Dark Matter Pair-Production in the MSSM and SDMMs at the LHC

Christoph Borschensky

Institute of Theoretical Physics, University of Tübingen

Based on work in progress in collaboration with Gabriele Coniglio and Barbara Jäger

DESY Theory Workshop

Particle Physics Challenges.

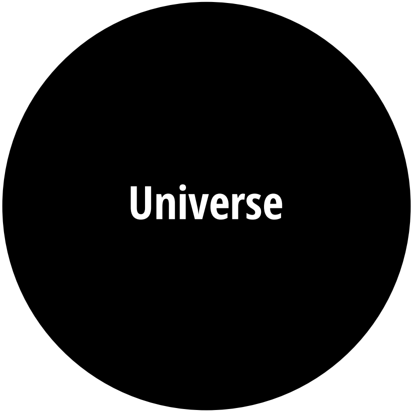
Hamburg, 27 September 2018

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

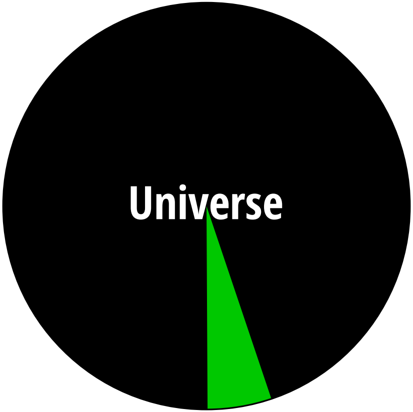
Outline

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

What today’s universe is made of



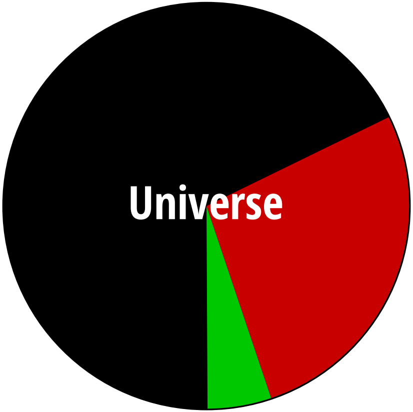
What today's universe is made of



$\sim$ 5% visible, atomic matter

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

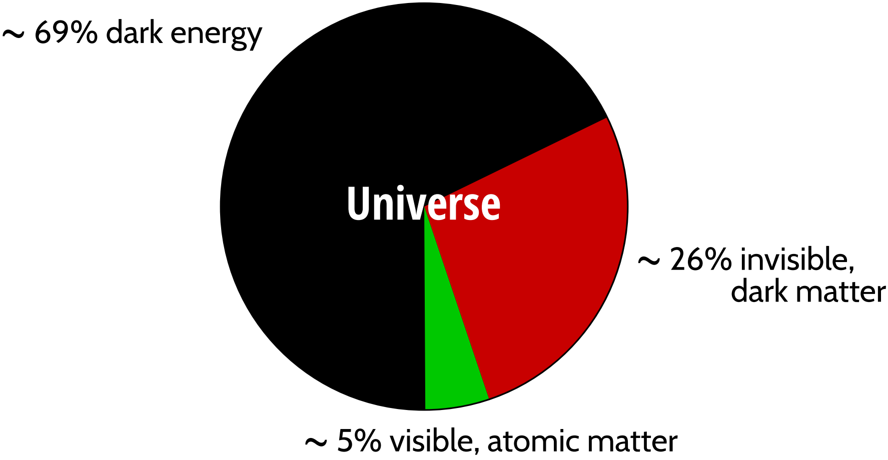
What today's universe is made of



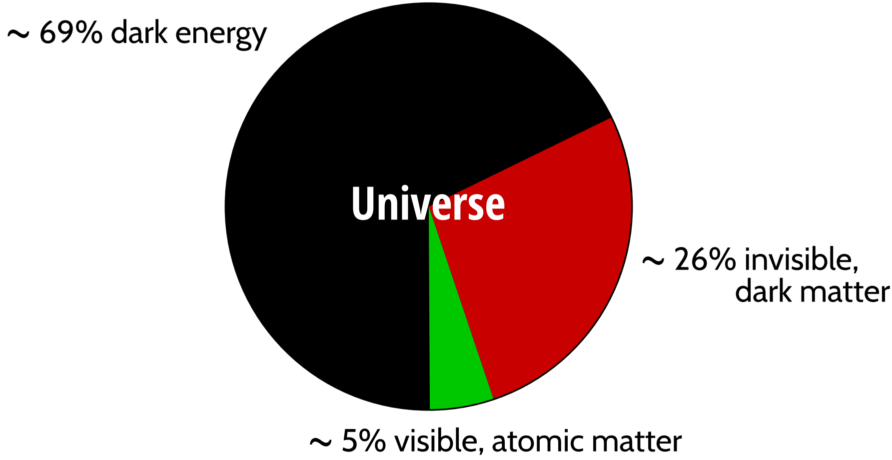
$\sim$ 26% invisible,
dark matter

$\sim$ 5% visible, atomic matter

What today’s universe is made of



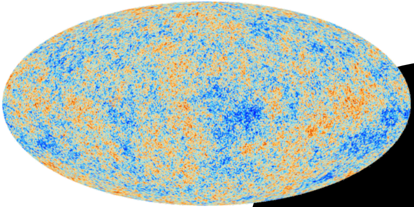
What today's universe is made of

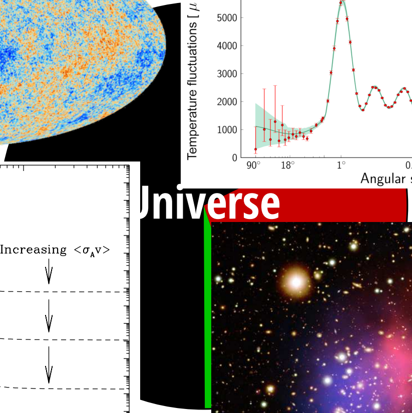


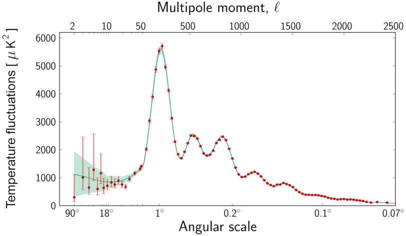
(< 1% neutrinos)

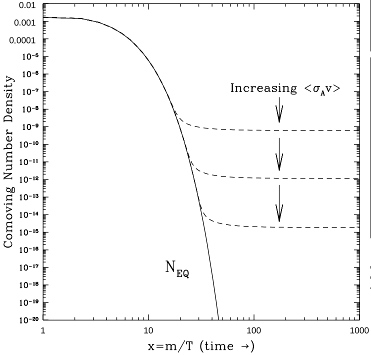
EBERHARD KARLS UNIVERSITÄT TÜBINGEN

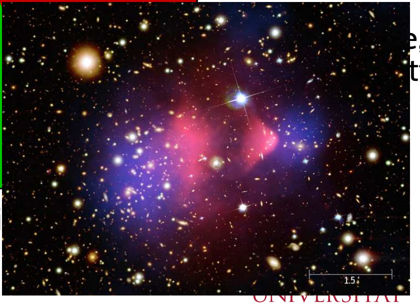
What today’s universe is made of



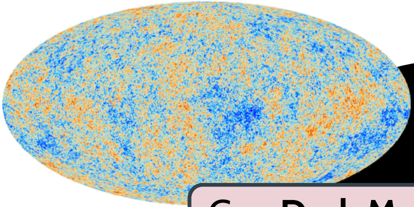


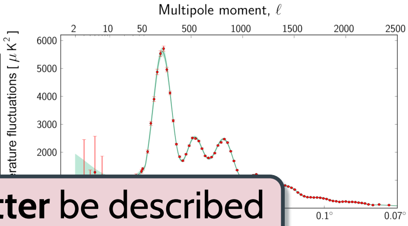




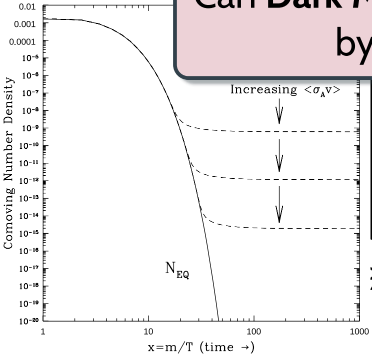


What today's universe is made of



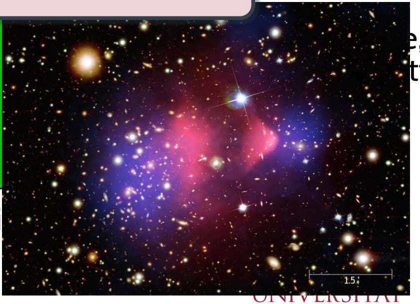


Can **Dark Matter** be described by particles?

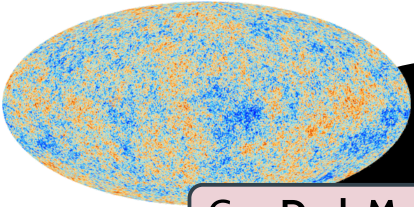


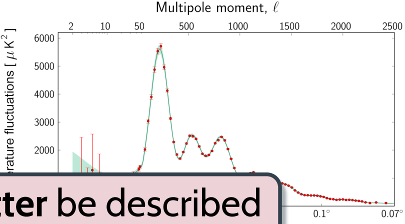
e,
tter

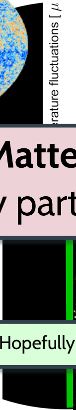
% visi

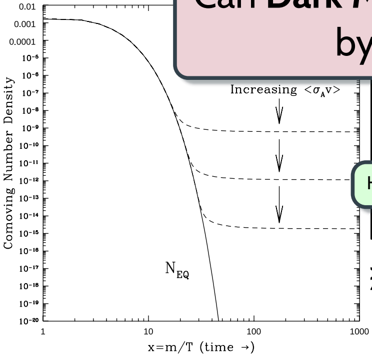


What today's universe is made of









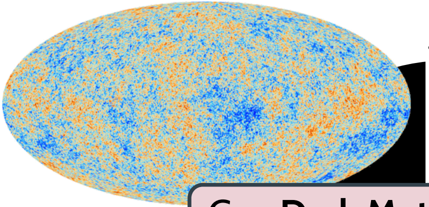
Can Dark Matter be described by particles?

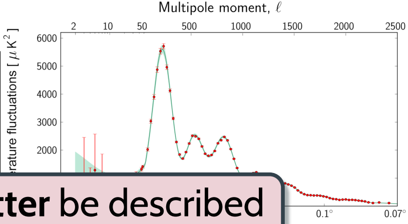
Hopefully it can...

e,
tter

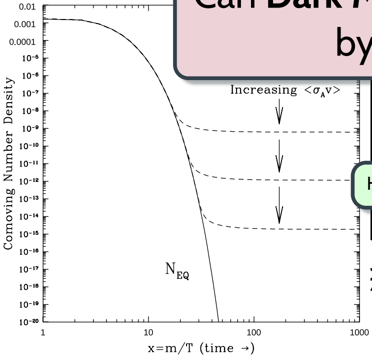
% visi

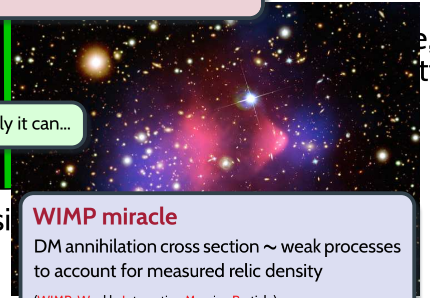
What today’s universe is made of





Can Dark Matter be described by particles?





e,
tter

% visi

Hopefully it can...

WIMP miracle

DM annihilation cross section ∼ weak processes to account for measured relic density

(WIMP: Weakly Interacting Massive Particle)

The dark matter model space

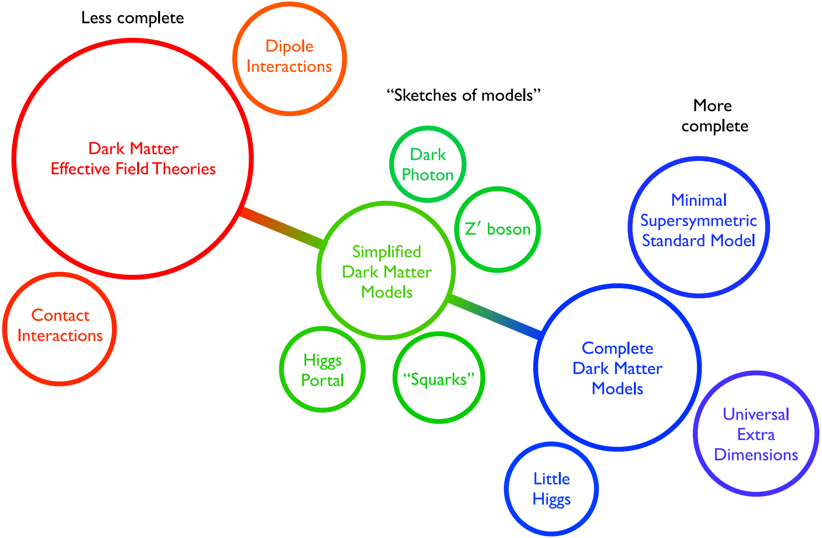


Figure taken from *[Abdallah et al. '15, arXiv:1506.03116]*

The dark matter model space

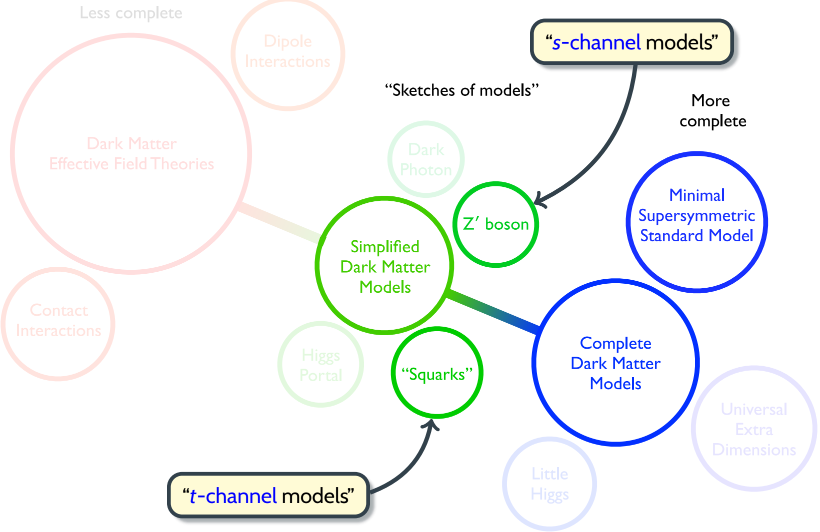
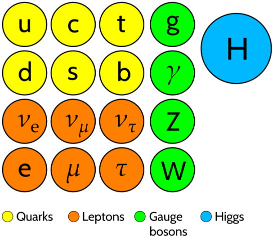


Figure taken from *[Abdallah et al. '15, arXiv:1506.03116]*

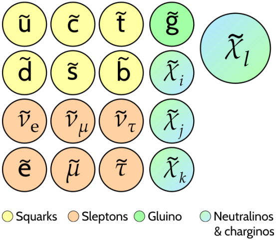
Intermission: What is Supersymmetry?

Supersymmetry connects bosonic and fermionic degrees of freedom

Standard Model particles



Supersymmetric partners



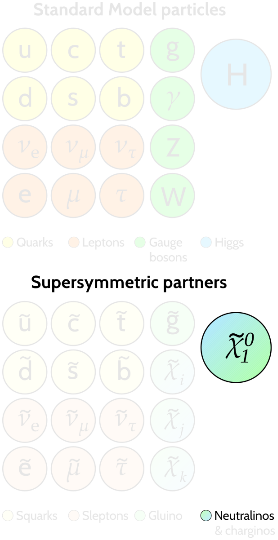
- New set of “mirrored” particles
- Possible solutions to several theoretical and experimental problems (e.g. *hierarchy problem*, *grand unification*, *dark matter*)
- Broken symmetry: $M_{\mathrm{SUSY}} \gg M_{\mathrm{SM}}$
- **R-parity**: SUSY particles are odd, SM particles are even

  ⇒ **Lightest supersymmetric particle (LSP) is stable (DM candidate)**
- Neutralinos are mixed states of interaction eigenstates of EW fields:

$$\tilde{\chi}^0_1 = N_{11}\tilde{B} + N_{12}\tilde{W}_3 + N_{13}\tilde{h}_1 + N_{14}\tilde{h}_2$$

Intermission: What is Supersymmetry?

Supersymmetry connects bosonic and fermionic degrees of freedom



- New set of "mirrored" particles
- Possible solutions to several theoretical and experimental problems (e.g. *hierarchy problem*, *grand unification*, *dark matter*)
- Broken symmetry: $M_{\text{SUSY}} \gg M_{\text{SM}}$
- **R-parity**: SUSY particles are odd, SM particles are even
  - $\Rightarrow$ **Lightest supersymmetric particle (LSP) is stable (DM candidate)**
- Neutralinos are mixed states of interaction eigenstates of EW fields:

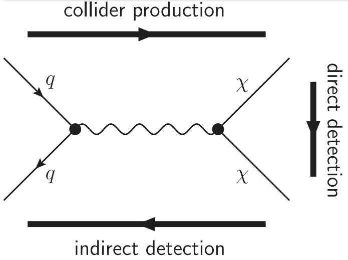
$$\tilde{\chi}_1^0 = N_{11}\tilde{B} + N_{12}\tilde{W}_3 + N_{13}\tilde{h}_1 + N_{14}\tilde{h}_2$$

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Different detection channels for DM

LHC searches

- If DM is light enough, it can be produced at colliders
- Missing E_T signatures



DM-nucleus interactions

- Searches for candidates in direct DM-nucleus scattering at e.g. the CRESST or XENON experiments
- Very low number of events expected per year

DM annihilation

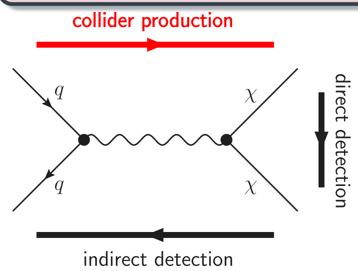
- Searches for excesses in γ-rays, antiparticles, high-energy νs

Different detection channels for DM

LHC searches

- If DM is light enough, it can be produced at colliders
- Missing E_T signatures

How well does χ-pair production at the LHC agree in SDMMs and the MSSM?



DM-nucleus interactions

- Searches for candidates in direct DM-nucleus scattering at e.g. the CRESST or XENON experiments
- Very low number of events expected per year

DM annihilation

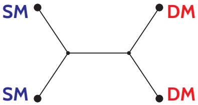
- Searches for excesses in γ-rays, antiparticles, high-energy νs

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Types of simplified DM models: The *s*-channel case

Assumption: DM (χ) is a singlet under SU(3) $\times$ SU(2) $\times$ U(1) and ...

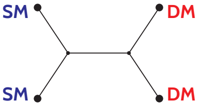
- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



Types of simplified DM models: The *s*-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



Possible Lagrangians with a scalar or vector mediator:

$$\mathcal{L}_S = g^S_\chi \bar{\chi}\chi S + \sum_q g^S_q \bar{q} q S$$

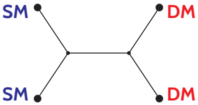
$$\mathcal{L}_P = i g^P_\chi \bar{\chi}\gamma_5 \chi P + \sum_q g^P_q \bar{q}\gamma_5 q P$$

$$\mathcal{L}_V = \bar{\chi}\gamma_\mu \left[g^V_\chi - g^A_\chi \gamma_5 \right] \chi V^\mu + \sum_q \bar{q}\gamma_\mu \left[g^V_q - g^A_q \gamma_5 \right] q V^\mu$$

Types of simplified DM models: The *s*-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



Possible Lagrangians with a ~~scalar~~ or vector mediator:

$$\mathcal{L}_S = g_\chi^S \bar{\chi}\chi S + \sum_q g_q^S \bar{q} q S$$

$$\mathcal{L}_P = i g_\chi^P \bar{\chi}\gamma_5 \chi P + \sum_q g_q^P \bar{q}\gamma_5 q P$$

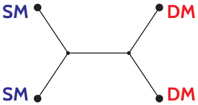
In this talk

$$\mathcal{L}_V = \bar{\chi}\gamma_\mu \left[g_\chi^V - g_\chi^A \gamma_5 \right] \chi V^\mu + \sum_q \bar{q}\gamma_\mu \left[g_q^V - g_q^A \gamma_5 \right] q V^\mu$$

Types of simplified DM models: The *s*-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



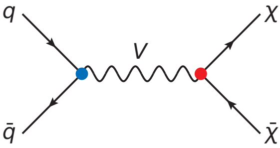
Interaction Lagrangian for a vector mediator:

$$\mathcal{L}_V = \bar{\chi}\gamma_\mu \left[g_\chi^V - g_\chi^A \gamma_5 \right] \chi V^\mu + \sum_q \bar{q}\gamma_\mu \left[g_q^V - g_q^A \gamma_5 \right] q V^\mu$$

with q: quark fields, χ: DM field, V^μ: vector mediator field, g^V, g^A: vector and axialvector couplings

Properties

- V is uncoloured and massive (M_V)
- Added to SM by sponanenously broken U(1)' symmetry to generate V mass
- Decays only into SM or DM pairs

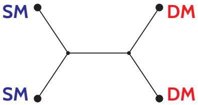


EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Types of simplified DM models: The *s*-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



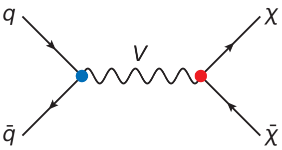
Interaction Lagrangian for a vector mediator:

$$\mathcal{L}_V = \bar{\chi}\gamma_\mu\left[g_\chi^V - g_\chi^A\gamma_5\right]\chi V^\mu + \sum_q \bar{q}\gamma_\mu\left[g_q^V - g_q^A\gamma_5\right]q V^\mu$$

with q: quark fields, χ: DM field, V^μ: vector mediator field, g^V, g^A: vector and axialvector couplings

Properties

- V is uncoloured and massive (M_V)
- Added to SM by sponanenously broken U(1)' symmetry to generate V mass
- Decays only into SM or DM pairs
- $g_\chi^{V/A} = g_q^{V/A} = 0.5$ so that $\frac{\Gamma_V}{M_V} < 0.5$



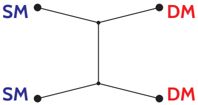
In this talk

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Types of simplified DM models: The *t*-channel case

Assumption: DM (χ) is a singlet under SU(3)$\times$SU(2)$\times$U(1) and ...

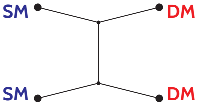
- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



Types of simplified DM models: The *t*-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



Interaction Lagrangian for a coloured scalar mediator:

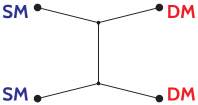
$$\mathcal{L}_{\tilde{Q}} = -\left[\lambda_{Q_L}\bar{\chi}P_L\tilde{Q}_L^{\dagger}\cdot Q + \lambda_{u_R}\tilde{Q}^*_{u_R}\bar{\chi}P_R u + \lambda_{d_R}\tilde{Q}^*_{d_R}\bar{\chi}P_R d + \mathrm{h.c.}\right]$$

with $\tilde{Q}_L = \begin{pmatrix}\tilde{Q}_{u_L}\\ \tilde{Q}_{d_L}\end{pmatrix}$ an SU(2)×U(1) doublet

Types of simplified DM models: The t-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



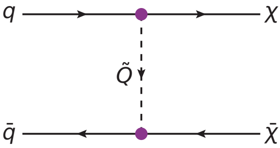
Interaction Lagrangian for a coloured scalar mediator:

$$\mathcal{L}_{\tilde{Q}} = -\Big[\lambda_{Q_L}\left(\tilde{Q}^*_{u_L}\bar{\chi}P_L u + \tilde{Q}^*_{d_L}\bar{\chi}P_L d\right) + \lambda_{u_R}\tilde{Q}^*_{u_R}\bar{\chi}P_R u + \lambda_{d_R}\tilde{Q}^*_{d_R}\bar{\chi}P_R d + \text{h.c.}\Big]$$

with u, d: up- and down-type quark fields, χ: DM field, $\tilde{Q}_{q_{L/R}}$: coloured scalar mediator fields (“squarks”), λ: DM-quark-squark Yukawa couplings, $P_{L/R}$: left- and right-handed chirality projectors

Properties

- $\tilde{Q}$ are coloured and flavoured (12 squarks)
- Heavier than χ so that the decay $\tilde{Q} \to q\chi$ is possible ($M_{\tilde{Q}} > m_\chi$)

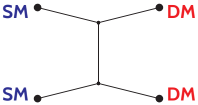


EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Types of simplified DM models: The t-channel case

Assumption: DM (χ) is a singlet under SU(3)×SU(2)×U(1) and ...

- ... consists of Dirac fermions
- ... interacts with the SM via the topology:



Interaction Lagrangian for a coloured scalar mediator:

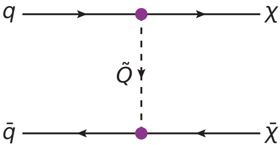
$$\mathcal{L}_{\tilde{Q}} = -\Big[\lambda_{Q_L}\left(\tilde{Q}^*_{u_L}\bar{\chi}P_L u + \tilde{Q}^*_{d_L}\bar{\chi}P_L d\right) + \lambda_{u_R}\tilde{Q}^*_{u_R}\bar{\chi}P_R u + \lambda_{d_R}\tilde{Q}^*_{d_R}\bar{\chi}P_R d + \text{h.c.}\Big]$$

with u, d: up- and down-type quark fields, χ: DM field, $\tilde{Q}_{q_{L/R}}$: coloured scalar mediator fields ("squarks"), λ: DM-quark-squark Yukawa couplings, $P_{L/R}$: left- and right-handed chirality projectors

Properties

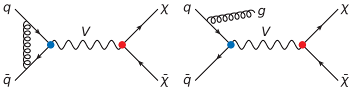
- $\tilde{Q}$ are coloured and flavoured (12 squarks)
- Heavier than χ so that the decay $\tilde{Q} \to q\chi$ is possible ($M_{\tilde{Q}} > m_\chi$)
- $\lambda_{Q_L} = \lambda_{u_R} = \lambda_{d_R} = 1$ for simplicity

In this talk



NLO QCD corrections in the simplified models

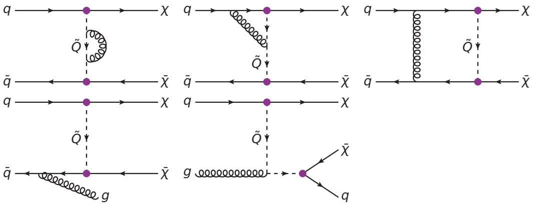
s-channel



Virtuals calculated with `FeynArts/FormCalc`
[Hahn, Perez-Victoria '98-'00]

Reals calculated with `MadGraph 4`
[Murayama et al., Stelzer et al., Alwall et al. '92-'07]

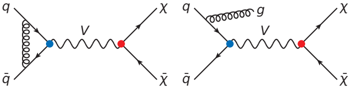
t-channel



Analogous to above, more loop diagrams due to coloured $\tilde{Q}$

NLO QCD corrections in the simplified models

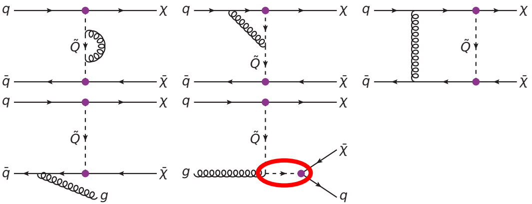
s-channel



Virtuals calculated with `FeynArts/FormCalc`
[Hahn, Perez-Victoria '98-'00]

Reals calculated with `MadGraph 4`
[Murayama et al., Stelzer et al., Alwall et al. '92-'07]

t-channel



Analogous to above, more loop diagrams due to coloured $\tilde{Q}$

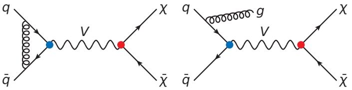
Subtlety in real corrections:

- Intermediate $\tilde{Q}$ can become resonant
- Corresponds to on-shell $\tilde{Q}$ production followed by $\tilde{Q}$ decay $\Rightarrow$ actually a different Born process
- Resonance needs to be subtracted to keep the perturbative series meaningful

Follow on-shell subtraction method from *[Baglio, Jäger, Kesenheimer '16-'17]*

NLO QCD corrections in the simplified models

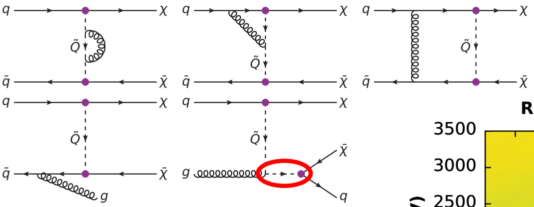
s-channel



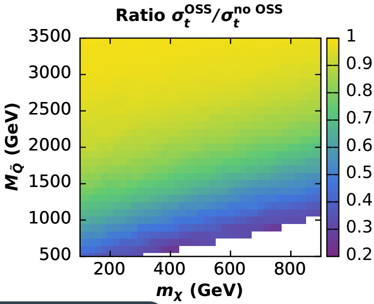
Virtuals calculated with `FeynArts/FormCalc` *[Hahn, Perez-Victoria '98-'00]*

Reals calculated with `MadGraph 4` *[Murayama et al., Stelzer et al., Alwall et al. '92-'07]*

t-channel



Analogous to above, more loop diagrams due to coloured $\tilde{Q}$



Subtlety in real corrections:

- Intermediate $\tilde{Q}$ can become resonant
- Corresponds to on-shell $\tilde{Q}$ production followed by $\tilde{Q}$ decay ⇒ actually a different Born process
- Resonance needs to be subtracted to keep the perturbative series meaningful

Follow on-shell subtraction method from *[Baglio, Jäger, Kesenheimer '16-'17]*

Tools and numerical setup

Roadmap of the calculation:

- *Generate points in MSSM parameter space*
  Spectrum generator: `SPheno 4.0.3` *[Porod '03; Porod, Staub '12]*

CMSSM *[Adeel Ajaib, Gogoladze '17]*	pMSSM10 *[de Vries et al. '15]*	
$M_0 \in [0, 10]$ TeV	$M_1 \in [-1, 1]$ TeV	$M_2 \in [0, 4]$ TeV
$m_{1/2} \in [0, 10]$ TeV	$M_3 \in [-4, 4]$ TeV	$m_{\tilde{q}_{1/2}} \in [0, 4]$ TeV
$A_0 \in [-3, 3] \times M_0$	$m_{\tilde{q}_3} \in [0, 4]$ TeV	$m_{\tilde{l}} \in [0, 2]$ TeV
$\tan\beta \in [2, 60]$	$M_A \in [0, 4]$ TeV	$A \in [-5, 5]$ TeV
$\mathrm{sign}\,\mu > 0$	$\mu \in [-5, 5]$ TeV	$\tan\beta \in [1, 60]$

  5000 points where $\tilde{\chi}_1^0$ is the LSP and the lightest Higgs mass satisfies 124 GeV $\leq m_h \leq$ 126 GeV

- *Fix parameters of s- and t-channel models*
  Choose: $m_\chi = m_{\tilde{\chi}_1^0}$, $M_V = 1$ TeV and 10 TeV, $M_{\tilde{Q}} =$ average of $\tilde{u}_{L/R}, \tilde{d}_{L/R}, \tilde{c}_{L/R}, \tilde{s}_{L/R}, \tilde{b}_{1/2}$ masses,
  $g_\chi^{V/A} = g_q^{V/A} = g = 0.5$, $\lambda_{Q_L} = \lambda_{u_R} = \lambda_{d_R} = \lambda = 1$

- *Calculate $pp \to \tilde{\chi}_1^0 \tilde{\chi}_1^0$ cross section in MSSM for each point*
  `POWHEG-BOX` *[Alioli, Nason, Oleari, Re '10]* with weakino code *[Baglio, Jäger, Kesenheimer '16]*

- *Calculate $pp \to \chi\bar{\chi}$ cross section in SDMMs for each point*
  `POWHEG-BOX` and for the t-channel model `COLLIER-1.2` *[Denner, Dittmaier, Hofer '17]*

LHC at $\sqrt{S}$ = 13 TeV, PDFs used: PDF4LHC15 NLO MC PDFs *[Butterworth et al. '16]*

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Tools and numerical setup

Roadmap of the calculation:

- *Generate points in MSSM parameter space*
  Spectrum generator: `SPheno 4.0.3` [Porod '03; Porod, Staub '12]

CMSSM [Adeel Ajaib, Gogoladze '17]	pMSSM10 [de Vries et al. '15]	
$M_0 \in [0, 10]$ TeV	$M_1 \in [-1, 1]$ TeV	$M_2 \in [0, 4]$ TeV
$m_{1/2} \in [0, 10]$ TeV	$M_3 \in [-4, 4]$ TeV	$m_{\tilde{q}_{1/2}} \in [0, 4]$ TeV
$A_0 \in [-3, 3] \times M_0$	$m_{\tilde{q}_3} \in [0, 4]$ TeV	$m_{\tilde{l}} \in [0, 2]$ TeV
$\tan\beta \in [2, 60]$	$M_A \in [0, 4]$ TeV	$A \in [-5, 5]$ TeV
$\mathrm{sign}\,\mu > 0$	$\mu \in [-5, 5]$ TeV	$\tan\beta \in [1, 60]$

  5000 points where $\tilde{\chi}_1^0$ is the LSP and the lightest Higgs mass satisfies 124 GeV $\leq m_h \leq$ 126 GeV

- *Fix parameters of s- and t-channel models*
  Choose: $m_\chi = m_{\tilde{\chi}_1^0}$, $M_V = 1$ TeV and 10 TeV, $M_{\tilde{Q}} =$ average of $\tilde{u}_{L/R}, \tilde{d}_{L/R}, \tilde{c}_{L/R}, \tilde{s}_{L/R}, \tilde{b}_{1/2}$ masses,
  $g_\chi^{V/A} = g_q^{V/A} = g = 0.5, \lambda_{Q_L} = \lambda_{u_R} = \lambda_{d_R} = \lambda = 1$

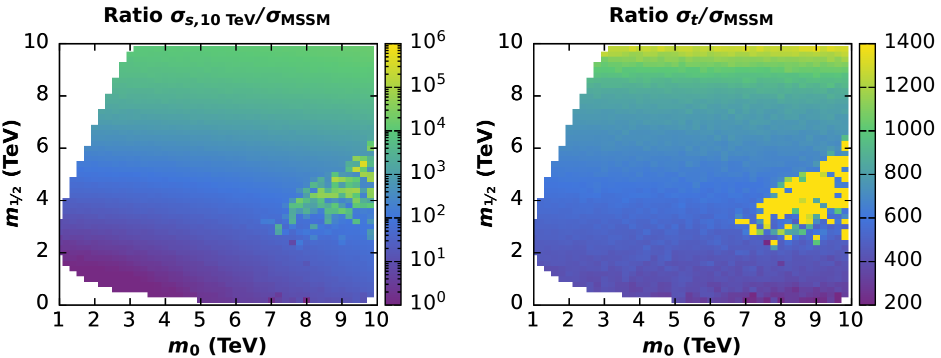
- *Calculate $pp \to \tilde{\chi}_1^0\tilde{\chi}_1^0$ cross section in MSSM for each point*
  `POWHEG-BOX` [Alioli, Nason, Oleari, Re '10] with weakino code [Baglio, Jäger, Kesenheimer '16]

- *Calculate $pp \to \chi\bar{\chi}$ cross section in SDMMs for each point*
  `POWHEG-BOX` and for the t-channel model `COLLIER-1.2` [Denner, Dittmaier, Hofer '17]

LHC at $\sqrt{S}$ = 13 TeV, PDFs used: PDF4LHC15 NLO MC PDFs [Butterworth et al. '16]

Preliminary results!

Parameter scan in the CMSSM



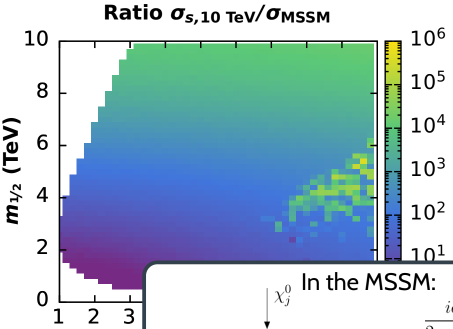
Ratios with respect to MSSM at NLO QCD

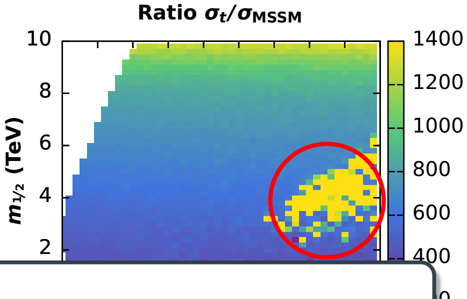
- Ratio involving s-channel model varies by several orders of magnitude
- Ratio involving t-channel model almost constant ($\sim$ factor 3)
- Effect at high M_0 and intermediate $m_{1/2}$ due to "higgsino mixing matrix suppression" in MSSM $\Rightarrow \sigma_{\mathrm{MSSM}}$ low

[CB, Coniglio, Jäger; in preparation]

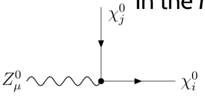
Preliminary results!

Parameter scan in the CMSSM





In the MSSM:



$$\frac{ie}{2 s_W c_W}\gamma^\mu\left((Z_N^{4i\star}Z_N^{4j} - Z_N^{3i\star}Z_N^{3j})P_L - (Z_N^{4i}Z_N^{4j\star} - Z_N^{3i}Z_N^{3j\star})P_R\right)$$

$$\mathcal{M} \propto |N_{14}|^2 - |N_{13}|^2$$

[Rosiek '95-'09]

Rati

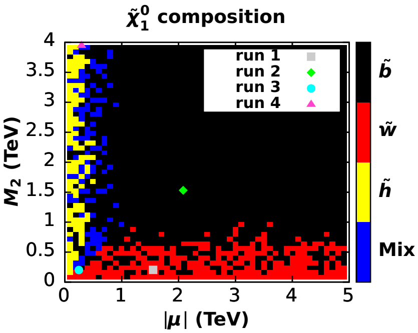
- Ratio involving s-channel model varies by several orders of magnitude
- Ratio involving t-channel model almost constant ($\sim$ factor 3)
- Effect at high M_0 and intermediate $m_{1/2}$ due to "higgsino mixing matrix suppression" in MSSM $\Rightarrow$ σ_{MSSM} low

[CB, Coniglio, Jäger; in preparation]

Preliminary results!

Parameter scan in the pMSSM10

[CB, Coniglio, Jäger; in preparation]



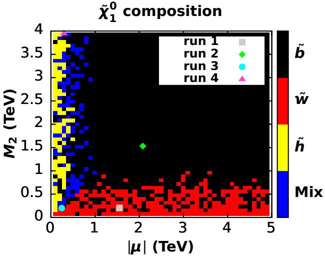
$\tilde{\chi}_1^0$ composition

- Distinguish between $\tilde{b}$ino, $\tilde{w}$ino, $\tilde{h}$iggsino
- Pure bino/wino: no Z exchange possible

Preliminary results!

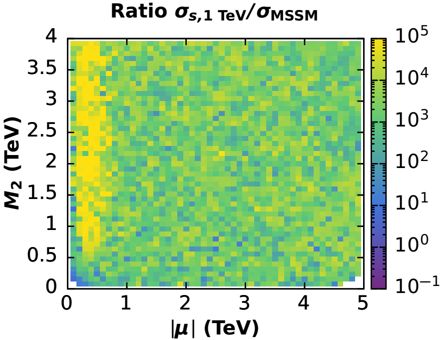
Parameter scan in the pMSSM10

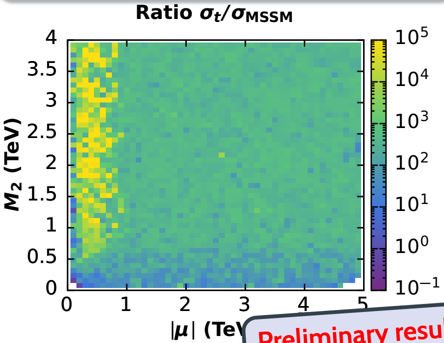
[CB, Coniglio, Jäger; in preparation]



$\tilde{\chi}_1^0$ composition

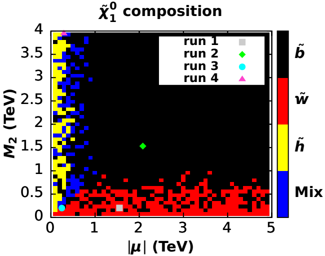
- Distinguish between $\tilde{b}$ino, $\tilde{w}$ino, $\tilde{h}$iggsino
- Pure bino/wino: no Z exchange possible
- Higher s-channel mediator mass M_V smoothens the bino region a bit, difficult to distinguish from t-channel model





Preliminary results!

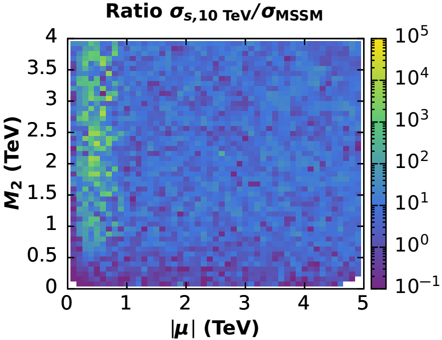
Parameter scan in the pMSSM10

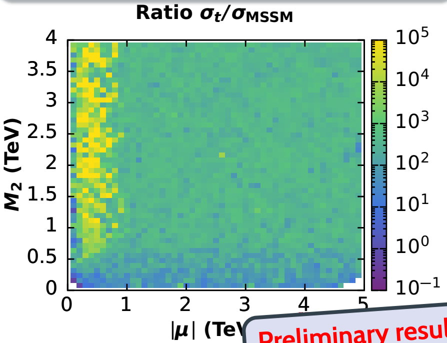


[CB, Coniglio, Jäger; in preparation]

$\tilde{\chi}_1^0$ composition

- Distinguish between $\tilde{b}$ino, $\tilde{w}$ino, $\tilde{h}$iggsino
- Pure bino/wino: no Z exchange possible
- Higher s-channel mediator mass M_V smoothens the bino region a bit, difficult to distinguish from t-channel model

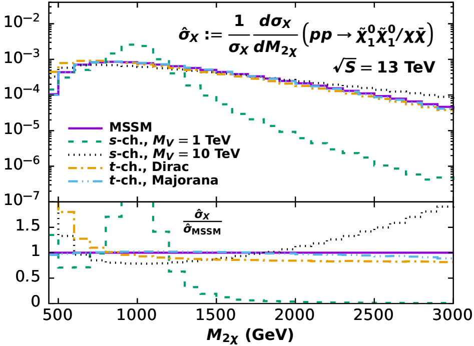


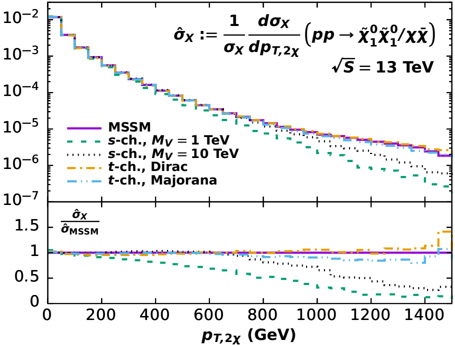


Preliminary results!

Distributions for a pMSSM10 parameter point: run 1

[CB, Coniglio, Jäger; in preparation]





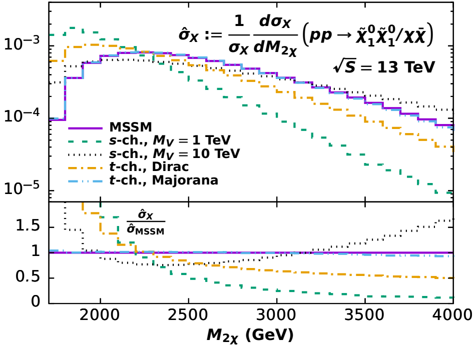
Analysis including parton shower

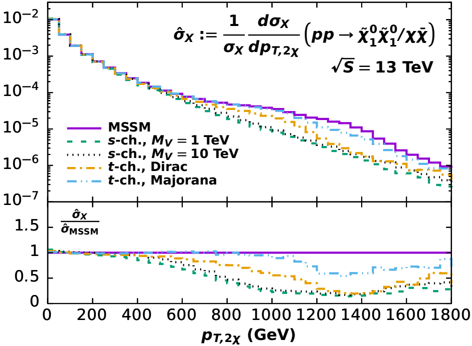
- $\tilde{\chi}_1^0$ mainly $\tilde{w}$ino, DM mass $\sim$ 220 GeV, squark masses $\sim$ 3 TeV
- *t*-channel very close to MSSM, agreement with *s*-channel (M_V = 1 TeV) is worst
- *s*- and *t*-channel almost indistinguishable in some regions of $M_{2\chi}$ and $p_{T,2\chi}$

Preliminary results!

Distributions for a pMSSM10 parameter point: run 2

[CB, Coniglio, Jäger; in preparation]





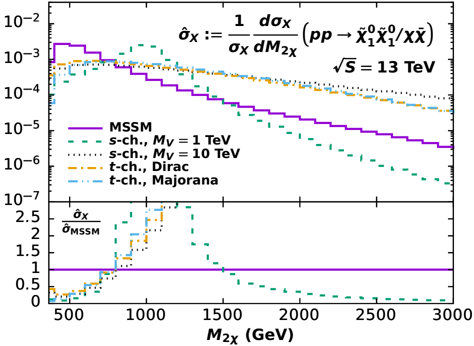
Analysis including parton shower

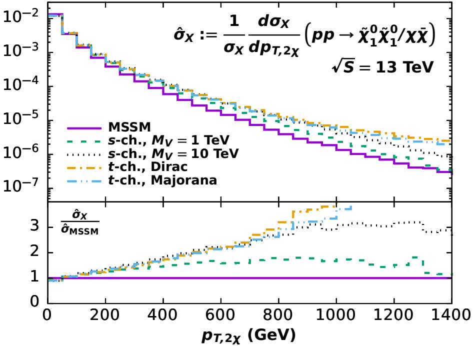
- $\tilde{\chi}_1^0$ mainly $\tilde{b}$ino, DM mass ~ 850 GeV, squark masses ~ 2.5 TeV
- *t*-channel close to MSSM, Majorana case better than Dirac
- Bump around $p_{T,2\chi} \approx 1.25$ TeV remnant of on-shell subtraction procedure

Preliminary results!

Distributions for a pMSSM10 parameter point: run 3

[CB, Coniglio, Jäger; in preparation]





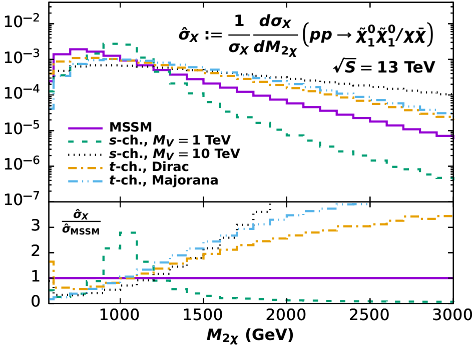
Analysis including parton shower

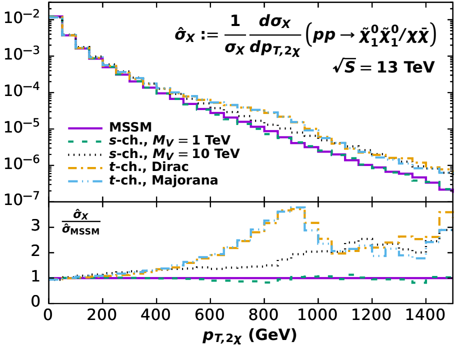
- $\tilde{\chi}_1^0$ mainly $\tilde{w}$ino-$\tilde{h}$iggsino, DM mass ~ 180 GeV, squark masses ~ 3.4 TeV
- No agreement between simplified models and MSSM for $M_{2\chi}$ and $p_{T,2\chi}$ distributions

Preliminary results!

Distributions for a pMSSM10 parameter point: run 4

[CB, Coniglio, Jäger; in preparation]





Analysis including parton shower

- $\tilde{\chi}_1^0$ mainly $\tilde{h}$iggsino-mix, DM mass $\sim$ 290 GeV, squark masses $\sim$ 1.8 TeV
- No agreement between simplified models and MSSM for $M_{2\chi}$ distribution
- Good agreement with s-channel (M_V = 1 TeV) for $p_{T,2\chi}$ distribution

Preliminary results!

Summary and conclusions

SDMMs: studying DM at the LHC with a minimal set of parameters

Summary and conclusions

SDMMs: studying DM at the LHC with a minimal set of parameters

Two specific models studied:

- *s*-channel model with a vector mediator, and *t*-channel model with coloured and flavoured scalar mediators
- NLO QCD corrections including PS calculated for DM pair-production and implemented in the `POWHEG-BOX` framework

Summary and conclusions

SDMMs: studying DM at the LHC with a minimal set of parameters

Two specific models studied:

- *s*-channel model with a vector mediator, and *t*-channel model with coloured and flavoured scalar mediators
- NLO QCD corrections including PS calculated for DM pair-production and implemented in the `POWHEG-BOX` framework

Comparison with $\tilde{\chi}_1^0$ pair-production in the MSSM:

- Simplified models can reproduce some MSSM features, in particular the *t*-channel model with only three parameters $(m_\chi, M_{\tilde{Q}}, \lambda)$
- However, poor agreement for studied models in several other regions
- Require more complex models, or SDMMs better suited for description of some other non-SUSY theory?

Summary and conclusions

SDMMs: studying DM at the LHC with a minimal set of parameters

Two specific models studied:

- *s*-channel model with a vector mediator, and *t*-channel model with coloured and flavoured scalar mediators
- NLO QCD corrections including PS calculated for DM pair-production and implemented in the `POWHEG-BOX` framework

Comparison with $\tilde{\chi}_1^0$ pair-production in the MSSM:

- Simplified models can reproduce some MSSM features, in particular the *t*-channel model with only three parameters $(m_\chi, M_{\tilde{Q}}, \lambda)$
- However, poor agreement for studied models in several other regions
- Require more complex models, or SDMMs better suited for description of some other non-SUSY theory?

THANK YOU FOR YOUR ATTENTION! ☺