Search for associate Chargino Neutralino production in Trilepton Final States

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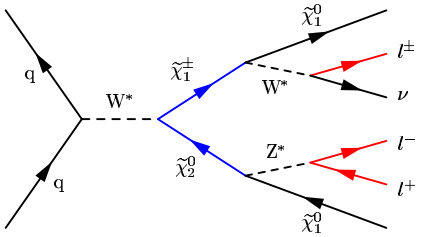

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  - **The $D\emptyset$ detector**
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On behalf of the $D\emptyset$ collaboration

The Minimal Supersymmetric Standard Model

- **Supersymmetric partner for each standard model degree of freedom**

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**
W-,Z-Boson	$W^{\pm}, Z$	*Wino, Zino*	$\tilde{W}^{\pm}, \tilde{Z}$	$\tilde{\chi}^0$
Higgs	$H^{\pm}, H^0$	*Higgsino*	$\tilde{H}_1^0\ \tilde{H}_2^+$	**2x 2 Charginos**
	h, A		$\tilde{H}_1^-\ \tilde{H}_2^0$	$\tilde{\chi}^{\pm}$
Gluon	g	*Gluino*	$\tilde{g}$	

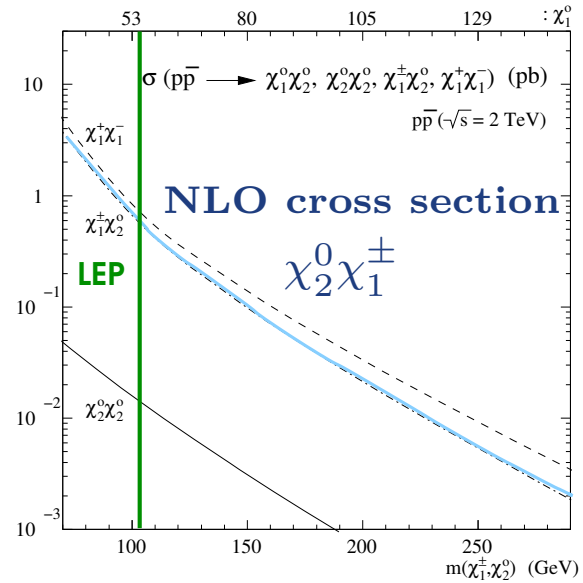
- **R-parity conservation:**
  $\rightarrow$ **stable Lightest Supersymmetric Particle, LSP** (χ_1^0)
  escapes detection
- **Unification of masses and couplings at GUT scale:**
  mSUGRA as a guideline
  - m_0: **common scalar mass at GUT scale $\rightarrow$ sfermion masses**
  - $m_{1/2}$: **common fermion mass at GUT scale ($\rightarrow$ $\mathrm{SU(2)_L}$ mass $\mathrm{M_2}$)**
  - $\tan\beta$: **ratio of Higgs vacuum expectation values**
  - μ: **higgs(ino)-mass parameter**
  - A_0: **trilinear coupling $\rightarrow$ sfermion-mixing**

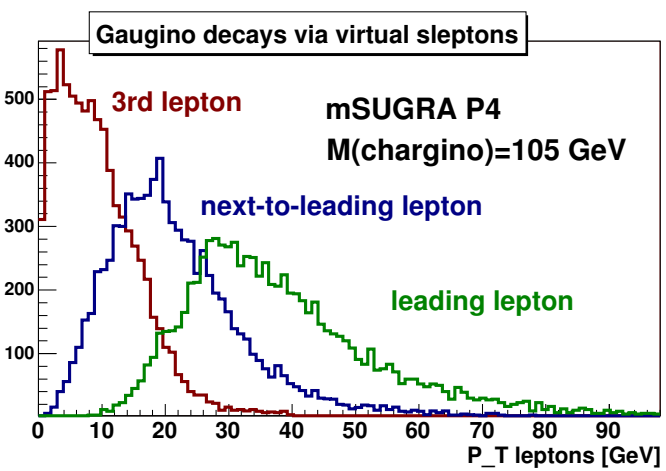
SUSY phenomenology

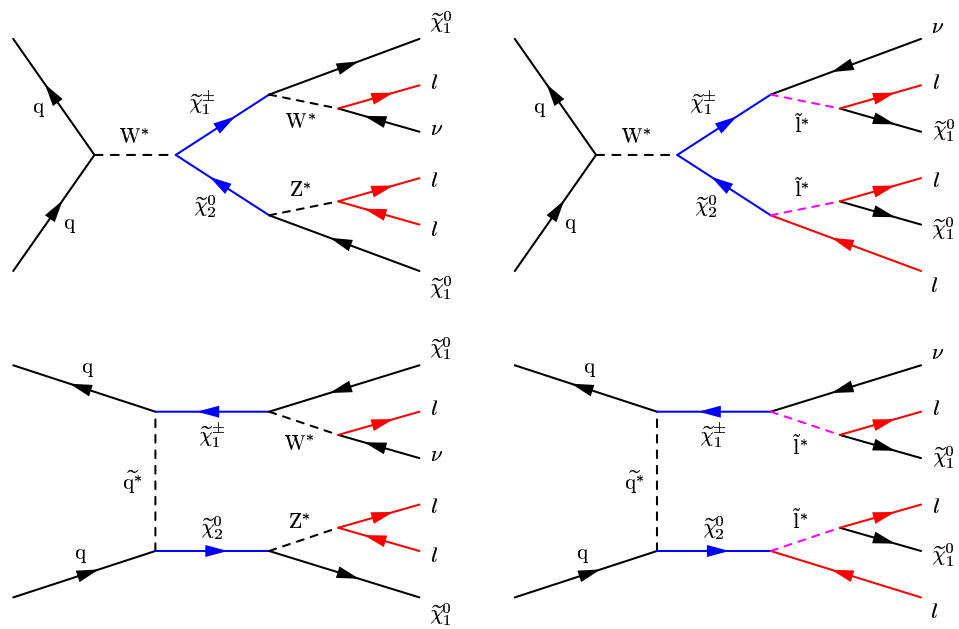
Sensitivity with the current data set requires:

- **large cross section:**
  $\rightarrow$ **low gaugino masses (low $m_{1/2}$)**
  $\rightarrow$ **large squark masses**
- **large leptonic branching fraction:**
  $\rightarrow$ **low Slepton masses ($\rightarrow$ low m_0)**
- **large e(μ) branching fraction:**
  $\rightarrow$ **low degree of $\tilde{\tau}$ mixing $\rightarrow$ low $\tan\beta$**

$\Rightarrow$ **Challenge: Soft leptons**



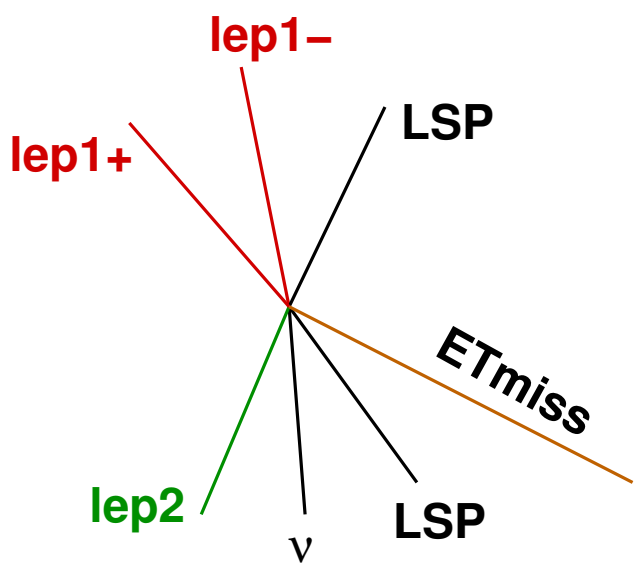


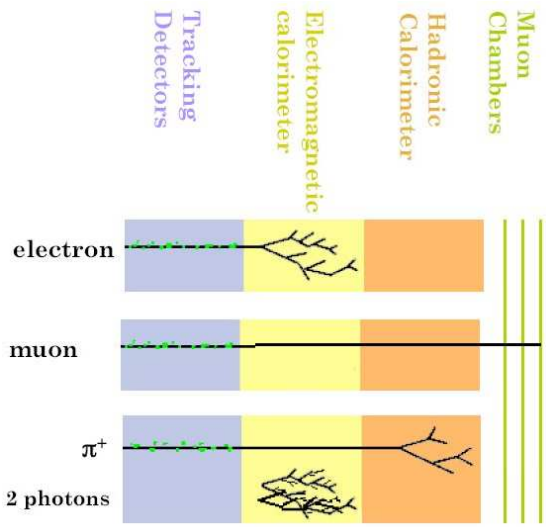


Strategy

(1) TriLeptons:

- **leading leptons:**
  select 2 leptons by tight ID cuts
- **3rd lepton:**
  select isolated track
  (covers electrons, muons, taus)
- **LSPs, neutrinos:**
  require large $\not\!\!E_T$



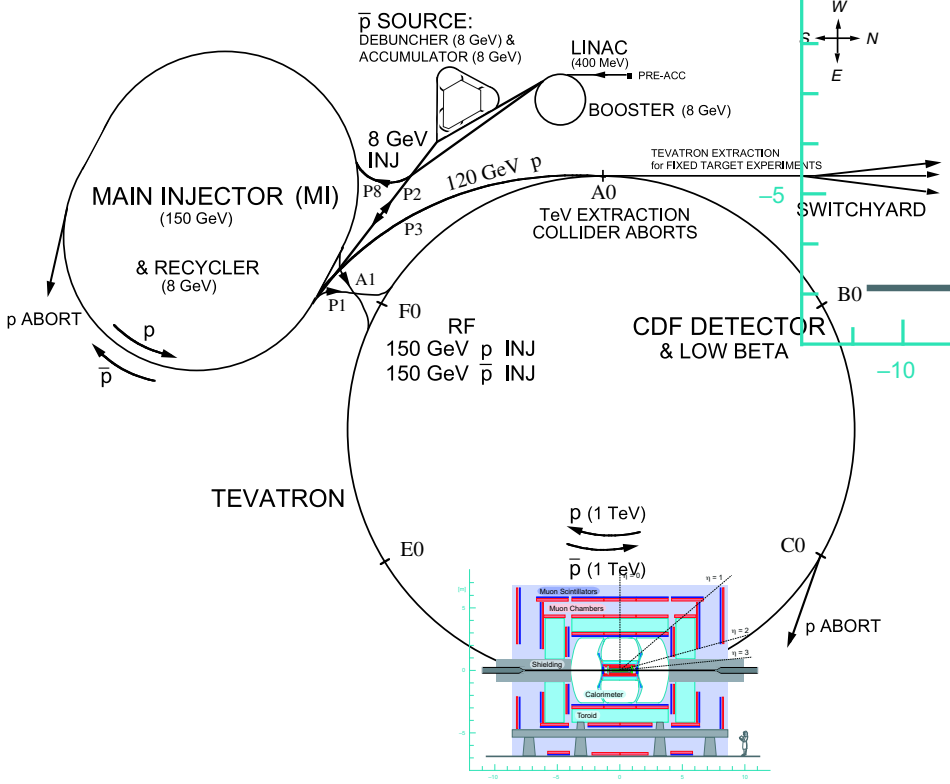


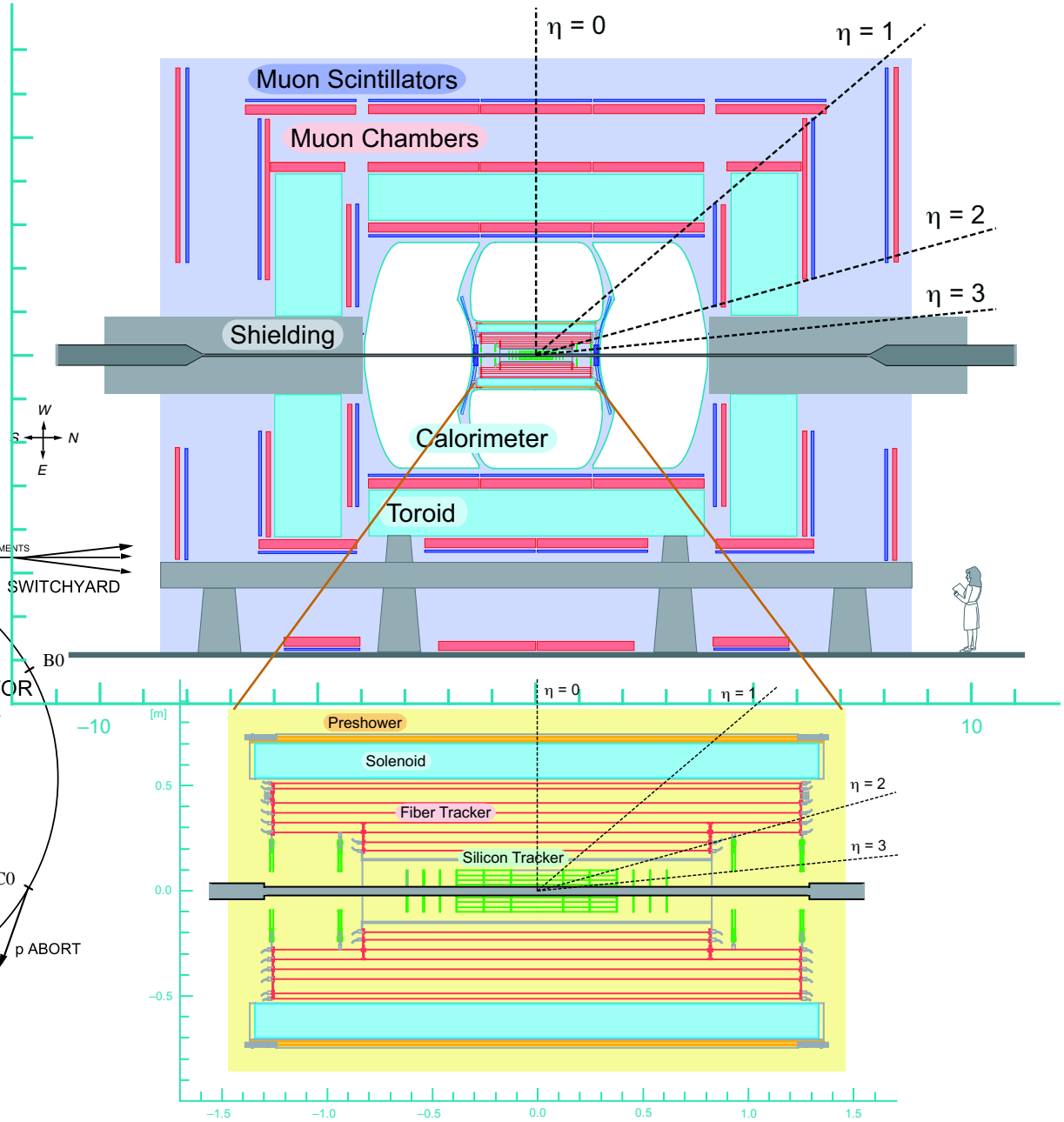
(2) Dileptons:

- **select two likesign leptons**
  → get leading lepton from chargino and leading lepton from neutralino.
- **LSPs, neutrinos:**
  require large $\not\!\!E_T$

The $D\emptyset$ detector

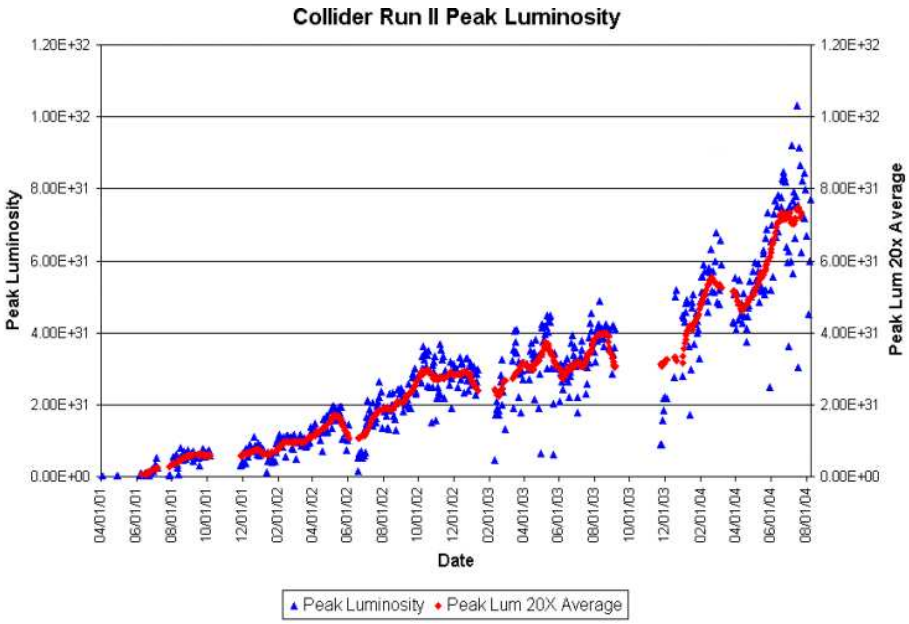
- **good calorimetry**
- **large η coverage:**
  - **tracks:** up to $\eta = 3.0$
  - **electrons:** up to $\eta = 3.0$
  - **muons:** up to $\eta = 2.0$





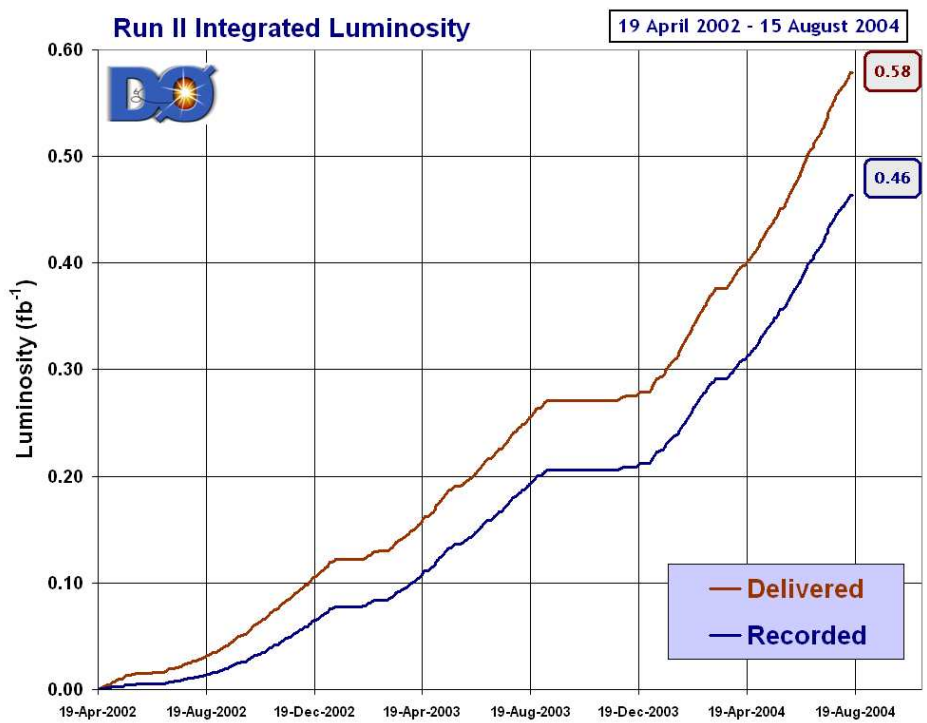
Data sample

Analyses use data collected from April 2002 up to April 2004



- $\mu + \mu + \ell$: $\int L\,dt = 221\text{pb}^{-1}$
- $\text{e} + \text{e} + \ell$: $\int L\,dt = 249\text{pb}^{-1}$
- $\text{e} + \mu + \ell$: $\int L\,dt = 235\text{pb}^{-1}$
- LS $\mu + \mu$: $\int L\,dt = 147\text{pb}^{-1}$

- **reached design luminosity:** $8\text{x}10^{31}/(\text{cm}^2 \cdot \text{sec})$
- **maximum peak luminosity :** $10\text{x}10^{31}/(\text{cm}^2 \cdot \text{sec})$
  . . . increasing further



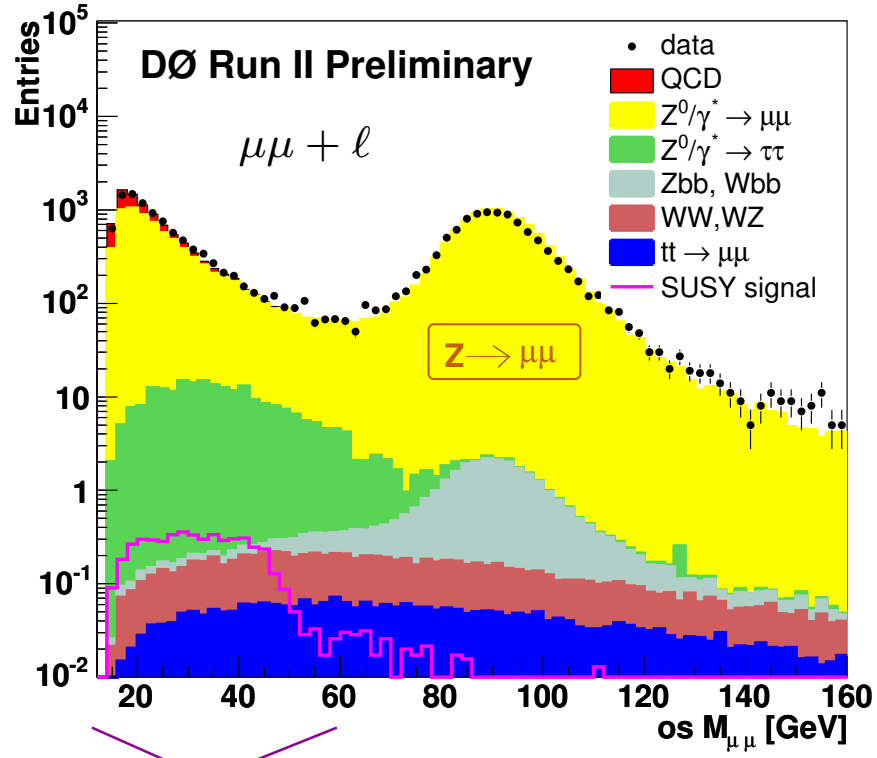
Preselection

- **select 2 leptons with tight ID cuts**
  $p_T > 8\,\mathrm{GeV} + 12\,\mathrm{GeV}(5\,\mathrm{GeV} + 15\,\mathrm{GeV})$

- **Muon ID**
  - **track match**
  - **anti-Cosmic cuts**
  - **Anti-$b\bar{b}$: Calorimeter isolation**

    Track isolation

- **Electron ID**
  - **EMfraction, calorimeter isolation**
  - **Anti $\mathrm{W} + \gamma \to \mathrm{e}\nu + \gamma$ with photon conversions: require silicon hits**
  - **Likelihood: track match, track isolation, calorimeter shower shape**



signal region

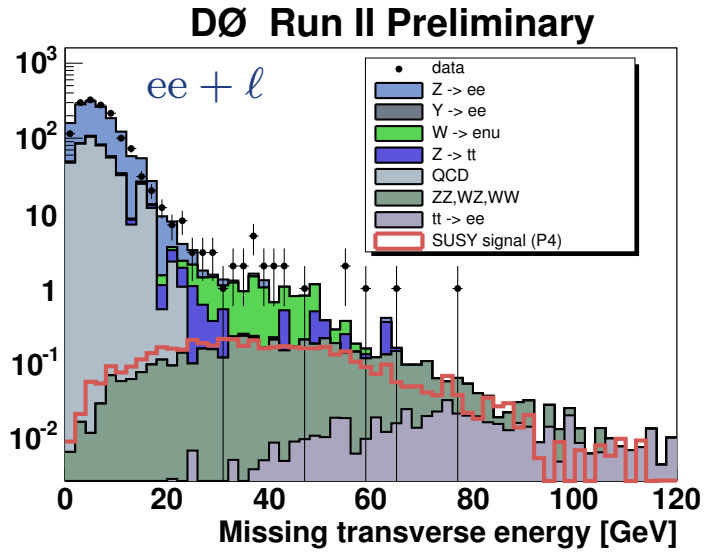
- **Anti-$Z \to \ell\ell$:**
  select low-invariant mass region

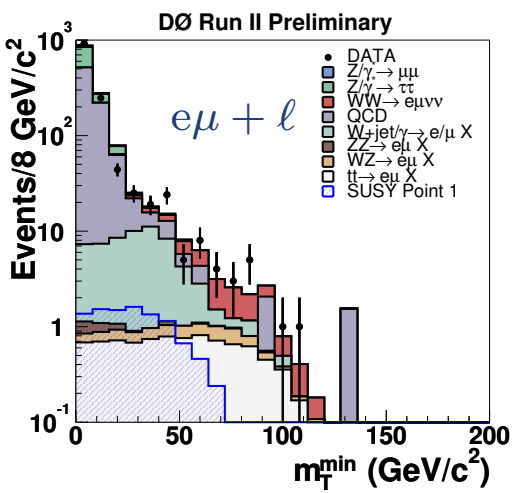
Anti-Z: Jets and $\not\!\!E_T$

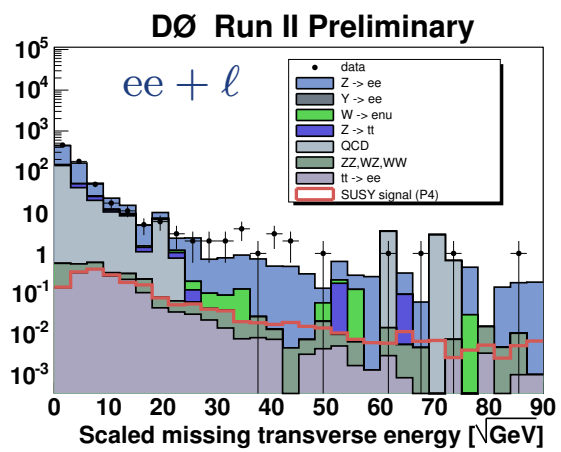
- DY $Z/\gamma \to \ell\ell$ is characterized by low $\not\!\!E_T$

- Large $\not\!\!E_T$:
  fluctuations of lepton and jet energies

- $\not\!\!E_T$ due to leptons:
  - require minimum $\Delta\phi(\ell, \not\!\!E_T)$
  - transverse mass(lepton, $\not\!\!E_T$)
    small for low $\not\!\!E_T$ and low $\Delta\phi(\ell, \not\!\!E_T)$
    $\Rightarrow$ require large transverse mass
- $\not\!\!E_T$ due to jets:
  - require large $\not\!\!E_T/\sigma(\mathrm{E_T(jet)})$

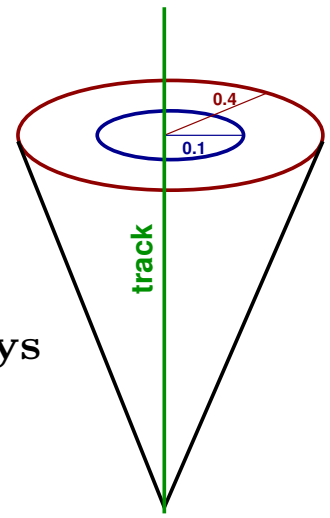


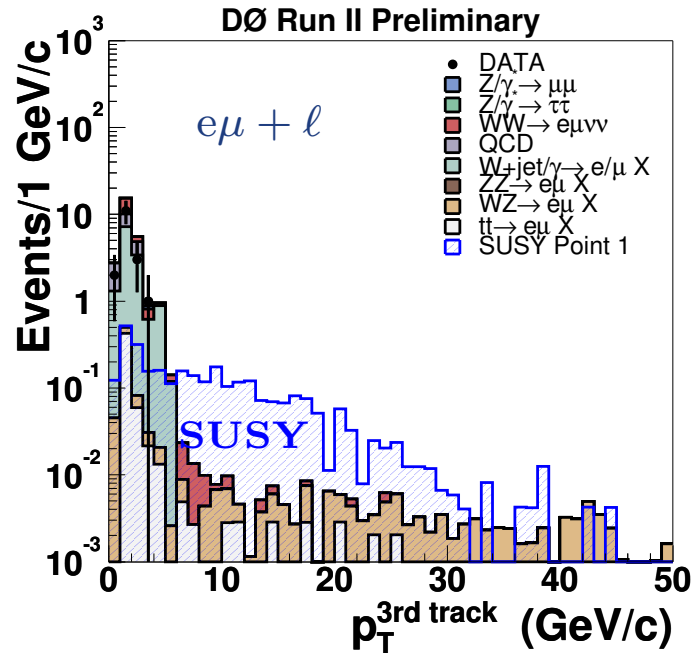




Tracks and $\not\!\!E_T$

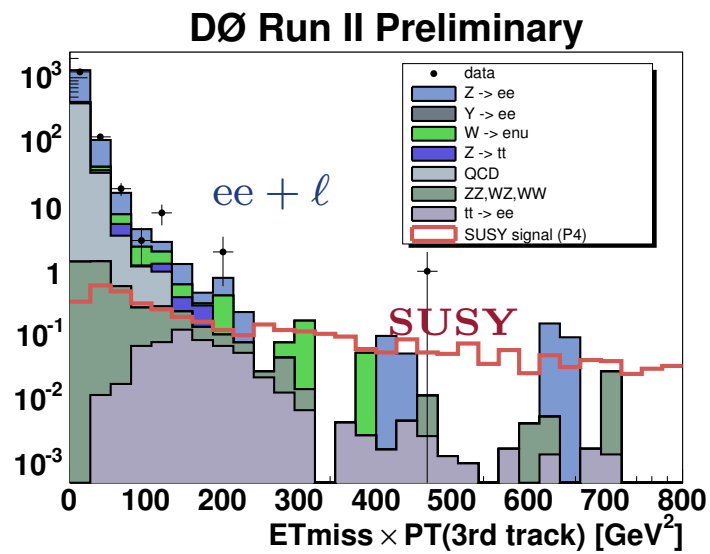
- 3rd track:
  electron, muon or tau
  ⇒**Track Isolation:**
  - hollow cone 0.1-0.4:
    → also hadronic τ decays
  - track p_T sum < 1 GeV





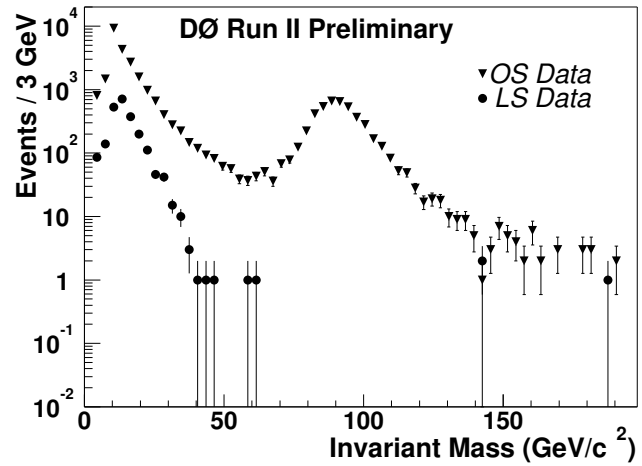
- background from Z/γ and W has low p_T(track) or low $\not\!\!E_T$
  ⇒**select large $\not\!\!E_T$ $\times$ p_T(track)**

- **Selections:**
- track isolation
- **track p_T> 3 GeV (5 GeV)**
  - large $\not\!\!E_T$ $\times$ p_T(track)



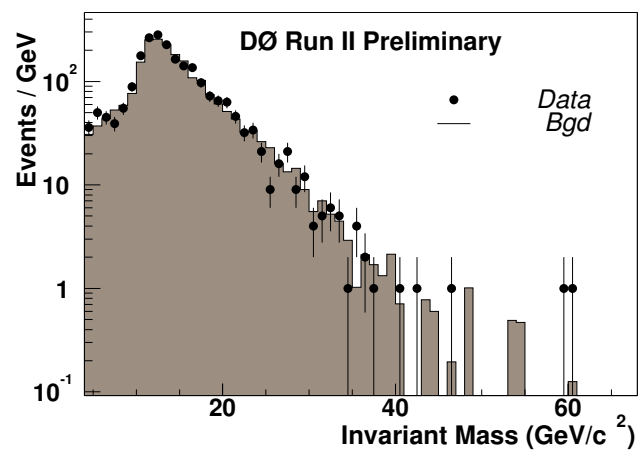
The like-sign $\mu + \mu$ selection $\not{E}_T$

- selection of two like-sign muons:
- $Z/\gamma \to \mu\mu$ background reduced



- **2 isolated muons,** $p_{\mathrm{T}} > 5, 11\,\mathrm{GeV}$
- $\Delta\phi_{\mu\mu} < 2.7$
- $\not{E}_T > 15\,\mathrm{GeV}$, **not collinear to** μ, **jets**
- **invariant mass** $(\mu.\mu) < 70$

- major background source: $\mathrm{b\bar{b}/c\bar{c}}$
- background estimate from data outside signal region: nearly isolated muons
- background normalized in $\mathrm{b\bar{b}/c\bar{c}}$ dominated region: $\Delta\phi_{\mu\mu} > 2.7$

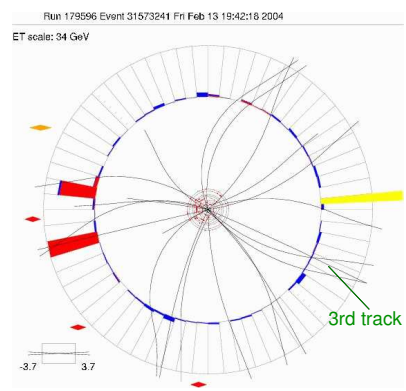


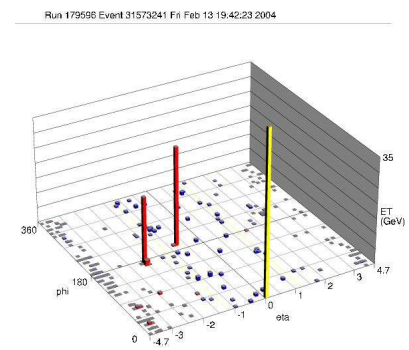
Results

	data	bkg expectation	main bkg	signal expectation $m_{\chi^\pm} = 105\,\mathrm{GeV}$
$\mathrm{ee}+\ell$	**1**	**0.68 ± 0.40 ± 0.32**	$\mathrm{Z}/\gamma, \mathrm{W}+\mathrm{jet}/\gamma, \mathrm{WW}, \mathrm{WZ}$	**1.65±0.07±0.09**
$\mathrm{e}\mu+\ell$	**0**	**0.29 ± 0.33 ± 0.02**	$\mathrm{WZ}, \mathrm{W}+\mathrm{jet}/\gamma, \mathrm{WW}$	**1.18±0.05±0.06**
$\mu\mu+\ell$	**1**	**1.83 ± 0.40 ± 0.21**	$\mathrm{Z}/\gamma \to \mu\mu(\tau\tau)$	**1.06±0.04±0.12**
$\mathrm{LS}\mu\mu$	**1**	**0.13 ± 0.06 ± 0.02**	$\mathrm{WZ}, \mathrm{b\bar{b}}, \mathrm{ZZ}$	**0.37±0.03±0.03**

$\mathrm{e}+\mathrm{e}+\ell$ candidate:

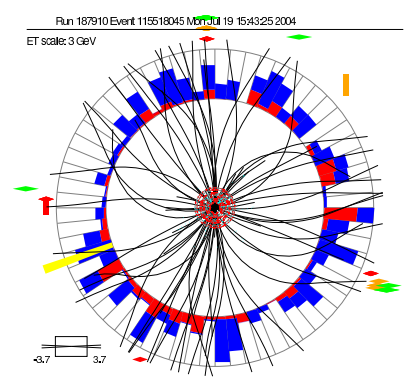
- **two LS electrons (33,26 GeV)**
- **track (9 GeV)**
- **$\not{E}_T$ = 52 GeV**
- **transverse mass: 85, 74 GeV**
- **consistent with $\mathrm{W}+\gamma \to \mathrm{e}\nu+\gamma$ with photon conversion**

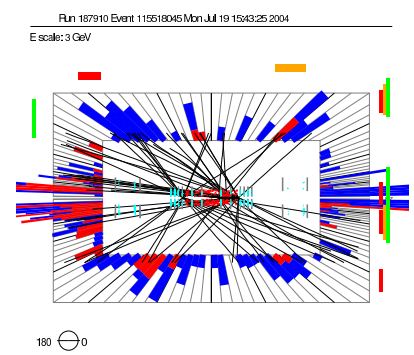




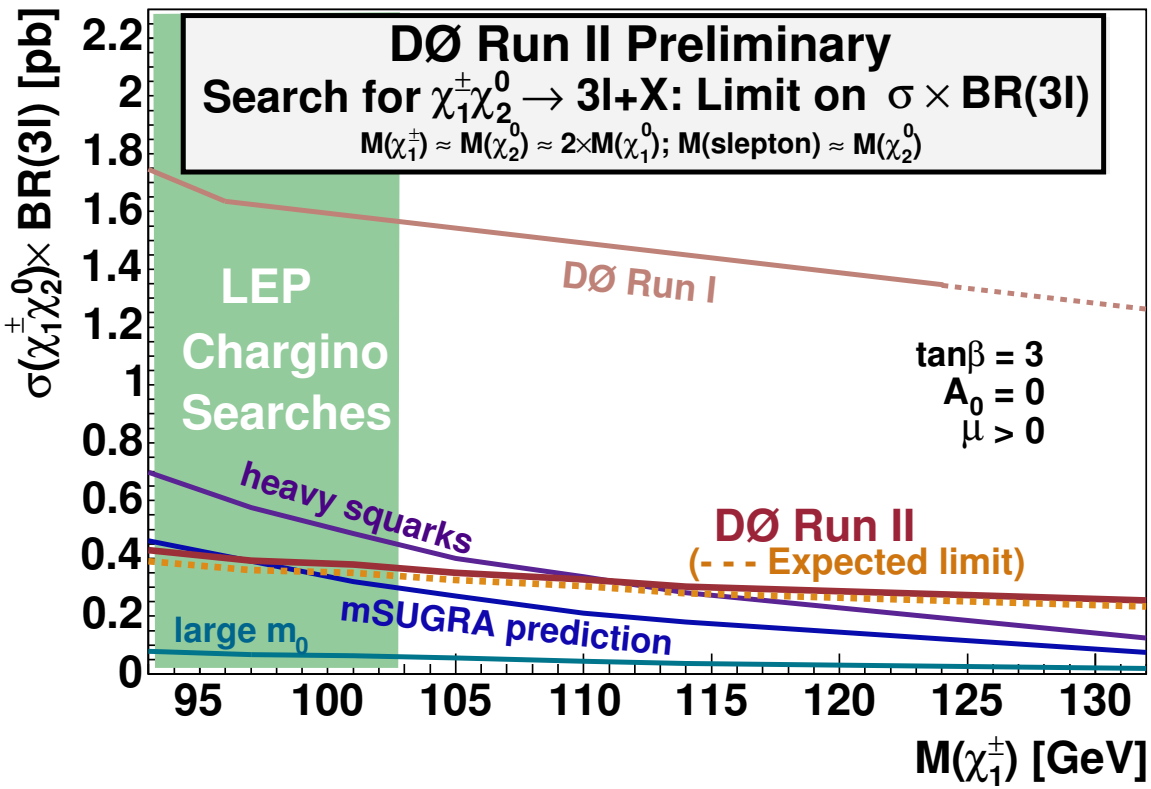
$\mu+\mu+\ell$ candidate:

- **two muons (19, 5 GeV)**
- **track (5 GeV)**
- **$\not{E}_T$ = 34 GeV**
- **$\mu\mu$ mass: 17 GeV**
- **consistent with $\mathrm{Z}/\gamma \to \mu\mu$**





Interpretation of the Results



- Chargino mass scan for slepton masses ≈ chargino mass
- Theoretical cross section for 3 scenarios as a reference:
  - heavy squarks (drop sfermion mass universality): enhanced cross section
  - mSUGRA with large leptonic branching fraction (light sleptons and bino LSP: enhanced BF via virtual sleptons)
  - heavy sleptons: chargino/neutralino decay via Z*/W*: small leptonic branching fraction

Summary

- **Searches for associated chargino-neutralino production have been performed in 4 final states ($\mathrm{ee}\ell, \mu\mu\ell, \mathrm{e}\mu\ell, \mathrm{LS}\mu\mu$) in the challenging low-mass region with soft leptons.**

- **The number of expected signal events is in the order of 1-2 events per analysis. 3 candidate events have been selected in agreement with the prediction of the standard model.**

- **The combined analysis improves on the Run I result and probes new SUSY mass regions beyond the LEP II limits down to cross section $\times$ BR(3 leptons) in the order of 0.3 pb.**

- **The analysis sets a chargino mass limit at 97 GeV in mSUGRA scenarios with large leptonic BF.**
  Sensitivity for mSUGRA beyond the LEP II chargino limits is expected with 25 % more data.

- **Already much more data on tape $\rightarrow$ stay tuned and expect updates soon !**