Search for extra dimensions via forward detectors at the LHC

Kimiko Yamashita (Ochanomizu Univ.)

Collaborators:
G. C. Cho and T. Kono (Ochanomizu Univ.),
K. Mawatari (Vrije Universiteit Brussel)

SUSY 2014
July 21st-26th, 2014
Manchester Univ.

Motivation (1/5)

KK gravitons in RS model are searched at the LHC by the ATLAS and the CMS

e.g. ATLAS Collaboration, New J. Phys. 15 (2013) 043007 …

In this talk …

1. Forward detectors at the LHC

   – ATLAS Forward Physics (AFP) project
     C. Royon, etal, (RP220 Collaboration) (2007)
     M. G. Albrow, etal (2009)

   – CMS-TOTEM forward detector scenario
     V. Avati and K. Osterberg (2006)
     O. Kepka and C. Royon (2008)

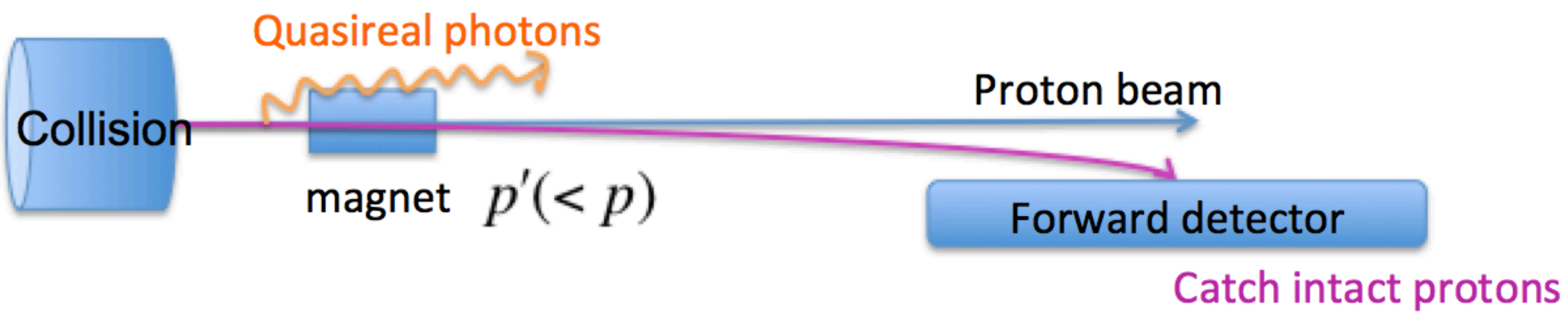
Motivation (2/5)

- A proton emits quasireal photons
  → intact, small-angle scattering
- Forward detector acceptance
  1. ATLAS Forward Physics (AFP) project

     $0.0015 < \xi < 0.15$ where $\xi = \frac{E_\gamma}{E_{beam}}$

  2. CMS-TOTEM forward detector scenario

     $0.0015 < \xi < 0.5$

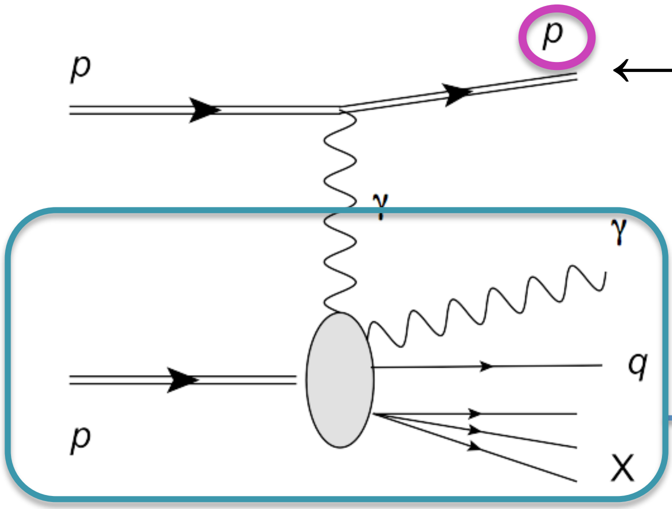


Motivation (3/5)

3. KK graviton search via forward detectors
   – Early work in parton level

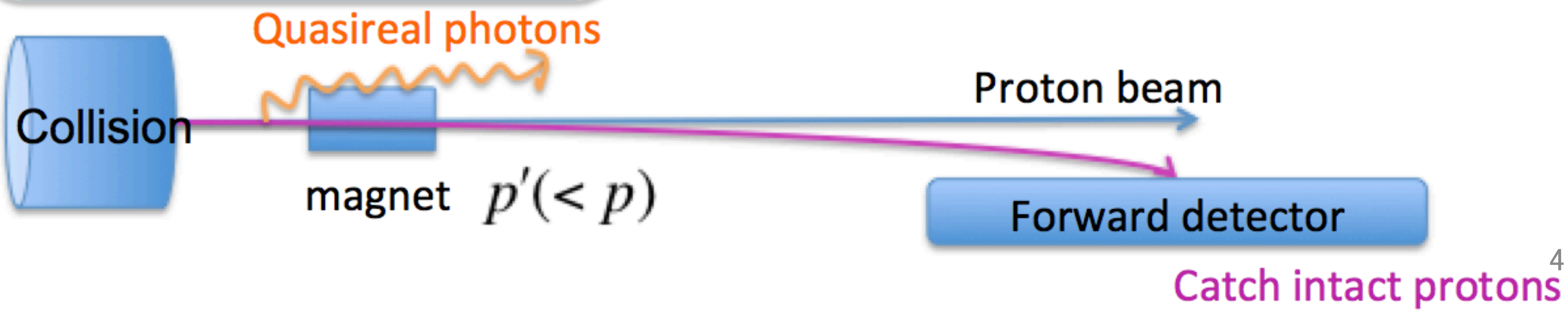
$$pp \to p\gamma p \to p\gamma qX$$

Sahin, etal, Phys.Rev.D88, 095016



← This proton is intact and small-angle scattering because this proton emits quasireal photons

→ Next page



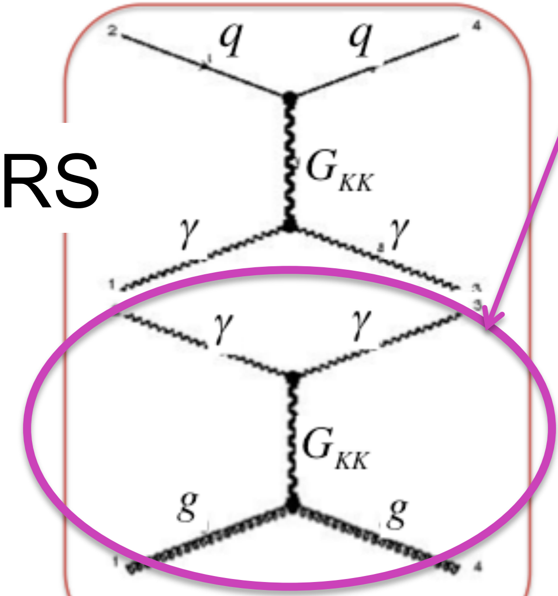
Motivation (4/5)

3. Our work (improvement of the previous study)
   - Including gluons

Sahin, etal, Phys.Rev.D88, 095016

$$pp \rightarrow p\gamma p \rightarrow p\gamma gX$$

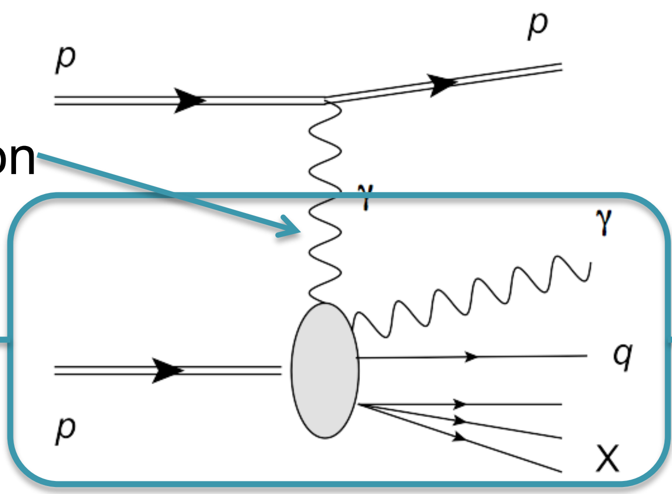
RS



KK gravitons exchange

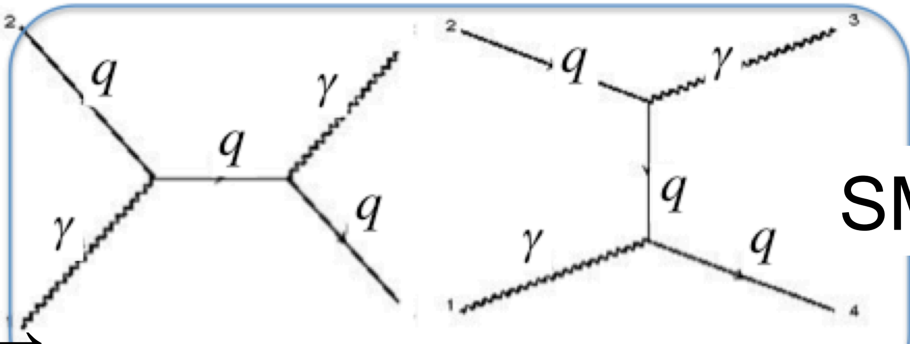
Nearly on-shell photon

Zoom



Zoom

SM



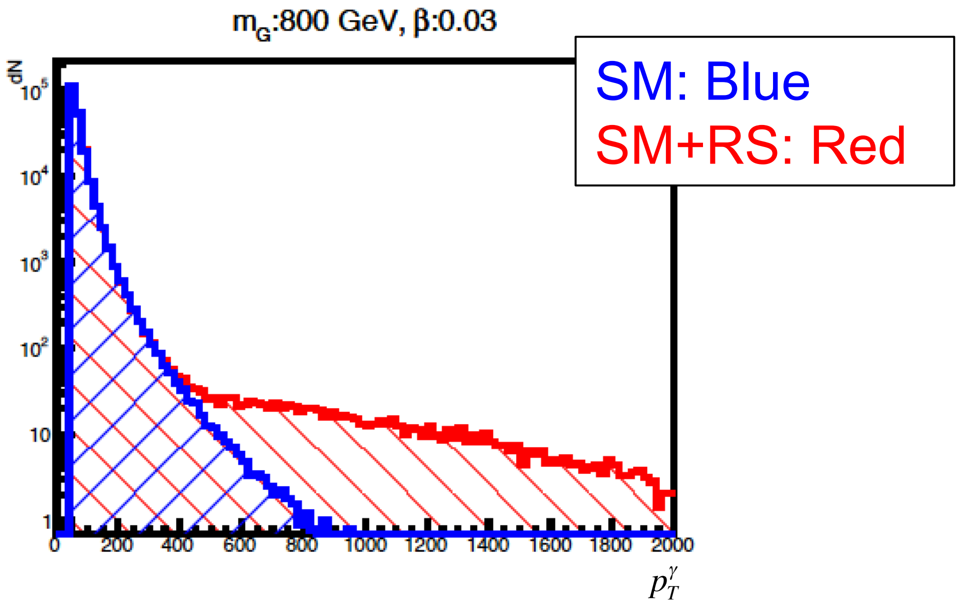
Compton Scattering(SM background)

No gluons →

Motivation (5/5)

– Applying additional cuts for suppressing SM backgrounds

  e.g. seeing transverse momentum distribution

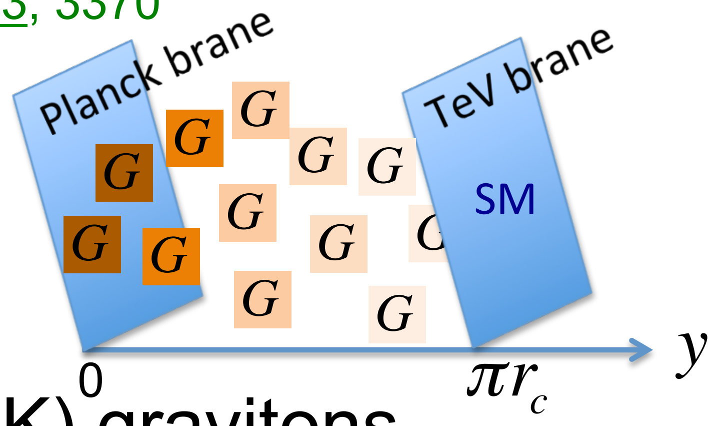


– Including parton shower and hadronization

RS model

5-dimensional model

Randall and Sundrum, PRL83, 3370



1. Metric

$$ds^2 = e^{-2k|y|}\eta_{\mu\nu}dx^\mu dx^\nu - dy^2,$$ where

k : Ads curvature ~ M_{pl} , kr_c ~ 12

2. Interaction of Kaluza-Klein(KK) gravitons

$$-\frac{1}{\Lambda_\pi}T^{\alpha\beta}(x)\sum_{n=1}^{\infty}h_{\alpha\beta}^{(n)}(x)$$, where $\Lambda_\pi = e^{-kr_c\pi}\bar{M}_{pl}$ ~ TeV ,

$$\bar{M}_{pl} = \frac{M_{pl}}{\sqrt{8\pi}}$$

All the massive KK gravitons are suppressed by Λ_π ~ TeV

3. Model parameters

(m_G, $\frac{k}{\bar{M}_{pl}}$), where $m_G = kx_1 e^{-kr_c\pi}(x_1 \cong 3.83)$

m_G : mass of the 1st KK graviton excitation state

Simulation tools

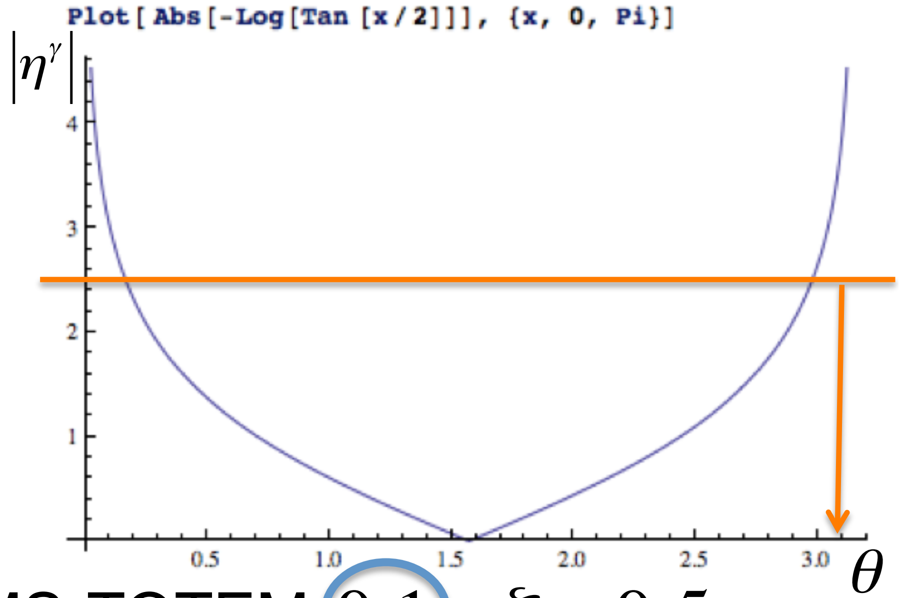
1. FeynRules
   - Implementation of RS model
   - 1^{st} - 4^{th} excitation of KK gravitons
2. Parton distribution functions of MSTW2008
3. MadGraph5_aMC@NLO
   - Computation of cross sections
   - Event generation
4. Pythia8
   - Parton shower and hadronization

Simulational kinematical cuts

Represents detectors physical condition

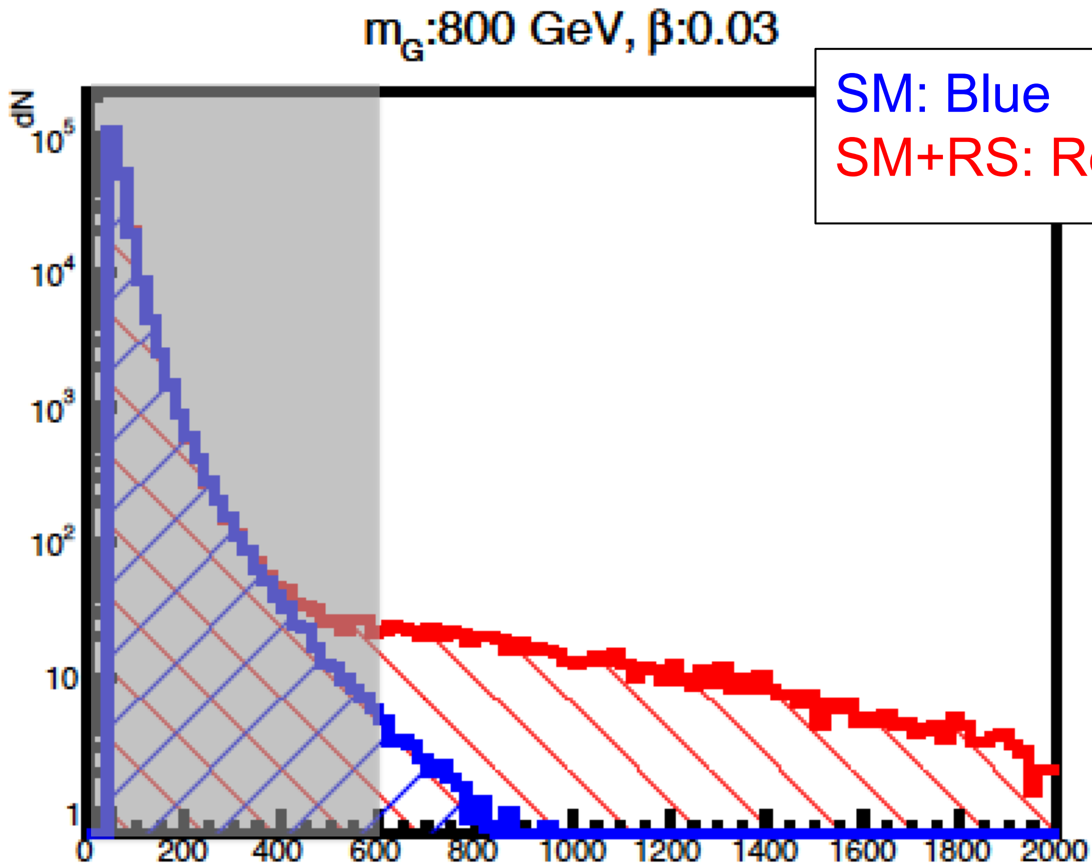
1. Pre-selection cuts
   - Photons
     $p_T^\gamma > 40$ GeV, $|\eta^\gamma| < 2.5$
   - Jets
     $p_T^j > 50$ GeV, $|\eta^j| < 3.0$
2. Additional cuts
   - $p_T^\gamma > 600$ GeV
   - AFP $0.1 < \xi < 0.15$ CMS-TOTEM: $0.1 < \xi < 0.5$
   - $-1 < \eta^\gamma$ when initial photon $p_Z^\gamma > 0$
     $\eta^\gamma < 1$ when initial photon $p_Z^\gamma < 0$

Pseudo rapidity



where P_T: transverse momentum, η : pseudo rapidity

Transverse momentum cut



$\beta = \dfrac{k}{\bar{M}_{pl}}$

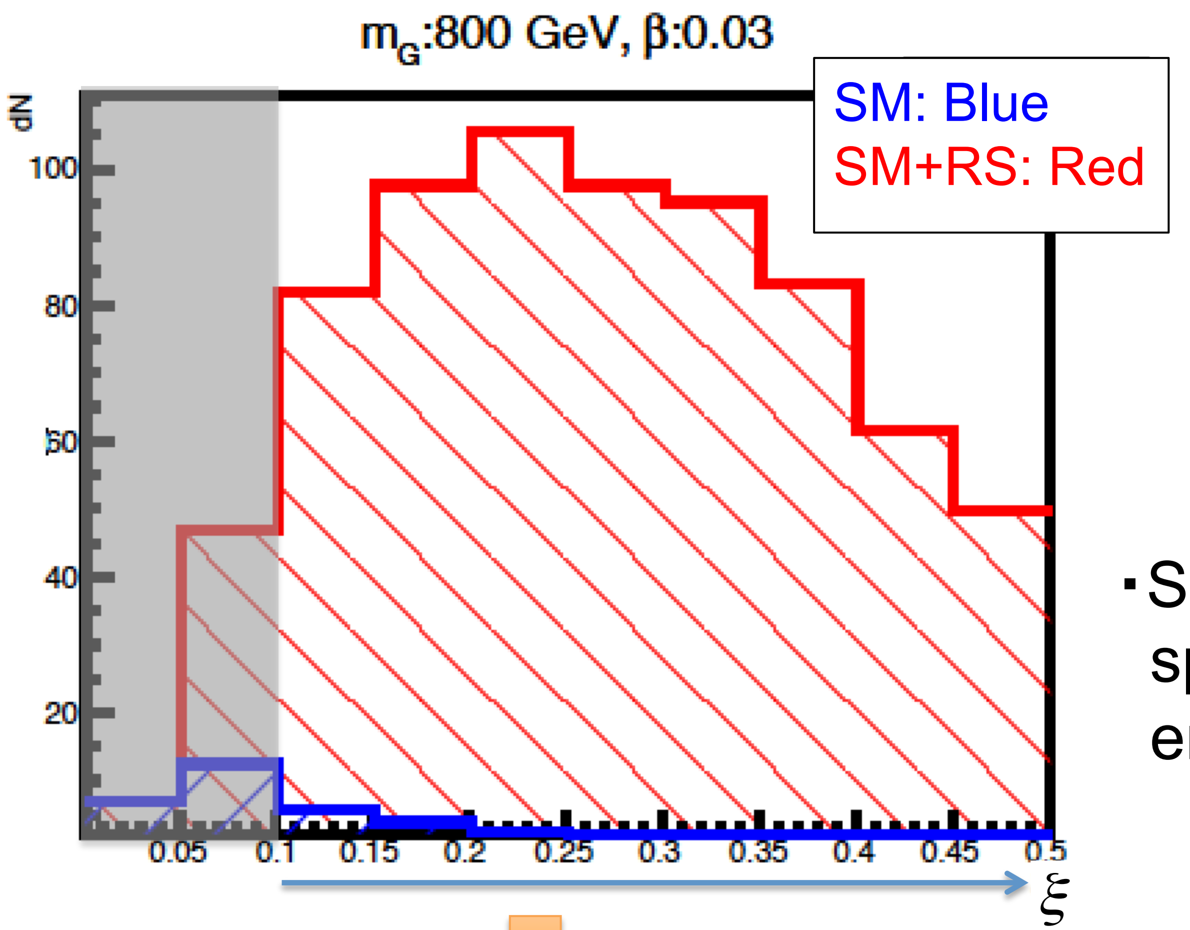
- SM+RS events are widespread

- In SM+RS,
  the heaver the kk mass,
  the widespread the
  angular distribution is more

p_T^{γ}

p_T^{γ} > 600 GeV is good.

ξ cut



p_T^{γ} > 600 GeV

$$\xi = \frac{E_{\gamma}}{E_{beam}}$$

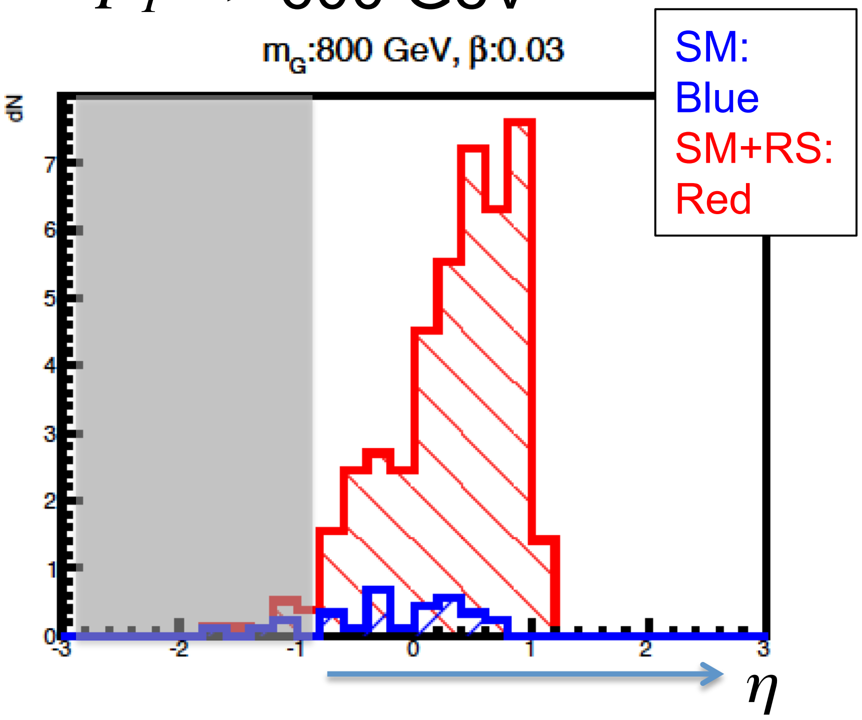
- SM+RS events spread over a high energy photon region.

AFP: $0.1 < \xi < 0.15$ CMS-TOTEM: $0.1 < \xi < 0.5$ is good.

Pseudo rapidity cut

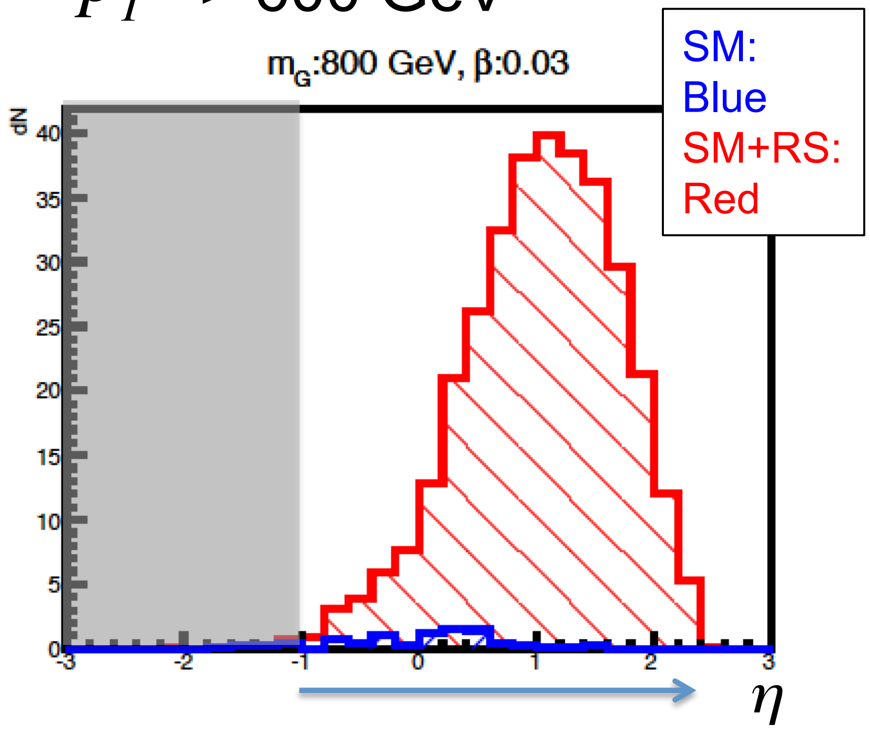
AFP: $0.1 < \xi < 0.15$

p_T^γ > 600 GeV



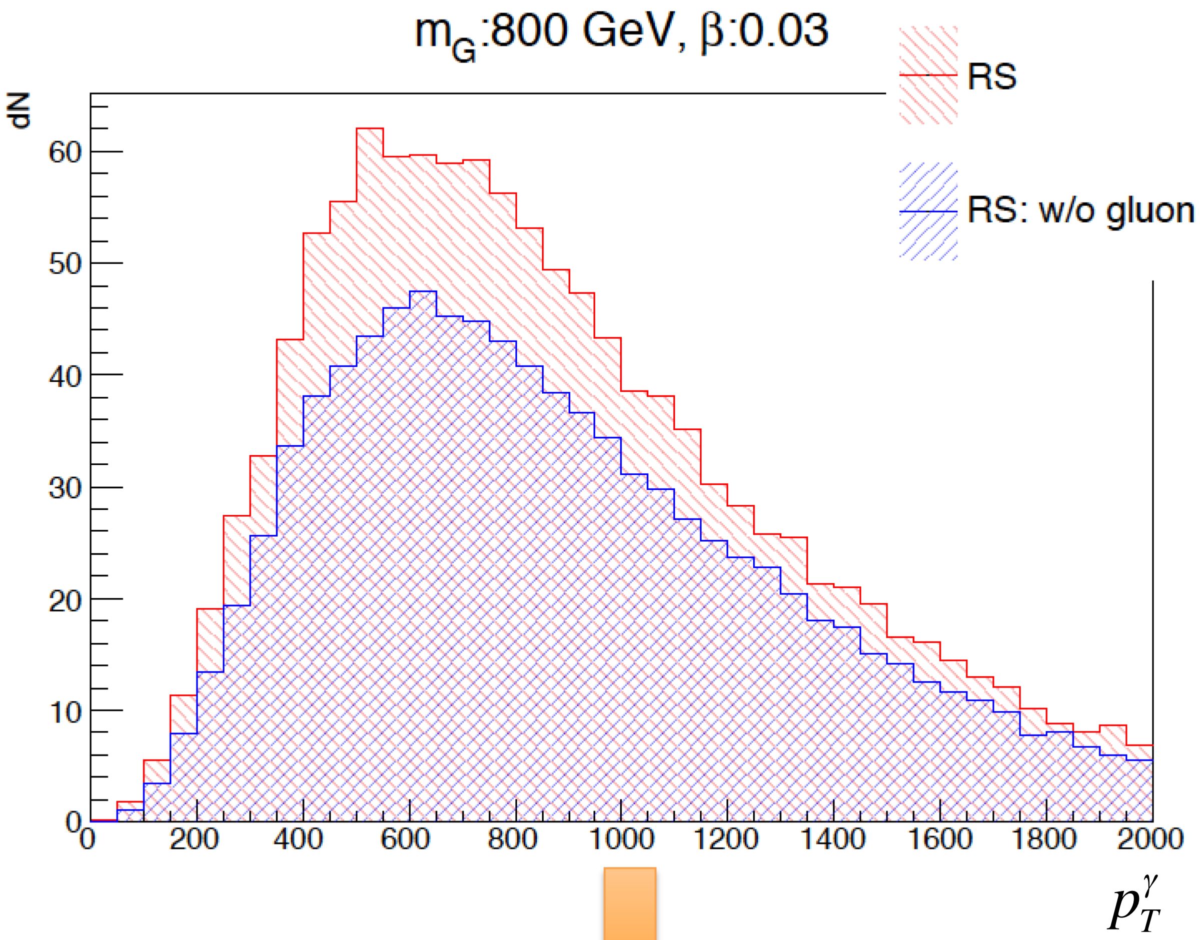
CMS-TOTEM: $0.1 < \xi < 0.5$

p_T^γ > 600 GeV



-1< η^γ is good when initial photon p_Z^γ >0

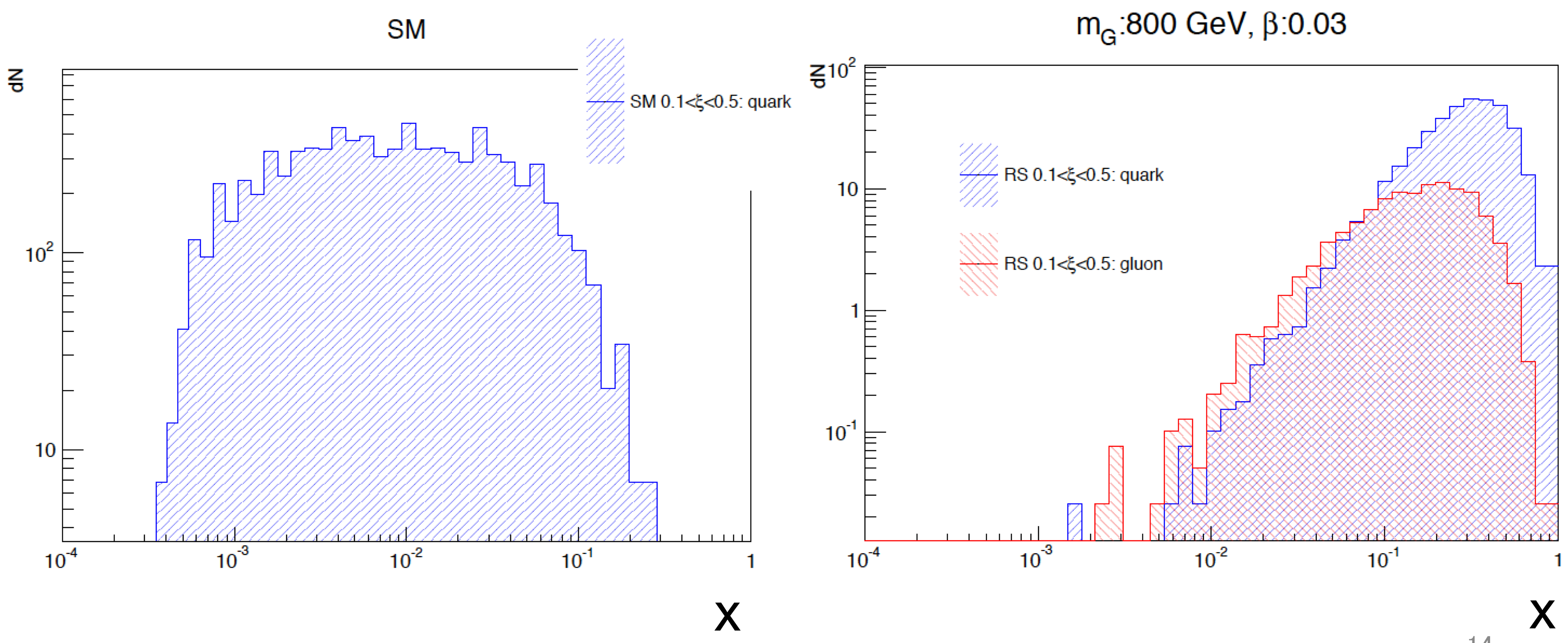
Effect of including gluons (1/3)



Gluons contribution is roughly 20 percent of events

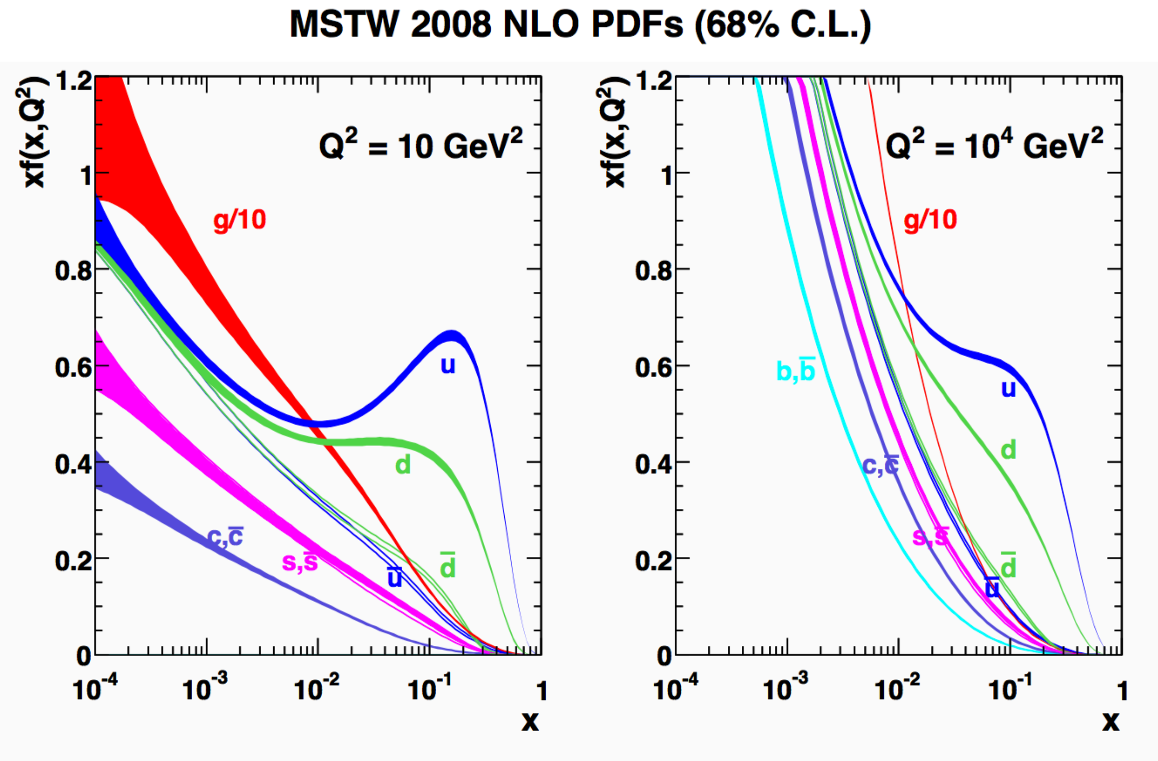
Effect of including gluons (2/3)

1. Gluon contribution is enhanced
   in higher momentum region



Effect of including gluons (3/3)

2. <u>However</u> Parton Distribution Function of gluons depends on lower momentum



A.D. Martin, etal, Eur.Phys.J.C63:189-285, 2009

3. Contribution of gluons is not so large

Method

survival probability: 0.7
photon identification efficiency: 0.8
Integrated Luminosity: 200/fb

1. χ^2 distribution

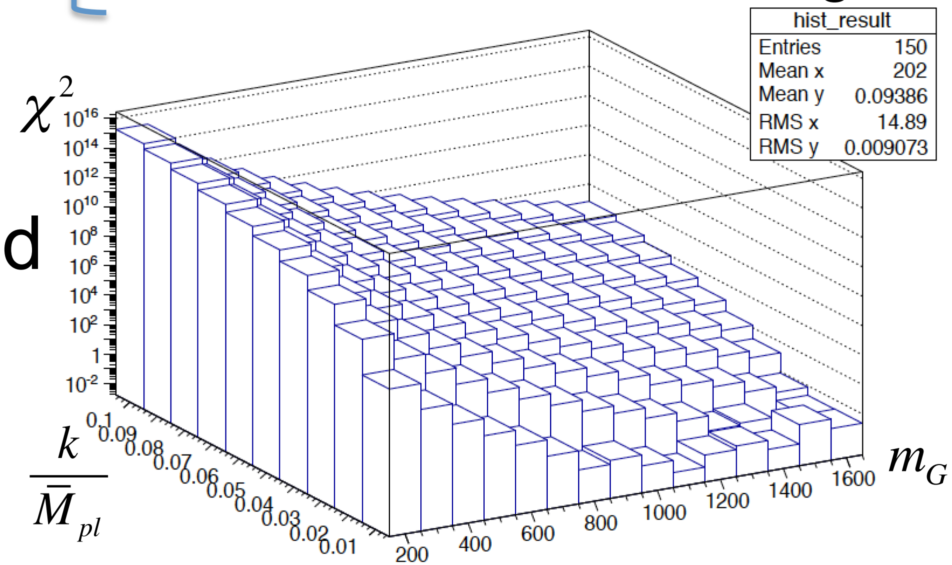
$$\frac{(N_{SM+RS} - N_{SM})^2}{N_{SM}}$$, where

N_{SM} : number of SM events
N_{SM+RS}: number of events including RS effects via KK gravitons

2. 150 sets of RS parameters are implemented

$$\chi^2(m_G, \frac{k}{\bar{M}_{pl}}) > 3.84$$

exclusion@95% CL.



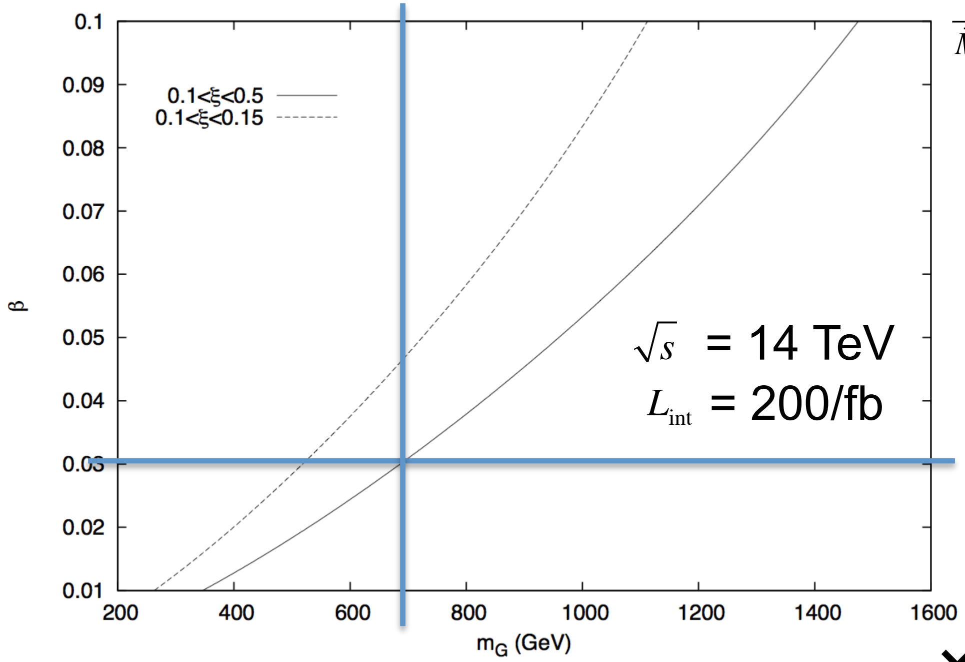
m_G : mass of the 1st KK graviton excitation state

Result (1/2)

$$\beta = \frac{k}{\bar{M}_{pl}}$$

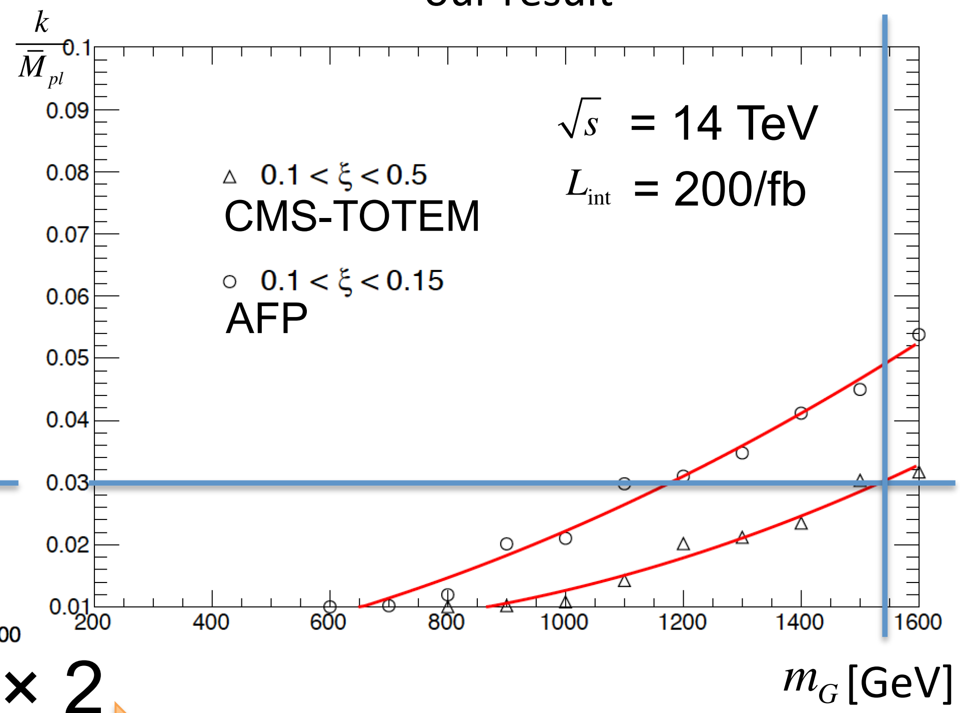
without gluon

Sahin, etal, PRD88, 095016



with kinematical cuts,
parton shower and hadronization

our result

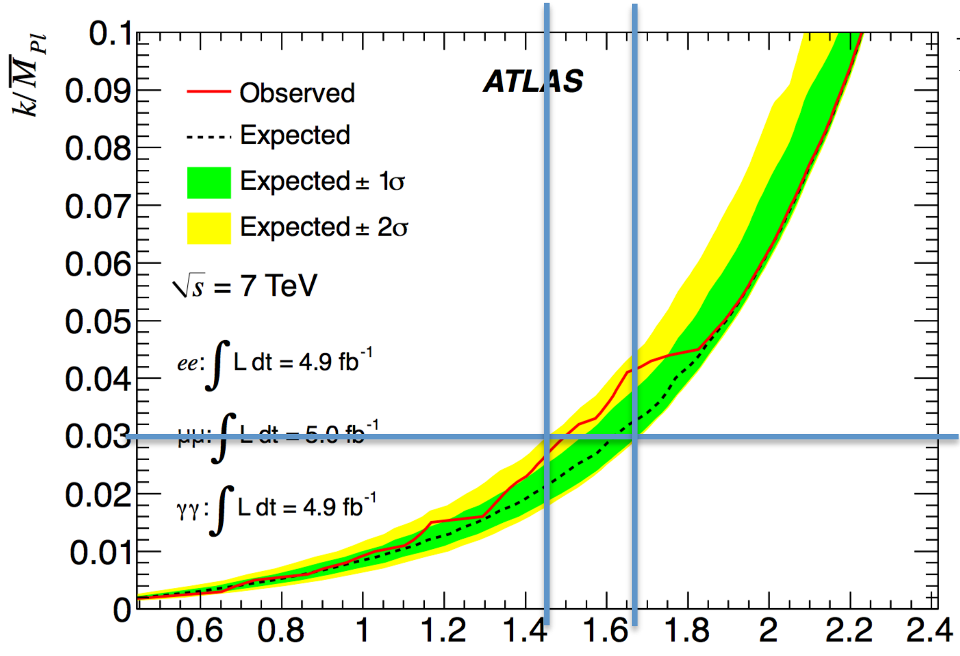


~ 700 GeV × 2 ~ 1500 GeV

If the experimental yields are compatible with the SM, regions above the curves are excluded @95% C.L.

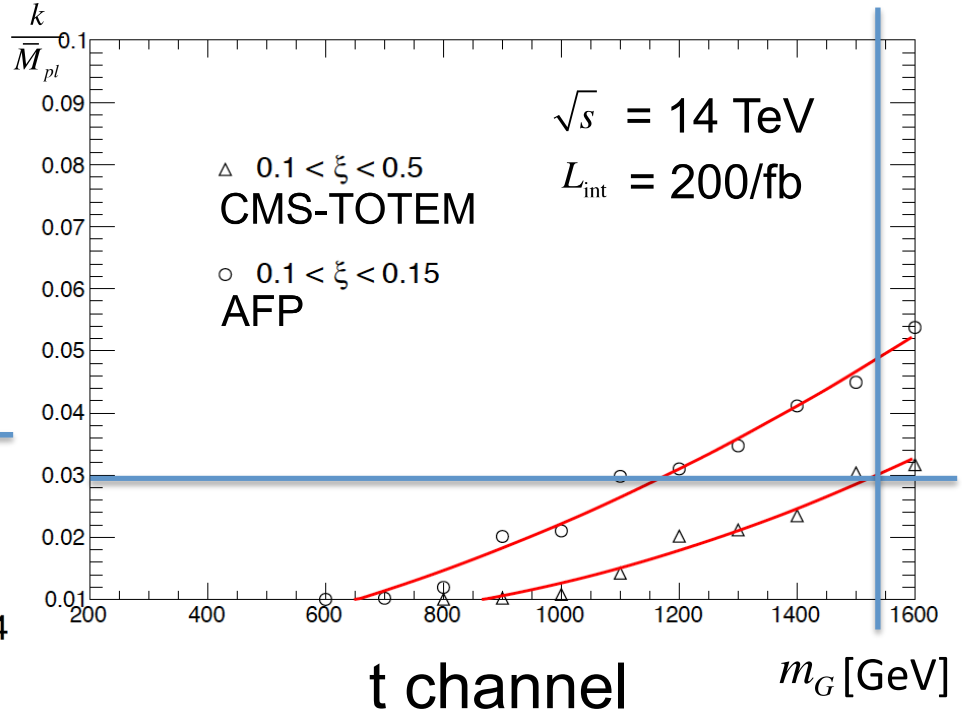
Result (2/2)

ATLAS Collaboration,
New J. Phys. 15 (2013) 043007



direct production

our result



t channel

× 1

1450 GeV ~ 1650 GeV → ~ 1500 GeV

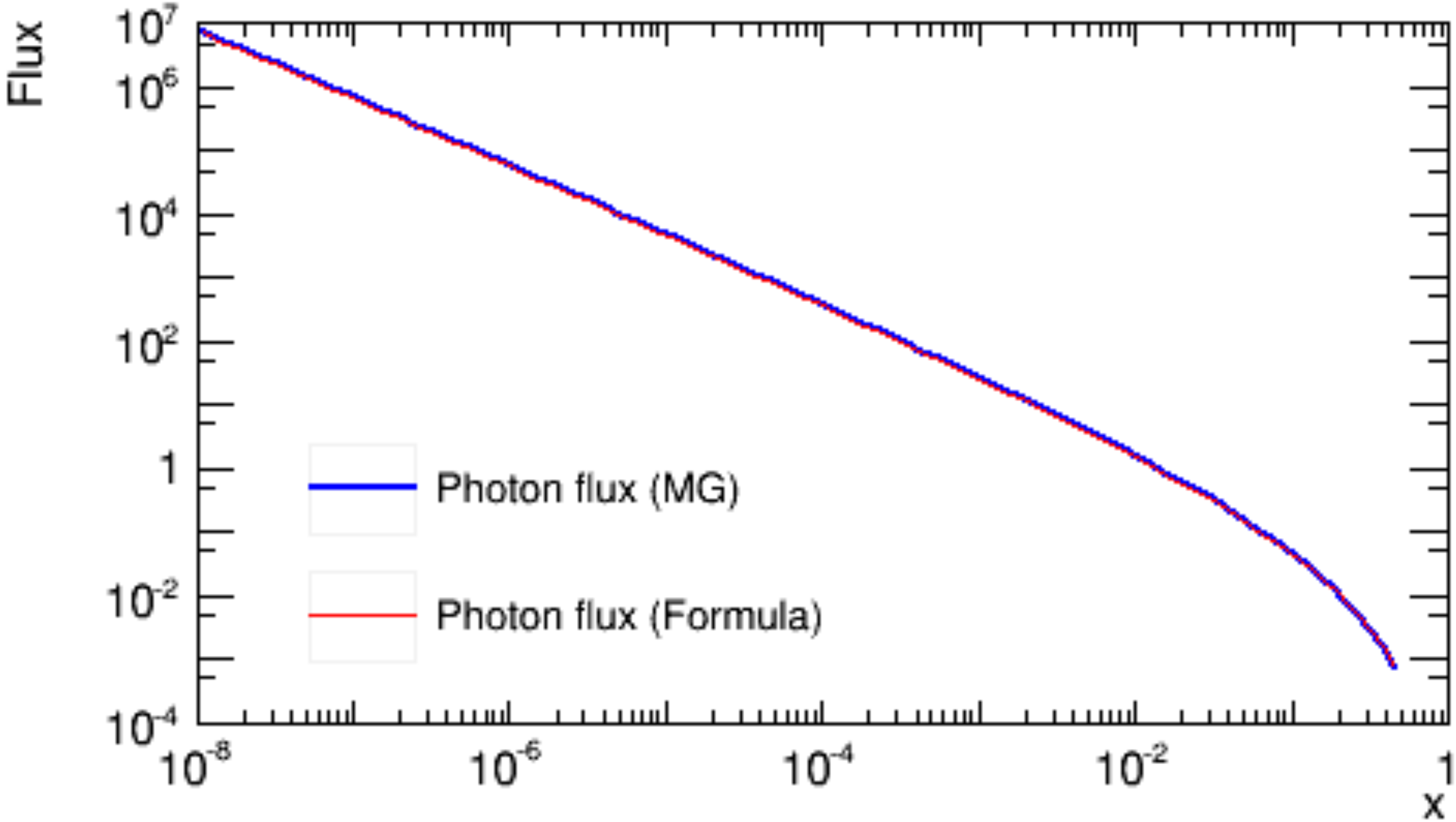
Summary and future plans

1. Limits on the RS gravitons have been estimated via $pp \to p\gamma p \to p\gamma qX$ with forward detectors at the LHC
   - Contribution of gluons is added
   - Kinematical cuts

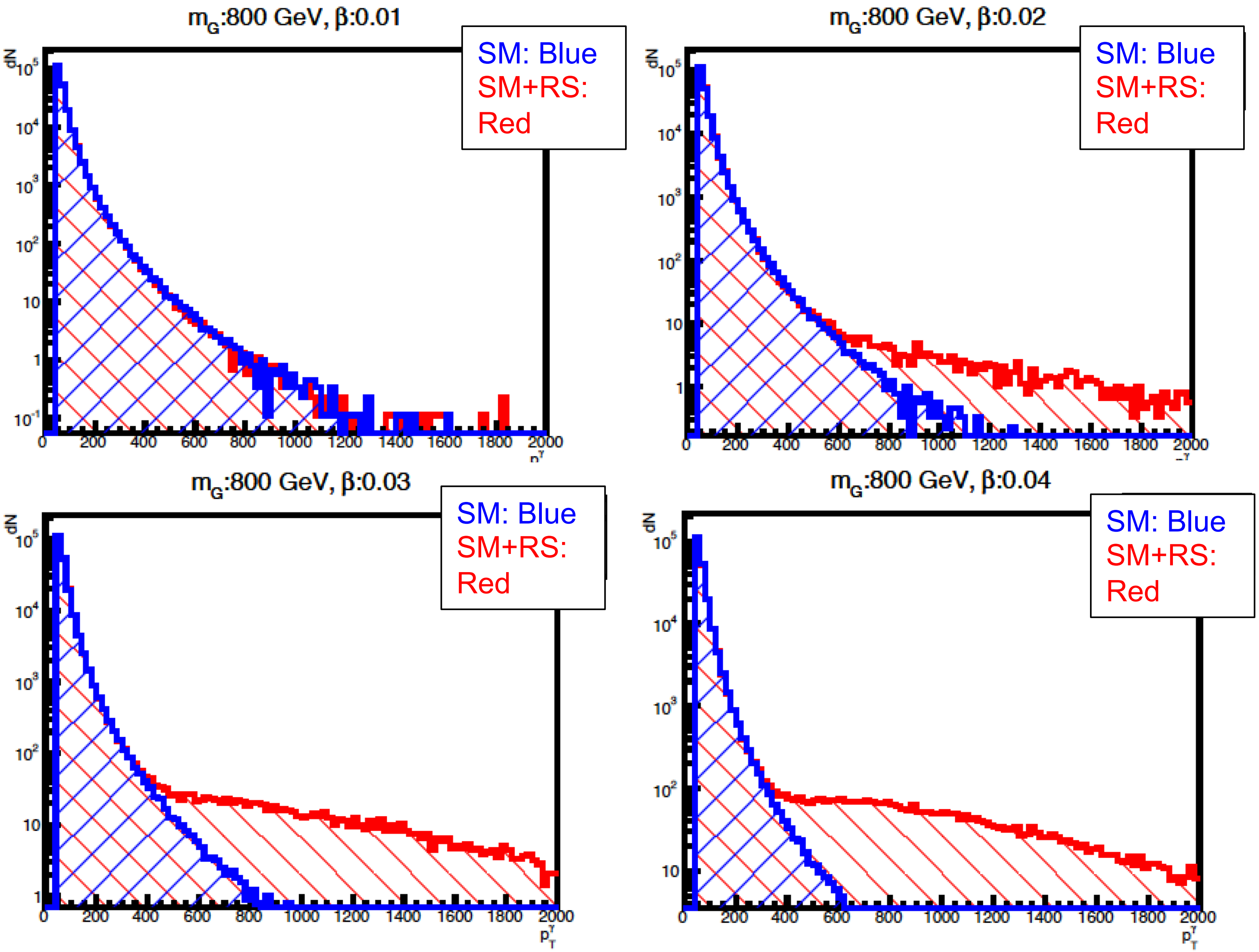
   → lower bounds on the mass of KK gravitons are improved
   e.g. $(m_G, \frac{k}{\bar{M}_{pl}})$: (700GeV, 0.03)→(1500GeV, 0.03)
2. Limits on the RS model parameters are comparable with direct search at the LHC
3. Limits on the large extra dimensional model parameter will be investigated

Backup

The equivalent photon distribution



Transverse momentum (1/2)



Transverse momentum (2/2)