Higgs Measurement @ JLC

LCWS99, Sitges, April 28 – March 5

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JSPS /

Introduction

$h^0 \to b\bar{b}$, $c\bar{c}$ and gg

$$\frac{Br(h^0 \to c\bar{c} + gg)}{Br(h^0 \to b\bar{b})} \propto \frac{1}{\tan^2\alpha \tan^2\beta} \approx \left(\frac{m^2_{A^0} - m^2_{h^0}}{m^2_{A^0} - m^2_{Z^0}}\right)^2$$

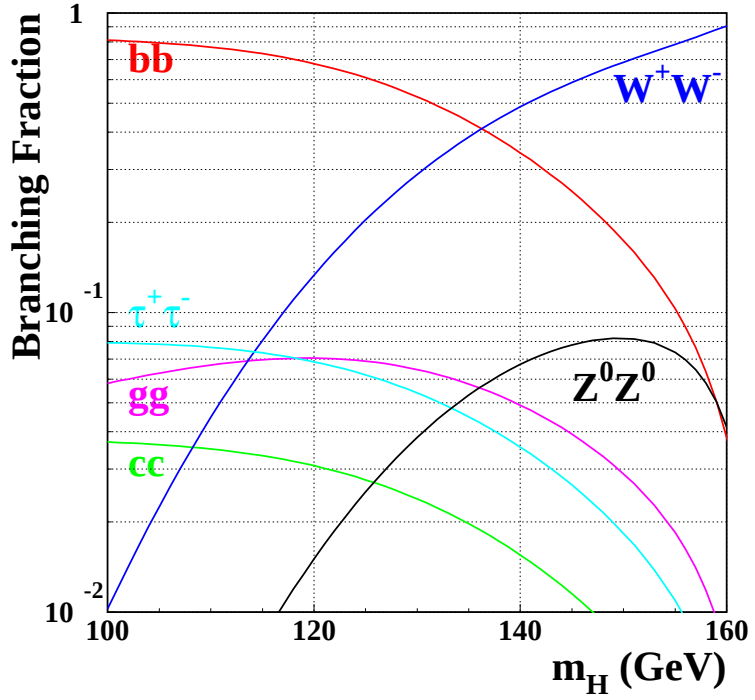
m_{A^0} can be estimated almost independently of m_{SUSY}
→J.Kamoshita et al. Phys. Lett. B391 124(1997): **LCWS95**

$h^0 \to W\ W$

$\Gamma(h^0 \to all)$ can be measured from $Br(h^0 \to WW)$

$$\Gamma(h^0 \to all) = \frac{\Gamma(H^0_{SM} \to WW) \cdot \sin^2(\beta - \alpha)}{Br(h^0 \to WW)}$$

Branching Fraction of H^0_{SM}



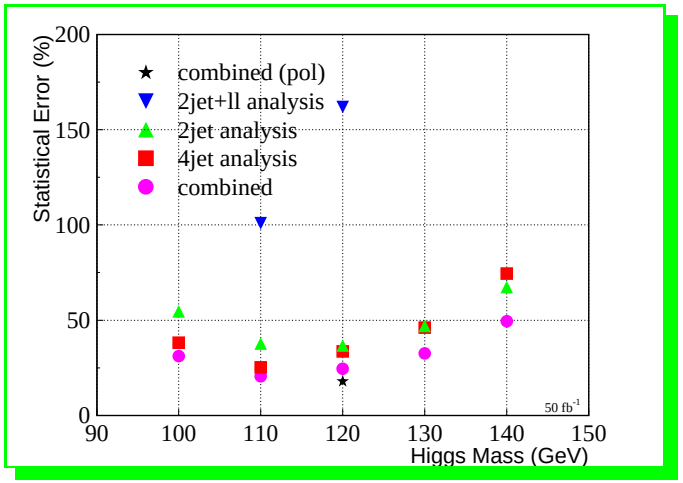
Introduction

Several studies for measurement of Higgs Properties were presented until the last LCWS

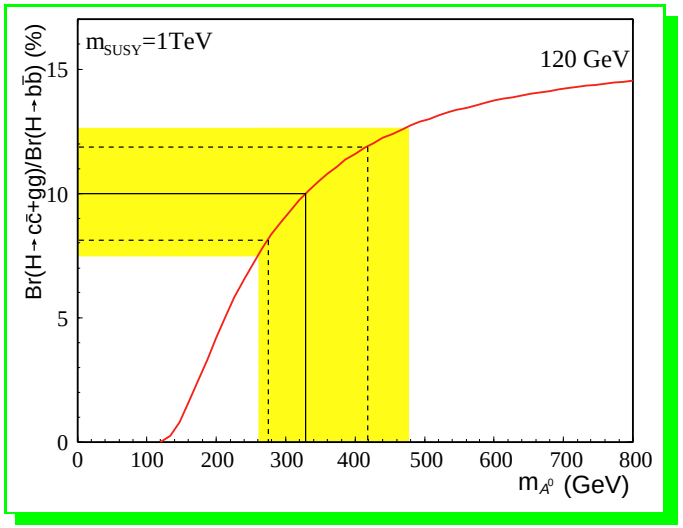
- JLC-I Report, KEK report No. 92-16 1992
- M.D. Hildreth et al., Physical Rev. D49, 3441(1994): **LCWS93**
- I.Nakamura, K.Kawagoe, Physical Rev. D54 3634(1996): **LCWS95**

- Update everything with:
  - ◇ **new** detector parameter
  - ◇ **new** b-tagging technique
  - ◇ **new** kinematic selection
- **Br($h^0 \to WW$)** with semileptonic decay

Br($h^0 \to c\bar{c}+gg$)/Br($h^0 \to b\bar{b}$)



Br($h^0 \to c\bar{c}+gg$)/Br($h^0 \to b\bar{b}$) vs m_{A^0}



I.Nakamura, K.Kawagoe LCWS95

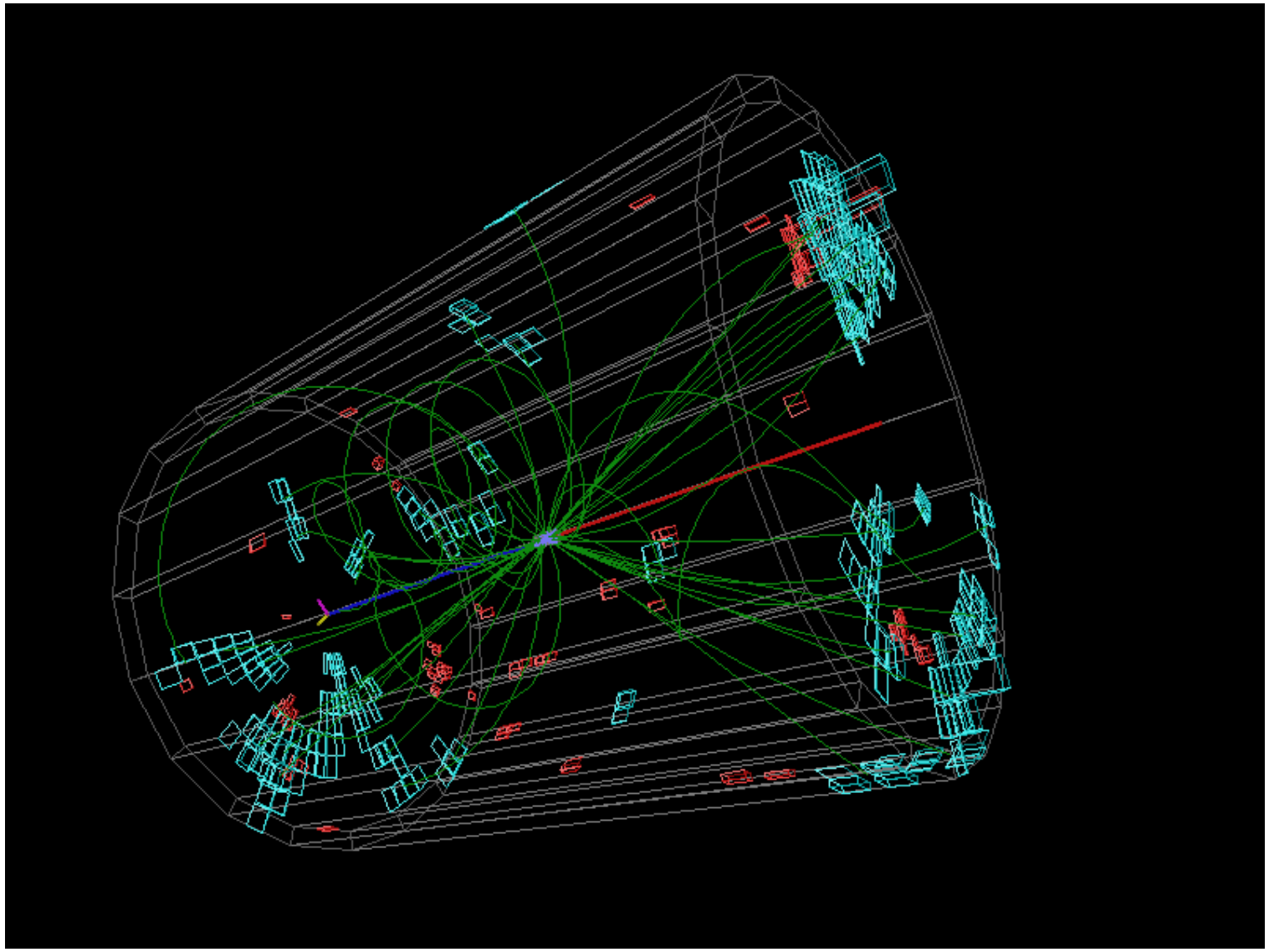
Simulation

- JSF Quick Simulator
  → K.Kawagoe's Talk
- Standard JLC Model Detector (**LCWS93**)
  + **New** VX Detector configuration
- $\sqrt{s}$ =300 GeV to avoid $t\bar{t}$ background
- Integrated Luminosity of 100 fb^{-1}
- 120 GeV Higgs as input
- No beamstrahlung
  → Following I.Ueda's Talk
- HZHA for cross-section
- HDECAY for Higgs Branching Fraction
- PYTHIA for Background

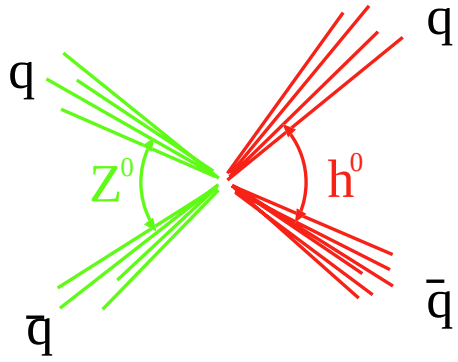
Cross-section, Branching Fraction and # Events expected for 100 fb^{-1}

channel	σ_{SM}(pb) / Br	#Event
$e^+e \rightarrow Z^0h^0$	0.183	**18,300**
$h^0 \rightarrow b\bar{b}$	67.8	12,407
$h^0 \rightarrow c\bar{c}$	3.08	564
$h^0 \rightarrow gg$	7.04	1,288
$h^0 \rightarrow \tau^+\tau$	6.85	1,254
$h^0 \rightarrow W^+W$	13.3	2,434
$e^+e \rightarrow q\bar{q}(\gamma)$	31.7	3.2 M
$e^+e \rightarrow W^+W$	13.2	1.3 M
$e^+e \rightarrow Z^0Z^0$	1.03	103 k
$e^+e \rightarrow e\nu W$	2.26	206 k
$e^+e \rightarrow e^+e\ Z^0$	3.81	381 k

JSF Quick Simulator Event Display



Event Selection (qqh^0 channel)

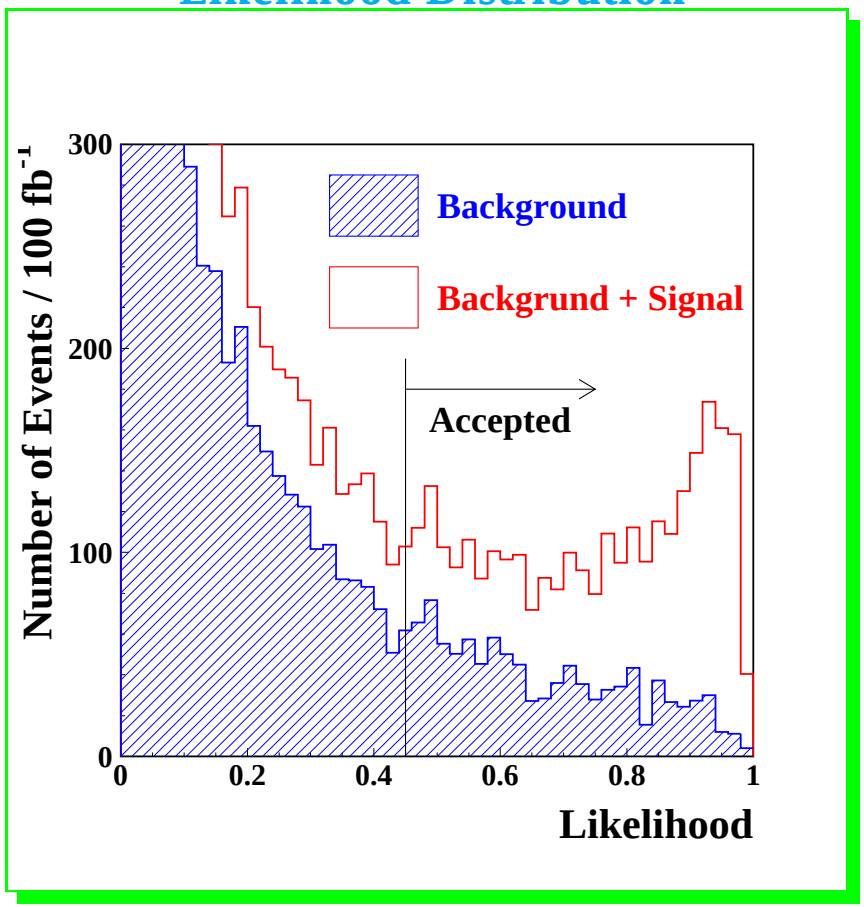


- Four-Jets topology
- Force four jets with Durham algorithm
- Selecting Jet pair with minimum χ^2

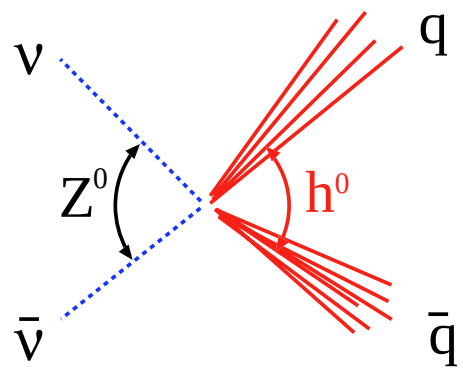
$$\chi^2 = \left(\frac{m_{ij} - m_{Z^0}}{\sigma_{m_{\text{jet}}}}\right)^2 + \left(\frac{m_{kl} - m_{h^0}}{\sigma_{m_{\text{jet}}}}\right)^2$$

- Likelihood with several kinematic variables
- Background from $q\bar{q}$, W^+W^-, Z^0Z^0

Likelihood Distribution



Event Selection ($\nu\nu h^0$ channel)

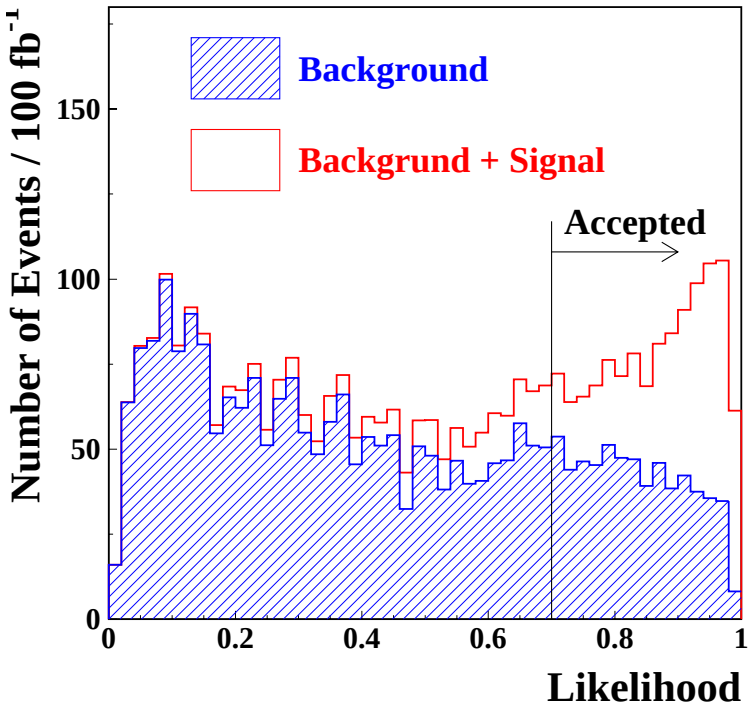


- Two acoplaner jets
- Calculate mass difference variable χ^2

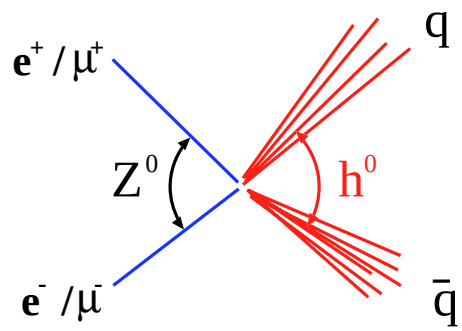
$$\chi^2 = \left(\frac{m_{\rm mis} - m_{Z^0}}{\sigma_{m_{\rm mis}}}\right)^2 + \left(\frac{m_{\rm vis} - m_{h^0}}{\sigma_{m_{\rm vis}}}\right)^2$$

- Likelihood with kinematic variables
- Main background W^+W^-, Z^0Z^0

Likelihood Distribution



Event Selection ($\ell\ell h^0$ channel)

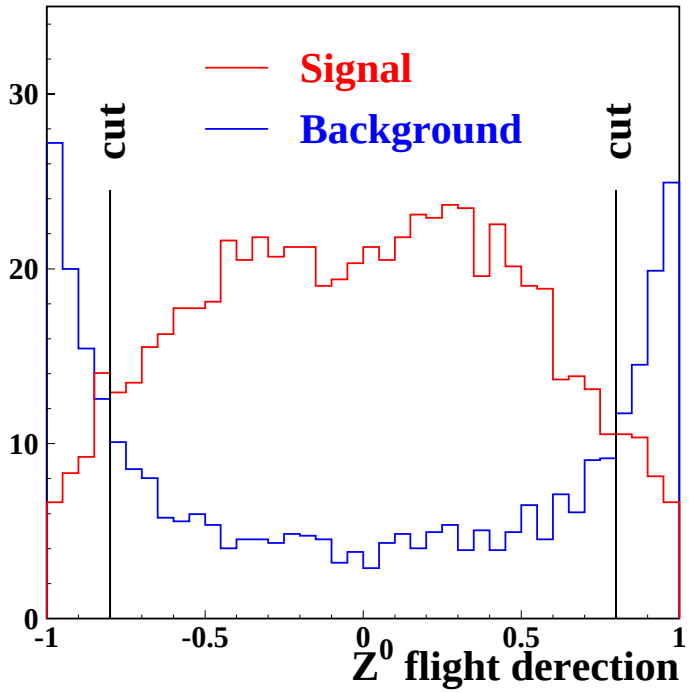


- Find two Isolated leptons
- Calculate mass difference

$$\chi^2 = \left(\frac{m_{\ell\ell} - m_{Z^0}}{\sigma_{m_{\ell\ell}}}\right)^2 + \left(\frac{m_{\text{recoil}} - m_{h^0}}{\sigma_{m_{\text{recoil}}}}\right)^2$$

- Z^0 direction calculated form leptons
- Sequential cut selection
- Background from Z^0Z^0

Z^0 direction calculated from Leptons



Event Selection (Results)

	$Z^0 \to q\bar{q}$		$Z^0 \to \nu\bar{\nu}$		$Z^0 \to e^+e$		$Z^0 \to \mu^+\mu$		Total Signal	
	eff	#Evt	eff	#Evt	eff	#Evt	eff	#Evt	eff	#Evt
$e^+e \to Z^0h^0$	**14.8**	**1,903**	**14.4**	**526**	**24.4**	**164**	**28.8**	**193**	**15.2**	**2,786**
$h^0 \to b\bar{b}$	17.9	1,552	14.4	358	27.3	124	32.7	148	17.6	2,182
$h^0 \to c\bar{c}$	19.8	78.1	20.8	23.5	31.5	6.5	35.1	7.2	20.4	115
$h^0 \to gg$	17.4	155	29.0	74.9	33.5	15.8	37.5	17.7	20.4	263
$h^0 \to W^+W$	6.9	118	14.3	70.0	19.4	17.3	21.7	19.4	9.2	225
$e^+e \to q\bar{q}(\gamma)$		285		—		—		—		285
$e^+e \to WW$		**497**		**314**		—		—		**811**
$e^+e \to Z^0Z^0$		256		152		**43.3**		**54.7**		506
$e^+e \to e\nu W$		—		18		—		—		18
$e^+e \to e^+e\ Z^0$		—		—		—		—		—
Total Bkg		**1,038**		**483**		**43**		**55**		**1,619**
S/N		1.83		1.09		3.81		3.51		1.72
$S/\sqrt{N}$		59.1		23.9		25.0		26.0		69.2

Results are for 100 fb^{-1}

Event Selection (Results w/ Beamstrahlung)

channel	$Z^0 \to q\bar{q}$		$Z^0 \to \nu\overline{\nu}$		$Z^0 \to e^+e^-$		$Z^0 \to \mu^+\mu^-$		Total Signal	
$e^+e^- \to Z^0h^0$	12.2	1,559	11.5	422	16.9	113	20.0	134	12.2	2,228
$h^0 \to b\bar{b}$	14.6	1,269	11.4	282	18.7	85.1	22.6	103	17.6	2,182
$h^0 \to c\bar{c}$	15.4	60.9	17.2	19.4	22.1	4.6	25.4	5.2	20.4	115
$h^0 \to gg$	14.2	128	24.0	61.9	24.4	11.5	26.4	12.4	20.4	263
$h^0 \to W^+W^-$	5.9	101	12.1	59.0	13.1	11.8	15.2	13.6	9.2	225
$e^+e^- \to q\bar{q}(\gamma)$		263		—		—		—		285
$e^+e^- \to WW$		661		511		—		—		811
$e^+e^- \to Z^0Z^0$		239		137		63.6		71.3		506
$e^+e^- \to e\nu W$		—		26		—		—		18
$e^+e^- \to e^+e^-Z^0$		—		—		—		—		—
Total Bkg		1,163		674		64		71		1,972
S/N		1.34		0.63		1.77		1.88		1.12
$S/\sqrt{N}$		45.7		16.3		14.2		15.9		50.2

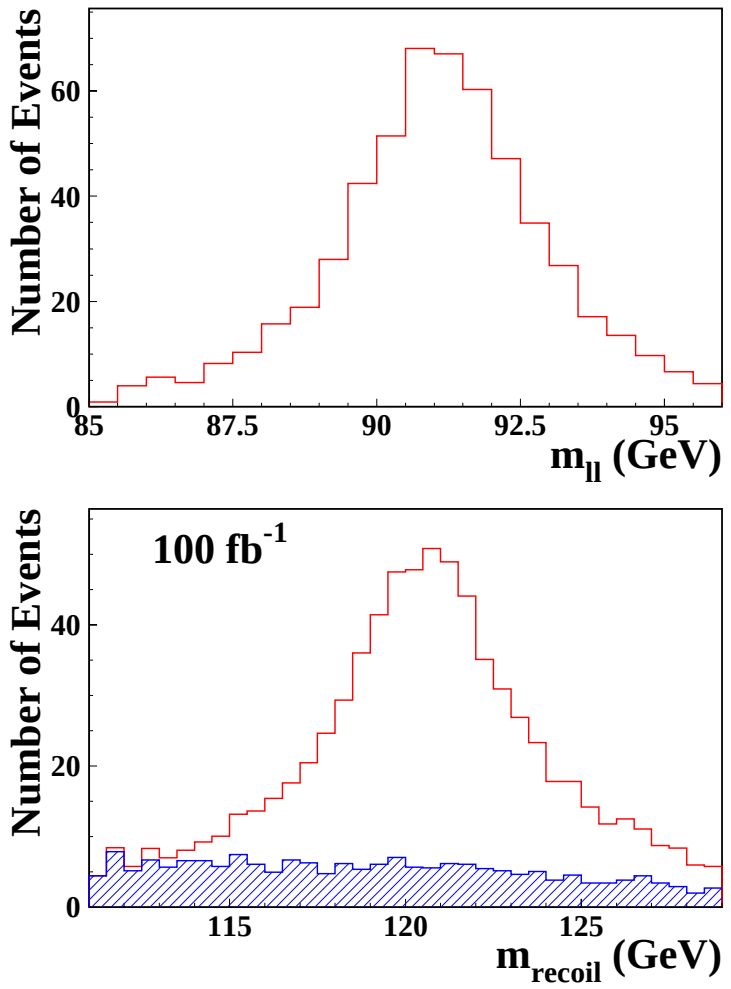
Cross-section Determination

Remove cut in Higgs Side jet from
e^+e^- and $\mu^+\mu^-$ channel selection

	e^+e^-	$\mu^+\mu^-$	Total
Signal	**216**	**234**	**450**
Background	**126**	**141**	**267**
S/N	1.7	1.7	1.7
$S/\sqrt{N}$	19.2	19.7	27.5
Stat. Acc. (%)	**8.6**	**8.2**	**6.0**

Results are for 100 fb^{-1}

Reconstructed Mass Distribution

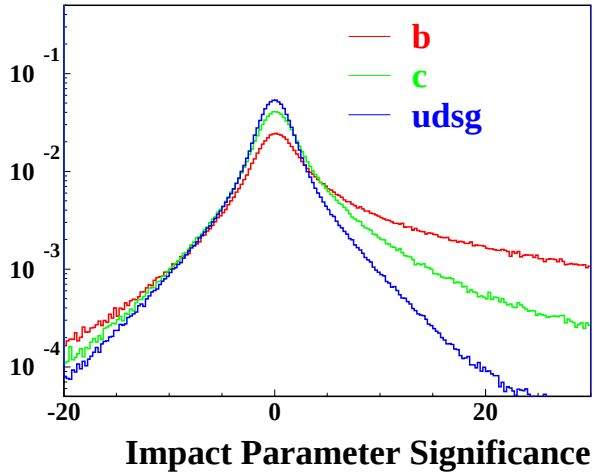


Flavor Tagging

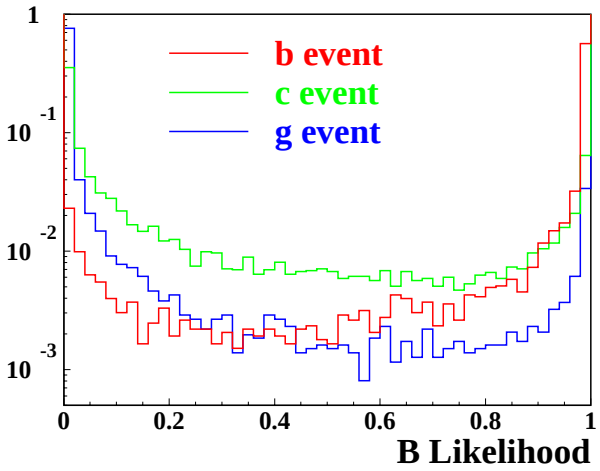
- Four layers of CCD VX detector are assumed
- CCD acceptance $|\cos\theta| < 0.9$
- Position Resolution $\sim 4\mu$m
- Track parameters are calculated including multiple scattering
- Primary Vertex fitting with Beam spot constraint
- Likelihood from Impact parameter distribution

Apply to the selected event

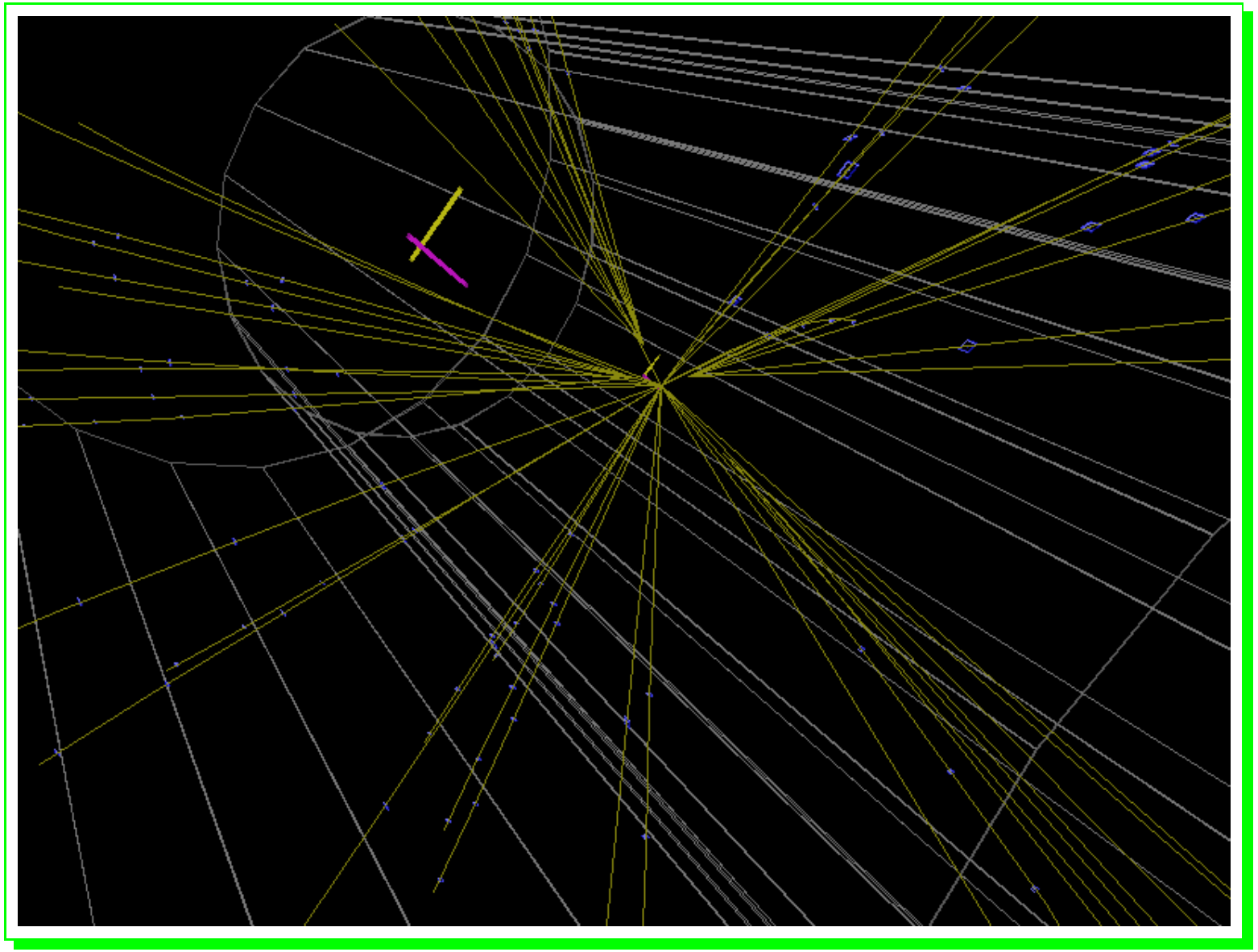
Impact Parameter Distribution



Likelihood Distribution



JSF Quick Simulator Vertex View



Flavor Tagging (Result)

	$h^0 \to b\bar{b}$				$h^0 \to c\bar{c}$				$h^0 \to gg$			
	qqqq	$\nu\nu q\bar{q}$	$\ell\ell q\bar{q}$	Total	qqqq	$\nu\nu q\bar{q}$	$\ell\ell q\bar{q}$	Total	qqqq	$\nu\nu q\bar{q}$	$\ell\ell q\bar{q}$	Total
$h^0 \to b\bar{b}$	**1376**	**316.0**	**225.7**	**1918**	142.4	35.5	20.1	198.0	33.9	6.2	4.9	45.0
$h^0 \to c\bar{c}$	19.0	5.6	3.0	27.7	**45.3**	**13.9**	**7.4**	**66.6**	13.8	4.0	2.2	20.0
$h^0 \to gg$	12.6	5.8	2.3	20.7	57.9	28.4	11.5	97.8	**84.1**	**40.7**	**17.0**	**141.8**
$h^0 \to WW$	13.3	6.2	3.6	23.2	54.5	34.7	15.5	104.7	50.6	29.1	14.6	94.2
Higgs Bkg	45.0	17.7	9.0	71.6	254.8	98.5	47.1	400.5	98.2	39.3	21.7	159.2
Other Bkg	173.7	74.7	26.8	275.2	385.3	186.1	28.7	600.2	478.9	222.7	42.4	744.0
Total Bkg	**218.7**	**92.3**	**35.7**	**346.8**	**640.2**	**284.7**	**75.9**	**1001**	**577.1**	**261.9**	**64.2**	**903.2**
Stat. Acc.	**2.9**	**6.4**	**7.2**	**2.5**	**57.8**	**124.7**	**123.2**	**49.1**	**30.6**	**42.7**	**53.1**	**22.8**

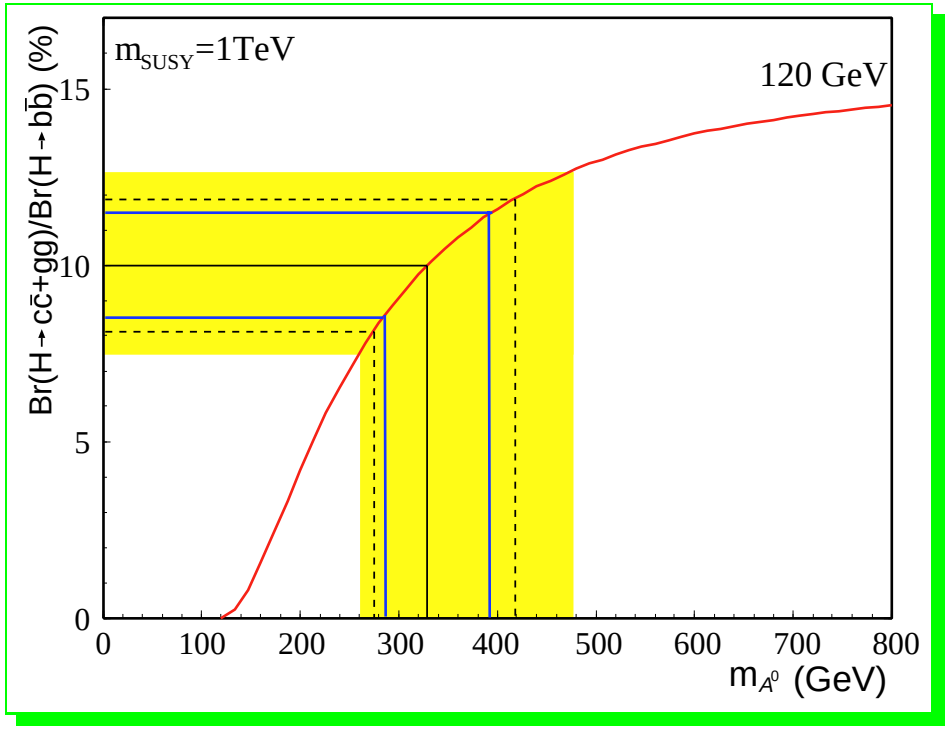
Results are for 100 fb^{-1}

Branching Fraction

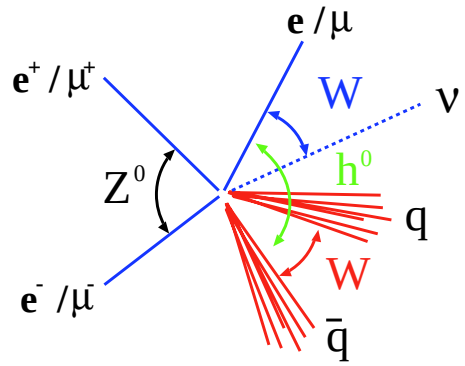
Result for $m_{h^0} = 120$ GeV with 100 fb^{-1}

- **Br($h^0 \to b\bar{b}$)** **2.5 %**
- **Br($h^0 \to c\bar{c}$)** **49 %**
- **Br($h^0 \to gg$)** **23 %**
- **Br($h^0 \to c\bar{c}+gg$)** **15 %**
- $\dfrac{\text{Br}(h^0 \to c\bar{c})}{\text{Br}(h^0 \to b\bar{b})}$ **49 %**
- $\dfrac{\text{Br}(h^0 \to c\bar{c}+gg)}{\text{Br}(h^0 \to b\bar{b})}$ **15 %**

Br($h^0 \to c\bar{c}+gg$)/Br($h^0 \to b\bar{b}$) vs m_{A^0}

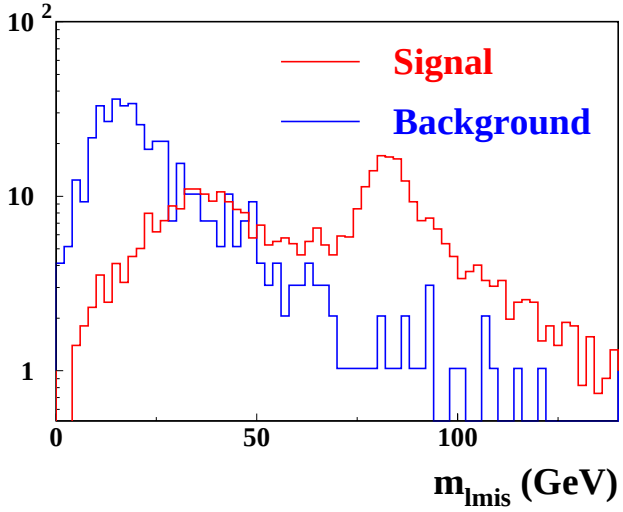


Measurement of Br($h^0 \to WW^*$)



- Use $e^+e^- \to Z^0h^0$
  $Z^0 \to q\bar{q}$ or $\ell^+\ell^-$
  $h^0 \to WW^* \to \ell\nu q\bar{q}$
- The final states are
  - $q\bar{q}\ell\nu q\bar{q}$, and
  - $\ell^+\ell^-\ell\nu q\bar{q}$
- Selecting one(three) lepton(s)
- $m_{jj}(m_{\ell\ell})$ compatible with m_{Z^0}
- Lepton Isolation
- Background from W^+W^-, Z^0Z^0

Invariant mass of 3rd Lepton and p_{mis}



	$q\bar{q}\ell\nu q\bar{q}$	$\ell^+\ell^-\ell\nu q\bar{q}$	total
Efficiency	**5.8 %**	**17.3 %**	
Signal	**99.3**	**28.4**	**137.7**
Higgs Bkg	8.7	8.0	16.7
Other Bkg	79.3	15.5	94.8
Total Bkg	**88.0**	**23.5**	**111.5**
Accuracy	**13.8**	**25.4**	**11.5**

efficiency is from all $h^0 \to W^+W^-$ decay

Summary

- A study for measuring Higgs Boson properties are updated
- Improvement with respect to **LCWS95**

	$\sigma_{Z^0h^0}$	Br($h^0 \to b\bar{b}$)	Br($h^0 \to c\bar{c}$)	Br($h^0 \to gg$)	$\frac{\text{Br}(h^0 \to c\bar{c})}{\text{Br}(h^0 \to b\bar{b})}$	$\frac{\text{Br}(h^0 \to c\bar{c}+gg)}{\text{Br}(h^0 \to b\bar{b})}$
Stat. Acc. (%)	**6.0**	**2.5**	**49**	**23**	**49**	**15**

- **Br($h^0 \to WW$)** is studied in two decay channels

	$q\bar{q}\ell\nu q\bar{q}$	$\ell^+\ell^-\ell\nu q\bar{q}$	total
Stat Acc. (%)	**13.8**	**25.4**	**11.5**

All results are for 100 fb^{-1}

Outlook

- More efficient Flavor tagging
- Good charm tag
- Sofisticated way to extract Branching fraction
- Include other channel for Br($h^0 \to WW^*$)
- Study requirement for detector performance