Top quark physics results at LHC

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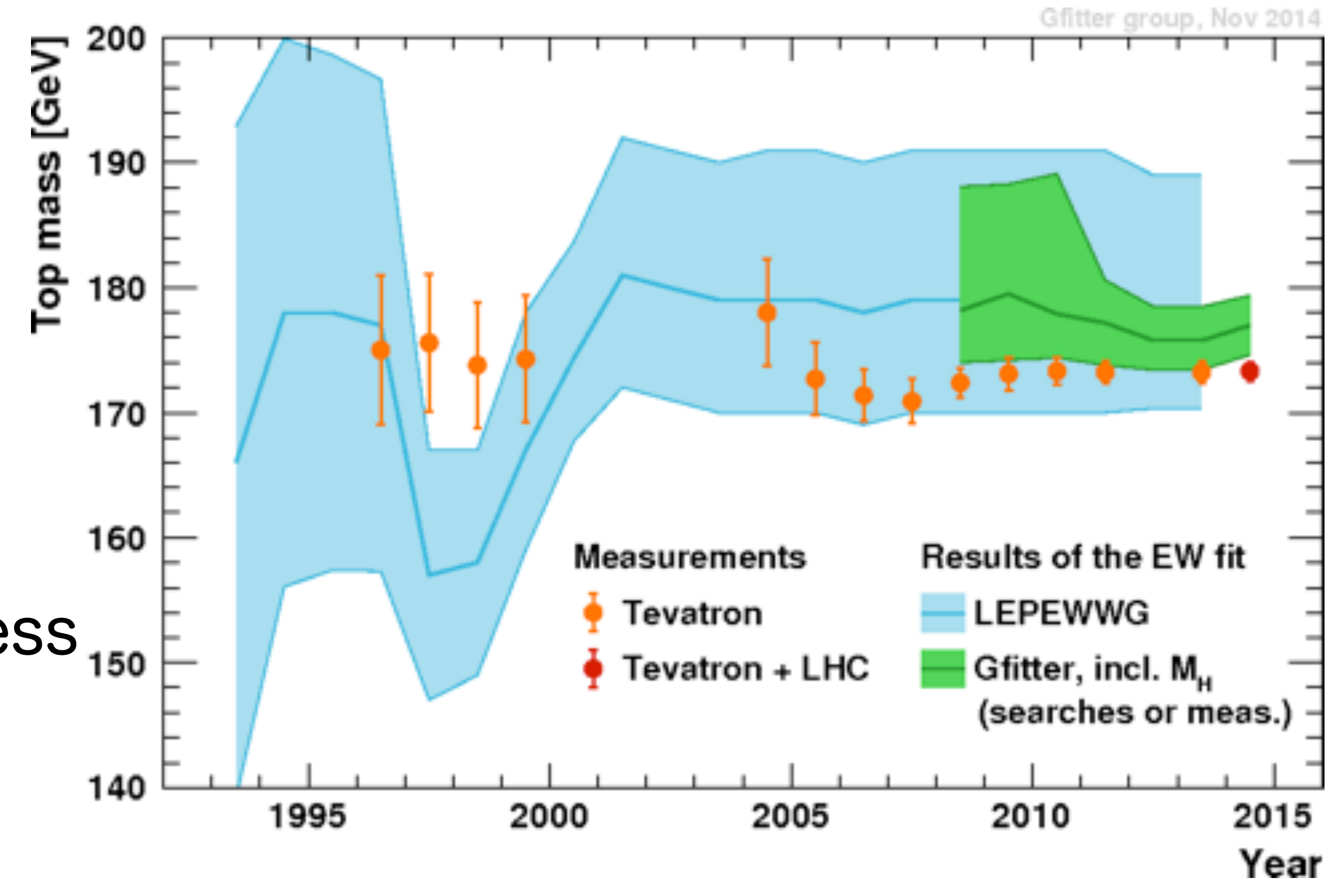
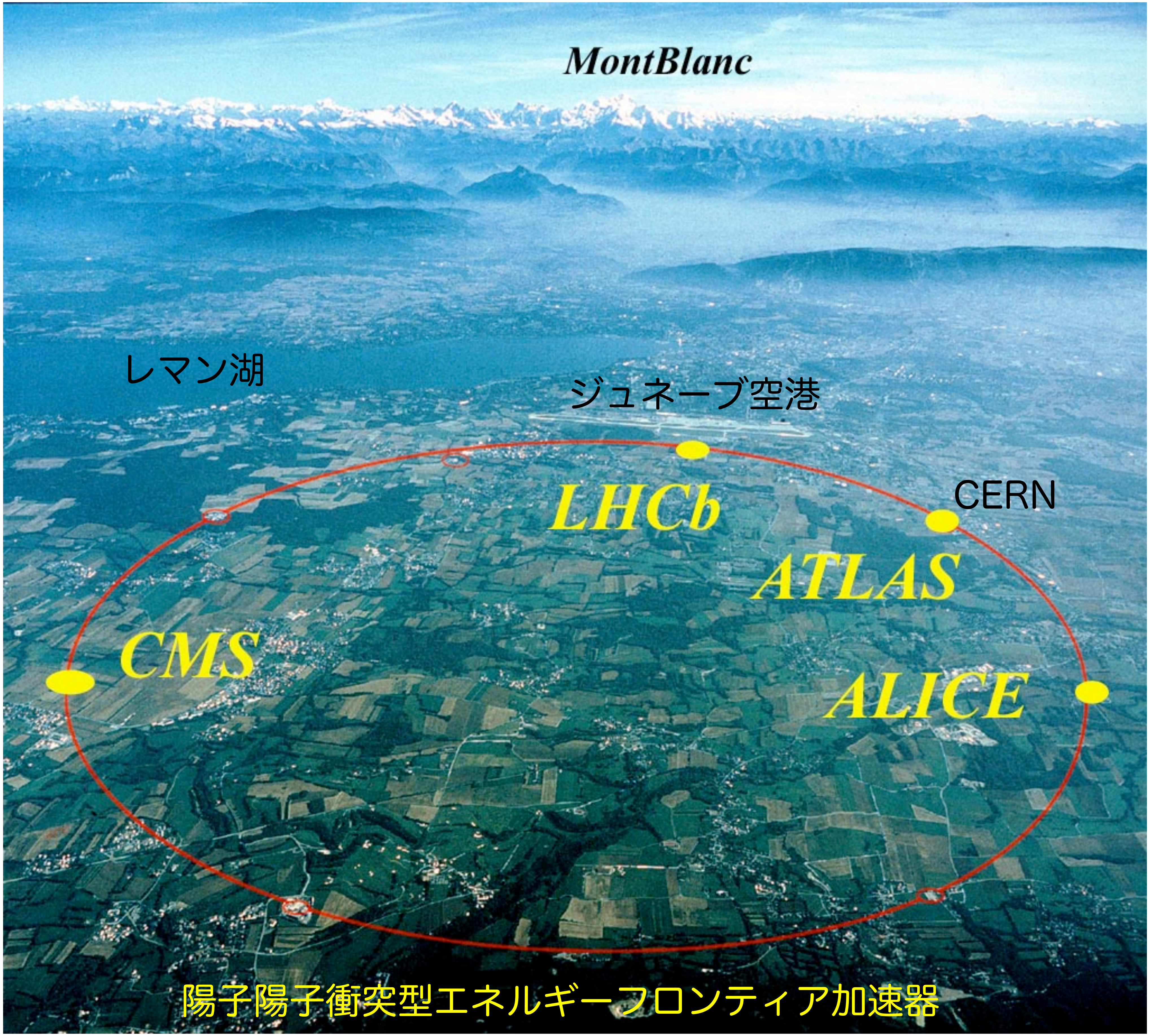
Introduction

- Discovered in 1995 at the Tevatron
- Heaviest particle in SM
  - Yt~1
  - Sensitive to new physics BSM
- Short lifetime ~ 10^{-25}s
  - Information on a bare quark
- top quark pair produced via QCD process
- Decays via EW process



- LHC is a top quark factory
  - In Run 2, a top quark pair every second
- Top quark physics is crucial to the LHC
  - Precise measurement of the QCD and EW
  - Probe couplings to Higgs, W, Z, γ
  - 3rd generation models within BSM (stop, …)
  - Significant background to searches and Higgs

Large Hadron Collider



LHC実験のこれまでの歩み

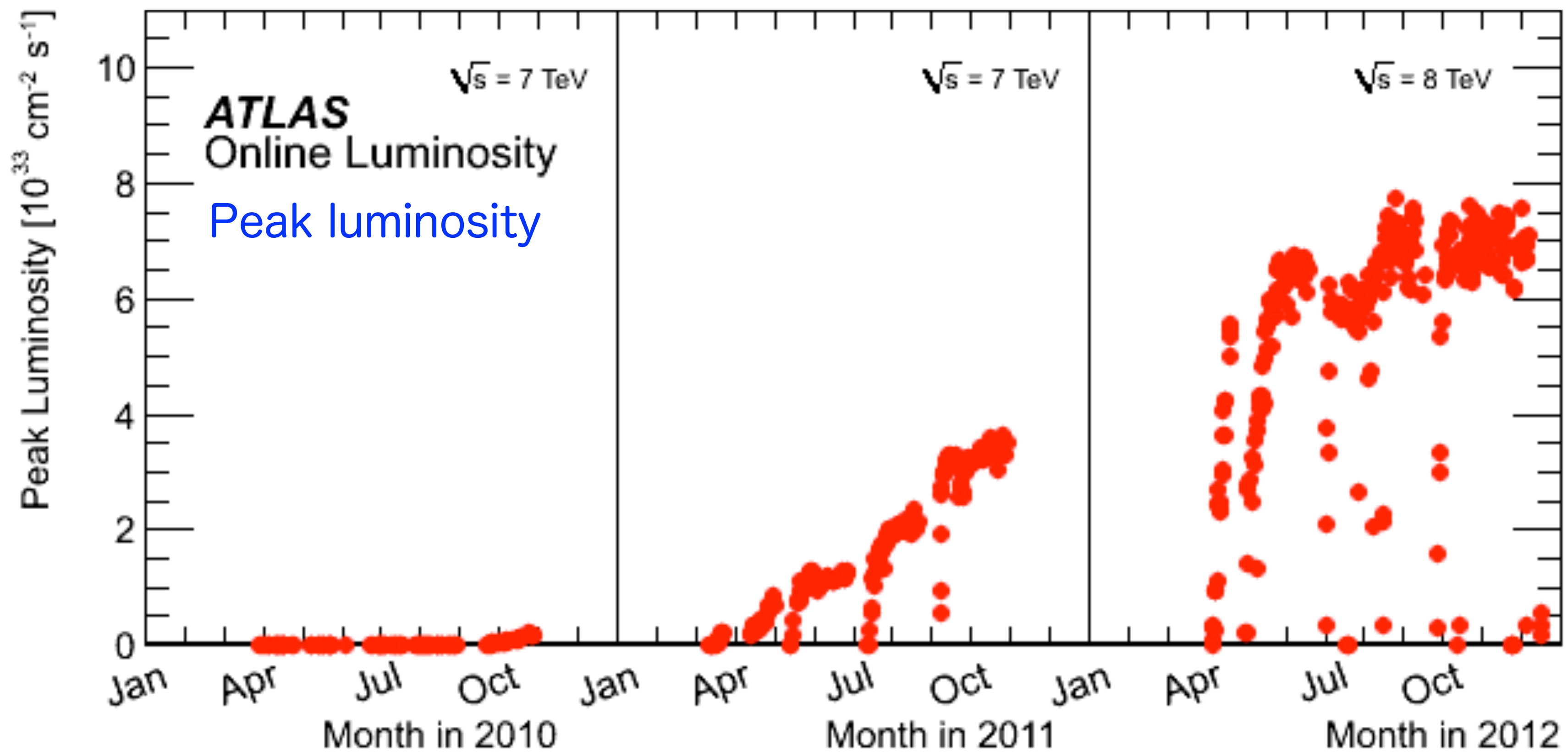
～2009	：建設	
2009	：加速器事故	
2010	：Physics run開始	
2011	：$\sqrt{s}$=7TeVの物理データ収集	} Run 1
2012	：$\sqrt{s}$=8TeVの物理データ収集	
2012/7/4	：ヒッグス粒子の発見	
2013-2015	：Shutdown	
2015	：$\sqrt{s}$=13TeVの物理データ収集	Run 2

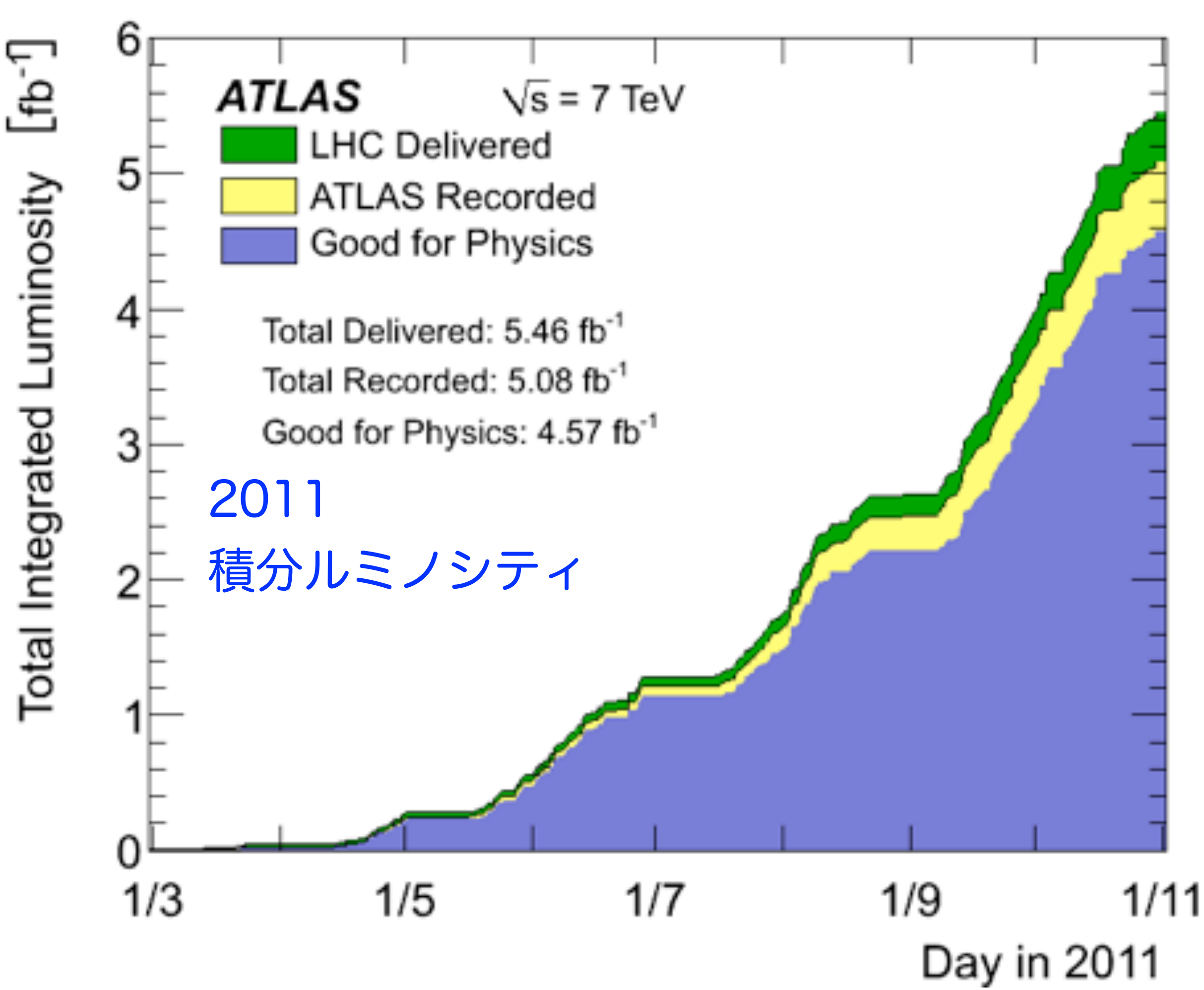
Publishされた論文数：477！
（2016年2月14日）

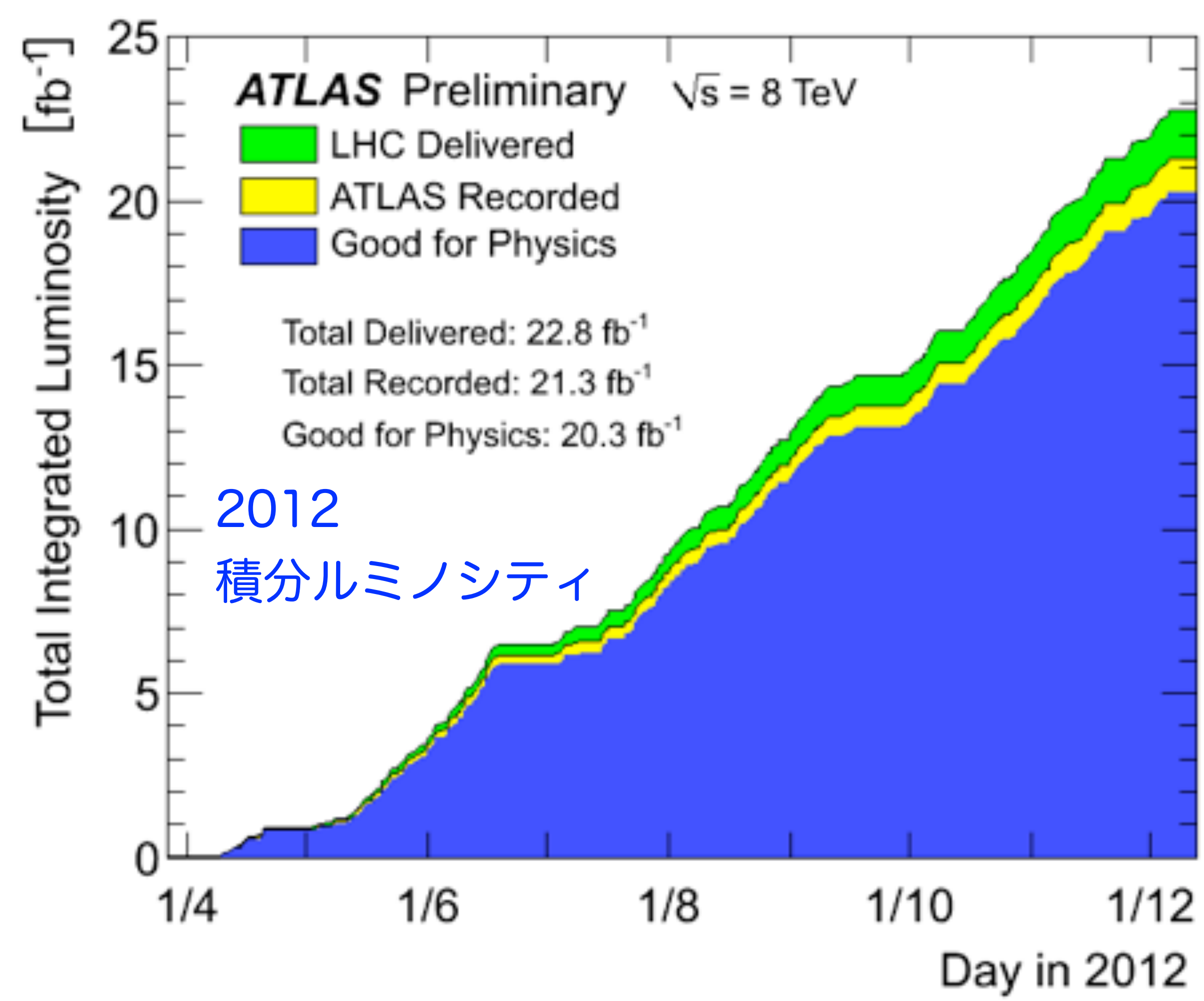
Run 1 : 2010 - 2012

$\sqrt{s}$=7~8TeV

50ns bunch spacing



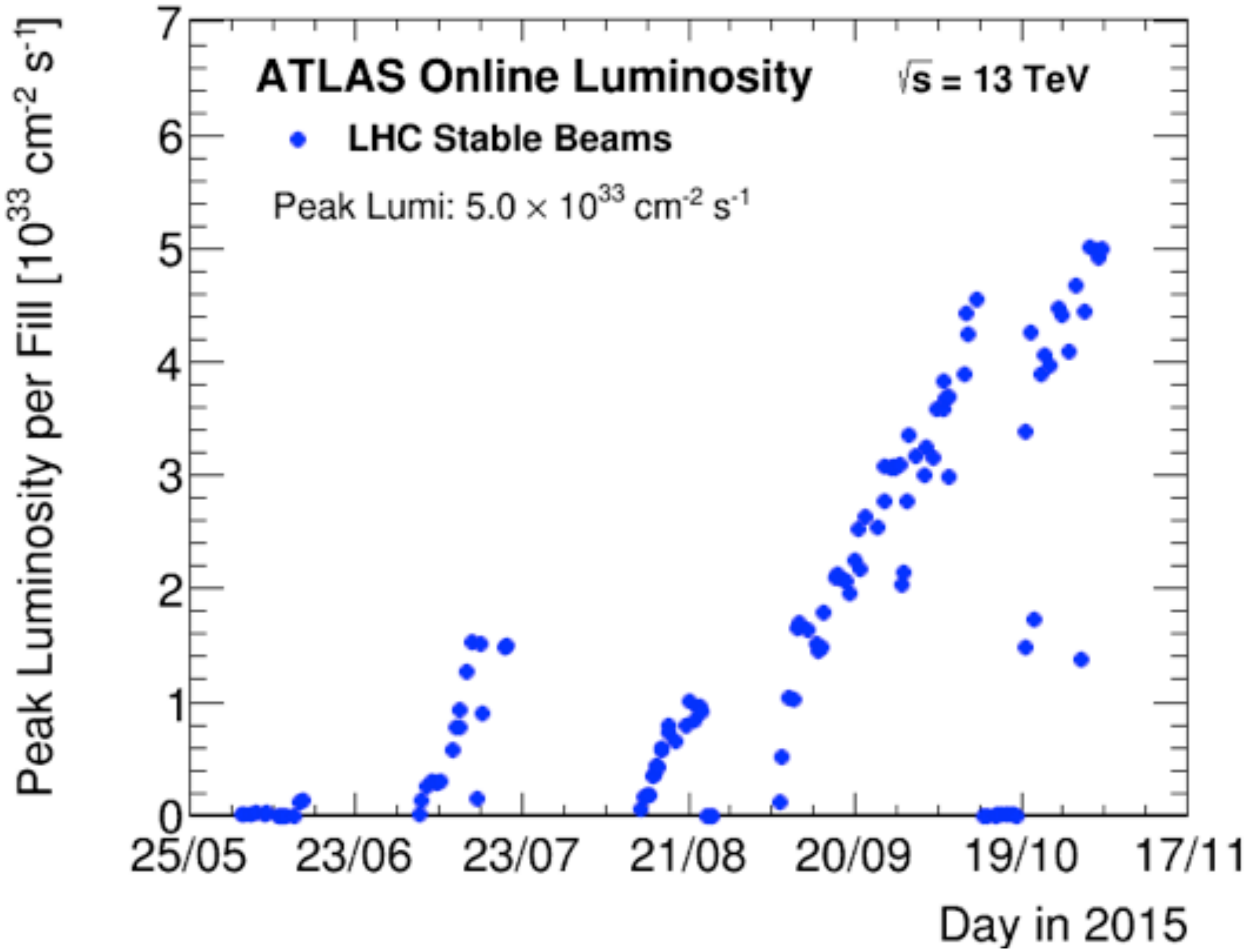




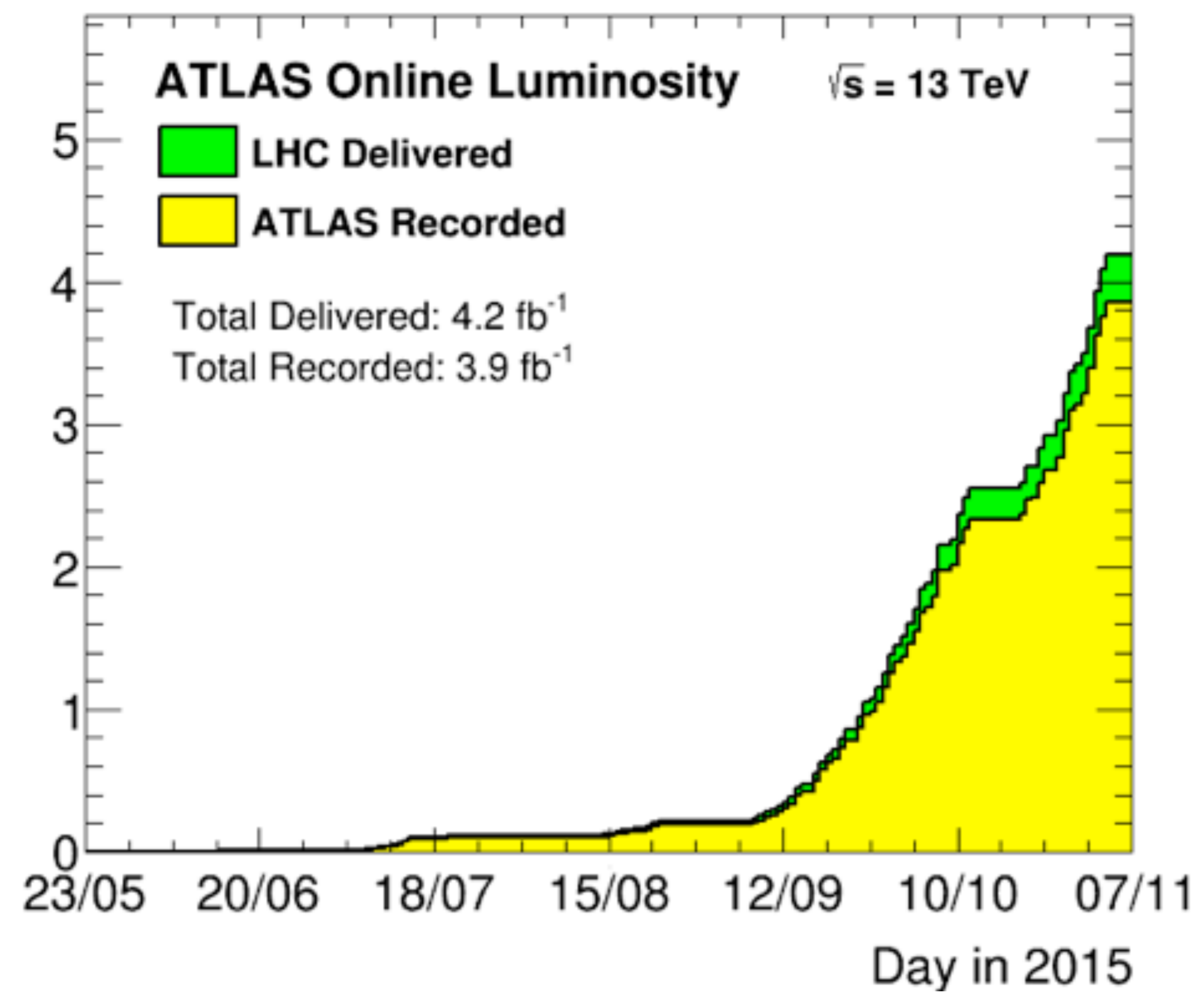
Run 2 ：2015 -

√s=13TeV
25ns bunch spacing

Peak luminosity



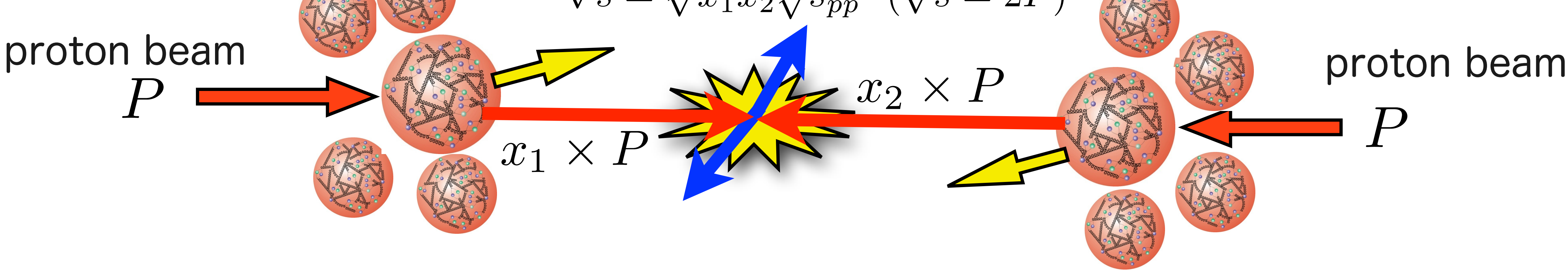
積分ルミノシティ

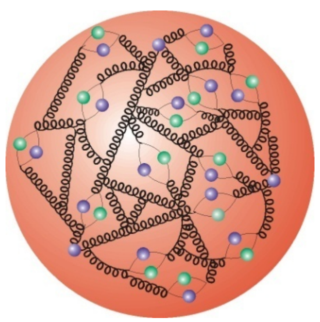


top quark pair production in p-p collision

effective energy

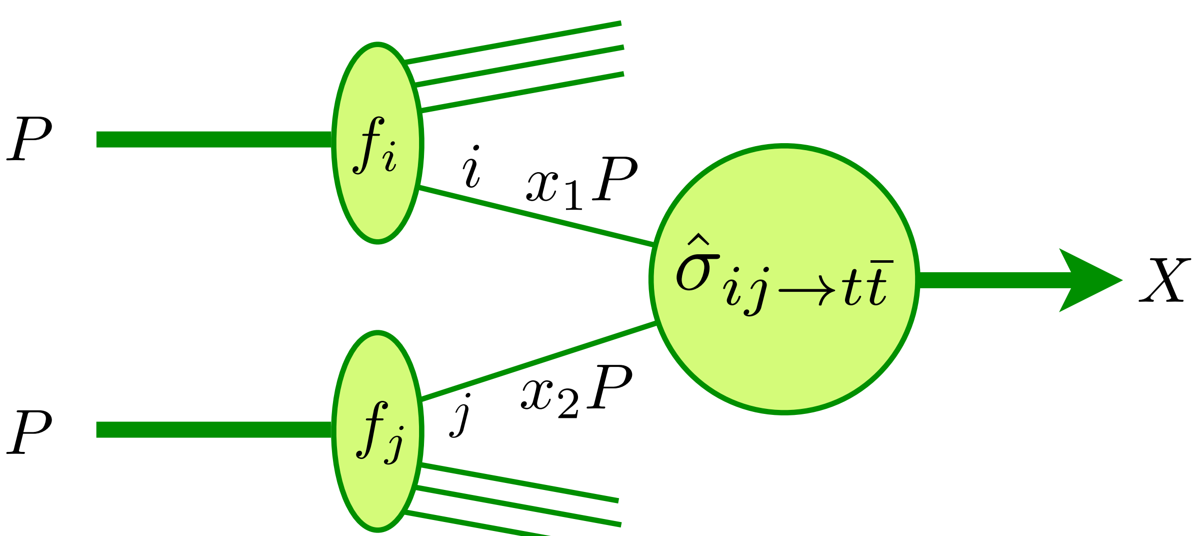
$$\sqrt{\hat{s}} = \sqrt{x_1 x_2}\sqrt{s_{pp}} \quad (\sqrt{s} = 2P)$$





A proton consists of not only u-u-d valence quarks but also huge amounts of sea quarks and gluons → parton
The cross section cannot be extracted without the knowledge of the parton density.

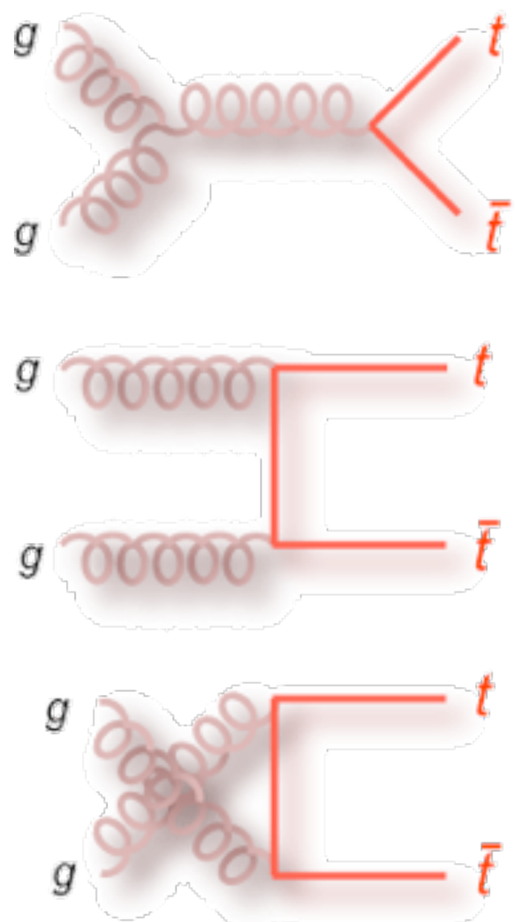
$$\sigma_{pp\to t\bar{t}} = \sum_{ij}\int \mathrm{d}x_1 \int \mathrm{d}x_2 \, f_i(x_1,\mu) f_j(x_2,\mu) \, \hat{\sigma}_{ij\to t\bar{t}}(s, \alpha_S(\hat{\mu}), Q/\mu)$$

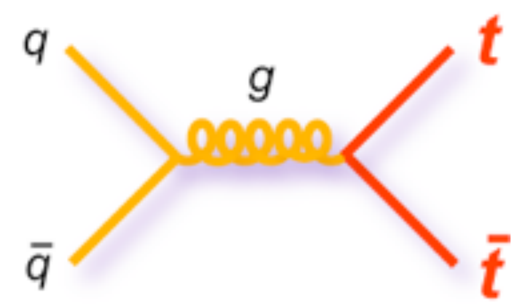


$\hat{\sigma}_{ij\to t\bar{t}}$ parton(i)-parton(j) cross-section → perturbative QCD

$f_i(x,\mu)$ Parton distribution function

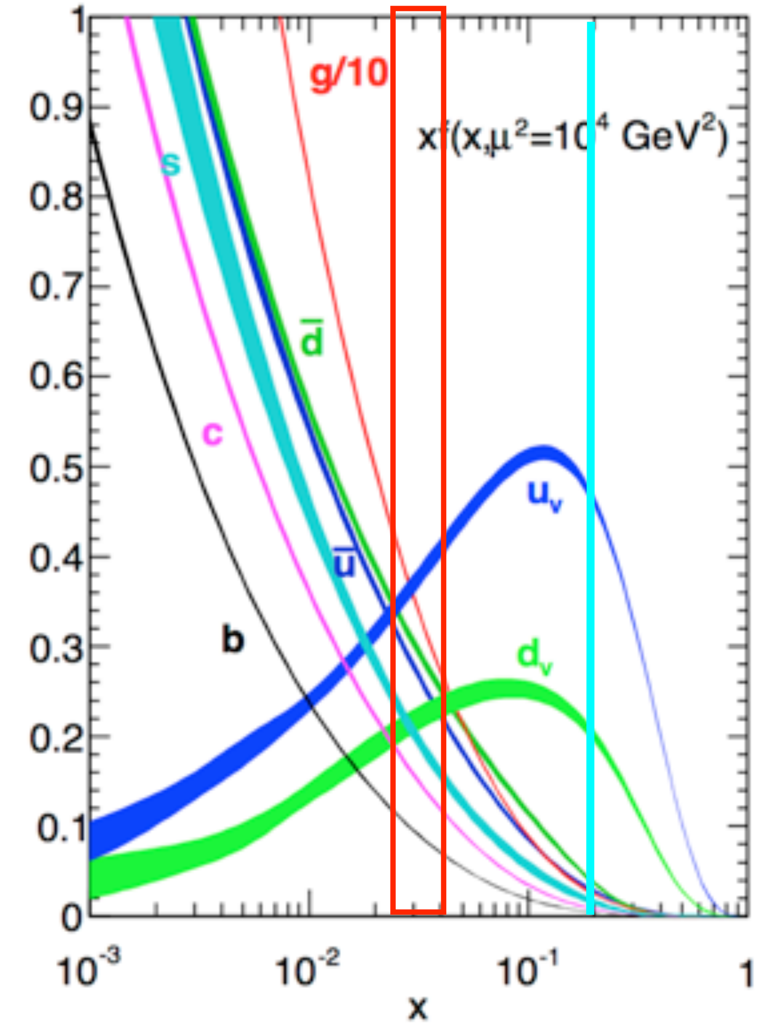
top quark pair production at LHC





$$\sqrt{\hat{s}} = \sqrt{x_1 x_2}\sqrt{s_{pp}} \qquad x \sim \frac{2m_t}{\sqrt{s}}$$

LHCはgluonのPDFに感度

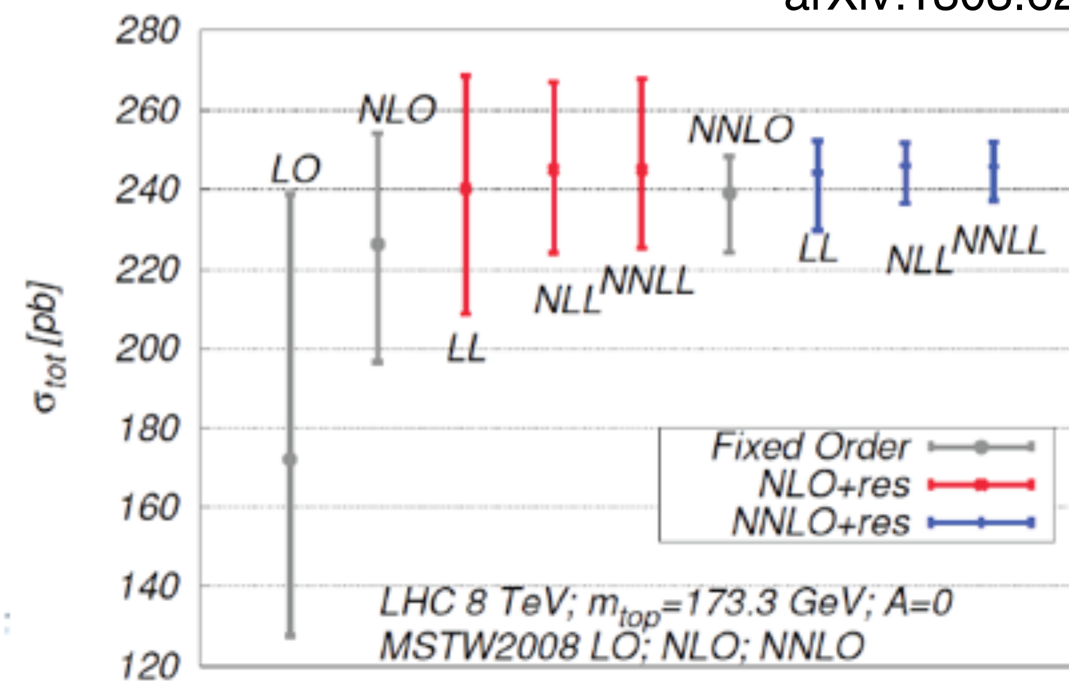


NNLO+NNLL (m_t=173.3, PDF=MSTW2008nnlo68cl)

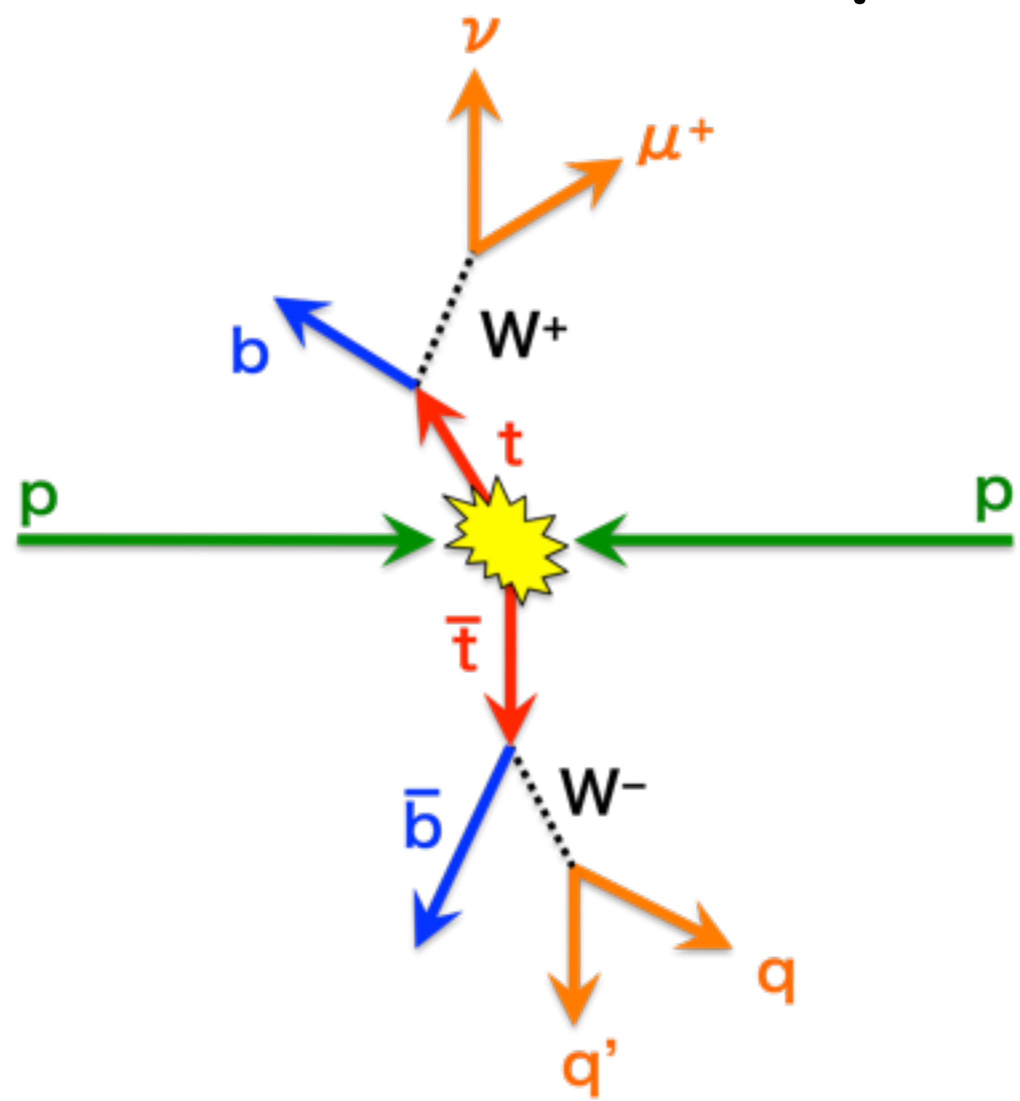
	x	qq : gg	σ_{tt} (pb)	±scale	±pdf
7TeV	0.049	15 : 85	172.0	~3%	2%3%
8TeV	0.043	12 : 88	245.8	~3%	~2.5%
14TeV	0.025	10 : 90	953.6	~3%	2%
Tevatoron 1.96 TeV	0.18	90 : 10	7.165	~2%	2%

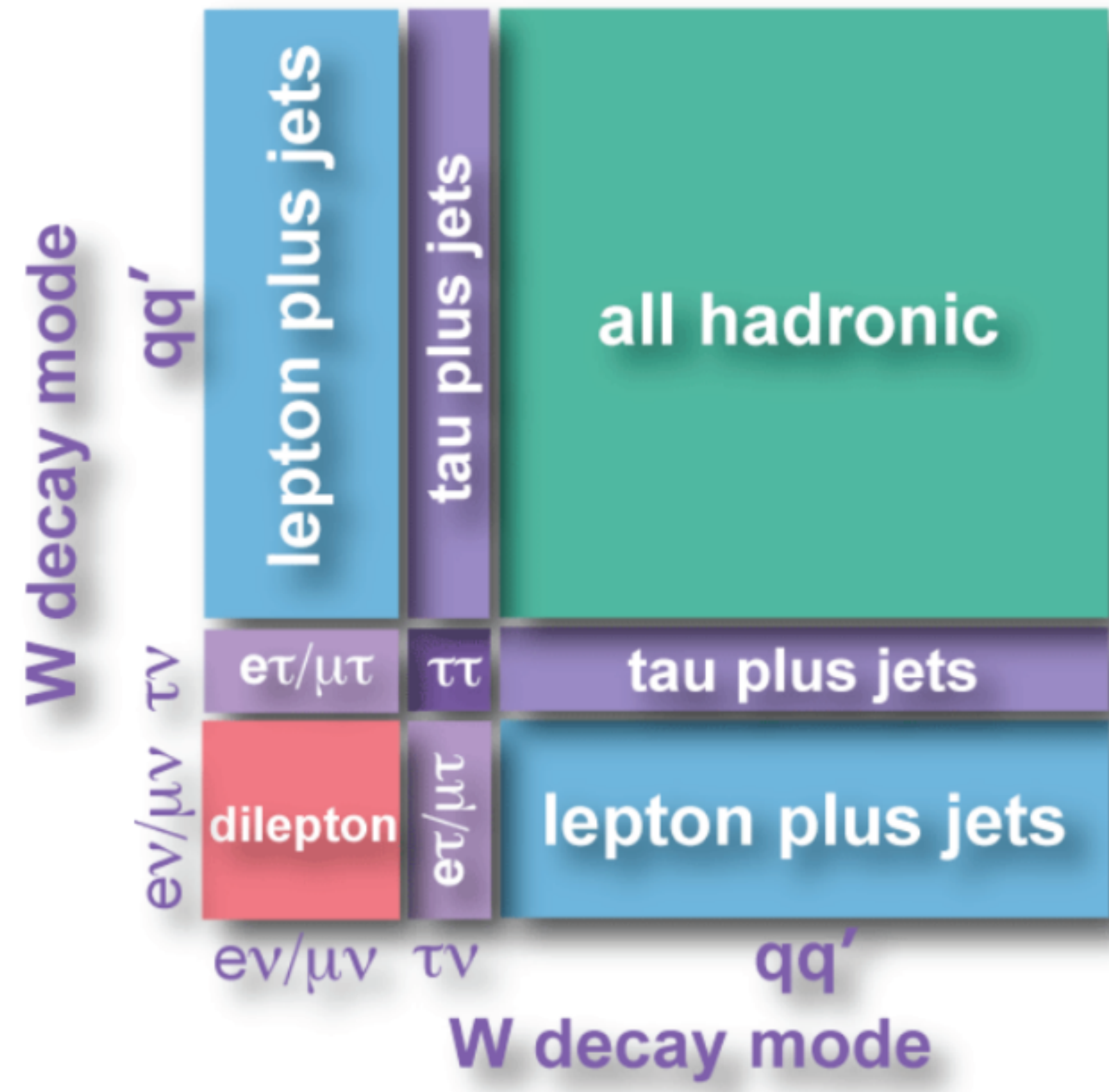
arXiv:1303.6254

Scale variation arXiv:1303.6254



Top quark decay





Br(t→Wb) ~ 100%

2つのWの崩壊によって、categorizeされる

- dilepton 5%
- lepton+jets 30%
- all jets 45%

- tau+X (charged Higgsに感度)
- rare decay (FCNC decayなど)

A Toroidal Lhc AppratuS

Calorimeters:
Tile & LAr

e/γ $\frac{\sigma(E)}{E} = \frac{10\%}{\sqrt{E}} + 0.7\%$

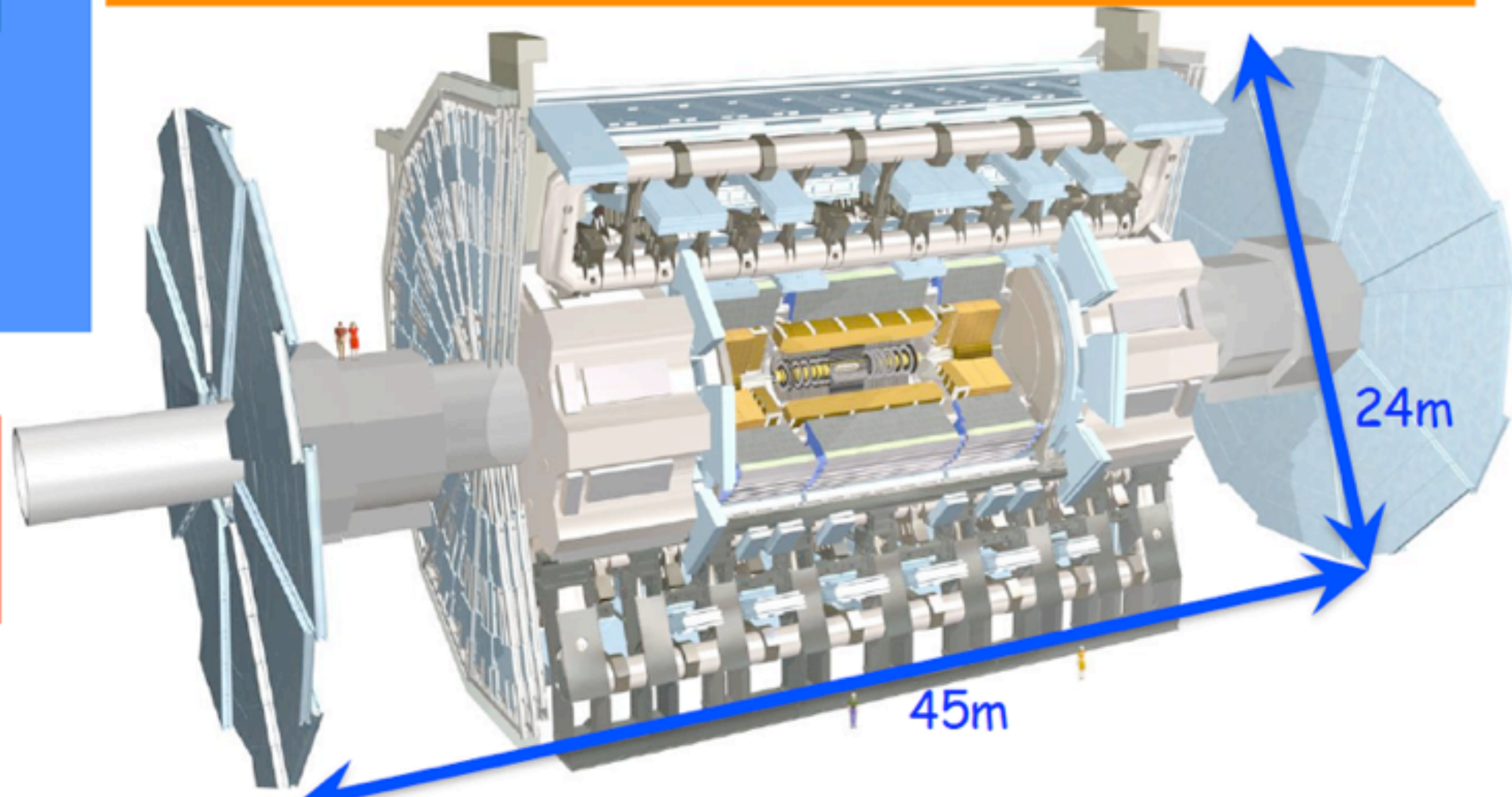
Hadron $\frac{\sigma(E)}{E} = \frac{50\%}{\sqrt{E}} + 3\%$ |η|<3, $\frac{\sigma(E)}{E} = \frac{100\%}{\sqrt{E}} + 10\%$ |η|>3

Muons:

Trigger TGC
RPC

Precision CSC
MDT

大きさ：24m × 45m
重量：7000 トン
読み出し：160M



Magnets:

Solenoid : 2テスラ

Toroidal :

$\int B \times d\ell$ = 2~6 (T×m)

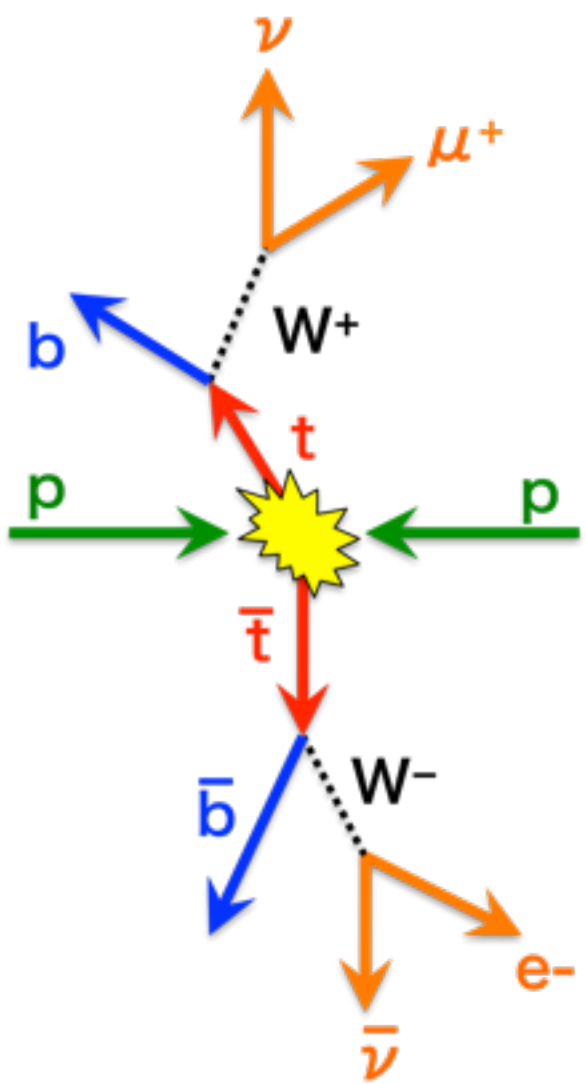
Inner Tracker: $\frac{\sigma}{P_T} = 0.05\% \times P_T + 1\%$ (2% @ 20GeV)

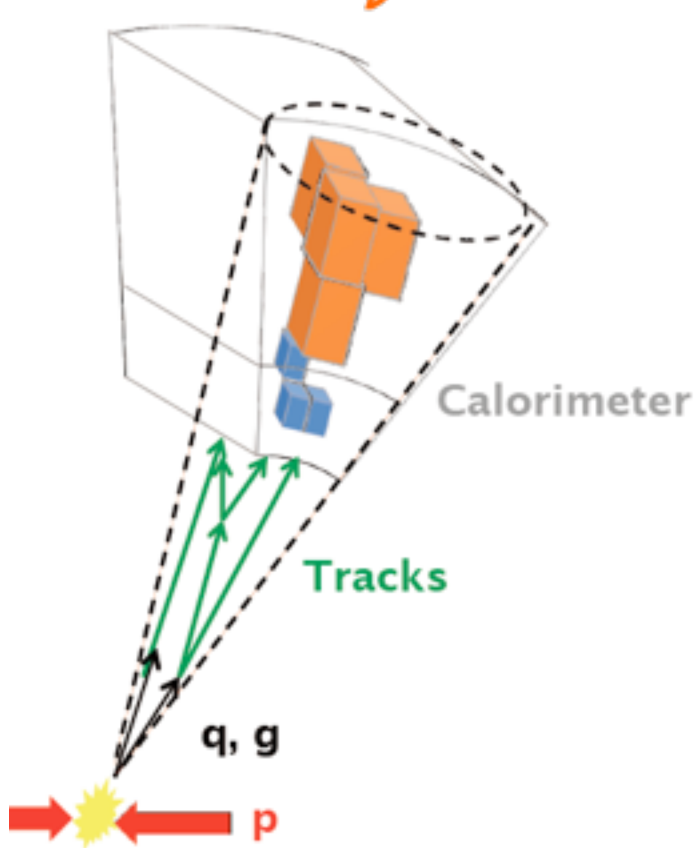
Pixel:
50×400μm^2
80M channels

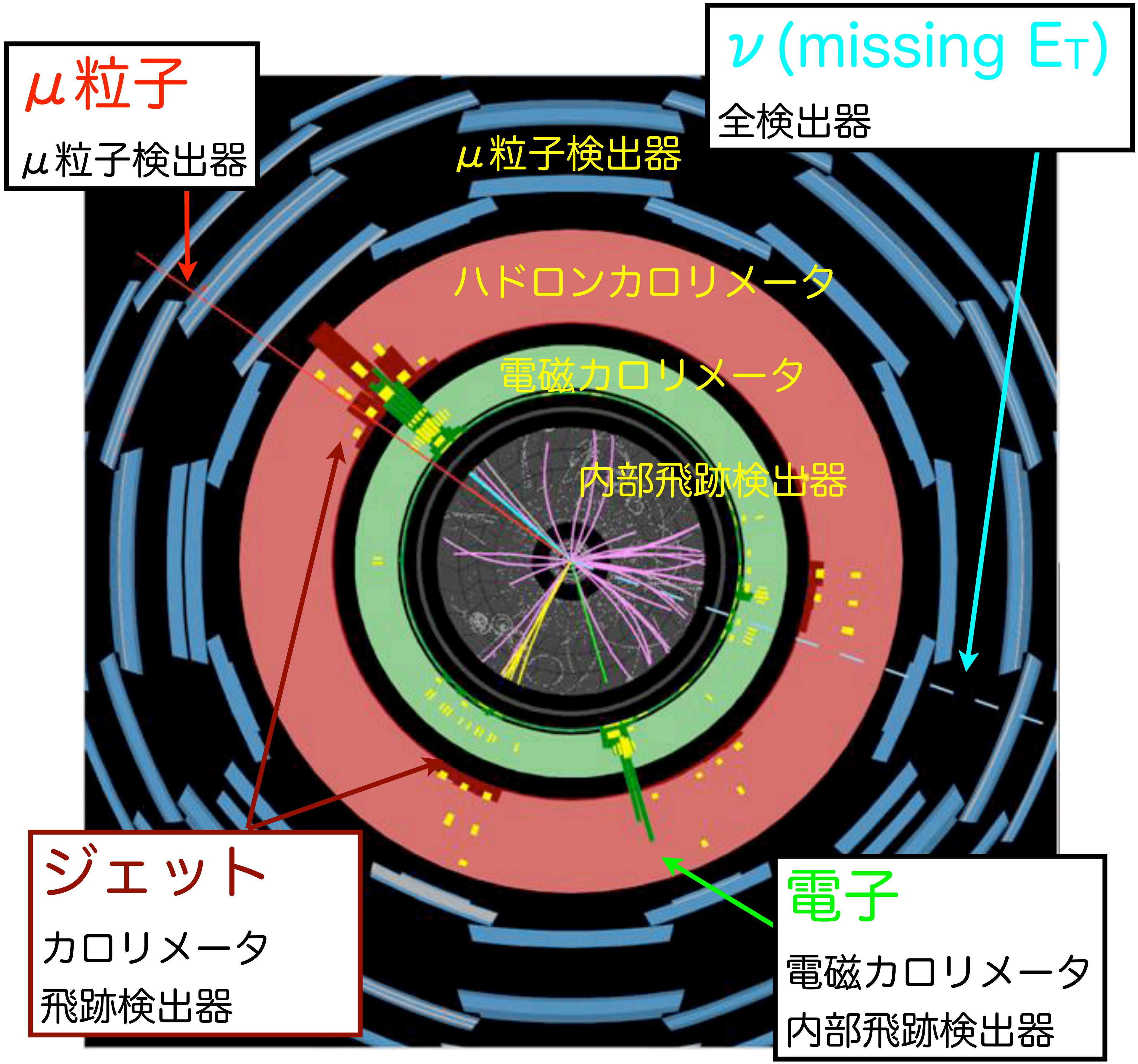
SCT:
80μm × 6cm
7M channels

TRT:
4mm φ straw tube
350k channels

Object ID


ν
μ+
W+
b
t
p
p
t̄
W−
b̄
e-
ν̄


Calorimeter
Tracks
q, g
p


μ粒子
μ粒子検出器
ν (missing ET)
全検出器
μ粒子検出器
ハドロンカロリメータ
電磁カロリメータ
内部飛跡検出器
ジェット
カロリメータ
飛跡検出器
電子
電磁カロリメータ
内部飛跡検出器

b-jet id & τ-id

b-jet id

jet内のmultiplicityが大

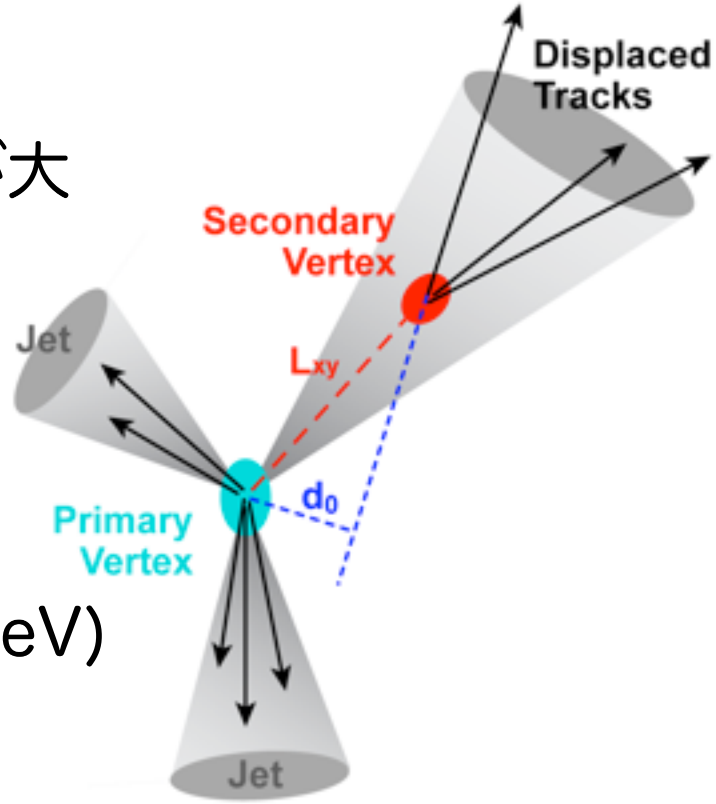
L_{xy}が大

jet内のd_0が大

$c\tau$ ～500μm

$\beta\gamma$～10 (@P~50GeV)

→ 5 mm位走る



Run 2からInsertable B layer (IBL)を導入

τ-jet id

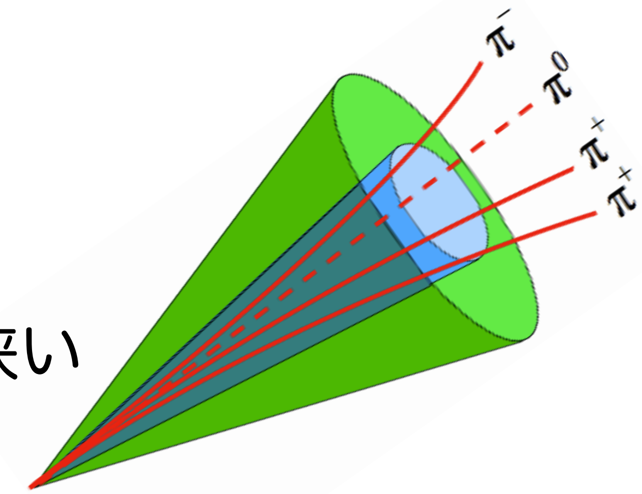
energyの広がり：

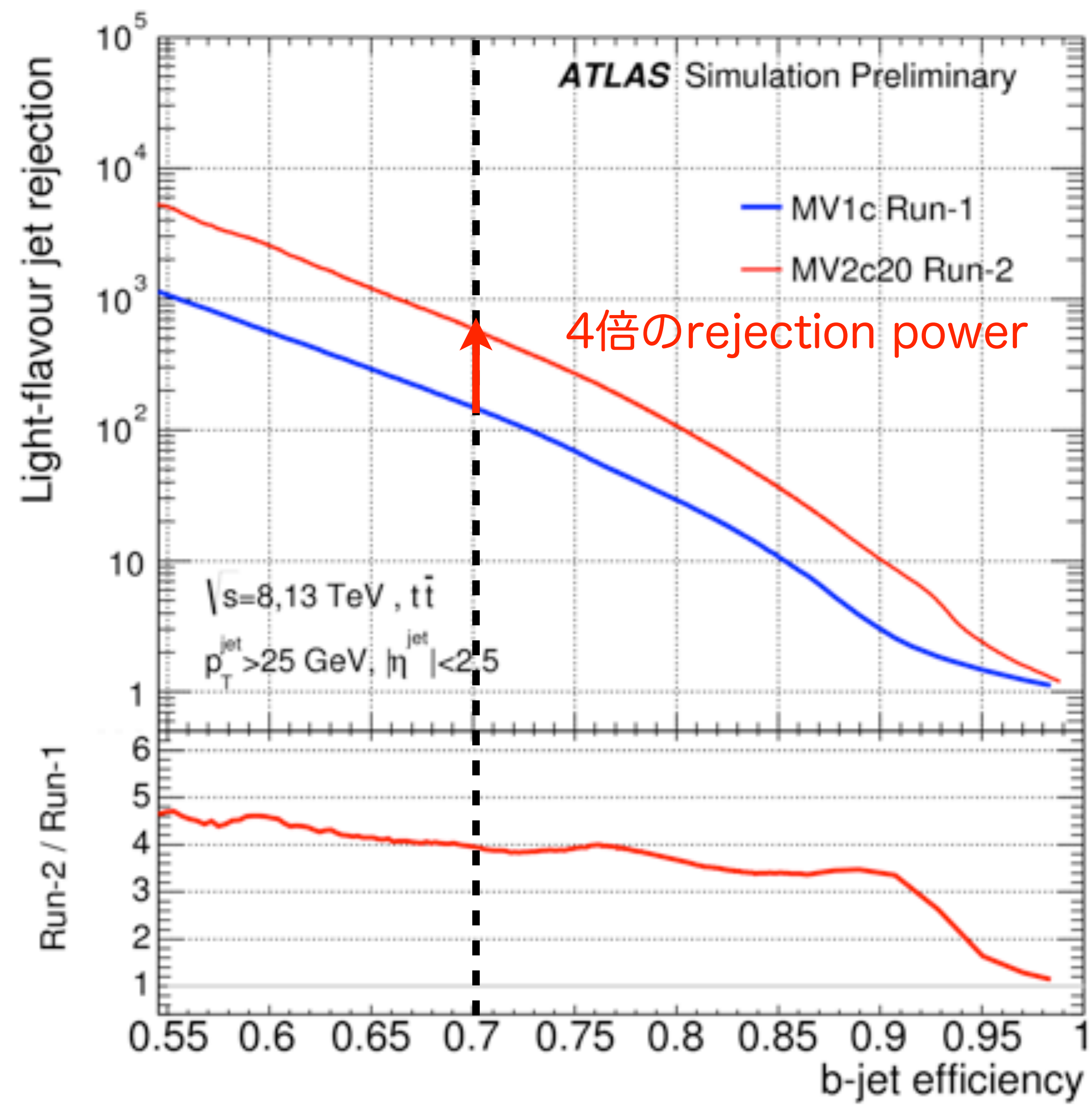
e/γより広い

quark/gluonより狭い

荷電粒子：

1本か3本がcollinearに





Event selection

○ dilepton

- 2 isolated leptons
- Z mass veto (for ee, $\mu\mu$)
- ≧2 jets, at least one jet b-tagged

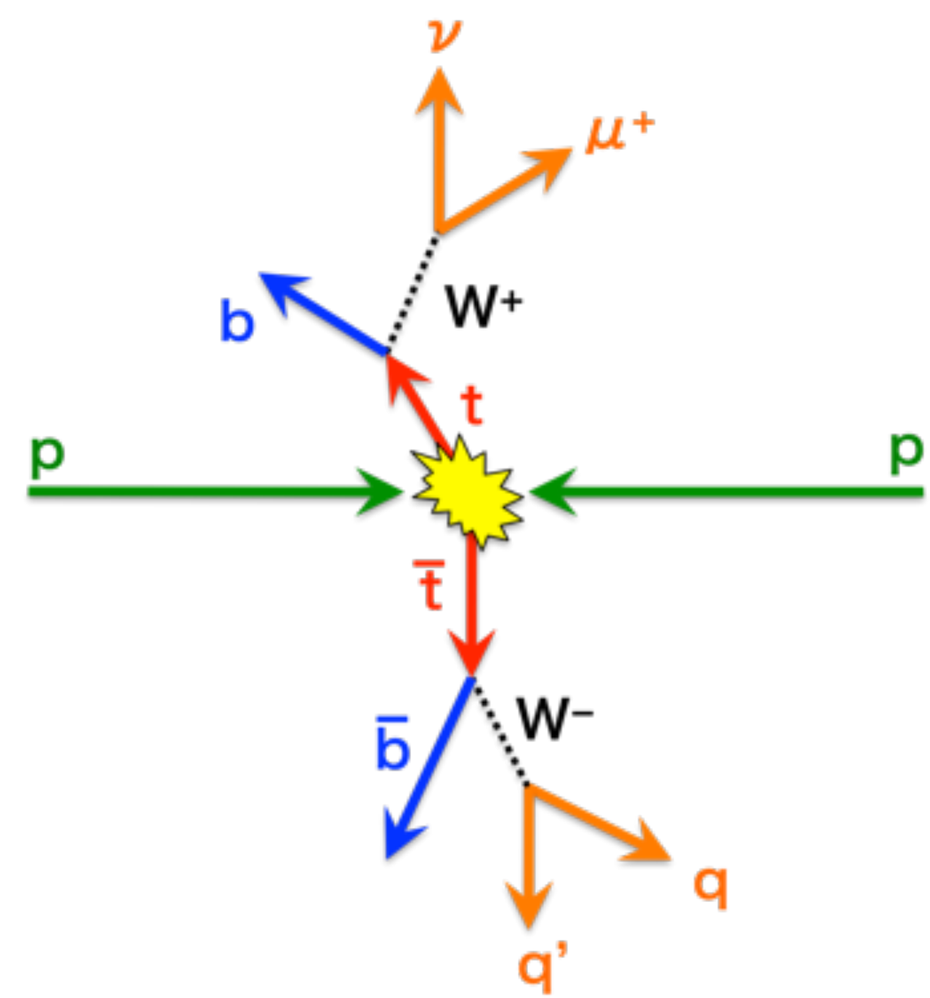
○ single lepton

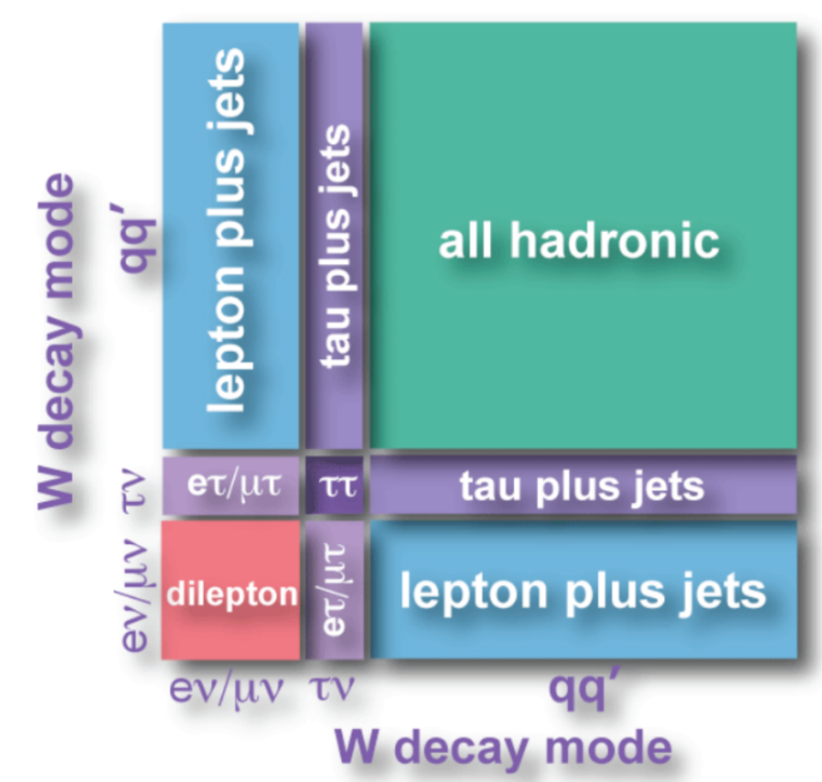
- 1 isolated lepton
- E_T^{miss}, $M_T(W)$でmulti-jet, W+jetsをcontrol
- ≧4 jets, at least one jet b-tagged

○ all-jets

- No isolated lepton
- ≧6 jets, 2 jets b-tagged
- Small E_T^{miss} significance, centrality

b-tag: typically ε=70%,
rejection factor=130 (light quark), 5 (c-quark)

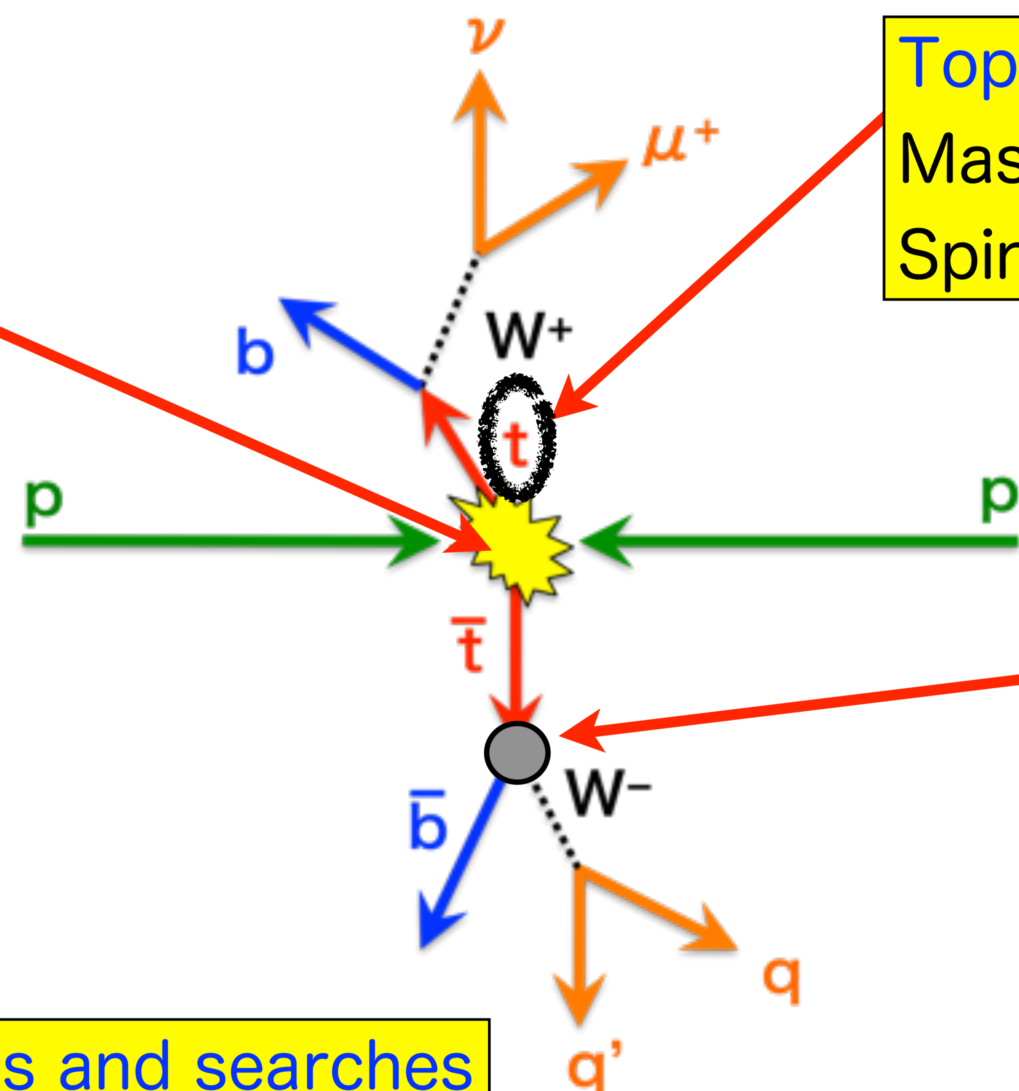




Top quark physics program

Top production
- test QCD
- Charge asymmetry
- anomalous coupling
- tt+X production
- Resonance Production
- top from new particle

Top properties
- Mass, Width, Spin, Charge
- Spin correlation, polarization



Top decay
- test EW
- W helicity
- Wtb coupling
- anomalous coupling
- CP violation
- FCNC
- New particle from top

Major background for Higgs and searches

Top quark pair production cross-section

Inclusive cross-section

ATLAS-CONF-2015-049

Event counts	N_1	N_2
Data	319	167
Wt single top	29.0 ± 3.8	5.6 ± 2.0
Dibosons	1.1 ± 0.2	0.0 ± 0.0
$Z(\to \tau\tau \to e\mu)$+jets	1.3 ± 0.7	0.1 ± 0.1
Misidentified leptons	6.0 ± 3.9	2.8 ± 2.9
Total background	37.3 ± 5.5	8.5 ± 3.5

} MC (Wt single top, Dibosons, Z+jets)

→ data (Misidentified leptons)

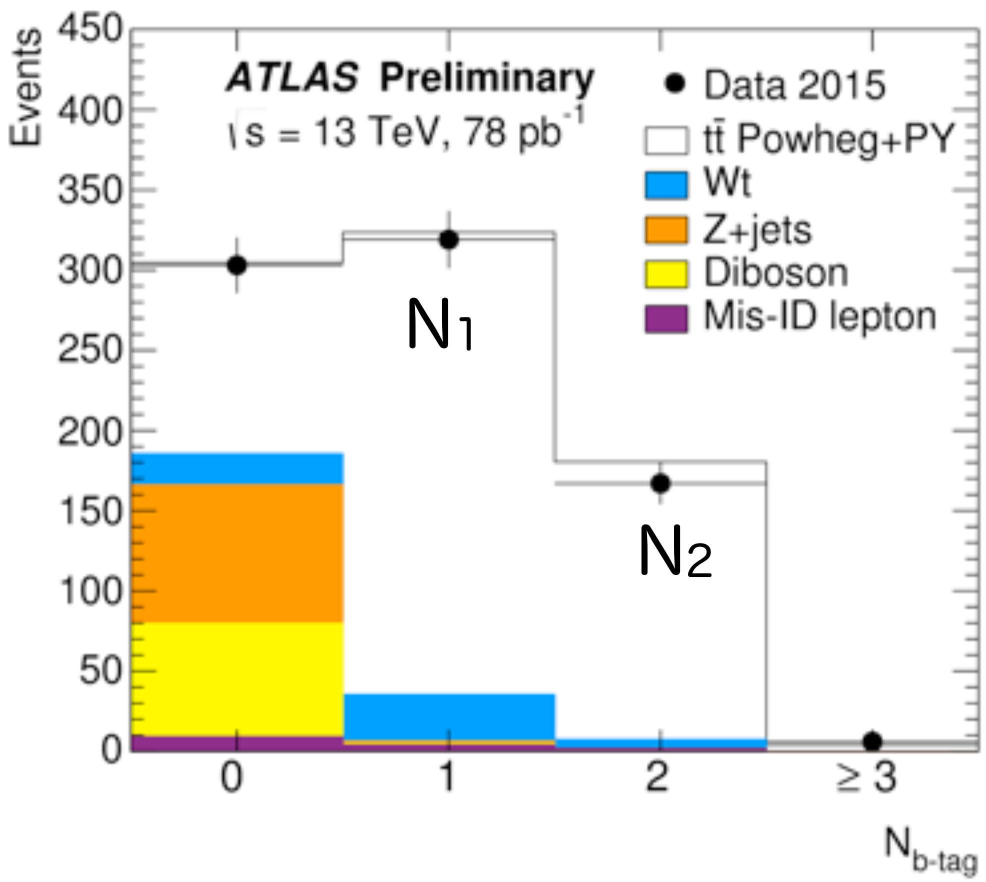
$$N_1 = L\sigma_{t\bar{t}}\, \epsilon_{e\mu} 2\epsilon_b (1 - C_b\epsilon_b) + N_1^{\mathrm{bkg}}$$

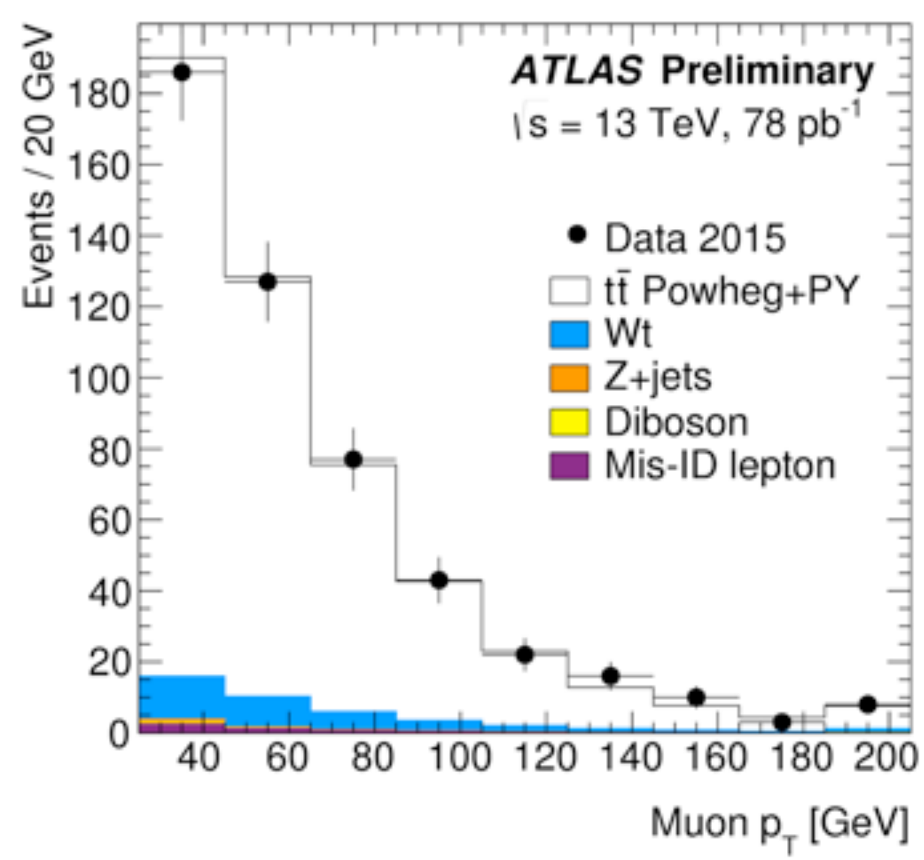
$$N_2 = L\sigma_{t\bar{t}}\, \epsilon_{e\mu} C_b {\epsilon_b}^2 + N_2^{\mathrm{bkg}}$$

$\varepsilon_{e\mu}$: $e\mu$ selection efficiency

ε_b : b-tag rate

C_b : correlation constant

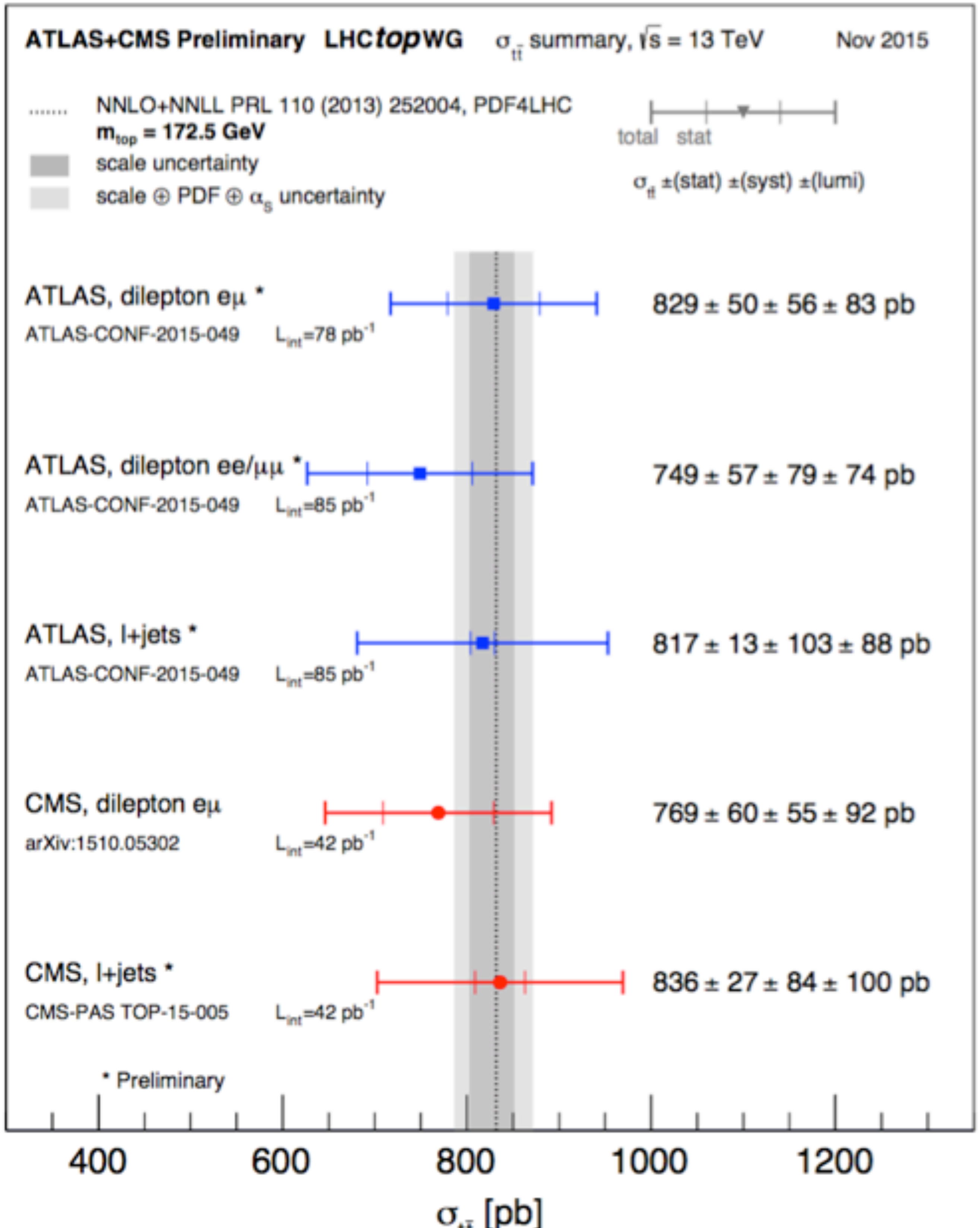




$$\sigma_{t\bar{t}} = 829 \pm 50 \pm 56 \pm 83 \text{ pb}$$

$$\sigma_{t\bar{t}}^{\mathrm{NNLO+NNLL}} = 832^{+20}_{-29}(\mathrm{scale})^{+35}_{-35}(\mathrm{PDF}\alpha_S) \text{ pb}$$

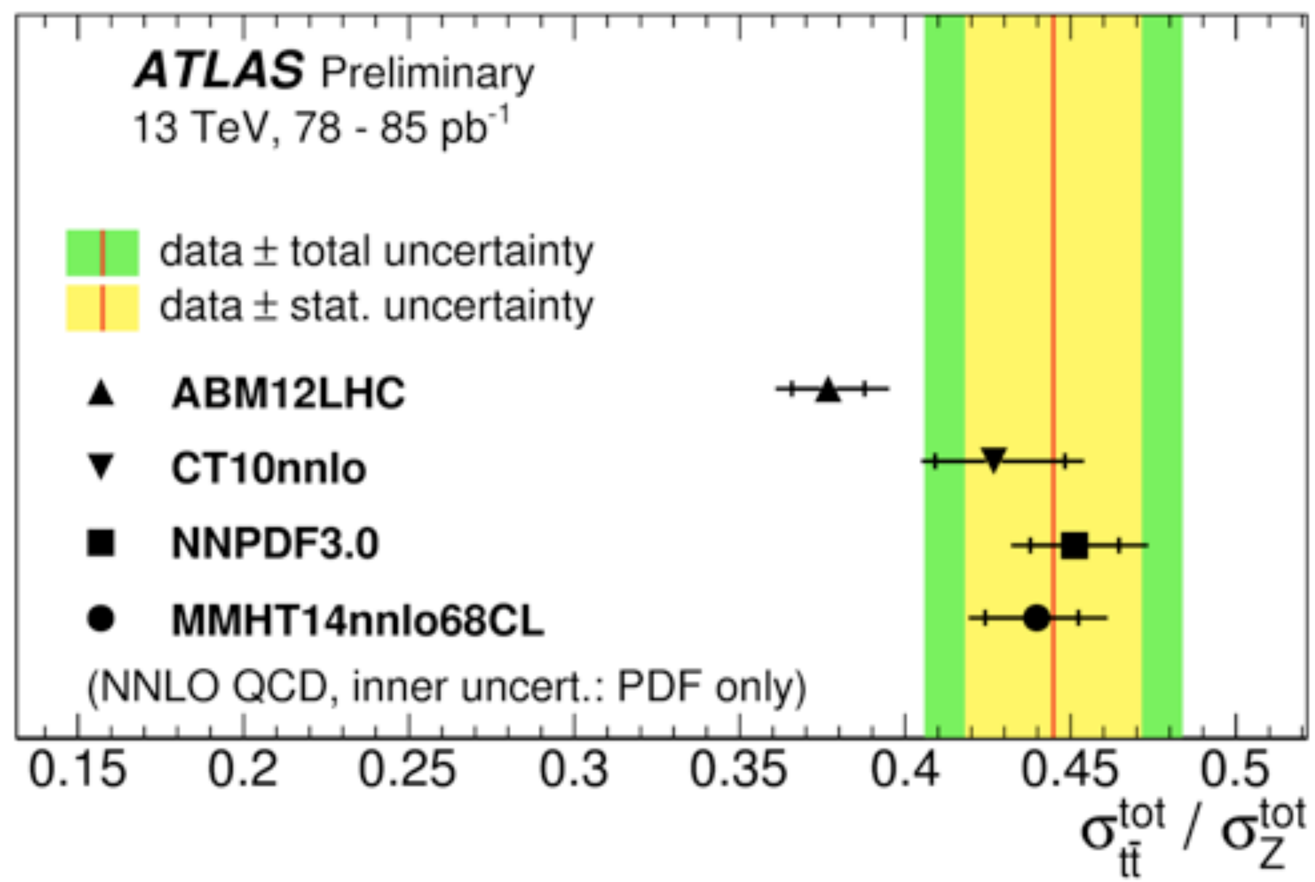
Inclusive cross-section in Run2



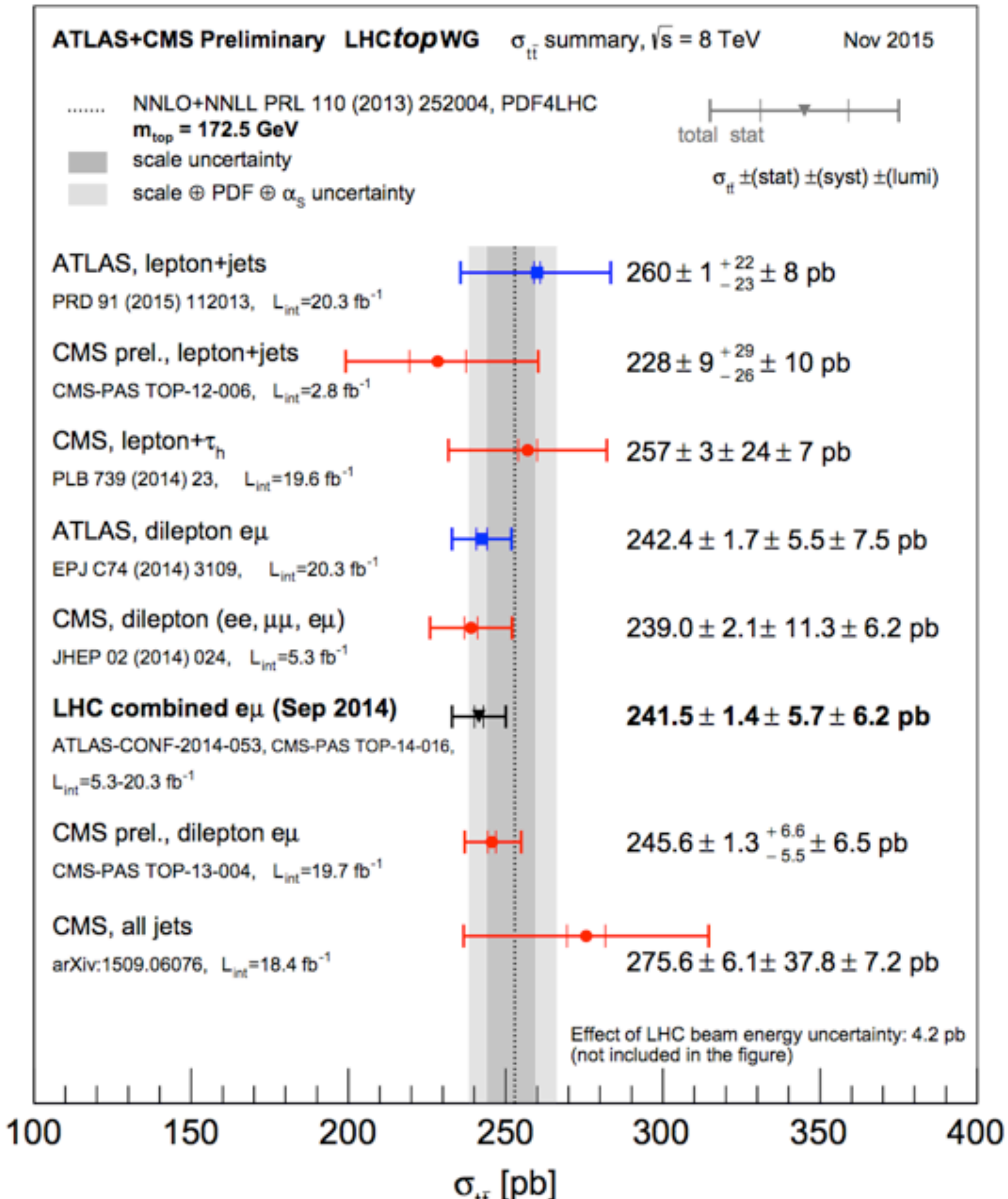
$$R_{t\bar{t}/Z} = \frac{\sigma_{t\bar{t}}}{0.5\left(\sigma_{Z\to ee} + \sigma_{Z\to\mu\mu}\right)}$$

gluonとsea-quark PDFに感度

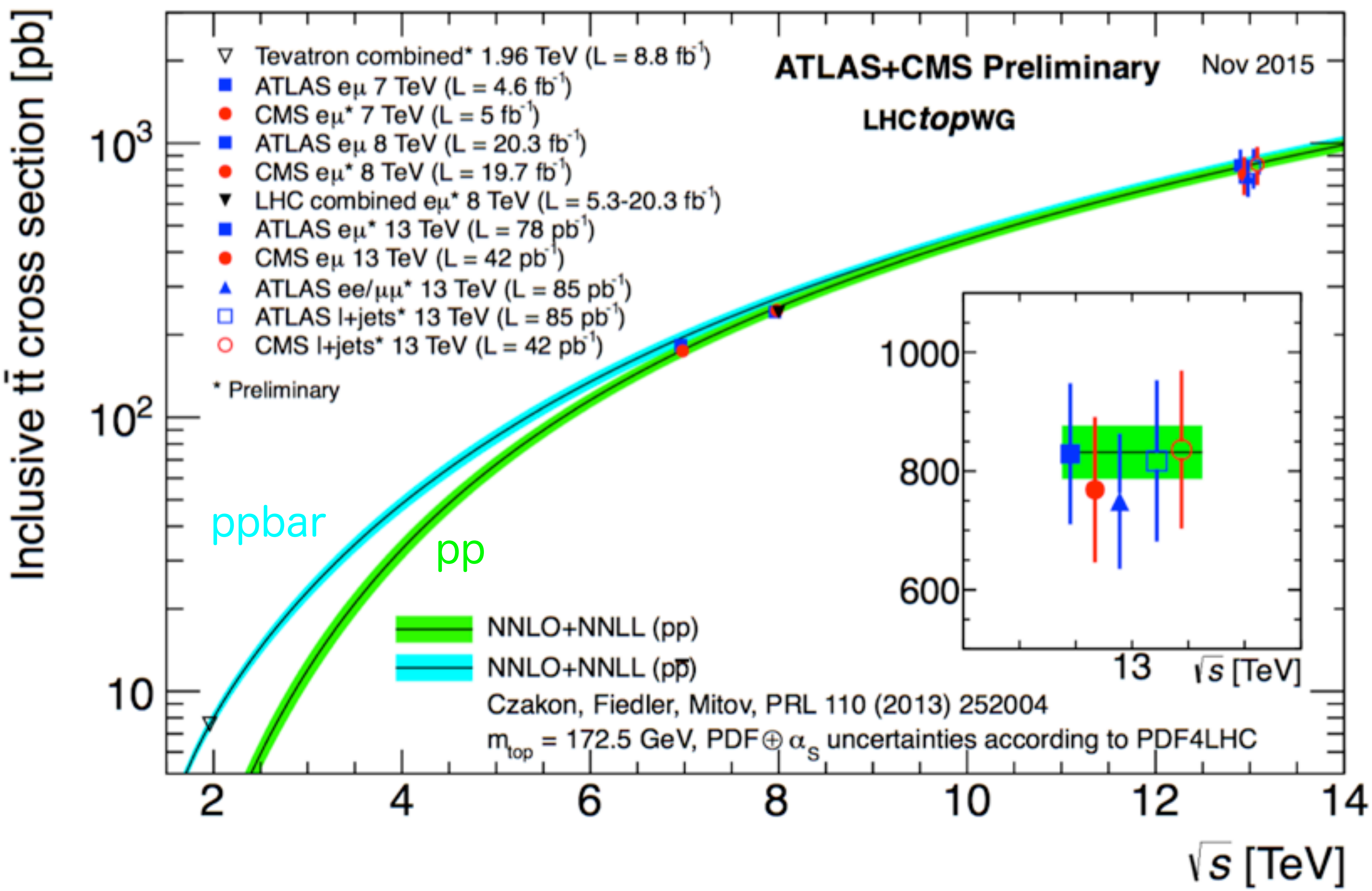
共通のSystematic uncertaintyをキャンセル



Inclusive cross-section in Run1



σ_{tt} vs $\sqrt{s}$



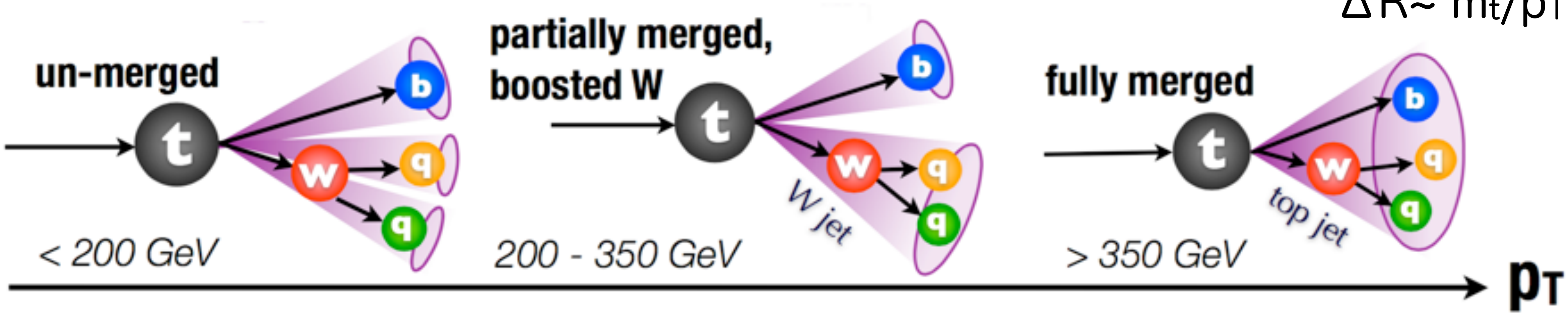
Differential cross-section

- PDF, kinematics of ttbar system, parton shower evolutionなどの検証
- p_T(top), p_T(ttbar), m(ttbar), y(ttbar), Njets ... 分布などの依存性を確認
  - pT(top)などはISR, FSRに感度
  - y(ttbar)はgluon のPDFに感度
  - m(ttbar)はHigh-Q^2の(新)物理に感度

$$y = \frac{1}{2}\ln\left[(E+p_z)/(E-p_z)\right] = \frac{1}{2}\ln\left(x_1/x_2\right)$$

- top quarkのboost具合に応じて：
  - “Resolved” regime : top quark からのlepton, jetが分離されている
  - “boosted” regime ：top quarkからの全粒子が”fat jet”として再構成

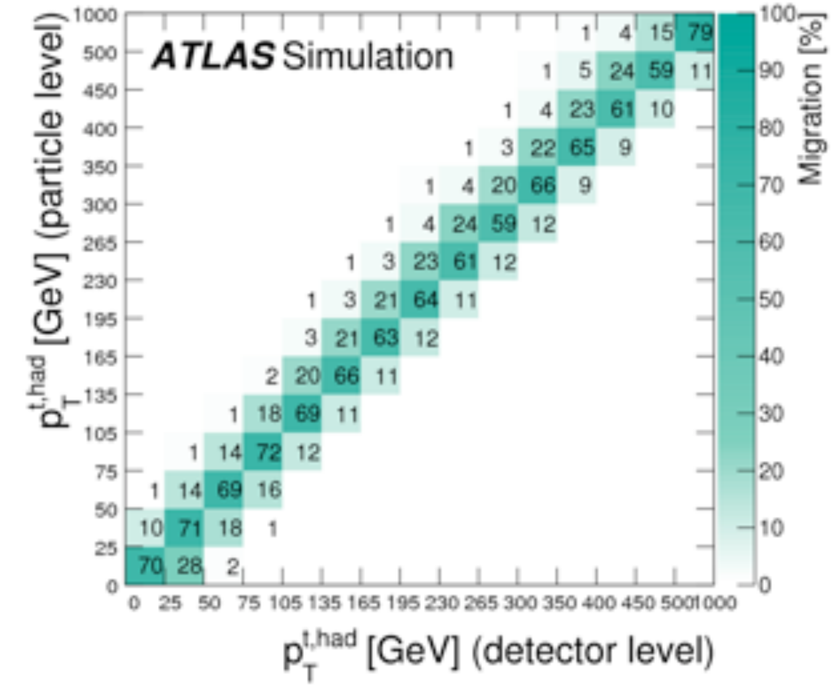
$\Delta R \sim m_t/p_T$

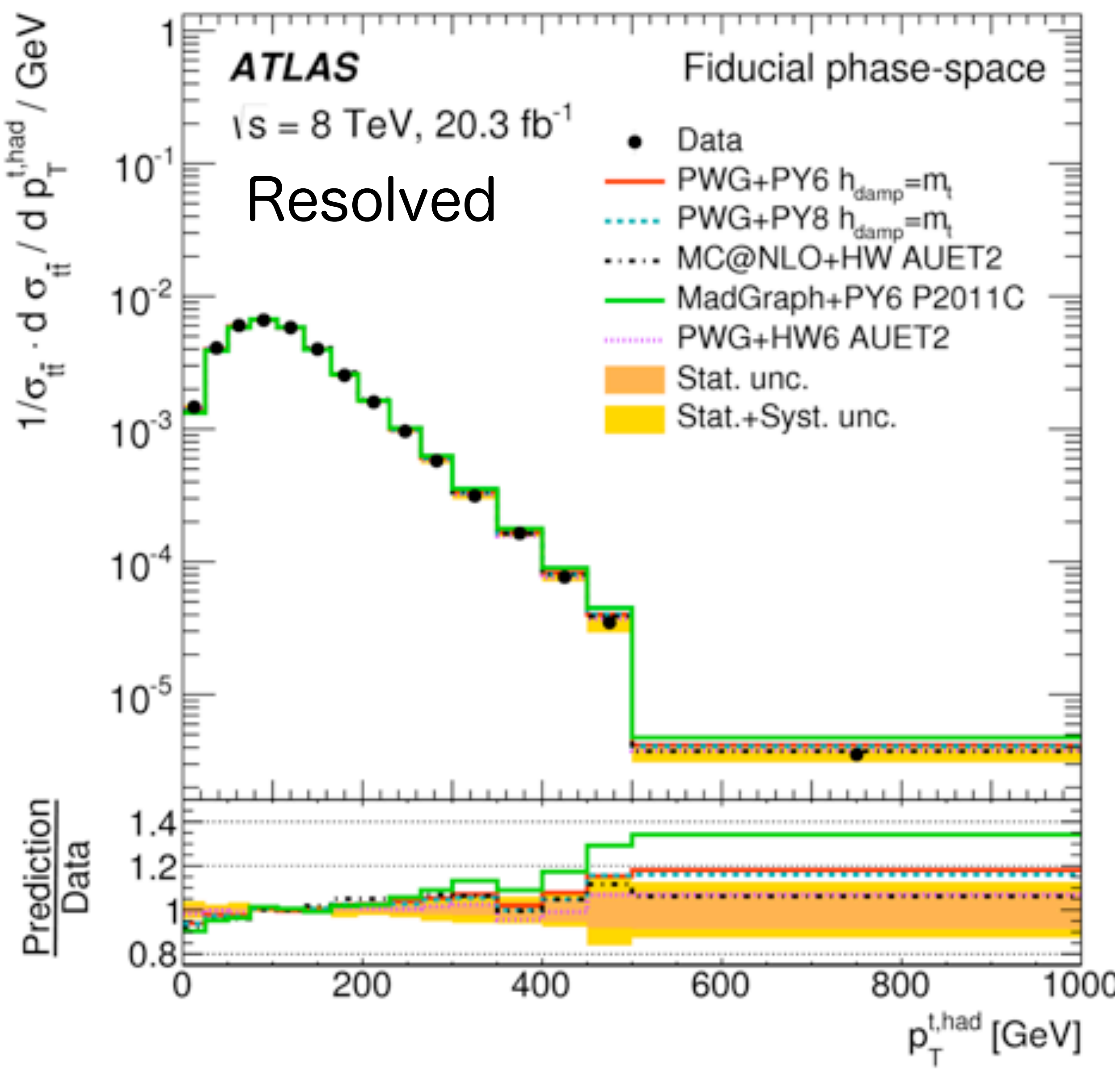


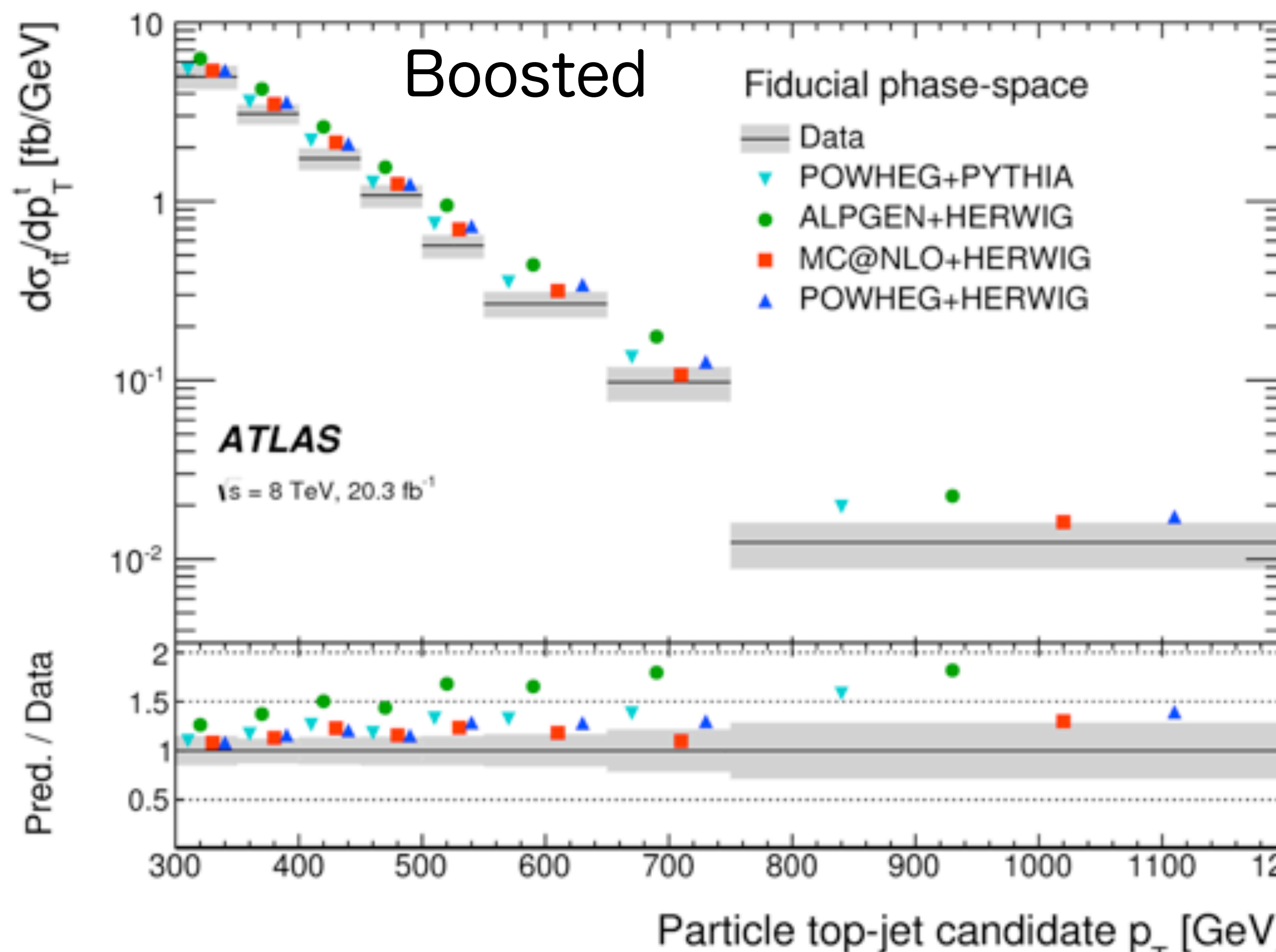
dσ/dpT differential cross-section

- Unfolding reconstructed object → particle level
  stable truth level particlesによる再構成
  parton levelへの更なる外挿の不定性を減らす

$$\frac{d\sigma^{\mathrm{fid}}}{dX^i} \equiv \frac{1}{\mathcal{L}\cdot\Delta X^i}\cdot f^i_{\mathrm{eff}}\cdot\sum_j \mathcal{M}^{-1}_{ij}\cdot f^j_{\mathrm{match}}\cdot f^j_{\mathrm{acc}}\cdot\left(N^j_{\mathrm{reco}}-N^j_{\mathrm{bg}}\right)$$

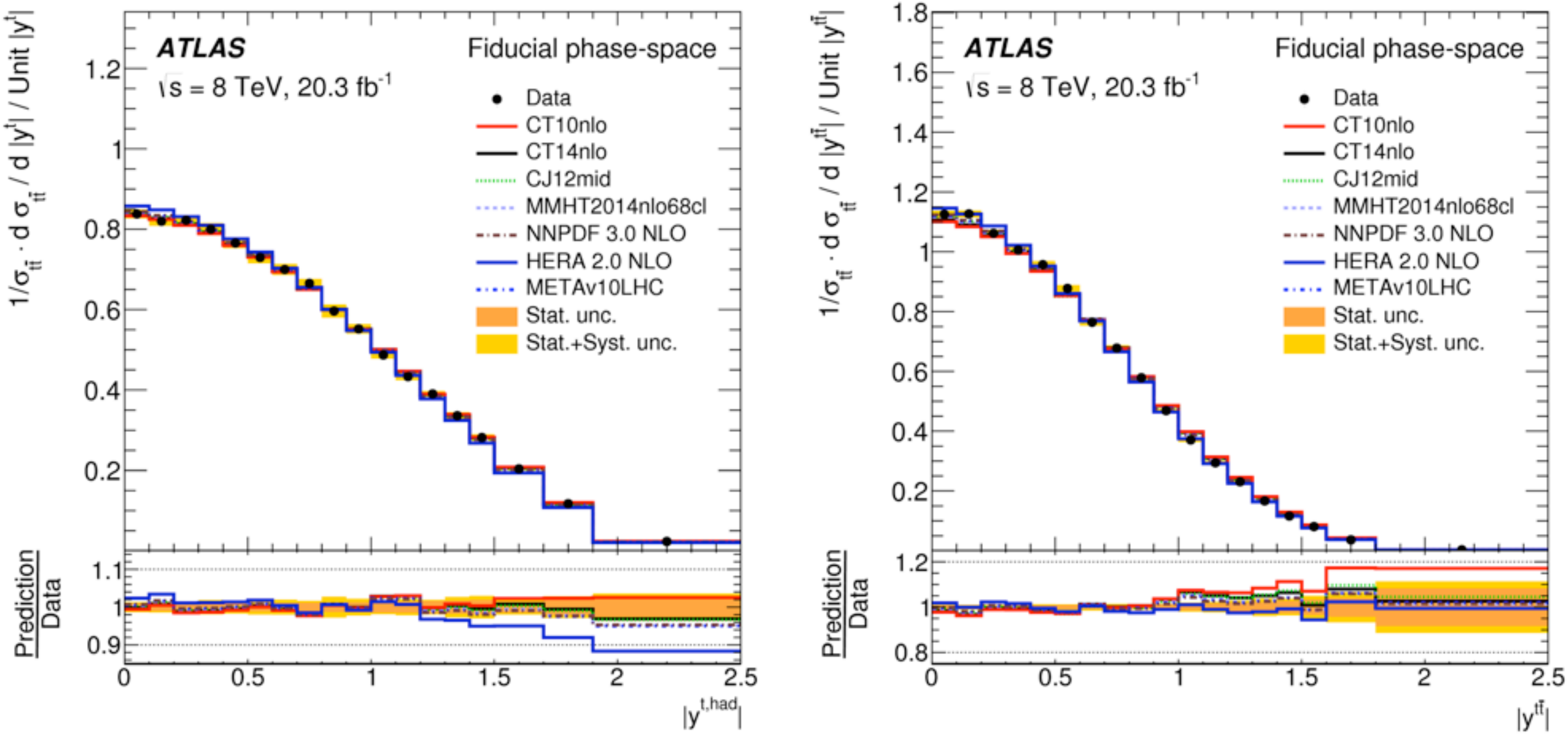






MCの方がdataよりもハードな傾向

dσ/dy differential cross section

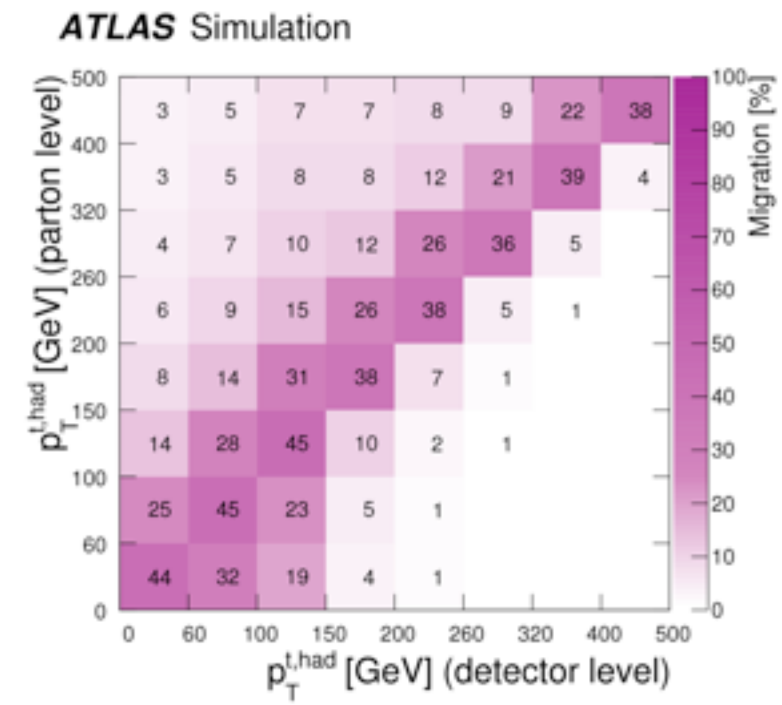


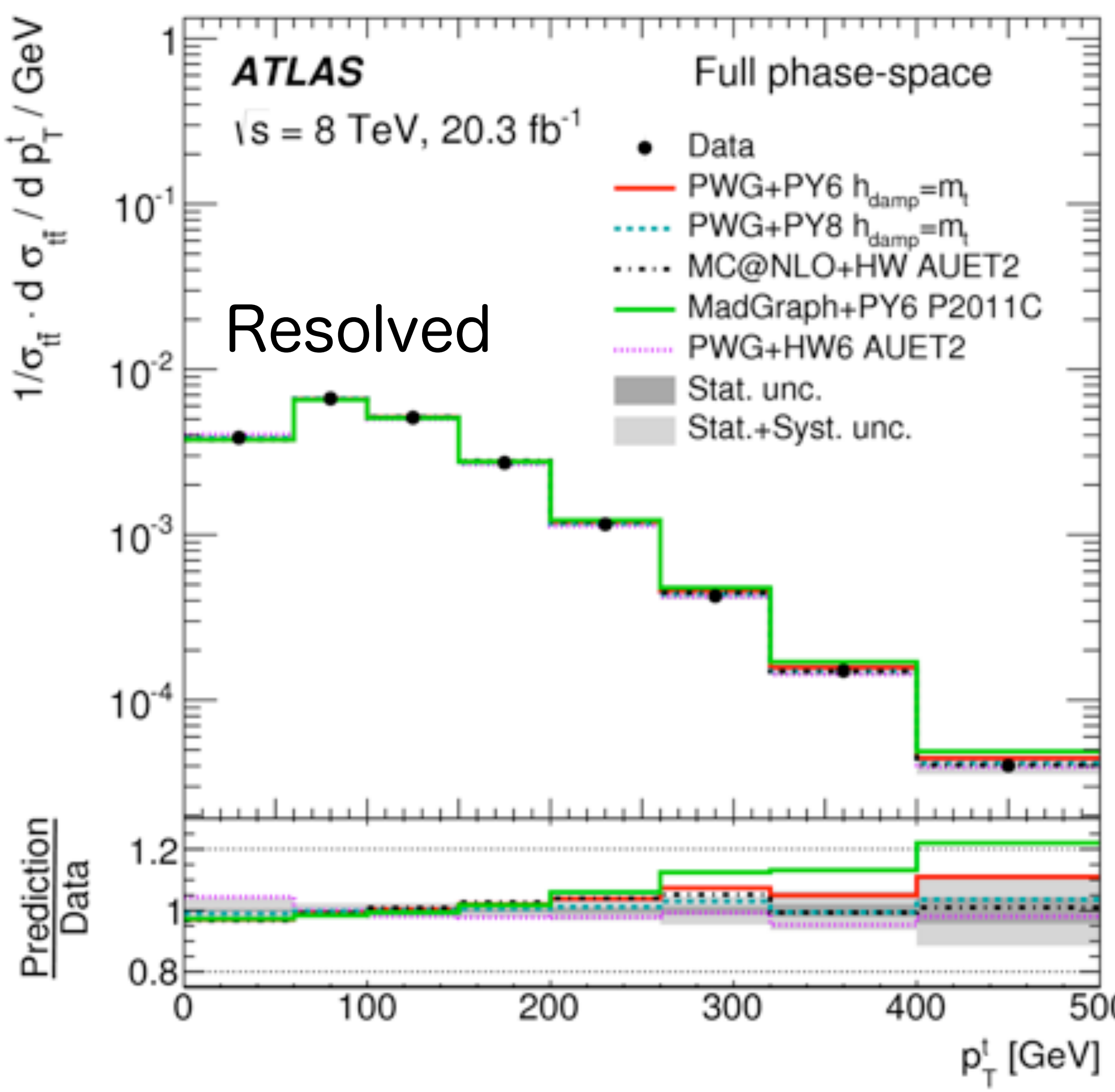
MC@NLO+HERWIG generator を使って、PDFの比較

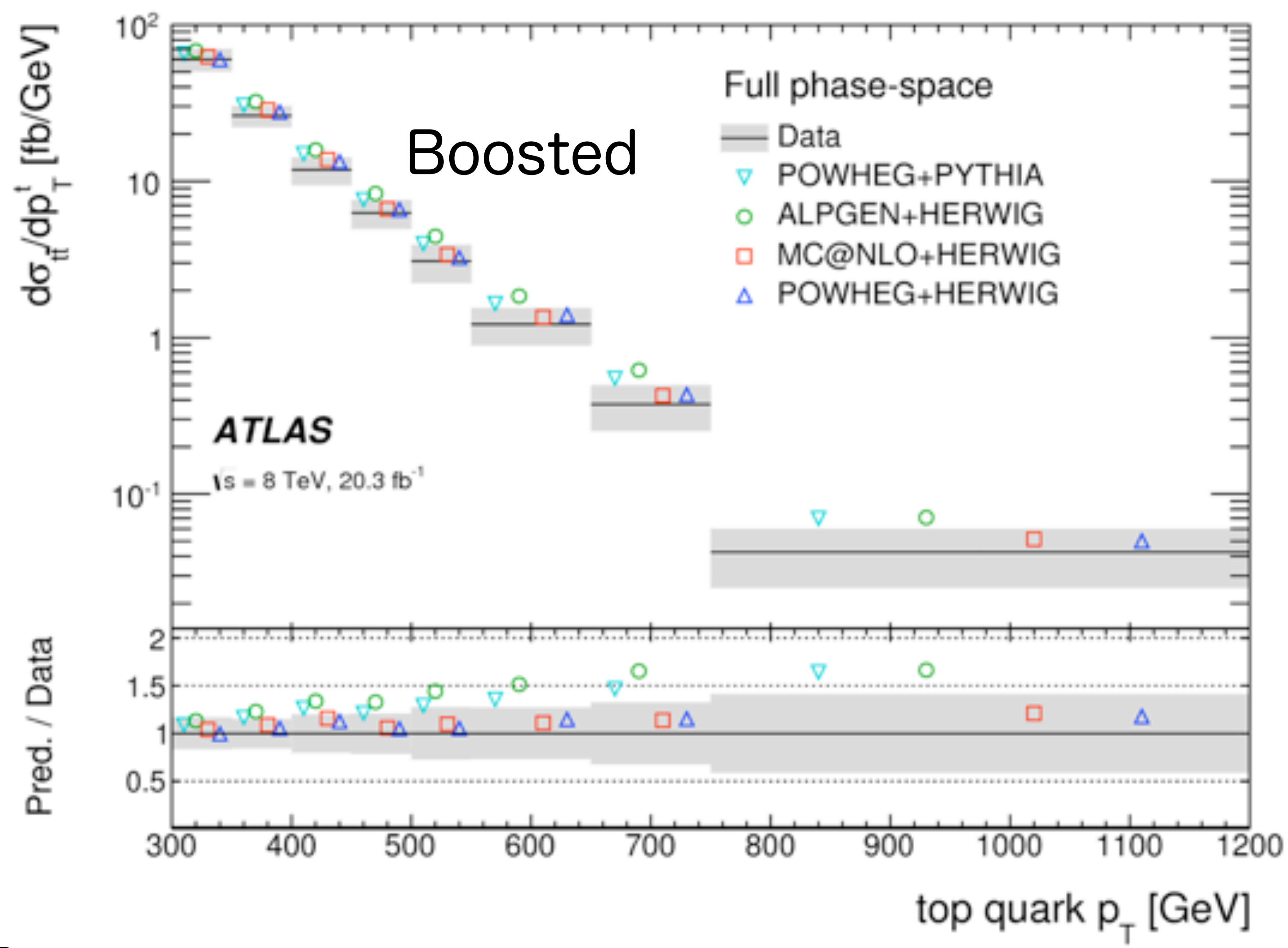
dσ/dp$_T$ differential cross-section

- Unfolding reconstructed object → parton level

$$\frac{d\sigma^{\mathrm{full}}}{dX^i} \equiv \frac{1}{\mathcal{L}\cdot\mathcal{B}\cdot\Delta X^i}\cdot\hat{f}^i_{\mathrm{eff}}\cdot\sum_j \hat{\mathcal{M}}^{-1}_{ij}\cdot\hat{f}^j_{\mathrm{acc}}\cdot\hat{f}^i_{\mathrm{ljets}}\cdot\left(N^j_{\mathrm{reco}}-N^j_{\mathrm{bg}}\right)$$

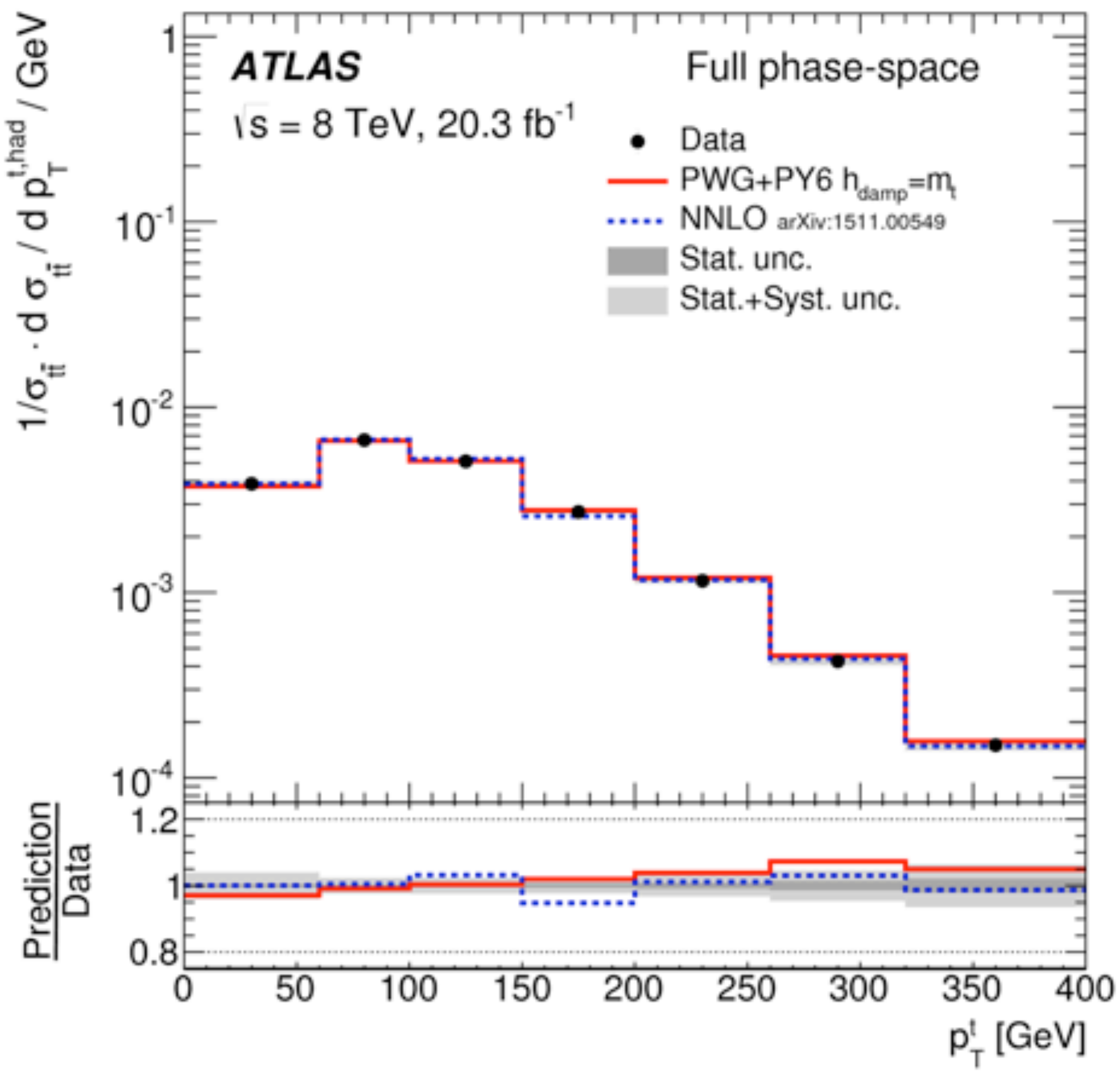


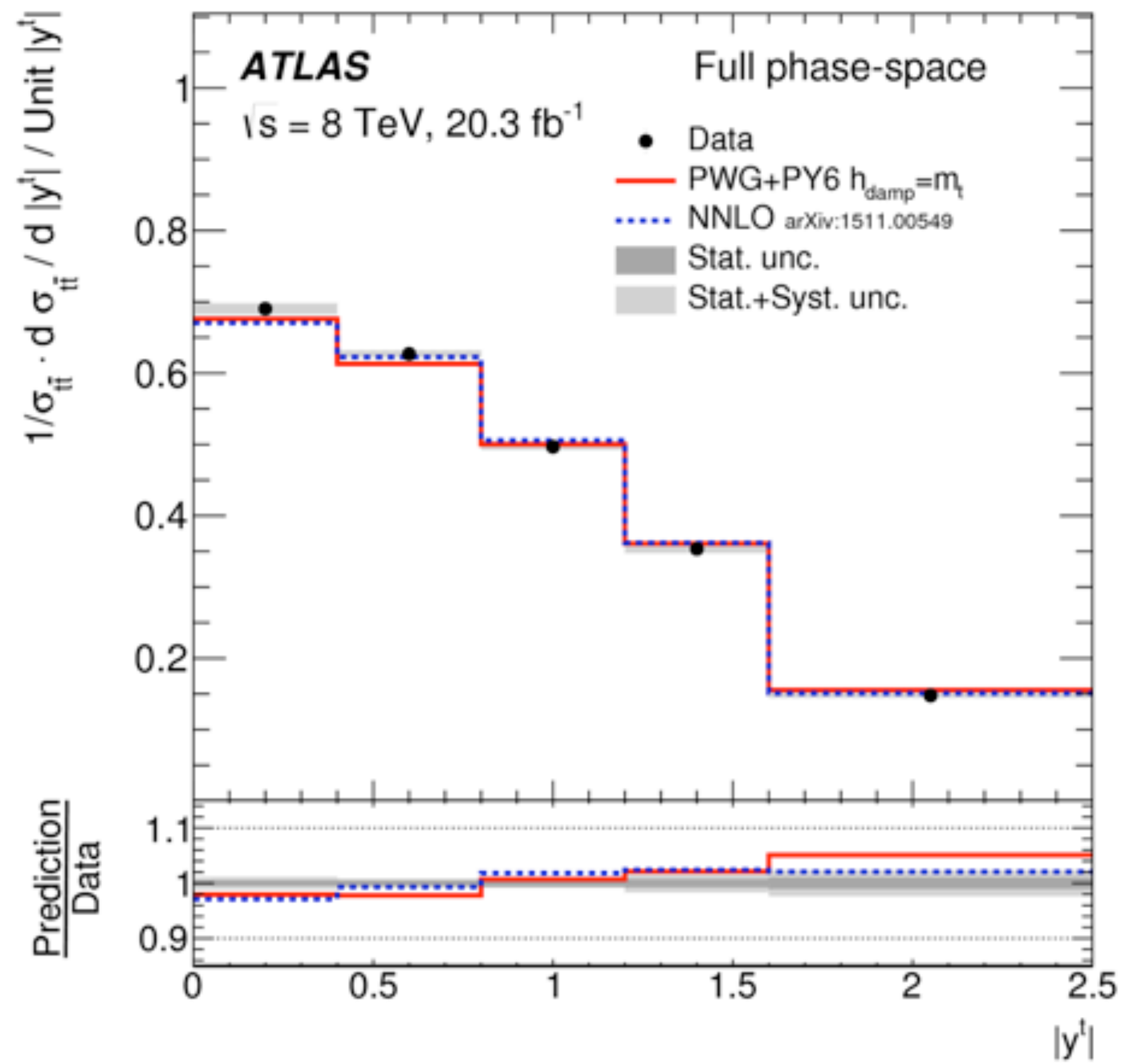




MCの方がdataよりもハードな傾向

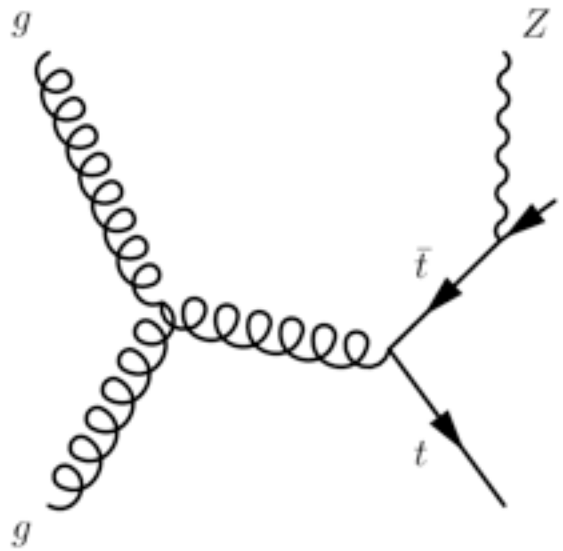
$d\sigma/dp_T$ differential cross-section

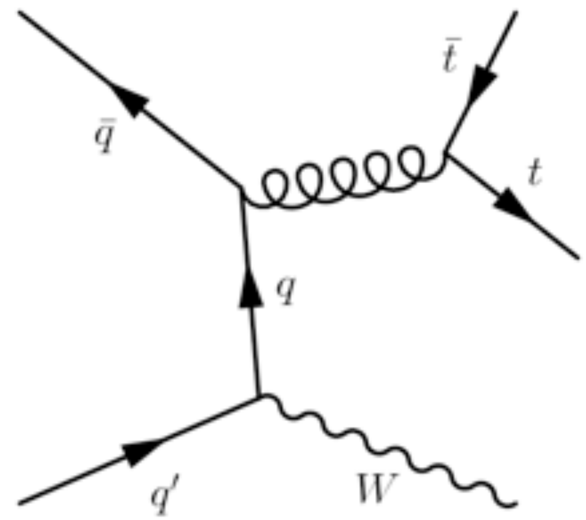


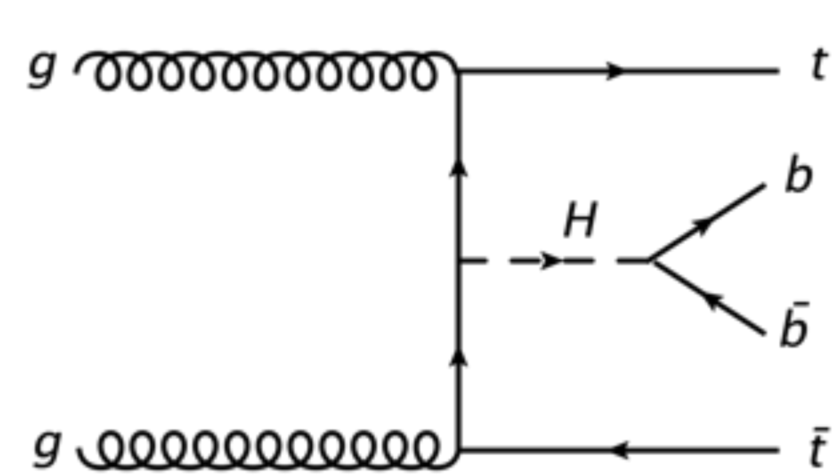


Full NNLO calculation is in good agreement with data.

ttbar+X cross-section

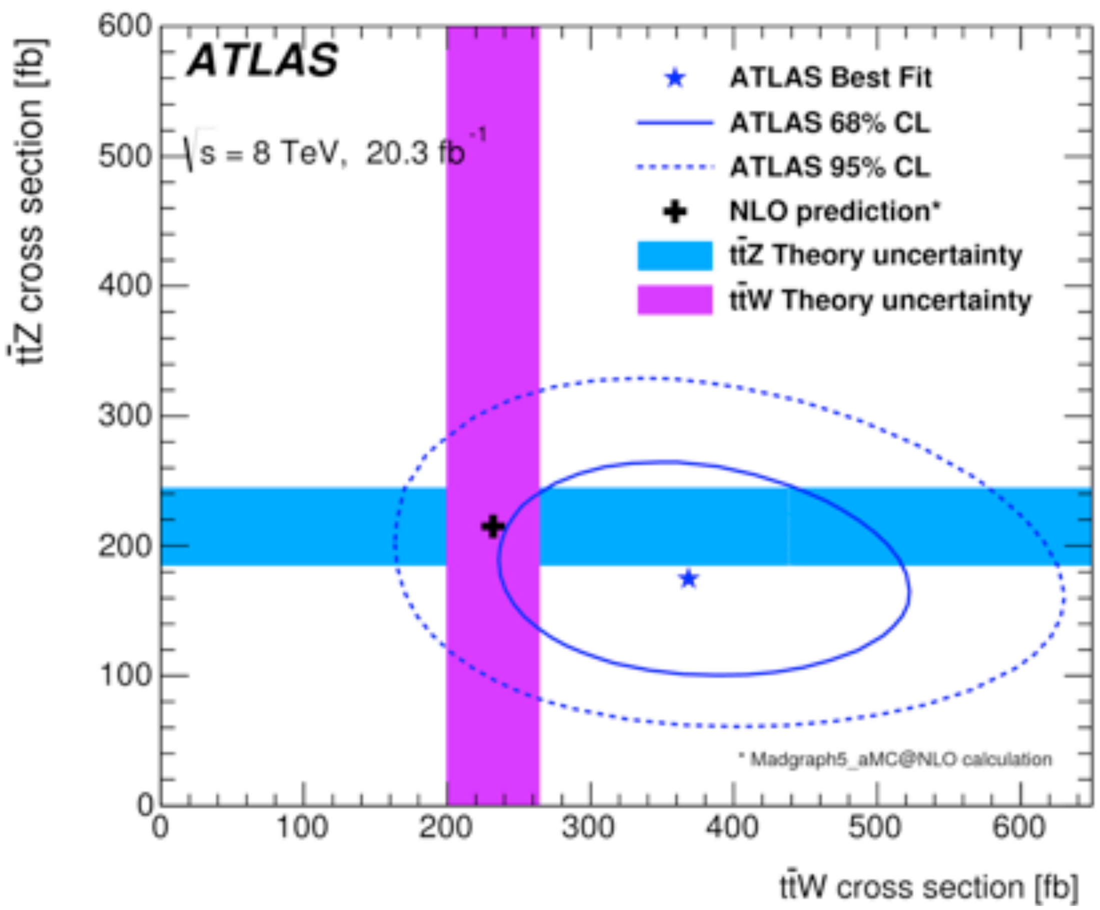


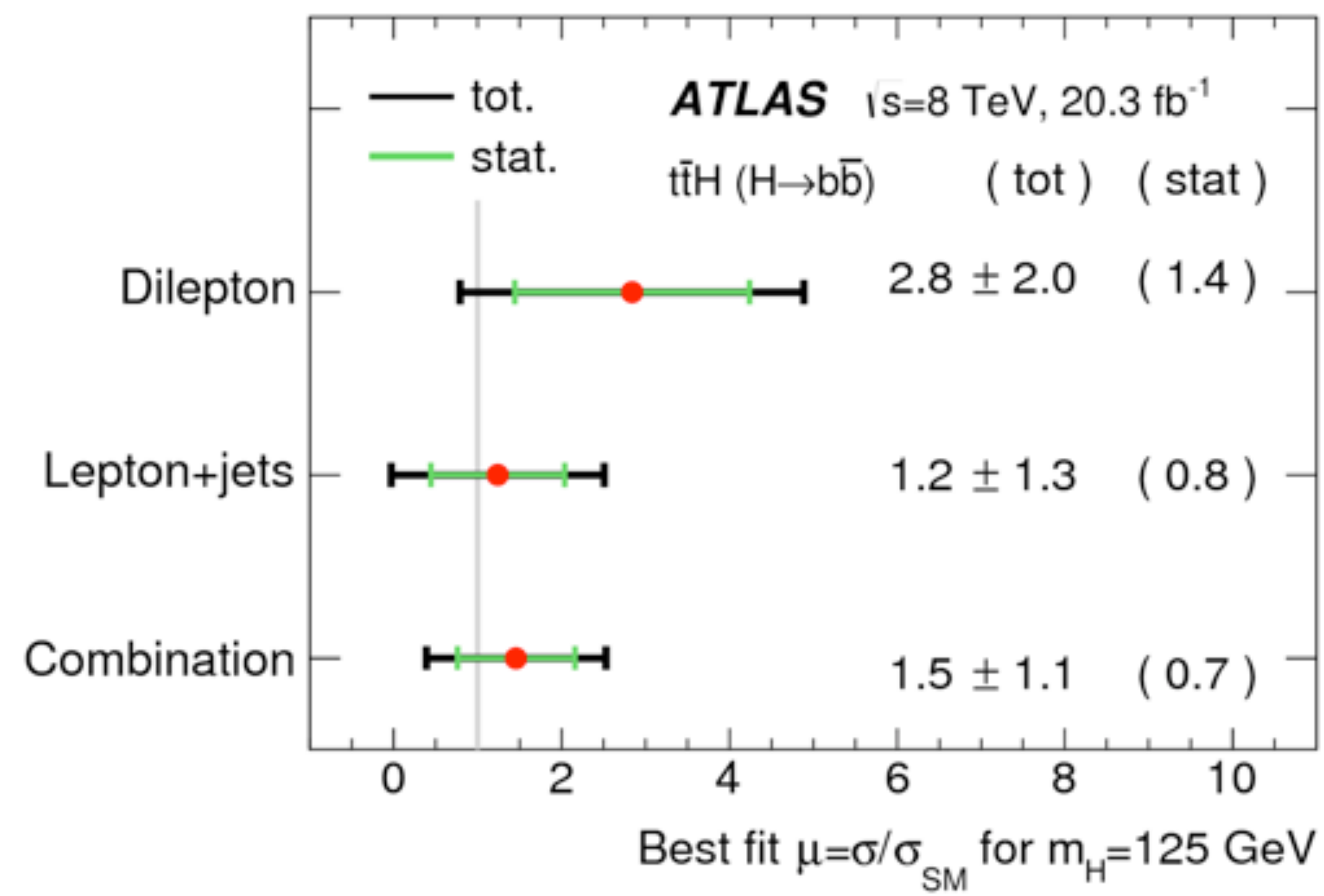




2ℓ same sign, 2ℓ opposite sign, 3ℓ, 4ℓ +bb

dilepton, l+jets, H→bb





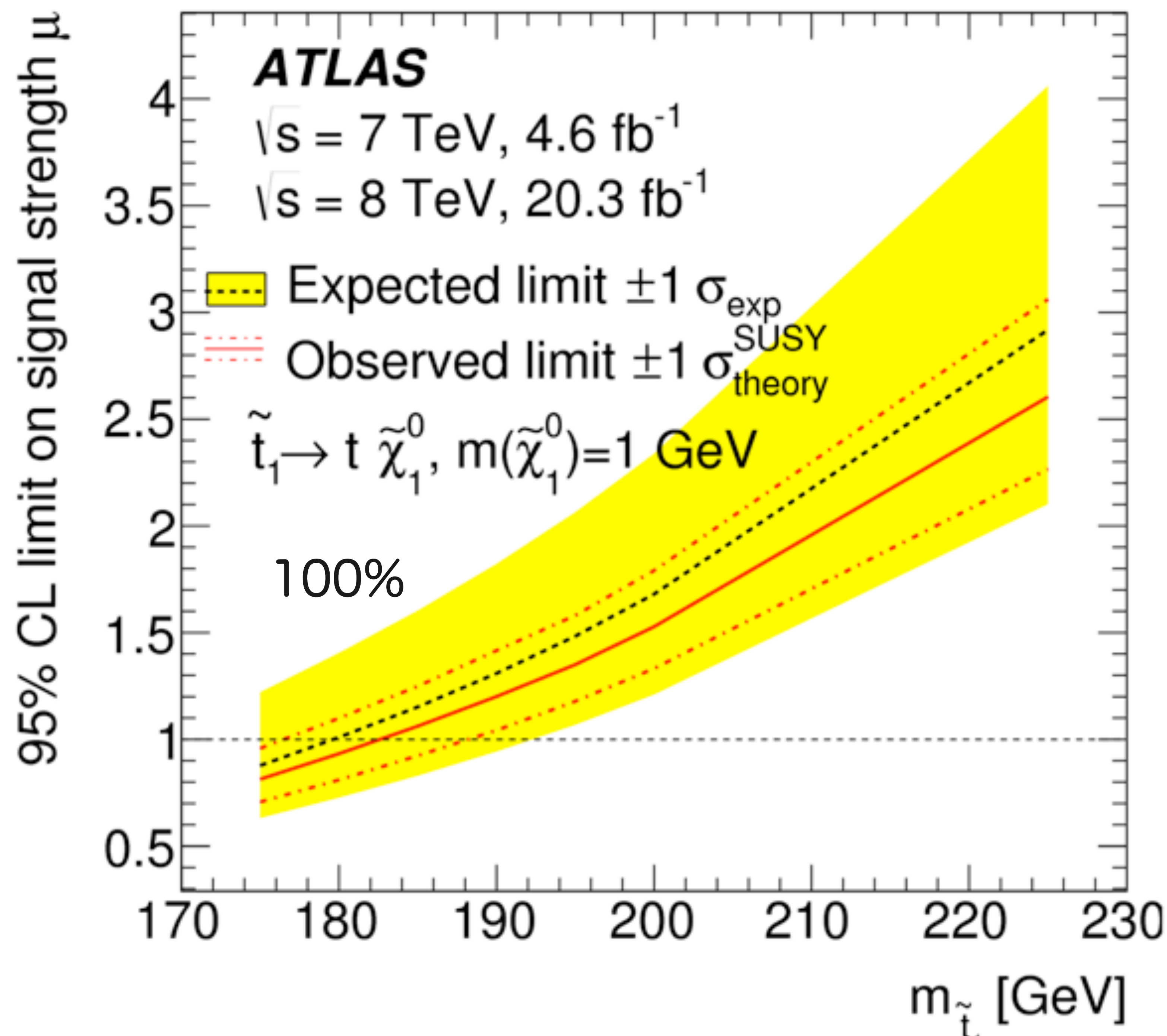
$\sigma_{t\bar{t}W} = 369^{+86}_{-79}\,(\text{stat.}) \pm 44\,(\text{syst.})\,\text{fb} = 369^{+100}_{-91}\,\text{fb}$ 5σ(3.2σ)

$\sigma_{t\bar{t}Z} = 176^{+52}_{-48}\,(\text{stat.}) \pm 24\,(\text{syst.})\,\text{fb} = 176^{+58}_{-52}\,\text{fb}.$ 4.2σ(4.5σ)

ttbar+MET

stop 探索に感度 $pp \to \tilde{t}_1\bar{\tilde{t}}_1 \to t\bar{t}\tilde{\chi}_1^0\tilde{\chi}_1^0 \quad (m_{\tilde{t}_1} > m_t + m_{\tilde{\chi}_1^0})$

$\sigma_{\tilde{t}_1\tilde{t}_1} = 40\ \mathrm{pb} \sim 20\ \mathrm{pb}\ (m_{\tilde{t}} = 175\ \mathrm{GeV} \to 200\ \mathrm{GeV})$



$m_t < m_{\tilde{t}} < 177\mathrm{GeV}$ excluded (95%CL)

Top quark mass

Top mass : Standard method

Eur. Phys. J. C (2015) 75:158 , Eur. Phys. J. C (2015) 75:330, etc

Kinematic likelihood fitでttbar事象を再構成

$$L = \mathcal{B}(\widetilde{E}_{\mathrm{p},1}, \widetilde{E}_{\mathrm{p},2} | m_W, \Gamma_W) \cdot \mathcal{B}(\widetilde{E}_{\mathrm{lep}}, \widetilde{E}_{\nu} | m_W, \Gamma_W) \cdot \mathcal{B}(\widetilde{E}_{\mathrm{p},1}, \widetilde{E}_{\mathrm{p},2}, \widetilde{E}_{\mathrm{p},3} | m_t, \Gamma_t) \cdot \mathcal{B}(\widetilde{E}_{\mathrm{lep}}, \widetilde{E}_{\nu}, \widetilde{E}_{\mathrm{p},4} | m_t, \Gamma_t) \cdot \mathcal{W}(\hat{E}_x^{\mathrm{miss}} | \widetilde{p}_{x,\nu}) \cdot \mathcal{W}(\hat{E}_y^{\mathrm{miss}} | \widetilde{p}_{y,\nu}) \cdot \mathcal{W}(\hat{E}_{\mathrm{lep}} | \widetilde{E}_{\mathrm{lep}}) \cdot \prod_{\mathrm{i}=1}^{4} \mathcal{W}(\hat{E}_{\mathrm{jet,i}} | \widetilde{E}_{\mathrm{p,i}}) \cdot \prod_{\mathrm{i}=1}^{4} P(\mathrm{tagged} \mid \mathrm{parton\ flavour}),$$

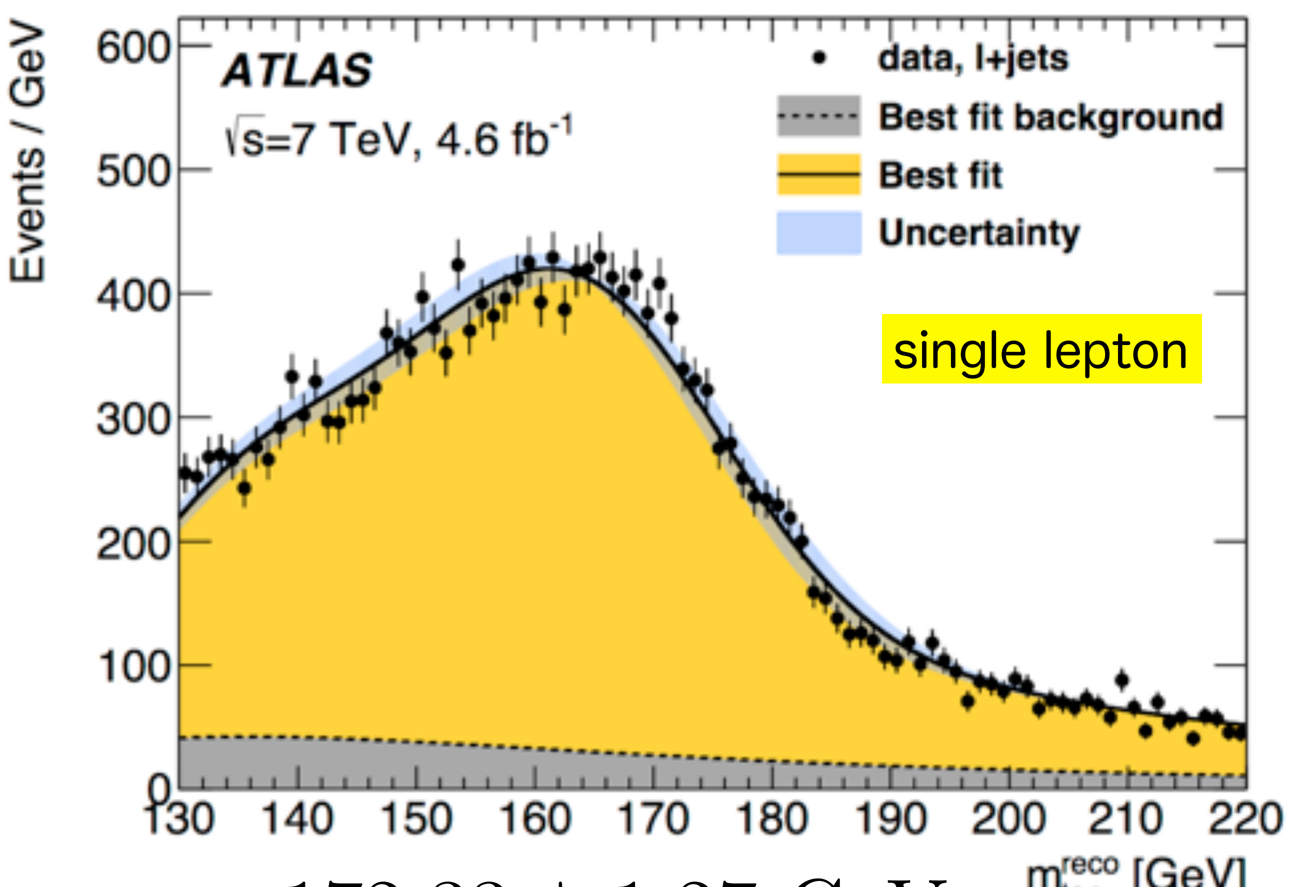
dilepton : 2 leptons, 2 b-jets→m_{lb}

single lepton : lepton, E_T^{miss}, 2 b-jets, 2 light-jets→m_{top}^{reco}, m_W^{reco}, R_{bq}^{reco}

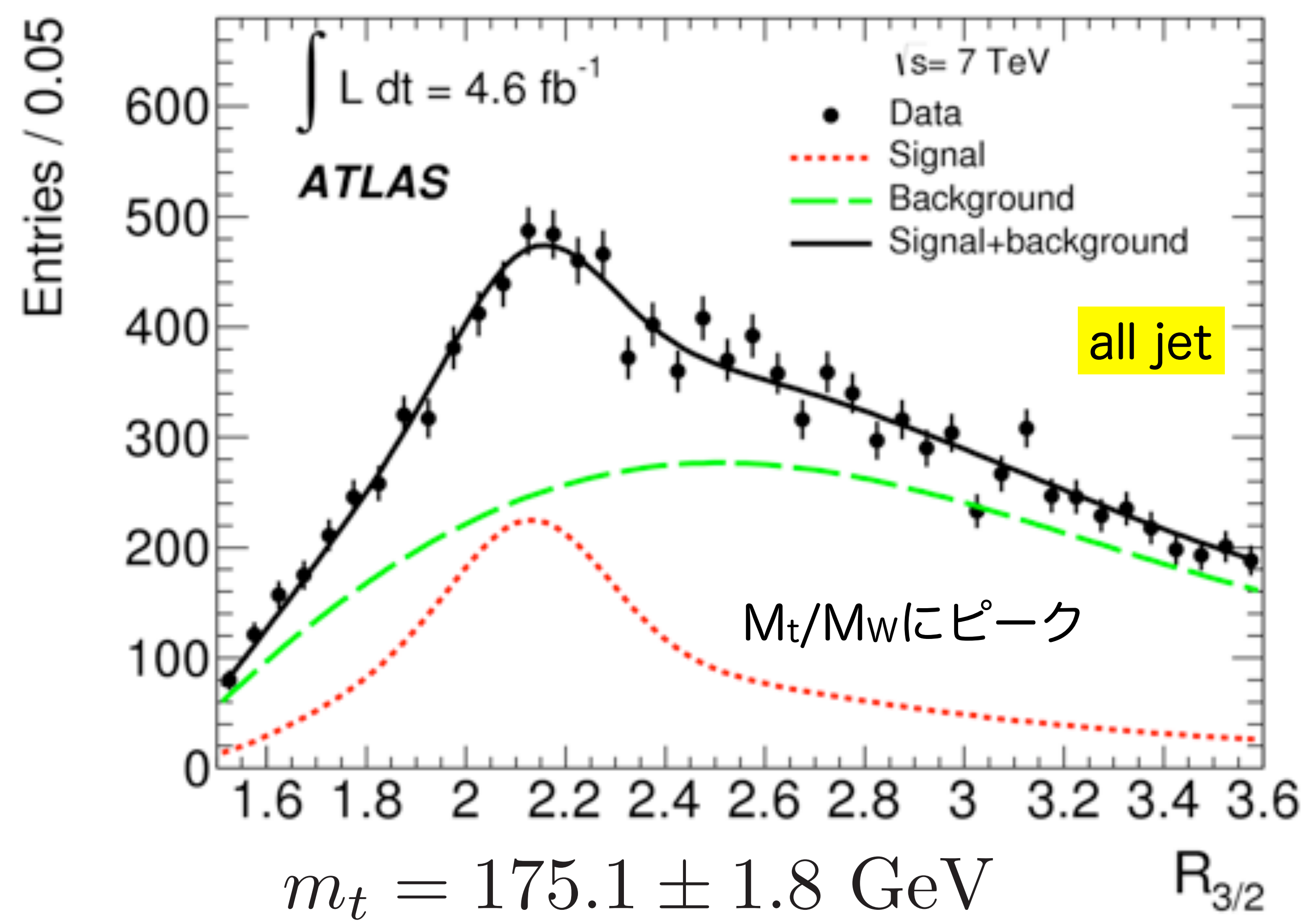
m_{top}^{reco}, m_W^{reco}, R_{bq}分布の3D fitからm_t, JSF, bJSFを同時決定

all jets : 2 b-jets, 4 light-jets→$R_{3/2}=m_{jjj}/m_{jj}$

$$R_{bq}^{\mathrm{redo}} = \frac{p_{\mathrm{T}}^{b_{\mathrm{had}}} + p_{\mathrm{T}}^{b_{\mathrm{lep}}}}{p_{\mathrm{T}}^{W_{\mathrm{jet1}}} + p_{\mathrm{T}}^{W_{\mathrm{jet2}}}}$$

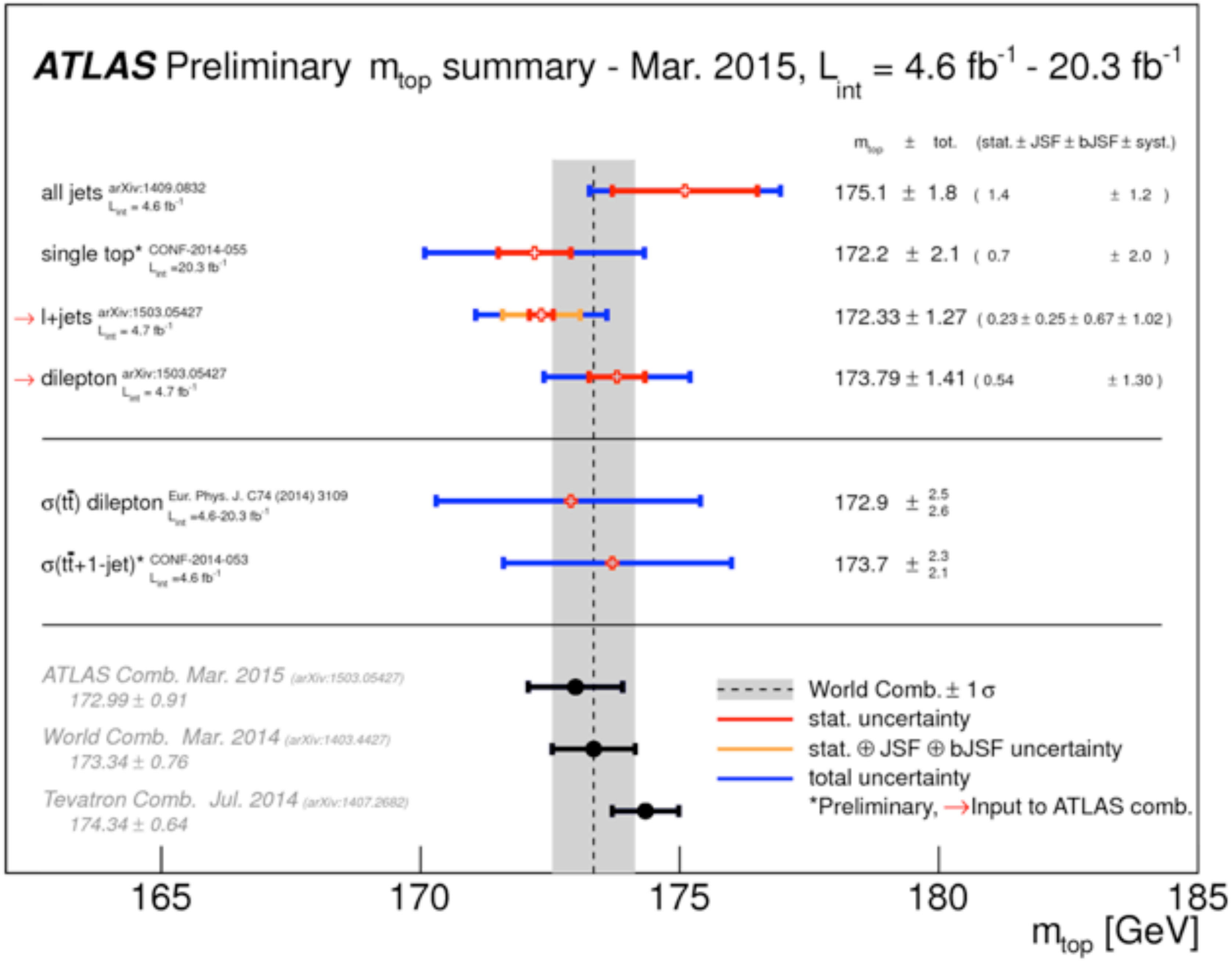


$$m_t = 172.33 \pm 1.27\ \mathrm{GeV}$$



$$m_t = 175.1 \pm 1.8\ \mathrm{GeV}$$

Standard Methodによる質量測定のまとめ



$m_t = 172.99 \pm 0.91\ \mathrm{GeV}$ (ATLAS Comb.) 0.5%

arXiv:1503.05427

$m_t = 173.34 \pm 0.76\ \mathrm{GeV}$ (World Comb.) 0.4%

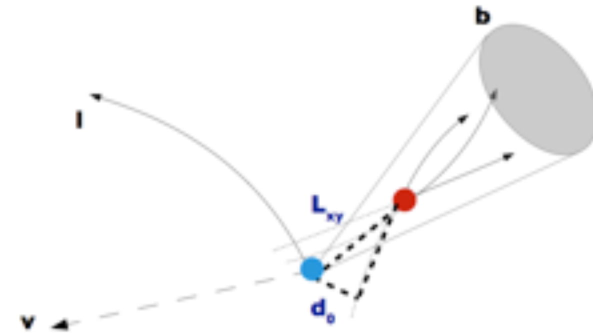
arXiv:1403.4427

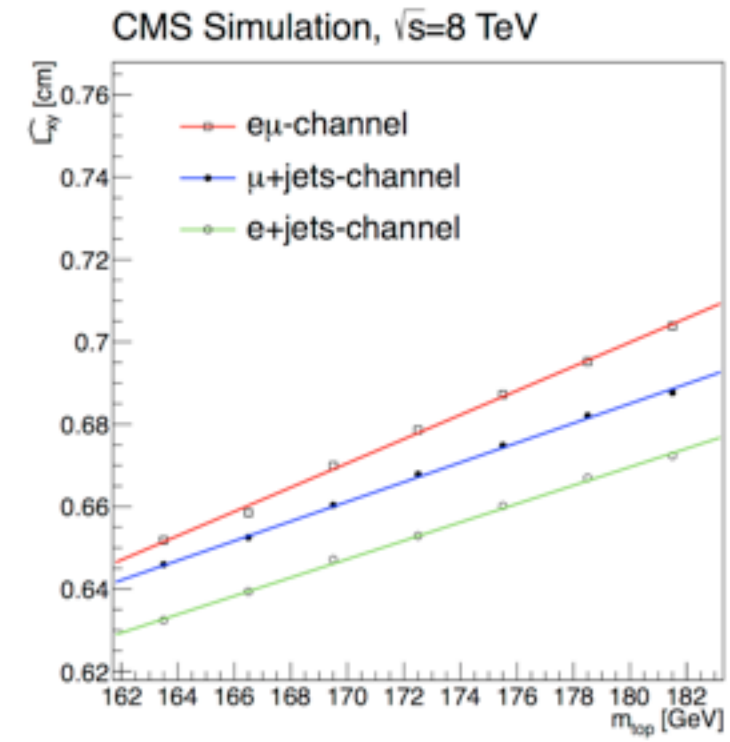
Top mass : Other methods

○ B-hadron Lifetime CMS-PAS-TOP-12-030

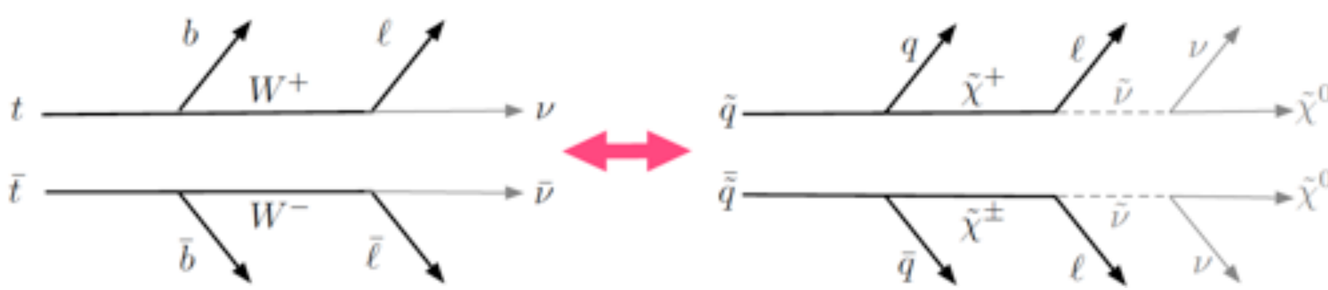
$$L_{xy} = \gamma_b \beta_B \tau_B \simeq 0.4 \cdot \frac{m_t}{m_B} \beta_B \tau_B \quad < L_{xy} > \sim 7 \text{ mm}$$

$$m_t = 173.5 \pm 1.5_{\text{stat}} \pm 1.3_{\text{syst}} \pm 2.6_{p_T(t)} \text{ GeV}$$





○ Kinematic Endpoint Eur.Phys.J.C(2013)73:2494

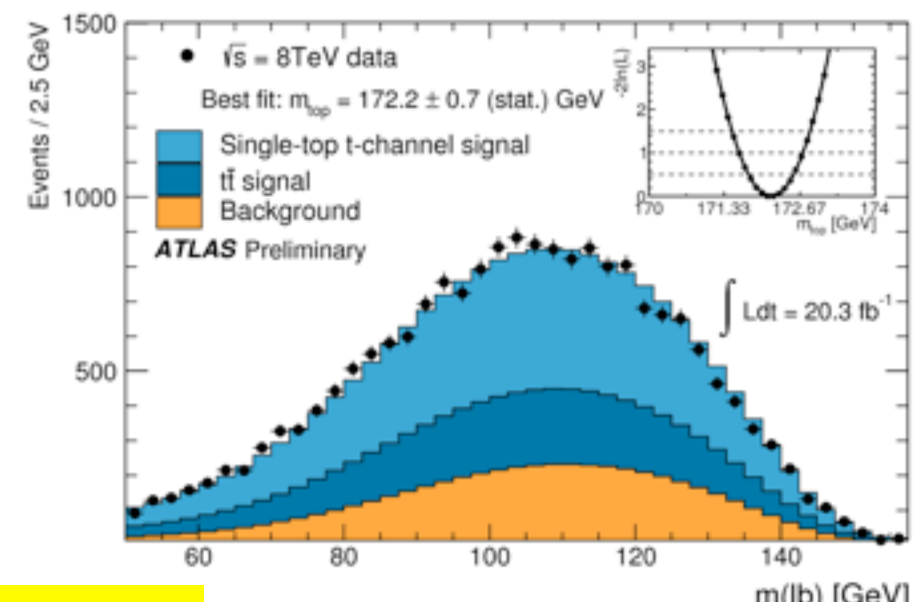


$$m_t = 173.9 \pm 0.9(\text{stat})^{+1.7}_{-2.1}(\text{syst}) \text{ GeV}$$

○ t-channel single top ATLAS-CONF-2014-055

Template fit of lepton-b-jet mass

$$m_t = 172.2 \pm 0.7(\text{stat}) \pm 2.0(\text{syst}) \text{ GeV}$$



→ Standard methodと異なるSystematics

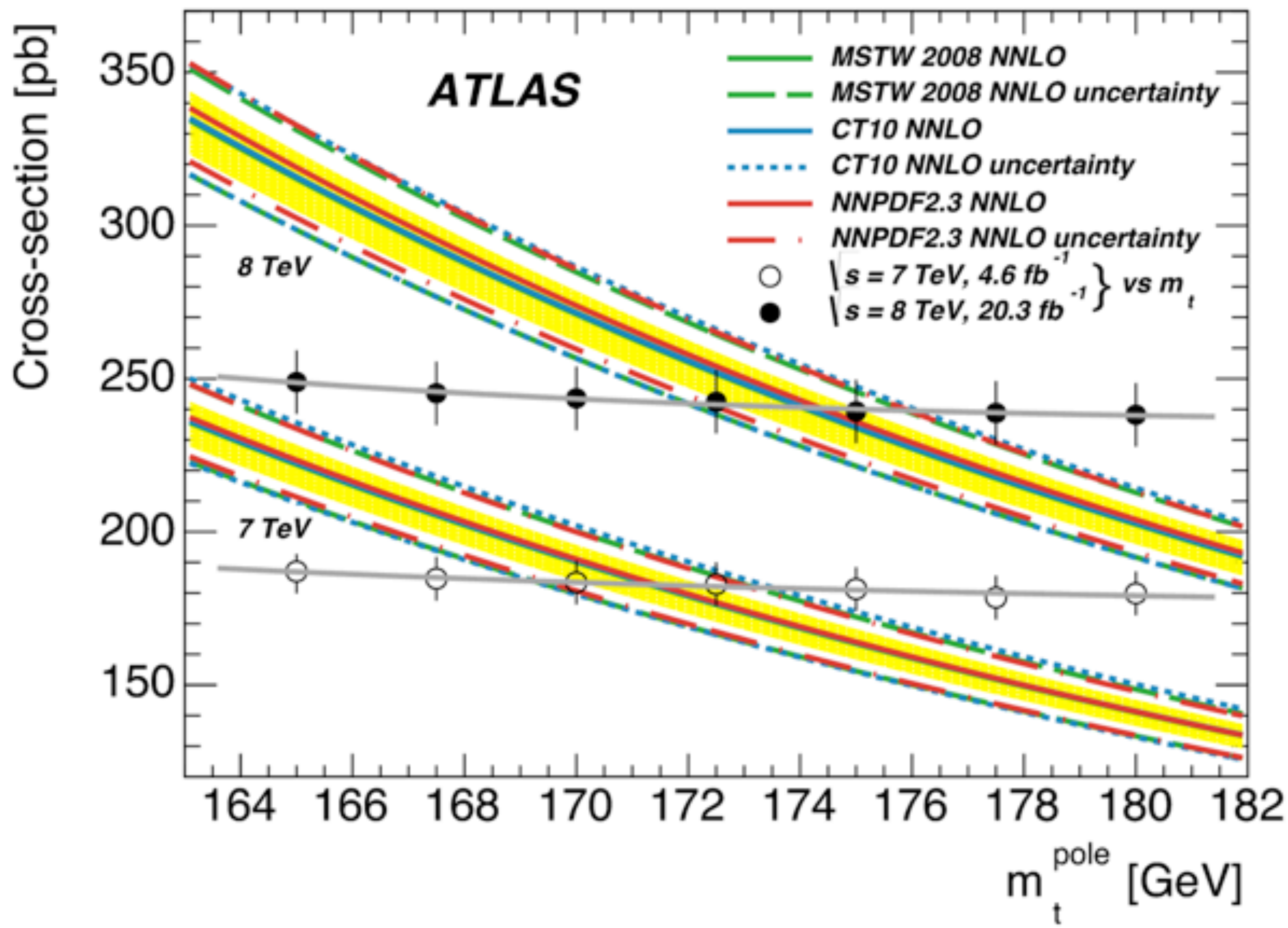
Top mass : pole mass from σ_{tt}

EPJ C74 (2014) 3109

arXiv:1303.6254

$$\sigma(m_t) = \sigma(m_{\rm ref}) \left(\frac{m_{\rm ref}}{m_t}\right)^4 \left[1 + a_1 \left(\frac{m_t - m_{\rm ref}}{m_{\rm ref}}\right) + a_2 \left(\frac{m_t - m_{\rm ref}}{m_{\rm ref}}\right)^2\right]$$

$m_t^{\rm ref} = 172.5\ {\rm GeV}$



$m_t^{\rm pole} = 171.4 \pm 2.6\ {\rm GeV}$ (7TeV)

$m_t^{\rm pole} = 174.1 \pm 2.6\ {\rm GeV}$ (8TeV)

$m_t^{\rm pole} = 172.9^{+2.6}_{-2.6}\ {\rm GeV}$ (combined)

Top mass : pole mass with ttbar+1 jet

arXiv:1507.01769

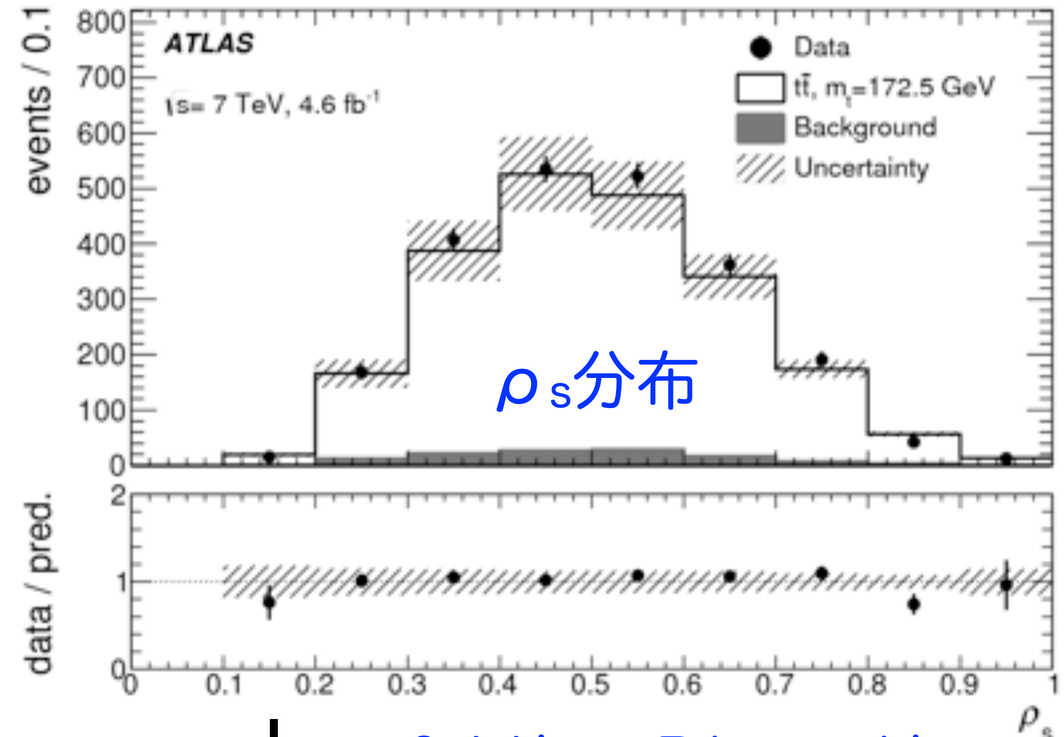
○ Differential cross sectionによる間接的なpole mass測定

Eur. Phys. J C73 (2013) 2438, arXiv:1303.6415で紹介

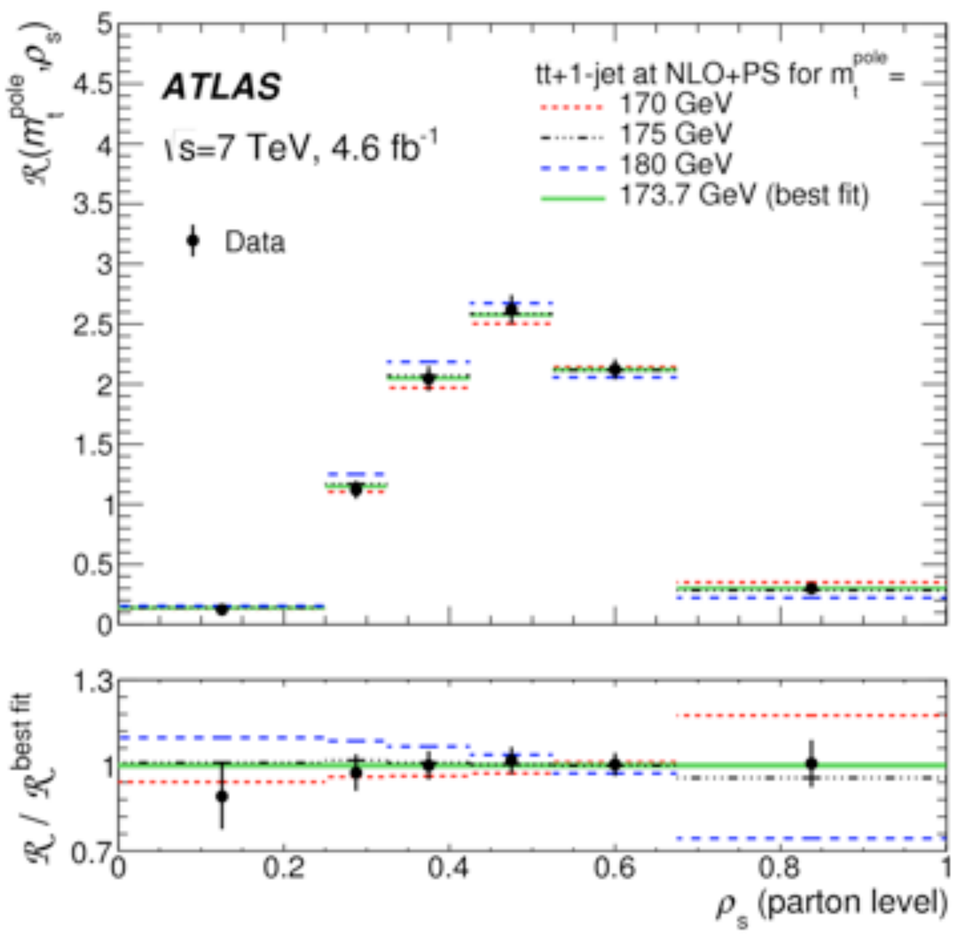
gluon radiationがtop quark massに依存することを利用

$$\mathcal{R}(m_t^{pole}, \rho_s) = \frac{1}{\sigma_{t\bar{t}+1\text{jet}}} \frac{d\sigma_{t\bar{t}+1\text{jet}}}{d\rho_s}(m_t^{pole}, \rho_s)$$

$$\rho_s = \frac{2m_0}{\sqrt{s_{t\bar{t}j}}} \qquad m_0 = 170 \text{ GeV}$$ (mt位の任意量)



↓ unfoldしてR(mt, ρ)に

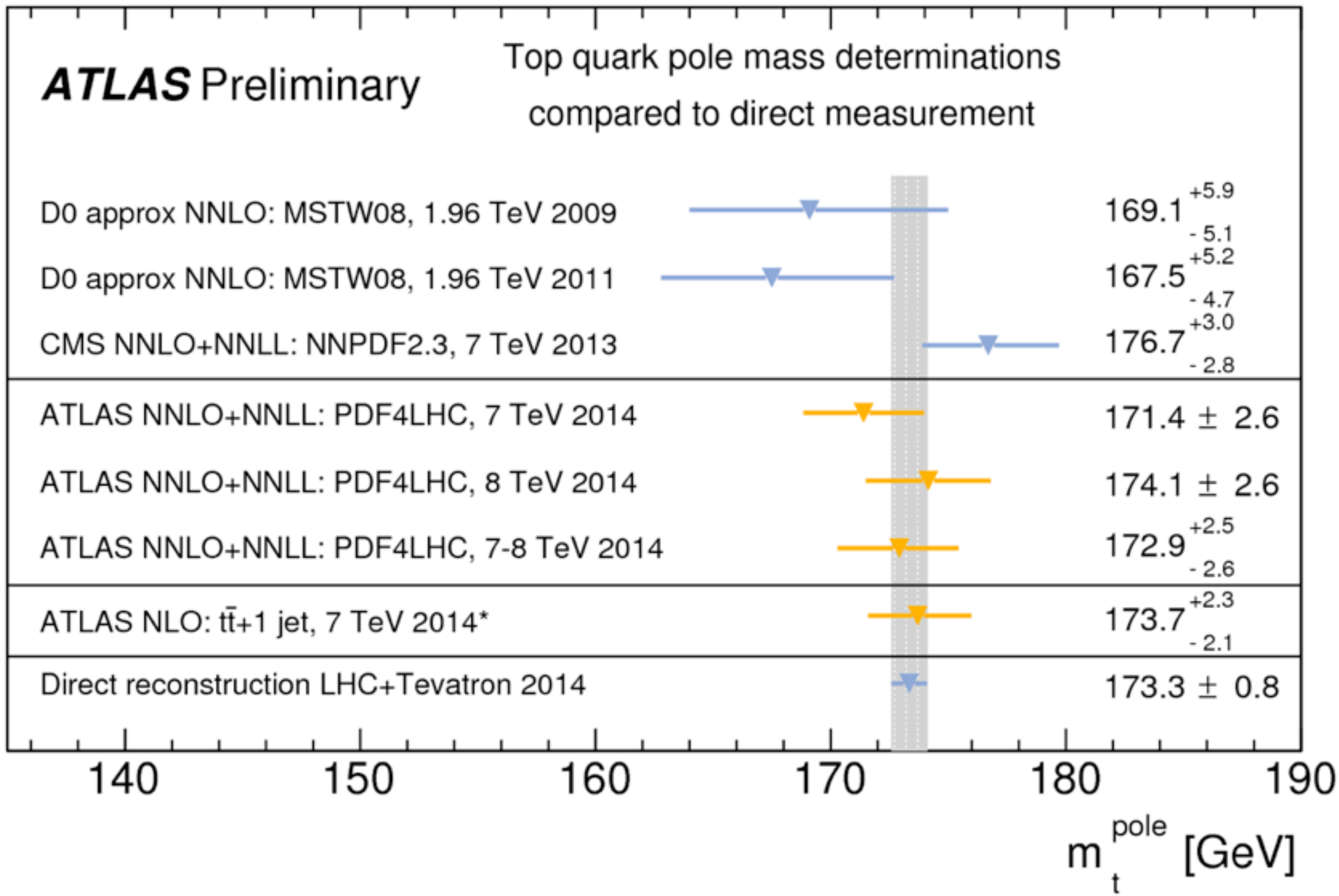


○ single lepton終状態による解析

- lepton, E_T^{miss}からleptonic topのWを再構成
- WのKinematics条件からhadronic top の2jetを選択
- $m_t^{\text{lep}} - m_t^{\text{had}}$ が最小となるb-jetとWの組を決定
- ttbar以外のjetは、pT>50GeVのleading jet
- ρ_s分布をunfoldしてχ^2 fitで質量を決定

$$m_t^{\text{pole}} = 173.7 \pm 1.5(\text{stat.}) \pm 1.4(\text{syst.}) \ ^{+1.0}_{-0.5}(\text{theo.}) \text{ GeV}$$

Top mass：pole mass測定のまとめ

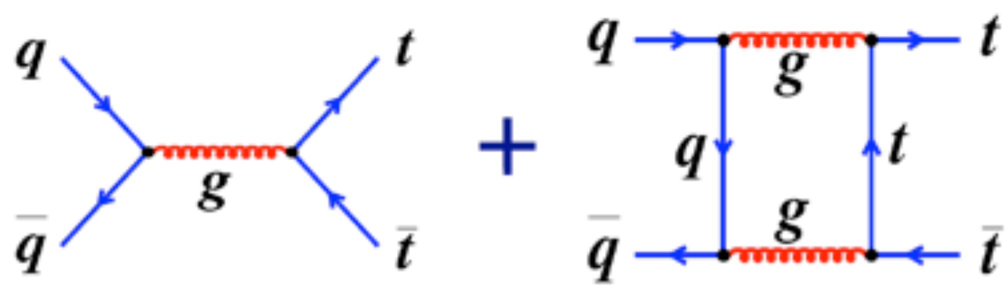


Top quark property

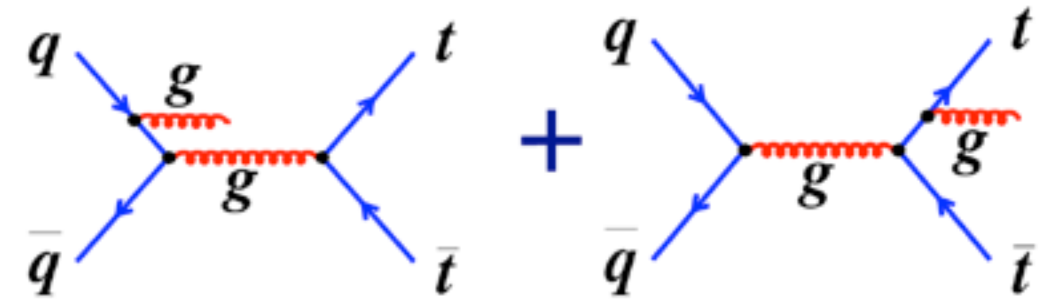
Charge asymmetry

SMによるasymmetry

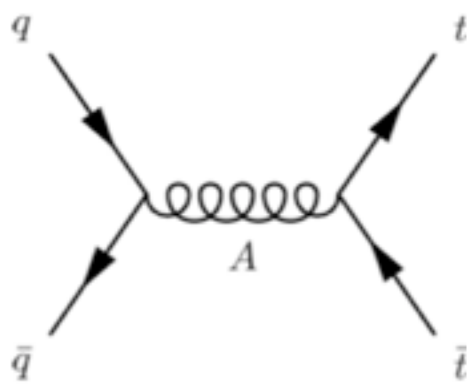
treeとboxのinterference

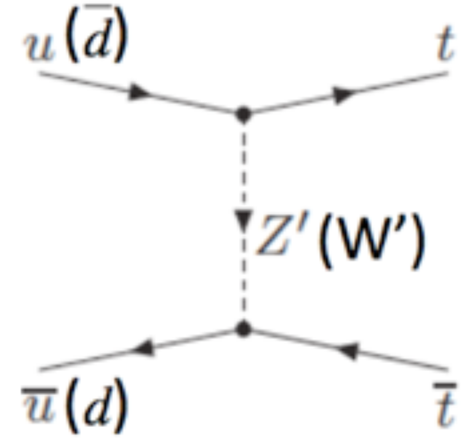


ISRとFSRのinterference

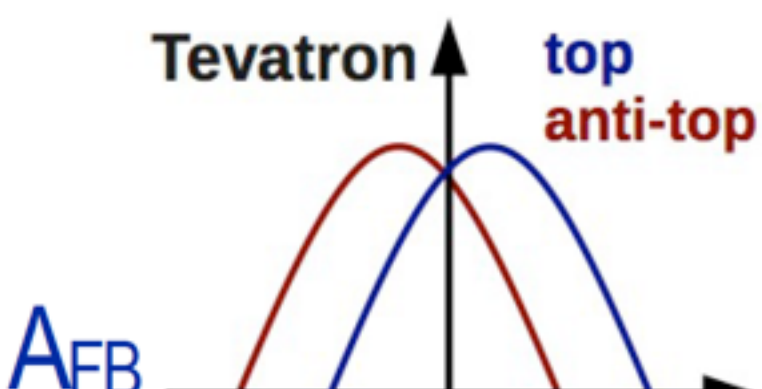


+新物理で標準模型からのズレ？



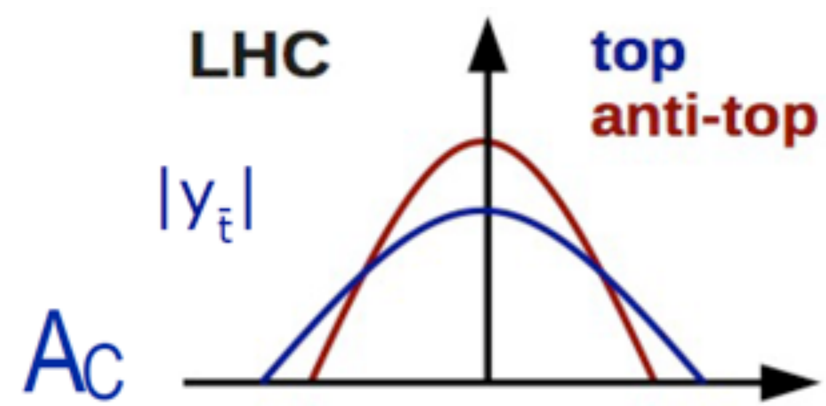


ppbarかppで見え方が異なる



$$A_{FB}^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

$$\Delta y_{t\bar{t}} = y_t - y_{\bar{t}}$$



$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

$$\Delta|y| = |y_t| - |y_{\bar{t}}|$$

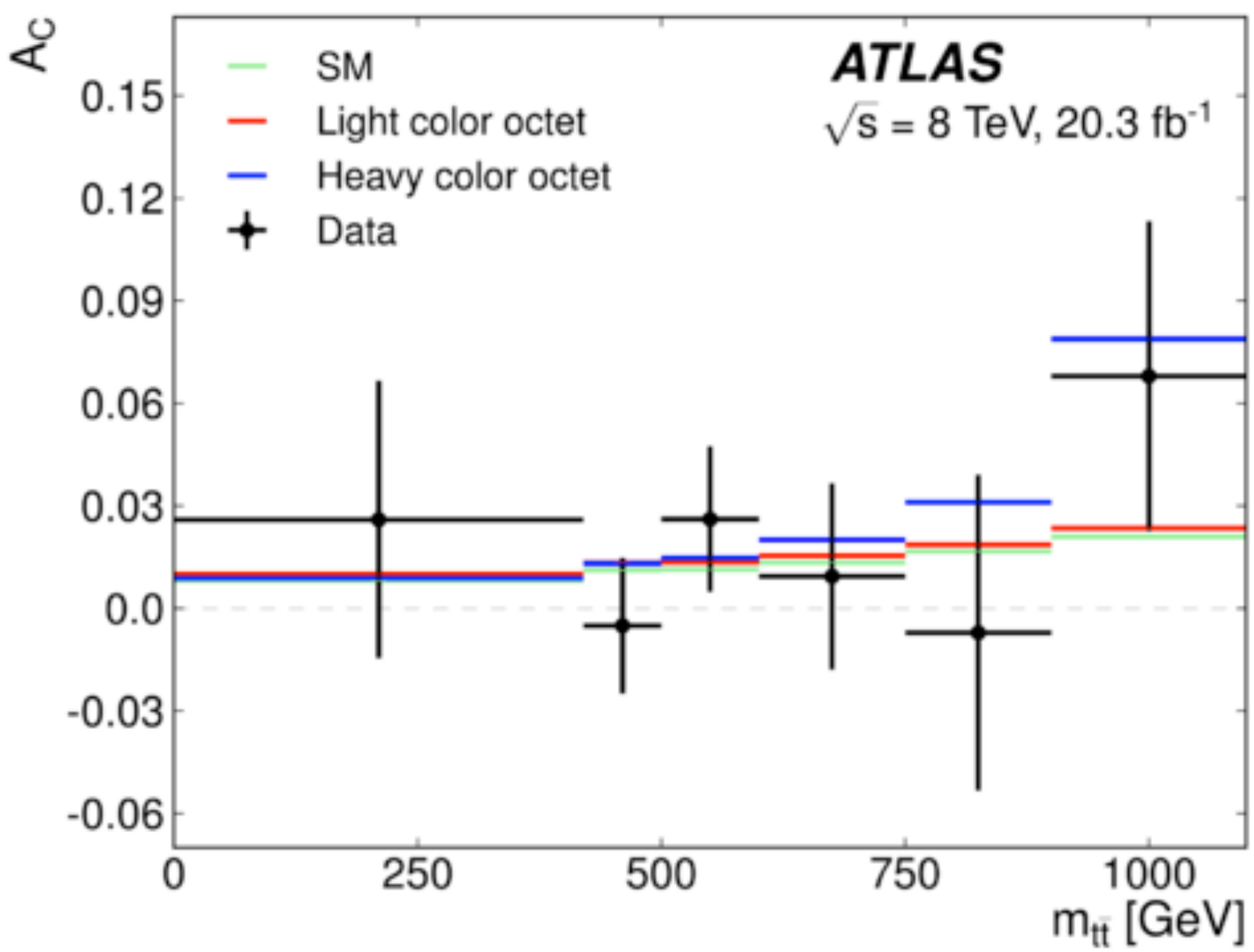
Charge asymmetry

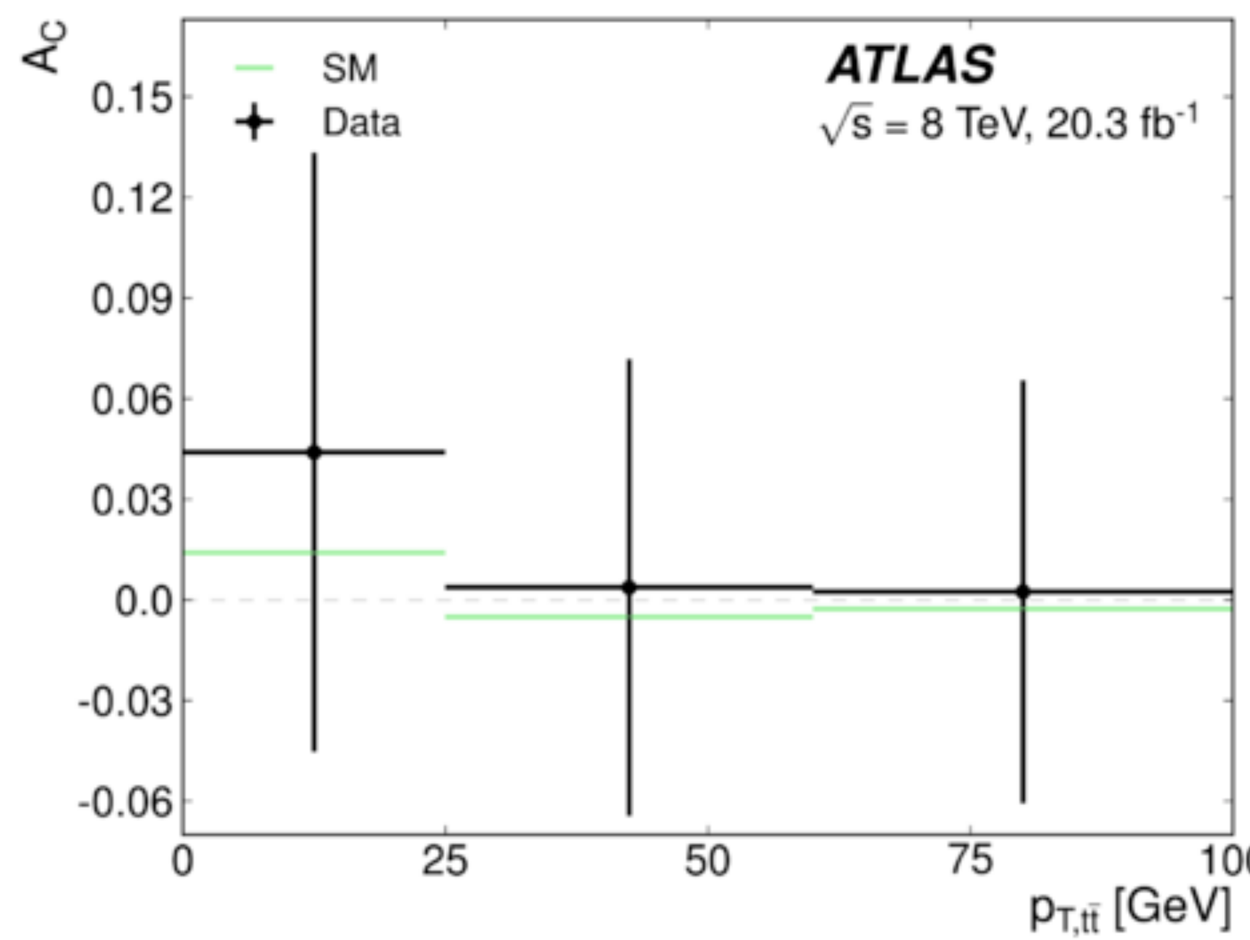
ttbar事象をkinematical fitを用いて再構成

Δ|y|分布をparton levelにunfold

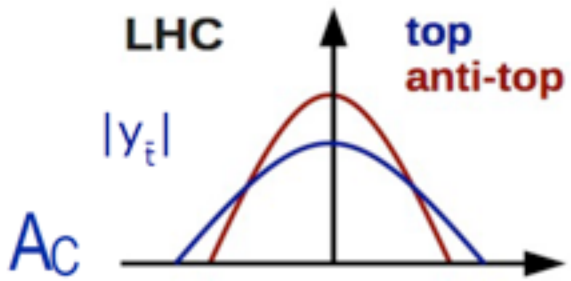
Inclusive測定の他に, m_{tt}, $p_{T,tt}$,などの関数でA_Cの測定

$$A_C = 0.009 \pm 0.005 \text{ (stat.+syst.)}$$





Charge asymmetry



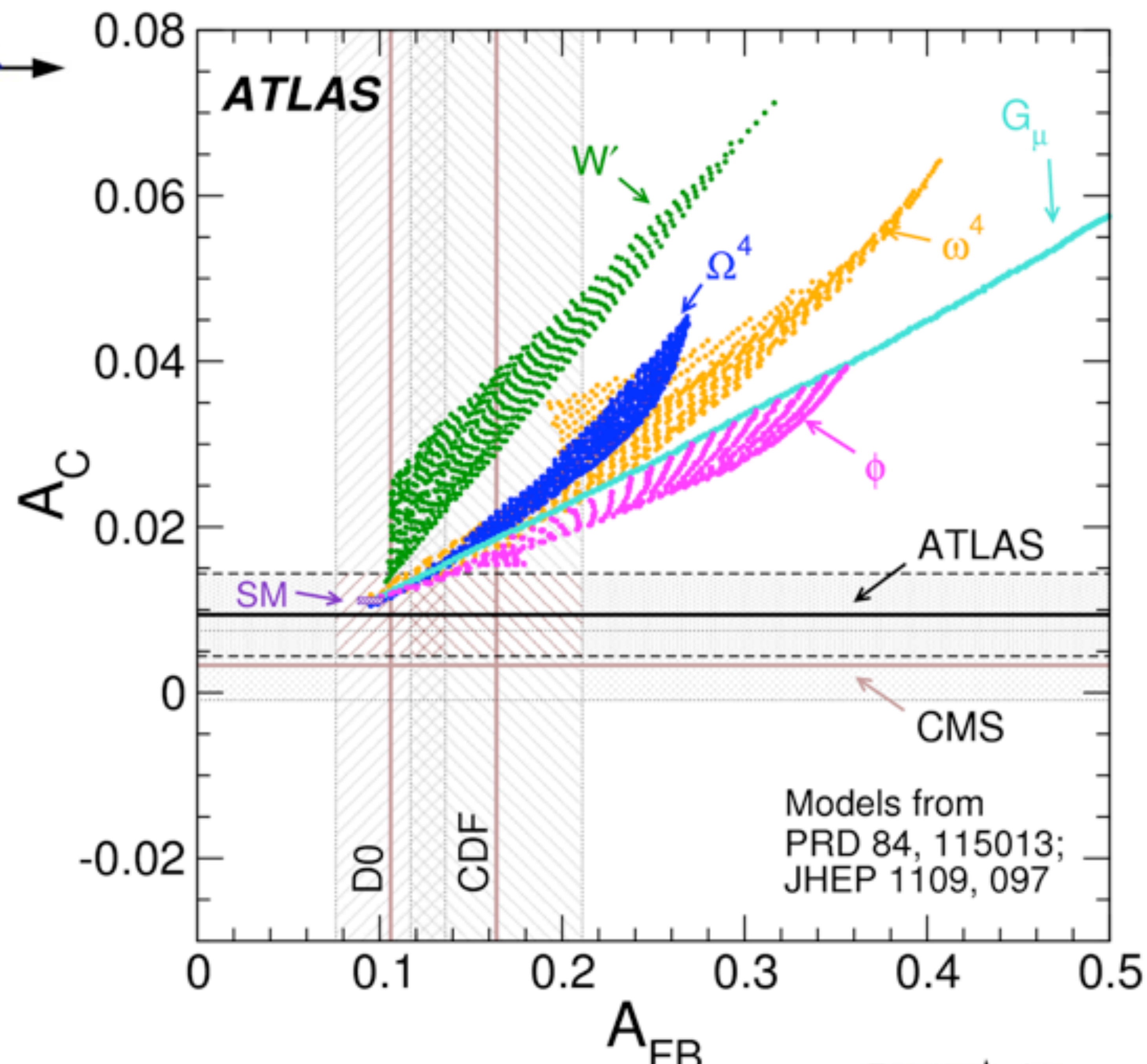
Z': Flavor violating Z' exchanged in t-channel in $u\bar{u} \to t\bar{t}$ and with right-handed Z'tu couplings

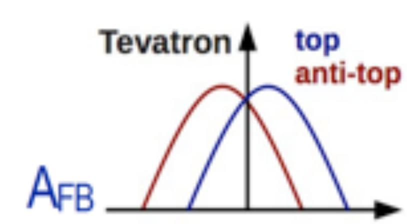
W': W' boson with right-handed couplings exchanged in t-channel in $d\bar{d} \to t\bar{t}$

Ω^4: Color-sextet scalar with right-handed flavor violating tu-couplings and exchanged in u-channel

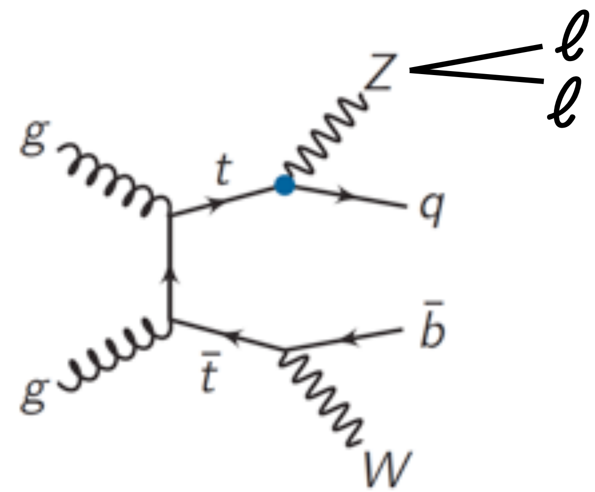
ω^4: Color triplet with flavor violating tu-couplings, right-handed, exchanged in u-channel in $u\bar{u} \to t\bar{t}$

$\mathcal{G}_\mu$: Axigluon, color octet vector with axial couplings



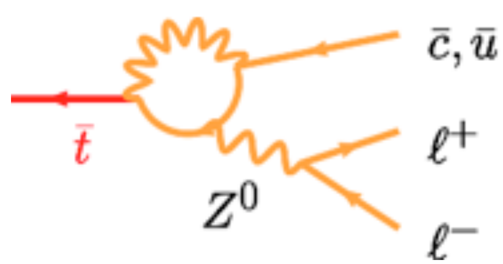


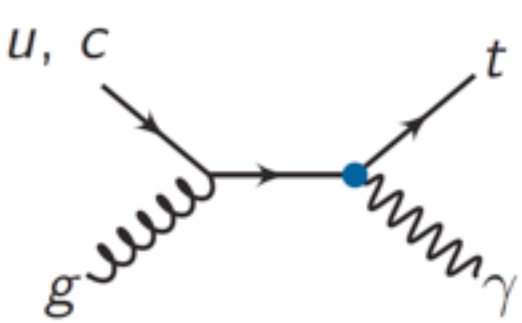
Flavor changing neutral current

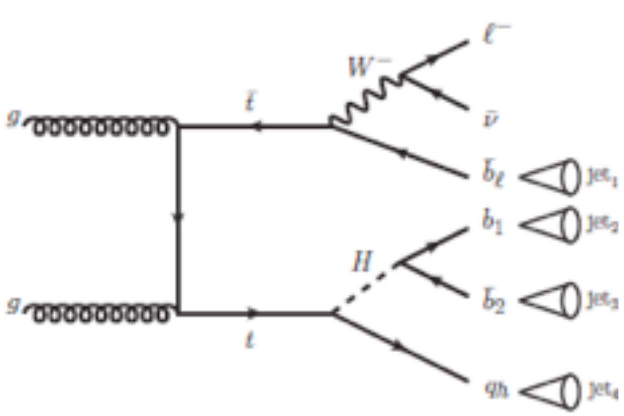


arXiv:1311.2028

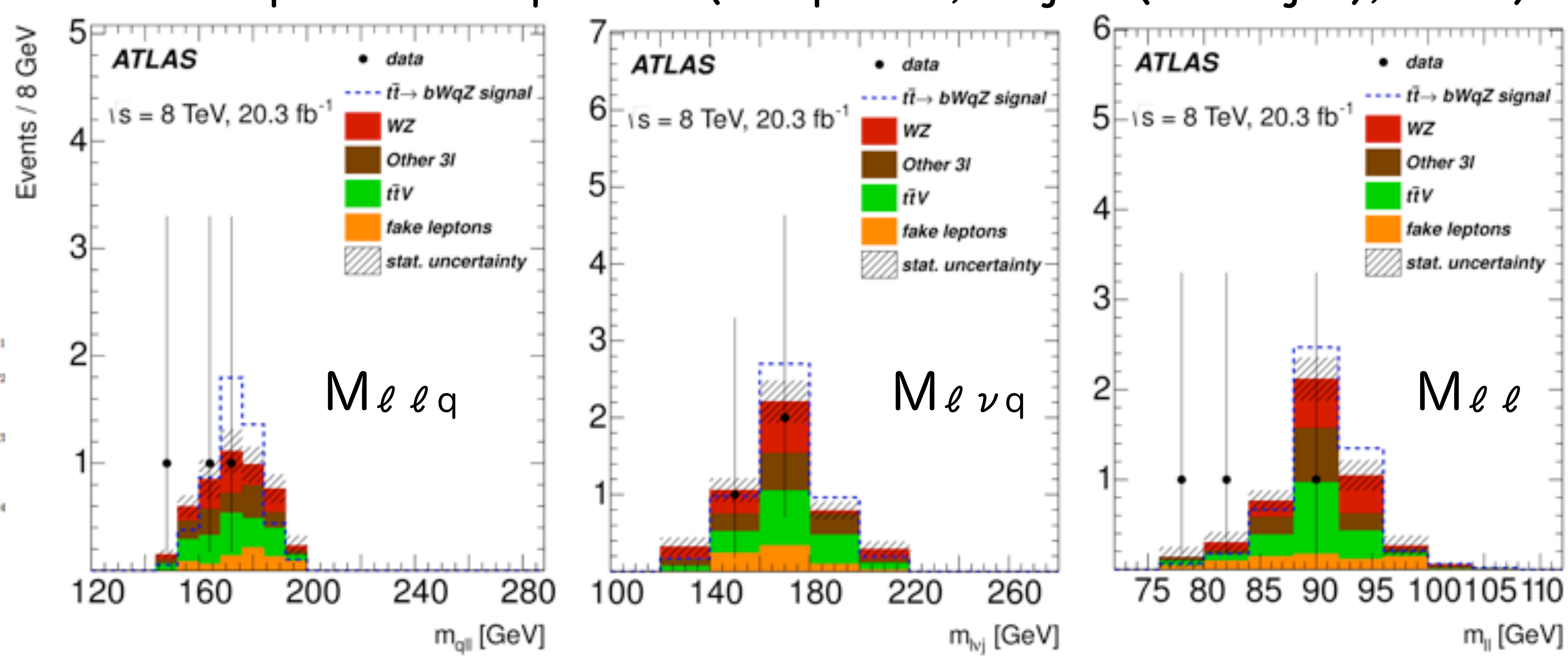
Process	SM	2HDM(FV)	2HDM(FC)	MSSM	RPV	RS
$t \to Zu$	7×10^{-17}	–	–	$\leq 10^{-7}$	$\leq 10^{-6}$	–
$t \to Zc$	1×10^{-14}	$\leq 10^{-6}$	$\leq 10^{-10}$	$\leq 10^{-7}$	$\leq 10^{-6}$	$\leq 10^{-5}$
$t \to gu$	4×10^{-14}	–	–	$\leq 10^{-7}$	$\leq 10^{-6}$	–
$t \to gc$	5×10^{-12}	$\leq 10^{-4}$	$\leq 10^{-8}$	$\leq 10^{-7}$	$\leq 10^{-6}$	$\leq 10^{-10}$
$t \to \gamma u$	4×10^{-16}	–	–	$\leq 10^{-8}$	$\leq 10^{-9}$	–
$t \to \gamma c$	5×10^{-14}	$\leq 10^{-7}$	$\leq 10^{-9}$	$\leq 10^{-8}$	$\leq 10^{-9}$	$\leq 10^{-9}$
$t \to hu$	2×10^{-17}	6×10^{-6}	–	$\leq 10^{-5}$	$\leq 10^{-9}$	–
$t \to hc$	3×10^{-15}	2×10^{-3}	$\leq 10^{-5}$	$\leq 10^{-5}$	$\leq 10^{-9}$	$\leq 10^{-4}$







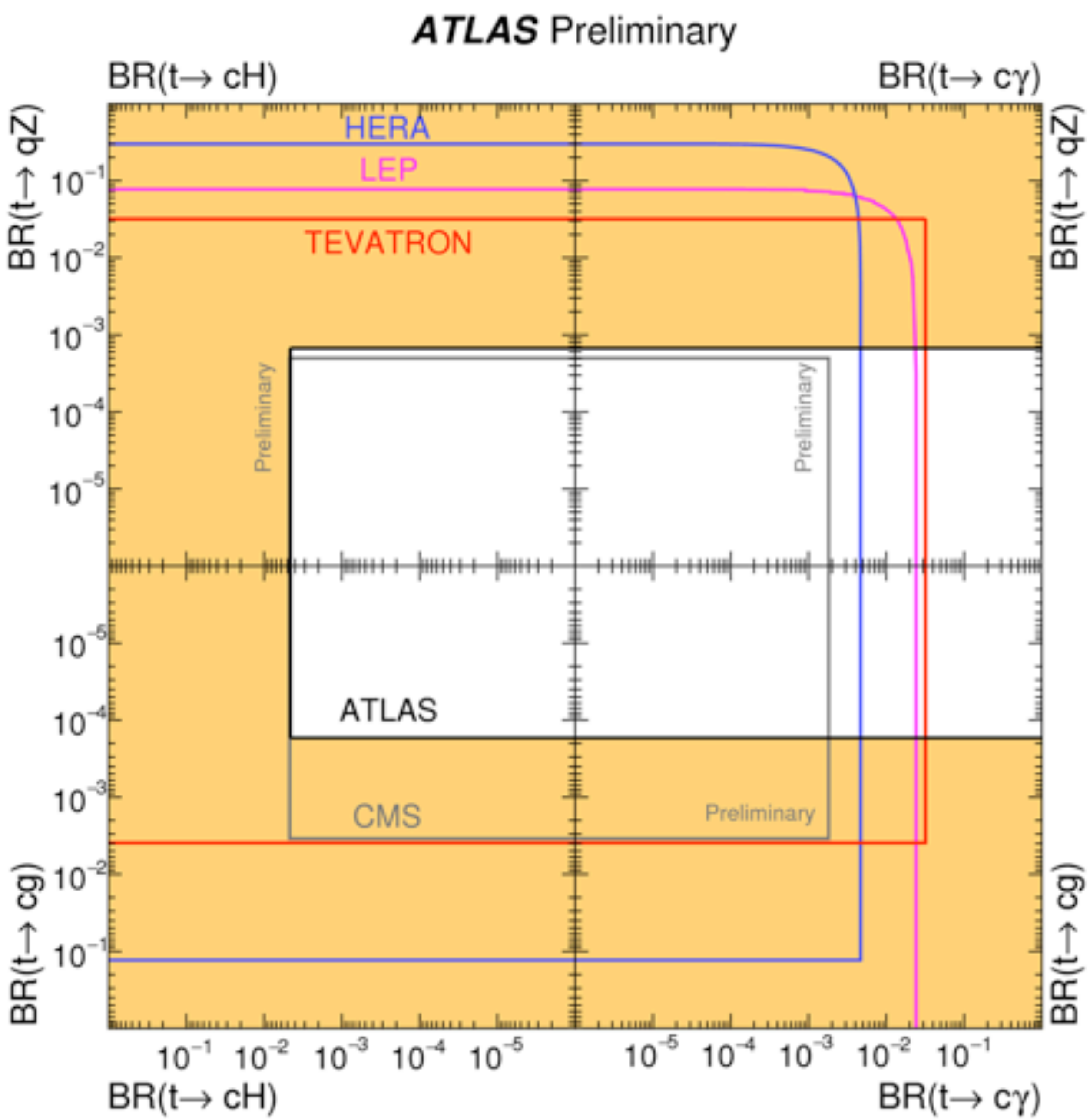
tt→ZqWb→ℓℓq ℓνb (3 leptons, ≧2jets(≧1 b-jet), MET)



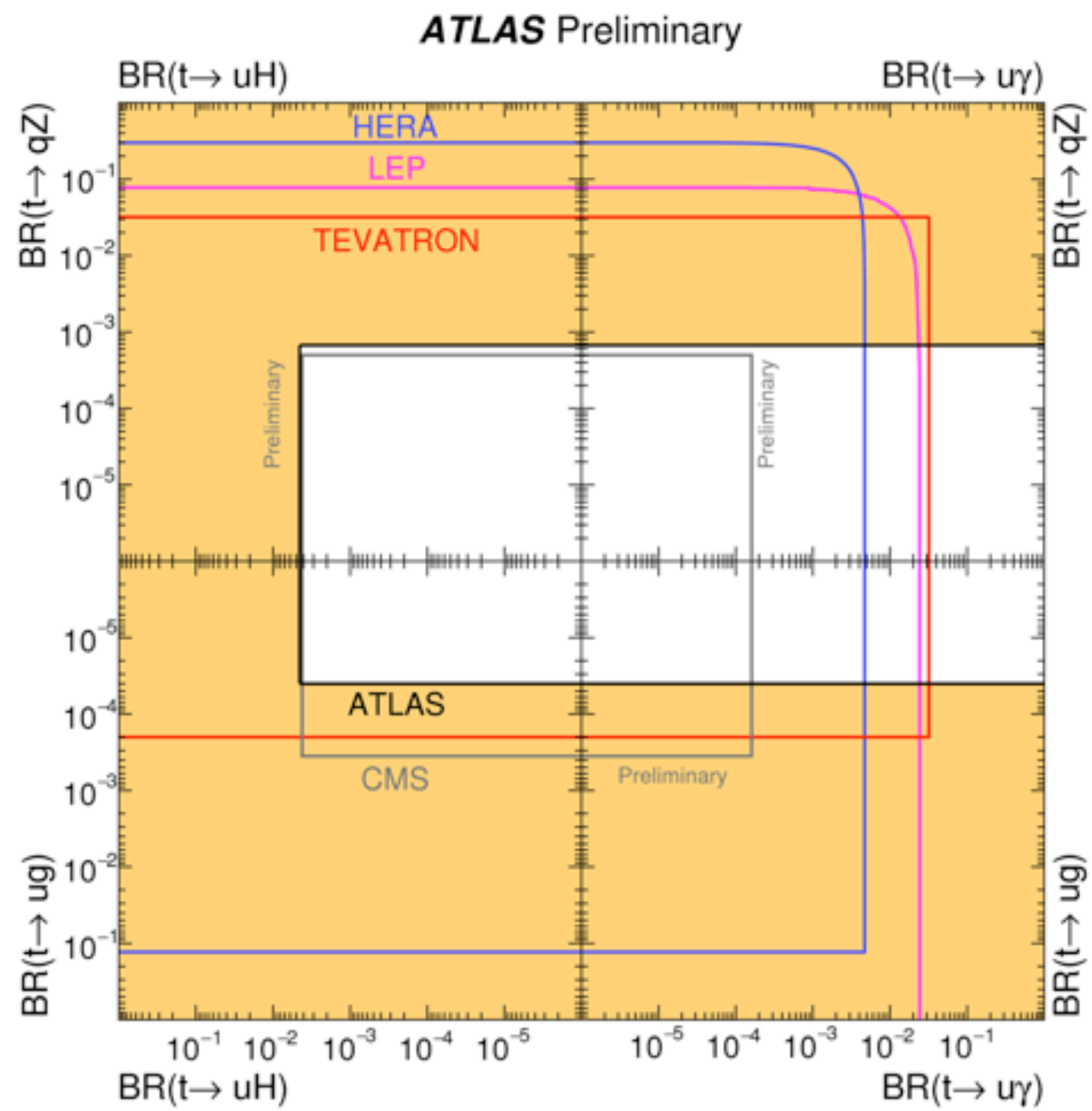
$$\mathrm{BR}(t \to Zq) < 7 \times 10^{-4}$$ @95%C.L.

Flavor changing neutral current

t→cX



t→uX



$\mathcal{B}(t \to Zq)$	19.5 fb^{-1} @ 8 TeV	300 fb^{-1} @ 14 TeV	3000 fb^{-1} @ 14 TeV
Exp. bkg. yield	3.2	26.8	268
Expected limit	$< 0.10\%$	$< 0.027\%$	$< 0.010\%$
1 σ range	0.06 – 0.13%	0.018 – 0.038%	0.007 – 0.014%
2 σ range	0.05 – 0.20%	0.013 – 0.051%	0.005 – 0.020%

CMS-PAS-FTR-13-016

その他のTop quark properties

○ Top quark charge JHEP11(2013)031

$$q_t = 0.64 \pm 0.02 \pm 0.08$$

○ Top polarization and spin correlation

Phys. Rev. Lett 111, 232002 (2013) Phys. Rev. Lett 114, 142001 (2015)

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_1 d\cos\theta_2} = \frac{1}{4}(1 + \alpha_1 P_1 \cos\theta_1 + \alpha_2 P_2 \cos\theta_2 - C\cos\theta_1\cos\theta_2)$$

○ Wtb coupling

JHEP06(2012)088 JHEP10(2013)167 arXiv:1410.1154

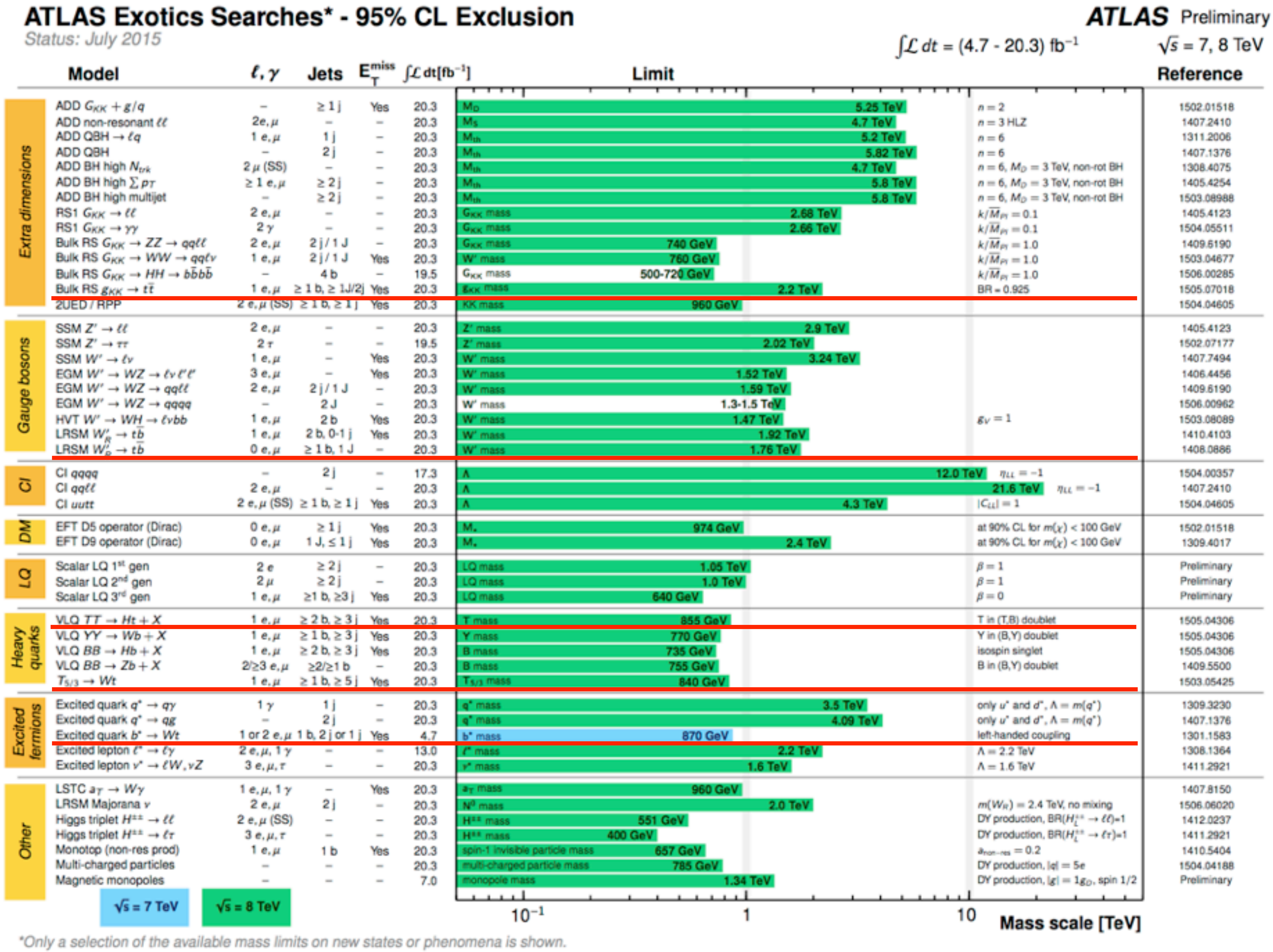
ATLAS-CONF-2013-032

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}(V_L P_L + V_R P_R)\,tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{m_W}(g_L P_L + g_R P_R)\,tW_{\mu}^{-} + \text{h.c.}$$

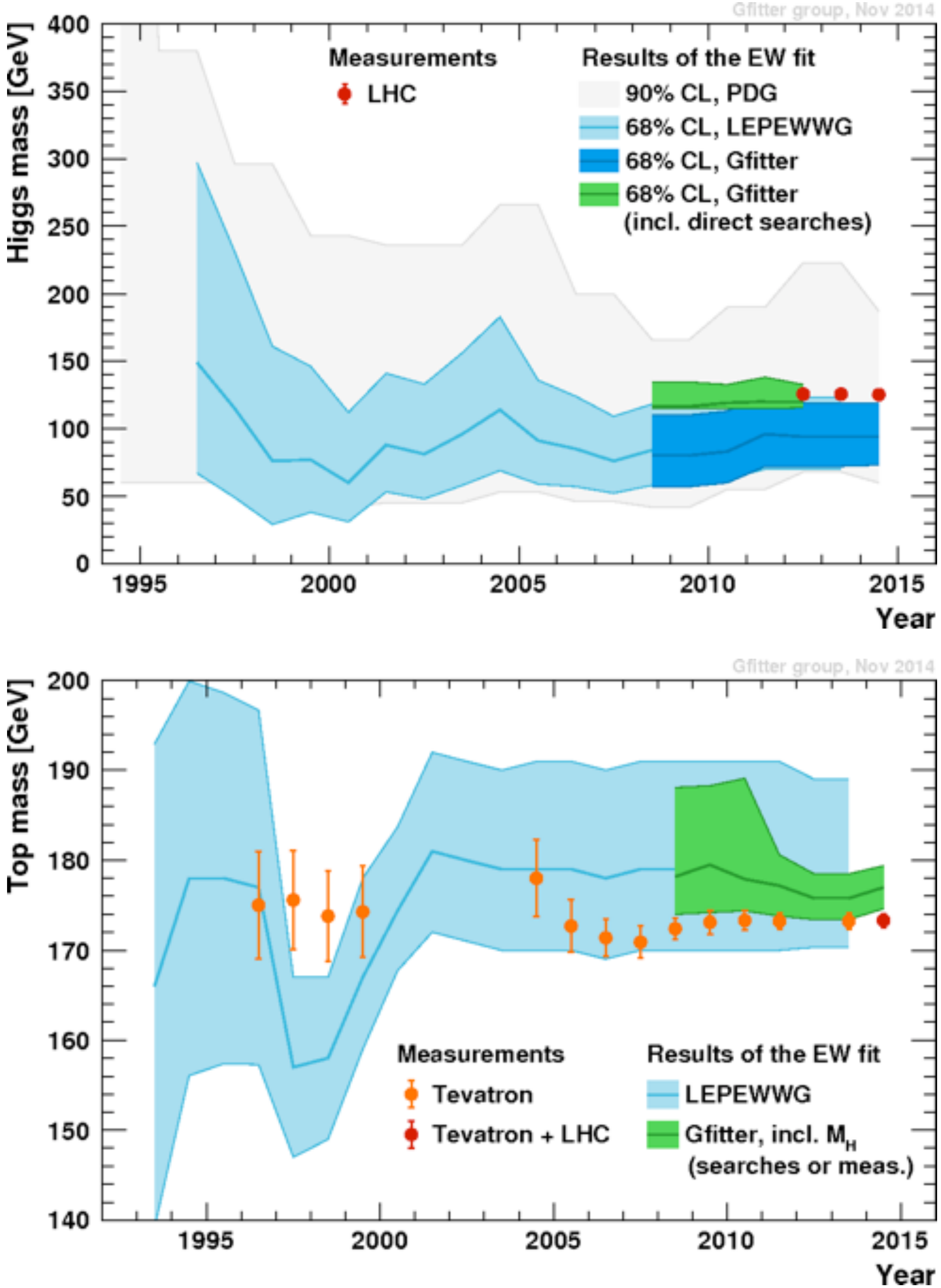
○ ...

Consistent with SM prediction

New physics search with top quark



backup

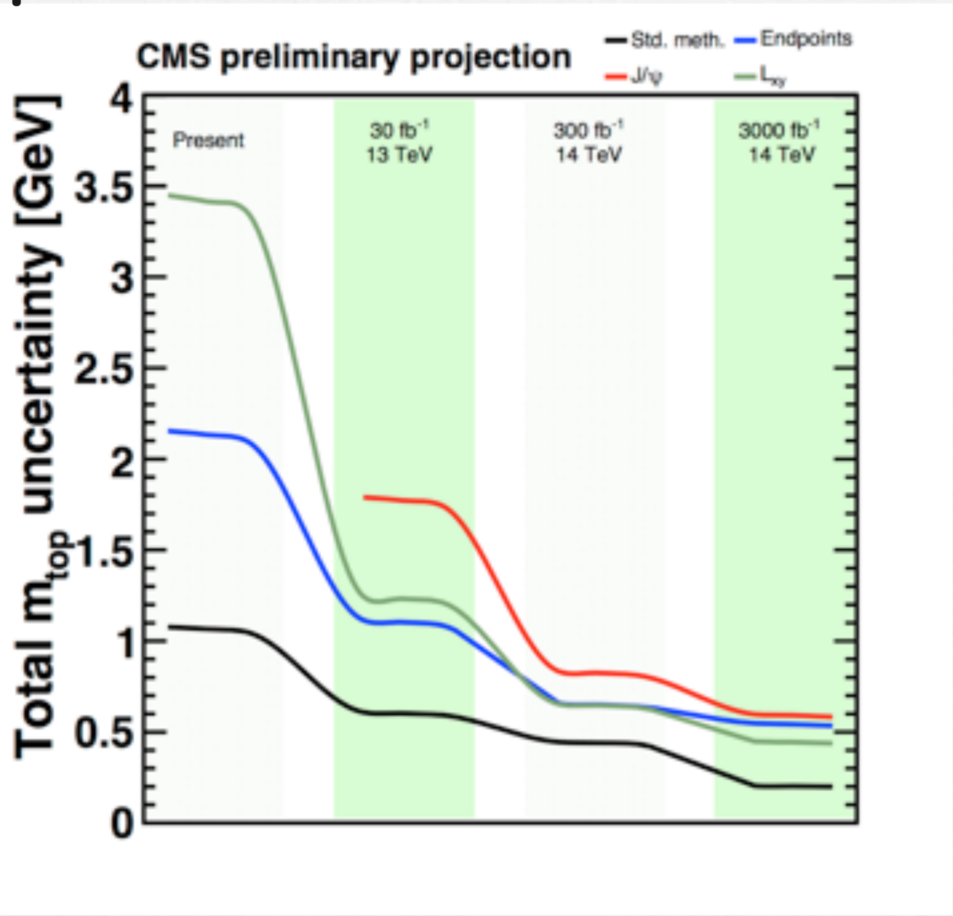

Gfitter group, Nov 2014
Higgs mass [GeV]
Year
Measurements
LHC
Results of the EW fit
90% CL, PDG
68% CL, LEPEWWG
68% CL, Gfitter
68% CL, Gfitter
(incl. direct searches)
Gfitter group, Nov 2014
Top mass [GeV]
Year
Measurements
Tevatron
Tevatron + LHC
Results of the EW fit
LEPEWWG
Gfitter, incl. M_H
(searches or meas.)

Run2とそれ以降に向けて： perspective

○ Cross-section

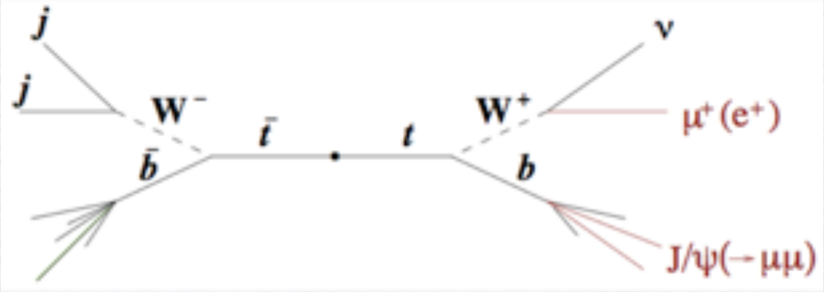
√s=13,14TeVの新しい点、Differential cross-section、light stop search

○ Top mass CMS-PAS-FTR-13-017



様々な手法で質量測定

Standard, Endpoint, L_{xy}, J/ψ method, ...



ATLASとCMSの良い解析手法を採用

Full NLO tools

○ 新物理 (FCNC) CMS-PAS-FTR-13-016

$\mathcal{B}(t \to Zq)$	19.5 fb^{-1} @ 8 TeV	300 fb^{-1} @ 14 TeV	3000 fb^{-1} @ 14 TeV
Exp. bkg. yield	3.2	26.8	268
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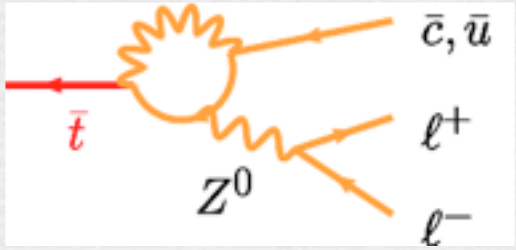
2 σ range	0.05 – 0.20%	0.013 – 0.051%	0.005 – 0.020%



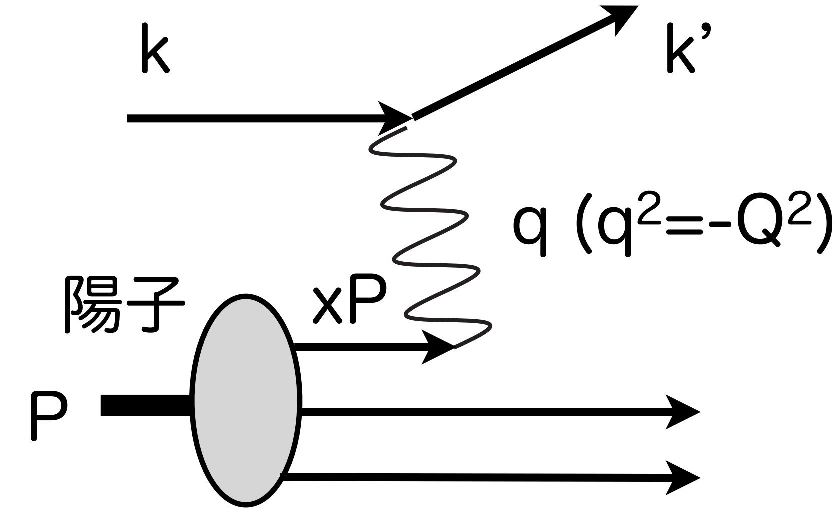
SM:10^{-12}~10^{-17}

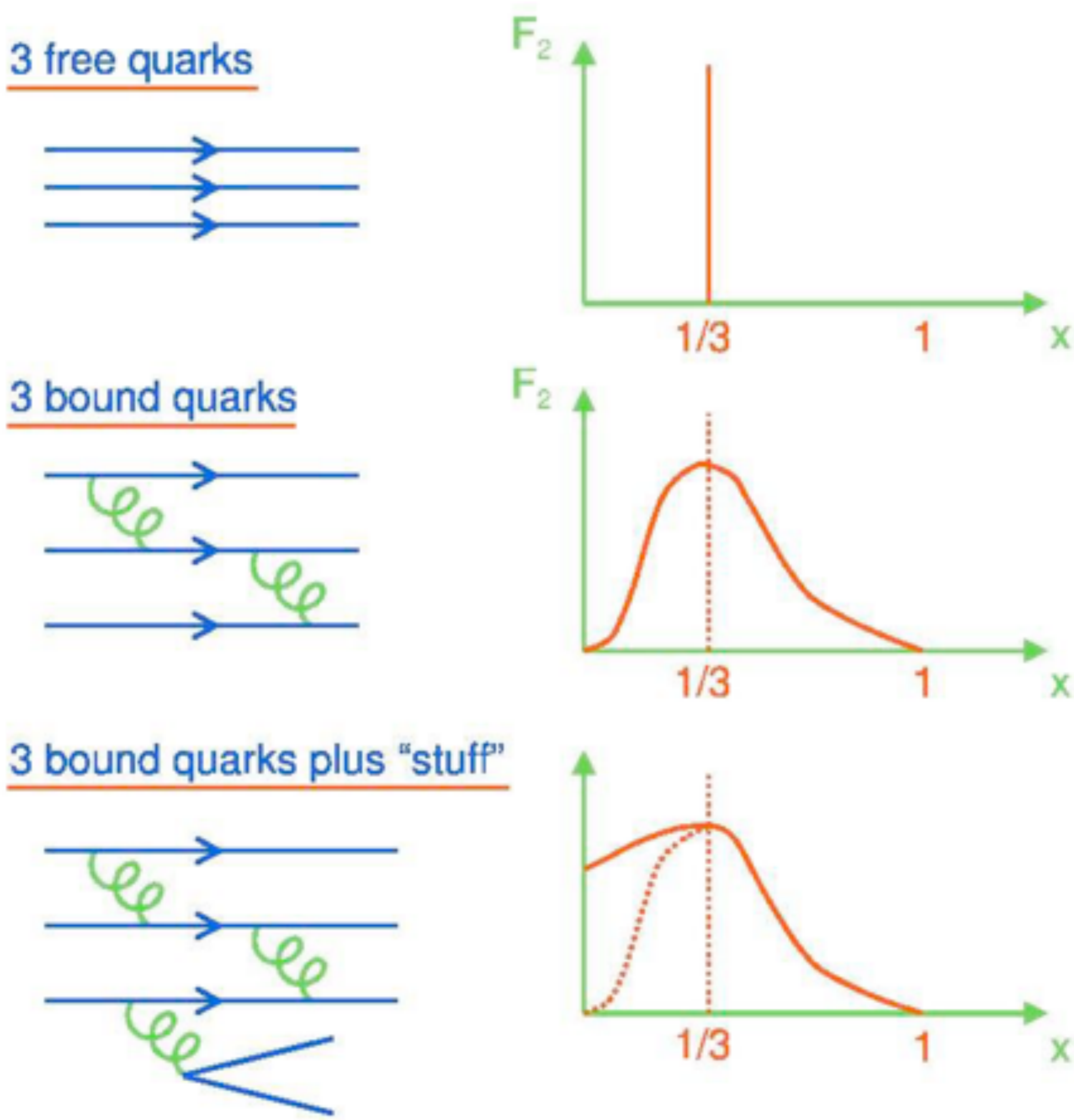
BSM: <10^{-4}

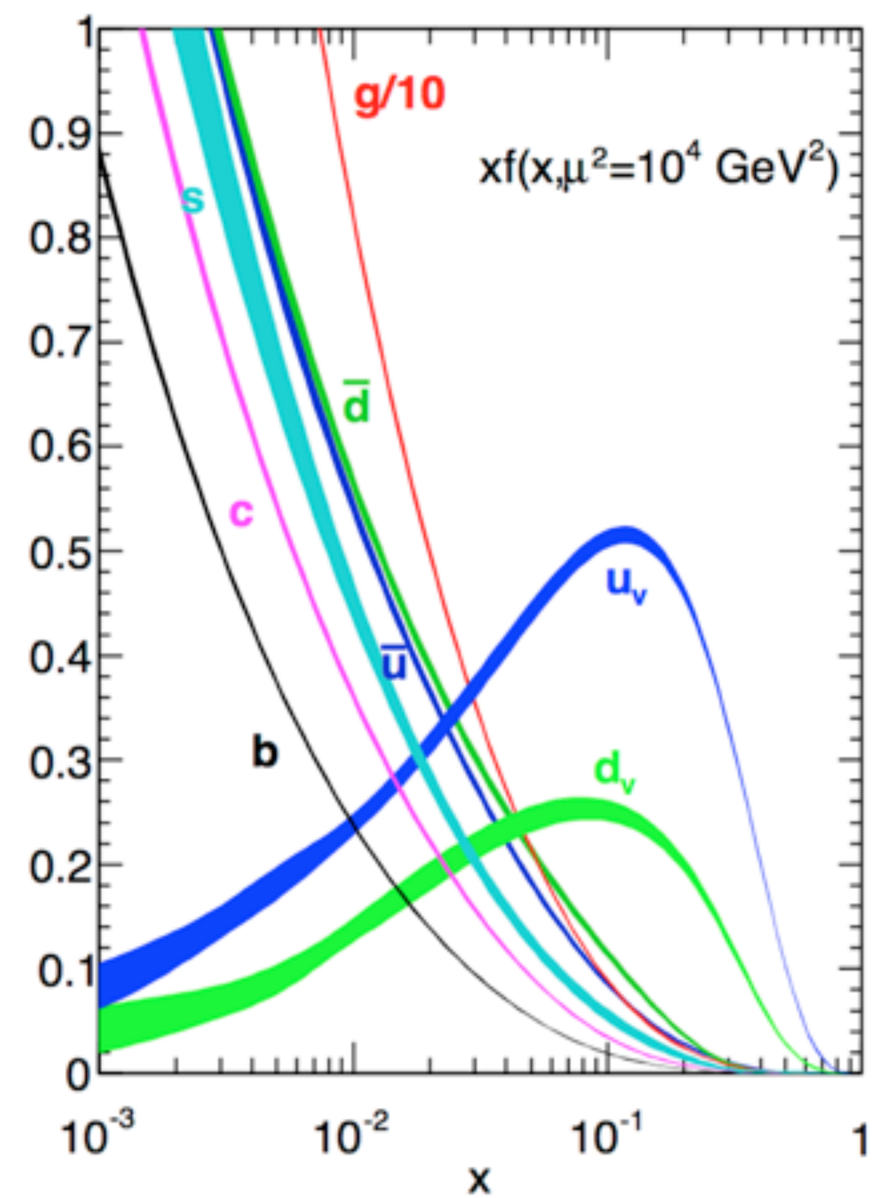
PDF: Parton Distribution Function

Hadron is non-perturbative object
→ PDF is obtained by fit of experimental data

Based on n-th fixed order calculation







$$y = \frac{1}{2}\ln\left[(E+p_z)/(E-p_z)\right] = \frac{1}{2}\ln\left(x_1/x_2\right)$$

Top quark production

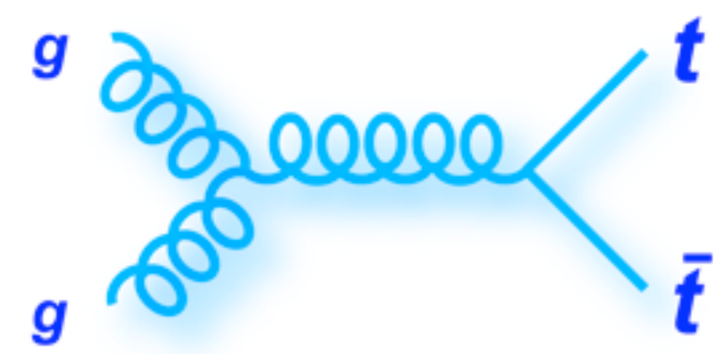
○ Top quark pair production via QCD

PRL 110 252004 (2013), arXiv:1303.6254

$$\sigma_{t\bar{t}} = 177.3^{+10.1}_{-10.8}\ \text{pb} \quad \text{(7TeV)}$$

$$\sigma_{t\bar{t}} = 252.9^{+13.3}_{-14.5}\ \text{pb} \quad \text{(8TeV)}$$

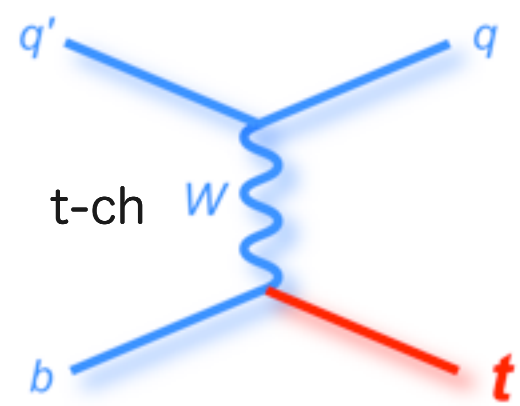
@NNLO+NNLL (m_t=172.5GeV) top++ 2.0

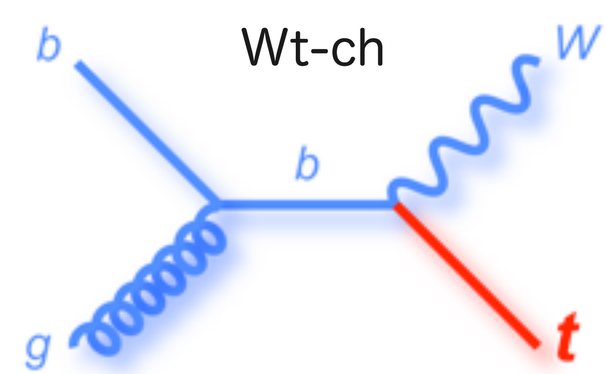


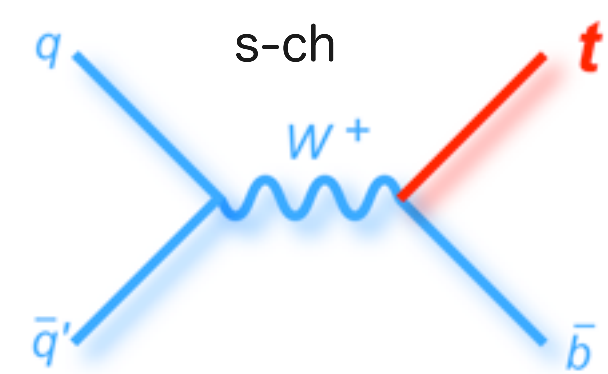
→ ~6.4M top quark pairs in LHC Run 1

○ Single top production via EW

Phys. Rev. D 83 (2011) 091503, arXiv:1103.2792 [hep-ph].
Phys. Rev. D 82 (2010) 054018, arXiv:1005.4451 [hep-ph].
Phys. Rev. D 81 (2010) 054028, arXiv:1001.5034 [hep-ph].







$$\sigma(\sqrt{s} = 7\text{TeV}) = \ 64.6 \pm 2.4\ \text{pb} \qquad 15.7 \pm 1.1\ \text{pb} \qquad 4.6 \pm 0.2\ \text{pb}$$

$$\sigma(\sqrt{s} = 8\text{TeV}) = \ 87.8 \pm 3.4\ \text{pb} \qquad 22.4 \pm 1.5\ \text{pb} \qquad 5.6 \pm 0.2\ \text{pb}$$

@NLO+NNLL (m_t=172.5GeV)

→ ~3M single tops in LHC Run 1