CDF Run-II の現状: top, bottom, new physics

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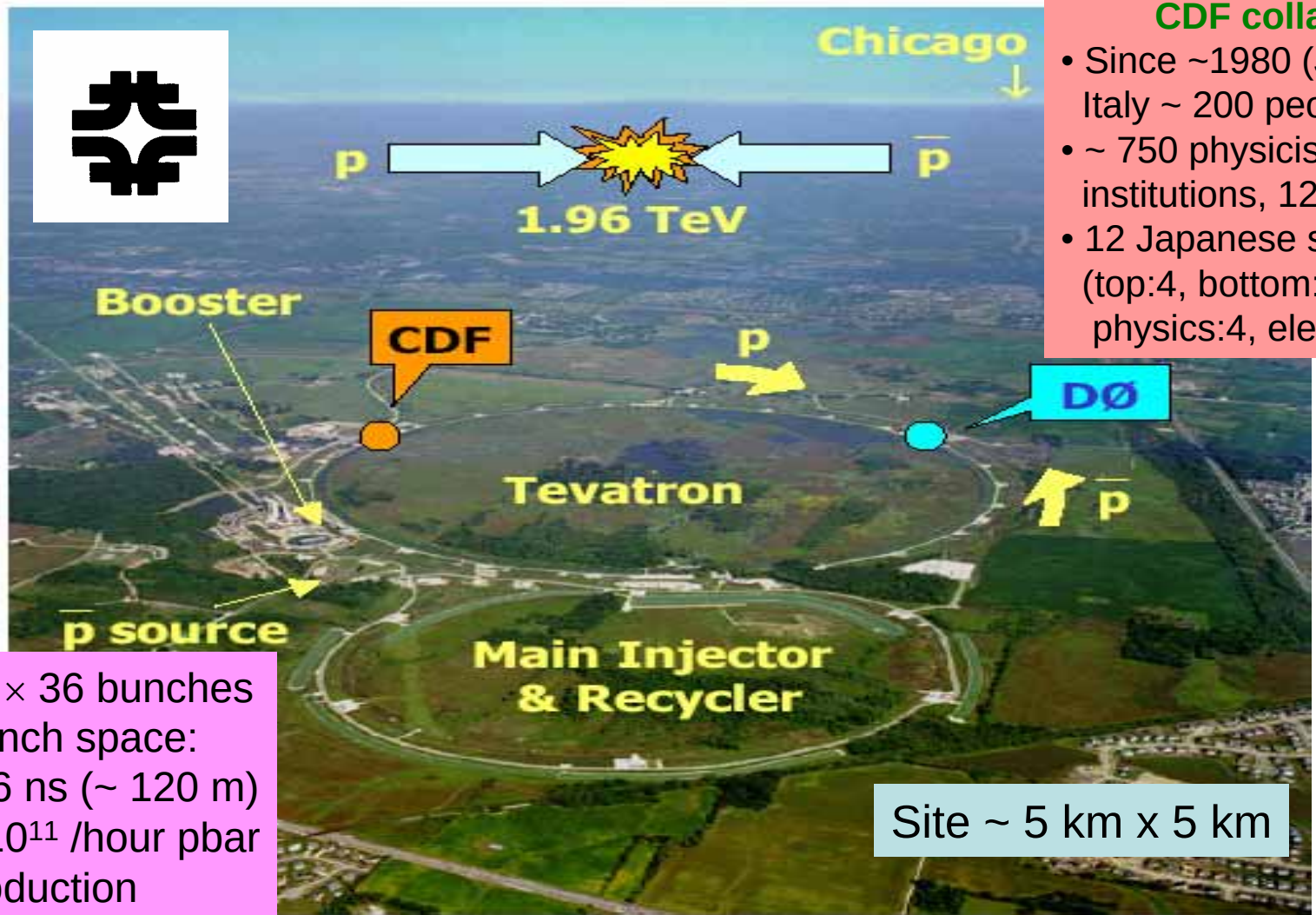
New/updated results since Mar/04

- Top: ~ 26 results
  - Cross section: 10 analyses
  - Mass: 8 analyses
  - $B_F(t \rightarrow Wb)$
  - $B_F(t \rightarrow \tau\nu b)$
  - W helicity: 2 analyses
  - Single top search
  - $t \rightarrow H^{\pm}b$ search
  - New physics search in dilepton
  - t' search
- New physics: ~ 8 results
  - SM $h \rightarrow WW$
  - MSSM $A \rightarrow \tau\tau$
  - $\chi_1^0 \rightarrow G\gamma$
  - $g\sim \rightarrow b\sim b$
  - Randall-Sundram graviton
  - Technicolor
  - $Z' \rightarrow \tau\tau$
  - Quasi-stable $H^{\pm\pm}$
- Bottom: ~ 19 results
  - Masses
  - Lifetime
  - Hadronic moment in $\ell\nu X_c$
  - B_d mixing: 3 analyses
  - Flavor tagging (Jet Q)
  - $B_F(B_s \rightarrow \phi\phi)$: observation
  - $B_F(B^{\pm} \rightarrow \phi K^{\pm})$, CP violation
  - $\Lambda_b \rightarrow p(K,\pi)$ search
  - $B_F(B \rightarrow hh)$, CP violation
  - $B \rightarrow \psi(K^{*0},\phi)$ angular analysis (time dependent)
  - Charm physics: 3 analyses
  - Pentaquark searches: 4 analyes

Many topics for students to work on

Introduction

Fermilab/CDF



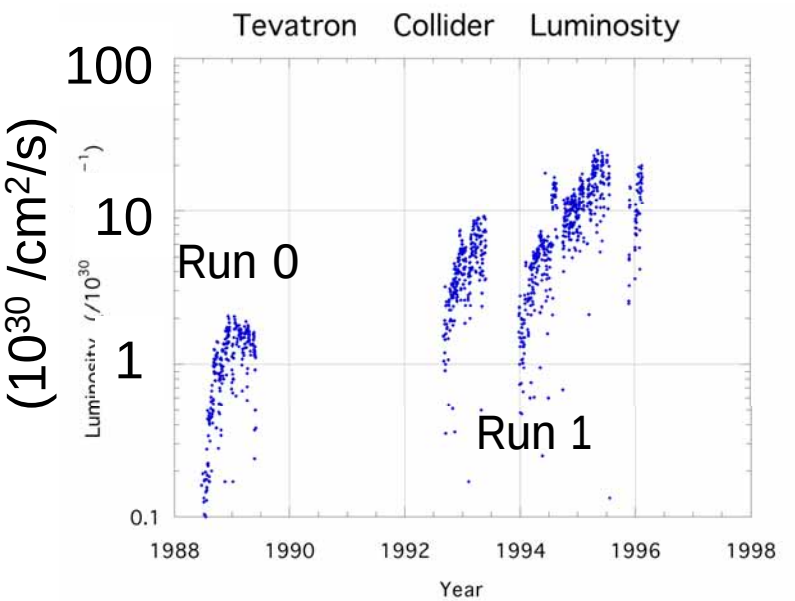
CDF collaboration

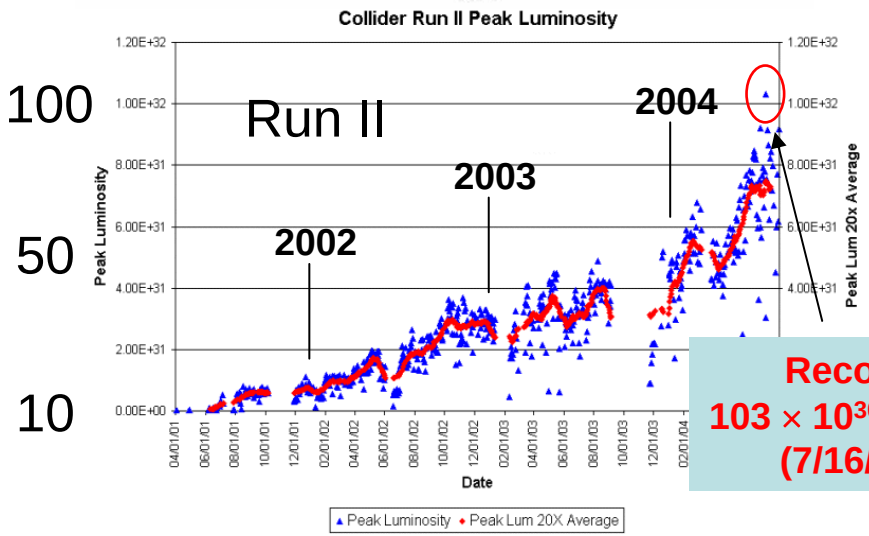
- Since ~1980 (Japan, US, Italy ~ 200 people)
- ~ 750 physicists, 59 institutions, 12 countries
- 12 Japanese students now (top:4, bottom:3, new physics:4, electroweak:1)

- 36 × 36 bunches
- Bunch space: 396 ns (~ 120 m)
- ~ 10^{11} /hour pbar production
- Store ~ 18 hours

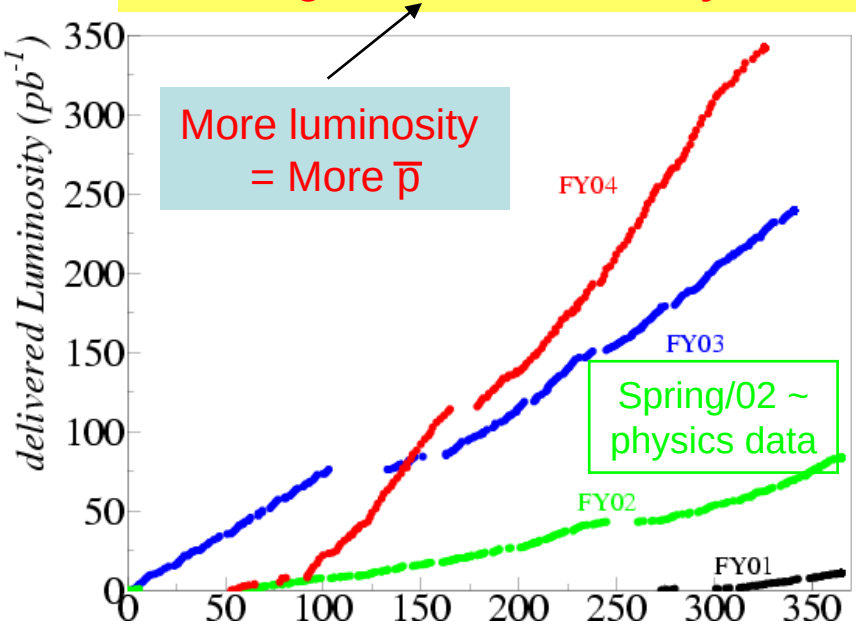
Site ~ 5 km x 5 km

Luminosity status





- **Total ~700 pb^{-1} delivered (~ 500 pb^{-1} on tape)**
- **FY04 goal 230 pb^{-1} achieved**
- **Run II goal: 4.4 ~ 8.6 fb^{-1} by FY09**

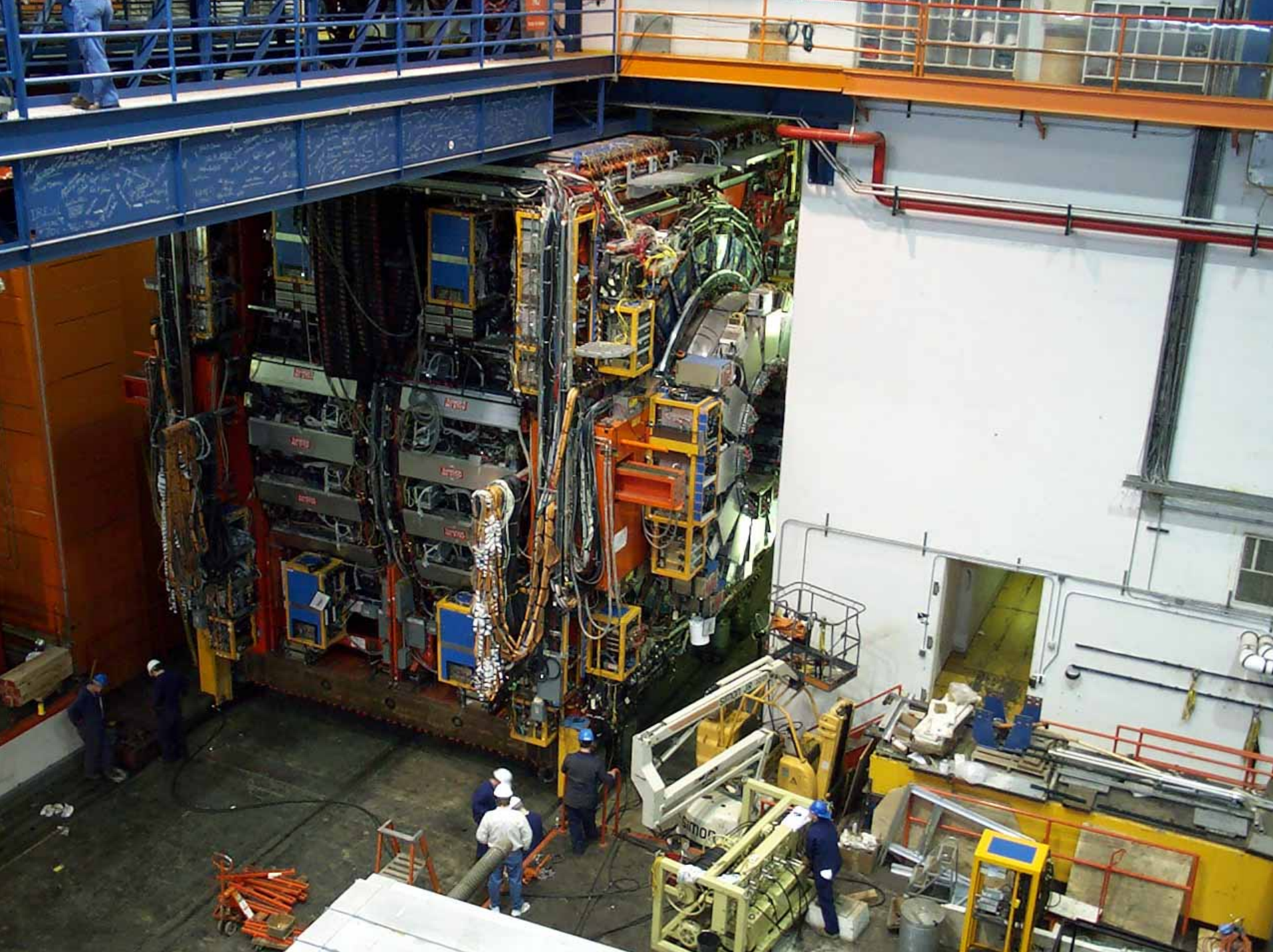


Fall/01: comissioning

Record 103 × 10^{30} /cm^2/s (7/16/04)

Results from ~ 200 pb^{-1} today


CENTRAL HADRON
CALORIMETER

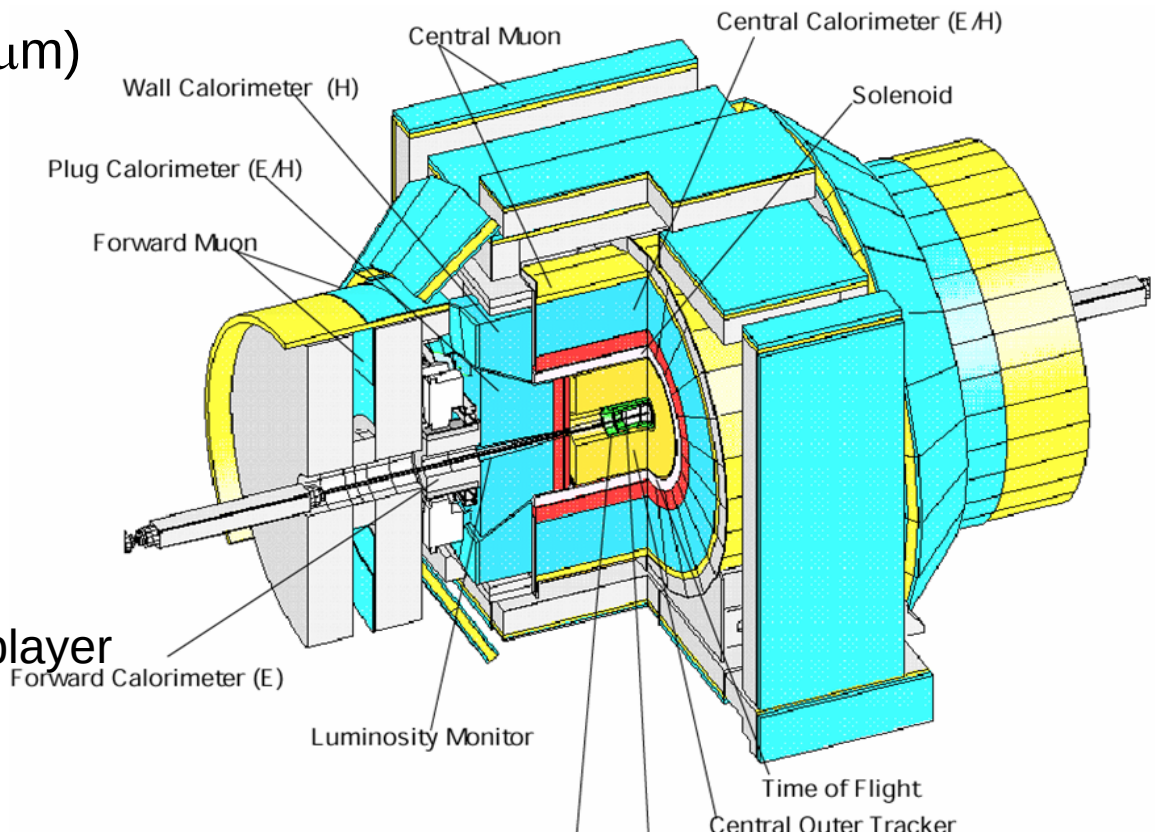


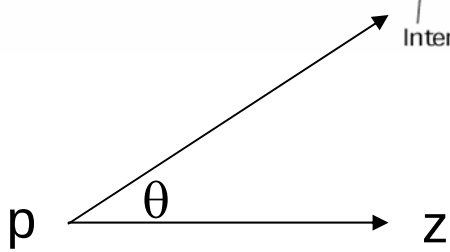

Sprite

The CDF detector

- Silicon tracking (σ_{d0} ~ 14 μm)
  - $|\eta| < 2$
- Central tracking in 1.4 T
  - drift chamber
  - $|\eta| < 1$
  - dE/dx
- Sampling CAL (scinti)
  - shower max embedded
- Muon chamber
  - $|\eta| < 1$ (forward is not a player yet)
- TOF (σ ~ 100 ps)
  - $|\eta| < 1$
- Preshower

Total 1 M channels, 250 kB/ev





$P_T = P\sin\theta$
$E_T = E\sin\theta$
$\eta = -\log(\tan(\theta/2))$
$|\eta| < 1$ Central = 40~140°
$|\eta| > 1$ forward

Collisions

Process	Cross section (pb)	Rate at 80×10^{30} cm^{-2}/s
Inelastic p-pbar	60000000000	4.8 MHz
Inclusive jets (E_T > 20 GeV)	20000000	1.6 kHz
bX (|y|<1)	30000000	2.4 kHz
WX $\rightarrow$ (eν)X	2500	0.2 Hz
tt	7	0.00056 Hz
Wh (m_h = 120 GeV/c^2)	0.2	0.000016 Hz

(~ 1/17 hours)

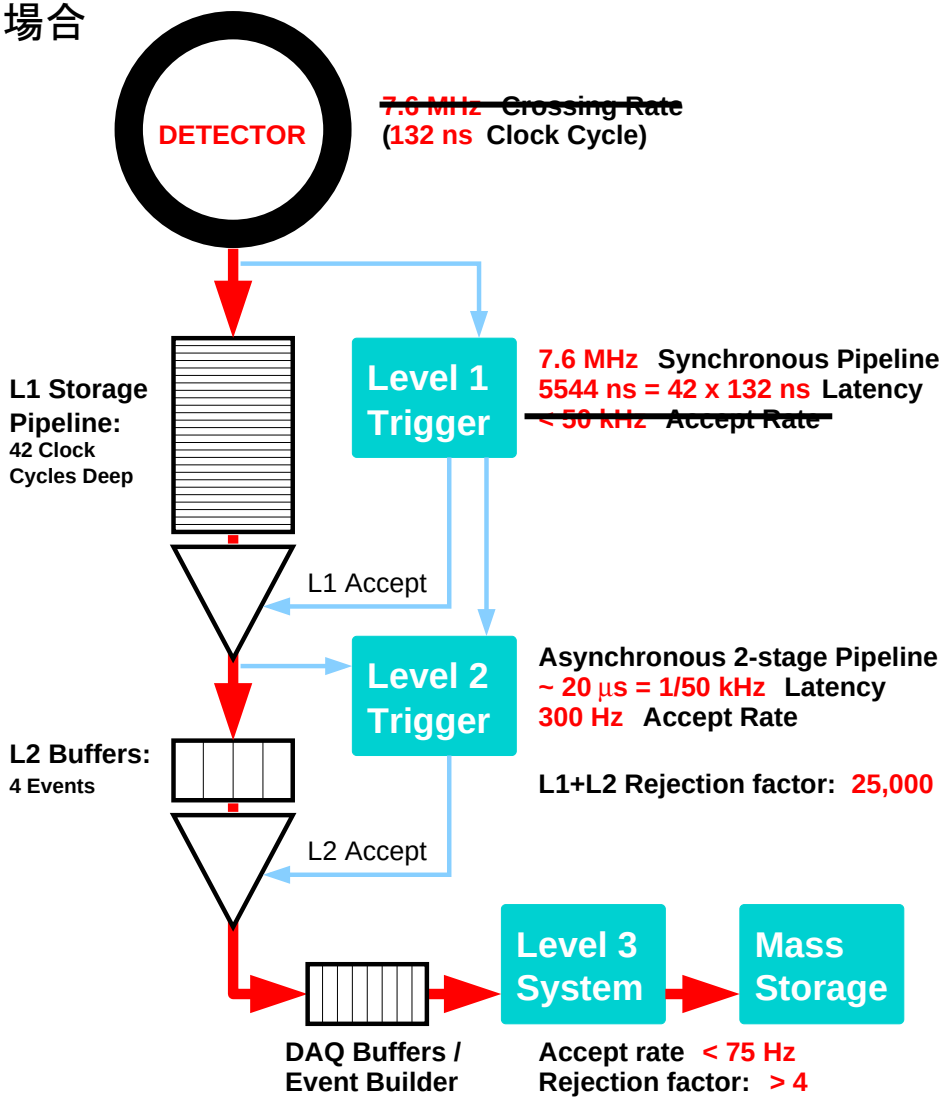
Trigger system

- Crossing: 1.7 MHz

inelastic 4.8 MHz の場合
crossing あたり平均
4.8/1.7=3 個の反応

- Level 1: hardware
  - Cal E, Muon stub, Missing E_T
  - XFT (fast track finder): p_T, $\Delta\phi$
  - < 8 kHz (reduction ~x200)
- Level 2: hardware
  - Cal. Cluster, Cluster-track match, E/P, Shower max
  - SVT links silicon tracks to Level 1 tracks: d_0, 2ndary vertex
  - Isolation
  - ~ 100 triggers
  - < 300 Hz (reduction ~x25)
- Level 3: Linux PC farm
  - Faster versions of offline
  - < 75 Hz (reduction ~ x6)

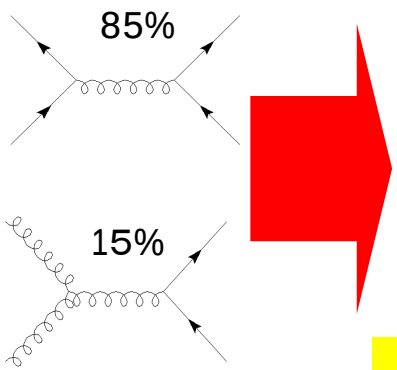
20 MB/sec outputs



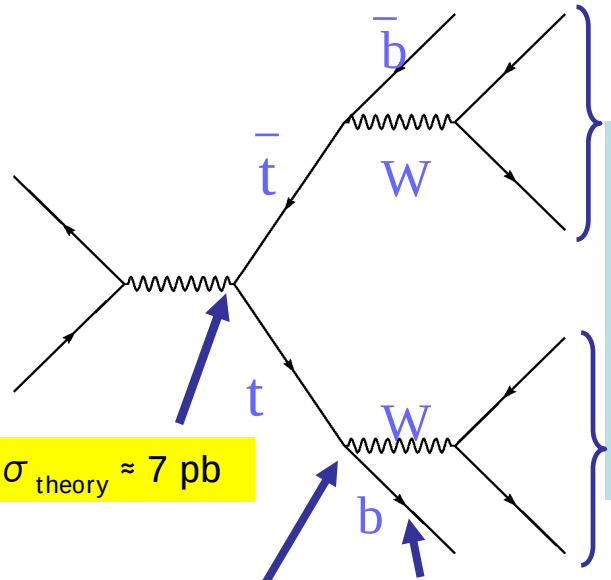
Top physics

Top-quark pair production and decay

Pair Production:



NB: qq, gg fractions reversed at LHC



$\sigma_{theory} \approx 7$ pb

BR($t \rightarrow Wb$) ≈ 100%

Event topology determined by the decay modes of the W's

b-jet tagging: identify via secondary vertex or soft lepton tag

Most favorable modes

- Dilepton (ee, μμ, eμ)
  - $\ell\ell$ + 2 b-jets + ν
  - BF = 5%
- Lepton (e, μ) + jets
  - ℓ + 4 jets (2b2q) + ν
  - BF = 30%
- All-hadronic
  - BF = 44%
  - 6 jets (2b4q), no ν
- Hadronic τ (τ_{had}) + X
  - e.g. eτ, μτ
  - BF = 21%

More challenging but still possible

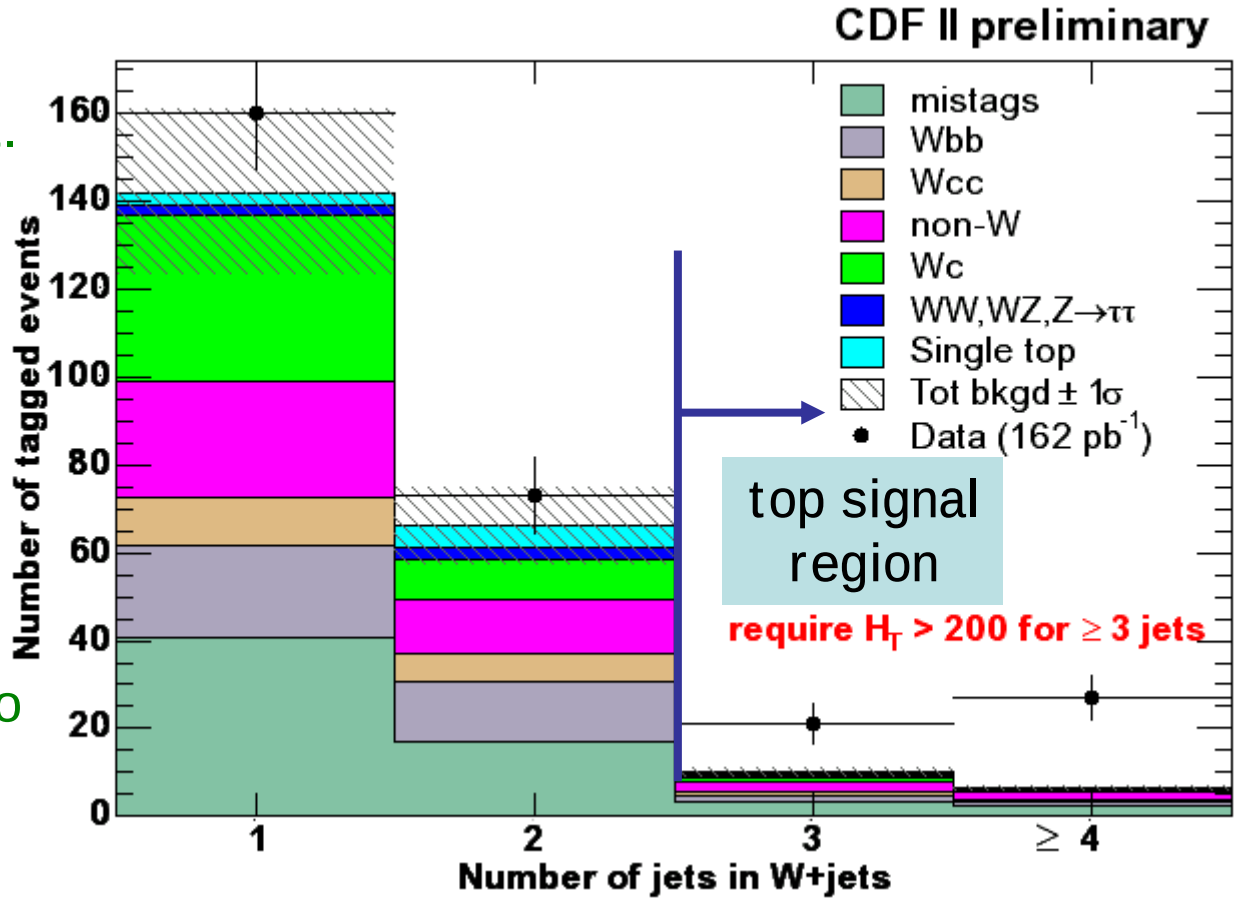
Cross section: lepton + jets SVX b-tag

- Lepton p_T > 20 GeV.
- Jet E_T > 15 GeV, $|\eta|$ < 2.
- Missing E_T > 20 GeV

- ≥ 1 b-tagged jet (displaced secondary vertex reconstruced by the Si detector)

- BG: W+jets dominant. MC composition, data to normalize.

- 48 observed, 14 BG



$5.6\ ^{+1.2}_{-1.0}(\text{stat})\ ^{+1.0}_{-0.7}(\text{syst})$ pb

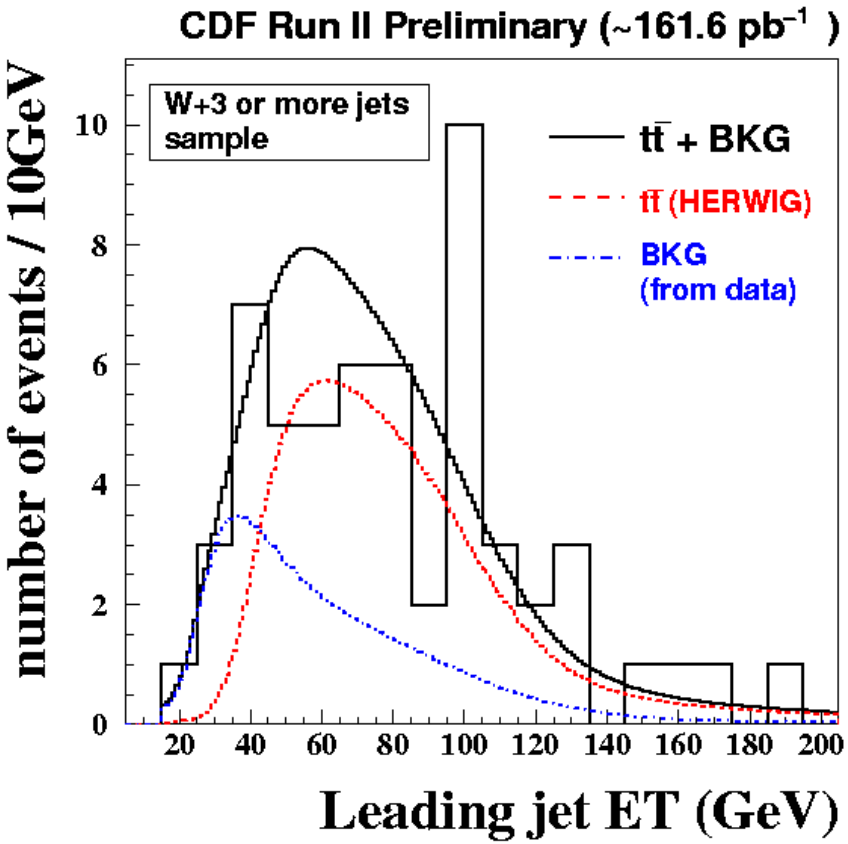
Cross section: lepton + jets SVX b-tag + Kinematical fitting

T. Maruyama (Tsukuba)

- Leading jet E_T sepctra are similar between various BG components.

⇓

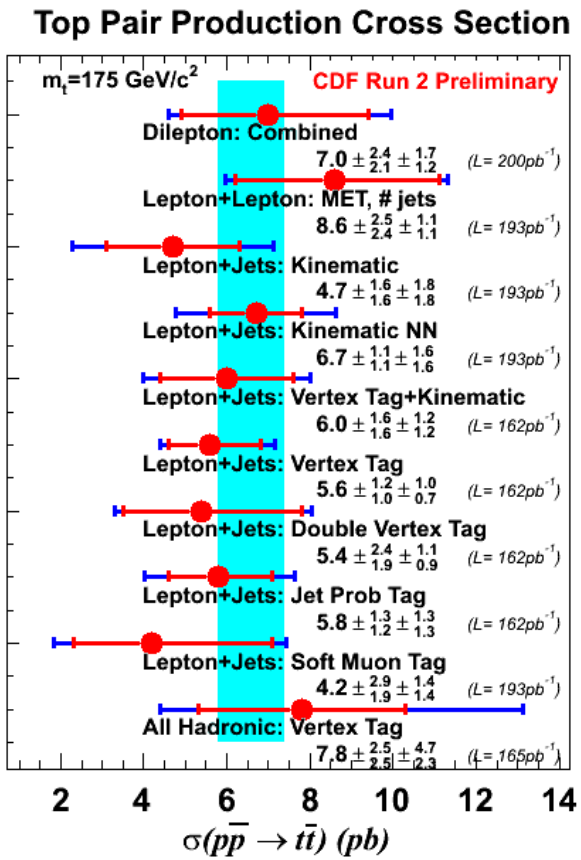
Use E_T spectra of jets not tagged as b jets in data to model BG shapes, then fit (unbinned)

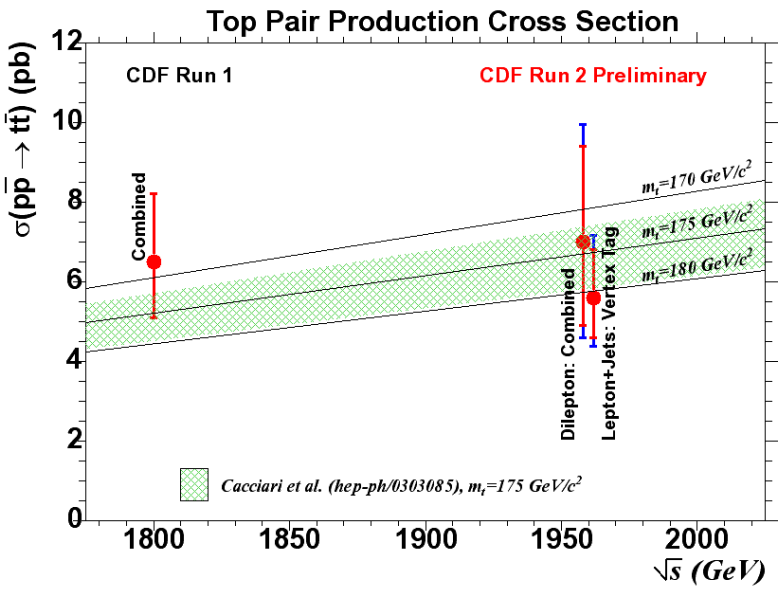


$6.0\ ^{+1.5}_{-1.8}(\text{stat}) \pm 0.8(\text{syst})$ pb

Summary of cross section measurements

(signatures) ⊗ (b-tagging algorithms) ⊗ (other details) ~ 10 groups





30% uncertainty (7% expected for 2 fb^{-1})

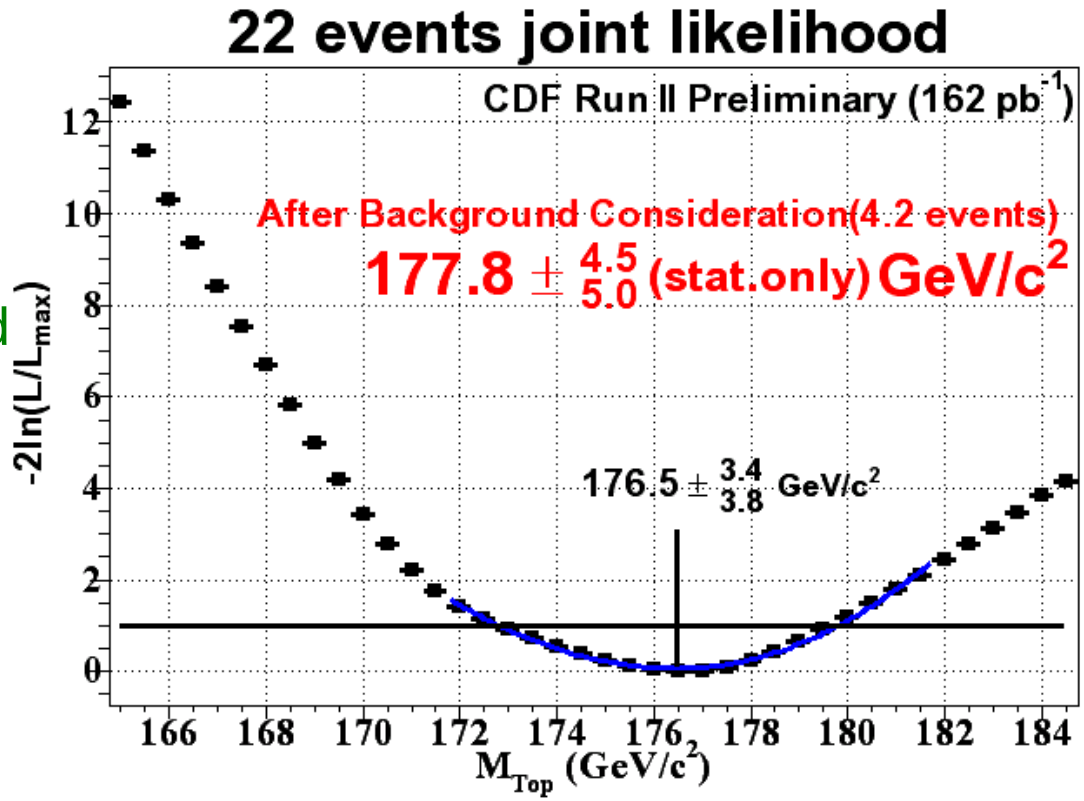
SM = $6.7\ ^{+0.71}_{-0.88}$ pb

Mass: lepton + jets

SVX b-tag, Dynamical Likelihood Method

Kohei Yorita, K. Kondo (Waseda)

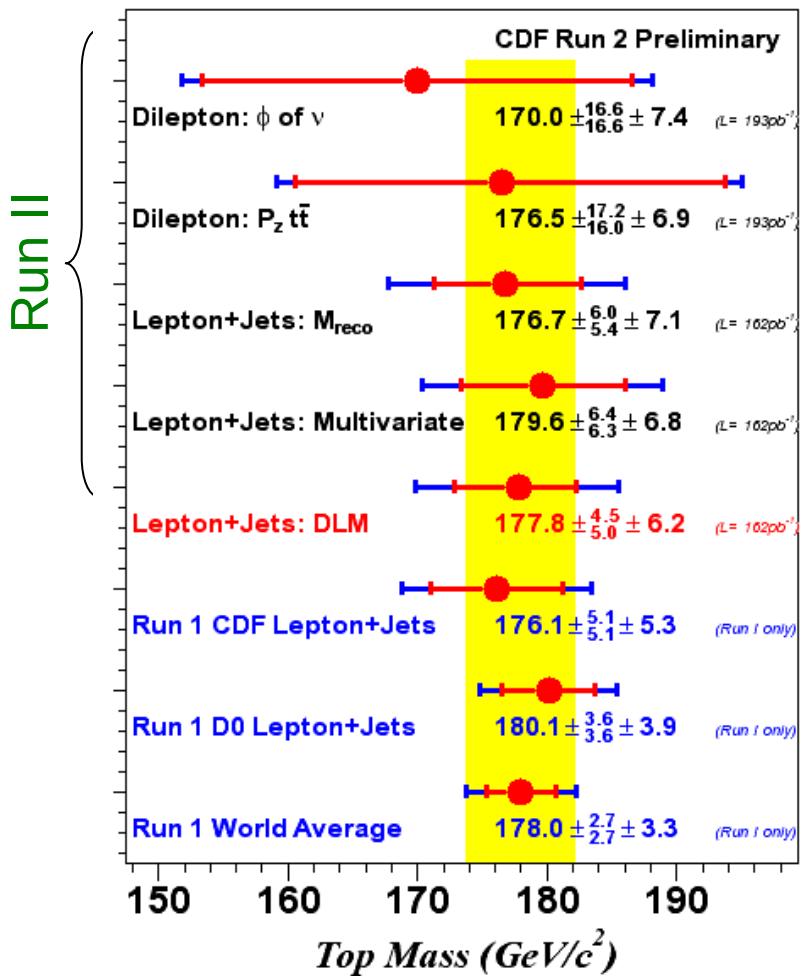
- ℓ + =4 jets
- Consider
  $(d\sigma) \otimes$ (detector effects)
  as the likelihood, and unbinned fit
- Needs BG fraction as input to rescale a raw value by the amount expected from MC studies

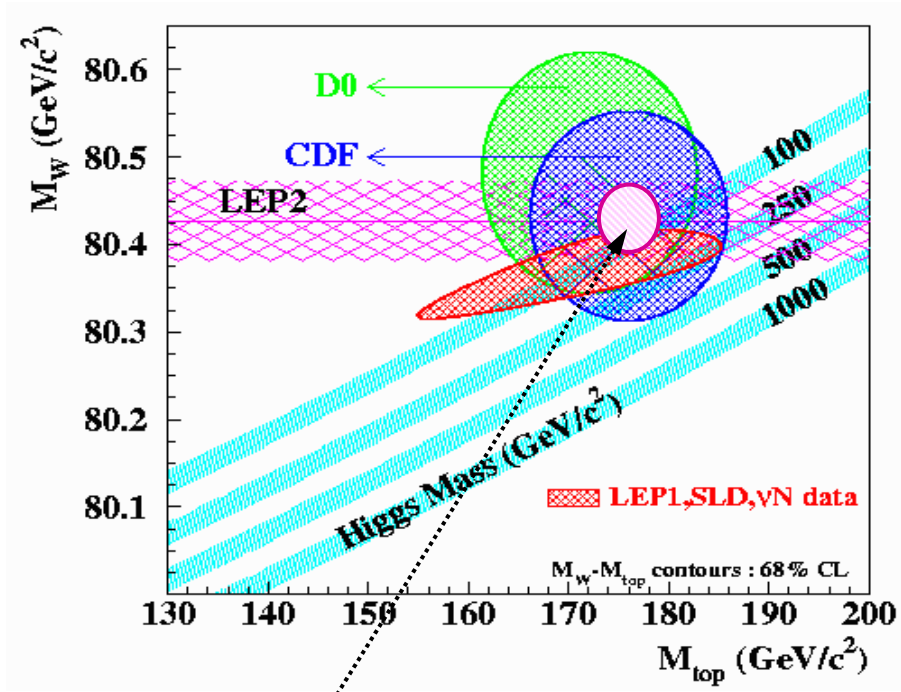


$177.8\ ^{+4.5}_{-5.0}(\text{stat}) \pm 6.2(\text{syst})\ \text{GeV}/c^2$

Summary of top mass measurements

~ 10 groups (4 Japanese students)





Run II goals

δM_W ~30 MeV

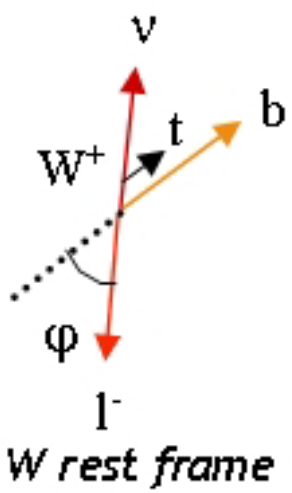
δM_t ~ 3 GeV

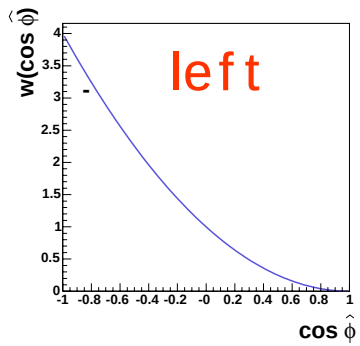
$\Delta m_h / m_h$ ~ 35%

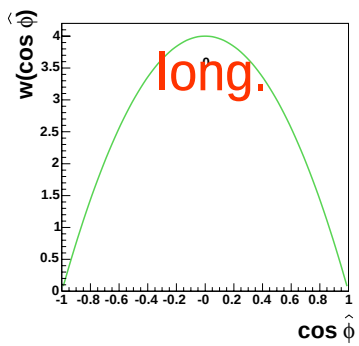
W helicity in top decays

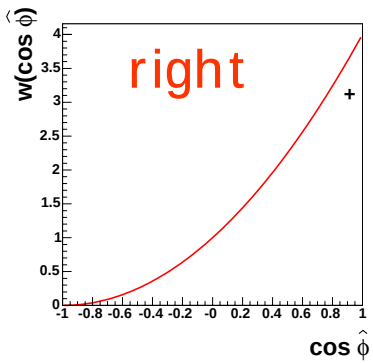
V–A test with a bare quark at ~ EWK breaking scale

$$w(\cos\varphi_{l^-\bar{b}}) = F_- \cdot \frac{3}{8}(1-\cos\varphi_{l^-b})^2 + F_0 \cdot \frac{3}{8}(1-\cos^2\varphi_{l^-b}) + F_+ \cdot \frac{3}{8}(1+\cos\varphi_{l^-b})^2$$









SM predictions (for m_b=0):

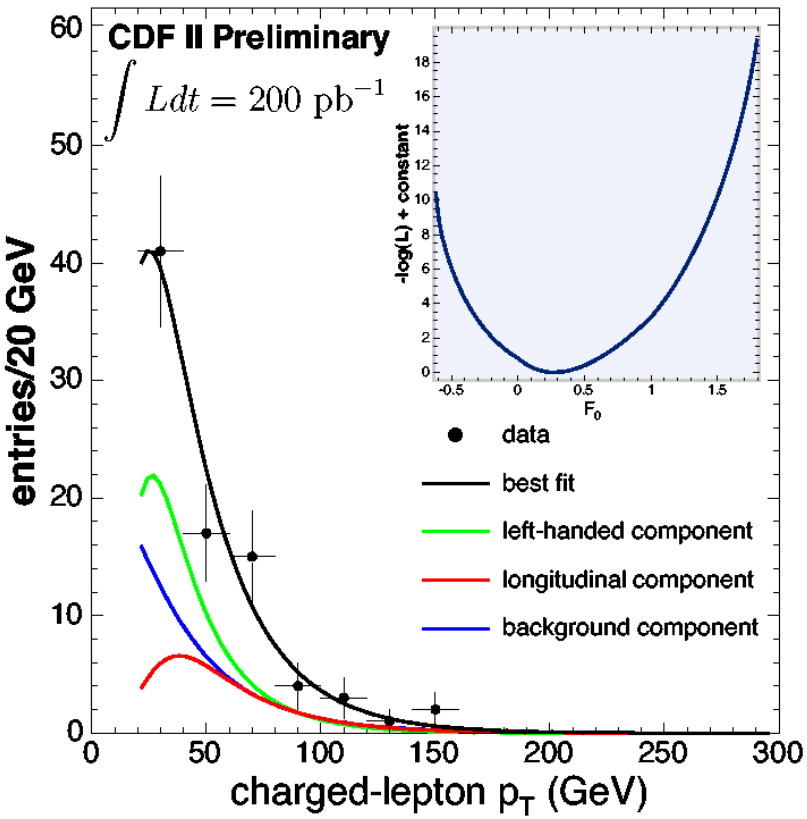
$$F_- = \frac{2\omega}{1+2\omega} \approx 0.3 \qquad F_0 = \frac{1}{1+2\omega} \approx 0.7 \qquad F_+ = 0$$

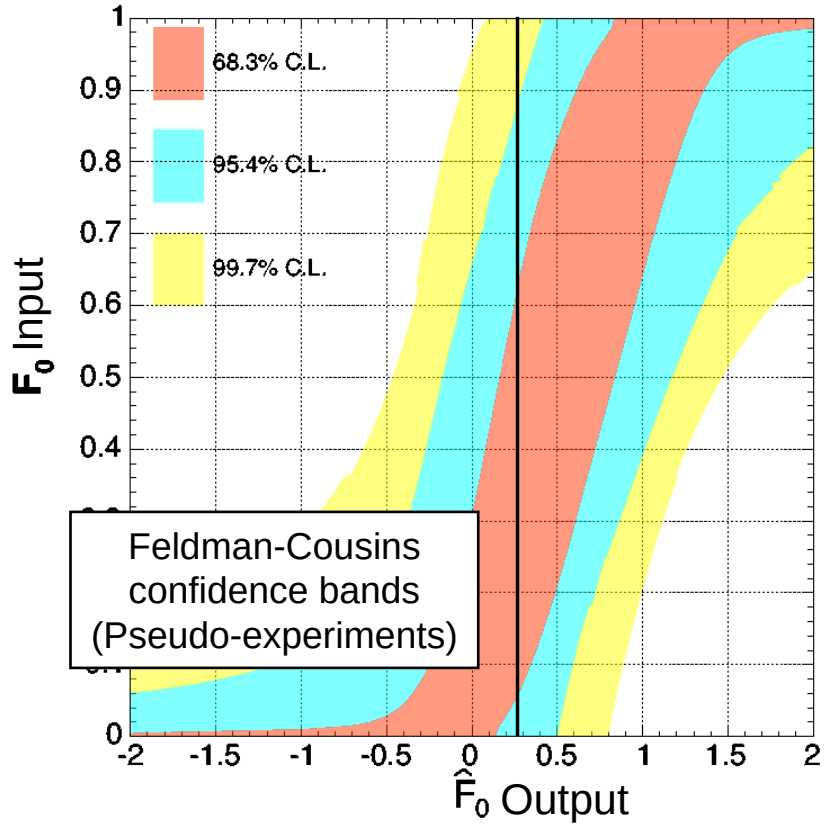
where $\omega = M_W^2/M_{top}^2$

parameter to measure

W helicity in top decays

lepton + jets and dilepton combined



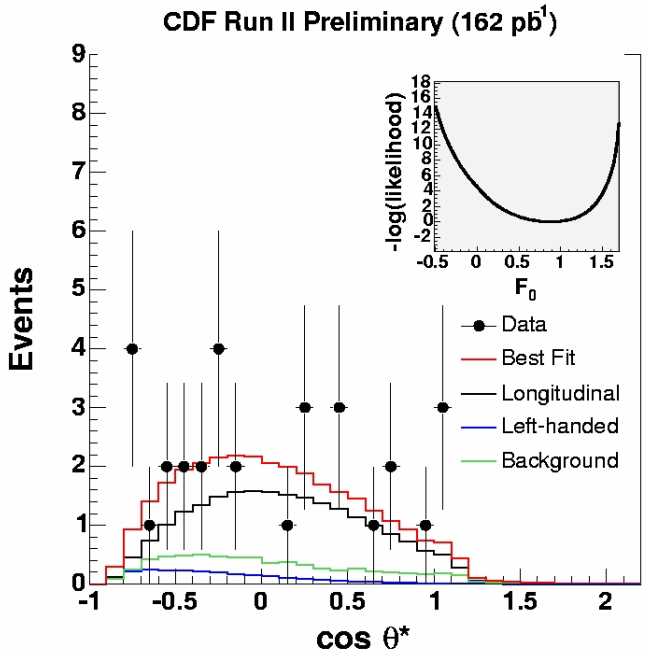


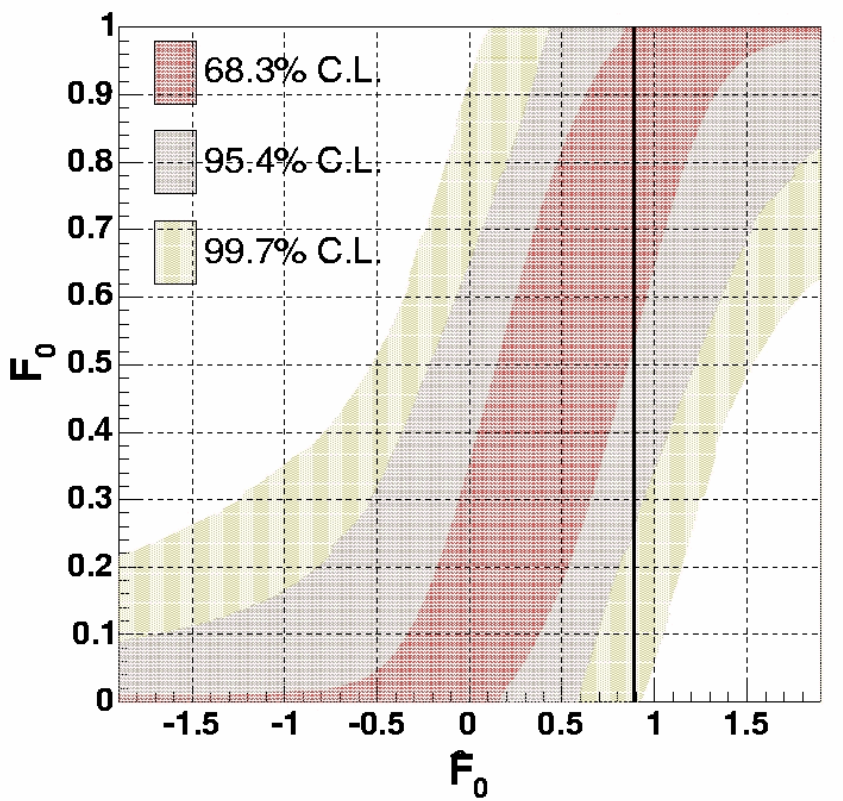
$F_0 = 0.27\ ^{+0.35}_{-0.21}$(stat+syst)

$F_0 < 0.88$ @ 95% C.L.

W helicity in top decays

- Binned fit to the approximated $\cos\theta^* \sim 2(M_{\ell b})^2/(m_t^2 - m_W^2) - 1$
- ℓ + ≥ 4 jets with ≥ 1 b-tag
- χ^2 fit to identify the b paired to ℓ (m_W, m_t constraints etc.)



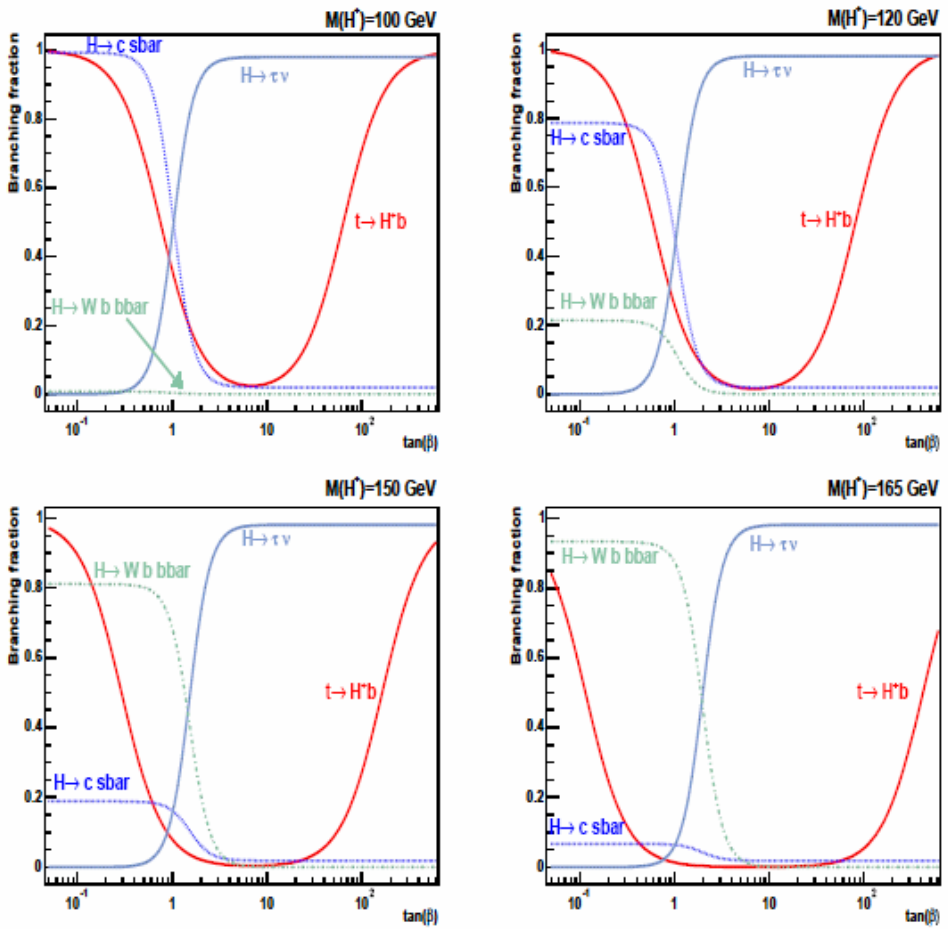


$F_0 > 0.25$ @ 95% C.L.

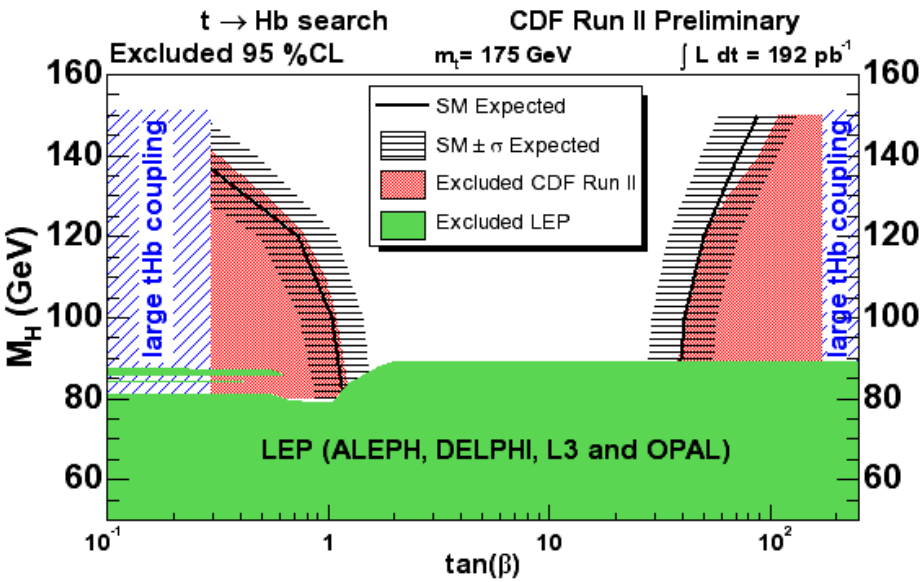
$F_0 = 0.89\ ^{+0.30}_{-0.34}$ (stat.) ± 0.17 (syst.)

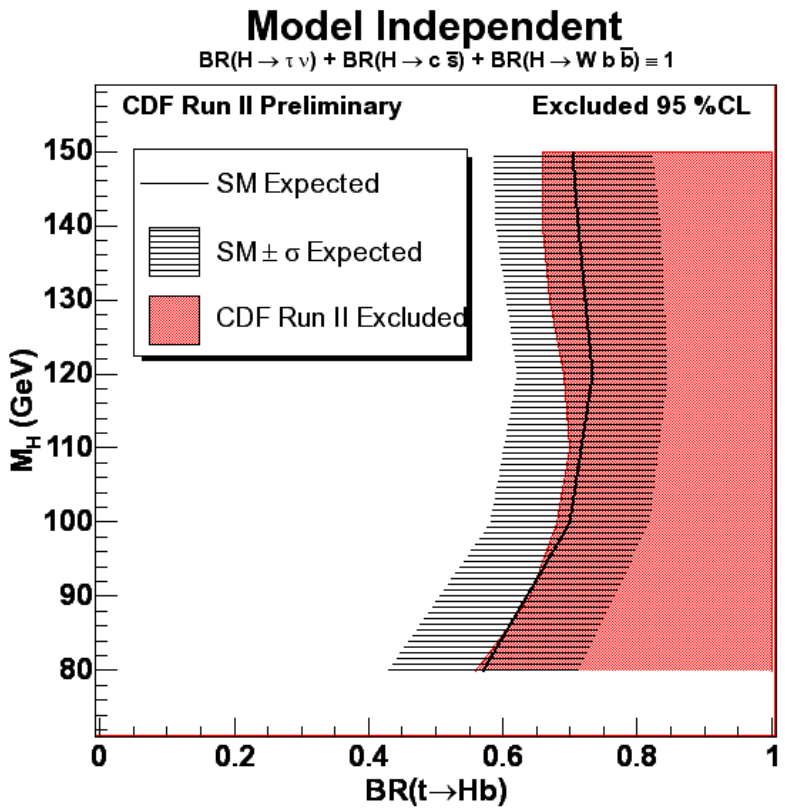
$t \to H^{\pm} b$ search

- MSSM: tree level only (= 2HDM-II)
  - $H^{\pm}(ud_L \cdot m_u \cot\beta + ud_R \cdot m_d \tan\beta)$
  - $H^{\pm} \to cs, \tau\nu, Wbb$
- Also, model independent analysis
- 2ℓ, ℓj, $\ell\tau_h$ combined
- Add $t \to H^{\pm} b$ in the counting experiment (Bayesian)
  - $\tan\beta$ scan at each m_H
  - B_F scan for the model independent



$t \to H^{\pm} b$ search



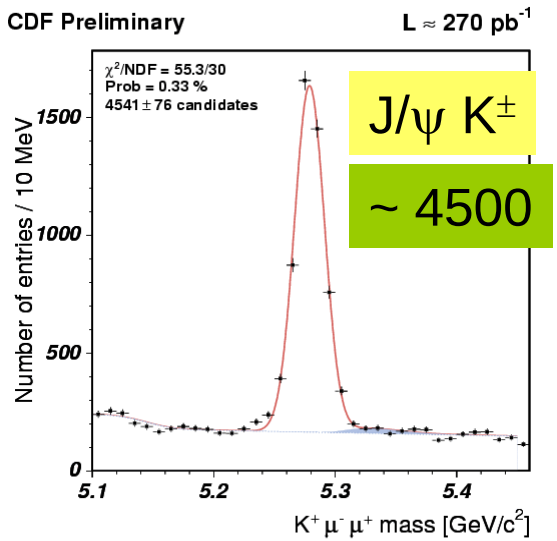


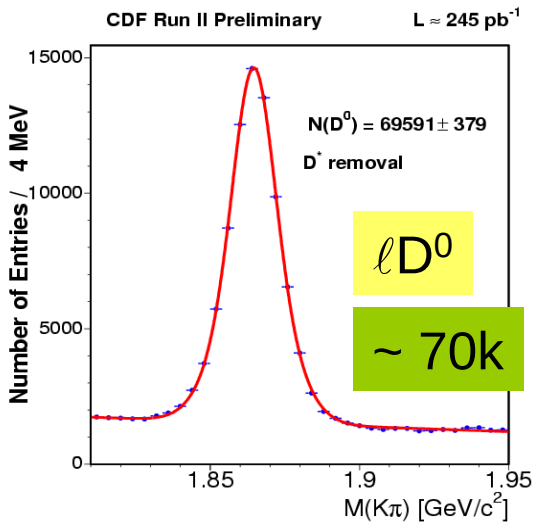
$B_F(t \to H^{\pm} b) < 0.7$ @ 95% C.L.
$(80 < m_H < 150$ GeV)

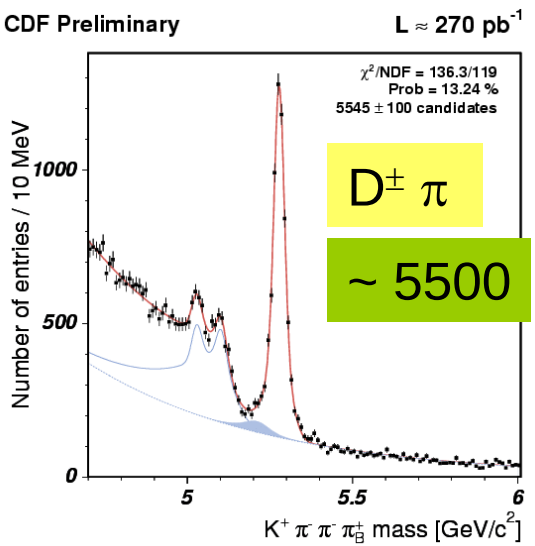
bottom physics

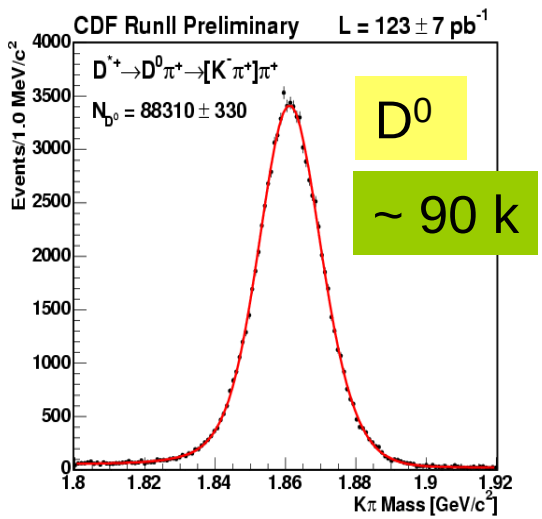
b triggers

- J/ $\psi \rightarrow \mu\mu$ (ee as well)
  - p_T > 1.5 GeV/c
- ℓ + SVT
  - ℓ + displaced track
  - p_T (ℓ,trk) > (4,2) GeV/c
  - d_0 > 120 μm
- Two track trigger
  - two displaced tracks from a decay
  - p_T > 2 GeV/c
  - d_0 > 120 μm
  - decay length > 200 μm





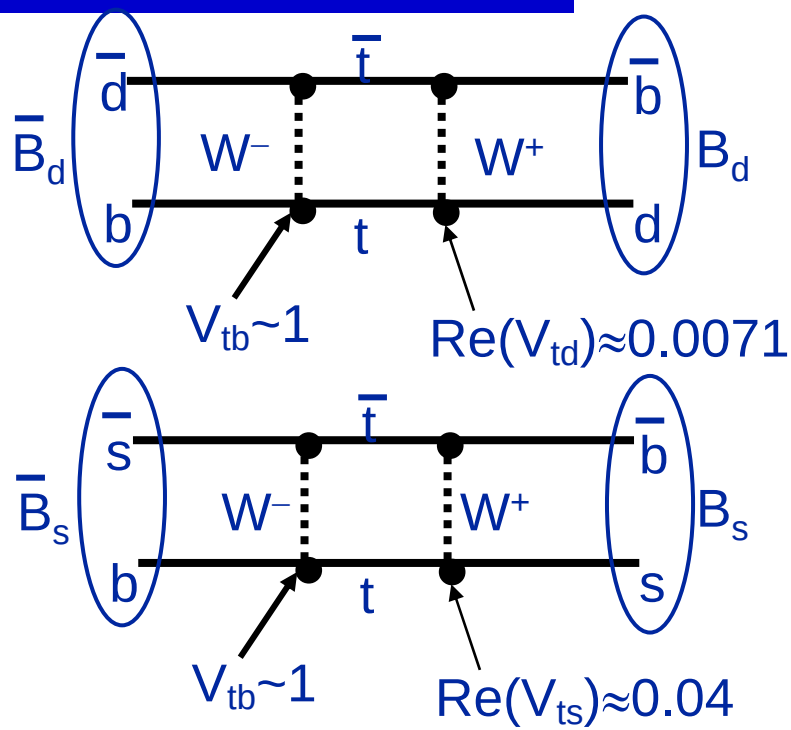


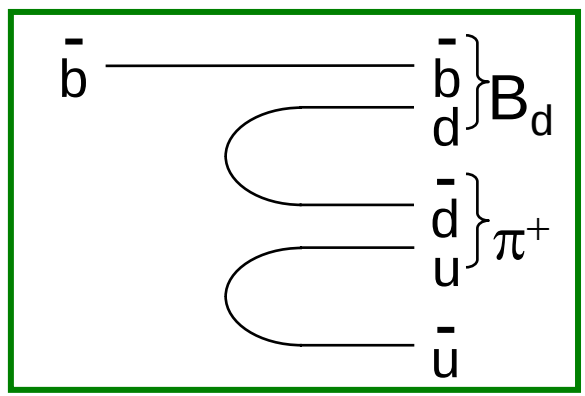


Mixing

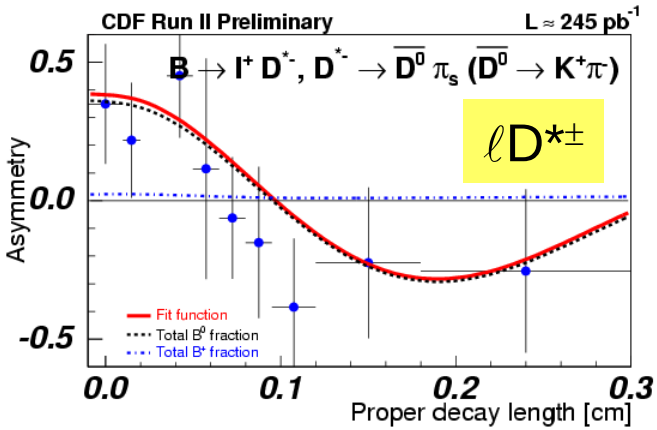
$$A(t) = \frac{(B \to B) - (B \to \bar{B})}{(B \to B) + (B \to \bar{B})} \propto \cos(\Delta m \cdot t)$$

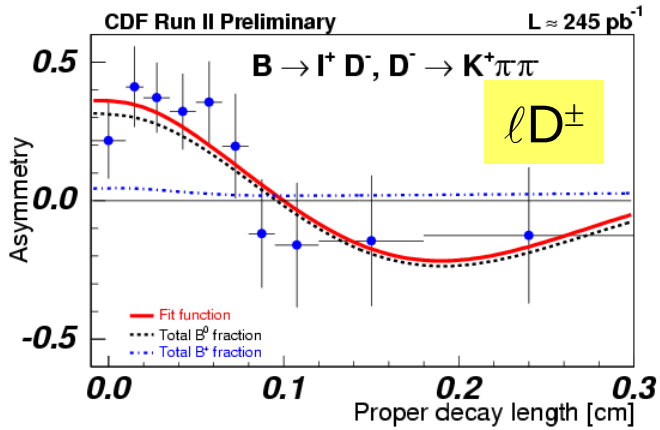
- B_d^0
  - $\Delta m_d \sim 0.5\ ps^{-1}$
  - fully mix in 4 lifetimes
- B_s^0
  - $\Delta m_s > 14.4\ ps^{-1}$ @ 95%C.L
  - fully mix in < 0.15 lifetime (0.23 ps)
- Need to know b or bbar at creation (flavor tagging)
  - Same side π/K tagging (SST)
  - Opposite side tagging (OST)
    - soft e/μ (SET, SMT)
    - jet charge (JQT)
  - $A_{obs} = (1-2f)A_{true} = D \cdot A_{true}$
    $(\Delta A_{obs})^2 \propto 1/(\varepsilon D^2)$

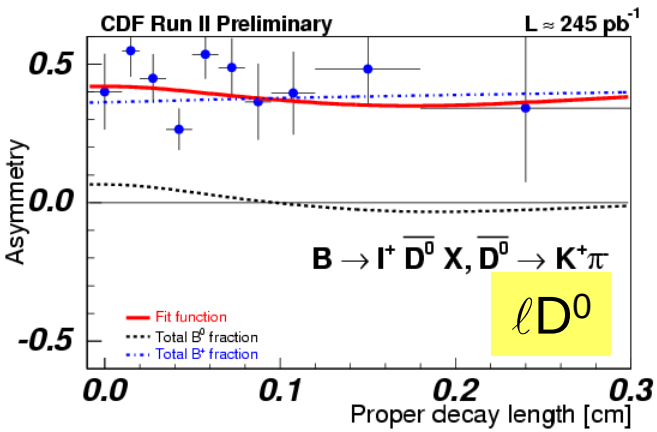




B_d Mixing Semileptonic, SST+OST







- SST + OST (3 kinds, priority-ordered)
- 3 samples × 10 tagging combinations

Example plot here

Dilution best = SST + SMT (agree)

(D ~ 40%, εD^2 ~ 0.2%)

(27 more plots)

$\Delta m_d = 0.443 \pm 0.052(\text{stat.}) \pm 0.030(\text{s.c.}) \pm 0.012(\text{syst.})\ ps^{-1}$ (SST)

$\Delta m_d = 0.536 \pm 0.037(\text{stat.}) \pm 0.009(\text{s.c.}) \pm 0.015(\text{syst.})\ ps^{-1}$ (SST+OST)

εD^2 (total) ~ 1.8%

$B_{d,s} \rightarrow hh'$

- Measure angle γ (ϕ_3) eventually using $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ (time dependent. After Δm_s)

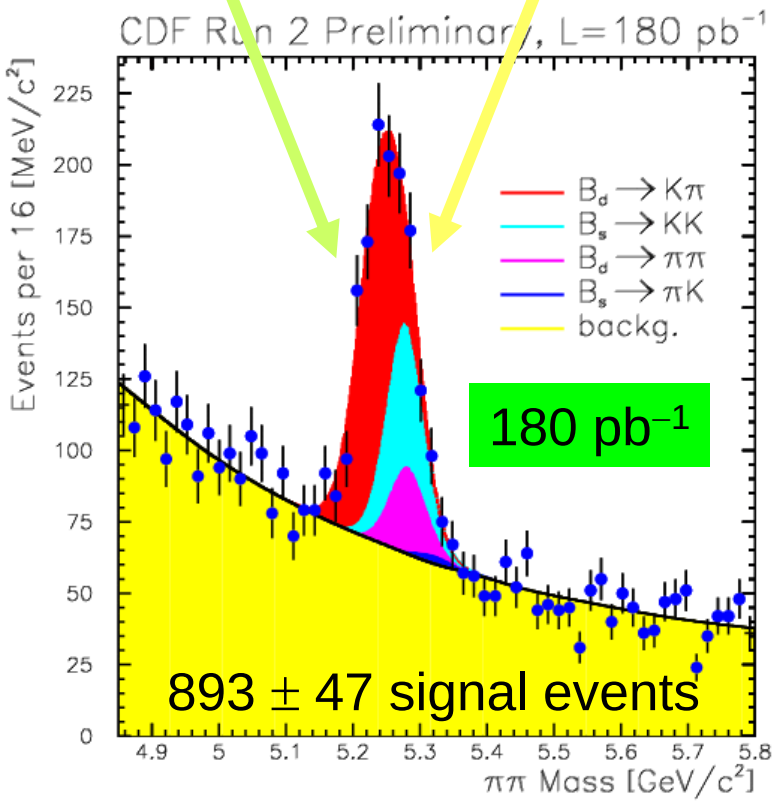
  (R. Fleischer, Phys. Lett. B459, 306 (1999))
- Can't quite identify K and π track-by-tack in the CDF $\rightarrow$ fit using
  - $M_{\pi\pi}$ vs. α, $\alpha \equiv (1-p_1/p_2)\cdot Q_1$, $p_1 < p_2$ and
  - COT dE/dx vs. p

Mode	Fraction	Yield
$B_d^0 \rightarrow K\pi$	0.57 ± 0.03(stat)	$\sim 509 \pm 37$
$B_d^0 \rightarrow \pi\pi$	0.15 ± 0.03(stat)	$\sim 124 \pm 26$
$B_s^0 \rightarrow KK$	0.26 ± 0.03(stat)	$\sim 216 \pm 27$
$B_s^0 \rightarrow K\pi$	0.02 ± 0.03(stat)	$\sim 18 \pm 25$

First observed by CDF

$B_s \rightarrow KK$
$B_s \rightarrow K\pi$

$B_d \rightarrow \pi\pi$
$B_d \rightarrow K\pi$



$B_{d,s} \to hh'$

Results (180 pb^{-1})

$$\frac{BF(B_d \to \pi^{\pm}\pi^{\mp})}{BF(B_d \to K^{\pm}\pi^{\mp})} = 0.24 \pm 0.06(\text{stat.}) \pm 0.05(\text{syst.})$$

$$A_{CP} = \frac{N(\overline{B}_d \to K^-\pi^+) - N(B_d \to K^+\pi^-)}{N(\overline{B}_d \to K^-\pi^+) + N(B_d \to K^+\pi^-)} = -0.04 \pm 0.08(\text{stat.}) \pm 0.01(\text{syst.})$$

$$\frac{f_d \cdot BF(B_d \to \pi^{\pm}\pi^{\mp})}{f_s \cdot BF(B_s \to K^{\pm}K^{\mp})} = 0.48 \pm 0.12(\text{stat.}) \pm 0.07(\text{syst.})$$

$$\frac{f_s \cdot BF(B_s \to K^{\pm}K^{\mp})}{f_d \cdot BF(B_d \to K^{\pm}\pi^{\mp})} = 0.50 \pm 0.08(\text{stat.}) \pm 0.07(\text{syst.})$$

from ~ 500 decays

Belle: $A_{CP} = -0.101 \pm 0.025(\text{stat.}) \pm 0.005(\text{syst.})$ from 2140 $B_d \to K\pi$ decays

J/ψ(K^{*0}, φ): angular analysis

- Statistically separates different polarization configurations (parity states).
  - P=+1: $A_{\parallel}$ = parallel in the plane transverse to the B decay axis.
    A_0 = both along the B decay axis (longitudinal).
  - P=−1: $A_{\perp}$ = perpendicular in the transverse plane.
- B_s^0 - $\overline{B}_s^0$ system (to J/ψφ)
  - two mass-eigenstates (Low and High) ≈ CP eigenstates.
  - a large lifetime difference is expected ($\Delta\Gamma/\Gamma_{ave}$=5 ~ 10%).

cf. 0.3% for B_d

⇓

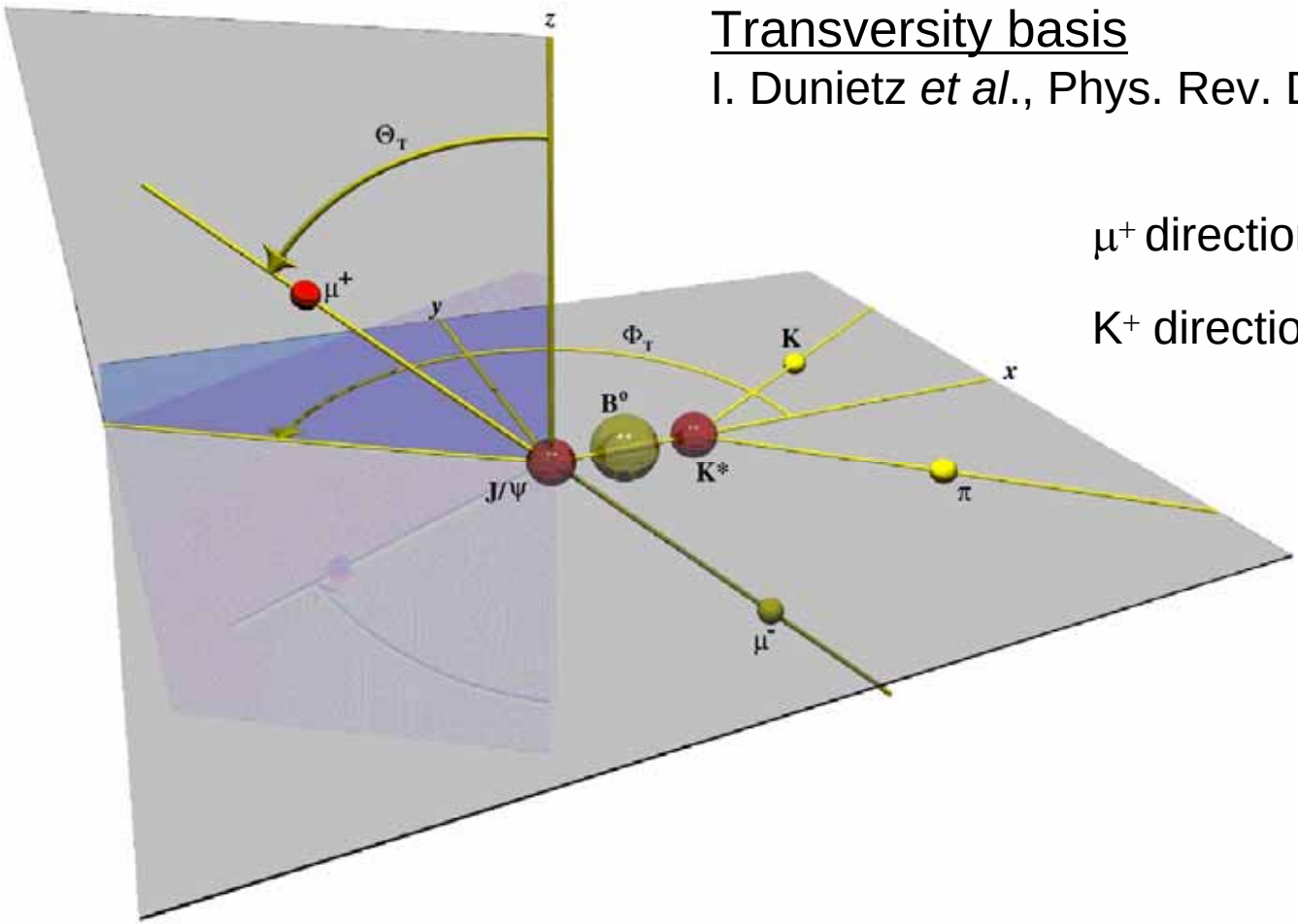
Time-dependent mixtures of the amplitudes ($A_{\parallel}$, A_0, $A_{\perp}$).

$$\sim (A_0 + A_{\parallel})e^{-\Gamma_L t/2 + im_L t} + A_{\perp} e^{-\Gamma_H t/2 + im_H t}$$

⇓

Time-dependent angular analysis can extract two lifetimes.

J/ψ(K^{*0}, φ): angular analysis



Transversity basis

I. Dunietz *et al*., Phys. Rev. D 43, 2193 (1991)

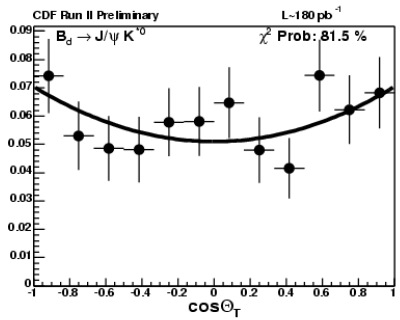
μ^+ direction: Θ_T, Φ_T

K^+ direction: Θ_K = helicity angle for φ decays

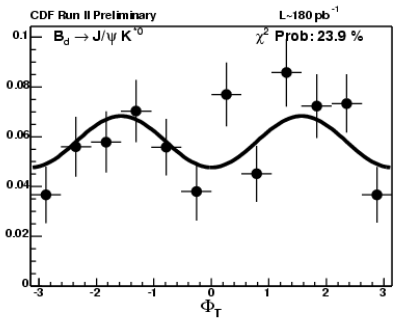
J/ψ(K^{*0}, φ): angular analysis

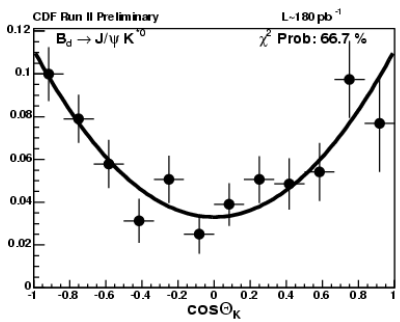
$B_d \rightarrow J/\psi\ K^{*0}$

$\cos\Theta_T$

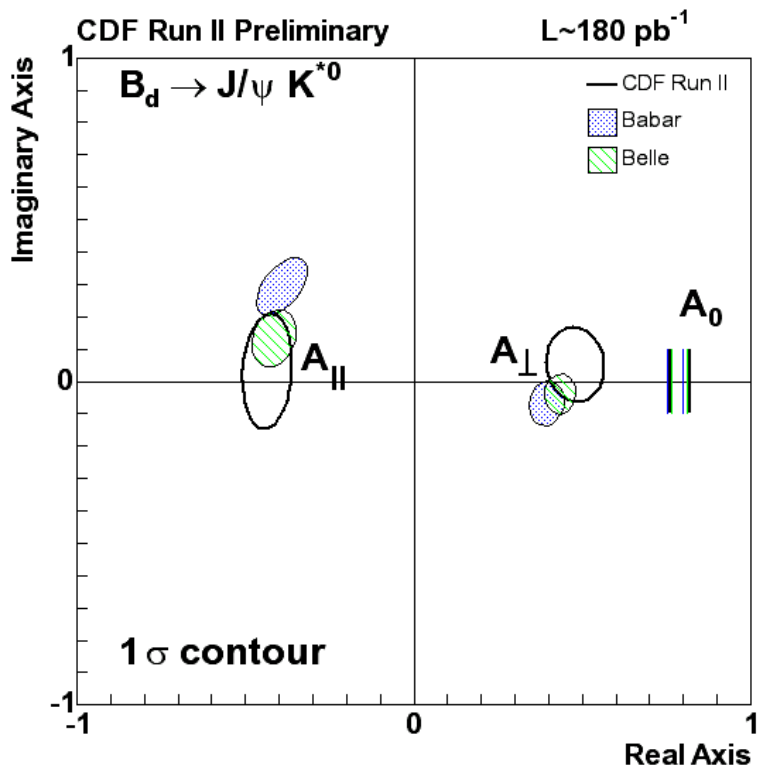


Φ_T



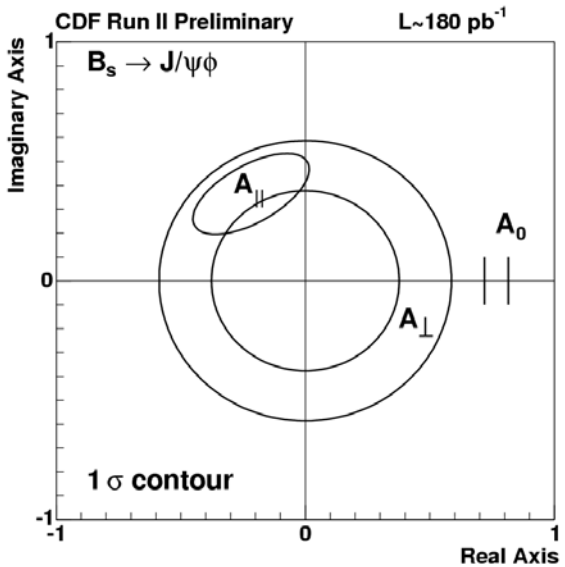


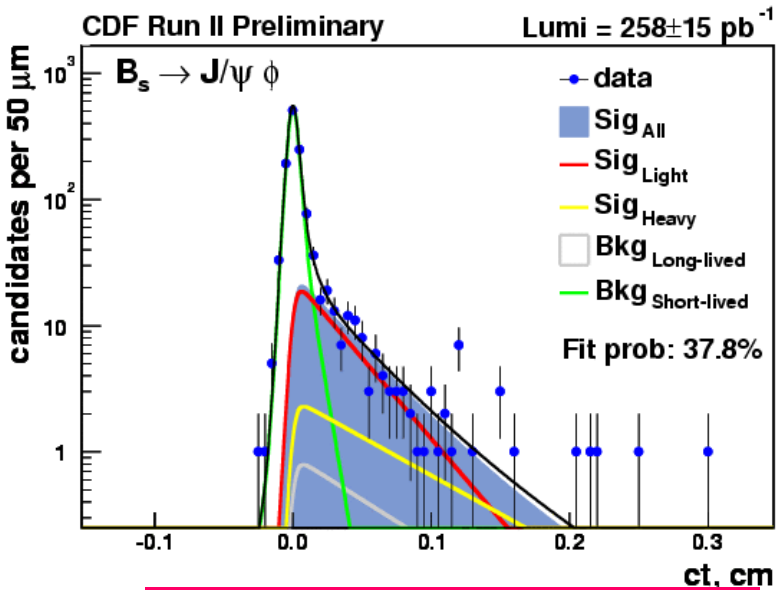
$\cos\Theta_K$

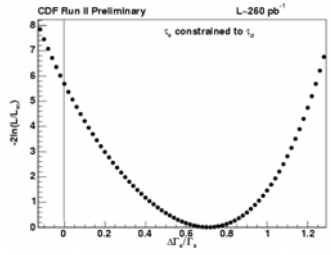


J/ψ(K^{*0}, φ): angular analysis

$B_s \to J/\psi\ \phi$







$$A_0 = 0.784 \pm 0.039 \pm 0.007$$

$$A_\parallel = (0.510 \pm 0.082 \pm 0.013) \times \exp(1.94 \pm 0.36 \pm 0.03)i$$

$$|A_\perp| = 0.354 \pm 0.098 \pm 0.003$$

$$\tau_L = 1.05^{+0.16}_{-0.13} \pm 0.02 \text{ ps}$$

$$\tau_H = 2.07^{+0.58}_{-0.46} \pm 0.03 \text{ ps}$$

$$\Delta\Gamma/\Gamma = 0.65^{+0.25}_{-0.33} \pm 0.01$$

$$\Delta\Gamma = 0.47^{+0.19}_{-0.24} \pm 0.01 \text{ ps}^{-1}$$

SM: $\Delta\Gamma_s/\Delta m_s = (3.7^{+0.8}_{-1.5}) \times 10^{-3}$

⇓

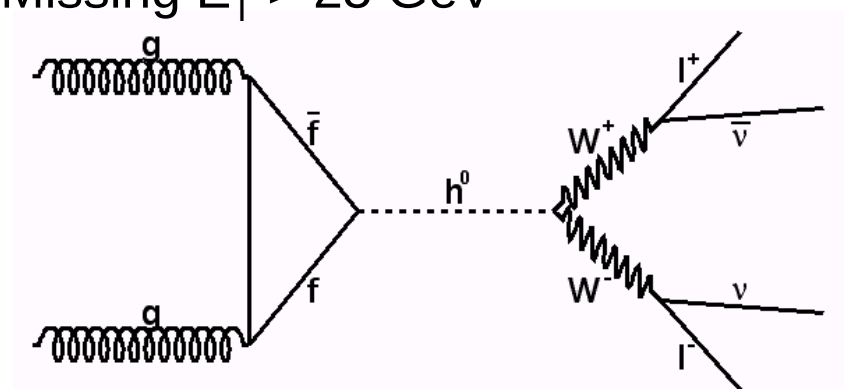
$\Delta m_s = 125^{+69}_{-55}$ ps^{-1}

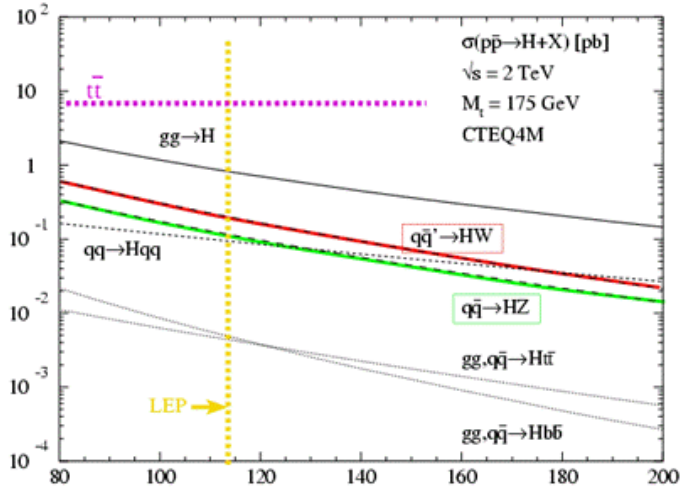
New Physics

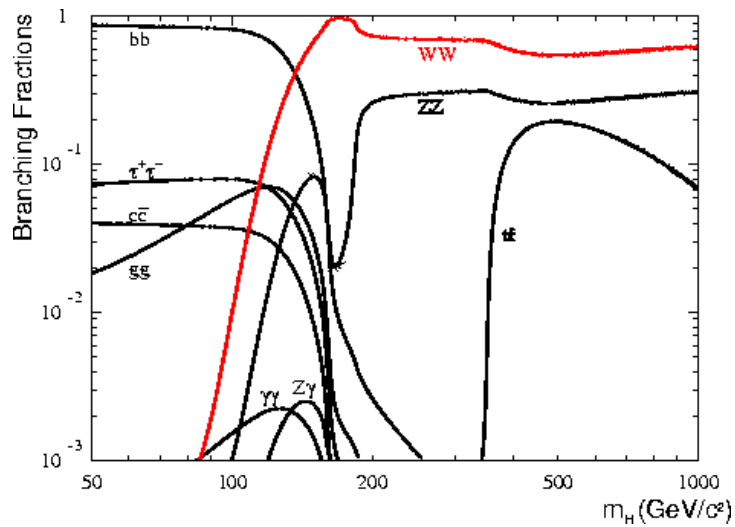
SM $h^0 \rightarrow W^+W^-$

(“golden” mode at the Tevatron)

- Cross section = 10 × Wh (~ 300 -1000 fb)
- h → bb (low mass) too hard, WW could be OK → high mass (160 GeV/c^2) region
- Opposite-sign dilepton pairs:
  - p_T > 20 GeV
  - includes plug electrons with an Si track
- Missing E_T > 25 GeV

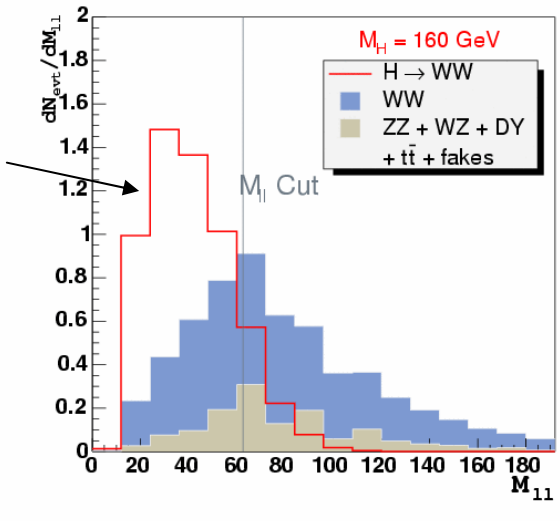




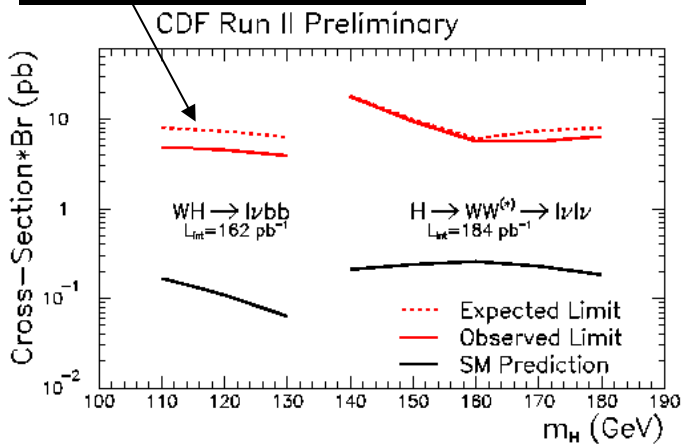


SM $h^0 \rightarrow W^+W^-$

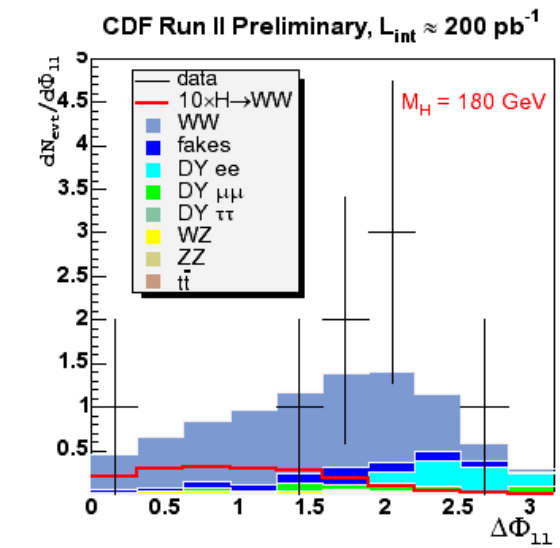
Signal normalized (× ~15) to the total BG



This Wh result is by Y. Ishizawa (Tsukuba)



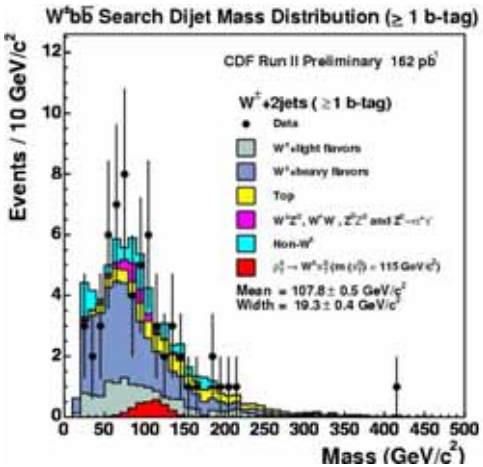
- Require small (< 60 ~ 80 GeV/c^2) dilepton mass
  - scaler → small $\Delta\phi_{\ell\ell}$ (azimuthal)
- Efficiency = 0.1 ~ 0.5% including BF(W → $\ell\nu$)
- Fit lepton opening angle

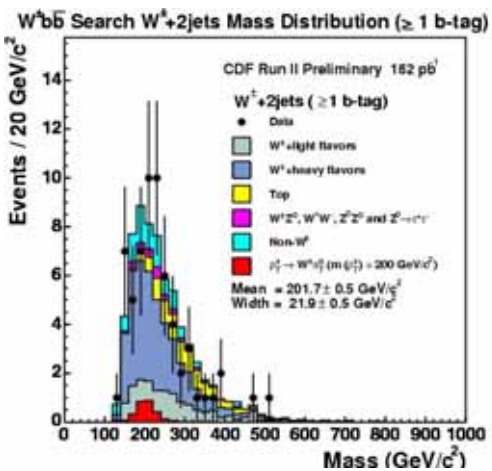


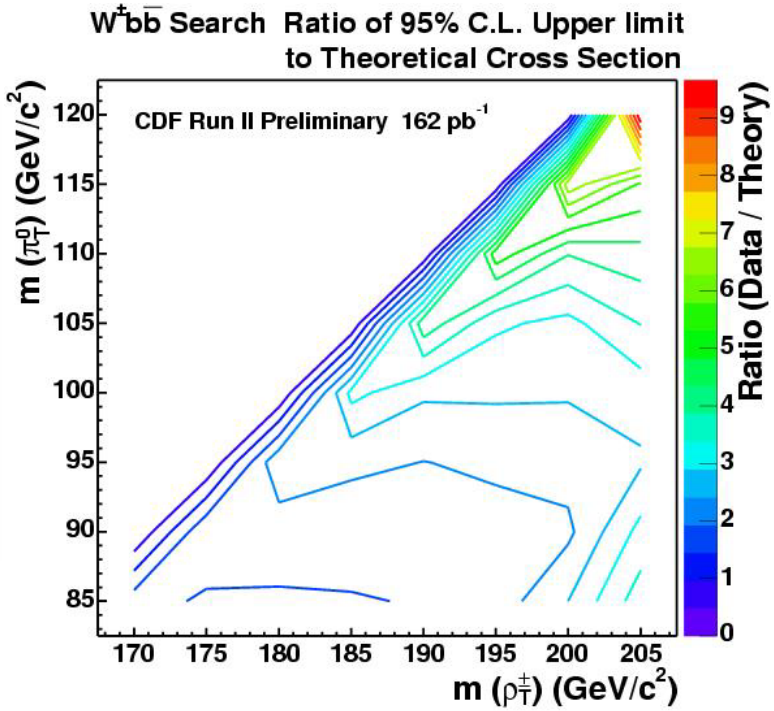
- Observed 2 ~ 8 ev (BG consistent)
- Signal level: 0.1 ~ 0.2 ev
- < 6 ~ 20 pb @ 95% C.L.

$\rho_T \rightarrow W\pi_T \rightarrow (\ell\nu)(bb)$

Yoshio Ishizawa (Tsukuba)





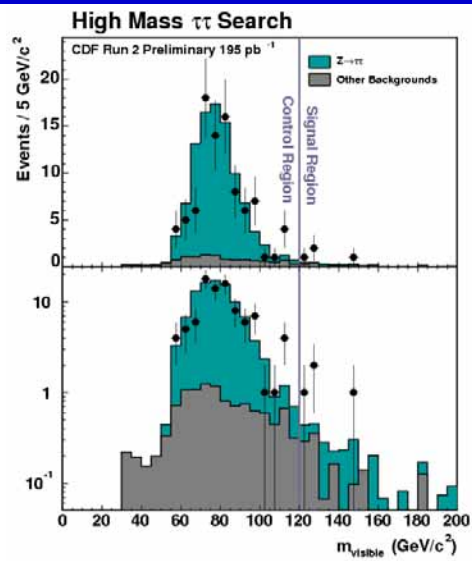


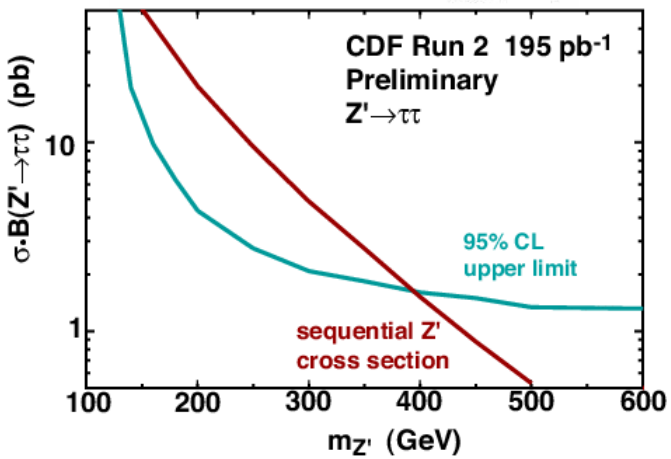
- Same analysis as the SM higgs search Wh $\rightarrow (\ell\nu)(bb)$
- W + 2 jets mass vs. 2 jets mass to extract limits

95% limits are ~ 8 pb

$Z' \rightarrow \tau\tau$

- ℓ + hadronic τ-decay
- τ + missing E_T trigger (20 GeV, 20 GeV) is added to include $\tau_h\tau_h$
- Signal region: M_{vis} = mass(ℓ, τ, missing E_T) > 120 GeV/c^2 (blinded)
- Efficiency = 1~4%
- 3 expected (DY dominant); 4 observed
- Counting experiment





m(Z') > 394 GeV/c^2 @ 95% C.L.

Bosophilic (and high-mass SM) higgs

$WH \rightarrow WWW \rightarrow$ LIKE SIGN DILEPTON ANALYSIS AT CDF RUN II

Hirokazu Kobayashi
*Kazuhiro Yamamoto
*Yoshihiro Seiya

Tsukuba University, *Osaka City University