LHCでのExotics探索

素粒子物理学の進展2017
2017年7月31日

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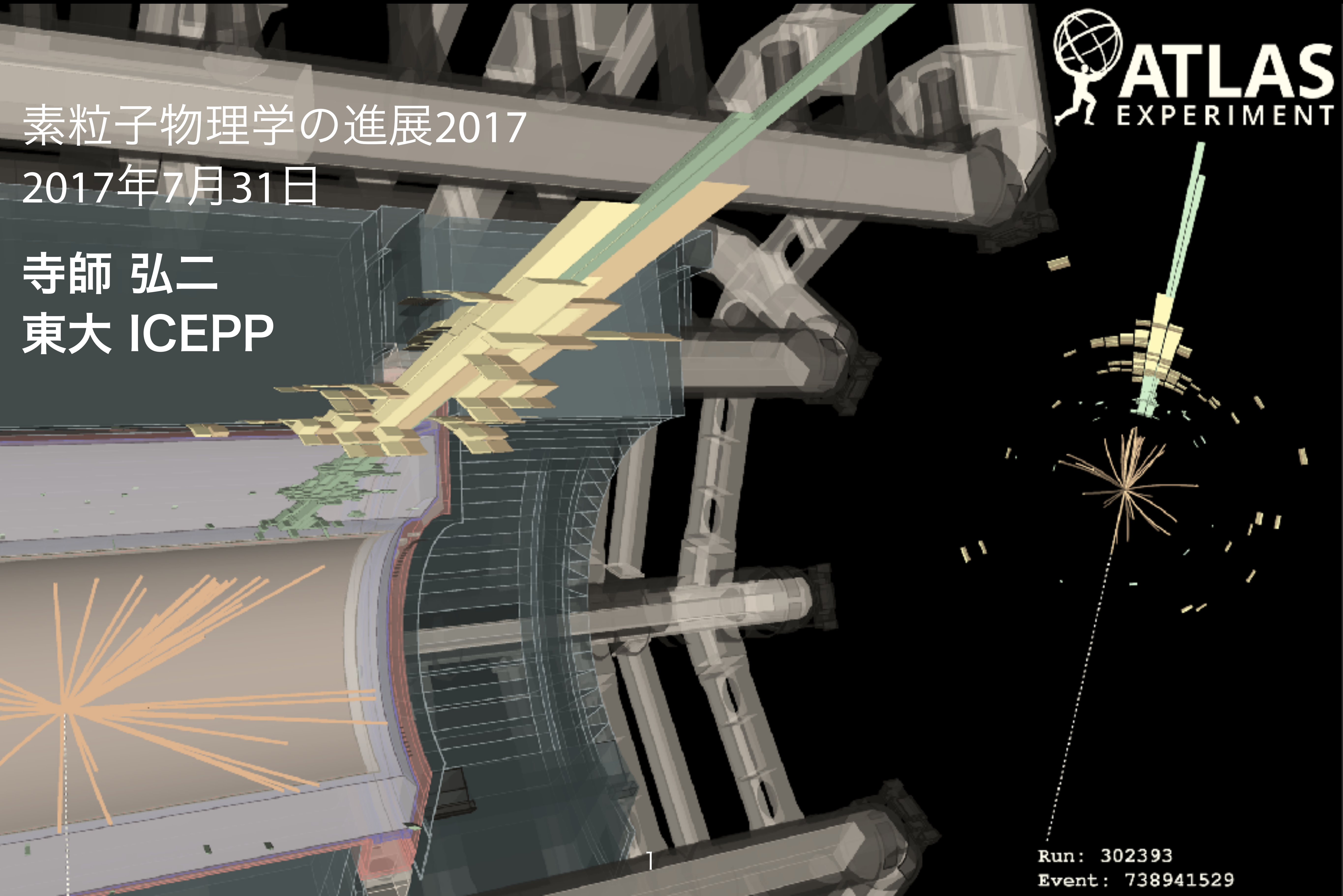
東大 ICEPP



Outline

SUSY以外の新物理探索の結果（36 fb^{-1} at 13 TeV）

High-mass領域での新粒子探索

- Diphoton
- Diboson
- Dijet
- Dilepton

Low-mass領域での新粒子探索

- Dijet + ISR jet

暗黒物質の探索

まとめ（に代えて）

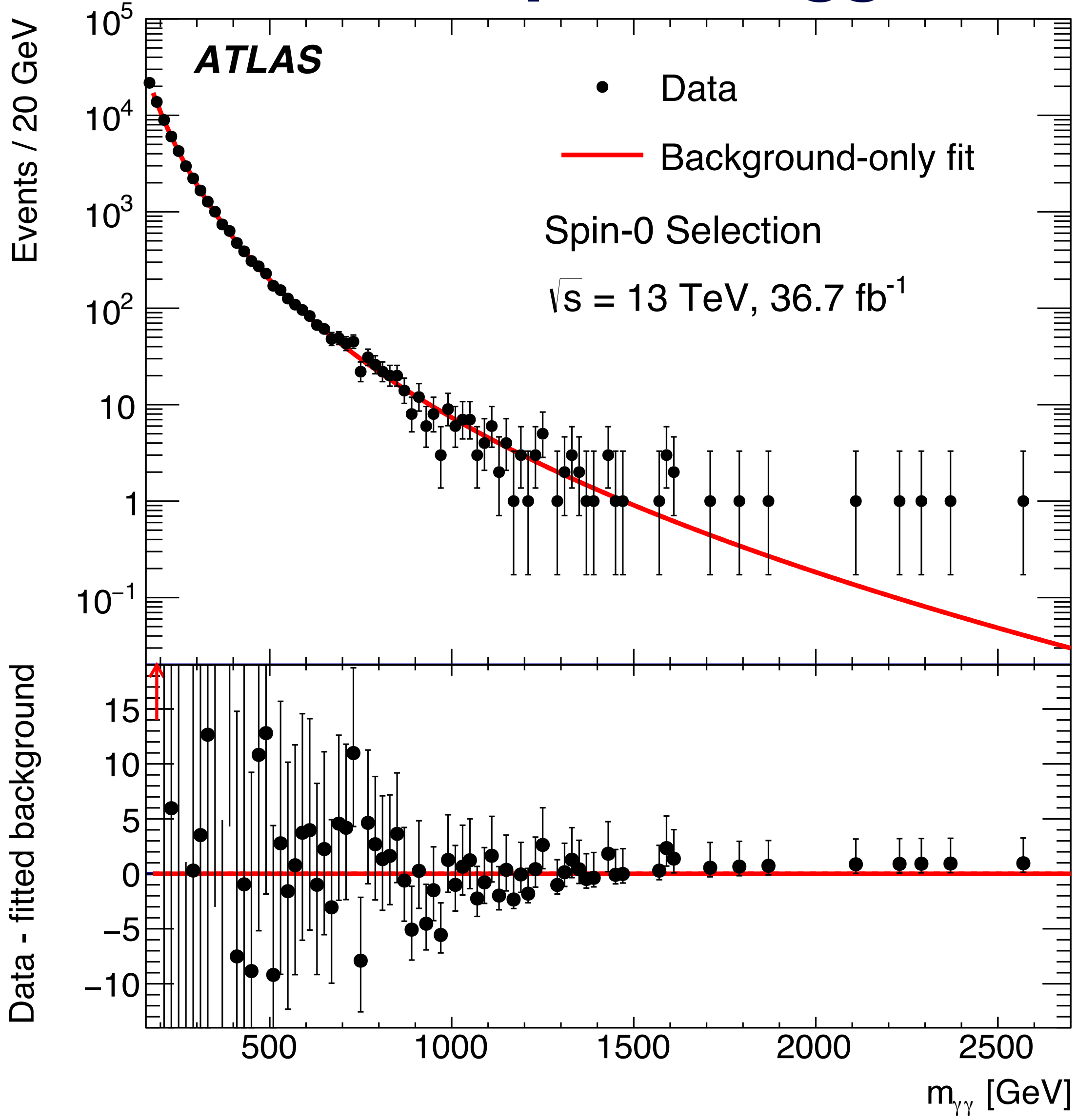
Open Eyes Wide!!

.. and Look Carefully!!

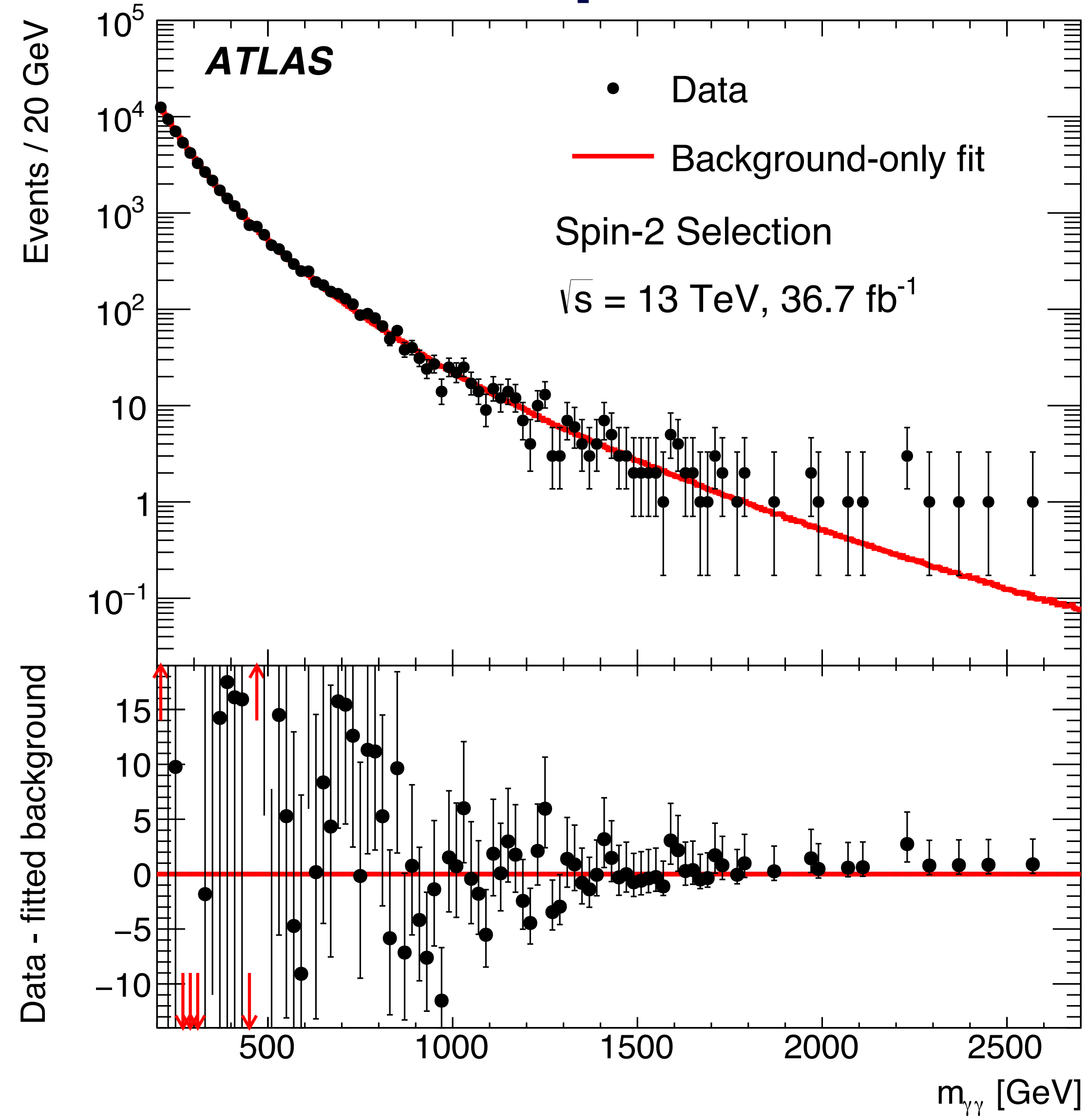
今の“750 GeV”

CMSは去年のICHEP以来アップデートなし（やる気なし…） HIGG-2016-17

Spin-0 (Higgs-like)



Spin-2 (Graviton)



Tight isolated photon
$E_T\gamma^{1(2)} > 0.4(0.3)m_{\gamma\gamma}$ (low acc. in forward)
探索領域： $m_X = [0.2 - 2.7]$ GeV
$\Gamma_X/m_X = [0 - 10]\%$

Tight isolated photon
$E_T\gamma^{1,2} > 55$ GeV (high acc. in forward)
探索領域 : $m_{G*} = [0.5 - 2.7]$ GeV
$\kappa/\overline{M}_{Pl} = [0.01 - 0.3]$
$(\Gamma_{G*}/m_{G*} = [0.01 - 11]\%)$

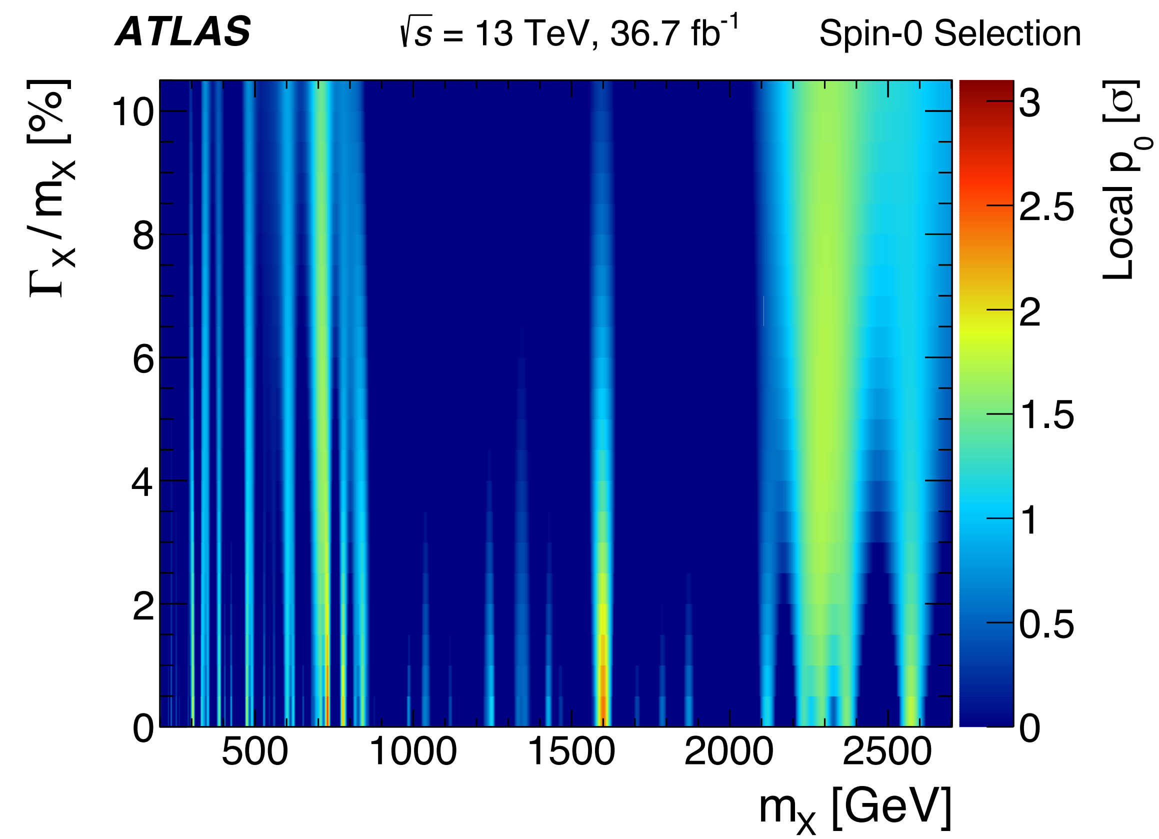
サンプルのDiphoton purity ~ 91%,
残りはPhoton+jet, Dijet由来

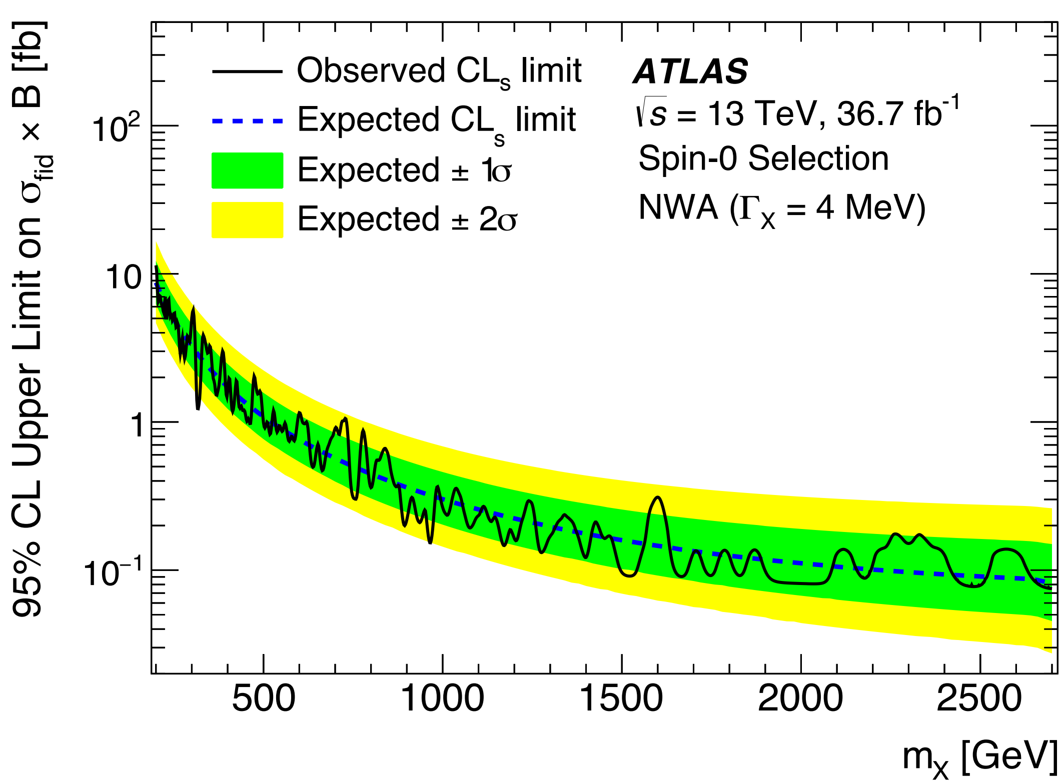
今の“750 GeV”

HIGG-2016-17

Spin-0

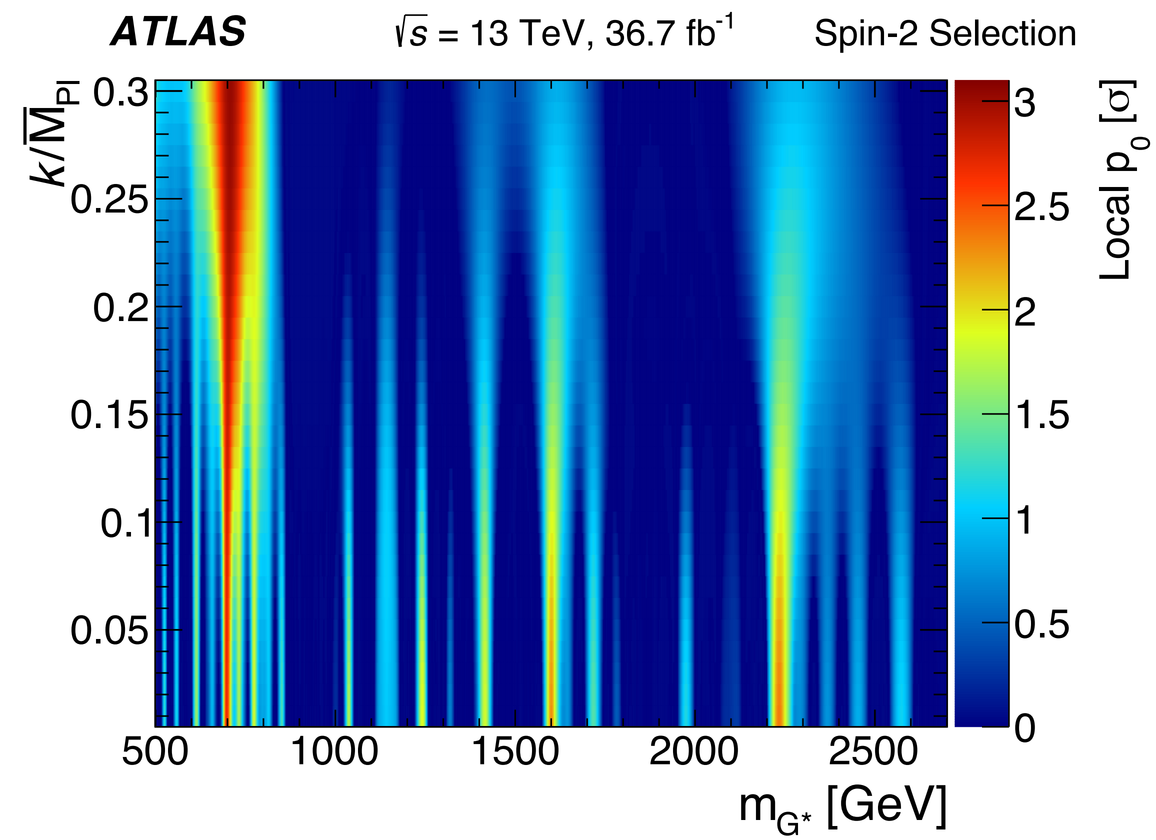
local 2.6σ (null global) at
m_X~730 GeV, narrow width

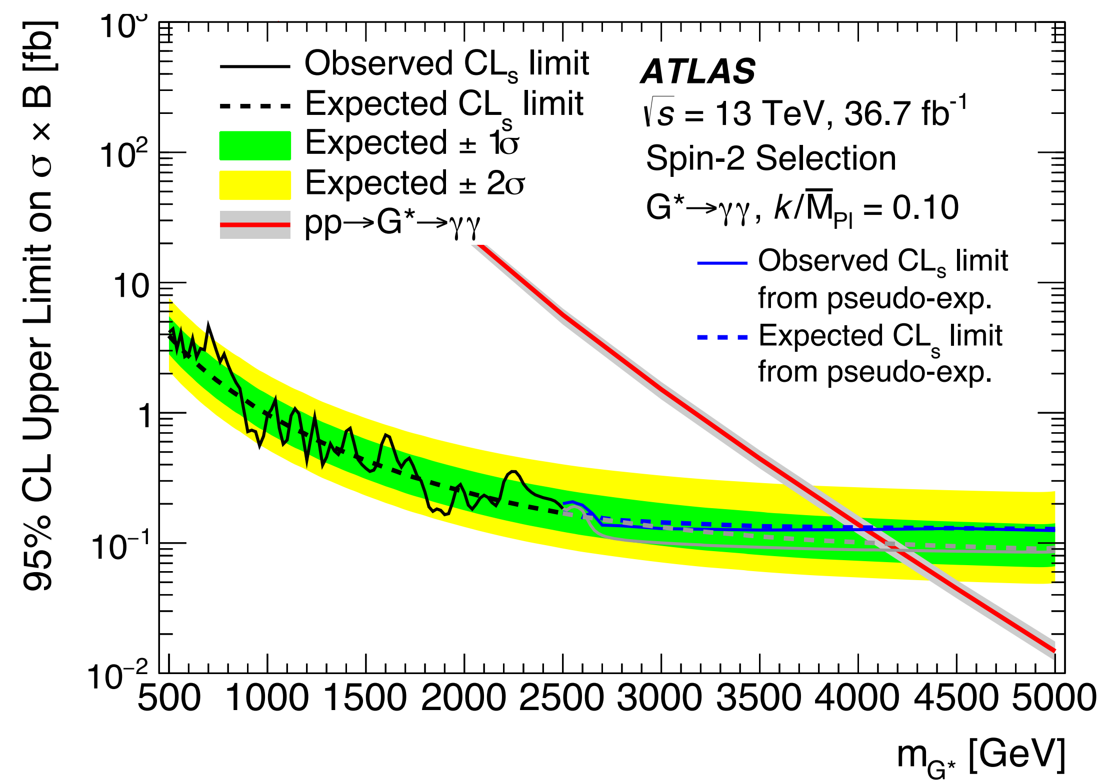




Spin-2

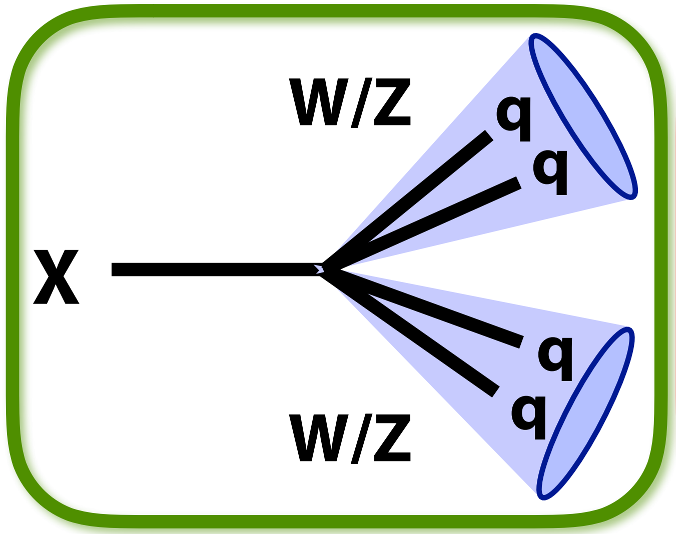
local(global) 3.0(0.8)σ at
m_{G^*}~708 GeV, $\kappa/\overline{M}_{Pl}$~0.3



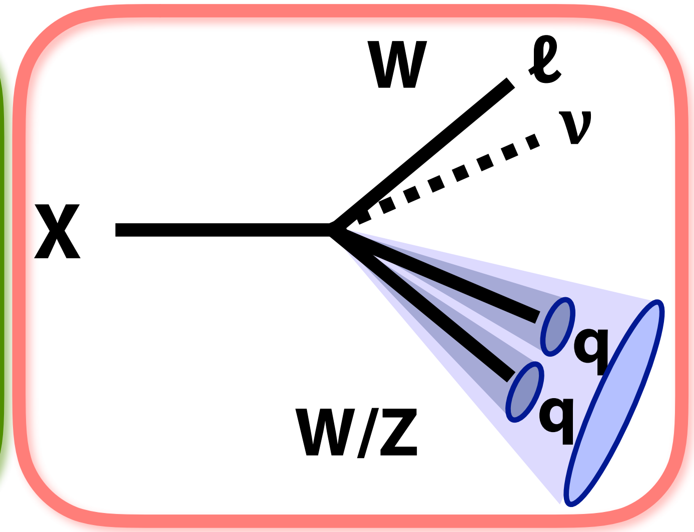


Diboson Resonance

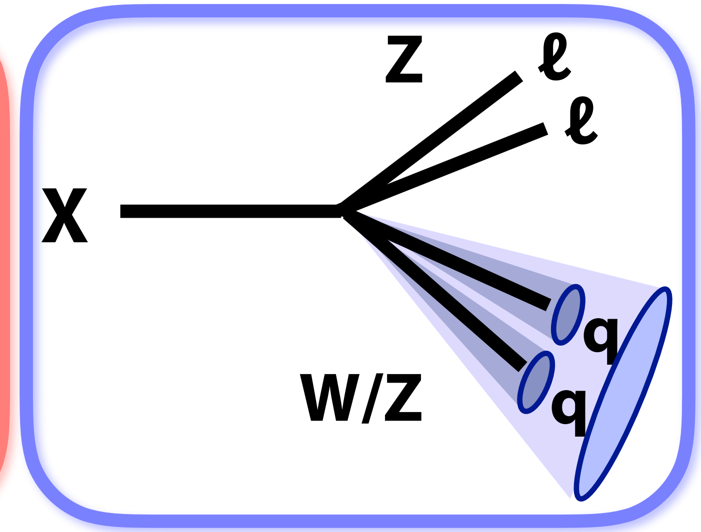
VV→qqqq



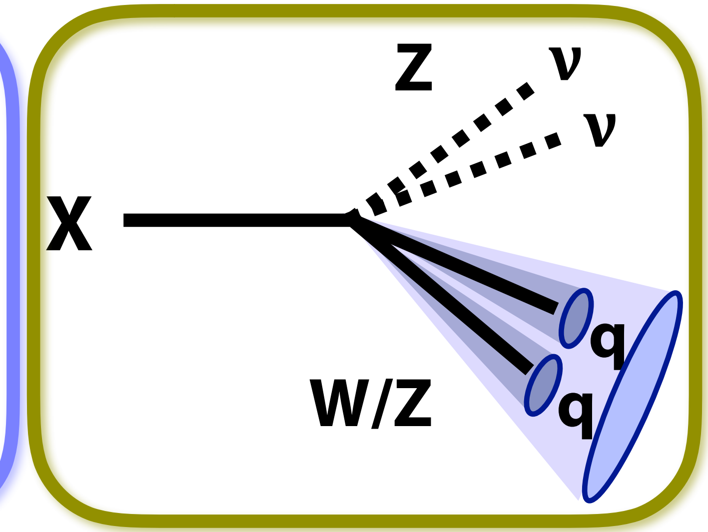
WW/WZ→lνqq



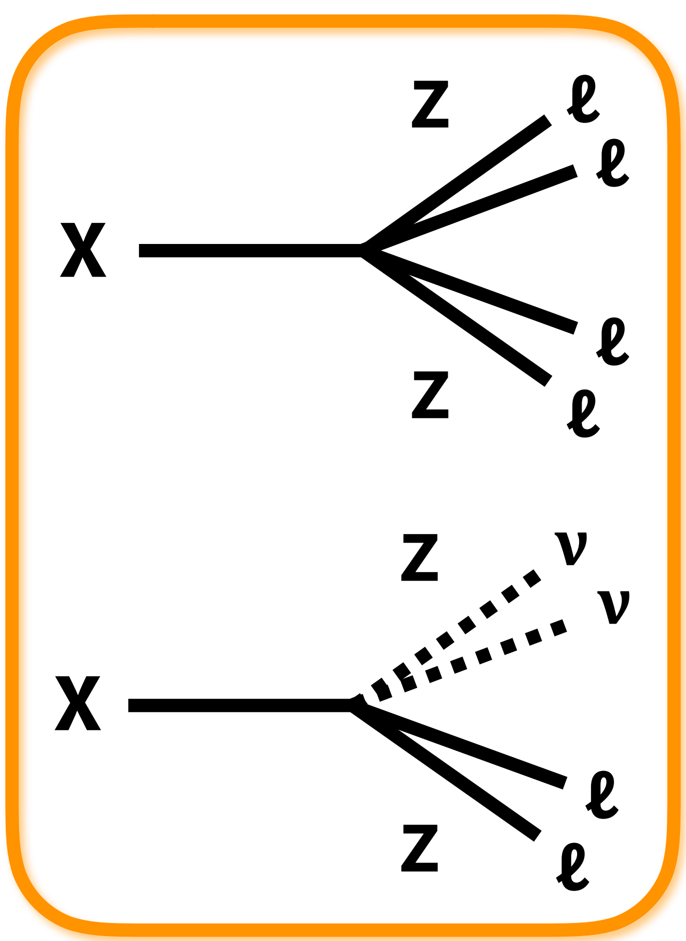
ZW/ZZ→llqq

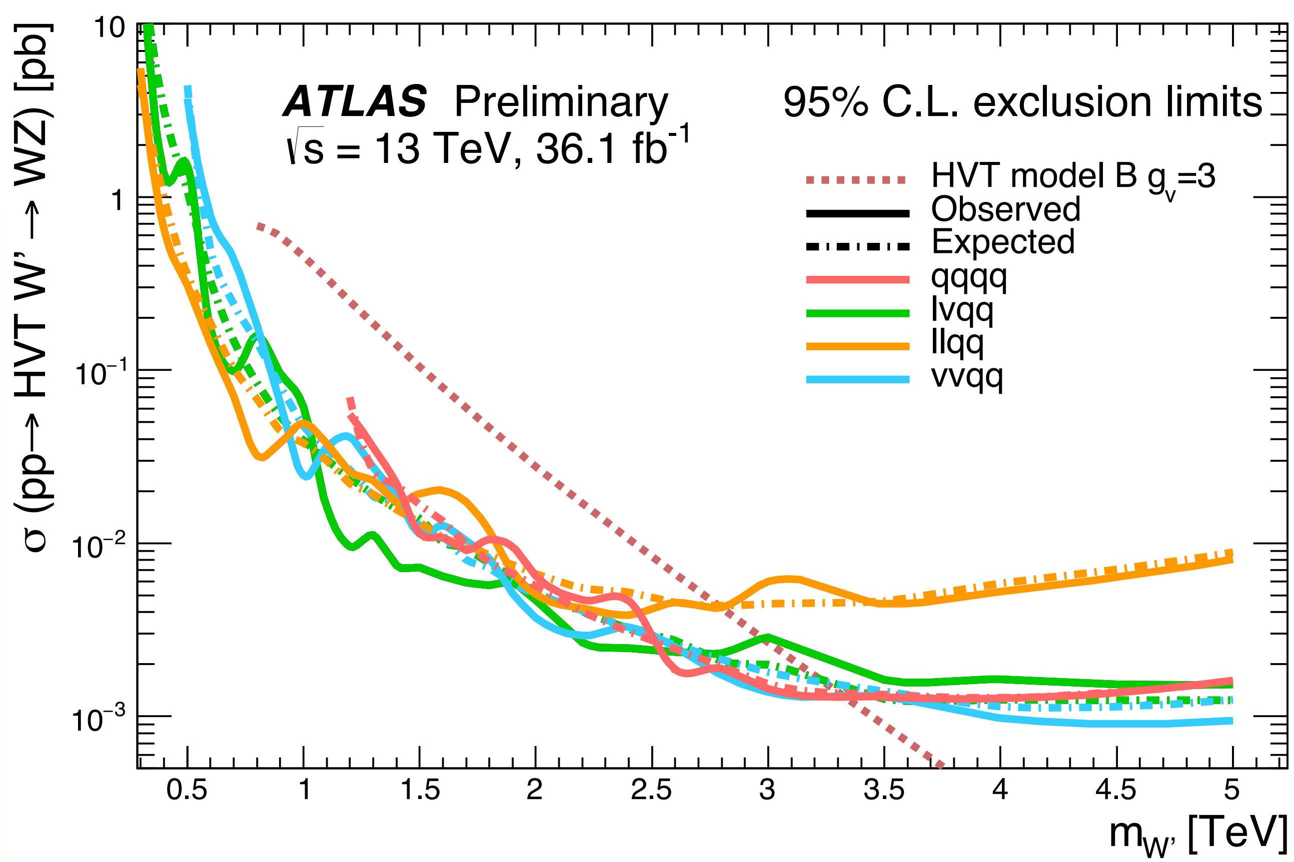


ZW/ZZ→ννqq



ZZ→llll/llνν



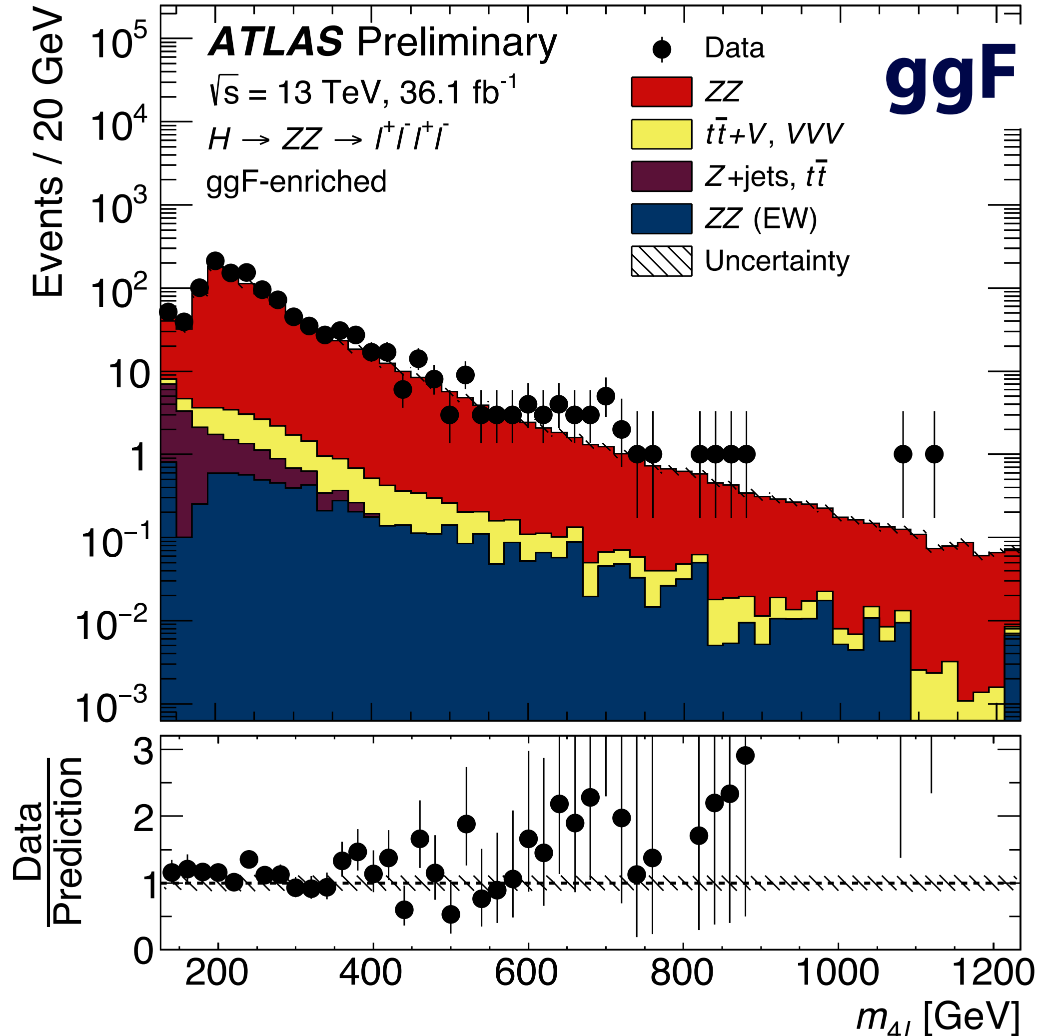


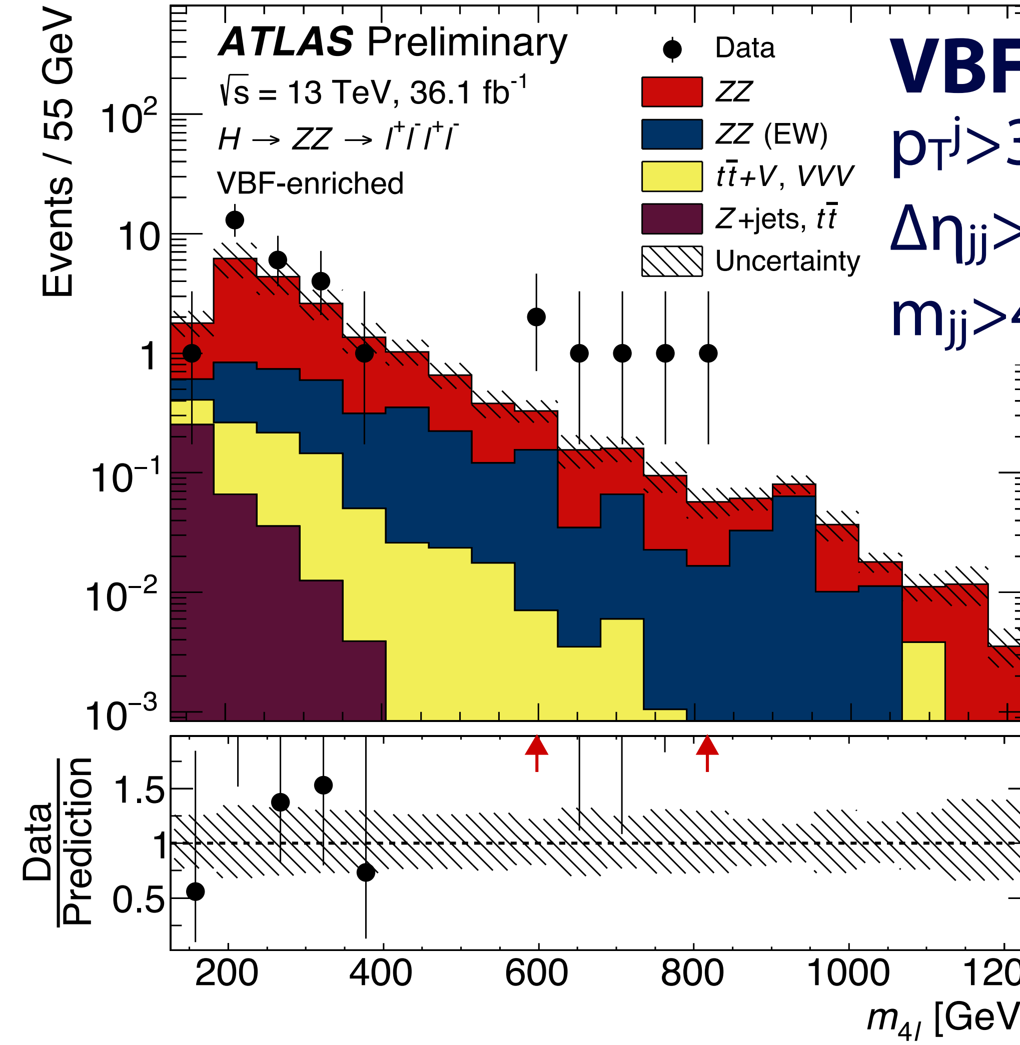
- 主要な崩壊モードは全て網羅
- 各解析はお互いにExclusiveな事象選別を行う
- 発見時の検証, Combinationによる Limitの改善

- Low-mass ⇒ Full-leptonicが強い
- High-mass ⇒ Full-had, Semi-leptonicが強い

ZZ→llll Search

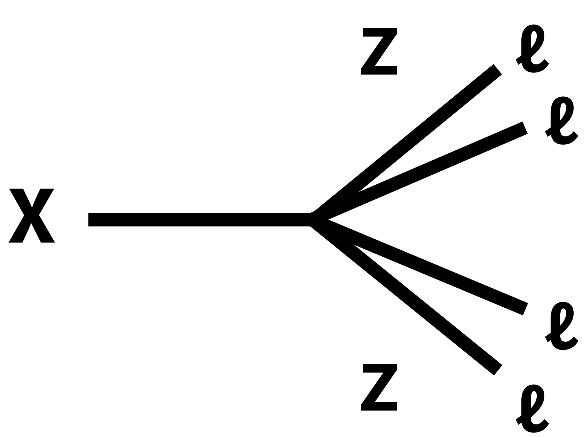
CONF-2017-058





VBF
$p_T^j > 30$ GeV,
$\Delta\eta_{jj} > 3.3$,
$m_{jj} > 400$ GeV

ZZ→4e/2e2μ/4μ



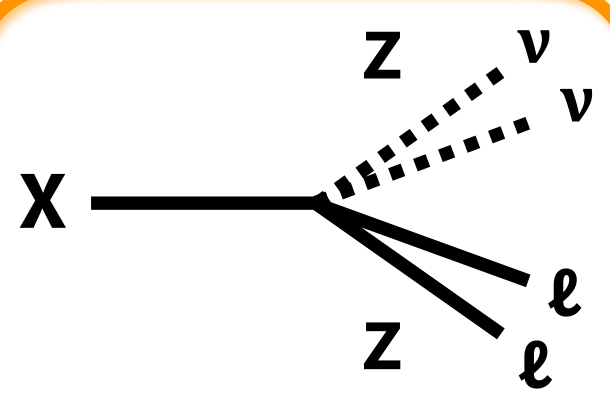
- $p_T^{e/\mu} > 7(5)$ GeV
- $p_T^{l1(2,3)} > 20(15,10)$ GeV
- $50 < m_{12} < 106$ GeV
- $X < m_{34} < 115$ GeV, where
  - $X = 12$ ($m_{4l} < 140$ GeV)
  - $X = 12 \rightarrow 50$ ($m_{4l} = 140 \rightarrow 190$ GeV)
  - $X = 50$ ($m_{4l} > 190$ GeV)

- Non-reso ZZ BGはSherpa+(NLO QCD+NLO EW)で評価
- 2箇所にmodest excess:
  - local(global) 3.6σ (2.2σ) at m_X~240 & 700 GeV, NWA
  - mostly 4e for 240 GeV
  - all channels/categories for 700 GeV

ZZ→llνν Search

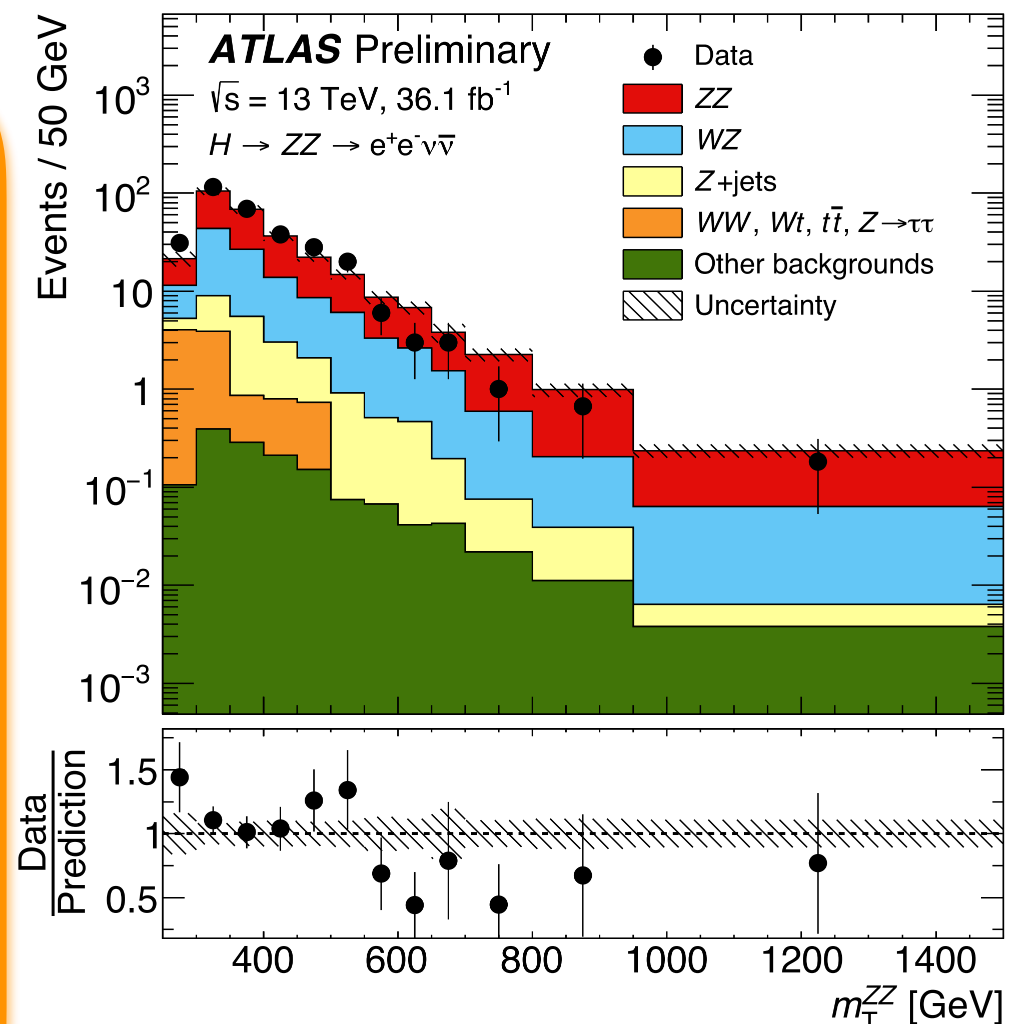
CONF-2017-058

ZZ→llll/llνν

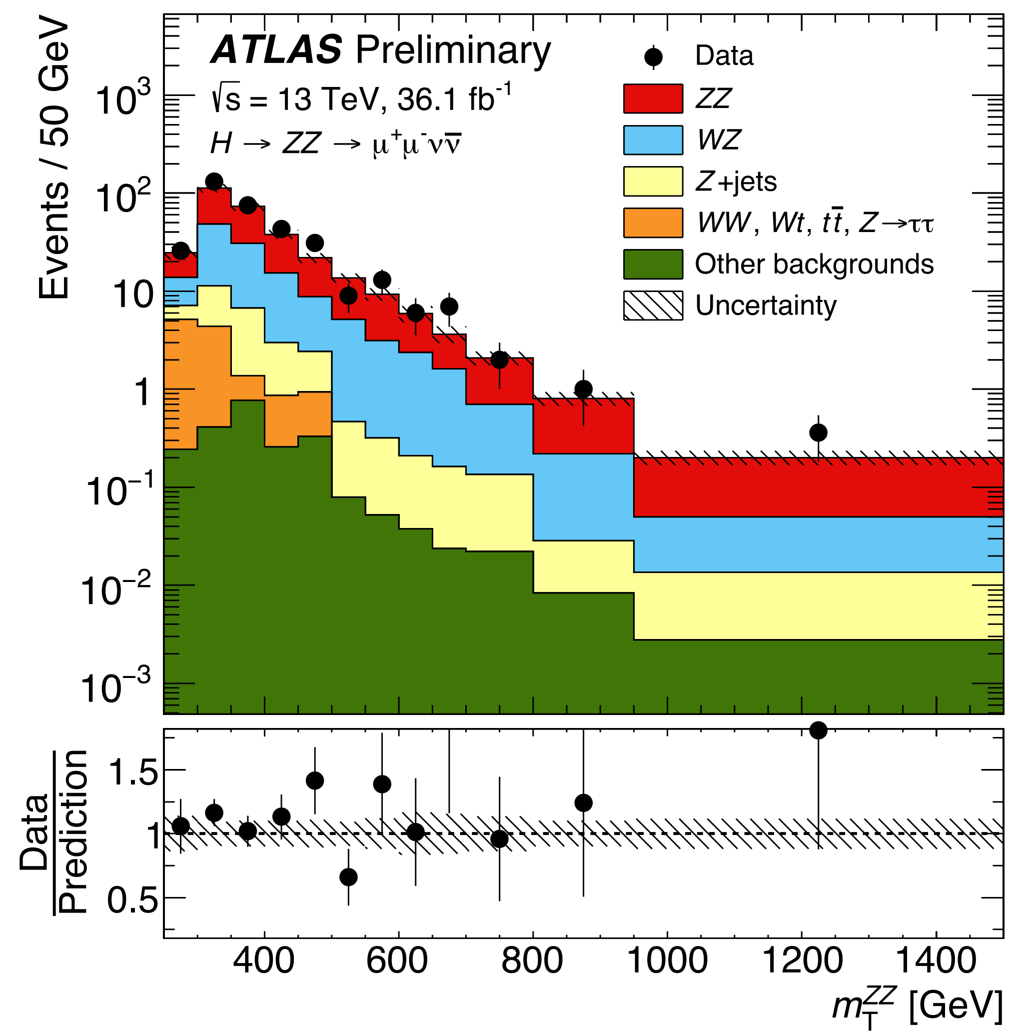


- 2 OS leptons
  p_T>30/20 GeV
- E_T^{miss} >120 GeV
  E_T^{miss}/H_T>0.4
- 76<m_{ll}<106 GeV
  ΔR_{ll}<1.8
- $\Delta\phi(ll, E_T^{miss})$ > 2.7

eeνν

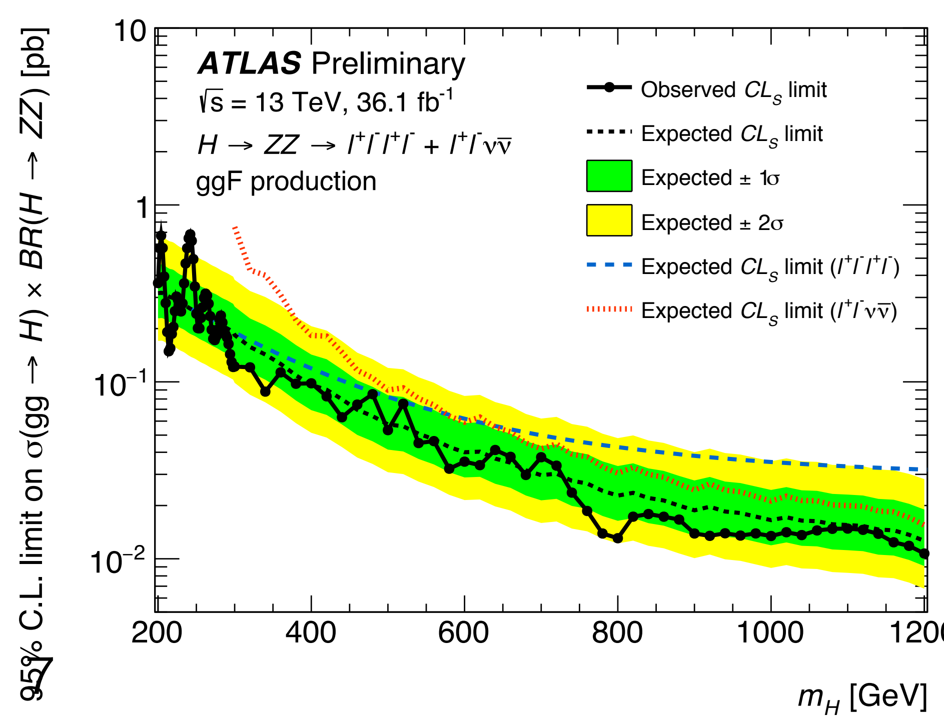


μμνν



- Non-reso ZZ BGはPowheg (NNLO QCD+NLO EW)で評価
- m_T分布でlikelihood Fit

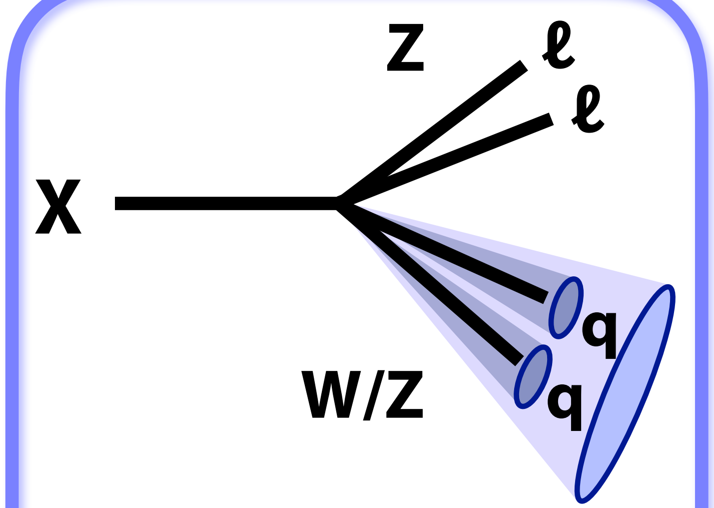
$$m_T \equiv \sqrt{\left[\sqrt{m_Z^2 + \left(p_T^{\ell\ell}\right)^2} + \sqrt{m_Z^2 + \left(E_T^{miss}\right)^2}\right]^2 - \left|\vec{p_T}^{\ell\ell} + \vec{E}_T^{miss}\right|^2}$$



4lの700 GeV excessとはincompatible

ZV→llqq Search

ZW/ZZ→llqq



VBF & ggF/DY

Boosted & Resolved

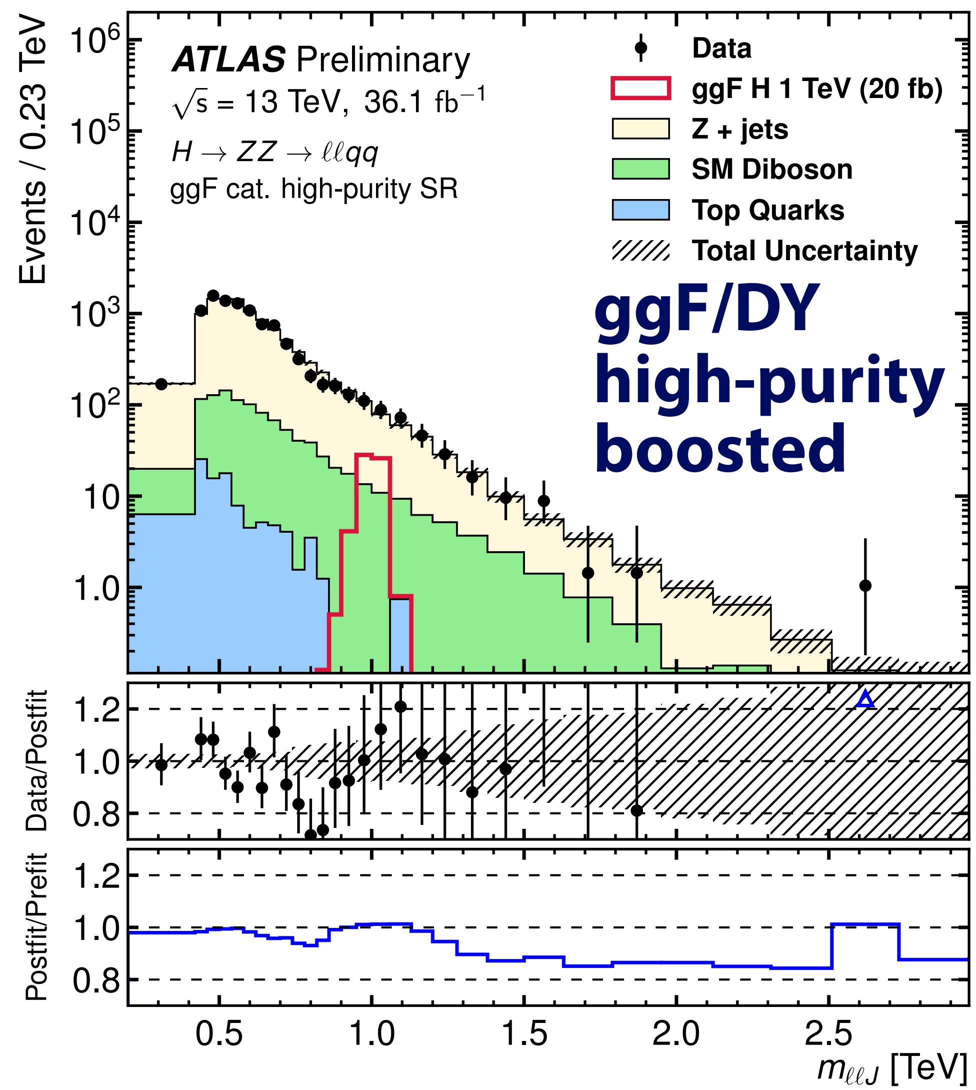
$p_T^V \gtrsim 0.3\text{-}0.5\ m_{VV}$

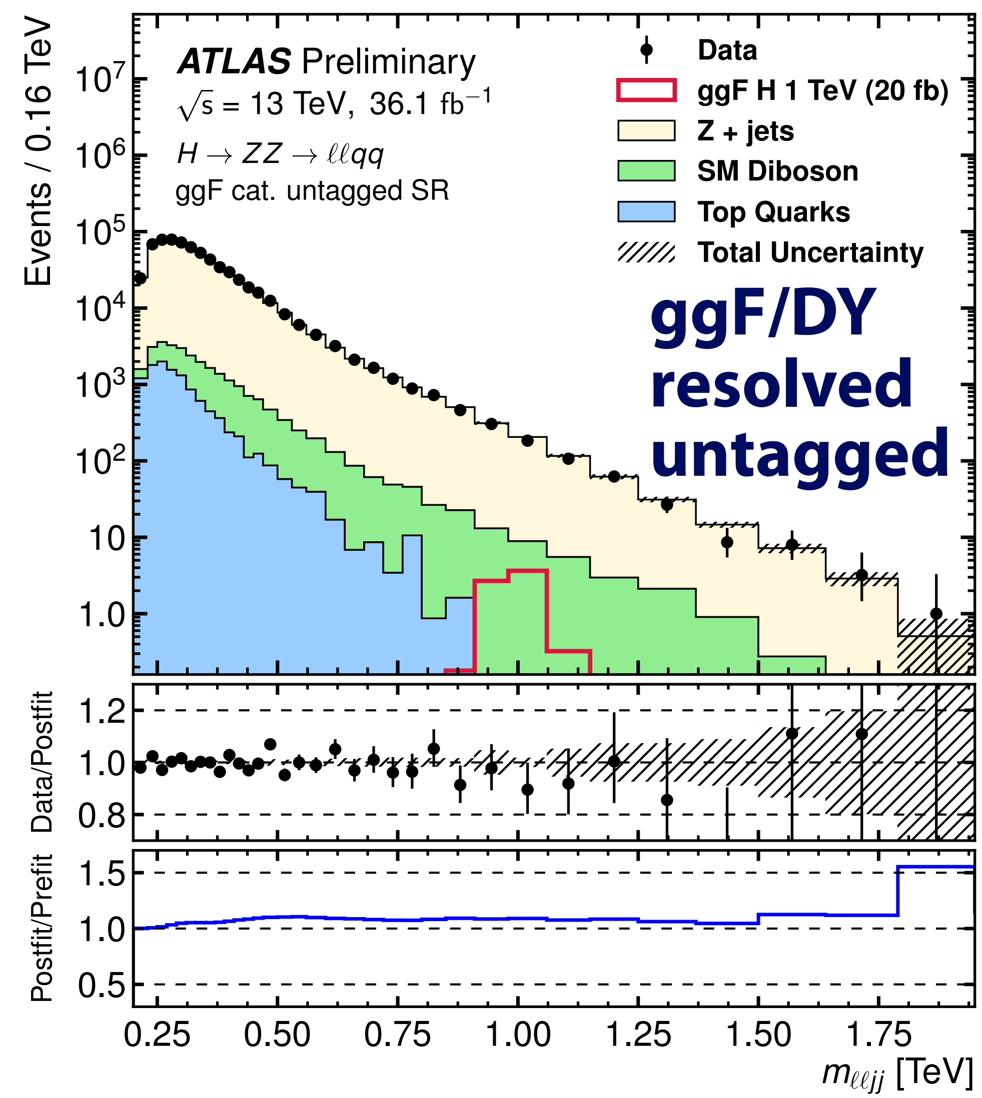
$m_{J/jj} \sim m_{W/Z}$

$m_{ll} \sim m_Z$

Signal領域のカテゴリ分け

- **VBF** : high & low-purity boosted, resolved
- **ggF/DY** : high & low-purity boosted, resolved b-tag & untagged





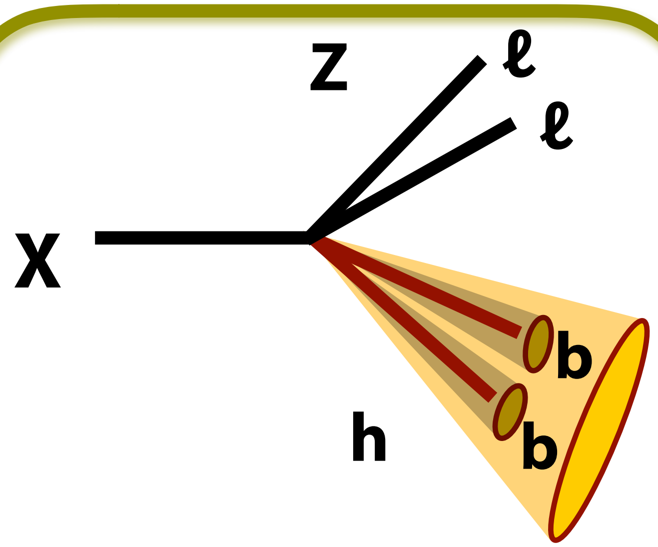
Z+jets BGはmass sidebandで決定。Top BGはeμ事象, DibosonはMCで評価。

事象の超過はなし…

Zh→ll+bb

CONF-2017-055　Wh→lνbb, Zh→ννbbはここ参照

Zh→llbb



Boosted & Resolved

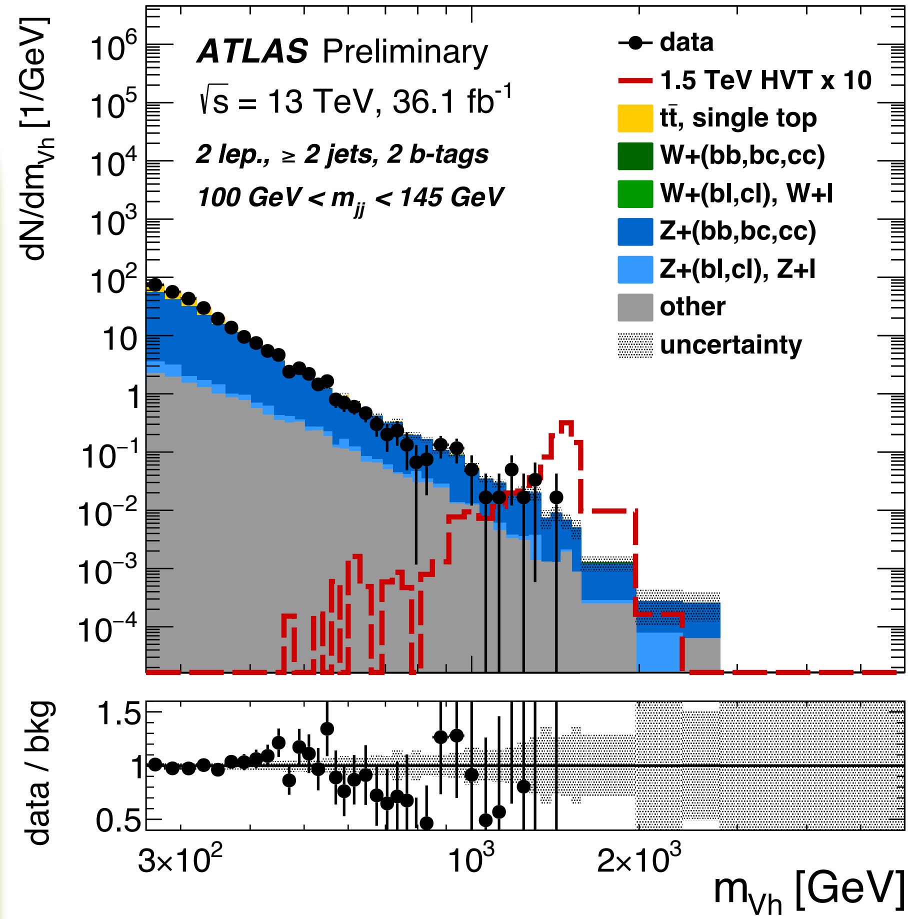
p_T^{ll} cut (m_{Vh} dep.)

$m_{J/jj} \sim m_h$

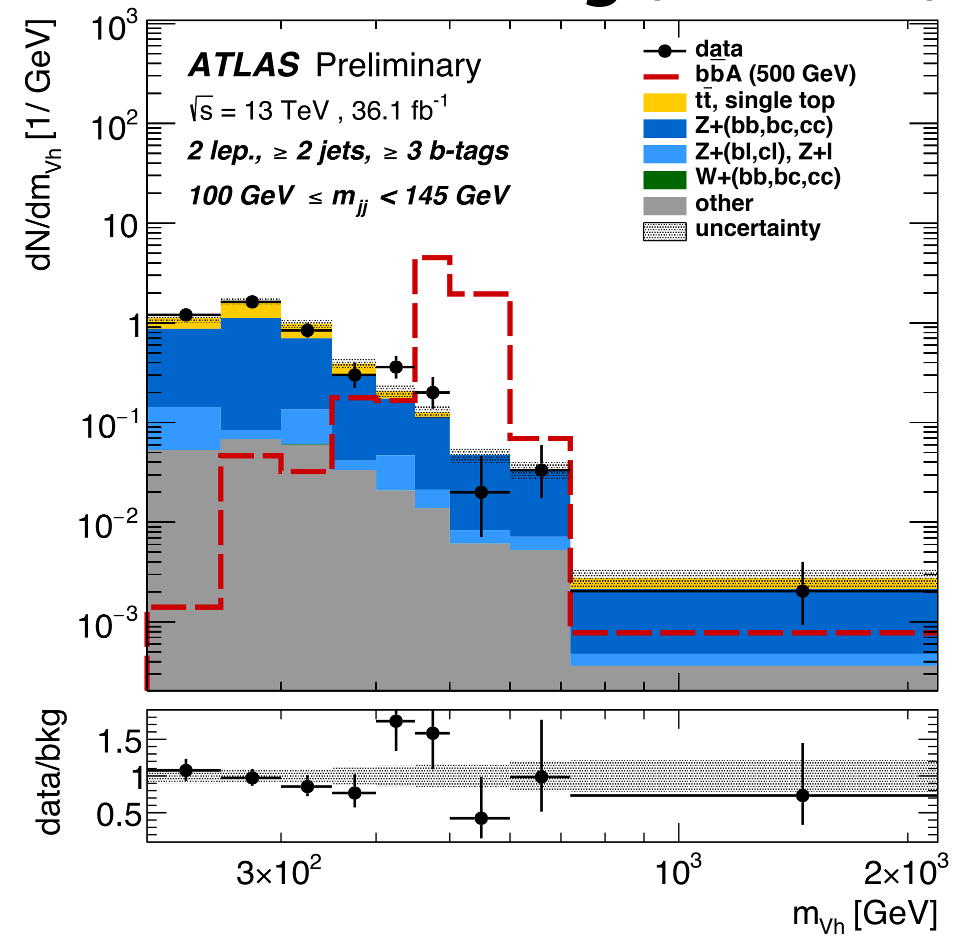
$m_{ll} \sim m_Z$ (m_{Vh} dep.)

1, 2, 3+ b-tag

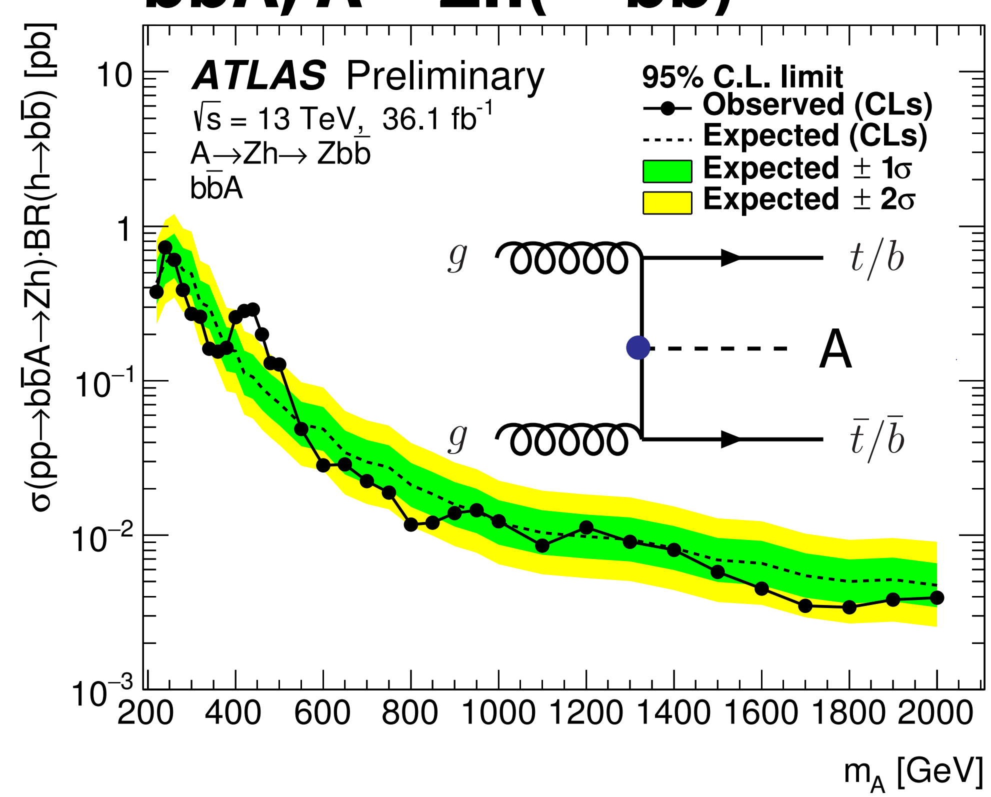
ll + 2b-tag (resolved)



ll + ≥3b-tag (resolved)



bbA, A→Zh(→bb)



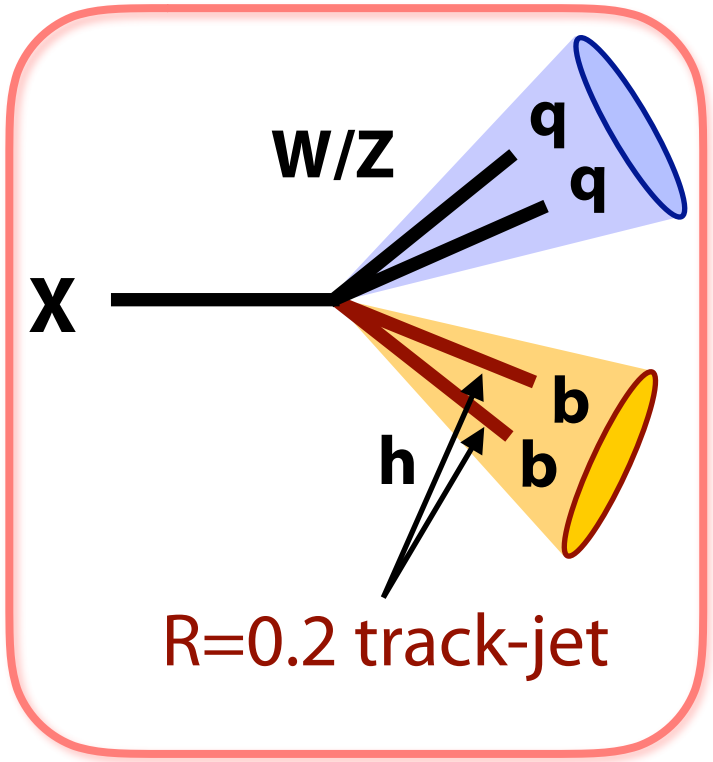
Z+jets [(bb,bc,cc) & (bℓ,cℓ) & (ℓℓ)に分ける]
は0-lepとともに, CR & SR Fitで決定

- Heavy vector triplet, 2HDMに対する制限
- bbA(→Zh) fit with 3+ b-tagにmild excess
  - local 3.6σ (global 2.4σ) at m_A~440 GeV
  - CMSの結果はまだ

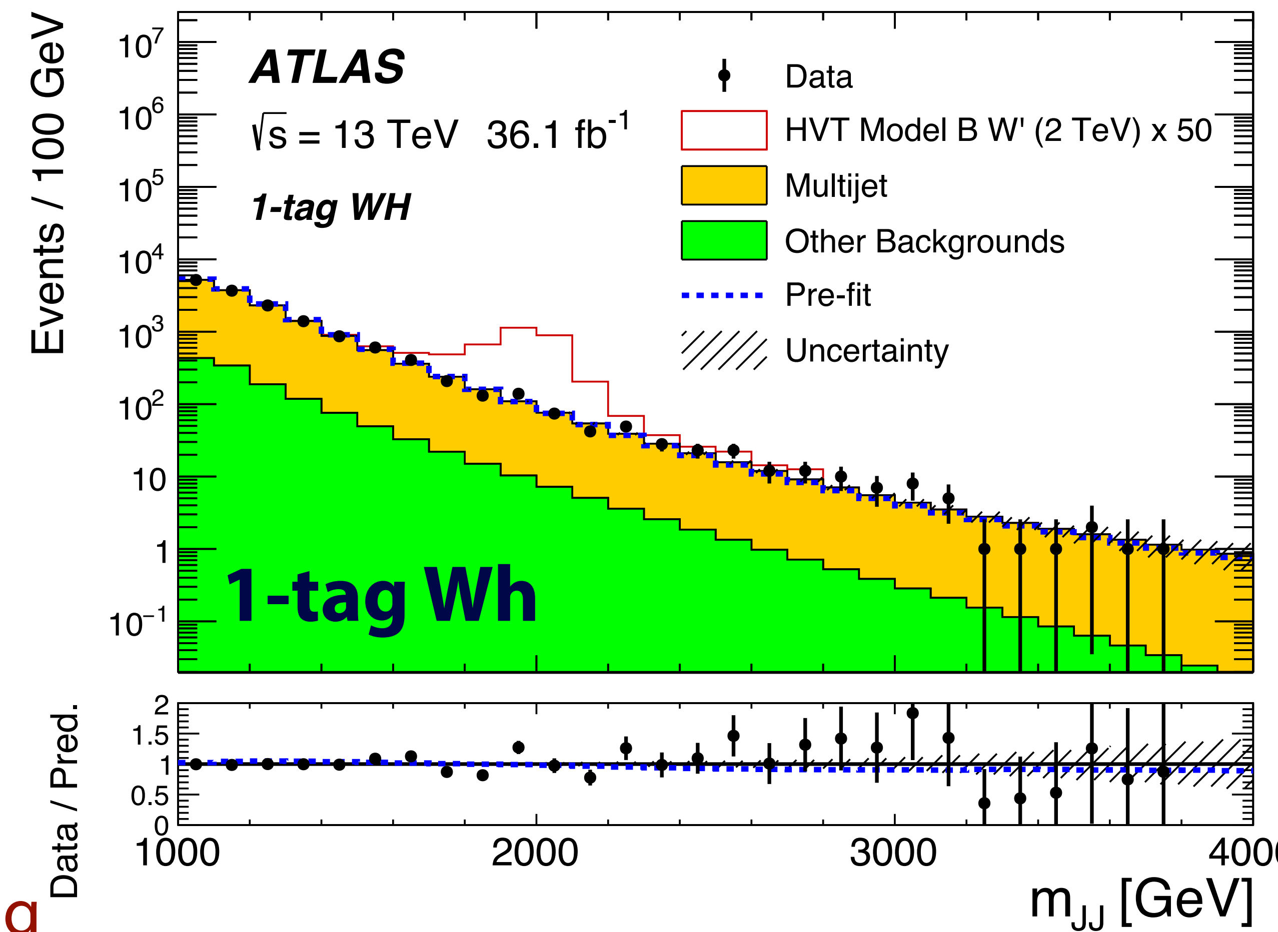
Vh→qqbb

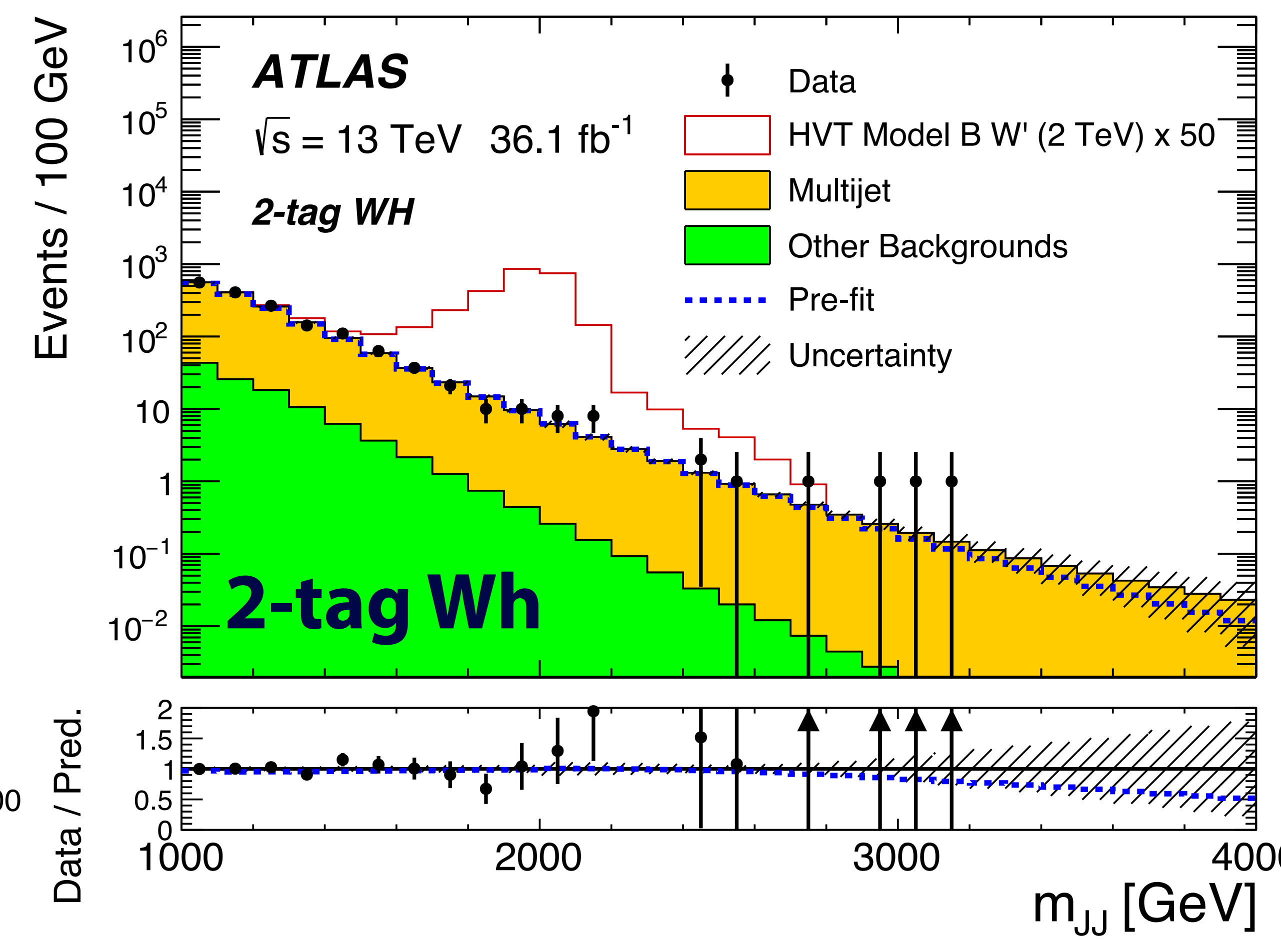
EXOT-2016-12

Vh→qqbb



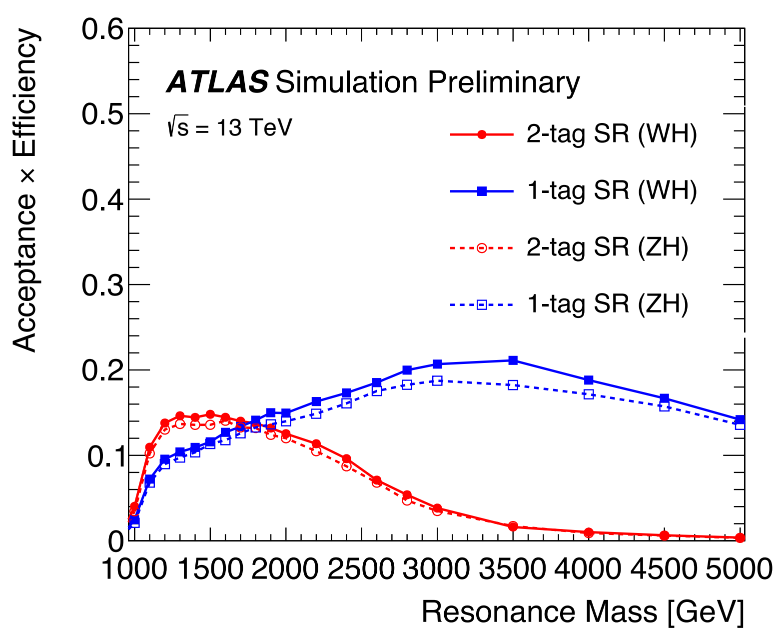
- p_T^{J1} >450 GeV
- $|y_1 - y_2| < 1.6$
- Large-R jets with
  - W/Z boson tagging
    - $m_J = m_{W/Z}$, D_2
  - Higgs boson tagging
    - $m_J = m_{Higgs}$
    - track-jet 1 & ≥2 b-tag





Multijet BGはデータから評価

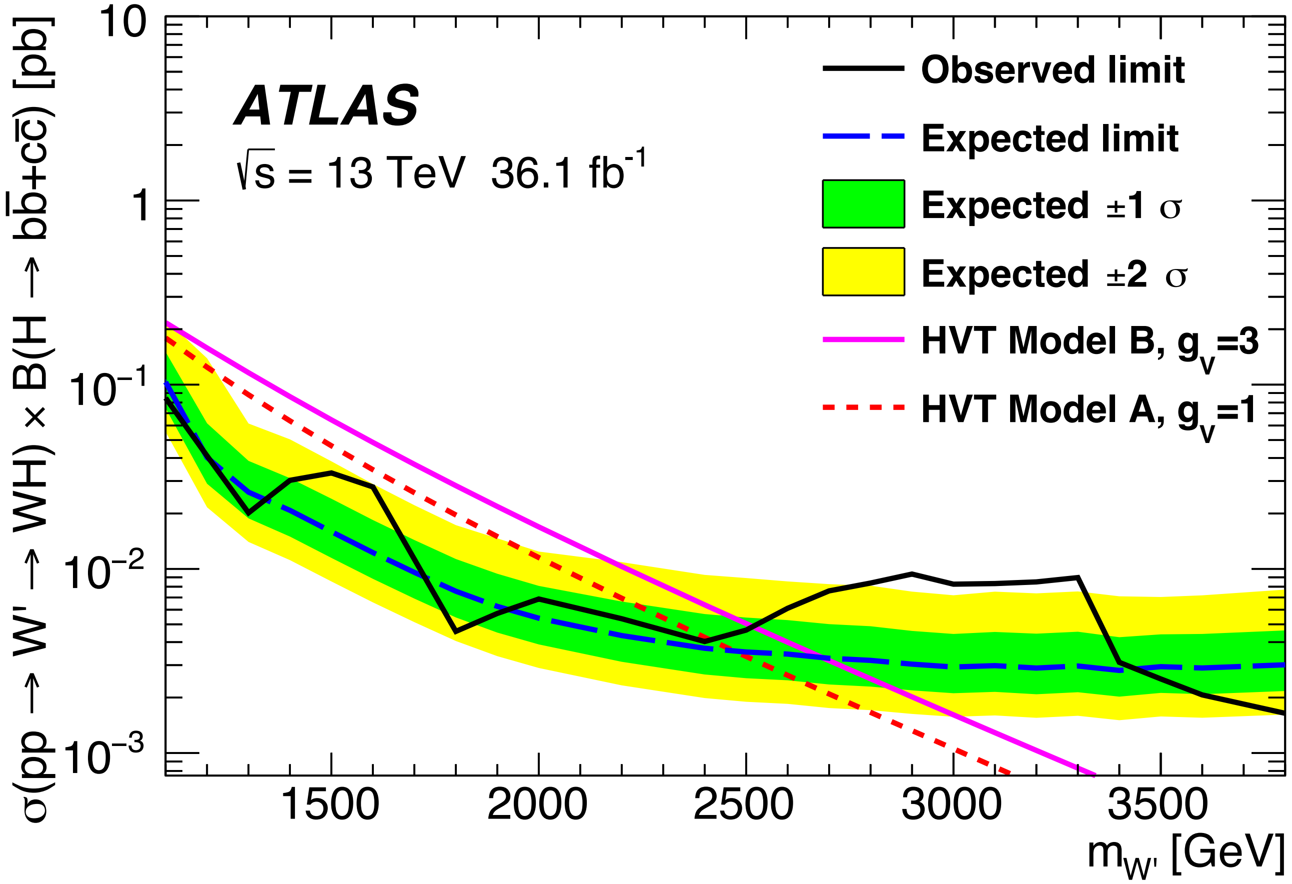
- 0 b-tag CRから m_{Vh} shapeを導出
- Mass sidebandのFitで, 0→1/2 b-tag normalizationを決定



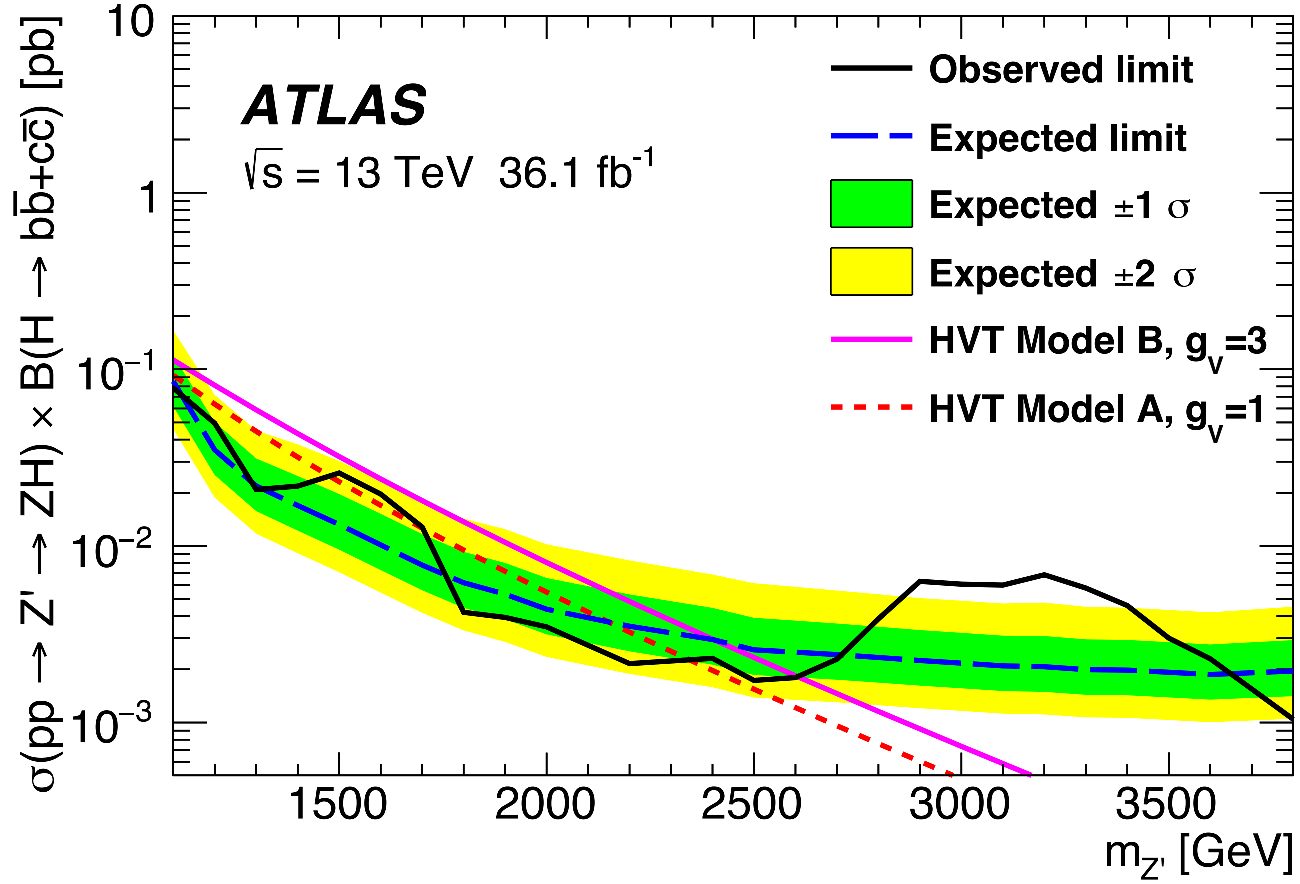
Vh→qqbb

EXOT-2016-12

Wh



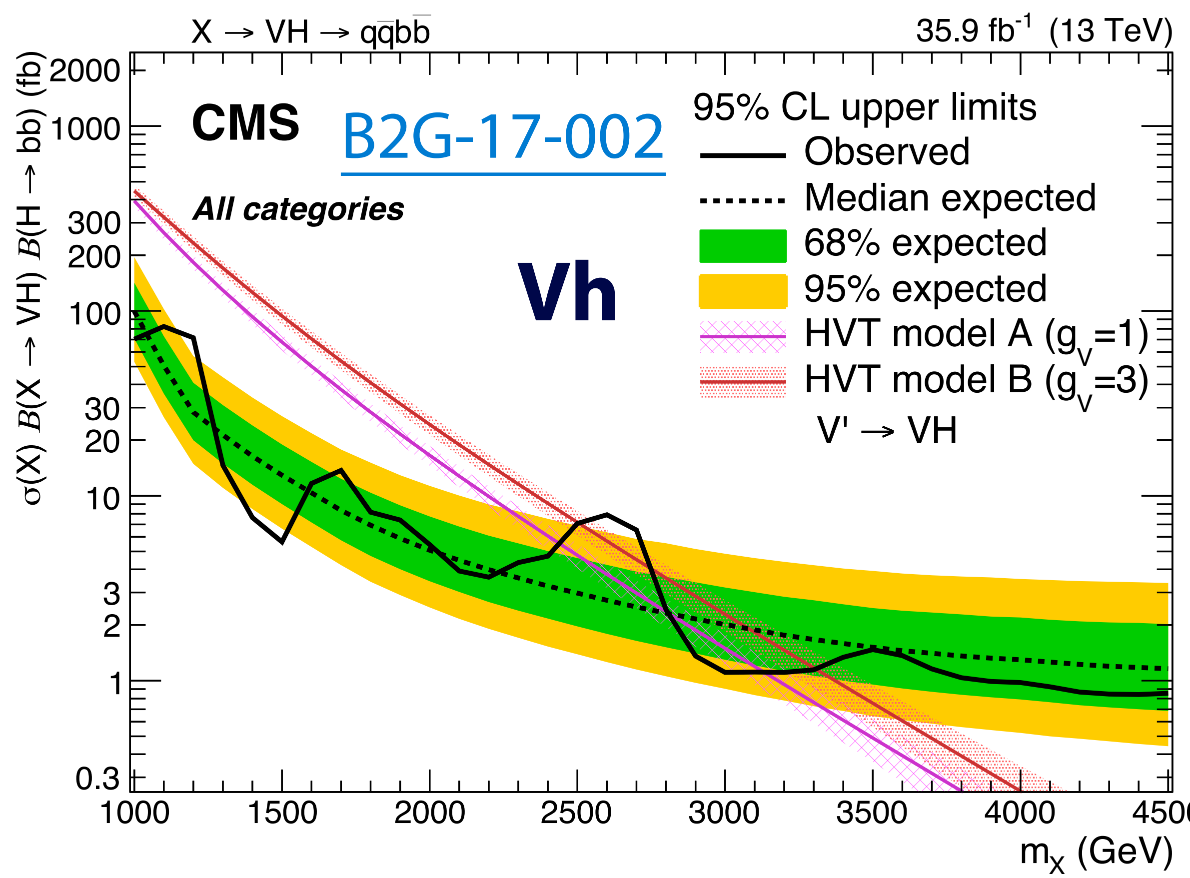
Zh



1 & ≥2-tagで事象の超過

- 3.5σ local, 2.5σ global at ~3 TeV

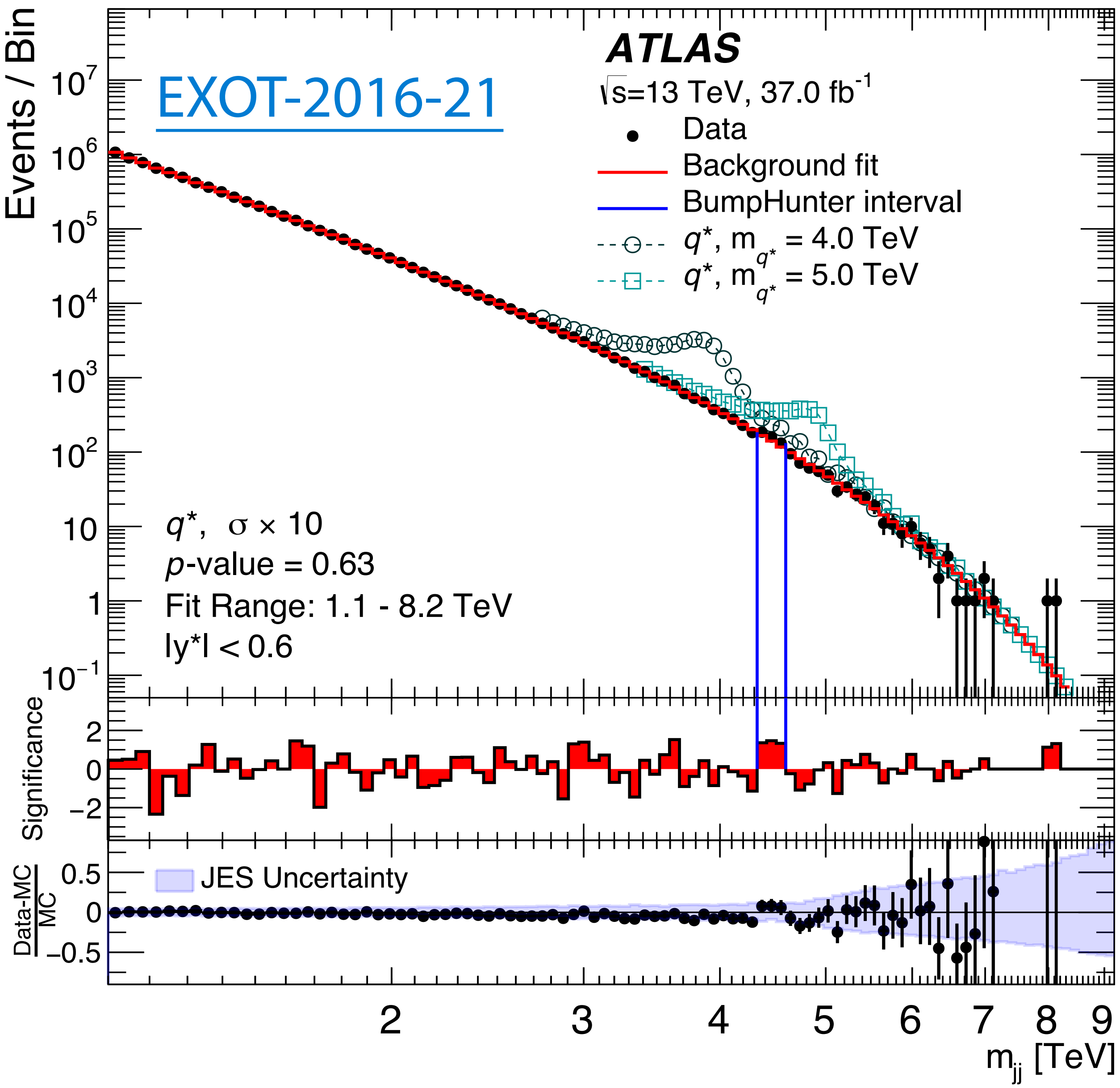
CMSは2.6 TeVに2.6σ local,
0.9σ globalのmild excess
→ 場所が違う…。



Dijet
→ 高いスケールへ

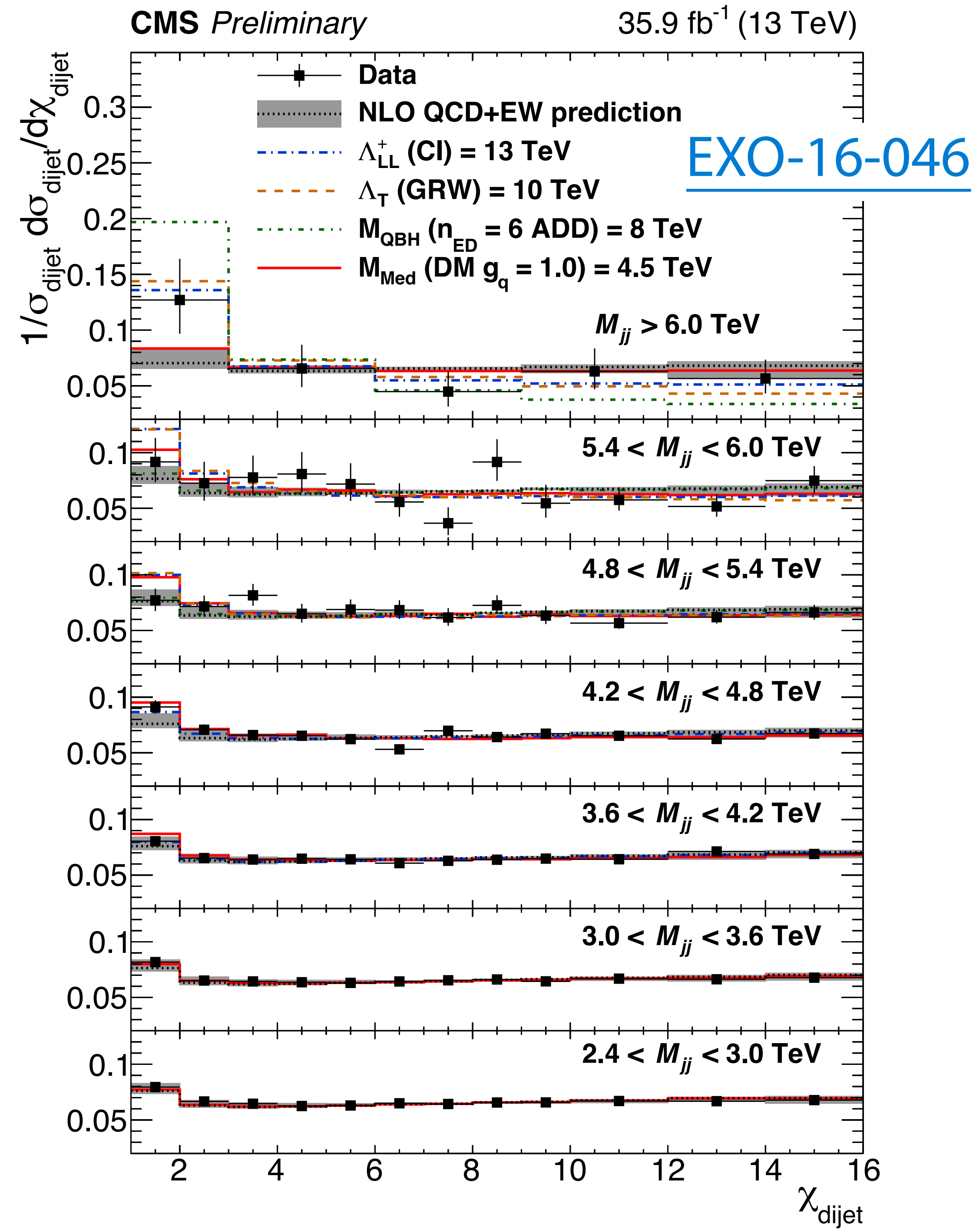
Smooth function fitによるBump Hunting

$$f(x) = p_1(1-x)^{p_2}x^{p_3} \quad x = m_{jj}/\sqrt{s}$$



→ q* limit = 6 TeV (ATLAS, CMS)

Kinematicsの限界に近づいている…



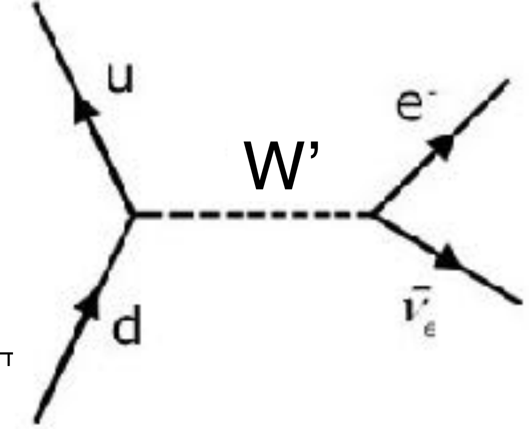
大角度散乱による
Contact Interactionの検証

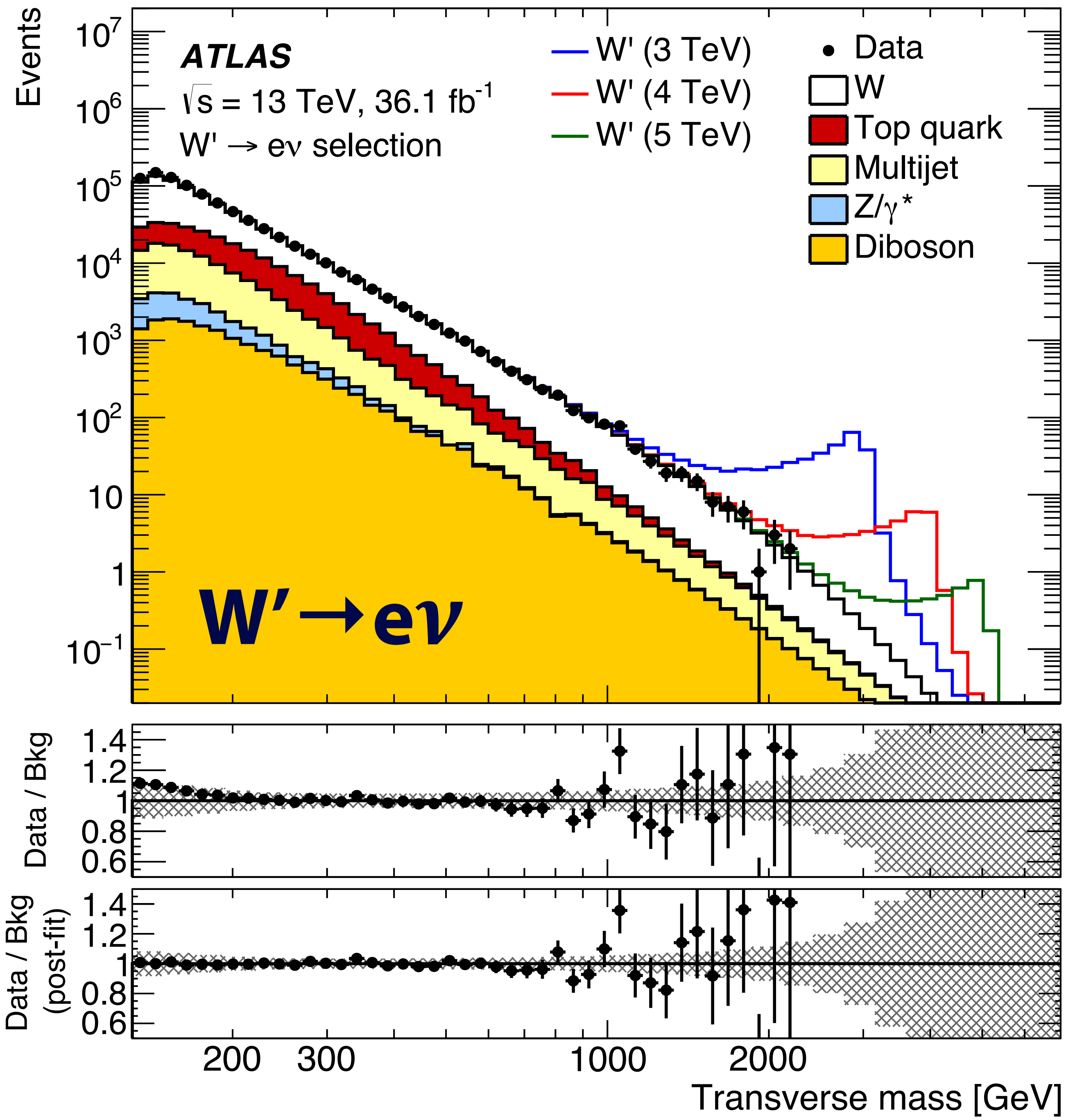
$$\chi = e^{|y_1 - y_2|} \sim \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

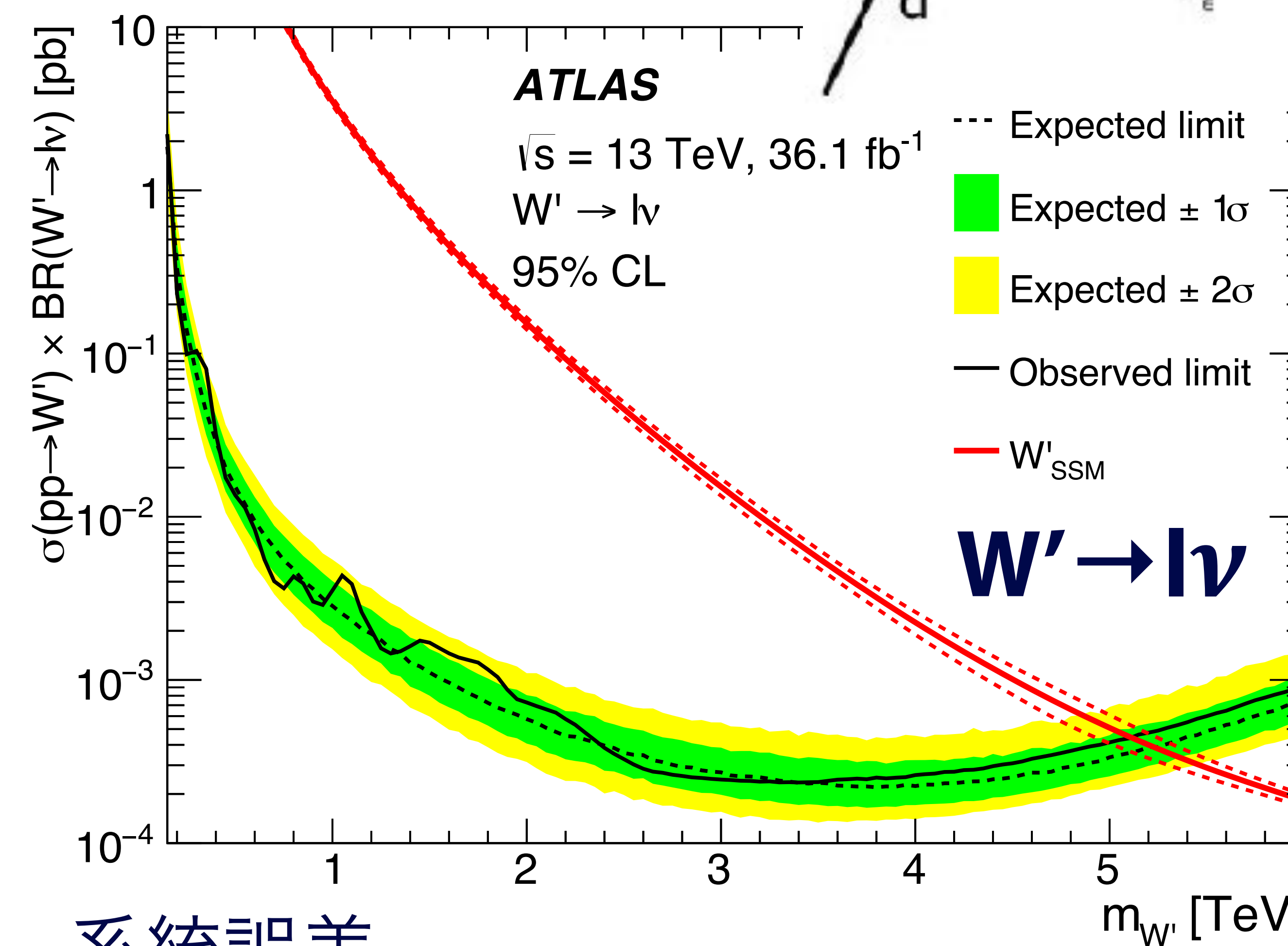
pQCD予想 (NLO QCD+EW) との比較

Dilepton

EXOT-2016-06







- 1 e(μ) : p_T > 65(55) GeV, loose isolation
- E_T^{miss} > 65(55) GeV, m_T > 130(110) GeV

W BGはPowheg+Pythia with mass-dep. k-factor (NNLO QCD, NLO EW)で評価

系統誤差

- Jet, E_T^{miss} at low mass
- Non-DY BG extrapolation, muon resolution, PDF at high mass

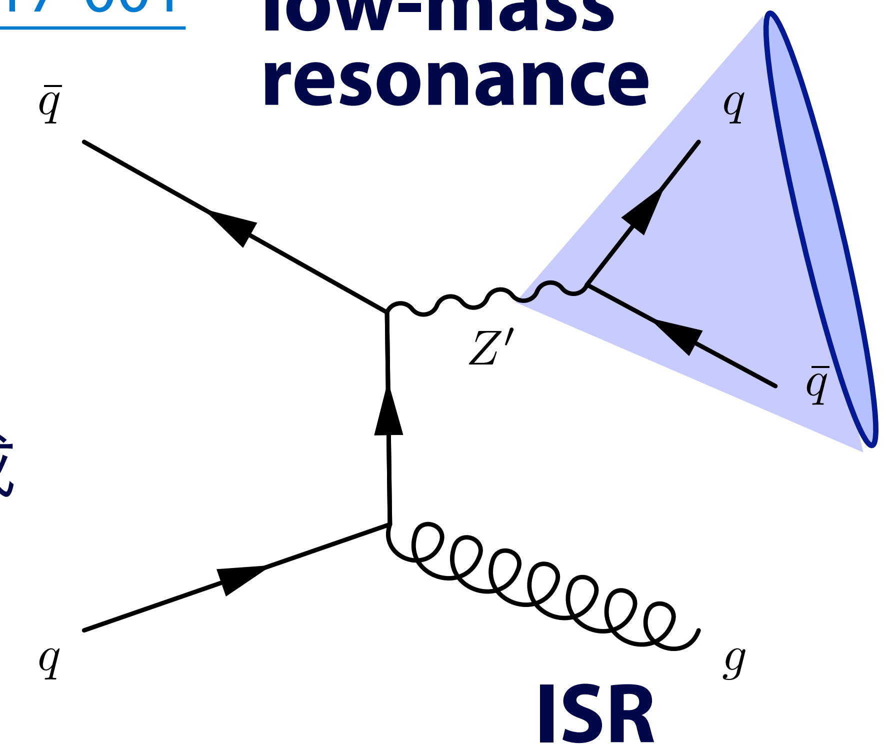
W'$_{SSM}$ limit [Tev]	Exp.	Obs.
eν	5.1	5.2
μν	4.7	4.5
lν	5.2	5.1

低いスケールへ

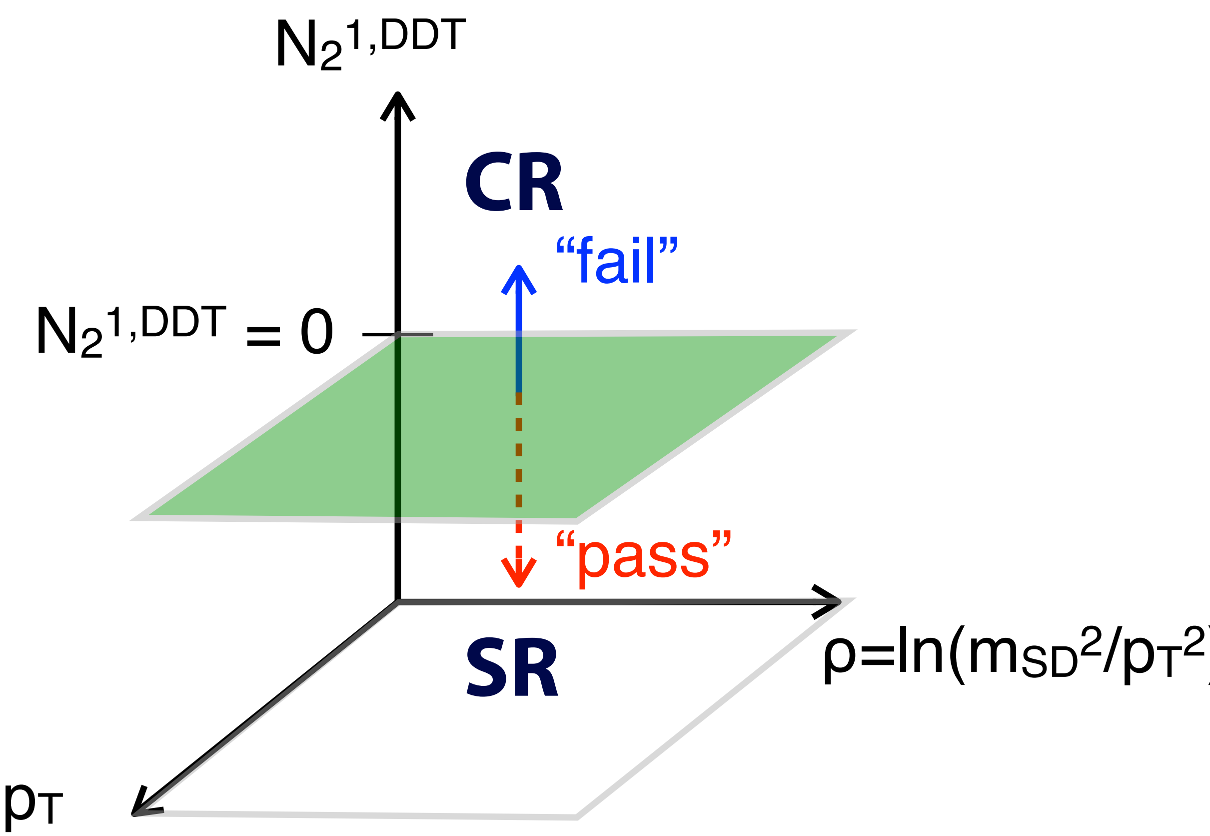
低質量の新粒子をHard ISRジェットによるブーストを使って探索する

- ブーストするZ'→qqを大半径ジェットで再構成
- Jet substructureを使ってQCD jetから識別
- ジェット質量分布でのピーク探索

EXO-17-001

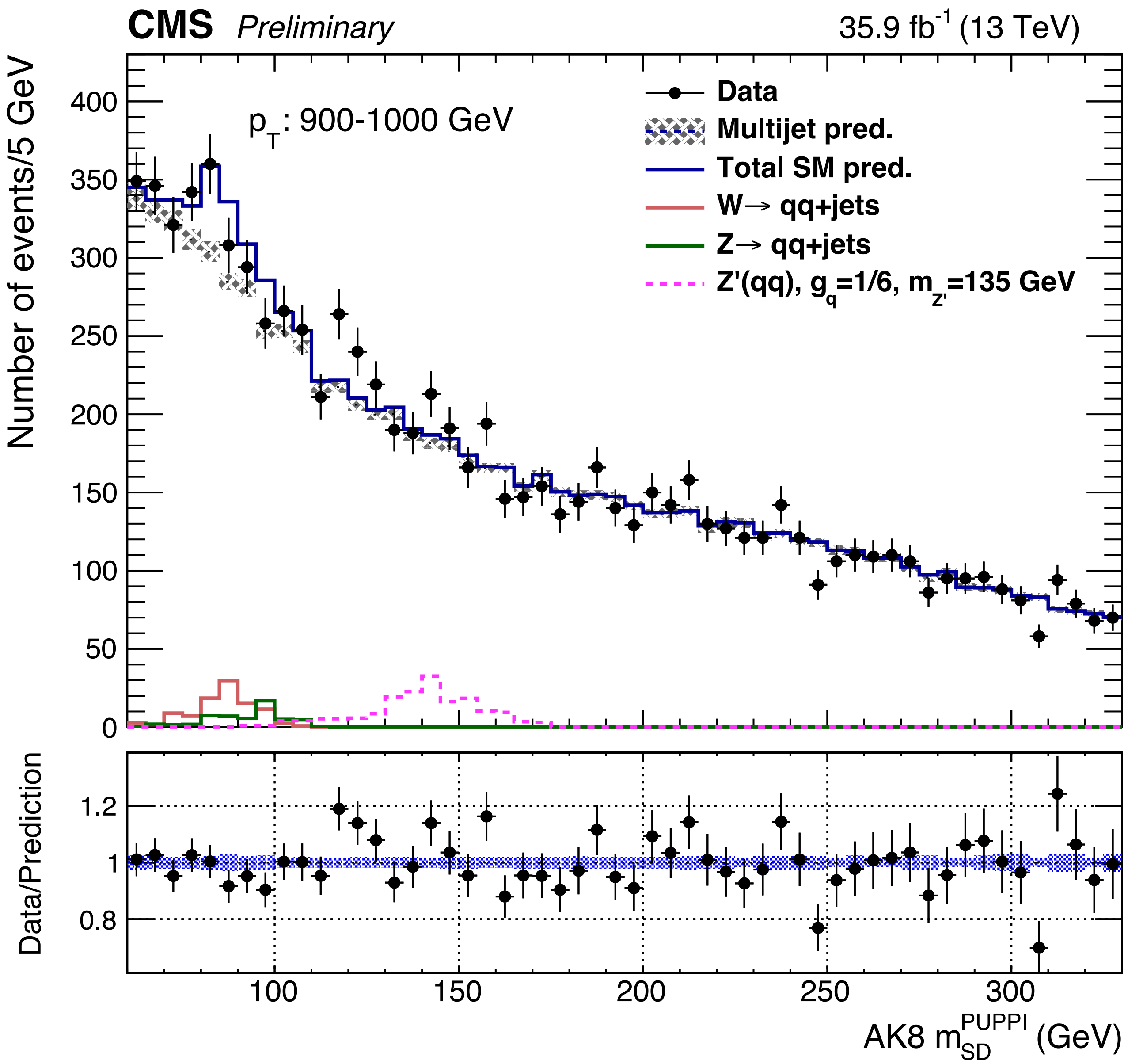


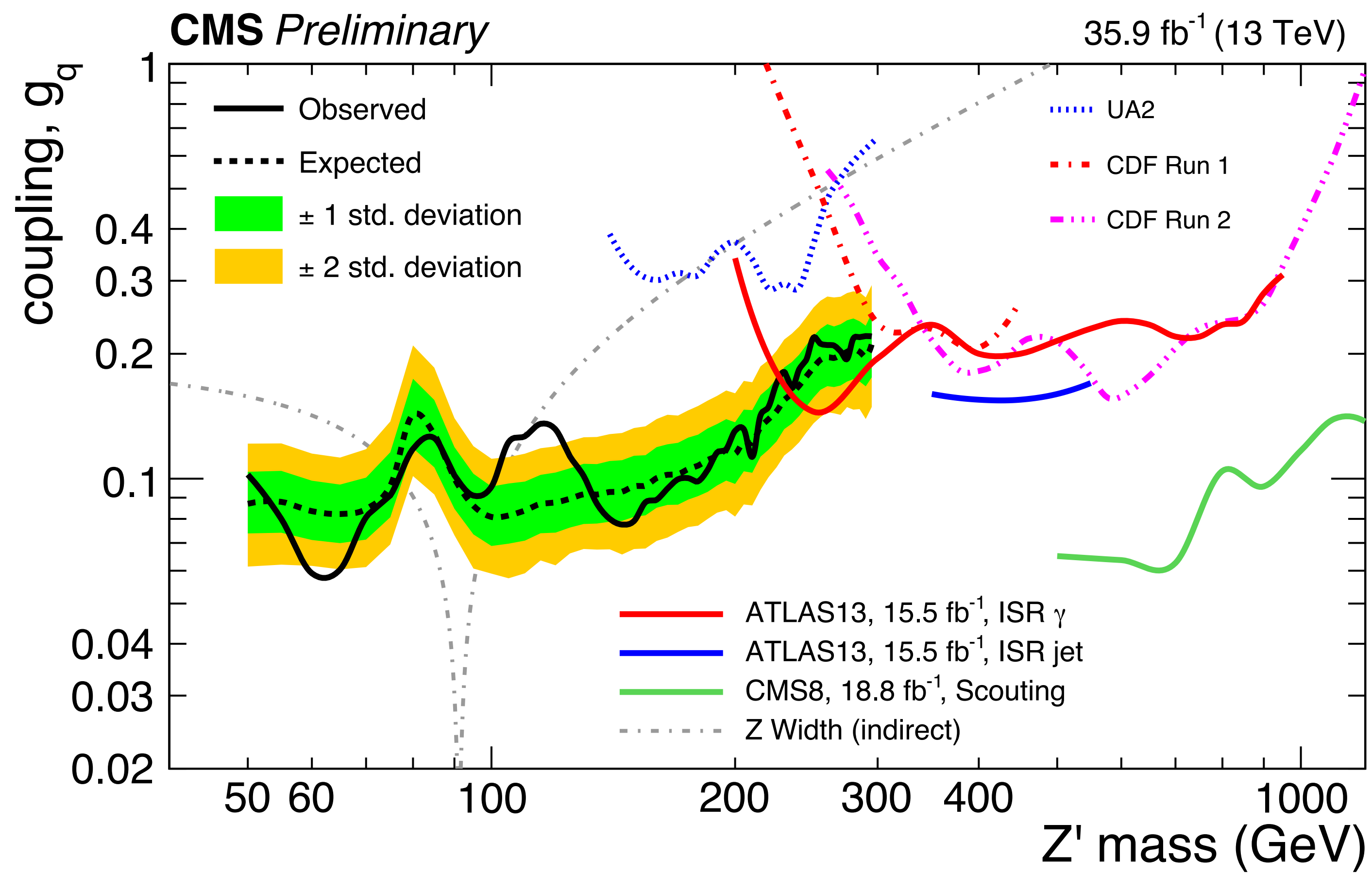
- p_Tと$\rho = \ln(m_{jet}^2/p_T^2)$平面でjet分布を記述
- $N_2^{\beta=1}$ (energy correlation function ratio) で2-prong構造を識別
- "Decorrelated" $N_2^{\beta=1}$ ($N_2^{\beta=1,DDT}$) でCRとSRを区別
- CRのm_{jet}分布をSR/CR比でスケールしてSR中の背景事象分布を評価
- 探索領域 : m_{jet} = 50-300 GeV



ISRジェット+ Resonance

EXO-17-001





ISR photon+Dijetと組み合わせて,

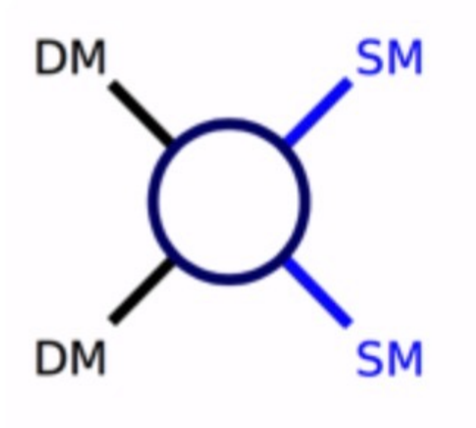
30 GeV<$m_{Z'}$<~1 TeV領域をカバーできる

(1 TeV以上はHigh-mass Dijetが担当)

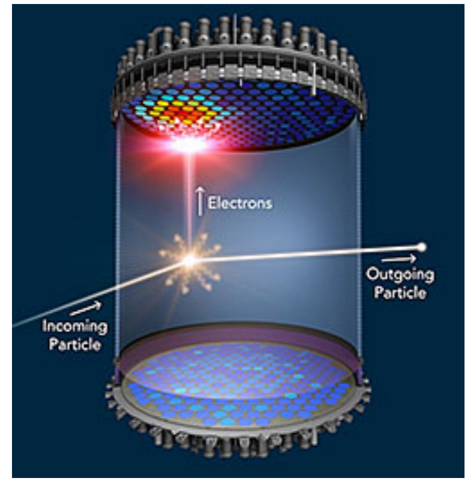
- W/Zピークを使って, $N_2^{\beta=1}$カット効率, m_{jet}スケール等をconstrain
- local 2.9σ (global 2.2σ) at $m_{Z'}$~115 GeV
  - ちょっと幅が狭い?

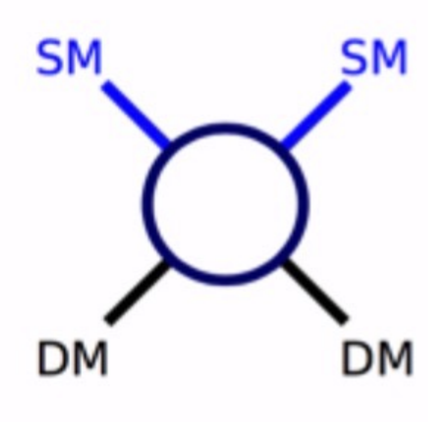
➔ Vector mediator (DM simplified model) への制限

暗黒物質の探索

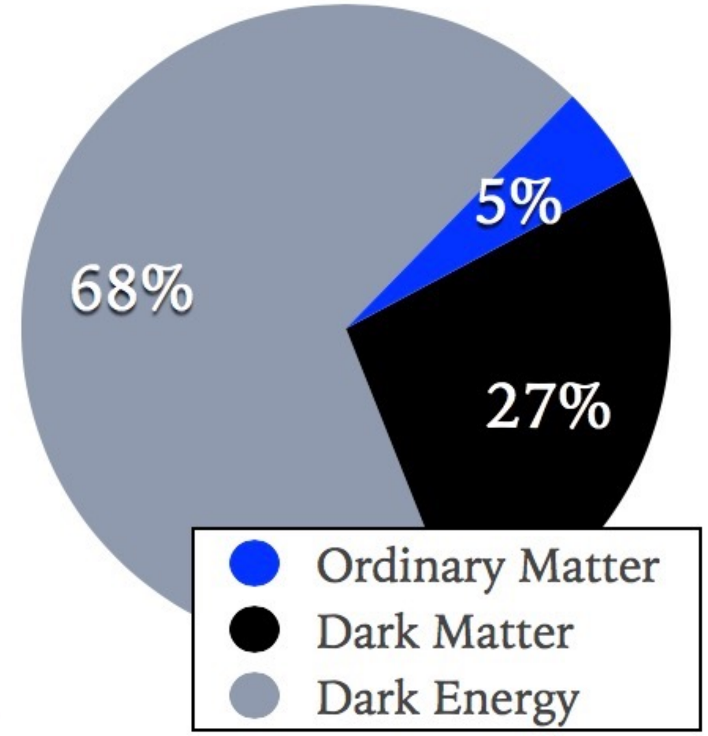


Indirect Detection

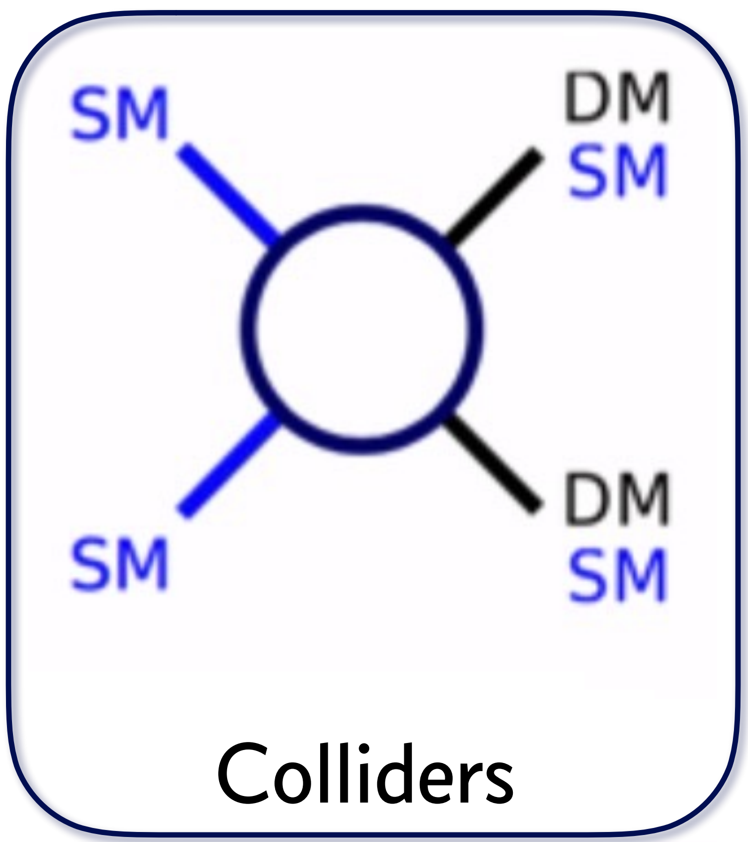




Direct Detection



➡ 加速器実験での暗黒物質の探索

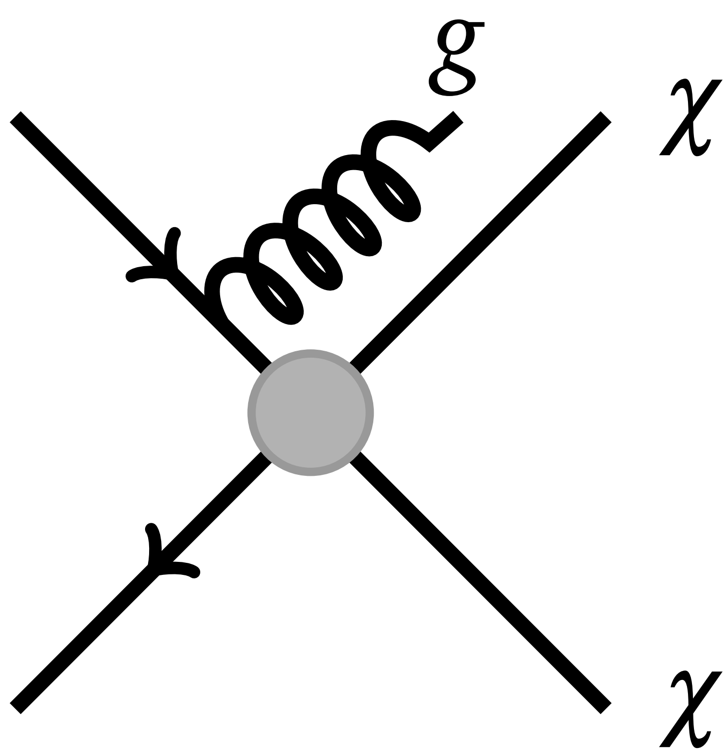


LHCでは何が可能か?

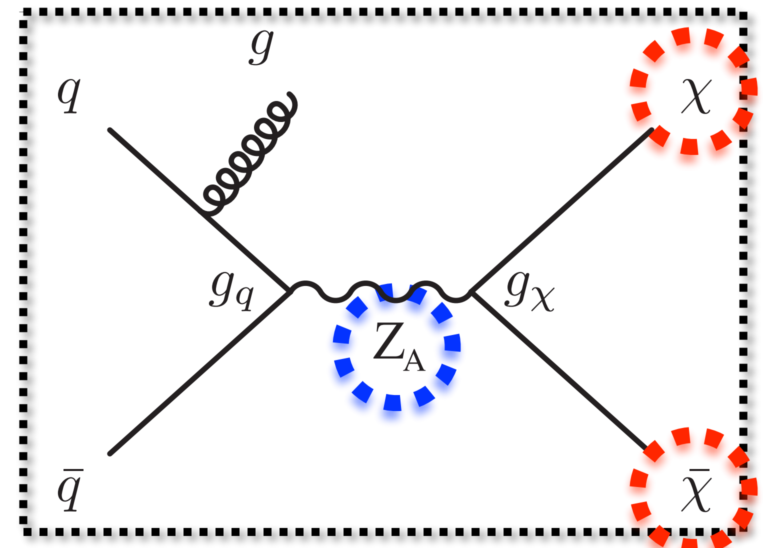
- カスケード崩壊からの暗黒物質の探索
  例) SUSY (Neutralino), UED (KK photon)
- 暗黒物質(WIMP)と媒介粒子の直接探索
- より軽い媒介粒子の探索 (Dark Sector)

暗黒物質の探索

暗黒物質と媒介粒子の直接生成を探す

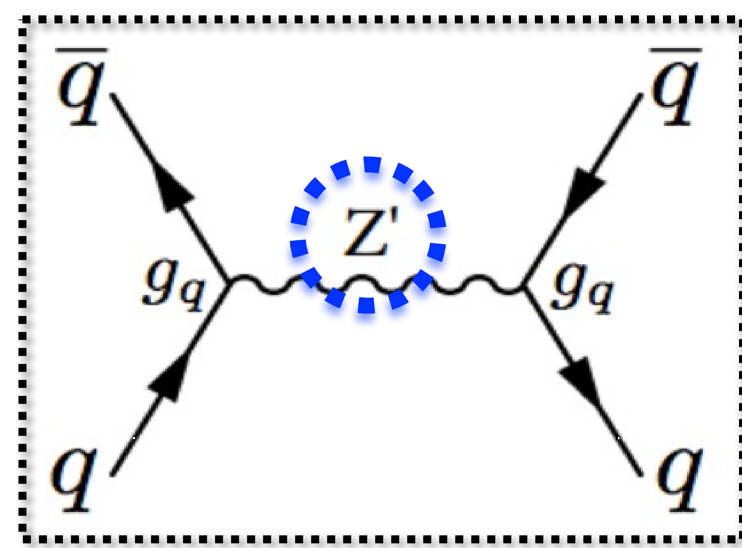


暗黒物質 → Mono-X信号



→ E_T^{miss} + jet,W/Z/H,γ, top, ..

媒介粒子 → SM粒子への崩壊



→ dijet, ditop, dilepton, …

Simplified modelによるInterpretation

(EFTはQ_{tr}^2 ~ EFT M*の領域では有効でなくなる)

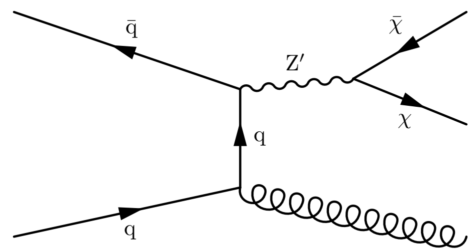
	spin 0	spin 1
Charge	Q=0 for s-channel	
Interaction type	scalar pseudo-scalar	vector axial-vector
Coupling	∝ mass	∝ charge

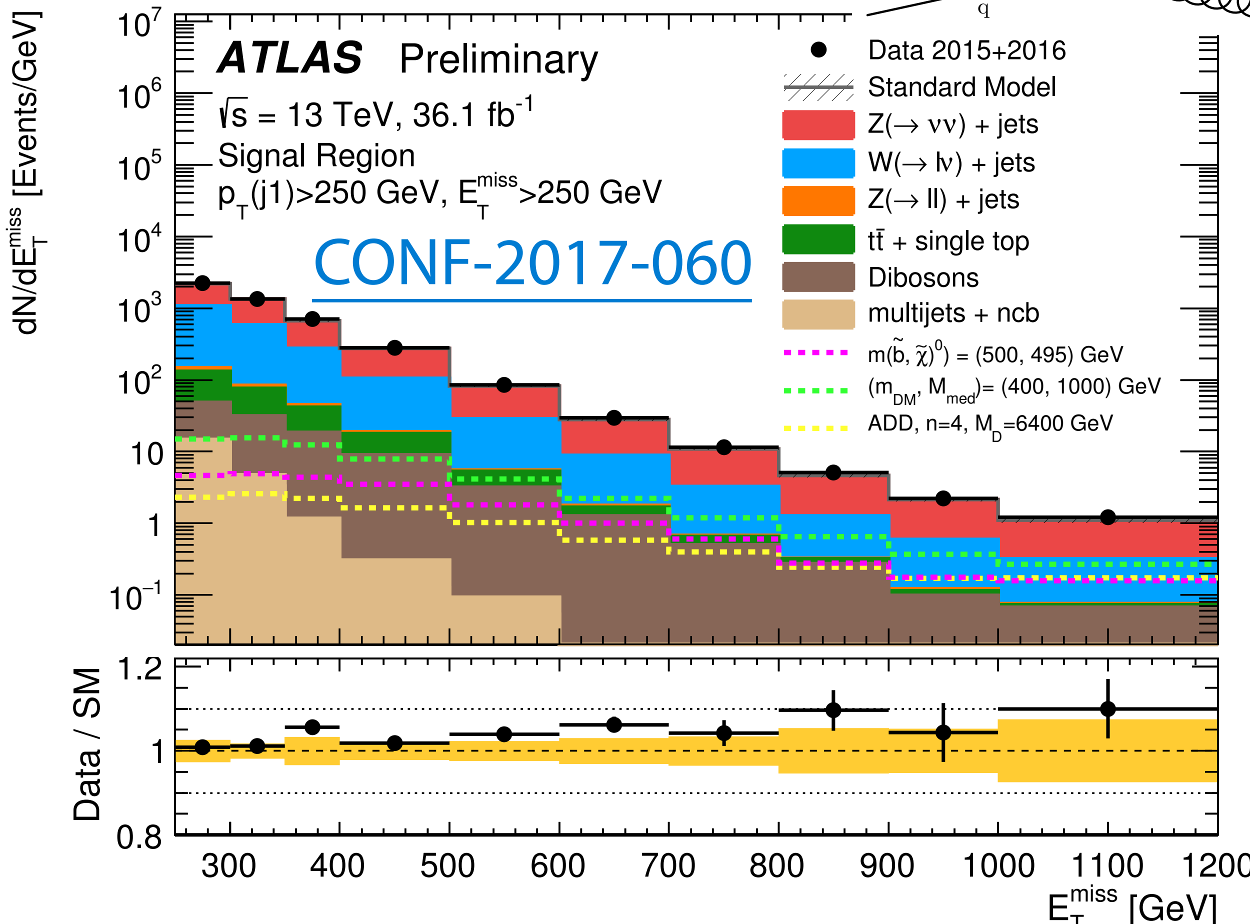
パラメータ：

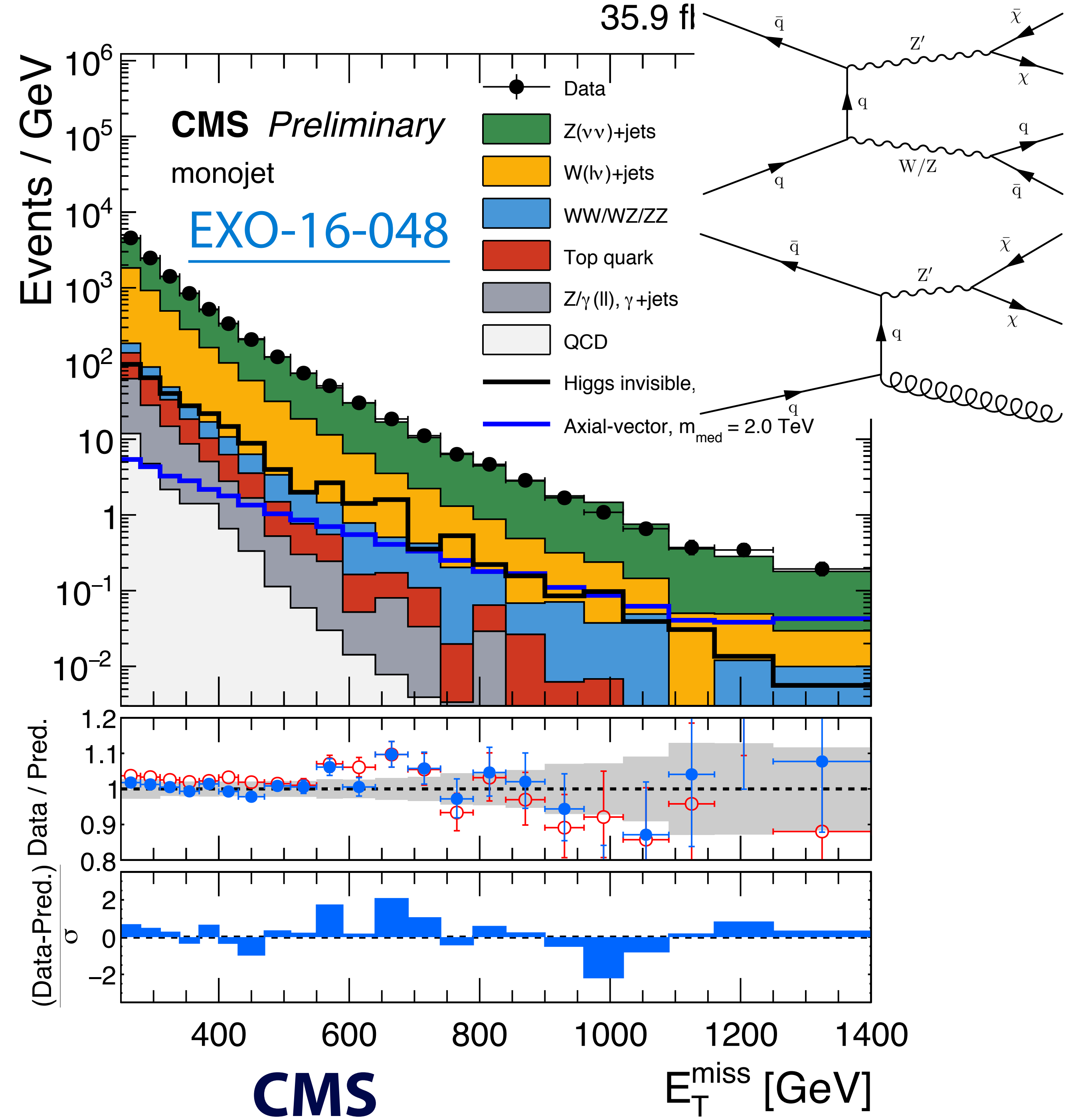
m_{med}, m_χ, g_q, g_χ,

Interaction type

Mono-jet







ATLAS

- E_T^{miss} >250 GeV, $\Delta\phi$(jet, p_T^{miss}) > 0.4
- Jet1 p_T>250 GeV, $|\eta|$<2.4
- N_{jets} (p_T>30 GeV, $|\eta|$<2.8) ≤ 4

CMS

- E_T^{miss} >250 GeV
- Jet1 p_T>100 GeV, $|\eta|$<2.5
- Not selected as "mono-V" events

Mono-V events

- R=0.8 jet1 pT>250 GeV
- m_{jet} ~ $m_{W/Z}$, 2-prong

W/Z+jets BG

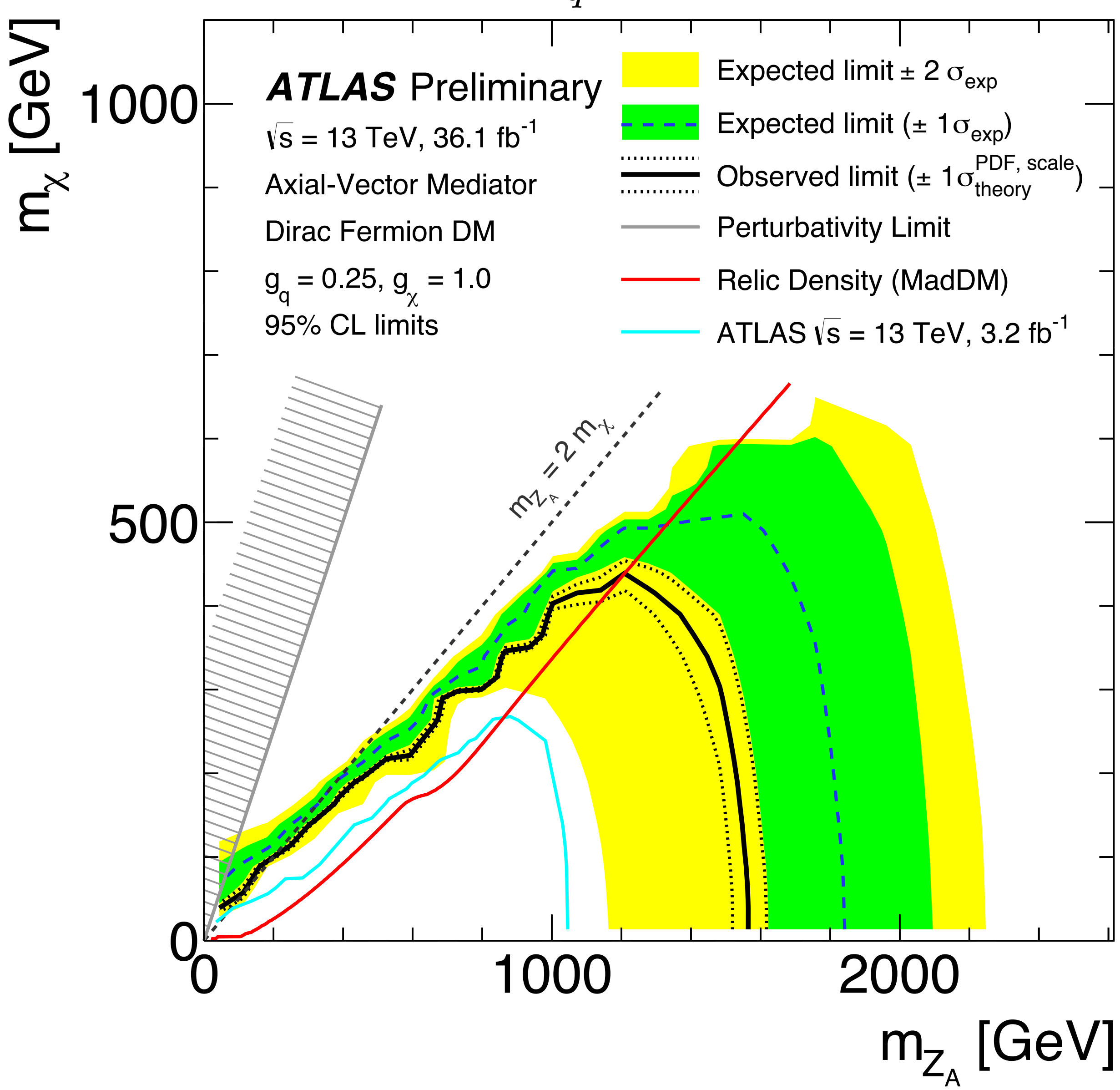
- NNLO (NLO) QCD + NLO EW with 2-loop Sudakov logs in ATLAS (CMS), following arXiv:1705.04664
- $e\nu$, $\mu\nu$, ee(CMS), $\mu\mu$, γ+jet CR + transfer factorで決定

Mono-jet

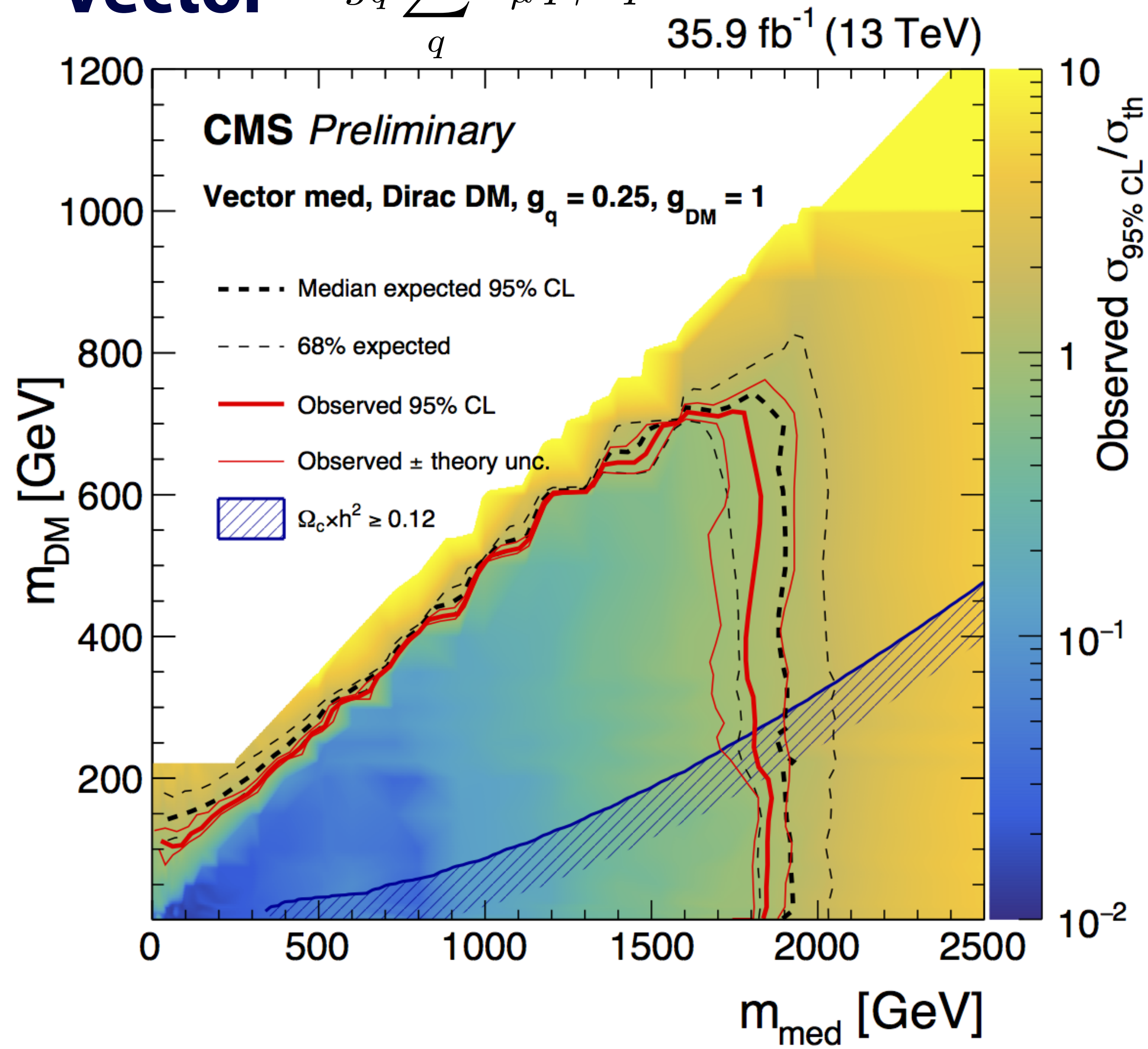
CONF-2017-060

EXO-16-048

Axial-vector $\sim g_q \sum_q A_\mu \bar{q}\gamma^\mu\gamma^5 q$



Vector $\sim g_q \sum_q V_\mu \bar{q}\gamma^\mu q$



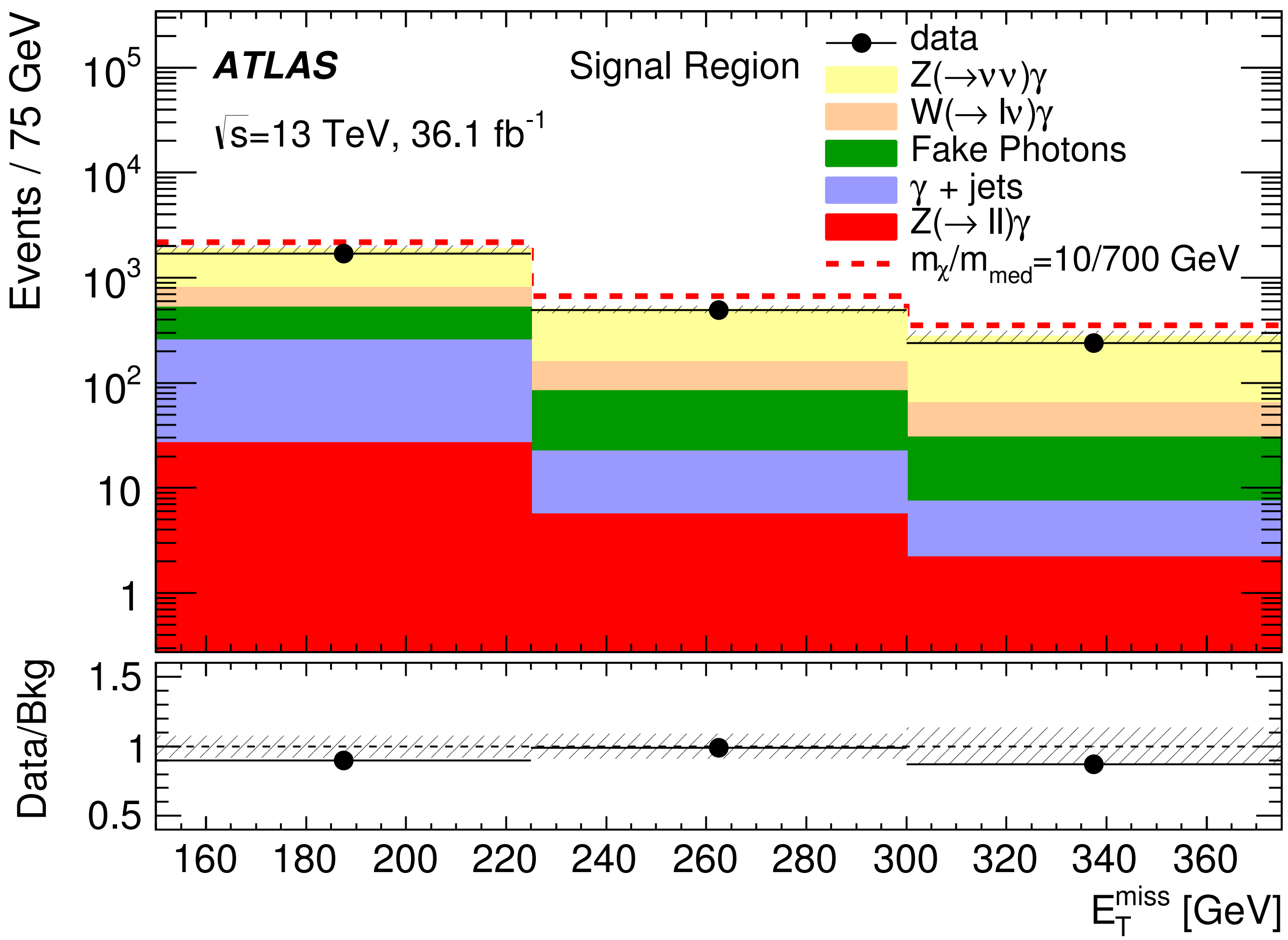
For vector and axial-vector interactions :

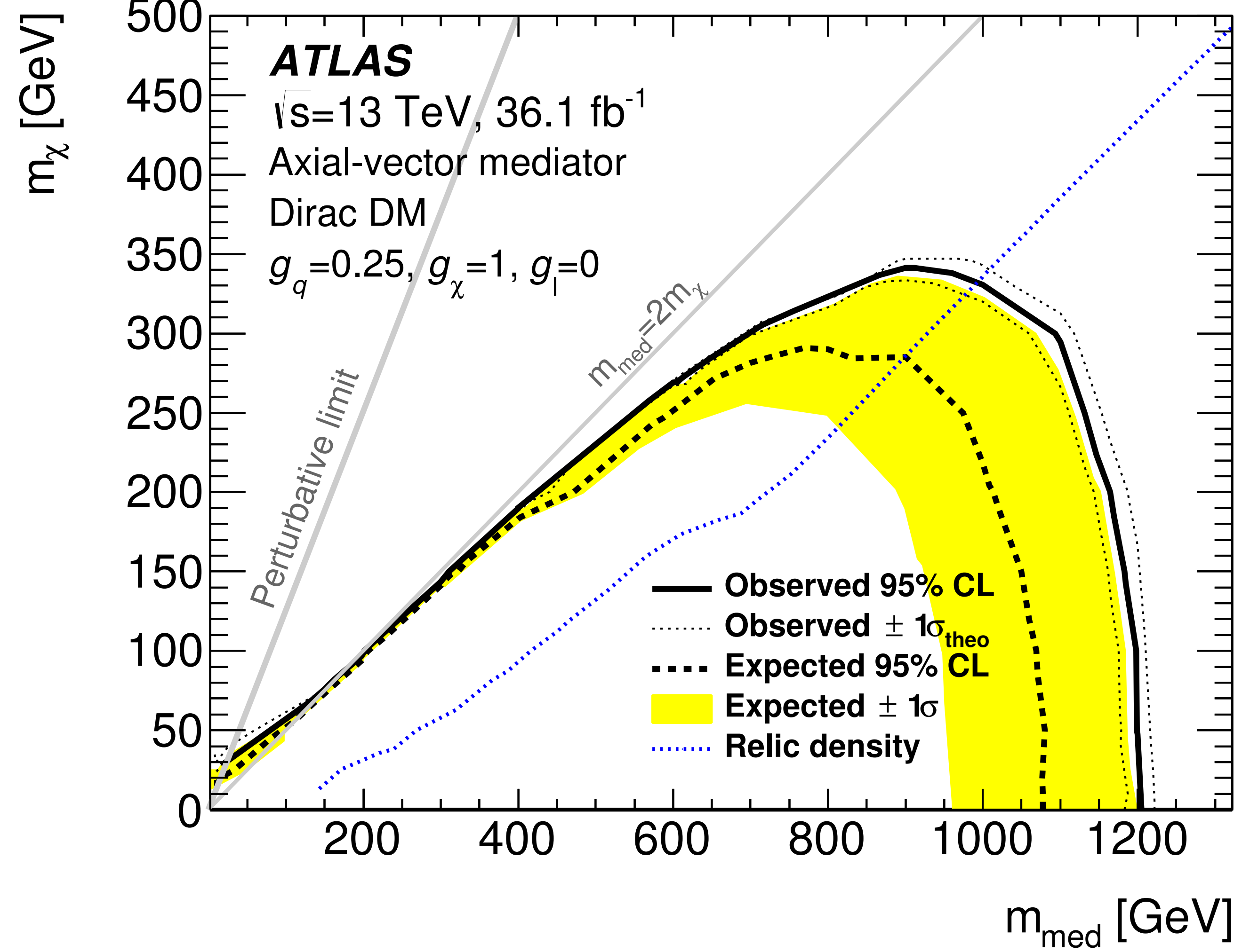
- Mediator mass excluded up to 1.6-1.8 TeV
- DM mass excluded up to 400-700 GeV

Mono-photon

EXOT-2016-32

Axial-vector ~ $g_q \sum_q A_\mu \bar{q} \gamma^\mu \gamma^5 q$





- Photon E_T>150 GeV, |η|<2.37
- $E_T^{miss}/\sqrt{\Sigma E_T}$ >8.5 GeV$^{1/2}$
- Δϕ(photon, E_T^{miss}) > 0.4
- N_{jets} (p_T>30 GeV, |η|<4.5) ≤ 1

- $W\gamma$, $Z\gamma$, γ+jets BGを, 1μ, 2e+2μ, γ+jets (low E_T^{miss}) CRで決定
- 棄却のためにMulti-E_T^{miss} binを設定

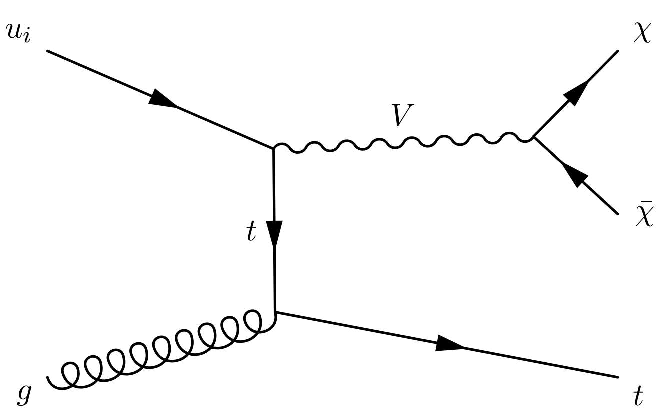
For vector and axial-vector interactions :

- Mediator mass excluded up to 1.2 TeV
- DM mass excluded up to 340-480 GeV

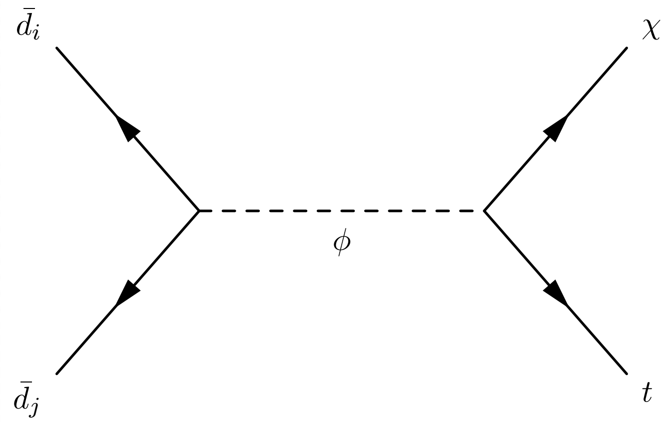
Mono-top

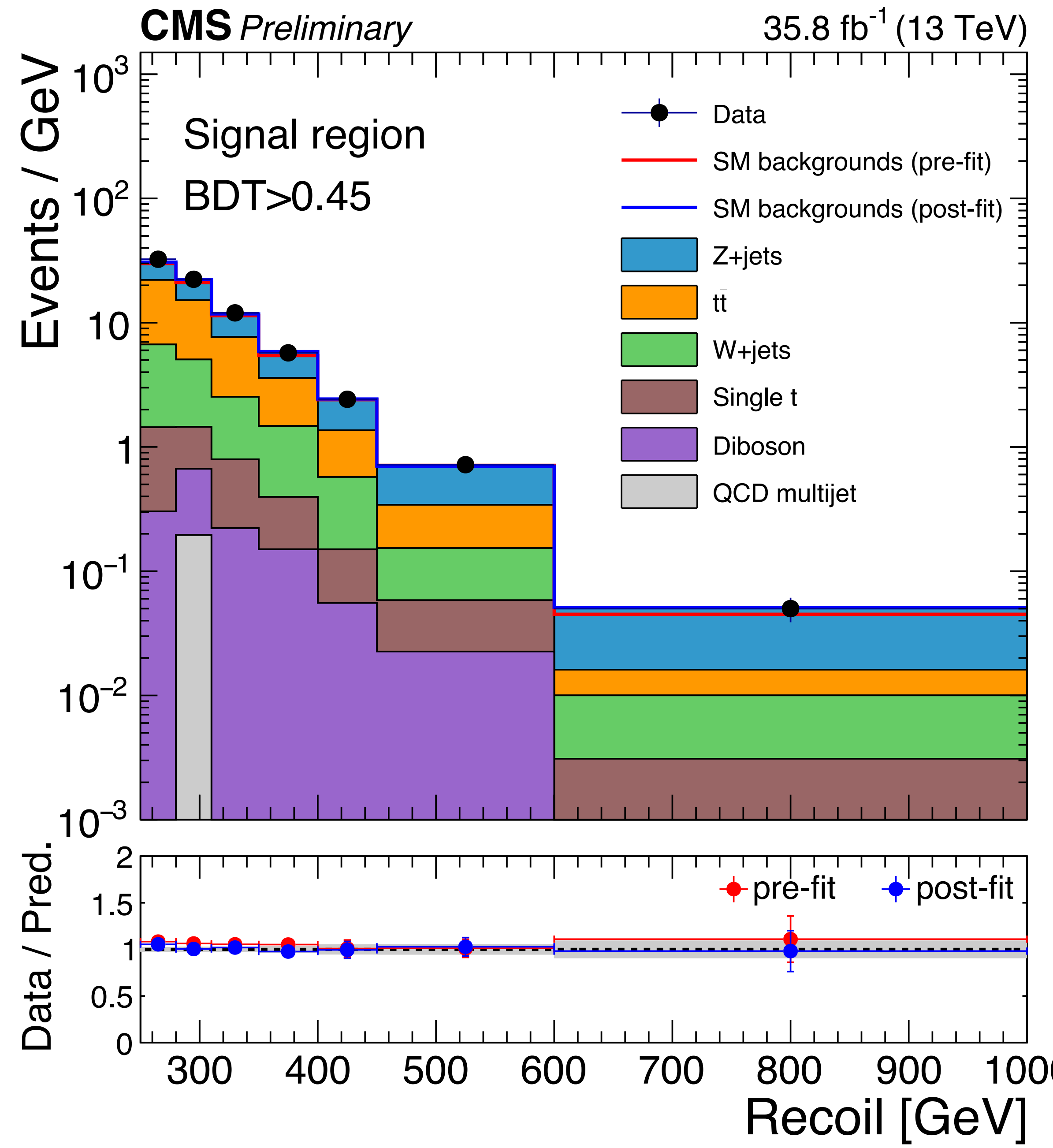
EXO-16-051

FCNC with vector-boson mediator



Colored, charged scalar mediator





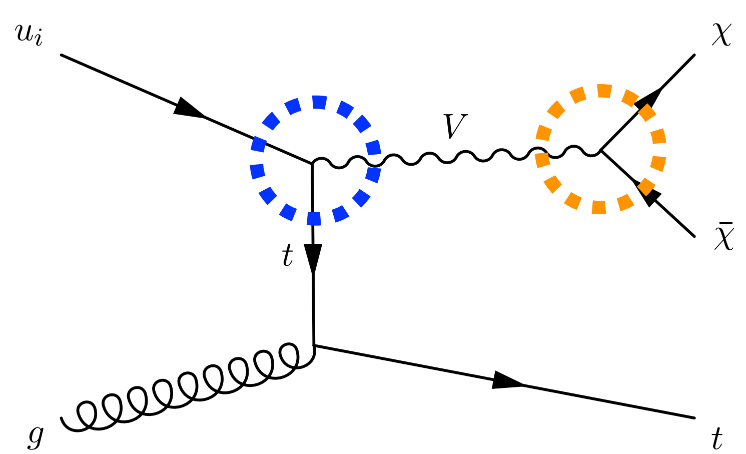
- "top"-tagged jet :
  - R=1.5, p_T>250 GeV
  - 110<m_{jet}<210 GeV, =1 b-tagged sub-jet
  - BDT with N-subjettiness ratio, HEPTopTagger, ECFs
- p_T^{miss} > 250 GeV
- no lepton, no b-jet outside top-tagged jet

- ttbar, W/Z+jets BGを1L b-tag, 1L no-btag, 2L CRでE_T^{miss}にFitして決定
- CR→SRはMCで求めたtransfer factorを使用

Mono-top

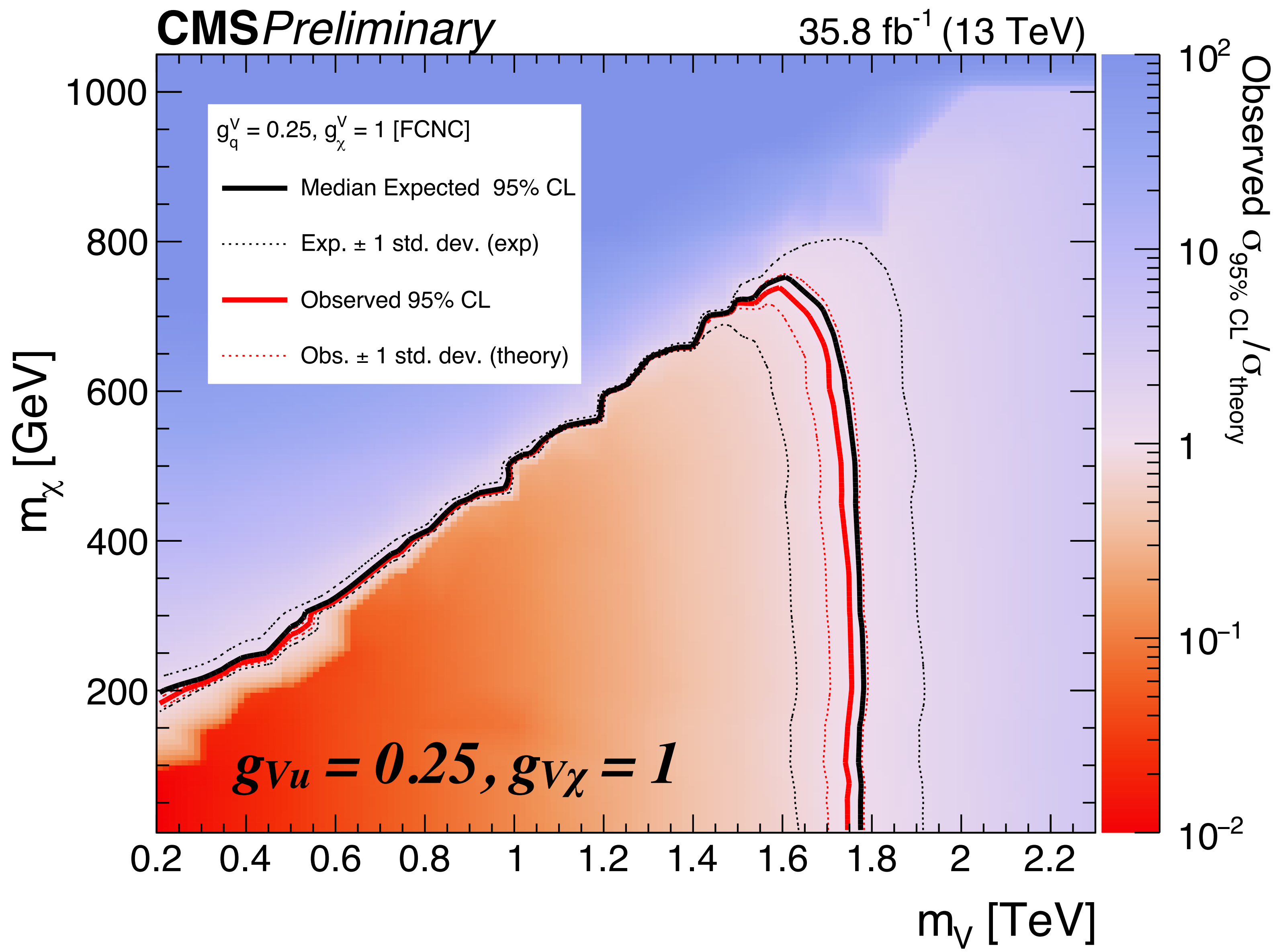
EXO-16-051

FCNC with vector-boson mediator



$$\mathcal{L} \sim V_\mu \bar{\chi}\gamma^\mu (g_{V_\chi} + g_{A_\chi}\gamma_5)\chi$$
$$+ \bar{q}_u \gamma^\mu (g_{V_u} + g_{A_u}\gamma_5) q_u V_\mu$$
$$+ \bar{q}_d \gamma^\mu (g_{V_d} + g_{A_d}\gamma_5) q_d V_\mu$$

$g_{Vu} = g_{Vd}, g_{Au} = g_{Ad}$ を仮定



For FCNC model :

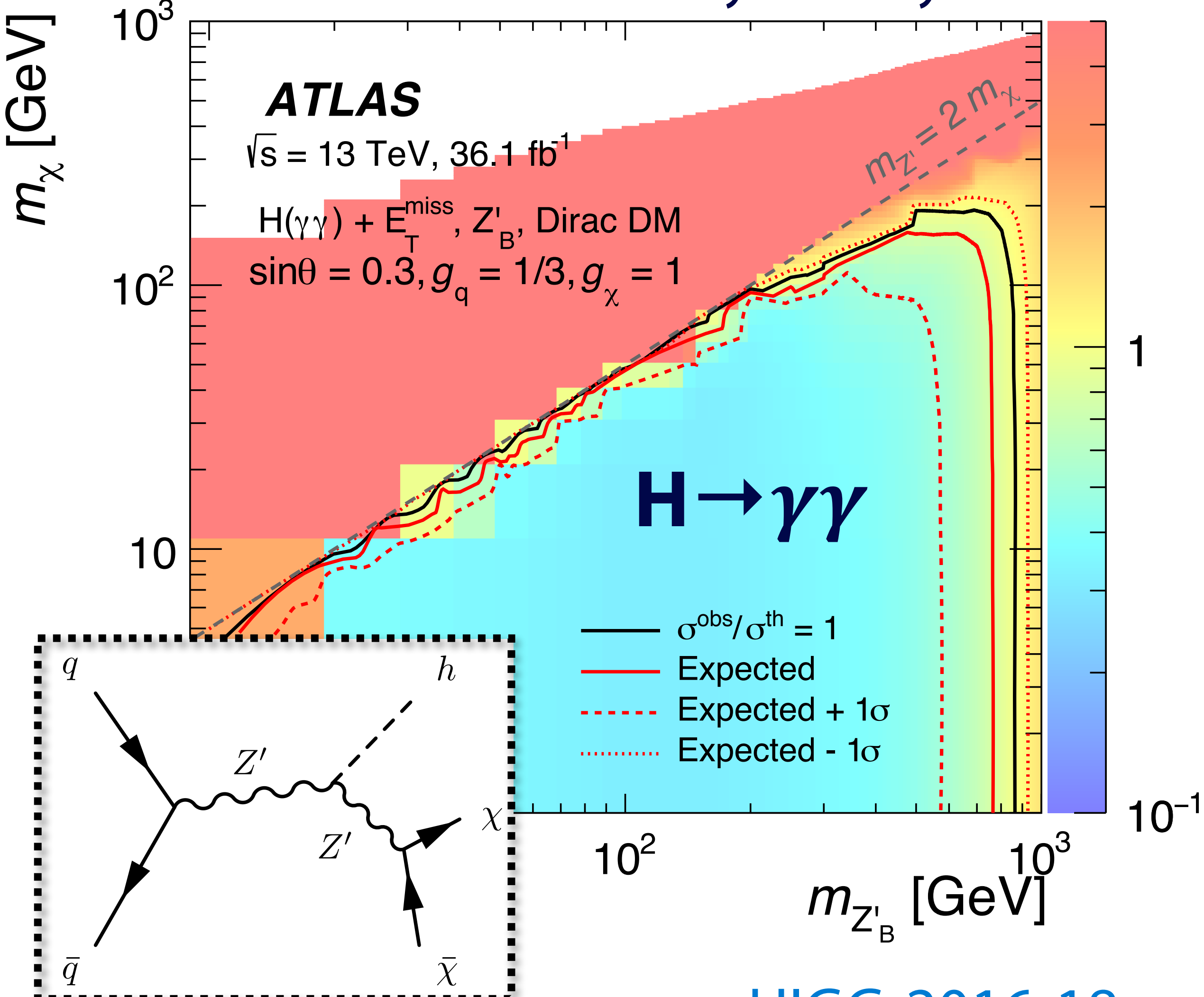
- Mediator mass excluded up to 1.75 TeV
- DM mass excluded up to 750 GeV

Mediator mass vs g_{Vq} or $g_{V\chi}$ (fixed m_χ)
での棄却領域も出している

Mono-Higgs

Z'$_B$

New U(1) with baryon number symmetry



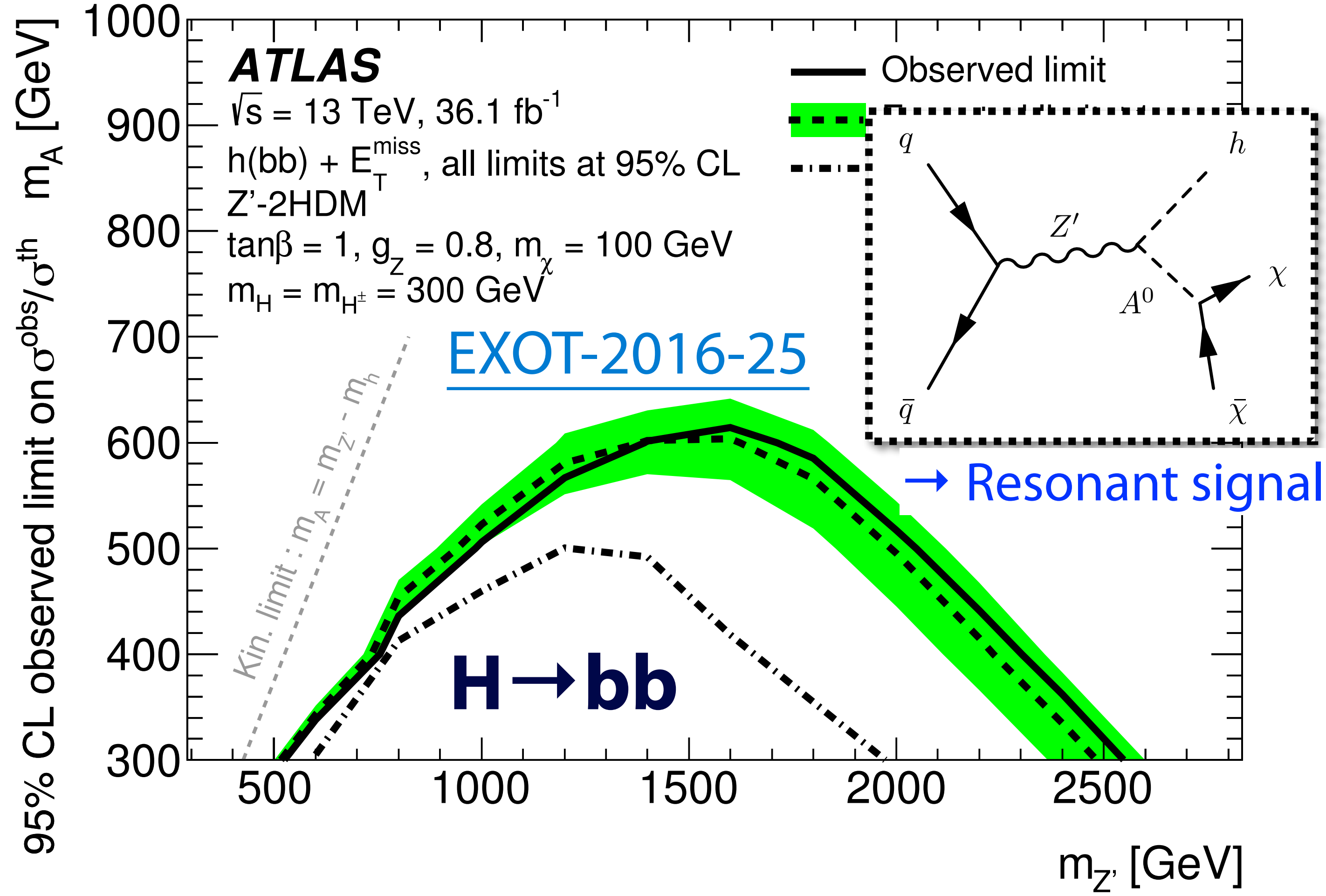
→ Non-resonant signal

HIGG-2016-18

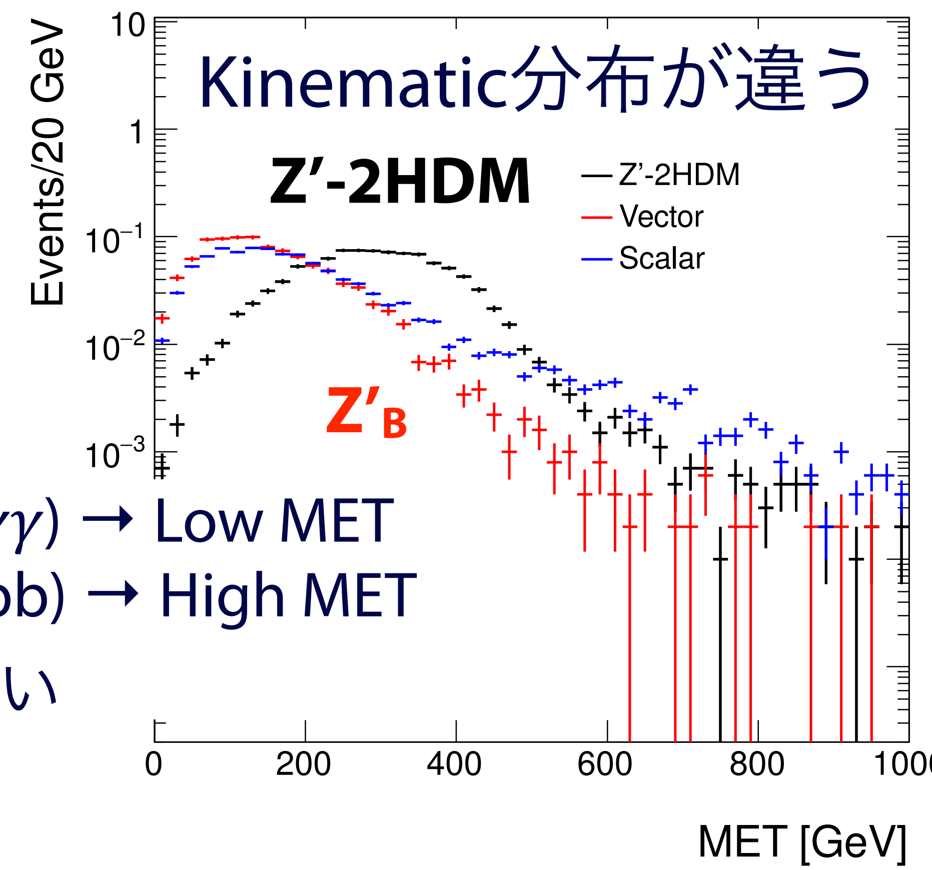
- Z'$_B$ mass excluded up to 0.8 TeV for Z'$_B$ model
- Z' (A) mass excluded up to 2.6 (0.6) TeV for Z'-2HDM model

Z'-2HDM

New pseudo-scalar → DM pair



→ Resonant signal



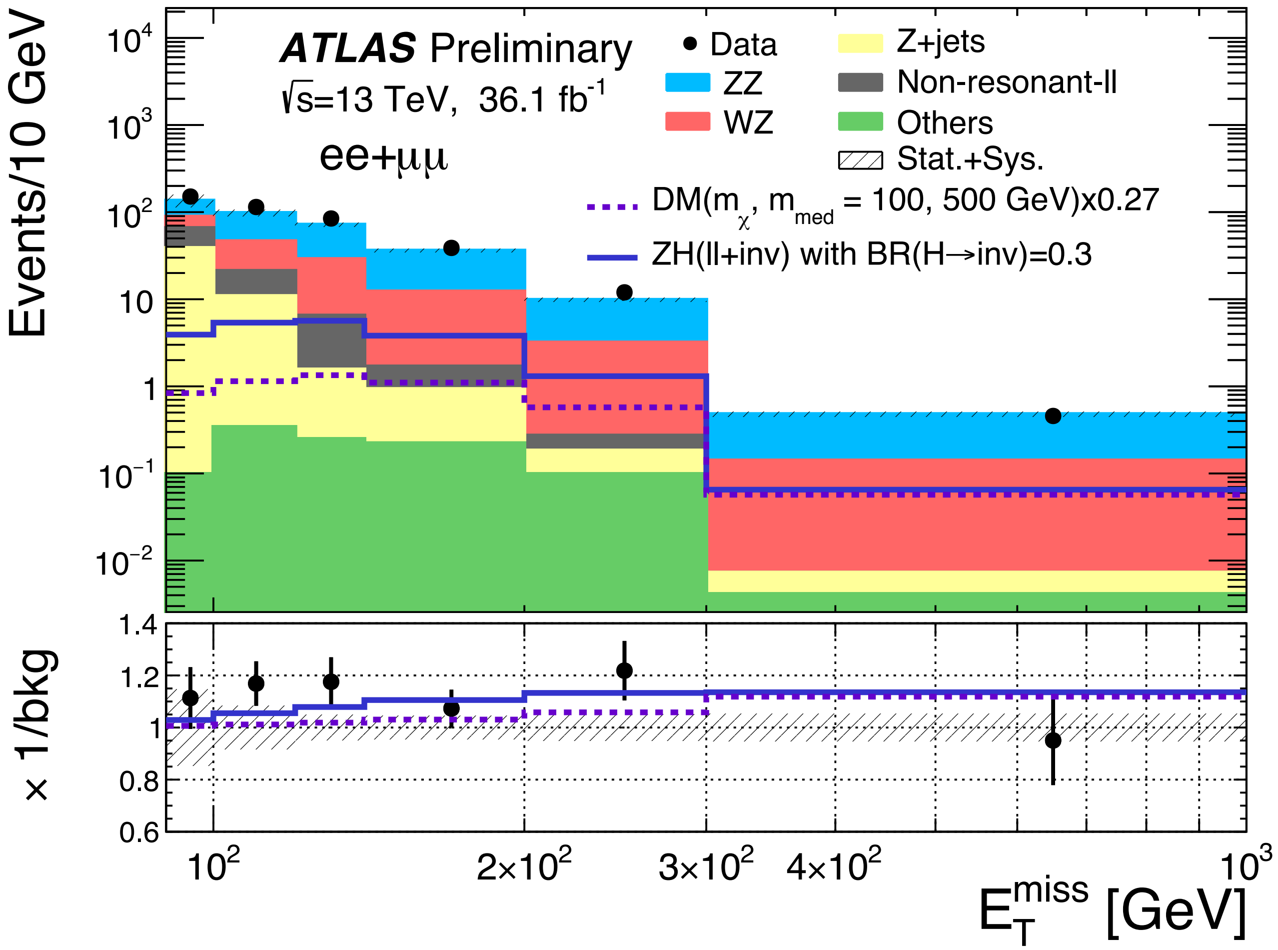
- Mono-H($\gamma\gamma$) → Low MET
- Mono-H(bb) → High MET

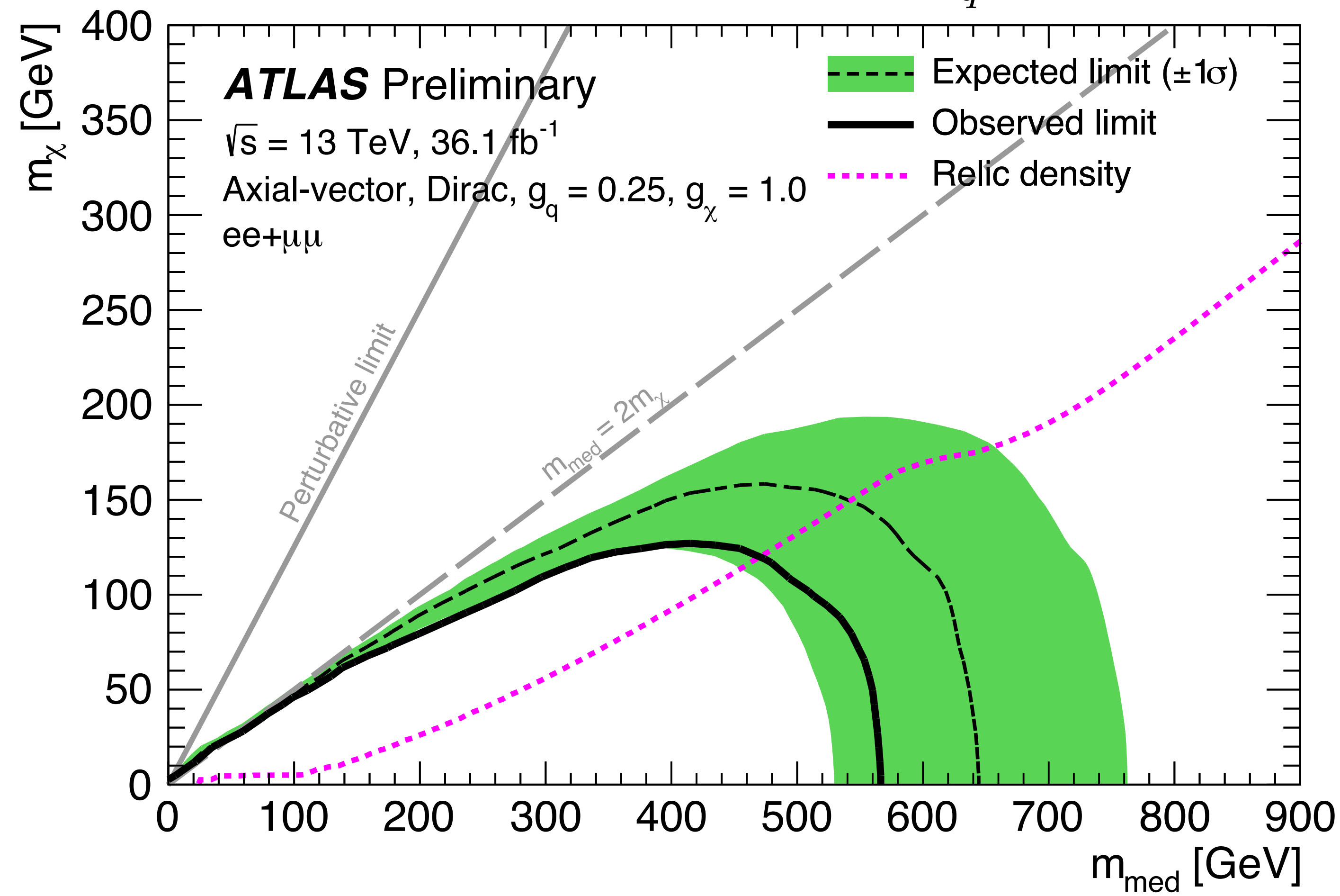
に感度が高い

Mono-Z

CONF-2017-040

Axial-vector ~ $g_q \sum_q A_\mu \bar{q}\gamma^\mu\gamma^5 q$





- 2 OS leptons p_T>30/20 GeV
- 76<m_{ll}<106 GeV, ΔR_{ll}<1.8
- E_T^{miss}>90 GeV, E_T^{miss}/H_T>0.6
- $\Delta\phi(ll, E_T^{miss})$ > 2.7, $N_{b\text{-jets}}$ = 0

- ZZはNNLO QCD+NLO EW MCで評価 (誤差~10%)
- WZは3-lep CRからのSFで評価 (誤差~5%)

H→Invisibleに対する制限 σ_{ZH}(SM)を仮定

$BR_{H\to inv}$ limit	Exp.	Obs.
ee+μμ	39^{+17}_{-11}%	67%

統計誤差 13%

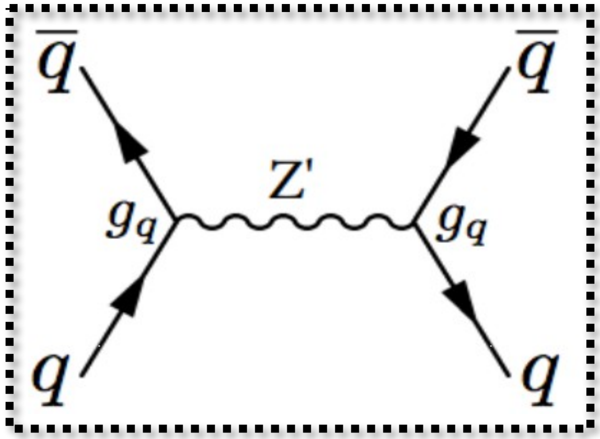
系統誤差 16% (qqZZ & ggZZ modeling, W+jets & WZ data-driven estimate, luminosity)

CMS $BR_{H\to inv}$ limit (ZH→ll+inv) :
40% Obs., 42% Exp. EXO-16-052

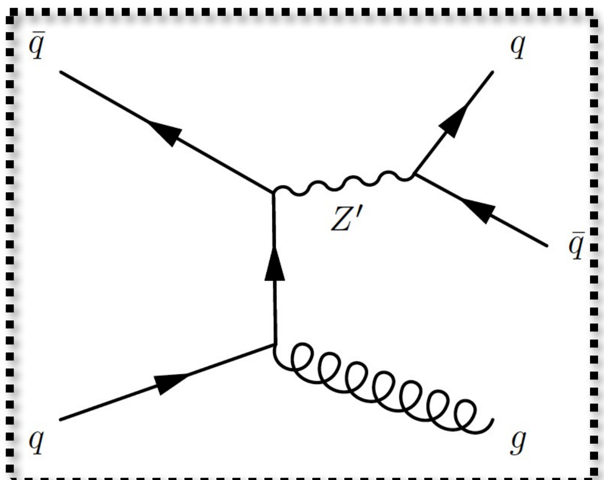
感度はまだ限定的…

Dijet

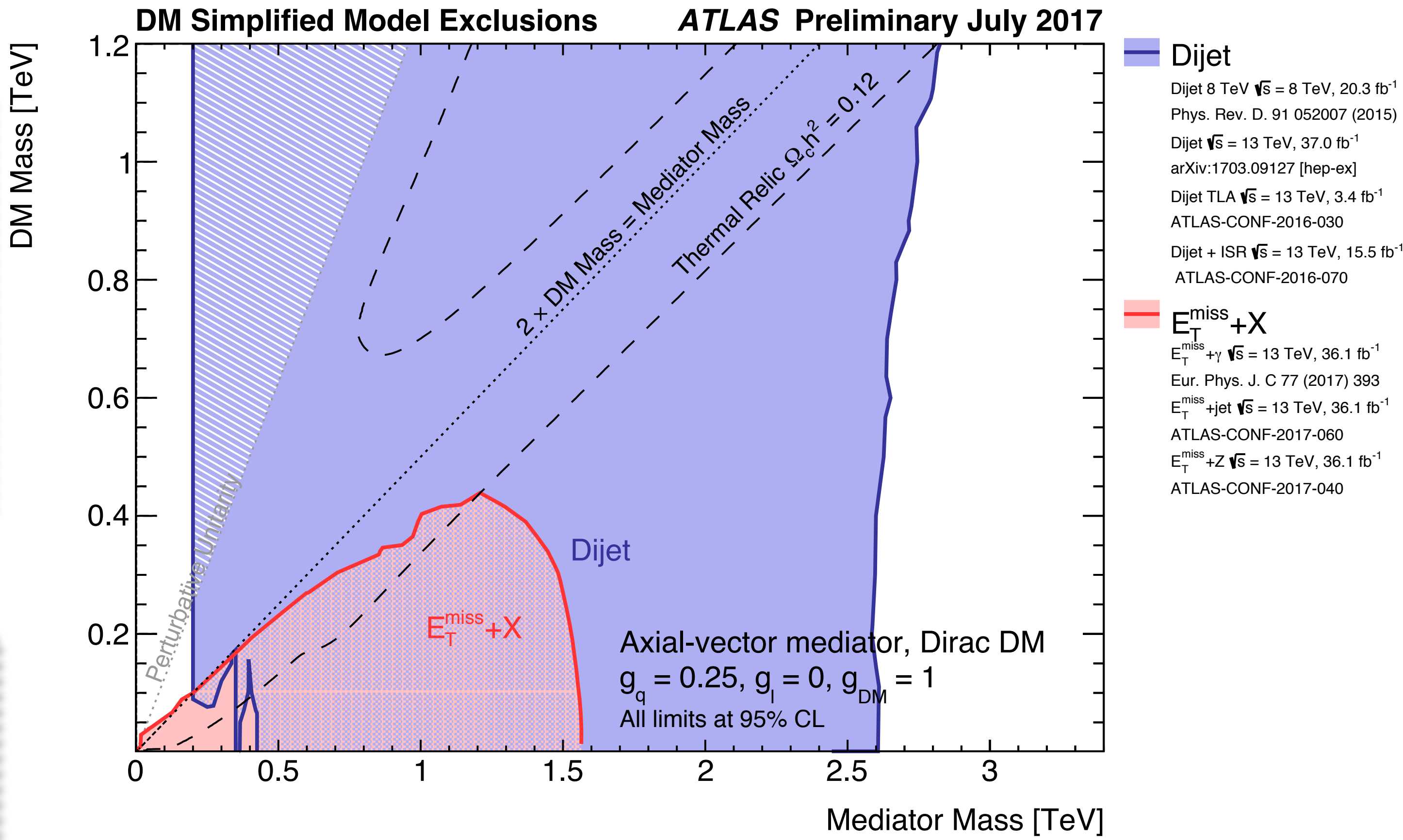
$Z' \rightarrow qq$



ISR+$Z' \rightarrow qq$

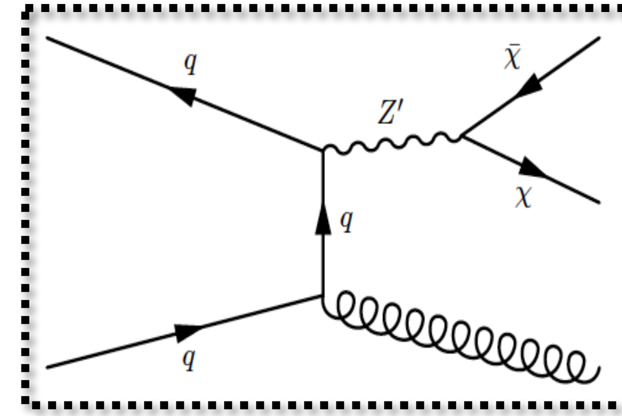


$g_q = 0.25$, $g_l = 0$, $g_{DM} = 1$

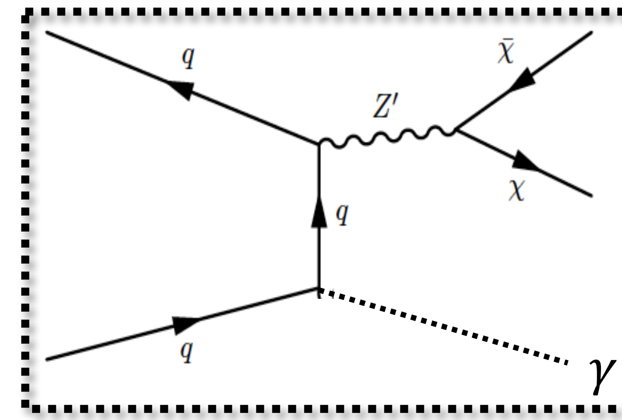


E_T^{miss}+X

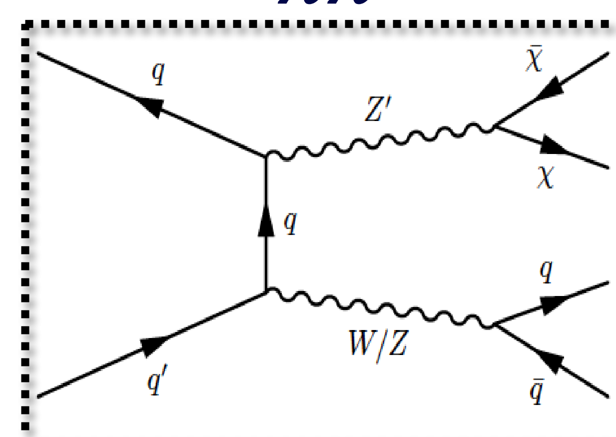
Jet+$Z' \rightarrow \chi\chi$



γ+$Z' \rightarrow \chi\chi$



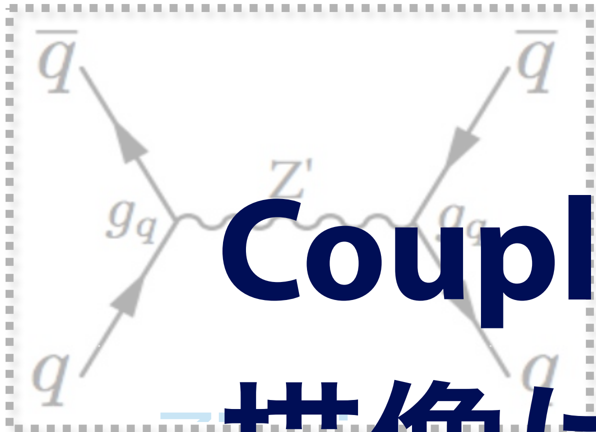
Z+$Z' \rightarrow \chi\chi$



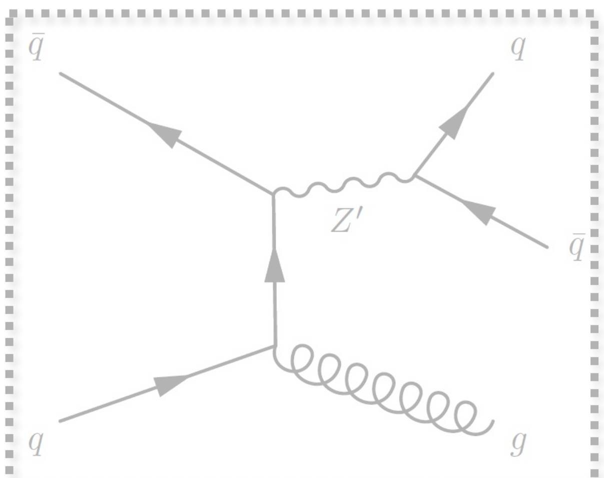
Mono-X vs Direct Mediator Searches

Exotics Summary plots

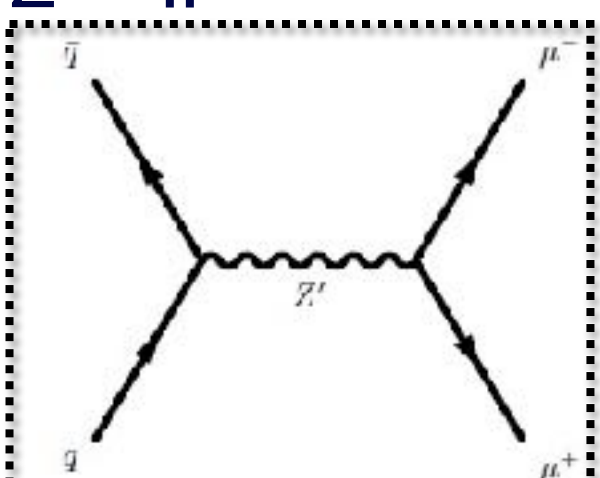
Dijet
Z′→qq



ISR+Z′→qq

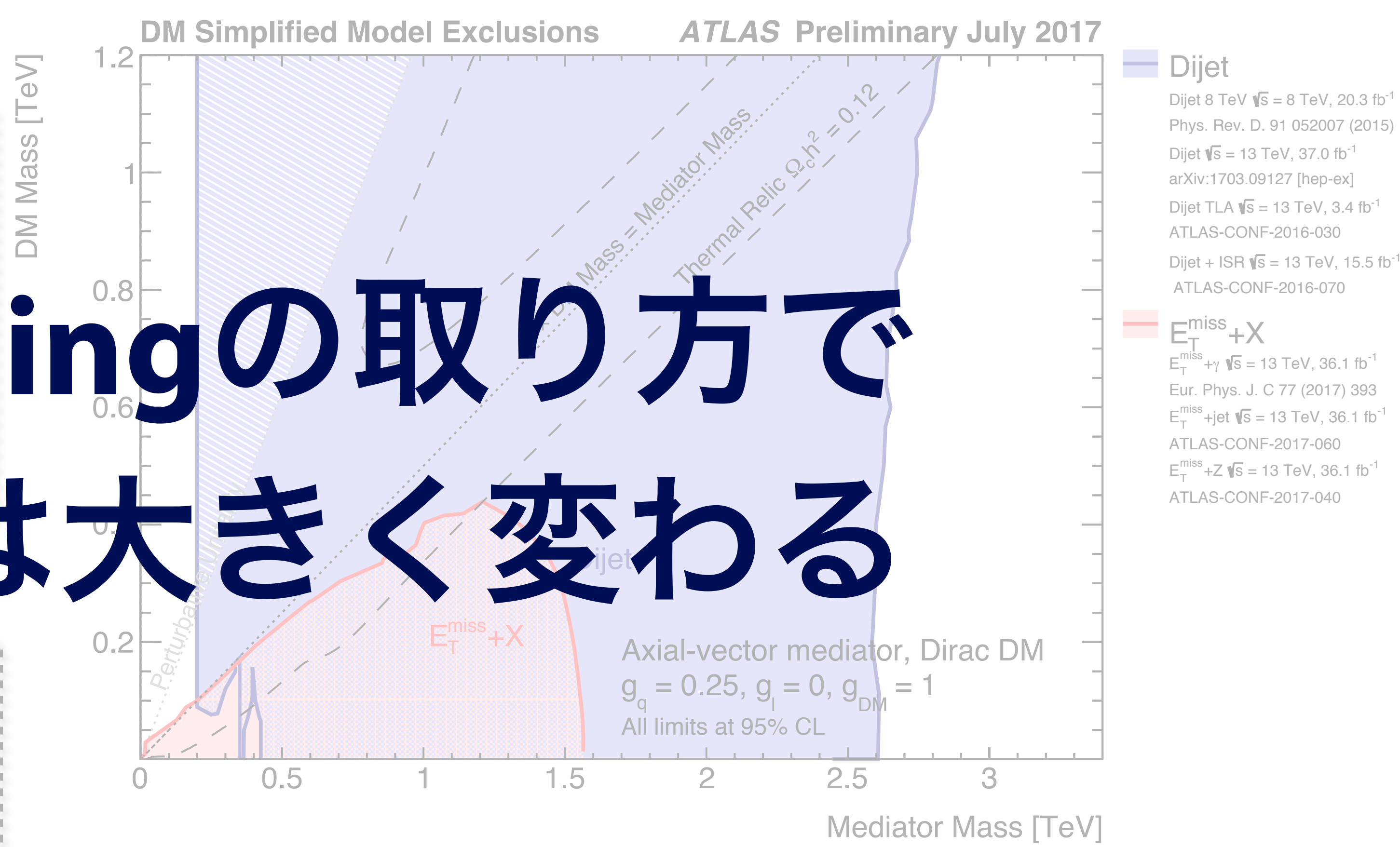


Dilepton
Z′→ll

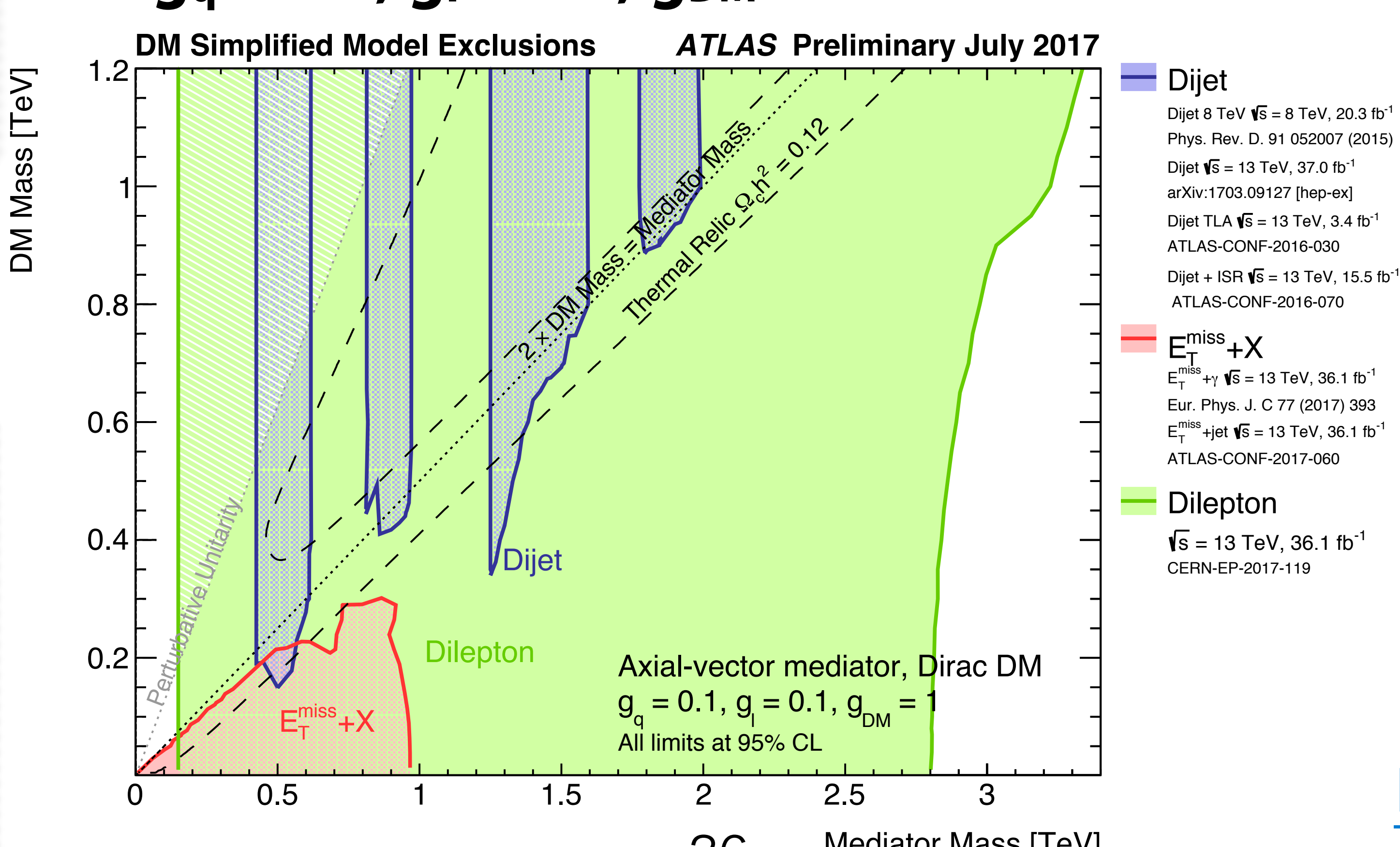


Couplingの取り方で描像は大きく変わる

$g_q = 0.25, g_l = 0, g_{DM} = 1$

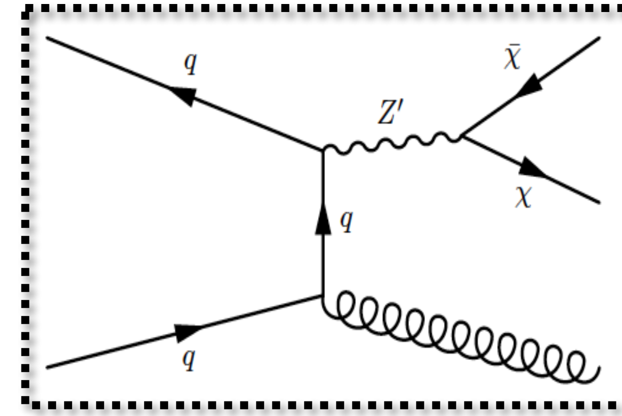


$g_q = 0.1, g_l = 0.1, g_{DM} = 1$

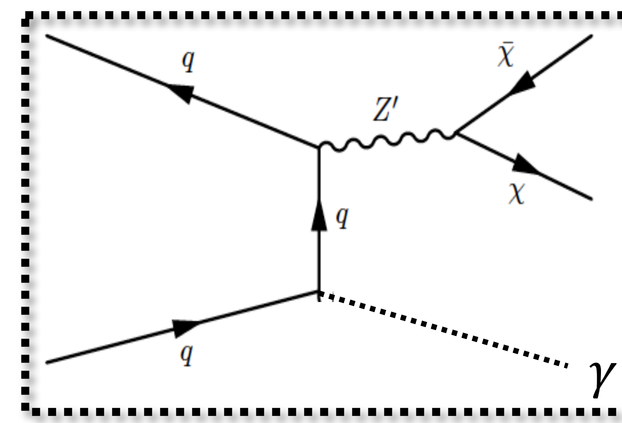


E_T^{miss}+X

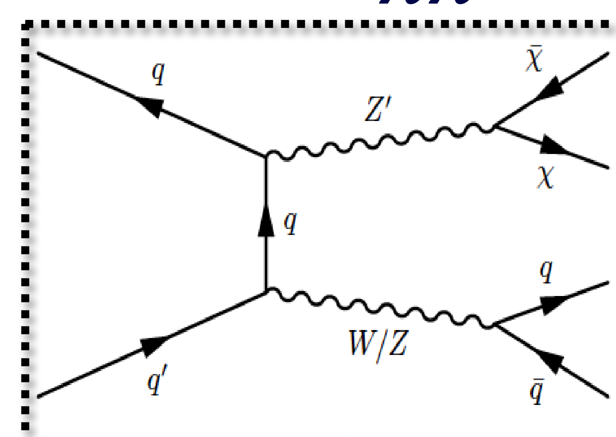
Jet+Z′→χχ



γ+Z′→χχ



W/Z+Z′→χχ

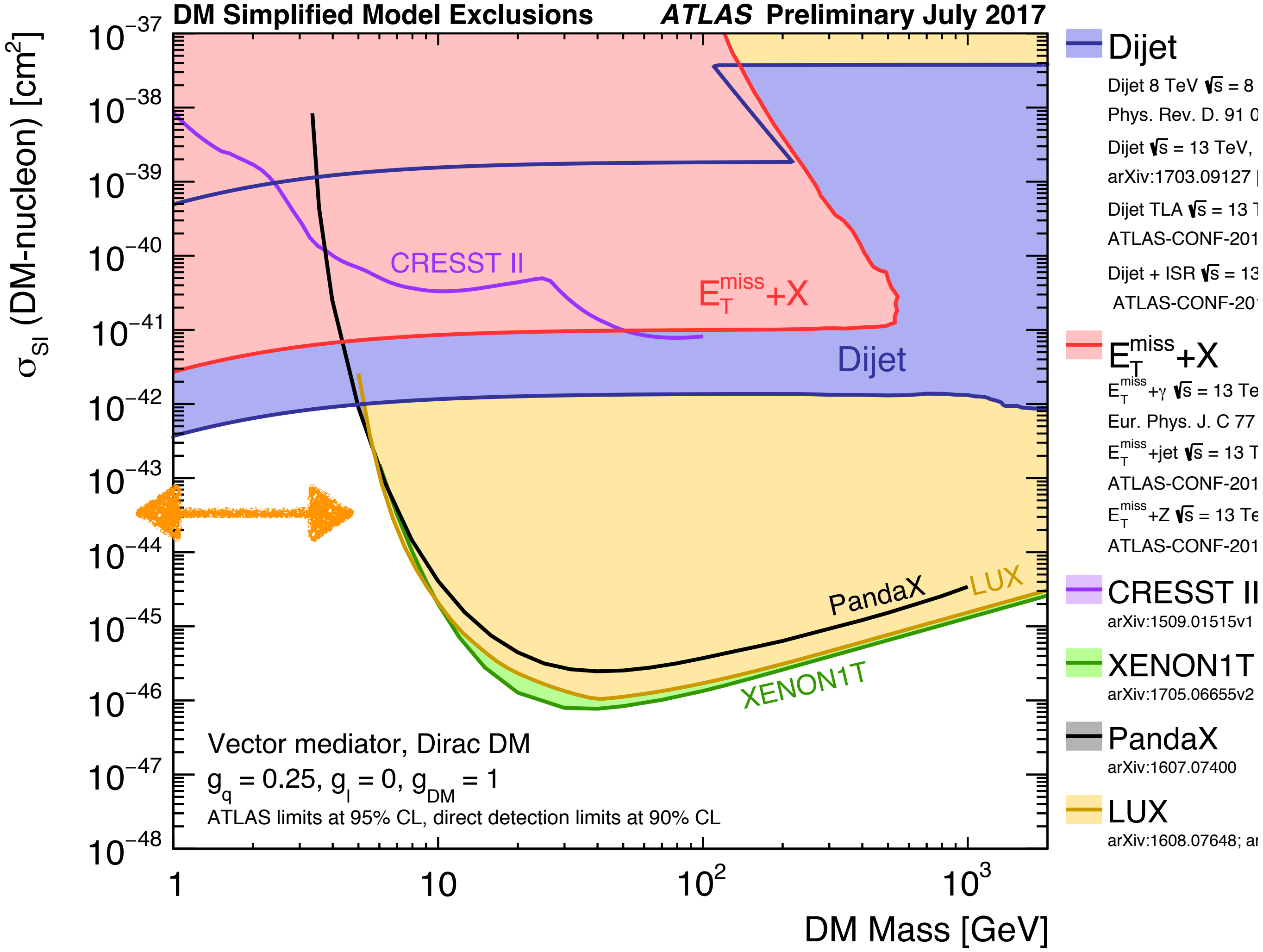


[Exotics Summary plots]

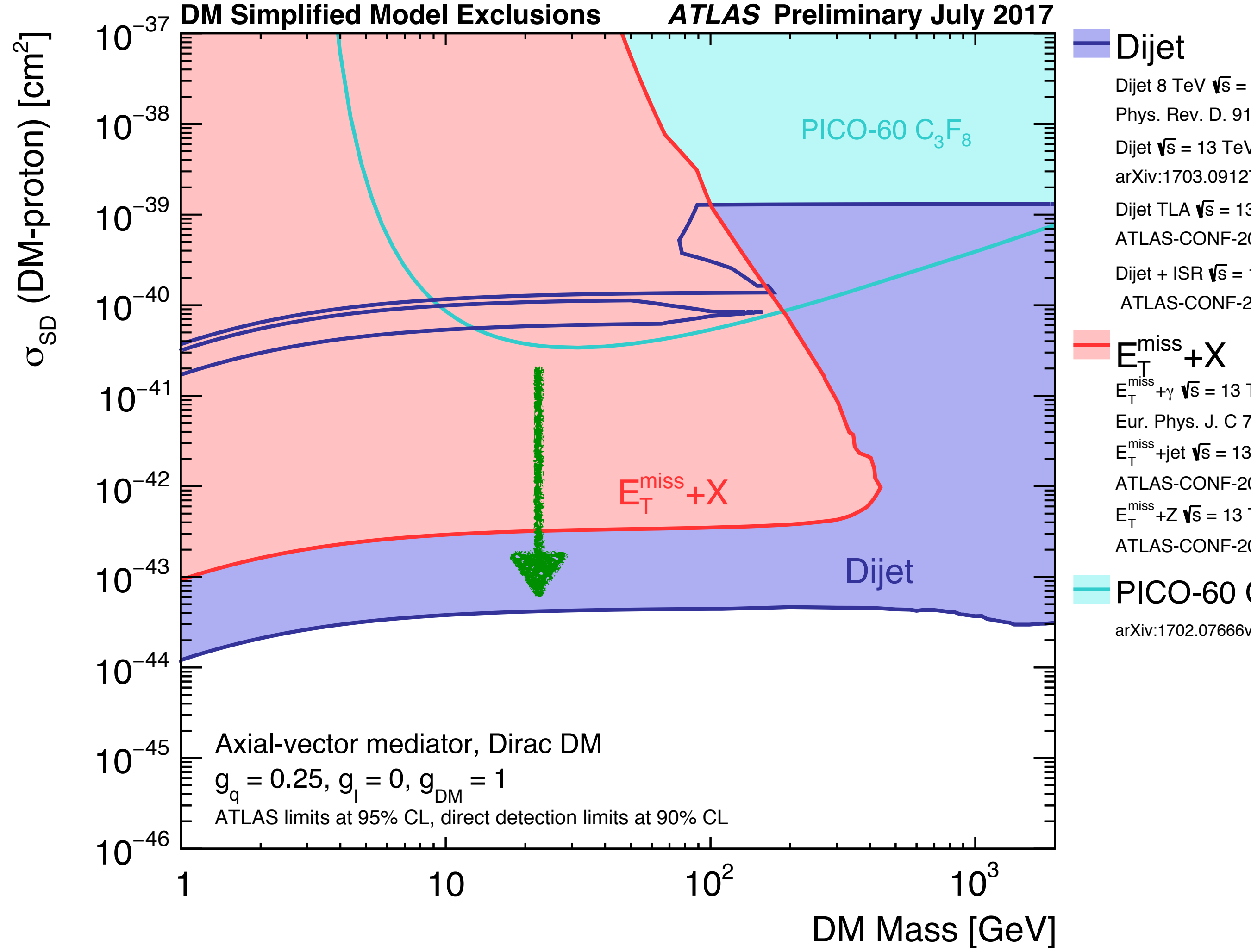
直接探索との比較

Exotics Summary plots

SI DM-nucleon cross section vs m_{DM}



SD DM-proton cross section vs m_{DM}



σ_{SI} for vector mediator :

$$\sigma_{SI} \simeq 6.9 \times 10^{-41}\ \mathrm{cm}^2 \cdot \left(\frac{g_q g_{DM}}{0.25}\right)^2 \left(\frac{1\,\mathrm{TeV}}{M_{med}}\right)^4 \left(\frac{\mu_{n\chi}}{1\,\mathrm{GeV}}\right)^2$$

σ_{SD} for axial-vector mediator :

$$\sigma^{SD} \simeq 2.4 \times 10^{-42}\ \mathrm{cm}^2 \cdot \left(\frac{g_q g_{DM}}{0.25}\right)^2 \left(\frac{1\,\mathrm{TeV}}{M_{med}}\right)^4 \left(\frac{\mu_{n\chi}}{1\,\mathrm{GeV}}\right)^2$$

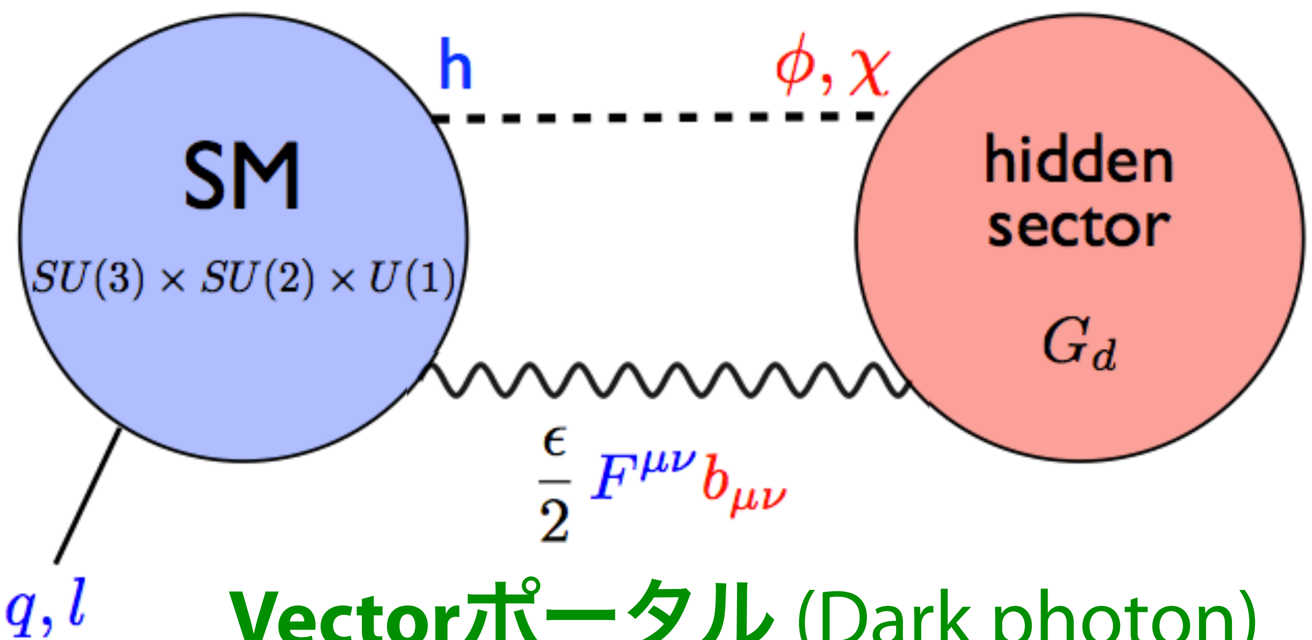
***Under the coupling assumptions*, collider searches**

- **are sensitive at low DM (<~5 GeV) for SI DM-nucleon cross section**
- **have ~3 orders of magnitude better sensitivity for SD DM-nucleon cross section**

ダークセクター

Higgsポータル (Scalar DM)

➔ 実験からの制限はきつい



Vectorポータル (Dark photon)

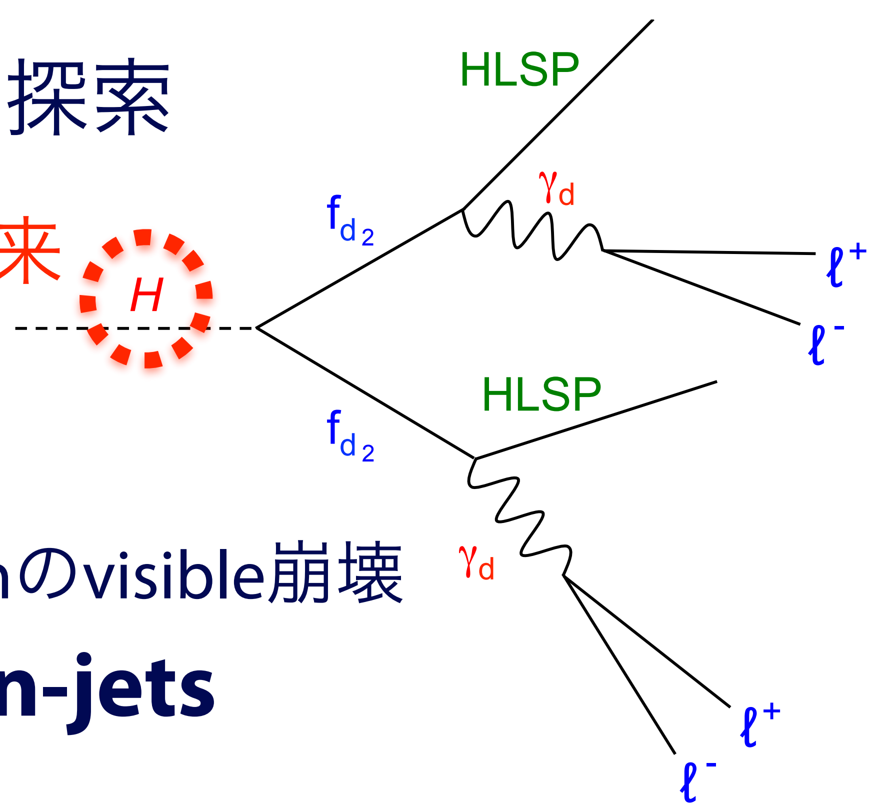
➔ 様々な可能性!!

Vectorポータル

- SM photonとDark photonの間のkinetic mixing (strength ~ εe)
- kinetic mixingでSM粒子に崩壊する
- Small mixing ➞ 長寿命
- Scalar ϕ or fermion χ（DM候補）

ATLASでの探索

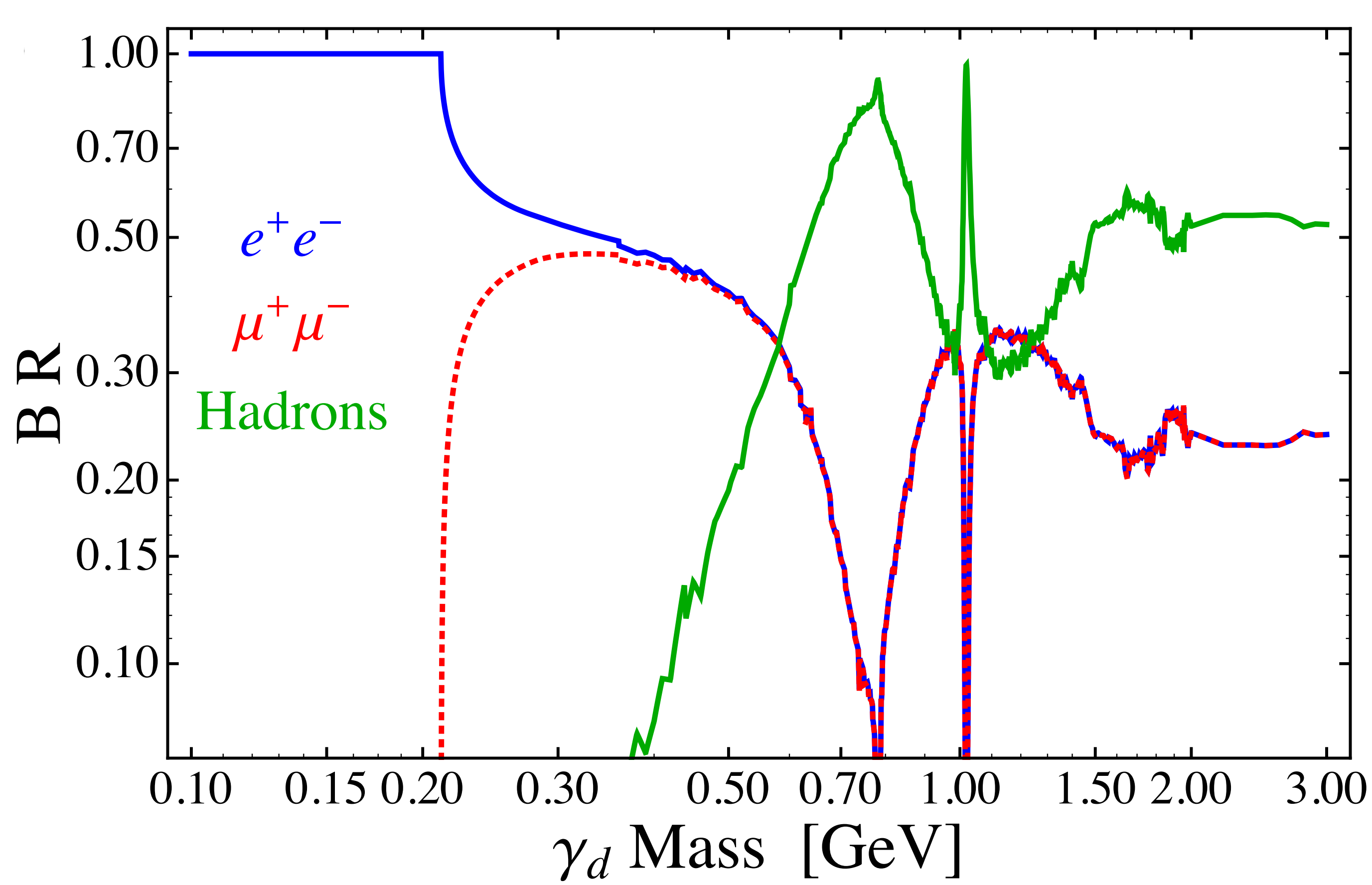
ヒッグス由来の信号



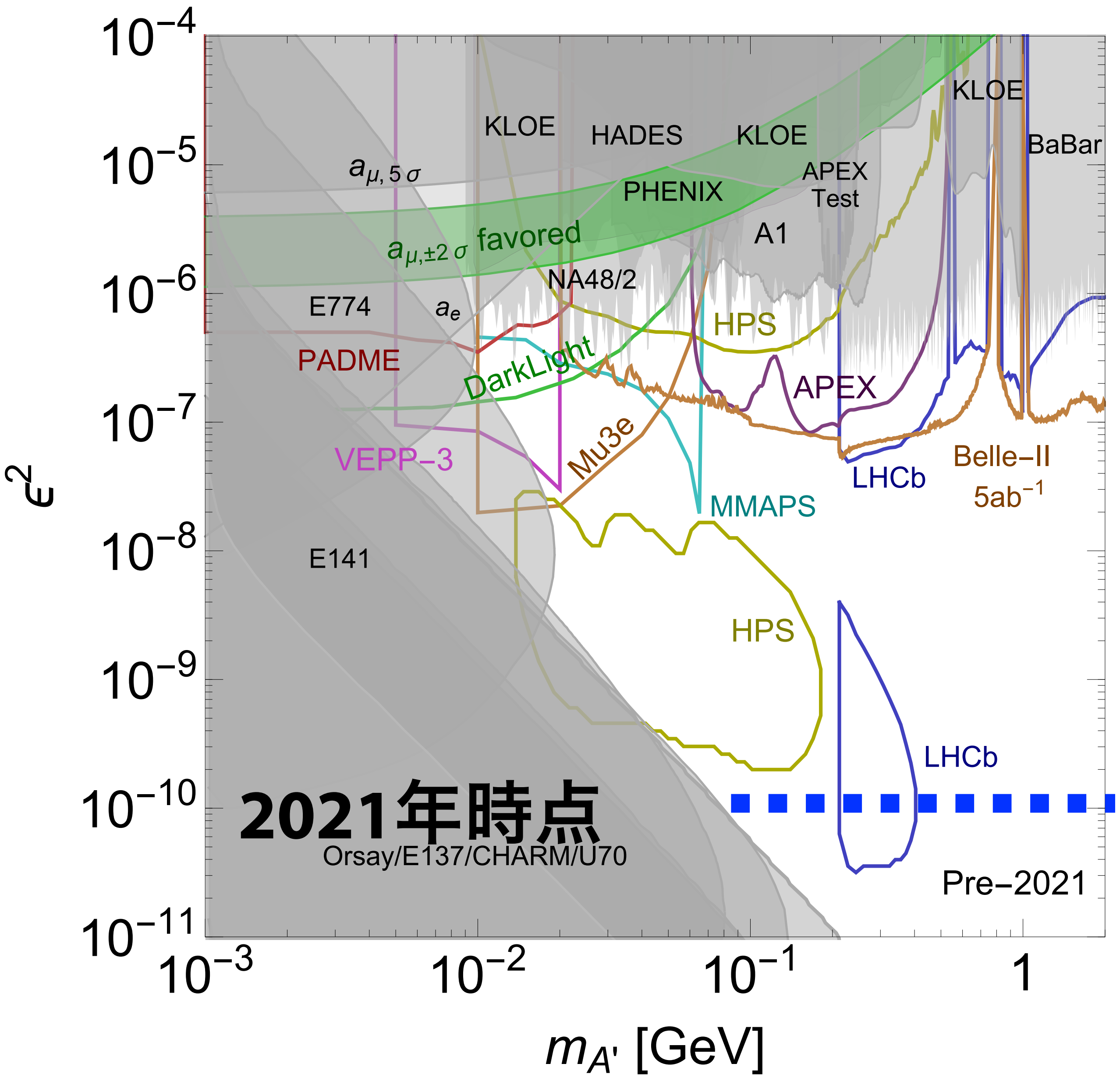
Dark photonのvisible崩壊

⇒ Lepton-jets

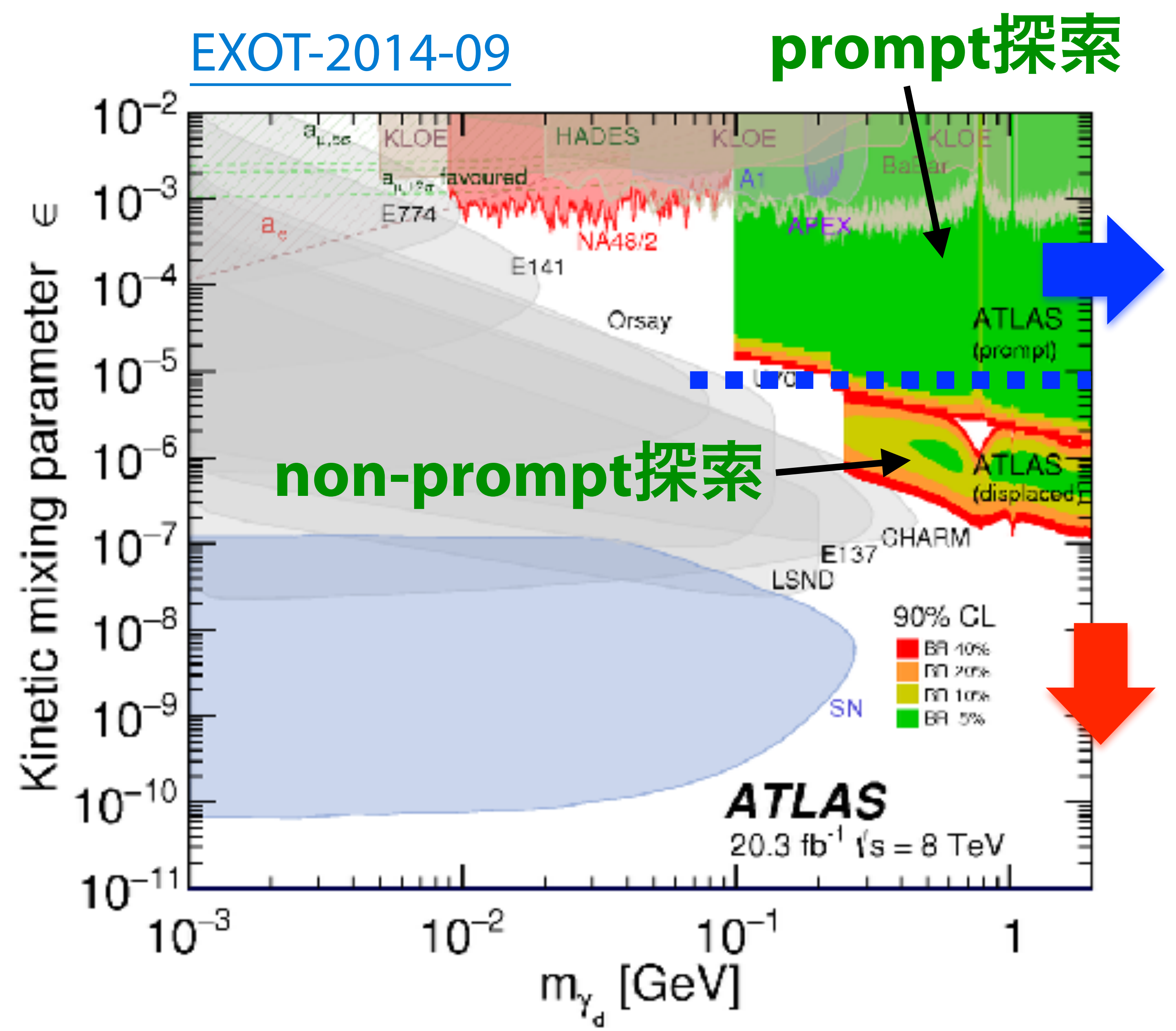
γ_d Branching Ratio



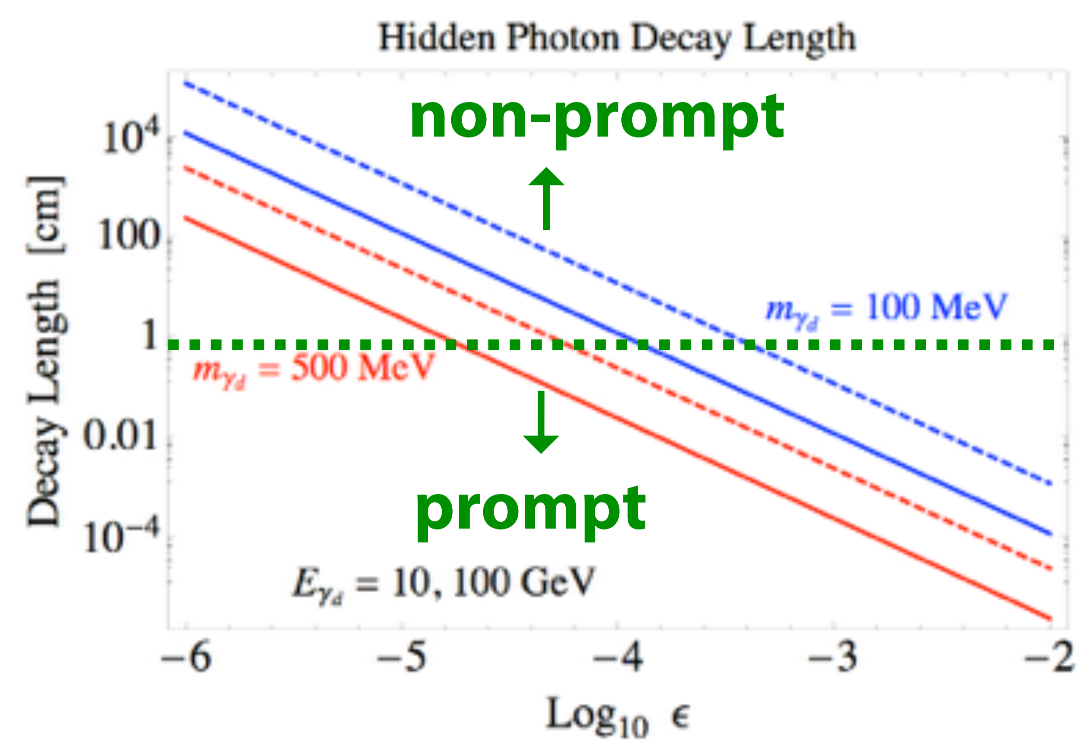
Dark Photon



EXOT-2014-09



- 新しいBeam Dump実験が進行/計画中
- LHCではHigh $m_{\gamma d}$, Low ε方向への拡張が大事



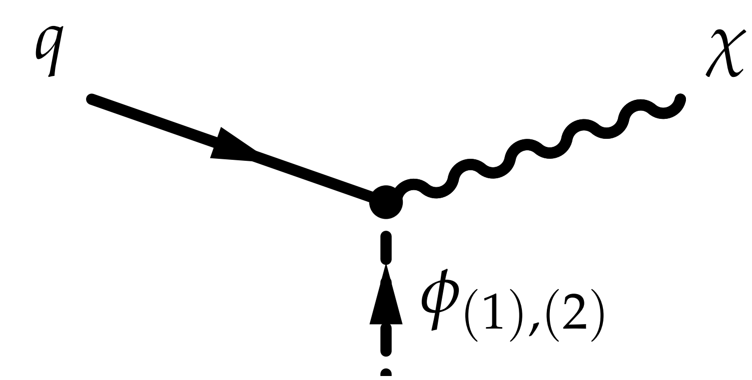
カラーを持つ媒介粒子

DM探索のSimplified modelはs-channel mediatorが中心

積極的にt-channel mediator (colored scalar mediator)を考える動機？

⟺ SUSYとのconnection

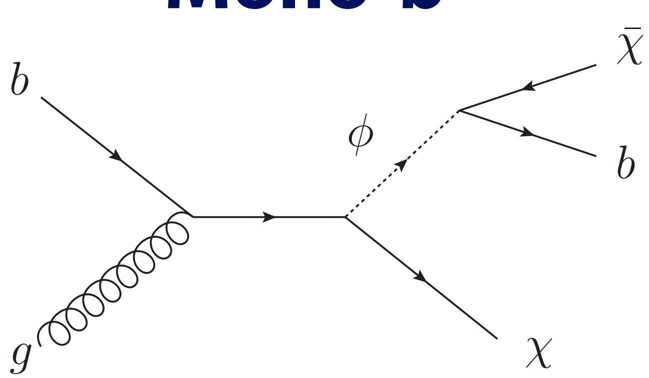
⟺ SUSYとは異なるトポロジー・Kinematics?



$$\mathcal{L}_\chi = \lambda_q \bar{\chi} \phi^* q + h.c.$$

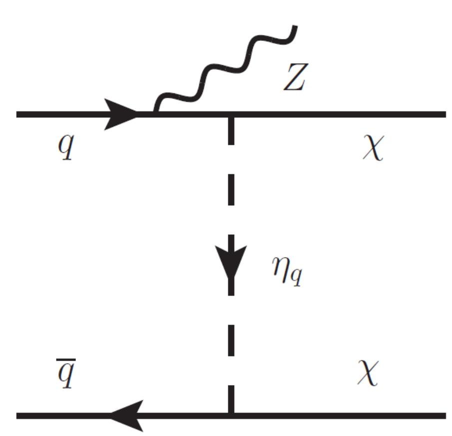
ベンチマークとして考えられているもの

Mono-b

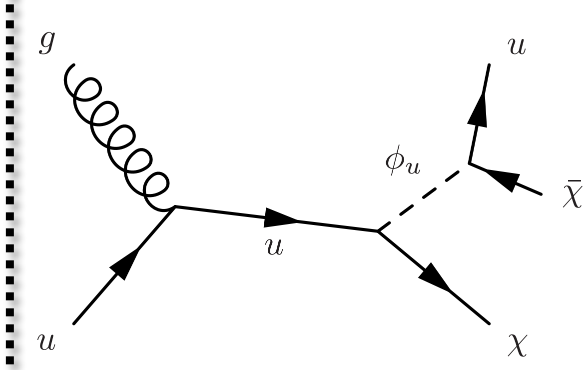


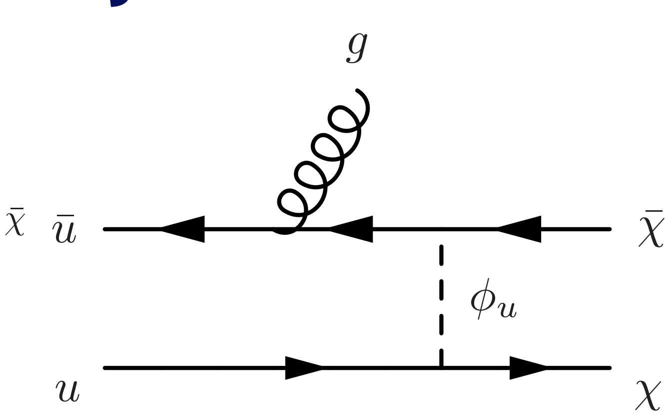
b-FDM model

Mono-Z

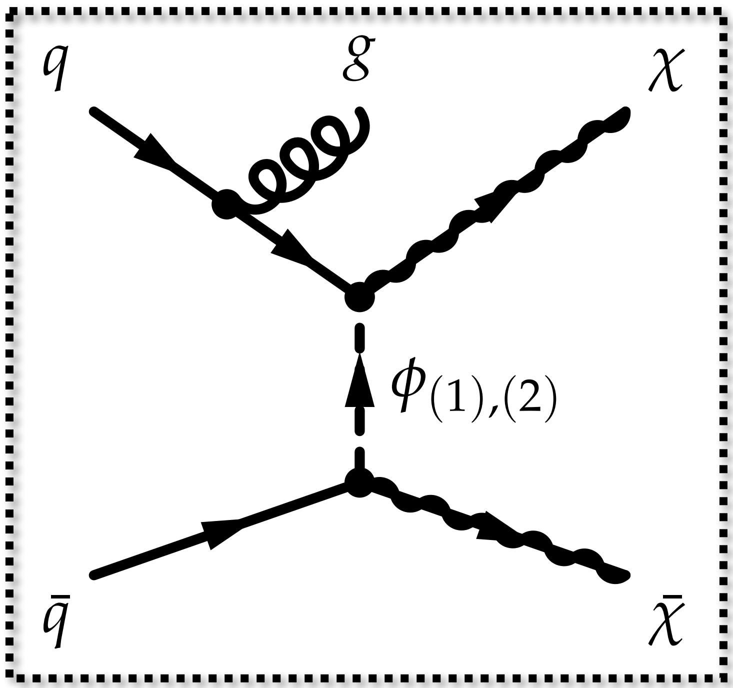


Mono-jet

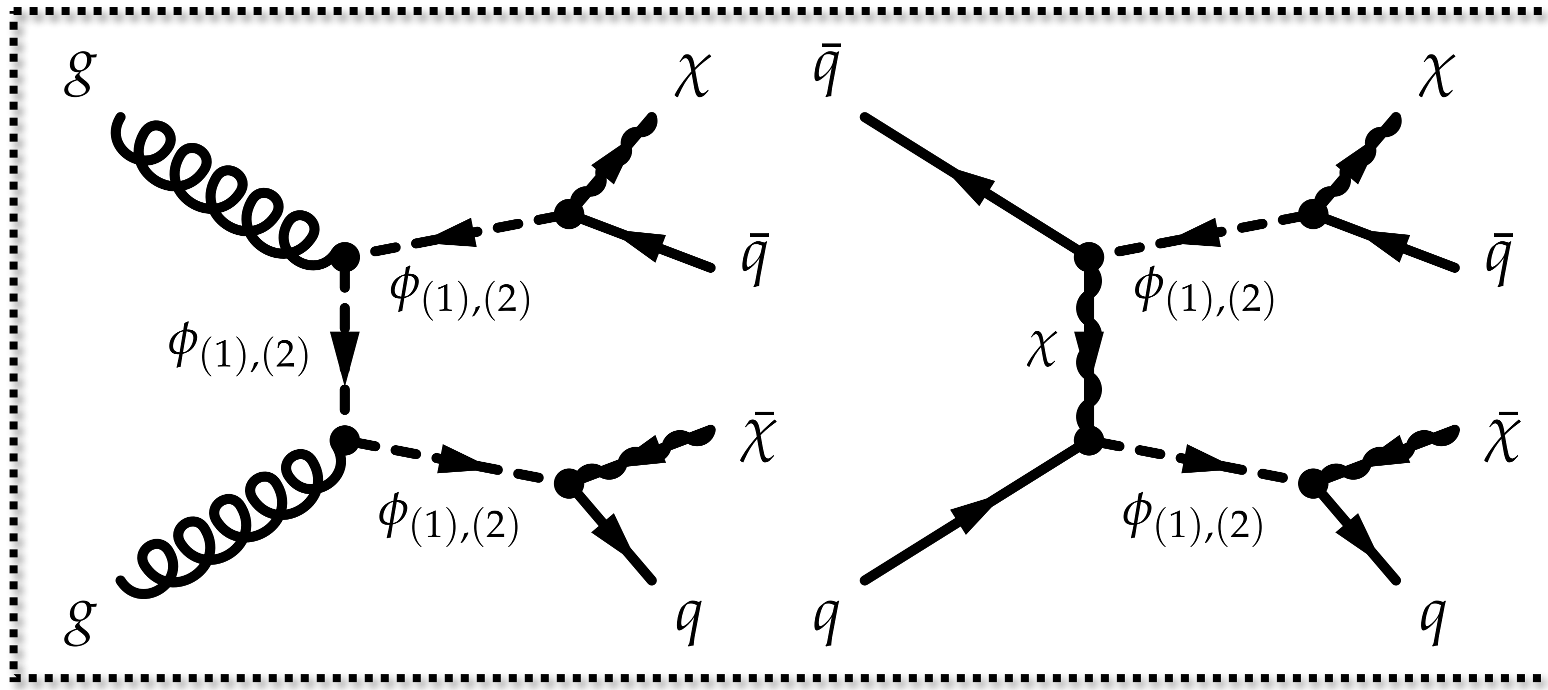




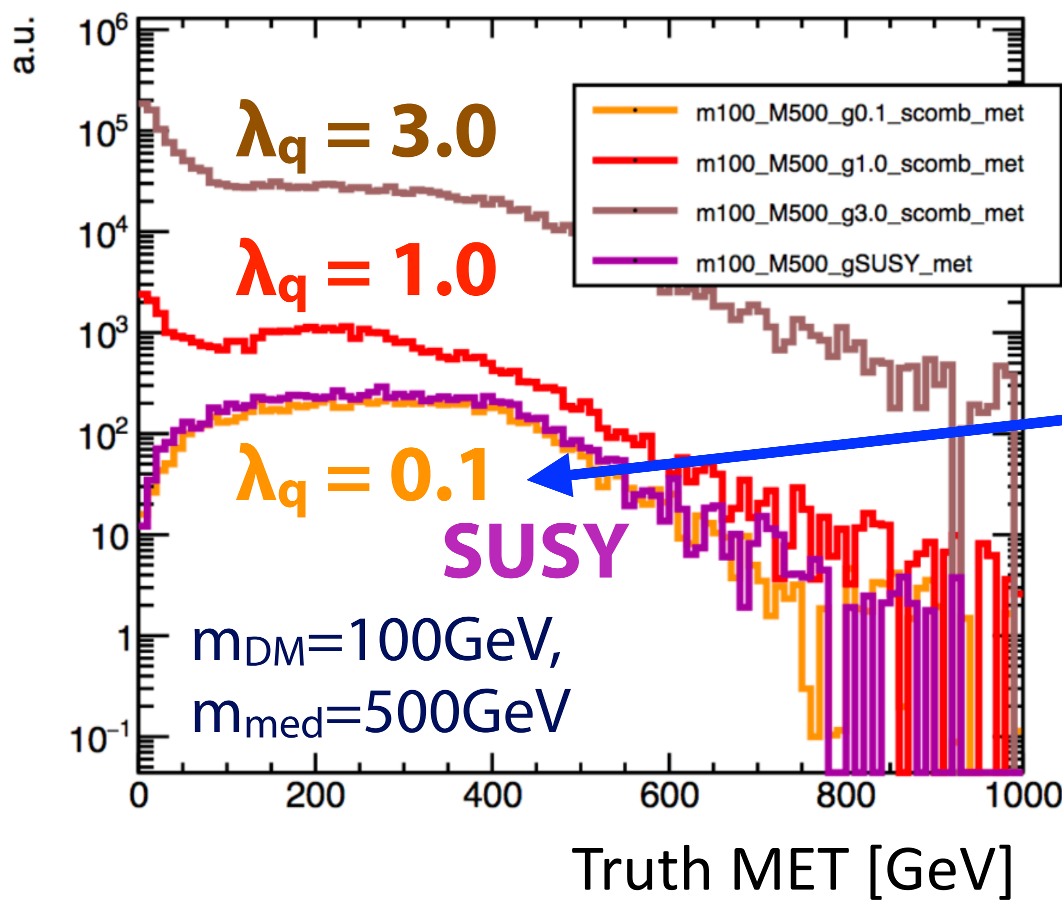
Mono-jet, Dijet+E_T^{miss}

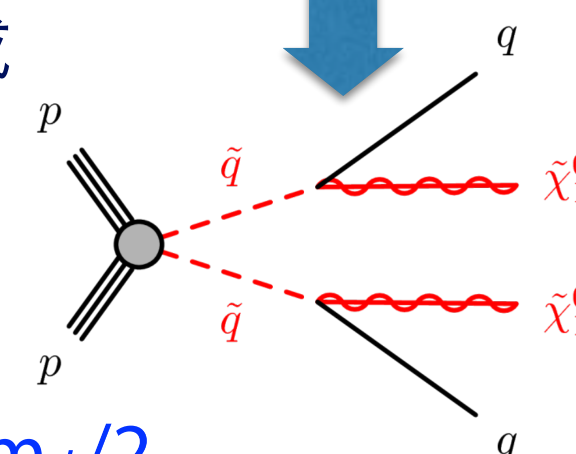


ISR gluon + t-channel mediatorによるDM対生成



t-channel mediatorあるいはDM粒子交換によるDijet生成





MediatorのOn-shell崩壊

→ "Resonant" DM生成

→ E_T^{miss} ~ Jacobian peak at $m_\phi/2$

Squark modelと同じ断面積

Large couplingではSquarkからずれる

➡ 異なるKinematics (off-shellの効果)

Future Exotics Search (まとめに代えて)

High-mass探索はKinematicsの限界へ

➔ 今後の発見はHL-LHCのみ?!

より難しいPhase spaceへ

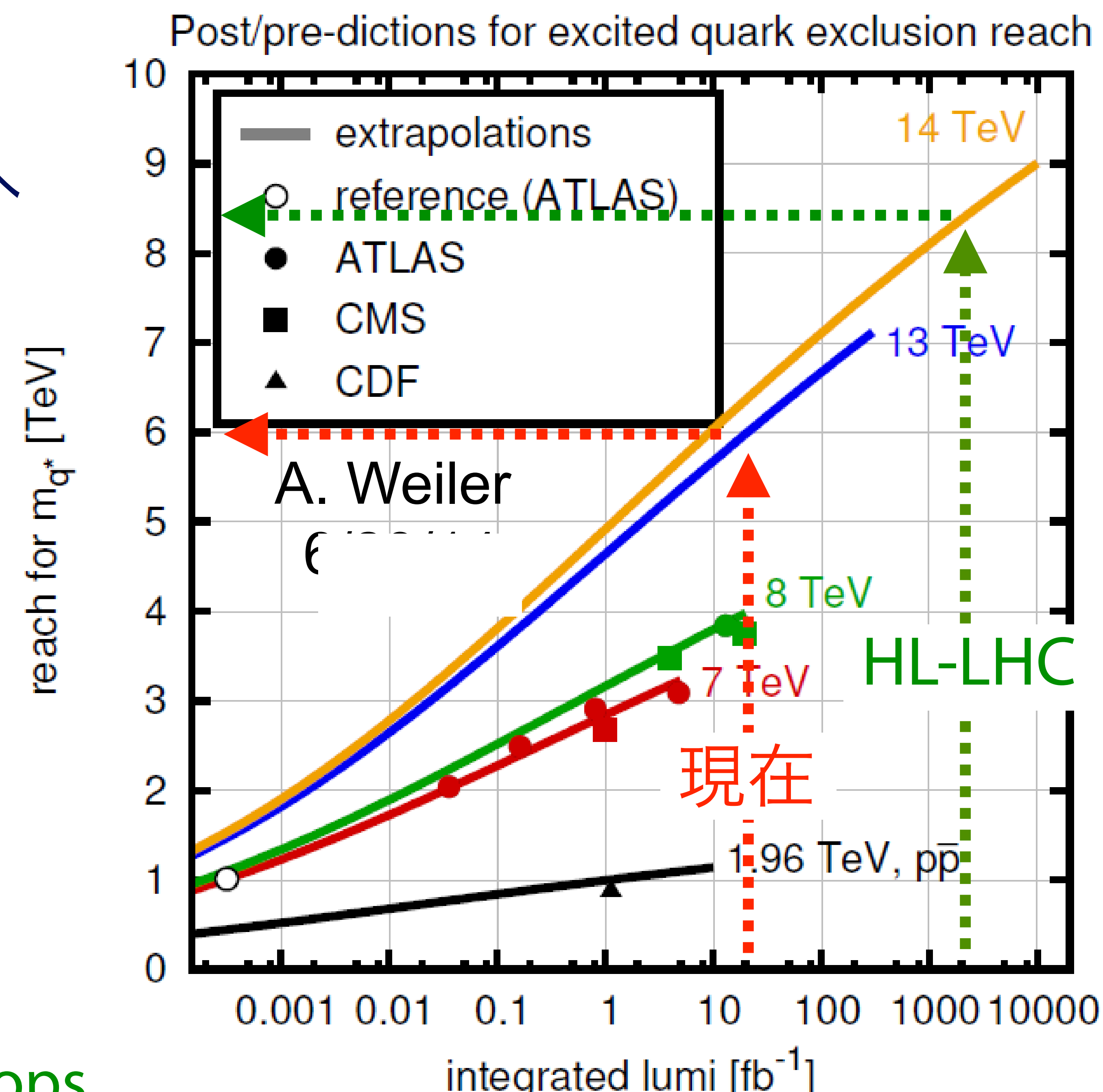
- Resonance + “X" (= jet, lepton, E_T^{miss}, b-jet, …)
- Low-mass resonances
- Long-lived signature
- Multi-objects, Complex topologies

HL-LHCでは何を目指すべきか？

- HL-LHC (& HE-LHC) physics workshops (kick-off on 10/31-11/1, 2017)

より高いエネルギーへ？

qg → q* → 2-jet



→ Mass reach ∝ log(Lumi)

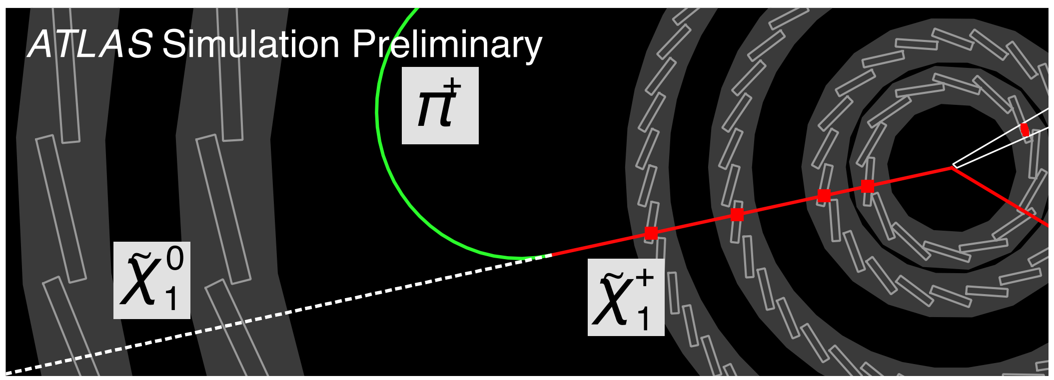
1 TeV改善に~10倍のデータが必要

FCC (HE-LHCを含めて)

FCC week 2017

Minimal DM (Disappearing track)

- Wino LSP leads **meta-stable chargino** (τ **=0.2 nsec**)
- c τ ~ 6 cm → directly detectable
  - chargino tracks disappear in the tracker.



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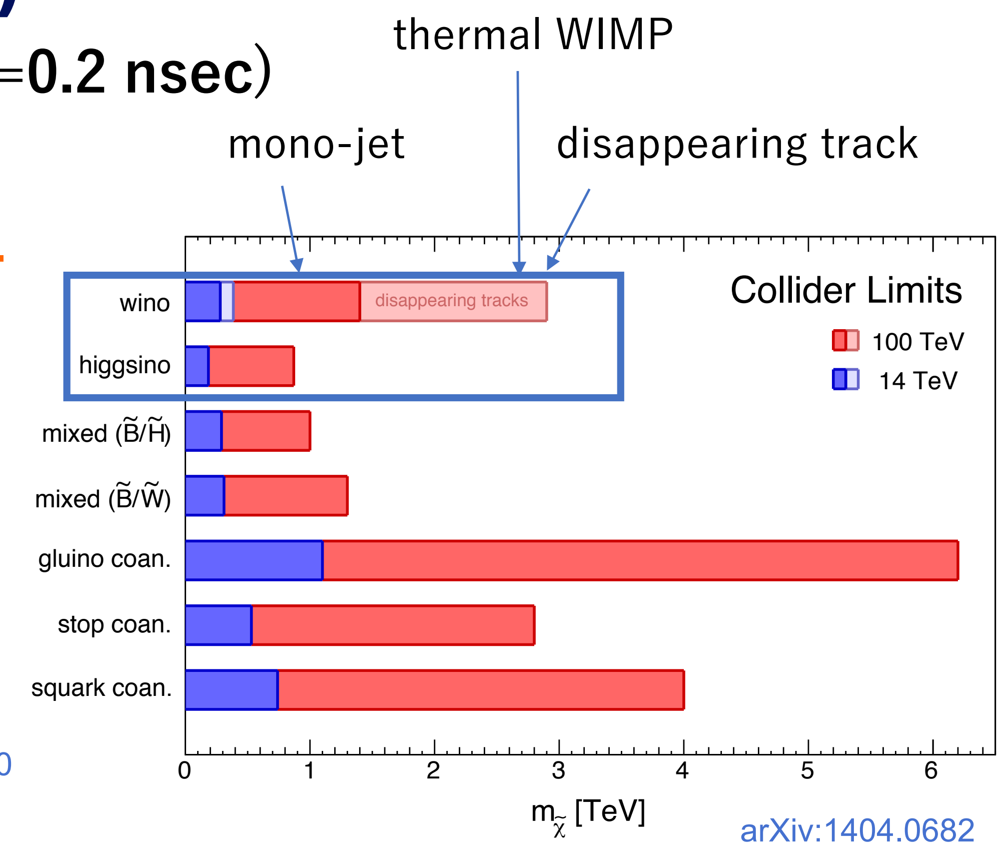


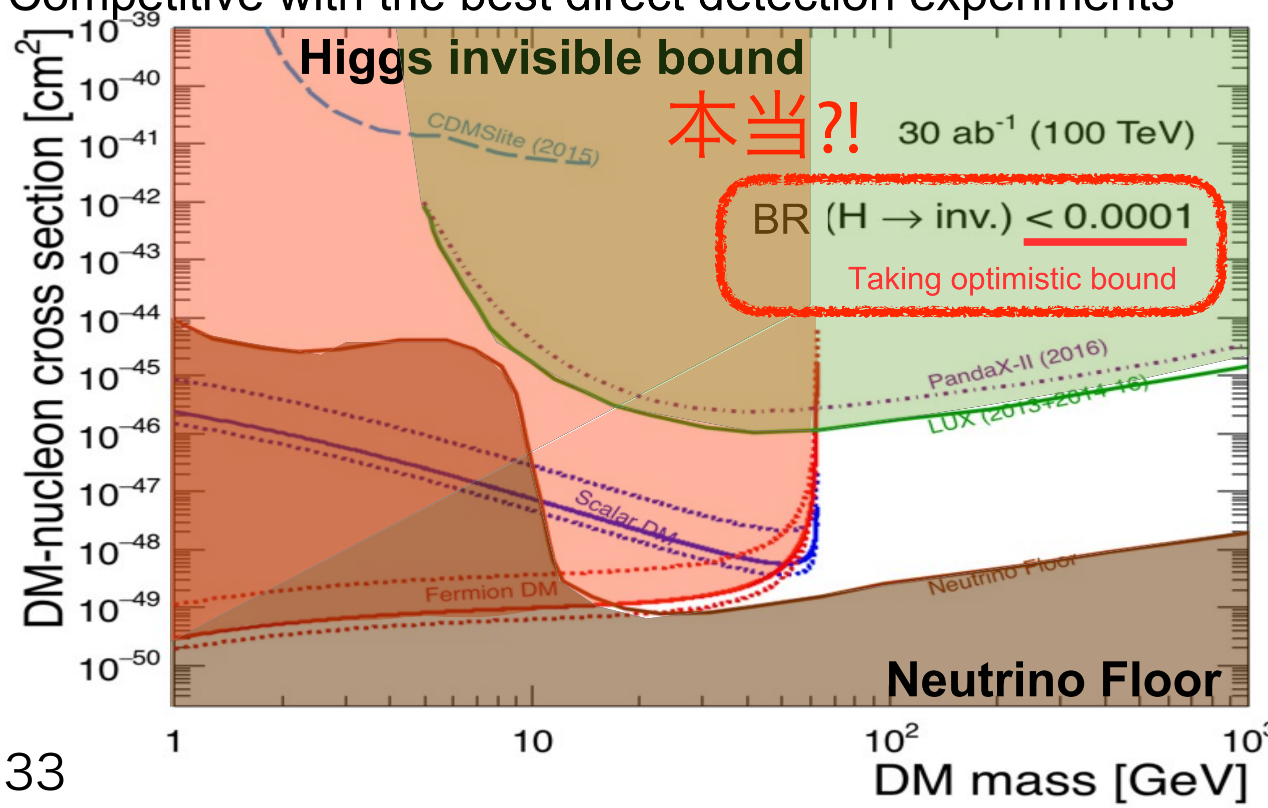
arXiv:1404.0682

DM from H→inv

Higgs invisibleからLow-mass scalarへの制限 (P. Harris et al.)

- 高統計のデータ
  $N_{100}^{20ab^{-1}}/N_{14}^{3ab^{-1}} = 110(120, 420)$ for ggF (VH, ttH)
- W/Z p_Tの(超)精密測定

Competitive with the best direct detection experiments



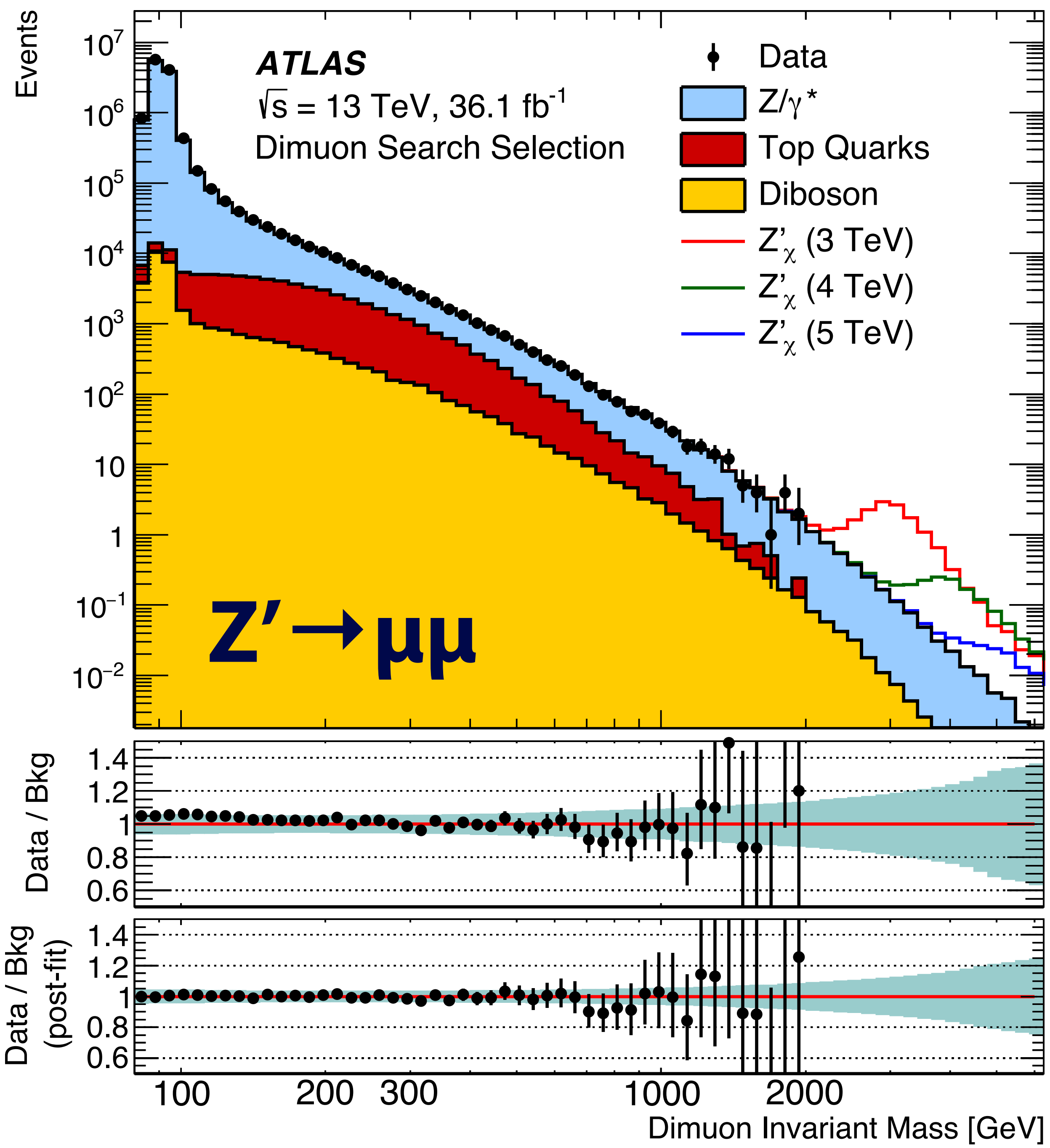
Backup

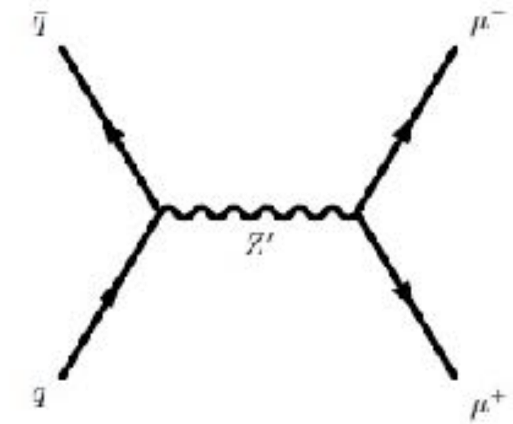
Excesses?

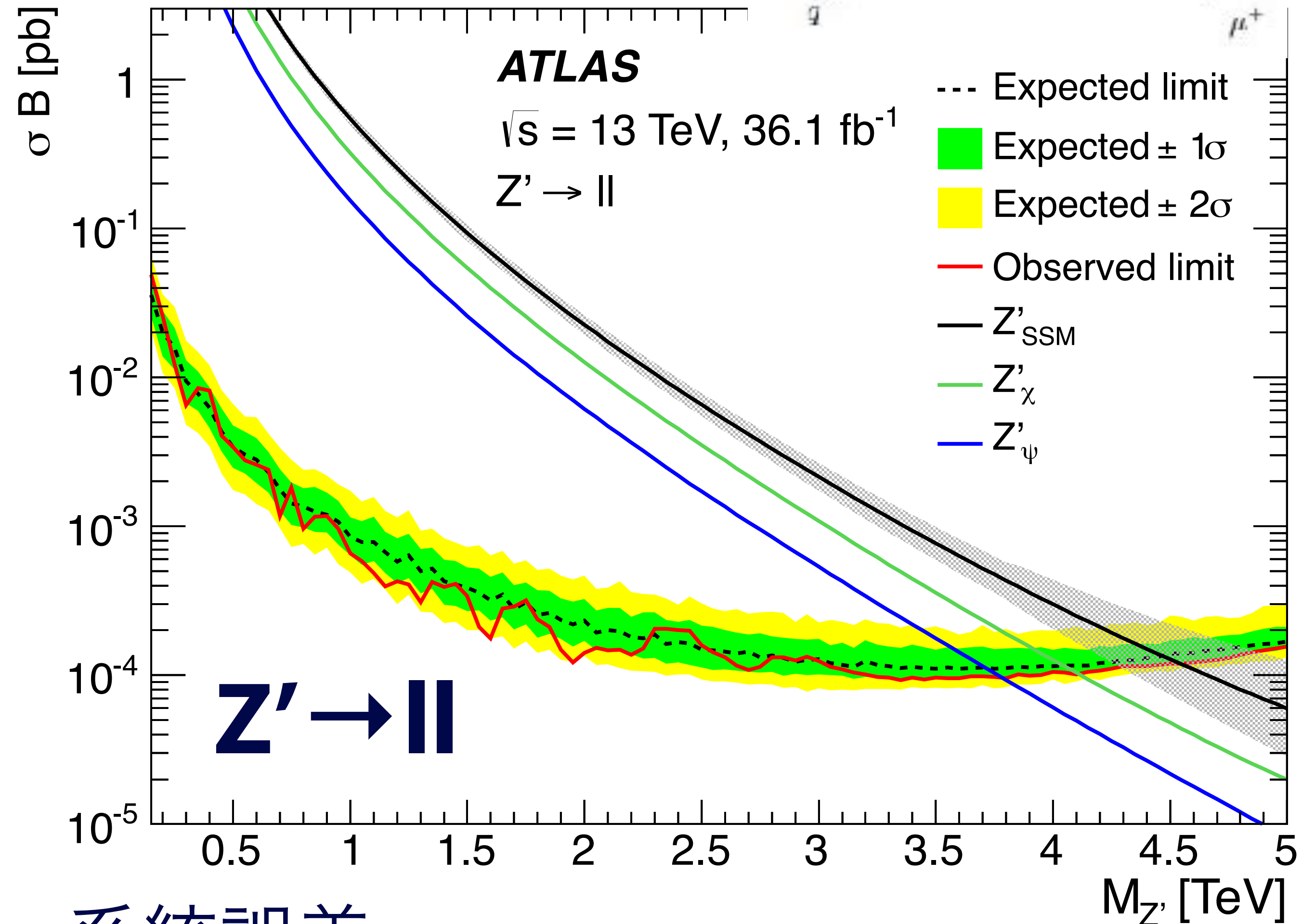
H → ZZ → 4l (HIGG-2016-19) : ▸ 3.7(2.6)σ local(global) excess at 700 GeV? ▸ CMS : 4l at 13.9 fb^{-1}, 4 events at ~660 GeV, ~1.5-2σ local (HIG-16-033)	2.6σ
VH → qqbb (EXOT-2016-12) : ▸ 3.3(2.2)σ local(global) at ~3 TeV (mostly ZH) ▸ CMS : 2.6(0.9)σ local (global) at 2.6 TeV (B2G-17-002)	2.2σ
ZH → llbb (EXOT-2016-10) : ▸ 3.6(2.4)σ local(global) excess at ~450 GeV, mostly in dimuon 3+ tag region ▸ CMS : high-mass only at 3.2 fb^{-1} in 13 TeV (B2G-16-003)	2.4σ
Dijet+ISR in CMS (EXO-17-001) : ▸ ~2.9(2.2)σ local(global) at ~115 GeV ▸ ATLAS : on-going	2.2σ
Inclusive squark/gluino (SUSY-2016-12) : ▸ 1-lepton in 2J b-veto SRs	-

Dilepton

EXOT-2016-05







系統誤差

- PDF, energy scale for ee channel
- Reco eff., PDF, resolution for μμ channel

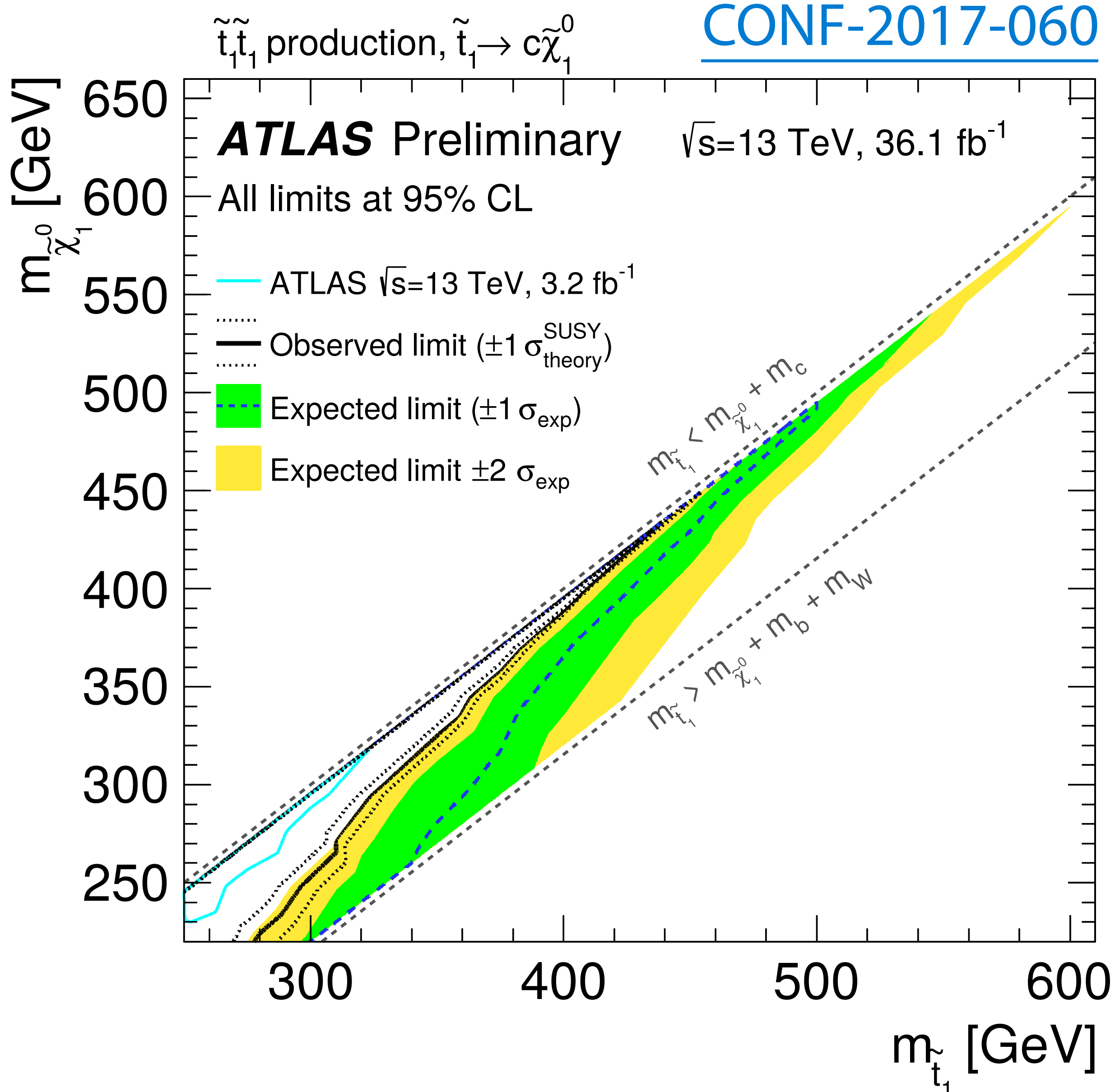
Z'$_{SSM}$ limit [TeV]	Exp.	Obs.
ee	4.3	4.3
μμ	3.9	4.0
ll	4.5	4.5

- 2e or 2μ : p_T > 30 GeV, loose isolation
- m_{ll} > 80 GeV (OS for 2μ)

Z/γ* BGはPowheg+Pythia with mass-dep. k-factor (NNLO QCD, NLO EW)で評価

Mono-jet

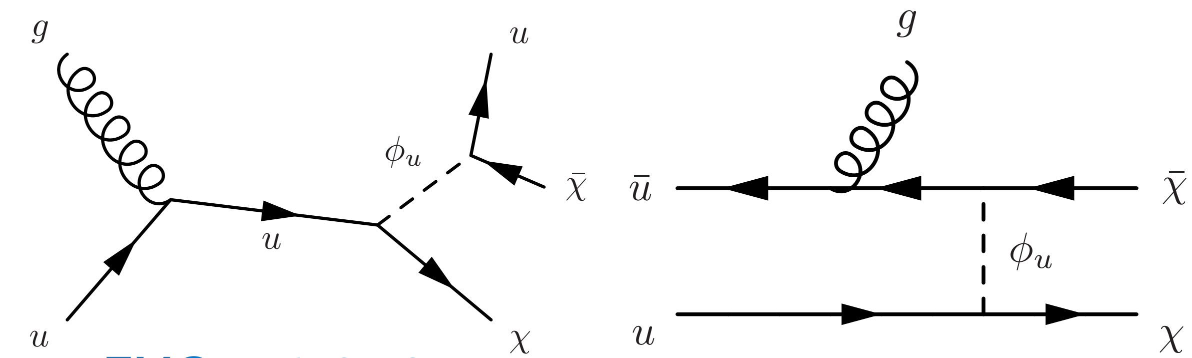
CONF-2017-060



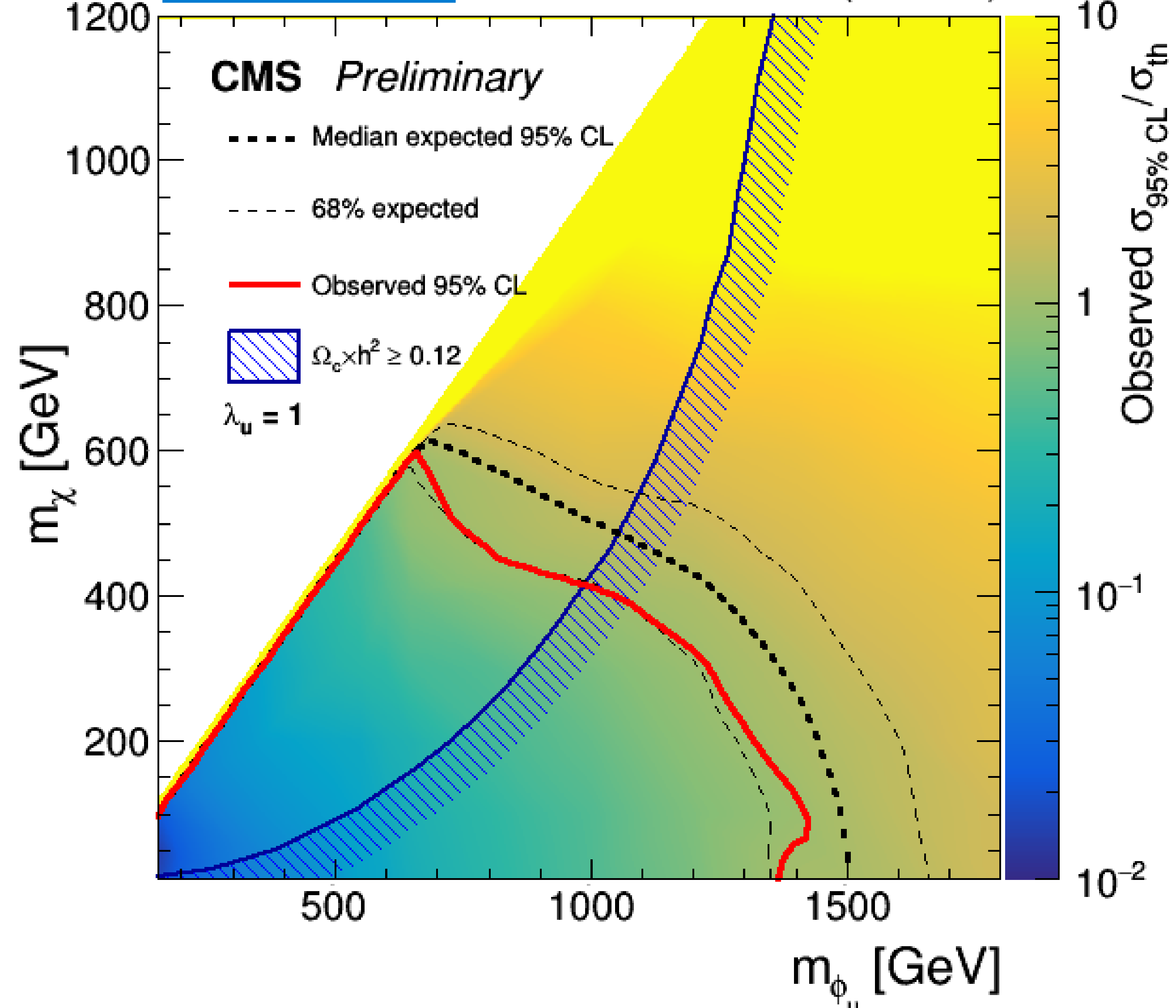
stop → charm + neutralino

stop mass excluded up to 430 GeV

($m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ >5 GeV)



EXO-16-048



Fermion portal DM model

- Colored-scalar mediator
- DM coupling only to *u*-type quark ($\lambda_u = 1$)

mediator mass excluded up to ~1.4 TeV

DM mass excluded up to 600 GeV