Detecting the Cosmic Neutrino Background

Jack Shergold

& Martin Bauer; 2207.12413

IP3

Durham University

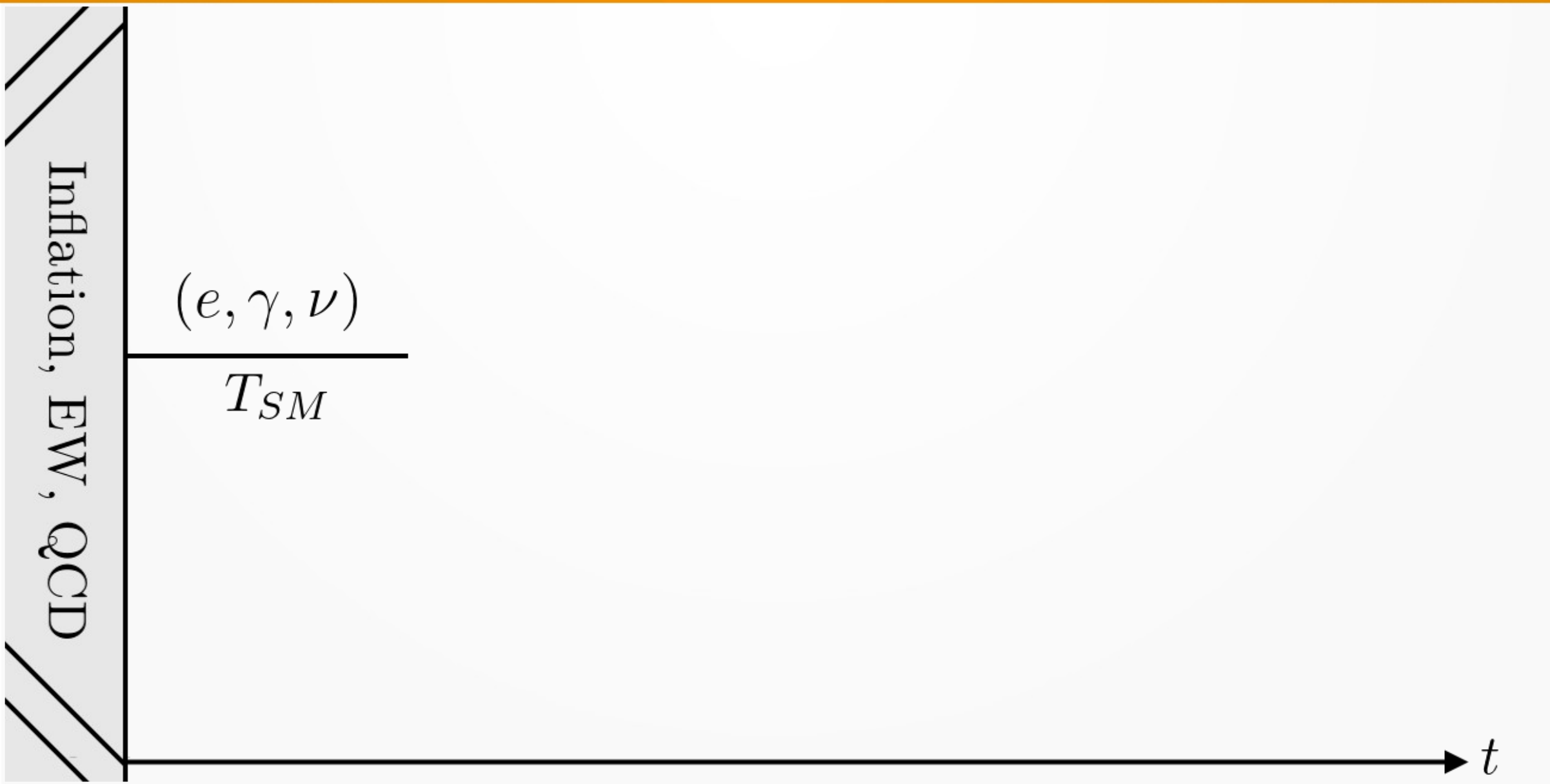
Contents

- What is the CνB?
- How might we go about detecting it?

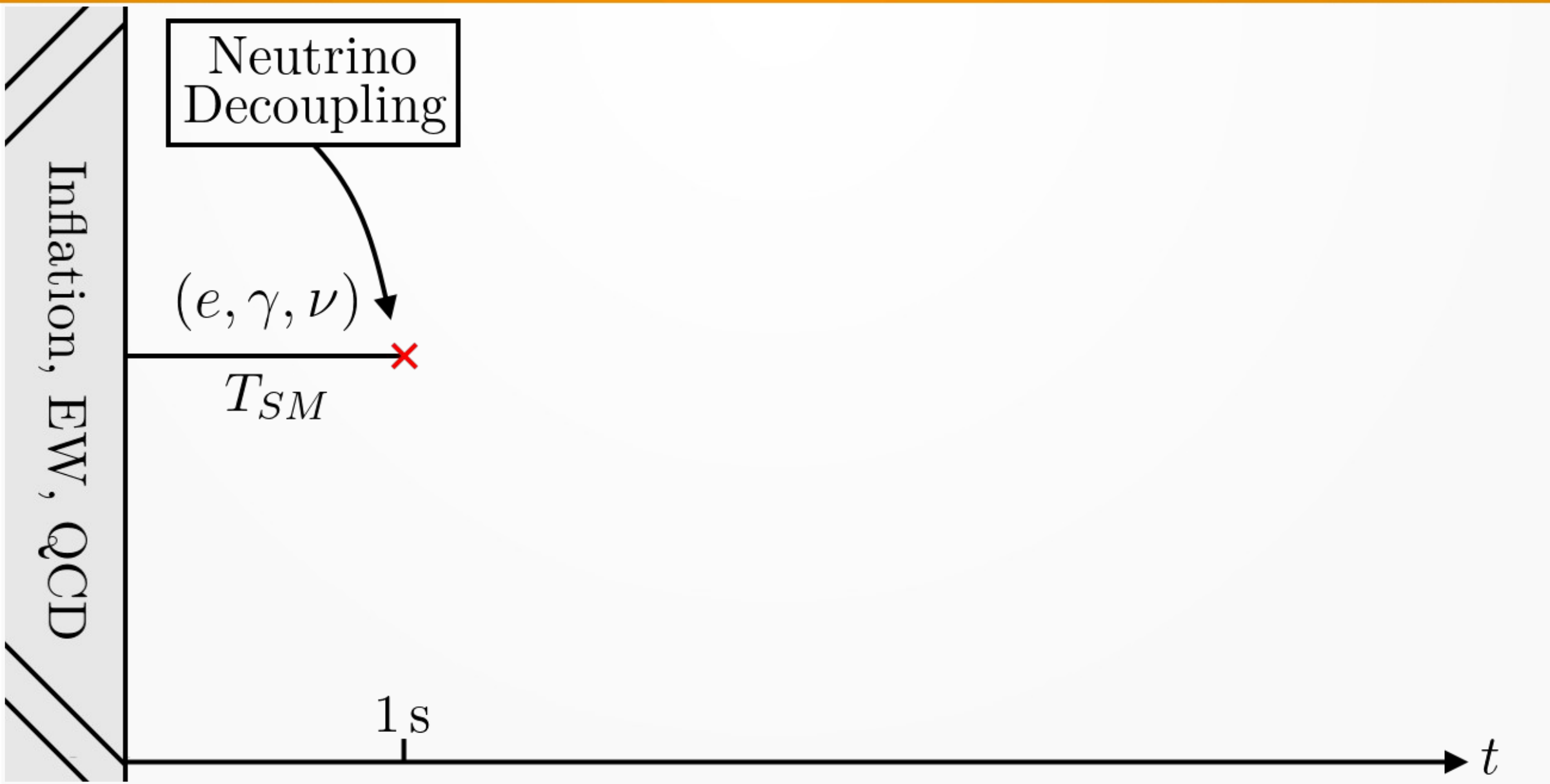
Contents

- What is the CνB? ⇦
- How might we go about detecting it?

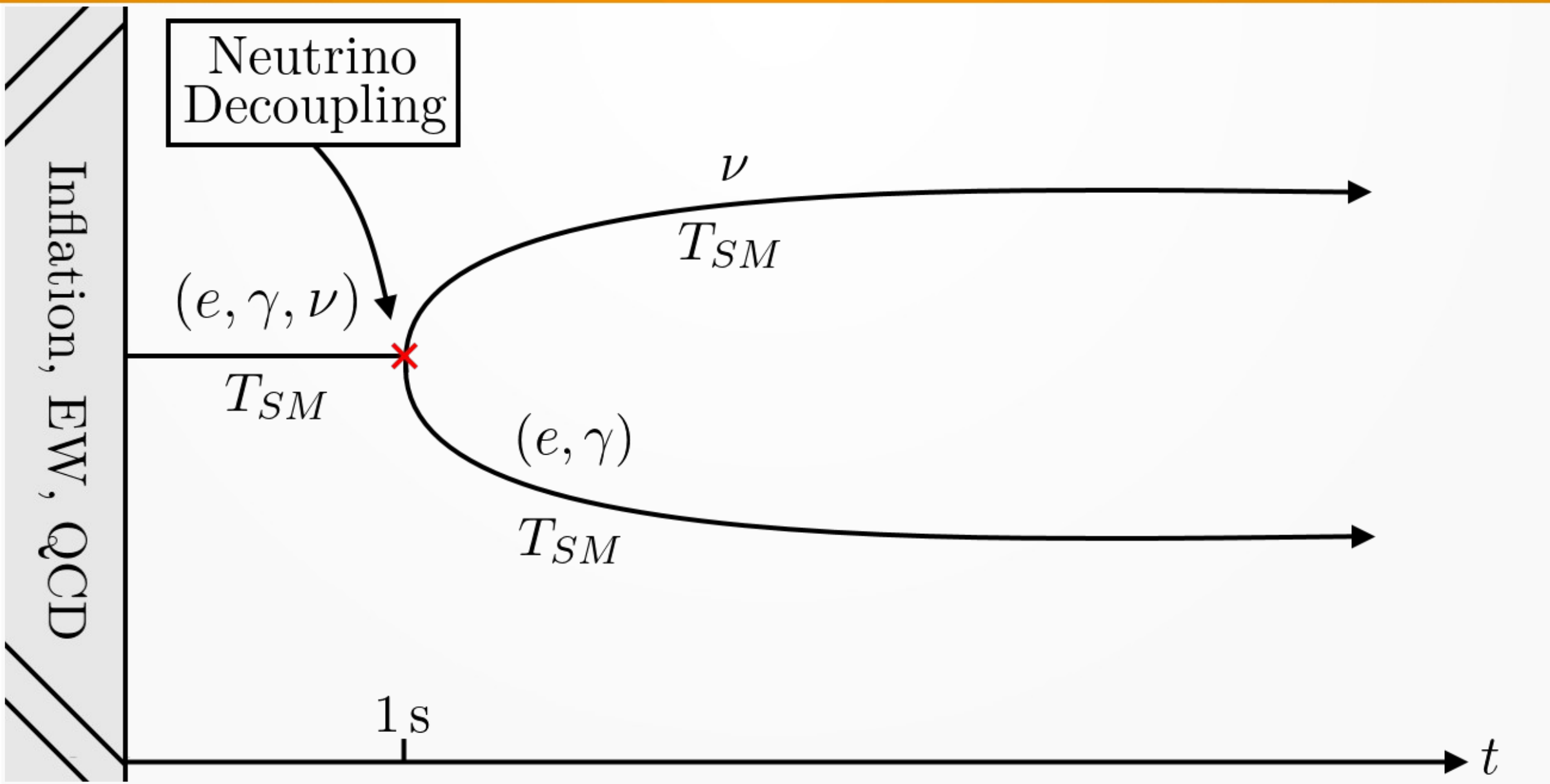
What is the CνB?



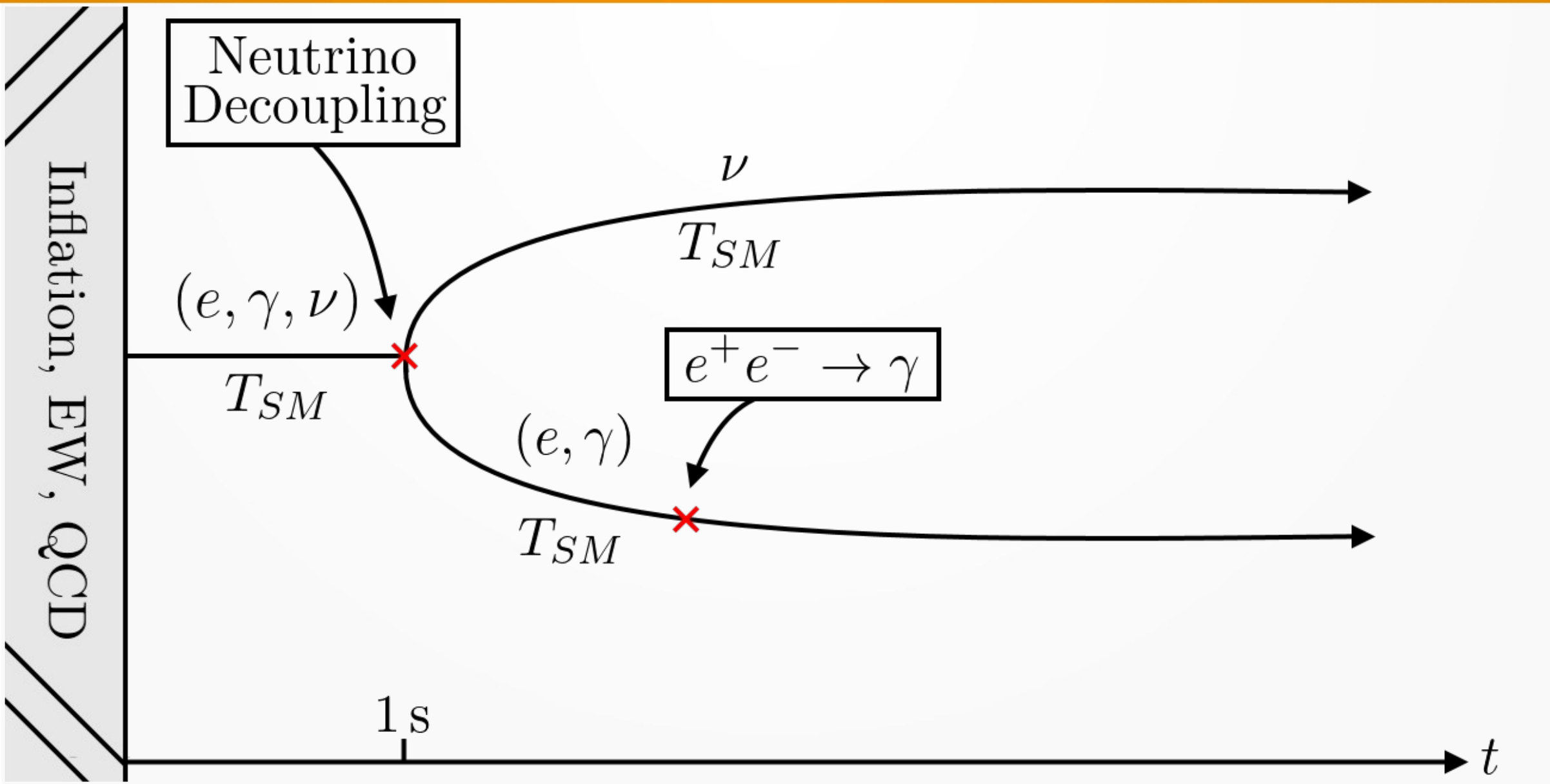
What is the CνB?



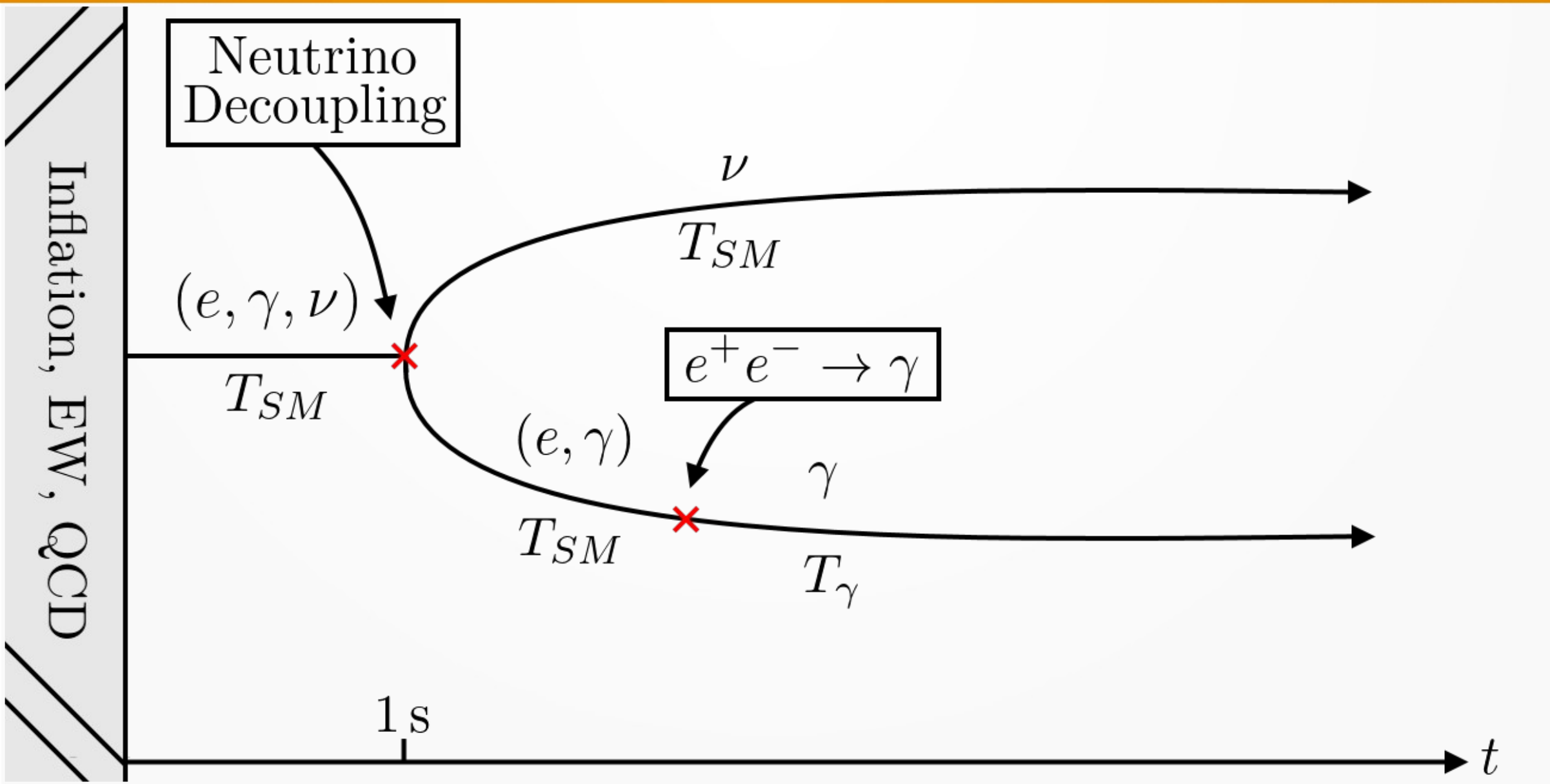
What is the CνB?



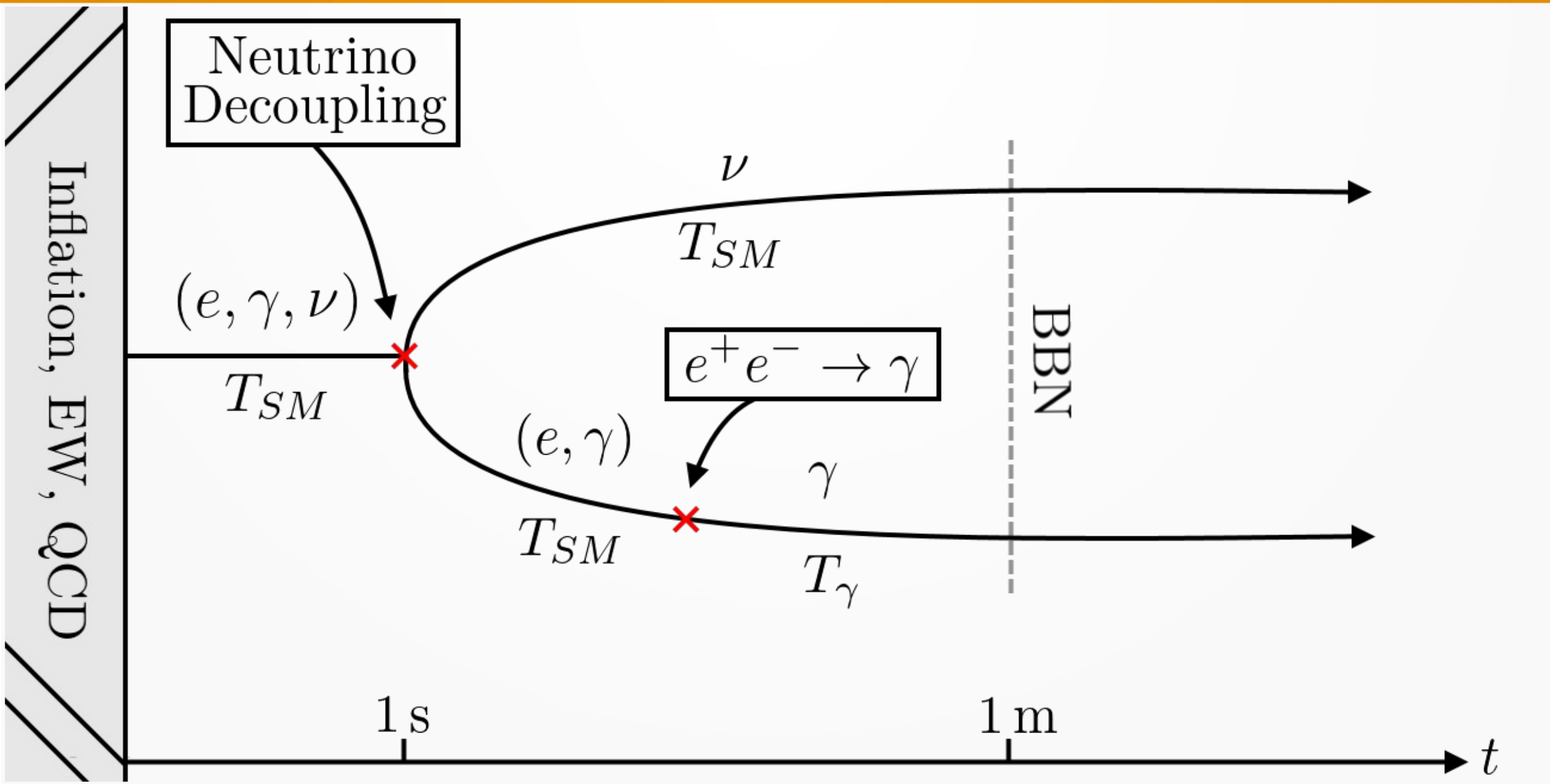
What is the CνB?



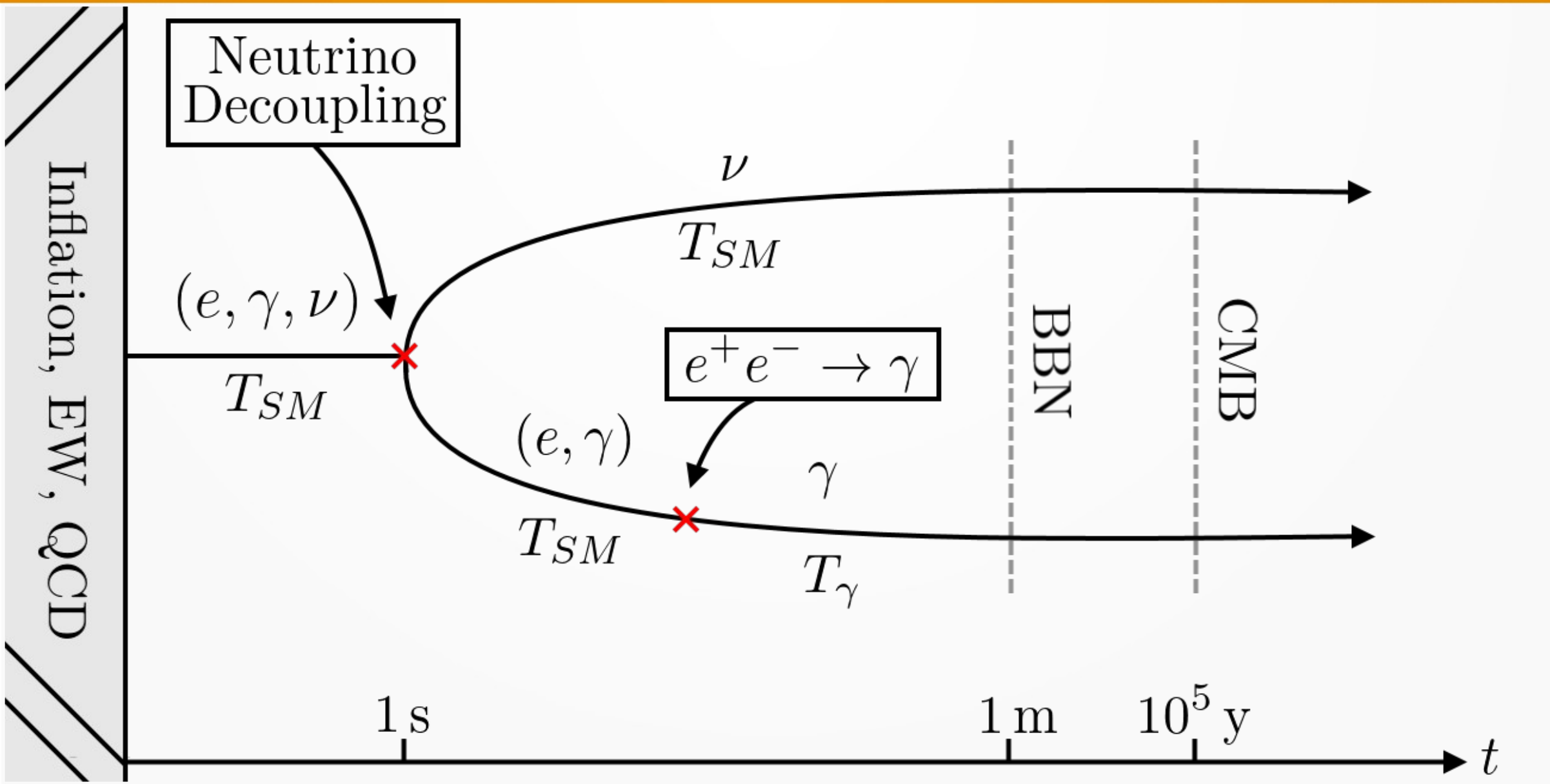
What is the CνB?



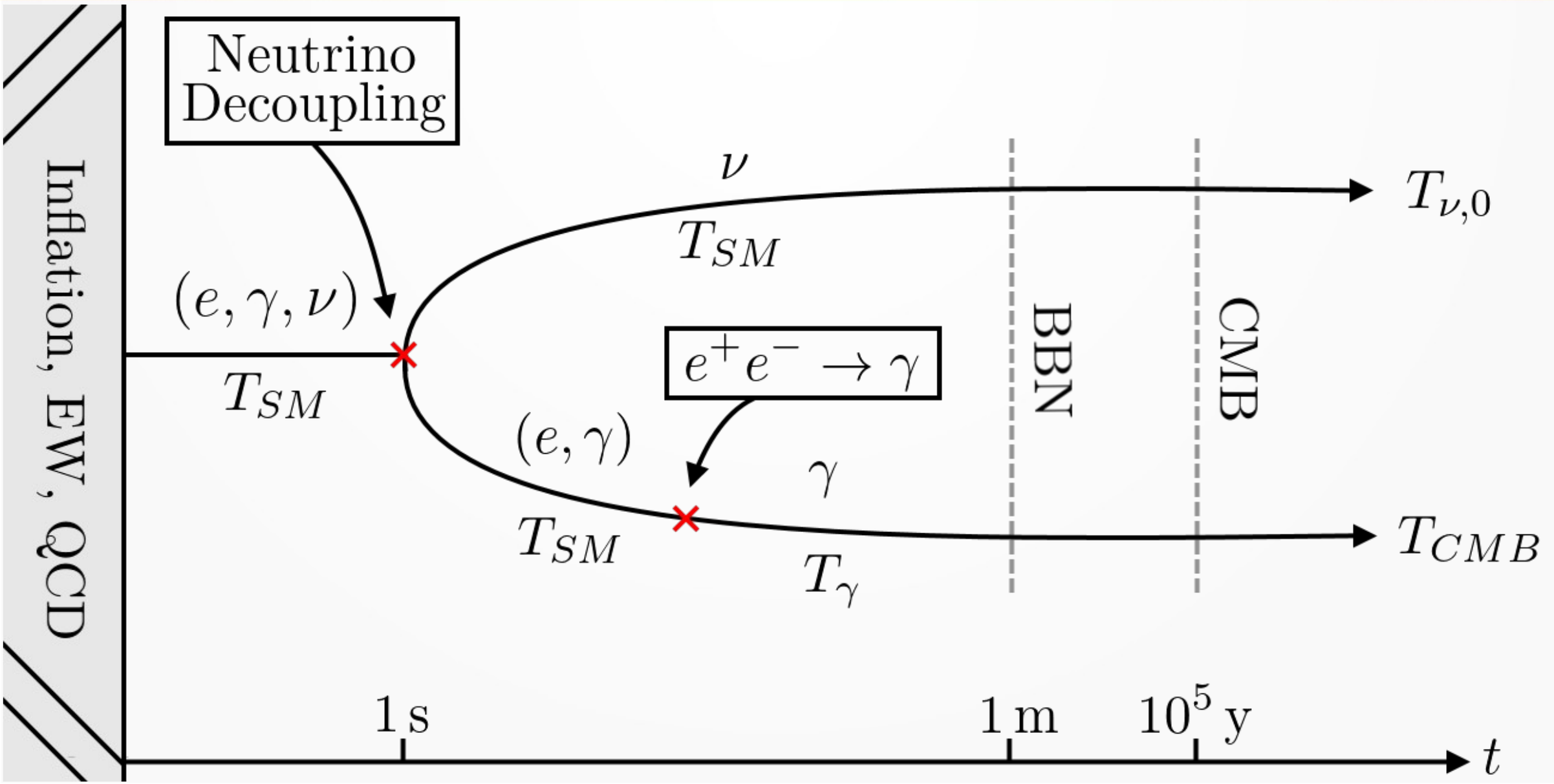
What is the CνB?



What is the CνB?



What is the CνB?



The CνB today

- Redshifted to temperature:

$$T_{\nu,0} = \left(\frac{4}{11}\right)^{\frac{1}{3}} T_{CMB}$$

The CνB today

- Redshifted to temperature:

$$T_{\nu,0} = 0.168\,\mathrm{meV}$$

The CνB today

- Redshifted to temperature:

$$T_{\nu,0} = 0.168\,\mathrm{meV}$$

- Expect these to follow a Fermi-Dirac distribution with:

The CνB today

- Redshifted to temperature:

$$T_{\nu,0} = 0.168\,\mathrm{meV}$$

- Expect these to follow a Fermi-Dirac distribution with:

$$n_\nu = 56\,\mathrm{cm}^{-3}$$

The CνB today

- Redshifted to temperature:

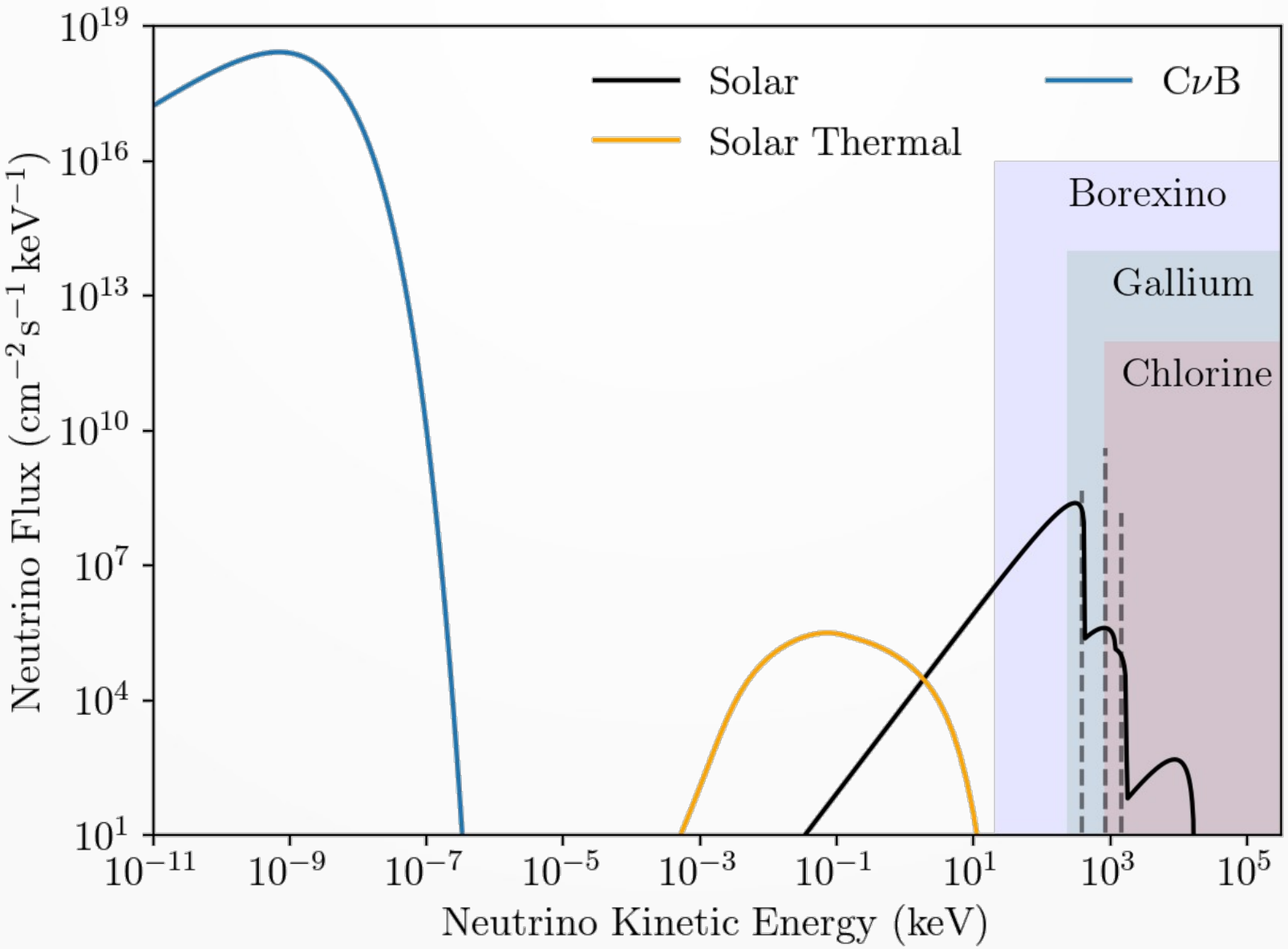
$$T_{\nu,0} = 0.168\,\mathrm{meV}$$

- Expect these to follow a Fermi-Dirac distribution with:

$$n_\nu = 56\,\mathrm{cm}^{-3}$$

- May be overdense, *e.g.* clustering, decays to neutrinos

The CνB today



Contents

- What is the CνB?
- How might we go about detecting it? ⇦

How might we detect the CνB?

- Threshold:
  - Look for thresholdless process
  - Find some way to bridge it

How might we detect the CνB?

- Threshold:
  - Look for thresholdless process
  - Find some way to bridge it

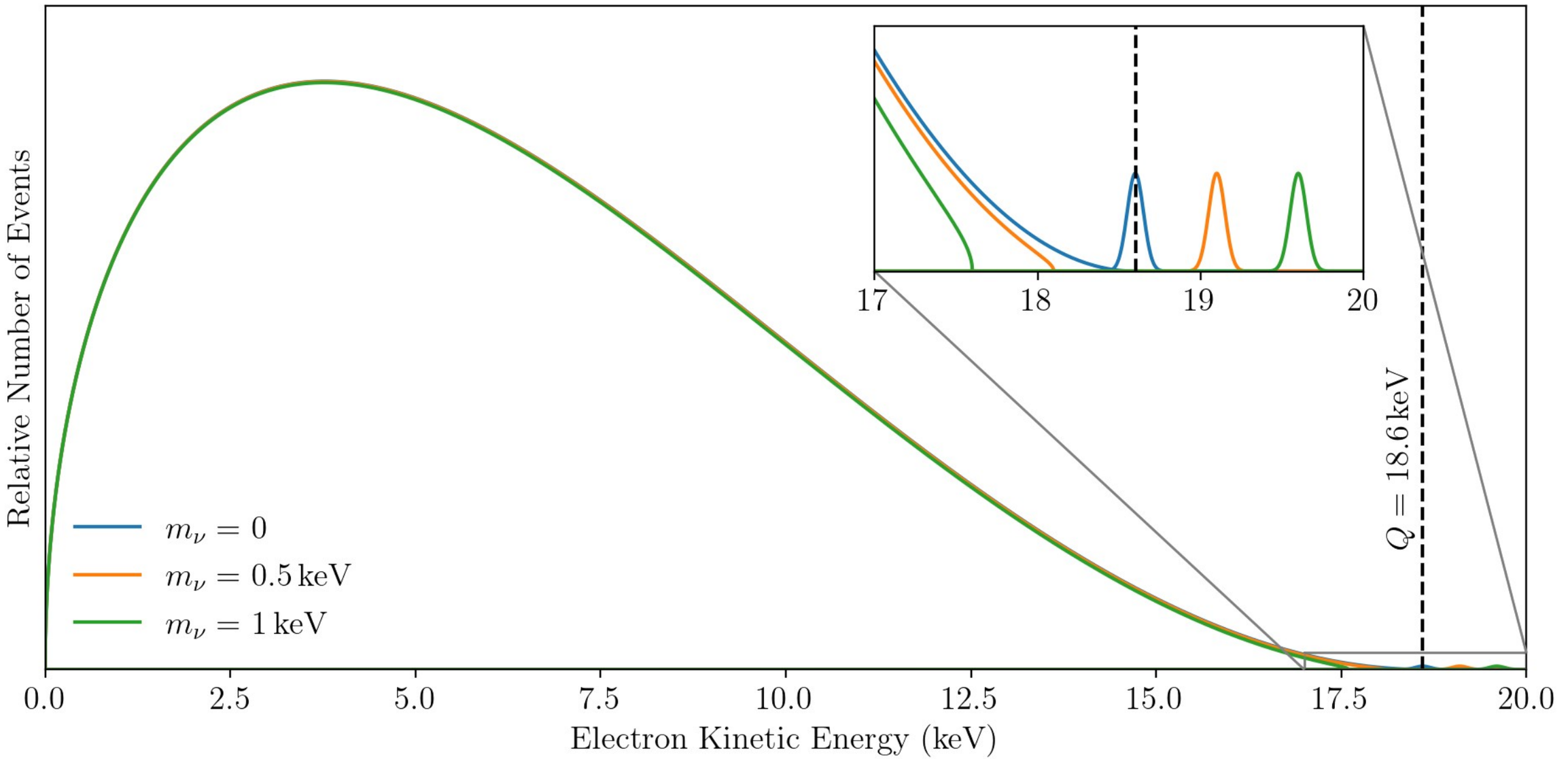
- Event rate:
  - Use a huge number of targets
  - Increase the cross section

PTOLEMY

- PTOLEMY experiment (Weinberg '62):

$$\nu_e + {}^3\mathrm{H} \rightarrow e^- + {}^3\mathrm{He}^+$$

PTOLEMY


Relative Number of Events
$m_\nu = 0$
$m_\nu = 0.5\,\mathrm{keV}$
$m_\nu = 1\,\mathrm{keV}$
$Q = 18.6\,\mathrm{keV}$
17
18
19
20
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Electron Kinetic Energy (keV)

Coherent scattering

- Coherent scattering (Opher '74, ... , JS '21):

$$\nu + X \to \nu + X$$

Coherent scattering

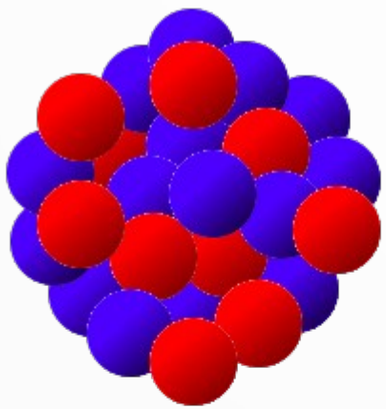
- Coherent scattering (Opher '74, ... , JS '21):

$$\nu + X \to \nu + X$$

- Significantly enhanced event rates:

$$\Gamma \sim N_T \longrightarrow \Gamma_{\rm coh} \sim N_T^2$$

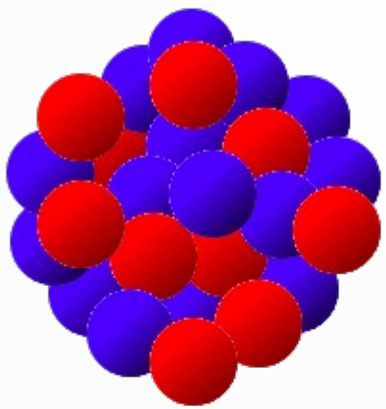
Coherent scattering



$$\lambda \sim \mathrm{fm}$$

$$\Gamma \sim (A - Z)^2$$

Coherent scattering



$\lambda \sim \mathrm{fm}$

$\lambda \sim \mathrm{mm}$

$\Gamma \sim (A - Z)^2$

$\Gamma \sim N_A^2$

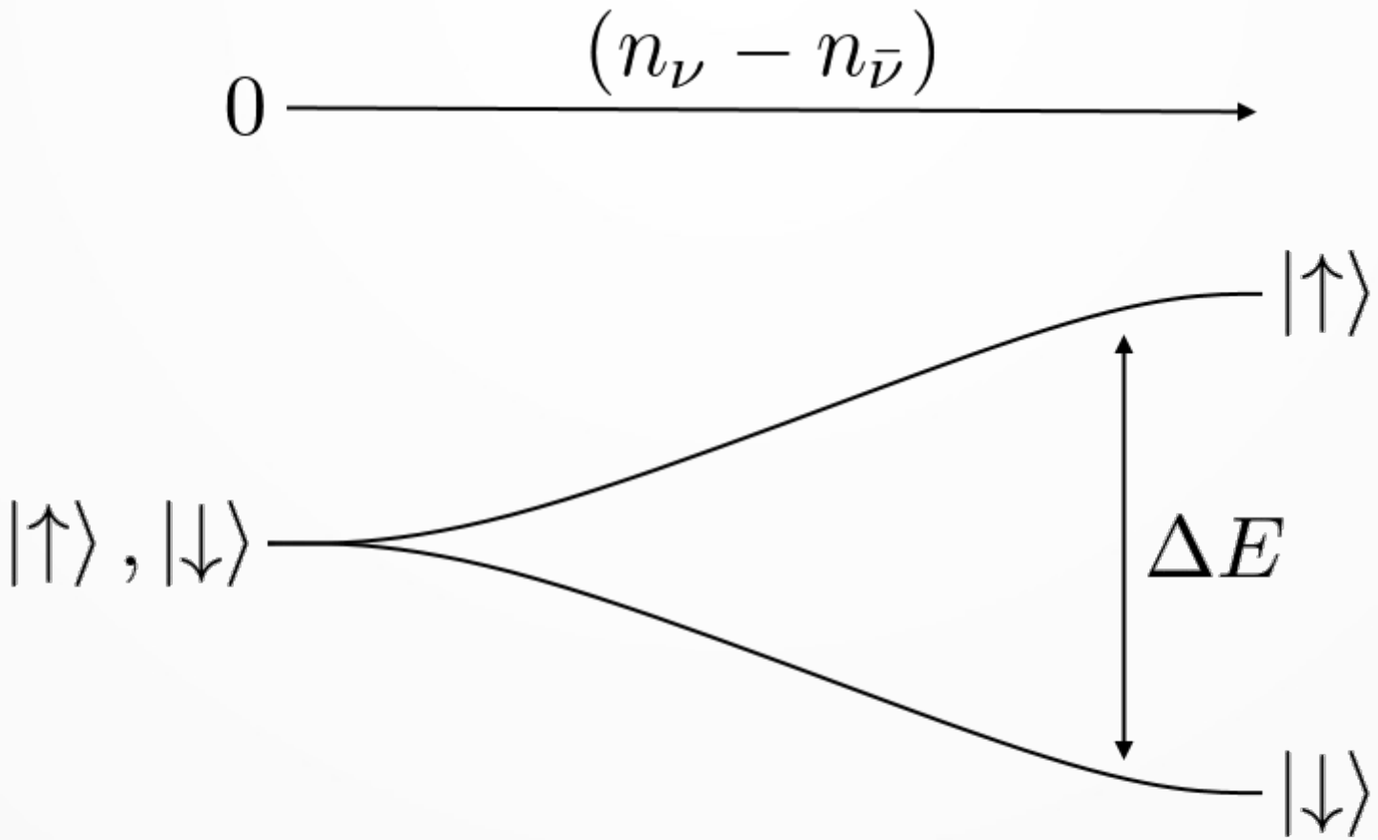
Stodolsky effect

- Stodolsky effect (Stodolsky ‘75, Duda ‘01)

Stodolsky effect

- Stodolsky effect (Stodolsky '75, Duda '01)
- Only effect linear in G_F (Cabibbo '82, Langacker '83)

Stodolsky effect



$$\Delta E \sim G_F(n_\nu - n_{\bar{\nu}})$$

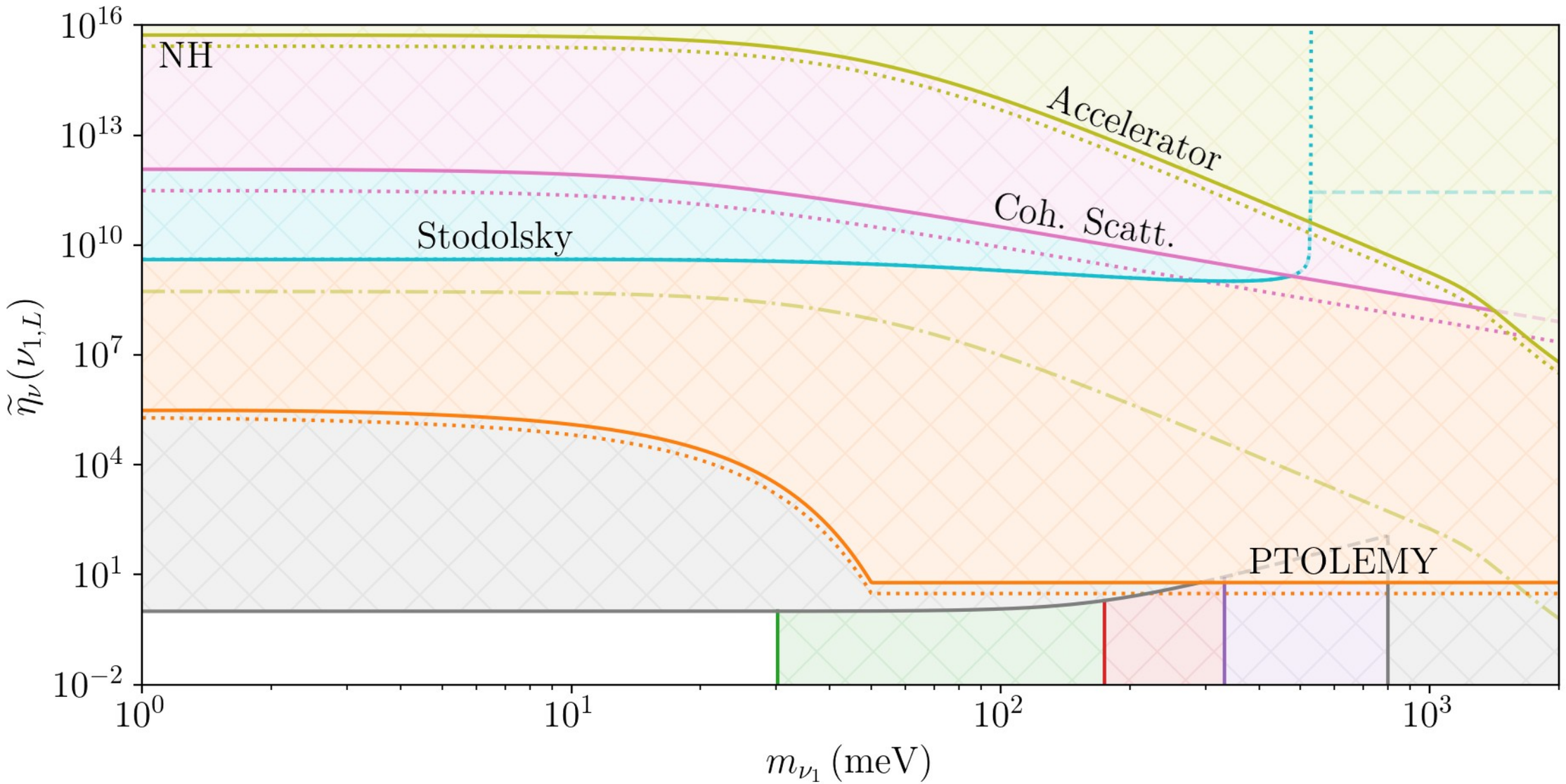
Accelerator

- Accelerator experiment (JS '21):

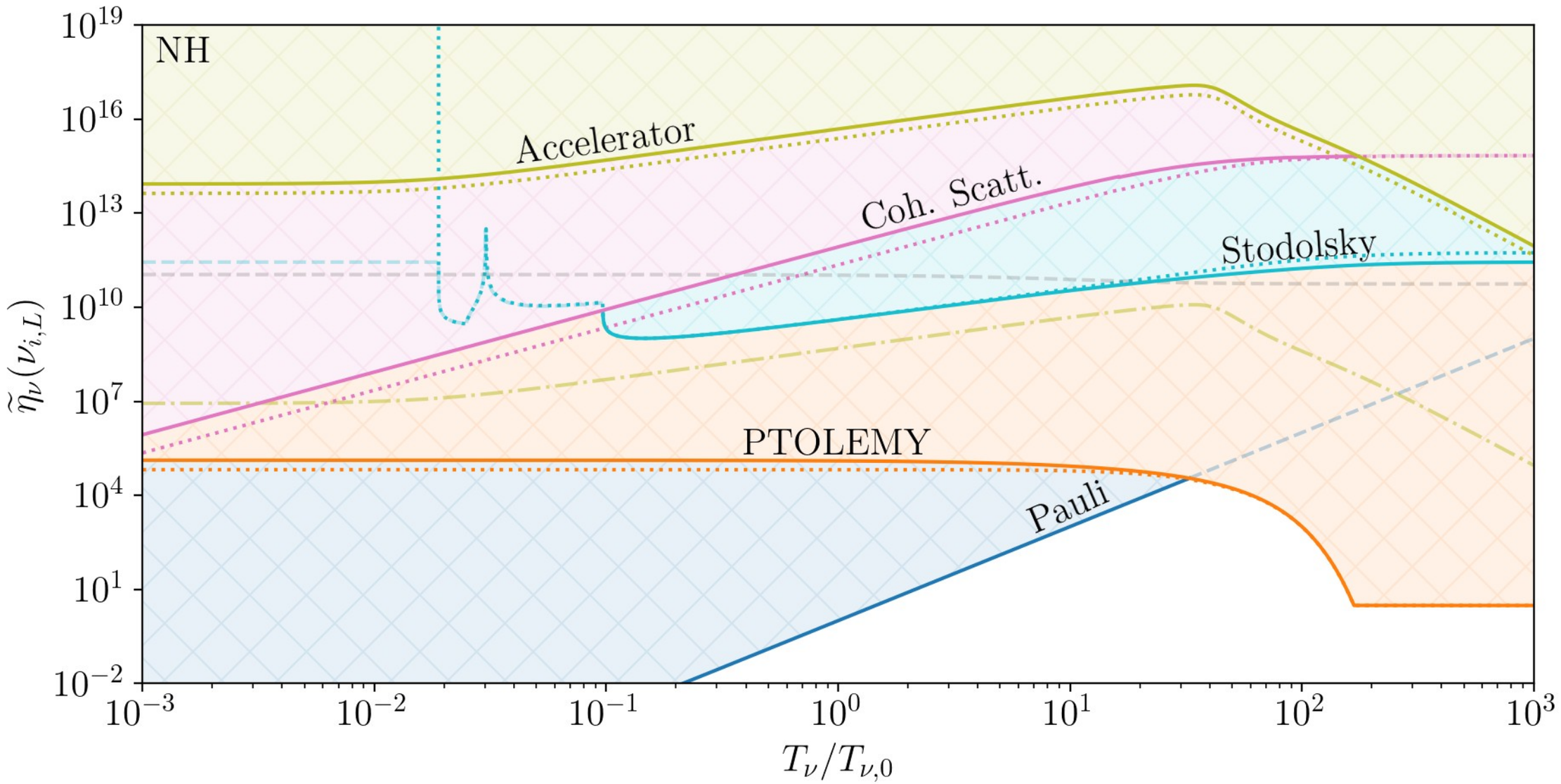
$$ {}^{A}_{Z}P + e^{-}(\text{bound}) + \bar{\nu}_e \rightarrow {}^{A}_{Z-1}D $$

$$ {}^{A}_{Z}P + \nu_e \rightarrow {}^{A}_{Z+1}D + e^{-}(\text{bound}) $$

Sensitivity



Sensitivity



Summary

- The CMB is currently the furthest we can look back through time

Summary

- The CMB is currently the furthest we can look back through time
- Detecting the CνB could reveal a wealth of new physics

Summary

- The CMB is currently the furthest we can look back through time
- Detecting the CνB could reveal a wealth of new physics
- Detection made difficult by neutrino properties

Summary

- The CMB is currently the furthest we can look back through time
- Detecting the CνB could reveal a wealth of new physics
- Detection made difficult by neutrino properties
- Many exciting proposals to detect the CνB!

Thank you!
Questions?