Machine and Detector Performance Issues in the Light of Higgs Physics

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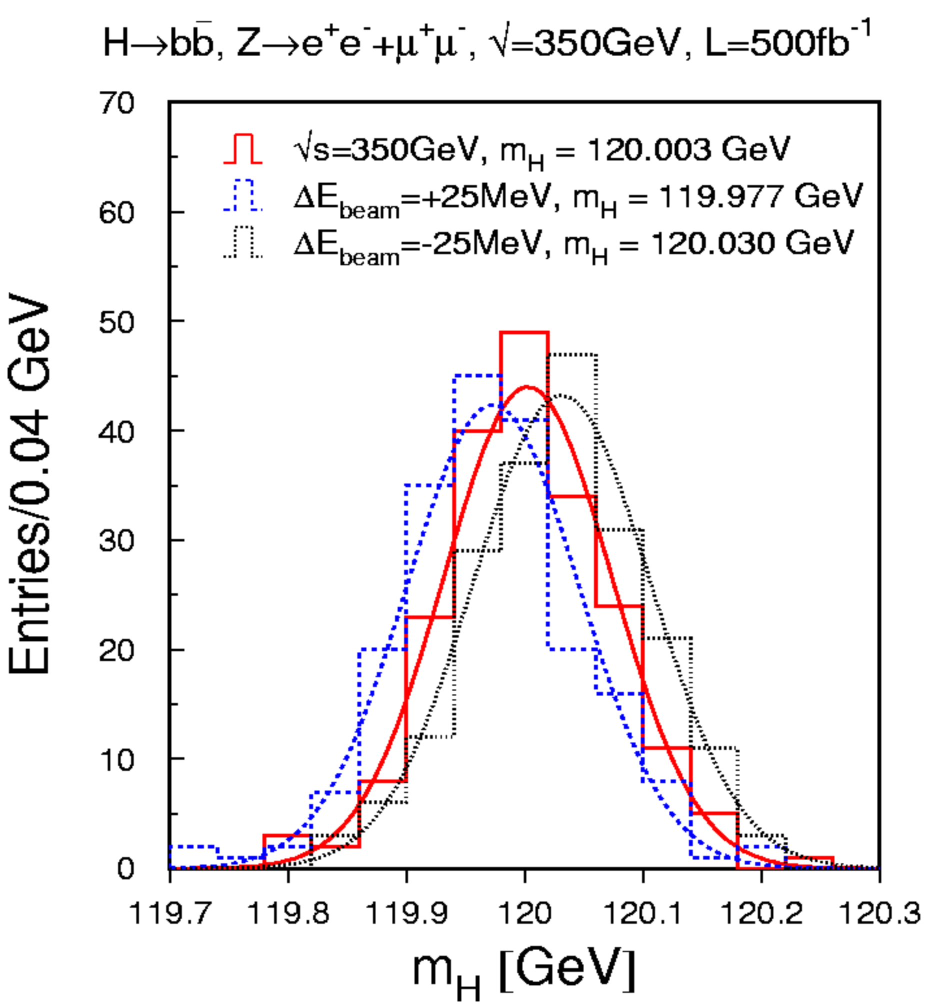
based on talks at parallel Higgs session by J.C. Brient, H. Heath, J. Ciborowski, A. Raspereza

Higgs Physics and Detector Optimization

- ILC Collaboration enters the phase of detector and machine optimization
- Expertise of people doing physics analyzes is desperately needed
- Need to map machine, detector and reconstruction software performance with precision of measurements in Higgs sector

Higgs vs. Machine Performance (Existing analyzes)

- Issue has been addressed by studies on Higgs mass measurements @ ILC
- One needs $dE_{beam}/E_{beam} < 10^{-4}$ to keep systematic error on Higgs mass below statistical uncertainty
- Beam spread (0.15% for e^- beam and 0.032% for e^+ beam as expected for cold machine) has negligible effect on Higgs boson mass measurement
- Luminosity spectrum can be determined from the analysis of Bhabha events with precision allowing to keep systematic uncertainty on Higgs mass well below statistical one



Jet Energy Resolution

the jet energy resolution

$$\Delta E_J = \mathbf{a} \times \sqrt{E_J} \oplus \mathbf{b} \times E_J + \mathbf{c}$$

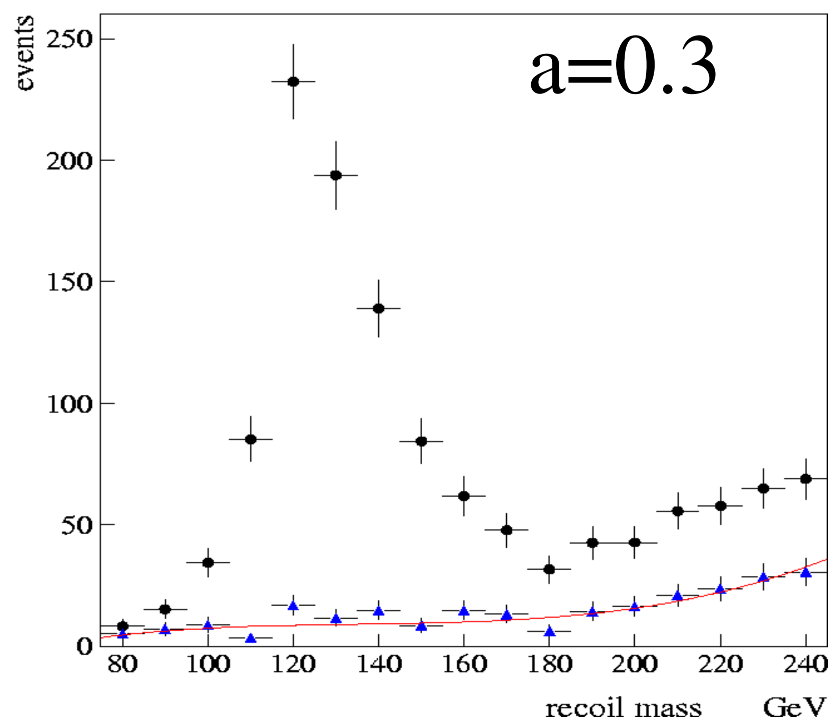
Many Higgs channels involve multijet final states
ZH=>4jets,
HHZ=>6jets,
HZ=>WWqq=>6jets)

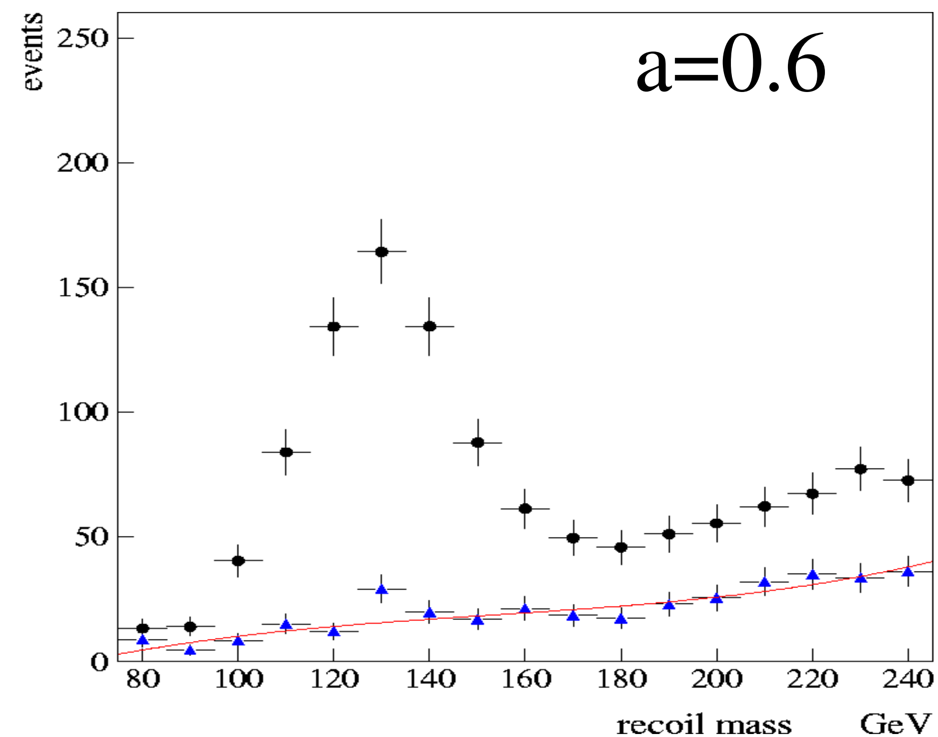
Jet energy resolution is crucial
=> Particle flow concept

	a	b	c (GeV)
ALEPH Method quasi PFA	0.59	0	0.6
ATLAS	0.6	0.03	0
H1	0.5	0.05	0
PFLOW-ILC	0.3	0	0.5

Higgs vs. Detector Performance (Existing analyzes)

- Impact of jet energy resolution on precision of B(H=>WW) is investigated by J.-C. Brient (LC Note LC-PHSM-2004-001)
- Investigated channel HZ=>WWjj=>lνjjjj





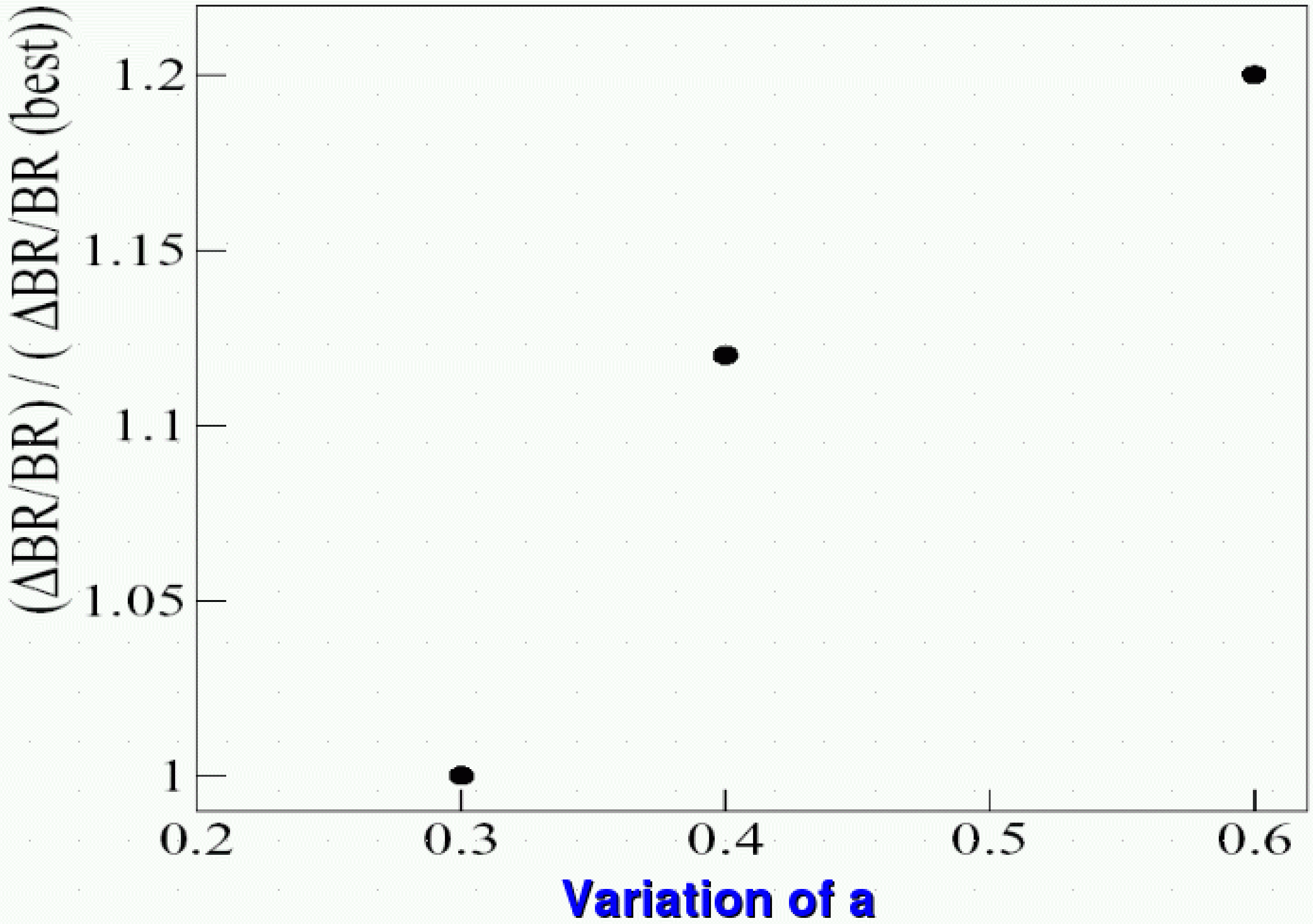
Signal-to-noise ratio considerably degrades with going from a=0.3 (goal for ILC) to a=0.6 (ALEPH)

Measurement : Higgs branching fraction ($H \rightarrow WW$)

Going from **a=0.3** to **a=0.6** is equivalent to **a loss of 45% of the luminosity** (running time)

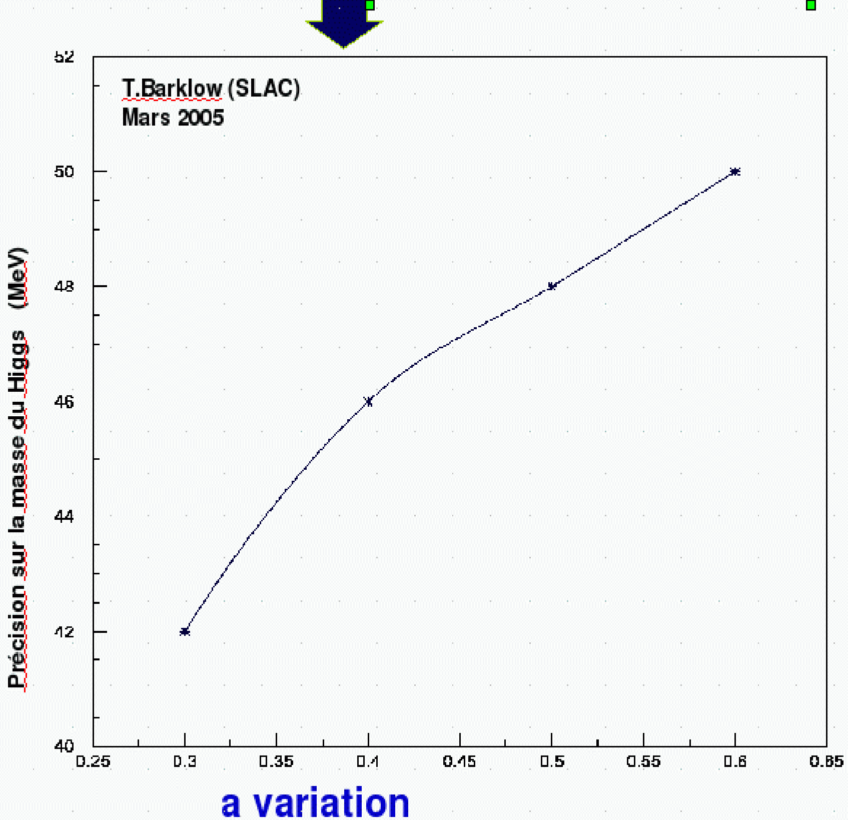
About 1 year every 3 years

1 year of running is about 120 M$



Measurement : Higgs mass (ZH in 4 jets)

Going from **a=0.3** to **a=0.6** is equivalent to **a loss of 45% of the luminosity** (running time)



Measurement : Higgs self coupling

Observation possible (signal at 5σ) **only for a=0.3**

From the TDR

Probably something to re-do now

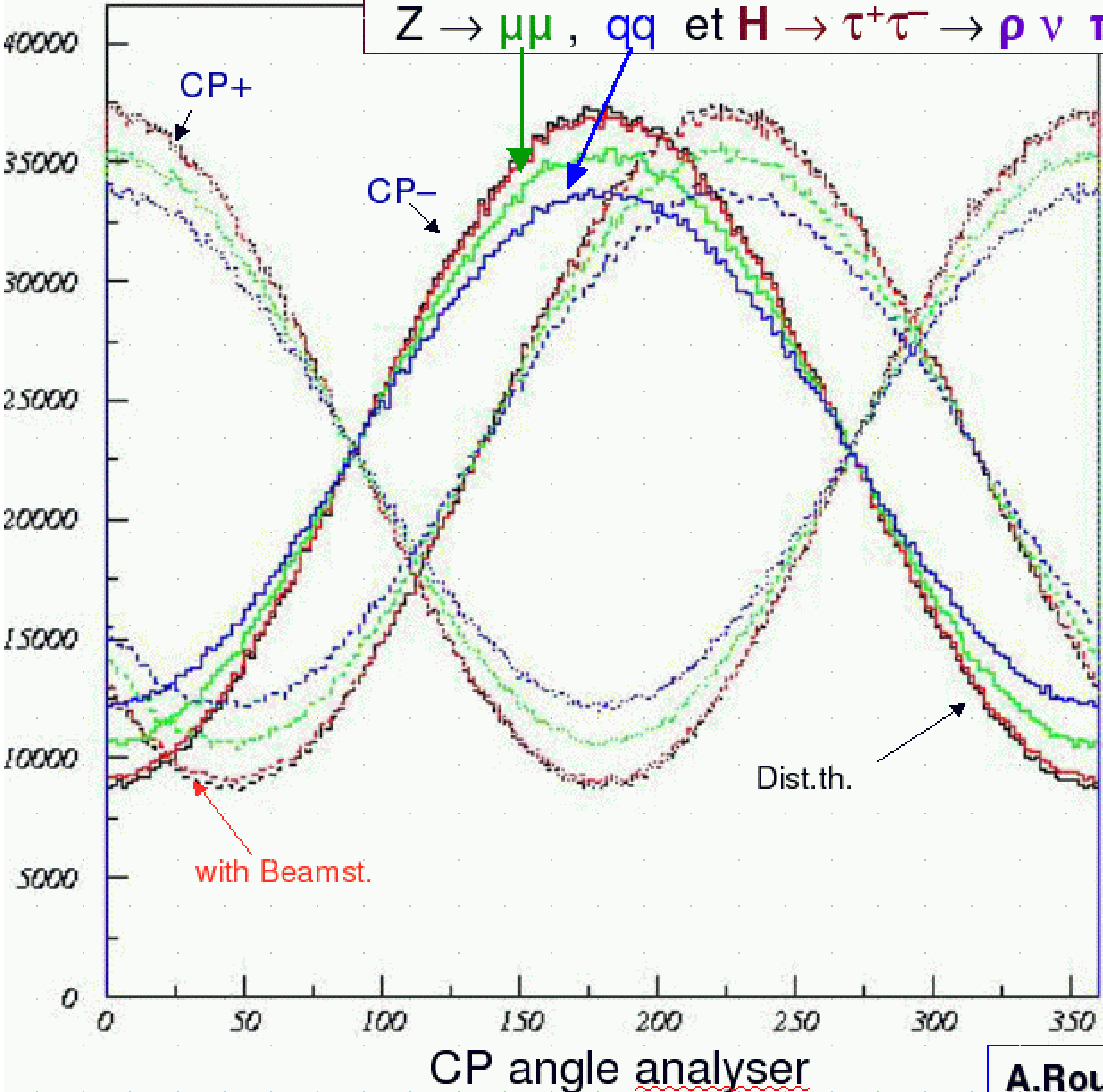
(TDR is only for 800 GeV and ZHH)

a = 0.3 seems justified

CP violation, Higgs sector

$e^+e^- \to ZH$

$Z \to \mu\mu$, qq et $H \to \tau^+\tau^- \to \rho\,\nu$ $\pi\,\nu$



Need
an ECAL which disentangles π, ρ, a_1 in the τ decays

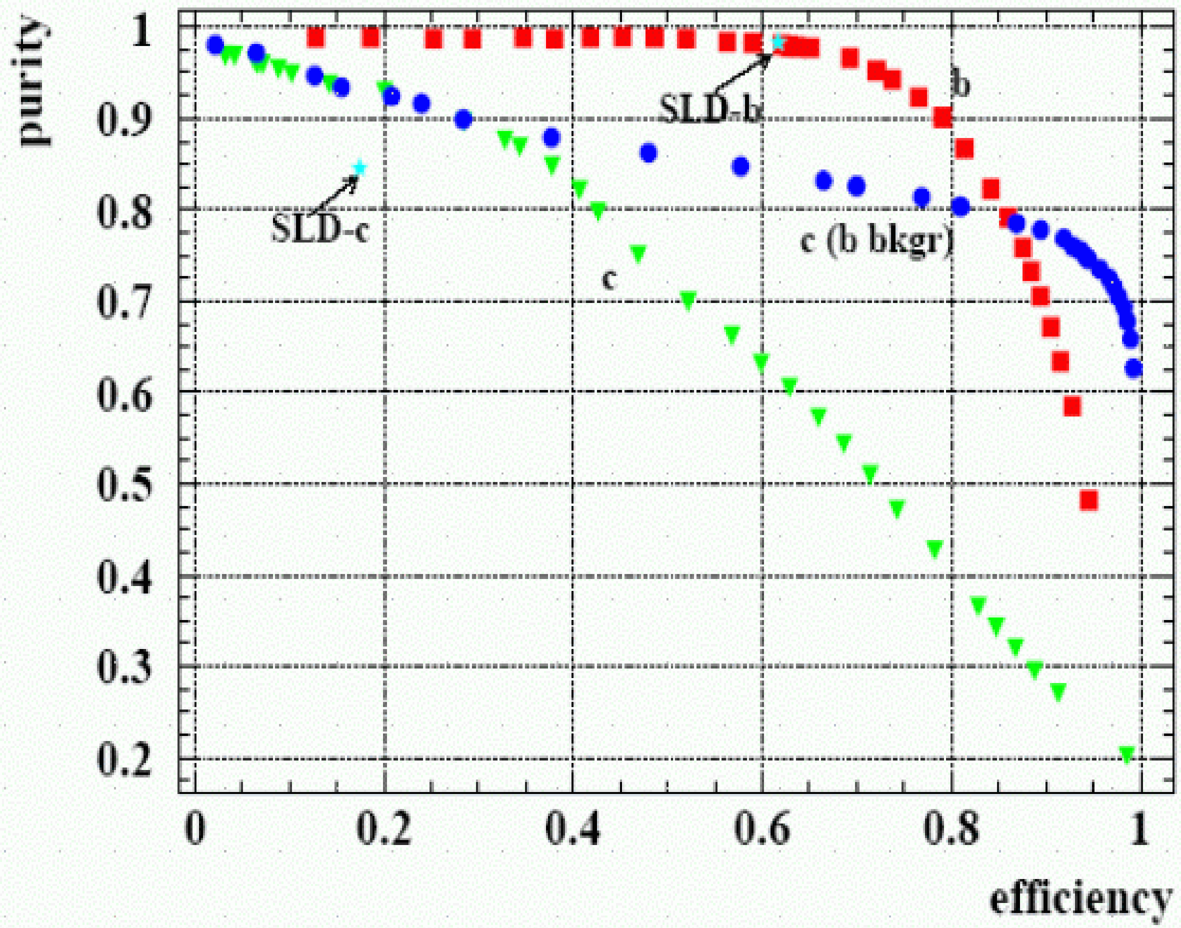
A.Rougé, Phys. Lett. B619 (2005), 43

Flavour Tagging

- e.g. $e^+e^- \to Z^0H^0 \quad H^0 \to cc \quad \sqrt{s}=0.35GeV$
  - Need to separate cc from bb background

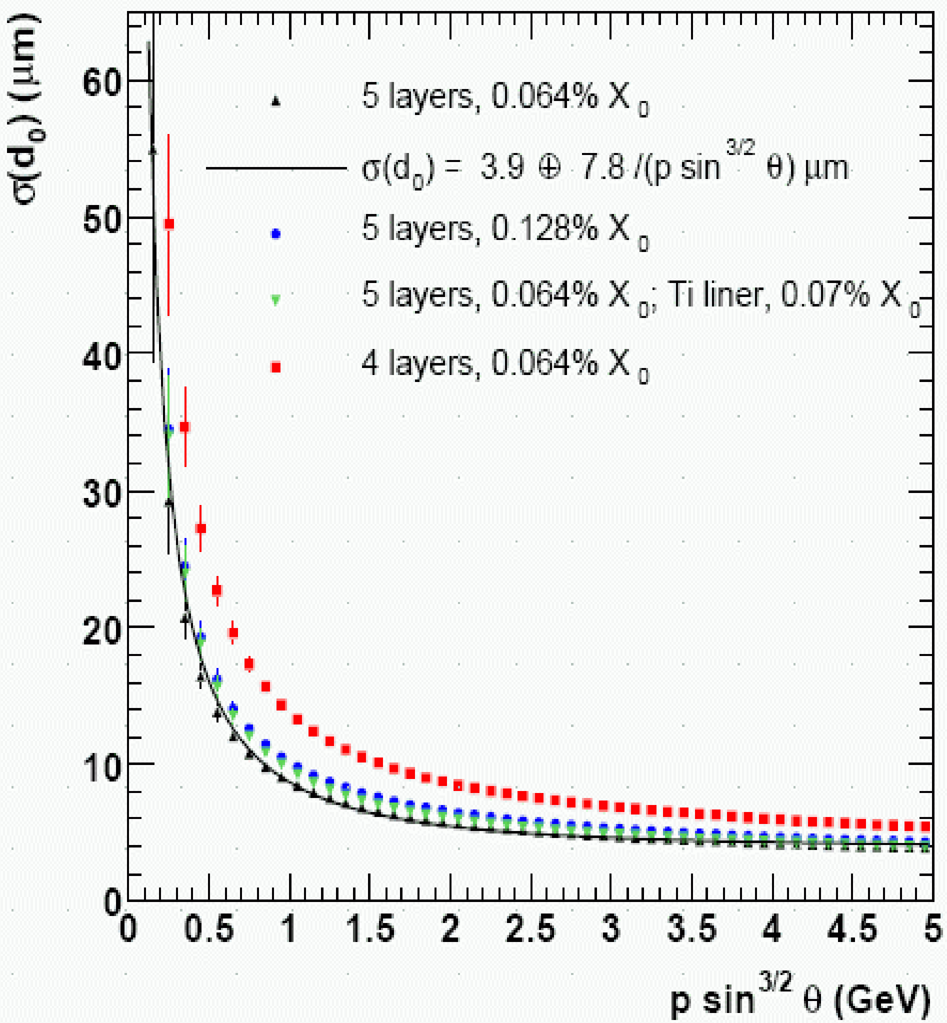
LCFI simulation using neural net

qq produced at Z^0 pole



Impact Parameters

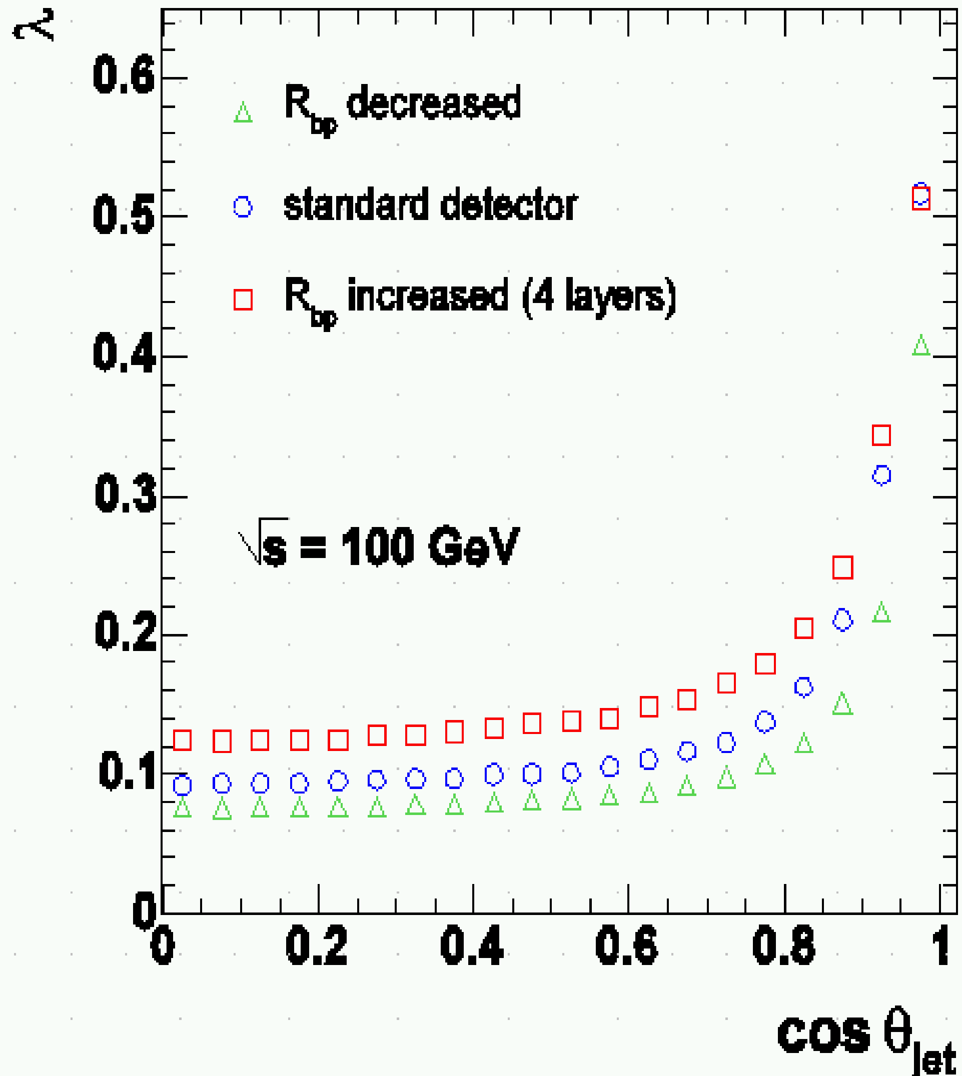
- e.g. $e^+e^- \rightarrow Z^0H^0$ $H^0 \rightarrow \tau\tau$ $\sqrt{s}$=0.35GeV
  - Large 1-prong branching ratio



Vertex Charge

- e.g. $e^+e^- \rightarrow Z^0H^0H^0$ $H^0 \rightarrow bb$
  - Reconstructed Vertex charge reconstruction reduces combinatorial background
  - (also gives information on angular correlations)

λ- leakage of bbar jets into b sample depends on beam pipe radius

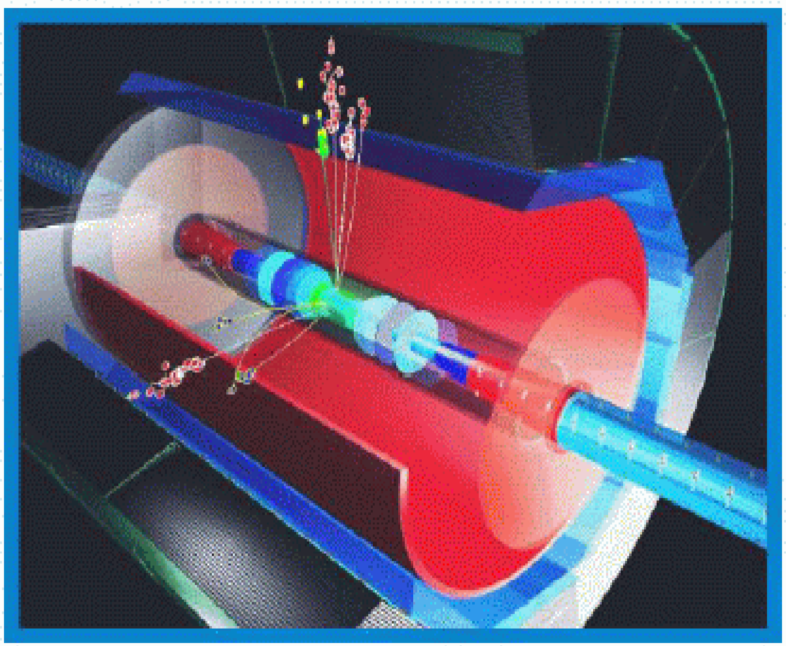


Machine Backgrounds

- Effects of Beam backgrounds need to be investigated
  - Small beam pipe/ inner layer close to IP
    - Improved vertex charge, impact param etc. ☺
    - Reduced multiple scattering (thinner BP) ☺
    - More decays after the first layer ☹
    - Inner VXD layer may get fried ☹
  - Needs full simulation
    - Backgrounds are detector specific

Study of VXD geometry for flavour tagging

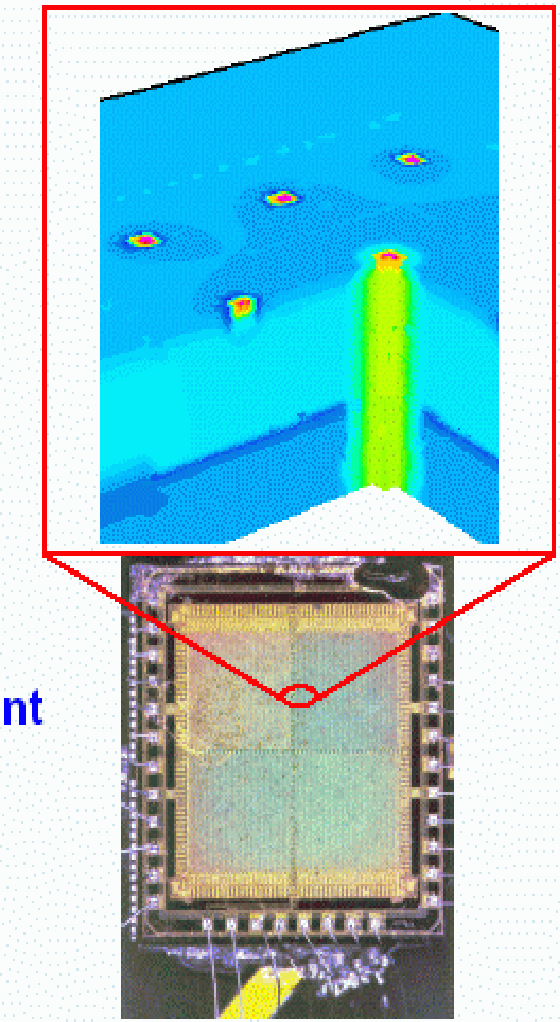
presented *) by
Jacek Ciborowski
Warsaw University
and
Lodz University



- $e^+e^- \rightarrow Zh,\ h \rightarrow$ **jets**
- Flavour tagging in presence of SM background

Results:

- Precision of b.r. measurement $\Gamma(h \rightarrow c\bar{c}), \Gamma(h \rightarrow b\bar{b})$ for different sets of VXD parameters



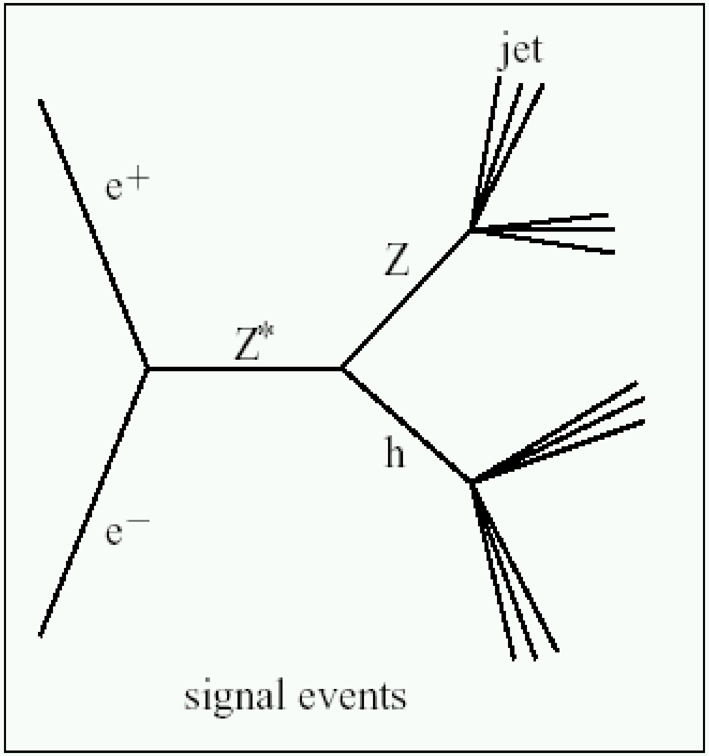
*) P. Łużniak (Lodz University), M. Adamus (Inst. Nucl. Studies, Warsaw)

Simulation

- **Event generator - PYTHIA :**
  Signal: $e^+e^- \to Zh \quad (h \to c\bar{c},\ h \to b\bar{b})$

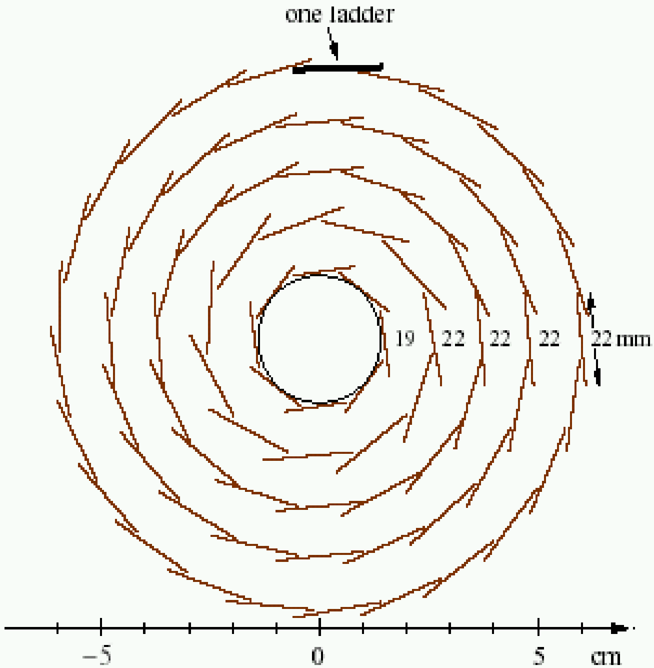
  - **SM:** M_h = 127 GeV
  - **MSSM:** M_A = 350 GeV,
    M_2 = 200 GeV,
    $A_{\tilde{f}}$ = 2450 GeV,
    M_h , Γ_h, b. r. from HDECAY
    M_h = 127 GeV

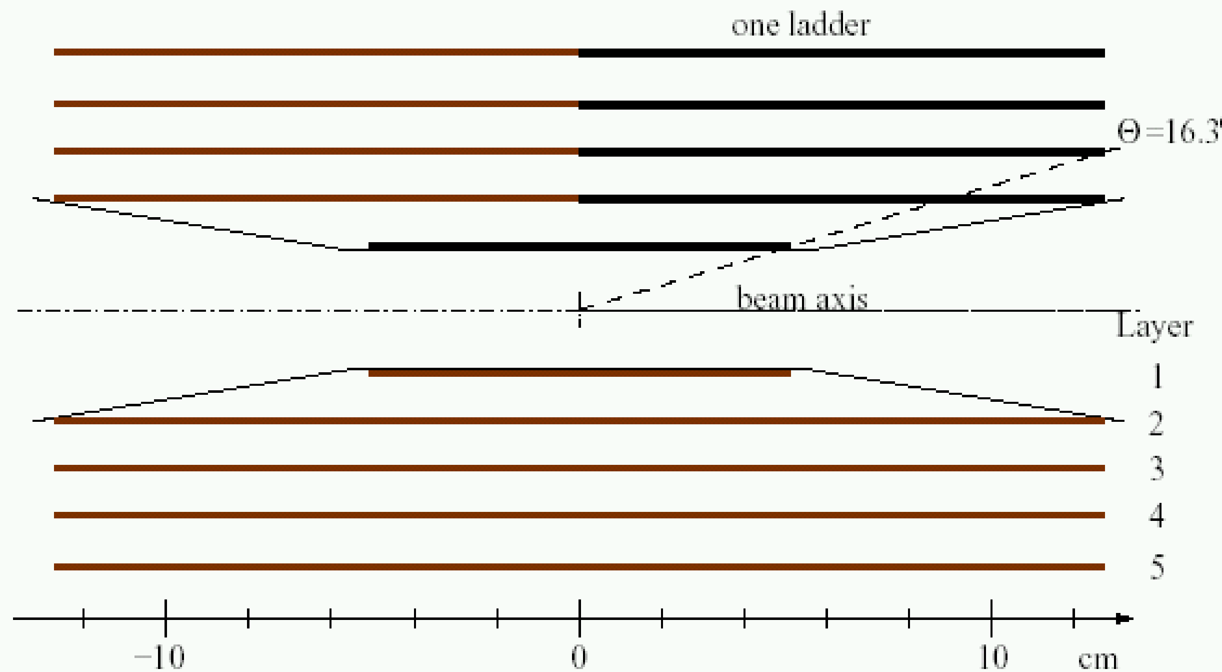
  Background: $e^+e^- \to W^+W^-$,
  $e^+e^- \to q\bar{q}$, $e^+e^- \to ZZ$, other higgs decays



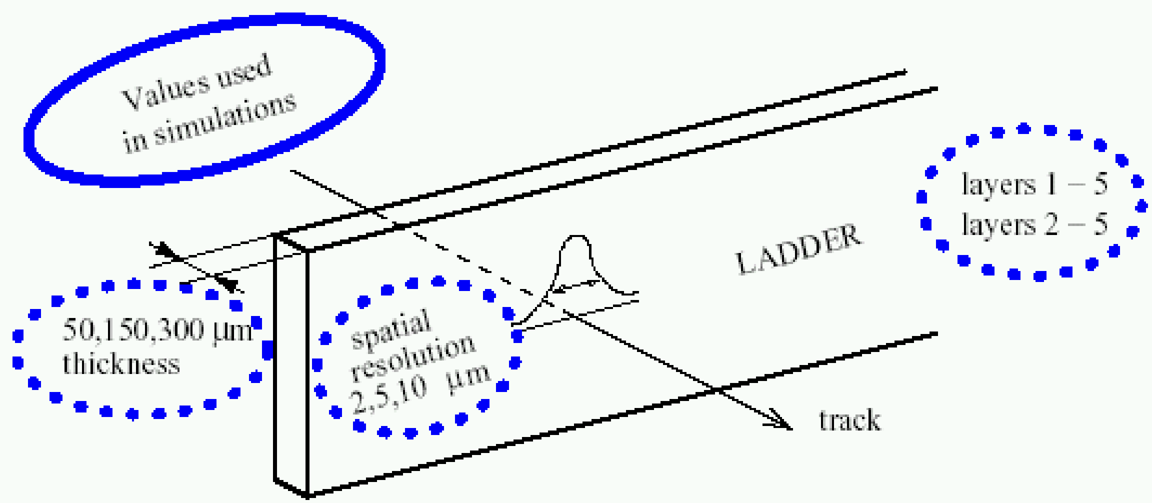
- Centre of mass energy 500 GeV
- Corresponding luminosity 500 fb^{-1}
- **Detector:**
  - Simulation à Grande Vitesse 2.30
  - The entire ILC detector as in TESLA TDR
  - Varying VXD parameters (long barrel)

Description of the VXD geometry

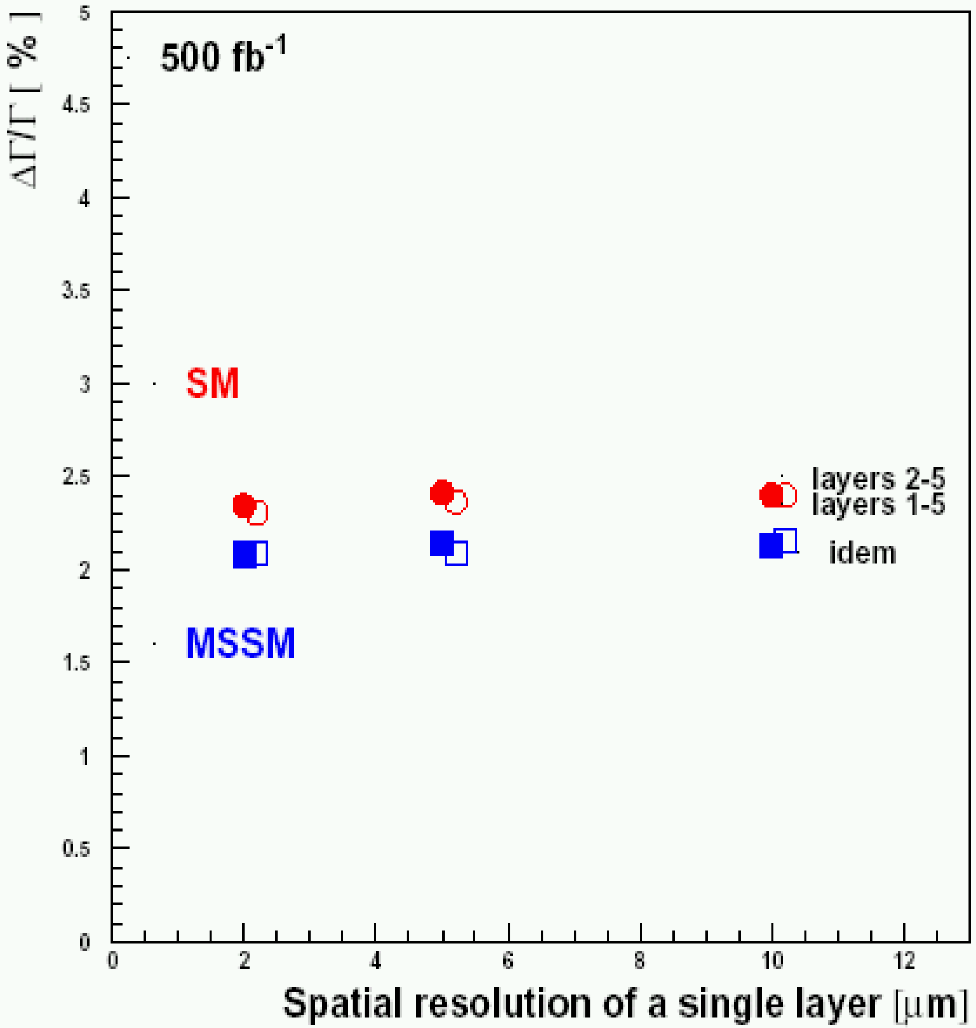




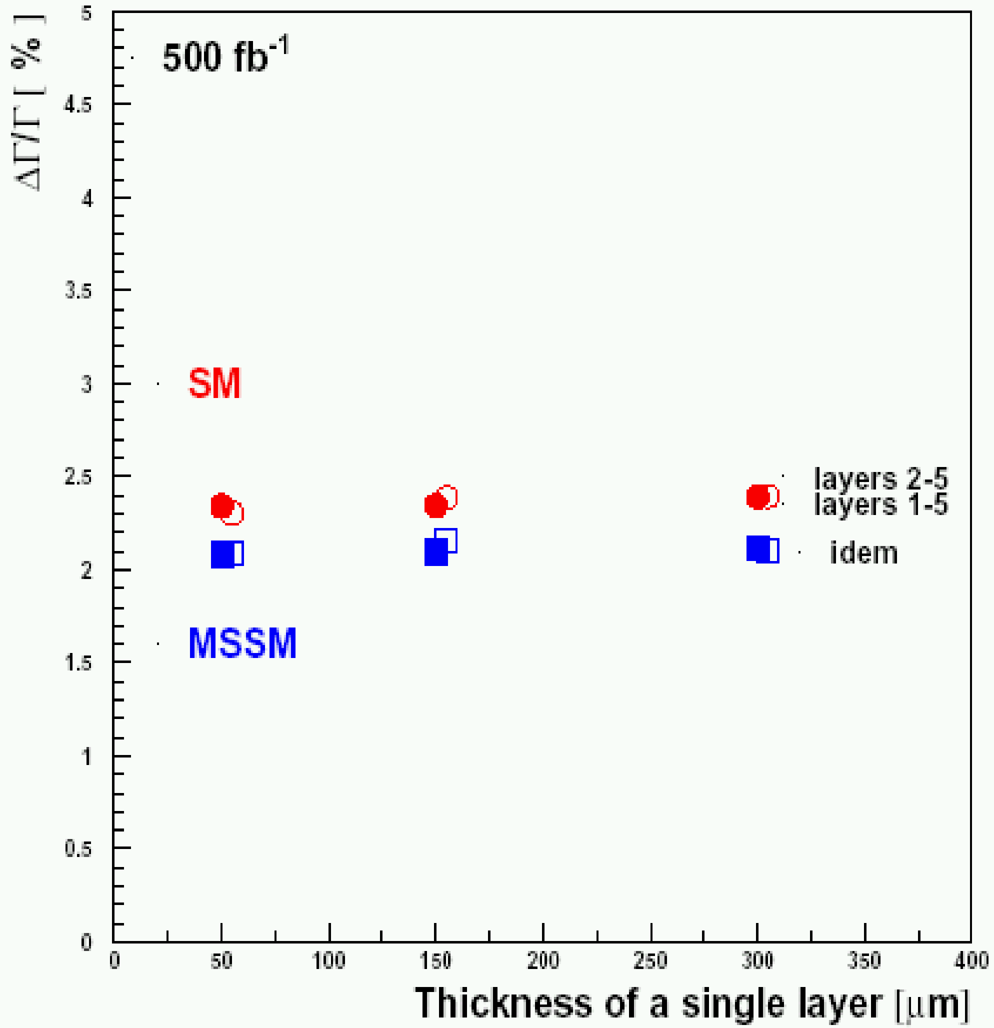
Layer	Radius	# ladders
1	15 mm	8
2	26 mm	22
3	37 mm	32
4	48 mm	40
5	60 mm	50



Precision of the b.r. measurement $\Gamma(h \to b\bar{b})$



layer thickness $50\mu m$



spatial resolution $2\mu m$

Conclusions

- Little impact of studied VXD parameters on $\Gamma(h \to b\bar{b})$
  Explanation:
  more signal than $h \to c\bar{c}$ (typical $\Delta\Gamma/\Gamma$ with b-tagging $\approx$ 2.3 %, without b-tagging $\approx$ 4 %), signal and background easier to separate (jets from background are less likely to mimic b - jets)
- For $h \to c\bar{c}$ strong dependence on:
  - spatial resolution
    $\approx 2\mu m$ has been achieved (e.g. MAPS)
  - layer thickness
    important to have as thin as possible
  - presence of the innermost layer

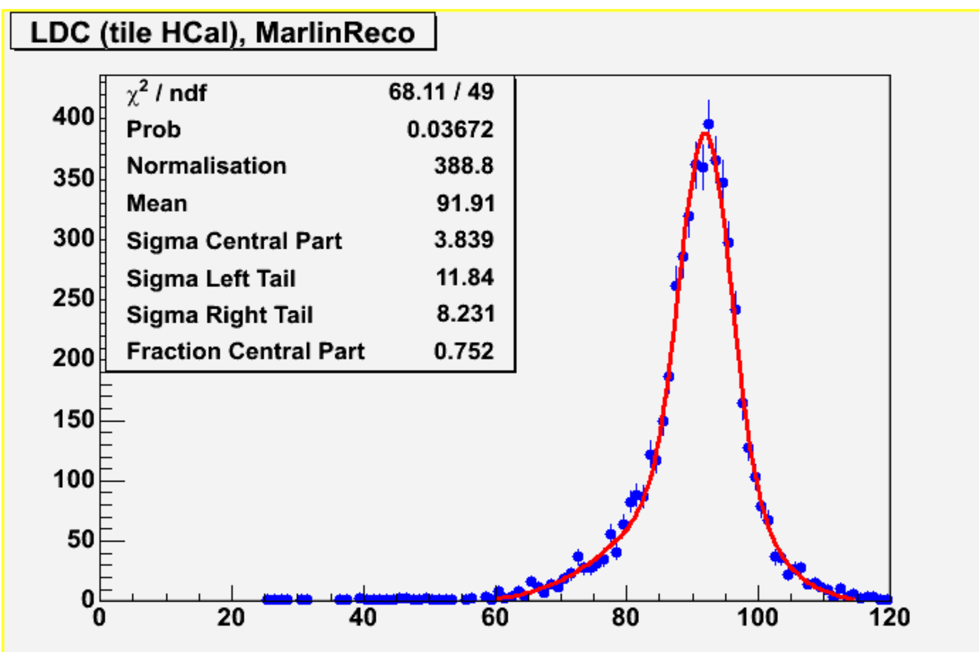
Comments on Existing Higgs Analyzes

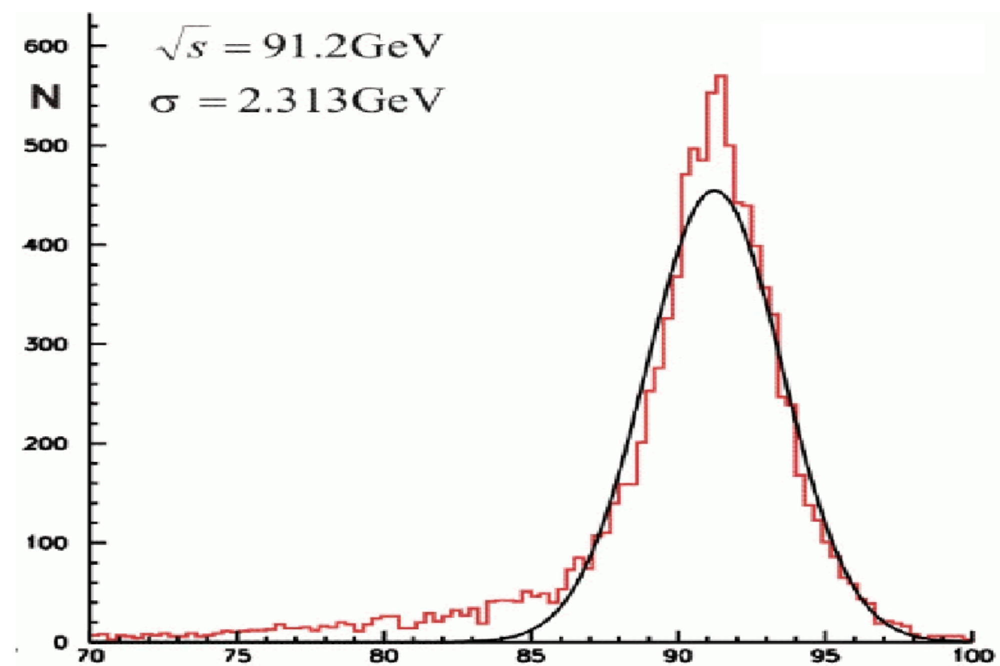
- All of the Higgs analyzes @ ILC have been done with fast MC simulators of detector response (Simdet, SGV, *etc*)
- Features of fast MC simulators
  - non-flexible; implement specific detector configuration (Simdet <=> TESLA detector)
  - smears momenta of final state particles according to resolutions anticipated for a given particle type
  - Example : TESLA detector <=> Simdet program
    - $dE/E = 11\%/\sqrt{E}$ for single photons (ECAL performance)
    - $dE/E = 50\%/\sqrt{E}$ for single neutral hadrons (ECAL + HCAL performance)
    - $dP_T/P_T = 7 \cdot 10^{-5} P_T$ for charged particles (Tracker performance)
  - detector resolution functions for various particle species and detector acceptance are obtained from MC studies with full Geant3/Geant4 based simulation on single particle samples
  - Most of fast MC simulators assume highly performant pattern recognition in the tracking system and calorimeters in multijet events ($dE_{jet}/E_{jet} = 25\%/\sqrt{E_{jet}}$ in Simdet)

Comments on Fast Monte Carlo

- Concerns:
  - Fast MC simulators with hardcoded detector resolution functions are not suitable for detector optimization studies.
  - Do fast simulators realistically emulate detector performance ?
  - Don't we overestimate physics potential of LC ?
- Example Z0=>hadrons events @ Z pole
  - Full simulation + reconstruction

SIMDET





Tools Available on the Market

- Until recently no tools were available to address this issue
  - Absence of dedicated reconstruction tools
  - Absence of flexible detector simulation tools allowing to modify detector geometry
- Situation changed. Now we have :
  - Detector simulators implementing in a flexible way various detector geometries (Mokka with scalable detector models, SLIC, Jupiter)
  - Dedicated reconstruction algorithms (org.lcsim, MarlinReco)
  - flexible fast MC programs, allowing to specify detector resolutions for various types of particles and fudicial cuts, reflecting detector acceptance (see talks by N.Graf and T.Barklow)

Strategy to Address Higgs vs. Detector Performance Issues

- Using flexible fast MC simulators
  - New Detector Configuration => dedicated studies with full G4 based program => new deduced resolution functions => appropriate parameterization in fast MC (resolutions for single particles, particle ID efficiencies, flavour-tagging performance)=> run fast MC => do Higgs analysis => report results to detector experts
  - fast but probably needs verification with full simulation and realistic reconstruction

Strategy of Addressing Higgs vs. Detector Issues

- Using full G4 based simulation and realistic reconstruction tools
  - Generate hepevt / stdhep files for your favorite process => feed these files to G4 based simulation program => LCIO files with raw information => feed this files event reconstruction software => LCIO file with reconstructed objects => do analysis on these files => report your results to detector experts
  - time-consuming procedure
  - a more conservative evaluation of ILC physics potential (present reconstruction software needs further optimization)
  - provides estimate of reconstruction software performance
  - emulation of perfect reconstruction is possible (Track and Cluster cheating => perfect particle reconstruction and ID)

Summary

- Detector performance can and should be benchmarked by Higgs analyzes
- Need to map performance of various detector components with precision of measurements in the Higgs sector
  - required jet energy resolution
  - required track momentum resolution
  - flavor-tagging performance
  - ...
- A lot of software tools became recently available on the market; these tools can be used to establish mapping between detector performance and precision of measurements in Higgs sector