Z' Signature from Muon Pair Production at the LHC

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BRAZIL

We search for signatures of the extra neutral gauge boson Z', predicted in some extensions of the Standard Model, from the analysis of some distributions for $p + p \rightarrow \mu^+ + \mu^- + X$, where the only exotic particle involved is Z'. In addition to the invariant mass and charge asymmetry distributions, we propose in our search to use the transverse momentum distribution p_T to distiguish the models.

We do our calculation for two values of the LHC center of mass energy (7 and 14 TeV), corresponding to 1 and 100 fb^{-1} of luminosity, in order to compare our findings from some models with the distributions following from the Standard Model. By applying convenient cuts in the final invariant mass, we show that the final p_T particle distributions can reveal the presence of an extra neutral gauge boson contribution. We also claim that it is possible to disentangle the models considered here and we emphasize that the minimal version of the model, based on $SU(3)_C \times SU(3)_L \times U(1)_X$ symmetry, presents the more clear signatures for Z' existence.

Motivation

- Standard Model $SU(3)_c x SU(2)_L x U(1)_{em}$
- Good Accord with Experimental Data $\approx$ GeV

but …

To confirm

- Mass Generation Mechanism (Higgs / equivalent)
- The Mass Spectrum
- Dark Matter **(80% Universe)**
- Supersymmetry

New Physics

- Extra Neutral Gauge Boson Z'
- New Scalars Higgs's (neutral and charged)
- New Charged Gauge Boson
- Lepton Number Violation (Majorana)
- Dark Energy & Dark Matter

Higher Energy Colliders → 2010/2011

- LHC (Large Hadron Collider)

  2010 E_{CM} → 7 TeV & 1 fb^{-1} ← *Luminosity*

  2014 E_{CM} → 14 TeV & 100 fb^{-1} ← *Luminosity*

- Linear collider ILC (2013) / CLIC (2017)

  E_{CM} → 500 GeV to 2 TeV & 100 fb^{-1} ← *Luminosity*

Models with Z'

- 3-3-1* F. Pisano and V. Pleitez, Phys. Rev. D 46, 410 (1992), P. H. Frampton, Phys. Rev. Lett. 69, 2889 (1992).
- Little Higgs N. Arkani-Hamed, A. G. Cohen and H. Georgi, Phys. Lett. B 513, 232 (2001).
- Left-right symmetric* R. N. Mohapatra and P. B. Pal, "Massive Neutrinos in Physics and Astrophysics", World Scientific, Singapore (1998).
- Superstring inspired E_6* P. Langacker, R. W. Robinett and J. L. Rosner, Phys. Rev. D 30, 1470 (1984).
- Extra dimensions (K-K excitations) T. G. Rizzo, SLAC-PUB-10753, SSI-2004-L013, Sep 2004. hep-ph/0409309.

SM similar phenomenology @ GeV scale

$$\mathcal{L}^{NC} = -\frac{g}{2\cos\theta_W}\sum_f \left[\bar{f}\,\gamma^\mu\,(g_V + g_A\gamma^5) f\,Z_\mu + \bar{f}\,\gamma^\mu\,(g'_V + g'_A\gamma^5) f\,Z'_\mu\right]$$

	3-3-1 MIN		3-3-1 RHN	
	g'_V	g'_A	g'_V	g'_A
$Z'\bar{l}l$	$-\frac{\sqrt{3}}{2}\sqrt{1-4\sin^2\theta_W}$	$\frac{\sqrt{3}}{6}\sqrt{1-4\sin^2\theta_W}$	$\frac{-1+4\sin^2\theta_W}{2\sqrt{3-4\sin^2\theta_W}}$	$-\frac{1}{2\sqrt{3-4\sin^2\theta_W}}$
$Z'\bar{u}u$	$-\frac{1+4\sin^2\theta_W}{2\sqrt{3-12\sin^2\theta_W}}$	$\frac{1}{\sqrt{3-12\sin^2\theta_W}}$	$\frac{3-8\sin^2\theta_W}{6\sqrt{3-4\sin^2\theta_W}}$	$-\frac{1}{2\sqrt{3-4\sin^2\theta_W}}$
$Z'\bar{d}d$	$\frac{1-2\sin^2\theta_W}{2\sqrt{3-12\sin^2\theta_W}}$	$-\frac{1+2\sin^2\theta_W}{2\sqrt{3-12\sin^2\theta_W}}$	$\frac{3-2\sin^2\theta_W}{6\sqrt{3-4\sin^2\theta_W}}$	$-\frac{\sqrt{3-4\sin^2\theta_W}}{6}$

	Sym L-R		$E_6 - \chi$	
	g'_V	g'_A	g'_V	g'_A
$Z'\bar{l}l$	$\frac{-1+4\sin^2\theta_W}{2\sqrt{\cos^2\theta_W-\sin^2\theta_W}}$	$\frac{\sqrt{\cos^2\theta_W-\sin^2\theta_W}}{2}$	$\frac{2\sin\theta_W}{\sqrt{6}}$	$\frac{\sin\theta_W}{\sqrt{6}}$
$Z'\bar{u}u$	$\frac{3-8\sin^2\theta_W}{6\sqrt{\cos^2\theta_W-\sin^2\theta_W}}$	$-\frac{\sqrt{\cos^2\theta_W-\sin^2\theta_W}}{2}$	0	$\frac{\sin\theta_W}{\sqrt{6}}$
$Z'\bar{d}d$	$\frac{-3+4\sin^2\theta_W}{6\sqrt{\cos^2\theta_W-\sin^2\theta_W}}$	$\frac{\sqrt{\cos^2\theta_W-\sin^2\theta_W}}{2}$	$-\frac{2\sin\theta_W}{\sqrt{6}}$	$-\frac{\sin\theta_W}{\sqrt{6}}$

Present Work

$p + p \rightarrow \mu^+ + \mu^- + X$ for $800\ GeV < M_{Z'} < 1200\ GeV$

Detector Acceptance / background reduction

Cuts (CMS)

- invariant mass $M\mu\mu > 500\ GeV$
- pseudo rapidity $|\eta_\mu| \leq 2.5$
- $p_t > 20\ GeV$

Observables

1- Invariant mass distribution

2- A_{FB}

3-Transverse momentum distribution

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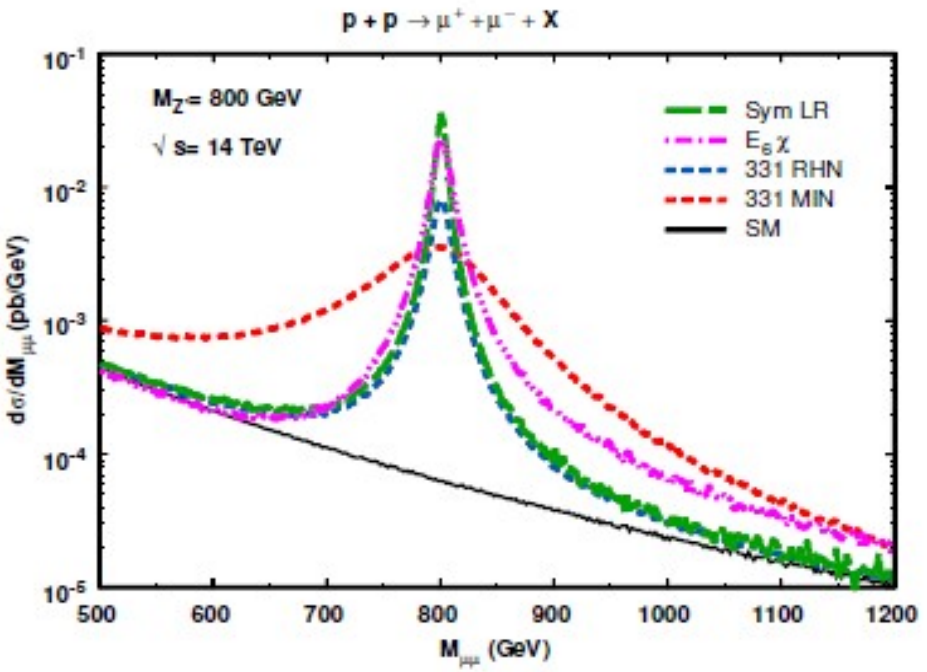
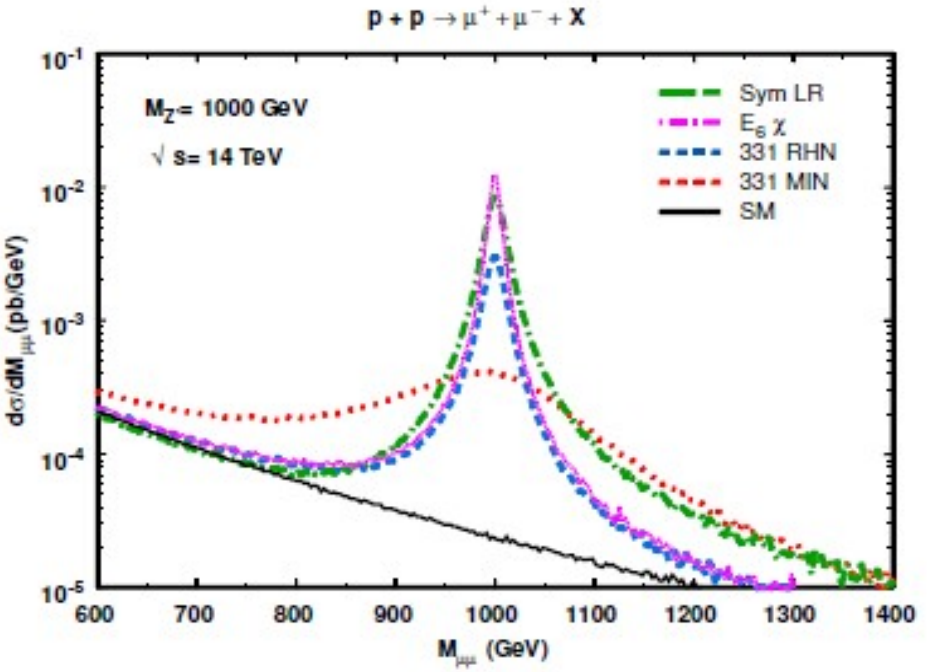
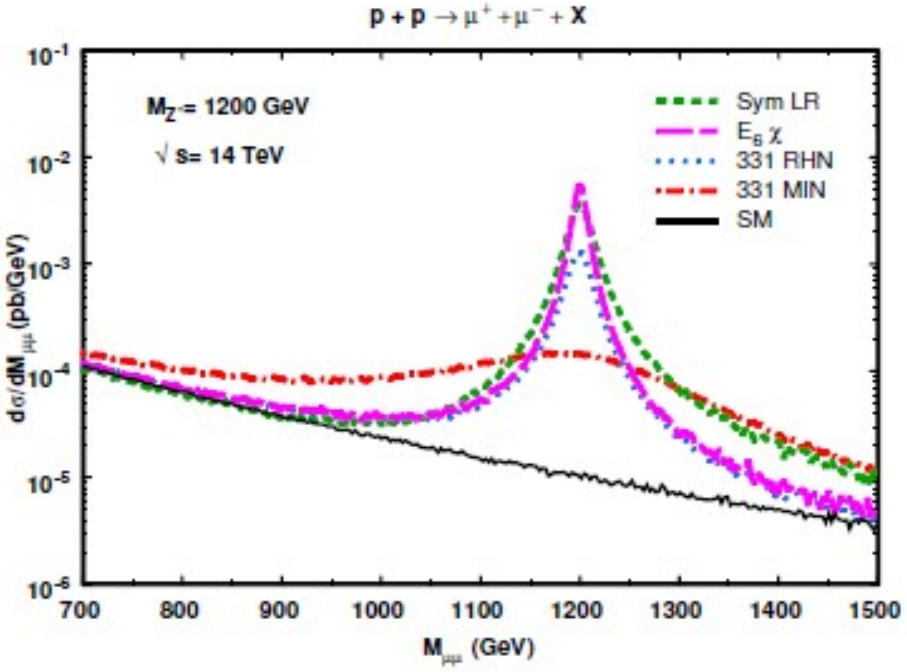
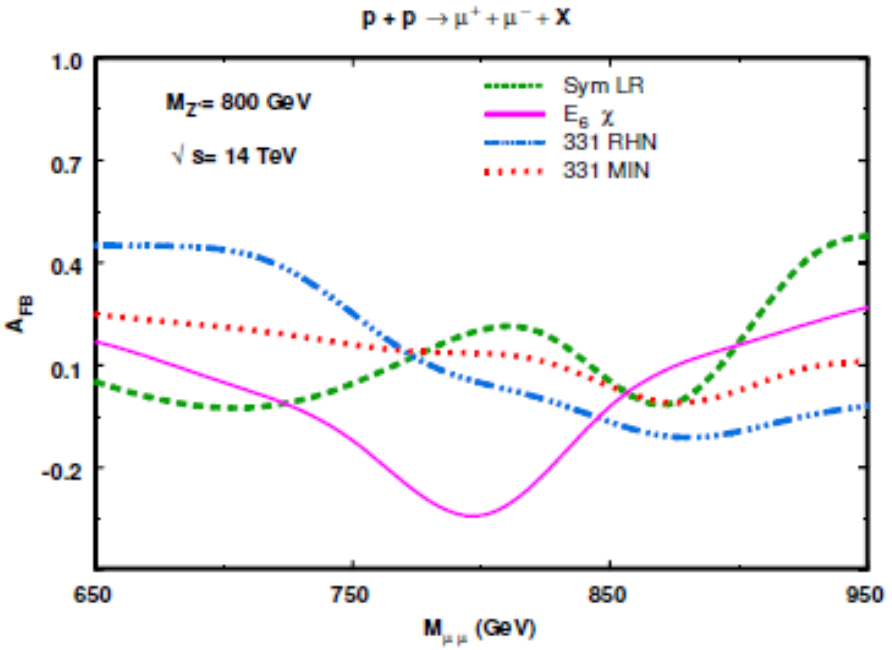


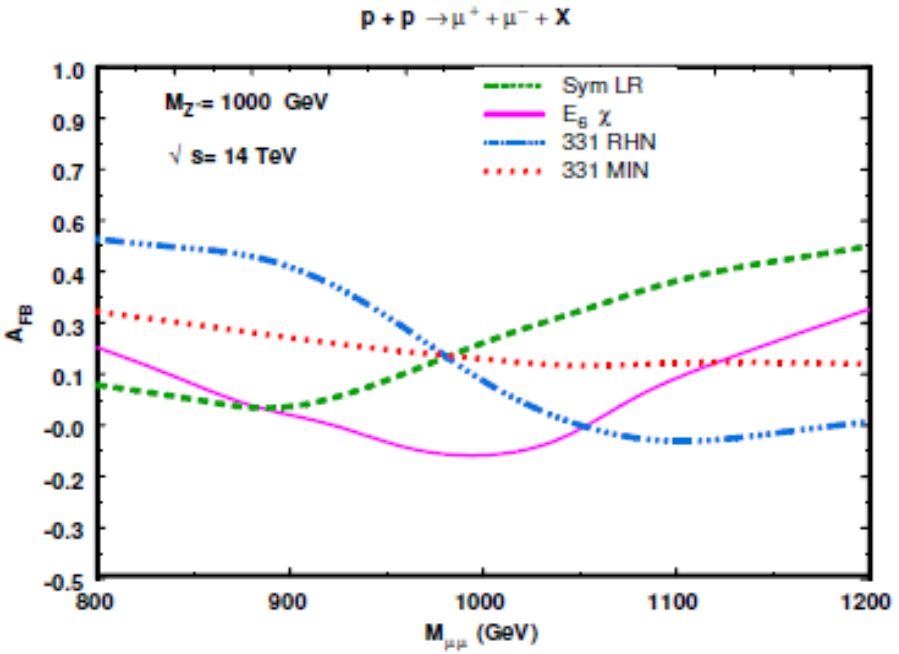


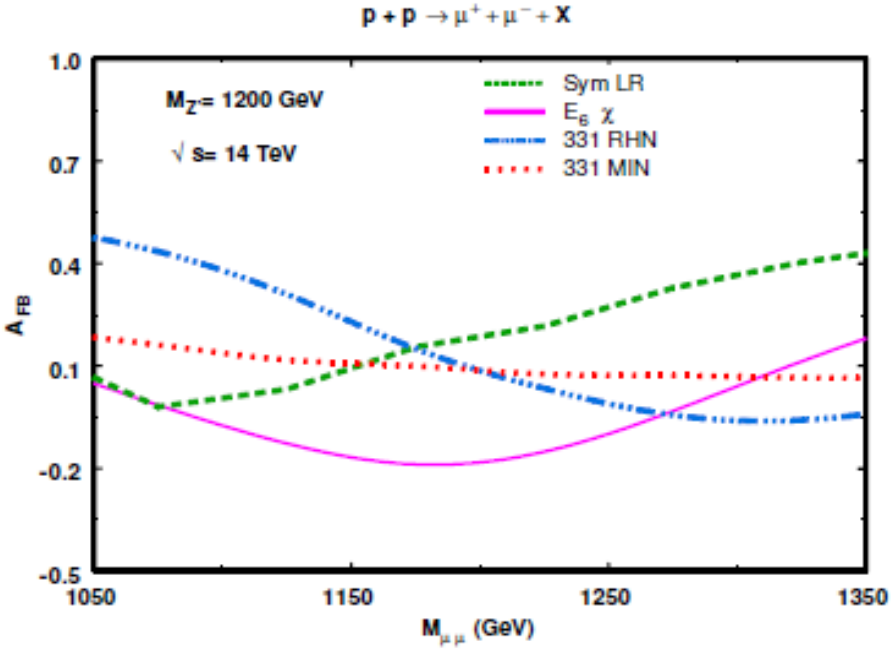


Invariant mass distribution

E_{cm} = 14 TeV







Forward-backward asymmetry

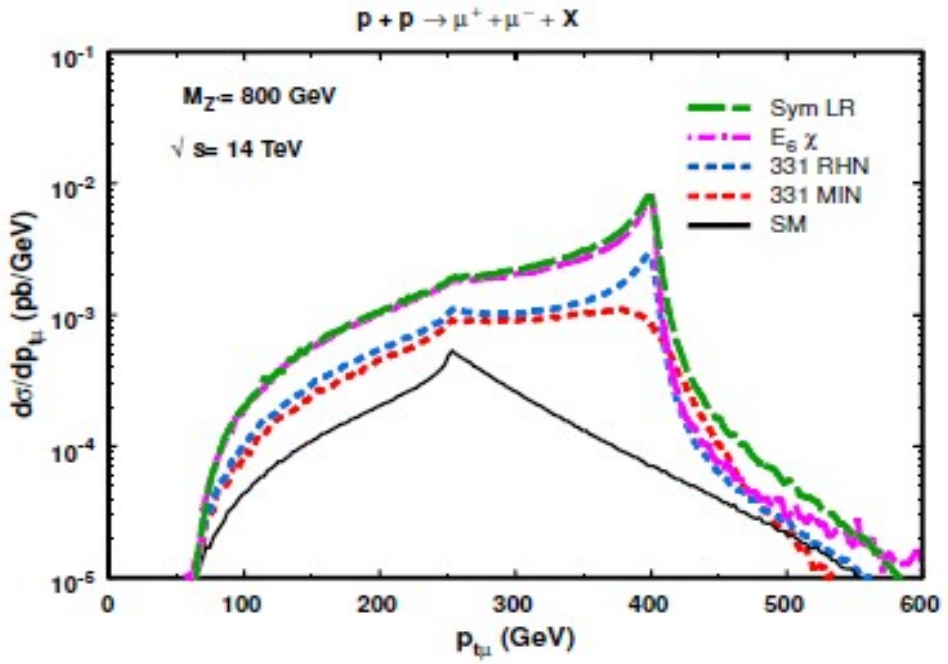
quark direction

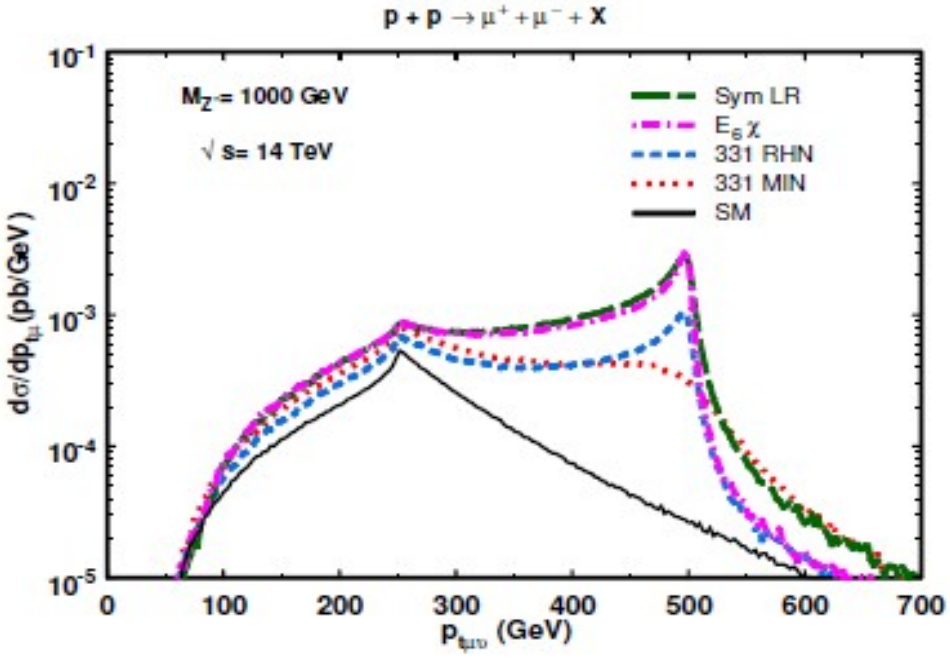
≈

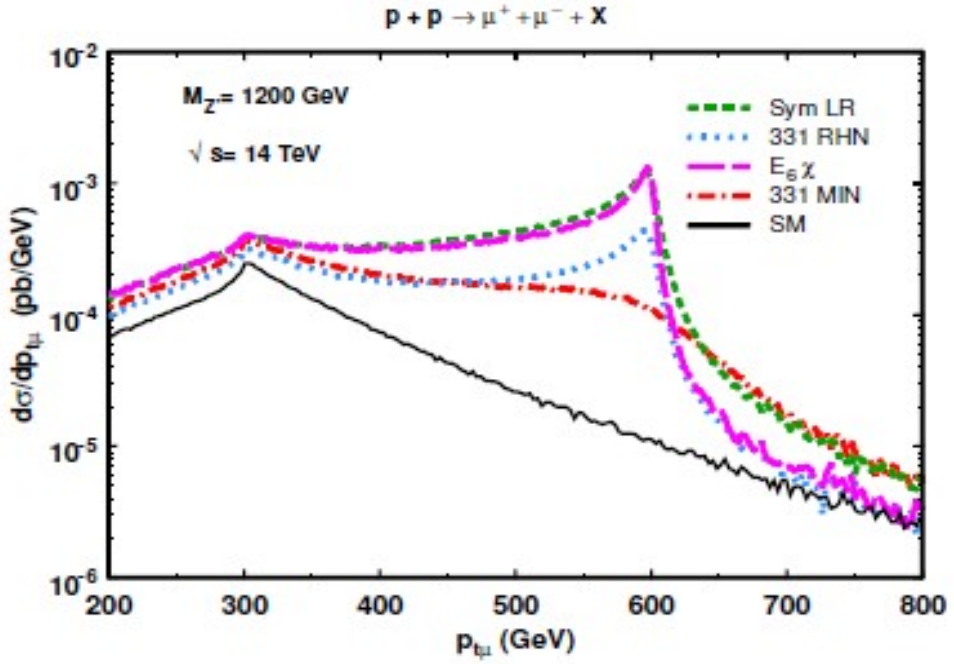
boost direction

(connecting dimuon system with beam axis)

$|y_{\mu\mu}| > 0.8$







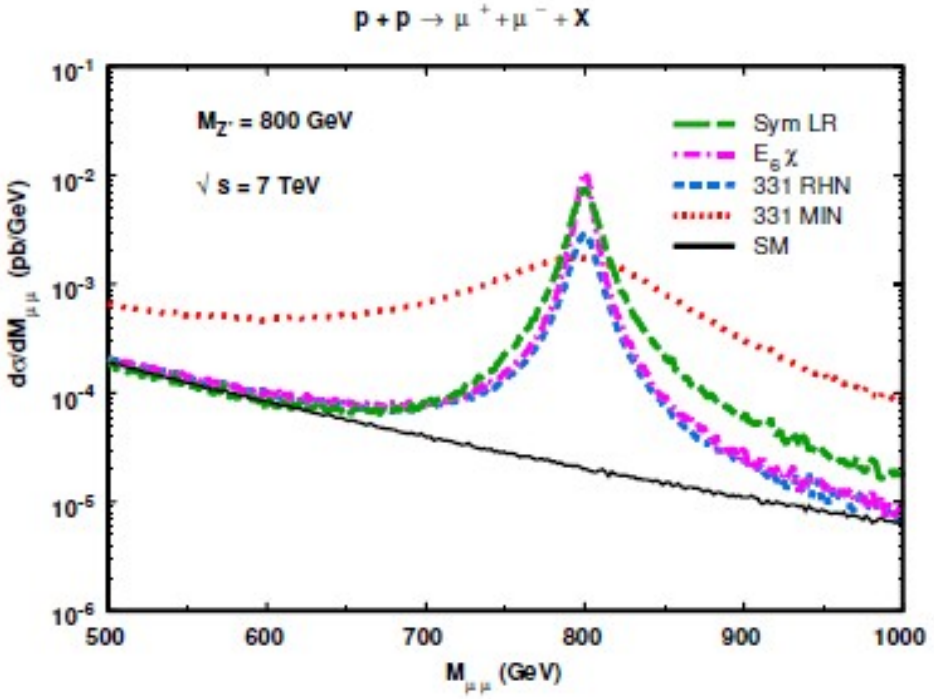
Transverse momentum distribution

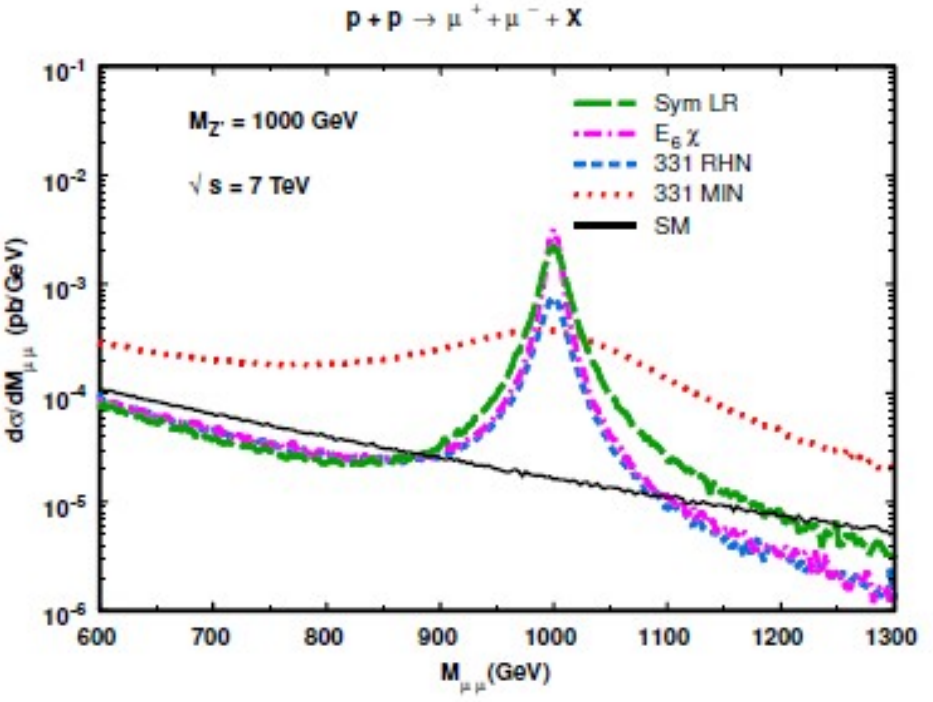
E_{cm} = 14 TeV

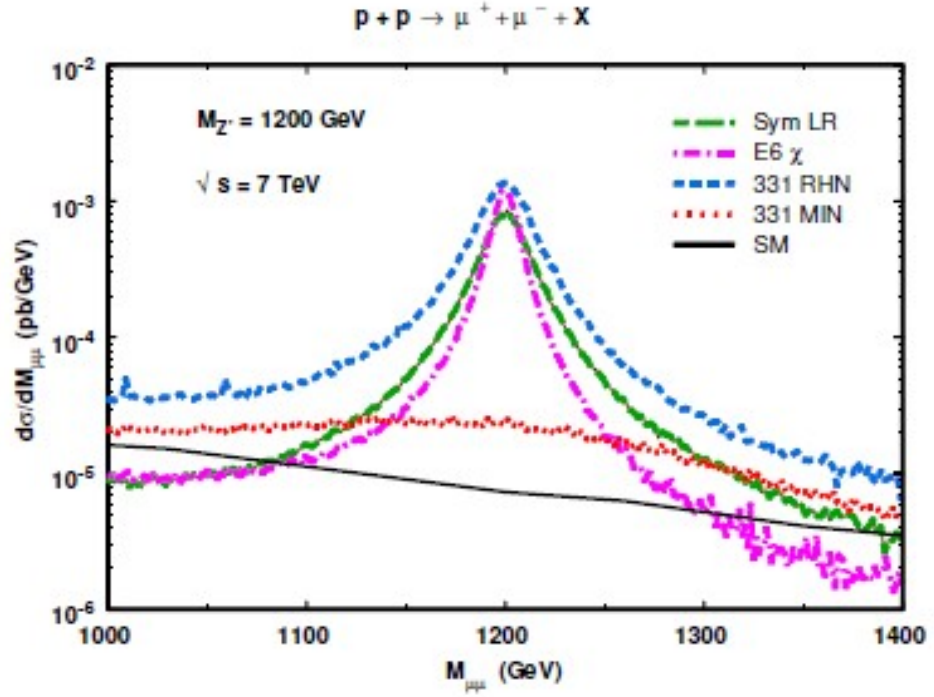
Two poles in σ_{elem} for M_Z e $M_{Z'}$

$p_t \approx M_{Z,Z'}/2$ (maximum)

Jacobian Peak

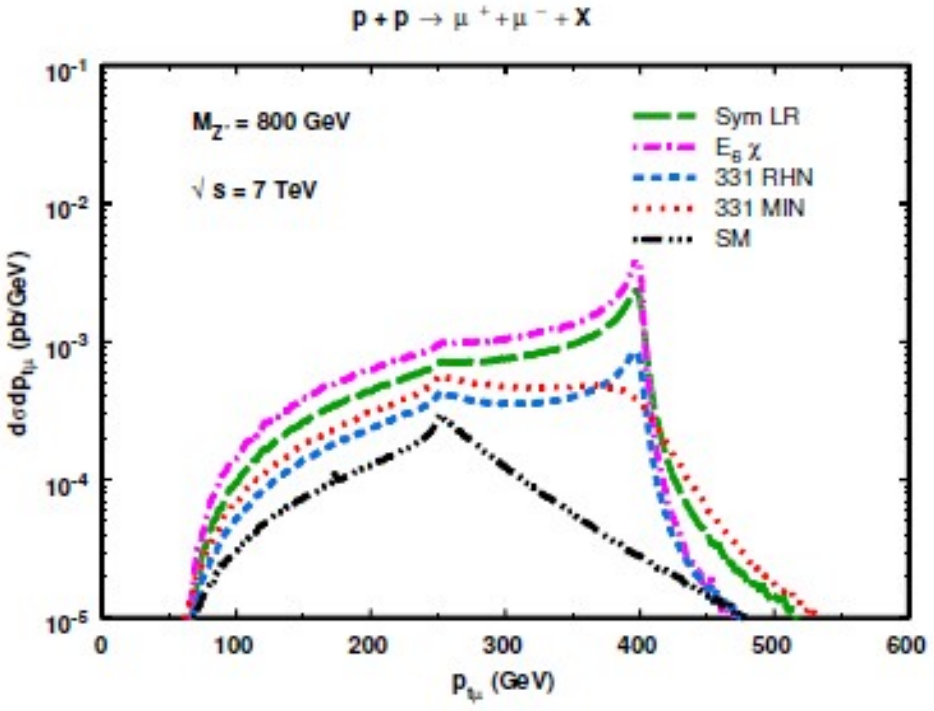


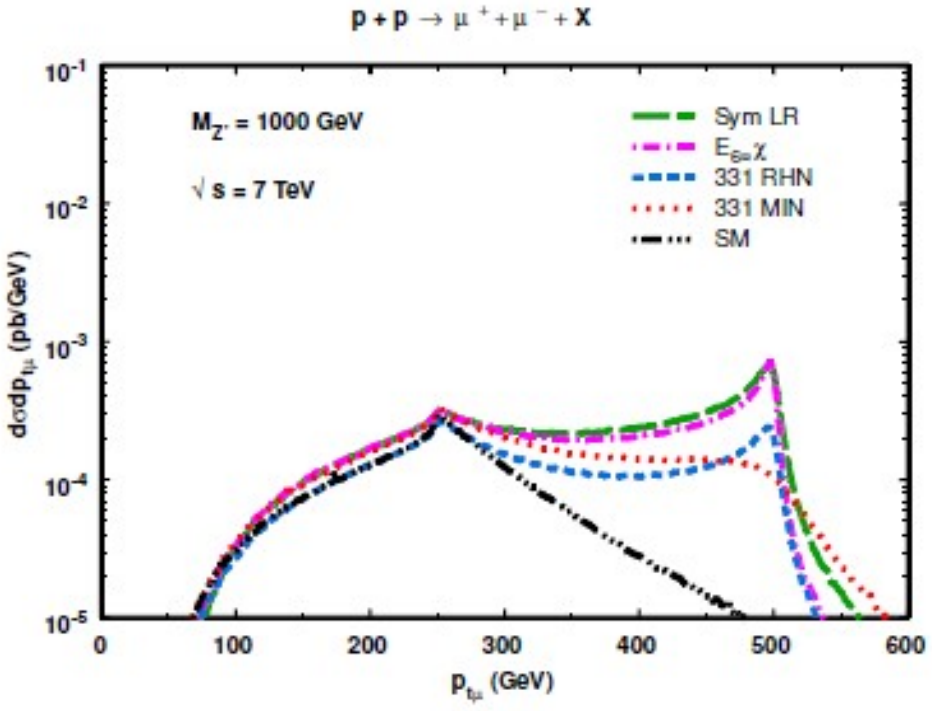


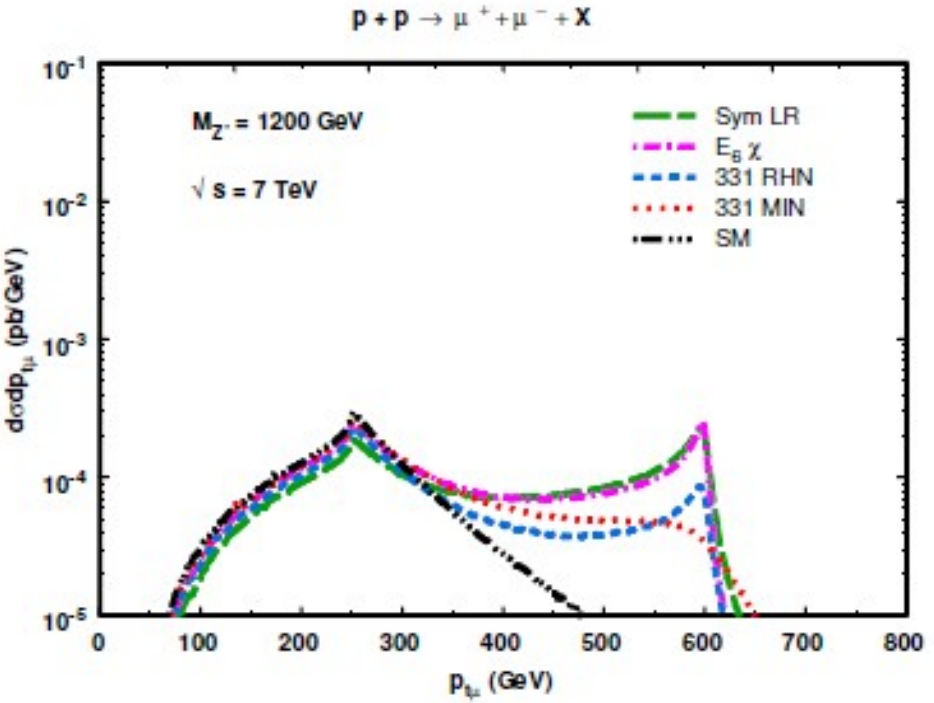


Invariant mass distribution

E_{cm} = 7 TeV







Transverse momentum distribution

E_{cm} = 7 TeV

Conclusions & Perspectives

Muon pair production

A_{FB} desintangle the models

events 3x10^4 - 12x10^4 $E_{CM} \rightarrow$ 14 TeV & 100 fb^{-1}

events 40 - 140 $E_{CM} \rightarrow$ 7 TeV & 1 fb^{-1}

In addition to A_{FB} asymmetry, the muon p_T distribution is a very promising tool for LHC experimental groups to discover the seed for new physics.

Phys. Lett. B 689, 36 (2010)