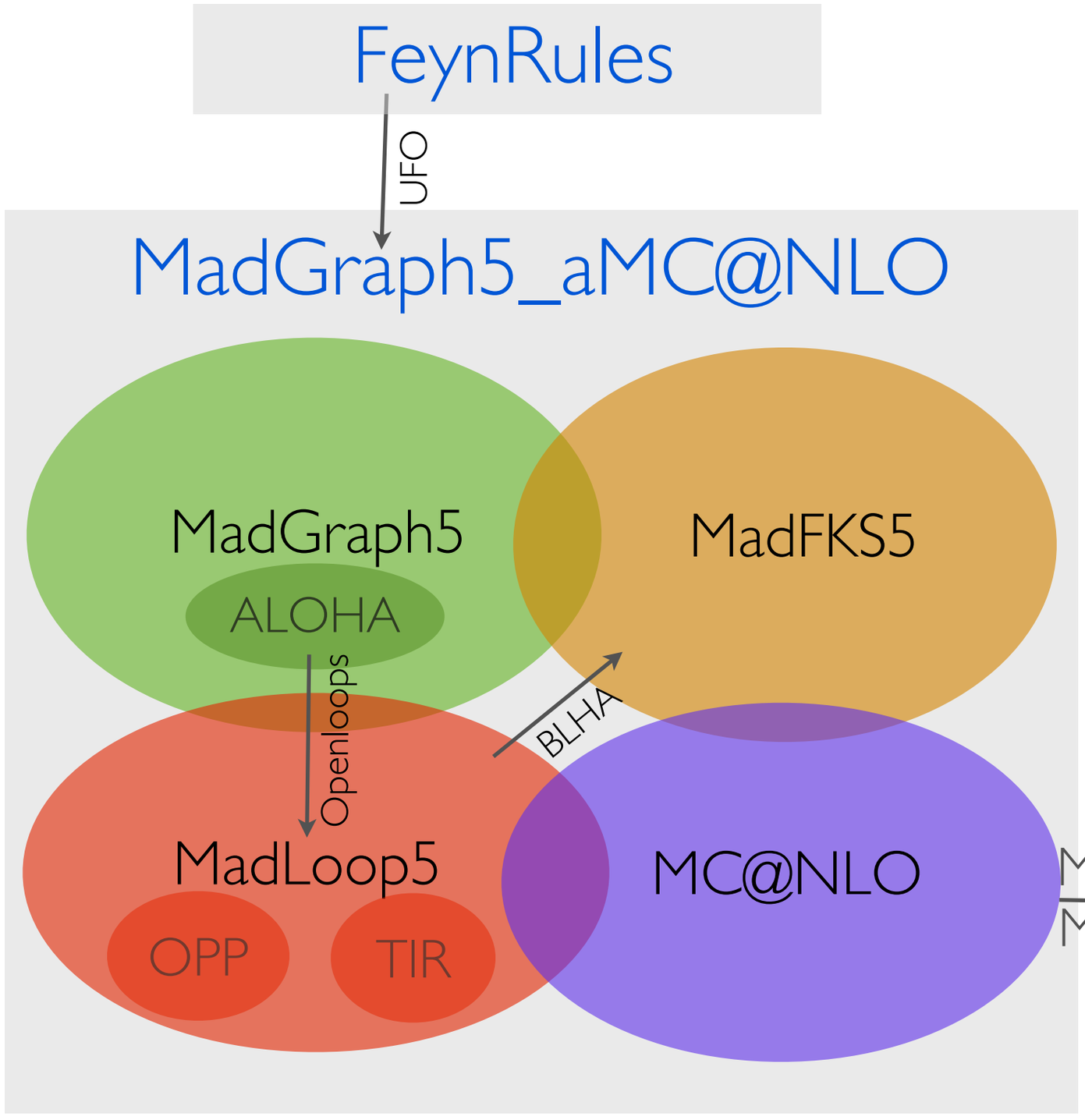
HUA-SHENG SHAO

- **2012 - 2013, visitor at CERN as a Ph.D. student (supported by ERC grant LHCtheory).**
- **2014 June, Ph.D. at Peking University.**
- **2014 - now, Postdoctral fellow at CERN (supported by ERC grant LHCtheory).**
- **Interests:**
  - **Higher-order corrections: QCD and/or EW corrections to LHC processes.**
  - **QCD physics at colliders: hadron physics, jet physics ...**
  - **Monte-Carlo tools: MadGraph5_aMC@NLO, HELAC-Onia**
  - **Other tools: IREGI (tensor integral reduction)**

JOINT EFFORTS FOR AUTOMATION AT NLO

J. Alwall, R. Frederix, S. Frixione, V. Hirschi, F. Maltoni, O. Mattelaer, HSS, T. Stelzer, P. Torrielli, M. Zaro (2014)



- First official (non-beta) version was released in 16 Dec 2013.
- A first public code that provides NLO-QCD in SM and its interface to the shower automatically.
- At the same level, NLO-EW and BSM should be available in recent years.

NLO EW:
TOP QUARK PAIR+H/Z/W

S. Frixione, V. Hirschi, D. Pagani, HSS, M. Zaro (2014,2015)

$t\bar{t}H$: σ(pb)	13 TeV
LO QCD	$3.617 \cdot 10^{-1}$ $(1.338 \cdot 10^{-2})$
NLO QCD	$1.073 \cdot 10^{-1}$ $(3.230 \cdot 10^{-3})$
LO EW	$4.437 \cdot 10^{-3}$ $(3.758 \cdot 10^{-4})$
LO EW no γ	$-1.390 \cdot 10^{-3}$ $(-2.452 \cdot 10^{-5})$
NLO EW	$-4.408 \cdot 10^{-3}$ $(-1.097 \cdot 10^{-3})$
NLO EW no γ	$-4.919 \cdot 10^{-3}$ $(-1.131 \cdot 10^{-3})$
HBR	$3.216 \cdot 10^{-3}$ $(2.496 \cdot 10^{-4})$

$$\sigma_{\rm HBR}(t\bar{t}H) = \sigma(t\bar{t}HH) + \sigma(t\bar{t}HZ) + \sigma(t\bar{t}HW^+) + \sigma(t\bar{t}HW^-),$$

$t\bar{t}H$: δ(%)	13 TeV
NLO QCD	$29.7^{+6.8}_{-11.1} \pm 2.8$ $(24.2^{+4.8}_{-10.6} \pm 4.5)$
LO EW	1.2 ± 0.9 (2.8 ± 2.0)
LO EW no γ	-0.4 ± 0.0 (-0.2 ± 0.0)
NLO EW	-1.2 ± 0.1 (-8.2 ± 0.3)
NLO EW no γ	-1.4 ± 0.0 (-8.5 ± 0.2)
HBR	0.89 (1.87)

- EW correction is moderate in inclusive cross sections.
- It can be important in the boosted regime (values in parentheses)
- Photon-induced contribution is important, especially in boosted regime.
- HBR contribution is small. It is only partly cancel NLO EW.

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NLO EW:
TOP QUARK PAIR+H/Z/W

S. Frixione, V. Hirschi, D. Pagani, HSS, M. Zaro (2014,2015)

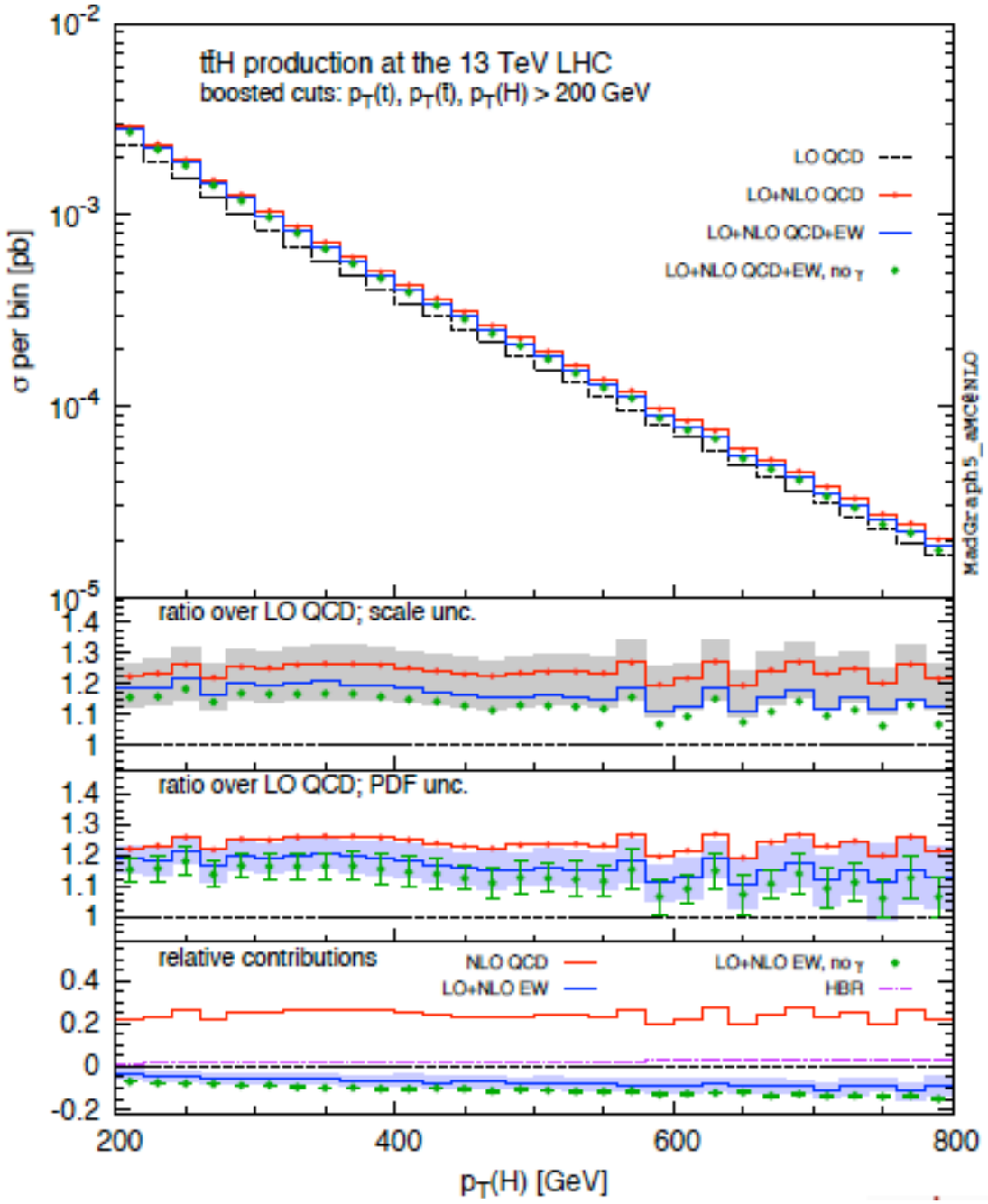
$t\bar{t}Z$: σ(pb)	13 TeV
LO QCD	$5.282 \cdot 10^{-1}$ $(1.955 \cdot 10^{-2})$
NLO QCD	$2.426 \cdot 10^{-1}$ $(7.856 \cdot 10^{-3})$
LO EW	$-2.172 \cdot 10^{-4}$ $(4.039 \cdot 10^{-4})$
LO EW no γ	$-5.771 \cdot 10^{-3}$ $(-6.179 \cdot 10^{-5})$
NLO EW	$-2.017 \cdot 10^{-2}$ $(-2.172 \cdot 10^{-3})$
NLO EW no γ	$-2.158 \cdot 10^{-2}$ $(-2.252 \cdot 10^{-3})$
HBR	$5.056 \cdot 10^{-3}$ $(4.162 \cdot 10^{-4})$

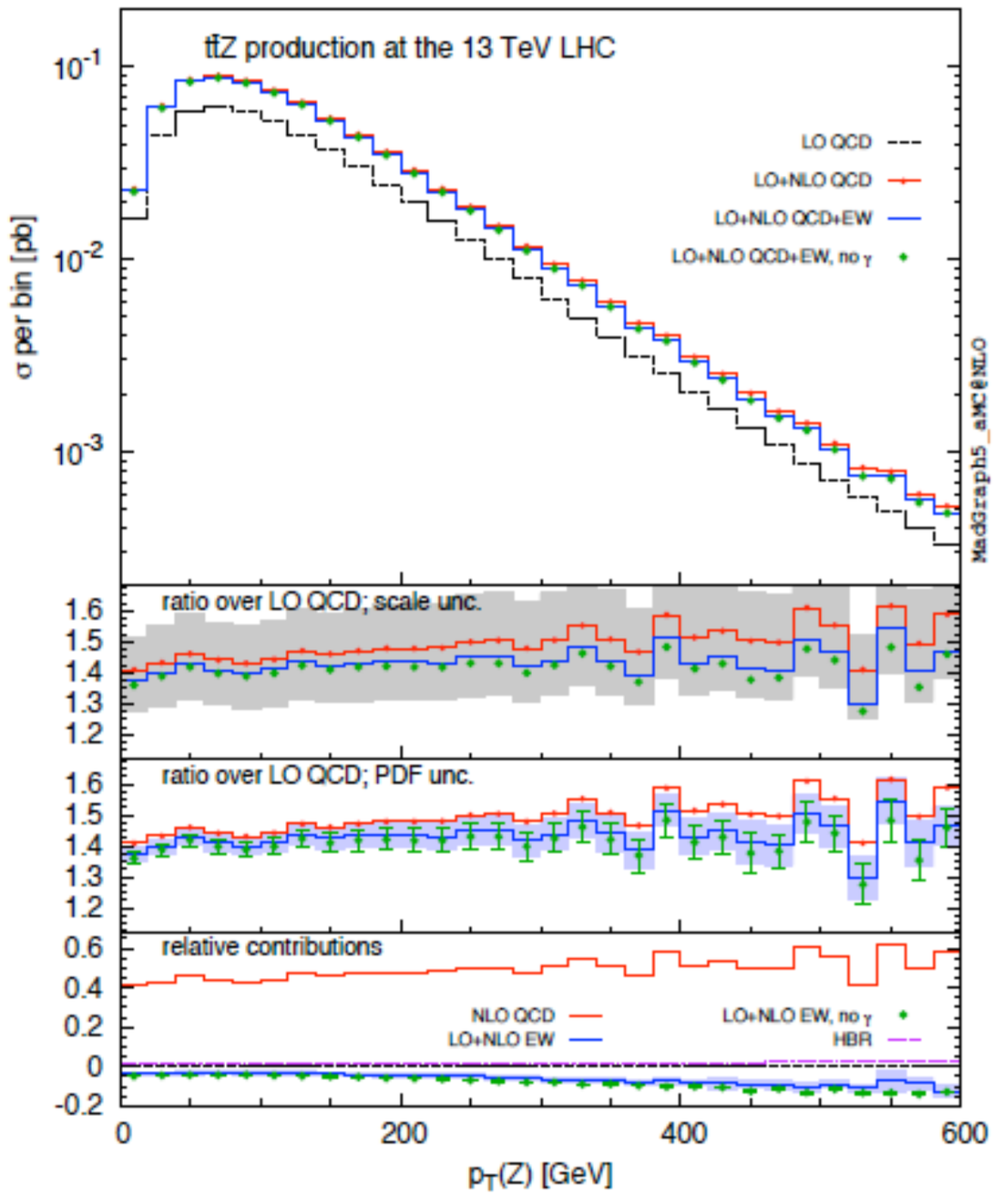
$t\bar{t}Z$: δ(%)	13 TeV
NLO QCD	$45.9^{+13.2}_{-15.5} \pm 2.9$ $(40.2^{+11.1}_{-15.0} \pm 4.7)$
LO EW	0.0 ± 0.7 (2.1 ± 1.6)
LO EW no γ	-1.1 ± 0.0 (-0.3 ± 0.0)
NLO EW	-3.8 ± 0.2 (-11.1 ± 0.5)
NLO EW no γ	-4.1 ± 0.1 (-11.5 ± 0.3)
HBR	0.96 (2.13)

- EW correction is moderate in inclusive cross sections.
- It can be important in the boosted regime (values in parentheses)
- Photon-induced contribution is important, especially in boosted regime.
- HBR contribution is small. It is only partly cancel NLO EW.
  - ttZ is similar to ttH.

NLO EW:
TOP QUARK PAIR+H/Z/W

S. Frixione, V. Hirschi, D. Pagani, HSS, M. Zaro (2014,2015)





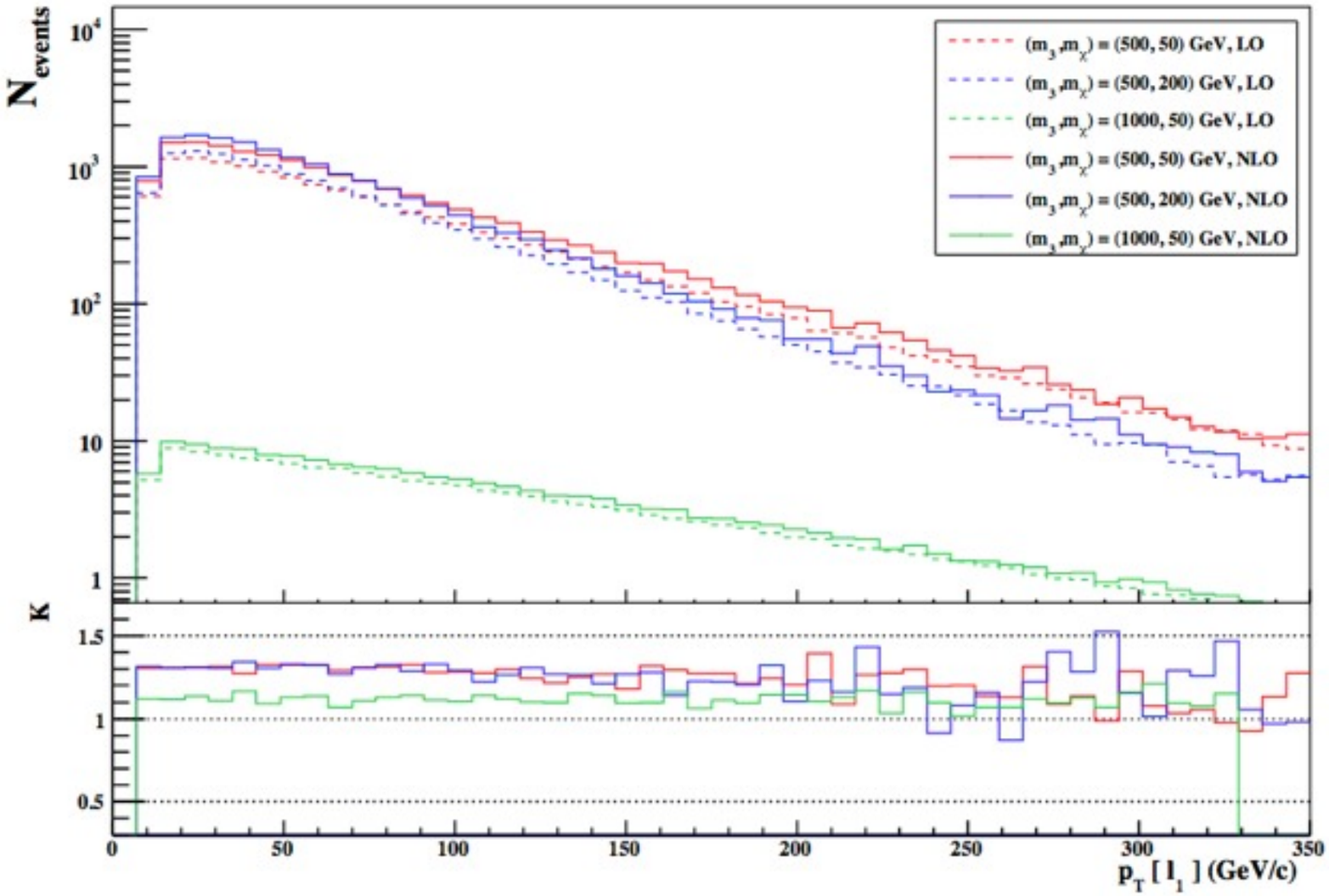
BSM@NLO: COLOR-SCALAR PAIR

C. Degrande B. Fuks, V. Hirschi, J. Proudom, HSS (2014)

$$\mathcal{L}_3 = D_\mu \sigma_3^\dagger D^\mu \sigma_3 - m_3^2 \sigma_3^\dagger \sigma_3 + \frac{i}{2}\bar{\chi}\partial\!\!\!/\chi - \frac{1}{2}m_\chi \bar{\chi}\chi + \left[\sigma_3 \bar{t}\left(\tilde{g}_L P_L + \tilde{g}_R P_R\right)\chi + \text{h.c.}\right]$$

Production

Decay



- **Stop-pair search**
- **NLO QCD + PS**
- **New UV and R2**
- **New color structure**
- **Fermion flow violation**

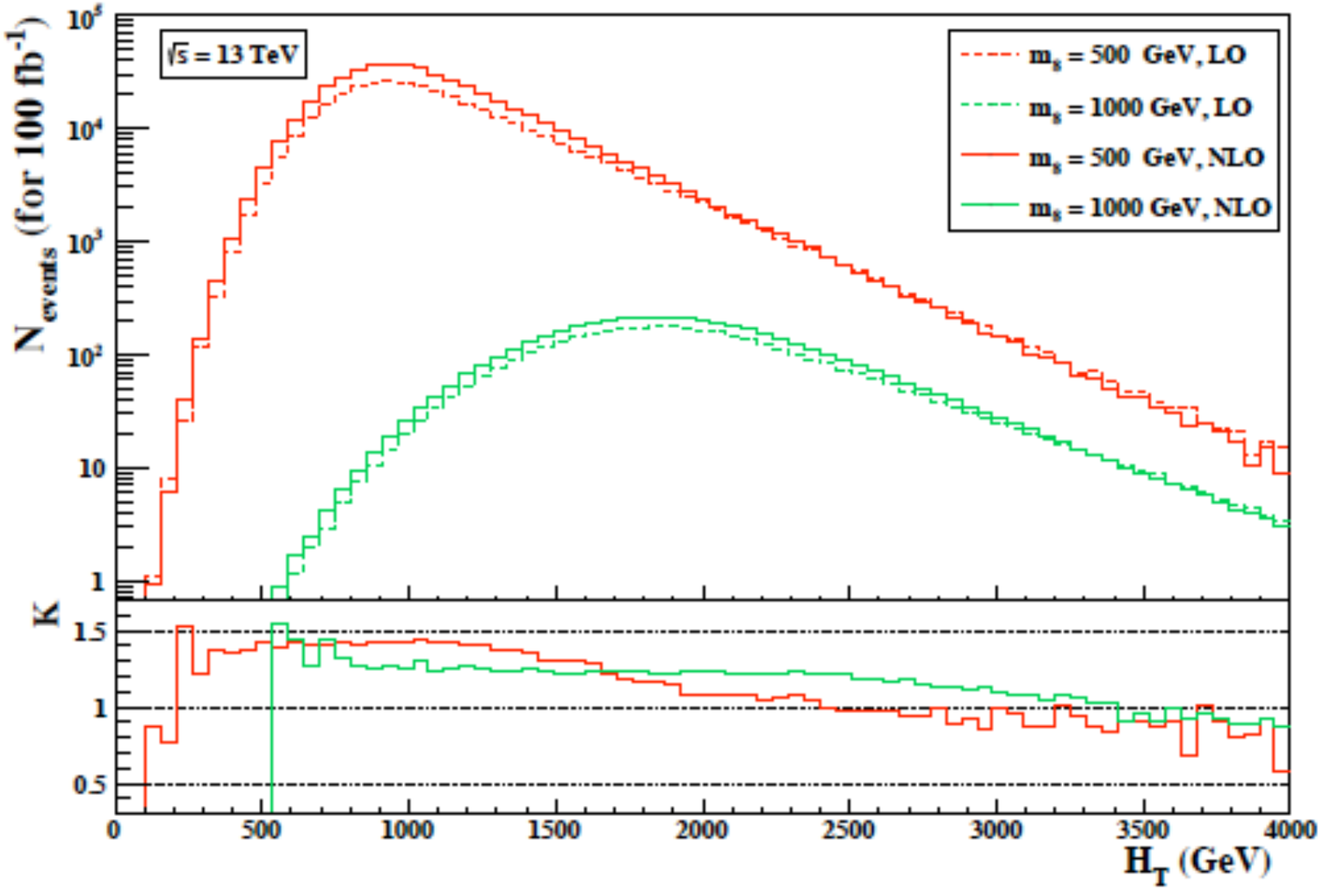
BSM@NLO: COLOR-SCALAR PAIR

C. Degrande B. Fuks, V. Hirschi, J. Proudom, HSS (2014)

$$\mathcal{L}_8 = \frac{1}{2} D_\mu \sigma_8 D^\mu \sigma_8 - \frac{1}{2} m_8^2 \sigma_8 \sigma_8 + \frac{\hat{g}_g}{\Lambda} \sigma_8 G_{\mu\nu} G^{\mu\nu} + \sum_{q=u,d} \left[\sigma_8 \bar{q} \left(\hat{g}_q^L P_L + \hat{g}_q^R P_R \right) q + \text{h.c.} \right]$$

Production

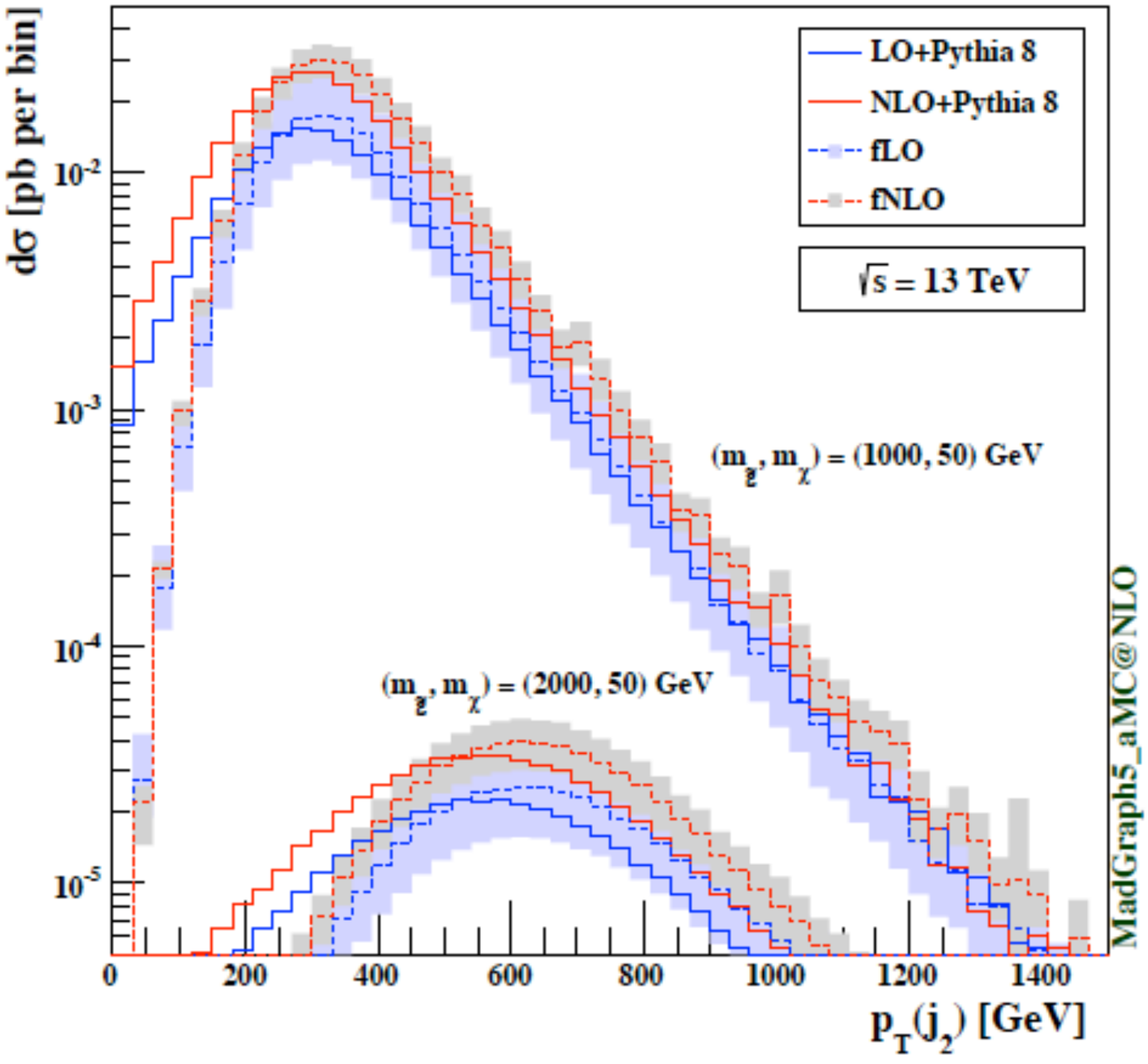
Decay



- **sgluon-pair search**
- **NLO + PS**
- **Non-renormalizable operators**

BSM@NLO: GLUINO-PAIR

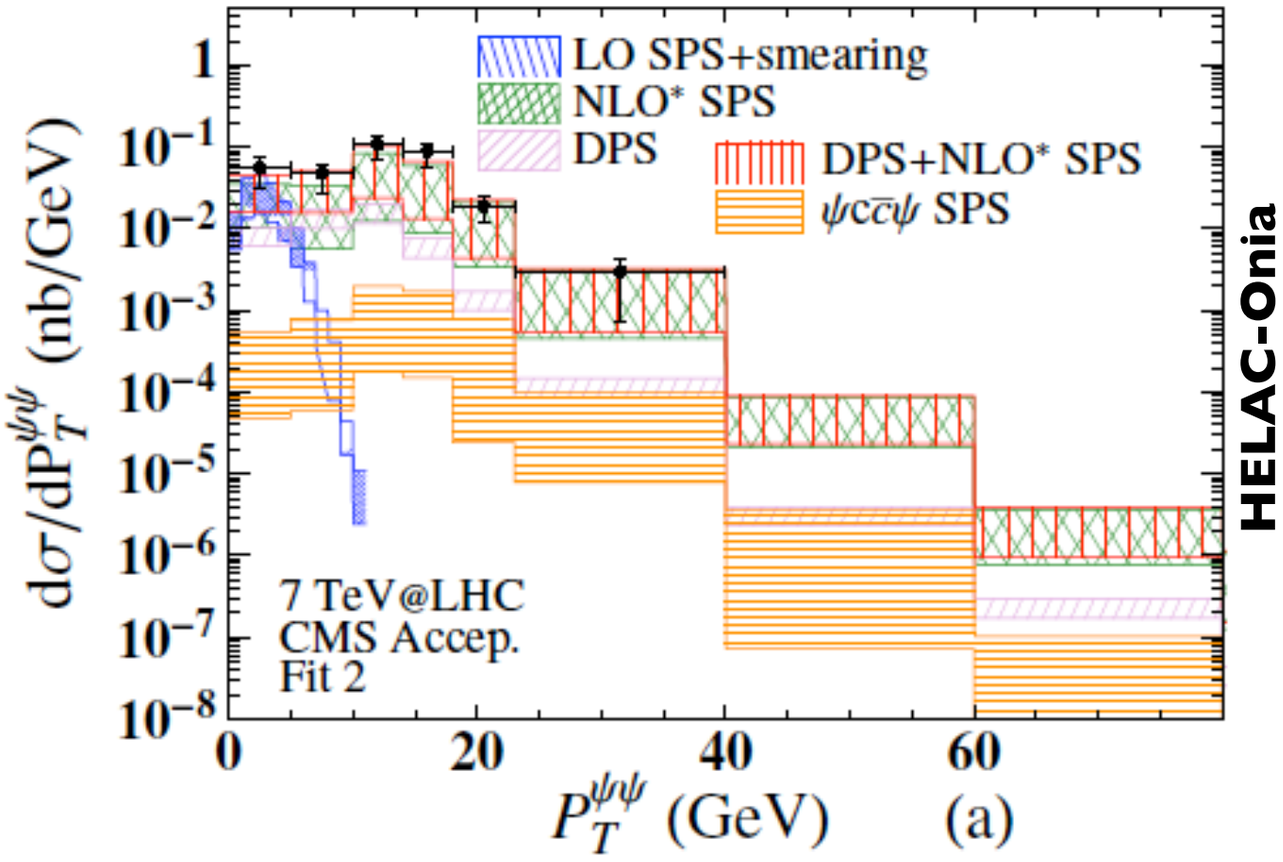
C. Degrande B. Fuks, V. Hirschi, J. Proudom, HSS (2015)

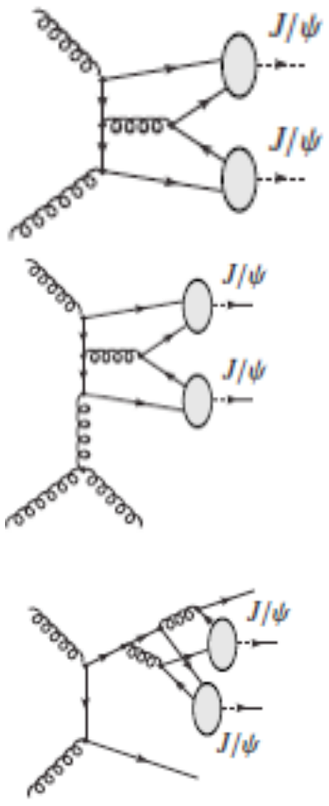


- **SUSY QCD**
- **NLO + PS**
- **Majorana**
- **On-shell subtraction (in future)**
- **How far we can go ?**

HADRON PHYSICS: J/PSI-PAIR

J. Lansberg, HSS (2013,2014,2015)





$$\sim \alpha_s^4 \left(\frac{m_\psi}{P_T^\psi}\right)^8$$

$$\sim \alpha_s^5 \left(\frac{m_\psi}{P_T^\psi}\right)^6$$

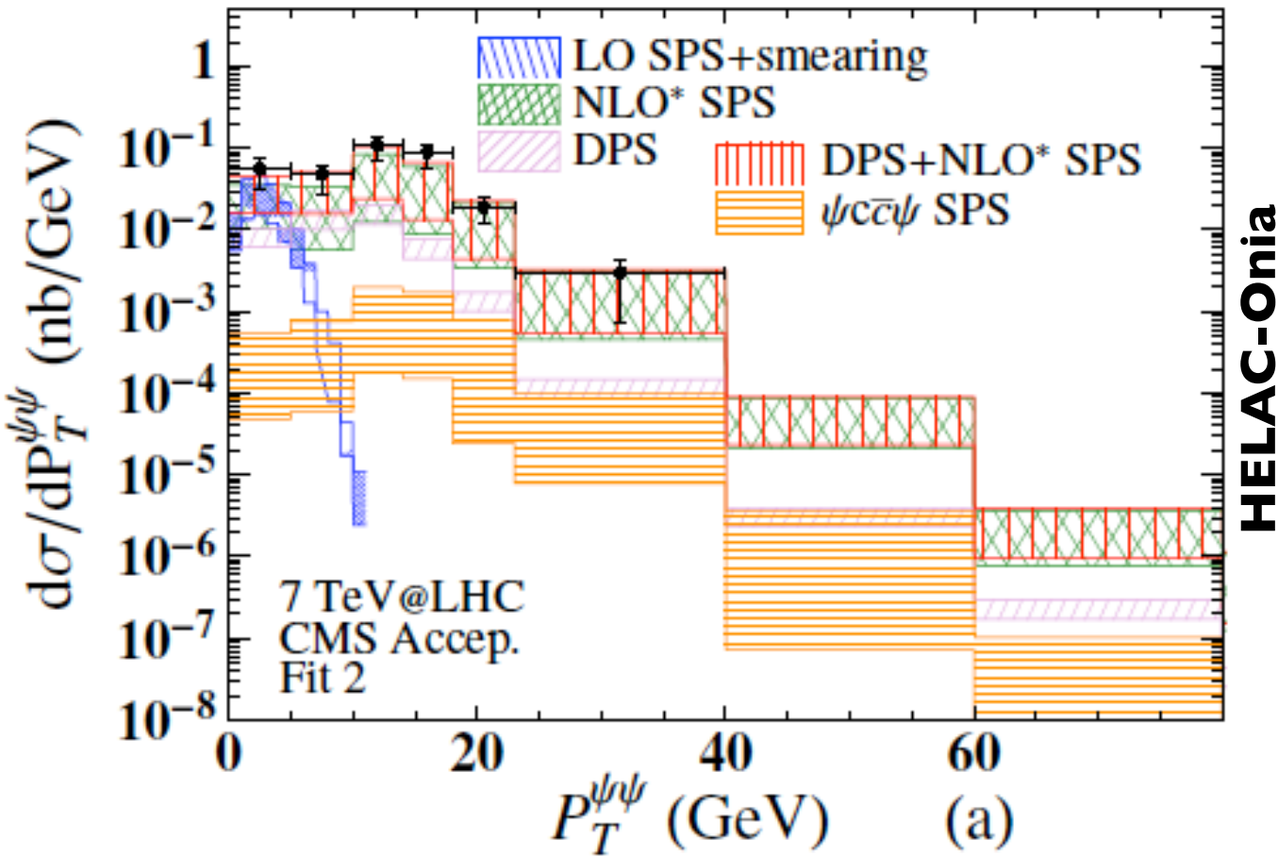
$$\sim \alpha_s^6 \left(\frac{m_\psi}{P_T^\psi}\right)^4$$

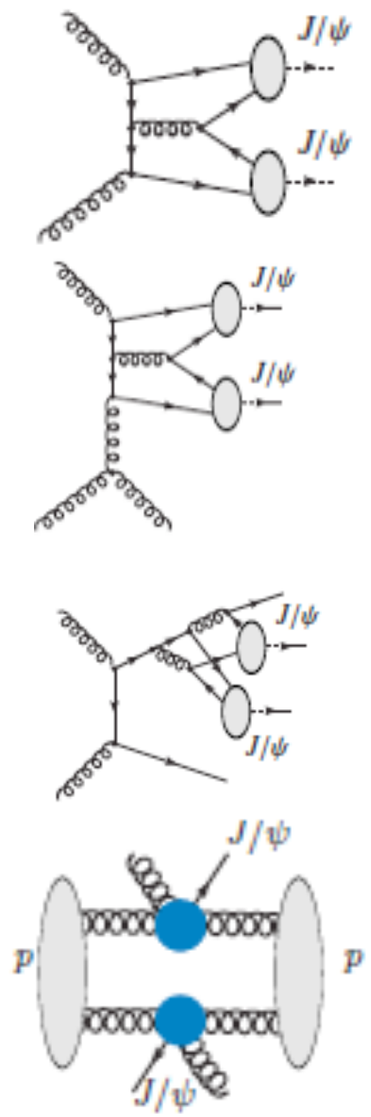
SPS

- Big QCD corrections in Single-Parton Scattering (SPS).

HADRON PHYSICS: J/PSI-PAIR

J. Lansberg, HSS (2013,2014,2015)





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SPS

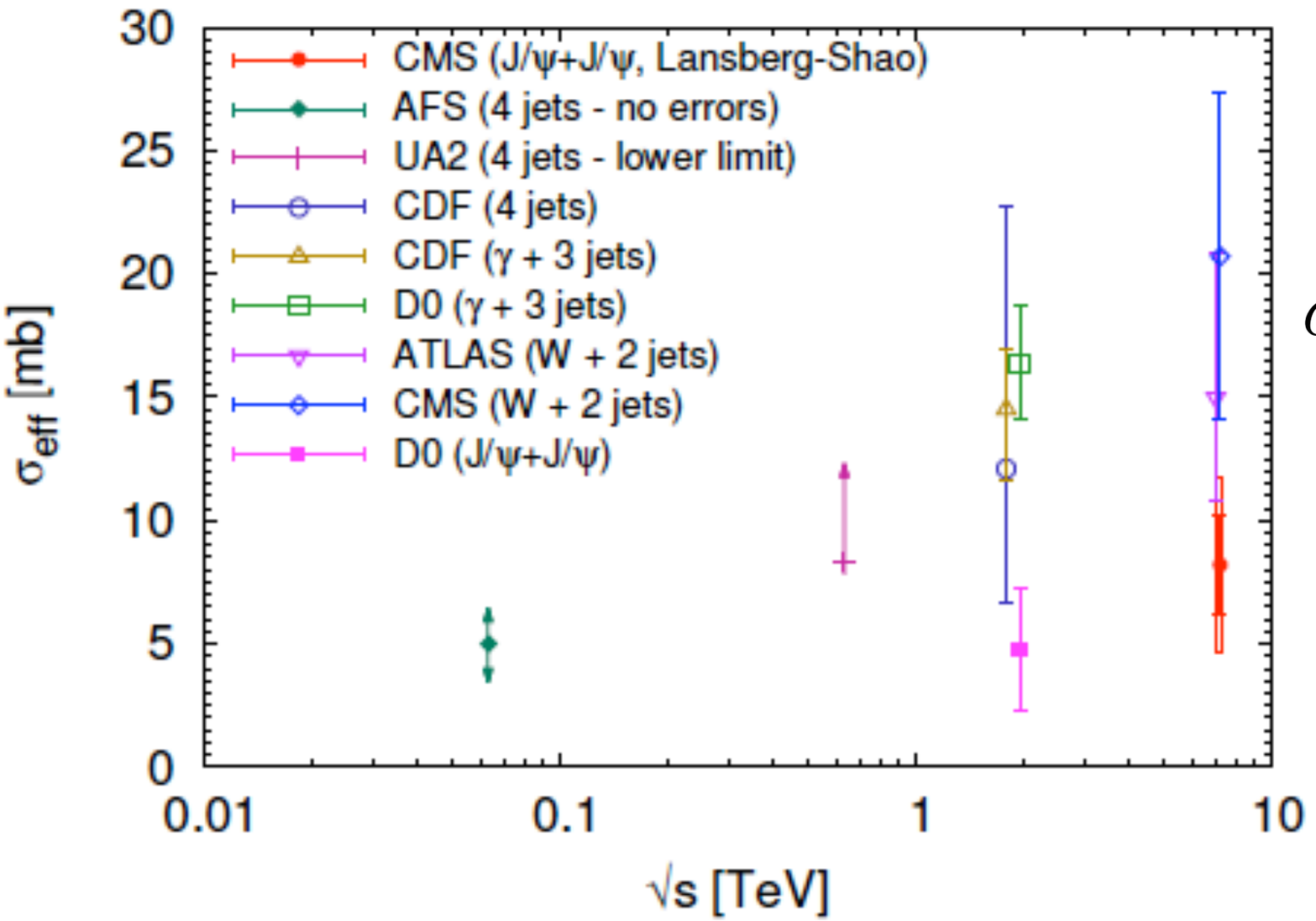
DPS

- Big QCD corrections in Single-Parton Scattering (SPS).
- Substantial Double-Parton Scattering (DPS).

HADRON PHYSICS: J/PSI-PAIR

J. Lansberg, HSS (2013,2014,2015)

$$\sigma_{\rm eff} = 8.2 \pm 2.9|_{\sigma_\psi \text{ fit}} \pm 2.0|_{\text{SPS theory+CMS data}} \text{ mb}$$



$$\sigma^{\rm DPS}_{J/\psi J/\psi} = \frac{1}{2}\frac{\sigma_{J/\psi}\sigma_{J/\psi}}{\sigma_{\rm eff}}$$