Enlarged pattern bank and upper i.p cut in SVT triggers

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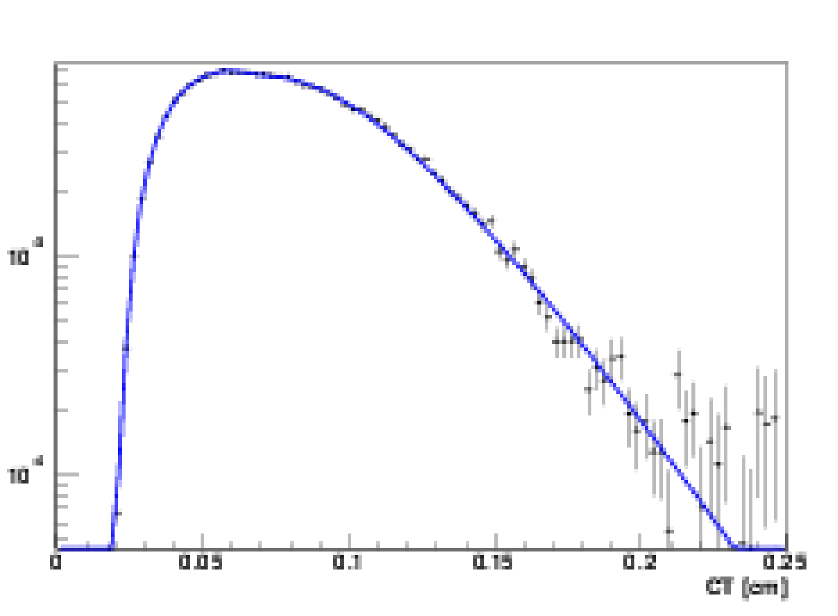
Trigger Upgrade Review

7/27/2006

<u>Outline</u>

- Physics opportunities
- Issues
- Plans



Introduction

We are here but:

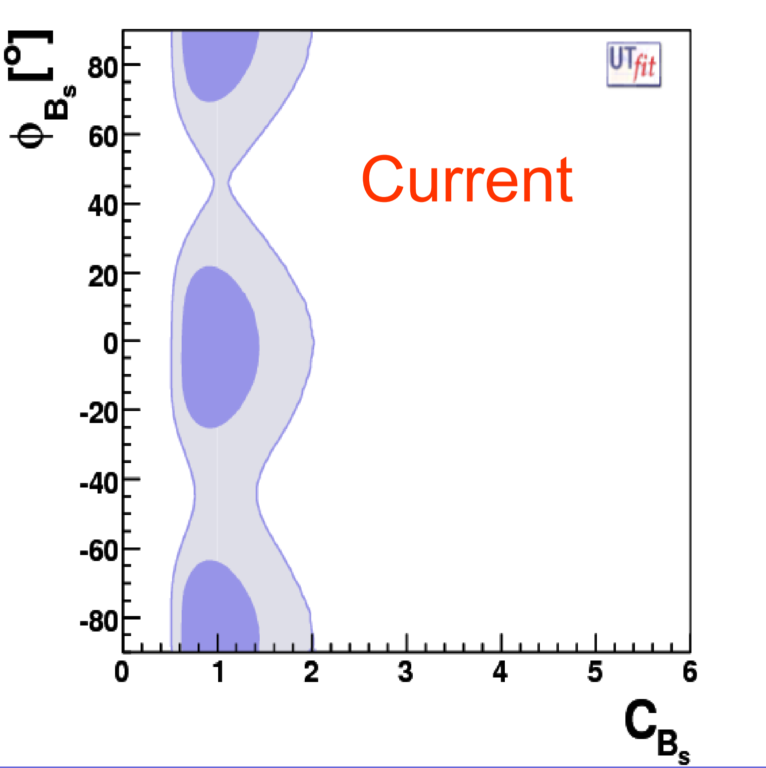
- In principle don't necessarily need extra hardware to accomplish this single option on its own
  - Extra load for fitter should be kept reasonable
  - Possible compromises with other needs should be possible
- Apologies: not a great deal of additional studies since May 12th trigger workshop

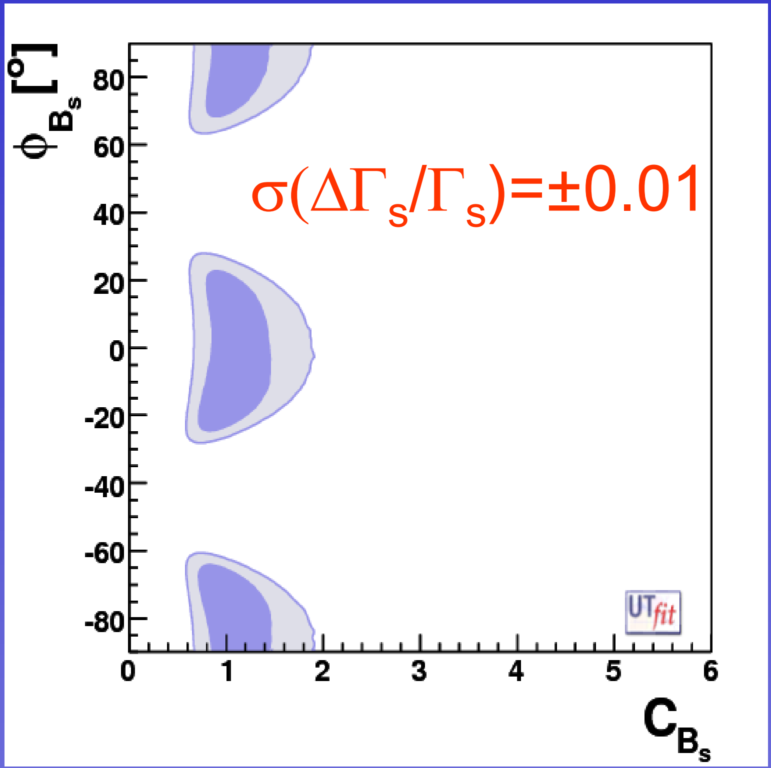
Motivations

- B_s lifetime measurements very interesting:
  - non-negligeable decay width difference ($\Delta\Gamma_s$) expected for B_s mass eigenstate (unlike for B_d)
  - Still large experimental uncertainty on a fundamental property of B_s meson !
  - Richer phenomenology allows exploring CP violation through lifetime measurement alone (no tagging required!)
- B_s mixing has given the first constraint on the size of possible New Physics contributiong to B_s mixing amplitude, but no contraint on its phase (β_s) exists yet → accessible via $\Delta\Gamma_s$
- One possible high-light of the B-physics program for Run II before LHCb takes over

Effect of $\Delta\Gamma_s$

Bounds on NP contribution to B_s mixing phase



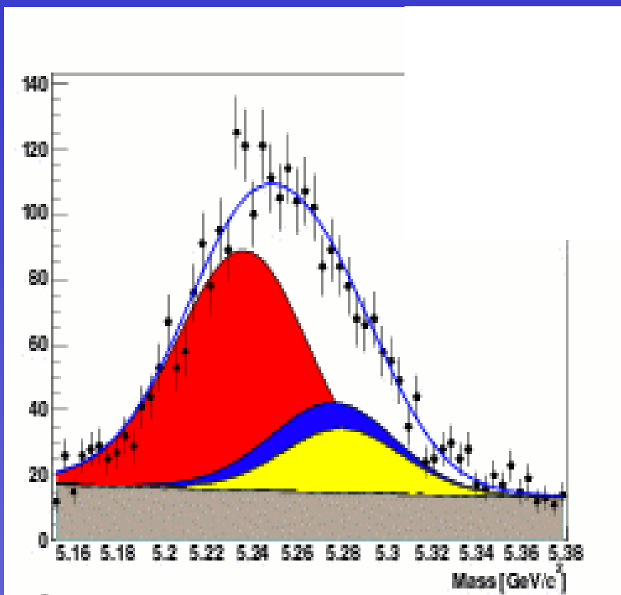


Similar impact of direct bs measurement at Tevatron!

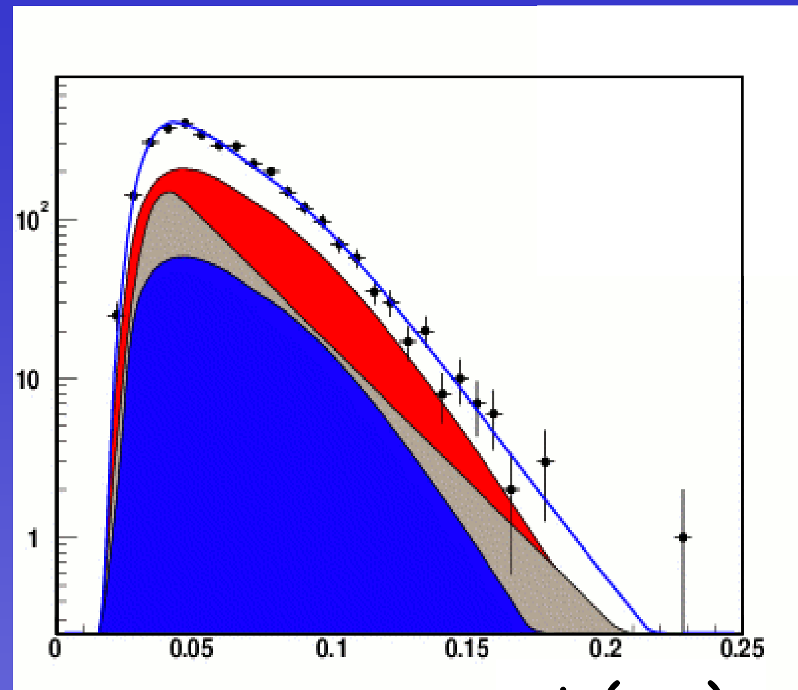
(From Luca Silvestrini's talk at Elba meeting)

$\Delta\Gamma_s$ from $B_s \rightarrow KK$ (350 pb^{-1})

M.Donega', S.Giagu



mass



ct (cm)

Use W.A

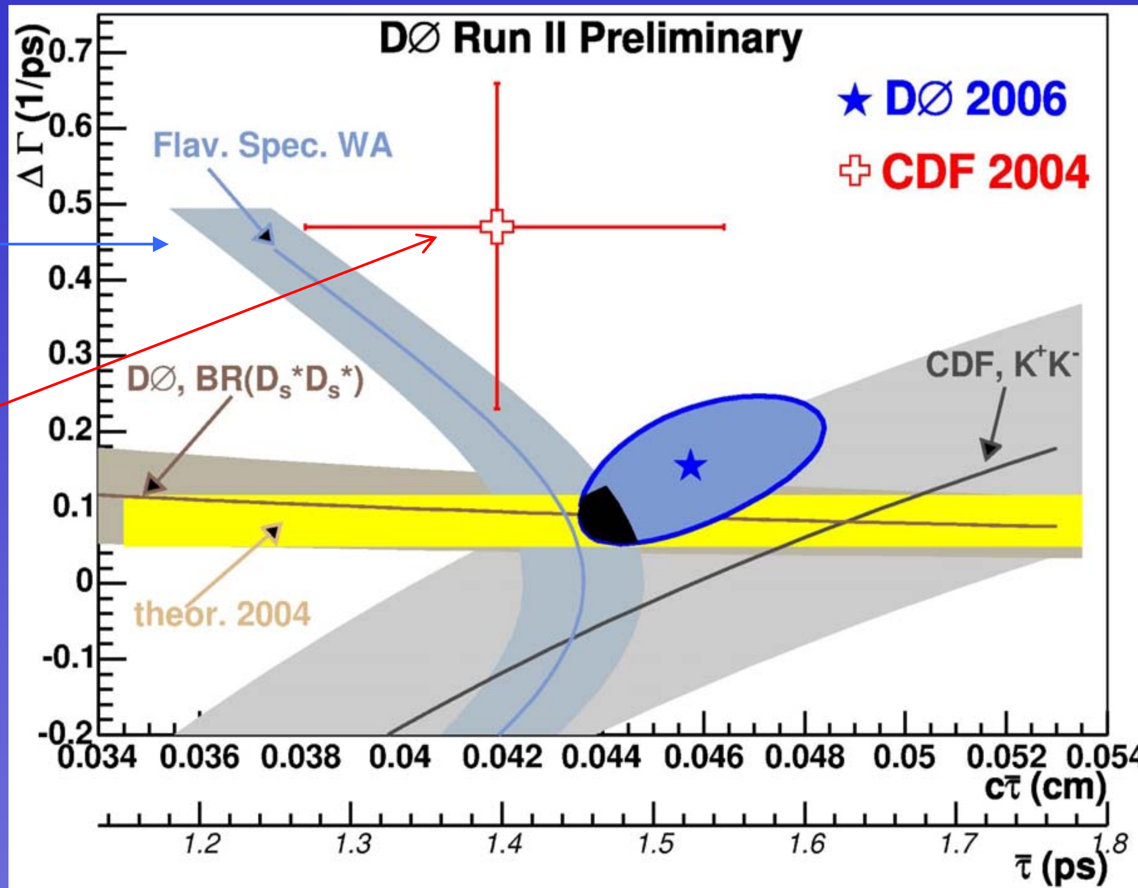
$c\tau_s$=436±12 um

	$c\tau(B_d)$ floating	$c\tau(B_d)$ PDG constrained
$C\tau(B_d)$	452 ± 24	460 ± 4
$C\tau(B_s \rightarrow KK)$	463 ± 56	458 ± 53
$\Delta\Gamma_{CP}/\Gamma_{CP}$		-0.08 ± 0.23

$\Delta\Gamma_s$ vs Γ_s

$B_s \rightarrow D_s l\nu$, $D_s\pi$

$B_s \rightarrow J/\psi\phi$



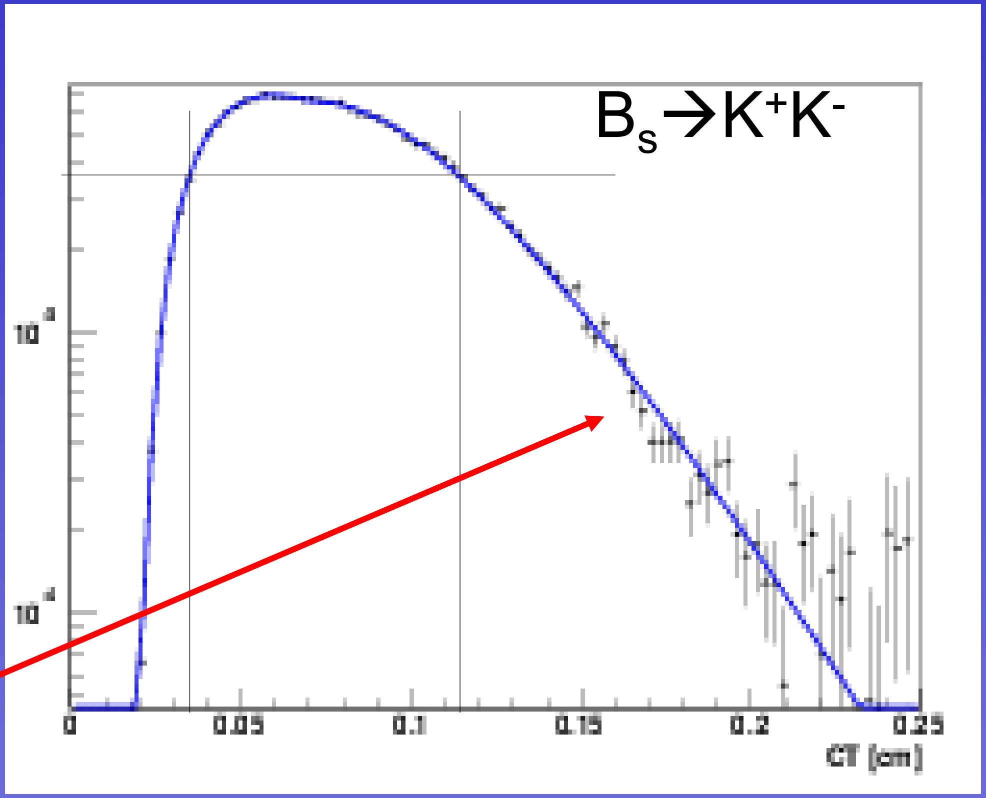
$B_s \rightarrow K^+K^-$

- All these measurements should converge
- $B_s \rightarrow KK$ test theory at loop level as opposed to tree level $B_s \rightarrow J/\psi\phi$

cτ efficiency curve

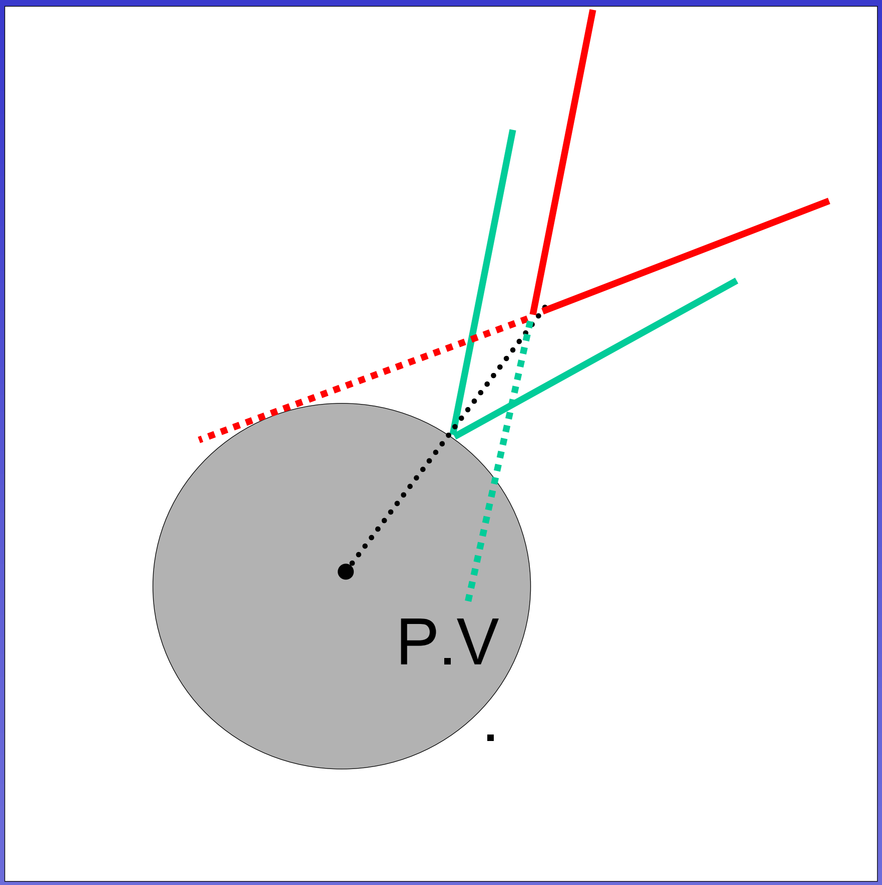
- Current Two Track Trigger requires:
  - 2 SVT track
  - Minimum i.p. 100/120 um
  - Minimum L_{xy} 200 um
  - Max i.p of 1 mm
- Efficiency drops significantly beyond ~1mm
- Due to both trigger cut and pattern efficiency, can improve now thanks to last year trigger upgrades

Note Log scale on y axis!



Can double the effective luminosity by moving the cut to 2 mm: analytical calculation CDF 7359

Trigger limitations



- Pattern generated only for tracks originating inside a disk centered around beam-line (32 K pattern limitation in the original AM bank)
- Maximize signal purity at trigger level (fake have wider i.p. distribution)
- Disk radius used to be 1.2 mm, gradually increased to 1.4 mm
- With the 512 K bank there should be pattern space to increase more without comprising too much timing
- We should also be able to sustain an higher L2 accept rate at least at relatively lower lumi where the TTT will be live (and especially on spacialized triggers: BPIPI, PHI triggers)

Upper Lifetime Cuts and Stat. Power per Event

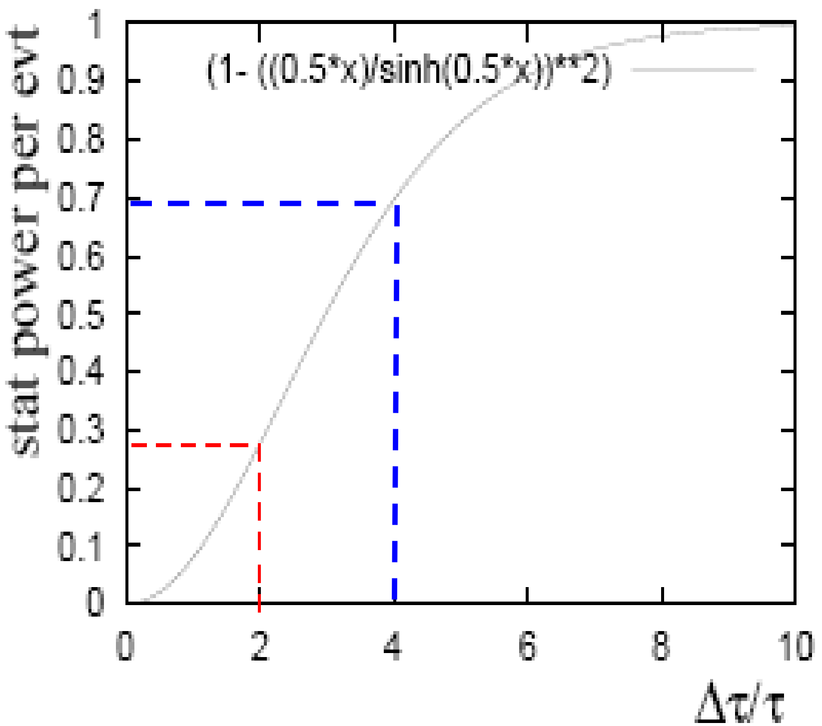
The stat. error increases as the time-window $\Delta\tau$ decreases:

$$\sigma(\tau) = \frac{\tau}{\sqrt{N \cdot \mathcal{P}}}$$

The statistical power per evt:

$$\mathcal{P} = 1 - \left\langle \left(\frac{\frac{1}{2}\Delta\tau/\tau}{\sinh\left(\frac{1}{2}\Delta\tau/\tau\right)} \right)^2 \right\rangle$$

Like εD^2 for asymmetries.



The plot shows the stat power $\mathcal{P}$ as fct of $\Delta\tau/\tau$. E.g. 1 evt with $\Delta\tau/\tau = 2$ is worth ~ 0.3 evts without τ cut.

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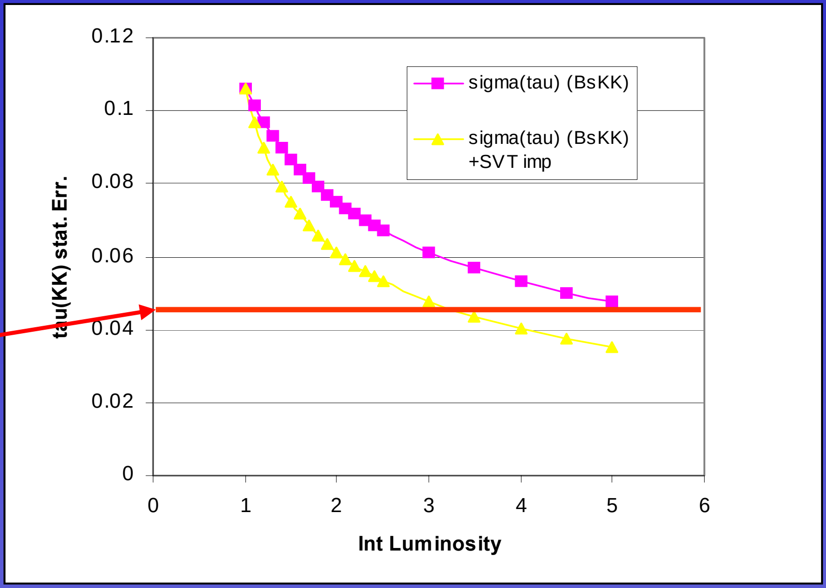
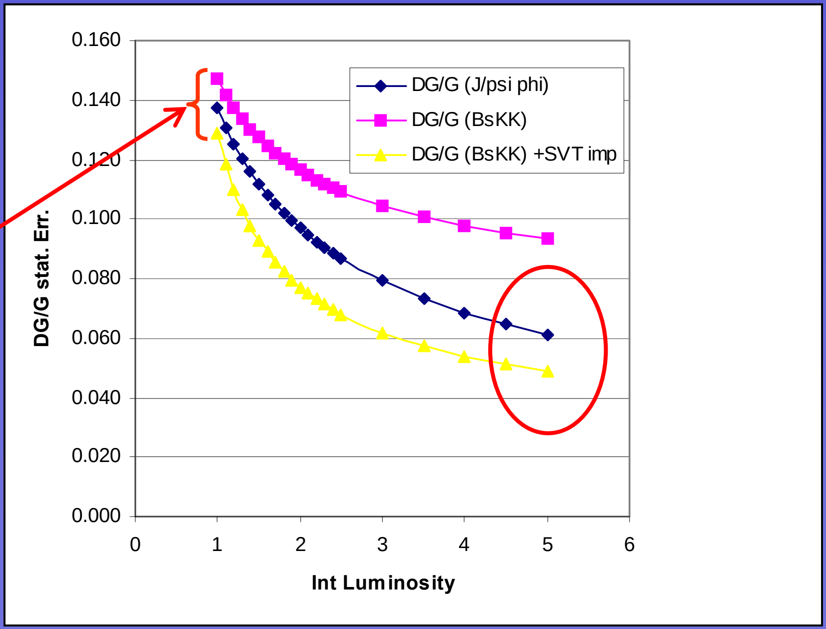
Analytical calculation by Jonas Rademacker (CDF 7359)

$\Delta\Gamma_s$ from $B_s \rightarrow KK$ (future)

- Key points:
  - Mantain trigger yield (B_PIPI)
  - Save dE/dx for PID
- Could reach O(3%) accuracy
- Could do it much before and/or reach 2% accuracy with looser max i.p. cut at Level2/3
- Exclude @ >3σ new physics phase around 90° in $B_s \rightarrow KK$ through lifetime measurement
- $\Delta\Gamma_s/\Gamma_s$ reach comparable or better than $J/\psi\phi$!
- Need better precision on B_s lifetime from flavor specific modes: $B_s \rightarrow D_s l\nu$, $D_s\pi$
- Assumed a 3X improvement over W.A. 12 um → 4 um





What do we need?

- Goal is increase the trigger cut to ~2 mm (instead of 1 mm): would provide more than double effective luminosity!
- How much does it cost?
  - In term of L2 processing time
    - Extra pattern firing because of larger super strips
  - In term of pattern usage
    - How many more patterns do we really need for this application?
  - In term of L2 rate
  - In term of L3 rate

What has been done

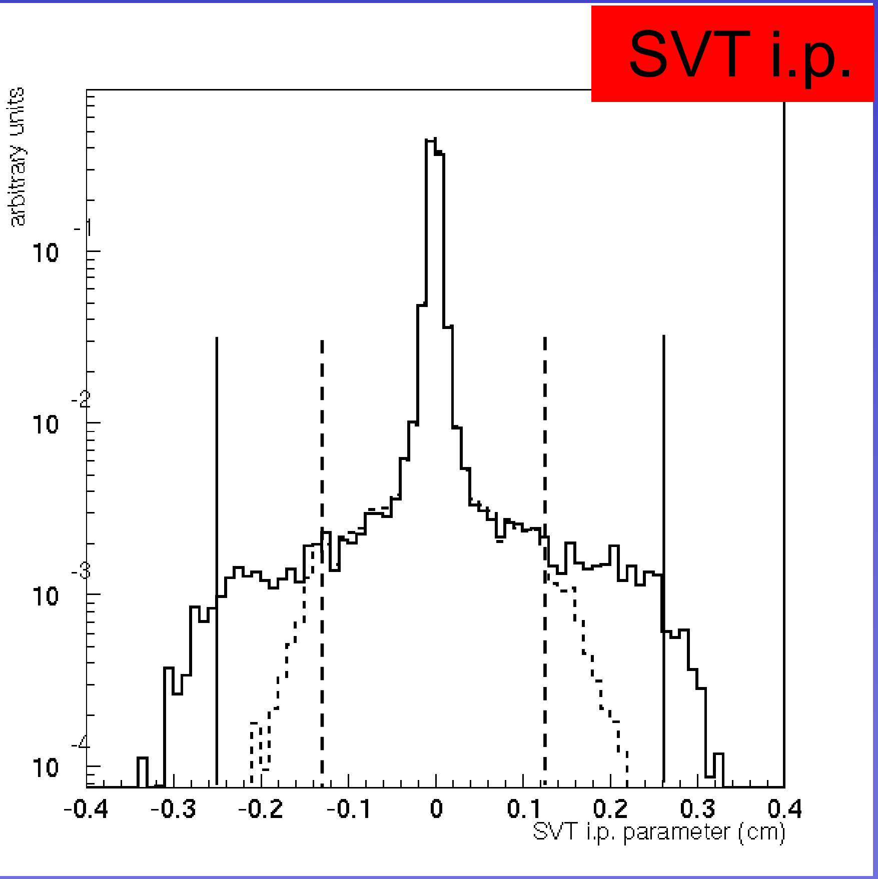
- Stefano Torre generated new pattern bank starting from the 128 Kpattern one
  - Enlarge beam spot from 1.3 mm → 2.5 mm
  - Same superstrip as in original the 128 K case
  - For 95% coverage 300K pattern has been generated (to be optimized yet)
- Today: some plots on recent data re-run with svtsim and new pattern bank

First real data with bigger spot

- 400 K L1 prescaled backup triggers
- Efficiency looks OK : 659K tracks vs 639K tracks in real data
- Behave as expected (increased number of tracks at high i.p.)
- Efficiency for 1.5 mm ip tracks not negligeable also for standard pattern, need new pattern to have decent acceptance at 2 mm
- Don't probably need to go far out to 3 mm (less extra patterns)

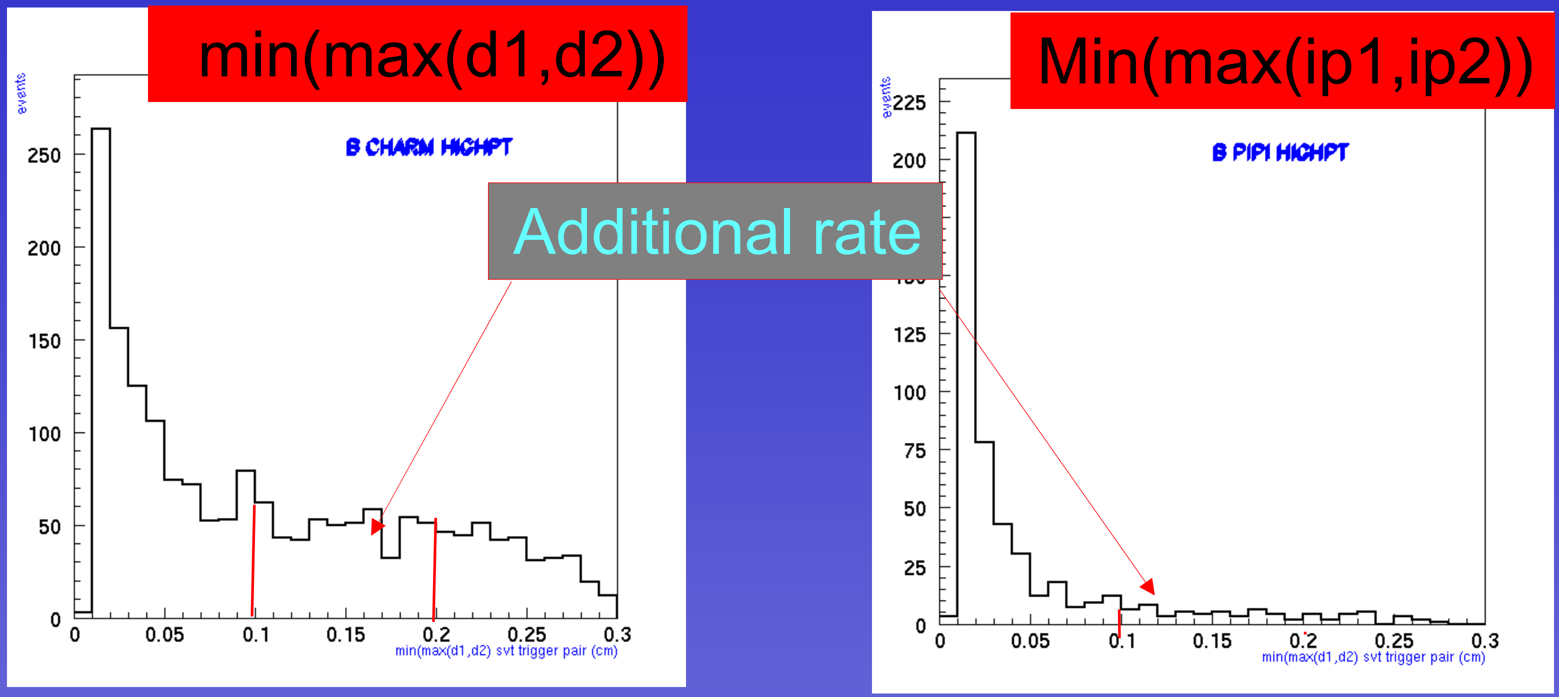
Run # 211539,211554

L_{inst} = 180 → 20 E30 $cm^{-2}s^{-1}$



First real data with bigger spot

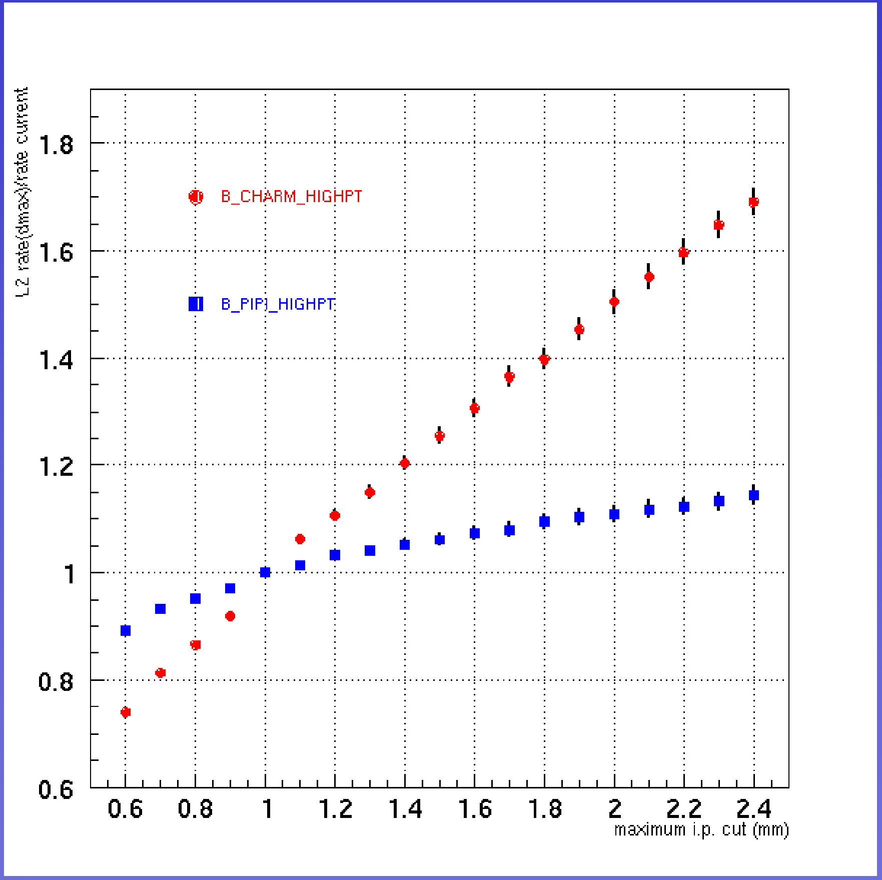
Run # 211539,211554



- 400 K L1 prescaled backup triggers
- Efficiency looks OK : 659K tracks vs 639K tracks in real data
- Behave as expected (increased number of tracks at high i.p.)
- L2 rate increase linearly with upper i.p. cut (fake dominated background is flat in i.p.)

Estimate of additional rate

- Extra rate at L2
- Limited impact an B_PIPI trigger path (<10%)
- More troublesome on generic B_CHARM (~40%)
  - Maybe not a problem because we don't rely on this trigger path at high lumi anyhow
- Need to check L3 rates
  - Expect milder effect, SVT tracks at high i.p. suffer from a higher fake rate than offline tracks



Plans and conclusions

- A summer student from Rome (Sara Borroni) is here in August/September to look at recent data, and refine studies and proposal
  - Seems very easy to implement test triggers
- Will continue looking at data:
  - Optimize pattern usage together with SVT folks
  - Make realistic L2/L3 rate estimate as a function of inst. Lumi.
  - Study quality of i.p. measurement by SVT for very displaced tracks
- Produce MC samples to be used by for evaluating resolution improvements (with Mauro Donega')
- If no resource-conflicts will be found seems feasible to make lumi to come even more valuable for B_s physics!

Backup

In pursuit of New Physics (with $B_s \to \phi\phi$)

- If sin(2β) b→s anomaly confirmed expect same New Physics σ phase to appear also in $B_s \to \phi\phi$
- Finding two lifetime components in B_s decays to a CP defined final state (like $(J/\psi\varphi)_{0,//}$) signal New Physics!
  - B_s mass eigenstate ≠ CP eigenstate (Bs mixing phase ≠ 0) (Dunietz,Fleisher,Nierste – 2000)
- Time dependence of $B_s \to K^+K^-$ or CP even component of $B_s \to \phi\phi$:

$$\Gamma(t) \propto \frac{1+\cos(\beta_s + 2\sigma)}{2} e^{-\Gamma_L t} + \frac{1-\cos(\beta_s + 2\sigma)}{2} e^{-\Gamma_H t}$$

- Compare lifetime from to $1/\Gamma_L$ from Bs→ $J/\psi\varphi$
- Establish New Physics if different !
  - (see U.Nierste Chigago Flavour Seminar: Feb 25th 2005)
- $B_s \to \phi\phi$ similar in scope to $B_s \to KK$ lifetime analysis

What's next?

- NP has few corner for NP to hide in B/Flavor physics
- B_s mixing frequency started constraining the last big one…

$$A_q^{\mathrm{full}} = A_q^{\mathrm{SM}} e^{2i\phi_q^{\mathrm{SM}}} + A_q^{\mathrm{NP}} e^{2i(\phi_q^{\mathrm{SM}}+\phi_q^{\mathrm{NP}})} = C_{B_q} e^{2i(\phi_q^{\mathrm{SM}}+\phi_{B_q})} A_q^{\mathrm{SM}}$$

- B_s mixing phase not constrained by Δm_s !
- Other observables are needed to obtain constraints (Luca Silvestrini's talk)
- Tevatron is already doing a good job and will do better before LHC takes over !

$\Delta\Gamma s$

- Light and Heavy B_s mass eigenstate expected to have sizeable width difference

$$\Delta\Gamma = \Gamma_H - \Gamma_L = 2|\Gamma_{12}|\cos\phi_s$$

- Mass eigenstate coincide with CP eigenstate in SM (no CP violation in mixing)

- Two ways to measure it:
  - In decays to $CP^{+,-}$ modes measure $\tau_L=1/\Gamma_L$, $\tau_H=1/\Gamma_L$ (e.g. $B_s \rightarrow KK$)
  - Or measure τ_L, τ_H in modes with both CP state ($B_s \rightarrow J\psi\phi$)

- CP violation in mixing will result in both Heavy and Light state having a component of both CP states. This result in:

$$\Delta\Gamma' = \Delta\Gamma\cos\phi_s = \Delta\Gamma_{SM}\cos^2\phi_s$$

B_s decays to VV ($B_s \rightarrow J/\psi\ \phi$)

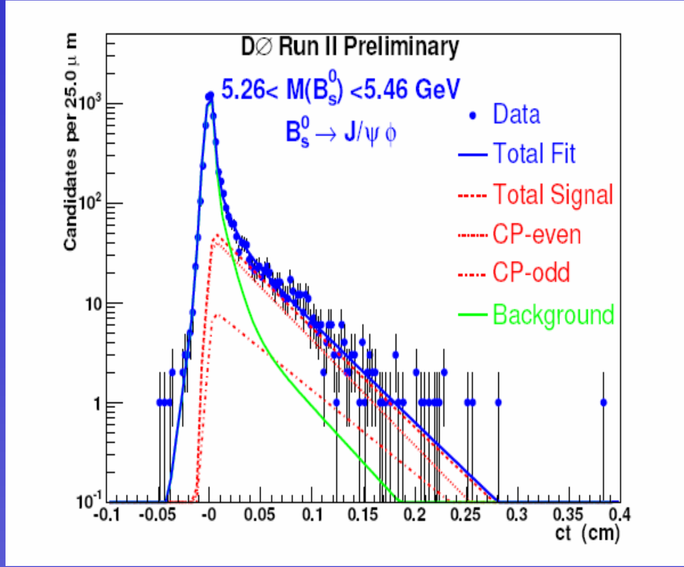
$$\frac{d^4\mathcal{P}(\vec{\rho},t)}{d\vec{\rho}\,dt} \propto |A_0|^2 \cdot g_1(t) \cdot f_1(\vec{\rho}) + |A_\parallel|^2 \cdot g_2(t) \cdot f_2(\vec{\rho})$$
$$+ |A_\perp|^2 \cdot g_3(t) \cdot f_3(\vec{\rho}) \pm Im(A_\parallel^* A_\perp) \cdot g_4(t) \cdot f_4(\vec{\rho})$$
$$+ Re(A_0^* A_\parallel) \cdot g_5(t) \cdot f_5(\vec{\rho}) \pm Im(A_0^* A_\perp) \cdot g_6(t) \cdot f_6(\vec{\rho})$$

term i	Amplitudes and time evolution ($g_i(t)$)
1	$\lvert A_0\rvert^2[e^{-\Gamma_L t} \mp e^{-\Gamma t}\sin(\Delta m_s t)\delta\phi_s]$
2	$\lvert A_\parallel\rvert^2[e^{-\Gamma_L t} \mp e^{-\Gamma t}\sin(\Delta m_s t)\delta\phi_s]$
3	$\lvert A_\perp\rvert^2[e^{-\Gamma_H t} \pm e^{-\Gamma t}\sin(\Delta m_s t)\delta\phi_s]$
4	$\pm\lvert A_\parallel\rvert\lvert A_\perp\rvert[e^{-\Gamma t}\sin(\delta_\perp - \delta_\parallel - \Delta m_s t) \pm \frac{1}{2}[e^{-\Gamma_H t} - e^{-\Gamma_L t}]\cos(\delta_\perp - \delta_\parallel)\delta\phi_s]$
5	$\lvert A_0\rvert\lvert A_\parallel\rvert\cos\delta_\parallel[e^{-\Gamma_L t} \mp e^{-\Gamma t}\sin(\Delta m_s t)\delta\phi_s]$
6	$\pm\lvert A_0\rvert\lvert A_\perp\rvert[e^{-\Gamma t}\sin(\delta_\perp - \Delta m_s t) \pm \frac{1}{2}[e^{-\Gamma_H t} - e^{-\Gamma_L t}]\cos(\delta_\perp)\delta\phi_s]$

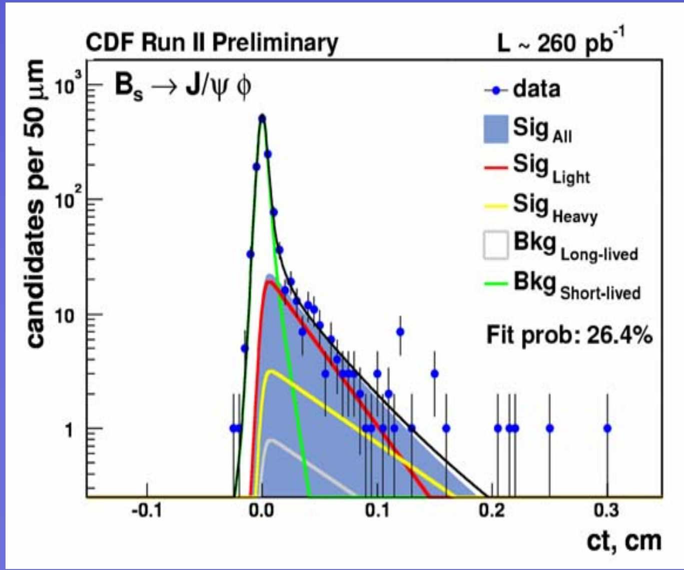
- Angular analyis allowsdisentanging the two CP component
- Give eventually access to Bs mixing phase ($\delta\phi_s$) $\rightarrow$SM ~0 in tagged and untagged (if $\Delta\Gamma_s$ big) measurement!
- Untagged measurement are very interesting for CDF!

$\Delta\Gamma_s$ from $B_s \rightarrow J/\psi\phi$ (present)

Observable	CDF '04 ref. [7]	DØ '05 ref. [2]	DØ '06 CP conserved	DØ '06 free $\delta\phi$
$\Delta\Gamma$ (ps^{-1})	$0.47^{+0.19}_{-0.24} \pm 0.01$	$0.17^{+0.20+0.02}_{-0.27-0.03}$	$0.15^{+0.10+0.03}_{-0.10-0.04}$	$0.17^{+0.09}_{-0.09}$
$\bar{\tau}$ (ps)	$1.40^{+0.15}_{-0.13}$	$1.39^{+0.13\ +0.01}_{-0.16\ -0.02}$	$1.53^{+0.08\ +0.01}_{-0.08\ -0.04}$	$1.53^{+0.08}_{-0.08}$
$\delta\phi$	$\equiv 0$	–	$\equiv 0$	-0.9±0.7
$R_\perp$	0.13 ± 0.08	0.16 ± 0.10	$0.19 \pm 0.05 \pm 0.01$	0.19 ± 0.05
$\lvert A_0(0)\rvert^2 - \lvert A_\parallel(0)\rvert^2$	$\equiv 0.355$	$\equiv 0.355$	0.35±0.07± 0.01	0.34±0.07
δ_1 - δ_2	1.94±0.36	–	2.5±0.4	2.6±0.4

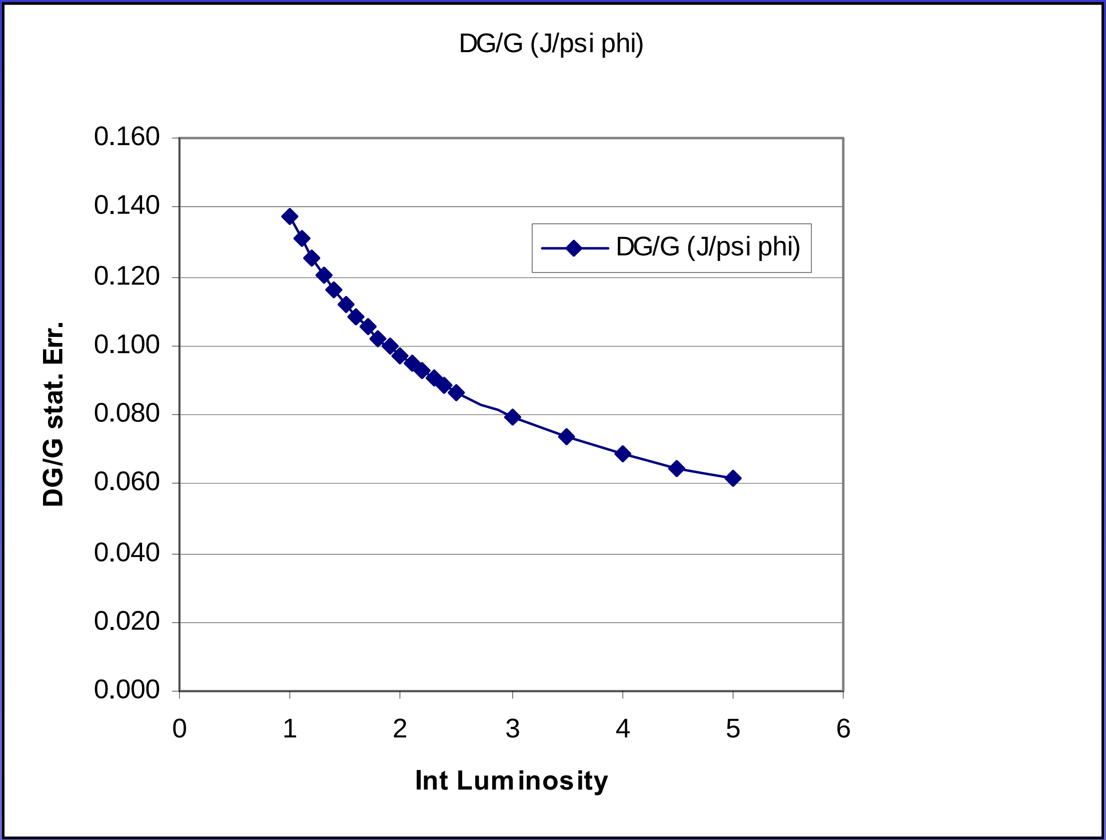


- CDF and D0 similar sensitivity:
  - Yield (D0)=1200 ev. /fb^{-1}
  - Yield (CDF)=1000 ev. /fb^{-1} (after cτ cut, see later)
- Resolution on $\Delta\Gamma_s$ scale as $\sqrt{N}$



$\Delta\Gamma_s$ from $B_s \rightarrow J/\psi\phi$ (future)

- Key points:
  1. Mantaining yield of J/ψ
  2. Good vertexing
  3. Controlling resolution function tails
- Final resolution expected similar to RUN II early expectations O(0.05)
- Improvement possible:
  1. Add other modes
  2. Add further $J/\psi\phi$ from other triggers (TTT)

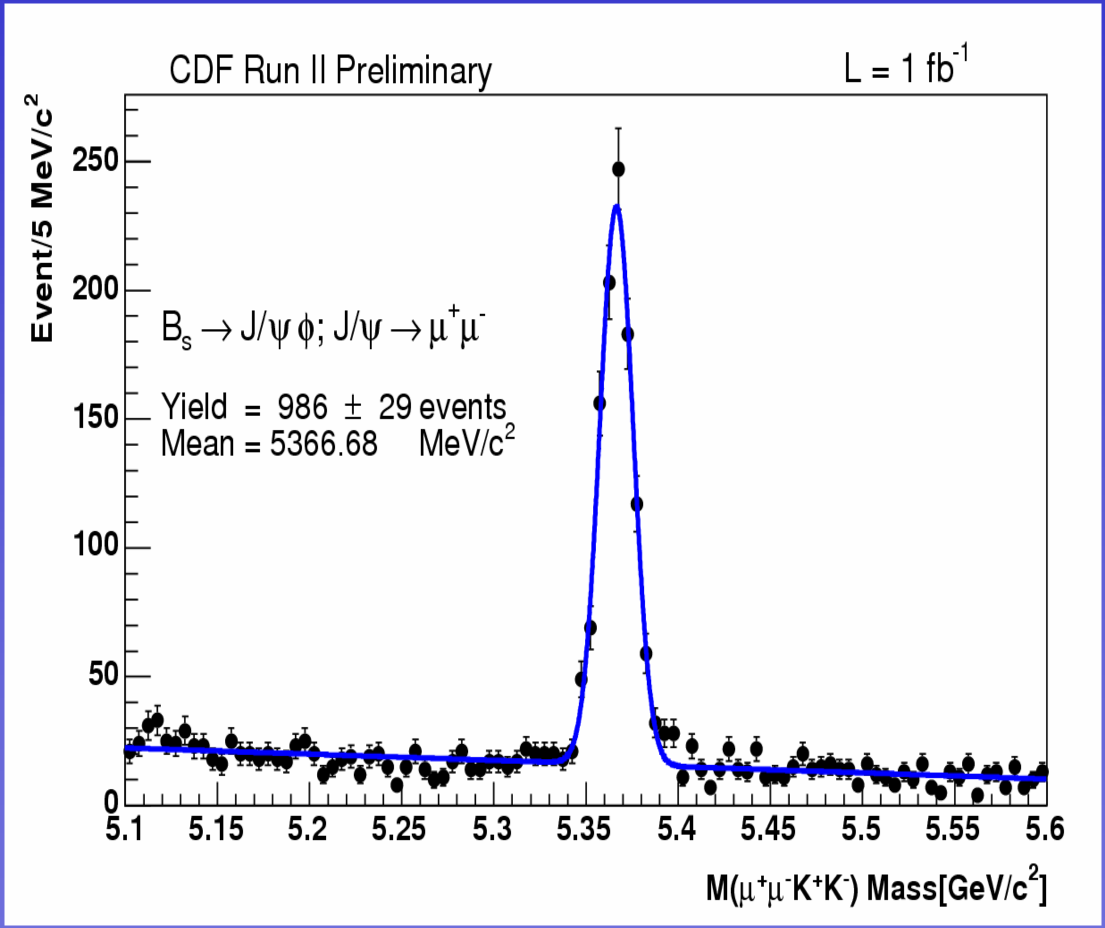


Direct meausrement of ϕ_s

- In analogy to sin2β from J/ψKs measure time dependent CP asymmetry in $B_s \rightarrow J/\psi\phi$
  - Single amplitude b→ccs dominate
  - CP asymmetry in the interference of mixing and decays measure 2*mixing phase

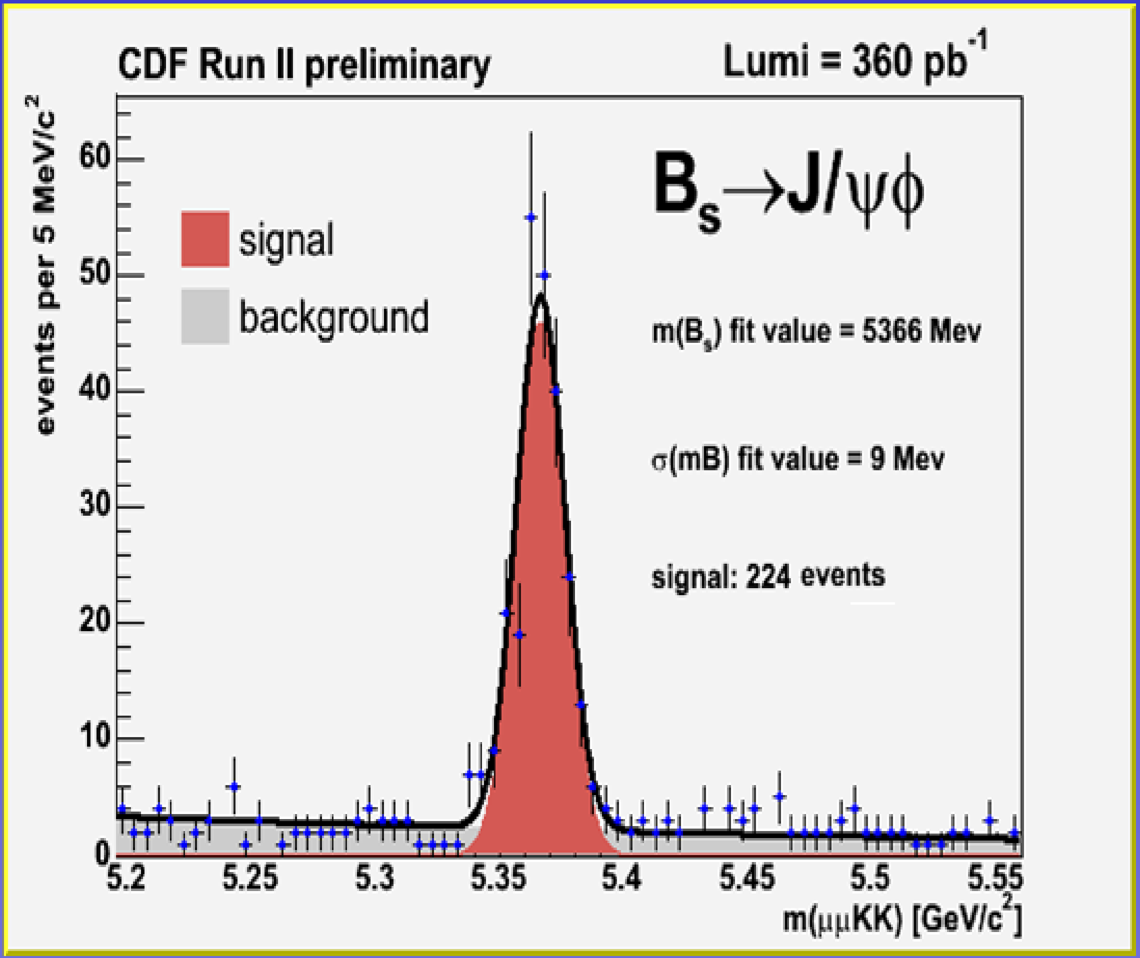
- Measurement builds on mixing measurement legacy:
  - Require resolving mixing oscillation
  - Require tagging
  - Require statistics…

$B_s^0 \rightarrow J/\psi\phi$ signal



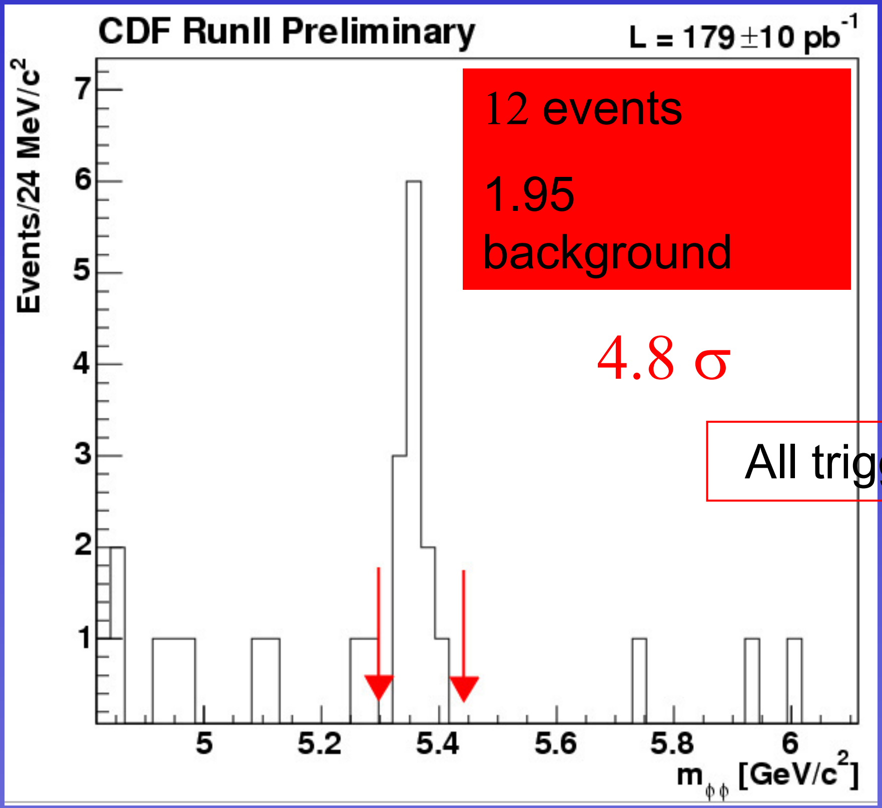
- From J/PSI trigger path
- S/N ~5
- Cut on Lxy applied

$B_s^0 \rightarrow J/\psi\phi$ signal

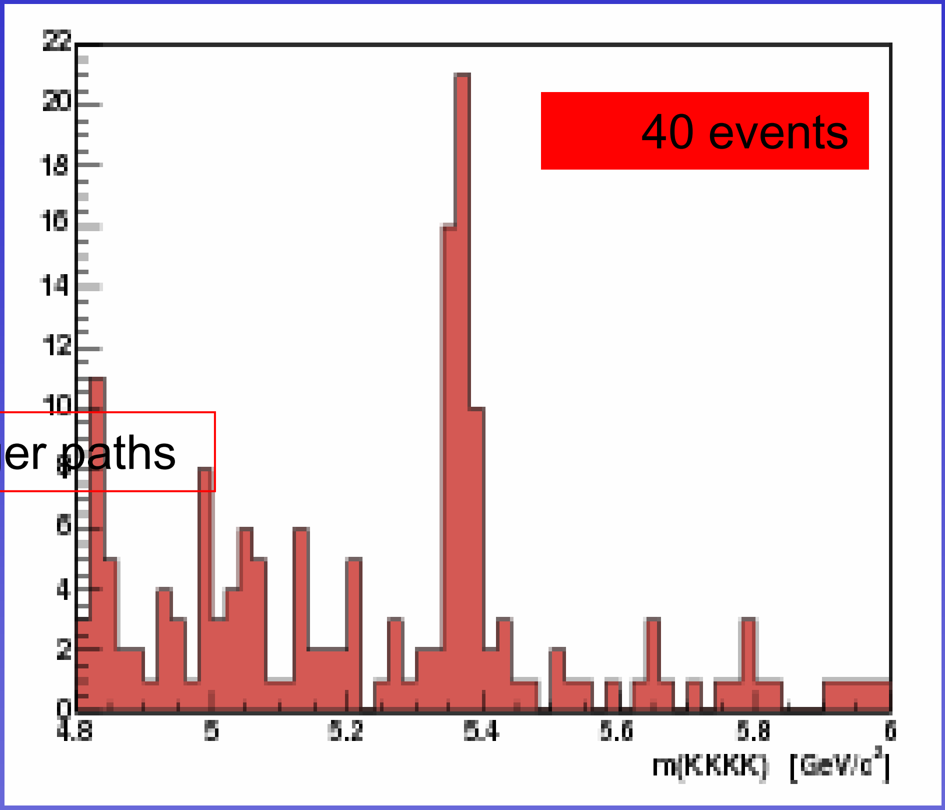


- Include all two track trigger path
- Prescaled LOWPT +30%
- ~80% of events unique to TTT
- S/N ~3
- Few % contamination from Bd modes

Bs→ϕϕ signal



All trigger paths



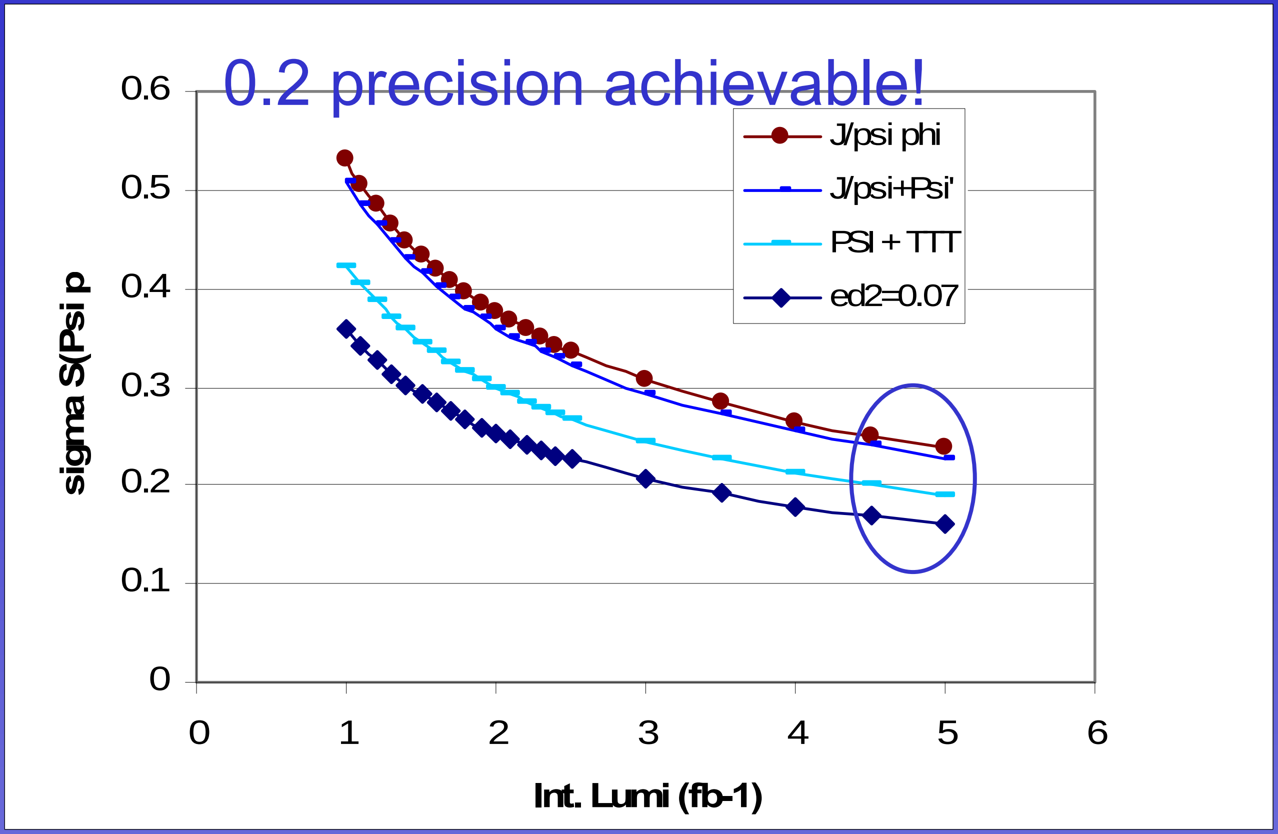
$B_s \rightarrow \phi\phi$ **12 events (180 pb^{-1})** ⟶ **40 events (360 pb^{-1})**

- Same selection as published analysis (BR(Bs→ϕϕ) with 180 pb^{-1})
- Expect 0.10-0.15 error on longitdinal pol. (similar to B-factory first PRL)

A_{CP}(mix) from $B_s^0 \to J/\psi\phi$

- Input from latest Δm_s measurement :
  - $\sigma_{c\tau}$ = 86 fs
  - εD^2 = 0.04/0.05 depending on the sample (also with “minor” improvement up to 0.07)
  - Yield as in the 1st fb^{-1}
  - Include extra dilution from disentangling CP state (CDF 6628) using measured CP odd fraction
    - 0.18± 0.04 → worse resolution by 50%
  - Include S/N terms (assumed constant in t)
  - Include TTT data + ψ'
- Not evaluated yet sensitivity to ϕ_s from interference term in the untagged sample
  - D0 claims $\Delta\sin(\phi_s)$=0.7 with 1fb^{-1} in the $\Delta\Gamma_s/\Gamma_s$ paper !

A_{CP}(mix) from $B_s^0 \to J/\psi\phi$



- Compare with ACP(mix)$_{th}$ = 0.07± 0.50 (Luca's Talk)
- Should generate a coherent effort from CDF like it was done for Δm_s
- Have sin2β from J/ψKs to break the ice!

Obiettivi e scopo di Sara

- Imparare a conoscere il sistema di trigger di CDF
- Imparare ad utilizzare differenti dataset per stimare il trigger rate → trigger table building
- Utilizzo del fitter di “vita-media” sul MC per stimare miglioramento delle prestazioni
- Partecipare alla review sui trigger upgrade (prima review prevista per il 27 Luglio) e all’elaborazione di una nota di supporto:
- Ottimizzazione larghezza della beam-spot anche in relazione alle altre proposte (e.g. abbassamento soglie in momento trasverso)