Precise top-quark mass from diphoton mass spectrum

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S. Kawabata & HY, arXiv:1607.00990 [EPJC77]

Introduction:

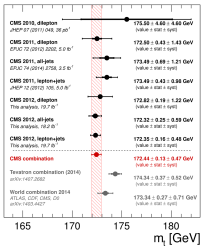
Top-quark mass has been measured at the Tevatron and LHC very precisely; $\delta m_t < 0.5$ GeV

However, its theoretical interpretation is not clear yet. (so-called the MC mass)

Many alternative methods have been proposed. For example, pole-mass can be determined from σ_{tt}, although its error is no better than ~ 1 GeV.

New methods to determine the well-defined top-quark mass are awaited for future experiments.

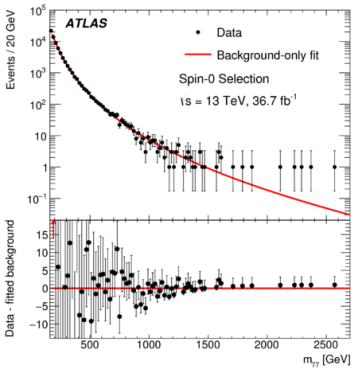
(Top-quark short-distance mass can be determined with $\delta m_t < 50$ MeV by the threshold scan method at future $e^+ e^-$ colliders.)



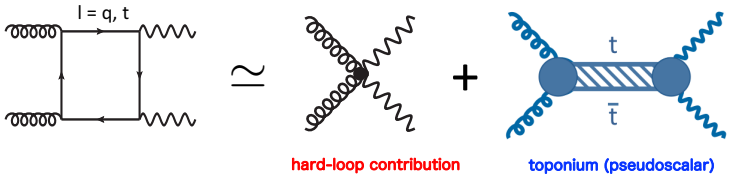
Diphoton mass spectrum

Photon is experimentally clean object, and its momentum can be measured with good precision

- Quark-antiquark annihilation
  $\mathcal{O}(\alpha^2)$ dominant source
- **Gluon fusion**
  $\mathcal{O}(\alpha^2\alpha_s^2)$ enhanced by gluon PDFs
- Fragmentation, fake photons are reducible by photon isolation cut



Gluon-fusion process @ $M_{\gamma\gamma} \sim 2m_t$



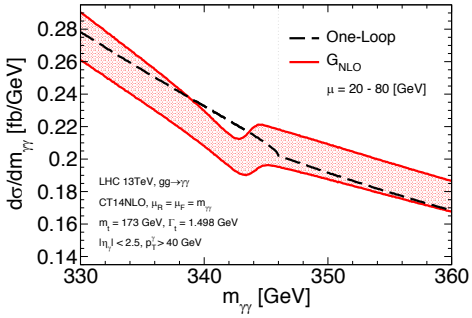
$$\mathcal{M}_t^{\rm NR} = \mathcal{A}_t(\theta) + \mathcal{B}_t \cdot G(\vec{0}, \mathcal{E}) + \mathcal{O}(v^2)$$

Matching coefficients: A_t (B_t) is known up to LO (NLO)

Green function in NRQCD:

$$G(\vec{0}; E) = i \int d^4x e^{iEt} \langle 0|T\{j_p(x) j_p(0)\}|0\rangle$$

Dip & bump due to the interference effects

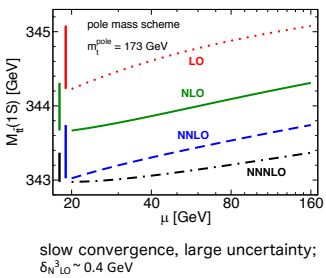


- **QCD uncertainty mostly on the normalization of the spectrum**
- **Top-quark mass can be determined from the dip&bump position**

Renormalon cancelation

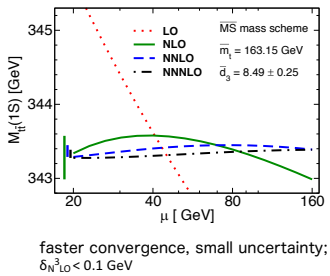
$$M_{1S} = 2m_t + \Delta E_{1S}$$

Pole-mass scheme



slow convergence, large uncertainty;
$\delta_{N^3LO} \sim 0.4$ GeV

$\overline{\rm MS}$-mass scheme

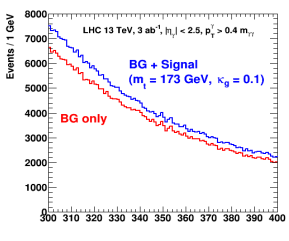


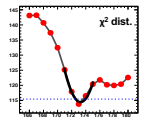
faster convergence, small uncertainty;
$\delta_{N^3LO} < 0.1$ GeV

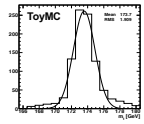
Simulation study:

fit the spectrum by "signal" template with smooth BG functions

LHC 13TeV, 3 ab^{-1}







stat. error

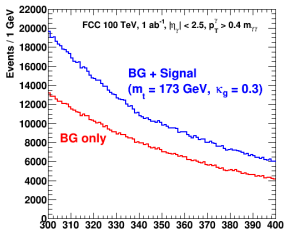
$\delta m_t \sim 2$ GeV to 3 GeV

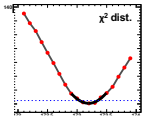
depending on the assumption of the signal-to-BG ratio [10% to 5%]

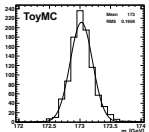
syst. error
(photon energy scale)

$\delta m_t \sim 0.3\% * m_t \sim 0.5$ GeV

100TeV collider







stat. error

$\delta m_t \sim 0.2$ GeV to 0.6 GeV (0.06 GeV to 0.2 GeV)

assuming the s/b ratio to 30% to 10%, and L = 1 ab^{-1} (10 ab^{-1}).

syst. error may dominate the total uncertainty.

Summary:

Top-quark mass can be measured from the diphoton mass spectrum at the future LHC or 100TeV colliders

Theoretically clean process: color-singlet resonance, no FSI, no FSR, extraction of the short-distance mass
Experimentally also clean and simple: inclusive two photon process, reconstruct their invariant mass only

Higher-order corrections are in progress, and simulation analysis for the detailed experimental effects are also required