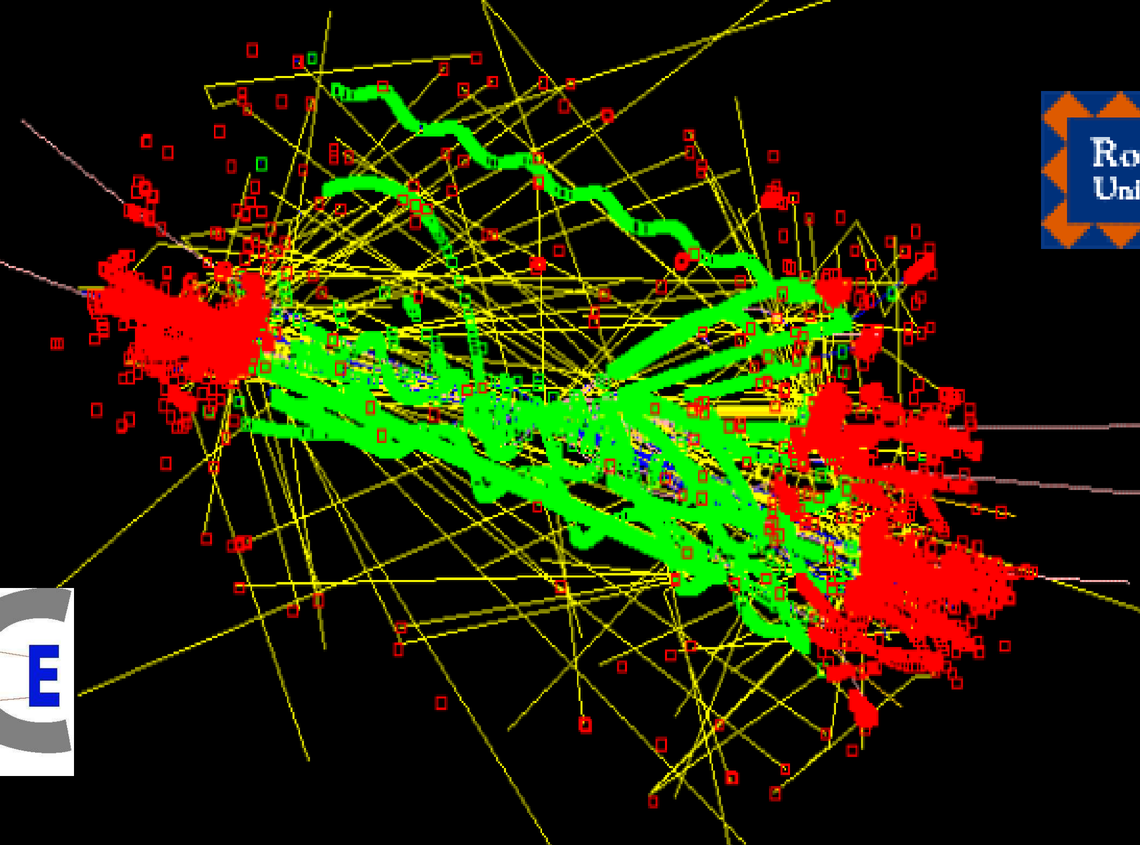
ZHH: Linear collider Benchmark



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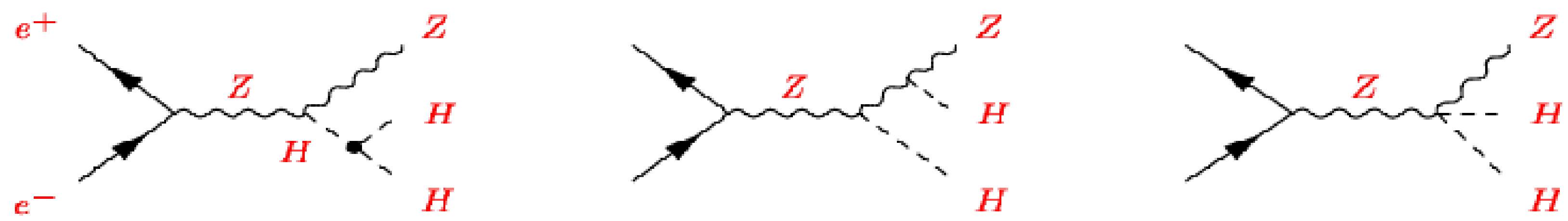
Fabrizio Salvatore

Outline

- Why ZHH?
- Software
- Selection criteria for Z and H
- Comparison between detectors
- Conclusion

ZHH

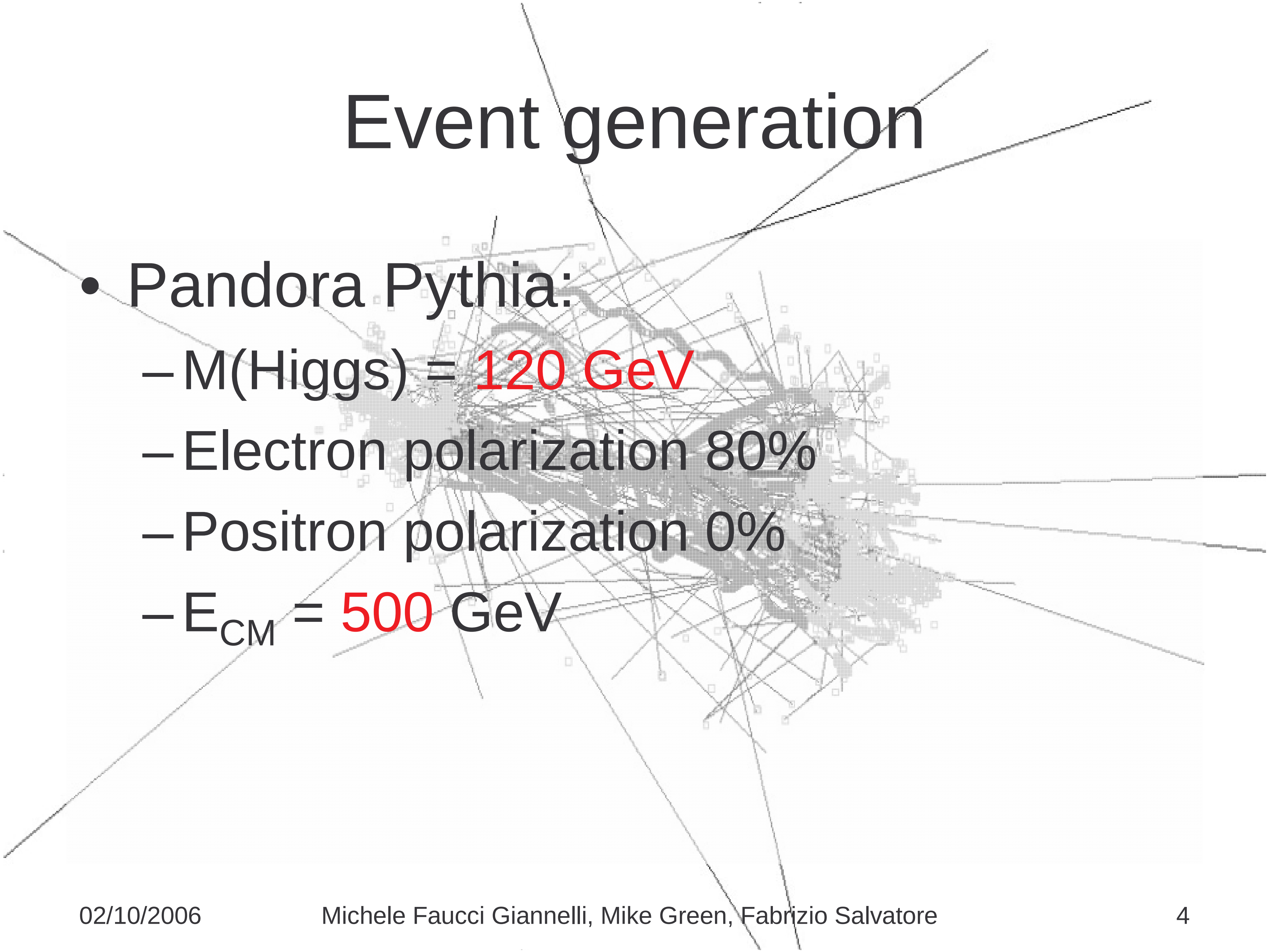
- Study of Higgs self coupling constant



- These events can also be used as benchmark:
  - Different detector model
  - Particle flow algorithms

Event generation

- Pandora Pythia:
  - M(Higgs) = 120 GeV
  - Electron polarization 80%
  - Positron polarization 0%
  - E_{CM} = 500 GeV

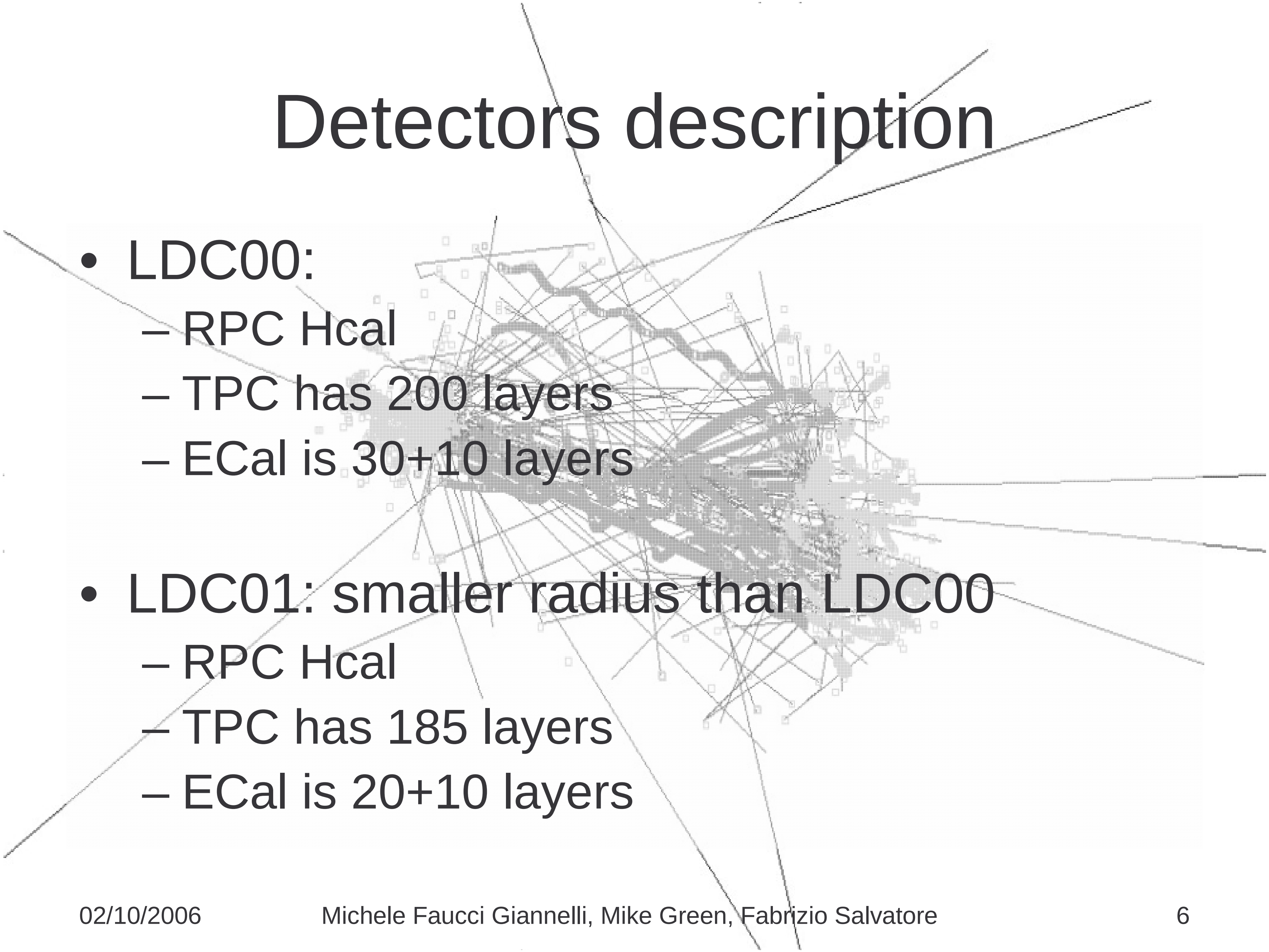


Detector Simulation

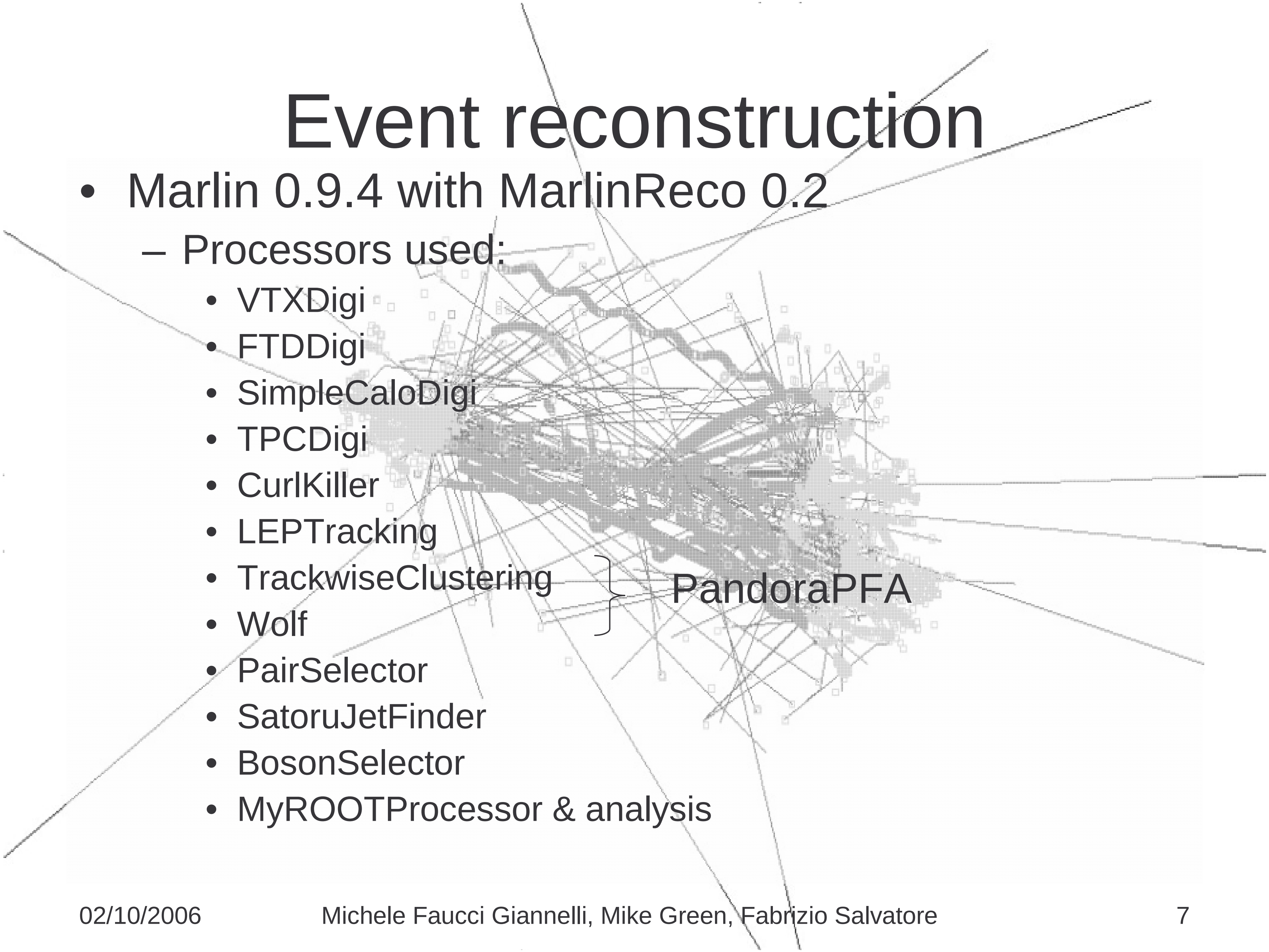
- Mokka V6.0
  - Two different detector model
    - LDC00
    - LDC01
  - Very slow processing time, could be a problem when simulating large MC samples.

Detectors description

- LDC00:
  - RPC Hcal
  - TPC has 200 layers
  - ECal is 30+10 layers
- LDC01: smaller radius than LDC00
  - RPC Hcal
  - TPC has 185 layers
  - ECal is 20+10 layers



Event reconstruction



- Marlin 0.9.4 with MarlinReco 0.2
  - Processors used:
    - VTXDigi
    - FTDDigi
    - SimpleCaloDigi
    - TPCDigi
    - CurlKiller
    - LEPTracking
    - TrackwiseClustering } PandoraPFA
    - Wolf }
    - PairSelector
    - SatoruJetFinder
    - BosonSelector
    - MyROOTProcessor & analysis

ZHH, first look at the backgrounds

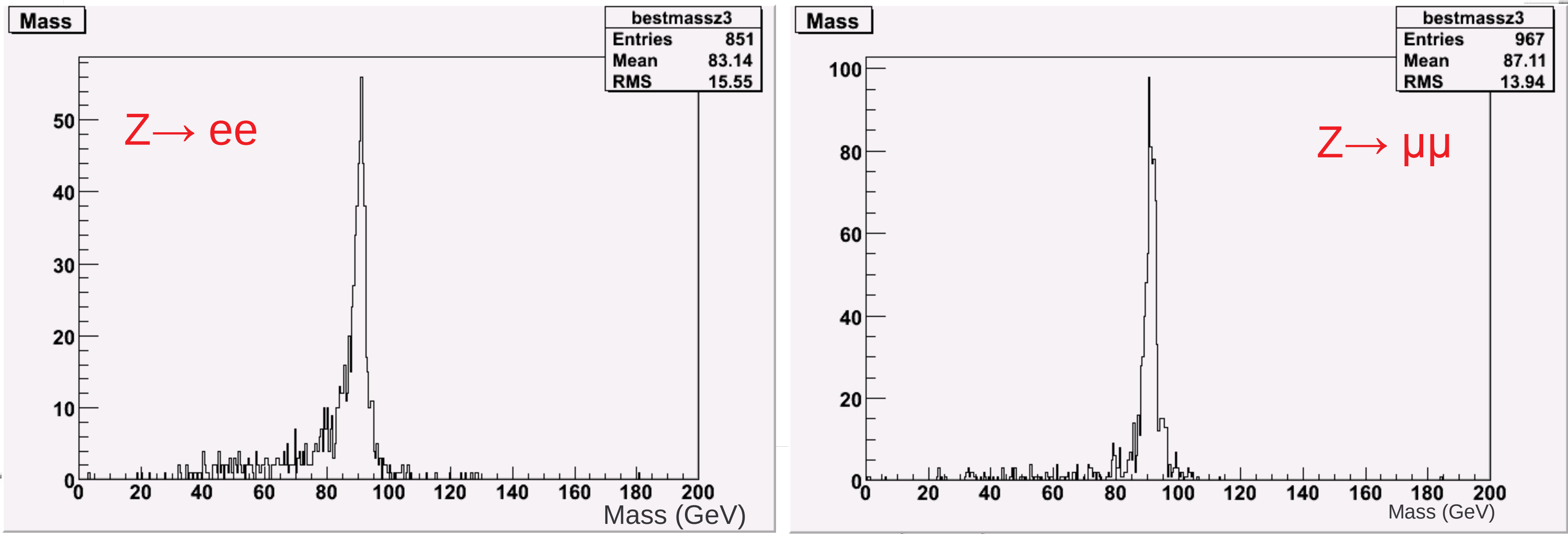
- Only ZZH and bbH available in Pandora.

Channels	Cross section (fb)
ZHH (total)	0.142
ZHH ($Z\rightarrow e^+e^-$, $H\rightarrow bb$)	0.00237
ZZH ($Z1\rightarrow e^+e^-$,Z2, $H\rightarrow bb$)	0.00358
bbH (total)	7.2

- Ratio bbH/ZHH ~ 3000

Z selection

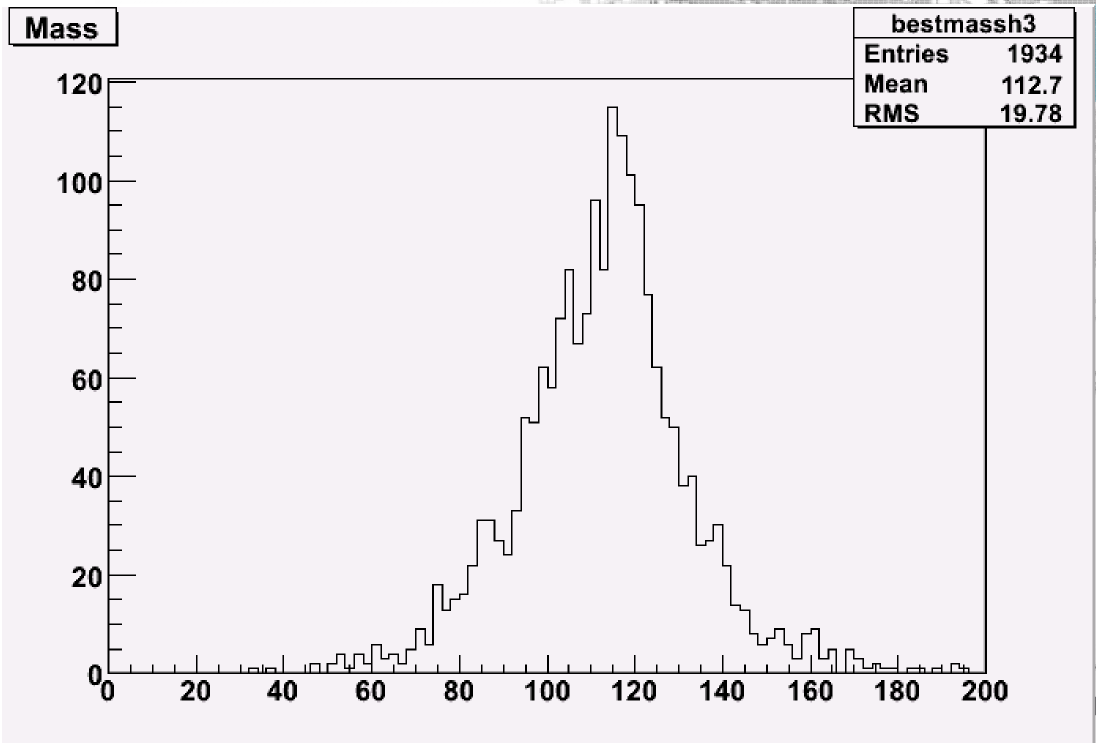
- In PairSelector:
  - two particles (electrons or muons) of opposite charge
  - Each of them must have an energy > 10 GeV



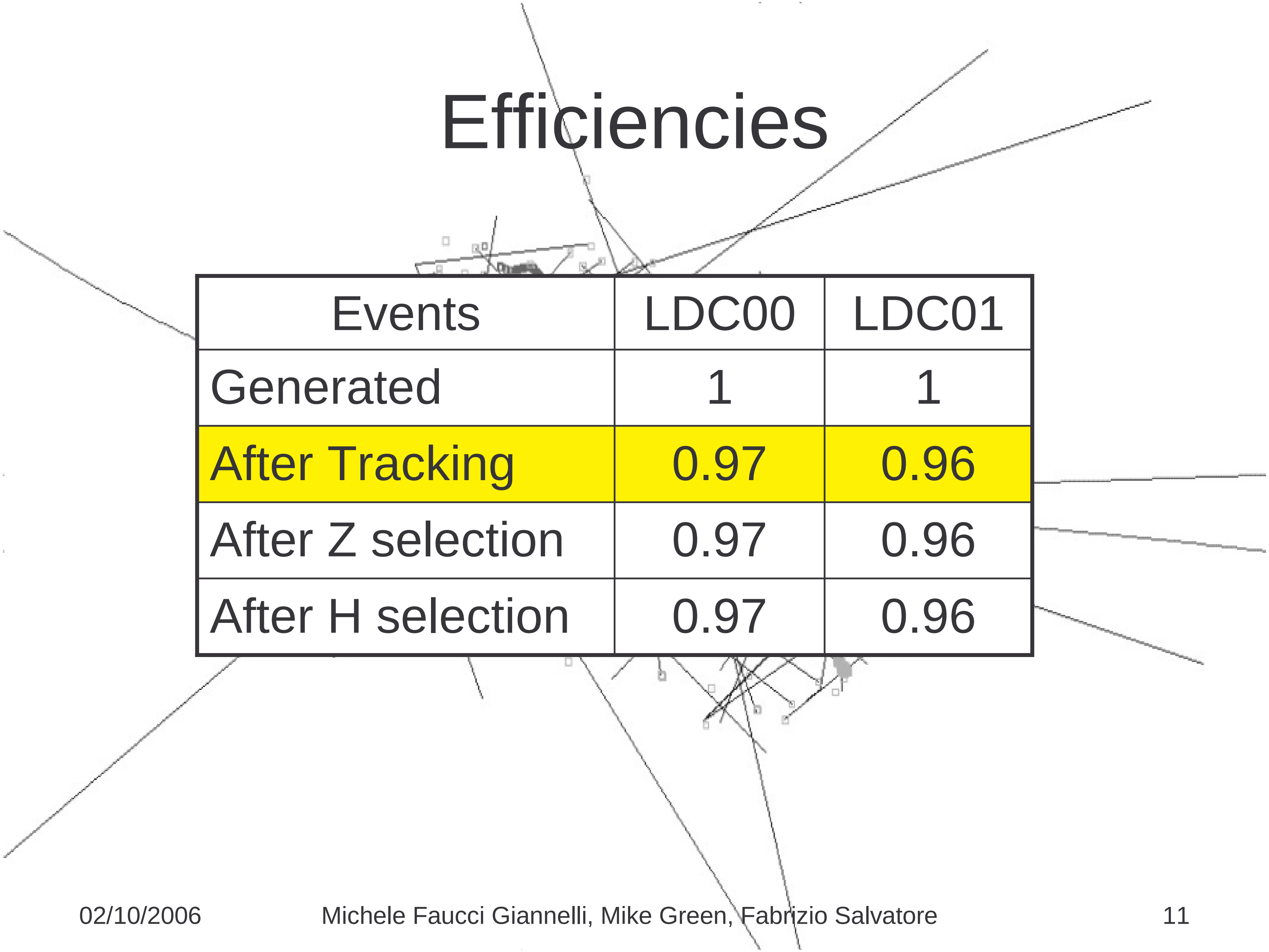
Higgs Selection

- In SatoruJetFinding
  - Request 4 jets
- In BosonSelector:
  - Combine the jets to minimize

$$_{hh}^{2} = (m_{12} - m_h)^2 + (m_{34} - m_h)^2$$



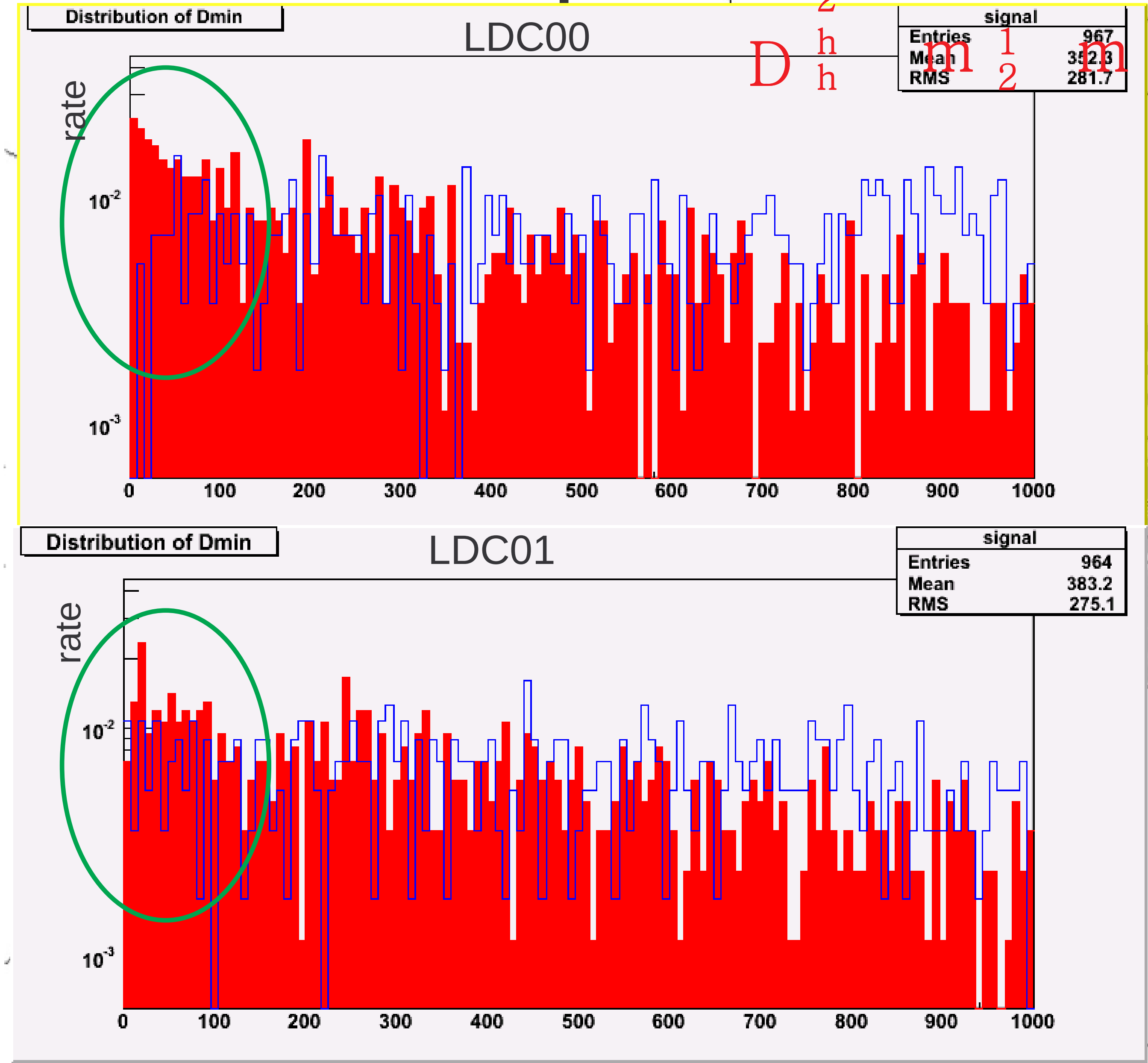
Efficiencies



Events	LDC00	LDC01
Generated	1	1
After Tracking	0.97	0.96
After Z selection	0.97	0.96
After H selection	0.97	0.96

D^2 plot

$$D_{hh}^2 = (m_{12} - m_h)^2 + (m_{34} - m_h)^2$$

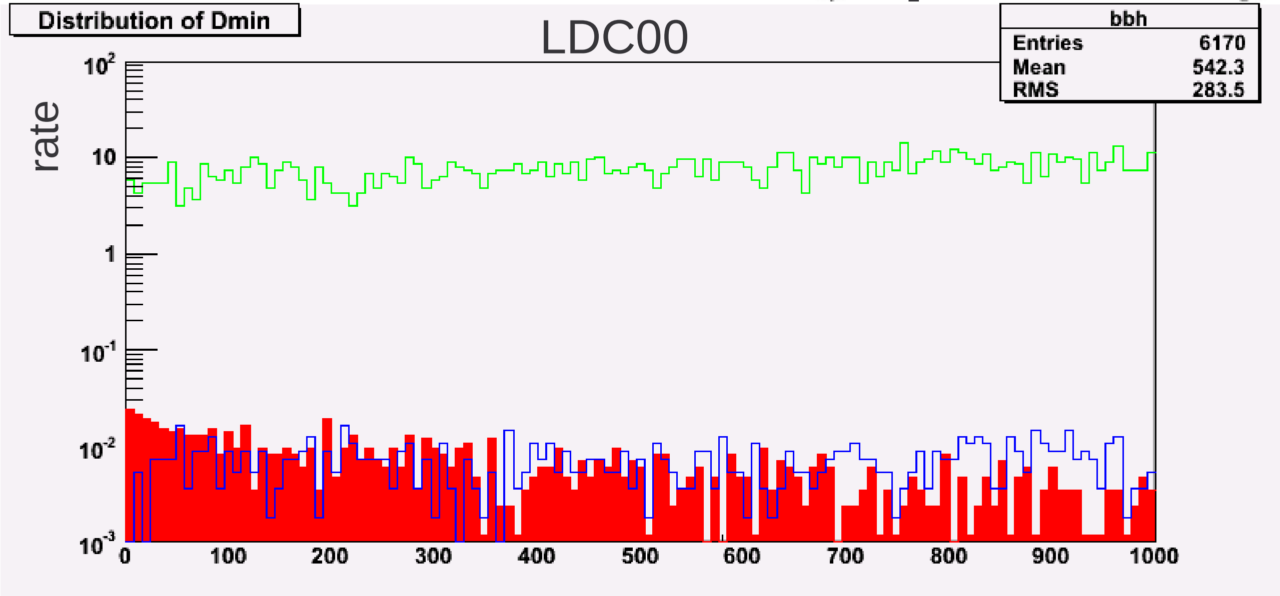


- Signal ZHH (Z→ μμ)
- ZZH Background

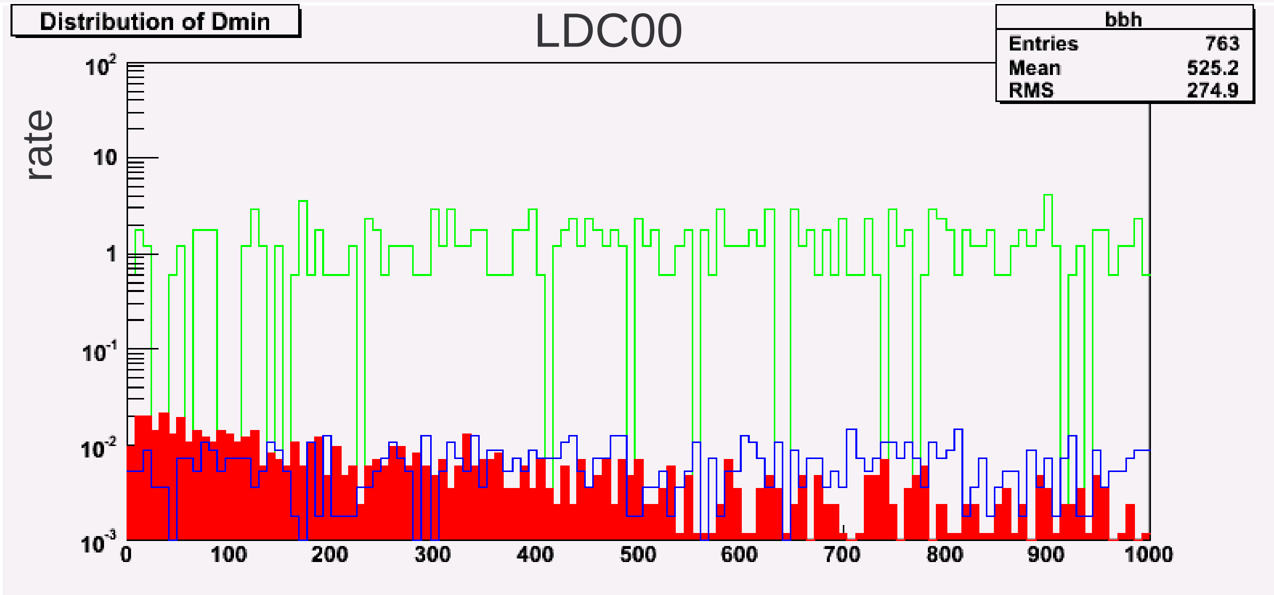
- **First physical evidence of the need of a bigger detector**

500 fb^{-1}

D^2 plot

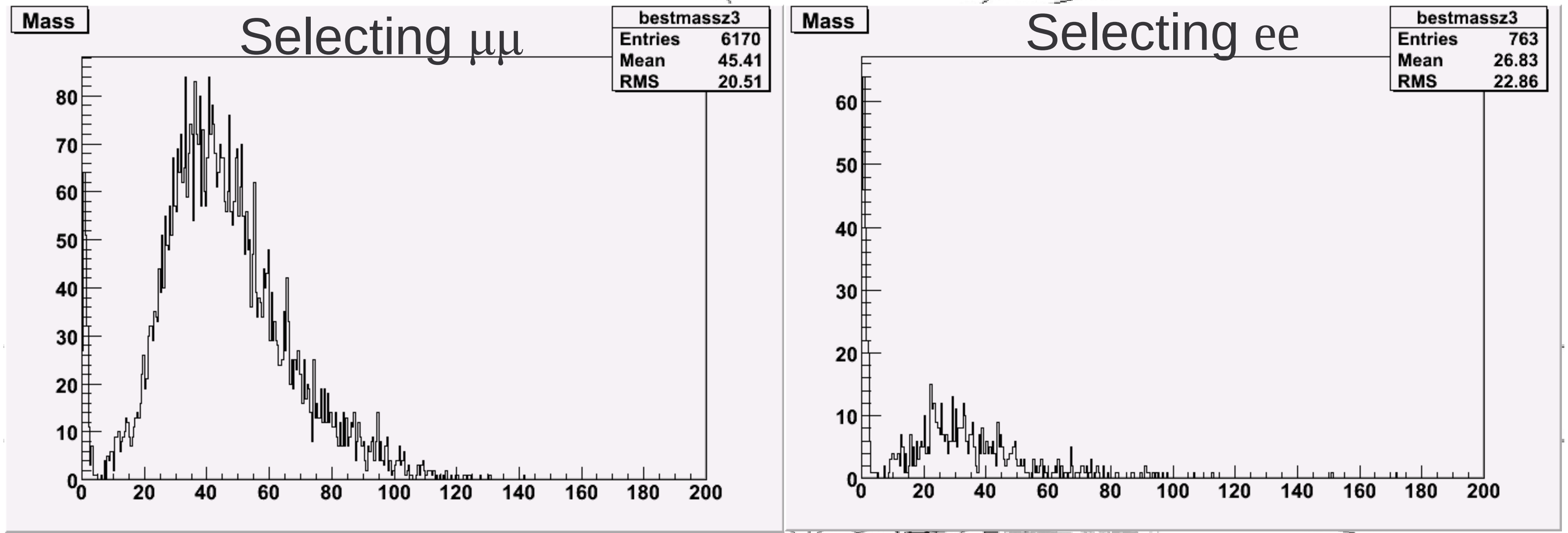


- Signal ZHH (Z→ μμ)
- ZZH Background
- bbH Background



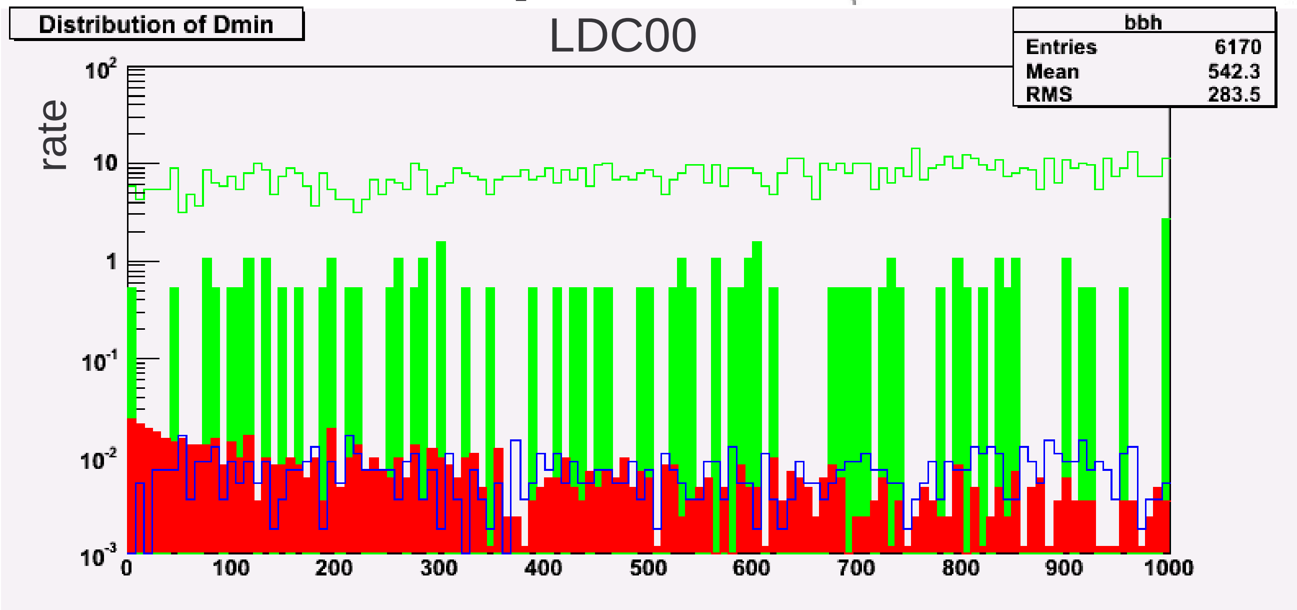
- Signal ZHH (Z→ ee)
- ZZH Background
- bbH Background

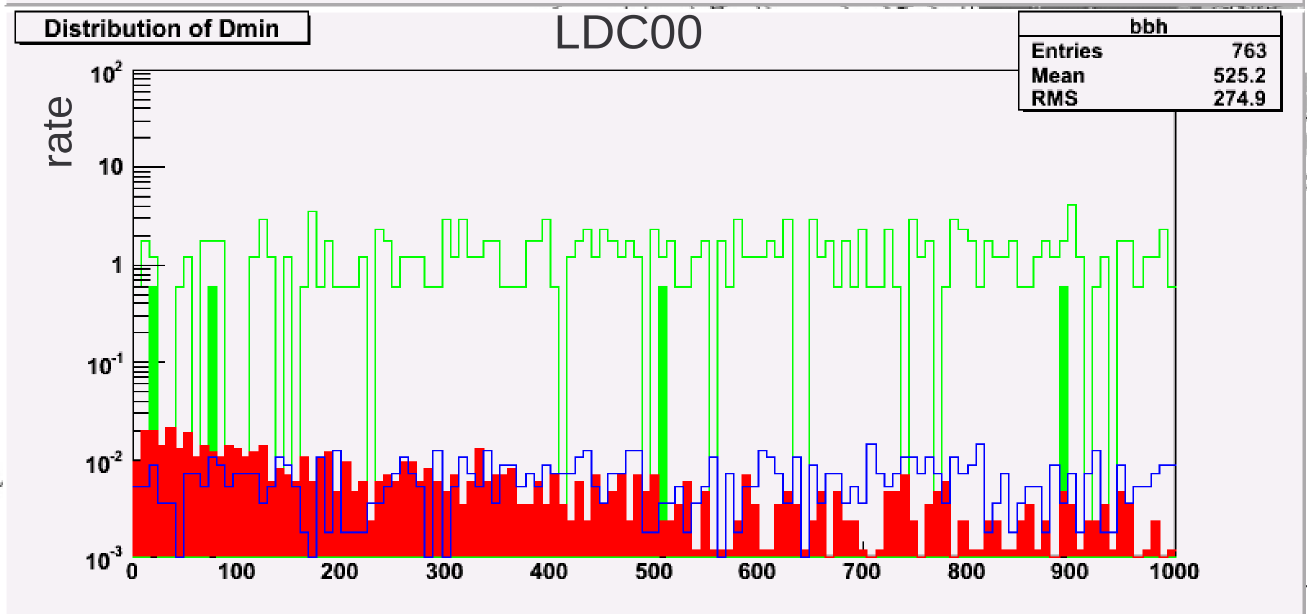
Reconstructed Z Mass for bbH



- The difference is due to the missing muon id:
  - Muons and pions are not separated
  - one or both “muons” can be a pion
- Then there are more “muons” than electrons

D^2 plot with Z mass cut





- Signal ZHH (Z→ μμ)
- ZZH Background
- bbH Background

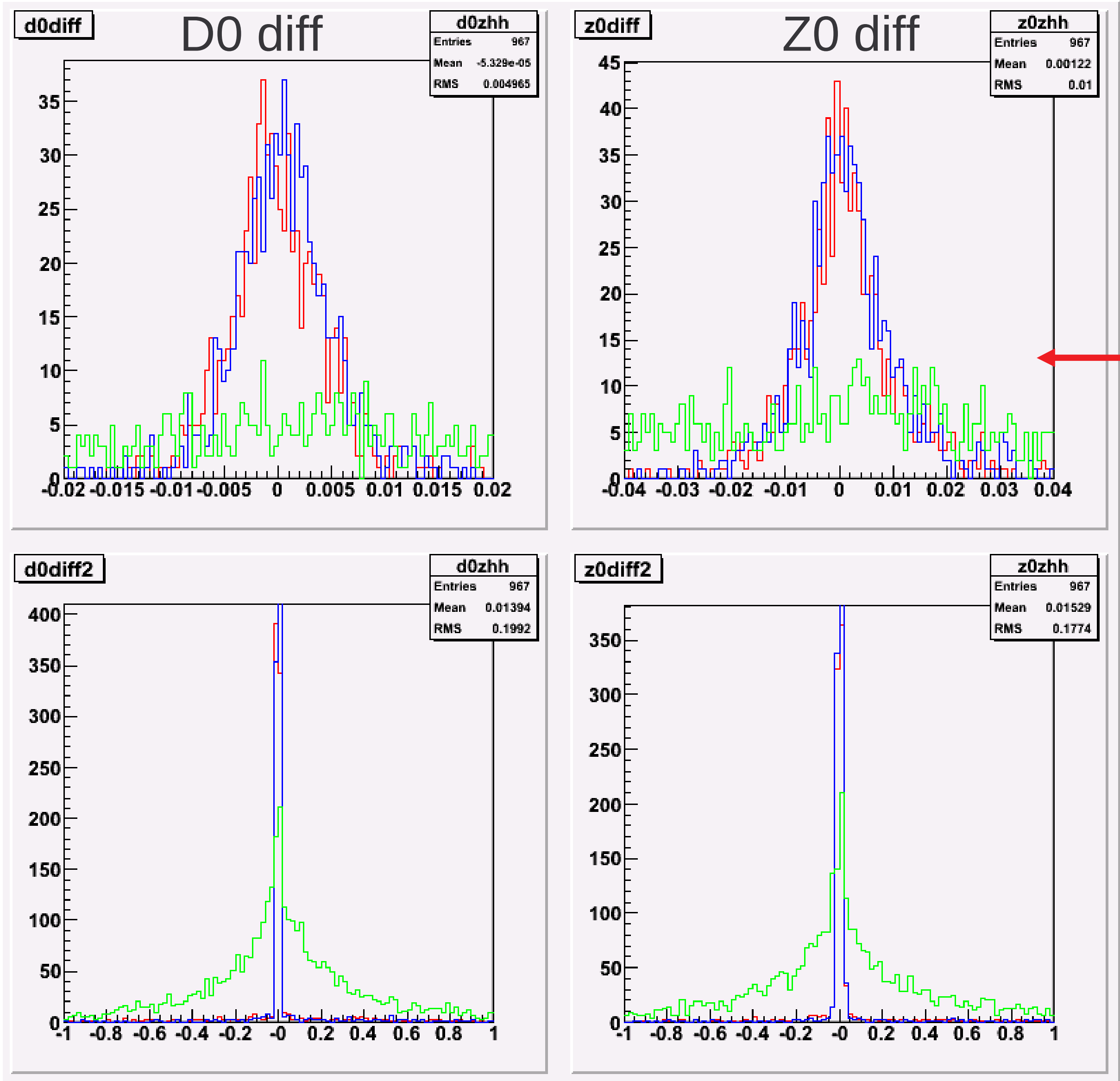
Bold Green

Cut on Z mass

80 < Select < 100

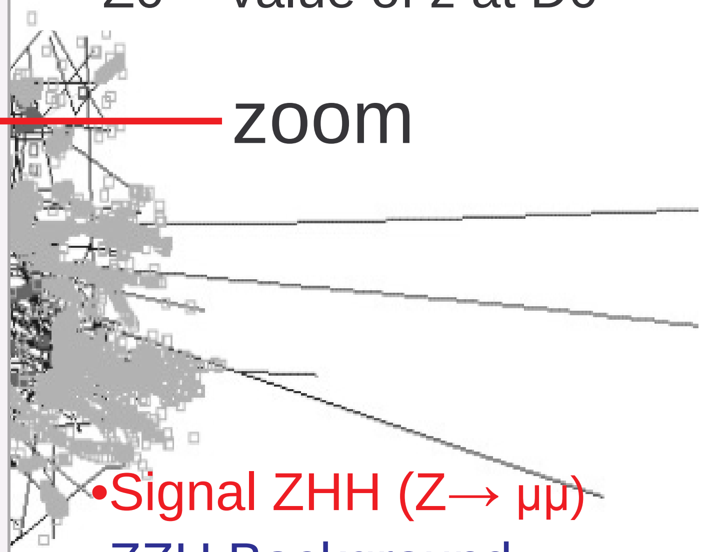
- Signal ZHH (Z→ ee)
- ZZH Background
- bbH Background

ΔD0 and ΔZ0 for lepton tracks



D0 = distance of closest approach to z axis

Z0 = value of z at D0

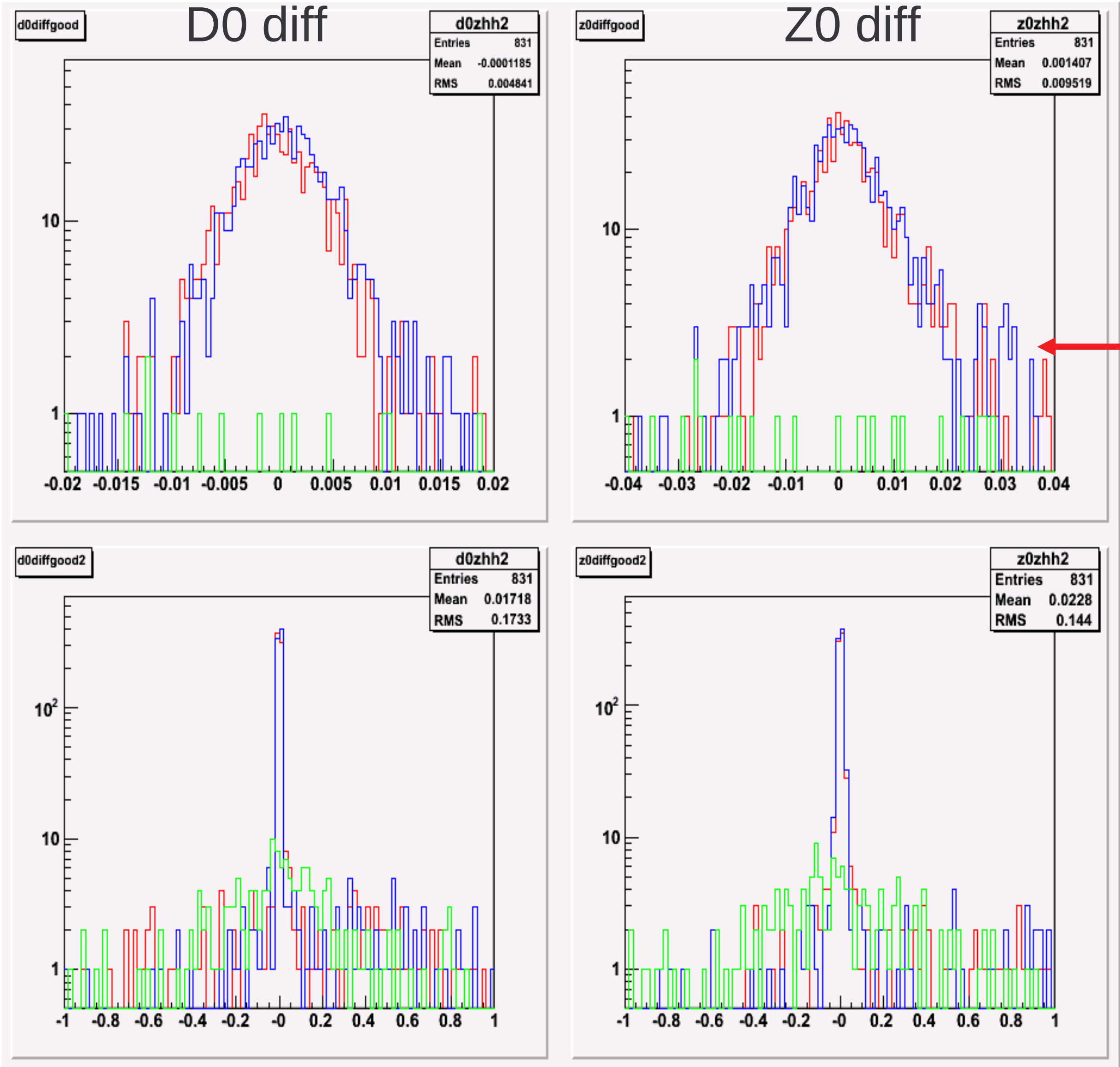


zoom

- Signal ZHH (Z→ μμ)
- ZZH Background
- bbH Background

No cut on Z mass

ΔD0 and ΔZ0 for lepton tracks



Cut on Z mass

80 < Select < 100

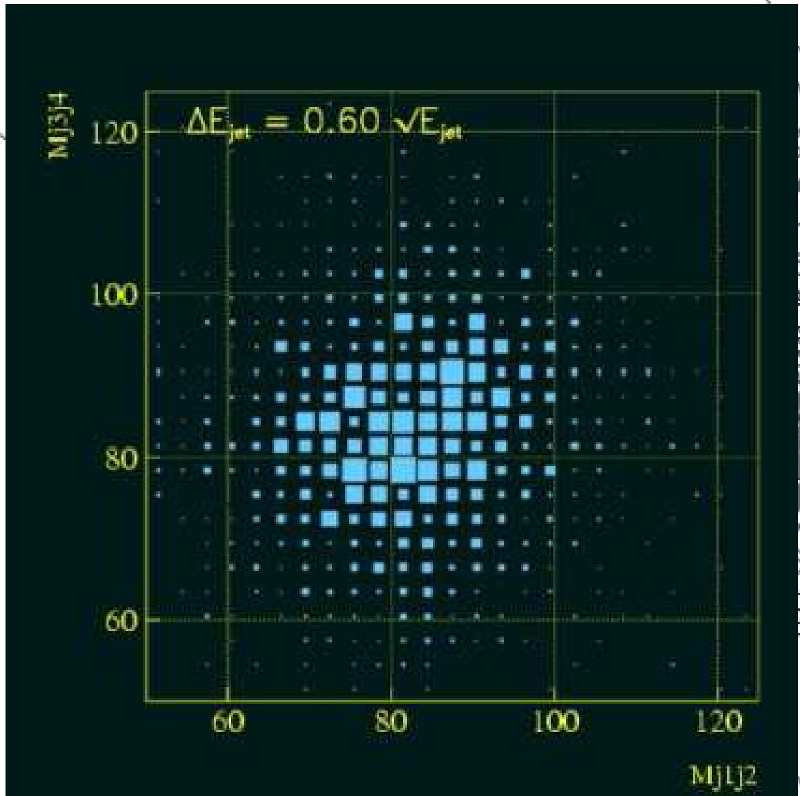
zoom

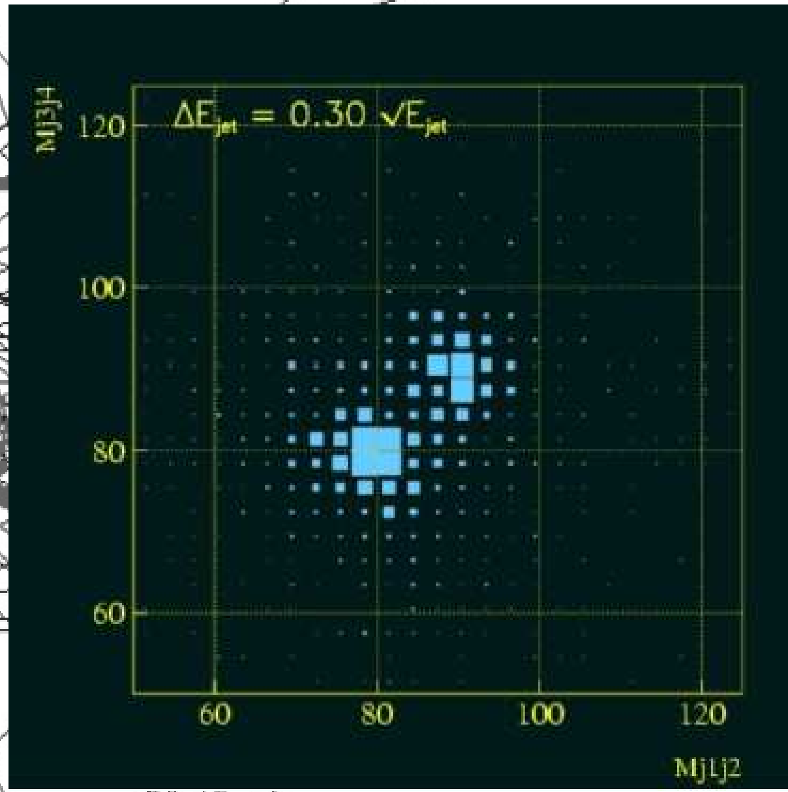
- Signal ZHH (Z→ μμ)
- ZZH Background
- bbH Background

Possible improvements

- Looking for other variables to discriminate signal from bHH background:
  - Angle between lepton and jet, small for bbH, large for ZHH.
  - $D' = (m_{12} + m_{34} - 2m_H)$
- Need for more background statistic
- Investigating possibility to use fast simulation

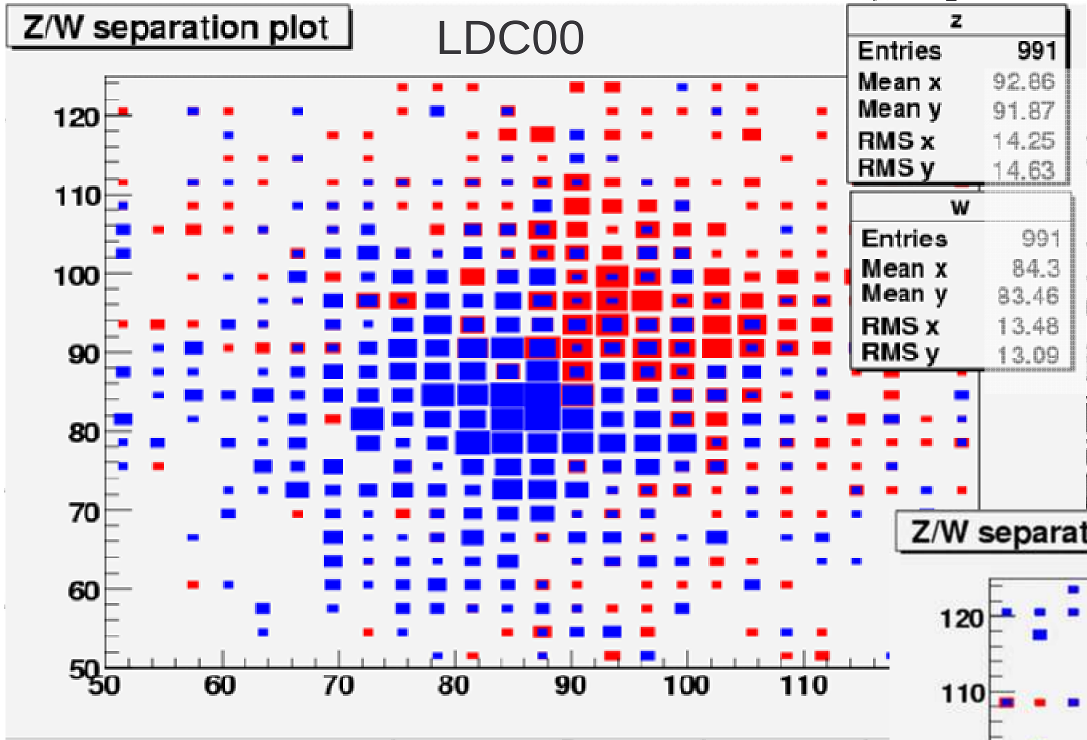
Z/W separation





- Simulation using MC information

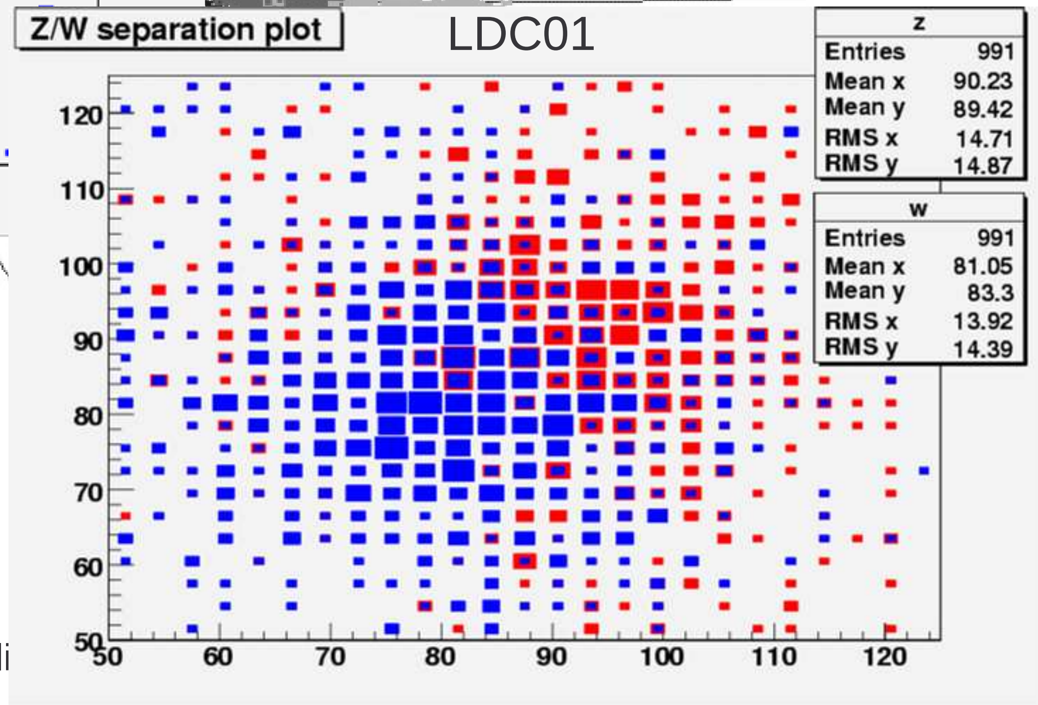
Z/W separation



WOLF

+

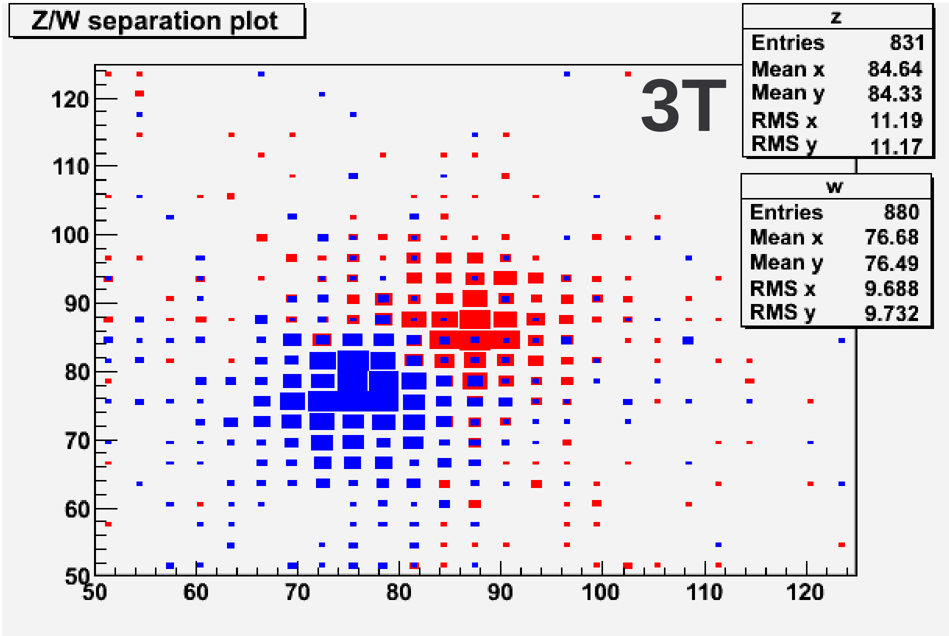
TrackWise Clustering

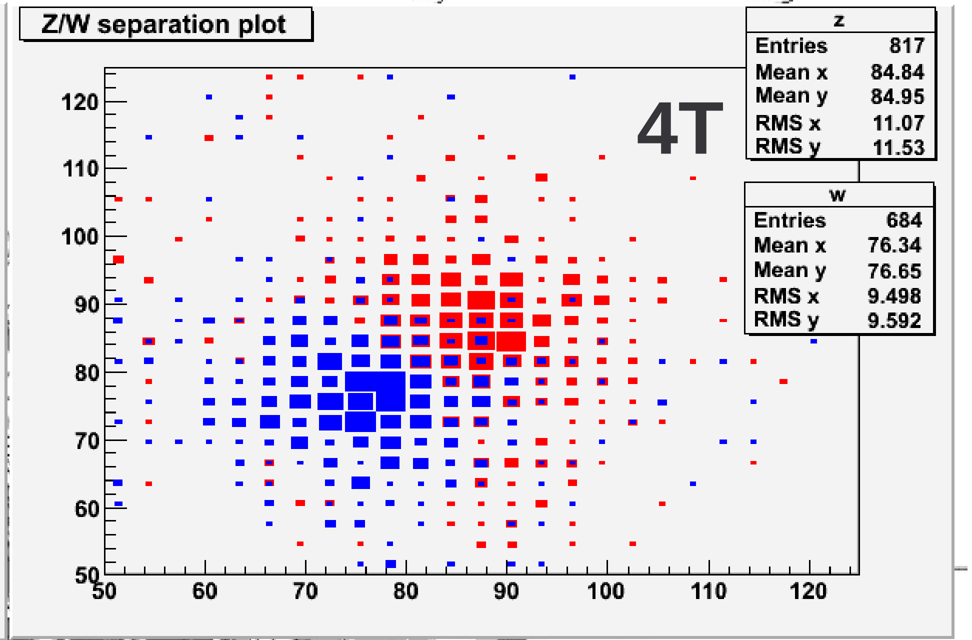


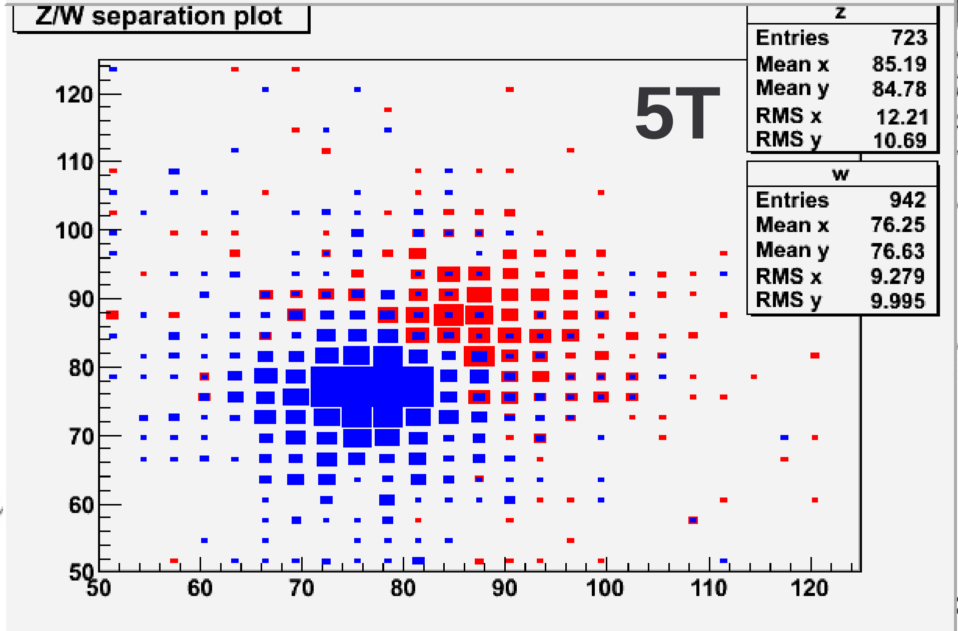
Blue is WW

Red is ZZ

Z/W separation with Pandora PFA







Blue is WW

Red is ZZ

Very Preliminary

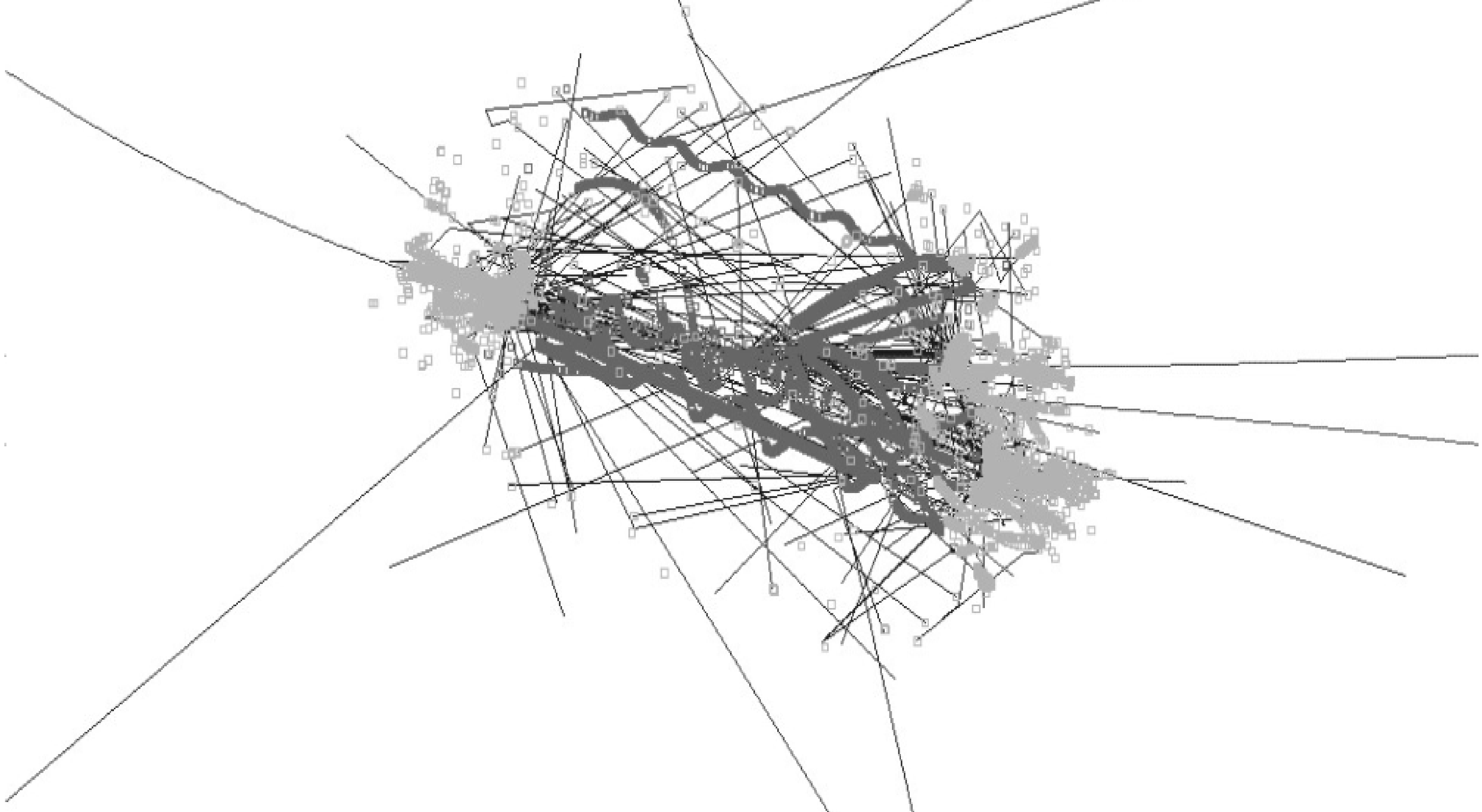
Conclusion

- Started study on the background, as expected the biggest problem is the contamination.
- We can use ZHH and ZZH to discriminate between detectors.
- First physical evidence of the need of a bigger detector!
- Z/W separation plot using WOLF, closer to 60%/√E that 30 %/√E.
- Preliminary results from Pandora PFA are promising.

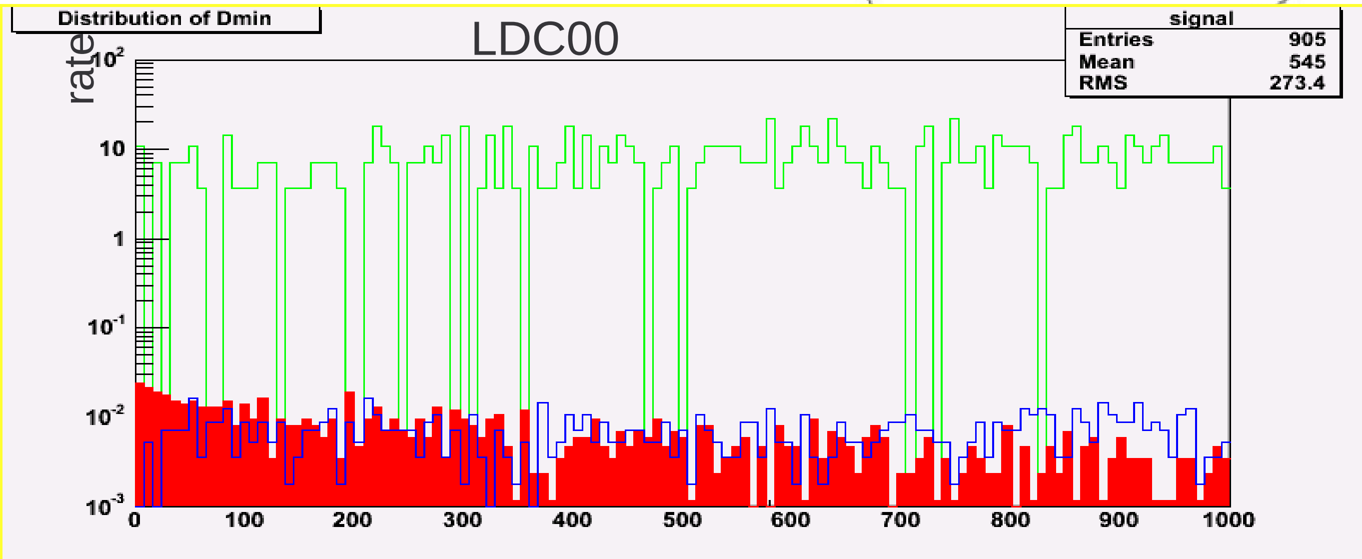
Future plans

- Continue ZHH analysis:
  - More backgrounds,
  - New event generator for comparison,
  - New PFA,
  - 6j study.
- Use Z/W separation plot with different:
  - PFA (better study of Pandora)
  - Magnetic Fields
  - Detectors
- Release of new analysis processors for Marlin

Backup slides

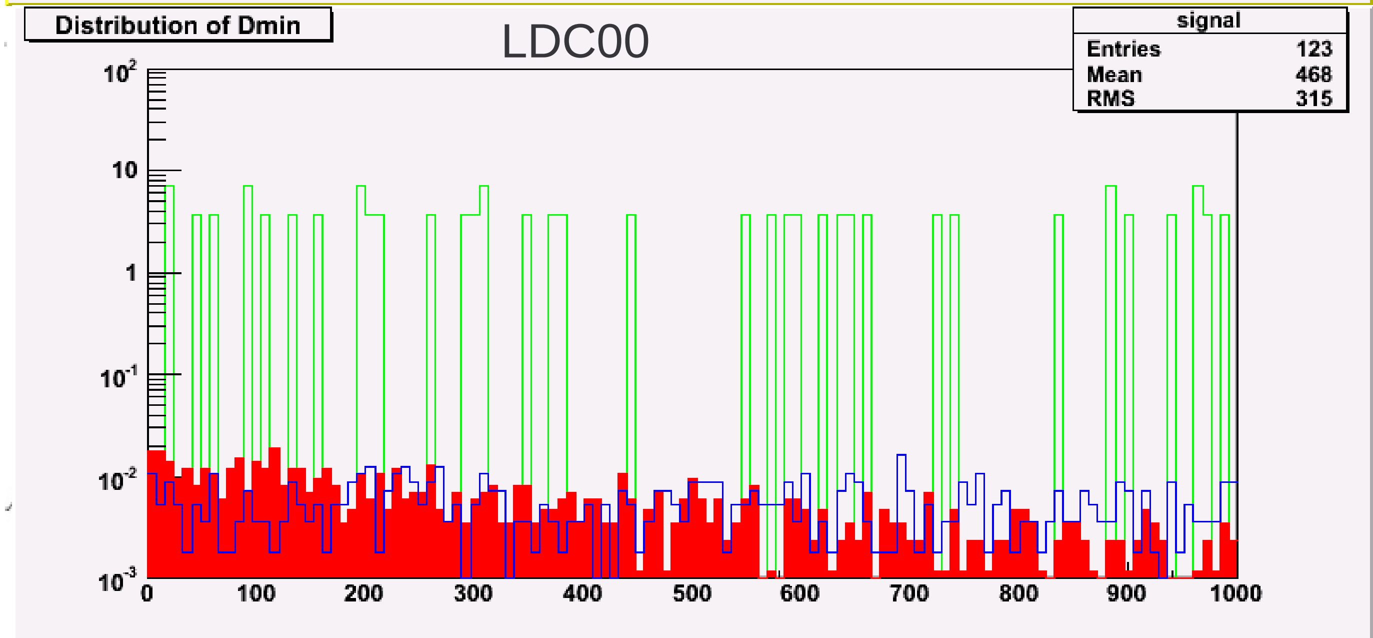


D^2 plot



- Signal ZHH (Z→ μμ)
- ZZH Background
- bbH Background

No cut on Z mass



- Signal ZHH (Z→ ee)
- ZZH Background
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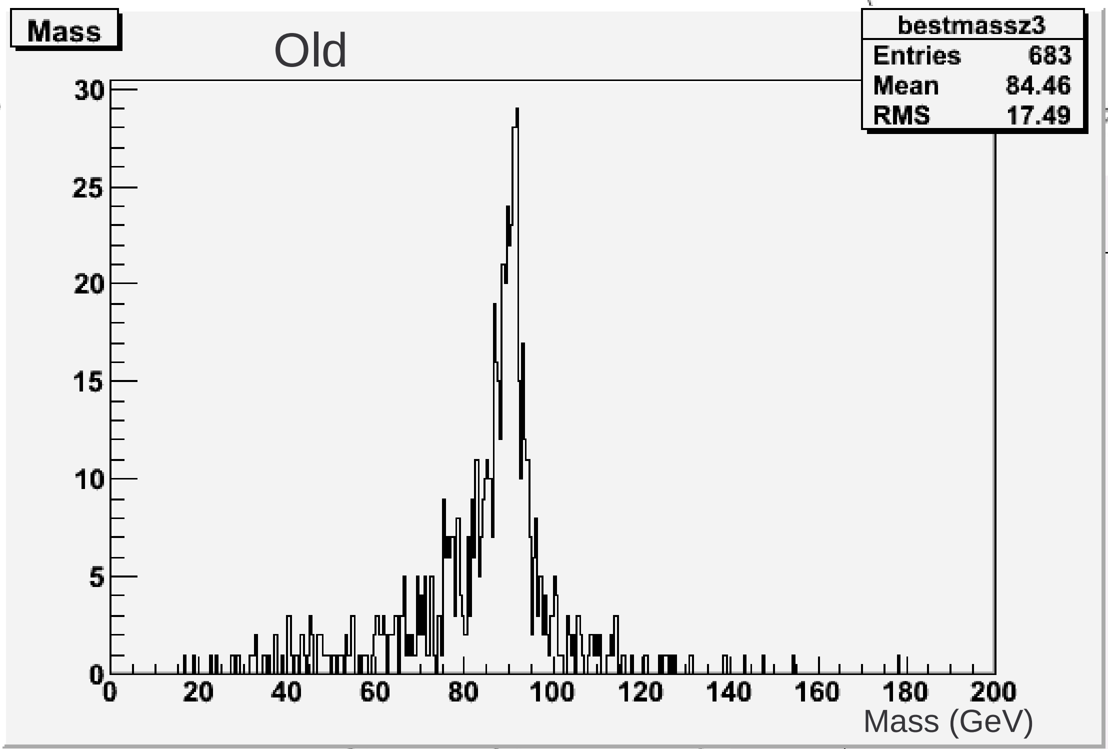
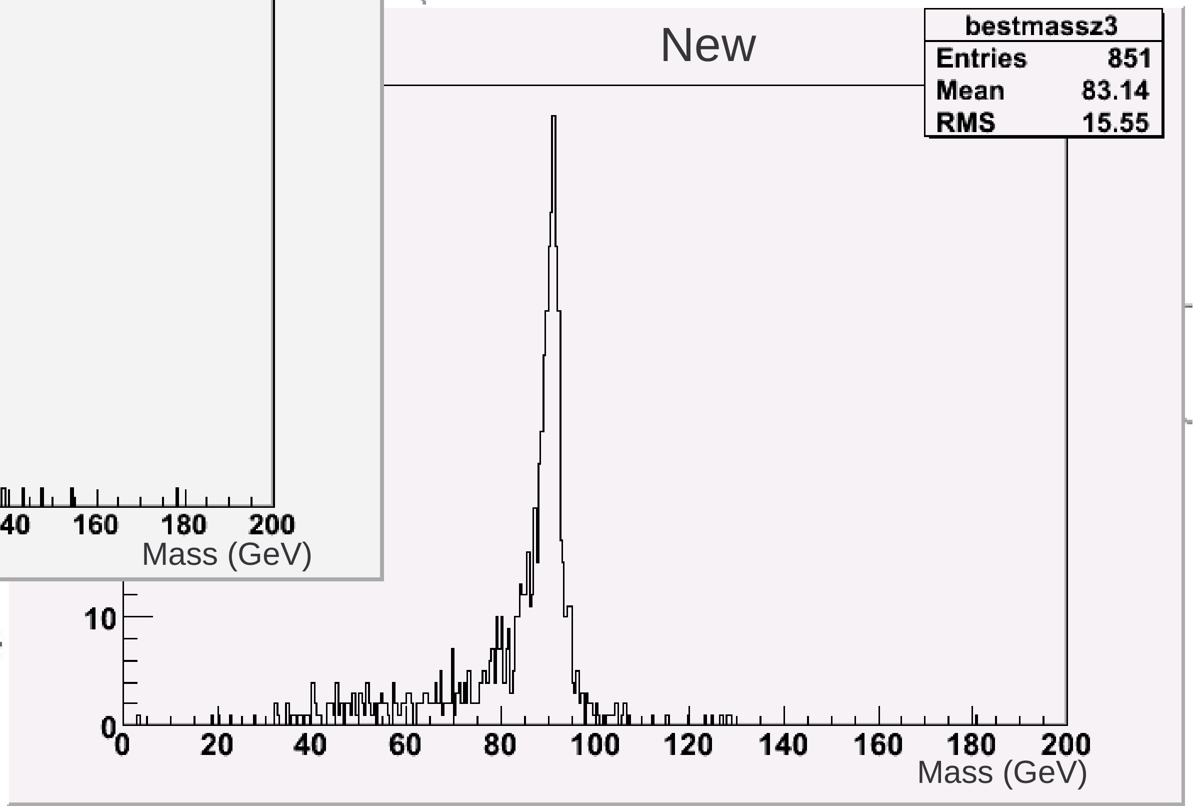
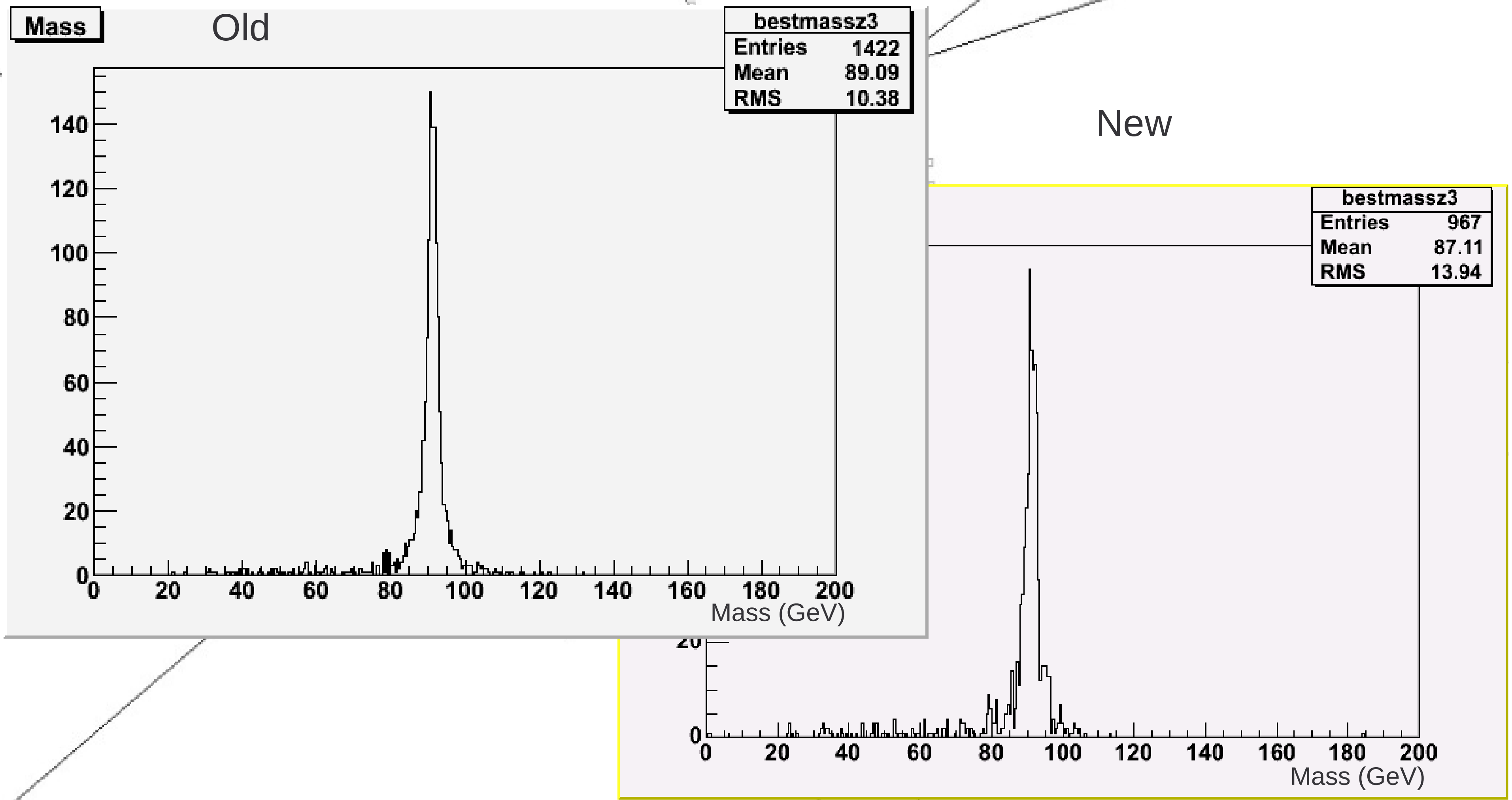
ZHH, Z→electrons





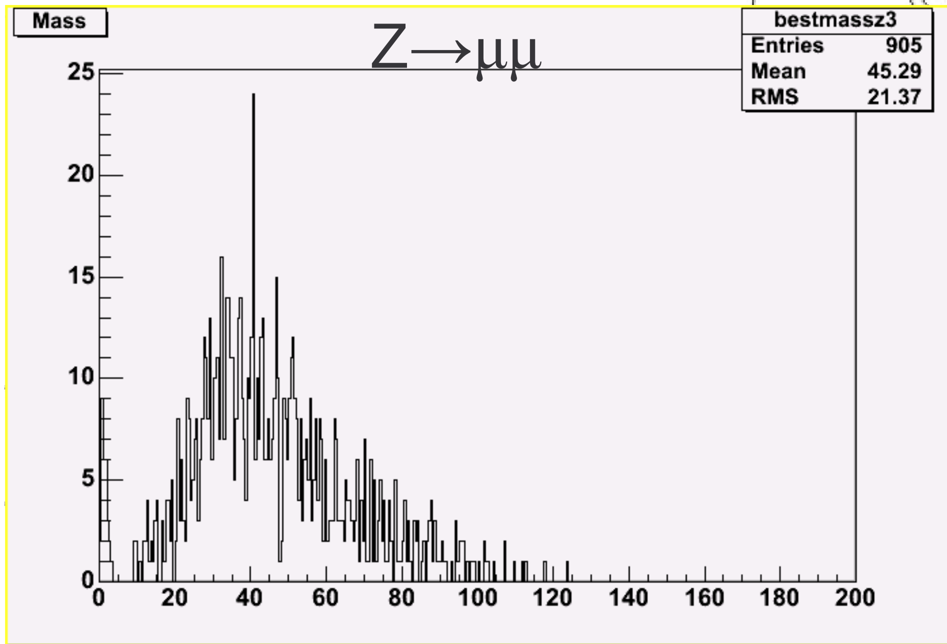
Using Marlin 0.9.2 and 0.9.4

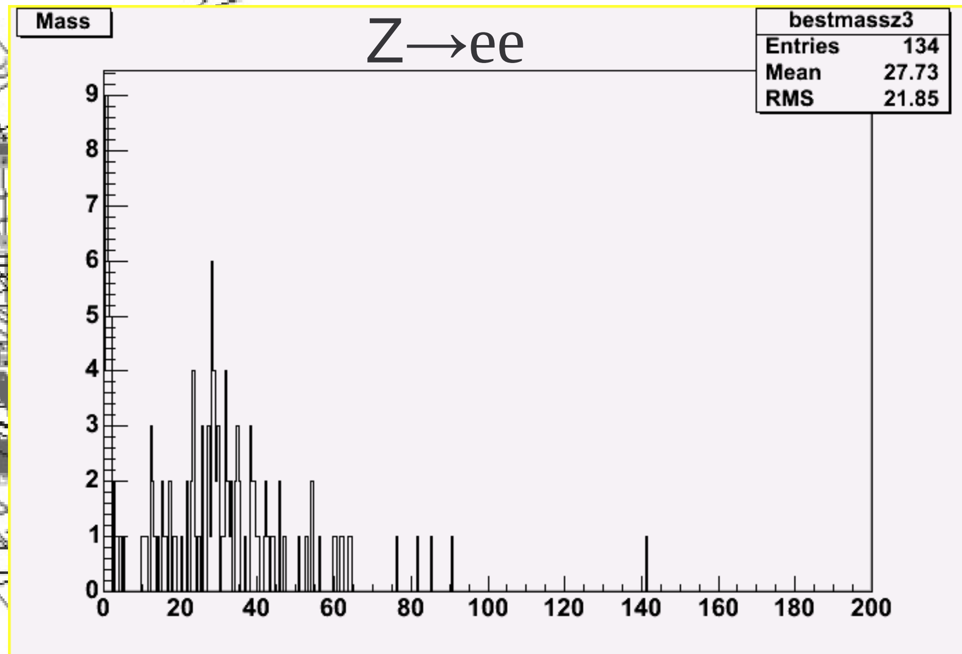
ZHH, Z→muons



Using Marlin 0.9.2 and 0.9.4

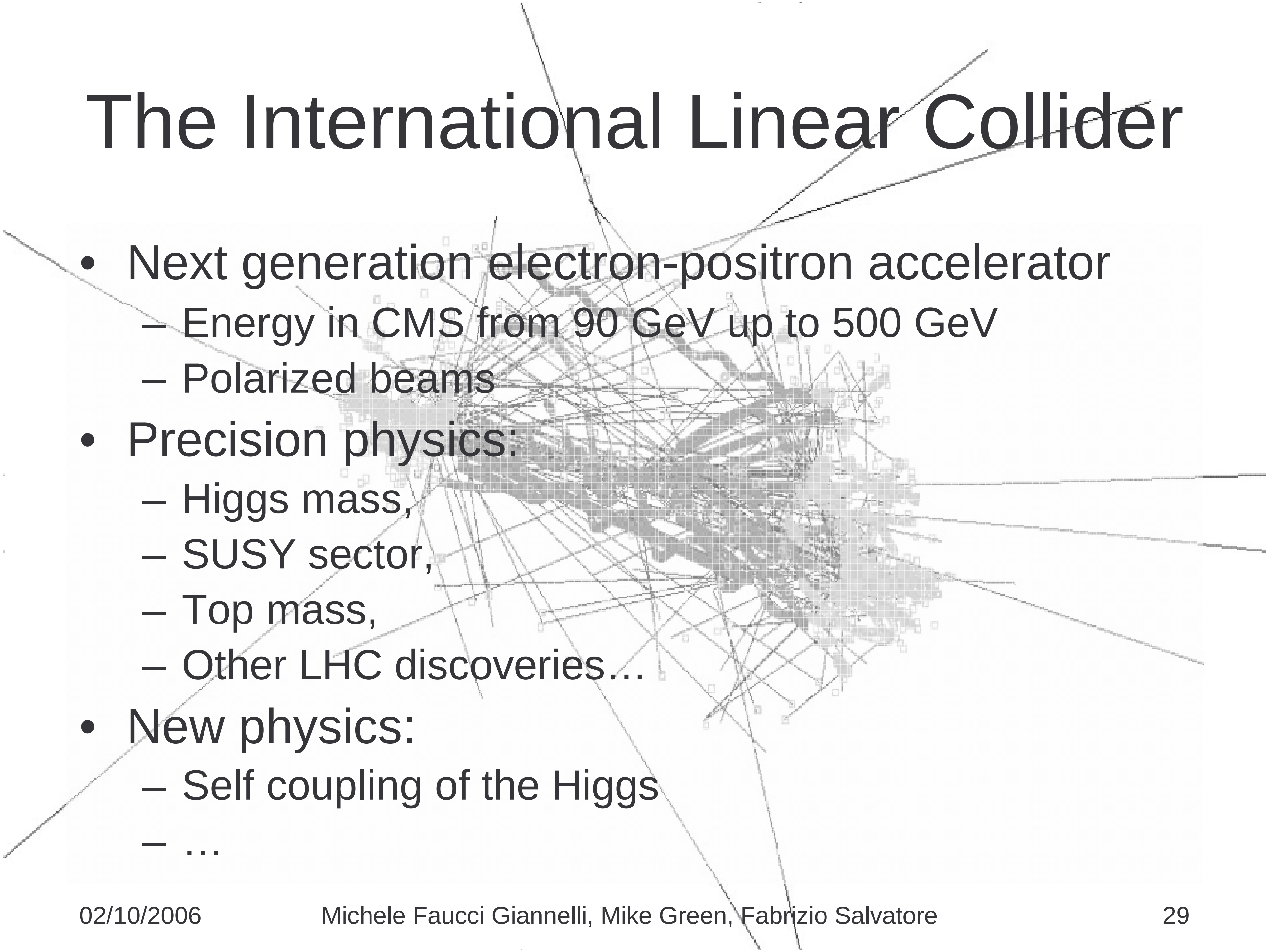
Reconstructed Z Mass for bbH





- The difference due to the missing muon id:
  - Muons and pions are not separated
- Then "muons" are many more than electrons

The International Linear Collider



- Next generation electron-positron accelerator
  - Energy in CMS from 90 GeV up to 500 GeV
  - Polarized beams
- Precision physics:
  - Higgs mass,
  - SUSY sector,
  - Top mass,
  - Other LHC discoveries…
- New physics:
  - Self coupling of the Higgs
  - …

Detector requirement

To achieve ILC goals there are several requirements:

- Good momentum resolution
- High granularity calorimetry
- Improved particle flow algorithm

In order to test different algorithms and detector designs, we need several benchmark channels:

- ZH
- WW, ZZ
- ttbar
- ZHH