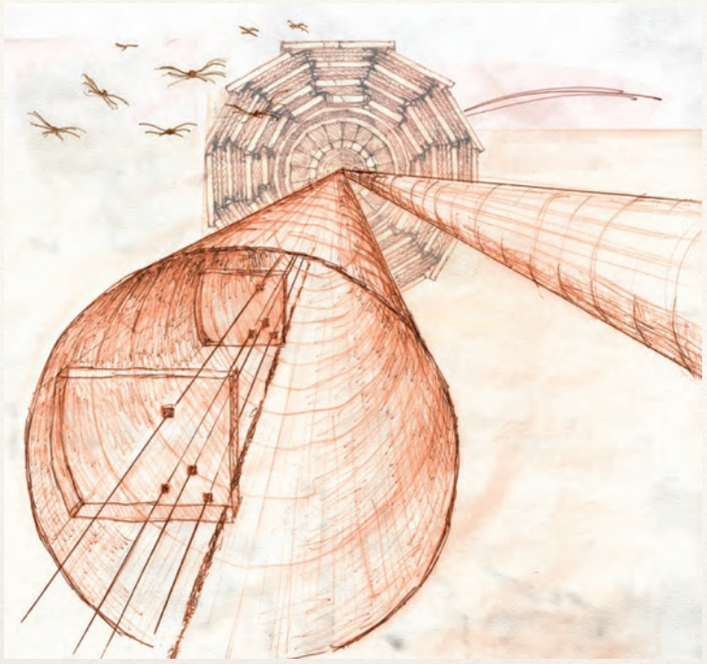


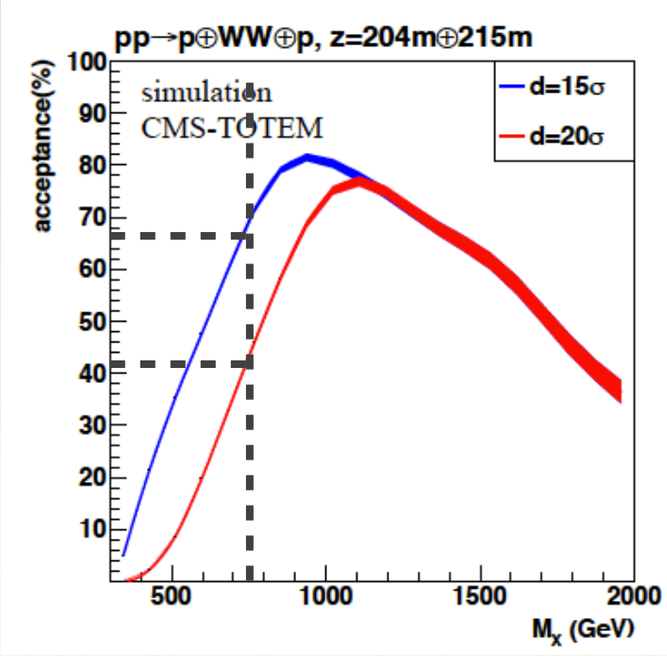
Physics simulations: resonances in γγ->γγ with CT-PPS

Jonathan Hollar (LIP)

LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTICULAS

Introduction

- A number of papers since December consider $\gamma\gamma$ production of a 750GeV resonance decaying to $\gamma\gamma$
- **"Easier" scenario than channels studied for CT-PPS TDR: high-mass, low background, very good resolution in central CMS (no jets or missing E_T)**
  - Good acceptance near 750GeV (**with previous LHC optics from TDR!**)



Fichet, von Gersdorff, Royon (arXiv:1601.01712)

Fichet, von Gersdorff, Royon (arXiv:1512.05751)

Csaki, Hubisz, Terning (arXiv:1512.05776)

Csaki, Hubisz, Terning (arXiv:1601.00638)

Harland-Lang, Khoze, Ryskin (arXiv:1601.07187)

Anchordoqui, et al (arXiv:1512.08502)

Nomura and Akada (arXiv:1601.00386)

d'Eramo, de Vries, Panci (arXiv:1601.01571)

Danielsson, Enberg, Ingelman, Mandal (arXiv:1601.00624)

Ben-Dayan and Brunstein (arXiv:1601.07564)

Martin and Ryskin (arXiv:1601.07774)

Barrie, et al (arXiv:1602.00475)

Molinaro, Sannino and Vignaroli (arXiv:1602:07574)

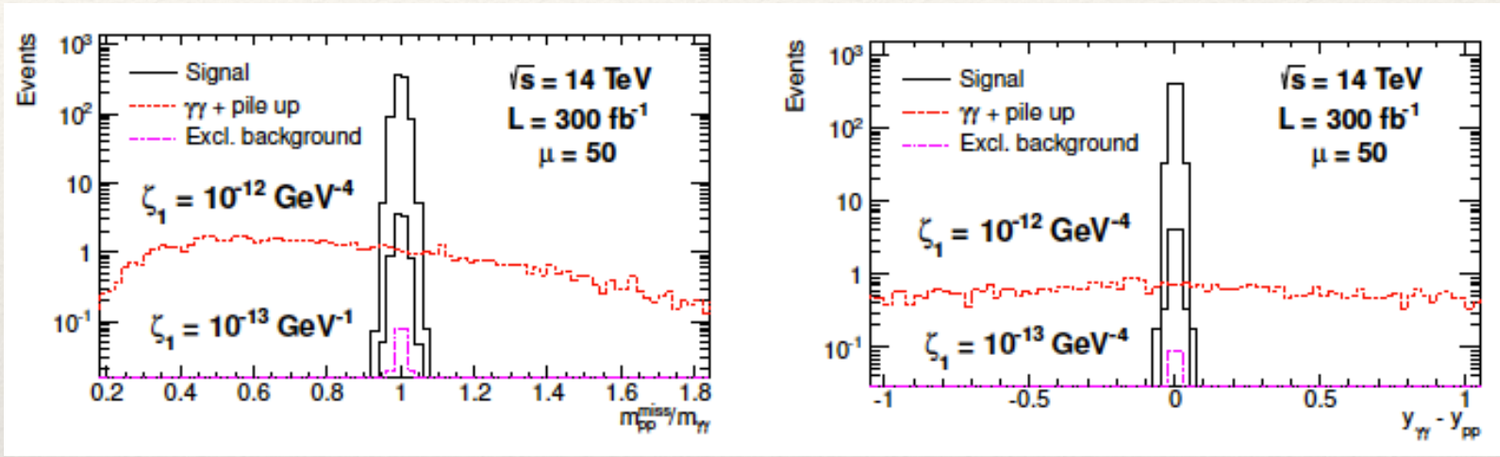
Abel and Khoze (arXiv:1601.07167)

…

+ talks from yesterday / today

Previous studies

- Earlier published high-mass (>600GeV) $\gamma\gamma$->$\gamma\gamma$ studies in context of ATLAS/AFP
  - Indicated good efficiency + bkg. suppression possible with tracking only up to $<\mu>=50$
  - Fichet, von Gersdorff, Lenzi, Royon, Saimpert (arXiv:1411.6629 + talk yesterday)



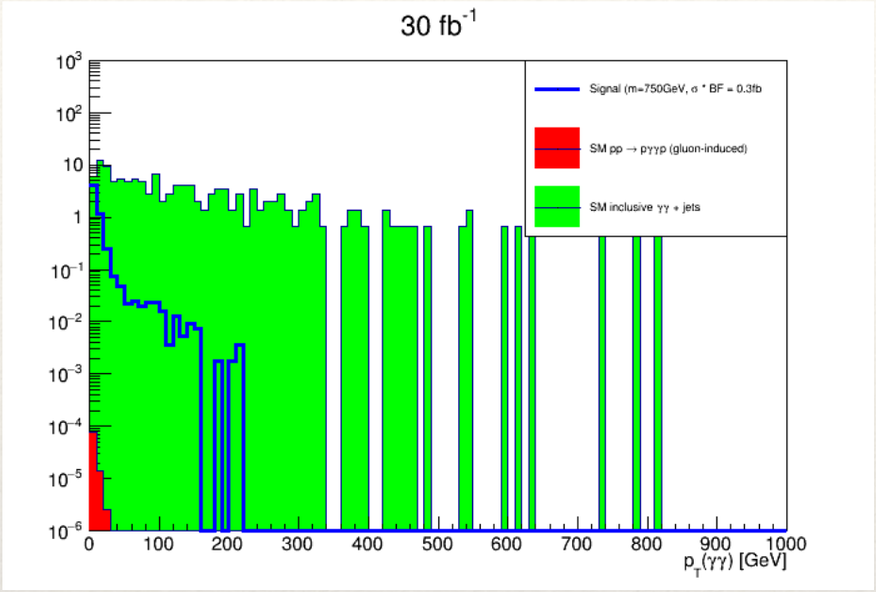
JHEP 1502 (2015) 165, arXiv:1512:05751

- Repeat similar very rough study assuming only central CMS + proton tracking from TOTEM Si strips available

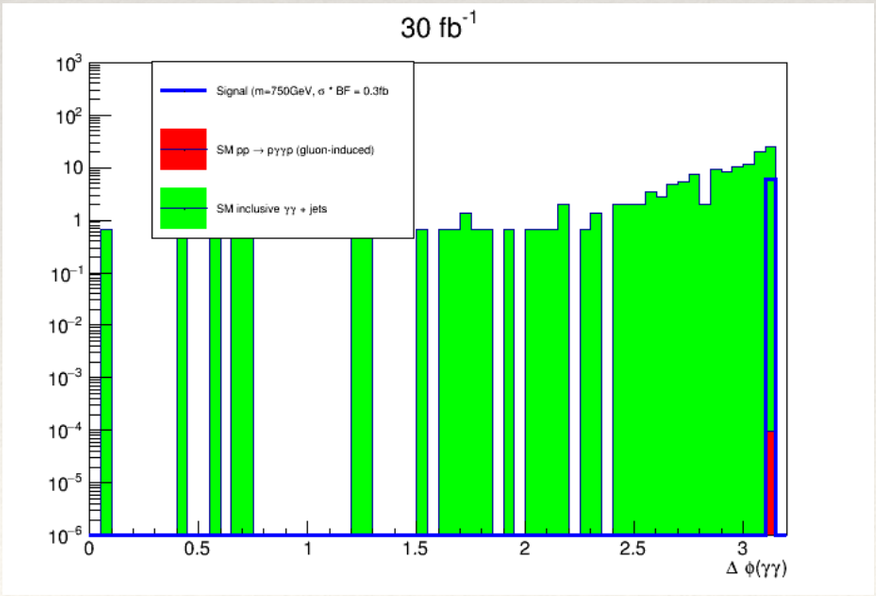
Samples/selection

- Assume projected ~2016-like luminosity/pileup scenario: 30fb^{-1}, <μ>=25
  - Physics pileup simulated, beam backgrounds not included
- Backgrounds
  - Inclusive γγ+jets generated with Sherpa, scaled to NNLO cross section
  - "Irreducible" SM background from gluon-induced pp->pγγp (Exhume, scaled to section of arXiv: 1411.6629)
- Signal model as used in 2015 CMS inclusive search: RS graviton (spin-2), with m=750GeV and k/MPl=0.07: σ*BF=0.3 fb
  - Only used to study acceptance, not necessarily meant to be realistic model for the 750GeV ATLAS/CMS excess
- Photon selection: acceptance/pT cuts based on CMS 13TeV inclusive search (EXO-15-004), compatible with 100% efficiency for expected 2016 diphoton trigger
- Protons: CTPPS fast simulation of tracking detectors **(but with old LHC optics - see talk by Mario)**

Diphoton kinematic cuts



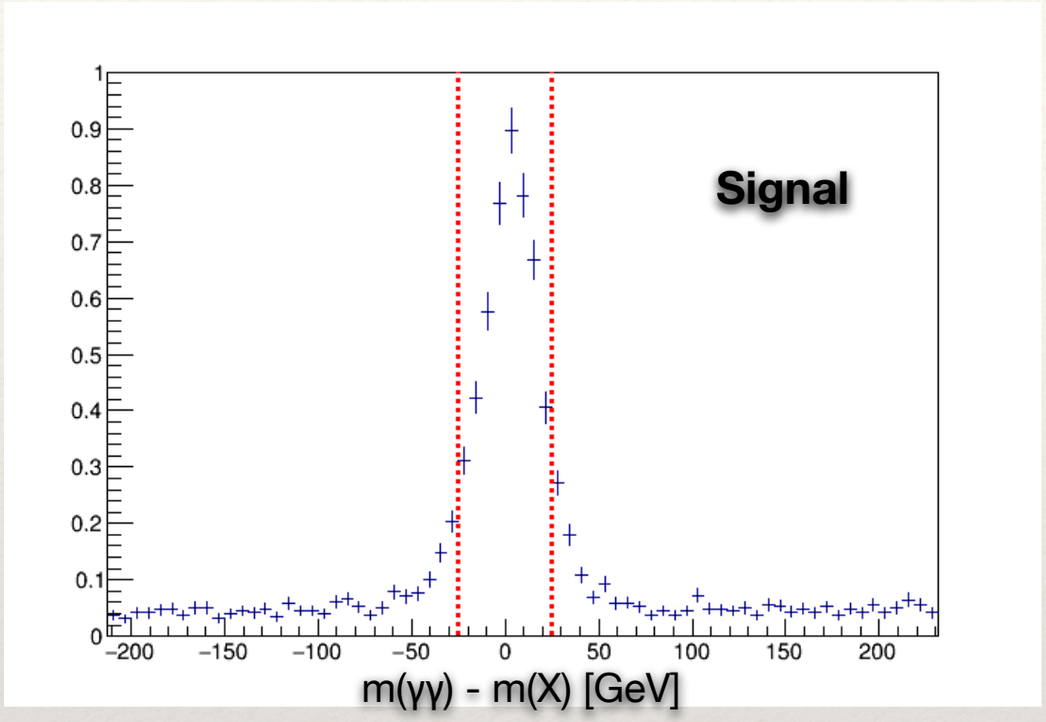
$p_T(\gamma\gamma)$

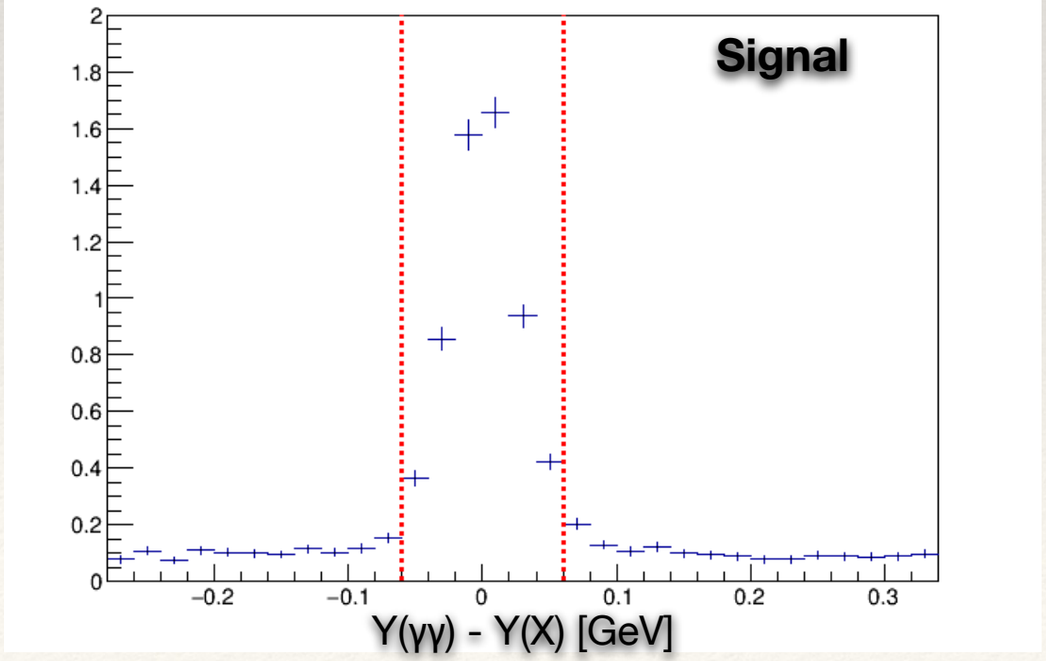


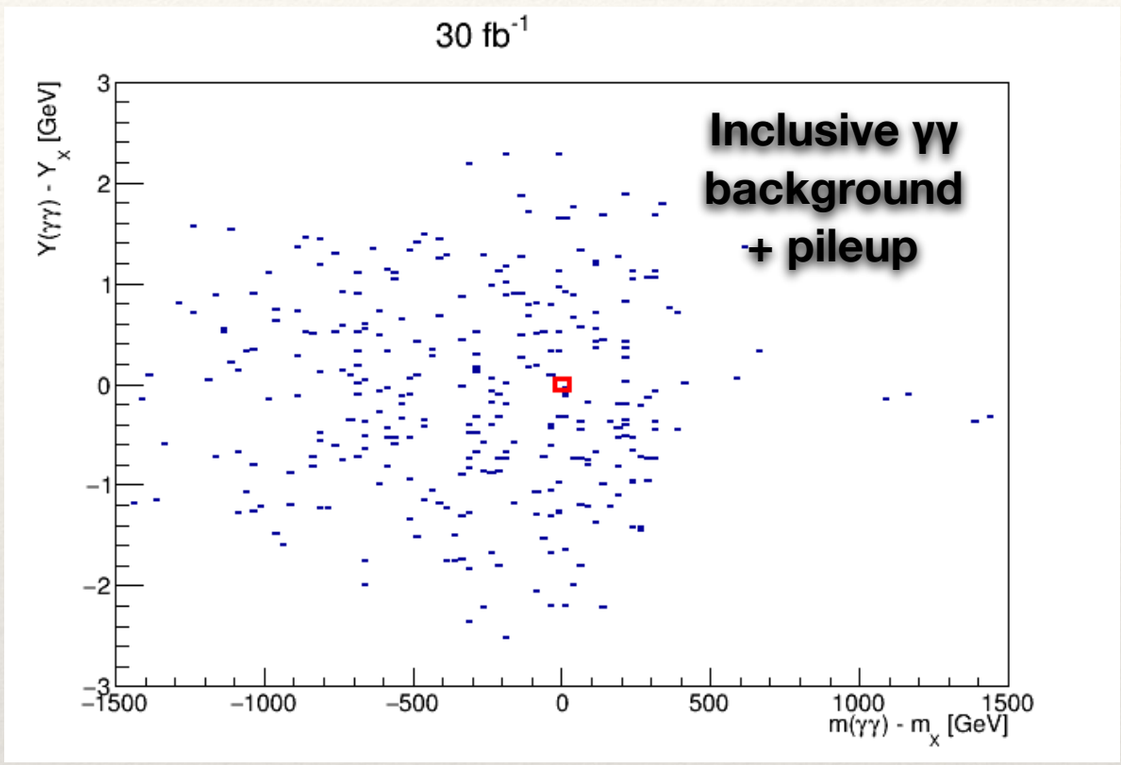
$\Delta\phi(\gamma\gamma)$

- After diphoton selection and proton tagging in both arms, ~130 inclusive background events in 0.5-1.0 TeV range in 30fb^{-1}
  - SM gluon induced exclusive background already << 1 event in this mass range
- Further suppression of inclusive backgrounds with cuts on photon pair kinematics
  - Exclusive signal should be back-to-back in delta-phi, balanced in pT (pair pT~0 or delta-pT~0 or pT1/pT2~1)
    - Adopt cuts from ATLAS study (arXiv:1411.6629)
      - $E_T(\gamma 2)/E_T(\gamma 1) > 0.95$
      - $\Delta\phi(\gamma\gamma) > \pi - 0.01$

Diphoton-diproton matching cuts



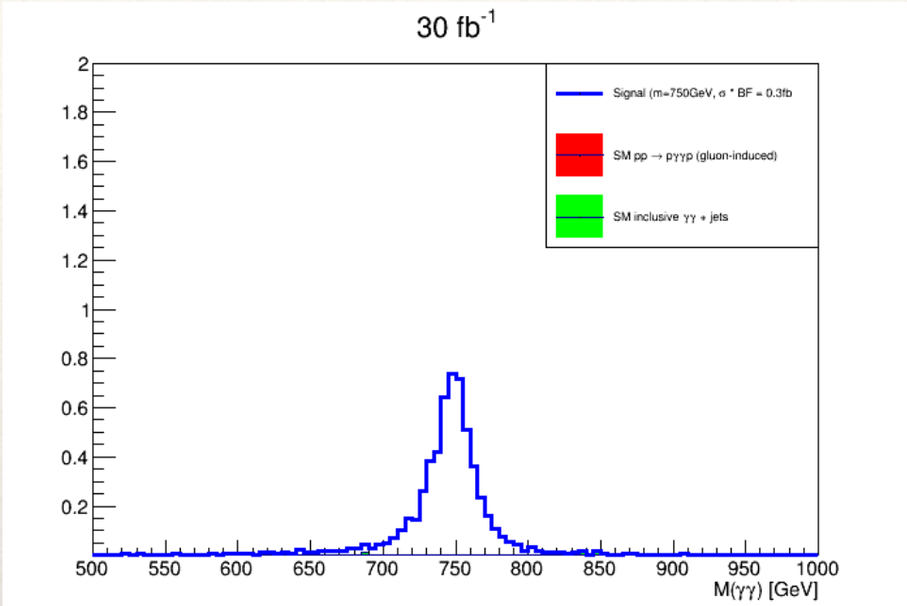




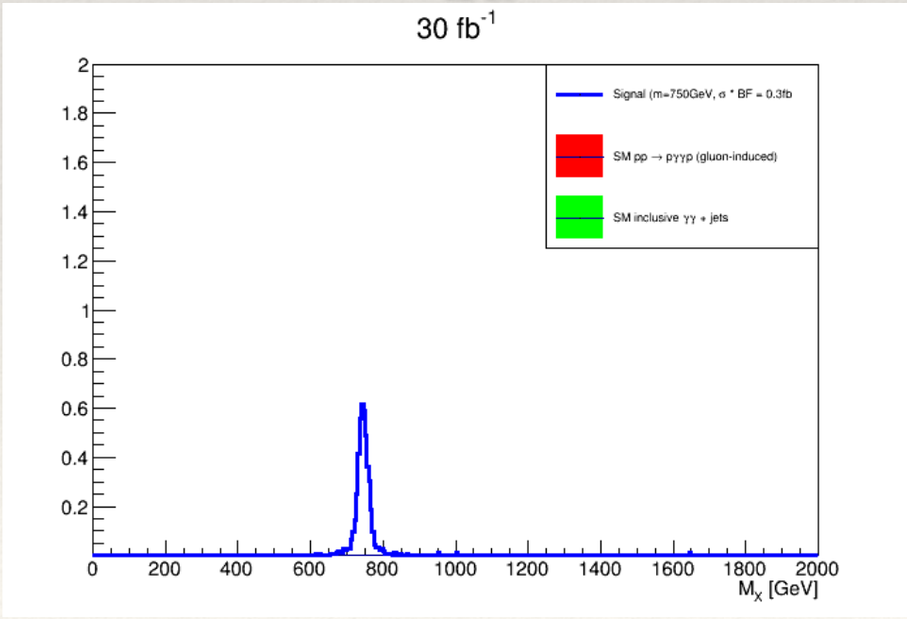
- Require mass and rapidity matching cuts between photons and protons
  - $|m(\gamma\gamma) - m(X)| < 25$ GeV
  - $|Y(\gamma\gamma) - Y(X)| < 0.06$
  - (pT ratio and delta-phi cuts inverted to enhance statistics of inclusive background plot)

After diphoton-diproton matching and diphoton kinematic cuts

- Acceptance*efficiency for signal: ~29-41% for 20σ-15σ approach
  - Based on distances used in CT-PPS TDR and previous LHC optics
  - Restricting to events with <=2 pileup protons/arm for Si strip reconstruction retains ~86% of events
- SM backgrounds:
  - inclusive γγ + pileup: <~ 0.1 events
    - Expect inclusive γ+jet and jet+jet backgrounds < γγ background after all selections, based on CMS inclusive search
  - SM (gluon-induced) exclusive γγ: <10^-4 events
    - Also expect O(ab) visible cross section for SM γγ->γγ continuum



m(γγ)

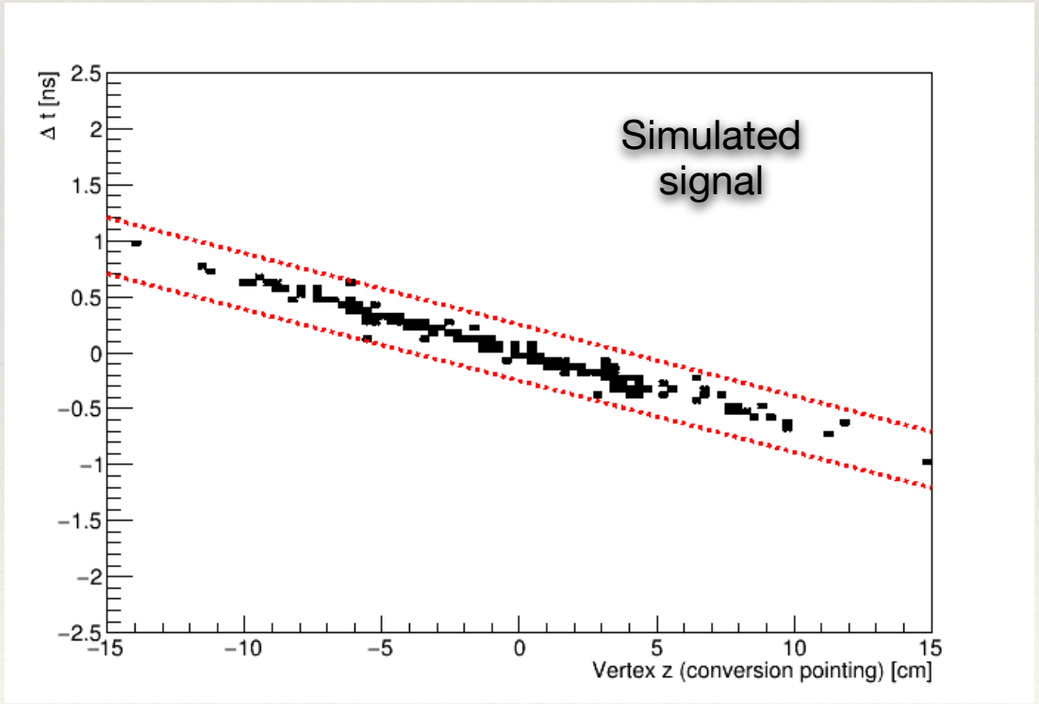


m(X) [X = 13TeV - m(pp)]

Timing detectors

- So far assumed no timing detectors at startup - additional options when these are installed
  - Diamond detectors (see talk by Mirko) can be used also for tracking together with or in place of Si strips

- Subset of events with converted photons can be used to point to collision vertex in CMS
  - Same vertex-finding method used with conversions in CMS H->$\gamma\gamma$ analyses
  - Reduces statistics, but allows matching with Δ(ToF) of protons, vertex track-counting



Vertex z position from conversion

Summary

- Initial rough look at simulation of exclusive production of a 750GeV resonance in diphoton channel with proton tagging for CT-PPS
  - Qualitatively similar to previously published studies for AFP/ATLAS:
    - **=> Large suppression of inclusive backgrounds seems possible using tracking alone, with reasonable acceptance for a 750GeV resonance**
      - (LHC optics permitting)
    - Expect similar background suppression for other high-resolution channels with only photons/leptons in central CMS (l^+l^-, $Z\gamma$ and ZZ with leptonic Z decays)
- Could have a few $\gamma\gamma$ events in $30fb^{-1}$ for assumed σ*BF as low as ~0.3fb
- Timing detectors will contribute to proton tracking measurements, or to vertex matching with converted photons in CMS (with some loss of statistics) when installed
  - Timing detectors critical for full physics program including final states with jets, missing E_T

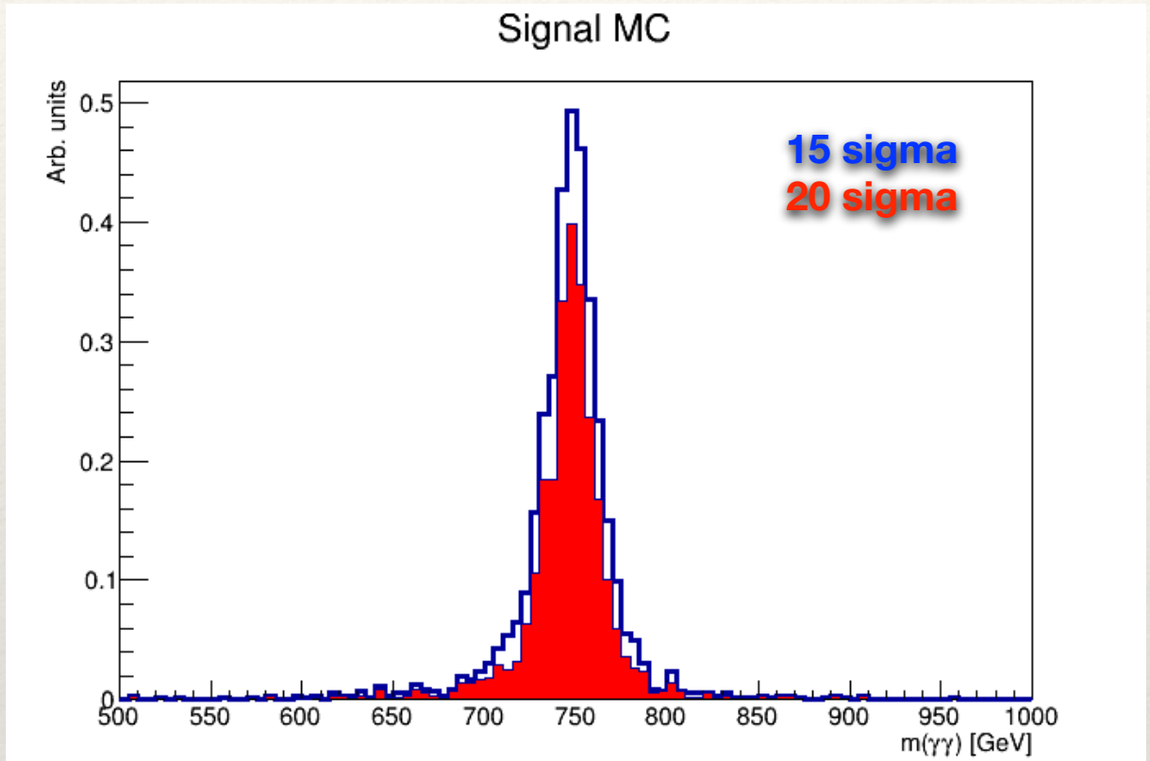
Extra

Comparison to dijets

- x-check with numbers from TDR dijet analysis (mu=25 pileup scenario, including beam backgrounds)
  - 1.7E-4 rejection factor on inclusive dijets, without any ToF or N(tracks) cuts (assuming these factorize from other cuts)
  - SM inclusive diphoton x-section for 500<m<1000 = 227fb, with k-factor
  - -> ~1 event in 30fb-1, before photon delta-phi and pT cuts

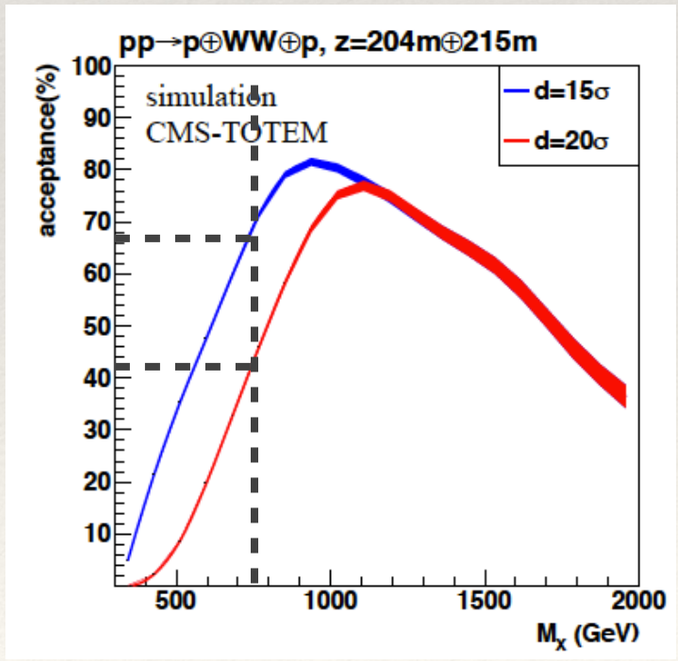
Selection	Exclusive dijets		DPE		SD		Inclusive dijets	
	events	ϵ (%)	events	ϵ (%)	events	ϵ (%)	events	ϵ (%)
total number of events	652±5	100	290×10^3	100	2.6×10^6	100	2.4×10^{10}	100
≥ 2 jets (p_T >100 GeV, $\|\eta\| < 2.0$)	250±4	38	25×10^3	8.7	190×10^3	7.6	3.4×10^8	1.4
PPS tagging (fiducial)	50±2	8	15×10^3	5.1	12×10^3	0.5	0.1×10^8	0.05
no overlap hits in ToF detectors	43±2	7	14×10^3	4.8	$10\ (18) \times 10^3$	0.4	0.1×10^8	0.04
ToF difference, Δt	30 (23)±2	4.6	$11\ (9) \times 10^3$	3.8	3×10^3	0.1	$0.3\ (0.6) \times 10^6$	1×10^{-3}
$0.70 < [R_{jj} = (M_{jj}/M_X)] < 1.15$	20 (15)±1	3.1	15 (14)±3	0.01	85 (110)±15	-	$16\ (30) \times 10^3$	1×10^{-4}
$\Delta(y_{jj} - y_X) < 0.1$	15 (12)±1	2.4	6 (4)±2	-	3 (11)±3	-	$1.8\ (3.4) \times 10^3$	-
N_{tracks}	7.4 (5.8)±0.4	1.1	0.8 (0.6)±0.3	-	1±1	-	19 (35) ± 1	-
≥ 2 jets (p_T > 150 GeV, $\|\eta\| < 2.0$)	3.5 (2.6)±0.2	0.5	0.2 (0.1)±0.1	-	1±1	-	9 (17) ± 1	-

Acceptance vs. RP approach

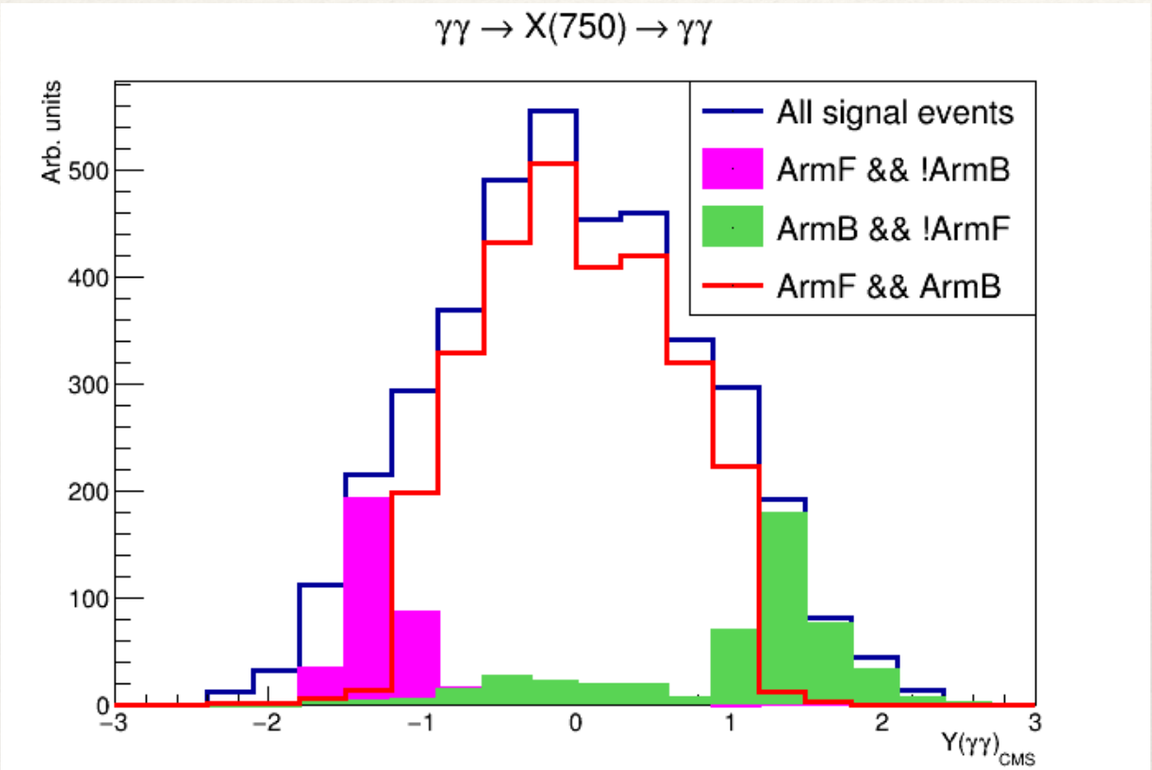


- From TDR γγ->WW:
  - N(20sigma)/N(15sigma) ~ 0.42/0.67 = 0.63

- Ratio of signal yields, after photon acceptance and pT/delta-phi cuts in central detector:
  - N(20sigma)/N(15sigma) = 0.71

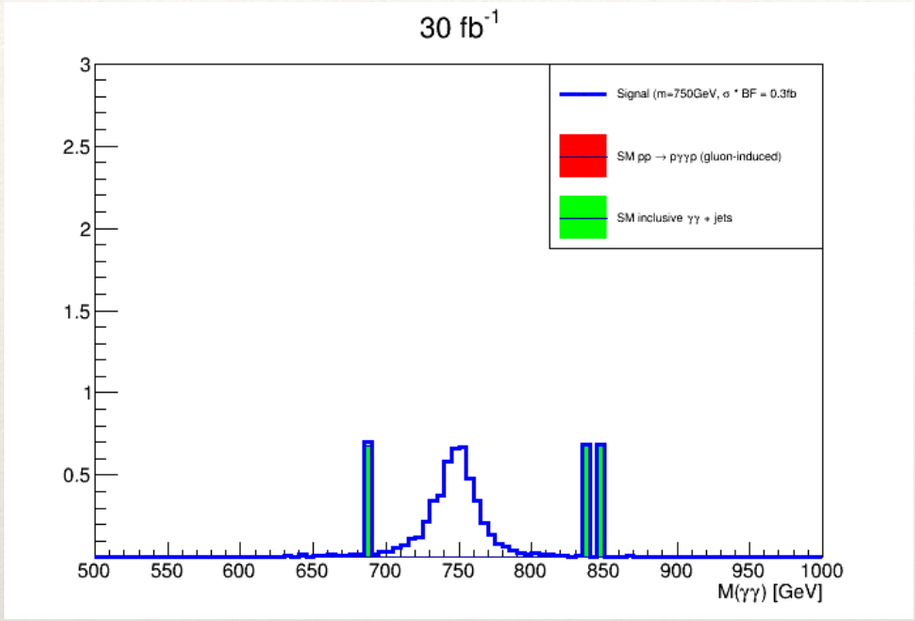


Rapidity acceptance + proton tagging

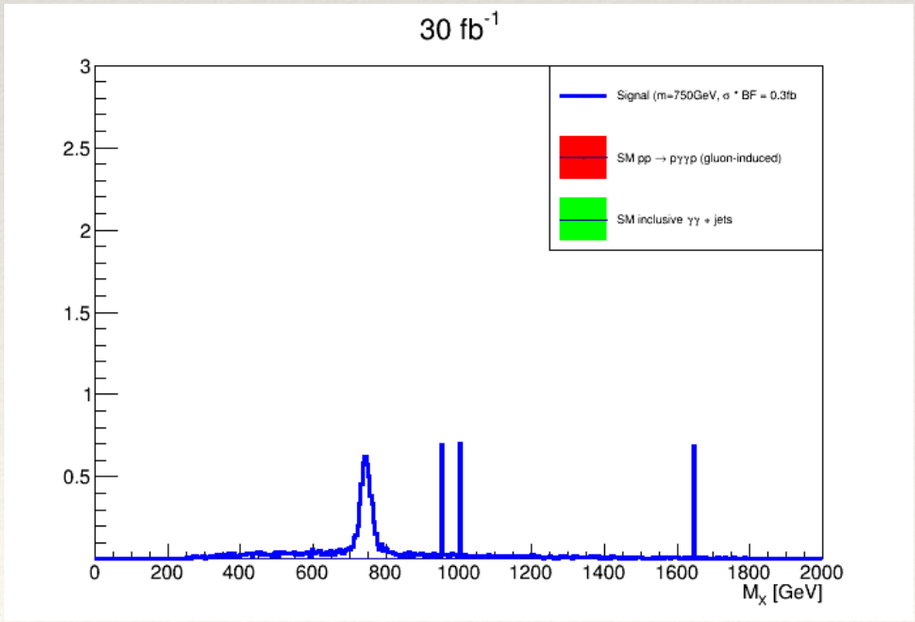


- Proton tagging acceptance best for central production of a X(750) resonance
  - Forward production corresponds to asymmetric xi, 1 proton often missed
- Spin-2 model: ~70% of signal events have both protons in acceptance (15sigma approach)
  - Spin-0 should be even more central

After diphoton kinematic cuts



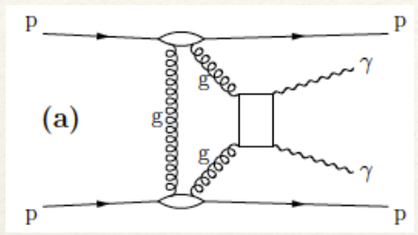
m(γγ)



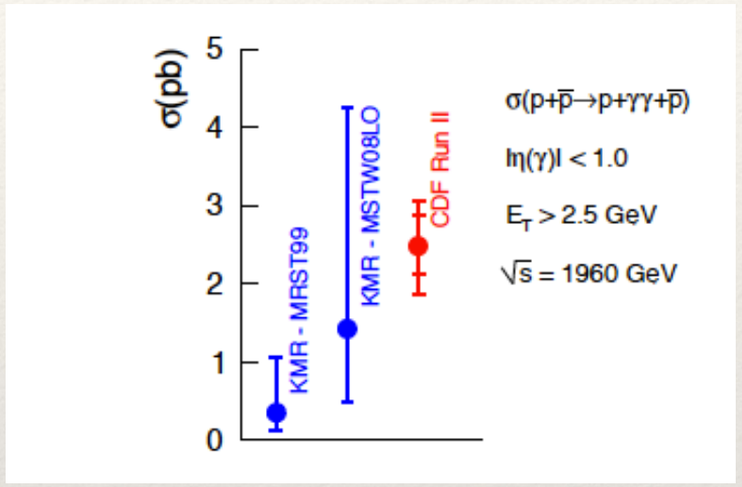
m(X)

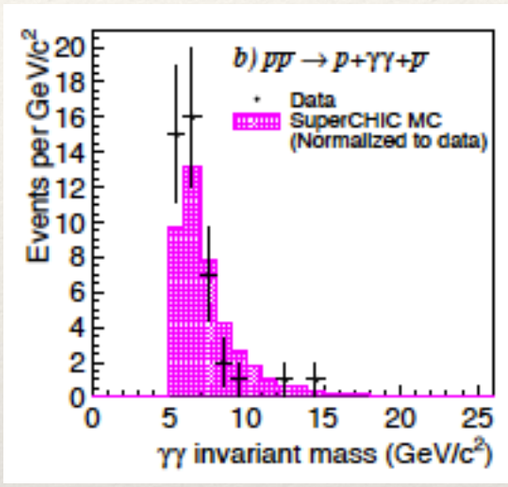
- Remaining background in the range 500 GeV<m(γγ)<1000GeV
  - ~2 inclusive background+pileup candidates
  - <10^-4 gluon-induced SM exclusive background

Gluon-induced excl. diphoton bkg.



- CDF: Signal observed in upper range of theory predictions for $m(\gamma\gamma) = \sim 5\text{-}15$ GeV





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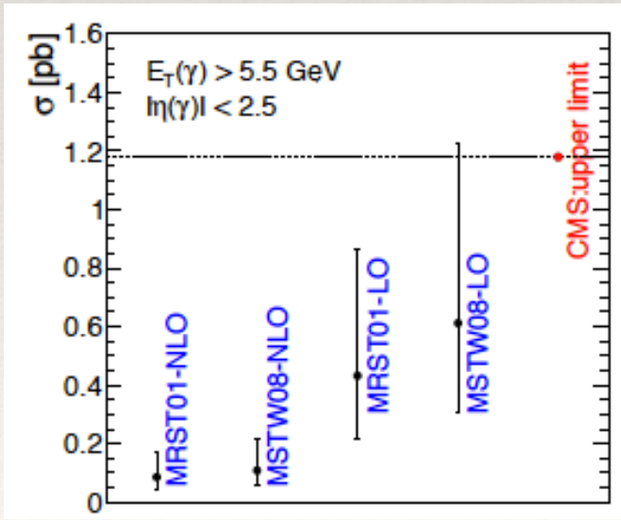
- CMS (2010 data): 0 events observed, upper limit just above predictions for $m(\gamma\gamma) > 11$ GeV



JHEP 1211 (2012) 080

Spin-2/graviton models

- Resonance decaying to $\gamma\gamma$ must be spin-0 or spin-2
- Many papers covering spin-0 possibilities
- Typical spin-2 example: graviton in ED models
- Pros:
  - Can reproduce hypothetical 750GeV diphoton signal (arXiv:1602:02793)
  - Couples to everything -> many other decay modes possible
- Cons: only marginally consistent (but not completely excluded) with lack of signal in other inclusive searches, especially l+l-

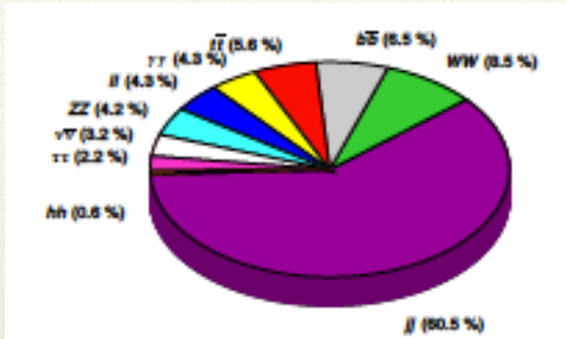


FIG. 3. The decay branching ratios of the 750 GeV KK graviton.

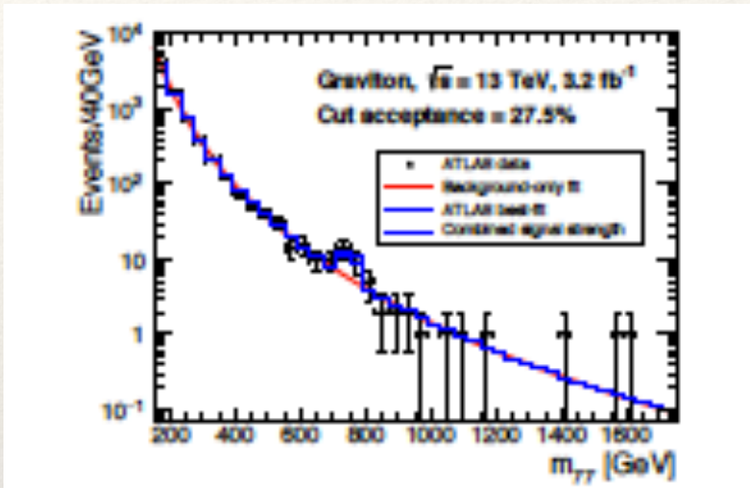


FIG. 1. The best-fit result to the 13 TeV LHC diphoton excess with a lightest KK graviton. The narrow width approximation is used in the fit. The solid blue line is our best-fit to the 13 TeV ATLAS data. The dashed blue line is the best-fit from a combination of the 13 TeV CMS results (from the CMS collaboration [3]) and our best-fit of the 13 TeV ATLAS data.

arXiv:1602:02793