

The logo consists of a solid blue square with the text 'S'Cool LAB' in white. 'S'Cool' is on the top line and 'LAB' is on the bottom line, both in a bold, sans-serif font.

**S'Cool  
LAB**

**CosMO- Cosmic Muon Observer**

Student worksheet

en

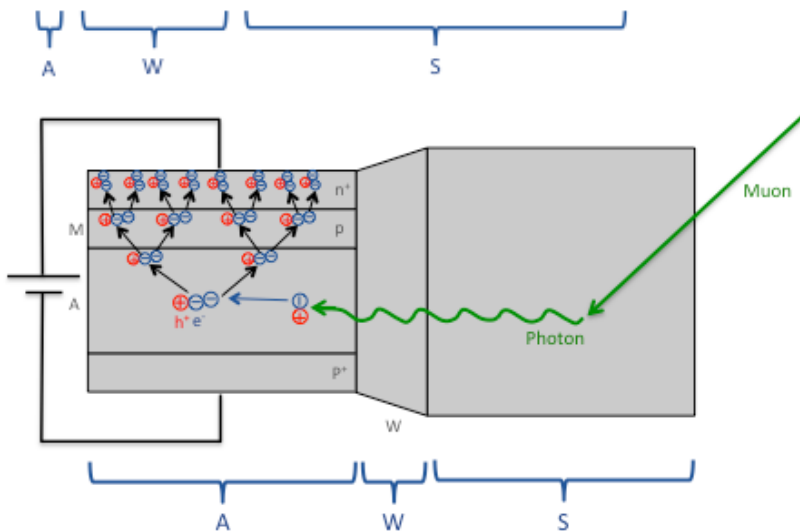
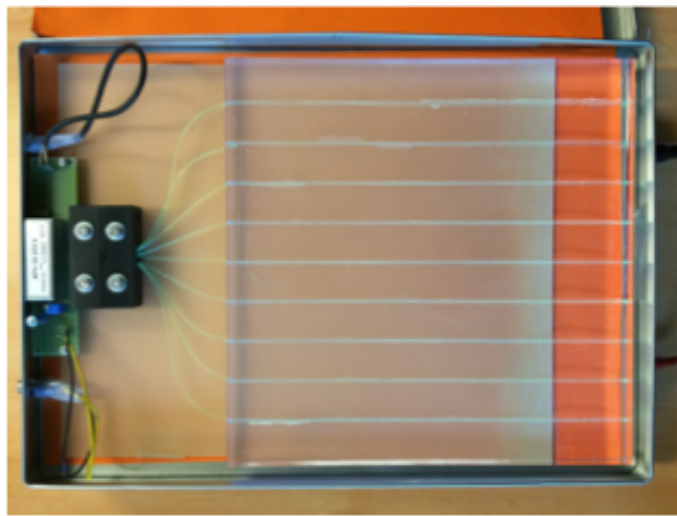
05/11/15

**⚠ Safety instructions**

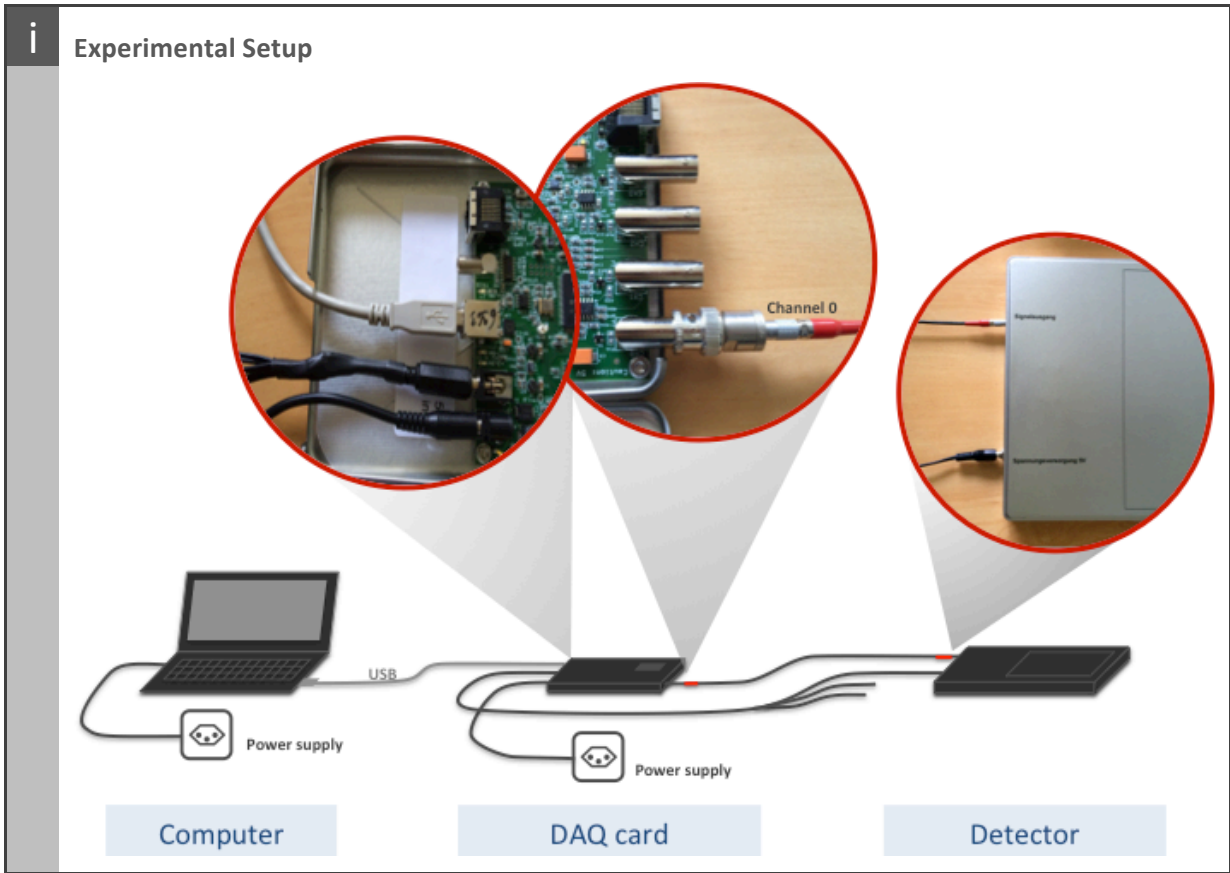
- **Do not connect the DAQ card to the power supply** until your tutor has checked your setup!
- **Do not open** the detector during the measurement!

**i Before you start, you should know**

- ✓ the different components of CosMO and how they work together
  - detector (including scintillator, waveguides, photomultiplier)
  - DAQ card (Data Acquisition card)
  - computer
- ✓ how CosMO detects particles



A	Avalanche photodiode	M	Multiplication
W	Waveguide	A	Absorption
S	Scintillator		



**i** “muonic” program startpage

Illustrated rate per second

Average number of muons passing through the detector of channel 0 per second

Total number of muons passing through the detector on channel 0 since the start of a measurement

	rate [1/s]	counts
channel 0	--	--
channel 1	--	--
channel 2	--	--
channel 3	--	--
trigger	--	--

Total number of muons passing through the detector on channel 1 since the start of a measurement

When measuring coincidences, average number per second of muons passing through the detectors

Measured time

To start a measurement

To stop a measurement



## Experiment 1: Detecting muons



### Prediction

Do you think that you can detect muons here without any special muon source?

	Yes	No
Student 1	<input type="checkbox"/>	<input type="checkbox"/>
Student 2	<input type="checkbox"/>	<input type="checkbox"/>
Student 3	<input type="checkbox"/>	<input type="checkbox"/>
Student 4	<input type="checkbox"/>	<input type="checkbox"/>

Why do you think this?

Student 1:

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Student 2:

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Student 3:

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Student 4:

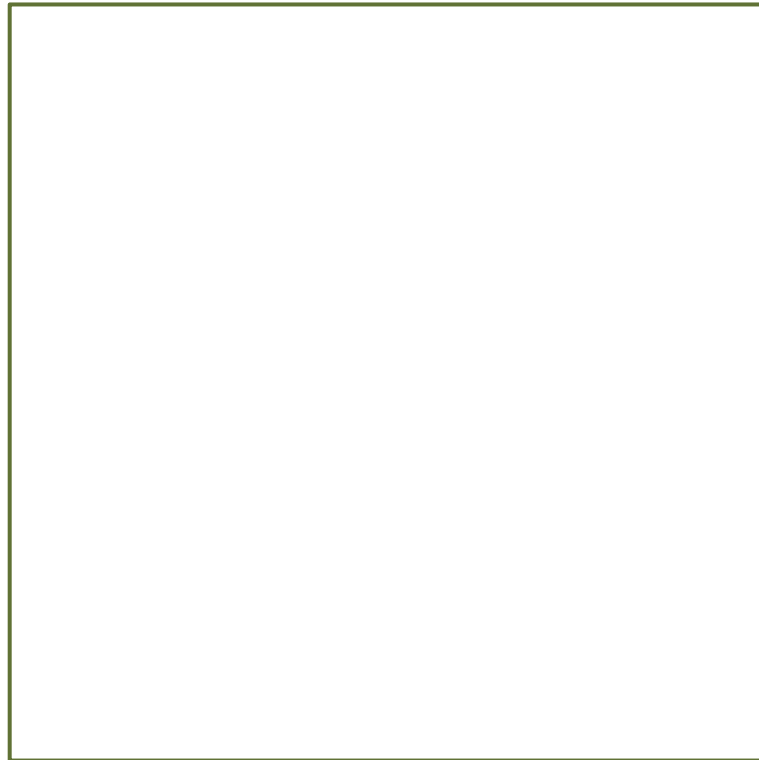
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**If you answered “yes”:** How many muons do you think pass through an area the size of the green box on the next page per second?

Student 1	<input type="text"/>
Student 2	<input type="text"/>
Student 3	<input type="text"/>
Student 4	<input type="text"/>

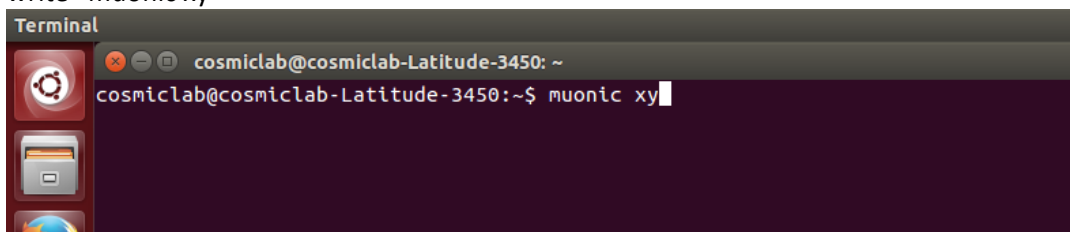


### To do

- Connect the components according to the experimental setup on page 3.
- **⚠ Do not connect to the power supply** until your tutor has checked your setup!
- Turn the computer on, then log in using the password “Astro11\*”
- After connecting to the power supply start the program “muonic” in the following way:
  - open the terminal with this button



- write “muonic xy”

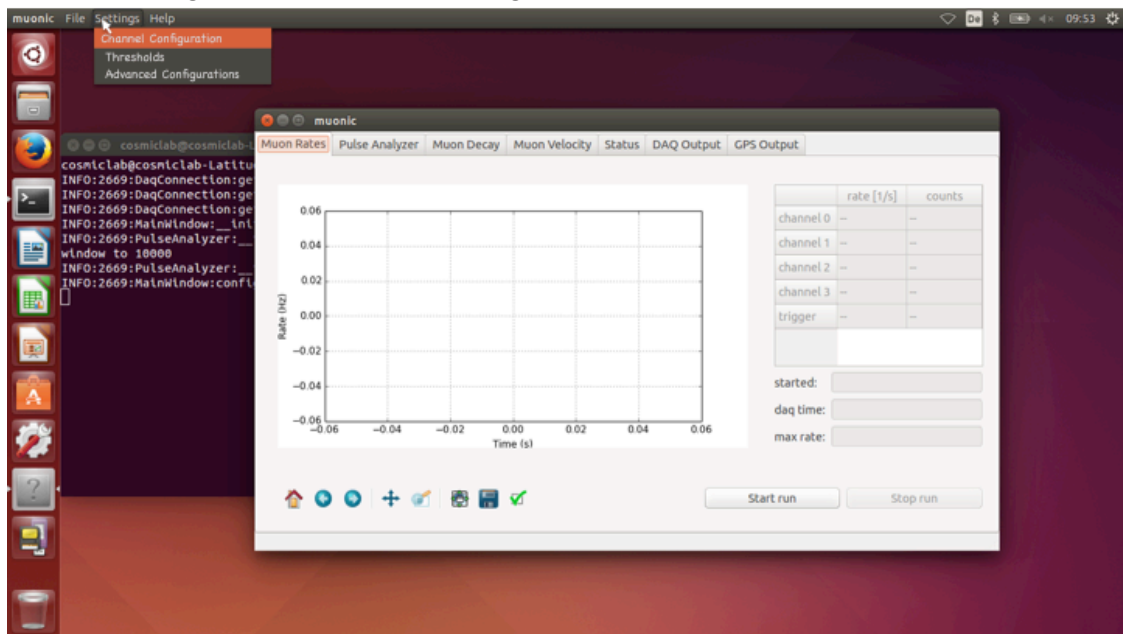


- press enter

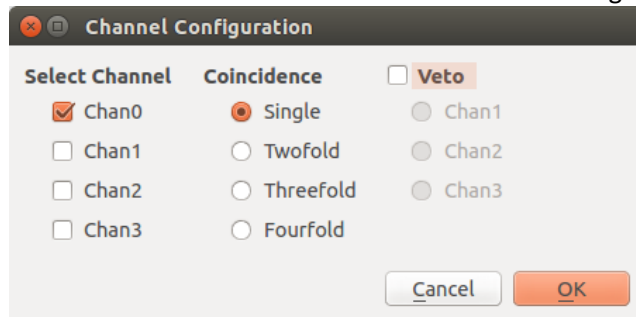
The start page of muonic which now appears is explained in the picture on page 3.

- For the first measurement, you will only use one detector (which you already connected to input channel 0). Therefore, the computer should be configured to count signals from just one detector:

Click on “settings”, then on “channel configuration”



then select channel “Chan0” and coincidence: “single”. Do not tick “veto”.



- Start a measurement by clicking on “Start run”.
- After one minute, stop the measurement by clicking on “Stop run”.



### Observation

What is the muon rate you have just measured?



**Some calculations**

On average, how many muons pass through the scintillator of the detector per minute?

What is the rate of muons per  $\text{cm}^2$  per minute?

If you were to repeat the measurement, would you expect the same number of muons to pass through the detector? Why, or why not?

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## Experiment 2: Catching muons in your hand

For the following experiments, you will use two detectors.

The computer shows the number of muons passing through the first detector per second as you have seen it in the first experiment. Similarly, it shows the rate of muons passing through the second detector.

Now, we also want to know how many muons pass through *both* detectors. Because muons move at almost the speed of light, we can say that the two detectors must register a muon within a very short time of each other. In this case, the so-called “trigger” software counts a signal. The computer thus shows the number of muons which passed through both detectors in the box called “trigger”.

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### Coincidence measurement

The measurement method of setting a trigger which only counts when there is a signal in several detectors at almost the same time is called “coincidence”. Triggering by counting simultaneous signals from two detectors is called “twofold coincidence”.

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### Have you understood coincidence?

Let’s do an example.

Please fill in the following table.

1 means a muon was registered in the detector.

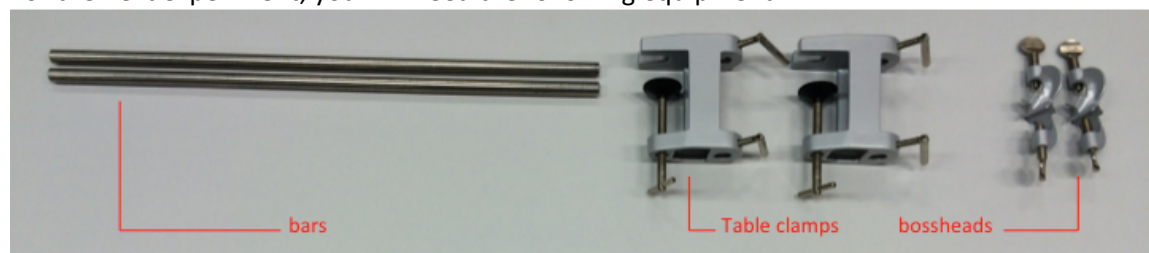
0 means **no** muon was registered in the detector.

Write a 1 for “the trigger counts a signal” and a 0 for “the trigger counts **no** signal”.

Detector 1	0	1	1	0	1	1
Detector 2	0	0	1	1	1	1
Trigger						

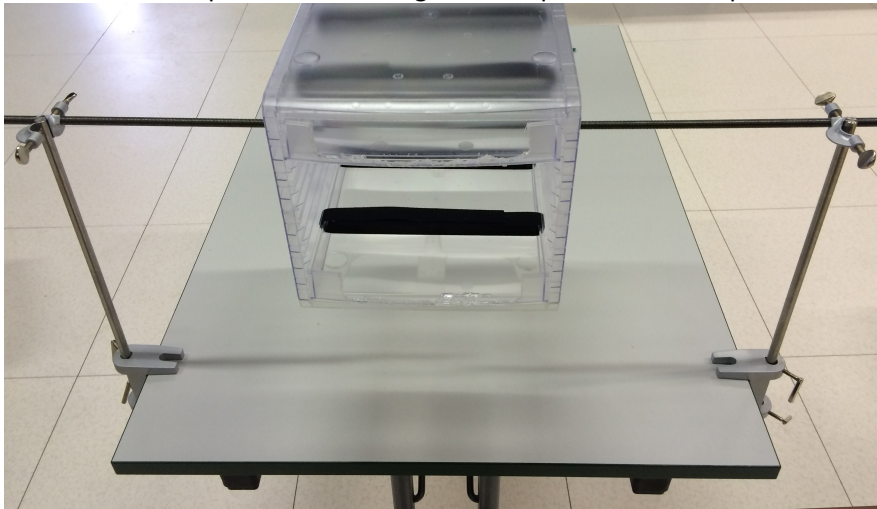
### To do

For the next experiment, you will need the following equipment:



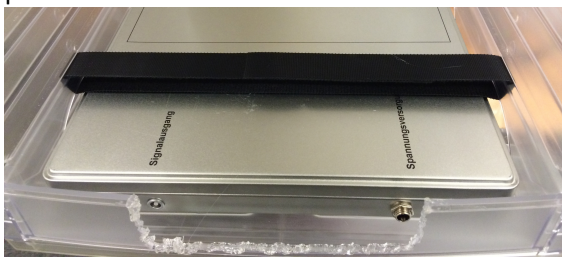


- Connect the components according to the experimental setup below



Please, tighten the screws well!

- Put two detectors into the drawers and fix them with the Velcro stripes as shown in the picture below



The box should be horizontally. If you can not fix it, ask the tutor.

- Connect the detectors with channel 0 and channel 1
- To set a twofold coincidence, click on “settings”, then on “channel configuration”

	rate [1/s]	counts
channel 0	--	--
channel 1	--	--
channel 2	--	--
channel 3	--	--
trigger	--	--

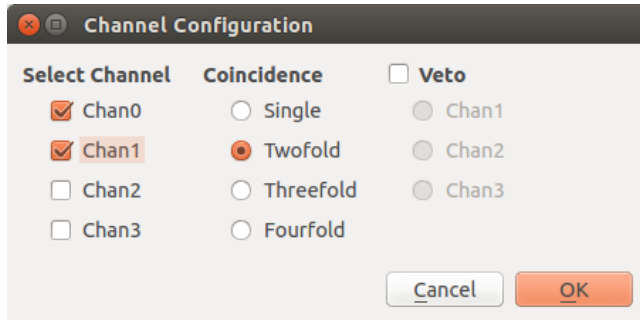
started:

daq time:

max rate:

Start run      Stop run

then select channel 0 and 1 and a twofold coincidence



### Prediction

What number of muons passing through *both* detectors per second (“trigger rate”) do you expect?

Student 1	
Student 2	
Student 3	
Student 4	



### To do

- Start a measurement and stop it after one minute



### Observation

What rate did you measure in the detector connected to channel 0?

What rate did you measure in the detector connected to channel 1?

What trigger rate did you measure?




### Question

Does the observation match your predictions? How would you explain this?

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**Prediction**

In the previous measurement you got a trigger rate for muons passing through both detectors as shown in situation 1.



Situation 1



Situation 2

What trigger rate would you expect in situation 2 with your hands between the detectors? Is the rate about the same, much lower, or much higher as in situation 1? Why?

	much lower	about the same	much higher
<b>Student 1</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Why? _____		
<b>Student 2</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Why? _____		
<b>Student 3</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Why? _____		
<b>Student 4</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Why? _____		



**To do**

- Place your hands between the two detectors as shown in situation 2 and start a measurement. Keep your hand between the detectors during the entire measurement.
- Stop the measurement after one minute.



**Observation**

Note the trigger rate.



**Additional questions**

What did you observe?

The trigger rate in situation 2 compared with the trigger rate in situation 1 was...

	much lower	about the same	much higher
<b>together</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How would you explain the observation?

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Approximately how many muons pass through the palm of your hand every minute?

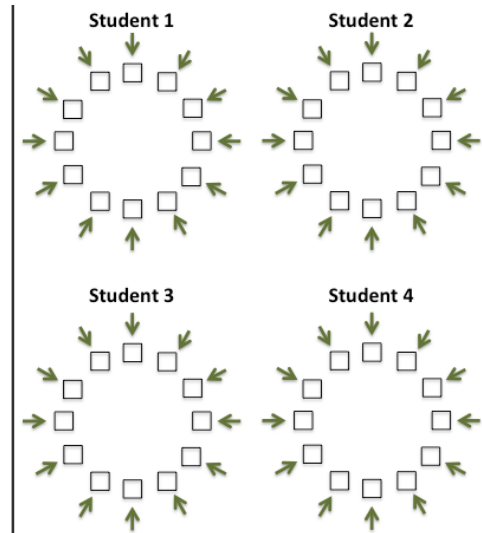
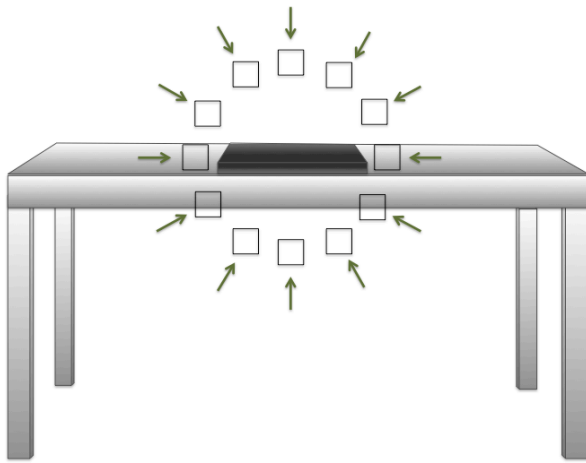


### Experiment 3: Determining the orientation of muons’ paths



#### Prediction

Where do you think muons come from? In the image below, tick the box(es) corresponding to your opinion.



#### To do

How can you check your prediction? Plan an experiment and perform several (>3) measurements for 1 minute each.



#### Observation

Describe the conditions for each measurement in your experiment and note the corresponding trigger rates.

description				
rate				



#### Additional questions

How would you interpret your observation? Compare your results with your predictions about the orientation of the muons’ paths.

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**? Any Questions**

Do you have any questions? Is there anything extra you want to know about muons or other particles?

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**i Summary – What you should have learned with CosMO**

- ✓ At what rate do muons arrive at Earth’s surface?
- ✓ Do muons pass through human hands?
- ✓ What are the orientations of muons’ paths?

**i Summary – What you should have learned in general**

- ✓ What are cosmic particles?
- ✓ What properties do cosmic particle have?
- ✓ Why are cosmic particle interesting (for you, for CERN)?