Analysis of the hadronic Higgs Branching Ratios for the $ZH \rightarrow llqq$ channel at the ILC

ALCPG11, Eugene
Nina Herder, University of Bonn
20 March 2011

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- Motivation
- Higgs Strahlung Process
- Event Selection
- Fitting Method & Branching Ratios
- Summary & Outlook

ilc

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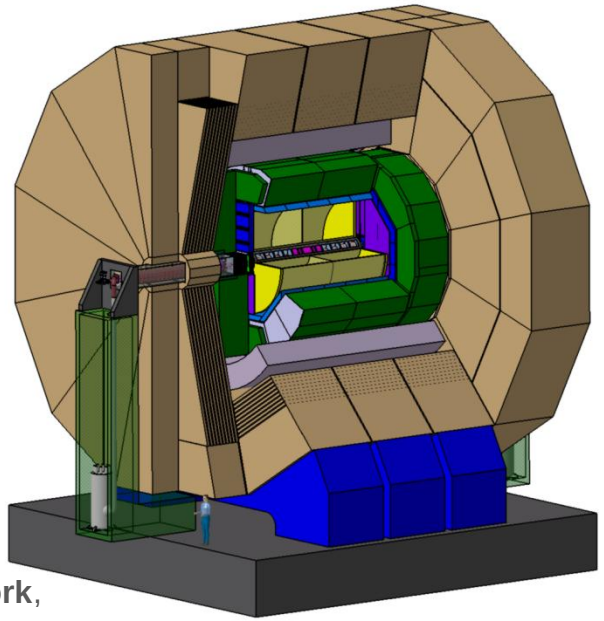
Motivation

- GEANT4 based full Monte Carlo Data Samples for an ILC large Detector (ILD_00) can be used
- Higgs Branching Ratio Studies have been done for 250 GeV collision energy
- What about 350 GeV where also tt production is allowed (t not included yet)?



Source: **ILD concept detector group plan future work**, http://www.linearcollider.org/newsline/readmore_20100211_ftr1.html (10 March 2011)

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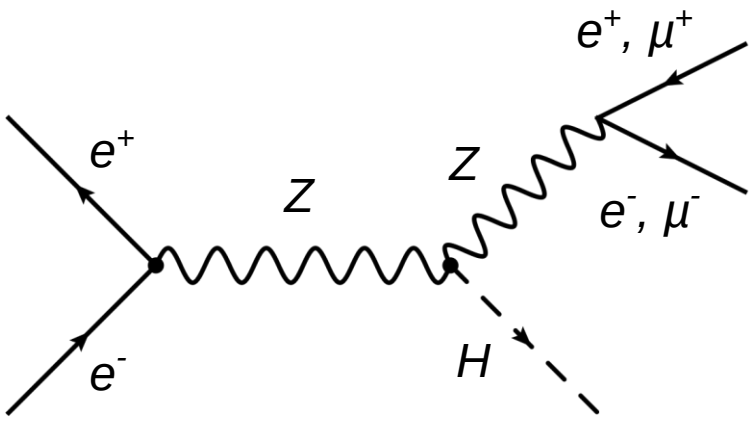
Higgs Strahlung Process

- one of the leading Higgs production processes ($\sigma_{ZH} \approx$ 200 fb) at E_{cms}=350 GeV

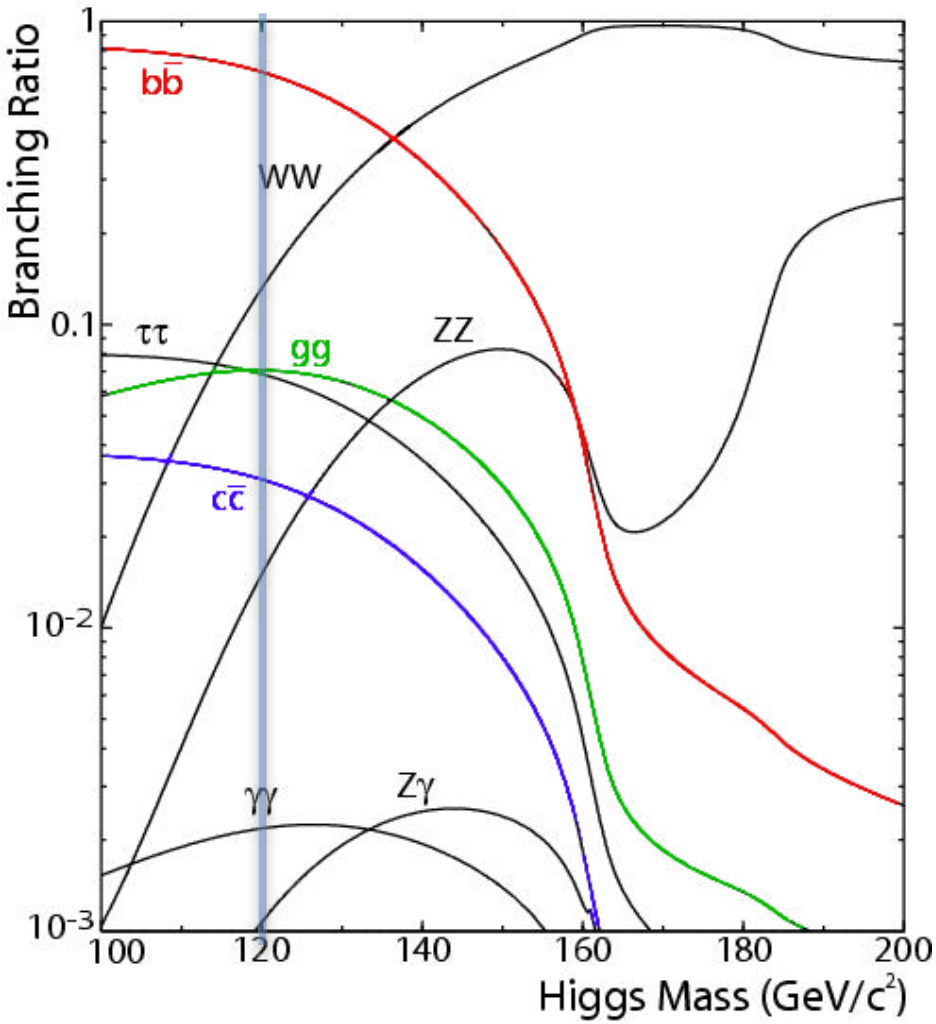


- Light SM-Higgs (m_H=120 GeV)
- Polarization (-80%, +30%)
- Z decays only to 3% into e^+e^- ($\mu^+\mu^-$)
  - ➢ but good lepton identification
- Possibility of an absolute cross section determination via the recoil mass of the leptons
- Signal definition for e^+e^-H necessary since sample contains a superposition with the Z-fusion process

Higgs Strahlung Process

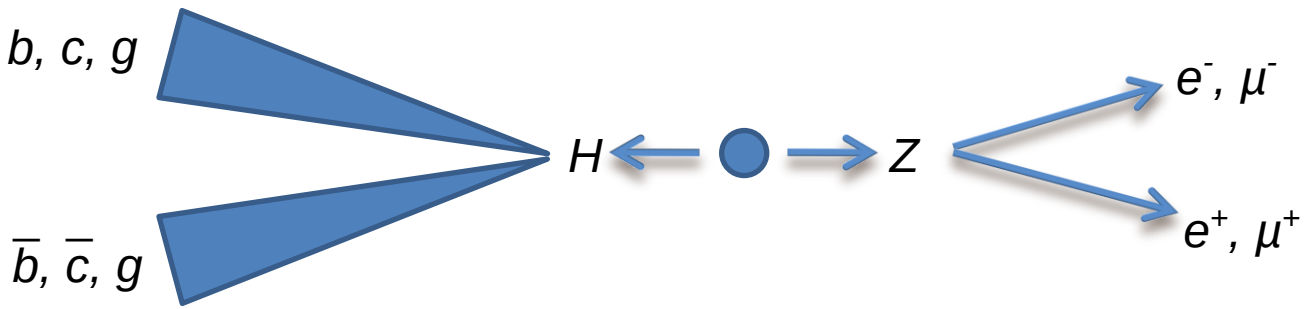
- Higgs decay
  for a light SM Higgs

Higgs Decay	Pythia BR (rel.)
bb	65.7%
cc	3.6%
gg	5.5%



Higgs Strahlung Process

- Signal Process:



- Identification of the 2 leptons

  $\varepsilon(Z \rightarrow \mu^+\mu^-)$=91.7%

  $\varepsilon(Z \rightarrow e^+e^-)$=86.4%

- Forcing the other particles into 2 jets

Higgs Strahlung Process

- Lepton Identification
  - Electron Identification
    - $p_{track} > 15$ GeV
    - $E_{em}/E_{tot} > 0.6$
    - $E_{tot}/p_{track} > 0.9$
  - Muon Identification
    - $p_{track} > 15$ GeV
    - $E_{em}/E_{tot} < 0.5$
    - $E_{tot}/p_{track} < 0.3$
- Loop to select the two hardest leptons

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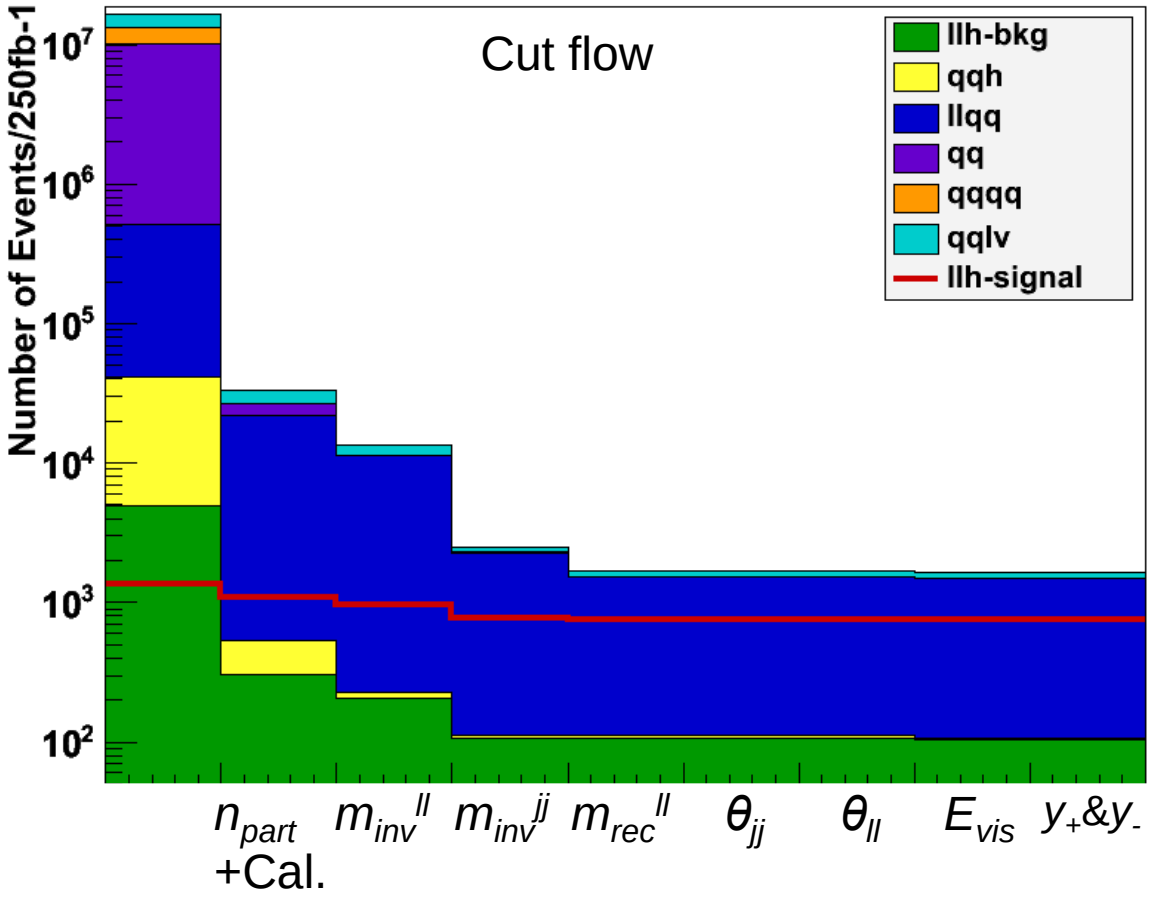
Event Selection

#	Cut	Value
1	Calorimeter Entries + #particles n_{part}	Specific for muons and electrons > 30
2	**Di-lepton Mass** m_{inv}^{ll}	$\mu^+\mu^-$: 80-100 GeV, e^+e^-: 80-105 GeV
3	**Di-jet Mass** m_{inv}^{jj}	100-150 GeV
4	Di-lepton Recoil Mass m_{rec}^{ll}	115-250 GeV
5	Angle between Jets θ_{jj}	< 2.8 rad
6	Angle between Leptons θ_{ll}	< 2.6 rad
7	Visible Energy E_{vis}	> 250 GeV
8	Jet-Finder (Durham) y_+ y_-	 < 0.2 < 0.7

Event Selection

- Muon Channel - Signal Efficiency: 56.7%

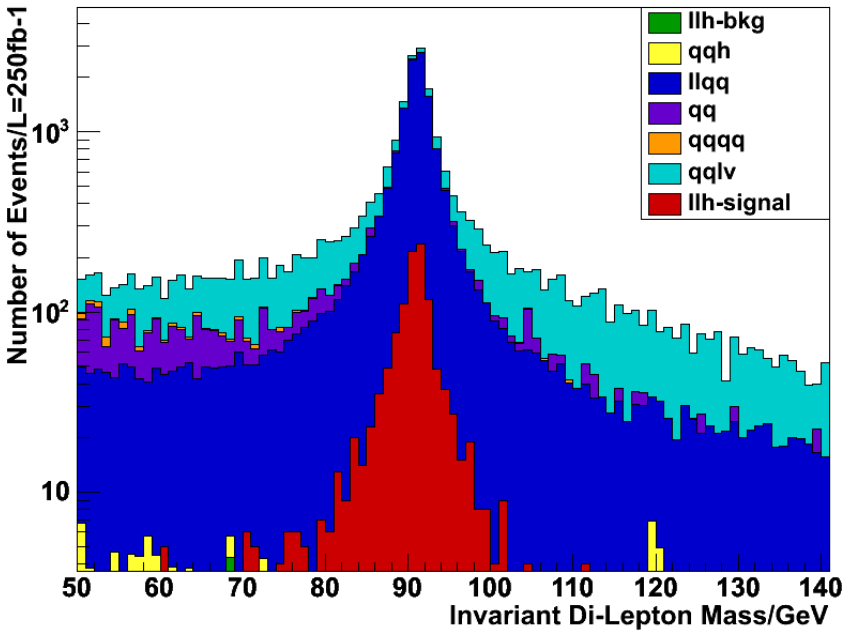


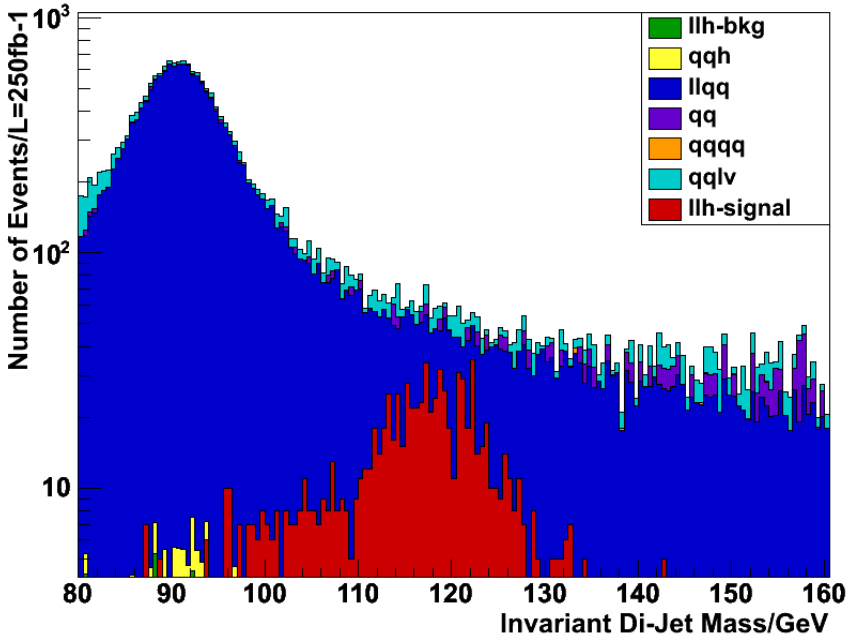
$$\frac{S}{\sqrt{B}} = 19.5$$

Event Selection

- Muon Channel - Signal Efficiency: 56.7%

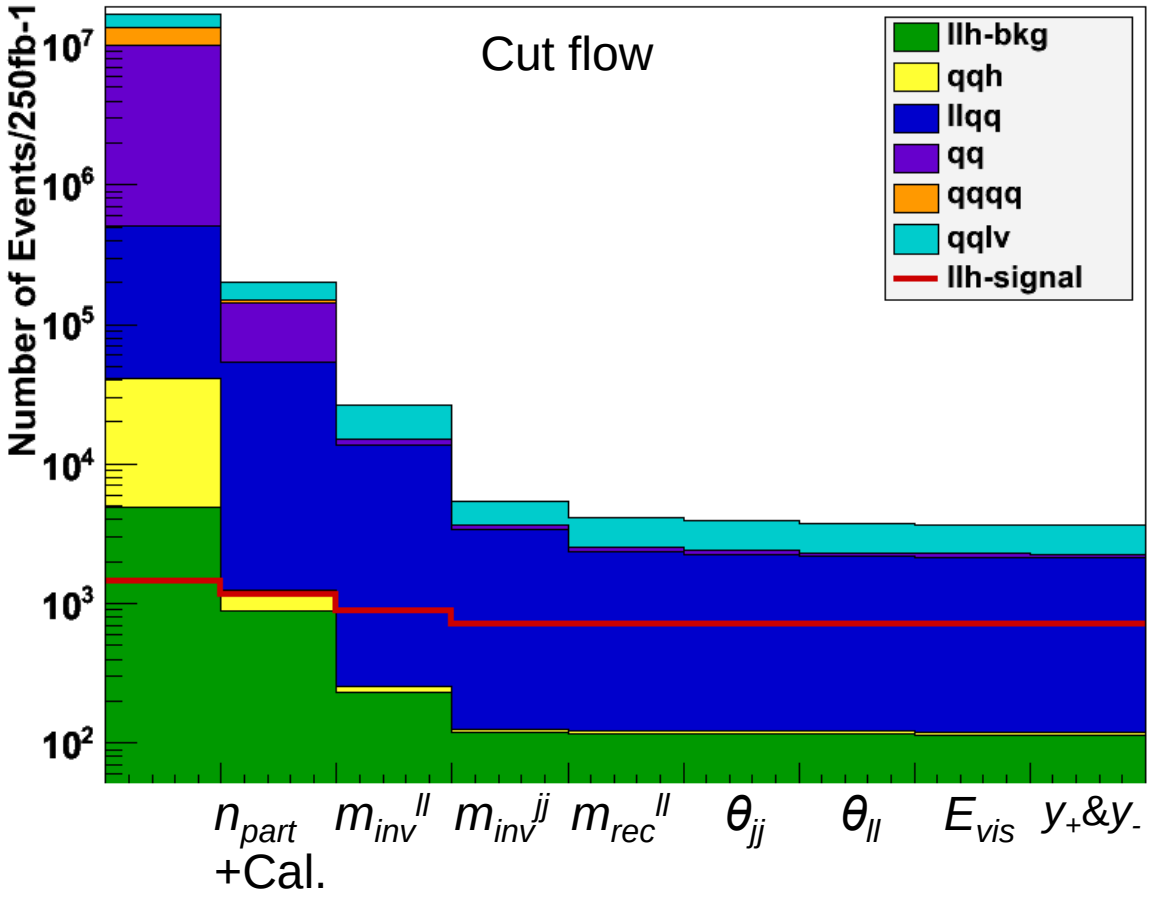
  Main selection variables (without cuts):





Event Selection

- Electron Channel - Signal Efficiency: 47.7%

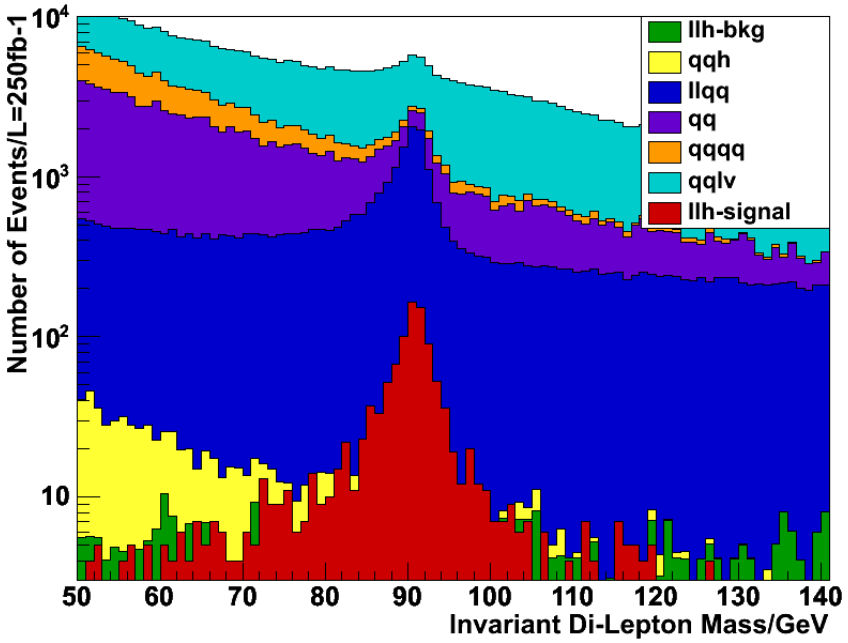


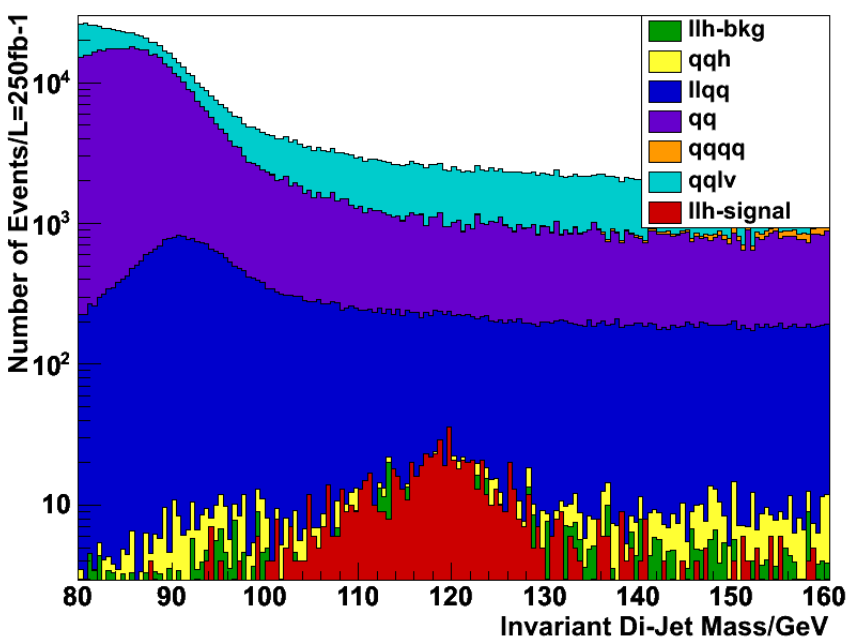
$$\frac{S}{\sqrt{B}} = 12.0$$

Event Selection

- Electron Channel - Signal Efficiency: 47.7%

  Main selection variables (without cuts):

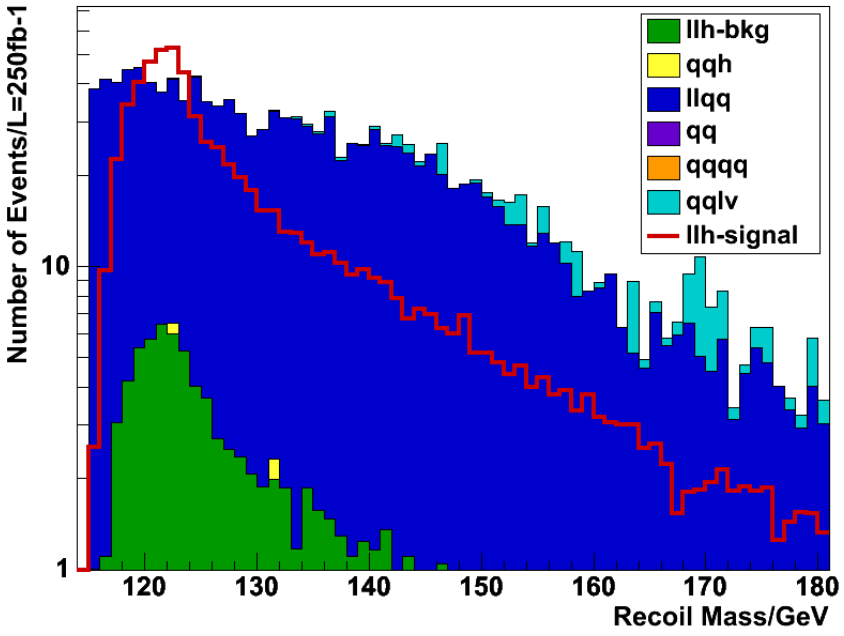




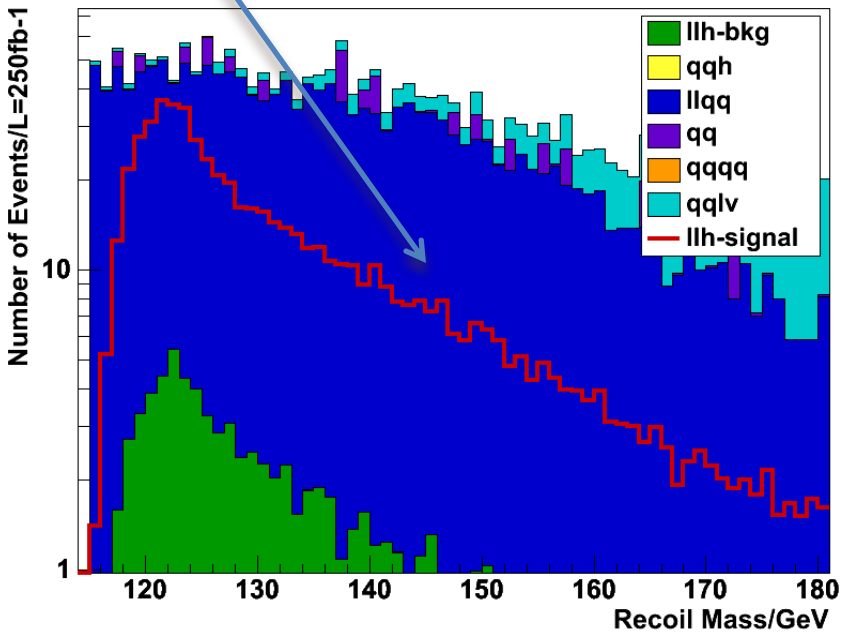
Event Selection

- Recoil Mass for muons and electrons (after all cuts)

longer tail because of photon radiation



Muon Channel



Electron Channel

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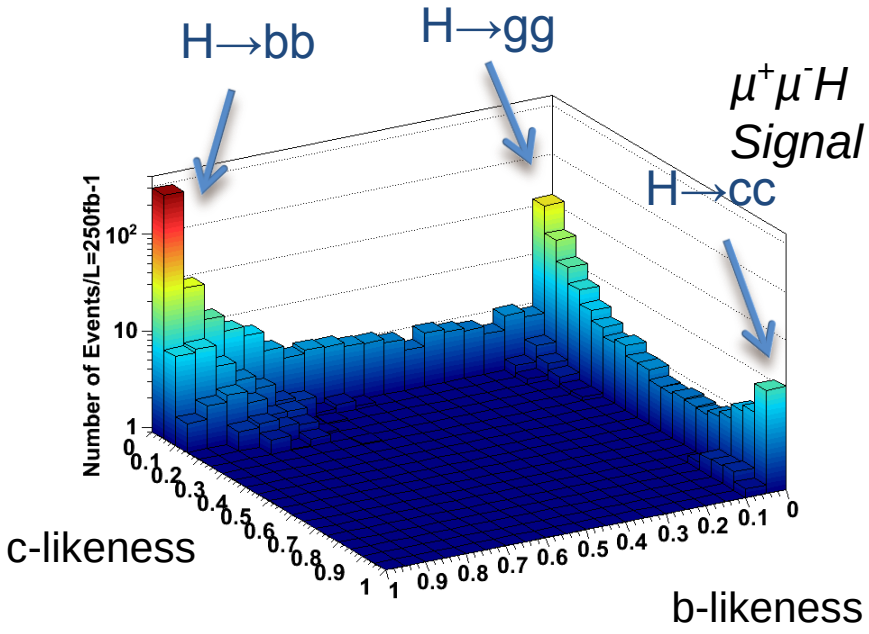
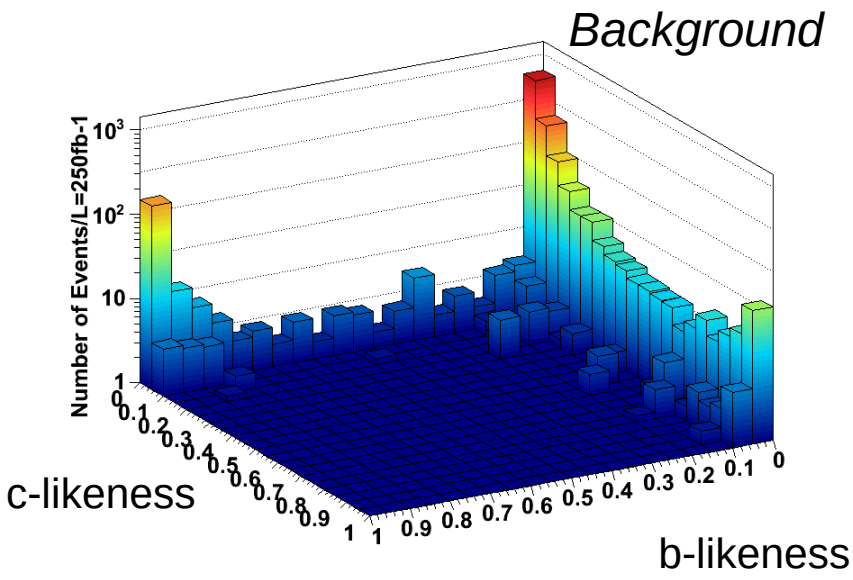
Fitting Method & Branching Ratios

- Use of 2-D b-likeness/c-likeness templates to perform a Likelihood-Fit

$$x-likeness = \frac{x_1 x_2}{x_1 x_2 + (1-x_1)(1-x_2)},$$

$$x = b,\ c \text{ and } x_{1,2} \text{ b/c} - \text{tag value for Jet } 1, 2$$



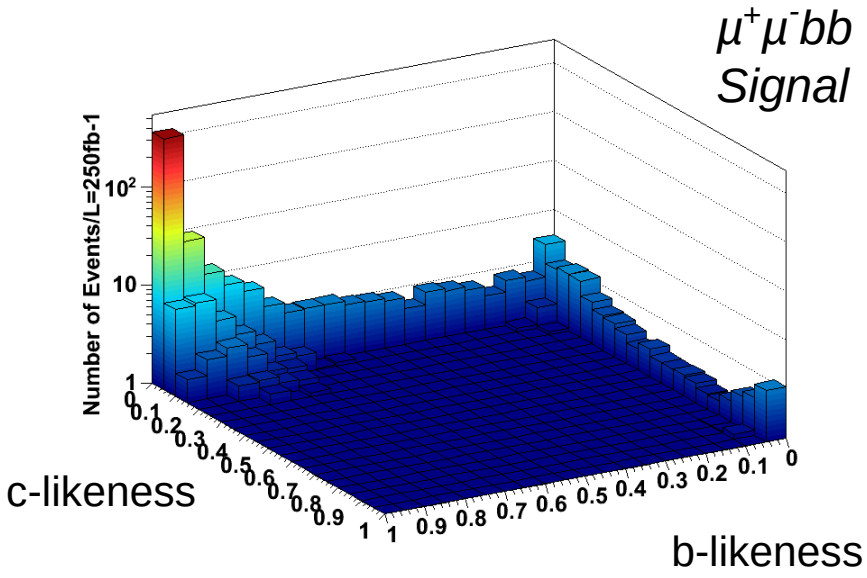


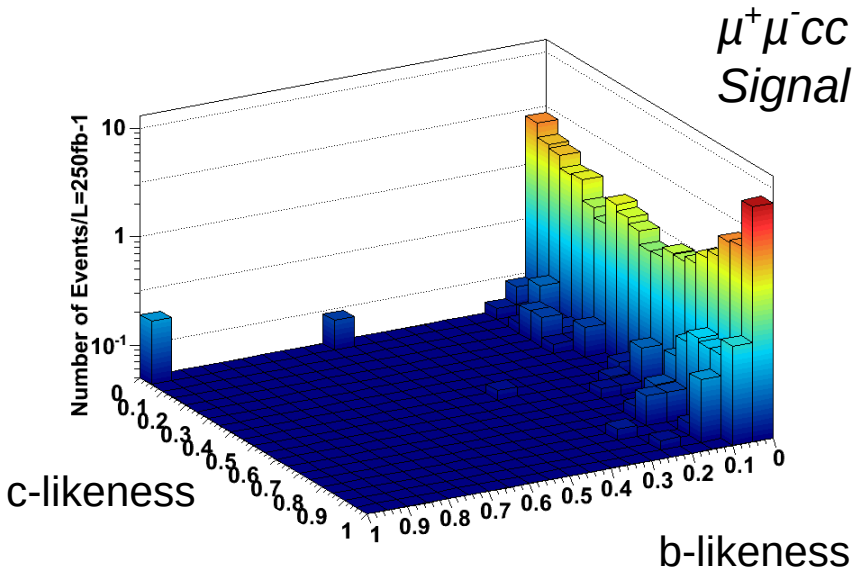
Fitting Method & Branching Ratios

- Use of 2-D b-likeness/c-likeness templates to perform a Likelihood-Fit

  statistic of templates is about more than

  50 times higher





Fitting Method & Branching Ratios

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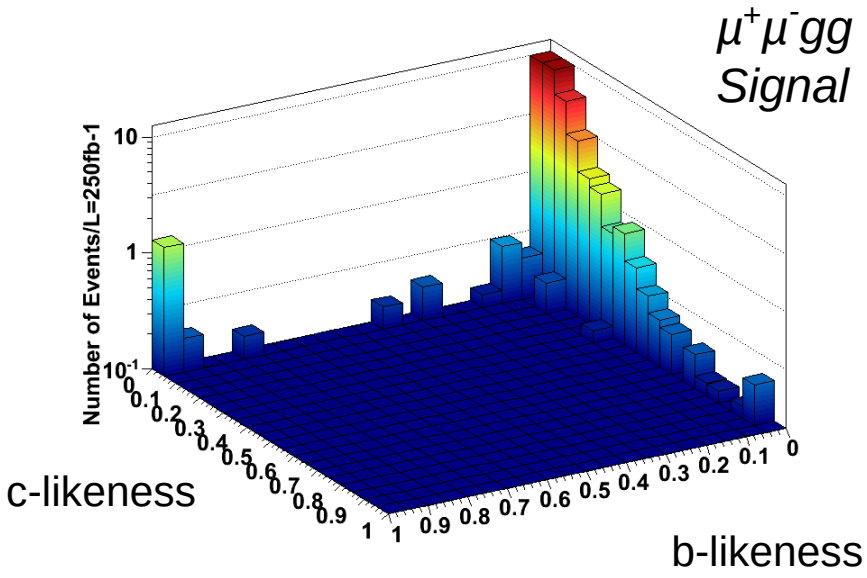

Fitting Method & Branching Ratios

- Fitter:TFractionFitter implemented in ROOT
- Evolves the fraction of each template by performing a Likelihood-Fit
- Maximizes:

$$\ln L = \sum_{i,j} N_{i,j}^{data} \ln\left(\sum_{s} r_s p_{i,j}^{s} \right)$$

N^{data}: number of data in bin
i, j: bins
r_s: fraction of template s
p_s: binned probability of tempate s
s: Higgs decay channel (bb, cc, gg)

- Uses Poisson statistics

Fitting Method & Branching Ratios

- Produce an expected signal and scale the templates by a factor of 1000 to suppress the errors of the Monte-Carlo-Statistics

- Background not yet considered in fit

Preliminary fit results for L=250 fb^{-1}

Fraction	Fitted value for muon channel
r_{bb}	0.86 ± 0.03
r_{cc}	0.06 ± 0.01
r_{gg}	0.09 ± 0.01

Fraction	Fitted value for electron channel
r_{bb}	0.87 ± 0.04
r_{cc}	0.05 ± 0.01
r_{gg}	0.08 ± 0.01

Fitting Method & Branching Ratios

- Calculation of the Branching Ratios according to

$$BR(H \to s) = \frac{r_s}{r_s^{Pythia}} \times BR(H \to s)_{Pythia}$$

r_s: decay fraction, s: decay channel (bb, cc, gg)

- Preliminary results for the Higgs BRs with electron and muon channel combined

Higgs Decay	BR(H→s)
bb	(64.6 ± 1.8)%
cc	(4.2 ± 0.5)%
gg	(6.3 ± 0.5)%

Fitting Method & Branching Ratios

- Further steps of the fitting method
  - Produce toy data samples to extract the deviations caused by the statistics of the „measured“ sample
  - assure that the used template statistics are enough to produce a negligable error for the Branching Ratios
  - Include the background

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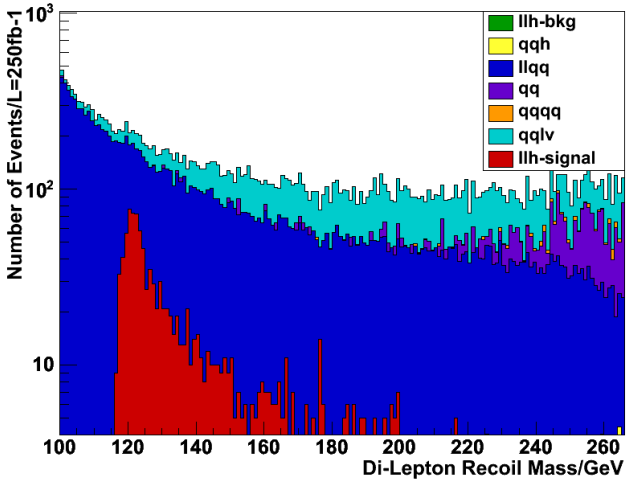
Summary & Outlook

- Cuts seem to lead to a good Signal to Background Ratio
- The preliminary fitting method for the Branching Ratio extraction shows good results and has to be further tested



- Outlook:
  - Working on a kinematic fit including ISR, m_Z and m_h to further separate signal from background
  - Extraction of the absolute Branching Ratios via the Di-lepton Recoil Mass

Thank you for your attention.

BACKUP

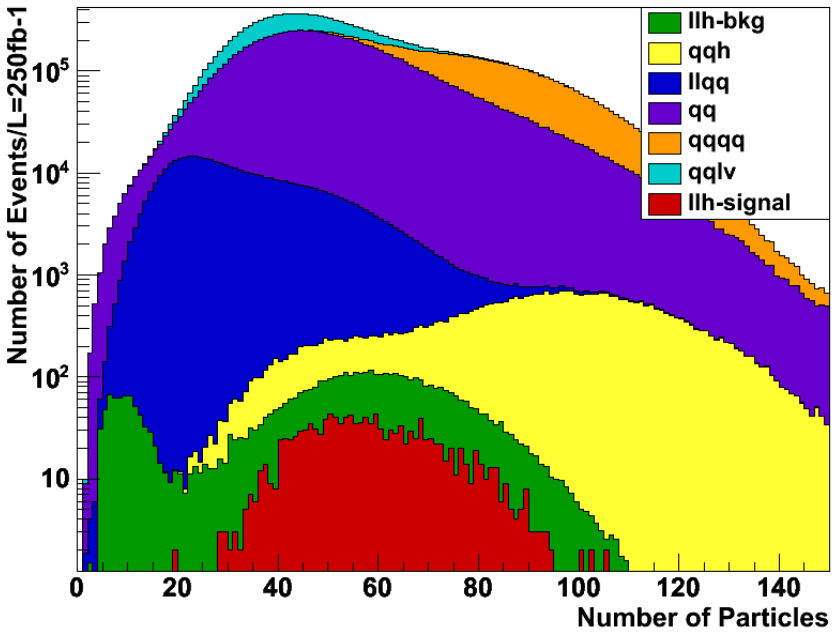
Cut flow

Cut	Muon Channel		Electron Channel	
	Signal	Background	Signal	Background
No cuts	1358	16594487	1462	16607288
Calorimeter Entries + #particles n_{part}	1083	51647	1165	176107
Di-lepton Mass m_{inv}^{ll}	947	30278	914	23546
Di-jet Mass m_{inv}^{jj}	788	12172	761	4897
Di-lepton Recoil Mass m_{rec}^{ll}	782	2334	714	3755
Angle between Jets θ_{jj}	782	1598	710	3660
Angle between Leptons θ_{ll}	782	1590	709	3476
Visible Energy E_{vis}	772	1556	699	3374
Jet-Finder (Durham): y_+&y_-	770	1552	697	3347
Efficiency after all cuts	0.567	0.00009	0.477	0.0002

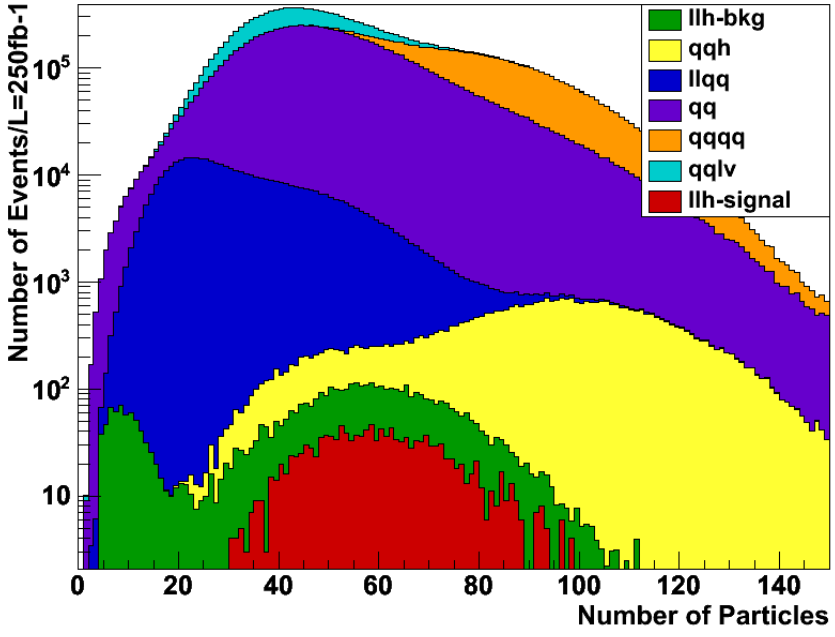
Further Cut Variables

Number of particles

Muon Channel



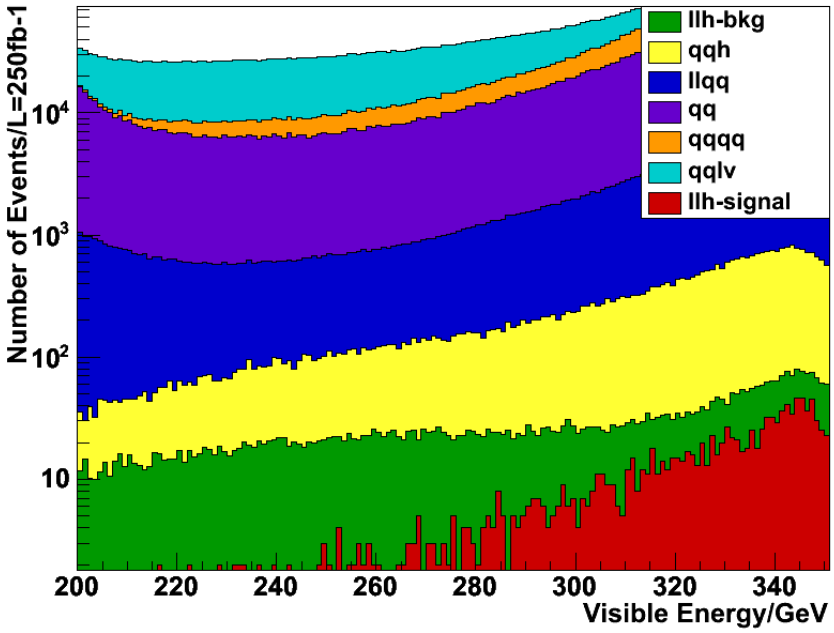
Electron Channel



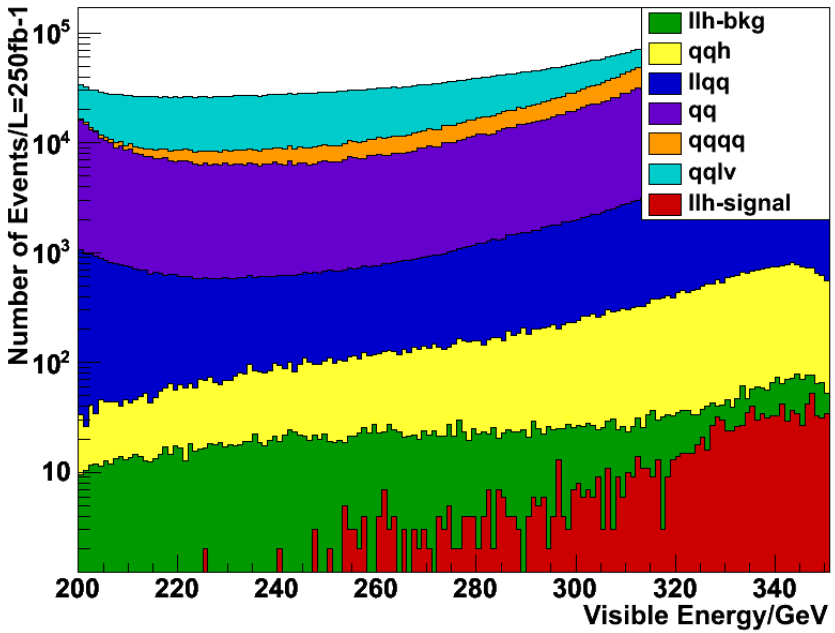
Further Cut Variables

Visible Energy

Muon Channel



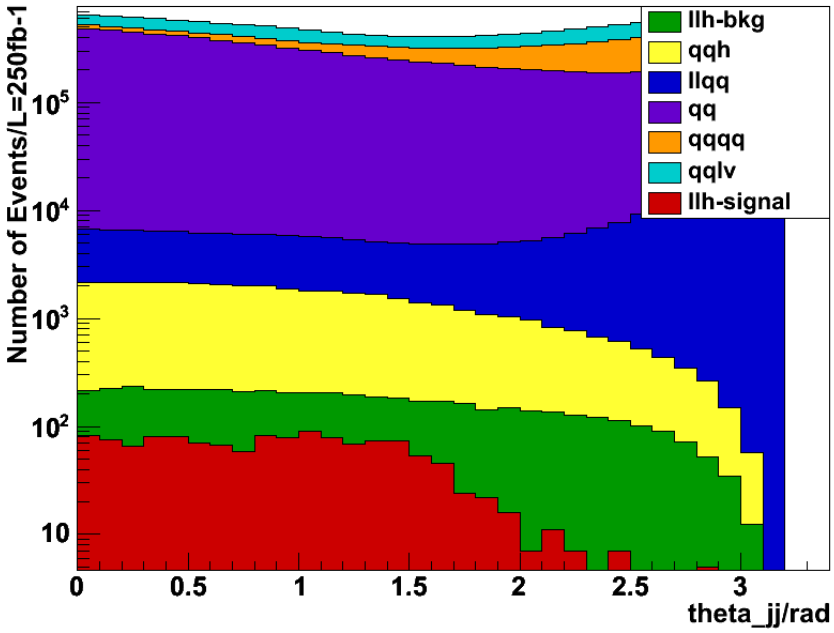
Electron Channel



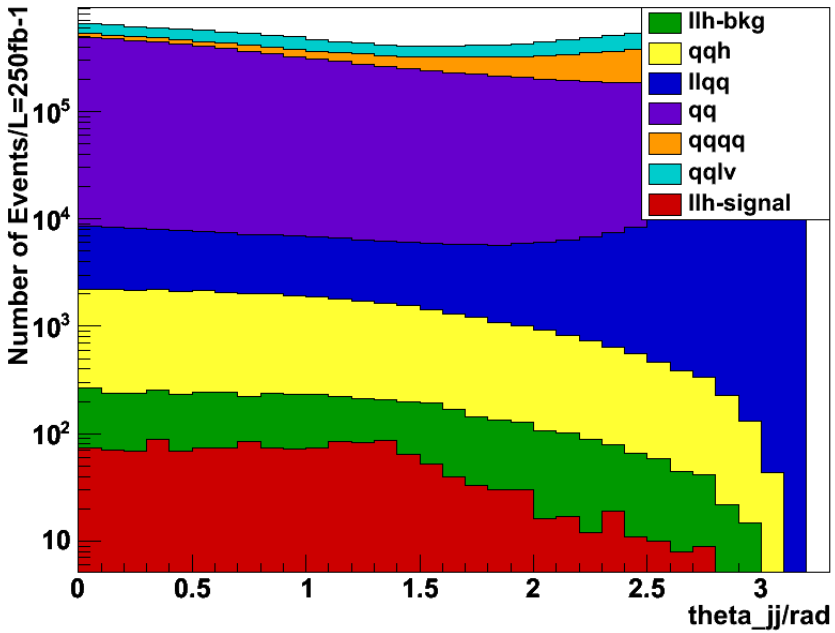
Further Cut Variables

Angle between Jets

Muon Channel



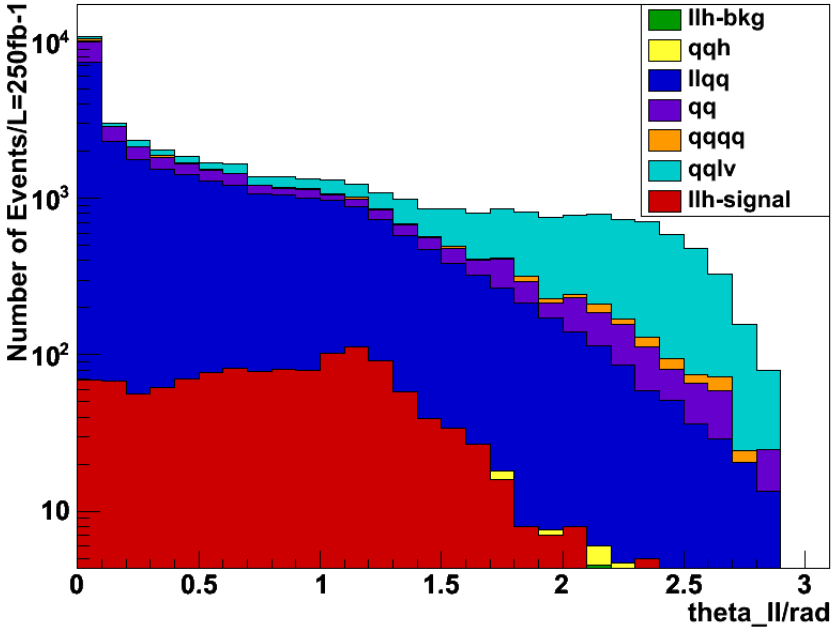
Electron Channel



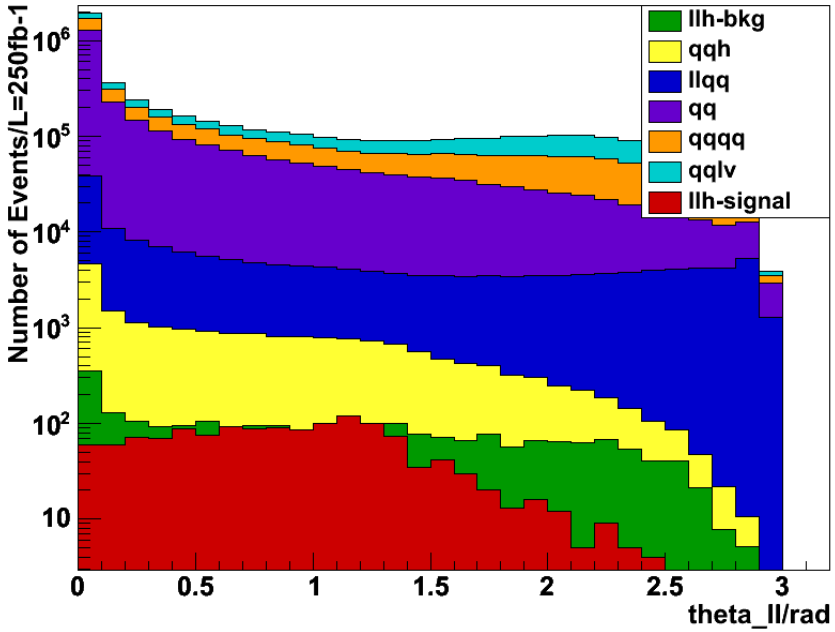
Further Cut Variables

Angle between Leptons

Muon Channel



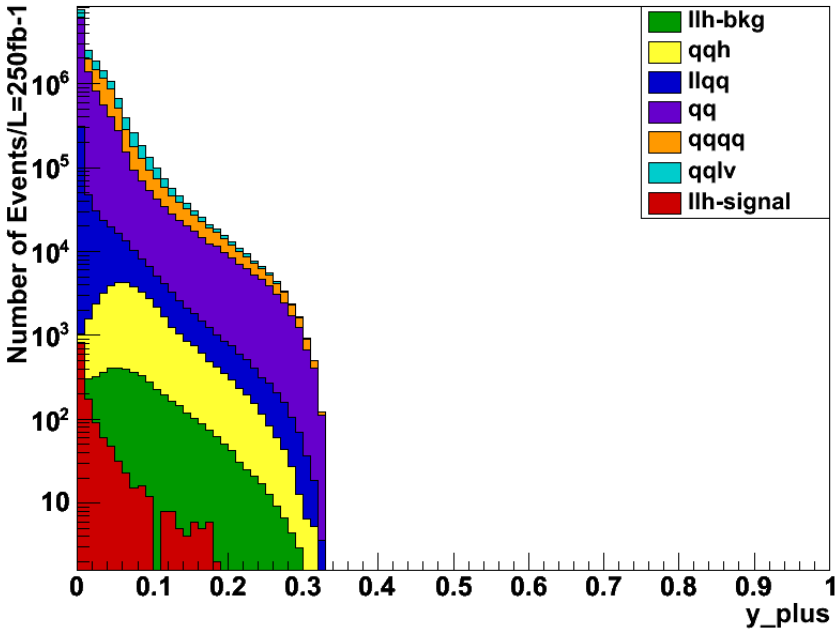
Electron Channel



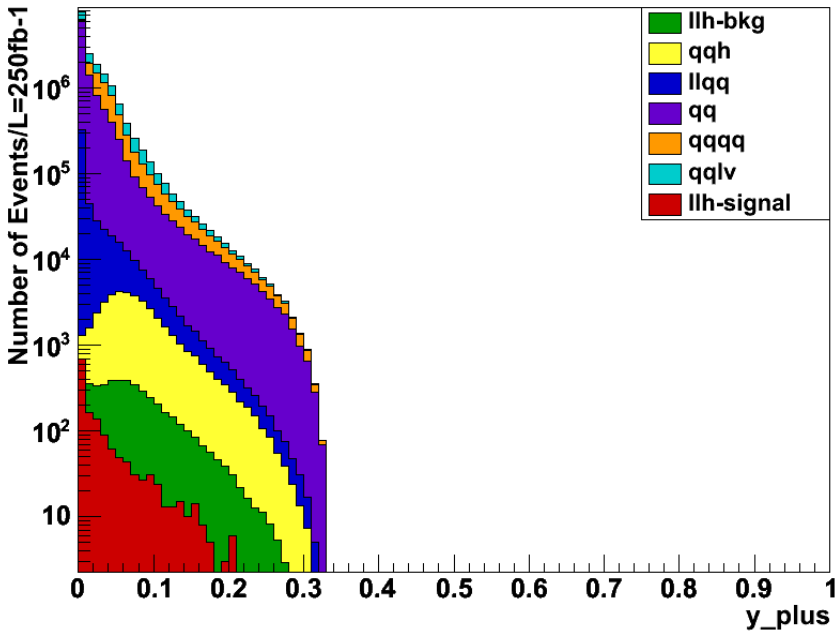
Further Cut Variables

Jet-Finder: y_+

Muon Channel



Electron Channel



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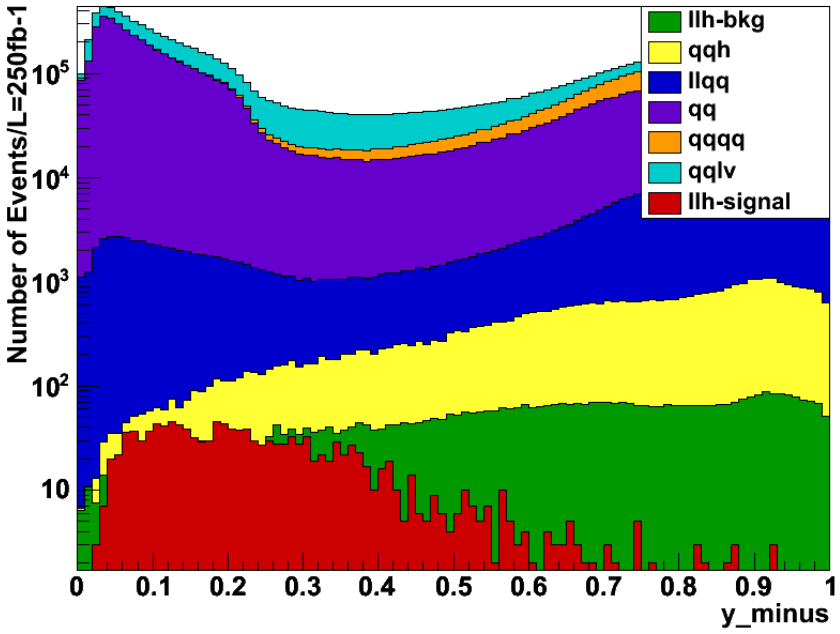
Jet-Finder: y_{-}

Muon Channel



Electron Channel