



CDF Physics Results and Detector Status

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International Finance Committee

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Entry to Physics at CDF

http://www-cdf.fnal.gov/CDForg/Physics_Groups_1.html



The CDF Collaboration

North America



3 Natl. Labs
28 Universities



3 Universities

12 countries

62 institutions

800 physicists

Europe



1 Research Lab
6 Universities



1 University



4 Universities



2 Research Labs



1 University



1 University



1 University
1 lab

Asia



5 Universities
1 Research Lab



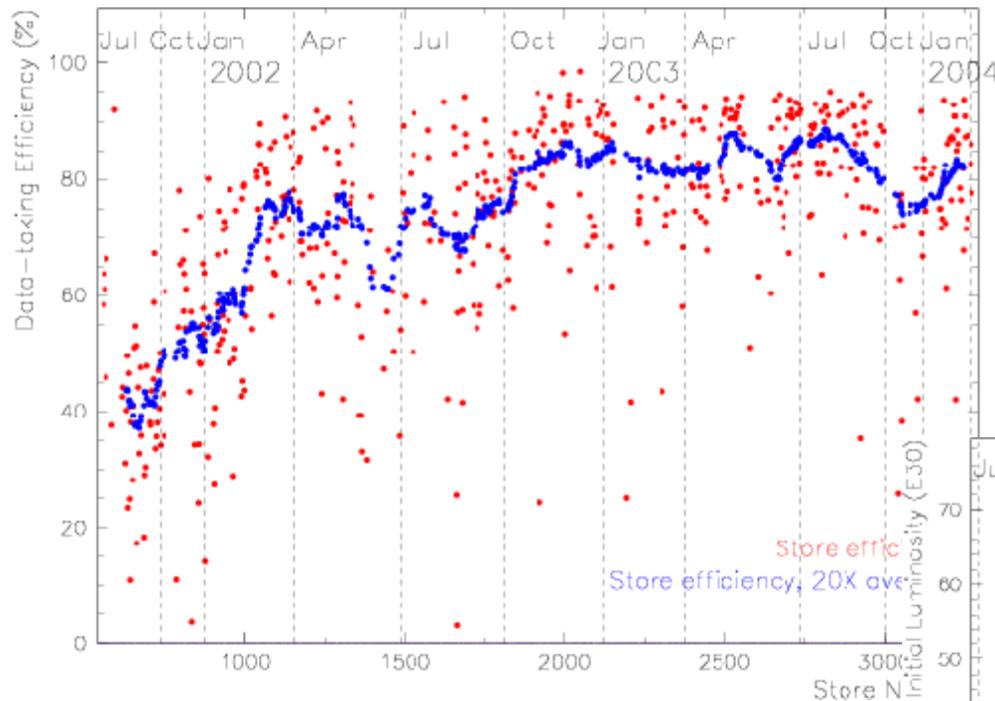
1 University



3 Universities



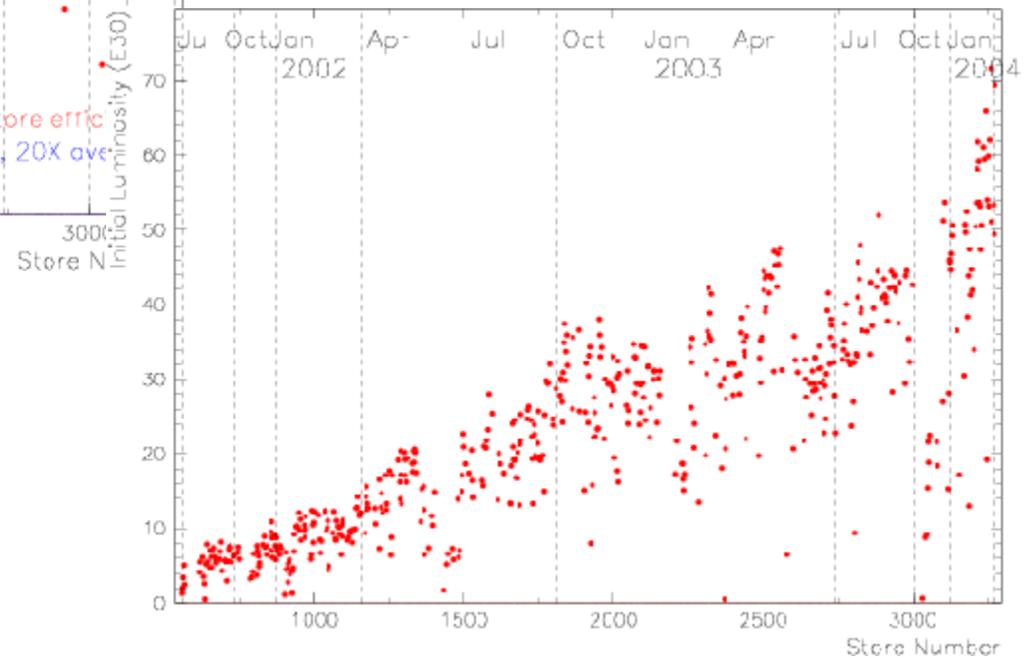
Luminosity and Efficiency



- Efficiency to tape reached $\langle 85 \rangle\%$
- Lower recently due to COT 80%
- Increasing again

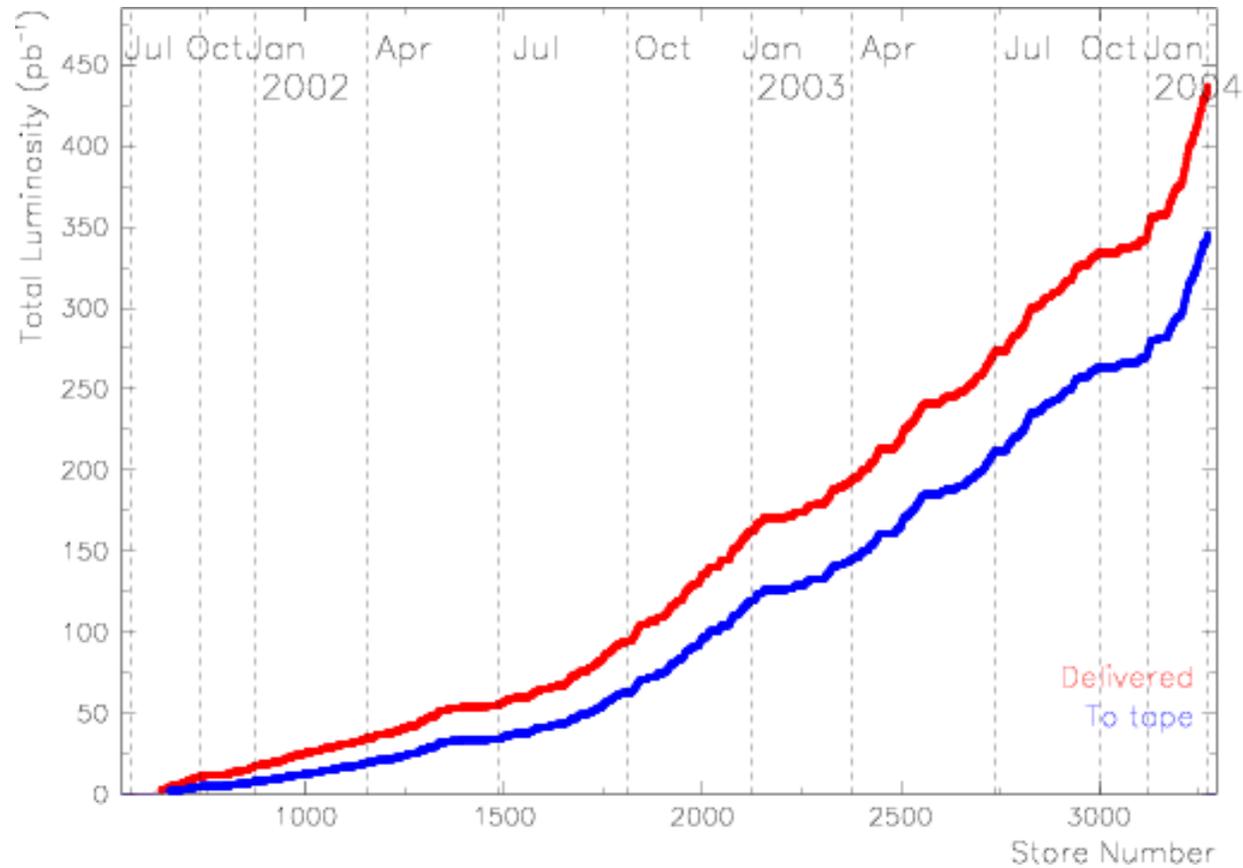
- Instantaneous initial luminosity as measured by CDF

• **Best is $7.2E31$**





Luminosity Delivered and To Tape



- Total data recorded for physics is about 300 pb^{-1}
- Run 1 X 3
- Expect Run1 X 4 by end of summer



Outline of Presentation

- Detector Performance
 - COT status
 - Tracking performance
 - Operations > 2006
 - Offline performance (Liz Sexton-Kennedy)
 - Detector upgrades (Pat Lukens)
- Status of analyses and publication plan
 - Heavy Flavors
 - Exotics
 - Electroweak
 - QCD
 - Top
- Conclude



Detector



CDF status

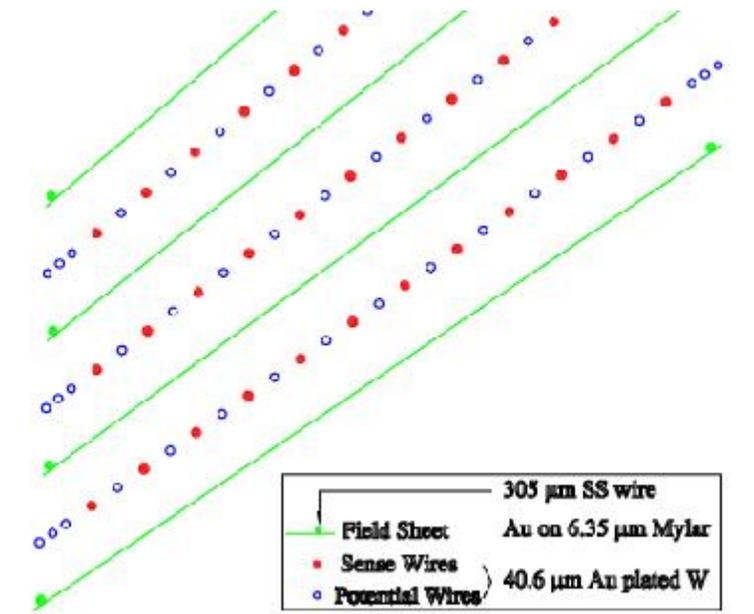
- CDF detector working well, but...
- COT is having “early” gain loss problems
- Focused effort to understand and fix the problem
- We are always concerned about silicon safety
 - beam incidents highlight concerns
- Beam position centered by Accelerator Division
 - This was an essential move for us because of trigger efficiency
 - CDF appreciates the large effort by Accelerator Division
- Offline production proceeding well
 - ~8 million events/day
- Central Analysis Facility (CAF) big success



COT Super Cell Geometry

COT (Central Outer Tracker)

- 8 Superlayers:
 - 4 Axial, 4 Stereo ($\pm 2^\circ$)
- Spans $40 < R < 138$ cm
 - SL1 – 47 cm, SL8 – 129 cm
- 168(SL1) – 480(SL8) cells/SL
- Each cell has 29 wires
 - 12 sense, 13(+4) potential
- Au/Mylar planes between cells





COT "Aging" Issues

What does "COT Aging" mean?

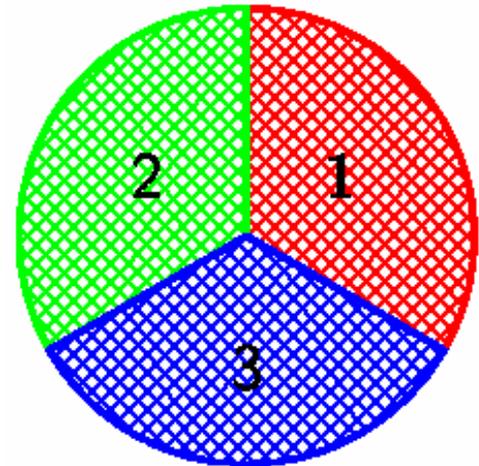
- Drift chamber aging
 - Decline in operating performance with time
 - More specifically, loss of gain under irradiation
 - Usually caused by deposits on wire surfaces
- How do we detect aging
 - Loss of gain means less charge – shorter pulse widths
 - Decrease of COT hit widths, COT/XFT efficiency
 - Small chambers directly monitor gas going to chamber
- Details:
 - http://www-cdf.fnal.gov/upgrades/cot/aging_committee.html



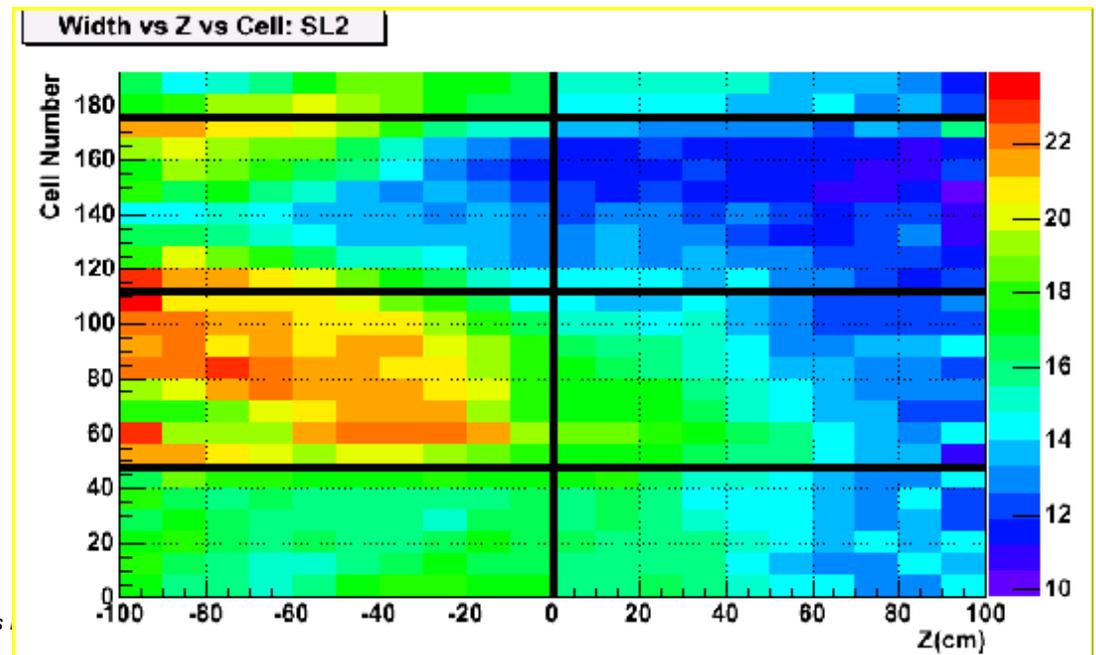
COT Aging

Time Dependence for Regions of SL2

- 6 Regions: 3 in $\phi \times 2(z < 0, z > 0)$
- Divisions in ϕ for SL2
 1. Cells 176-191, 0-47
 2. Cells 48-111 (**All Good** for $z < 0$)
 3. Cells 112-175 (**All Bad** for $z > 0$)

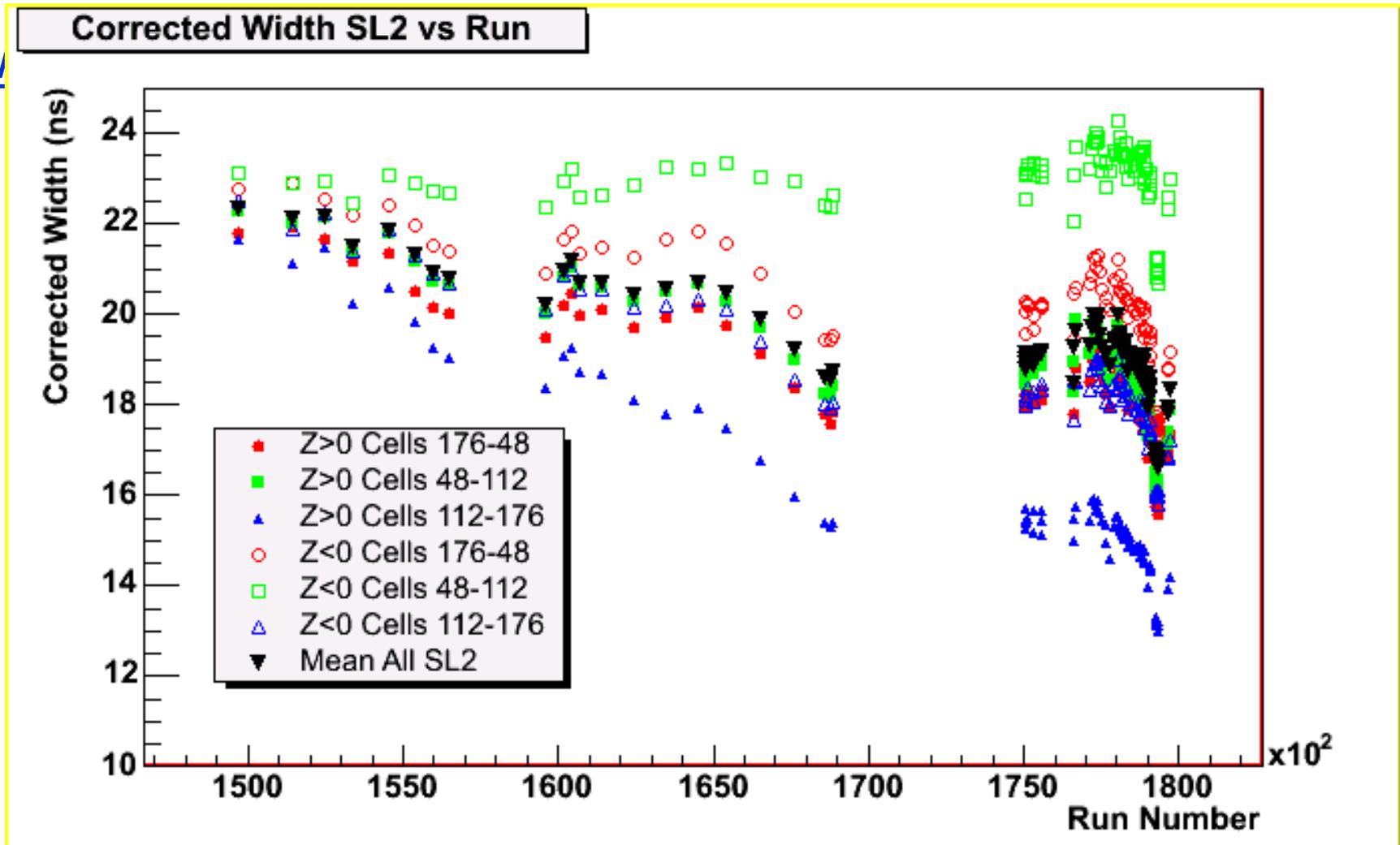


- Gas flow is left to right
- Inlet side shows less degradation
- Experts say increase flow rate X10



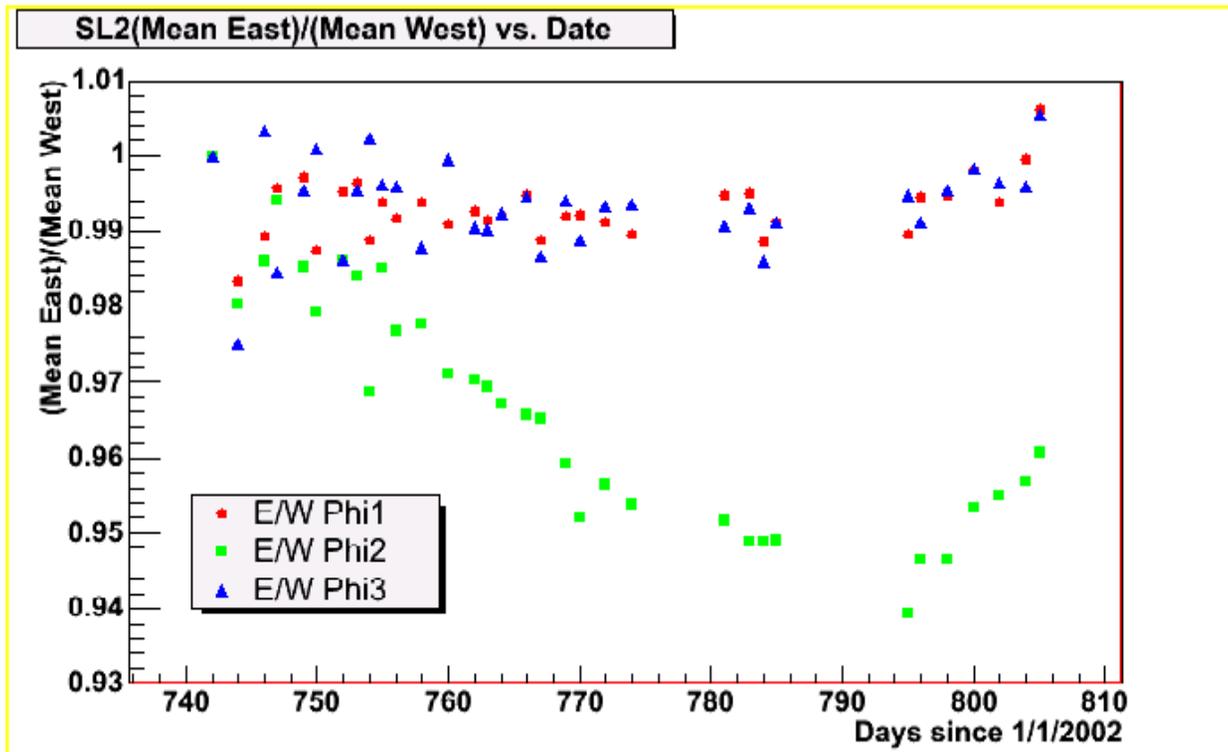


SL2 versus Run Number Widths





SL2 East/West Widths vs Run



- Gas flow reversal changes behavior of gain loss
- Conclude: increased flow should mitigate effect
- How much?

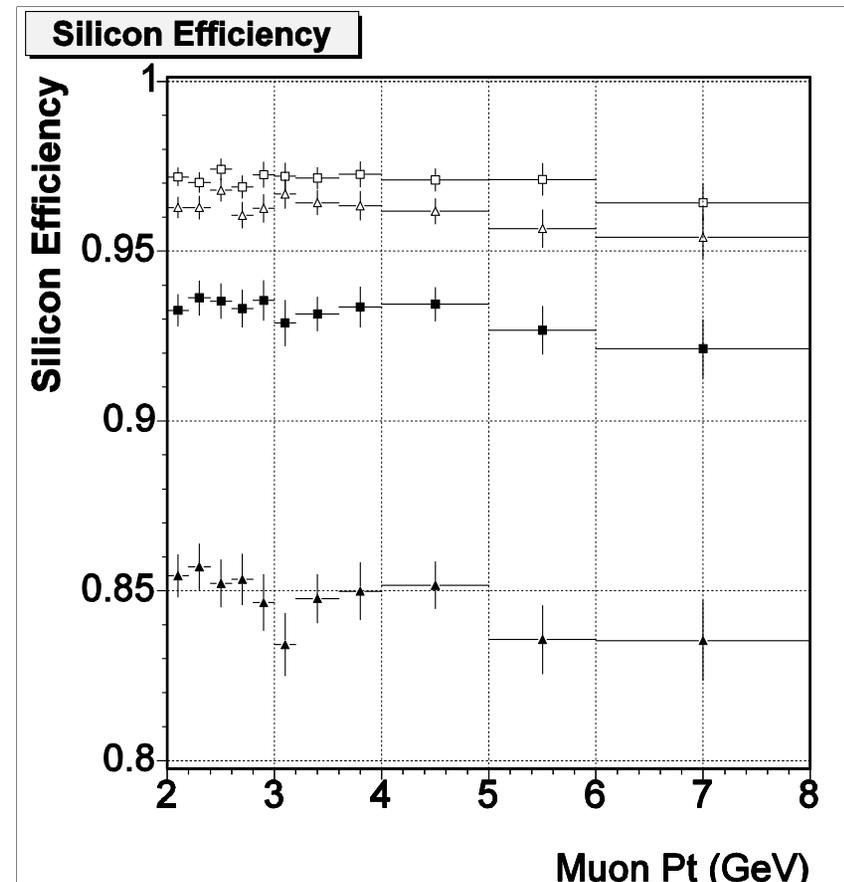


Silicon Tracking Performance and b-jet tagging (continuing to improve on going work)



Silicon Tracking Efficiency

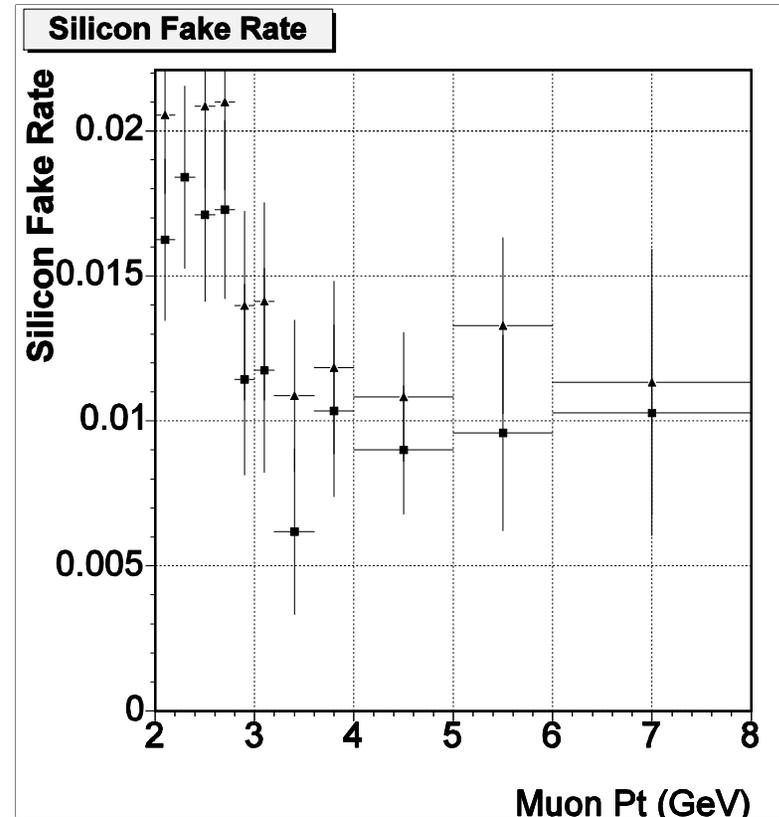
- Sample of muons from J/psi's
- Track is in fiducial volume
 - 3 SVXII layers needed
- Top two curves are axial and stereo acceptance (ladders alive)
- Bottom two curves are efficiency
- 3-hits define a track (5 layers total)
- 3-D uses available stereo(2) & Z(3) strips
- Ratios provide rating for pattern recognition





Rate of Mis-measured Tracks

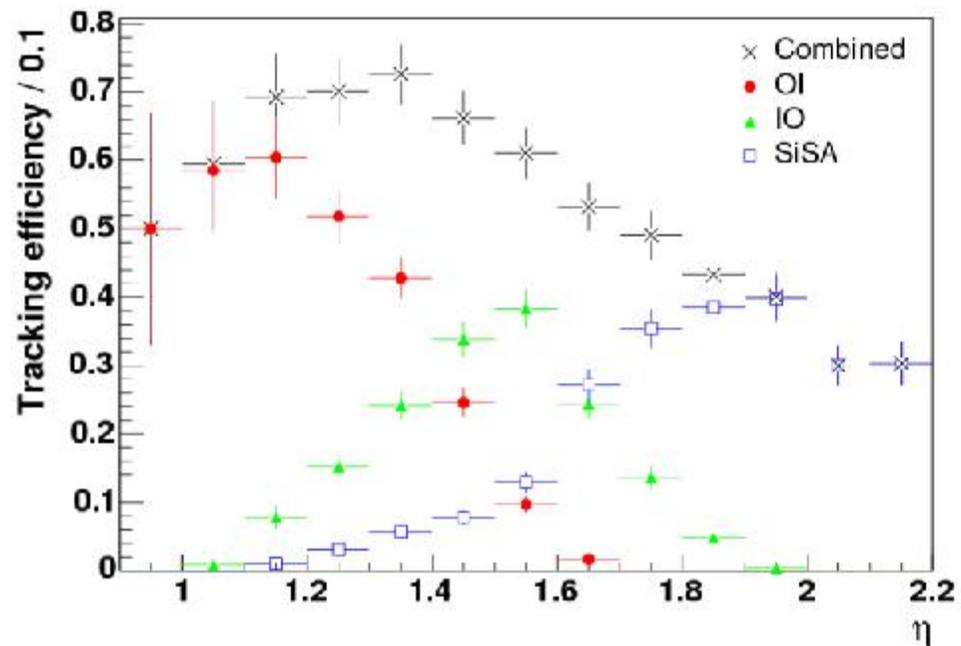
- Negative impact parameters define possibly mis-measured tracks
- Fakes beyond 3 sigma plotted
- Triangles have stereo information
- Much better than Run 1





Forward Tracking Efficiency

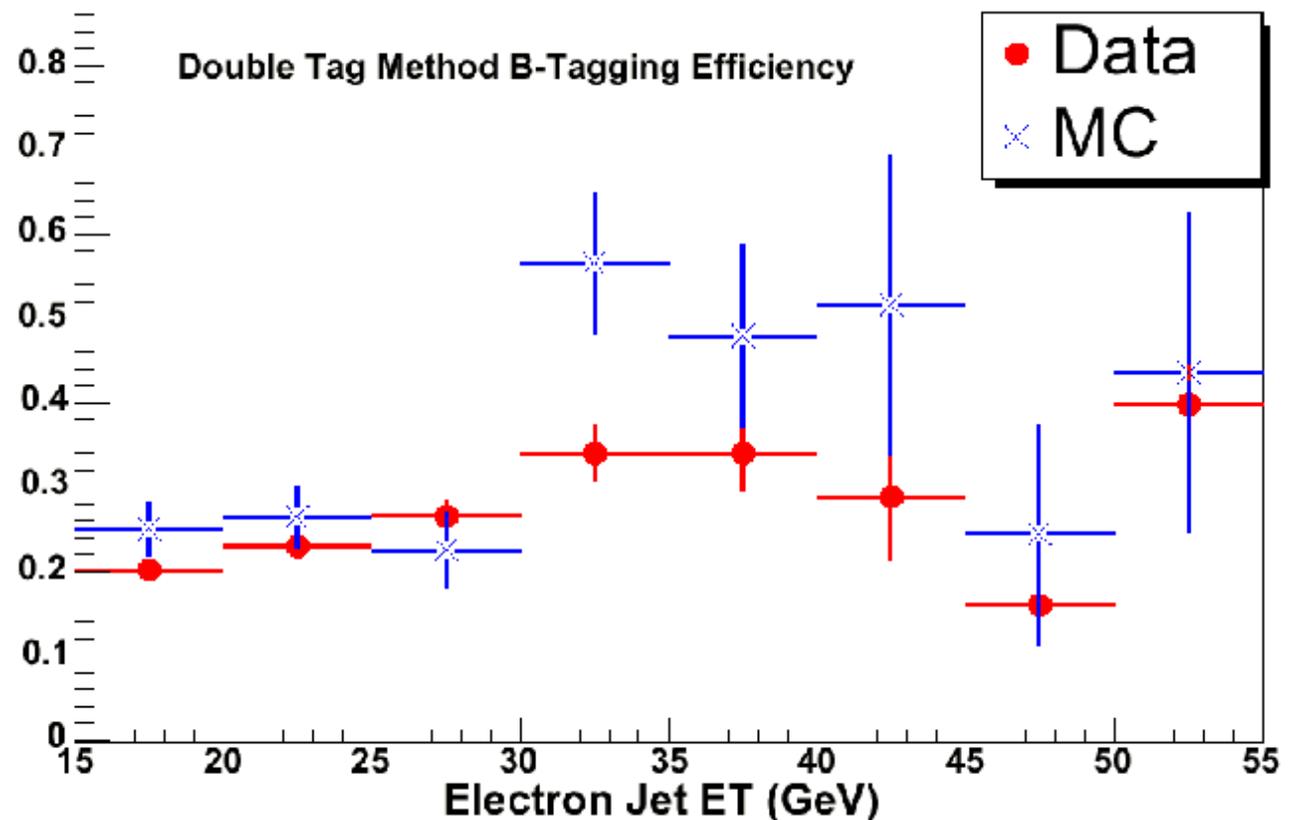
- $Z \rightarrow ee$ central+plug
- plug energy is denominator
- ISL+SVXII only
- Two 3-D hits & vertex seed silicon track (SISA)
- OI seeded by COT hits
- IO attaches COT hits to SISA





b-jet tagging Efficiency

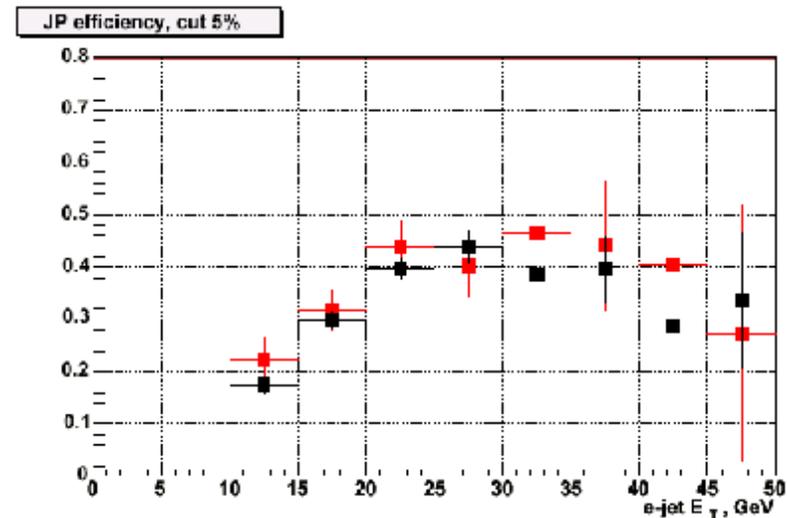
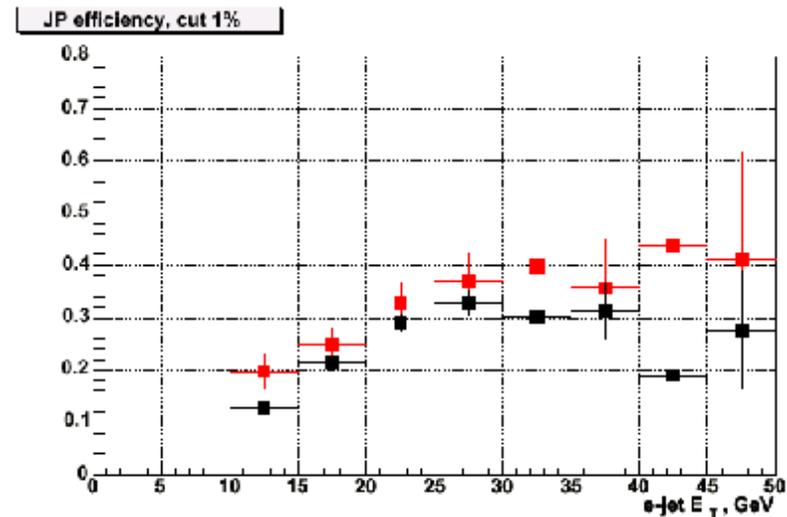
- 8 GeV electrons
- Vertex algorithm
- Fiducial jets 15 GeV
- No requirement on tracks or hits
- Tag away jet and measure efficiency on the electron jet
- 2-D SVXII
- Heavy flavor content is needed
- Expect to be flat
- Gives scale factor





b-jet tagging Efficiency

- 8 GeV electron sample
- Jetprob algorithm
- Uses impact parameter
- Data is black, MC is red
- Top plot is 1% cut less fakes
- Bottom plot 5% cut more fakes
- Bottom plot higher eff than secvtx
- More charm with jetprb





b-jet tagging in top events

- Work in progress, not yet final
- Efficiency to tag at least one b-jet in a top event is $52.3 \pm 0.3 \pm 7.0\%$
- TDR 65%
- Will look into getting forward going jets with silicon stand alone tracking and IO tracking +3-D tagging may help
- Layer00 will be included (two double bulkheads for three barrels of silicon)
- Recent improvements in tracking not yet included



Operations > 2006

- CDF MOUs with institutions good through 2005
- Renegotiate for > 2006
- Many groups being “downsized” by pressures from funding and need to ramp up on LHC
- Will get very difficult to operate detector & do physics
- CDF considering special status for LHC post docs that permits service work on LHC and physics/operations on CDF
- Postdocs need physics analysis for career advancement
- Could be 2 years on LHC and 2 years on CDF for example
- LPC(LHC Physics Center) - promise to mitigate sudden flow
 - post docs can find critical mass of people at Fermilab preparing for LHC
 - Maintain a role in both CDF and LHC



Physics Opportunities Run2

- Explore the high energy frontier
 - Experiments will guide theory
 - Probe high statistics top
- No clear paradigm for new physics
 - SUSY, extra dimensions, leptoquarks.....



Publication plans

- We have recorded about 220 pb^{-1} of physics quality data up to the end of August 2003
- We consider this a complete dataset - twice Run1
- All physics groups are planning to publish analyses on this dataset
- The time scales for publication vary from short term (next week) to the end of the year
- This is due to different degrees of sophistication required by each particular analysis
- We expect to publish 20-40 papers on this dataset



Heavy Flavours



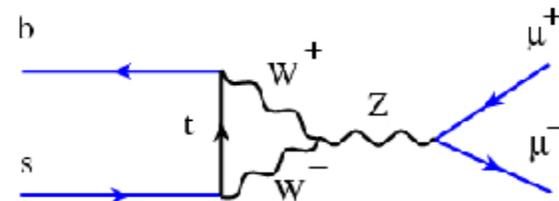
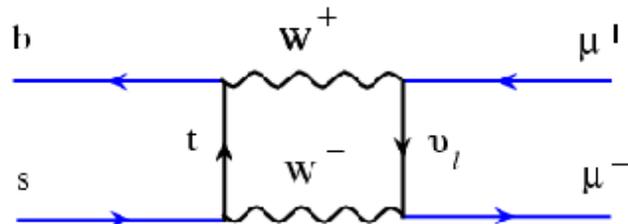
Heavy Flavors

- 4 papers submitted or published
 - D_s, D^+ mass difference (Phys. Rev. D68, 072004, 2003)
 - Search for $D \rightarrow \mu\mu$ (Phys. Rev. D68, 091101, 2003)
 - Prompt Charm cross section (Phys.Rev.Lett.91,241804(2003))
 - Observation of $X(3872)$ - used 220pb^{-1} (PRL comments--sent back)
- 6 papers in godparent publication review
 - D^* relative BR and CP asymmetry
 - Pentaquark search
 - Inclusive J/Ψ cross section
 - B hadron masses (including B_s and Λ_b)
 - BR of $\Lambda_b \rightarrow \Lambda_c \pi$
 - BR of $B_s \rightarrow D_s \pi$
- 3 analyses blessed – godparents soon
- 10 more papers moving towards blessing and pub

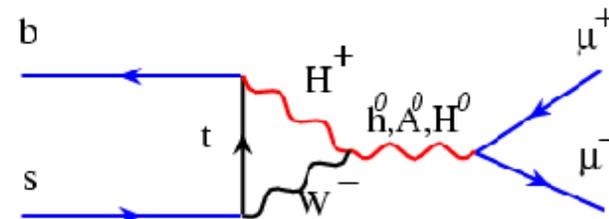
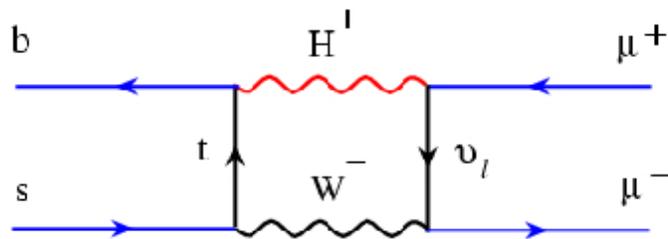


$BR(B_s \rightarrow \mu\mu)$: Why is this interesting?

- $BR(B_s \rightarrow \mu\mu)$ in the SM is few $10E-9$
- Unique to Tevatron so complements b-factory work

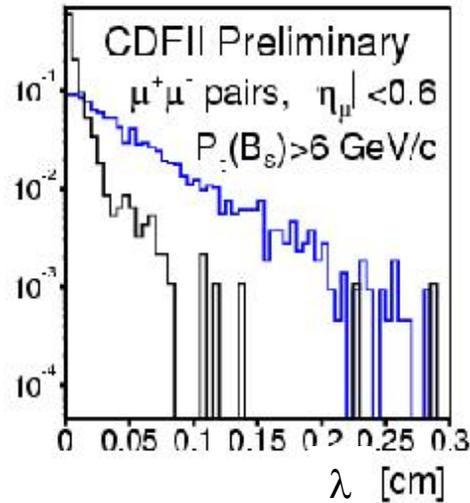
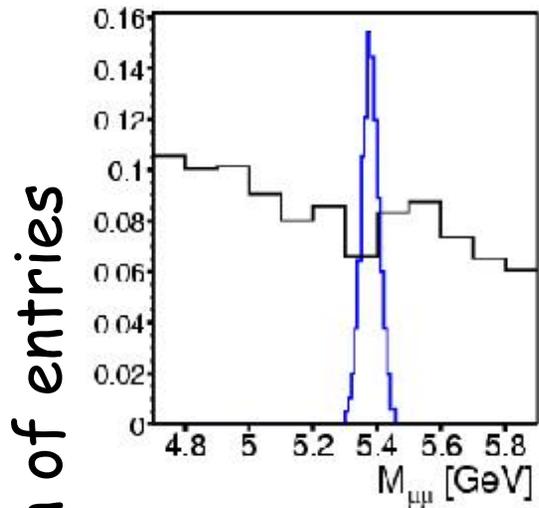


- Can be enhanced by 10-1000 in SUSY
 - Consistent with Δa_μ , and Ω_{cdm}
 - Observable with $\sim 2 \text{ fb}^{-1}$
 - Would imply light Higgs $M_h \sim 120 \text{ GeV}$



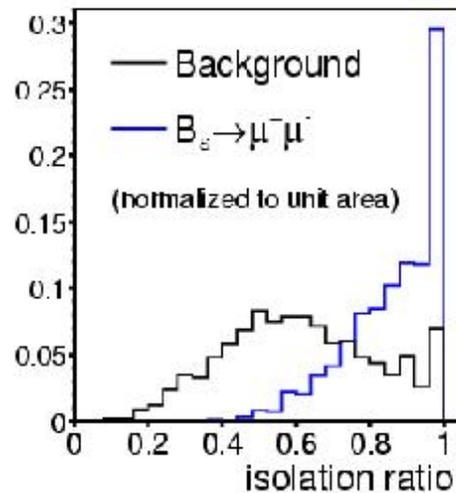
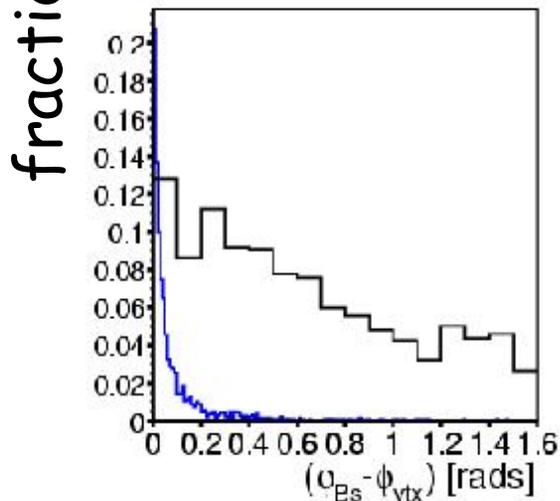


How do we discriminate signal from bckg?



Discriminating Variables

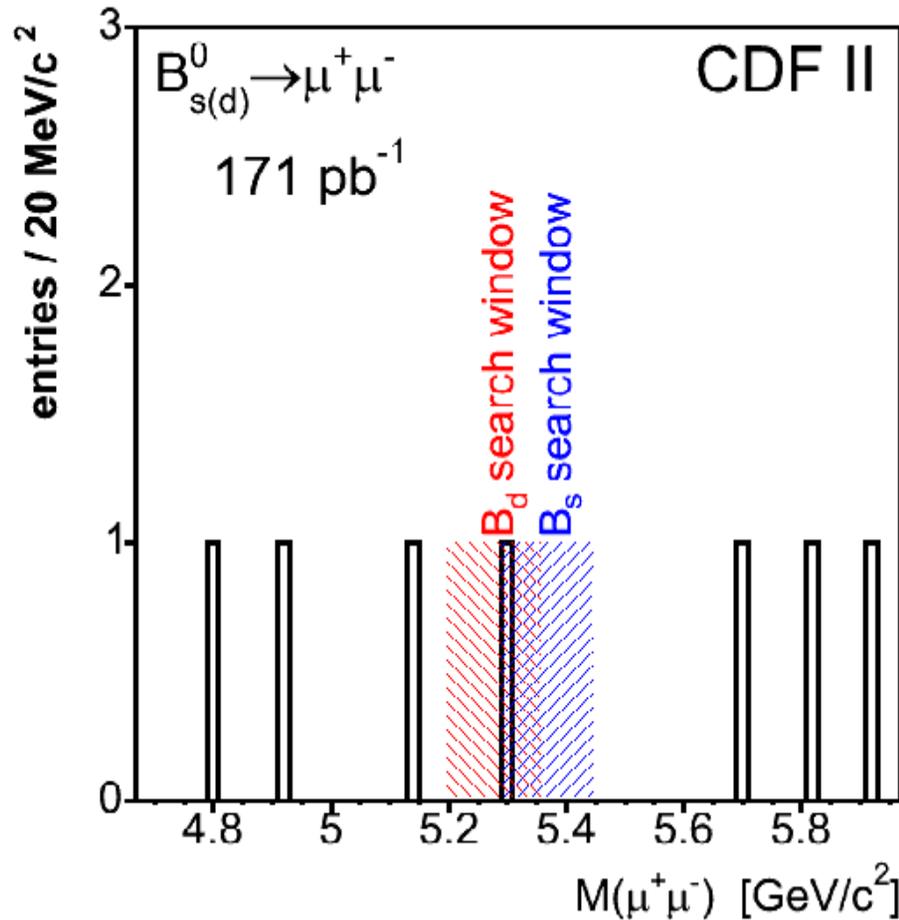
- Invariant mass
- $\lambda : c L_{xy} * M / P_{t_B}$
- $\Delta\Phi : \phi(B) - \phi(vtx)$
- Isol: $P_{t_B} / (\Sigma_{trk} + P_{t_B})$



Choose optimal selection criteria a priori ("blind")



Results

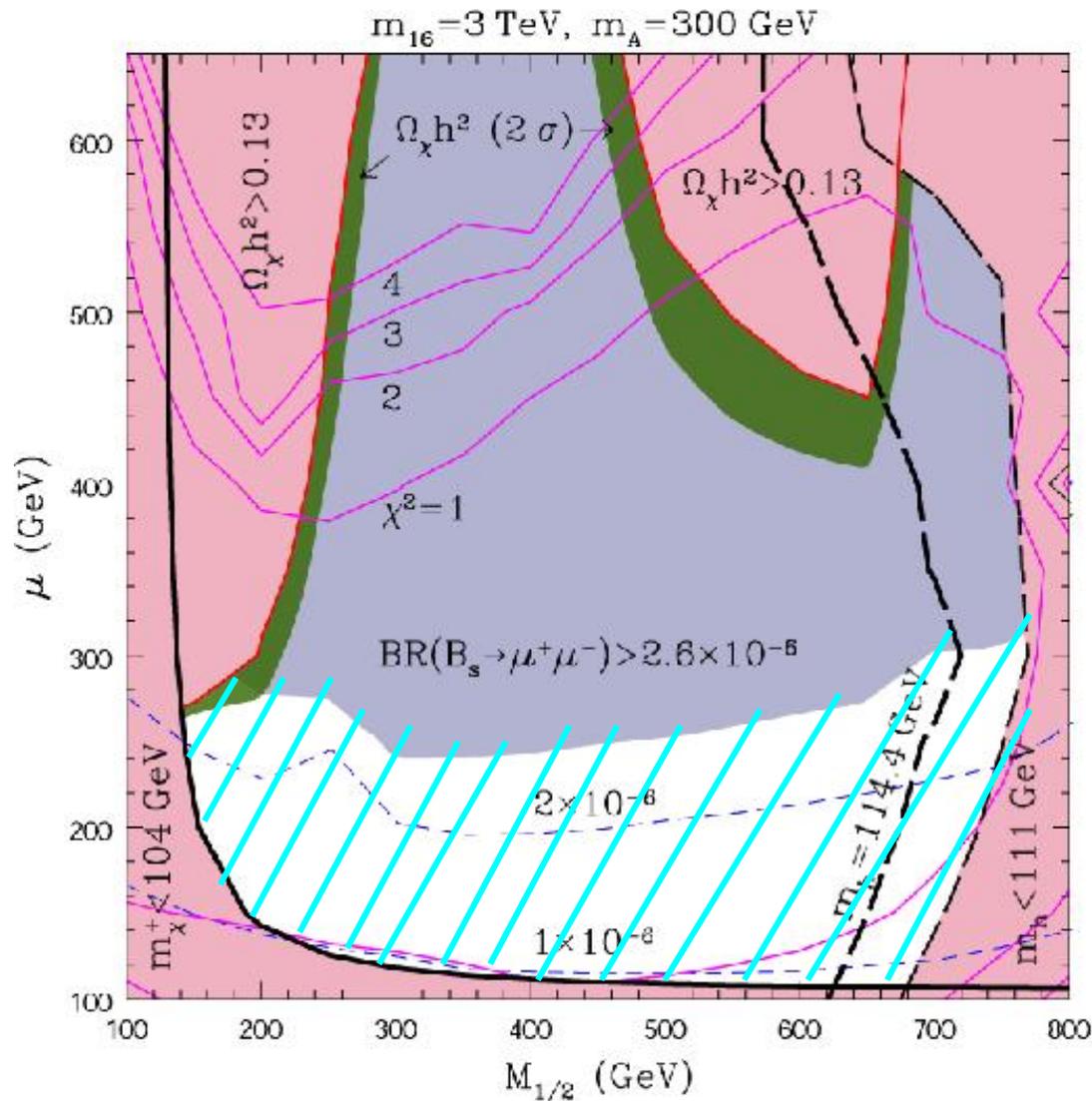


$BR(B_s \rightarrow \mu\mu) < 5.8 E-7$
 $BR(B_d \rightarrow \mu\mu) < 1.5 E-7$
(at 90% CL)

- $B_s \rightarrow \mu\mu$ limit x3 improvement relative to previous limit
- $B_d \rightarrow \mu\mu$ limit better than Belle's recent publication
- expect to increase acceptance(CMX), reduce background and collect more data



Results: Exclusions



SO_{10} space excluded by this result

• Hep-ph/0304101

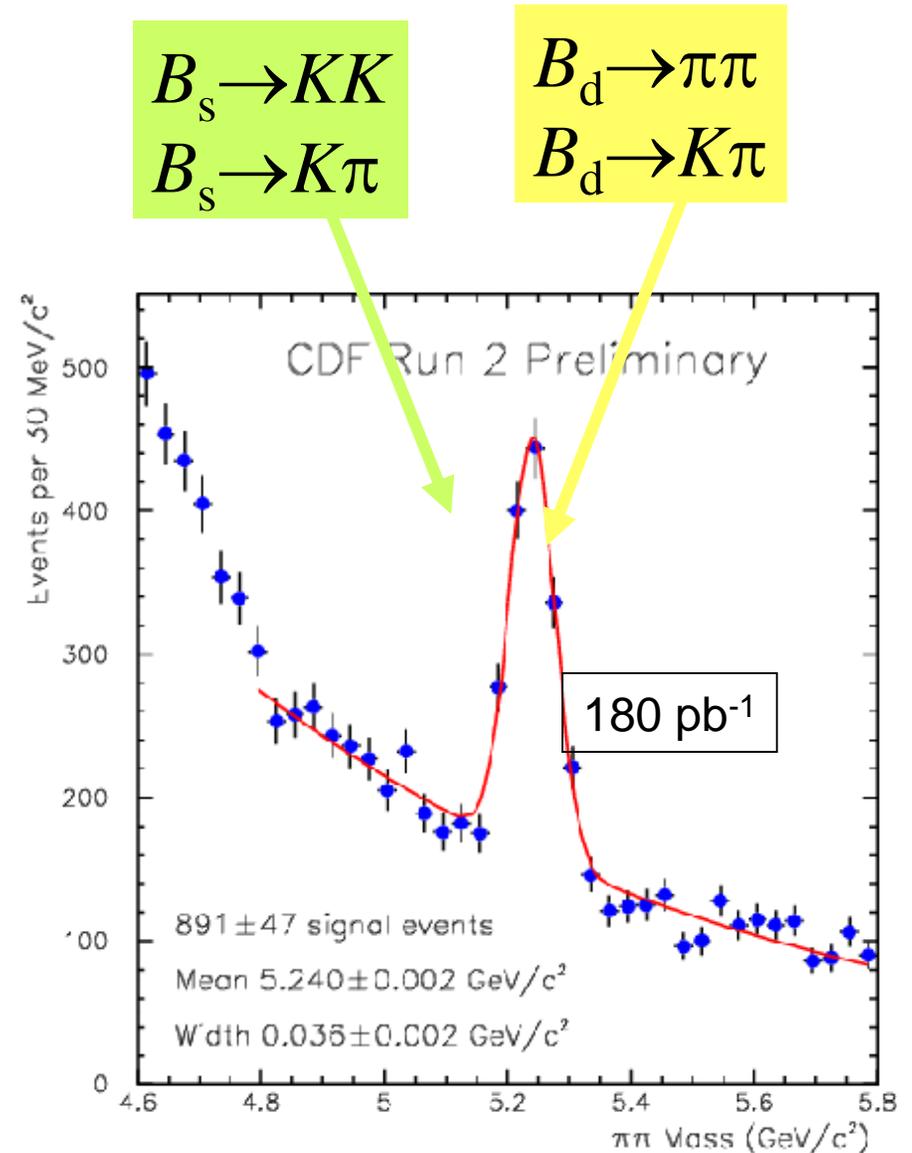
• also excludes large parts of R-parity violating models

• smaller exclusion in standard mSugra MSSM



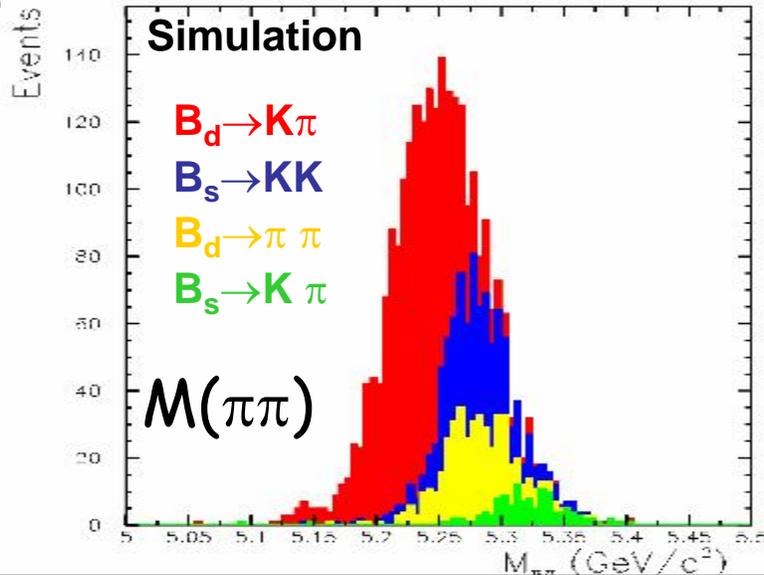
$B \rightarrow h^+ h^-$ Decays

- ⊙ $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ modes are sensitive to CP angle γ . (Fleischer)
- ⊙ $B_{(d,s)} \rightarrow K\pi$ and above modes are separated statistically by kinematics and particle ID.
- ⊙ $B(B_d \rightarrow \pi\pi)/B(B_d \rightarrow K\pi) = 0.26 \pm 0.11 \pm 0.055$.
- ⊙ First observation of $B_s \rightarrow K^+ K^-$.
- ⊙ New results soon-much improved dE/dx





BR($B_s \rightarrow K^+ K^-$)

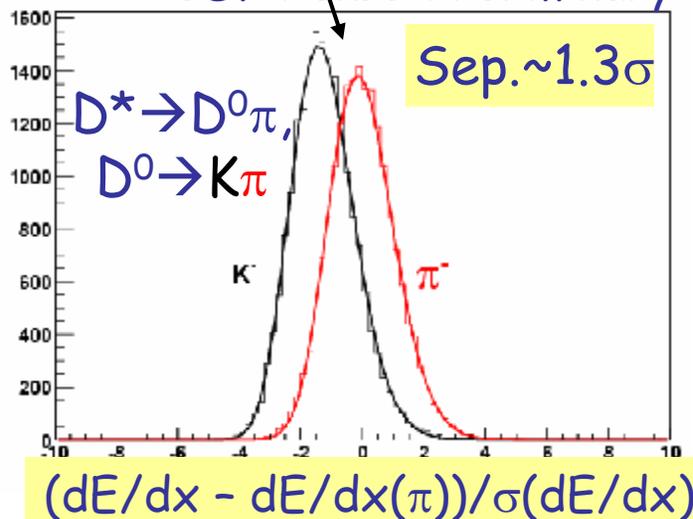


Fitted contributions:

mode	Yield (65 pb ⁻¹)
$B^0 \rightarrow K\pi$	$148 \pm 17(\text{stat.}) \pm 17(\text{syst})$
$B^0 \rightarrow \pi\pi$	$39 \pm 14(\text{stat.}) \pm 17(\text{syst})$
$B_s \rightarrow KK$	$90 \pm 17(\text{stat.}) \pm 17(\text{syst})$
$B_s \rightarrow K\pi$	$3 \pm 11(\text{stat.}) \pm 17(\text{syst})$

kinematics & dE/dx to separate contributions

CDF RunII Preliminary



First observation of $B_s \rightarrow K^+ K^-$!!

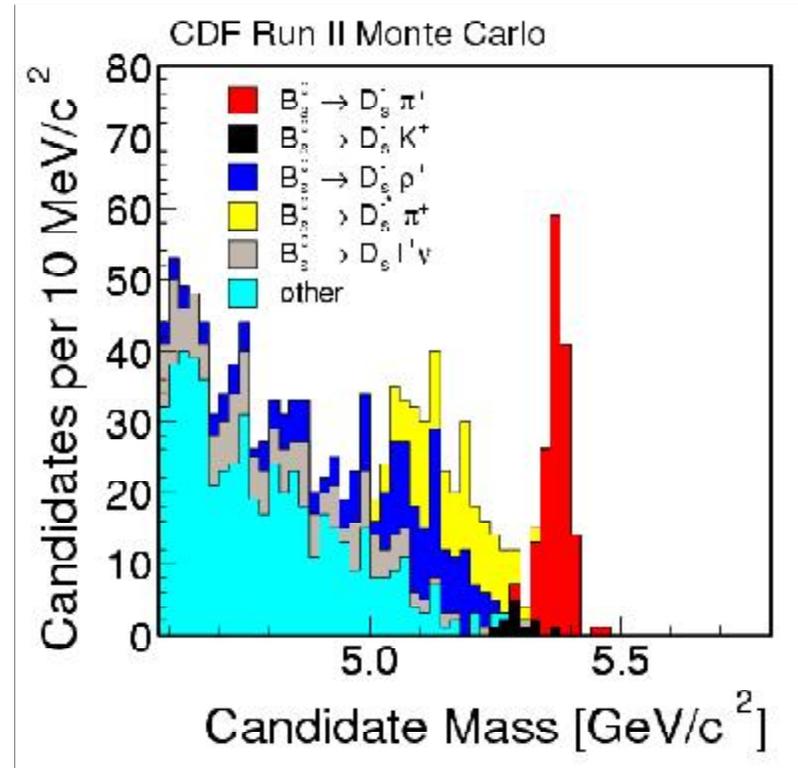
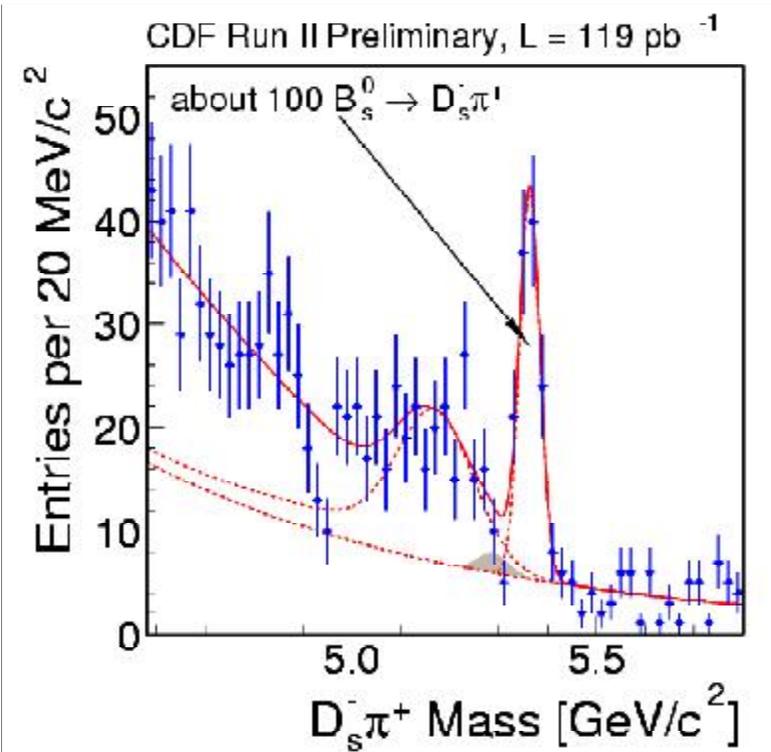
$$\text{Result: } \frac{f_s BR(B_s \rightarrow KK)}{f_d BR(B^0 \rightarrow K\pi)} = 0.74 \pm 0.20 \pm 0.22$$

Measure A_{CP}

$$\frac{N(\bar{B} \rightarrow K^- \pi^+) - N(B \rightarrow K^+ \pi^-)}{N(\bar{B} \rightarrow K^- \pi^+) + N(B \rightarrow K^+ \pi^-)} = 0.02 \pm 0.15 \pm 0.02$$



B_s hadronic yields (B_s mixing)



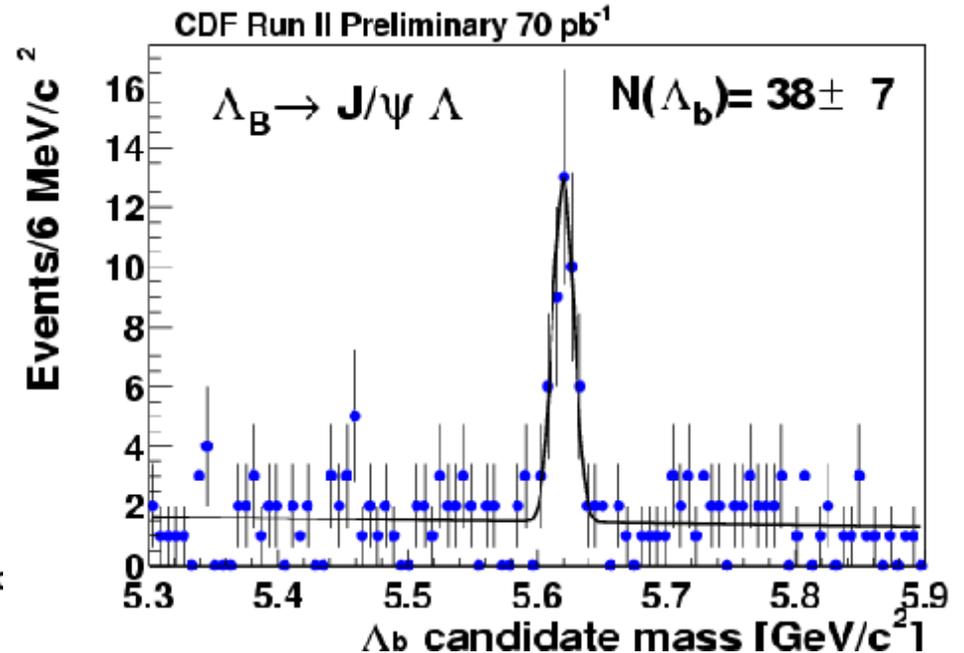
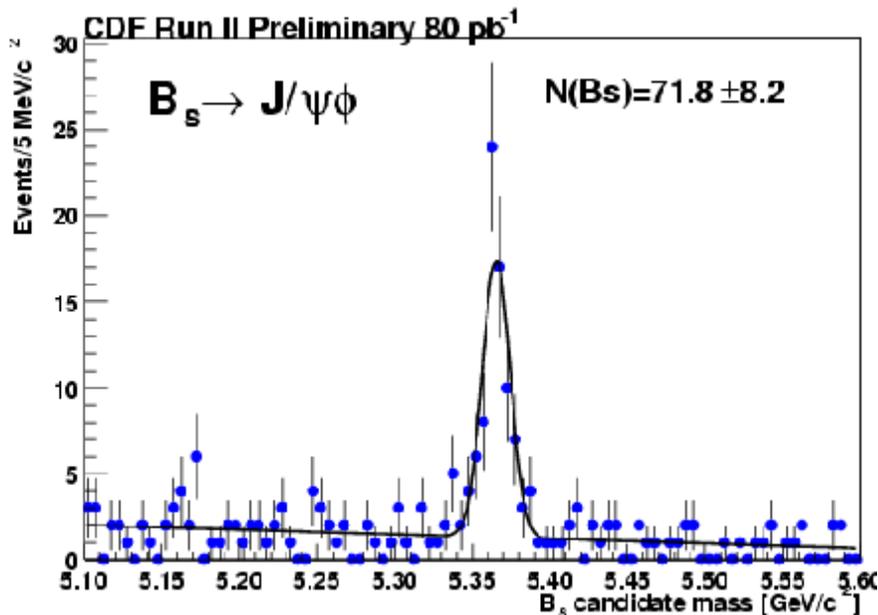
$B_s^0 \rightarrow D_s^- \pi^+$ with $D_s^- \rightarrow \phi \pi^-$ and $\phi \rightarrow K^- K^+$

$$\frac{f_s BR(B_s^0 \rightarrow D_s^- \pi^+)}{f_d BR(B^0 \rightarrow D^- \pi^+)} = 0.35 \pm 0.05 (stat) \pm 0.03 (syst) \pm 0.09 (BR)$$

$$\frac{BR(B_s^0 \rightarrow D_s^- \pi^+)}{BR(B^0 \rightarrow D^- \pi^+)} = 1.4 \pm 0.2 (stat) \pm 0.1 (syst) \pm 0.4 (BR) \pm 0.2 (PR)$$



B Hadron Masses



@ World's best mass measurements for B_s and Λ_B :

$$M(B_s) = 5365.50 \pm 1.29 \pm 0.94 \text{ MeV} \text{ and } M(\Lambda_B) = 5620.4 \pm 1.6 \pm 1.2 \text{ MeV}$$

@ Lifetime measurements for B_s and Λ_B :

$$B_s \text{ lifetime } 1.33 \pm 0.14_{(\text{stat})} \pm 0.02_{(\text{sys})} \text{ ps (PDG } 1.461 \pm 0.057 \text{ ps)}$$

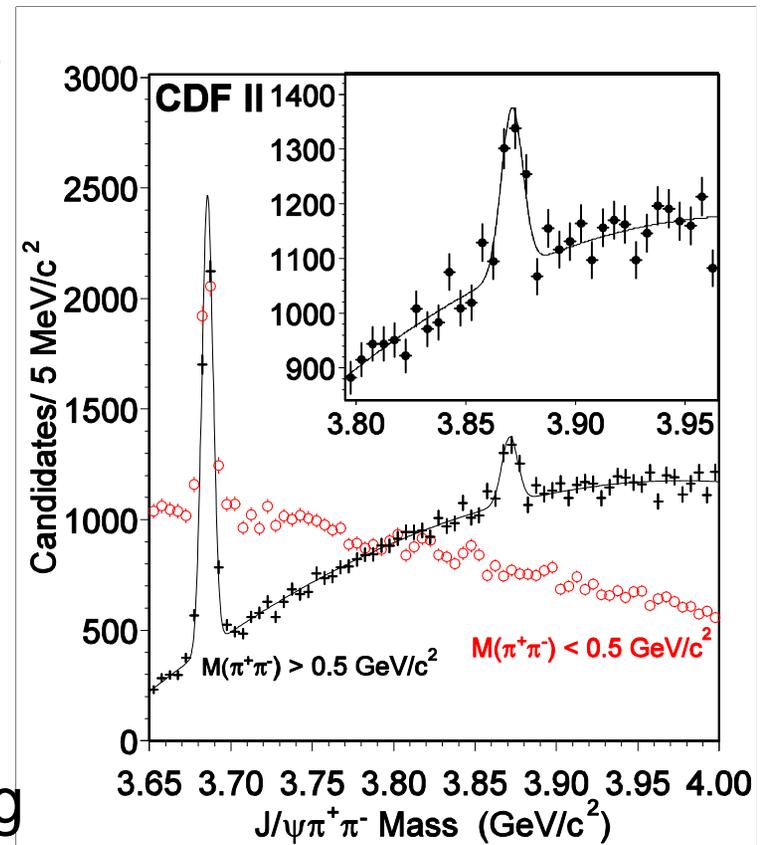
$$\Lambda_B \text{ lifetime } 1.25 \pm 0.26_{(\text{stat})} \pm 0.10_{(\text{sys})} \text{ ps (PDG } 1.229 \pm 0.08 \text{ ps)}$$

First lifetime from fully reconstructed Λ_b decay!



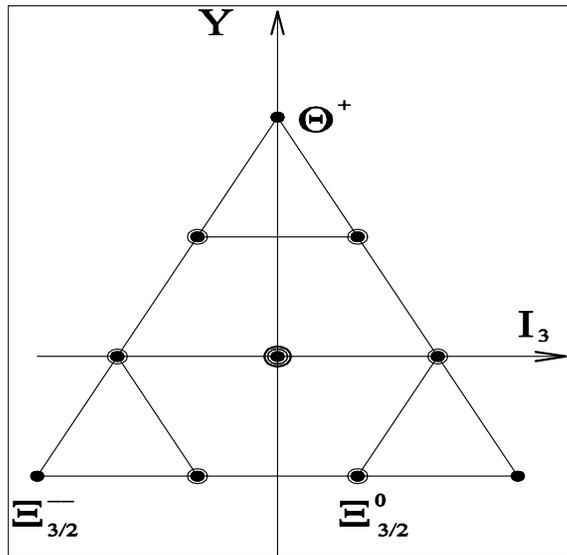
Exotic Spectroscopy

- Recall CDF X(3872) confirmed Belle discovery
- $> 10 \sigma$ result
- Pursuing production mechanisms
- Search for exotic $S=-2$ Baryons (pentaquark)
- NA49 claim of θ^+ & cascade π
- CDF uses standalone silicon tracking for long lived cascade hyperons (jet 20+SVT trigger sample)



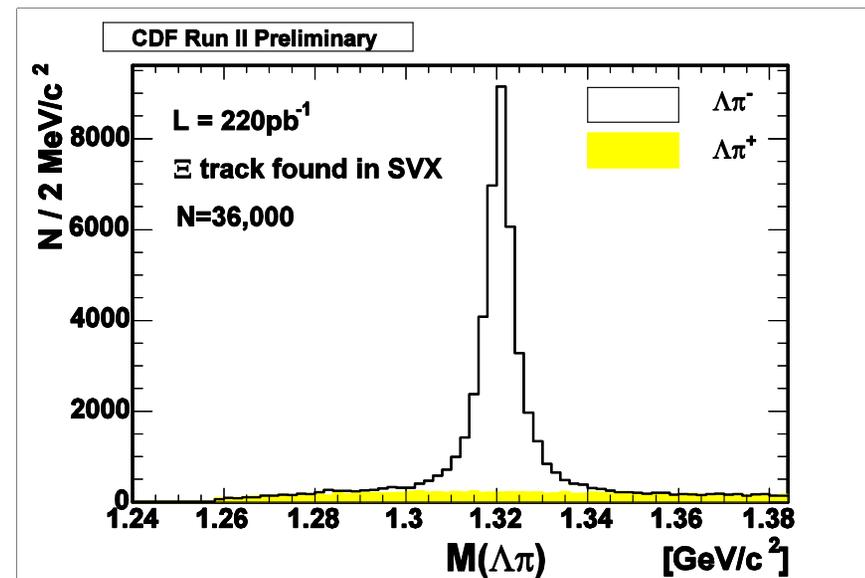
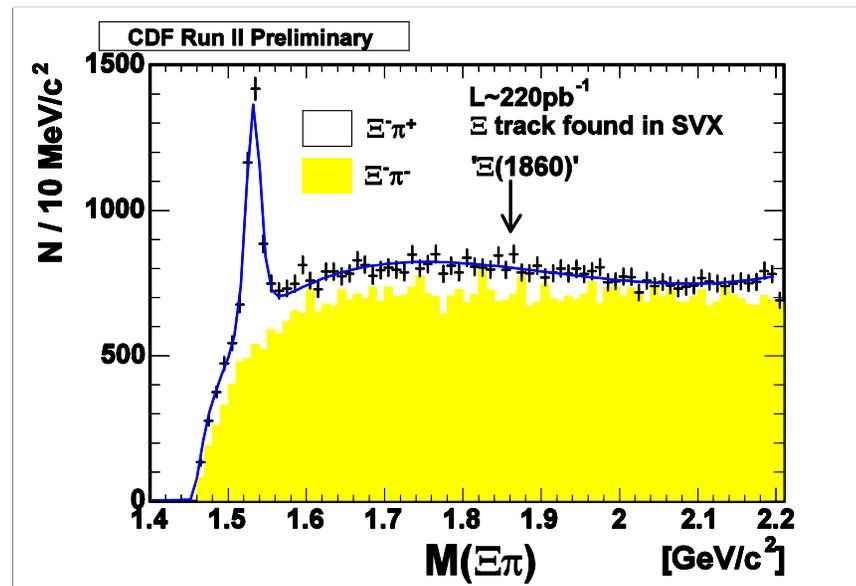


Exotic Spectroscopy



- NA49 has about 2000 cascades
- CDF has 36,000 cascades
- See big cascade (1530) signal
- Search for cascade' (1860)
- 95%CL UL 0.04 double charged
- 95%CL UL 0.07 neutral

March 12, 2004





Exotics

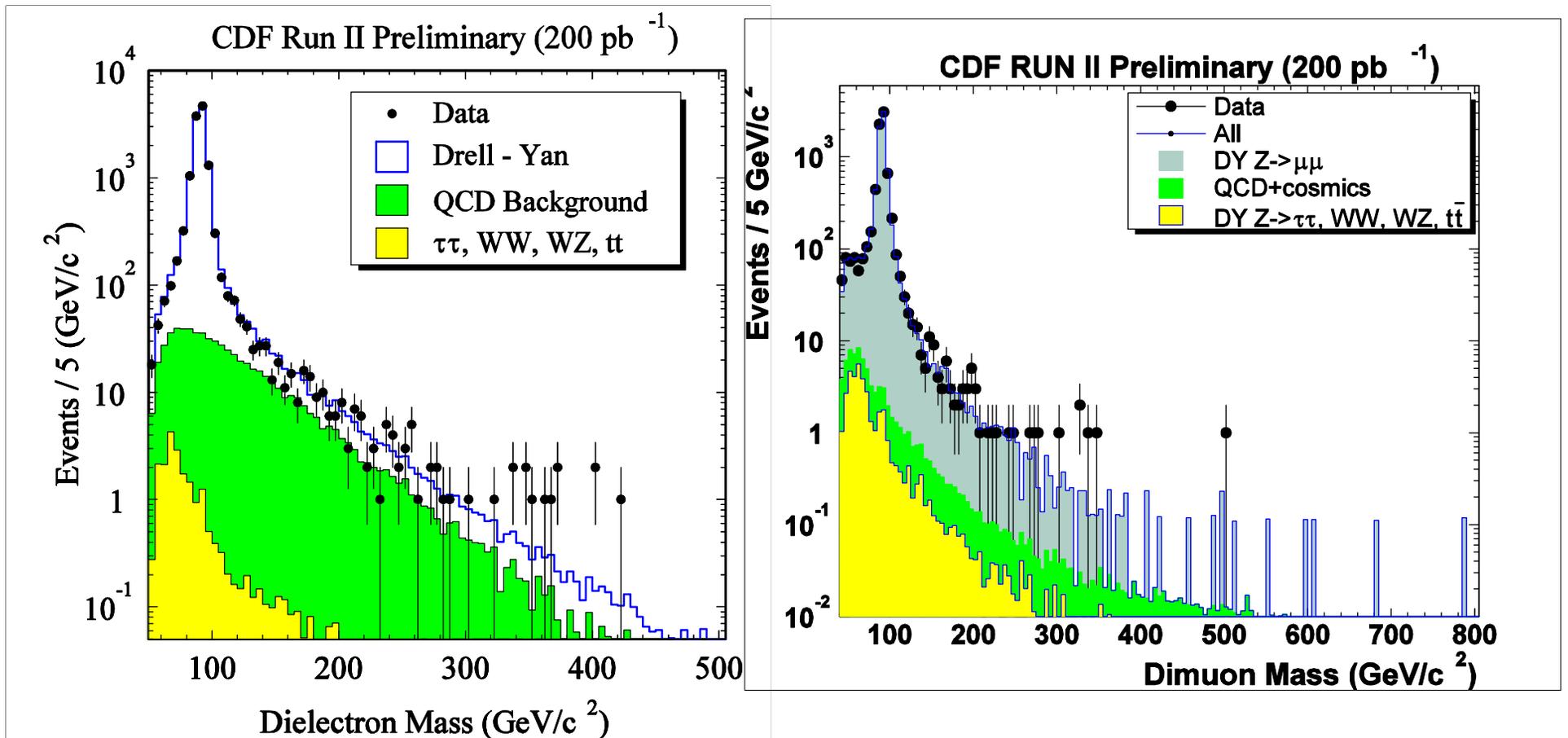


Exotics

- 1 paper to PRL last week
 - Bd, Bs \rightarrow $\mu\mu$ (complete and PRL sent out March 19th)
- Formed godparent committees for 6 analyses
 - Search for $Z' \rightarrow ee, \mu\mu$
 - Search for 1st and 2nd generation leptoquarks
 - Search for leptoquarks in missing ET
 - $e^* \rightarrow e$ gamma
 - $H^{++} \rightarrow ee, \mu\mu, e\mu$
 - WH standard model limit
- 12 analyses moving towards final blessing
- ~ 20 additional analyses under way



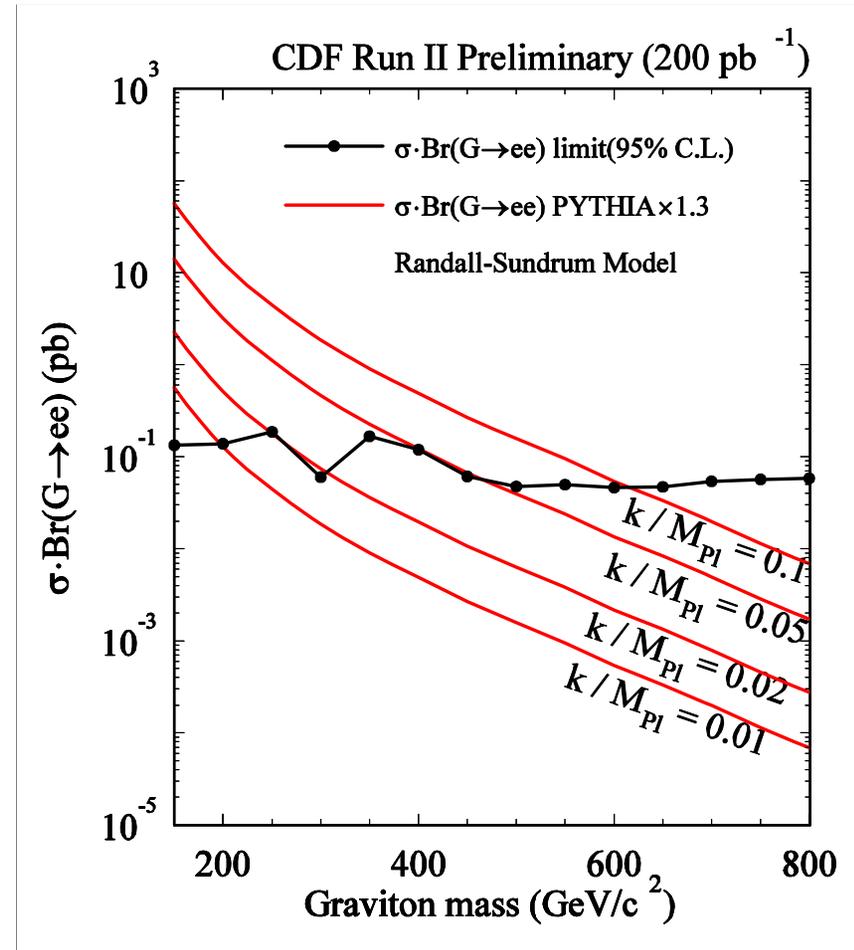
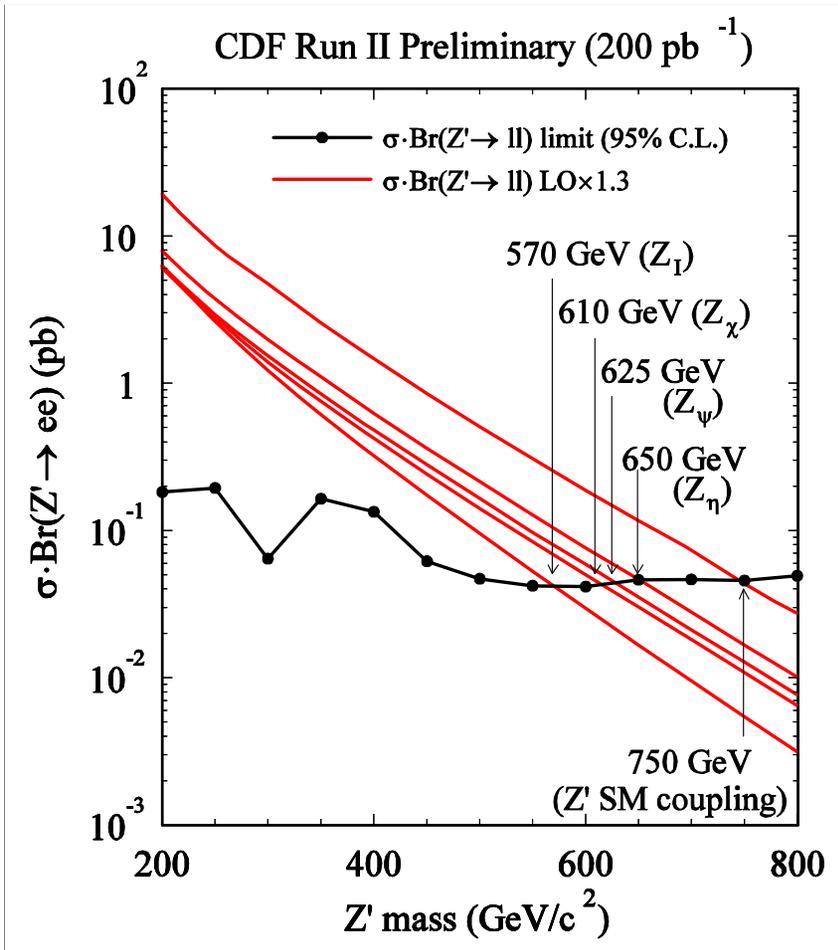
Search for the Z'





Z' and RS Graviton Mass Limits

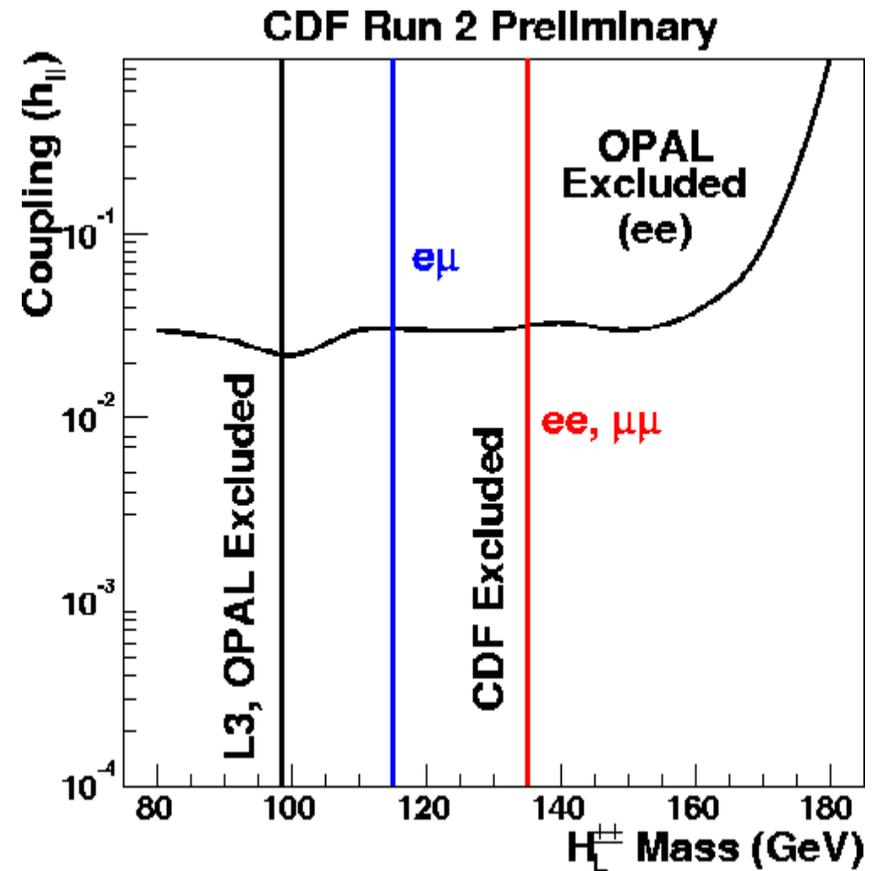
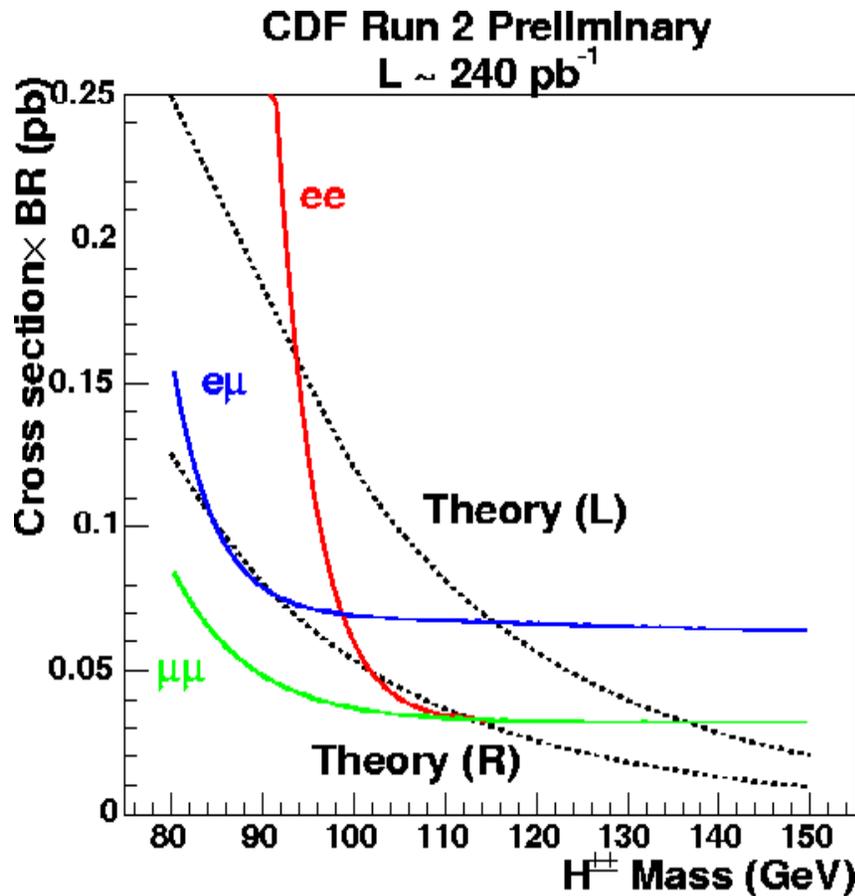
e^+e^- and $\mu^+\mu^-$ combined





Search for the H^{++} in same sign dileptons

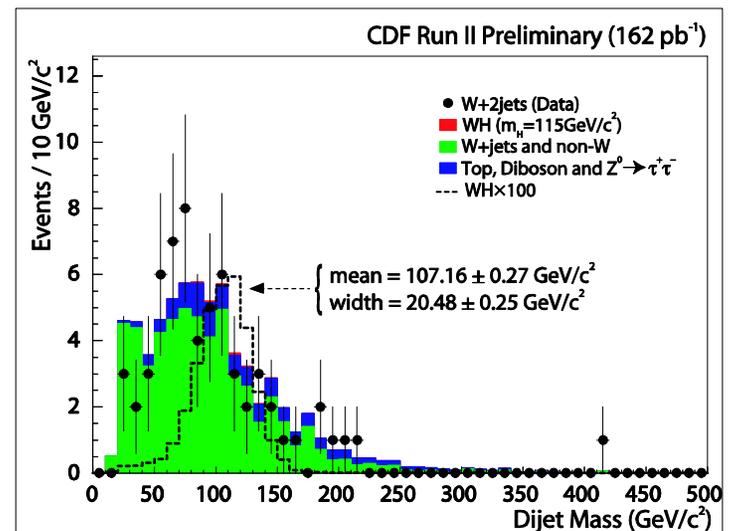
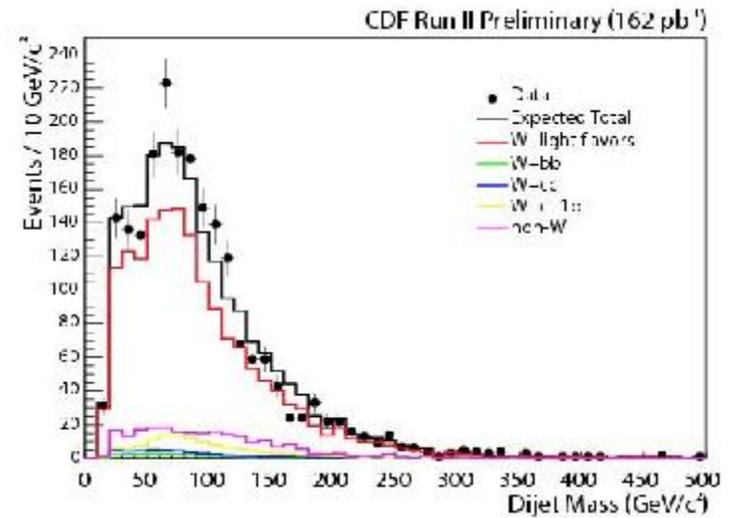
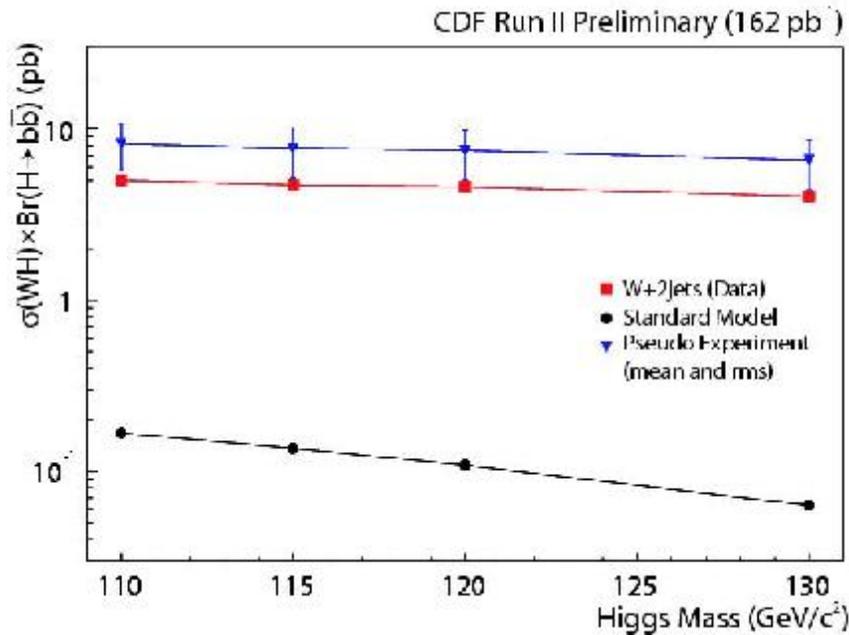
- Doubly-charged Higgs particles predicted by LR symmetric models,
- SUSY LR models predict low-mass H^{++} (~ 100 GeV to 1 TeV)





Search for WH

- 2 jets + 1 b-tag + lepton + missing E_t
- Dijet Mass resolution achieved 17%
- Improve by adding special corrections for b-jets, tracks, muons





Search for 1st & 2nd Generation LeptoQuarks

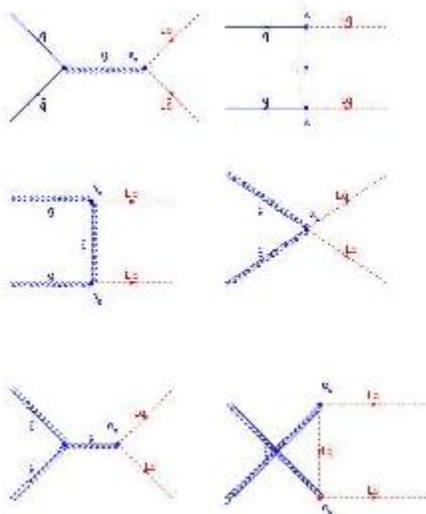
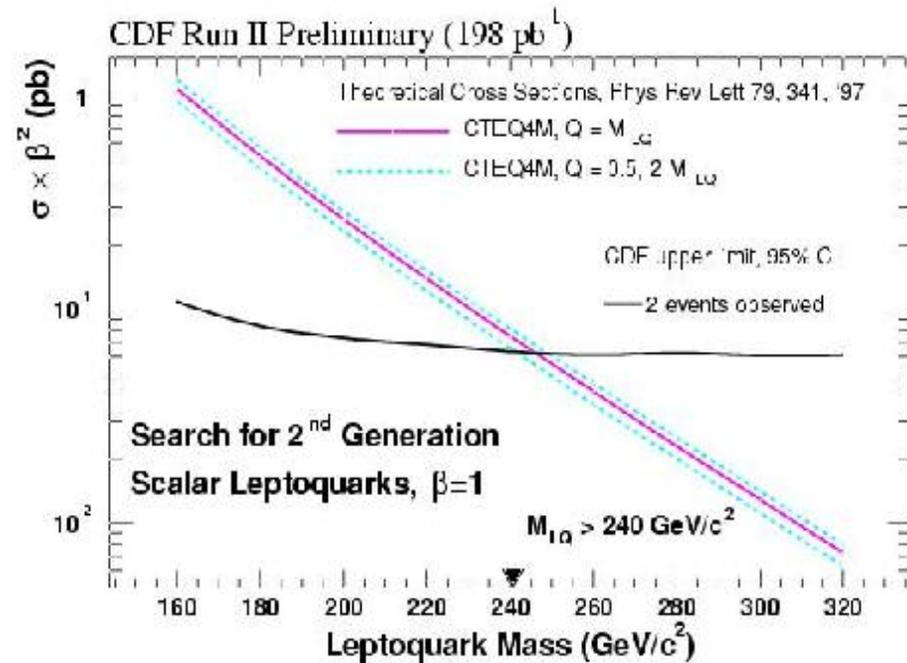


Figure 2.4: Feynman diagrams for pair production of leptoquarks at hadron colliders.

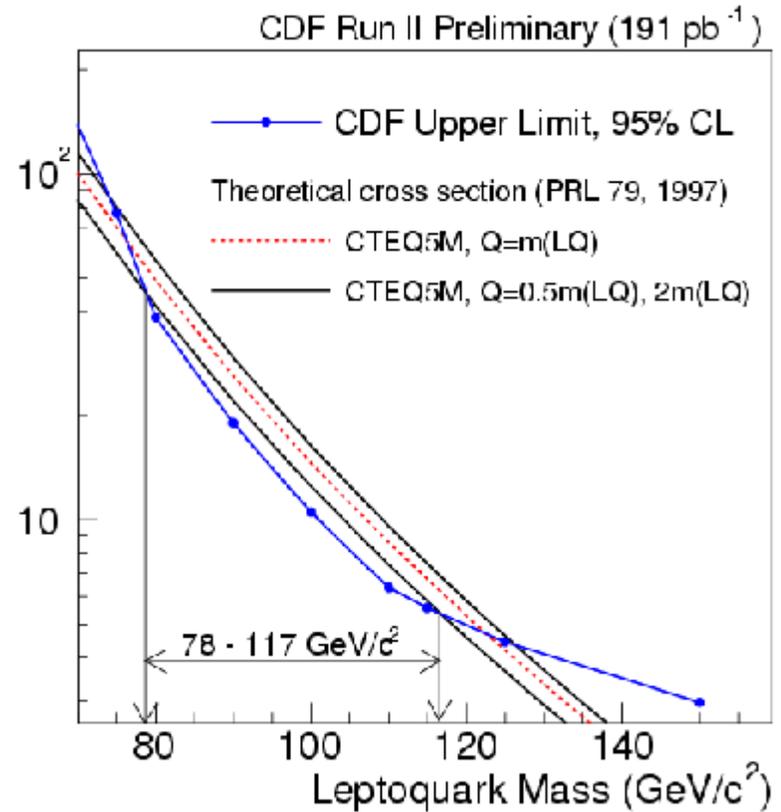
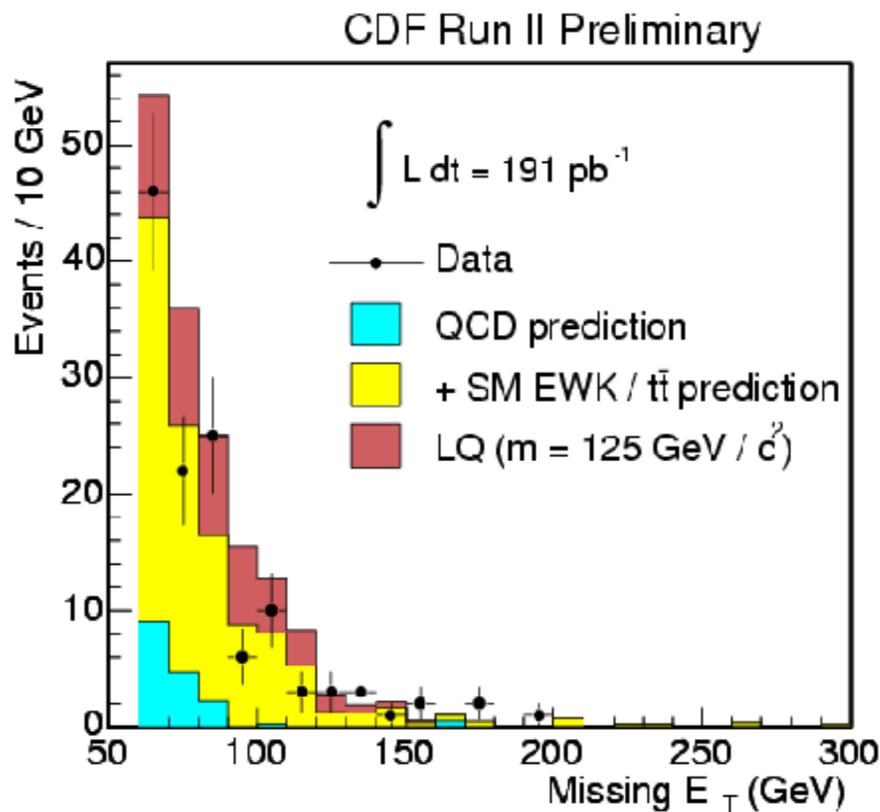


- Some models beyond SM have an extra symmetry between quarks and leptons
- leptoquarks transition between leptons and quarks
- Have lepton and baryon numbers with unknown couplings
- Search for two muons and two jets $M(LQ) > 240 \text{ GeV}/c^2$
- two electrons and two jets reported $M(LQ) > 230 \text{ GeV}/c^2$
- 1 electron+2jets+missing Et $M(LQ) > 166 \text{ GeV}/c^2$



Search for Any Generation LQs

- Signal is missing E_T plus two jets



Exclude 78 - 117 GeV/c^2



Electro-Weak

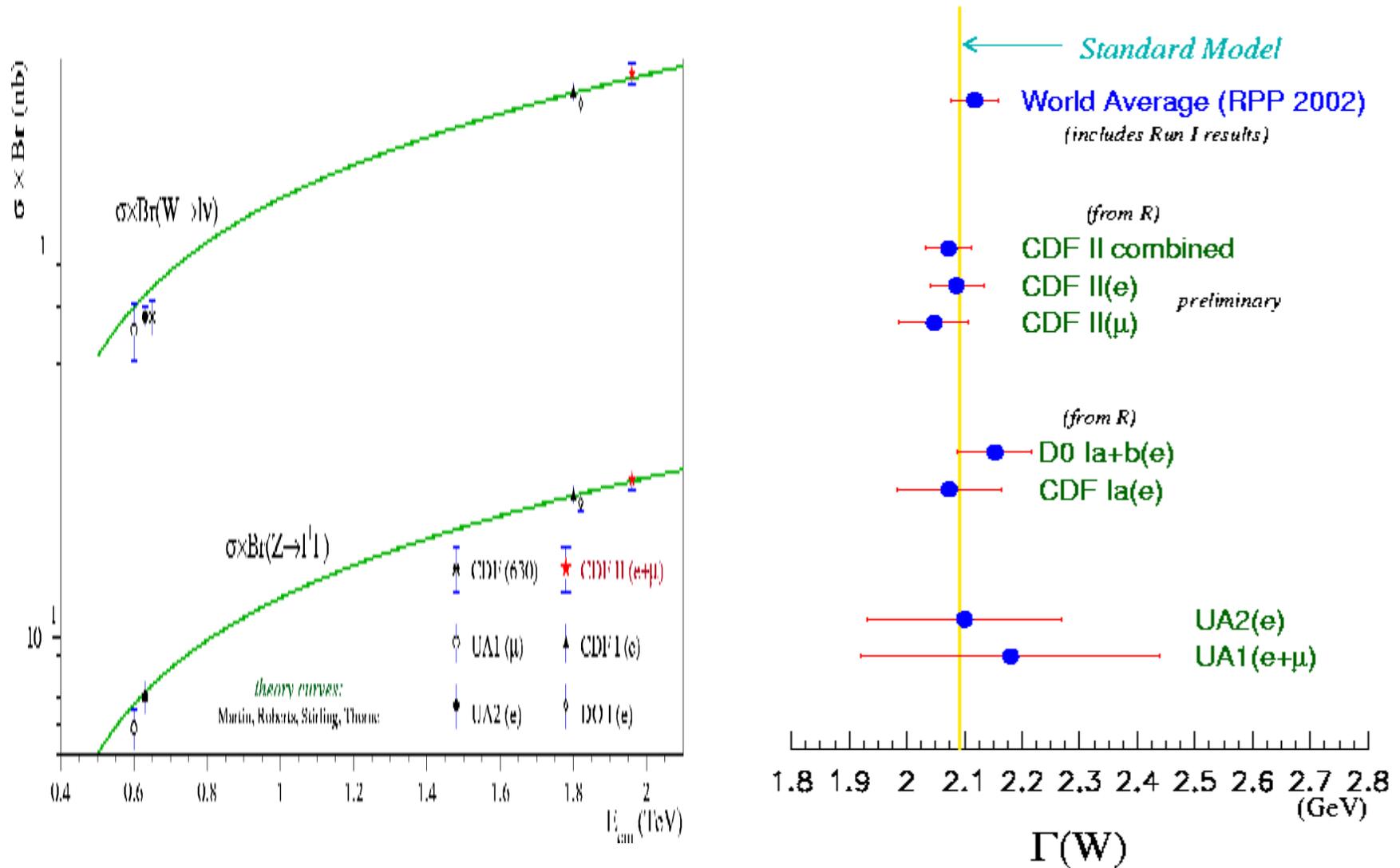


Electro-Weak

- 2 papers in godparent publication review
 - Forward-backward asymmetry in $Z \rightarrow e^+e^-$
 - Second draft ready for Collaboration in ~2 weeks
 - W/Z cross section e, μ
 - First draft ready
- Formed godparent committee
 - WW cross section in dilepton channel
- Forming godparent committee for
 - W/Z cross section in tau channel
- Moving towards final blessing
 - W mass

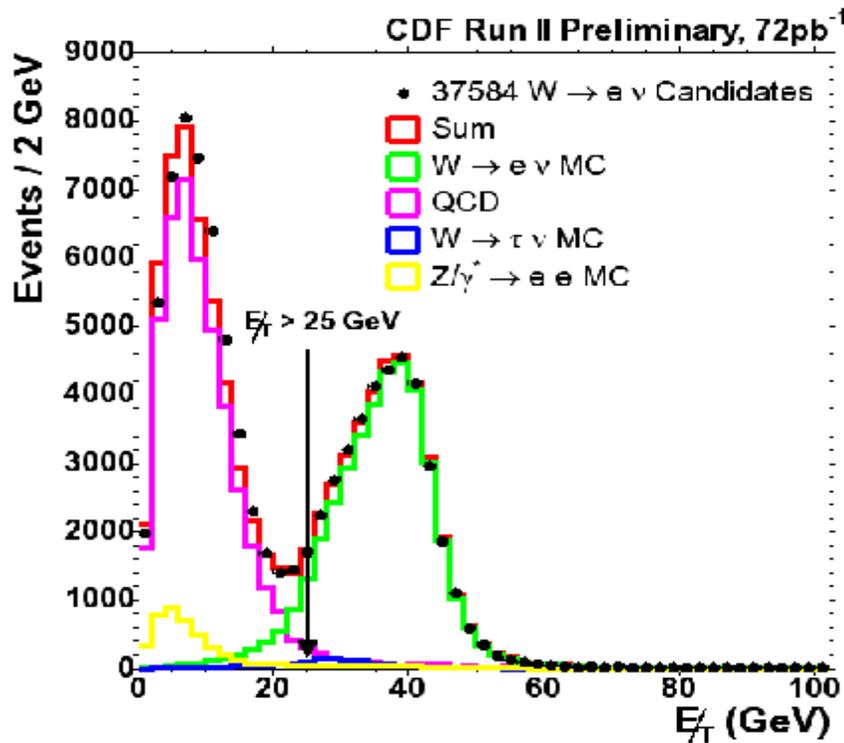


W&Z Cross Section and W width

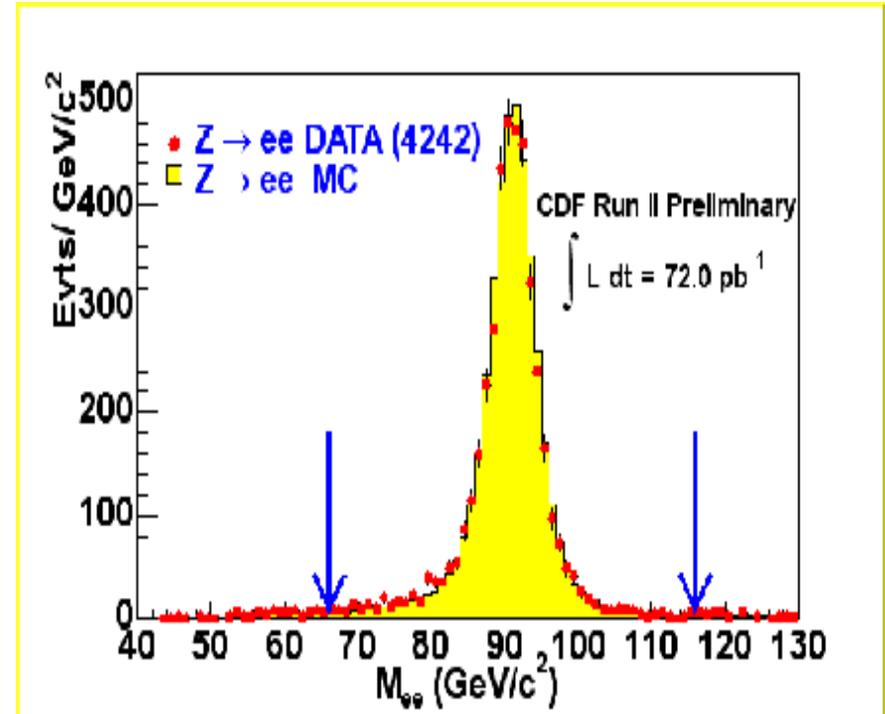




W/Z production: understanding the systematic effects



$$\sigma(pp \rightarrow W \rightarrow l \nu) = 2777 \pm 10_{\text{stat}} \pm 52_{\text{syst}} \pm 167_{\text{lum}} \text{ pb}$$

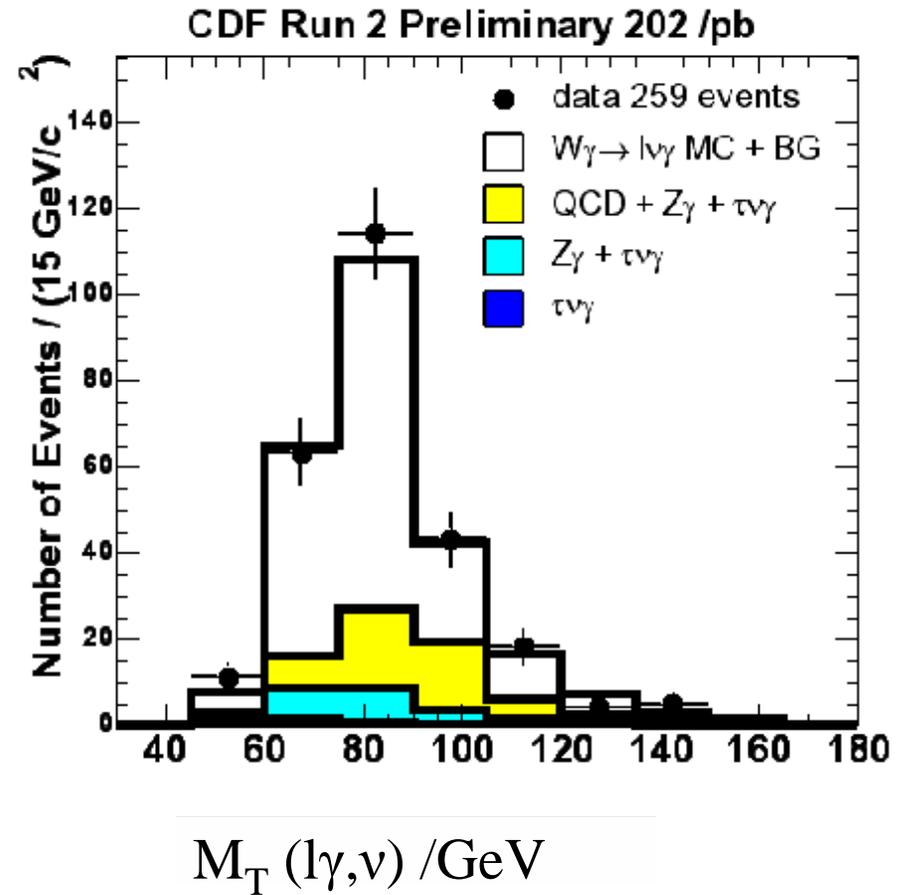
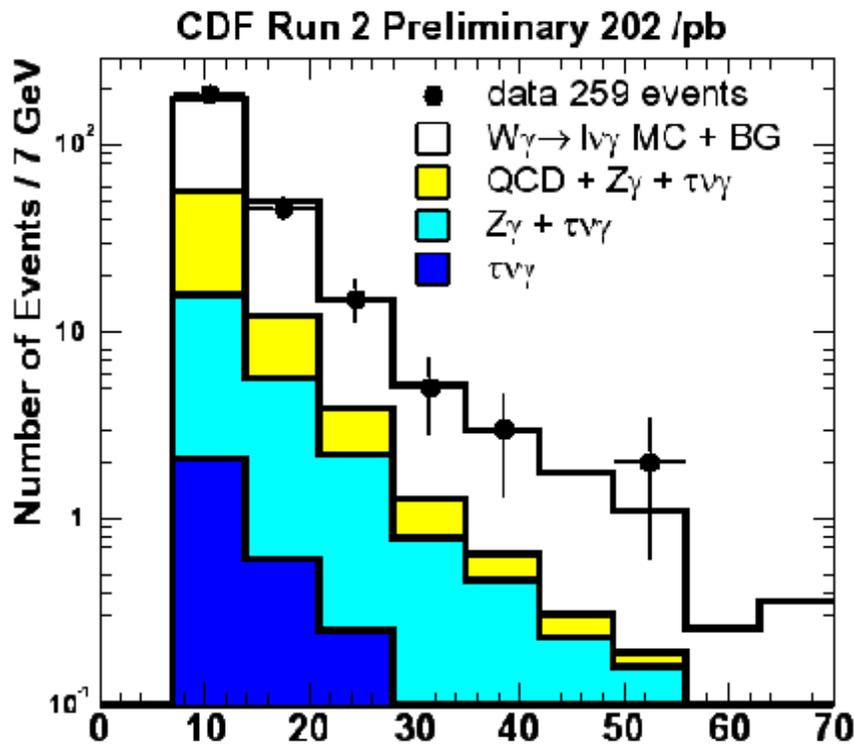


$$\sigma(pp \rightarrow Z/\gamma^* \rightarrow ll) = 254 \pm 3.3_{\text{stat}} \pm 4.3_{\text{syst}} \pm 15.2_{\text{lum}} \text{ pb}$$

$$R = 10.93 \pm 0.15_{\text{stat}} \pm 0.14_{\text{syst}}$$



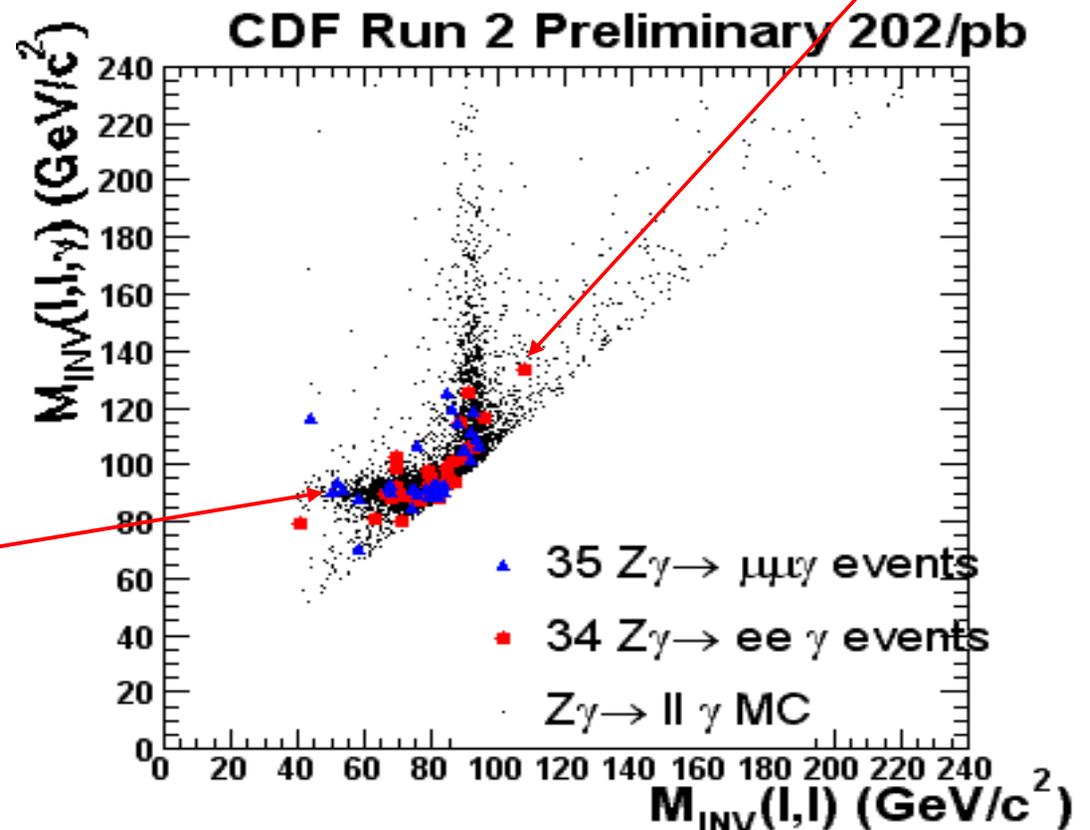
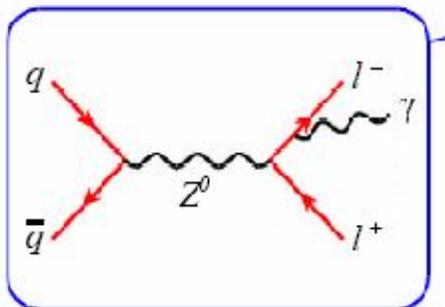
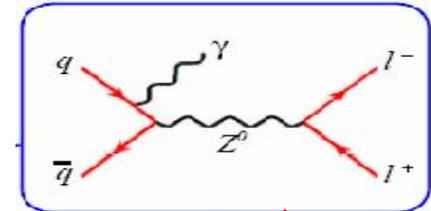
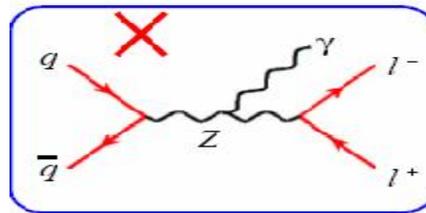
$W\gamma$ production: agreement with SM





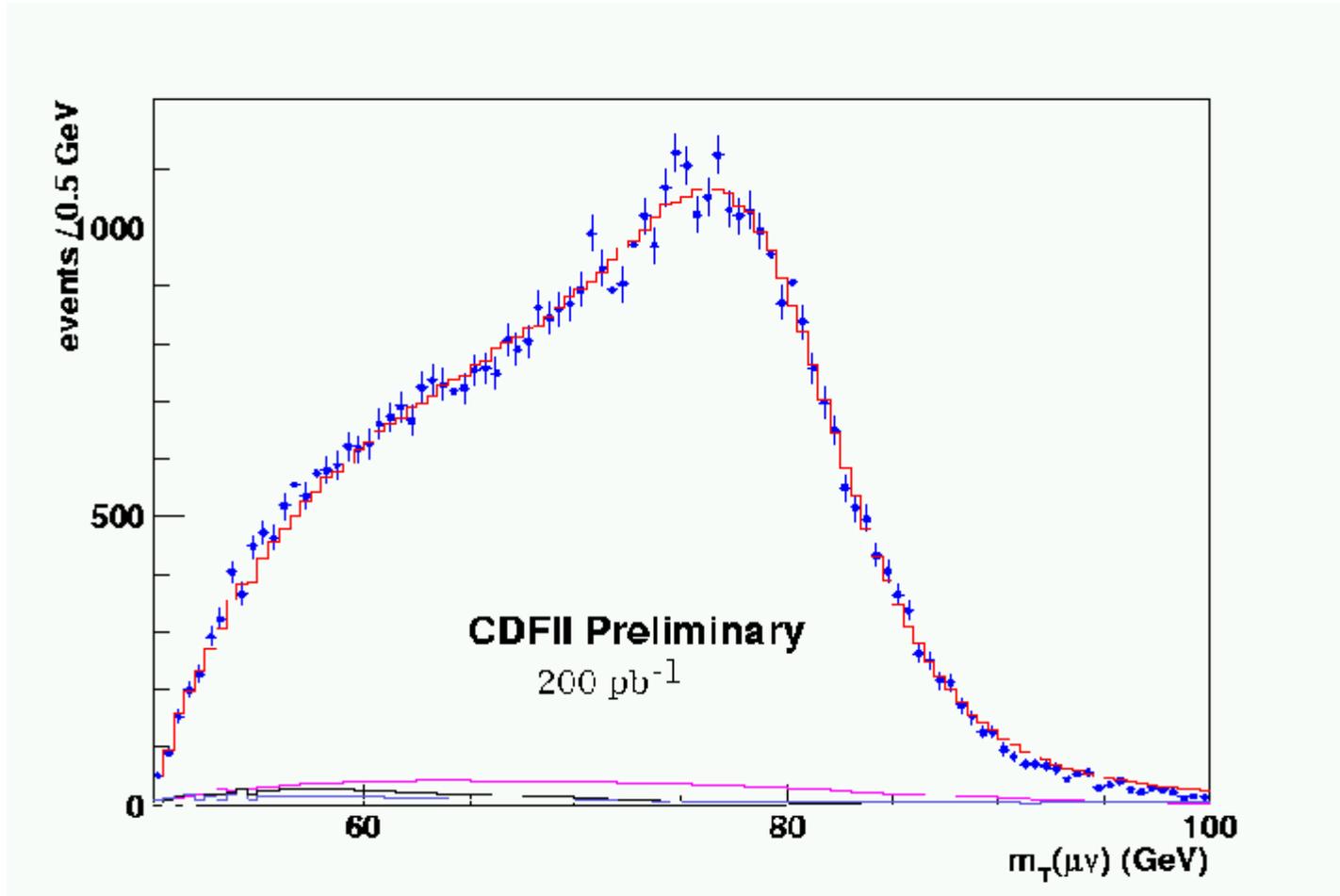
Z γ with 200 pb⁻¹: indications of a new physics?

$pp \rightarrow Z\gamma \rightarrow l+l-\gamma$
 2 leptons with $E_t > 25$ GeV
 1 photon with $E_t > 7$ GeV,
 $\Delta R(l_\gamma) > 0.7$





W mass measurement: finalizing the results





QCD

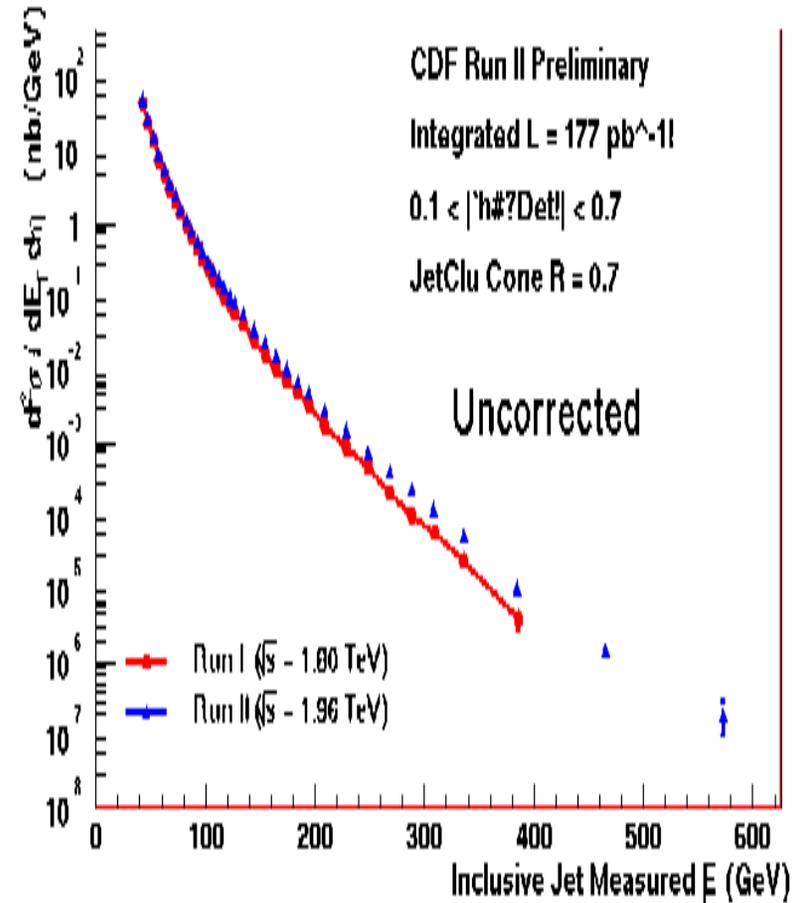
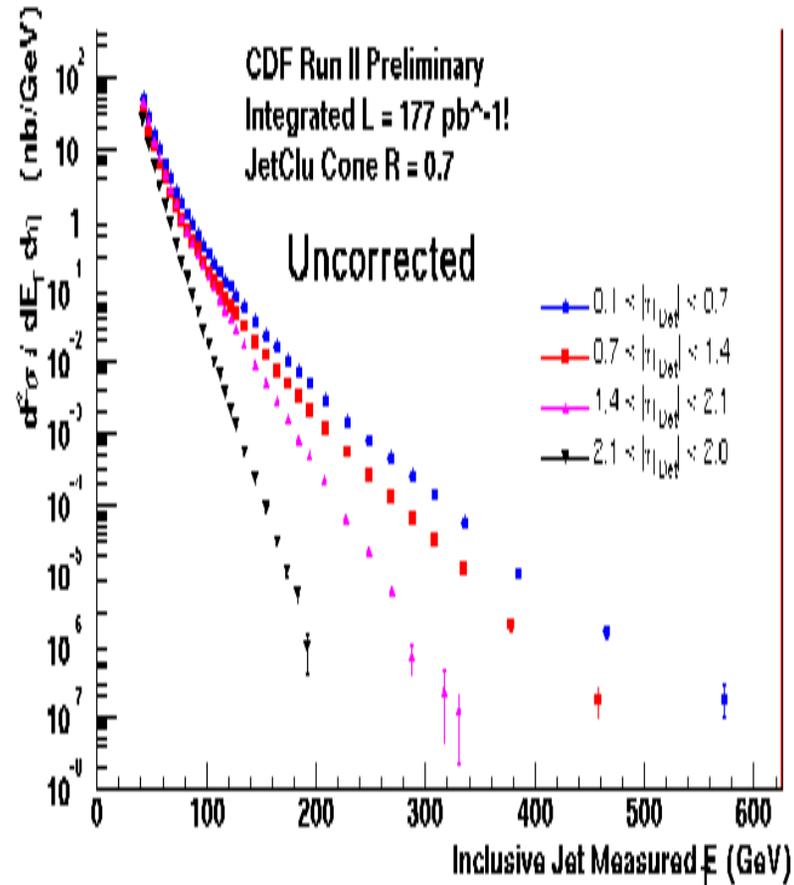


QCD

- Formed godparents
 - Jet shapes/energy flow using the MidPoint Algorithm
 - Diphoton cross section
- Form godparents by summer
 - Inclusive jet cross-section
 - Dijet mass
 - Heavy Flavor + gamma
- Form godparents by fall
 - Diffractive exclusive χ_c production...
 - W+jets cross section
 - B jet cross section
 - Dijet angular distributions

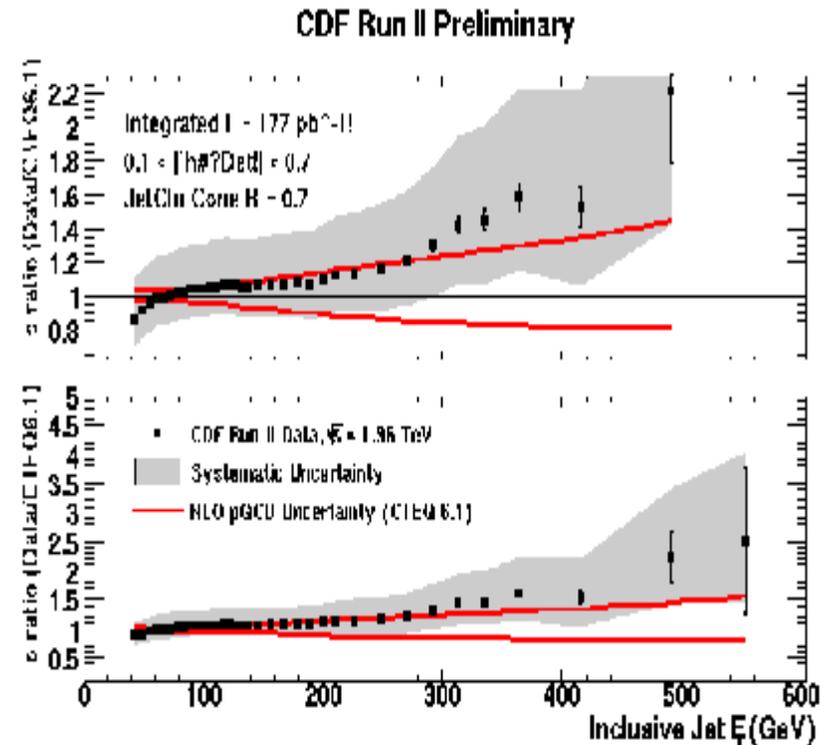
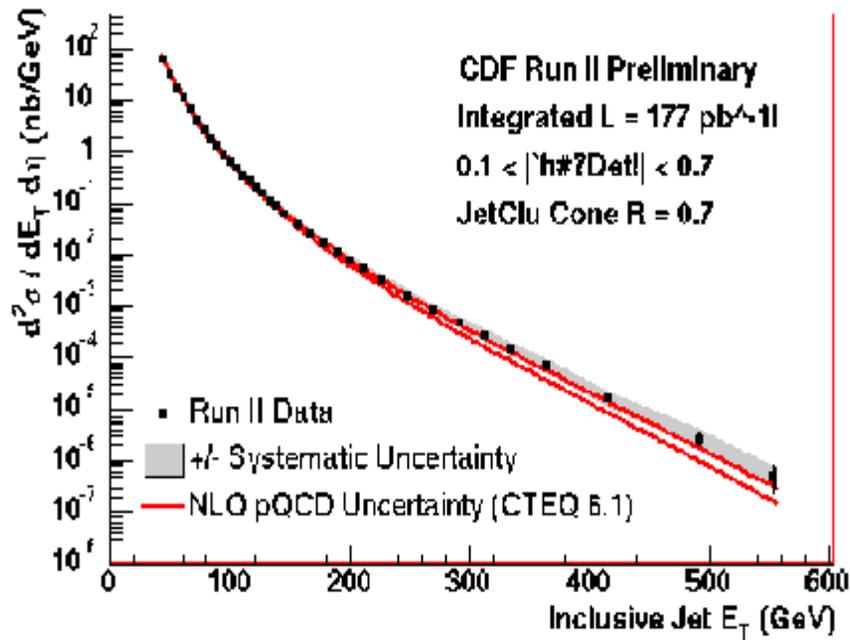


Inclusive Jet cross section





Inclusive Jet Cross Section vs NLO QCD



- Theoretical error dominated by PDF's
- Data currently agrees with NLO prediction within estimated errors



Top



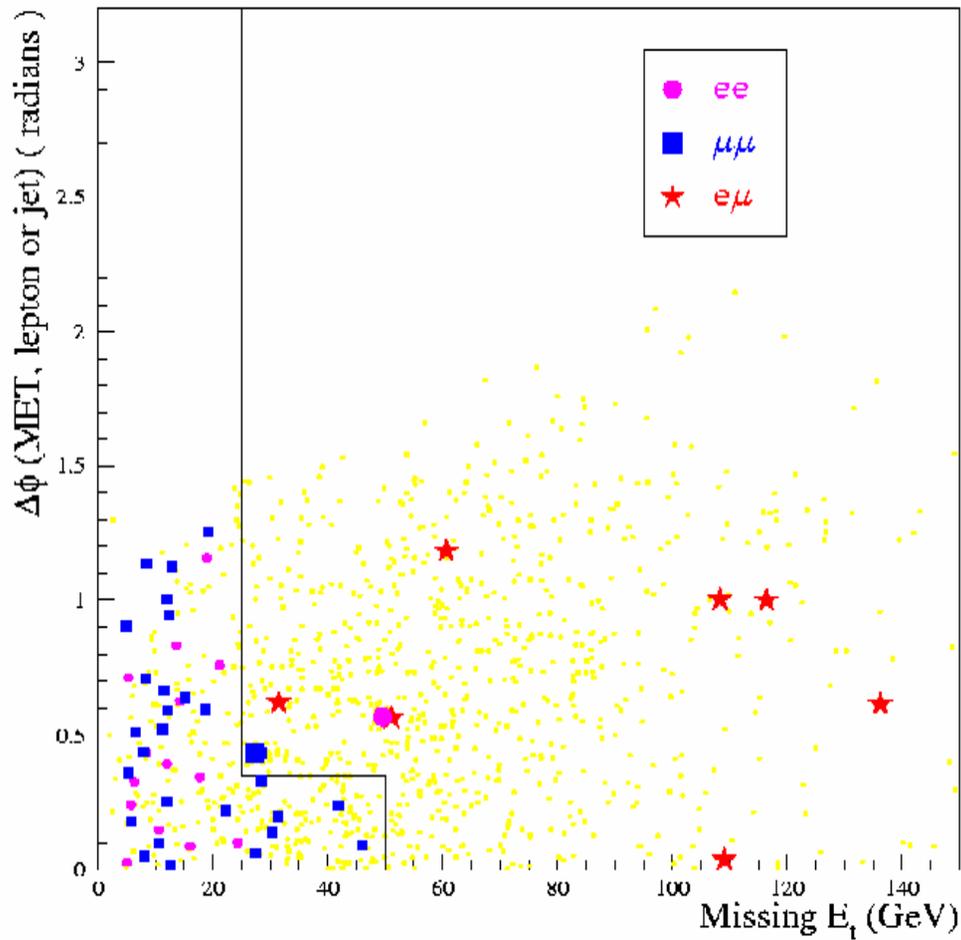
Top

- First Paper draft for top dilepton to collaboration
 - Comments back and positive
 - Final draft in preparation
 - hopefully send to PRL by end of month
- Formed godparent committees for Top cross-sections
 - Kinematic cross section (H_t)
 - Kinematic cross section (ET+b-tag)
 - W+jets – vertex tag of b-jet
 - W+jets – soft lepton tag
- Formed godparent committee for Top mass
 - Expect to publish by end of year (several new methods)
 - Bless new result hopefully for Moriond
- Forming godparent committee for single top
- Moving towards final blessing
 - W helicity
 - Single top with neural net



Run 1 Dilepton kinematics

Run 1 dilepton data (109 pb⁻¹)

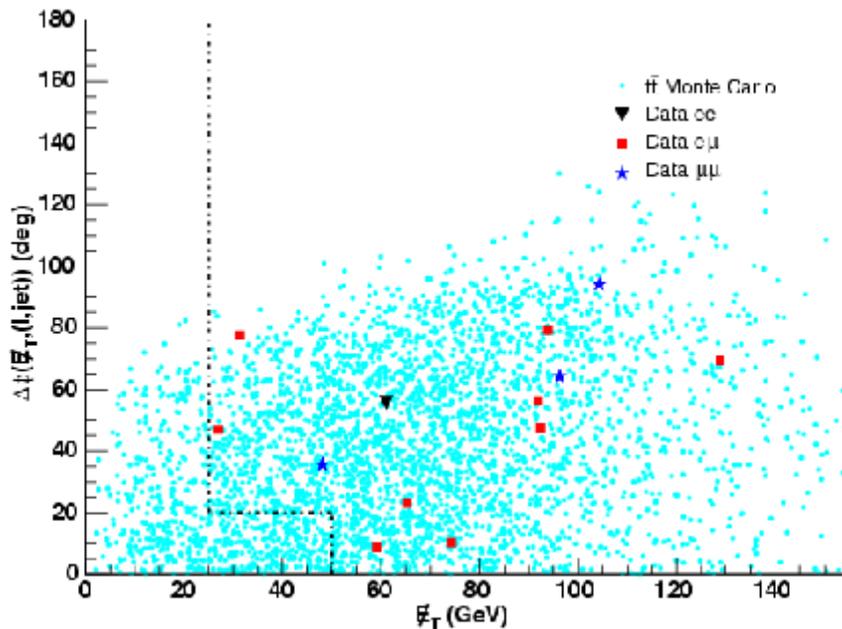


- Events at large missing ET
- Study run2 sample

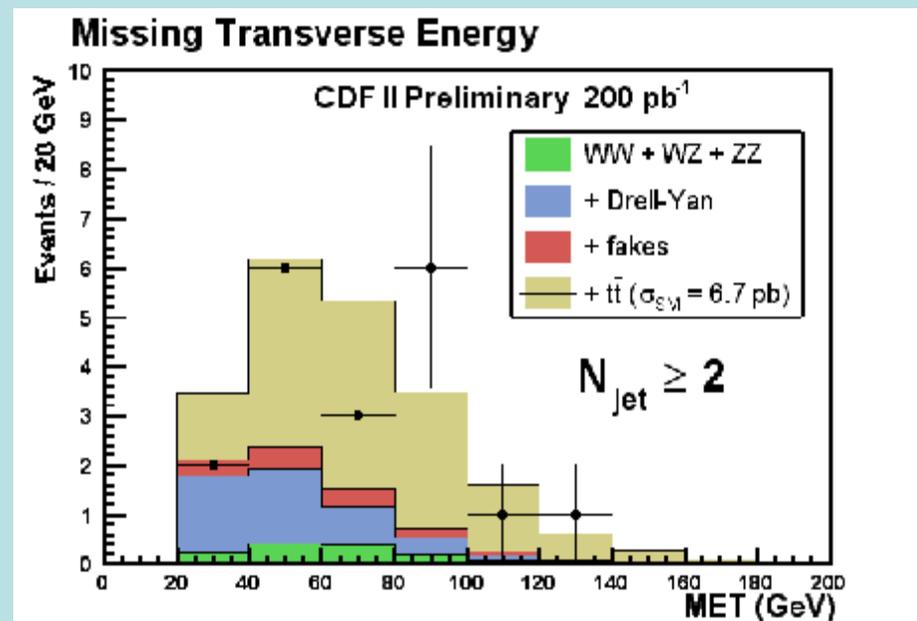


Top Dilepton Cross Section

Tight e/μ selection complemented by e/μ + tracks selection



Lepton + track sample has looser ID requirements for second lepton



Sensitive also to τ lepton final states

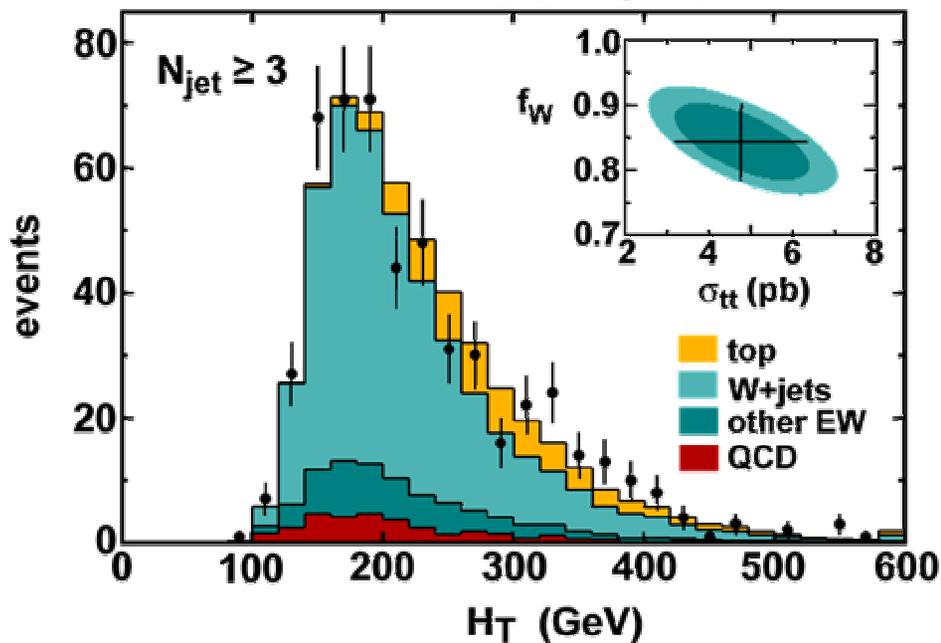
2 lepton + 2 jets sample is small but very clean for top signal



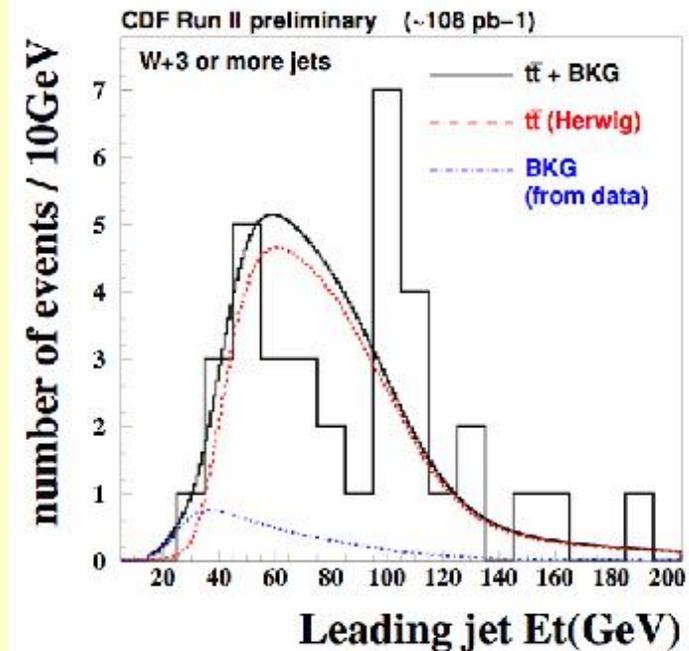
Kinematic Fits to Lepton + Jets Sample

Provides another way of estimating the background contribution

Sample before tagging
CDF Preliminary (195 pb⁻¹)



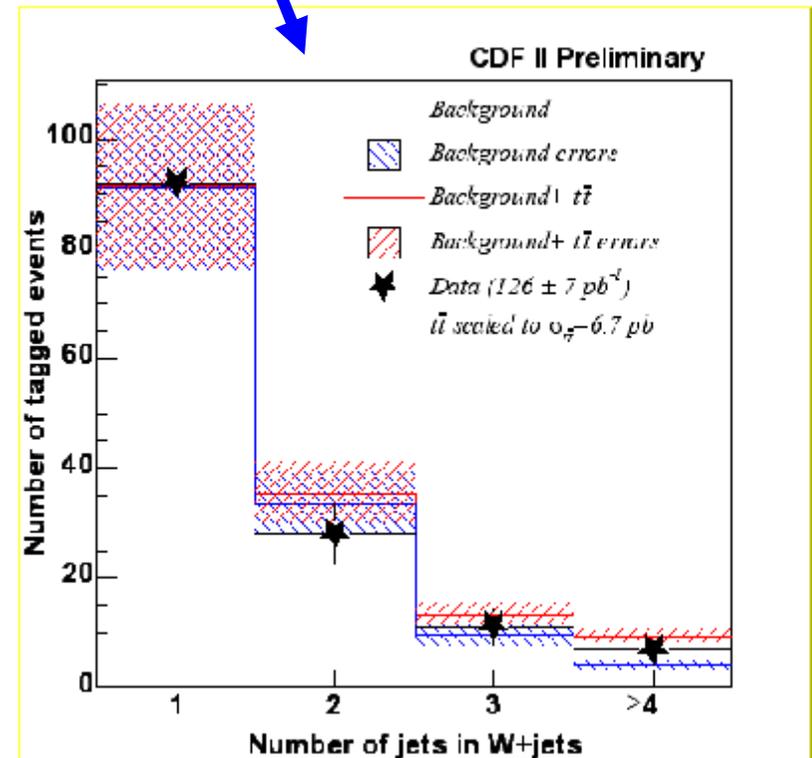
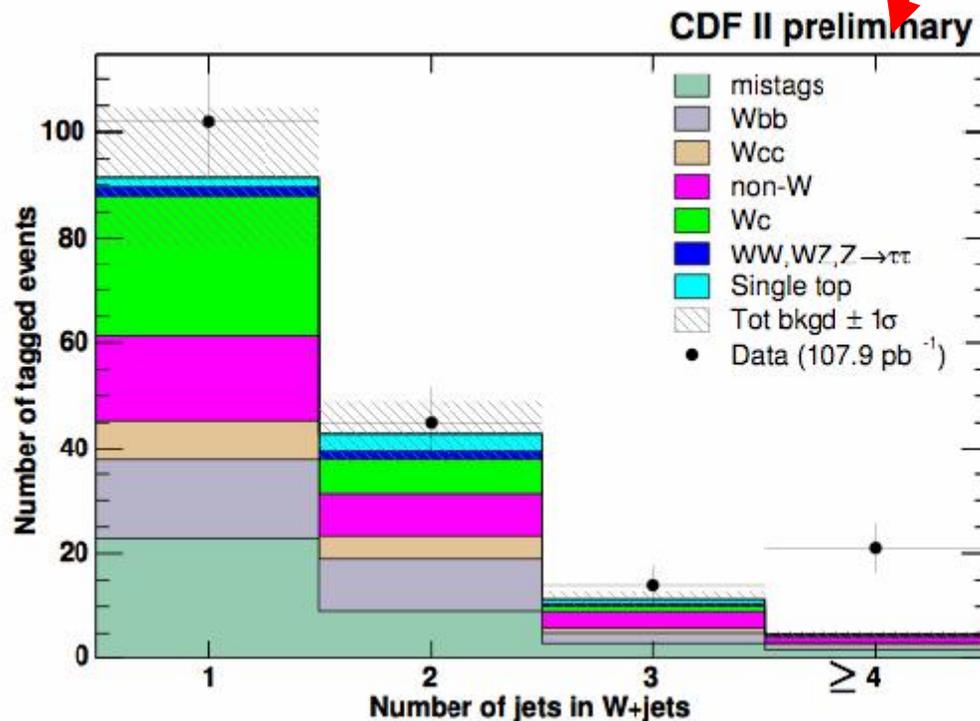
Vertex-tagged sample





Cross Section Results using Tagging

Counting experiments with **vertex tag** and **soft muon tag** in 3,4-jet bins

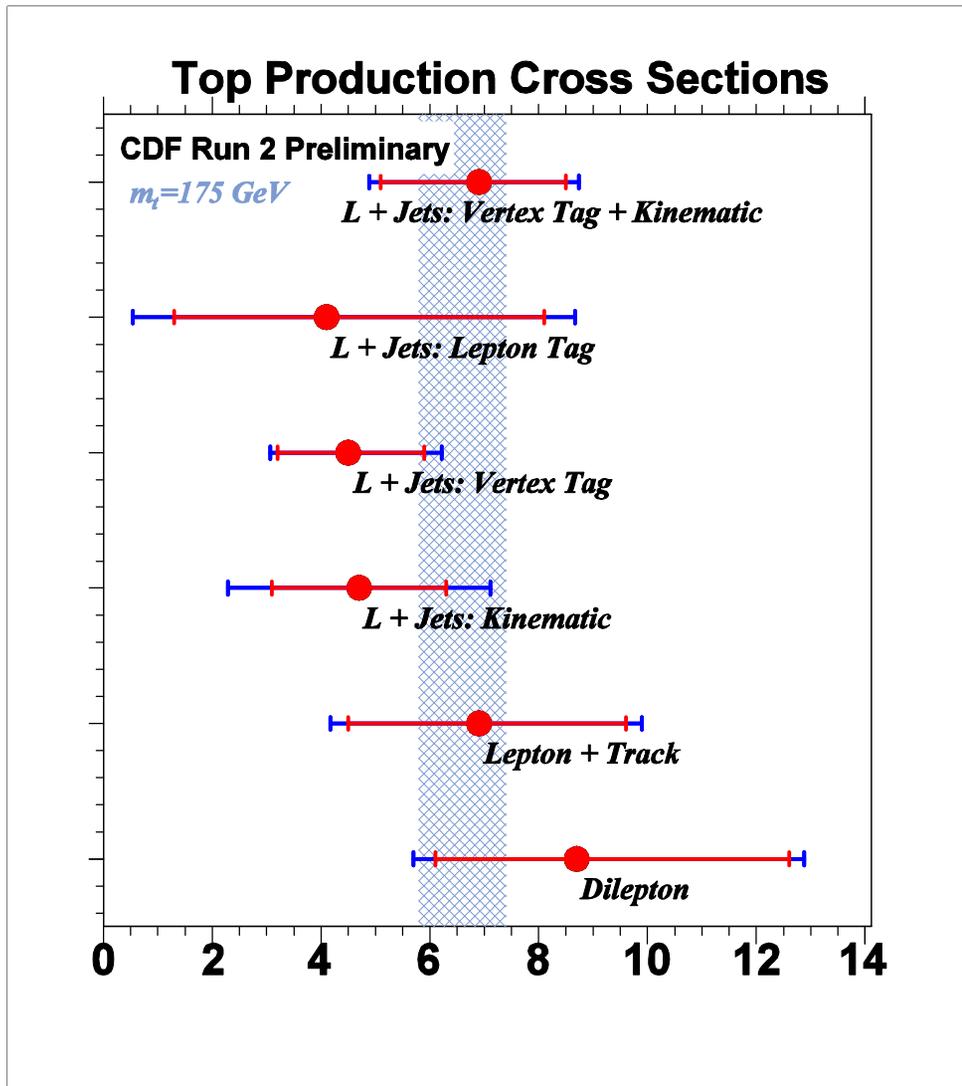


Estimate backgrounds in the lepton + jets sample from first principles:

- Using data as much as possible (non-W QCD, fake tags)
- Some MC calculations for diboson and W + heavy flavor backgrounds



CDF Top Cross Section Summary



108 pb^{-1}

$6.9^{+1.6}_{-1.8}(\text{stat.}) \pm 0.9 (\text{syst.})$

126 pb^{-1}

$4.1^{+4.0}_{-2.8}(\text{stat.}) \pm 2.2 (\text{syst.})$

108 pb^{-1}

$4.5^{+1.4}_{-1.3}(\text{stat.}) \pm 0.8 (\text{syst.})$

195 pb^{-1}

$4.7 \pm 1.6(\text{stat.}) \pm 1.8 (\text{syst.})$

202 pb^{-1}

$6.9^{+2.7}_{-2.4}(\text{stat.}) \pm 1.3 (\text{syst.})$

193 pb^{-1}

$8.7^{+3.9}_{-2.6}(\text{stat.}) \pm 1.5 (\text{syst.})$



Conclusion

- The CDF detector overall is working very well (silicon stable)
- Complex 3-level trigger in good shape
- COT aging needs to be understood and fixed (short and long term issue)
- Physics publications from all groups this year-very busy good progress
- Top cross section publication this month to PRL (first hipt pub)
- Top mass > 1 method for APS
- Bottom group very busy with many topics
 - Bs mixing -will be hard—
- Taus: good signal-to-noise longer term potential for discovery encouraging
- W's and Z's to leptons look good-W mass coming along
- Searches far exceed RunI level
- Double the data again by summer hopefully (4X Run 1)
- Opportunity for discovery good with new confidence in luminosity