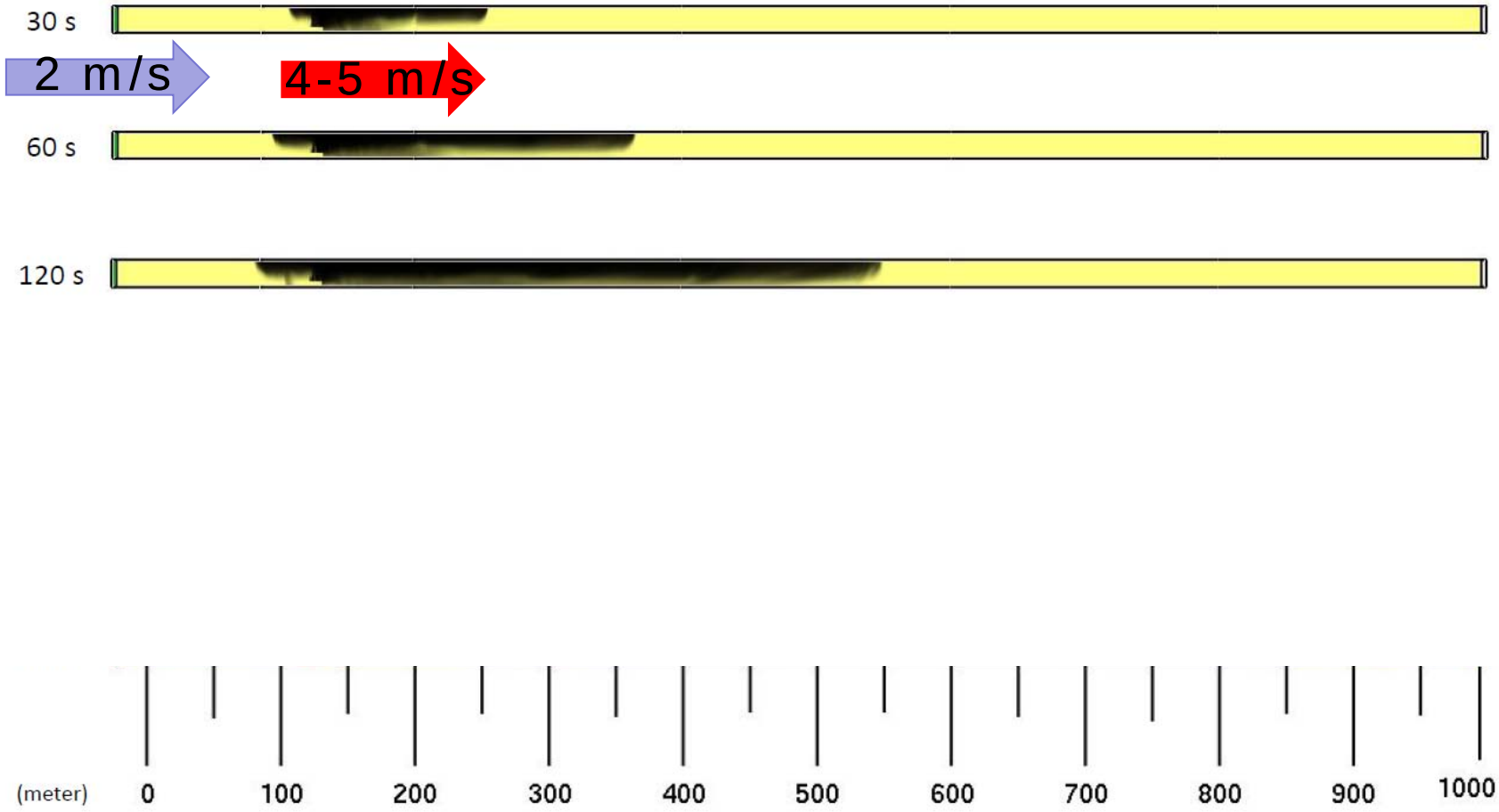

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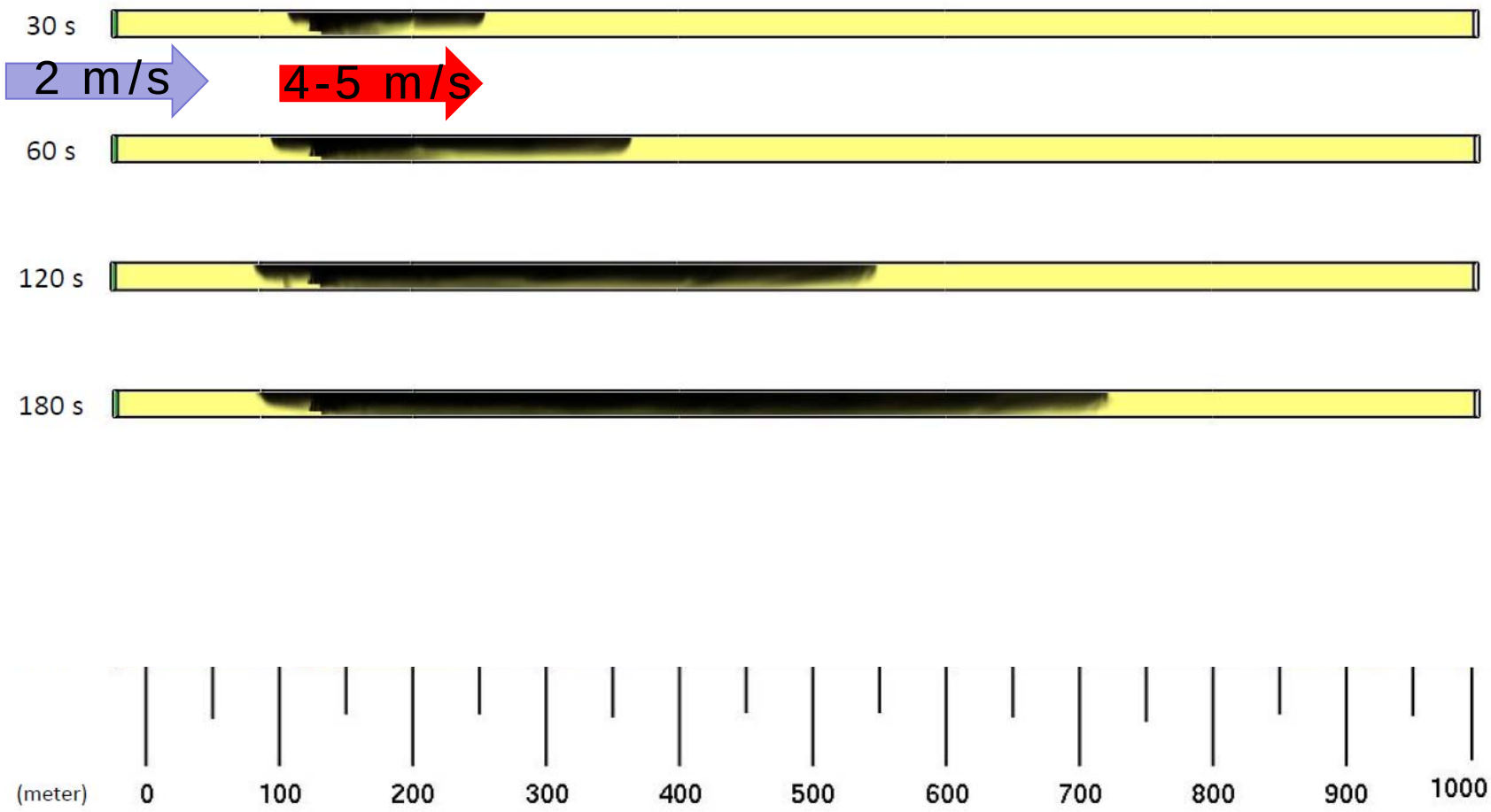

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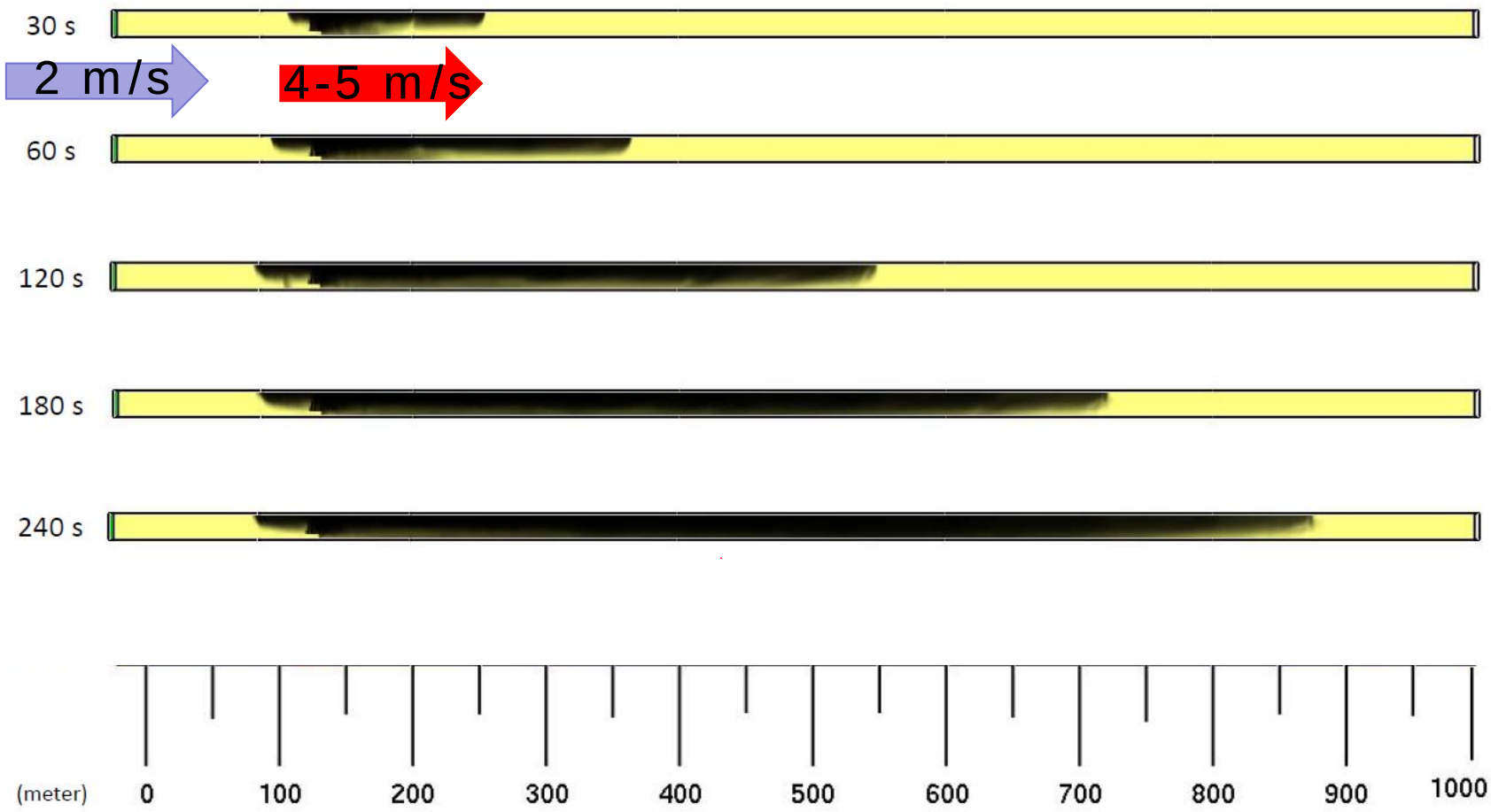

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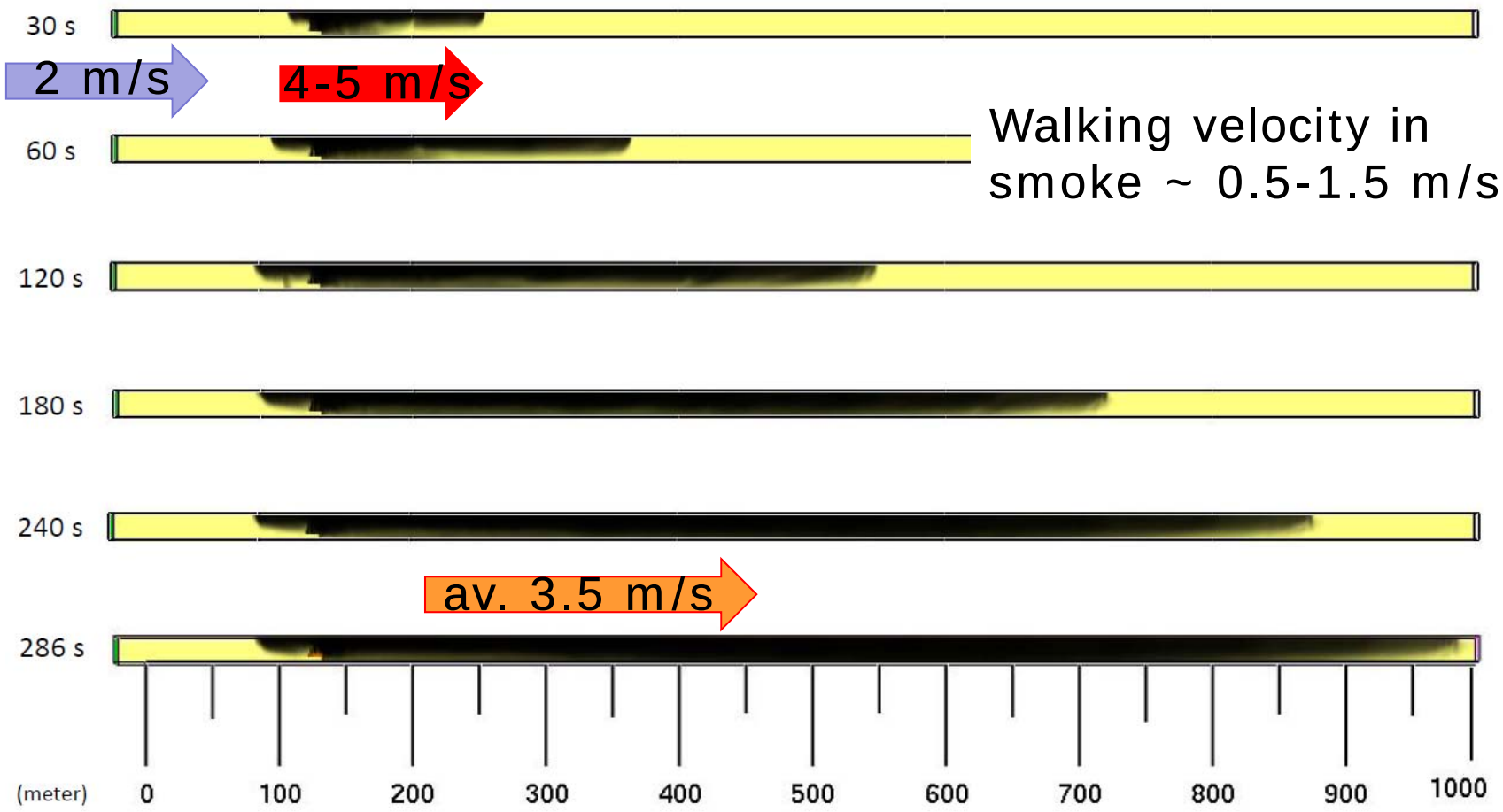
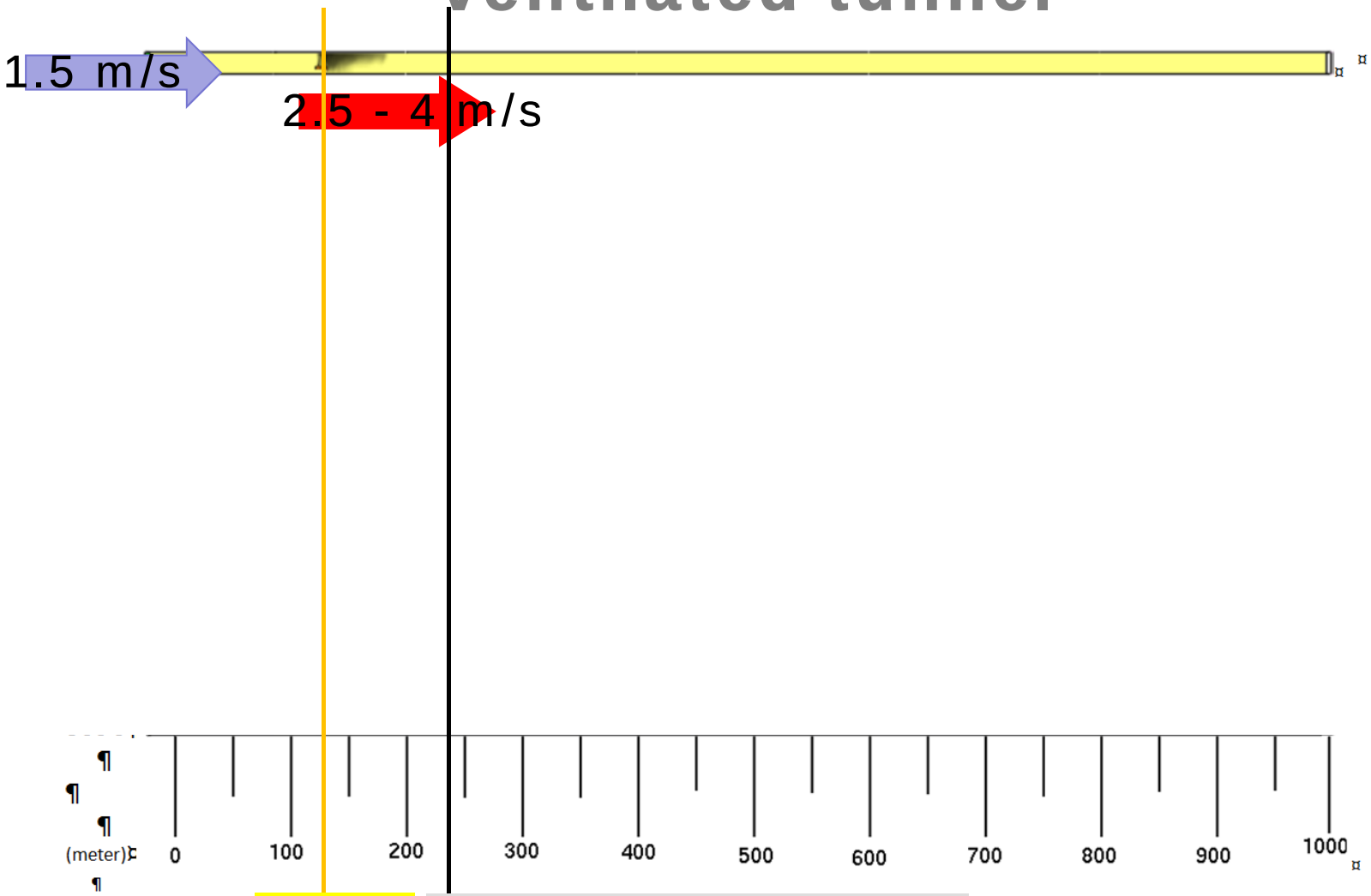


Walking velocity in smoke ~ 0.5-1.5 m/s

Smoke propagation in a Transverse ventilated tunnel



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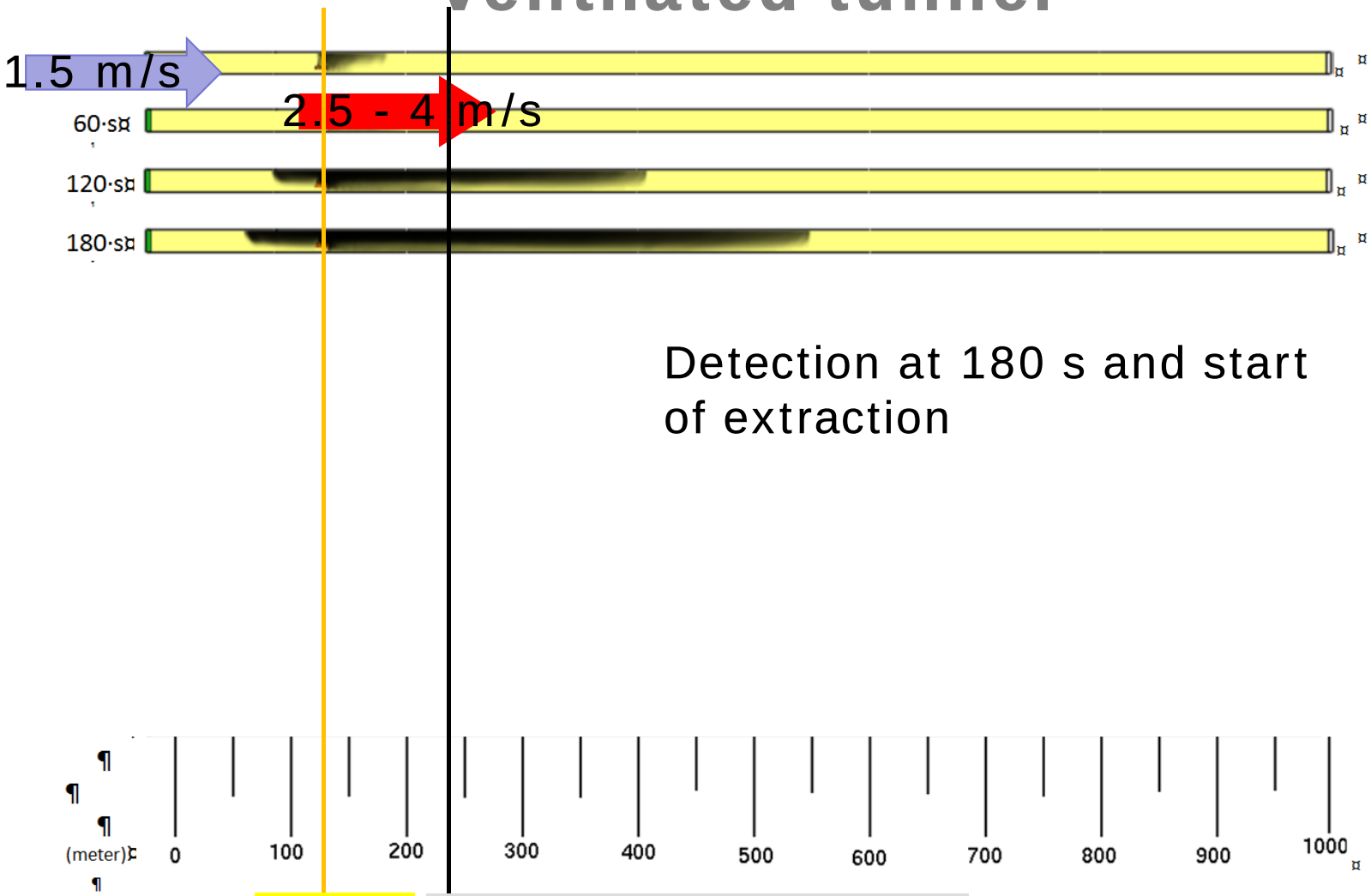
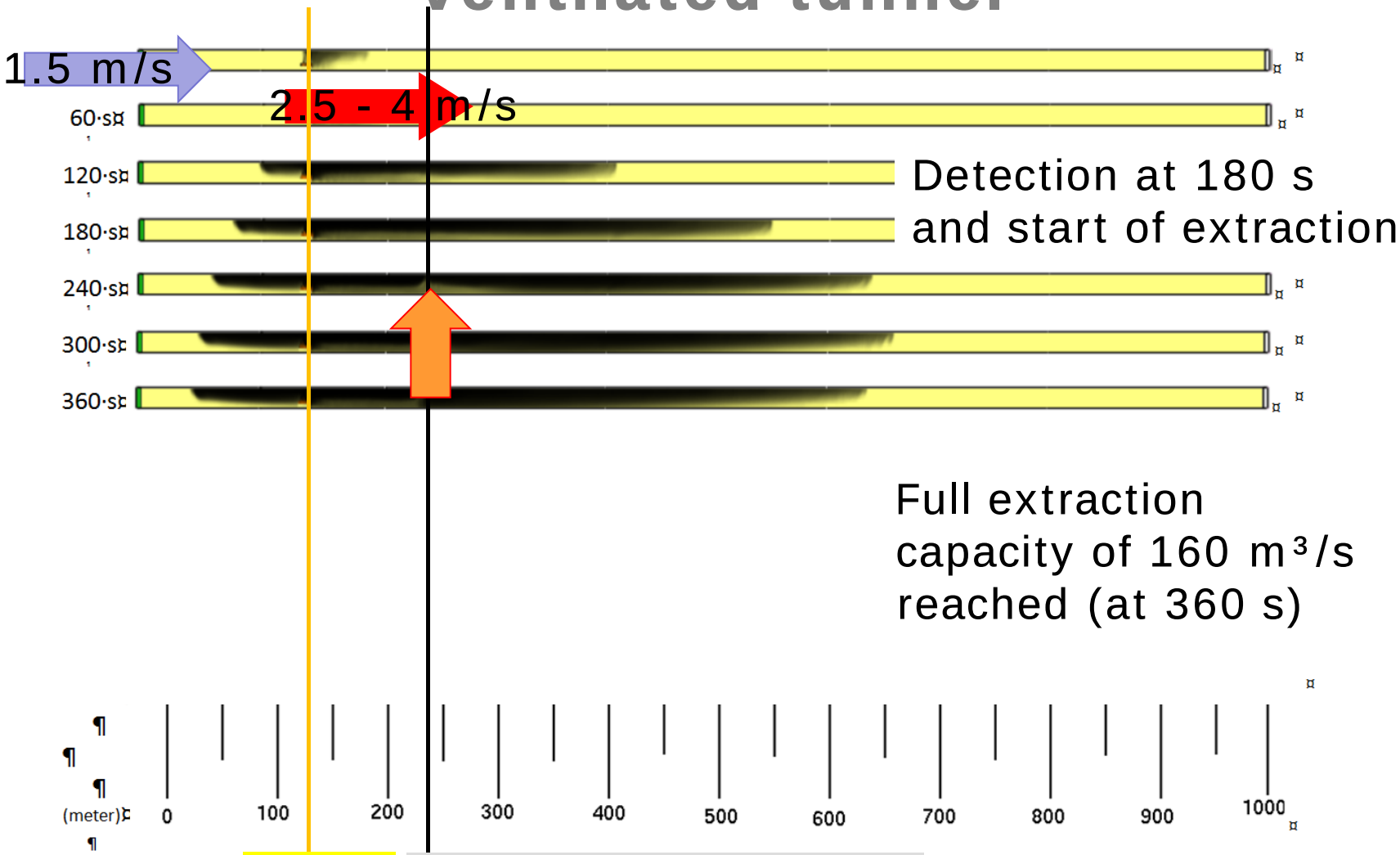


Detection at 180 s and start of extraction

Smoke propagation in a Transverse ventilated tunnel



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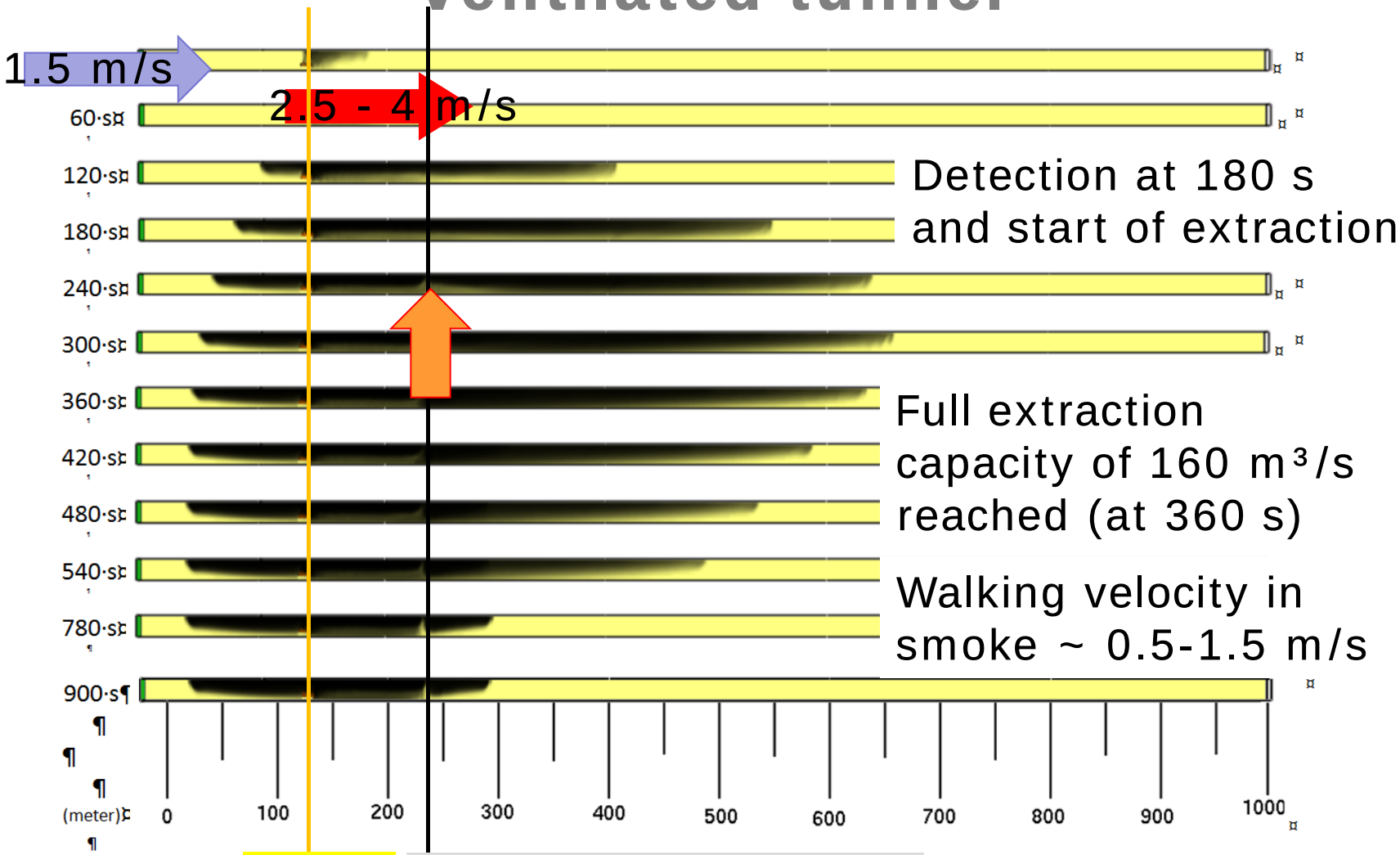
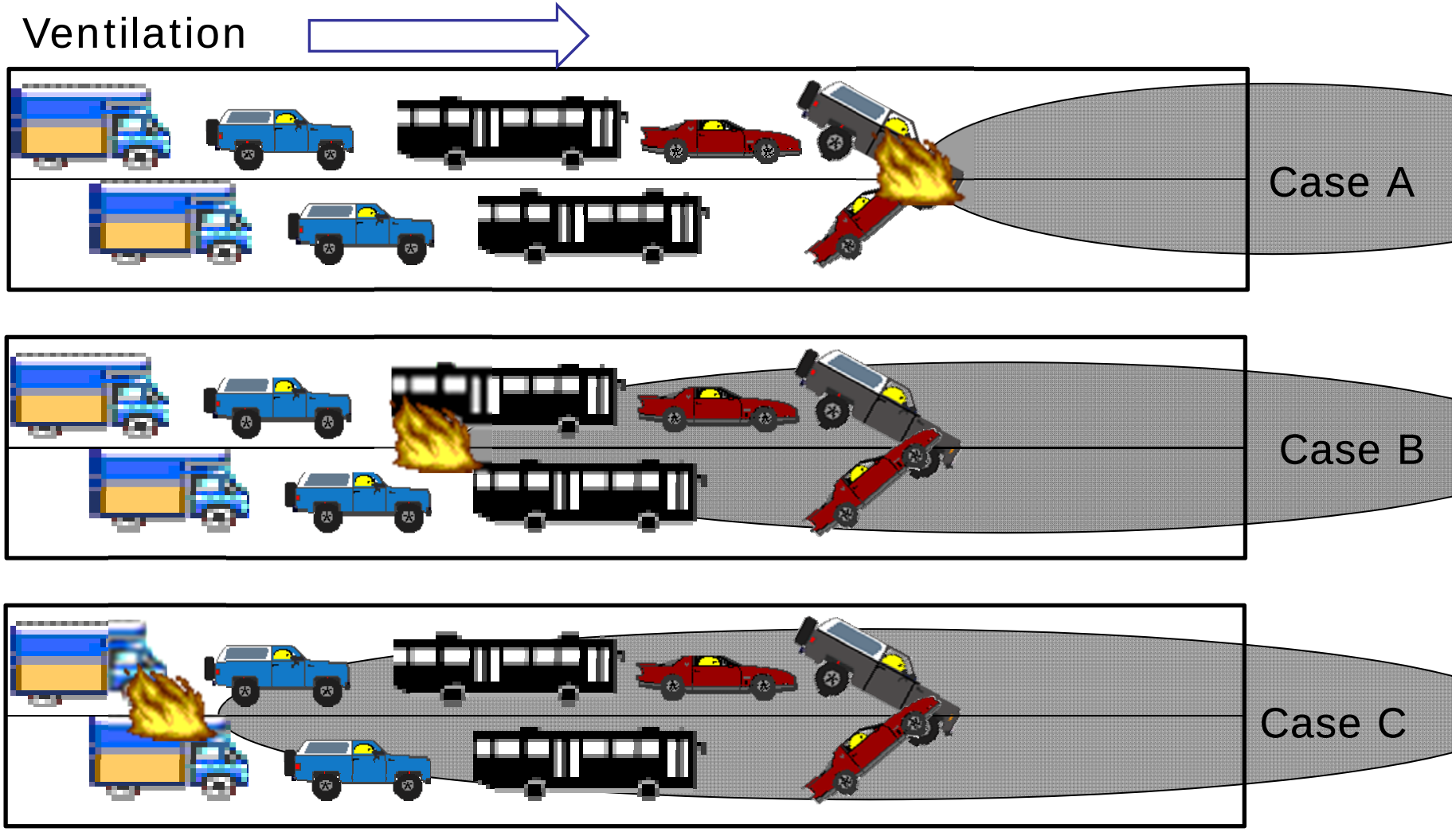
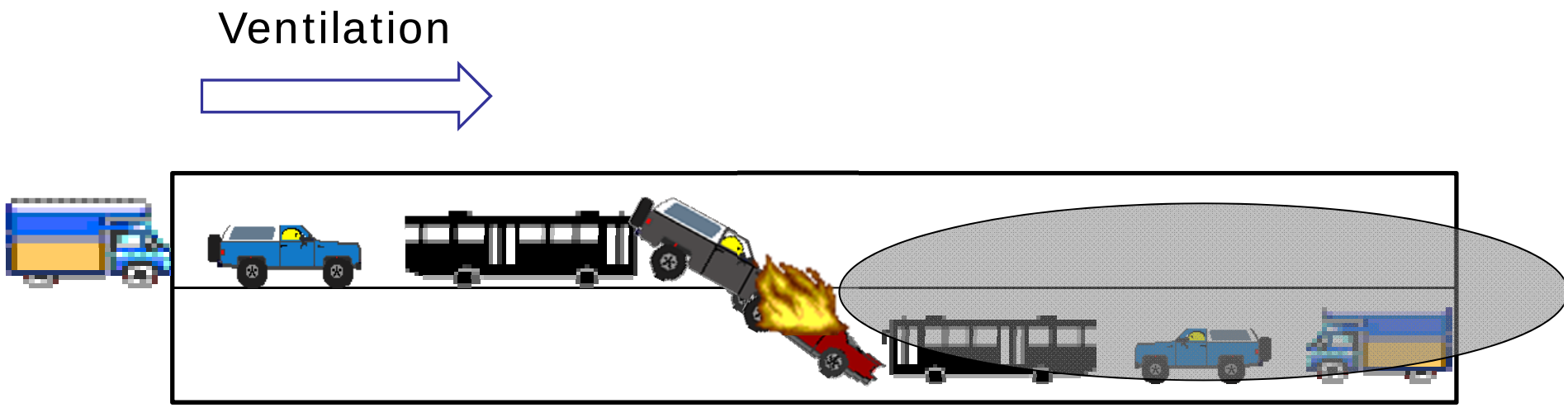


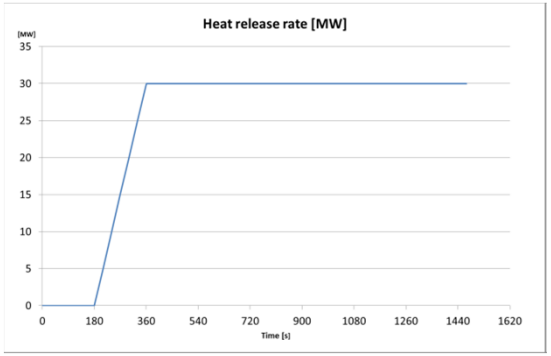
Incident in tunnels with unidirectional traffic



Incident in tunnels with bi-directional traffic



Incident in a longitudinal ventilated tunnel



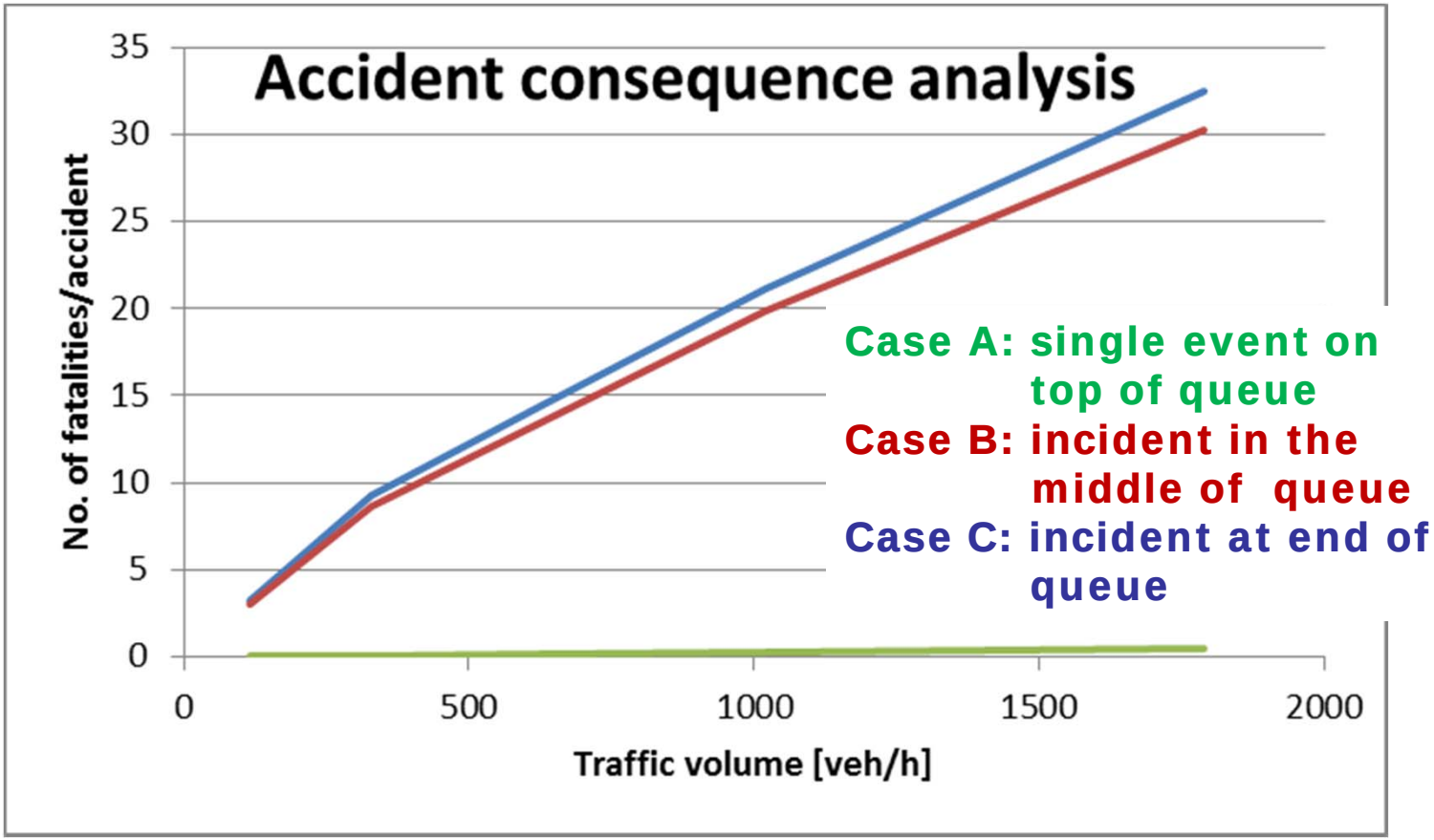
Boundary conditions:

- Tunnel length:1000 m
- Jet fans: 5 fans á 1000N
- Initial Velocity: dependent on traffic volume
  Heat release rate: 30 MW linear increase over 3 minutes
- Traffic volume: variable
- Detection time: 150 s after ignition
- Fan activation: in 10 s intervals as long as target velocity 2.4 m/s +/- 0.3 m/s is not reached

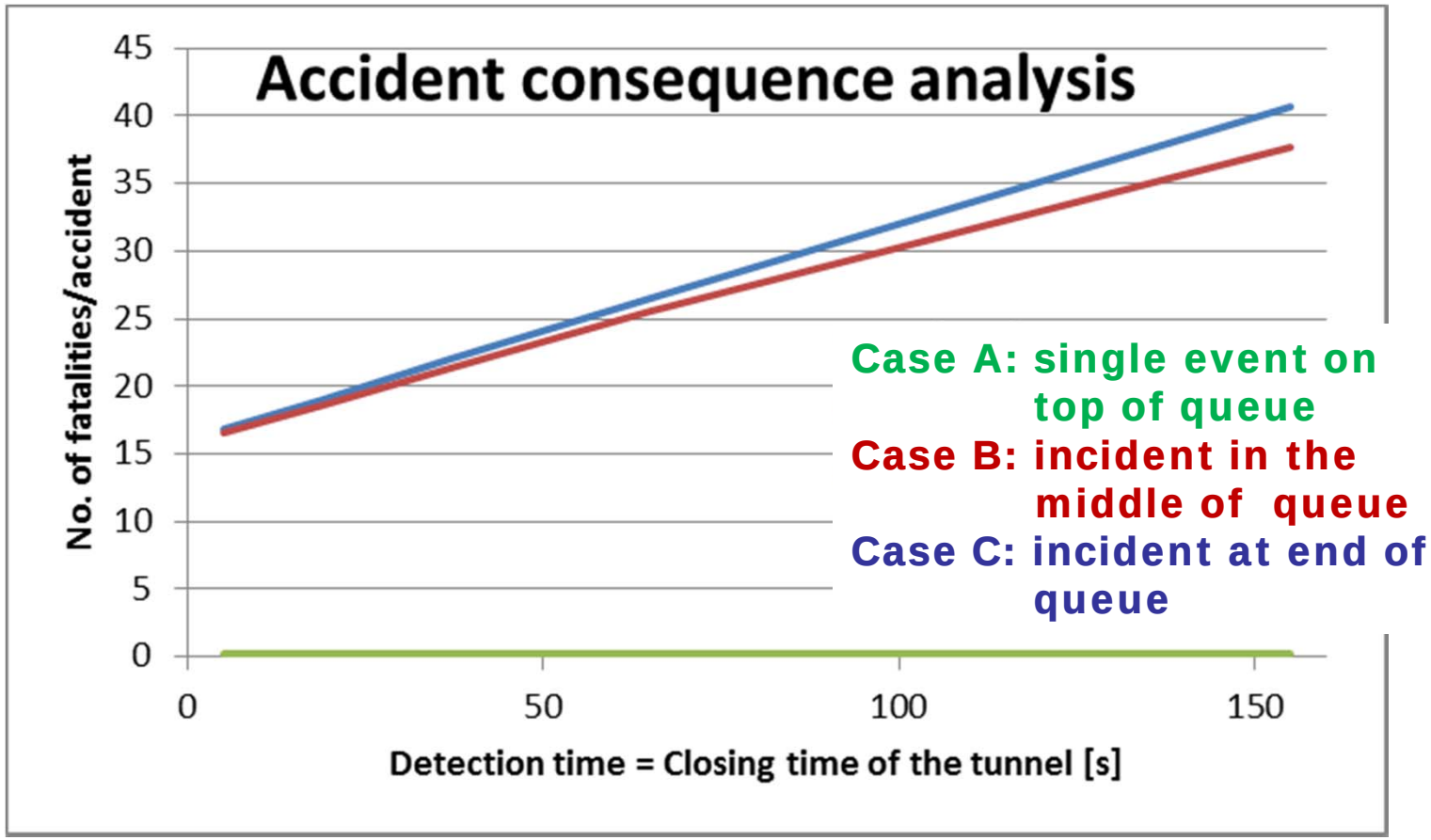
Simulation tool: FDS

Emergency exits every 500 m

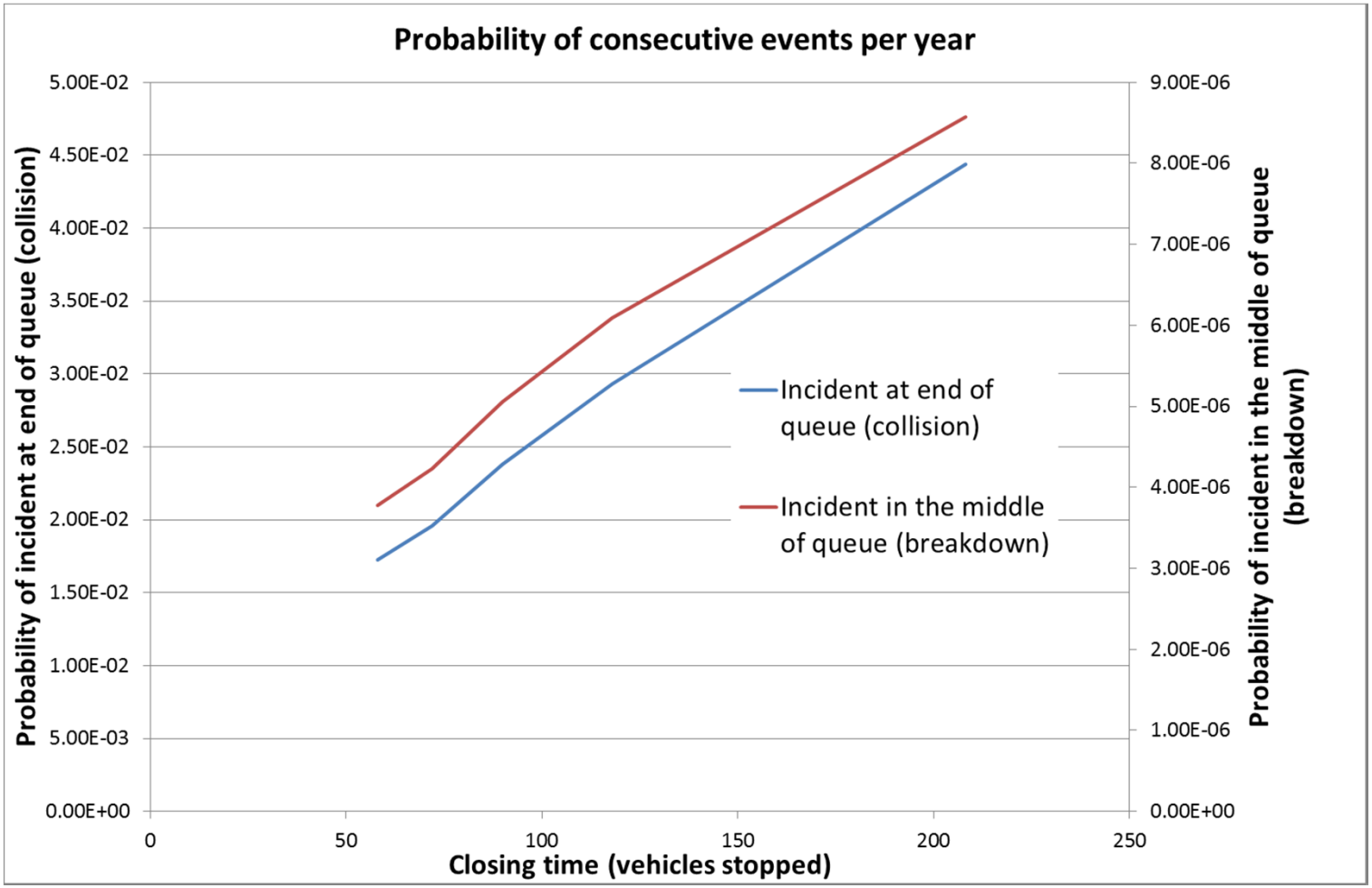
Longitudinal ventilated tunnel, unidirectional traffic, incidents with fire



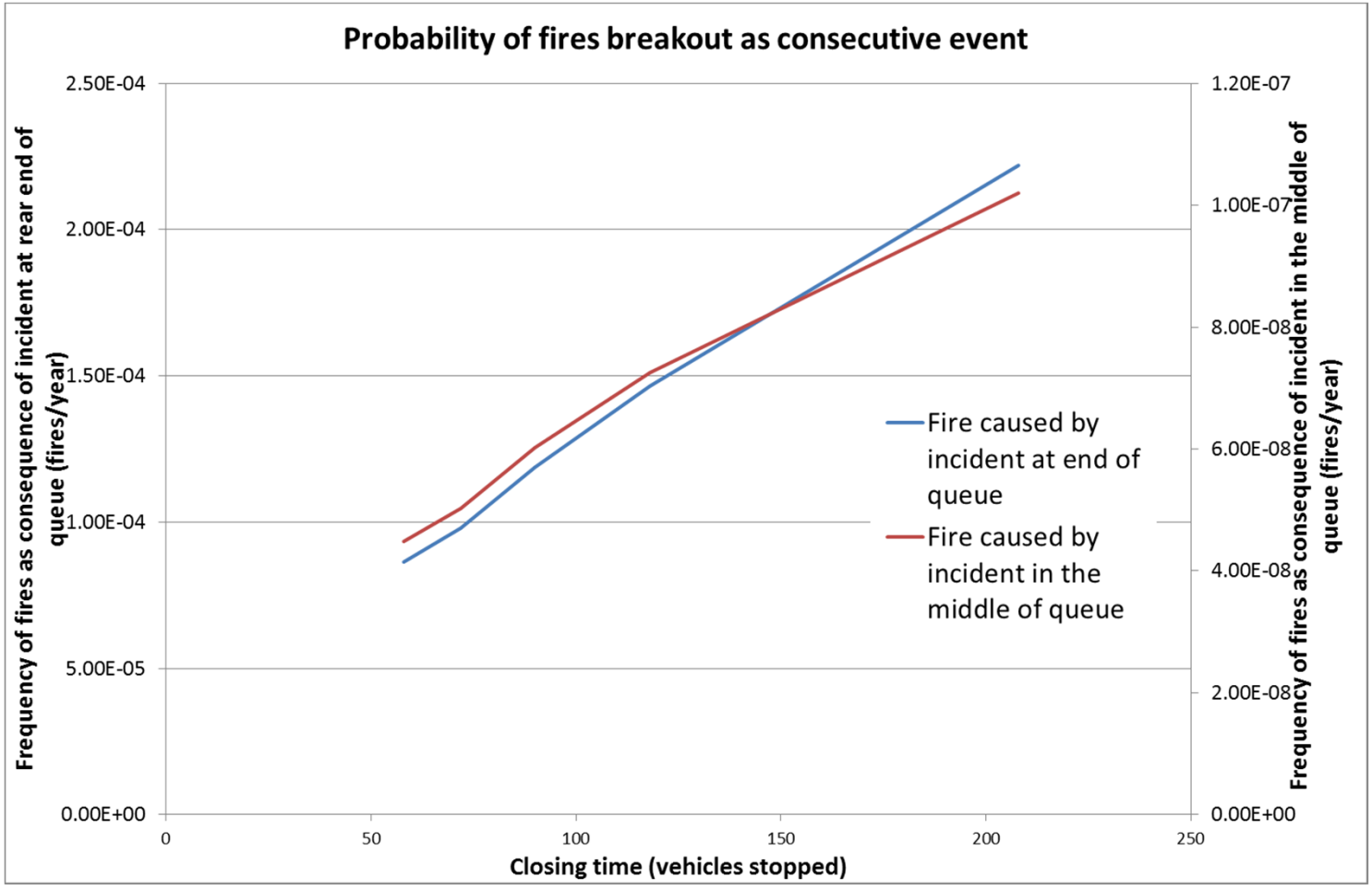
Longitudinal ventilated tunnel, unidirectional traffic, incidents with fire



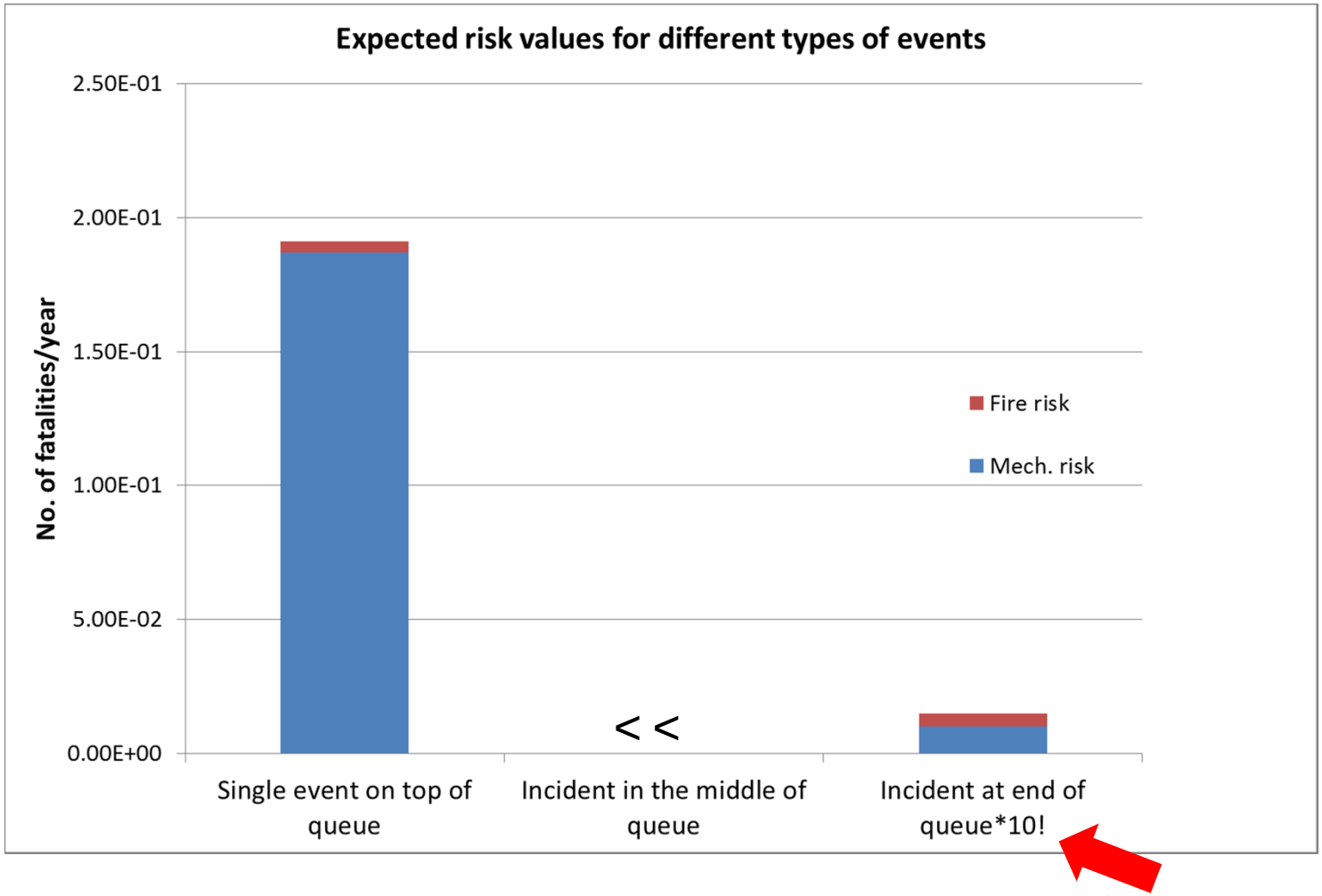
Longitudinal ventilated tunnel, unidirectional traffic, probability of incidents



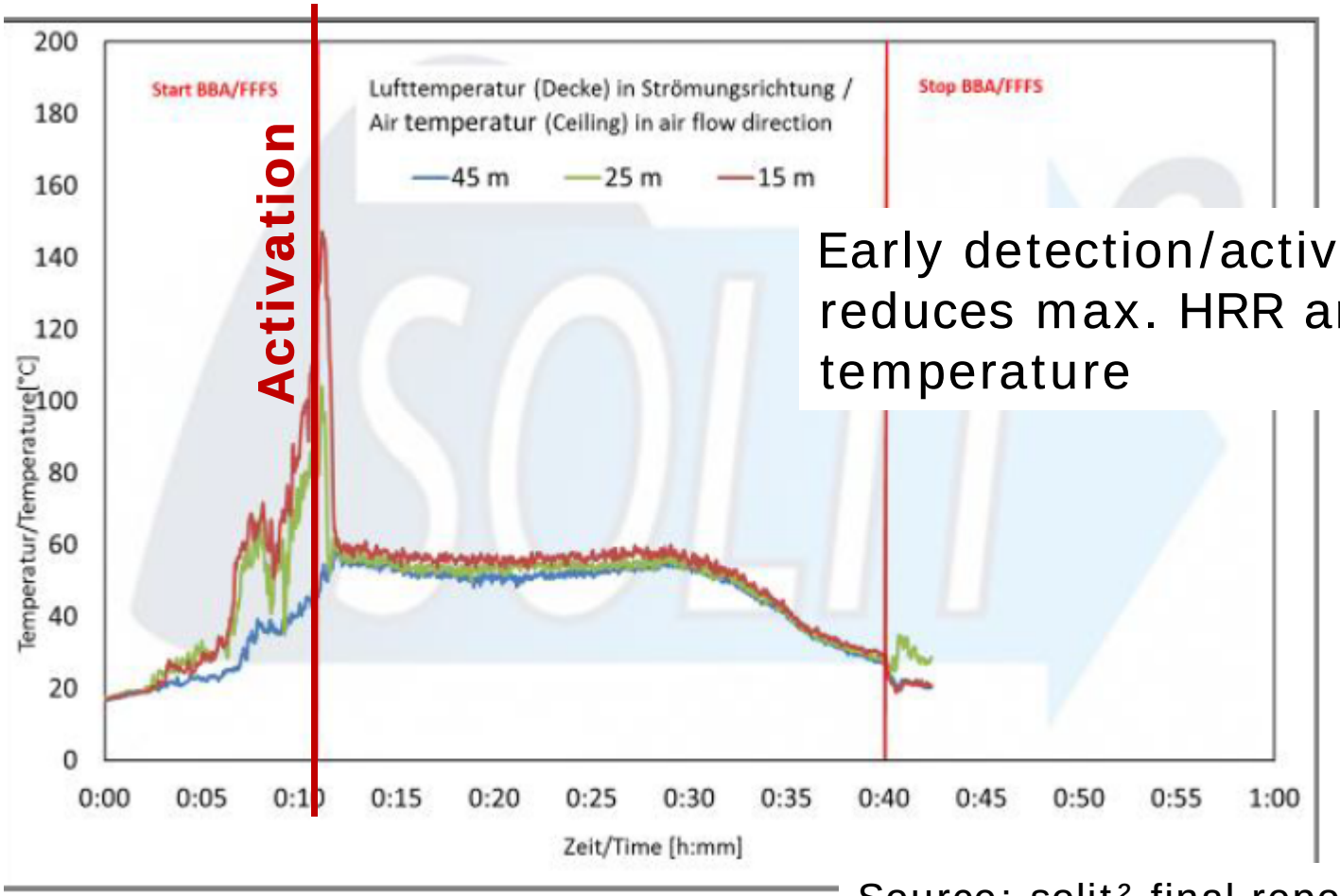
Longitudinal ventilated tunnel, unidirectional traffic, frequency of incidents with fire



Longitudinal ventilated tunnel, unidirectional traffic, incidents with fire



Water mist system: downstream temperatures as a function of time and location



Early detection/activation reduces max. HRR and temperature

Source: solit² final report

CONCLUSIONS

- Incident detection is based on sensor information
- Early detection allows for an early reaction
- Consequence of the incident is dependent on many time dependent parameters
  - Closing time of tunnels correlates with the probability, number and effect of incidents
  - Quick activation of ventilation reduces negative effects of smoke propagation
  - Quick detection allows for an improved self rescue
  - Quick activation of important safety installations like FFFs result in lower heat release rates and hence lower temperatures within the smoke filled zone

CONCLUSIONS

- In order to reduce the consequences of incidents with fire a quick detection of the incident is of highest priority
- This requires reliable detection systems in order to minimise false alarms
- Reduction of detection/activation time from 2 to 1 minute could reduce the consequences of incidents with fire within a queue by 30 to 40%