Recent DØ Results on Beyond Standard Model Physics

Gérald Grenier
Université Lyon 1, IPN Lyon, IN2P3

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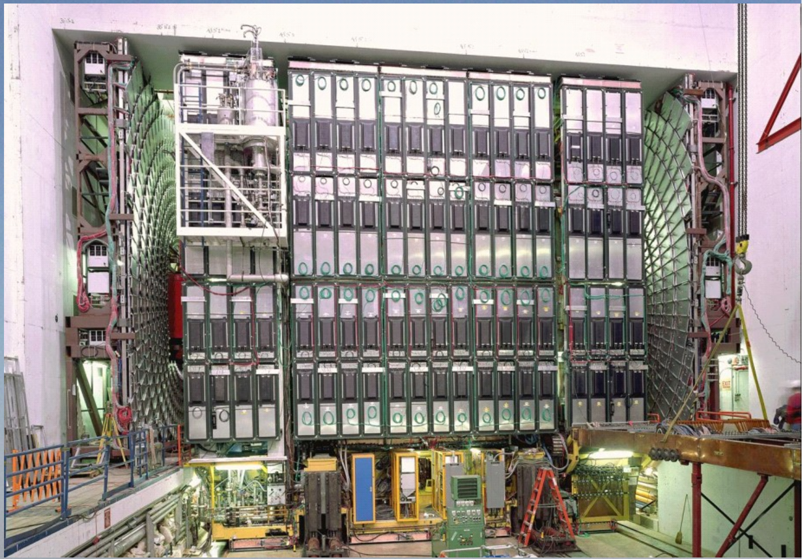
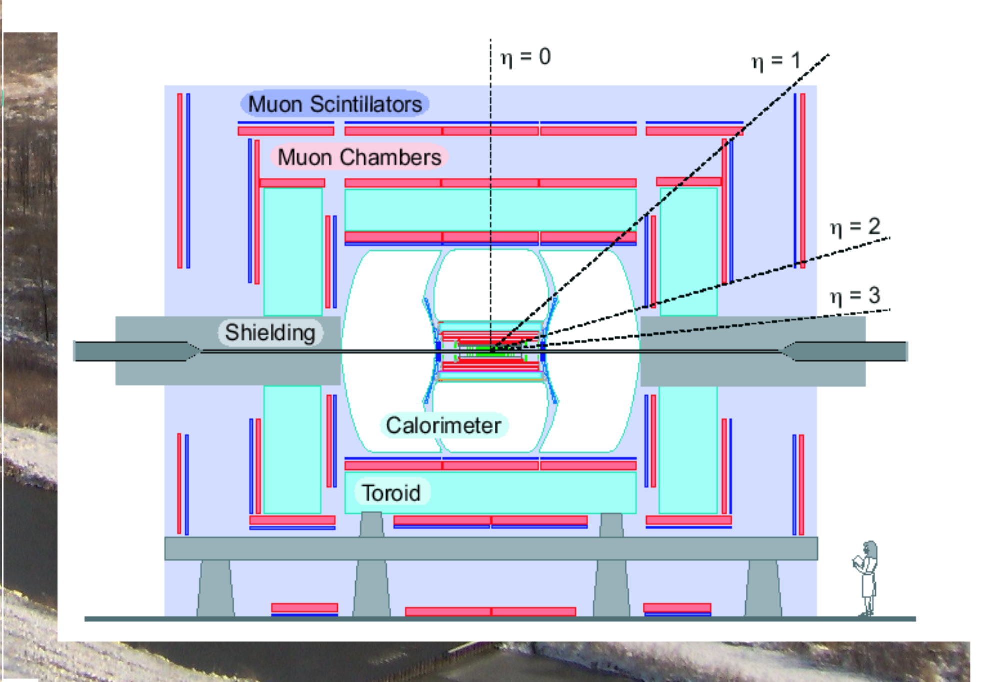
On behalf of the DØ collaboration

D0 at the Tevatron

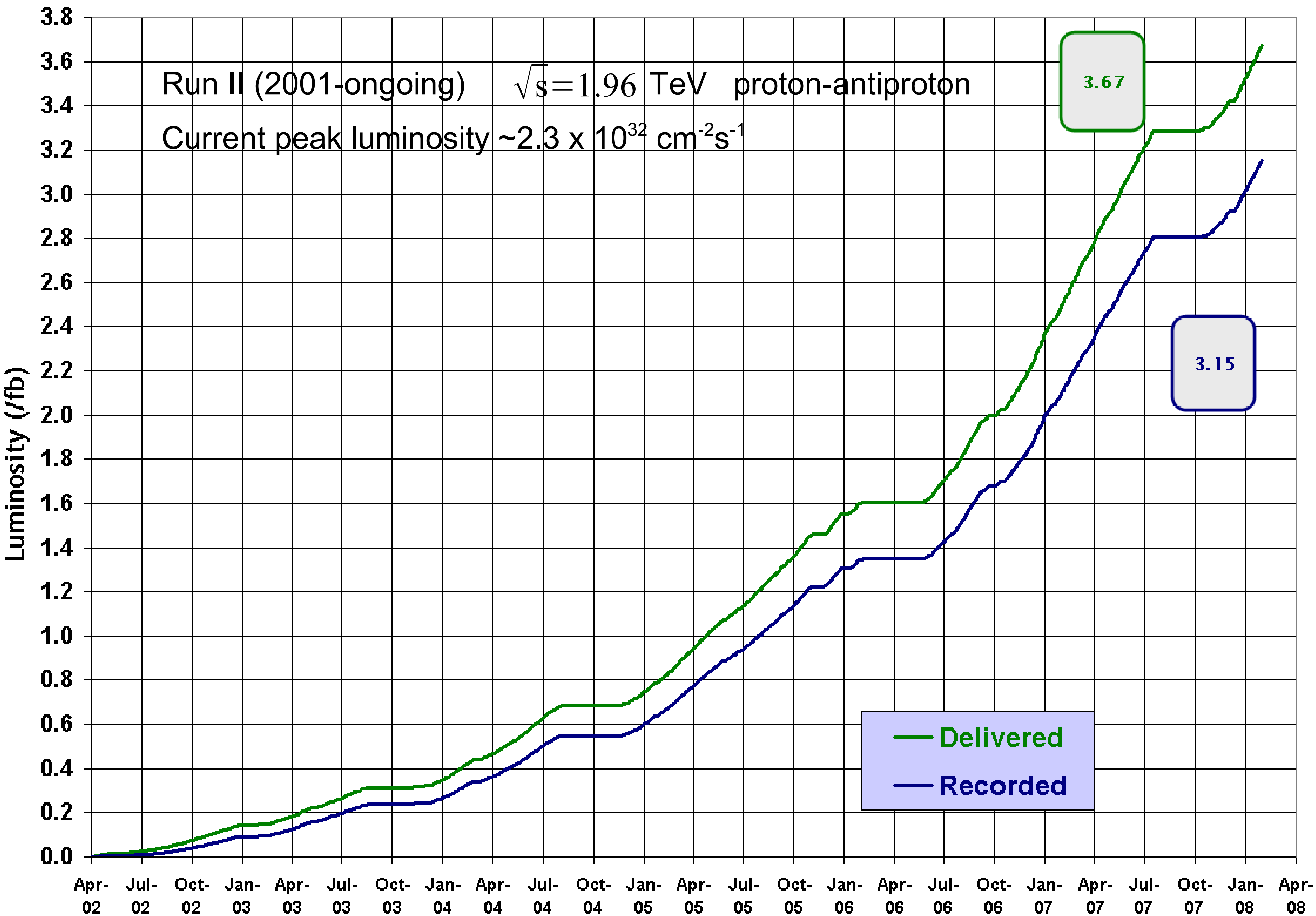
General Purpose Detectors:	DØ
Electron ID acceptance	$\|\eta\|<3.0$
Muon ID acceptance	$\|\eta\|<2.0$
& trigger	$\|\eta\|<2.0$
Precision tracking (Si)	$\|\eta\|<3.0$
Jet ID	$\|\eta\|<4.2$





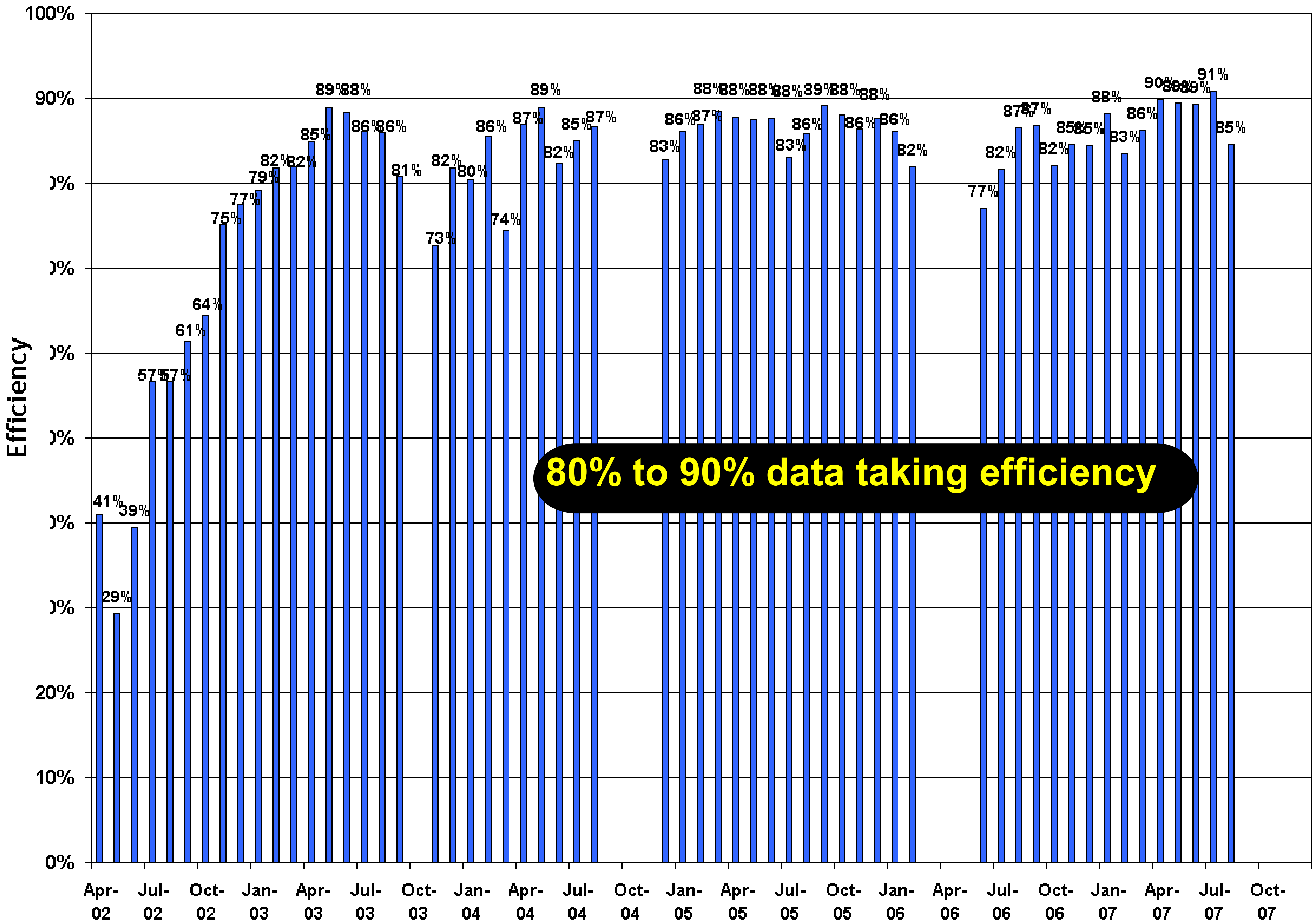
Run II Integrated Luminosity

19 April 2002 - 17 February 2008



Monthly Data Taking Efficiency

19 April 2002 - 1 October 2007



Standard Model Monte Carlo

To look for Beyond the Standard Model, one has to know what is the Standard Model.

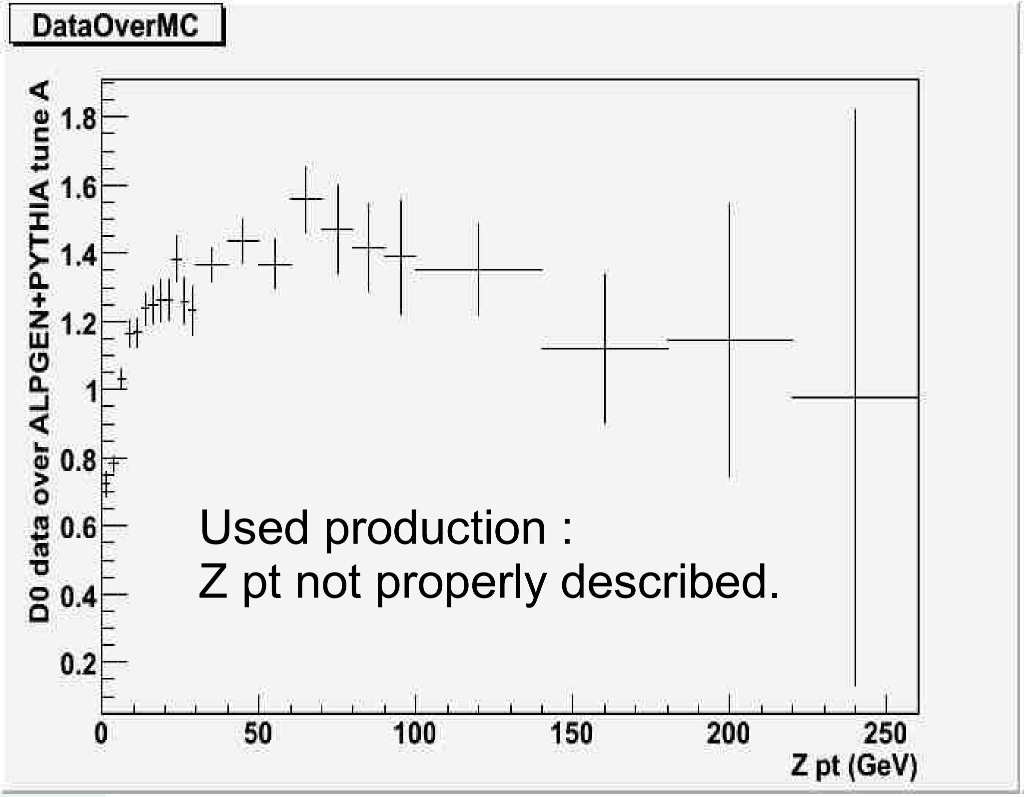
Standard Model modelisation in DØ :
-- Shape and normalisation from Monte Carlo simulations (rare : LO not enough)
-- Shape from MC and normalisation from data.
-- Shape from MC and normalisation from literature or other program (e.g. **MCFM**).
-- Shape and normalisation measured from data (QCD and instrumental background).

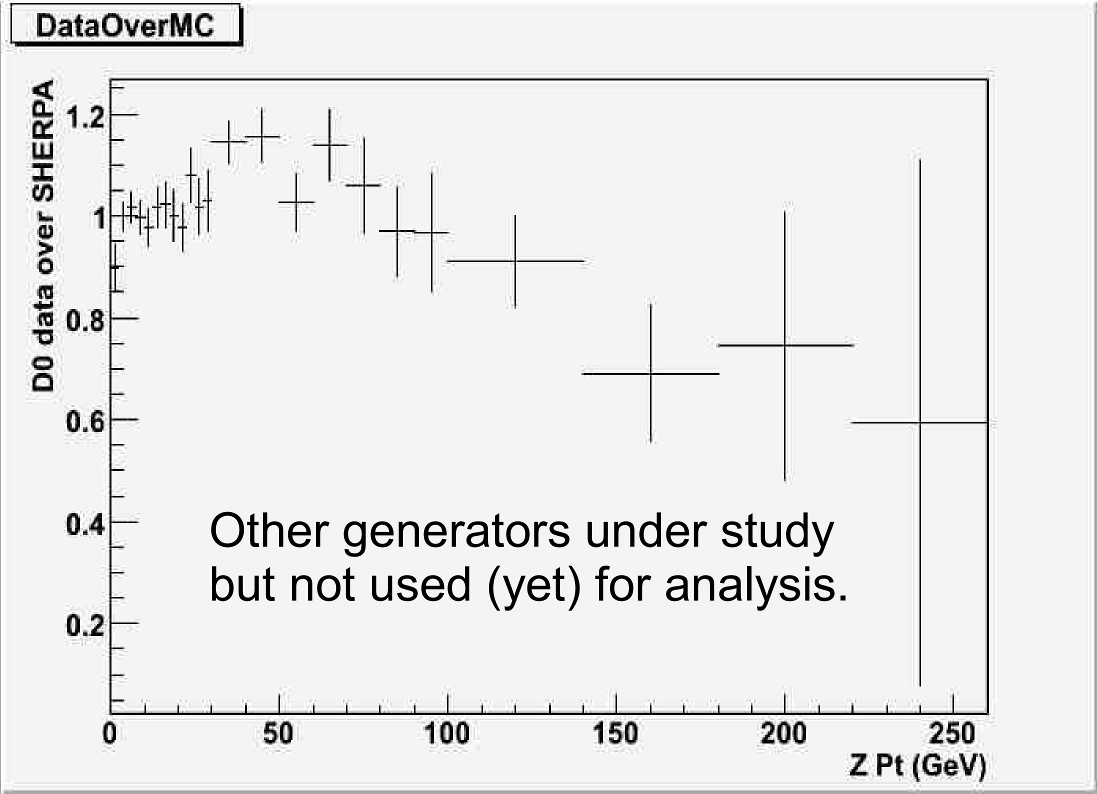
Monte Carlo simulation is a 3 steps process :
- generation using (for recent dataset): **PYTHIA** (6.3.23 and 6.4.09)
  ALPGEN+PYTHIA (version 2.05 to 2.12).
  COMPHEP for single top
- detector simulation with **GEANT 3**.
- digitization and addition of Zero Bias events to simulate multiple ppbar collisions.

Since for Standard Model, we have the data to compare extra shape corrections (reweighting) might be applied to the Monte Carlo distribution based on data distribution.

Standard Model Monte Carlo

Examples : Z-pt distribution.





Other reweighting that can eventually be done :
Luminosity profile between data and Zero Bias overlay.
W-pt, leading jet η, ΔR between the 2 leading jets, ... $\Delta R(j_1, j_2) = \sqrt{(\eta_2 - \eta_1)^2 + (\phi_2 - \phi_1)^2}$

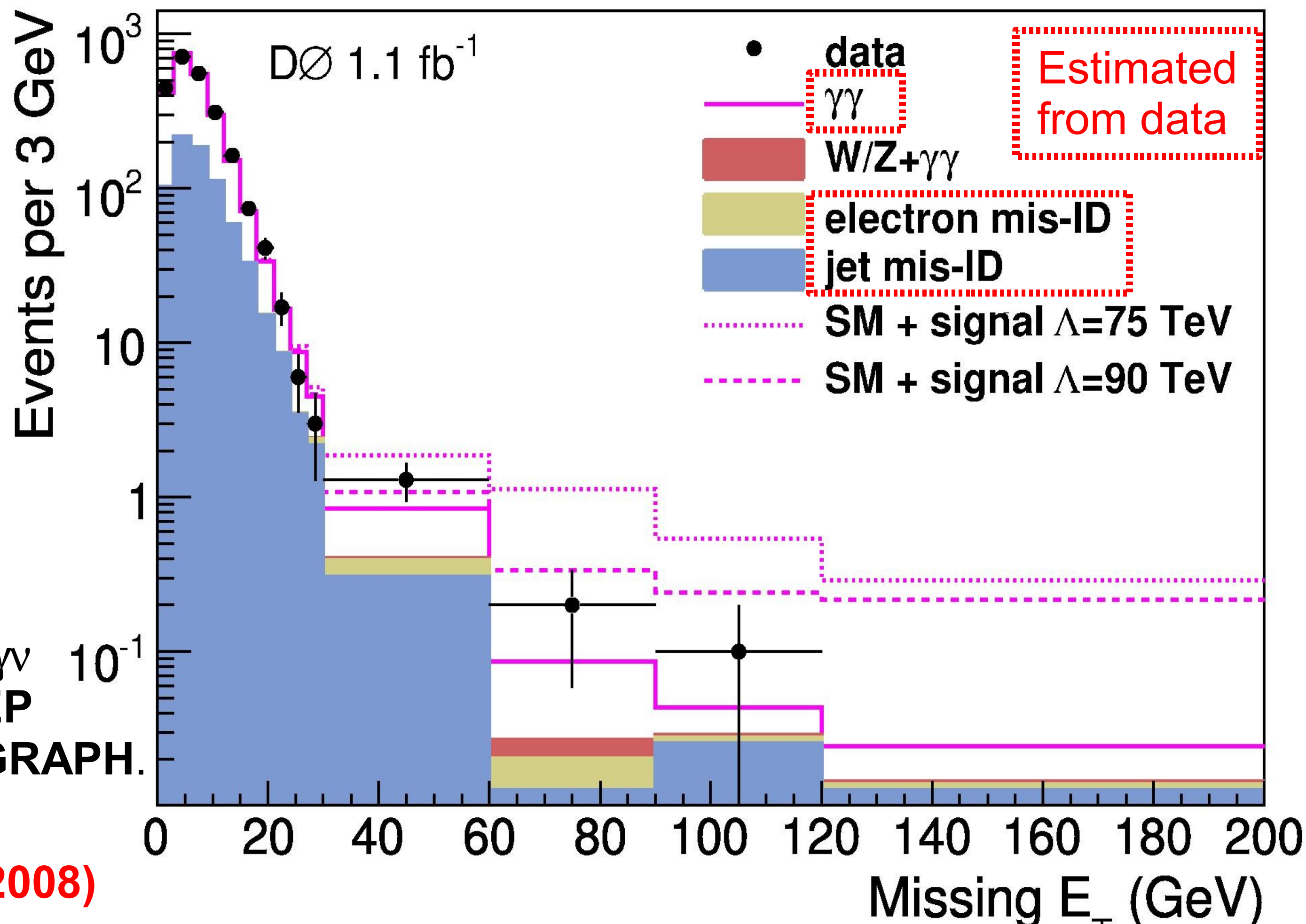
Some reweighting functions (Z pt, W pt) might depend on the number of jets.

SUSY

SUSY : GMSB two photon

GMSB with lightest neutralino as NLSP decaying in photon + gravitino.
Model "Snowmass Slope SPS 8" :
1 messenger with mass 2Λ, $\tan\beta = 15$ and sign(μ)=+1.
Λ is the SUSY breaking scale.
It is assumed the neutralino decays sufficiently promptly.

Selection :
2 γ (E_T>25 GeV)
coming from the primary interaction vertex
(photon vertex accuracy 2.3 ± 0.3 cm measured in $Z \rightarrow ee\gamma$ data sample :
"EM pointing" algorithm)

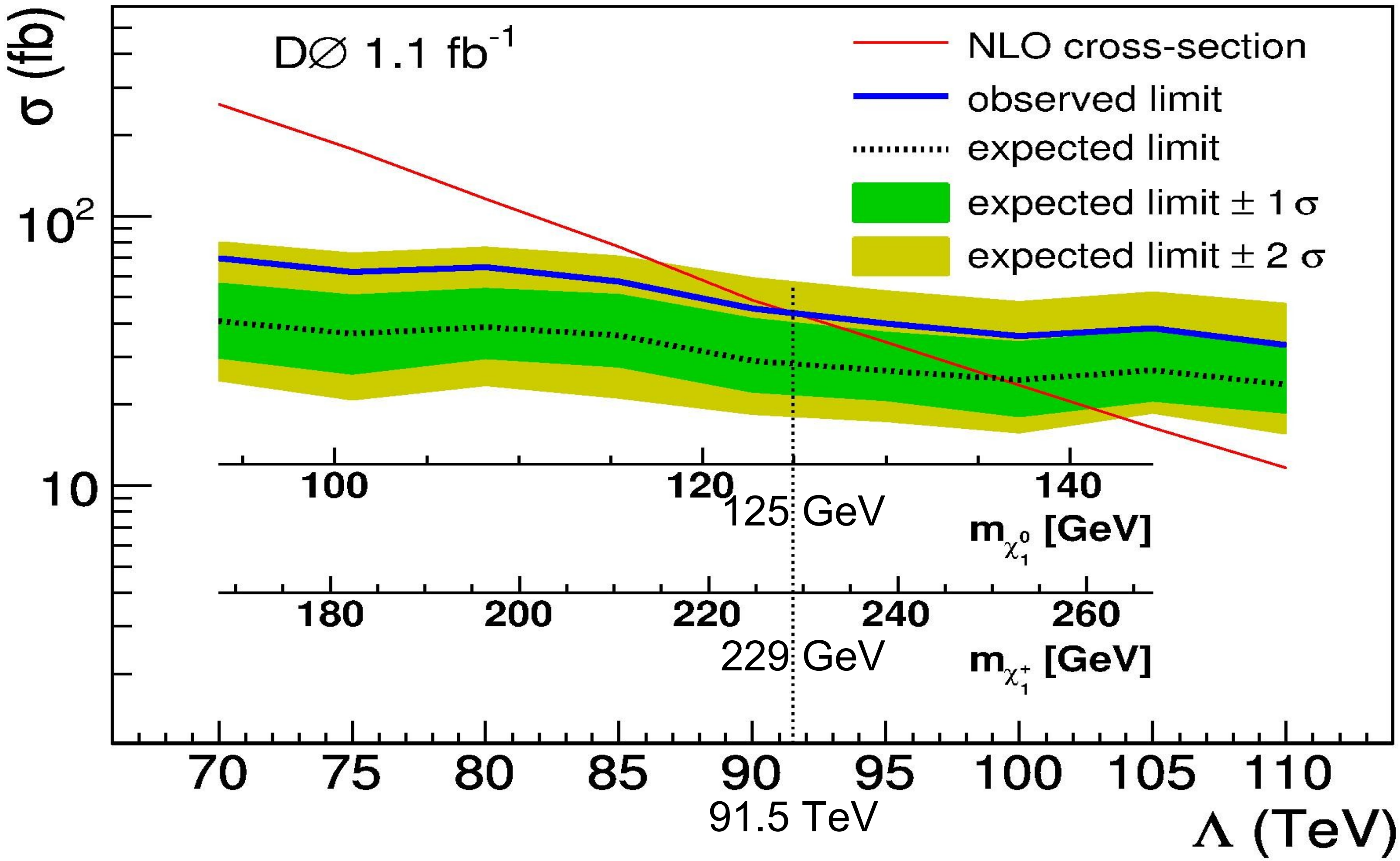


$Z\gamma\gamma \rightarrow \nu\nu\gamma\gamma$ and $W\gamma\gamma \rightarrow l\gamma\gamma\nu$
estimated using **COMPHEP**
cross-checked with **MADGRAPH**.

Phys. Lett. B659, 856 (2008)

SUSY : GMSB two photon

GMSB signal : spectrum and couplings from **ISAJET 7.58**.
Simulated with **PYTHIA 6.319**.
K-factors for normalisation taken from
W. Beenakker et al., Phys. Rev. Lett. 83, 3780 (1999).



SUSY : RPV sneutrino

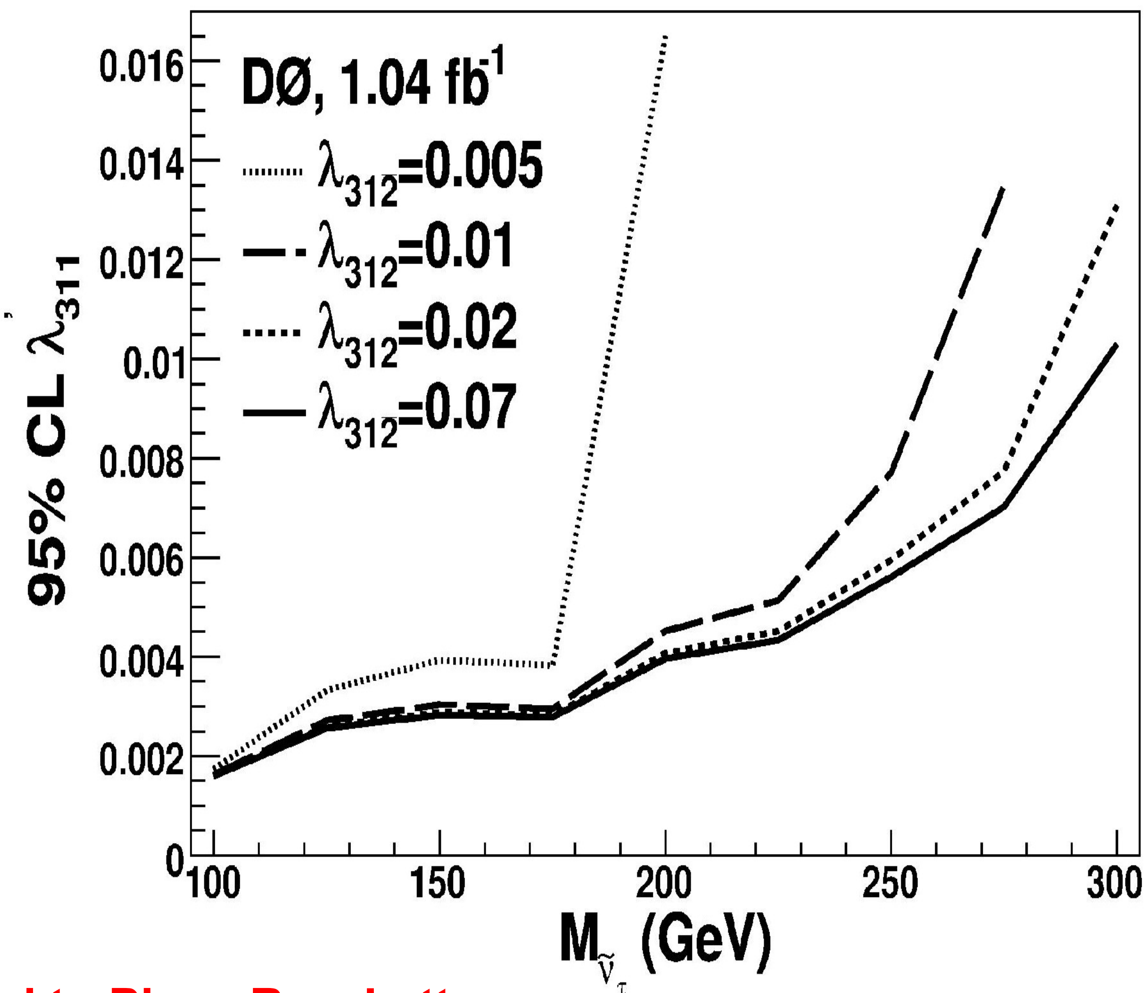
$\tilde{\nu}_\tau$ LSP, dominantly produced and decaying to eμ.

Signal simulated with **COMPHEP**. Standard Model simulated with **PYTHIA**.

$$\underbrace{p\,\bar{p}}_{\lambda'_{311}} \rightarrow \tilde{\nu}_\tau + X \underbrace{\rightarrow e\,\mu}_{\lambda_{312}} + X$$

Assuming sneutrino total width smaller than the DØ detector resolution.

95 % C.L upper limits.



hep-ex/0711.3338 submitted to Phys. Rev. Lett.

SUSY : squarks gluinos

"dijet" analysis

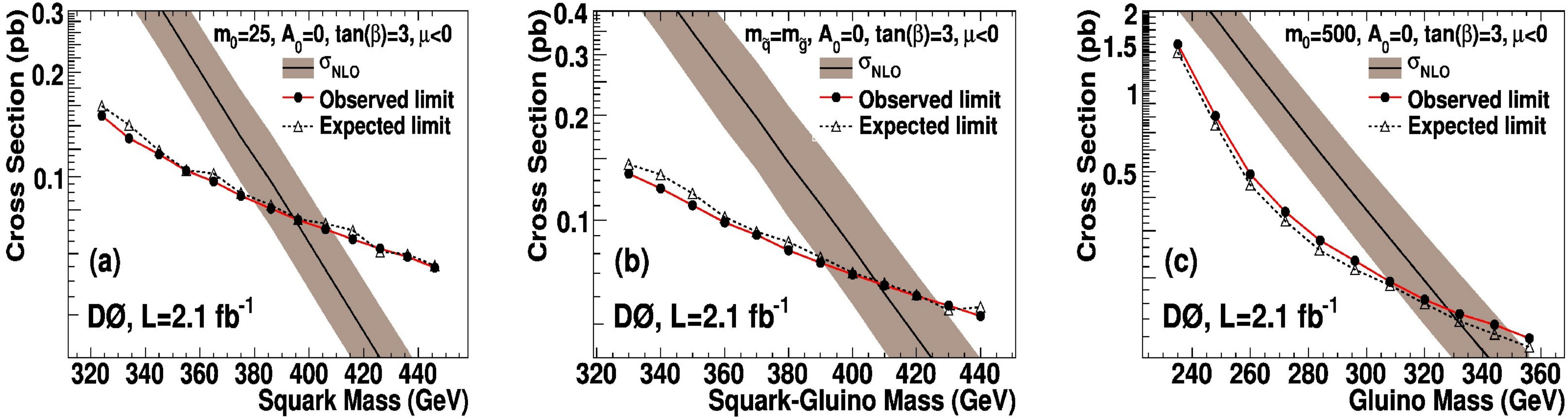
$$p\bar{p} \to \tilde{q}\bar{\tilde{q}} \to q\tilde{\chi}_1^0\bar{q}\tilde{\chi}_1^0$$
$$p\bar{p} \to \tilde{q}\tilde{q} \to q\tilde{\chi}_1^0 q\tilde{\chi}_1^0$$

"3-jets" analysis

$$p\bar{p} \to \tilde{q}\tilde{g} \to q\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$$

"gluino" 4-jets analysis

$$p\bar{p} \to \tilde{g}\tilde{g} \to q\bar{q}\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$$



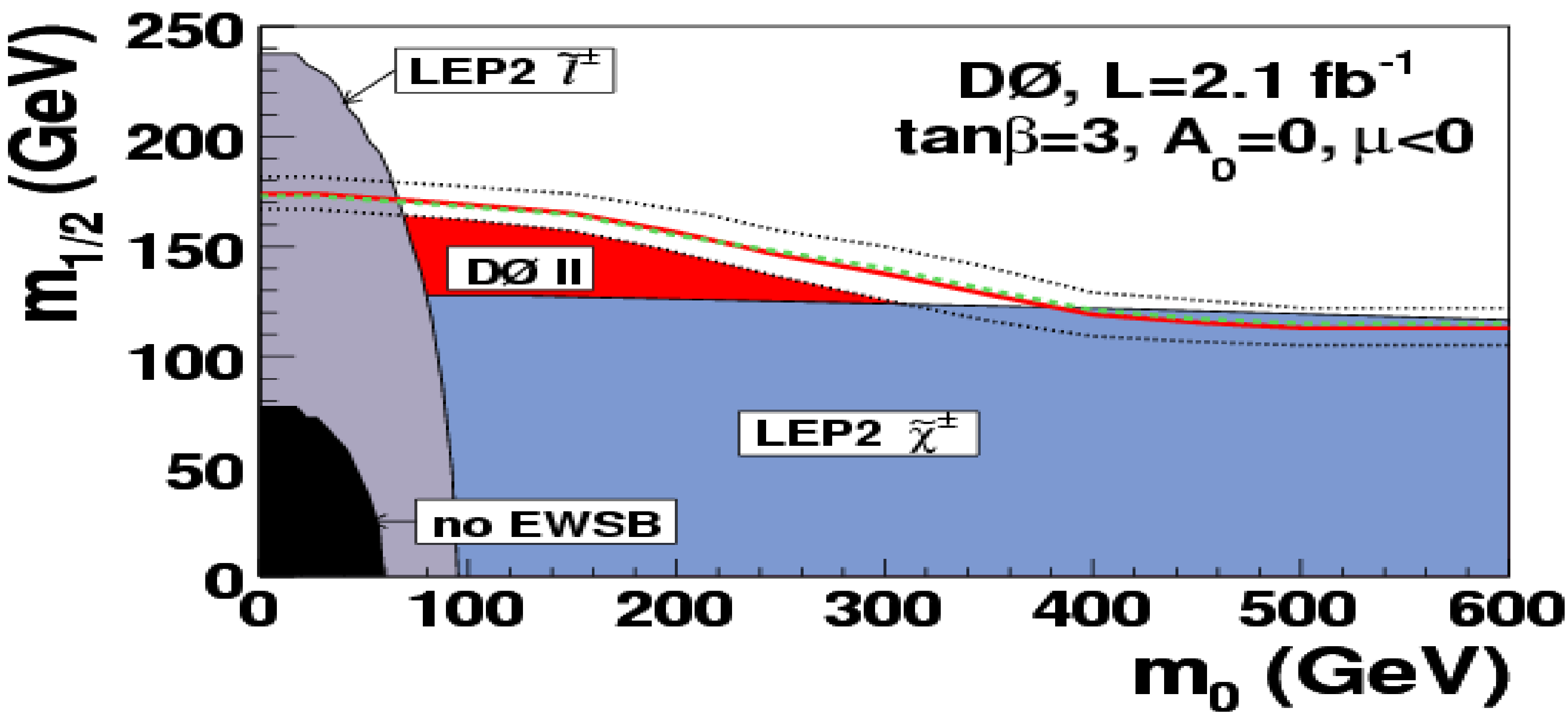
SM simulated with **PYTHIA** and **ALPGEN**.
Signal simulated with **PYTHIA**.
Spectrum from **SUSPECT**, decay rates from **SDECAY**, cross section from **PROSPINO2**

Phys. Lett. B660, 449 (2008)

SUSY : squarks gluinos

Split analysis in independent samples.

Selection	"dijet"	"3-jets"	"gluino"	$N_{\text{obs.}}$	$N_{\text{backgrd.}}$
Combination 1	yes	no	no	8	9.4 ± 1.2 (stat.) $^{+2.3}_{-1.8}$ (syst.)
Combination 2	no	yes	no	2	4.5 ± 0.6 (stat.) $^{+0.7}_{-0.5}$ (syst.)
Combination 3	no	no	yes	14	12.5 ± 0.9 (stat.) $^{+3.6}_{-1.9}$ (syst.)
Combination 4	yes	yes	no	1	1.1 ± 0.3 (stat.) $^{+0.5}_{-0.3}$ (syst.)
Combination 5	yes	no	yes		kinematically not allowed
Combination 6	no	yes	yes	4	4.5 ± 0.6 (stat.) $^{+1.8}_{-1.3}$ (syst.)
Combination 7	yes	yes	yes	2	0.6 ± 0.2 (stat.) $^{+0.1}_{-0.2}$ (syst.)
At least one selection				31	32.6 ± 1.7 (stat.) $^{+9.0}_{-5.8}$ (syst.)



SUSY : light stop

Look for pair production of lightest stop : $p\bar{p} \rightarrow \tilde{t}_1 \tilde{t}_1 + X$

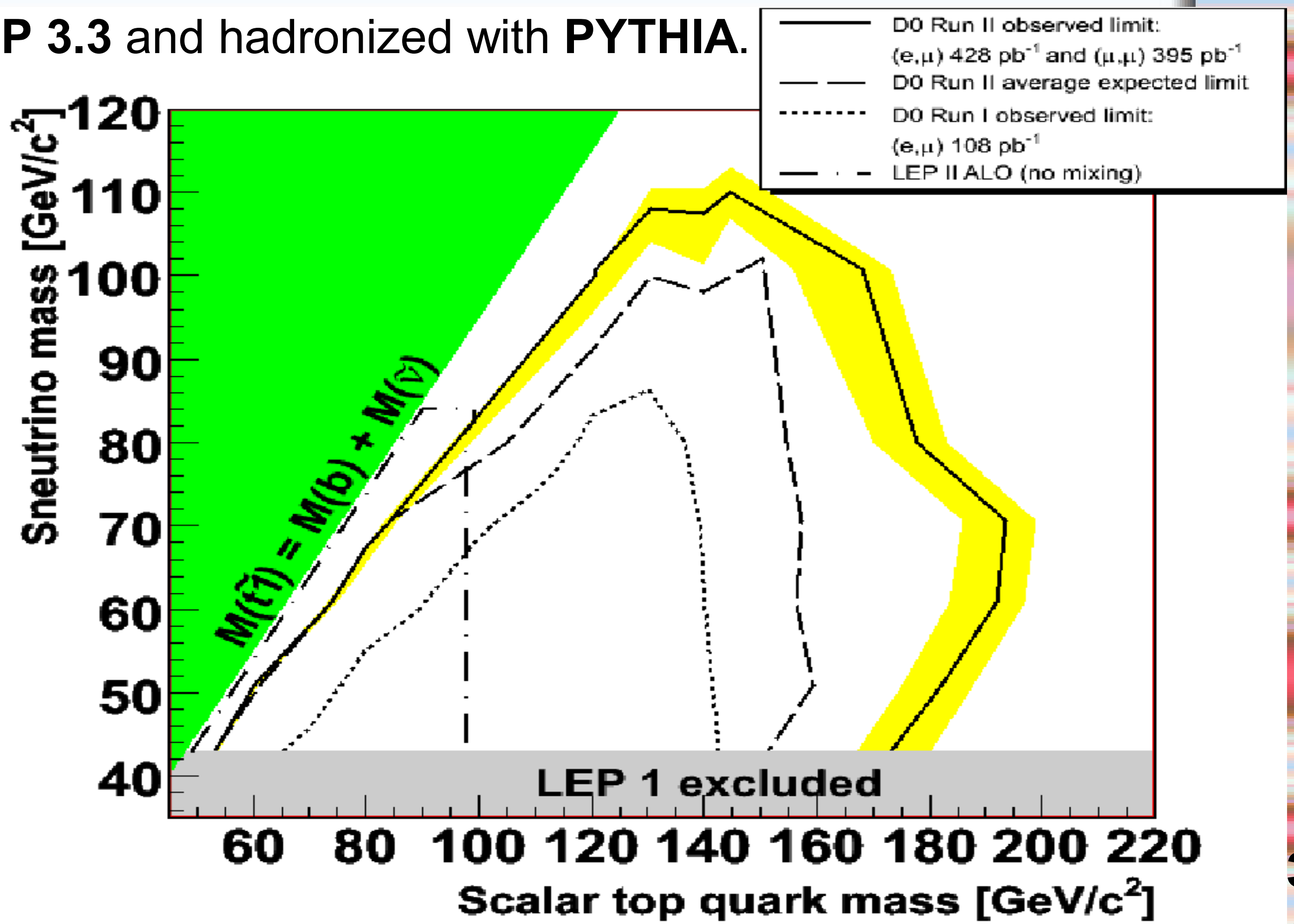
Hypothesis : stop decays at 100% through $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm *} \rightarrow bl\tilde{\nu} \rightarrow bl\nu\tilde{\chi}_1^0$

Here l is a charged lepton. $\tilde{\nu}$ NLSP
Chargino decay rate supposed to be the same for each family.

Signature : $b\bar{b}ll'\nu\bar{\nu}\tilde{\chi}_1^0\tilde{\chi}_1^0$: Jets, isolated leptons , Missing Tranverse Energy (MET)

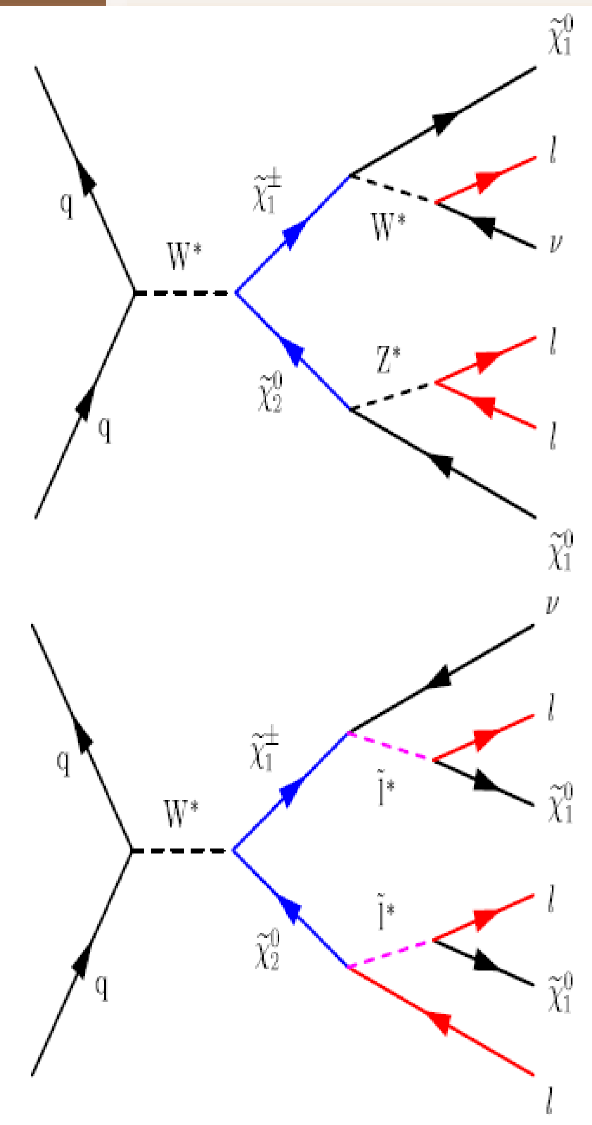
Signal generated with **COMPHEP 3.3** and hadronized with **PYTHIA**.

Look signal with
ll' = eμ or μμ.



Phys. Lett. B 659, 500 (2008)

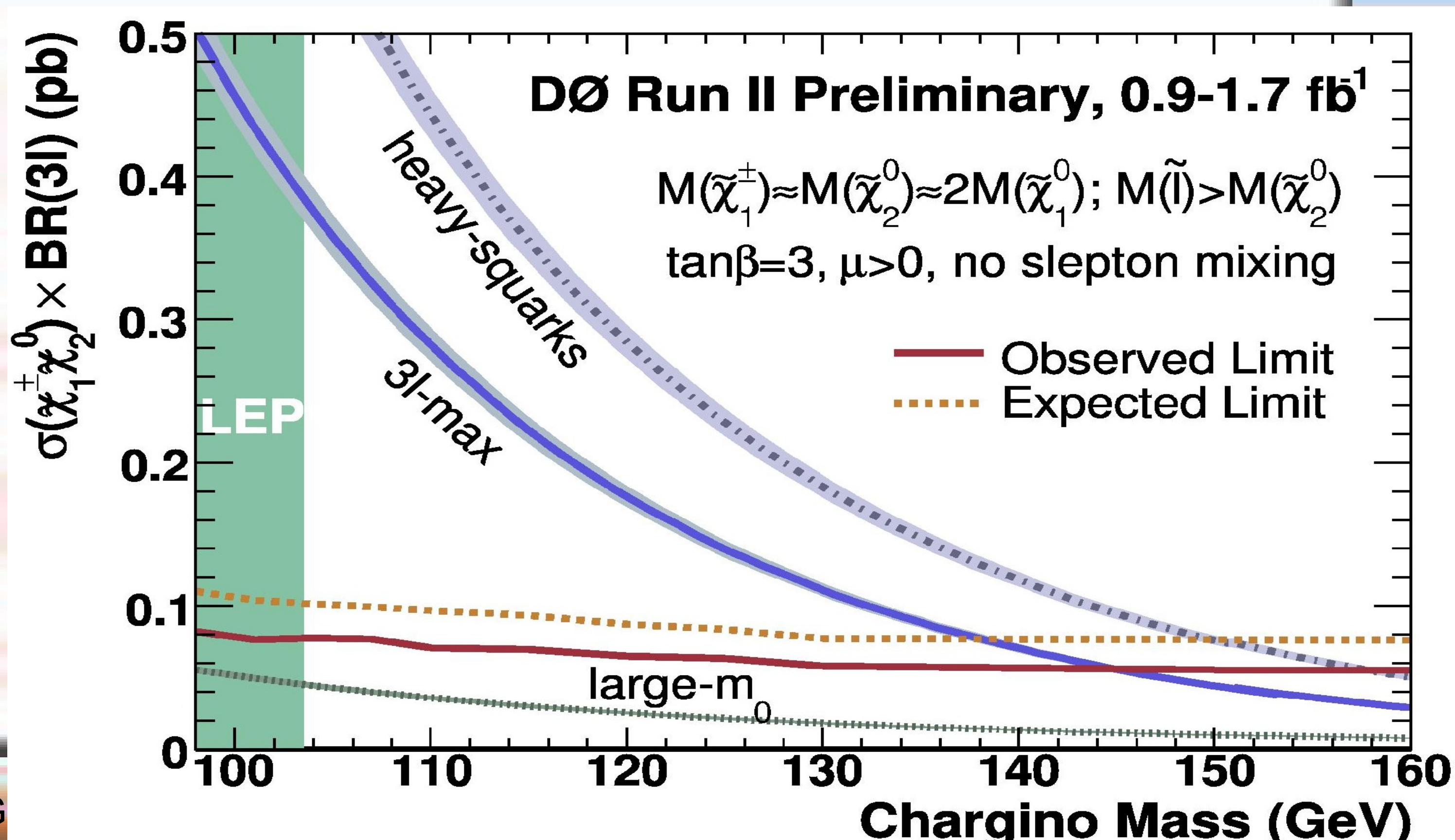
SUSY : trilepton



New combination :

analysis	luminosity	generator
ee+track	1.7/fb	PYTHIA 6.319
same signe μμ	0.9/fb	PYTHIA 6.323
μμ+track	1.1/fb	PYTHIA 6.319
eμ+track	1.1/fb	PYTHIA 6.319

QCD estimated from data, other SM and signal with PYTHIA



Preliminary

Stopped gluinos

Long lived gluinos (split SUSY) hadronizes into R-hadrons.
By going through matter, neutral R-hadrons can transform into charged R-hadrons.
Charged R-hadrons lose energy by ionisation in dense material like a calorimeter.
Finally R-hadrons comes to a stop inside the calorimeter and decays later.

Hypothesis used : R-hadron decay occurs in a recorded events different than the one corresponding to the collision who produced it.
This implies a lifetime above 30 μs.

From an analysis point of view, it is an isolated jets with lots of MET.

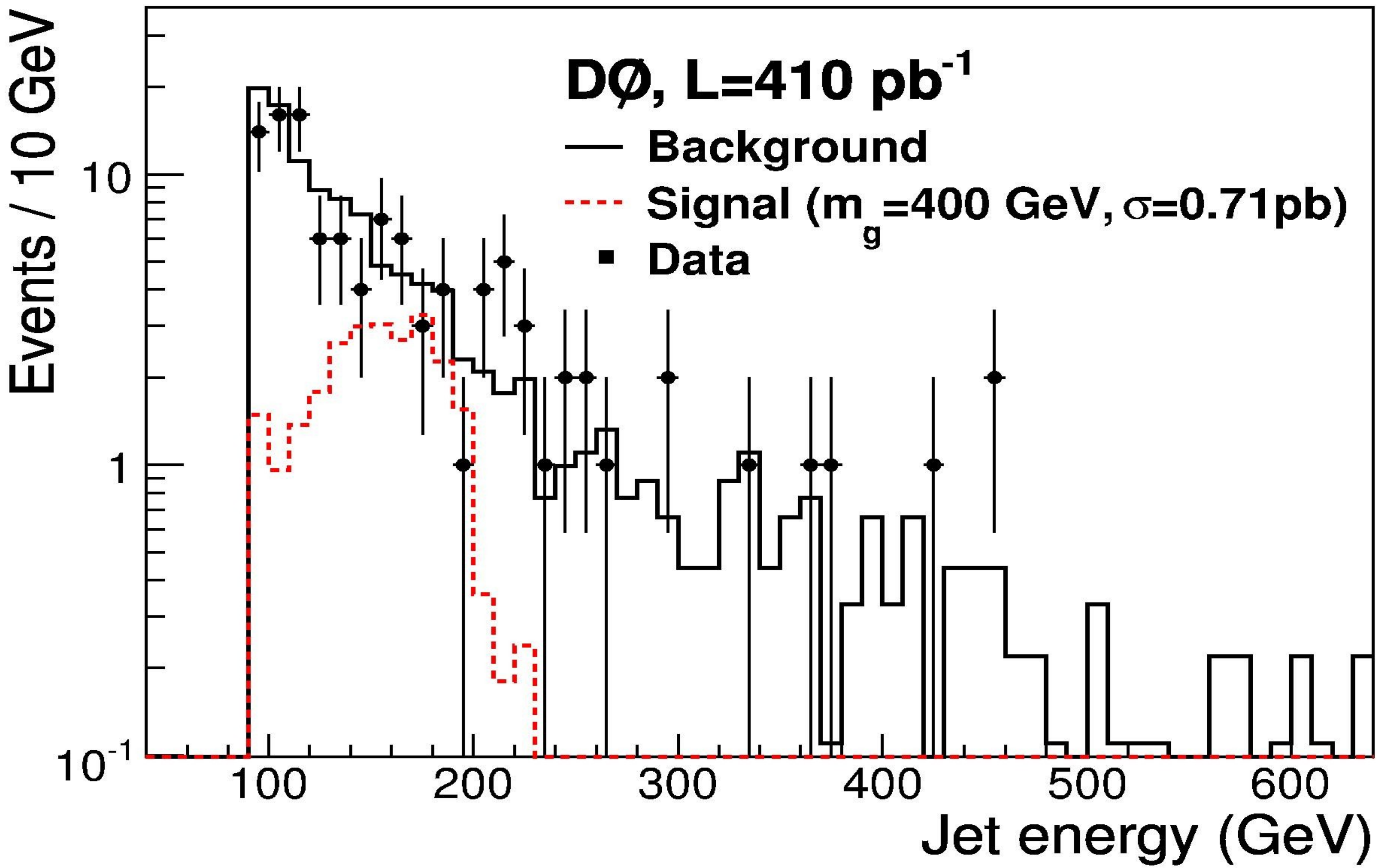
The analysis selects events with one jet of energy above 90 GeV and $|\eta|<0.9$ and no other jet with transverse energy above 8 Gev.

Trigger eficiency has been modeled for lifetime up to 100 hours.
The model takes into account TeVatron colliding period and refilling period, data acquisition running and stopping, ...
Event selection has various quality requirements to only keep evants compatible with the trigger efficiency modelisation.

Main background are cosmic interaction from muon and beam related noises.
Both are estimated from data.

Phys. Rev. Lett. 99, 131801 (2007)

Stopped gluinos



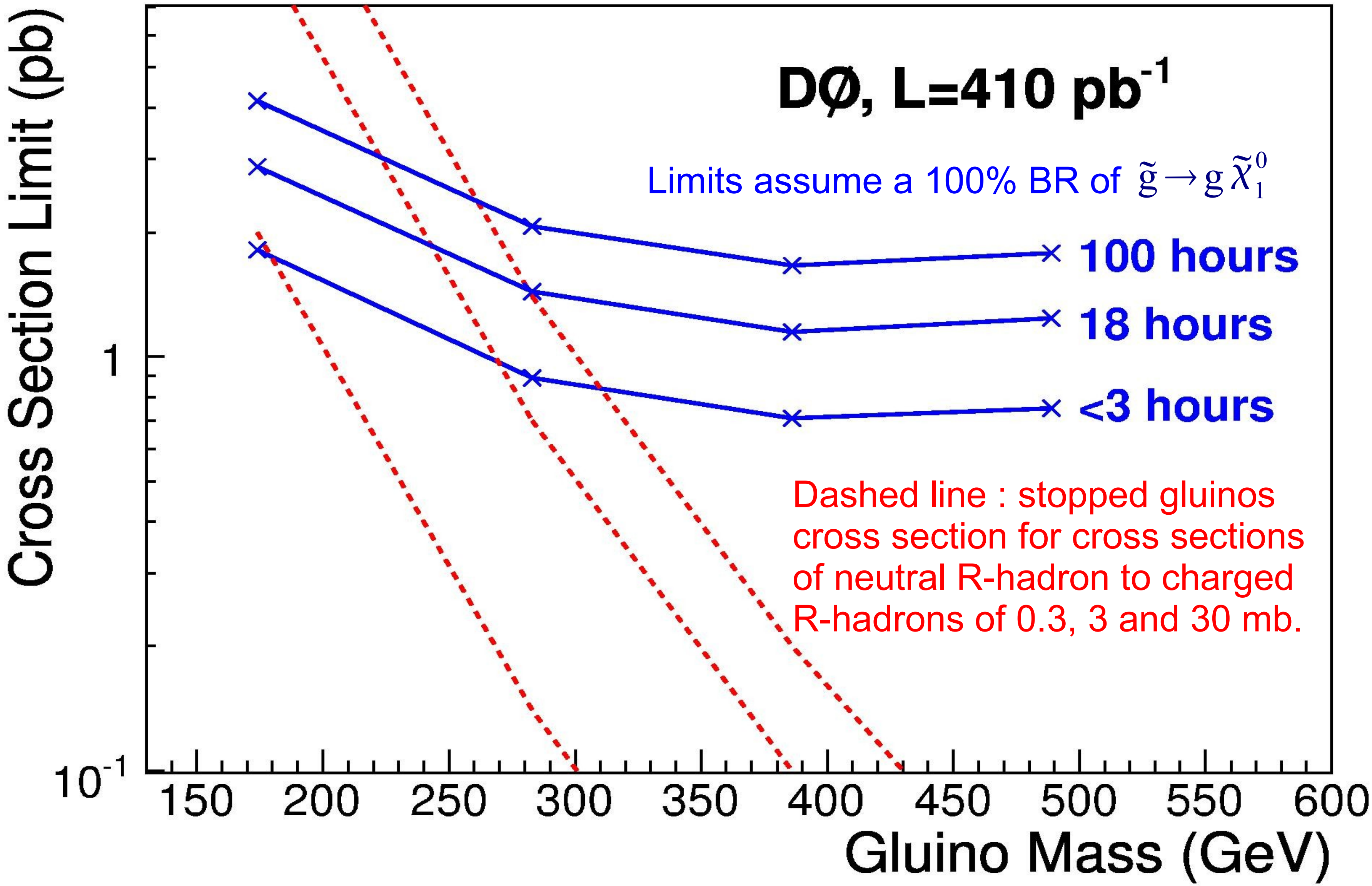
Stopped gluinos simulation

There is no MC directly available for this analysis.

PYTHIA has been used to produce Z+gluon events with $Z \rightarrow \nu\nu$
with ISR and MPI turned off.
The PYTHIA Underlying Event is removed by removing particules with Pz/E > 0.95.

The event vertex is randomly put inside the DØ calorimeter.
Event is given a weight according to the expected radial distribution of stopped gluinos in the DØ detector.
The PYTHIA event is randomly rotated to get a uniform angular distribution of the gluino decays.

Stopped gluinos 95% C.L limits



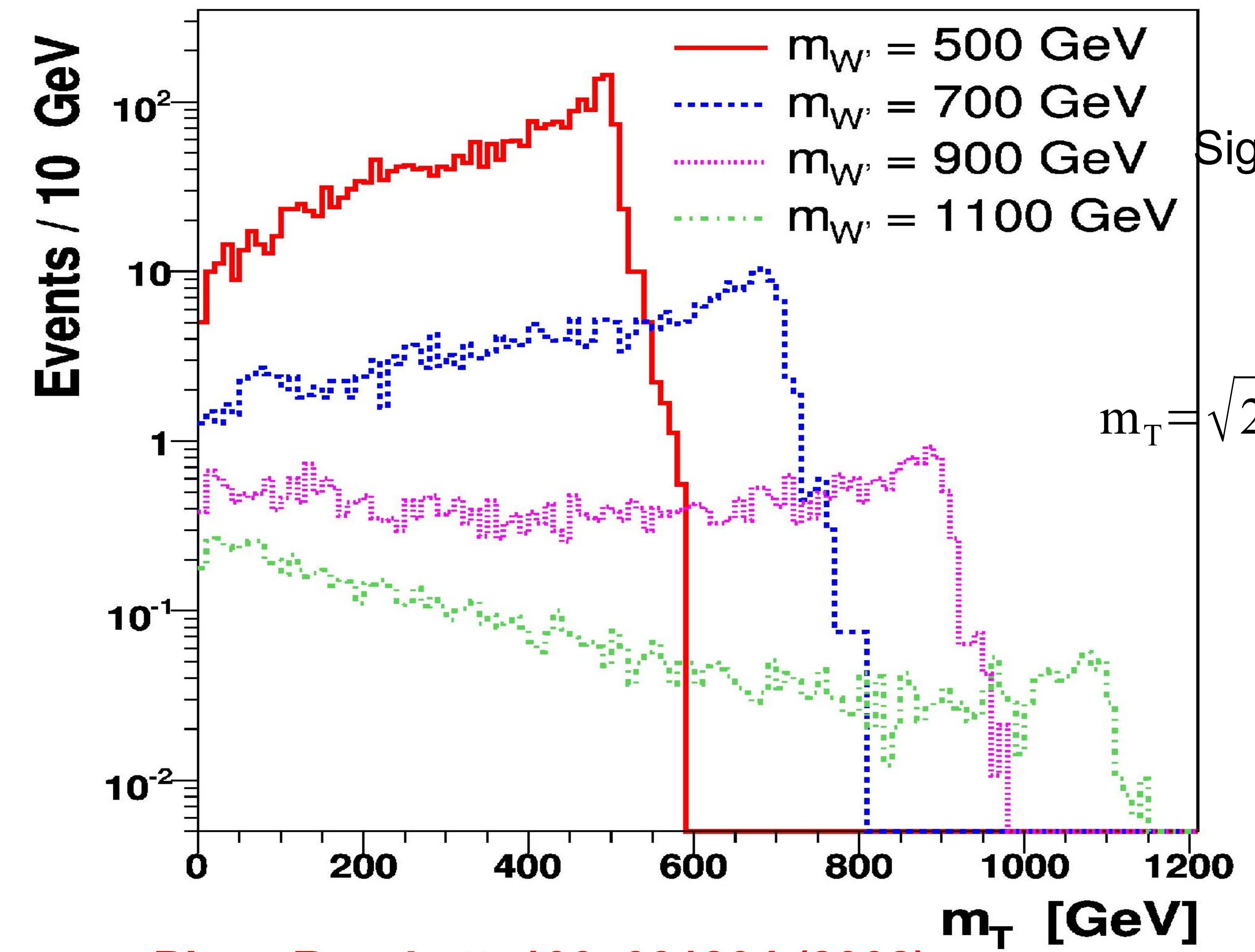
NON SUSY

Extra gauge boson W'

Look for a heavy W boson with couplings to SM particles identical to SM W couplings.

$$\Gamma_{W'} = \frac{4}{3}\frac{m_{W'}}{m_W}\Gamma_W$$

Model defined in G. Altarelli *et. al.*, Z. Phys. C **45**, 109 (1989)



Signal simulated with **PYTHIA 6.323**.

Look for W' →eν.

$$m_T = \sqrt{2\,E_T^{el}\,MET\,(1-\cos\Delta\phi(el, MET))}$$

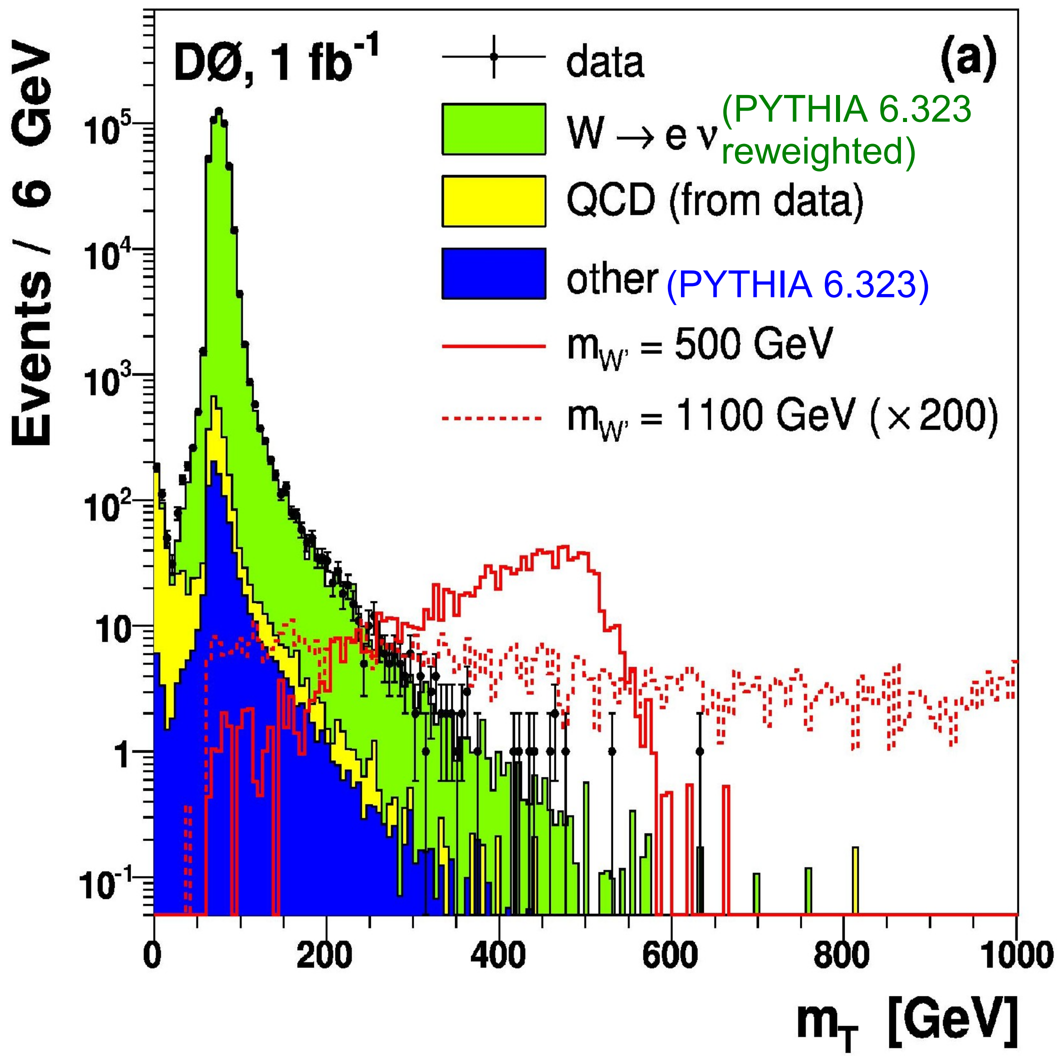
Phys. Rev. Lett. 100, 031804 (2008)

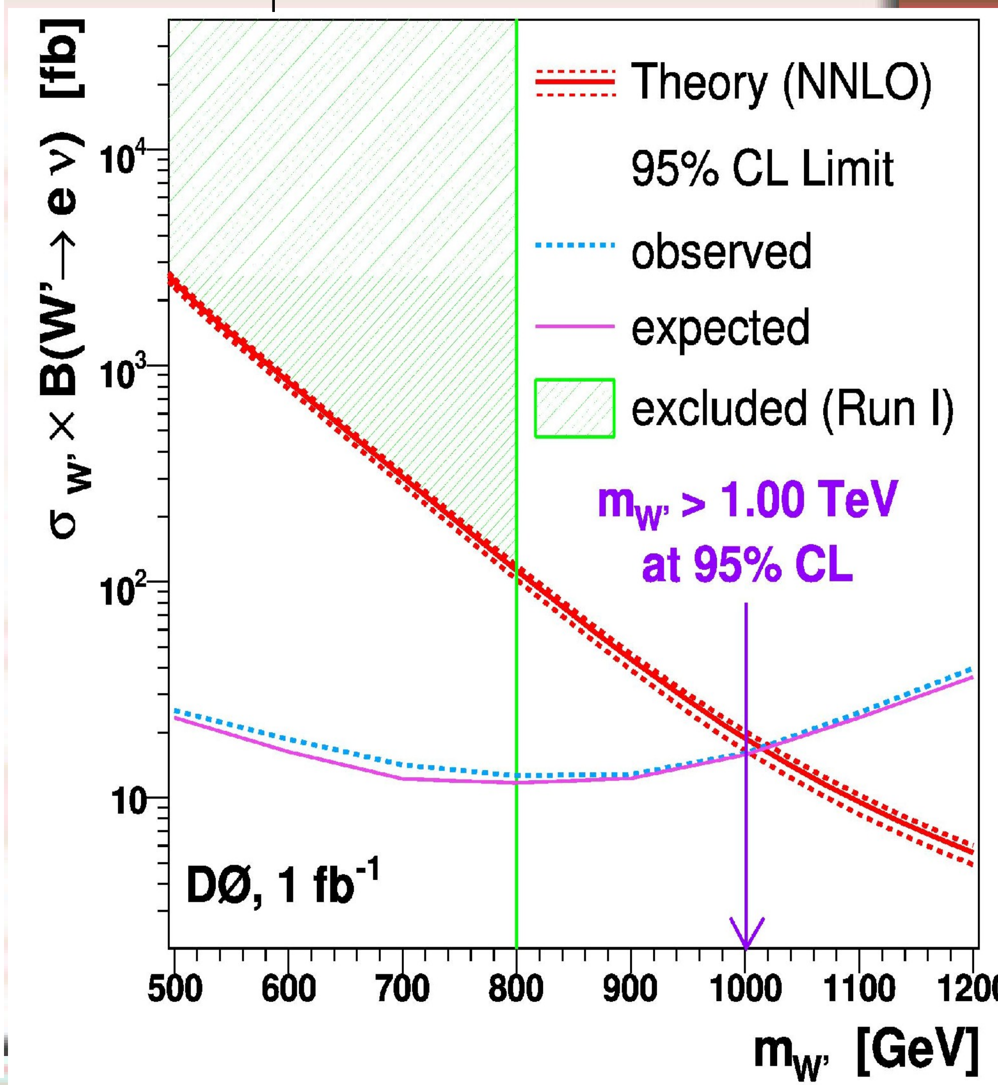
Extra gauge boson W'

e^- : E_T >30 GeV,
MET > 30 GeV
0.6 < E_T^{el}/MET < 1.4
No jets (P_T>15 GeV) aligned with e^- or MET

W+jets MC has a W-P_T reweighting depending on the number of jets (1, 2 and ≥ 3 jets)

Used 140<m_T<1000 GeV to derive limits

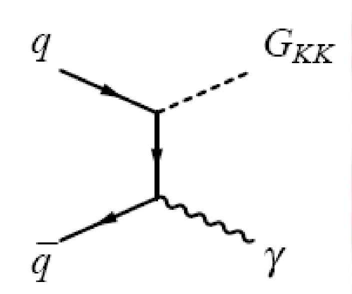




Large Extra Dimension

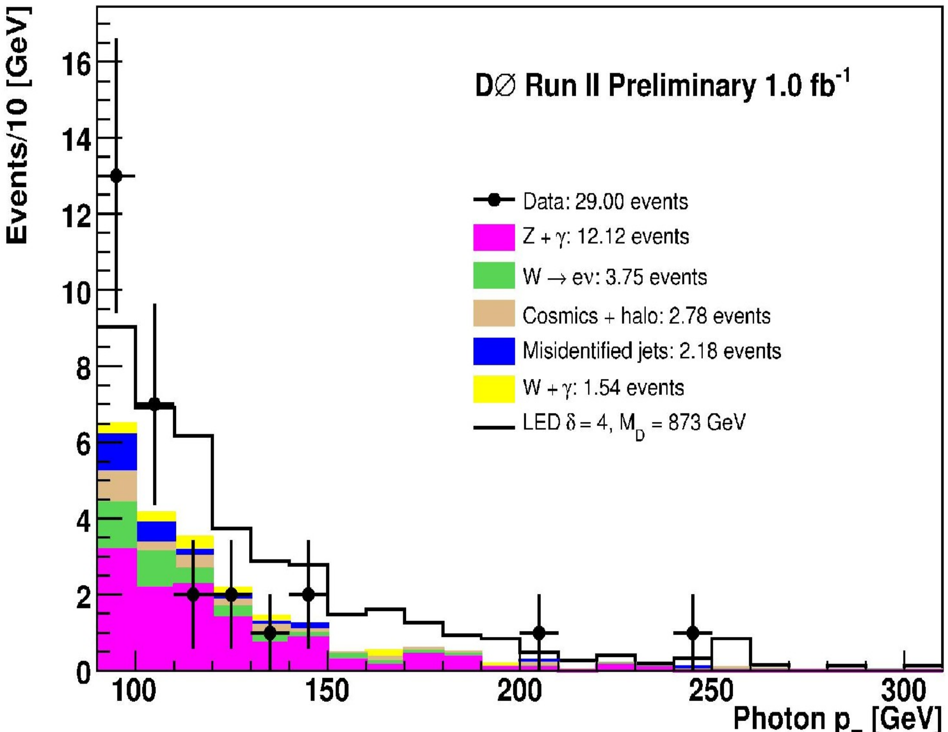
Arkani-Hammed, Dimopoulos, Davli-like models

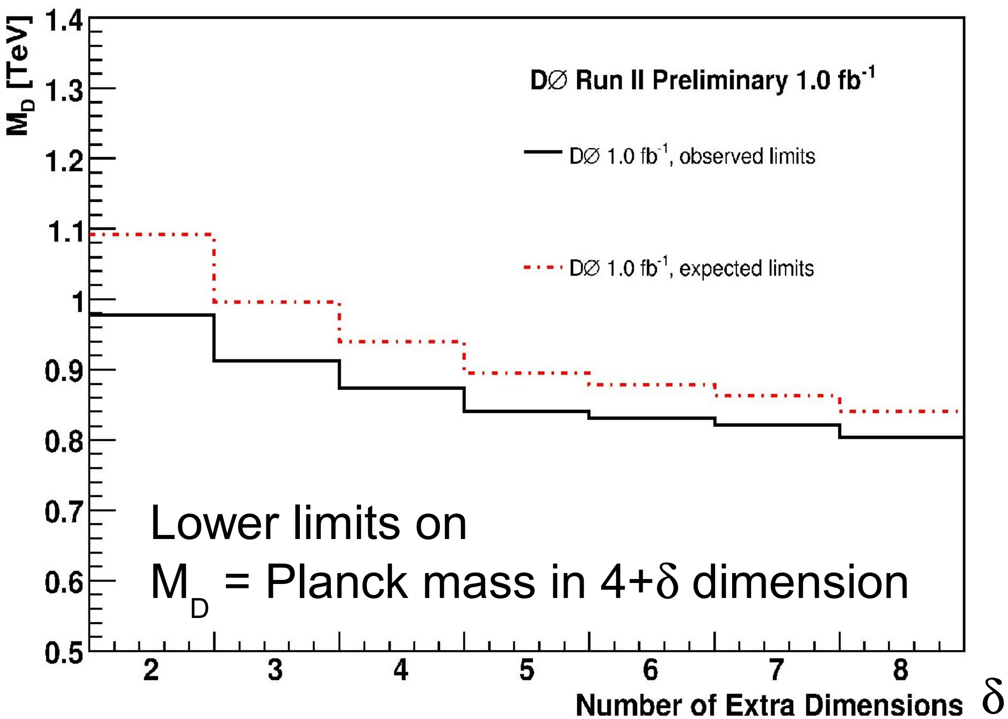
Single photon signal.



Signal simulated with **PYTHIA**.

Analysis requires :
One photon with Pt>90 GeV and 'EM pointing' vertex within 10 cm of primary vertex.
MET > 70 GeV
Veto on muons, isolated tracks with Pt>6.5 GeV and jets with Pt>15 GeV.





Lower limits on
M_D = Planck mass in 4+δ dimension

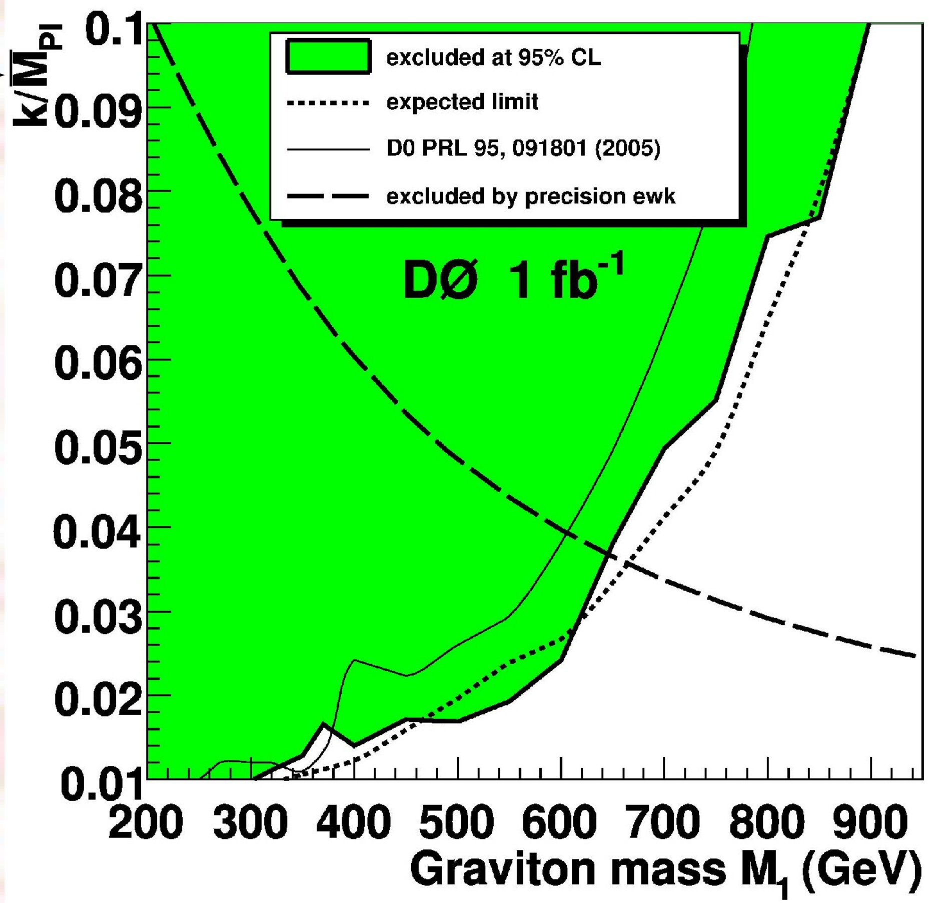
Randall Sundrum graviton

Look for narrow resonnances in $\gamma\gamma$ and e^+e^- using EM objects of P_T>25 GeV and |η|<1.1 +sliding mass window cut

QCD estimated from data. Other SM processes and signal simulated with **PYTHIA**.

Dimensionless coupling of graviton to SM fields

$$\overline{M}_{pl} = \frac{M_{pl}}{\sqrt{8\pi}}$$

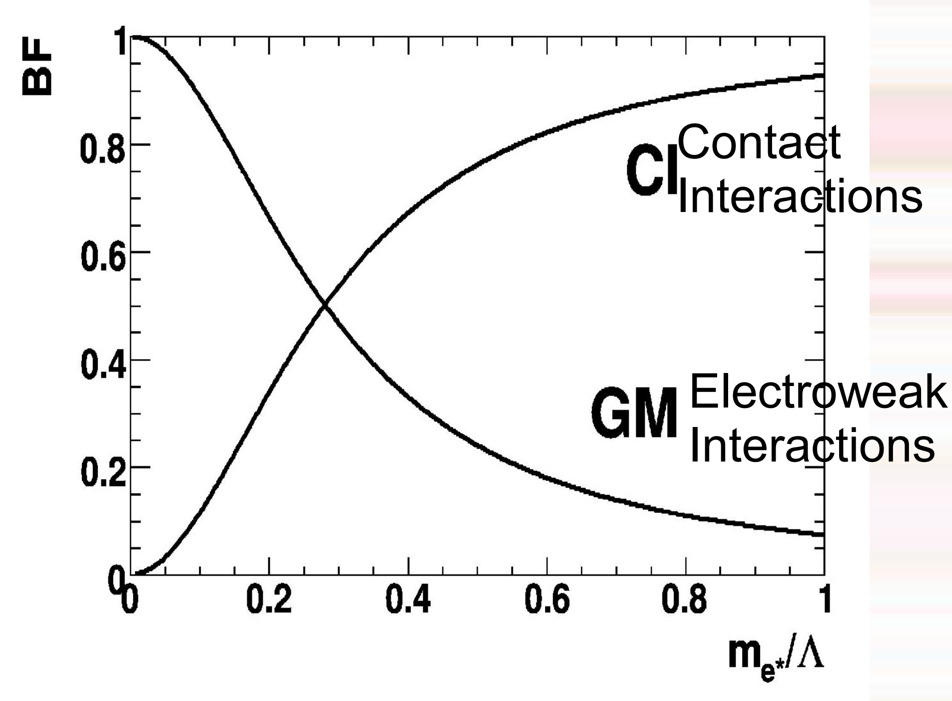


hep-ex/0710.3338 accepted by Phys. Rev. Lett.

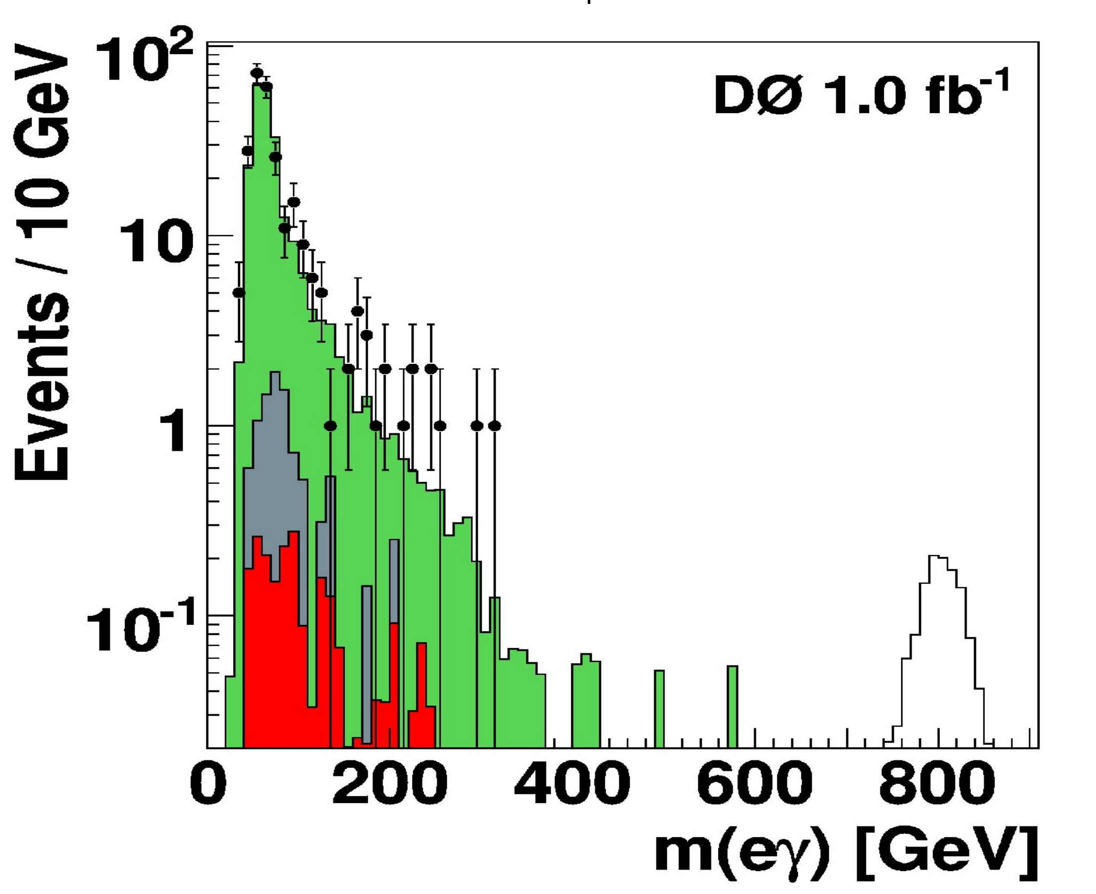
Compositeness : excited electrons

Search for : $p\bar{p} \rightarrow e e^{*} + X \text{ and } e^{*} \rightarrow e\gamma$

Excited electron produced through 4 fermions Contact Interactions.



Selects 2 isolated electrons with P_T>25 GeV and 1 isolated photon with P_T> 15 GeV.



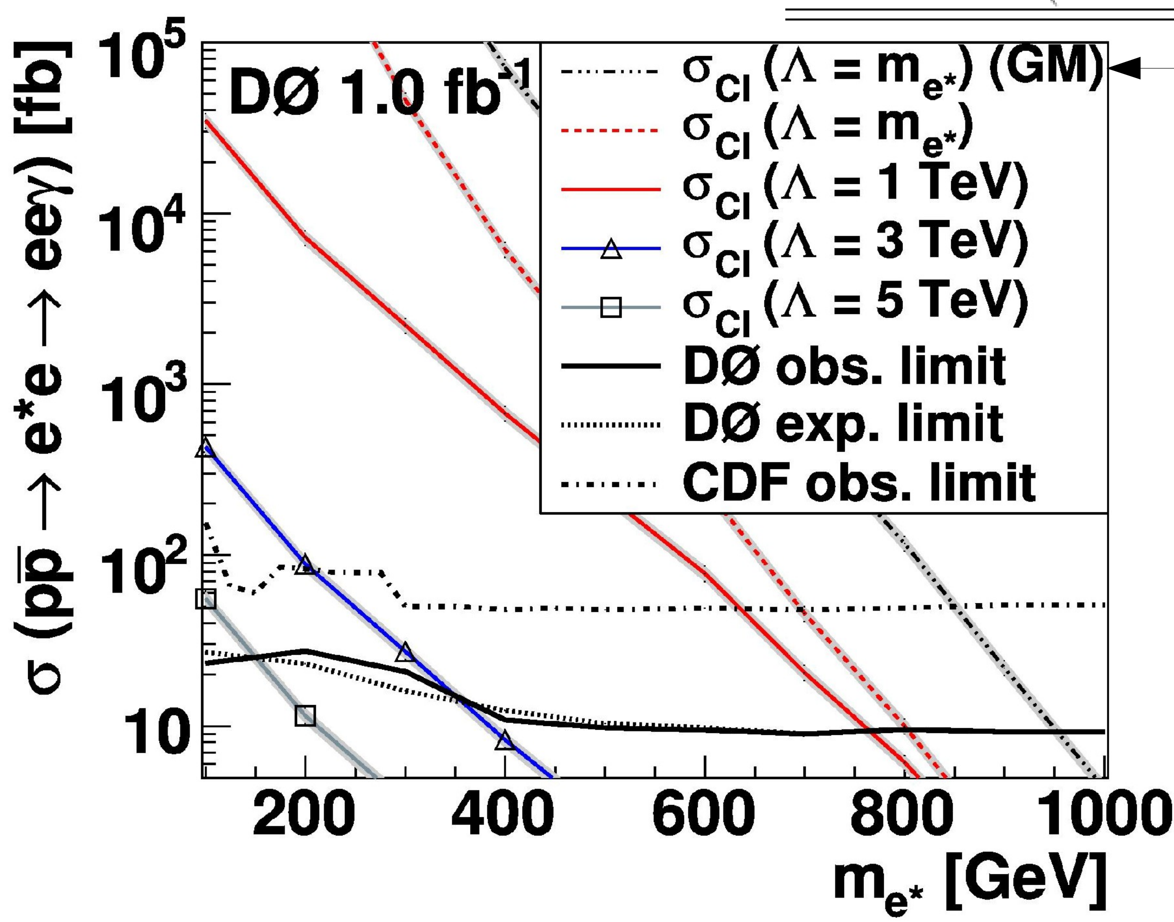
Signal simulated with **PYTHIA** but **PYTHIA** doesn't simulate the Contact Interaction decays.

hep-ex/0801.0877 submitted to Phys. Rev. Lett.

Compositeness : excited electrons

Add excited electron mass dependant cuts on events kinematics.

m_{e^*} [GeV]	Data	SM expectation	Signal eff. [%]
100	0	$0.33 \pm 0.09 \pm 0.03$	$13.2 \pm 0.6 \pm 1.3$
200	1	$0.52 \pm 0.16 \pm 0.05$	$16.5 \pm 0.6 \pm 1.6$
300	1	$0.32 \pm 0.12 \pm 0.03$	$22.2 \pm 0.7 \pm 2.2$
400	0	$0.26 \pm 0.11 \pm 0.03$	$28.3 \pm 0.8 \pm 2.8$
500	0	$0.12 \pm 0.08 \pm 0.01$	$31.5 \pm 1.0 \pm 3.1$
600	0	$(0.57 \pm 0.54 \pm 0.06) \times 10^{-1}$	$32.3 \pm 0.9 \pm 3.2$
700	0	$(0.82 \pm 0.37 \pm 0.09) \times 10^{-3}$	$34.3 \pm 1.1 \pm 3.4$
800	0	$(0.48 \pm 0.28 \pm 0.06) \times 10^{-3}$	$32.2 \pm 0.8 \pm 3.2$
900	0	$(0.17 \pm 0.17 \pm 0.02) \times 10^{-3}$	$33.2 \pm 0.8 \pm 3.3$
1000	0	$(0.17 \pm 0.17 \pm 0.03) \times 10^{-3}$	$33.3 \pm 0.9 \pm 3.3$

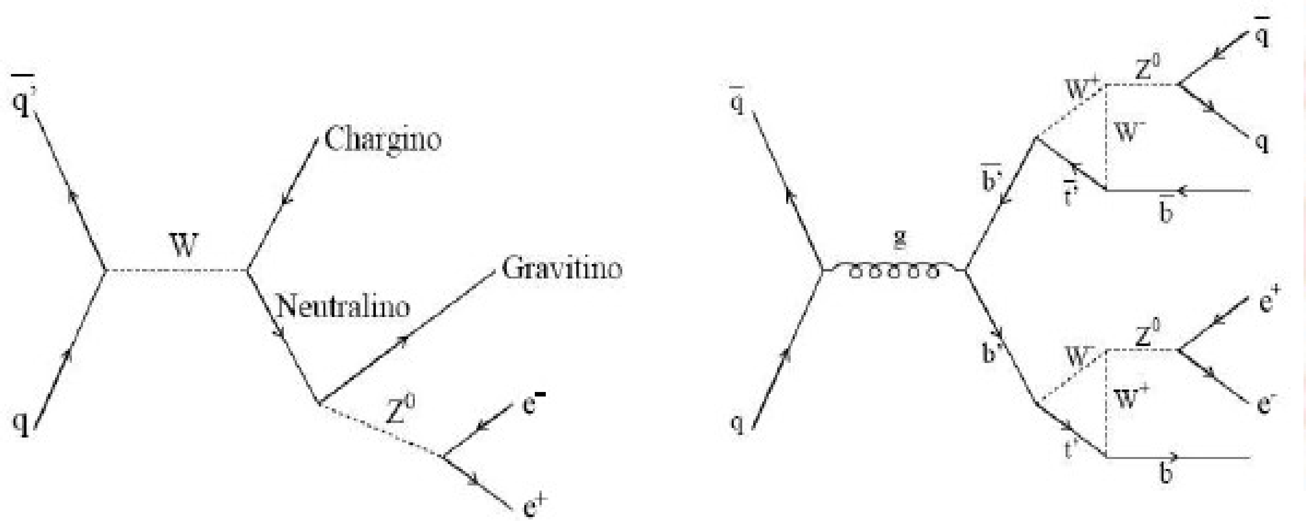


Assuming no CI decays.

Λ is the compositeness scale.

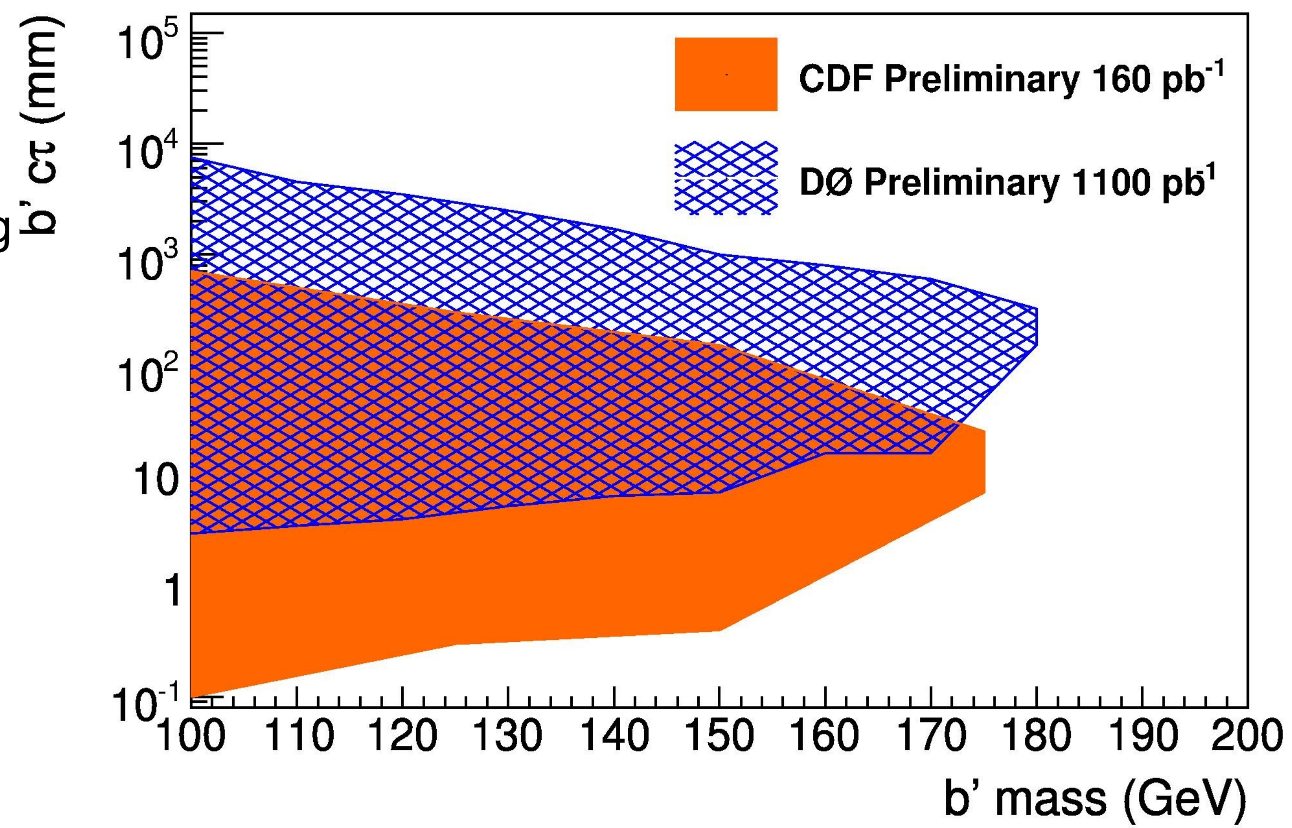
Upper limits are 95% C.L.

Long lived particles decaying into Z bosons



Signal simulated with **PYTHIA 6.202** using b' pair production

Look for Z decaying in electrons. Analysis based on reconstructing Z vertices from direction of electrons as reconstructed in the calorimeter ("EM pointing")



Preliminary

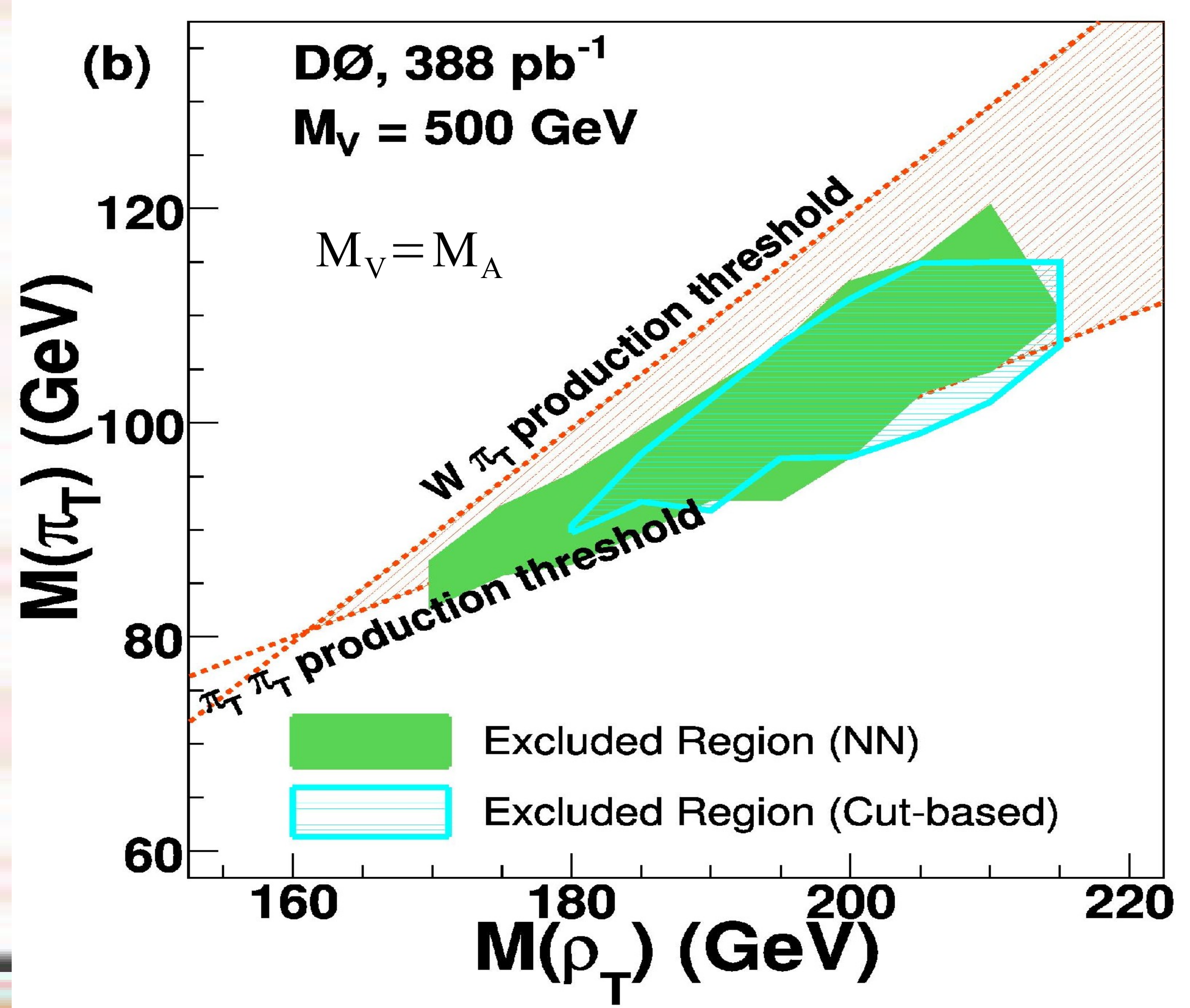
Technicolor

$$p\bar{p} \rightarrow \rho_T/\omega_T + X$$
$$\rho_T/\omega_T \rightarrow W\pi_T$$
$$W \rightarrow e\nu \wedge \pi_T \rightarrow b\bar{b}, c\bar{b}, b\bar{c}$$

SM MC **PYTHIA 6.224** and **ALPGEN**
Signal MC **PYTHIA 6.224**

Preselection :
e^- : P_T>20 GeV, |η|<1.1
MET > 20 GeV
$M_T(e^-$,MET)>30 GeV
2 jets P_T>20 GeV, |η|<2.5
At least 1 b-tagged jet

Final selection cut based or with Neural Net using combinations of angular variables and object transverse momenta.

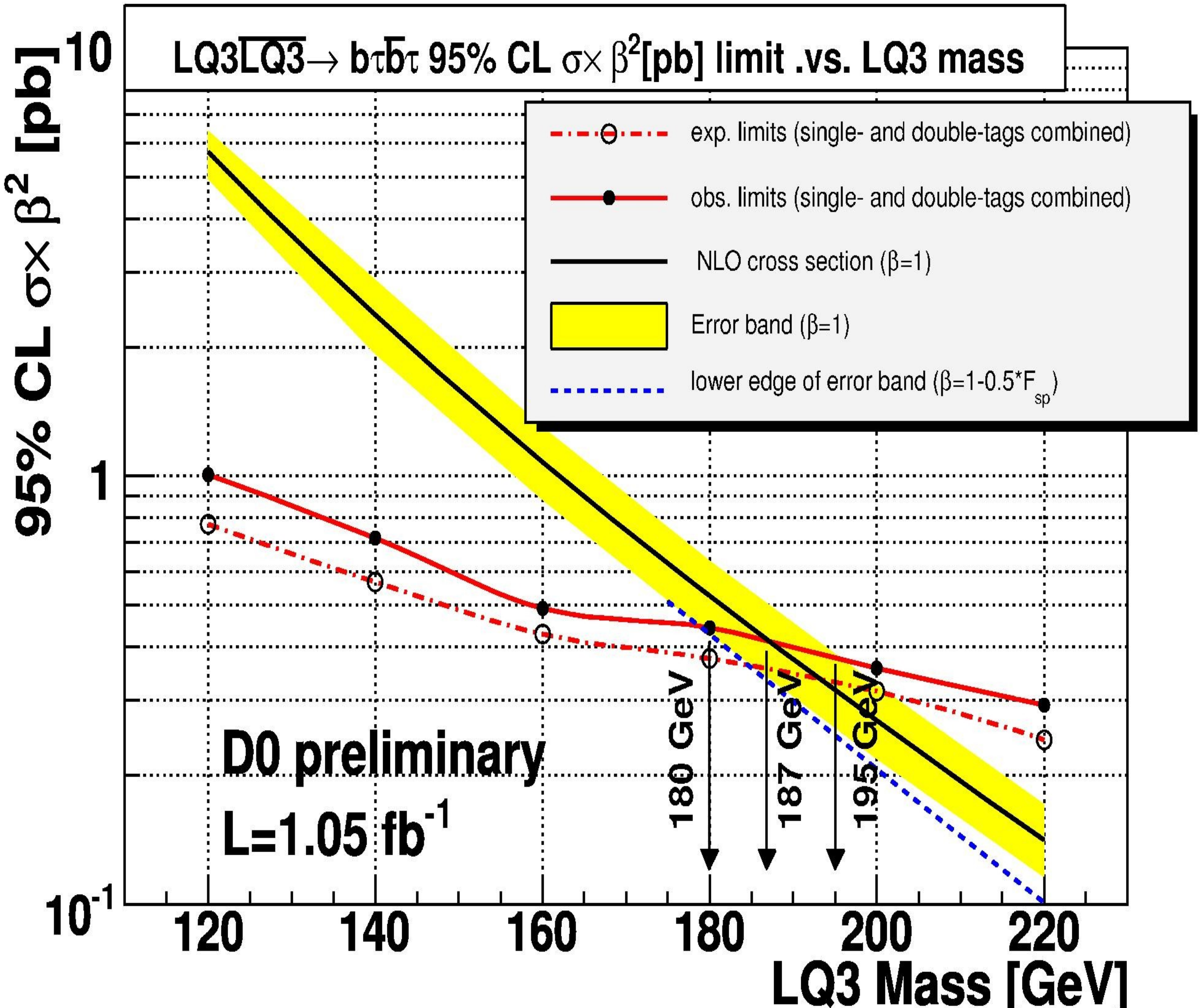


Phys. Rev. Lett. 98, 221801 (2007)

Leptoquarks

Signal simulated with **PYTHIA 6.319**

SM simulated with **PYTHIA 6.319** and **ALPGEN 2.05**

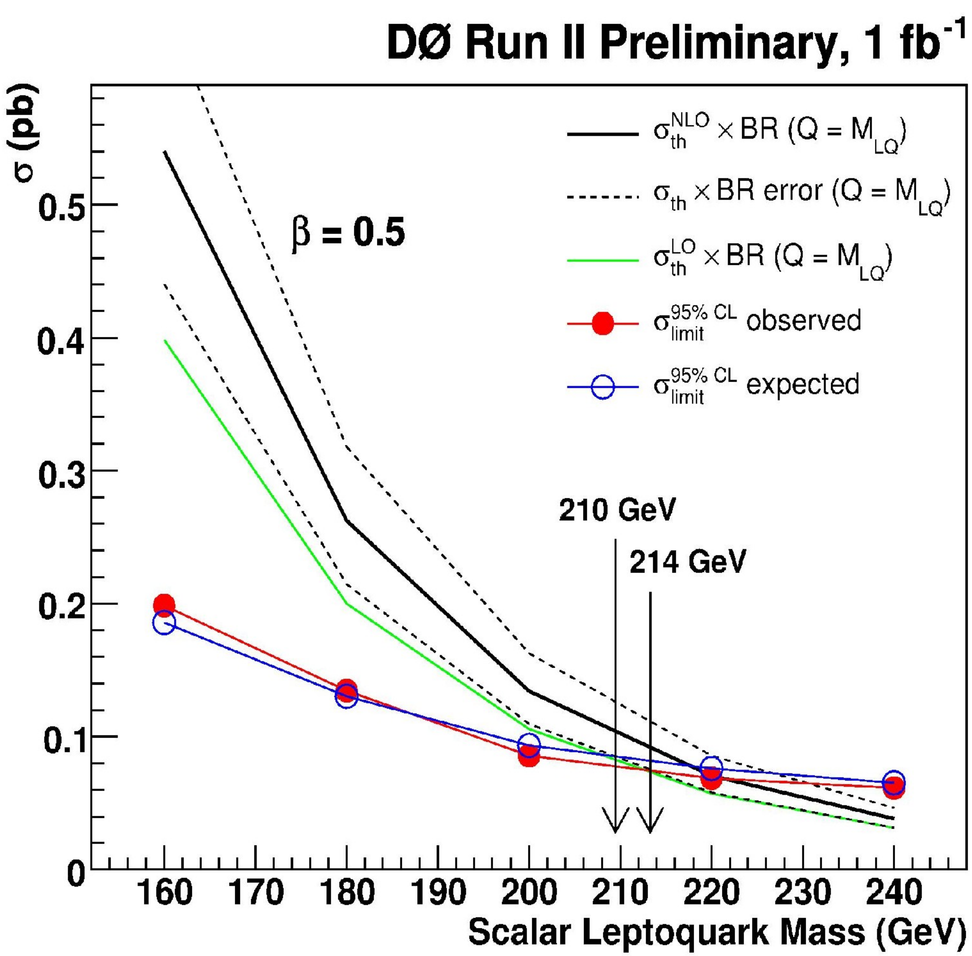


Leptoquarks

LQ2 LQ2 → $jj\mu\nu_\mu$

Signal simulated with **PYTHIA 6.319**

SM simulated with **PYTHIA 6.319** and **ALPGEN 2.05**

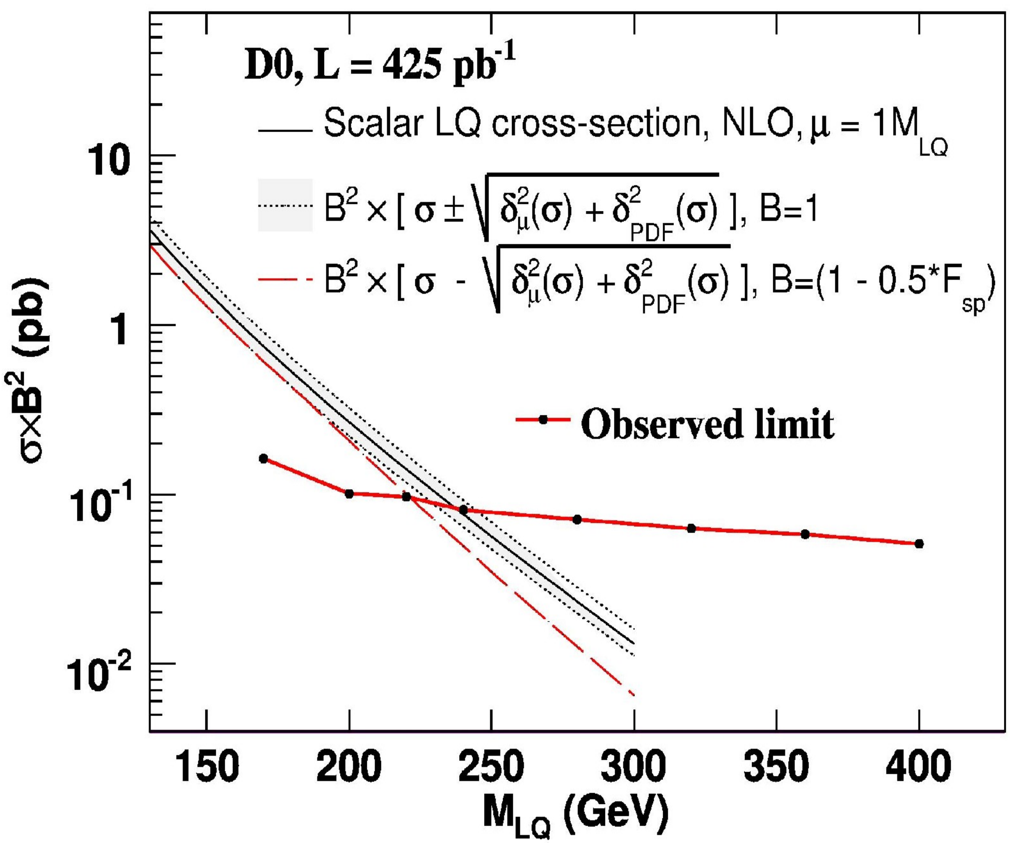


LQ3 LQ3 → $b\nu_\tau \, b\nu_\tau$

Signal simulated with **PYTHIA 6.202**

SM simulated with **ALPGEN** and **COMPHEP**

Phys. Rev. Lett. 99,061801 (2007)

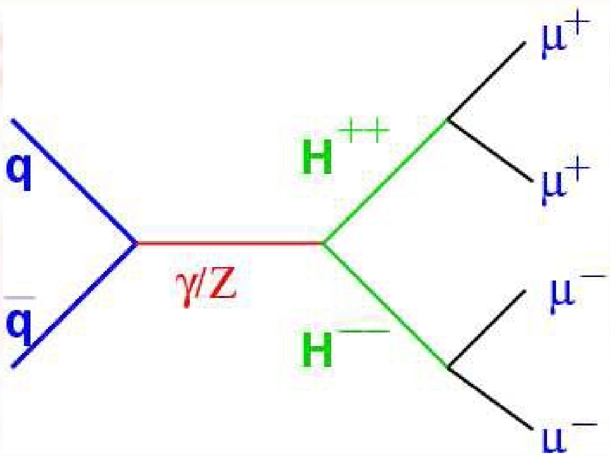


H^{++}

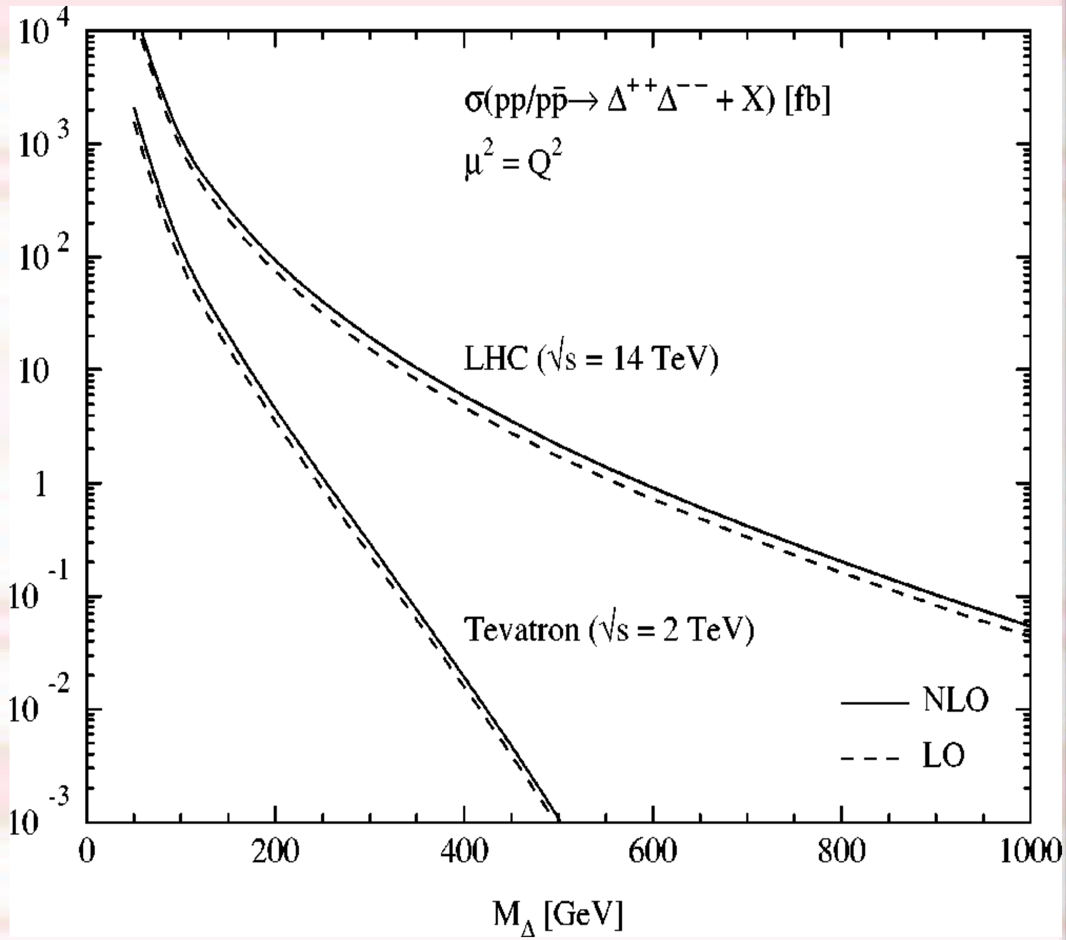
H^{++} looked within the context of Left Right Supersymmetric models :

- $SU(2)_R \times SU(2)_L \times U(1)_{B-L}$
- seesaw mechanism for neutrino mass generation
- 4 Higgs triplets, one bidoublet and one singlet
- **low mass doubly charged Higgs (H_L^{++} and H_R^{++})**

Main production channel



Cross section depends on H^{++} mass and electroweak quantum numbers.

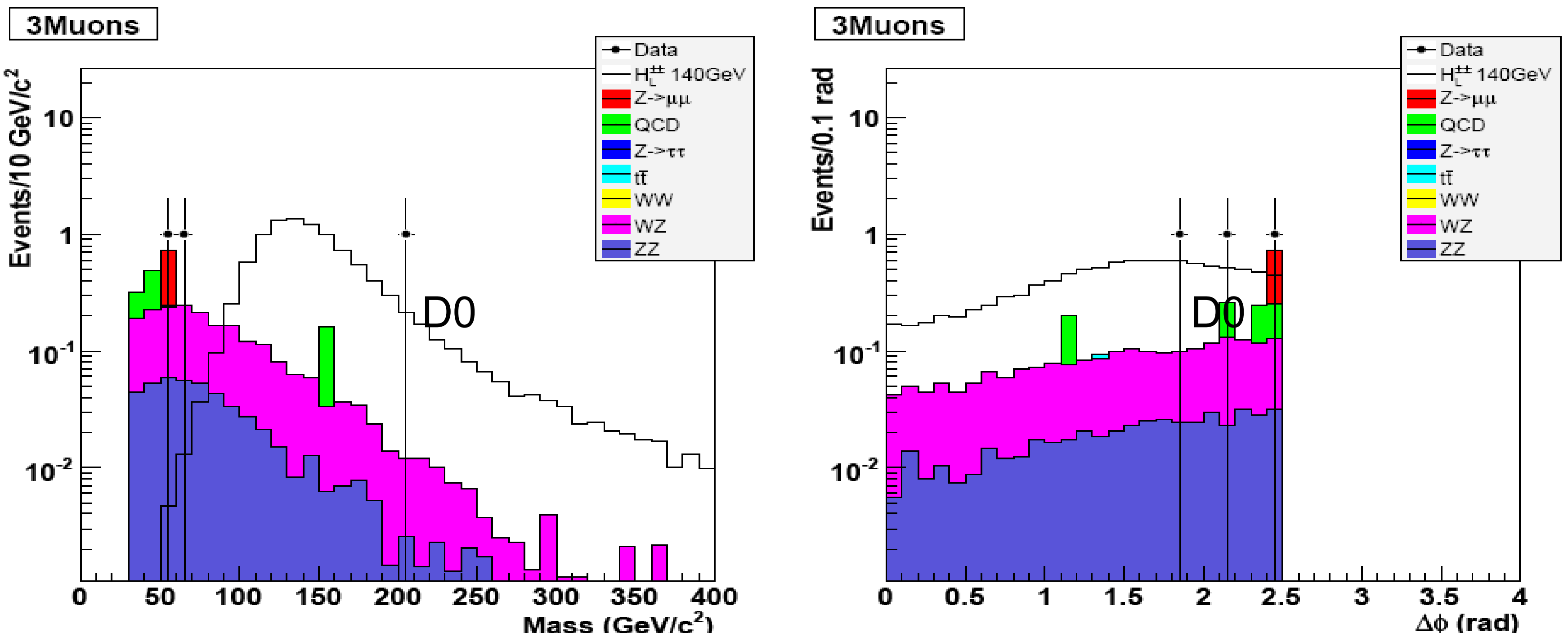


Cross sections are taken from M. Mühlleitner and M. Spira, Phys. Rev. **D** 68, 117701 (2003)

$H^{++} \to \mu^+ \mu^+$

Trigger : di-muon
have a like signe muon pair with
P_T (muon) > 15 GeV and isolation cuts and anti-cosmic cuts
for at least 2 muons : $\Delta \Phi_{\mu\mu} < 0.8\pi$ and request a 3rd muon.

SM and signal simulated with **PYTHIA 6.323**



For the 2 highest P_T muons

	Lumi (pb^{-1})	Data	Bkgd
DØ	1100	3	3.1 ± 0.5

95 % CL :

$Br(H^{++} \to \mu^+ \mu^+) = 1$

$M_{H_L^{++}} > 150\,\text{GeV}$

$M_{H_R^{++}} > 126.5\,\text{GeV}$

Preliminary

Conclusion

Beyond Standard Model physics are searched in many many different models.

No sign of new physics have been yet seen in the DØ data set analysed.

Before doing BSM searches,
the MC should be able to describe the Standard Model.

BSM generator in DØ : dominantly PYTHIA :
used for SUSY, W', Large Extra Dimension, Randall-Sundrun gravitons,
compositeness, 4^{th} generation quarks, technicolor, leptoquarks, H^{++}
Other BSM generator : COMPHEP for some SUSY signals.

Some tools that might be added :
Generators for stopped gluinos profile and decays.
Compositeness in PYTHIA :
Add Contact Interaction decay to allow search with multilepton decays.
Add 2^{nd} and 3^{rd} generation excitation (μ^*,τ^*,b^*,c^*)

Backup

Lyon 1

SUSY : light stop backup

Bin (eμ)	Total background	Data	Signal Point A	Signal Point B
$S_T \in [0,70[$ GeV, $H_T = 0$	2.6 ± 1.1	1	7.3 ± 1.0	0.0 ± 0.0
$S_T \in [70,120[$ GeV, $H_T = 0$	9.2 ± 1.2	14	4.8 ± 0.7	0.2 ± 0.1
$S_T \in [120,...[$ GeV, $H_T = 0$	7.7 ± 0.7	5	0.8 ± 0.3	1.8 ± 0.2
$S_T \in [0,70[$ GeV, $H_T \in]0,60]$	1.9 ± 0.7	2	5.2 ± 0.7	0.0 ± 0.0
$S_T \in [70,120[$ GeV, $H_T \in]0,60]$	3.6 ± 1.2	4	5.3 ± 0.8	1.2 ± 0.2
$S_T \in [120,...[$ GeV, $H_T \in]0,60]$	3.0 ± 0.4	2	0.6 ± 0.3	6.3 ± 0.5
$S_T \in [0,70[$ GeV, $H_T \in]60,120]$	0.4 ± 0.6	0	0.6 ± 0.3	0.0 ± 0.0
$S_T \in [70,120[$ GeV, $H_T \in]60,120]$	0.7 ± 0.2	1	1.2 ± 0.3	1.3 ± 0.2
$S_T \in [120,...[$ GeV, $H_T \in]60,120]$	3.6 ± 0.8	2	0.1 ± 0.1	4.3 ± 0.3
$S_T \in [0,70[$ GeV, $H_T \in]120,...[$	0.0 ± 0.0	0	0.0 ± 0.0	0.0 ± 0.0
$S_T \in [70,120[$ GeV, $H_T \in]120,...[$	0.8 ± 0.6	1	0.0 ± 0.0	0.4 ± 0.1
$S_T \in [120,...[$ GeV, $H_T \in]120,...[$	3.7 ± 1.1	2	0.1 ± 0.1	1.7 ± 0.3

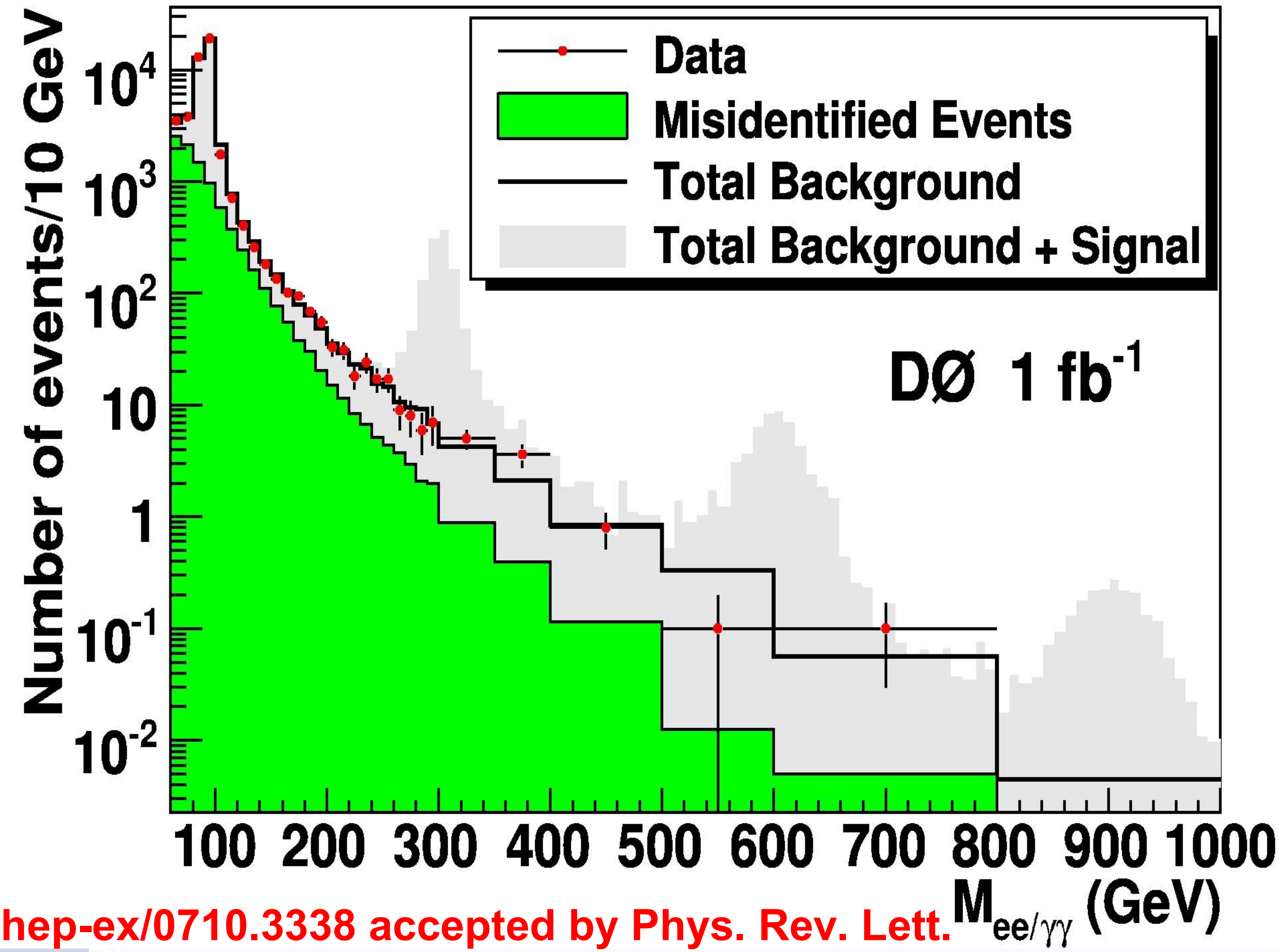
Bin (μμ)	Total background	Data	Signal Point A	Signal Point B
$H_T \in]0,40]$ GeV	0.11 ± 0.0	0	2.0 ± 0.3	0.5 ± 0.1
$H_T \in]40,80]$ GeV	0.89 ± 0.4	0	1.1 ± 0.3	1.0 ± 0.1
$H_T \in]80,120]$ GeV	0.75 ± 0.0	0	0.2 ± 0.1	0.8 ± 0.1
$H_T \in]120,160]$ GeV	0.56 ± 0.0	1	0.0 ± 0.0	0.4 ± 0.1
$H_T \in]160,...[$ GeV	0.57 ± 0.0	0	0.0 ± 0.0	0.4 ± 0.1

Total : data 35 events, MC 40.0 events

Remove the line in the red rectangle, it lefts 21 data events for 30.8 MC events
The fluctuation is roughly 2σ.

Randall Sundrum graviton

Look for narrow resonnances in $\gamma\gamma$ and e^+e^- using EM objects of P_T>25 GeV and $|\eta|$<1.1



QCD estimated from data.
Other SM processes and signal simulated with **PYTHIA**.

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