IKTP-Institutsseminar
Technische Universität Dresden
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Search for Flavor Changing Neutral Currents in Top Quark Decays at CDF

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Outline of the Talk

What are Flavor Changing Neutral Currents?

The CDF Experiment at the Tevatron

Top Quark Physics at CDF

Search for FCNC in Top Quark Decays

Summary & Conclusions

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- The CDF Experiment at the Tevatron
- Top Quark Physics at CDF
- Search for FCNC in Top Quark Decays
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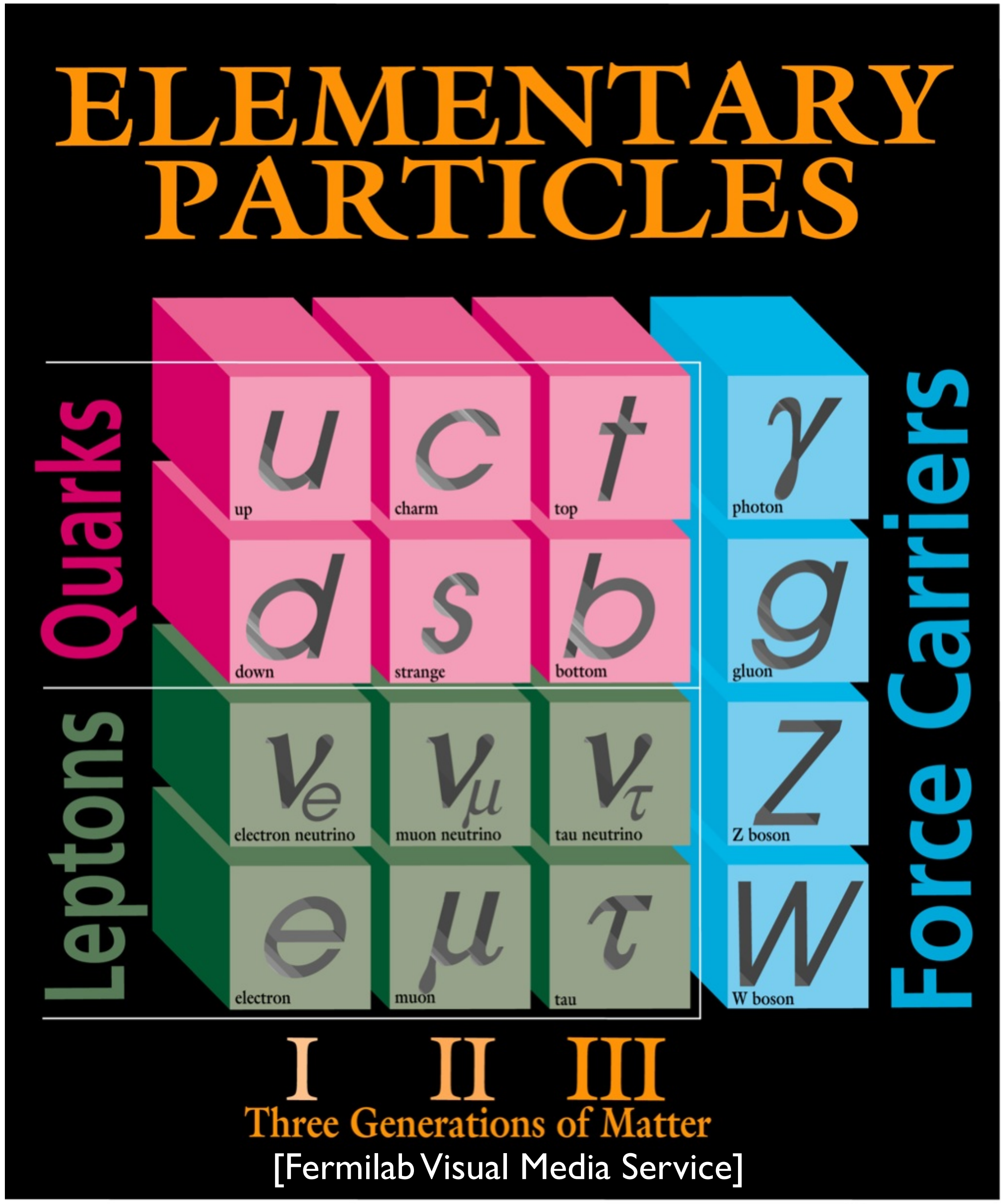
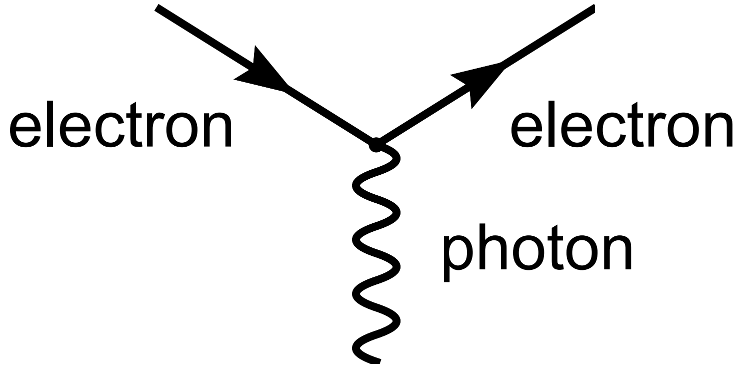
Standard Model of Particle Physics



Fermilab 95-759

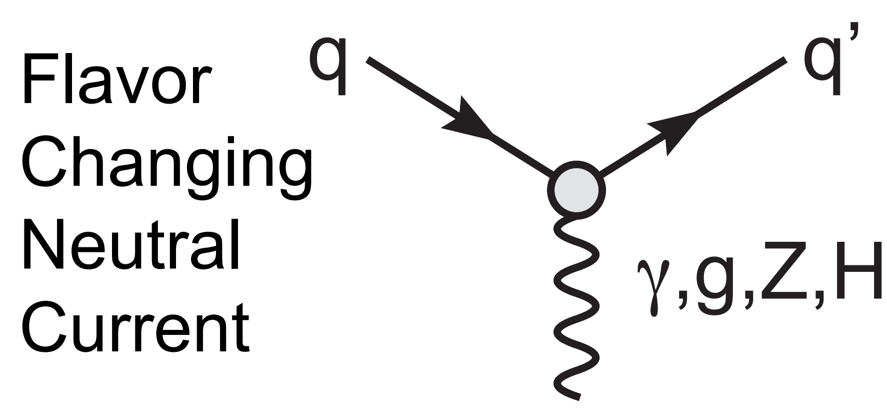
- Matter in the standard model: 12 fermions in three generations
  - Six quarks and their anti-particles
  - Six leptons and their anti-particles
- Forces in the standard model:
  - Strong force (carrier: gluon)
  - Electroweak force (carriers: photon, $W^\pm$ bosons, Z boson)
- Interactions = "currents" coupling to gauge bosons, e.g. electromagnetic current



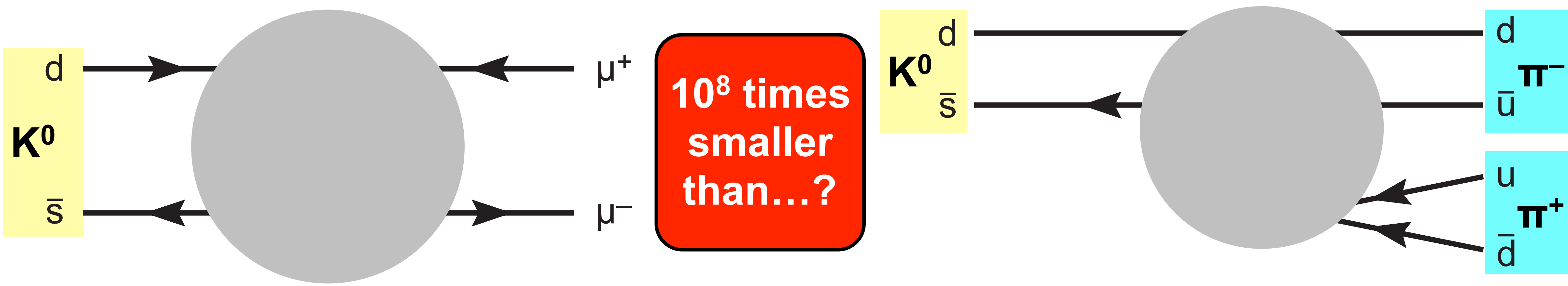
$$\mathscr{L}^{\text{em}} = -q\,\bar{e}\gamma_\mu e A^\mu \equiv j_\mu^{\text{em}} A^\mu$$

Flavor Changing Neutral Currents

- Flavor changing neutral current (FCNC):
  - Transition: from a quark q of flavor A and charge Q to quark q' of flavor B with the same charge Q
  - Examples: $b \to s\gamma$, $t \to cH$, …



- 1960s: only three light quarks (u,d,s) known, mystery in neutral kaon system:



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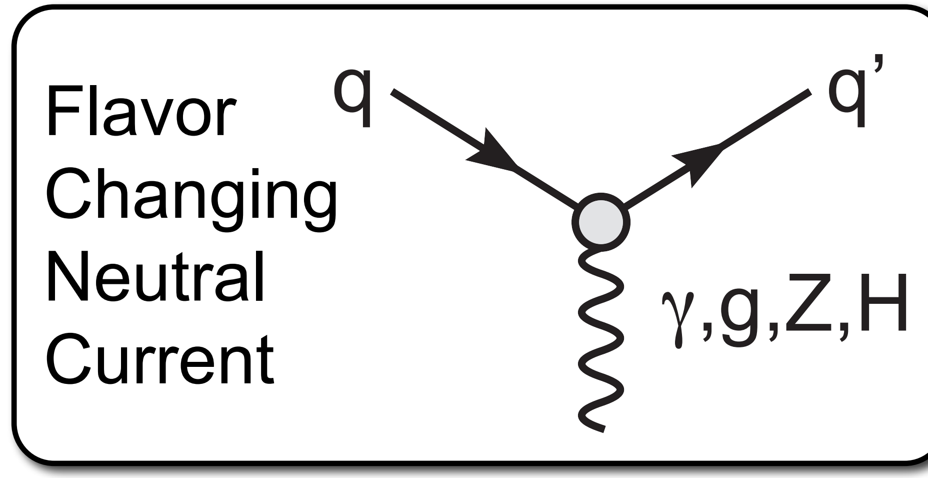

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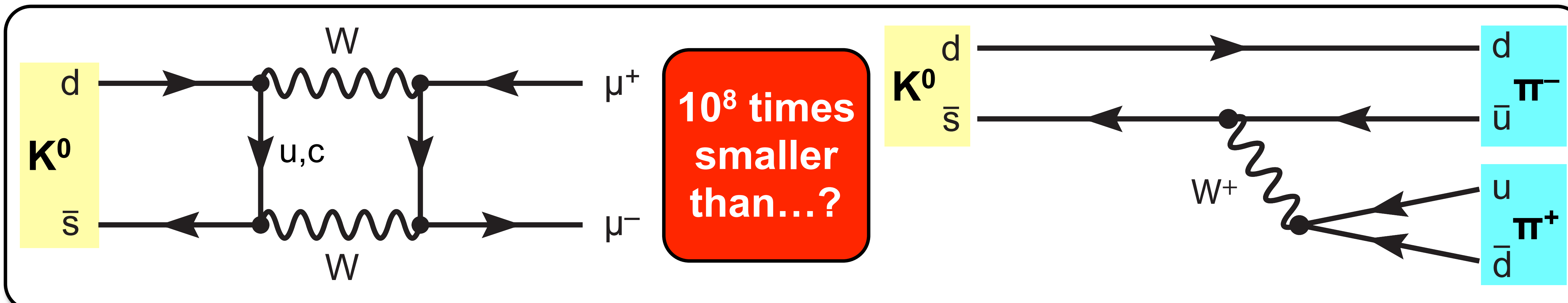
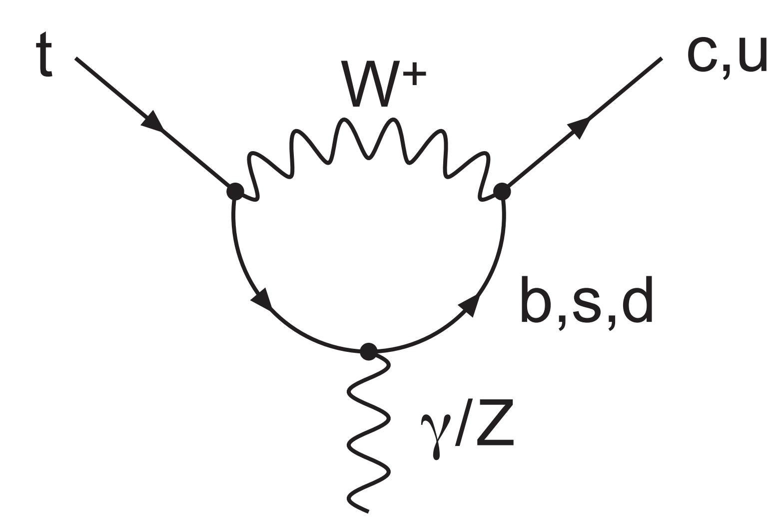


- Solution: "GIM Mechanism" (Glashow, Iliopoulos, Maiani, 1970)
  - Fourth quark needed for cancellation in box diagram: prediction of charm quark
  - Cancellation exact if all quarks had the same mass: estimate of charm quark mass

Top FCNC & New Physics

- Top FCNC not at tree level, only in higher orders → very rare in SM: $B(t \to Zq) \approx 10^{-14}$ (q=u,c)
- Top FCNC enhanced in many models of physics beyond the SM → signal at CDF = new physics
- Enhancement mechanisms:
  - FCNC interactions at tree level
  - Weaker GIM cancellation by new particles in loop corrections
- Examples:
  - New quark singlets: Z couplings not flavor-diagonal → tree level FCNC
  - Two Higgs doublet models
  - Supersymmetry: gluino/neutralino and squark in loop corrections

Penguin Diagram



Model	$\mathbf{BR}(t \to Zq)$
Standard Model	$\mathcal{O}(10^{-14})$
$q = 2/3$ Quark Singlet	$\mathcal{O}(10^{-4})$
Two Higgs Doublets	$\mathcal{O}(10^{-7})$
MSSM	$\mathcal{O}(10^{-6})$
R-Parity violating SUSY	$\mathcal{O}(10^{-5})$

[after J.A. Aguilar-Saavedra, Acta Phys. Polon. **B35** (2004) 2695]

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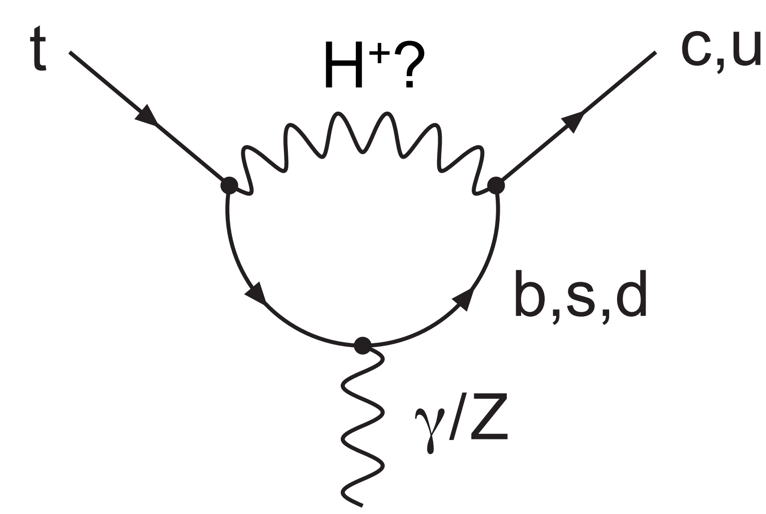

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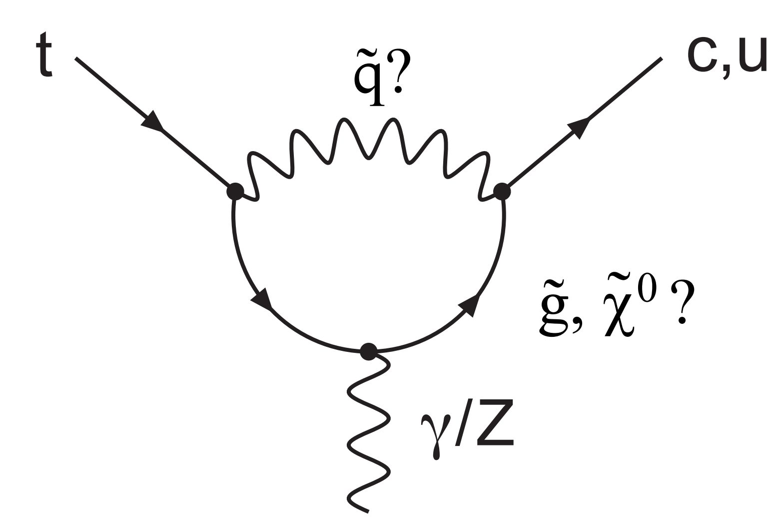

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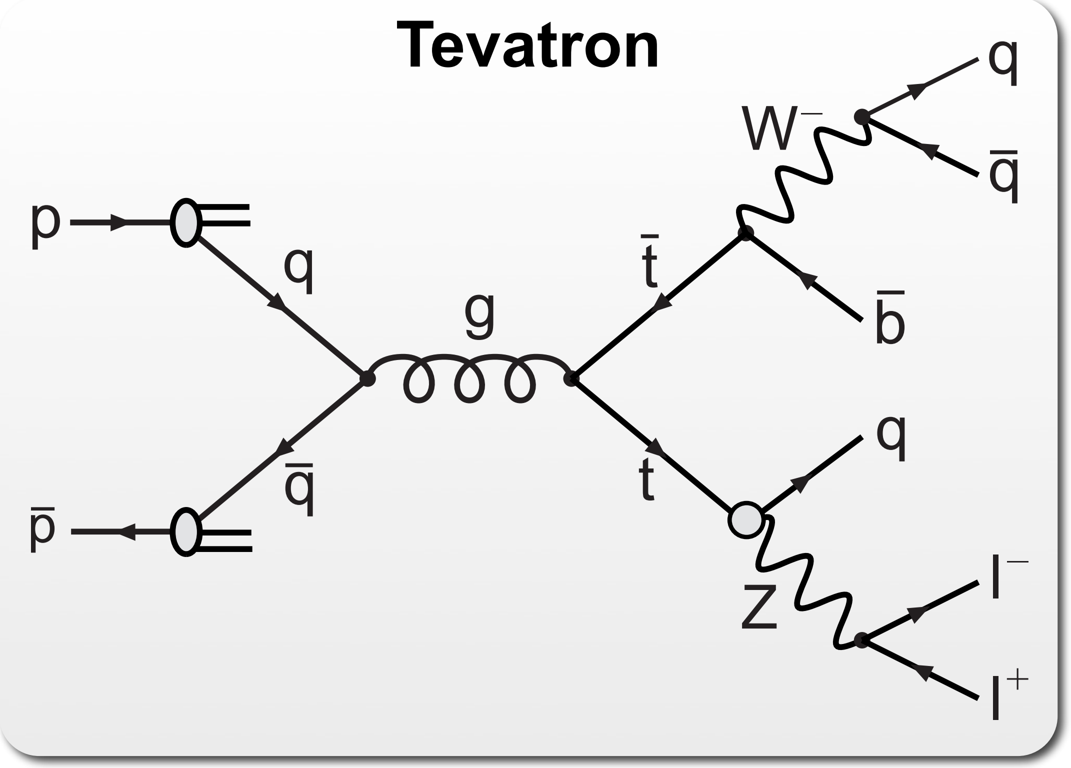
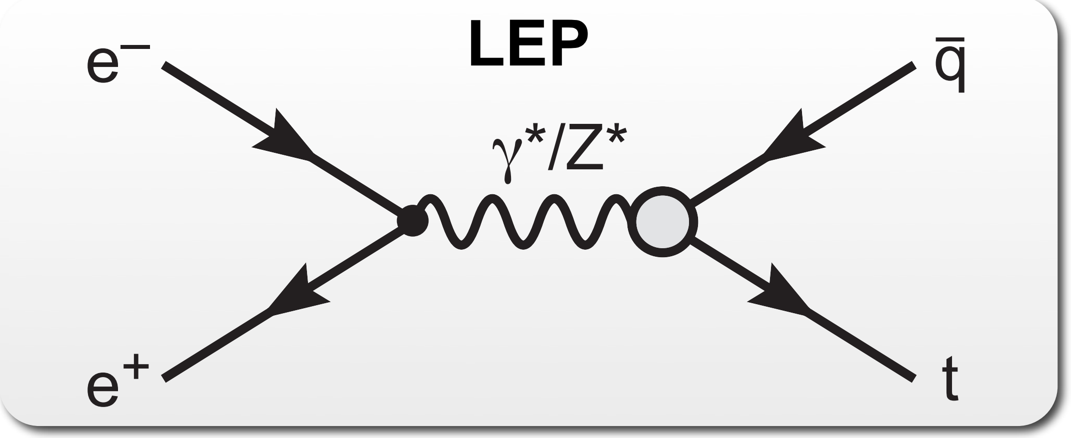
Previous Searches for Top FCNC

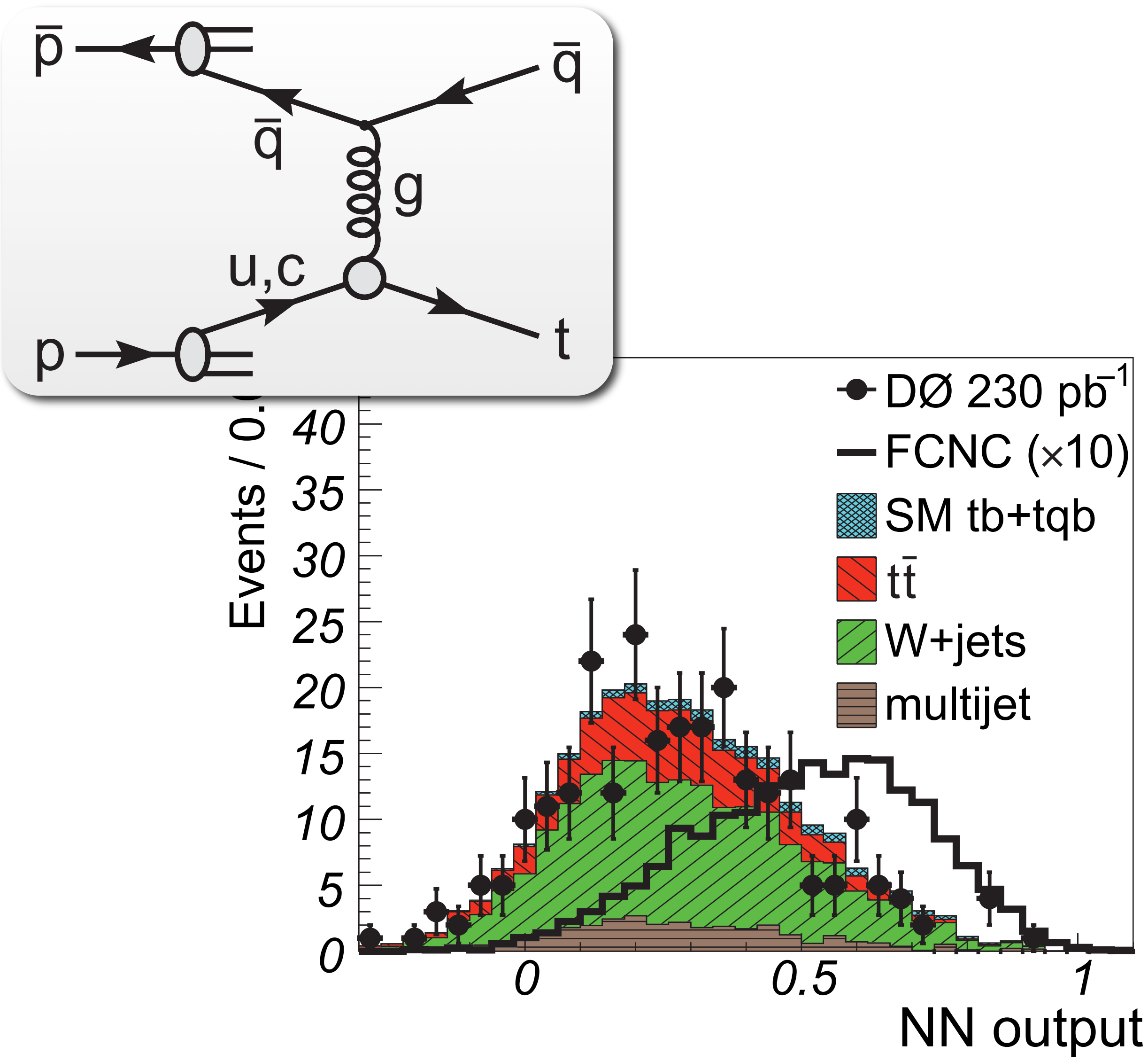
- CDF Run I search:
  F. Abe *et al.*, PRL **80** (1998) 2525.
  - Signature: $Z \to l^+ l^-$ + 4 jets (1 b-jet) → starting point for Run II analysis
  - Limit on BR(t→Zq): 33%



- LEP searches:
  P. Achard *et al.* (L3), Phys. Lett. **B549** (2002) 290.
  G. Abbiendi *et al.* (Opal), Phys. Lett. **B521** (2001) 181.
  J. Abdallah *et al.* (Delphi), Phys. Lett. **B590** (2004) 21.
  A. Heister *et al.* (Aleph), Phys. Lett. **B453** (2002) 173.
  - Anomalous single top production in e^+e^- collisions
  - Very similar results among all LEP experiments, best limit on BR(t→Zq): 13.7% (L3)



DØ: *t*-channel production
→ top + 1 jet final state: W+2 jets

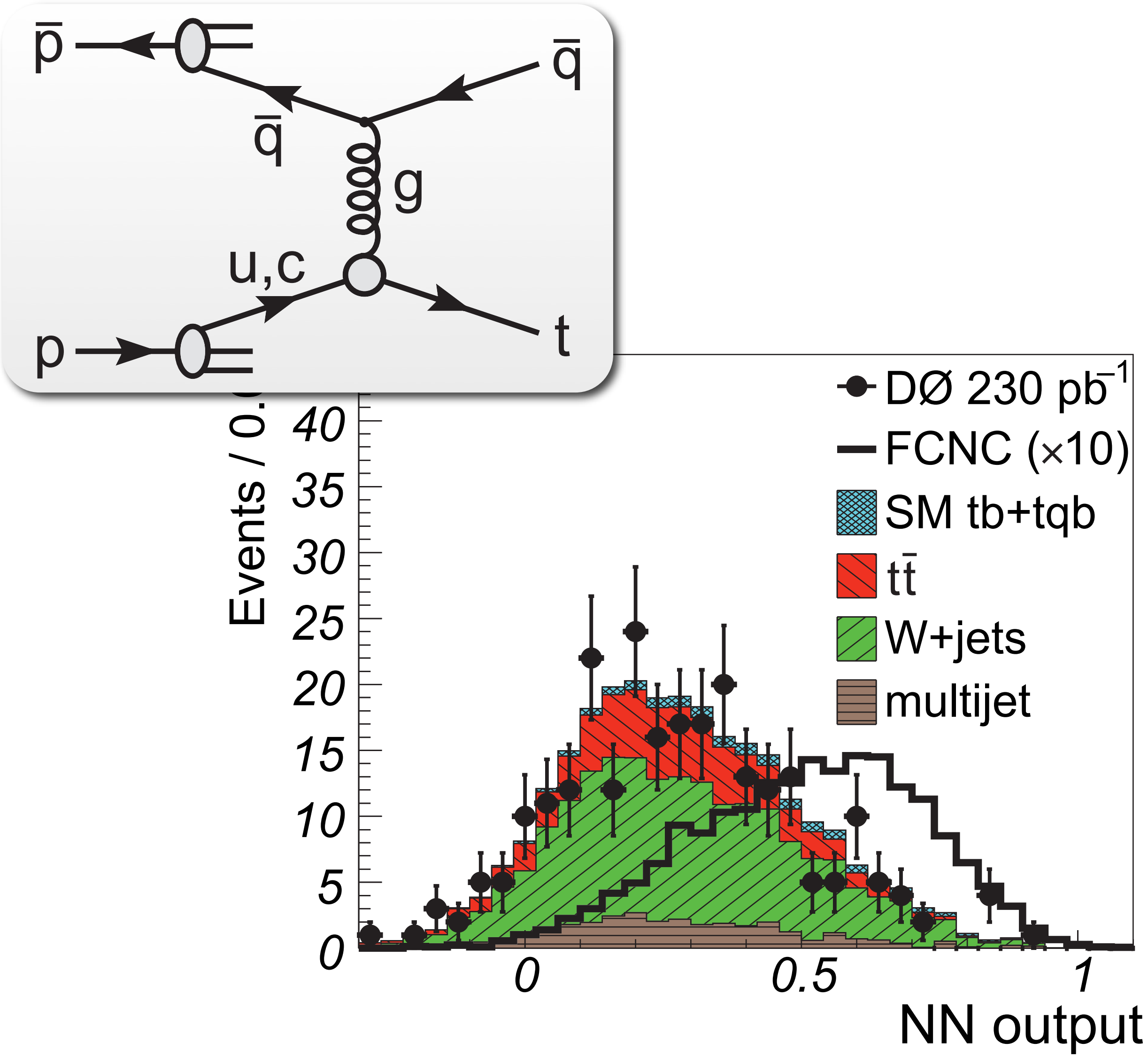


$$\left(\kappa_g^c/\Lambda\right)^2 < 0.023\,\mathrm{TeV}^{-2} \quad (95\%\ \mathrm{C.L.})$$
$$\left(\kappa_g^u/\Lambda\right)^2 < 0.0014\,\mathrm{TeV}^{-2} \quad (95\%\ \mathrm{C.L.})$$

[V. M. Abazov *et al.*, Phys. Rev. Lett. **99** (2007) 191802]

FCNC in Single Top Production

DØ: *t*-channel production
→ top + 1 jet final state: W+2 jets



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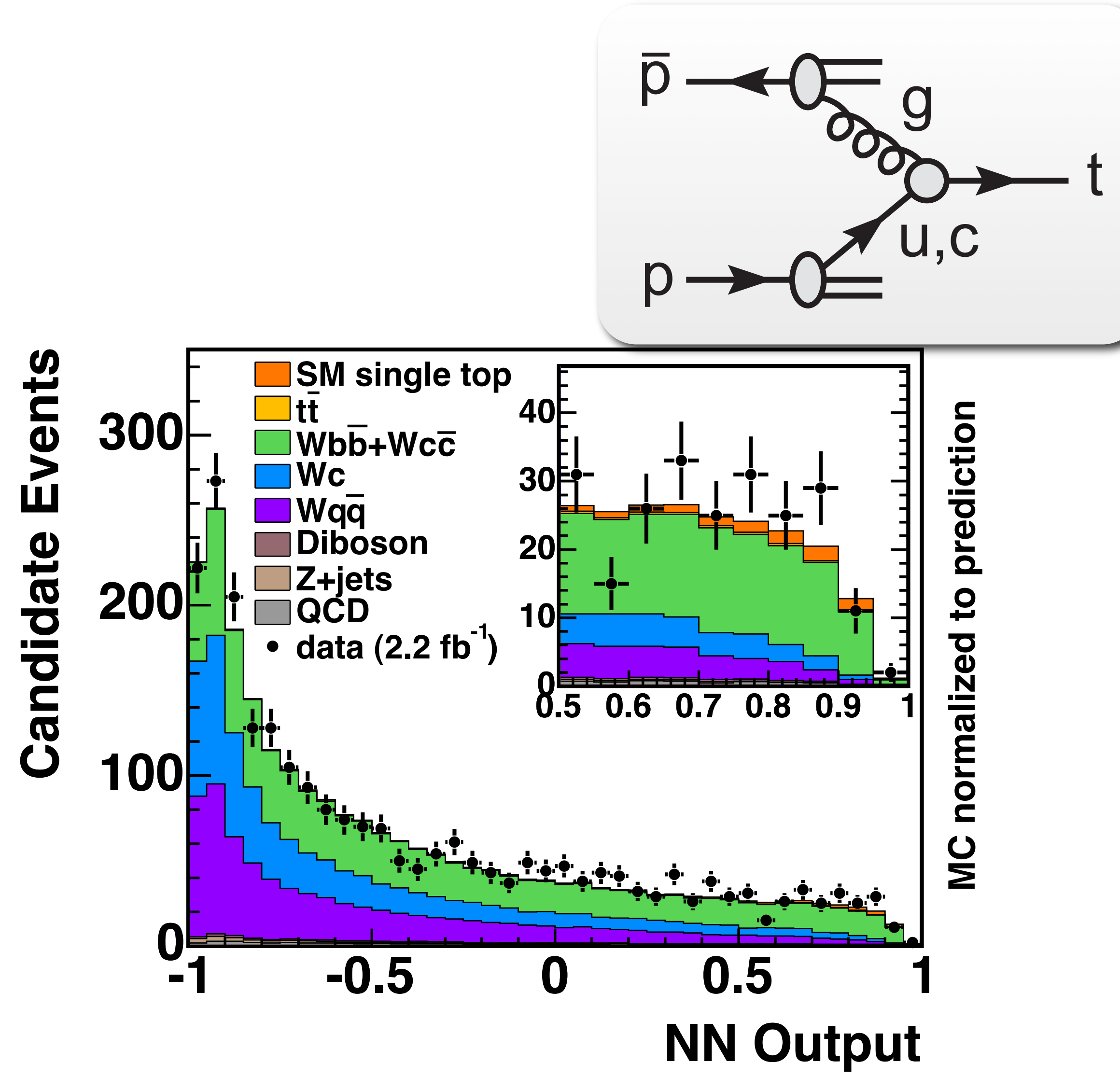
[V. M. Abazov *et al.*, Phys. Rev. Lett. **99** (2007) 191802]

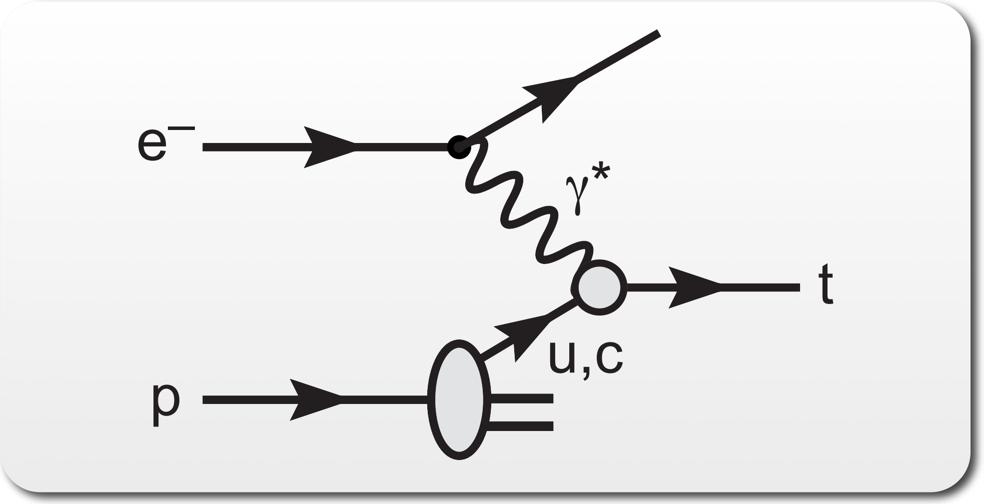
CDF: *s*-channel production
→ W + 1 jet final state



$$(\kappa_g^c/\Lambda)^2 < 0.005\,\mathrm{TeV}^{-2} \quad (95\%\ \mathrm{C.L.})$$
$$(\kappa_g^u/\Lambda)^2 < 0.0003\,\mathrm{TeV}^{-2} \quad (95\%\ \mathrm{C.L.})$$

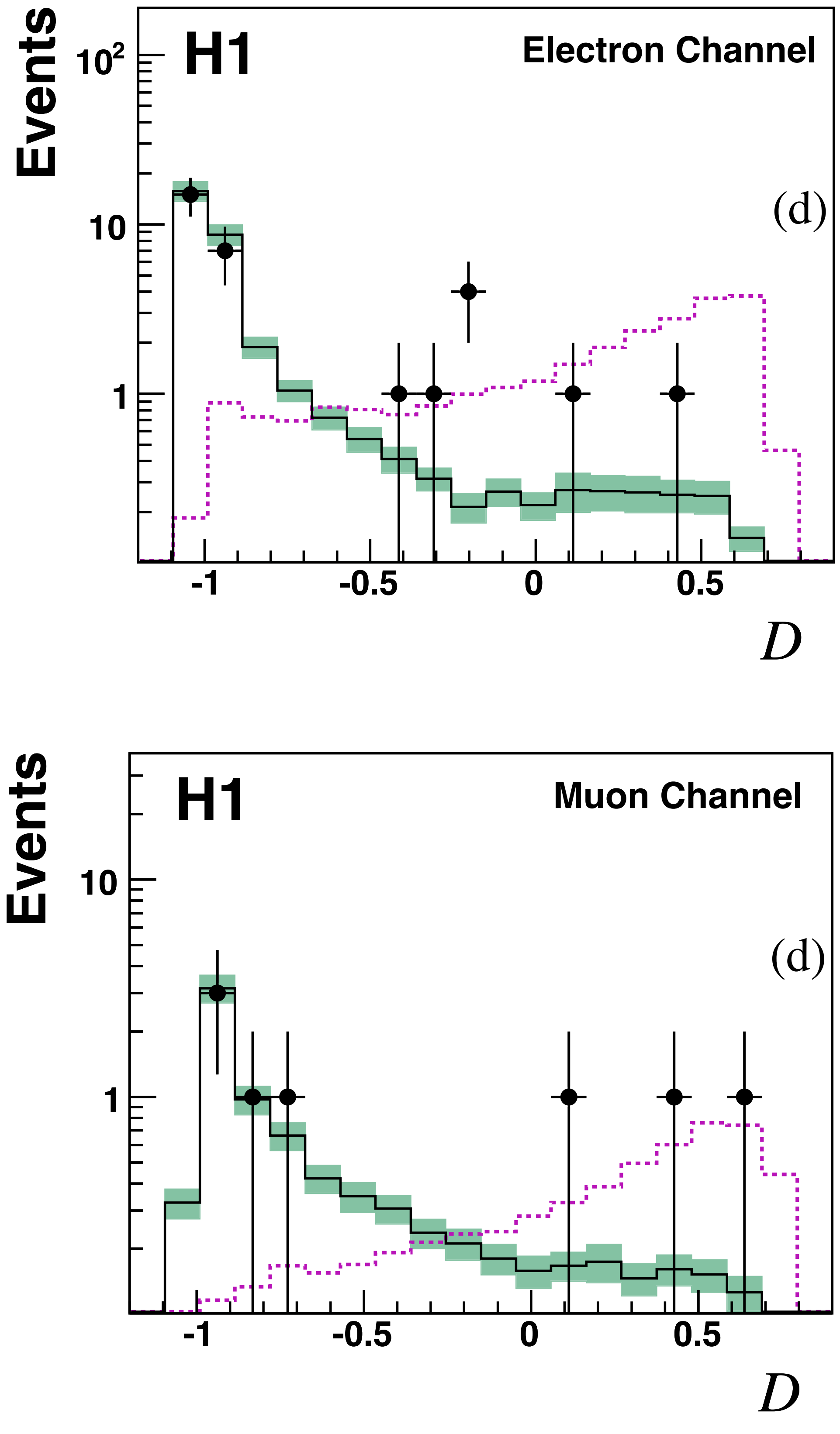
[T. Aaltonen et al., Phys. Rev. Lett. **102** (2009) 151801]

- HERA searches:
  F.D. Aaron et al. (H1), Phys. Lett. **B678** (2009) 450,
  S. Chekanov et al. (ZEUS), Phys. Lett. **B559** (2003) 153.
  - Anomalous single top production in ep collisions



  - Very competitive for tγq vertex, preference for u over c quarks due to proton sea quark content
  - H1: small excess in lepton channels

$$\mathcal{B}(t \to u\gamma) < 0.64\%(95\%\text{C.L.})$$



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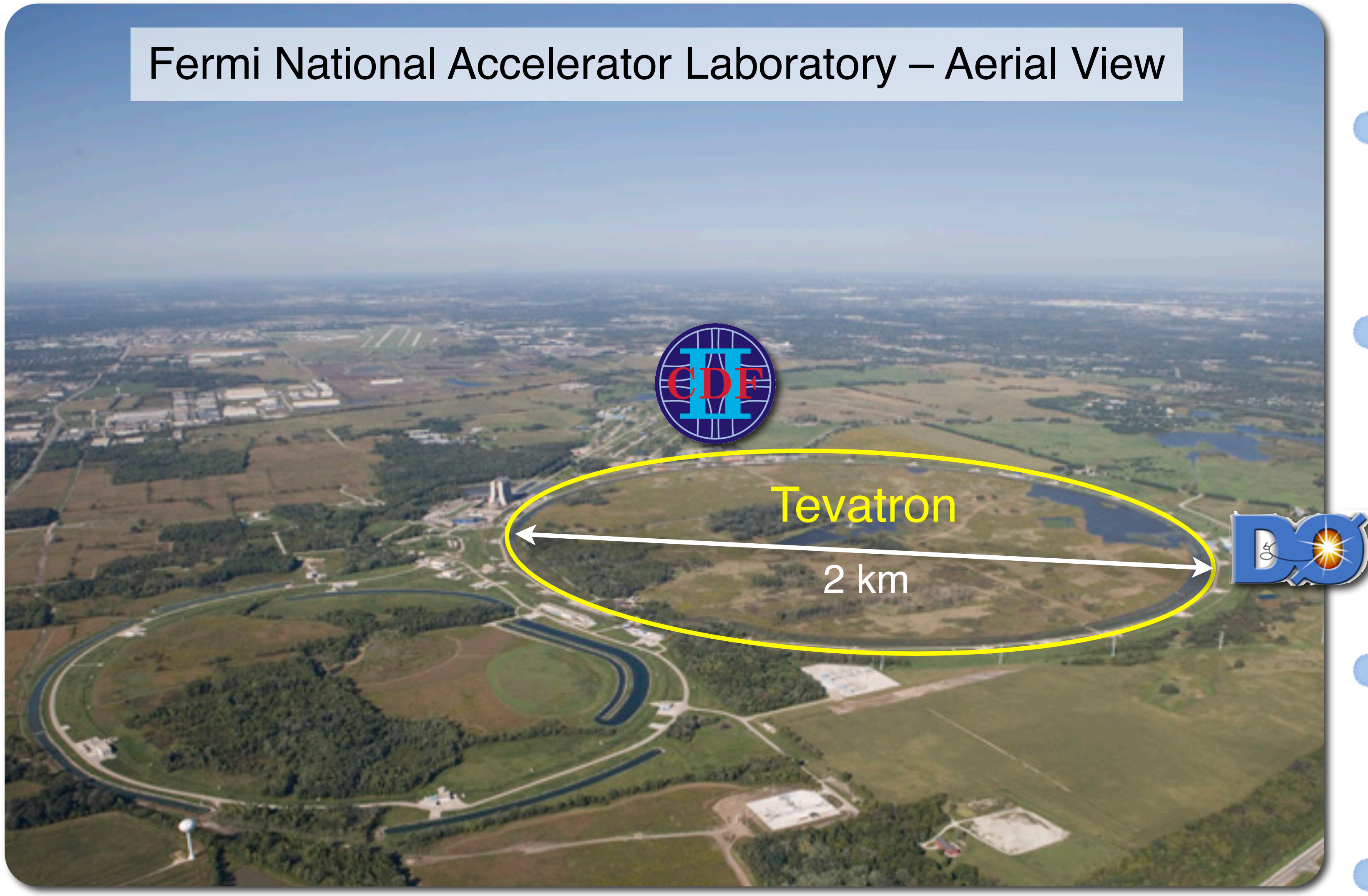
Tevatron Run II: 2001–2009 (2010?)

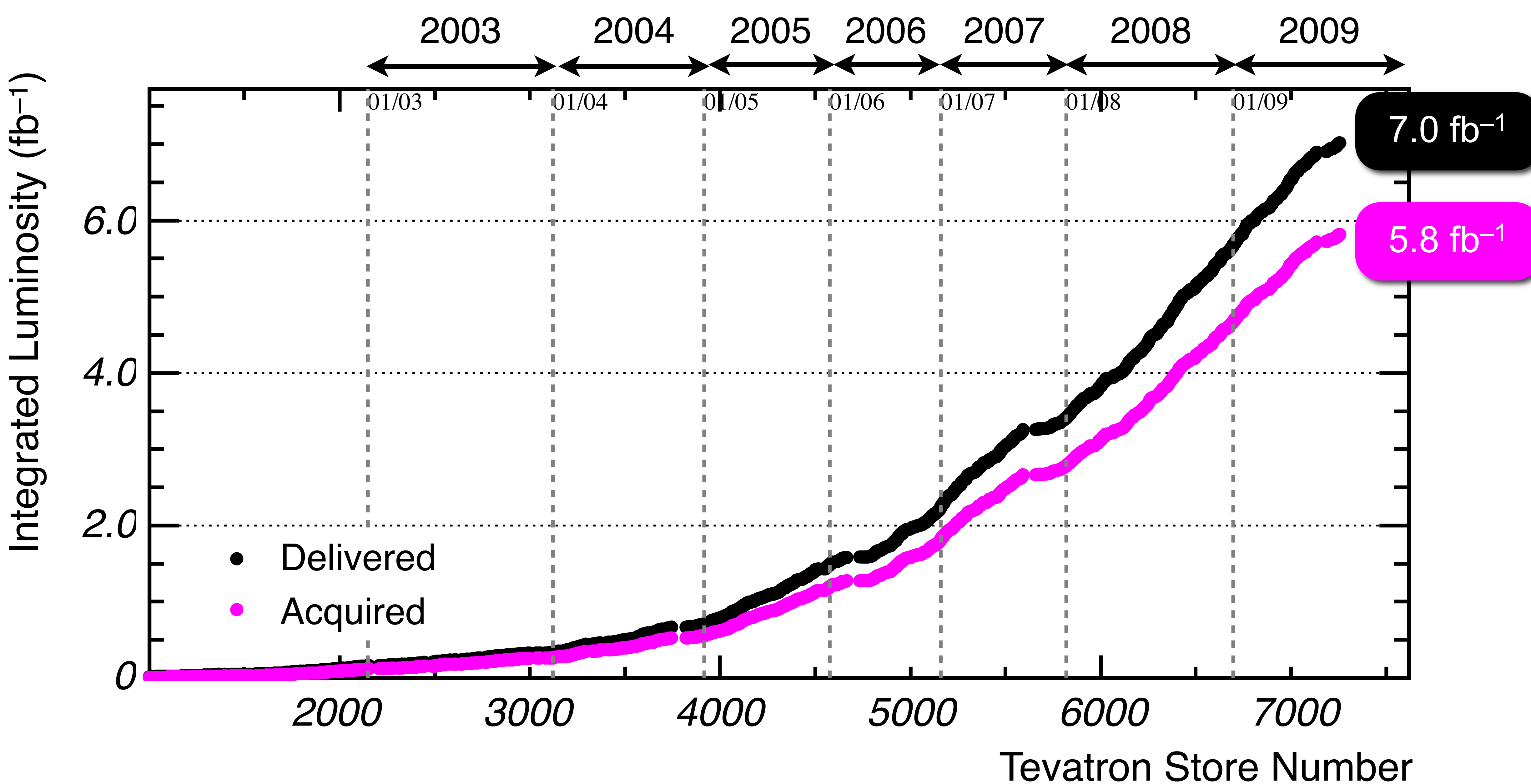


[Fermilab Visual Media Service]

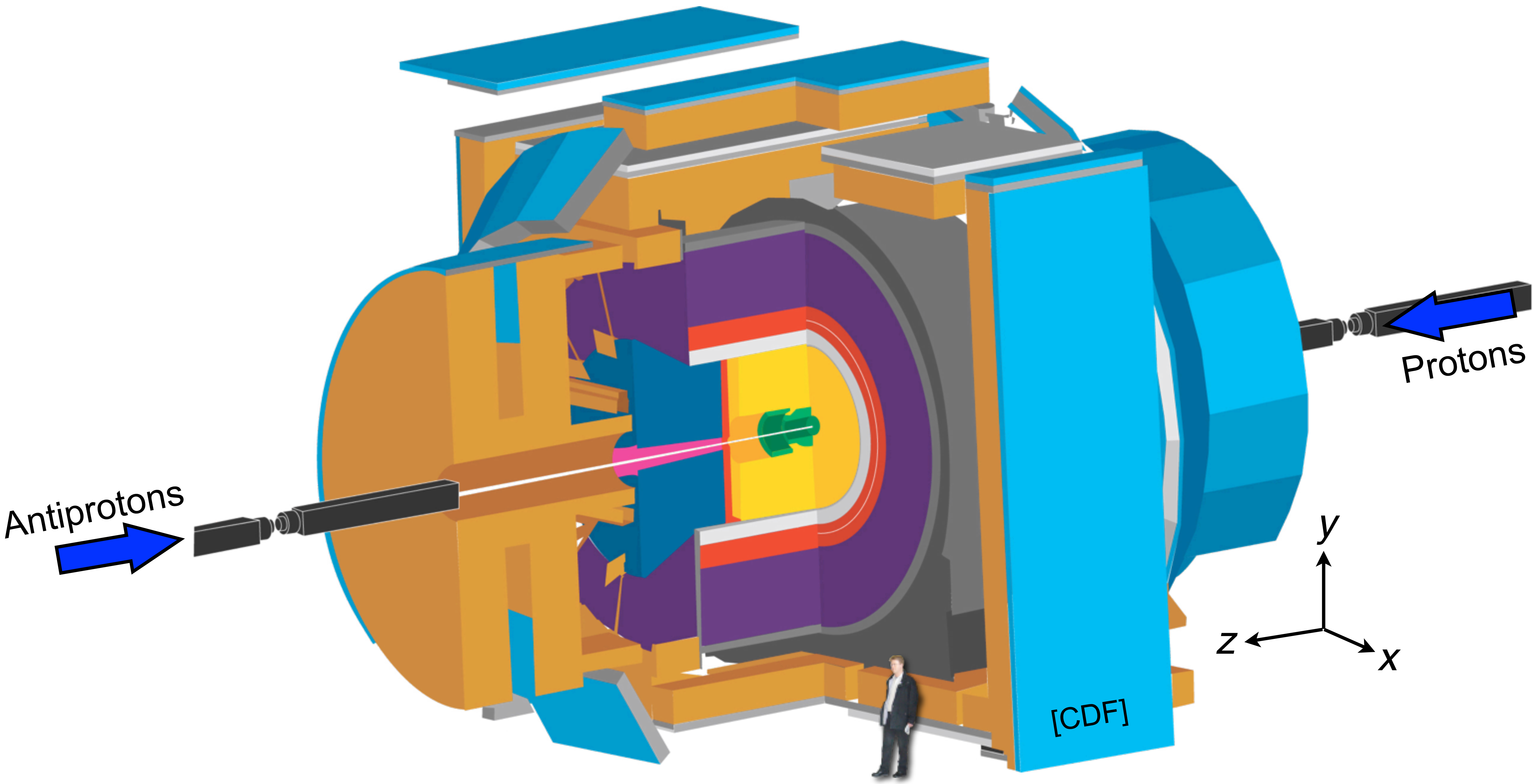
- Proton-antiproton collider: $\sqrt{s}$ = 1.96 TeV
- 36×36 bunches, collisions every 396 ns
- Record instantaneous peak luminosity: 372 $\mu b^{-1}\, s^{-1}$ (1 $\mu b^{-1}\, s^{-1}$ = $10^{30}\, cm^{-2}\, s^{-1}$)
- Integrated luminosity goal: 7.8–9.3 fb^{-1} by 2010
- Running in 2011 currently under discussion: 12 fb^{-1}
- Two multi-purpose detectors: CDF and DØ

Tevatron Performance

- Tevatron continues to perform extremely well:
  - More than 7 fb^{-1} delivered by Tevatron as of October 11, 2009
  - More than 5.8 fb^{-1} recorded by CDF



The CDF II Detector



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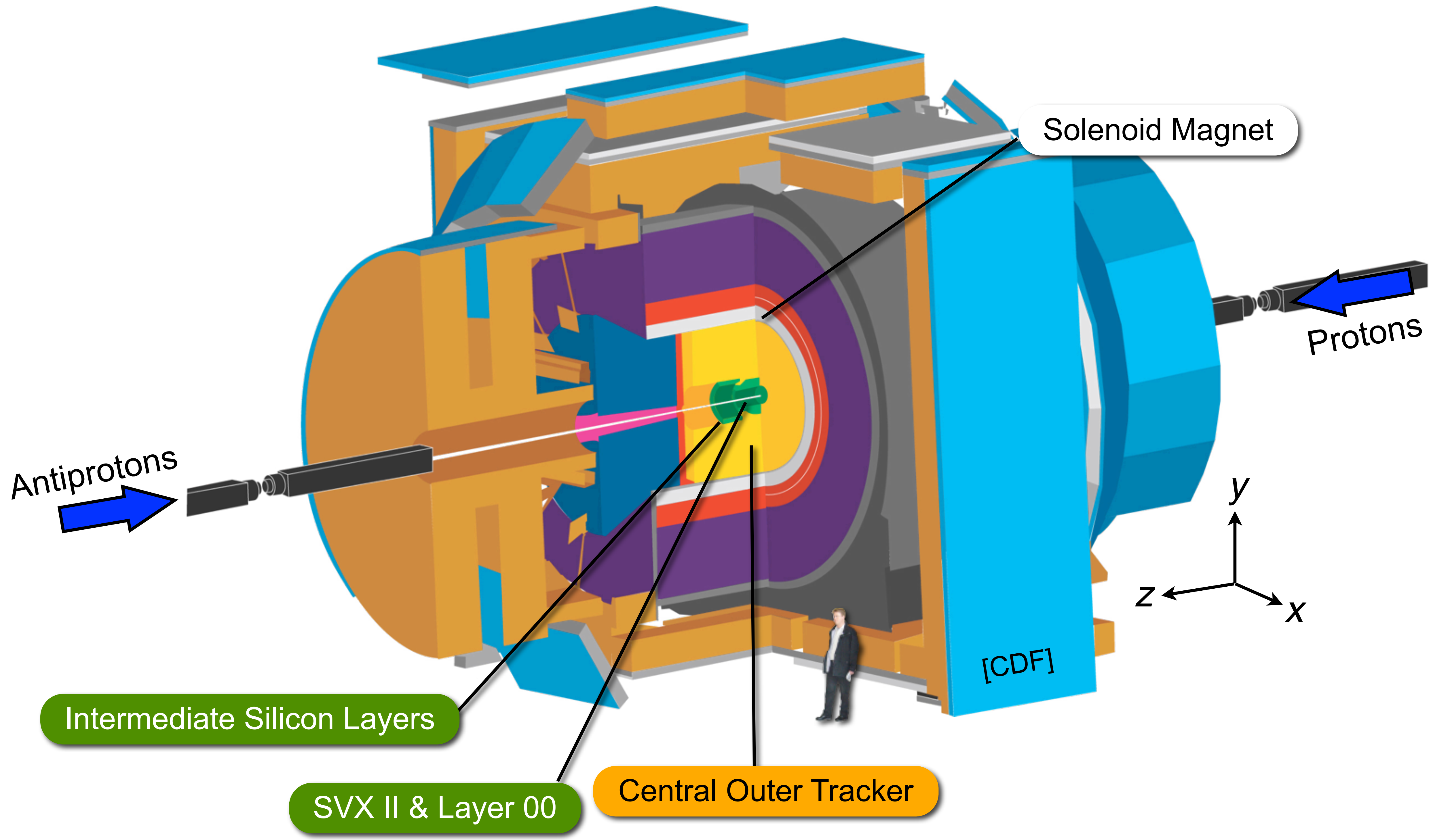

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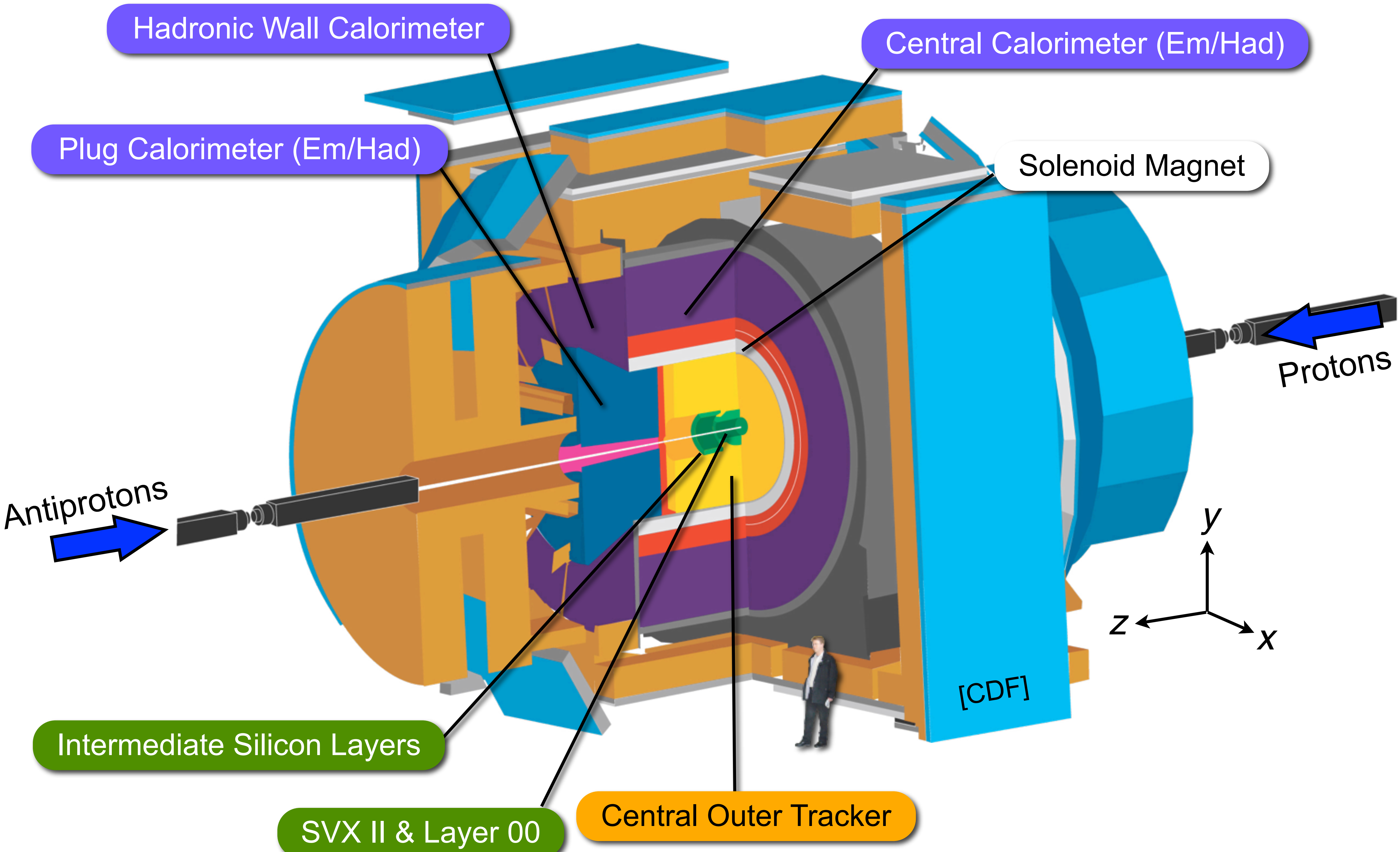

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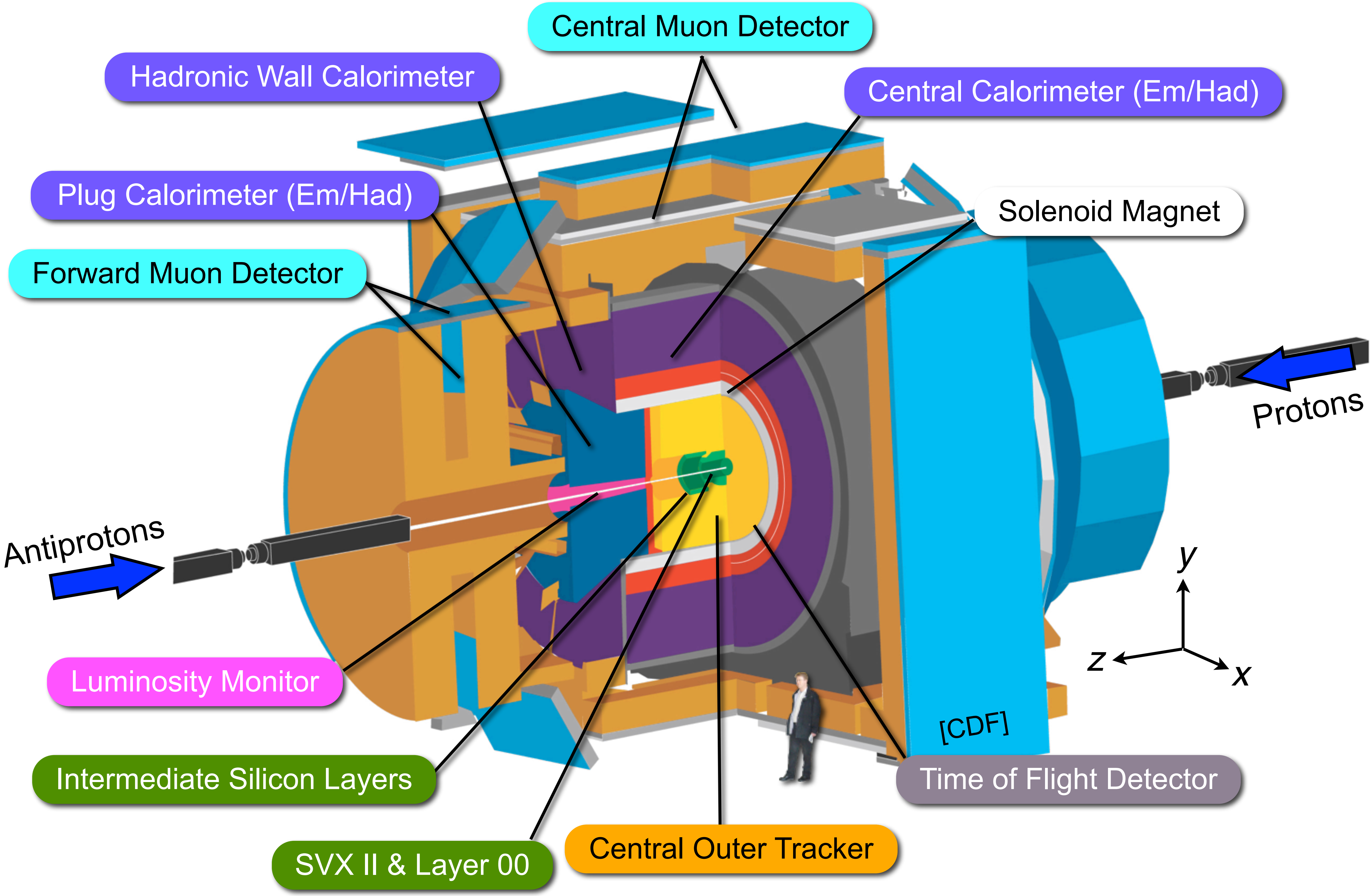
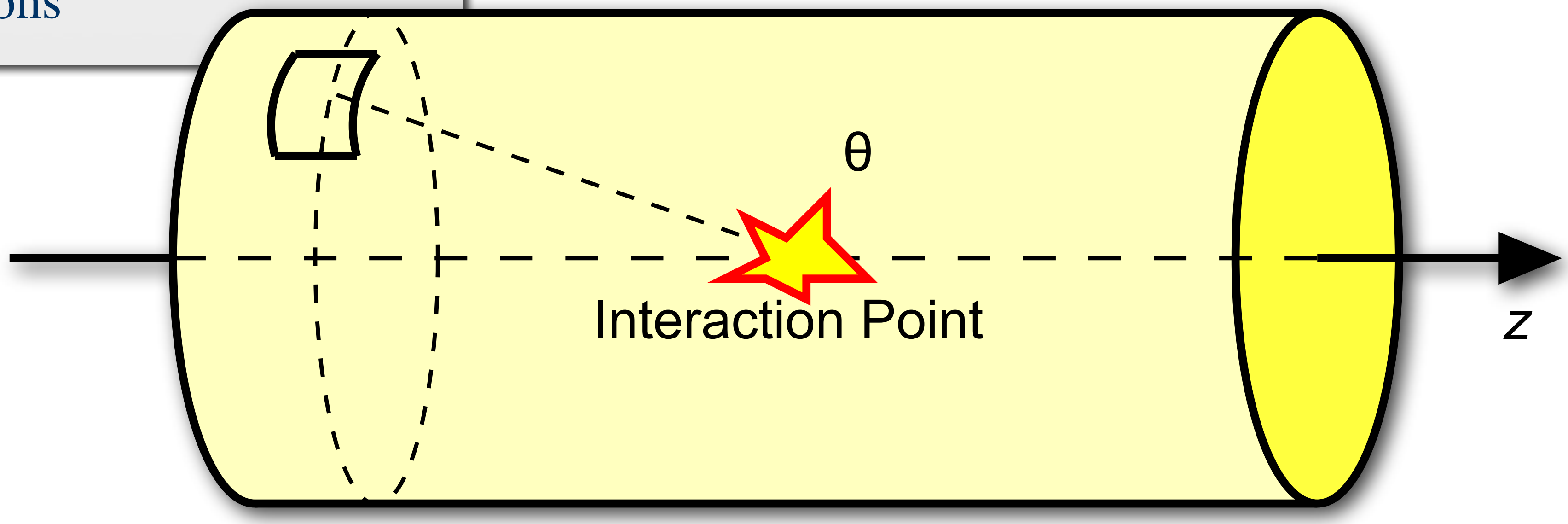


Hadron Collider Kinematics

- Cylindrical coordinate system:
  - θ: polar angle w.r.t. to proton direction
  - ϕ: azimuthal angle
  - Pseudorapidity:
    $\eta = -\ln\tan(\theta/2)$
  - Transverse energy:
    $$\vec{E}_T = \sum_{\text{cal towers}} E_i(\sin\theta_i, \phi_i)$$
  - Missing transverse energy ("MET"):
    $$\vec{\not{E}}_T = -\sum_{\text{jets}} \vec{E}_T - \sum_{\text{leptons}} \vec{p}_T$$



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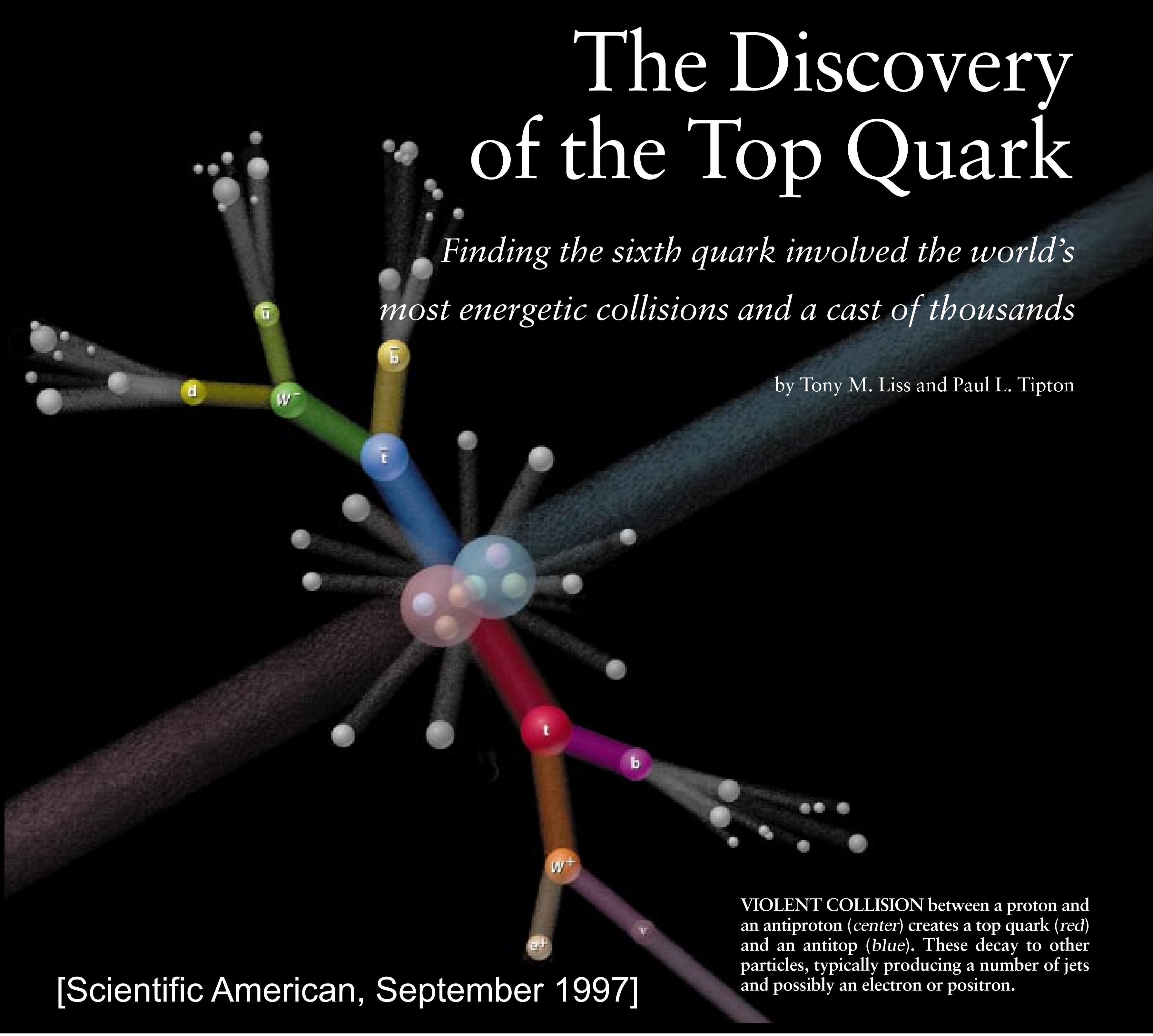
The Discovery of the Top Quark

Brief history of top quark discovery:

- 1977: Υ discovery – bottom quark
- 1980s: Searches for “light” top (m_t < m_W): isospin partner of bottom at PETRA, $Sp\bar{p}S$, LEP, CDF Run 0
- 1992/3: Tevatron Run I starts, first indications for top quark production
- March 2, 1995: CDF and DØ announce top quark discovery



[Scientific American, September 1997]

The Top Quark in the Standard Model

- The top is heavy: $m_t \approx 173$ GeV/c^2 (40×m_b, approx. mass of gold atom)
- Mass close to scale of electroweak symmetry breaking (EWSB), top Yukawa coupling $f \approx 1$:

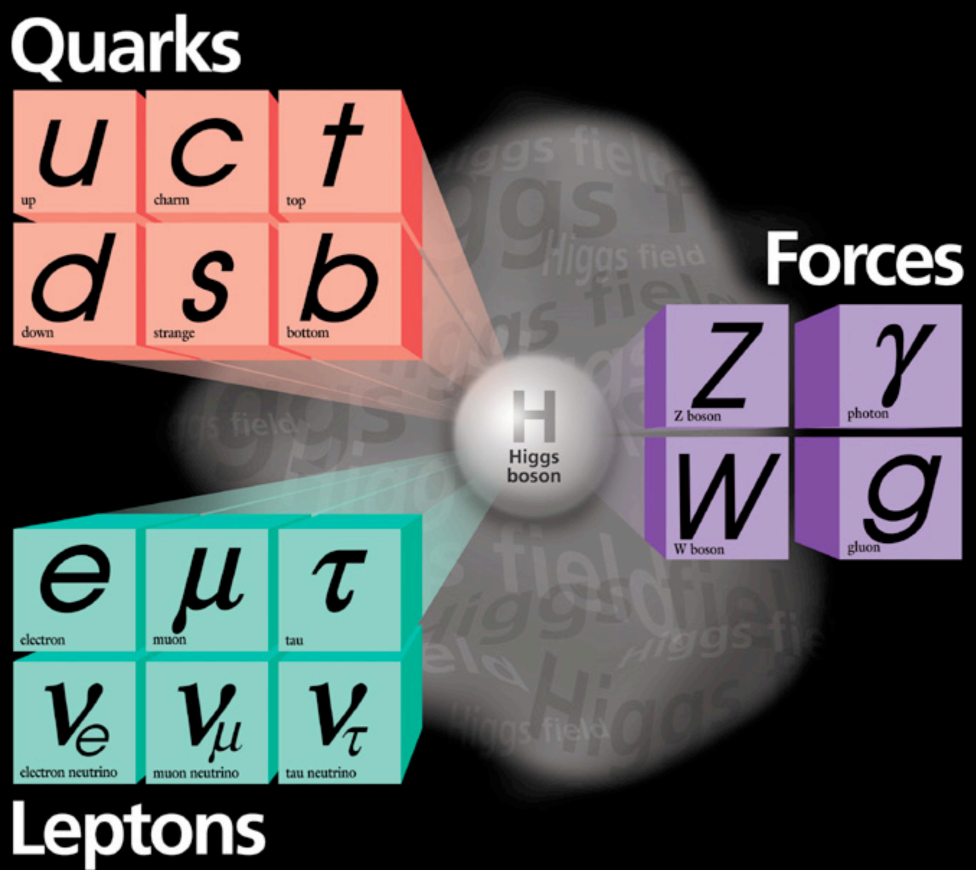
$$\mathscr{L}_{\mathrm{Yuk},t} = f \frac{v}{\sqrt{2}} \bar{t}_L t_R \equiv m_t \bar{t}_L t_R$$

(vacuum expectation value of Higgs field: $v/\sqrt{2} \approx 178$ GeV)
→ Important role in EWSB models

- Top is the only "free" quark: lifetime shorter than hadronization time

$$\tau = \frac{1}{\Gamma} \approx \frac{1}{1.5\,\mathrm{GeV}} < \frac{1}{\Lambda_{\mathrm{QCD}}} \approx \frac{1}{0.2\,\mathrm{GeV}}$$

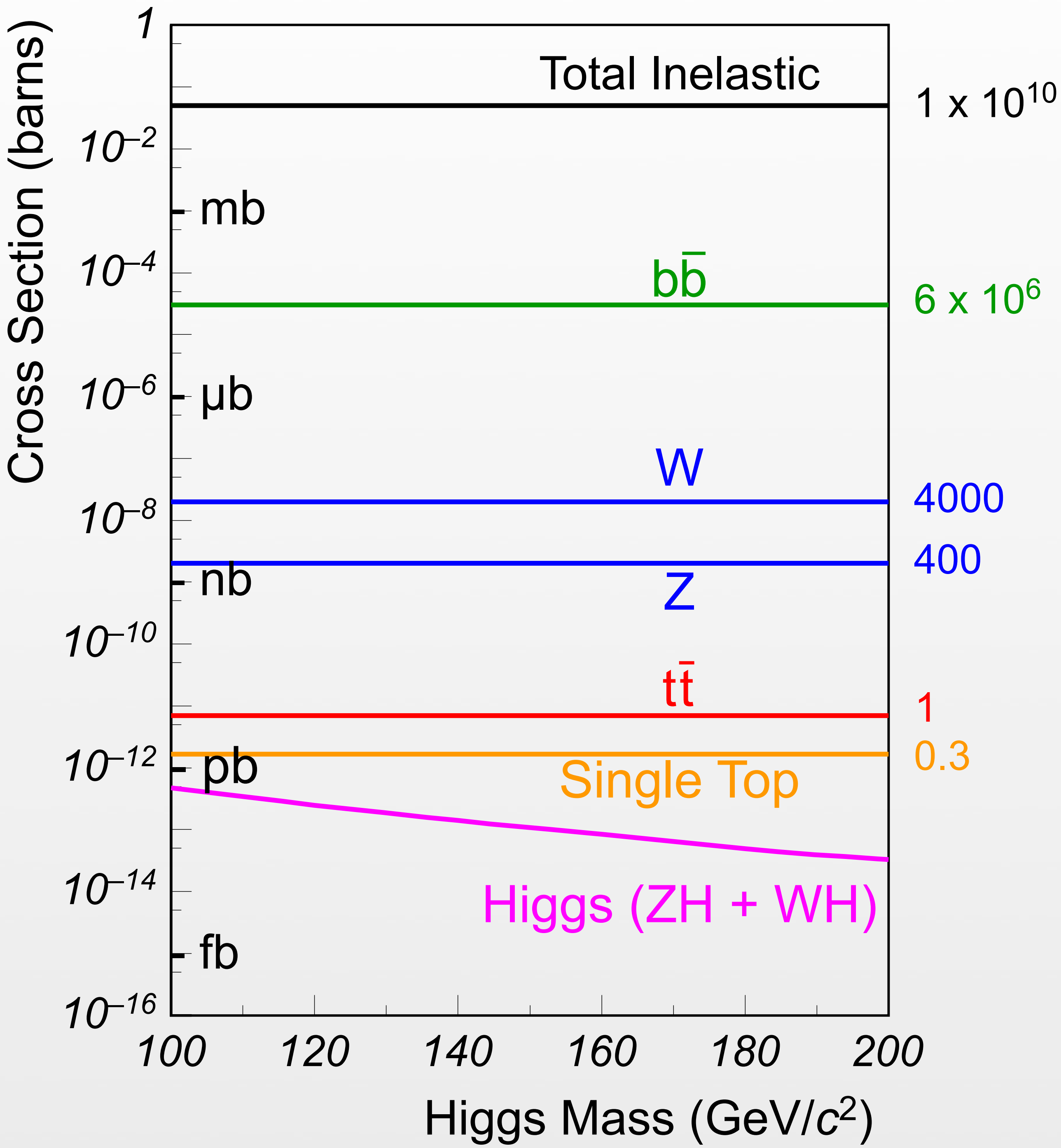
→ No spectroscopy of bound states
→ Spin transferred to decay products



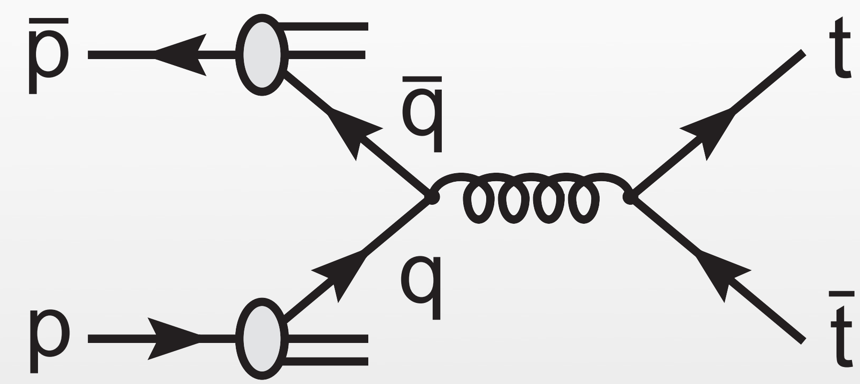
[Fermilab Visual Media Services]

Top Pair Production at the Tevatron

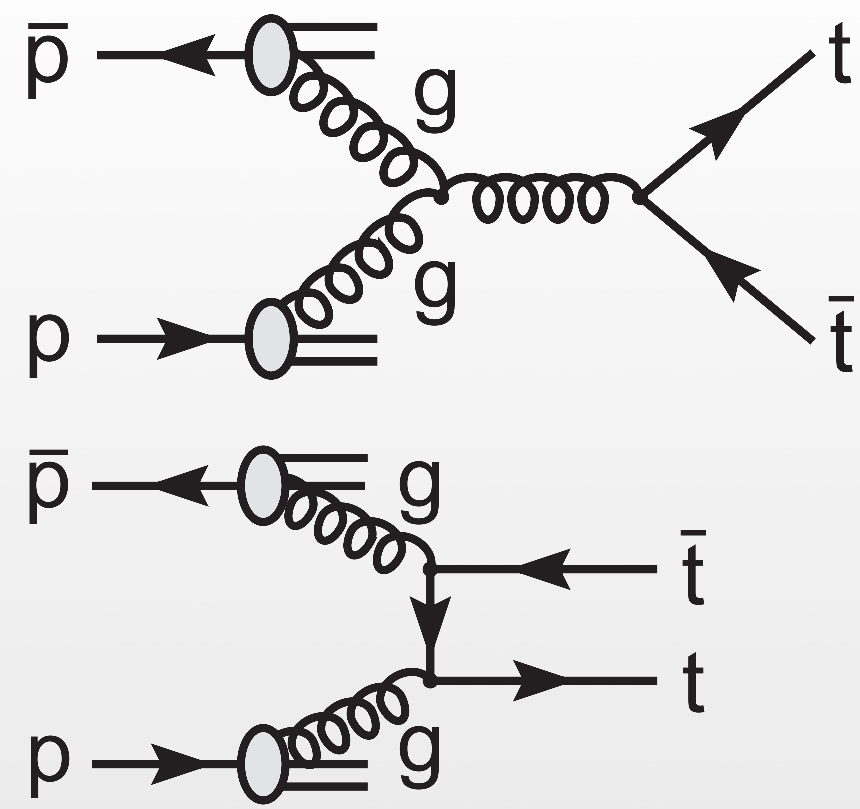
Top production is rare: one top quark pair produced every 10 billion collisions



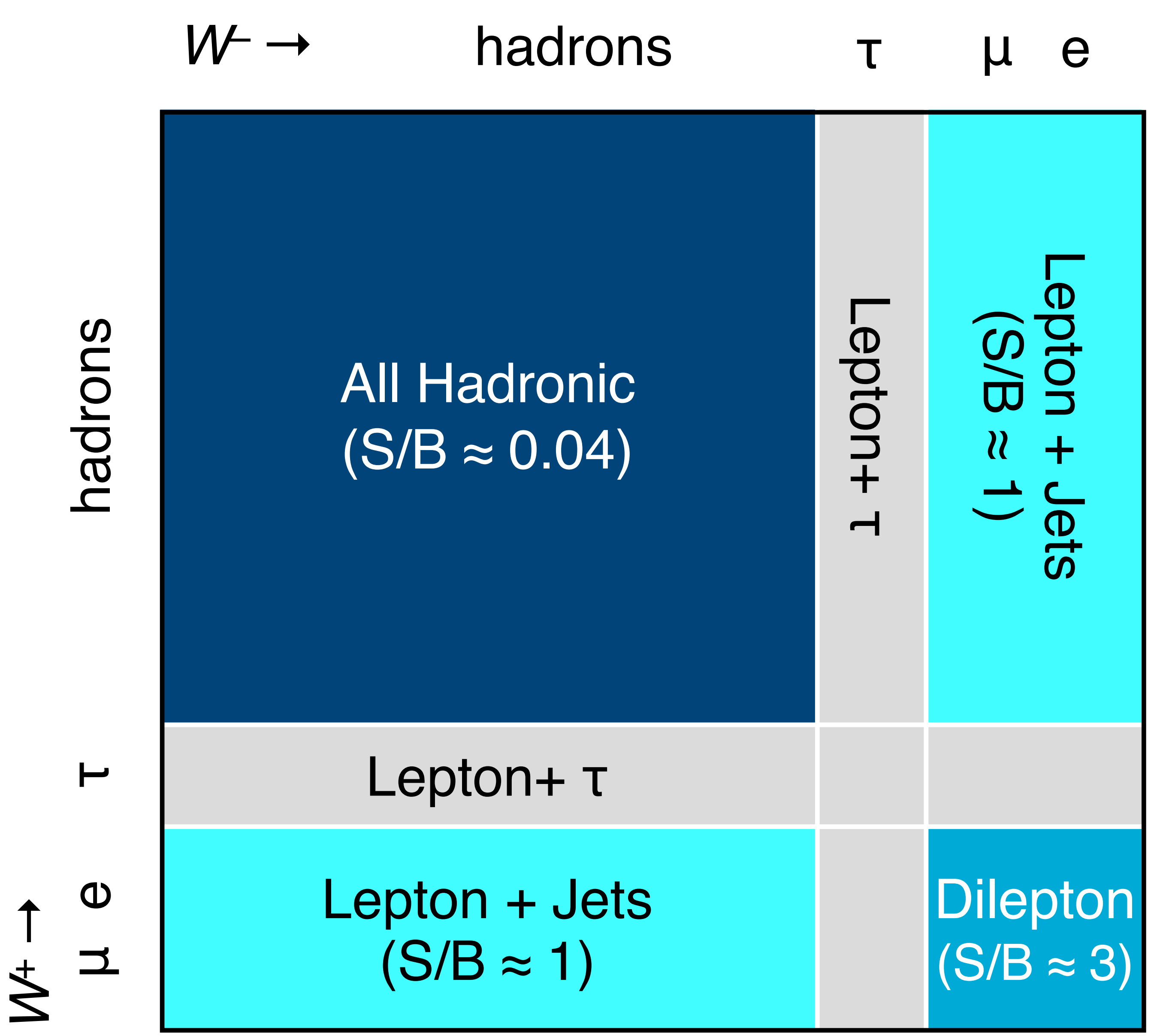
85% $q\bar{q} \rightarrow t\bar{t}$:



15% $gg \rightarrow t\bar{t}$:



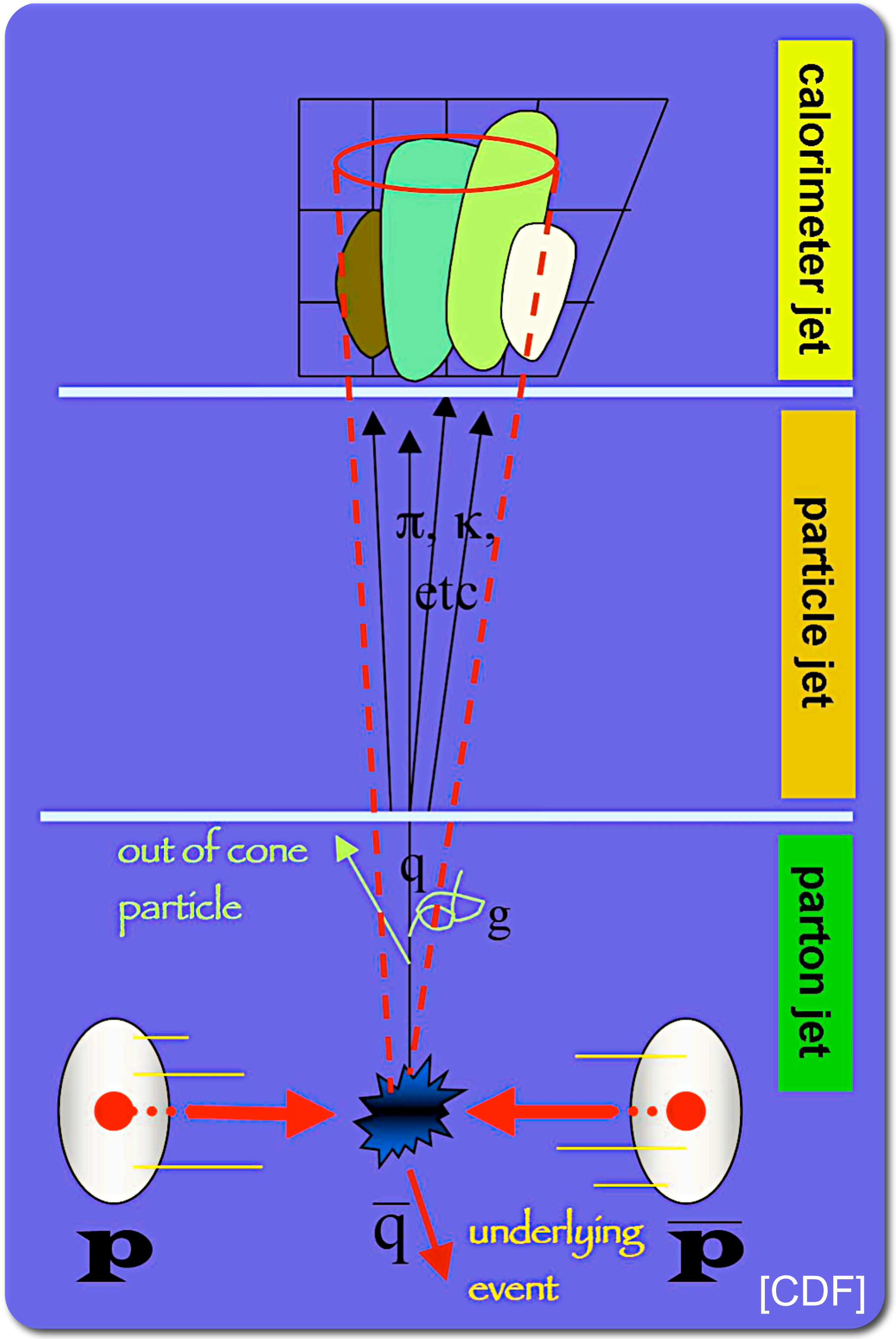
Analyzing Top Quark Events



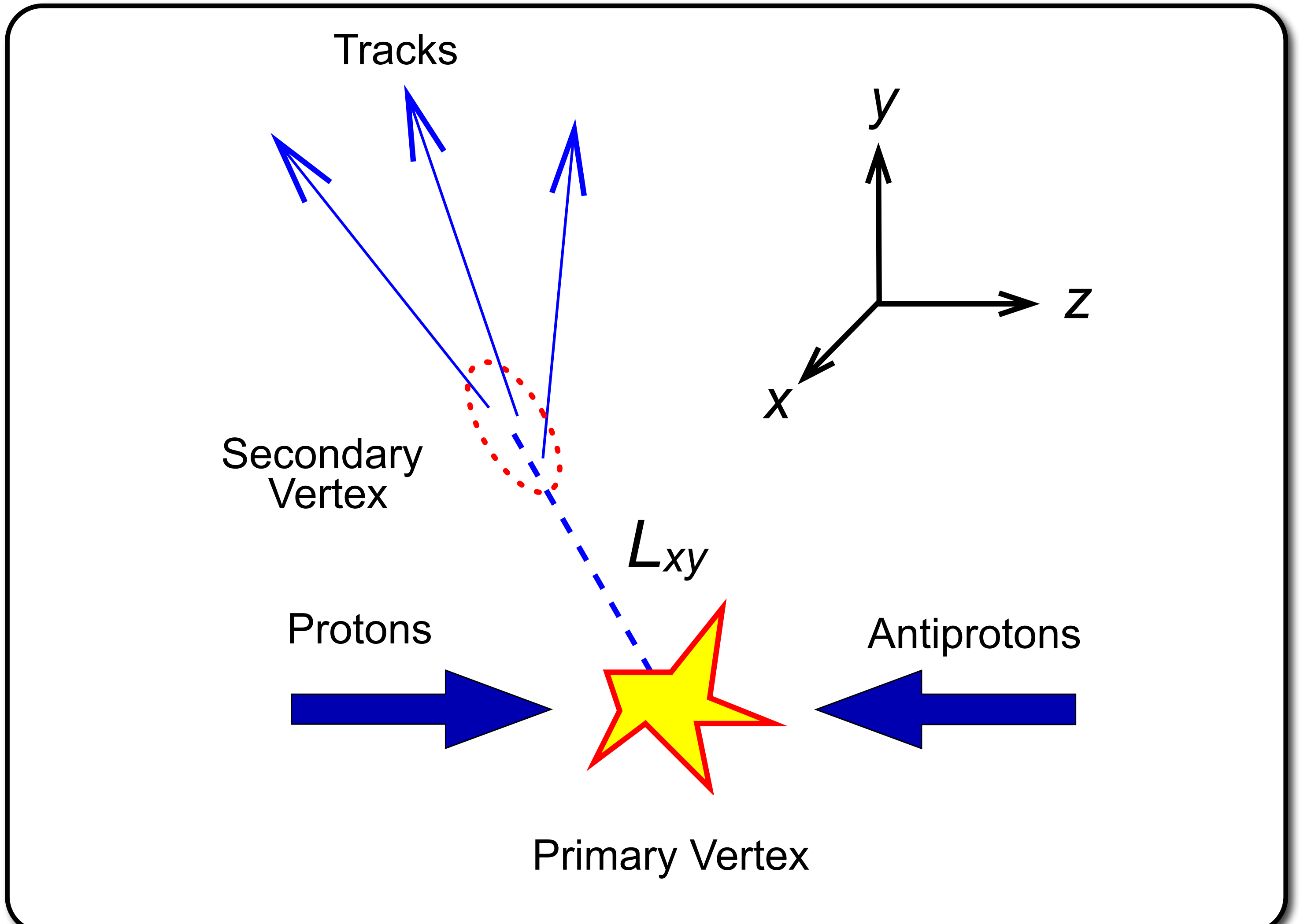
- Top decay in the standard model: t → Wb (BR ≈ 100%)
- $t\bar{t}$ decay signatures characterized by W decays:
  - All-Hadronic: 45% of all decays, large QCD background
  - Lepton+Jets: 30% of all decays, the "gold-plated" channel
  - Dilepton: 5% of all decays, very clean, but small branching fraction
- Main background process: "W+Jets" (production of W bosons in association with jets)
- $t\bar{t}$ events contain two b quarks: "b-tagging" (identification of jets from b quarks) crucial

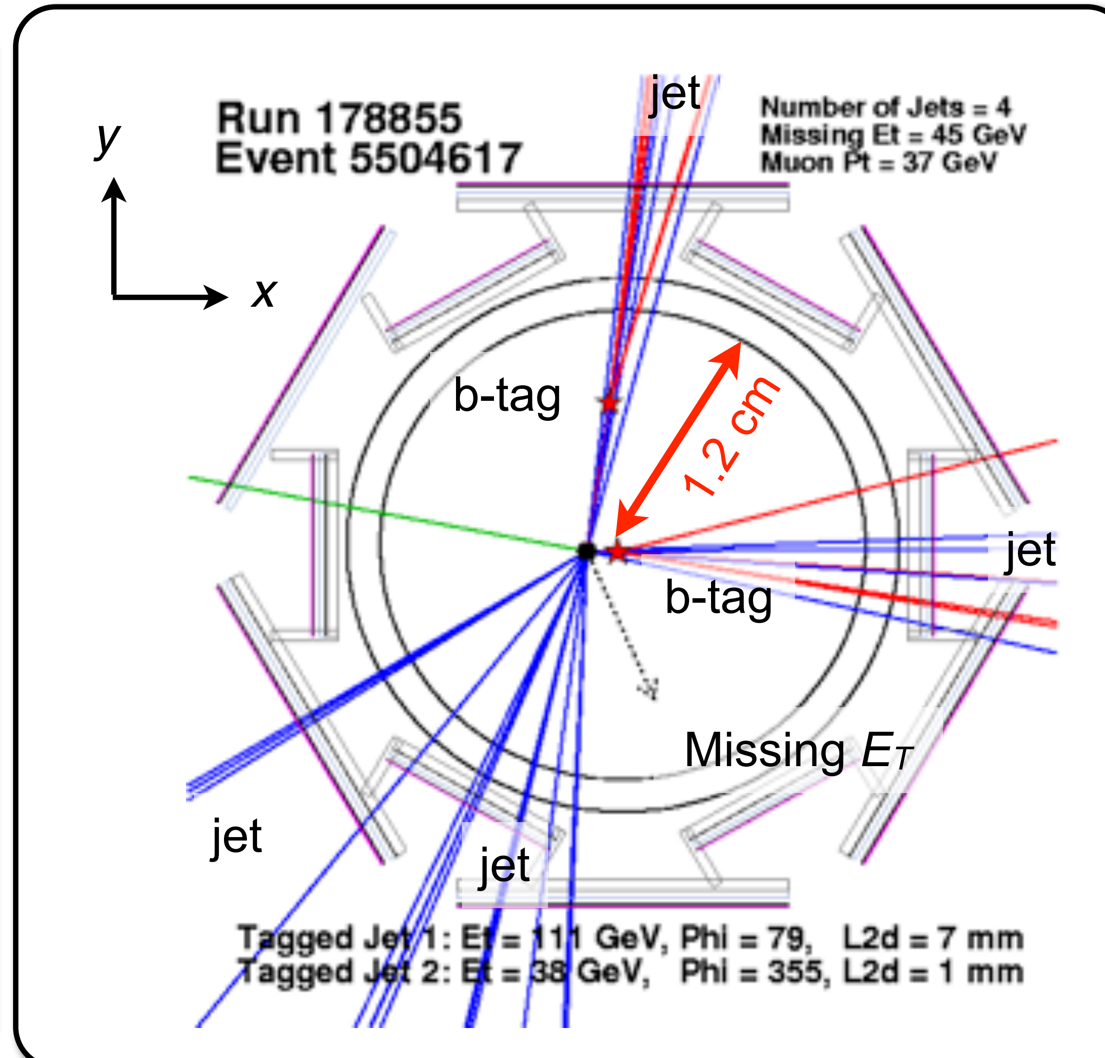
Lepton and Parton Identification

- High p_T electron identification:
  - Isolated charged particle track (no nearby tracks)
  - Almost all energy deposited in electromagnetic calorimeter
- High p_T muon identification:
  - Isolated charged particle track (no nearby tracks)
  - Little energy in calorimeters
  - “Stub” in dedicated muon detector
- Parton identification:
  - Reconstruct energies of jets, not partons
  - Jet energy scale (JES) correction: estimate parton energies from “raw” jet energies



Secondary Vertex B-Tagging

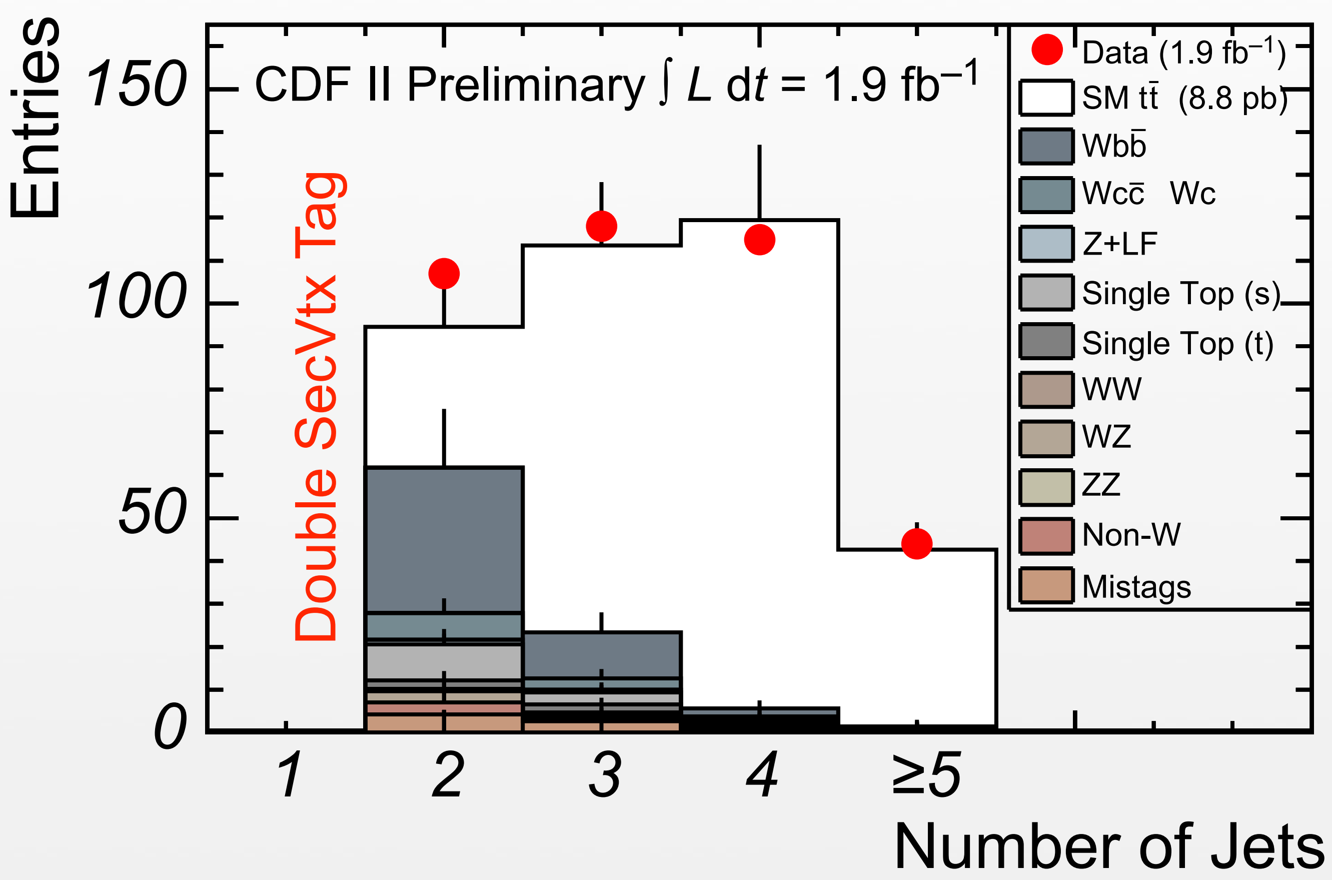




- CDF's standard "SecVtx" algorithm:
  - Long lifetime of B mesons: detect displaced secondary vertex
  - Main discriminant: significance of displacement in *xy* plane (L_{xy})

Top Basics: Mass and Cross Section

Top Cross Section (Lepton+Jets): Very Pure Top Sample



- Double SecVtx tag with 1.9 fb^{-1}: $\sigma_{t\bar{t}}$ = 8.8 pb
- Background cocktail used in many top analyses
- Normalization mode for FCNC analysis

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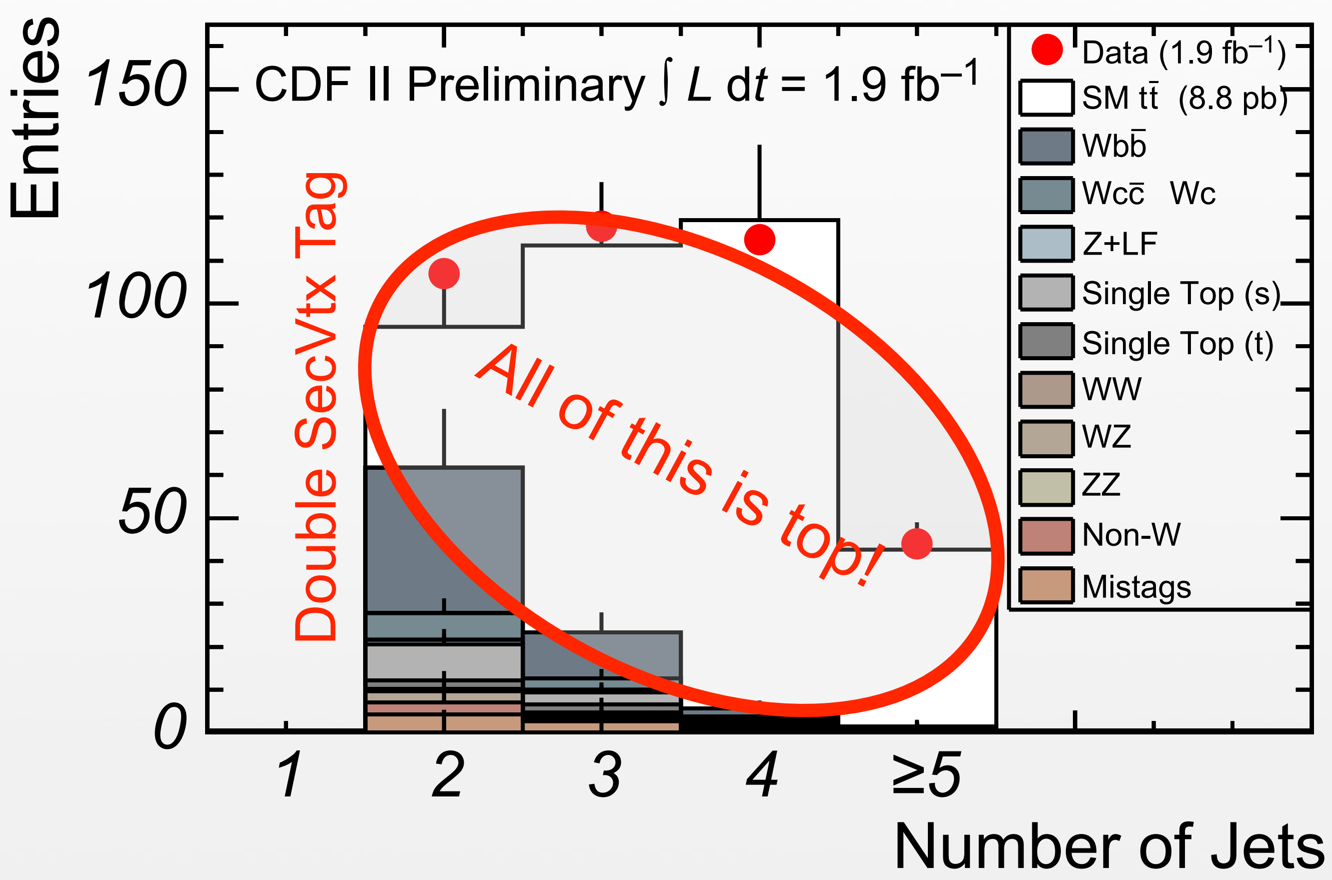

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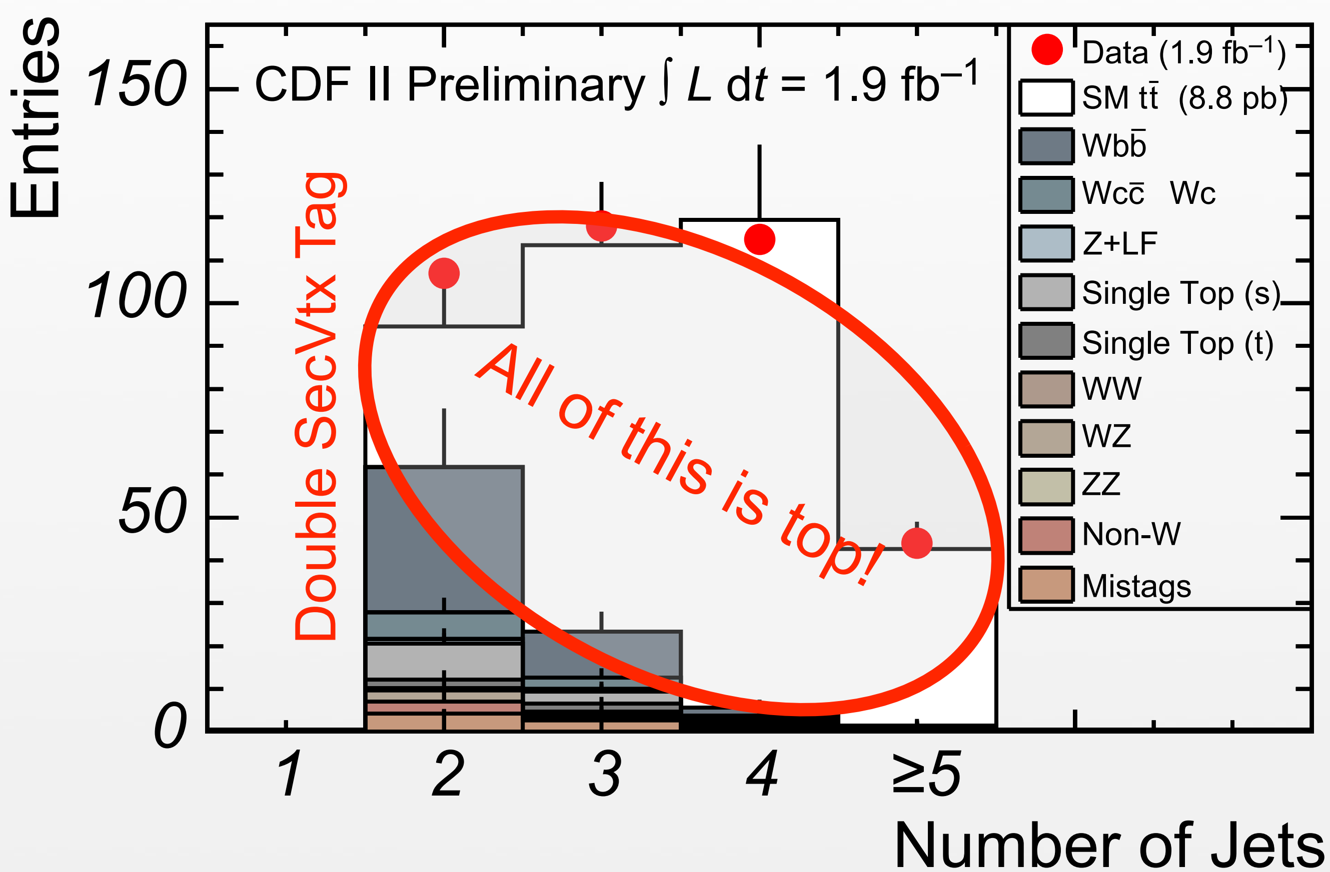

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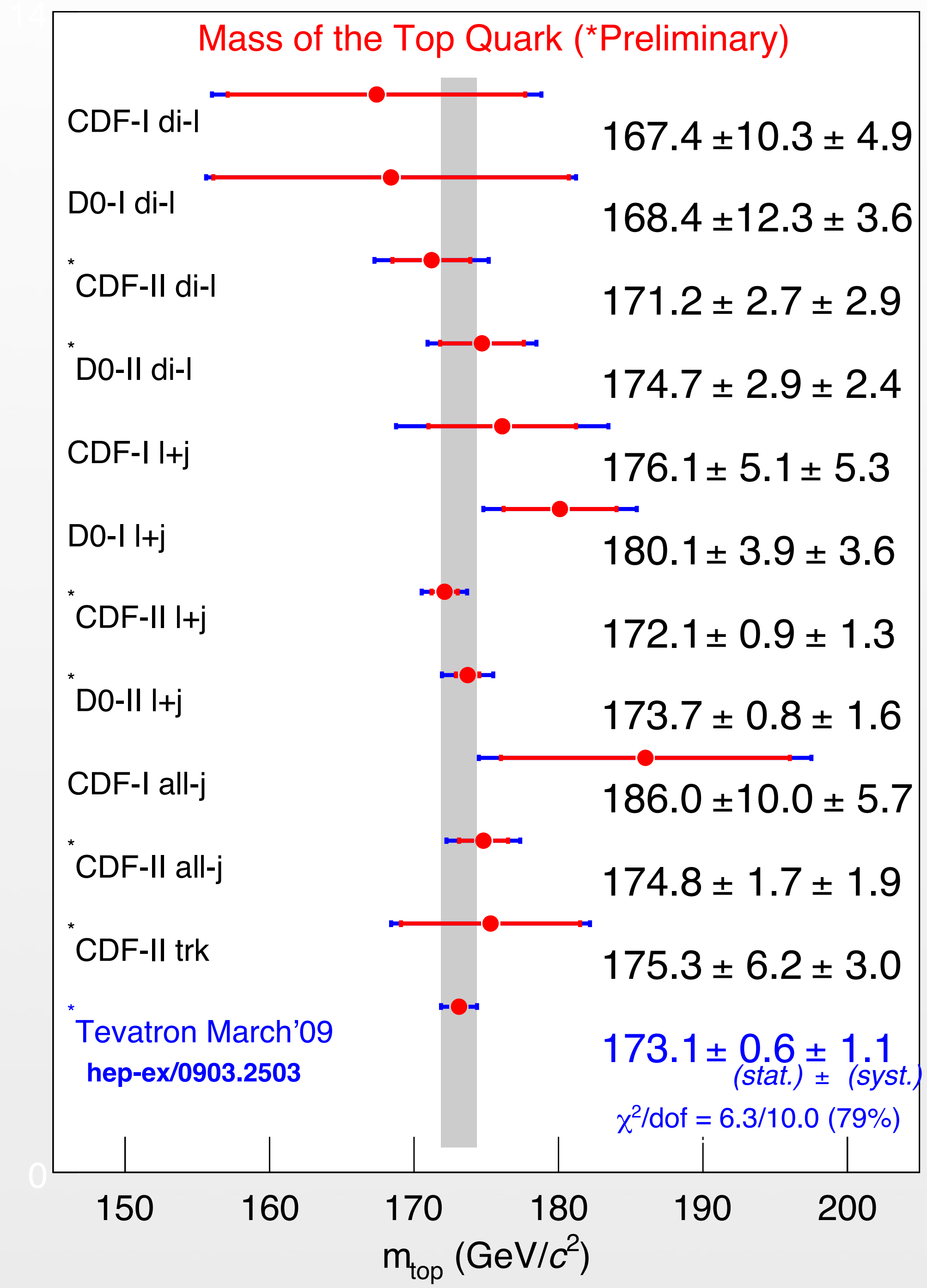
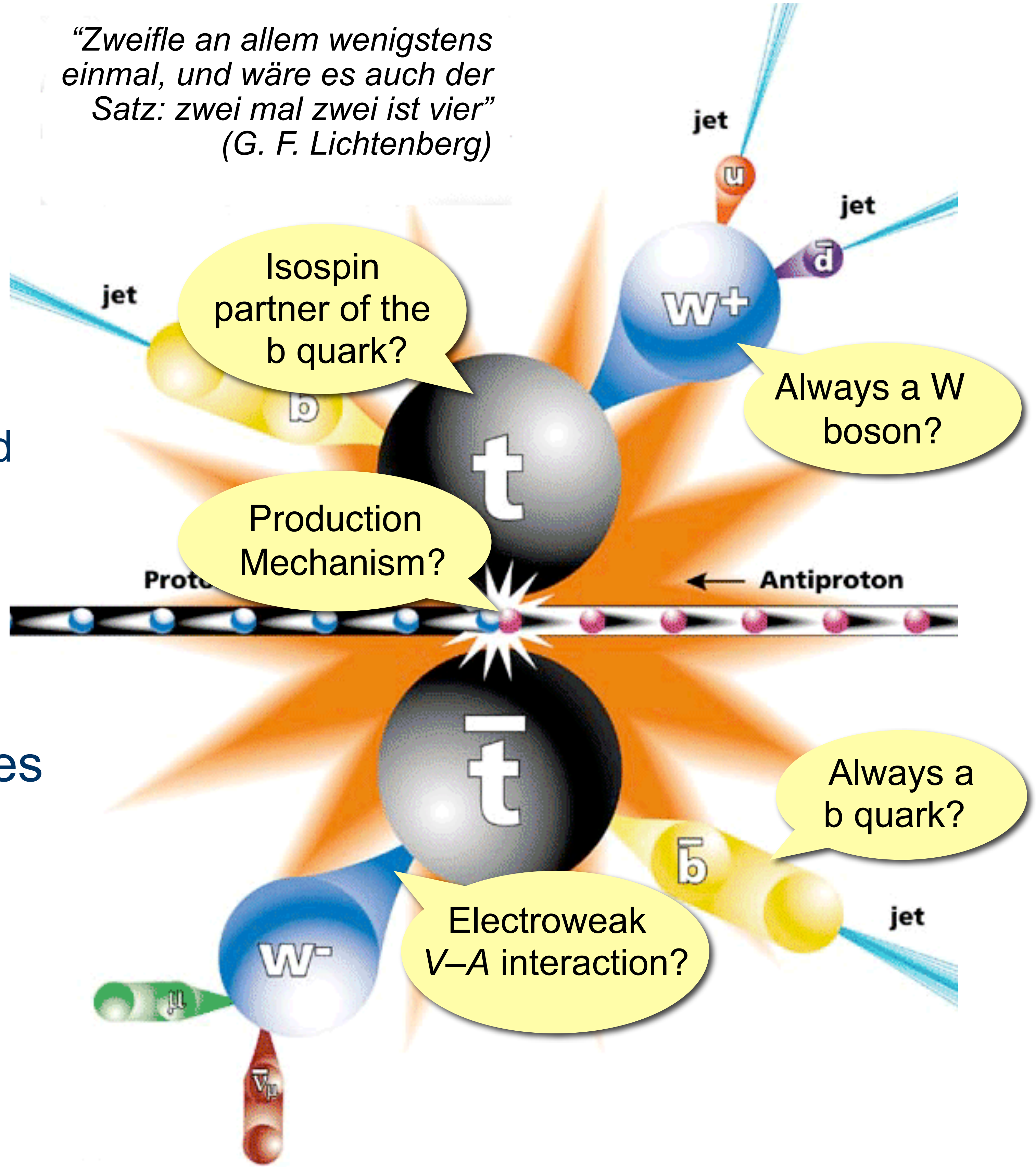
Top Mass Combination 2009: 0.7% Uncertainty



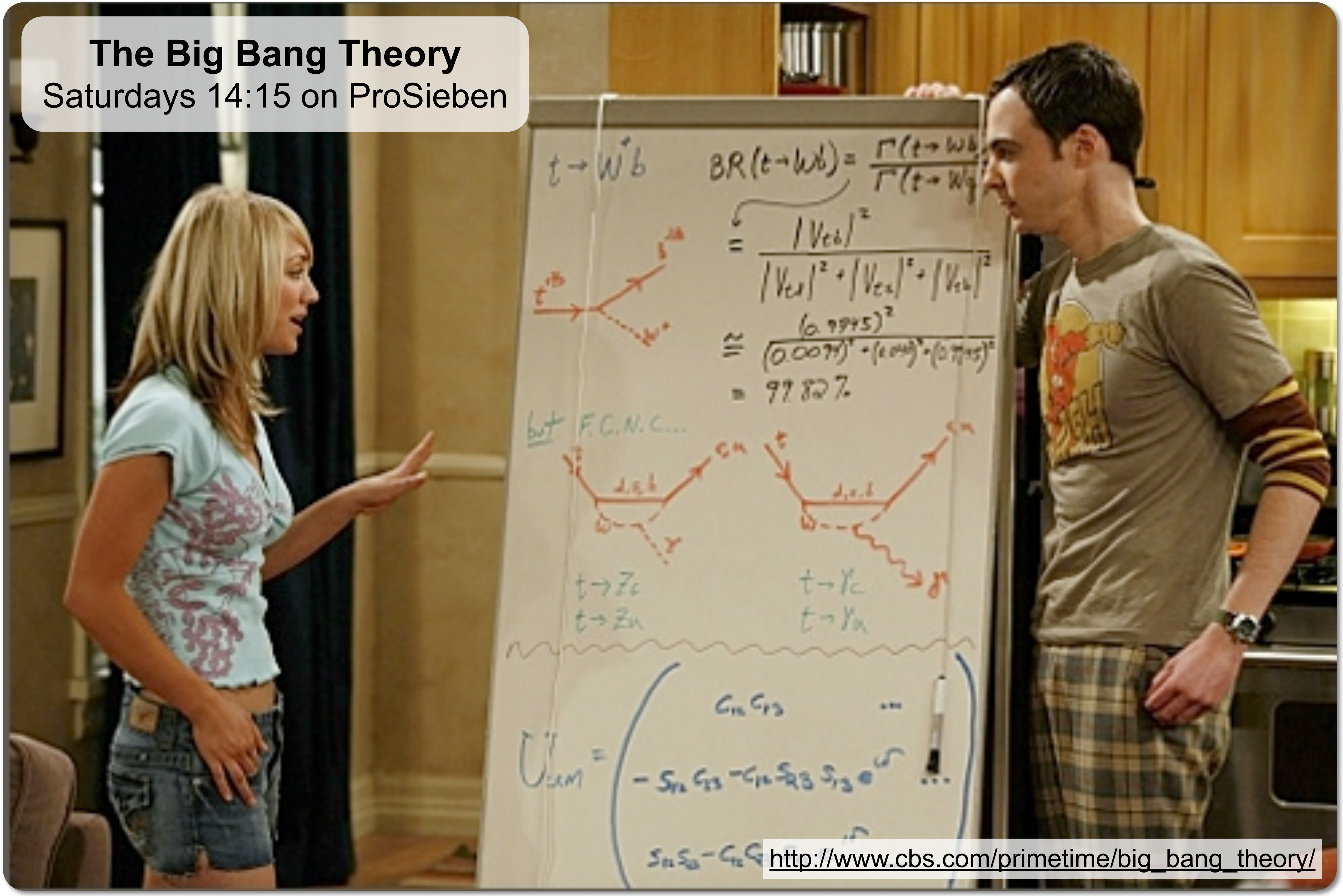
- From top discovery in 1995 to precision physics in 2009:
  - Large top samples
  - Precision mass measurements
  - Single top production discovered
- Broad top properties program (≈ 40 CDF results for summer conferences, 15 from top!)
- Measurements of top properties try to answer:

Is the top really the standard model top?

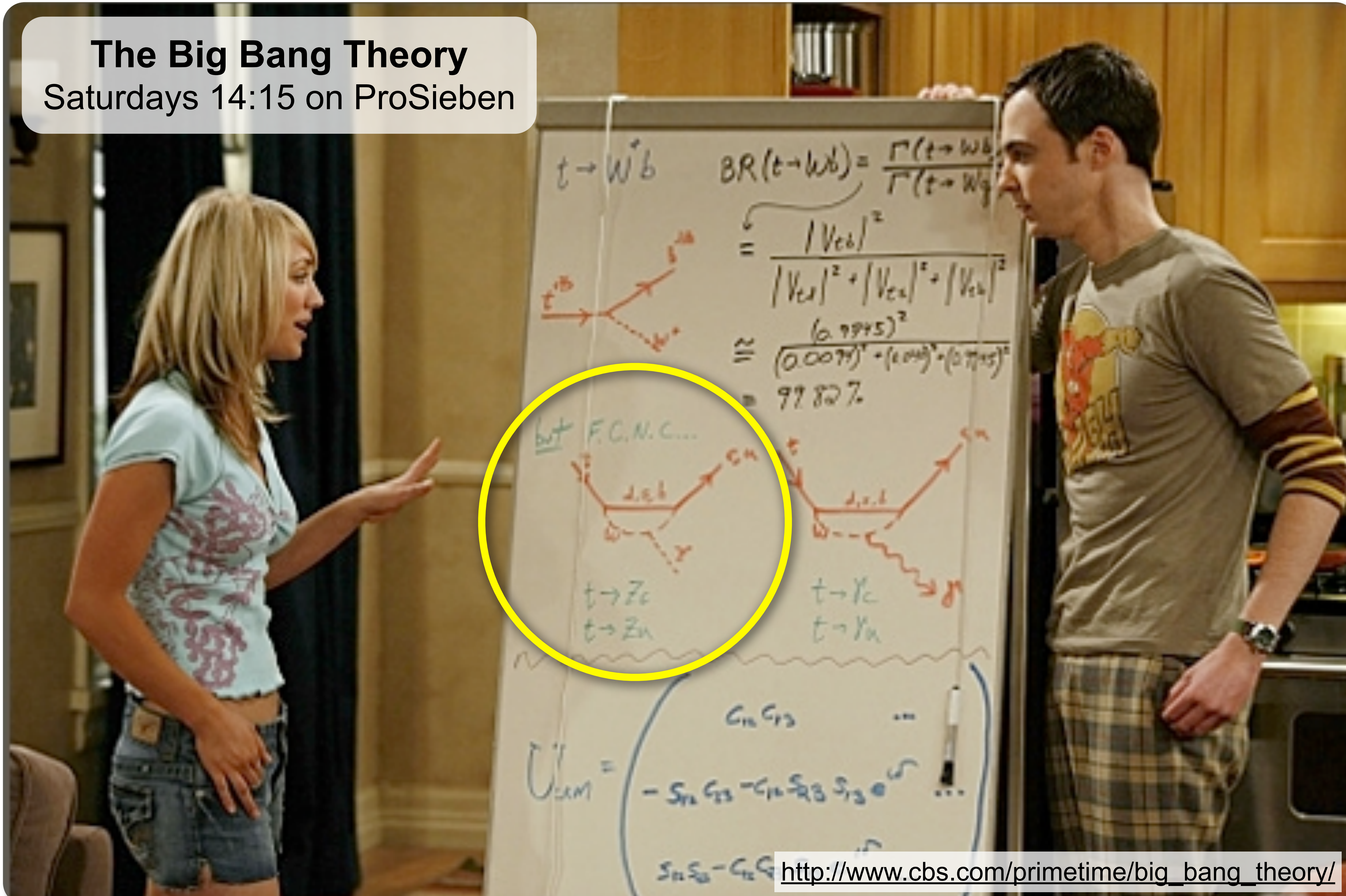
"Zweifle an allem wenigstens einmal, und wäre es auch der Satz: zwei mal zwei ist vier"
(G. F. Lichtenberg)



Top Physics Makes Prime Time!



The Big Bang Theory
Saturdays 14:15 on ProSieben



http://www.cbs.com/primetime/big_bang_theory/

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Search for FCNC in Top Quark Decays

Basic Ingredients:
Signal and Background

Round I:
Counting Experiment

Round II:
Template Fit

Outline of the Talk

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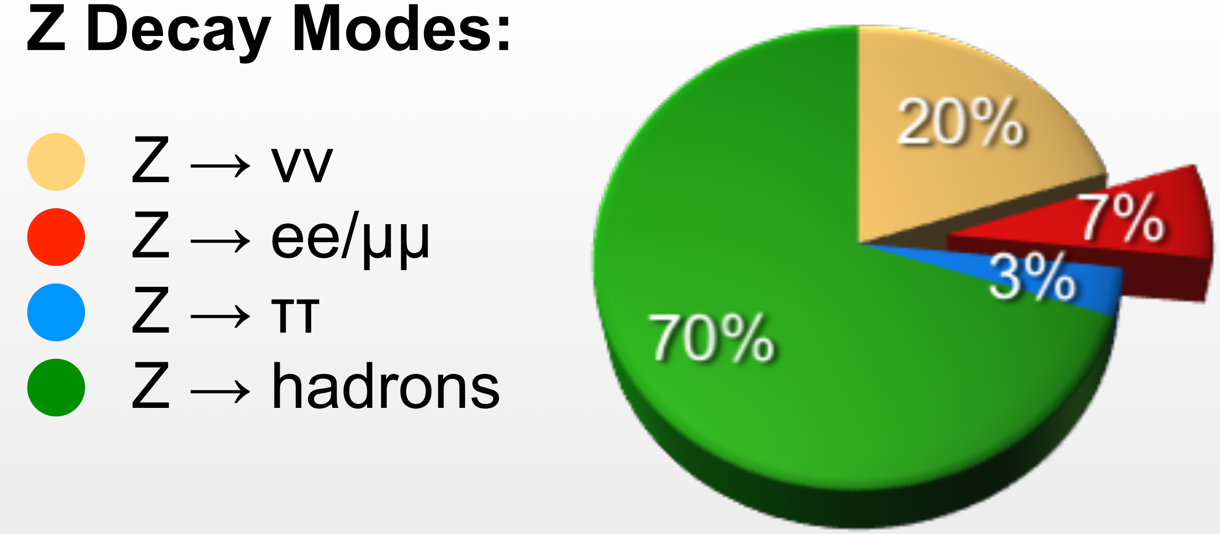
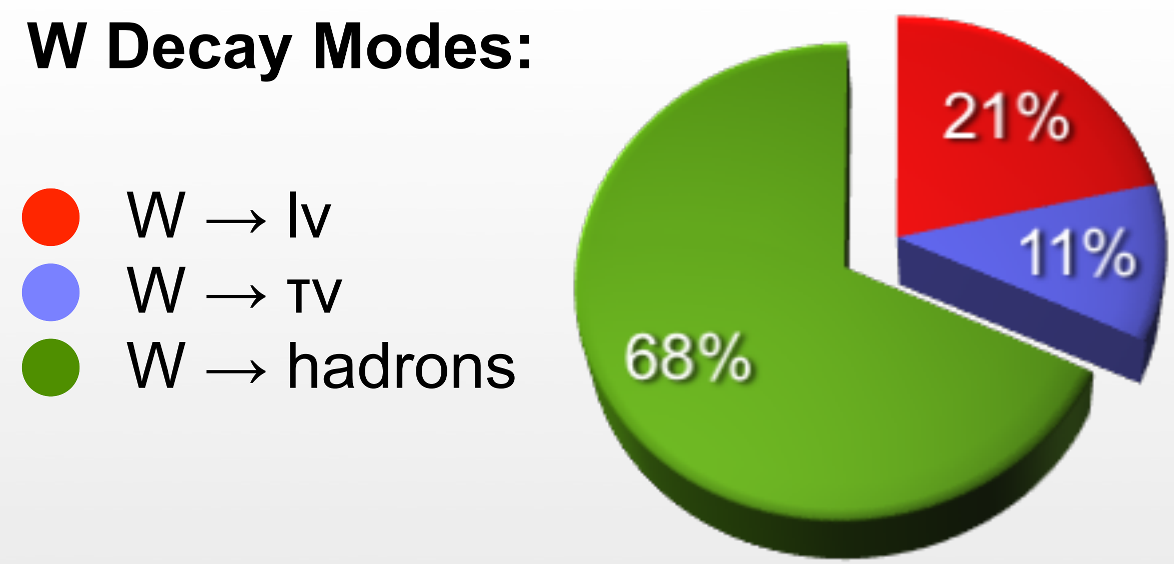
Top FCNC Event Signature

- Basic question: how often do top quarks decay into Zq?
- Result: discovery of top FCNC or limit on branching fraction B(t → Zq), where q=u,c
- Selected decay channels for $t\bar{t}$ → Zq Wb:
  - Z → charged leptons: very clean signature, lepton trigger
  - W → hadrons: large branching fractions, no neutrinos (→ event can be fully reconstructed)
- Final signature: Z + ≥4 jets

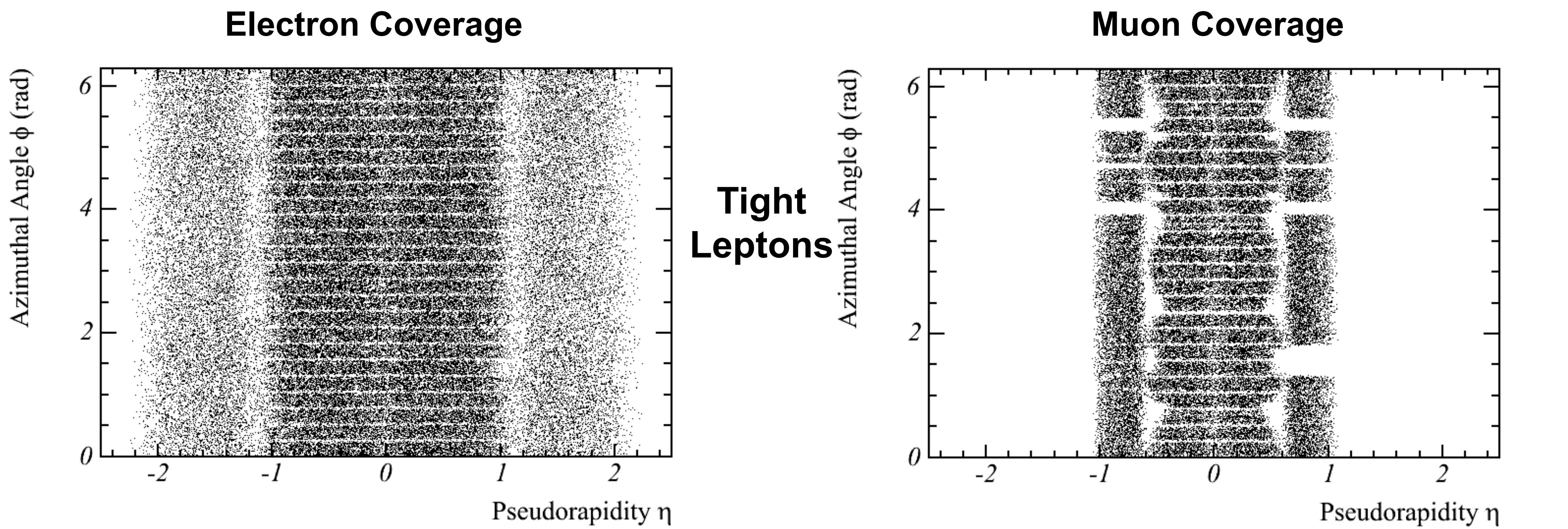
Z Decay Modes:



W Decay Modes:



Z Boson Reconstruction



- Simple trigger: single e/μ with p_T >18 GeV/c
- Sharp Z resonance, good lepton p_T resolution
  → mass window: 76 GeV/c^2 < M_{ll} < 106 GeV/c^2
- Enhancing the Z acceptance for this analysis:
  - Allow second lepton to be isolated track
    → doubles Z acceptance w.r.t. standard lepton selection
  - Correct track momentum with calorimeter energy → 3% more dielectron pairs

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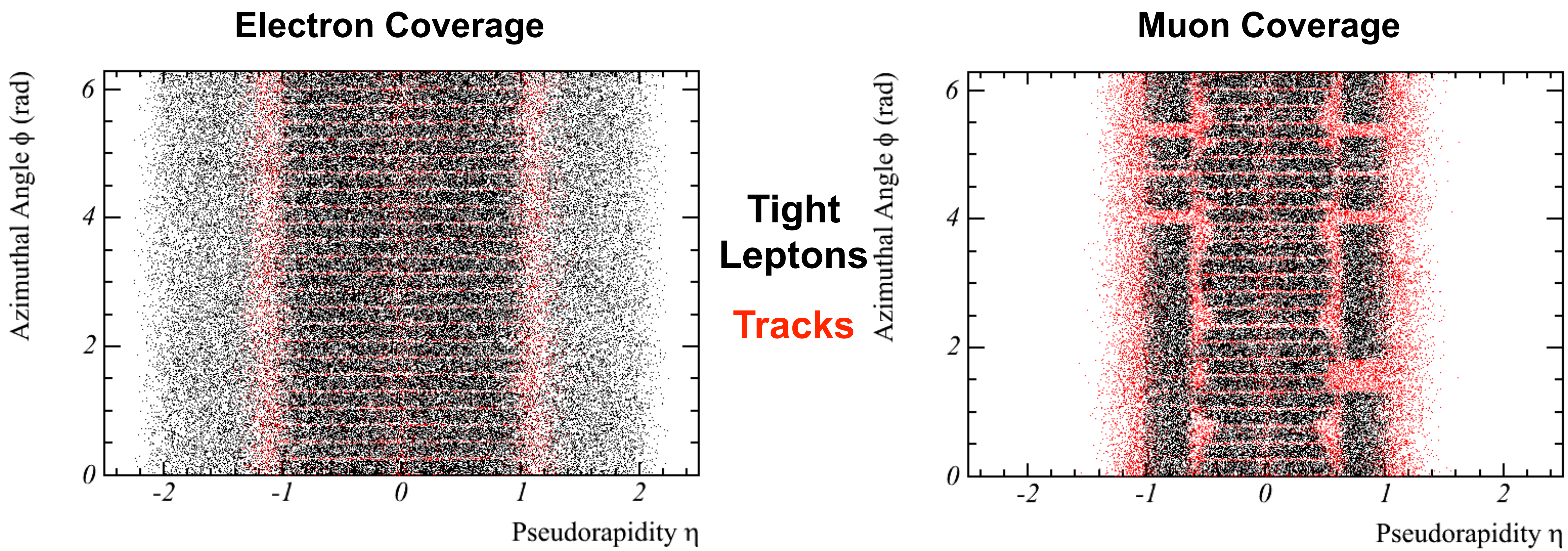

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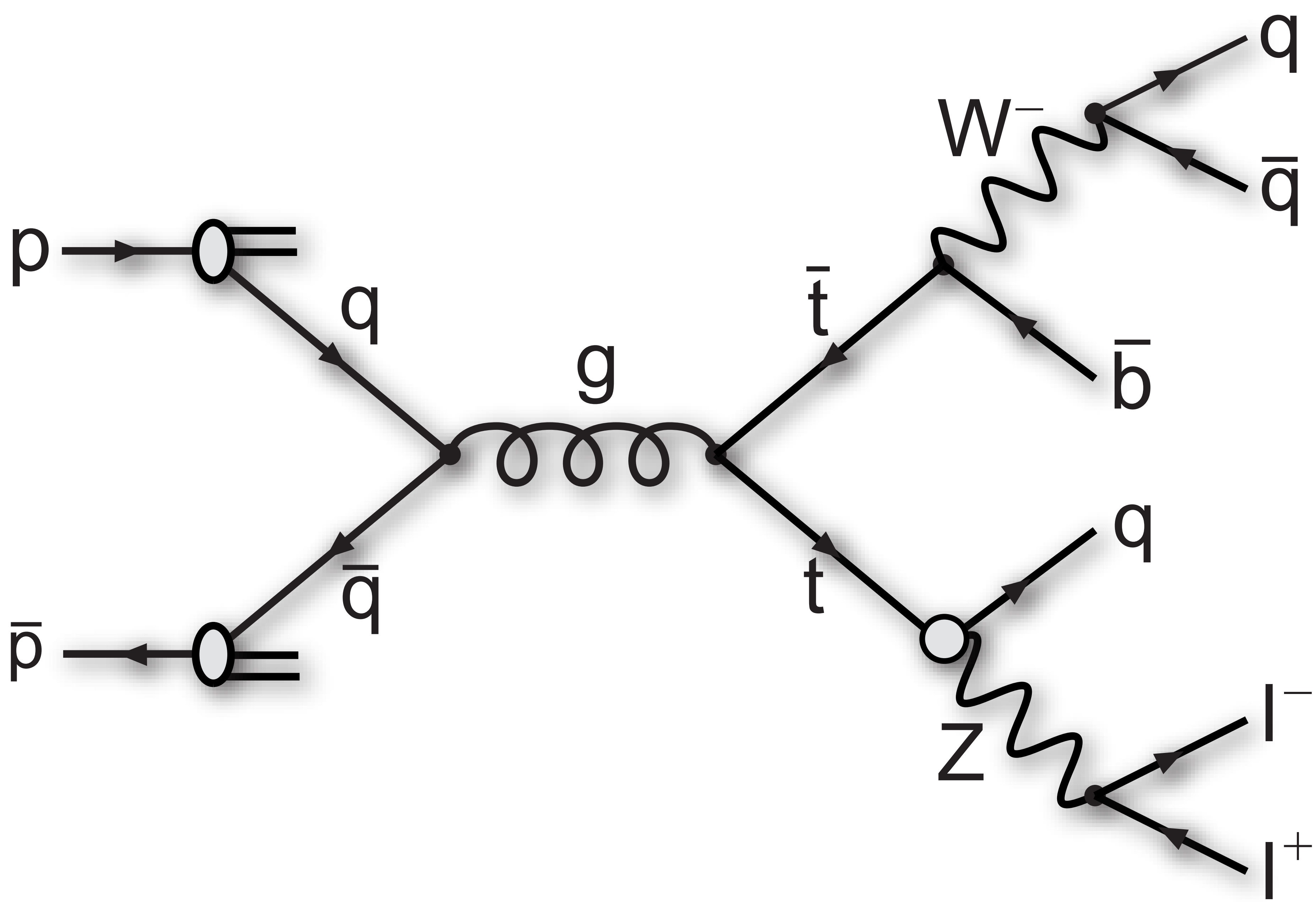
Kinematic Constraints



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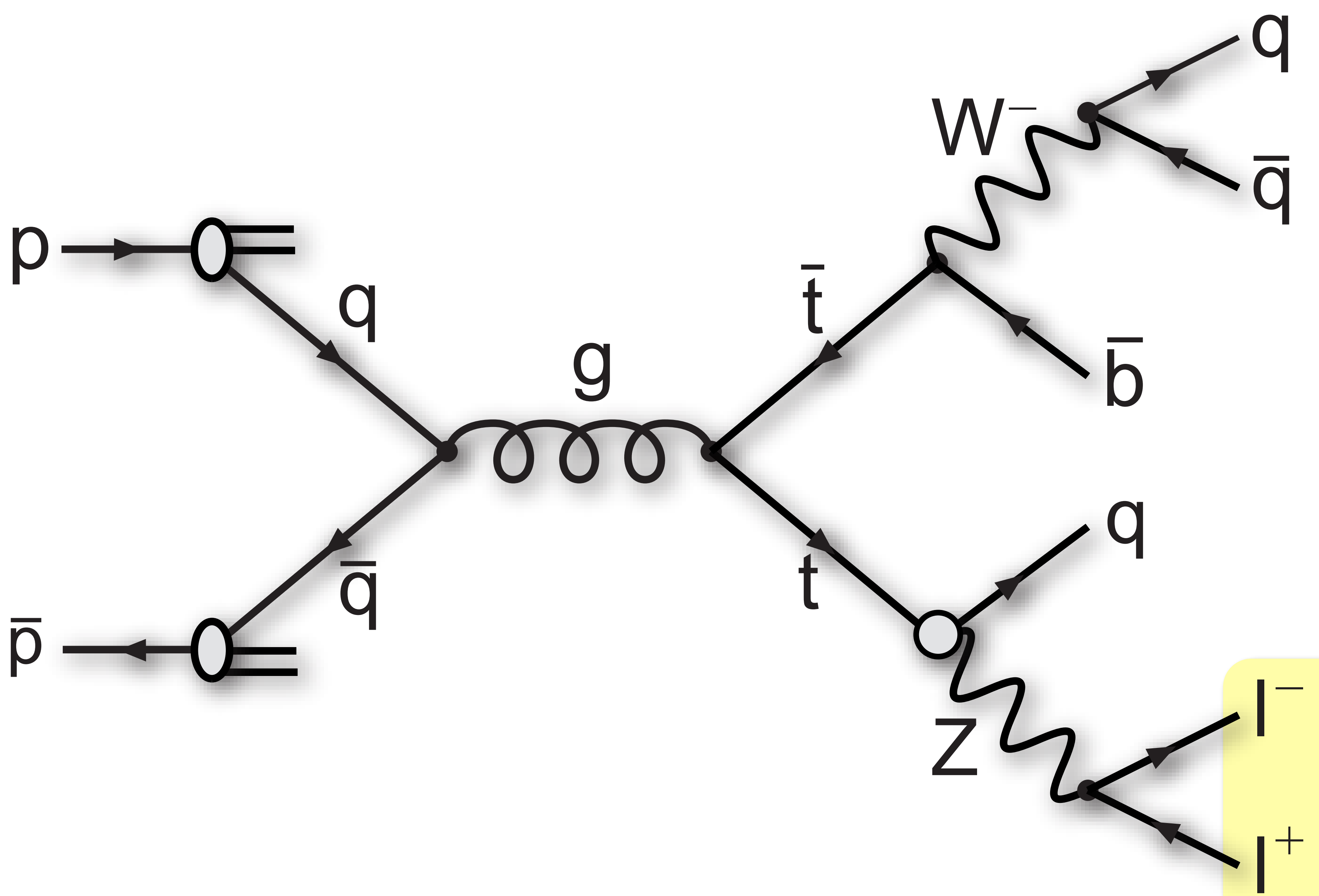
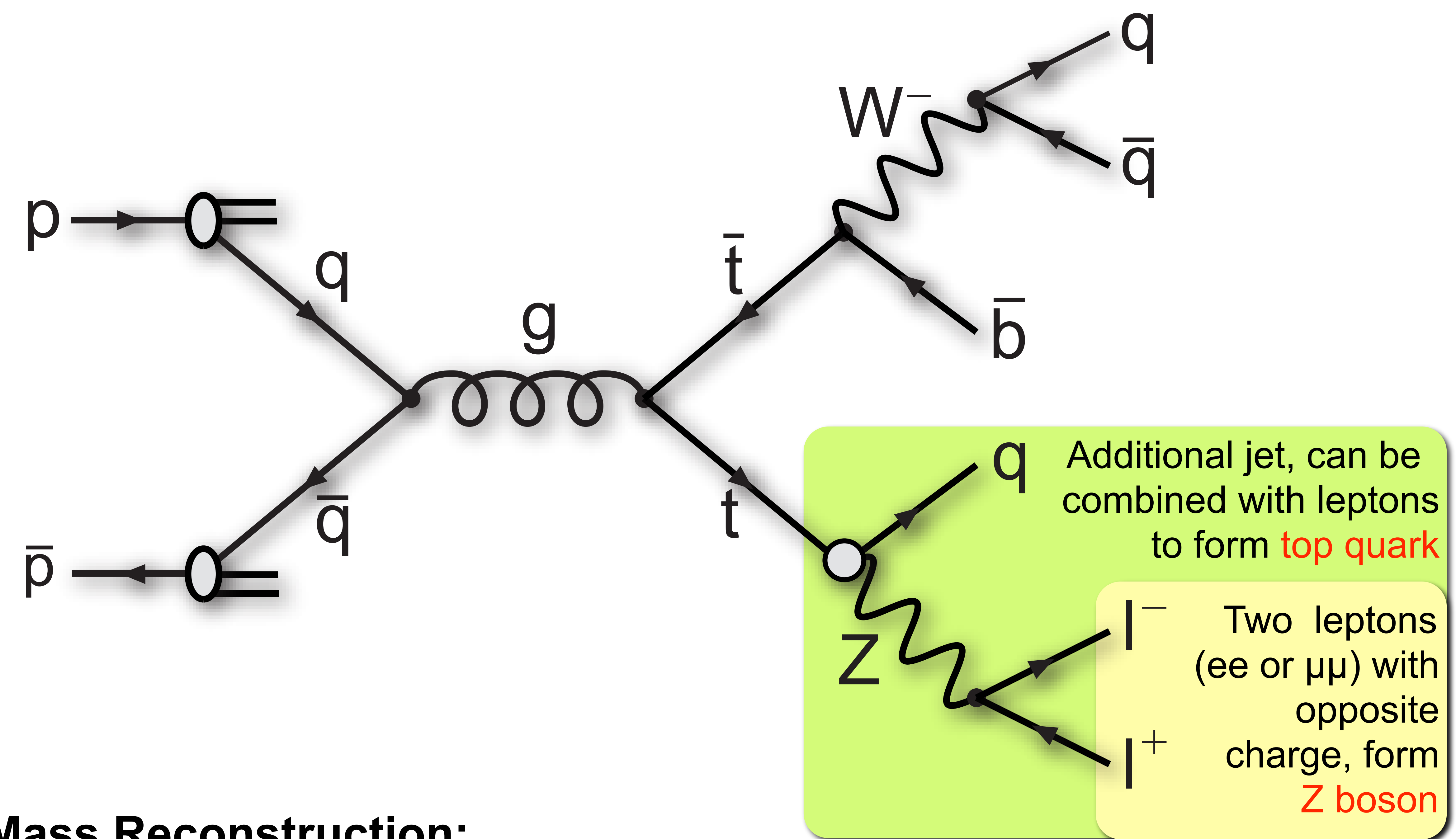


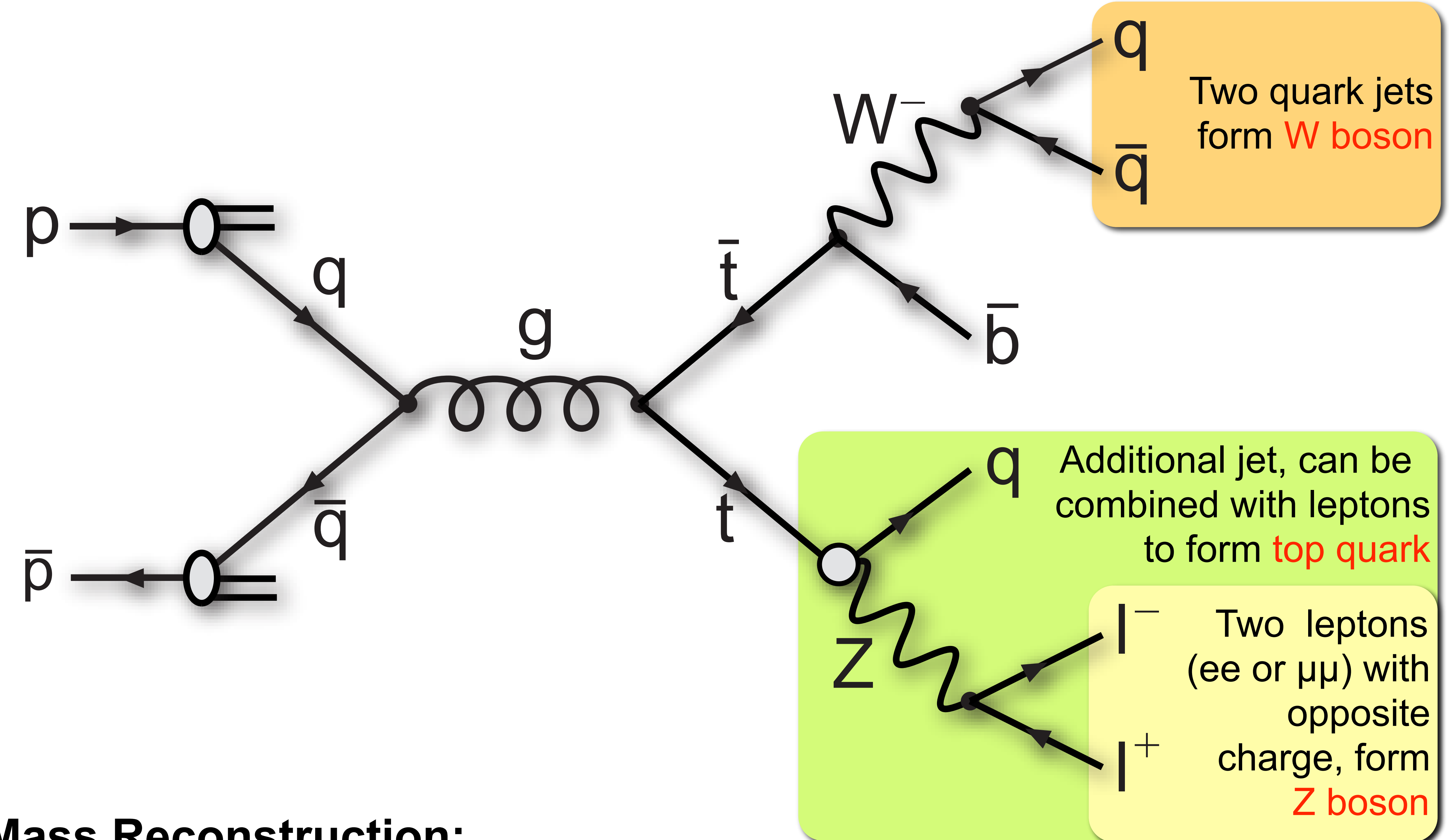
Two leptons (ee or μμ) with opposite charge, form Z boson



Mass Reconstruction:

$$\chi^2 = \left(\frac{m_{t\to Zq,\mathrm{rec}} - m_t}{\sigma_{t\to Zq}} \right)^2$$

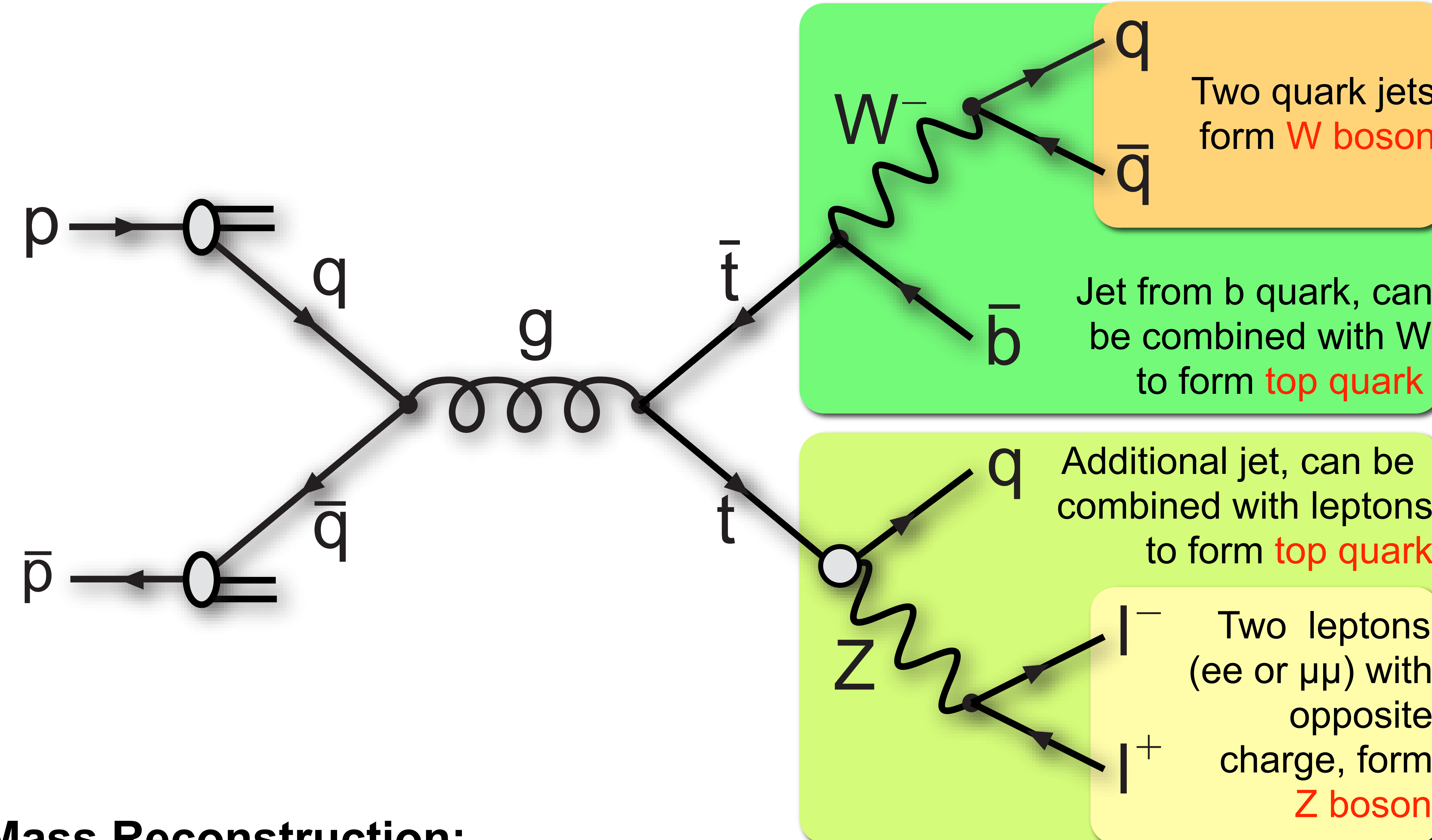
Kinematic Constraints



Mass Reconstruction:

$$\chi^2 = \left(\frac{m_{t\to Zq,\mathrm{rec}} - m_t}{\sigma_{t\to Zq}} \right)^2 + \left(\frac{m_{W,\mathrm{rec}} - m_W}{\sigma_W} \right)^2$$

Kinematic Constraints



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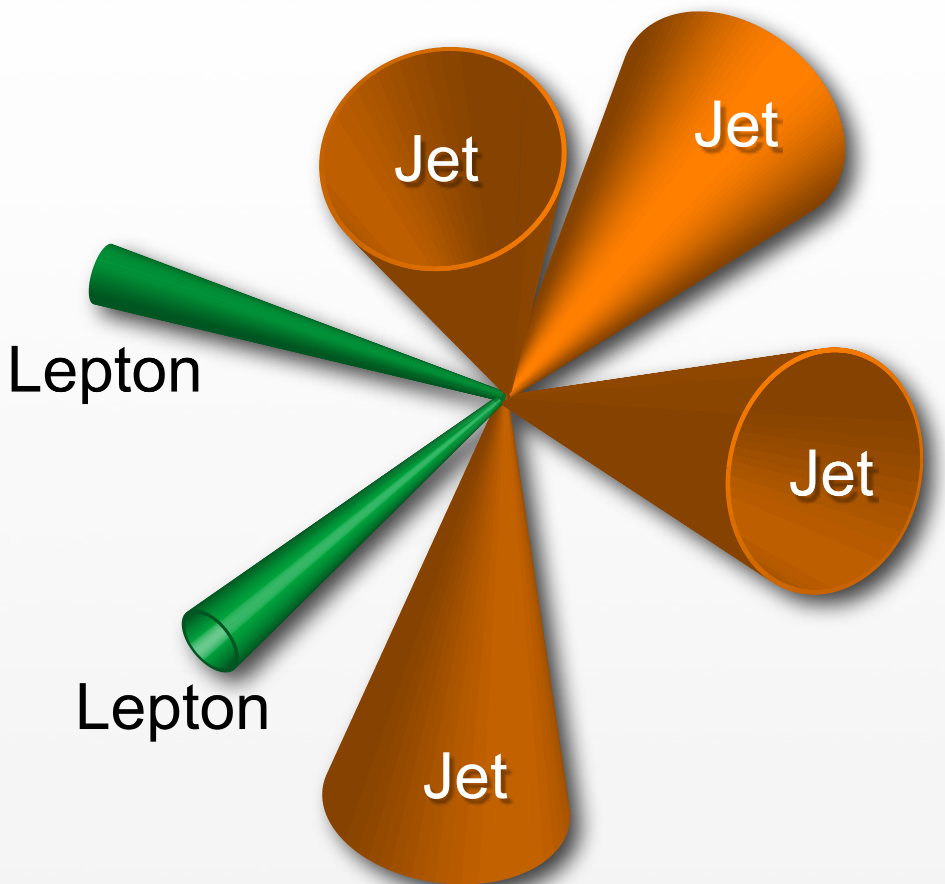
Mass χ^2 Details



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- Jet-parton assignment unknown:
  - Check all 12 possible combinations of four highest E_T jets
  - Pick combination with lowest mass χ^2
- “Fix” reconstructed W/Z masses
  - Vary momenta of W/Z daughters within resolution to adjust masses
  - Improves mass resolution → better sensitivity
- Widths reflect mass resolutions as measured in MC simulation:
  - $\sigma_{W,\mathrm{rec}}$ = 15 GeV/c^2
  - $\sigma_{t\to Wb,\mathrm{rec}}$ = 24 GeV/c^2
  - $\sigma_{t\to Zq,\mathrm{rec}}$ = 21 GeV/c^2

Expected Backgrounds

- How do you search for a signal that is likely not there?
  → Understand the background!

Standard Model Background	Signature	Importance	Estimated from
Z+Jets Production	Real Z boson, very similar to FCNC signal	Dominant, most difficult to estimate	Data (normalizations) & MC (shapes)

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Diboson Production: WZ, ZZ	Real Z boson	Small, more important if b-tag required ($Z \to b\bar{b}$)	Monte Carlo

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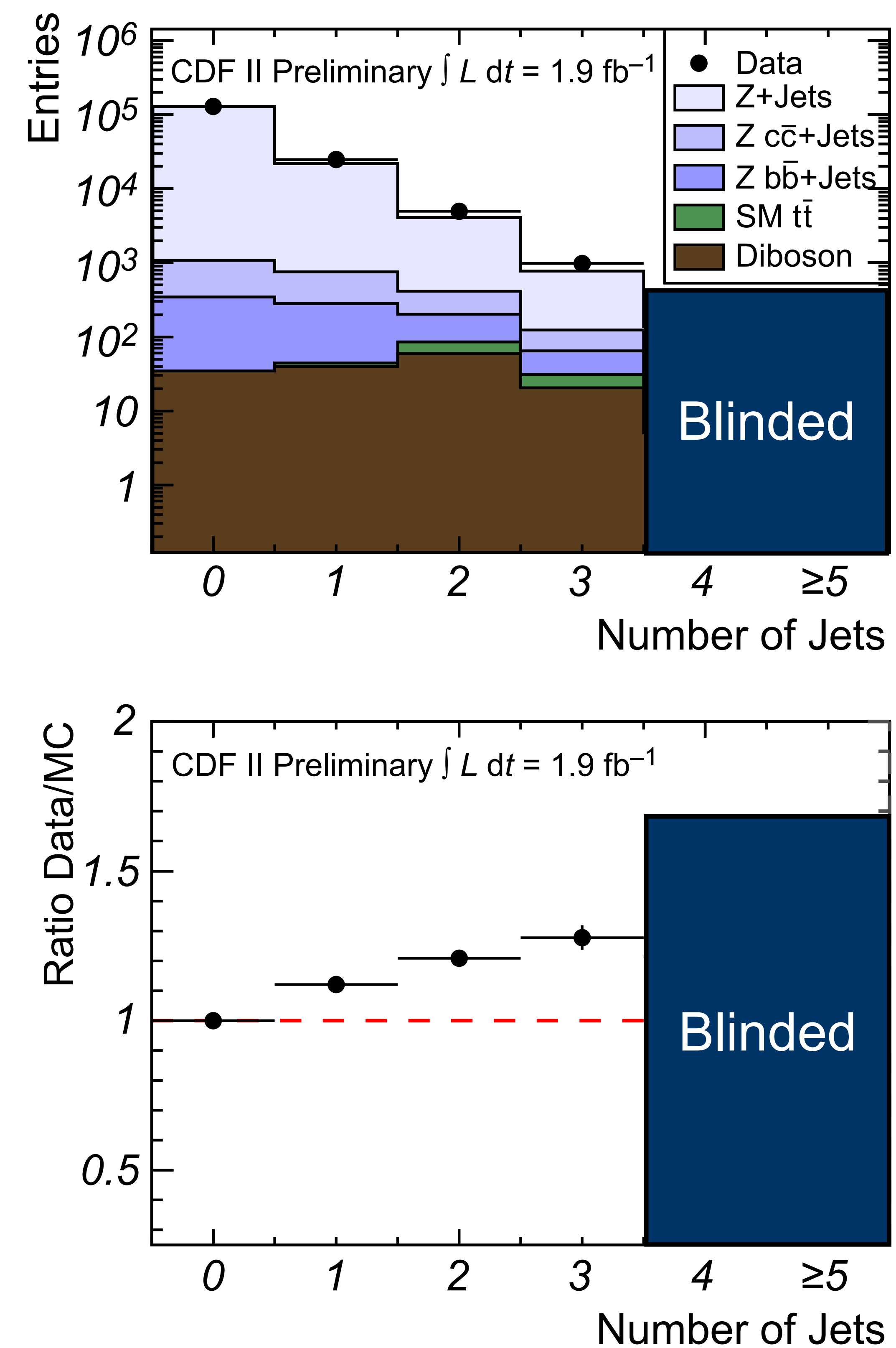
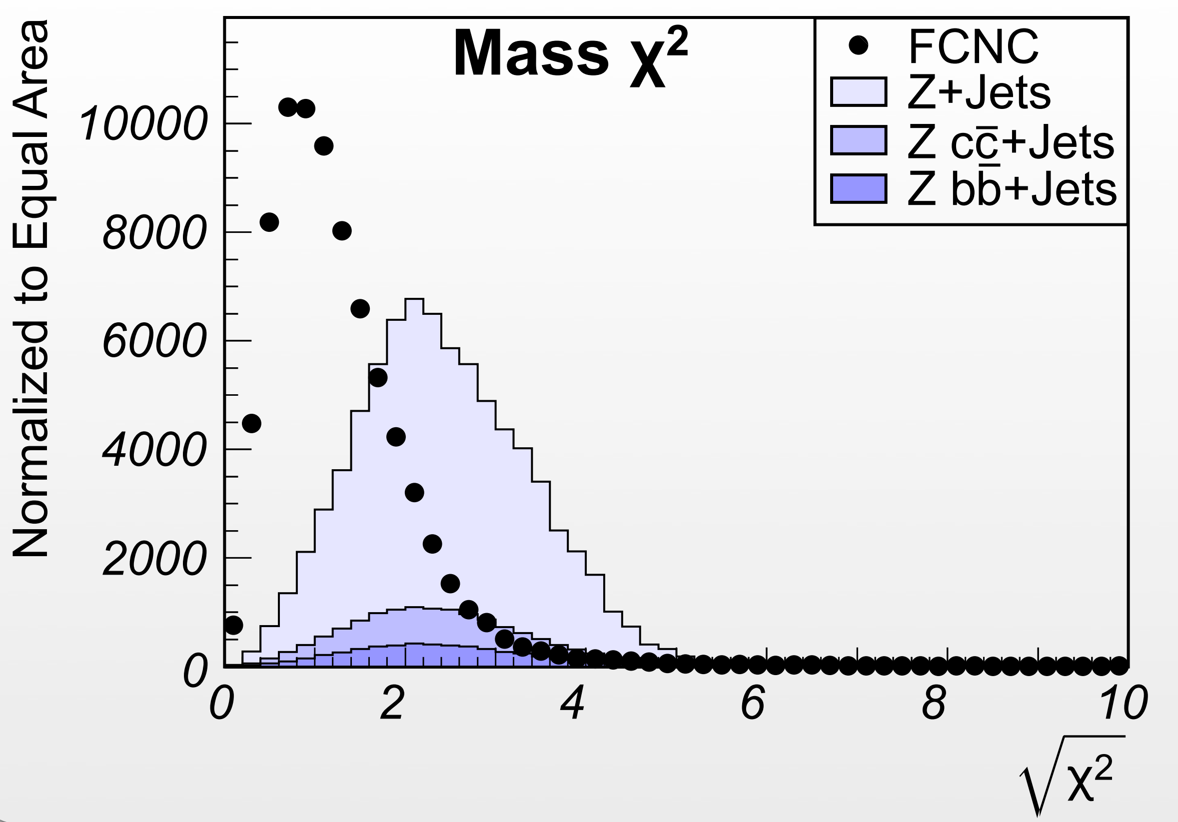
Diboson Production: WZ, ZZ	Real Z boson	Small, more important if b-tag required ($Z\to b\bar{b}$)	Monte Carlo
Others: W+Jets, WW Production	No real Z boson	Negligible	Monte Carlo & Data

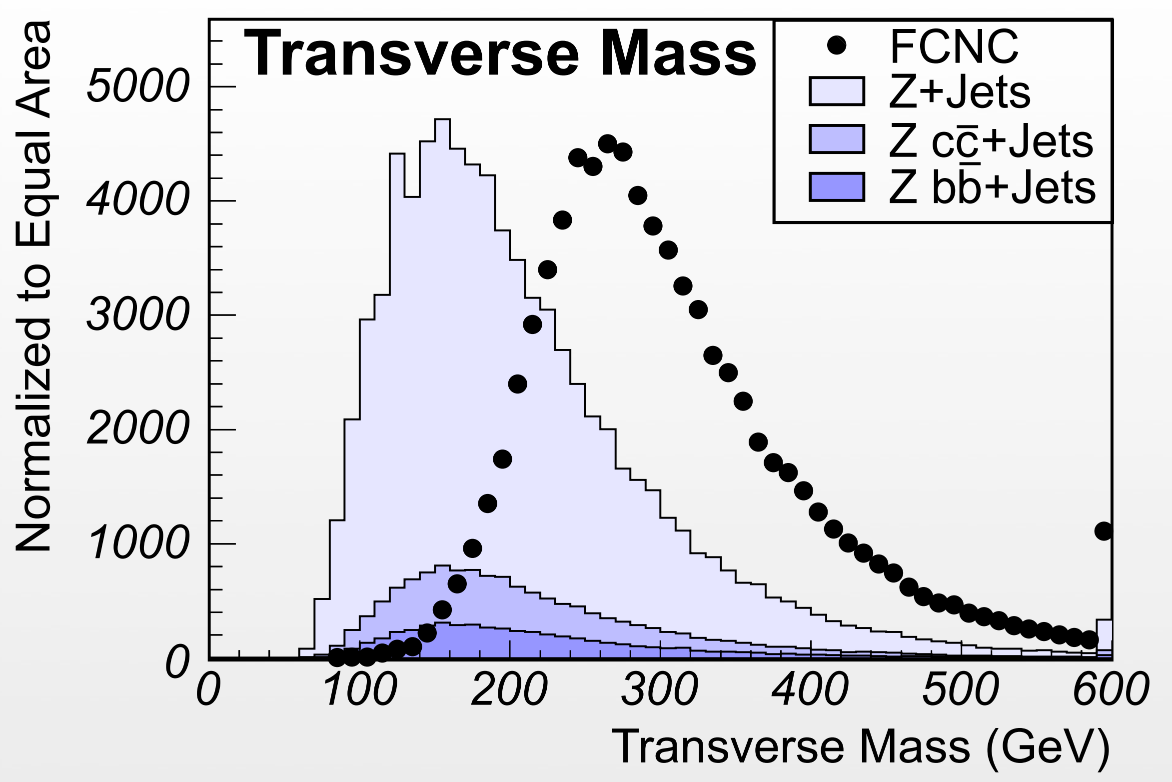
Z+Jets Production

- MC tool for Z+Jets: ALPGEN
  - Modern MC generator for multiparticle final states (exact 2→n matrix elements), PYTHIA for parton showers
  - “MLM matching”: remove overlap between jets from matrix element and partons showers
- Comparing ALPGEN with data:
  - Leading order generator: no absolute prediction for cross section
  - Underestimate of number of events with large jet multiplicities, large uncertainties
- Our strategy: only shapes of kinematic distributions from MC, normalization from control samples in data



Separating Signal from Background





- Mass χ^2: combination of mass constraints – best discriminator

$$\chi^2 = \left(\frac{m_{W,\mathrm{rec}} - m_W}{\sigma_W}\right)^2 + \left(\frac{m_{t\to Wb,\mathrm{rec}} - m_t}{\sigma_{t\to Wb}}\right)^2 + \left(\frac{m_{t\to Zq,\mathrm{rec}} - m_t}{\sigma_{t\to Zq}}\right)^2$$

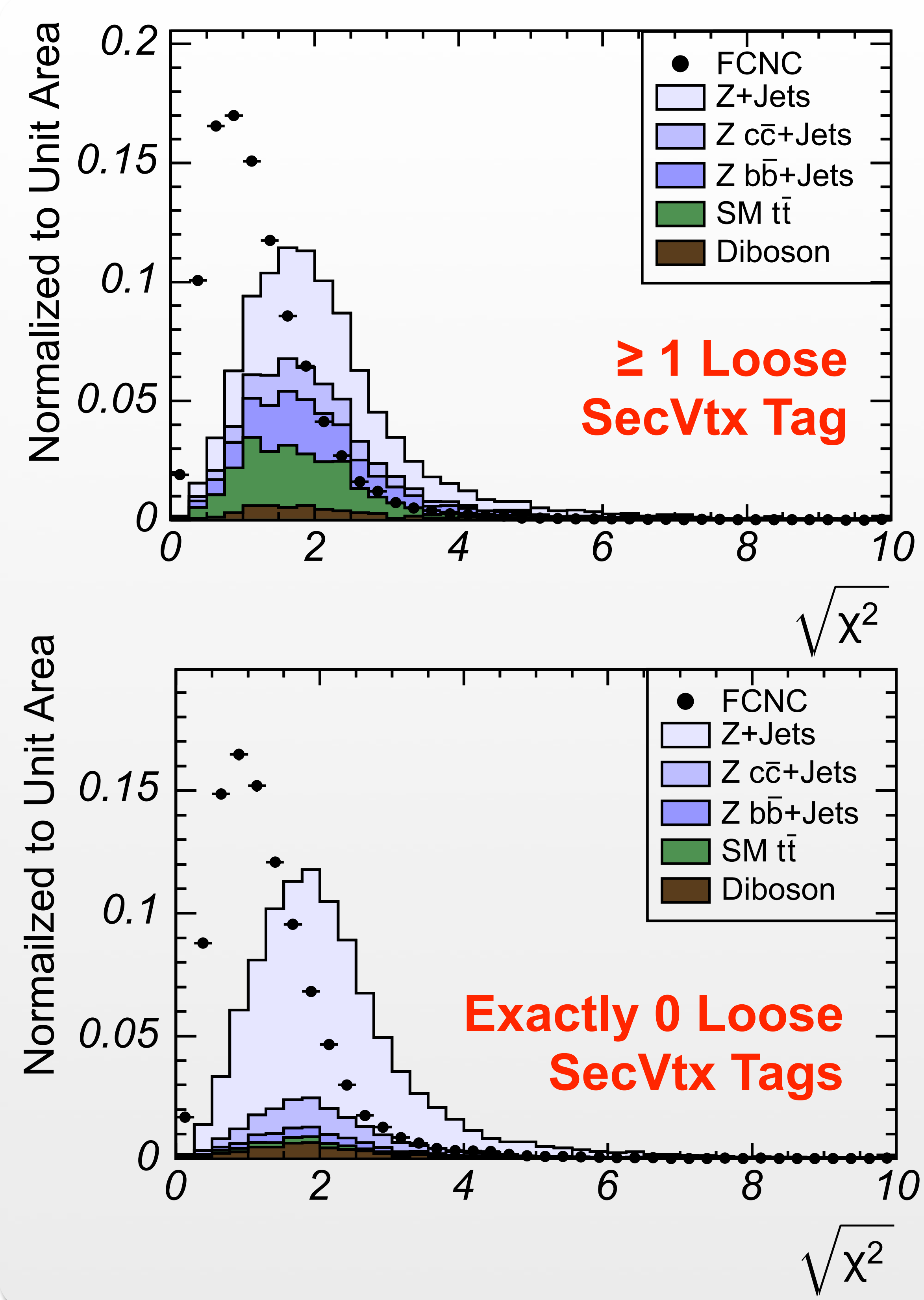
- Transverse mass: top decays (including FCNC) are more central than Z+jets

$$M_T = \sqrt{\left(\sum E_T\right)^2 - \left(\sum \vec{p}_T\right)^2}$$

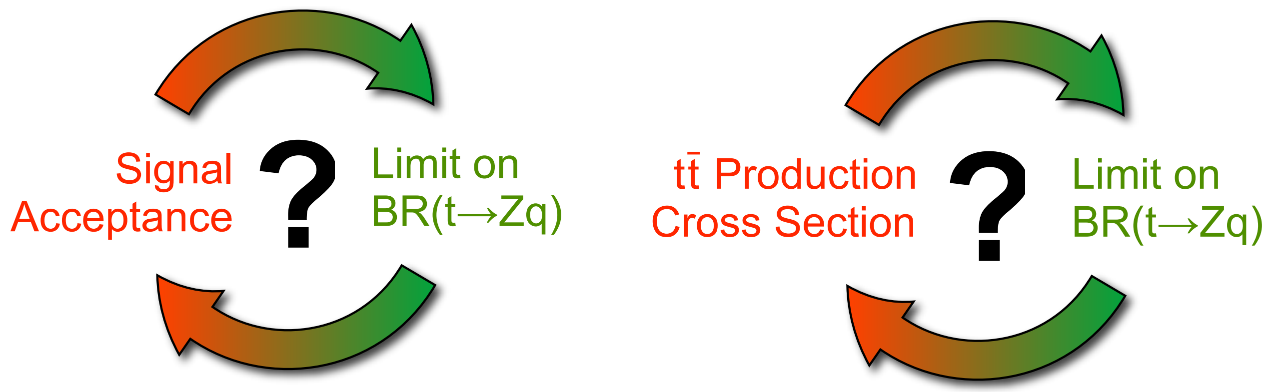
- Jet transverse energies: FCNC signal has four “hard” jets, background processes: jets have to come from gluon radiation

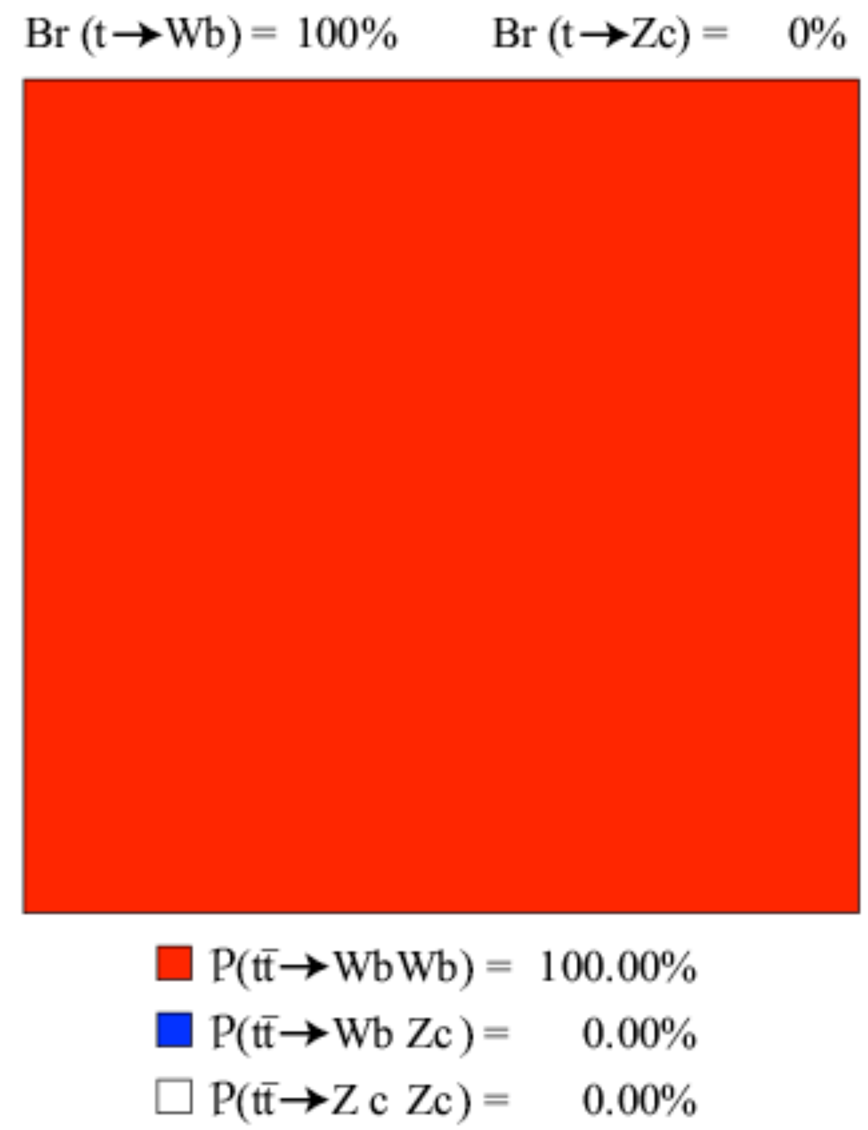
To B-Tag or not to B-Tag?

- Requiring a SecVtx b-tag?
  - Advantage:
    Better discrimination against Z+jets
  - Disadvantage:
    Reduction of data sample size
- Solution: use both!
  - Split sample in tagged and anti-tagged
  - Combine samples in limit calculation
- Need to take into account event migration between samples
  - Correlated systematic uncertainties:
    affect samples in same direction
  - Anti-correlated uncertainties:
    move events between samples (e.g. b-tagging efficiency)



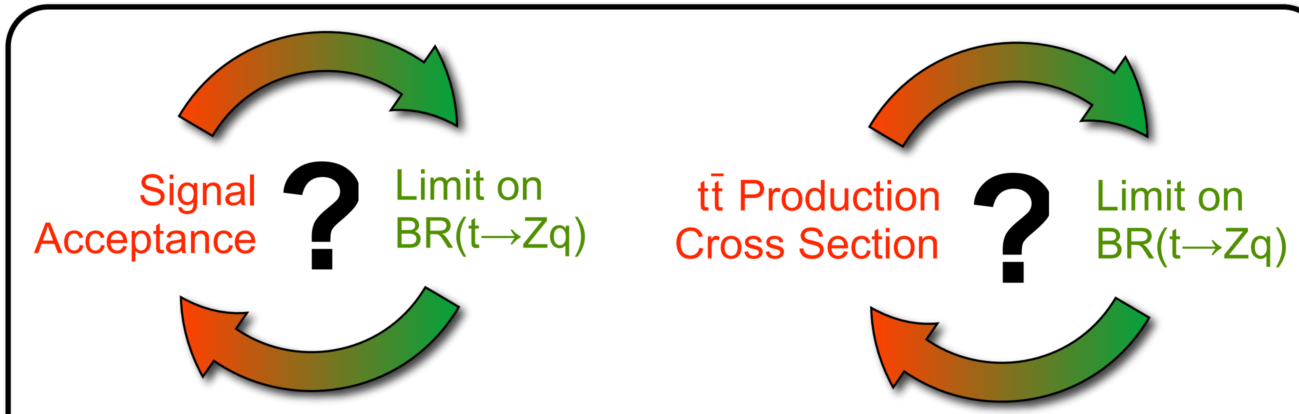
- Question: how do we convert event counts into limit on B(t→Zq)?
  - Circular dependency #1: Limit calculation requires signal acceptance, but signal acceptance depends on limit
  - Circular dependency #2: Measure limit on fraction of $t\bar{t}$ production cross section, but cross section changes with changing FCNC contribution

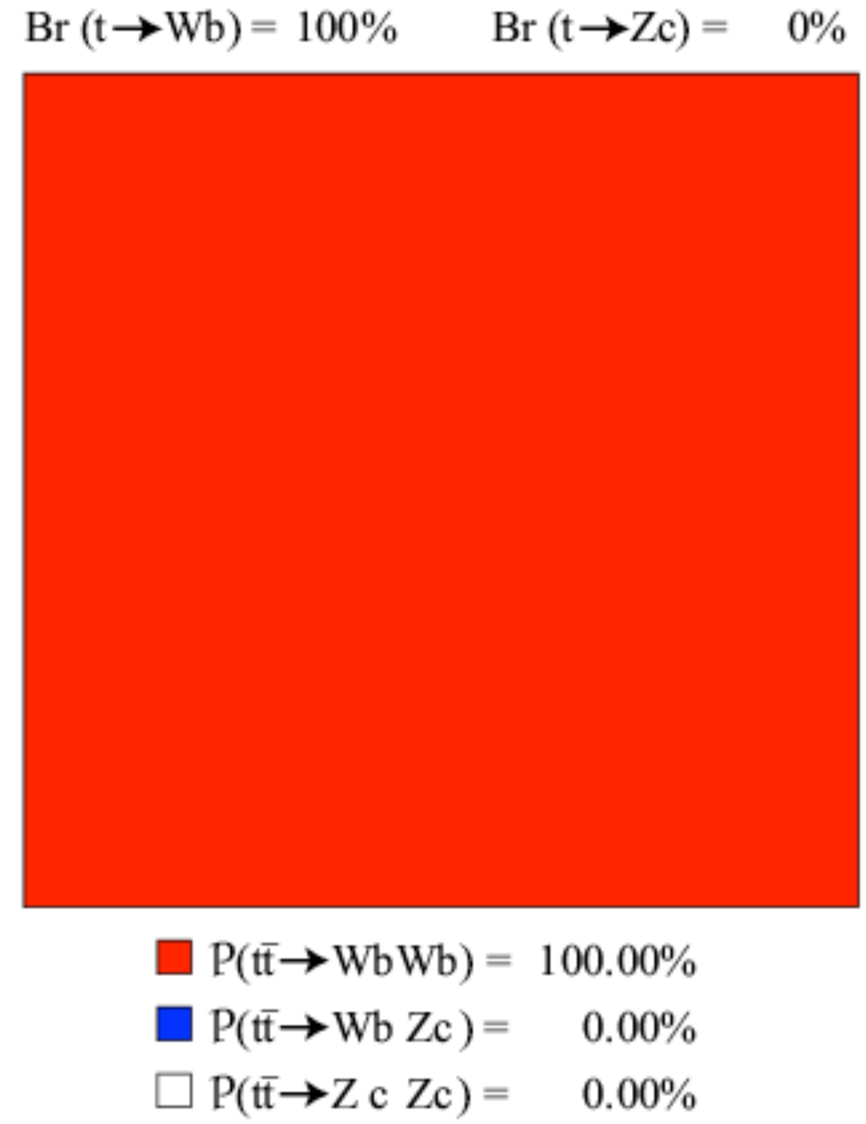




Acceptance Algebra: Catch 22?

- Question: how do we convert event counts into limit on $B(t\to Zq)$?
  - Circular dependency #1: Limit calculation requires signal acceptance, but signal acceptance depends on limit
  - Circular dependency #2: Measure limit on fraction of $t\bar{t}$ production cross section, but cross section changes with changing FCNC contribution
- Solution: "running acceptance" – functional form of dependencies implemented in limit machinery
  - Signal acceptance dynamically adjusted as a function of $B(t\to Zq)$
  - Signal normalized to measured $t\bar{t}$ production cross section measurement
  - $t\bar{t}$ cross section re-interpreted as a function of $BR(t\to Zq)$ to allow for FCNC contribution





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Template Fit

Blind Counting Experiment: Outline

- Blind analysis: avoid biases by looking into the data too early
- Analysis strategy :
  - Blind signal region: Z + ≥ 4 jets (minus control region in Z + ≥ 4 jets)
  - Optimization on data control regions and Monte Carlo (MC) simulation only (event selection, prediction of backgrounds, systematic uncertainties)
  - Very last step: "opening the box", i.e. look into signal regions in data (tagged and anti-tagged)

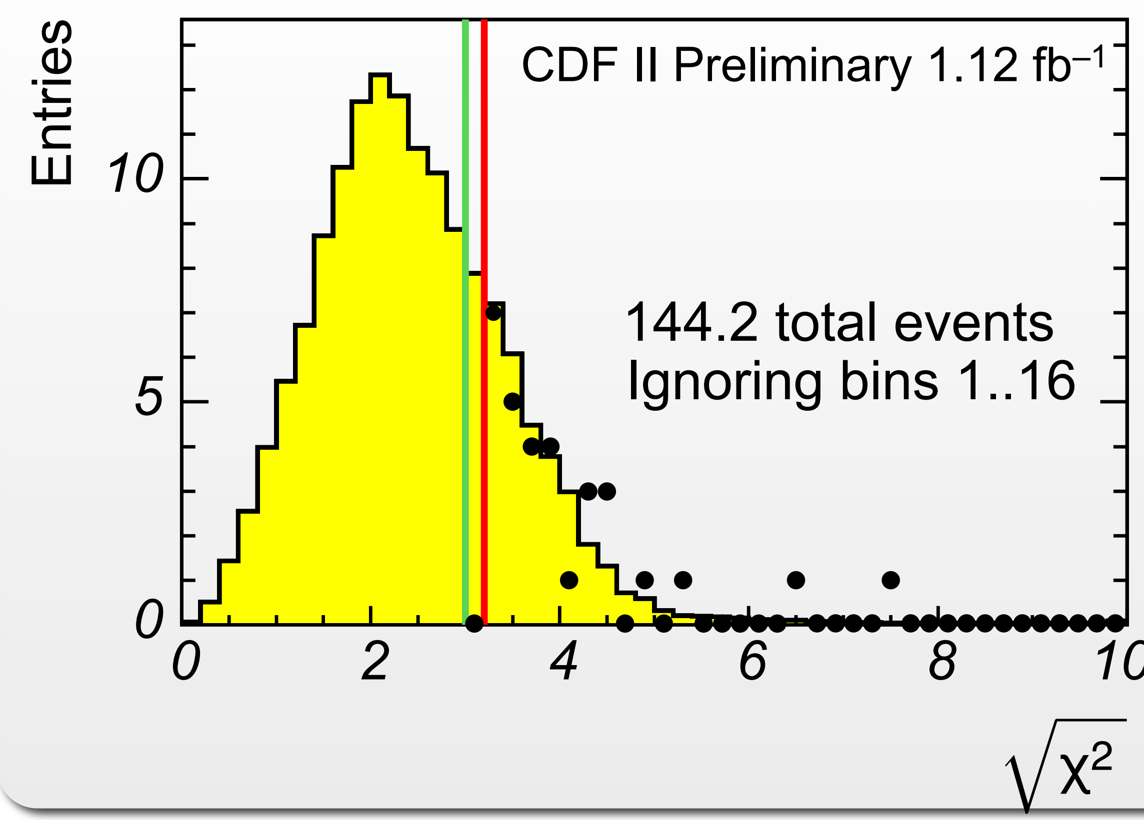
Optimization and Backgrounds

- Selection cuts optimized for best expected limit (in the absence of an FCNC signal)
  - Separately for tagged and anti-tagged sample
  - Expected 95% C.L. upper limit on B(t→Zq): 6.8% ± 3.0% (L3 limit: 13.7%)
- Background estimate: from data
  - Fit to tail of mass χ^2 distribution (little FCNC signal)
  - Use mass χ^2 shape from MC to estimate total background
  - Tagging rate: similar technique

Final Event Selection

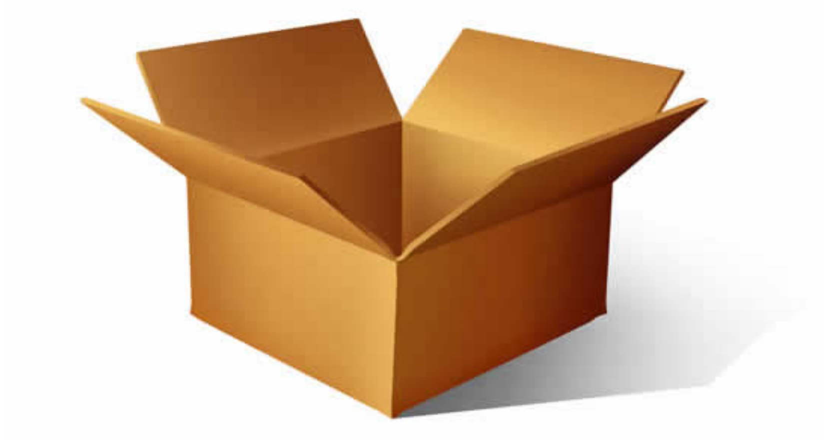
Kinematic Variable	Optimized Cut
Z Mass	$\in [76,106]\,\mathrm{GeV}/c^2$
Leading Jet E_T	$> 40\,\mathrm{GeV}$
Second Jet E_T	$> 30\,\mathrm{GeV}$
Third Jet E_T	$> 20\,\mathrm{GeV}$
Fourth Jet E_T	$> 15\,\mathrm{GeV}$
Transverse Mass	$> 200\,\mathrm{GeV}$
$\sqrt{\chi^2}$	< 1.6 (b-tagged)
	< 1.35 (anti-tagged)

Background Estimate



The World's Best Limit on B(t → Zq)

- Opening the box with 1.12 fb^{-1}



  - Event yield consistent with background only
  - Fluctuated about 1σ high: slightly unlucky

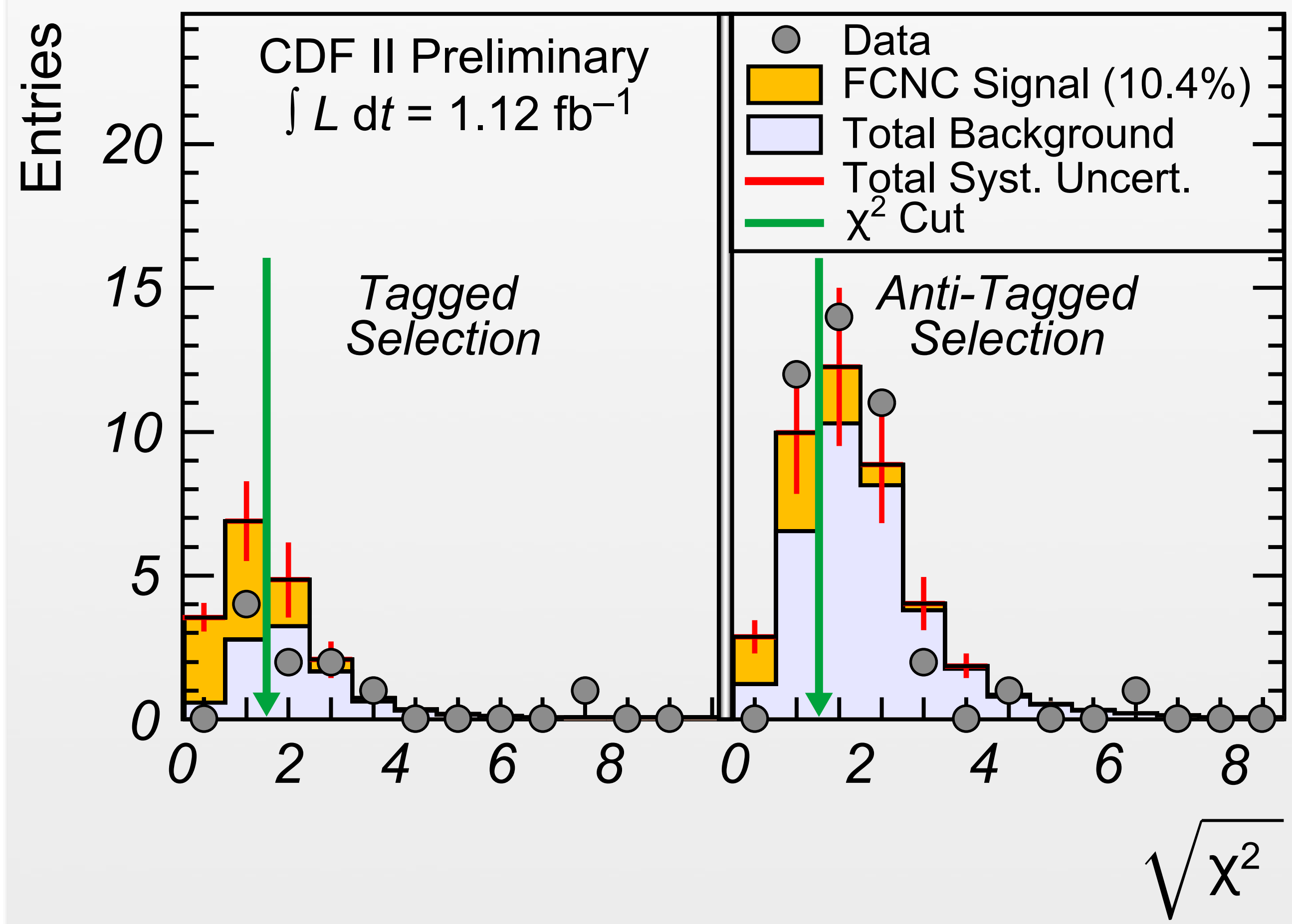
- Result: The World's Best Limit!

B(t→Zq) < 10.4% @ 95% C.L.

  - Expected limit: 6.8% ± 3.0%
  - 25% better than L3 (13.7%)
  - 3x better than CDF Run I (33%)

Selection	Observed	Expected
Base Selection	141	130±28
Base Selection (Tagged)	17	20±6
Anti-Tagged Selection	12	7.7±1.8
Tagged Selection	4	3.2±1.1

Mass χ^2 (95% C.L. Upper Limit)




007
The World's Is Not Enough
Best
Limit

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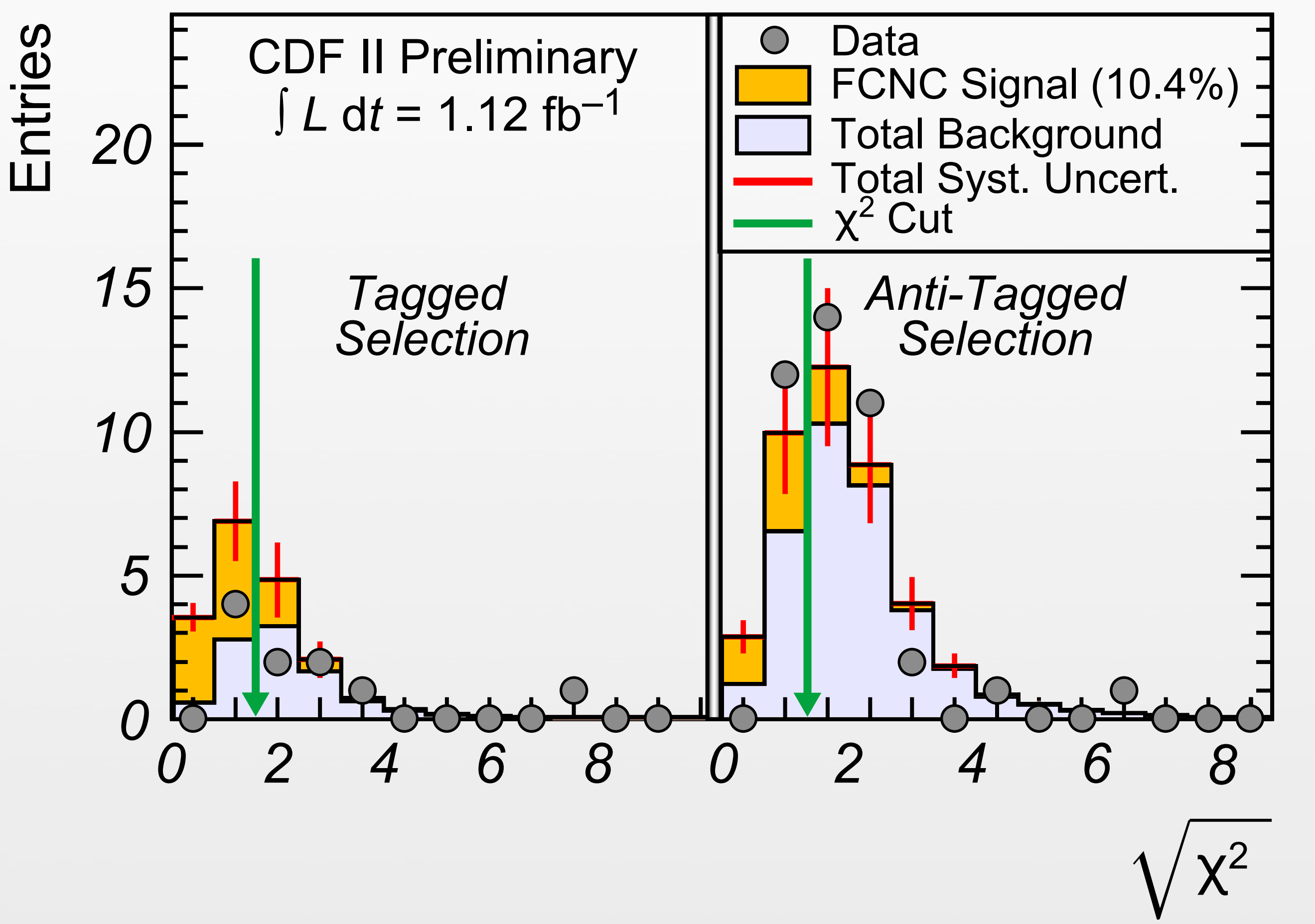
How can we do better?

- 70% more data:
  update with 1.9 fb^{-1}
- More sensitivity:
  template fit to $\sqrt{\chi^2}$ shape
  - Exploit full shape information
  - Reduce sensitivity to background normalization
- Build on previous experience:
  - Same event selection
  - Same acceptance algebra
  - Same method of calculating (most) systematic uncertainties

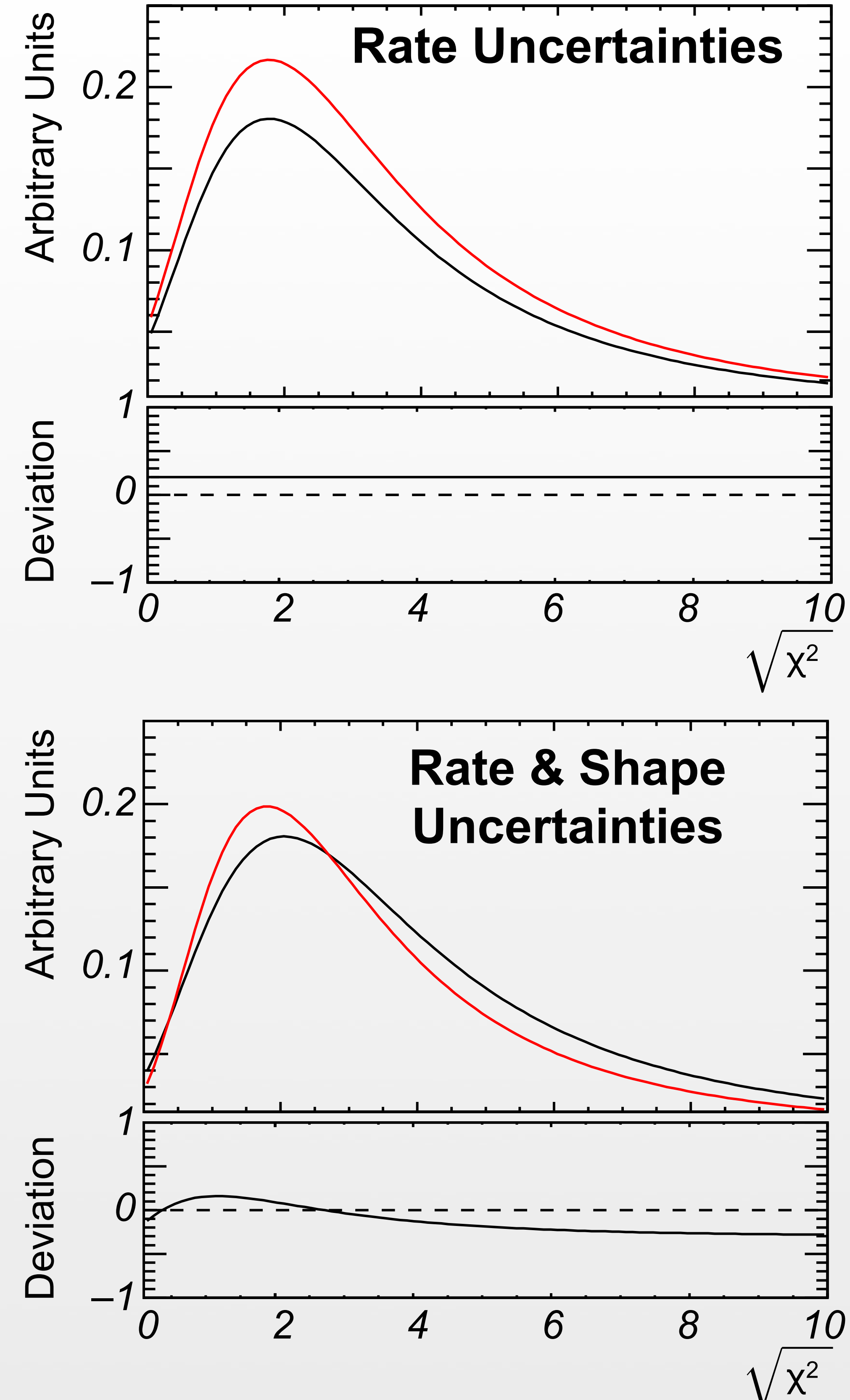
Counting Experiment
→ Template Fit

Mass χ^2 (95% C.L. Upper Limit)

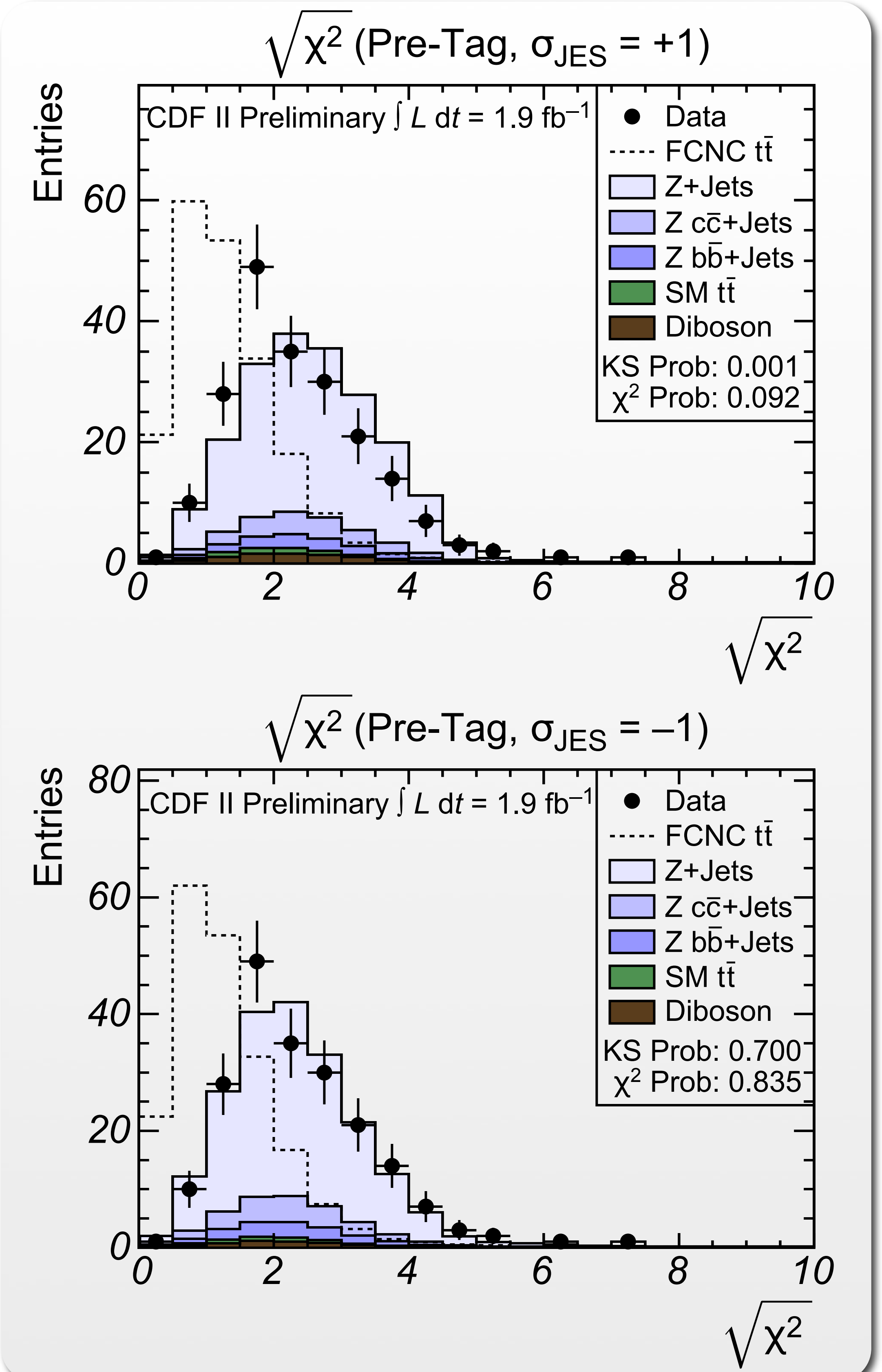


Mass χ^2 Template Fitting

- Strategy: fit signal and background templates to mass χ^2 distribution → extract B(t→Zq)
- Advantage: reduced uncertainty
  - Dominant uncertainty in counting experiment: absolute prediction of Z +Jets background
  - Fit total background and tagging rate → uncertainty reduced
- Challenge: shape systematics
  - Need to account for systematic uncertainties of template shape (in addition to rate uncertainties)
  - Investigated many sources, dominant effect: jet energy scale



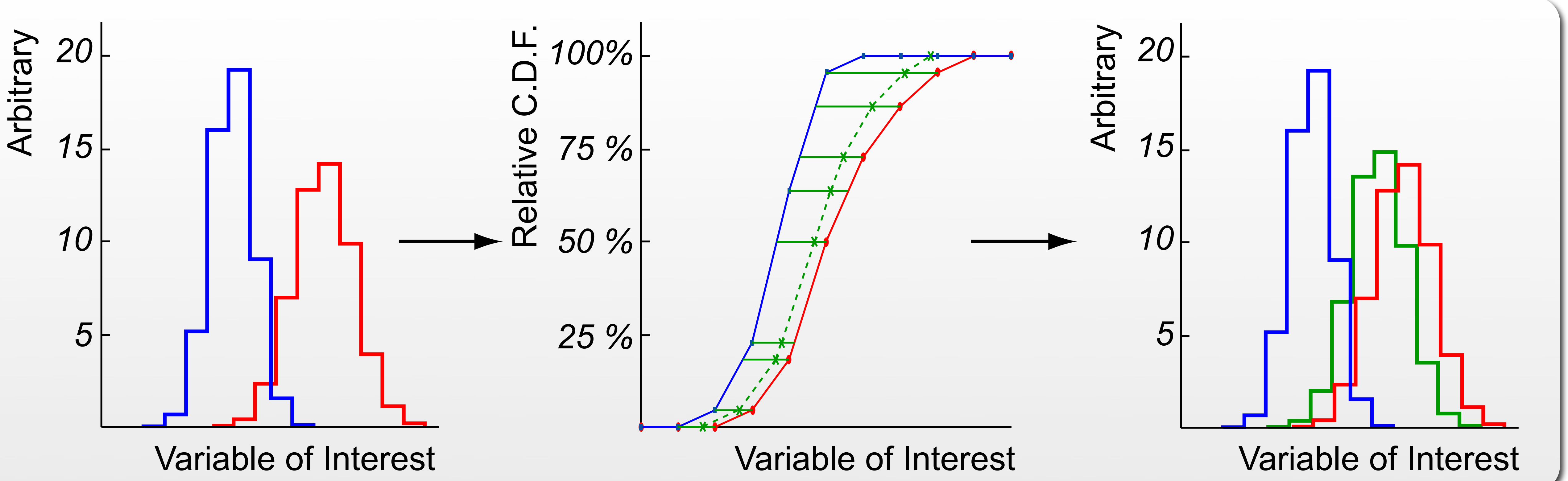
Shape Uncertainties



- Dominant uncertainty: jet energy scale (JES)
  - Translation from "raw" jet energy to partons energy
  - Many corrections: detector effects, neutral particles, underlying event, out-of-cone partons …
    → JES uncertainty $\pm\sigma_{JES}$
- Much smaller uncertainty: ALPGEN Z+jets MC simulation
  - Tunable parameters: factorization/ renormalization scale, vertex Q^2 scale
  - Big effect on jet multiplicity, small effect on mass χ^2 shape

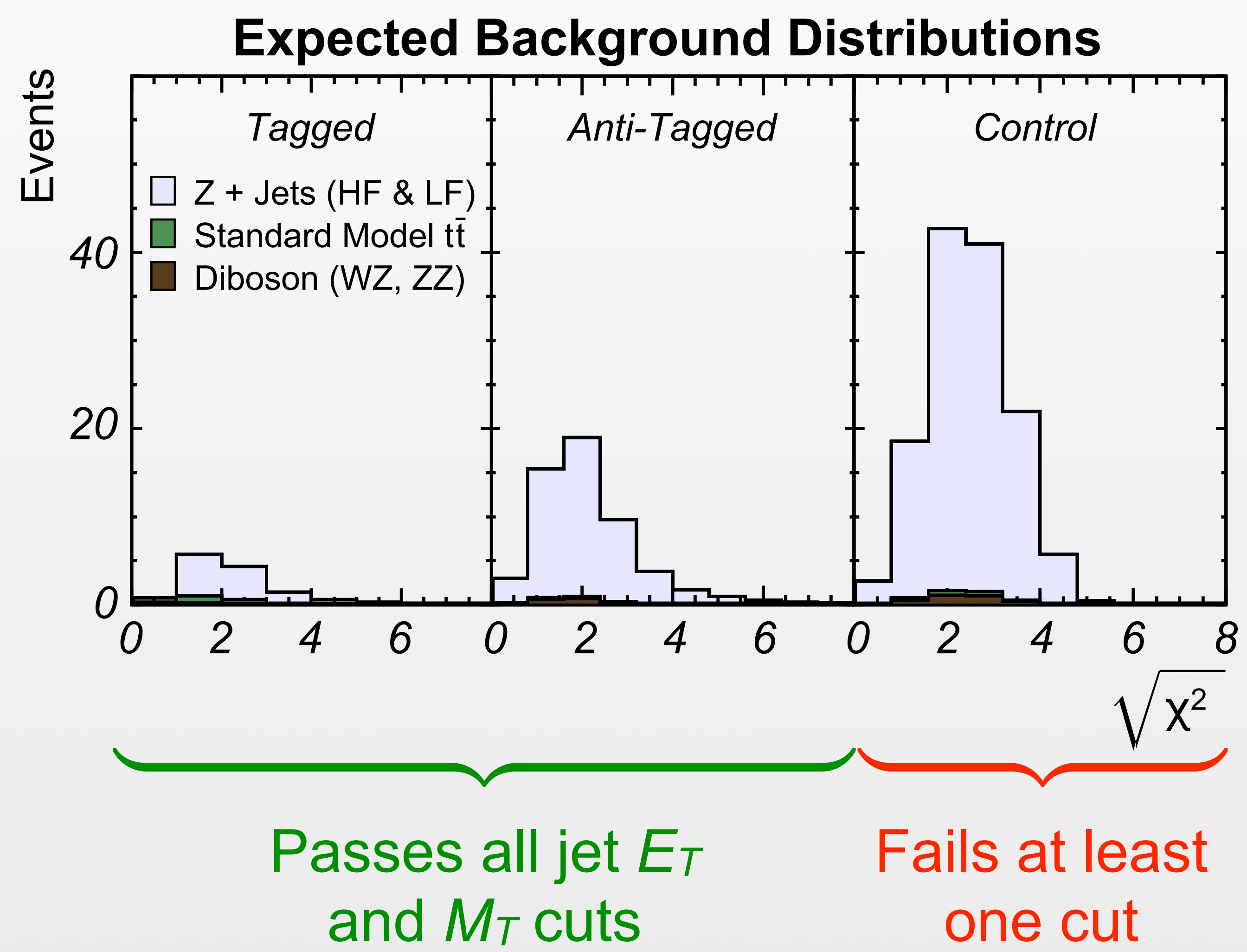
Template Morphing

- Treatment of shape uncertainties:
  - Assume that all shape uncertainties are due to JES
  - All others: much smaller effect → treated as systematic uncertainty
- Template fit: allow JES to float
  - Fitter knows how to "morph" templates → linear interpolation between normalized cumulative distribution functions (C.D.F.)
  - JES shift = free parameter in the fit



Adding a Control Region

- Challenge: control shape uncertainties but don't "morph away" a possible small signal
- Solution: add a control region
  - Definition: event fails at least one optimized cut (jet E_T, M_T)
  - Only 12% FCNC signal, but 67% Z+jets



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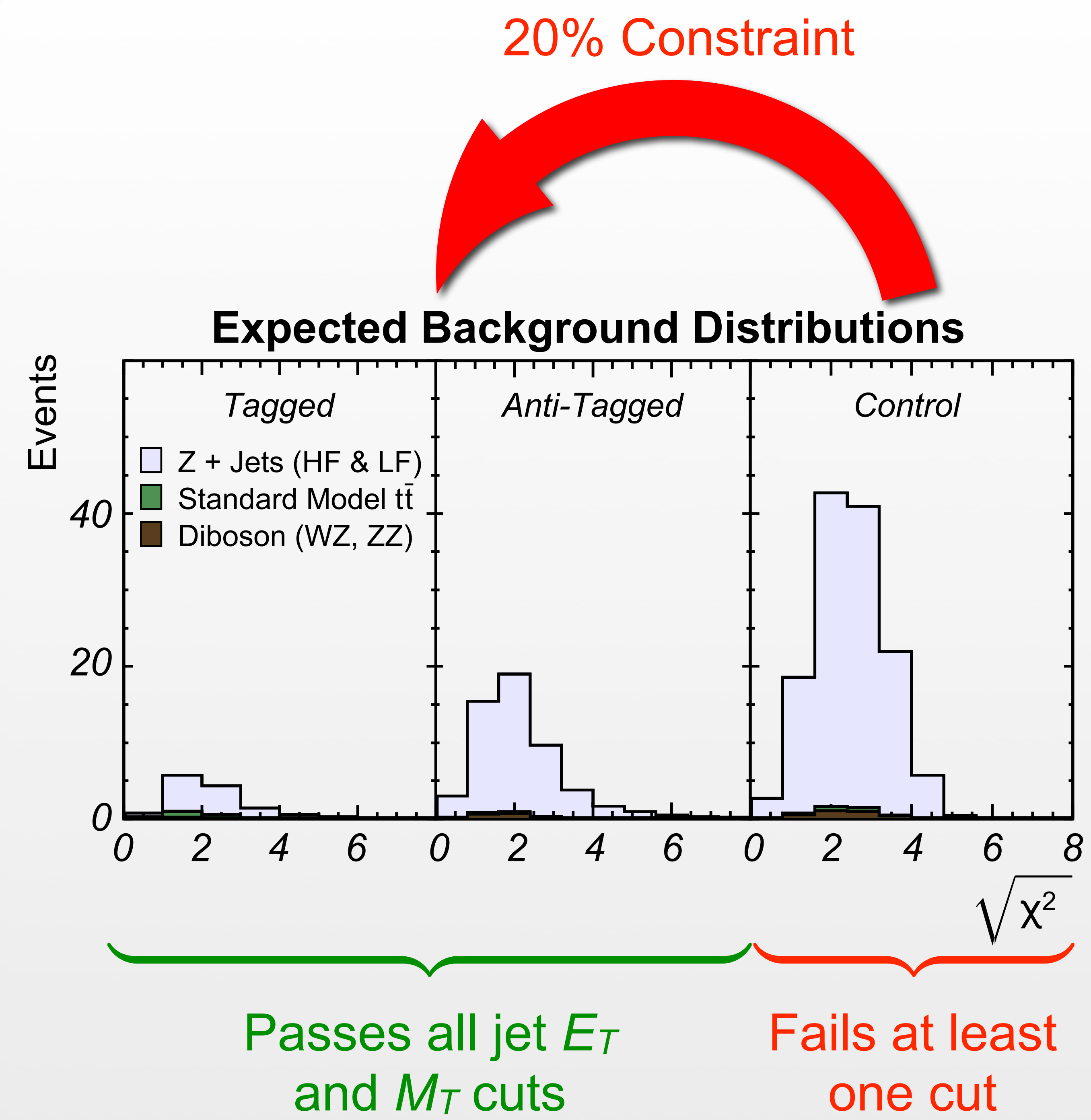
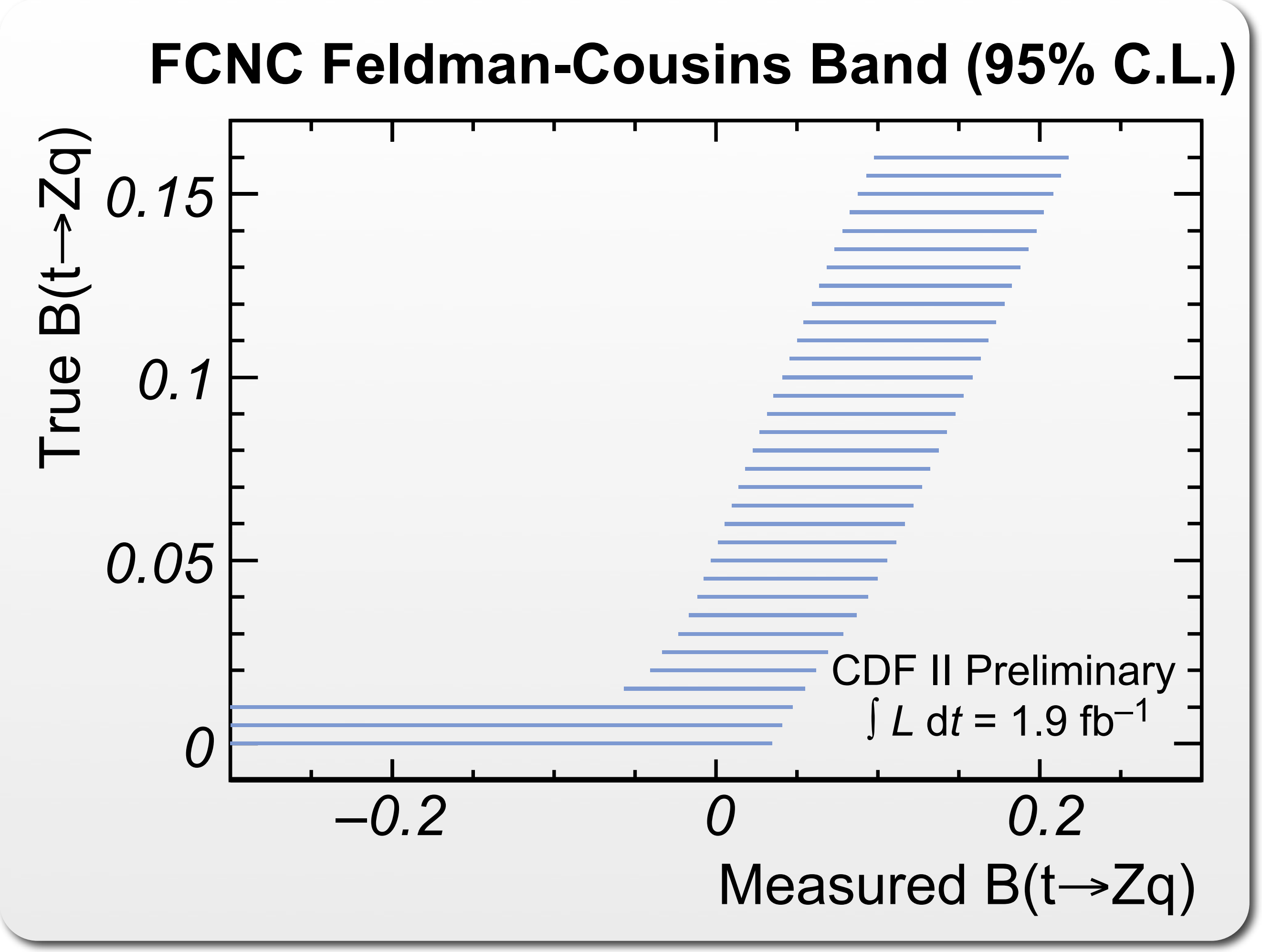
  - Only 12% FCNC signal, but 67% Z+jets
- Additional benefit: constrain Z+jets background
  - Trust MC within a jet bin, but not across jet bins
  - Use amount of Z+jets found in control region to constrain signal regions to within 20%



Feldman-Cousins Limit

- Interpretation of fitted B(t→Zq): Feldman-Cousins (FC) method [G.J. Feldman, R.D. Cousins, Phys. Rev. **D57** (1998) 3873]
- FC answers the question: "What range of true values are likely to lead to the fitted value?"
- FC features:
  - Measurement or limit → data decide
  - Coverage of confidence intervals guaranteed
- Our implementation:
  - Includes systematic uncertainties
  - Based on "pseudo-experiments"



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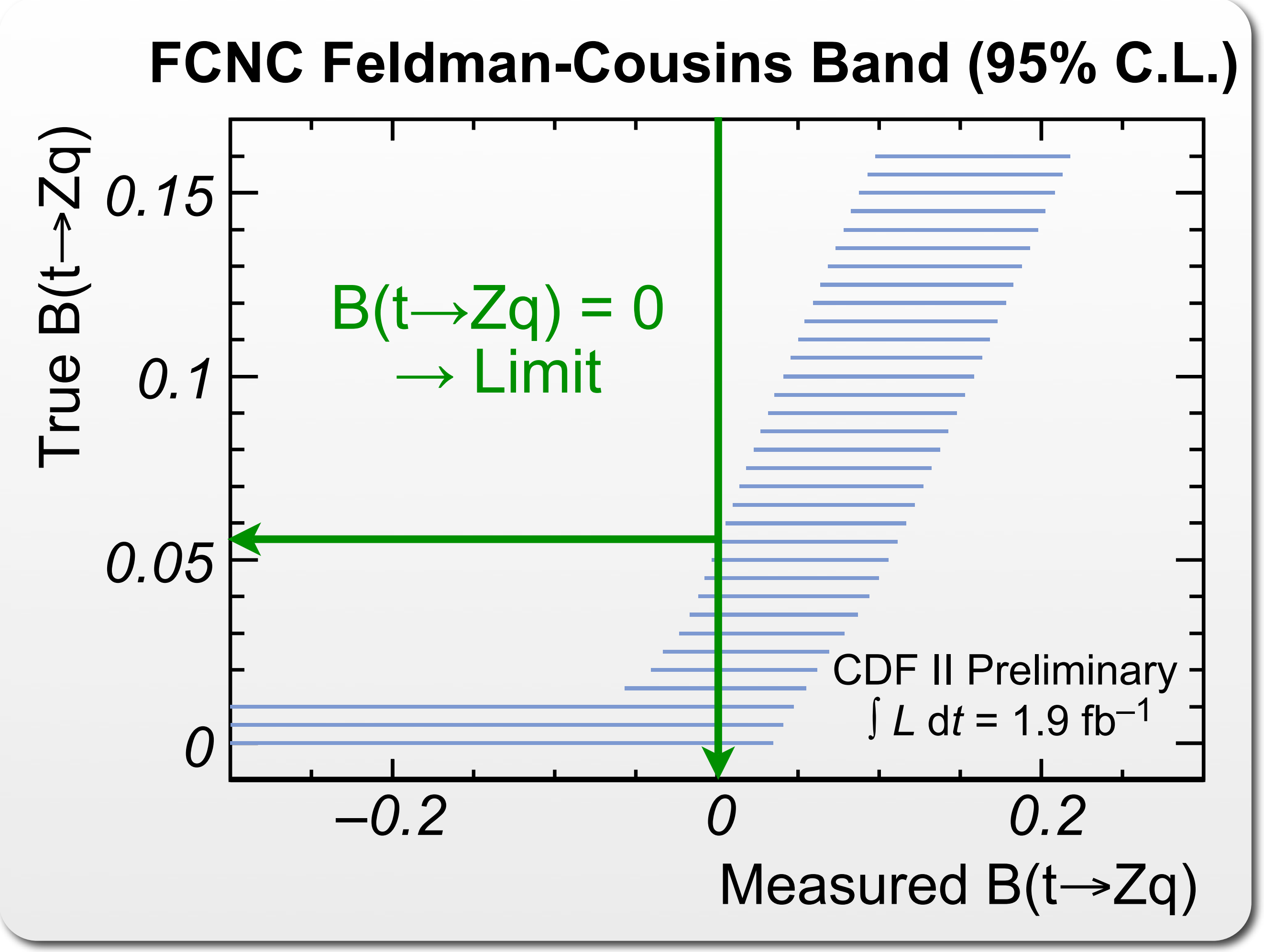

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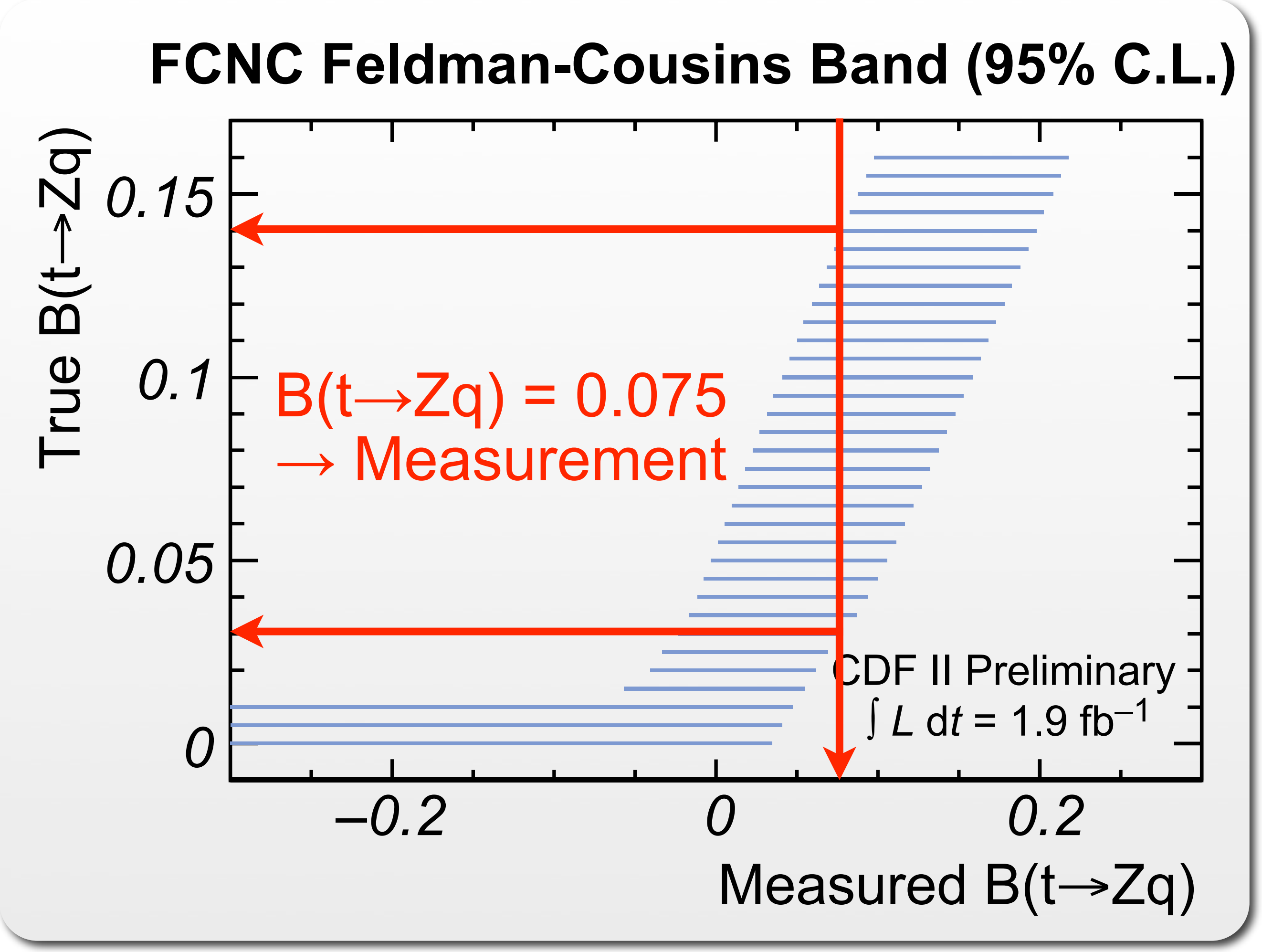

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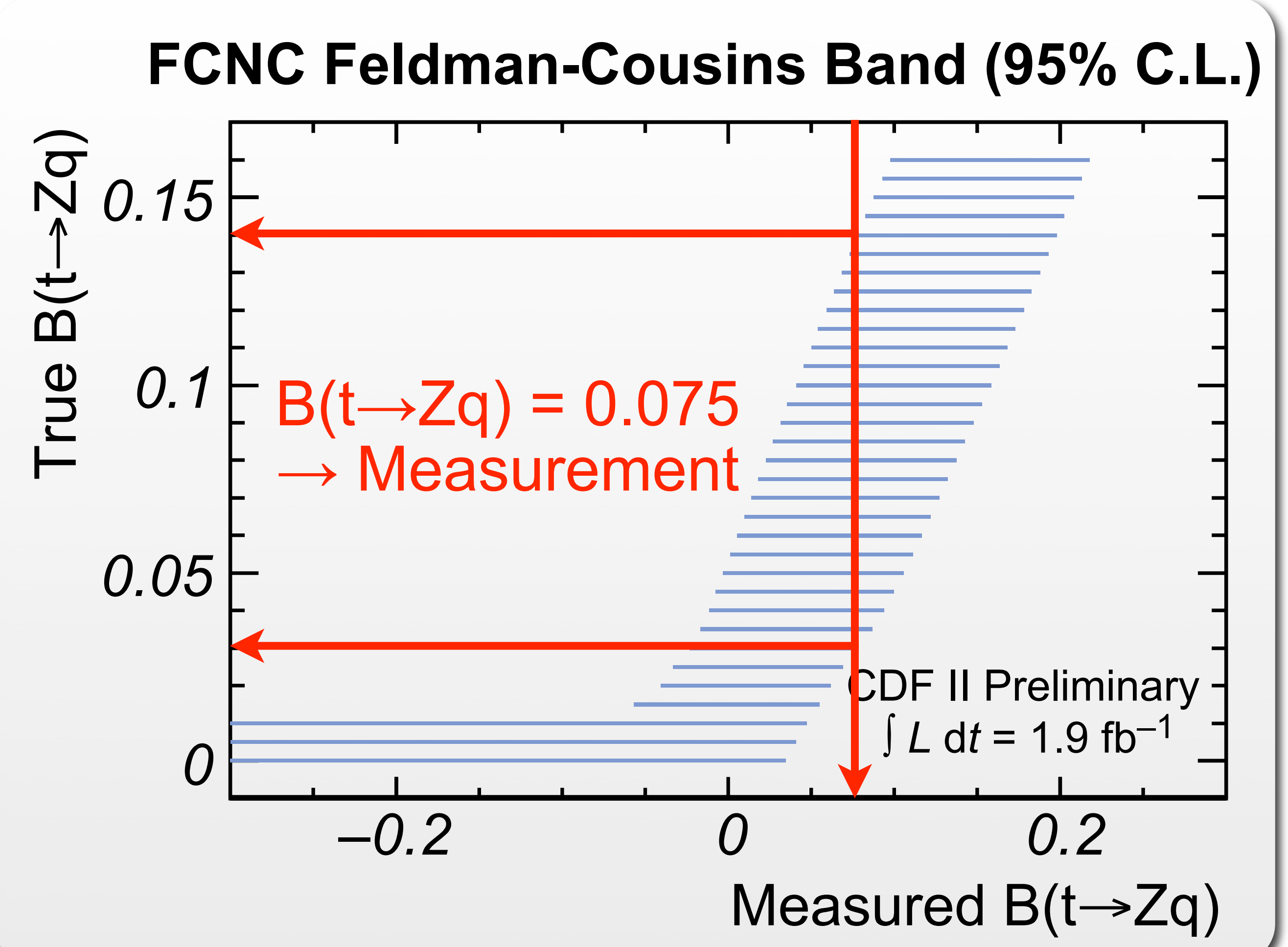
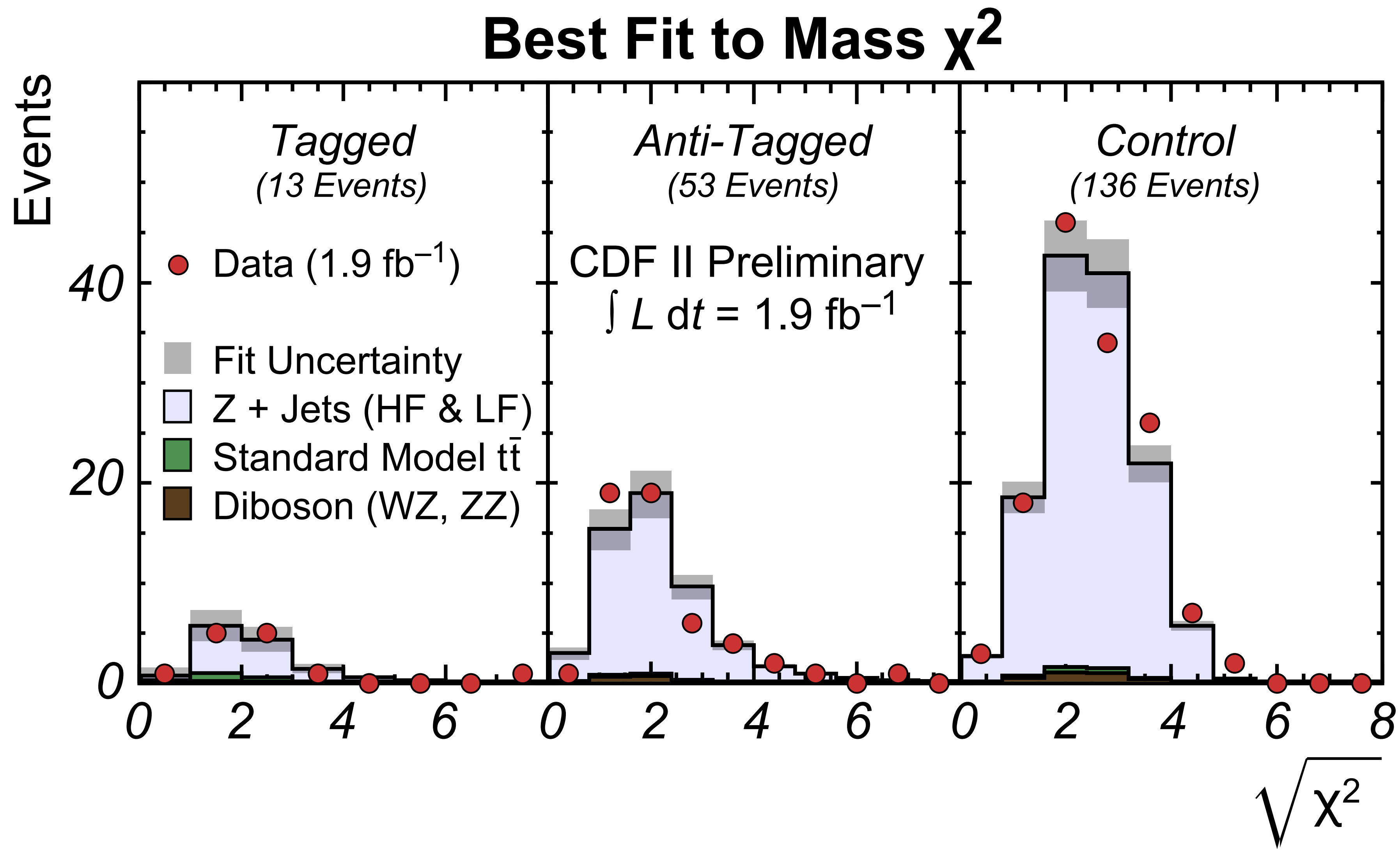


What are Pseudo-Experiments?

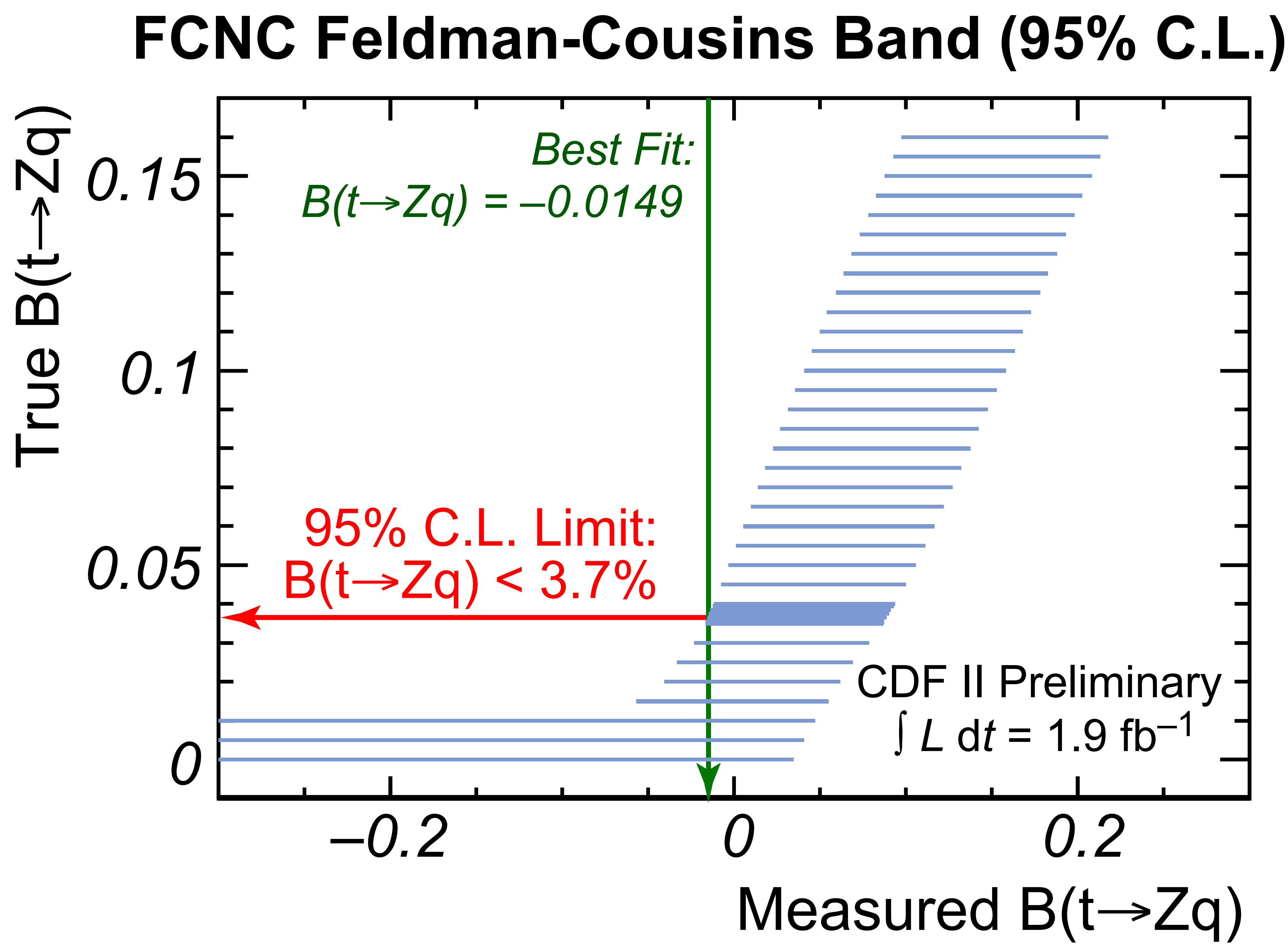
* Simulated experiments from MC
* Smear MC templates according to all known correlations and systematic uncertainties
* Draw Poisson random numbers from smeared MC templates → mass χ^2 distribution
* Fit as in data → "measured" B(t→Zq)
* Rinse and repeat…

Fit to the Data



Fit Parameter	Value		
Branching Fraction $B(t \to Zq)$ (%)	−1.49	±	1.52
Z+Jets Events in Control Region	129	±	11
Ratio Signal/Control Region (%)	52	±	7
Tagging Fraction (%)	20	±	6
Jet Energy Scale Shift (σ)	−0.74	±	0.43

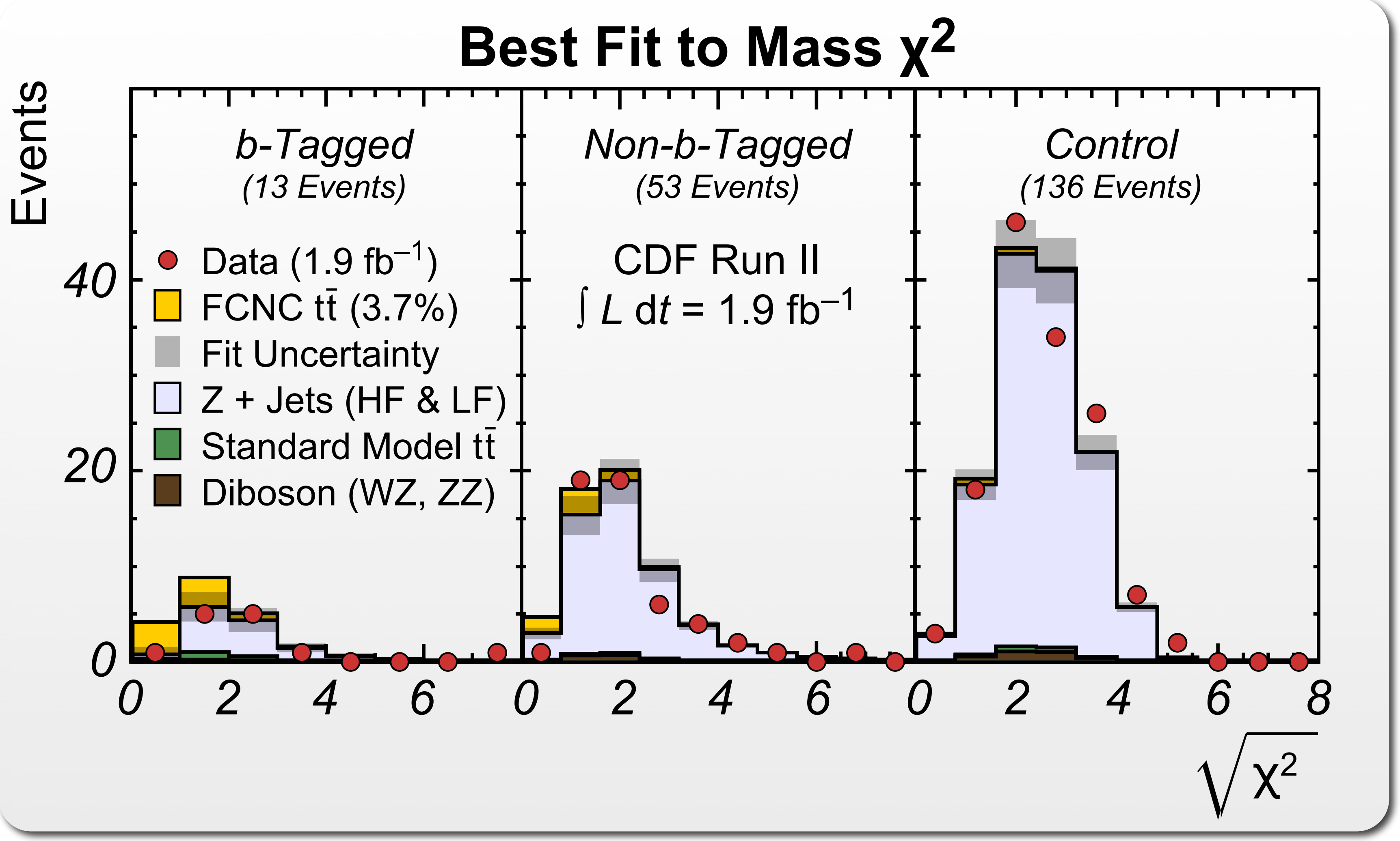
The World's New Best Limit



Summary

B(t→Zq) < 3.7% @ 95% C.L.

- Expected limit: 5.0% ± 2.2%
- Order of magnitude improvement over CDF Run I (33%)
- Almost 4× better than LEP (13.7%)



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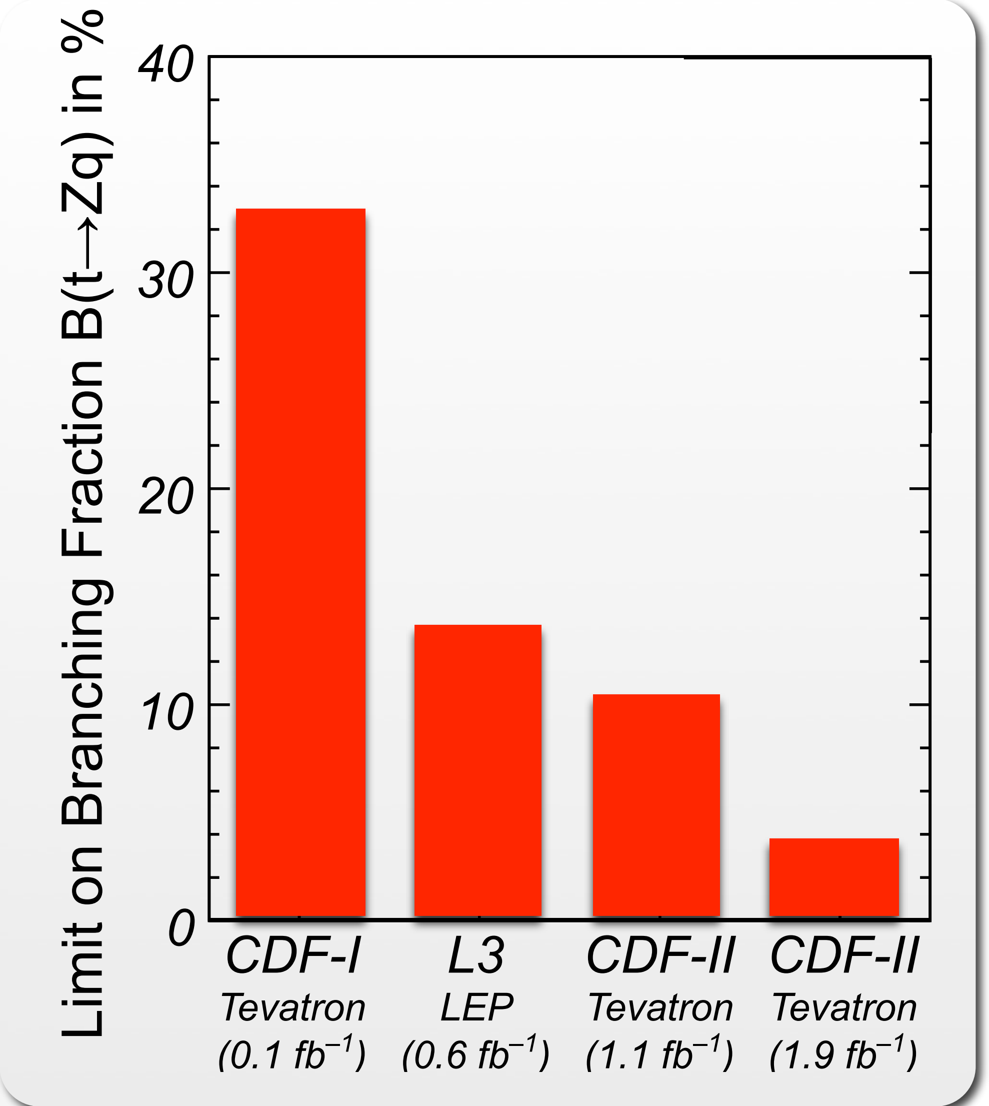
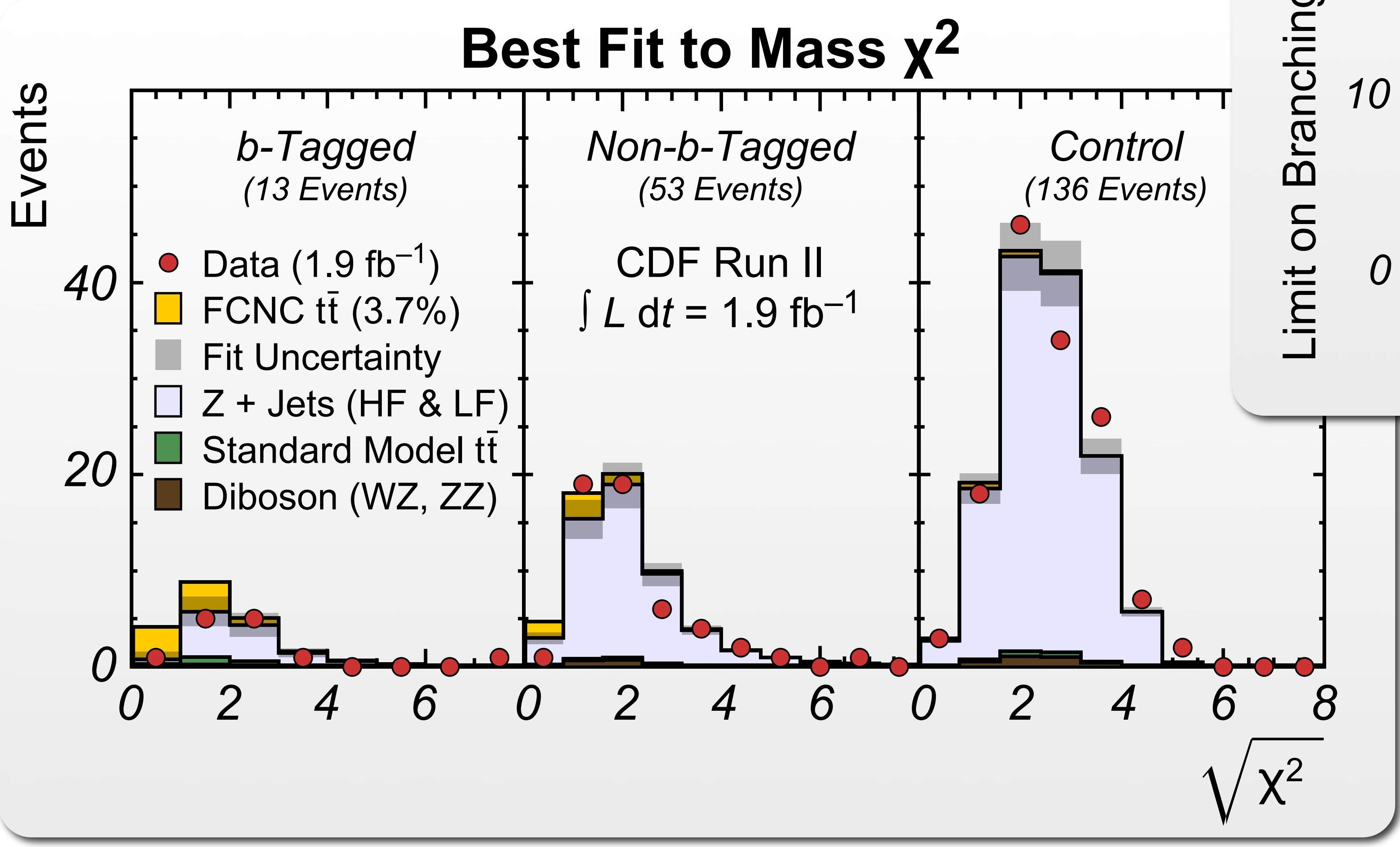
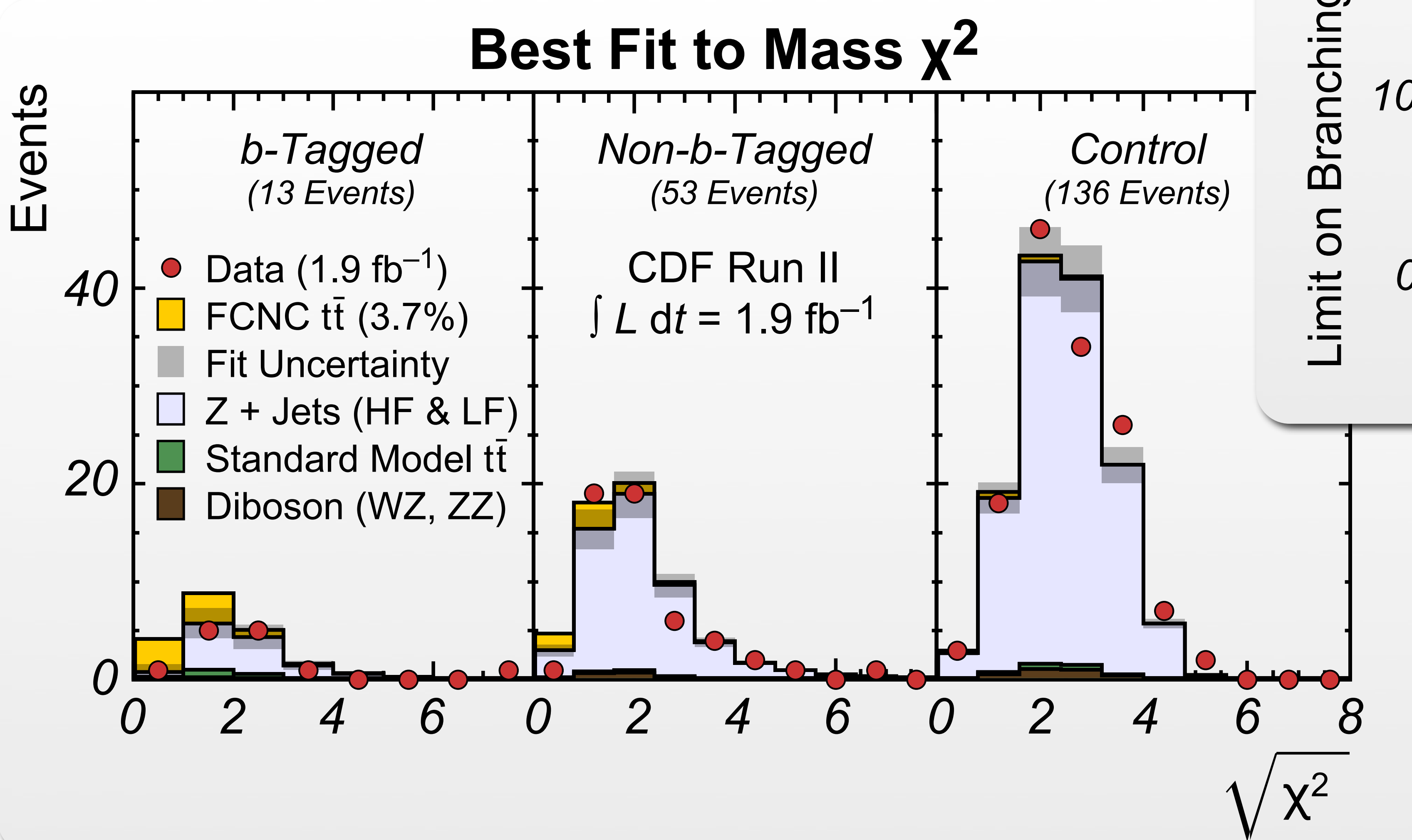


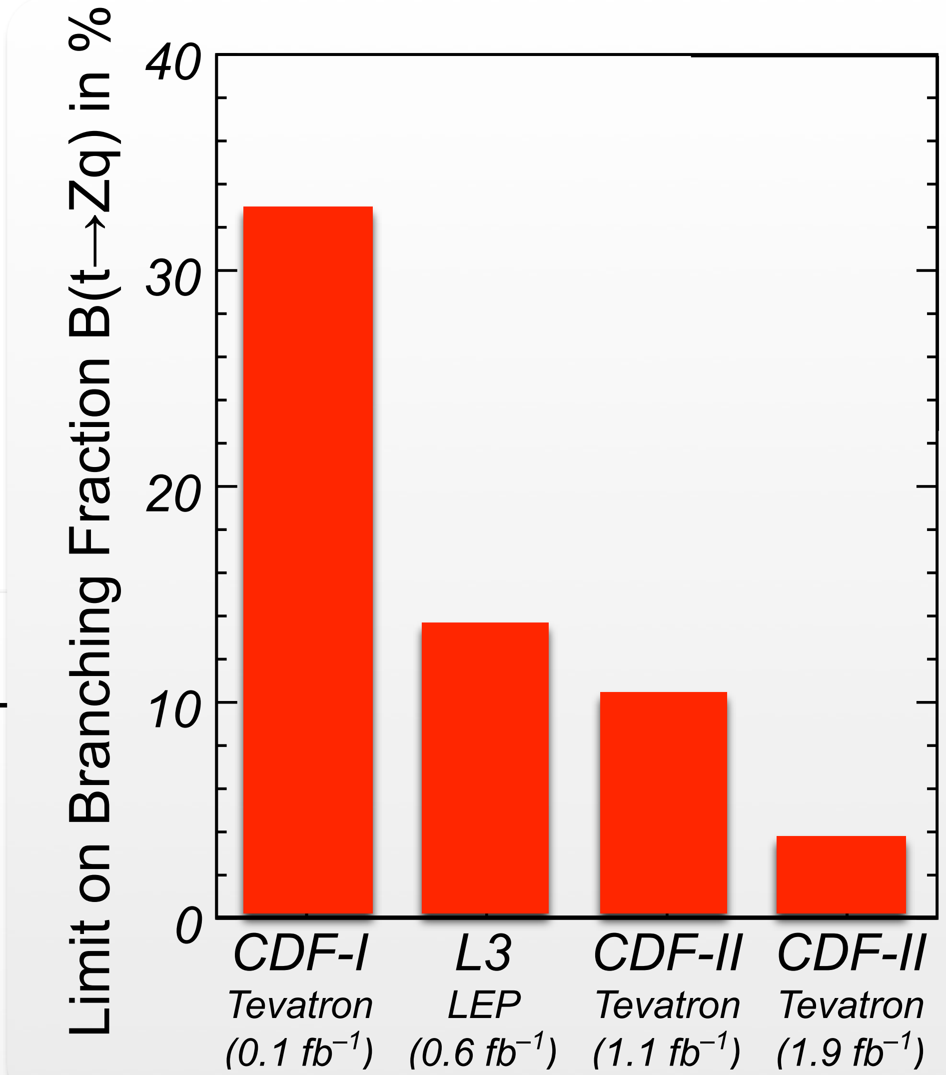


Summary

B(t→Zq) < 3.7% @ 95% C.L.

- Expected limit: 5.0% ± 2.2%
- Order of magnitude improvement over CDF Run I (33%)
- Almost 4× better than LEP (13.7%)



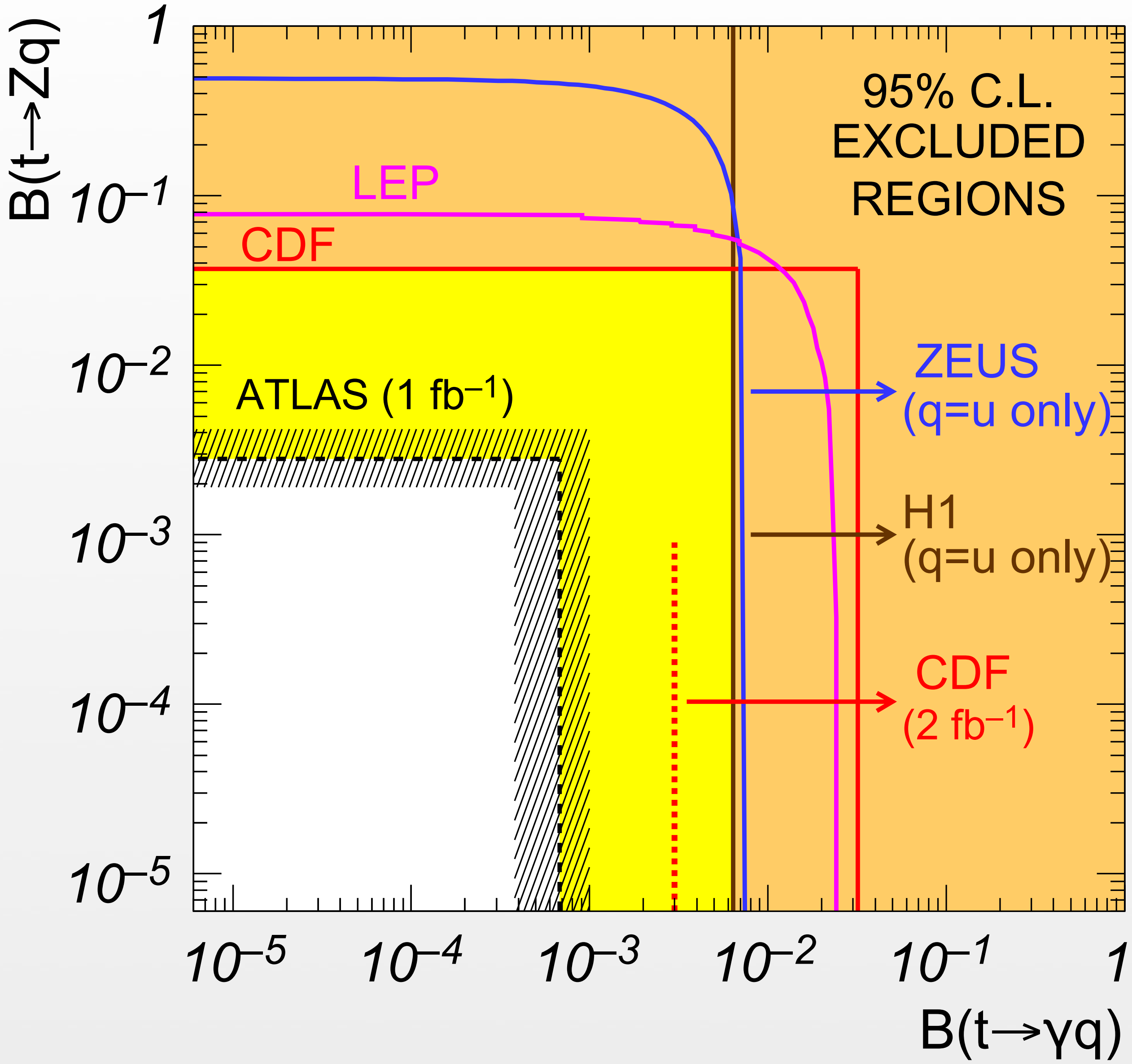


Note: alternative CDF analysis with different technique on 1.52 fb^{-1} [PRD **80** (2009) 052001]:

B(t→Zq) < 8.3–9.3% @ 95% C.L.

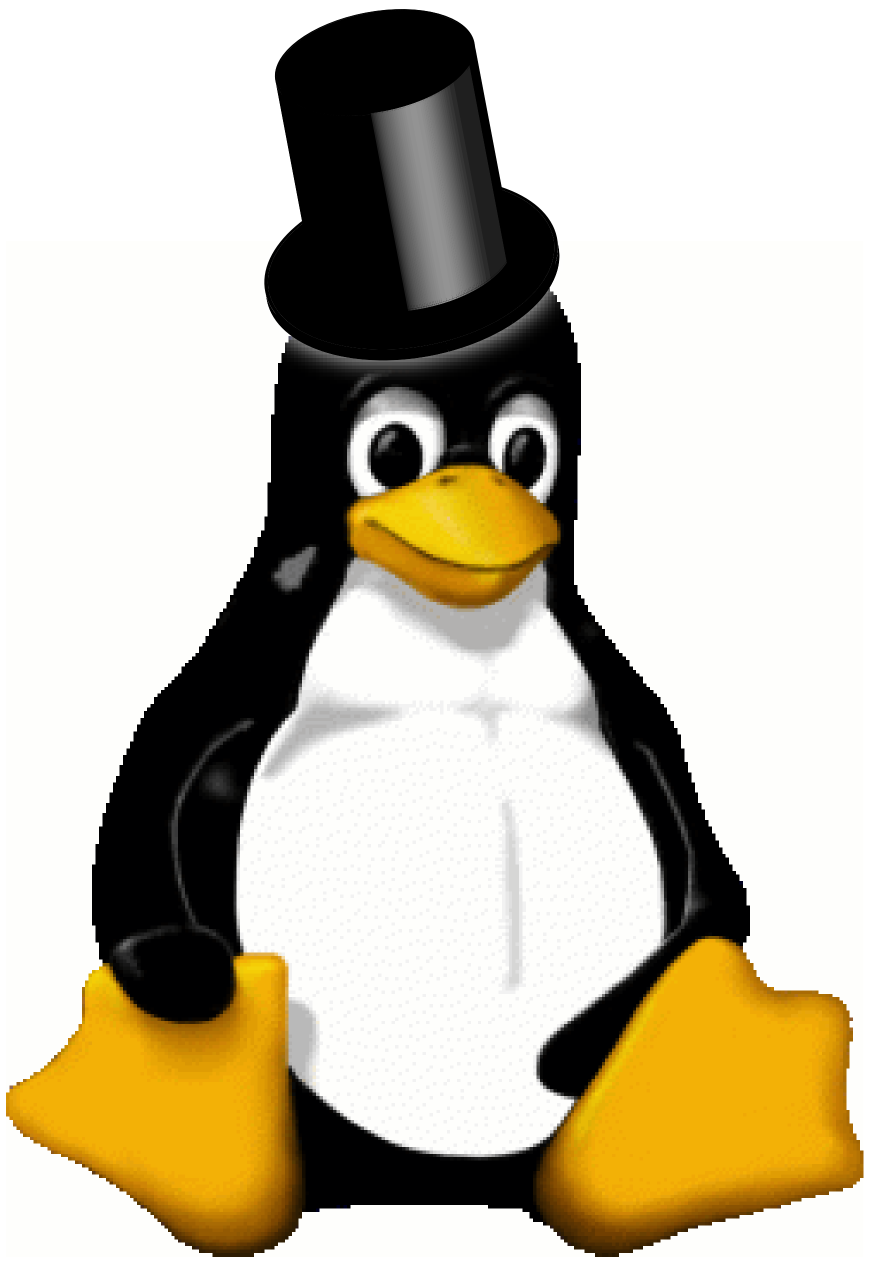
Outlook: Top FCNC at the LHC

- Large Hadron Collider (LHC):
  - Top FCNC searches can (and should!) be re-done at the LHC
  - ATLAS and CMS have already studied their FCNC sensitivities
- ATLAS study on sensitivity for top FCNC (1 fb^{-1} at 14 TeV)
  - Improvement of current limits on BR($t \rightarrow Zq$) by 1–2 orders of magnitude
  - Entering interesting regime of 10^{-3} to 10^{-4} → exclusion of first theoretical models?
  - Caveat: so far only MC studies, first data to come end of this year



[ATLAS CSC Book, CERN-OPEN-2008-20]

Conclusions



- Top flavor changing neutral current (FCNC) decays
  - Extremely rare in the standard model
  - Enhanced in theories beyond the standard model → any signal: new physics
- First Tevatron Run II search for FCNC $t \rightarrow Zq$ in top quark decays
  - Event signature: $Z + \geq 4$ jets
  - Mass χ^2 to separate signal from background
- No evidence for top FCNC found
  - World's best limit:
    $BR(t \rightarrow Zq) < 3.7\%$ at 95% C.L.
  - Analysis published in
    Phys. Rev. Lett. **101** (2008) 192002