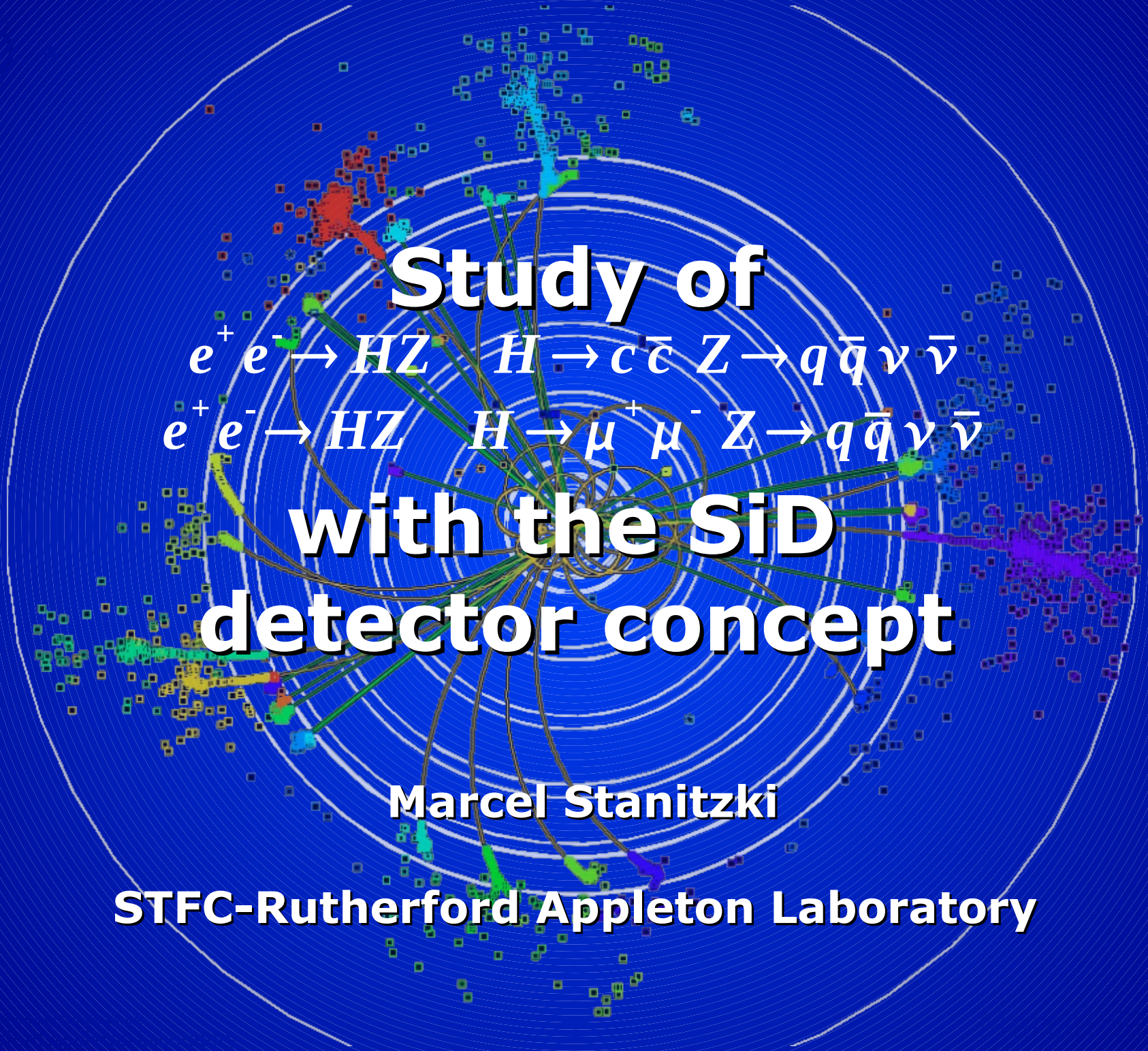

Study of

$$e^+e^- \to HZ \quad H \to c\bar{c} \quad Z \to q\bar{q}\,\nu\bar{\nu}$$

$$e^+e^- \to HZ \quad H \to \mu^+\mu^- \quad Z \to q\bar{q}\,\nu\bar{\nu}$$

with the SiD detector concept

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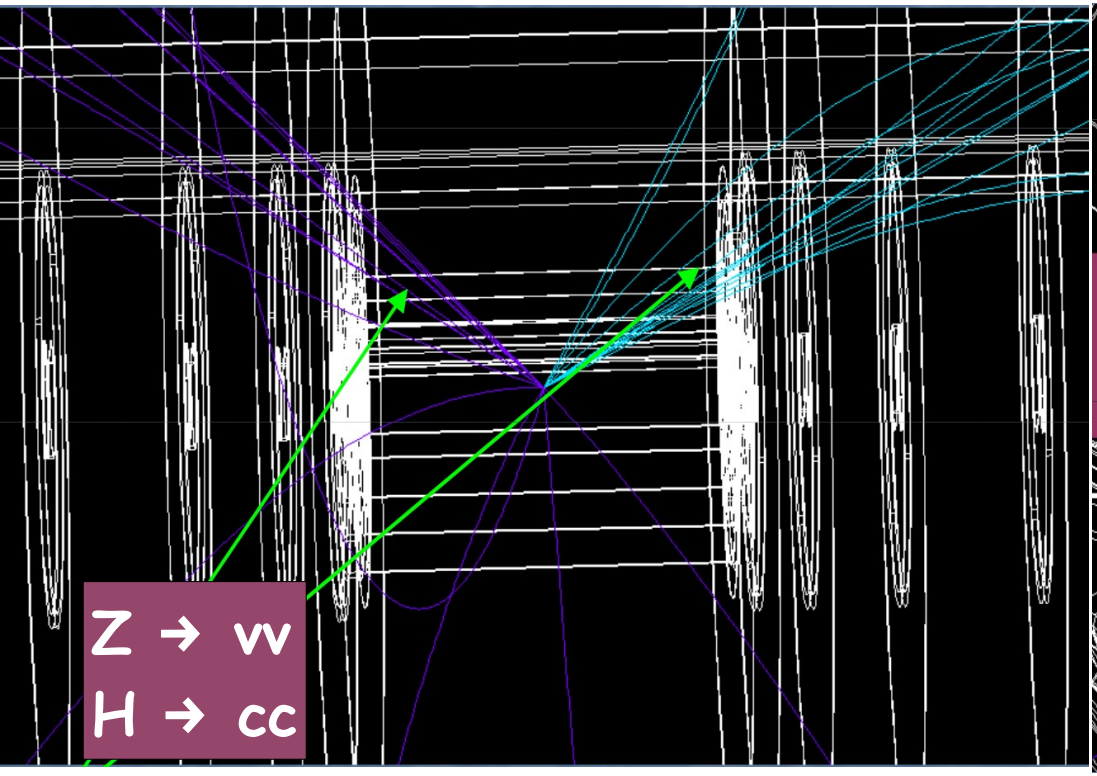
The Benchmark processes

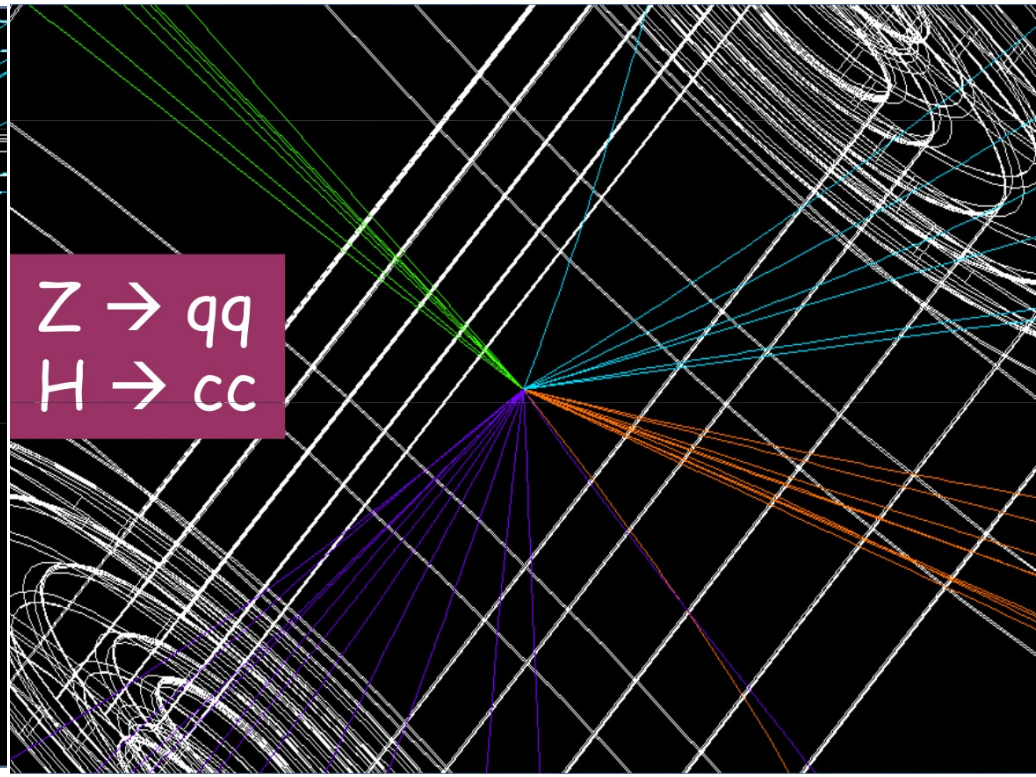
- $H \rightarrow cc$
  - Vertexing
  - Jet reconstruction
  - C-tagging performance
- $H \rightarrow \mu^+\mu^-$
  - Sensitivity to rare decays
  - Tracking performance
  - Muon-ID

$H \rightarrow cc$

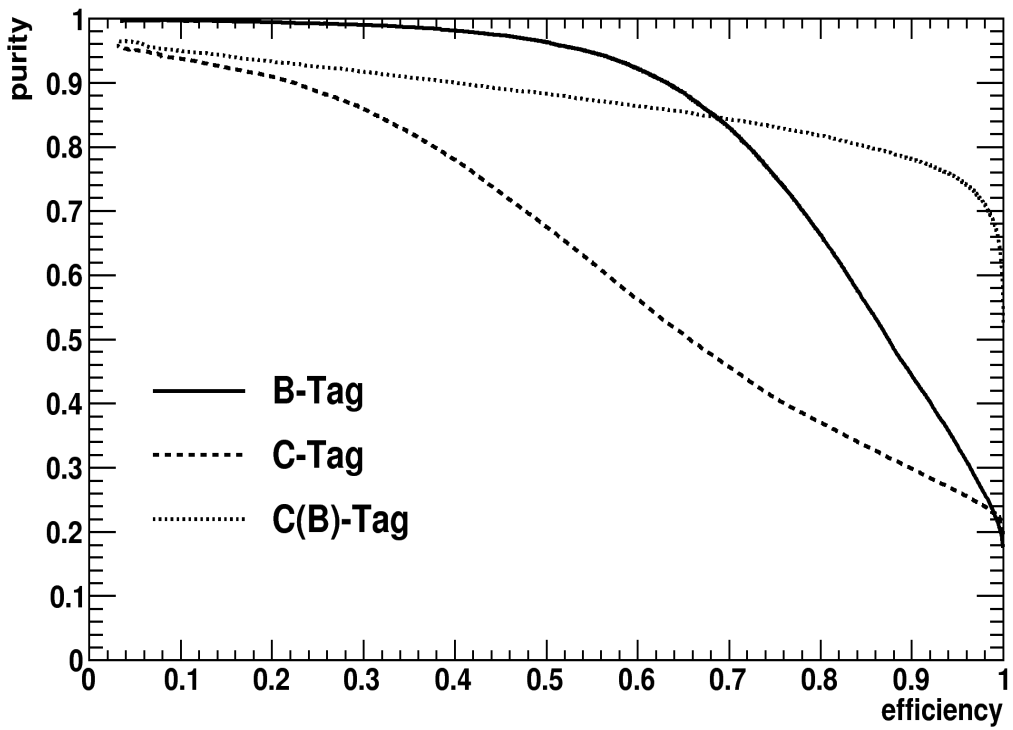
- To dedicated Analyses
  - missing energy final state
  - 4 jet final state
- Both rely on c-tagging from LCFI-Vertex package
- Both use a Neural Network (NN) to perform the final event selection
  - One network to discriminate between SM background and Higgs production
  - One to separate $H \rightarrow cc$ from other Higgs decay modes

Typical events

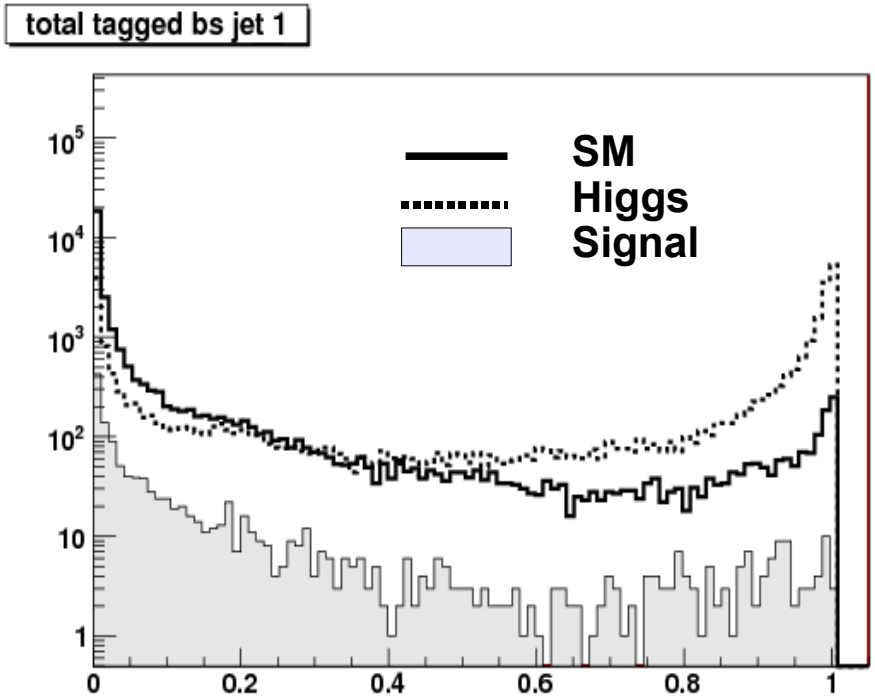


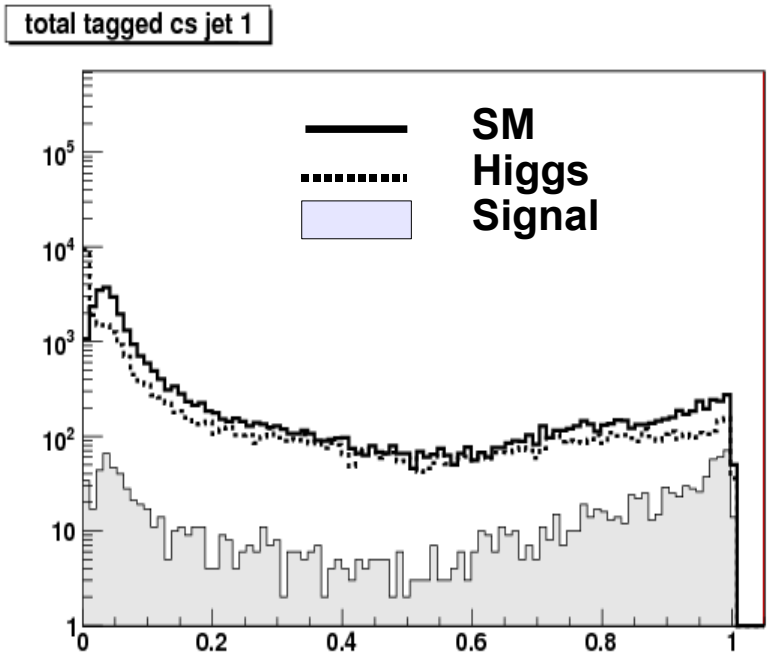


LCFI Flavor tagging

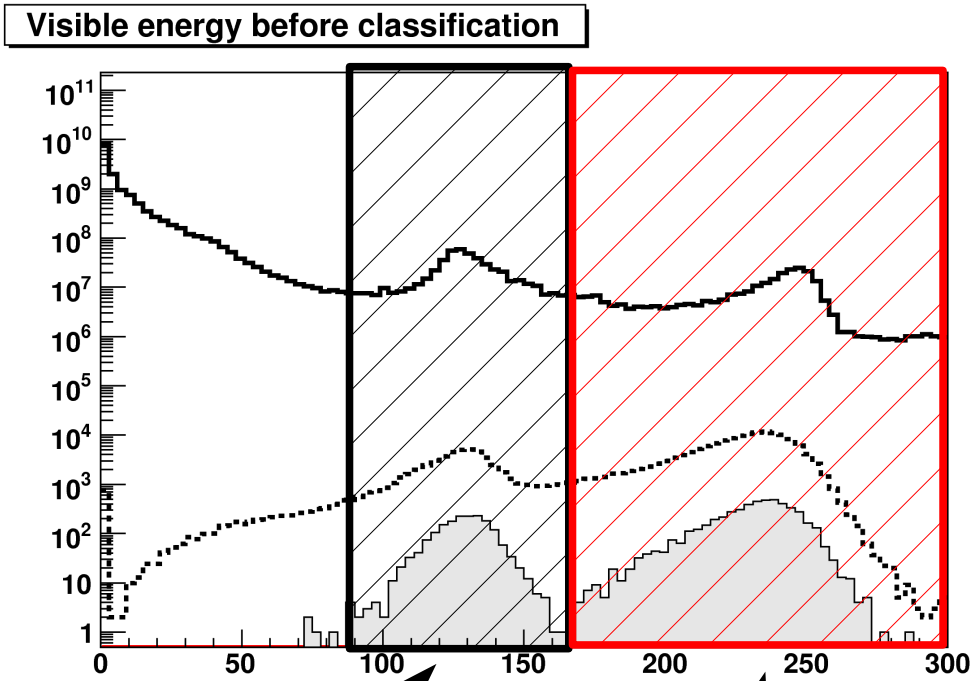


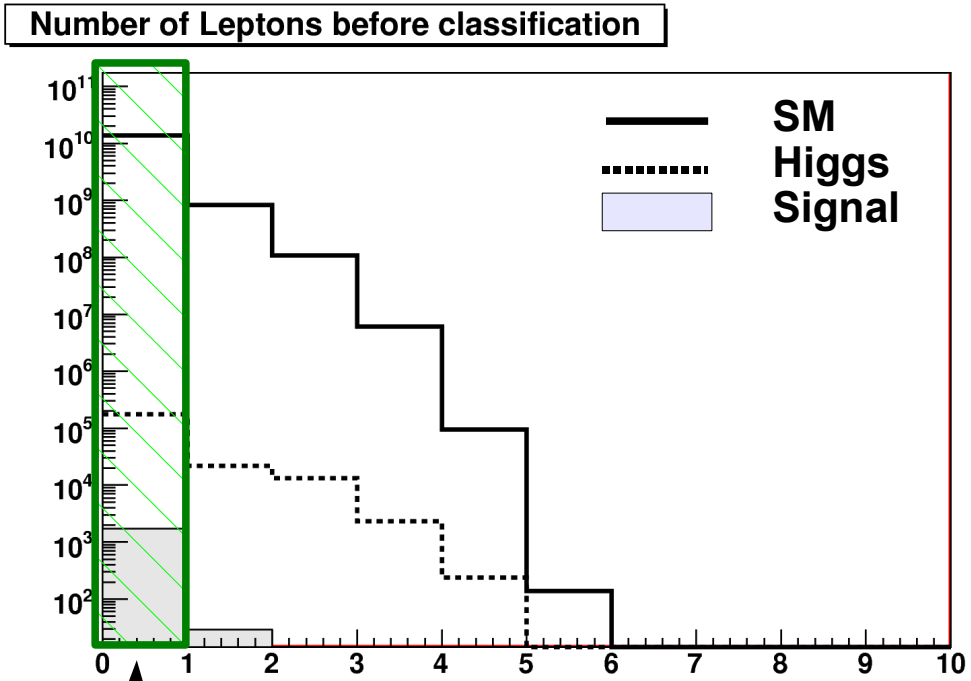
Optimized for SiD





Signal definition





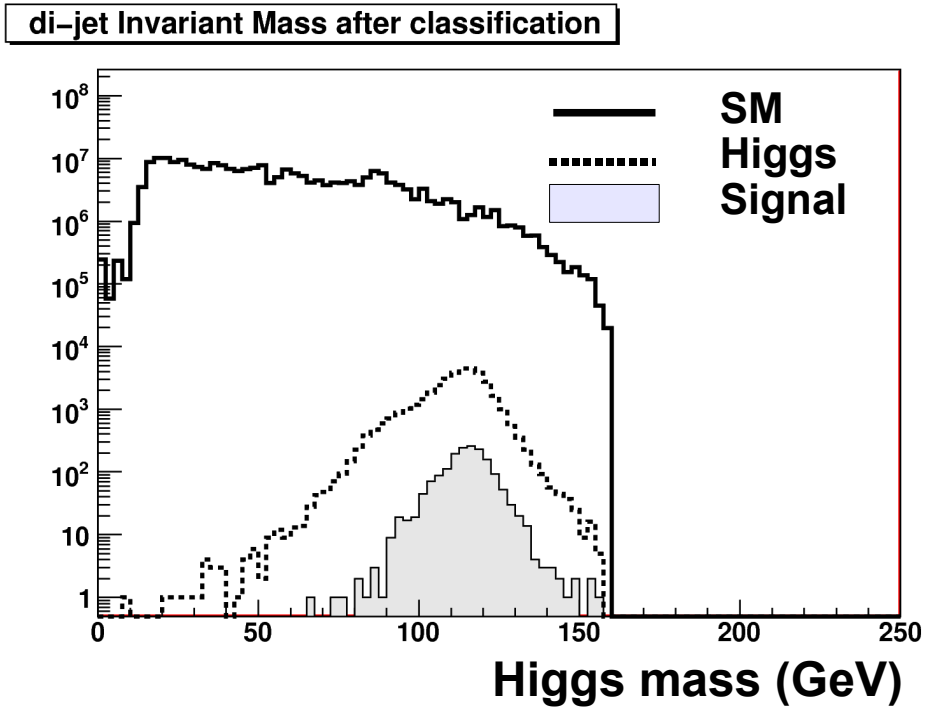
Missing energy channel

hadronic channel

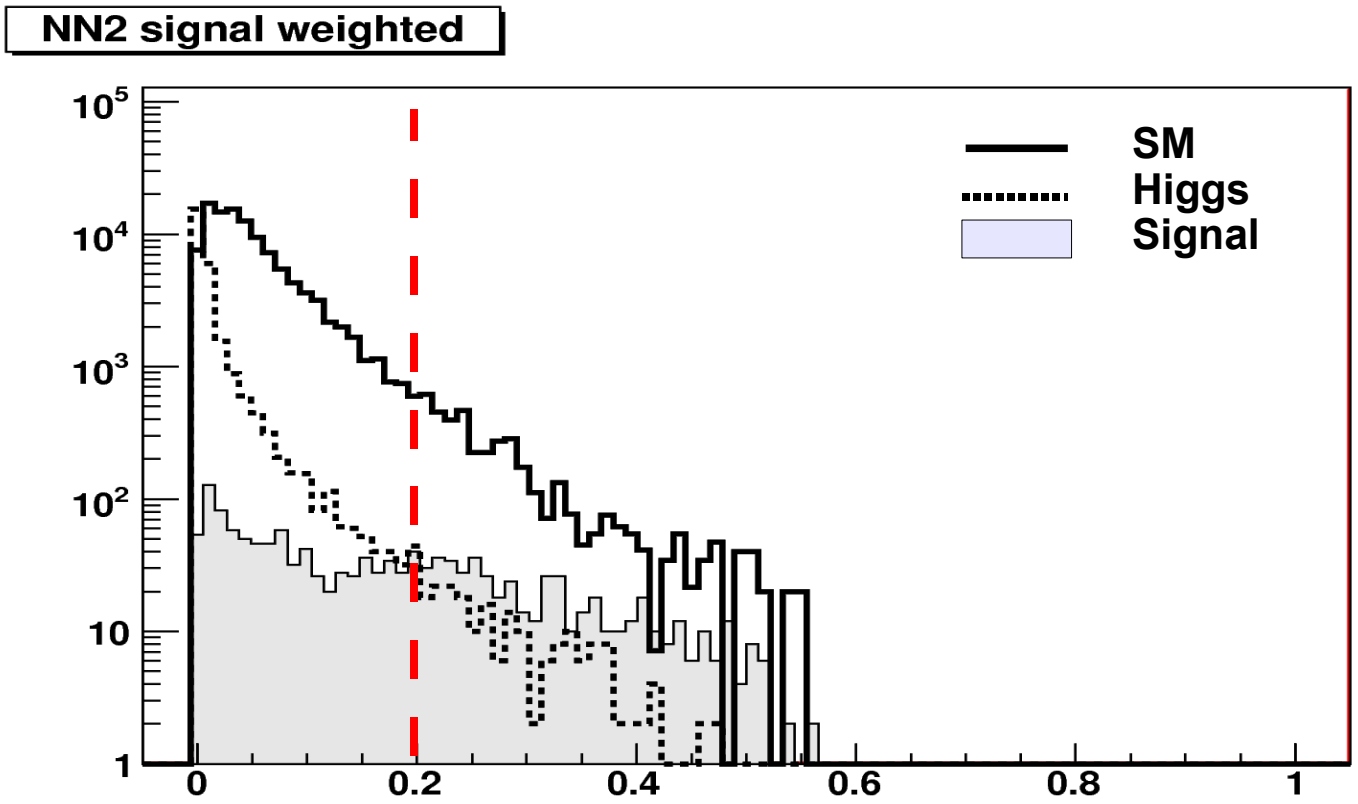
H → cc Signal

The missing energy channel

- Looking for
  - Dijet compatible with Higgs
  - Missing Mass compatible with Z
- Cuts
  - 20 <Jet P_T< 90 GeV
  - $-\log(y_{min})<0.8$
  - N_{tracks} (Jet)>4
  - Thrust <0.95 and cos(Thrust)<0.98
  - 100 < $Angle_{JetJet}$ 170°
  - 100 < m_{JetJet}<140 GeV
  - $E_{isol\ Photon}$< 10 GeV



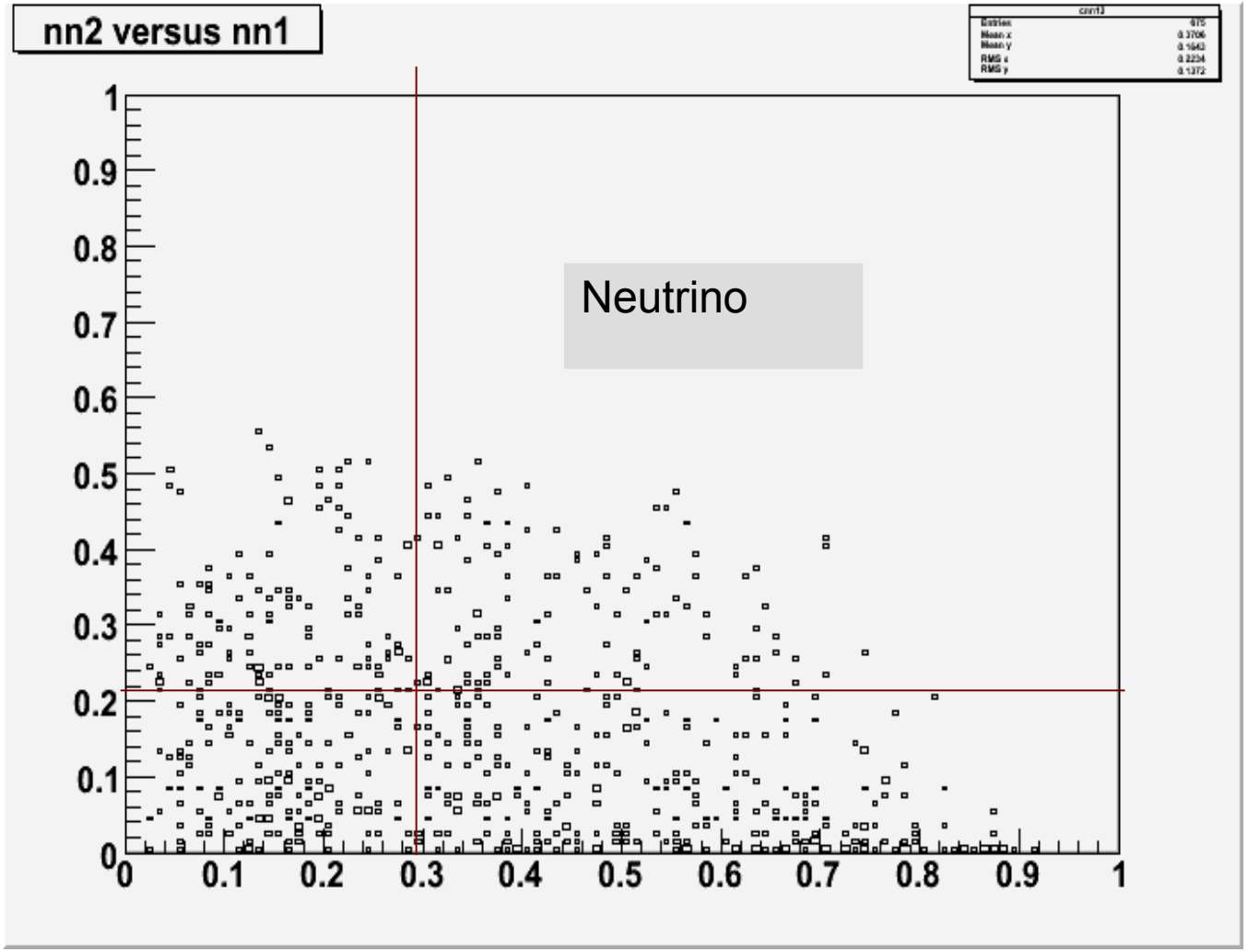
NN variables



Network 2

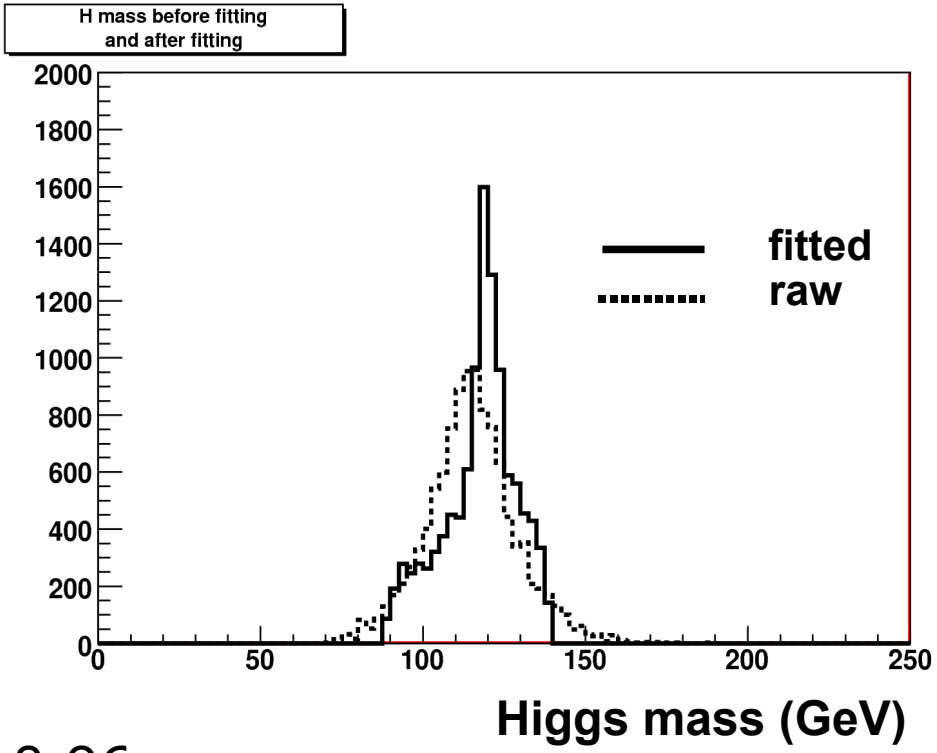
Higgs ↔ H→cc

2D-View

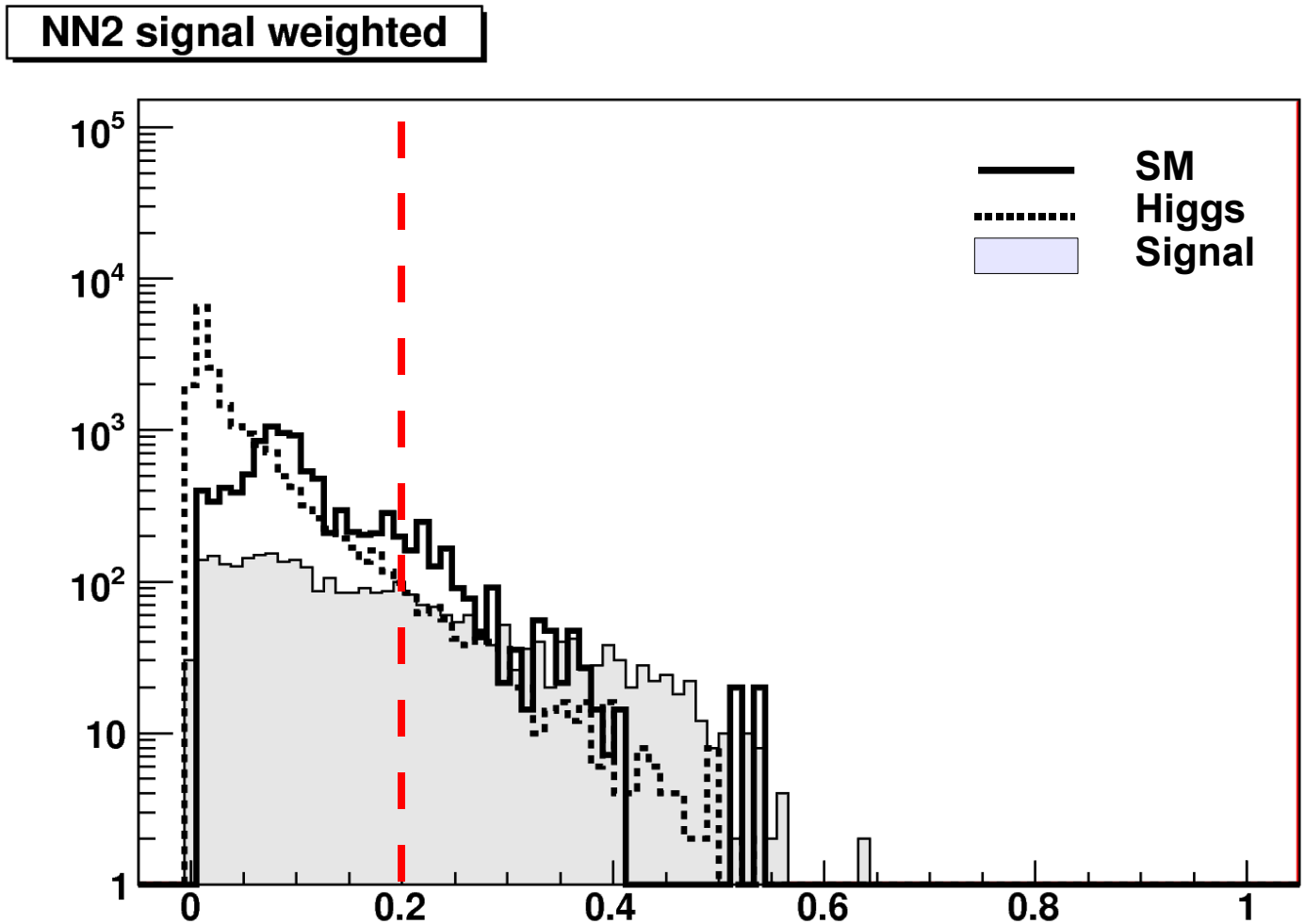


The hadronic channel

- Looking for
  - Dijet compatible with Higgs
  - Dijet compatible with Z mass
  - Pairing using kinematic fitting
- Cuts
  - $-\log(y_{min})<2.7$
  - N_{tracks} (Jet)>4
  - Thrust <0.95 and cos(Thrust)<0.96
  - $95 < m_{Higgs}<145$ GeV
  - $45 < m_Z<105$ GeV
  - $75 <\text{Angle}_{Jet1Jet3} < 165$
  - $50 <\text{Angle}_{Jet2Jet4} < 150$



NN variables



Network 2
Higgs ↔ H→cc

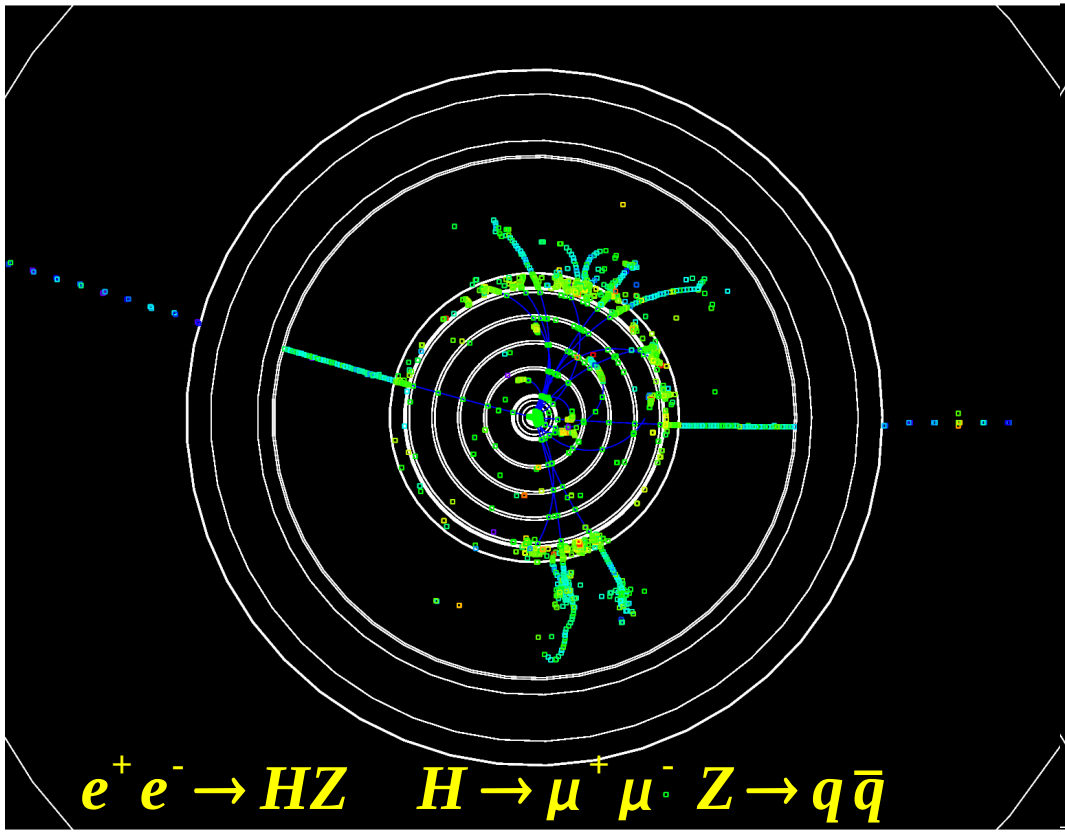
Results

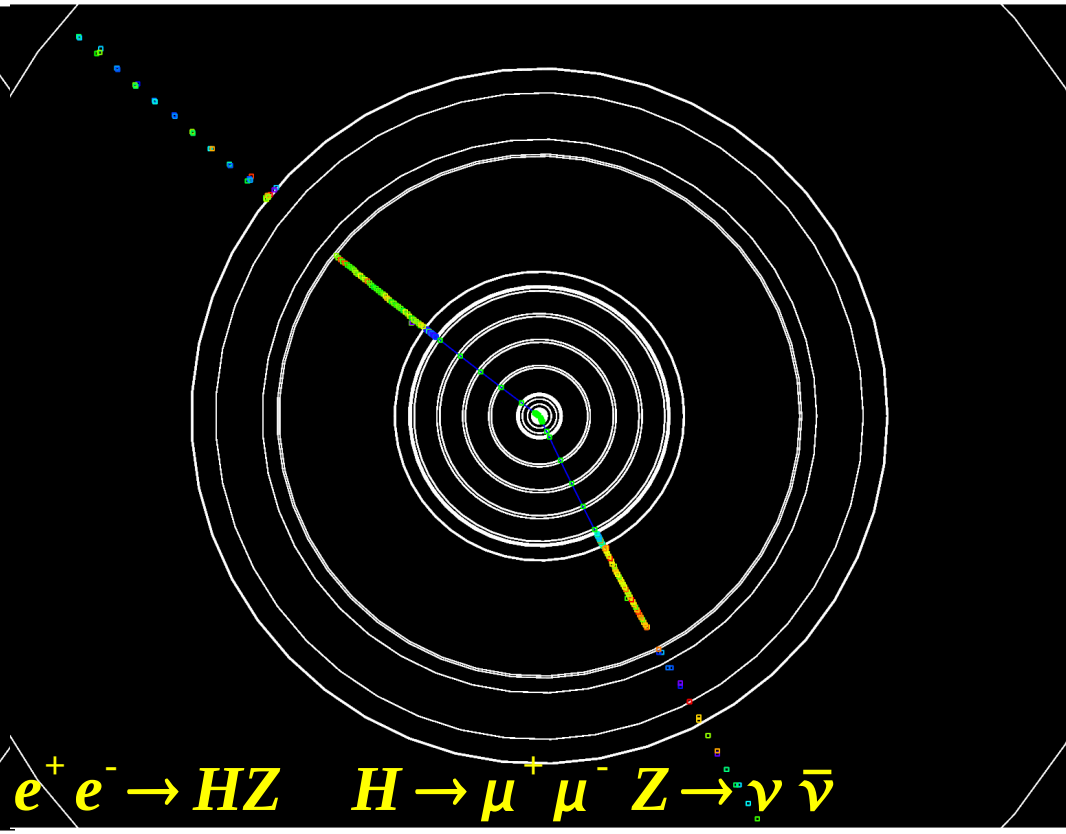
	Missing Energy	Hadronic
Sig. events	476	814
SM events	570	569
Higgs bk events	246	547
Signal efficiency	28%	47%
Signal σ	6.8±0.7 fb	6.9±0.4 fb
Br (H->cc)	3.3±0.4%	3.3±0.2%
ΔBr/Br	~ 11%	~ 6%

$H \rightarrow \mu^+\mu^-$

- Two analyses
  - Hadronic channel
  - Missing energy channel
- Common Muon preselection
  - Select two high momentum muons
- Final mass selection
  - Based on combined χ^2
- Main difficulty
  - Only 18.5 events in total
  - Dominated by 4-fermion background

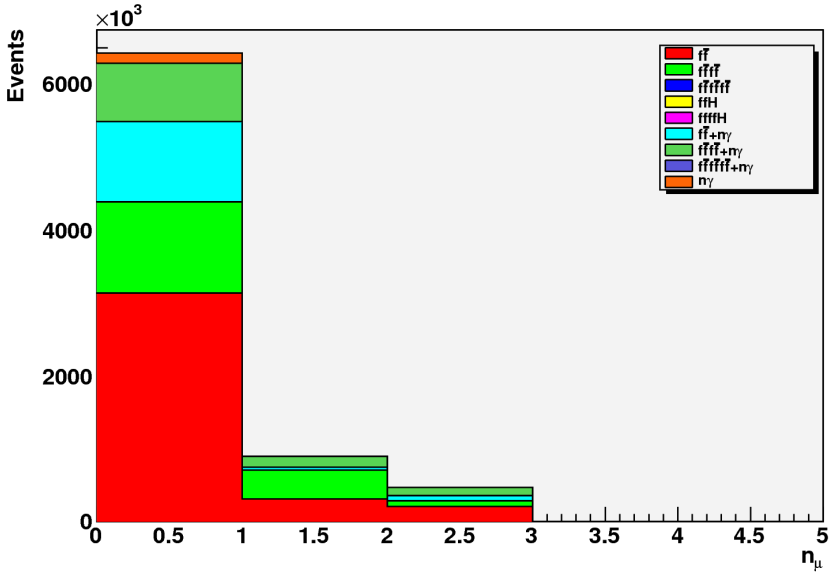
Typical Events

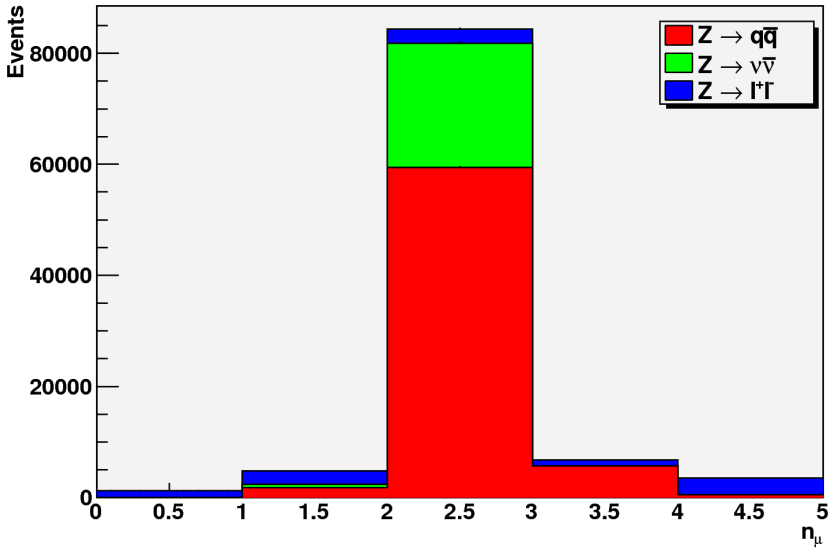




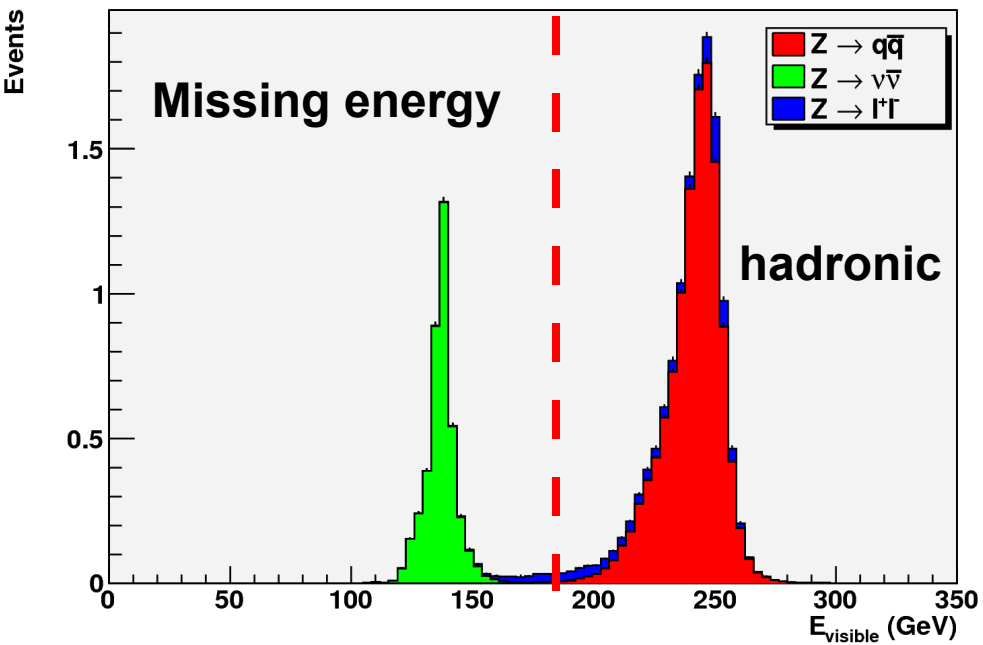
Selecting Muons

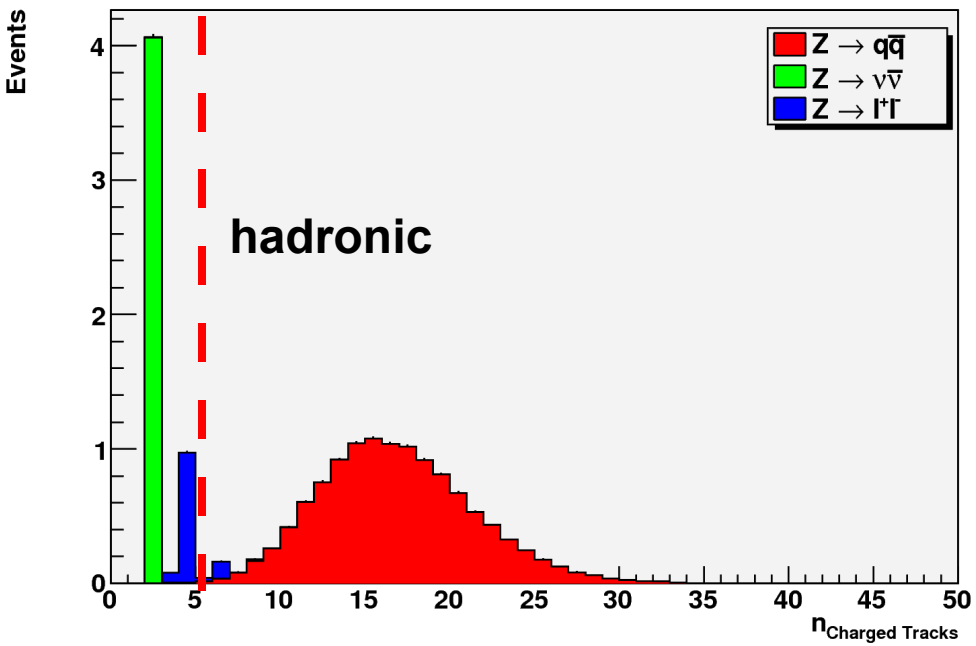
- Want two identified Muons
  - Following SiD-PFA Muon-ID
- Then we require the
  - Leading Muon E > 50 GeV
  - Second Muon E > 30 GeV
- 96 % efficient for signal
- Rejecting 99.7% of background





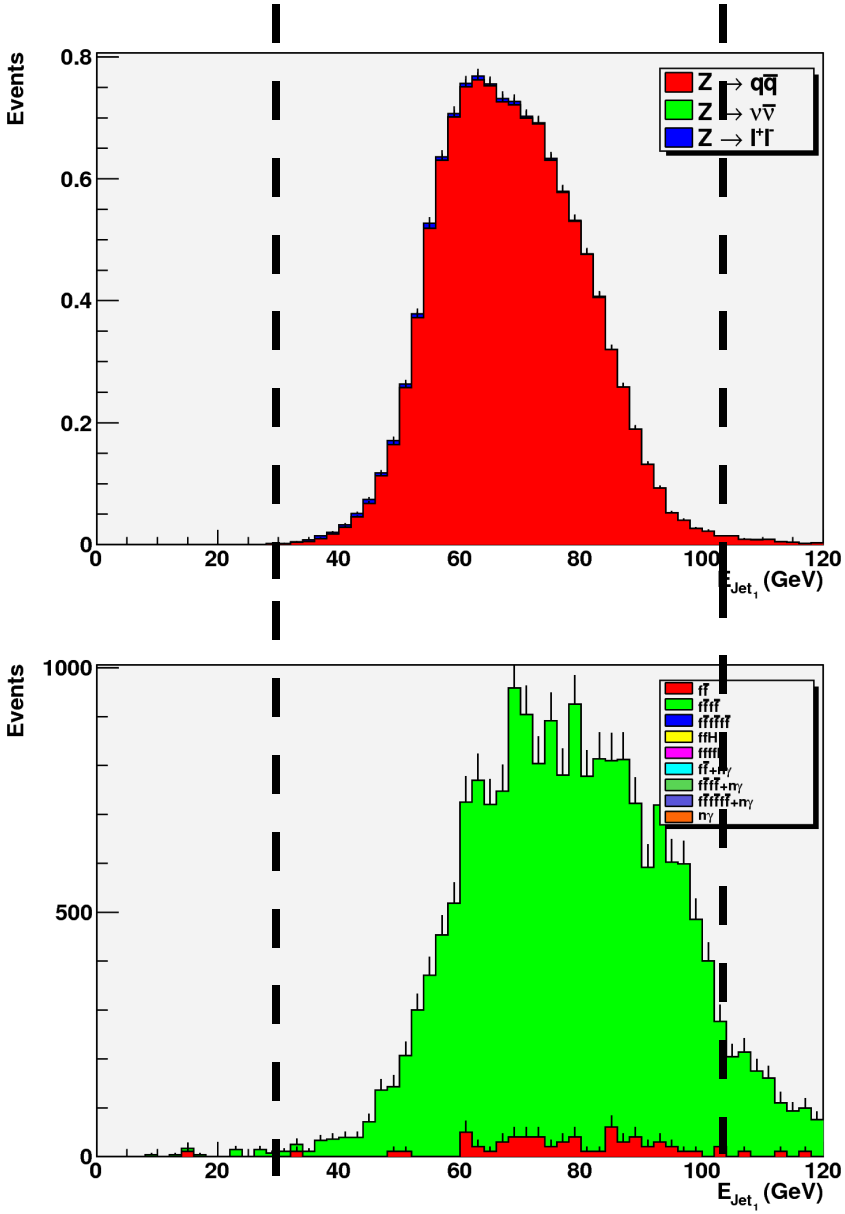
Defining the signal



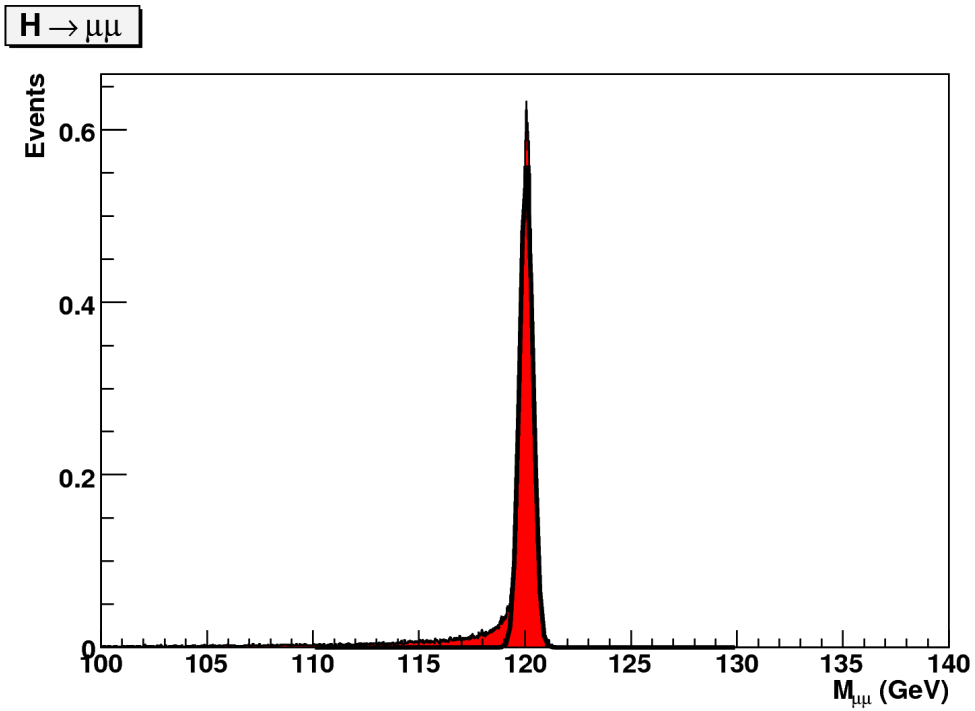


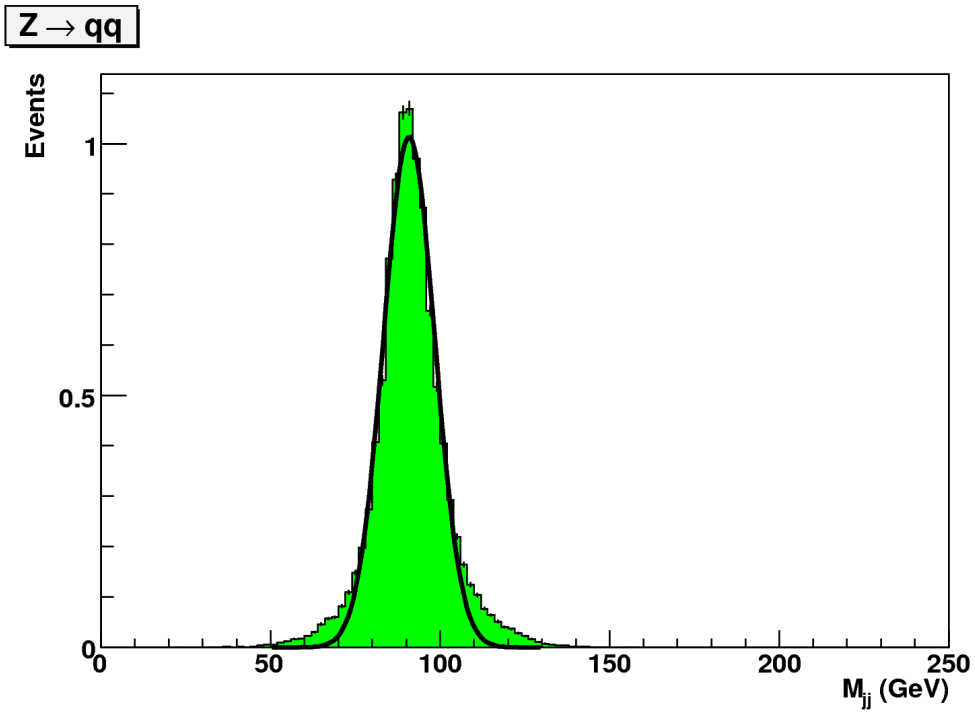
The hadronic channel

- Preselection
  - N_{Tracks} >5 , E_{vis} >190 GeV
  - Y_{cut}>0.05
  - 30 <E_{jet1} < 105 GeV
  - 10 <E_{jet2} < 70 GeV
  - $P_{T\ jet1,2}$ <90, 60 GeV
  - Muon Mass Window 120 ± 20 GeV



Mass resolution





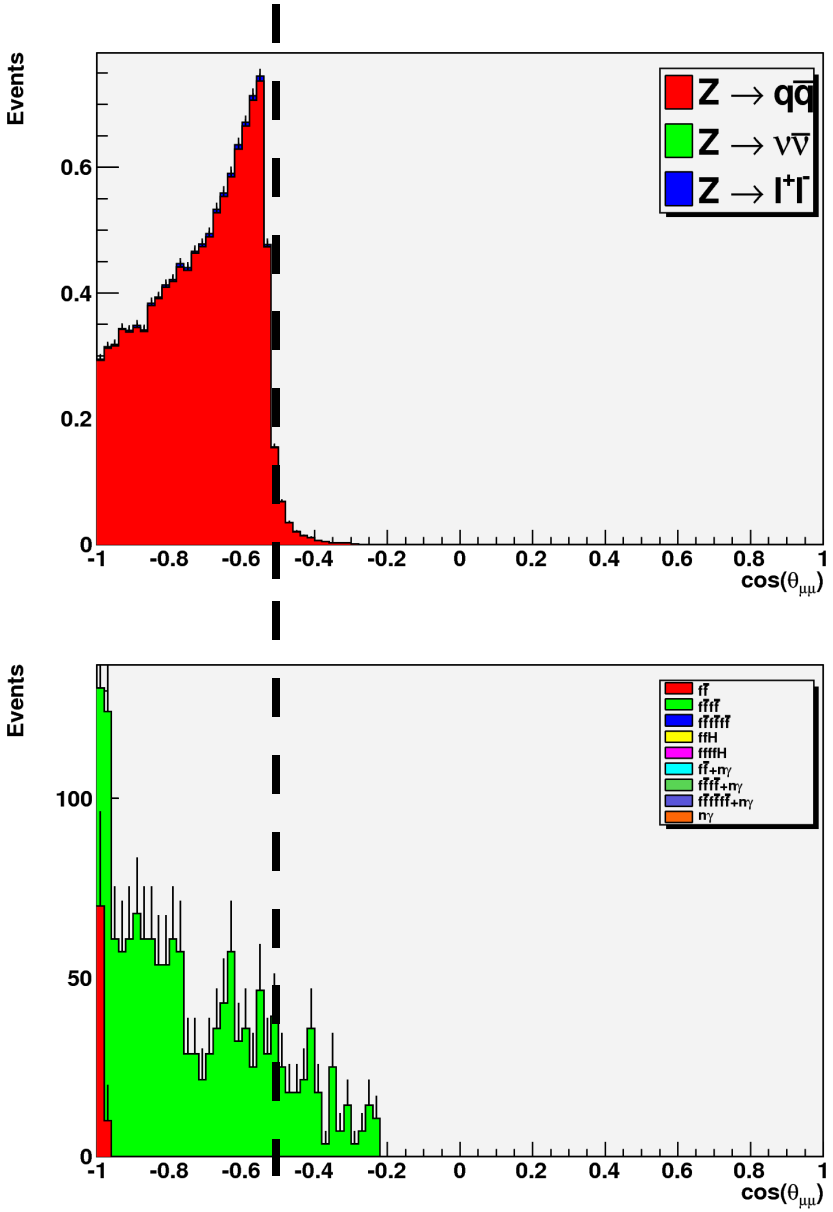
M_H=120.07 ± 0.30 GeV

M_H=90.84 ± 7.58 GeV

Using the Higgs signal sample after preselection
Using all Events in Barrel and Endcap

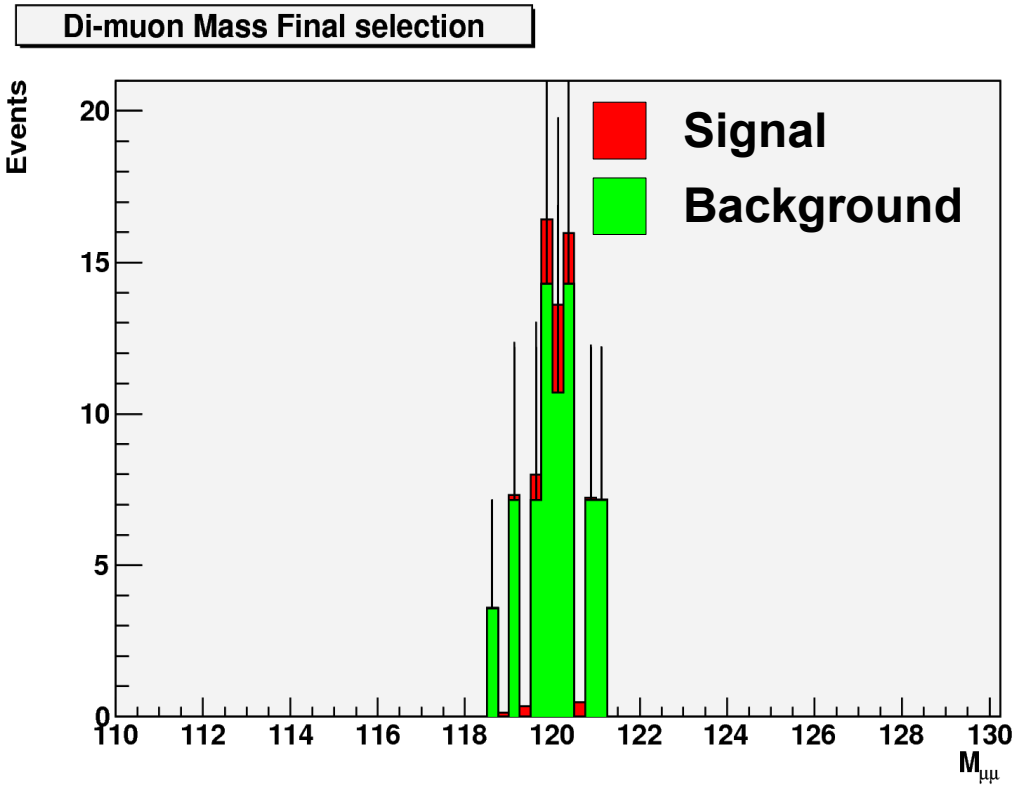
Event shape selection

- Muon opening angle $\cos(\theta_{\mu\mu}) < -0.5$
- Angle between reconstructed bosons $\cos(\theta_{BB}) < -0.8$
- Muon isolation angle w.r.t closest Jet > 0.1 rad
- Boson Acoplanarity > 2.8 rad



Results

- Final cut variables
  - $$\chi^2_{ZZ} = \left(\frac{m_{JJ} - M_Z}{\sigma_{JJ}}\right)^2 + \left(\frac{m_{\mu\mu} - M_Z}{\sigma_{\mu\mu}}\right)^2$$
  - $$\chi^2_{HZ} = \left(\frac{m_{JJ} - M_Z}{\sigma_{JJ}}\right)^2 + \left(\frac{m_{\mu\mu} - M_H}{\sigma_{\mu\mu}}\right)^2$$
- 7.66 Signal events
- 39.3 background events



- Cross section for $e^+e^- \to HZ \to \mu^+\mu^- q\bar{q}$
  - 0.074 ± 0.066 fb
- Remaining background
  - $e^+e^- \to ZZ/Z\gamma \to \mu^+\mu^- q\bar{q}$

Missing Energy channel

- Starting off with ~ 4 events
- With 250 fb^{-1} analysis has very limited reach
- Cut-based analysis is not sufficient
  - But need a lot more simulation for a NN
- A very quick check with FastMC looks promising
- Will pursuit this post-LoI

Outlook

- SiD is sensitive to this rare decay
- But
  - Need more MC to describe the tails
  - We are limited by available background simulation
  - Muon-ID could be made even better
  - Have plenty of ideas
- Stay tuned

Summary

- Studies based on Full simulation of SiD
- Big effort to produce all these samples
  - A Big thank you to the production team!
- Thanks to Y. Banda, T. Barklow and A. Nomerotski for comments and material.