Status of "some" New Physics Searches at DØ

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CPPM

for ...

Institutions:

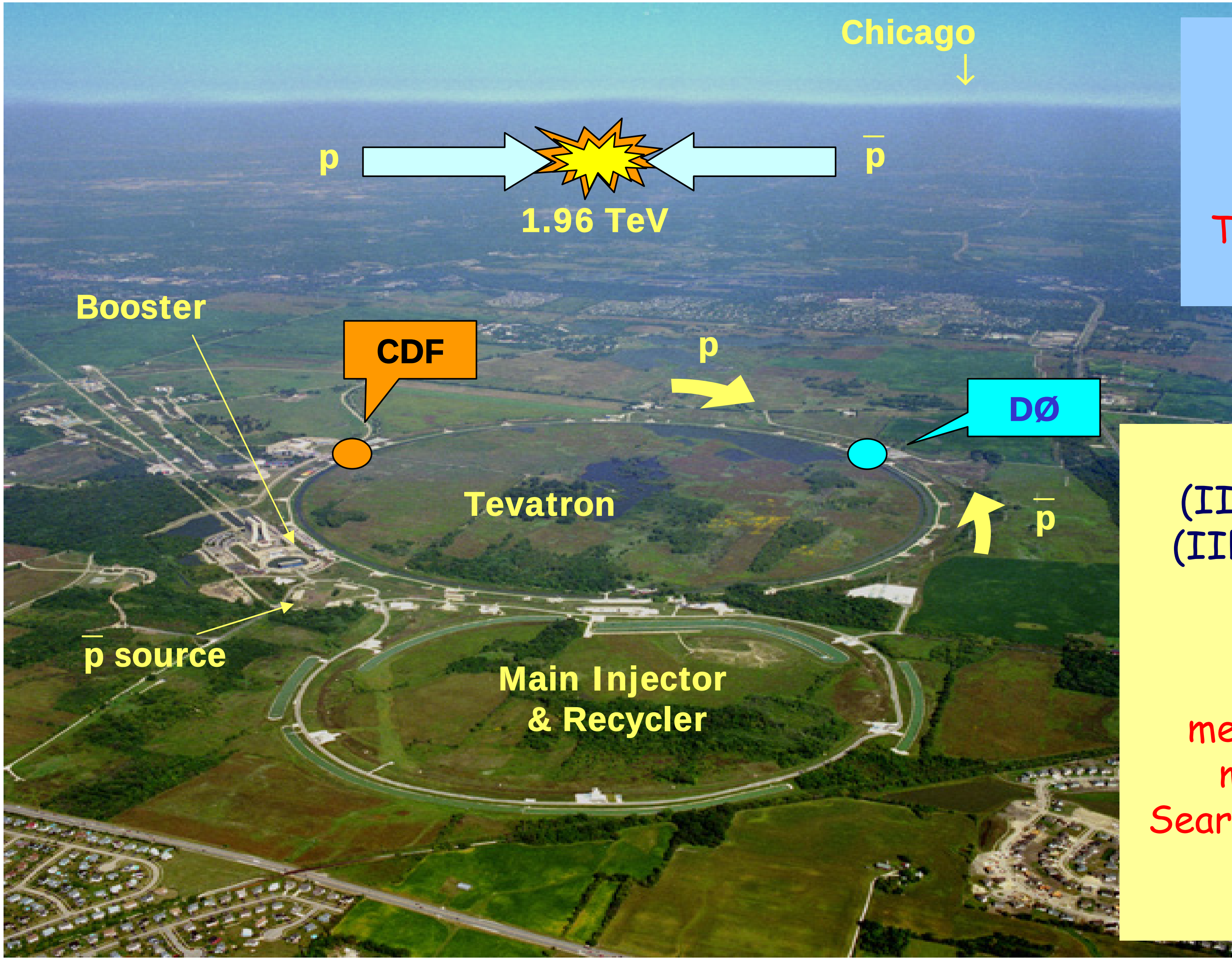
- 92 Total
- 39 US, 53 non-US

Collaborators

- ~ 671 Total
- ~ 50% from non-US institutions
- ~ 100 post-docs
- ~ 140 graduate students

The Stage

Fermilab, Tevatron and D0



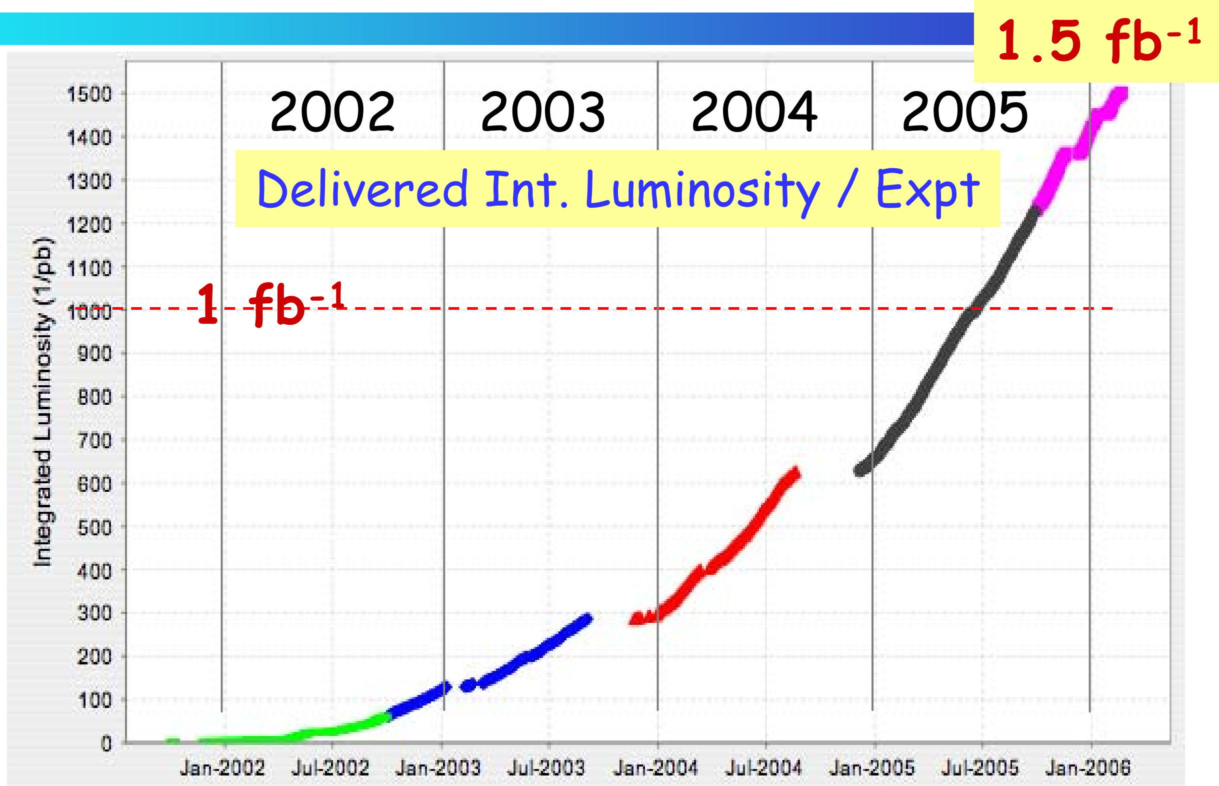
Run I
(92-96)
1.8 TeV
~0.1 fb^{-1}
Top discovery
...

Run II
(IIa 01-Feb 06)
(IIb Jun 06 ->...)
1.96 TeV
-> 8fb^{-1}
Precision measurements:
m_t, m_W, Δm_s
Searches for Higgs and BSM
...

Tevatron status at the end of Run IIa (Feb. 06)

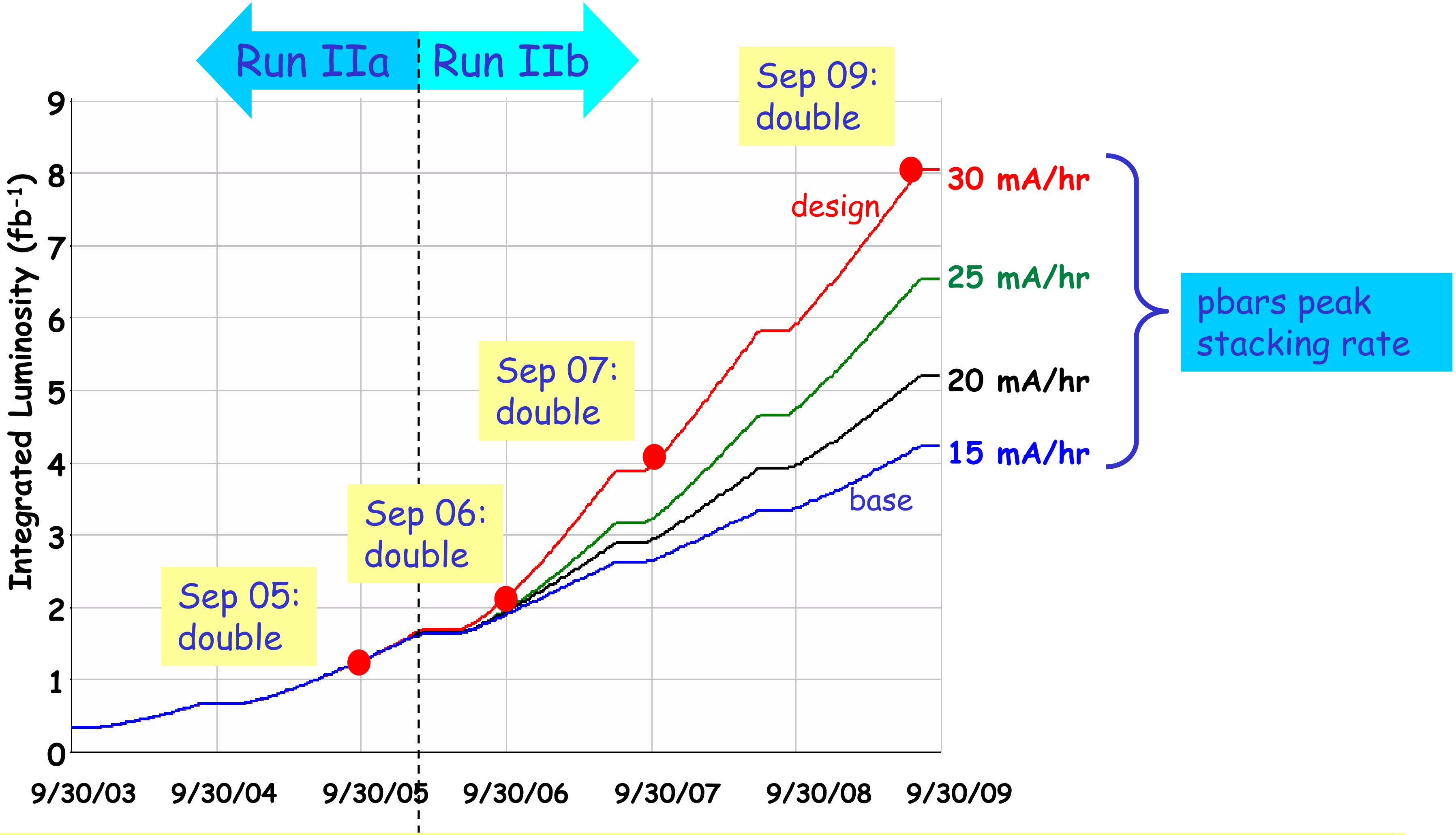
Tevatron works well and keeps getting better

just with performances reached at Run IIa
=> > 4 fb^{-1} en 2009!



- Record Luminosity: $1.8 \times 10^{32}\ cm^{-2}\ s^{-1}$
- Integrated Luminosity:
  - record: 27 pb^{-1} /semaine/expt
  - delivered: 1.5 fb^{-1} /expt
  - on tape: 1.3 fb^{-1} /expt
- pbars peak stacking rate > 20 mA/h

Luminosity evolution for Run II



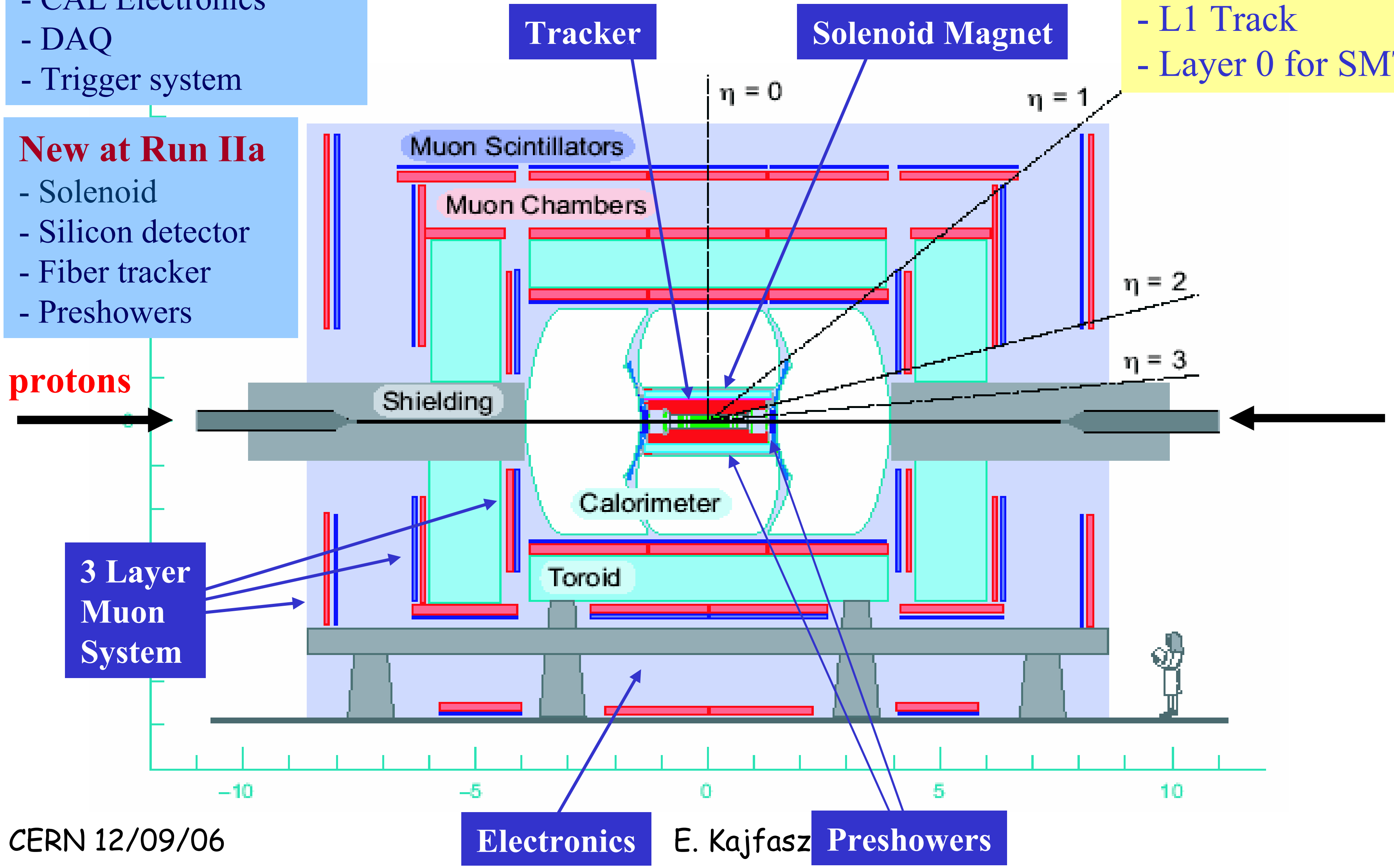
- last shutdown started ~ Mar 1, 2006 => transition Run IIa/Run IIb
- Run IIb first store occured on Jun 9: D0 was ready to take data

Upgrades for Run II

Run IIa Upgades
- Muon system
- CAL Electronics
- DAQ
- Trigger system

New at Run IIb
- L1 CAL
- L1 Track
- Layer 0 for SMT

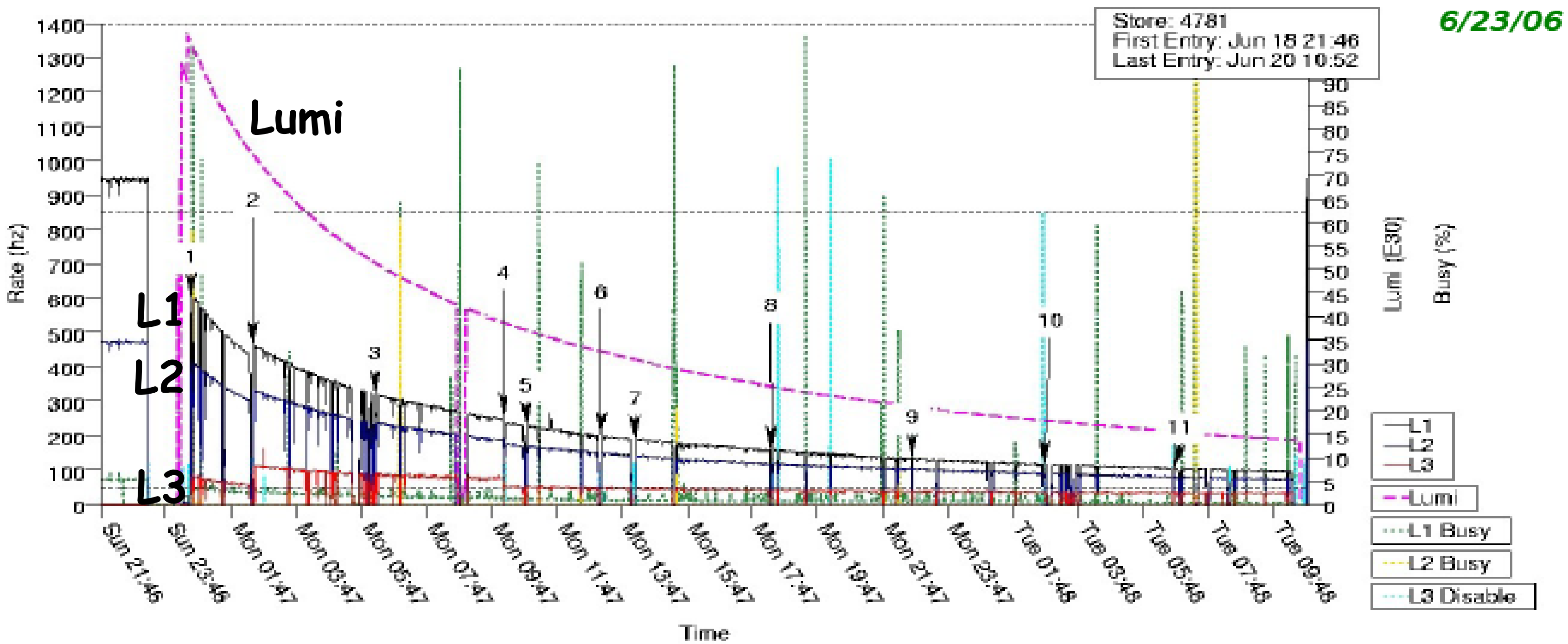
New at Run IIa
- Solenoid
- Silicon detector
- Fiber tracker
- Preshowers



Trigger commissioning

Run IIb installation and commissioning is a success !

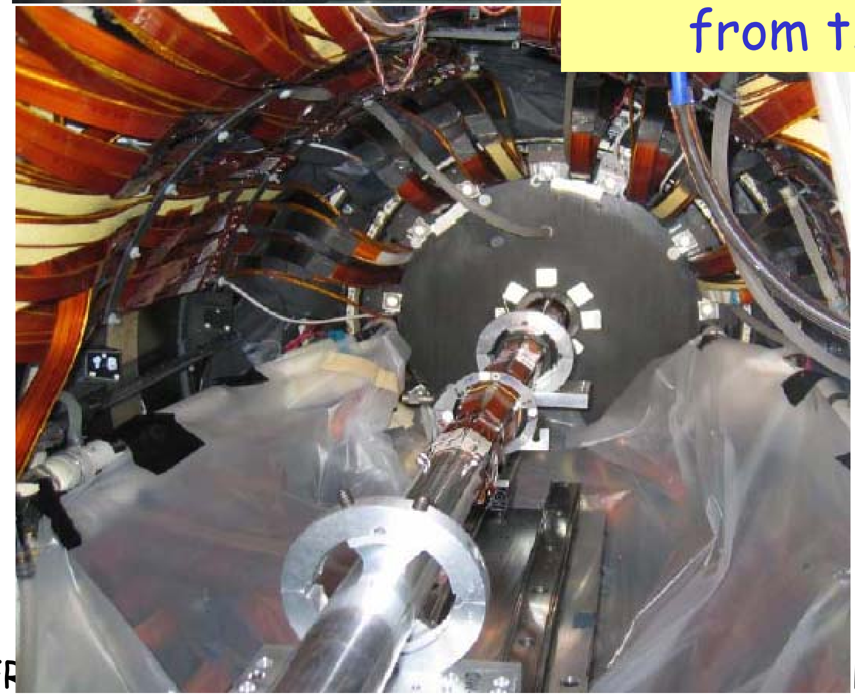
Started data taking within minutes of first Run IIb sore



Store: 4781
Initial luminosity: 100E30
Triggerlist: global_CMT-15.01.xml
L1/L2/L3 rates (Hz): 600/400/80

Layer 0 Commissioning

L0 is installed

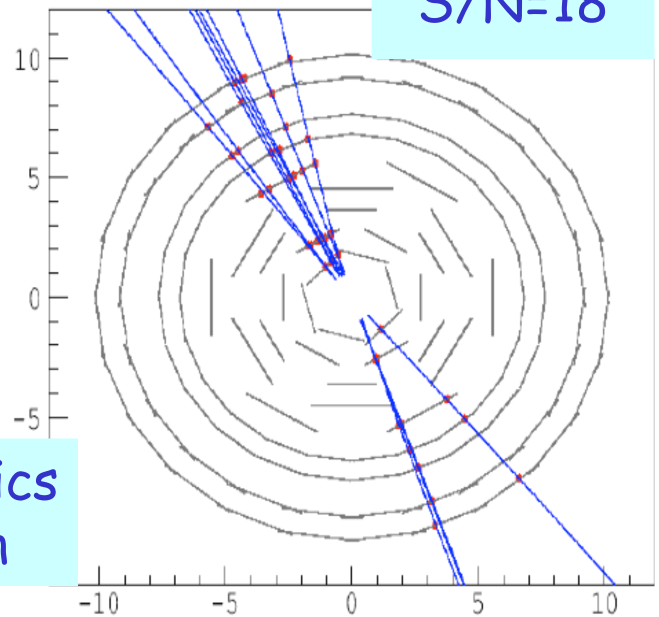


Threaded inside the existing detector on a new beam pipe at 1.6 cm from the beams

and operational

cosmic run

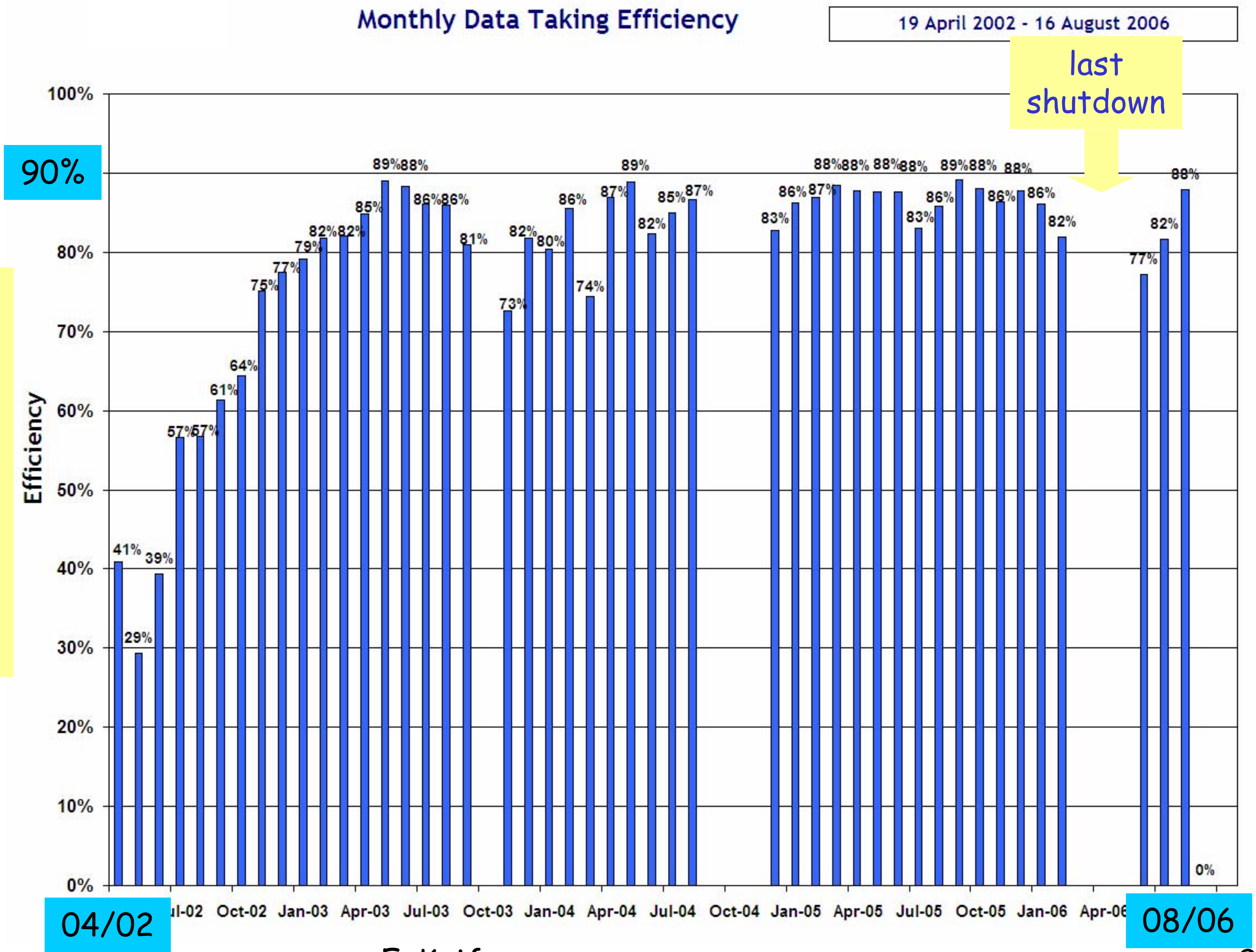
S/N=18



Physics run

Operations

Efficiency back to ~90% by the third month of Run IIb operations



Detector/trigger /DAQ downtime ~ 5%

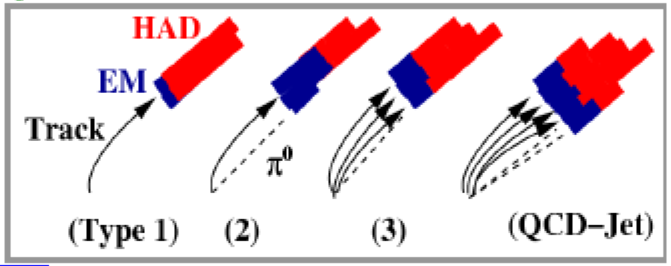
Store and run transitions ~ 2-3%

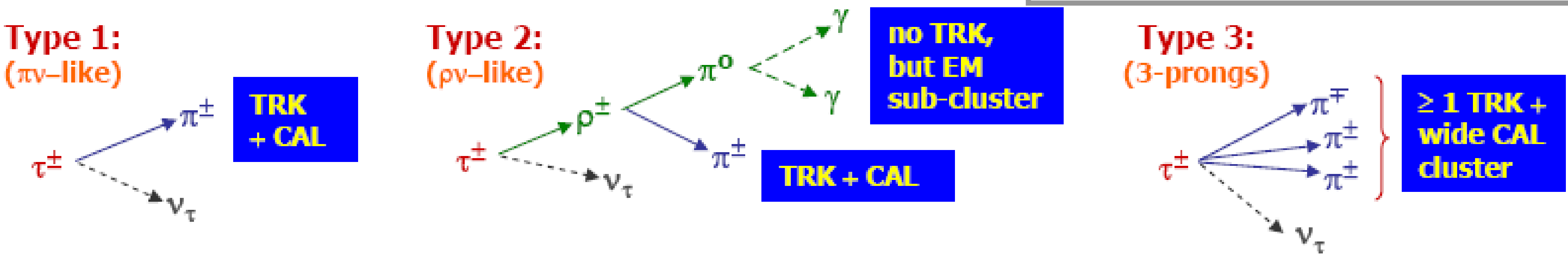
FEB ~ 3-5%

Some ID tools

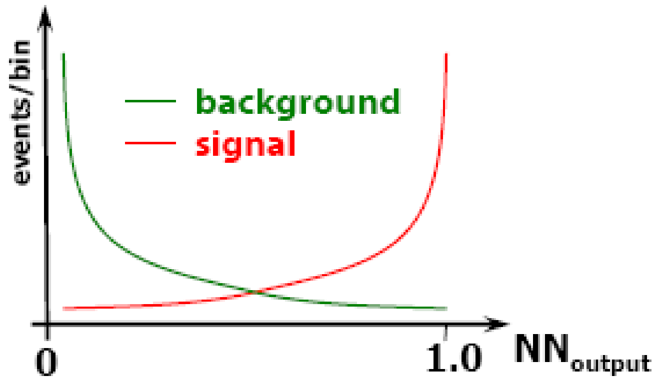
τ-ID

- narrow calorimeter energy clusters matched to tracks (narrow jet)
- separate τ's into 3 categories, defined by their decay mode
  - π-like (τ–type 1)
  - ρ-like (τ–type 2)
  - 3-prongs (τ–type 3)

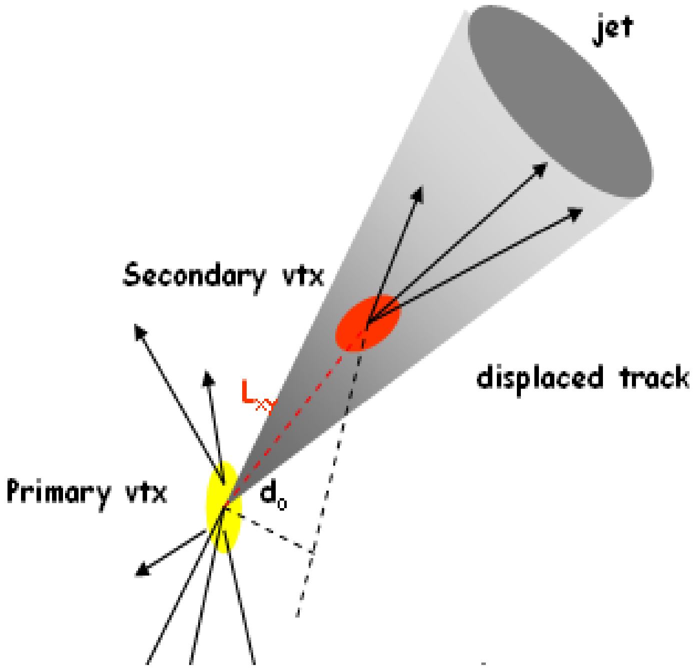




- implement neural nets (NN) for each τ–type to discriminate τ signal from QCD jets
  - NN input variables based on calorimeter and tracking quantities
  - convention: NN → 1.0 (signal),
    NN → 0.0 (background)
  - analysis ⇒ apply NN cut near 1.0 for τ–id

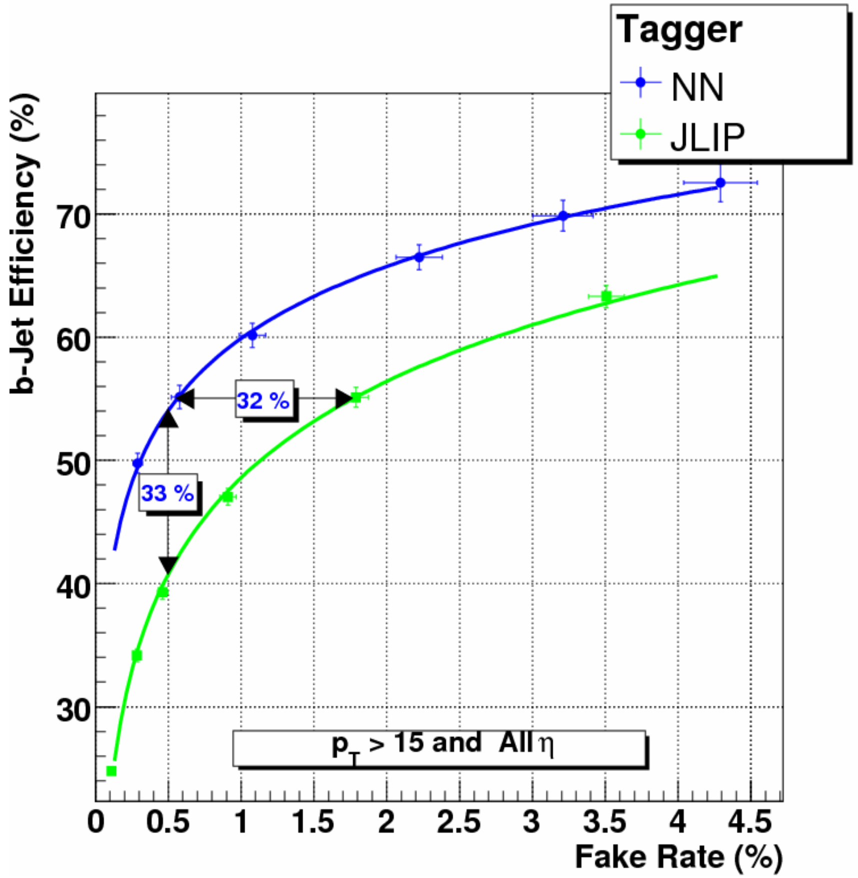


b-ID: different tagging algorithms ...



- **Secondary Vertex** (SVT)
- **Jet Lifetime Impact Parameter** (JLIP)
- Counting Signed Impact Parameter (CSIP)
- Soft Lepton

certified operating points



New b-tagging tool

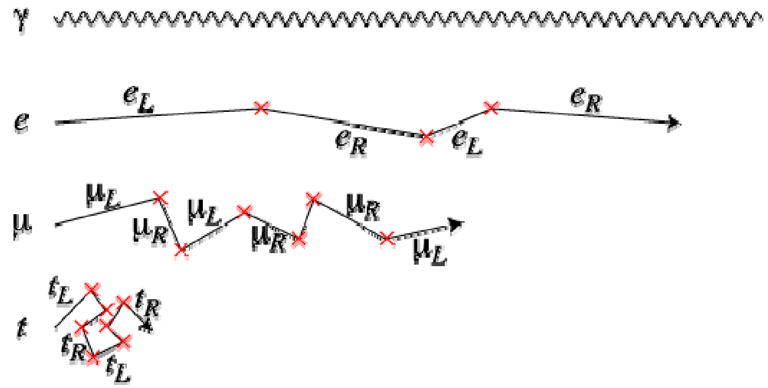
- Combines various variables from the track based b-tagging tools in a Neural Network
- Substantial improvement in performance over constituent input b-taggers

New Physics Searches

Standard Model

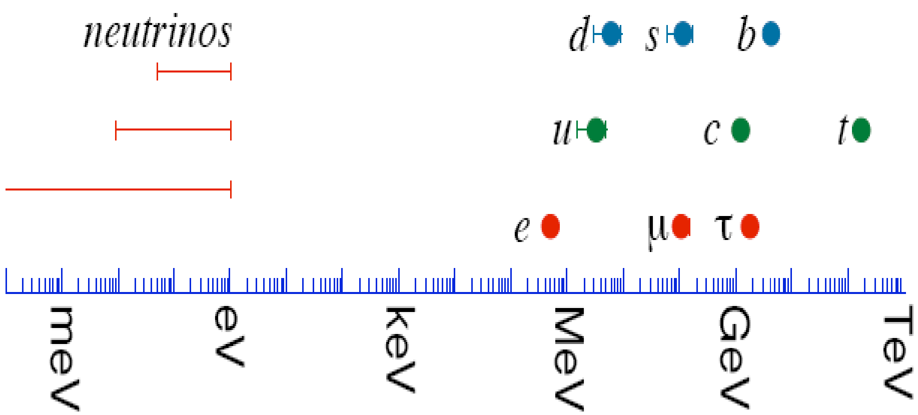
Based on:
- 4-D space-time
- Poincaré group
- $SU(3)_c \times SU(2)_L \times U(1)_Y$
- 3 generations of quarks and leptons
- Higgs mechanism

Phenomenologically **successful** so far, **but** many questions unanswered...



Higgs field filling our Universe and slowing down elementary particles. Is it elementary?

If so, some drawbacks:
- no dynamical explanation to EWSB
- unnatural, requires fine tuning
  -> M_H unstable against rad. corr.
- in GUTs, leads to hierarchy problem
  -> 2 very different scales
- no insight to flavor physics



Some Ways to go Beyond ...

To answer some of the questions ... new theories and models

- Alternative EWSB mechanisms -> **Technicolor**
- Relate quarks and leptons -> **Leptoquarks**
- Compositeness -> **scale**, μ^*, q^*
- Enlarge the gauge group -> **W'**
- Extend Poincaré -> **Supersymmetry**
  and include gravitation (**Supergravity**)
- Increase number of dimensions -> **LED** & **RS**

Notes, results, and publications on New Physics can be found at:
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

Technicolor

Technicolor

- Technicolor (TC - first introduced by Weinberg and Susskind):
  - New strong dynamics 'a la QCD' $SU(N_{TC})$ -> TC condensates of technifermions
  - Coupling of condensates with unbroken electroweak gauge fields -> mass to W&Z
  - Extended TC (ETC) [mass and mixing to quarks and leptons]
  - Walking Technicolor (WTC) [flavor changing neutral current in ETC]
  - Topcolor-assisted Technicolor (TC2) [high value of m_{top}]
- Technicolor Straw Man Model (TCSM2):

K. Lane, S. Mrenna *Phys. Rev.* **D 67** (2003)

  - Framework to search for light technihadrons (relevant for Tevatron searches).
    - lightest technifermions expected to be an isodoublet of color singlets
    - -> color-singlet vector mesons: ρ_T, ω_T
    - -> color-singlet pseudo-scalar mesons: $\pi_T^0, \pi_T^{+/-}$
    - produced with substantial cross-section at the Tevatron
  - cross-sections and branching fractions depend on:
    - masses of ρ_T and ω_T
    - technicolor charges of the technifermions
    - mass difference between vector mesons and technipions
    - 2 mass parameters:
      M_A for axial-vector and M_V for vector couplings
      one expects $M_A = M_V$ = few 100's GeV
  - Implemented in PYTHIA [S. Mrenna]

2 channels explored

$\rho_T^0 / \omega_T^0 \rightarrow e^+e^-$

$\rho_T^{+/-} \rightarrow W^{+/-} \pi_T^0$
$\quad \mapsto bb$

$\rho_T^0 \rightarrow W^{-/+} \pi_T^{+/-}$
$\quad \mapsto bc, bc$

for $m(\rho_T) - m(\pi_T) > m_W$

$\omega_T/\rho_T \rightarrow e^+e^-$

SELECTION:

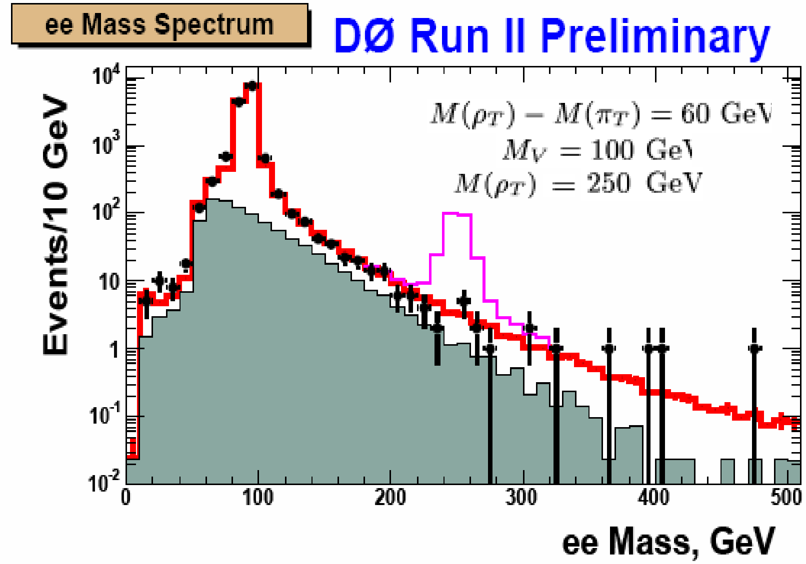
2 isolated EM objects
- at least 1 track matched
- $E_T > 25$ GeV
- $|\eta| < 1.1$ or $1.5 < |\eta| < 2.4$

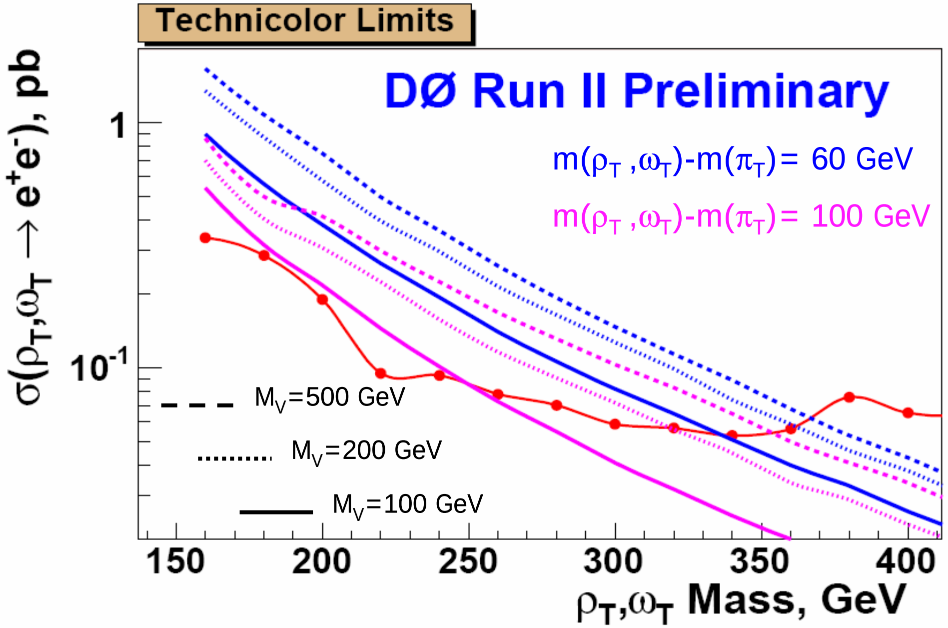
BACKGROUND:

- Drell-Yan production
- QCD

- Search for $\rho_T/\omega_T \rightarrow e^+e^-$ as a bump/excess at high dielectron mass (intrinsic width < 1 GeV)

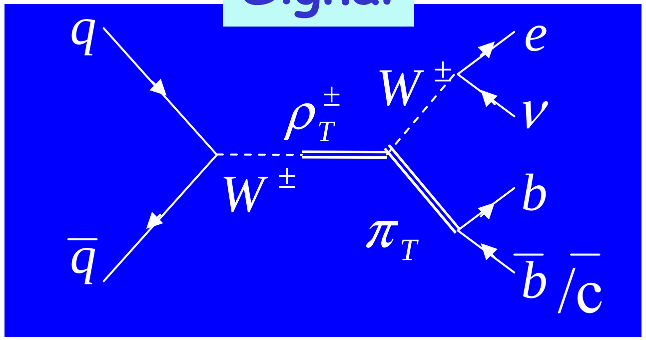
- Counting experiment in optimized 20-60 GeV windows centered around ρ_T/ω_T mass





$W(e\nu)\pi_T(bb/c)$ event selection

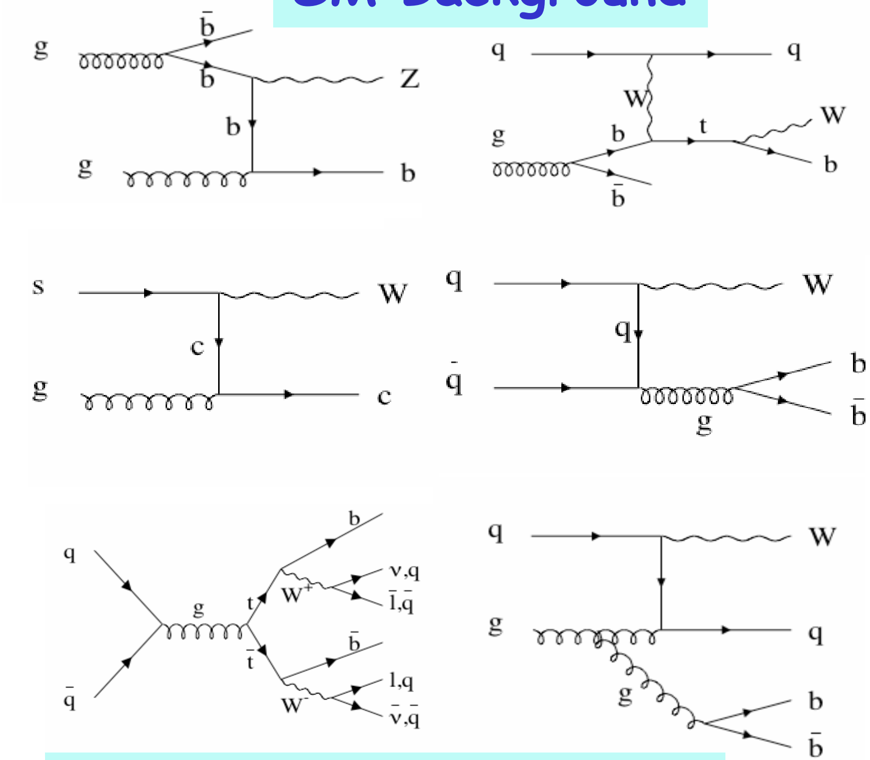
Signal



Select $W(e\nu)$+Heavy Flavor events

- One isolated electron (EM TRIGGER) $p_T > 20$ GeV, $|\eta| < 1.1$
  - select $W(\to e\nu)$ events
  - veto on other electrons to suppress Z
- Missing $E_T > 20$ GeV, $M_T > 30$ GeV
  - select $W(\to e\nu)$ events
  - eliminates multi-jets events
- Two jets $p_T > 15$ GeV, $|\eta| < 2.5$
  - At least one jet has to be associated with a Secondary Vertex (b-tagging)
  - Veto on a third jet, suppresses tt background

SM Background



Instrumental Background

estimated from data

- multijet production (mis-IDed electron)
- W + light flavored jets (mistag)

Cut based (CB) and Neural Net (NN) analyses

Cut based analysis

D0 Run II Preliminary 388 pb^{-1}

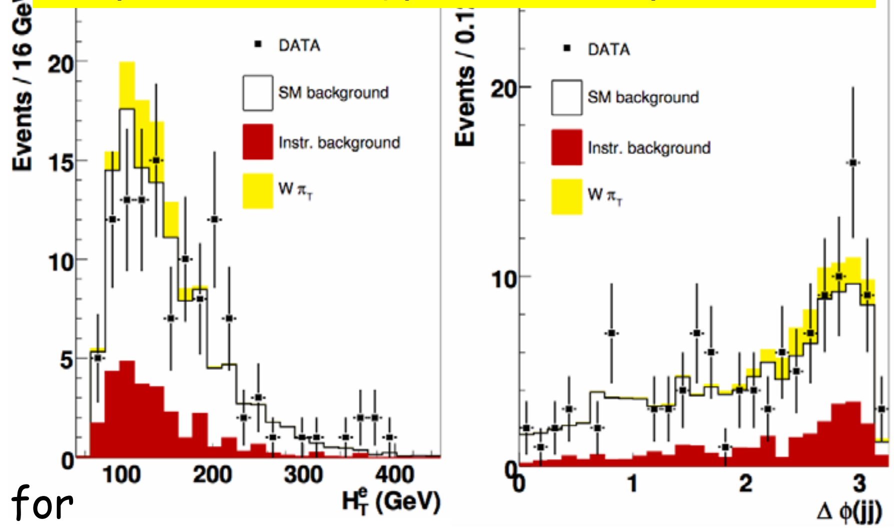
Define kinematic and topological quantities to extract the $W\pi_T$ signal

- H_T^e (electron p_T + Σ jet p_T) discriminates against tt
- $p_T(jj)$ (p_T of the dijet system) discriminates against tt
- $\Delta\phi(jj)$ and $\Delta\phi(e,MET)$ against multijet and W + light quarks
- M(jj) (inv. mass of the dijet system) -> indication of π_T narrow resonance
- M(Wjj) (W + dijet system) -> indication of ρ_T narrow resonance

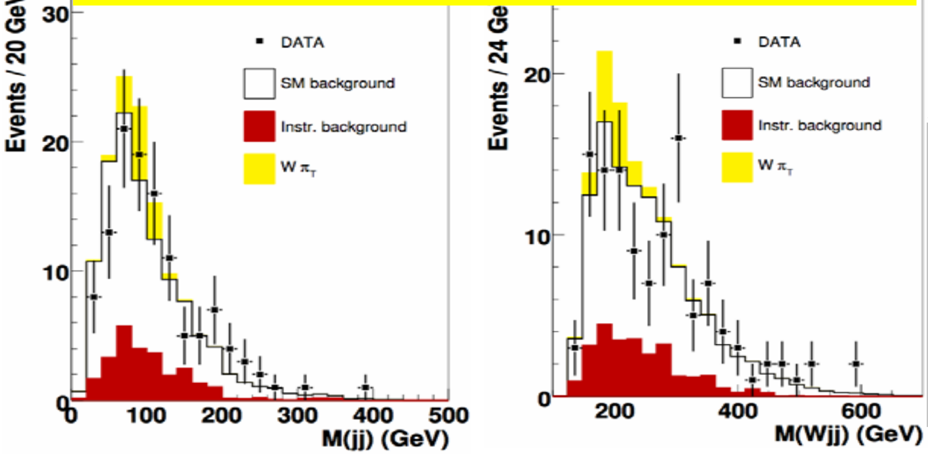
} look for concentration

Mass dependant optimization of cuts on $S/\sqrt{B}$

$M(\pi_T)$ = 105 GeV $M(\rho_T)$ = 200 GeV M_V = 500 GeV



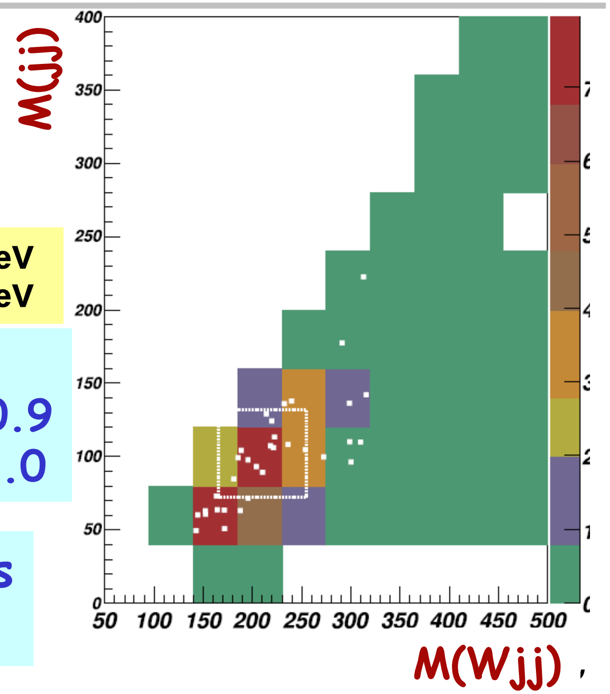
$M(\pi_T)$ = 105 GeV $M(\rho_T)$ = 200 GeV M_V = 500 GeV



$M(\pi_T)$ = 110 GeV
$M(\rho_T)$ = 210 GeV

Data: 12
Bkg: 12.7 ± 0.9
Signal: 10.3 ± 1.0

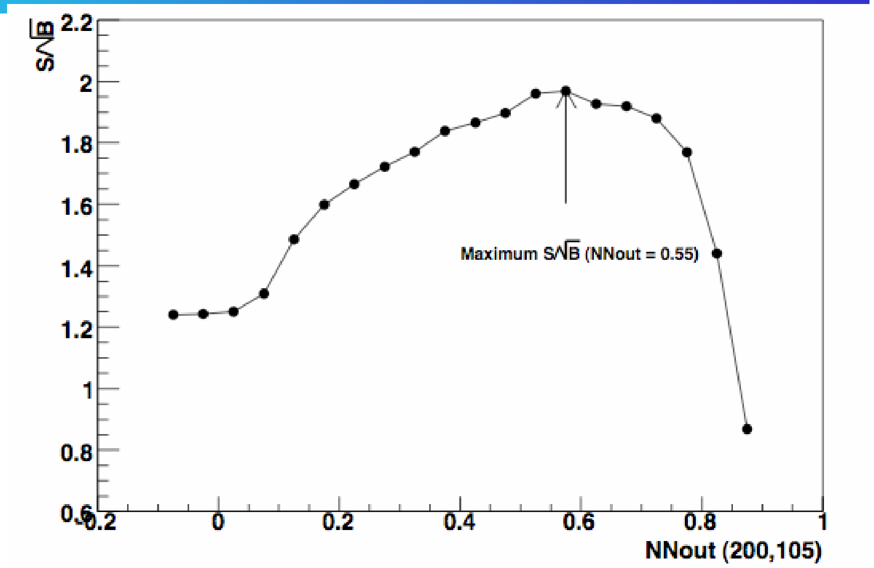
no excess seen ...



ajfasz

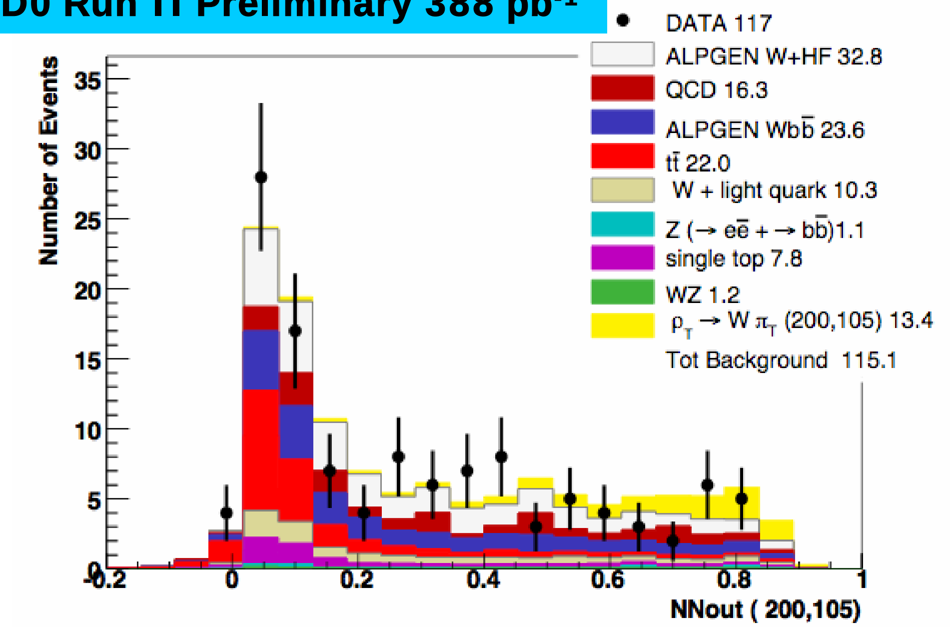
Neural Net analysis

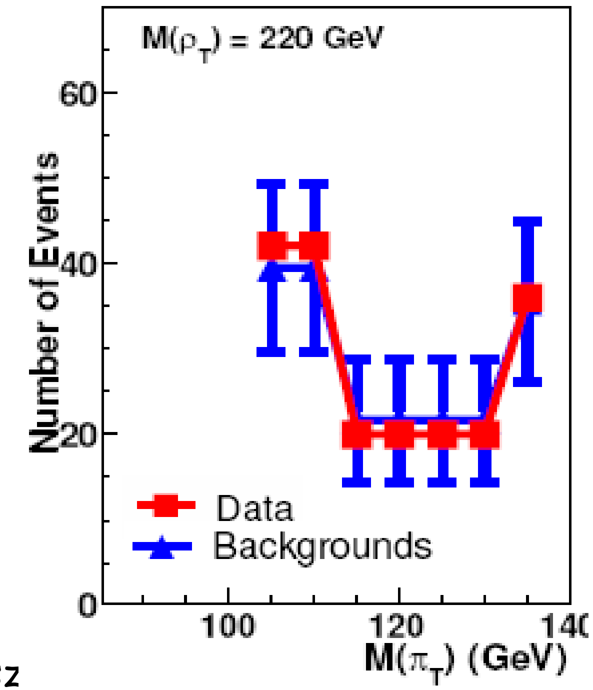
- 2 stage NN using 8 kinematic and topological variables
  H_T^e, $p_T(jj)$, $\Delta\phi(jj)$, $\Delta\phi(e,MET)$, $p_T(j1)$, $p_T(j2)$, $p_T(e)$, MET
- Mass dependent optimization on $S/\sqrt{B}$



$M(\pi_T)$ = 105 GeV $M(\rho_T)$ = 200 GeV M_V = 500 GeV

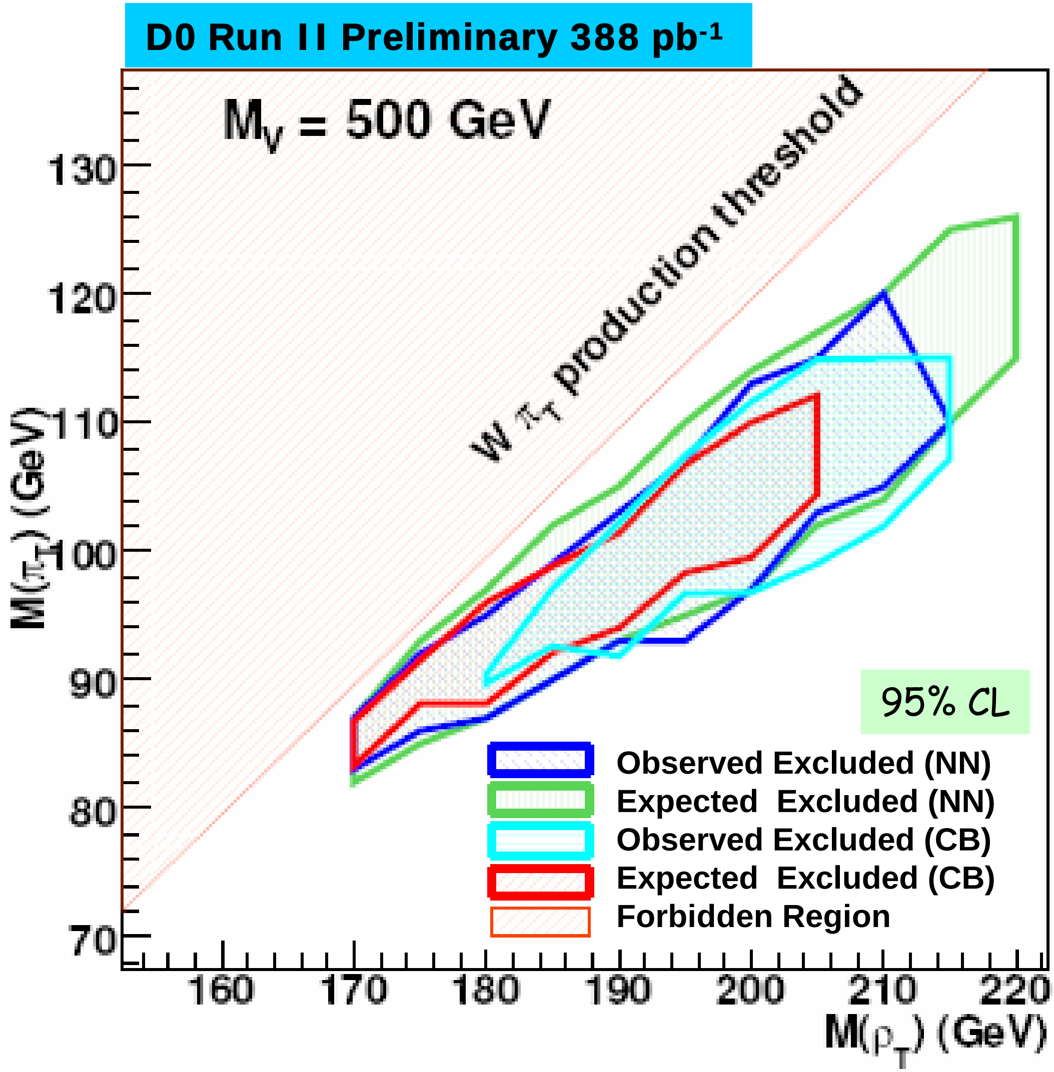
D0 Run II Preliminary 388 pb^{-1}





no excess seen ...

Result of the $W\pi_T$ analyses



Limits computed using:
- Bayesian statistics (CB)
- 2D maximum likelihood using (M(Wjj),M(jj)) correlations (NN)

- First measurement done with TCSM2 model (cannot be compared with the now obsolete TCSM)
- No evidence was found for π_T, ρ_T production for the parameters used with 388 pb^{-1}
- > 1 fb^{-1} is now available
- Add μ channels soon
- Possibility of exploring larger TC parameter space

Leptoquarks

Leptoquarks

- Predicted by many extensions of the SM
- Carry both lepton and quark quantum numbers
  => connection of lepton and quark sectors

First Generation $\begin{pmatrix} u \\ d \end{pmatrix} \leftrightarrow LQ_1 \leftrightarrow \begin{pmatrix} e \\ \nu_e \end{pmatrix}$

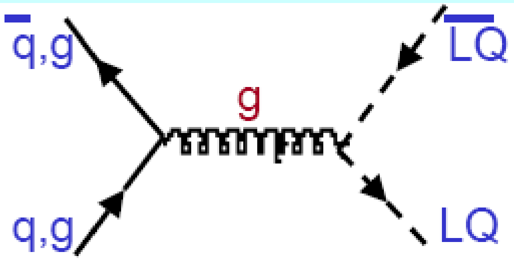
Second Generation $\begin{pmatrix} c \\ s \end{pmatrix} \leftrightarrow LQ_2 \leftrightarrow \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}$

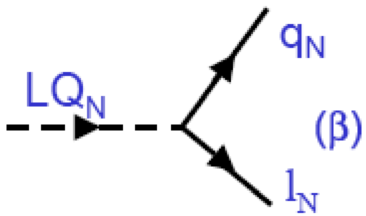
Third Generation $\begin{pmatrix} t \\ b \end{pmatrix} \leftrightarrow LQ_3 \leftrightarrow \begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix}$

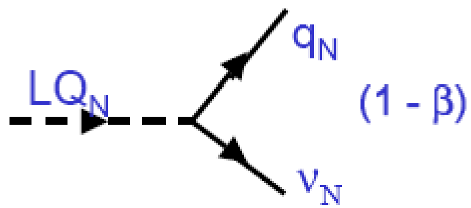
- Description with effective couplings
  - invariant under $SU(3)_C \times SU(2)_L \times U(1)_Y$
  - conserve lepton and baryon number separately (proton lifetime)
  - couple to lepton and quark in the same family (FCNC)
  - scalar and vector leptoquarks are possible but only limits for scalar leptoquarks will be shown (lower X-sections and less model dependant)

Pair production modes:
- quark anti-quark annihilation
- gluon fusion

Decay: parameterized by β the LQ branching fraction to charged lepton + quark







1st generation leptoquarks

eejj:

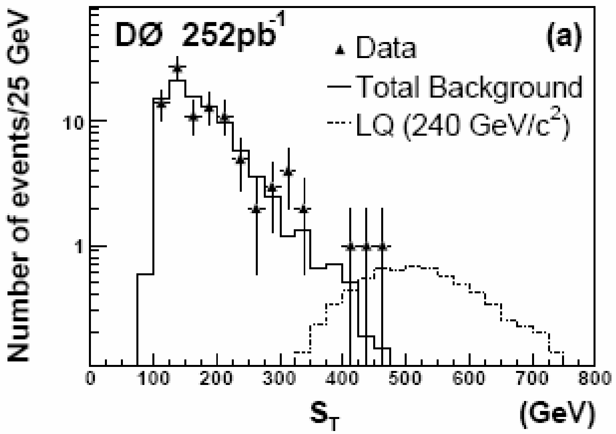
- 2 electrons E_T>25 GeV
  - > 1 elec. track matched
  - > 1 elec. in CC
- >=2 jets E_T>20 GeV $|\eta|$<2.4
- veto M_{ee} in [80,102] GeV
- S_T(e,e,j,j) > 450 GeV

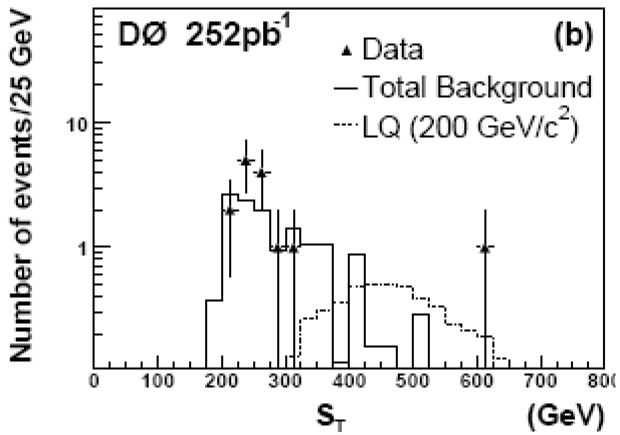
eνjj:

- 1 electron E_T>35 GeV in CC and track matched
- >=2 jets E_T>25 GeV $|\eta|$<2.4
- veto on μ's w/ pT>10 GeV ($t\bar{t}$)
- MET > 30 GeV
- Transv. mass(e,MET) (W)
- S_T(e,MET,j,j) > 330 GeV

	$eejj$	Z boson veto	S_T >450 GeV
Data	467	95	1
Total background	406 ± 100	92±17	0.54±0.11
Z/DY + jets	342 ± 99	41 ± 11	0.22±0.07
Multijet	59 ± 16	47 ± 13	0.27±0.08
$t\bar{t}$ production	4.7 ± 0.4	3.8 ± 0.3	0.05±0.01

	$\not{E}_T > 30$	$M_T^{e\nu} > 130$	$S_T > 330$
Data	900	14	1
Total background	902 ± 211	13.9 ± 4.4	3.6 ± 1.2
W + jets	811 ± 211	10.0 ± 4.4	2.2 ± 1.2
Multijet	76 ± 7	2.3 ± 0.5	0.72 ± 0.28
$t\bar{t}$ production	14.7 ± 2.9	1.6 ± 0.37	0.70 ± 0.17



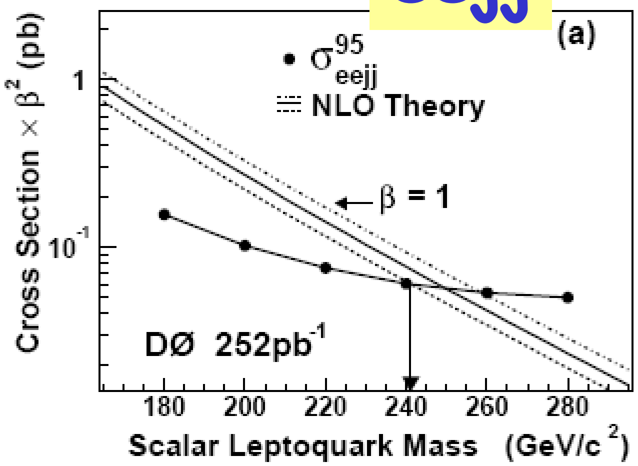


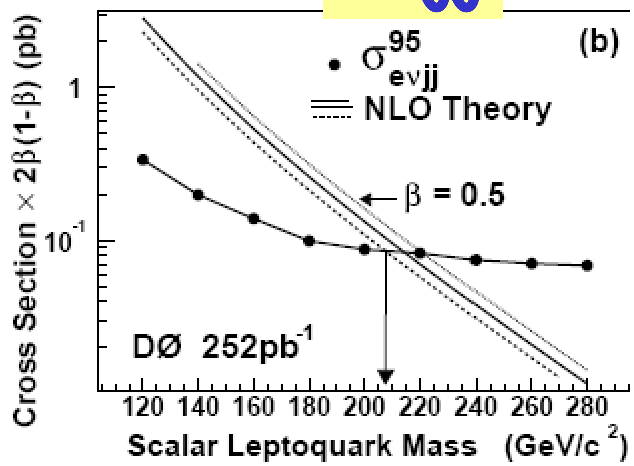
no excess seen ...

1st generation leptoquarks

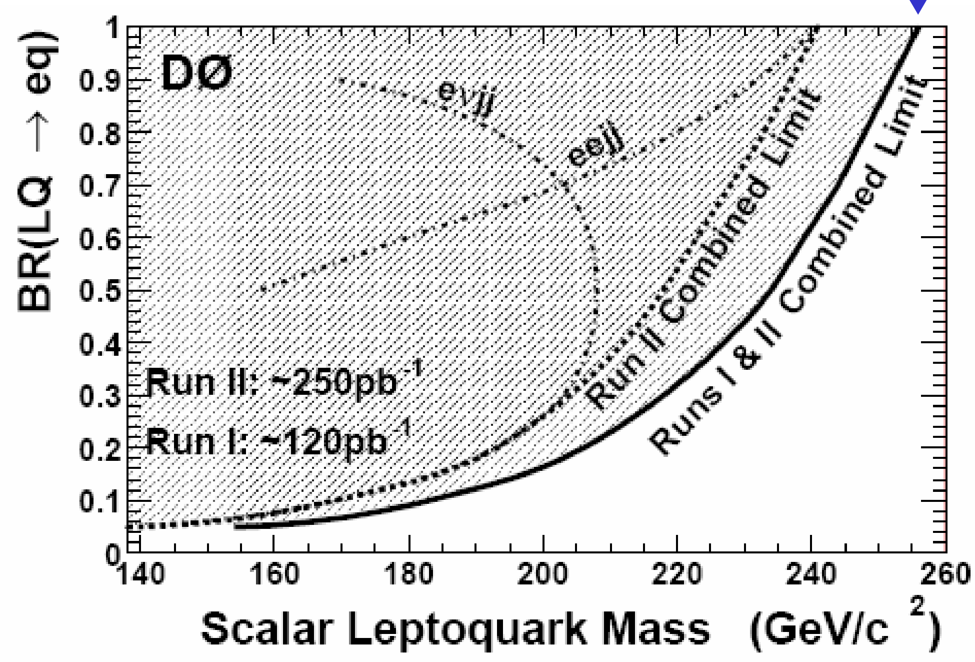
eejj

evjj





256 GeV



2nd generation leptoquarks

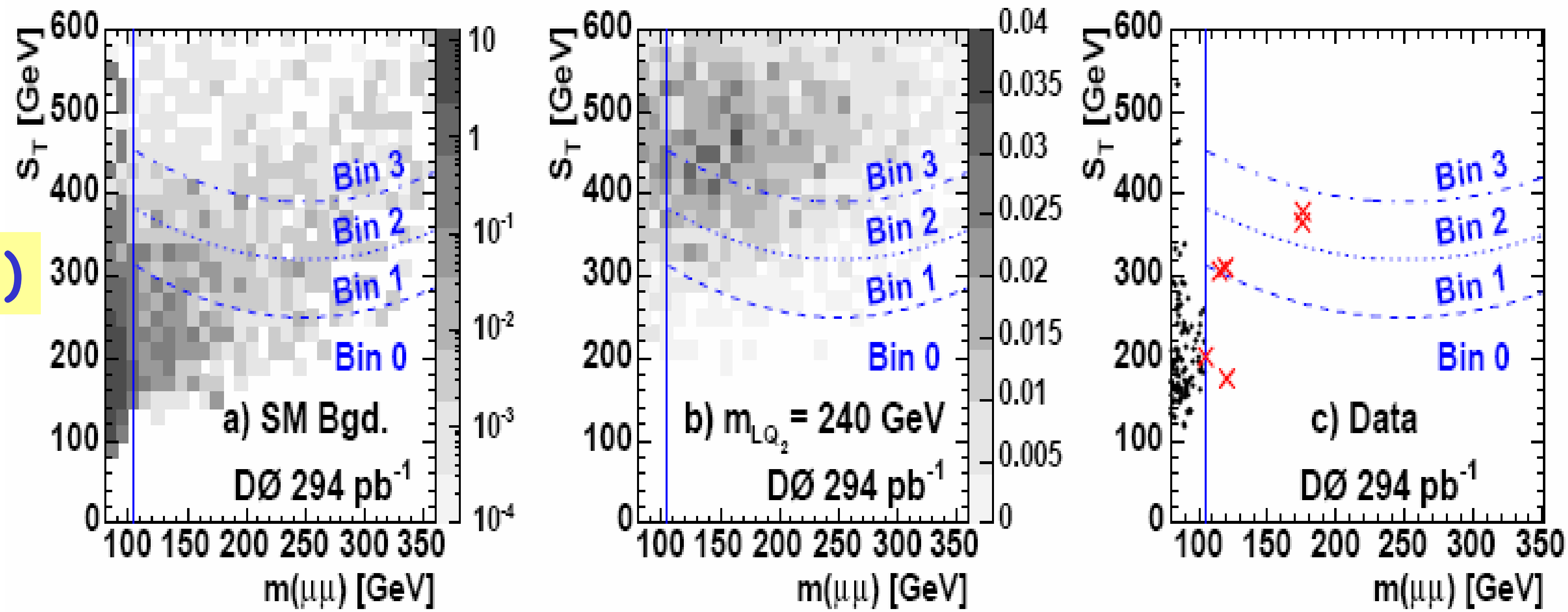
μμjj:

- 2 muons
  - cosmic vetos
  - matched to isolated tracks
  - $|\eta| < 2.4$
  - pT > 15 GeV
- >=2 jets E_T>25 GeV $|\eta|$<2.4
- $M_{\mu\mu}$ > 105 GeV (Z)

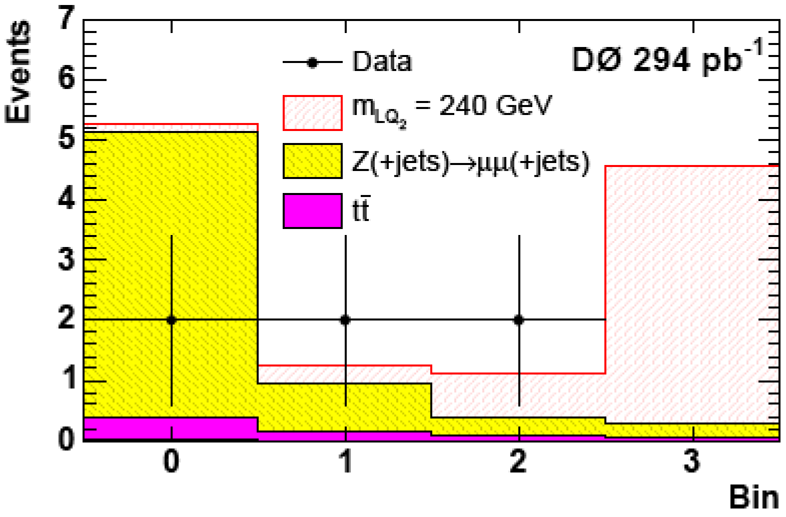
Data	6
Total Bkgs	6.8 ± 2.0
Z/DY	6.1 ± 2.0
tt	0.69 ± 0.07

no excess seen ...

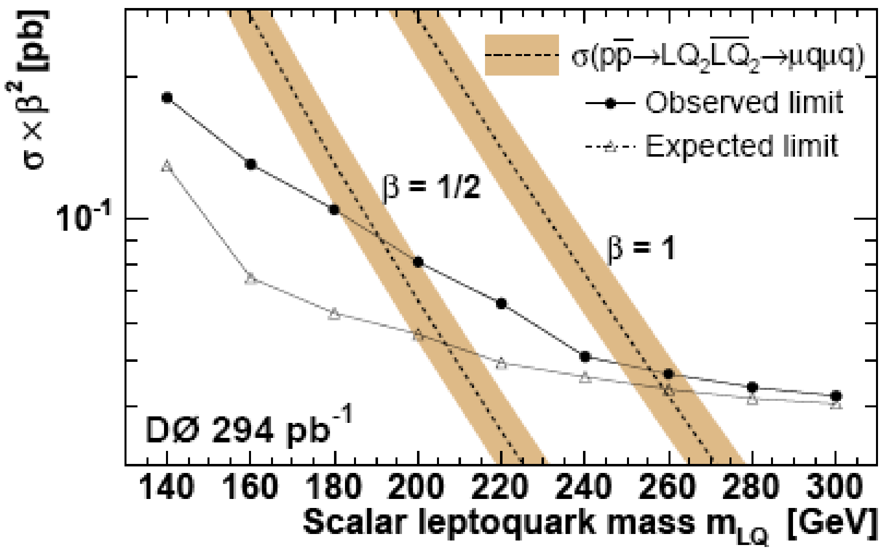
$S_T(\mu,\mu,j,j)$



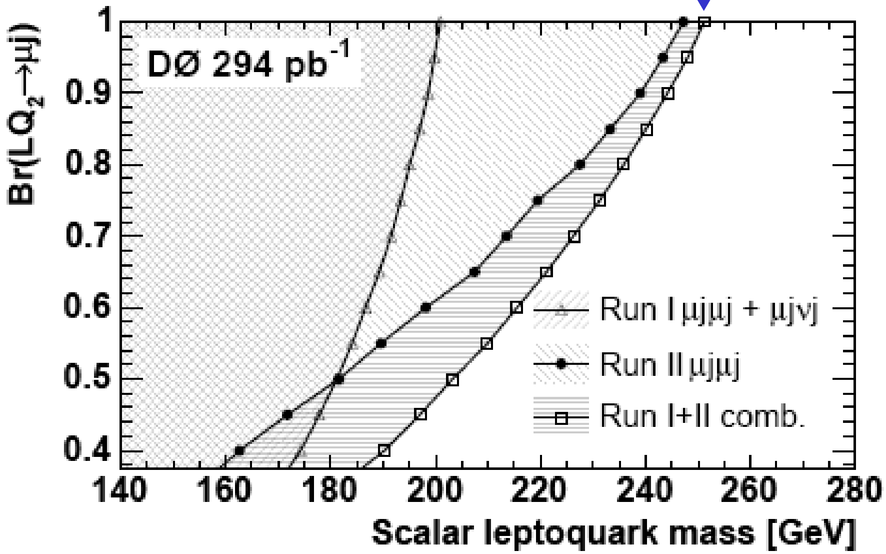
2nd generation leptoquarks



4 bins used as individual channels to extract limits using CL_s



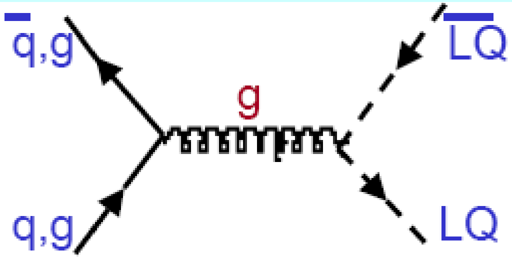
251 GeV



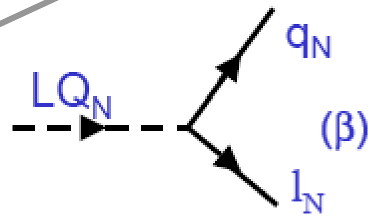
Leptoquarks search in jets+MET

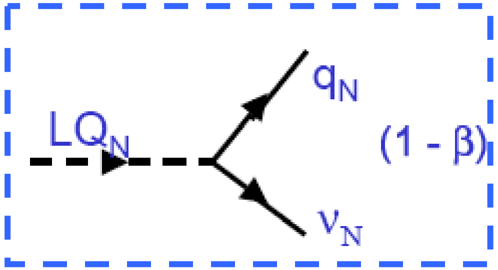
SIGNAL

Pair production modes:
- quark anti-quark annihilation
- gluon fusion



Decay: parameterized by β the LQ branching fraction to charged lepton + quark





Topology:
2 (light/b)-jets
+ missing energy

BACKGROUNDS

Standard Model (SM) :
(ALPGEN interfaced with PYTHIA)
- Vector boson production associated with jets
  - Z + 2 jets → νν + 2 jets (irreducible)
  - W + 2 jets → lν + 2 jets (l = e, μ, τ) (lepton not reconstructed)
  - W + 1 jet → lν + 1 jet (l = e, τ) (lepton identified as a jet)
- diboson production : WW, WZ, ZZ
- top production (single and pair)

'QCD' or instrumental:
- multijet production determined from data

Leptoquarks in acoplanar jet topology

Selection

Start with ~ 14 million events collected with the Jets+MET trigger

Initial cuts:

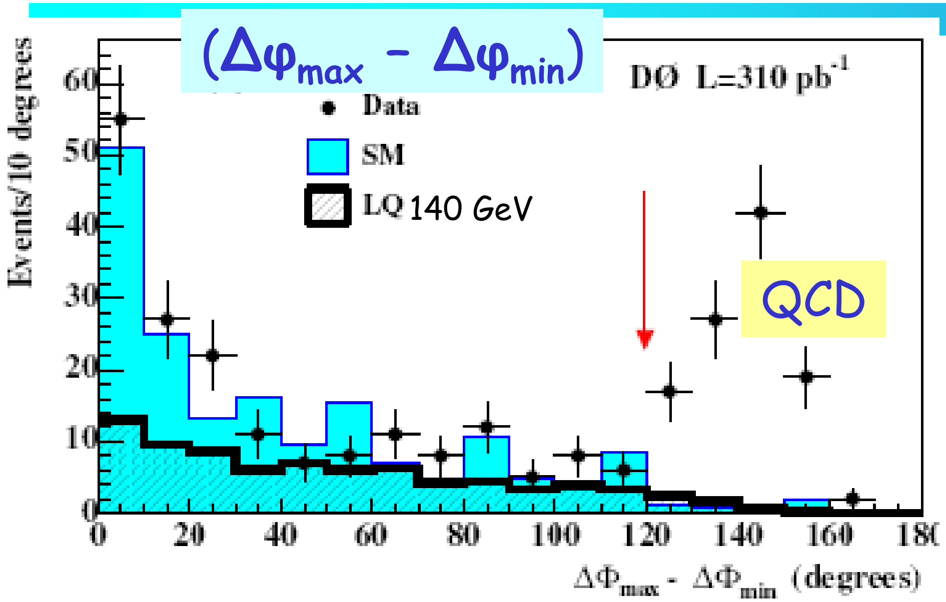
- MHT = $|\sum_{\text{jets}} \vec{p}_T|$ > 40 GeV
- MET > 40 GeV
- at least 2 jets
- $\Delta\Phi$(2 leading jets) < 165°
- $|z_{PV}|$ < 60 cm
- data quality cuts

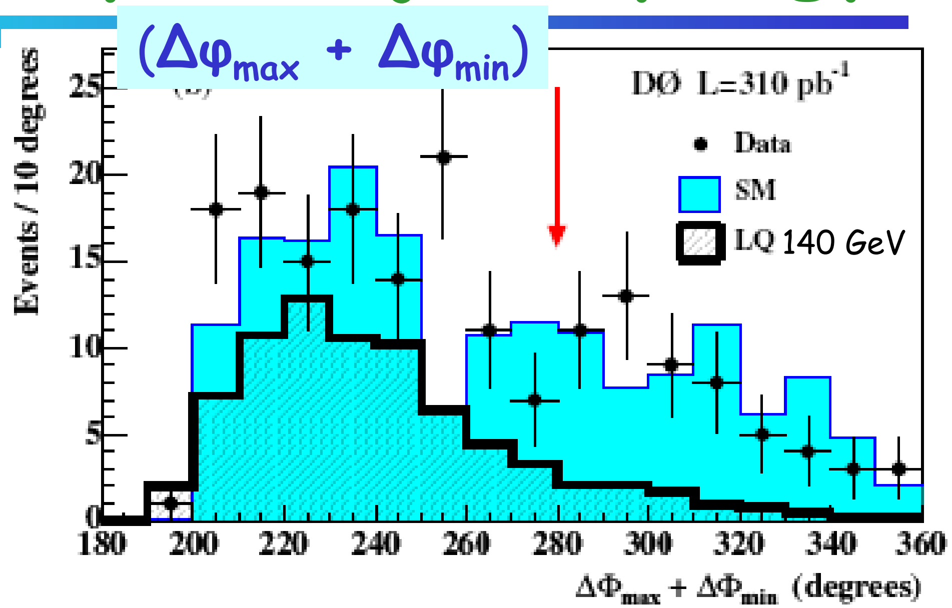
m_{LQ} = 140 GeV

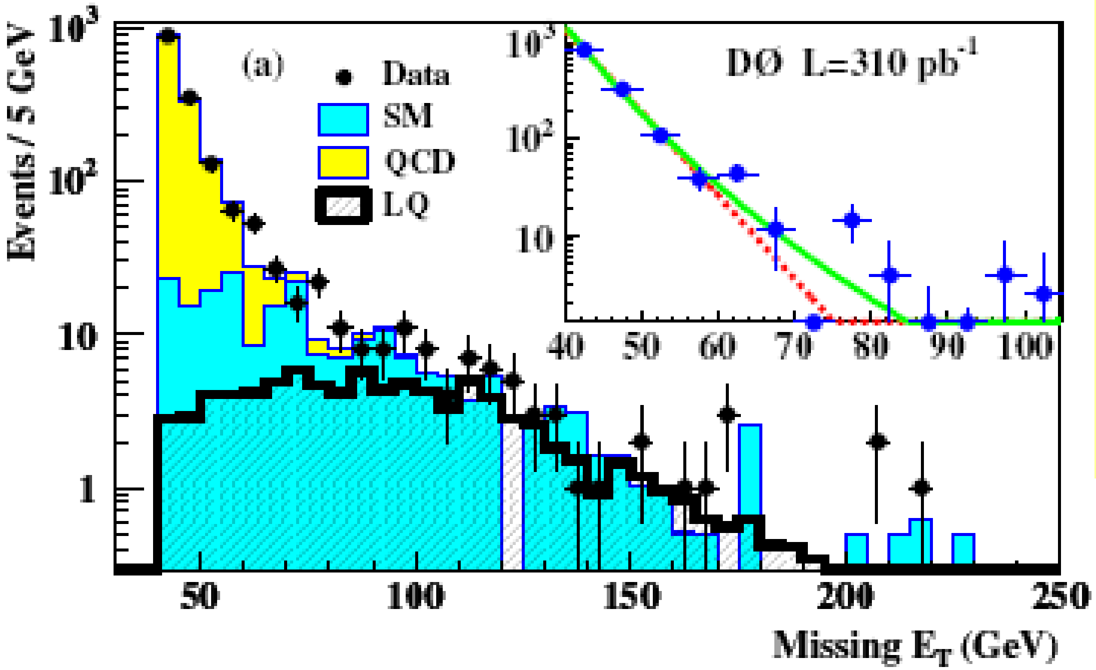
Cut applied	Events left	Efficiency (%)
Initial cuts	306,937	58.8
C1: jet-1 $p_T > 60$ GeV	206,116	48.7
C2: jet-1 $\lvert\eta_{\text{det}}\rvert < 1.5$	160,323	46.8
C3: jet-2 $p_T > 50$ GeV	48,979	24.8
C4: jet-2 $\lvert\eta_{\text{det}}\rvert < 1.5$	42,028	22.7
C5: jet-1 jet-2 EMF < 0.95	40,821	22.3
C6: jet-1 jet-2 CPF > 0.05	34,746	22.2
C7: exactly two jets	5,213	15.3
C8: $\not{E}_T > 70$ GeV	492	11.8
C9: isolated electron veto	465	11.7
C10: isolated muon veto	399	11.6
C11: isolated track veto	287	10.0
C12: $\Delta\Phi_{\max} - \Delta\Phi_{\min} < 120°$	180	9.4
C13: $\Delta\Phi_{\max} + \Delta\Phi_{\min} < 280°$	124	8.4
C14: $\not{E}_T > 80$ GeV	86	7.0

$\Delta\phi$(MET,j)

leptoquarks in acoplanar jet topology







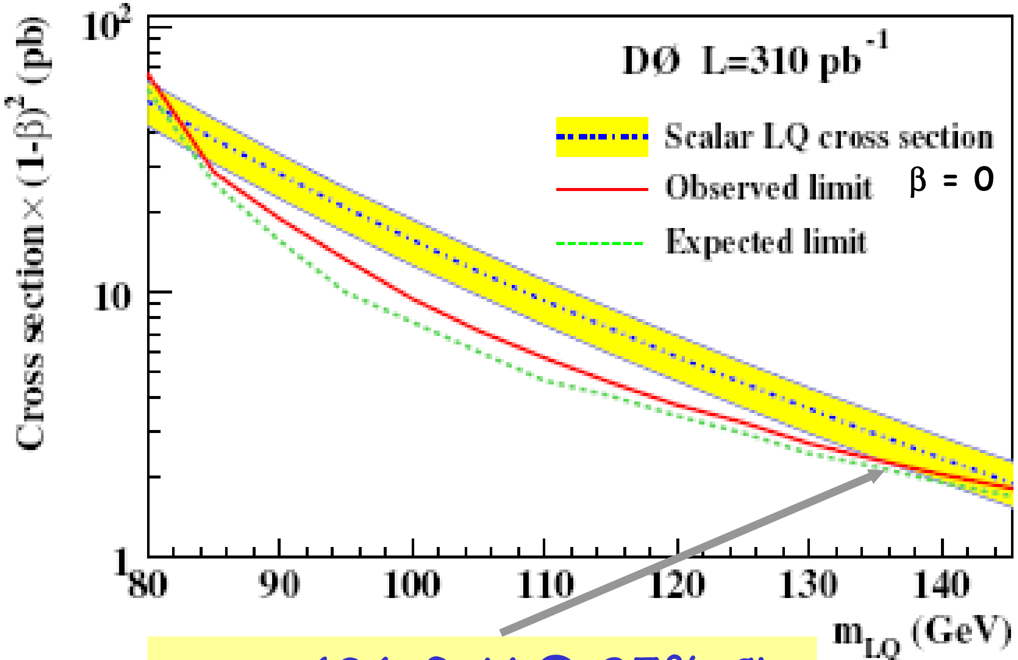
- Exp. and power law fits to MET distrib. in range [40,60] GeV after removal of the SM contribution
- extrapolated at high MET
- Average result of the 2 fits
  -> QCD background estimate
- Difference -> systematics

2.3 ± 1.2

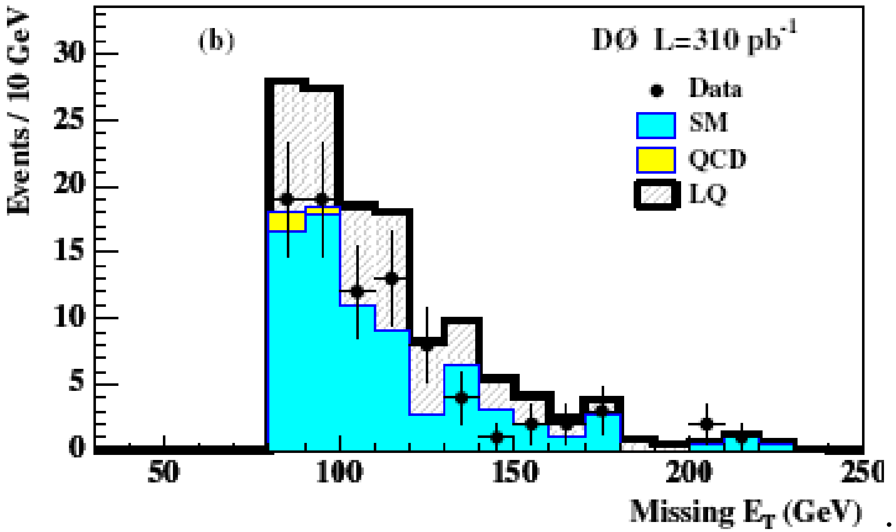
(for MET > 70 GeV)

leptoquarks in acoplanar jet topology

$(Z \to \nu\nu)$+2-jets	34.6 ± 4.3
$(W \to \ell\nu)$+jets	$35.0^{+9.1}_{-8.7}$
$(Z \to \ell\ell)$+jets	$0.3^{+0.4}_{-0.2}$
$t\bar{t}$	1.9 ± 0.1
WW, WZ, ZZ	1.2 ± 0.2
Total SM background	$72.9\ ^{+10.1}_{-9.7}\ ^{+10.6}_{-12.1}$
Instrumental background	2.3 ± 1.2
Total background	$75.2\ ^{+10.1}_{-9.7}\ ^{+10.7}_{-12.2}$
Data events selected	86
Signal ($m_{LQ} = 140$ GeV)	$51.8 \pm 1.8^{+5.6}_{-4.6}$



m_{LQ} > 136 GeV @ 95% CL

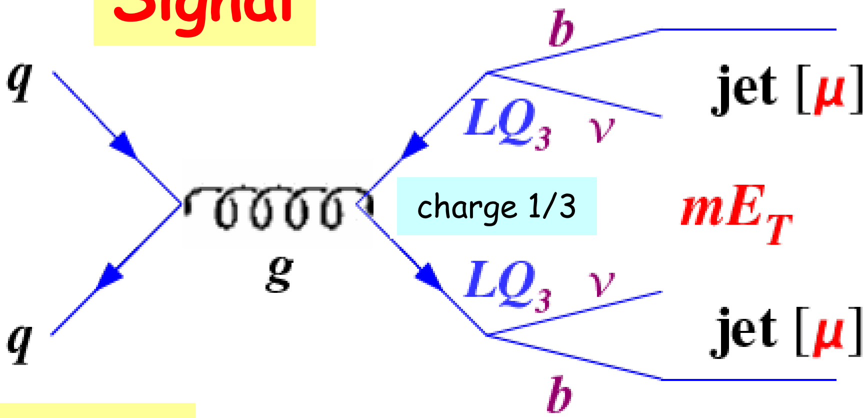


Most stringent limit for 1st and 2nd generation scalar leptoquarks decaying exclusively in a quark and a neutrino (β=0)

what about the 3rd generation?

3rd gen. LQ

Signal



Decay:
BR(LQ_3->bν) = 1
as long as M(LQ_3) < M(t)+M(τ)

Phase space suppression factor F_s for higher masses
BR(LQ_3->bν) = 1 - 0.5*F_s

Use b-tagging to increase sensitivity to signal

Selection

	Data	signal(acceptance), M_{LQ}=200 GeV
trigger, $\not\!\!E_T$ >40 GeV, $\Delta\phi(\not\!\!E_T$,jet) >0.5	482635	59.1 (71.1%)
$\not\!\!H_T > 40$ GeV	445280	58.6 (70.5%)
leading jet $E_T > 40$ GeV	419451	58.3 (70.1%)
second jet $E_T > 20$ GeV	167601	51.7 (62.2%)
no bad jets $E_T > 15$ GeV	91568	49.7 (59.8%)
the primary vertex $\lvert z\rvert < 60$ cm	87873	49.1 (59.1%)
leading jet $\lvert\eta\rvert < 1.5$	69892	47.9 (57.6%)
jet track confirmation	49494	45.9 (55.3%)
no isolated EM objects $p_T > 5$ GeV	46569	45.5 (54.8%)
no isolated muons	44198	45.0 (54.2%)
muon $p_T^{max} < 200$ GeV	44153	44.9 (54.1%)
$\Delta\phi(\not\!\!E_T$,jet) > 0.7	25348	41.6 (50.1%)
acoplanarity < 165°	24661	40.6 (48.8%)
$\not\!\!E_T$ >70 GeV	2804	36.5 (43.9%)
$\Delta R_{track-jet} \times p_T > 3.5$ GeV, $H_T > 110$ GeV $\Delta\phi(\not\!\!E_T$,jet) <3.0	1241	29.9 (35.9%)

Using b-tagging

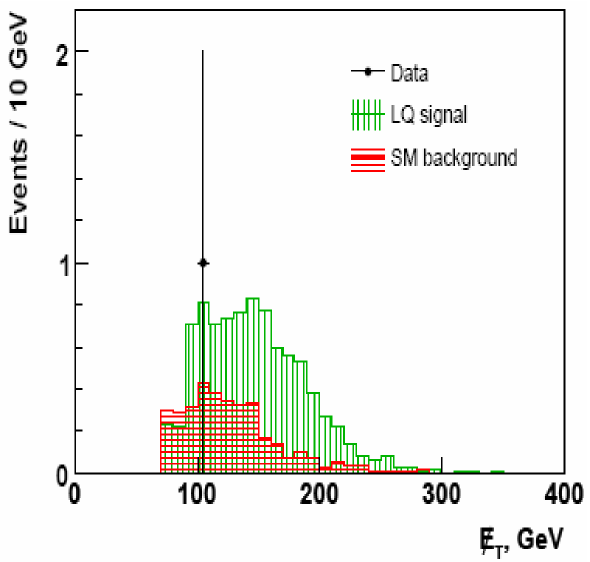
Two taggers used:

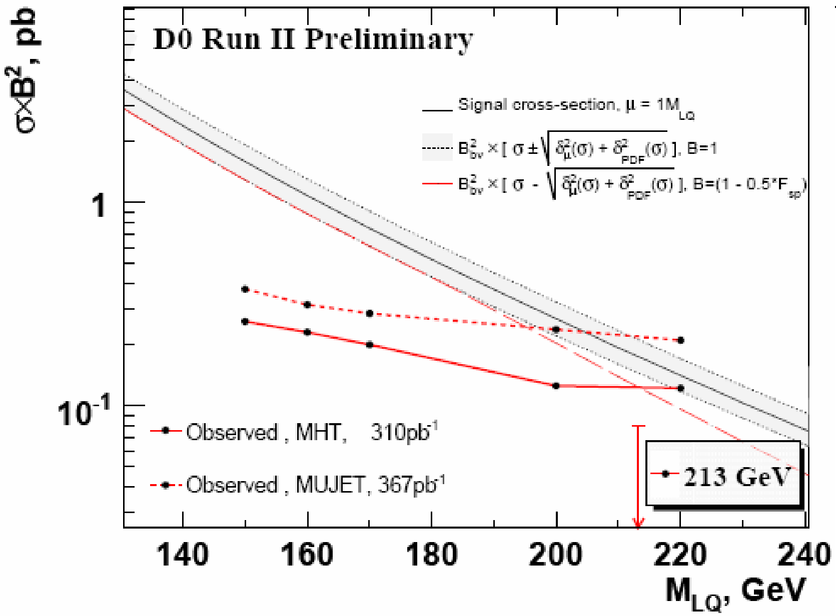
- Jet LIfetime Probability (JLIP)
- μ-tag: if muon within a cone $\Delta R = 0.5$ around the jet axis

2 b-tags are required:

- at least 1 μ-tag and at least 1 JLIP-tag
- 2 JLIP-tags and Xij > 0.8 ($X_{ij} \equiv (E_T^{tag1} + E_T^{tag2})/(\Sigma_{jets} E_T)$)

Process	Pretag	double JLIP tag ($\not{E}_T > 90$ GeV, $H_T > 150$ GeV)	Muon + Single JLIP tags ($\not{E}_T > 70$ GeV)	Total
$W \to \mu\nu +$ jj	287 ± 9	0.02 ± 0.01	0.15 ± 0.07	0.17 ± 0.07
$W \to e\nu +$ jj	320 ± 18	0.02 ± 0.01	0 ± 0	0.02 ± 0.01
$W \to \tau\nu +$jj	698 ± 44	0.15 ± 0.04	0 ± 0	0.15 ± 0.04
$Z \to \nu\bar{\nu} +$ jj	1062 ± 21	0.38 ± 0.14	0.03 ± 0.03	0.41 ± 0.14
top	60 ± 1	0.71 ± 0.06	0.80 ± 0.09	1.51 ± 0.11
$W/Z + b\bar{b}$	28 ± 1	0.66 ± 0.07	0.53 ± 0.11	1.19 ± 0.13
total SM expected	2456 ± 53	1.95 ± 0.17	1.52 ± 0.16	3.47 ± 0.24
# data events	2804	1	0	1
Signal (acceptance, %)				
$M_{LQ} = 200$ GeV	37 ± 1 (43.9)	5.8 ± 0.2 (6.9)	3.1 ± 0.2 (3.7)	8.8 ± 0.2 (10.6)





@ 95% CL if LQ_3

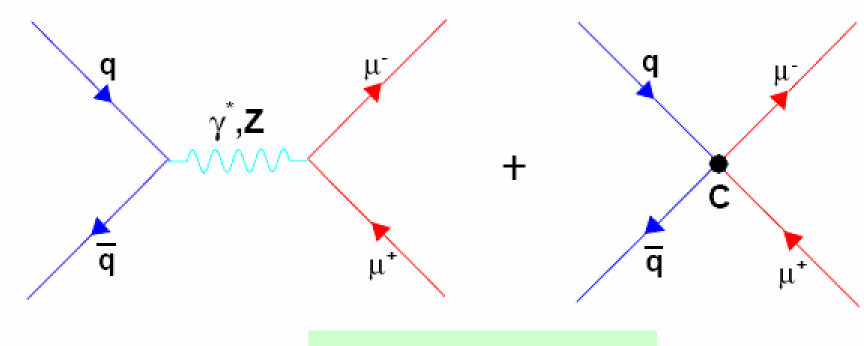
also decays in ττ:
m_{LQ} > 213 GeV

if not:
m_{LQ} > 219 GeV
[B(LQ -> bν) = 1]

Compositeness

Lepton-quark compositeness
Excited leptons and quarks

Lepton-Quark Compositeness



(for e's: μ <-> e)

effective lagrangian

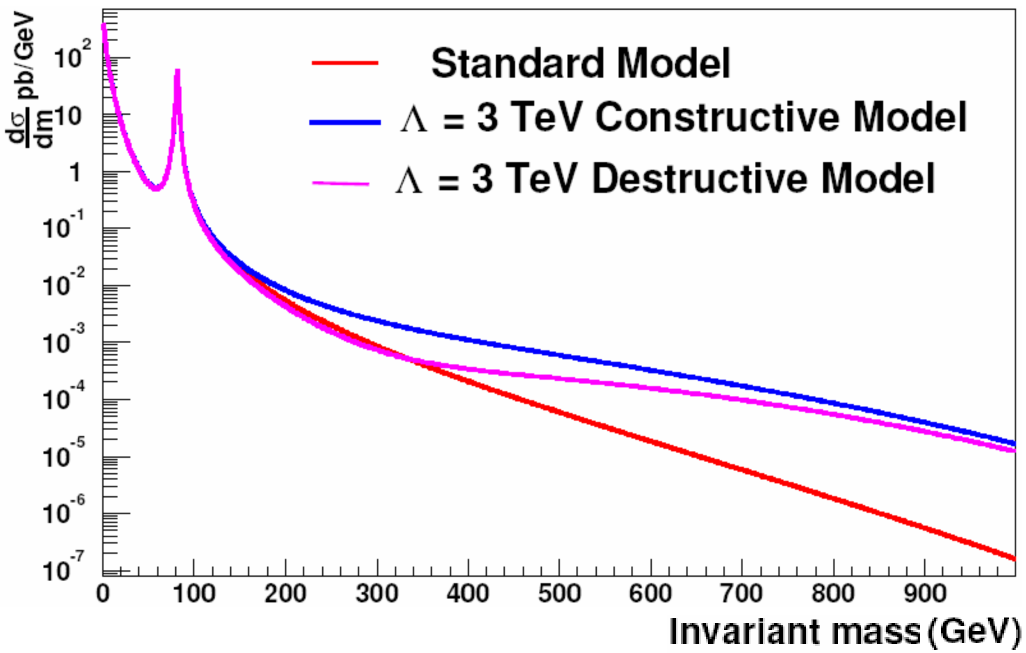
$$q_L = (u,d)_L$$

$$L_{ql} = \frac{g_0^2}{\Lambda^2}\{\eta_{LL}(\bar{q}_L\gamma^\mu q_L)(\bar{\mu}_L\gamma_\mu\mu_L) + \eta_{LR}(\bar{q}_L\gamma^\mu q_L)(\bar{\mu}_R\gamma_\mu\mu_R) + \eta_{RL}(\bar{u}_R\gamma_\mu u_R)(\bar{\mu}_L\gamma^\mu\mu_L) + \eta_{RL}(\bar{d}_R\gamma_\mu d_R)(\bar{\mu}_L\gamma^\mu\mu_L) + \eta_{RR}(\bar{u}_R\gamma^\mu u_R)(\bar{\mu}_R\gamma_\mu\mu_R) + \eta_{RR}(\bar{d}_R\gamma^\mu d_R)(\bar{\mu}_R\gamma_\mu\mu_R)\}$$

interference term

contact term

$$\frac{d\sigma_T}{dM} = \frac{d\sigma_{sm}}{dM} + \frac{I}{\Lambda^2} + \frac{C}{\Lambda^4}$$



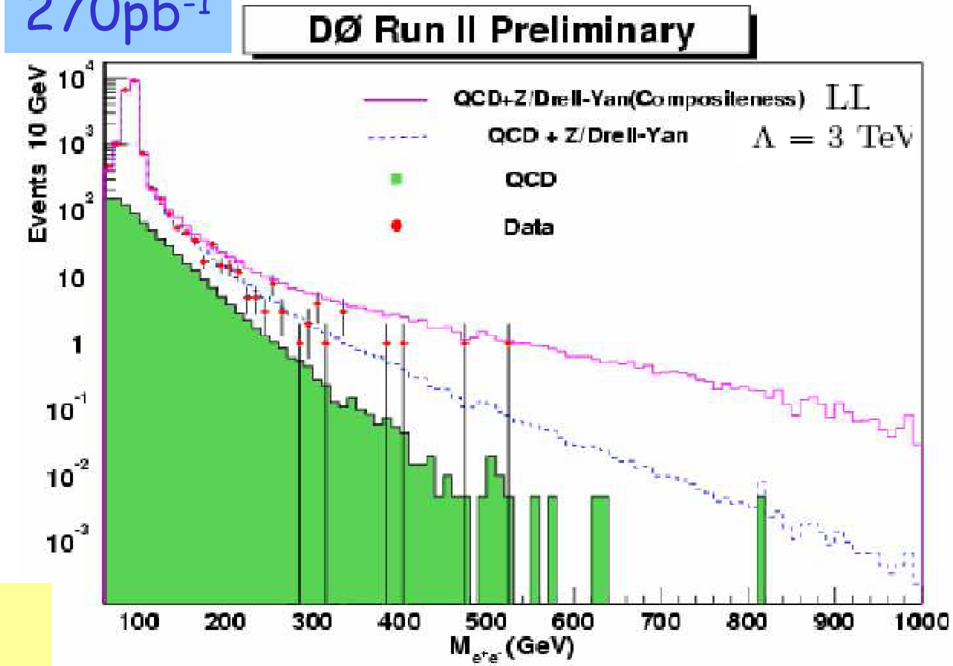
Model	η_{LL}	η_{RR}	η_{LR}	η_{RL}
$LL^\pm$	±1	0	0	0
$RR^\pm$	0	±1	0	0
$LR^\pm$	0	0	±1	0
$RL^\pm$	0	0	0	±1
$(LL+RR)^\pm$	±1	±1	0	0
$(LR+RL)^\pm$	0	0	±1	±1
$(LL-LR)^\pm$	±1	0	∓1	0
$(RL-RR)^\pm$	0	∓1	0	±1
$VV^\pm$	±1	±1	±1	±1
$AA^\pm$	±1	±1	∓1	∓1

VV (LL+RR+RL+LR)
AA (LL-LR-RL+RR)

Lepton-Quark Compositeness

ee channel

270pb^{-1}



SELECTION:
- 2 electrons w/ pT > 25 GeV
- in fiducial region and
  $|\eta_{det}| < 1.1$ for CC
  $1.5 < |\eta_{det}| < 2.4$ for EC
- at least one electron track matched

BACKGROUNDS:
- Z/DY ee production
- multijets estimated from data
- γ+jets estimated from multijets/γ+jets ratio

No excess =>
95% CL limits on Λ

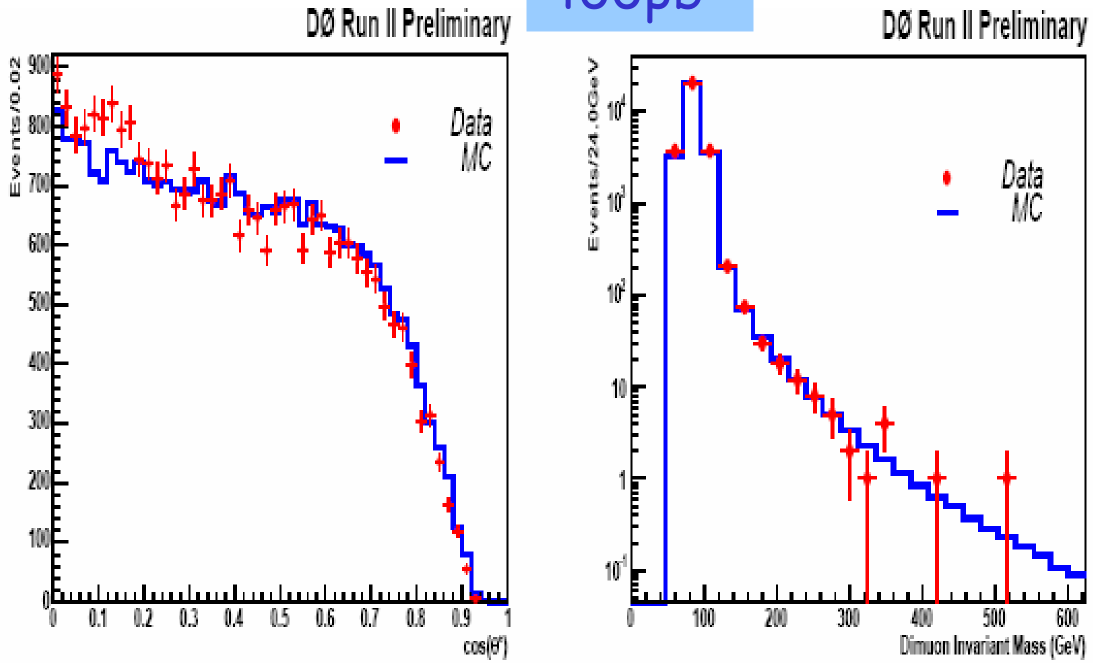
Model	Λ^+(TeV)	Λ^-(TeV)
LL	3.6	6.2
RR	4.3	5.0
LR	4.5	4.8
RL	3.8	5.8
LL+RR	4.1	7.9
LR+RL	5.0	6.0
LL-LR	4.8	6.4
RL-RR	4.7	6.8
VV	4.9	9.1
AA	5.7	7.8

Lepton-Quark Compositeness

$\mu\mu$ channel

400pb^{-1}

SELECTION:
- 2 muons w/ pT > 15 GeV
- $|\eta_{det}|$ < 2.0
- Track quality cuts
- Cosmic ray cuts
- Isolation cuts
- $M_{\mu\mu}$ > 50 GeV



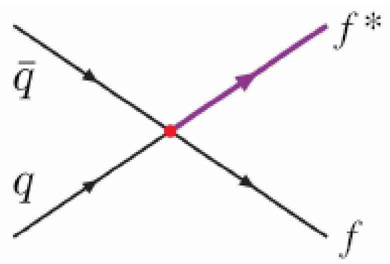
BACKGROUNDS:
- Z/DY $\mu\mu$ production
- $\tau^+\tau^-$ and bb DY production

No excess =>
95% CL limits on Λ

Model	Λ^+(TeV)	Λ^-(TeV)
LL	4.19	6.98
RR	4.15	6.74
LR	5.32	5.10
RL	5.31	5.17
LL+RR	5.05	9.05
LR+RL	6.45	6.12
LL-LR	4.87	7.74
RL-RR	5.07	7.41
VV	6.88	9.81
AA	5.48	9.76

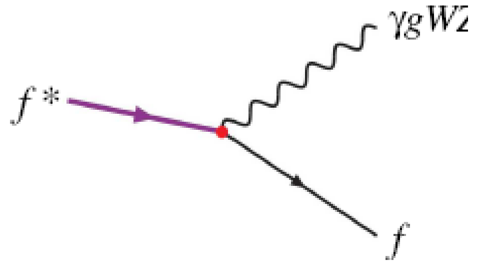
Excited Leptons and Quarks

- Have the same quantum numbers as known leptons or quarks.
- Occur in compositeness models where the known fermions are bound states of more fundamental particles which are bound together by a new strong interaction (Λ = Compositeness scale)
- model of Baur, Spira, & Zerwas, PRD 42, 815, (1990)



$\propto 1/\Lambda^2$

Four-fermion Contact Interactions

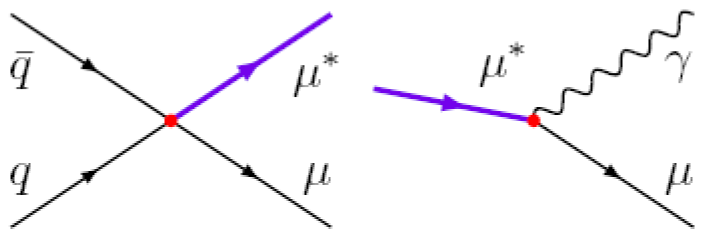


$\propto 1/\Lambda$

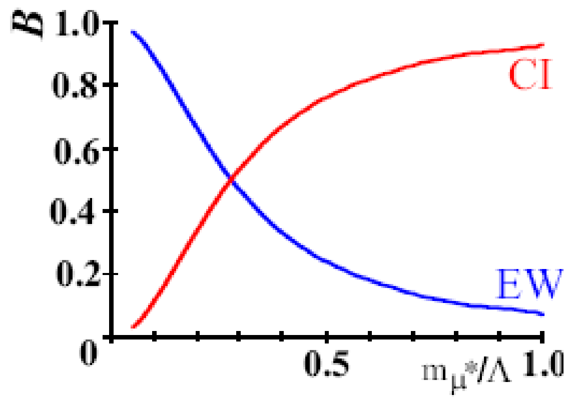
Gauge mediated transitions

Excited muons μ*

CI production and EW decay



BF CI/EW taken into account



SELECTION:

Two isolated muons p_T > 15 GeV

One isolated photon $|\eta|$ < 1.1, E_T > 27 GeV

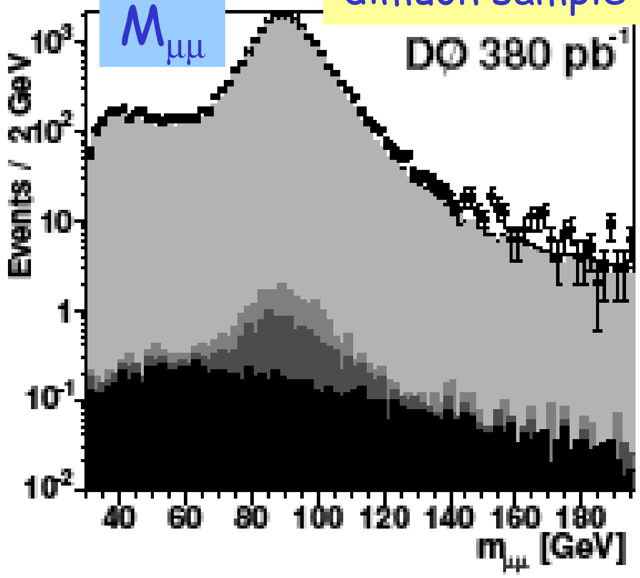
$M_{\mu\gamma}$>200 GeV (varies with μ* mass hypothesis)

BACKGROUNDS:

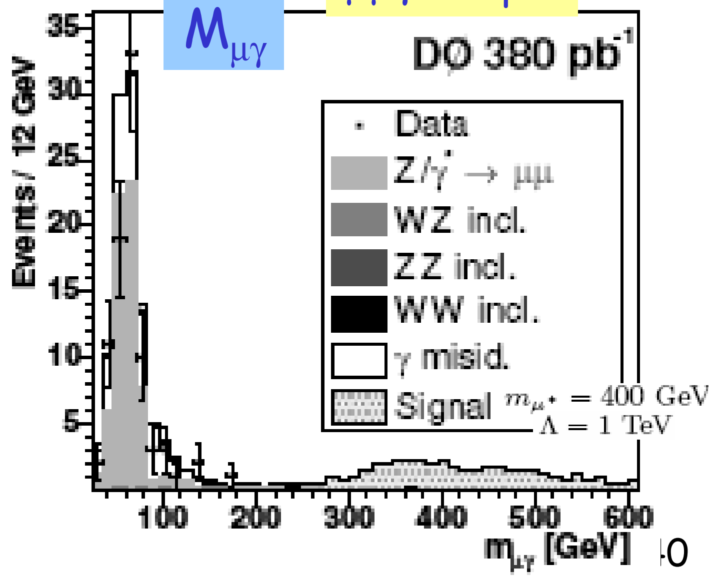
Mainly μμ DY with ISR/FSR γ

Others: fake γ, dibosons

$M_{\mu\mu}$ — dimuon sample



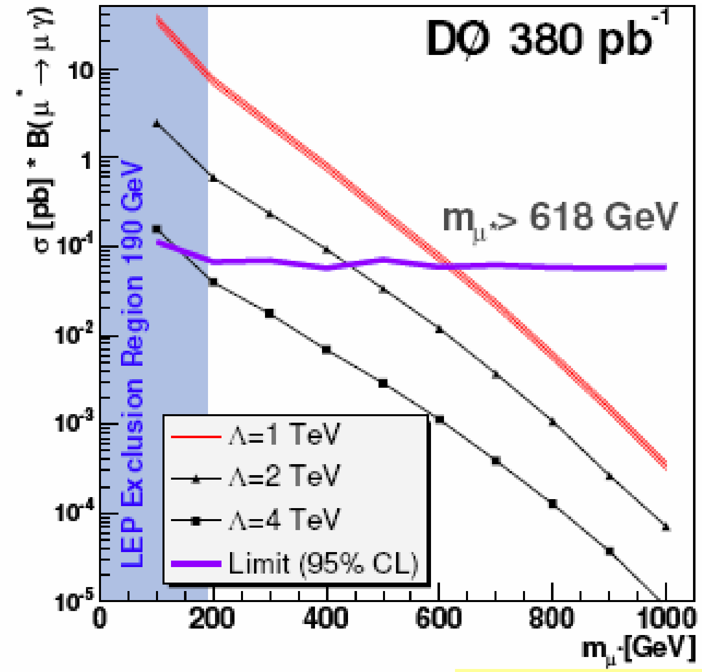
$M_{\mu\gamma}$ — μμγ sample

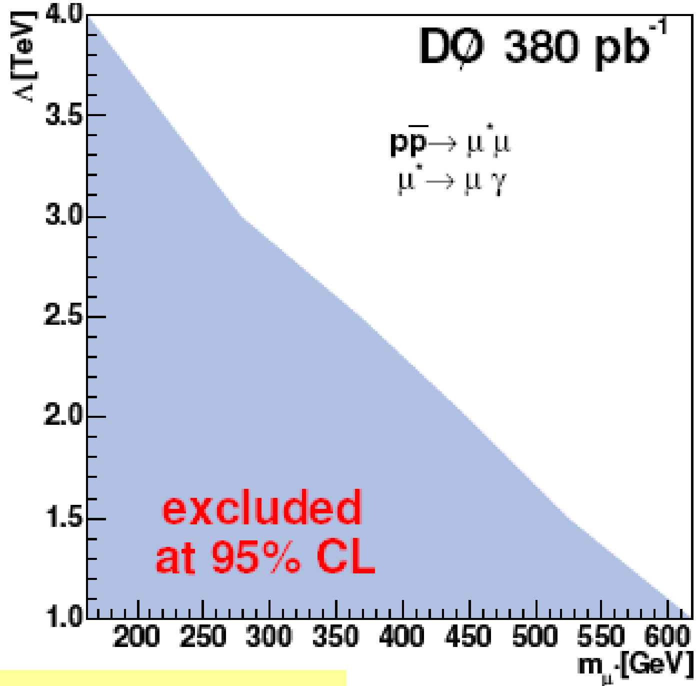


Excited muons μ*

m_{μ^*} [GeV]	$m_{\mu\gamma}$ cut [GeV]	Data	SM expectation	Signal eff. [%]
100	200	0	0.170 ± 0.126	7.5 ± 1.0
200	200	0	0.170 ± 0.126	12.5 ± 1.5
300	280	0	0.041 ± 0.023	12.1 ± 1.5
400	330	0	0.016 ± 0.011	14.7 ± 1.8
500	440	0	0.003 ± 0.001	11.9 ± 1.5
600	440	0	0.003 ± 0.001	14.4 ± 1.8
700	440	0	0.003 ± 0.001	13.6 ± 1.7
800	440	0	0.003 ± 0.001	14.5 ± 1.8
900	440	0	0.003 ± 0.001	14.7 ± 1.8
1000	440	0	0.003 ± 0.001	14.4 ± 1.8

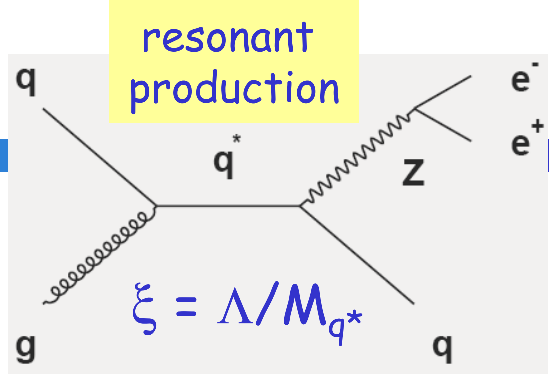
No excess => 95% CL limits





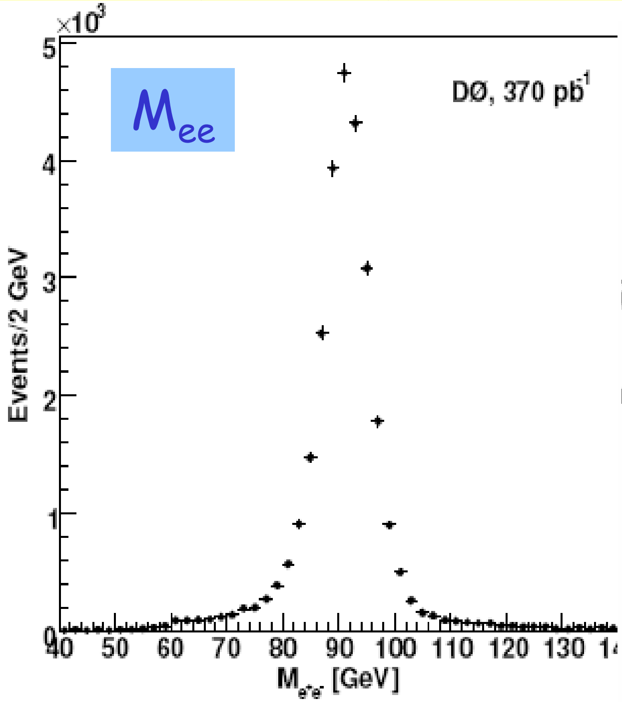
m_{μ^*} > 688 GeV for $\Lambda = m_{\mu^*}$

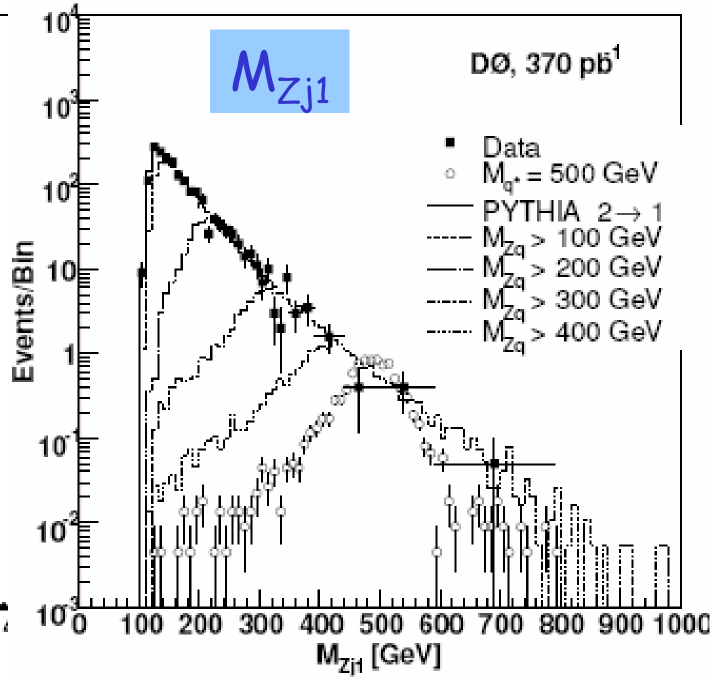
Excited quarks q*



SELECTION:
- Two isolated electrons:
  $E_T > 30, 25$ GeV
  $|\eta| < 1.1$ or $1.5 < |\eta| < 2.5$
- One jet: $E_T > 20$ GeV, $|\eta| < 2.5$
- 80 GeV < M_{ee} < 102 GeV
- Final selection using M_{Zj1} and p_{TZ} (depends on M_{q*} and Γ_{q*} [or ξ])

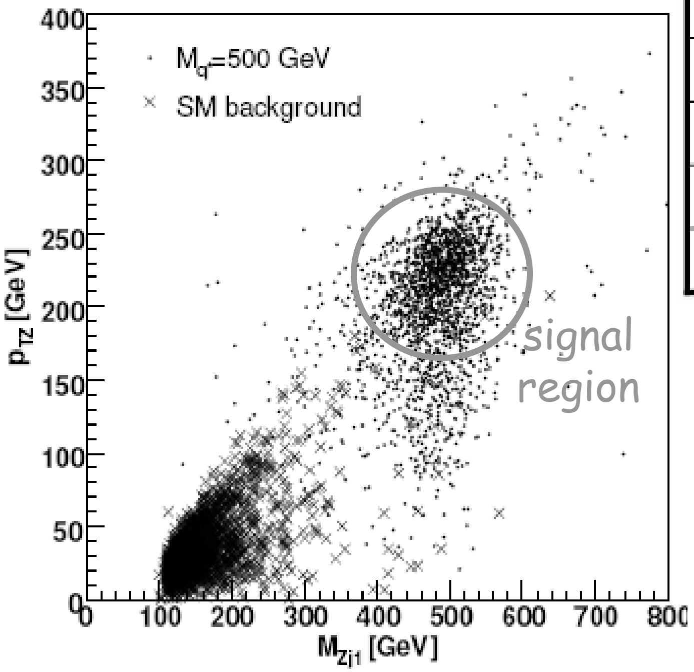
BACKGROUND:
- Main background by far: SM Z+jet production
- Instrumental backgrounds (fake electrons) very small





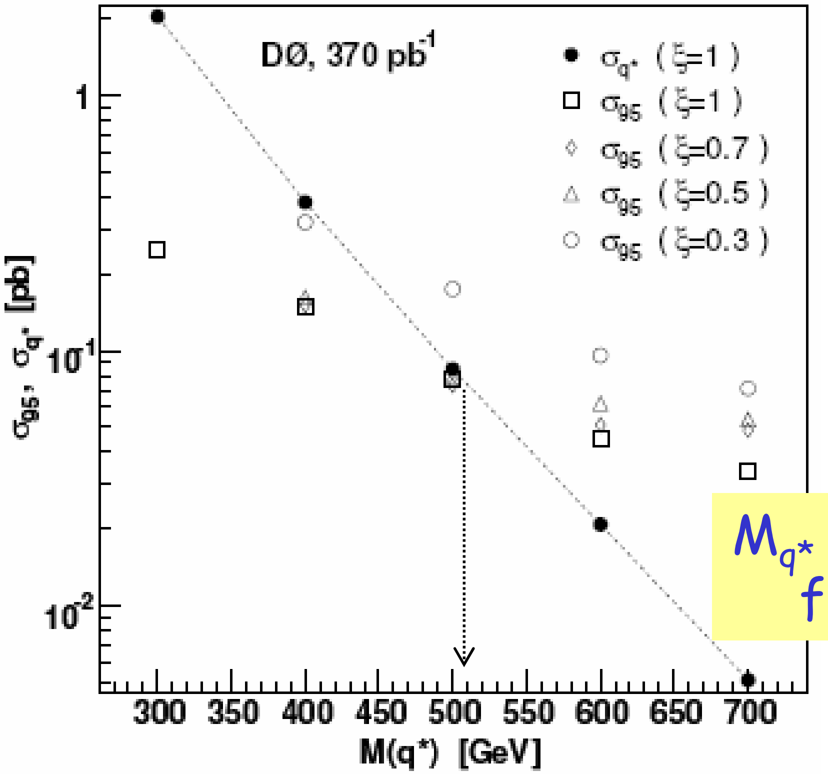
Excited quarks q*

(M_{Zj1}, p_{TZ}) optimized cut



M_{q^*} (GeV)	Data Events	Expected background
300	31	32.8 ± 2.9
400	9	7.5 ±0.8
500	3	2.9 ± 0.8
600	1	1.6 ± 0.6
700	0	0.64 ± 0.06

No excess => 95% CL limits



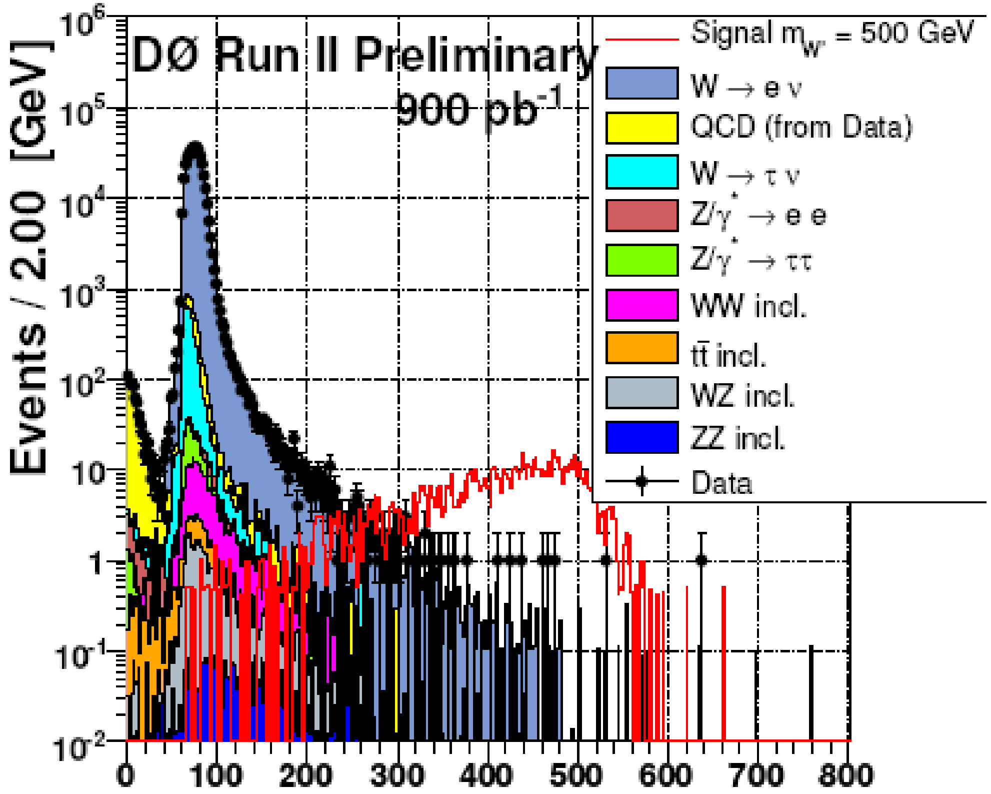
M_{q^*} > 510 GeV for ξ = 1

Extra Gauge Bosons

Search for W' -> eν

- Arises in SM extensions from the presence of additional symmetry groups
- Assumptions:
    - no W, W' mixing
    - SM coupling
    - W' -> WZ channel supressed
    - $\Gamma_{W'} = 4/3\ m_{W'}/m_W\ \Gamma_W$

SELECTION:
- 1 isolated track matched e
  $E_T > 30$ GeV and $|\eta| < 1.1$ (CC)
- MET > 30 GeV
- $0.7 < E_T/MET < 1.3$
- if jets w/ $E_T > 15$ GeV
  - $\Delta\phi(e,j) < 2.5$
  - $\Delta\phi(j,MET) < 2.5$ (dijets)



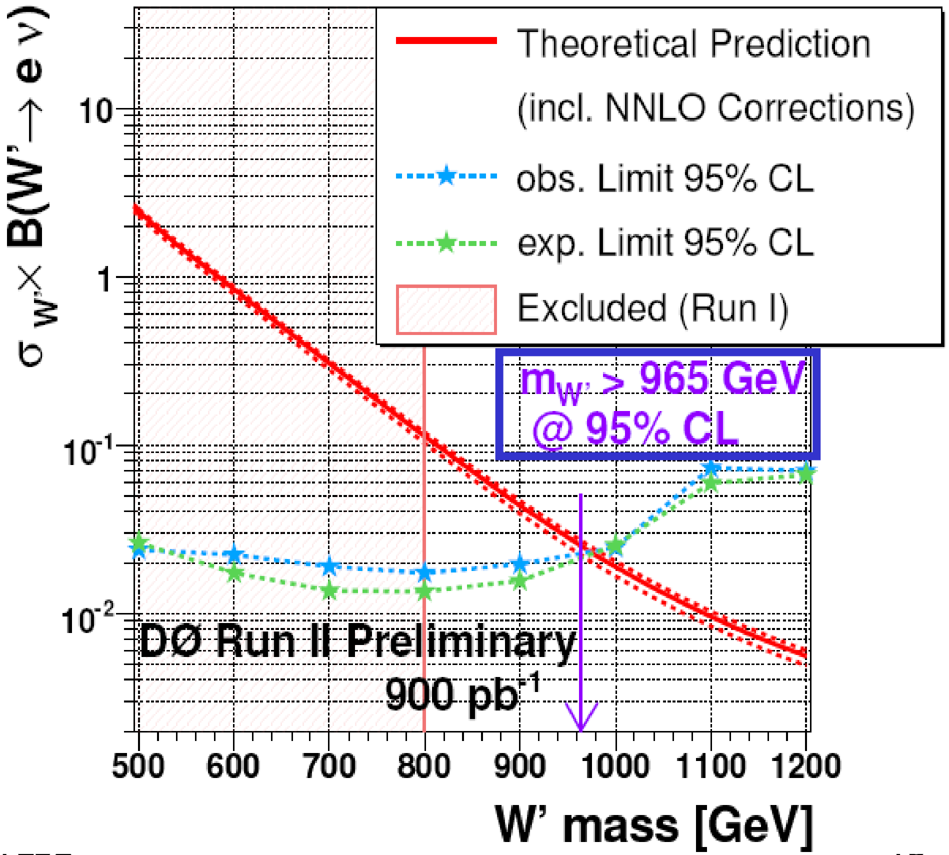
$m_T = (2E_T{*}MET(1-\Delta\phi(e,MET))^{1/2}$ [GeV]

- $m_T < 30$ GeV
  with loose e sample to normalize QCD
- $60 < m_T < 140$ GeV
  overall normalization (900 pb^{-1})
- $m_T > 150$ GeV
  to look for W' signal

Search for W' -> eν

Process	Events	Statistical error	Systematical error (+)	Systematical error (-)
Data	**630**			
Sum Backgrounds	622.93	17.91	82.65	75.25
$W \to e\nu$	572.73	17.49	77.42	71.19
$W \to \tau\nu$	10.10	2.26	3.37	1.86
$Z \to ee$	0.07	0.03	0.01	0.01
$Z \to \tau\tau$	1.11	0.08	0.32	0.18
$WW, WZ, ZZ, t\bar{t}$ (incl.)	15.47	1.08	2.57	2.75
QCD (from data)	23.46	2.97	0.94	0.94
$W' \to e\nu$ (500 GeV)	1032.16	22.45	164.19	164.00
$W' \to e\nu$ (600 GeV)	349.91	7.39	61.42	61.87
$W' \to e\nu$ (700 GeV)	131.02	2.93	30.92	29.93
$W' \to e\nu$ (800 GeV)	46.16	1.05	13.68	13.07
$W' \to e\nu$ (900 GeV)	16.64	0.39	6.86	6.06
$W' \to e\nu$ (1000 GeV)	6.56	0.16	3.54	2.95
$W' \to e\nu$ (1100 GeV)	3.01	0.07	1.76	1.36
$W' \to e\nu$ (1200 GeV)	1.51	0.04	0.78	0.58

no excess seen ...



Supersymmetry

SUSY Particles and their SM partners differ in spin by 1/2

Quark	q	*Squark*	$\tilde{q}_R, \tilde{q}_L$	
Lepton	l	*Slepton*	$\tilde{l}_R, \tilde{l}_L$	
Neutrino	ν	*Sneutrino*	$\tilde{\nu}$	
Photon	γ	*Photino*	$\tilde{\gamma}$	**4 Neutralinos** $\tilde{\chi}^0$
W-,Z-Boson	$W^{\pm}, Z$	*Wino, Zino*	$\tilde{W}^{\pm}, \tilde{Z}$	
Higgs	$H^{\pm}, H^0$	*Higgsino*	$\tilde{H}_1^0\ \tilde{H}_2^+$	**2x 2 Charginos** $\tilde{\chi}^{\pm}$
	h, A		$\tilde{H}_1^-\ \tilde{H}_2^0$	
Gluon	g	*Gluino*	$\tilde{g}$	

The SUSY menu

More or less constrained MSSM, à la mSUGRA
- if mSUGRA: m_0 $m_{1/2}$ $\tan(\beta)$ A_0 $\mathrm{sign}(\mu)$
- neutralino LSP
- -> R-Parity Conserving processes $R = (-1)^{3(B-L)+2s}$
  - -> charginos/neutralinos
  - -> generic squarks and gluinos
  - -> stop/sbottom
- -> R-Parity Violating processes: LSP unstable
- -> MSSM Higgs bosons

Gauge mediated SUSY breaking
- gravitino LSP and neutralino NLSP
- -> 2 photons + MET

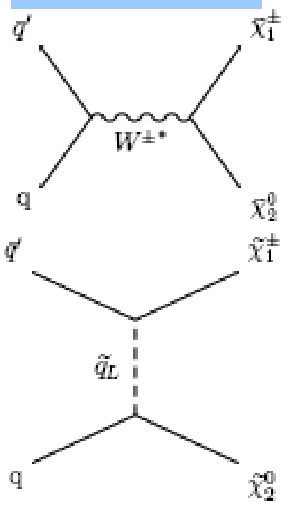
Anomaly mediated SUSY breaking
- -> long-lived charged particles

Split SUSY
- -> long-lived gluino

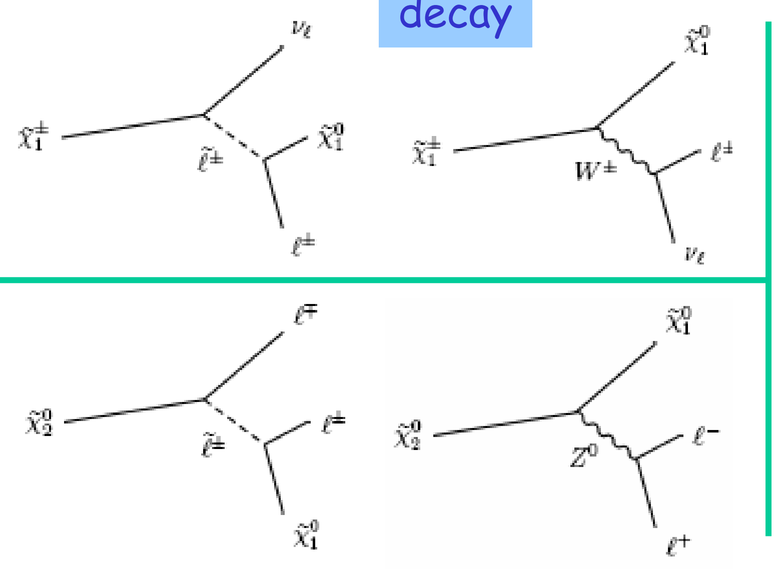
DØ "Trileptons" + MET

Chargino-neutralino production
clean signature

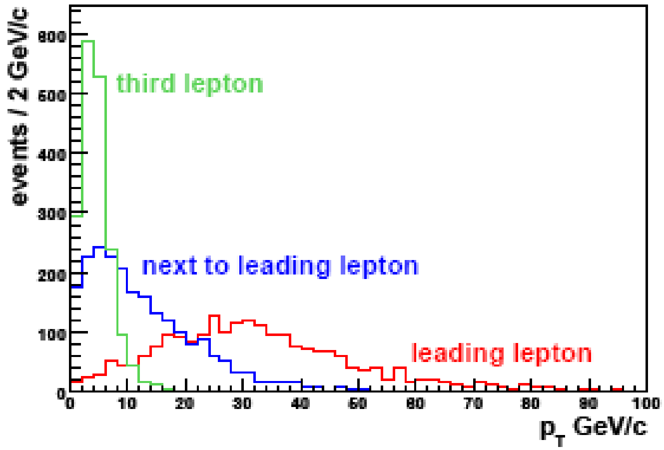
production

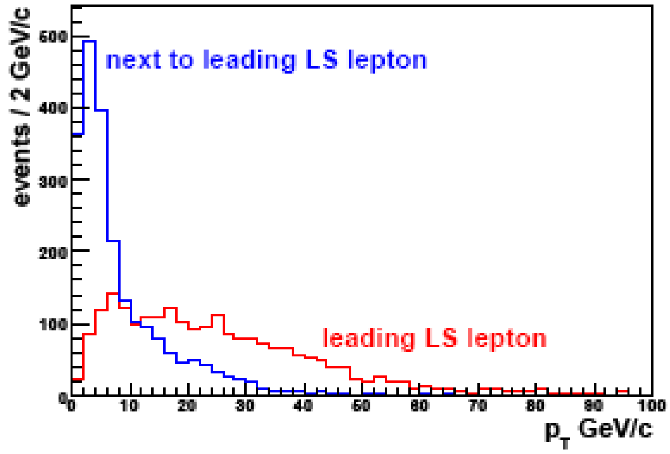


decay



=> Trilepton + MET
But Like Sign dileptons particularly relevant for very soft 3rd lepton (small χ_2-slepton mass difference)



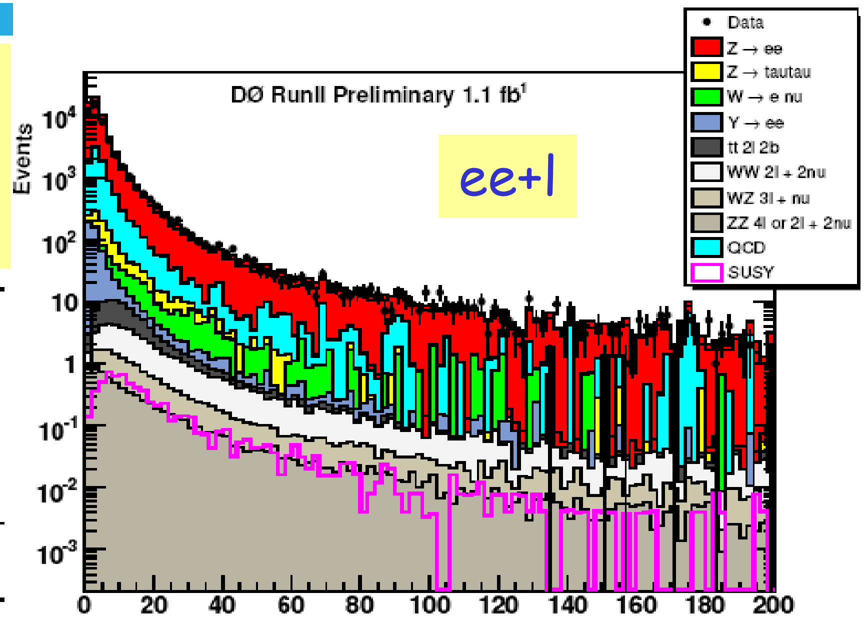


- low cross sections ($\times$ BR)
- soft leptons
- taus (at large tanβ)
  - => Need large integrated luminosity
  - => Combine various final states

eel + MET

SELECTION:
- Two isolated e's
- An isolated 3rd lepton or track (sensitive to τ's)
- Missing E_T

(1) Preselection	$p_T > 8$ GeV, 12 GeV electrons large electron likelihood electrons from primary vertex at least one electron in the central calorimeter at least 1 Hit in the inner SMT for $\mid z0 \mid < 35$cm likelihood tightened for $\mid z0 \mid > 35$cm
(2) Anti $Z/\gamma^* \rightarrow ee$	18 GeV $<$ inv. mass $<$ 60 GeV $\Delta\phi(e,e) < 2.9$
(3) Anti-Top	anti tt: $H_T < 80$ GeV
(4) Isolated Track	$p_T^{\ell 3} > 4.0$ GeV isolation $\Sigma p_T < 1$ GeV, $E_{iso} < 3$ GeV
(5) $\not{E}_T$ related	$\not{E}_T > 22$ GeV transverse mass $(e+\not{E}_T) > 20$ GeV Sig $(\not{E}_T) > 8.0$
(6) Tr$\times\not{E}_T$	$\not{E}_T \times p_T^{\ell 3} > 220$GeV^2



$$\mathrm{Sig}(\not{E}_T) = \frac{\not{E}_T}{\sqrt{\sum_{\mathrm{jets}} \sigma^2_{E_T^j \parallel \not{E}_T}}}$$

Data are well described at the preselection stage

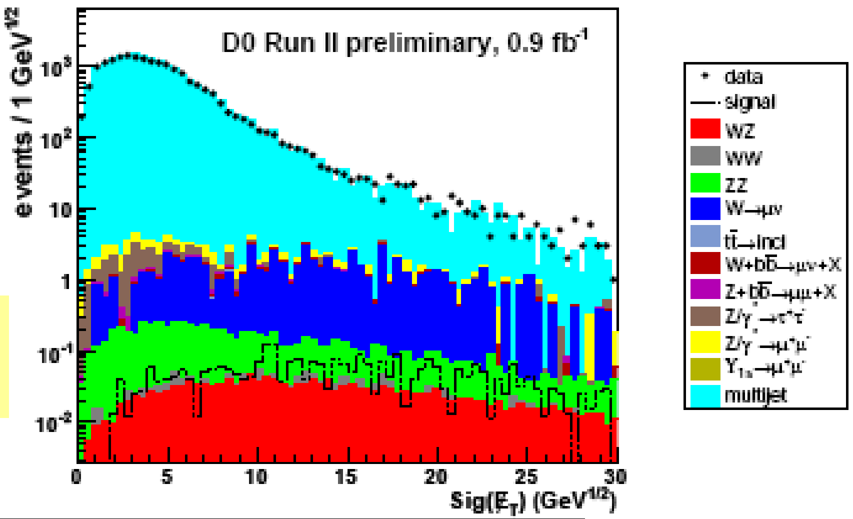
Cut	Data	Sum BG	$Z/\gamma^* \rightarrow ee$	$W\rightarrow e\nu$	$Z/\gamma^* \rightarrow \tau\tau$	WW/WZ	WZ	fakes
(1) Presel	118518	113592±175	95885±119	499±17	1029±18	83±0.43	18±0.4	16037±95
(2) Anti-Z	17459	18036±89	11053±51	297±12	287±11	26±0.33	2.01±0.04	6698 ±66
(3) Isolated Track	776	650±18	281±8	7.86±2.07	12±2	0.80±0.02	0.79±0.03	347±13
(4) $\not{E}_T$ related	2	1.97±0.73	0.16±0.16	1.77±0.73	0.32±0.32	0.43±0.02	0.46±0.02	0.48±0.28
(5) Tr$\times\not{E}_T$	0	0.76±0.67	0.0±0.16	0.0 ±0.59	0.32±0.32	0.14±0.011	0.25±0.01	0.00±0.09

2-4 signal evts expected

DØ LS μμ + MET

Start with: two isolated LS μ's pT > 5 GeV

Data are well described at the preselection stage



cut	QCD	WZ	ZZ	$W\to\mu\nu$	$Z/\gamma^*\to\mu^+\mu^-$	$Z/\gamma^*\to\tau^+\tau^-$
selection $\mathcal{B}$	14787±981	3.3±0.2	9.7±0.7	58±7	42±5	6.5±1.4
$M_{\mu^\pm\mu^\mp} \in [25-65]$ GeV/c^2 (a)	3452±232	0.66±0.05	0.70±0.06	16±3	4.2±1.0	1.7±0.4
$p_T^{\mu_2} < 35$ GeV/c (b)	3452±232	0.53±0.04	0.64±0.06	16±3	4.2±1.0	1.7±0.4
$p_T^{\mu_2} > 8$ GeV/c (c)	4.9±1.5	0.42±0.03	0.43±0.04	1.9±0.9	0.4±0.2	0.29±0.14
$p_T^{\mu_1} > 13$ GeV/c (d)	2.8±1.1	0.41±0.03	0.42±0.04	1.9±0.9	0.4±0.2	0.11±0.11
$M_{\mu^\pm\mu^\pm} \in [12-110]$ GeV/c^2 (e)	1.4±0.7	0.39±0.03	0.38±0.04	1.9±0.9	0.4±0.2	0.11±0.11
$M_T(\not{E}_T, p_T^{\mu_2}) \in [15-65]$ GeV/c^2 (f)	0.9±0.5	0.32±0.02	0.32±0.04	0.7±0.5	0.4±0.2	0
$\not{E}_T > 10$ GeV (g)	0.5±0.3	0.30±0.02	0.27±0.03	0.7±0.5	0.3±0.2	0
Sig($\not{E}_T$) > 12 GeV$^{1/2}$ (h)	0.19±0.19	0.198±0.015	0.16±0.02	0.7±0.5	0.21±0.14	0
$\not{E}_T \times p_T^{\mu_2} > 160$ GeV^2/c (i)	0.19±0.19	0.194±0.015	0.16±0.02	0.2±0.2	0.21±0.14	0

cut	Wbb	Zbb	WW	Υ_{1s}	tt	sum	data
selection $\mathcal{B}$	3.2±0.3	2.5±0.2	0.14±0.02	8.4±3.5	1.3±0.4	14922±981	15234
$M_{\mu^\pm\mu^\mp} \in [25-65]$ GeV/c^2 (a)	0.37±0.06	2.3±0.3	0.13±0.03	0.6±0.3	0.8±0.3	3479±232	3569
$p_T^{\mu_2} < 35$ GeV/c (b)	0.35±0.06	2.3±0.3	0.13±0.03	0.6±0.3	0.55±0.17	3479±232	3358
$p_T^{\mu_2} > 8$ GeV/c (c)	0.09±0.03	0.21±0.07	0.026±0.009	0	0.23±0.07	8.9±1.8	10
$p_T^{\mu_1} > 13$ GeV/c (d)	0.08±0.03	0.21±0.07	0.026±0.009	0	0.15±0.05	6.5±1.4	6
$M_{\mu^\pm\mu^\pm} \in [12-110]$ GeV/c^2 (e)	0.07±0.02	0.21±0.07	0.023±0.009	0	0	4.9±1.2	2
$M_T(\not{E}_T, p_T^{\mu_2}) \in [15-65]$ GeV/c^2 (f)	0.06±0.02	0.19±0.07	0.013±0.006	0	0	2.9±0.8	2
$\not{E}_T > 10$ GeV (g)	0.05±0.02	0.19±0.07	0.006±0.003	0	0	2.3±0.7	1
Sig($\not{E}_T$) > 12 GeV$^{1/2}$ (h)	0.03±0.015	0.16±0.06	0.006±0.003	0	0	1.7±0.6	1
$\not{E}_T \times p_T^{\mu_2} > 160$ GeV^2/c (i)	0.02±0.014	0.16±0.06	0.006±0.003	0	0	1.1±0.4	1

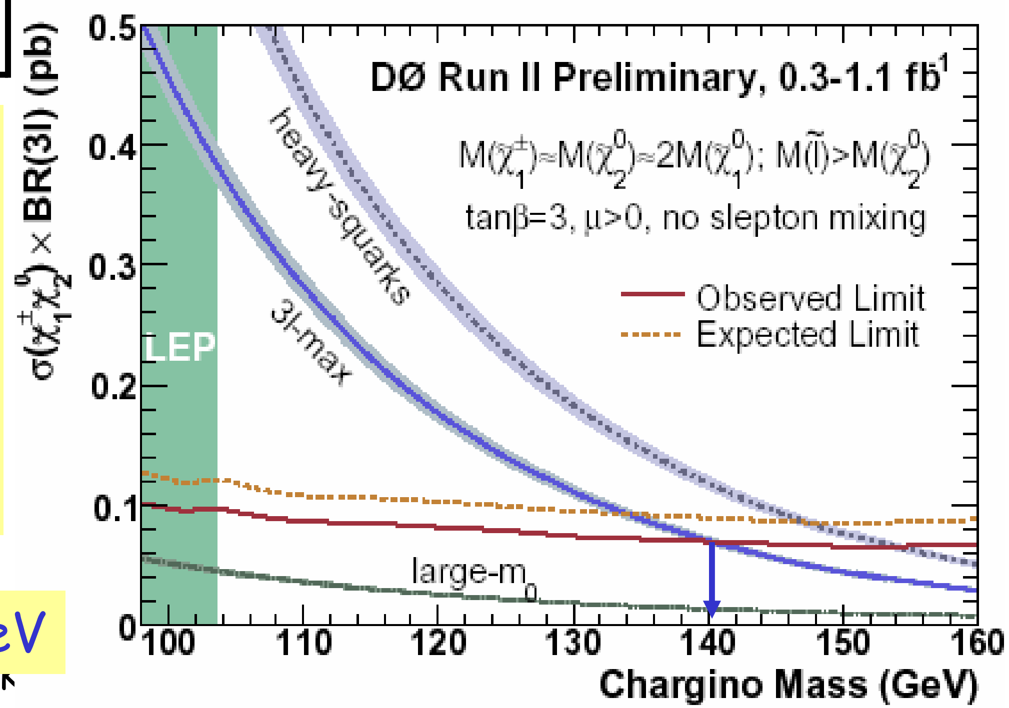
1-4 signal evts expected

"Trileptons" + MET

Analysis channel	Lumin. (fb^{-1})	Background predicted	Observed data
ee+track	1.1	0.76±0.67	0
$\mu^+\mu^+$/ $\mu^-\mu^-$	0.9	1.1 ± 0.4	1
eμ+track	0.3	0.31±0.13	0
μμ+track	0.3	1.75±0.57	2
$e\tau_h$+track	0.3	0.58±0.14	0
$\mu\tau_h$+track	0.3	0.36±0.13	1

Results of the various channels are combined, "weighted" according to their sensitivity, with overlaps taken into account.

heavy-squarks:
destructive t-channel contribution minimal
3l-max:
sleptons degenerate and m(sl) slightly greater than $m(\chi_2^0)$. Leptonic BR enhanced
large m_0:
at large slepton masses, W/Z exchange dominant => small leptonic BR



$m(\chi^+) > 140$ GeV

Generic squarks & gluinos

SIGNAL: strong production

- sq-sqbar and sq-sq (sq $\rightarrow q\chi$)
  => at least 2 jets + missing E_T (MET)
  @ small m_0
- sq-gl (gl $\rightarrow qq\chi$)
  => at least 3 jets + MET
  @ intermediate m_0
- gl-gl
  => at least 4 jets + MET
  @ high m_0

BACKGROUND:

- Instrumental
(QCD multijets with fake MET)

- (W→(missed lepton)+ν) +jets
(also from ttbar)

- (Z → νν) +jets (irreducible)

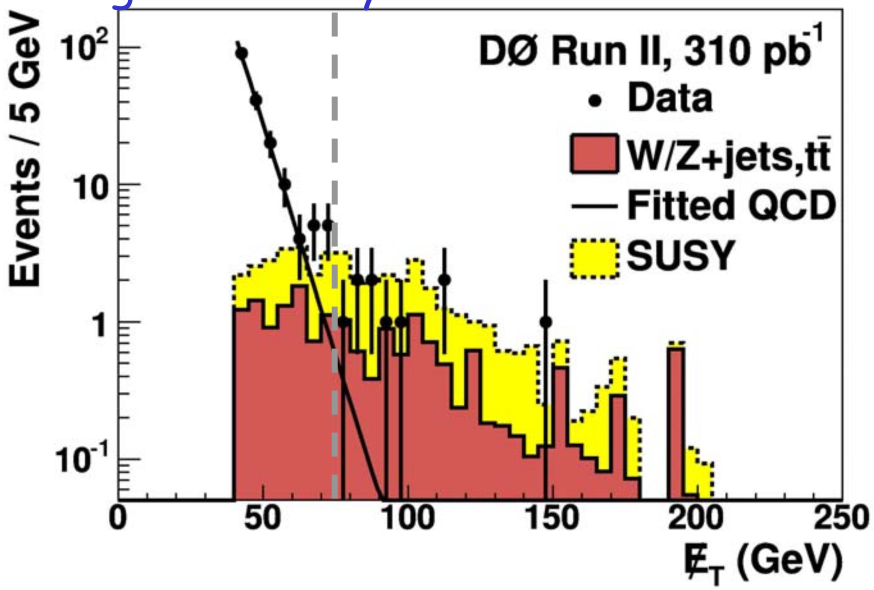
3 optimized analyses where QCD background reduced to negligible level

SELECTION:

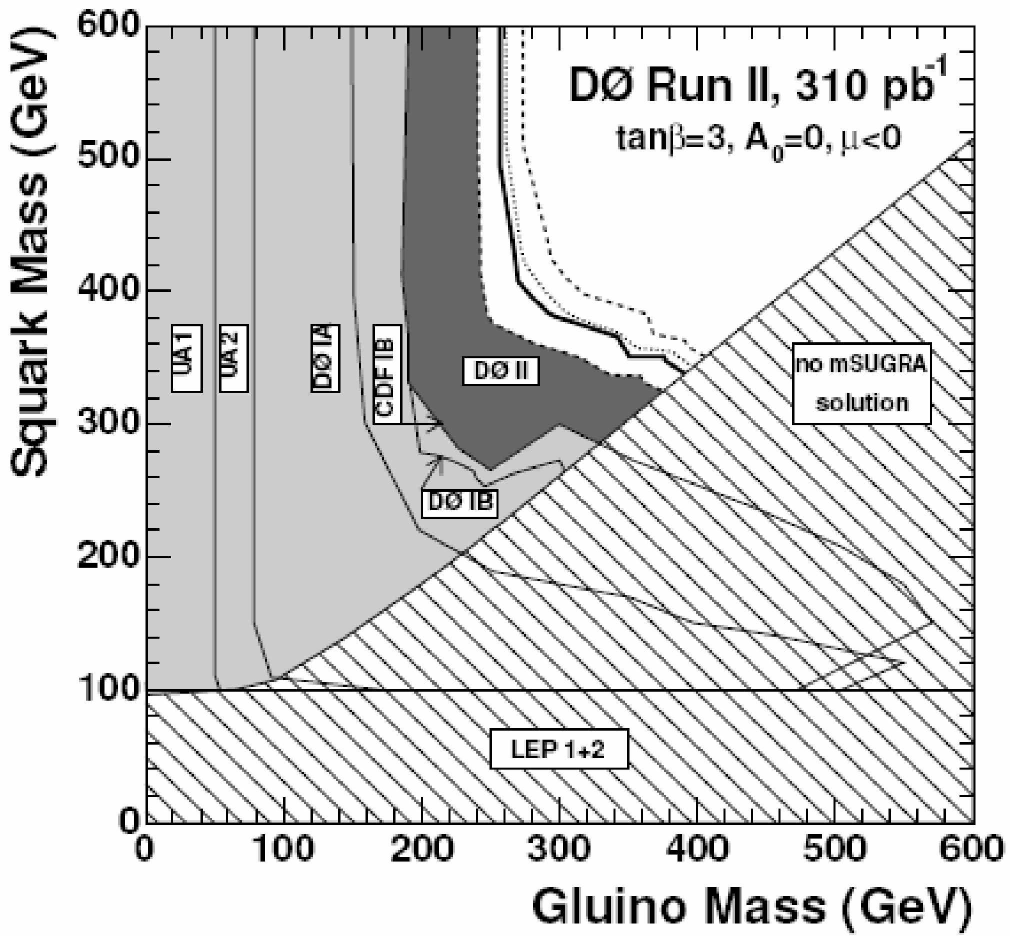
Preselection Cut	All Analyses		
$\not\!\!E_T$	≥ 40		
Acoplanarity	$< 165°$		
|Vertex z pos.|	< 60 cm		
Selection Cut	**"dijet"**	**"3-jets"**	**"gluino"**
1st jet $E_T{}^a$	≥ 60	≥ 60	≥ 60
2nd jet $E_T{}^a$	≥ 50	≥ 40	≥ 40
3rd jet $E_T{}^a$	–	≥ 30	≥ 30
4th jet $E_T{}^a$	–	–	≥ 20
Electron veto	yes	yes	yes
Muon veto	yes	yes	yes
$\Delta\phi(\not\!\!E_T, \text{jet}_1)$	$\geq 90°$	$\geq 90°$	$\geq 90°$
$\Delta\phi(\not\!\!E_T, \text{jet}_2)$	$\geq 50°$	$\geq 50°$	$\geq 50°$
$\Delta\phi_{\min}(\not\!\!E_T, \text{any jet})$	$\geq 40°$	–	–
H_T	≥ 275	≥ 350	≥ 225
$\not\!\!E_T$	≥ 175	≥ 100	≥ 75

Generic squarks & gluinos

"gluino" analysis



Analysis	Background expected	Events observed
≥ 2 jets	4.8 ± 4.5	6
≥ 3 jets	3.9 ± 1.5	4
≥ 4 jets	10.3 ± 2.4	10



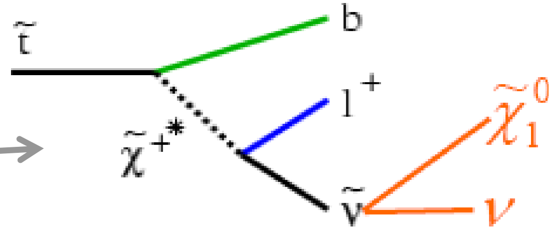
M_{gl} > 387 GeV/c^2 (when M_{gl}~M_{sq})

M_{gl} > 241 GeV/c^2 ; M_{sq} > 325 GeV/c^2

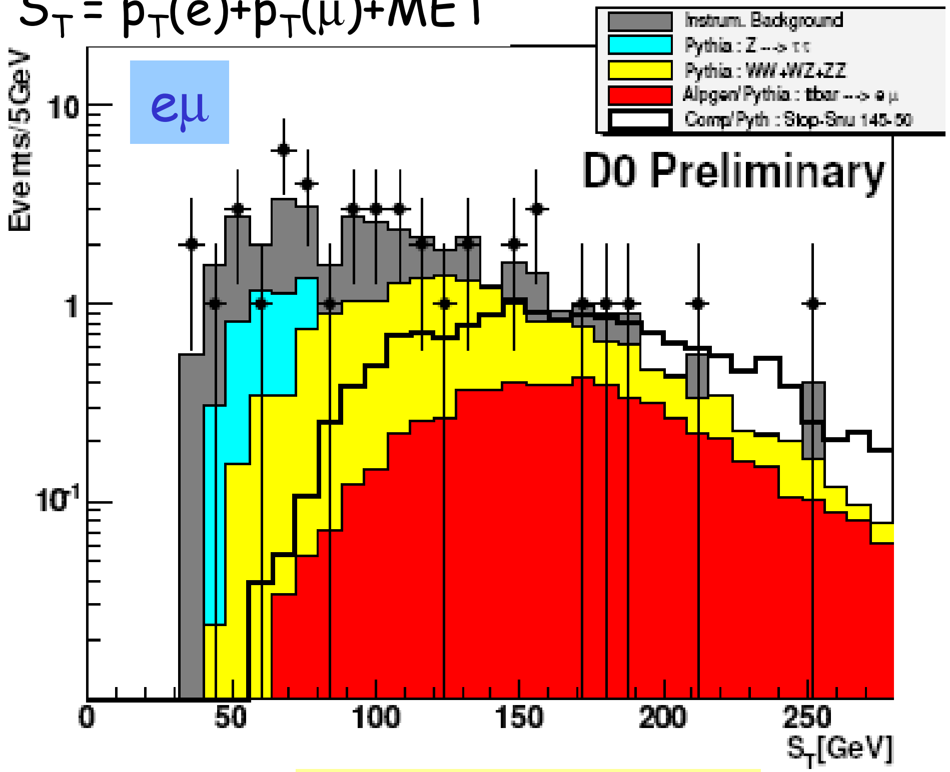
Stop

SIGNAL:

- stops pair produced (strong inter.)
- if sneutrino light
- eμ + MET and μμ + MET analyses optimized for various (m(st),m(sν))

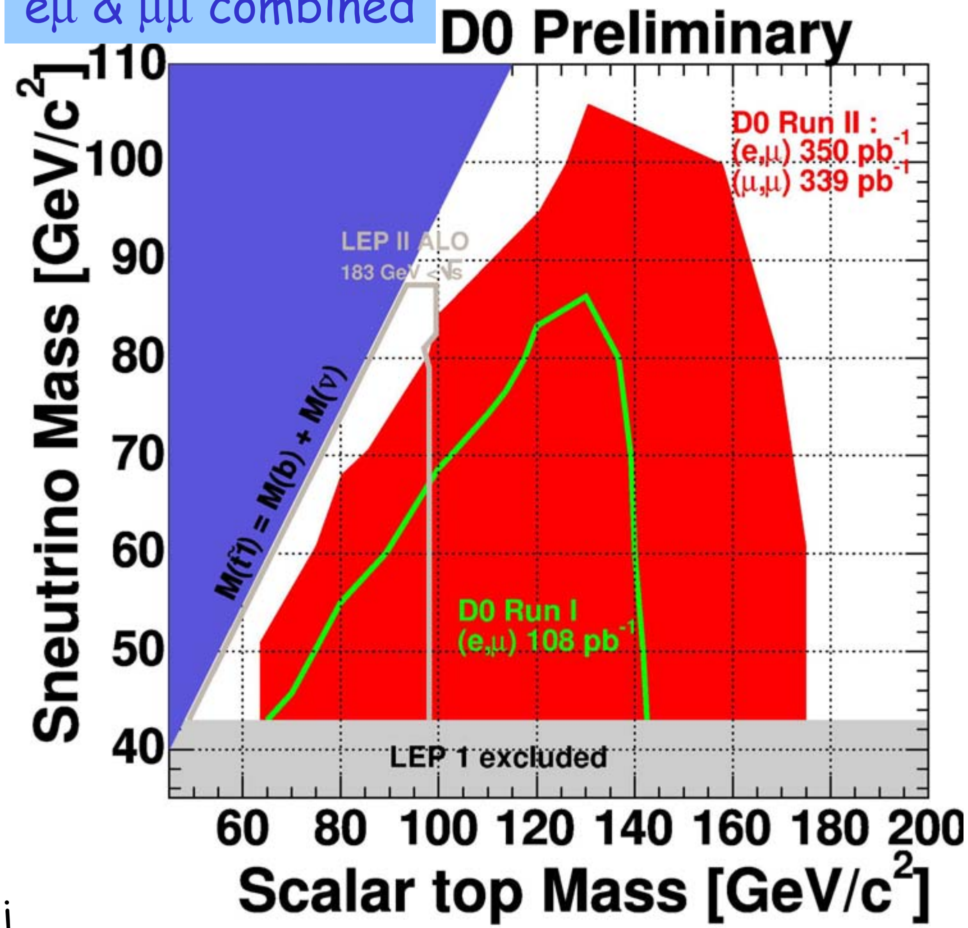


$S_T = p_T(e)+p_T(\mu)+MET$



no excess seen ...

eμ & μμ combined

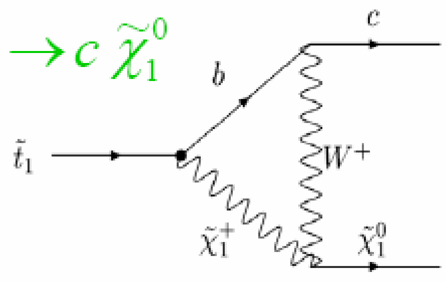


Stop

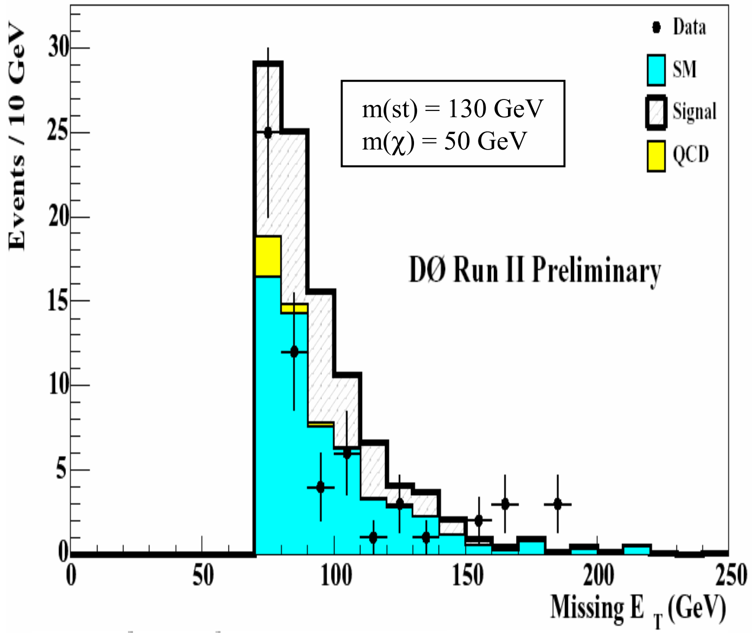
SELECTION:
- 2 jets
  $\geq$ 1 c-jet ("loose" b-tag)
- MET
- optimization on jet p_T's, MET and $\Delta\phi$(j,MET) for various (m(st),m_χ)

SIGNAL:
- stops pair produced (strong inter.)
- if st NLSP and χ LSP
  m(st) < $m_b + m_W + m_\chi$

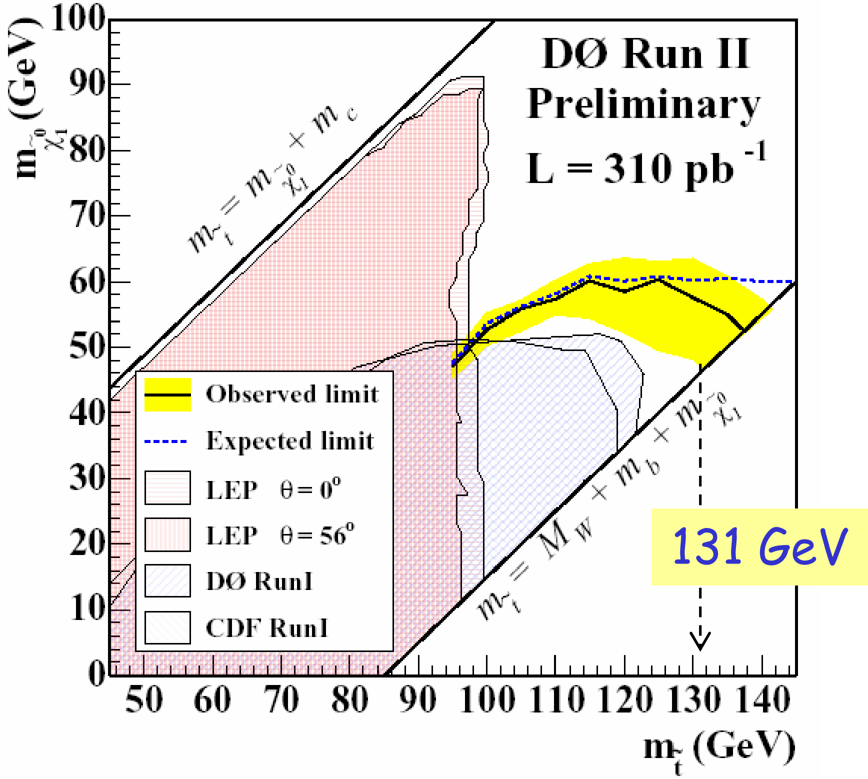
$\tilde{t} \rightarrow c\,\tilde{\chi}_1^0$



BACKGROUND:
Mainly W+jets and Z($\nu\nu$)+jets

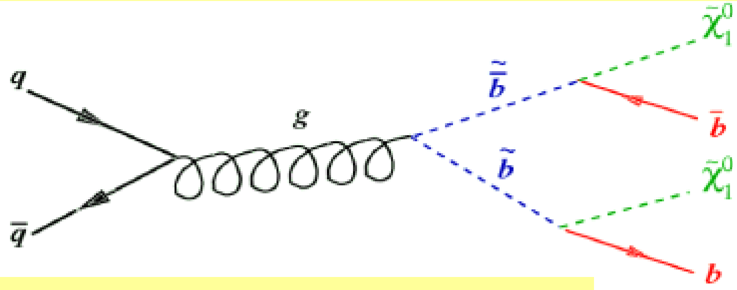


Total SM background	$56.1 \pm 8.3 \pm 9.7$
Instrumental background	3.3 ± 1.6
Total background	$59.4 \pm 8.3 \pm 9.8$
Data events selected	60
Reference signal	$39.5 \pm 2.0 \pm 4.8$



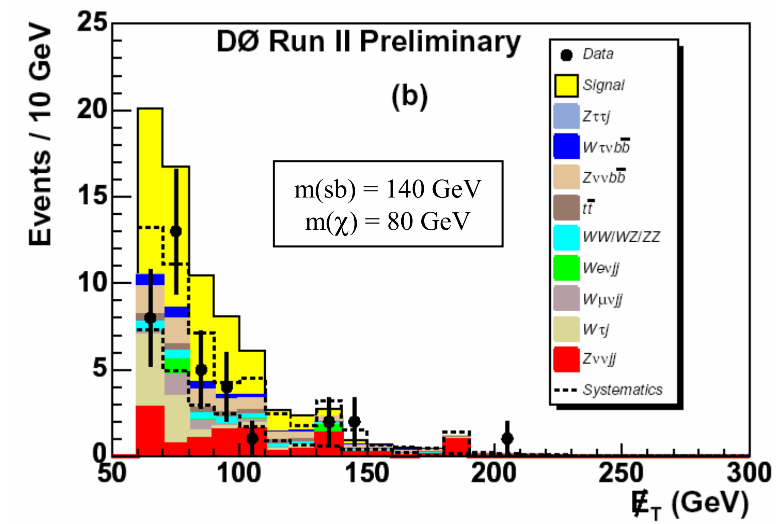
Sbottom

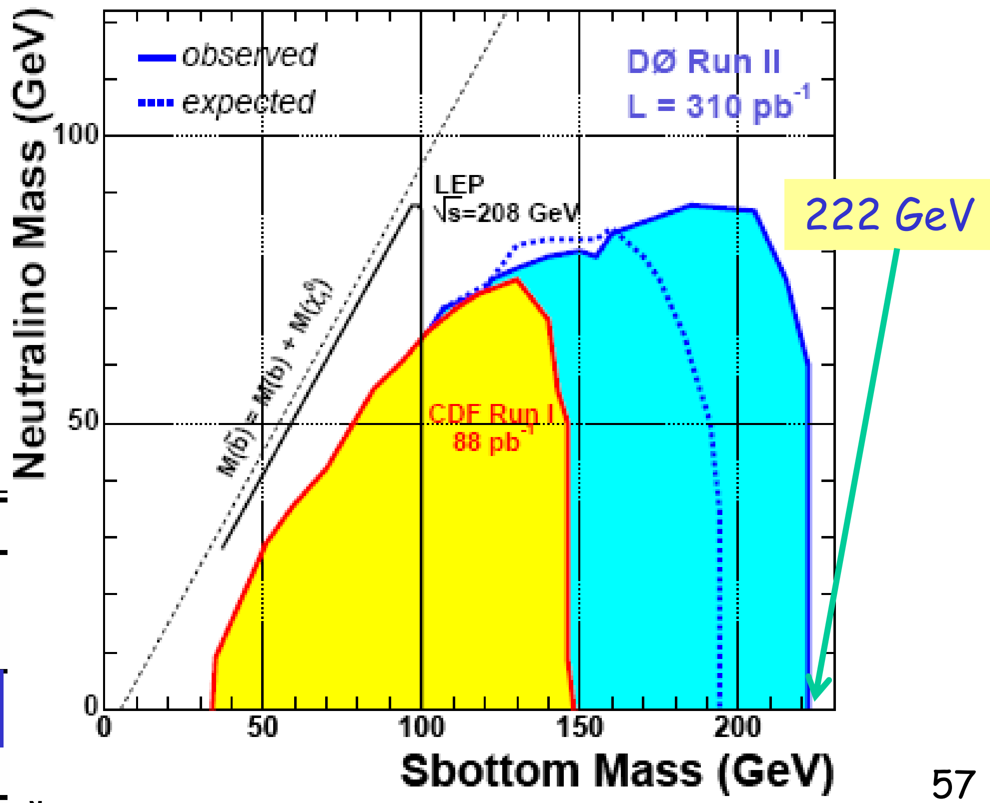
SIGNAL:
- sbottoms pair produced (strong inter.)
- χ LSP and B(sb->χ+b) = 100%



SELECTION:
- 2 or 3 jets (≥ 1 jet b-tagged)
- MET
- veto on isolated leptons/tracks
- angle between jets and MET
- optimization on jet p_T's, MET for various (m(sb),m_χ)

BACKGROUND:
Mainly Z($\nu\nu$)+jets, W($\tau\nu$)+jets, and top





$(m_{\tilde{b}}, m_{\tilde{\chi}_1^0})$ in GeV	(180,90)	(215,0)
C1: $\not{E}_T$ [GeV]	60	80
C2: jet 1 p_T [GeV]	70	100
C2: jet 2 p_T [GeV]	40	50
data	7	0
SM	8.9 ± 0.3	3.2 ± 0.2
signal	9.4 ± 0.3	4.6 ± 0.1

R-Parity Violation

possible terms in superpotential

$$W_{R_P} = \frac{1}{2}\lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \frac{1}{2}\lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k$$

$$R = (-1)^{3(B-L)+2s}$$

family indices

lepton number violation

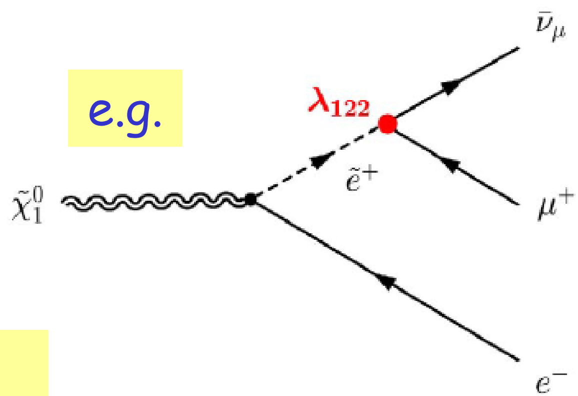
difficult at hadron collider

assume only one RPV coupling ≠ 0 at a time

LLE couplings λ_{ijk}

At pp collider:
- RPC pair production, e.g. $\chi^+\chi^-$, $\chi^0\chi^0$, $\chi^\pm\chi_2^0$, with (cascade) decays to LSP's
- followed by RPV decay

e.g.



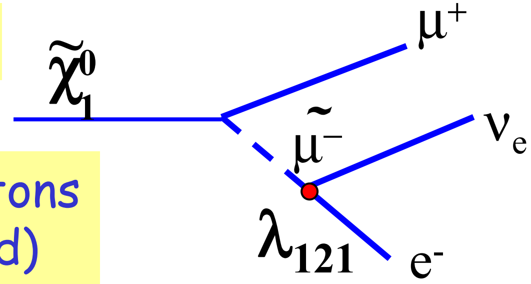
a) $\lambda_{ijk} > O(10^{-2})$: prompt decay
phenomenology independant of coupling

b) $\lambda_{ijk} < O(10^{-2})$: long-lived particule, decay inside detector

RPV: "large" LLE coupling λ_{ijk}

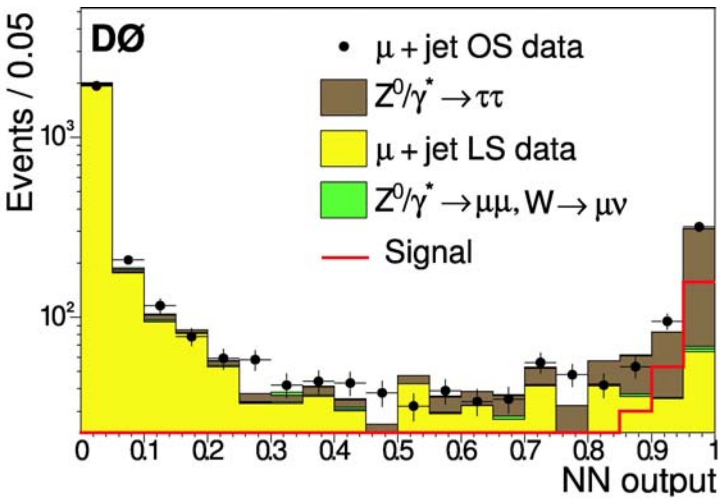
	λ_{121}	λ_{122}	λ_{133}
set value	0.01	0.01	0.003
upper limit	0.5	0.085	0.005

e.g.

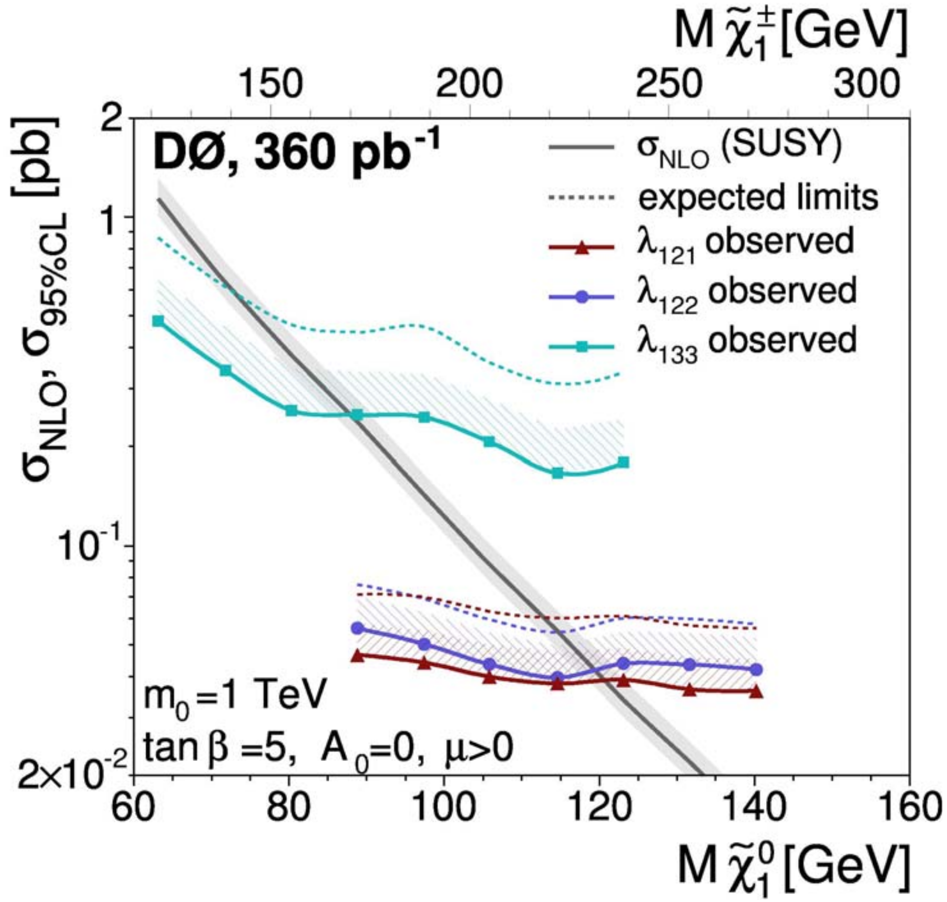


=> 4 charged leptons (only 3 required) and missing-E_T

channel	data observed	bck expected
ee+e/μ	0	0.9±0.4
μμ+μ/e	0	0.4±0.1
τee	0	1.3±1.8

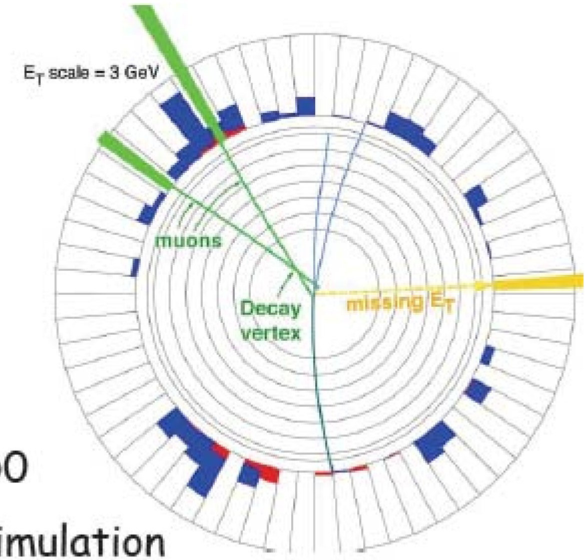


NN τ-ID validated with Z→ττ

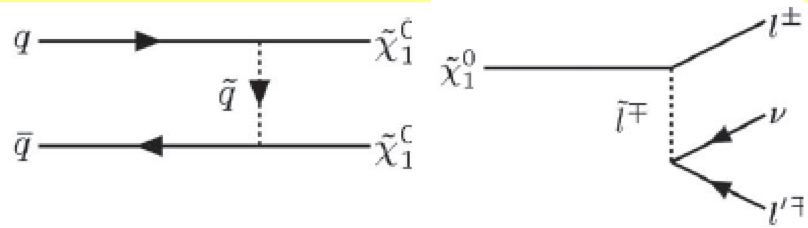


Small LLE coupling: long lived

DØ search motivated by 3 dimuon events in the NuTeV experiment
Production and decay model: SUSY RPV with a small λ_{122}

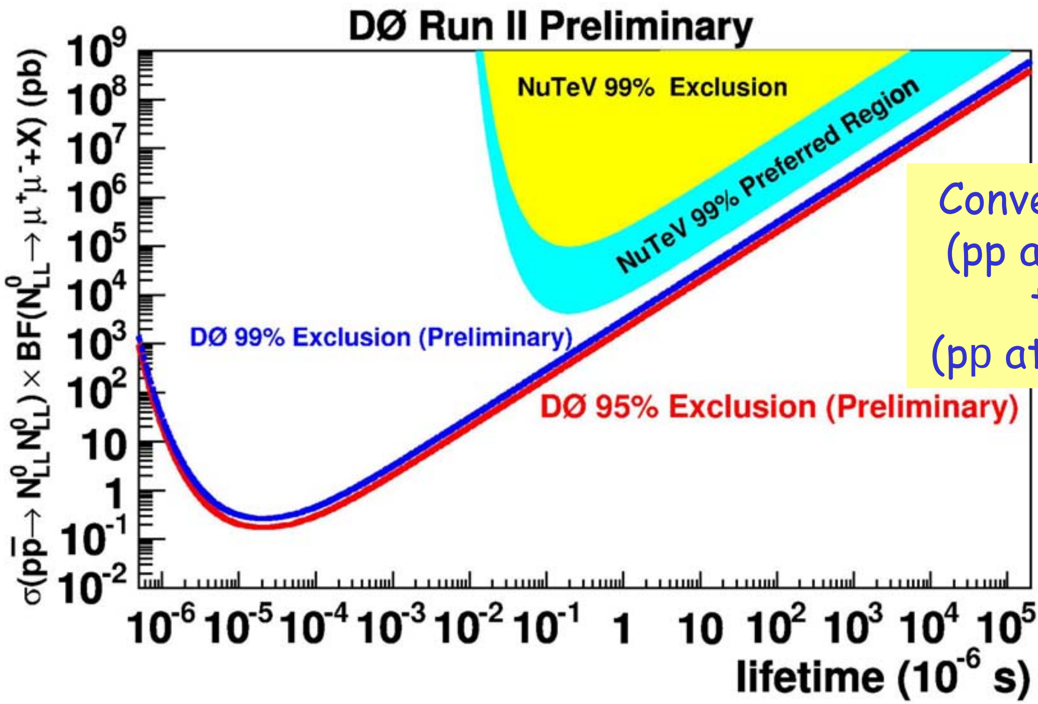


DO simulation



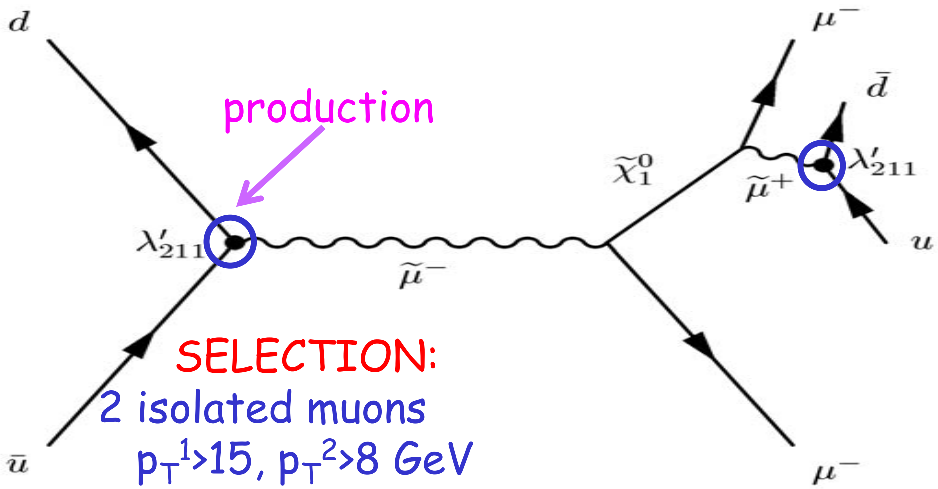
Look for displaced dimuon vertices (5-20 cm)
Calibrate with $K_s \to \pi\pi$ decays

0 data
0.8±1.6 bg.



Convert NuTeV
(pp at 38 GeV)
to DØ
(pp at 1.96 TeV)

RPV: LQD coupling λ'_{ijk}



SELECTION:

2 isolated muons

$p_T^1>15$, $p_T^2>8$ GeV

at least 2 jets, $p_T>15$ GeV

RECONSTRUCT:

$m(\chi_1^0)$ leading μ + 2j

m(sμ) 2μ + all jet

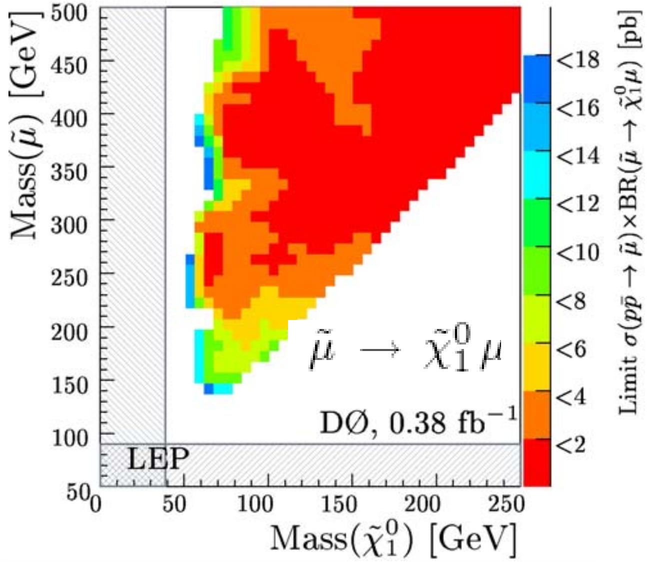
Because of QCD multijets and to be able to reconstruct the neutralino and smuon masses we want at least 2 muons in the final state => 3 channels:

$du \rightarrow \tilde{\mu} \rightarrow \tilde{\chi}_1^0 \mu$ $\quad \tilde{\chi}_1^{\pm} \rightarrow qq'\tilde{\chi}_1^0$

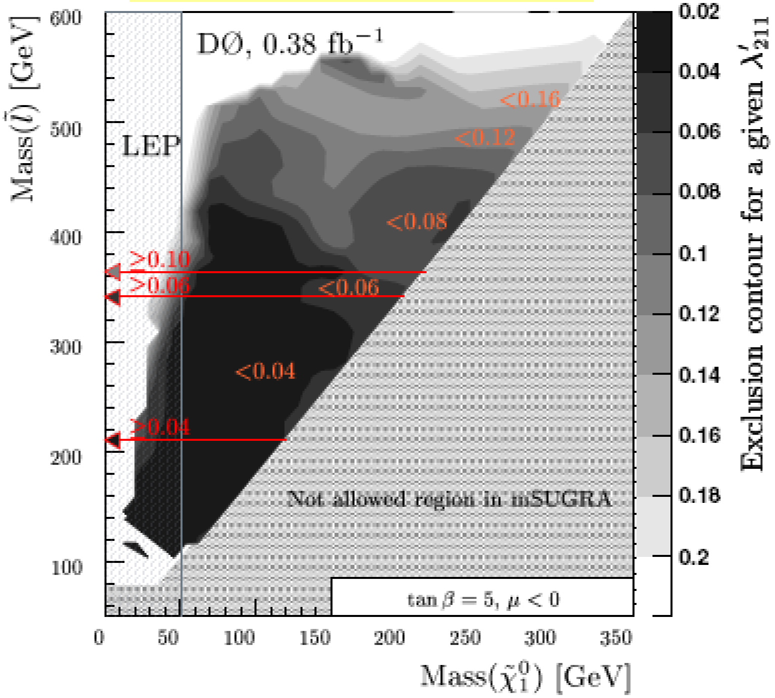
$du \rightarrow \tilde{\mu} \rightarrow \tilde{\chi}_{2,3,4}^0 \mu$ $\quad \chi_{2,3,4}^0 \rightarrow \chi_1^0 qq'q''...$

$dd \rightarrow \tilde{\nu}_\mu \rightarrow \tilde{\chi}_{1,2}^{\pm} \mu$ $\quad \tilde{\chi}_1^0 \rightarrow \mu q_1 \bar{q}'_1$

No signal observed => Exclusion for mass and coupling derived



all channels combined



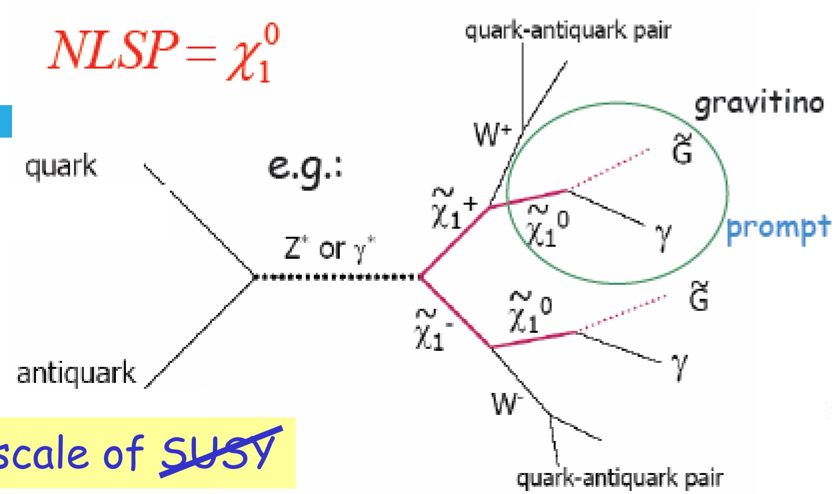
Excluded slepton mass range	Coupling strength
$m(\tilde{l}) \leq 210$ GeV	for $\lambda'_{211} \geq 0.04$
$m(\tilde{l}) \leq 340$ GeV	for $\lambda'_{211} \geq 0.06$
$m(\tilde{l}) \leq 363$ GeV	for $\lambda'_{211} \geq 0.10$

GMSB: 2 γ + MET

SELECTION:
- 2 central photons ($|\eta| < 1.1$), $E_T > 25$ GeV
- MET > 45 GeV
- if jets, $\Delta\phi(j, MET) < 2.5$

BACKGROUND:
Essentially instrumental
- QCD with real photons or jets mis-identified as photons
- $W(e\nu)+\gamma$, $W(e\nu)+j$ with e,j mis-identified as photons

$NLSP = \chi_1^0$



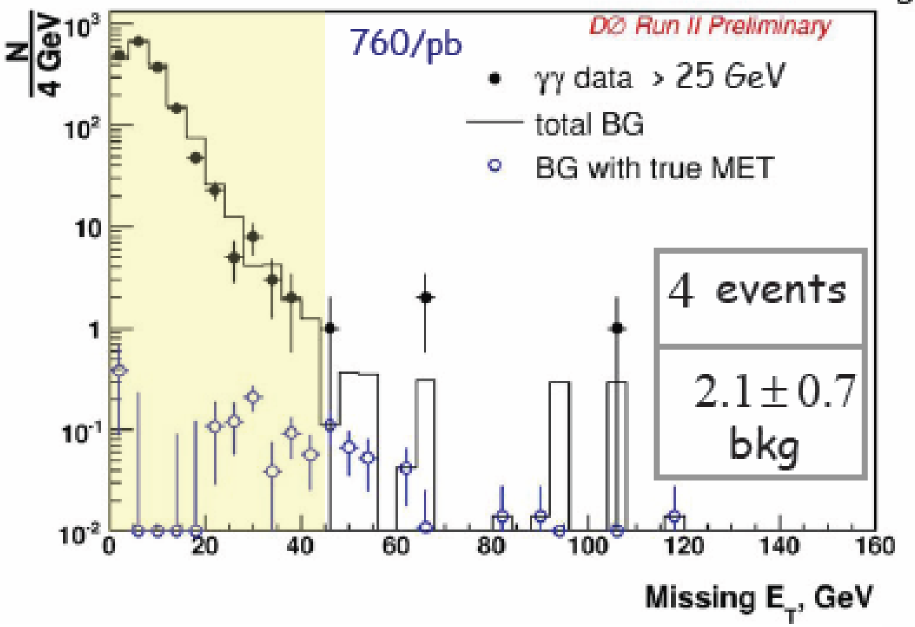
effective scale of ~~SUSY~~

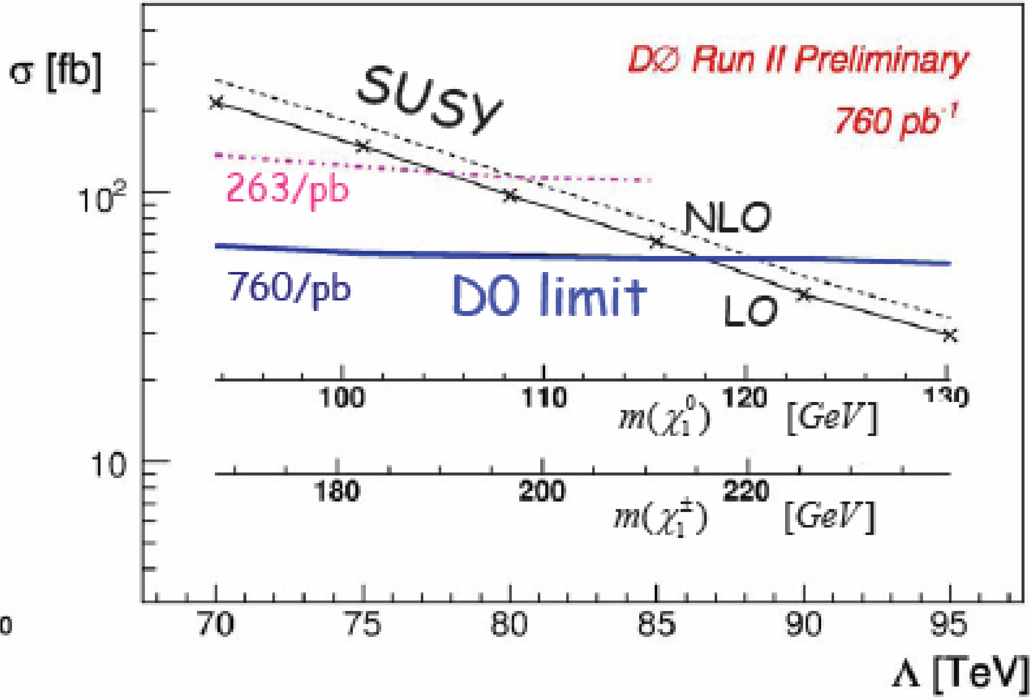
$M_m = 2\Lambda \qquad N_m = 1$

$\tan\beta = 15 \qquad \mu > 0$

SPS8

$m(\chi_1^0) > 120$ GeV
$m(\chi_1^\pm) > 220$ GeV





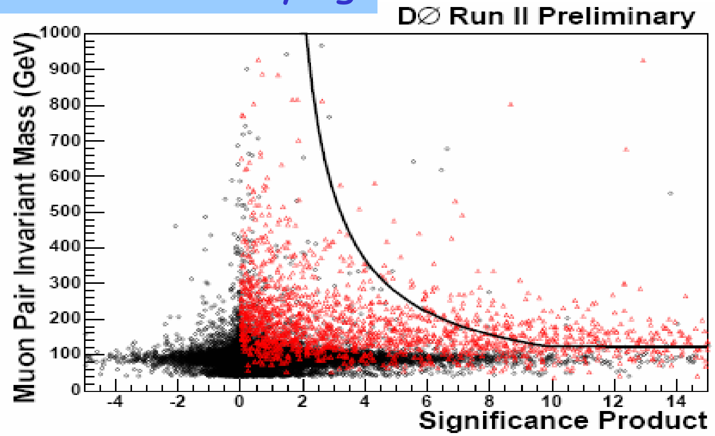
"Stable" lightest chargino

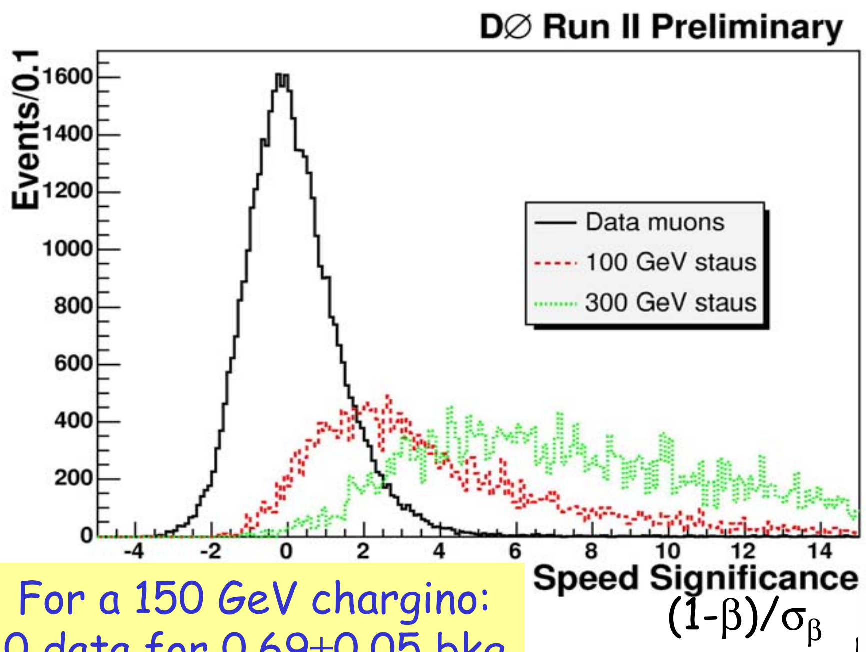
Stable = escapes the detector before decaying

Expected in some AMSB models with small $\chi_1^{\pm} - \chi_1^0$ mass difference
Pair produced => would appear in DØ as slowly-moving "muons"
=> Make use of the time information of the muon system scintillators

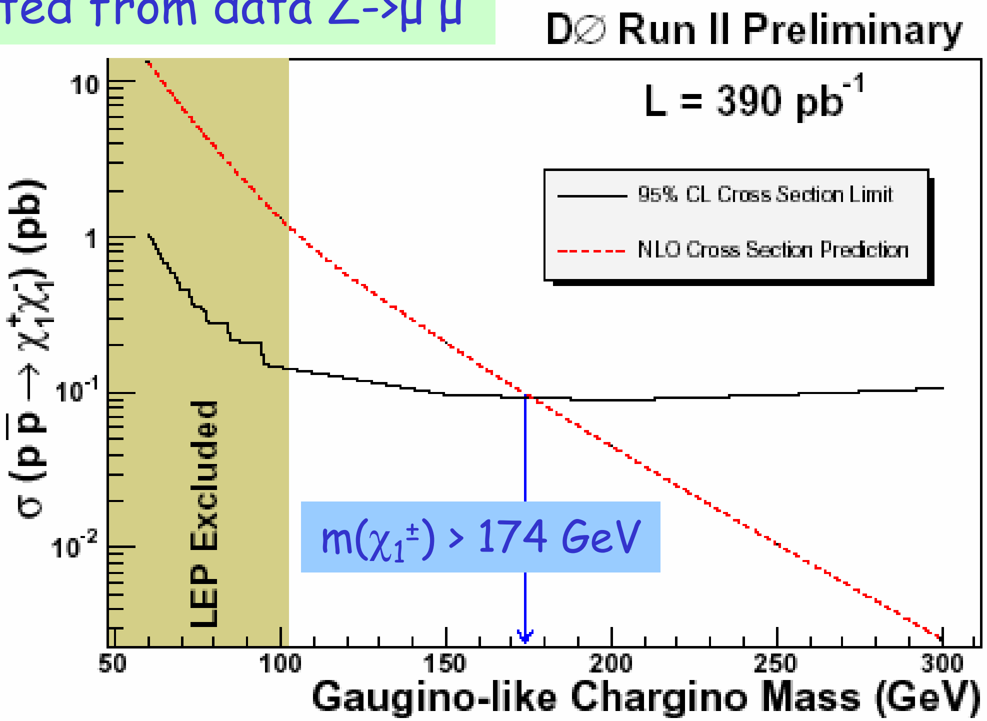
SELECTION:
-2 muons
- cosmics veto
- $p_T > 15$ GeV
- $\Delta\phi(\mu,\mu) > 1.0$

BACKGROUND:
muons w/ mismeasured time
estimated from data Z->μ μ





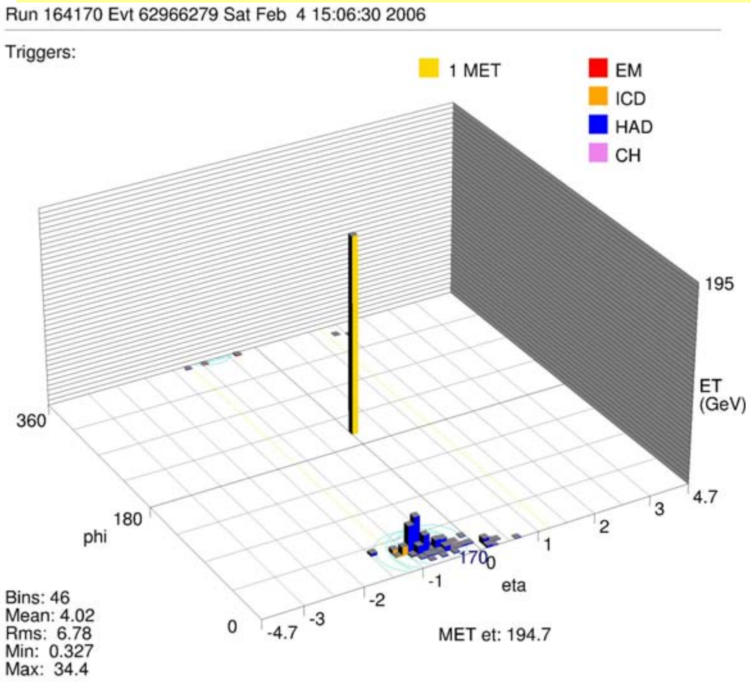
For a 150 GeV chargino:
0 data for 0.69±0.05 bkg

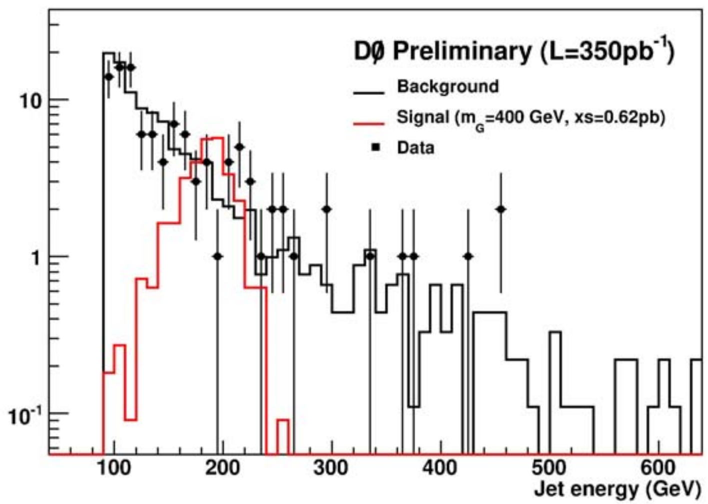


Stopped gluinos

In "Split-SUSY", squarks are very-heavy => long-lived gluinos. Such gluinos form R-hadrons which may stop in the DØ calorimeter. After a while, they decay into e.g. a gluon + χ_1^0 (q-qbar-χ_1^0 also possible).

(A. Arvanitaki et al., arXiv:hep-ph/0506242)





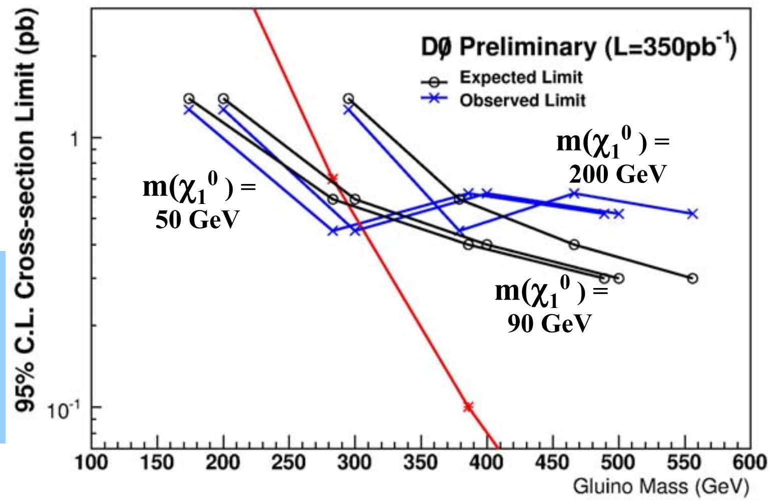
BACKGROUND:
beam and cosmic muons, estimated in data.

for sg -> g + χ_1^0

$$M_g = E + \sqrt{E^2 + M_{LSP}^2}$$

SELECTION:
look for a randomly oriented monojet in empty event (diffractive trigger)
- Central Jet in $|\eta|<0.9$
- 90 GeV < E < 900 GeV
- Δh and $\Delta\varphi$ of jet > 0.08 (wide jet)

Excludes gluino masses up to 300 GeV



SUSY Higgs

Higgs bosons in MSSM

- 2 complex Higgs doublets: H_u (H_d) couple to up- (down-) type fermions
- 8 Degrees of Freedom minus $W^{+/-}$, Z^0 longitud. polar. states
  ➔ 5 scalars predicted: h, H, A, H^+, H^-
- At tree-level, 2 independent params: m_A and $\tan\beta = \langle H_u \rangle / \langle H_d \rangle$
- 5 more params from rad. corrections
  - M_{SUSY} (mass scale of SUSY particles)
  - $X_t = A_t - \mu \cos\beta$ (stop mixing)
  - M_2 (gaugino mass term)
  - μ (Higgs mass parameter)
  - m_{gluino} (comes in via loops)

At high $\tan\beta$:

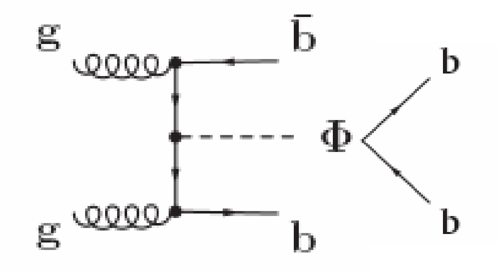
- Coupling of h/H/A ($\equiv\Phi^0$) with 'down'-type quark (e.g. bottom) quark and leptons enhanced over the SM by a factor $\tan\beta$
- A is almost degenerate with h/H
  - $\sigma(A) \approx \sigma(h/H)$, $\Gamma(A) \approx \Gamma(h/H)$
  - $Br(A\to bb) \approx Br(h/H\to bb) \sim 90\%$
  - $Br(A/h/H\to\tau^+\tau^-) \sim 10\%$

To search for Φ^0:
$\Phi^0 b(b)\to bbb(b)$ and $\Phi^0 X \to \tau^+\tau^- X$

m_h^{max}-scenario:
maximal $m_h(\tan\beta)$ for fixed m_t, M_{SUSY}

no-mixing scenario:
no mixing in scalar top sector

	m_h-max	no-mixing
M_{SUSY}	1 TeV	2 TeV
X_t	2 TeV	0
M_2	200 GeV	200 GeV
μ	±200 GeV	±200 GeV
m_g	800 GeV	1600 GeV



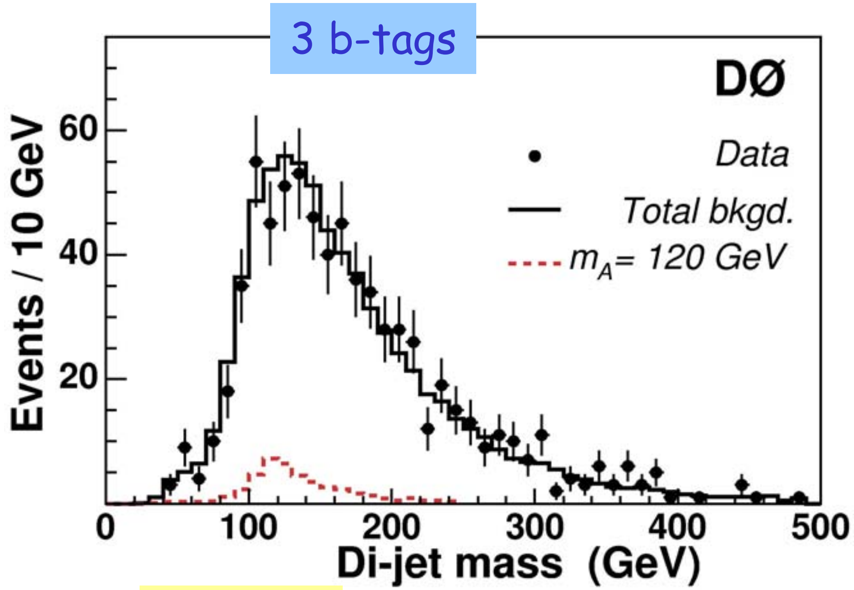
Search for b(b)ϕ^0(->bb)

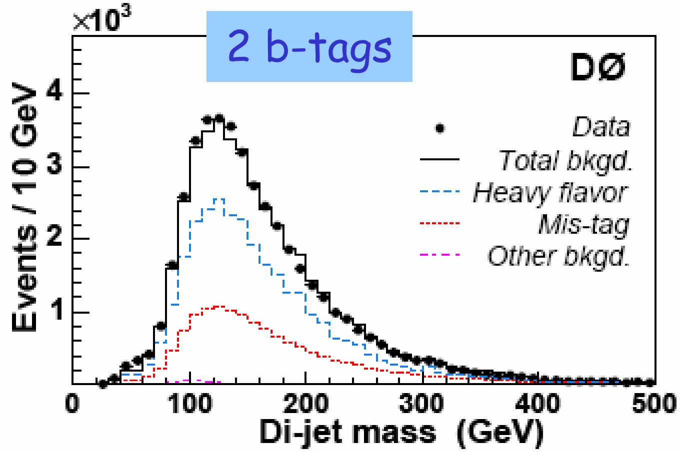
Start from large multijet trigger sample

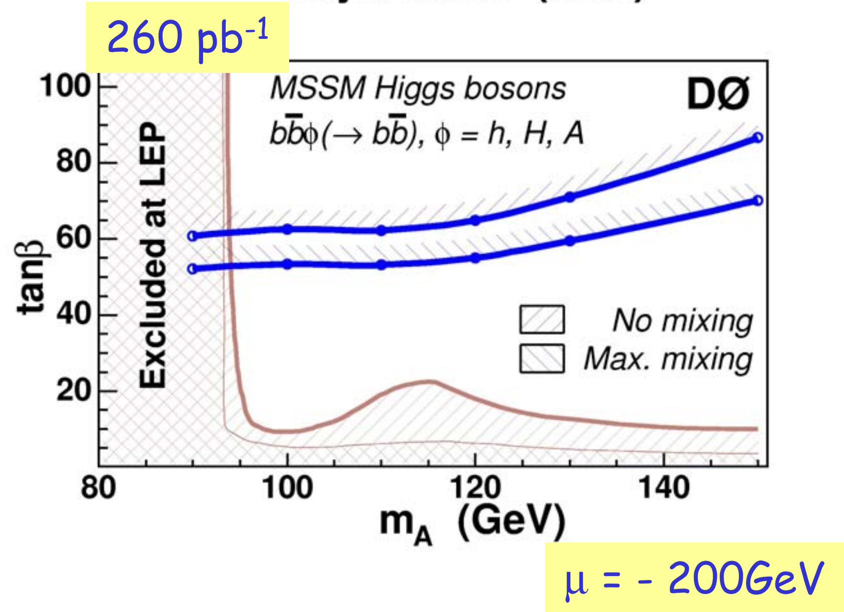
Require at least 3 jets w/ displaced secondary vertex

Form invariant mass of two leading b-jets, look for a bump

Shape and normalization of bkg determined from double-tagged data







Higgs bosons in the MSSM

Model dependence

Higher order corrections can be significant ...

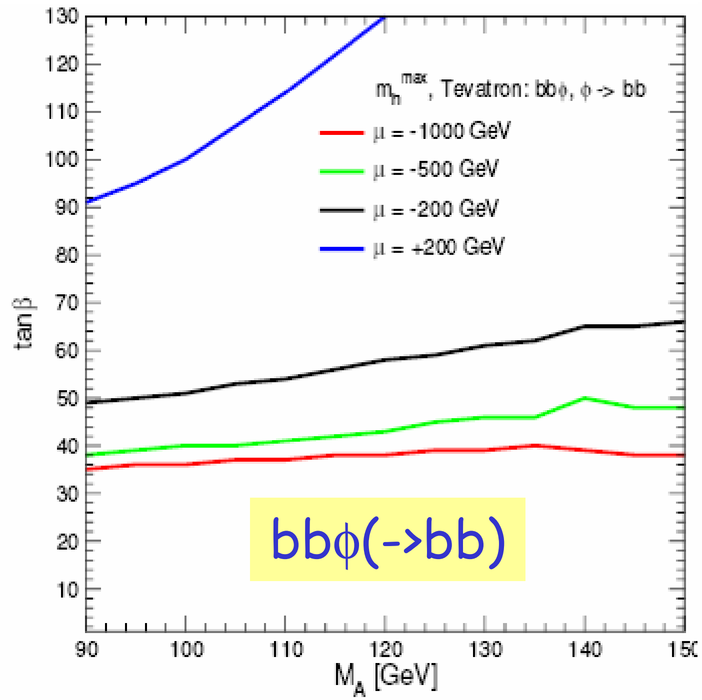
on previous slide ...
μ = - 200 GeV
m_h^{max} better than no-mix
m_h^{max}: Δ_b = -0.21
no-mix: Δ_b = -0.10

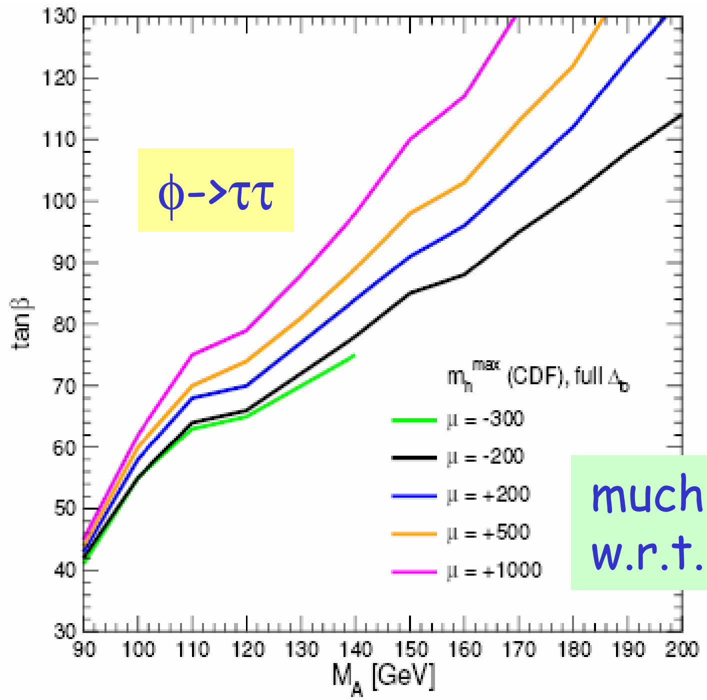
SUSY loops => corrections to bottom Yukawa coupling

$$y_b \sim \frac{m_b}{1+\Delta_b}$$

$$\Delta_b = \frac{2\alpha_s}{3\,\pi}\, m_{\tilde{g}}\, \mu\, \tan\beta \times I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}}) + \frac{\alpha_t}{4\,\pi}\, A_t\, \mu\, \tan\beta \times I(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu)$$

coupling enhanced for $\Delta_b < 0 \Leftrightarrow \mu < 0$

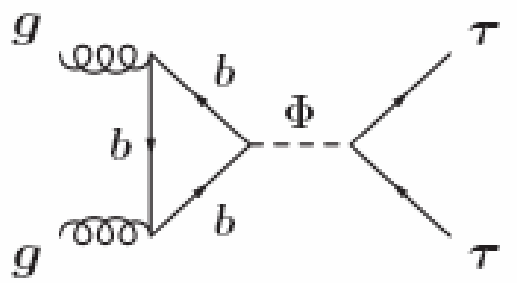




much more stable w.r.t. variation of μ

[M. Carena, S. Heinemeyer, C. Wagner, G. W. '05]

Search for $\phi^0(\rightarrow\tau\tau)$



Analysis	$e\tau_h$	$\mu\tau_h$	$e\mu$
Data	484	575	41
QCD	199 ± 26	62 ± 7	2.1 ± 0.4
$Z/\gamma^* \to \tau\tau$	203 ± 26	492 ± 53	39 ± 5
$Z/\gamma^* \to ee,\mu\mu$	10 ± 1	5 ± 1	0.6 ± 0.1
$W \to e\nu,\mu\nu,\tau\nu$	14 ± 2	14 ± 2	0.3 ± 0.2
Di-boson	0.5 ± 0.1	3.1 ± 0.3	1.0 ± 0.1
$t\bar{t}$	0.4 ± 0.1	1.2 ± 0.2	0.06 ± 0.02
Total expected	427 ± 55	576 ± 62	44 ± 5
Efficiency %	4.8 ± 0.4	8.6 ± 0.8	4.3 ± 0.5

Combination of three channels:
$e+\tau_h$, $\mu+\tau_h$, $e+\mu$

Hadronic taus (τ_h) identified with NN

"visible" mass

$$M_{\text{vis}} = \sqrt{(\underbrace{P_{\tau_1} + P_{\tau_2}} + \not{P}_T)^2}$$

$\not{P}_T = (\not{E}_T, \not{E}_x, \not{E}_y, 0)$

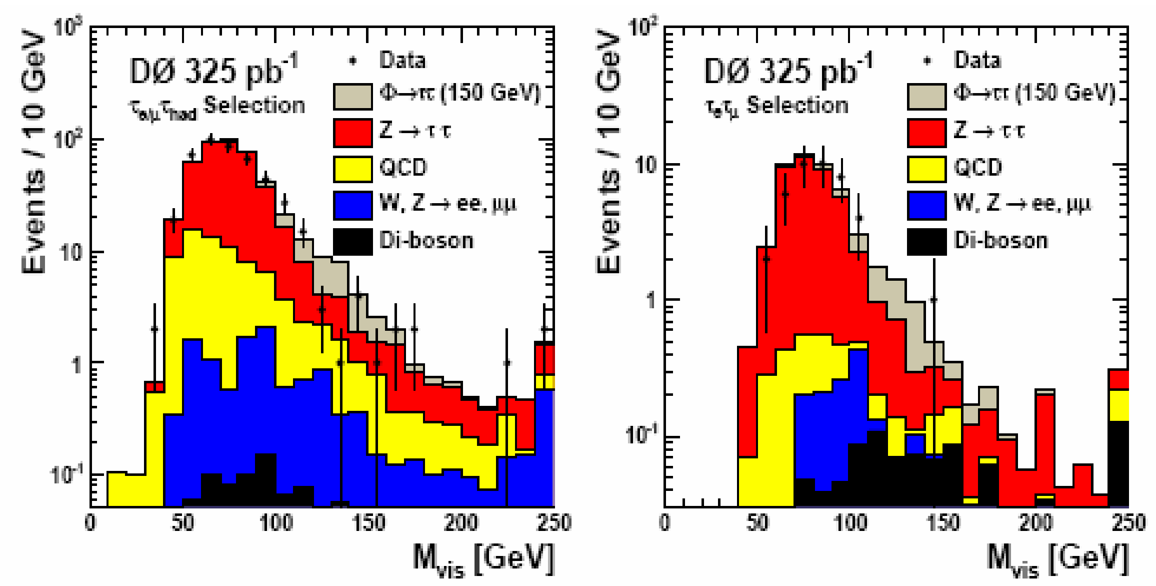
4-vec of visible τ's decay prod.

$$M_W^{e/\mu} = \sqrt{2\, E^\nu\, E^{e/\mu}\, (1-\cos\Delta\phi)}$$

$$E^\nu = \not{E}_T \cdot E^\ell / E_T^\ell$$

$$M_T^{e/\mu} = \sqrt{2\, p_T^{e/\mu}\, \not{E}_T\, (1-\cos\Delta\phi)}$$

$M_W^{e/\mu} < 20$ GeV
$M_T^{e/\mu} < 10$ GeV
to reduce W+jets bkg
$H_T < 70$ GeV
to reduce tt bkg

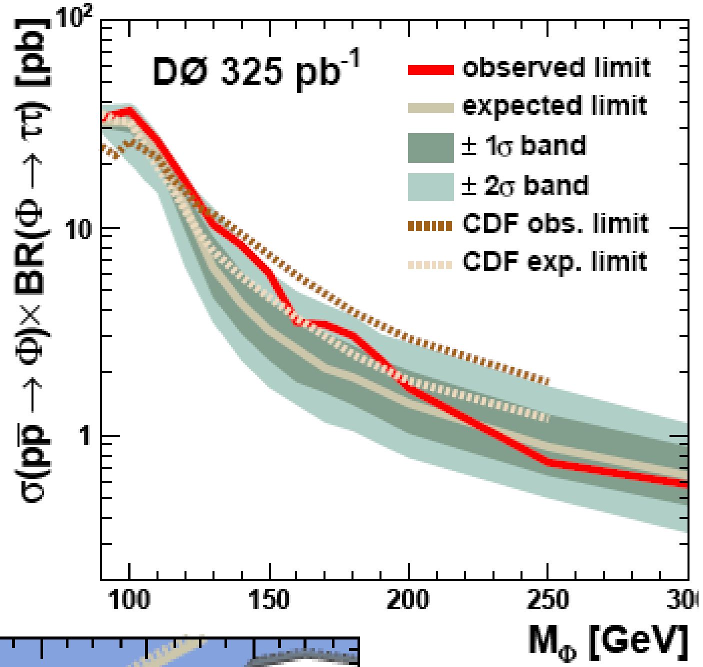


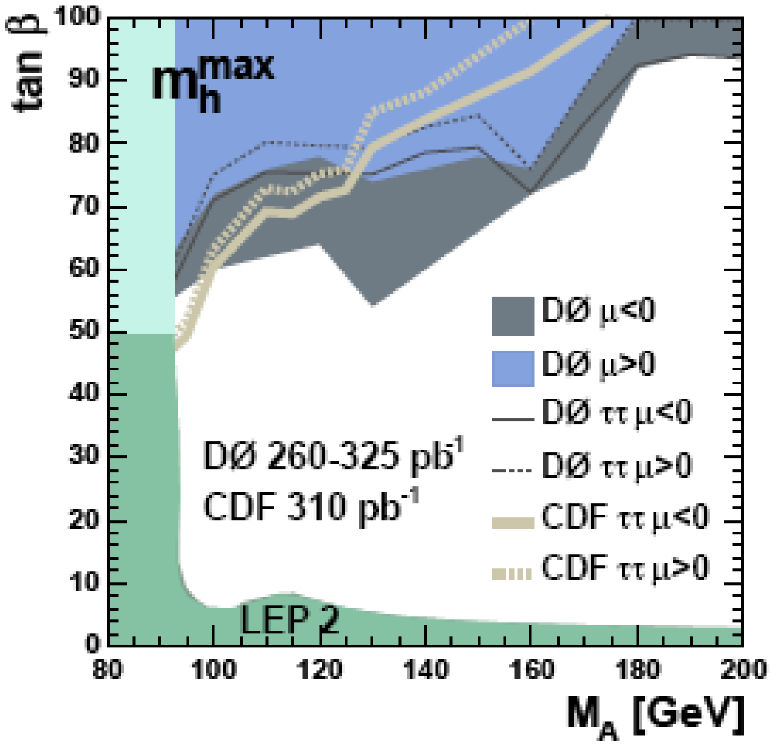
CERN 12/09/06

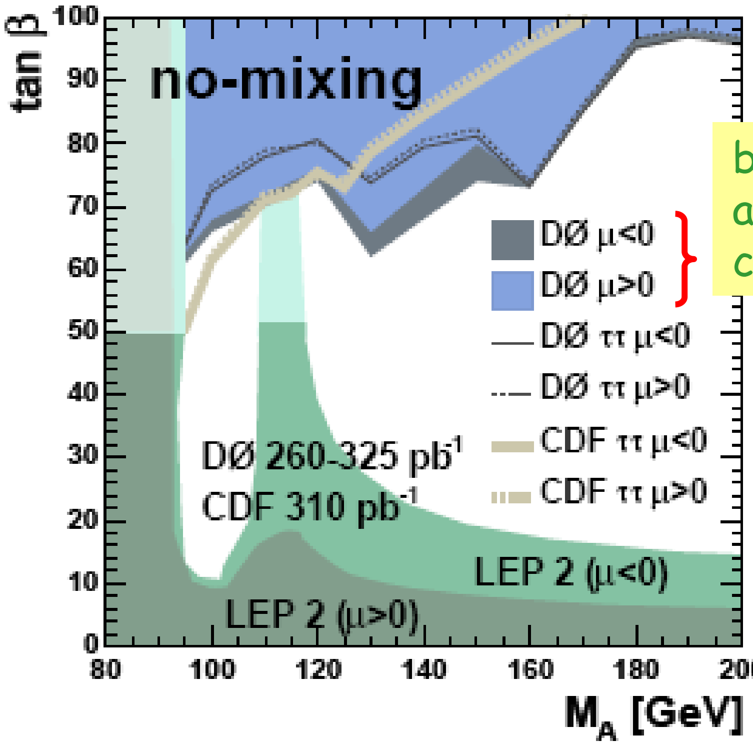
Search for $\phi^0(\to\tau\tau)$

Number of observed events consistent with background => limits at 95% CL

Estimated using M_{vis} distribution for subdivided samples:
- 3 types of τ's
- $M_W^{e/\mu} < 6$ GeV et $6 < M_W^{e/\mu} < 20$ GeV







$b(b)\phi^0(\to bb)$ and $\phi^0(\to\tau\tau)$ combined

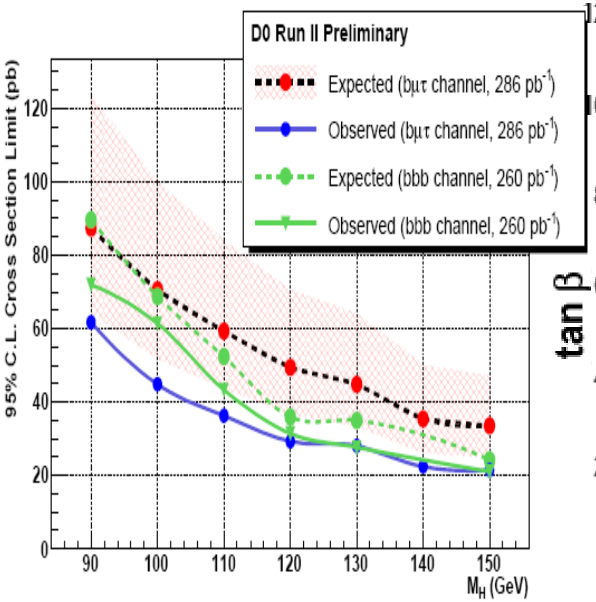
Search for $b(b)\phi^0(->\tau\tau)$

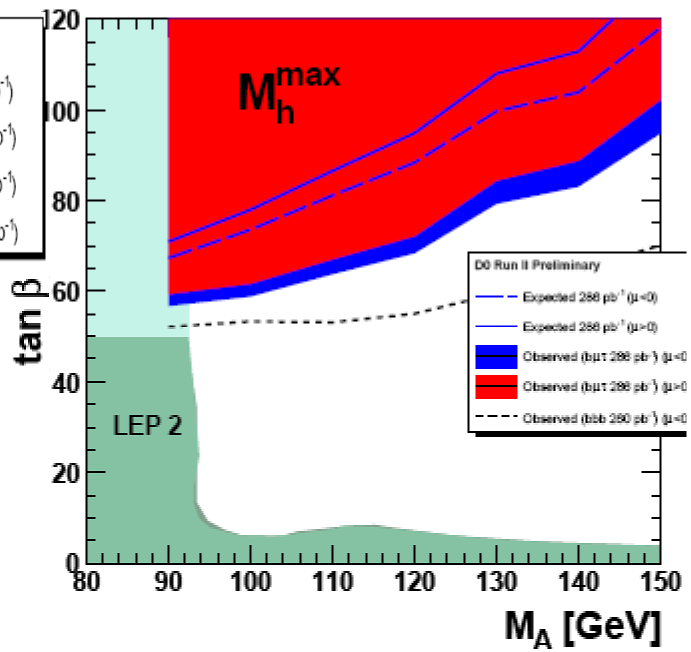
Look for: $\tau(->\mu\nu_\mu\nu_\tau)+\tau_h$
Hadronic tau (τ_h)
identified with NN
At least 1 b-jet (JLIP)
$|\eta|$ < 2.5 and E_T > 15 GeV

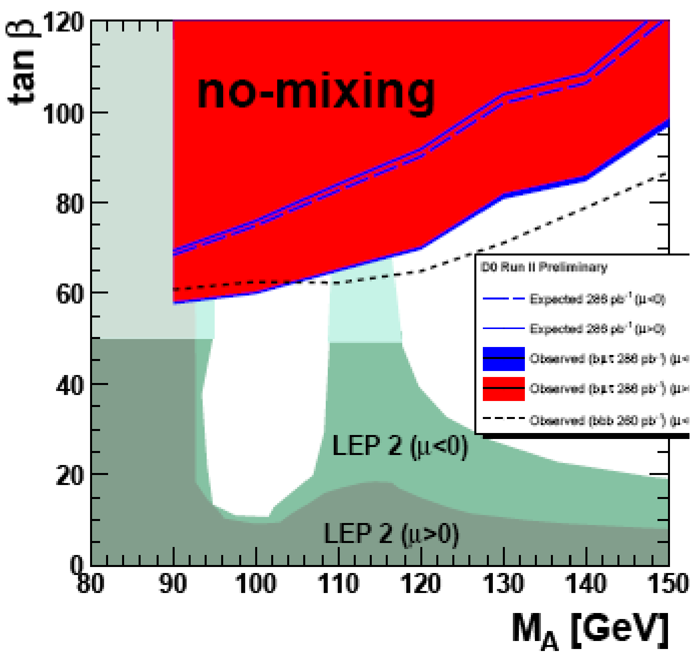
no excess seen ...

even though $B(\phi->bb)/B(\phi->\tau\tau)$ ~ 9
same sensitivity almost achieved

	Type 1	Type 2	Type 3
Signal Accept. (%)	0.15 ± 0.03	0.87 ± 0.11	0.30 ± 0.04
Expected Signal	0.6 ± 0.1	3.5 ± 0.5	1.2 ± 0.2
QCD	0.62 ± 0.22	0.51 ± 0.14	1.45 ± 0.18
Z+jet	0.34 ± 0.09	1.6 ± 0.3	0.35 ± 0.10
$t\bar{t}$ (di-l)	0.18 ± 0.03	0.50 ± 0.11	0.007 ± 0.0013
$t\bar{t}$ (l+jet)	0	0.008 ± 0.008	0.15 ± 0.04
W+jj	0.005 ± 0.005	0.05 ± 0.02	0.40 ± 0.14
W+cc	0.003 ± 0.002	0	0.003 ± 0.003
W+bb	0	0	0.016 ± 0.010
WW	0	0.010 ± 0.002	0.0013 ± 0.0004
Total Background	1.2 ± 0.2	2.6 ± 0.3	2.5 ± 0.2
Observed	0	1	2



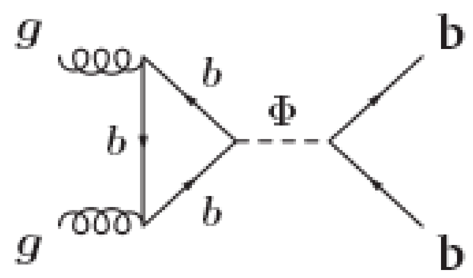


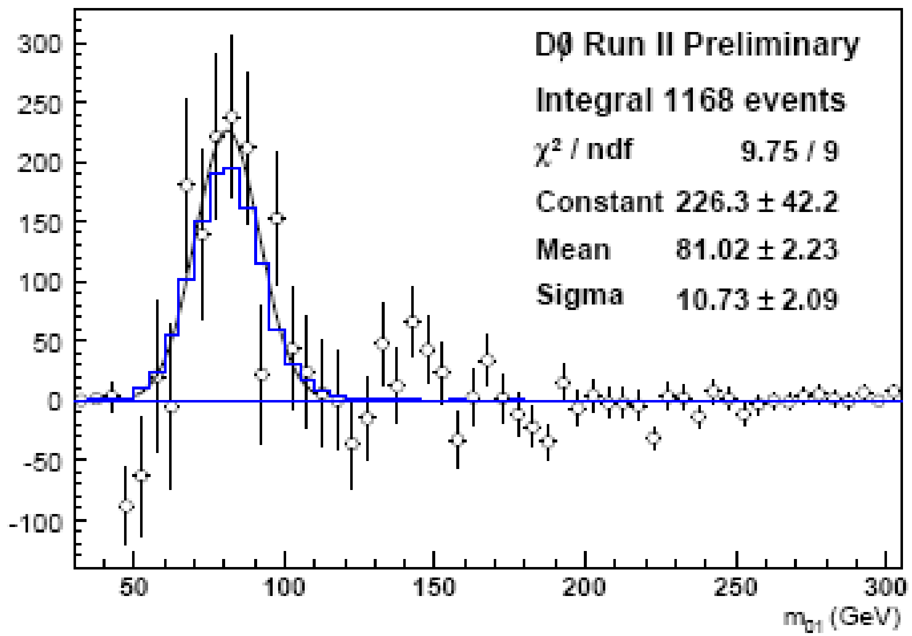


Higgs bosons in the MSSM

In the process of combining the differents channels:
bbb(b) b(b)ττ and ττ

More input to consider in the long term





At the limit set by h-> ττ for m_h=140 GeV, expect about 30 events from h->bb in Z->bb analysis ☺

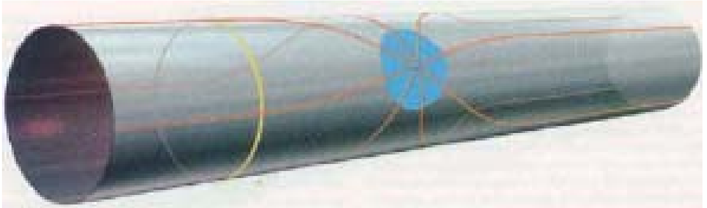
Extra dimensions

Extra Dimensions: LED Model

n extra dims and SM fermions live on a D3-brane

Large Extra Dimensions (LED) Arkani-Hamed, Dimopoulos, Dvali Phys Lett B429 (98)

- $M_{PL} \sim 10^{19}$GeV
- n >= 2 compact and flat - M_S : string/fundamental scale
  $M^2_{PL} \sim R^n M_S^{n+2}$ => M_S can be lowered to TeV scale
- gravitons propagate in the bulk => Kaluza-Klein tower $G^{(k)}$
- can't resolve successive modes
  (0.01eV:n=2; 1MeV:n=3; 100MeV:n=6)



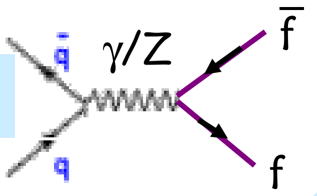
=> expect:

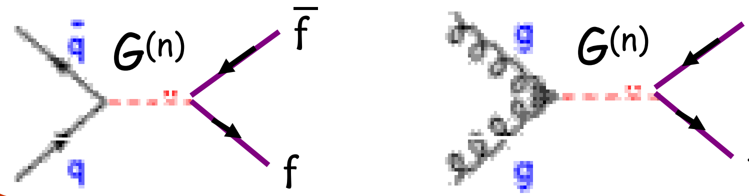
- virtual exchange of graviton KK modes
- real graviton emission

LED: Virtual Graviton Exchange

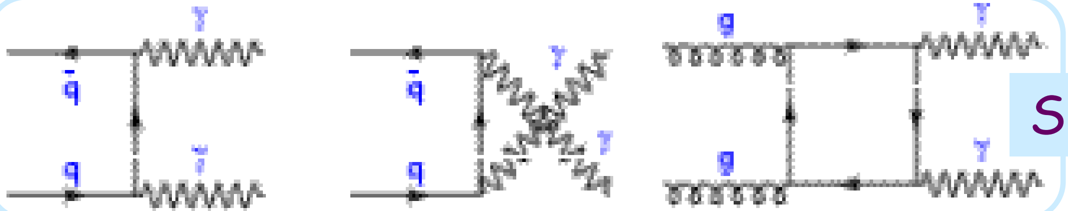
dilepton channel

SM





diphoton channel



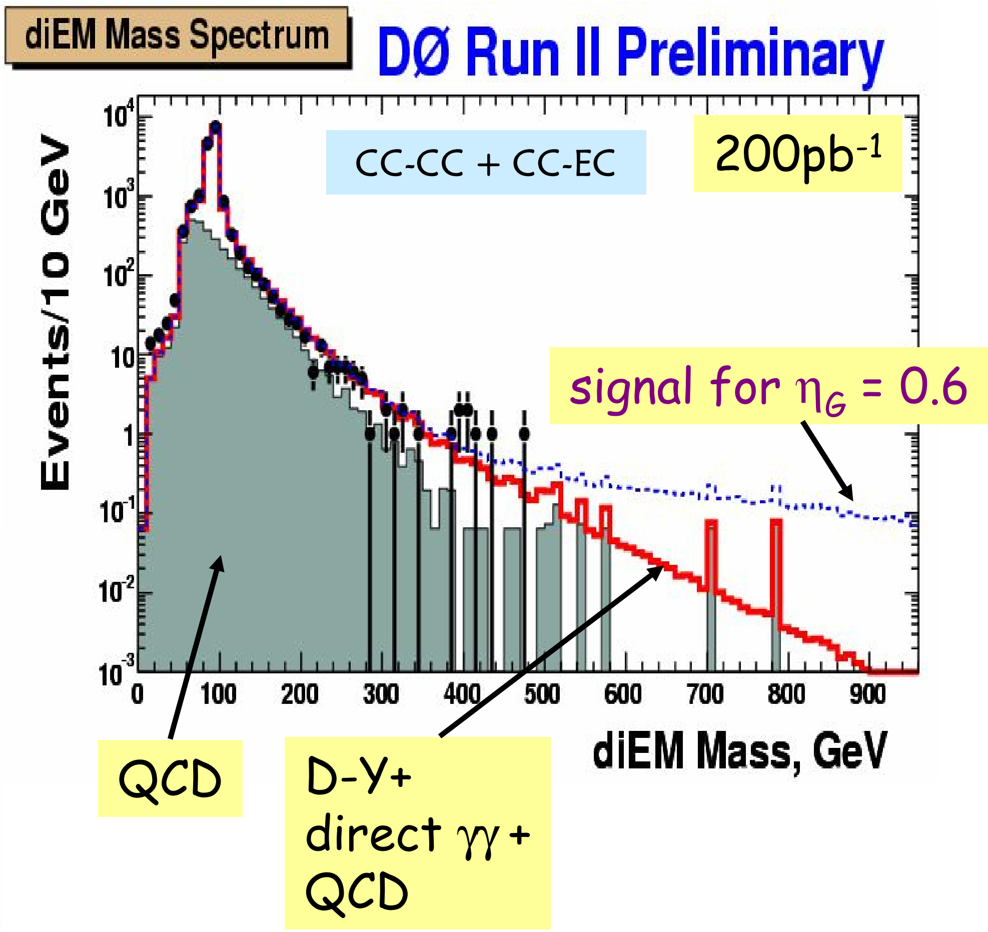
SM

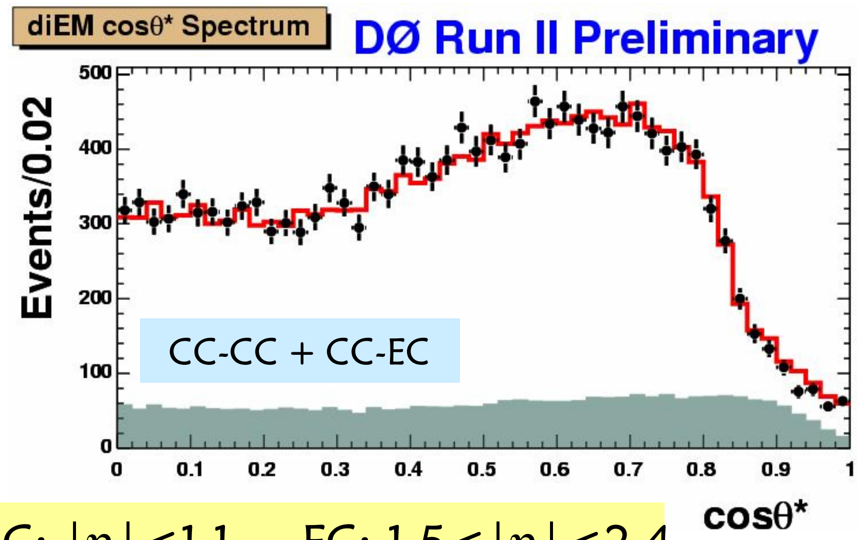
$$\sigma = \sigma_{SM} + \eta_G \sigma_{int} + \eta_G^2 \sigma_{KK}$$

- Effect of ED parameterized by a single variable: $\eta_G = F/ M_S^4$
- different formalisms have different definitions of M_S:
  - **Hewett**: (Hewett, Phys Rev Lett 82, 4765 (99)) $F = 2\lambda/\pi$ with $\lambda = \pm 1$
  - **GRW**: (Giudice, Rattazzi, Wells, hep-ph/9811291) $F=1$
  - **HLZ**: (Han, Lykken, Zhang, hep-ph/9811350) $F = \log(M_S^2/s)$ [n=2]; $F=2/(n-2)$ [n>2]

Large Extra Dimensions: Virtual Graviton Exchange

- diEM = combine ee and $\gamma\gamma$
  - 2 EM objects, E_T > 25 GeV with track isolation
  - overall ID efficiency: 85 ± 1 %
- for M_{diEM} > 350 GeV: N_{exp} = 9.7 (1.6 QCD), N_{obs} = 8
- Systematics: ~ 12%

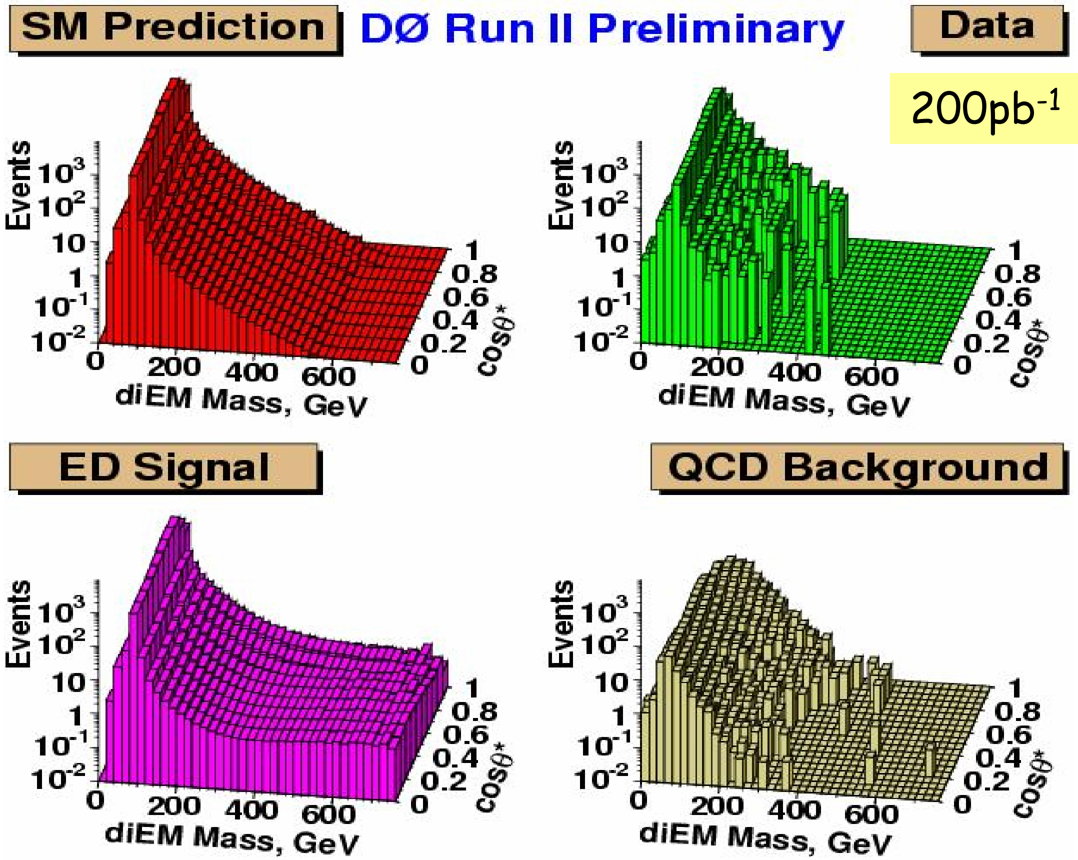




CC: $|\eta|<1.1$ EC: $1.5<|\eta|<2.4$

diEM

Large Extra Dimensions: Virtual Graviton Exchange



Data agree with SM =>
M_{diEM} vs|cosθ*| distrib.
used in 2D Binned Likelihood
=> Limits on η_G
- alone
- combined with Run I

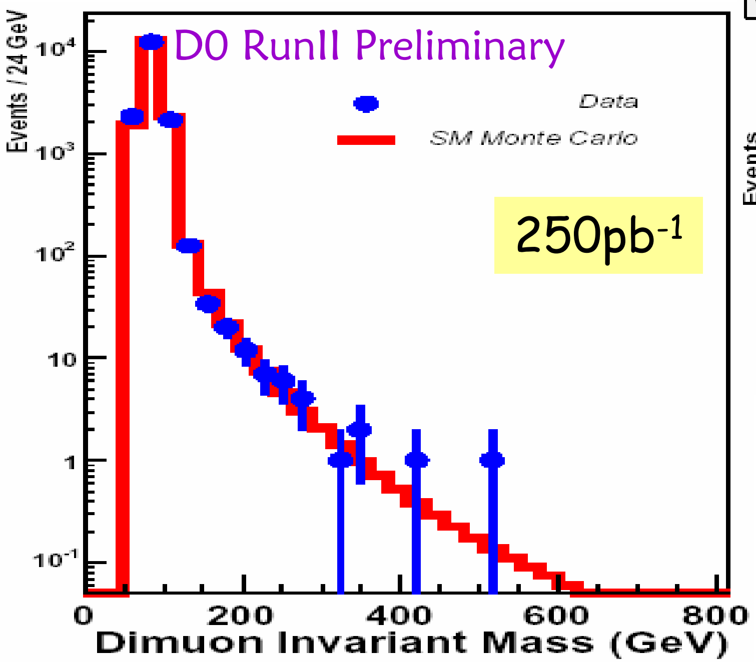
=> 95% CL limits on M_S (TeV)
Most stringent constraints on LED for n > 2 to date among all experiments

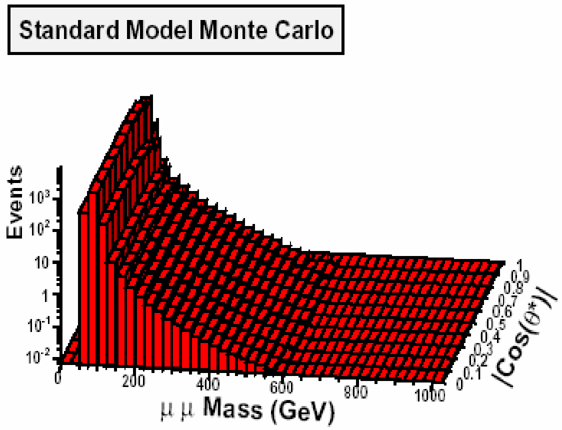
	Hewett		GRW	HLZ					(TeV, @95% CL)
	$\lambda = +1$	$\lambda = -1$		$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$	$n = 7$
Run II	1.22	1.10	1.36	1.56	1.61	1.36	1.23	1.14	1.08
Run I+II	1.28	1.16	1.43	1.67	1.70	1.43	1.29	1.20	1.14

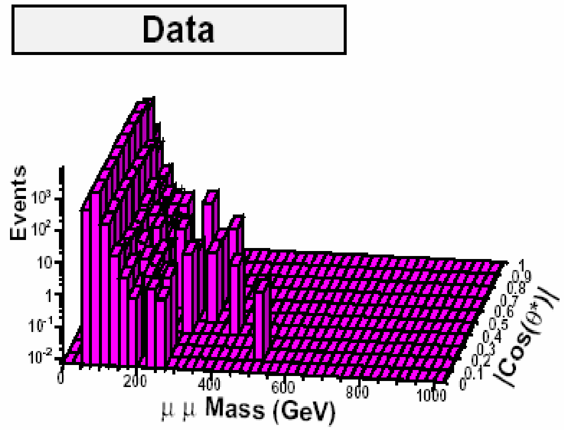
Large Extra Dimensions: Virtual Graviton Exchange

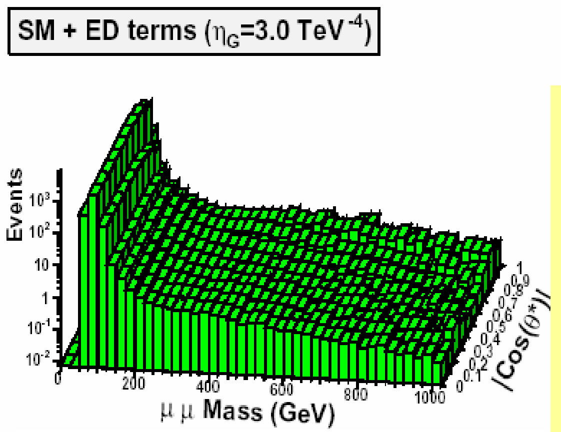
$\mu\mu$

- 2 μ's with P_T > 15 GeV
  - isolated, $|\eta|$<2.0
  - cosmic veto
  - $M_{\mu\mu}$ > 50 GeV
- for $M_{\mu\mu}$ > 300 GeV: N_{exp} = 6.4 and N_{obs} = 5
- Systematics: ~ 13%









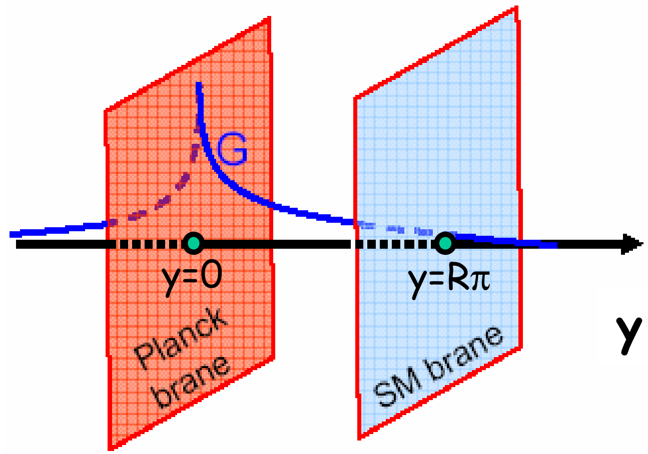
DØ Run II Preliminary

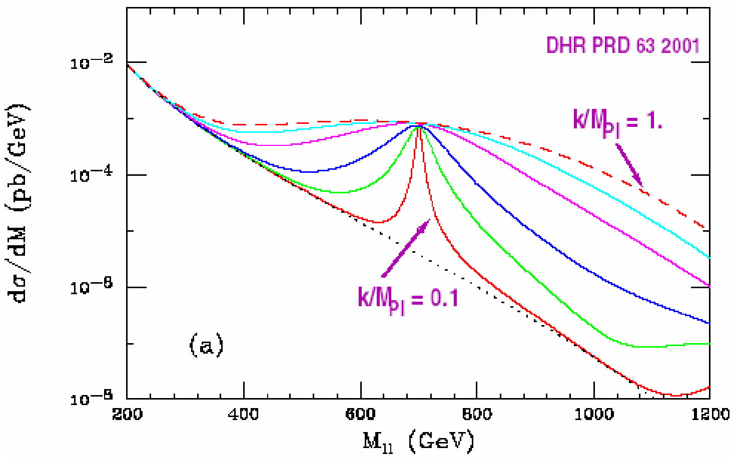
$M_{\mu\mu}$vs|cosθ*| distr. used in 2D Binned Likelihood
=> Set limits on η_G
=> 95% CL limits on M_S (TeV)

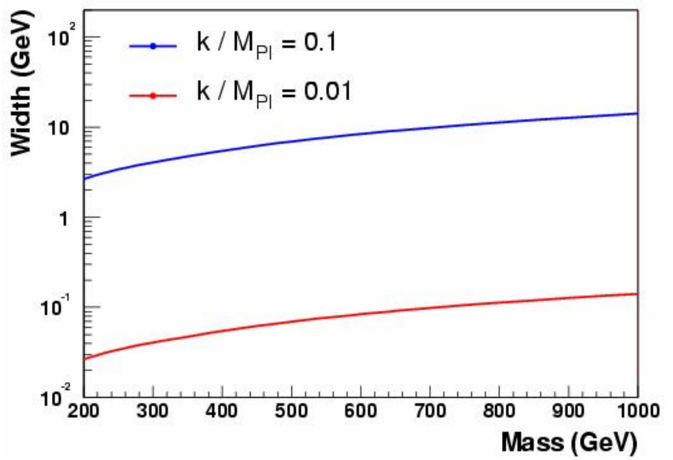
GRW [5]	HLZ [6]						Hewett [7]
	n=2	n=3	n=4	n=5	n=6	n=7	$\lambda = +1/-1$
1.09	1.00	1.29	1.09	0.98	0.91	0.86	0.97/0.95

Extra Dimensions: RS Model

- **Warped Extra Dimension (RS)** Randull,Sundrum Phys Rev Lett 83 (99)
  - ED of size R, highly curved, compactified on S_1/Z_2 orbifold: $y = R\phi$.
  - Zero mode graviton $G^{(0)}$ localized at the Planck-brane ($y = 0$)
  - SM fields localized on TeV-brane ($y = R\pi$)
  - metric: $ds^2 = e^{-2kR\phi}\,\eta_{\mu\nu}dx^\mu dx^\nu - R^2 d\phi^2$
    k: curvature scale
    for $kR \sim 11\text{-}12$, $\Lambda_\pi = M_{PL}e^{-kR\pi} \sim$ TeV
  - consistency => $0.01 < k/M_{PL} < 0.1$
  - Gravitons propagate in the bulk =>
    KK tower $G^{(n)}$ of modes of mass $m_n = x_n k e^{-kR\pi}$
    (x_n: 1st Bessel func. zeros i.e. 3.83, 7.02, 10.1
    => well separated modes
  - model characterized by **mass m_1** and **coupling k/M_{PL}**
  - **=> Look for first graviton resonance**



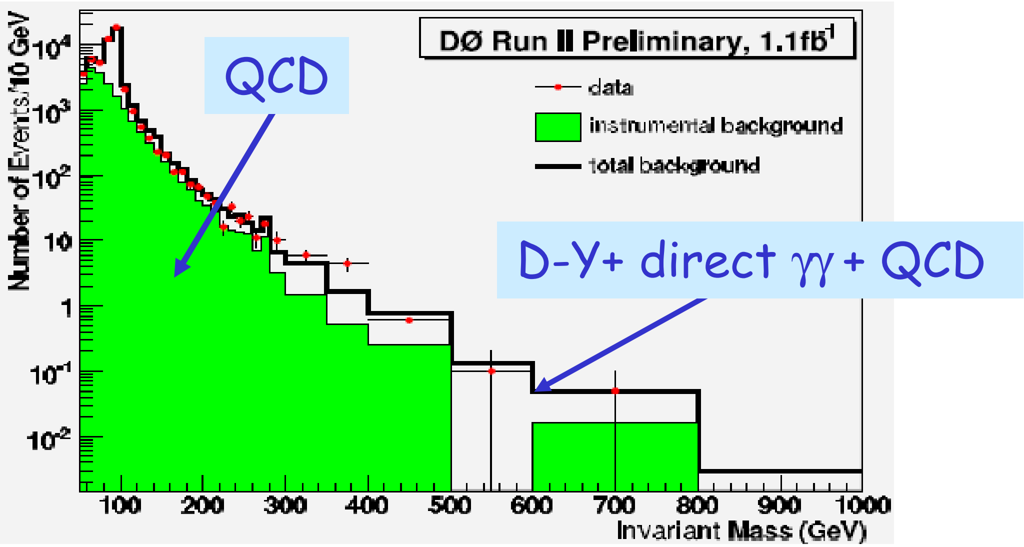


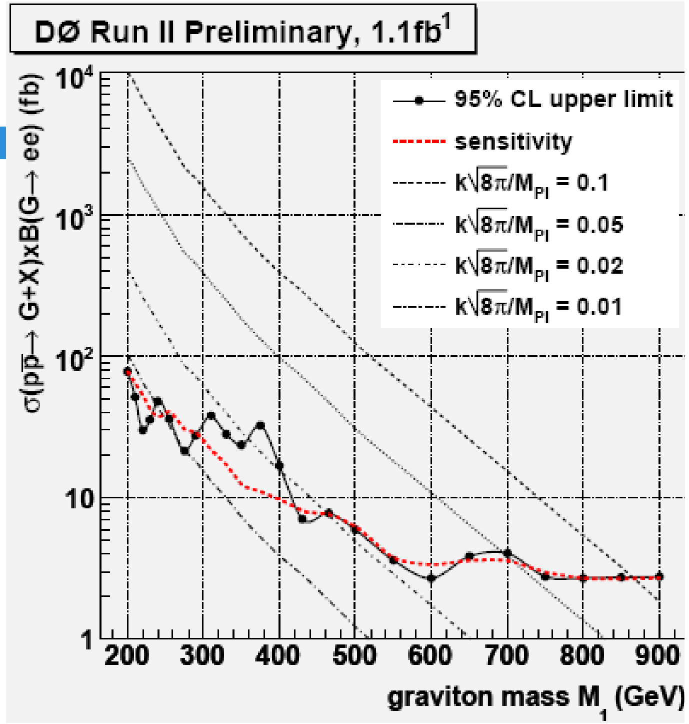


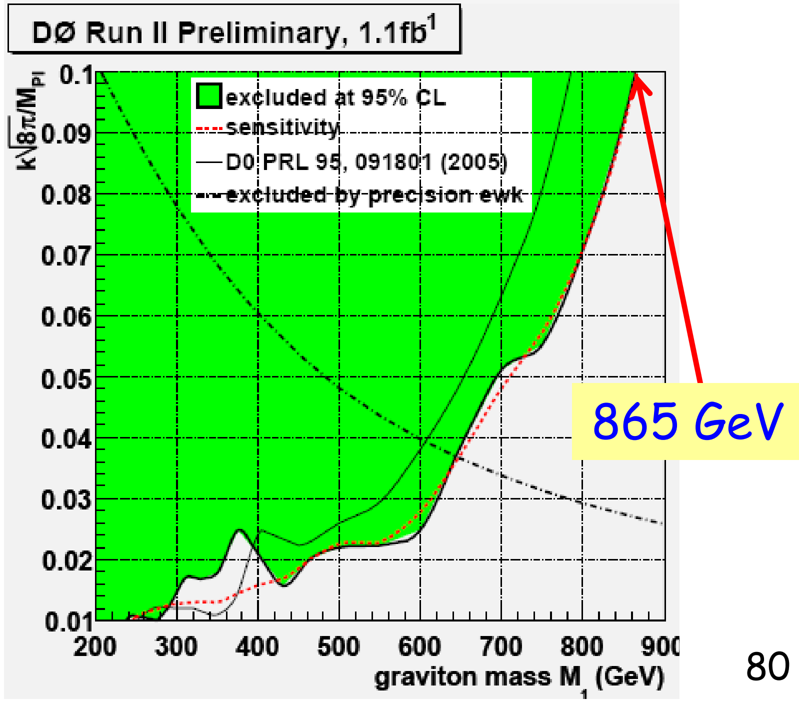
diEM RS Extra Dimension

SELECTION:

- 2 isolated EM clusters
  - $|\eta| < 1.1$ (CC)
  - $E_T > 25$ GeV
  - no track match equired (=> ee, $\gamma\gamma$)







- QCD (instrumental) shape estimated from data sample with EM obj. imcomp. with electromagnetic showers
- MC and QCD relative contrib. fitted to data in region $60 < M_{ee} < 140$ GeV

compare spectra for $M_{ee} > 140$ GeV
agreement => ...

Conclusions and Outlook

- So far, no convincing hint of physics BSM at D0
- But, substantially improved limits ...
  ... and we are still hopeful for discoveries ☺
- Results presented were obtained with up to 1.1 fb^{-1}
- analyses being updated to full available luminosity
- In the works:
  - LED in monojets + MET
  - LED, Z', RS in ee, $\mu\mu$
  - Squarks and gluinos
  - Stop in $t\chi$,S topottom in $b\chi$
  - Leptoquarks
  - excited e*
  - RPV sneutrino in $e\mu$
  - update and combine MSSM neutral Higgs analyses
  - SUSY H+ -> $\tau\nu$
  - Non Standard H -> $\tau\mu$
  - + ...

... Stay tuned ...

- More integrated luminosity is on its way with an improved detector...
  design goal of 8 fb^{-1} likely to be achieved ...
  => Even more exciting years ahead