Monojet signatures at the High-Luminosity and High-Energy LHC

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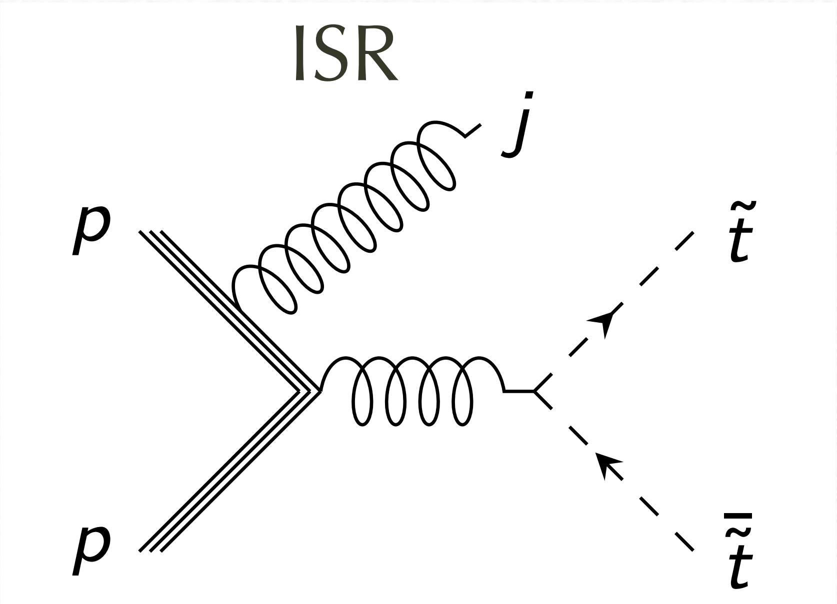
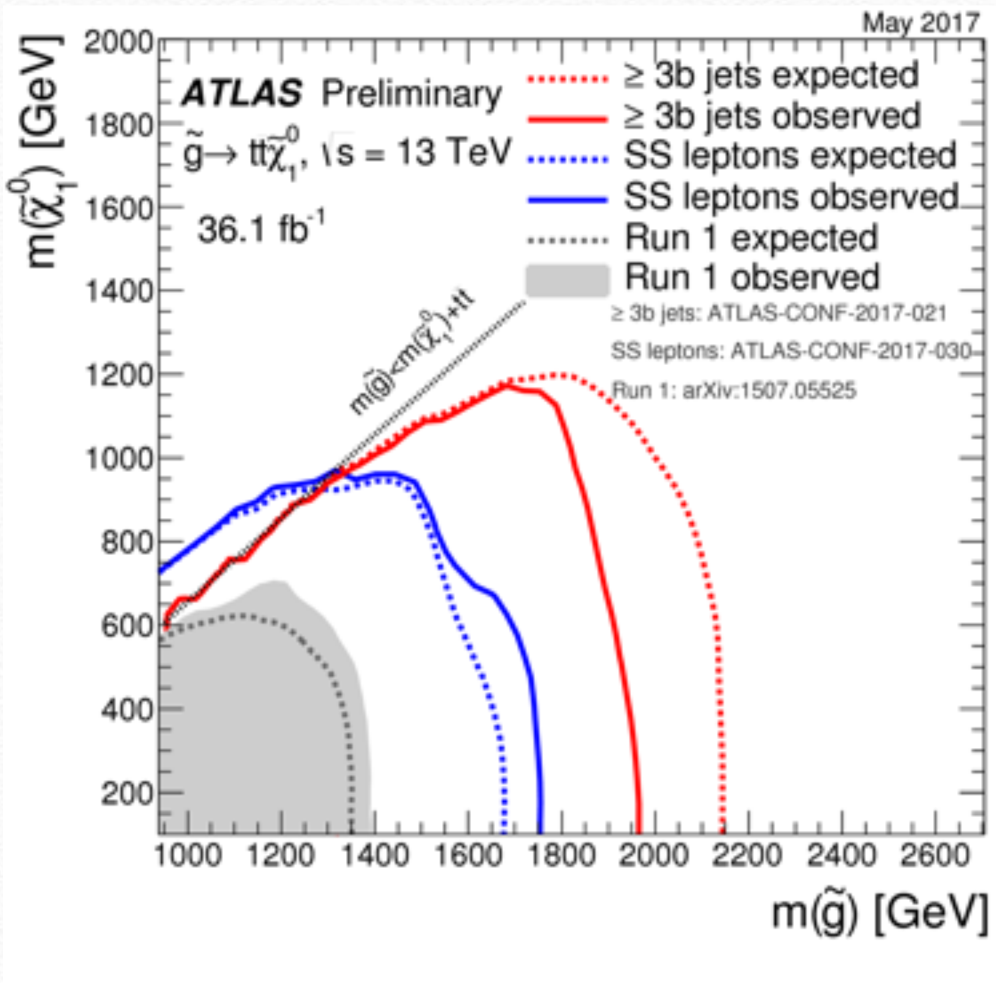
Dark matter from colored particle decay

- A class of model with Pair production of colored particle followed by the decay p p → QQ Q→ X + jets or lepton
- Q can be anything: **top partner T, gluino G, stop t …** followed by Q→X + visible objects with $E=m_Q-M_X$
- If E is small, trigger ISR (monojet)
- LHC explored significant parameter region already





Is Monojet signature viable at future colliders?

1. Experimental uncertainty at HL or HE- LHC (quick estimate)

   The reach significantly depend on background estimation

2. How distribution depends on Q? (spin 0 or 1/2 and color 3 or 8)
   Identify **theoretical precision** needed to **identify nature of Q**

3. MC uncertainty in NLO[MC@NLO] Top partner example:

   LO merging →TT(NLO) [This is where we are]

   [Today, we try current best MC we have]

   TT+j (NLO with jet PT cut) NLO[MG5_aMC@NLO: allows simulation of all kind of BSM particles]

   TT+njet MEPS@NLO [Sherpa, modifying ttbar generation]

baseline simplified models

Particle name		Color Rep.	Lorentz Rep.	Decay
Fermionic Top partner	(T_p)	**3**	Dirac fermion	$q + X$
Top squark	$(\tilde{t})$	**3**	Complex scalar	$t^* X \to bqq + X$
Gluino	$(\tilde{g})$	**8**	Majorana fermion	$qq + X$
Scalar Gluon	(σ)	**8**	Real Scalar	——

* Assume **QCD interaction for production.**

** Only **one colored particle** (no yukawa type processes in production)

*** decay by small Yukawa (I do not care, but you can think about fancy thing like displaced vertex, soft lepton..)

**** mass difference set to be 20GeV for a moment for simplicity, mass difference maybe fixed by DM density, but too much modeling

current status and extrapolation

[Summary]
HL-LHC may access Top partner up to 800GeV with 3000fb-1
HE-LHC(27TeV) improve signal and background

IM	E_T^{miss} [GeV]	predicted events	statistical error	total error
1	> 250	245900 ± 5800	0.2 %	2.3 %
2	> 300	138000 ± 3400	0.3 %	2.5 %
3	> 350	73000 ± 1900	0.4 %	2.6 %
4	> 400	39900 ± 1000	0.5 %	2.5 %
5	> 500	12720 ± 340	0.9 %	2.6 %
6	> 600	4680 ± 160	1.5 %	3.4 %
7	> 700	2017 ± 90	2.2 %	4.4 %
8	> 800	908 ± 55	3.3 %	6.1 %
9	> 900	464 ± 34	4.6 %	7.3 %
10	> 1000	238 ± 23	6.4 %	9.7 %

systematics dominate in low Emiss

statistics dominate and improve with high L

e **2**: The predicted number of SM background events and associated errors for the inclusive signal n (IM1-IM10) as given in [13]. The Statistical errors are estimated from the predicted number of s.

current status and HL-LHC

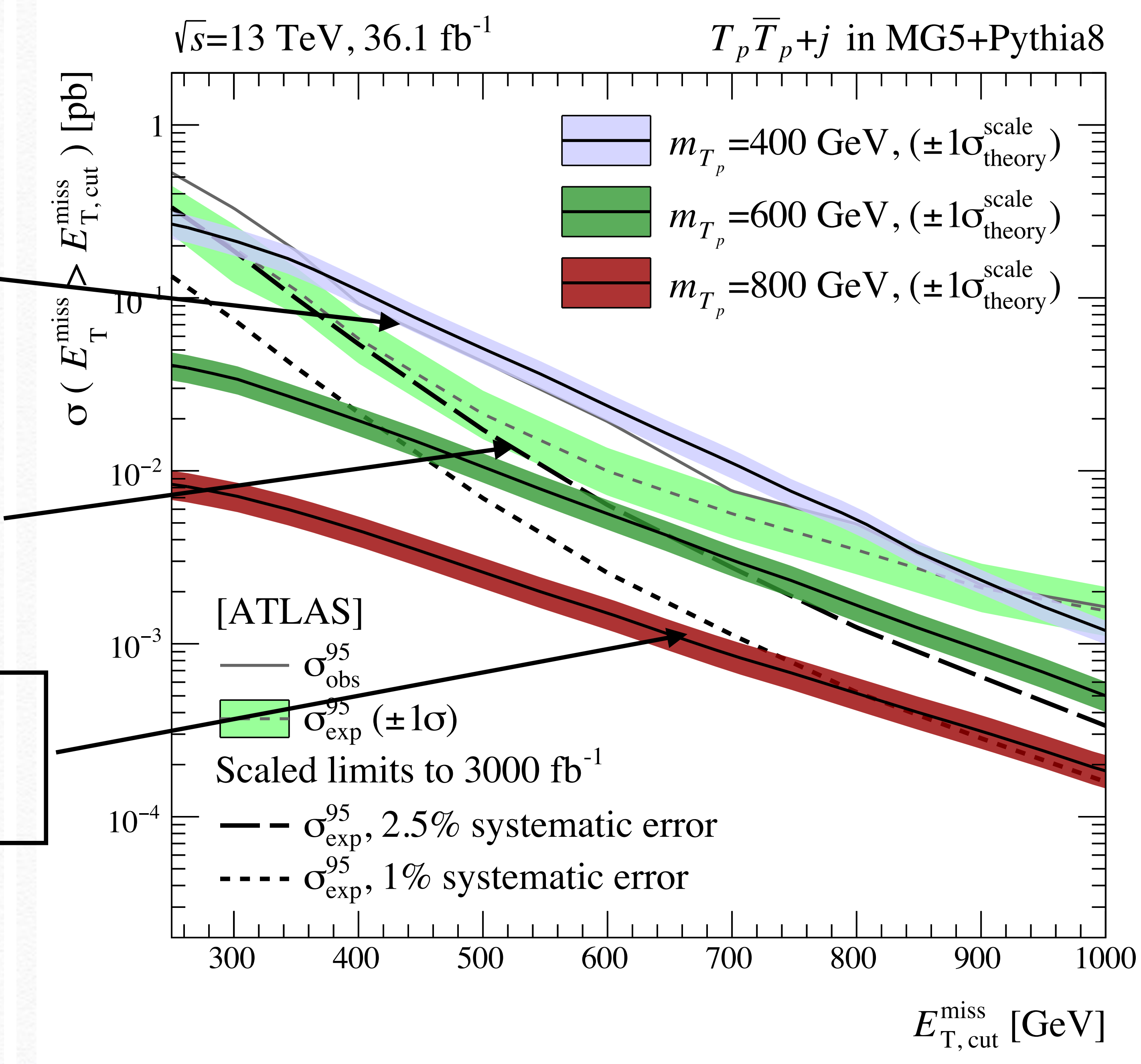
HL-LHC may access Top partner up to 800GeV with 3000fb-1

unlike current experimental study, we use QQ+ j (NLO) to estimate signal distribution

current upper limit mT~400GeV

2.5% systematics 3000fb^{-1} →m_T =600GeV

1% systematics → m_T =800GeV



High Energy LHC 27TeV

stop 600GeV, top parter 1100GeV, and Gluino 1800 GeV

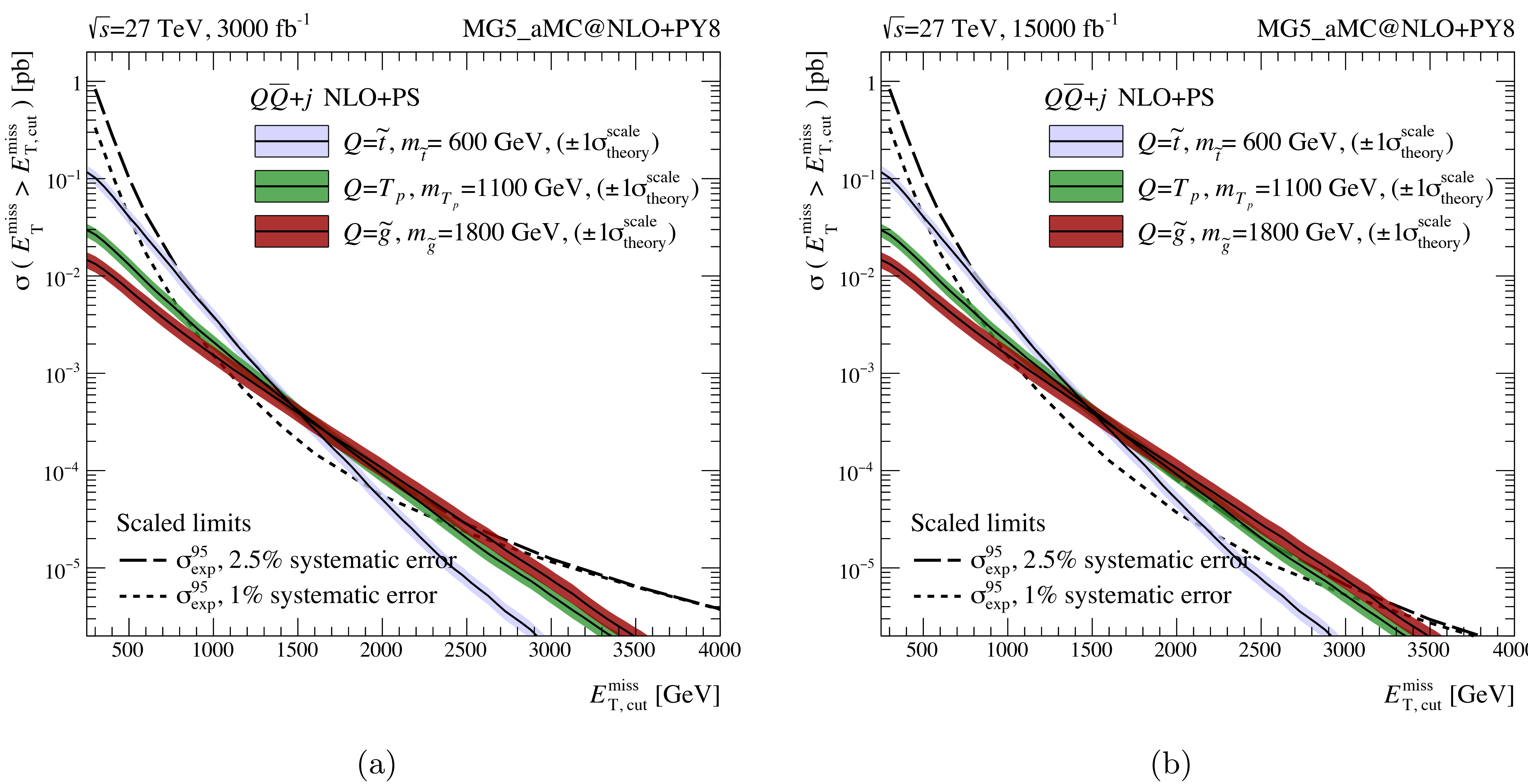
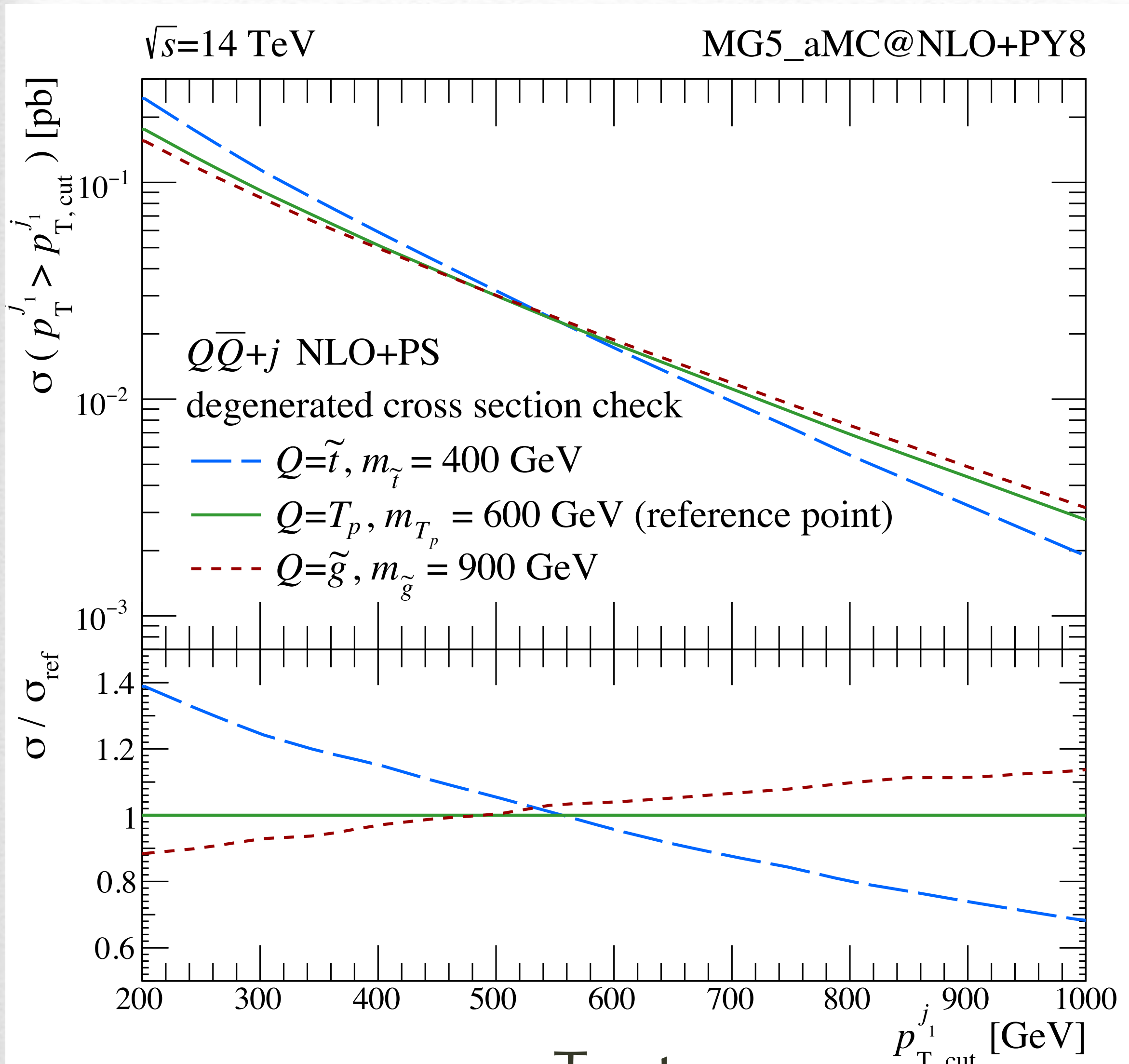


Figure 4: Same as Fig. 2 but scaled for $\sqrt{s} = 27$ TeV assuming (a) $\mathcal{L} = 3$ ab^{-1} and (b) 15 ab^{-1}.

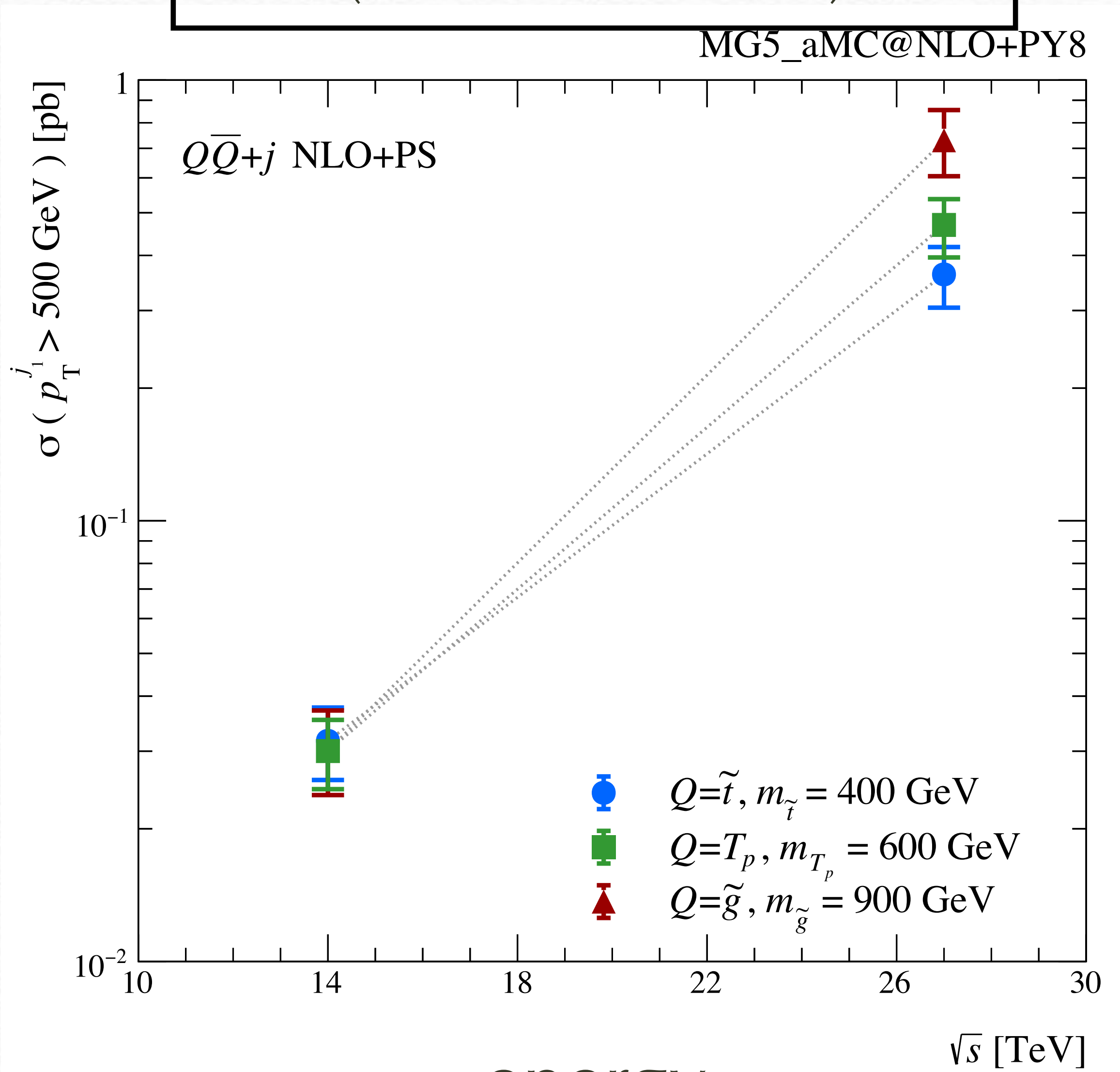
2. can we distinguish parent particle Q?

Changing pT cut(slope)

Changing beam energy (normalization)



pTcut



energy

ex: **increase pt cut** from 600 GeV to 800 GeV, σ (gluino)/ σ (stop)= 1.3

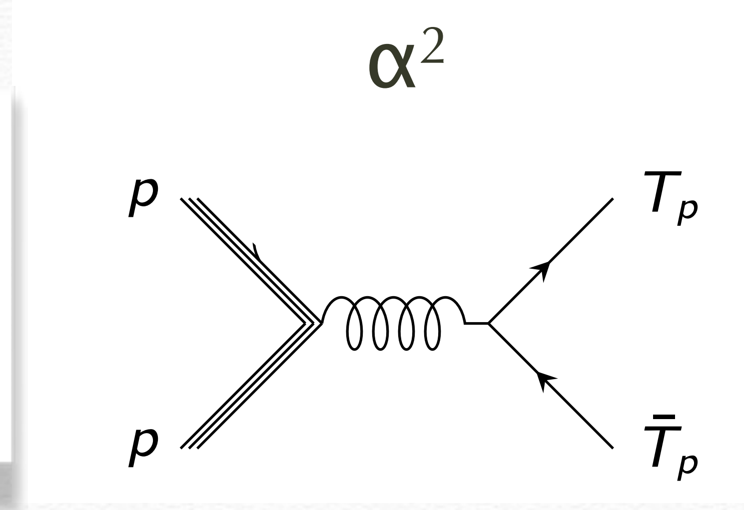
ex: **increase √s** =27TeV σ (gluino)/ σ (stop) =2.1 σ (T)/ σ (stop)= 1.35

3. NLO simulation for monojet signal

because our signal is a hard jet

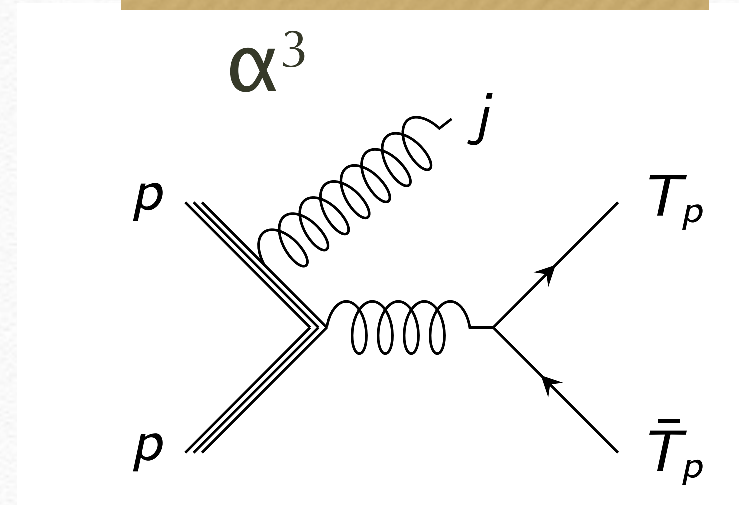
QQ NLO
Does not give useful prediction

BORN

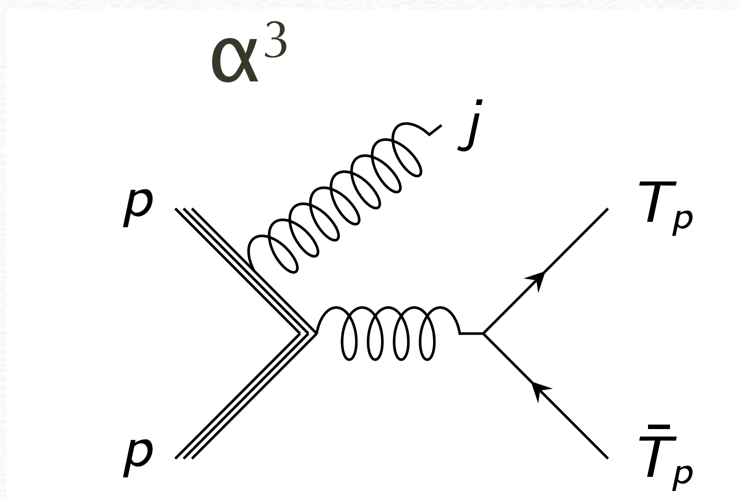


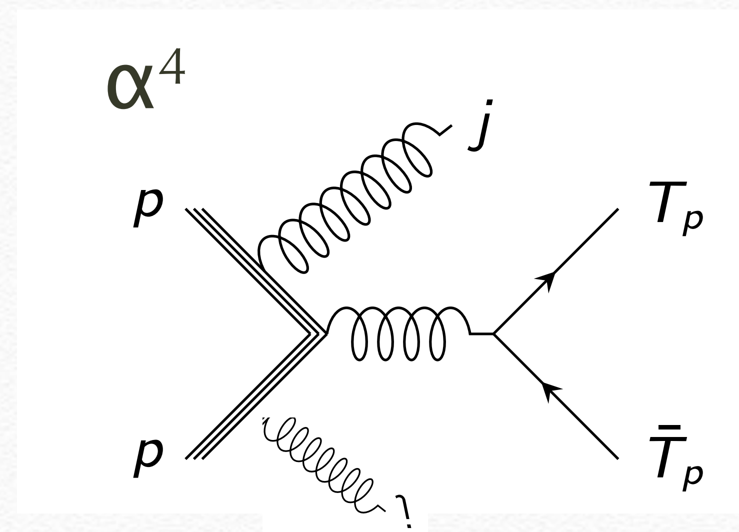
+

REAL emission

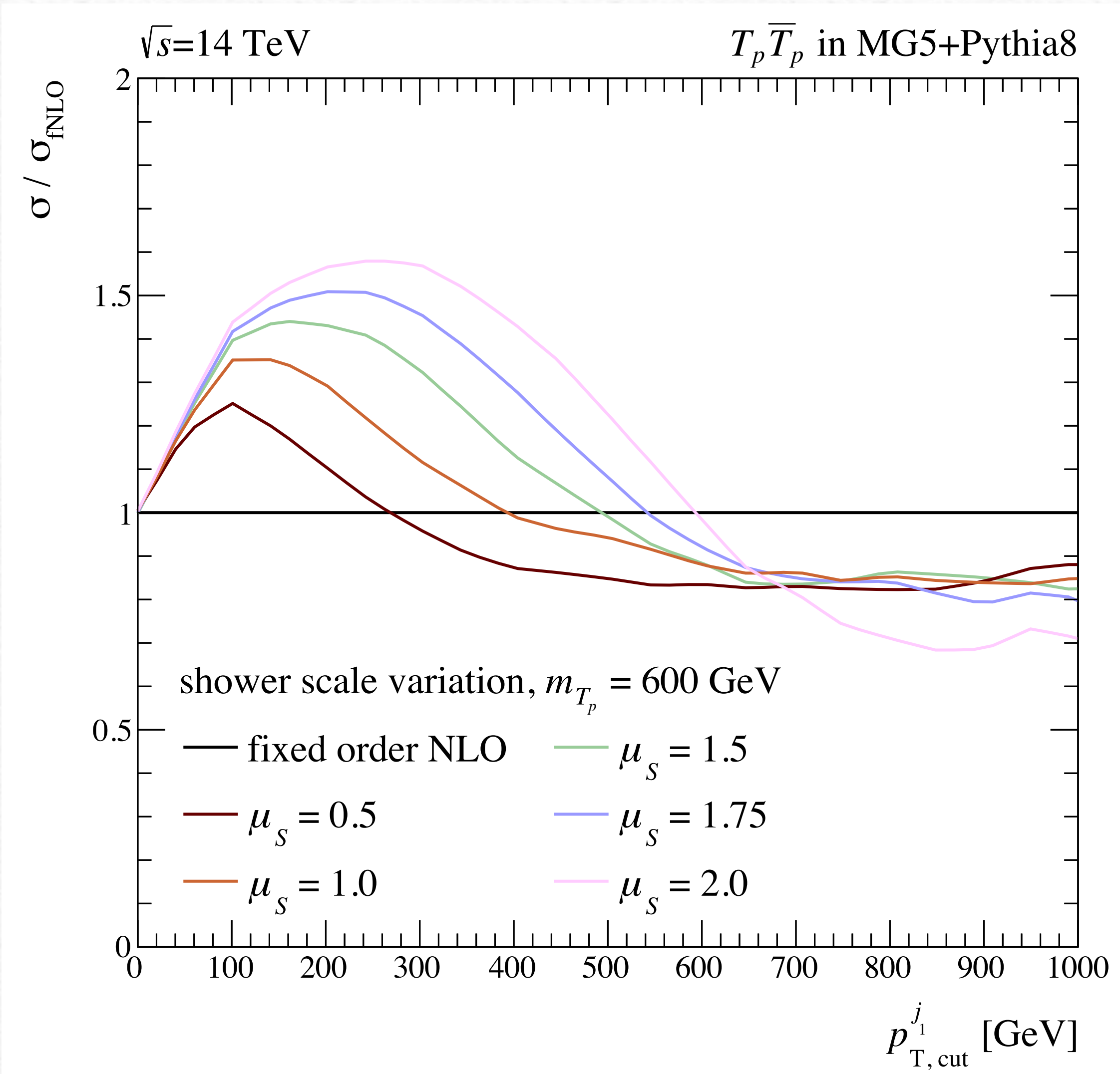


QQ+j NLO
…This is what we need

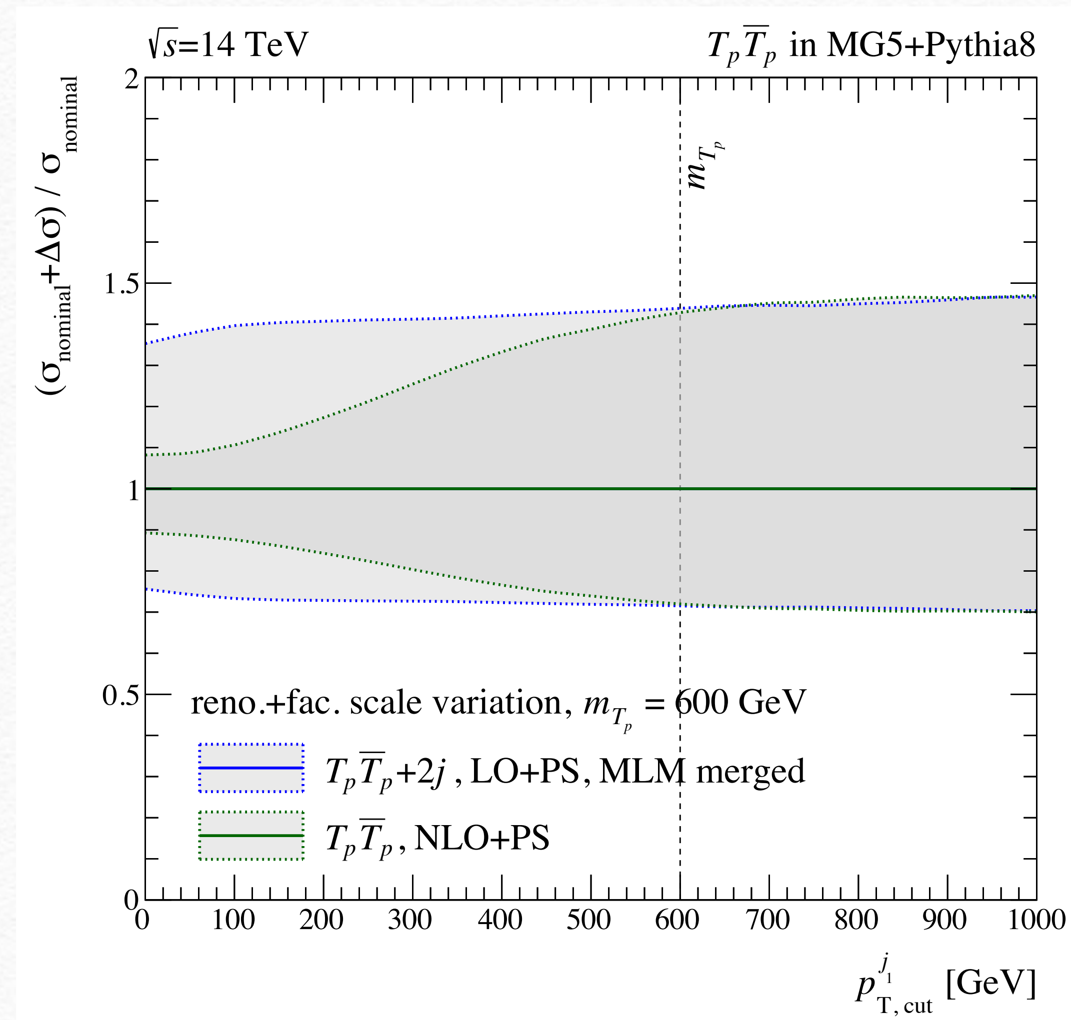




scale dependence of TT production (NLO)



changing shower starting scale
by factor of 2 → 1.5 increase



renormalization scale dependence
does not improve 30%~50%

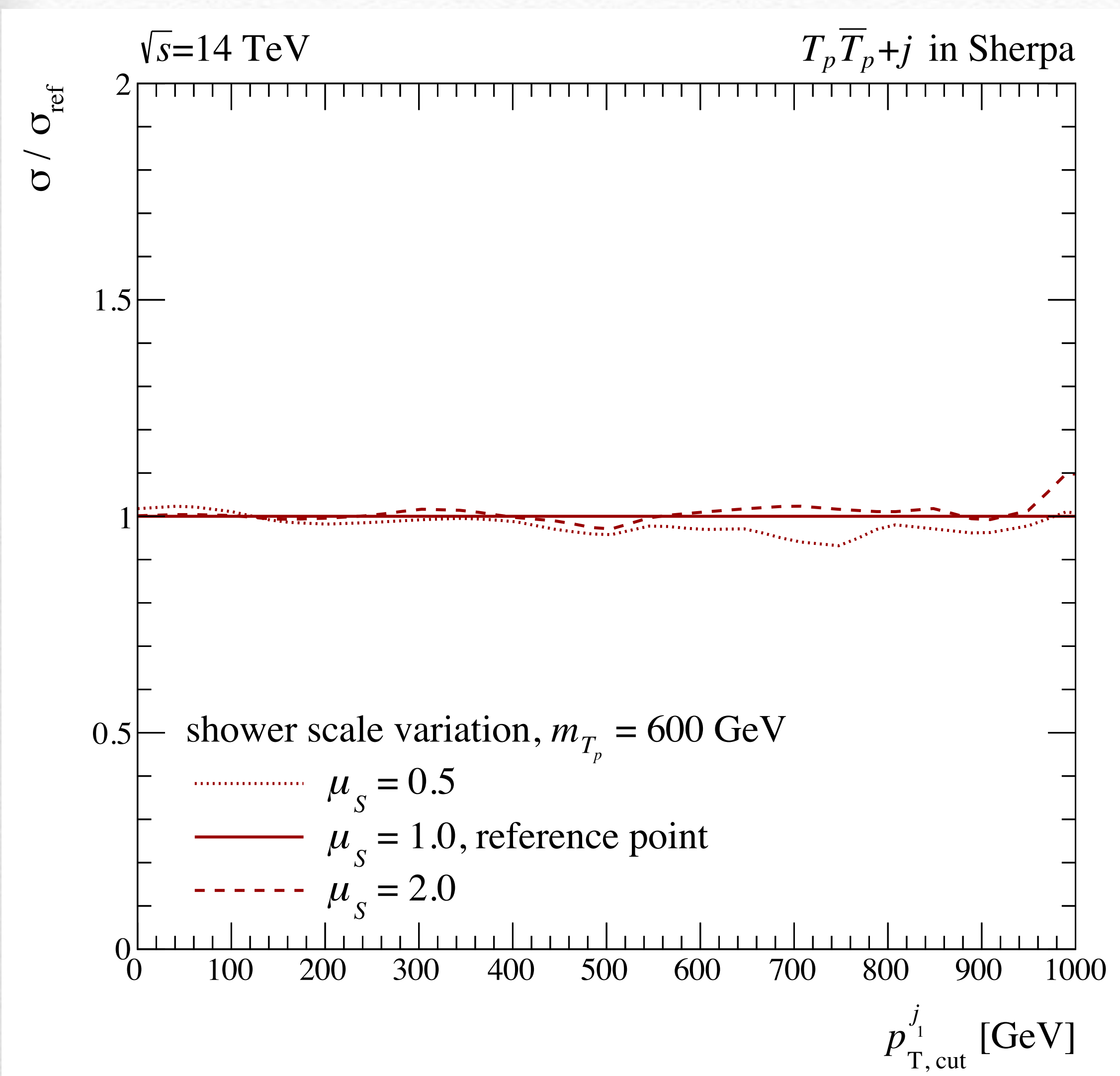
This is known feature for all MC@NLO
but especially large uncertainty for monojet process

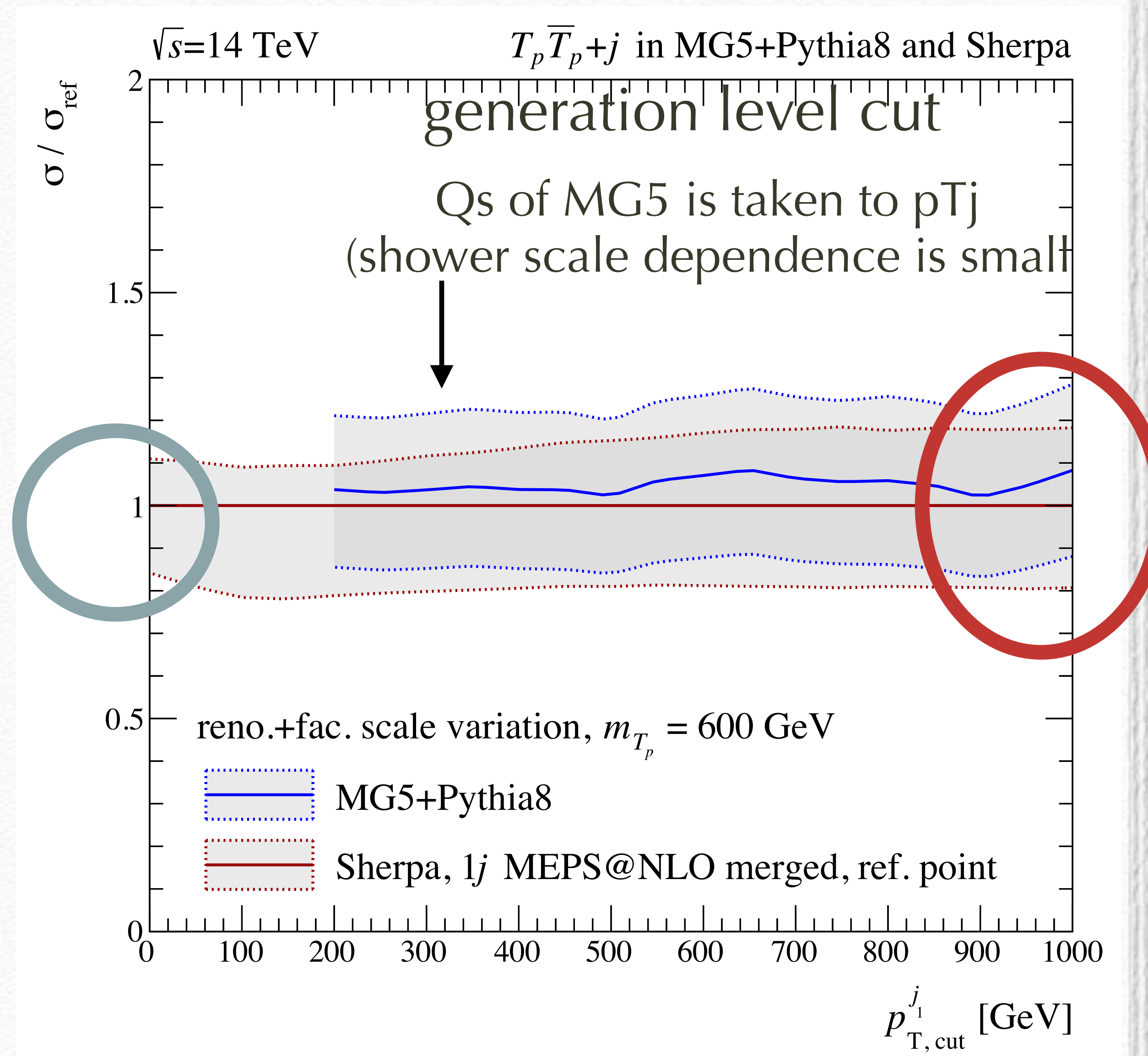
scale dependence of T T+ j NLO prediction

10% error for soft emission limit →20% error with hard emission

TpTp 2j(MEPS @NLO) Sherpa

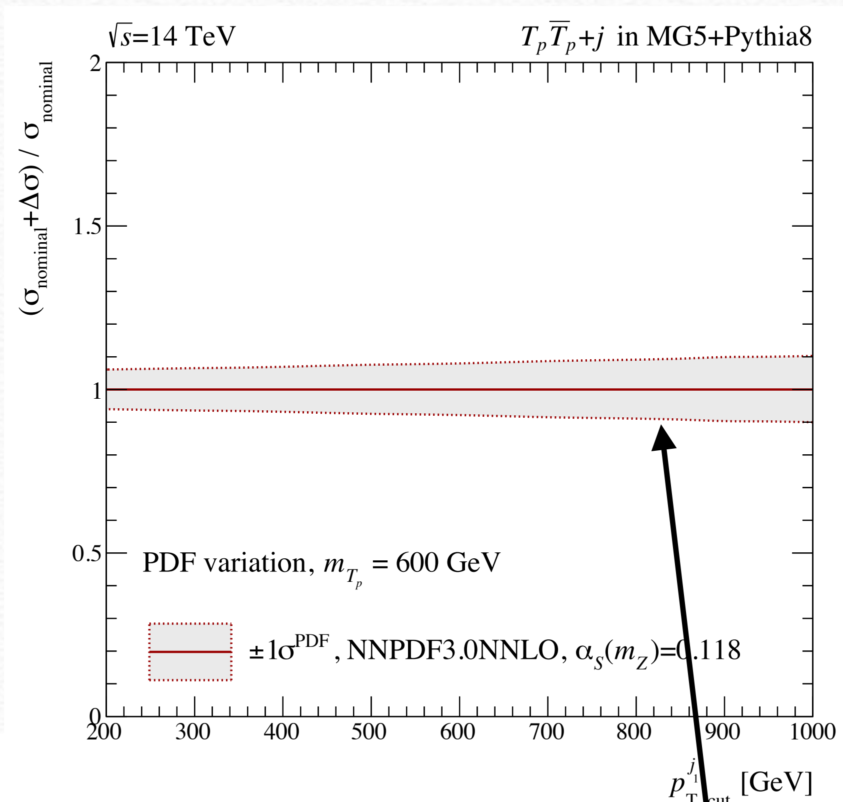
T T+ jets MEPS@NLO (Sherpa)
T T+ j (NLO) (MG5)

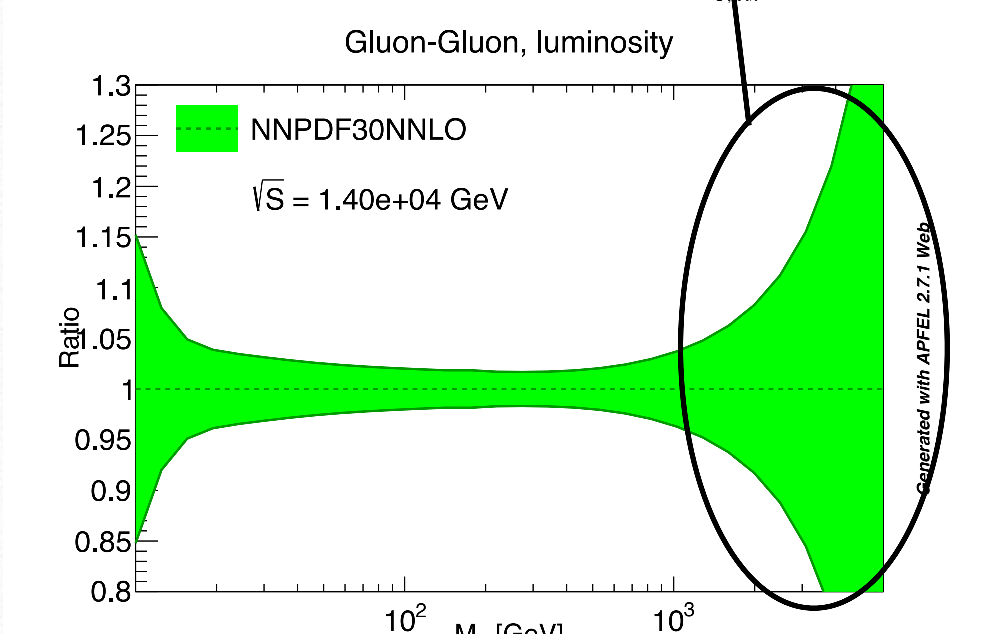


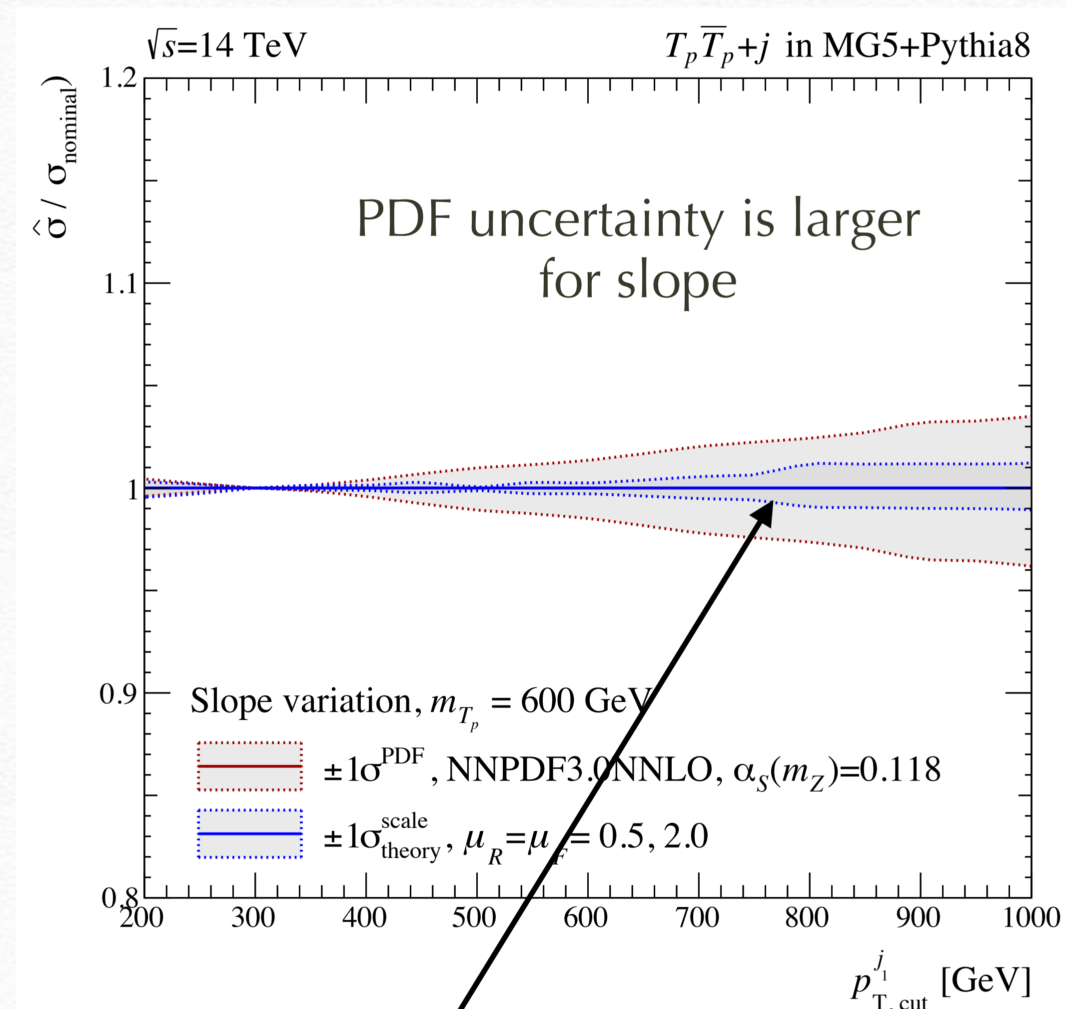


Error on the ratio of the cross section at different Etmiss cut

Large gluon PDF uncertainty → 3% slope uncertainty between 300GeV-1TeV







renormalization scale error cancel mostly
if we take common scale factor to the nominal ptcut

conclusion

- Monojet distribution contains some information on the parent particle. **spin independence of pT distribution, and mass dependence of cross section change with energy**

- **Discovery in future** Control of BG systematical errors is essential in High Luminosity Era

- In HE-LHC, you may identify nature of parent particle H from pT distribution of ISR jets.

- Question on normalizing (N)LO merged distribution by (N)NLO cross section