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 — Ecm = 250 - 500 GeV
1. High luminosity — 2 - 3 order higher than LEP
2. Small beam size ⟶ Good Primary Vetex Resolution
3. New technologies can be used...

Discovery (if LEP/TEVATRON/LHC did not)
is garanteed 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 ee eeee creation in a train collision ⟶ SI hits

2. Short bunch spacing & high luminosity per bunch

   Events overlap !!

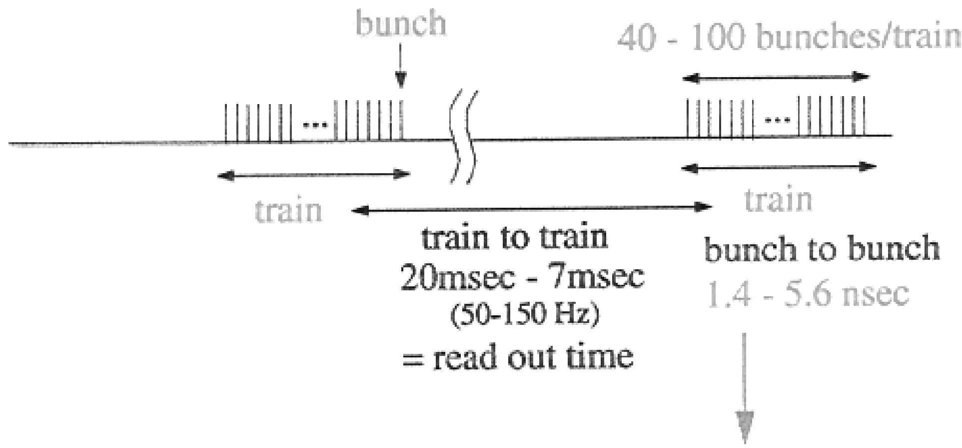
   two-photon process (mini-jet) + signal, bkg
   hard event + hard event ~ hZ, Ah can happen

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 colomn.. C. Damarell)

Huge Number of Hits on Si VTX per train

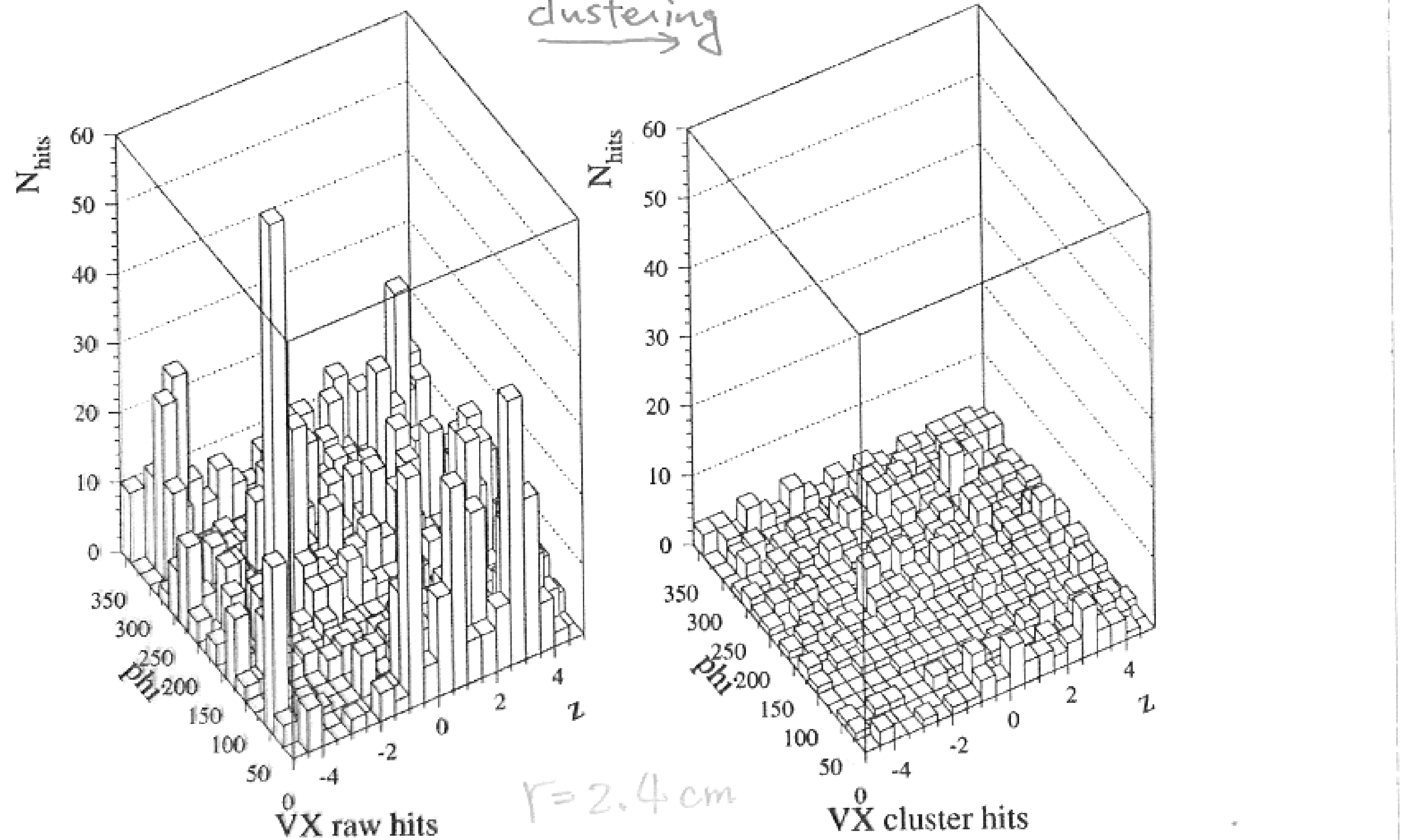
beam-beam interaction (incoherent scattering) (T.Tauchi) for Most Inner Si (R=2.4 cm) ~ 1 hits / mm^2 !!

We have to select correct Si-hits using outer detector for Higgs measurements just 10 bunch (~1/10 train)

ϕ vx. z distribution

99/04/27 22.26

clustering →

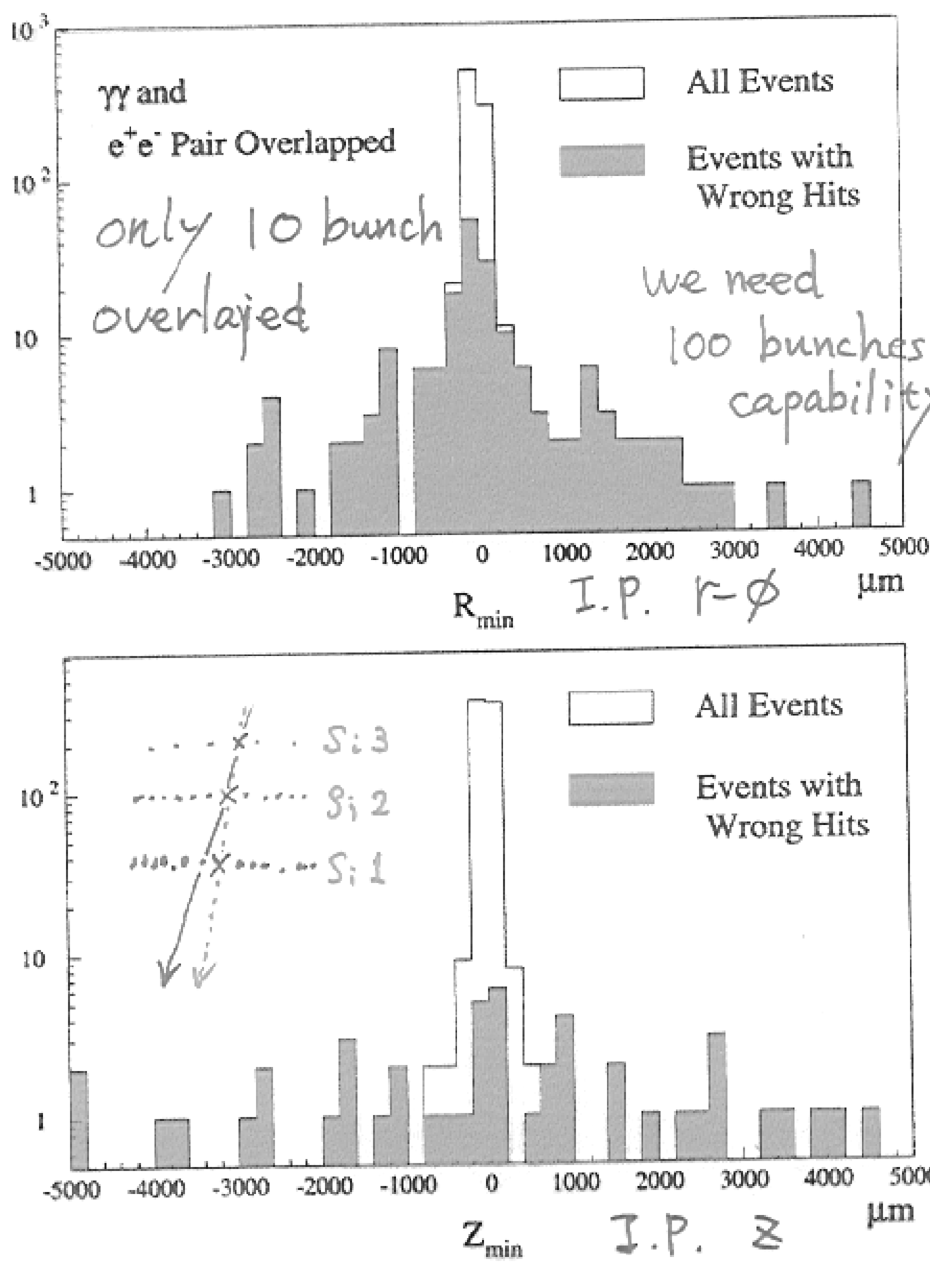


r=2.4cm

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

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

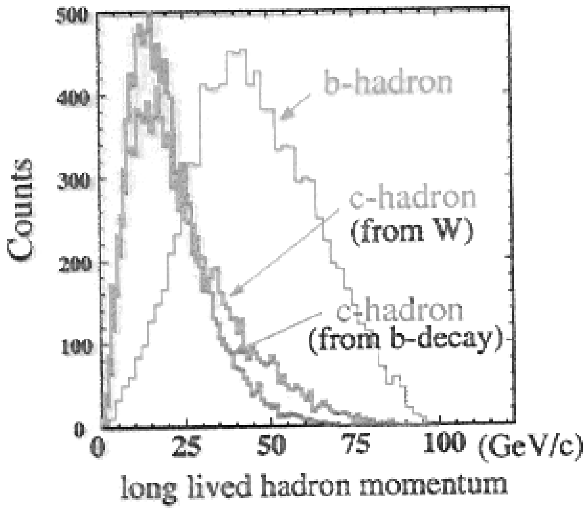
Reconstructed R_{min} and Z_{min} for 1 GeV/c μ



Several b related properties

Ecm = 250 GeV   Mh = 120 GeV

b/c hadron momentum spectrum for signal/WW



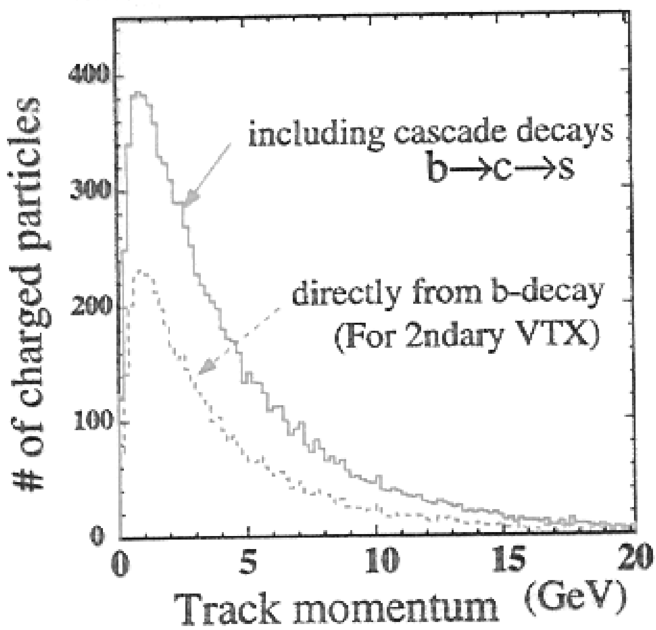
large boost (average $\gamma \sim 10$)

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

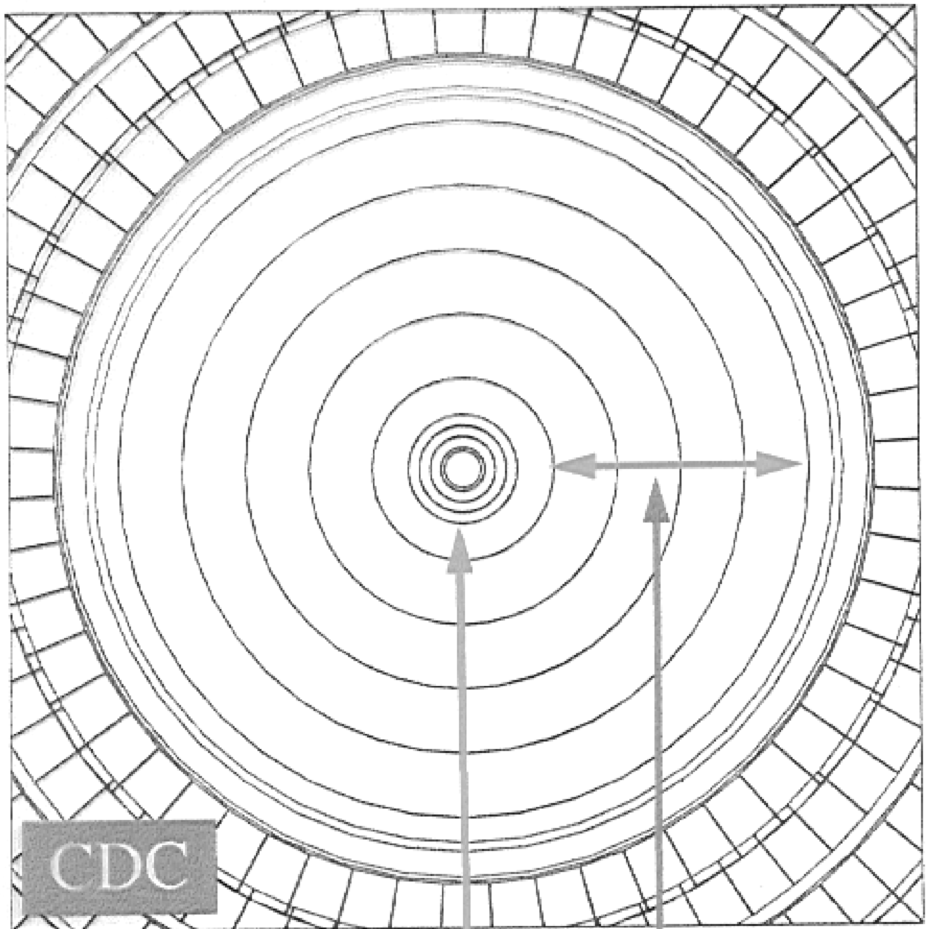


Due to many track sharing b-momentum

charged track momentum is in general low

Low momentum tracks are important

target : good reconstruction for P ~ 1 GeV/c



r = 450 - 2300 mm | z | < 2300 mm

$\sigma_{r\phi}$ ~ 100 μm σ_z ~ 1 - 3 mm

R&D results '98
$\sigma_{r\phi}$ ~ 85 μm with baby chamber
(JLC CDC subgroup)

5 Intermediate Tracker

r = 100-380 mm | cos θ | < 0.9

$\sigma_{r\phi}$ ~ 20 μm σ_z ~ 20 μm

300 μm thick Si x 5 layers

(assumption)

4 layer SiVTX (CCD)

r=24 - 60 mm | cos θ | < 0.9 300 μm thick x 4 layers

σ ~ 4 μm

beam test results at KEK '98.
σ = 3 μm (JLC VTX subgroup)

Single track muon p = 0.5-10 GeV cosθ ~ 0.8

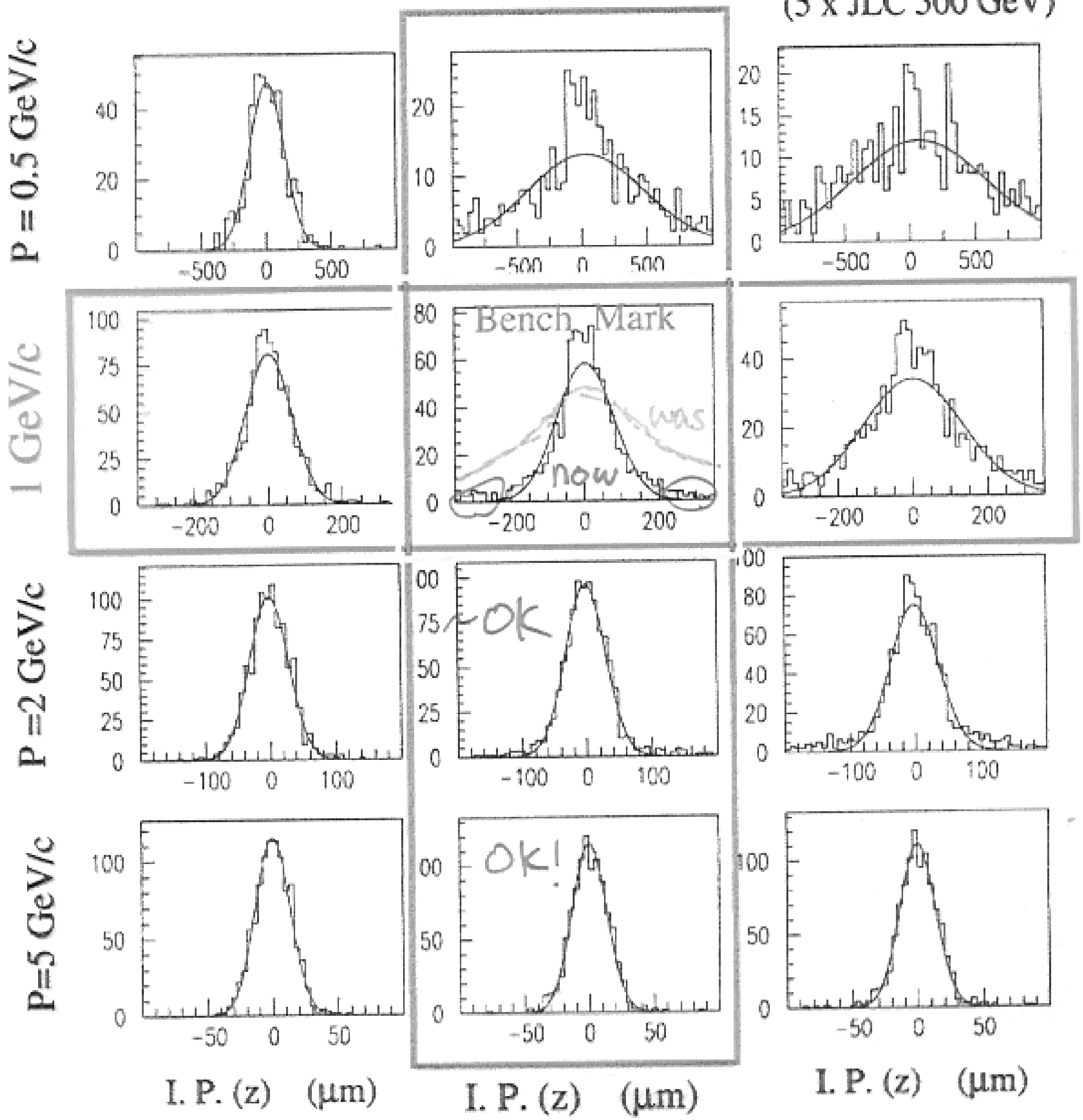
beam-beam interaction : ABEL program

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

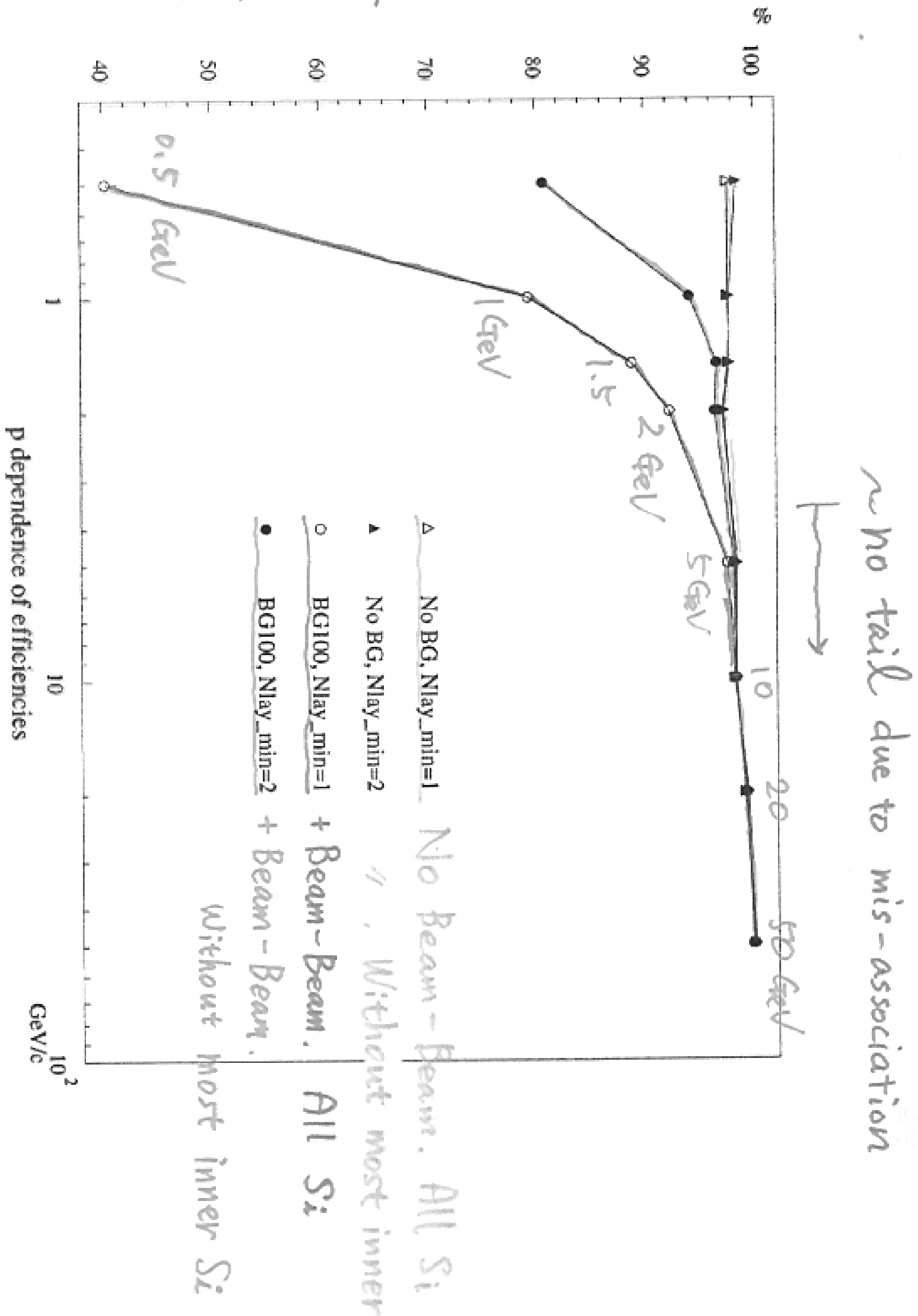
FULL DETECTOR SIMULATION (JIM)

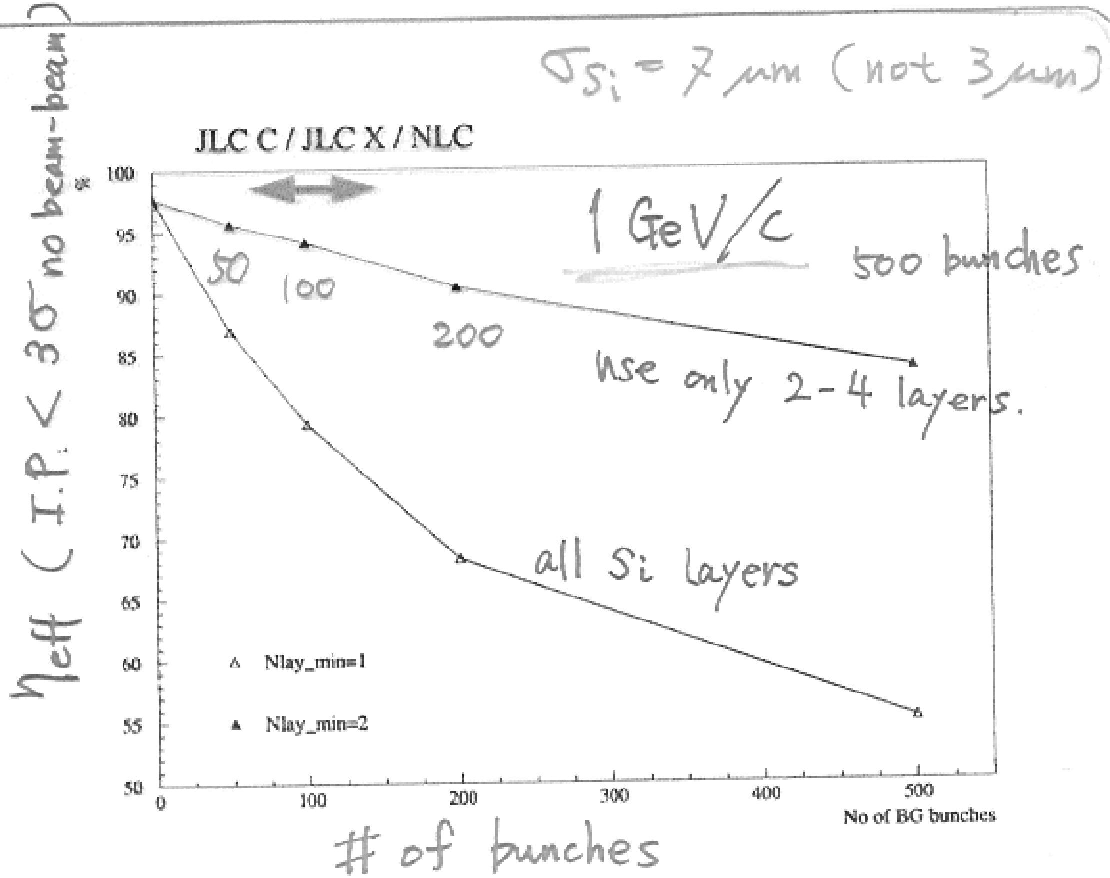
But using σ_{Si} = 7 μm (instead of 3 μm) for safety!

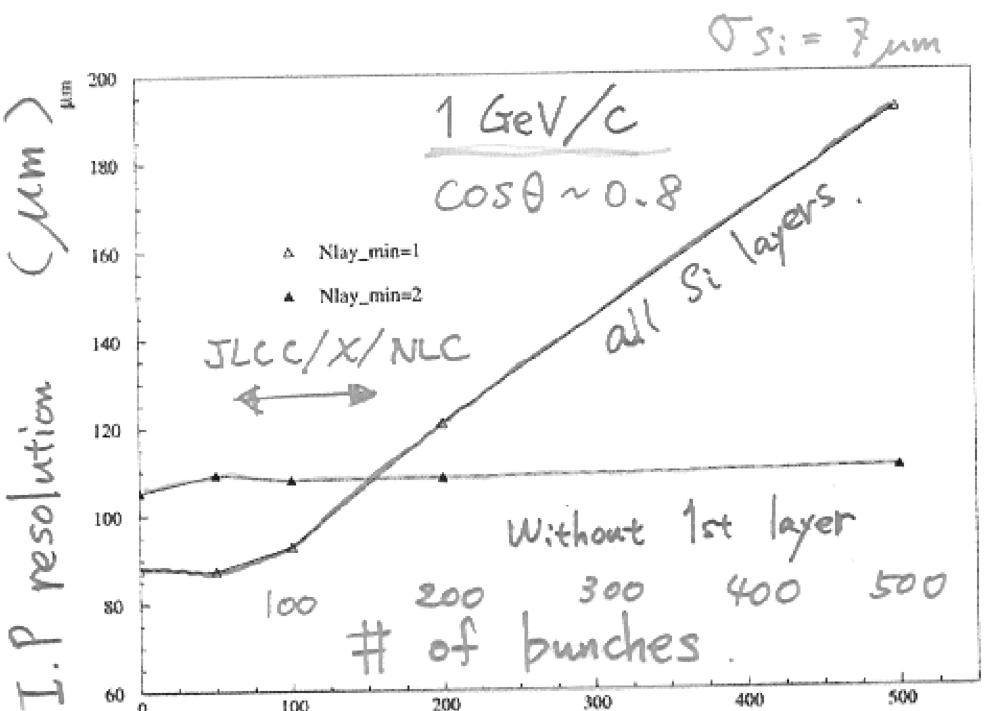
No beam-beam	100 bunch beam-beam ABEL beam-beam MC JLC (~1 hits/mm**2)	500 bunch beam-beam (5 x JLC 500 GeV)



η eff (Impact Parameter < 3σ no beam-beam)







BG dependence of $\sigma(R_{min})$ for 1 GeV/c muon

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 GeV/c the effect can be neglected.

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

To realize the good measurements expected by "smearing - type" Monte Calro simulation for Higgs,

we have a lot of room to improve

> Si first layer radius optimization
>
> eg. r = 2.4 cm → 3.0 cm
>
> \+ thickness 300 μm → 200 μm
>
> → 100 μm
>
> 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 siginificant rate, due to Huge "Luminosity per Bunch" (L_B)

LEP-II ~ 10^{-6} nb^{-1} / bunch
SLC ~ 10^{-5} nb^{-1} / bunch

JLC-C band / JLC-X / NLC / TESLA(low/high lumi)
Next LCs $L_B = 0.5 - 2 \times 10^{-3}$ nb^{-1} / bunch
(@ 500 GeV parameter)

3 order of magnitude higher than LEP !

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

example : 66 nb @ Ecm=500 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

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

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

Monte Carlo Study

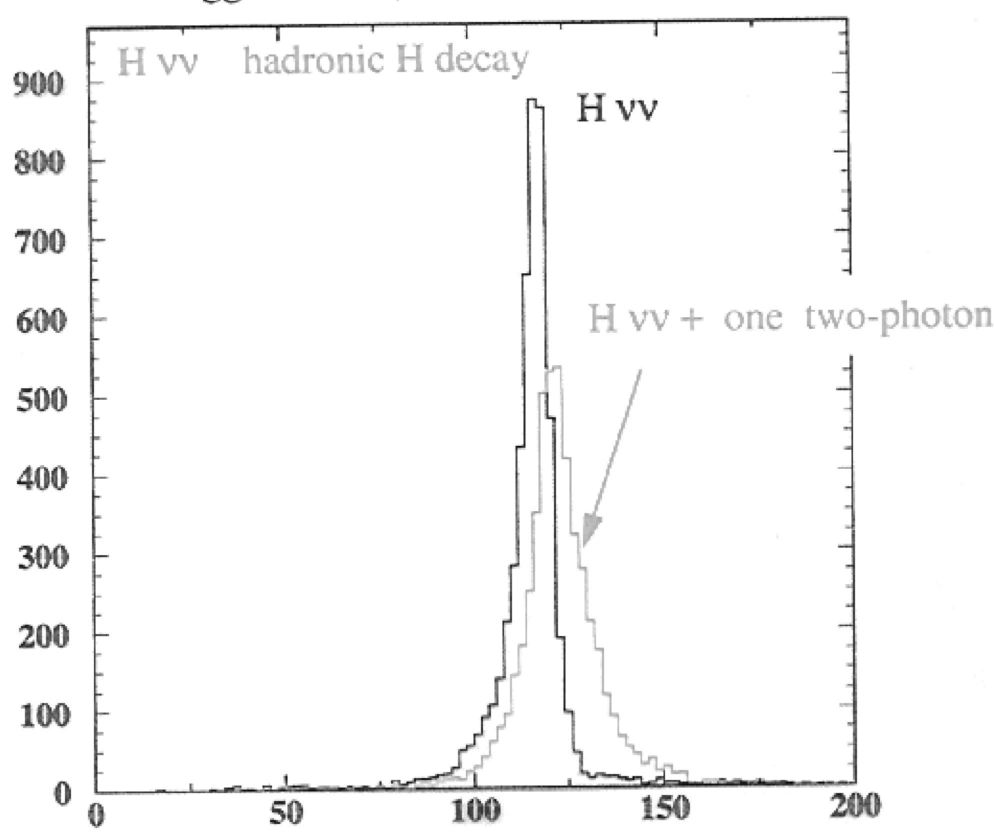
Higgs signal / bkg events (ff, WW, ZZ, Wev, Zee with Pythia)
with beam-strahlung Ecm smearing/tail

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

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

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-ϕ ?

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 ?

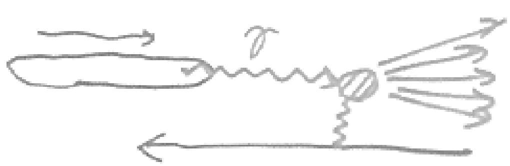
B) Two-photon cross-section depends on beam dinamics

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 $|\cos\theta|<0.95$

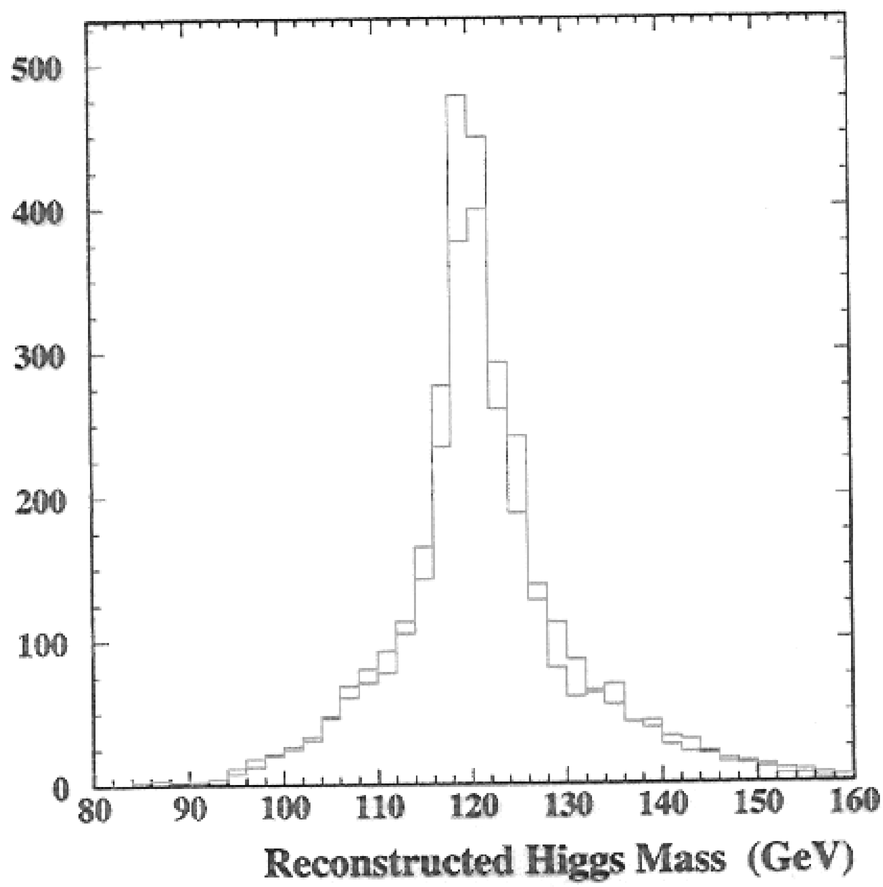
(VERMASEREN eeee ee$\mu\mu$ ee$\tau\tau$ + PHOJET)

Thanks to R. Nisius for VERMASEREN lecture

4 jet channel

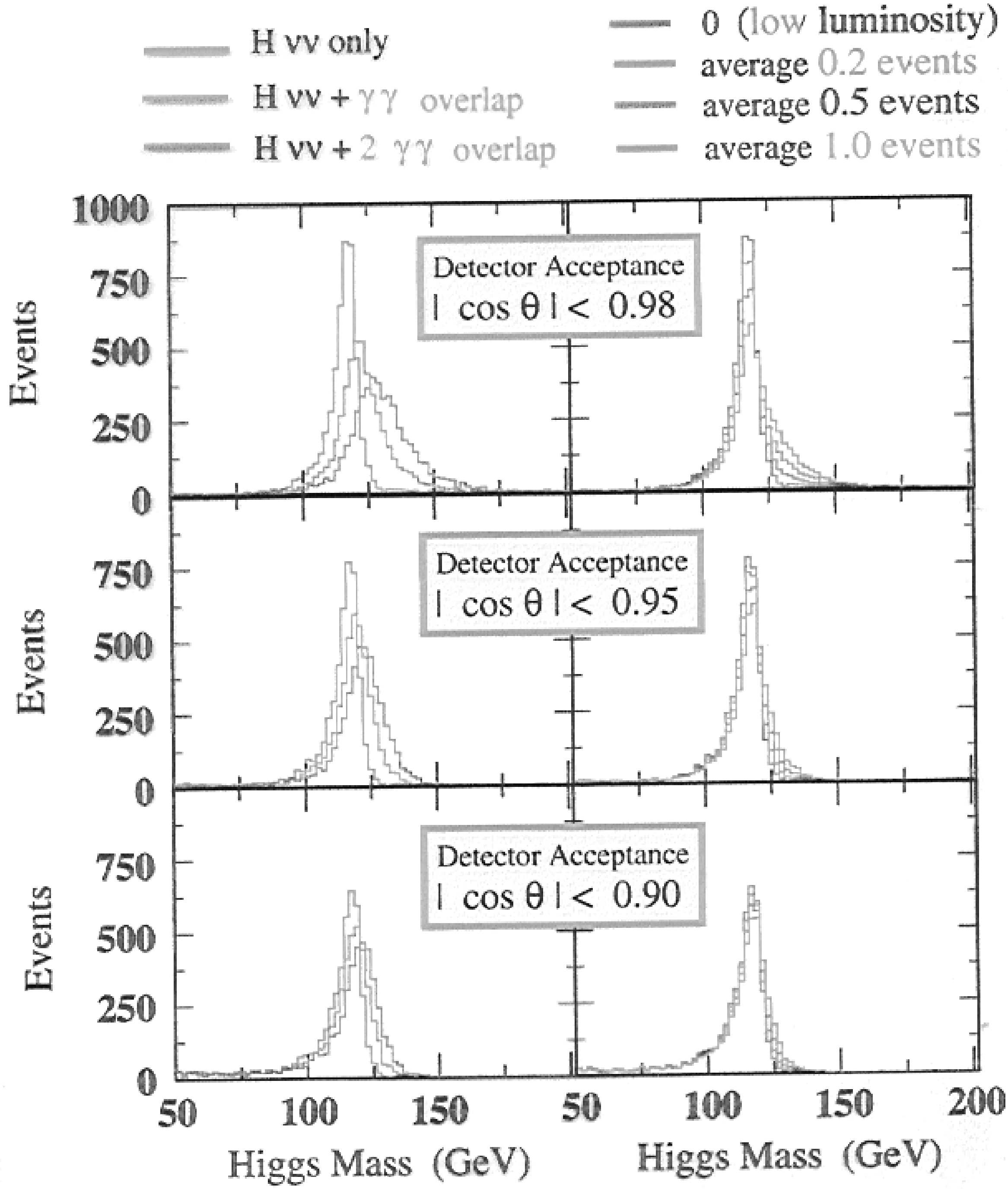
Mass relorution is relatively stable

if we apply beam constraints scaling



Background increased by ~30 % for bkg + mini-jet

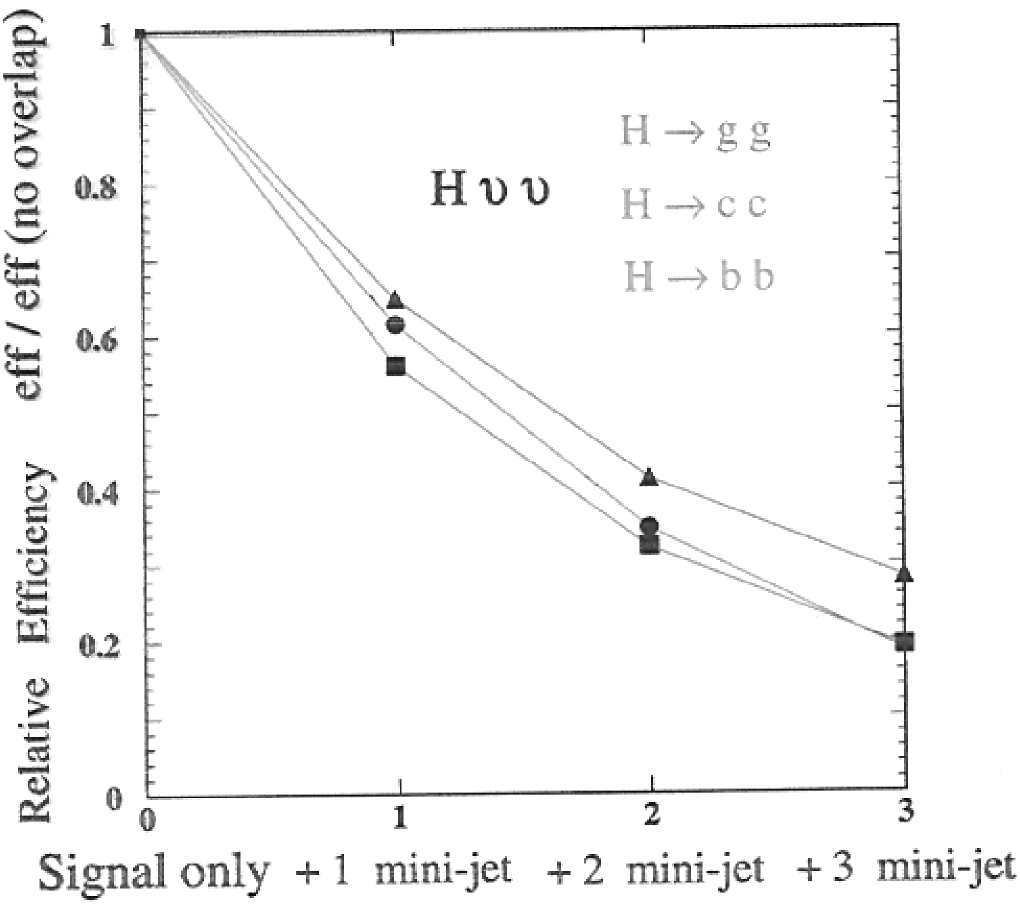
Hνν channel is very sensitive to the overlap



If we don't use forward region, small dependence on the rate. But eff ↘ bkg ↗

Effect on kinematic selection efficiency

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



Background level is almost same.

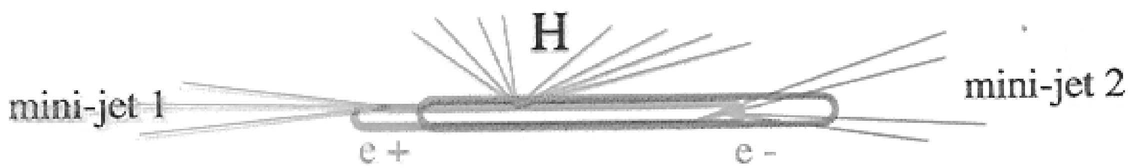
Wev increased rapidly, but still small.

Effect on the flavour tagging

Example for extreme case

Higgs (ννH) + 2 x mini-jet events

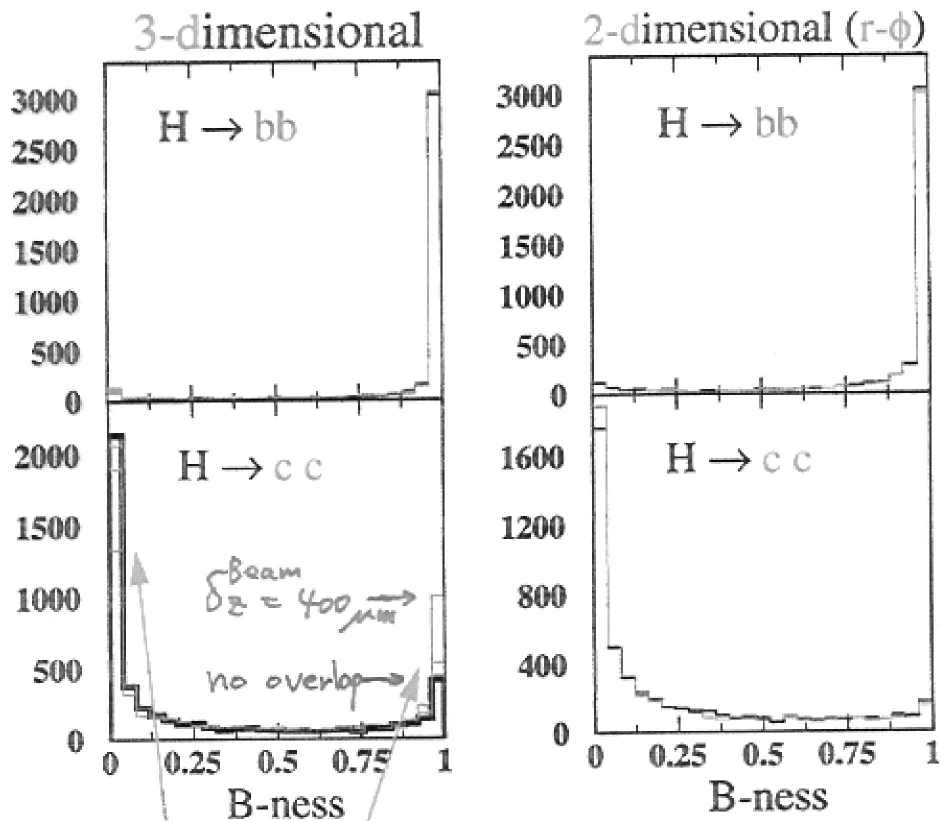
Check for different beam z-width (80 and 400 μm)



— overlap (σz beam = 0 : same pos)

— Higgs only — overlap (σz beam = 80 μm)

— overlap (σz beam = 400 μm)



b-c decay separation is sensitive to overlap rate.

No problem if overlap rate < 20 %

Insensitive to overlap rate

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

Note: Using only tracks in |cosθ| < 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 x 10^{-3} 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 controle 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 deterctor : (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 (scintilator, 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 ..)