Higgs from $b\bar{b}$ fusion

at LHC:
signatures from $\tau^+\tau^-$ final states.

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Main Topics:

- **TAUOLA technicalities**
- **universal interface of TAUOLA.**
- **application for Higgs boson discovery estimates at LHC.**
- **Summary**

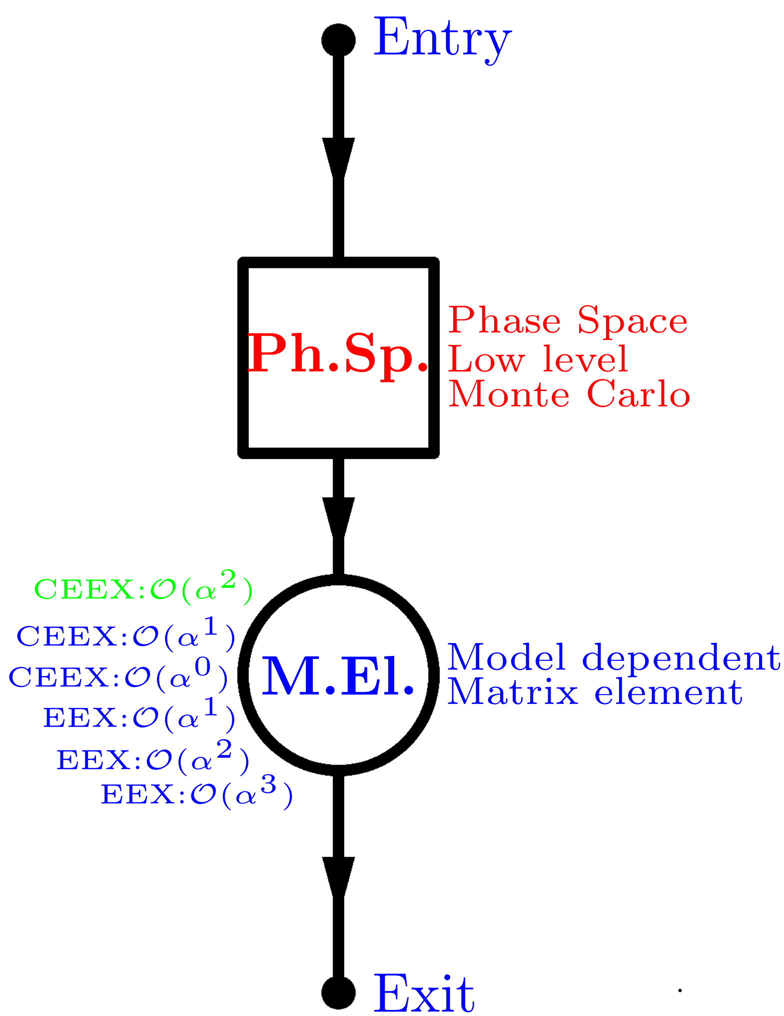
My web page is at http://home.cern.ch/wasm

Basic structure

and assumptions

- **Phase space.**
- **Matrix element**
- **Electroweak vertex.**
- **Leptonic decays:** $\tau \to e(\mu)\nu_\tau\nu(\gamma)$.
- **Semileptonic decays: Hadronic current.**
- **Spin treatment, details delegated to tomorrow.**
- **Feedback from collaborations.**

Textbook principle “matrix element $\times$ full phase space” ASSUMED



In the Monte Carlo realization it means that:

- Universal Phase-space Monte Carlo simulator is a separate module producing “raw events” (including importance sampling for possible intermediate resonances)
- Library of several types of hadronic currents provides input for “model weight” which is another independent module
- Electroweak vertex $\tau - \nu_\tau - W$ is a separate sub-part of calculation of the “model weight”
- Caluclation of weights involving anomalous couplings come after of course; approximations are used there.
- This is exactly like in case of KORALZ or KKMC.

General formalism for semileptonic decays

- The differential partial width for the channel under consideration reads

$$d\Gamma_X = G^2 \frac{v^2+a^2}{4M} d\mathrm{Lips}(P; q_i, N)(\omega + \hat{\omega} + (H_\mu + \hat{H}_\mu)s^\mu)$$

- The phase space distribution is given by the following expression where a compact notation with $q_5 = N$ and $q_i^2 = m_i^2$ is used

$$d\mathrm{Lips}(P; q_1, q_2, q_3, q_4, q_5) = \frac{1}{2^{23}\pi^{11}} \int_{Q^2_{min}}^{Q^2_{max}} dQ^2 \int_{Q^2_{3,min}}^{Q^2_{3,max}} dQ_3^2$$

$$\int_{Q^2_{2,min}}^{Q^2_{2,max}} dQ_2^2 \quad \times \quad \int d\Omega_5 \frac{\sqrt{\lambda(M^2, Q^2, m_5^2)}}{M^2} \int d\Omega_4 \frac{\sqrt{\lambda(Q^2, Q_3^2, m_4^2)}}{Q^2}$$

$$\times \quad \int d\Omega_3 \frac{\sqrt{\lambda(Q_3^2, Q_2^2, m_3^2)}}{Q_3^2} \int d\Omega_2 \frac{\sqrt{\lambda(Q_2^2, m_2^2, m_1^2)}}{Q_2^2}$$

$$Q^2 = (q_1 + q_2 + q_3 + q_4)^2, \quad Q_3^2 = (q_1 + q_2 + q_3)^2, \quad Q_2^2 = (q_1 + q_2)^2$$

$$Q_{min} = m_1 + m_2 + m_3 + m_4, \quad Q_{max} = M - m_5 \; Q_{3,min} = m_1 + m_2 + m_3, \quad Q_{3,max} = Q - m_4$$

$$Q_{2,min} = m_1 + m_2, \qquad Q_{2,max} = Q_3 - m_3$$

- These formula if used directly, are inefficient for a Monte Carlo algorithm if sharp peaks due to resonances in the intermediate states are present. The changes affect the program efficiency, but the actual density of the phase space remains intact. No approximations are introduced.

General formalism for semileptonic decays

- Matrix element used in TAUOLA for semileptonic decay

$$\tau(P,s) \to \nu_\tau(N) X$$
$$\mathcal{M} = \frac{G}{\sqrt{2}} \bar{u}(N)\gamma^\mu(v + a\gamma_5)u(P)J_\mu$$

- J_μ the current depends on the momenta of all hadrons

$$|\mathcal{M}|^2 = G^2 \frac{v^2+a^2}{2}(\omega + H_\mu s^\mu)$$
$$\omega = P^\mu(\Pi_\mu - \gamma_{va}\Pi^5_\mu)$$
$$H_\mu = \frac{1}{M}(M^2\delta^\nu_\mu - P_\mu P^\nu)(\Pi^5_\nu - \gamma_{va}\Pi_\nu)$$
$$\Pi_\mu = 2[(J^* \cdot N)J_\mu + (J \cdot N)J^*_\mu - (J^* \cdot J)N_\mu]$$
$$\Pi^{5\mu} = 2\,\mathrm{Im}\,\epsilon^{\mu\nu\rho\sigma} J^*_\nu J_\rho N_\sigma$$
$$\gamma_{va} = -\frac{2va}{v^2+a^2}$$

- If a more general coupling $v + a\gamma_5$ for the τ current and ν_τ mass $m_\nu \neq 0$ are expected to be used, one has to add the following terms to ω and H_μ

$$\hat{\omega} = 2\frac{v^2-a^2}{v^2+a^2} m_\nu M(J^* \cdot J)$$
$$\hat{H}^\mu = -2\frac{v^2-a^2}{v^2+a^2} m_\nu\,\mathrm{Im}\,\epsilon^{\mu\nu\rho\sigma} J^*_\nu J_\rho P_\sigma$$

Leptonic and semileptonic decays.

- Complete first order QED corrections can be swithced on/off in $\tau \to e(\mu)\nu_\tau\nu$.
- For double bremsstrahlung effects PHOTOS can be used instead. Like in semileptonic channels.
- In semileptonic modes, for up to 5 final state scalars, any current can be easily installed/remodelled with automatic proper treatment of the rest (phase space, spin, leptonic $\tau - \nu_\tau - W$ current) assured. Thus many versions !
- For 6 pions or more flat space was only used so far.
- Spin treatment will be discussed tomorrow.
- In total well over 20 distinct τ decay modes installed.
- 3 versions of formfactors in authors hands CLEO 1998 ALEPH (lep1) and 'published CPC.
- Such organization of the code is OK if non-factorizable electroweak corrrections of order $\frac{\alpha}{\pi}$ can be neglected.

Main references:

1. R. Decker, S.Jadach, M.Jeżabek, J.H.Kuhn, Z. Was, Comput. Phys. Commun. 76 (1993) 361, ibid. 70 (1992) 69, ibid. 64 (1990) 275
2. P. Golonka, B. Kersevan ,T. Pierzchala, E. Richter-Was, Z. Was, M. Worek (hep-ph/0312240), technical stuff mainly.

Also:

1. ● Alain Weinstein www home page: http://www.cithep.caltech.edu/~ajw/korb_doc.html#files
2. ● B. Bloch, private communications.
3. R. Decker, M. Finkemeier, P. Heiliger and H.H. Jonsson, Z. Phys. C **70** (1996) 247, now standard 4π formfactors.
4. A. E. Bondar, S. I. Eidelman, A. I. Milstein, T. Pierzchala, N. I. Root, Z. Was and M. Worek, Comput. Phys. Commun. **146**, 139 (2002)
5. P. Abreu et al., Phys. Lett. B426 (1998) 411 (alternative 3π formf.)
6. Sherry Towers alternative formf. in K$\pi\pi$ modes, hep-ex/9908013, Eur. Phys. J. **C13** (2000) 197.

Formfactors secret life

Often analysis within collaborations were relying on refits of form-factors, many versions were/are regularily created for more general, or specific purposes. I have seen only some of them.

Comparison between different parameterizations

- Version of comparison of CLEO and new Novosibirsk current in TAUOLA. The ω contribution in an old CLEO current is scaled down from *68* % to *40* %.

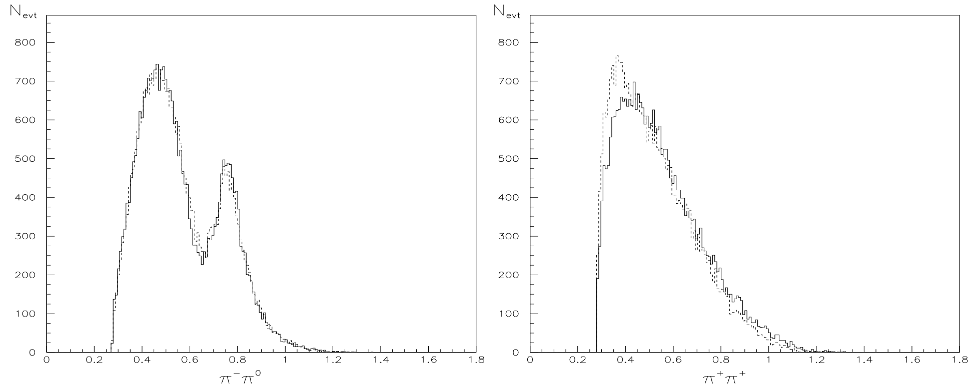


Figure 3: *The $\bar\nu_\tau \pi^+\pi^+\pi^-\pi^0$ channel. The Left-hand side plot $\pi^-\pi^0$ invariant mass distribution, right-hand side plot $\pi^+\pi^+$ invariant mass distribution. Continuous line for an old scaled down to 40 % CLEO current, dotted line for a new Novosibirsk current.*

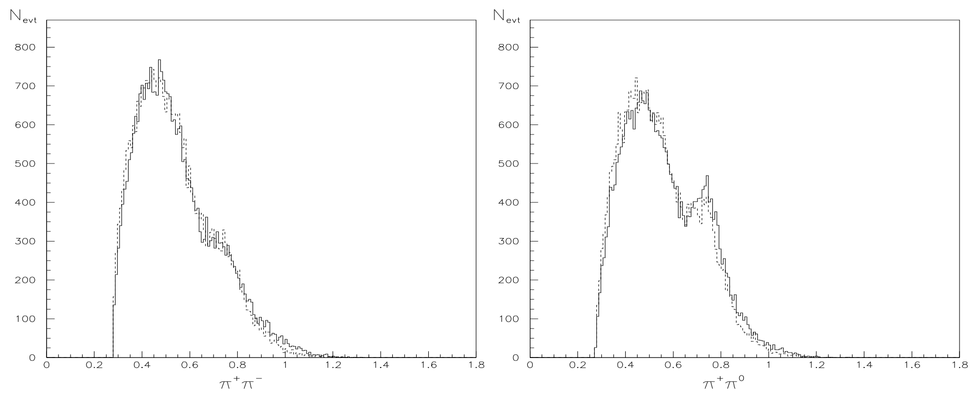


Figure 4: *The $\bar\nu_\tau \pi^+\pi^+\pi^-\pi^0$ channel. The Left-hand side plot $\pi^+\pi^-$ invariant mass distribution, right-hand side plot $\pi^+\pi^0$ invariant mass distribution. Continuous line for an old scaled down to 40 % CLEO current, dotted line for a new Novosibirsk current.*

Basic properties of TAUOLA solution

- Phase space.
- Matrix element.
- Theoretical models.
- Hadronic currents.
- Fits to different data, LEP CLEO, low energy e^+e^-,
- also BELLE BaBar in future
- All will be available for LHC, not much ambiguities from that.
- Design precision and benchmarks.

TAUOLA universal interface

- To run generator for tau decays it must be combined with part for tau production.
- I will concentrate on physics points.
- I will skip technicalities related to the way how HEPEVT common block is filled in 3 versions of PYTHIA conventions and HERWIG.
- TAUOLA universal interface reads information from HEPEVT common block, there τ leptons to be decayed are found,
- and their spin states are calculated from kinematical configurations of hard processes leading to τ's.

Formalism for $\tau^+\tau^-$

- Because narrow τ width approximation can be obviously used for phase space , cross section for the process $f\bar{f} \to \tau^+\tau^- Y; \tau^+ \to X^+\bar{\nu}; \tau^- \to \nu\nu$ reads:

$$d\sigma = \sum_{spin} |\mathcal{M}|^2 d\Omega = \sum_{spin} |\mathcal{M}|^2 d\Omega_{prod}\, d\Omega_{\tau^+}\, d\Omega_{\tau^-}$$

- This formalism is fine, but because of over 20 τ decay channels we have over 400 distinct processes. Also picture of production and decay are mixed.

- but (only τ spin indices are explicitely written):

$$\mathcal{M} = \sum_{\lambda_1 \lambda_2 = 1}^{2} \mathcal{M}^{prod}_{\lambda_1 \lambda_2}\, \mathcal{M}^{\tau^+}_{\lambda_1} \mathcal{M}^{\tau^-}_{\lambda_2}$$

- Formula for the cross section can be re-written

$$d\sigma = \Big(\sum_{spin} |\mathcal{M}^{prod}|^2\Big)\Big(\sum_{spin} |\mathcal{M}^{\tau^+}|^2\Big)\Big(\sum_{spin} |\mathcal{M}^{\tau^-}|^2\Big) wt\; d\Omega_{prod}\, d\Omega_{\tau^+}\, d\Omega_{\tau^-}$$

- where

$$wt = \Big(\sum_{i,j=0,3} R_{ij} h^i h^j \Big)$$

$$R_{00} = 1, \quad < wt >= 1, \quad 0 \le wt \le 4.$$

R_{ij} can be calculated from $\mathcal{M}_{\lambda_1 \lambda_2}$
and h^i, h^j respectively from $\mathcal{M}^{\tau^+}$ and $\mathcal{M}^{\tau^-}$.

- Bell inequalities tell us that it is impossible to re-write wt in the following form

$$wt \neq \Big(\sum_{i,j=0,3} R^A_i h^i \Big) \Big(\sum_{i,j=0,3} R^B_j h^j \Big)$$

that means it is impossible to generate first τ^+ and τ^- first in some given ‘ quantum state’ and later perform separatelly decays of τ^+ and τ^-

- It can be done only if approximations are used !!!

- May be often reasonable, but nonetheless approximations.

Approximate spin generation

Example of reasonable approximation: KORALZ at LEP

S. Jadach, B.F.L. Ward, Z. Was Comput. Phys. Commun. 79 (1994) 503

- Generates first pair of τ leptons
- Generates helicity states of both τ^+ and τ^- i.e. approximation is used
- Provides helicty states and relation between τ's restframe and LAB to TAUOLA
- TAUOLA performs decay of 100 % polarized τ's.
- This solution worked in all cases, except τ-lifetime measurement with impact parameter difference method and simulations for direct measurement of transverse spin correlations
- In all other cases correlations of transverse (with respect to $\tau^\pm$ dirrections) components of $\tau^\pm$ decay products momenta could be neglected
- Backup solution was however always at hand.
- Such solution is used by TAUOLA universal interface in all cases except Higgs boson.

Exact spin generation

Example: KORALB and KKMC

S. Jadach, Z. Was Comput. Phys. Commun. 64 (1991) 267

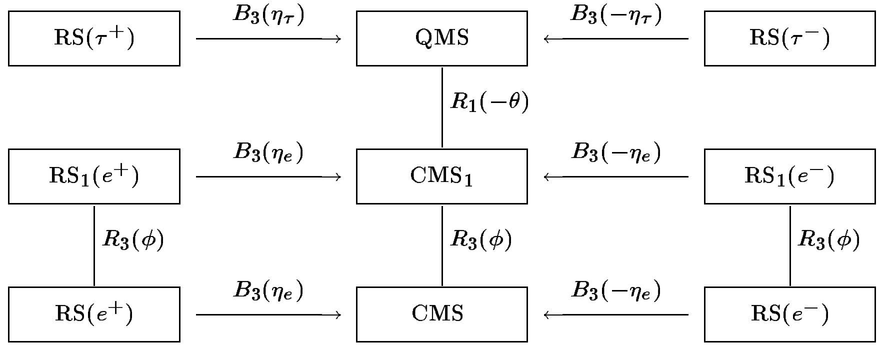
S. Jadach, B. F. L. Ward, Z. Was Comput. Phys. Commun. 130 (2000) 260

- Generate first pair of τ leptons, no polarization
- Calculate density matrix for the two-τ (plus photon(s))quantum state
- TAUOLA performs decay of unpolarized τ's.
- Spin weight is calculated from production and decay variables.

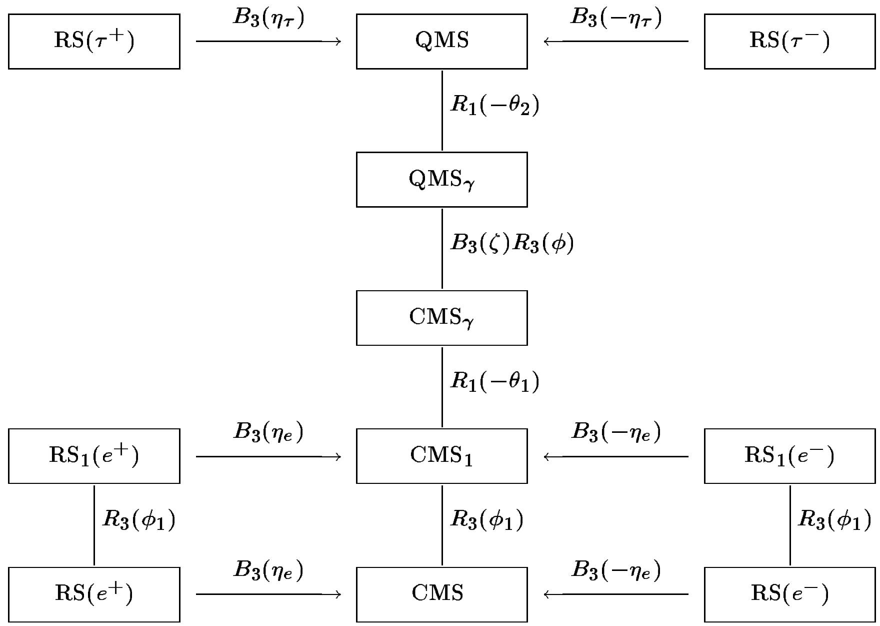
- Complete spin effects are introduced by rejection.
- in KORALB density matrix for $2 \to 2$ and $2 \to 3$ processes was used.
- in KKMC more universal solution suitable to any process $2 \to 2 + n$ was applied.
- Slightly different solution is used in HERWIG
- and in software of BaBar.
- such solution is used in TAUOLA universal interface for Higgs boson decays

Tree of KORALB boosts, used in spin quantization

Figure 2



(2a)



(2b)

35

Case of KKMC

- Refined solution like in KORALB is used.
- For details see S. Jadach, B.F.L. Ward, Z. Was Eur. Phys.J. **C22** (2001)423.

H *produced at LHC from* $b\bar{b}H$ *Yukawa coupling*

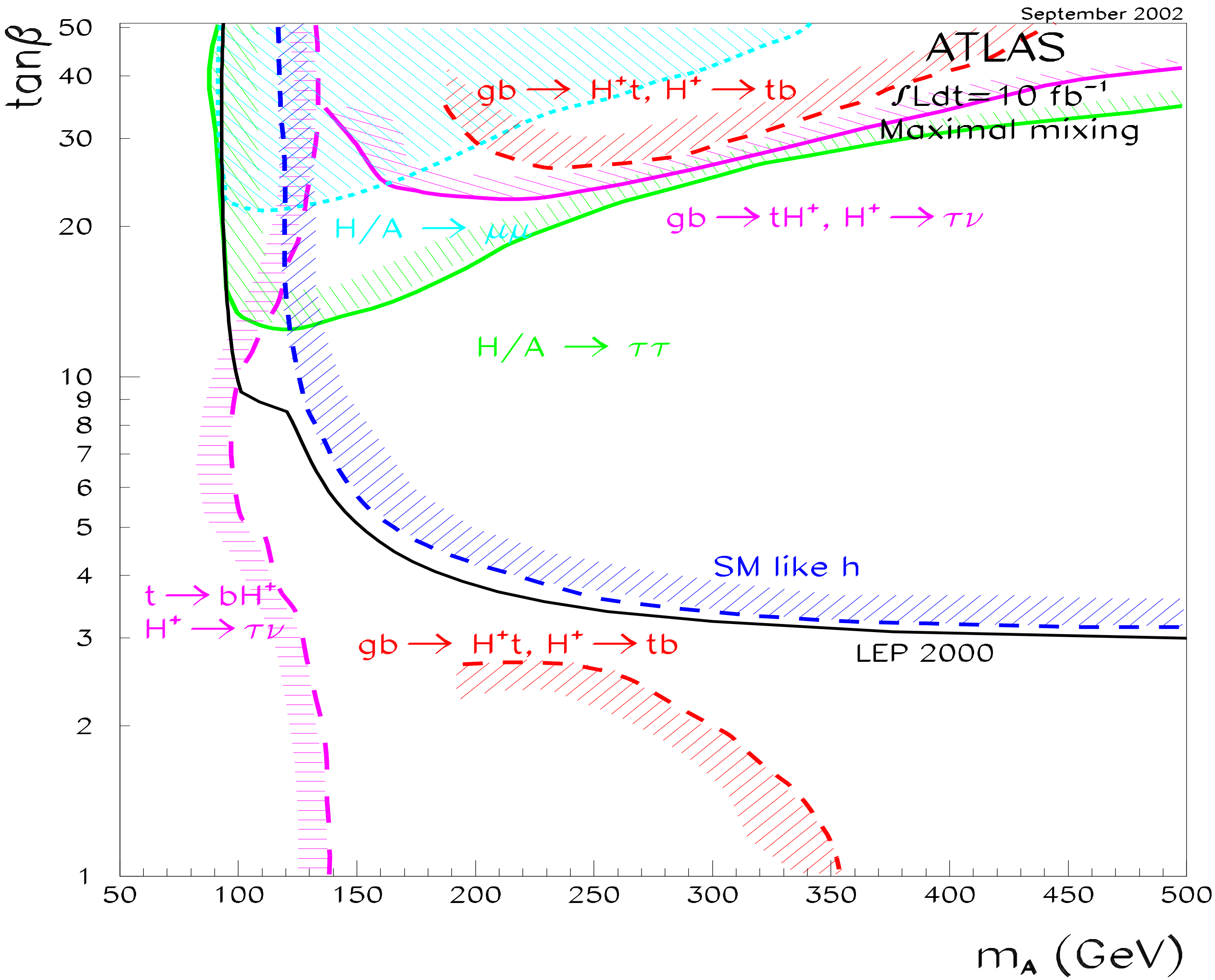
In case of MSSM $m_H = 100 - 200 GeV$ Higgs boson it is the key signature, see plot on the next transparency.

That is why I will recall results from the following papers:

- E. Richter-Was, T. Szymocha and Z. Was, "Why do we need higher order fully exclusive Monte Carlo generator for Higgs boson production from heavy quark fusion at LHC?," arXiv:hep-ph/0402159.
- E. Richter-Was, T. Szymocha, "The lihght Higgs decay into τ-lepton pair: reconstruction in different production processes", ATL-COM-PHYS-2004, in preparation.

After one year of LHC (2007/8) in search of H/A ...

That is why we will need to understand signature quickly, when detector will not be understood in full.



Issues of overall normalizations clarified

Let me just mention theoretical points I do not want to talk today:

- Cross section for the process $b\bar{b} \to H$ was calculated at NNLO by R. V. Harlander and W. B. Kilgore within so called variable flavour number scheme (VFS).
- It was also calculated at the NLO for the parton level process $gg(q\bar{q}) \to b\bar{b}H$ within fixed flavour scheme (FFS), eg.by Spira
- Willenbrock et al. choose to start from $gb \to bH$.
- Results obtained in these schemes for inclusive cross sections seem to become compatible with each other.
- Nonetheless just to be on the safe side let us look at how the experimental signatures may look like.

Case for LHC

- For simulation PYTHIA, TAUOLA combined with our universal interface can be used.
- None of the production processes implemented in PYTHIA is expected to be modelled at present sufficiently well. We will use the standard options (corresponding roughly to the lowest orders of aproaches listed in previous transparency) to check if the choice may affect some conclusions or not.
- The choices correspond to lowest order in different approaches for calculation of inclusive cross sections.
- Detector effects are simulated with the help of AcerDET (hep-ph/0207355) by B. Kersevan and E. Richter-Was.
- Significant amount of work by LHC collaboration and over years, should be mentioned. That is why, there is also technical reason to use PYTHIA.
- Selection cuts-offs etc. are not defined by me but by the collaborations. Some ofd them may be changed easily some other not ... This is beyond this talk.

$\boxed{\text{Let us now show numerical results}}$

Caption for the table on the next transparency

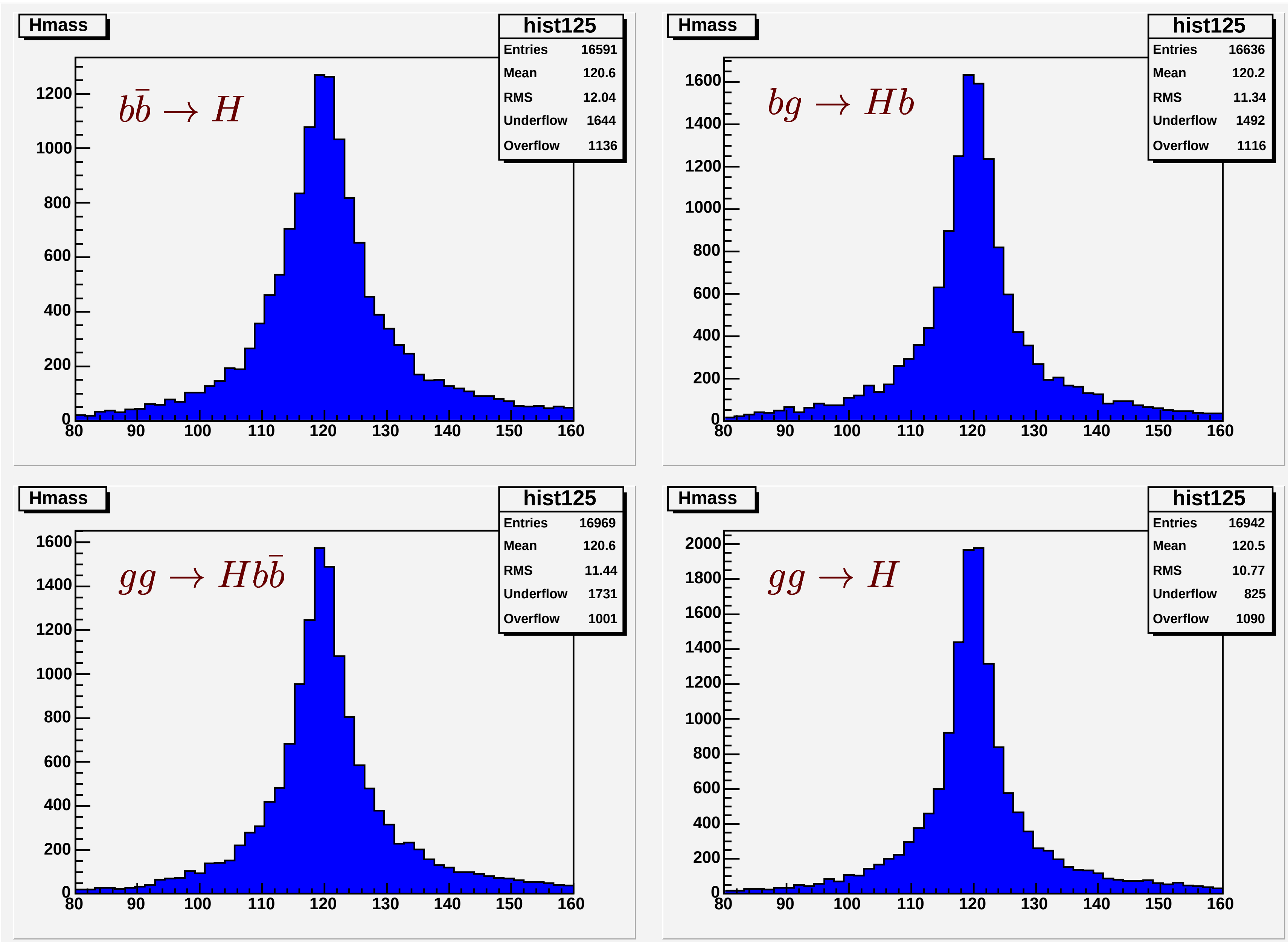
1. Let us look at the case when one of the τ's decays hadronically and second leptonically, then the final signature is thus $(\ell\ \tau$-jet $E_T^{miss})$.
2. The cumulative acceptances for the selection criteria and for different approaches of modeling production process will be shown
3. For each subsequent line effect of the additional cut off is added. Separate blocks correspond:
4. Particle level only
5. Detector effects included
6. There is small technical point. Tau-leptons are not observed directly neutrino momenta have to be reconstructed from kinematical fit.
7. Small tau-mass limit is used and condition of momentum conservation in transverse plane, that is: $p_T^{mis} = p_T^{\nu_\tau} + p_T^{\bar{\nu}_\tau} + p_T^{\ell}$
8. Acceptance denotes fraction of events which pass selection cuts.

Case for LHC

Selection	$b\bar{b} \to H$	$gb \to bH$	$gg \to b\bar{b}H$	$gg \to H$	$--$
1 iso ℓ, $p_T^\ell > 20$ GeV 1 τ-jet, $p_T^{\tau-jet} > 30$ GeV	$19.5 \cdot 10^{-2}$	$19.3 \cdot 10^{-2}$	$19.7 \cdot 10^{-2}$	$19.5 \cdot 10^{-2}$	
PARTICLE level					
resolved neutrinos	$16.6 \cdot 10^{-2}$	$16.6 \cdot 10^{-2}$	$16.9 \cdot 10^{-2}$	$16.9 \cdot 10^{-2}$	**A**
$\lvert sin(\Delta\phi_{\ell\ \tau-jet})\rvert > 0.2$	$9.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$	$9.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$	
$m_T^{\ell,miss} < 50$ GeV	$8.9 \cdot 10^{-2}$	$9.7 \cdot 10^{-2}$	$8.9 \cdot 10^{-2}$	$9.8 \cdot 10^{-2}$	
Additional selection					
$p_T^{miss} > 30$ GeV	$1.3 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	$1.8 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	
$cos(\Delta\phi_{\ell\ \tau-jet}) > -0.9$	$8.5 \cdot 10^{-3}$	$2.2 \cdot 10^{-2}$	$1.4 \cdot 10^{-2}$	$3.1 \cdot 10^{-2}$	
$R_{\ell\ \tau-jet} < 2.8$	$6.1 \cdot 10^{-3}$	$1.9 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	**B**
DETECTOR level					
resolved neutrinos	$11.0 \cdot 10^{-2}$	$11.6 \cdot 10^{-2}$	$11.1 \cdot 10^{-2}$	$12.5 \cdot 10^{-2}$	**C**
$\lvert sin(\Delta\phi_{\ell\ \tau-jet})\rvert > 0.2$	$5.9 \cdot 10^{-2}$	$7.1 \cdot 10^{-2}$	$6.5 \cdot 10^{-2}$	$8.2 \cdot 10^{-2}$	
$m_T^{\ell,miss} < 50$ GeV	$5.5 \cdot 10^{-2}$	$6.6 \cdot 10^{-2}$	$6.2 \cdot 10^{-2}$	$7.6 \cdot 10^{-2}$	
Additional selection					
$p_T^{miss} > 30$ GeV	$9.1 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$1.4 \cdot 10^{-2}$	$3.0 \cdot 10^{-2}$	
$cos(\Delta\phi_{\ell\ \tau-jet}) > -0.9$	$6.5 \cdot 10^{-3}$	$1.8 \cdot 10^{-2}$	$1.1 \cdot 10^{-2}$	$2.7 \cdot 10^{-2}$	
$R_{\ell\ \tau-jet} < 2.8$	$4.9 \cdot 10^{-3}$	$1.5 \cdot 10^{-2}$	$9.3 \cdot 10^{-3}$	$2.3 \cdot 10^{-2}$	**D**

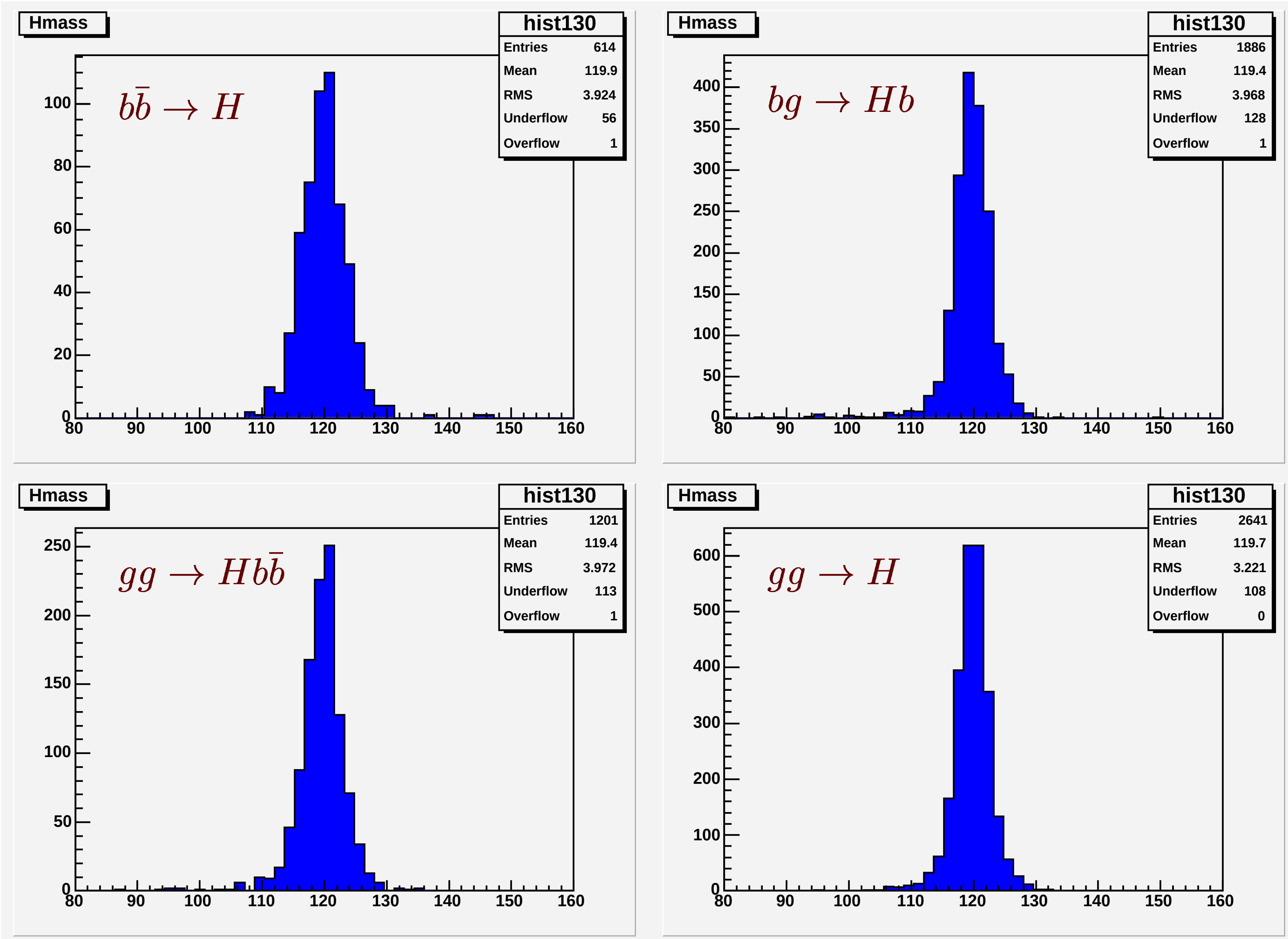
Case for LHC

Reconstructed Higgs peak, selection A



Case for LHC

Reconstructed Higgs peak, selection B

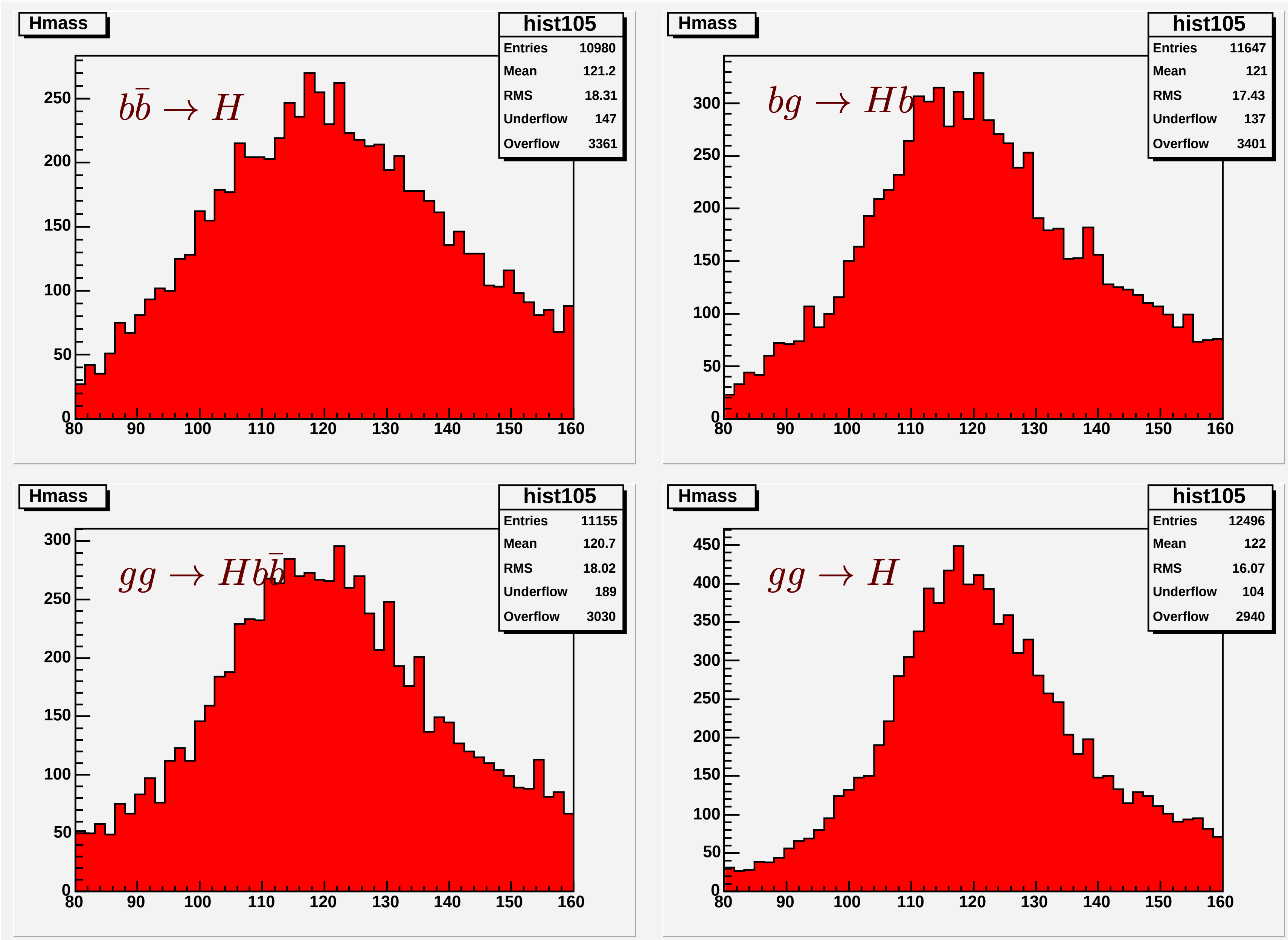


Mini Conclusions for Particle Level

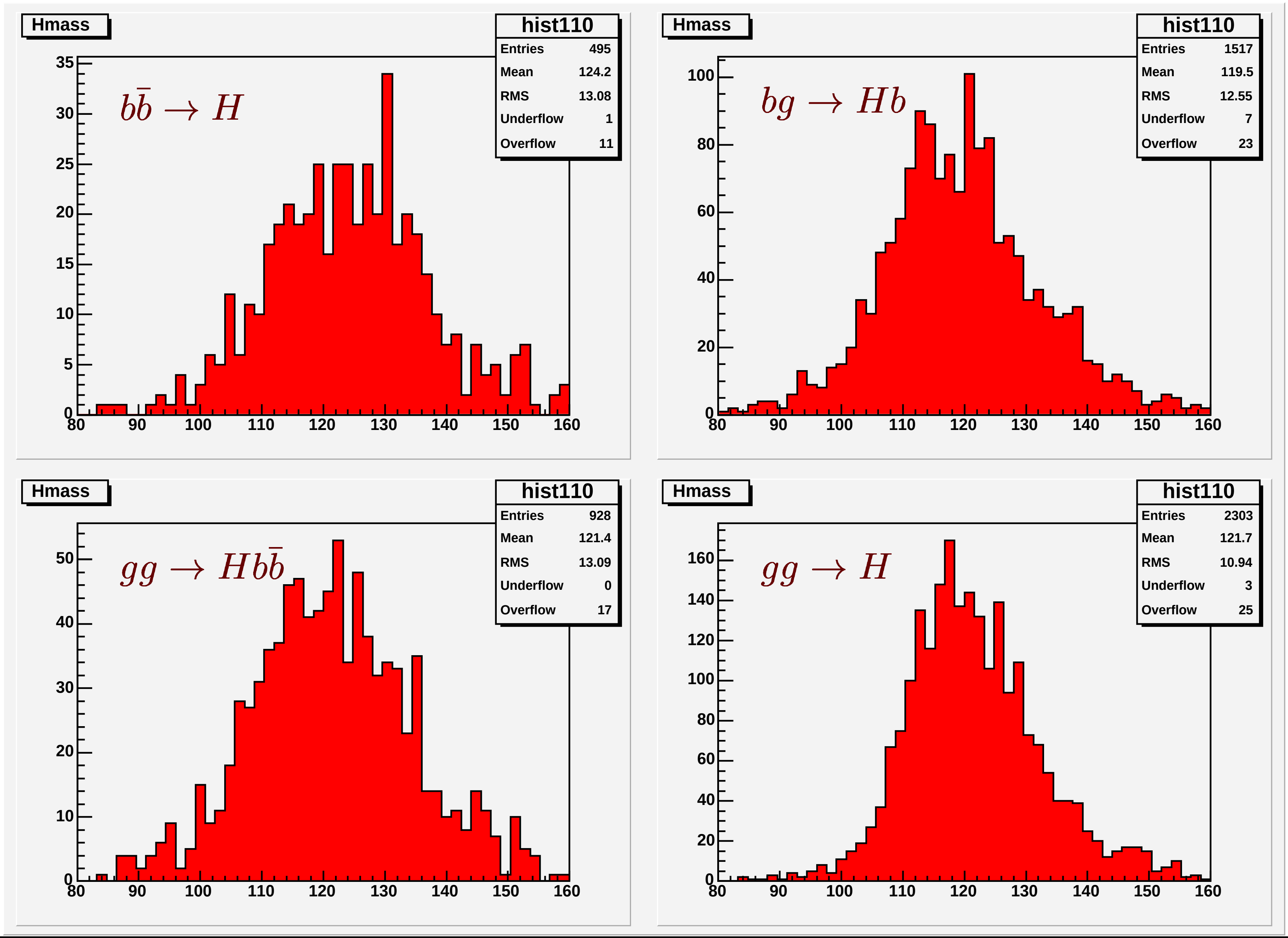
- *At Particle Level (A) all look like confirmed nice thing,*
- *Peaks for Higgs resonance are clearly visible tails are small.*
- *Acceptances are independent of the hard process used in PYTHIA.*
- *Clearly production of the Higgs, decay of the Higgs and detection separate nicely, as should be.*
- *At Particle Level (B) we get even sharper peaks, because of additional selection,*
- *It look like doubtful improvement, acceptance becomes hard process dependent.*
- *Unnecessary complication ?*
- *Let's move to the case when full detector effects are on ...*

Case for LHC

Reconstructed Higgs peak, selection C



Reconstructed Higgs peak, selection D



Case for LHC

Selection	$b\bar{b} \to H$	$gb \to bH$	$gg \to b\bar{b}H$	$gg \to H$	$--$
1 iso ℓ, $p_T^\ell > 20$ GeV 1 τ-jet, $p_T^{\tau-jet} > 30$ GeV	$19.5 \cdot 10^{-2}$	$19.3 \cdot 10^{-2}$	$19.7 \cdot 10^{-2}$	$19.5 \cdot 10^{-2}$	
PARTICLE level					
resolved neutrinos	$16.6 \cdot 10^{-2}$	$16.6 \cdot 10^{-2}$	$16.9 \cdot 10^{-2}$	$16.9 \cdot 10^{-2}$	**A**
$\lvert sin(\Delta\phi_{\ell\ \tau-jet})\rvert > 0.2$	$9.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$	$9.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$	
$m_T^{\ell,miss} < 50$ GeV	$8.9 \cdot 10^{-2}$	$9.7 \cdot 10^{-2}$	$8.9 \cdot 10^{-2}$	$9.8 \cdot 10^{-2}$	
Additional selection					
$p_T^{miss} > 30$ GeV	$1.3 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	$1.8 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	
$cos(\Delta\phi_{\ell\ \tau-jet}) > -0.9$	$8.5 \cdot 10^{-3}$	$2.2 \cdot 10^{-2}$	$1.4 \cdot 10^{-2}$	$3.1 \cdot 10^{-2}$	
$R_{\ell\ \tau-jet} < 2.8$	$6.1 \cdot 10^{-3}$	$1.9 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	**B**
DETECTOR level					
resolved neutrinos	$11.0 \cdot 10^{-2}$	$11.6 \cdot 10^{-2}$	$11.1 \cdot 10^{-2}$	$12.5 \cdot 10^{-2}$	**C**
$\lvert sin(\Delta\phi_{\ell\ \tau-jet})\rvert > 0.2$	$5.9 \cdot 10^{-2}$	$7.1 \cdot 10^{-2}$	$6.5 \cdot 10^{-2}$	$8.2 \cdot 10^{-2}$	
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Additional selection					
$p_T^{miss} > 30$ GeV	$9.1 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$1.4 \cdot 10^{-2}$	$3.0 \cdot 10^{-2}$	
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$R_{\ell\ \tau-jet} < 2.8$	$4.9 \cdot 10^{-3}$	$1.5 \cdot 10^{-2}$	$9.3 \cdot 10^{-3}$	$2.3 \cdot 10^{-2}$	**D**

Mini Conclusions for Detector Level

- At Detector Level (C) all look like confirmed nice thing,
- Acceptances are independent of the hard process used in PYTHIA.
- Production, decay,and detection of Higgs separate nicely (C) -line acceptances equal.
- But peaks for Higgs resonance nearly disapeared.
- At Detector Level (D) we get peaks back, because of additional selection,
- But acceptance becomes hard process dependent up to a factor of 4 !!!
- We need to:
  1. ask for money for better detector
  2. improve theoretical control of the predictions $\rightarrow$
  3. improve experimental analysis $\rightarrow$
- Definitely Monte Carlo is essential in such a studies.
- Which solution seem to be feasible? Where can I help?

Summary

- *We have reviewed tools for simulation:*
  - *TAOLA as generator for τ decays*
  - *TAUOLA interfaces for applications in different conditions.*
  - *PYTHIA was not presented.*
- *With the help of the tools we have shown applications:*
  - *For LHC and Higgs boson in $b\bar{b} \to h \to \tau^+\tau^-$ where separation seem to break because of combined theoretical and experimental effects on p_T^{mis}.*
- *we conclude that control of systematic errors for MC simulations may be important for LHC*
- *we do not conclude that it must be done from theoretical calculations, it may come from any source,* **HERA data for example**.
- **But it must be done ! That is the purpose of my talk here !**

Summary

- **I have skipped completelly the presentation of techniques for studies of systematic errors.**
- **That is nonetheless essential part of the work.**

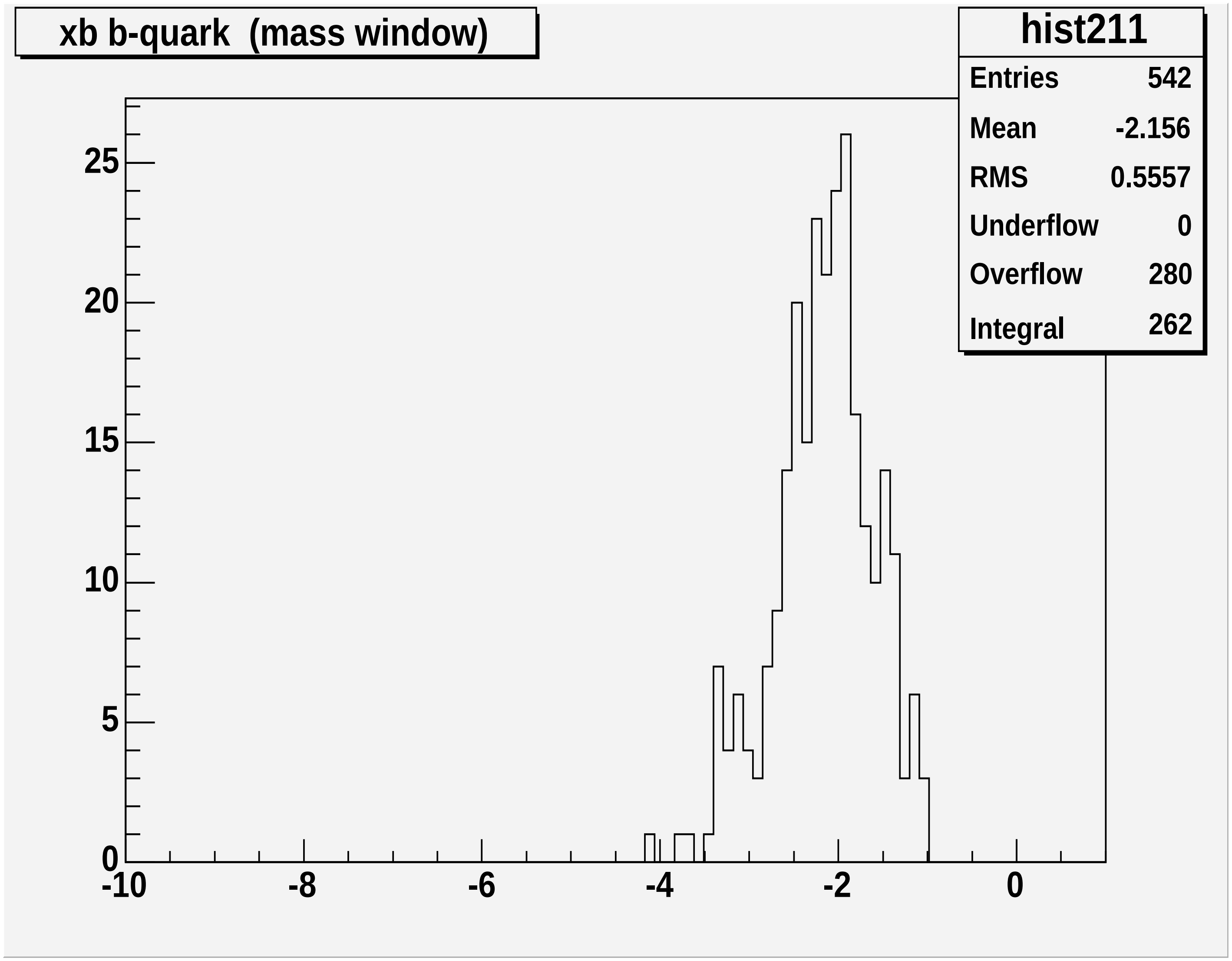
Slides from discussions

- **To visualise interesting regions of partonic parameters we have collected distributions for events which passed all cuts.**

- **One can see that even in case of $gg \to b\bar{b}H$ cuts on Higgs boson decay products enforce partons to have p_T's quite high**
- **for $b\bar{b}$ effect is of course huge.**
- **This indicates better how importan for predictions is control over p_T.**
- **HERA data may be helpful?**

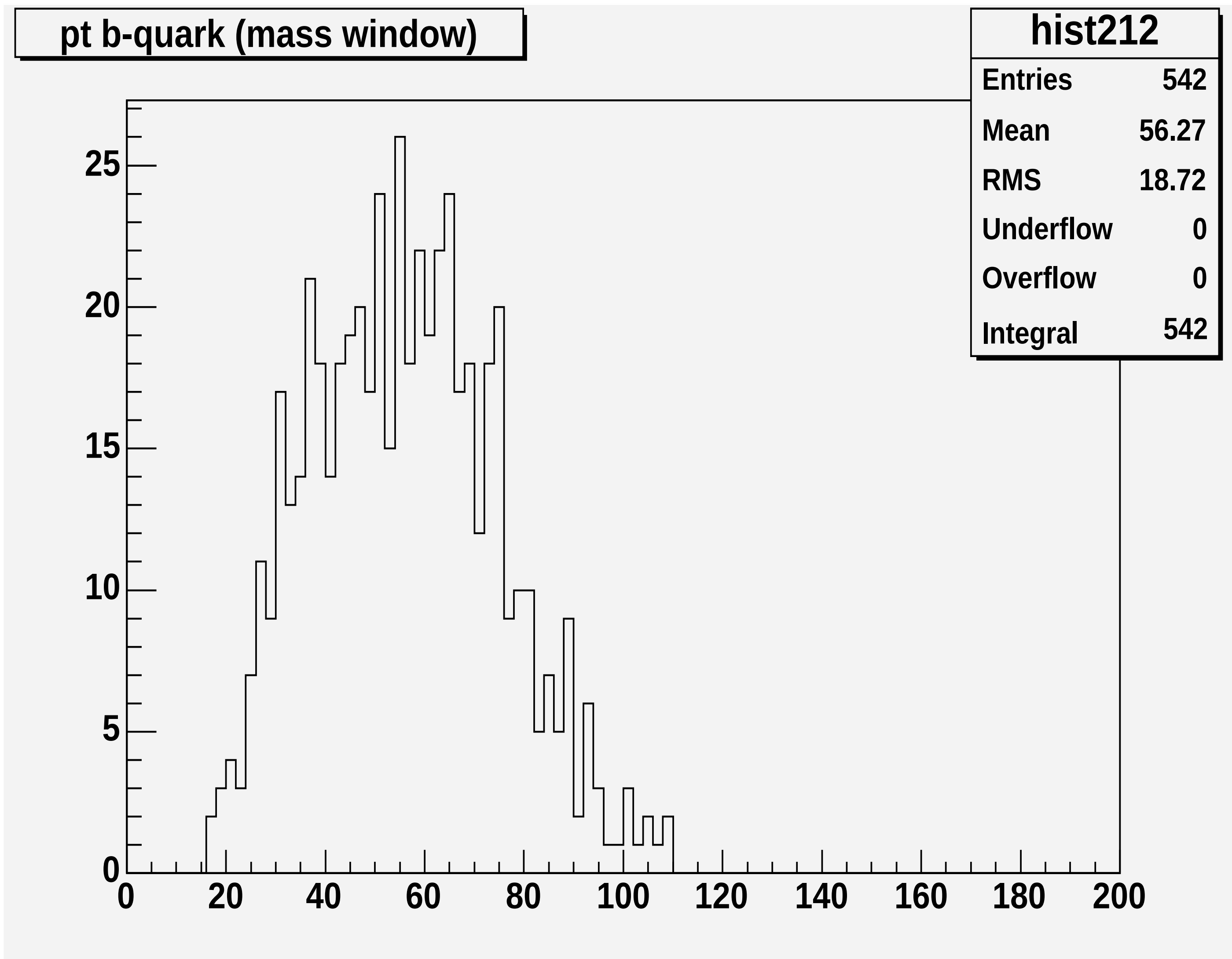
FROM DISCUSSION

- Bjorken x for a single b (of higher p_T) entering the hard process $b\bar{b} \to H$.



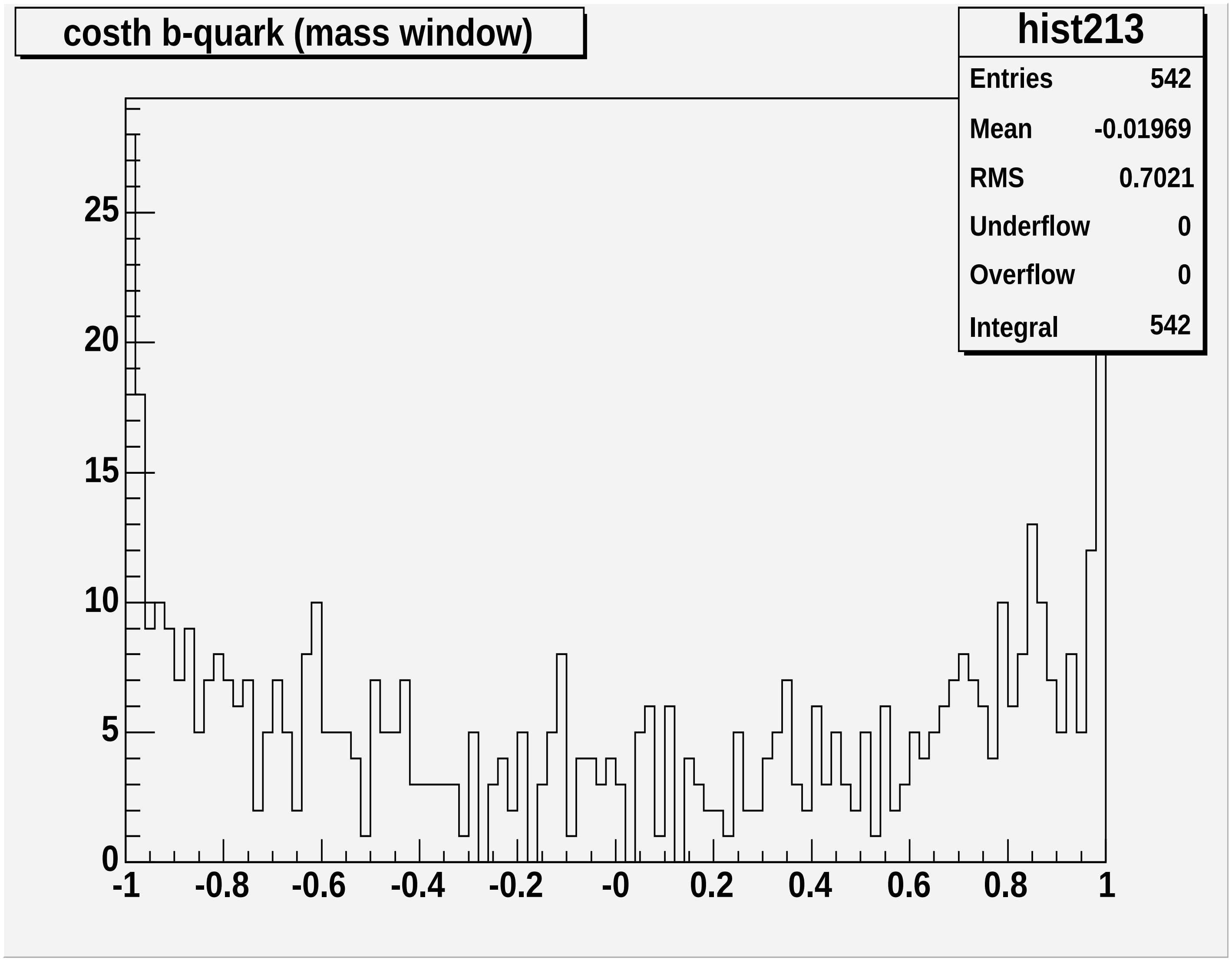
FROM DISCUSSION

- p_T for a single b (of higher p_T) entering the hard process $b\bar{b} \to H$.



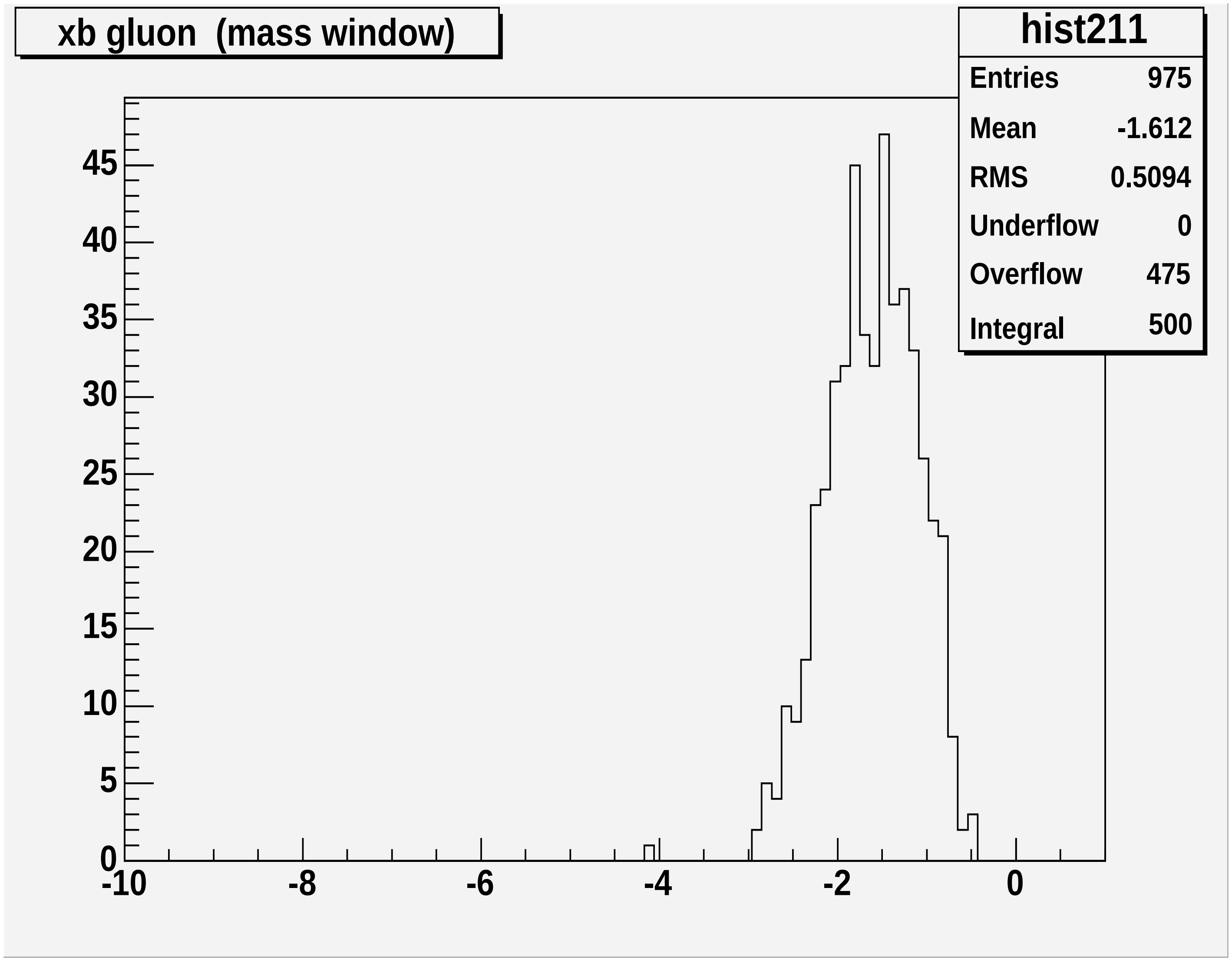
FROM DISCUSSION

- costhe for a single b (of higher p_T) entering the hard process $b\bar{b} \to H$.



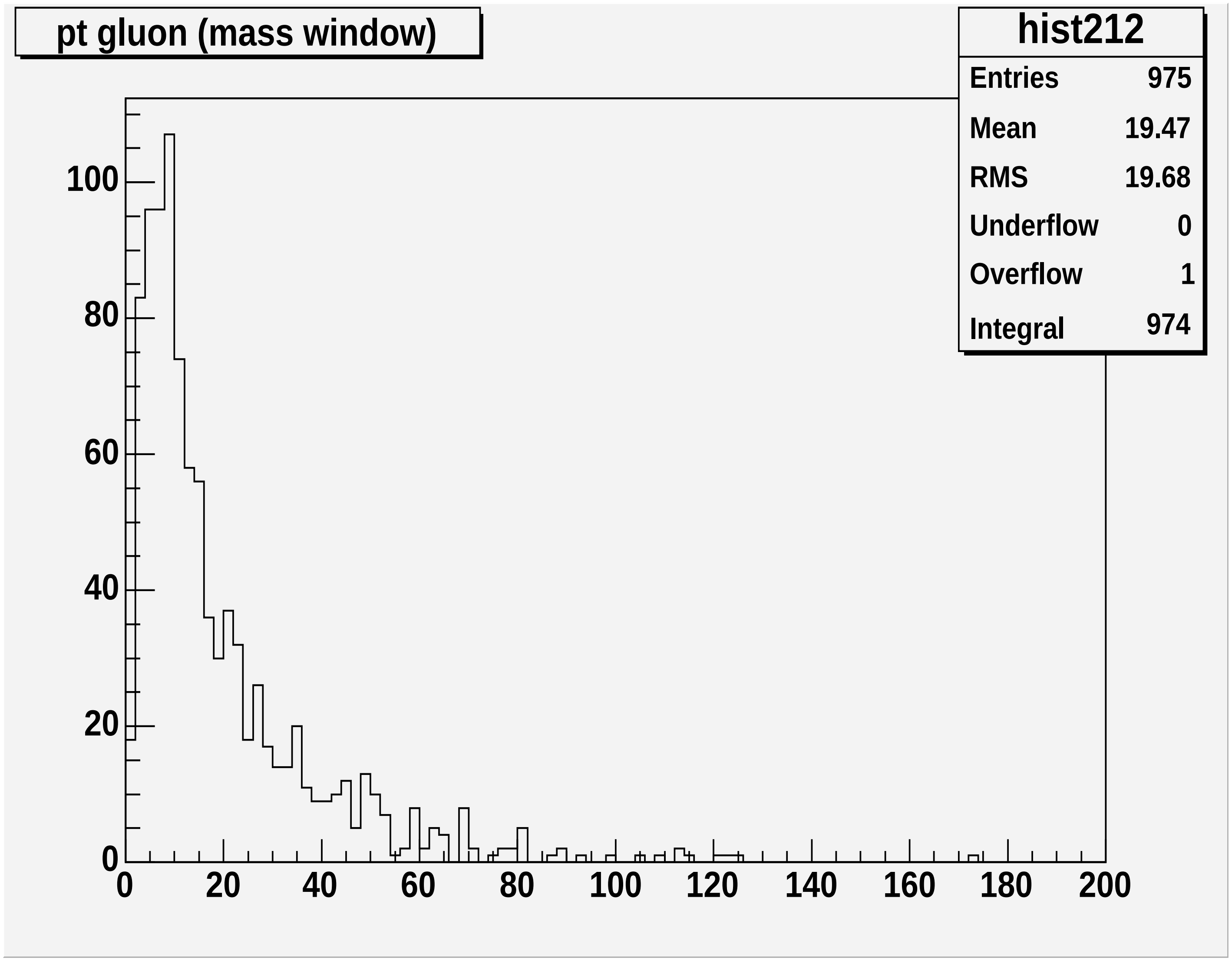
FROM DISCUSSION

- Bjorken x for a single gluon (of higher p_T) entering the hard process $gg \to b\bar{b}H$.



FROM DISCUSSION

- p_T for a single gluon (of higher p_T) entering the hard process $gg \to b\bar{b}H$.



FROM DISCUSSION

- costhe for a single gluon (of higher p_T) entering the hard process $gg \to b\bar{b}H$.