

Relativity – Lecture 2

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Key points of Lecture 1

- Maxwell's equations imply a speed of light that is independent of the speed of the light source;
- 19th Century experiments tried to determine the state of the 'ether' – the proposed medium for light waves;
- Einstein explains the conflicting results of the Fizeau experiment and the famous Michelson-Morley null-result by proposing there is no ether.

1905: Einstein's Special Relativity postulates

1. The laws of physics are the same in all inertial reference frames. *Relativity Principle*
2. The speed of light is independent of the speed of the source.
- 2b. The speed of light in vacuum is constant in all inertial frames.

What is an inertial frame?

An inertial frame is a frame in which isolated bodies move uniformly.

OR:

An inertial frame is a frame in which the law of inertia holds. if $F=0$, then $\frac{dp}{dt}=0$

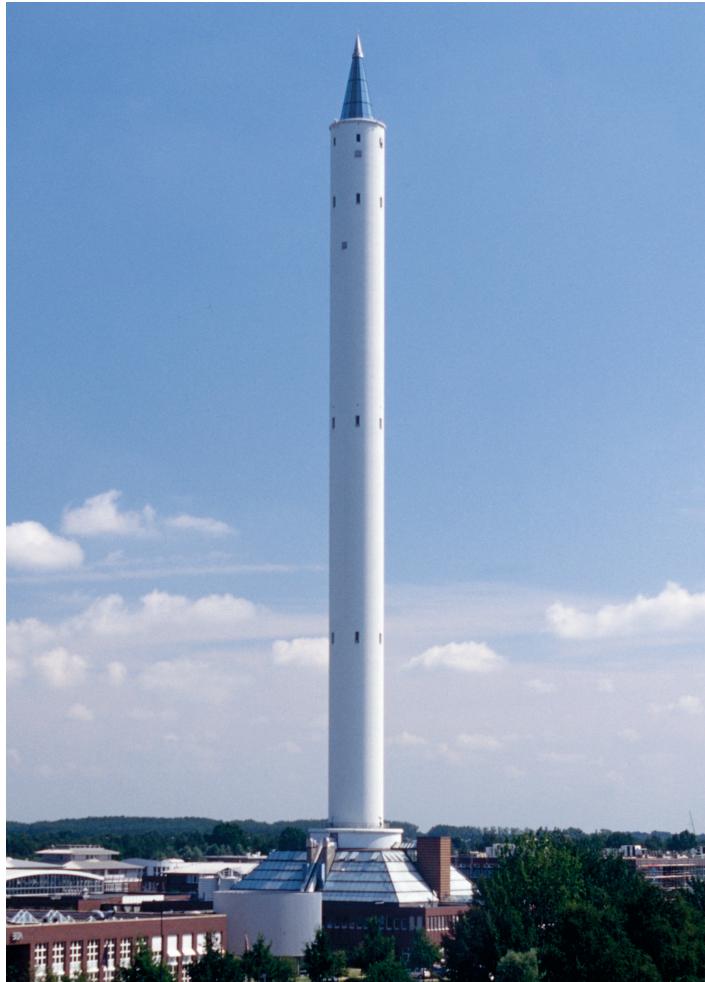
\Rightarrow There is a constant relative velocity between two inertial frames.

All of Newton's laws are the same in all inertial frames \Rightarrow no mechanics experiment can distinguish between 2 inertial frames.

Examples of inertial frames

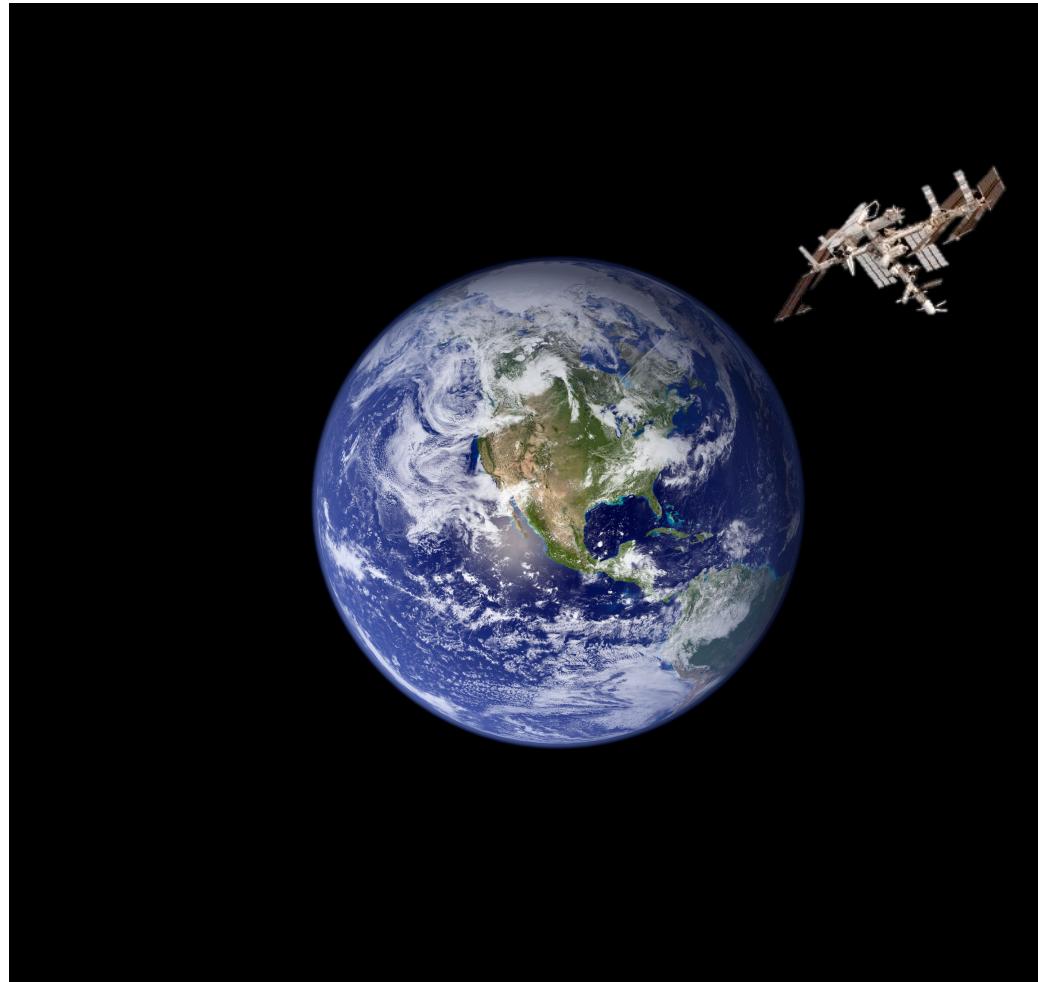


Examples of inertial frames



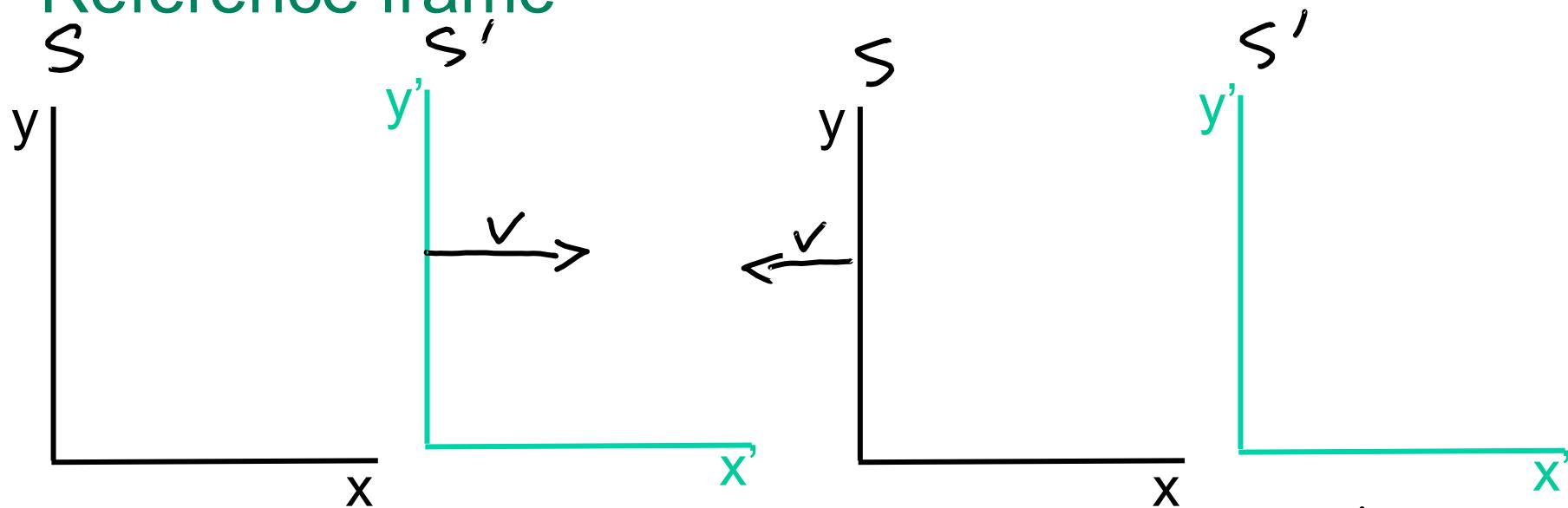
Bremen drop tower

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Satellites in orbit

Reference frame

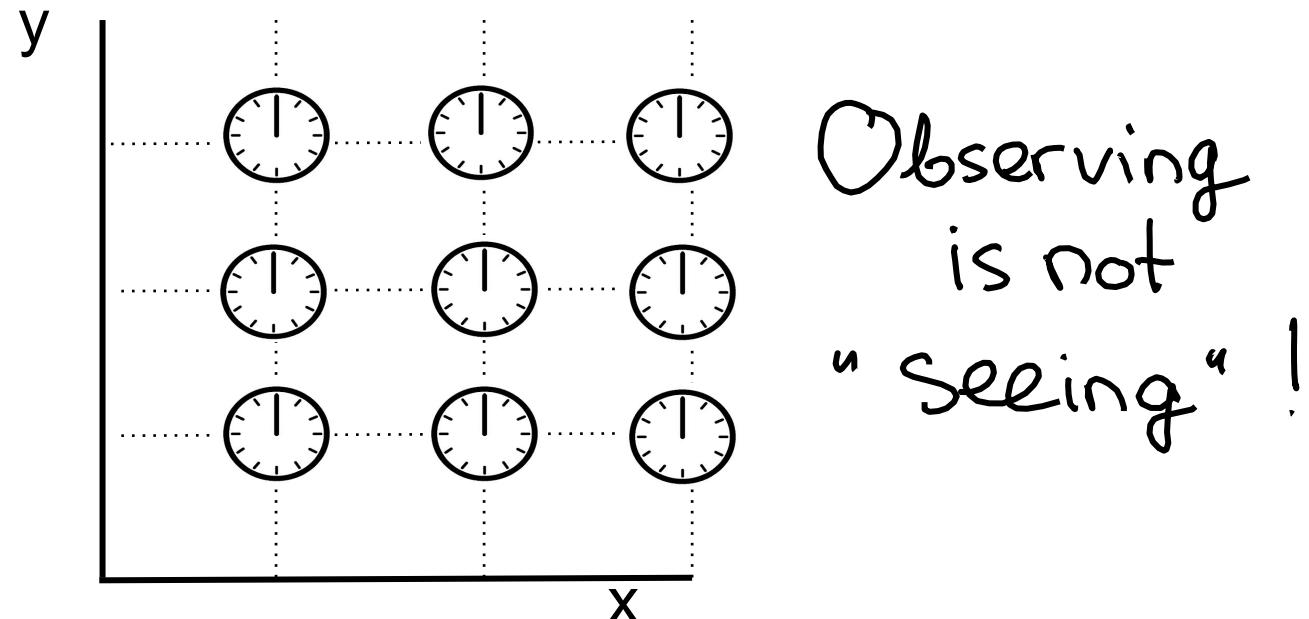


Reference frame is a set of coordinates,
e.g. Ref. frame S with (x, y) or S' with (x', y') .
[In 4-D: (t', x', y', z')]

To simplify maths: we say origins overlap at $t=0$,
and the relative velocity is along the x-direction.

Observers

Each reference frame contains an infinite number of observers with synchronised clocks who know their position.

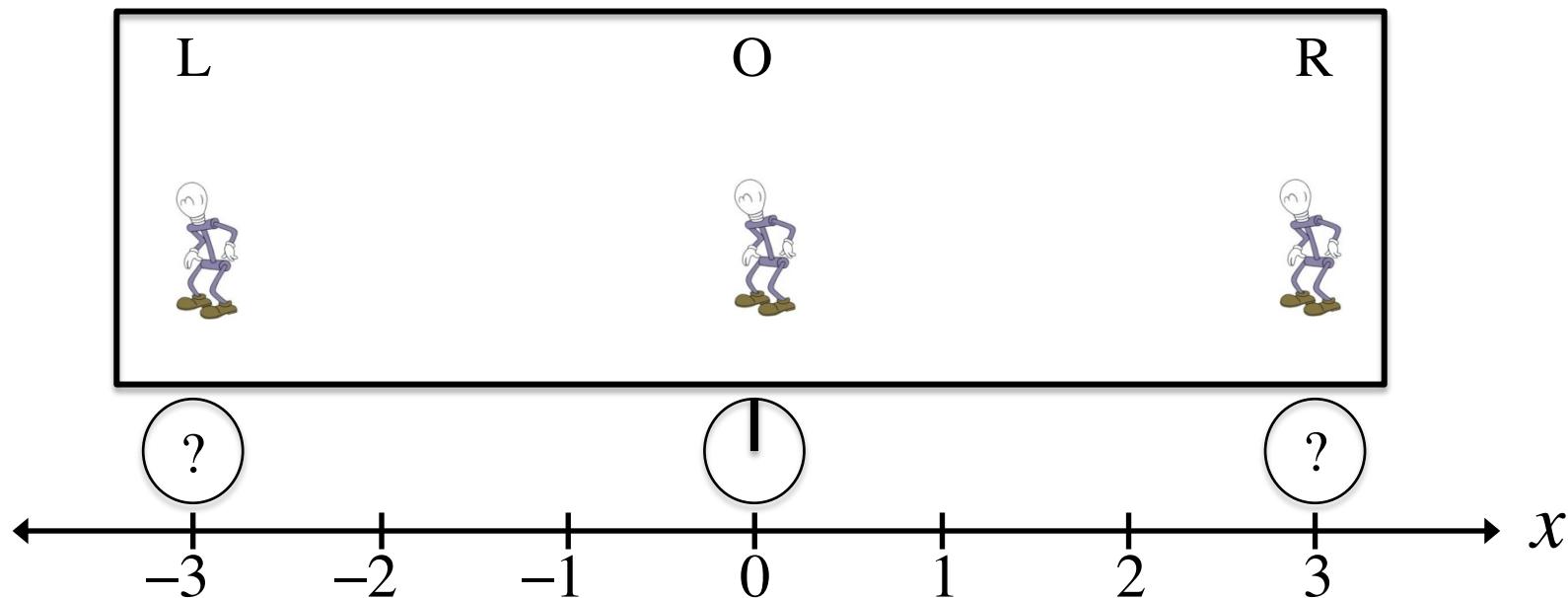


Oscar sits at the origin of reference frame S ($x = 0$).

Meter sticks establish distances in S .

Local observers at $x = -3$ m (Lucy) & $x = +3$ m (Ricky).

Procedure to synchronize all clocks in S ?

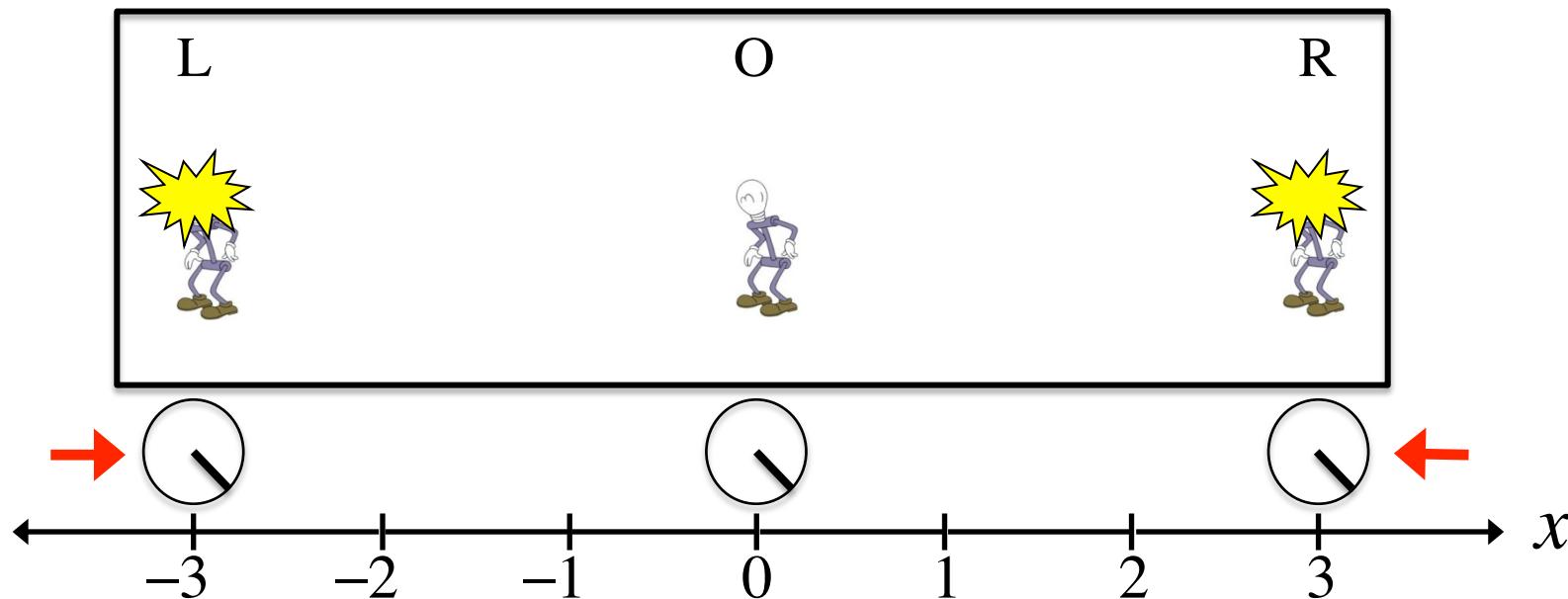


Procedure to synchronize all clocks in S :

Oscar emits a light flash at $t = 0$.

Light spreads outwards in a spherical wavefront.

At $\Delta t = (+3 \text{ m})/c$ the wavefront reaches Lucy and Ricky.



Lucy & Ricky know to set their clocks to $t = (0 + 3 \text{ m})/c$!

Events

Events happen at a particular position and a particular time (t, x, y, z) or (t', x', y', z') .

Examples:

- particle collision
- lamp turned on
- light detected by observer

Not 1 event :

- measuring length of rod
- Olympics 2012
- Opening Ceremony

Events

Events happen at a particular position *and* a particular *time* (t,x,y,z) or (t',x',y',z') .



Proof of postulate 2b

The laws of physics are the same in all inertial reference frames.

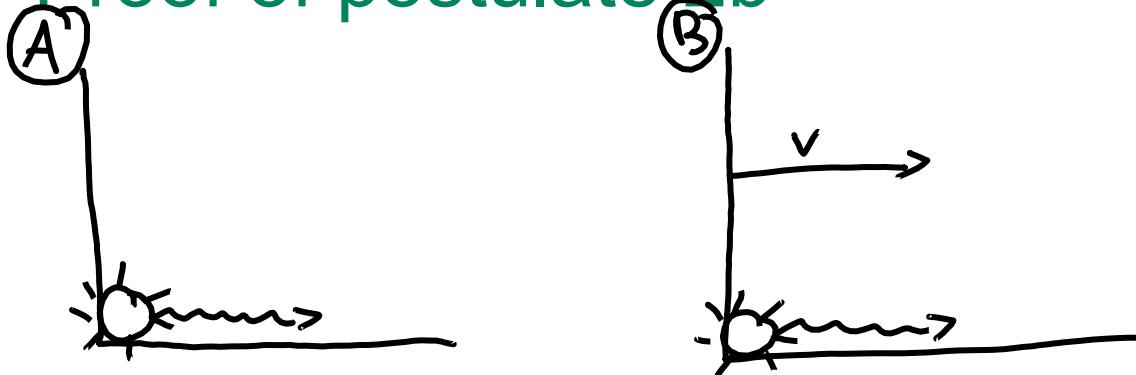
+

The speed of light is independent of the speed of the source or observer.

=

The speed of light in vacuum is constant in all inertial frames.

"Proof" of postulate 2b



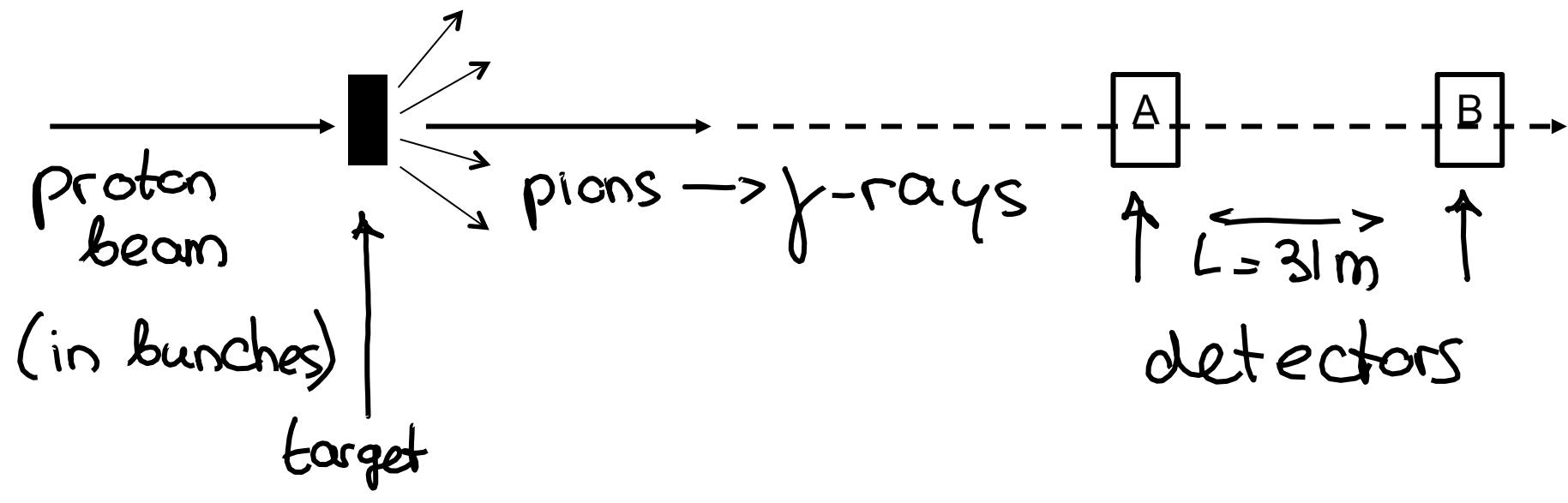
Ⓐ and Ⓑ are inertial reference frames.

Ⓐ and Ⓑ have identical lamps at rest in their frames.

By postulate 1, they must measure identical speed from their own lamps.

By postulate 2, Ⓑ must measure the same speed of light from Ⓐ's lamp as Ⓐ.
And vice versa!

Alvager experiment (1964) confirms c is constant



pion speed measured : $0.99c$

γ -ray burst measured at $2.9979(4) \times 10^8 \text{ m/s}$

Confirmation that c is independent
of speed of the light source!