

# Collider Constraints on Low Mass Dark Matter

---

Haipeng An  
University of Maryland

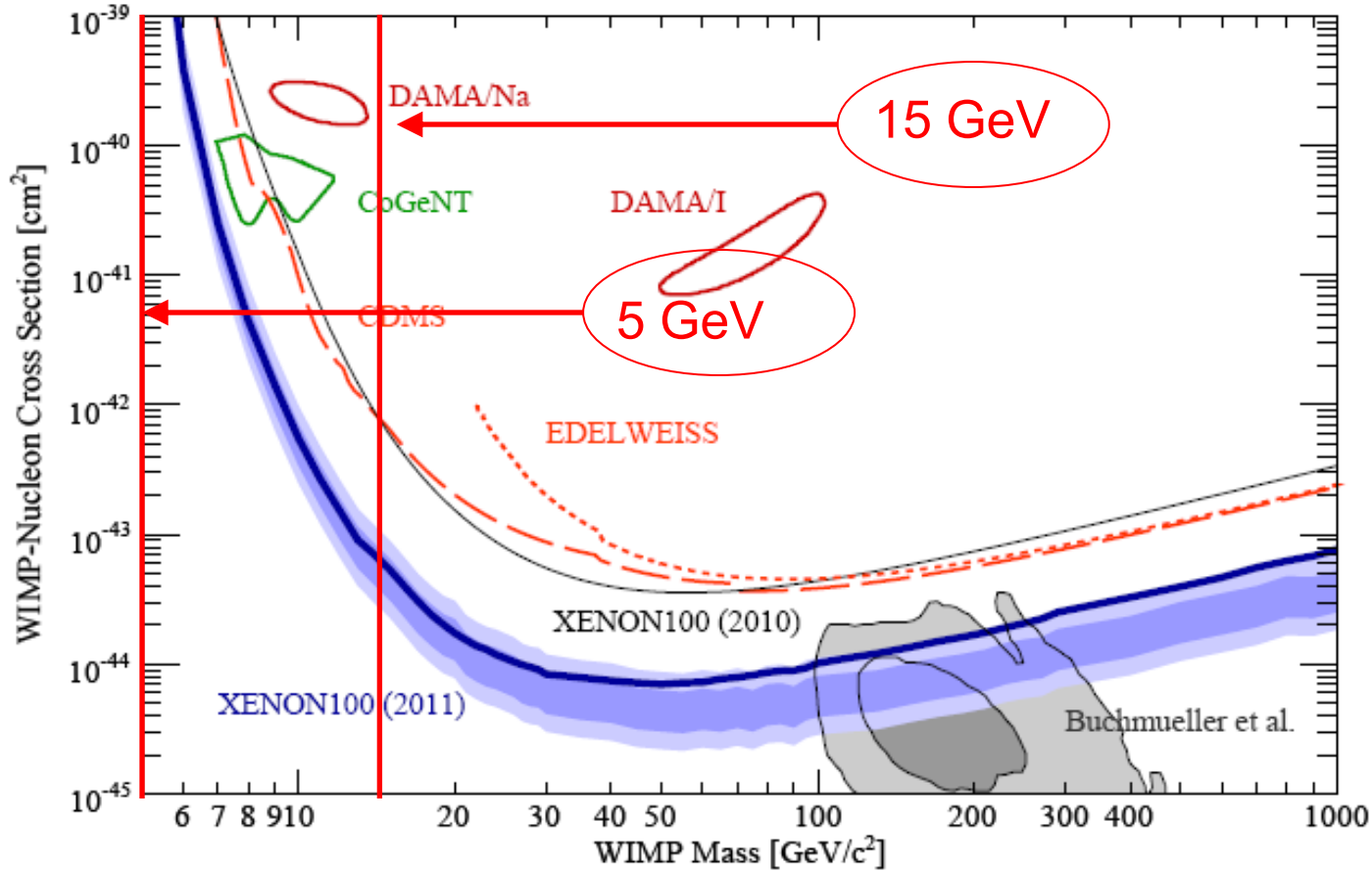
In collaboration with Xiangdong Ji and Liantao Wang

# Outline

---

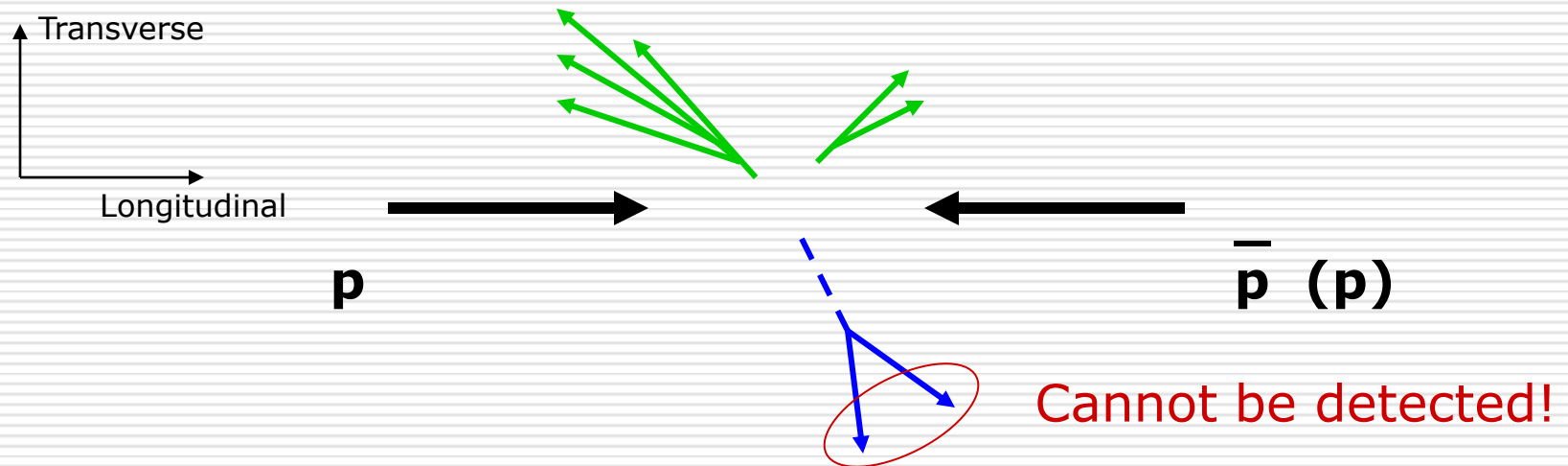
- Motivation
- From Mediator to Contact Interaction
- Current Collider Constraint
- LHC Reach
- Summary

# Dark Matter Direct Detection



# Observable

---



The transverse momentum ( $p_T$ ) is conserved.

The signal is missing transverse momentum (MET).

# Relevant searches with MET

---

## □ Tevatron Constraints

$$p \bar{p} \longrightarrow \text{MET} + \text{Mono-jet}$$

*CDF Collaboration, PRL 101, 181602, 2008.*

*Yang Bai, Patrick Fox, Roni Harnik 1005.3797.*

*Goodman, Ibe, Rajaraman,*

*Shepherd, Tait, Yu 1005.1286, 1008.1783;*

## □ LEP constraints

$$e^+ e^- \longrightarrow \text{MET} + \text{Mono-photon}$$

*L3 Collaboration, Phys. Lett. B 587, 16, 2004.*

*Patrick J. Fox, Roni Harnik,*

*Joachim Kopp, Yuhsin Tsai 1103.0240*

# Outline

---

- Motivation
- From Mediator to Contact Interaction
- Current Collider Constraint
- LHC Reach
- Summary

# Collider Constraints

---

Yang Bai, Patrick Fox, Roni Harnik 1005.3797.  
Goodman, Ibe, Rajaraman,  
Shepherd, Tait, Yu 1005.1286, 1008.1783;  
Patrick J. Fox, Roni Harnik,  
Joachim Kopp, Yuhsin Tsai 1103.0240  
Jean-Francois Fortin, Tim M.P. Tait 1103.3289

} Effective  
operator

If the mass of the intermediate particle is around a few hundred GeV, the interaction cannot be described by a contact local operator.

Mediator: vector boson, scalar boson, ...

Dark matter: spinor, scalar, ...

Interaction: vector-like, dipole-like, ...

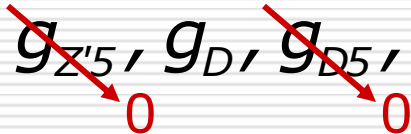
# Z' model

---

1. Leptophobic vector boson ( $Z'$ ) couples to SM quarks universally and dark matter particle.
2. Dark Matter particle is a Dirac spinor.
3. The coupling between  $Z'$  and dark matter can be either vector-like.

$$L = Z'_\mu [\bar{q}(g_{Z'}\gamma^\mu + g_{Z'5}\gamma^\mu\gamma_5)q + \bar{\chi}(g_D\gamma^\mu + g_{D5}\gamma^\mu\gamma_5)\chi].$$

$$g_{Z'}, g_{Z'5}, g_D, g_{D5}, M_{Z'}, M_D$$



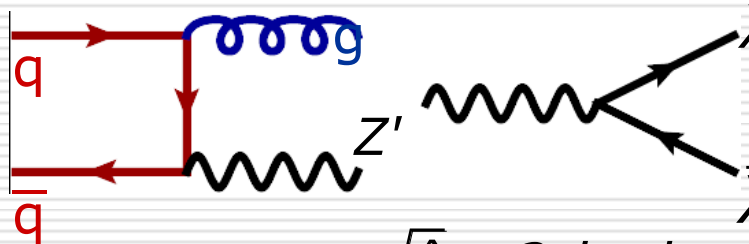
$$\sigma_{SI} = \frac{3^2 g_{Z'}^2 g_D^2 M_N^2 M_D^2}{\pi M_{Z'}^4 (M_N + M_D)^2}$$



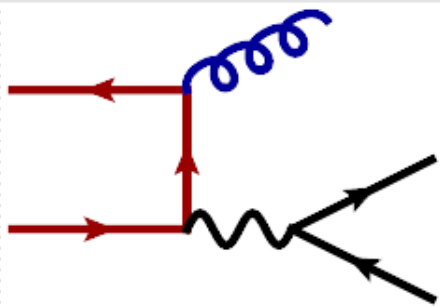
# From Mediator to Contact Interaction

$p \bar{p} \rightarrow \text{MET} + \text{Mono-jet}$

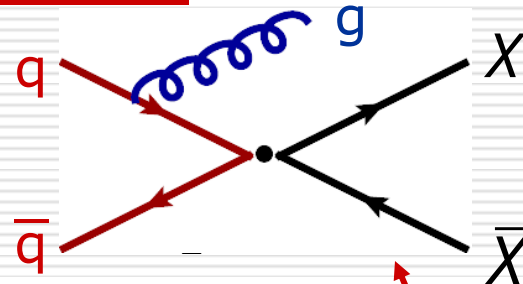
$g_{Z'} = g_D, g_{Z'}/M_{Z'} = 400 \text{ GeV}$



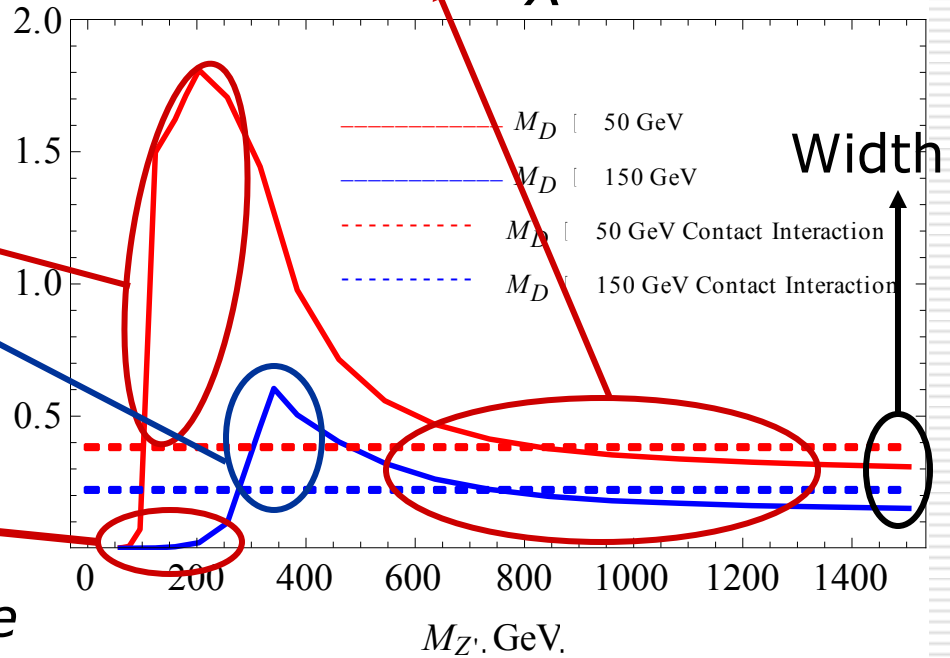
$2M_D < M_{Z'} < \sqrt{\hat{s}}, 2\text{-body}$



$M_{Z'} < 2M_D, 3\text{-body final state}$



Contact interaction

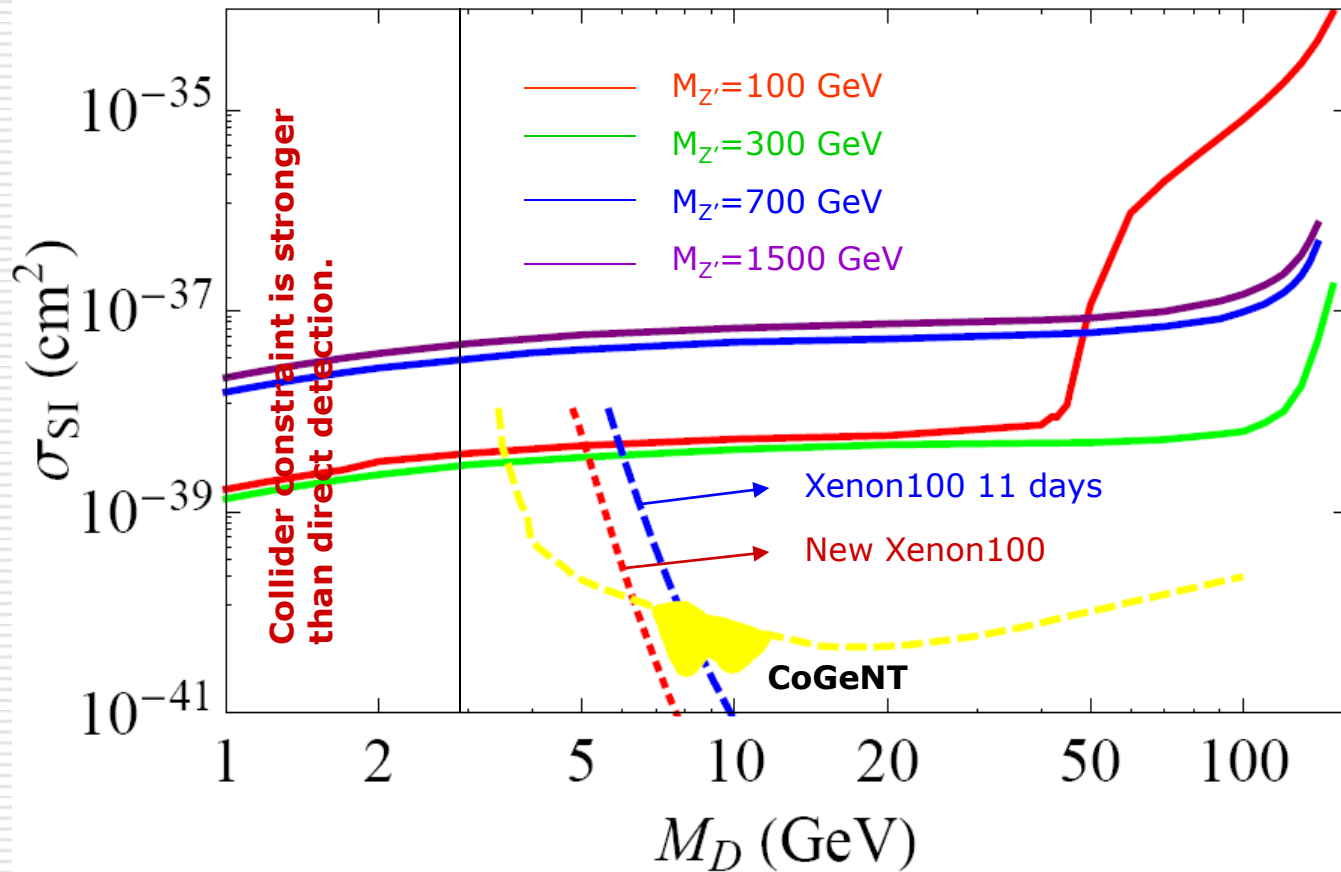


# Outline

---

- Motivation
- From Mediator to Contact Interaction
- Current Collider Constraints
- LHC Reach
- Summary

# Tevatron Constraint



No axial couplings;

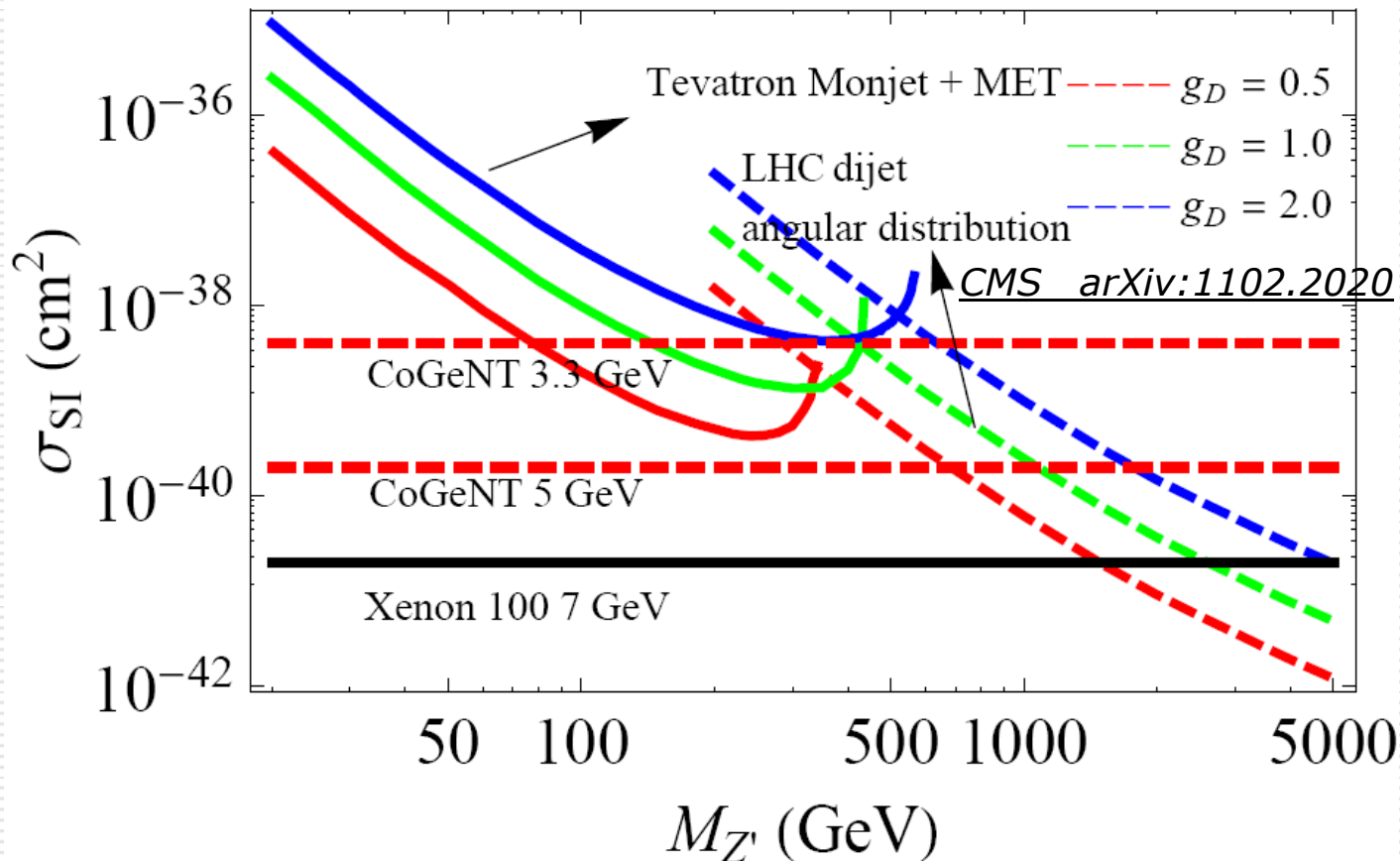
$g_{Z'}=g_D$ ;

$g_{Z'5}=0$ ;

$g_{D5}=0$ .

CalcHEP2.5.7

# Tevatron + LHC



# Outline

---

- Motivation
- From Mediator to Contact Interaction
- Current Collider Constraint
- LHC Reach
- Summary

# LHC Reach

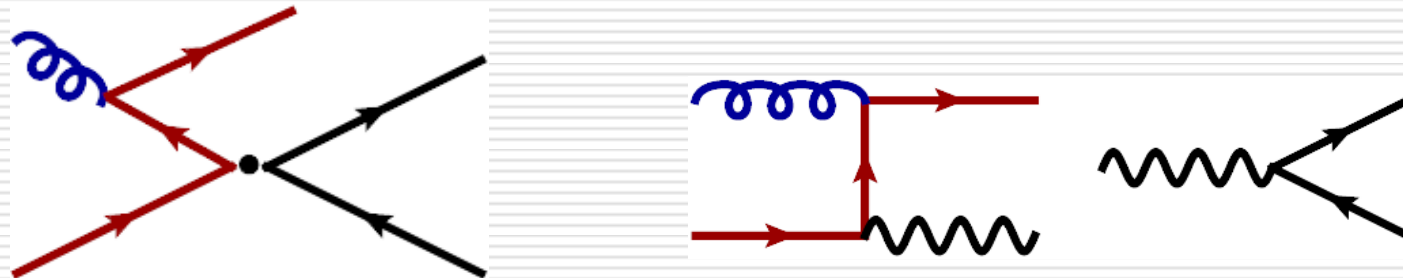
$p p \longrightarrow$  Missing  $E_T$  + Monojet

Missing  $E_T > 500$  GeV,  $100 \text{ fb}^{-1}$  luminosity.

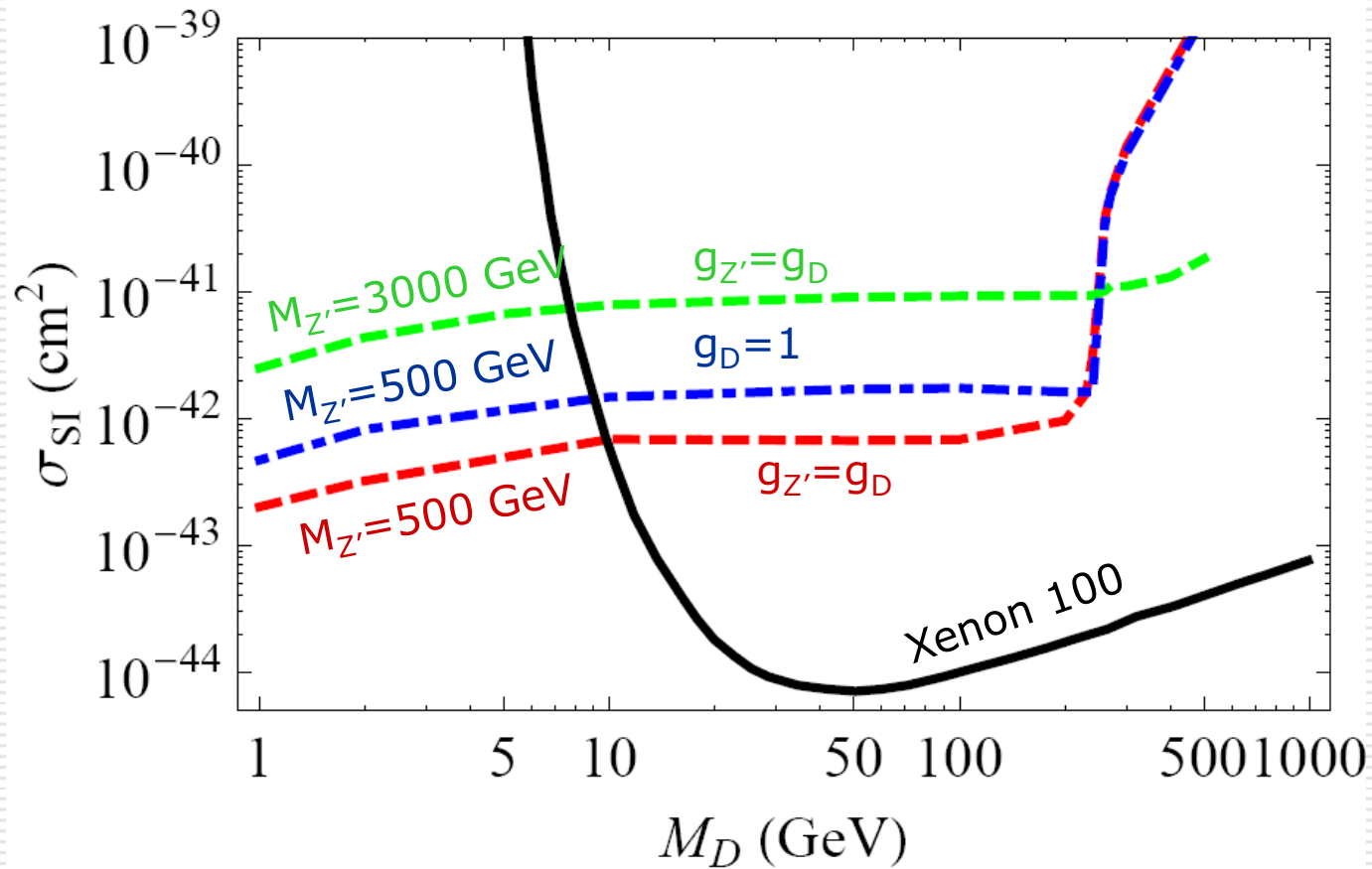
*Vacavant and Hinchliffe, J. Phys. G 27 (2001) 1839-1850*

SM background  $\approx 20000$ .  $S > 5\sqrt{B}$

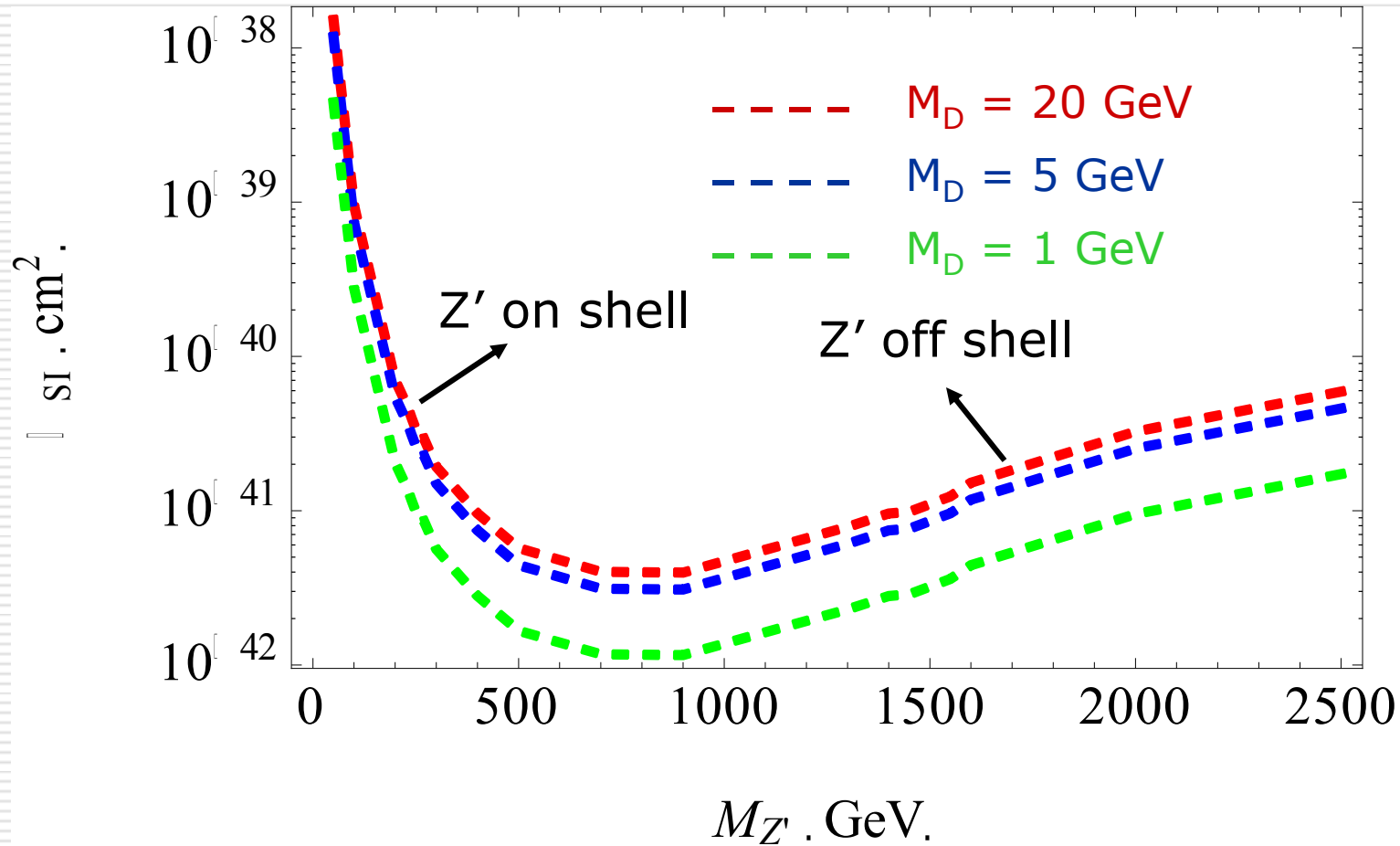
*Shepherd, Tait, Yu 1005.1286, 1008.1783*



# LHC Reach

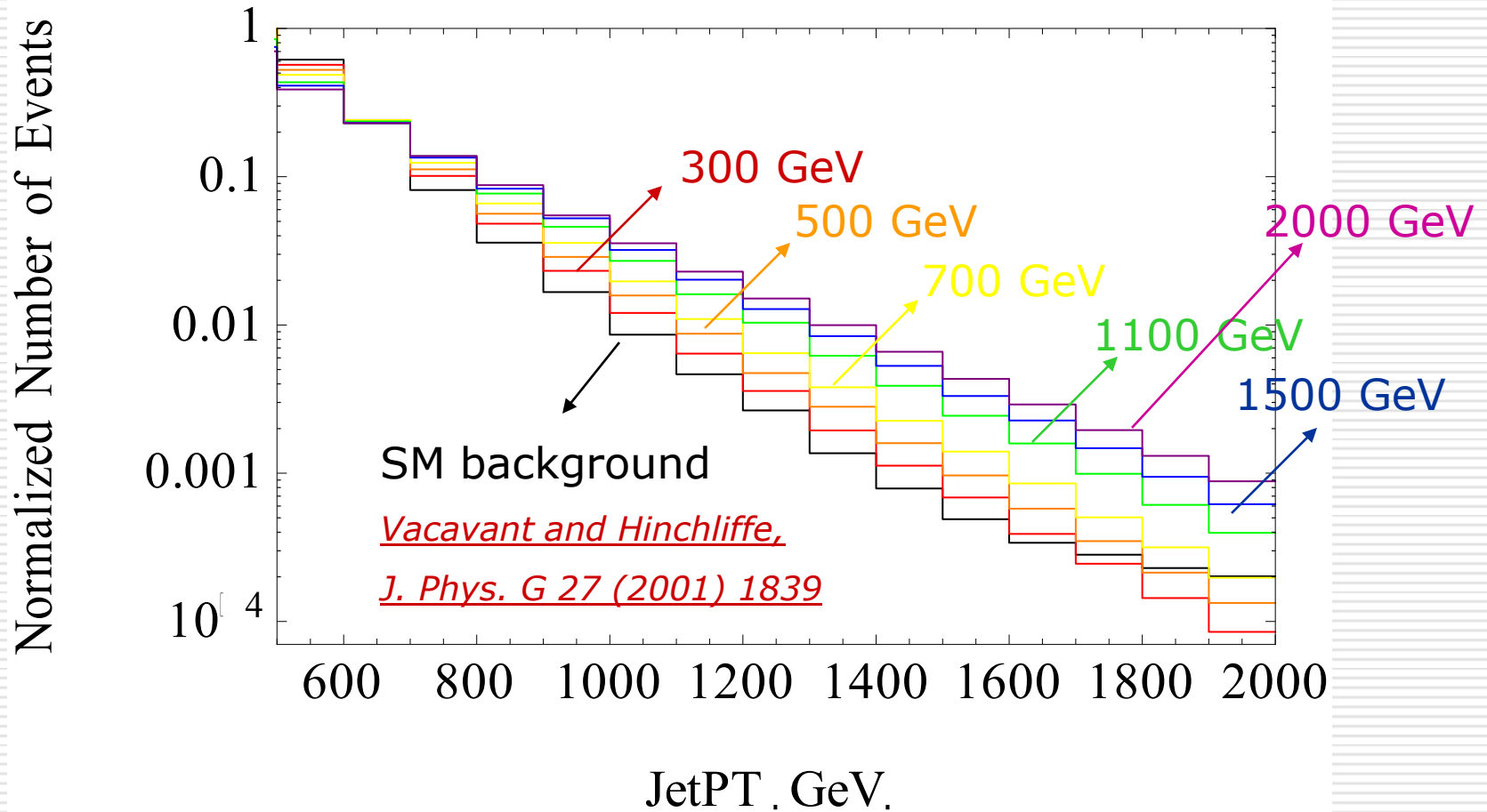


# LHC Reach

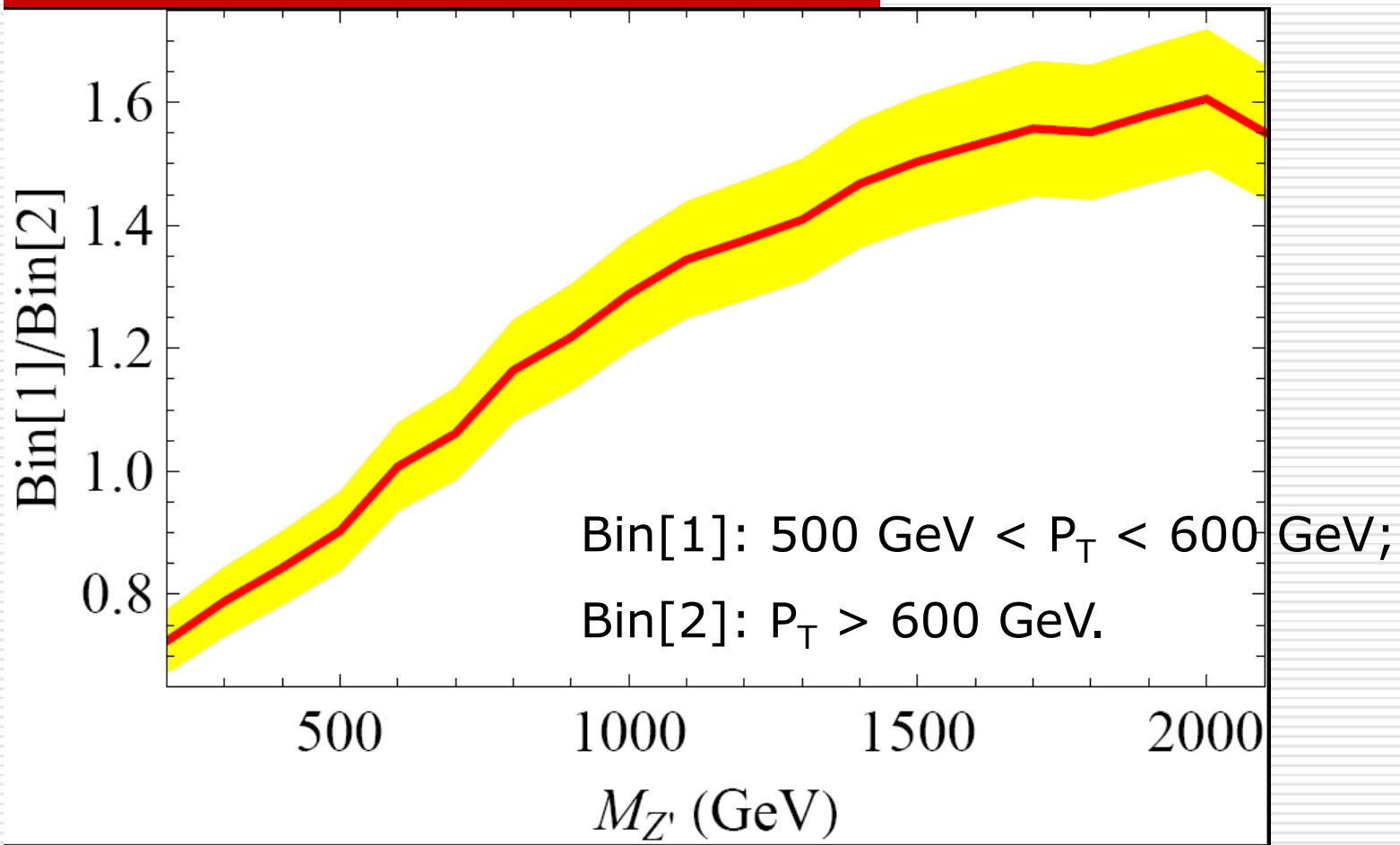




# Determine the Mass of $Z'$



# Determine the Mass of $Z'$

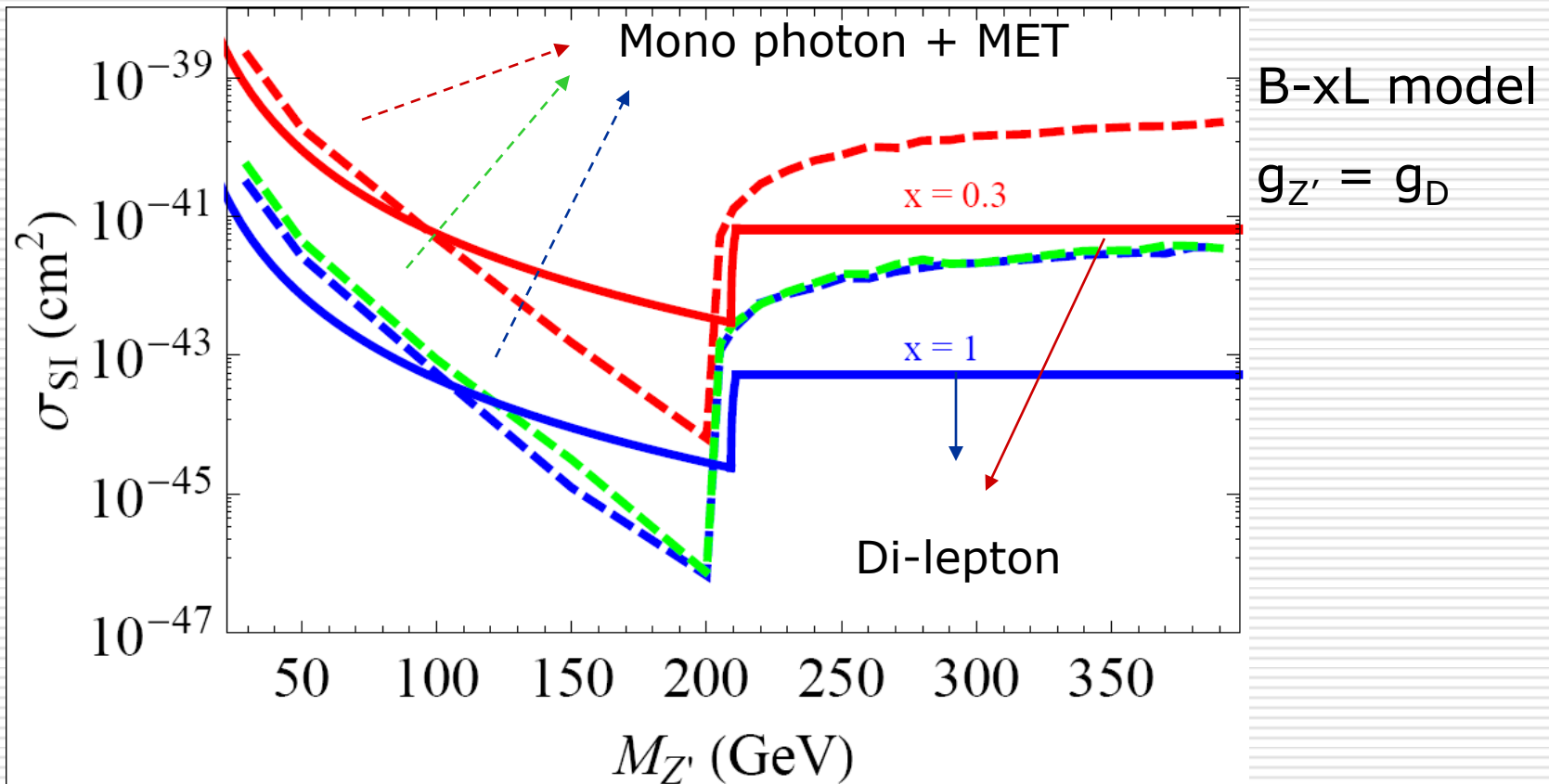


# Summary

---

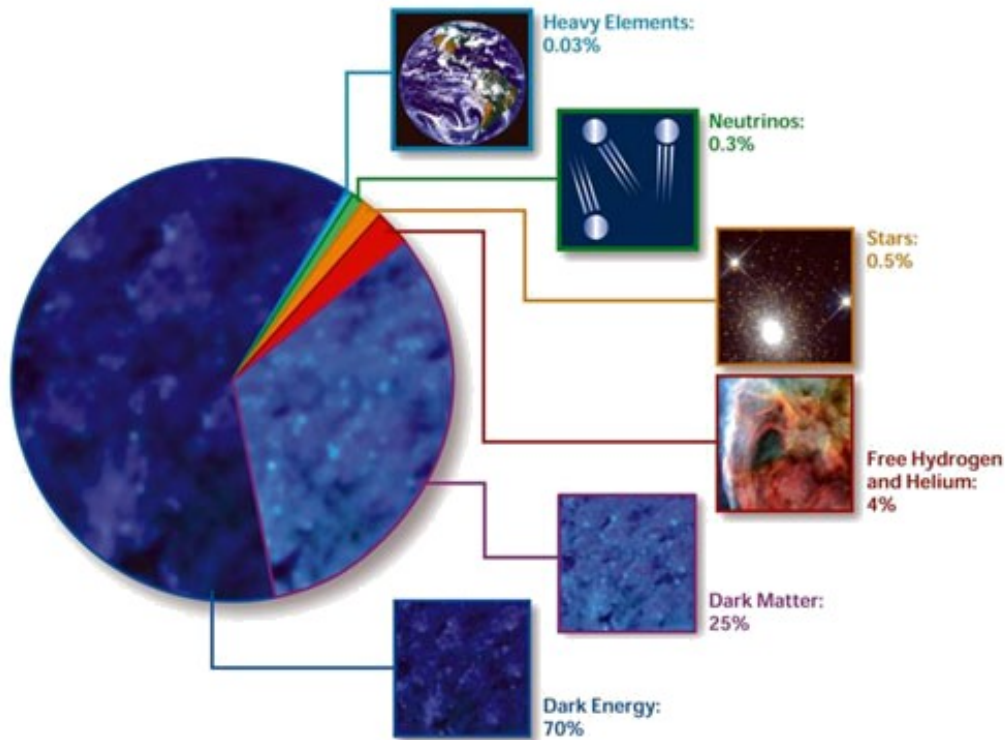
- Collider constraints are very important in the case of low mass dark matter;
- Tevatron constraints and LHC reach strongly depends on the mass of  $Z'$ ;
- The mass of  $Z'$  can be determined from the distribution of jet transverse momentum.

# Backup: LEP constraint



# Overview

## COMPOSITION OF THE COSMOS



- Existence;
- Dark;
- Massive;
- Stable;
- Relic abundance  
~ 25%;
- Not identified yet.

# Tevatron Constraints on Direct Detection Cross section

