Project Review Talk:
Neutrino Physics Leaving the Standard Path

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Based on:

some “highlights“ & work in progress

Project Review, 15-12-2014

1. Astroparticle Physics Group

- **Dr. habil. Georg Raffelt** *(group leader)*
- **Dr. Frank Daniel Steffen** *(permanent scientist)*
- **Dr. Sovan Chakraborty** *(postdoc)*
- **Dr. Alexander Kartavtsev** *(postdoc)*
- **Dr. Alexander Merle** *(postdoc)*
- **Dr. Antonio Palazzo** *(postdoc)*
- **Alexandra Dobrynina** *(Ph.D. student)*
- **Ignacio Izaguirre** *(Ph.D. student)*
- **Maximilian Totzauer** *(Ph.D. student)*
- **Hendrik Vogel** *(Ph.D. student)*
- **Jost Migenda** *(Master student)*
- **Moritz Platscher** *(Master student)*
- **Julia Stadler** *(Master student)*

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In case you did not pay attention before:

This is the weird guy talking to you right now.

1. Astroparticle Physics Group

RESEARCH DONE IN THE ASTROPARTICLE GROUP:

- **supernova neutrinos**
- **(non-standard) Dark Matter candidates: (s)axions, gravitinos, sterile neutrinos,...**
- **leptogenesis**
- **non-equilibrium QFT**
- **low energy neutrino phenomenology**
- **neutrino mass and flavour model building**
- **...**

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I will concentrate on those two subjects.

At MPP, I work with 2 very talented students:

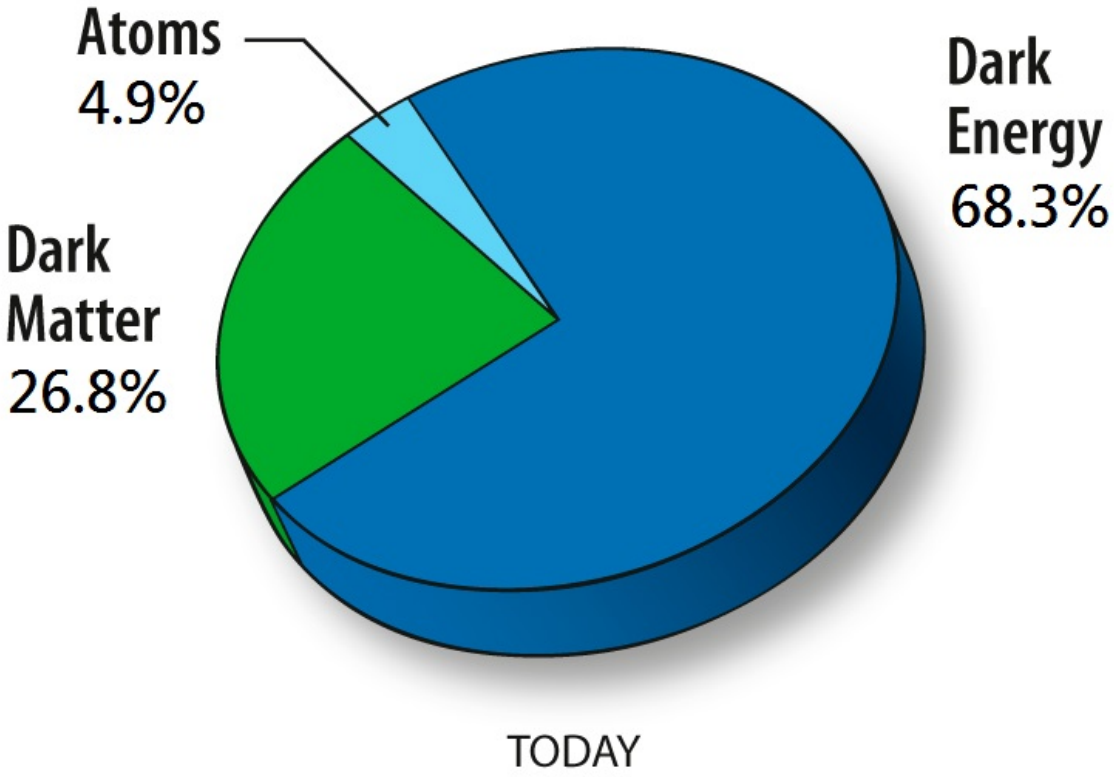
2. Sterile neutrino Dark Matter

(work done in collaboration with Max Totzauer)

We know from various observations:

There is about 5 times more "Dark Matter" in the Universe than ordinary matter (the stuff we consist of).

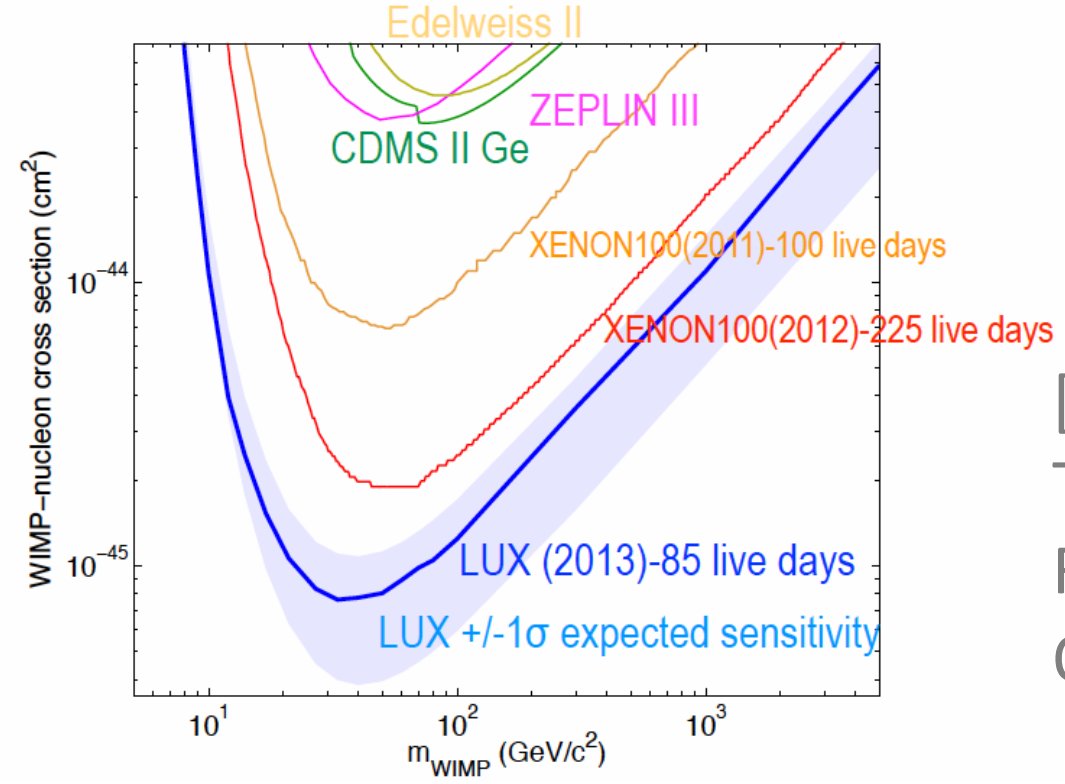
BUT:
We don't know what it is...



2. Sterile neutrino Dark Matter

(work done in collaboration with Max Totzauer)

We had a very good guess for which particles could be behind the Dark Matter…



[McKinsey & Gaitskell: Talk at Sanford Research Facility, 30 October 2013]

BUT: They seem to WIMP out!!!

2. Sterile neutrino Dark Matter

(work done in collaboration with Max Totzauer)

A possible way out: ***THINK OF ALTERNATIVES*****!**

- ***axion, gravitino,...***
- ***sterile neutrino with a mass of...***
  - ➔ ***read here if you are an experimentalist: a few keV/c^2***
  - ➔ ***read here if you are a theorist: a few keV***
  - ➔ ***read here if you are a string theorist: nearly zero***

in practice:

Like ordinary neutrino just a larger mass and suppressed interactions

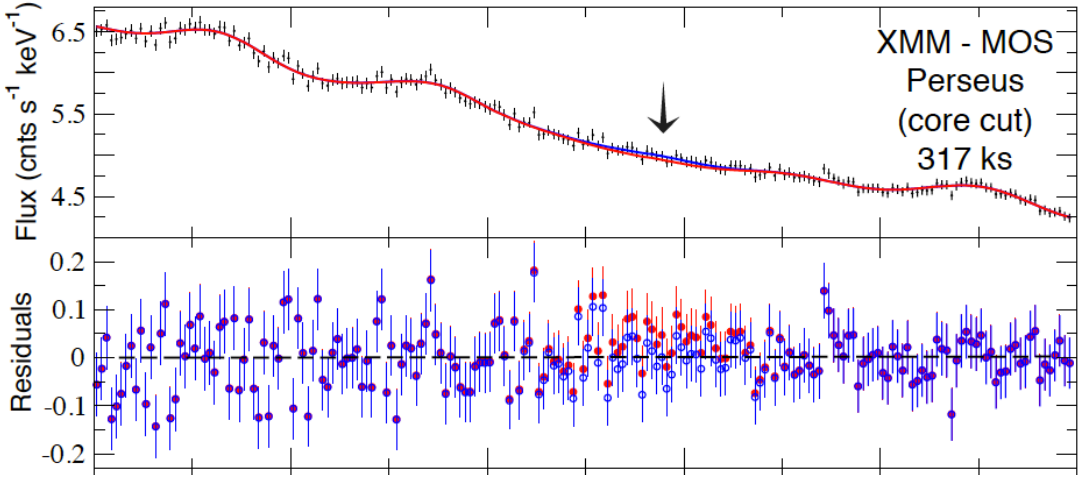
2. Sterile neutrino Dark Matter

(work done in collaboration with Max Totzauer)

Such a sterile neutrino could be the Dark Matter if:

- *it has the right mass and coupling*
- *we find a way to produce it in the early Universe*

This is a hot topic due to a (tentative, controversial, extensively discussed) signal seen earlier this year:



mass=7.1 keV?!?

(7.1 keV/c^2?!?)

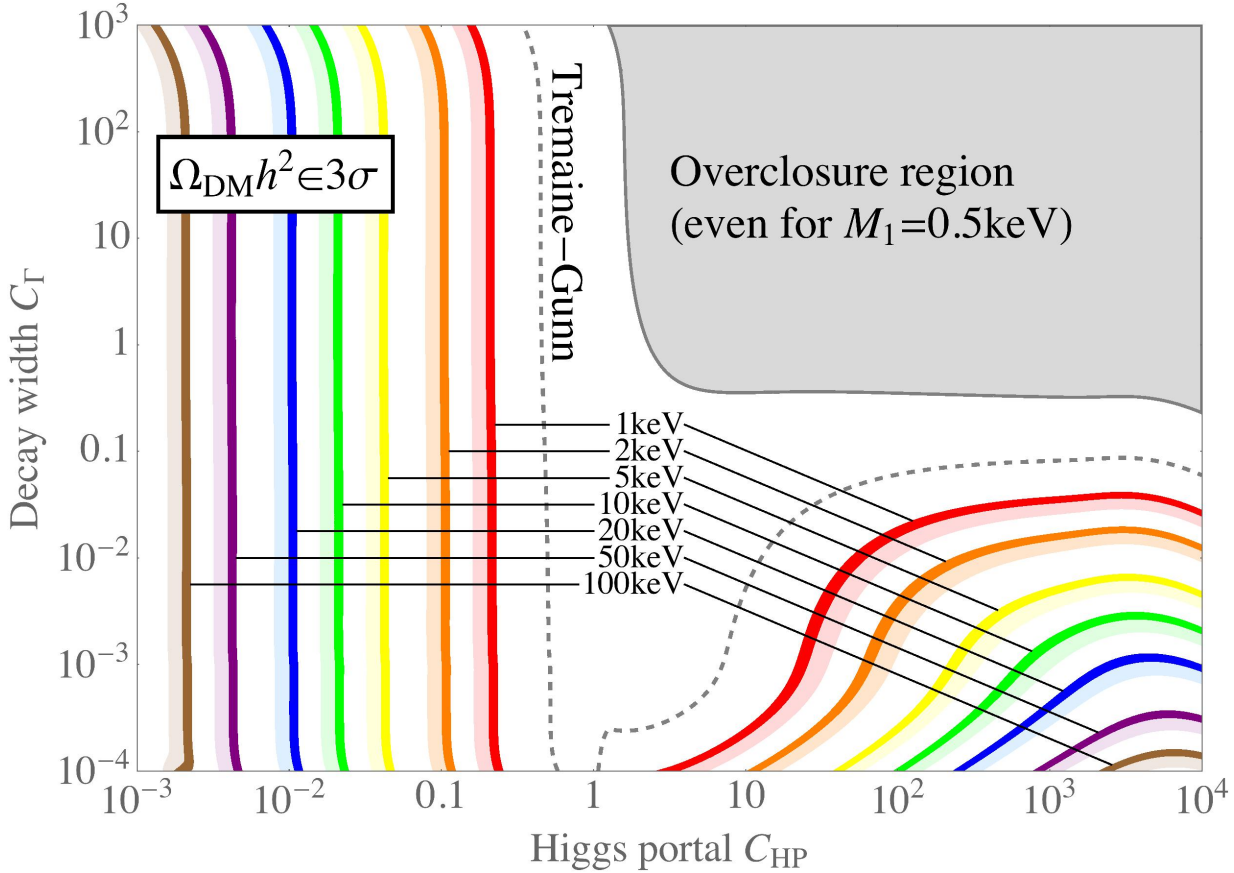
(nearly zero?!?)

Stay tuned...

2. Sterile neutrino Dark Matter

(work done in collaboration with Max Totzauer)

My work with Max: *(non-thermal) production of keV sterile neutrinos by decays of e.g. scalars*



We're not afraid to look into the details!

3. Radiative Neutrino Masses

(work done in collaboration with Moritz Platscher)

We know that neutrinos have a tiny mass (<1 eV):

$|m_{ee}| < 0.3\text{-}0.6$ eV [KamLAN-Zen: Phys. Rev. **C85** (2012) 045504]
$|m_{ee}| < 0.\ 140\text{-}0.\ 380$ eV [EXO-200: Phys. Rev. Lett. **109** (2012) 032505]
$|m_{ee}| < 0.300\text{-}0.710$ eV [CUORECINO: Astropart. Phys. **34** (2011) 822-831]
$m_\beta < 2.3$ eV [MAINZ, Eur. Phys. J. **C40** (2005) 447-468]
$\Sigma < 0.23$ eV [Planck+WP+highL+BAO, Astron. Astrophys. **571** (2014) A16]

BUT WHY IS IT SO SMALL?!?

(http://imprinttrainingcenter.blogspot.co.uk/2010/12/understanding-and-controlling-anger.html)

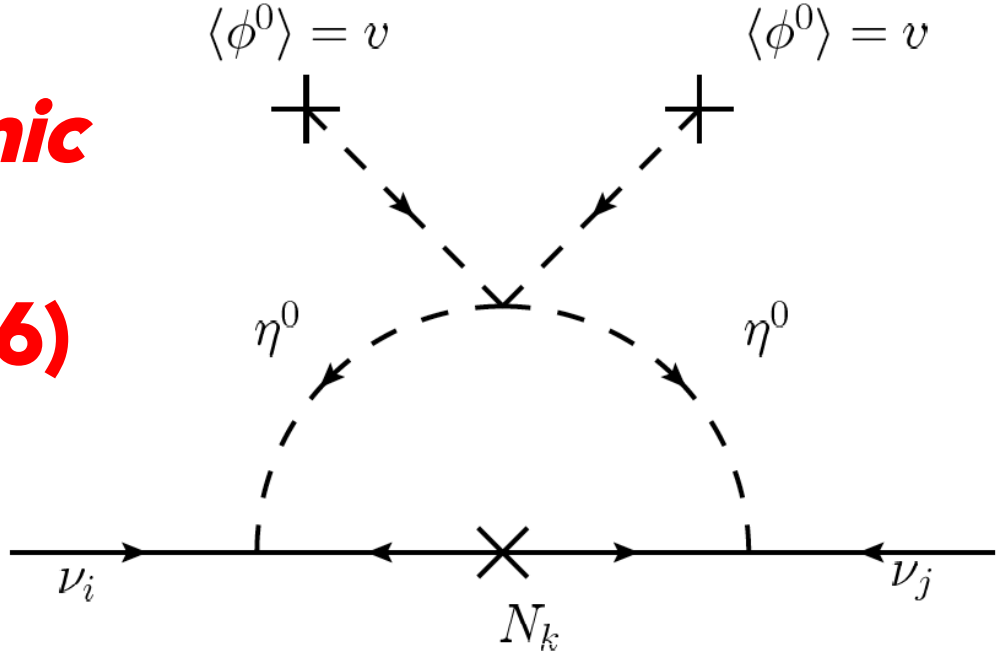
3. Radiative Neutrino Masses

(work done in collaboration with Moritz Platscher)

A natural explanation:

Neutrinos have a **NATURAL MASS OF ZERO** but only **OBTAIN A NON-ZERO MASS** by a (small) **QUANTUM LOOP CORRECTION** induced by **NEW PHYSICS**

Scotogenic model (Ma, 2006)



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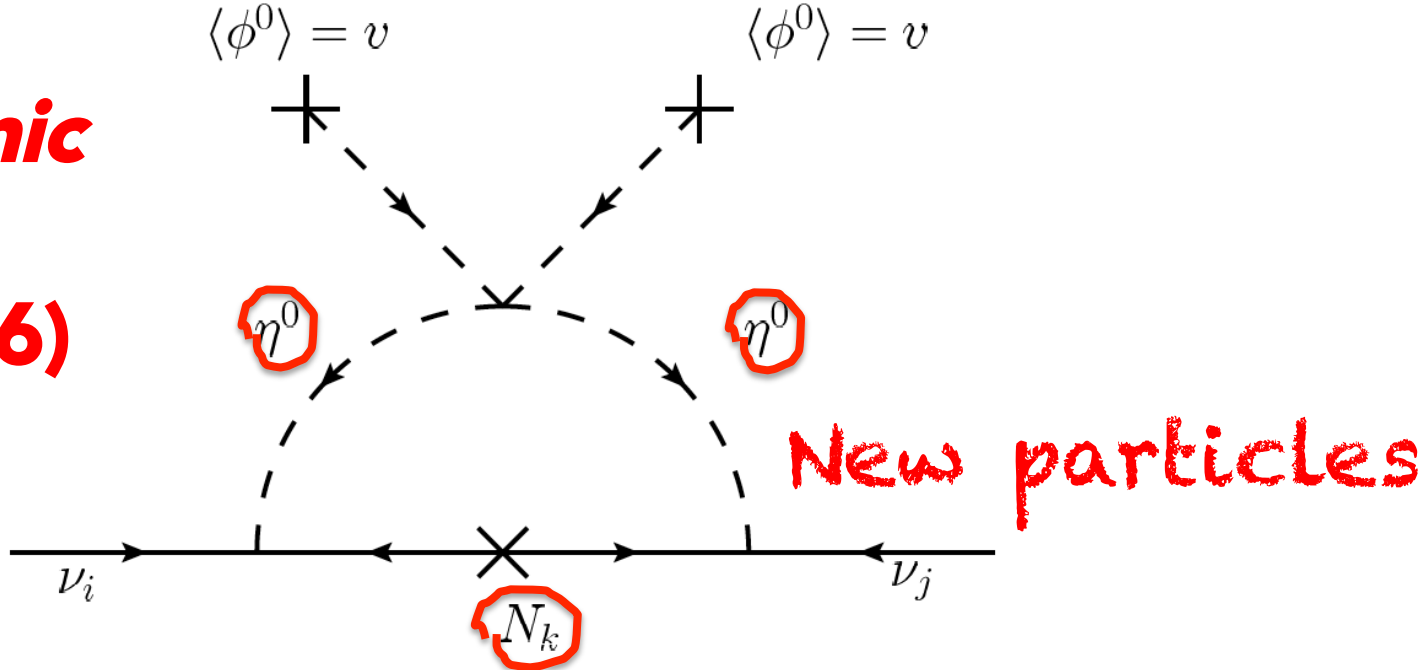
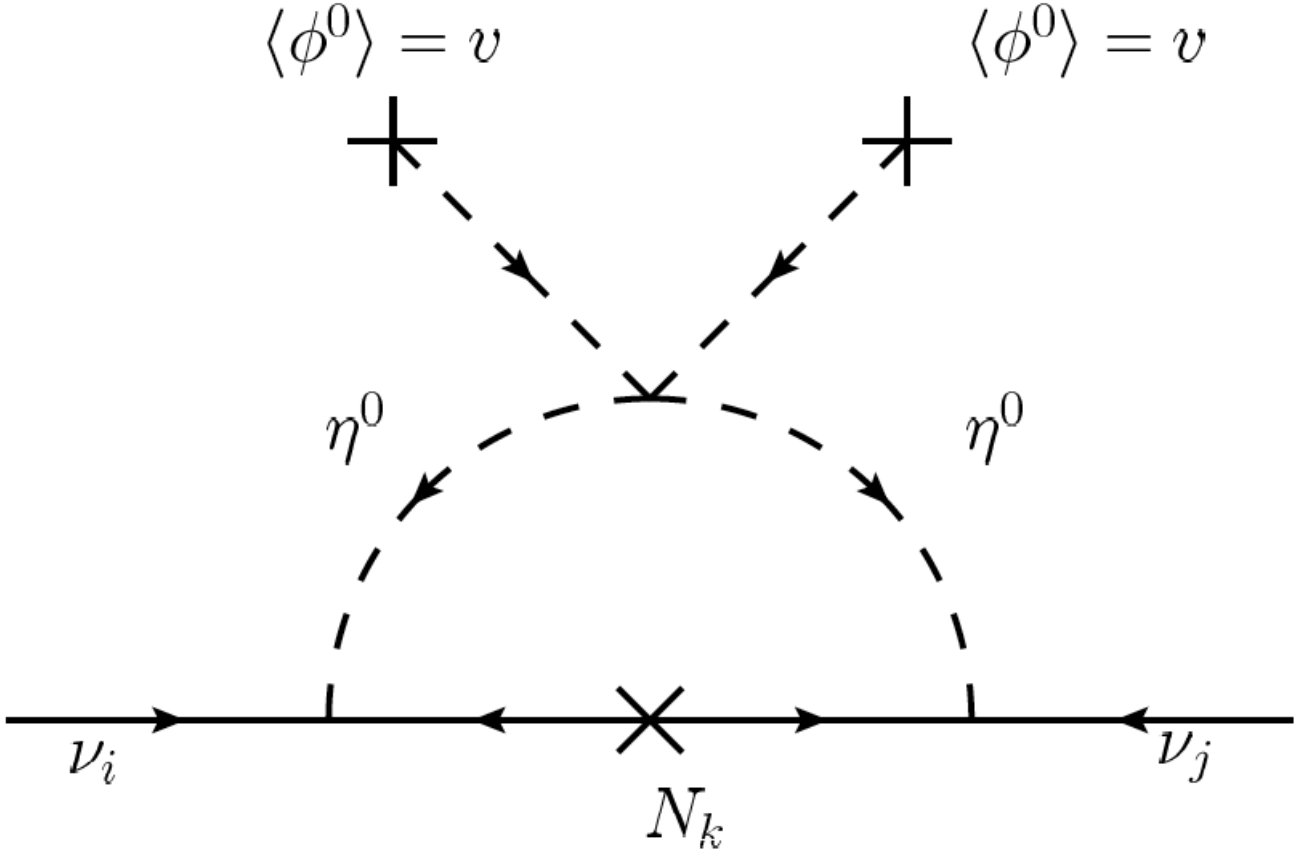


3. Radiative Neutrino Masses

(work done in collaboration with Moritz Platscher)

This stuff has many relations to other groups at MPP:



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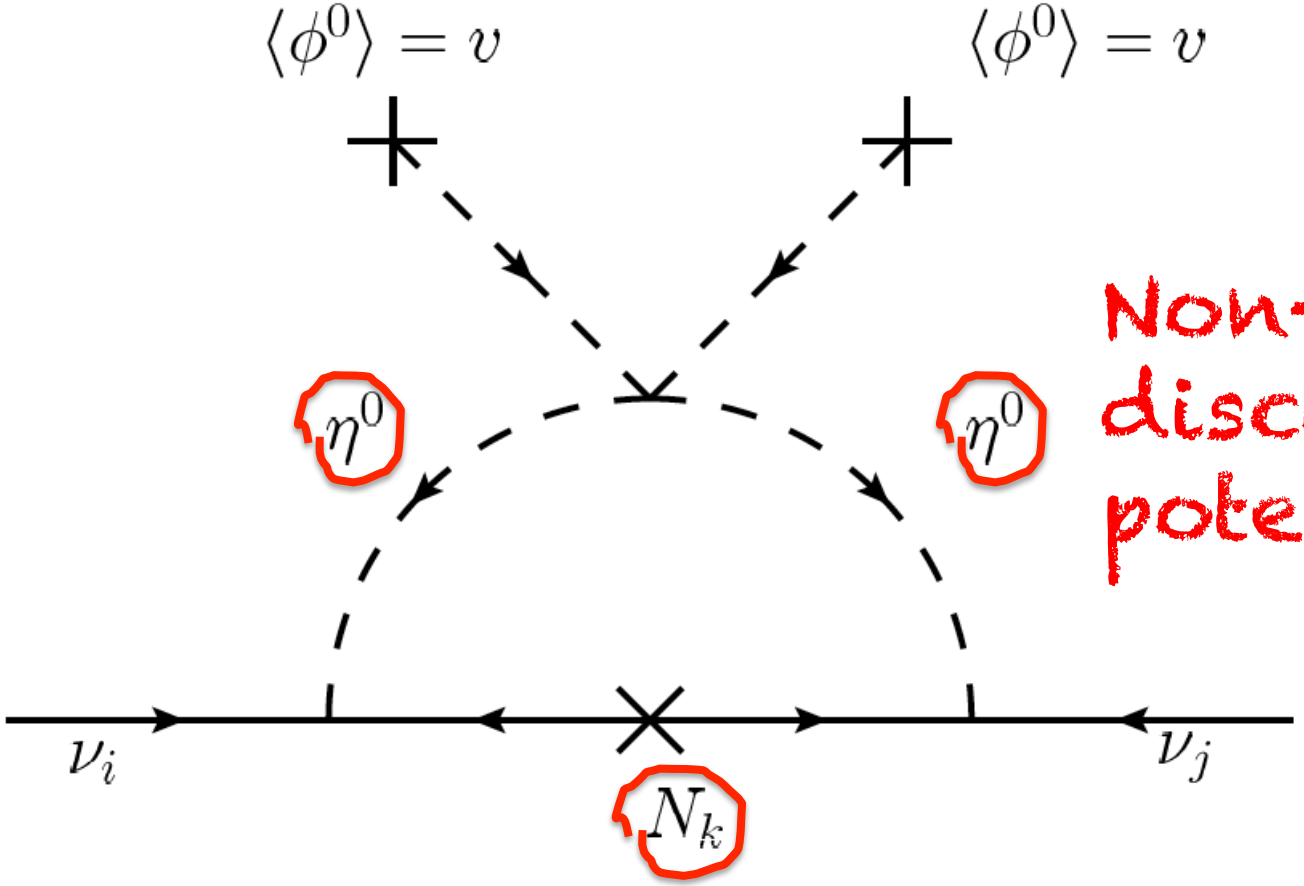

Non-negligible discovery potential at LHC

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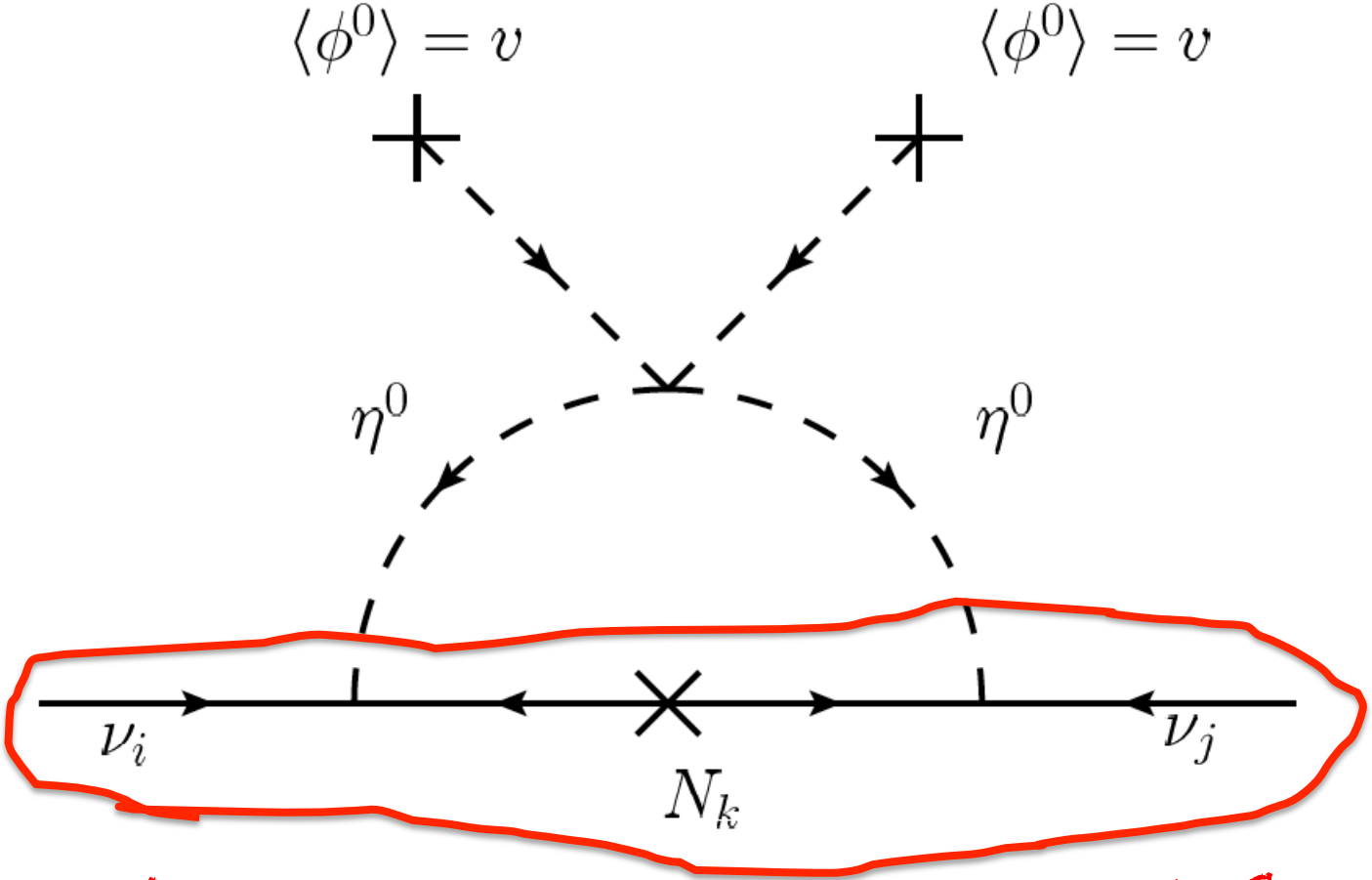

Majorana neutrinos hunted for in GERDA

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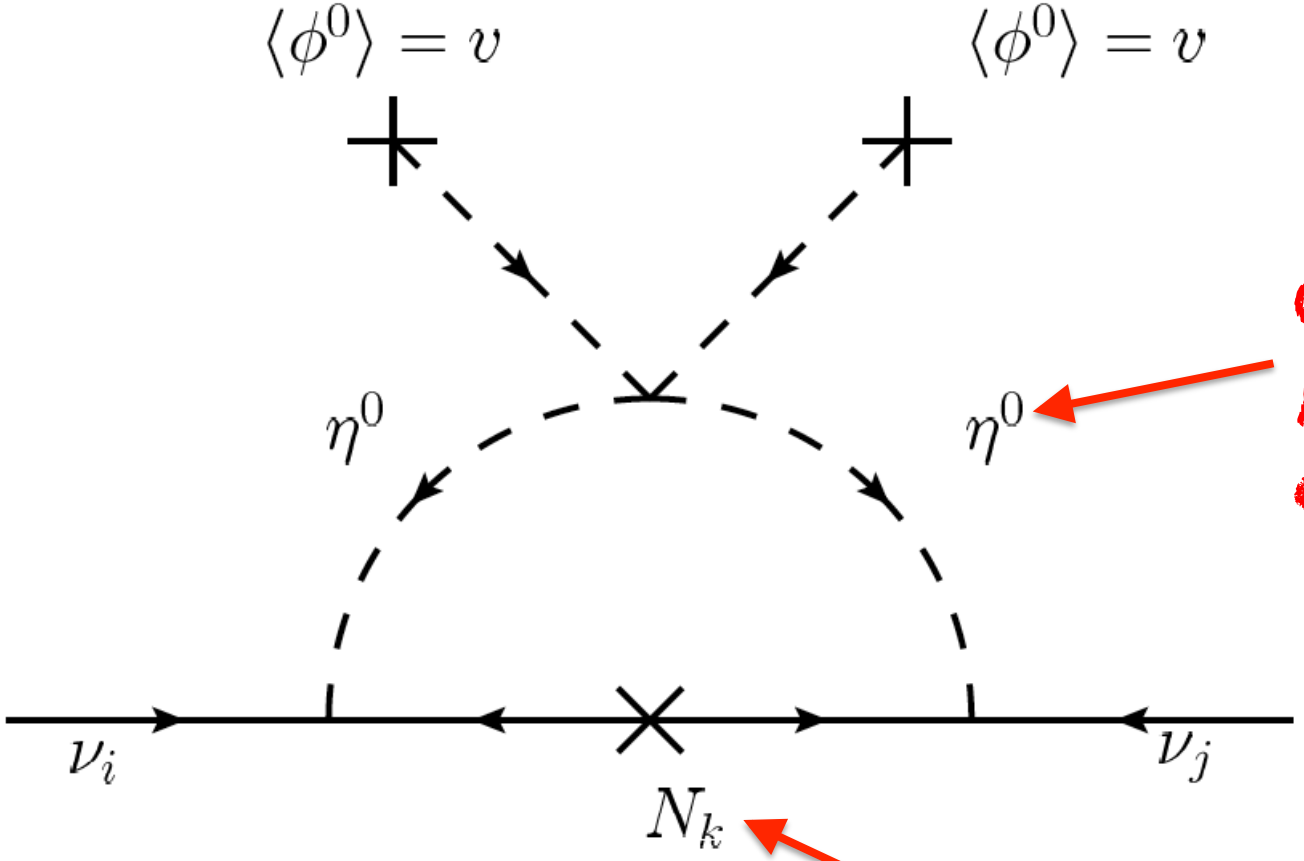

Cold Dark Matter candidate

Cold/Warm Dark Matter candidate

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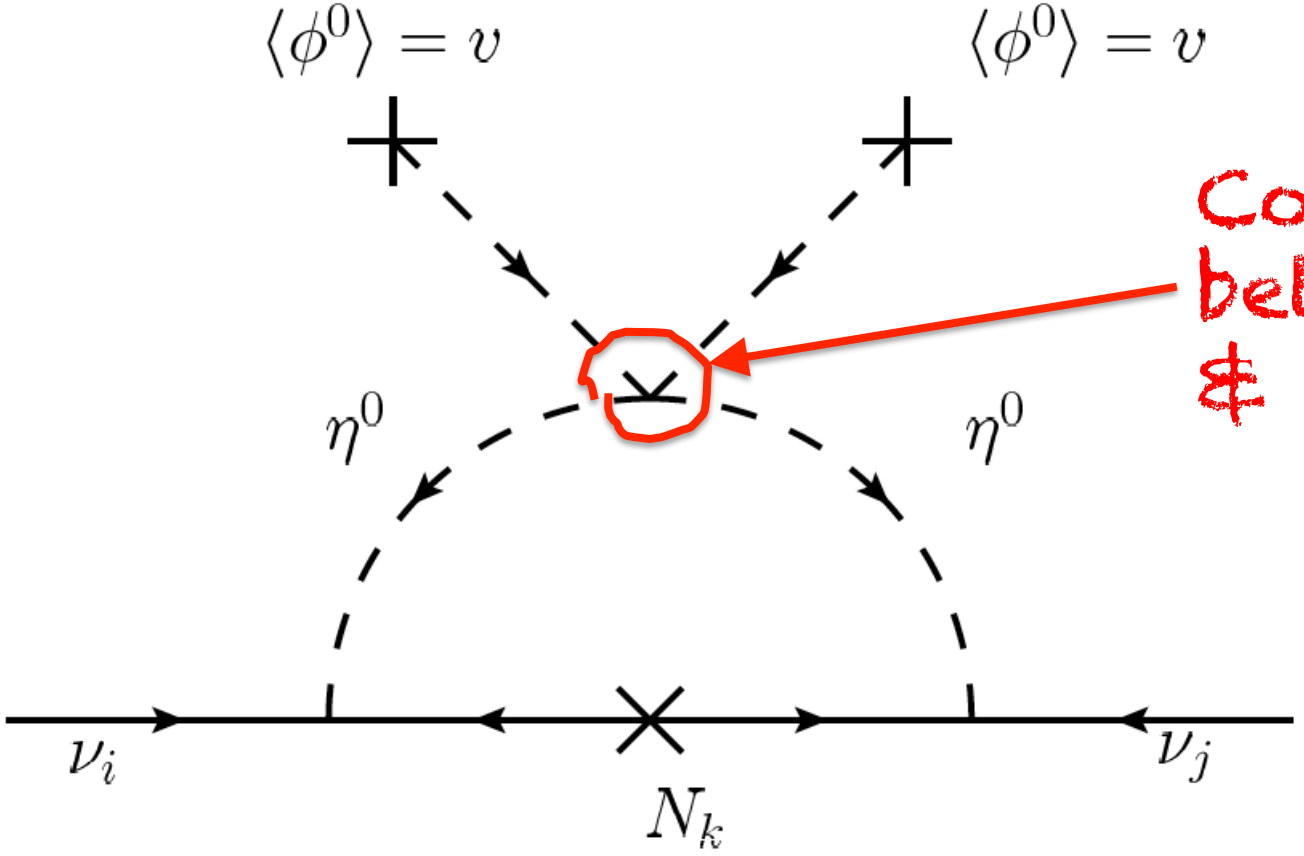

Connection between LNV & EWSB

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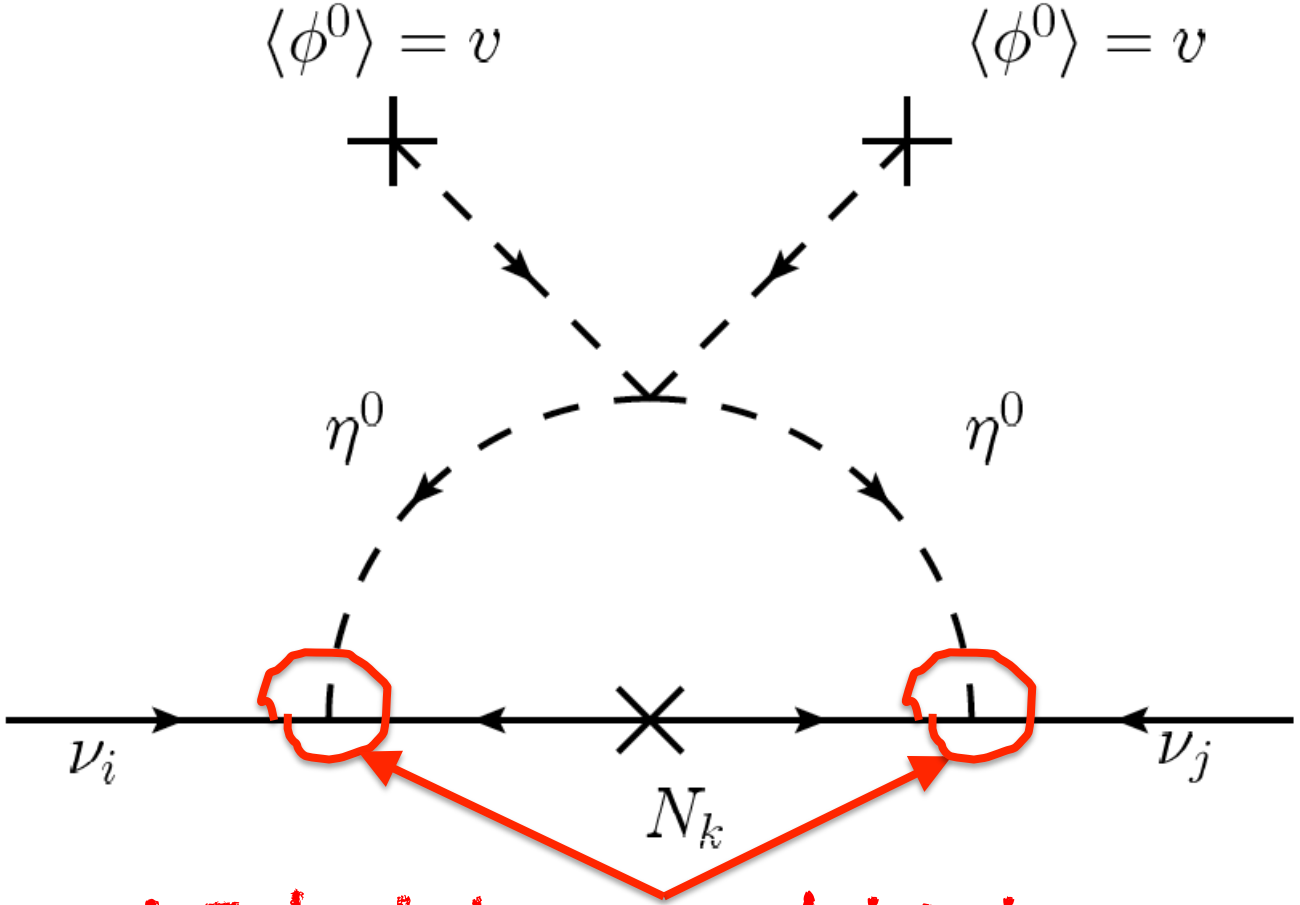


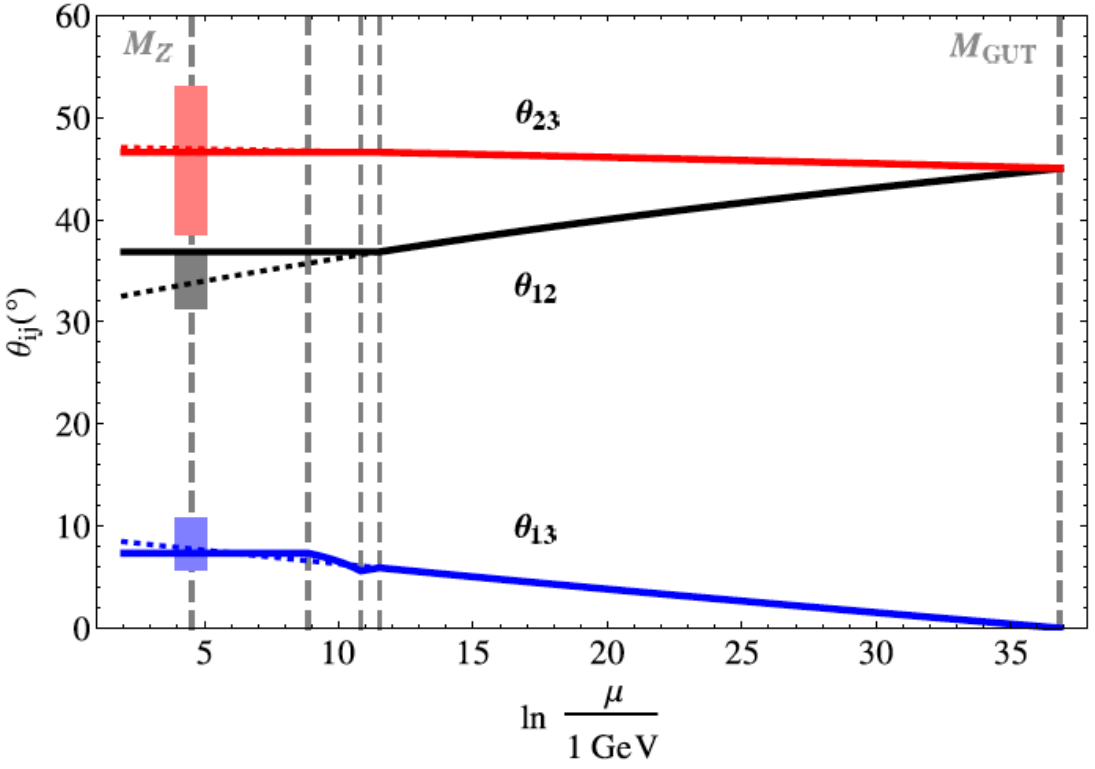
LFV at low and high energies

3. Radiative Neutrino Masses

(work done in collaboration with Moritz Platscher)

My work with Moritz: *renormalisation of the scotogenic model & phenomenological investigation*

Potentially strong running effects, not realised until 2012... ➔ it's about time to put the model to the test!!!



[Bouchand, AM: JHEP **1207** (2012) 084]

4. Conclusions

- **there is a lot going on in the astroparticle physics group... sorry I couldn‘t cover everything!**

- **interesting times lie ahead of us... 2015 could bring a new physics discovery such as a clear Dark Matter signal or news from LHC**

- **but for now, the last thing I want to say is...**

MERRY X-MAS & HAPPY NEW YEARS!!!

(http://d1lwft0f0qzya1.cloudfront.net/dims4/COKE/2ff0804/2147483647/thumbnail/596x334/quality/75/?url=http%3A%2F%2Fassets.coca-colacompany.com%2F70%2F70%2Fe57115594b02850a516335b8d46c%2Fhilf-santa-santa-claus.png)