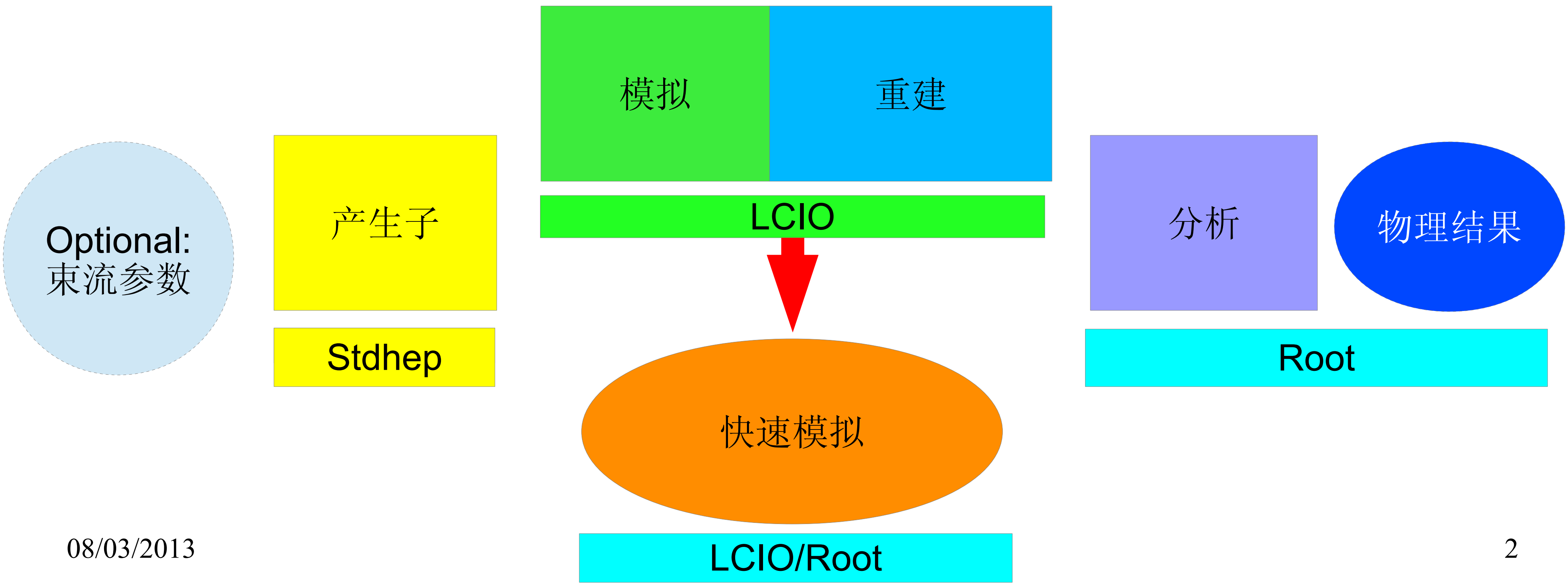
Fast simulation of Br(H→bb, cc, gg) measurement

Manqi

快速模拟软件

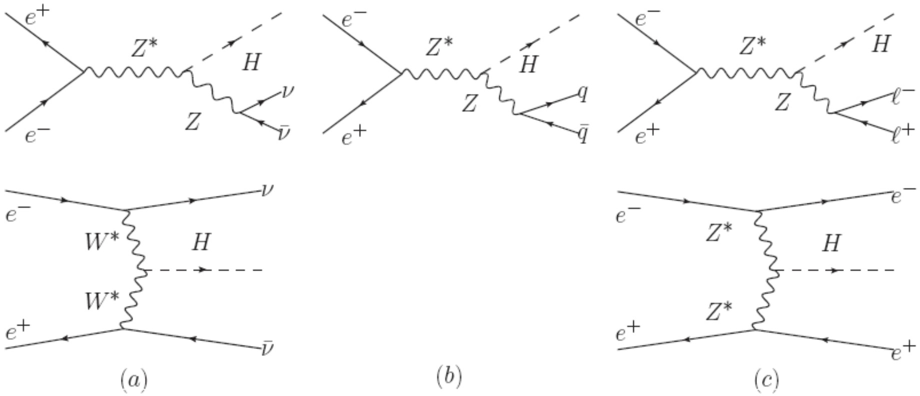
海量数据： ~10^7 事例 /(探测器 * 束流设置)

对任一可观测量 (喷注能量， 丢失能量， 径迹动量， 轻子， 夸克味道鉴别效率 ...) :
重建结果 = 真值分布 ⊗ 分辨率 ⊗ 系统效应（效率，偏差等）
可调试及开发相应快速模拟算法：
第一阶段：仅仅考虑探测器分辨率
第二阶段：系统效应的模拟 （效率，接受率，偏差 ...)：由全模拟数据分析建模



CEPC: 8 + 2 measurements for SM higgs

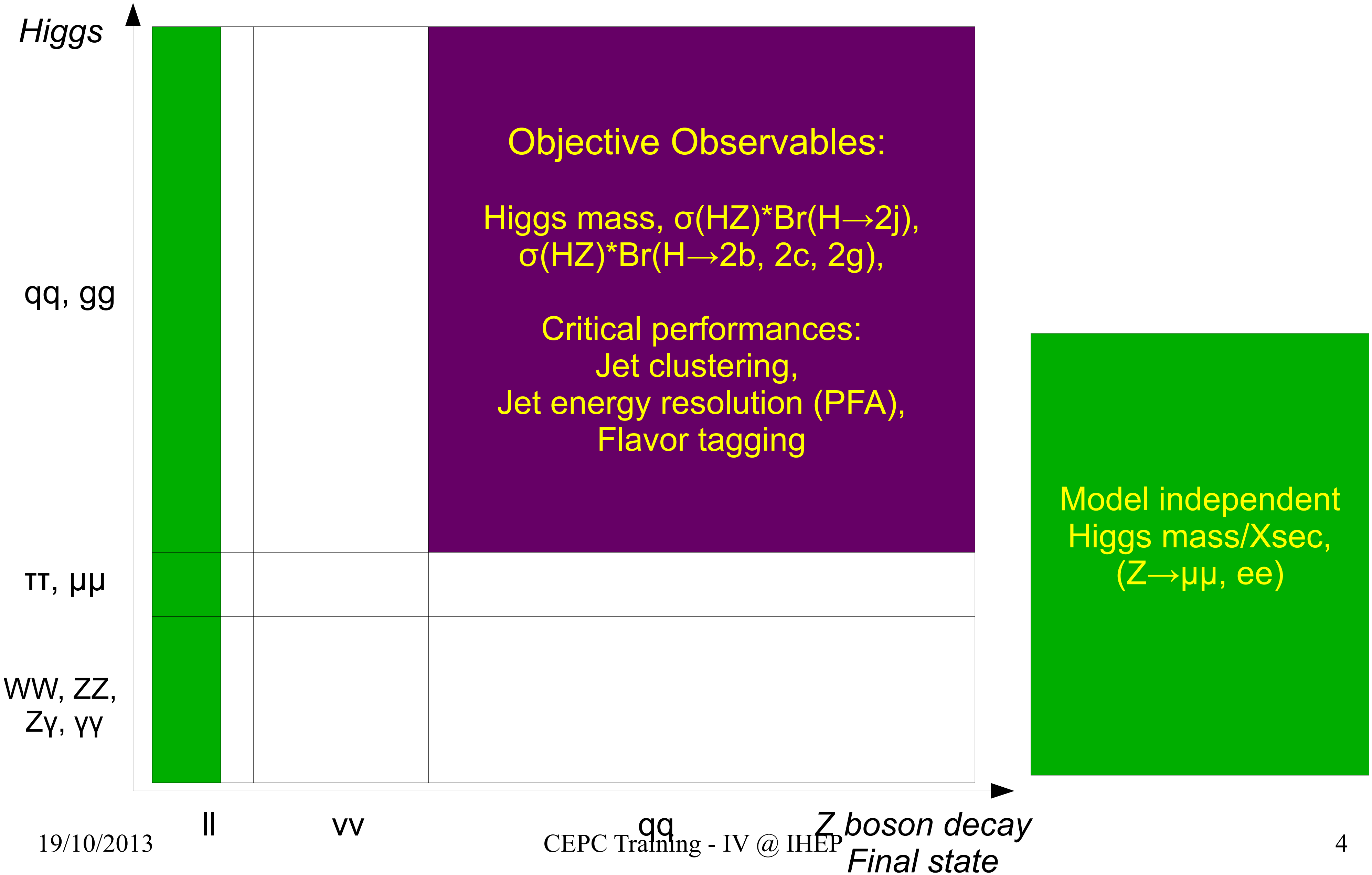
- Mass, spin, total cross section
- Branching ratios (b, c, tau, g, W)
- Branching ratios (gamma, mu)
- Calculate: width – coupling
- Other measurements, SM & exotics...



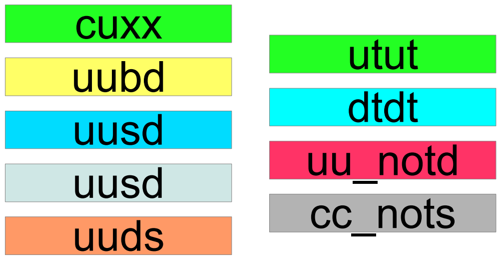
Mode	$b\bar{b}$	$c\bar{c}$	gg	WW^*	$\mu^+\mu^-$	$\tau^+\tau^-$	ZZ^*	$\gamma\gamma$	$Z\gamma$
BR (%)	57.8	2.7	8.6	21.6	0.02	6.4	2.7	0.23	0.16

g(Hbb), g(Hcc), g(Htt), g(HWW)/Γ_H, g(Hμμ), g(Hττ), g(HZZ)/Γ_H, g(HWW)/g(Htt)

σ(H→2j) & Br(H→bb, cc, gg)



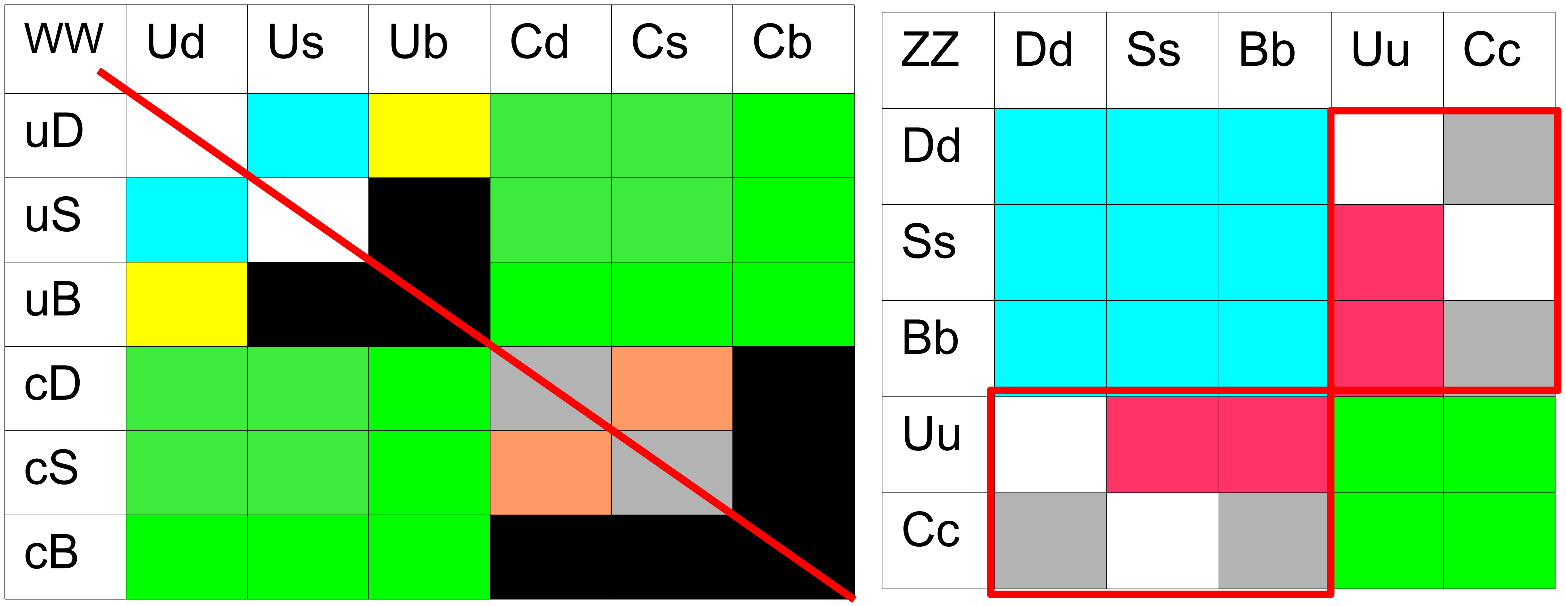
Background: WW & ZZ, hadronic



Single W:

	V	Br
Ud	~ 0.974 ~	0.475
Us	~ 0.225 ~	0.025
Ub	~ 0.004 ~	0
Cd	~ 0.23 ~	0.025
Cs	~ 1.006 ~	0.475
Cb	~ 0.04 ~	7e-4

Single Z:
Uu ~ 15%
Dd ~ 12%



Xsec/fb	LL	LR	RL	RR	Non-pola/evts at 500 fb^{-1}
ww_h		14874	136.4		3752 fb ~ 1.87 M
zz_h		1402	604		502 fb ~ 250 k
zzorww_h		12383	225		3152 fb ~ 1.58 M

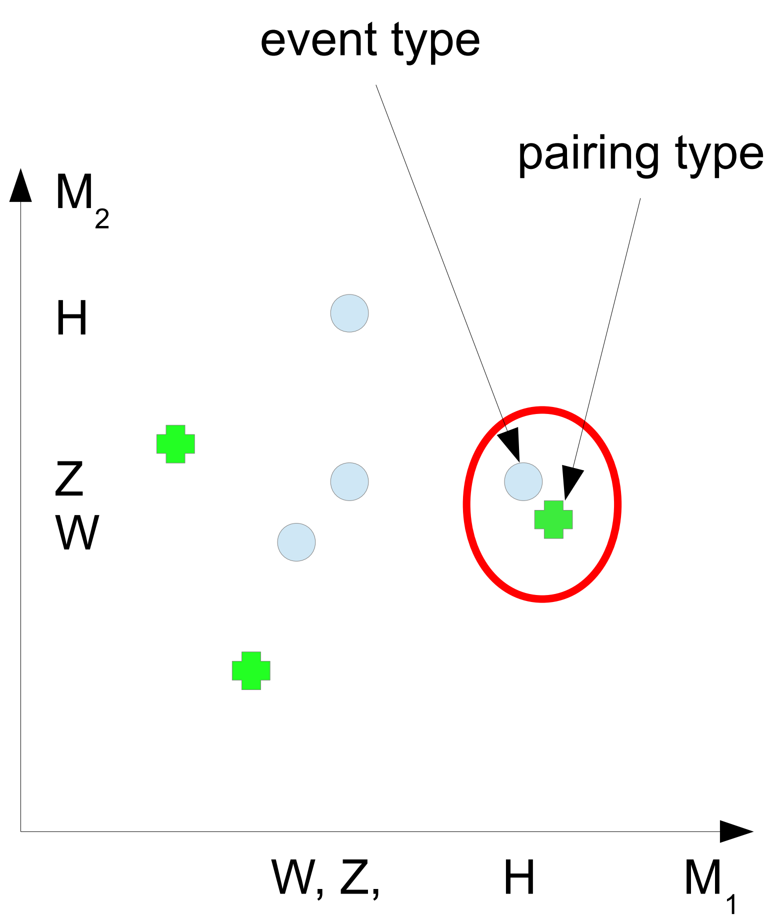
Signal, ZH with Z to qq and Higgs to qq or gg ~ 48.6 k

Pairing quarks

- Represent reconstructed jets (FS-0):
  - MC Truth quark * percentage energy smearing
  - *Ignore neutrinos & misidentification of 4 jets events and other events*

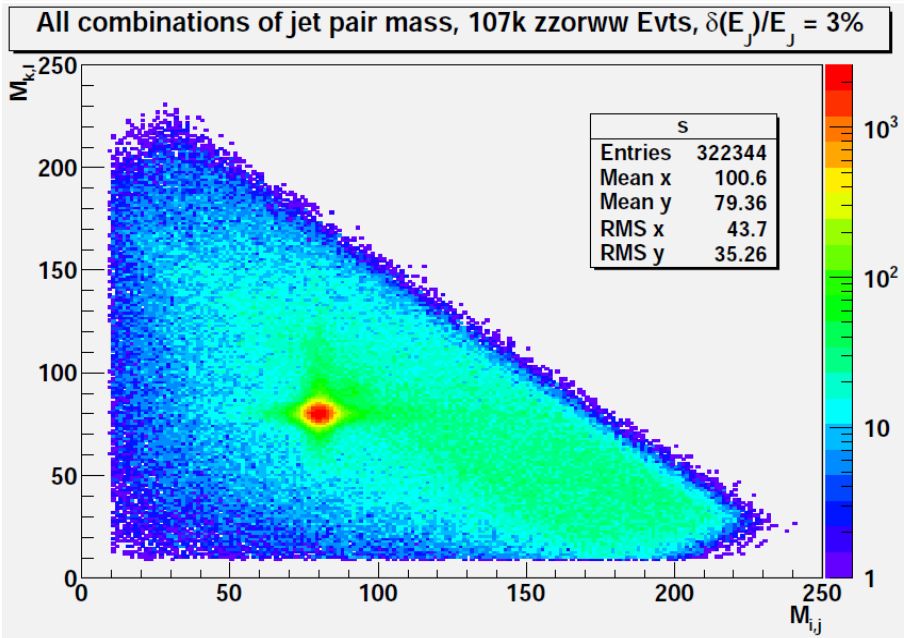
- Define Chi2 = $((M_{i,j} - MB_1)/\sigma_1)^2 + ((M_{k,l} - MB_2)/\sigma_2)^2$
  - weighted by breit-wigner & resolution

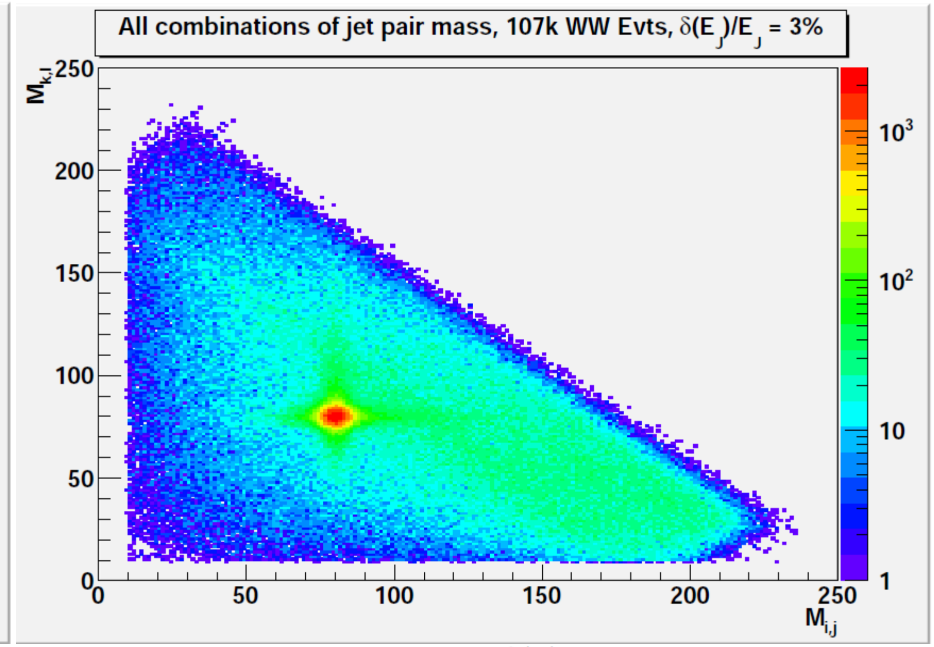
    σ = sqrt(B-W Width**2 + InvMassError**2),
    - InvMassError = JetEreso*InvMass/sqrt(2)
    - B-W width - W: 2.12 GeV, Z: 2.45 GeV
    - Ijkl runs over 3 combinations
    - B1, B2 = ZZ, WW, ZH or HZ

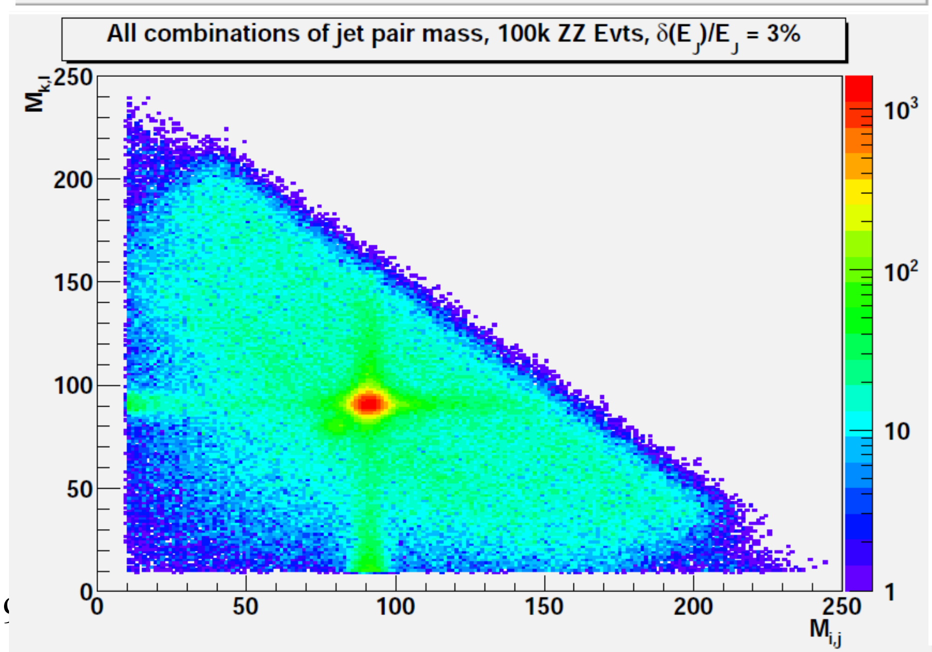


- The minimal chi2 indicate both event type and jet pairing

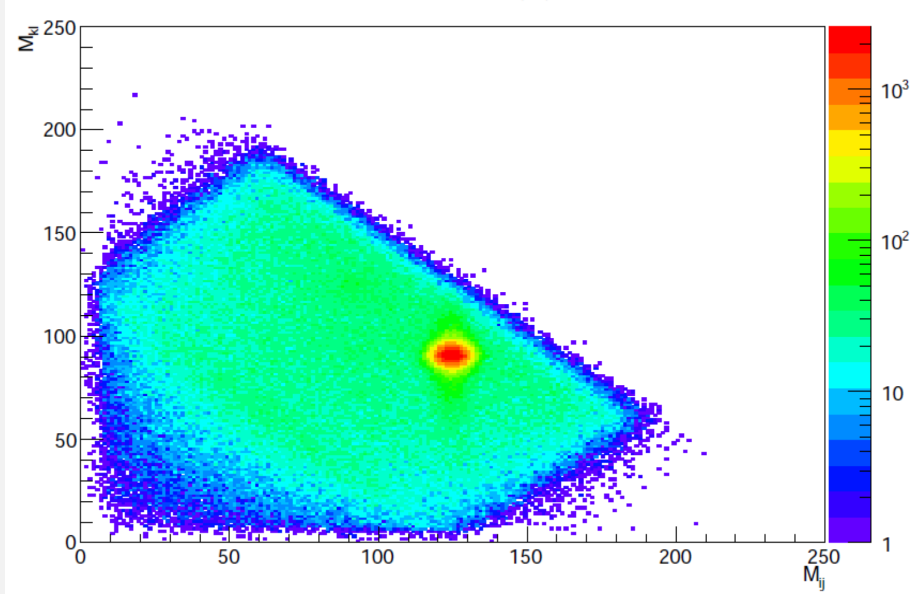
$M_1 - M_2$ distributions



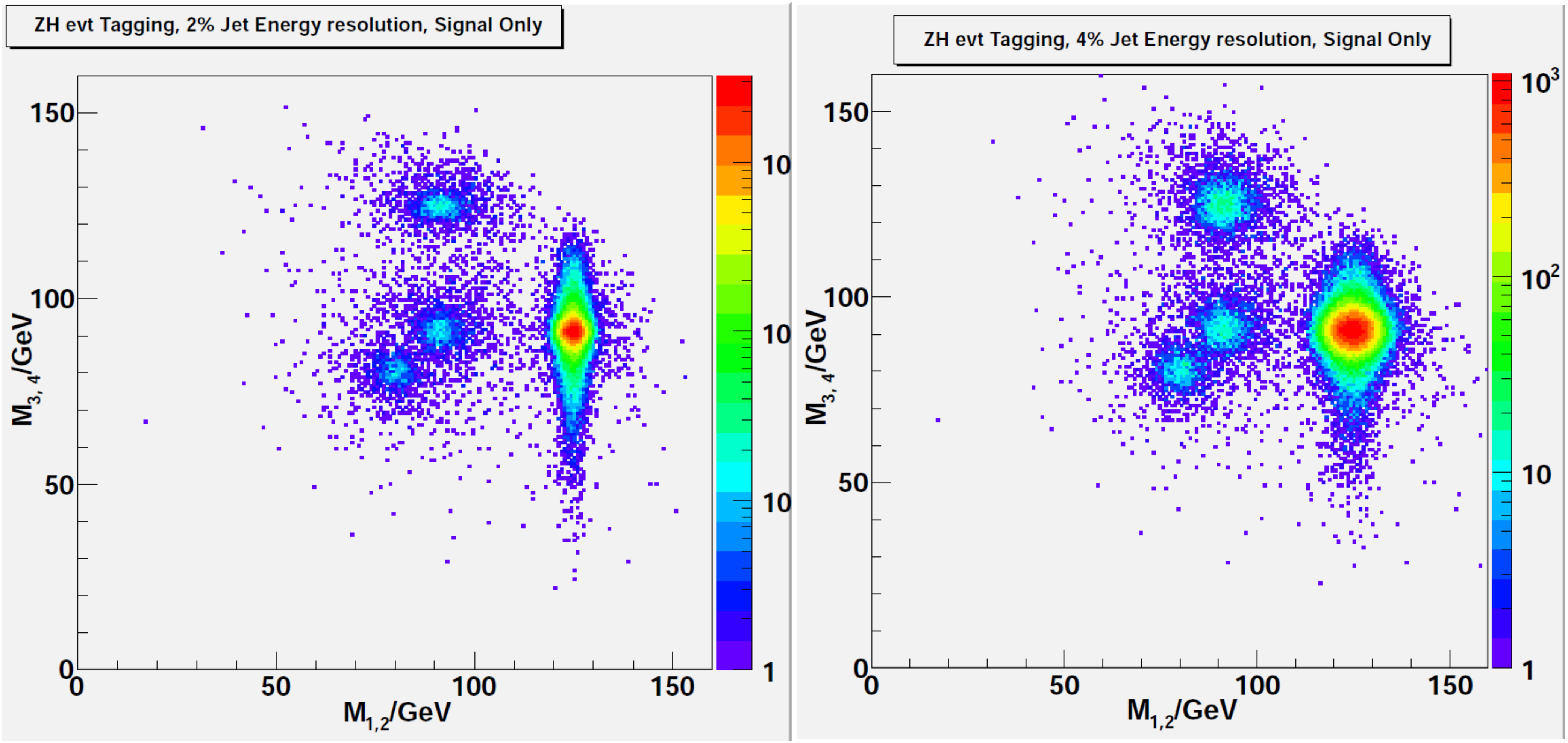




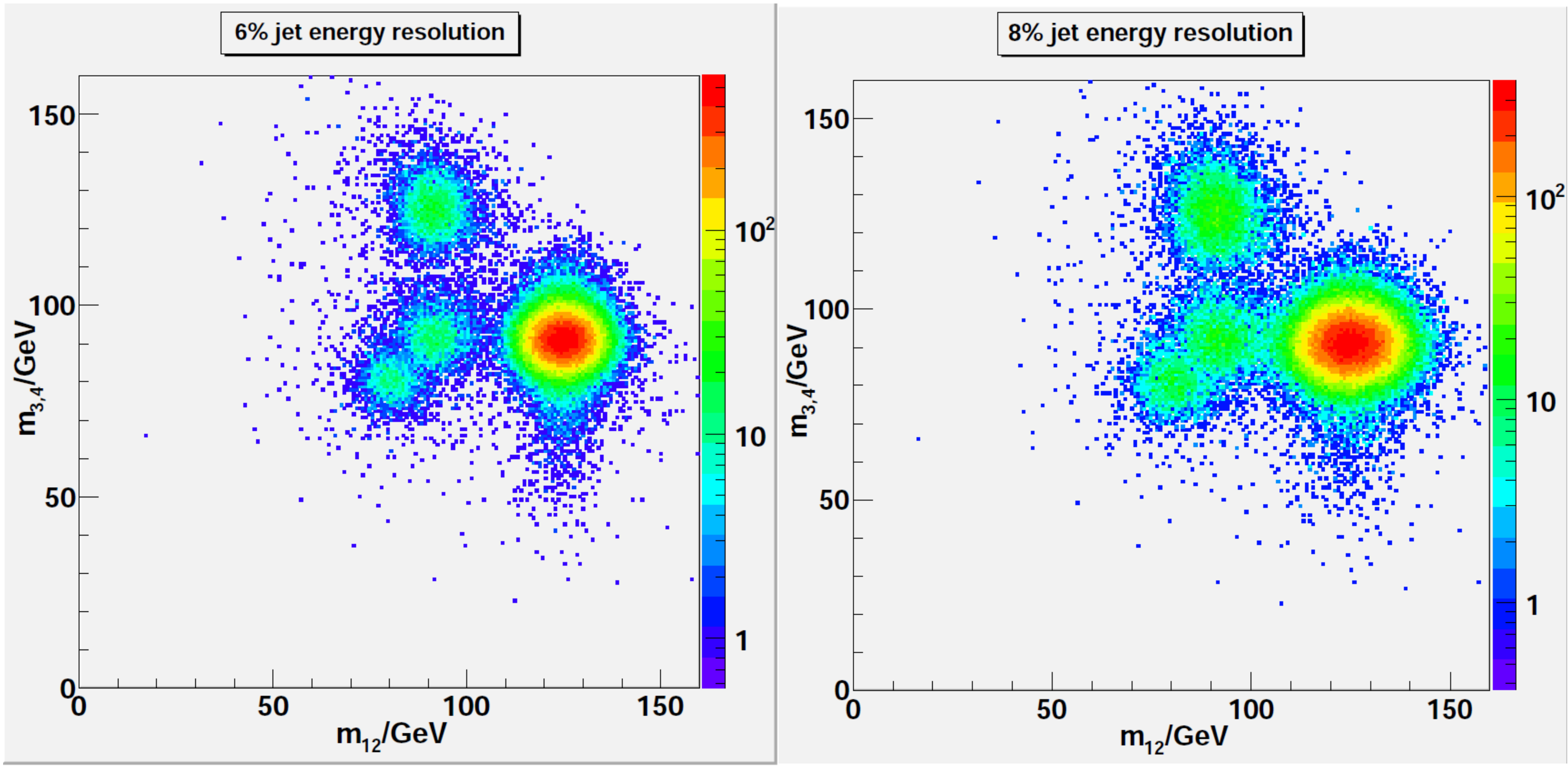
137k ZH evts at δ(E)/E = 4%



Event classification with ZH: at different jet energy resolution



Event classification with ZH: at different jet energy resolution



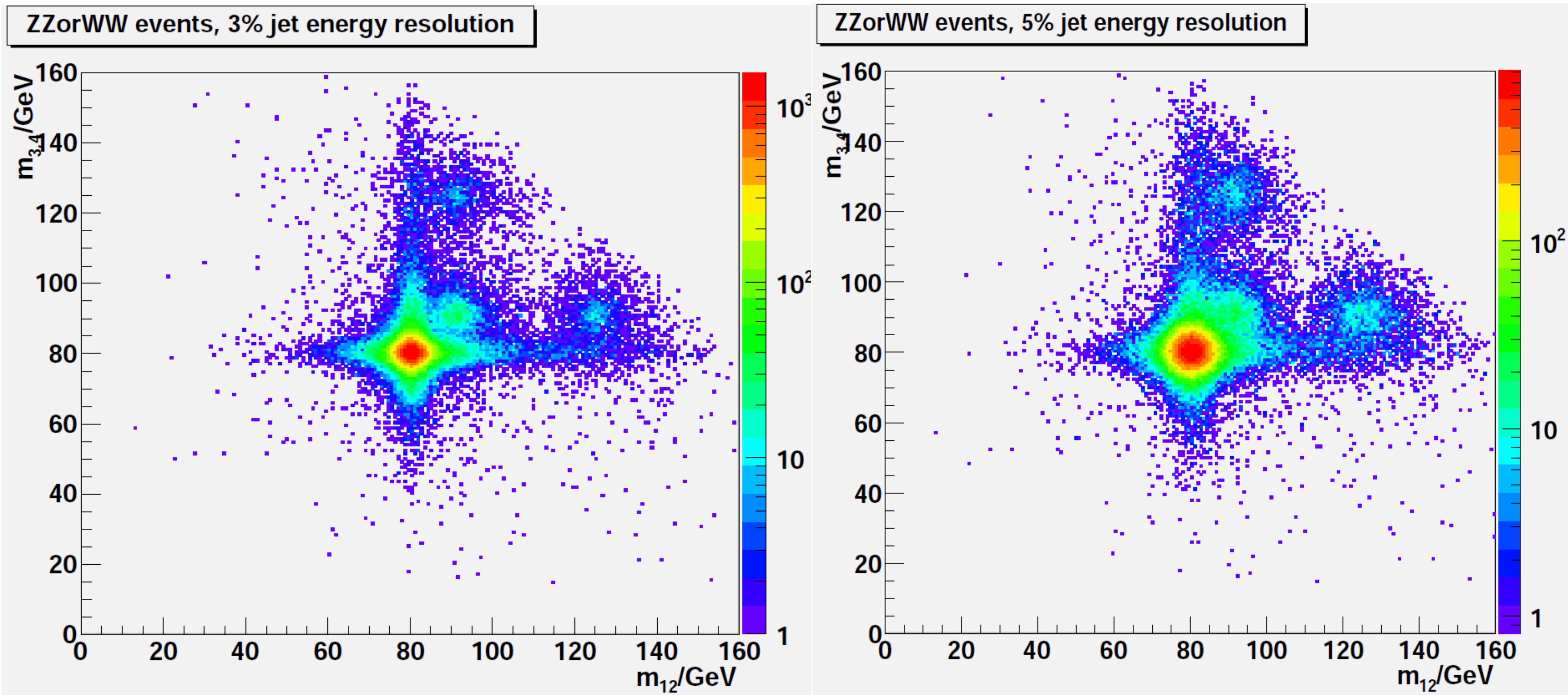
8%: fake ZZ & WW separation became difficult...

ZH event output: at different jet energy resolution

- Event identification on pure signal (137k after selection ~ 1400 fb)
  - ZH': still identified as ZH event, however, the pairing is not correct
  - Of course one can use other variables, for example b-likelihood and direction of boson – but here is what has been associated directly with Jet energy resolution...

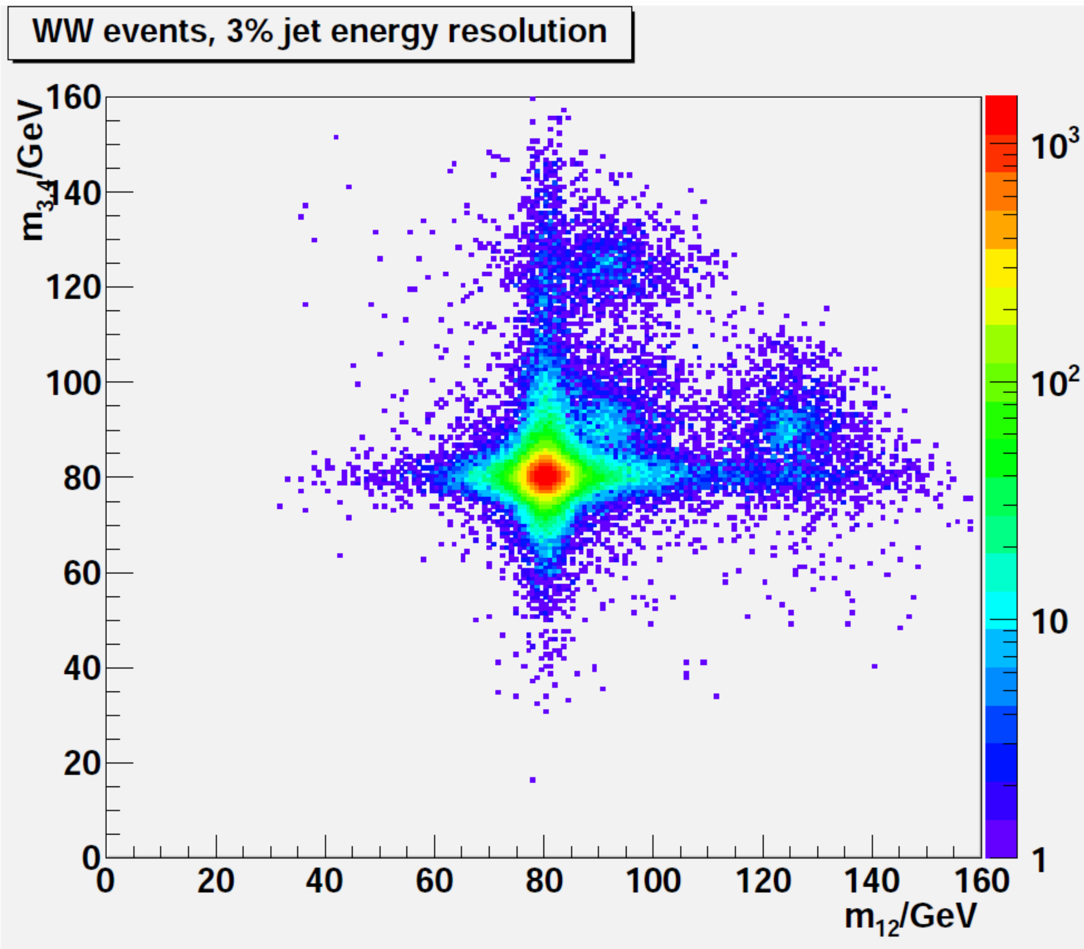
Jet Energy resolution:	ZH	ZH'	ZZ	WW
2%	96.3%	1.4%	1.4%	0.9%
3%	95.4%	2.0%	1.6%	1.1%
4%	94.3%	2.6%	1.8%	1.2%
5%	93.0%	3.3%	2.2%	1.5%
6%	91.5%	4.1%	2.7%	1.7%
7%	89.7%	4.9%	3.4%	2.0%
8%	87.6%	5.7%	4.3%	2.4%

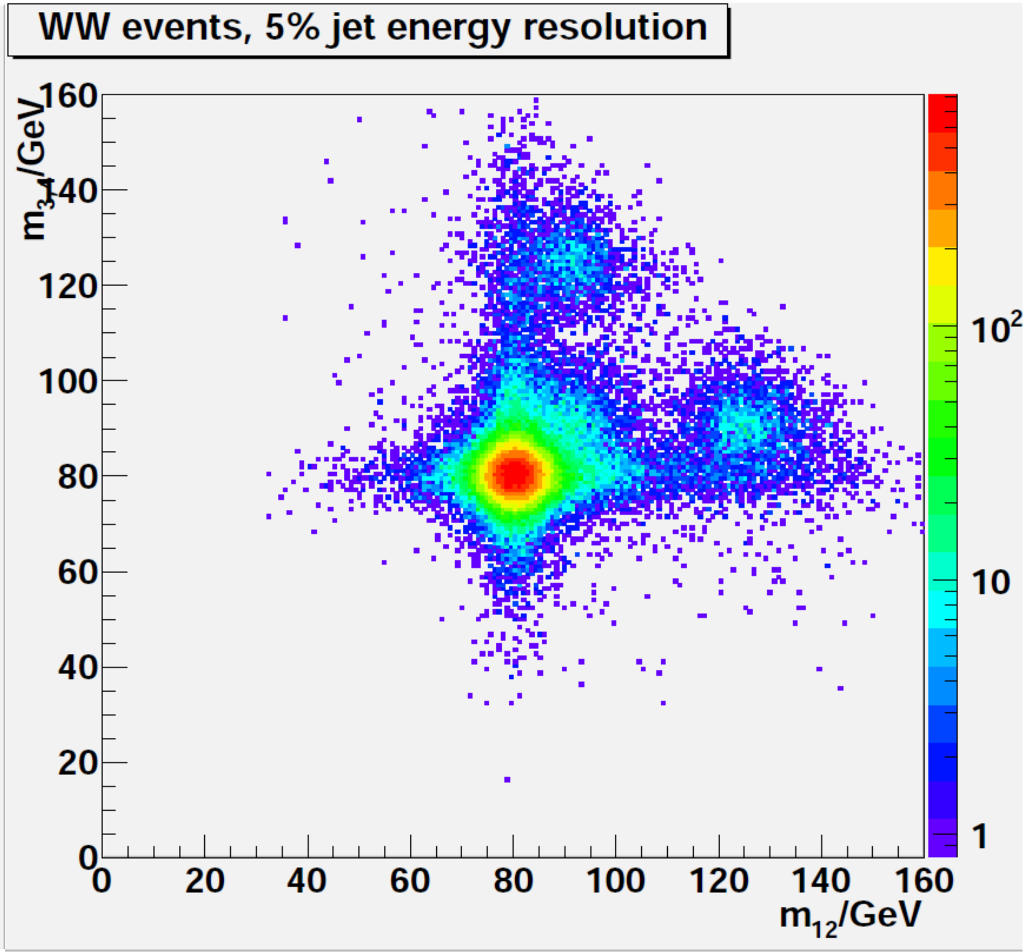
Event classification: zzorww



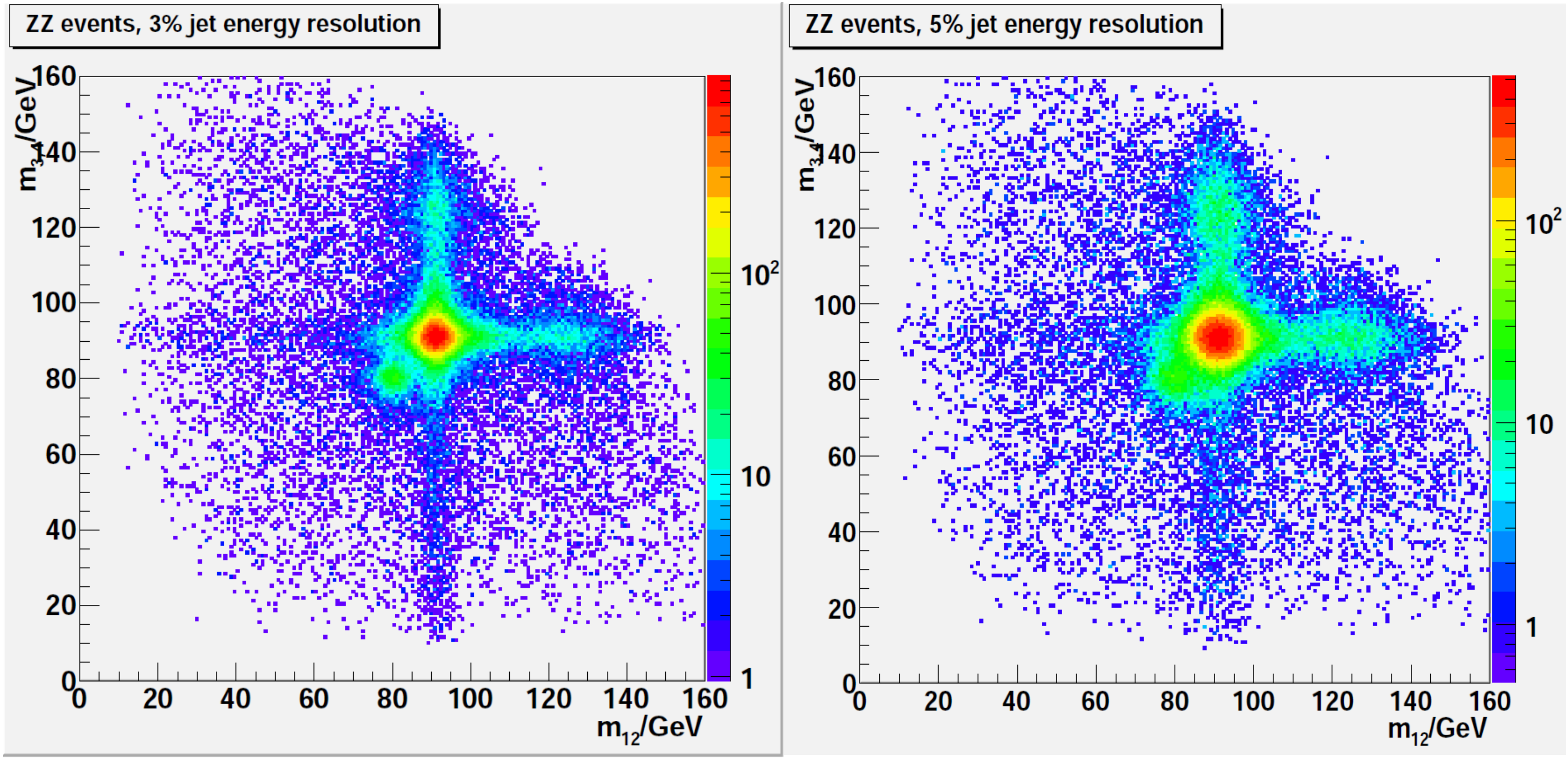
- Identify signal as background may not be really a serious problem – even at 7% jet energy resolution (conventional) we can still have an efficiency of 90% - but identify backgrounds as signal would be another story...

WW

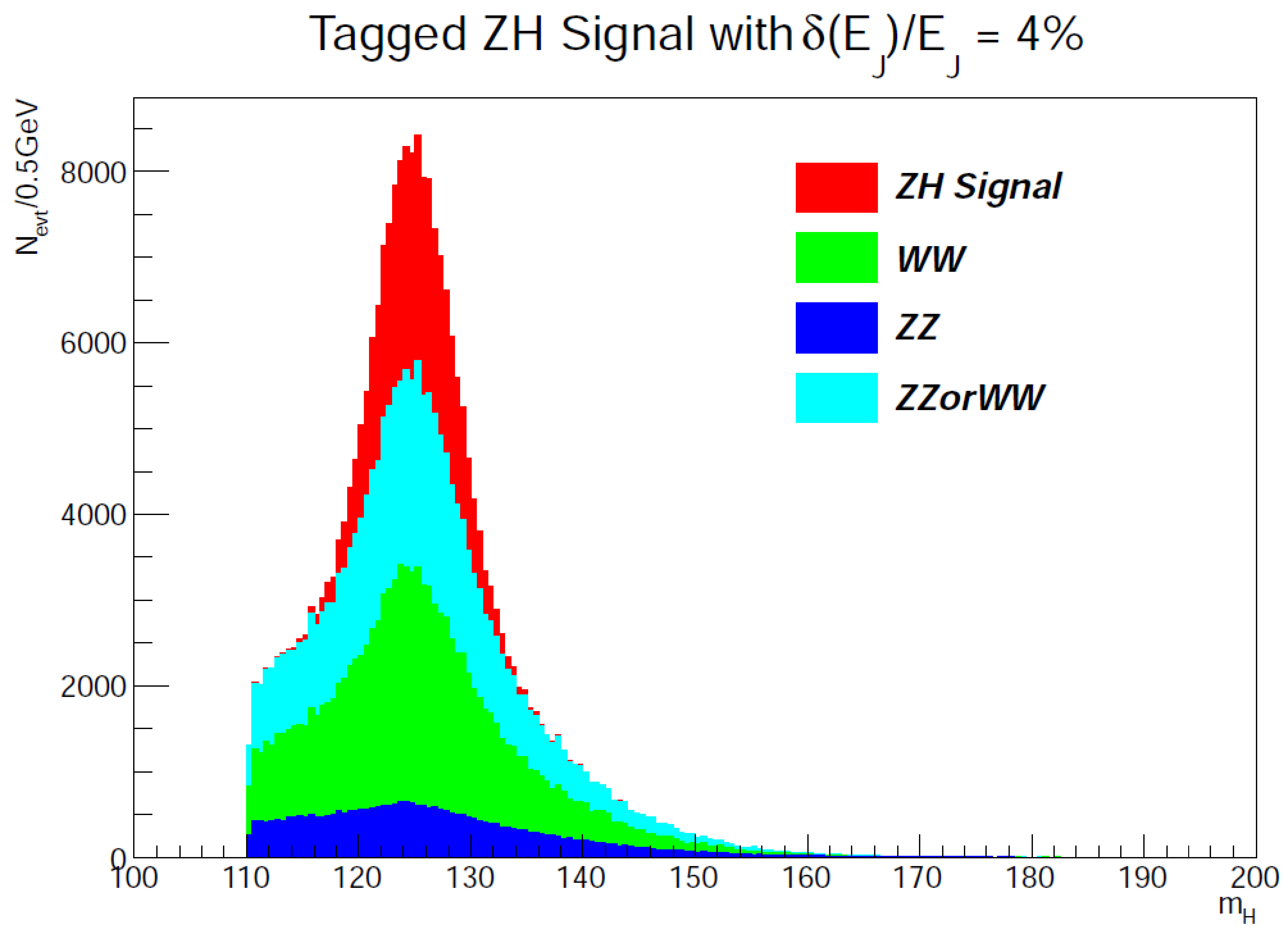

WW events, 3% jet energy resolution
m34/GeV
m12/GeV
160
140
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160
10^3
10^2
10
1


WW events, 5% jet energy resolution
m34/GeV
m12/GeV
160
140
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160
10^2
10
1

ZZ



ZZ events, 3% jet energy resolution
ZZ events, 5% jet energy resolution
m34/GeV
m12/GeV



Tagged ZH Signal with δ(E_J)/E_J = 4%
N_evt/0.5GeV
ZH Signal
WW
ZZ
ZZorWW
0
2000
4000
6000
8000
100
110
120
130
140
150
160
170
180
190
200
m_H

Pairing quarks on backgrounds

Sample statistic:

zz, 100k;
ww, 107k;
zzorww, 107k;

$\delta E_J/E$, zz	ZH	ZH'	ZZ	WW
2%	4.8	5.1	81.6	9.5
3%	5.5	5.7	78.6	10.1
4%	6.0	6.2	77.0	10.8
5%	6.3	6.5	75.2	12.0
6%	6.5	6.8	73.0	13.7
7%	6.7	7.0	70.6	15.8
8%	7.0	7.2	67.9	17.9

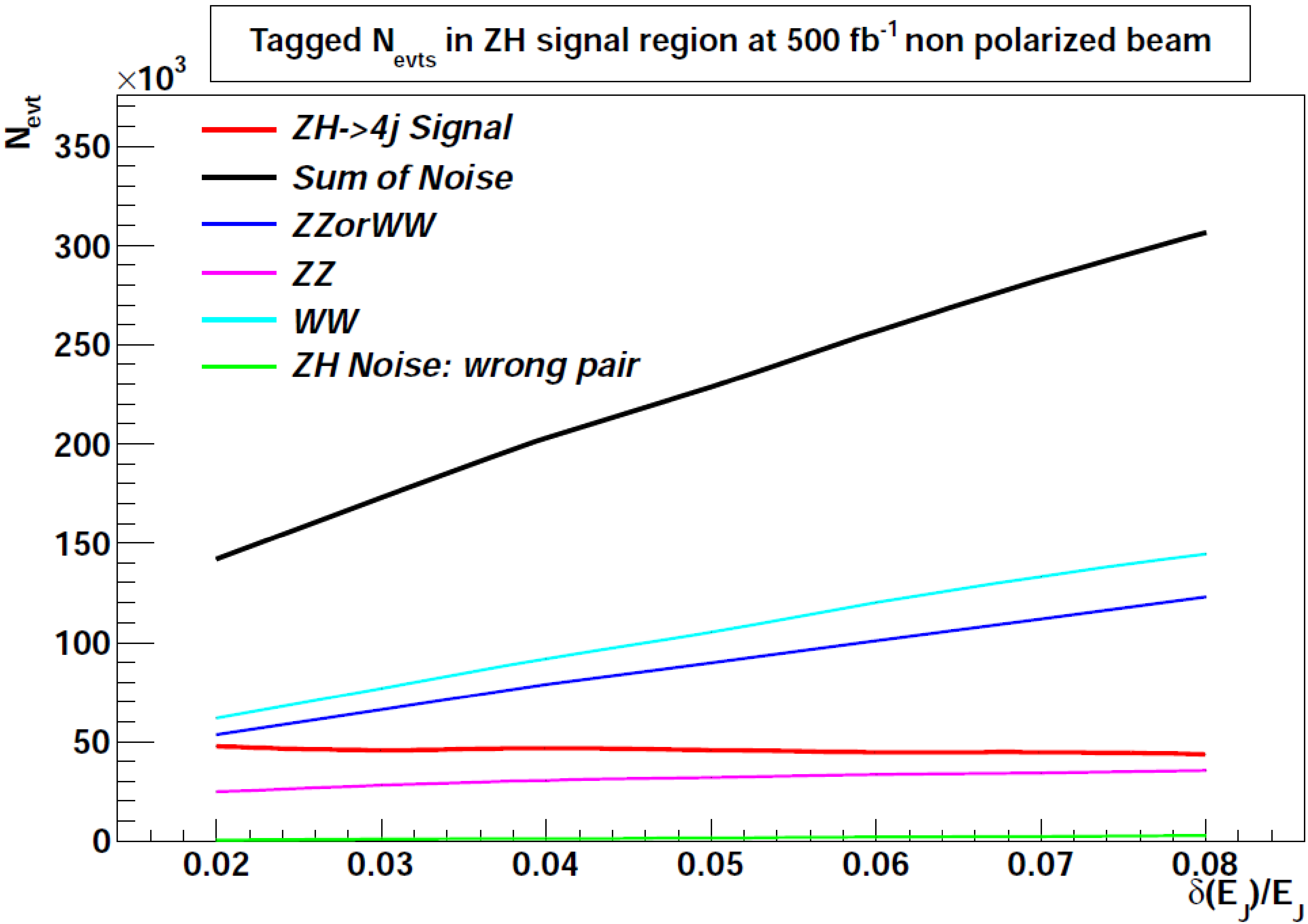
$\delta E_J/E$, ww	ZH	ZH'	ZZ	WW
2%	1.8	1.5	6.8	90.0
3%	2.2	1.9	6.5	89.4
4%	2.7	2.2	6.7	88.5
5%	3.1	2.5	7.3	87.1
6%	3.6	2.8	8.2	85.4
7%	3.9	3.2	9.4	83.6
8%	4.3	3.4	10.7	81.6

$\delta E_J/E$, zzorww	ZH	ZH'	ZZ	WW
2%	1.9	1.5	8.1	88.5
3%	2.3	1.9	7.9	87.8
4%	2.8	2.2	8.0	87.0
5%	3.2	2.5	8.6	85.7
6%	3.6	2.8	9.4	84.2
7%	4.0	3.1	10.6	82.3
8%	4.4	3.4	11.9	80.3

Signal/noise statistics, in ZH region

- At 500 fb^{-1}, non-polarized beam.
- ZH' refers to ZH event identified but with wrong pair of quarks. Regard as noise
- Inverse of S/N ratio gives the precision on Cross section measurement – however, model dependent (Higgs to quarks + gluon branching ratio)

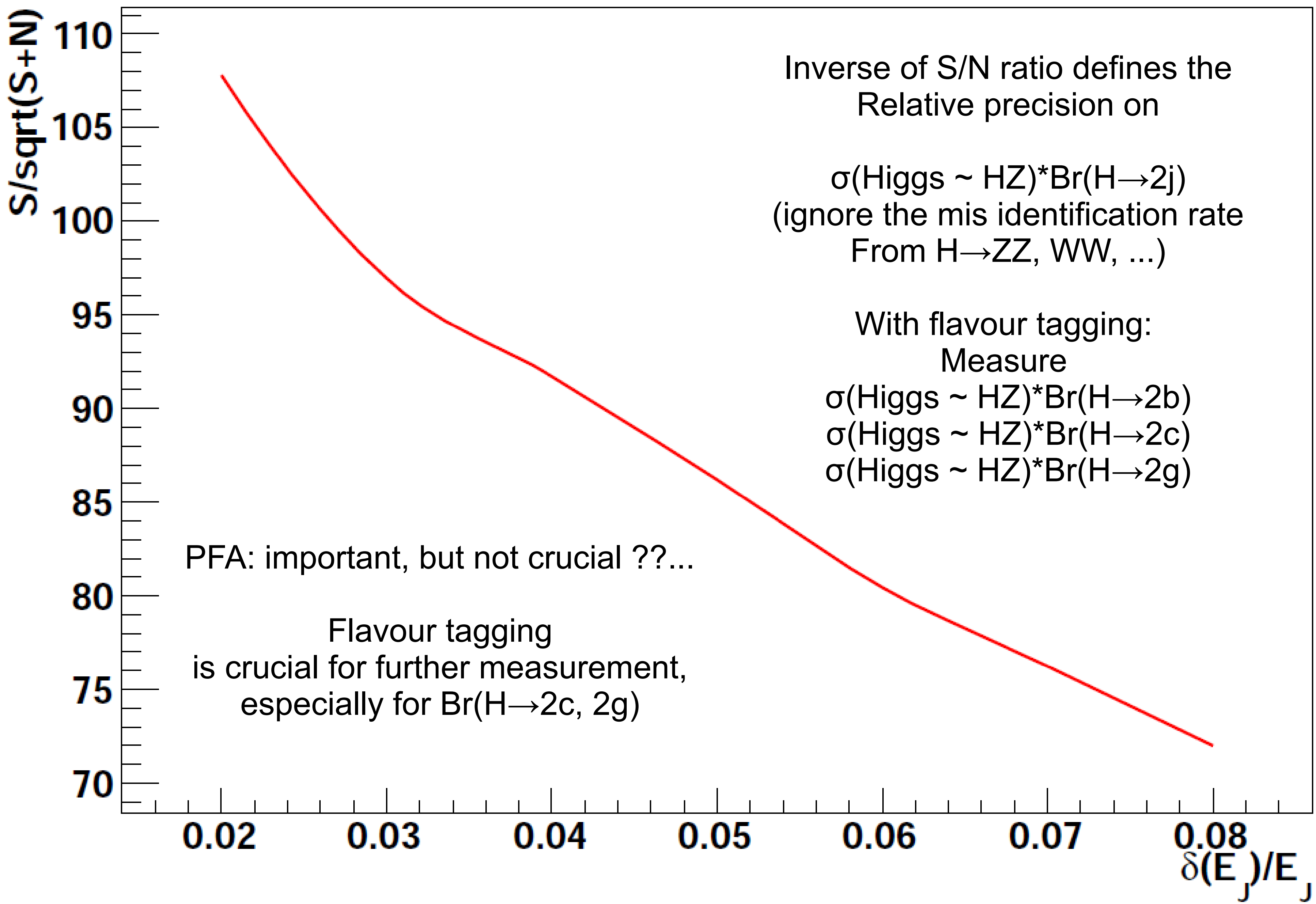
	ZH	ZH'	ZZorww	zz	ww	S/sqrt(S+N)
Total Xsec	97 fb		3152	502	3752	
2%	46.7k	0.7k	53.6k	24.8k	61.9k	107.8
3%	46.2k	1.0k	66.2k	28.1k	76.9k	98.9
4%	45.7k	1.3k	78.8k	30.6k	91.9k	91.7
5%	45.1k	1.6k	89.8k	32.1k	105.1k	86.2
6%	44.1k	2.0k	100.9k	33.4k	120.1k	80.4
7%	43.5k	2.4k	111.9k	34.4k	133.2k	76.3
8%	42.5k	2.8k	122.9k	35.6k	144.5k	72.0



Tagged N_{evts} in ZH signal region at 500 fb^{-1} non polarized beam
N_{evt}
$\times 10^3$
0
50
100
150
200
250
300
350
ZH->4j Signal
Sum of Noise
ZZorWW
ZZ
WW
ZH Noise: wrong pair
0.02
0.03
0.04
0.05
0.06
0.07
0.08
$\delta(E_J)/E_J$

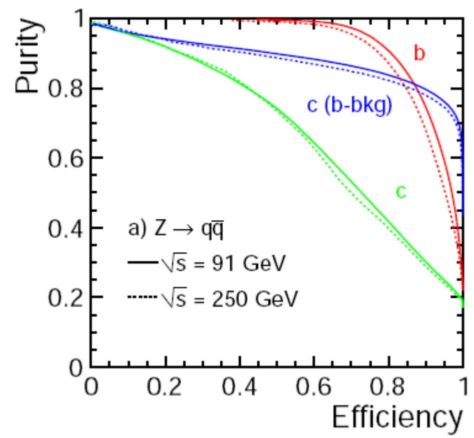
Signal over Noise Ratio

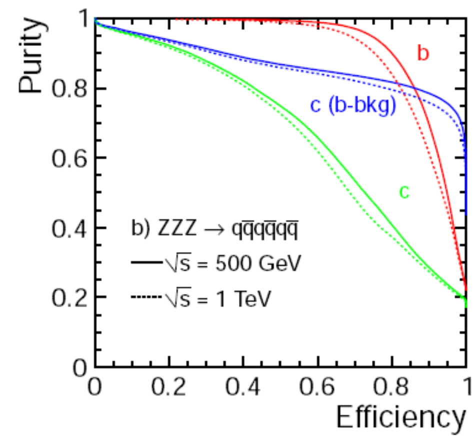
Other event distinguish variables?

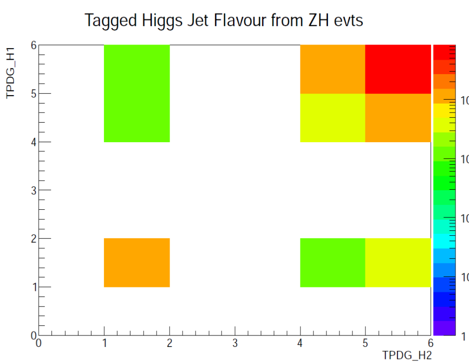


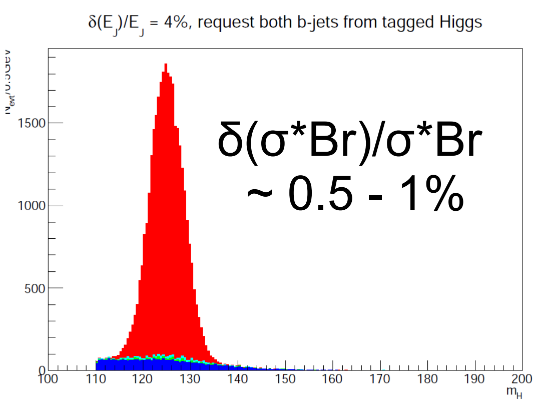
Modelling of Flavour tagging

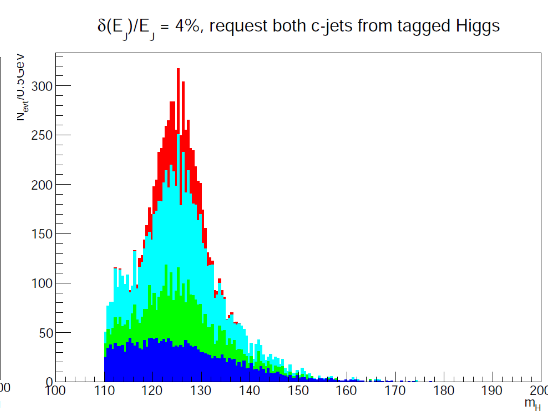
	b	c	uds	undef
b	0.90	0.08	0.02	
c	0.25	0.70	0.05	
uds	0.03	0.06	0.91	

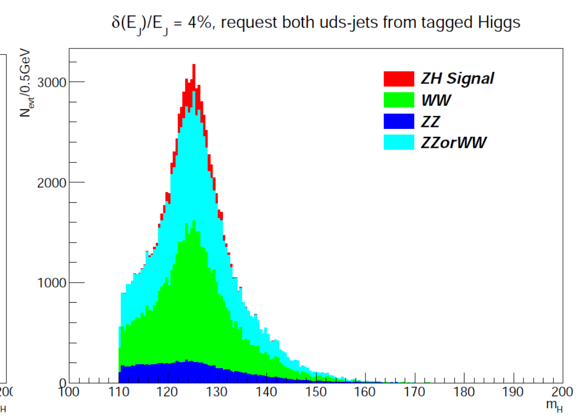






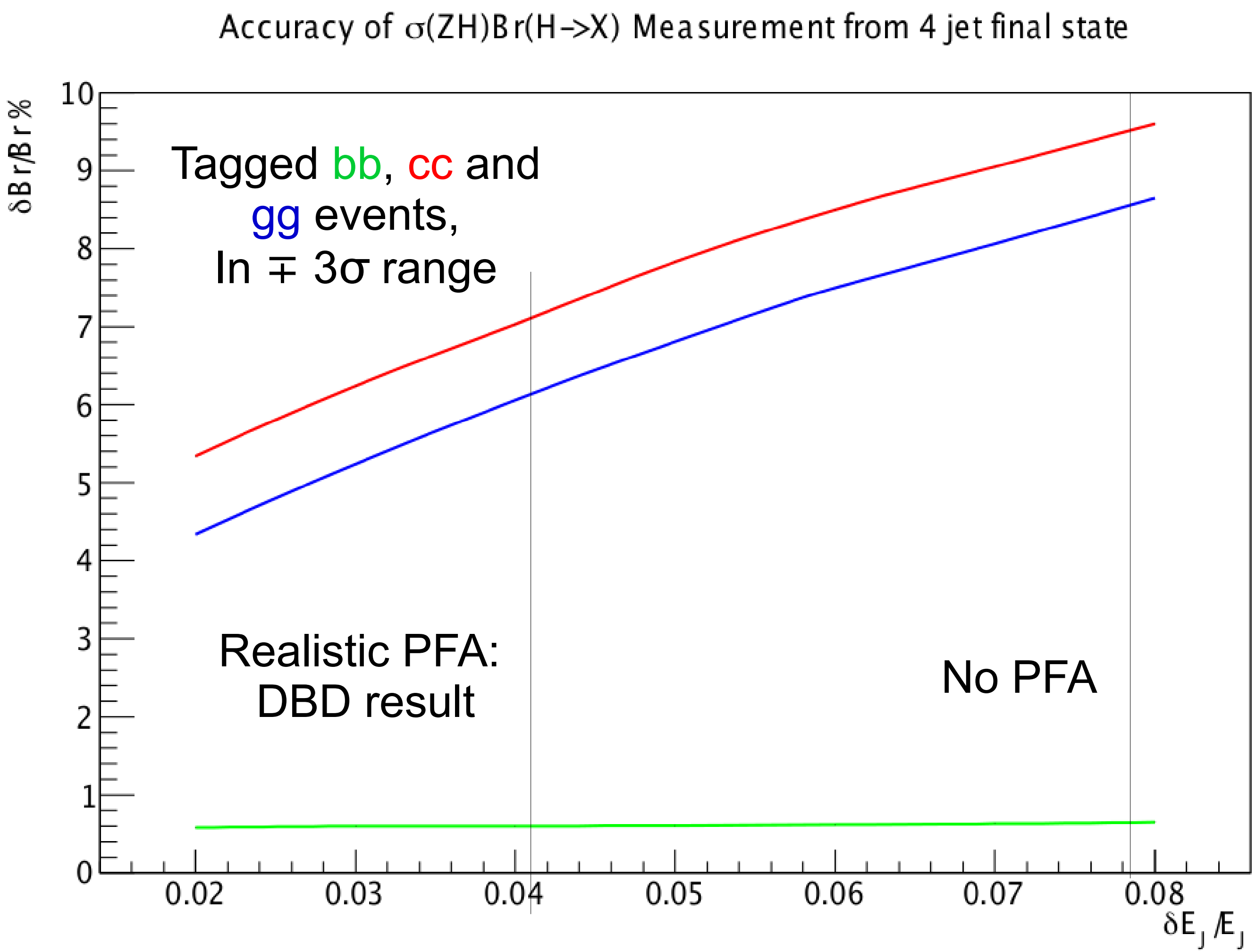






*O = M*T; M, Migration Matrix*
O, T: vector of number of events in each final state, Observed & Truth
T = T(Branching ratios)

Measuring Nevent of different type



Remarks:

Measurements from HZ, Z->ll, vv Can be combined to Improve the result

Fit range and event Selection can be improved

Migration Matrix information Should be used

bb, cc accuracies Should be worse in realistic because of Neutrinos

Trends shall not be Changed after including All above effects

PFA is still important for Br(H->gg, cc) measurement !...

Most Sensitive Performances

- VTX:
  - Flavor tagging performance
  - Migration Matrix & dependency on Detector Design (Du Chun)

- Calorimeter and Particle Flow Algorithm
  - Negligible impaction on Br(H→bb) (precision ~ 0.5-1%)
  - Important for Br(H→cc, gg) (precision ~ 4% - 10%)
  - Critical for CEPC Physics Program

Fast Simulation Package

- lxslc5.ihep.ac.cn:/afs/ihep.ac.cn/users/m/manqi/Analysis/FourFermionAna

```
#include <TRandom.h>
#include <Rtypes.h>
#include <sstream>
#include <cmath>
#include <vector>

const float mZ = 91.2;
const float mW = 80.4;
const float mH = 125;
const float JetReso = 0.08;     // 8% of jet energy resolution
const float Zwidth = 2.495;
const float Wwidth = 2.085;
const float sqrtS = 250.0;

//~~~~~ Migration Matrix of Flavor Tagging;
const float Pb[3] = {0.90, 0.09, 0.01};
const float Pc[3] = {0.25, 0.70, 0.05};
const float Pg[3] = {0.03, 0.06, 0.91};

FourFermionAna a_FourFermionAna_instance;

FourFermionAna::FourFermionAna()
        : Processor("FourFermionAna"),
        _output(0)
{
        _description = "Print MC Truth" ;

        _treeFileName="MCTruth.root";
        registerProcessorParameter( "TreeOutputFile" ,
                                "The name of the file to which the ROOT tree will be written" ,
                                _treeFileName ,
                                _treeFileName);
```