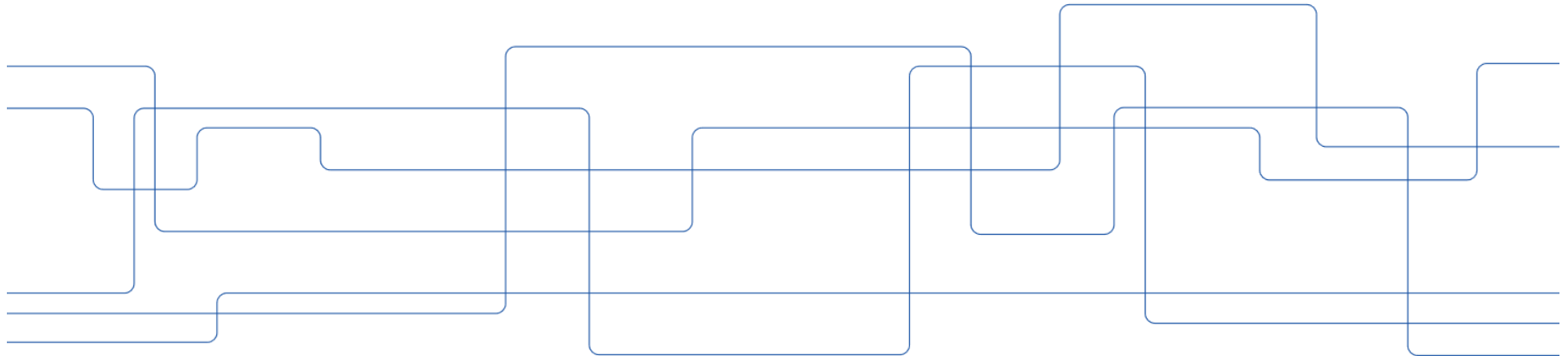


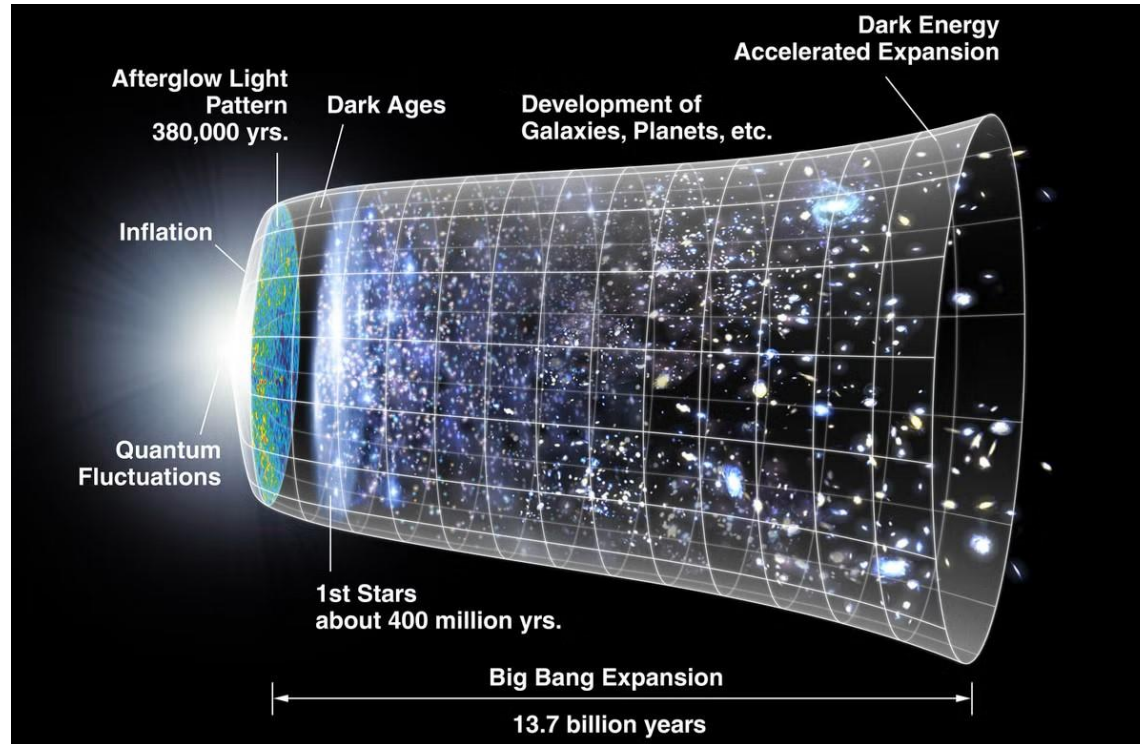


Dr. Sampsa Vihonen
Researcher, Kungliga Tekniska Högskolan

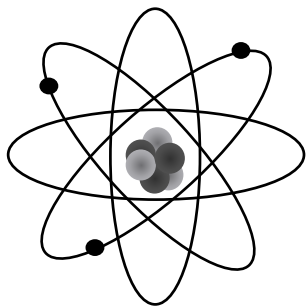
Neutrinos from the ESS: Why is there only matter and no antimatter after the Big Bang, and how can neutrinos help find the answer?



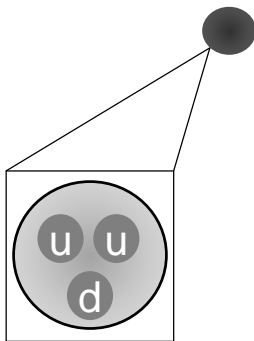
Short introduction to particle physics



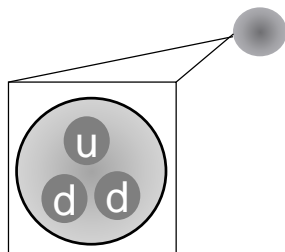
What are all beings made of?



atoms



quarks



neutrons

protons

electrons





Short introduction to particle physics

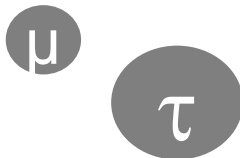
Also γ , W^\pm , Z^0 , g , H^0

Is that it?

More quarks...



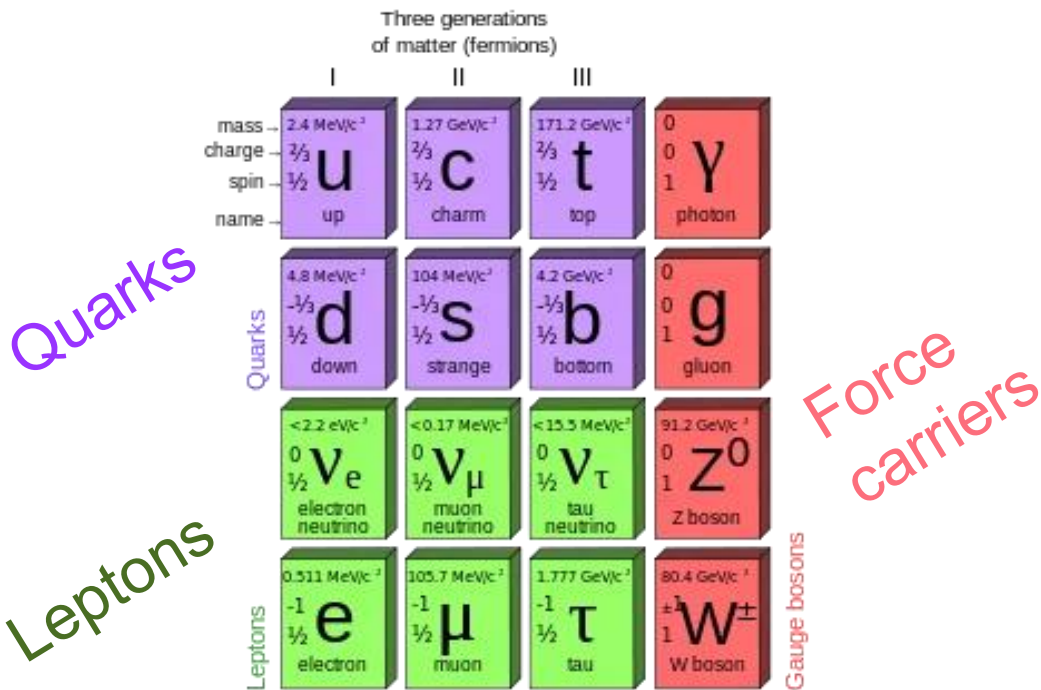
...leptons...



...and neutrinos



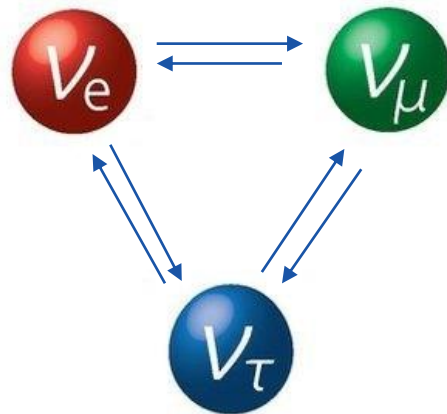
Standard Model of particle physics



The wonderful world of neutrinos

What are neutrinos?

There are three types...



...and they **oscillate!**

$$\nu_{\mu} \longrightarrow \nu_e$$

The wonderful world of neutrinos

Why do neutrinos oscillate?

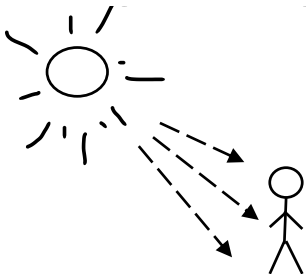
- Neutrino mass is not so easily measured
- Each type is a unique mix of different mass states



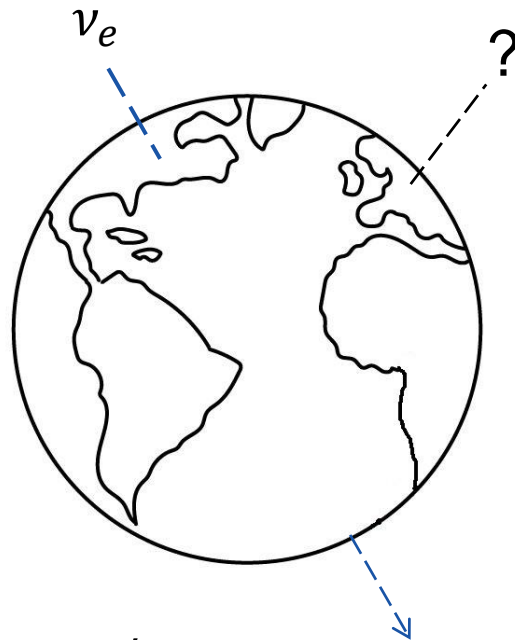
The wonderful world of neutrinos

Where are the neutrinos?

- Nuclear reactors, colliders...
- Stars, supernovae, the Sun...



The Sun:
> 60 billion / cm² / s

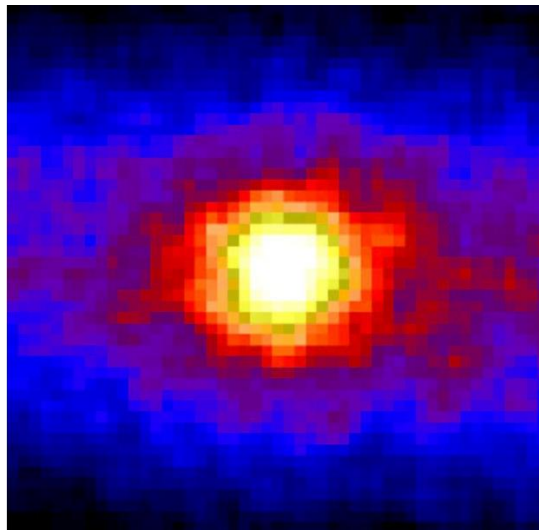


The wonderful world of neutrinos

The neutrino Sun shines around the clock!



Day



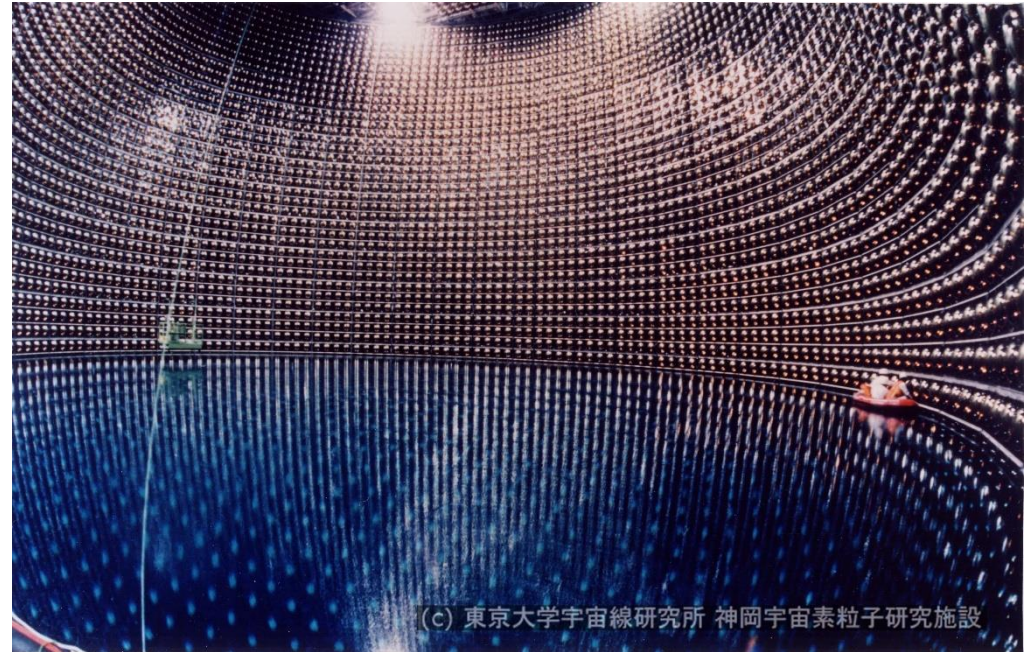
Night

The wonderful world of neutrinos

How do we see neutrinos?

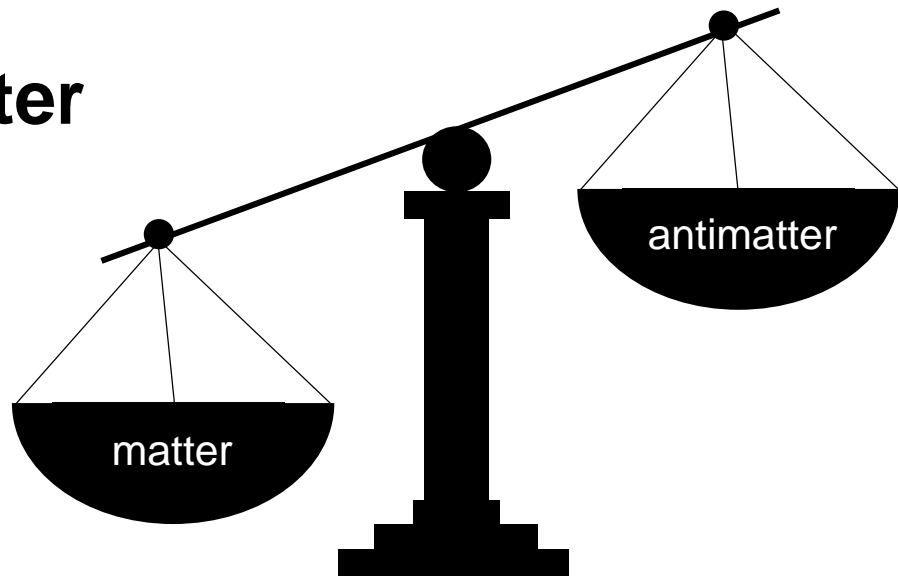
Answer: Build a giant detector...

...and place it underground.



Matter-antimatter asymmetry

Where is all the antimatter from the Big Bang?



Matter-antimatter asymmetry

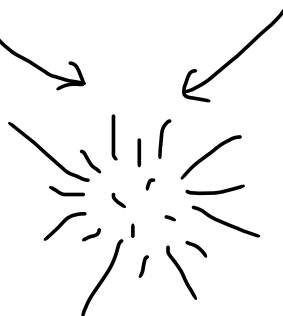
What is antimatter?

Particle

e^-

e^+

Antiparticle



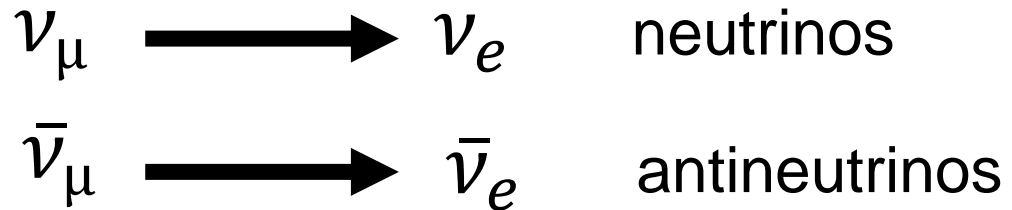
But the space is
not empty...?

Annihilation

Matter-antimatter asymmetry

How can neutrinos help us solve the problem?

By comparing oscillations:

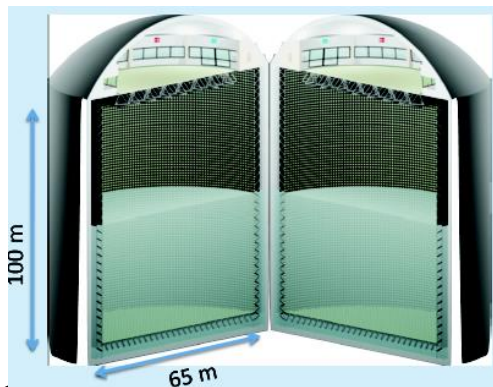


The ESSnuSB+ project

Distance
~ 360 km

Zinkgruvan

ESS Lund



Neutrino detector

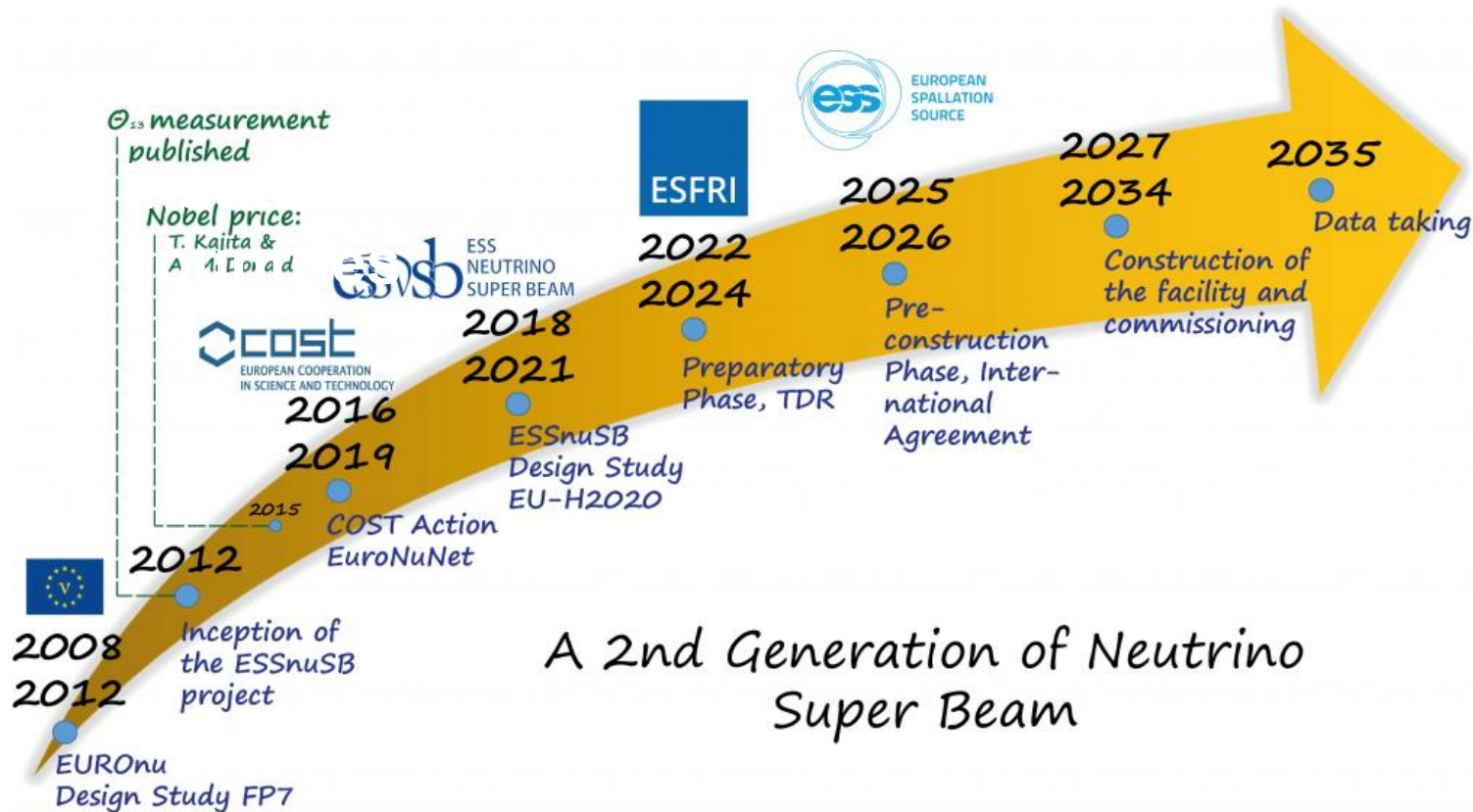
560 000 tonnes of purified water



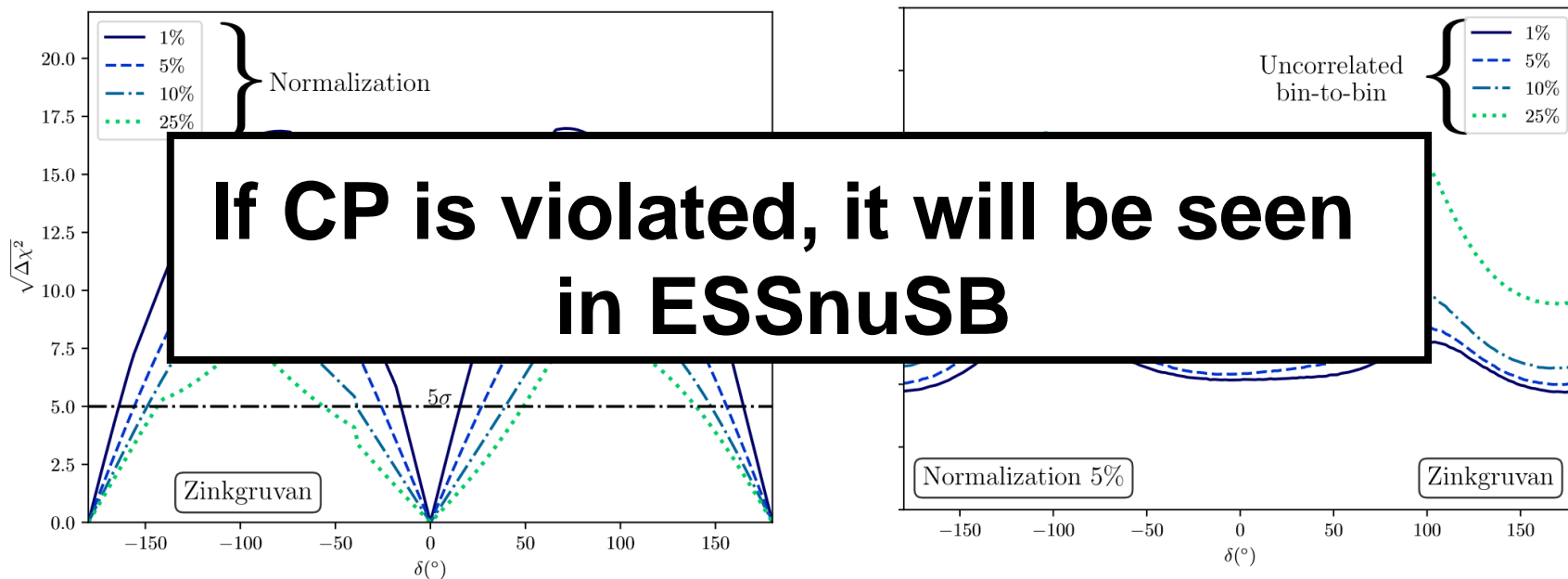
Neutrino beam

Europe's brightest neutron source

The ESSnuSB+ project in Sweden



The ESSnuSB+ project





The ESSnuSB+ project

**Thank you for
watching!**