Associated Higgs+jets production at LHC and CCFM dynamics in proton

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in collaboration with
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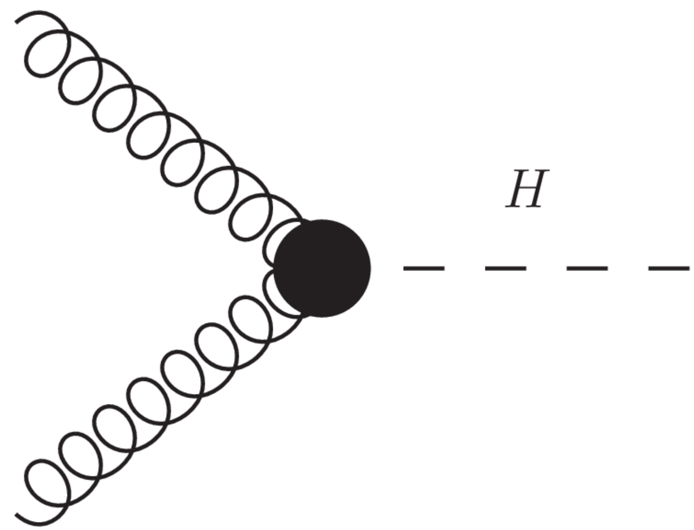
A.V. Lipatov, M.A. Malyshev, arXiv:2009.04908

Outline

1. Motivation
2. Theoretical framework
3. Numerical results
4. Conclusion

Motivation



- Good test for pQCD predictions;
- Leading contribution from gluon fusion — allows to probe gluon distributions;
- Jet associated production allows to study special kinematical regions.

Motivation

The goal of the present work is:

- to test applicability of the k_T-factorization approach to a new process
- to test different parametrizations of CCFM TMD parton distribution functions.
- CASCADE3+PEGASUS: k_T-factorization with parton showers.

In this work we include for the first time parton showers for Higgs production in k_T-factorization.

k_T-factorization

Main ingredients:

- Off-shell matrix elements
- TMD (unintegrated) parton densities.

The cross-section:

$$d\sigma(pp \to H + X) = d\sigma(g^* g^* \to H + X) \otimes$$

$$\otimes f_g(x_1, k_{T1}^2, \mu_{\rm fact}^2) f_g(x_2, k_{T2}^2, \mu_{\rm fact}^2)$$

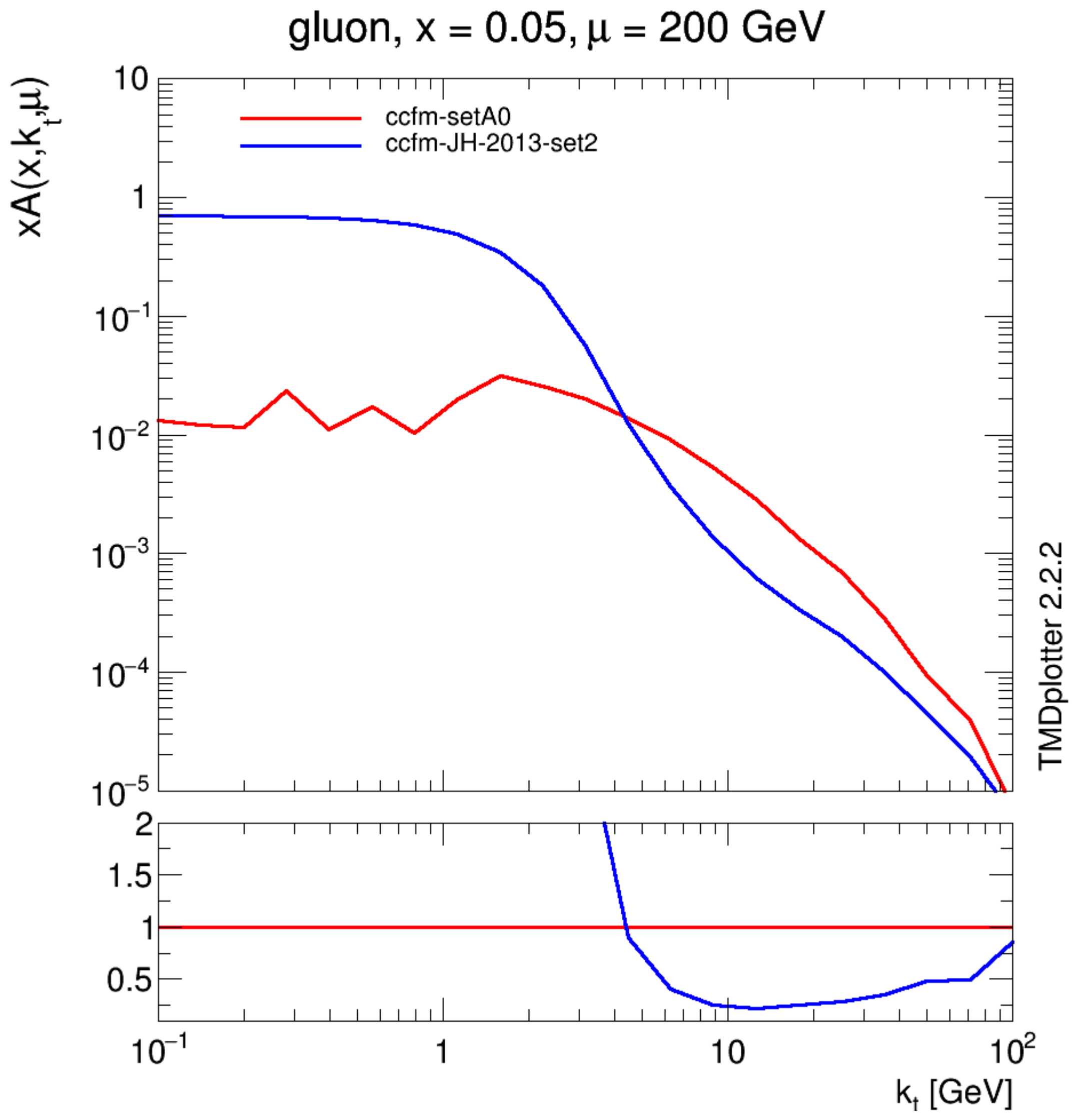
k_T-factorization: TMDs

CCFM-based unintegrated distributions

Numerical solutions of Catani-Ciafaloni-Fiorani-Marchesini evolution equation.

The starting distribution is chosen to satisfy data on proton structure functions $F_2(x,\mu^2)$ only (A0) or both $F_2(x,\mu^2)$ and $F_2^c(x,\mu^2)$ (JH2013-set-2)
[H. Jung, hep-ph/0411287, F. Hautmann, H. Jung, Nucl. Phys. **B883** (2014) 1].

CCFM distributions



PEGASUS

- parton level Monte-Carlo event generator for pp and $p\bar{p}$ processes with simple user-friendly grafical interface;
- can work with TMDs;
- a lot of implemented processes (heavy quarks, quarkonia, etc.);
- can generate an event record according to the Les Houches Event (*.lhe) format;
- an easy way to implement various kinematical restrictions;
- compatible with HEPData repository https://www.hepdata.net;
- built-in plotting tool PEGASUS Plotter

A.V. Lipatov, M.A. Malyshev, S.P. Baranov, Eur. Phys. J. C80, 4, 330 (2020);
https://theory.sinp.msu.ru/doku.php/pegasus/overview

Parameters

- Theoretical uncertainties are connected with the choice of the factorization and renormalization scales. We took $\mu_R = m_H$. We took $\mu_F^2 = (s+\mathbf{Q}_T^2)$, where s and $\mathbf{Q}_T^2$ are the energy of scattering subprocess and transverse momentum of the incoming off-shell gluon pair, respectively. Auxilliary „+“ and „-“ distributions were used to estimate theoretical uncertainties.

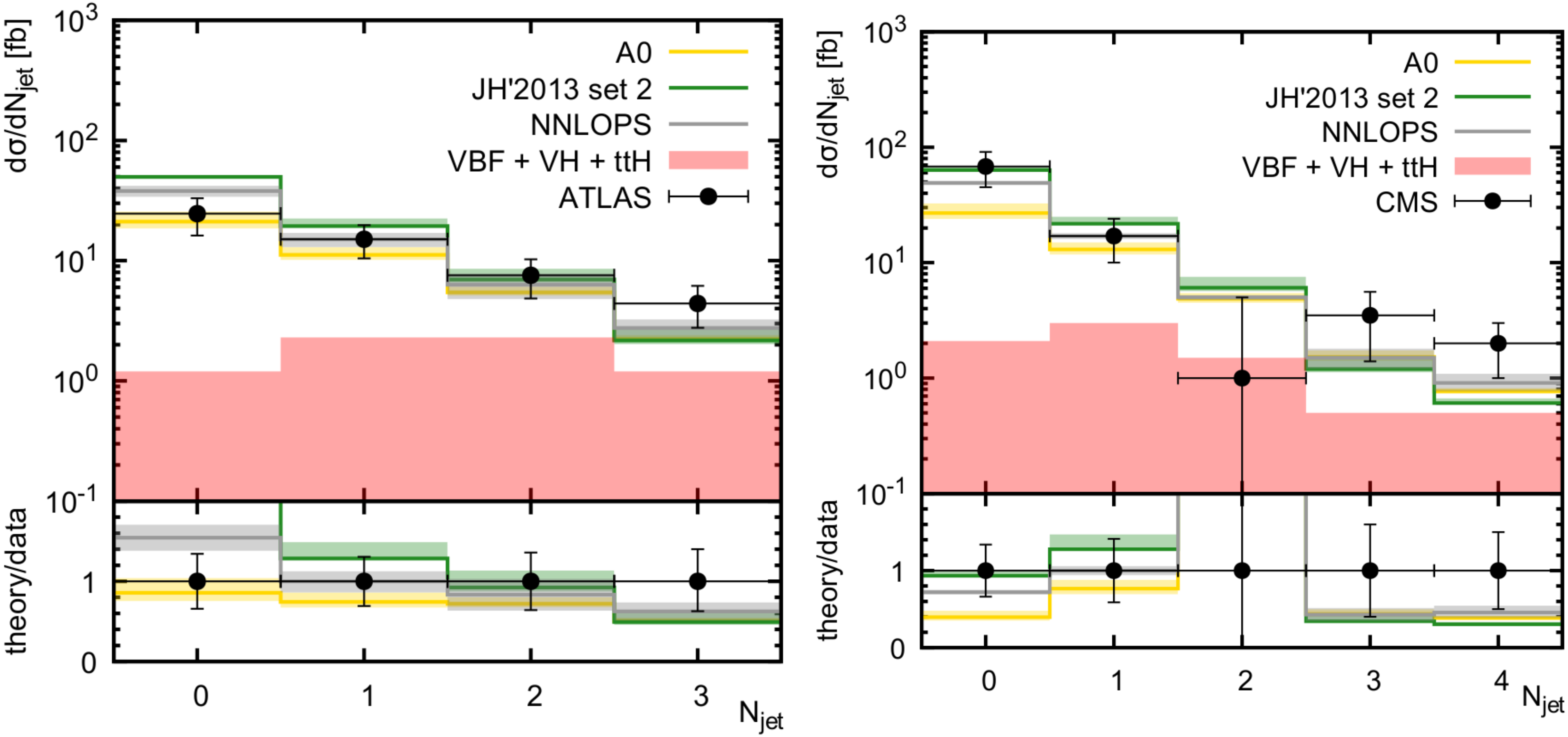
- We use 2-loop (1-loop) formula for the strong coupling constant $\alpha_s(\mu^2)$ with $n_f = 4$ active quark flavors at $\Lambda_{QCD} = 200\ (250)$ MeV for JH2013 (A0) distributions.

- Parton showers are produced with CASCADE3.

- We use anti-k_T-algorythm to construct jets with FastJet.

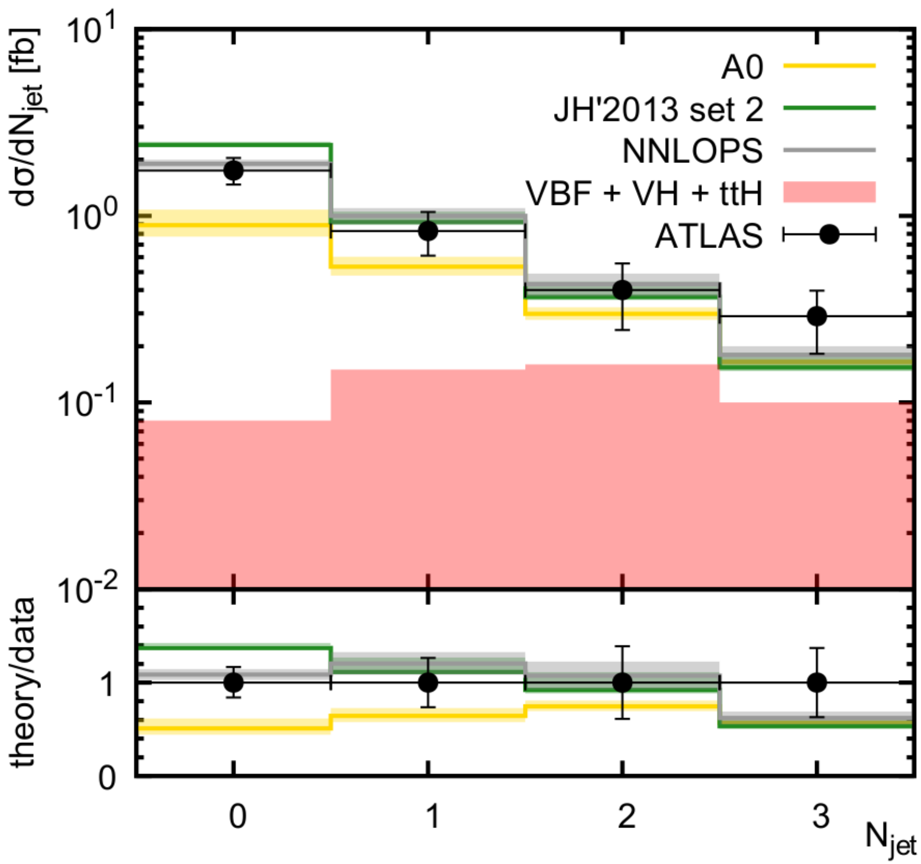
- Non-leading contributions (ttH, VBF, etc.) are taken from experimental papers

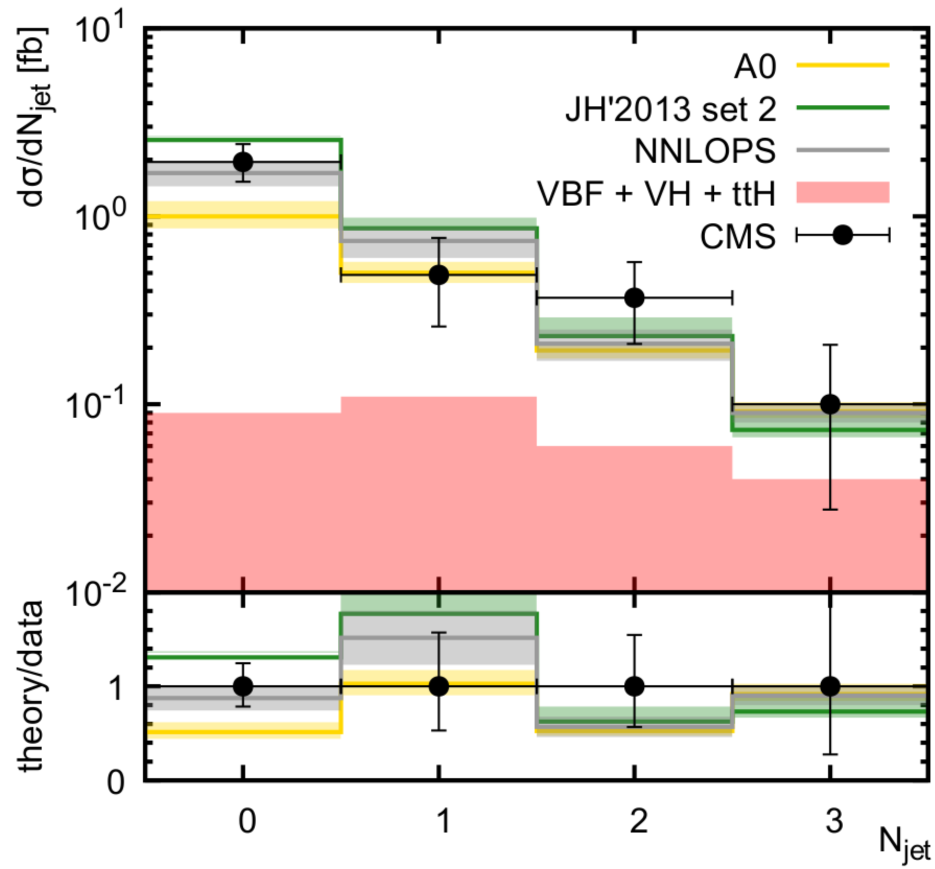
Numerical results



Diphoton channel, $\sqrt{S}$=13 TeV

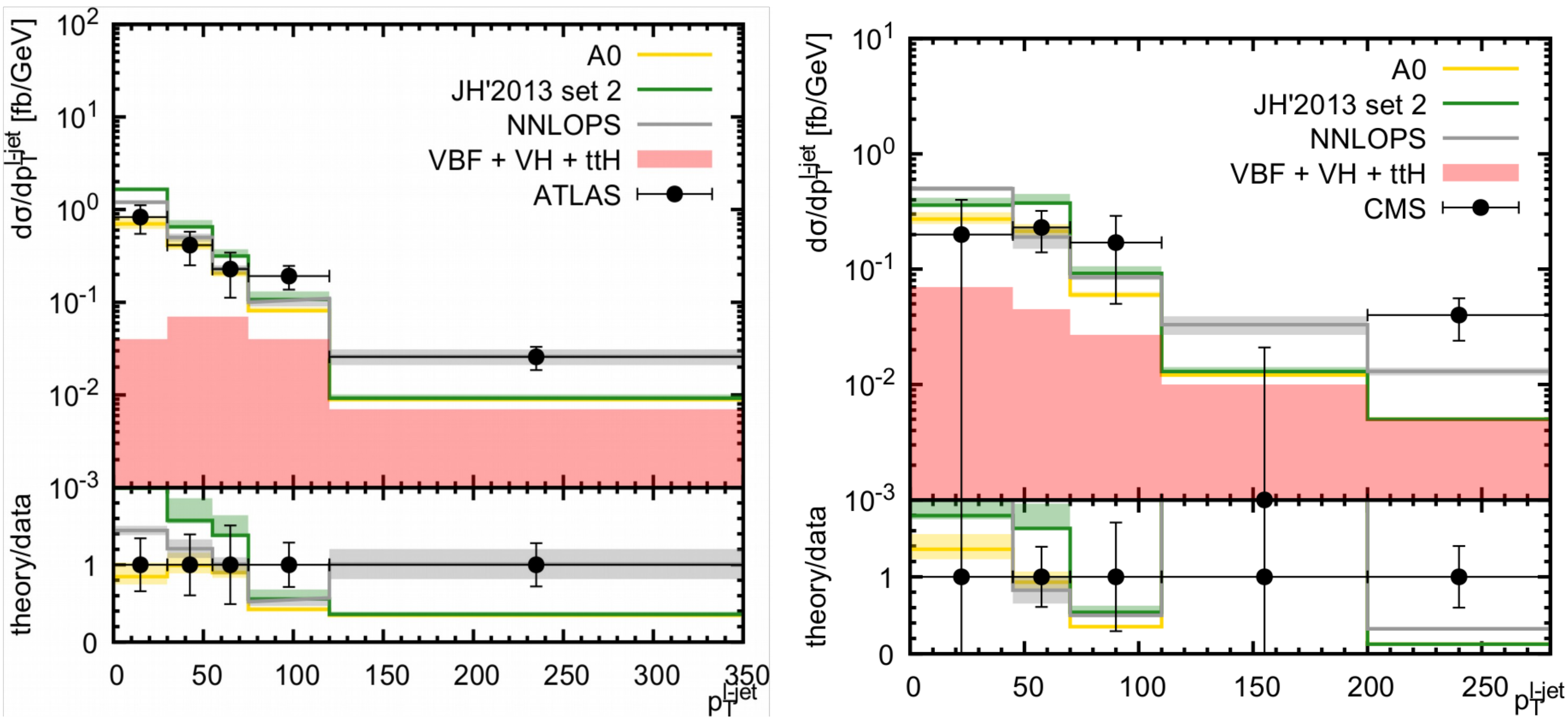
Numerical results





ZZ* channel, $\sqrt{S}$=13 TeV

Numerical results



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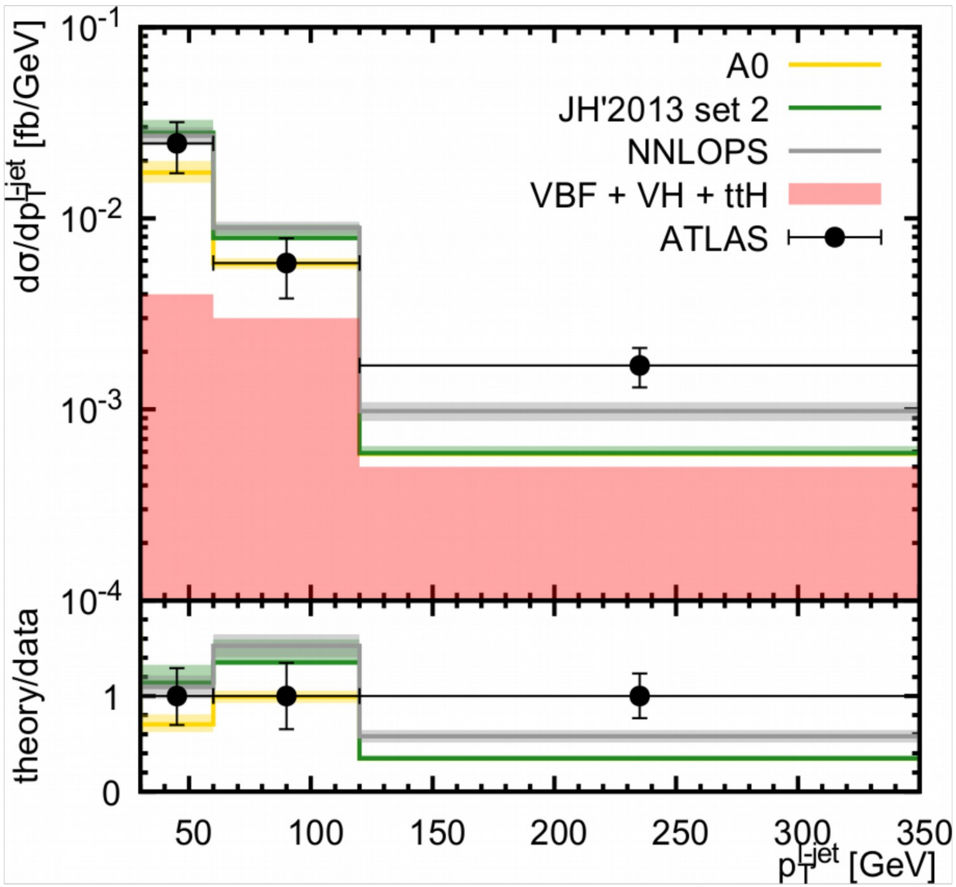
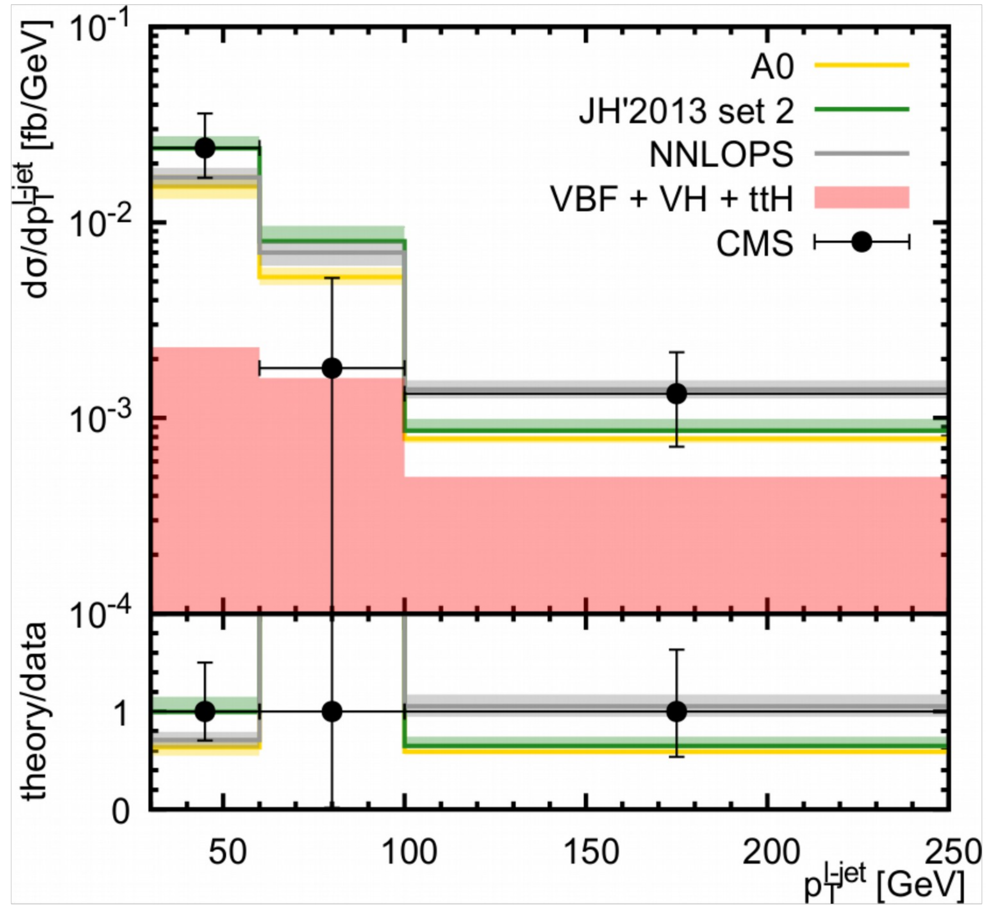
Numerical results





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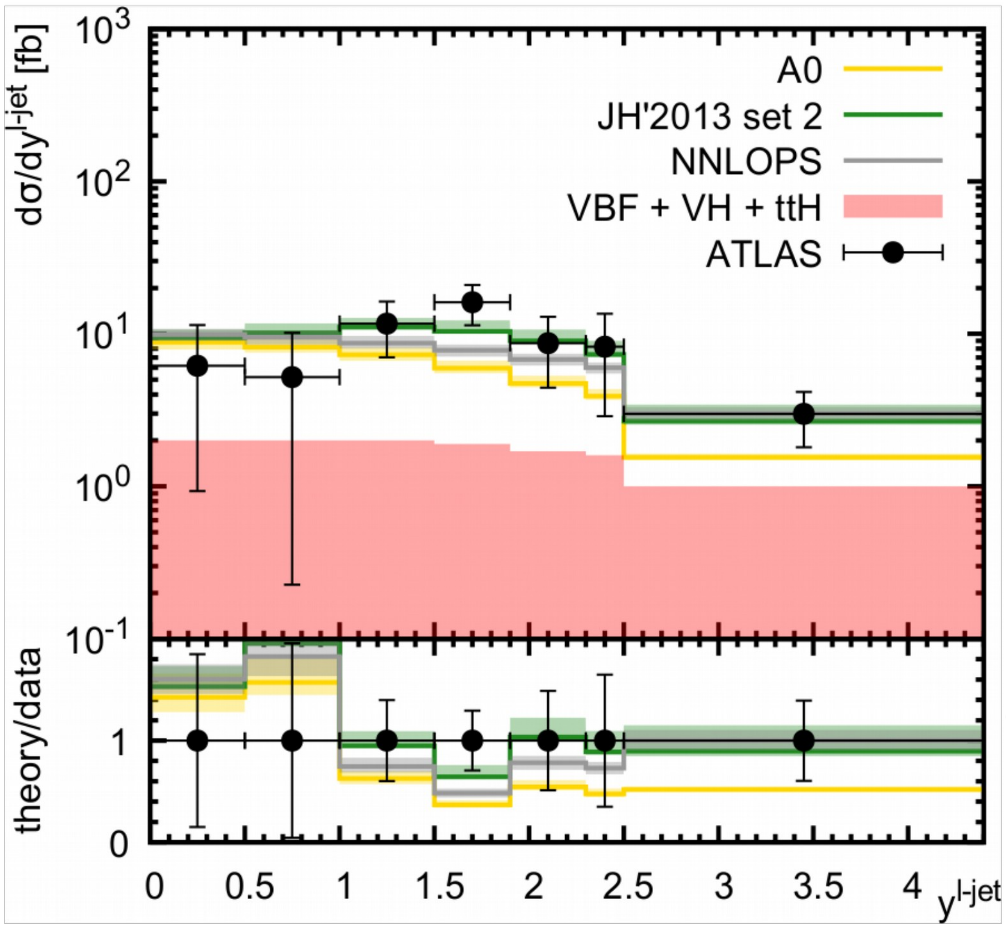
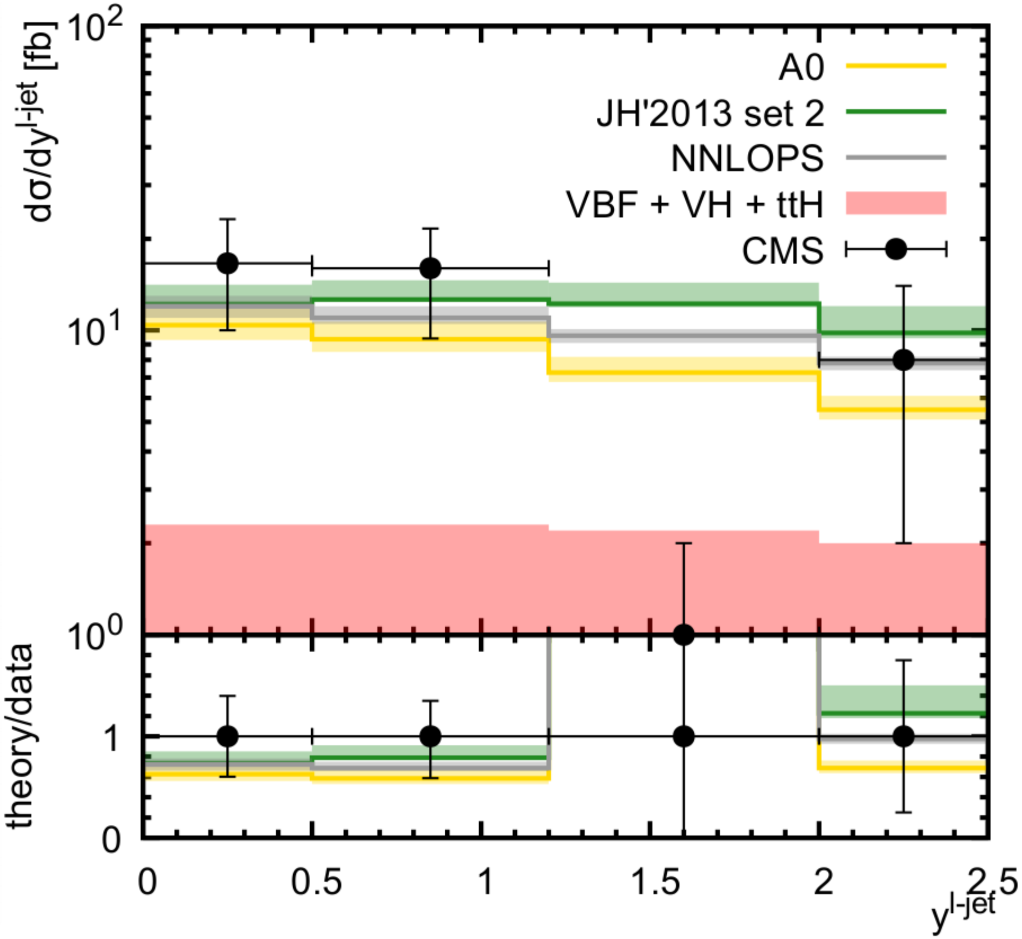
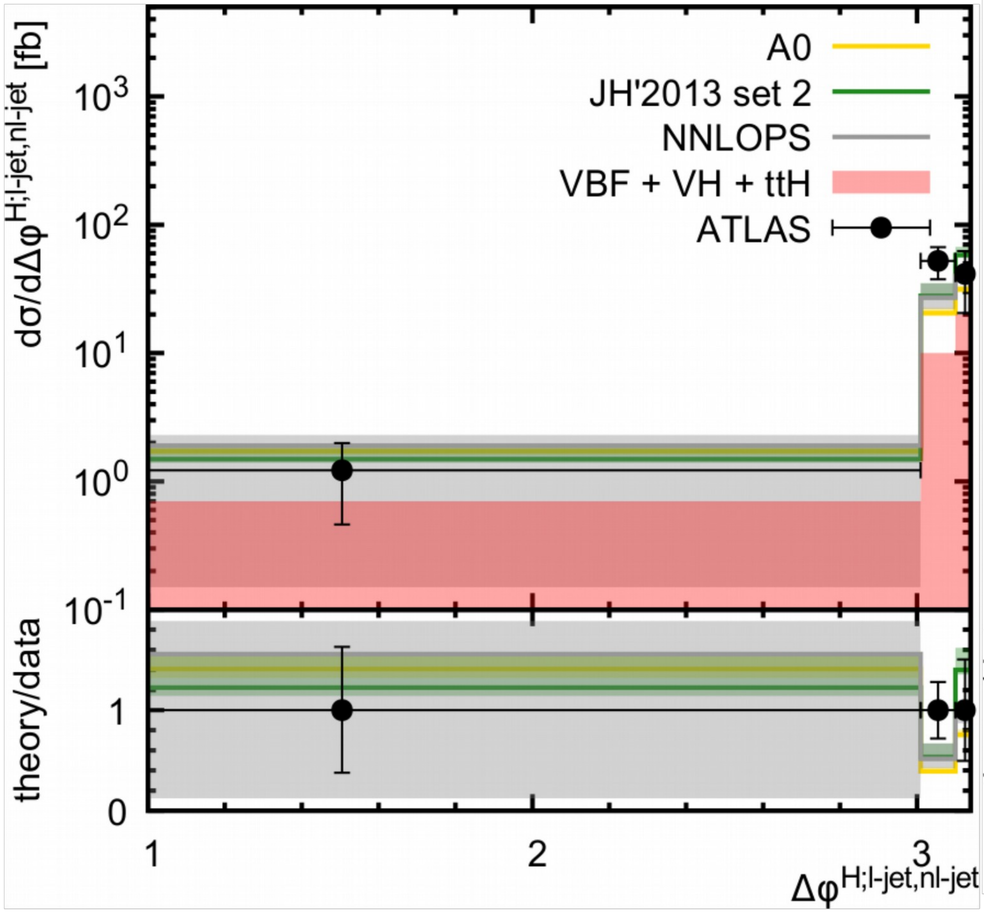
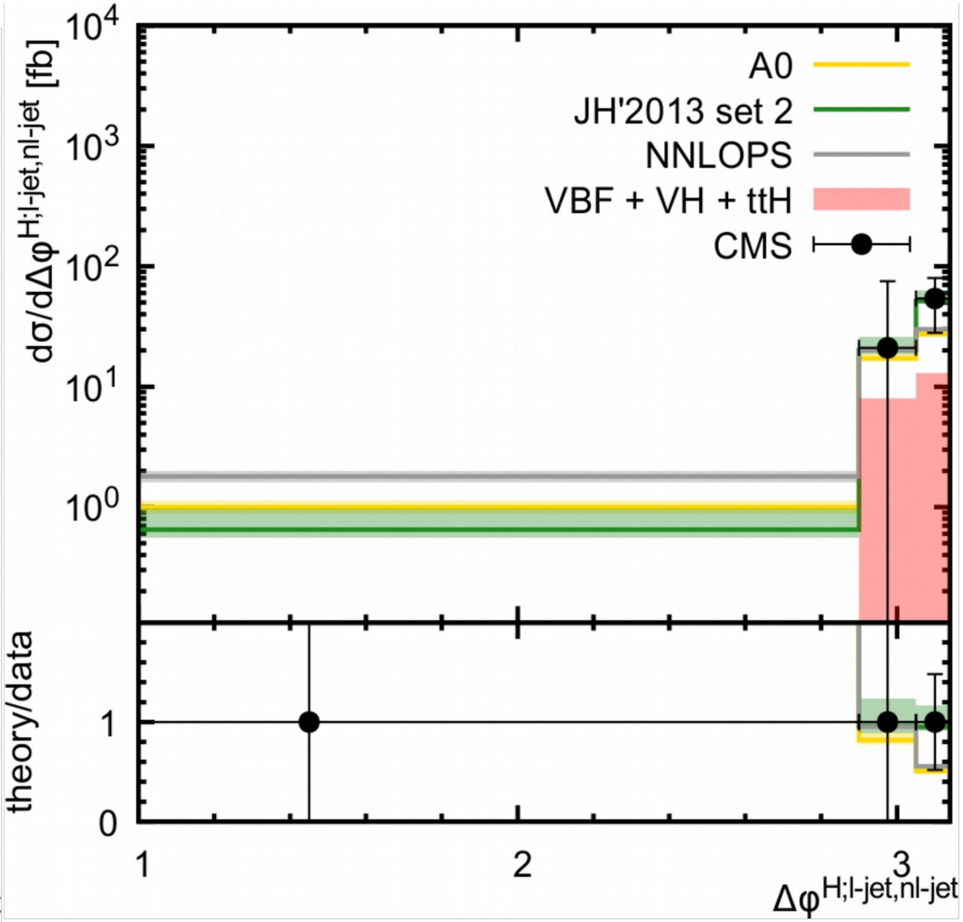




Diphoton channel, $\sqrt{S}$=13 TeV

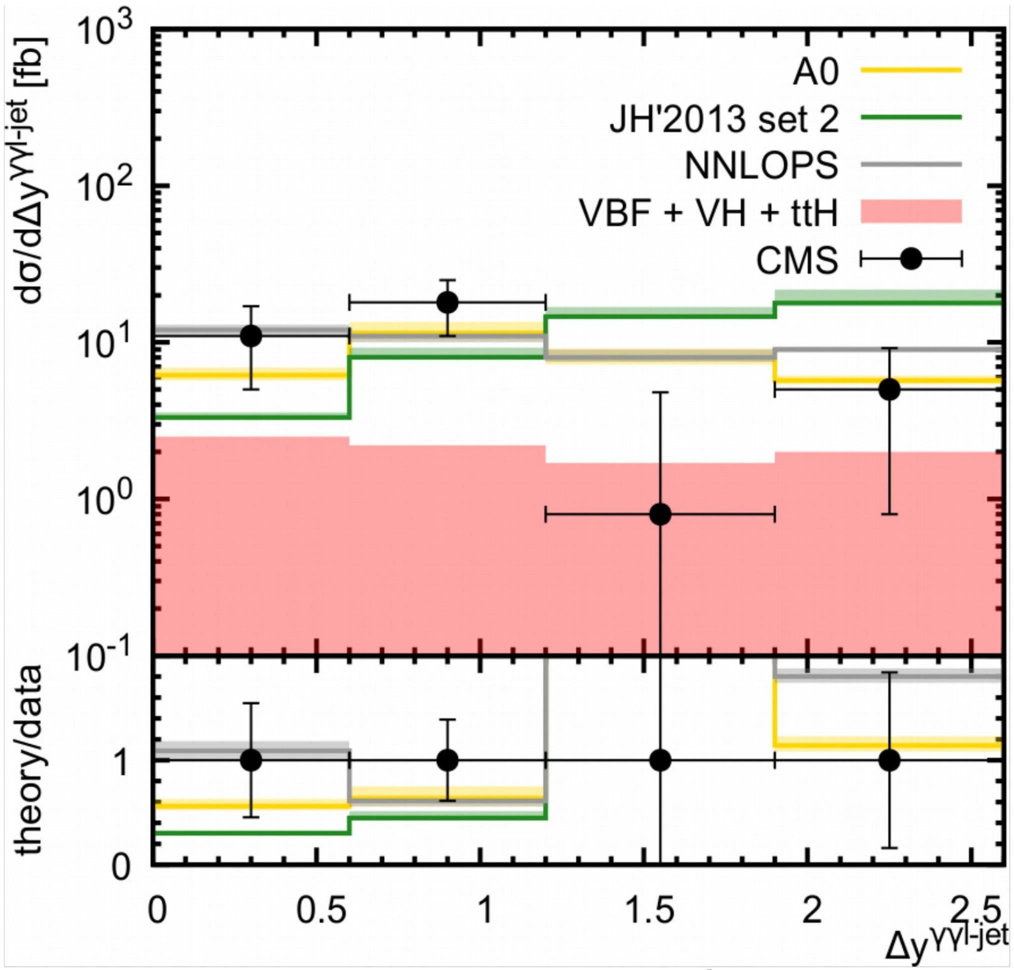
Numerical results

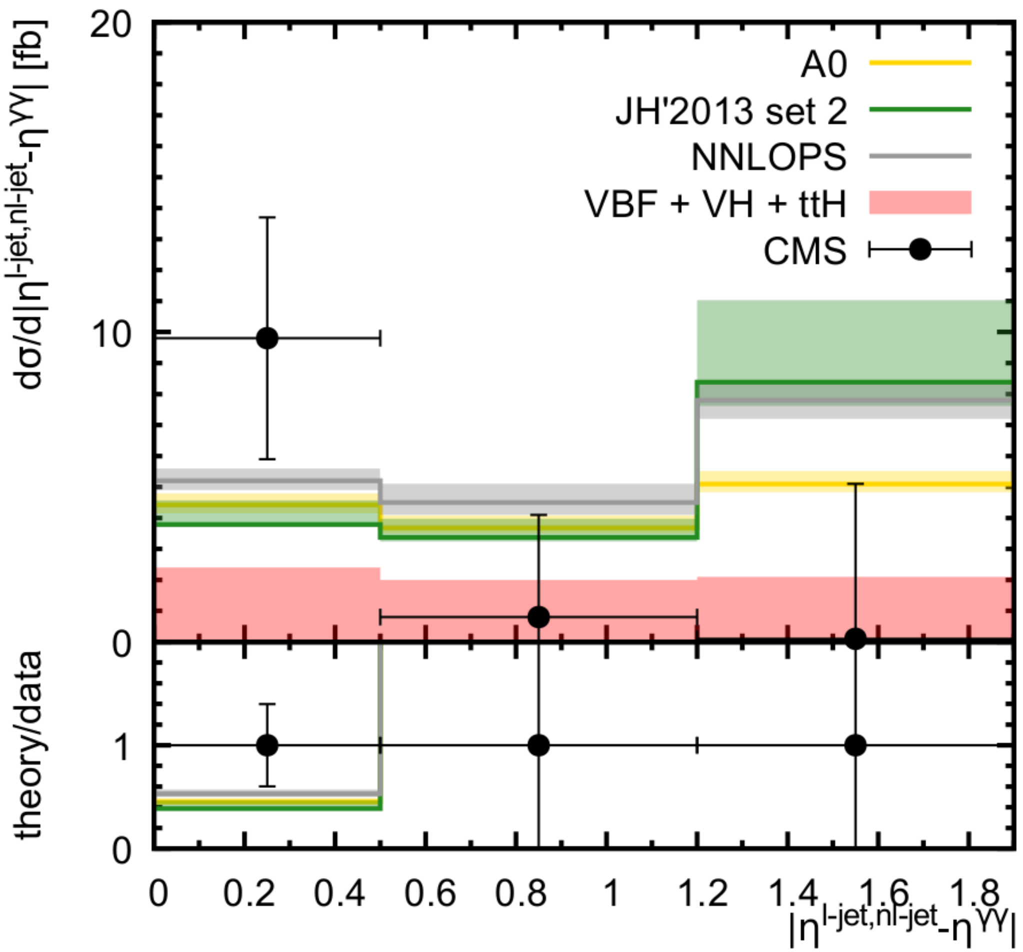




Diphoton channel, $\sqrt{S}$=13 TeV

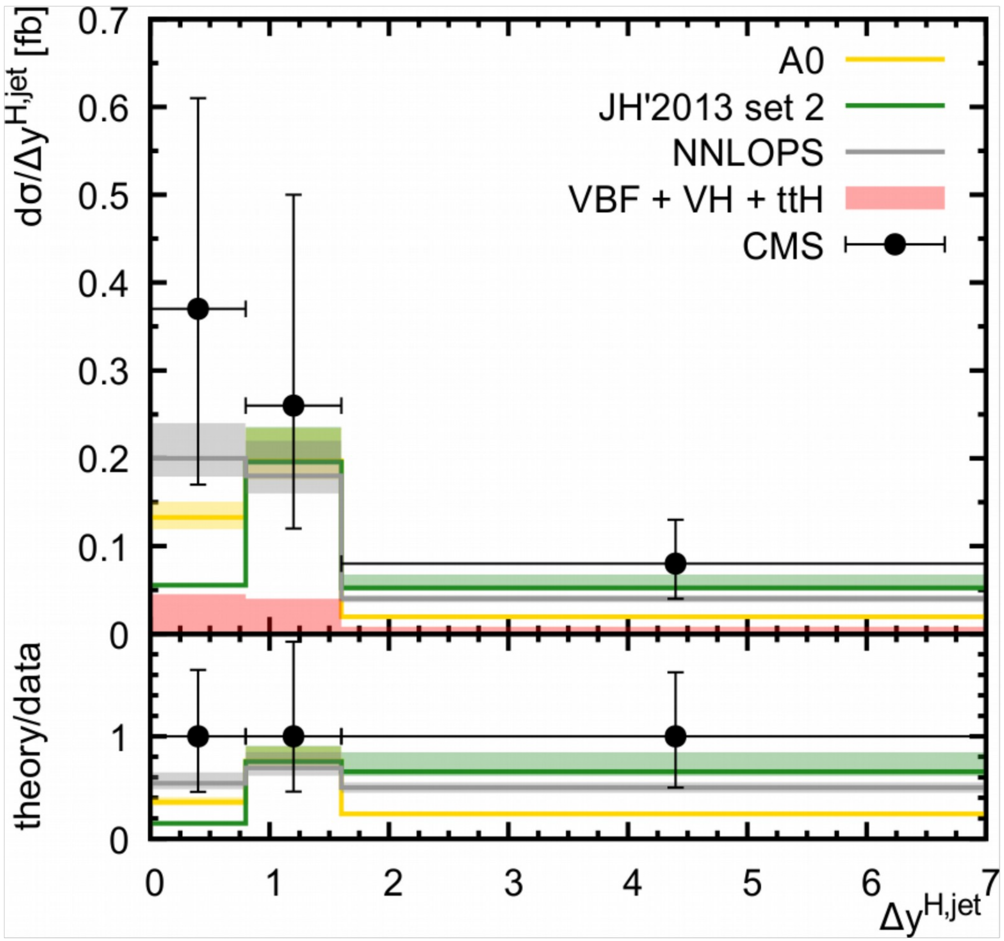
Numerical results



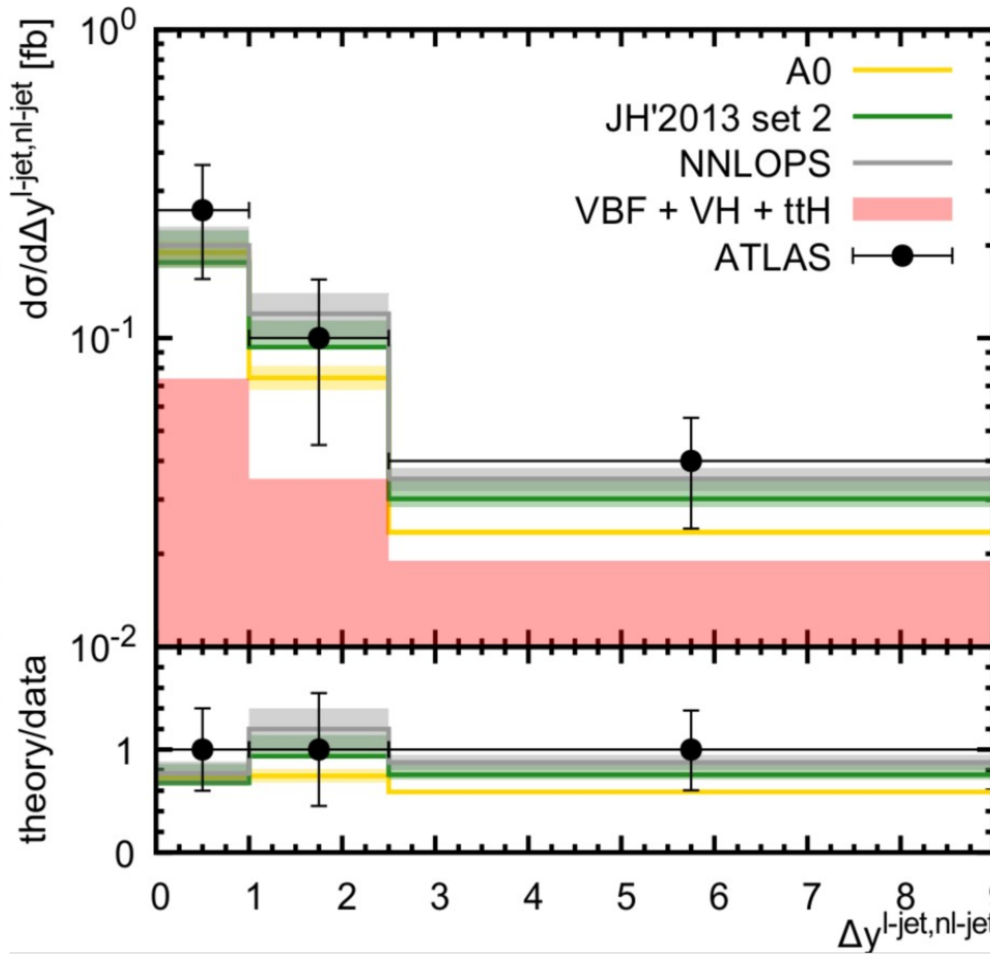


Diphoton channel, √S=13 TeV

Numerical results

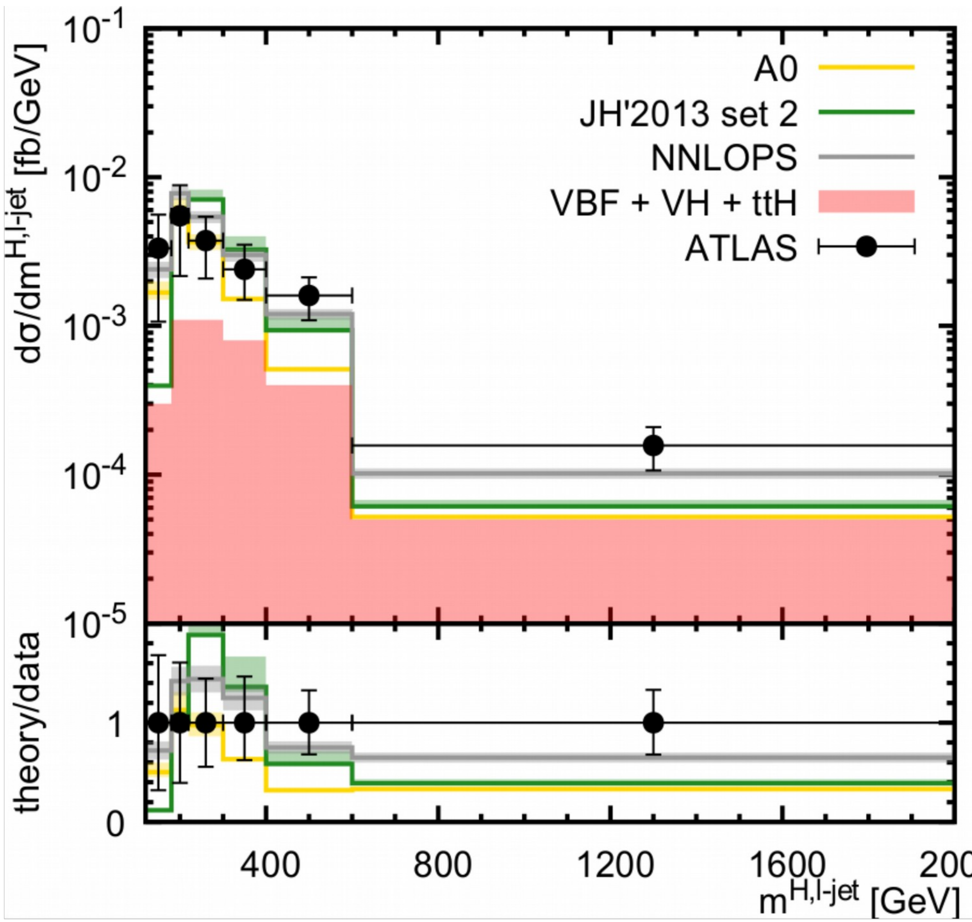


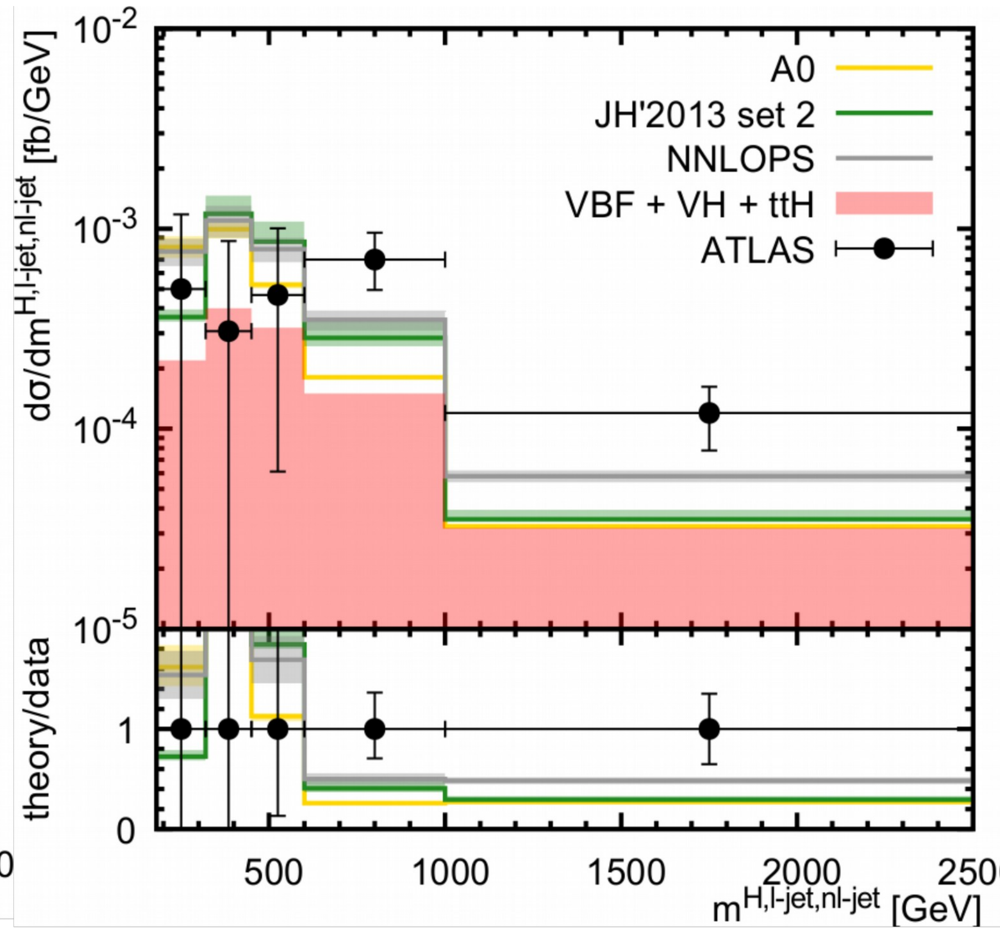
ZZ* channel, √S=8 TeV



ZZ* channel, √S=13 TeV

Numerical results





ZZ* channel, $\sqrt{S}$=13 TeV

Conclusion

Associated Higgs+jet(s) production at LHC ($\sqrt{s}$=8, 13 TeV) has been considered.

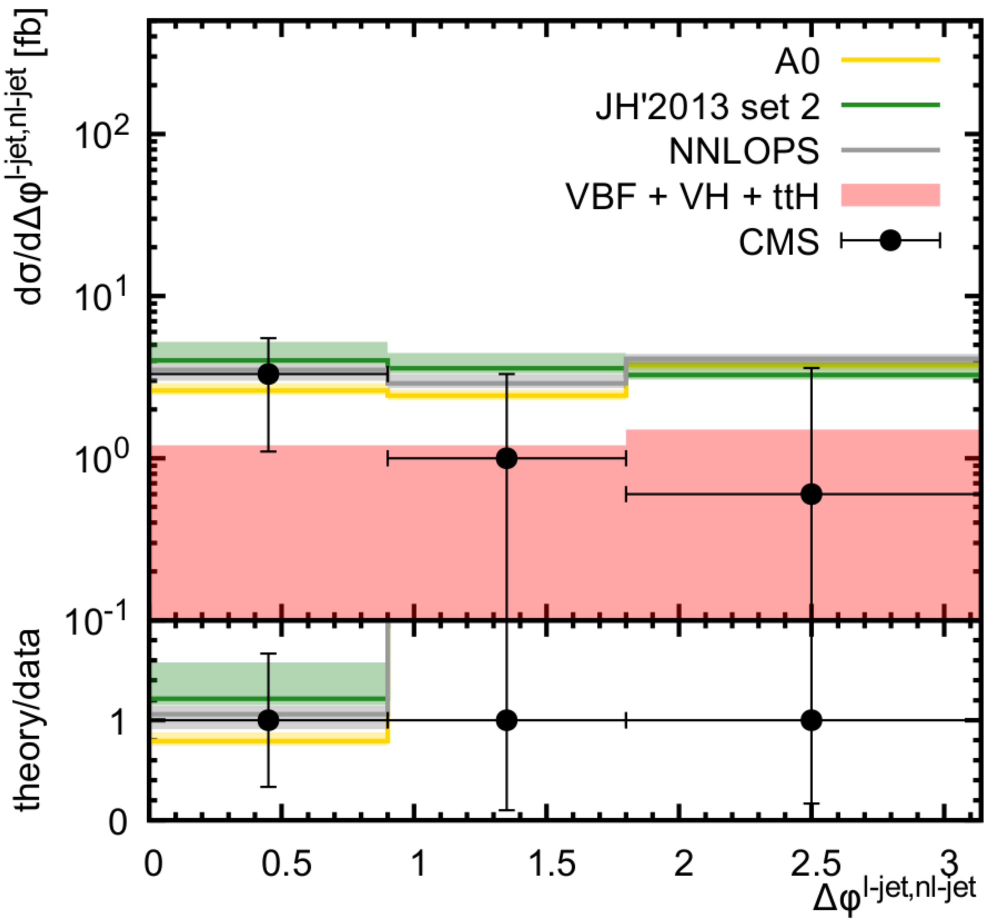
- Reasonable description of ATLAS and CMS data is obtained.

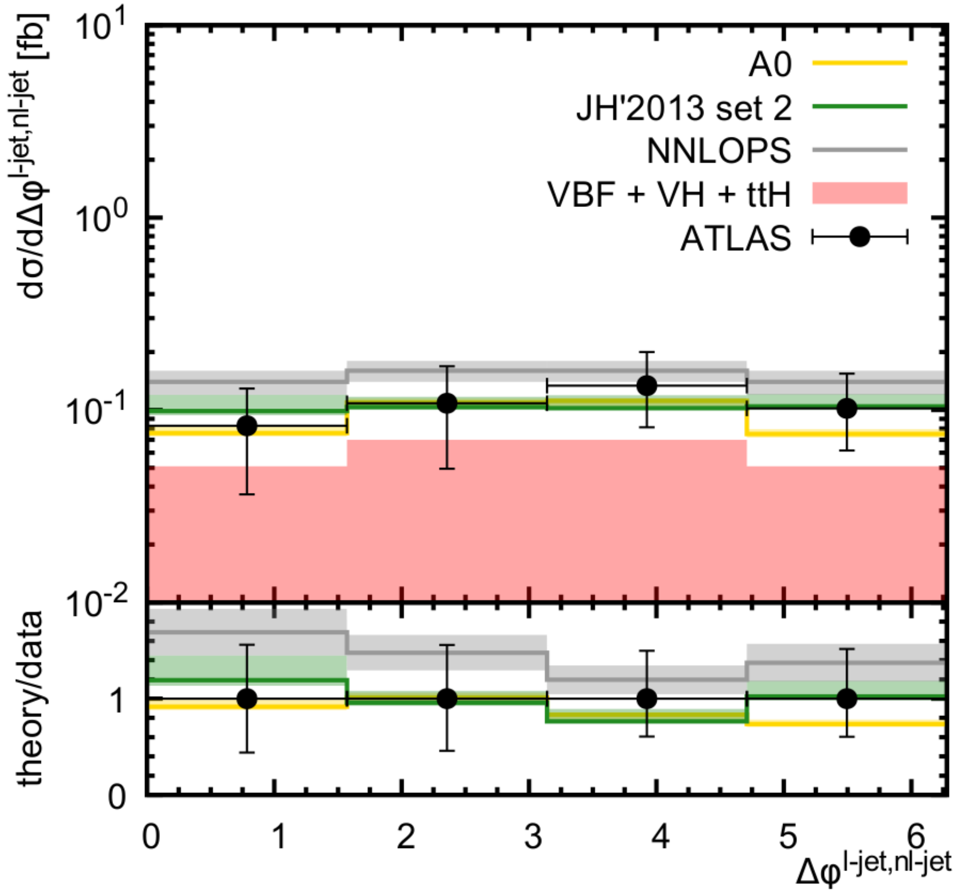
- The process is sensitive to the choice of TMDs.

- Some observables (Δy, $\Delta\varphi$, m) can be used to distinguish very clearly between CCFM A0 and JH2013 TMD distributions.

Back up

Numerical results





Diphoton channel, $\sqrt{S}$=13 TeV ZZ* channel, $\sqrt{S}$=13 TeV

Off-shell gluon polarization sum

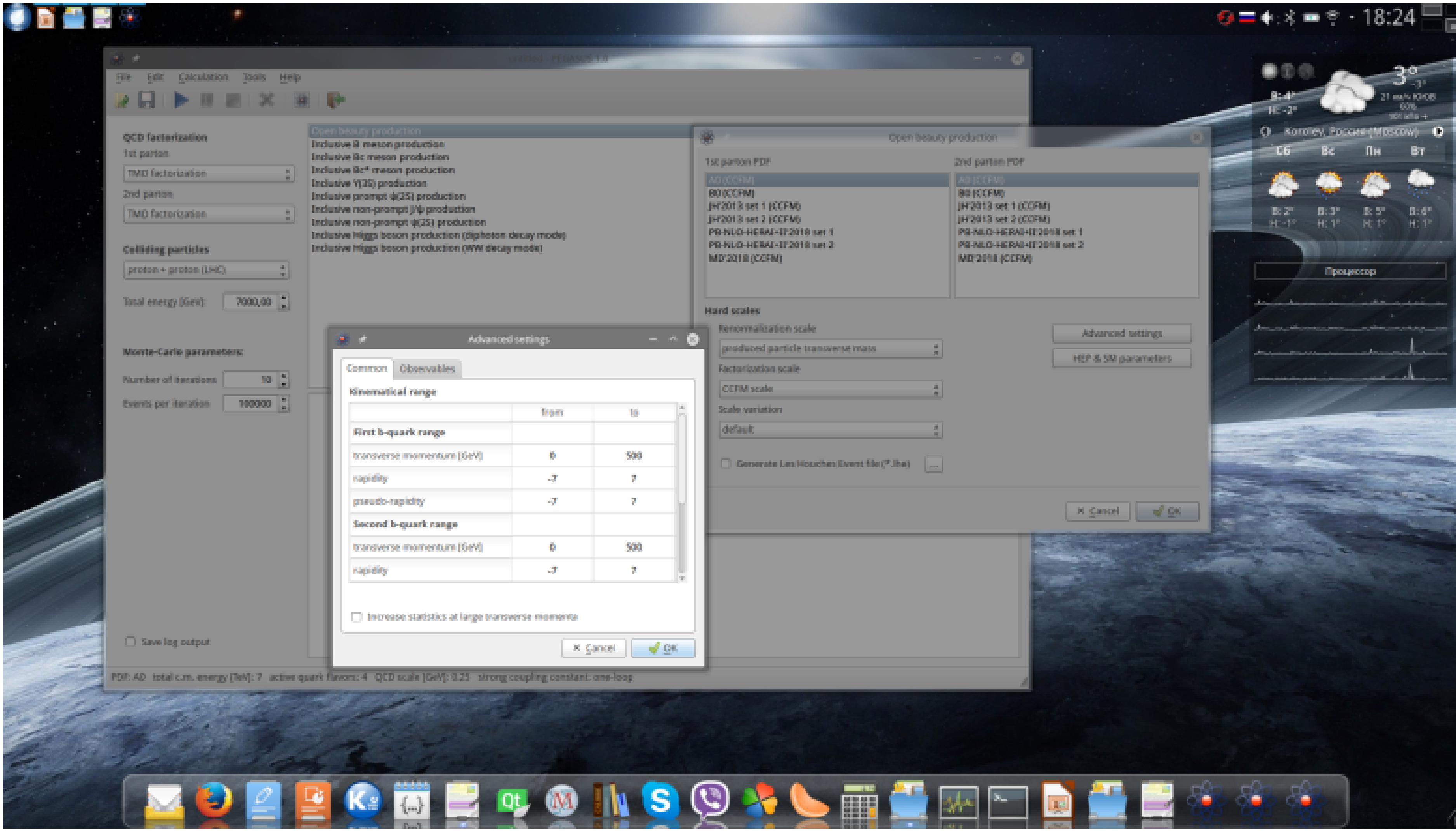
$$\epsilon_\mu \epsilon_\nu^* = \frac{k_T^\mu k_T^\nu}{\mathbf{k}_T^2}$$

CCFM equation

$$\mathcal{A}(x,k_t,p) = \mathcal{A}_0(x,k_t,p) + \int \frac{dz}{z} \int \frac{dq^2}{q^2} \Theta(p - zq) \times \Delta(p, zq) \mathcal{P}(z,q,k_t) \mathcal{A}\left(\frac{x}{z}, k_t + (1-z)q, q\right)$$

$$P_g(z,q,k_t) = \bar{\alpha}_s(q^2(1-z)^2) \left(\frac{1}{1-z} - 1 + \frac{z(1-z)}{2}\right) + \bar{\alpha}_s(k_t^2) \left(\frac{1}{z} - 1 + \frac{z(1-z)}{2}\right) \Delta_{ns}(z,q^2,k_t^2)$$

PEGASUS Particle Event Generator: A Simple-in-Use System



A.V. Lipatov, S.P. Baranov, M.A. Malyshev, in preparation (2019)

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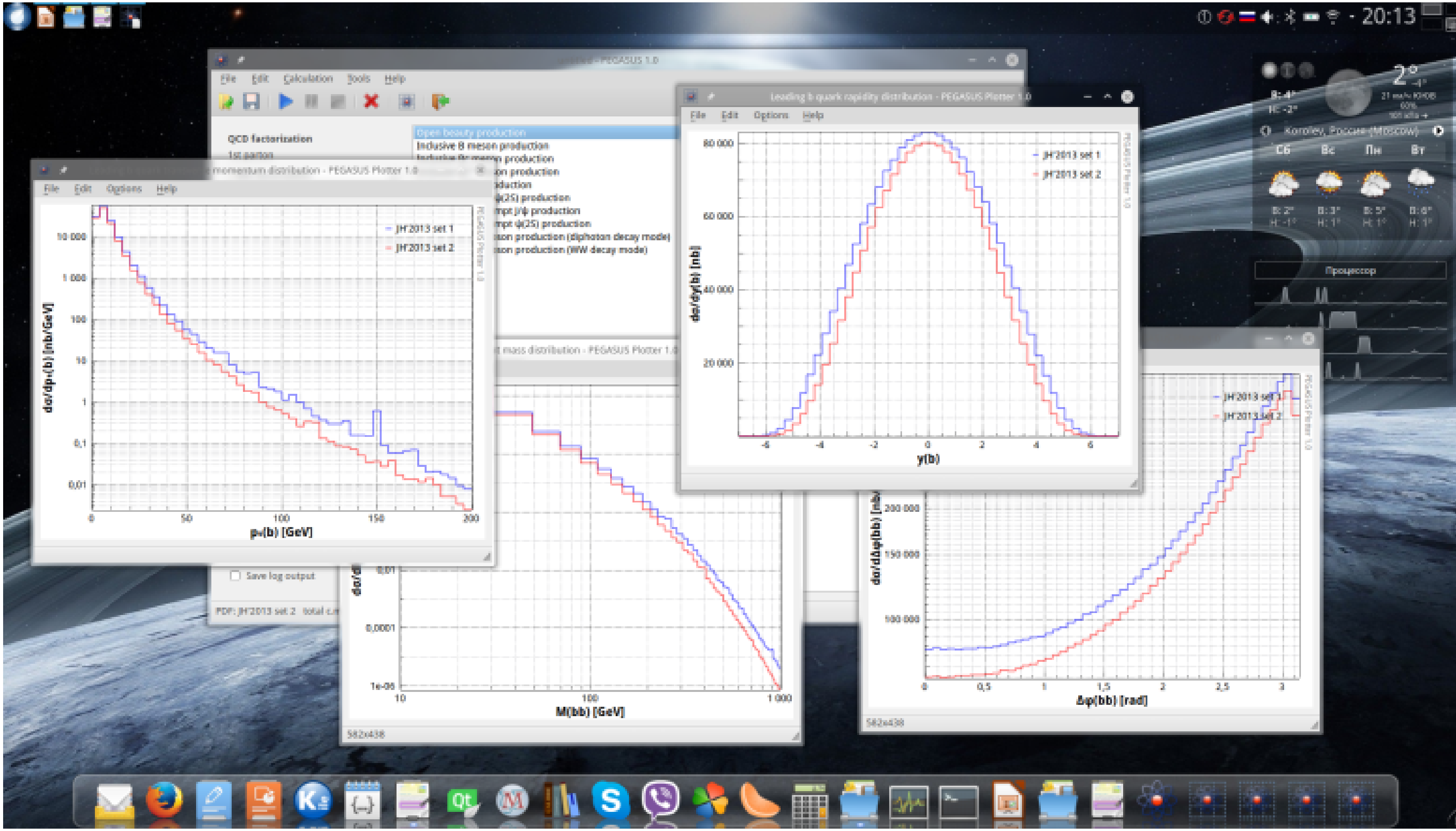

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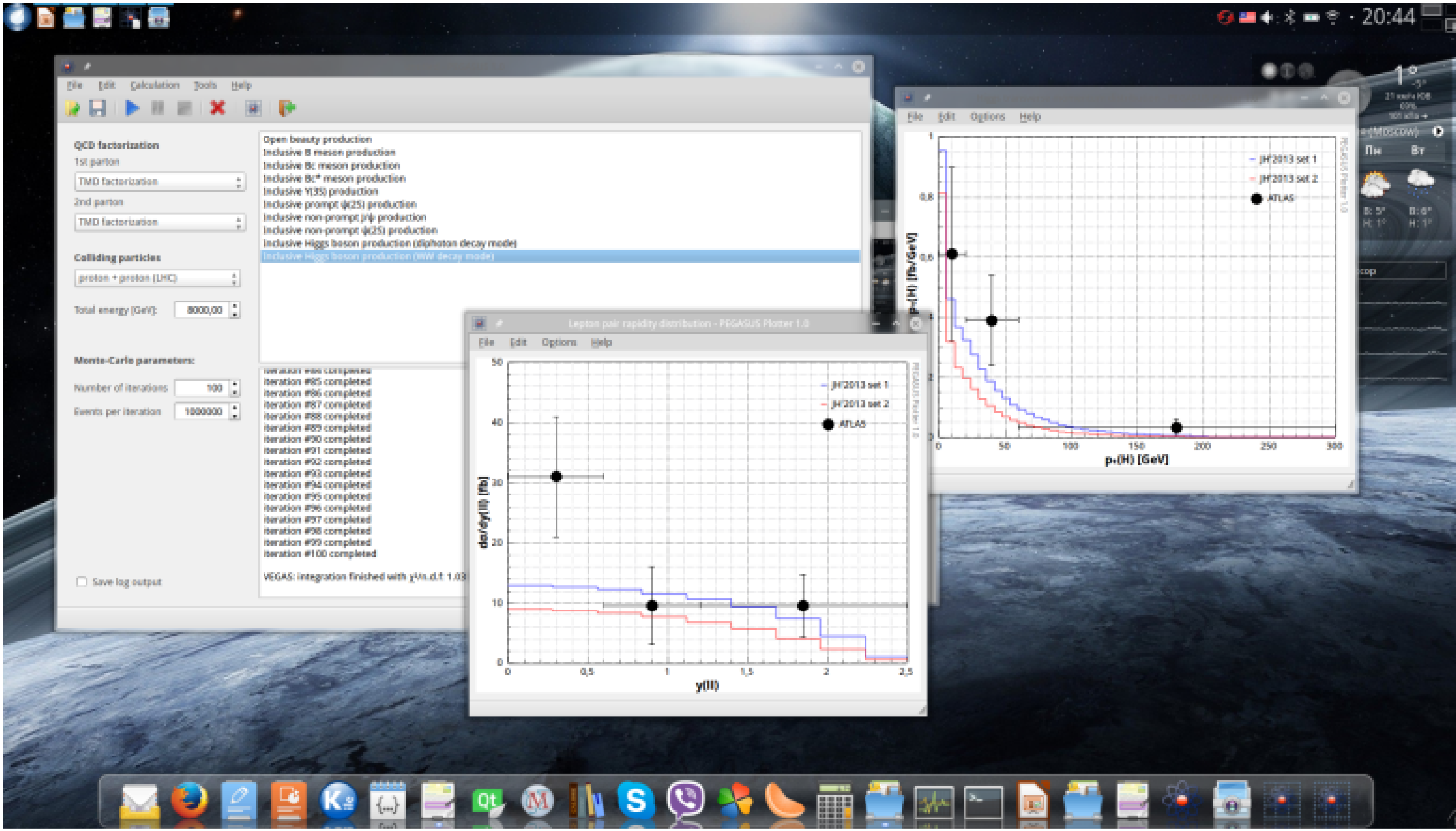

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