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SVX b Physics Prospects

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ABSTRACT

CDF has enhanced its capabilities for b-physics with the installation of a silicon vertex detector (SVX)[1], which provides precise 2-dimensional tracking. The SVX impact parameter (IP) resolution ($\sim 13\mu m$ for $P_t > 10$ GeV) is well suited to detecting displaced secondary vertices (SV) from b-hadron decays ($c\tau_B \simeq 390\mu m$). In this paper we show evidence of SV detection using the $\Psi \rightarrow \mu^+\mu^-$ sample, which is b-enriched, and describe some prospects of b physics opened by the SVX with 25 pb^{-1}, the goal integrated luminosity of present run.

1. Vertex Finding with the SVX

The search for SV's takes advantge of the good SVX IP and primary vertex (PV) resolution. The IP resolution can be parametrised as $\sigma_{IP} = \sqrt{(a/P_t)^2 + b^2}$. The P_t dependence is due to multiple scattering and is estimated to be $a = 39\mu m$ GeV from simulation. Given the SVX geometry, simulation studies predict that $b \simeq$ intrinsic position resolution. With current alignment constants, the position resolution that we extract from track residuals in the data is $\simeq 13\mu m \simeq b$.

At CDF the PV position averaged over a data taking run is known with $\sigma_{PV} \simeq 40$ μm, which is the size of the Tevatron transverse luminous region. If the IP is calculated wrt the average PV, from the data we measure $\sigma_{IP}(P_t > 5\text{GeV}) = 561 \pm 13\mu m$ without the SVX and $44 \pm 1\mu m$ with the SVX (dominated by σ_{PV}). We also try to reconstruct the PV event by event: in a $t\bar{t}$ ($b\bar{b}$) Montecarlo sample 35 (13) tracks are used in the average to determine the PV and $\sigma_{PV} \simeq 12\mu m$ ($\simeq 35\mu m$). The efficiency of this algorithm ($\simeq 70\%$) is dominated by the SVX geometrical acceptance and the longitudinal spread of the luminous region ($\simeq 30$ cm).

We estimated the rate of fake SV's from the inclusive jet sample, which is b-depleted, and found a result consistent with Montecarlo expectations. We found, instead, a statistically significant excess of displaced SV's in b-enriched samples, like the inclusive electron and the $\Psi \rightarrow \mu^+\mu^-$ samples.

3. Physics with the $\Psi \rightarrow \mu^+\mu^-$ Sample

At the Tevatron Collider a significant fraction of Ψ's come from B-meson decays. Using the 1989 Ψ sample, CDF identified the exclusive decay $B^\pm \rightarrow \Psi + K^\pm$ and measured $\sigma(b)$,the b-quark production cross section[2]. With current run CDF will enlarge the size of the Ψ sample thanks to the improved muon detection, which is providing a factor 5.3 increase of the $\mu\mu$ trigger rate. In addition, the measurement of the Ψ decay length with the SVX allows discriminating $B \rightarrow \Psi$ from zero lifetime $\chi \rightarrow \Psi$ decays. The expected yield of Ψ's in the SVX ($\sim 50\%$ acceptance) is of the order of 45,000. With this sample we will measure $\sigma(b)$, F_B, the fraction of Ψ's from B, the inclusive B lifetime and separate B lifetimes from exclusive decays.

We analysed a limited sample of Ψ's ($\sim 1{,}000$ events) to study the feasibility of a lifetime measurement. Results reported below are preliminary and not corrected for systematic effects. We

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compute the $\mu^+\mu^-$ invariant mass requiring the muons to come from a common vertex. We use SVX + CTC (outer central tracking chamber) and CTC tracking only, getting respectively 17 Mev and 26 MeV resolution, the improvement being due to the increased tracking lever arm provided by the inner SVX hits. We define the signal ($/Psi$) region to be $\pm$ 50 MeV around the central vaule of $M(\mu^+\mu^-) = 3.093$ GeV. We then look at the 3-dim. signed decay length for the signal and the side band regions, which will serve as a measure of the non-Ψ background (fig. 1). We observe a long tail for positive decay lengths, which is a clear indication of non-sero lifetime in the sample. Negative decay lengths are due to: 1) non-Ψ background and prompt-χ contributions, which we assume symmetric around sero with width equal to the decay length resolution; 2) smearing of $B \rightarrow \Psi$ events from the convolution of a falling exponential with the resolution function. In fig. 2 we show the Ψ decay length after side band subtraction and correction for the average parent b-hadron $\beta\gamma$, determined with the ISAJET+CLEO Montecarlo as a function of $P_t(\Psi)$. This quantity, $c\tau$, is expected to represent the proper b-hadron decay length for $c\tau > 0.05$ cm (Montecarlo estimate). The $c\tau$ distribution is indeed exponentially falling for large values and within the statistical error it is consistent with the world average measurement of the inclusive b-hadron lifetime. This result shows that lifetime measurements at CDF are becoming feasible thanks to the SVX.

The yields of exclusive B decays in the SVX suffer from large uncertainties on F_B for the $P_t(\Psi) > 3.0$ GeV region now accessible with the trigger. We expect approximately 180-360 $B^\pm \rightarrow \Psi + K^\pm$, 140-280 $B^* \rightarrow \Psi + K^*$ (both already observed by CDF), $\sim$ 40-80 $B_S \rightarrow \Psi + \Phi \rightarrow \mu^+\mu^-K^+K^-$ and ≤ 100 $\Lambda_b \rightarrow \Psi + \Lambda \rightarrow \mu^+\mu^-p\pi^-$ events. The limit on Λ_b comes from CDF 90% CL upper limit on Λ_b production. The SVX will provide excellent combinatoric background rejection by requiring a common displaced vertex for the decay products. This will be very effective for B_S (four particle SV plus Ψ, Φ mass constraints). For the Λ_b search the SVX can also help by increasing the angular/P_t acceptance with standalone tracking and identifying a Λ_c signal (LEPwise) from the cascade decay $\Lambda_b \rightarrow l\nu\Lambda_c \rightarrow l\nu + pK\pi$.

2. QCD Topics

The b-quark production dynamics can be tested by studying the spectrum of Φ, η, P_t and invariant mass correlations of $b\bar{b}$ pairs[3]. For example, study of small $\delta\Phi(b\bar{b})$ for $P_t(b) > 20$ GeV will allow measuring the amount of gluon splitting[4] ($g \rightarrow b\bar{b}$). We estimate that for $P_t(b) > 20$ GeV, the SVX will provide $\sim$ 600 double b-tags in the inclusive lepton sample.

QCD predicts large variations in the behavior of b-hadron production cross section in jets, $\sigma(jet)BR(jet \rightarrow b\text{-hadron}+X)$, vs. the fragmentation variable, $z = E(b\text{-hadron})_{\|}/E_{jet}$. Three very different regimes can be distinguished depending on E_{jet}: 1) for $E_{jet} \ll 100$ GeV the production rate vs. z follows the Peterson model, with the typical peak for $z \rightarrow 1$ due to direct $b\bar{b}$ production; 2) for $E_{jet} \sim 100$ GeV two peaks are predicted ($z \rightarrow 0, 1$), with the low z peak due to gluon splitting; 3) for $E_{jet} \gg 100$ GeV, the $z \rightarrow 1$ peak disappers and b production behaves just like the π fragmentation function, with the important difference that the b-hadron fragmentation function can be calculated in QCD from first principles. Quantitative predictions for these three regimes are known for supercollider energies[5], but the same qualitative behavior is expected at the Tevatron[6].

4. Conclusions

A preliminary analysis of data taken in three months of running shows that the SVX is opening to CDF interesting b physics prospects. With 25 pb^{-1} some of these prospects include EWK measurements (inclusive and exclusive b-hadron lifetimes with the $\Psi \rightarrow \mu^+\mu^-$ sample), QCD measurements ($b\bar{b}$ correlations, b production in jets) and identification of B_S and Λ_b hadrons.

6. References

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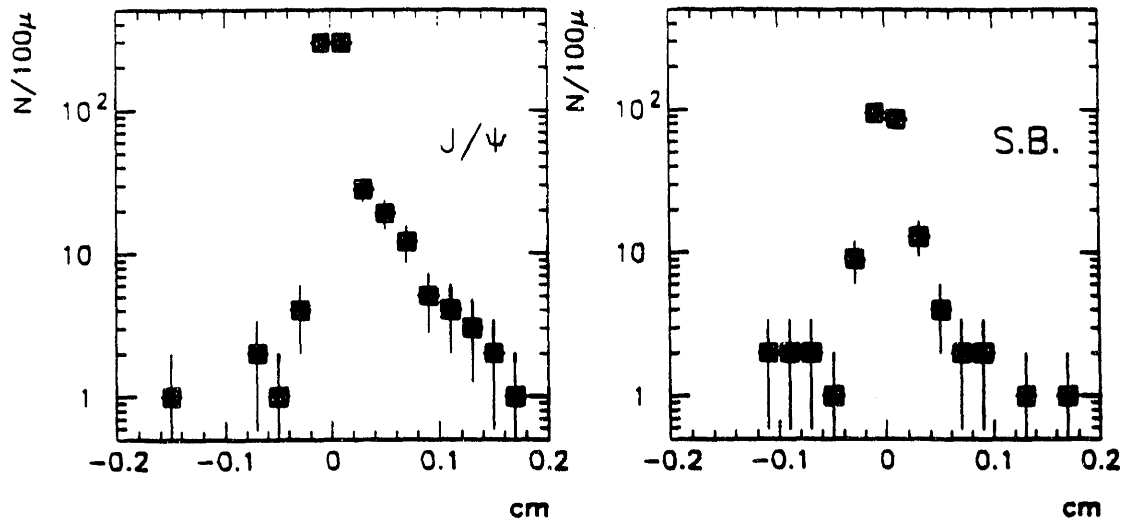

Figure 1: Decay length distribution of the signal (J/Ψ) and side band (S.B.) region.

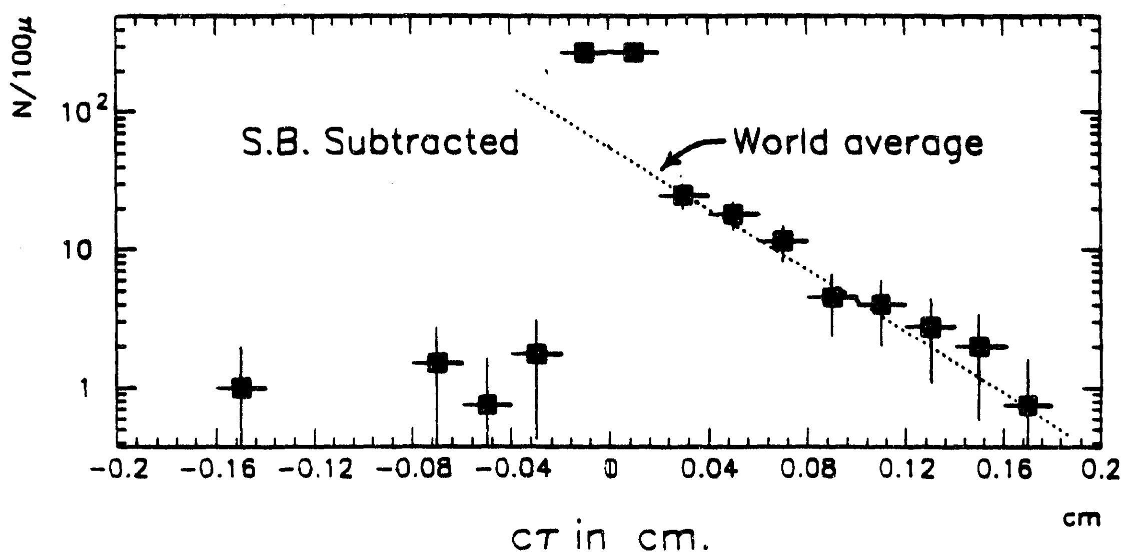

Figure 2: Ψ decay length side band subtracted and corrected for kinematics.

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