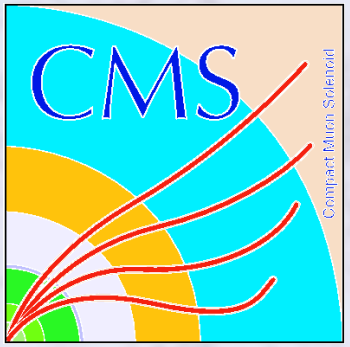
Search for FCNC in Top Pair Events in pp Collisions



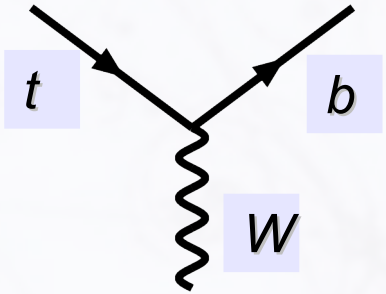
Yuan CHAO,
(National Taiwan University, Taipei, Taiwan)
On behalf of the CMS collaboration

ICHEP 2012 Melbourne, Australia
2012/07/04-11

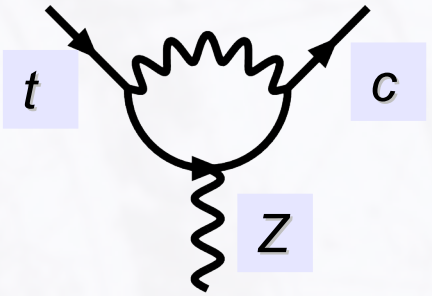
Motivation

- Top quark decay channels:

T



Charged Current (CC)



Flavor-Changing
Neutral- Current (FCNC)

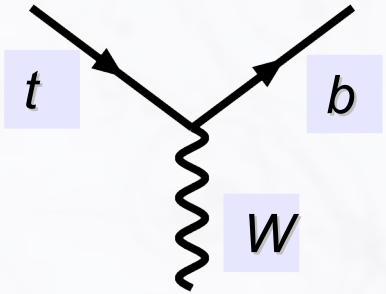
P

  - Normal t → bW is tree-process
- FCNC t → cZ penguin-process (loop diagram)
  - **Standard Model:** FCNC suppressed by $O(10^{-14})$
  - Could be enhanced through new physics at the loop level
  - Some theoretical models can give up to $O(10^{-4})$:
    - R-parity violated SUSY Phys. Lett. B502 (2001) 115-124
    - TopColor assistant technicolor models Phys. Rev. D68 (2003) 015002

Motivation (cont.)

- Top quark decay channels:

T



Charged Current (CC)

Flavor-Changing
Neutral- Current (FCNC)

P

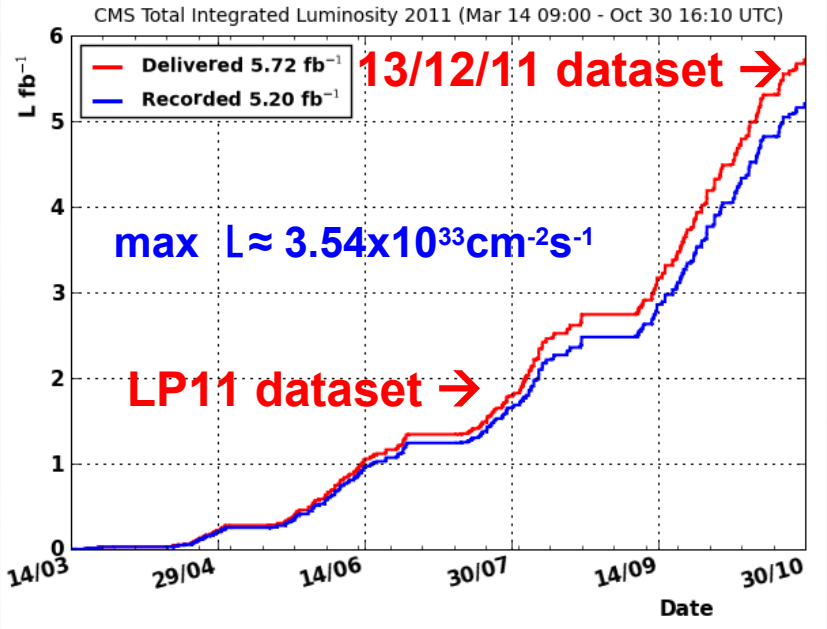
- Recently from Tevatron experiment:
  - CDF: Br(t → cZ) < 3.7 % at 95% C.L.

    Phy. Rev. Lett. 101 (2008) 192002
  - DØ: Br(t → cZ) < 3.2 % at 95% C.L.

    Phy. Lett. B 701 (2011) 313
- Results from Atlas: (previous speaker)

Data & Analysis Strategy

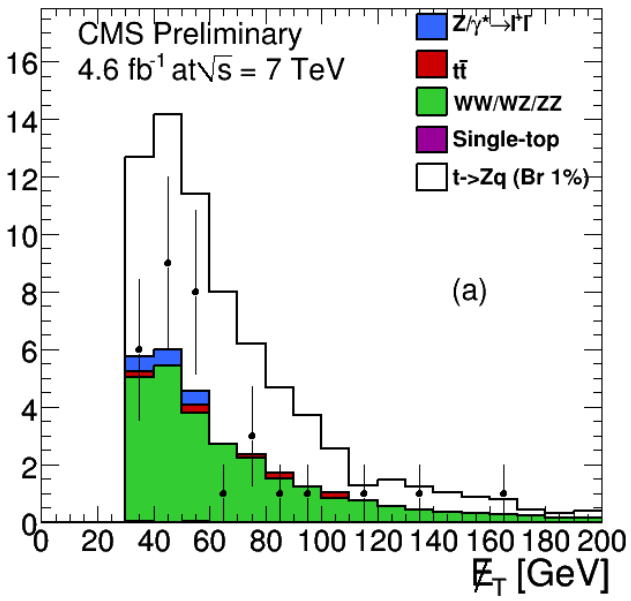
- Data recorded with the CMS detector
  - Full data set collected in 2011:
    ~4.6/fb at 7 TeV

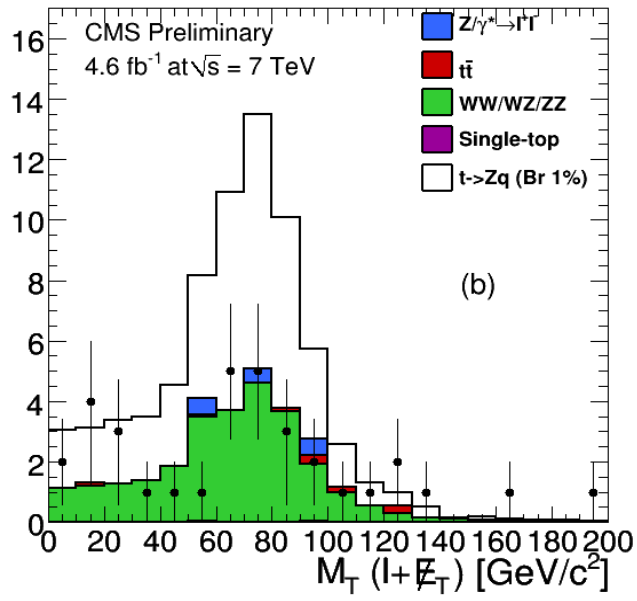


- One of the top pair goes to the FCNC decay channel
- Event signature:
  $tt \rightarrow (W \rightarrow l\ nu) + (Z \rightarrow ll) + j\ j$
  - Full leptonic decays of W & Z
    (tri-lepton final state)
    → very clean background
  - Dominant backgrounds: tt, Drell-Yan, WZ, ZZ
  - Suppress non-ttbar bkg. with b-tagging requirement
- Two approaches
  - Without b-tag → similar to previous studies
  - With b-tag → even cleaner background

Event Selection

- Common selection for both approaches
  - Basic Vertex selection
  - High Level Trigger (HLT): di-lepton paths
  - Three leptons with **identification** and **isolation** requirements
    - Min. pT > 20 GeV,
    - Pseudo rapidity: elec. |η| < 2.5, muon |η| < 2.4
  - Z-boson selection: best within the **mass window** 60-120 GeV
  - W from isolated lepton plus neutrino
    - **Missing ET > 40 GeV** and veto against 4th lepton





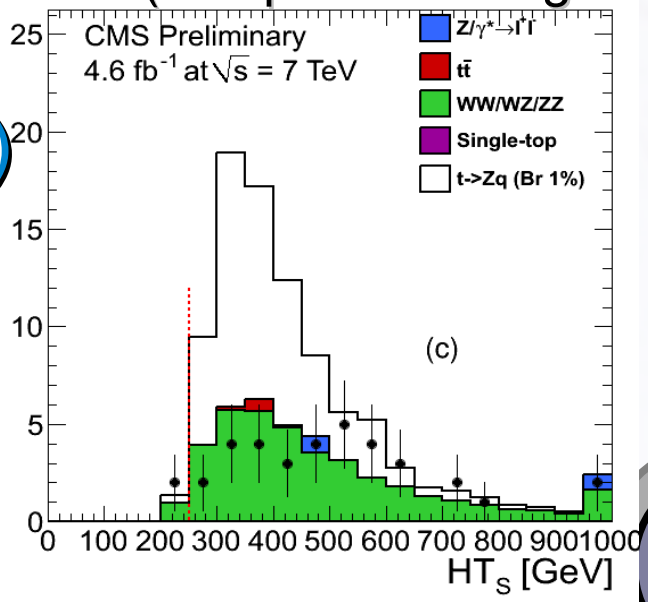
Event Selection (cont.)

- SM background yields after common pre-selection:

Channel	$\mu\mu e$	$\mu\mu\mu$	eee	$ee\mu$
Drell–Yan	$2.0 \pm 1.4 \pm 0.3$	$0.9 \pm 1.0 \pm 0.1$	$2.8 \pm 1.7 \pm 0.4$	$0.9 \pm 1.0 \pm 0.1$
WZ	$46.1 \pm 6.8 \pm 6.1$	$60.3 \pm 7.8 \pm 8.0$	$40.9 \pm 6.4 \pm 5.4$	$48.6 \pm 7.0 \pm 6.4$
ZZ	$17.7 \pm 4.2 \pm 2.3$	$21.7 \pm 4.7 \pm 2.9$	$15.1 \pm 3.9 \pm 2.0$	$18.2 \pm 4.3 \pm 2.4$
WW	≤ 0.001	≤ 0.001	$0.2 \pm 0.3 \pm 0.0$	≤ 0.001
$t\bar{t}$	≤ 0.001	$0.5 \pm 0.7 \pm 0.1$	$0.9 \pm 0.9 \pm 0.1$	$0.9 \pm 0.9 \pm 0.1$
Single-top	≤ 0.001	$0.1 \pm 0.4 \pm 0.0$	$0.0 \pm 0.2 \pm 0.0$	≤ 0.05
Total	$66 \pm 8 \pm 7$	$84 \pm 9 \pm 9$	$60 \pm 8 \pm 6$	$69 \pm 8 \pm 7$
Data	73	87	85	61

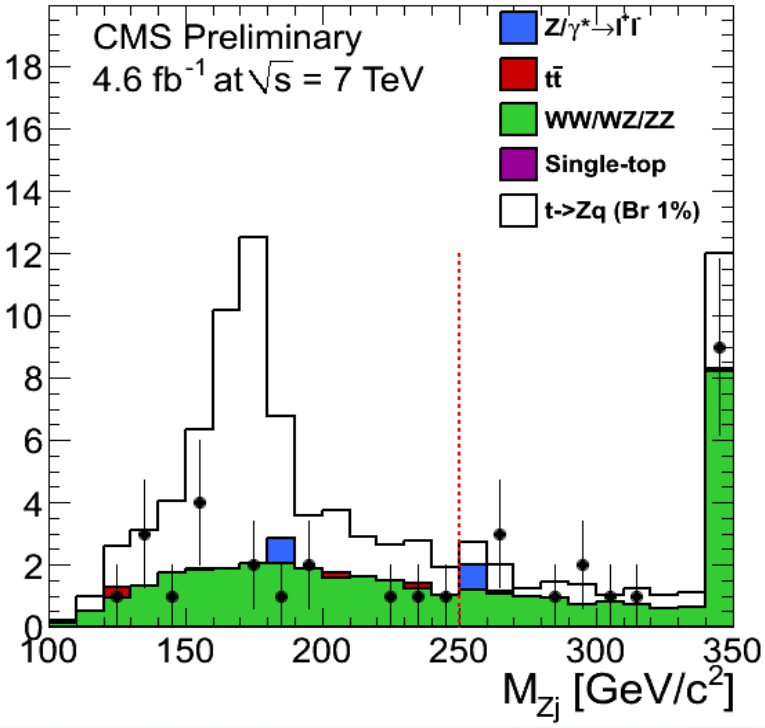
- Top quark reconstruction (two approaches):
  - $HT_S = \Sigma\ p_T$ (lepton) + $\Sigma\ E_T$ (jets) + MET (of top cand. daughters)
  - b-tag method
- Signal efficiencies (final selection)

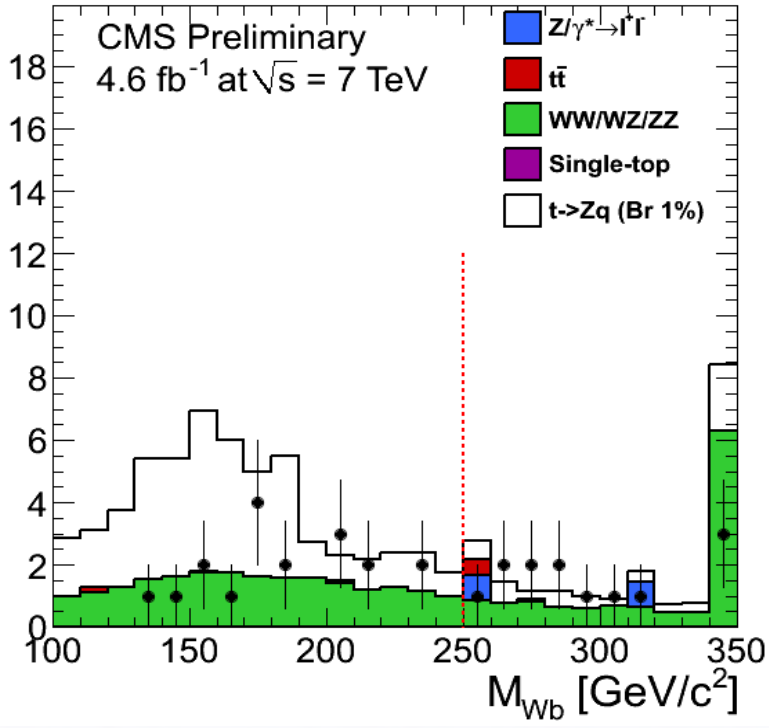
Channel	HT_S-cut Based Selection	b-tag Based Selection
eee	12.4 ± 1.1	3.8 ± 0.6
$ee\mu$	13.8 ± 1.2	5.0 ± 0.7
$\mu\mu e$	14.8 ± 1.2	5.1 ± 0.7
$\mu\mu\mu$	14.7 ± 1.2	5.3 ± 0.7



Top Reconstruction (HT_s)

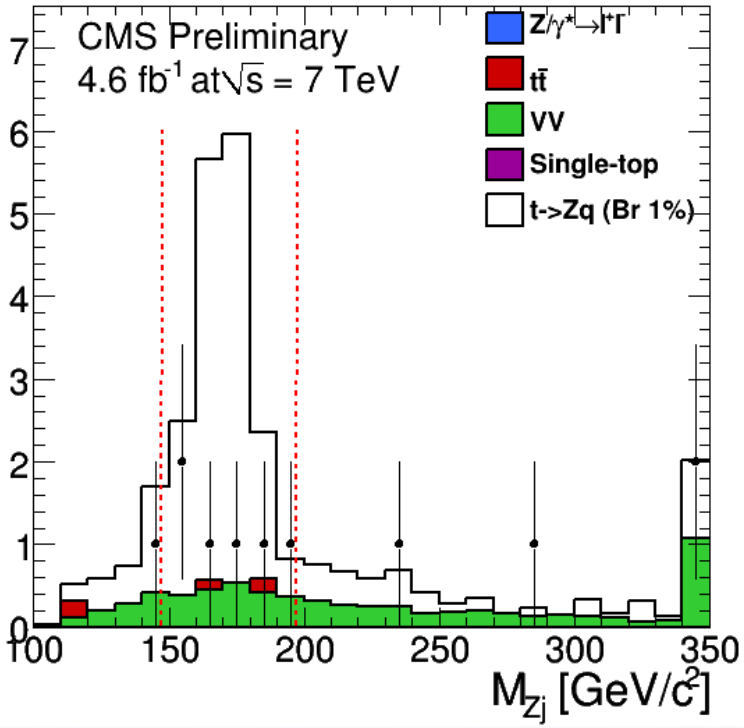
- Top reconstruction: assume nominal W-mass
- Find most **back-to-back** top cand. with jet pT>30 GeV
  - Applying HT_s cut to reduce combinatorics
- Estimation of backgrounds
  - WZ & ZZ from MC, normalized to **N_jet=0** bin in data
  - tt + DY from data: **matrix method** (lepton isolation control region)

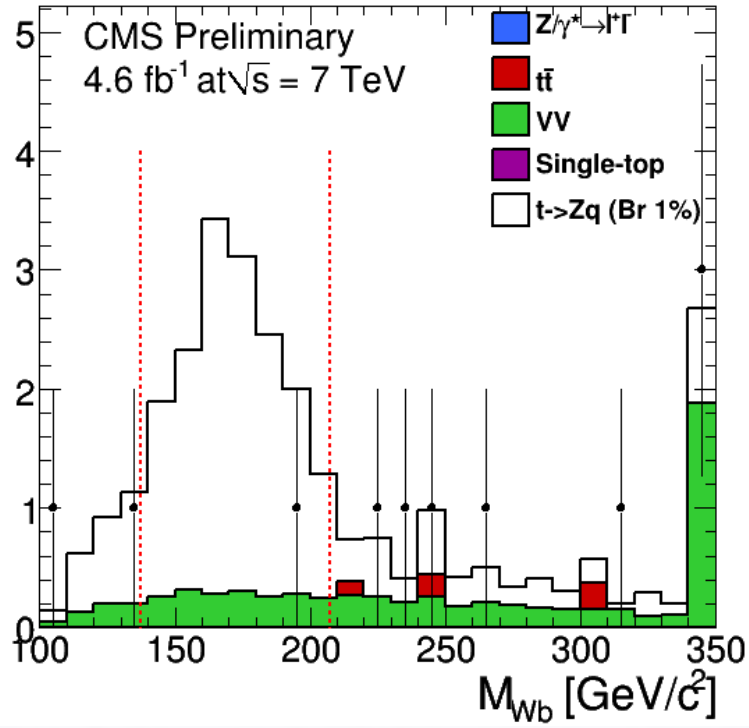




Top Reconstruction (b-tagged)

- Exactly one b-tagged jet is required (pT > 30 GeV)
  - No ambiguity to combine with W boson
  - Best non-b-jet on reconstructed top mass
- Background yields estimated from data
  - Using HT_s estimation plus b-tag efficiency and fake rate
  - Extrapolate to top mass window





Final Result

Selection	HT_S	b-tag
Background yield	**16.2 +/- 2.6***	**0.6+/- 0.1***
Data yield	**11**	**0**
Expected BR U.L.	**< 0.42%**	**< 0.34%**
(1-sigma bound)	**[0.30% - 0.64%]**	**[0.34% - 0.48%]**
Observed Upper Limit	**< 0.39%**	**< 0.34%**

- No significant signal
  - Both methods see **smaller yields** than expected
- Upper limit calculated
  - Counting method
  - BR upper limits determined at 95% confidence level (CL)
  - Expected BR limits and 1-sig. bounds based on MC study

* Errors contain statistics from MC study and extrapolation plus systematics uncertainties

Systematics

- Luminosity uncertainty: 4.5%
- Dominant syst. from ttbar x.-sec.
  → not included in the background yields of previous table
- Numbers are in percentage of the event yields

Source	HT_S (%)	b-tag (%)
Trigger Efficiency	4	4
PDF & cross section	6	6
Lepton selection	7	7
Pile-up events	7	7
Missing energy resolution	8	8
Cross sections (normalization)	11 (7)	11
B-tagging	---	9
Jet energy scale	10	10
Total	21	23

Summary

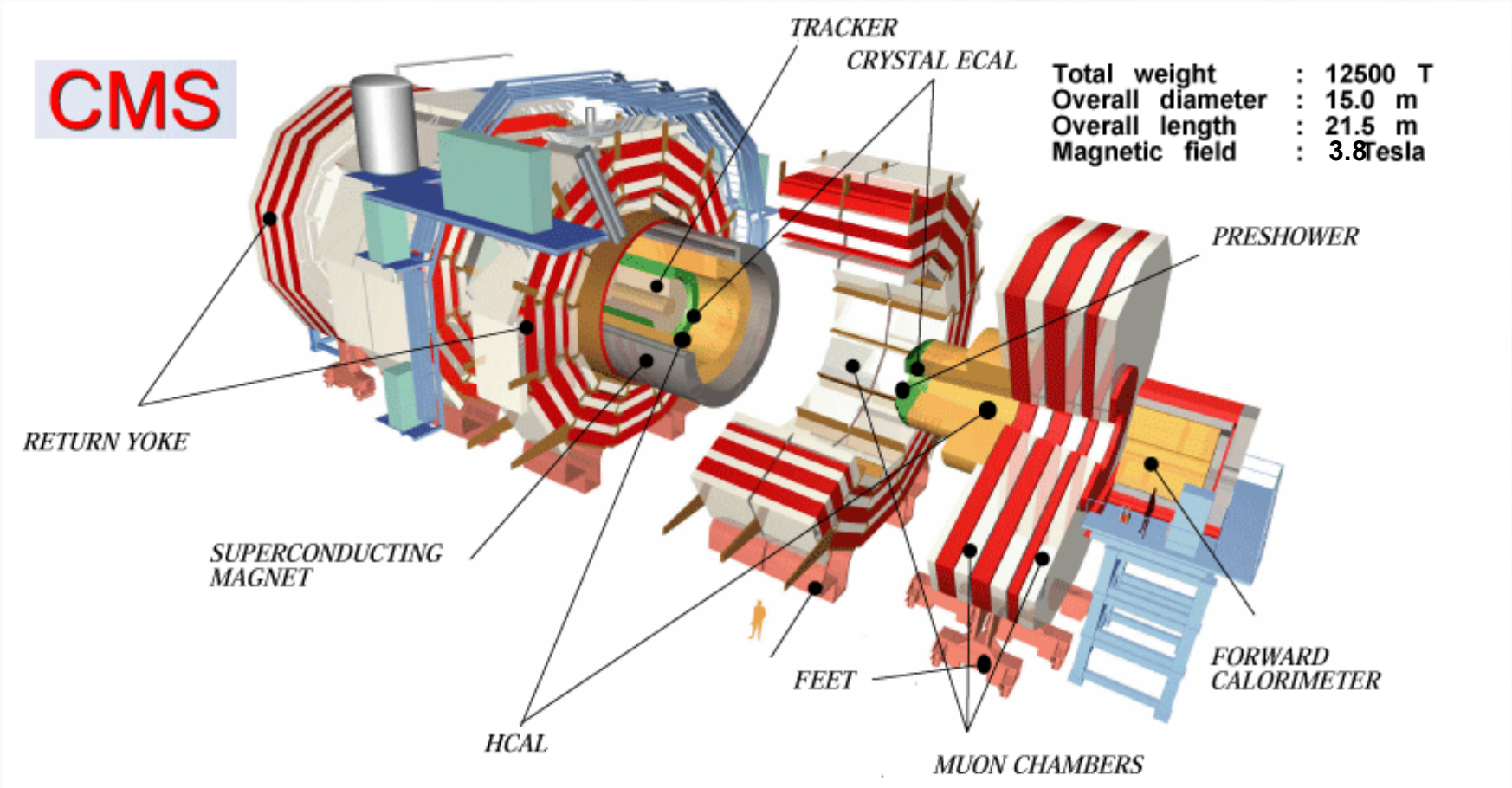
- Search for “Flavor changing neutral currents” in ttbar performed using 2011 CMS data
  - Data (~5/fb) taken at 7 TeV
  - Using events with three isolated leptons (e or μ) in final state
  - Two analyses: with and w/o b-tagging
- Analysis yields shows no indication of significant FCNC
  - Upper limit Br($t \rightarrow cZ$) < 0.3% at 95% C.L. given
- 2012 data at 8 TeV:
  - More integrated luminosity and higher energy
  - Stay tuned!

謝謝

Thank YOU!

CMS Detector

- Compact Muon Solenoid
  - A general purposed detector



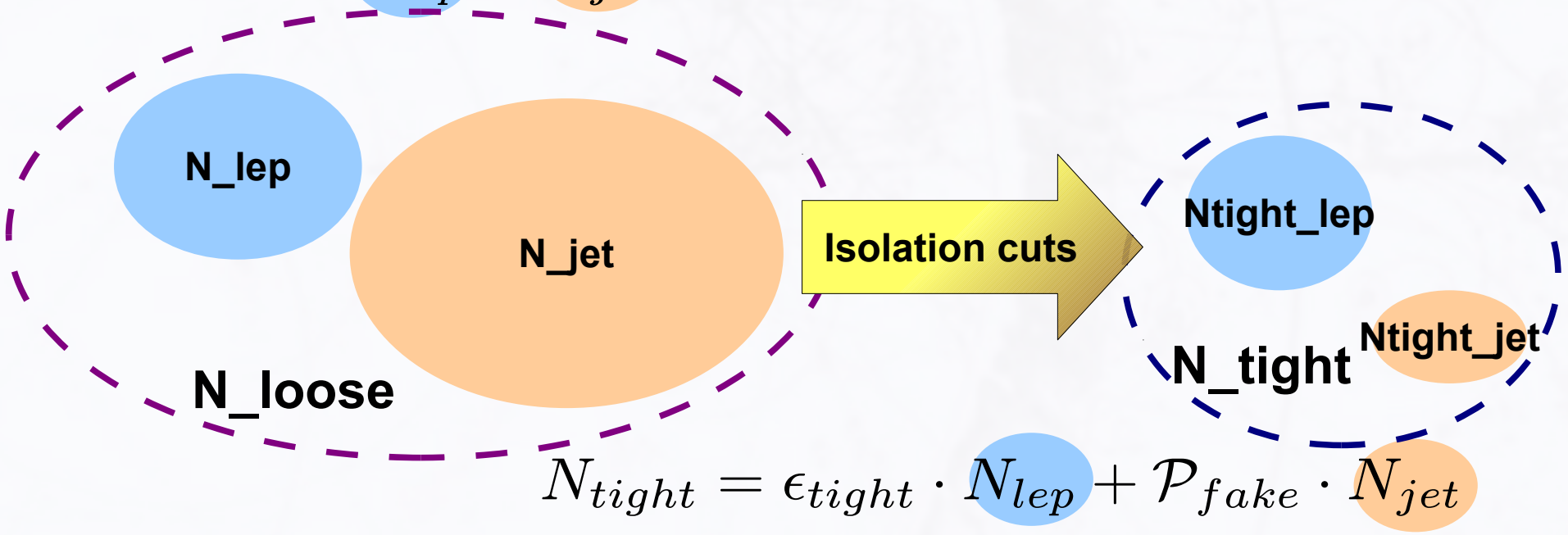
Event Selection

- Vertex:
  - At least one valid (good+non_fake) vertex
  - Number of DOF > 4, |Z| < 24 mm, Rho < 2
- Lepton: (di-lepton)
  - PF Electron
    - Gsf, pT > 20 GeV, |eta| < 2.1, Avoid ECL crack: eta 1.442-1.566
    - No near-by "clean" muon within |dR| < 0.1
    - Loose: CiC Tight with ID + conversion veto + RelIso 0.125
    - Tight: CiC SuperTight with ID + conv. veto + RelIso 0.1
  - Muon
    - pT > 20 GeV, |eta| < 2.4, Muon ID
    - Loose: relative combined PF isolation < 0.125
    - Tight: relative combined PF isolation < 0.1
- Z boson:
  - mass 60 – 120 GeV from loose leptons, min dR>0.05
  - Best Z chosen by mass difference, 2nd Z veto
- W boson:
  - PF Missing ET > 30 GeV with one-and-only-one tight lepton
- Jet: Particle-flow AK5 jets with L1,2,3 JEC
  - pT > 30 GeV, |eta| < 2.4
  - JetID Loose selection, constitute tracks associate to Z Tight

Data driven analysis

- To estimate the tt and DY contribution
  - WZ is **irreducible** for the only difference is # of jets
- Estimating background from 2lep+X(N_{jet}) & 3lep+X (N_{lep})

$$N_{loose} = N_{lep} + N_{jet}$$



$$N_{tight} = \epsilon_{tight} \cdot N_{lep} + \mathcal{P}_{fake} \cdot N_{jet}$$

- Extrapolation to b-tag selection:
  - **Efficiencies** and **fake rates** for b-jet and light-jets
  - Top mass window from MC