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CDF Research Program

Doug Glenzinski
Fermilab

April 22, 2005

The CDF Collaboration

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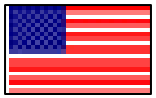
North America



3 Natl. Labs
28 Universities

3 Universities

Europe

1 Research Lab
6 Universities

1 University

4 Universities

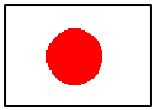
2 Research Labs

1 University

1 University

1 Research Lab
1 University

Asia



1 Research Lab
5 Universities

1 University

3 Universities

12 countries

62 institutions

650 authors

The FNAL Group on CDF

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- 63 FNAL authors (excluding 6 visitors)
  - 38 from Particle Physics Division
  - 10 from Computing Division
  - 8 from Technical Division
  - 7 from Accelerator Division
- This includes 7 Research Associates (i.e. post-docs).
- Many exclusively contribute technical expertise.
- Many have other (i.e. non-CDF) obligations.
- About 25/63 active on Run2 Data Analysis

Leadership

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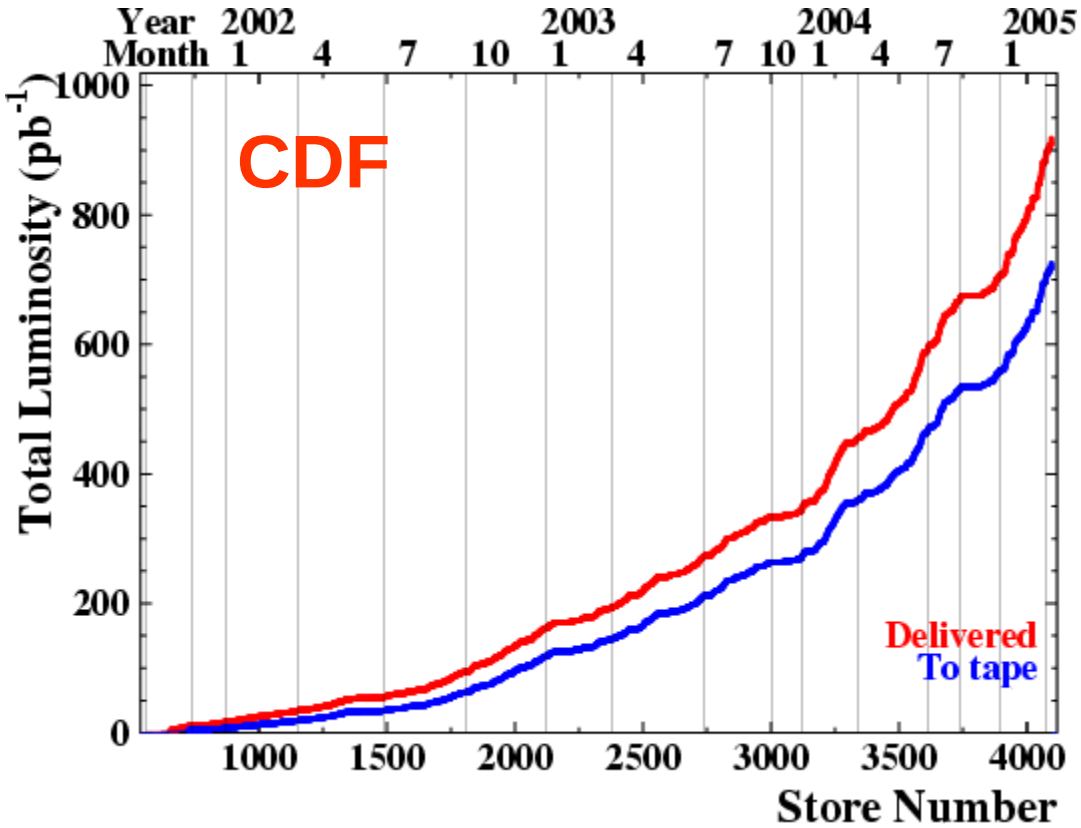
- Over the last 2 years, these 63 FNAL authors
  - Have held 15 analysis convenorships
  - Have held ~30 major leadership positions in online/offline operations
  - Include The Project Leader for Run2B (P.Lukens)
  - Include The SpokesPerson Elect (R.Roser)

CDF Operations



- Have recorded ~700/pb (x6 Run1 Data set)
- running smoothly with 80-90% efficiency
- COT aging mitigated last summer
- Run2b upgrades in good shape
- maintenance requires constant/substantial effort

CDF Data Taking Efficiency

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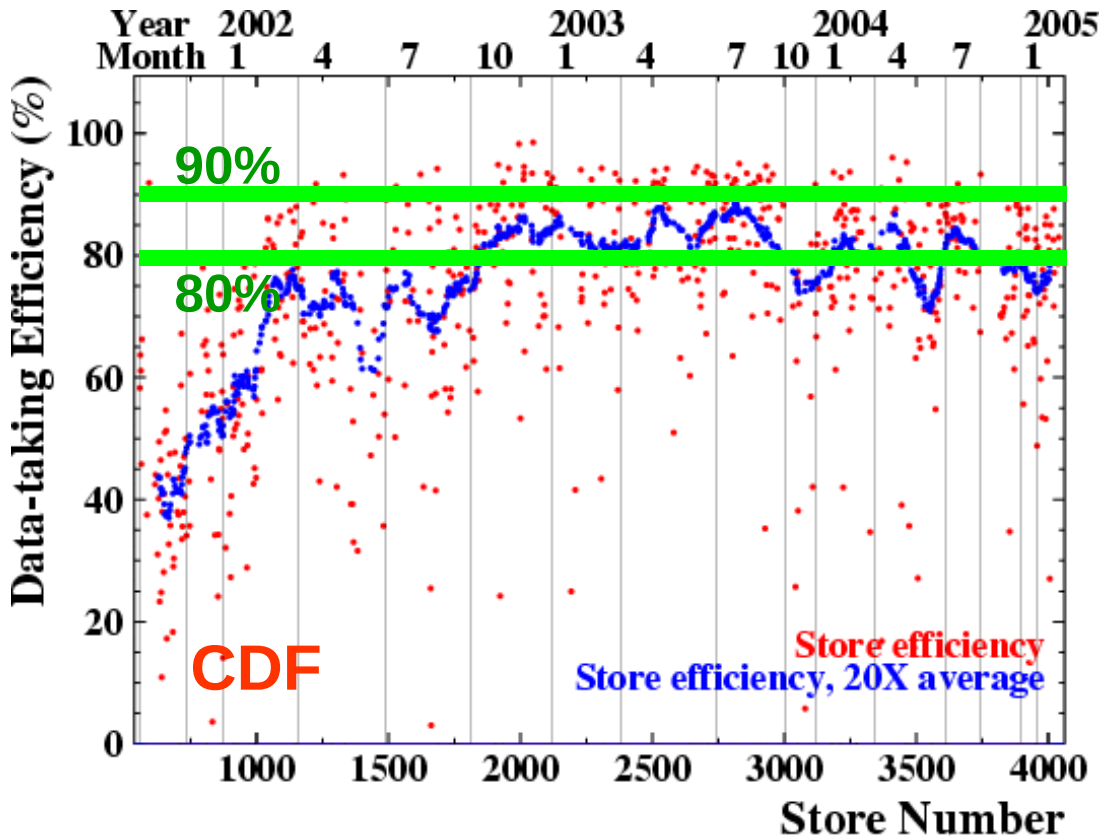

- trigger deadtime is typically 5% averaged over store
- beam-related issues also a major source of inefficiency
- myriad sub-detector, DAQ issues contribute remainder

CDF Central Tracker Aging

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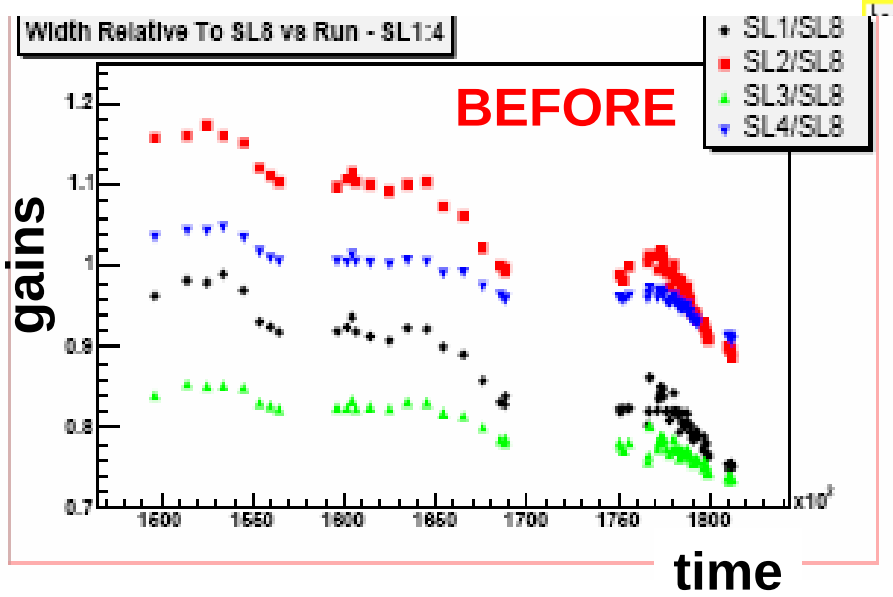

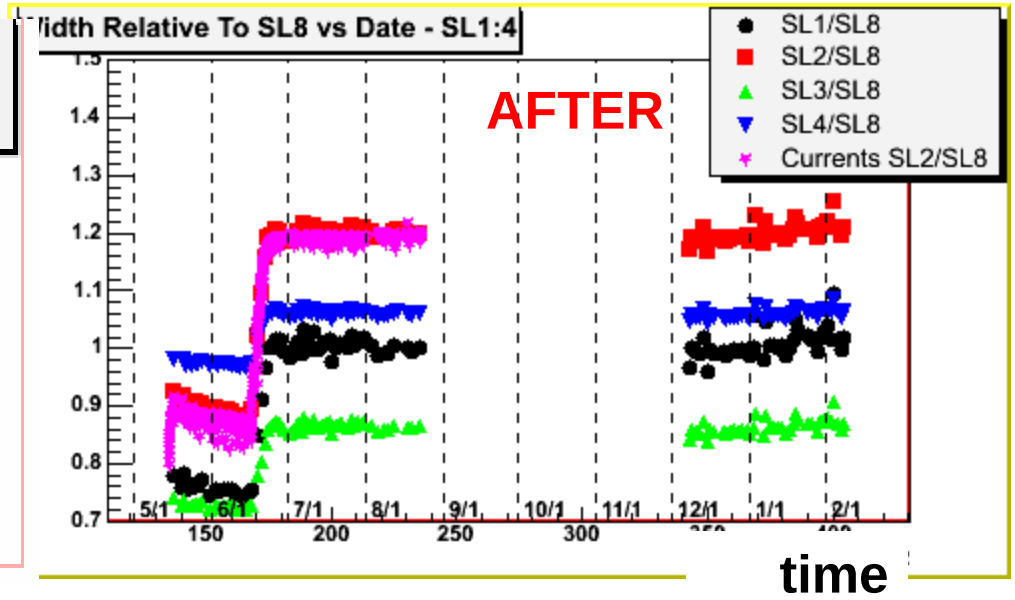

- At the time of the FY04 Review, CDF was experiencing significant aging (25% reduction in gain) in its Central Outer Tracker
- Substantially increased gas flow and added ~100 ppm of oxygen to the 50/50 Ar-Eth mixture to solve the problem. COT back to “as new” condition and gains are constant (ie. no sign of re-aging).

CDF Run2B Upgrades

- Pre-Shower Installed last shutdown (Sep-04)
- Pulsar (trigger upgrade) default L2 decision since start April-2005
- Upgraded COT TDC 25% installed (aim to finish prior to next shutdown, Sep-05)
- SVT, XFT, Event Builder in progress
  - *none* require collision hall access
  - Staged or parasitic commissioning plans in place to minimize “lost” data for these upgrades

CDF Maintenance

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- Keep the collaborations together and working effectively through FY09
  - LHC Physics Center (LPC) should help (13/63 FNAL staff split time between CDF/CMS)
  - Signed Memorandum of Understanding (MOU)
- Maintain and operate the detector subsystems for 5 additional years
- React to changing Beam Conditions
  - Losses from the beam instabilities
  - Increase in luminosity (from 1.2→2.8 E32)

CDF Computing

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- Production Farms
  - Can process 10^7 events/day
  - First pass processing done 1-2d after data taking
  - Have reprocessed ~0.5 x 10^9 events in 2 mos while simultaneously processing new data
  - Implementing plan to have final processing within 1 month of data-taking (saves $, simplifies operations, speeds physics)
- Analysis Farms
  - 5.5 THz available
  - ~45% from offsite farms around the world
  - Will grow with data volume

    (within constraints of budget and technology)

✓ **computing resources are/will not be major issue**

FNAL Operations Responsibilities

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- Line responsibility for CDF Safety
  - Flammable gas, cryogenics, solenoid, etc.
  - All (collision hall) access related training
- Line responsibility for CDF computing
  - Long term data storage
  - Offline software and re-processing
- CDF MOU responsibility for
  - Central Outer Tracker
  - Silicon Vertex Detector
  - Online Data Acquisition
  - Upgraded Level 2 Trigger

CDF Physics

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- All aspects of analysis are mature
- 14 Publications
  - 2003 : 3
  - 2004 : 4
  - 2005 : 7 (so far)
- 5 Accepted
- 8 Submitted

Another 31 are presently under internal review.

From these 27, FNAL significantly contributed (ie. we're internally listed as authors) to 10.

CDF Physics: Recent Highlights

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- World's Best Top Mass (better than world average)
  - Using 318/pb of data

$$M_t = 173.5^{+4.1}_{-4.0}\ \mathrm{GeV/c^2}$$

- First Preliminary B_s Mixing Result
  - Using semi-leptonic and fully-hadronic decays
  - Sensitivity: 8.4 ps^{-1}, Observed: 7.9 ps^{-1}
  - With ~2/fb: Sensitivity over full Standard Model (SM) range
- A slew of "World's Best" Results
  - B hadron masses, Branching Ratios, etc.
  - Top Quark cross-sections and properties
  - Limits on New Physic beyond the Standard Model

FNAL Physics on CDF

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- We're organized into 4 broad analysis groups
  - Main purpose is to provide guidance and technical support to the young scientists (i.e. Wilson Fellows, Associate Scientists, Research Associates)
  - Each WF, AS, RA is assigned an "advisor", whose job it is to help ensure this person succeeds in their next job search
  - These analysis groups meet 1/wk or more
  - FNAL group meets 1/mo to share progress and exchange thoughts/comments/suggestions

RA Track Record

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- Our RAs have done well

  2003
  - A.P.Colijn (Faculty Univ.Amsterdam)
  - M.Martinez (Faculty Univ.Barcelona)

  2004
  - M.Bishai (BNL Scientist – hired with tenure)
  - T.Nelson (SLAC - hired with tenure)
  - R.Erbacher (Faculty UCDavis)

  2005
  - P.Merkel (Res.Sci. Purdue Univ)
  - J.Thom (Faculty offers: UWash, UMinn, Cornell, Princeton)

Since 1993: 4/24 still with us, 18/20 took tenure track positions in the field!

FNAL Physics on CDF: Highlights

- Recently Publish, Accepted or Submitted
  - W and Z Cross-sections
  - Dilepton Top Quark Cross-section
  - Kinematic Top Quark Cross-section
  - J/Psi and B-Hadron Cross-sections
  - Search for Anomalous Diphoton+MET Events
- Manuscripts in Preparation
  - Precision Determination of the Top Quark Mass
  - Search for Φ^{--}, Φ^{0} Penta-quarks
  - Search for High Mass Dilepton Pairs
  - Search for the Rare $B_{s(d)} \rightarrow \mu^+\mu^-$ Decays
- Work in Progress
  - Improved Sensitivity to Supersymmetry

FNAL Physics on CDF: Highlights

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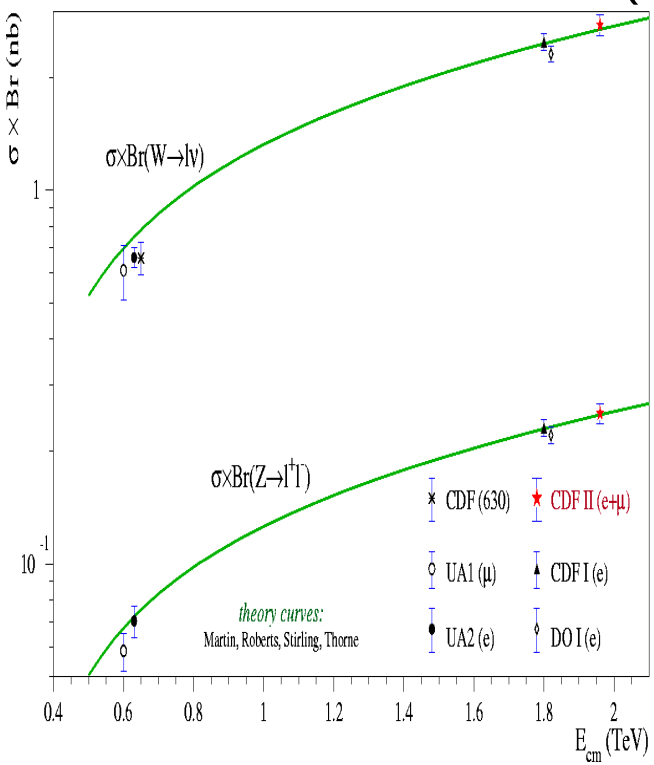
σ(W) and σ(Z) using e and μ Decays (72/pb)

Accepted by PRL (2005).

(E.James, P.Murat)



Why?

- ✓ **W&Z are "standard candles"**
- ✓ **infer (world's best) Γ(W)**
- ✓ **test e-μ universality**

Experimental Signature

- ✓ **Z: 2 high energy leptons**
- ✓ **W: 1 high energy lepton**
  + large missing E_T (from ν)
- ✓ **high purity (>90%) samples**

FNAL Physics on CDF: Highlights

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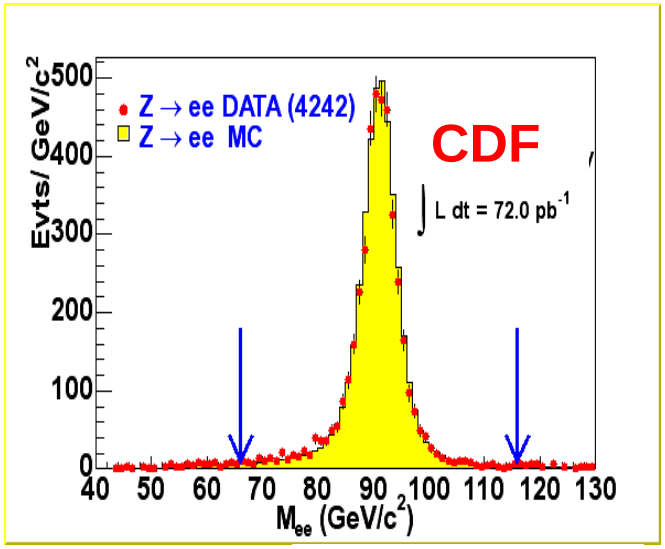

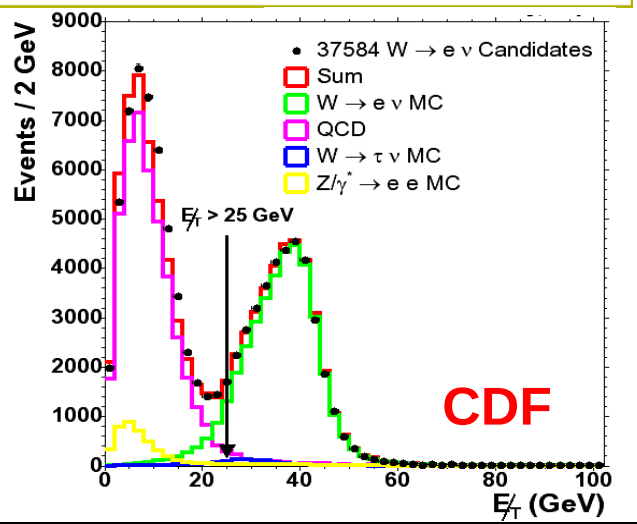

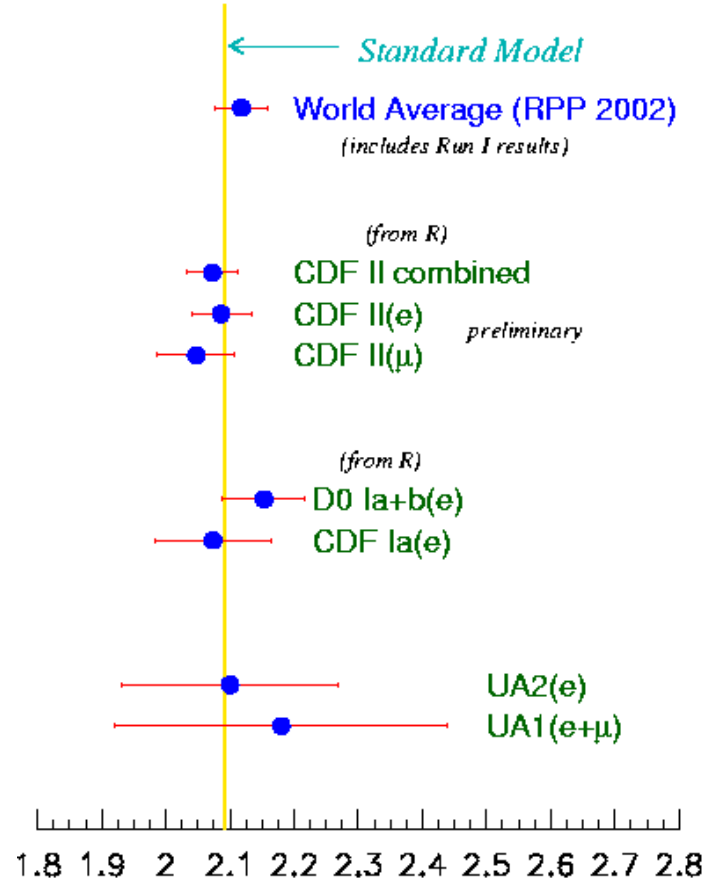

Γ(W) from indirect constraints (GeV)

FNAL Physics on CDF: Highlights

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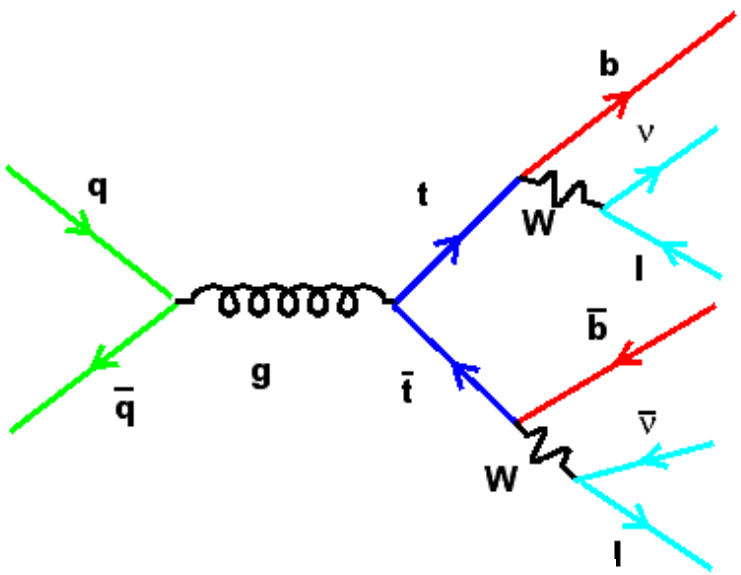
σ(tt) using the Dilepton Final State (200/pb)

PRL 93, 142001 (2004)

(A.Hocker, P.Merkel, J.Thom, A.Yagil)



BR = 11%, good S/B

Why?

- ✓ **confirm SM production & decay**

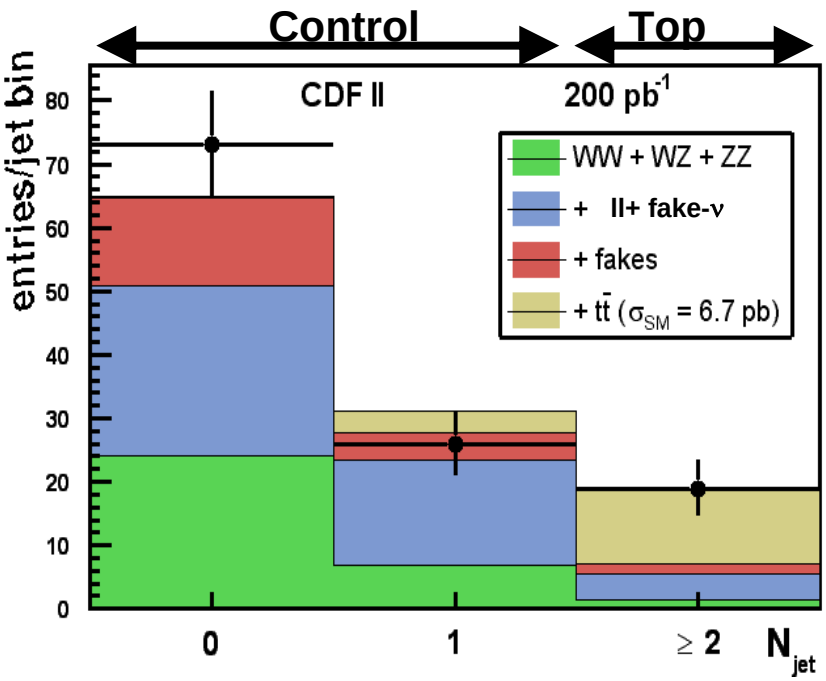
Experimental Signature

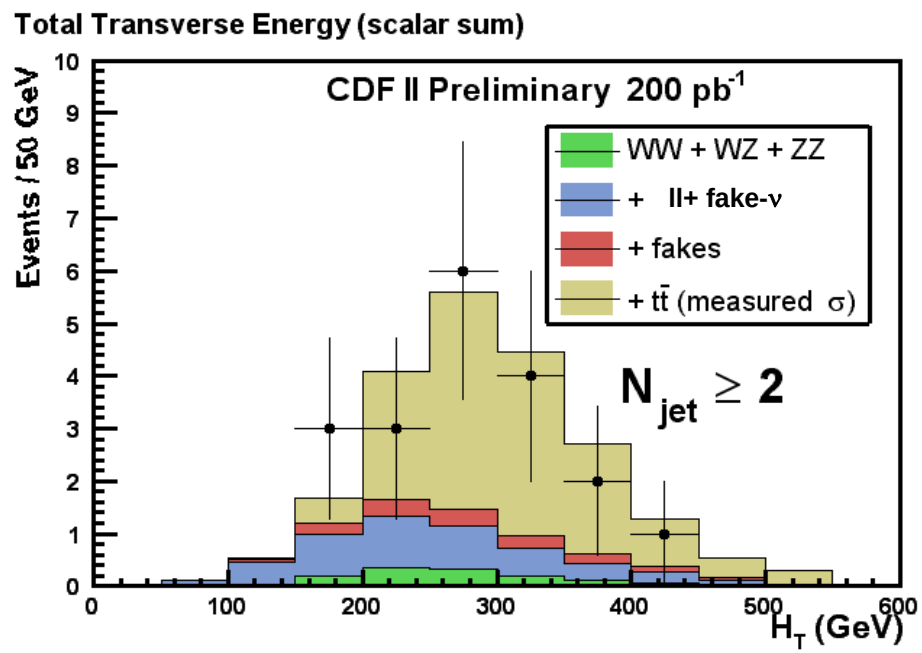
- ✓ **2 high energy leptons**
- ✓ **large missing E_T (from ν)**
- ✓ **2 high energy jets**
- ✓ **improve with novel selection**

Backgrounds

- ✓ **WW, WZ, ZZ**
- ✓ **pp→dilepton + fake-ν**
- ✓ **fake-lepton(s)+fake-ν**

FNAL Physics on CDF: Highlights





$$\sigma(t\bar{t}) = 6.9^{+2.7}_{-2.4} \pm 1.3 \text{ pb}$$

(stat) (syst)

- **cross-section and kinematics consistent w/ SM**

FNAL Physics on CDF: Highlights

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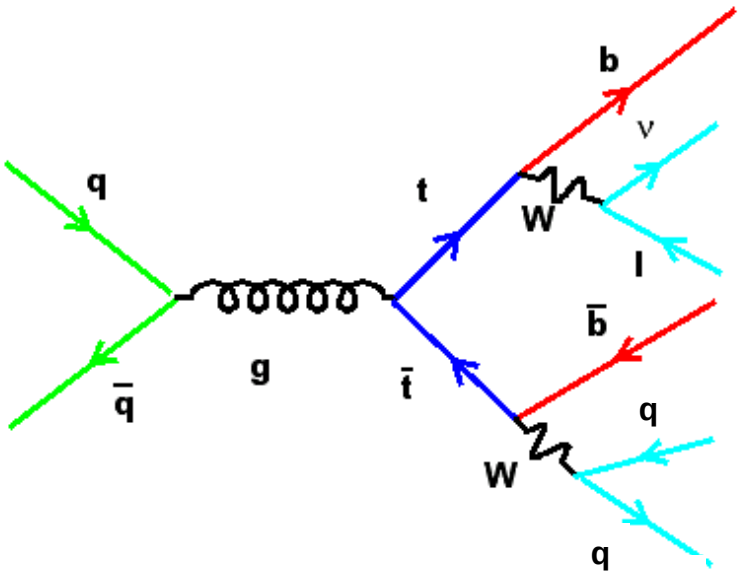
σ(tt) using the Lepton+Jets Final State (200/pb)

Accepted PRD (2005).

(R.Erbacher, R.Marginean, R.Roser)



BR = 30%, use kinematics to improve S/B

Why?

- ✓ **confirm SM production & decay**

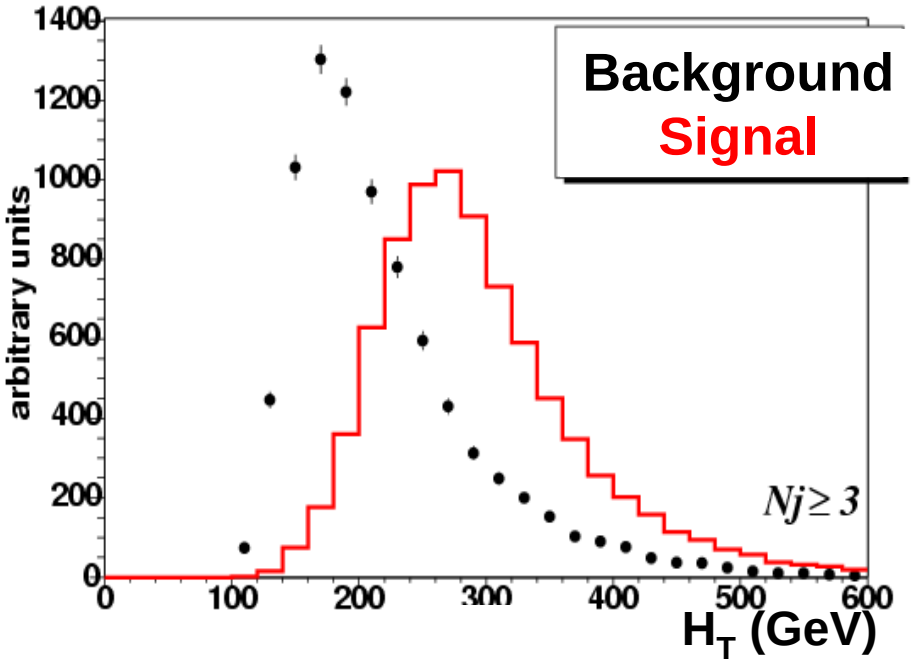
Experimental Signature

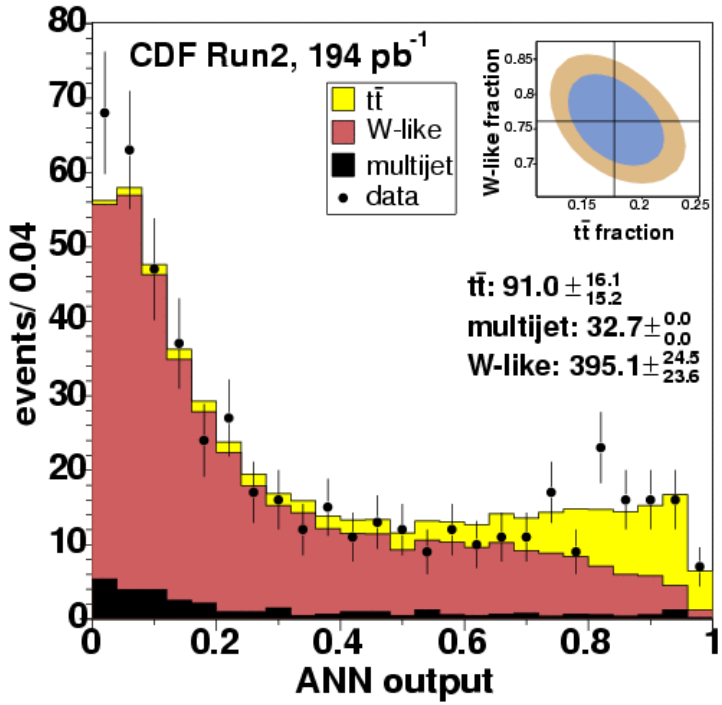
- ✓ **1 high energy leptons**
- ✓ **large missing E_T (from ν)**
- ✓ **4 high energy jets**

Backgrounds

- ✓ **W+jets**
- ✓ **Jets+fake-lepton+fake-ν**
- ✓ **novel technique to improve S/B**

FNAL Physics on CDF: Highlights





$$\sigma(t\bar{t}) = 6.6 \pm \underset{\text{(stat)}}{1.1} \pm \underset{\text{(syst)}}{1.5} \text{ pb}$$

- **total uncertainty same as "traditional" B-tag method**

FNAL Physics on CDF: Highlights

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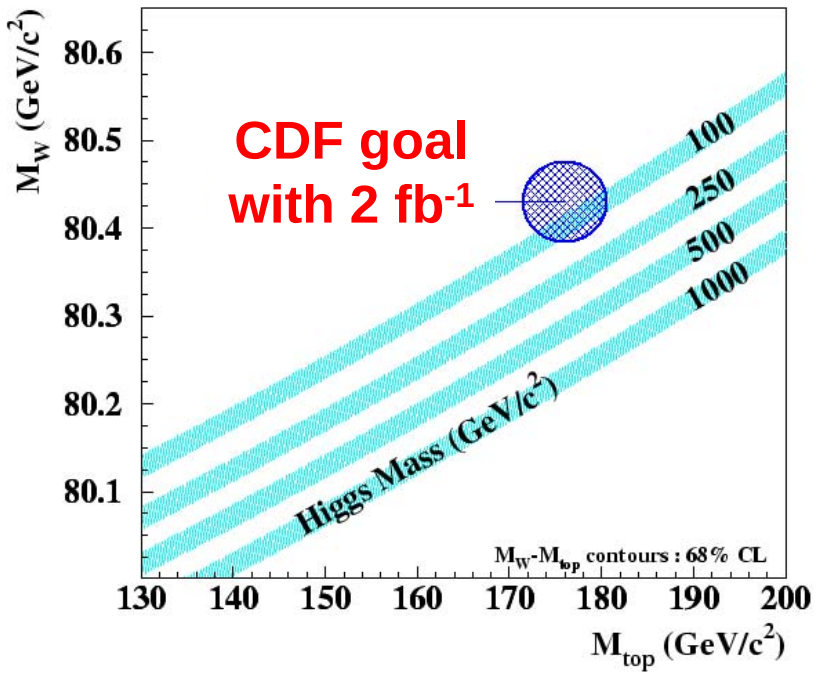
Determining the Top Quark Mass (320/pb)

Manuscript in preparation

(D.Ambrose, G.Velev, D.Glenzinski)



Why?

- ✓ **Mt important SM parameter**
- ✓ **Mt+Mw constrain Higgs mass in Standard Model**

Experimental Signature

- ✓ **use Lepton+Jets Channel**
- ✓ **also DiLepton Channel**
- ✓ **very challenging**

FNAL Physics on CDF: Highlights

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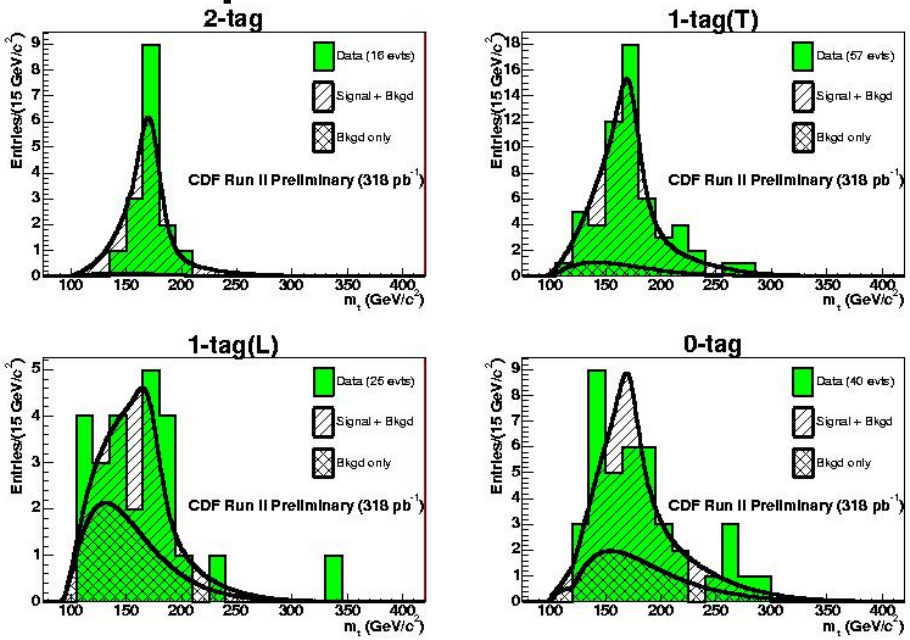
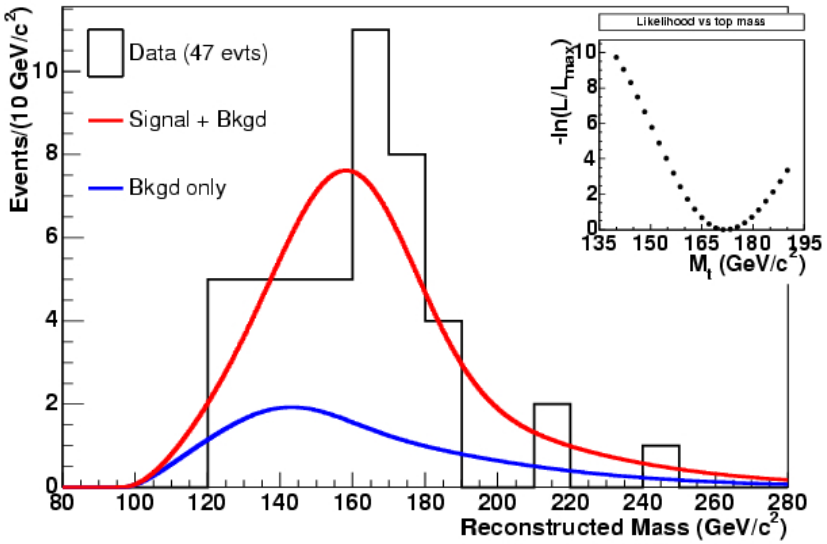
Lepton + Jets Channel



$$M_t = 173.5^{+4.1}_{-4.0}\ \mathrm{GeV/c^2}$$

DiLepton Channel



$$M_t = 171.9^{+7.8}_{-8.0}\ \mathrm{GeV/c^2}$$

- ✓ **The two channels are consistent**
- ✓ **Lepton+Jets alone is better than world average**

FNAL Physics on CDF: Highlights

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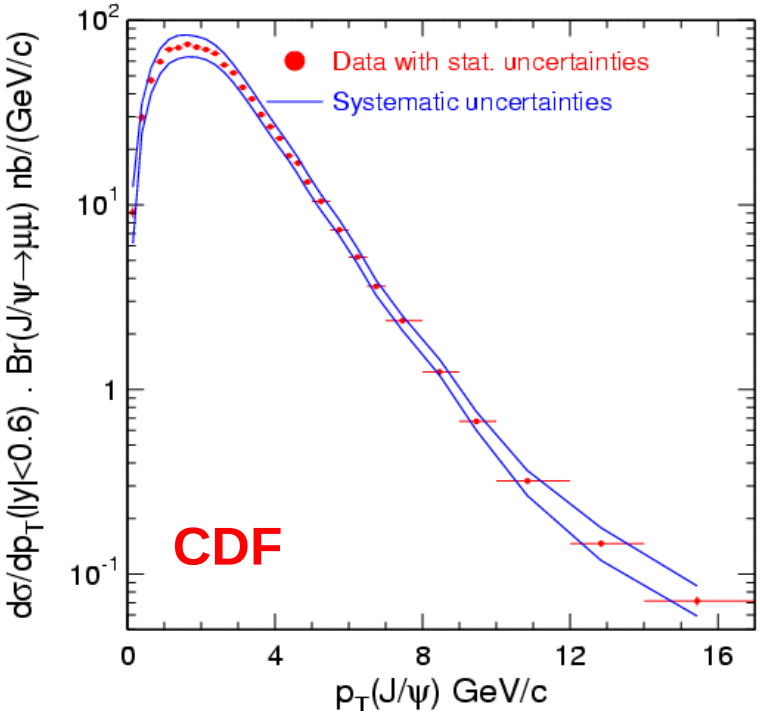
$\sigma(J/\Psi)$ and the Inclusive $\sigma(B)$ (40/pb)

PRD 71, 032001 (2005).

(M.Bishai, J.Lewis, T.Miao, S.Tkaczyk)



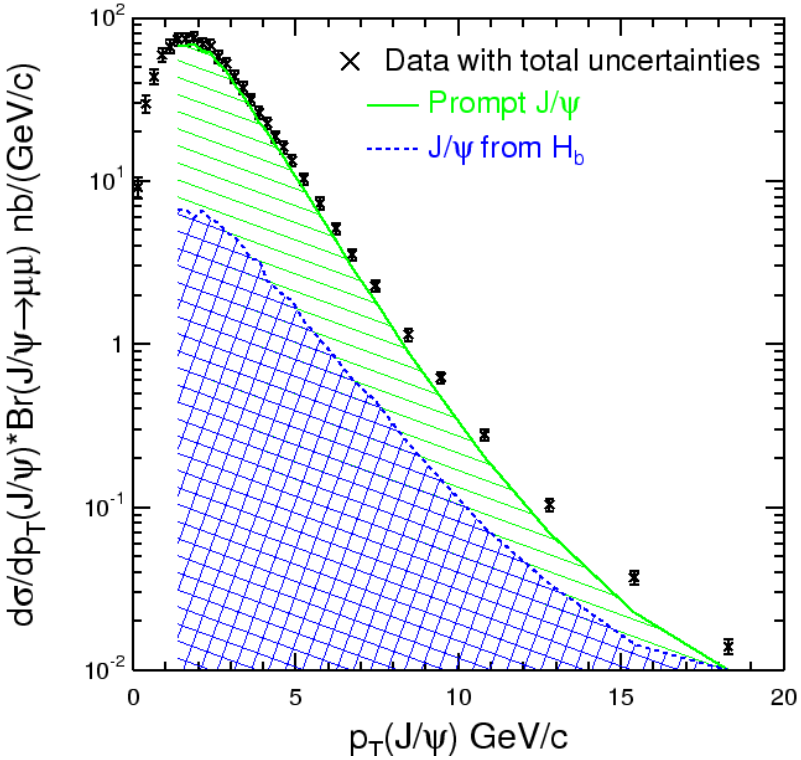
Why?

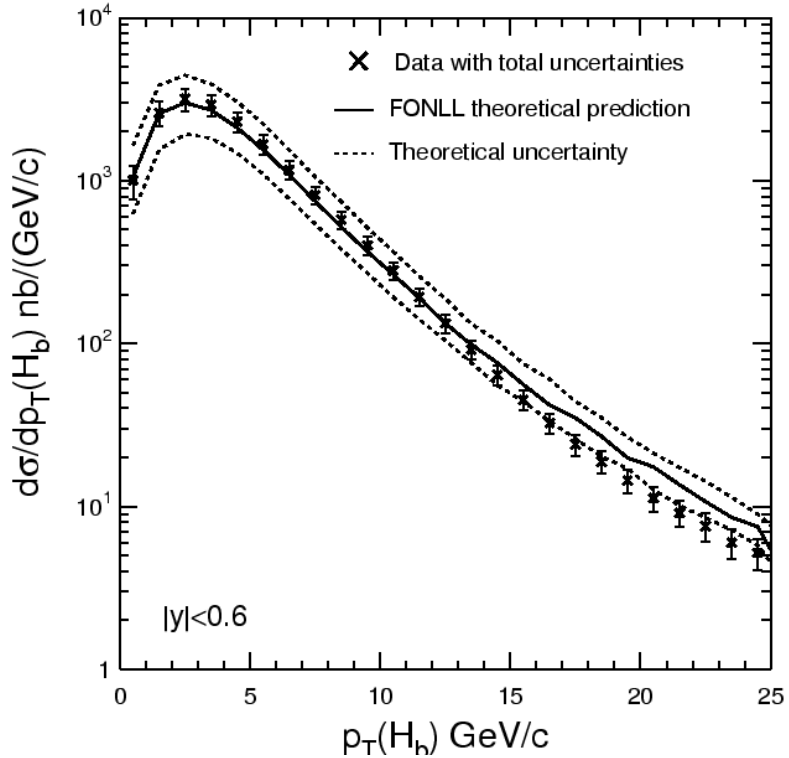
- ✓ **measure full $d\sigma(J/\Psi)/dp_T$**
- ✓ **some J/Ψ are from long-lived B-hadrons… so can infer $\sigma(B)$ using "lifetime"**

Experimental Signature

- ✓ **2 muons ($J/\Psi \rightarrow \mu^+\mu^-$)**
- ✓ **high purity (>90%)**
- ✓ **exploits Run2 trigger**

FNAL Physics on CDF: Highlights





- ✓ **nice agreement with Theory over full pT range**
- ✓ **first σ(B) cross-section measurement of Run2**

FNAL Physics on CDF: Highlights

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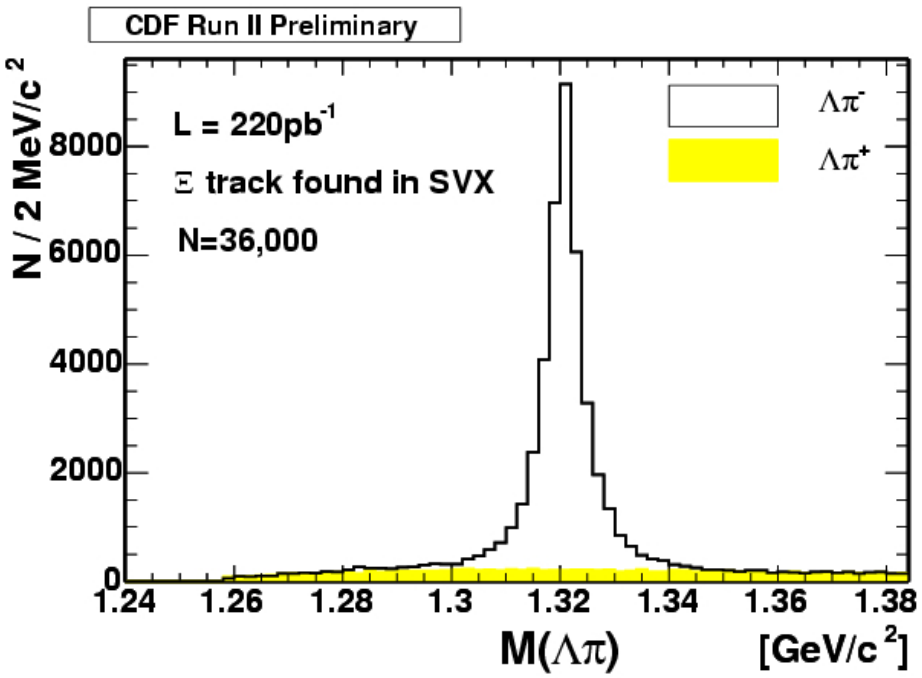
Search for S=-2 Pentaquarks (220/pb)

Manuscript in preparation.

(D.Litvintsev, P.Lukens)



(cf. NA49 has 2000 $\Xi^- \rightarrow \Lambda\pi^-$)

Why?

- ✓ **S=+1 Pentaquarks observed**
- ✓ **S=-2 should exist**
- ✓ **NA49 claims to see it**

Experimental Signature

- ✓ $\Phi \rightarrow \Xi^-\pi \rightarrow \Lambda\pi^-\pi \rightarrow p\pi^-\pi^-\pi$
- ✓ **normalize to Ξ(1530)**
- ✓ **exploits Run2 SVT trigger**
- ✓ **employs novel SVX tracking**

FNAL Physics on CDF: Highlights

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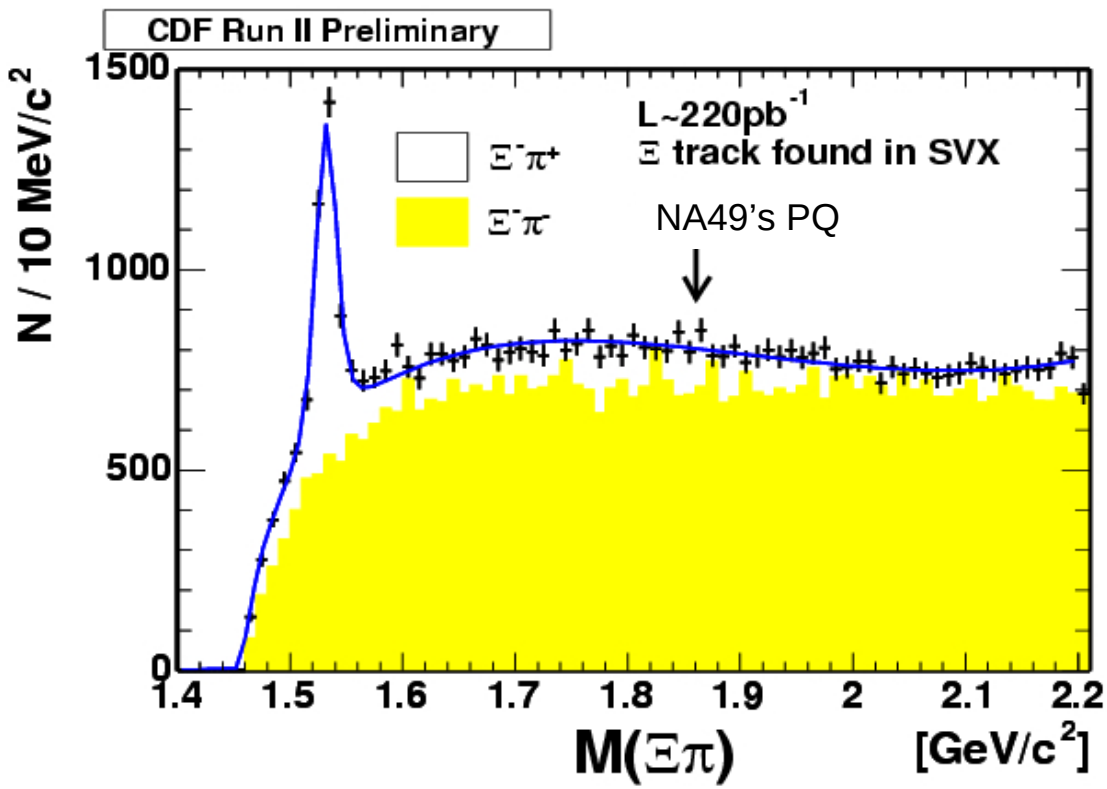

- ✓ **no evidence of S=-2 PQ in wide mass range**
- ✓ **yields stringent limits on $\sigma(\Phi)$ relative to $\sigma(\Xi(1530))$**

FNAL Physics on CDF: Highlights

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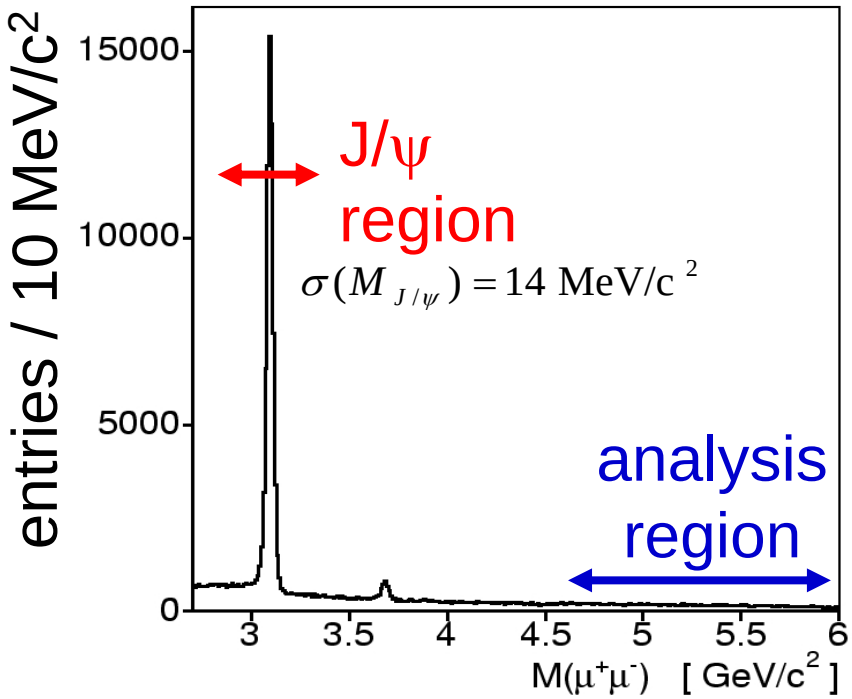
Search $B_{s(d)} \rightarrow \mu^+\mu^-$ Decays
PRL 93, 032001 (2004) (171/pb)
New manuscript in preparation (364/pb)
(D.Glenzinski, C.-J.Lin)



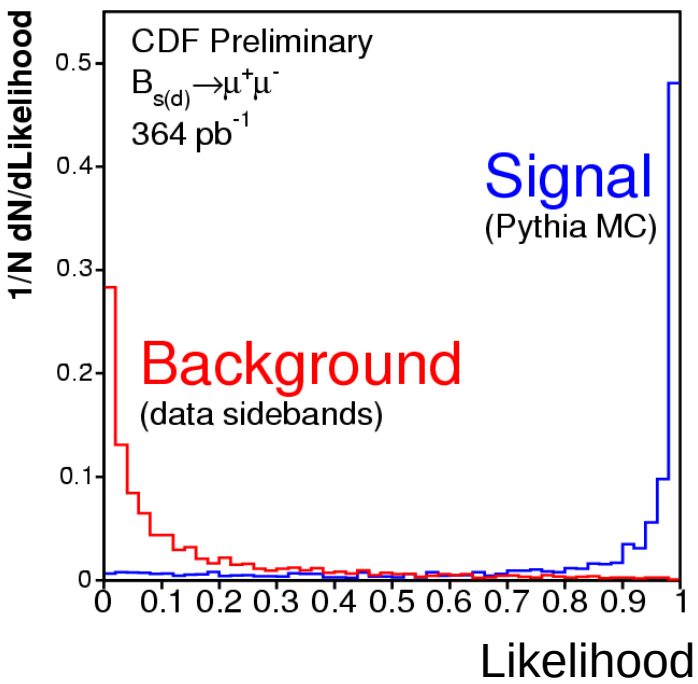
Why?

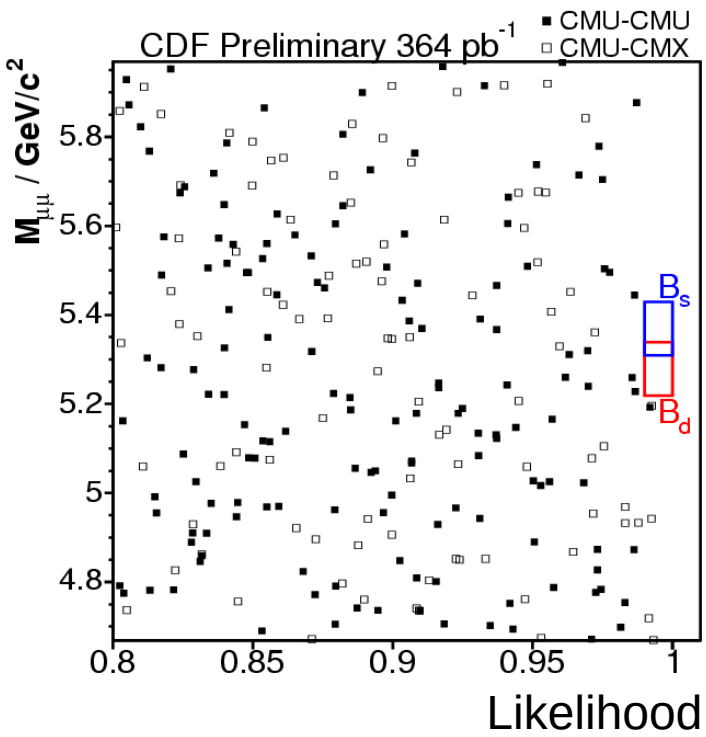
- ✓ **SM Branching Ratio very small**
- ✓ **An observation is unambiguous evidence of New Physics**

Experimental Signature

- ✓ **2 muons ($B_s \rightarrow \mu^+\mu^-$)**
- ✓ **normalize to $B^+ \rightarrow J/\Psi K^+ \rightarrow \mu^+\mu^- K^+$**
- ✓ **HUGE background**
- ✓ **employ new multivariate discriminant to improve sensitivity**

FNAL Physics on CDF: Highlights





At 90% CL

$$BR(B_s \to \mu^+\mu^-) < 1.5\times10^{-7}$$

$$BR(B_d \to \mu^+\mu^-) < 3.8\times10^{-8}$$

- ✓ **Factor of 3 better than our PRL**
- ✓ **World's Best B_s limit (D0: 4.1E-7, 240/pb)**
- ✓ **World's Best B_d limit (BaBar: 8.3E-8, 111/fb)**

FNAL Physics on CDF: Highlights

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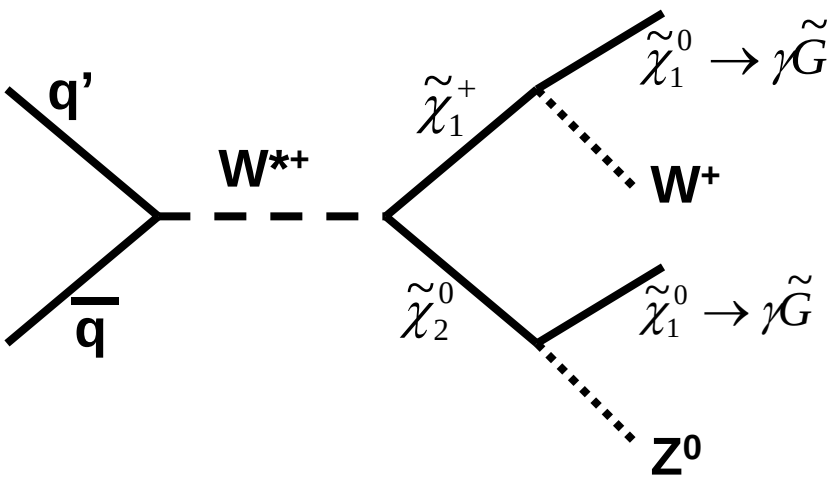
Search for Anomalous $\gamma\gamma$+Missing E_T

PRD 71, 031104 (2005).

(R.Culbertson)



Why?

- ✓ **Sensitive to "Gauge Mediated" SuperSymmetry Models**
- ✓ **Run1 Hoopla: ee$\gamma\gamma\not{E}_T$ datum**

Experimental Signature

- ✓ **2 photons**
- ✓ **large missing E_T (from SuperSymmetric $\tilde{G}$)**

FNAL Physics on CDF: Highlights

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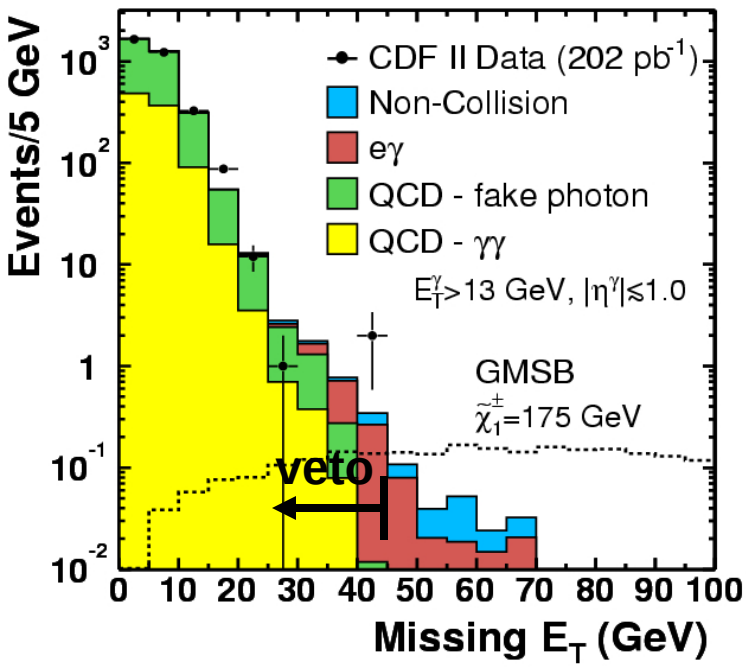

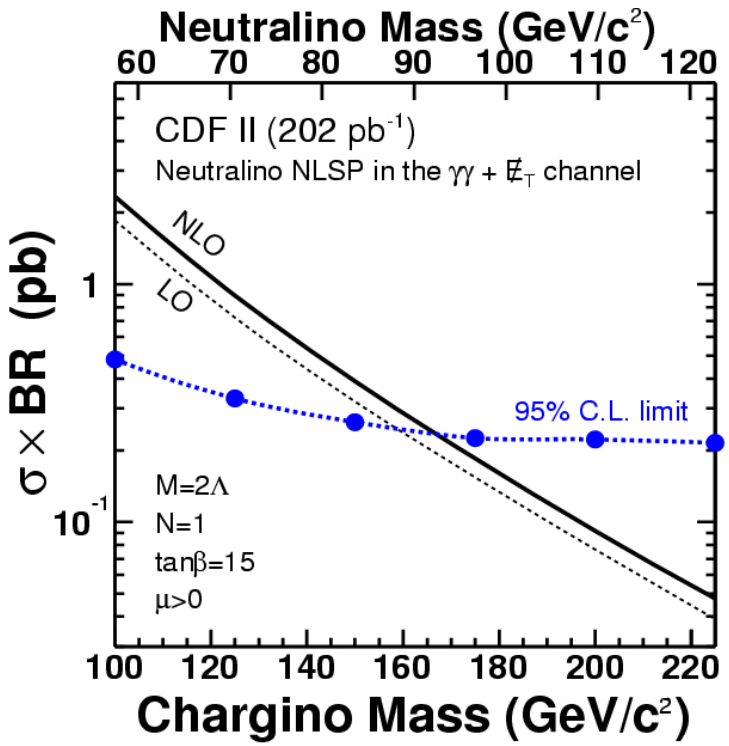

At 95% CL

$$M(\tilde{\chi}_1^+) > 167\,\mathrm{GeV}/c^2$$

$$M(\tilde{\chi}_1^0) > 93\,\mathrm{GeV}/c^2$$

✓ **Competitive with LEP2**

✓ **Will improve with more data**

FNAL Physics on CDF: Highlights

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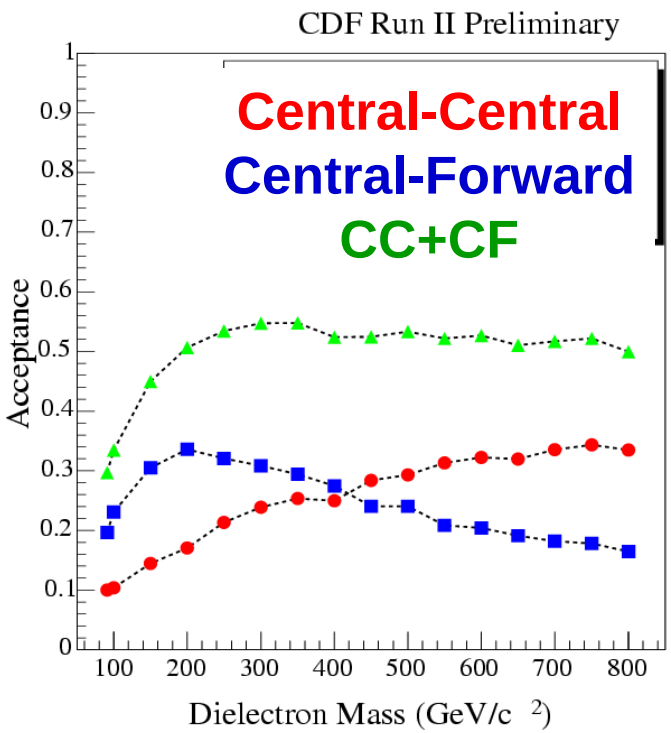
Search for High Mass DiLepton Events

Manuscript in preparation.

(K.Maeshima, T.Nelson)



Why?

- ✓ **Sensitive to many different types of New Physics**

Experimental Signature

- ✓ **2 high energy leptons (e or μ)**
- ✓ **form their invariant mass M_{l+l-}**
- ✓ **employ novel "forward" tracking to improve sensitivity**

FNAL Physics on CDF: Highlights

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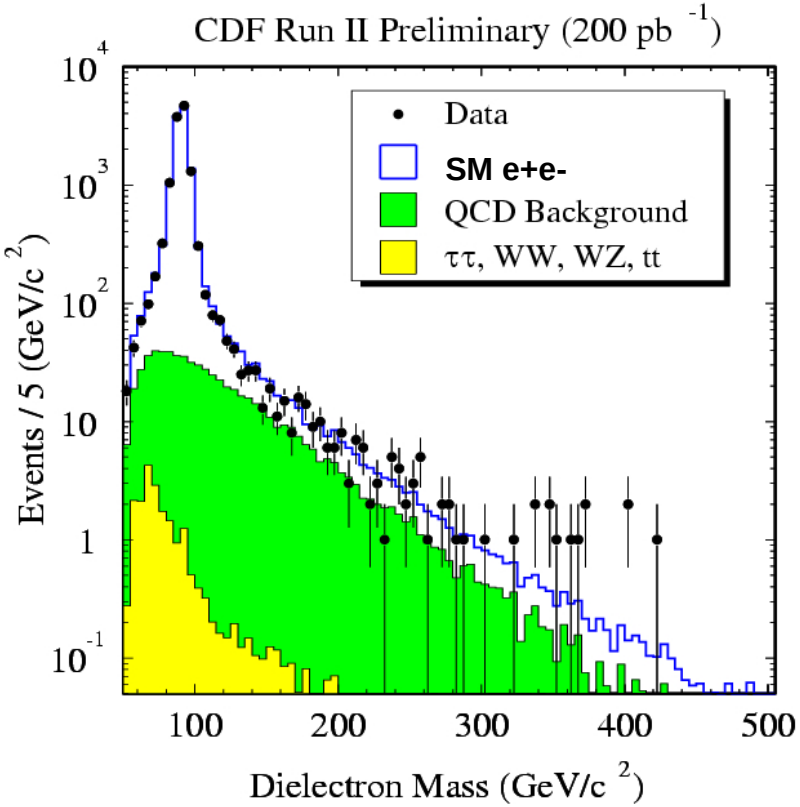

Lower Limits at 95% CL

$M(\tilde{\nu}) > 730\ \mathrm{GeV/c^2}$	**spin 0**
$M(Z'_{SM}) > 835\ \mathrm{GeV/c^2}$	
$M(Z'_{\psi}) > 690\ \mathrm{GeV/c^2}$	
$M(Z'_{\eta}) > 720\ \mathrm{GeV/c^2}$	**spin 1**
$M(Z'_{\chi}) > 675\ \mathrm{GeV/c^2}$	
$M(Z'_{I}) > 615\ \mathrm{GeV/c^2}$	
$M(G_{RS}) > 710\ \mathrm{GeV/c^2}$	**spin 2**

✓ **Stringent Limits on wide variety of Models**

✓ **Will improve with more data**

FNAL Physics on CDF: Highlights

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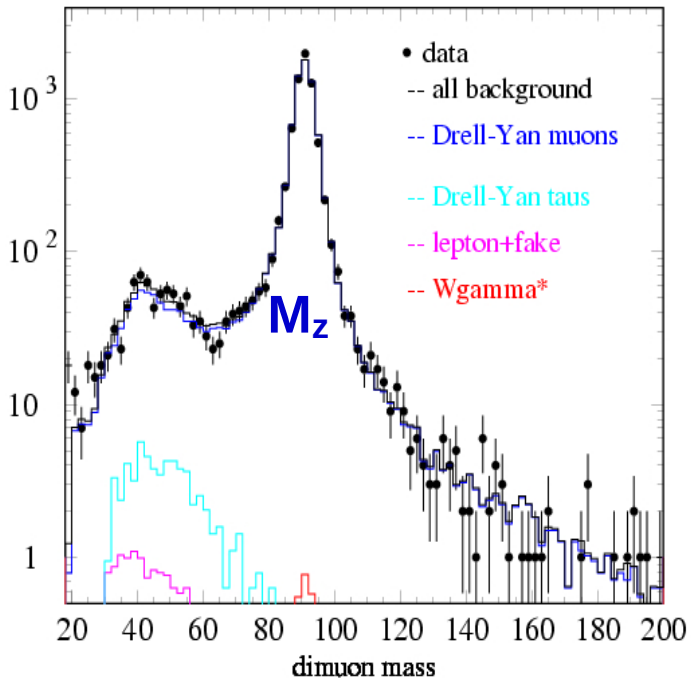
Search for SuperSymmetry using Sliding q_T Ratio

Work in Progress.

(J.Nachtman)



Why?

- ✓ **Sensitive to many different types of New Physics**
- ✓ **novel technique to improve sensitivity**

Experimental Signature

- ✓ **2 high energy leptons (e or μ)**
- ✓ **form their invariant mass M_{l+l-}**
- ✓ **calculate their sum $p_T = q_T$**
- ✓ **use well know $M_{l+l-}=M_Z$ to normalize q_T distribution**

FNAL Physics on CDF: Highlights

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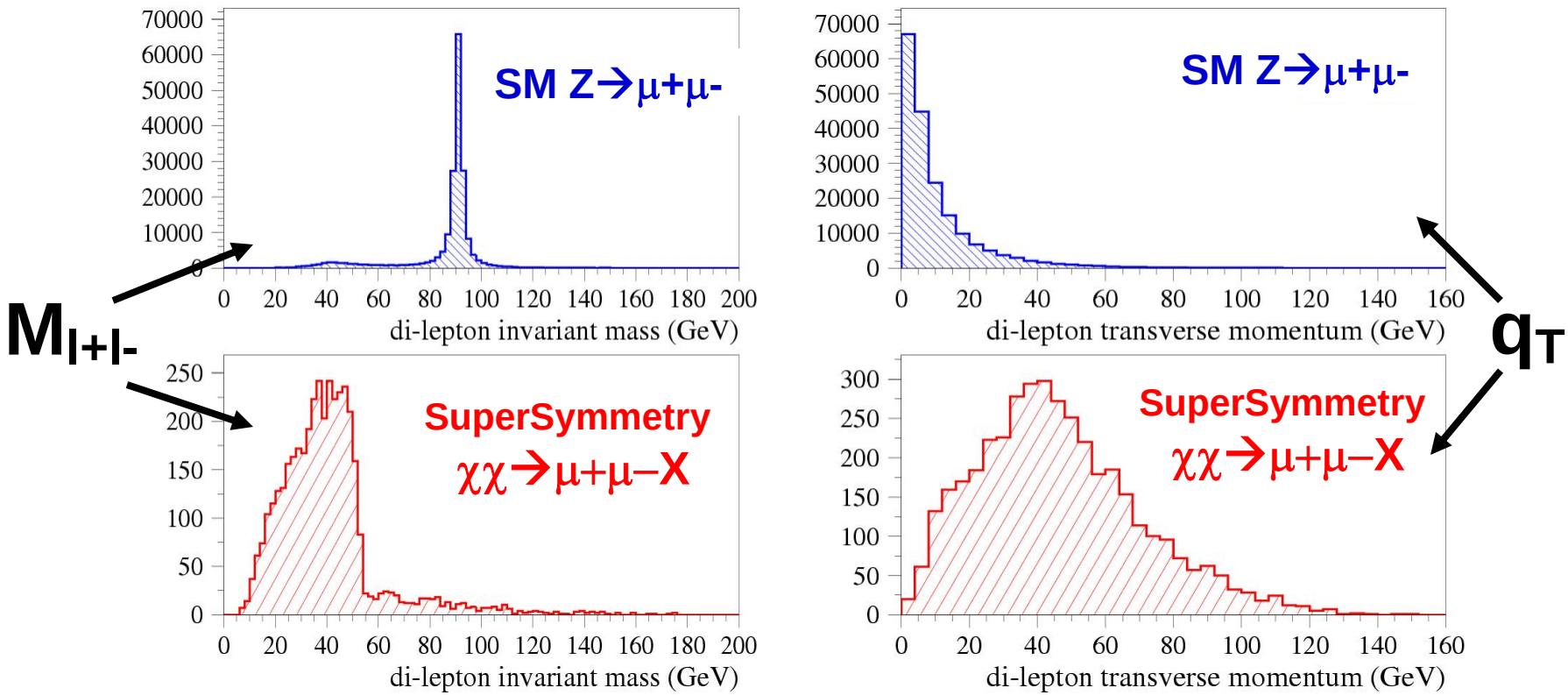

- ✓ **Sensitivity only using μ+μ- competitive with "traditional" methods**
  - ✓ **Will improve with addition of e+e- channel**

Conclusions

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- FNAL contributes 63/650 authors to CDF
- CDF so far has 27 papers (published+accepted+submitted) – FNAL authored 10 of them
  - FNAL CDF analysis groups proving very productive
  - Have been very successful in placing our post-docs
- CDF regularly taking data with high efficiency
  - Maintenance and coping with the increasing luminosity are the principal challenges facing CDF
- CDF analysis in full swing
  - Producing world class results
  - Looking forward to analysis with ~1/fb of data by year's end!