# ITN Invisibles: UDUR

29 March 2012

**Invisibles Pre-meeting**
UAM - Madrid

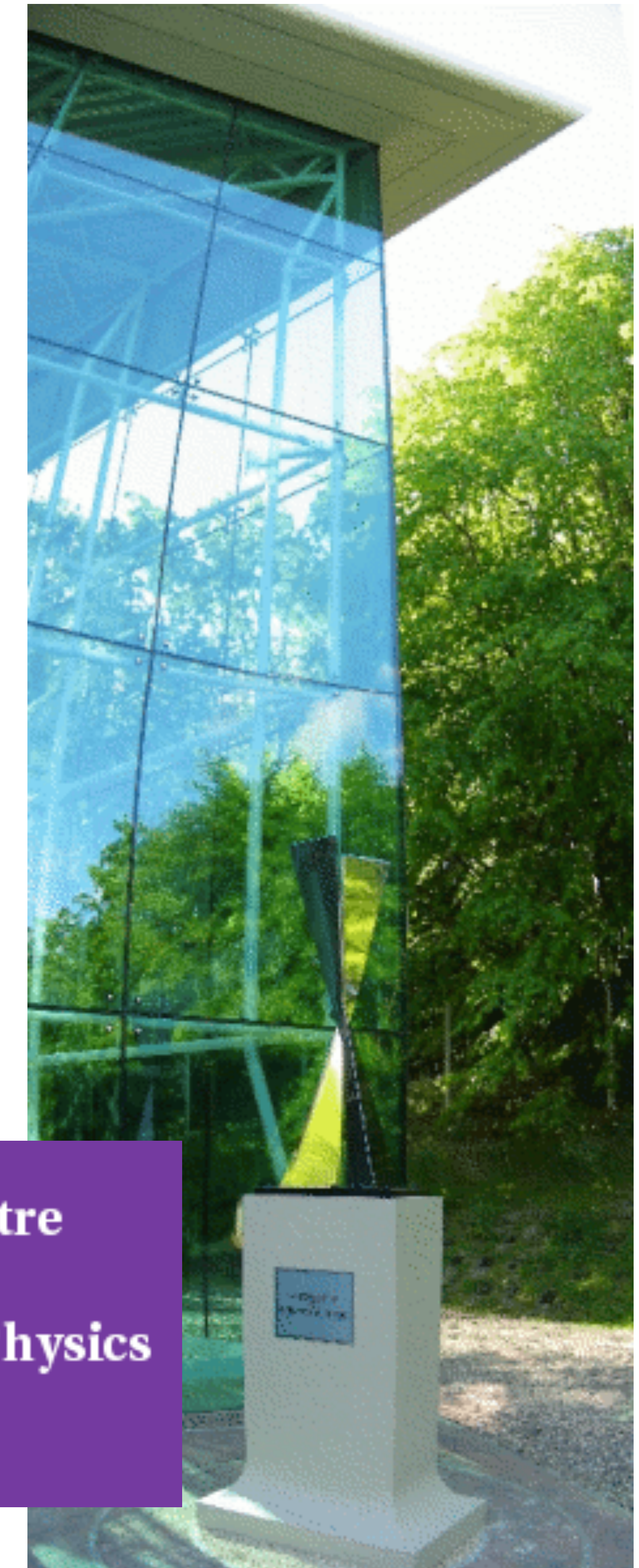
Silvia Pascoli

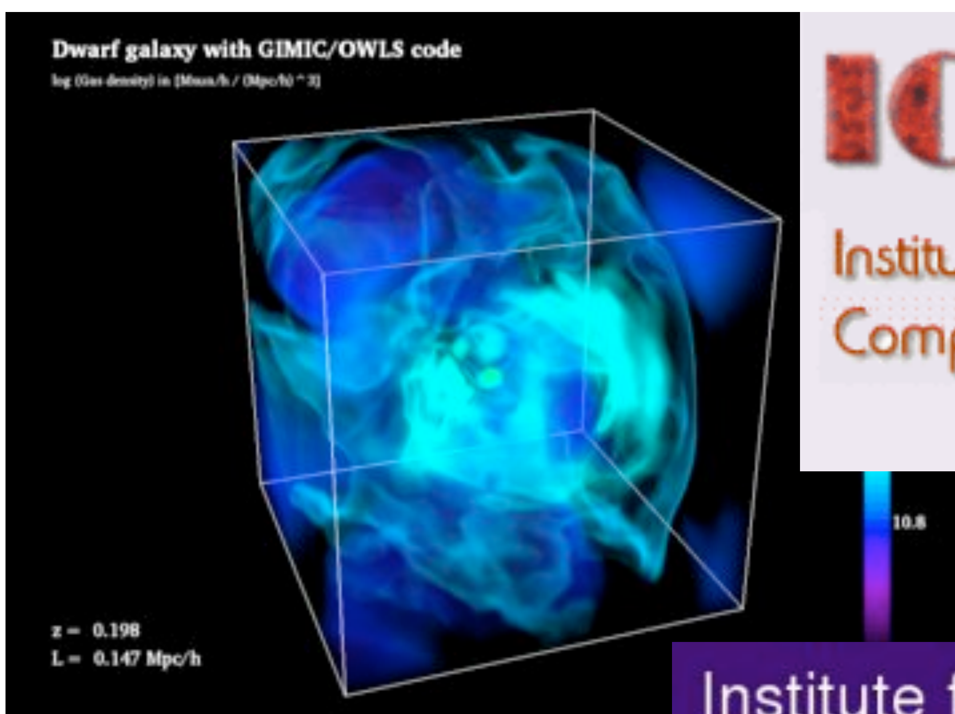
IPPP-Durham University

Durham
University

Durham University is one of the leading Universities in UK.

It hosts two worldclass institutes: the IPPP and the ICC in the Ogden Center for Fundamental Physics.

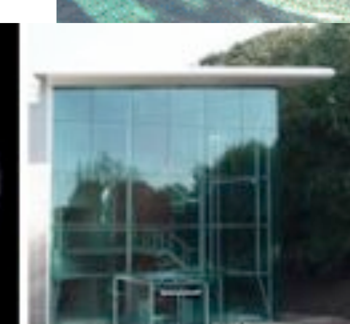





ICC
Institute for
Computational Cosmology

The Ogden Centre
For
Fundamental Physics

Institute for
Particle Physics
Phenomenology



The **Institute for Particle Physics Phenomenology (IPPP)** aims to foster world-class research in particle physics phenomenology.

Very active scientific environment with cutting edge research, seminars, colloquia, visitor programme, PG schools, workshops, conferences, journal clubs, lecture courses, many international collaborations and projects, and other training opportunities for PhD students.

A large research group is focussed on Neutrino and Dark Matter:


C. Boehm: DM


V. Khoze


S. Pascoli


C. Baugh


C. Frenk


S. Cole


J. Jaeckel


S.  Abel

A. Jenkins


T.  Theuns

# Postdocs and PhD students in the IPPP on Neutrino and DM

C. Luhn

P. Dechant

J. Lopez Pavon

Steven Wong: neutrinoless double beta decay and NF

Chris Wallace: light dark matter

Peter Ballett: Neutrino phenomenology and theory

Jonathan Davis: Dark Matter direct detection

Alexandre Barreira: LSS in modified gravity models

Jascha Schewtschenko: neutrinos and LSS

# ESR Training

First year: extensive set of lectures. Given within the CPT (Centre for Particle Theory joint between the Physics and Maths Departments).

Courses offered in the Michaelmas Term:

| abbr. | course name | lecturer | no. of lecures | weeks taught |
|---|---|---|---|---|
| IFT | Introductory Field Theory | Joerg Jaeckel | 24 | 1-4 |
| GRP | Group Theory | Kasper Peeters | 16 | 1-4 |
| SM | The Standard Model | Peter Richardson | | |
| GR | General Relativity | Ruth Gregory | | |
| QFT | Quantum Field Theory | Douglas Smith | | |
| QED | Quantum Electrodynamics | Daniel Maitre | | |
| CFT | Conformal Field Theory and Strings | Peter Bowcock | | |

The students take two sets of exams.

Courses offered in the Epiphany Term:

| abbr. | course name | lecturer | no. of lecures | weeks taught |
|---|---|---|---|---|
| AN | Anomalies | Chong-Sun Chu | 8 | 16-19 |
| COS | Cosmology | Celine Boehm | 16 | 11-14 |
| SS | Supersymmetry | Adrian Signer | 16 | 11-14 |
| DBR | Superstrings and D-branes | Mukund Rangamani | 16 | 16-19 |
| NPP | Non-perturbative Physics | Paul Sutcliffe | 16 | 11-14 |
| EFT | Euclidean Field Theory | Marija Zamaklar | 16 | 16-19 |
| NAP | Neutrinos and Astroparticle Physics | Silvia Pascoli | 16 | 16-19 |
| SIP | Strong-Interaction Physics | Chris Maxwell | 16 | 11-14 |
| FPE | Flavour Physics and Effective Field Theories | not taught this year | 16 | 16-19 |
| 2DQ | Two-dimensional QFT | Patrick Dorey | 8 | 16-19 |

Additional courses are provided in Easter term.

From second year: research project in cutting-edge phenomenology with one of the supervisors.
Joint projects are also encouraged.

Complementary training: workshops and courses covering

- Research skills and techniques
- The research environment
- Research management
- Personal effectiveness
- Communication skills
- Networking and teamworking
- Career management.

Durham University's Research Training Programme won the Outstanding Support for Early Career Researchers award at the annual 2009 THE award ceremony in London.

# Invisibles research

## WP1: Neutrino Physics

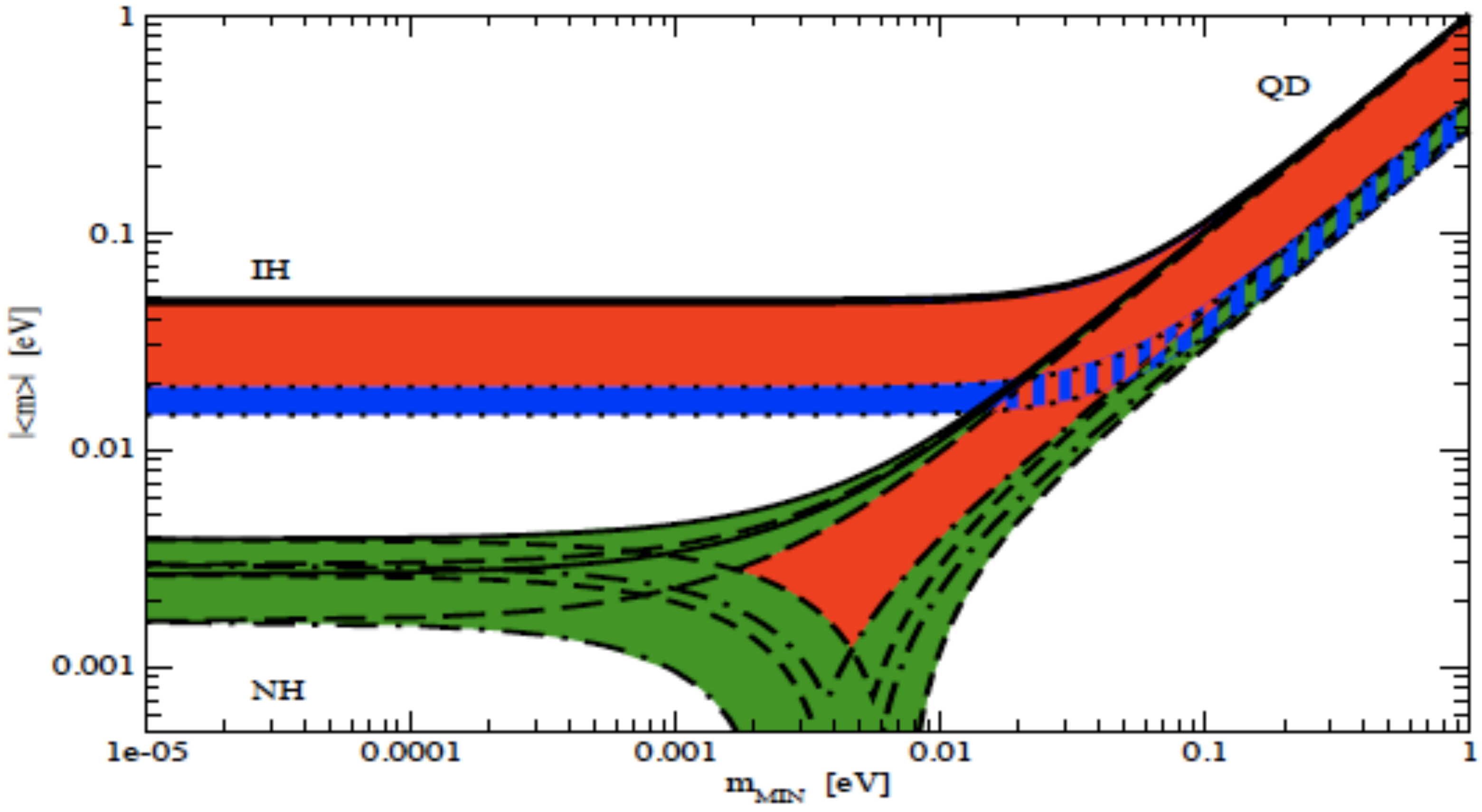
- Neutrino phenomenology: neutrinoless double beta decay, long baseline neutrino experiments, sterile neutrino searches (SP, Lopez Pavon, Ballett, Wong)

- Neutrino theory: models of leptonic flavour, neutrino masses in see-saw and other models, testing neutrino generation at the LHC (SP, Lopez Pavon, Luhn, Ballett)

- Neutrino astroparticle physics (also WP3): sterile neutrinos as DM, neutrinos and LSS (Boehm, SP)

# Neutrino phenomenology

Some of our activity focusses on neutrinoless double beta decay. This process is the prime search for lepton number violation and can provide information on neutrino masses and CP-violation.




SP, Petcov, PRD77

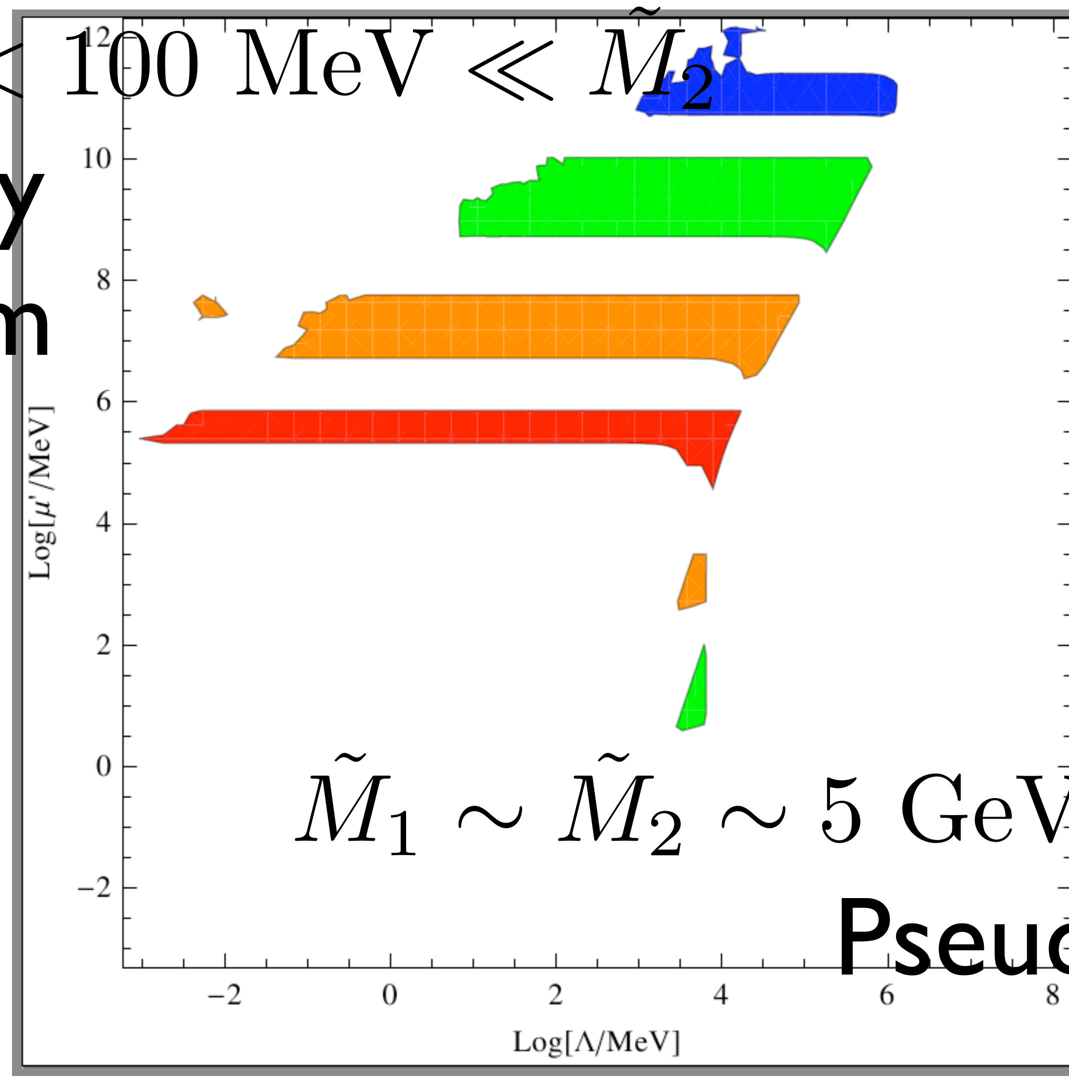
Collaboration with INFN.

Neutrinoless double beta decay can be induced by various mechanisms: light nu masses, heavy neutrinos, R-parity violation... Can heavy neutrinos dominate?

In the usual see-saw, the contribution to neutrinoless double beta decay is constrained by neutrino masses. Some exceptions can be found if no masses at tree-level (e.g. inverse see-saw).

$$\tilde{M}_1 < 100 \text{ MeV} \ll \tilde{M}_2$$

Hierarchical heavy neutrino spectrum




J. Lopez-Pavon, SP, C.-F. Wong

$$\tilde{M}_1 \sim \tilde{M}_2 \sim 5 \text{ GeV}$$

PseudoDirac neutrinos

# Long baseline neutrino experiments

We are involved in the study of future facilities and their physics reach. Thanks to the new Daya Bay results, the focus is now on

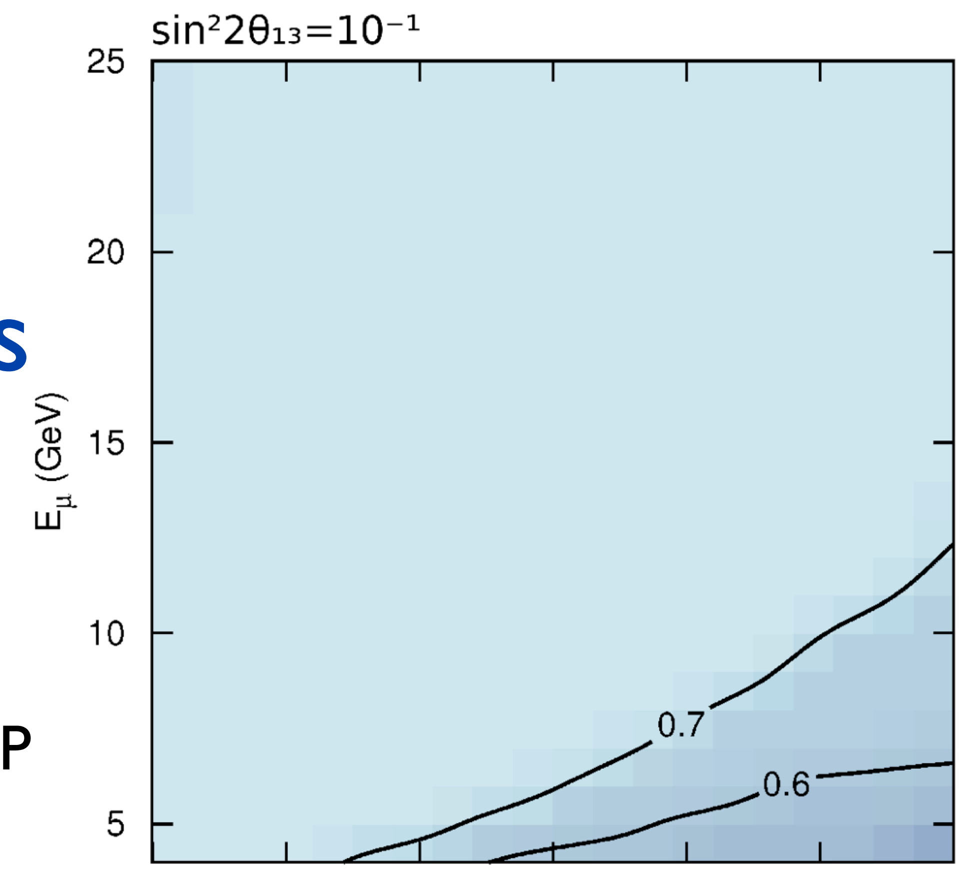
- the mass hierarchy,
- CP-Violation
- tests of the three-neutrino scenario (sterile neutrinos, NSI...).

UDUR is part of EUROnu, LAGUNA, LAGUNA-LBNO and the IDS-NF: this allows close collaboration with experimental groups resulting in detailed and reliable performance studies.

| Location | Distance from CERN [km] | 1st osc max [GeV] |
|---|---|---|
| Fréjus (France) | 130 | 0.26 |
| Canfranc (Spain) | 630 | 1.27 |
| Umbria (Italy) | 665 | 1.34 |
| Sierozsowice (Poland) | 950 | 1.92 |
| Boulby (UK) | 1050 | 2.12 |
| Slanic (Romania) | 1570 | 3.18 |
| Pyhäsalmi (Finland) | 2300 | 4.65 |

## Superbeams (see Li's talk)
## Collaboration with UVEG

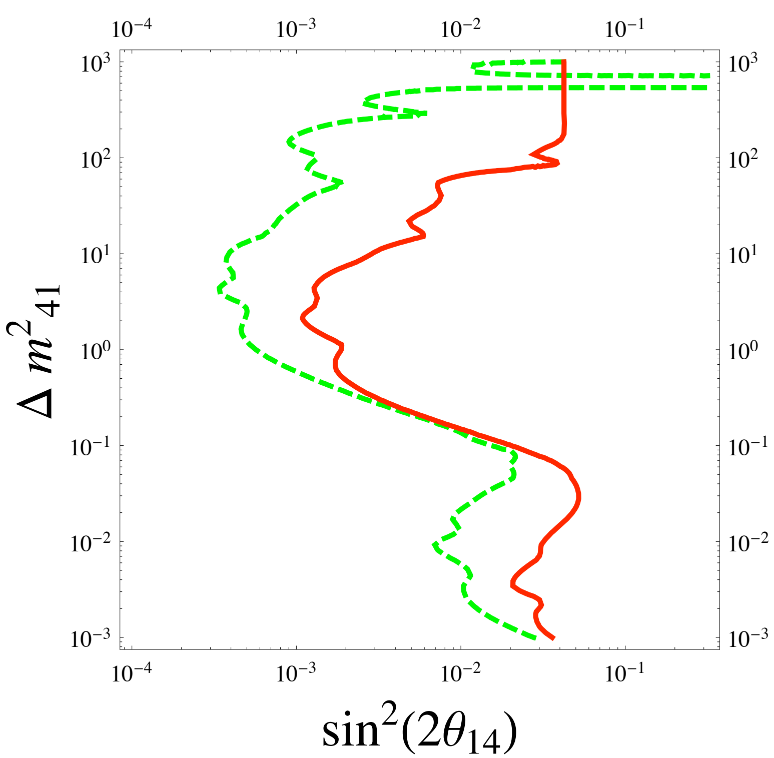
Coloma, Li, SP




## Optimisation of LENF;
## Study of precision measurements

## See Ballett's talk

Ballett, SP




## Sterile and NSI neutrino searches
## Collaboration with HRI, DU.

SP, Wong

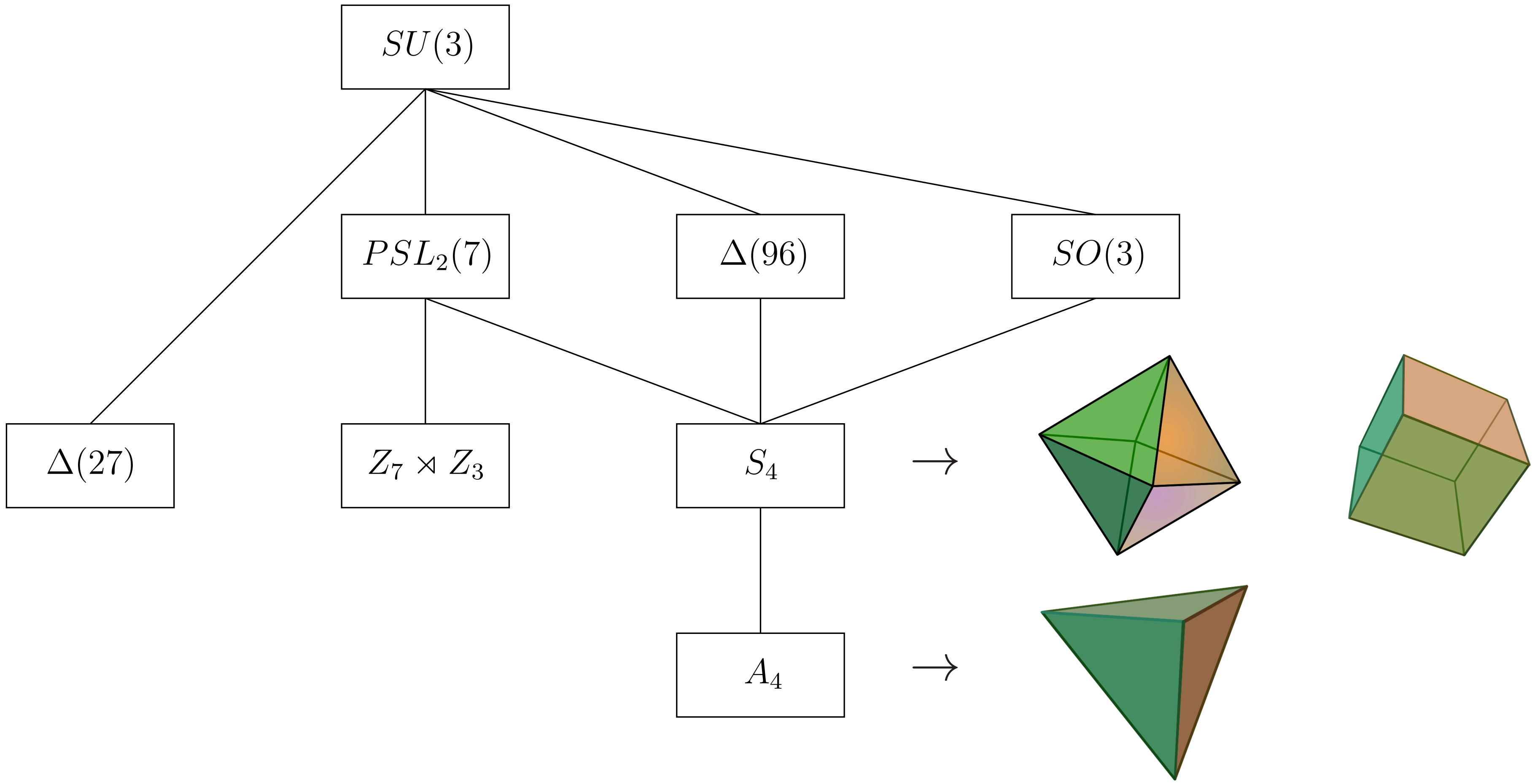
# Neutrino theory

## Non-Abelian family symmetries

**unify three families in multiplets of family symmetry**

**symmetry group should have three-dimensional representations**

**tri-bimaximal (TB) neutrino mixing suggests groups like $A_4$, $S_4$, Δ(27)**




Christoph Luhn (Durham)

## Neutrino mass models and sizable $\theta_{13}$

experimental evidence for sizable $\theta_{13}$ (Daya Bay, T2K, etc.)

review role of family symmetries $\mathcal{G}$

what is the Klein symmetry $\mathcal{K}$ of the neutrino mass matrix

how does $\mathcal{K}$ arise – directly ($\mathcal{K} \subset \mathcal{G}$) or indirectly via flavon alignments

strategies of implementing sizable $\theta_{13}$

- corrections to TB mixing:
  new ingredients required, e.g. new flavon field
  (charged lepton, RG, higher order corrections typically too small)

- direct models: new symmetries, e.g. $\mathcal{G} = \Delta(384)$

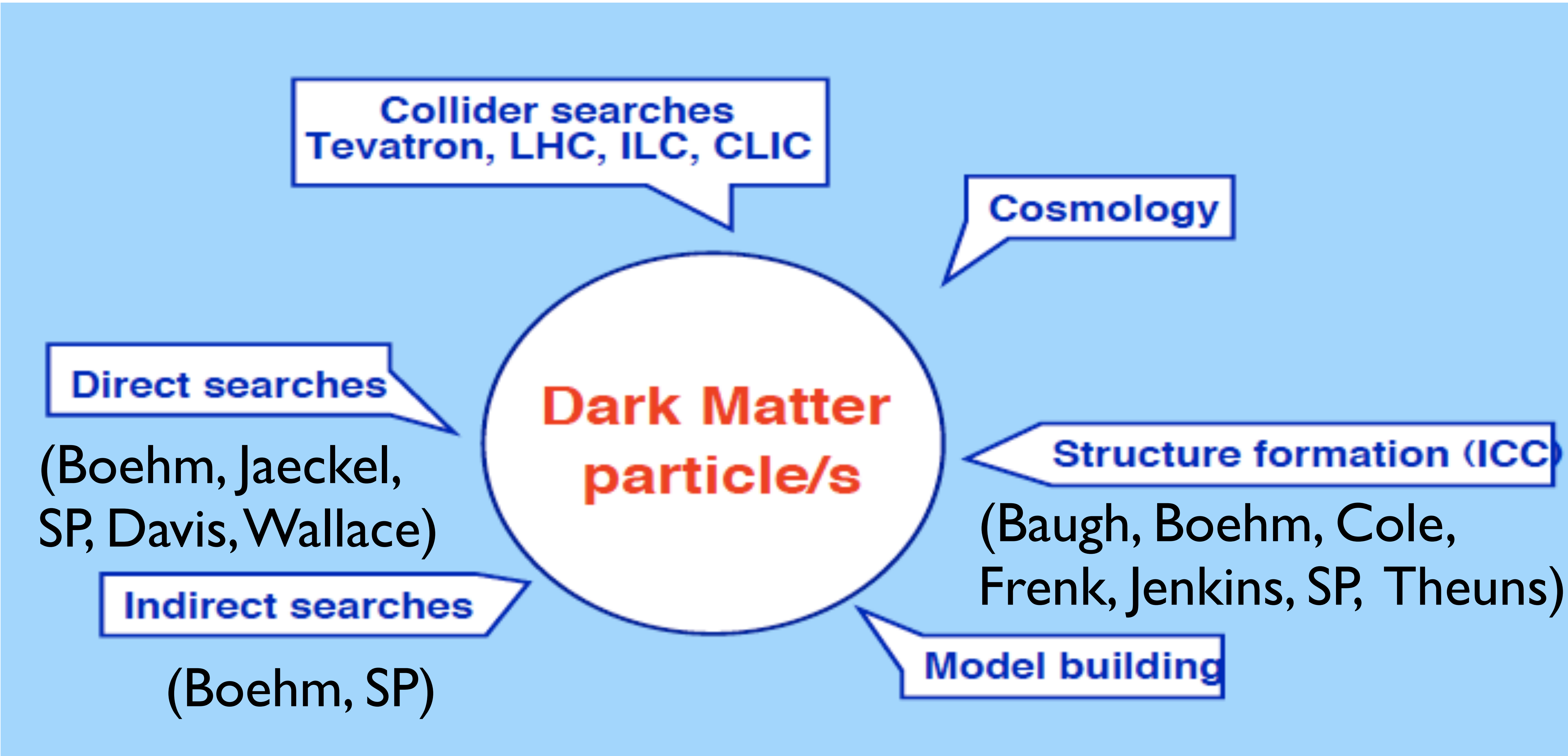
- indirect models: non-standard flavon alignments, e.g. $(1, 2, 0)^T$

deviations from TB mixing angles can be correlated – testable rules

C. Luhn;
Also P. Ballett, SP, P. Dechant.

Collaboration with SOTON.

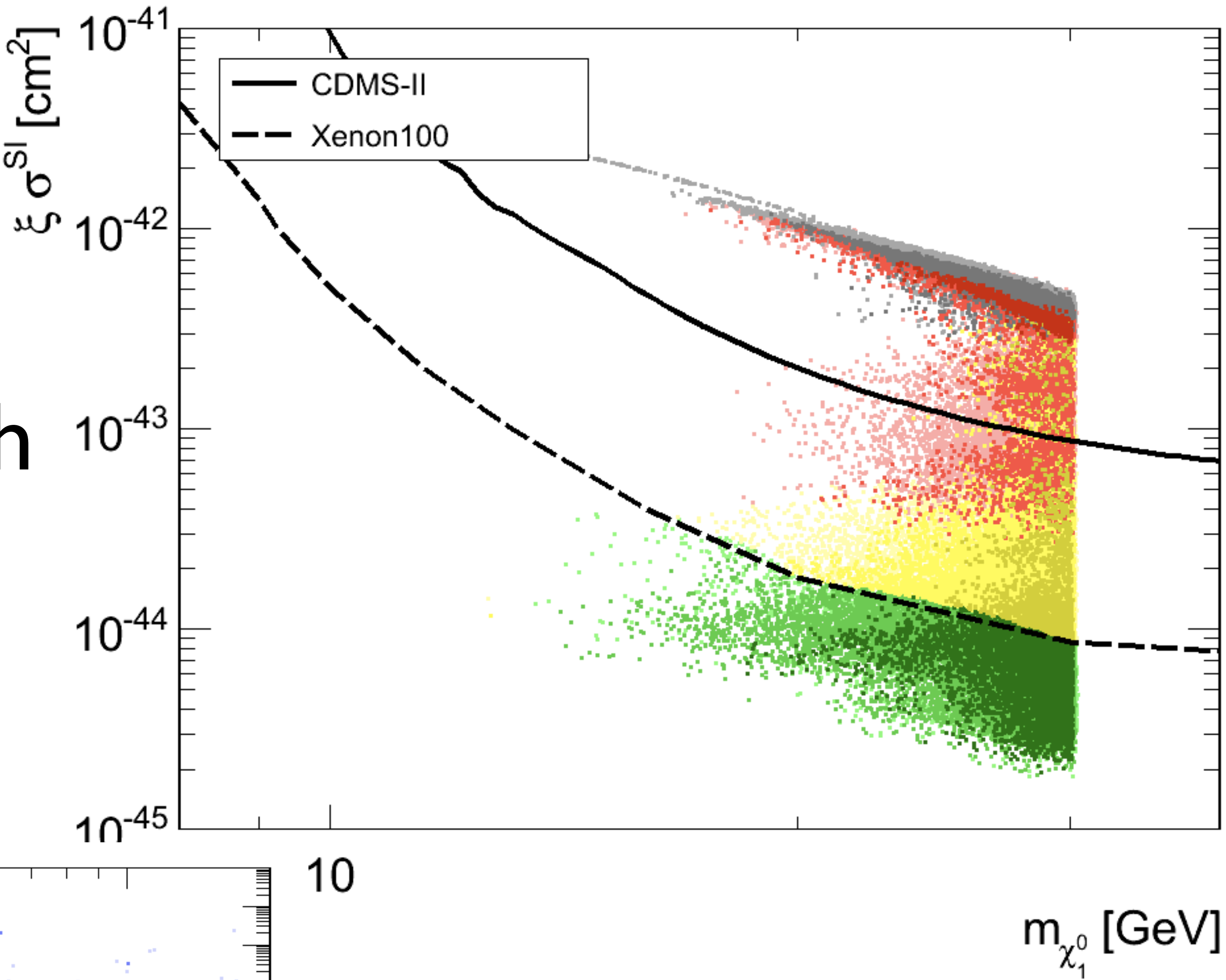
# WP2: Dark Matter Physics

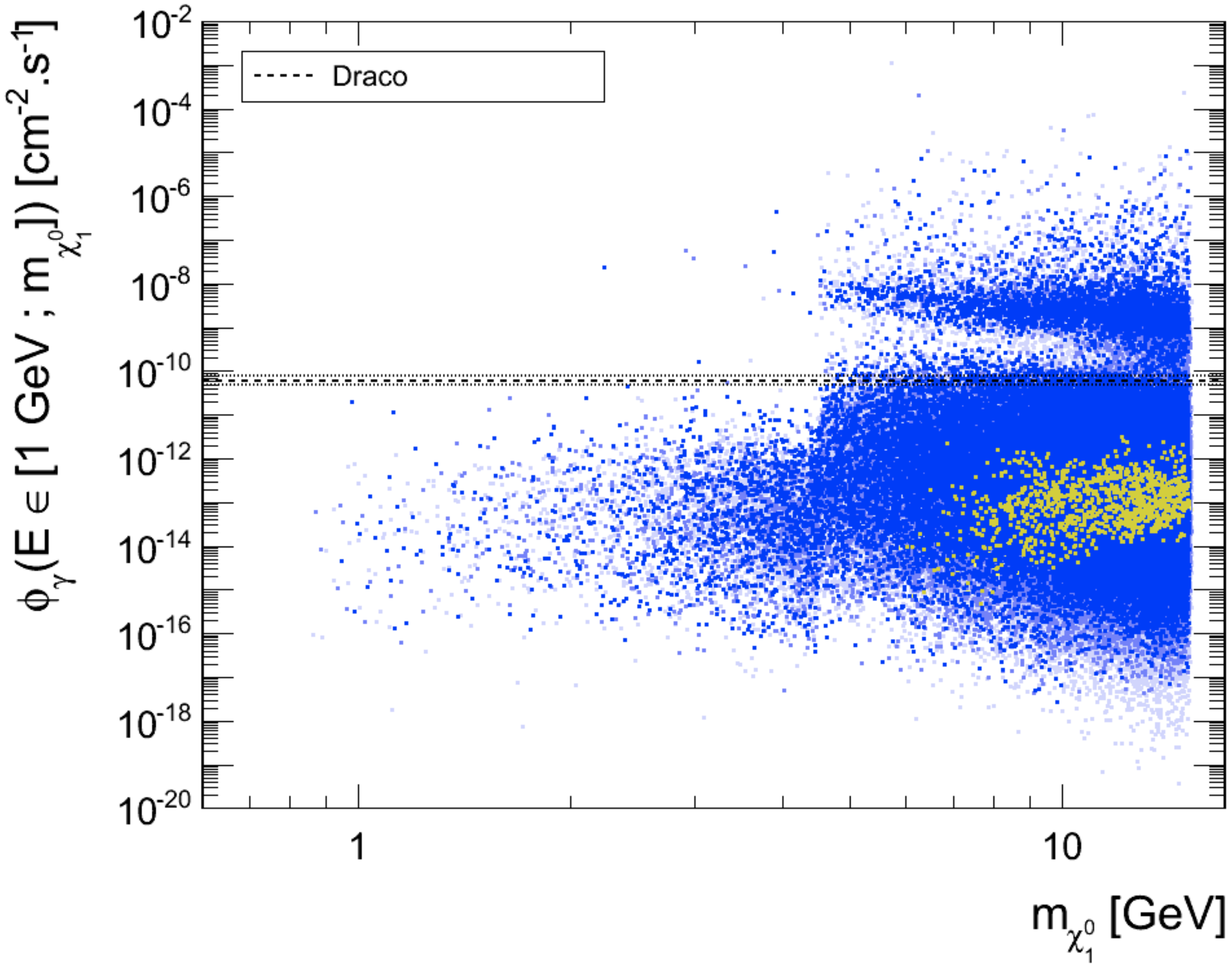



(Boehm, Jaeckel, Khoze, SP, Davis, Wallace)

# Dark matter detection

Light neutralinos and their compatibility with experiments




Boehm at al.

Indirect detection from gamma-rays in the galaxy

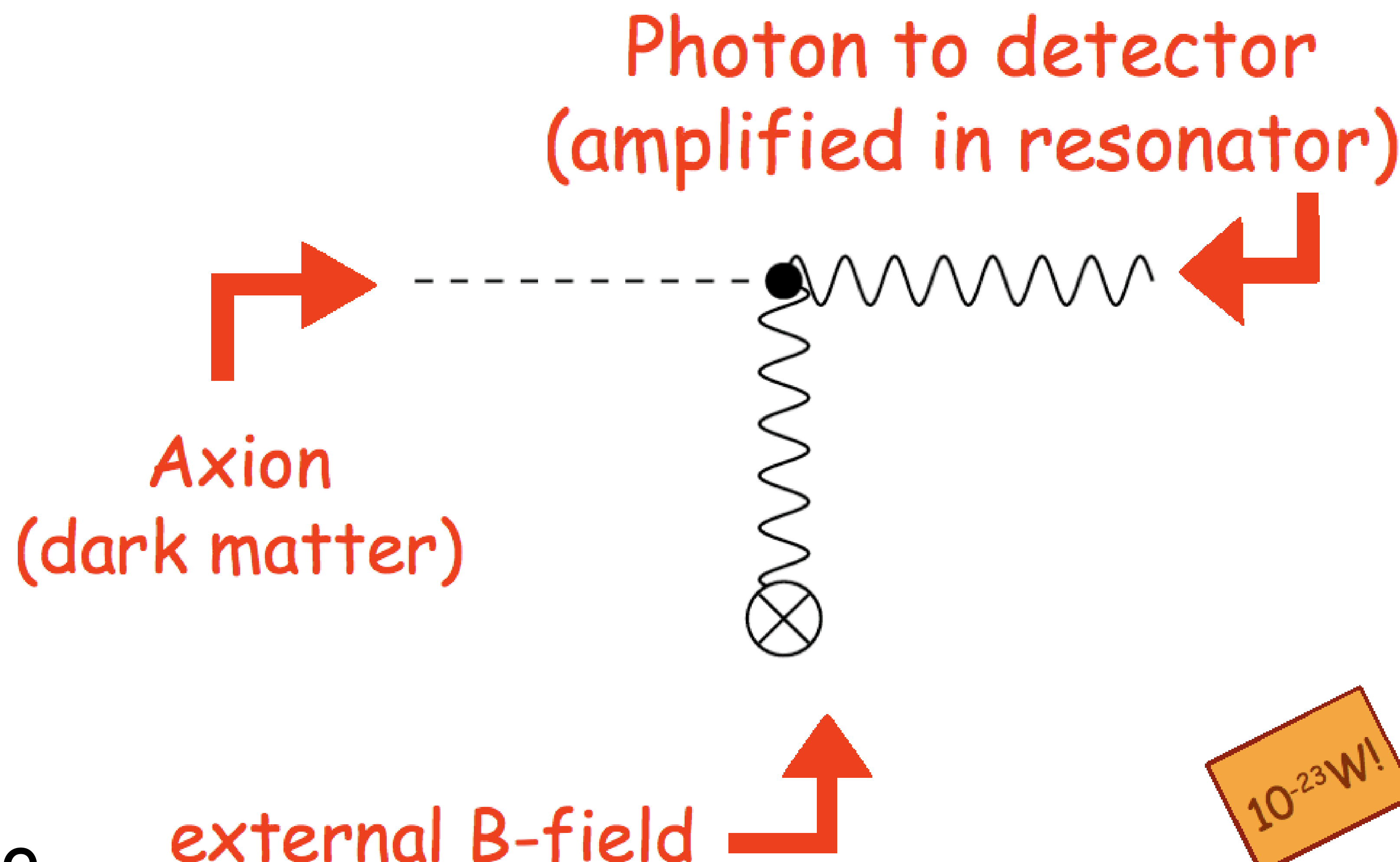
# Axions

DM can be made of very light (m<<MeV) particles (very Weakly Interacting Slim Particles), if produced non- thermally. Examples: Axions, "hidden" U(1) gauge bosons.

They appear naturally in many extensions of the SM (motivated by to strong CP, string theory…).

Can and will be tested in lab experiments

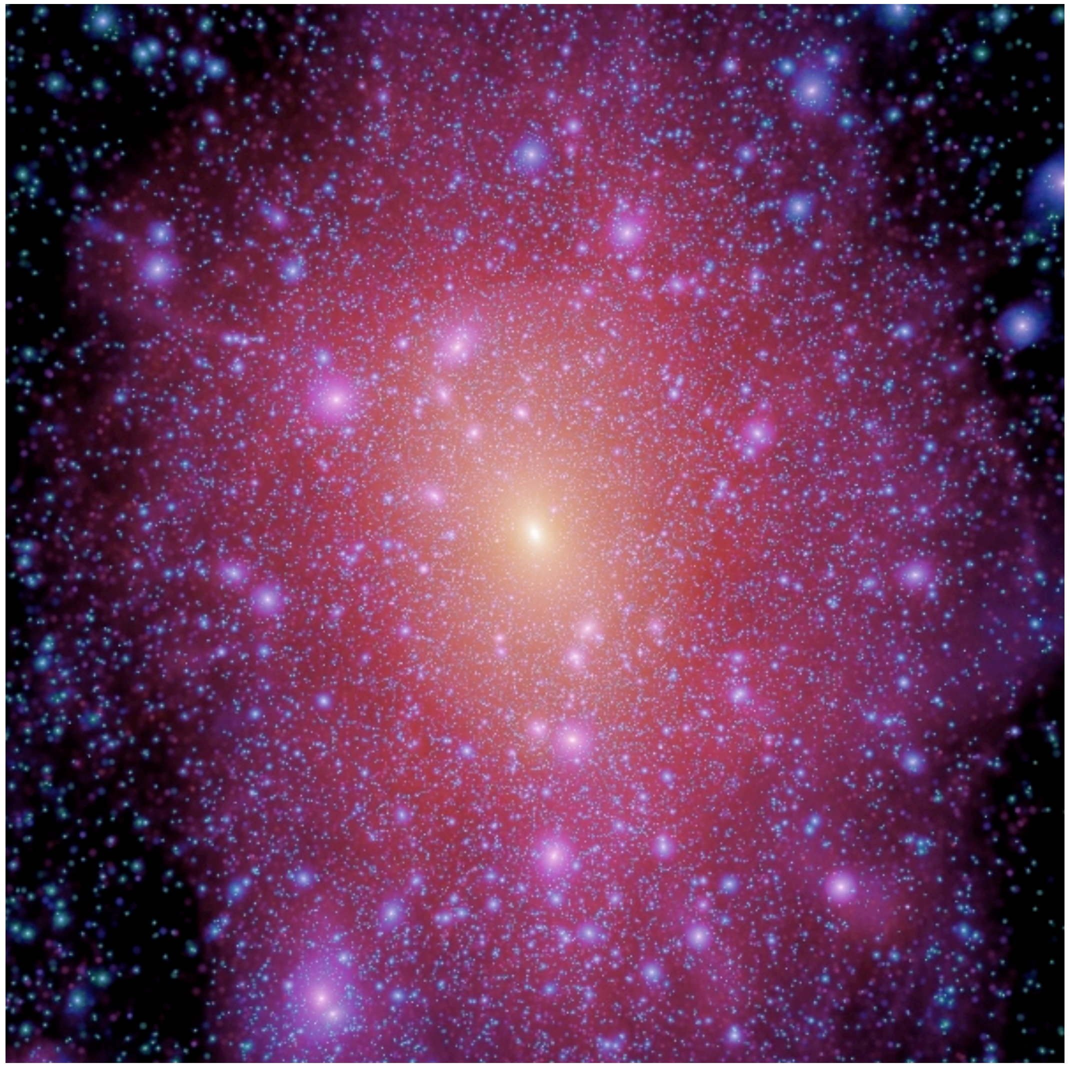
- DM detection: ADMX, + more soon
- Production and det.: ALPS, GammeV, +…



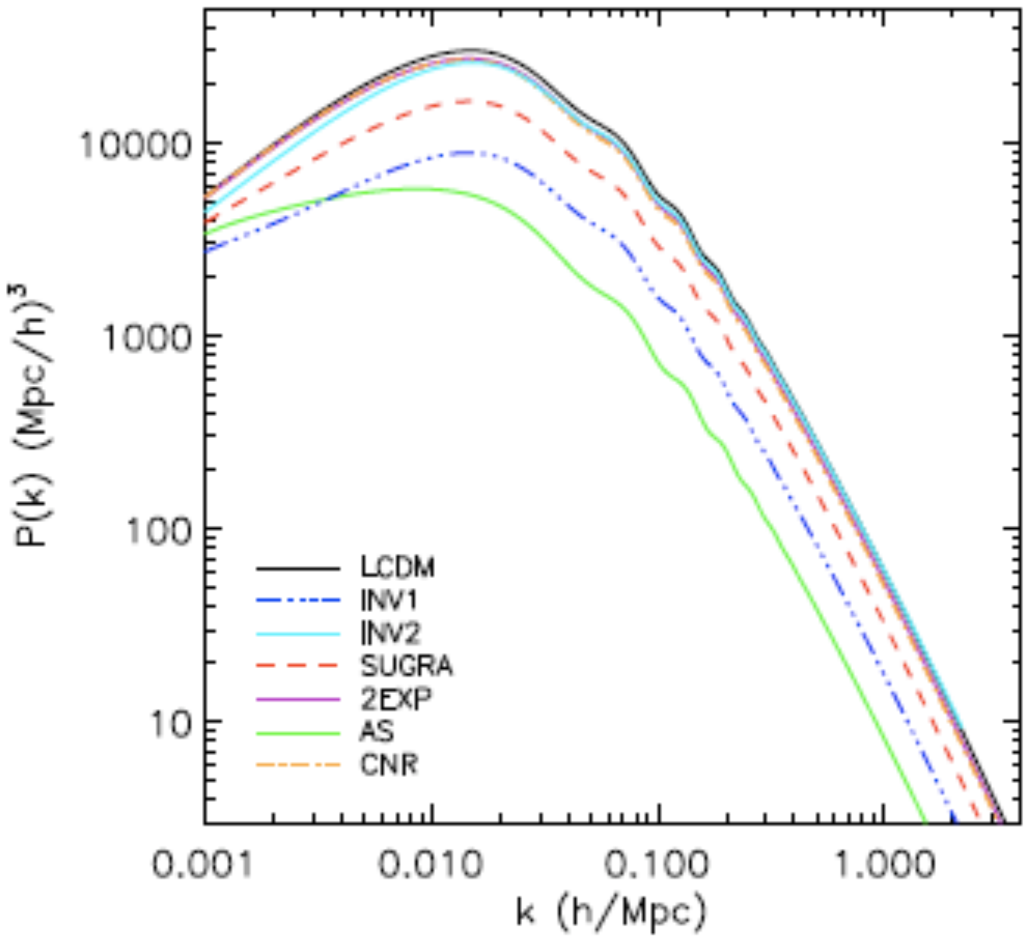

Jaeckel, Wallace

# Large scale structure formation

ICC is worldclass institute focussed on understanding the evolution of the Early Universe by means of HPC cosmological simulations.



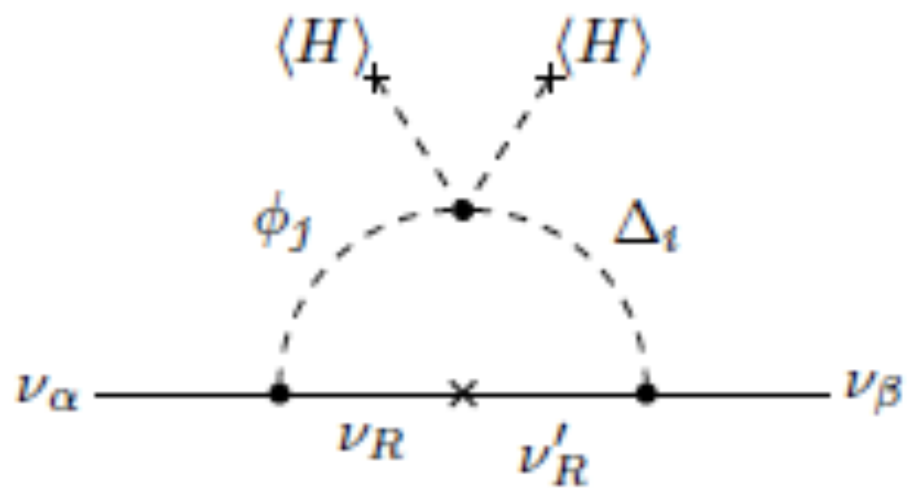
Aquarius DM halo




Jennings et al.

# WP3: Dark Matter and Neutrino connection

## Models of neutrino masses and DM BSM



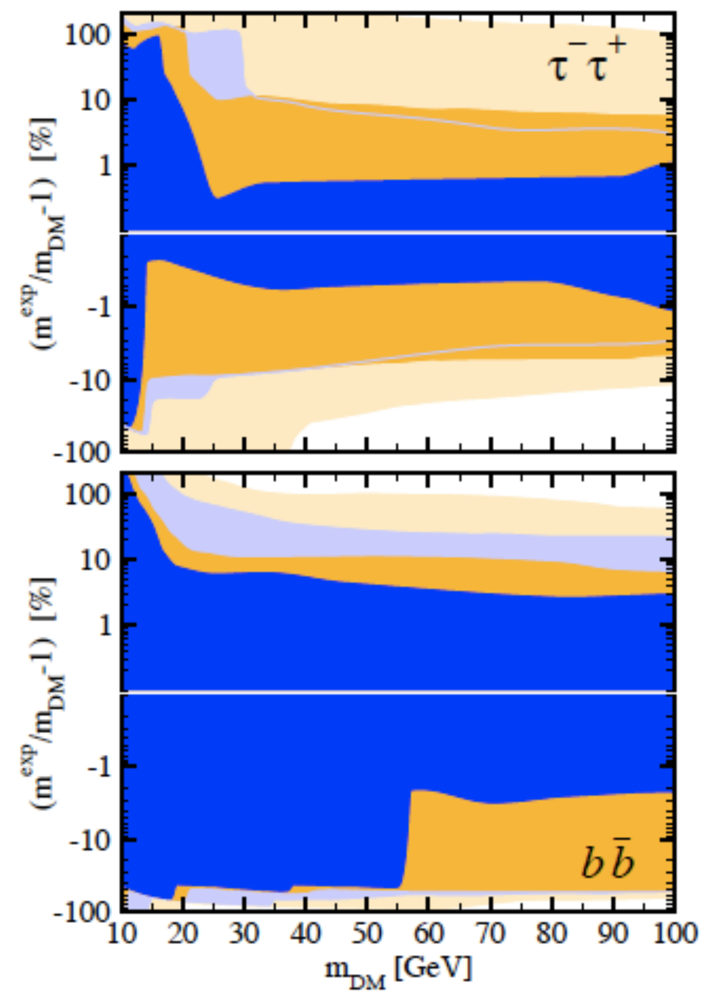

The symmetry which prevents the see-saw guarantees the stability of DM. Strong link with lepton number violating processes and collider searches.

Farzan, SP, Schmidt. Collaboration with IPM.

## Indirect DM searches with neutrinos

DM annihilations can be searched for in the galaxy and in the Sun with neutrino detectors.

Das, Mena, Palomares-Ruiz, SP.
Collaboration with UVEG.



# Conclusions

- UDUR hosts two worldclass institutes, the IPPP and the ICC, in which the Invisibles activities will take place.

- Expertise and research interests range from neutrino theory to experiments and phenomenology, from dark matter models to its searches, and on the connection between dark matter and neutrinos.

- The IPPP, and ICC, provide a very lively environment and collaborations with other nodes are very encouraged!!!