Direct and indirect searches for WIMP dark matter

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DESY
Theory Fellow Meeting
31.10.2016

A few words about me

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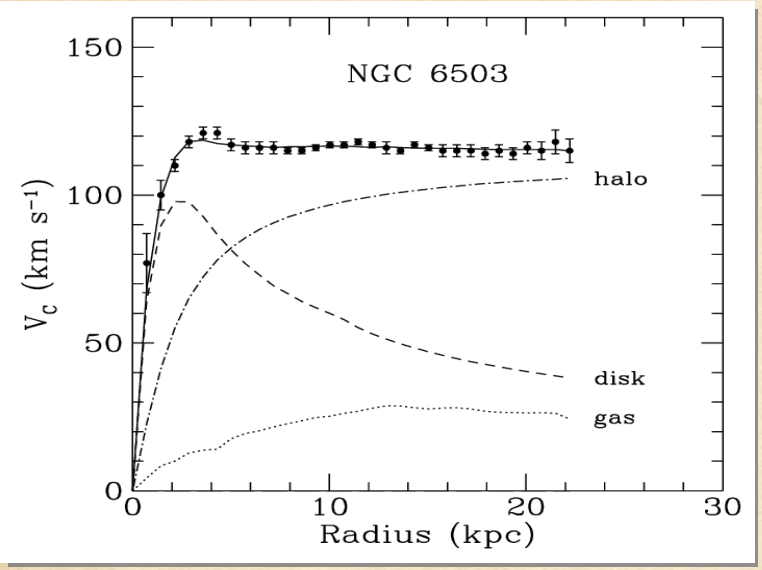
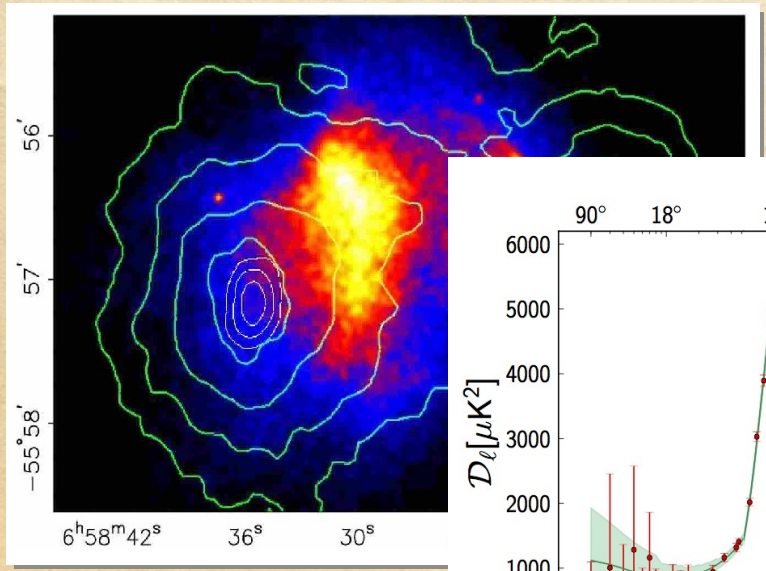
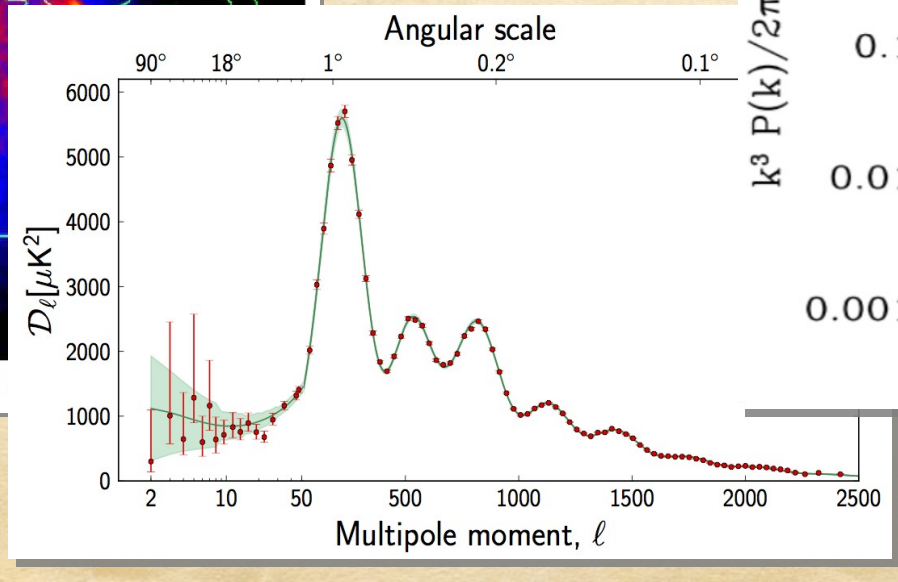
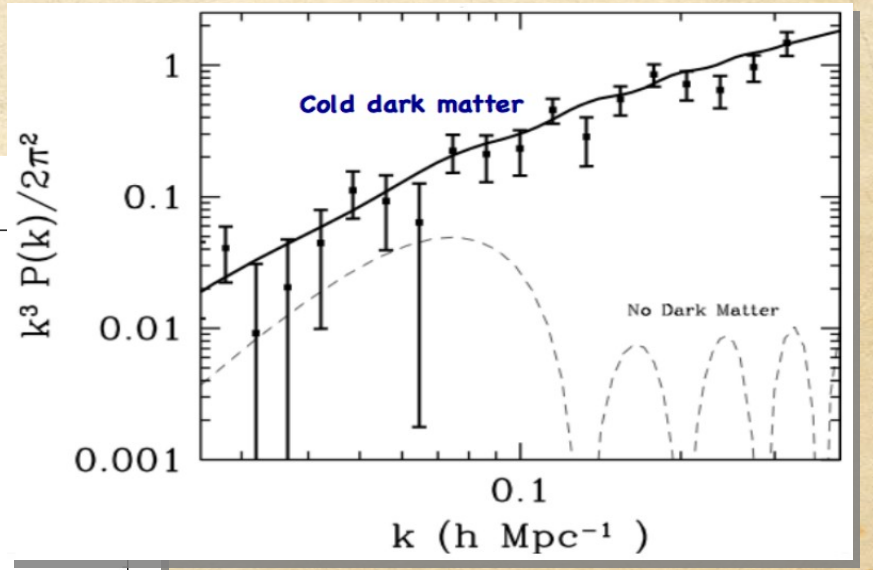
- I did my PhD at **TU Munich** (with Alejandro Ibarra), and finished in September this year
- Since the beginning of October, I'm a fellow in the DESY theory group

Topic of research (so far): dark matter





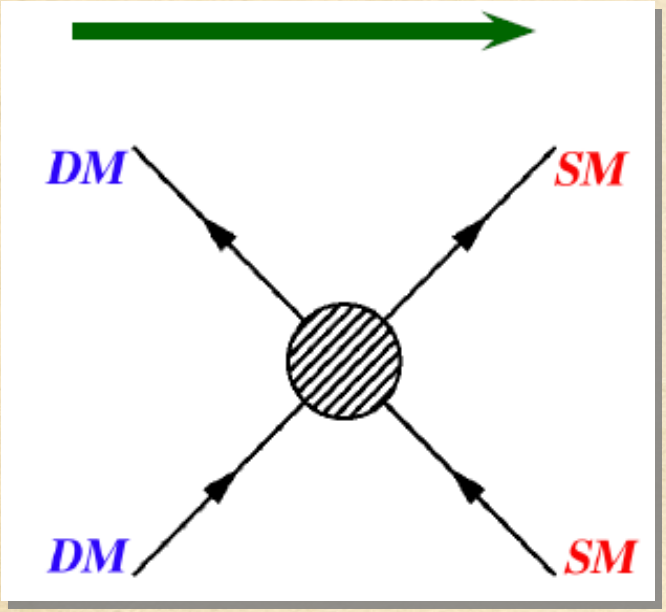


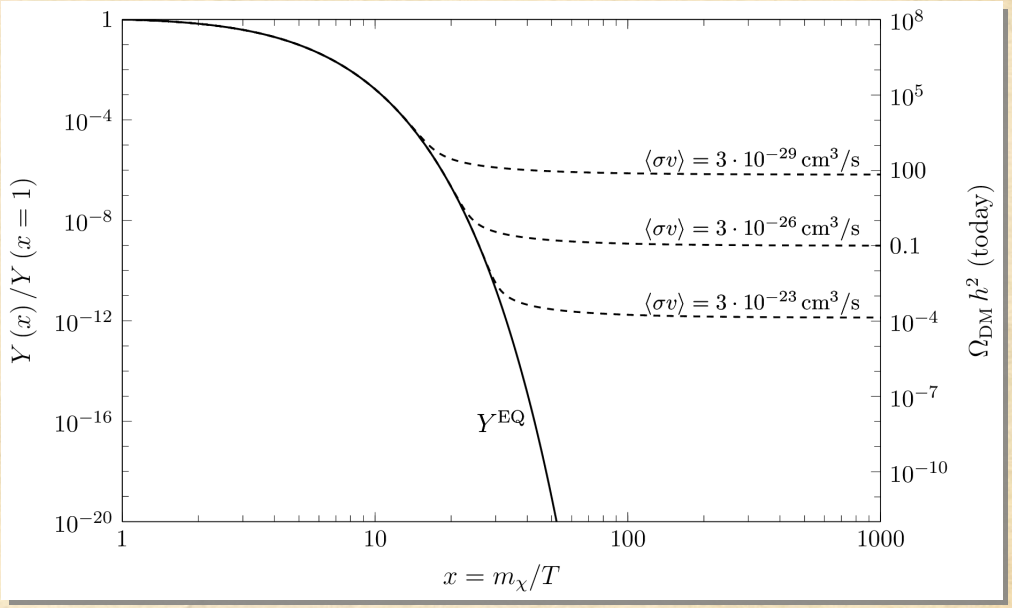


WIMP dark matter

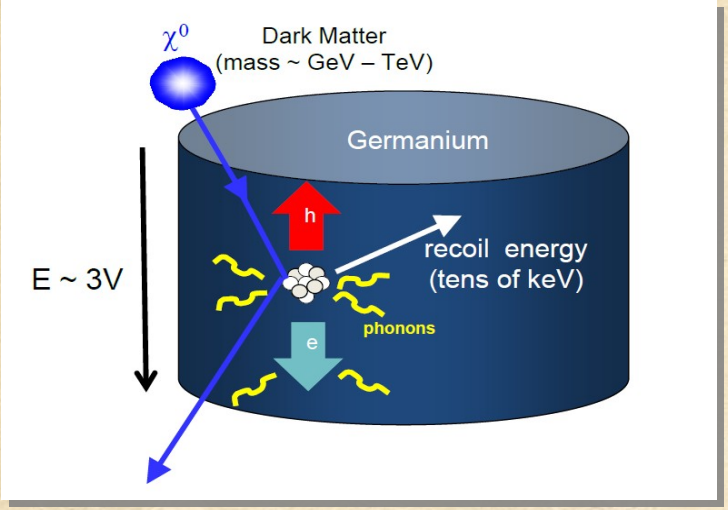
Hypothesis: 1) $m_{\rm DM} \simeq 1\,{\rm GeV} \ldots 100\,{\rm TeV}$

2) DM has weak-scale interactions with SM particles



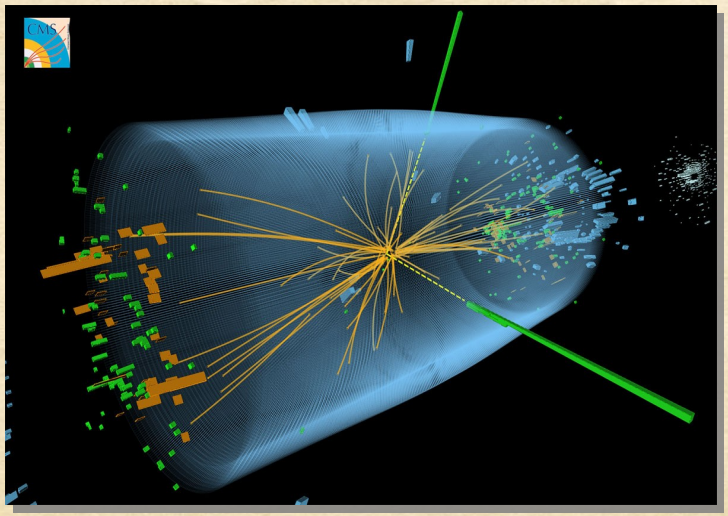


Detection of WIMPs



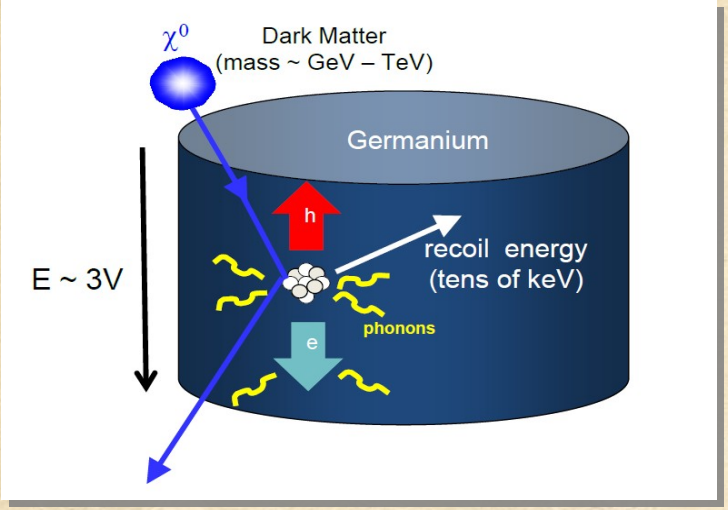
Direct detection:
DM + nucl. → DM + nucl.

Indirect detection:
DM + DM → SM + SM



Production at colliders:
SM + SM → DM + DM

Detection of WIMPs



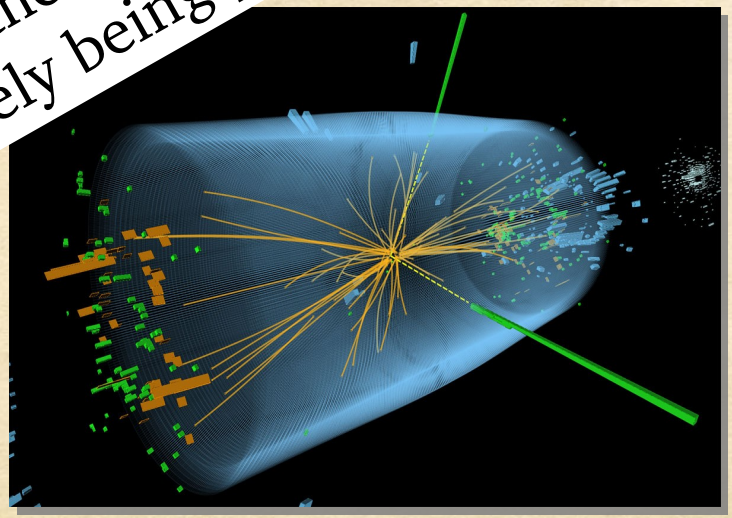
Direct detection:

DM + nucl. → DM + n

Indirect detection:

DM + DM → SM + SM

All of these techniques are nowadays actively being pursued by experiments!



Production at colliders:

SM + SM → DM + DM

I am working on...

Dark matter theory:
Simplified models, higher-order corrections,
connection to freeze-out history of DM, …

Dark matter phenomenology:
Comparing theory to experiments, re-analyzing experimental data,
astrophysical uncertainties, ...

(WIMP) dark matter is a very interdisciplinary field!
→ BSM theory and phenomenology, cosmology,
galactic and extragalactic astrophysics,
nuclear physics
→ tight connection between theory & experiments

Simplified models for dark matter

Idea: instead of looking at “full” models (MSSM, …), consider only the degrees of freedom which are **relevant for dark matter pheno**

→ typical setup: Standard Model + dark matter particle + one mediator
→ only a few new parameters!
→ ideal for **complementarity studies** between direct detection, indirect detection, and collider searches

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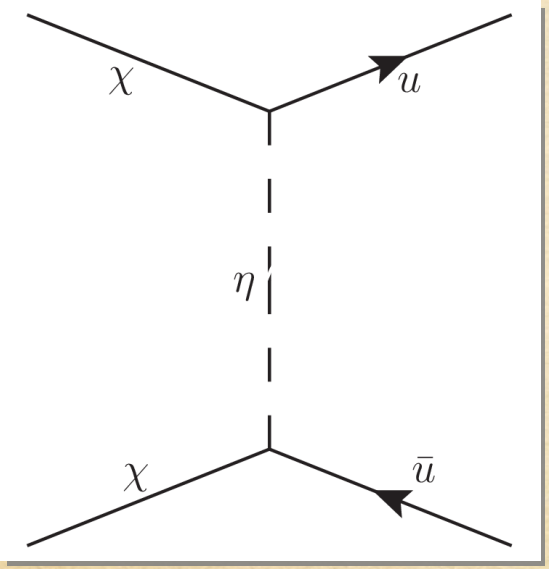
t-channel simplified models

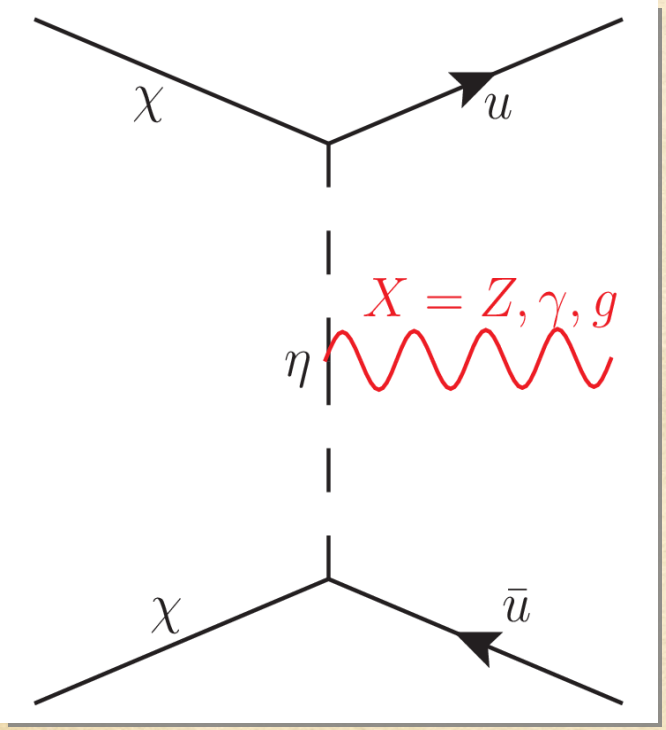


- Singlet DM particle (Dirac, Majorana, or scalar)
- Charged mediator (Scalar or Dirac)
- Yukawa coupling to one SM fermion

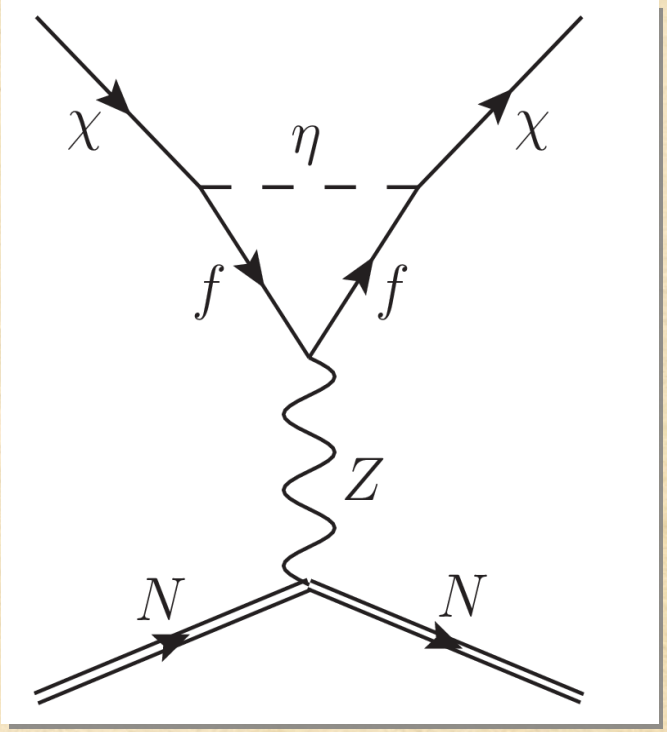
Collaborations with
Ibarra, Tytgat, Lopez-Honorez, Toma, Totzauer, Giacchino

Simplified models for dark matter

Particular focus of my work: impact of **higher-order corrections** on the phenomenology of the t-channel simplified models

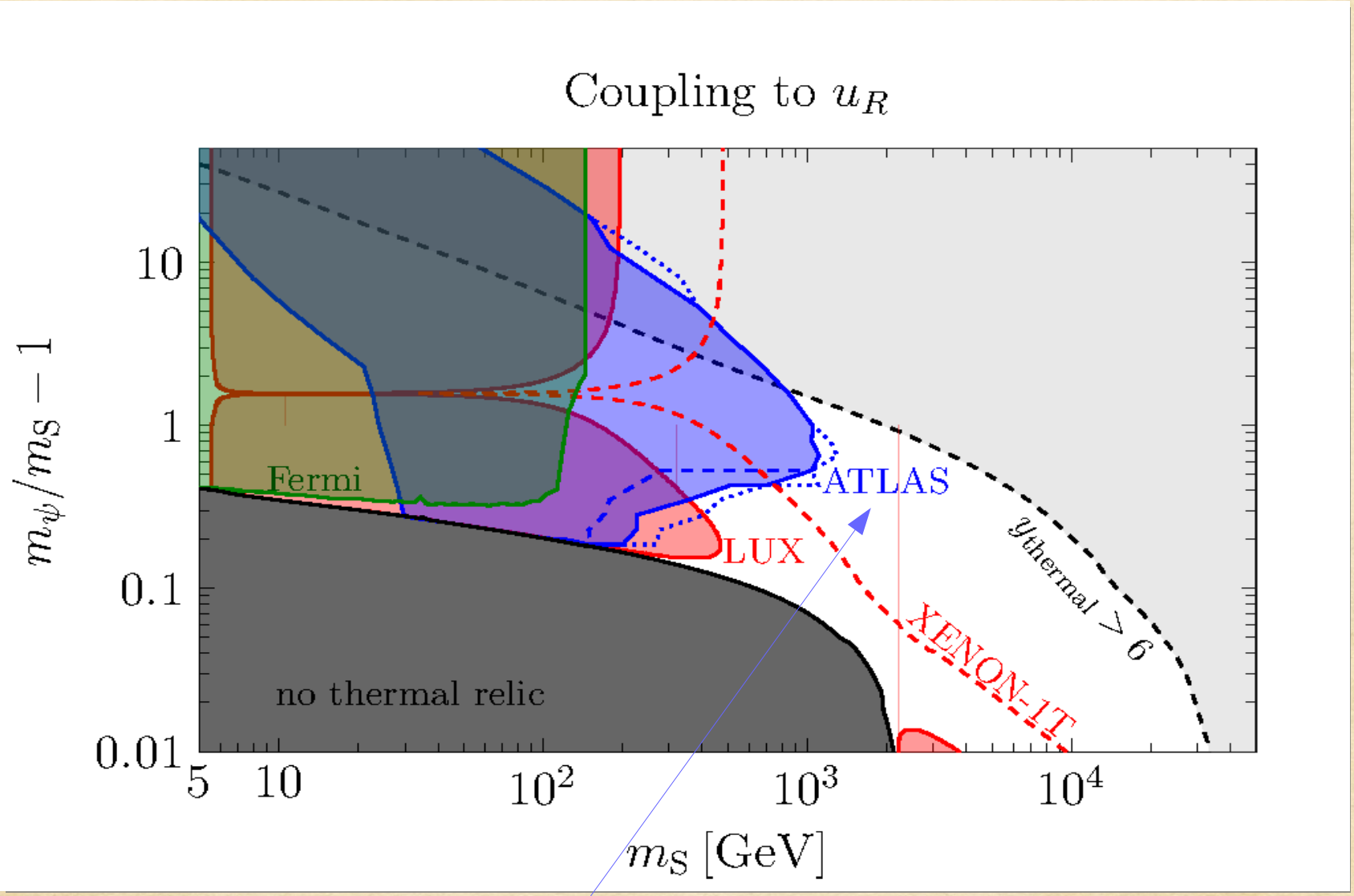


Gamma-ray spectral features



One-loop induced direct detection

Simplified models for dark matter

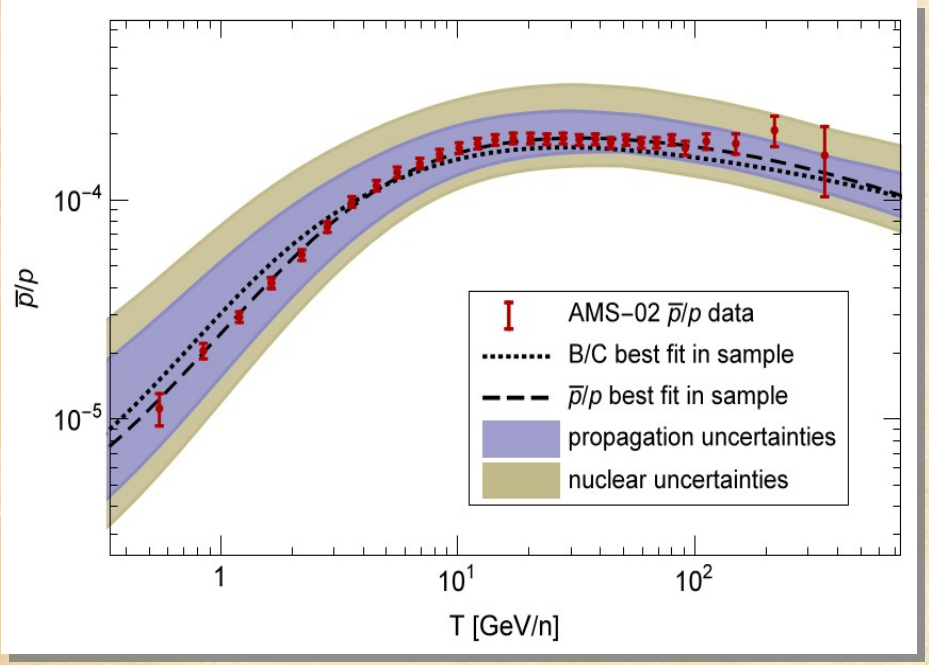


Using CheckMATE!

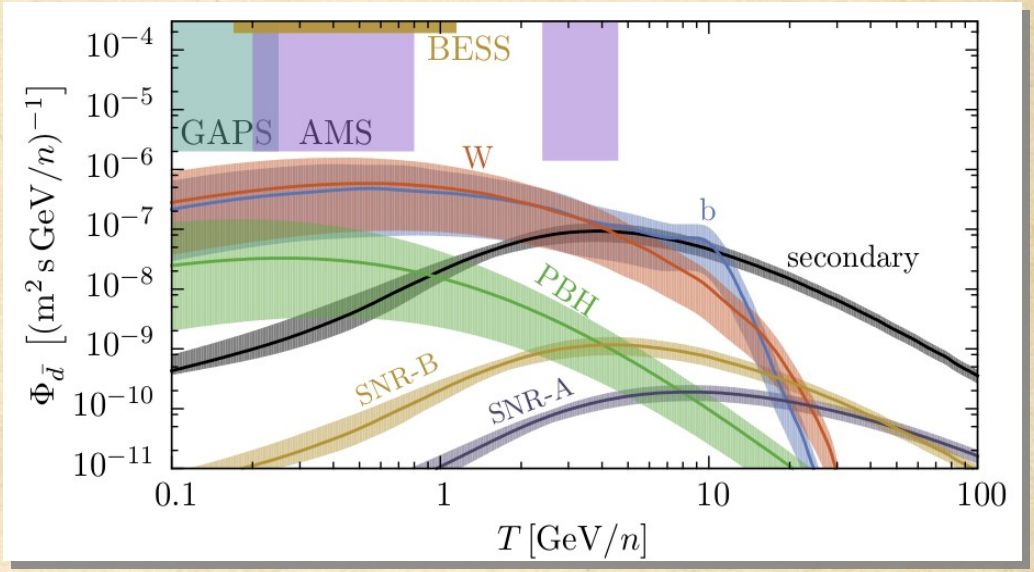
Indirect detection with cosmic ray antinuclei

$$\mathrm{DM\ DM} \to q, Z, W, \cdots \to p, \bar{p}, n, \bar{n}, \pi, \ldots$$

Kappl & Winkler [1506.04145]



SW+ [1610.00699]



Antiprotons:

- Data is compatible with background
- Difficult situation, hard to improve...

Antideuterons:

- Large signal-to-noise ratio
- Lower absolute flux
- Something to have in mind for the future!

even more crazy: antihelium from DM annihilations SW+ [1401.2461]

Halo-independent methods in direct detection

Generic problem for direct detection:

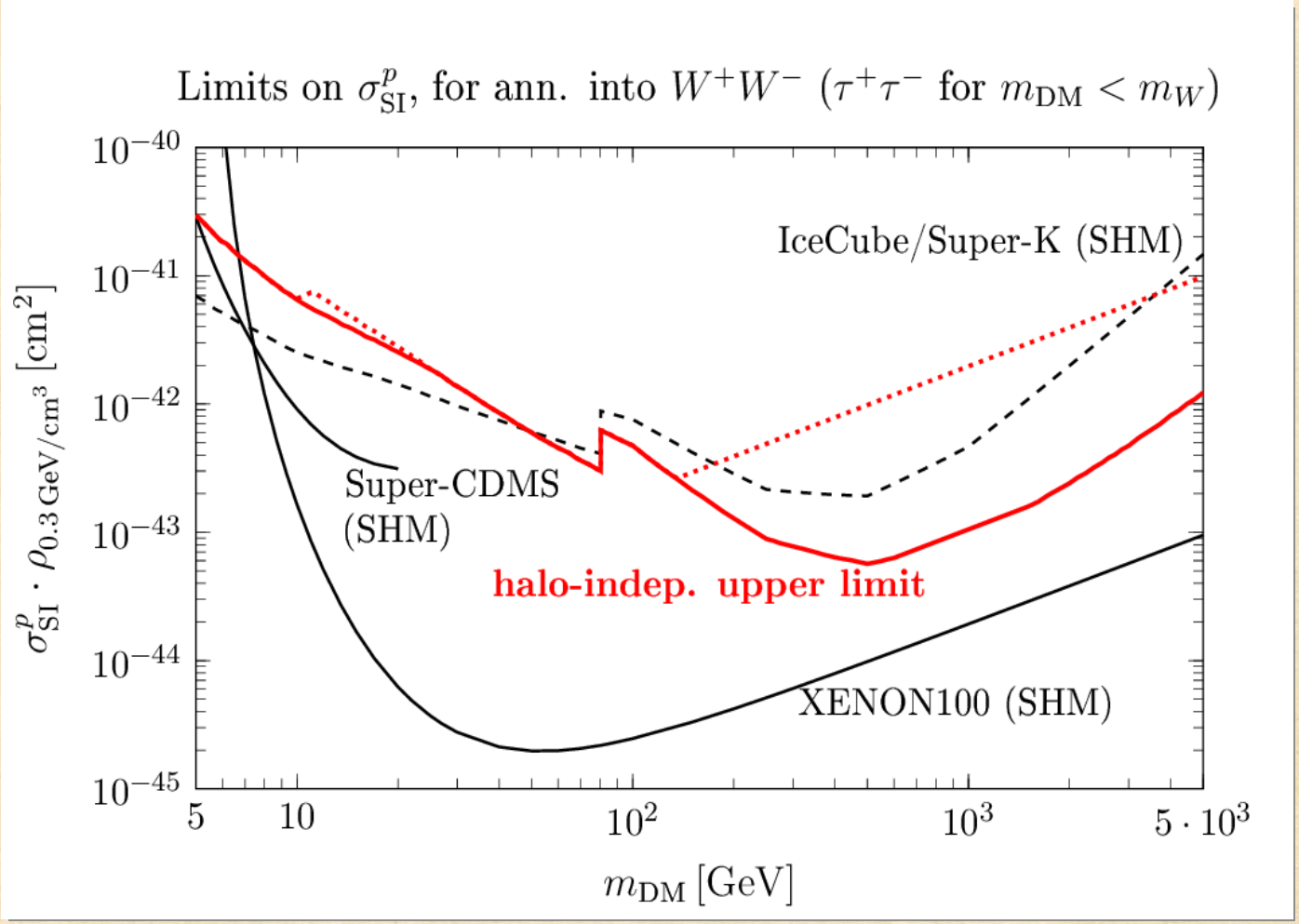
$$\frac{\mathrm{d}R}{\mathrm{d}E_R} = [\text{particle physics}] \times [\text{local DM velocity distribution}]$$

Recoil rate:
observable quantity

(basically) unknown...

Halo-independent methods: derive statements about the particle physics of DM, **without specifying the velocity distribution**
→ this is possible by combining information from several experiments

Halo-independent methods in direct detection



Collaborations with A. Ibarra, F. Ferrer, F. Kahlhoefer

GAMBIT

I am a member of the GAMBIT collaboration:

GAMBIT: The Global And Modular BSM Inference Tool

gambit.hepforge.org

- Fast definition of new datasets and theoretical models
- Plug and play scanning, physics and likelihood packages
- Extensive model database – not just SUSY
- Extensive observable/data libraries
- Many statistical and scanning options (Bayesian & frequentist)
- *Fast* LHC likelihood calculator
- Massively parallel
- Fully open-source

ATLAS	A. Buckley, P. Jackson, C. Rogan, M. White,
LHCb	M. Chrząszcz, N. Serra
Belle-II	F. Bernlochner, P. Jackson
Fermi-LAT	J. Conrad, J. Edsjö, G. Martinez, P. Scott
CTA	C. Balázs, T. Bringmann, J. Conrad, M. White
HESS	J. Conrad
IceCube	J. Edsjö, P. Scott
XENON/DARWIN	J. Conrad, R. Trotta
Theory	P. Athron, C. Balázs, T. Bringmann, J. Cornell, J. Edsjö, B. Farmer, T. Gonzalo, A. Fowlie, J. Harz, S. Hoof, F. Kahlhoefer, A. Krislock, A. Kvellestad, M. Pato, F.N. Mahmoudi, J. McKay, A. Raklev, R. Ruiz, P. Scott, R. Trotta, C. Weniger, M. White, S. Wild

31 Members, 9 Experiments, 4 major theory codes, 11 countries

Thank you!

P.S.: I'm sitting in building 2A, room 302
Step by for discussing at any time!