Production of SM Higgs at an LHeC

- **Motivation**
- **Methodology**
- **Benchmarks**
- **First Results for CC e-p**
- **HO Corrections**
- **Outlook**

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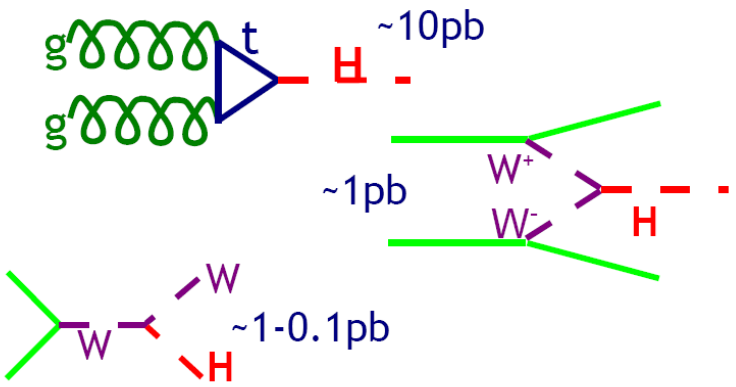
2nd CERN-ECFA-NuPECC LHeC Workshop
September 2, 2009

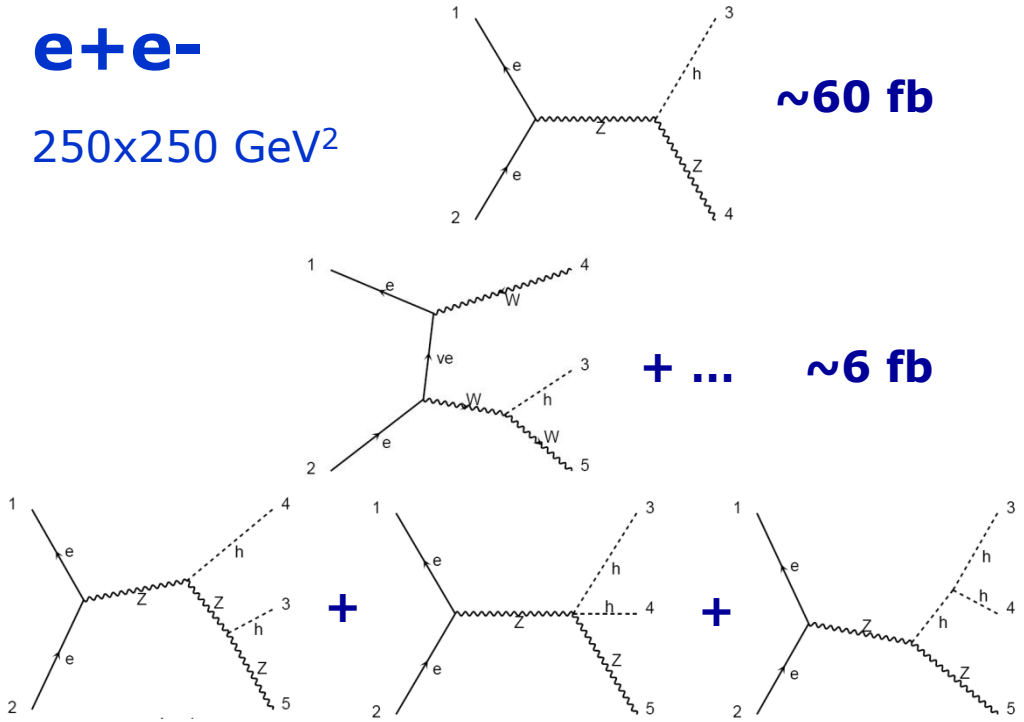
SM Higgs Production Examples

pp



e+e-

250x250 GeV^2



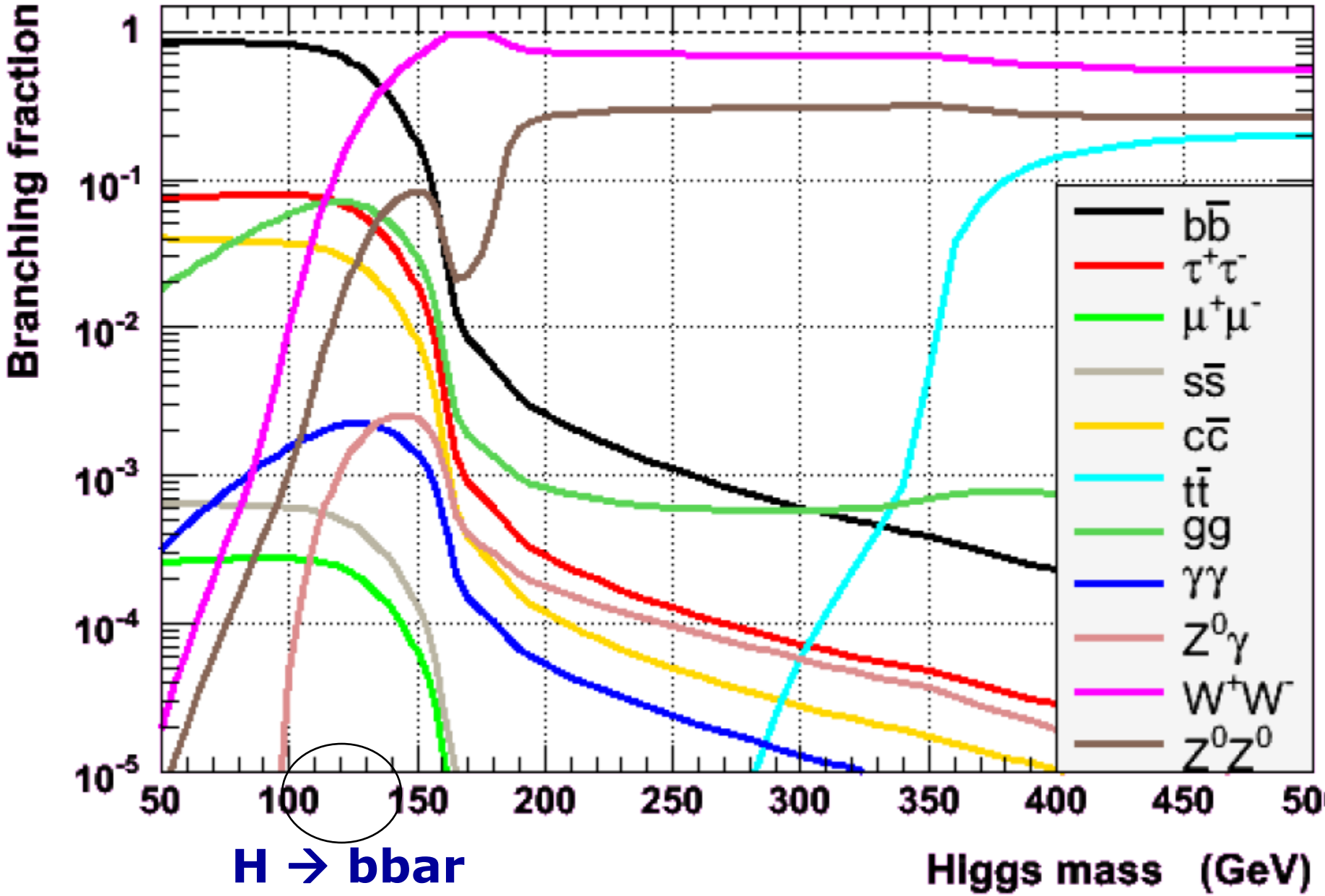
Decay depends strongly on m_h

- **low masses : bbar, but also $\gamma\gamma$, $\tau^+\tau^-$**
- **high masses : WW, ZZ … ttbar**

Variety of search topologies with different S/B

(ee: my MadGraph calc. numbers)

SM Higgs Branching Fractions (HDECAY 2.0)



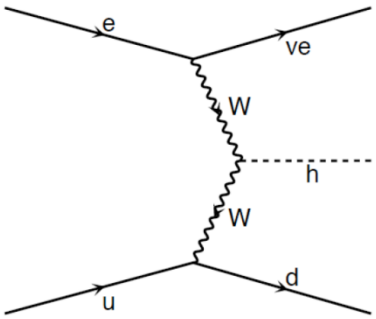
CC : LO SM Higgs Production

ep

~ 200 fb

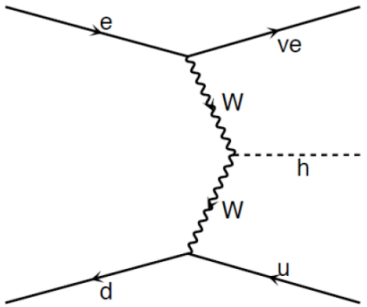
e-p (swap charges for e+p)

e- u -> ve h d



around 90-80%

e- d~ -> ve h u~



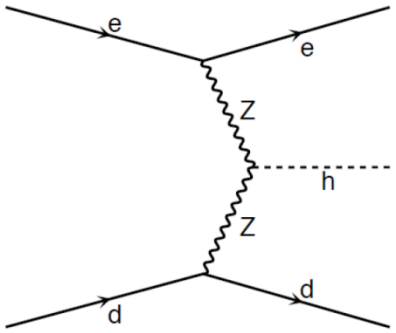
around 10-20%

NC : LO SM Higgs Production

~ 50 fb
(Z heavier
than W and
couplings to
fermions
smaller)

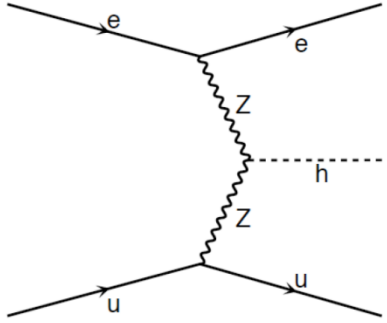
e-p (swap charges for e+p)

e- d -> e- h d



around 1/3

e- u -> e- h u



around 1/3

Methodology

MadGraph : tree level calculations of various processes

e.g. alpha_s, alpha_s^2 and alpha_s^3

Code generated according to request via web interface or using downloaded code

→ you have to know what are you doing…

SM parameters can be steered via SM parameter calculator (param_card.dat)-> e.g. allows to study a variation of MH

Beam energy, phase space cuts, PDF, scales etc. via steering card (run_card.dat)

Higgs decay modes can be considered (package DECAY).

Madgraph produced all diagrams shown in this talk.

I used version 4.4.8 and 4.4.17.

Used Settings

PDF : CTEQ6l1 (LO PDF and LO alpha_s=0.13)

Factorization and renormalizations scales set to partonic c.m.s.

Usually no phase space cuts except stated otherwise -> total cross sections

Higgs mass 120 GeV except stated otherwise, all other parameters according to tree level calculations (e.g. Z and W widths)

Proton beam energy fixed to 7000 GeV

Electron and positron beam energies set to 50, 100 and 150 GeV.

NEWS

MadGraph is interfaced to Pythia and to a 'Pretty Good Simulator' (PGS) of LHC and Tevatron detectors which works very successful for pp and ee

→ Goal was : to use this for LHeC / DIS studies as well!

→ After a lot of tests and contact to authors : present version is not usable

However, after more discussions and

→ after some hints from Masaki (CompHep + Pythia interface), I could change the pythia-pgs package such, that it works for DIS

→ tested via many processes, here first results for CC e-p higgs and dijets are shown, more are in the pipeline…

My Benchmark Studies …

pp : DY and Z production : detailed comparisons with MCFM, FEWZ and HORACE

(setting of EW scheme matters for a precise comparison)

ee : e.g. Higgs associated with a W-boson pair

mh = 120 GeV, 250 GeV x 250 GeV

Ref: S.Mao et al., arXiV.0808.3018v1 5.63 fb

MadGraph 5.7 fb

ep : NC ep cross section y<0.6 and theta_e < 174 deg

H1 1992 : 92 +- 16 (tot) nb

Madgraph : 87 nb

NC, CC e+-p higgs cross esction comparisons with numbers from B. Kniehl and E. Perez in Divonne'08

CC e-p Higgs Cross Sections (fb) versus Electron Beam Energy

Ep = 7000 GeV, 100 k events

	100 GeV	120 GeV	160 GeV	200 GeV	240 GeV	280 GeV
50 GeV	102.4	80.6	50.3	31.6	19.9	12.5
100 GeV	201.3	165.3	113.2	78.6	55.2	39.1
150 GeV	286.3	239.5	170.4	123.3	90.5	67.1

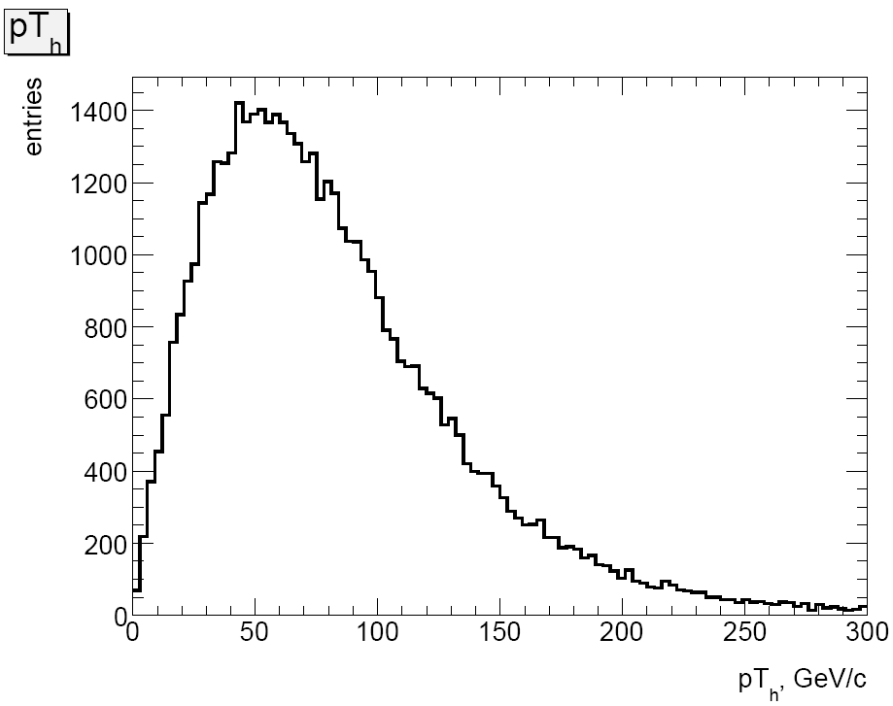
Comparison for Ee=140 GeV and mh=115 GeV
CompHEP : 256.2 fb (M. Ishitsuka)
Madgraph : 235.7 +- 0.12 fb

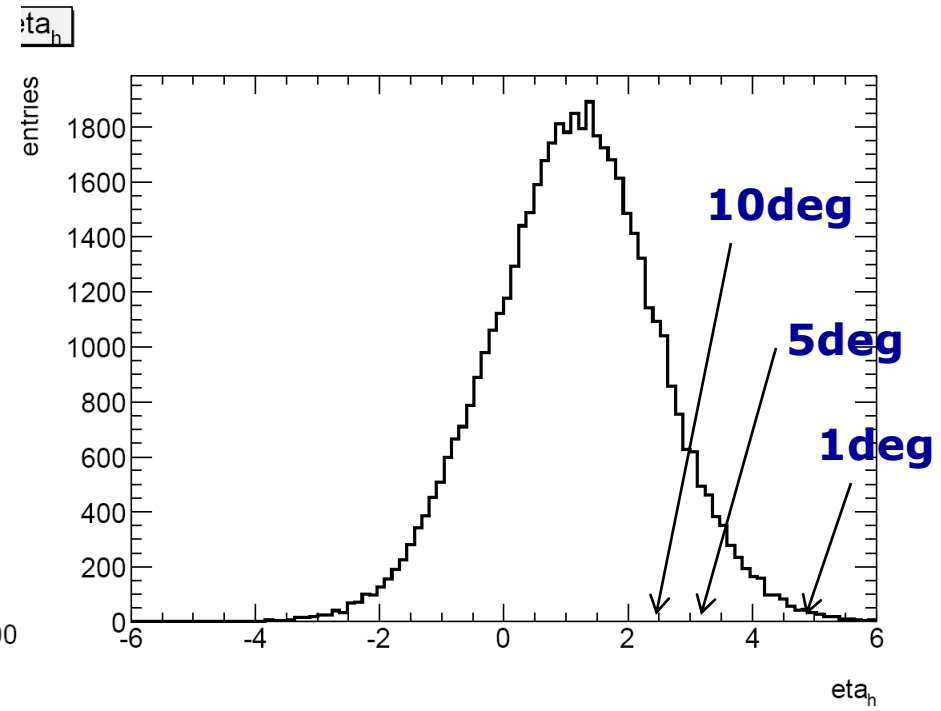
First Results for e-p CC Higgs

- 50 k CC higgs events, mh=120 GeV, 150 GeV x 7000 GeV
- Higgs decay via Pythia :

~68% into bbar + other decay modes

…somewhat lower than expected, similar number via DECAY in Madgraph (not an issue at the moment)





Higgs rapidity in central to forward region

‘Detector’

…events passed thru PGS generic LHC detector

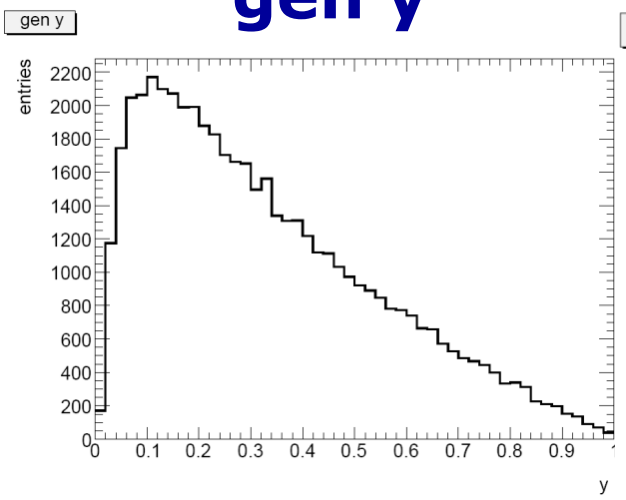
```
LHC              ! parameter set name
320              ! eta cells in calorimeter
200              ! phi cells in calorimeter
0.0314159        ! eta width of calorimeter cells  |eta| < 5
0.0314159        ! phi width of calorimeter cells
0.01             ! electromagnetic calorimeter resolution  const
0.2              ! electromagnetic calorimeter resolution * sqrt(E)
0.8              ! hadronic calolrimeter resolution * sqrt(E)
0.2              ! MET resolution
0.01             ! calorimeter cell edge crack fraction
cone             ! jet finding algorithm (cone or ktjet)
5.0              ! calorimeter trigger cluster finding seed threshold (GeV)
1.0              ! calorimeter trigger cluster finding shoulder threshold (GeV)
0.5              ! calorimeter kt cluster finder cone size (delta R)
2.0              ! outer radius of tracker (m)
4.0              ! magnetic field (T)
0.000013         ! sagitta resolution (m)
0.98             ! track finding efficiency
1.00             ! minimum track pt (GeV/c)
3.0              ! tracking eta coverage
3.0              ! e/gamma eta coverage
2.4              ! muon eta coverage
2.0              ! tau eta coverage
```

Eele 20%
Ehad 80%

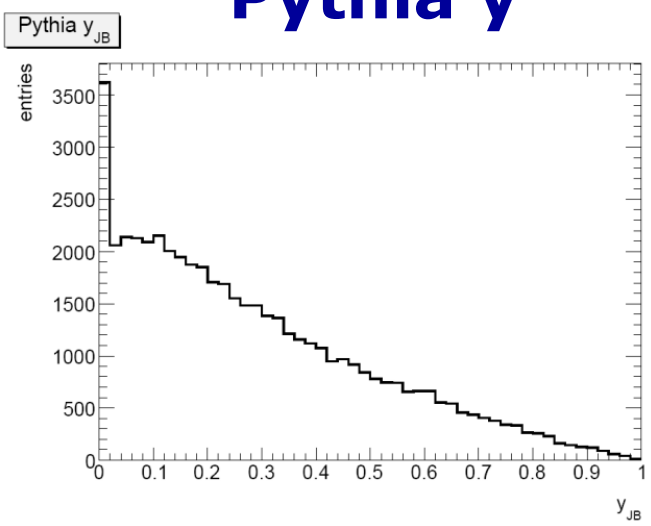
jets: cone<0.5

Kinematics (rec=JB)

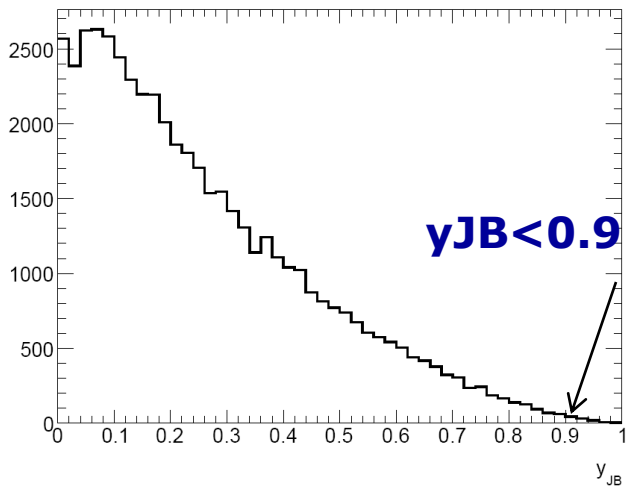
gen y



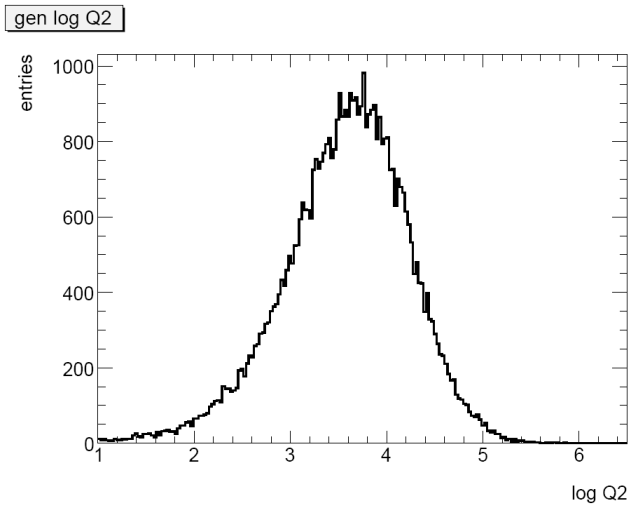
Pythia y



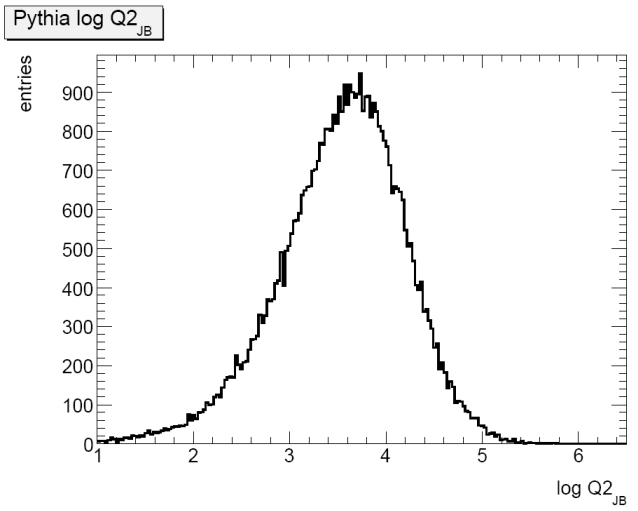
rec y_JB



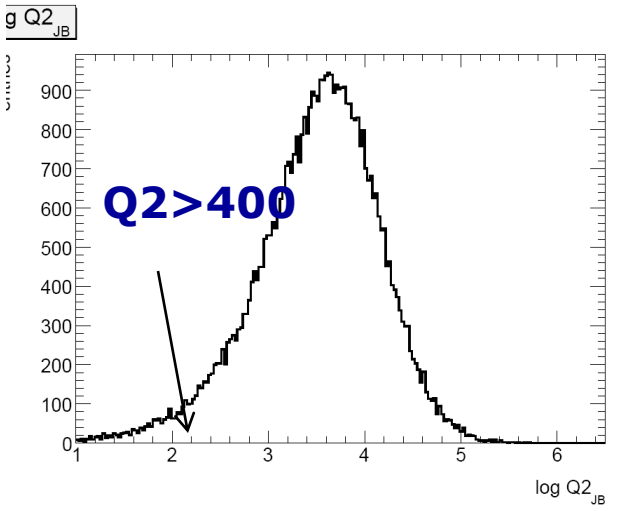
gen Q2



Pythia Q2

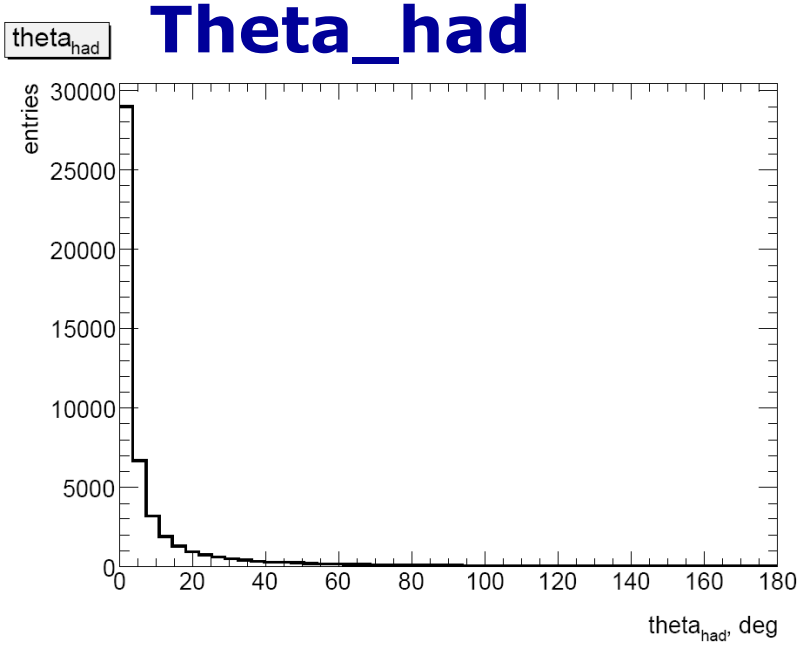


rec Q2_JB

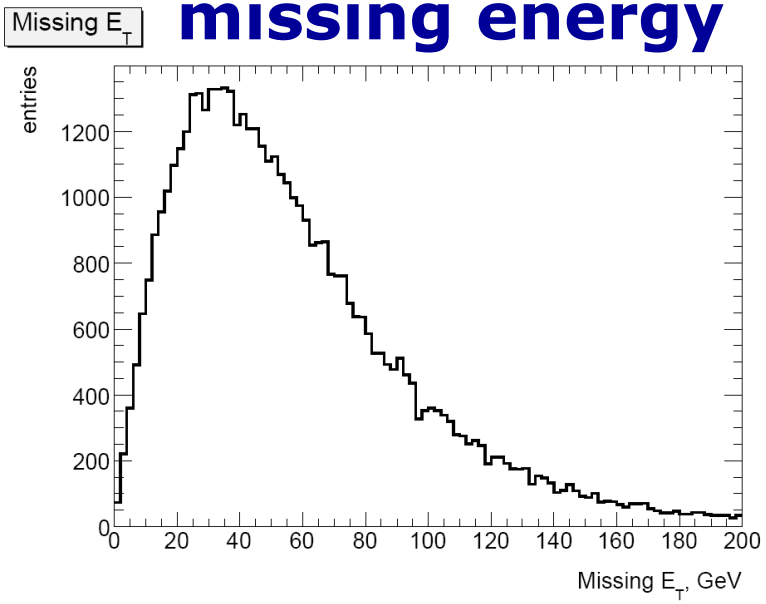


More rec. Kinematics …

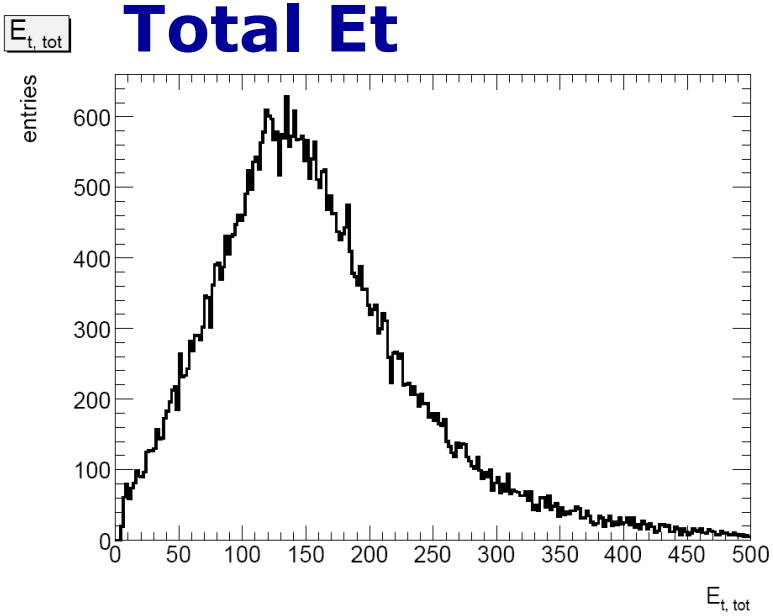
Theta_had



missing energy



Total Et

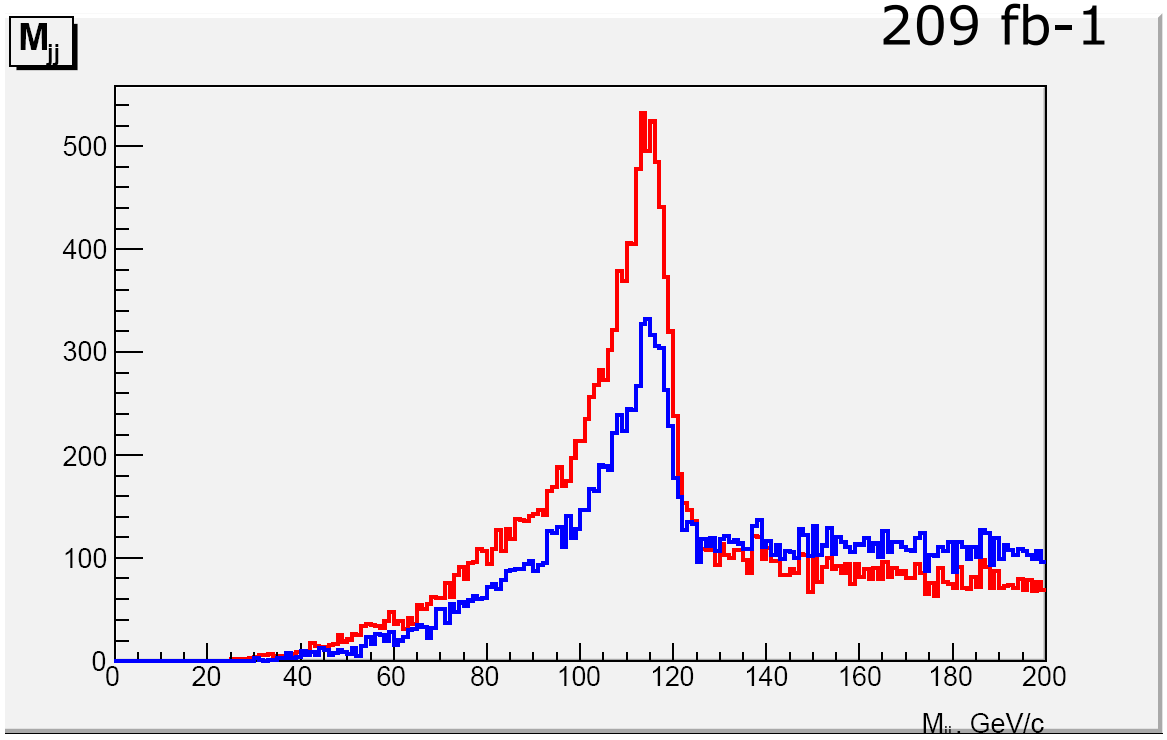


Invariant Dijet Mass

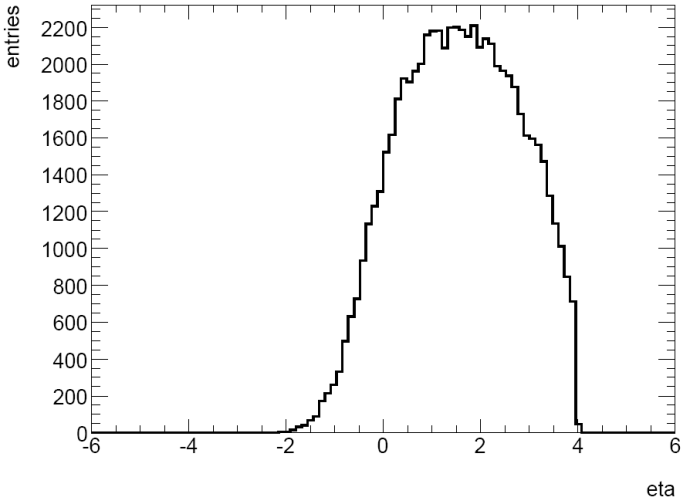
Q2>400 GeV2, yJB<0.9, Et_jet>20 GeV, Etmiss>20 GeV, jet_angle>1 degree (CAL), NO b-tagging (!)

RED : 2 jets with lowest rapidity & Et_total>100 GeV

BLUE : 2 jets with highest pT



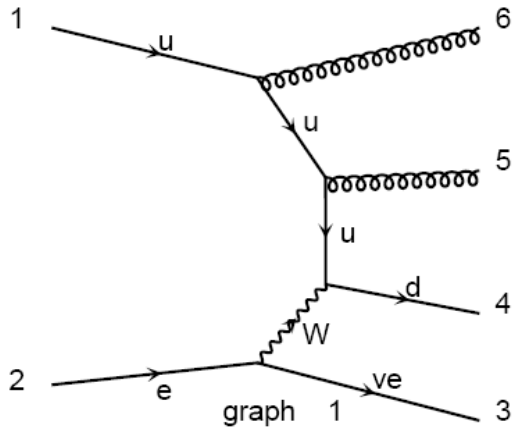
Rapidity of 2 'red-sel.' jets

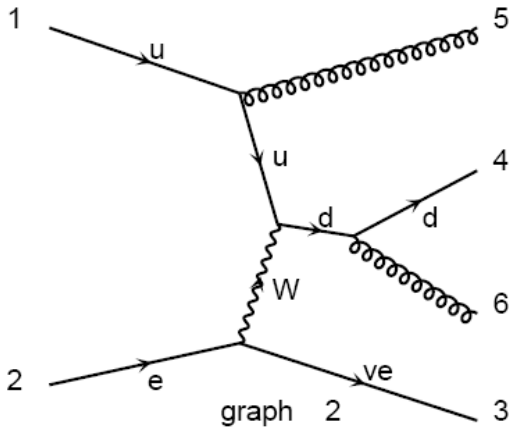


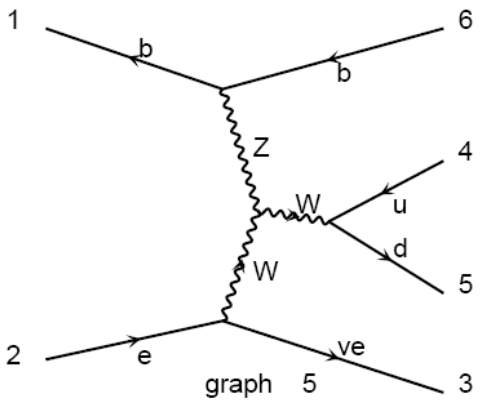
4 :=2.1 deg

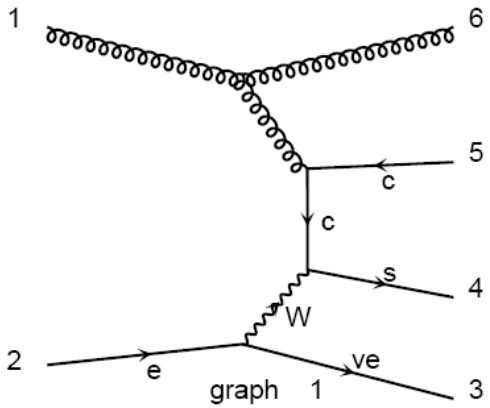
Background

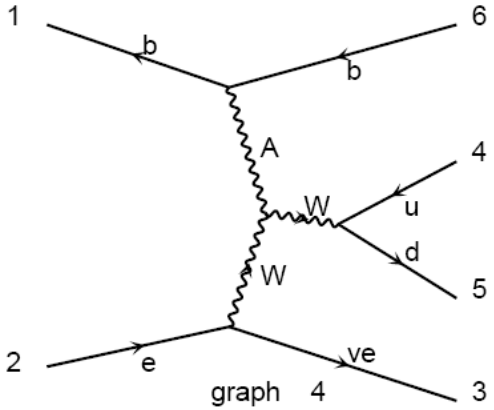
20 k CC dijet events, E_jet>5 GeV, theta_jet>0.5 deg, Mjj>30 GeV
58.8 pb
MadGraph generated 542 diagrams including higgs…, e.g.

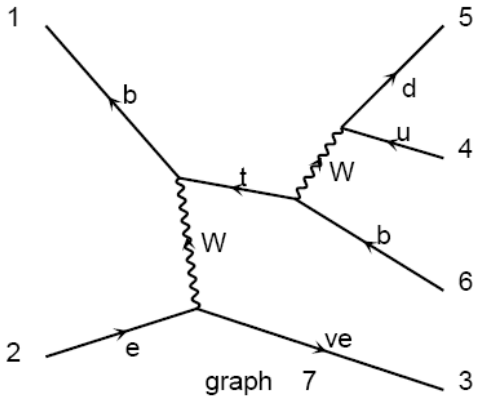








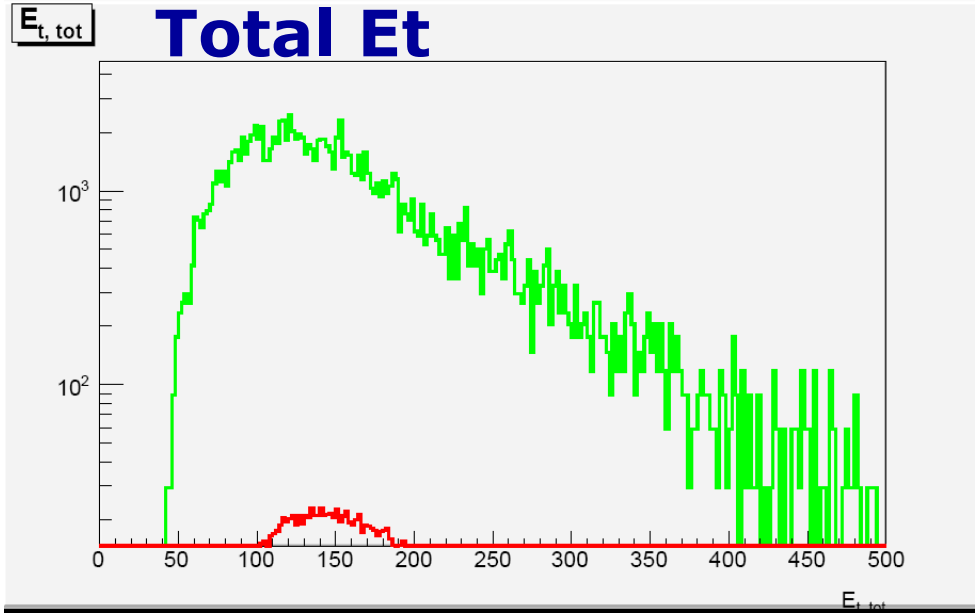


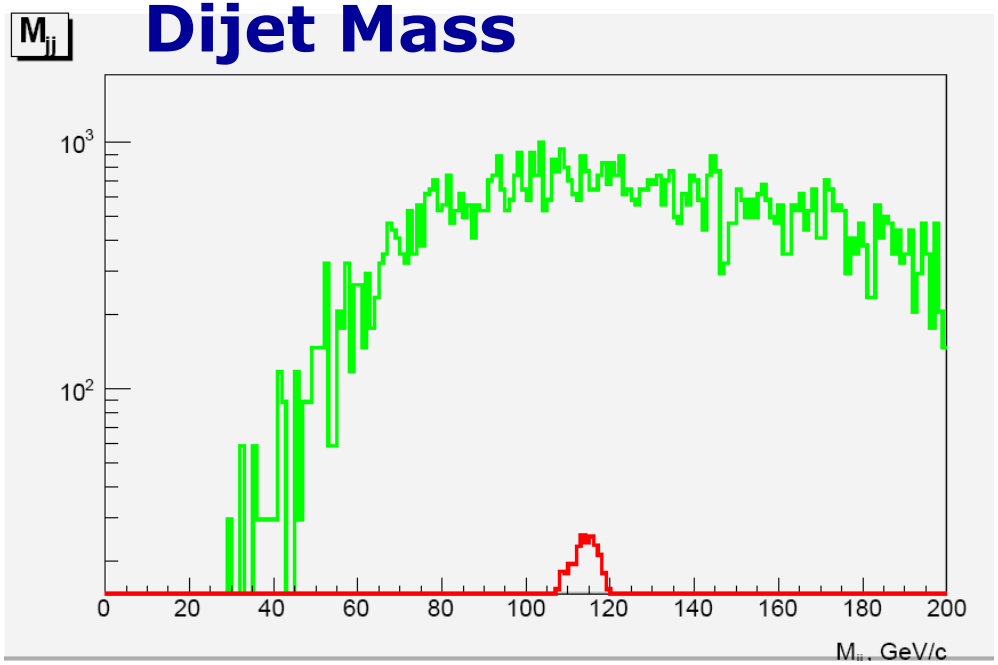


Signal and Background

- 10 fb-1
- 2-jets with lowest rapidity
- Total Et for pre-selected

events (kin. cuts) is different for signal and background





80 < Mjj < 125 GeV

Signal (red) : 534.52

Signal + Background : 30873.2

Ratio S/(S+B) = 1.73 %

Ratio S/sqrt(S+B) = 3.04

B-tagging will be crucial.

B tagging - an attempt

Idea : using jets with |eta_rec| < 2.5

option: select 3 jets per event

- assign jets to generated b/bbar quarks requiring a cone of R<1 : apply a 'b-tag' efficiency of 0.6
- assign jets to generated c/cbar quarks requiring a cone of R<1 : apply a misidentification efficiency of 0.1
- if there is a remaining jet → light quark or gluon jet : apply a misidentification efficiency of 0.01

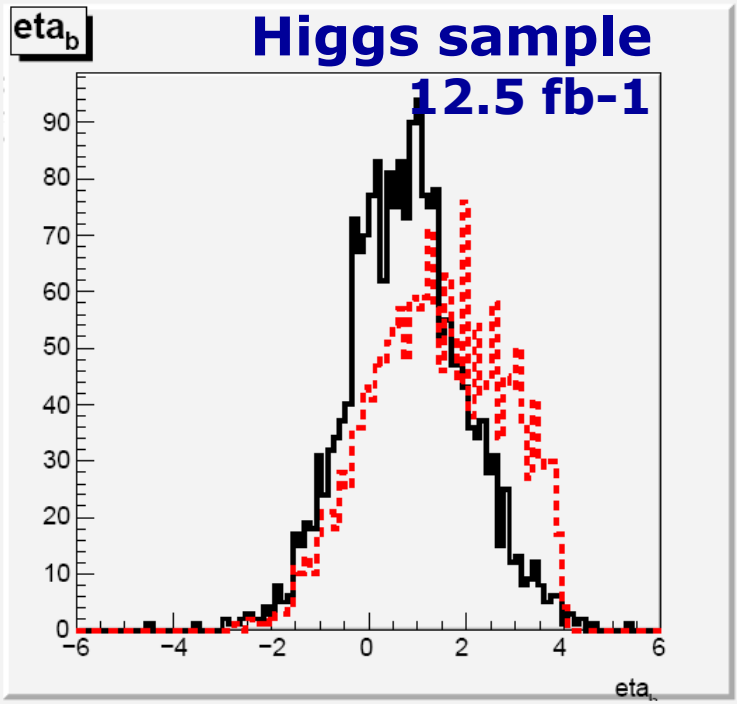
➔ CC e-p background sample : dijets mainly either formed from

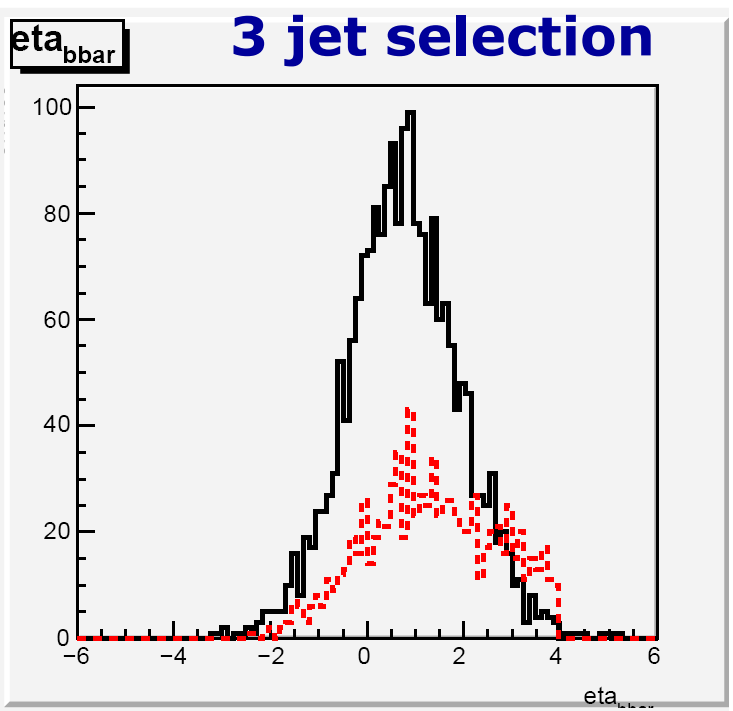
cbar and s quarks (~40%)

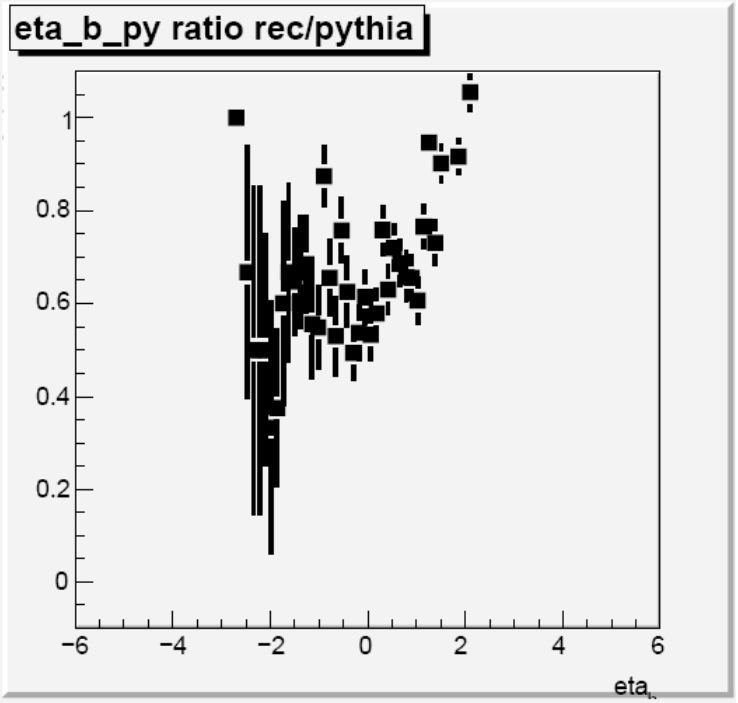
ubar and d quarks (~40%)

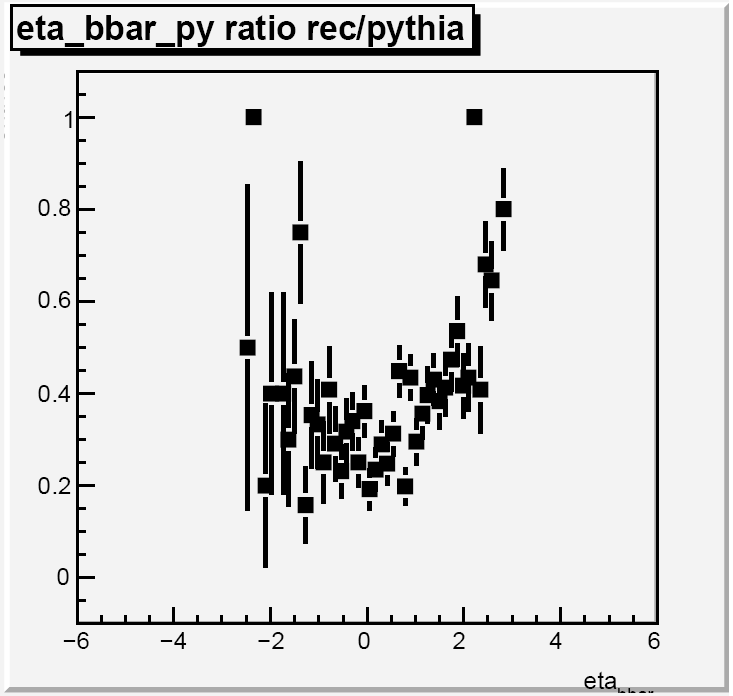
+ gluon

- I found 2% jets from b-quarks and 9% from bbar-quarks.









- only around 60% (30% for 3 jet sel.) of b/bbar generated jets are reconstruc-ted in central region
- bias towards forward region?

Idea is simple, but not so easy to perform with PGS/LHC det.

WE NEED OUR OWN DETECTOR

Nuclear Physics B395 (1993) 35–59
North-Holland

NUCLEAR PHYSICS B

HO QCD and QED Corrections

QCD and QED corrections to Higgs-boson production in charged-current ep scattering

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First-order QCD and leading QED corrections to Higgs-boson production in the channel $e^- p \to \nu H^0 X; H^0 \to b\bar{b}$ are calculated for the kinematical conditions at LEP ⊗ LHC ($\sqrt{s} = 1360$ GeV) and the interesting mass range $80 < M_H < 150$ GeV. In the DIS scheme the QCD corrections (not including the corrections to the branching ratio, which are well known) are found to be about 1% for the total cross section and −13% to −10% for the observable cross section as defined by appropriate cuts. The latter results depend on the definition of these cuts. The QED corrections amount to about −5%.

QCD Corrections

At hadronic vertex

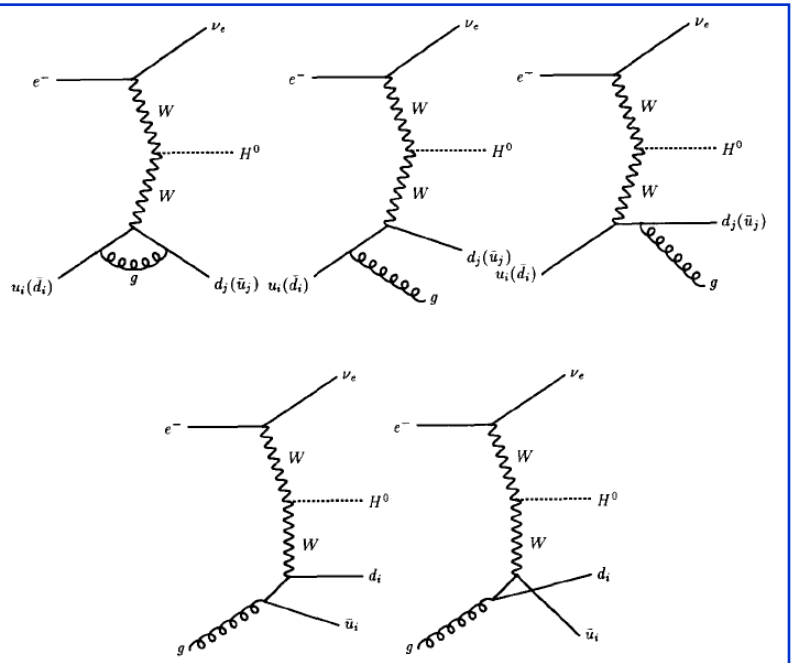

Fig. 4. The $O(\alpha_s)$ diagrams contributing to the QCD corrections at the hadronic vertex.

Cut dependent!

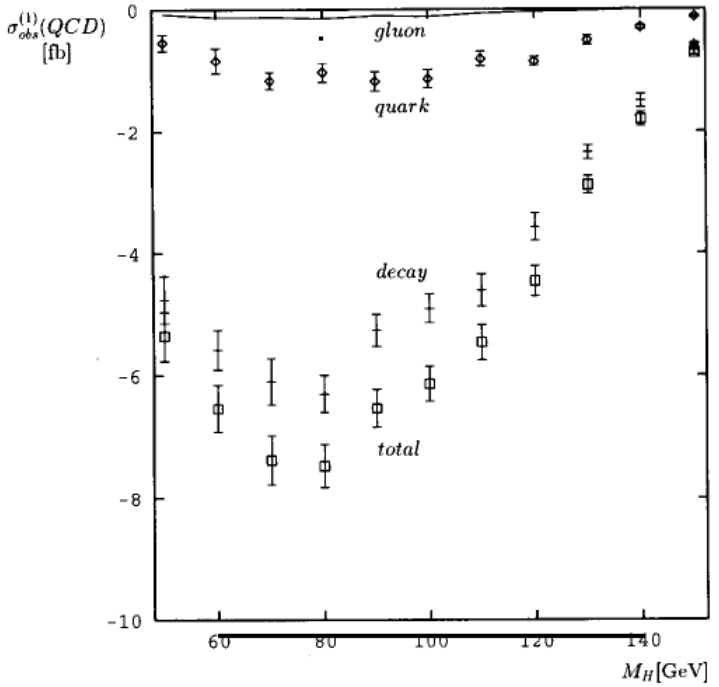

Fig. 6. The $O(\alpha_s)$ QCD corrections including the cuts explained in sect. 2. The corrections to the production process $ep \to \nu H^0 X$ from quarks and gluons and to the decay process $H^0 \to b\bar{b}$ are shown separately. The total sum $\sigma^{(1)}_{obs}$ (QCD) is the appropriate $O(\alpha_s)$ correction to the observable cross section $\sigma^{(0)}_{obs}$ (which already includes the QCD corrected $Br(H^0 \to b\bar{b})$). The error bars indicate the precision of the Monte Carlo calculation.

At decay vertex

- irrelevant for total cross section
- sensitive to final state cuts, e.g. here the req. of exactly 3 jets.

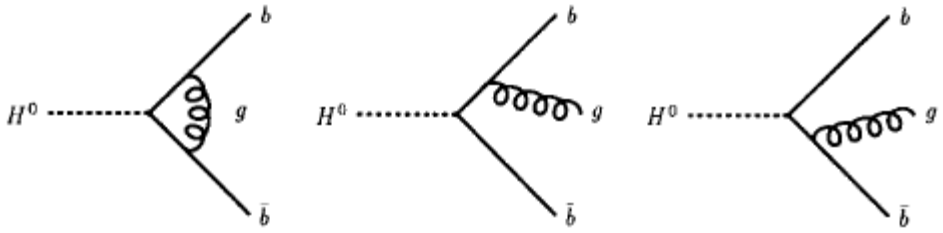

Fig. 7. The $O(\alpha_s)$ diagrams contributing to the QCD corrections to the decay vertex.

QED Corrections

Leading contribution: ISR

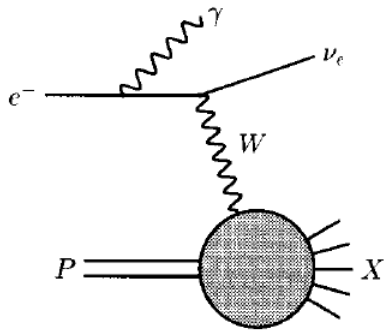

Fig. 8. Diagram representing the leading QED correction to charged-current ep processes.

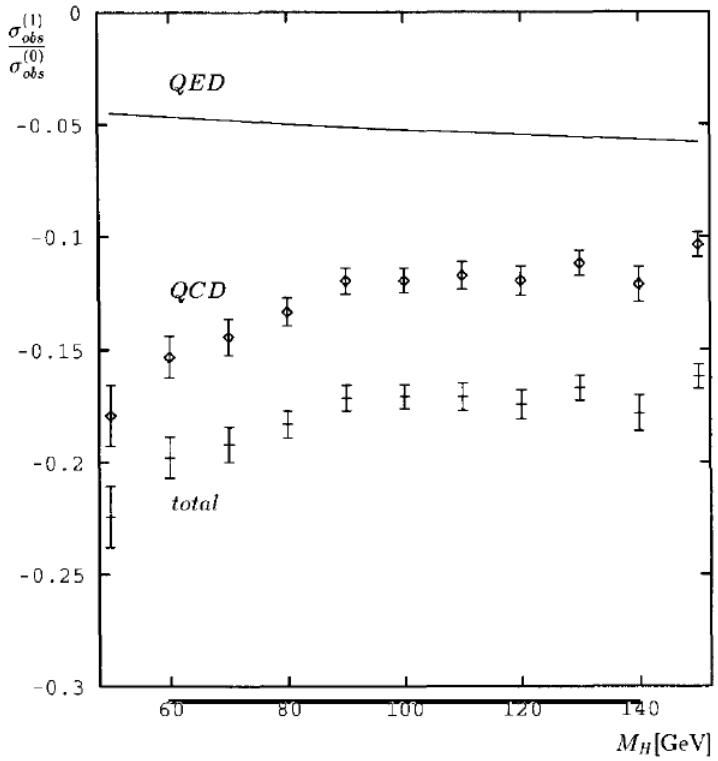

Fig. 10. The relative corrections $\sigma^{(1)}_{obs}/\sigma^{(0)}_{obs}$ to the observable cross section for $e^- p \to \nu H^0 X; H^0 \to b\bar{b}$, including the cuts given in sect. 2. The QCD and the leading QED corrections are shown separately. The error bars indicate the statistical precision of the Monte Carlo calculation.

- HO QCD and QED corrections are moderate, but sensitive to chosen exp. cuts

→ this calculations were stat. limited

→ need an update of calculations for our cuts

→ need similar calculations for background processes

Outlook

- **NEW: Full MadGraph + Pythia + PGS chain is working for DIS !**

➔ **Pythia Madevent files can be read in into our own detector simulation tools!** (see detector session)

- **A first look to CC e-p higgs production confirms the early LEP+LHC studies on dominant dijet background and the importance of the b-tagging – studies ongoing!**
- **HO QCD and QED corrections are moderate but cut dependent for Higgs signal, but an update of calculations is desirable.**

- **More detailed background sources for CC e-p higgs should be studied** (σ for 150 GeV, Etjet>5 GeV):

  NC W+ and W- production (~ 6 pb)

  CC W- production (~9 pb)

  CC Z production (~ 1 pb)

  CC top production (~4-6 pb)

  Also important dijets in DIS & photoproduction …but PHP not in MadGraph (yet running)