Studies of the Higgs boson and direct searches for new phenomena at the Tevatron

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Rencontres de Moriond 2015
Electroweak Interactions and Unified Theories

Outline

- Tests of Higgs models with exotic spin and parity
- Search for fermiophobic Higgs in triphoton final states
- Search for W' boson decaying to top-bottom quark pair
- Search for Dirac magnetic monopole

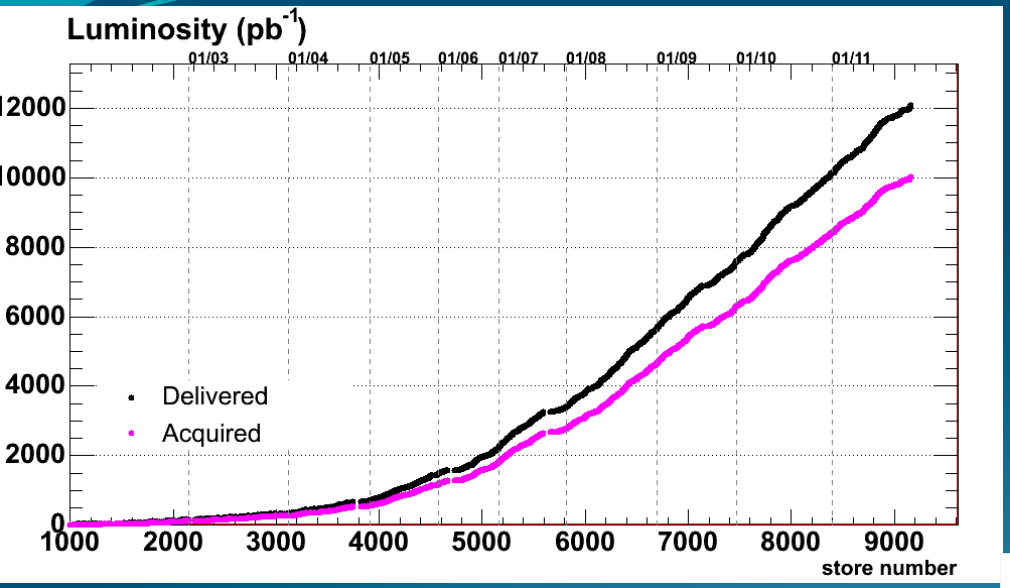
Tevatron

Proton-antiproton collider operating at a collision energy √s = 1.8 TeV from 1989 to 1996 (Run I) and √s = 1.96 TeV from 2001 to 2011 (Run II)

Highest-energy collider until 2010

- ✓ Located at Fermilab near Chicago
- ✓ 1 km radius
- ✓ 1976: Construction started
- ✓ 1985: Commissioning
- ✓ 1987: CDF Run 0
- ✓ Continuous upgrades in 25 years of operations

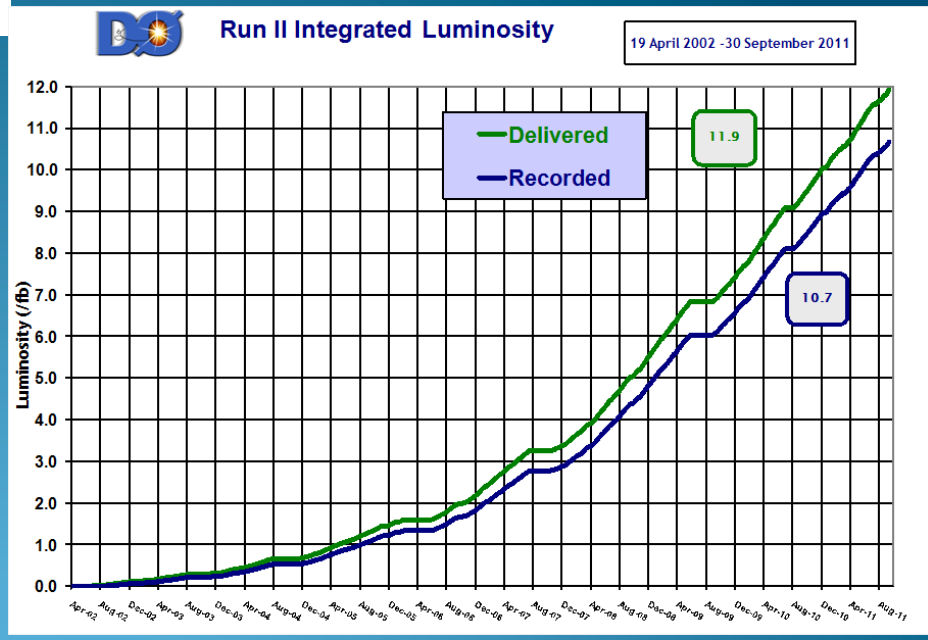
Run II sample



Delivered 12 fb^{-1}
Acquired 10 fb^{-1}/experiment

15B + 9B events total in Run II

Total dataset 10 + 9 PB
(including Monte Carlo)



- ✧ A well understood sample
- ✧ Special track and vertex triggers
- ✧ Variety of collision energies
- ✧ Unique p-pbar initial state (unlikely to have again)

arXiv:1502.00967, submitted to PRL

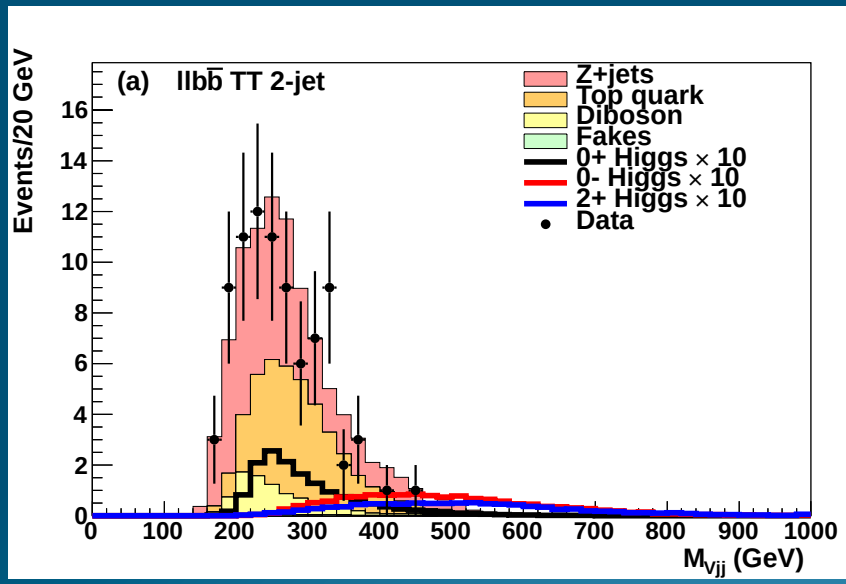
Tests of Higgs models with exotic J^P in VH(bb)

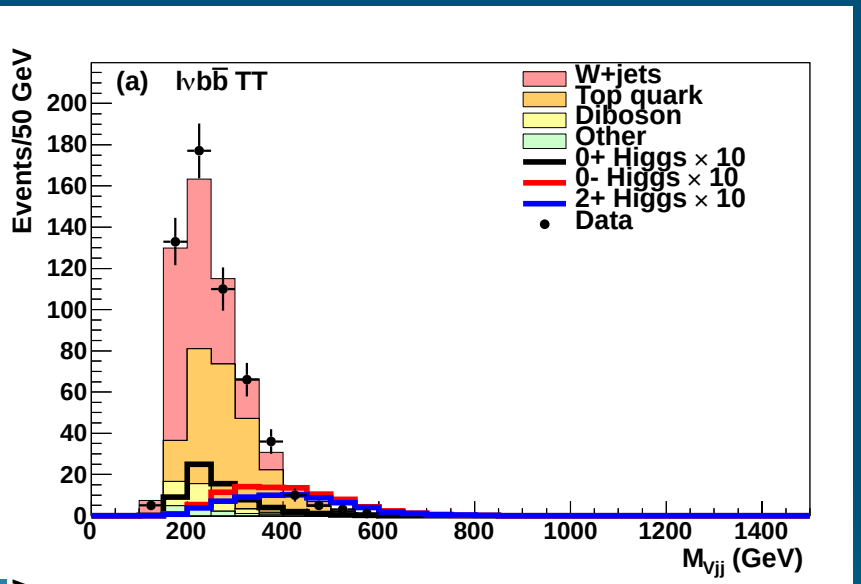
- Tevatron is sensitive to VH(bb), where LHC is not yet, worth trying to test Higgs properties in this production & decay mode
- Theorists proposed that Higgs models of exotic $J^P = 0^-$ and 2^+ at the measured mass of 125 GeV/c^2 be tested especially in this mode
- Models exploit kinematic differences near threshold between VX(bb) and VH(bb) + SM backgrounds, where $V \rightarrow ll$, $l\nu$, or $\nu\nu$ (missing E_T)
- Models do not predict production & decay rates of exotic candidates

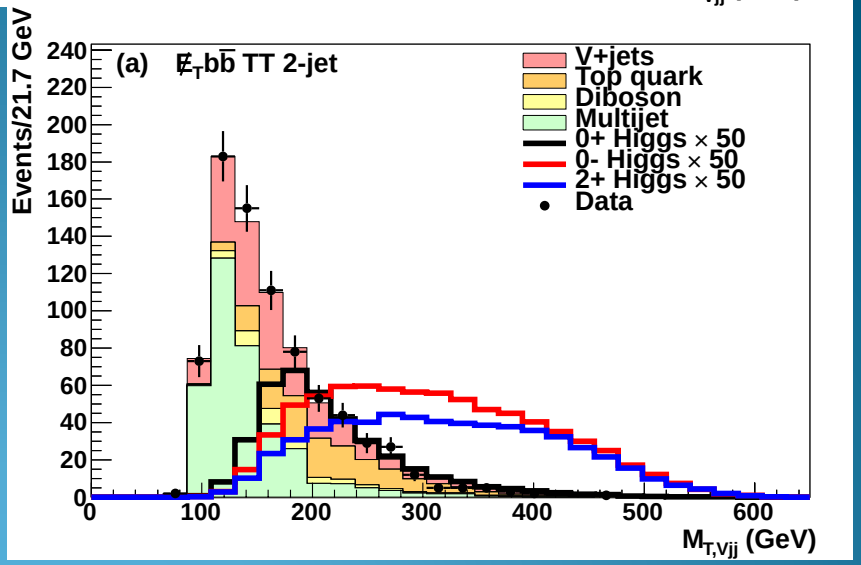
J. Ellis et al., JHEP 1211 (2012) 134

arXiv:1501.04875, accepted in PRL

Tests of Higgs models with exotic J^P in VH(bb)



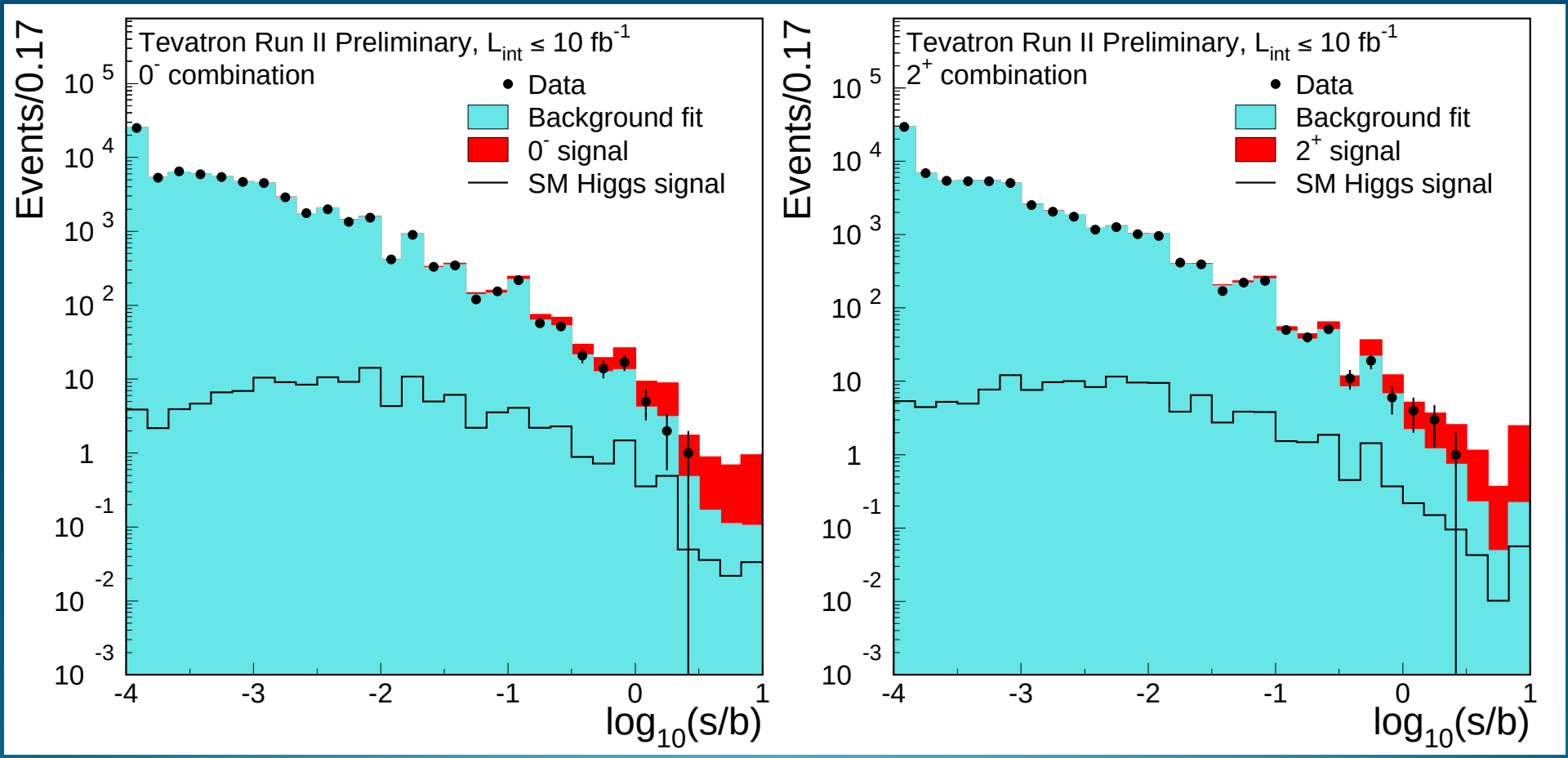




Difference is maximal in total invariant mass of the final state, but full MVA discriminants of the SM Higgs searches (including the invariant mass) were used

arXiv:1502.00967, submitted to PRL

Tests of Higgs models with exotic J^P in VH(bb)



Discriminants for all modes & all categories optimized on lepton & jet ID were combined together

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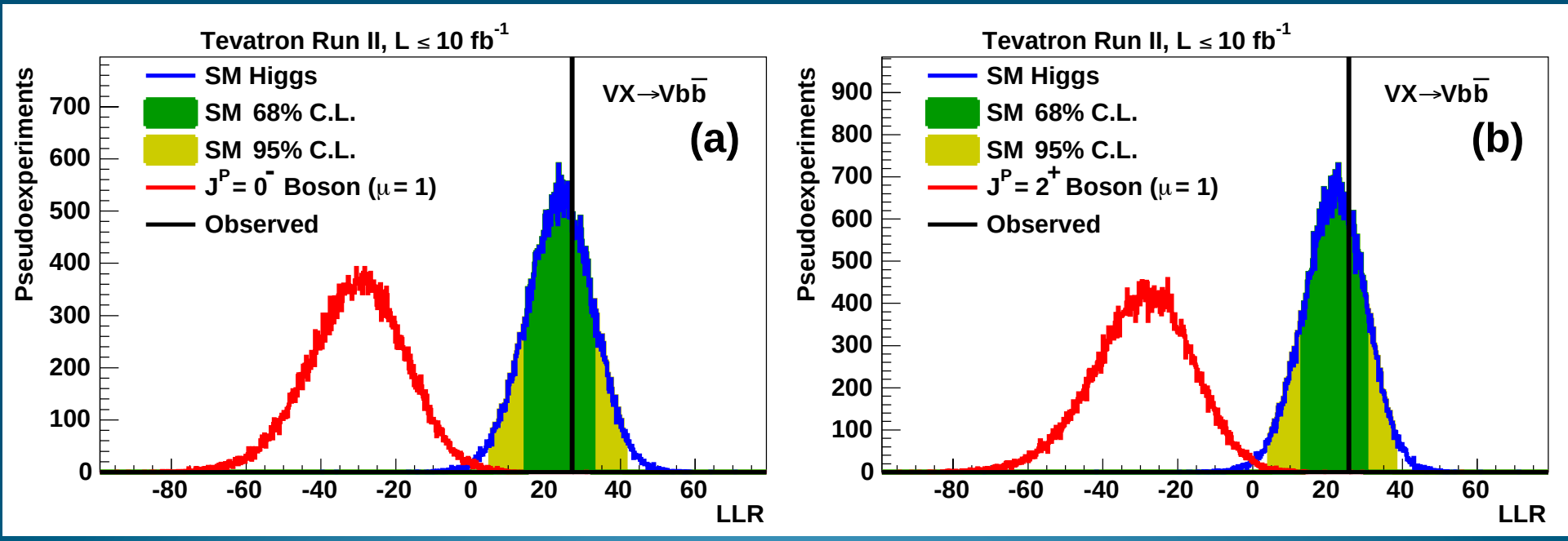
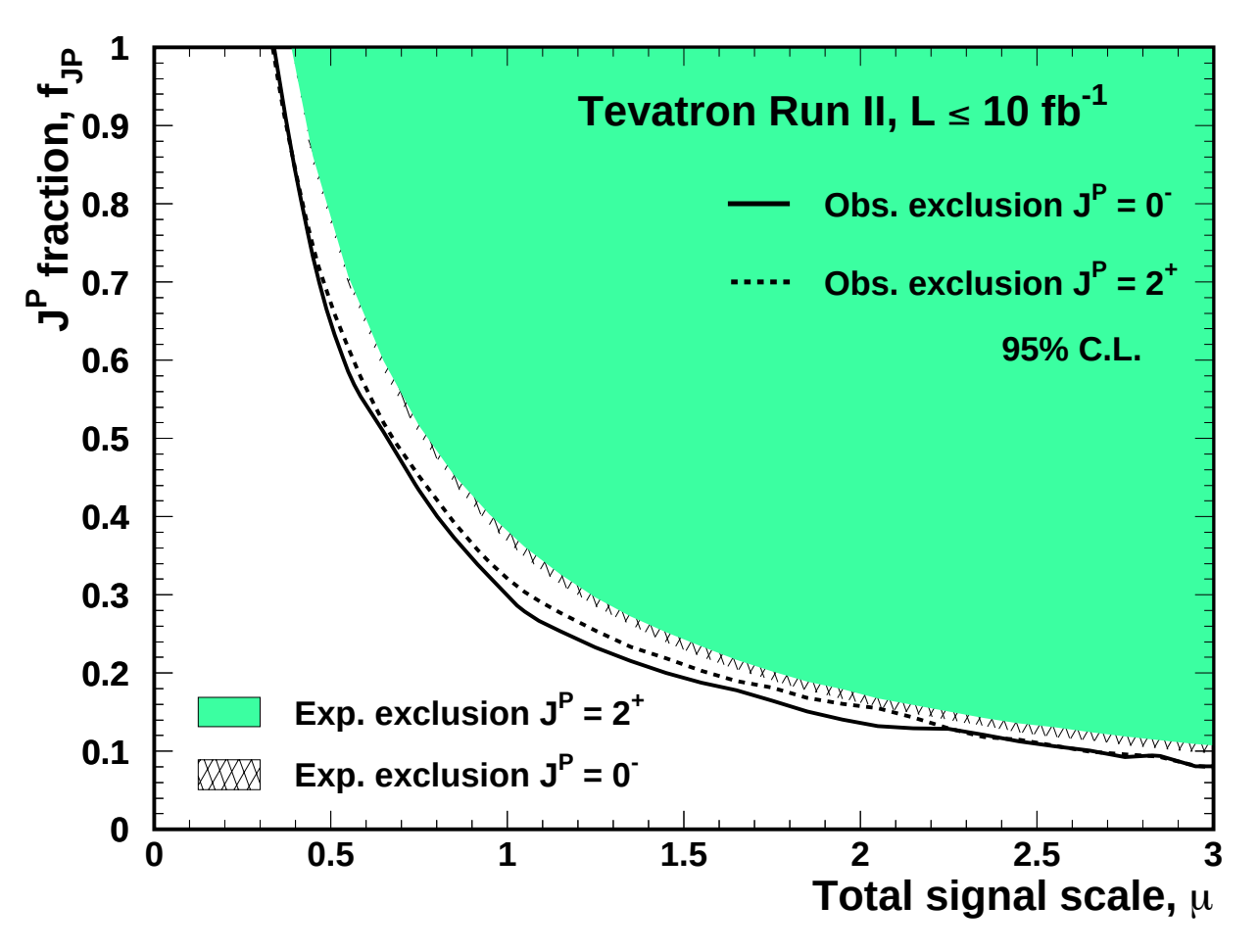
Tests of Higgs models with exotic J^P in VH(bb)



- ✓ 0^- excluded at 4.9σ and 2^+ at 5σ, in the absence of 0^+, assuming SM production and decay rates
- ✓ 95% CL limits of production rates at 36% of SM rate set for both 0^- and 2^+, in the absence of 0^+

arXiv:1502.00967, submitted to PRL

Tests of Higgs models with exotic J^P in VH(bb)



$$f_{JP} = \mu_{exotic} / (\mu_{exotic} + \mu_{SM}), \quad \mu = \mu_{exotic} + \mu_{SM}$$

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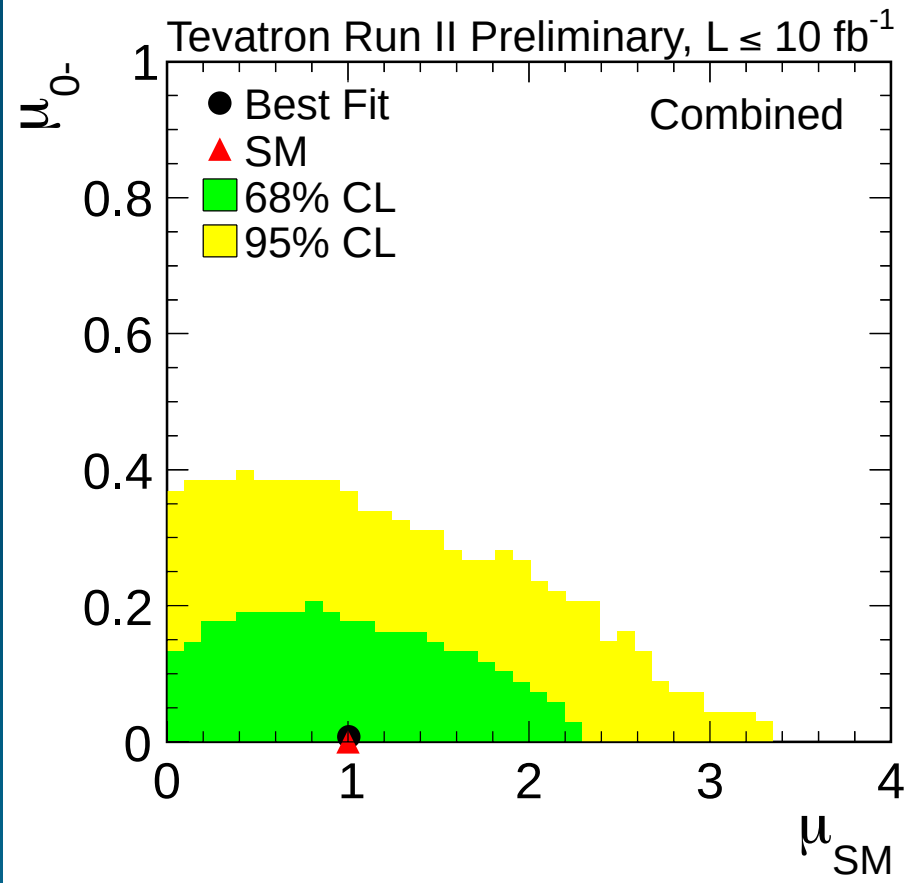
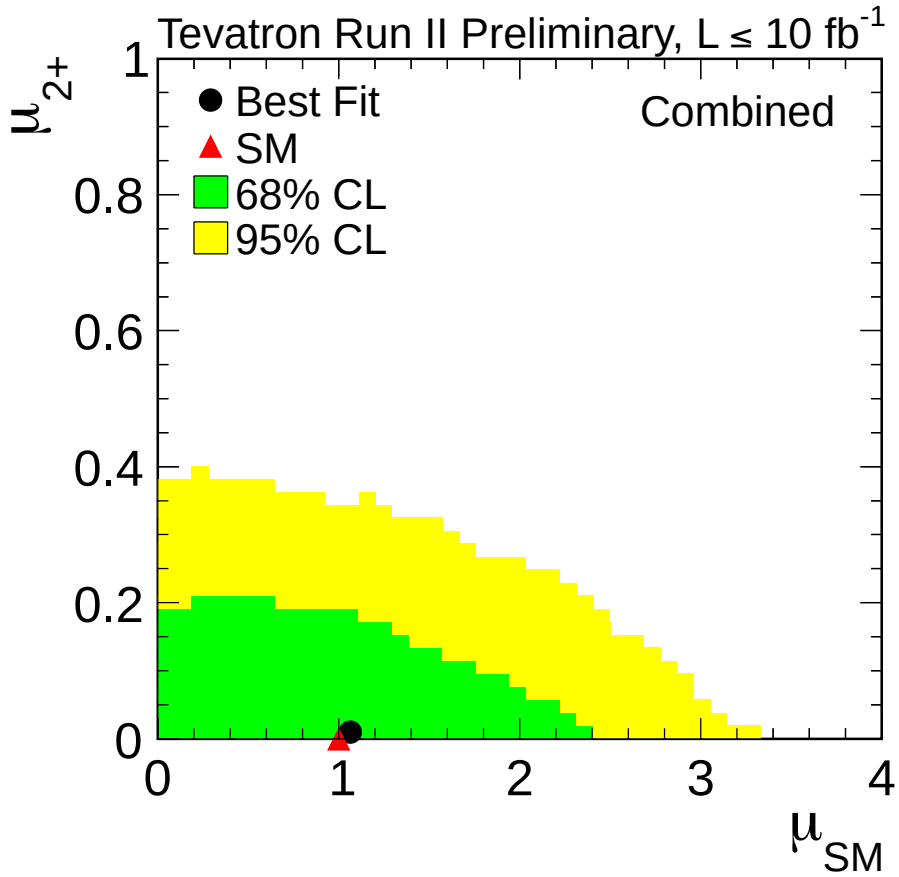
Tests of Higgs models with exotic J^P in VH(bb)



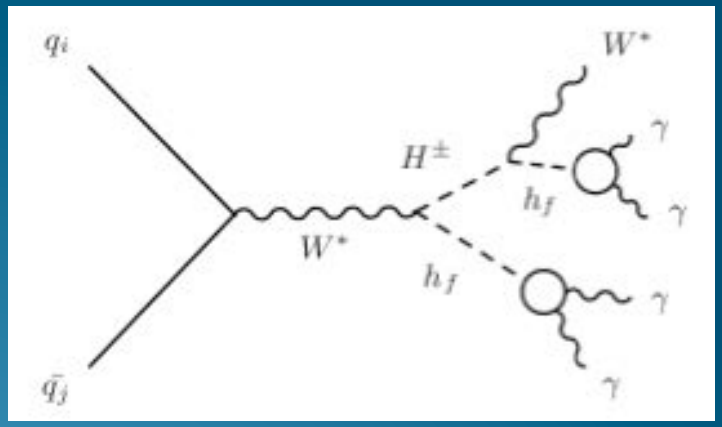


CDF conf. note 11116

Search for FP Higgs in 3γ + X final states

- LEP, Tevatron, LHC exclude so far fermiophobic (FP) scenarios assuming SM-like $h_f VV$ couplings → room for light h_f in SM extensions

- Light (< 100 GeV/c^2) FP Higgs in type I two Higgs doublet model (2HDM) decays predominantly into 2 photons

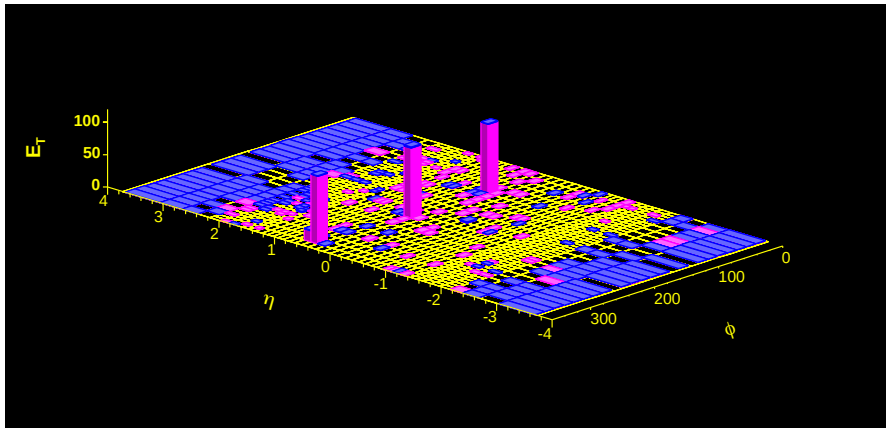


- Looked for decays into 3 prompt, central, isolated, high-p_T γ's, found 5 events in data, with expected SM background of 3 ± 1

- Expected signal yield depends on model parameters → limits are functions of $H^\pm$ and h_f masses for fixed H^0, A^0 masses and tanβ

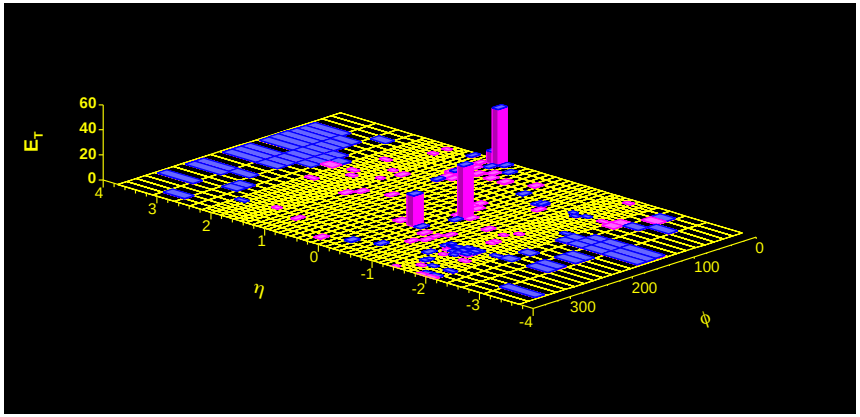
Search for FP Higgs in 3γ + X final states

Run=244996, Ev=6884022



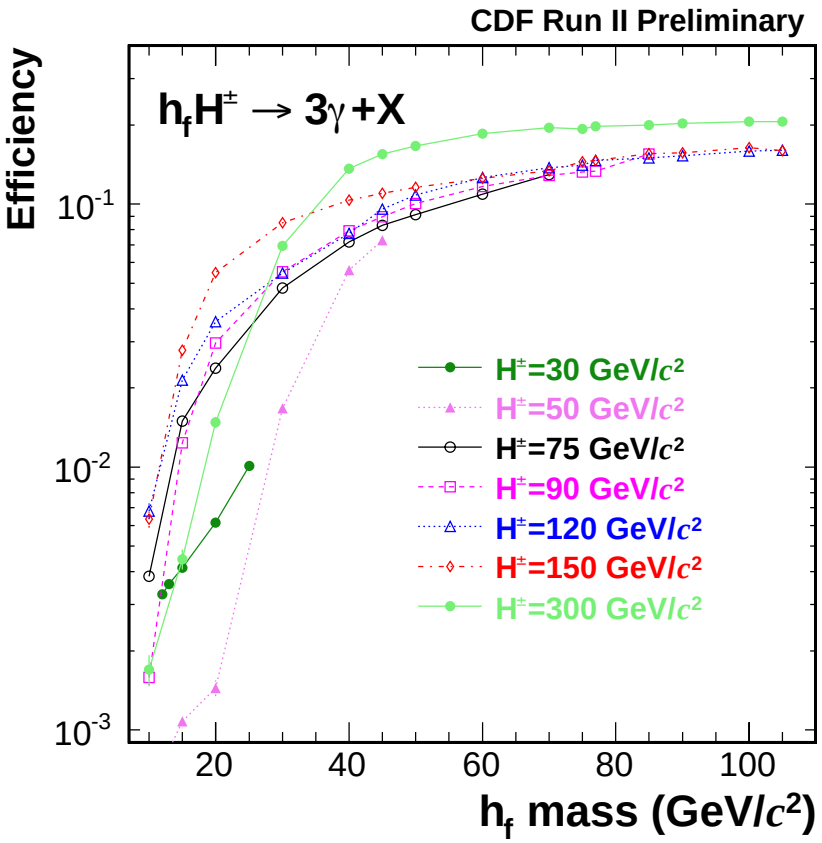
Run = 244996, Event = 6884022		
1st (E_T, η, ϕ)	=	$(117 \text{ GeV}, +0.58, 5.87)$
2nd (E_T, η, ϕ)	=	$(106 \text{ GeV}, +0.40, 3.56)$
3rd (E_T, η, ϕ)	=	$(100 \text{ GeV}, +0.44, 1.53)$
Corrected $\not\!\!E_T$	=	18 GeV
$\phi(\not\!\!E_T)$	=	5.12
(M_{12}, M_{23}, M_{31})	=	$(214, 181, 187)$ GeV/c^2

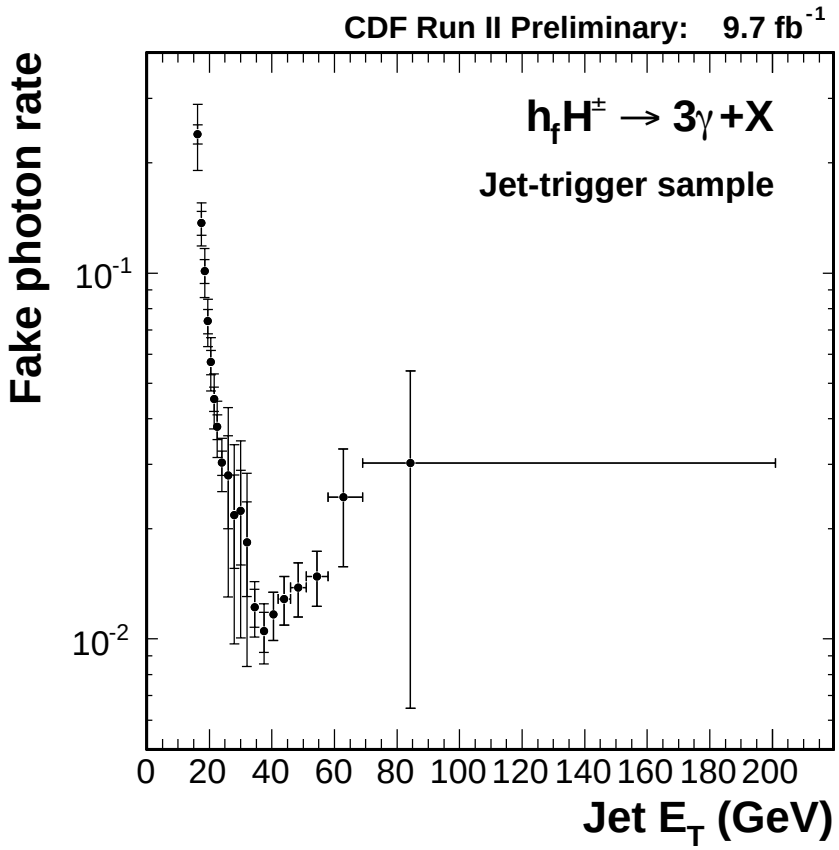
Run=265489, Ev=11130875



Run = 265489, Event = 11130875		
1st (E_T, η, ϕ)	=	$(54 \text{ GeV}, +0.68, 0.19)$
2nd (E_T, η, ϕ)	=	$(40 \text{ GeV}, -0.59, 3.08)$
3rd (E_T, η, ϕ)	=	$(24 \text{ GeV}, -0.36, 4.02)$
Corrected $\not\!\!E_T$	=	24 GeV
$\phi(\not\!\!E_T)$	=	0.70
(M_{12}, M_{23}, M_{31})	=	$(112, 29, 79)$ GeV/c^2
Extra jet $(E_T > 10 \text{ GeV})$ (E_T, η, ϕ)	=	$(15 \text{ GeV}, -1.55, 4.63)$

Search for FP Higgs in 3γ + X final states





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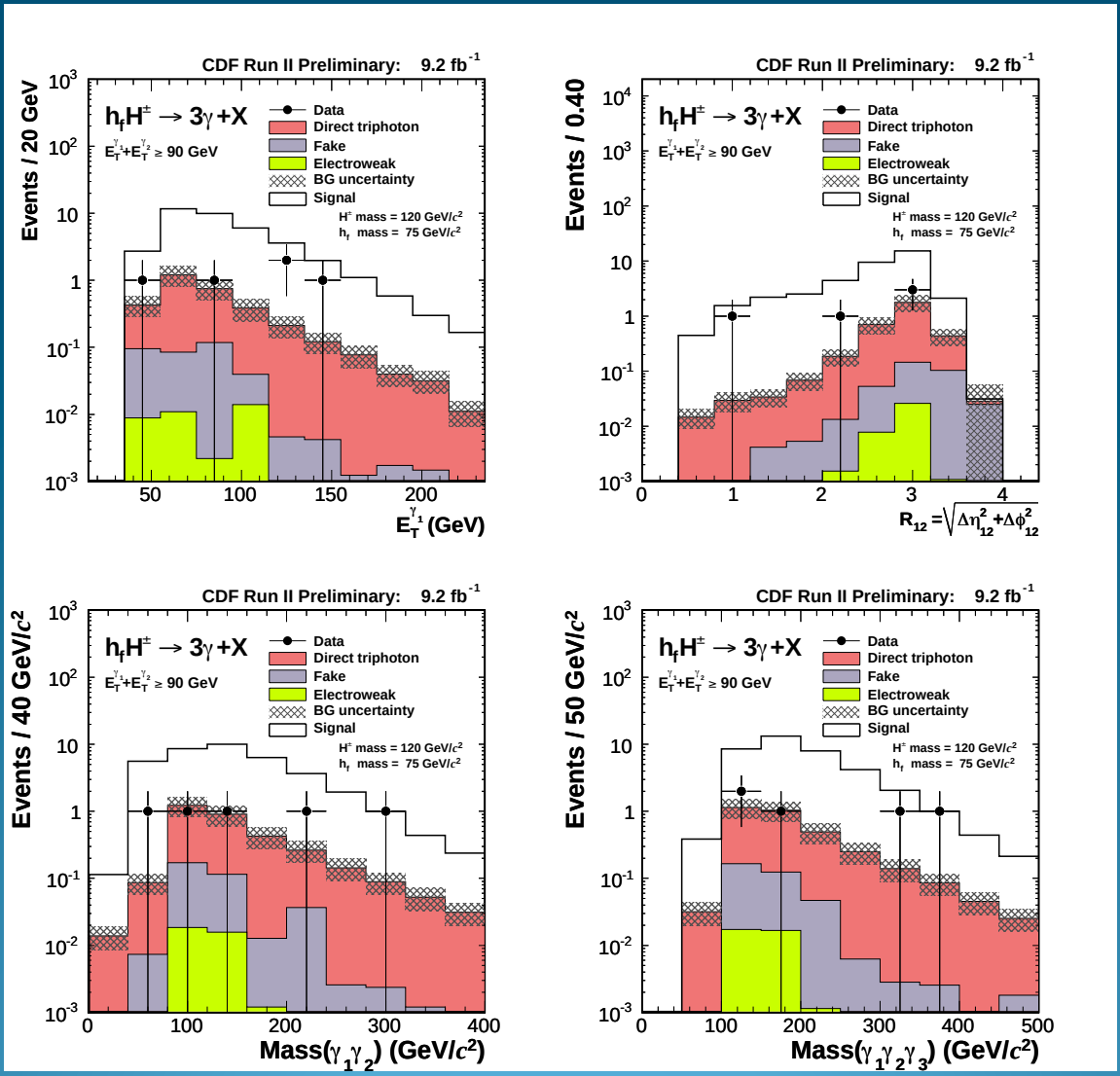
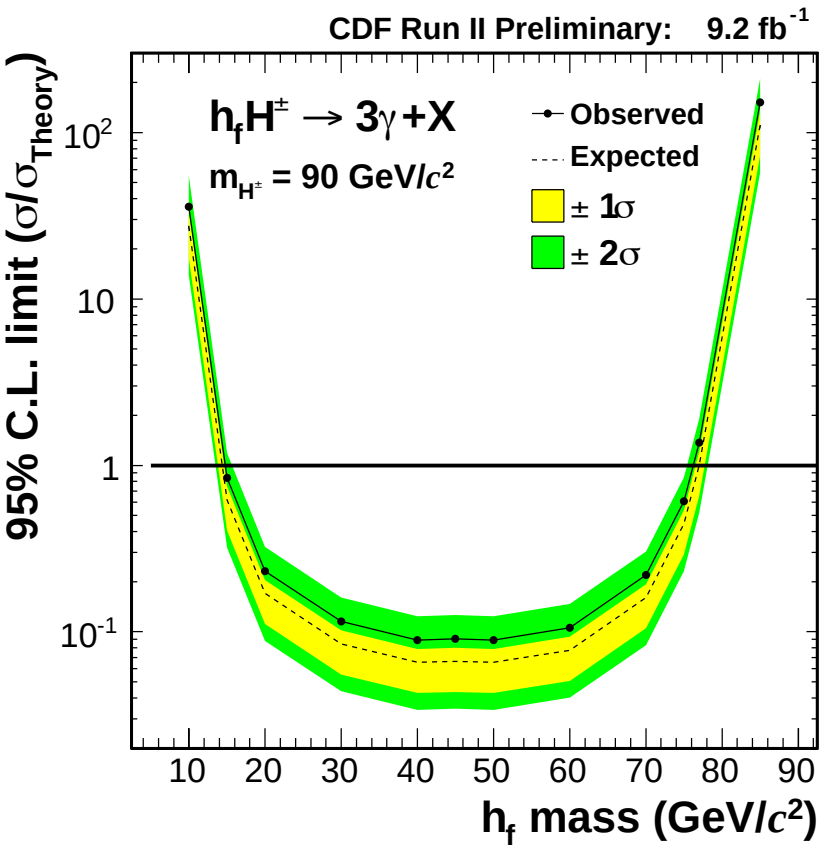
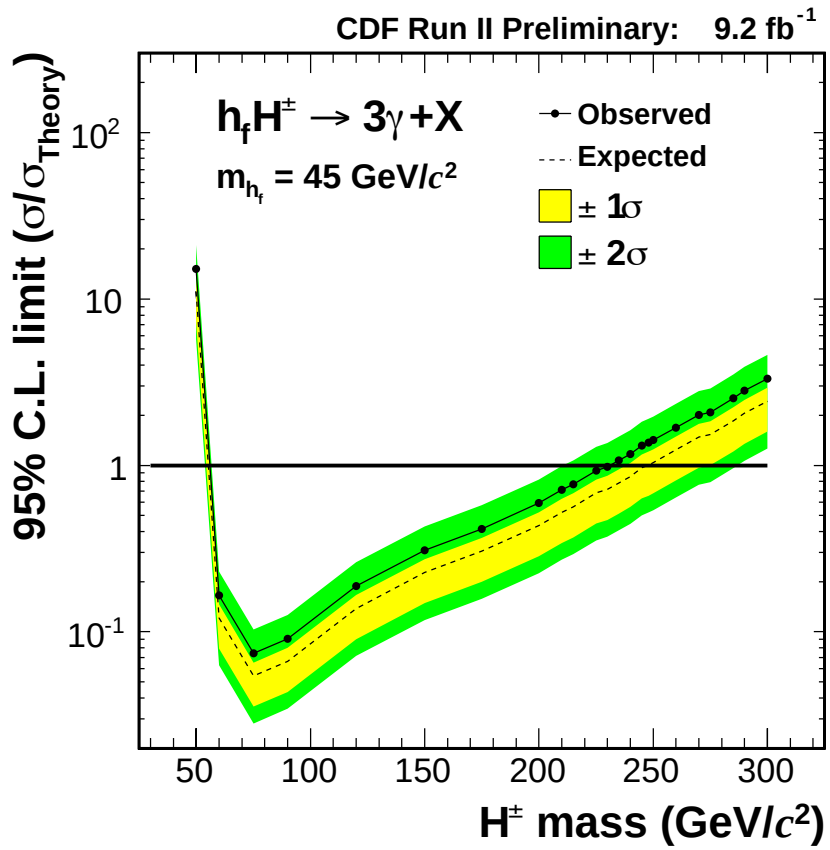


Search for FP Higgs in 3γ + X final states

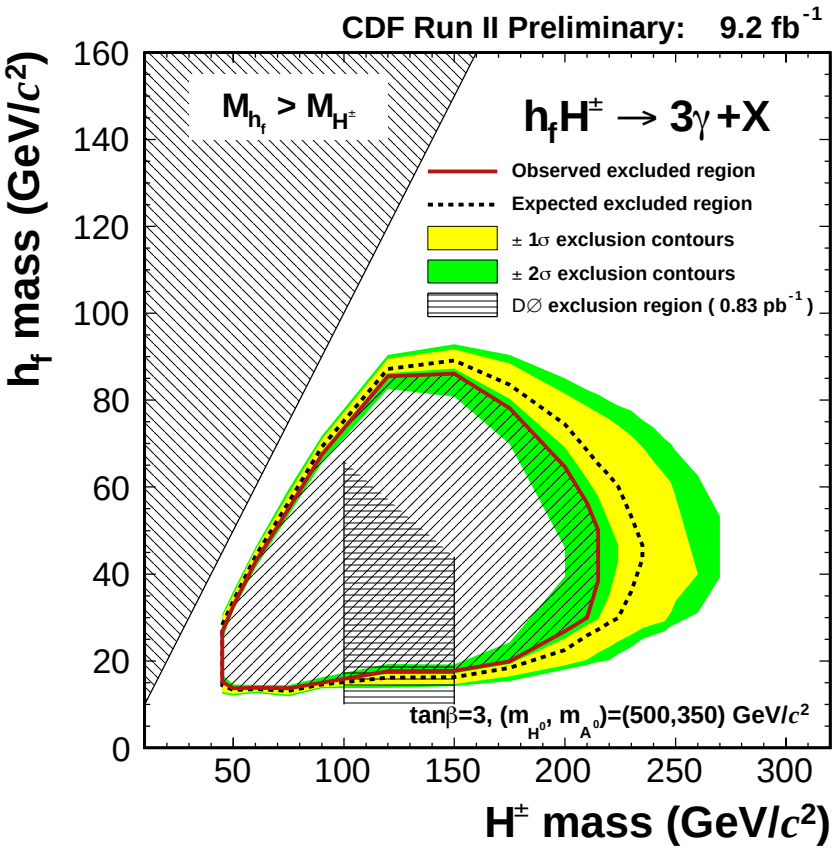


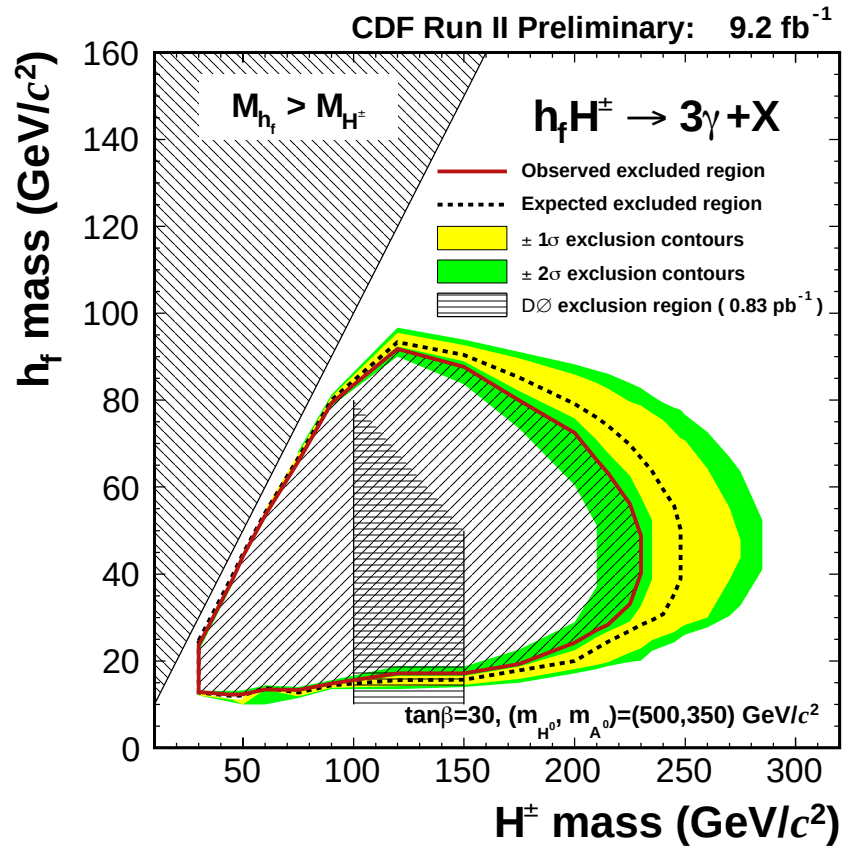


- ✓ Exclude h_f in the mass range 15 – 75 GeV/c^2 for $H^\pm$ of mass 90 GeV/c^2
- ✓ Exclude $H^\pm$ in the mass range 50 – 230 GeV/c^2 for h_f of mass 45 GeV/c^2

CDF conf. note 11116

Search for FP Higgs in 3γ + X final states





DZero conf. note 5067

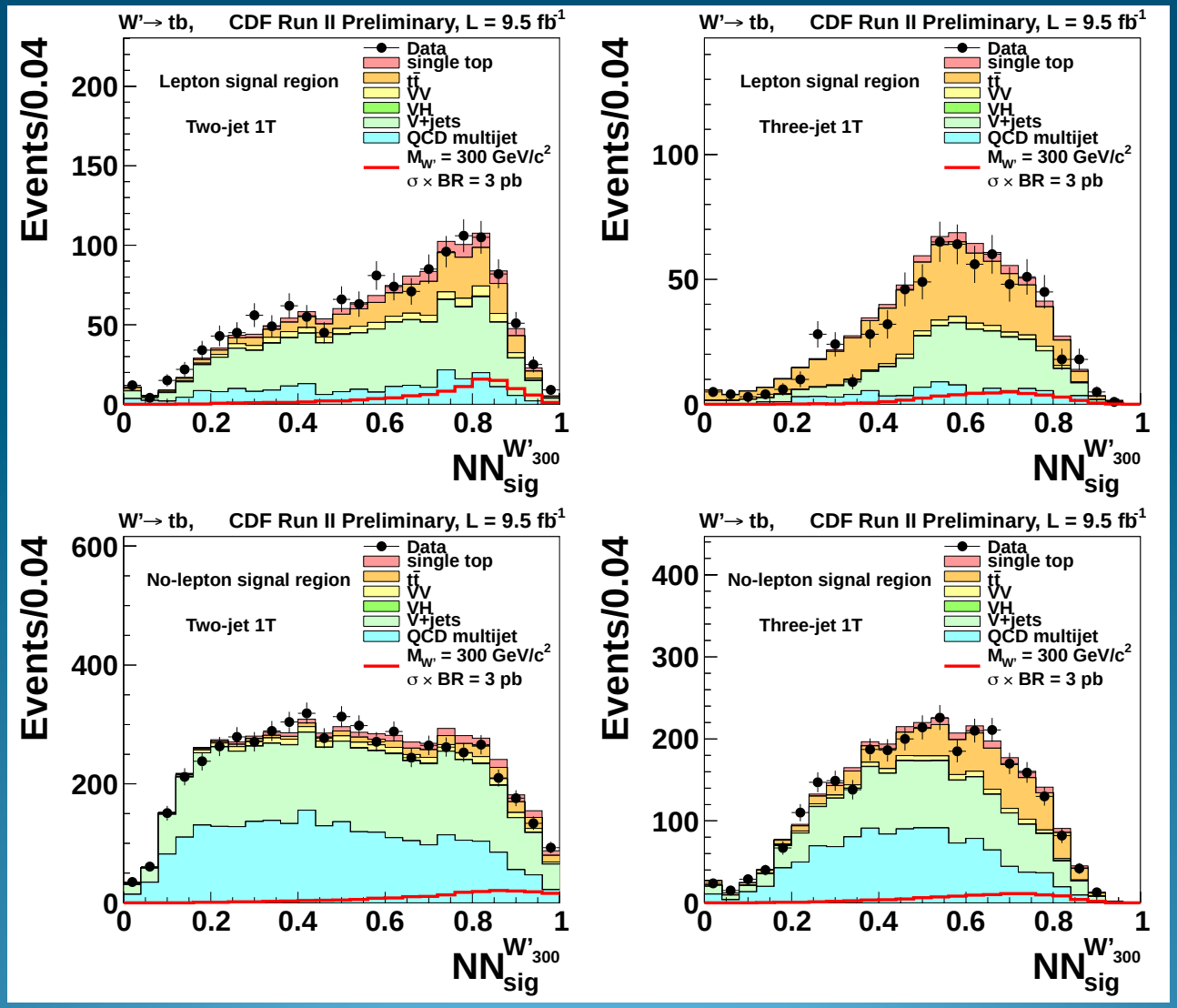
CDF conf. note 11110

Search for W' boson decaying to t + b quark pair

- Tevatron is sensitive to recently observed single top production through a time-like virtual W boson
- Same topology can be studied to search for a heavier W' boson
- Search conducted with a MET-based trigger, optimizing into channels including and not including a charged lepton
- Benchmark left-right symmetric NLO model examined, assuming SM couplings of W' and allowed or forbidden leptonic decay modes

CDF conf. note 11110

Search for W' boson decaying to t + b quark pair



CDF conf. note 11110

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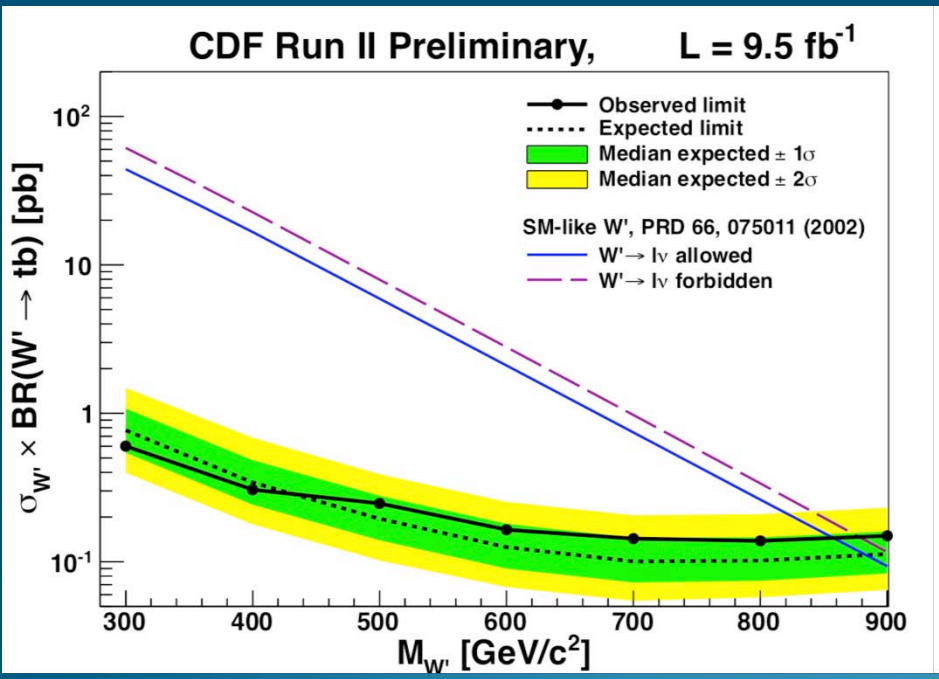
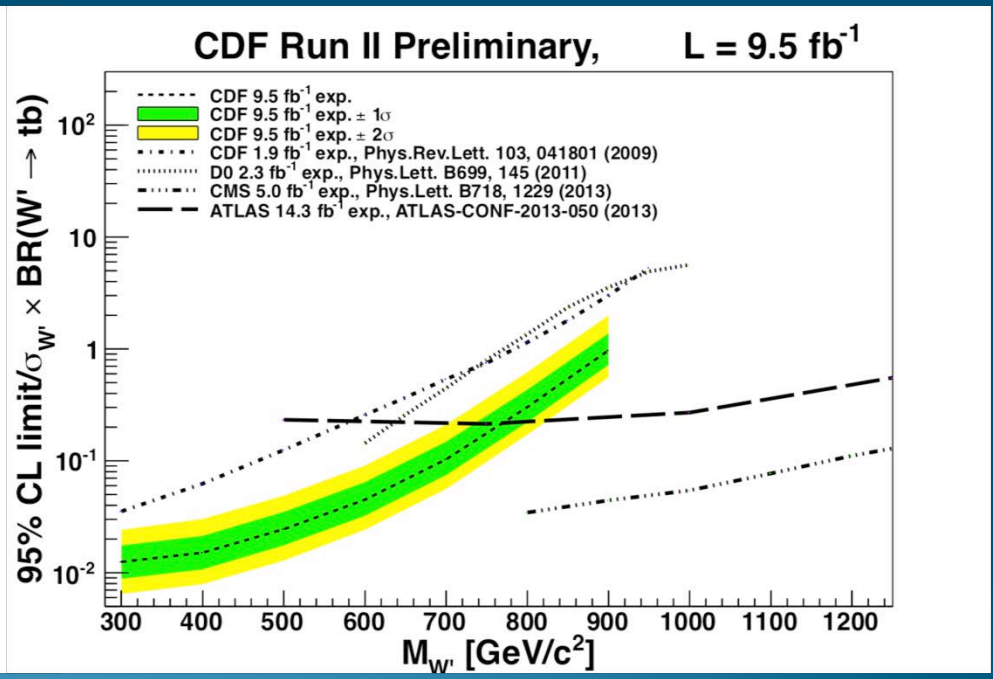
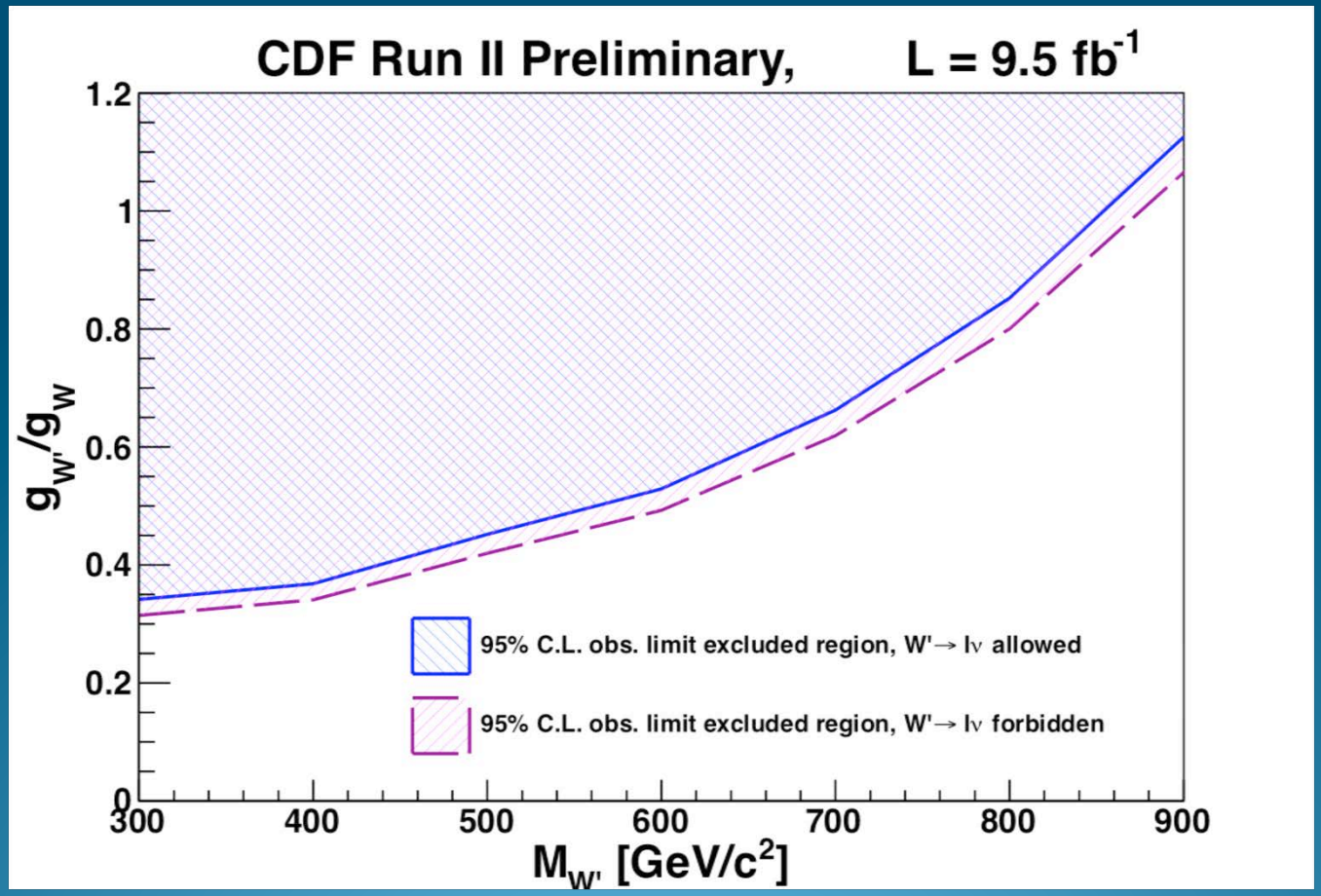




- ✓ W' excluded up to 860 (880) GeV/c^2, assuming allowed (forbidden) leptonic decay modes
- ✓ Best exclusion limit below 700 GeV/c^2

CDF conf. note 11110

Search for W' boson decaying to t + b quark pair

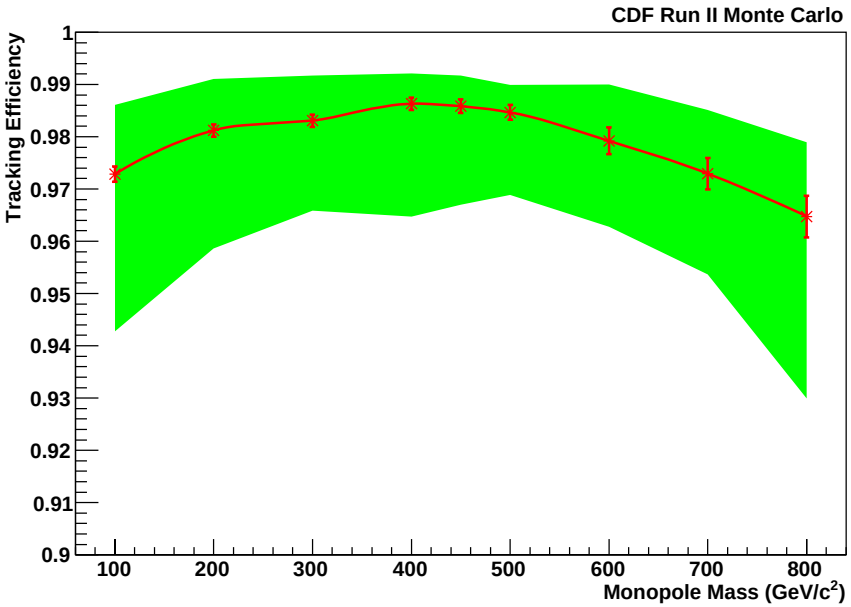


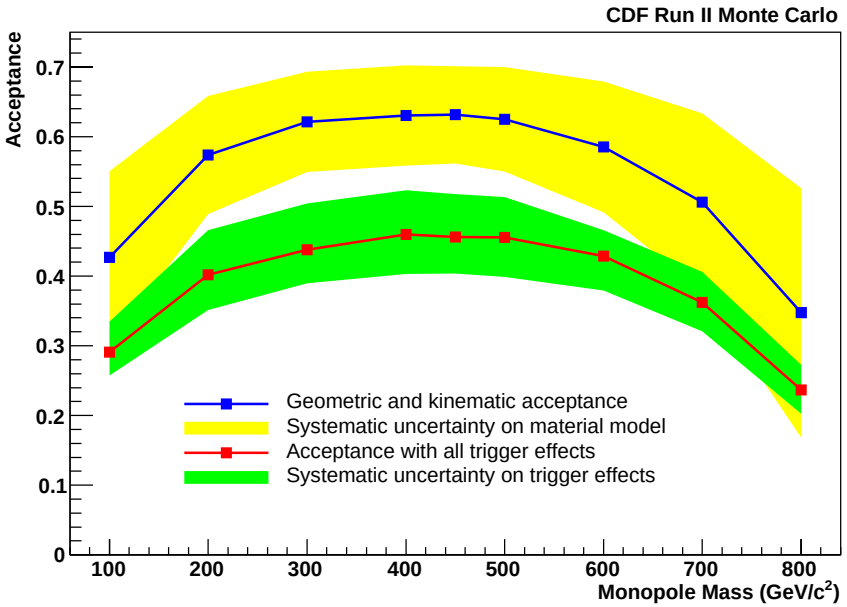
Relaxing the hypothesis of SM-like couplings, W' coupling strength excluded down to 35% of SM strength for W' mass of 300 GeV/c^2

Search for Dirac magnetic monopole

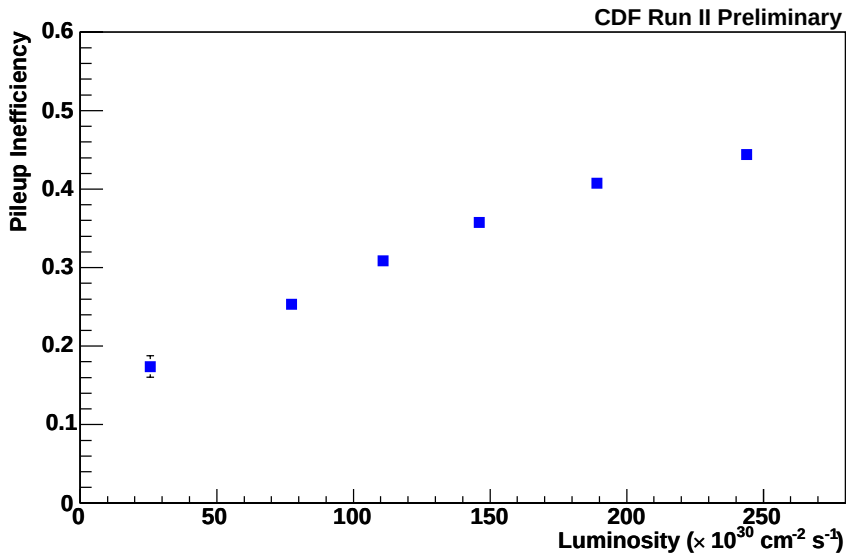
- Search based on the distinct monopole signature in the detector: unlike ordinary charged particles, it is accelerated along the B field
- Use dedicated trigger, recalibrated in 2010, firing on large light pulse in TOF detector caused by monopole's ionization effects in COT
- Collected 1.21 fb^{-1} in 2011, searched for tracks with no curvature in $r-\phi$ plane and abnormally high ionization in COT
- Used benchmark Drell-Yan ($qq \rightarrow ee$) – like model for simulations

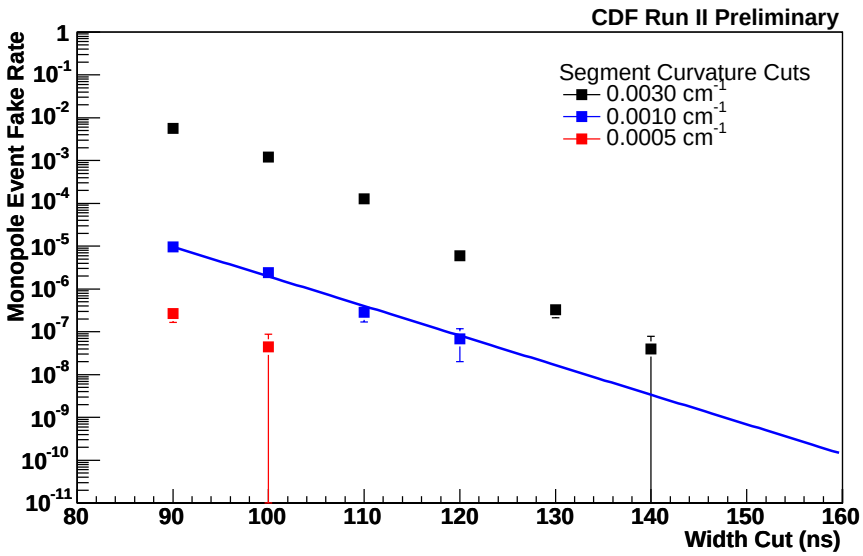
Search for Dirac magnetic monopole





Search for Dirac magnetic monopole

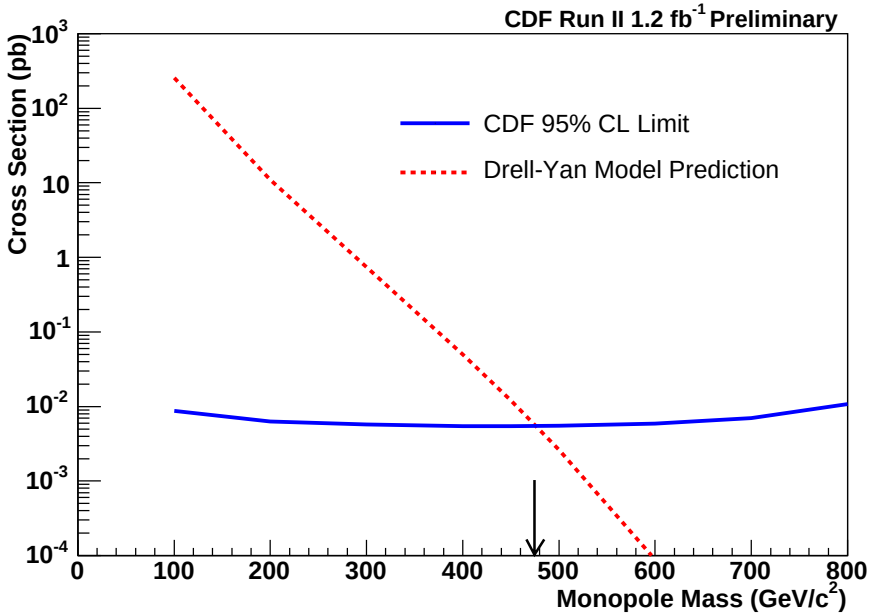


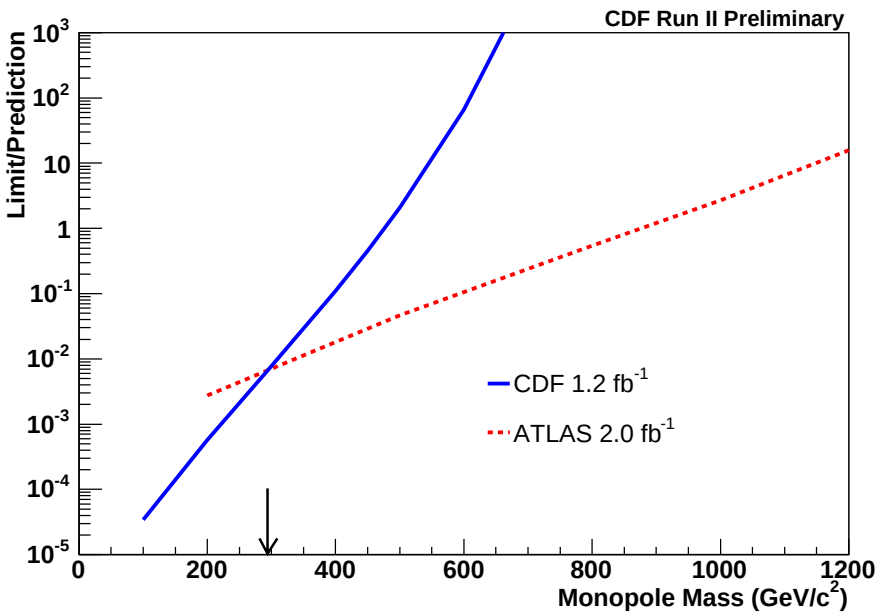


- Particles firing TOF earlier than monopoles cause pileup inefficiency studied by MC
- Studied fake event rate by varying curvature and hit-width cuts Expected rate of $(3.4\pm1.6)\times10^{-9}$ on 1.2×10^{7} events implies 0.040 ± 0.019 expected fakes

CDF conf. note 11102

Search for Dirac magnetic monopole





PRL 109, 261803 (2012)

- ✓ Excluded monopole up to a mass of 476 GeV/c^2 at 95% CL
- ✓ Best limit up to 300 GeV/c^2

Summary

- Exploit Tevatron p-pbar initial state to perform tests and searches complementary to the LHC
- Exclude $J^P = 0^-$ & 2^+ Higgs models of mass 125 GeV/c^2 at 5σ in VH(bb)
- Exclude h_f in the mass range 15 – 75 GeV/c^2 for $H^\pm$ of mass 90 GeV/c^2 and $H^\pm$ in the mass range 50 – 230 GeV/c^2 for h_f of mass 45 GeV/c^2
- Exclude W' boson up to a mass of 860 GeV/c^2
- Exclude Dirac monopole up to a mass of 476 GeV/c^2
- Competitive limits on new phenomena in the low mass range