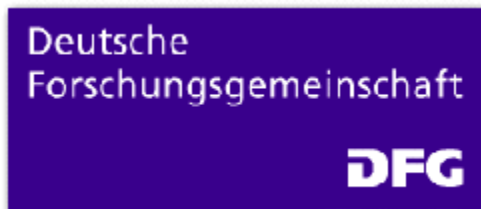


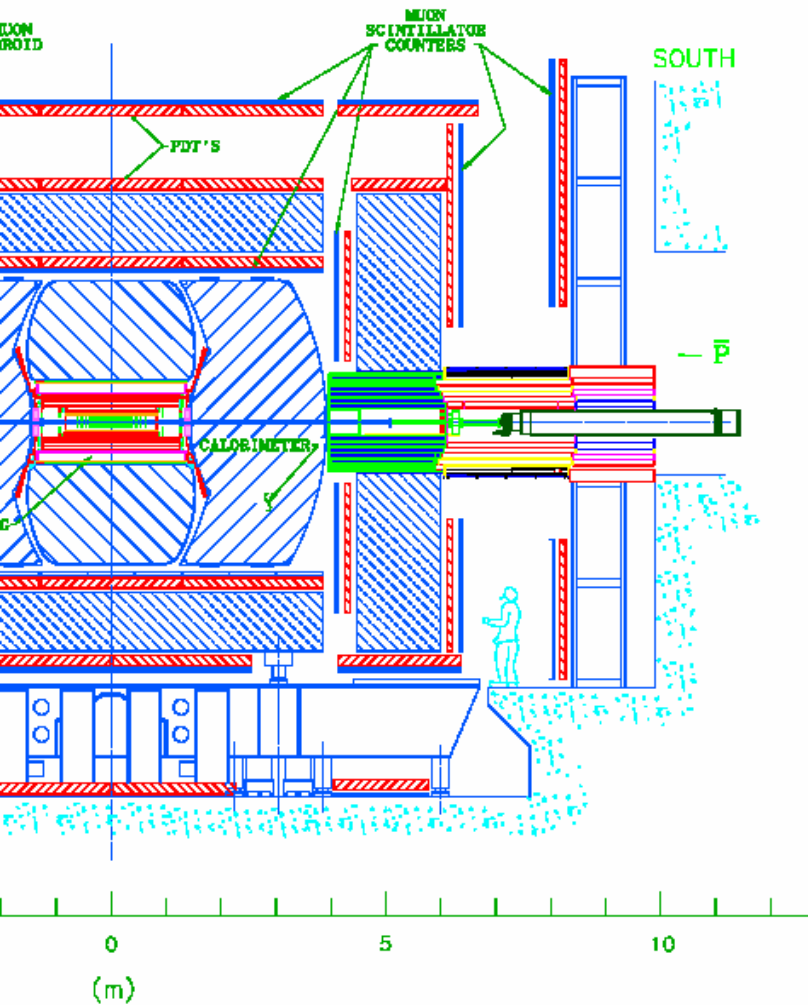
Search for R-Parity violating SUSY with the DØ-Experiment

Christian Autermann, RWTH Aachen
on behalf of the DØ-Collaboration

- **R-parity violating Supersymmetry**
- **SUSY pair and resonant production**
- **Decay channels**
- **3 Analyses approaches depending on the
R-parity violating coupling λ_{121} , λ_{122} , λ'_{211}**
- **Preliminary Results**

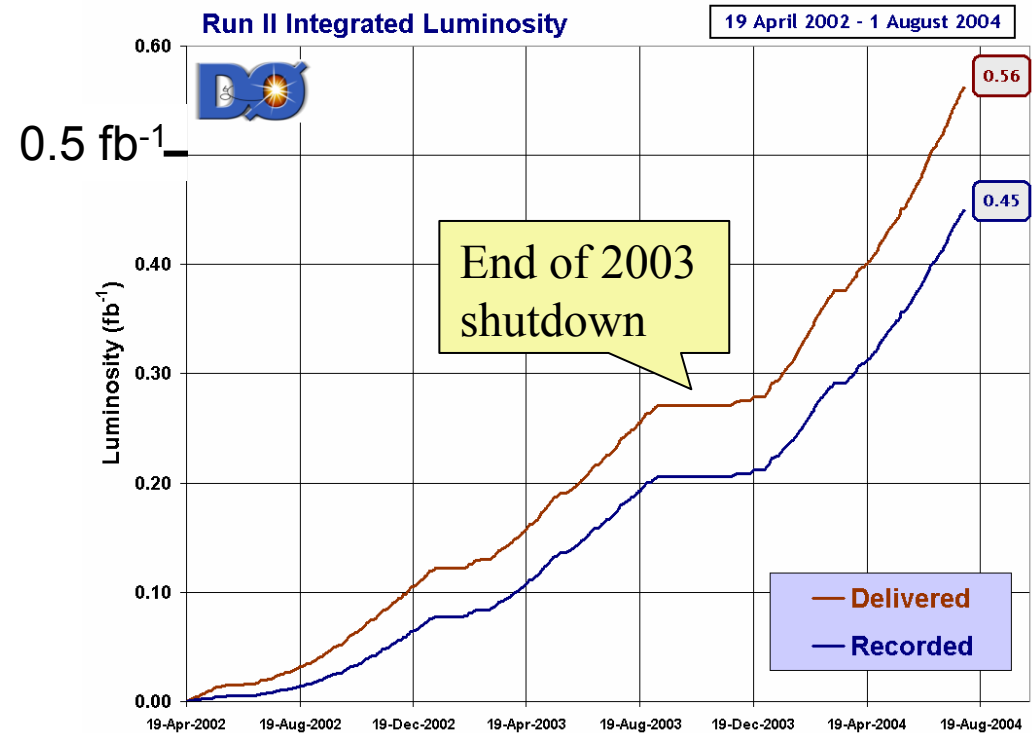
Supported by





Effective Luminosity used for analyses:

$$\int \mathcal{L} dt = 160 - 240 \text{ pb}^{-1}$$



R - parity : $R_p = (-1)^{3B+L+2S}$

S is the particle spin,
B is the baryon number,
L is the lepton number

$$W = W_{MSSM} + W_{R_p}$$

$$W_{R_p} = \frac{1}{2} \lambda_{ijk} \varepsilon_{ab} L_i^a L_j^b E_k^c + \lambda'_{ijk} \varepsilon_{ab} L_i^a Q_j^b D_k^c + \lambda''_{ijk} \varepsilon_{xyz} U_i^{cx} D_j^{cy} D_k^{cz} + \kappa_i \varepsilon_{ab} L_i^a H_2^b$$

$i, j, k = 1, 2, 3$ generation indices

Trilepton channel
→ multi lepton final state

Resonant production
→ two muon and two jets final state

Chiral superfields:

L: lepton doublet superfield

E: lepton singlet superfield

Q: quark doublet superfield

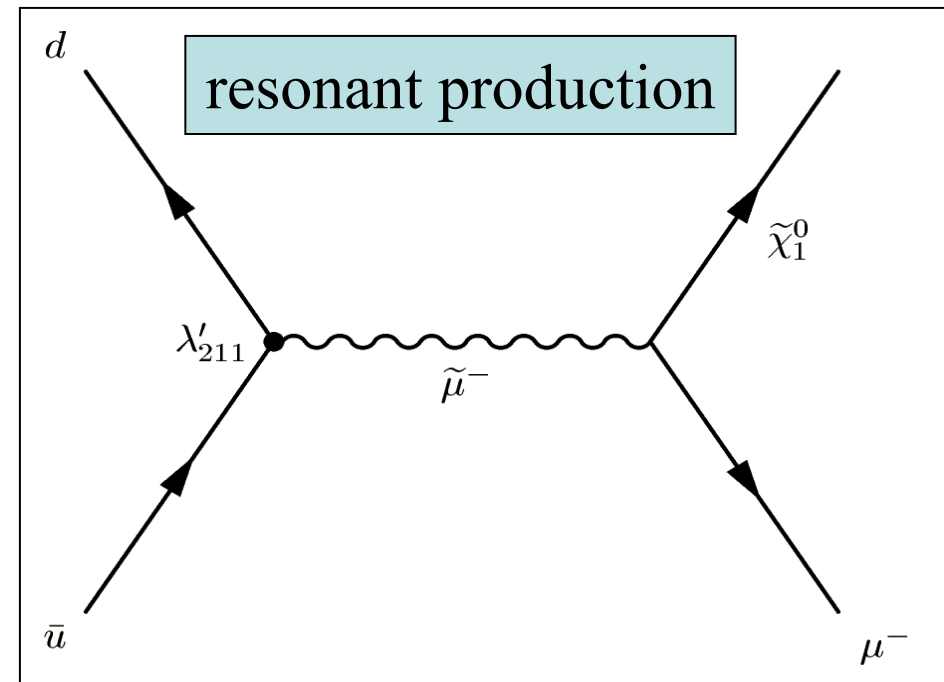
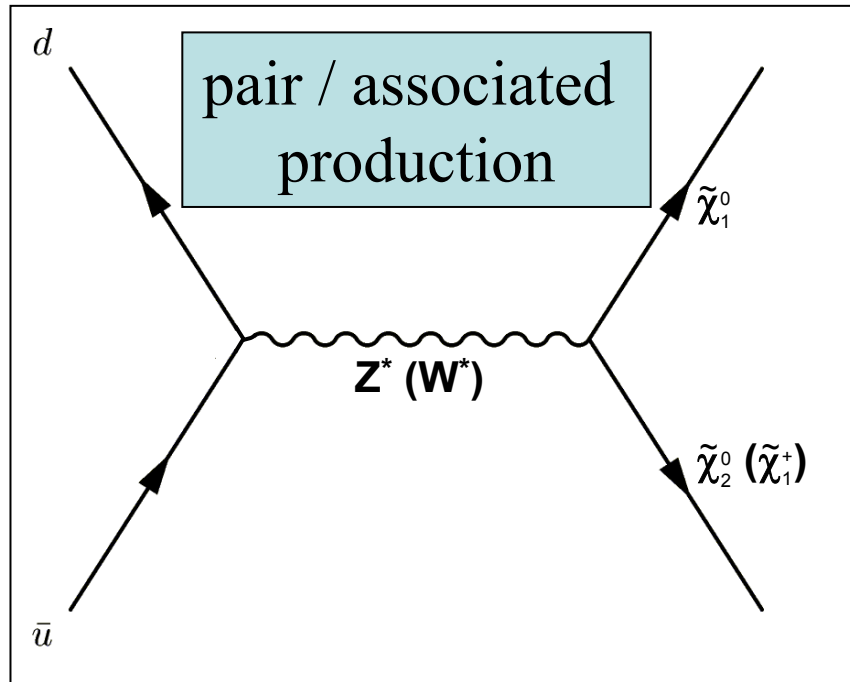
D: down-like quark singlet superfield

} Resonant production at hadronic accelerators

$\lambda, \lambda', \lambda''$: Yukawa couplings

References:

H. Dreiner, et.al., *Search for R-Parity Violation at Run-II of the Tevatron*, hep-ph/9906224
N.Ghodbane, S.Katsanevas, P.Morawitz, E.Perez, *SUSYGEN 3*, hep-ph/9909499

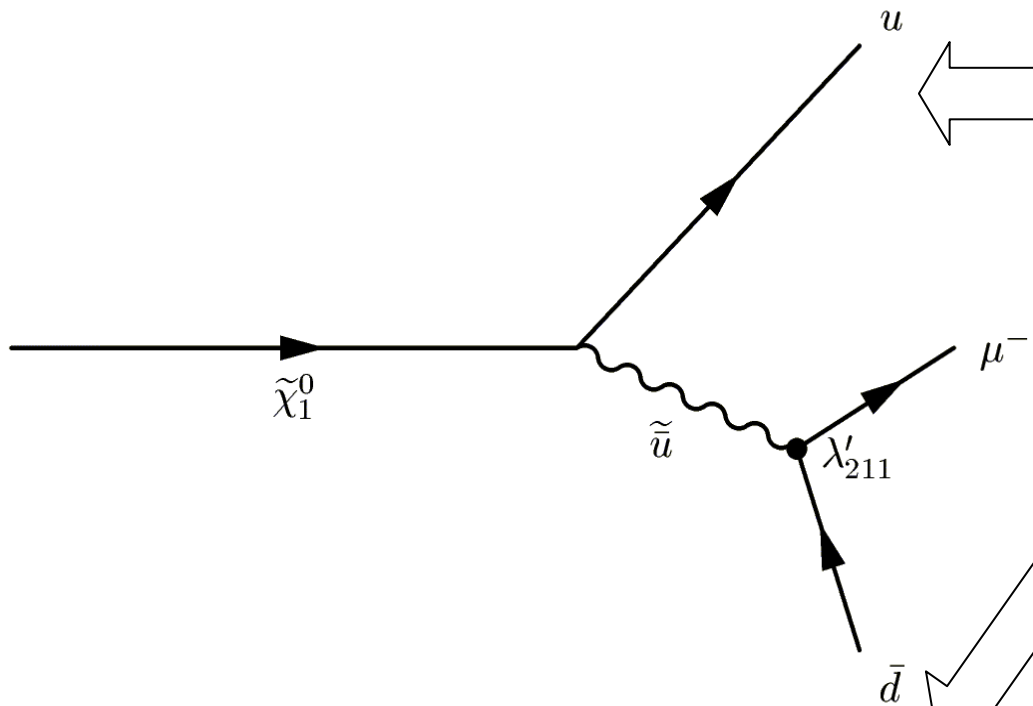


- R-parity conserved
 - Search for subsequent decays of the neutralinos and charginos via the tri-lepton R-parity violating LLE couplings λ_{121} , λ_{122} and λ_{133} .
- Final states with 4 leptons or more; analyses ask for at least 3 leptons.

- R-parity violating production (λ'_{211})
- Di-muon and di-jet final state

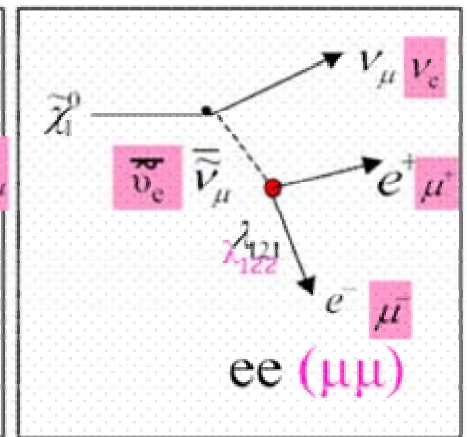
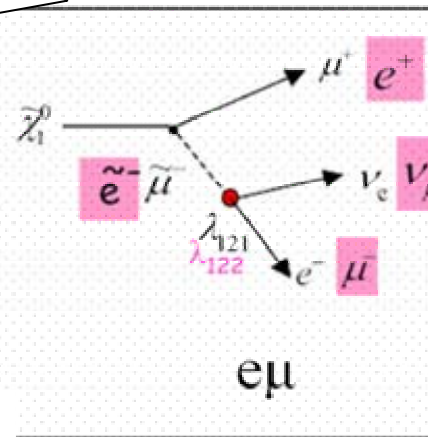
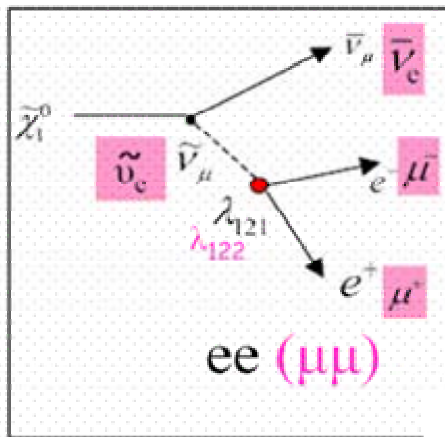
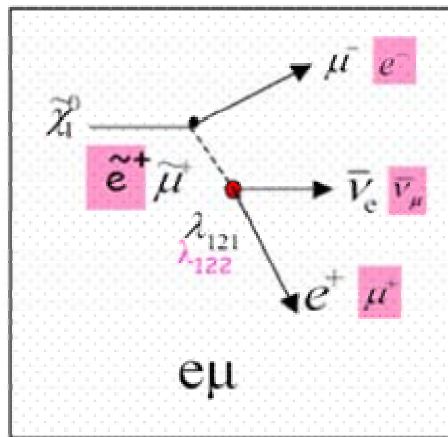
Other modes:

- sneutrino resonance
→ di-jet, muon & missing E_T final state
- t-channel slepton exchange



- Only 1 neutralino in **resonant** channel
- no missing E_T
- $\mu\mu$ jet jet

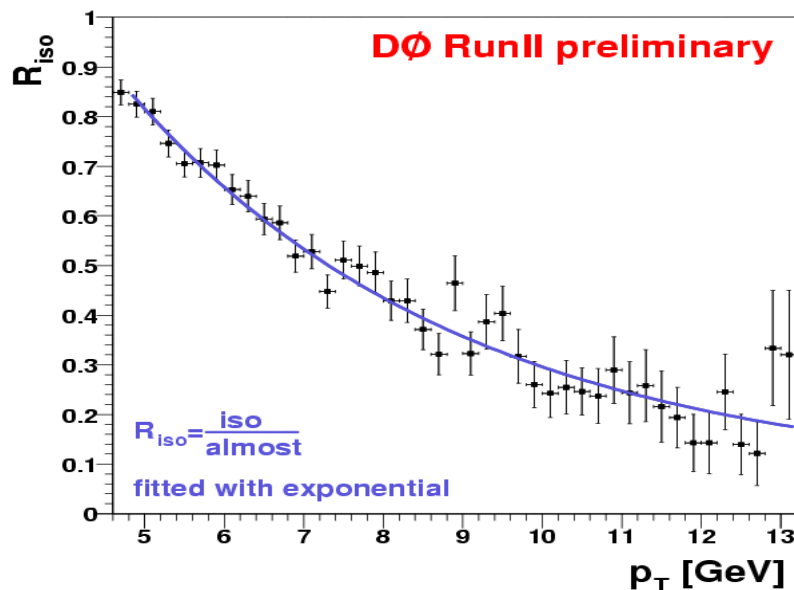
- **Pair produced** neutralinos decay each via LLE couplings λ into 2 charged leptons and 1 neutrino.
- More than 1 possible final state for each coupling λ .
- missing E_T (2 neutrinos in final state)
- $eeee$, $eee\mu$, $ee\mu\mu$, $e\mu\mu\mu$, $\mu\mu\mu\mu$, $ee\tau\tau$, $e\tau\tau\tau$, $\tau\tau\tau\tau$ (+ $\nu\nu$)



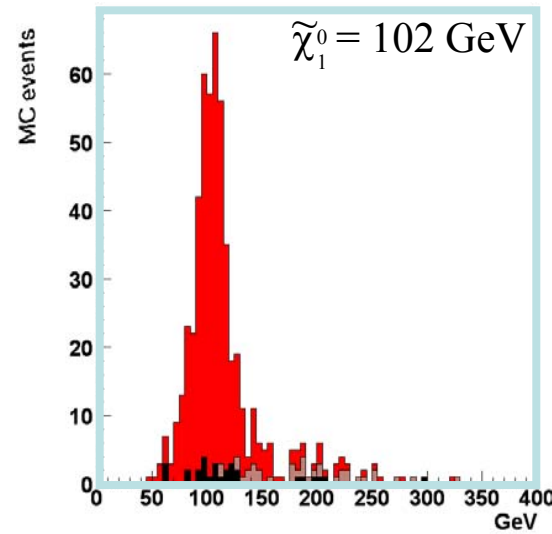
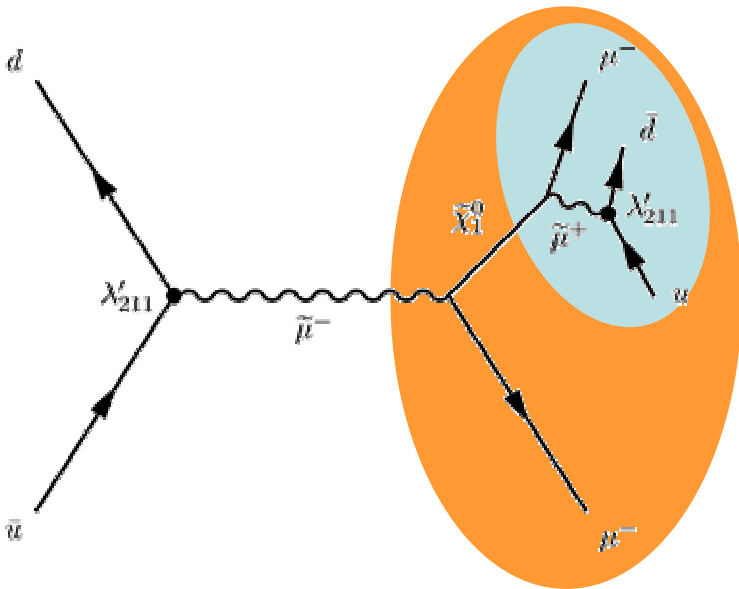
Dominating: mostly heavy flavor (bbar and cbar), hard to simulate
→ **estimate from data**

Background-Sample: like-sign muons, “almost” isolated (avoid signal region!);
“QCD”-background dominates compared to other SM-processes
Contamination from a possible signal estimated to be
negligible compared to the statistical and systematic uncertainty

isolation criteria	tight	soft
CAL: $E_{\text{cal}}(R<0.4) - E_{\text{cal}}(R<0.1)$	$< 2.5 \text{ GeV}$	$2.5 < \text{iso} < 7.0 \text{ GeV}$
Track: $\sum p_T(R<0.4) - \sum p_T(R<0.1)$	$< 2.5 \text{ GeV}$	$2.5 < \text{iso} < 7.0 \text{ GeV}$



- Create two more sub-samples:
 - two isolated μ 's (**A**)
 - 1 iso. μ + 1 almost-iso. μ (**B**)
- Weight the events of the almost-iso sample with: **Riso=A/B**
- Finally normalize to the data

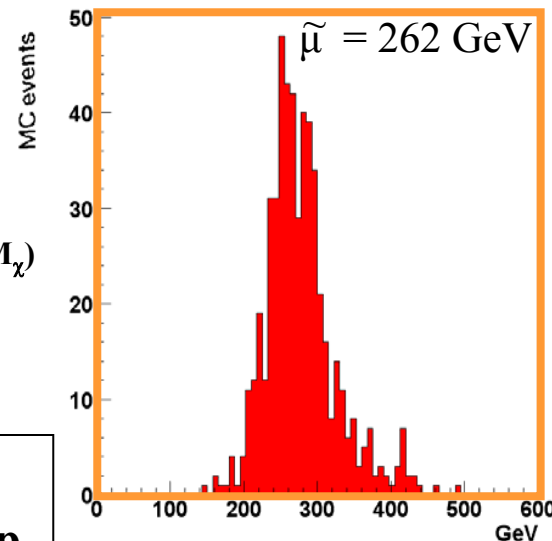


Invariant mass of 2 jets and the lower energetic muon

- muon is from $\tilde{\chi}$ -decay
- muon is from $\tilde{\mu}$ -decay
- neither nor

Final cuts **depend on neutralino and slepton mass** of the SUSY point under study:

cut	range
$p_T(\mu_1) > 21 \text{ GeV} + 15/80 (M_\mu - M_\chi)$	
$91 \text{ GeV} - (5 + M_\chi/9) < M_{\mu\mu}$	$< 91 \text{ GeV} + (5 + M_\chi/9)$
$M_\chi - 40 \text{ GeV} < M_{\mu 2, \text{jet}1, \text{jet}2}$	$< M_\chi + 20 \text{ GeV}$
$M_\mu - 0.2 \cdot M_\mu < M_{\mu 1 \mu 2, \text{jet}1, \text{jet}2}$	$< M_\mu + 0.2 \cdot M_\mu$



Invariant mass of 2 jets and 2 muons

Generated with SUSYGEN and passed through full detector simulation & reconstruction.

After all cuts
2 events found, 1.1 ± 0.5 SM events exp.

- cut 1:** $p_T(\mu 1) > 11$ GeV, $p_T(\mu 2) > 6$ GeV, matched central track
- cut 2:** tight muon isolation
- cut 3:** separation in ΔR between muons (and possible jets)
- cut 4:** vertex quality cuts

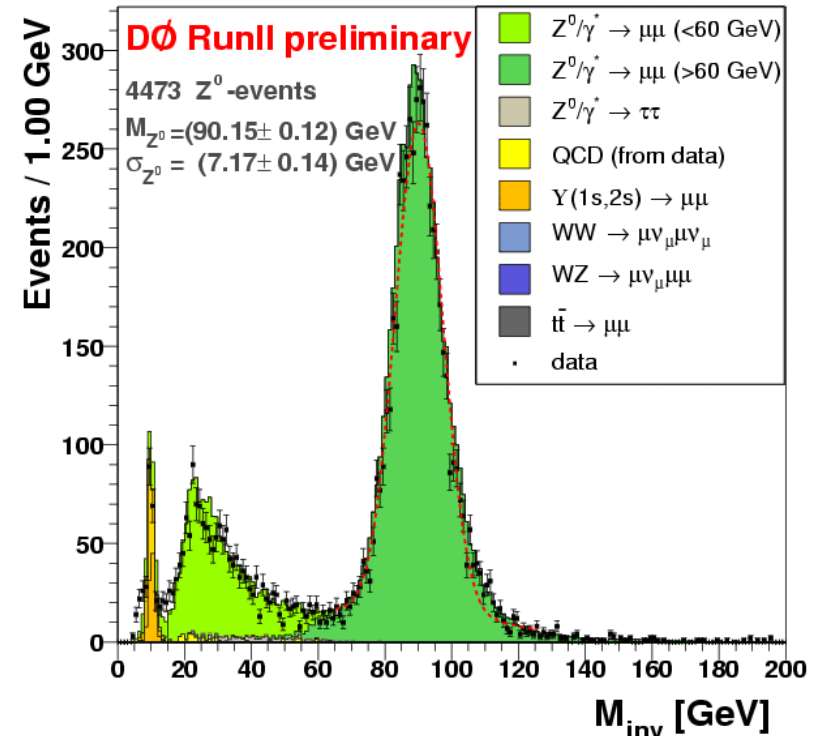
$$\lambda_{122} \geq 2 \mu's$$

2-dimensional cuts:

- cut 5:** MET – $M_{\mu 1 \mu 2}$ plane: Signal tends to have higher MET and lower $M_{\mu 1 \mu 2}$ than the bg.
- cut 6:** MET – $p_T(\mu 1) + p_T(\mu 2)$ plane
- cut 7:** $\Delta\phi(\mu 1, \mu 2)$ – $M_{\mu 1 \mu 2}$ plane

Details:

- cut 5:** $M_{\mu 1 \mu 2} < 6$ GeV / $(-6.5 \cdot 10^{-4} \cdot \text{MET} + 0.027 \text{ GeV}) + 240$ GeV,
 $M_{\mu 1 \mu 2} > -4.4 \cdot \text{MET} + 75$ GeV
- cut 6:** MET > $-4 \cdot (p_T(\mu 1) + p_T(\mu 2)) + 80$ GeV
MET > $0.5 \cdot (p_T(\mu 1) + p_T(\mu 2)) - 20$ GeV
- cut 7:** $\Delta\phi(\mu 1, \mu 2) < 2.6$ for: $80 \text{ GeV} < M_{\mu 1 \mu 2} < 100 \text{ GeV}$

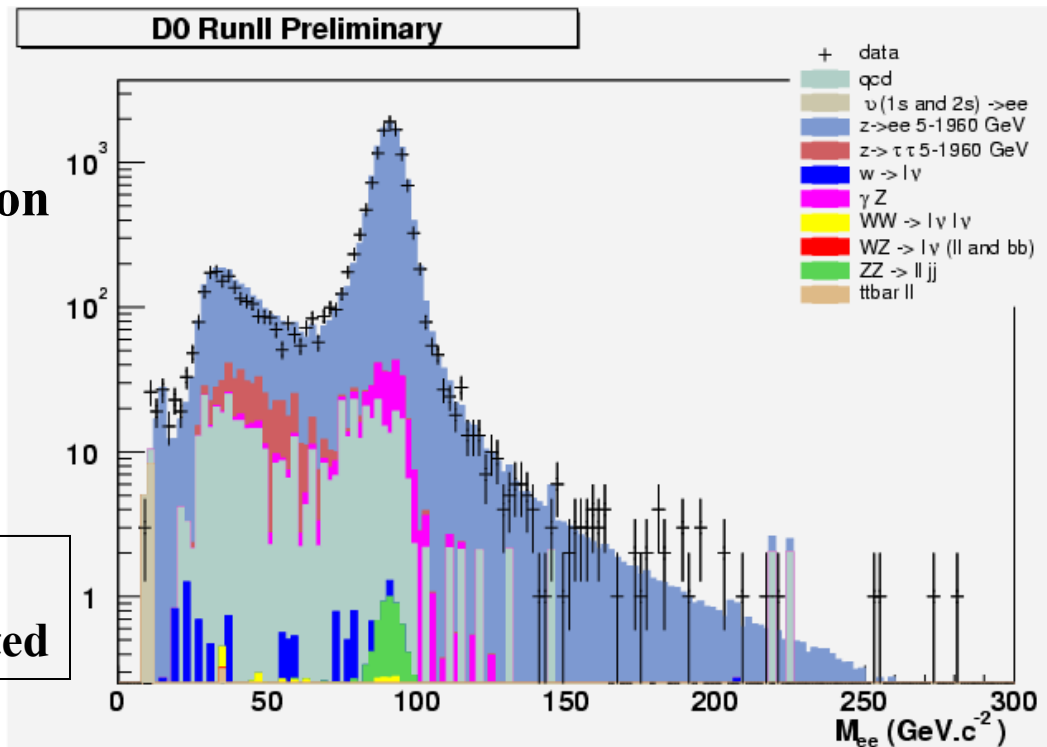


After all cuts

2 events found, 0.6 ± 1.9 events expected

- 3 leptons ($\Delta R > 0.7$ between leptons) with $p_T > 15, > 10, > 5$ GeV
- vertex quality cut
- **cut 1:** good tracking for muons
- **cut 2:** cut away Z mass ± 10 GeV
- **cut 3:** isolated muons
- **cut 4:** lepton track quality:
at least 2 hits in the silicon
- **cut 5:** missing $E_T > 15$ GeV

$$\lambda_{121}, \geq 2 \text{ e's}$$



After all cuts
0 events found, 0.5 ± 0.4 events expected

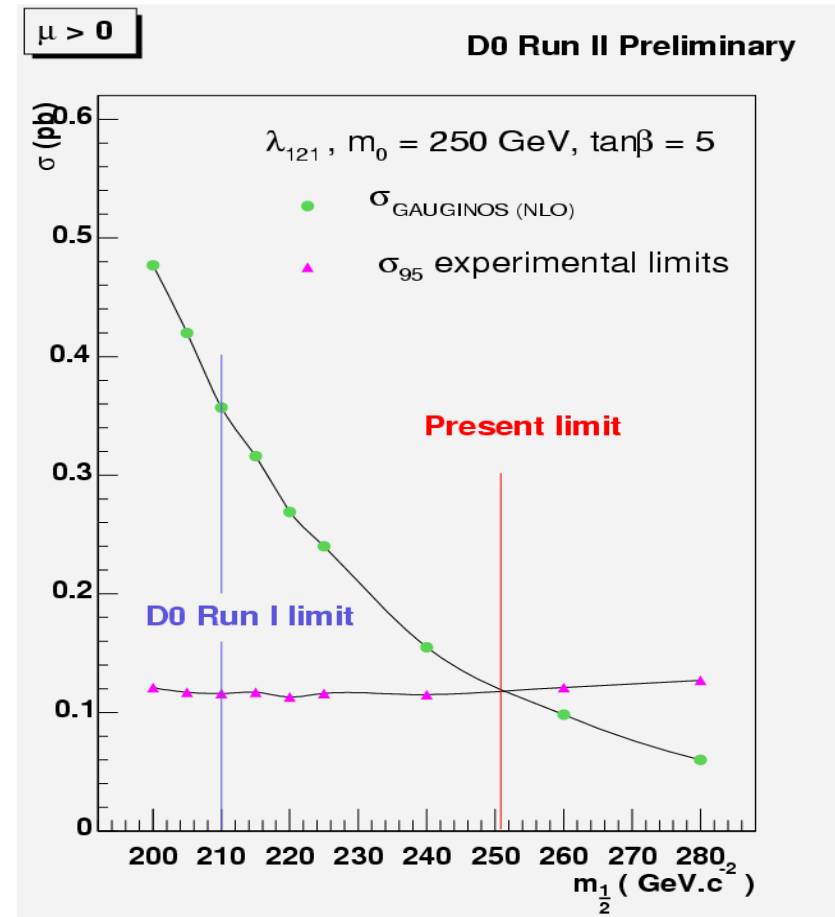
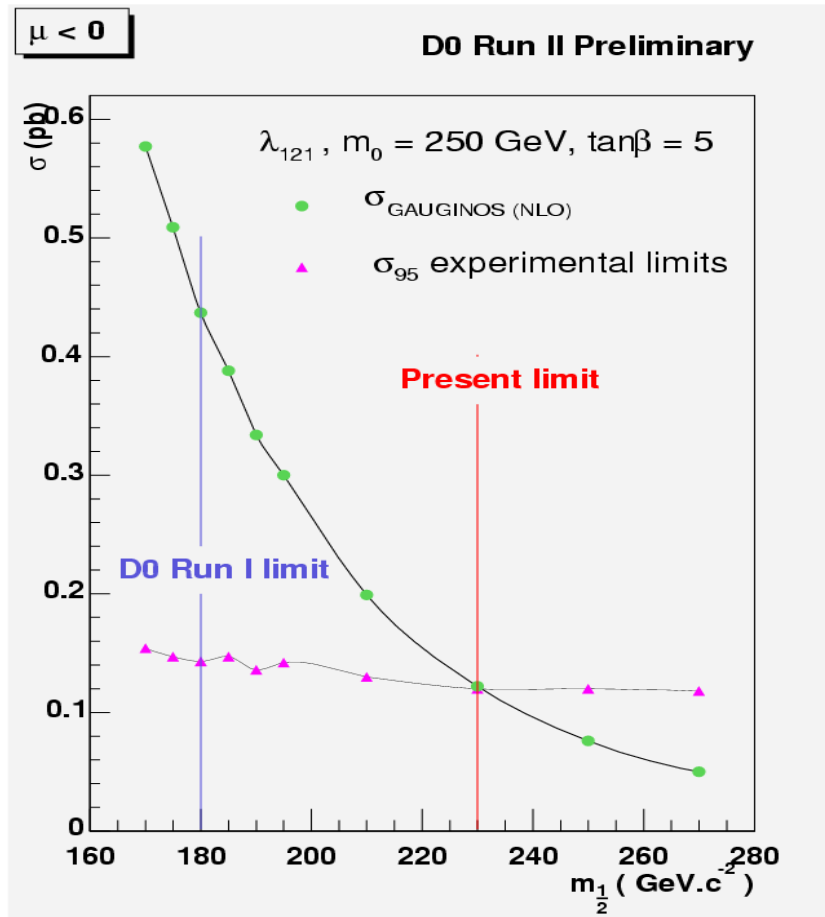
- **all analyses**
- luminosity: 6.5 % absolute
- **muons:** reconstruction, isolation, trackmatching efficiency corr. 4%
- **electrons:** identification, likelihood
- Uncertainty on Z/γ^* cross section (difference NLO/NNLO) 3%

- **λ_{121}**
- electron trigger efficiency $\sim 2\%$

- **λ_{122}**
- muon trigger efficiency (varied weighting factor): 5% to 12%
- uncertainty on QCD-background (dominant: low statistics)

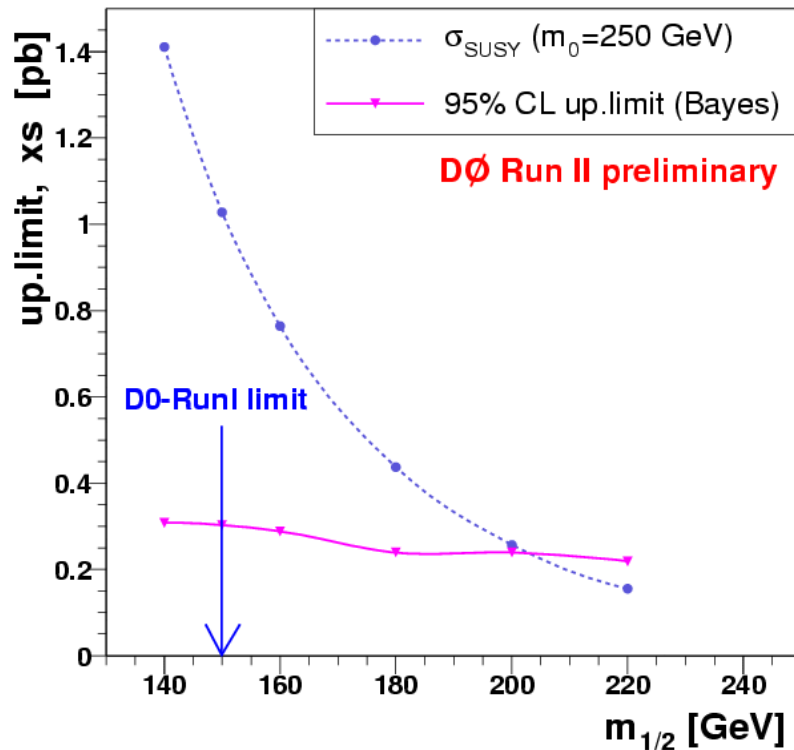
- **λ'_{211}**
- muon trigger efficiency (varied weighting factor): 6% to 9%
- Jet Energy Scale (dominant) 30%

Channel with at least 2 e's

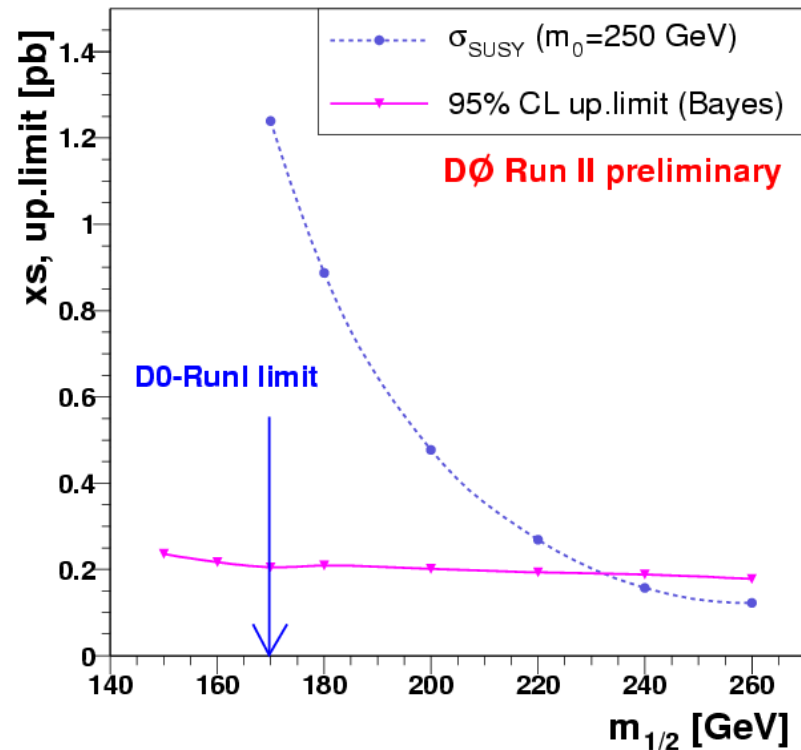


Channel with at least 2 μ 's

$\mu < 0$



$\mu > 0$



This translates to:

$$m_{\tilde{\chi}_1^0} > 84 \text{ GeV}$$

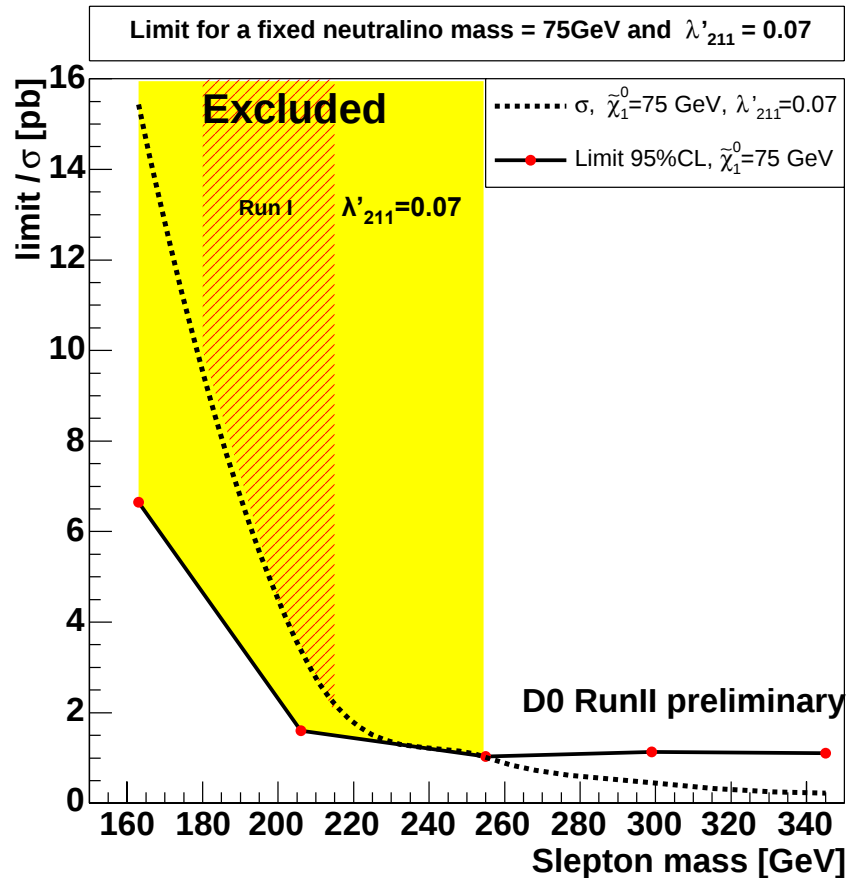
$$m_{\tilde{\chi}_1^\pm} > 160 \text{ GeV} \quad \text{for } \mu < 0$$

$$m_{\tilde{\chi}_1^0} > 90 \text{ GeV}$$

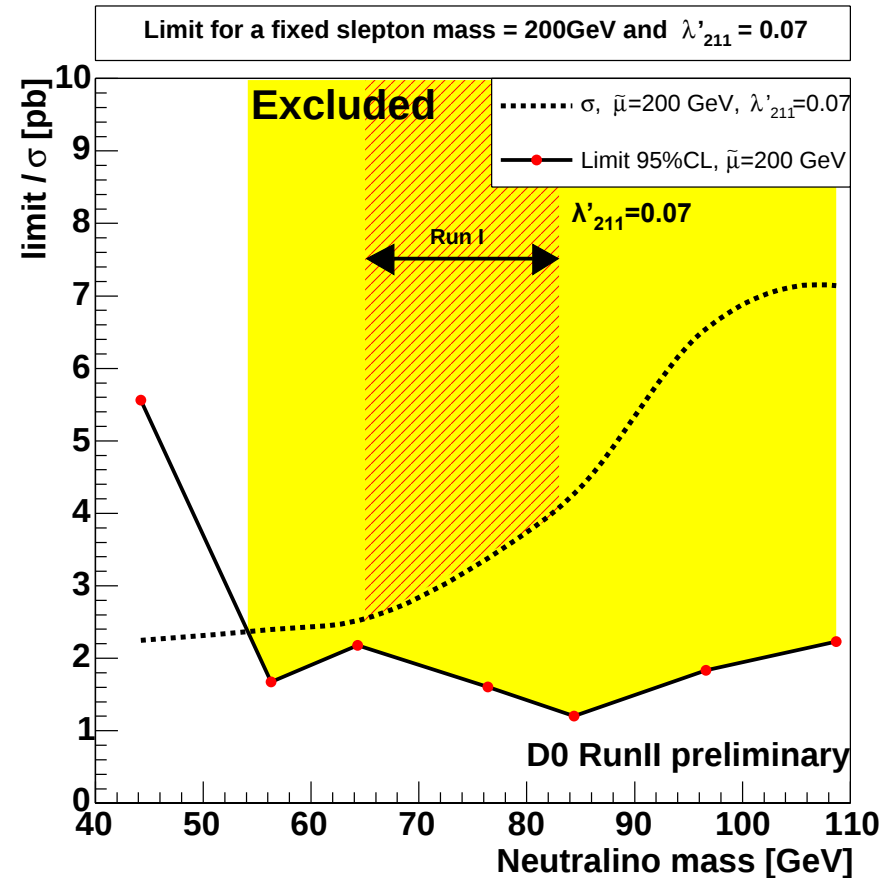
$$m_{\tilde{\chi}_1^\pm} > 165 \text{ GeV} \quad \text{for } \mu > 0$$

Resonant Channel

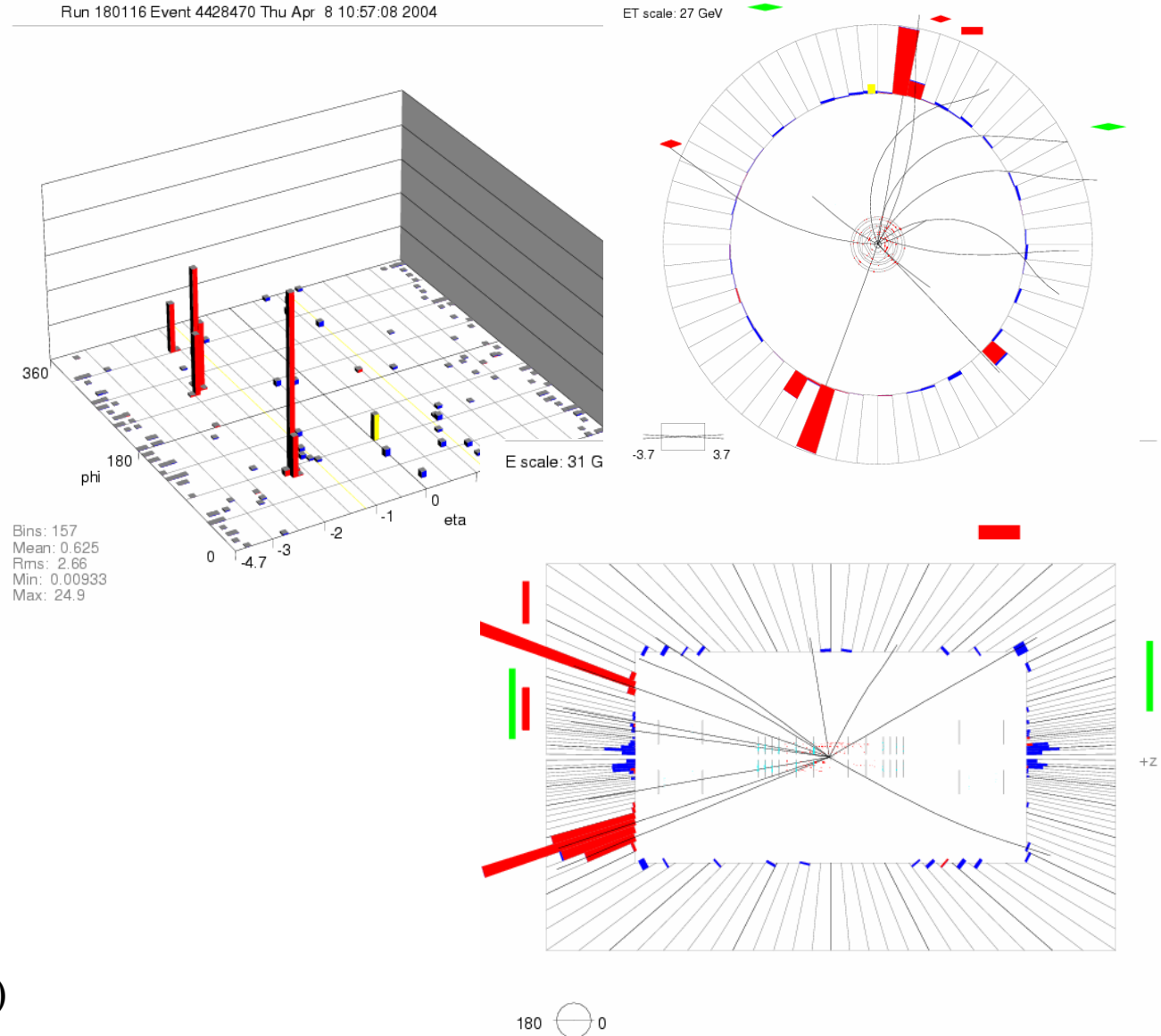
$m_{\tilde{\chi}_1^0} = 75 \text{ GeV}$



$m_{\tilde{\mu}} = 200 \text{ GeV}$



	Event #2
Runnum	180 116
Evtnum	4 428 470
type	eee
MET	8.3
# of muons (pt, eta, phi)	1 (nseg = -2) (17.4, 1.99, 2.02)
Mee 1-2, 2-3, 1-3, (M_{123})	63.4, 17.7, 31.9 (73.1)
Pt 1, 2, 3	35.6, 28.4, 9.1
Eta 1, 2, 3	-1.78, -1.83, -1.64
Phi 1, 2, 3	1.39, 4.36, 5.50
Charge 1, 2, 3	+1, -1, -1



Fails last cut ($MET > 15$ GeV)

- Presented Searches for RPV SUSY through
 - LLE couplings $\lambda_{121}, \lambda_{122}$ into multi lepton final state and
 - LQD coupling λ'_{211} in the two muons plus two jets final state
 - Data agrees well with Standard Model expectation
 - Exclusion limits have been set, improving on DØ Run I results
 - Already 0.5 fb^{-1} data on tape $\approx 2 - 3$ times more than used for these analyses
-
- Conference Notes 4522, 4531 and 4535 with more detailed information are available at
<http://www-d0.fnal.gov/Run2Physics/WWW/results/NP/np.htm>
 - Thanks to *Daniela Käfer, Anne-Marie Magnan, Arnd Meyer* and *G rard Sajot*