Measuring $\Delta\Gamma_s$ at CDF with charmless two body decays

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3 March 2004

SPS Meeting Neuchatel

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Phenomenology

- Measurements of $\frac{\Delta\Gamma_s}{\Gamma_s} = \frac{2(\Gamma_L - \Gamma_H)}{\Gamma_L + \Gamma_H}$
- Interest:
  - $\frac{\Delta\Gamma_s^{SM}}{\Delta m_s^{SM}} = 3.7^{+0.8}_{-1.5}\, 10^{-3}$
  - if large possibility study of CP violation on untagged samples
  - sensitivity to new physics
- LQCD calculation $\frac{\Delta\Gamma_s}{\Gamma_s} = 0.12 \pm 0.06$ (R.Fleischer hep/ph 0204101)
- Today limit $<$ 0.54 (CL=95%) (HFAG-2003)

Methodology

Severeal method proposed to measure $\Delta\Gamma_s$:

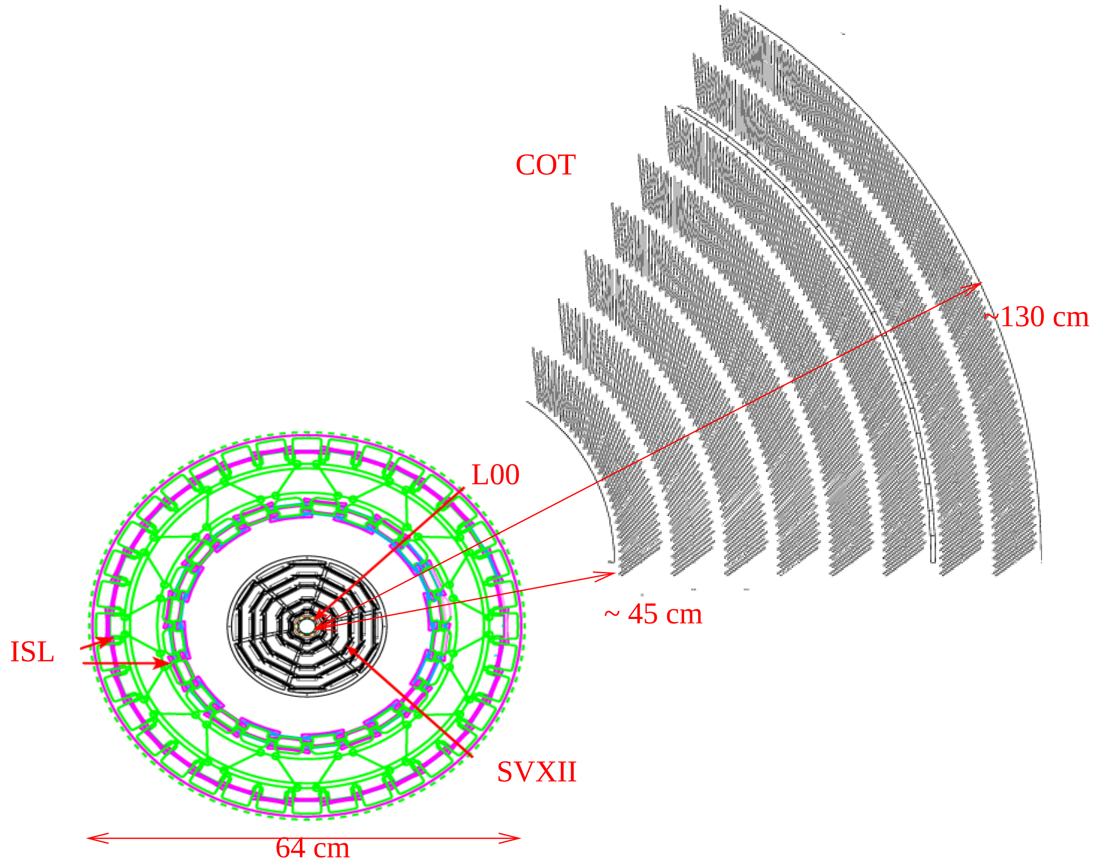
- any CP+ CP- decays, fit two exponentials
- angular analysis $B_s \to J/\psi\ \phi$
- $B_s \to D_s^{(*)\pm} D_s^{(*)\mp}$

This method:

- measure the lifetime of the CP even $B_s \to K^+K^-$
- measure the lifetime of flavour specific
  - $B_s \to K^-\pi^+$ (low statistics)
  - $B_s \to D_s^+\pi^+$ (detached study)
- workout $\Delta\Gamma_s$ and Γ_s

Systematics: normalize to $B_d \to \pi^+\pi^-$ $(B_d^0 \to D^-\pi^+)$

CDF Tracker



Silicon:

- 8 Layers (1+5+2)
- L00 precision point at 1.3 - 1.6 cm
- Standalone Tracking up to $|\eta| = 2.0$ (ISL)

Drift Chamber:

- 8 Superlayers
- 100 nsec max drift

CDF Trigger

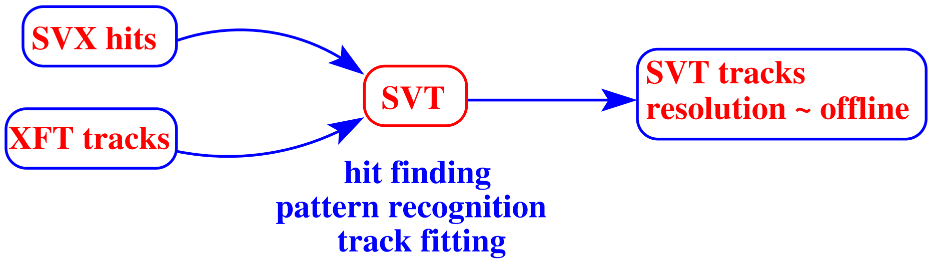
L1 20 KHz 5.5 us Calorimeter transverse Energy, COT–XFT, Muons

L2 300 Hz 30 us 2 stage pipeline:

1. HW processors assemble information from a section of the detector (Calorimetric clusters, Si tracks)
2. "alpha" processors on objects coming from 1

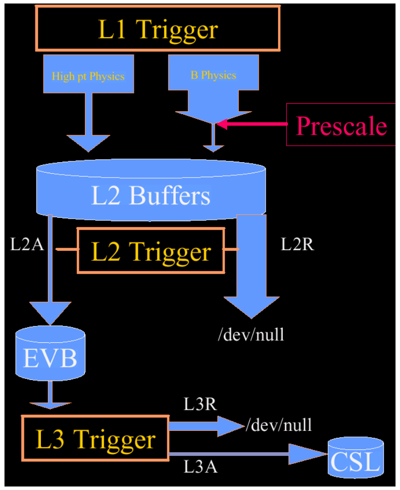
L3 50 Hz (on tape) ~250 linux PC farm

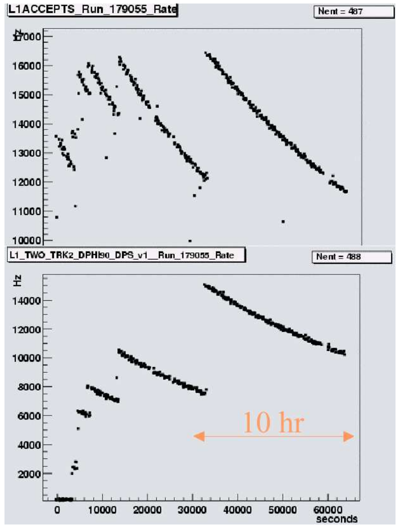
SVT L2 reconstruction of charged particles in the transverse plane



15 us

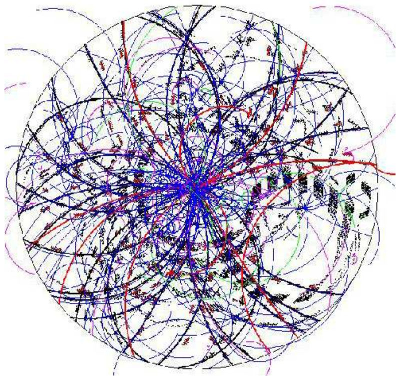
Bandwidth - Prescale



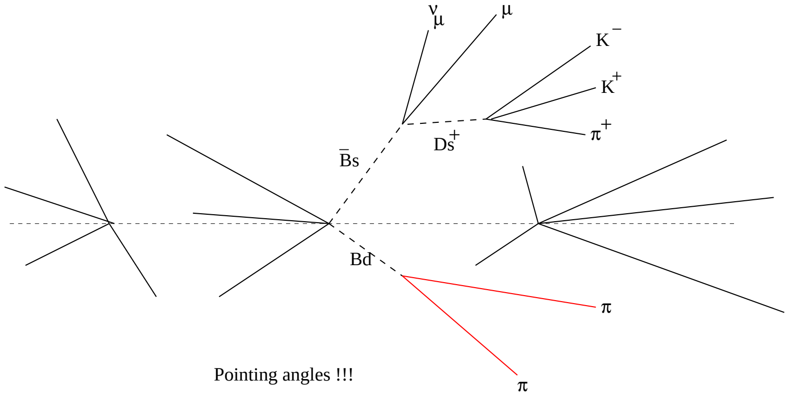


SVT - Two Track Trigger

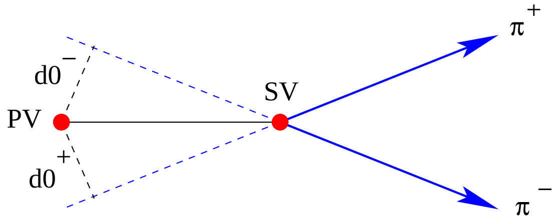
...how to find your two pions in:



...zoom in

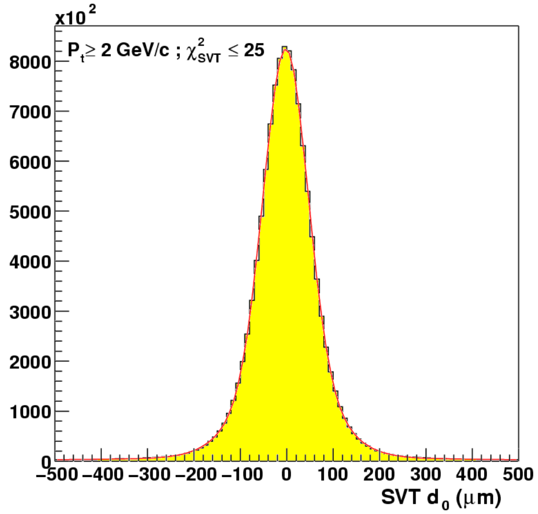


Trigger on two displaced tracks



$$P_t > 2 \text{ GeV/c}$$

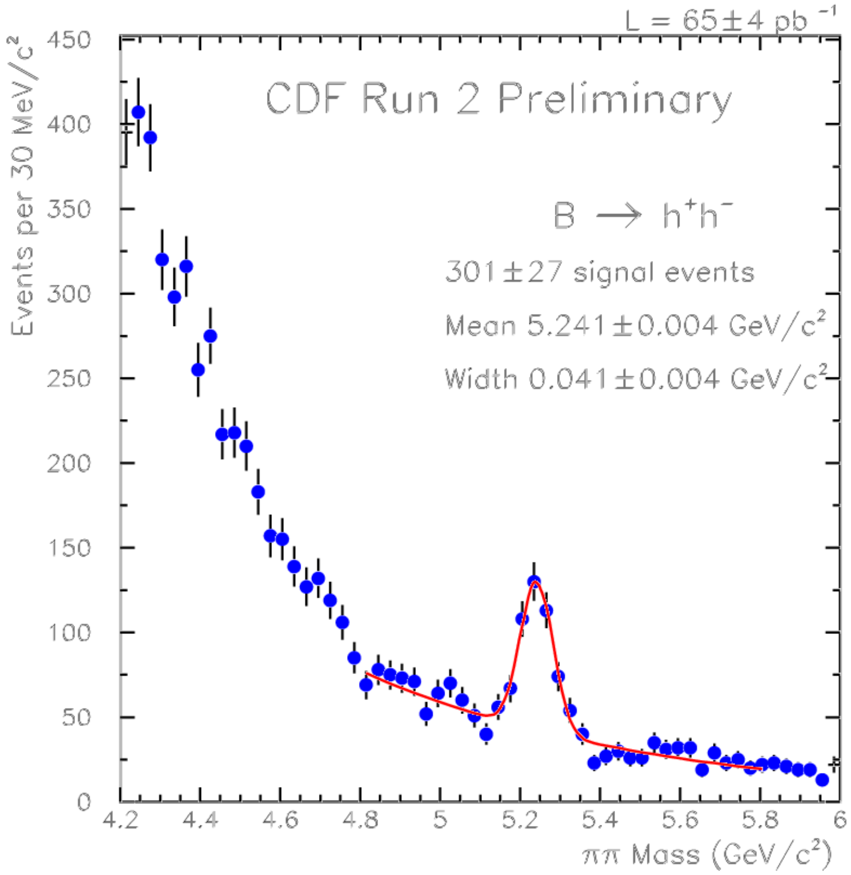
$$120\ \mu m < |do| < 1mm$$



$\sim 50\mu m = 35\mu m$ (SVT) $\oplus 33\mu m$(beam)

$B^0 \to h^\pm h^\mp$ sample

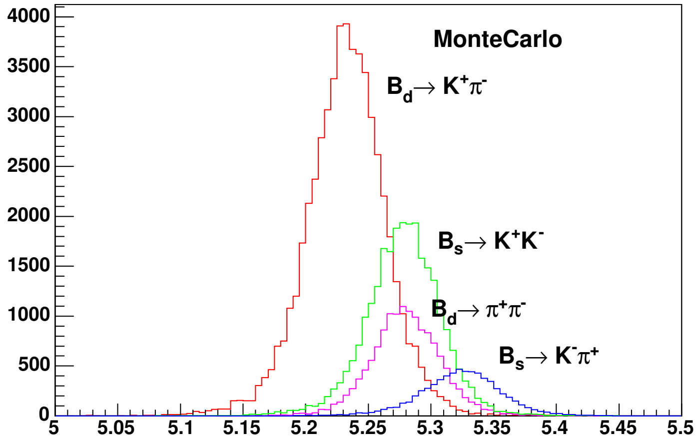
TTT extracts the $B^0 \to h^\pm h^\mp$ peak



Signal components

$B_d \to \pi^+\pi^-$ $B_d \to K^+\pi^-$

$B_s \to K^+K^-$ $B_s \to K^-\pi^+$

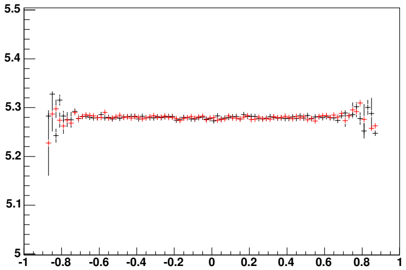


(reconstructed in m_π assignment)

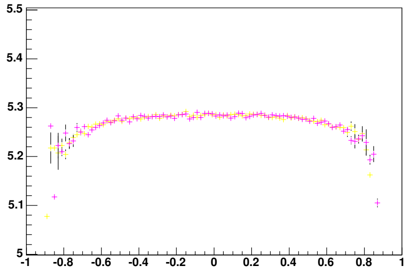
m(B_d)=5.2794 GeV

m(B_s)= 5.3696 GeV

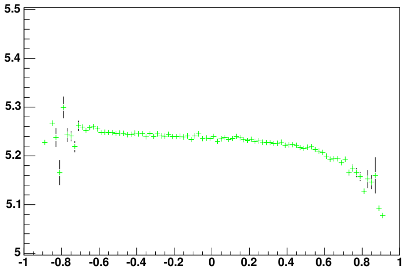
Disentangling the signal components



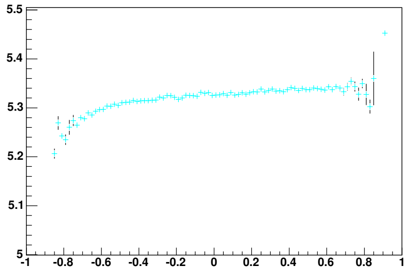
$B_d \to \pi^+\pi^-$



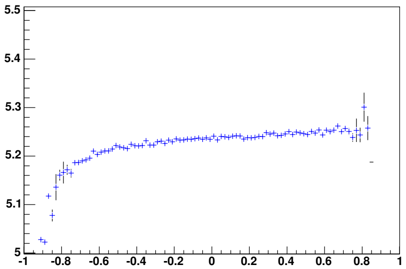
$B_s \to K^+K^-$



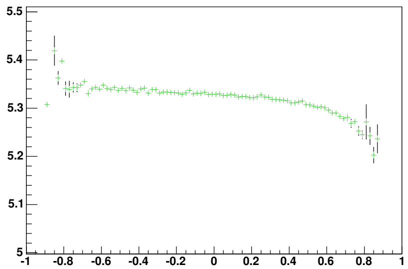
$B_d \to K^+\pi^-$



$B_s \to K^-\pi^+$



$\bar{B}_d \to K^-\pi^+$



$\bar{B}_s \to K^+\pi^-$

Kinematics:

- Two body decay

- little mass differences

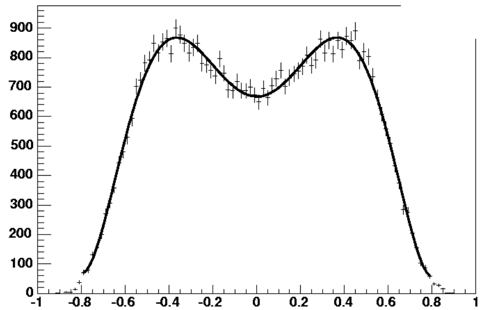
Unbalance $\alpha := (1 - \frac{|\vec{p}_1|}{|\vec{p}_2|})q_1$

$(|\vec{p}_1| < |\vec{p}_2|)$

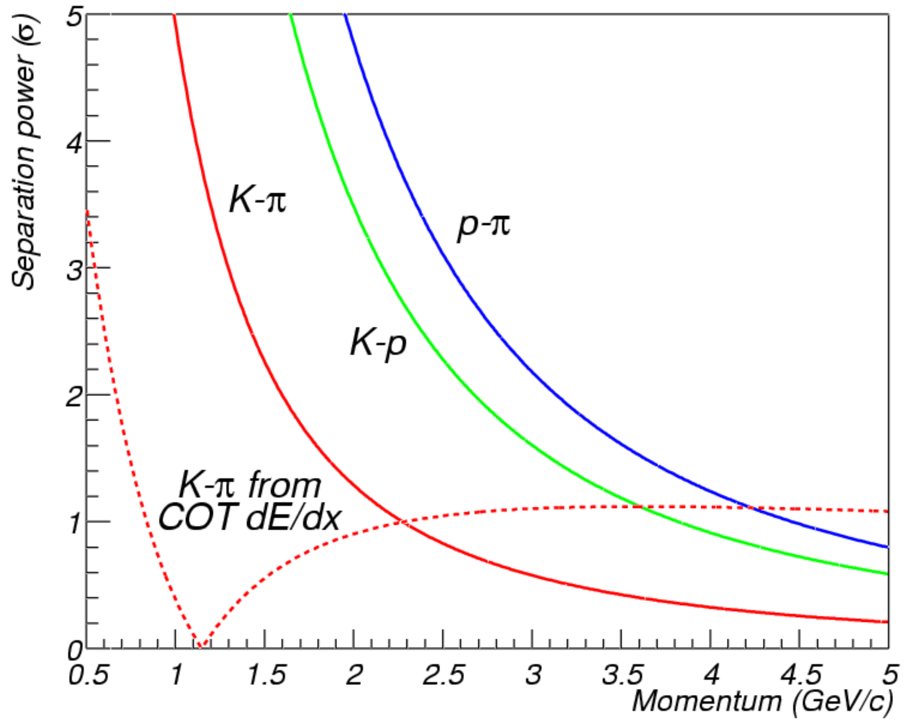
Lifetimes:

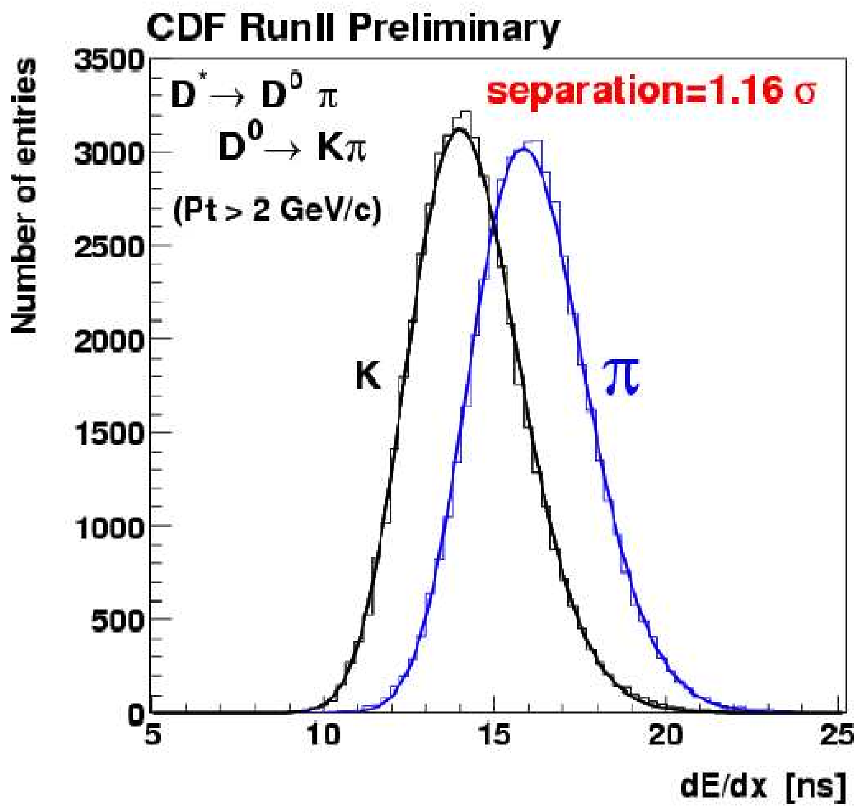
$c\tau(B_d) = 462\mu m$

$c\tau(B_s) = 438\mu m$



Particle ID





Not enough separation power for event by event separation

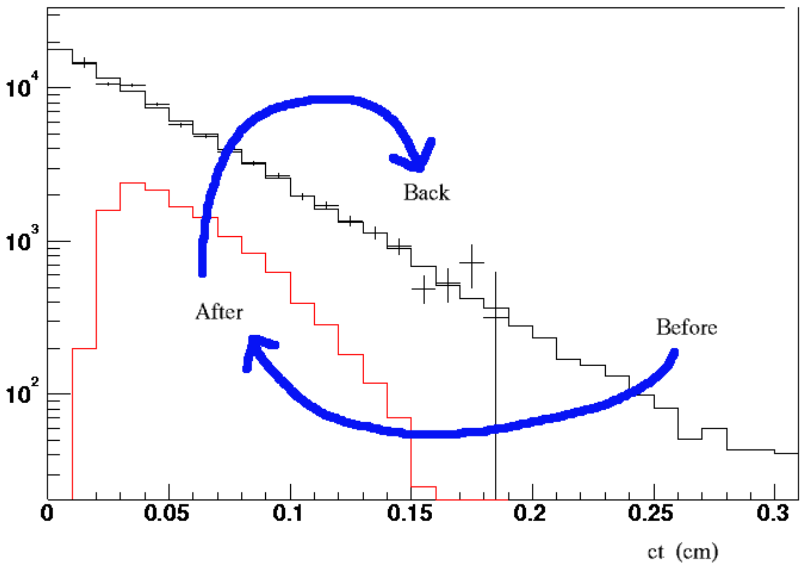
$$(P_T(tracks) > 2GeV/c)$$

Statistical Separation

Signal: $\mathcal{F}_i = G(M_{\pi\pi} - M_i(\alpha), \sigma)\, P(\alpha)\, G_{\mu 1 \sigma 1}(ID1)\, G_{\mu 2 \sigma 2}(ID2)\, T(c\tau; \sigma_{c\tau}, SVT)$

Background: $\mathcal{F}_{BG} = E(M_{\pi\pi})\, P'(\alpha)\, G_{\mu 1 \sigma 1}(ID1)\, G_{\mu 2 \sigma 2}(ID2) T(c\tau; \sigma_{c\tau})$

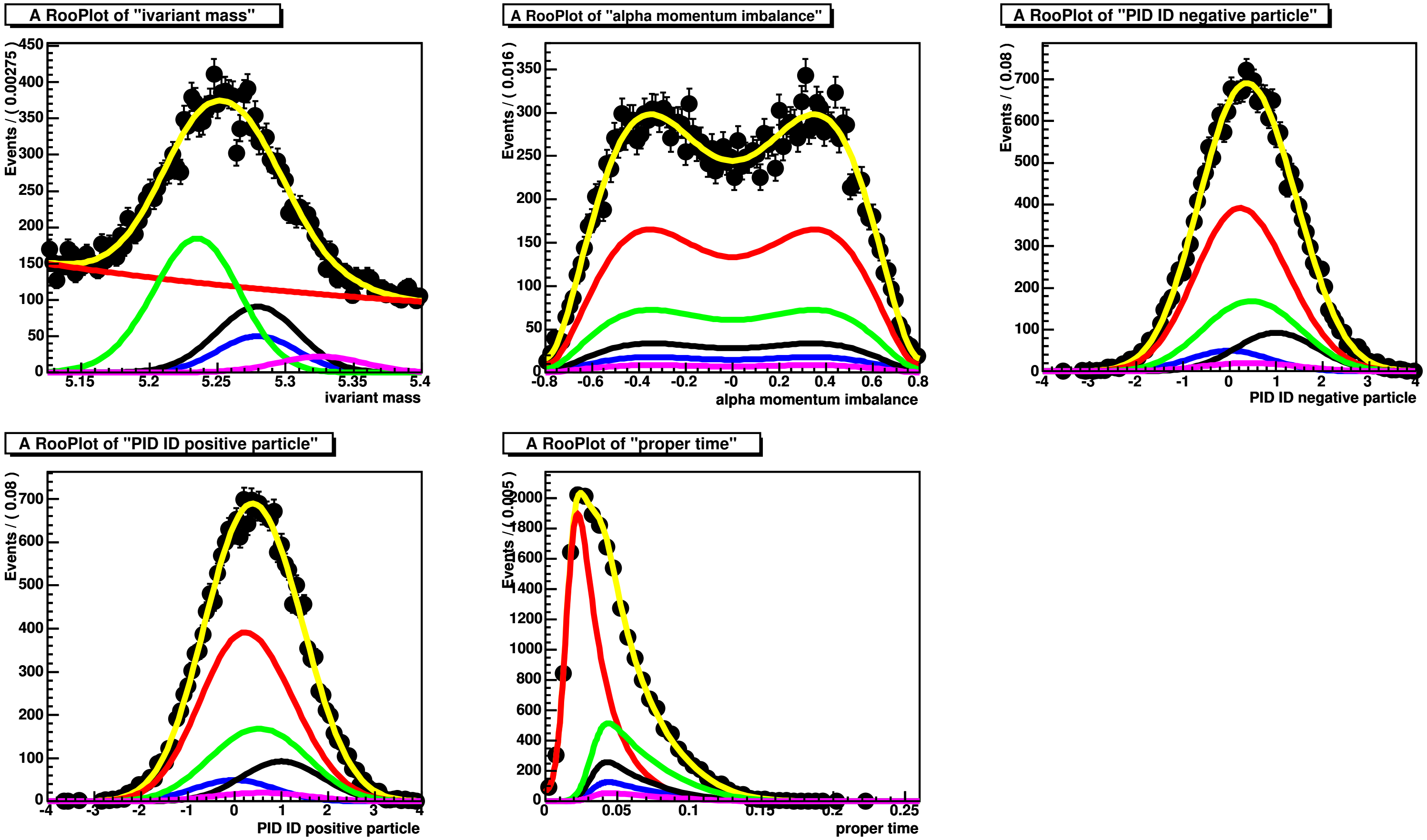
$$\mathcal{L} = \prod_{N events} \{(1-b) \sum_i f_i\, \mathcal{F}_i + b\, \mathcal{F}_{BG}\}$$



SVT bias models:

- bin/bin correction
- accurate MC study
- sliding back

Fit Results



We can fit lifetimes out of the Bhh sample !

CDF characteristics
(thing to work on...)

$\sigma_m = 0.029$ GeV	Work on alignment	$(\rightarrow 0.021)$
PID = 1.16 σ	Work on dE/dx tuning	$(\rightarrow 1.38\ \sigma)$
background fraction $\sim$ 55%	Work on cuts	$(\rightarrow\sim 45)$

What is the sensitivity on $\frac{\Delta\Gamma_s}{\Gamma_s}$?

$$\sigma\left(\frac{\Delta\Gamma_{CP}}{\Gamma}\right) = 2\frac{\tau_{CP-}}{<\tau>}\sqrt{\left(\frac{\sigma_{\tau CP-}}{\tau_{CP-}}\right)^2 + \left(\frac{\sigma_{<\tau>}}{<\tau>}\right)^2}$$

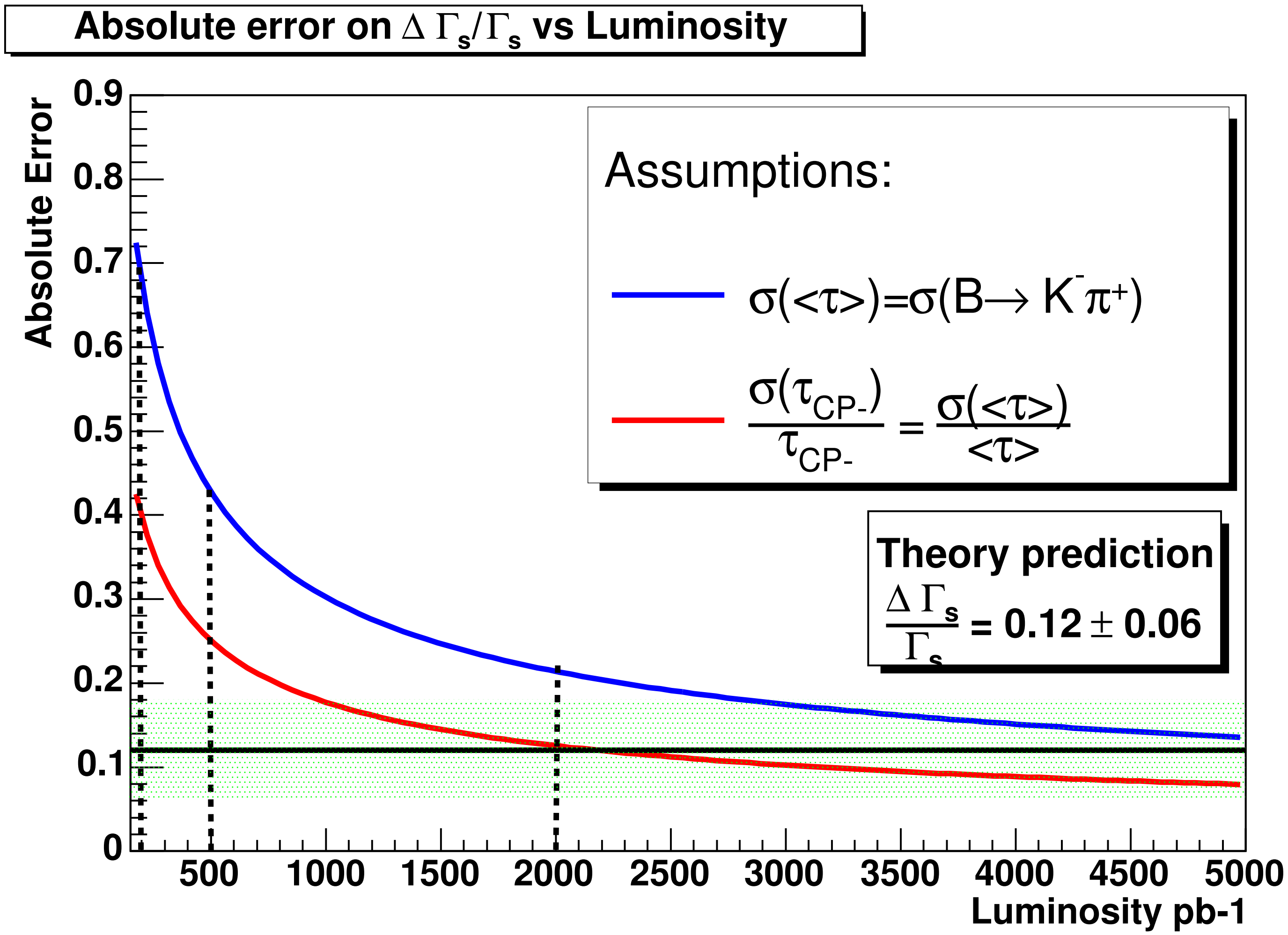
(Absolute Error)

At 500 pb^{-1}: $\sigma_{\tau CP-} \simeq 38\mu m$

$\sigma_{<\tau>} \simeq 98\mu m$

Results

$$\sigma\left(\frac{\Delta\Gamma_{CP}}{\Gamma}\right) = 2\frac{\tau_{CP-}}{<\tau>}\sqrt{\left(\frac{\sigma_{\tau CP-}}{\tau_{CP-}}\right)^2 + \left(\frac{\sigma_{<\tau>}}{<\tau>}\right)^2}$$

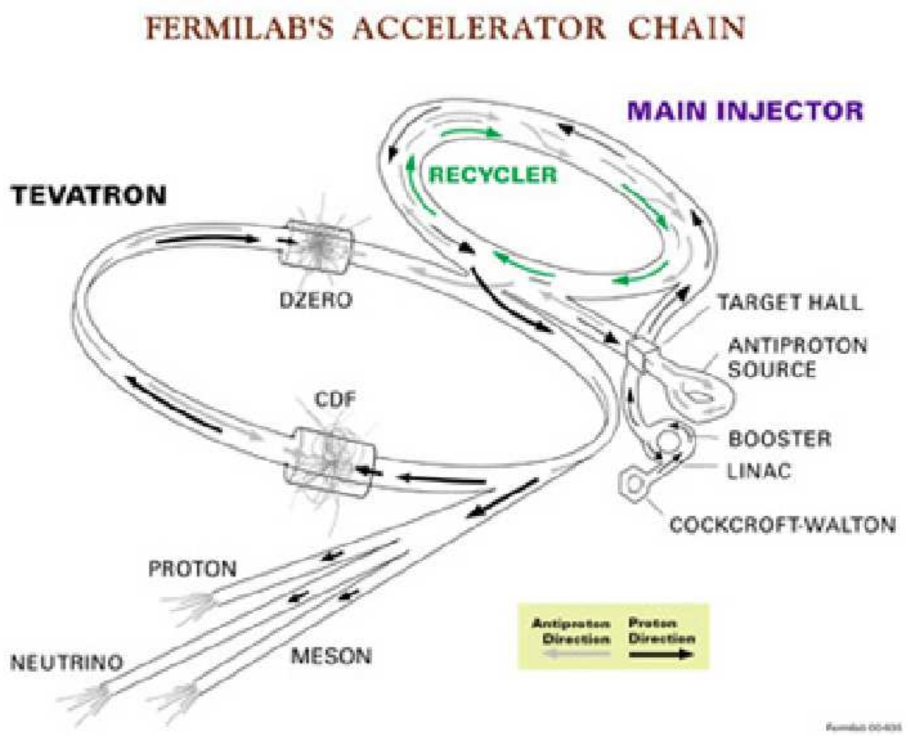


Summary

- CDF represents a great opportunity to study B_s before LHC
- $\Delta\Gamma_s$ expected to be large O(12%)
- $\Delta\Gamma_s$ distinguishable from 0.0 with 2 fb^{-1}
- Work in progress:
  - Improve PID
  - Improve SVT bias model
  - Understand background lifetime
  - Systematics

Backup - slides

Tevatron Upgrade



$p\bar{p}$ collider at $\sqrt{s} = 1.96$ TeV

new injection stage

more efficient transfer lines

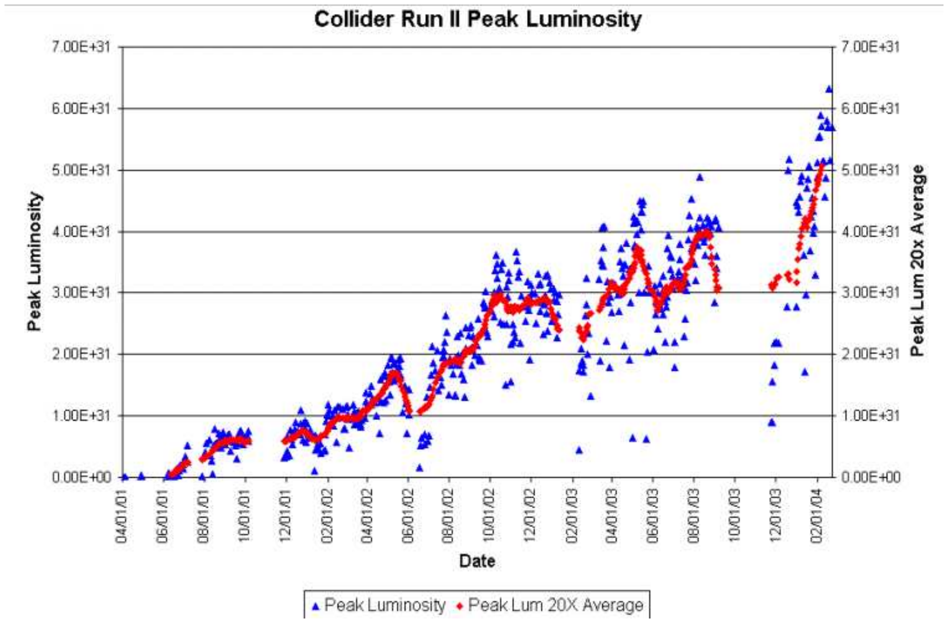
$\bar{p}$ recycler

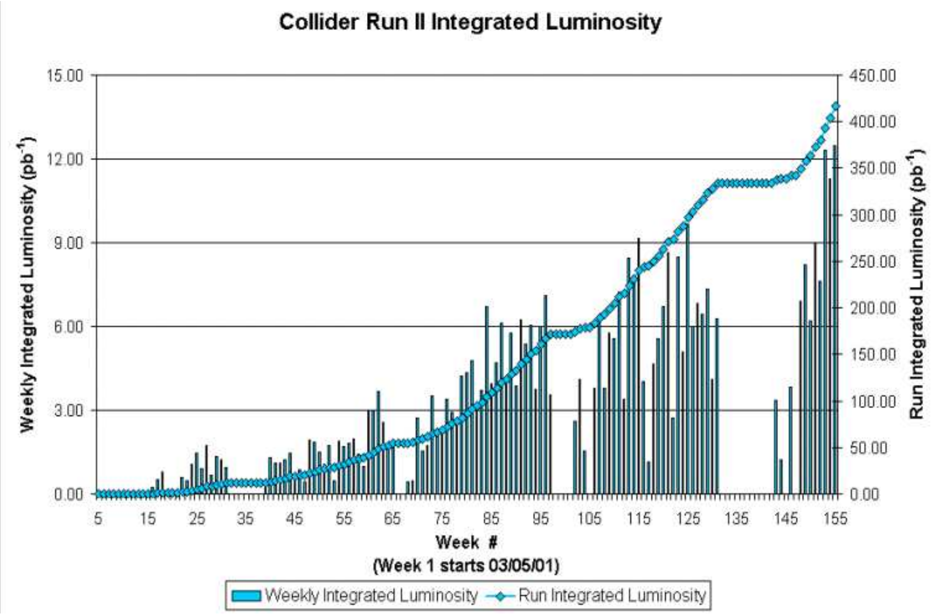
36 x 36 $p\bar{p}$ bunches 396 nsec

Luminosity:

- Delivered: 370 pb^{-1}
- On tape: 290 pb^{-1}
- Silicon: $\sim 200\ \mathrm{pb}^{-1}$

Tevatron Performance





Peak luminosity

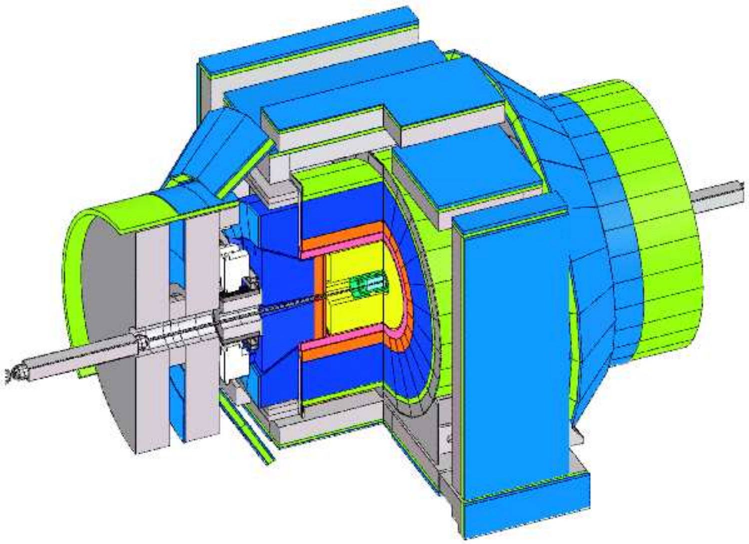
Integrated luminosity

Luminosity:

- Delivered: 370 pb^{-1}
- On tape: 290 pb^{-1}
- Silicon: $\sim 200\ \mathrm{pb}^{-1}$

New peak record: 6.8 10^{31} (7.2 10^{31} at CDF)

CDF Run II



Increase Silicon coverage:

- tracking up to $|\eta| = 2$
- SVT - displaced track trigger at L2

Faster tracker Chamber (COT)

Time Of Flight: $\pi\ K\ p$ PID

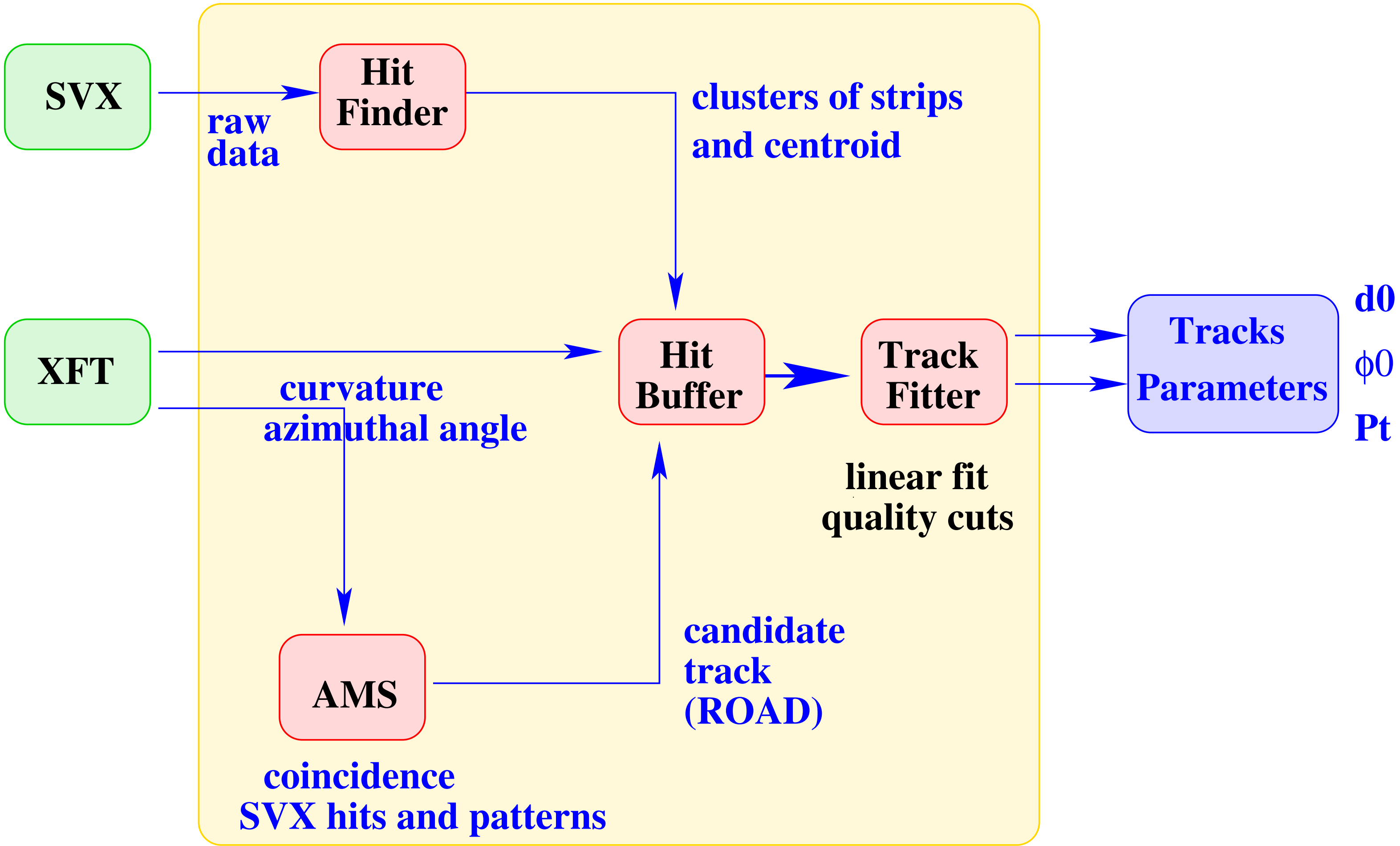
Increase Muon coverage up to

$$|\eta| = 1.5$$

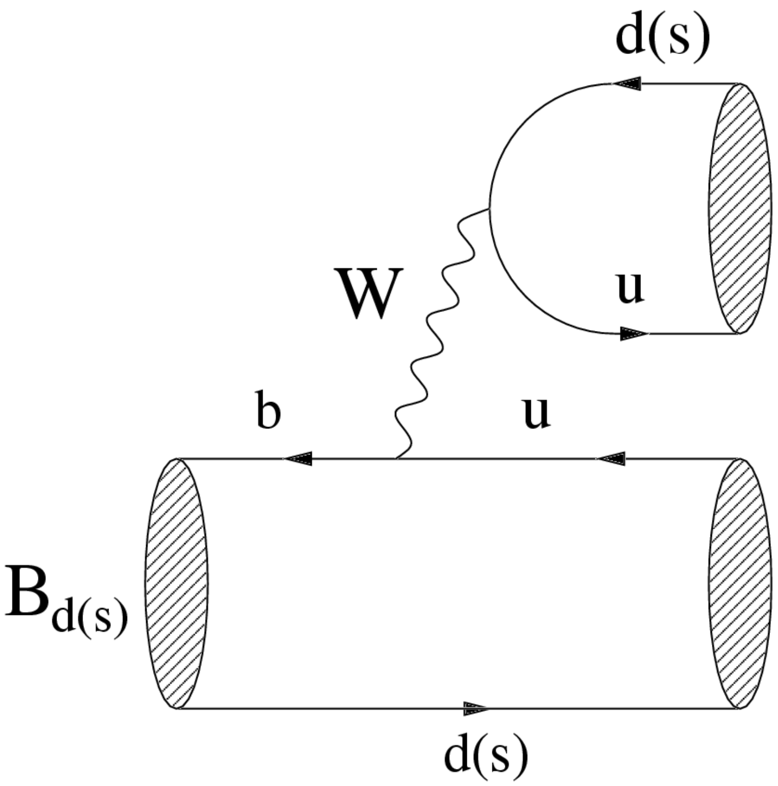
Faster trigger system

SVT details

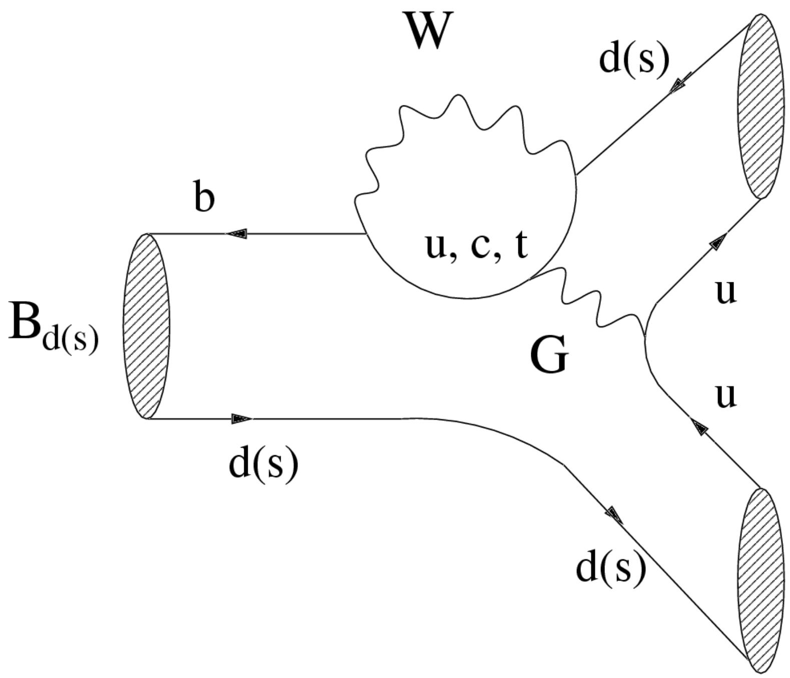
12 VME boards (parallel) – 12 SVX wedges



Decay diagrams



Tree



Penguin