Summary of SUSY+Cosmology sessions

International Workshop on Linear Colliders 2010 (ECFA-CLIC-ILC Joint Meeting)

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CERN, Theory Unit & IPhT CEA Saclay

Many talks on mass/parameter determination mostly within standard susy framework:

SUSY Prediction for the ILC — *Sven Heinemeyer,*

Determination of Heavy Smuon and Selectron Mass at CLIC — J-J.Blaising

A Study of Light-flavored SQuark Production at CLIC — **Peter Schade**, **Frank Simon**

A Study of Chargino and Neutralino Masses using W and h Energy Spectra and Threshold Scans at CLIC. — **N.Alster**

Measuring a light neutralino mass at the ILC — John Conley

$M_{\chi_1^0} =$ a few GeV.

Measuring Unification — Michael Rauch

Polarized positrons for Higgs and SUSY — *Gudrid Moortgat-Pick*

On the possibility of stop mass determination in photon-photon and e^+e^- collisions at ILC — A.N.Skachkova

and within less common susy

Dirac gauginos and their scalar partners

Jan Kalinowski

Bilinear R parity violation at the ILC

Neutrino physics at colliders?

Benedikt Vormwald

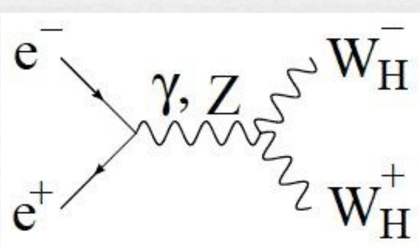
Sneutrino dark matter

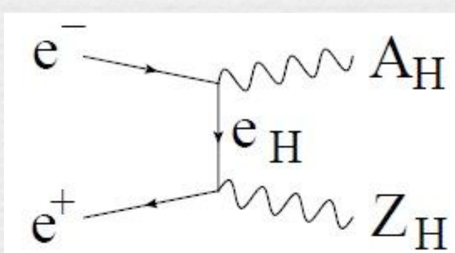
G. Bélanger

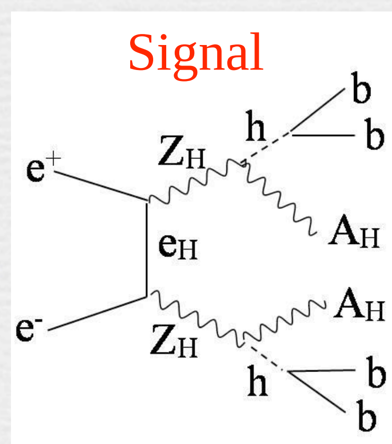
invisible higgs decay (almost 100% BR) into sneutrinos

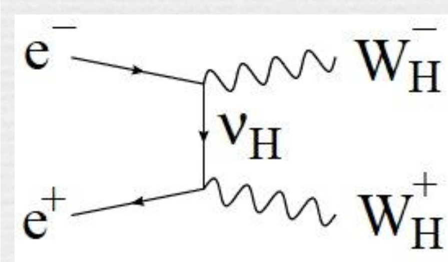
and beyond susy (heavy gauge bosons in little higgs models)

Y. Takubo









and model-independent approaches

Model Independent WIMP Searches
with Polarized Beams at the ILC

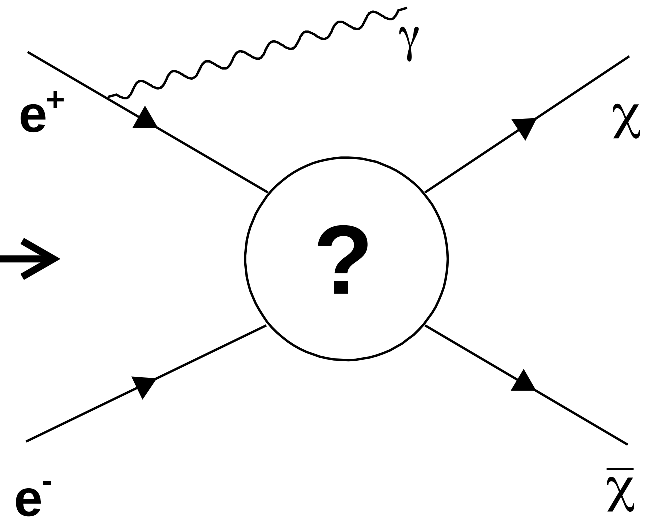
Christoph Bartels

WIMP Detection with ISR

$$e^+e^- \longrightarrow \chi\chi\gamma$$

Is it possible to extract
Masses and J_0 from data?
Required Luminosity,
Polarised beams?
What can we learn about
the question mark?

→

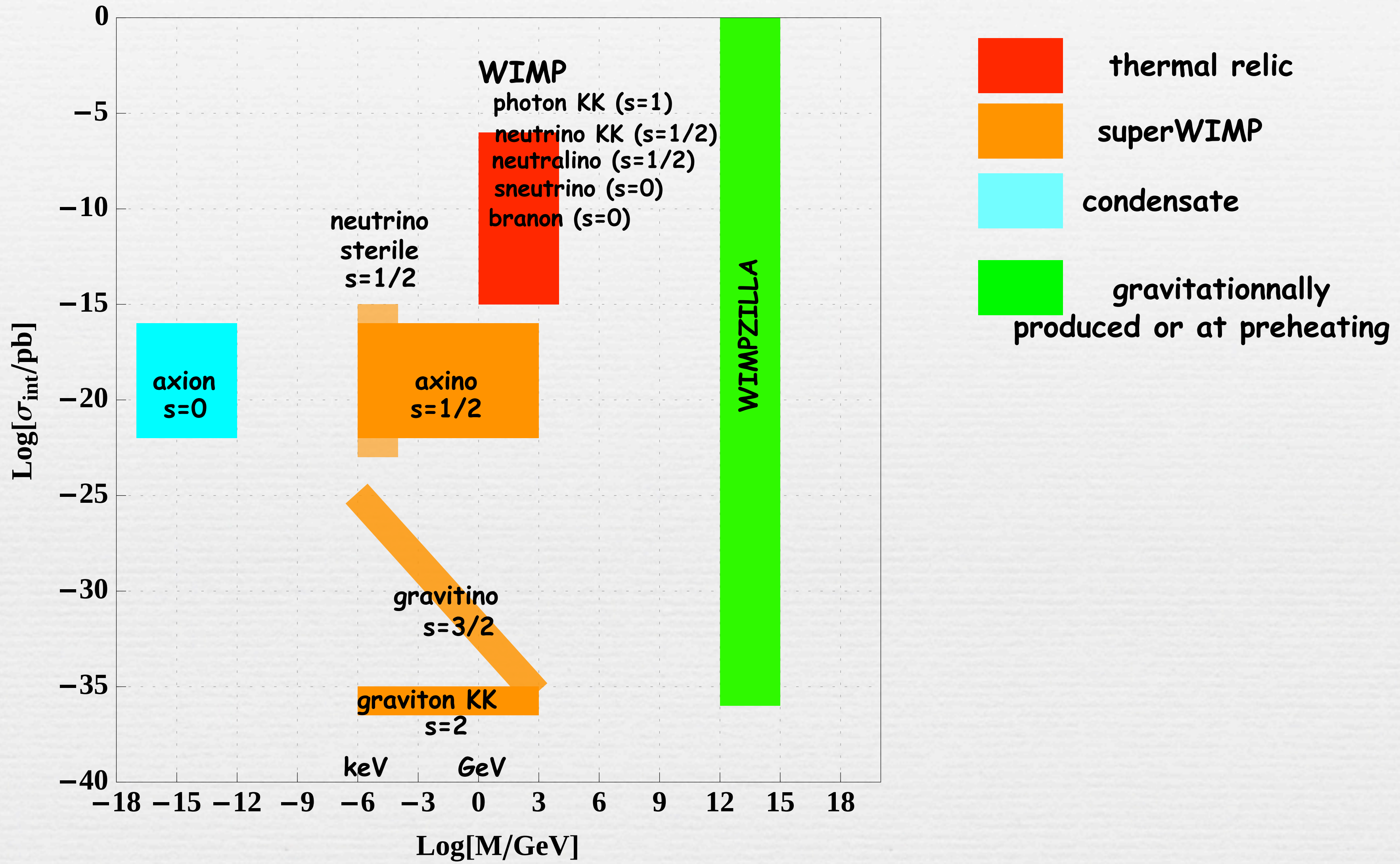


and beyond any expectation

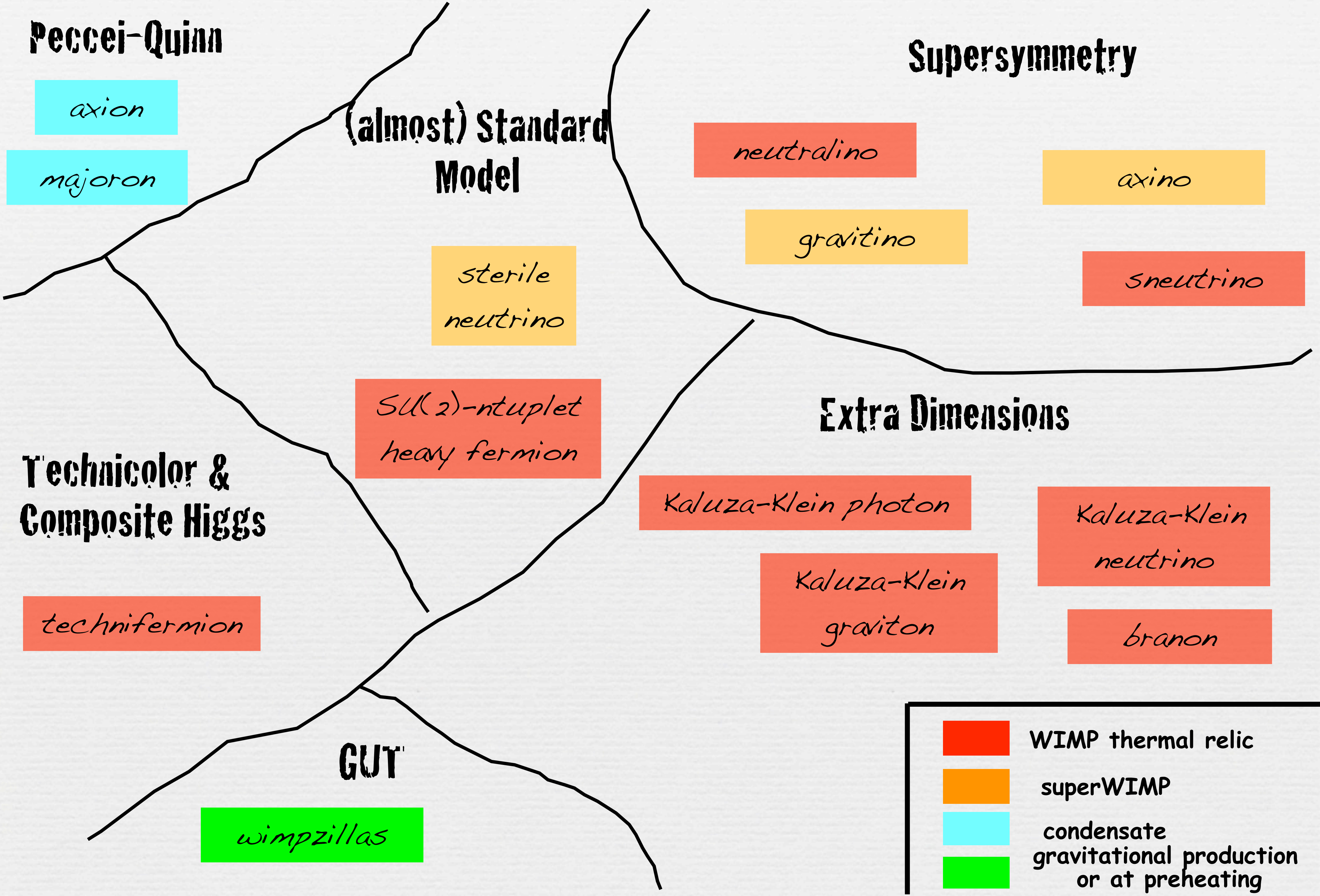
Dark Energy at Colliders?

Philippe Brax

Dark Matter Candidates Ω~1



In Theory Space



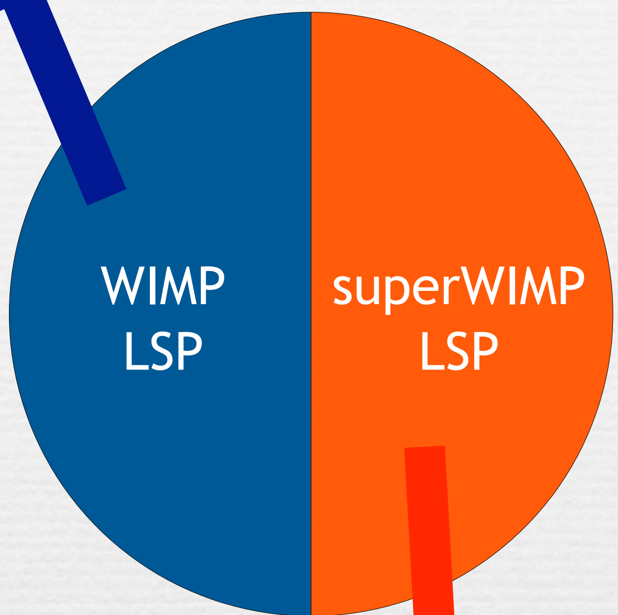
On LONG-LIVED STAUS (A. Ibarra)

Canonical SUSY scenario:

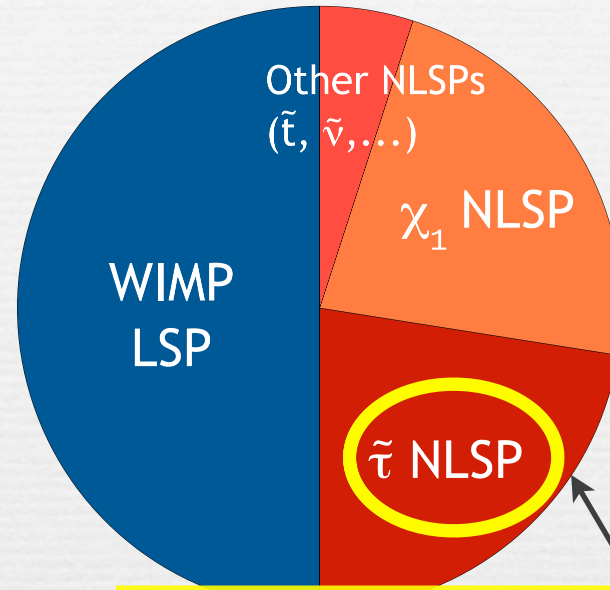
LSP: neutralino

next-to-LSP: lightest stau, chargino (sneutrino, stop)

SUSY models



SUSY models



we should be prepared for this possibility

The LSP could also be a **superweakly interacting particle:**

gravitino | axino | Hidden U(1) gaugino

Bolz, Brandenbutg, Buchmüller;
Pradler, Steffen;
Rychkov, Strumia

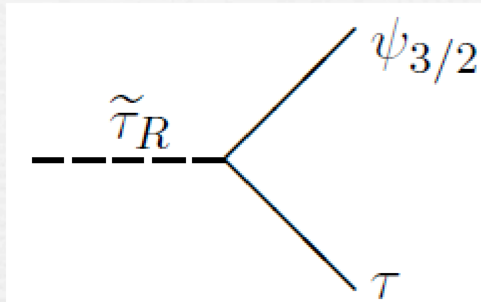
Asaka, Yanagida;
Covi, Kim, Kim, Roszkowski;
Brandenbutg, Steffen.

AI, Ringwald, Weniger

Interesting and viable scenarios, which could account for the dark matter of the Universe

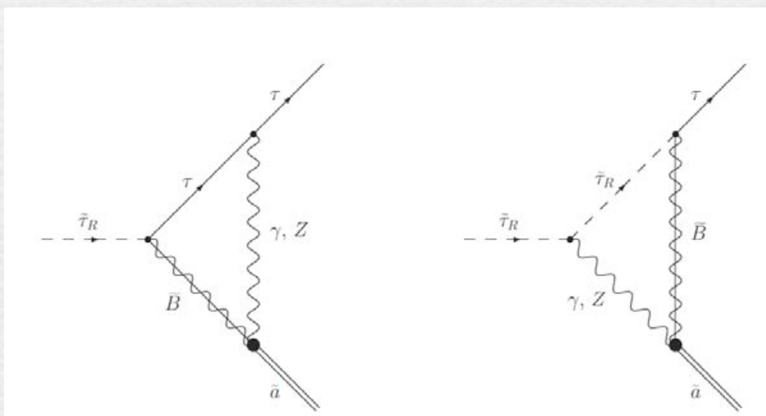
Scenarios with superWIMP LSP share one common feature: if R-parity is conserved, the NLSP is very long lived!

gravitino



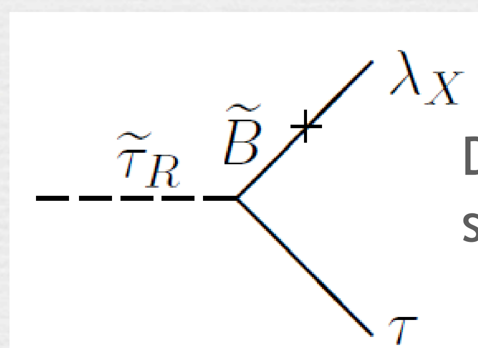
Decay rate suppressed by the Planck mass (or more properly, by the SUSY breaking scale $F=\sqrt{3}\, m_{3/2}\, M_P$)

axinos



Decay rate suppressed by the Peccei-Quinn scale

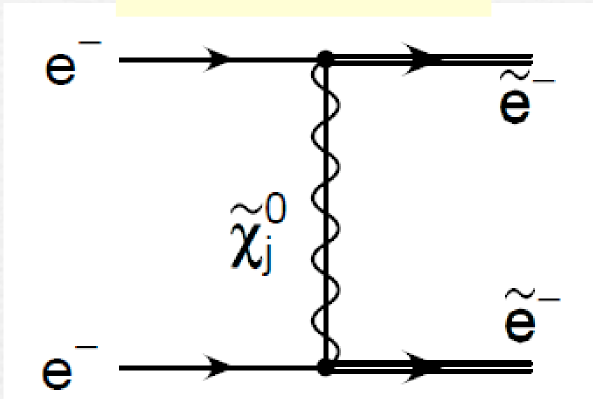
hidden U(1) gauginos



Decay rate suppressed by the small kinetic mixing.

Production of long lived staus

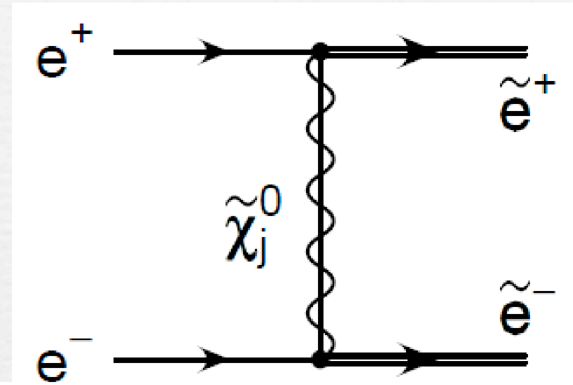
e^-e^- collider

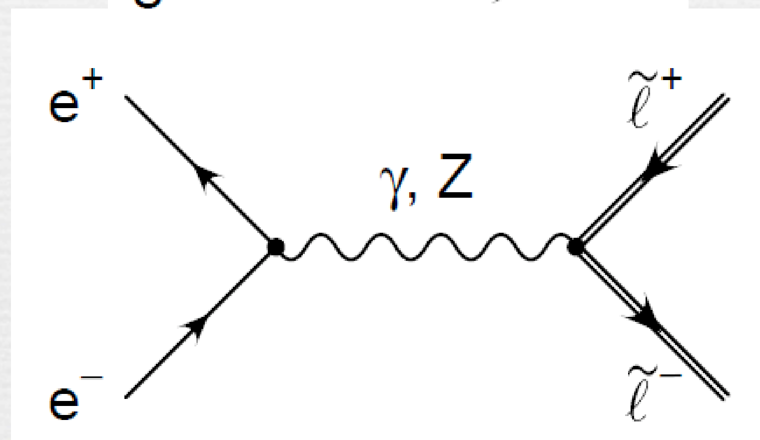


The selectron decays producing staus:

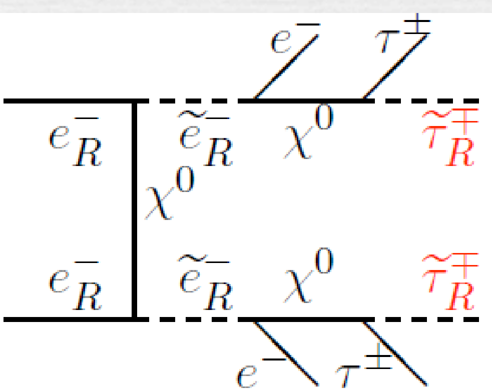
$$\tilde{e}^-_R \longrightarrow e^- \ \tau^\pm \ \tilde{\tau}^\mp_1$$
$$\tilde{e}^-_L \longrightarrow e^- \ \tau^\pm \ \tilde{\tau}^\mp_1$$
$$\tilde{e}^-_L \longrightarrow \nu_e \ \bar{\nu}_\tau \ \tilde{\tau}^-_1$$

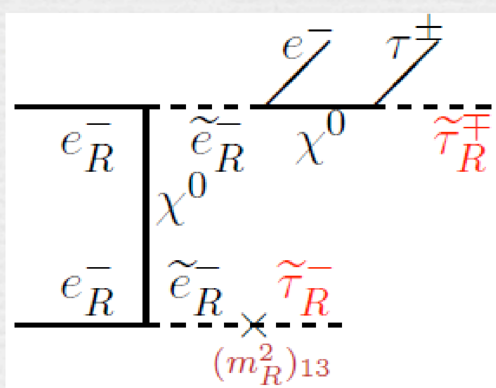
e^+e^- collider





Direct production of staus





- Four/Two charged fermions and two heavily ionizing tracks

Detection of long lived staus

Charged track in the detector. Very similar to a muon, but with some differences:

- Large mass. Use kinematical cuts.
- Slow. Use a good Time of Flight (ToF) device.

  In a large detector (r=2m), the mean time of flight of a muon (β=1) is 6.7 ns. A heavy particle (β<1) will reach the detector later. Assuming a time of flight measurement with an error of 50ps, the cut $\Delta t > 0.13$ ns removes 99% of the muon background.
  $\Rightarrow$ Efficiency in the identification 60-80% for stau masses 140-250 GeV

- Ionizing particle. Use a good Time Projection Chamber (TPC)

  In contrast to muons (which lose energy mostly by radiation), heavy charged particles lose energy by ionization. Assuming a 5% resolution in the measurement of dE/dx, the cut $\frac{dE/dX - dE/dX(\mathrm{muon})}{\sigma(dE/dX)} > 3$ provides an efficiency in the identification >90% for stau masses larger than 180 GeV.

Physics opportunities with long lived staus

1- Mass measurements

2- Searches for lepton flavour violation

AI, Roy

Hamaguchi, AI

If the LSP is the gravitino, measure the Planck mass

Buchmüller, Hamaguchi, Ratz, Yanagida

$$M_P = \sqrt{\frac{t_{\tilde{\tau}} m_{\tilde{\tau}}}{48\pi} \frac{m_{\tilde{\tau}}^2}{m_{3/2}}} \left[1 - \frac{m_{3/2}^2}{m_{\tilde{\tau}}^2}\right]^2$$

If the LSP is the axino, estimate the Peccei-Quinn scale

Brandenburg et al

If the LSP is the hidden gaugino, measure the kinetic mixing

AI, Ringwald, Weniger

Determine the spin of the invisible particle

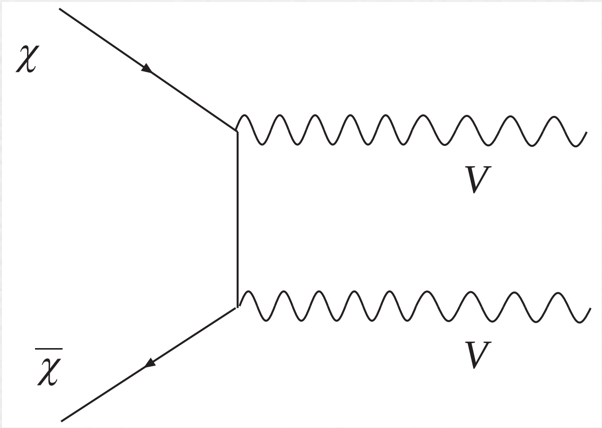
Buchmuller et al.
Brandenburg et al

Hidden sectors and Dark forces (B. Batell)

Secluded Dark Matter

Pospelov, Ritz, Voloshin '07

- Dark Matter is a SM gauge singlet
- Talks to SM through mediator

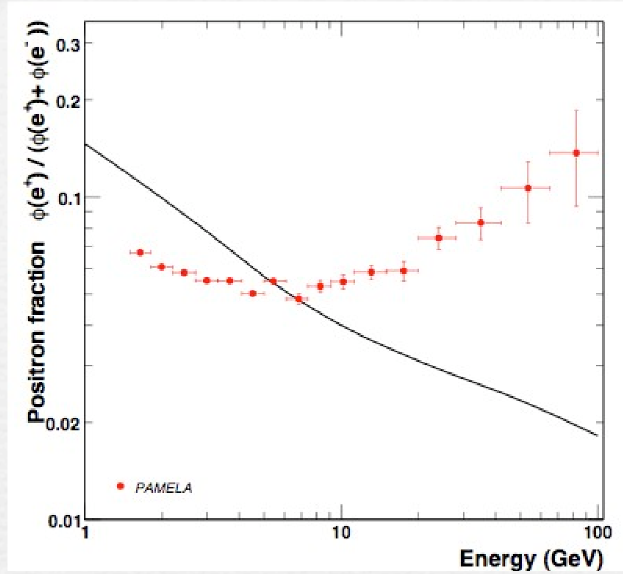


Example:dark matter via kinetic mixing

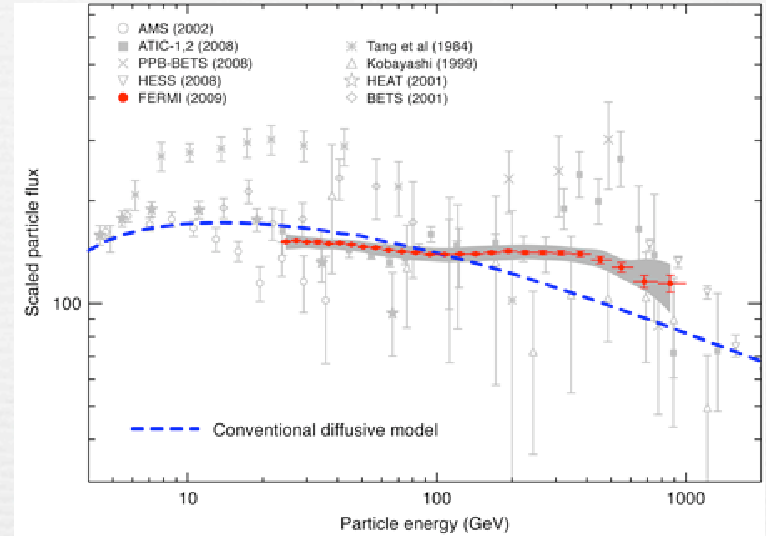
$$\mathcal{L} = i\overline{\chi}\gamma^{\mu}(\partial_{\mu} - ig_D V_{\mu})\chi - \frac{\kappa}{2} V_{\mu\nu} B^{\mu\nu} + \ldots$$

Motivation

PAMELA



FERMI

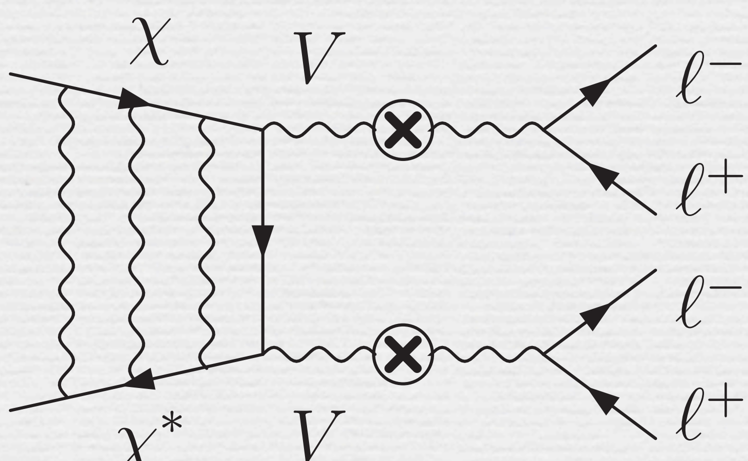


GeV-scale 'Dark' force

Arkani-Hamed, Finkbeiner, Slatyer, Weiner '08

Pospelov, Ritz '08

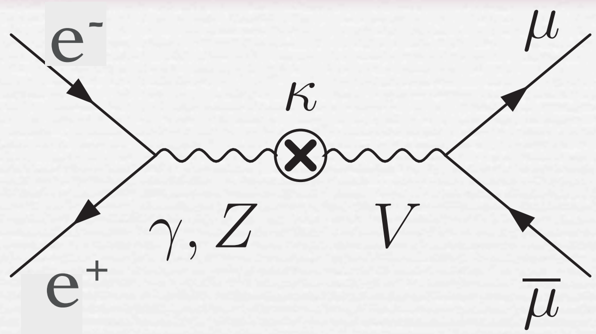
- Long range attractive force enhances $\langle \sigma v \rangle_{\mathrm{halo}}$
- Annihilation products cannot decay to anti-protons by kinematics



Hidden sector at ILC

Kumar, Wells '06

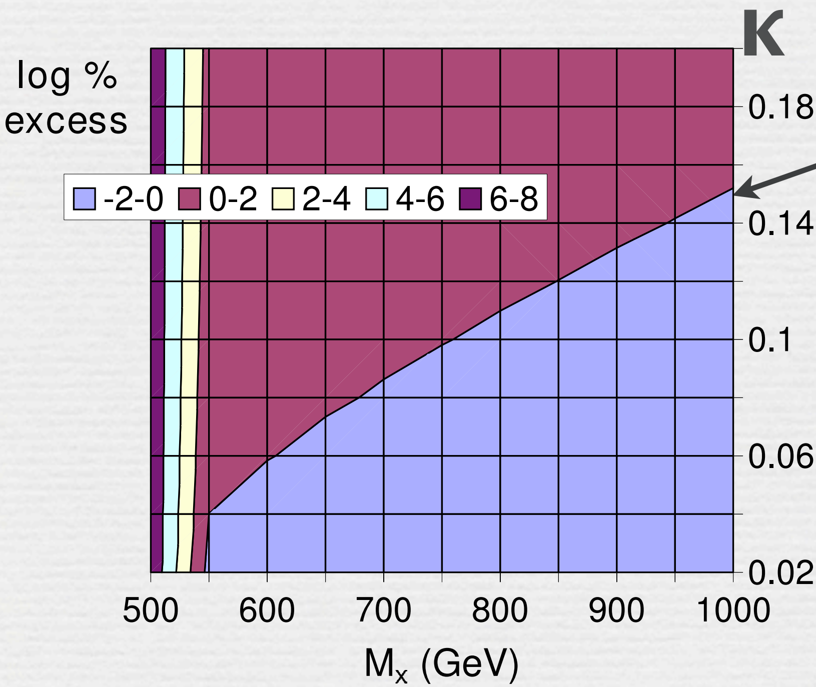
$$\mathcal{L} \supset -\frac{\kappa}{2} B_{\mu\nu} V^{\mu\nu}$$



- Direct production $\Longrightarrow$ pay κ^2

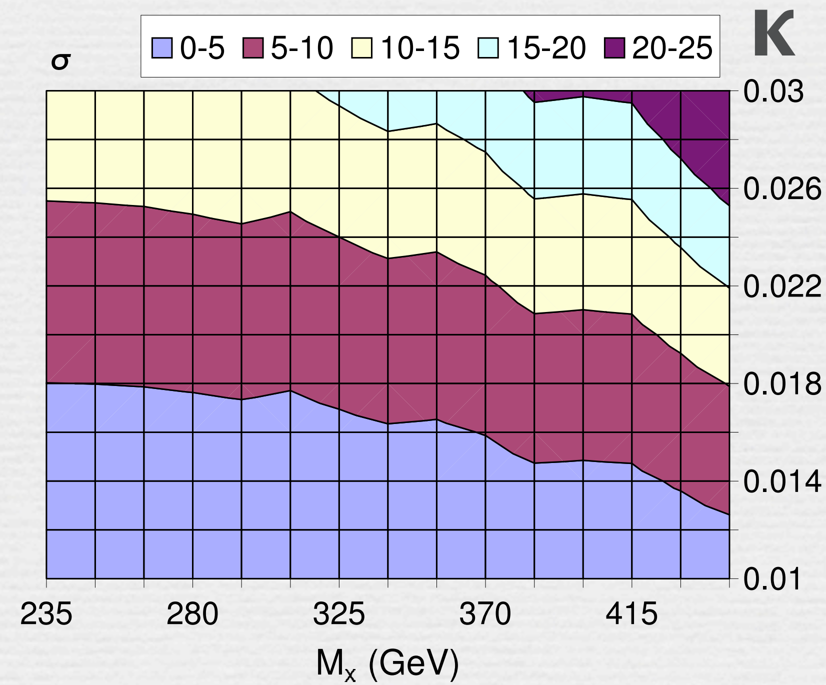
at ILC at $\sqrt{s} = 500\,\mathrm{GeV}$
for $500\,\mathrm{fb}^{-1}$

Deviations of $e^+e^- \to \mu\bar{\mu}$



1% deviation contour

Signal significance plot of
$e^+e^- \to \gamma X \to \gamma\mu\bar{\mu}$



Possible bridges to the hidden sector

- W, Z
- Higgs — Higgs portal $\mathcal{L} \supset \lambda H^\dagger H S^2$
- LSP, LKP, LTP, ...
- Z'
- Techni-ρ
- RS Gravitons

Exotic Higgs Decays:

- $h \to SS \to$ missing energy

Silveira, Zee '85

- $h \to aa \to 4b, 4c, 4\tau \ldots 4\gamma$

Dobrescu, Landsberg, Matchev '01

Dermisek, Gunion '04

Chang, Fox, Weiner '05

- $h \to VV \to 4l$

Gopalakrishna, Jung, Wells '08

- $h \to \eta\eta \to 4g, 4c$

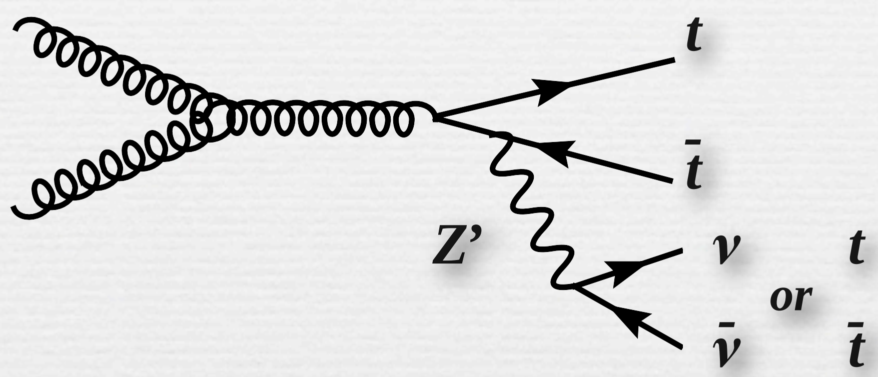
Bellazzini, Csaki, Falkowski, Weiler '01

Collider signatures of a top (and DM)-philic Z′

- ~~$f\overline{f} \to Z' \to t\bar{t}$~~

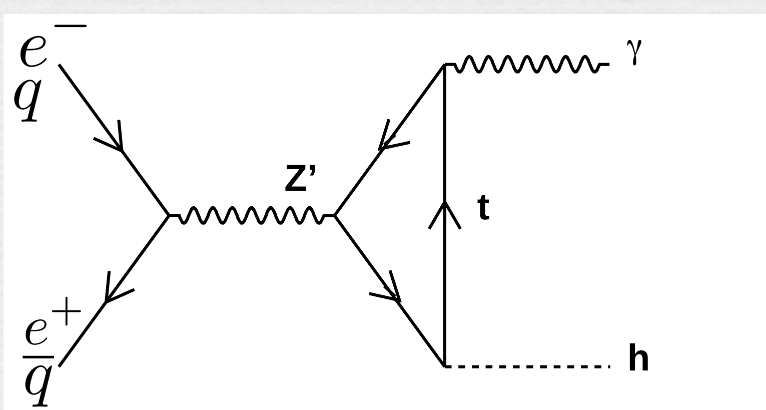
Z′ has suppressed couplings to light quarks
-> no observable $t\bar{t}$ resonances

- $gg \to t\bar{t} + Z'$
  - $Z' \to \nu\bar{\nu}$: $t\bar{t} + \not{E}_T$
  - $Z' \to t\bar{t}$: $t\bar{t}t\bar{t}$



- $f\overline{f} \to Z' \to \gamma H$

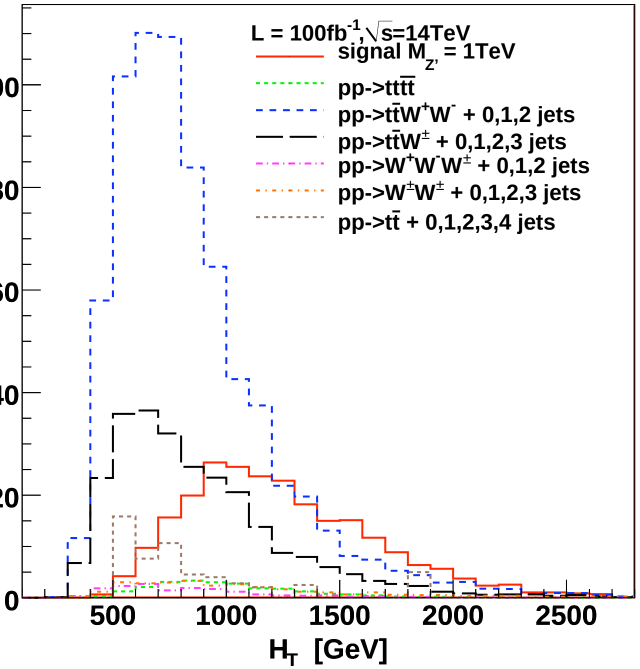
energetic monochromatic γ

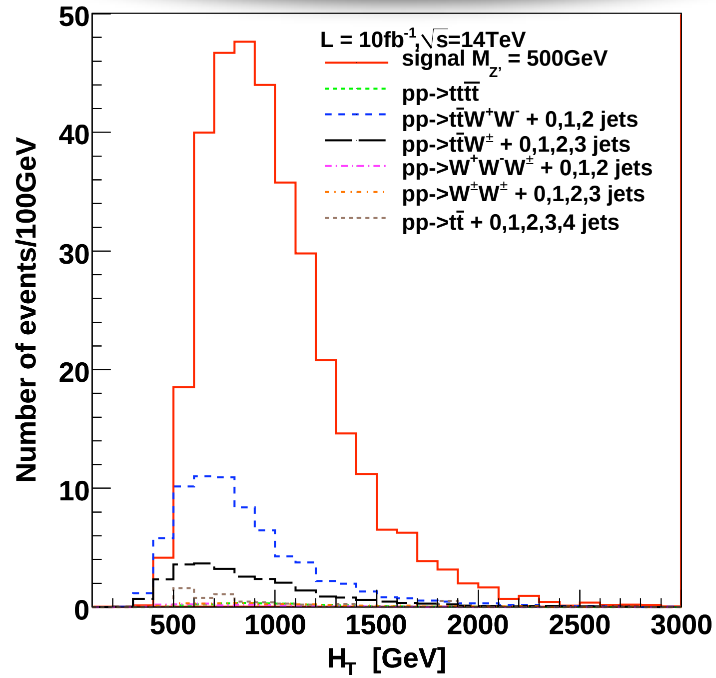


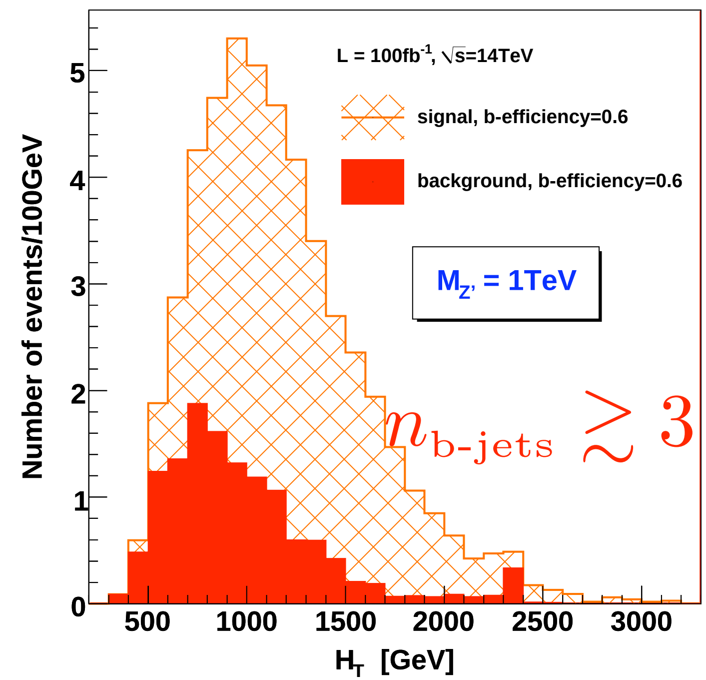
$n_j \geq 6, p_T > 30$ GeV

pp → $t\bar{t}t\bar{t}$ @ 14 TeV LHC

in same-sign dilepton channel

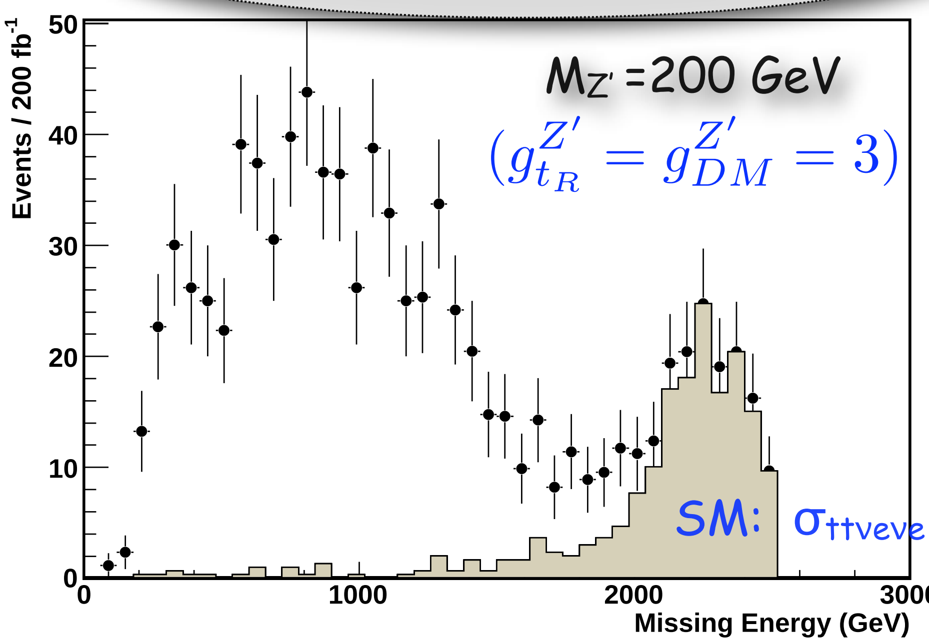






Gauthier-Servant

$e^+ e^- \to t\bar{t} + \not{E}_T$ @ 3 TeV CLIC



SM: σ_{ttveve} = 4.1 fb

Battaglia-Servant 1005.4632

A common signature:

$$t\,\bar{t} + \text{large}\ \not{E}_T$$

from pair-production of top partners that decay into DM

scalar

Majorana fermion

SUSY: $\tilde{t} \to \chi_0\ t$

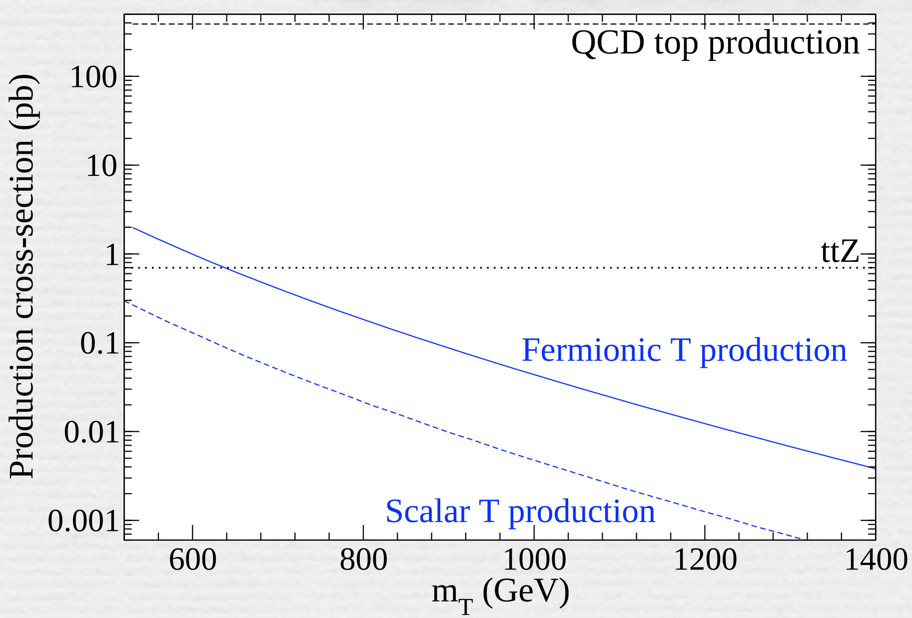
Little Higgs $T \to A_H\ t$

Gauge bosons

Universal extra dimensions $t^{(1)} \to B^{(1)}\ t$

Randall-Sundrum GUTs $t^{(1)'} \to \nu^{(1)'}\ \nu^{(1)'}\ t$

Dirac fermions



Z_3 symmetry in the SM:

Agashe-Servant'04

number of color indices

$$\Phi \to \Phi\, e^{2\pi i \left[B - \frac{(\alpha - \bar{\alpha})}{3} \right]}$$

conserved in any theory where baryon number is a good symmetry

any non-colored particle that carries
baryon number will be charged under Z_3

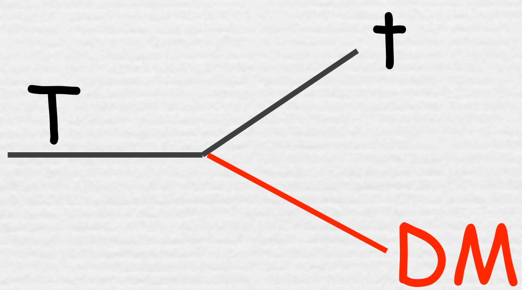
e.g warped GUTs

Z_2 versus Z_3 Dark Matter

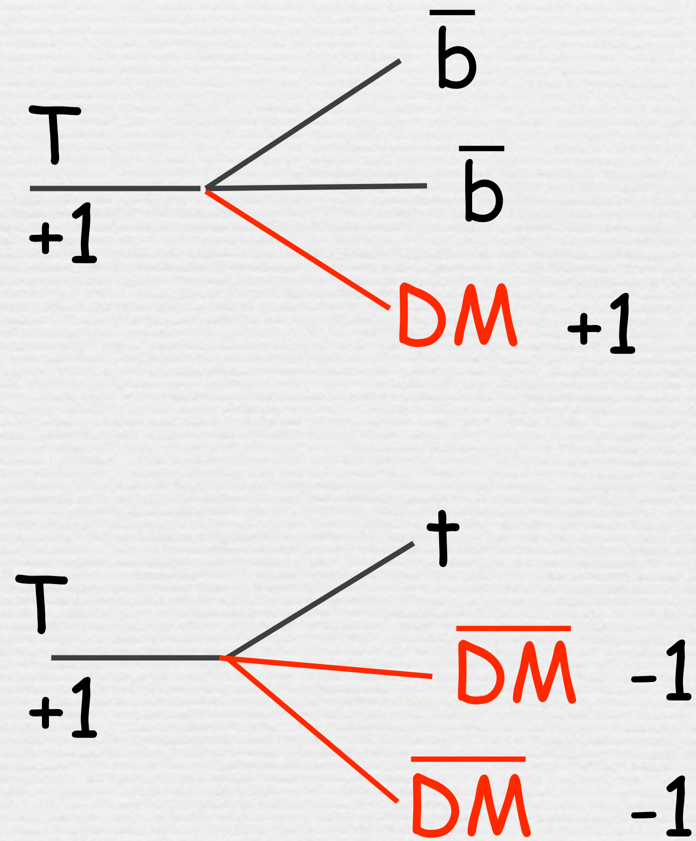
Agashe et al, 1003.0899
Mahbubani-Servant, in prep.

Most Dark Matter models rely on a Z_2 symmetry. However, other symmetries can stabilize dark matter. Can the nature of the underlying symmetry be tested?

Z_2

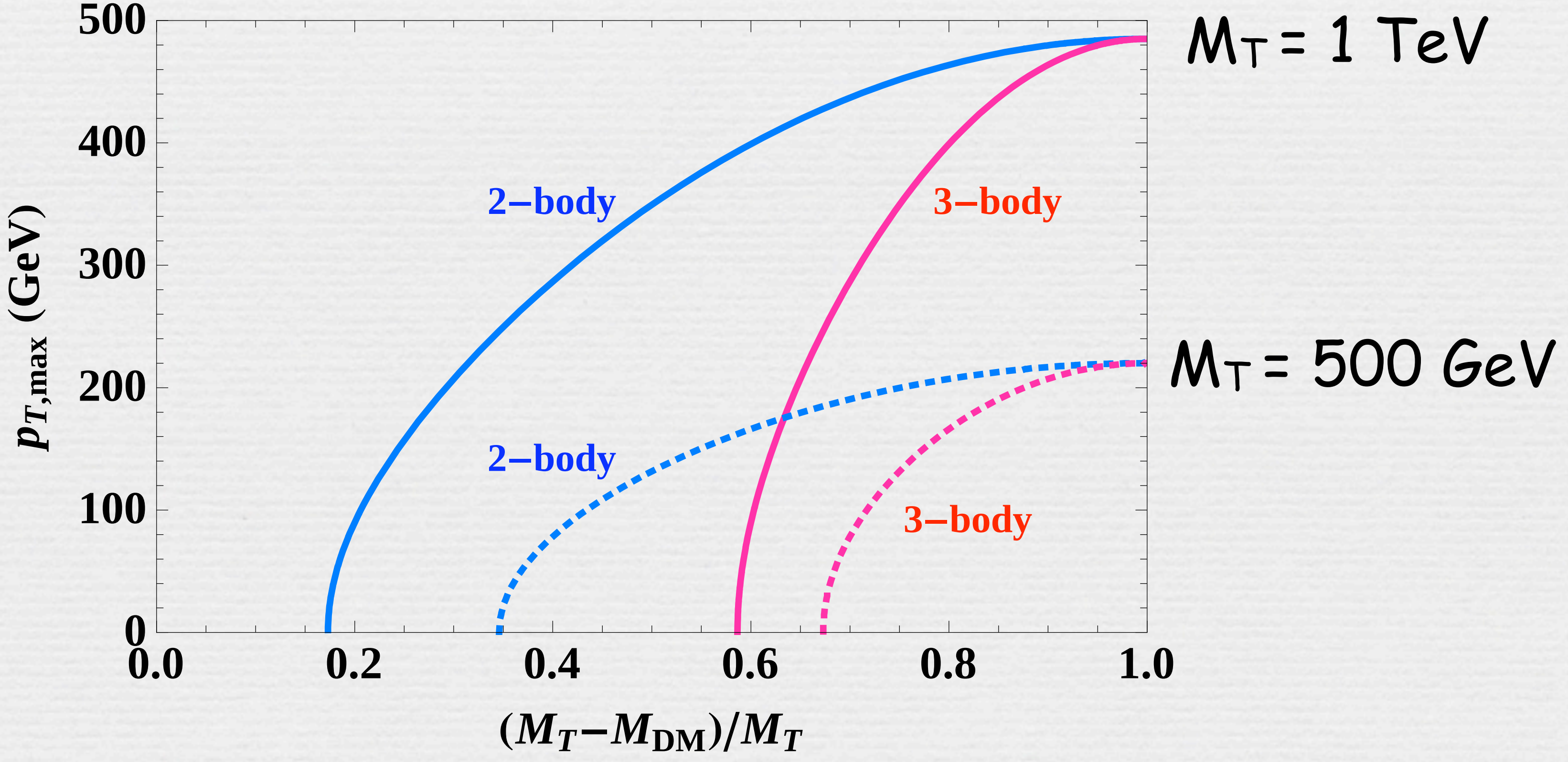


Z_3 (+1=-2)



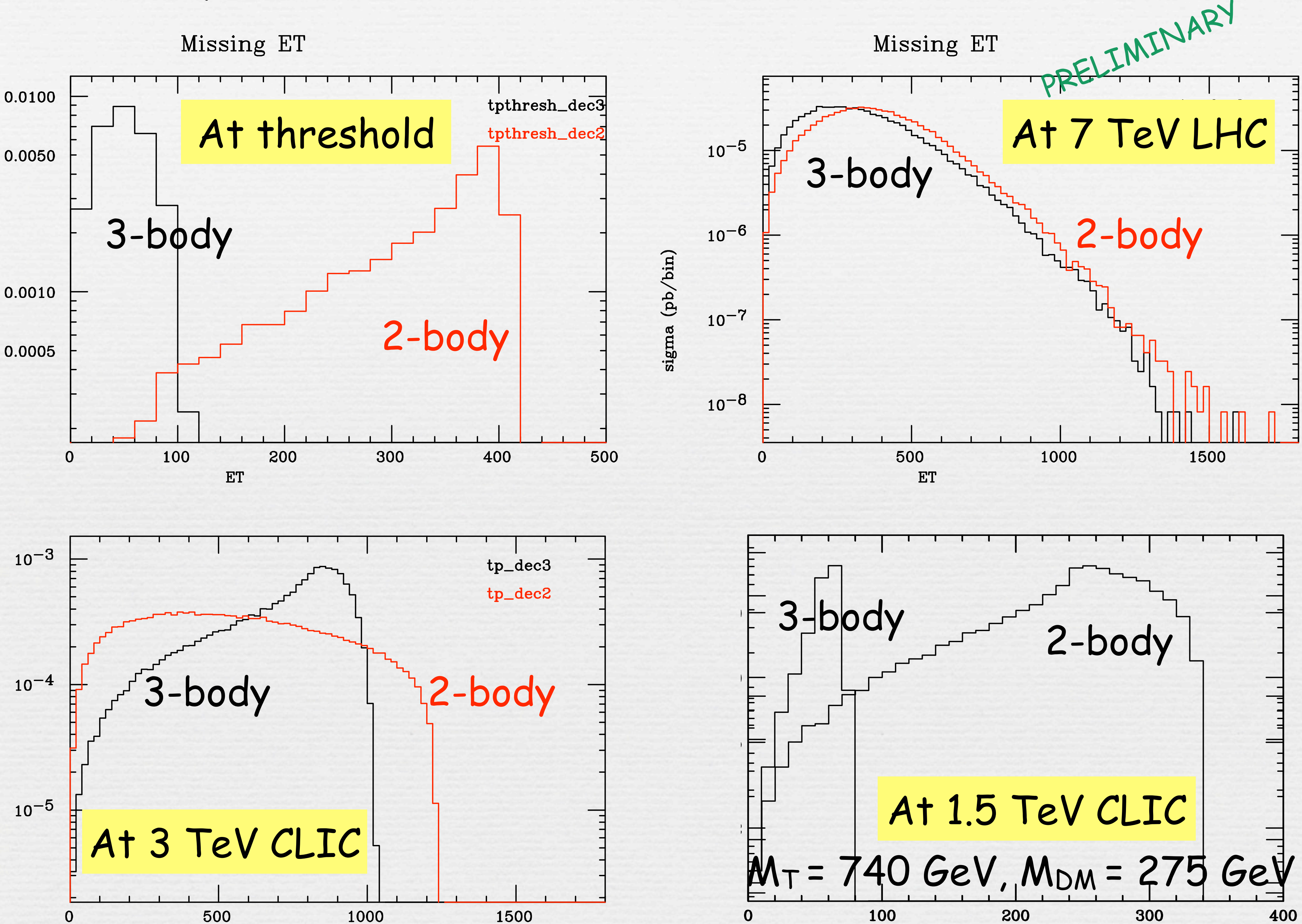
Z_2 versus Z_3 Dark Matter

In rest frame of the mother particle, the maximum of the p_T distributions is different in these 2 cases:



Example: $M_T = 1$ TeV, $M_{DM} = 400$ GeV

Mahbubani-Servant



Conclusion

Large effort in susy studies

Little outside of the standard susy scenario.

Very little beyond susy (as far as DM is concerned)