Probing EWIMPs with Precision Measurements at 100 TeV Colliders

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Precision EWIMP search motivated by Higgsino

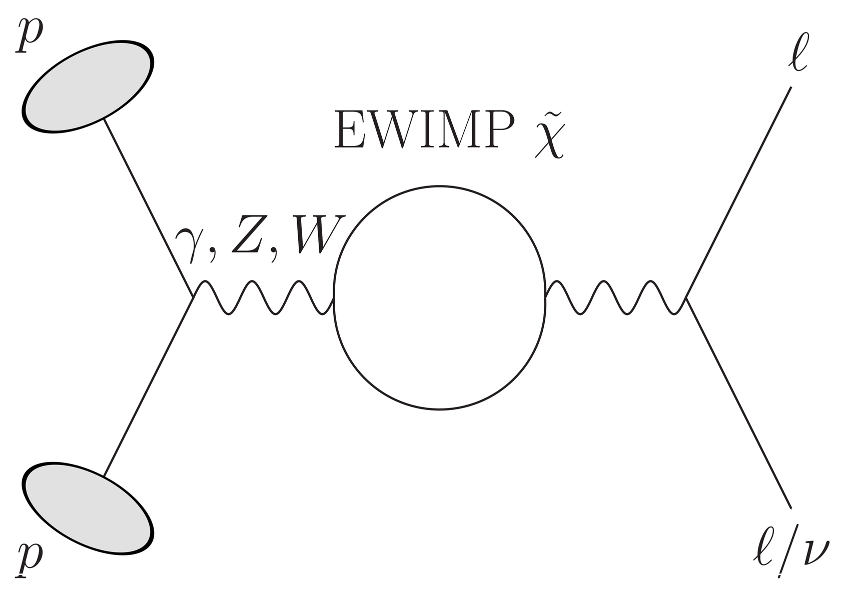
ElectroWeakly Interacting Massive Particles

Well-motivated DM candidates in many models

Many ways to probe

- DM direct / indirect detection
- Disappearing track search
- Mono-X search

BUT Higgsino difficult : Today focus on ⇒



Difficulties in Higgsino search

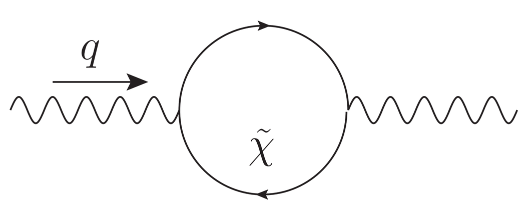
- ✖ Small $SU(2)_L$ charge
- ✖ (Possibly) short lifetime of $\tilde{\chi}^{\pm}$

Precision measurement of $\ell\ell/\ell\nu$ production

- ✔ Large statistics
- ✔ Independent of lifetime

Good probe of EWIMPs including Higgsino

EWIMP effect on $\ell\ell/\ell\nu$ production processes

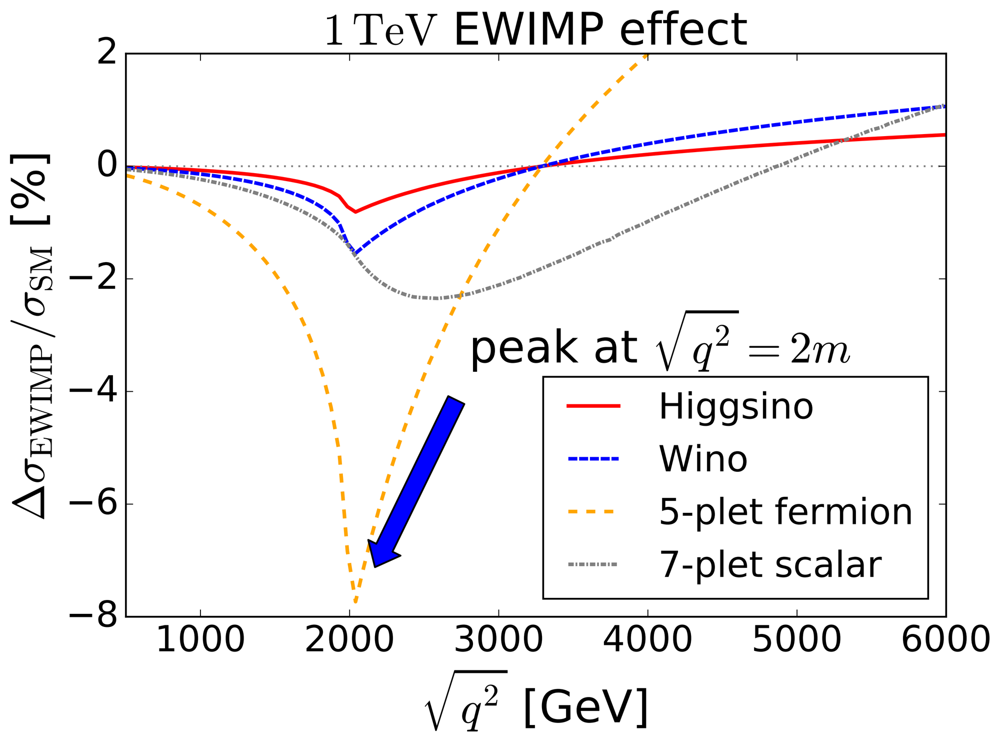


$$\equiv ig^2(q^2 g^{\mu\nu} - q^\mu q^\nu)\Pi(q^2/m^2) \Big|_{\text{finite}}$$

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + C_1 W^a_{\mu\nu}\Pi\left(-\frac{D^2}{m^2}\right)W^{a\mu\nu} + C_2 B_{\mu\nu}\Pi\left(-\frac{\partial^2}{m^2}\right)B^{\mu\nu}$$

$C_1 = g^2,\ C_2 = g'^2$ for Higgsino

$C_1 = 0,\ C_2 = 2g^2$ for Wino



For $pp \to W^* \to \ell\nu$ process

Use m_T instead of $\sqrt{q^2}$:

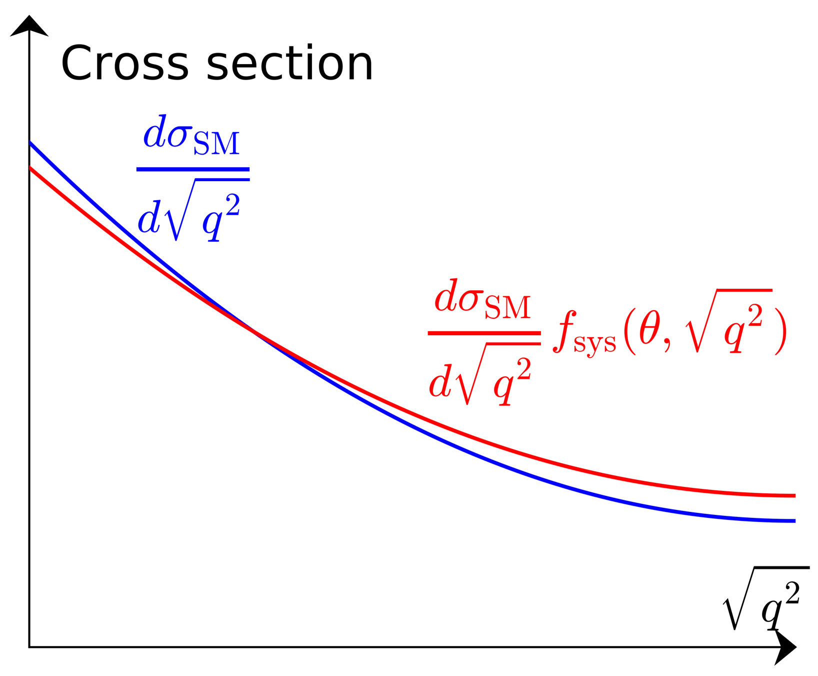
$$m_T^2 \equiv 2\,|\vec{p}_{T,\ell}|\,|\vec{\not{p}}_T| - 2\vec{p}_{T,\ell}\cdot\vec{\not{p}}_T$$

✔ Same peak structure at $m_T = 2m$

How to treat Systematic errors?

Systematic uncertainties modify event numbers

- luminosity error
- beam energy error
- choice of renormalization scale
- choice of factorization scale
- choice of PDF
- etc $\cdots$



Fitting based analysis

$$\widetilde{N}_i^{(\text{SM})}(\boldsymbol{\theta}) \equiv N_i^{(\text{SM})} \times f_{\text{sys}}(\boldsymbol{\theta}, m_{\ell\ell,i})$$

$f_{\text{sys}}(\boldsymbol{\theta}, m_{\ell\ell})$: smooth modification of event numbers

CDF collaboration '09

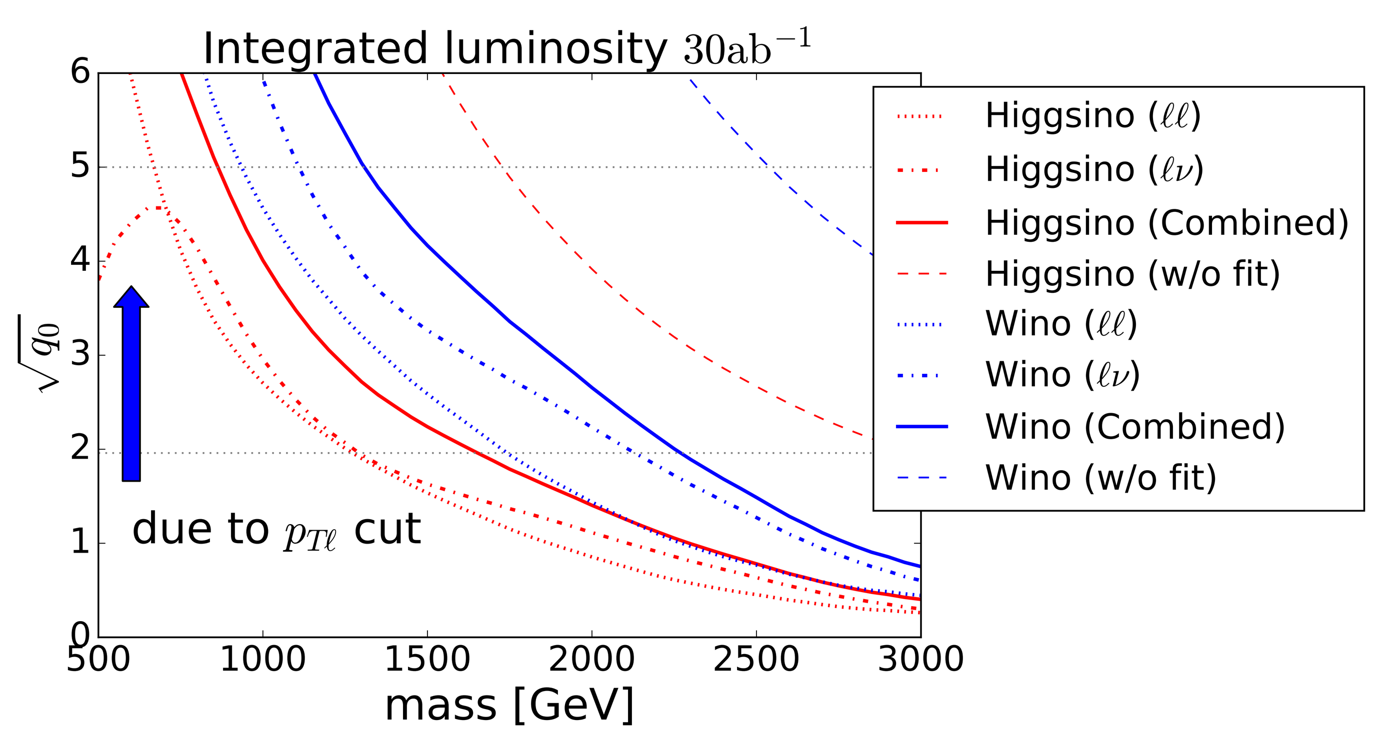
✔ Systematic errors are well absorbed by f_{sys}

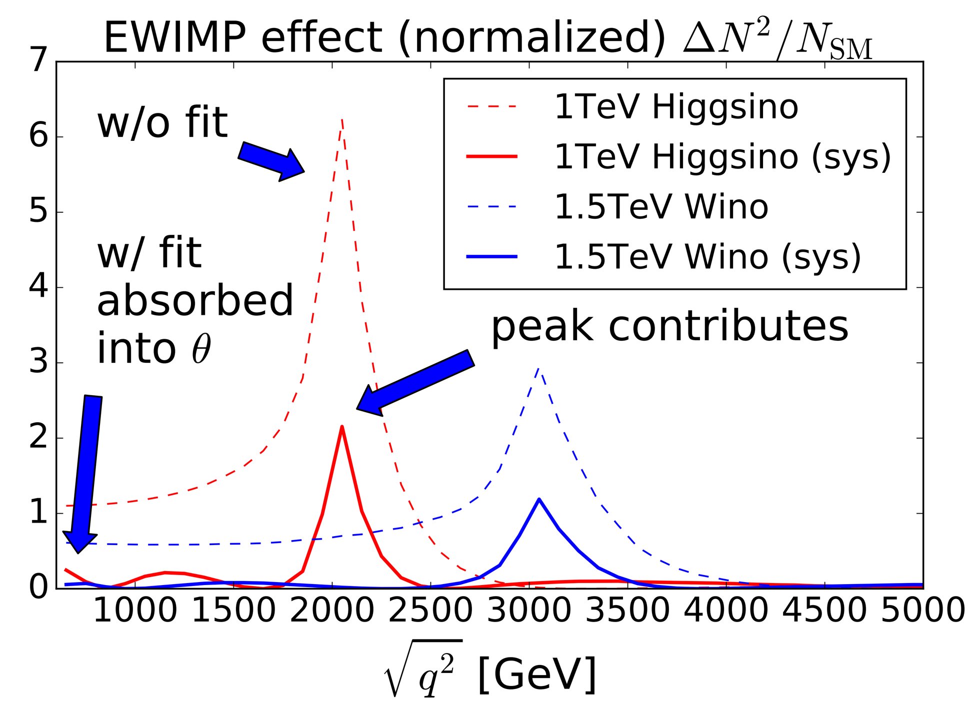
Detection reach of EWIMPs

Signal significance $\cdots$ $\dfrac{\text{EWIMP effect}}{\text{Statistical error}}$

$$q_0 \sim \min_{\theta} \sum_{i,\text{bin}} \frac{(N_i^{\text{SM+EWIMP}} - \widetilde{N}_i^{\text{SM}}(\boldsymbol{\theta}))^2}{\widetilde{N}_i^{\text{SM}}(\boldsymbol{\theta})}$$

$\sim \chi^2$ distribution with (d.o.f.) $= 1$





Higgsino reach $m < 850\,\text{GeV}(1.6\,\text{TeV})$ at $5\sigma(95\%\ \text{C.L.})$ c.f. mono-jet search: $200 \sim 500\,\text{GeV}$ at 5σ T. Han+ '18

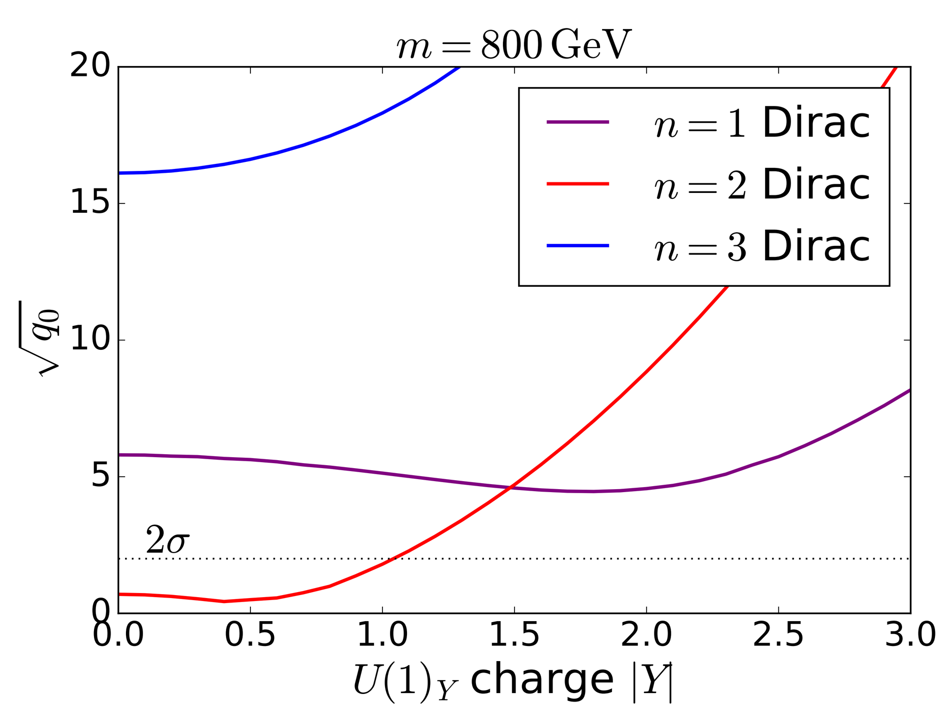
Determination of EWIMP properties

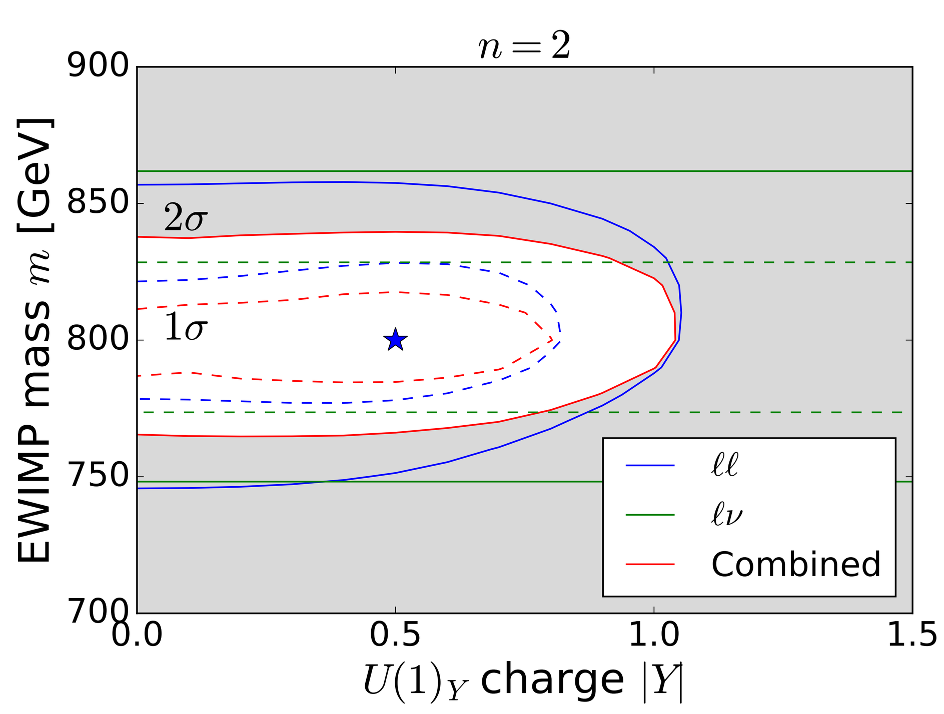
Peak structure represents EWIMP properties

- Peak position = mass
- Peak height = $SU(2)_L,\ U(1)_Y$ charges
- Independent observables $\ell\ell$ and $\ell\nu$

✔ We can determine $m,\ n,\ Y$

Ex) Assume $800\,\text{GeV}$ Higgsino ⇒





$$m = 800\,\text{GeV} \pm 20\,\text{GeV},\ n = 2,\ |Y| = 0.5^{+0.3}_{-0.5}$$