SUMMARY OF DARK MATTER WORKSHOPS

Caterina Doglioni – Lund University

Science Coffee, Lund University, 16/04/2015

OUTLINE OF THE WORKSHOPS

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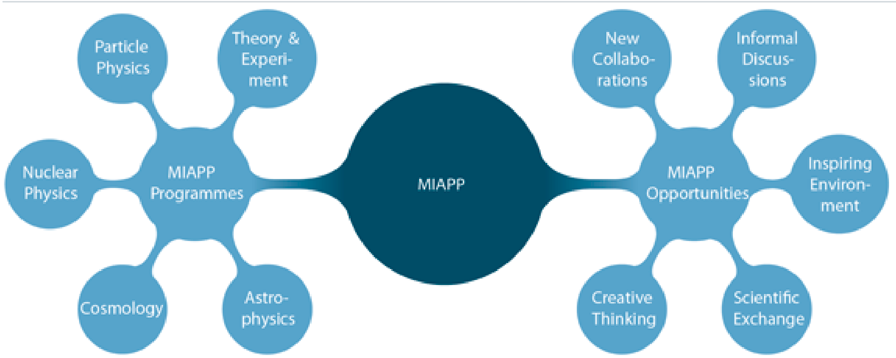
MIAPP: Dark MALT

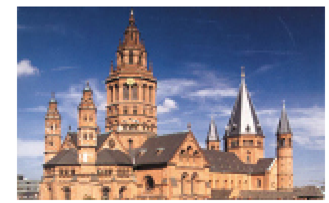


DARK MATTER: ASTROPHYSICAL PROBES, LABORATORY TESTS, AND THEORY ASPECTS (DARK MALT 2015)

Applied to discuss interplay between theory, collider and other experiments in DM

MITP: Effective Theories and DM

mitp Mainz Institute for Theoretical Physics



Invited by the organizers to present and discuss Run-1 ATLAS results on DM

This Science Coffee:

an ATLAS experimentalist's perspective on DM after presentations and discussions with theory/Direct Detection researchers

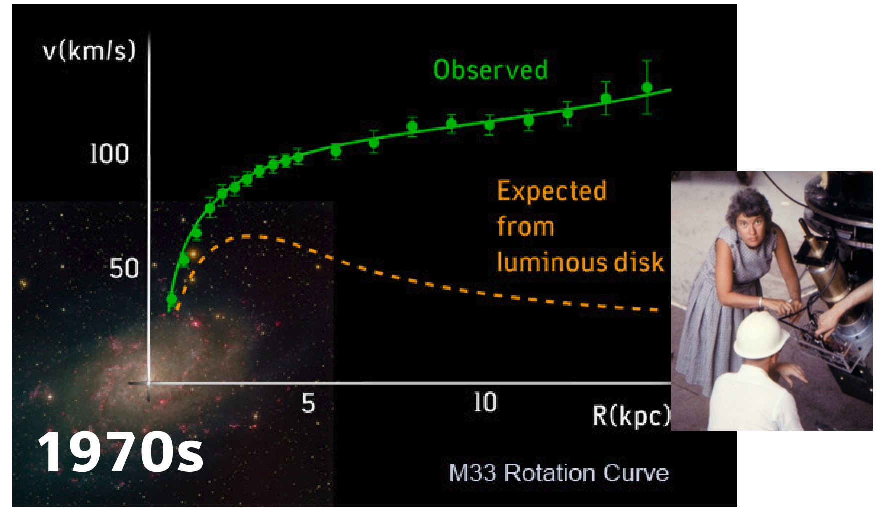
My (formal) interests in these workshops

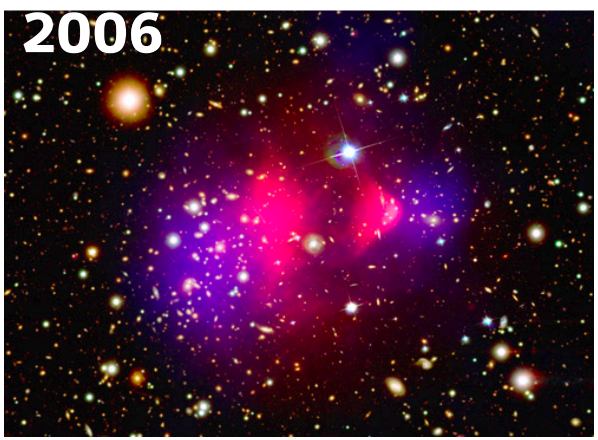
- ATLAS Astroparticle Forum:
  - Mandate:
    - Enhance contribution of ATLAS searches and measurements to open problems in cosmology and astrophysics
    - Perform joint measurements with other experiments towards answers to those problems
- ATLAS/CMS Dark Matter Forum
  - Mandate:
    - Agree upon benchmarks models for DM searches at ATLAS and CMS for the upcoming LHC run
    - Establish solid grounds of comparisons between experiments for Contact Interaction benchmark theories ("Effective Theories")

RECAP: WHAT WE KNOW ABOUT DARK MATTER

F. Zwicky – Coma cluster: mass vs light output

V. Rubin – Velocity of gas near Andromeda galaxy

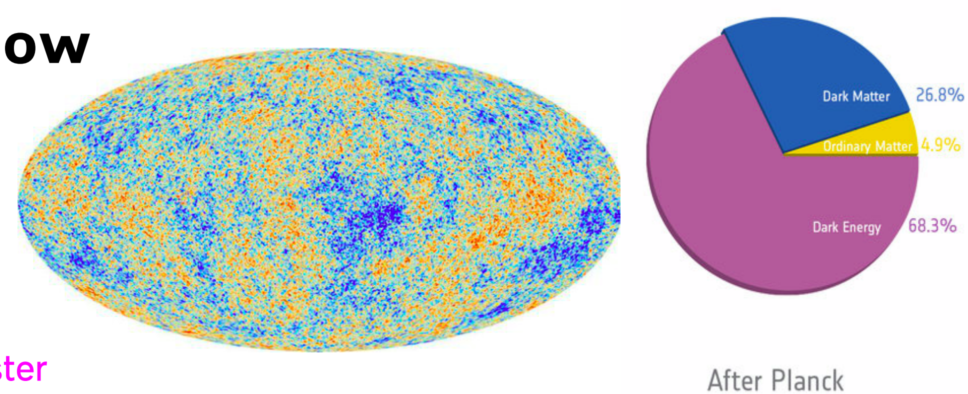




Chandra/Hubble (NASA) – Visible mass of bullet cluster vs dark mass inferred from gravitational lensing

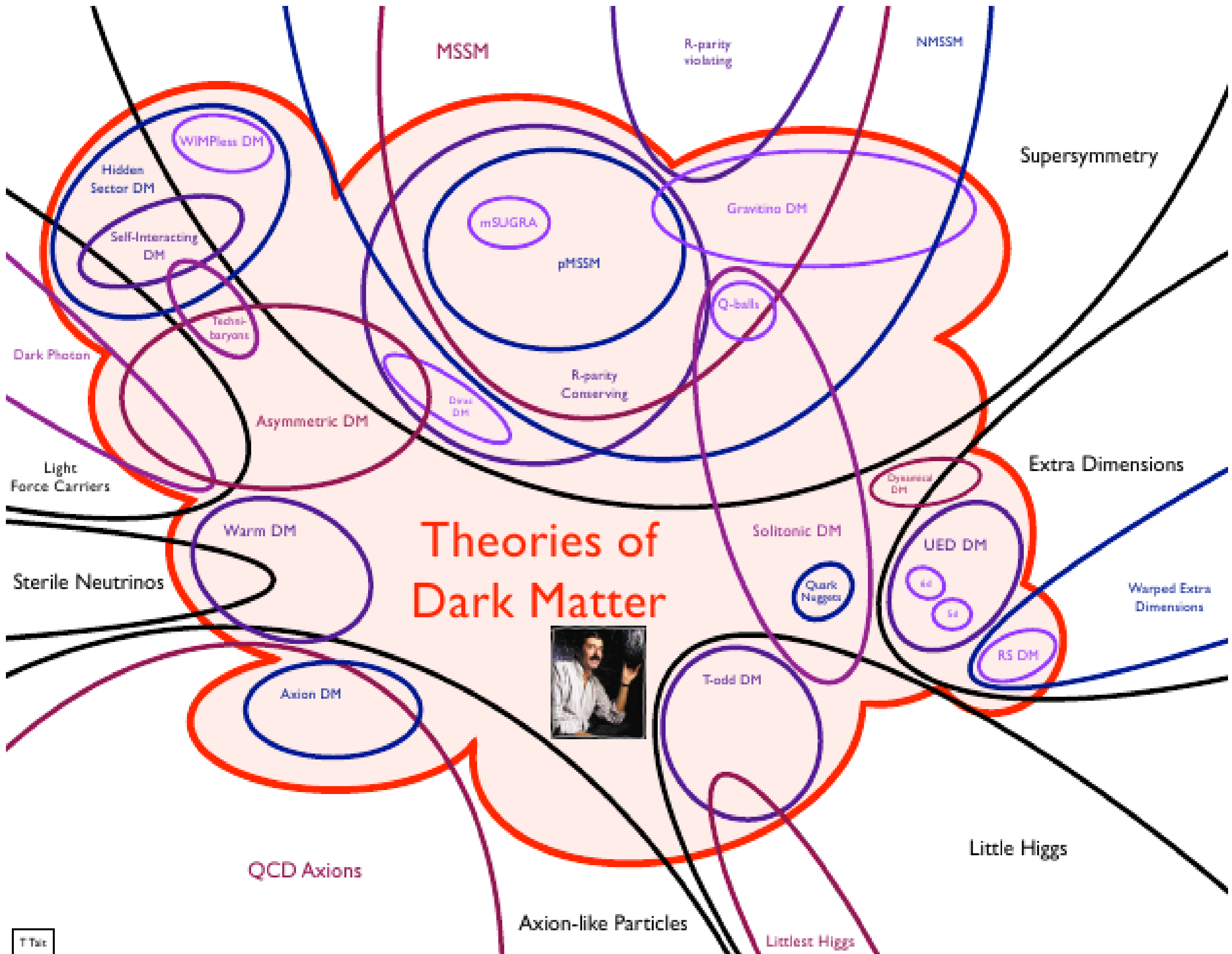
Planck – Dark matter vs standard matter composition using CMB (temperature) fluctuations

2013 -now



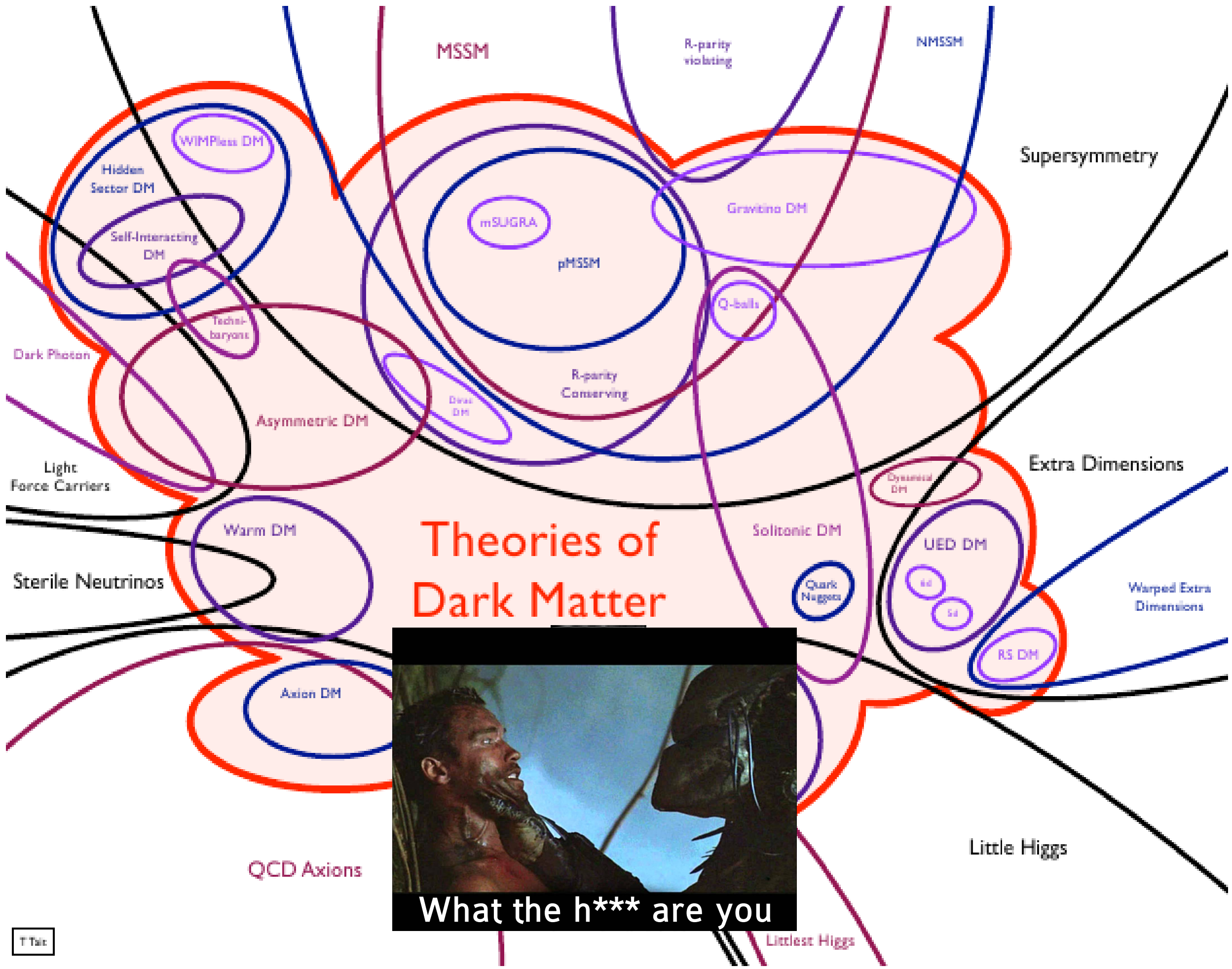
WHAT WE DON'T KNOW ABOUT DARK MATTER

Tim Tait, DM@LHC 2013



WHAT WE DON'T KNOW ABOUT DARK MATTER

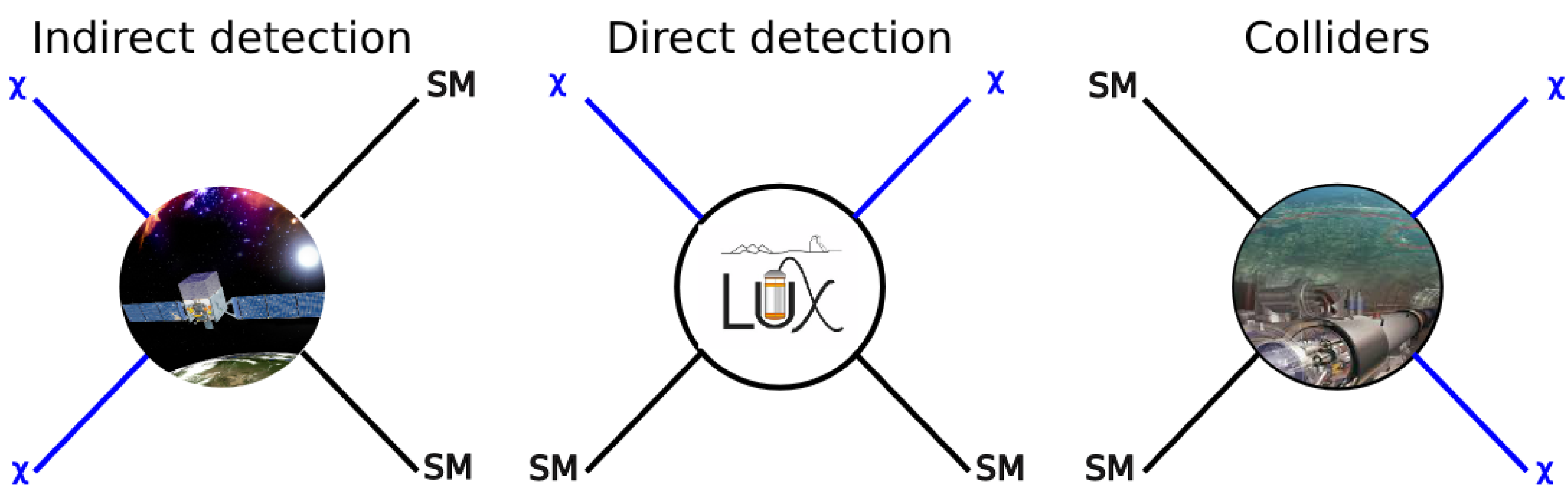
[Tim Tait, DM@LHC 2013]



WHAT WE WOULD LIKE DARK MATTER TO BE

(Our) **preferred DM candidate**
matches cosmological observations (e.g. thermal relic density):
dark, stable, cold, weakly interacting with SM
particles, mass of up to a few TeV → a **WIMP**

Complementarity between different experiments:



KEEPING OUR MINDS OPEN

http://en.wikipedia.org/wiki/Streetlight_effect

A story that an Iranian neutrino physicist told me during one lunch at MIAPP: (credits also to A. Boveia)

One late evening Nasreddin found himself walking home. It was only a very short way and upon arrival he can be seen to be upset about something. Alas, just then a young man comes along and sees the Mullah's distress.

"Mullah, pray tell me: what is wrong?"

"Ah, my friend, I seem to have lost my keys. Would you help me search them? I know I had them when I left the tea house."

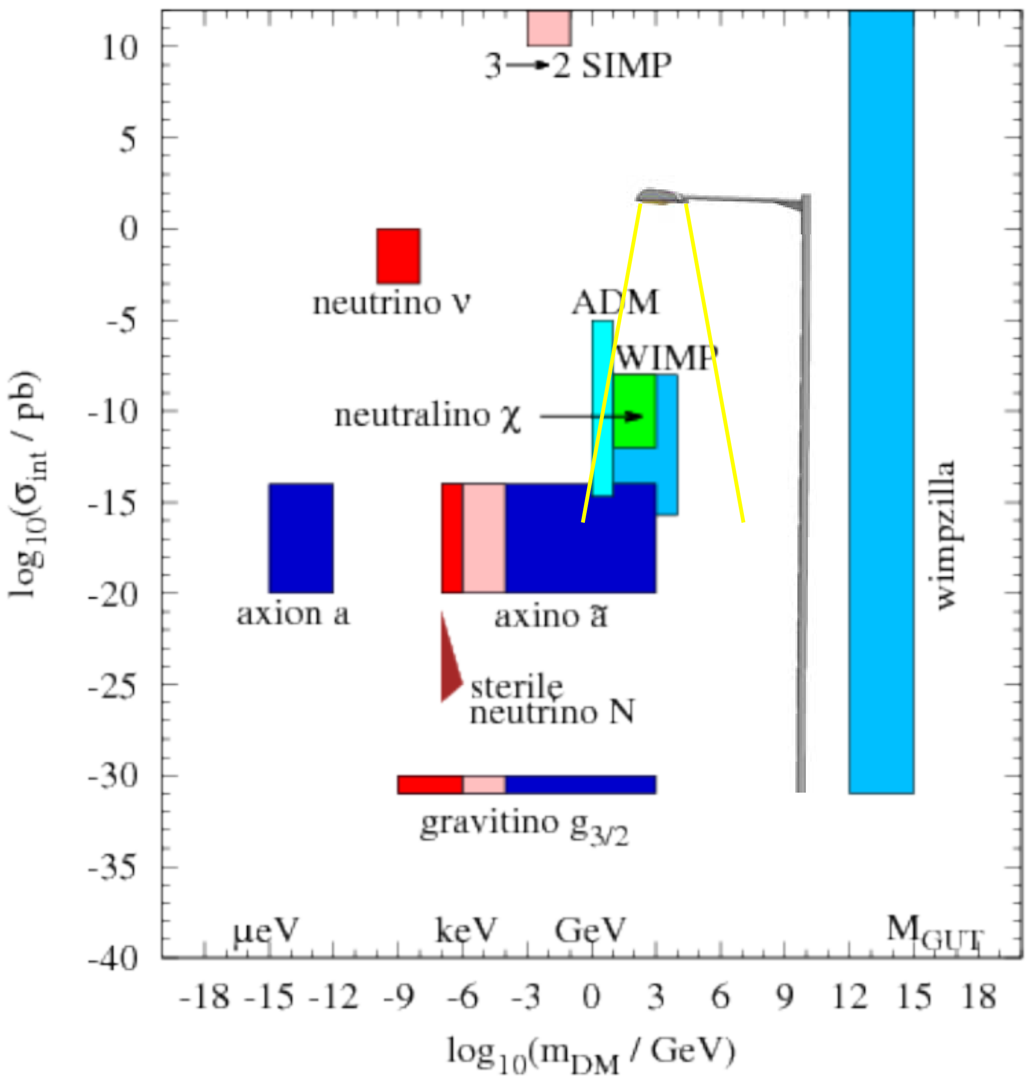
So, he helps Nasreddin with the search for the keys. For quite a while the man is searching here and there but no keys are to be found. He looks over to Nasreddin and finds him searching only a small area around a street lamp.

"Mullah, why are you only searching there?"

"Why would I search where there is no light?"

"Nasreddin (17th-century miniature)"
Topkapi Palace Museum Library

SEARCHING FOR DM UNDER/AWAY FROM STREETLIGHTS



Another workshop needed:
http://tomerv.wix.com/lightdm

Selected topics in today's talk:

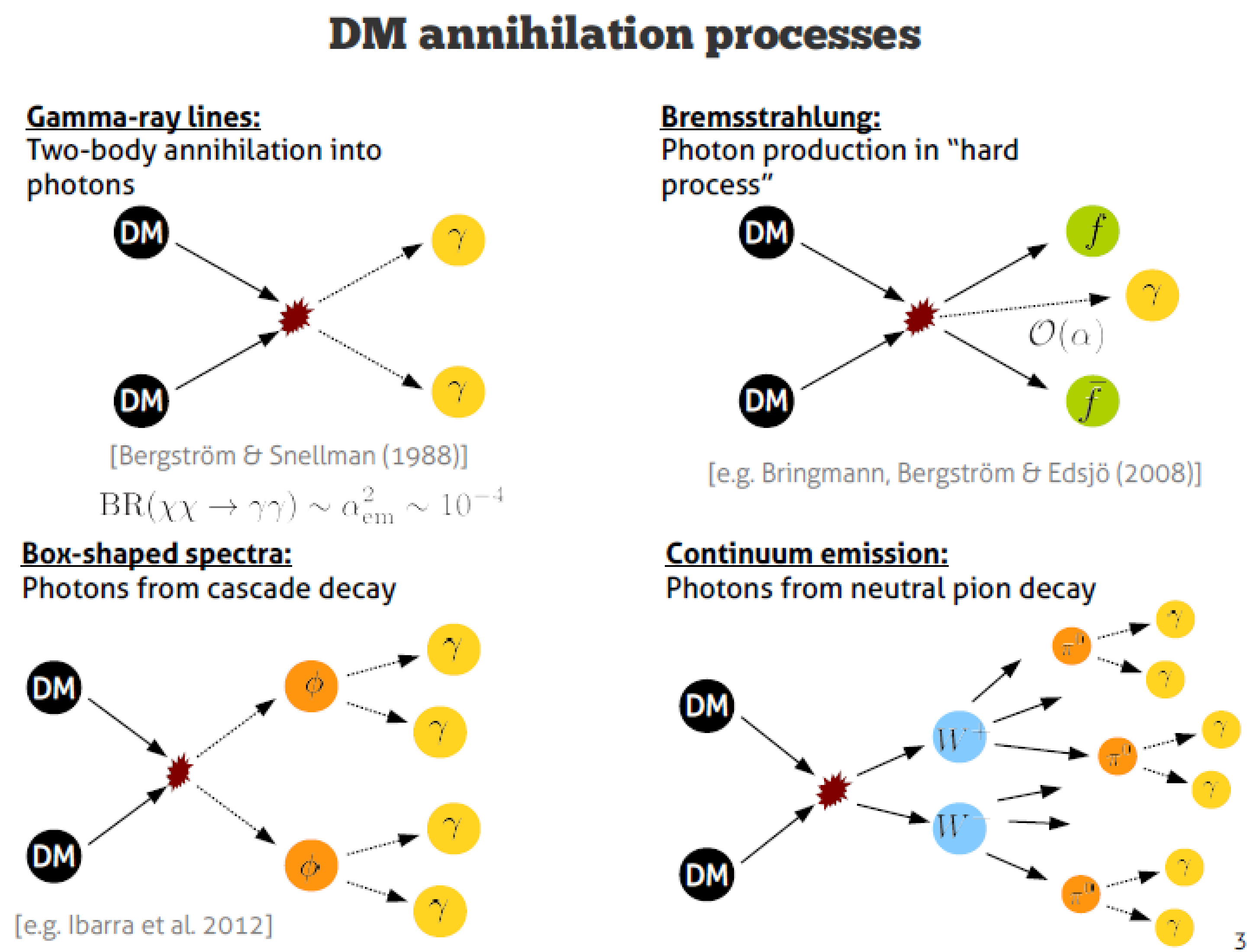
- Interpretation of hints from the galaxy
  - Galaxy center photon excess
  - 3.5 keV photon line
- Details of WIMP dark matter
  - Comparison of Colliders and Direct Detection experiments
    - Contact interactions and their validity
    - Low-WIMP-mass results from CRESST
  - Searches for DM (and mediators) at colliders

HINTS FROM THE GALAXY ?

Slides and pictures taken from:

- C. Weniger - Annihilation Phenomenology (MITP Workshop)
- C. Weniger - Fermi Gamma Ray Excess (MIAPP workshop)
- H. Min Lee - SUSY Higgs portal and gamma-ray lines (MIAPP workshop)

PHOTONS FROM DARK MATTER



C. Weniger

WHERE/HOW TO LOOK FOR PHOTONS FROM DM

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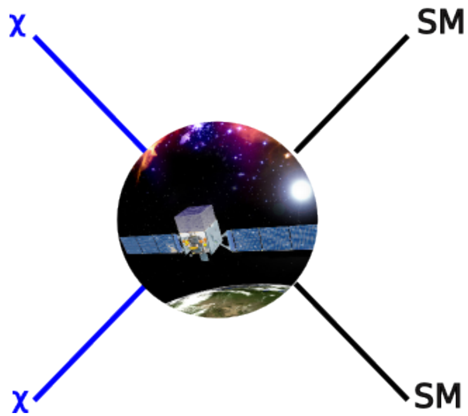
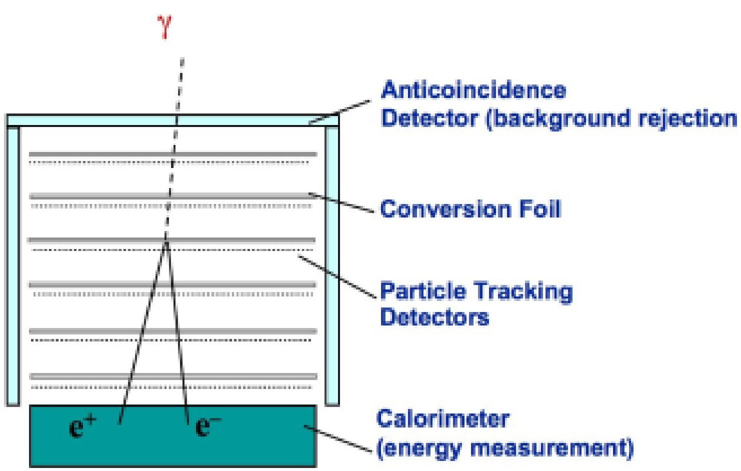
Fermi Large Area Telescope

https://www-glast.stanford.edu/

Indirect detection





Dark Matter annihilates in _the GC / dwarf galaxies_ to
a place
photons , which are detected by _Fermi, HESS, ..._ .
some particles — an experiment

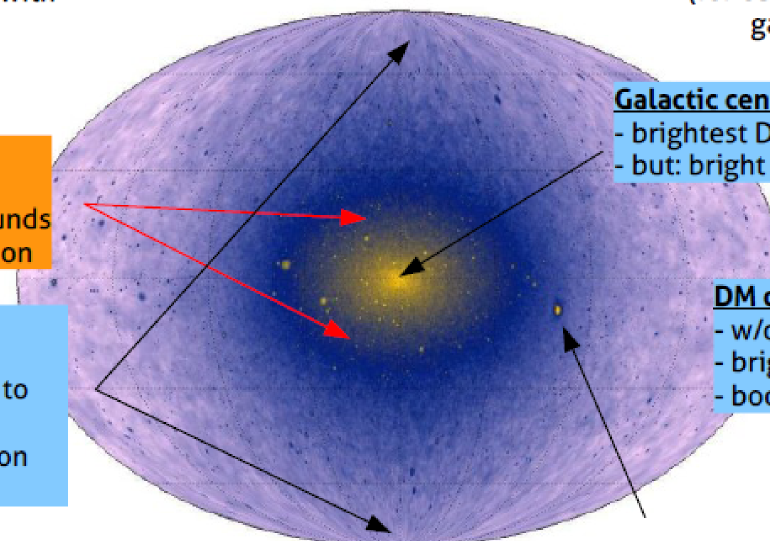
Potential targets for searches with photons

Signal is approx. proportional to column square density of DM:

$$\propto \int_{\mathrm{l.o.s.}} ds\, \rho^2_{\mathrm{DM}}$$

Extended or diffuse:
(for observations with gamma rays)

Point-like:
(for observations with gamma rays)



Galactic DM halo
- good S/N
- difficult backgrounds
- angular information

Extragalactic
- nearly isotropic
- only visible close to Galactic poles
- angular information
- Galaxy clusters?

Galactic center (~8.5 kpc)
- brightest DM source in sky
- but: bright backgrounds

DM clumps
- w/o baryons
- bright enough?
- boost overall signal

Dwarf Spheroidal Galaxies
- harbour small number of stars
- otherwise dark (no gamma-ray emission)

[review on N-body simulations: Kuhlen, Vogelsberger & Angulo (2012)]

C. Weniger

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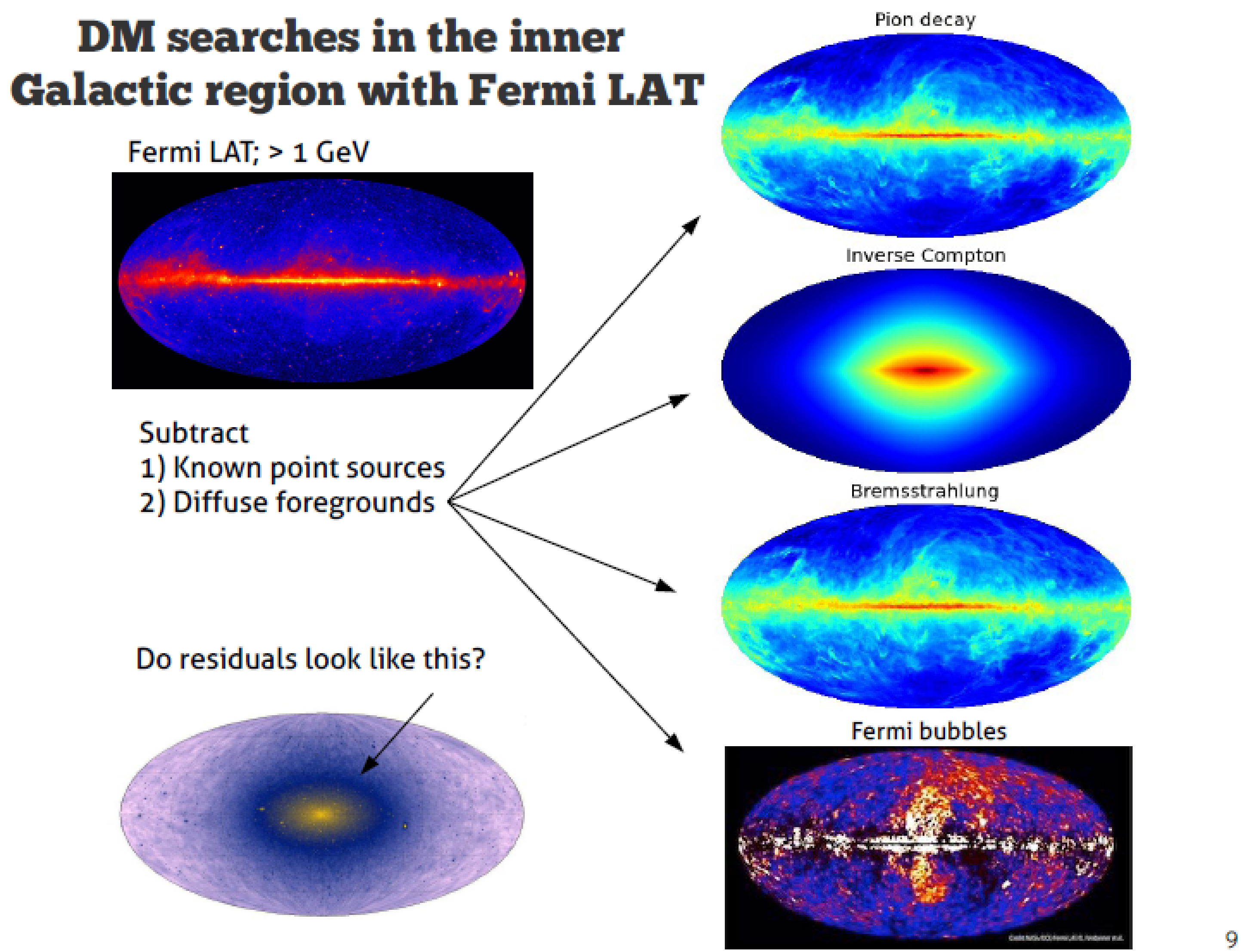
ATLAS EXPERIMENT

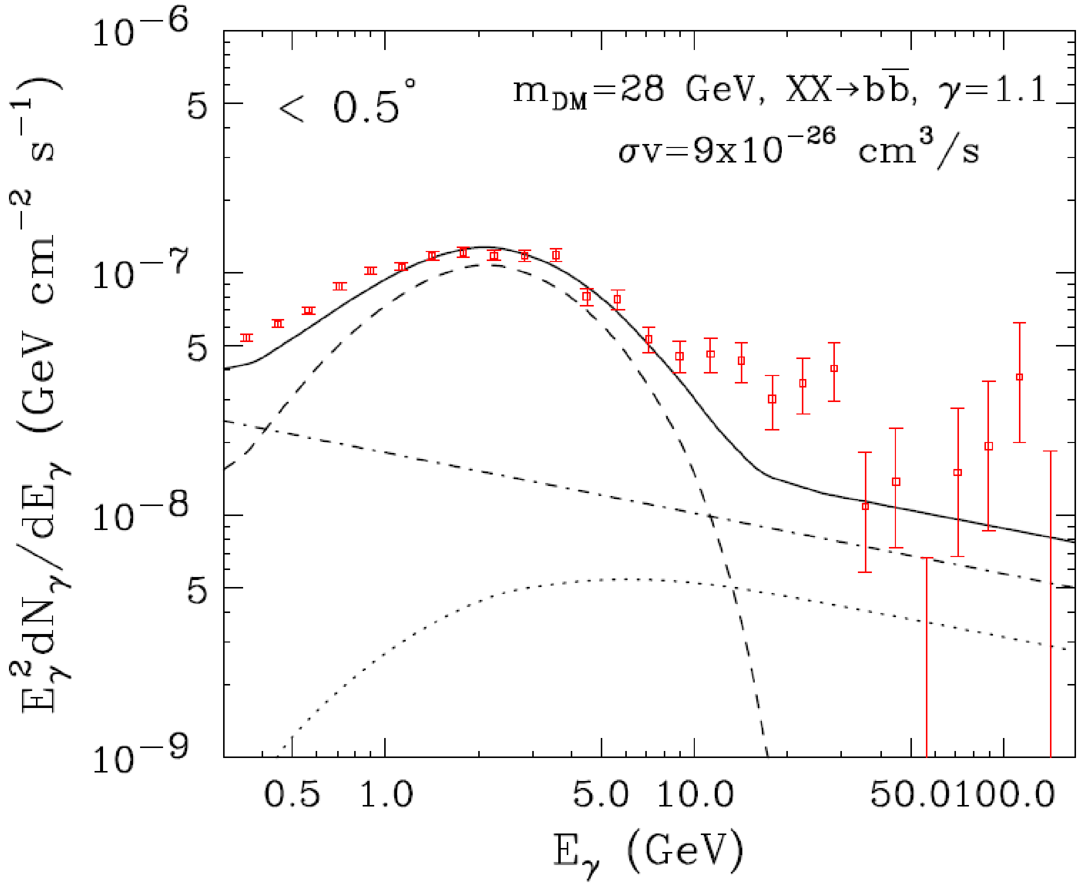
SEARCHES IN THE CENTER OF GALAXY, IN A NUTSHELL



C. Weniger

HISTORY AND CHARACTERIZATION OF AN EXCESS

First paper: http://arxiv.org/abs/1010.2752



Residuals can be fitted with signal from **DM annihilation into b-quarks** → fueled b-flavored Dark Matter models

More recent analysis presented at MITP workshop: http://arxiv.org/abs/1409.0042

Channel	$\langle\sigma v\rangle$ (10^{-26} cm^3 s^{-1})	m_χ (GeV)	χ^2_{min}	p-value
$\bar{q}q$	$0.83^{+0.15}_{-0.13}$	$23.8^{+3.2}_{-2.6}$	26.7	0.22
$\bar{c}c$	$1.24^{+0.15}_{-0.15}$	$38.2^{+4.7}_{-3.9}$	23.6	0.37
$\bar{b}b$	$1.75^{+0.28}_{-0.26}$	$48.7^{+6.4}_{-5.2}$	23.9	0.35
$\bar{t}t$	$5.8^{+0.8}_{-0.8}$	$173.3^{+2.8}_{-0}$	43.9	0.003
gg	$2.16^{+0.35}_{-0.32}$	$57.5^{+7.5}_{-6.3}$	24.5	0.32
W^+W^-	$3.52^{+0.48}_{-0.48}$	$80.4^{+1.3}_{-0}$	36.7	0.026
ZZ	$4.12^{+0.55}_{-0.55}$	$91.2^{+1.53}_{-0}$	35.3	0.036
hh	$5.33^{+0.68}_{-0.68}$	$125.7^{+3.1}_{-0}$	29.5	0.13
$\tau^+\tau^-$	$0.337^{+0.047}_{-0.048}$	$9.96^{+1.05}_{-0.91}$	33.5	0.055
[$\mu^+\mu^-$	$1.57^{+0.23}_{-0.23}$	$5.23^{+0.22}_{-0.27}$	43.9	0.0036]

UPDATED STUDY OF THE EXCESS

http://arxiv.org/abs/1409.0042
http://arxiv.org/abs/1411.4647

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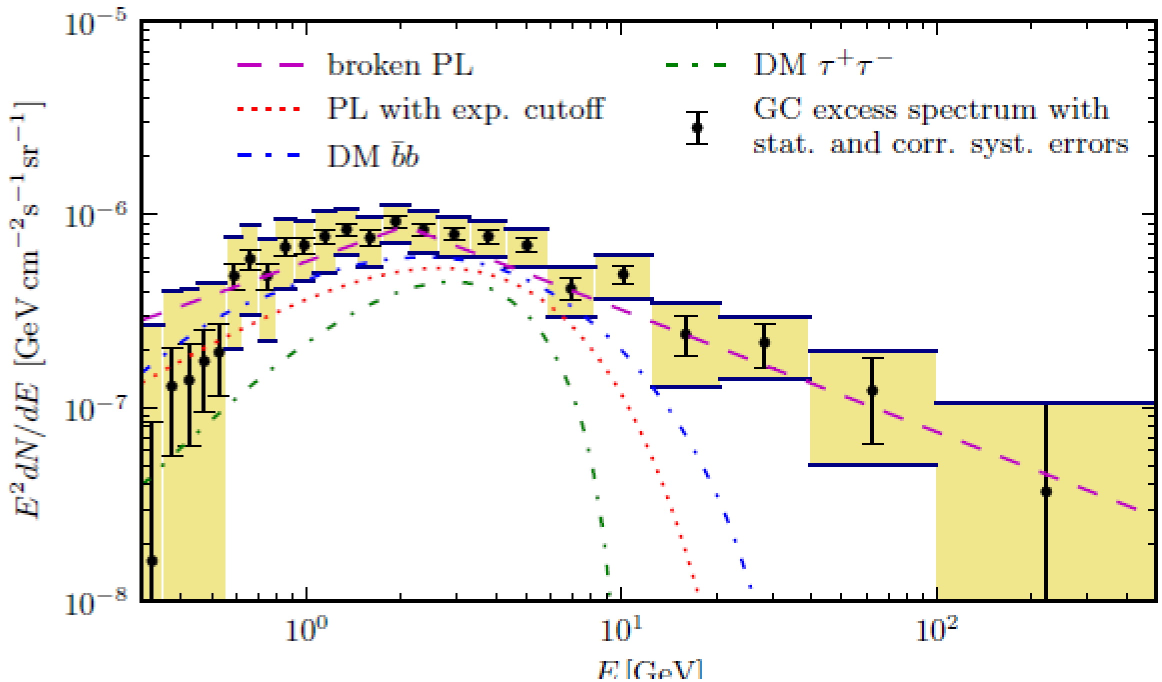
- Excess morphology:
  - Excess is spherical, uniform, behaves like a power law
- Uncertainties on spectrum:
  - New estimation of theoretical and empirical systematics
  - Treatment of correlated uncertainties in fits
- Characterization of excess in terms of DM annihilation:
  - Good fit for gluon and (heavy) quark final states, but preference for higher DM masses wrt previous studies
  - Exclusion of WW/ZZ-annihilating DM (w/caveats), but not HH
  - Not excluded: point sources, lepton burst events

ATLAS EXPERIMENT

EXAMPLE RESULTS: FITS WITH UNCERTAINTIES

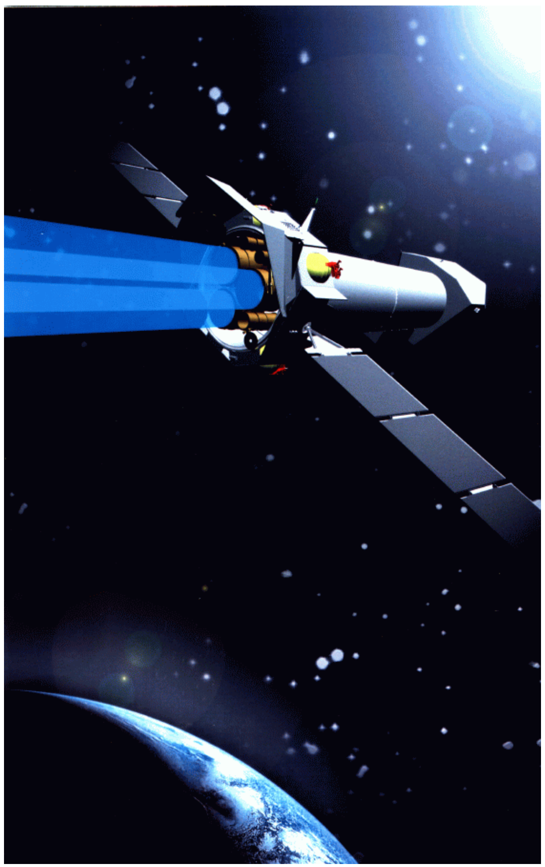


Spectrum	Parameters	χ^2/dof	p-value
broken PL	$\alpha_1 = 1.42^{+0.22}_{-0.31}$, $\alpha_2 = 2.63^{+0.13}_{-0.095}$, $E_{\rm break} = 2.06^{+0.23}_{-0.17}$ GeV	1.06	0.39
DM $\chi\chi \to \bar{b}b$	$\langle\sigma v\rangle = 1.76^{+0.28}_{-0.27} \times 10^{-26}$ cm^3 s^{-1}, $m_\chi = 49^{+6.4}_{-5.4}$ GeV	1.08	0.36
DM $\chi\chi \to \bar{c}c$	$\langle\sigma v\rangle = 1.25^{+0.2}_{-0.18} \times 10^{-26}$ cm^3 s^{-1}, $m_\chi = 38.2^{+4.6}_{-3.9}$ GeV	1.07	0.37
PL with exp. cutoff	$E_{\rm cut} = 2.53^{+1.1}_{-0.77}$ GeV, $\alpha = 0.945^{+0.36}_{-0.5}$	1.37	0.12
DM $\chi\chi \to \tau^+\tau^-$	$\langle\sigma v\rangle = 0.337^{+0.047}_{-0.048} \times 10^{-26}$ cm^3 s^{-1}, $m_\chi = 9.96^{+1.1}_{-0.91}$ GeV	1.52	0.06

SEARCHING FOR X-RAY LINES

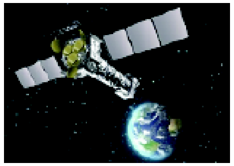
XMM Newton

http://xmm.esac.esa.int/



H. Minh Lee **Signal samples**

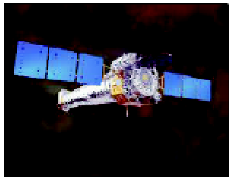
- Bulbul et al [XMM-Newton]



  - Perseus cluster
  - Nearby clusters: Coma, Centaurus, Ophiuchus
  - All stacked 73 galaxy clusters

  ➡ $E = 3.55 - 3.57 \pm 0.03\,\mathrm{keV}$ at $\gtrsim 3\sigma$.

  [Chandra] excess from Perseus, no line from Virgo cluster.



- Boyarsky et al [XMM-Newton]
  - Perseus cluster
  - Andromeda galaxy (M31)

  ➡ $E \sim 3.5\,\mathrm{keV}$

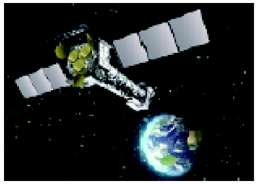
15년 2월 22일 일요일

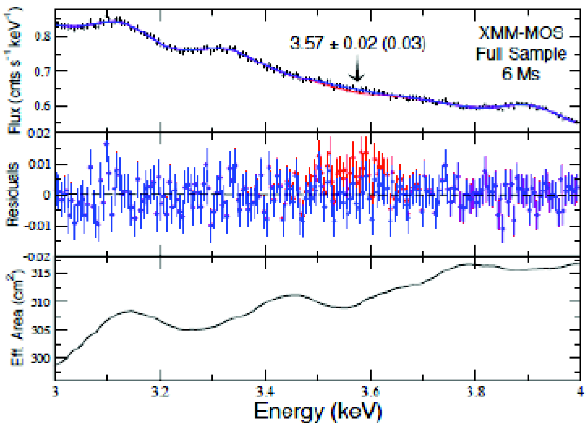
THE X-RAY LINE AT 3.55 KEV

X-ray line from galaxies

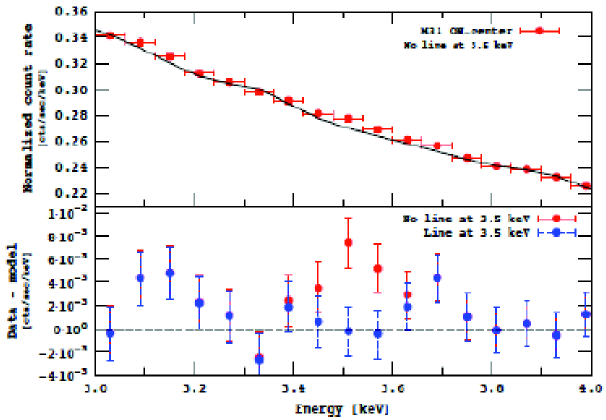
H. Minh Lee

- Monochromatic photon lines probe well indirect signals of dark matter due to directional information.
- X-ray spectra (XMM-Newton) of various galaxy clusters and Andromeda show an unidentified line signal at **3.55** keV at ~4σ.





[Bulbul et al, 1402.2301]



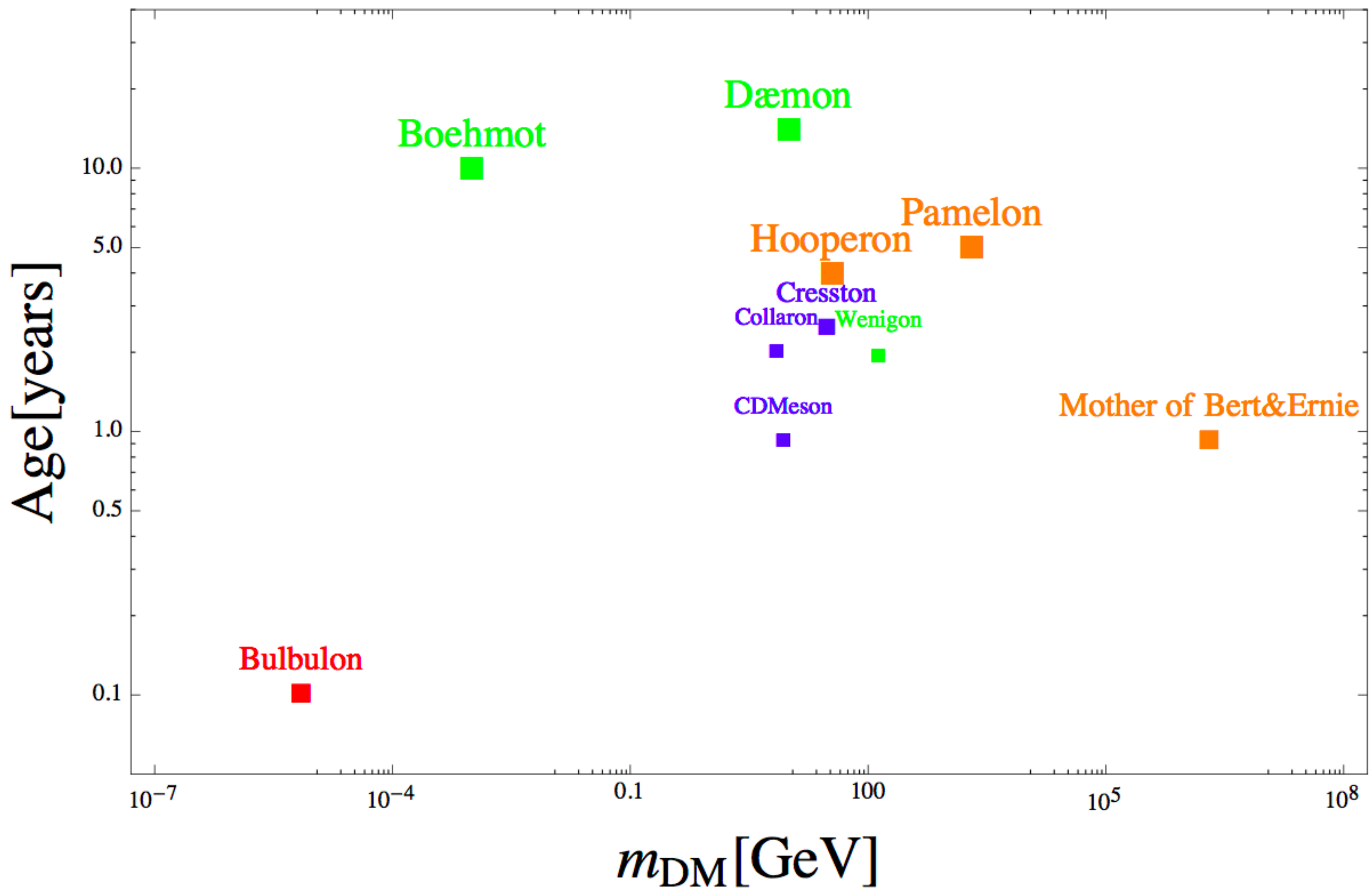
[Boyarsky et al, 1402.4119; 1408.2503 (also Milky way)]

15년 2월 22일 일요일

Possible interpretations: Sterile neutrinos, Axion-like scalars, Magnetic DM, SUSY Higgs-portal models...or none of them? http://arxiv.org/abs/1408.1699

FUN FROM A POPULAR HEP BLOG...

http://resonaances.blogspot.com.br/2014/03/weekend-plot-all-of-dark-matter.html



WIMP DARK MATTER

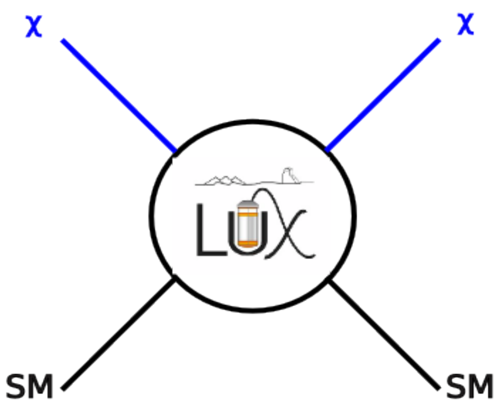
- Slides and pictures taken from:
- R. Strauss - CRESST low-mass results (MIAPP Workshop)
- Discussion on DM at colliders (MITP workshop)
- Mini-workshop on DM at colliders (MIAPP Workshop)

CRESST DIRECT DETECTION IN A NUTSHELL

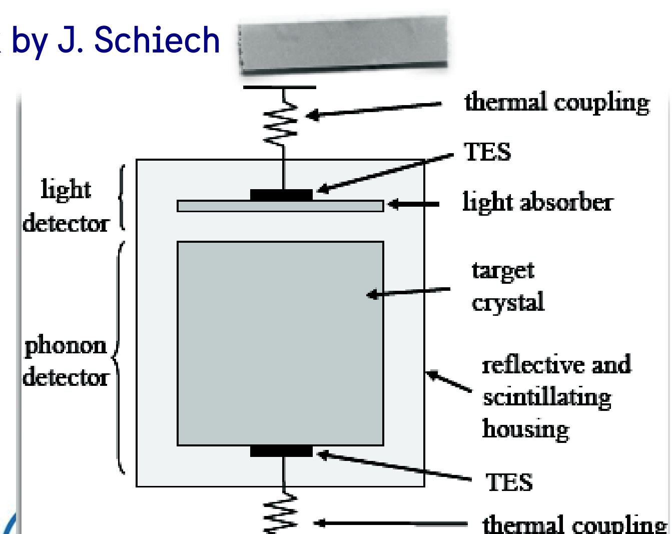
CRESST

http://www.cresst.de/exp_overview.php

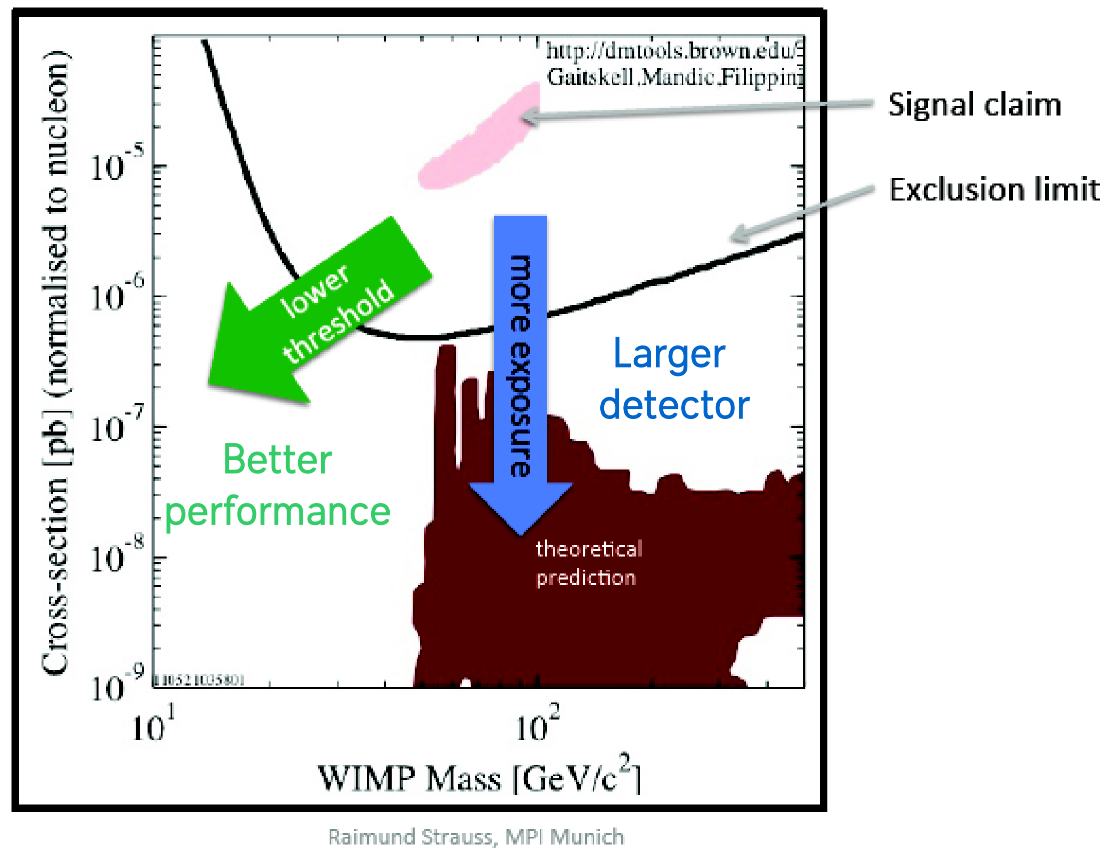
Direct detection



Talk by J. Schiech



Exclusion Plot – Comparison of Results



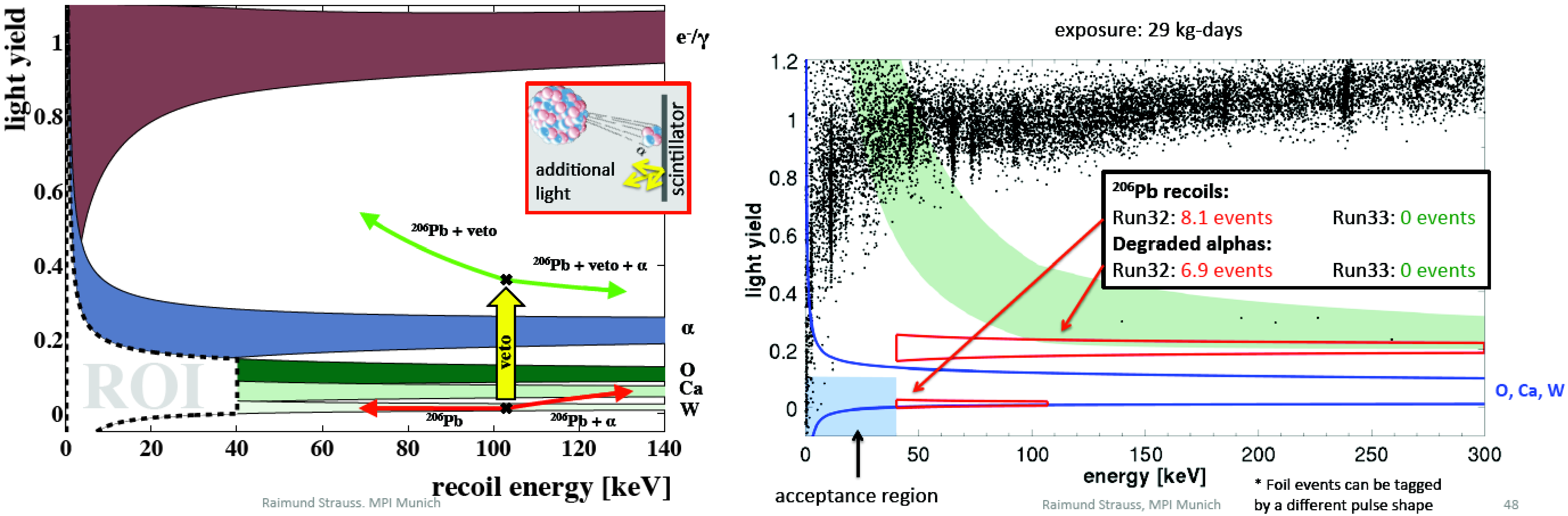
R. Strauss

DETECTOR IMPROVEMENTS FOR LOW-MASS SEARCH

http://arxiv.org/abs/1407.3146

- Upgrade towards CRESST-II:
  - Radio-pure, scintillating support structure
    - Backgrounds from previous Pb support structure problematic
  - New design for scintillating target (at TUM)
  - Veto of low-energy surface backgrounds
    - Using scintillating module shell signaling alpha particles
  - Low trigger threshold (0.60 keV)
  - Background-free from 12 keV
- Using a single upgraded detector module, 29.35 kg/live days (2013)

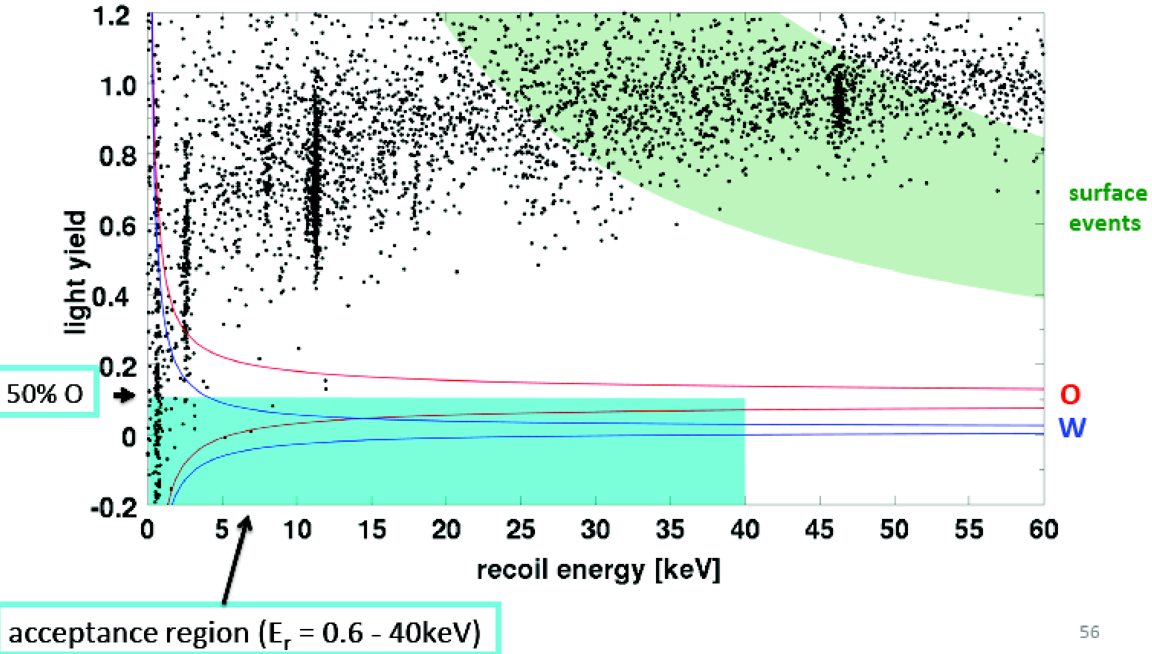
PRINCIPLE AND PRACTICE OF RECOIL DETECTION

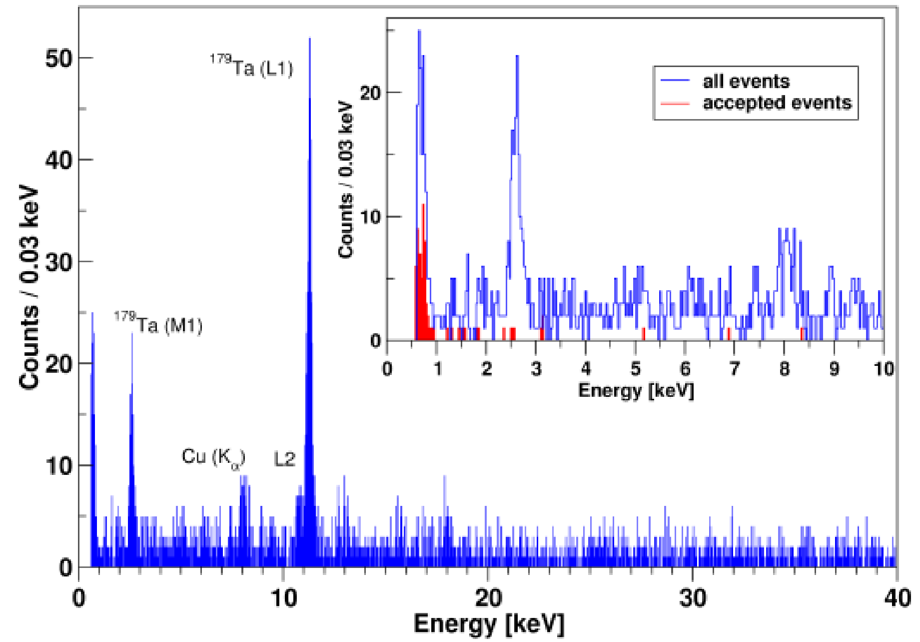


R. Strauss

- Exploit light yield to distinguish recoil types
- Much less background than previous run (Run32)

RECOIL RESULTS IN REGION OF INTEREST





- 79 events in **red** found in acceptance region
- No reliable background simulation yet: set limit, treat as signal
- **Bonus:** previous CRESST excess has been excluded and understood (possible background from support structure)

NEW CRESST LIMITS FOR LOW WIMP MASSES

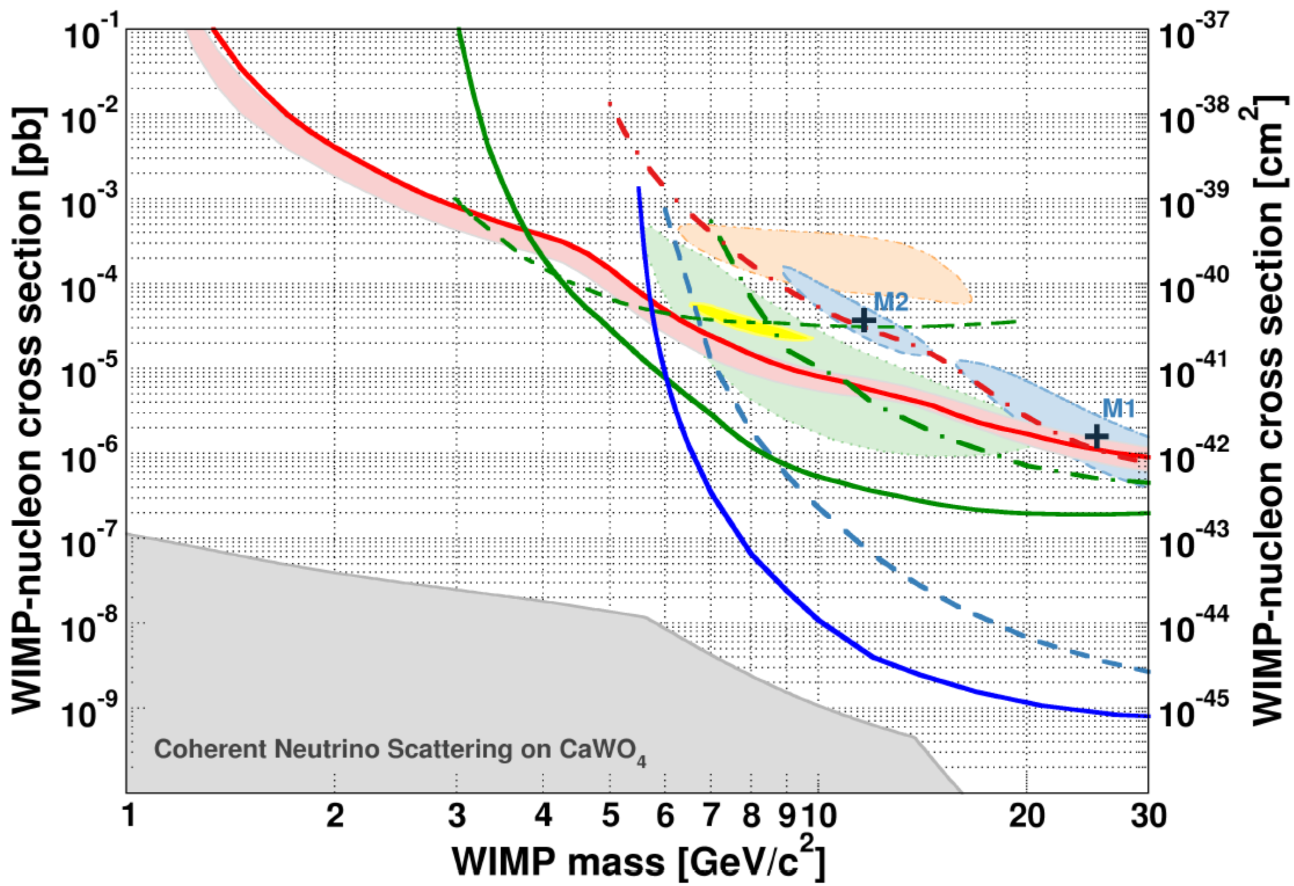
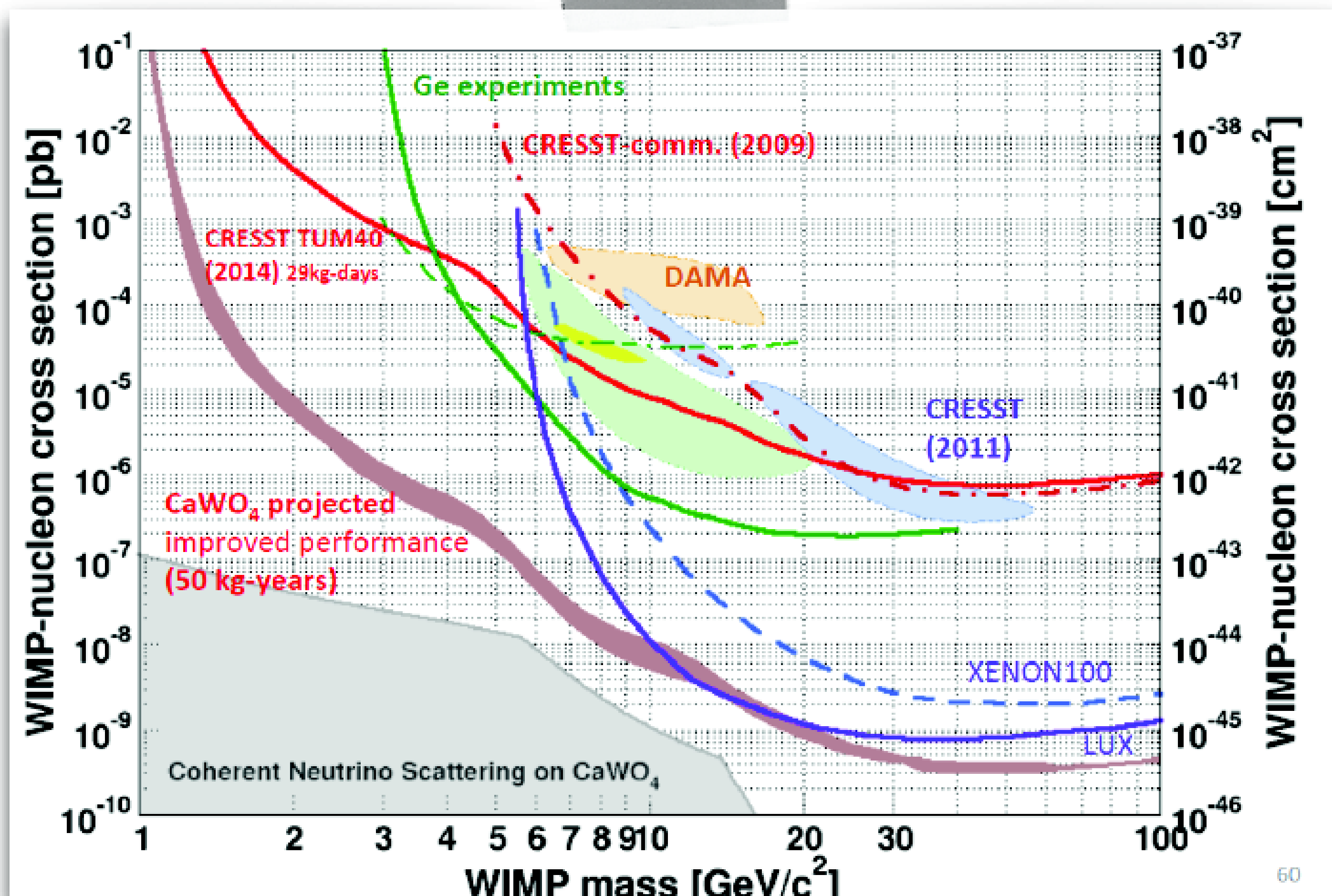


FIG. 5. WIMP parameter space for spin-independent ($\sim A^2$) WIMP-nucleon scattering. The 90 % C.L. upper limit (solid red) is depicted together with the expected sensitivity (1 σ C.L.) from the background-only model (light red band). The CRESST-II 2 σ contour reported for phase 1 in [3] is shown in light blue. The dash-dotted red line refers to the reanalyzed data from the CRESST-II commissioning run [24]. Shown in green are the limits (90 % C.L.) from Ge-based experiments: SuperCDMS (solid)[7], CDMSlite (dashed) [25] and EDELWEISS (dash-dotted) [26]. The parameter space favored by CDMS-Si [4] is shown in light green (90 % C.L.), the one favored by CoGeNT (99 % C.L. [2]) and DAMA/Libra (3 σ C.L. [27]) in yellow and orange. The exclusion curves from liquid xenon experiments (90 % C.L.) are drawn in blue, solid for LUX [6], dashed for XENON100 [5]. Marked in grey is the limit for a background-free $CaWO_4$ experiment arising from coherent neutrino scattering, dominantly from solar neutrinos [28].

Bonus: previous CRESST excess has been excluded and understood (possible background from support structure)

PROJECTIONS FOR FULL CRESST-II/UPGRADES

Expected Sensitivity with CRESST III



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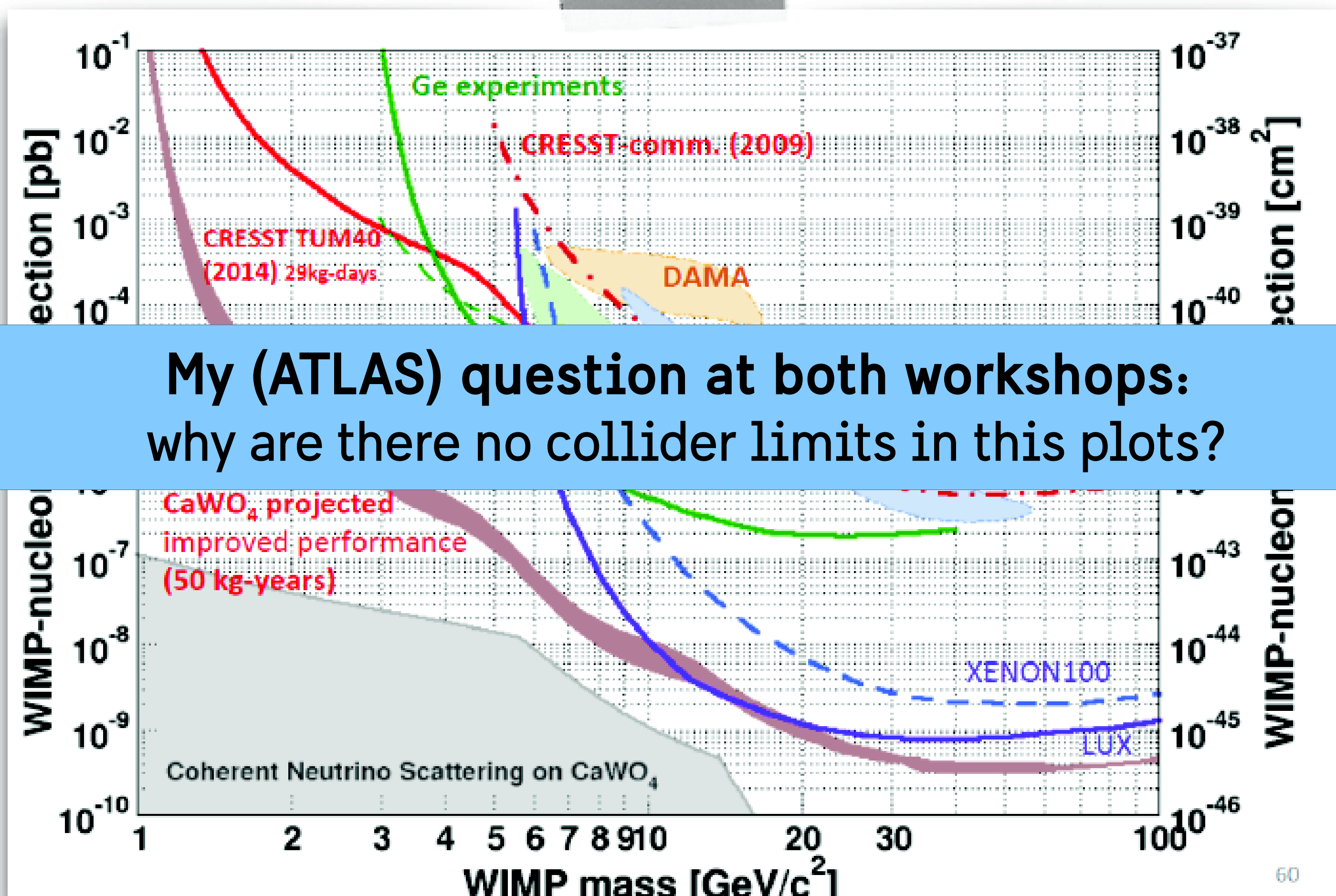
Talk by J. Schiech

PROJECTIONS FOR FULL CRESST-II/UPGRADES

Expected Sensitivity with CRESST III

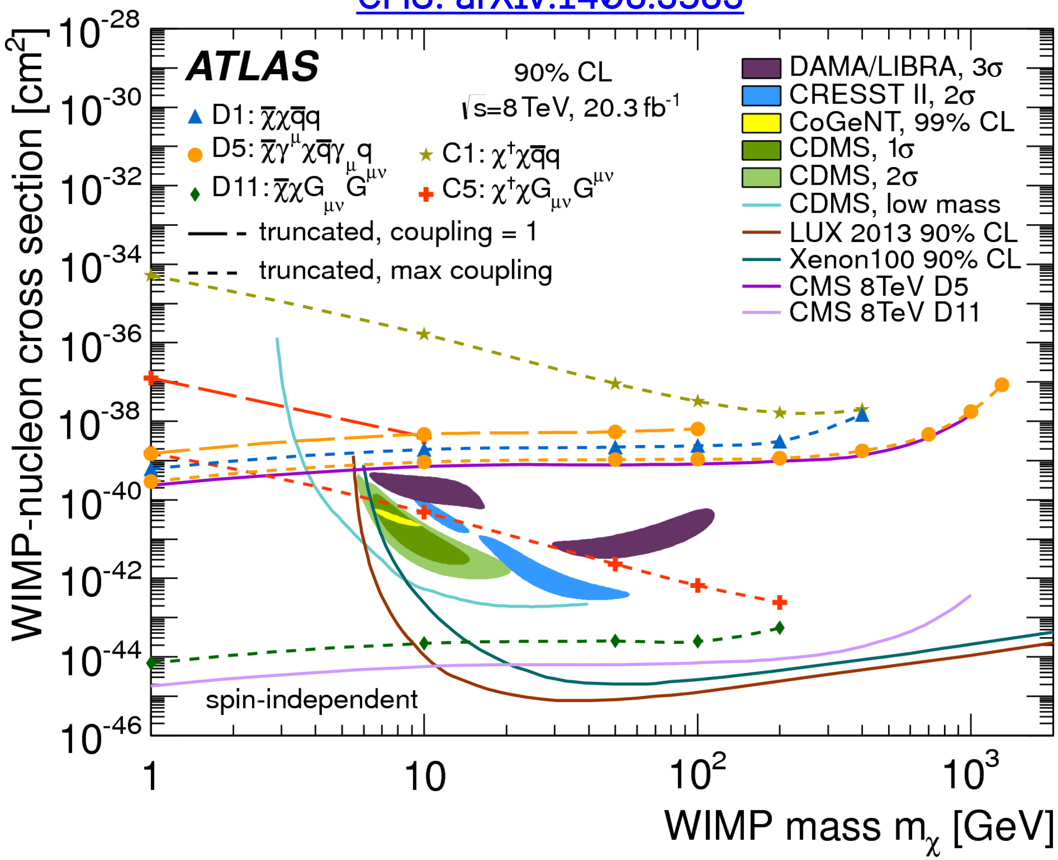


My (ATLAS) question at both workshops:
why are there no collider limits in this plots?

Talk by J. Schiech

Complementarity of dark matter searches

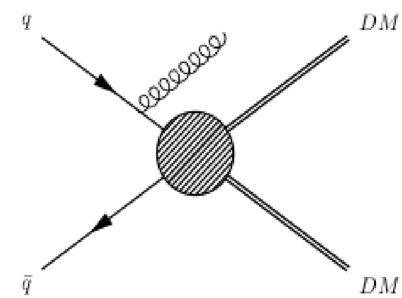
[ATLAS: arXiv:1502.01518](https://arxiv.org/abs/1502.01518)
[CMS: arXiv:1408.3583](https://arxiv.org/abs/1408.3583)



Caveat:

Model-dependent comparison
Needs **agreement**
on benchmarks and assumptions

especially on **contact interaction** benchmark models: **only valid if**



$$Q_{tr} \ll M_{med}$$

(a problem for LHC energies, not for Direct Detection)

Complementarity of DD/ID and colliders:
this plot can still outline strengths of each of the experiments

EFT validity at colliders: options discussed

- **Do not consider EFT as a benchmark at all**
  Pros: Focus on simplified models
  Cons: Theory community appreciates simplicity of EFT

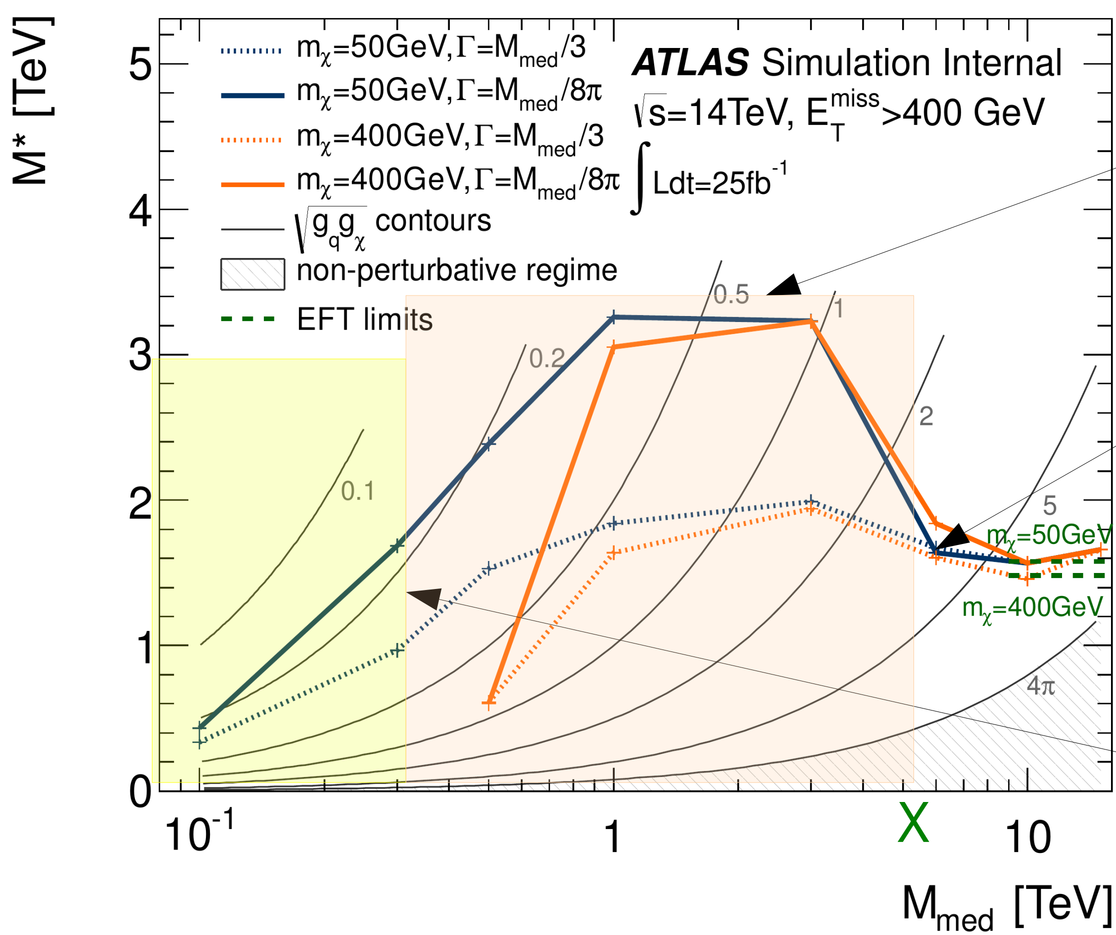
- **Keep EFT, untruncated**
  Pros: Keeps things simple for whoever knows how to use it
  Cons: Will be misinterpreted, can't be compared to direct detection

- **Truncate EFT (two methods available)**
  Pros: Consistent procedure, established within ATLAS
  Cons: Model-dependent, takes away from EFT simplicity

- **Only provide high-mediator-mass limit for simplified models**
  Pros: Equivalent to EFT to all effects, avoids validity problem by explicitly mentioning presence of mediator
  Cons: Needs EFT for models without clear UV completion/limit

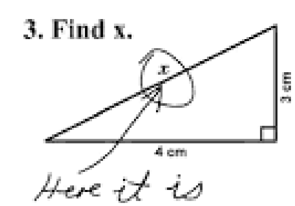
FAVORED OPTION BY MITP WORKSHOP PARTICIPANTS

Suggestion: experimentalists only give a Contact Interaction limit from models with explicit mediator, with very high mass mediators?



Don't want to use CI model here (it would be too conservative)

Region of interest for EFT limits: Mmed > X

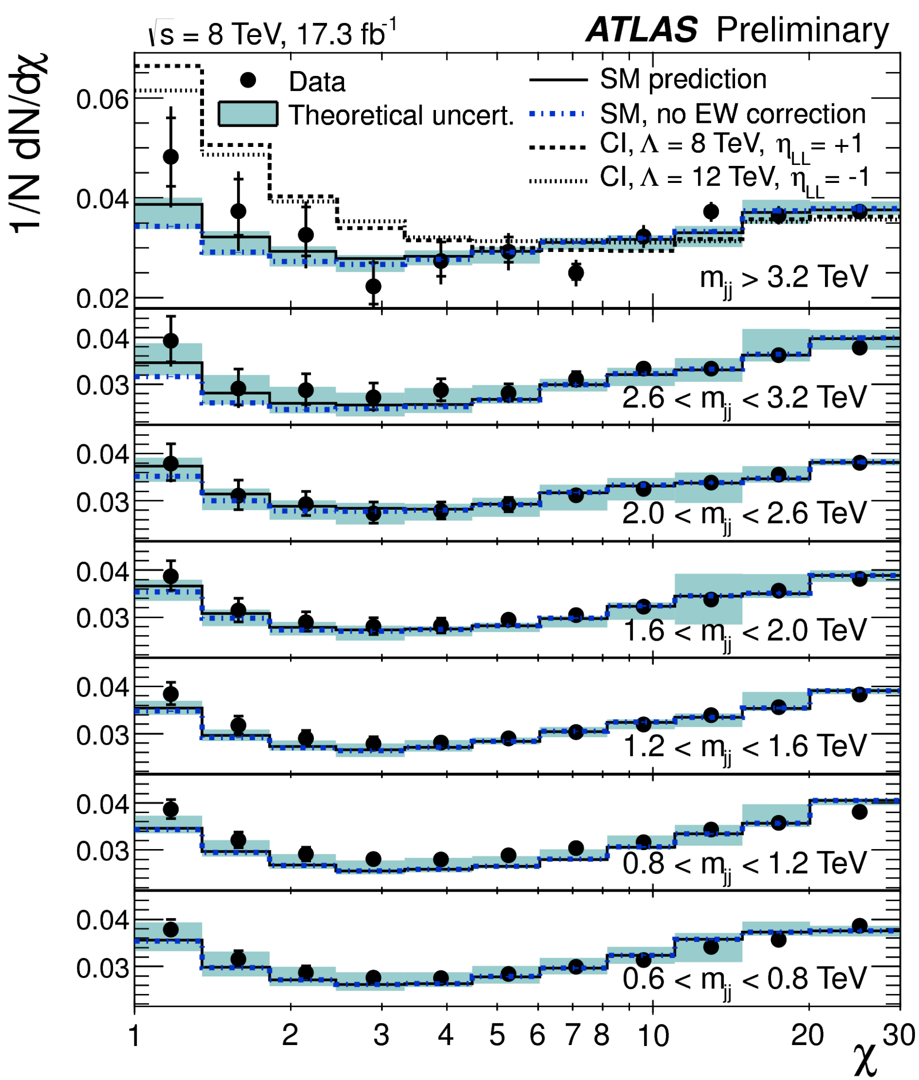


We would need to study the "turn-on"

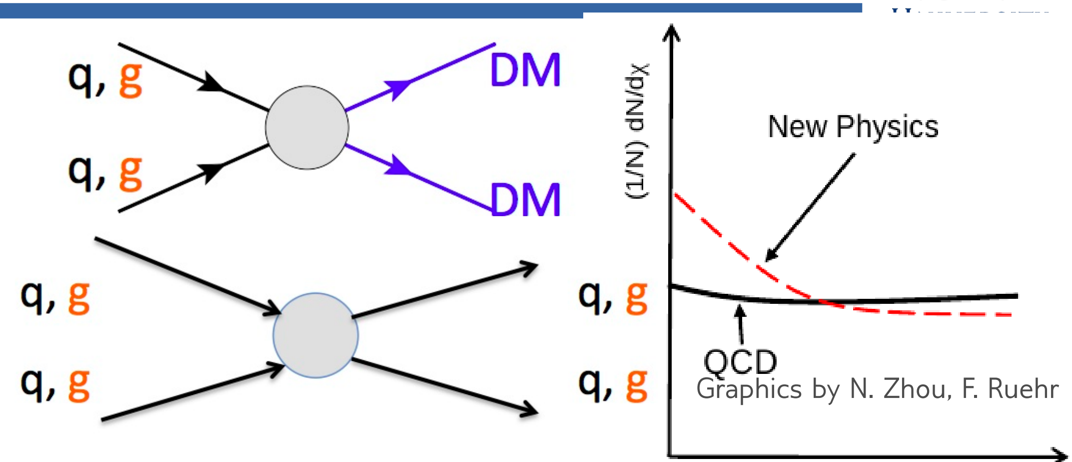
Cannot use an EFT here (it would contain invalid events)

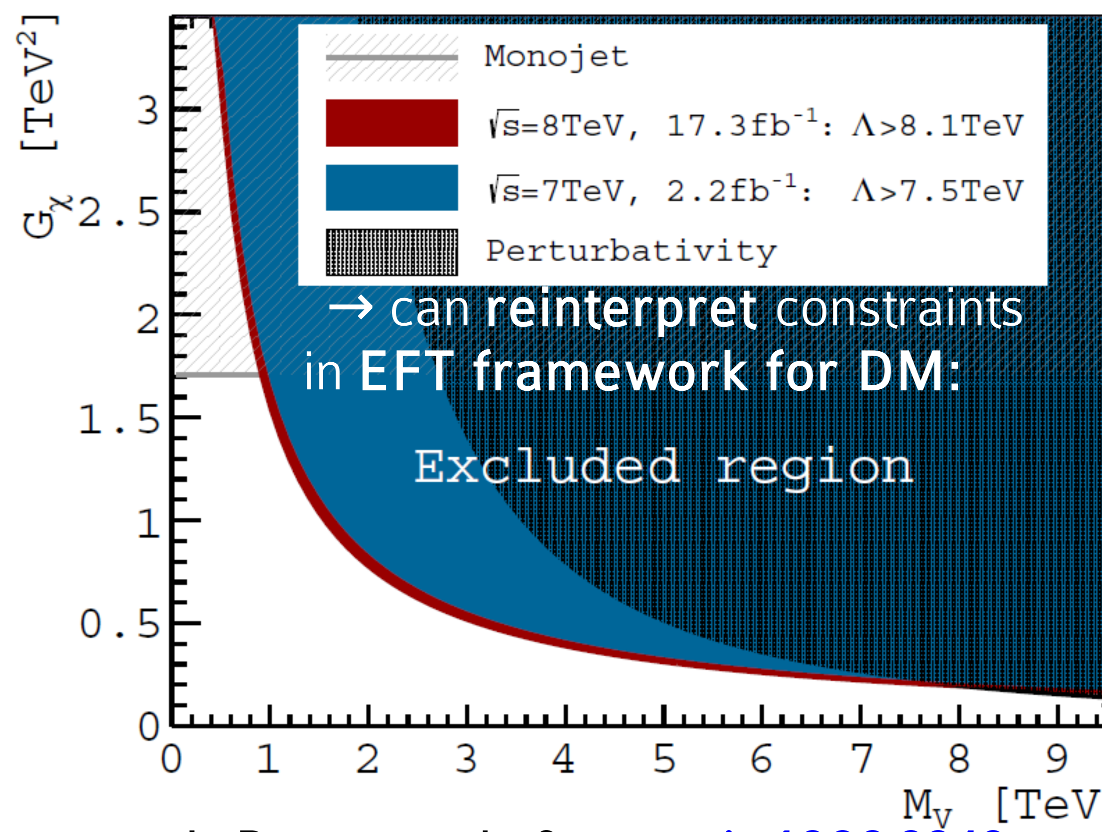
MORE ON CONTACT INTERACTIONS AT COLLIDERS

Dijet angular distributions
probe contact interactions



http://arxiv.org/abs/1504.00357

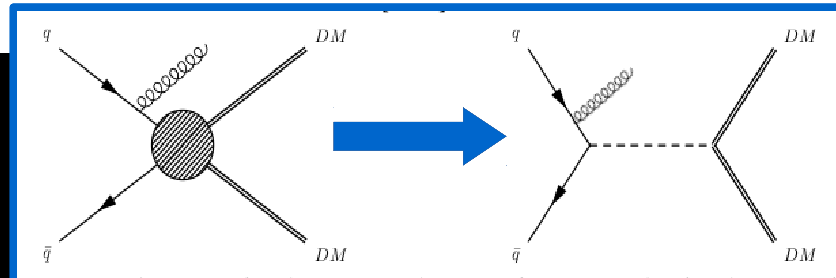


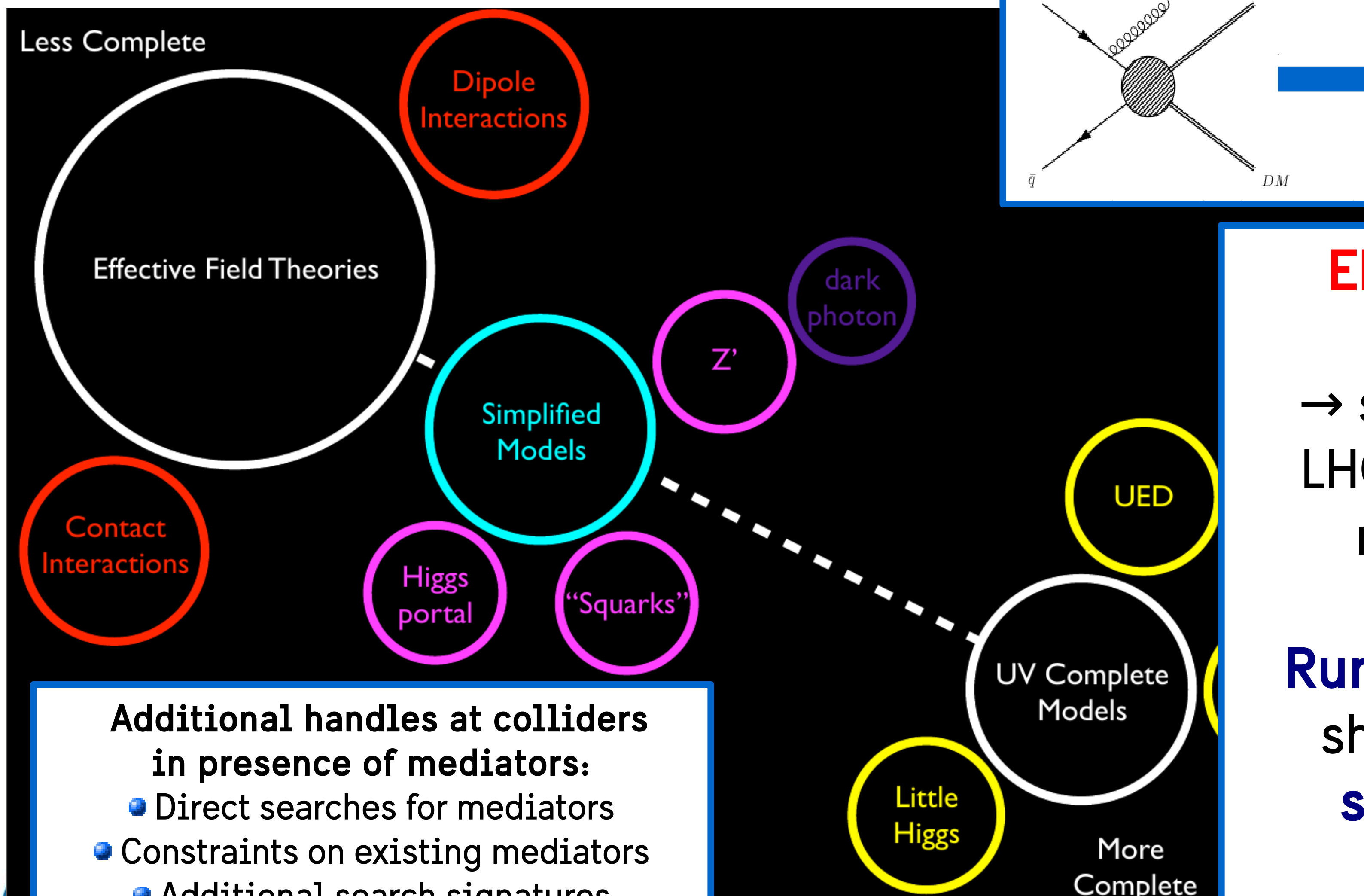


L. Bryngemark, from arxiv:1303.3348

TAKE-HOME MESSAGE FOR COLLIDER SEARCHES

- Guiding principle for choice of Run-2 benchmarks:
  How would a DM signal look at colliders?





Additional handles at colliders in presence of mediators:
- Direct searches for mediators
- Constraints on existing mediators
- Additional search signatures

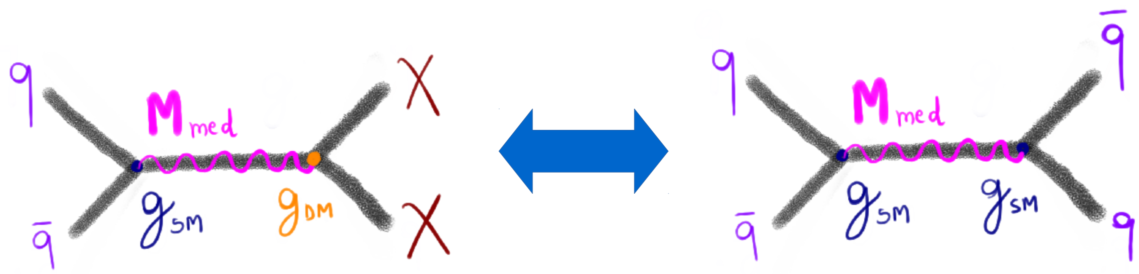
EFT validity issues:
→ sensitivity of LHC to explicit mediators

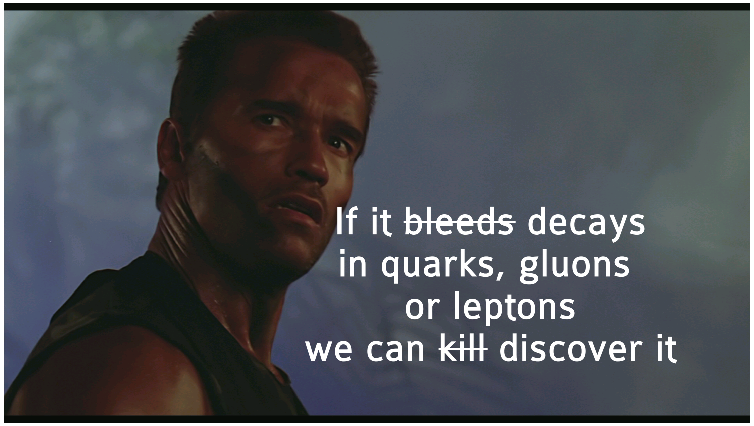
Run 2 searches shift focus to **simplified models**

SEARCHES FOR MEDIATORS (LUND ATLAS GROUP)

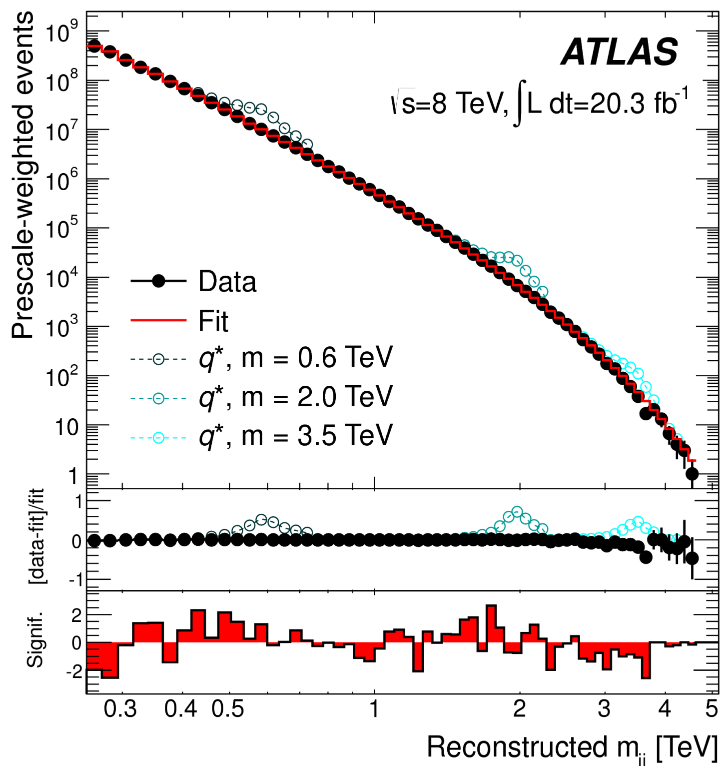
LUND UNIVERSITY

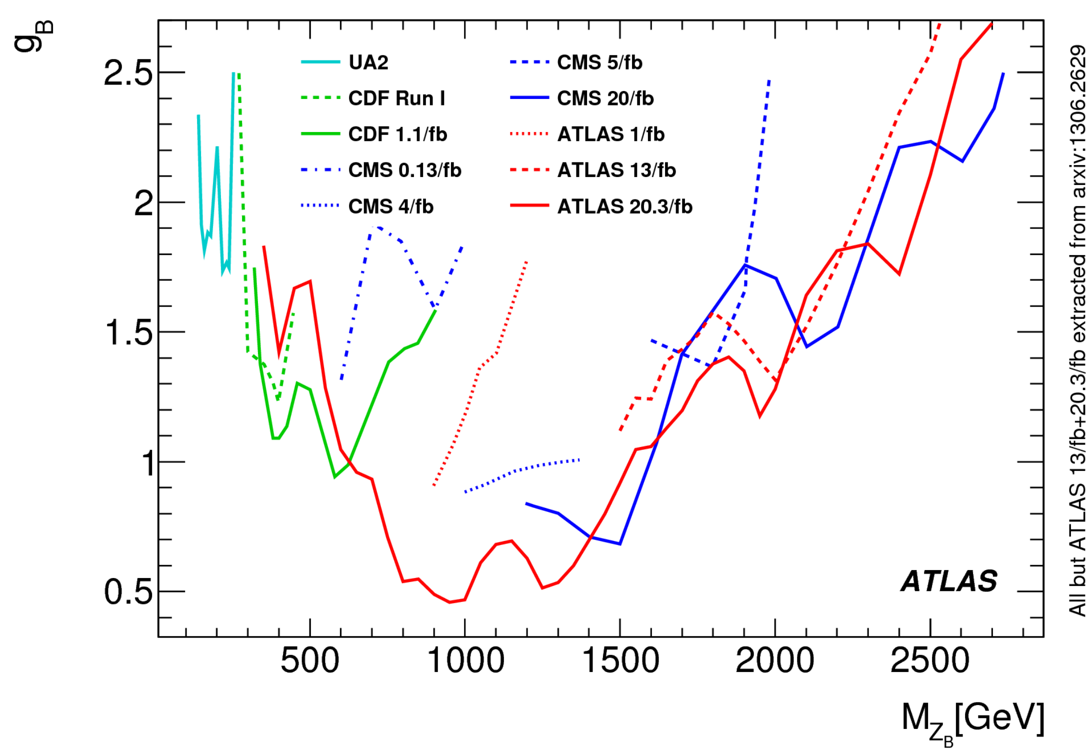
Dijet and dilepton searches
probe mediators directly





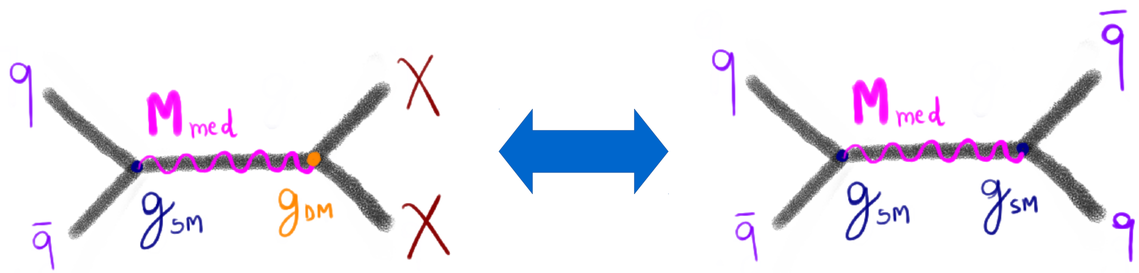
[ATLAS arxiv: 1407.1376]

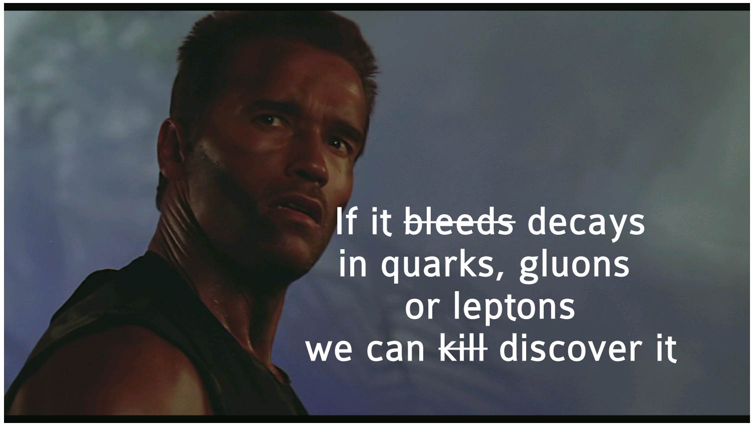




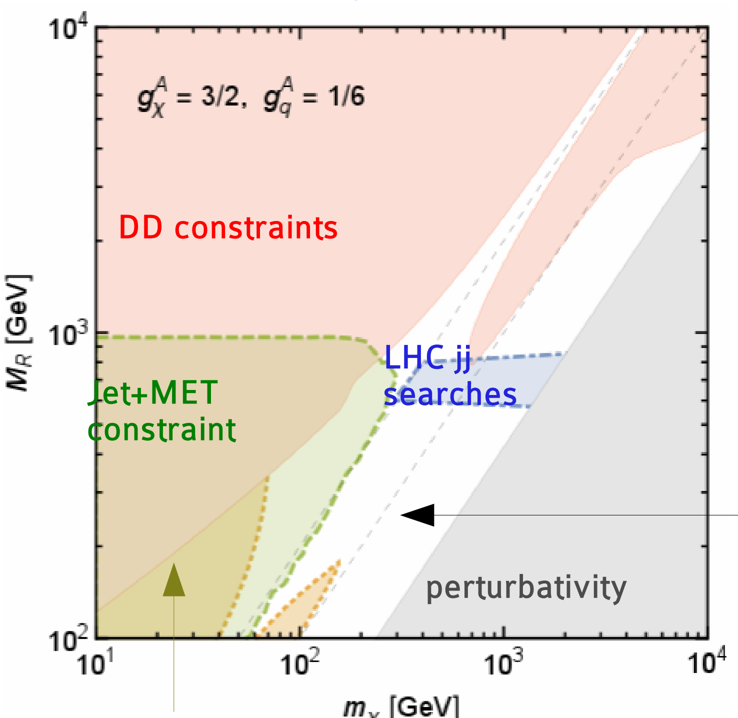
SEARCHES FOR MEDIATORS (LUND ATLAS GROUP)

Dijet and dilepton searches
probe mediators directly





http://arxiv.org/abs/1503.05916



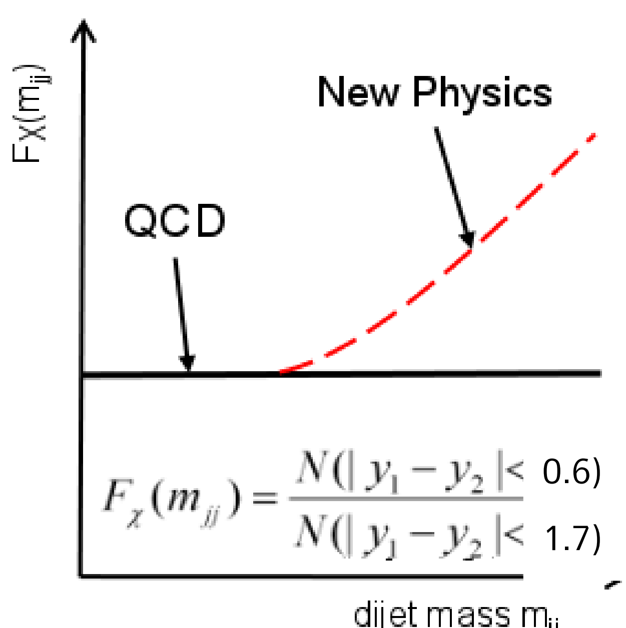
Low-mediator-mass region
(not covered by high-mass
dijet searches) will be investigated
by Lund ATLAS group
(see my Nov 6th Science Coffee)

SEARCHES FOR WIDE MEDIATORS (LUND ATLAS GROUP)

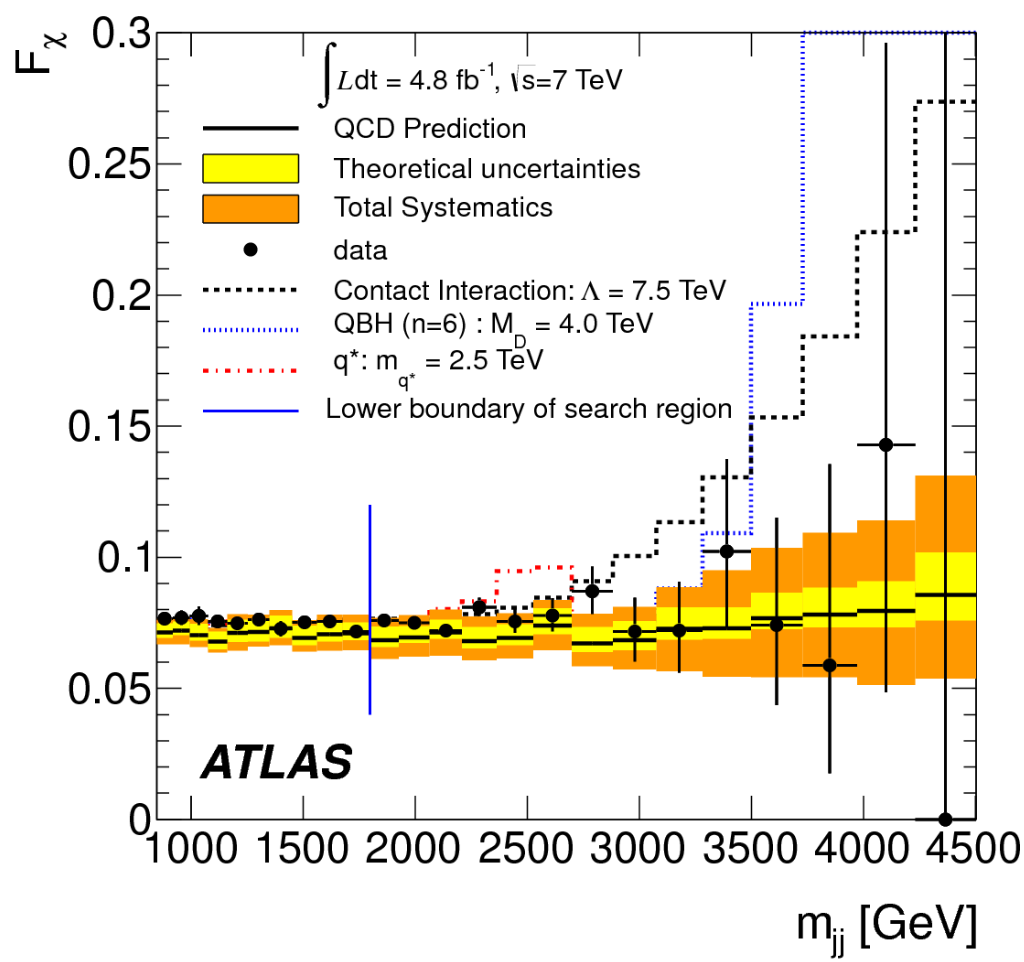
Problem: dijet search background estimation fitted to data may not be sensitive to **wide resonances**

→ **Dijet angular searches** are good tools to also look for **wide s-channel DM mediators**

arXiv:1210.1718



Graphics by F. Ruehr

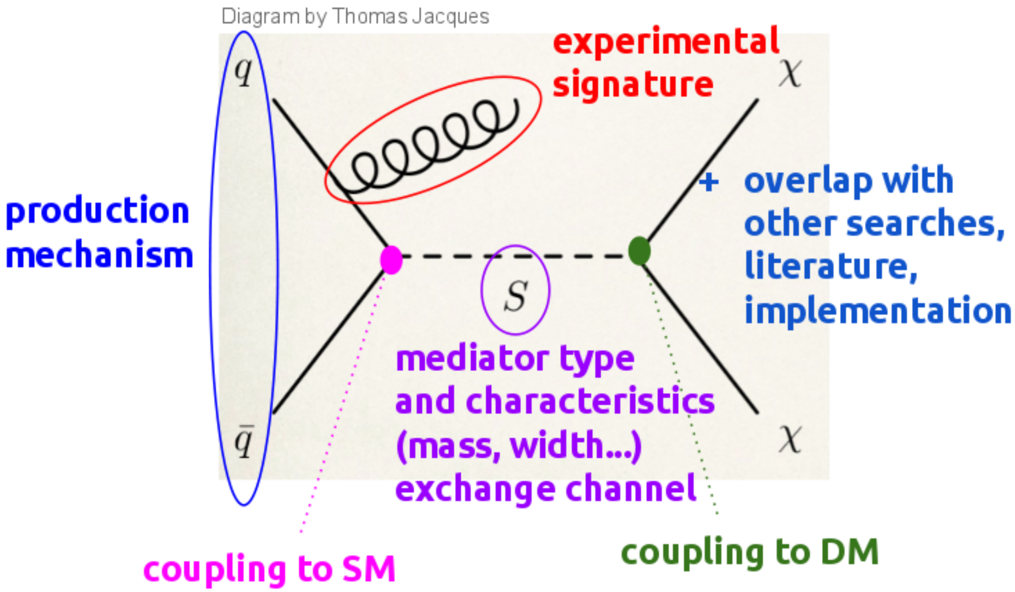


MORE ON LHC RUN-2 SIMPLIFIED MODELS: DM FORUM

ATLAS/CMS Dark Matter Forum:

experiment/theory discussion towards early Run-2 DM searches

Many possibilities
to be used as building blocks:



This Forum will agree upon:

- Prioritized **set of simplified models**
- Common **model implementation and details** (e.g. matching, scales)

towards MC generation of benchmarks

- **EFT validity** assessment procedure

This Forum will document:

models and choices
(arXiv write-up + SVN repository)

LIST OF SIMPLIFIED MODELS AND PARAMETER SCAN

- First guiding principle: how will (WIMP) DM look like?
- Further guiding principles for benchmark model choices:
  - Practical for experimentalists (MC generation)
  - Useful for theorists and DM community as a whole

- Does the kinematics change between model/model points
- Does the model add new, uncovered signatures?

  If so, we need to generate these models/model points

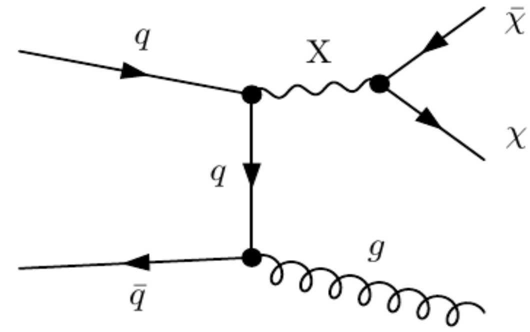
  If not, we give theorists sufficient information to reinterpret

Write-up: outline other benchmarks and possibilities to be investigated in future searches

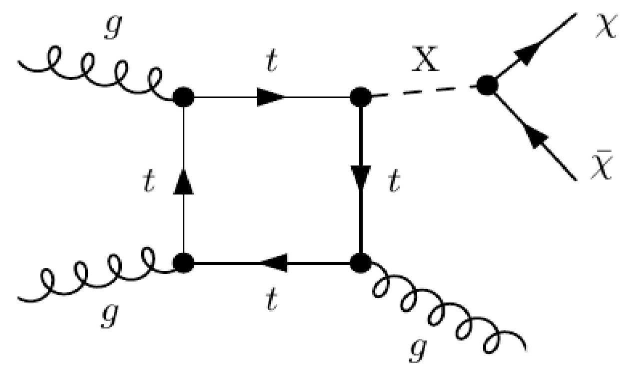
EXAMPLE: JET+MET, LIST OF SIMPLIFIED MODELS

Benchmark models for jet+MET searches:

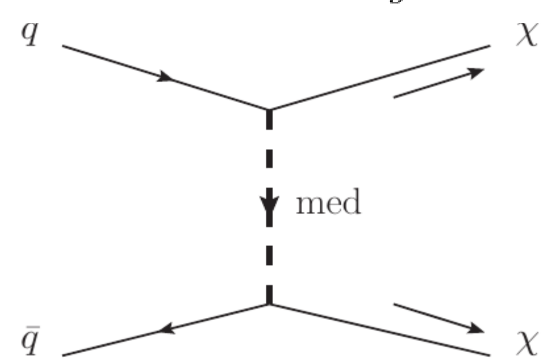
1. s-channel vector/axial vector mediator



2. s-channel scalar/pseudoscalar mediator
(top loop explicitly calculated)



3. t-channel colored scalar mediator

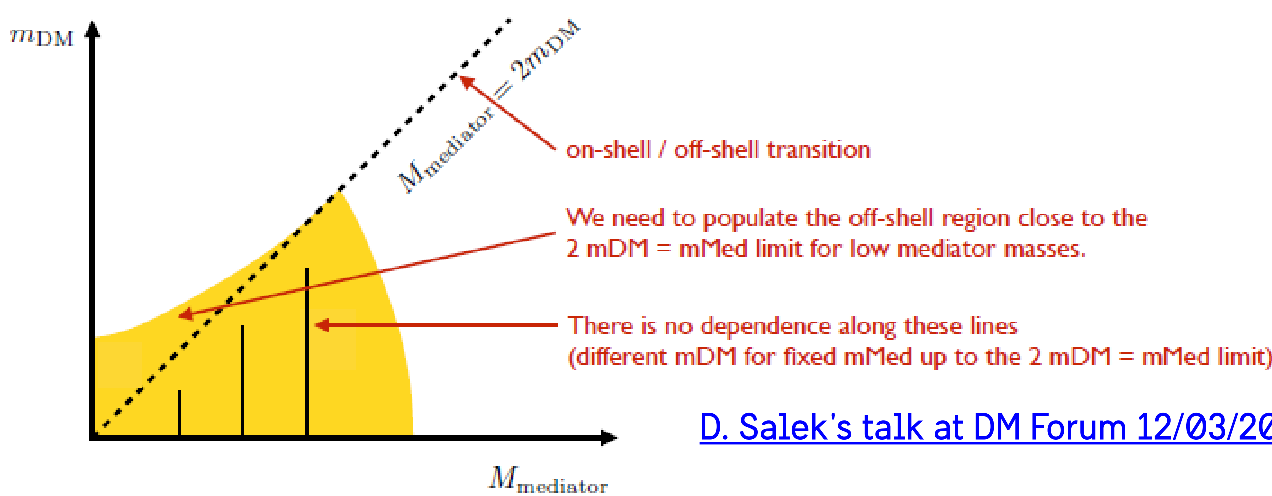


JET+MET: SCAN FOR S-CHANNEL MEDIATORS

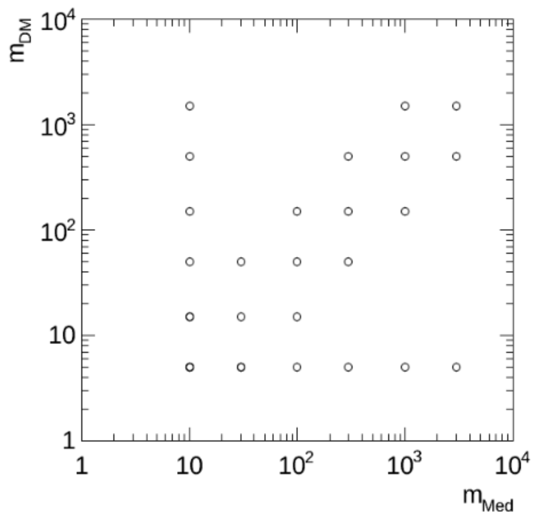
Free parameters: mediator width, couplings, m_{DM}, $m_{Mediator}$

3. DM/mediator masses:

- scan based on on/off-shell regions
- scalar and pseudoscalar grid takes into account ttbar threshold



D. Salek's talk at DM Forum 12/03/2015



JET+MET: SCAN FOR S-CHANNEL MEDIATORS

Free parameters: mediator width, couplings, m_{DM}, $m_{Mediator}$

1. mediator width:

- use minimal width (no additional visible/invisible decays except for quarks and DM), for all MET+X searches
- upper bound on width → upper bound on couplings

2. couplings:

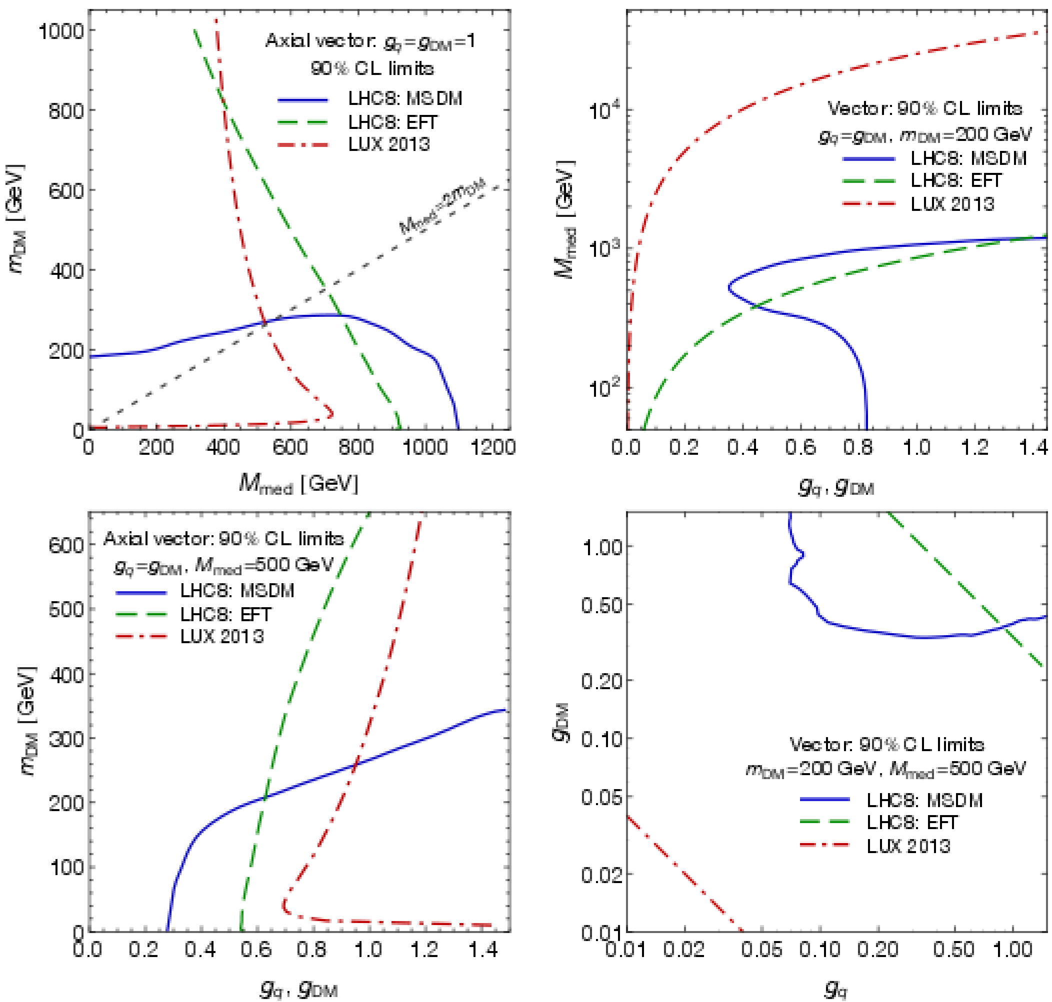
- no dependence on kinematics on coupling chirality
- cross-section scaling along lines of constant width → fix one coupling, scan on other coupling

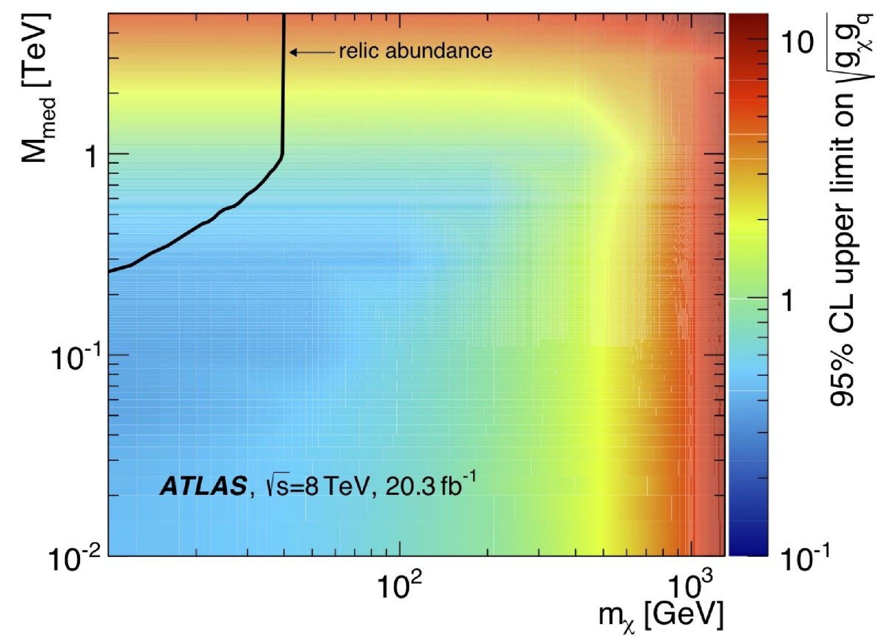
D. Salek's talk at DM Forum 12/03/2015

DM COMPLEMENTARITY WITH SIMPLIFIED MODELS

Suggestion from MIAPP discussion:

complement DM-nucleon plots with the following plots





Proposal slides from Bristol workshop (1407.8257)

CONCLUSIONS

Dark Matter: extremely active topic in HEP

all researchers benefit from cross-talk for dedicated period of time

→ workshop format very useful in bringing together theorists and experimentalists (shall we try and organize one ourselves?)

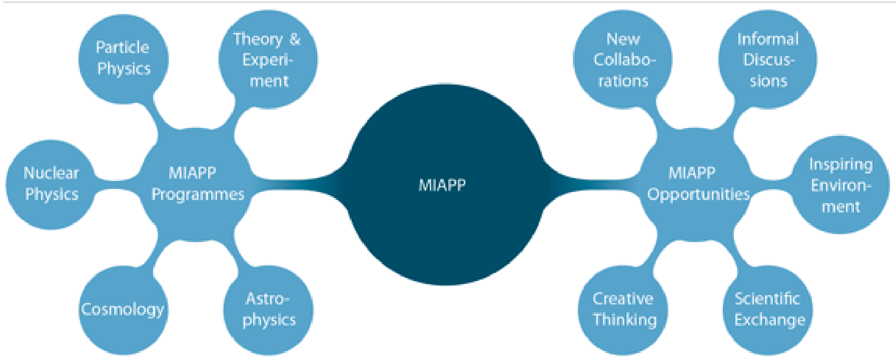
Selected messages from today's talk:

- Interpretation of hints from the galaxy:
  - Non-understood excesses and interpretations exist:
    let's use them as guidance for searches, while still keeping the door open for non-standard-WIMP DM (model-independent)
- Details of WIMP dark matter, colliders and DD
  - Discussion of benchmarks crucial to fully exploit complementarity
  - Colliders are best suited to search for DM mediators: eagerly awaiting for Run-2!

MOST IMPORTANT LESSON LEARNED

Don't follow Dark Matter theorists to breakfast or this will happen at 9 am:

MIAPP: Dark MALT



DARK MATTER: ASTROPHYSICAL PROBES, LABORATORY TESTS, AND THEORY ASPECTS (DARK MALT 2015)

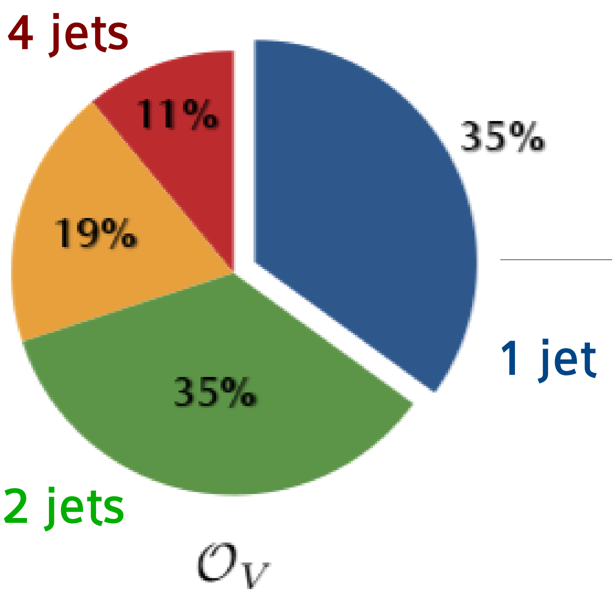
MITP: Effective Theories and DM

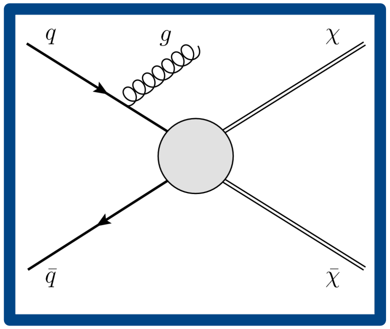
Mainz Institute for Theoretical Physics

BACKUP SLIDES

THEORY-EXPERIMENT INTERACTION FOR JET+MET

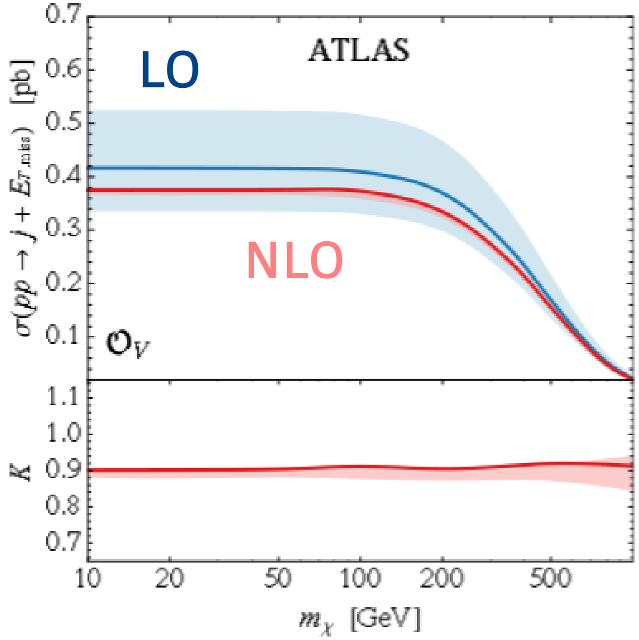
arXiv:1310.4491, Emanuele Re's talk





Naive monojet doesn't quite capture all QCD effects

NLO reduces uncertainties

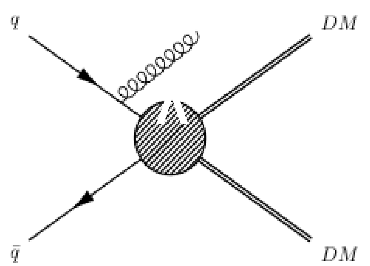


ATLAS 8 TeV analysis: ATLAS: arXiv:1502.01518

use **NLO signals**, **release jet veto** (but keep monojet-like topology)

→ improvements in EFT limits

CONTACT INTERACTION VALIDITY: TRUNCATION (ATLAS)



Valid if

$$Q_{tr} < M_{med}$$

(minimal constraint)

Connect **mediator mass and EFT scale Λ**:
need information on **theory completion**
→ coupling-dependent condition,
precise and well-defined within choices

Operator(s)	Relation between M_{med} and M_*	Coupling term range
D1	$M_{med} = \sqrt{y_q g_\chi}\ \sqrt{M_*^3/m_q}$	$0 < \sqrt{y_q g_\chi} < 4\pi$
C1	$M_{med} = y_q \lambda_\chi \zeta_\lambda\ M_*^2/m_q$	$0 < y_q \lambda_\chi \zeta_\lambda < (4\pi)^2 \zeta_\lambda$
D5, D8, D9	$M_{med} = \sqrt{g_q g_\chi}\ M_*$	$0 < \sqrt{g_q g_\chi} < 4\pi$
D11	$M_{med} = \sqrt[3]{a g_\chi}\ M_*$	$0 < \sqrt[3]{a g_\chi} < \sqrt[3]{16\pi}$
C5	$M_{med} = \sqrt{a \lambda_\chi \zeta_\lambda}\ M_*$	$0 < \sqrt{a \lambda_\chi \zeta_\lambda} < 4\sqrt{\pi \zeta_\lambda}$

Key parameter for truncation: $R^{tot}_{M_{med}}$ fraction of events passing $Q_{tr} < M_{med}$

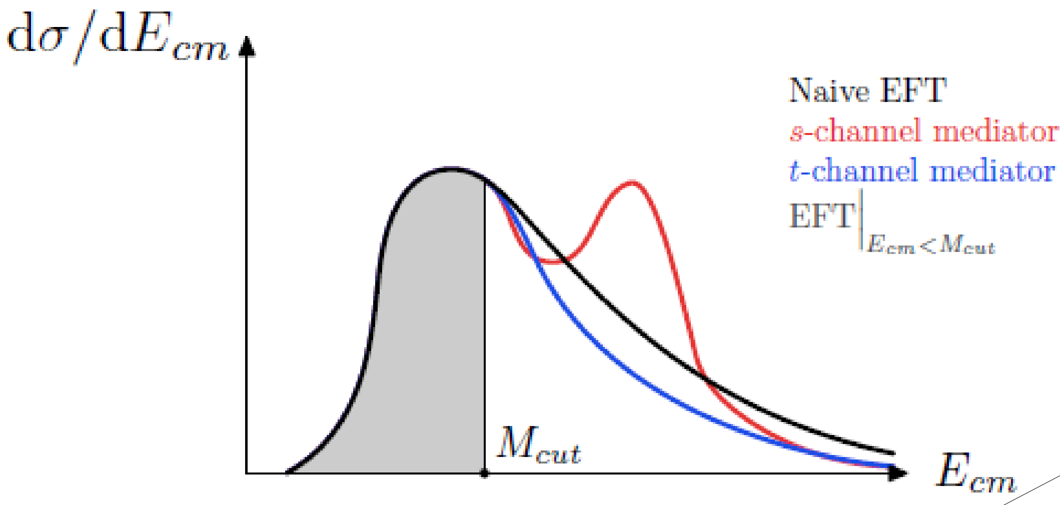
Two equivalent procedures:

cross-section truncation, corresponding only to valid events(used in 8 TeV papers)
iterative rescaling of M* limits after determining R (used in 14 TeV studies)

ALTERNATIVE CI TRUNCATION

arXiv:1502.01518

LUND UNIVERSITY



$$\mathcal{L}_{\text{EFT}} = -\frac{1}{M_*^2}\left(\overline{X}\gamma^\mu\gamma^5 X\right)\left(\sum_{\text{flavours}} \overline{q}\gamma_\mu\gamma^5 q\right)$$

- We restrict the signal to the events for which

$$E_{\text{cm}} < M_{\text{cut}},$$

where E_{cm} is the total invariant mass of the hard final states of the reaction:

$$E_{\text{cm}} = \sqrt{\hat{s}} = \sqrt{\left(p^\mu(\text{DM}_1) + p^\mu(\text{DM}_2) + p^\mu(\text{jet})\right)^2}.$$

- Indeed, the following *always* holds:

$$\sigma^{\text{signal}}_{\text{true model}} > \sigma^{\text{signal}}_{\text{corresp. EFT}}\Big|_{E_{\text{cm}}<M_{\text{cut}}}.$$

Thus we obtain conservative but reliable limits.

Mcut = g*M*

- only depends on parameters of the EFT as opposed to needing information on UV completion (still, physical interpretation requires assumptions)

- can be scanned

Davide Racco | Robust collider limits on heavy-mediator Dark Matter | 3 / 11

ATLAS EXPERIMENT

ALTERNATIVE CI TRUNCATION

arXiv:1502.01518

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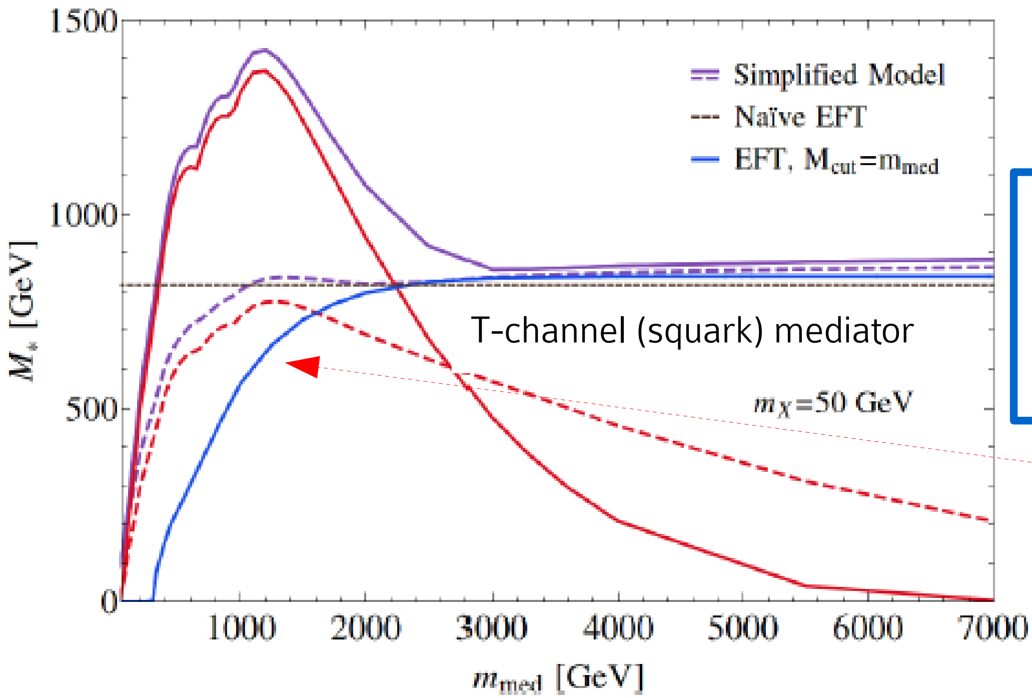
Comparison with the simplified model



Direct comparison with simplified model: shows very (too?) conservative region after truncation

- Blue line: from model-independent limit, with the identification

$$M_* = \frac{2\widetilde{m}}{g_{DM}}, \qquad M_{cut} = \widetilde{m}.$$

- Red lines: only from the resonant production of the mediator.

The EFT limit is complemented by the limit from the resonant production.

ATLAS EXPERIMENT