Search for SUSY in photonic states and for long-lived particles at the Tevatron

E. Nagy (CPPM)

for the

CDF and DØ

Collaborations

SUper SYmmetry

Symmetry of Nature for Boson<->Fermion interchange
- Basic ingredient for unification with gravity (SuperString/M-theory)
- The only nontrivial extension of the Lorentz-Poincaré group
- Provides elegant solution to evade the fine tuning problem

Minimal extension of the SM: MSSM
- every SM particle has $\Delta S = \pm 1/2$ partner
- $R = (-1)^{3B+L+2S}$ = +1 (SM); = -1 (SUSY)
- 2nd Higgs doublet is needed

R = +1

$$q, l \Leftrightarrow \tilde{q}, \tilde{l}$$

$$g \Leftrightarrow \tilde{g}$$

$$\gamma, Z, h, H, A \Leftrightarrow \chi^0_{1,\ldots,4}$$

$$W^\pm, H^\pm \Leftrightarrow \chi^\pm_{1,2}$$

R = -1

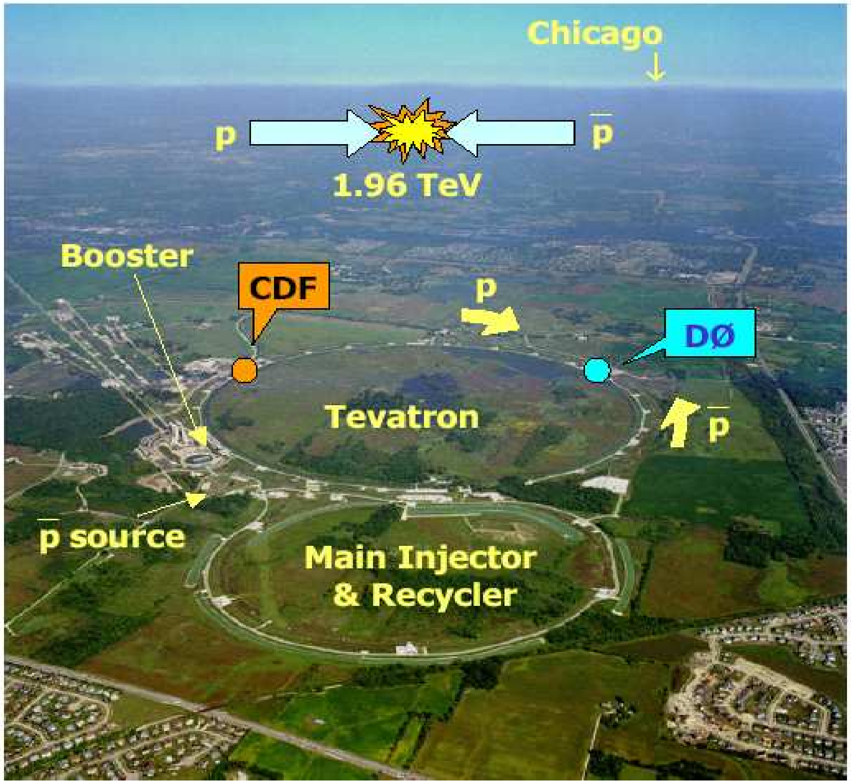
If SUSY were exact: only 1 additional parameter (μ) needed

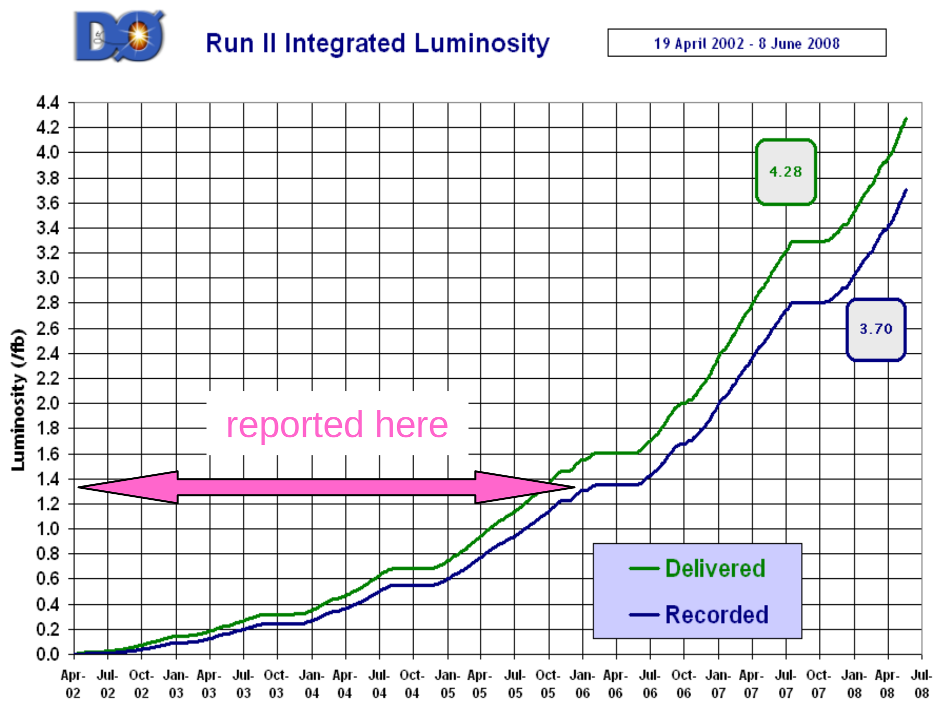
SUSY is a broken symmetry since nobody has seen the partners
many more parameters describe breaking.
With additional hypotheses they are reduced, e.g.
in gravitation mediated (mSUGRA) model to 5 (m_0, $m_{1/2}$, $\tan\beta$, $\mathrm{sgn}\mu$, A_0)
in gauge mediated (GMSB) model to 6 (Λ, M_m, N_5, $\tan\beta$, $\mathrm{sgn}\mu$, C_{grav}) parameters.
In anomaly mediated (AMSB) model – no mass unification is assumed.

In most cases R-parity is assumed to be conserved:
since there are severe limits on B- and L-violating processes.
Then: SUSY partners are pair produced
LSP is stable (neutral and weakly interacting) – dark matter candidate

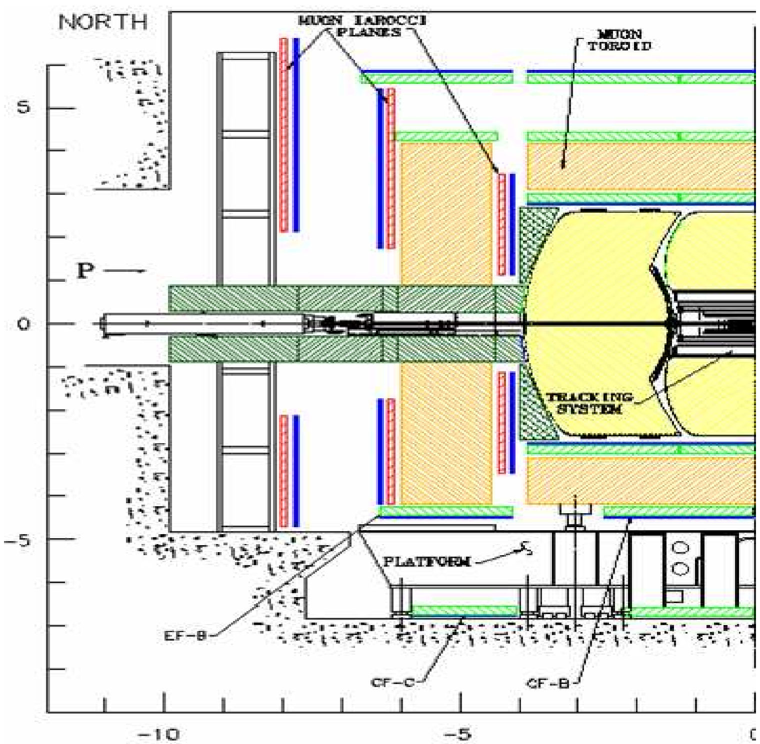
In this talk we assume R-parity conservation and use models with GMSB and AMSB

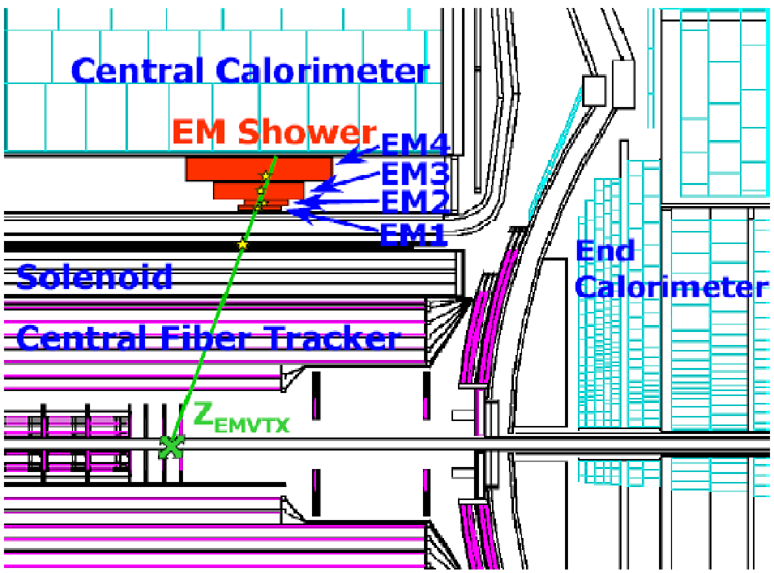
Tevatron





Run IIa ended in March 2006 – full dataset 1.3 fb^{-1} (10x Run I) reported here
Run IIb started in June 2006 – hoping to reach 8 fb^{-1} by ~2010
→ an order of magnitude of potential improvement in luminosity for the analyses



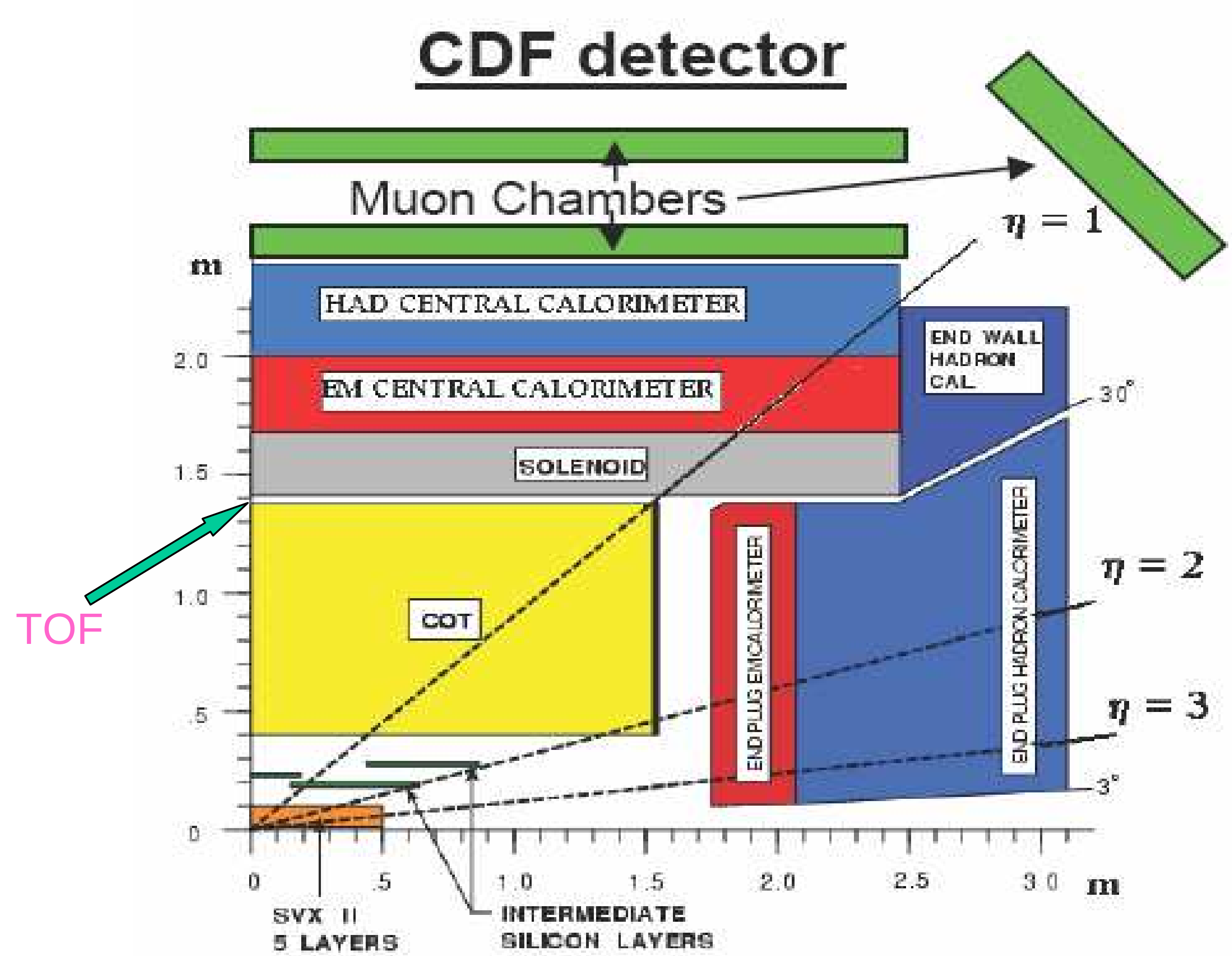


The central preshower (CPS) is particularly useful:

to provide photon (high p_T electron) pointing

to disentangle electromagnetic and hadronic jets

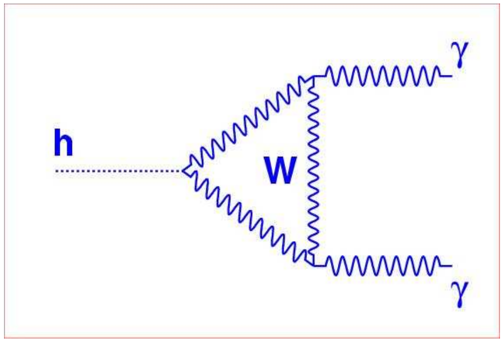
Timing information from muon scintillation trigger counters



Timing information:

- TOF counters at the end of the tracking volume
- Track residuals from COT drift time measurements
- EM Timing system: measures arrival time of electrons and photons in the calo

Fermiophobic Higgs

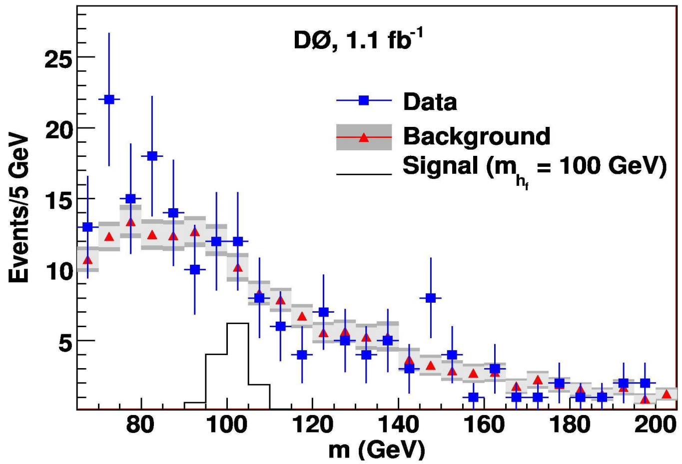


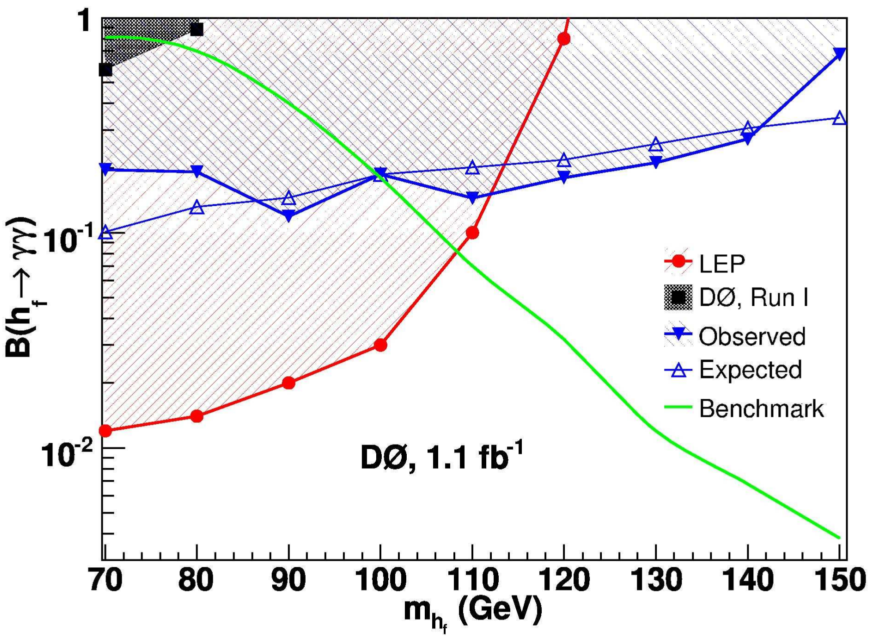
In some extensions of the SM BR($h \rightarrow \gamma\gamma$) can be ~ 1 since only h → V V (V=W,Z) exists

An example is the 2H doublet model (e.g. SUSY) with mixing between the CP even h^0 and H^0 $\alpha=\pi/2$

DØ: searches for peaks in $M_{\gamma\gamma}$

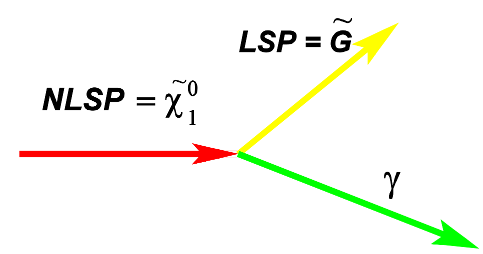
Background: jets faking photons separated by their shapes in the CPS





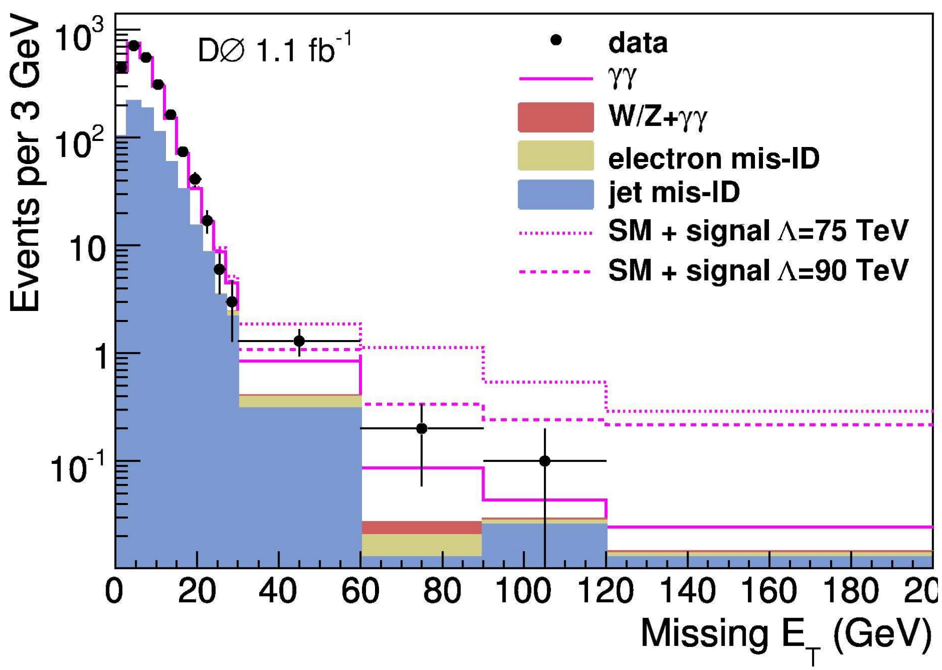
GMSB

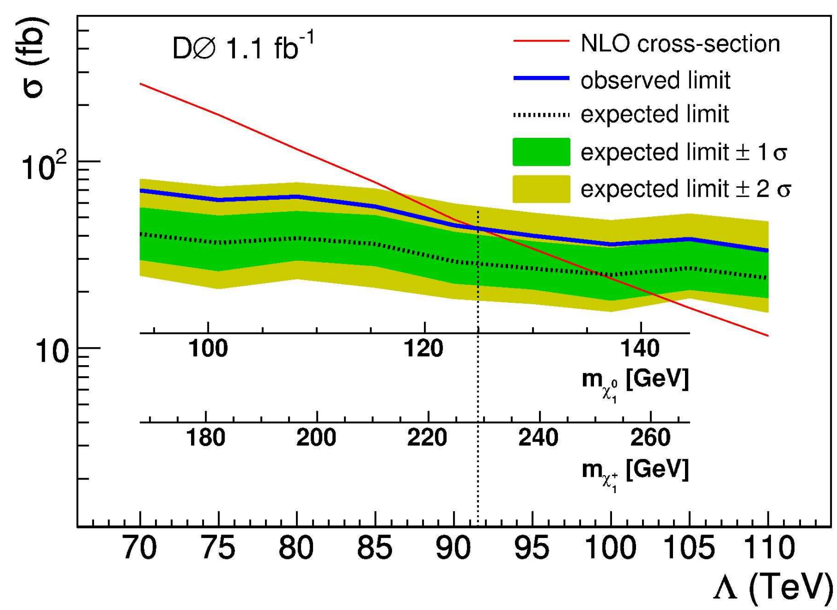
Signal: 2 photons and MET
Background: mainly instrumental
mismeasured MET from $\gamma\gamma$
jets faking photons



Photon pointing algorithm developed using em cluster centroids and CPS helps choosing primary vertex

$N_5=1$, $\tan\beta=15$, $\mu>0$, $M_m=2\Lambda$
C_{grav} chosen for prompt decays



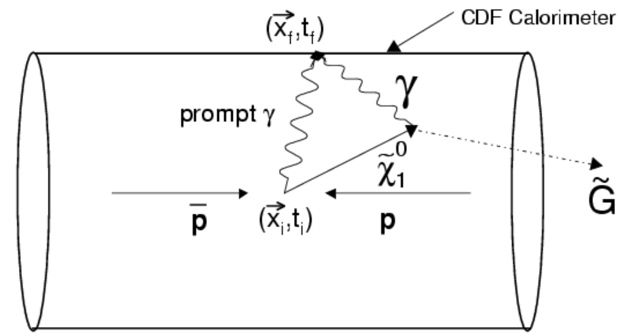


$m_{\chi_1^\pm} < 229$ GeV
$m_{\chi_1^0} < 125$ GeV
excluded

GMSB

$N_5=1$, $\tan\beta=15$, $\mu>0$, $M_m=2\Lambda$

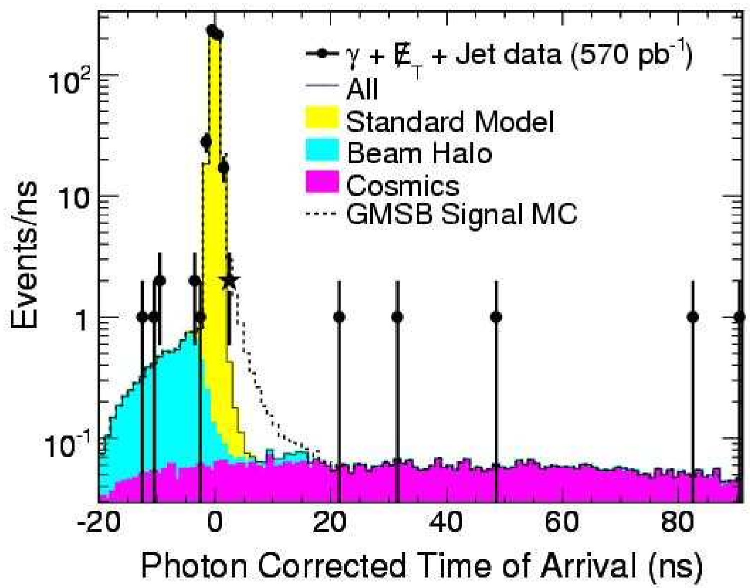
C_{grav} chosen for long decaytime



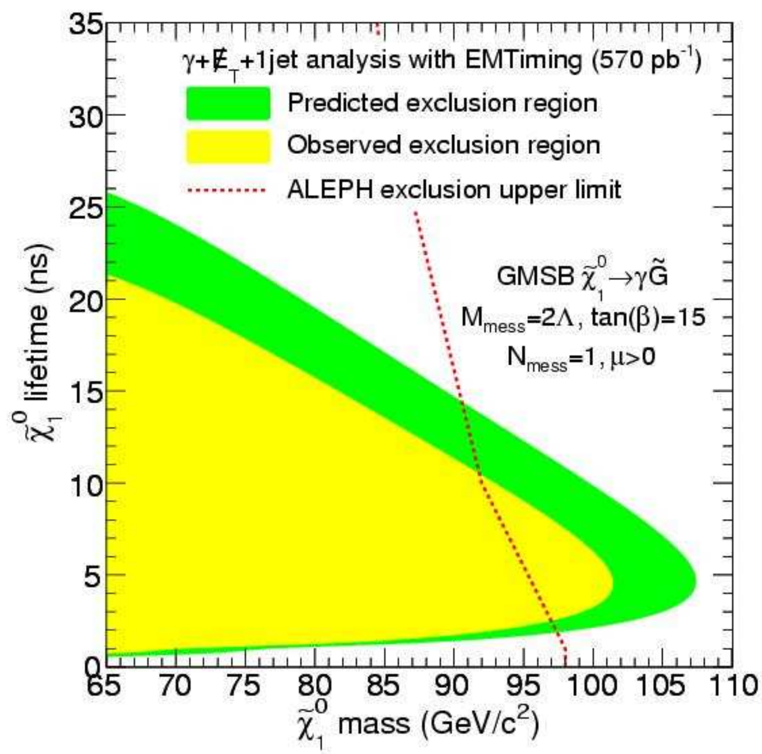
Signal: $E_T^\gamma>30$ GeV, MET>40 GeV, $E_T^j>35$ GeV

Bg: SM (misID γ, W→eν), cosmics, beam halo

Selected by: $2ns < t_c^\gamma = t_f - t_i - \frac{|\vec{x}_f - \vec{x}_i|}{c} < 10ns$

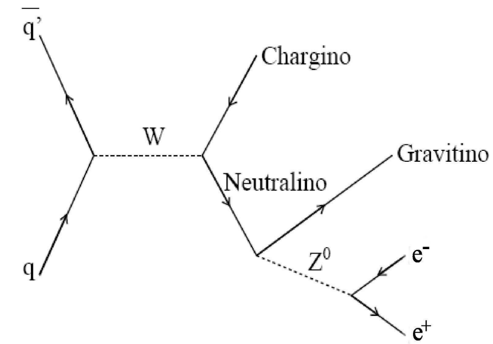


Observed:
2 events
Predicted:
1.25±0.66

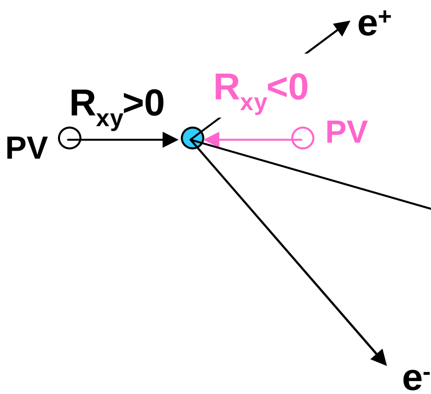


GMSB

Long-lived $\chi_1^0 \rightarrow \tilde{G} + Z$

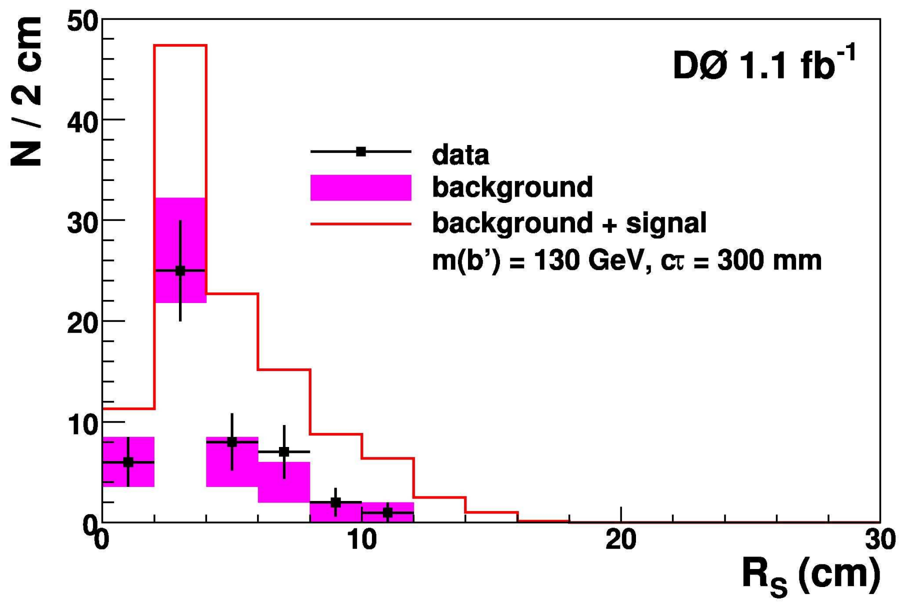


χ_1^0 can travel several meters
The displaced vertex is reconstructed by the tracker (CDF)
or using the calorimeter and CPS (DØ)

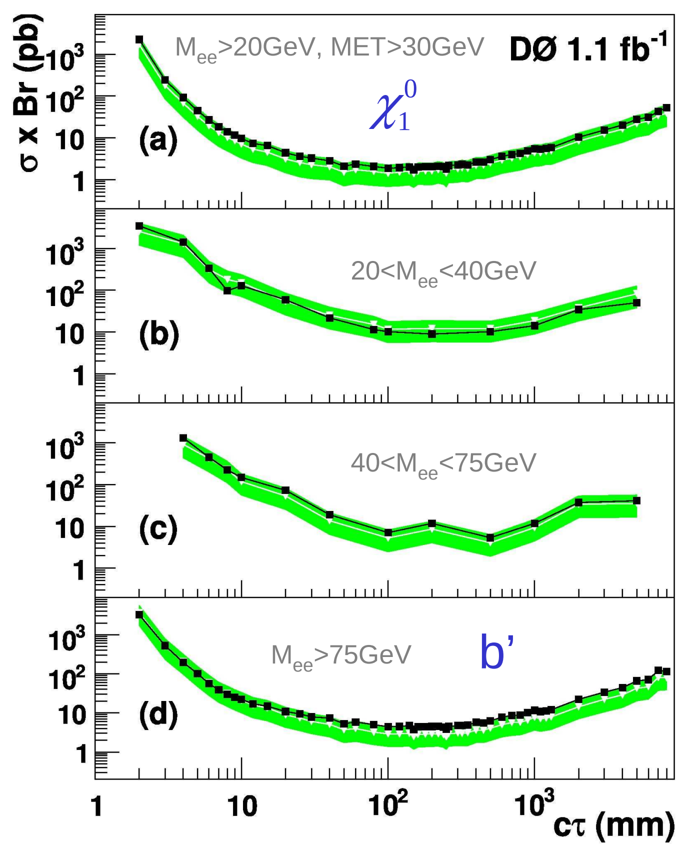


For long-lived particles
excess of R_{xy} >0 expected
Not observed in data

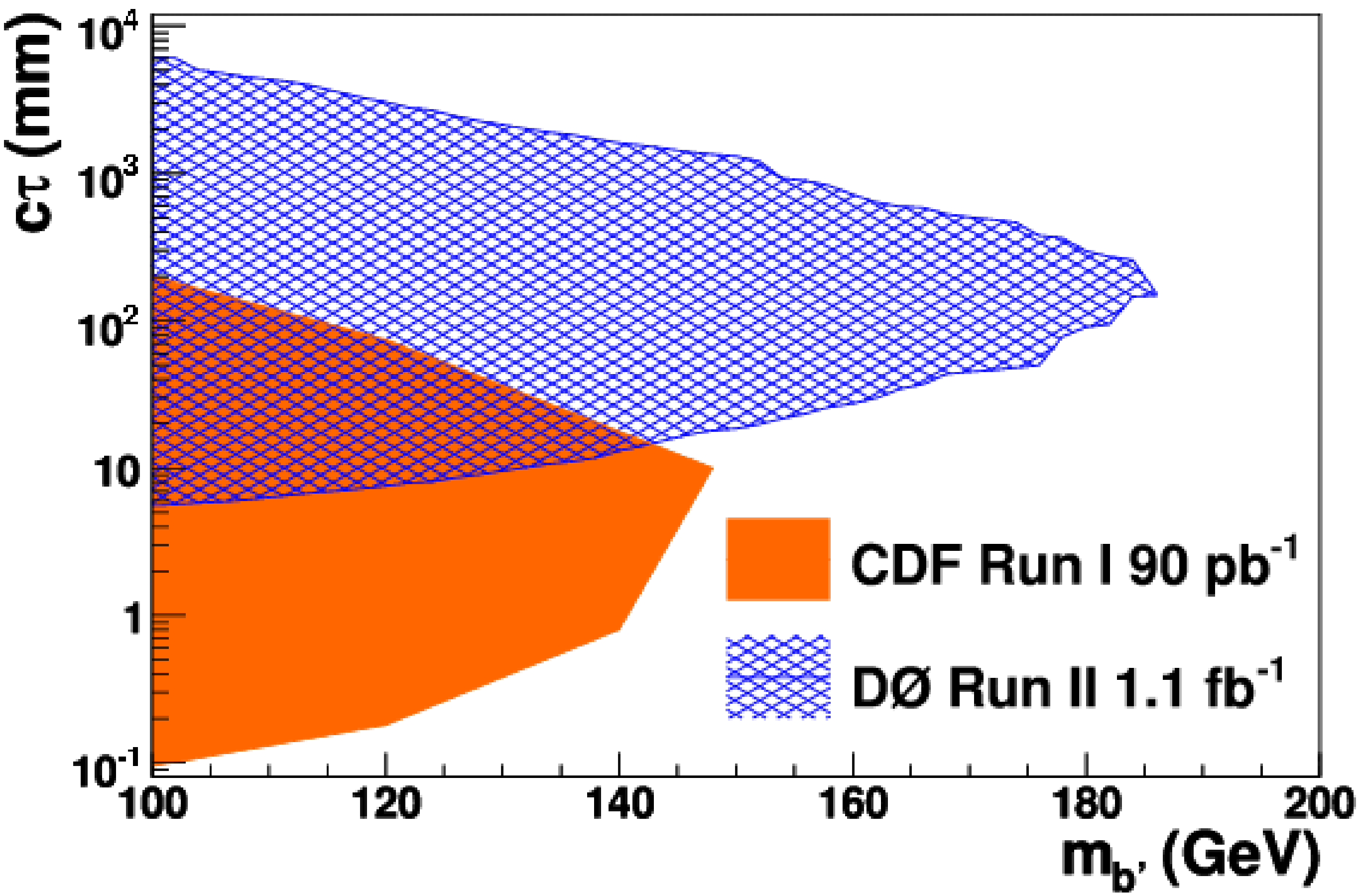
Bg estimated from R_{xy}<0



Cross section x BR limits



Several meters of lifetime have been excluded for $b' \rightarrow Z+b$ ($m_{b'} < m_t$)



GMSB

$N_5=3$, $\tan\beta=15$, $\mu>0$, $M_m=2\Lambda$, $\Lambda=19 \rightarrow 100$ TeV
C_{grav} chosen for long decay time

These staus live long (CMSP) appear as muons in the detector, but they are slower: $v \sim p/E$
Speed significance (sps): $(1-v)/\sigma_v$
$\sigma_t \sim 2$-3 ns in D0 muon detector

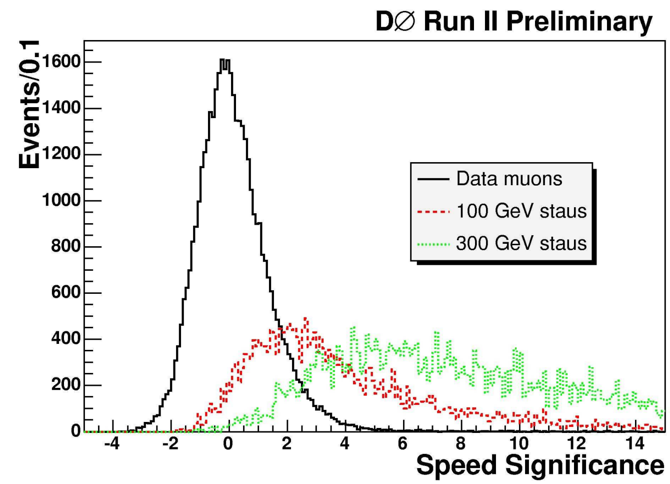
Select: 2 muons $p_T>15$ GeV
- at least 1 muon isolated
- cosmic ray veto
- sps > 0 for both muon
- cut optimized in the $M_{\mu\mu}$ vs $sps_1 * sps_2$ plane depending on the CMSP mass

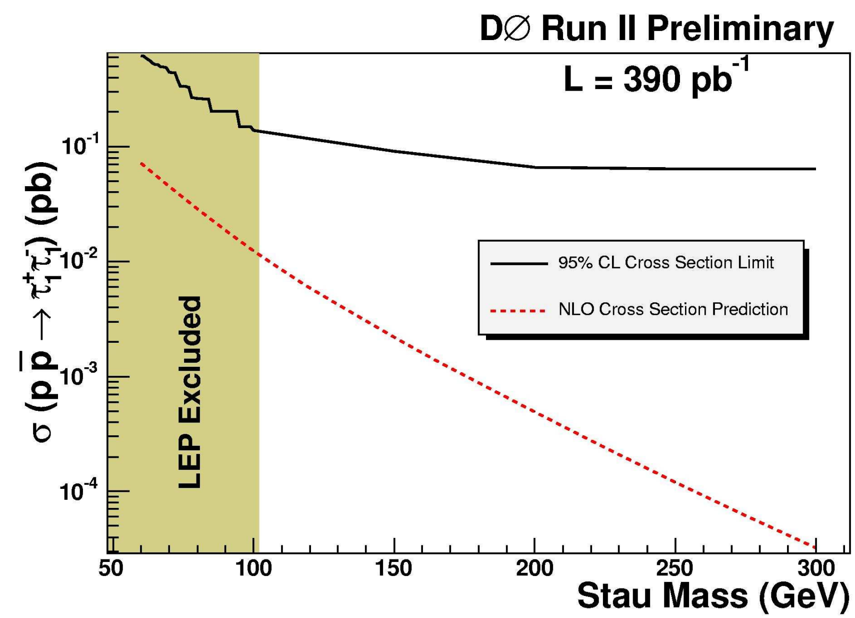
Background are muons of missmeasured time: estimated from data $Z \rightarrow \mu\,\mu$ (sps<0)

Data is compatible with expectation of the SM
No event observed for M_{CMSP}>=100 GeV
typical background: 0.60 ± 0.05
(depending slightly on the mass)

95% upper limits on stau pair production
No mass limit yet

Long-lived stau (NLSP) pair production in GMSB



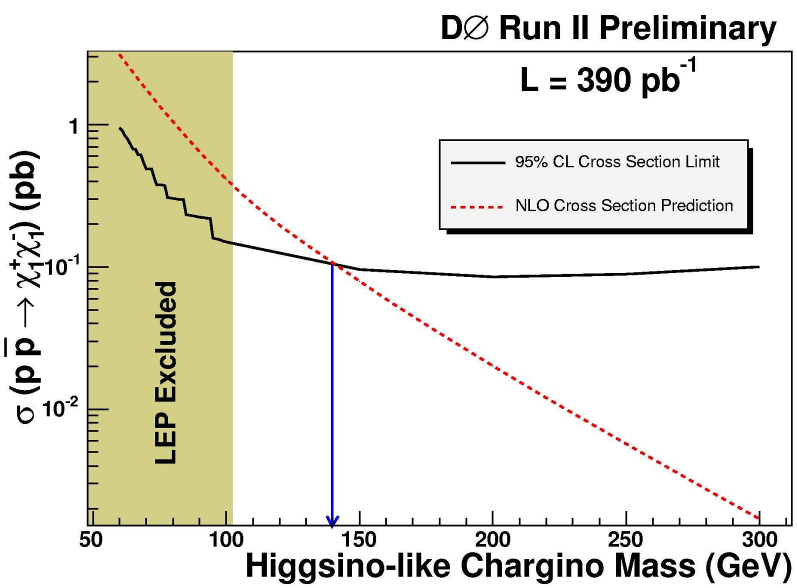


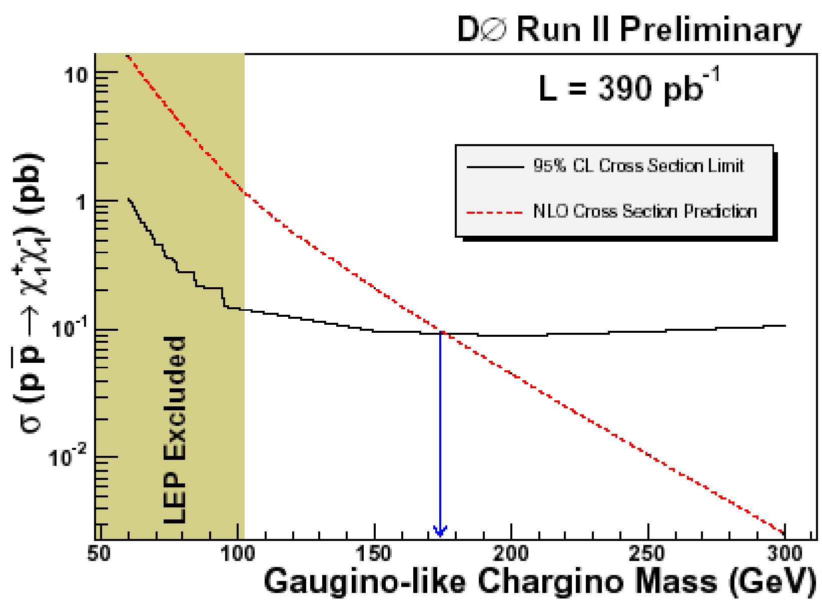
AMSB

Long-lived chargino pair production

if $M_{\chi_1^\pm} - M_{\chi_1^0} \leq 150$ MeV

DØ reinterpreted the search for GMSB staus





Exclude $M_{\chi\pm} < 140$ GeV (higgsino-like)

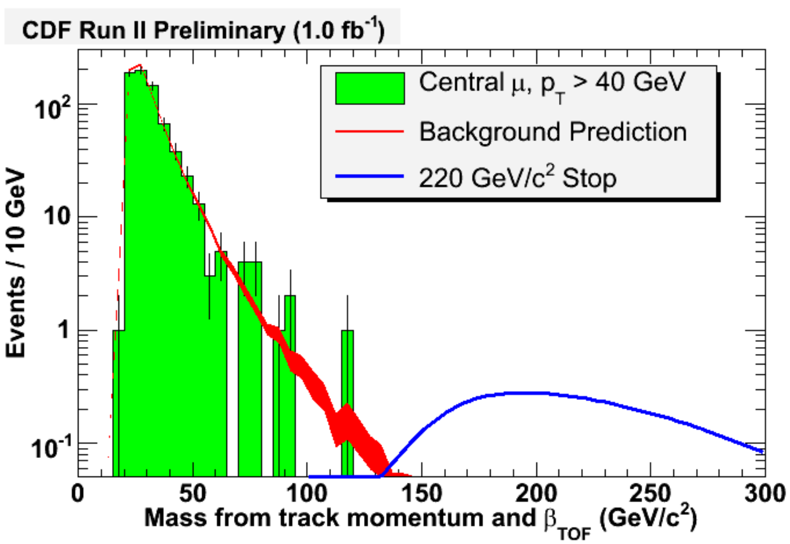
Exclude $M_{\chi\pm} < 174$ GeV (gaugino-like)

CHAMP

Search for charged, massive stable particles (stop)

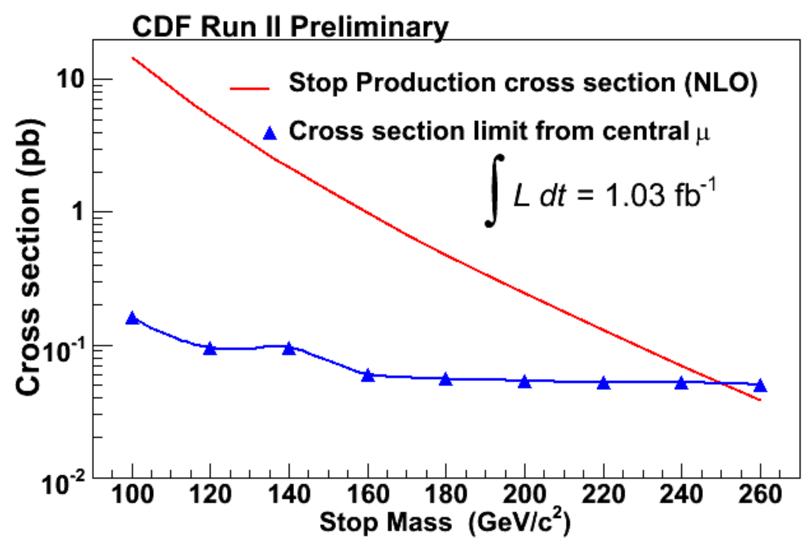
Select: 2 high p_T (p_T>40 GeV)
slow ($v < 0.9$)
penetrating (muon-like) tracks
Reject cosmics
Calculate mass: $M^2=p^2(1/v^2-1)$

1 event remains beyond M > 100 GeV
Distribution agrees with bg prediction



Determine: $v = d_{TOF}/(t_{TOF}-t_0)$
t_0 from p_T<20 GeV particles
in TOF and in COT track residuals

Estimate background by convoluting
p^2 and $1/v^2-1$ distributions of particles
with 20 < pT < 40 GeV (mainly $W \rightarrow l\nu$)



$M_{\tilde{t}}$ < 250 GeV excluded

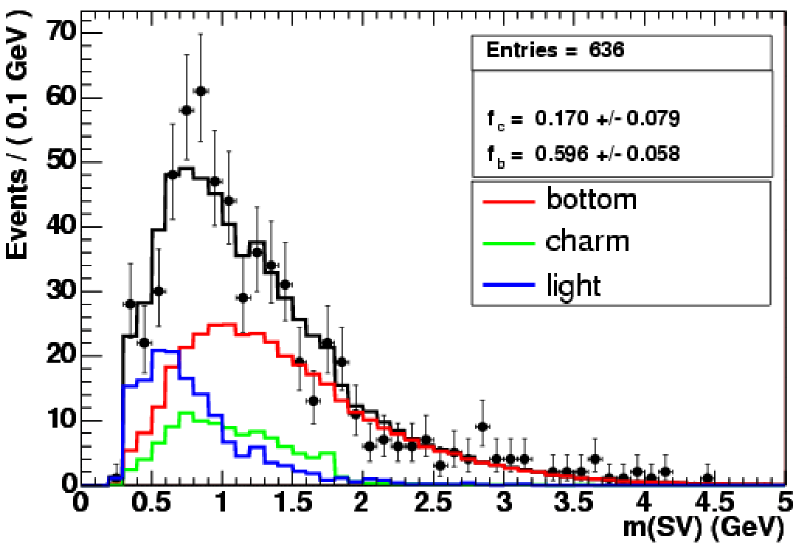
Search for anomalous production of γ+b+j+MET

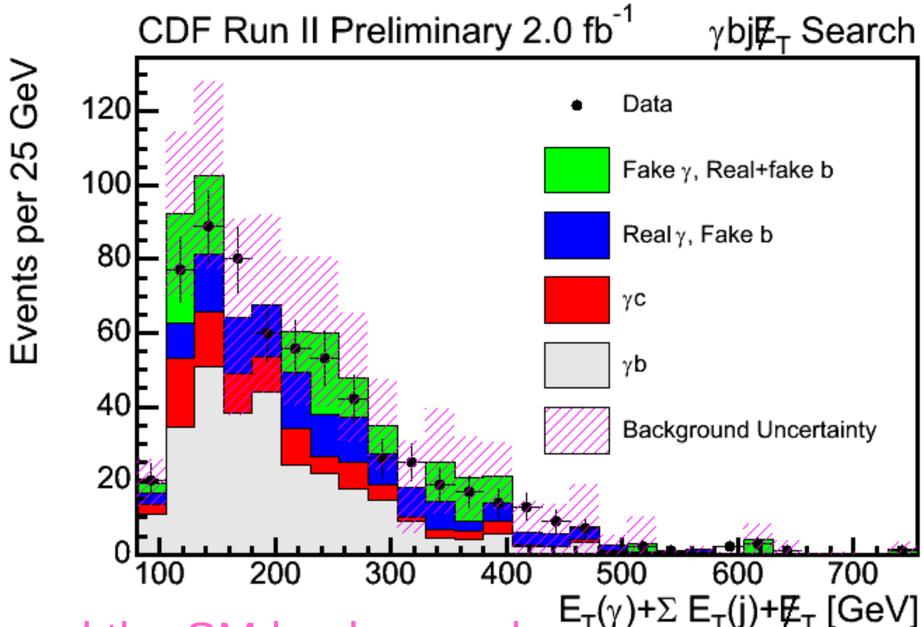
From chargino-neutralino pair-prod: $\chi_1^\pm \chi_2^0 \rightarrow (b\tilde{t})(\gamma\chi_1^0) \rightarrow (bc\chi_1^0)(\gamma\chi_1^0) \rightarrow \gamma bcMET$

Select: photon E_T > 25 GeV, 2 jets (1b-tag) E_T > 15 GeV, MET > 25 GeV

Photons and jets are separated by shape in the shower-maximum detector (low ET) and in the preshower (high ET)

HF are separated by the mass templates of the secondary vertex





No excess has been found beyond the SM background

Conclusions

Photonic final states and long-lived particles are powerful tools for searching new physics at the Tevatron

The excellent performance of the collider and detectors together with innovative methods in the analyses allowed to study these topologies

No evidence for new physics has been found so far

New domains have been excluded thereby shrinking considerably the allowed parameter space

Acknowledgements

for help in preparing this material to:

CDF and D0 physics coordinators
group conveners
and the authors of the analyses

More information can be found on:
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm
http://www-cdf.fnal.gov/physics/exotic/exotic.html