Higgs boson production from heavy quark fusion at LHC systematics from parton shower approach

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-> Prospects for bbh/H/A->tau tau observability at LHC

-> Theoretical predictions: inclusive cross-section with NNLO

->Theoretical predictions: Monte Carlo generators with
LO matrix elements + parton shower

=> steps of experimental analysis (simplified largely)
events generated with PYTHIA, HERWIG, ARIADNE

=> impact from different choices of Q2 definition

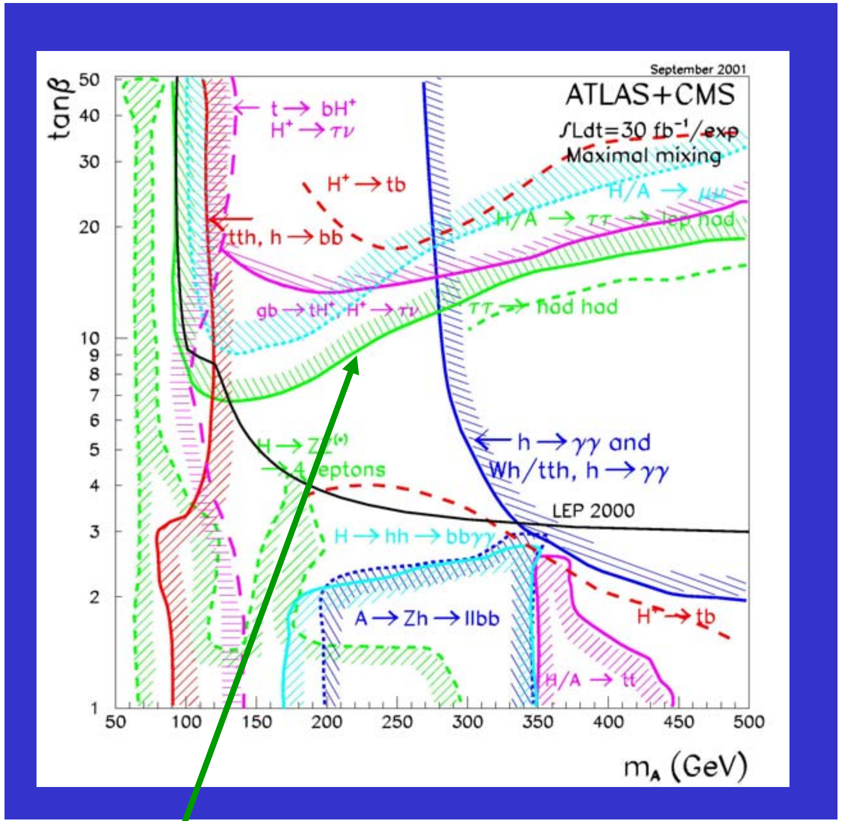
=> impact from different choices of PDF

-> Summary

Motivation: prospects for bbh/H/A->tau tau observability at LHC

-> important channel for MSSM Higgs search
   at large and moderate tanβ
-> coupling bbH, bbA scales like taβ^2,
   enhanced xsection and BR with respect to SM Higgs
-> accessible already at low luminosity
-> planned experimental analysis
  => trigger on high p_T lepton from one tau
  => identify second tau decaying in hadronic mode
  => reconstruct invariant mass of the tau system
    (collinear approximation in tau decays
      key is an excellent E_T^{miss} resolution)
  => combine events with no b-jet and with single b-jet tag
-> dominant backgrounds
  => irreducible: Z->tau tau, bbZ -> tau tau
    severe problem for Higgs mass not far from Z mass
  => reducible: W+jet, ttbar
-> expected number of events (ATLAS Physics TDR)
  tanβ=10, m_H= 150 GeV, 30fb^{-1}
  analysis with single b-jet tag: S/sqrt(B) = 8.0
    74 evt - signal (97% from bbH)
    86 evt - total bgd
  analysis with b-jeto veto: S/sqrt(B) = 3.9
    105 evt – signal (47% gg->H, 53% bbH)
    714 evt – total bgd
  combined significance = 8.9

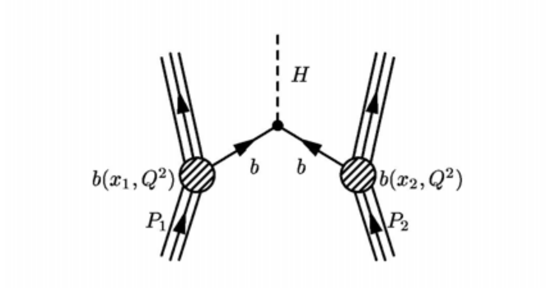
discovery potential



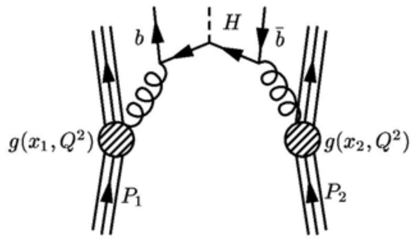
bbh/H/A->ττ->lep-had

also measurement of Δtanβ/tanβ with 15% accuracy

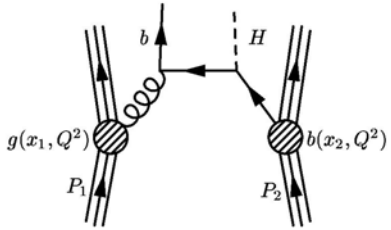
Production processes from heavy quark fusion



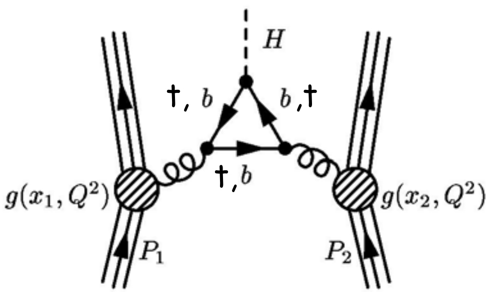
bb->H lowest-order ME with b-quarks PDF's



gg-> bbH lowest-order ME with no b-quarks PDF's



gb->bH lowest-order process ME with single b-quark



gluon-fusion production

Theoretical predictions: inclusive cross-section with NNLO

Predictions of the total cross-section for Higgs boson production in association with bottom quarks, where neither bottom quark need to be detected: pp -> (bb) H + X

variable flavour scheme (VFS):

leading-order partonic process is bb->H

NLO calculations: A. D. Dicus, S. Willenbrock, Phys.Rev.D39 (1989) 751.
A. D. Dicus et. al. Phys. Rev. D59 (1999) 094016.
F. Maltoni et. al. Phys. Rev. D67 (2003) 093005.
F. I. Olness, Nucl. Phys. B308 (1988) 813.

NNLO calculations: R. V. Harlander, W. B. Kilgore, Phys.Rev.D68:013001,2003.

fixed flavour scheme (FFS):

leading order partonic process is gg->bbH
(bottom quarks do not appear in the initial state)

NLO calculations: L. Reina et. al. Phys. Rev. Lett. 87 (2001) 201804.
L. Reina et. al. Phys. Rev. D67 (2003) 071503
W. Beenakker et. al. Nucl. Phys. B653 (2003) 151.

leading order partonic process is gb->bH

NLO calculations: J. Campbell et. al. Phys. Rev. D67 (2003) 095002

ongoing discussion on the relative merits of both approaches

with $\mu_F = m_H/4$

disagreement between results from both approach significantly reduced

Theoretical predictions: inclusive cross-section with NNLO

Theoretical uncertainties on the cross-section:
(from R. V. Harlander, W. B. Kilgore, Phys.Rev.D68:013001,2003)

up to two loops: bb->H
up to one loop: bb->gH, gb->Hb
at tree level: bb->Hgg, bb->Hqq
bb->Hbb, gb->Hgb
bb-> Hbb, bq-> Hbq
gg->Hbb
qq-> Hbb

(μ_R, μ_F) varied in range: $(1, 0.1)m_H$, $(1, 0.7)m_H$
for m_H = 120 GeV: 70% at LO
40% at NLO
15% at NNLO

We can conclude that the inclusive cross-section for Higgs boson production in bottom quark annihilation is under good theoretical control.

What about Monte Carlo events generation?
What theoretical precision should I expect for number of signal events after experiment-like analysis?

Theoretical predictions:
Monte Carlo generators with LO matrix elements + parton shower

pythia: uses the collinear algorithm with an angular veto to reproduce effect of angular ordered shower

available processes:

- gg->H (with improved parton shower, matrix-element matching ($O(\alpha_s)$))
- bb->H (with basic parton shower)
- gb->bH (with basic parton shower)
- gg->bbH (with basic parton shower)

ariadne: colour dipole model

apply parton shower scheme to PYTHIA events

herwig: angular ordered parton shower which resumes both soft and colliners singularities

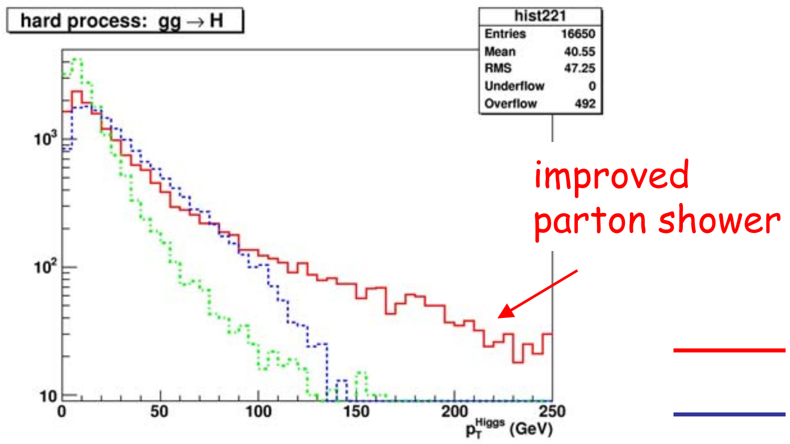
available processes:

- gg->H
- bb->H
- gb->bH
- gg->bbH

AcerMC framework with interfaces to PYTHIA/HERWIG/ARIADNE/LHAPDF
CPC 149 (2003) 142, hep-ph/0405247 available from http://borut.home.cern.ch/borut
see talk by Elzbieta RW

What is the starting point from different shower models for Higgs boson transverse momenta, p_T^{Higgs}

$< p_T^{Higgs} >$	PYTHIA	ARIADNE	HERWIG
gg->H	33 GeV	17 GeV	32 GeV
bb->H	23 GeV	39 GeV	25 GeV
gb->bH	30 GeV	23 GeV	48 GeV
gg->bbH	26 GeV	34 GeV	46 GeV



Higgs transverse momenta

pythia

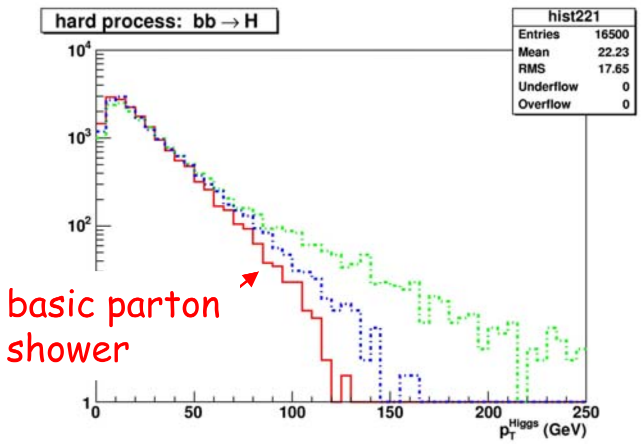
herwig

ariadne

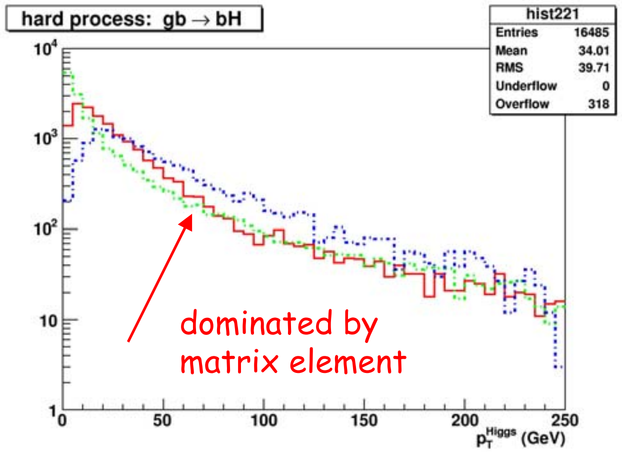
pythia: improved parton-shower gives spectrum with hard tail

herwig: hardest pT in 2->2 processes

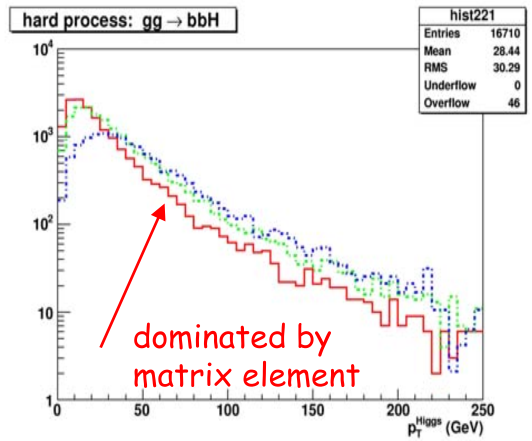
ariadne: hardest radiation from quarks fails for cascade from gluons



Higgs transverse momenta



Higgs transverse momenta



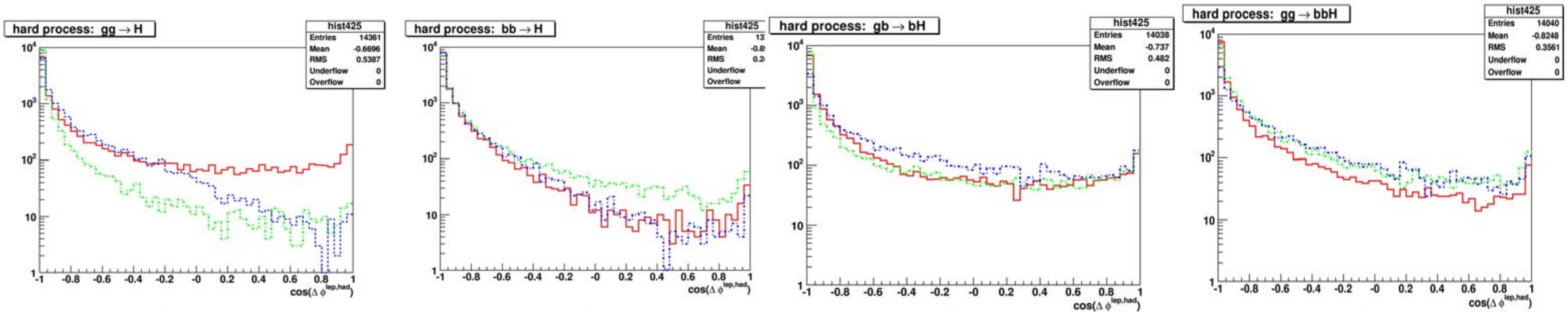
Higgs transverse momenta

What are steps in experimental analysis

Shown are results obtained with simplified reconstruction AcerDET, hep-ph/0207355 available from http://borut.home.cern.ch/borut (see talk by Elzbieta RW)

-> basic selection:
reconstruct lepton (p_T > 20 GeV) and tau-hadronic jet (p_T > 30 GeV), both $|\eta|$ < 2.5; resolve neutrino system
cumulated acceptance: about 13%-16%
(lep-had mode generated)
comparable for all processes and MC parton shower models

-> remove back-to-back configurations, cuts on $\Delta\phi$(lep, had): $|\sin(\Delta\phi(\text{lep, had})| > 0.2$
$\cos(\Delta\phi(\text{lep, had})) > -0.9$



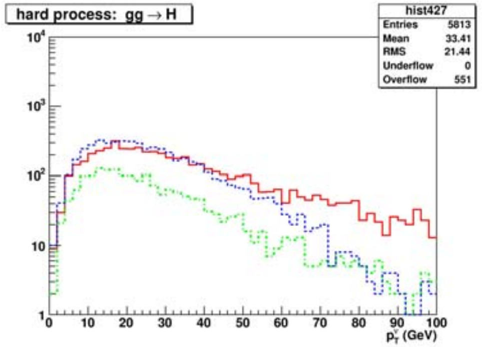
cos ϕ(lep-had) | cos ϕ(lep-had) | cos ϕ(lep-had) | cos ϕ(lep-had)

Cumulated acceptance:

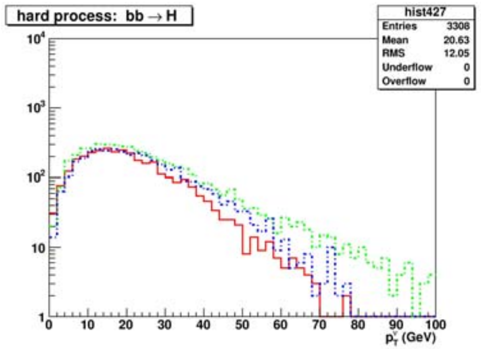
gg → H	bb → H	gb → bH	gg → bbH
5.8% pythia	3.3% pythia	5.0% pythia	4.2% pythia
~~1.8% ariadne~~	4.6% ariadne	4.1% ariadne	6.4% ariadne
5.1% herwig	3.7% herwig	8.7% herwig	7.0% herwig

What will be the steps in experimental analysis

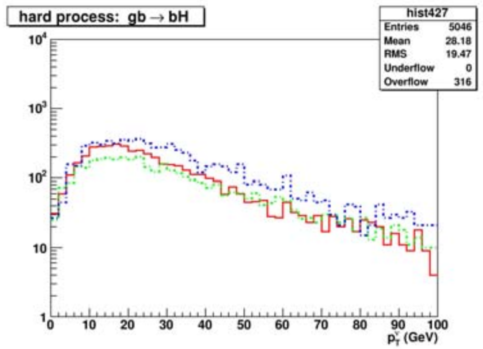
-> improves further resolution, suppresses bgds.: cuts on p_T^{miss}> 30 GeV, m_T^{miss} < 50 GeV :



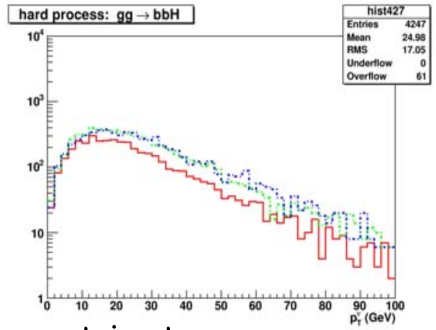
neutrino transverse momenta



neutrino transverse momenta



neutrino transverse momenta

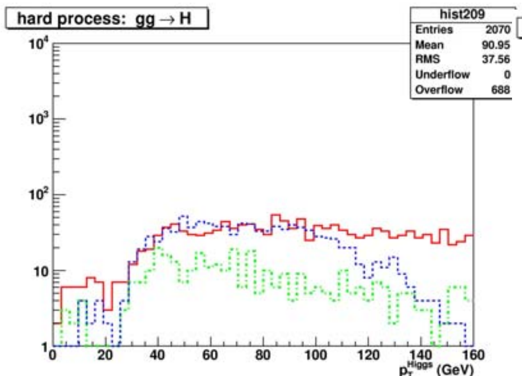


neutrino transverse momenta

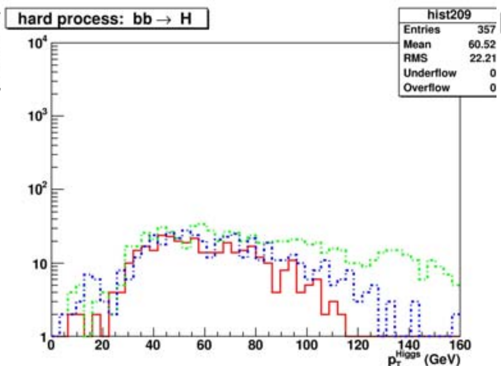
Cumulated acceptance:

gg → H	bb → H	gb → bH	gg → bbH
2.1% pythia	0.4% pythia	1.2% pythia	0.8% pythia
~~0.4% ariadne~~	0.9% ariadne	1.2% ariadne	1.4% ariadne
1.0% herwig	0.5% herwig	2.6% herwig	1.7% herwig

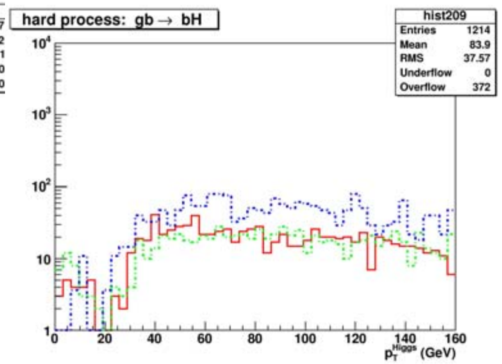
-> what is the effective Higgs p_T spectra after selection: mostly region with p_T^{Higgs} > 40 GeV



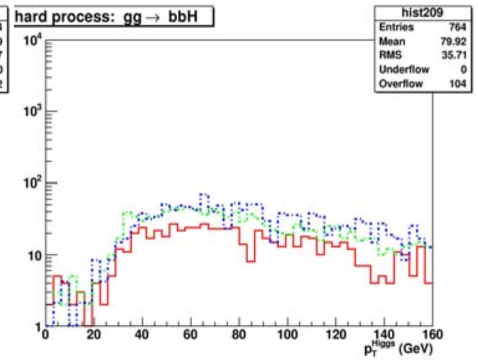
Higgs transverse momenta



Higgs transverse momenta



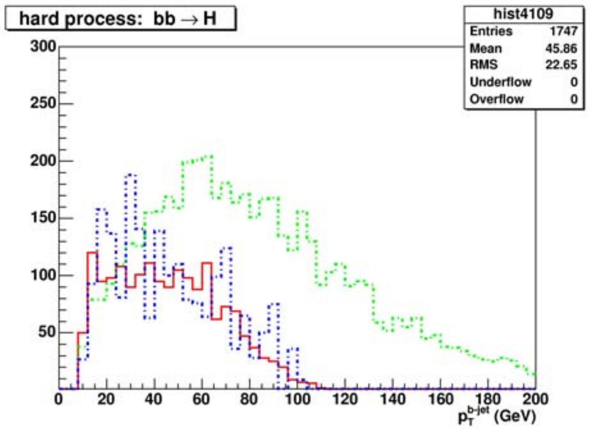
Higgs transverse momenta

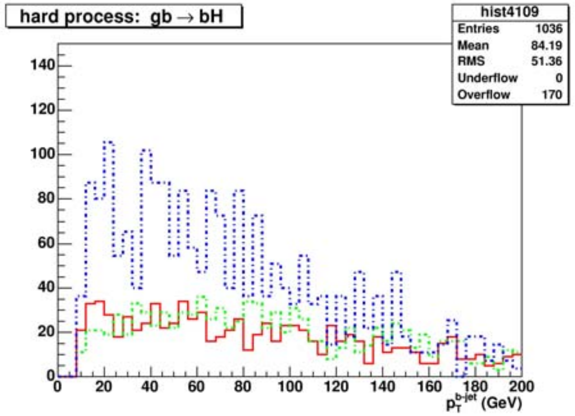


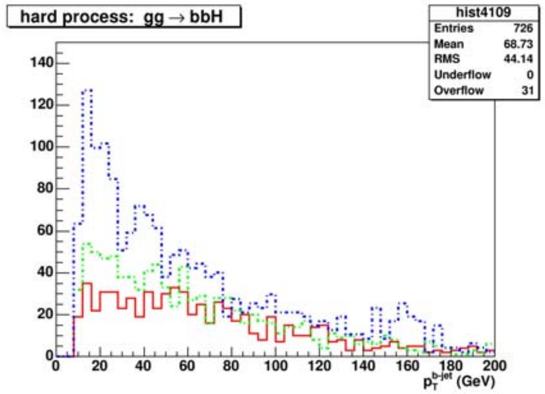
Higgs transverse momenta

What will be the steps in experimental analysis

-> if at least single b-tag required: $p_T^{bjet} > 20$ GeV, $|\eta| < 2.5$







<u>fraction of already accepted events, but with single b-tag</u>

bb → H	gb → bH	gg → bbH
70.1% pythia	79.3% pythia	86.4% pythia
86.9% ariadne	89.3% ariadne	68.2% ariadne
68.0% herwig	79.8% herwig	66.9% herwig

Summary on uncertainties from parton shower model: cumulated acceptance of kinematical selection

analysis with single b-jet tag, starting from gb->bH :

pythia : 0.28%
ariadne : 0.78%
herwig : 0.34%

analysis with single b-jet tag, starting from bb->H :

pythia : 0.95 %
ariadne : 1.07 %
herwig : 2.07 %

analysis with single b-jet tag, starting from gg->bbH :

pythia : 0.70 %
ariadne : 0.95 %
herwig : 1.13 %

analysis with b-jet veto, starting from gg->H :

pythia : 2.1%
~~ariadne : 0.4%~~
herwig : 1.0%

Uncertaintity from parton-shower only:

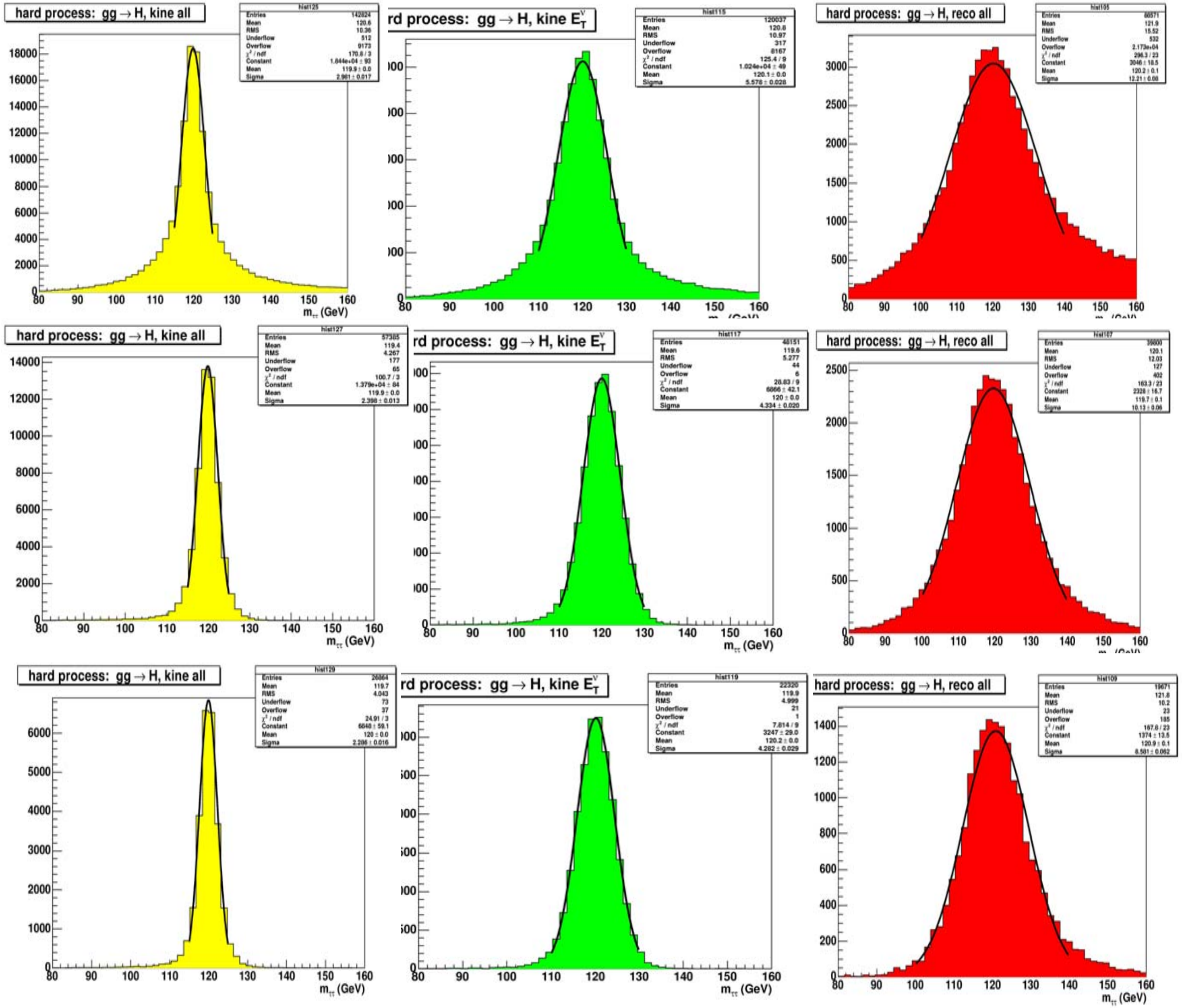
150 % – 200 %

...still not discussed more subtle effects, like impact on:
- -> efficiency of b-jet tagging
- -> efficiency of hadronic tau identification

$m_{\tau\tau}$ reconstruction

why optimisation is indeed necessary....

particle-level | still kine E_T^ν | simplified detector



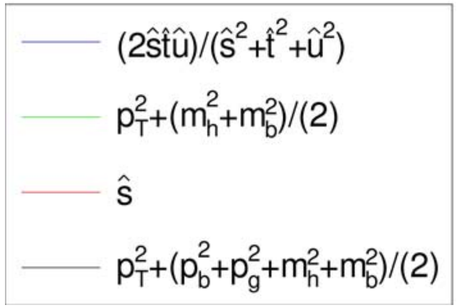
basic selection →

+ optimisation with $\Delta\phi$ cuts →

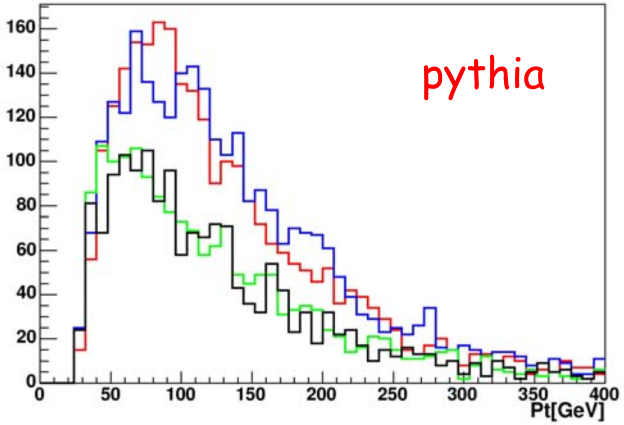
+ optimisation with p_T^ν, m_T^{miss} cuts →

much better resolution;
helps to suppress background:
narrower mass window,
less Z->$\tau\tau$ under the peak

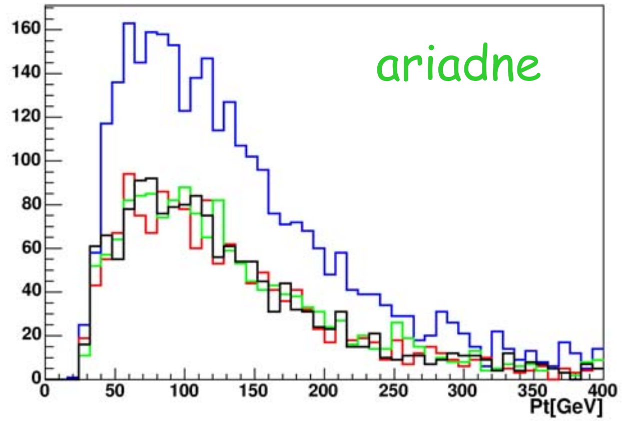
Impact from different choices of Q2 definition: (1) the gb->bH process



cumulative acceptance

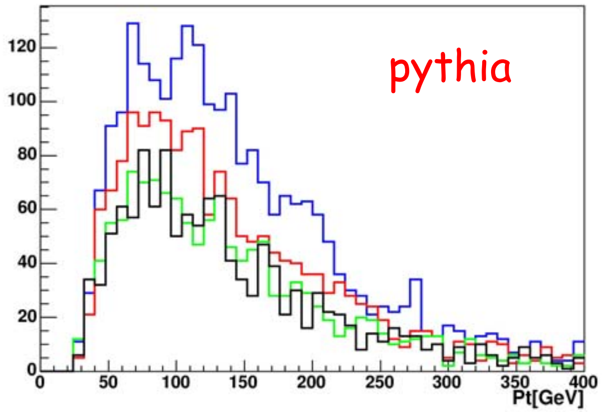


1.2 %
2.2 %
2.3 %
1.2 %

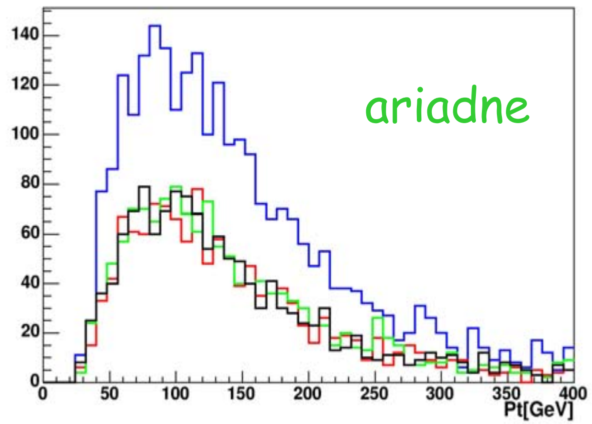


1.2 %
1.0 %
2.4 %
1.2 %

fraction of accepted events with single b-jet tag

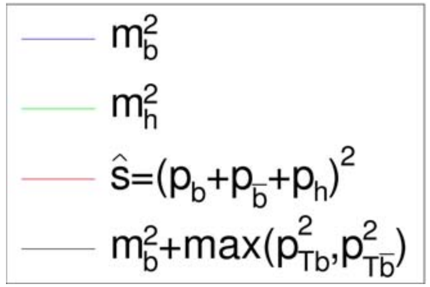


77.9 %
63.7 %
86.6 %
78.2 %

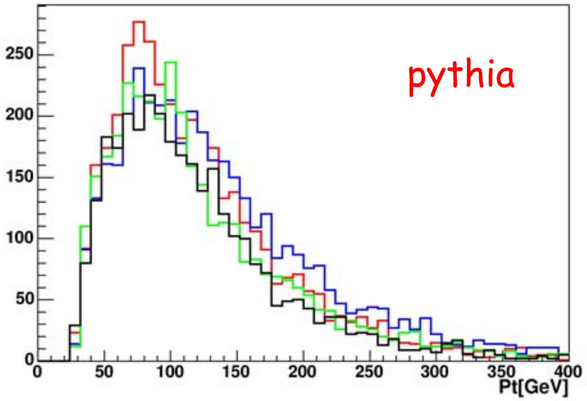


85.5 %
86.3 %
87.3 %
87.5 %

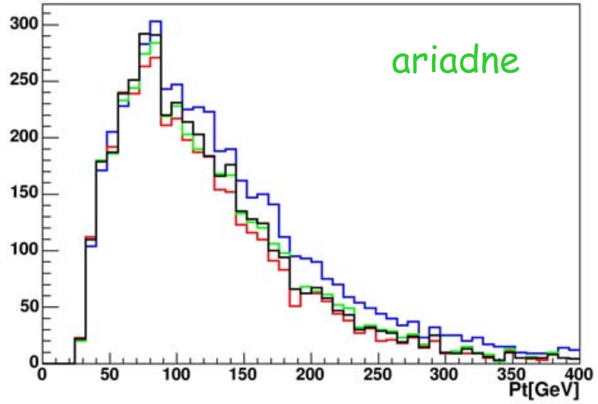
Impact from different choices of Q2 definition: (2) the gg->bbH process



cumulative acceptance (not same analysis)

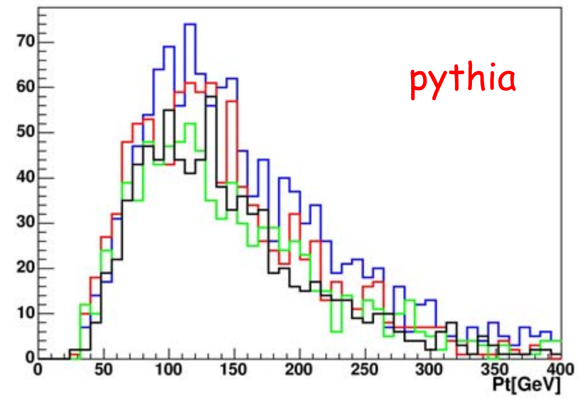


3.2 %
3.9 %
4.1 %
3.5 %

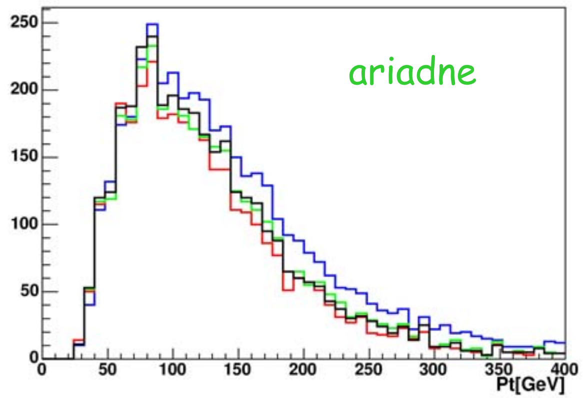


4.2 %
3.9 %
4.9 %
4.2 %

fraction of accepted events with single b-jet tag



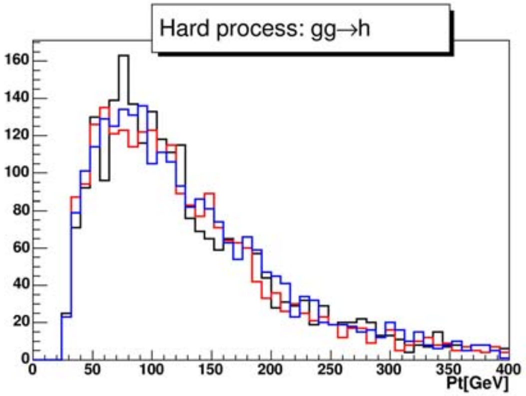
90.0 (26.9) %
83.4 (23.4) %
93.9 (31.5) %
85.6 (25.6) %



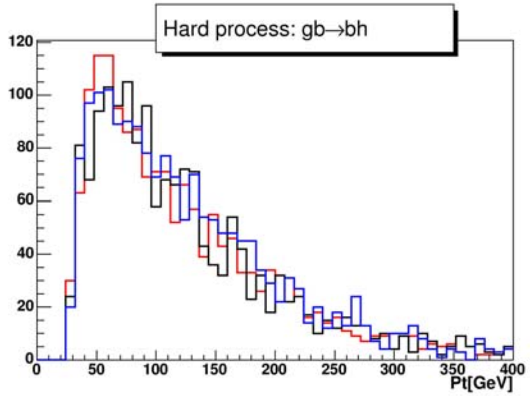
84.6 (24.2)%
83.5 (23.0)%
84.7 (24.4)%
84.5 (23.8)%

Impact from PDF:
different choices of LO parametrisations

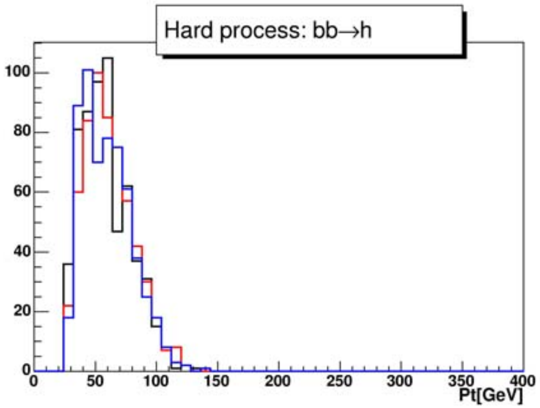
cumulative acceptances



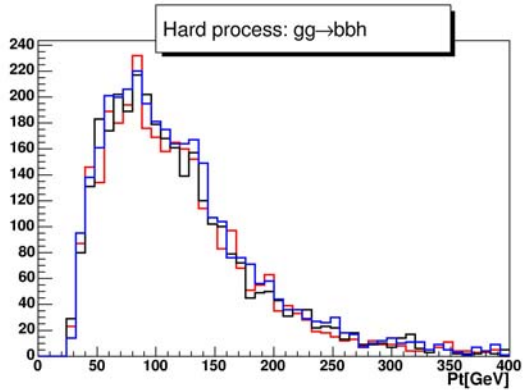
pythia	ariadne
2.1%	0.4%
2.1%	0.5%
2.2%	0.5%



pythia	ariadne
1.2%	1.2%
1.2%	1.2%
1.3%	1.3%



pythia	ariadne
0.4%	0.9%
0.4%	1.0%
0.4%	0.9%



(not same analysis)

pythia	ariadne
3.2%	4.2%
3.1%	4.0%
3.4%	4.1%

Summary

We have studied impact from the partons shower model, choice of PDF's and Q^2 definition on the theoretical predictions for expected number of signal events after semi-experimental analysis for MSSM h->tau tau search:

- -> events were generated with PYTHIA or HERWIG
- -> the ISR/FSR from PYTHIA/HERWIG/ARIADNE shower model
- -> final acceptance due to the model used can differ by 150%-200% after simplified, *experiment-like*, selection.
- -> impact from the Q2 choice, in extreme cases could also reach 200%
- -> impact from the choice of PDF's, for recent sets is relatively small, less then 10% difference.

Ariadne, not used so far for LHC simulations, gives rather hard spectrum for radiation from quarks. Very interesting possibility for studies of bgds and signal in different analyses.

So far, observed uncertainties from theory on cross-section for exclusive events, are order of magnitude larger than what was achieved for inclusive cross-section with NNLO calculations (15%).

What should be my guideline for trying to come with the best tuning of MC parameters for studying this complicated channel ?