

Effects of beam-beam interaction and event-overlap in Higgs study

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1. Introduction
2. Effects of beam-beam interaction background hits
on VTX detector
3. Effects of event overlap
4. Requirements / summary

At Next Linear Collider (1st phase)

- 0. High energy $E_{cm} = 250 - 500 \text{ GeV}$
- 1. High luminosity 2 - 3 order higher than LEP
- 2. Small beam size \longrightarrow Good Primary Vertex Resolution
- 3. New technologies can be used...

Discovery (if LEP/TEVATRON/LHC did not)
is guaranteed if Higgs exists in energy reach

We expect great Higgs "measurements"
from our experiences at LEP/SLC

More consideration

Worse than LEP / SLC ?

1. Beam-beam interaction

Energy spread, tail : depending on luminosity

So many e^+e^- creation in a train collision \longrightarrow SI hits

2. Short bunch spacing & high luminosity per bunch

Events overlap !!

two-photon process (mini-jet) + signal, bkg

hard event + hard event \sim hZ, Ah can happen

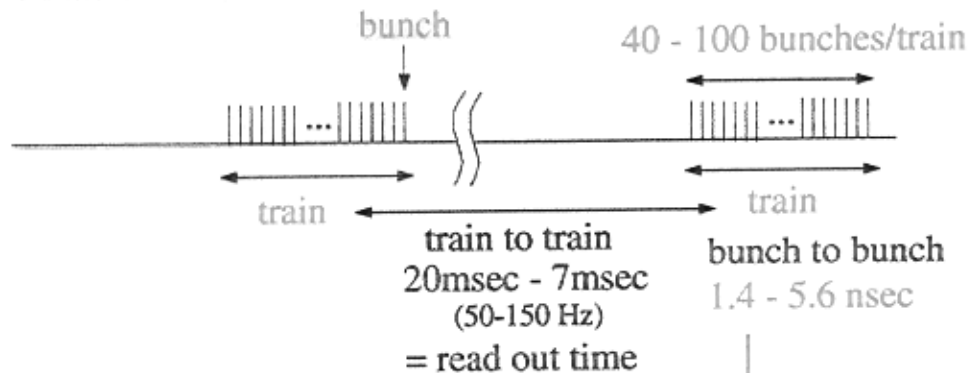
3. Acceptance

can not cover very forward region ?

Time Structure of the Beam

JLC-C
JLC-X/NLC

beam time structure



We can not separate SiVTX Hits (CCD)
= hits are integrated in a train

Situation can be similar at TESLA (CCD x column.. C. Damarell)

Huge Number of Hits on Si VTX per train

beam-beam interaction (incoherent scattering)

(T.Tauchi)

for Most Inner Si (R=2.4 cm) ~ 1 hits / mm² !!

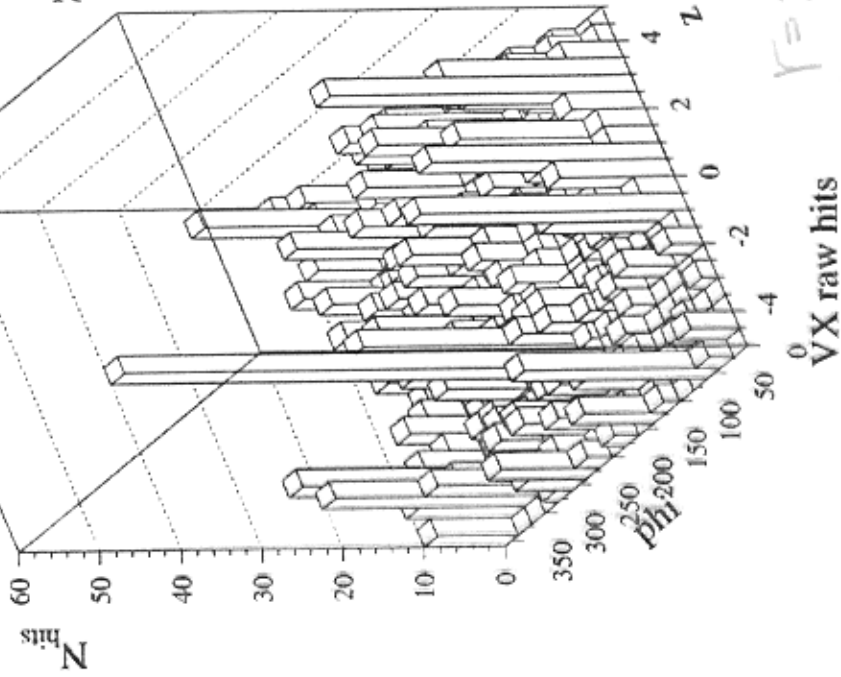
We have to select correct Si-hits using outer detector
for Higgs measurements

just 10 bunch ($\sim 1/10$ train)

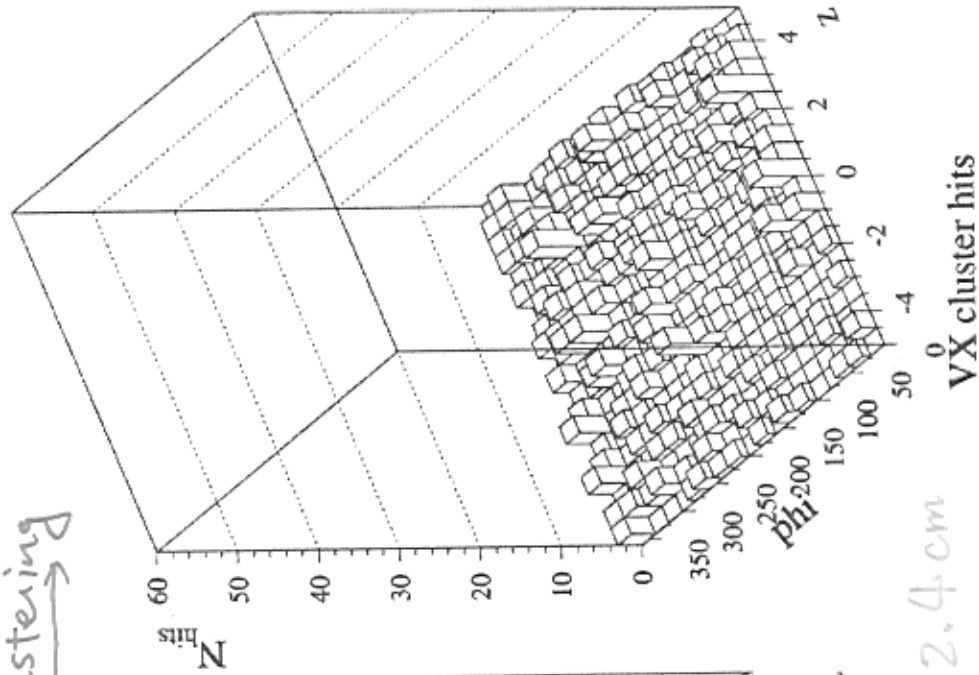
99/04/27 22.26

ϕ vx. z distribution

clustering \rightarrow



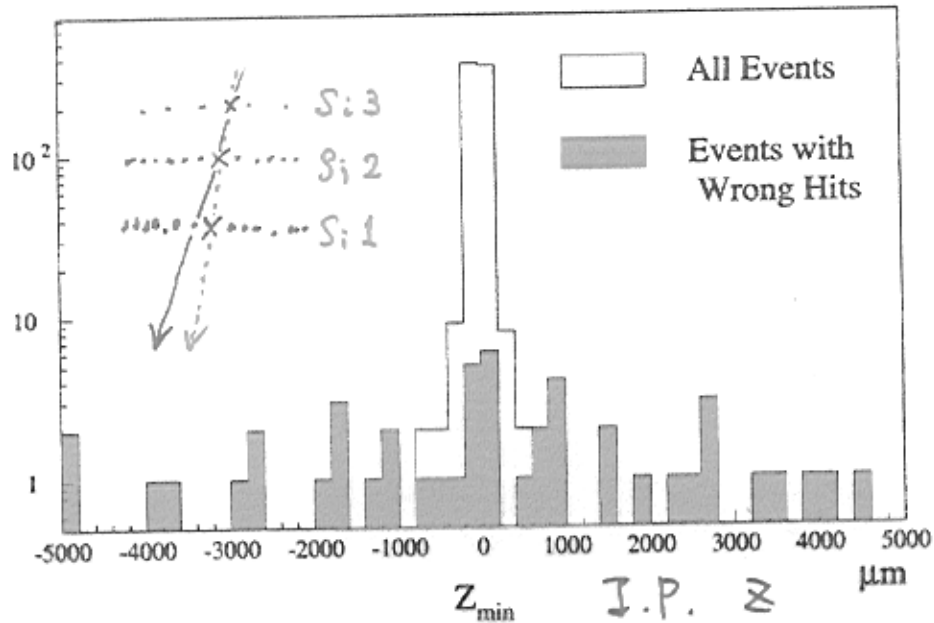
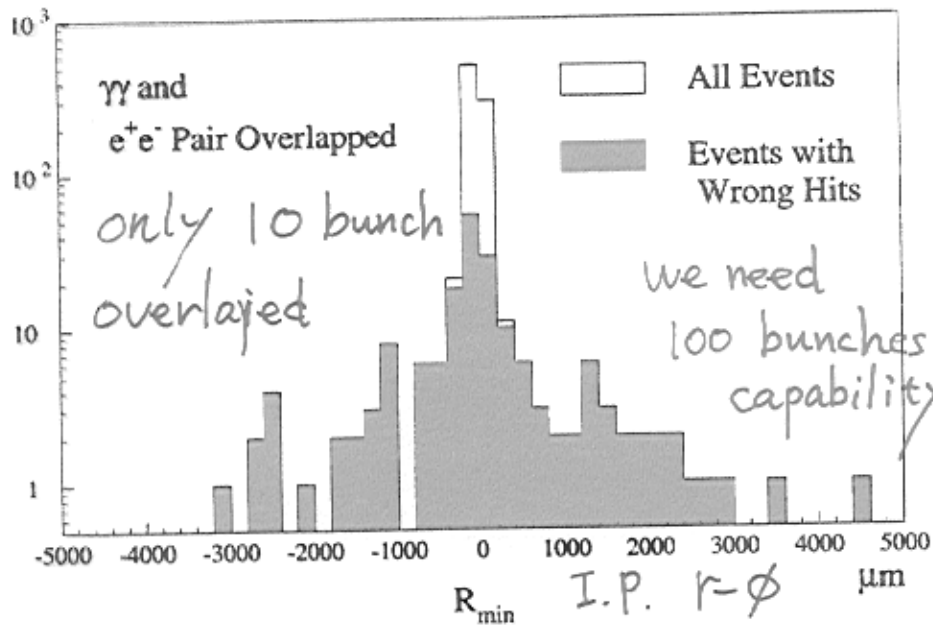
$r = 2.4 \text{ cm}$



How worse Impact Parameter may come from the wrong hits association ?

study with JLC-I old-detector ('95) design

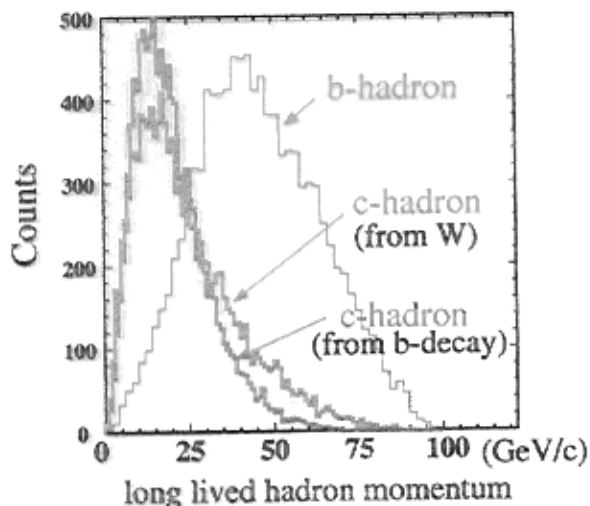
Reconstructed R_{\min} and Z_{\min} for 1 GeV/c μ



Several b related properties

$E_{cm} = 250 \text{ GeV}$ $M_h = 120 \text{ GeV}$

b/c hadron momentum spectrum for signal/WW



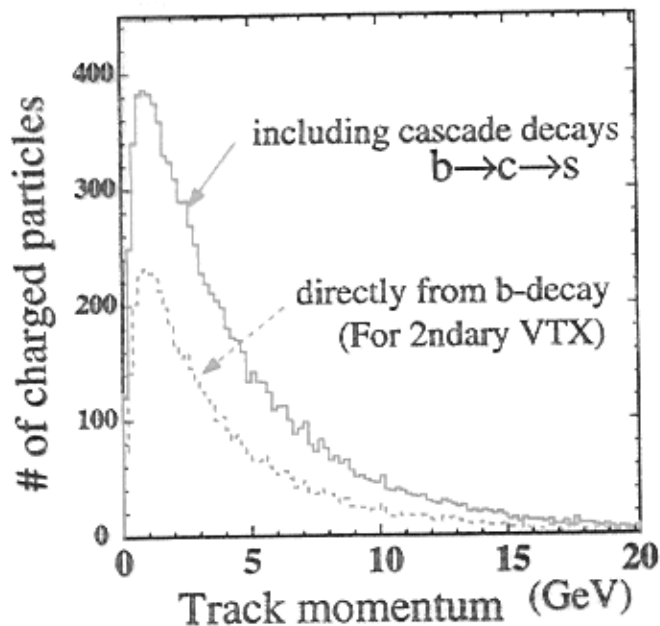
large boost (average $\gamma \sim 10$)

many tracks (hits)
in narrow detector region

b ~ 5 tracks / 10 mstr
c like τ at LEP-I

need good Si-CDC matching

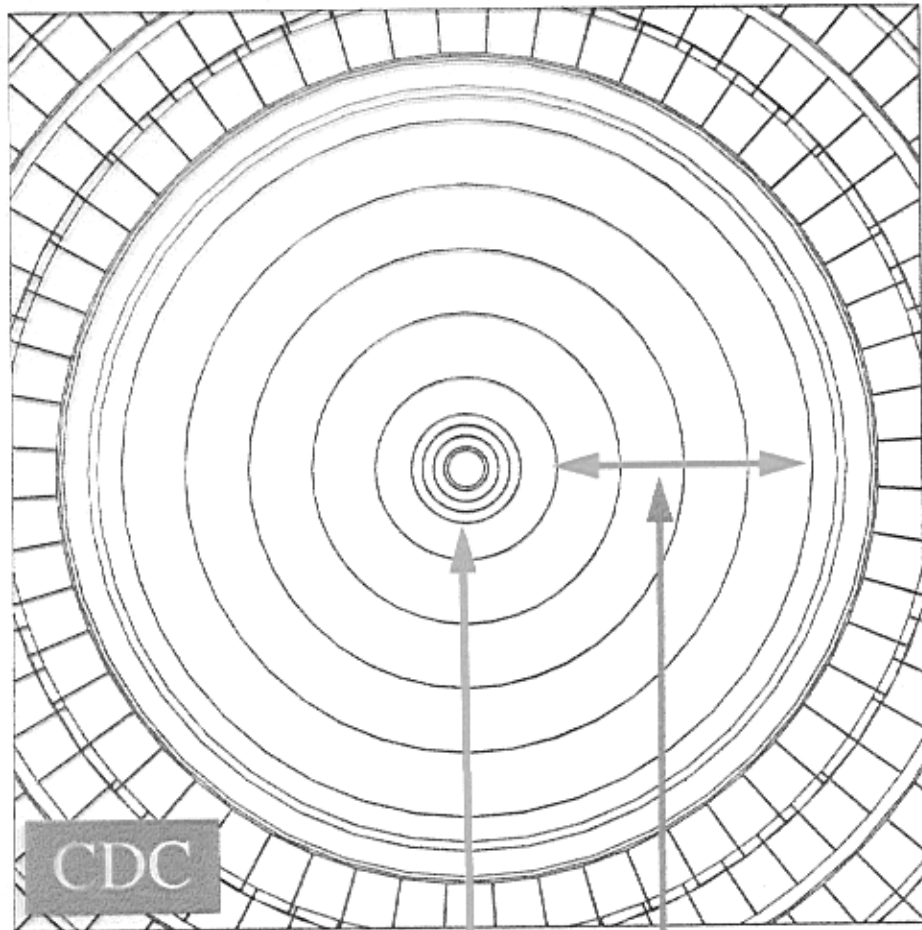
Momentum Distribution of charged particles from b-decay



Due to many track sharing b-momentum

charged track momentum is
in general low

Low momentum tracks are important
target : good reconstruction for $P \sim 1 \text{ GeV/c}$



$r = 450 - 2300 \text{ mm} \quad |z| < 2300 \text{ mm}$

$\sigma_{r\phi} \sim 100 \mu\text{m} \quad \sigma_z \sim 1 - 3 \text{ mm}$

R&D results '98

$\sigma_{r\phi} \sim 85 \mu\text{m}$ with baby chamber
(JLC CDC subgroup)

5 Intermediate Tracker

$r = 100 - 380 \text{ mm} \quad |\cos \theta| < 0.9$

$\sigma_{r\phi} \sim 20 \mu\text{m} \quad \sigma_z \sim 20 \mu\text{m}$

300 μm thick Si x 5 layers
(assumption)

4 layer SiVTX (CCD)

$r = 24 - 60 \text{ mm} \quad |\cos \theta| < 0.9 \quad 300 \mu\text{m} \text{ thick x 4 layers}$

$\sigma \sim 4 \mu\text{m}$

beam test results at KEK '98.

$\sigma = 3 \mu\text{m}$ (JLC VTX subgroup)

Single track muon $p = 0.5-10 \text{ GeV}$ $\cos\theta \sim 0.8$

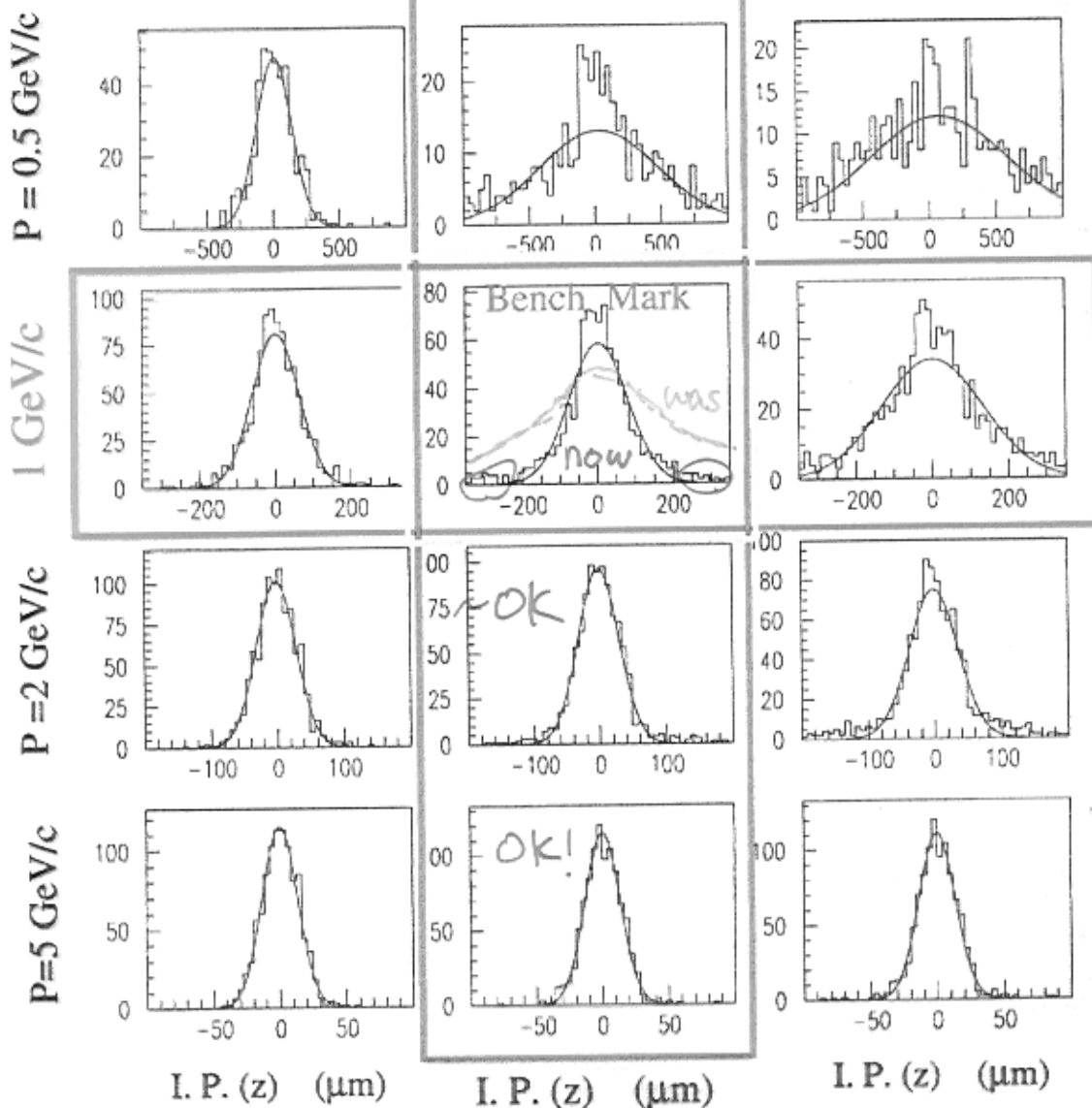
beam-beam interaction : ABEL program

T.Tauchi, K.Yokoya, P.Chen Pair creation from beam-beam interaction in linear collider
Particle Accelerators 1993 Vol 41 pp29-39.

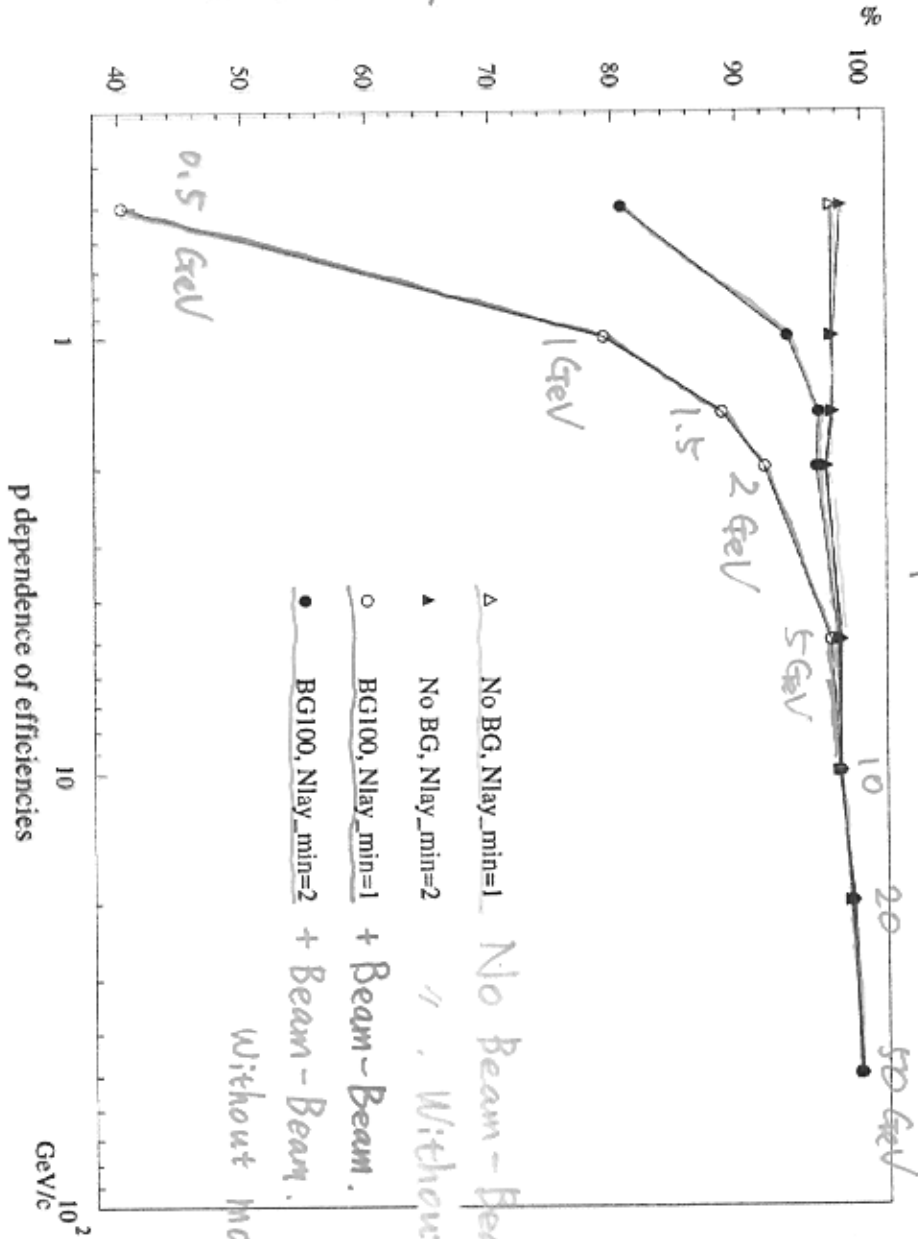
FULL DETECTOR SIMULATION (JIM)

But using $\sigma_{si} = 7 \mu\text{m}$ (instead of $3 \mu\text{m}$)
100 bunch beam-beam for safety!

No beam-beam ABEL beam-beam MC 500 bunch beam-beam
JLC ($\sim 1 \text{ hits/mm}^{**2}$) (5 x JLC 500 GeV)



η_{eff} (Impact Parameter $< 3\sigma$ no beam-beam)

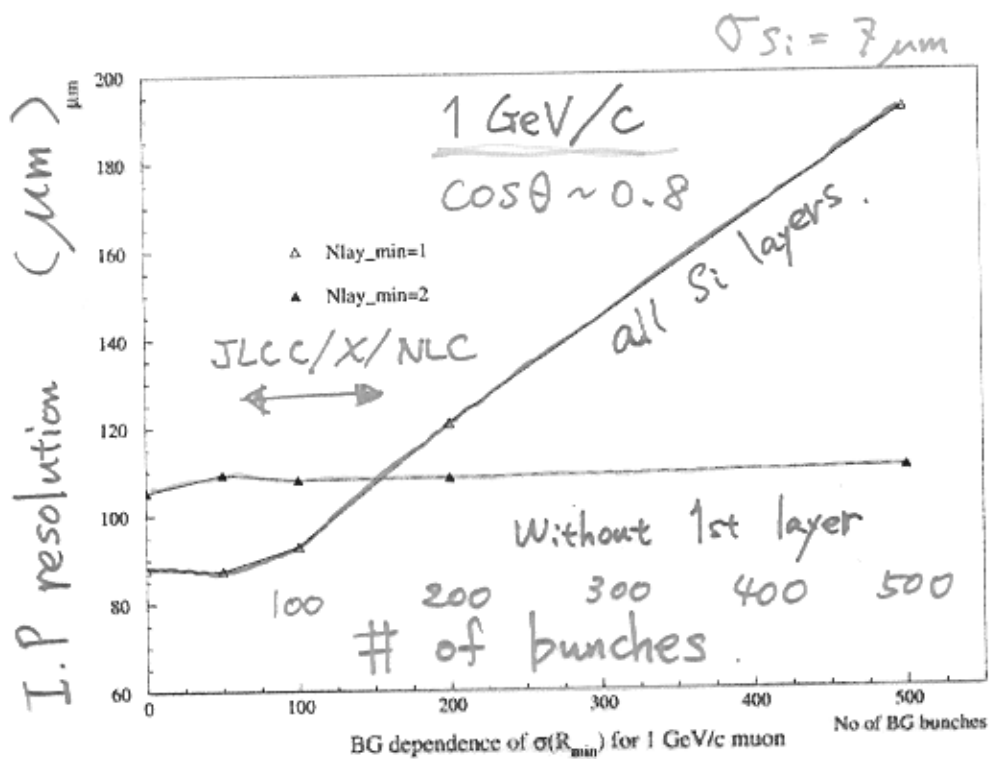
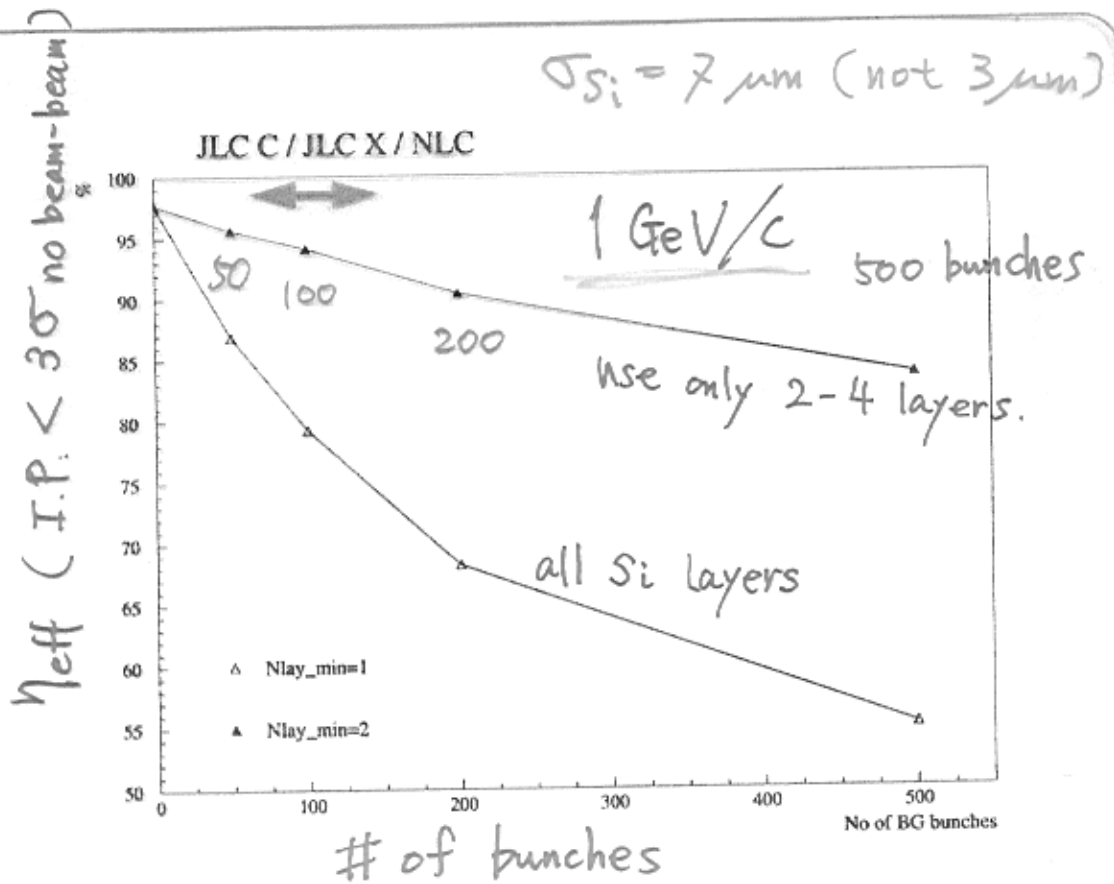


~ no tail due to mis-association

Particle momentum

p dependence of efficiencies

- △ No BG, Nlay_min=1 No Beam-Beam. All Si
- ▲ No BG, Nlay_min=2 " Without most inner
- BG100, Nlay_min=1 + Beam-Beam. All Si
- BG100, Nlay_min=2 + Beam-Beam. Without most inner Si



Summary for beam-beam hits

Full simulation has been done with realistic beam-beam interaction effects.

The effects is very big since hits are not random.

Newly implemented intermediate tracker is greatly helpful for the correct association of hits

For track $> 4 \text{ GeV}/c$ the effect can be neglected.

Wrong association of Si-vtx hits still dominates the impact-parameter tail for low momentum ($< 3 \text{ GeV}$).

To realize the good measurements expected by "smearing - type" Monte Carlo simulation for Higgs, we have a lot of room to improve

Si first layer radius optimization

eg. $r = 2.4 \text{ cm}$ \longrightarrow 3.0 cm

+ thickness $300 \mu\text{m}$ \longrightarrow $200 \mu\text{m}$

\longrightarrow $100 \mu\text{m}$

More optimization of intermediate tracker

time resolution .

Better track finder

§ 2

Two photon (mini-jet) background

1. Two-photon events and signal event can overlap even in Single Bunch with significant rate, due to Huge "Luminosity per Bunch" (L_B)

$$\text{LEP-II} \quad \sim 10^{-6} \text{ nb}^{-1} / \text{bunch}$$

$$\text{SLC} \quad \sim 10^{-5} \text{ nb}^{-1} / \text{bunch}$$

JLC-C band / JLC-X / NLC / TESLA (low/high lumi)

$$\text{Next LCs } L_B = 0.5 - 2 \times 10^{-3} \text{ nb}^{-1} / \text{bunch}$$

(@ 500 GeV parameter)

3 order of magnitude higher than LEP !

Two photon "cross-section" $\sigma_{\gamma\gamma} \sim 10 - 100 \text{ nb}$ order
(in detector region : hadronic+leptonic)

example : 66 nb @ $E_{cm}=500 \text{ GeV}$ (Hadronic: DG1 simulator)
(T.Tauchi LCWS'93: JLC-I '93, minimum Pt 2 GeV/c)

Two-photon overlap rate on "any" signal or bkg

$$\text{Probability} = \sigma_{\gamma\gamma} \times L_B \quad 1\% \sim 20\%$$

Can be higher..... depending on Detector acceptance
Machine parameters etc.

Monte Carlo Study

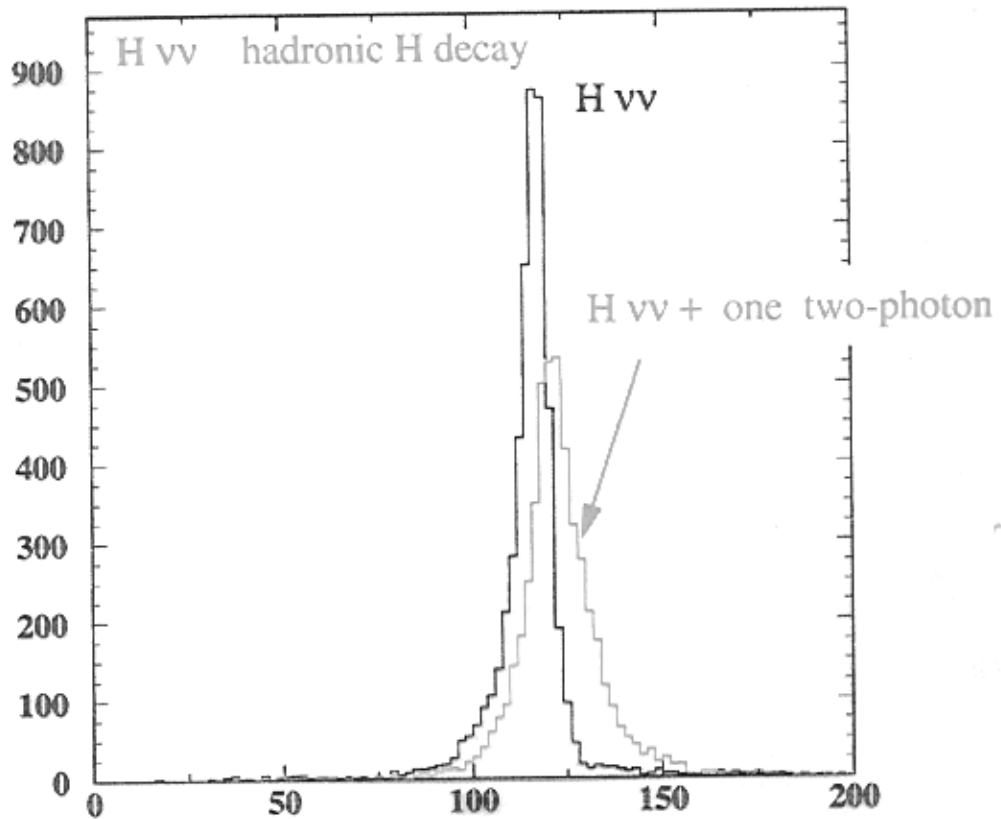
Higgs signal / bkg events (ff, WW, ZZ, W ν , Z ν with Pythia)
with beam-strahlung Ecm smearing/tail

+ Two-photon sample : PHOJET (thanks to S.Soldner-Rembold)
 $M_{\gamma\gamma} > 2 \text{ GeV}$ $E_{cm} = 300 \text{ GeV}$

Use JSF Quick simulator, No beam-beam hits overlaid.

Effects on Higgs Mass reconstruction

Higgs Mass (visible mass) distribution



1. Event topology, Evis, Acop, Higgs Mass... can be distorted.
2. Track(s) from overlapping two-photon event comes from different production point in beam spot size. Use only $r-\phi$?



c-meson rate is not negligible.

Flavour tagging can be affected.

Selection efficiency, S/N should be affected. Systematic error ?

Can be difficult to control the systematic error.

because

- A) it depends on the luminosity bunch by bunch.

Question to experts : How well can we monitor this ?
How stable it is ? Can we use average ?

- B) Two-photon cross-section depends on beam dynamics

Two sources of mini-jet

1. normal two-photon (virtual photon + virtual photon)



Machine/beam independent

2. beam-shtrahlung (real) photon + virtual photon



Machine/beam condition dependent

Same level of contribution from 1. and 2. (T. Tauchi JLC-I)

BUT we want to MEASURE Higgs property PRECISELY.

Selection of leptonic channel

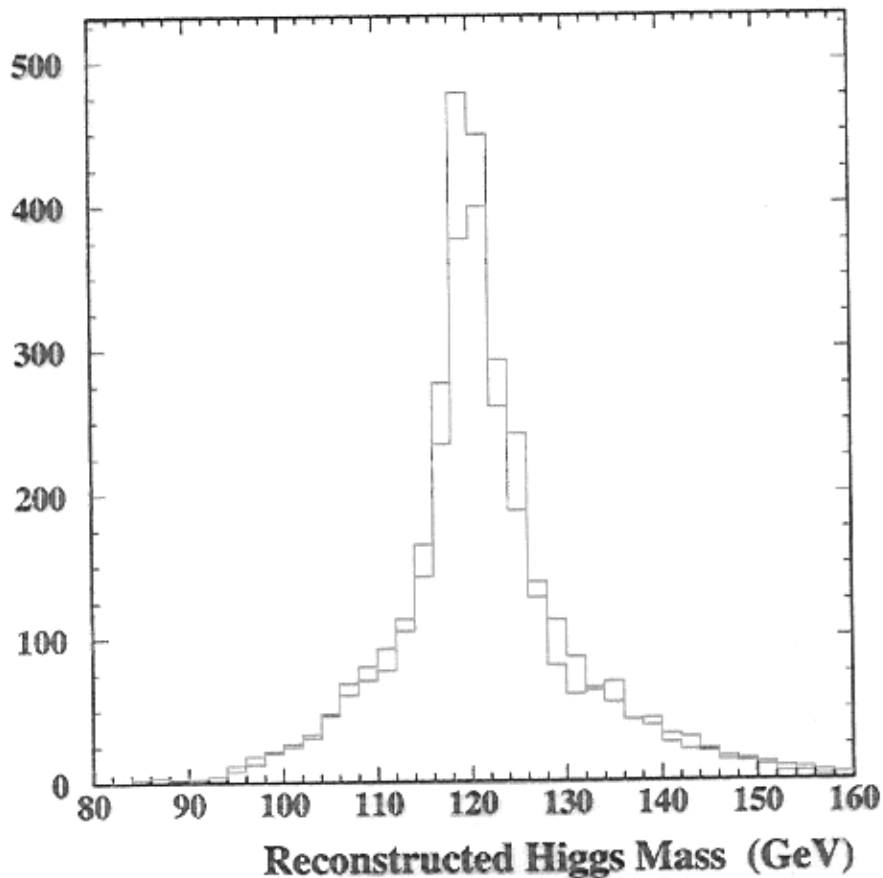
Insensitive to the overlap effects if selection rely only on high p (>20 GeV/c) leptons ($|\cos\theta|<0.95$)

$\sigma < 1$ nb for any isolated lepton $p > 20$ GeV/c $|\cos\theta|<0.95$
(VERMASEREN $eeee$ $ee\mu\mu$ $ee\tau\tau$ + PHOJET)

Thanks to R. Nisius for VERMASEREN lecture

4 jet channel

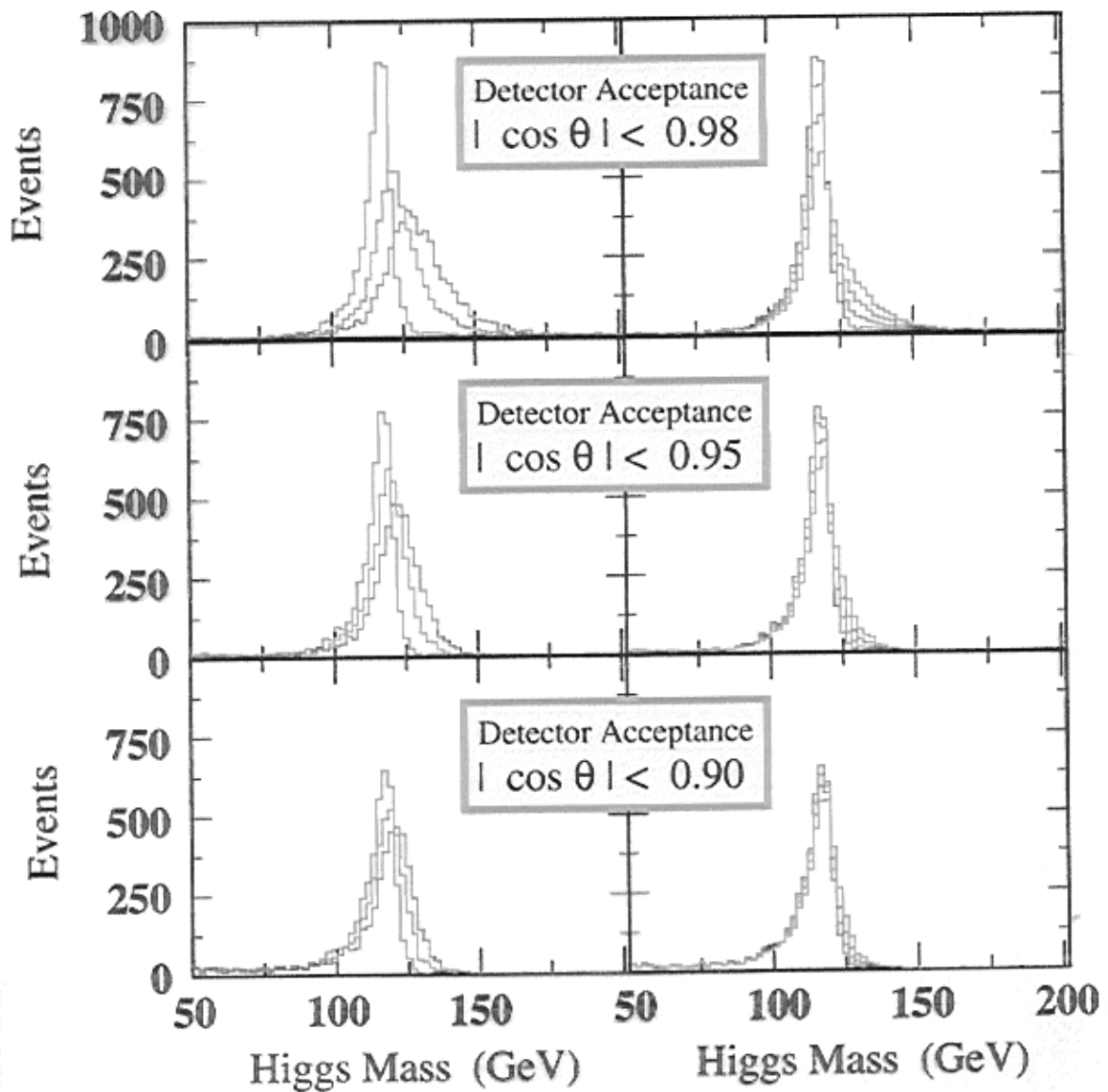
Mass resolution is relatively stable
if we apply beam constraints scaling



Background increased by $\sim 30\%$ for bkg + mini-jet

H $\nu\nu$ channel is very sensitive to the overlap

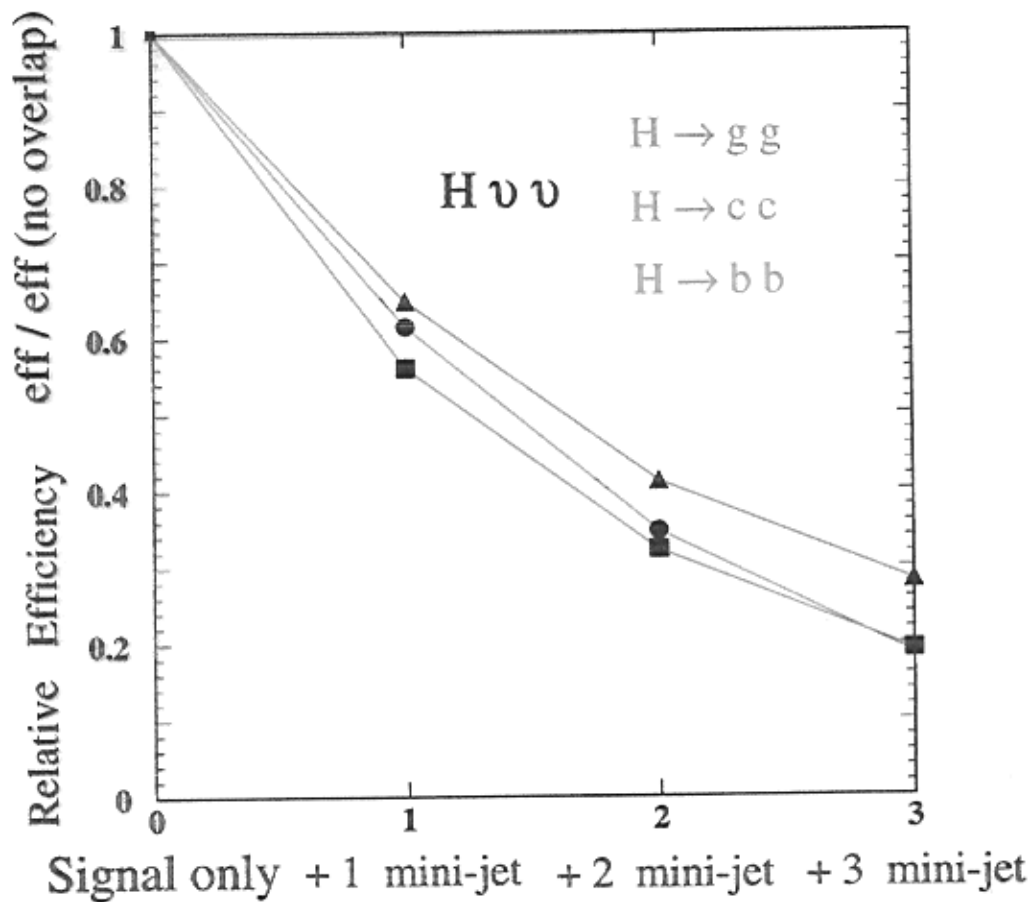
- | | | | |
|---|-------------------------------------|---|--------------------|
| — | H $\nu\nu$ only | — | 0 (low luminosity) |
| — | H $\nu\nu + \gamma\gamma$ overlap | — | average 0.2 events |
| — | H $\nu\nu + 2 \gamma\gamma$ overlap | — | average 0.5 events |
| — | | — | average 1.0 events |



If we don't use forward region, small dependence on the rate. But $\text{eff} \downarrow$ $\text{bkg} \uparrow$

Effect on kinematic selection efficiency

Just applying selection optimised for no-overlap (I. Nakamura's talk)



Background level is almost same.

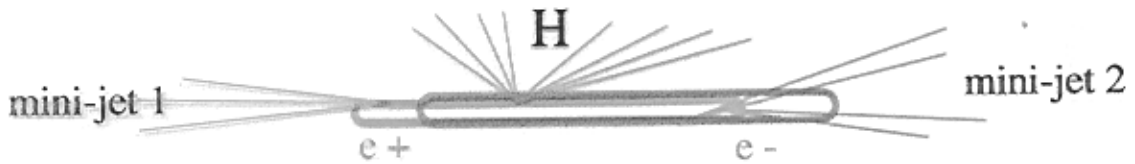
W_{eff} increased rapidly, but still small.

Effect on the flavour tagging

Example for extreme case

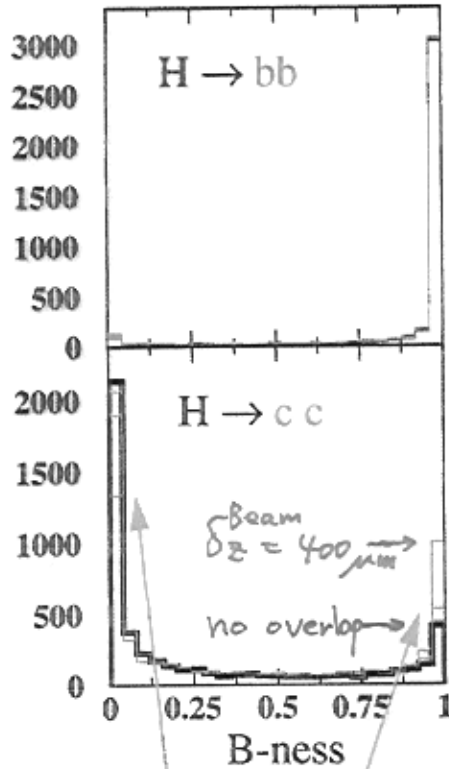
Higgs (vvH) + 2 x mini-jet events

Check for different beam z-width (80 and 400 μm)



- overlap (σ_z beam = 0 : same pos)
- Higgs only
- overlap (σ_z beam = 80 μm)
- overlap (σ_z beam = 400 μm)

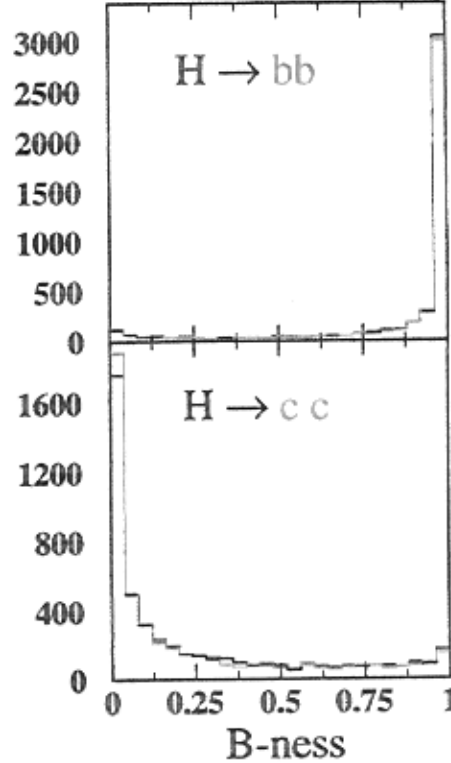
3-dimensional



b-c decay separation is sensitive to overlap rate.

No problem if overlap rate < 20 %

2-dimensional (r- ϕ)



In insensitive to overlap rate

For very high luminosity. Sensitivity is lower than 3-d

Note : Using only tracks in $|\cos\theta| < 0.9$

Conclusion

The bunch ID is very important for minimizing two-photon event overlap.

dT (bunch spacing) = 2.8 nsec for JLC -C/X/NLC

Lumi / bunch is about $0.6 - 0.9 \times 10^{-3} \text{ nb}^{-1}$

When we have ~ perfect bunch ID

→ average 2 - 7 % overlap = No problem

Acceptable Limit for Higgs precision measurement

Mix +/- 1 bunch = 6 - 20 % overlap
(~TESLA high lumi)

Need strategy to control systematic error

Use unbiased (BX) triggered events to monitor.
overlay to low lumi run data?

This overlap effect is machine condition dependent.

(depends not only on the bunch-by-bunch luminosity,
but also beam-strahlung since emitted gamma + virtual
photon produce additional two photon cross-section)

→ Need very stable operation of machine.

Requirements as summary

JLC / NLC type accelerator

Requirement to detector : (for ~ perfect bunch-ID)

Central tracker : < 1 nsec self-fit time resolution

Calorimeter : < 1 nsec time resolution

Especially forward (EndCap) region is important
because of two-photon bkg nature.

TOF counter for charged particle in front of CAL for EndCap?

Fast EM-CAL (scintillator, lead glass, pure-CsI...)

TESLA type accelerator

Bunch ID is easy ($dT > 300$ nsec)

Too High Luminosity / bunch for high -lumi option
should be avoided for Higgs precise measurement.

To get useful higher statistics data,
prefer to increase number of bunches
keeping luminosity per bunch as it is now
with present bunch spacing,
instead of increasing luminosity per bunch.
(a bit more power consuming ..)