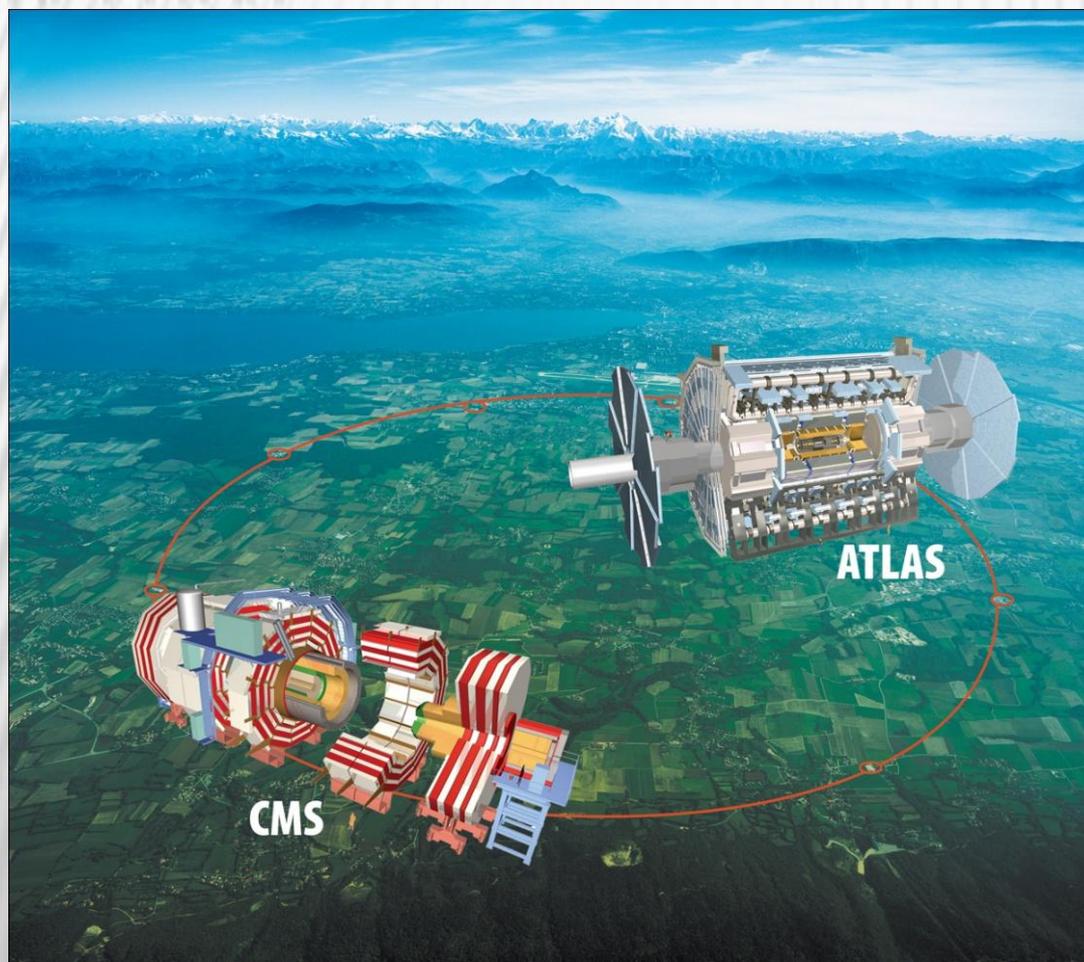


ЭКСПЕРИМЕНТАЛЬНОЕ НАБЛЮДЕНИЕ НОВОГО ДВУХФОТОННОГО РЕЗОНАНСА НА LHC?



Л.Н.Смирнова
9 Черенковские чтения
ФИАН, 19 апреля 2016

ОСНОВНЫЕ ПУБЛИКАЦИИ

ATLAS at 8 TeV

- × PRL 113,171801 (2014)
- × Phys.Prev.D92, 032004 (2015), 14 August 2015

ATLAS at 13 TeV

- × ALAS-CONF-2016-018, 24 March 2016

CMS at 8 TeV

- × PLB 750 (2015)494 18Dec 2015
- × CMS-PAS-EXO-12-045 May 2015
- × CMS-PAS-EXO-15-004 Dec 2015

CMS at 13 TeV

- × CMS-PAS-EXO-16-018

+ Презентации на Moriond EW 17 March 2016

МОТИВАЦИЯ АНАЛИЗА

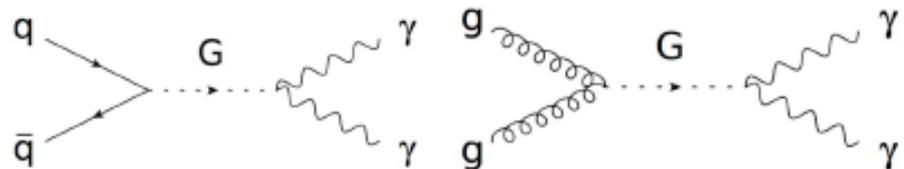
Why diphoton searches?

- Clean signal over smooth and well known background (e.g. $H(125) \rightarrow \gamma\gamma$)
- Several extensions of the Standard Model predict high-mass states decaying to two photons
- Benchmark models...

Spin-0 analysis
e.g. extended Higgs sector

Spin-2 analysis
e.g. Randall-Sundrum graviton

- 2HDM
 - ✓ 5 physical states h^0, H^0, A^0, H^\pm
 - ✓ Under certain conditions, scalar and/or pseudo-scalar states can have sizable branching ratio to diphoton
- Model predicts tower of Kaluza-Klein graviton states with TeV mass scale
- Phenomenology
 - ✓ m_{G^*} = mass of lightest KK excitation
 - ✓ κ/M_{Pl} = dimensionless coupling to SM fields

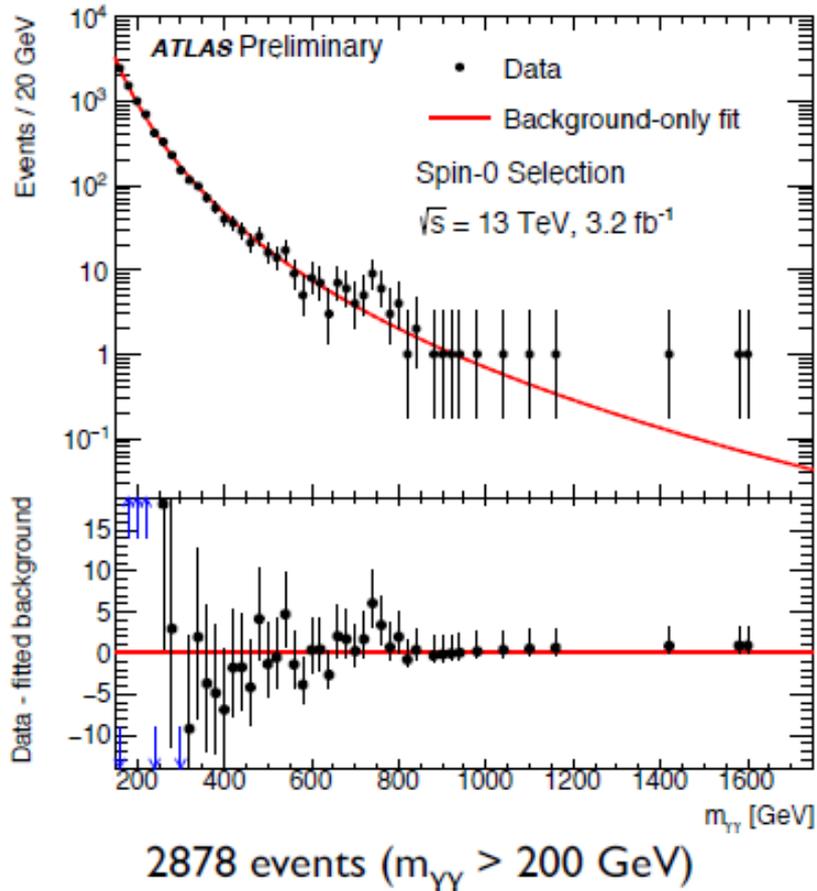


РЕЗУЛЬТАТЫ ATLAS ДЛЯ 13 ТЭВ

Results

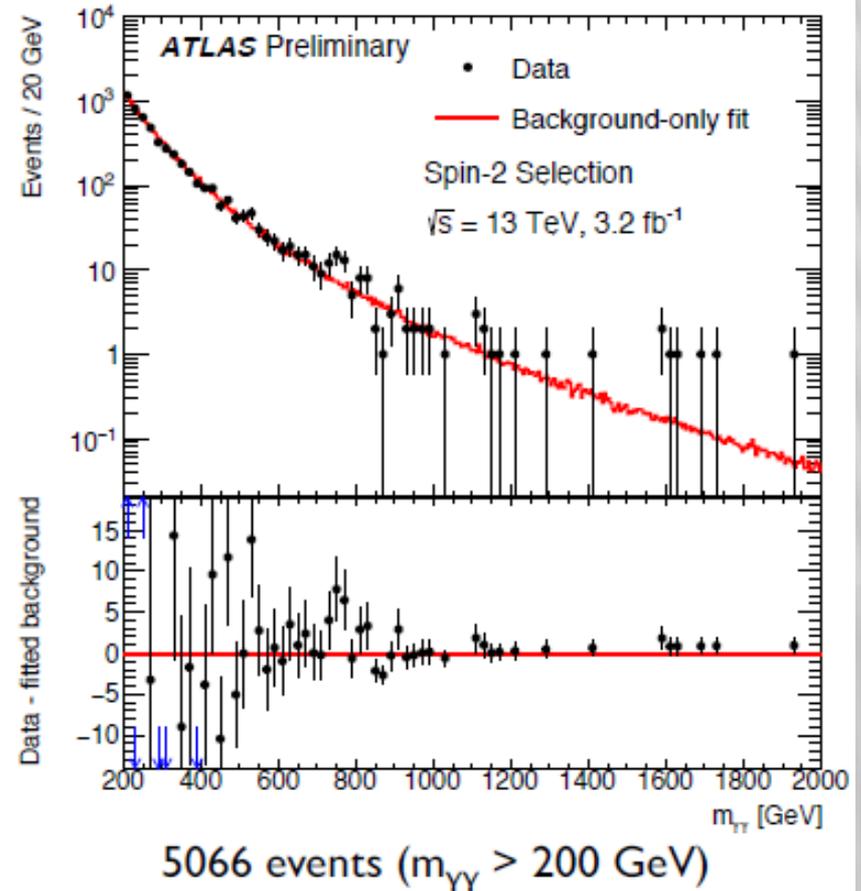
SPIN-0 ANALYSIS

background-only fit



SPIN-2 ANALYSIS

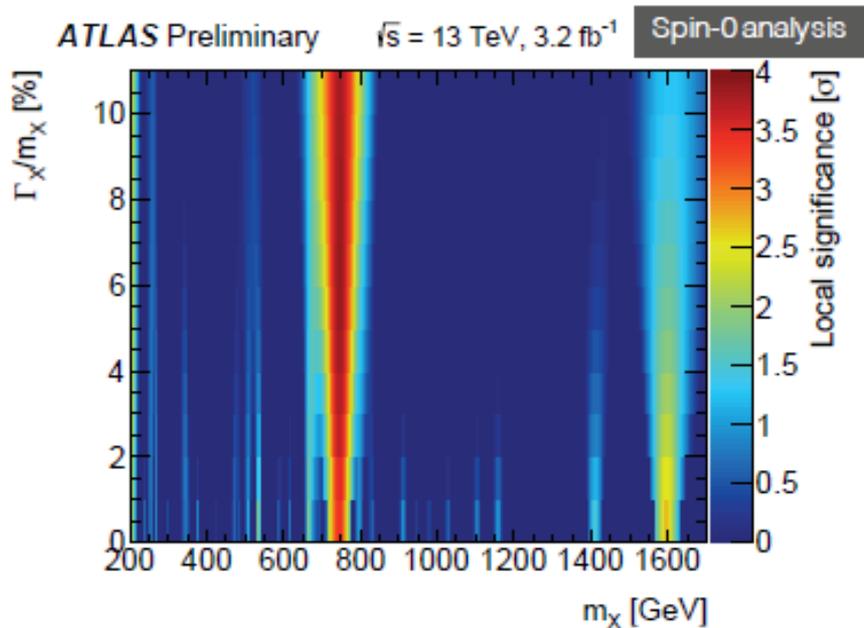
background-only fit



РЕЗУЛЬТАТЫ СКАНИРОВАНИЯ МАССЫ РЕЗОНАНСА M_X И ШИРИНЫ Γ_X / M_X

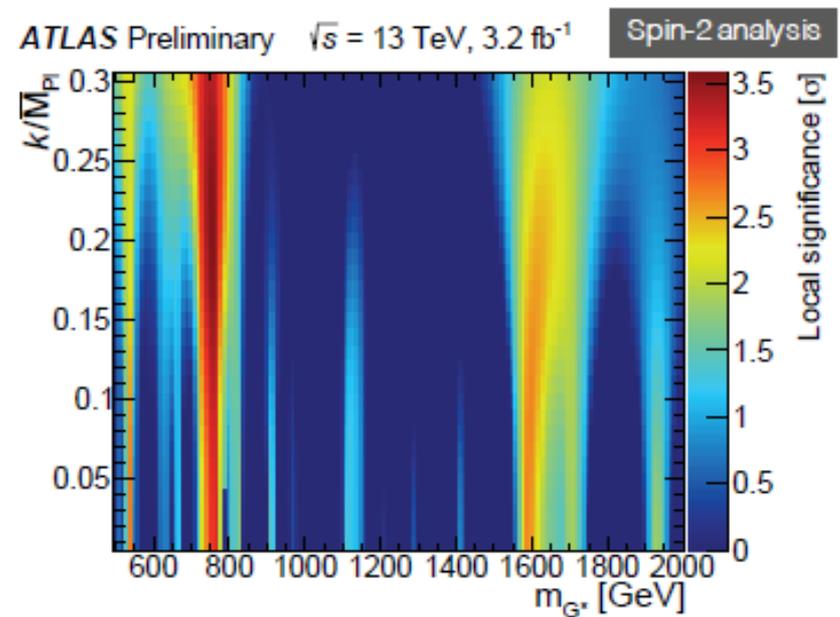
Event properties in signal region appear similar to those in sidebands, within large statistical uncertainties

Background-only p-value scan versus resonance mass and width:



Lowest p-value at $\sim 750 \text{ GeV}$, $\Gamma \sim 45 \text{ GeV}$ (6%)

Local/global Z = 3.9 / 2.0 σ



Lowest p-value at $\sim 750 \text{ GeV}$, $\Gamma \sim 7\%$ of mass

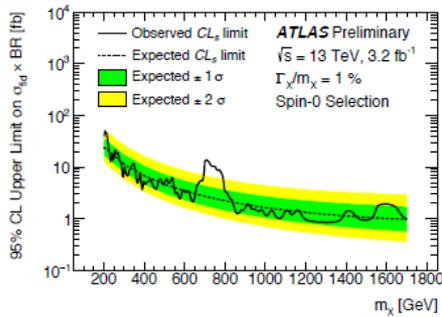
Local/global Z = 3.6 / 1.8 σ

Global p-values derived with respect to scan planes

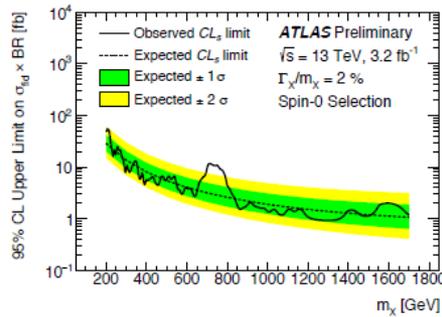
ВЕРХНИЕ ПРЕДЕЛЫ НА СЕЧЕНИЯ РОЖДЕНИЯ РЕЗОНАНСА

Спин = 0 при разных Γ_x/m_x

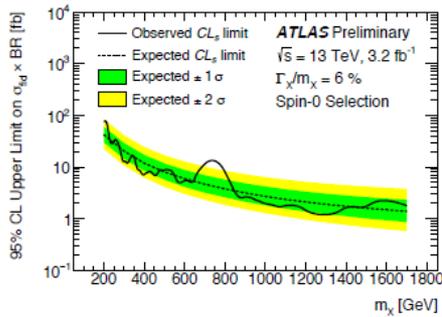
Спин = 2 при разных k/\overline{M}_{Pl}



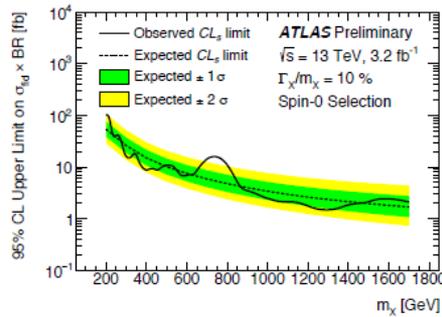
(a)



(b)

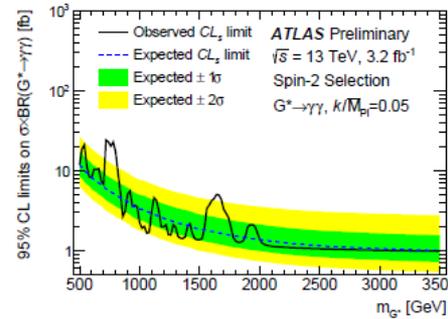


(c)

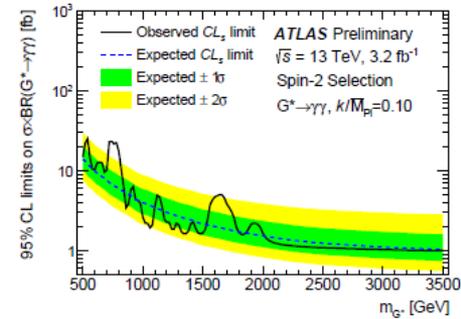


(d)

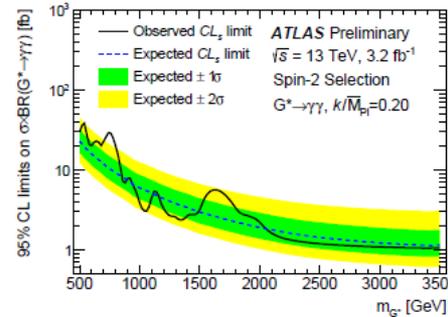
Figure 7: Upper limits on the fiducial cross section at $\sqrt{s}=13 \text{ TeV}$ of a spin-0 particle as a function of the assumed mass m_X , for different values of the decay width divided by the mass.



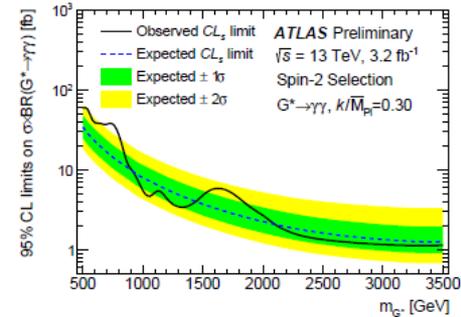
(a)



(b)



(c)



(d)

Figure 10: Upper limits on the production cross section of a RS graviton as a function of the assumed mass, for different values of k/\overline{M}_{Pl} .

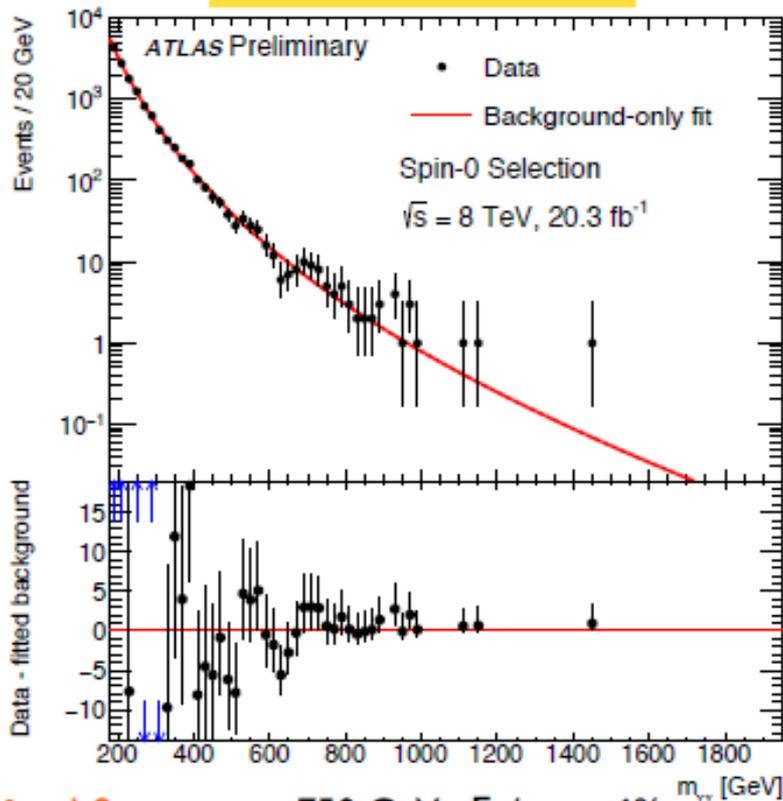
RS гравитон

ОБНОВЛЕННЫЙ АНАЛИЗ ПРИ 8 ТЭВ

Compatibility with 8 TeV data

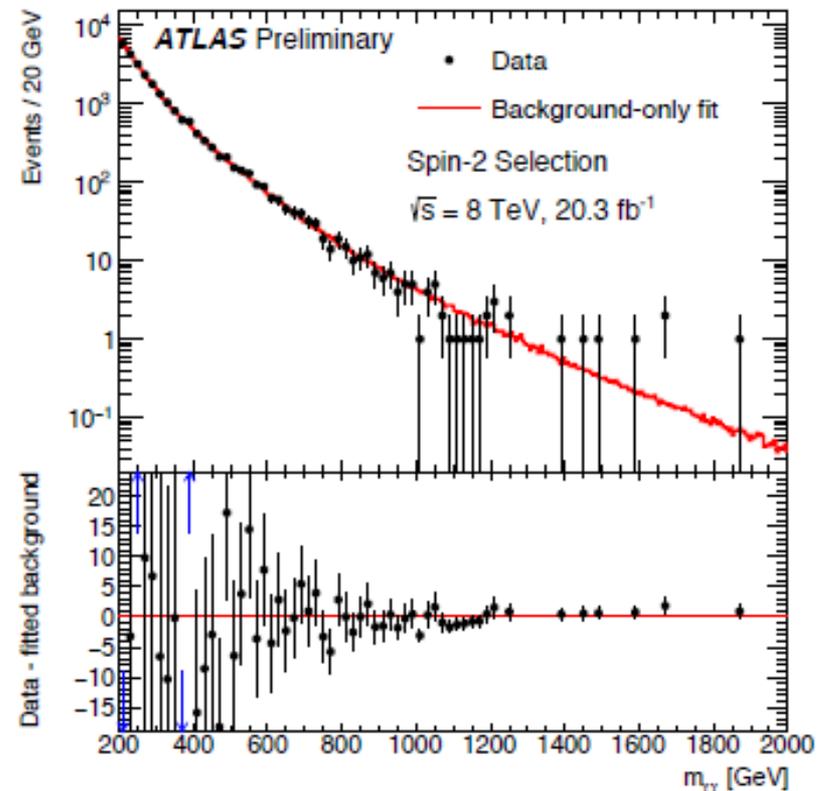
- 8 TeV data re-analyzed: latest Run I γ calibration + same Run I selections + 13 TeV analysis methods

SPIN-0 ANALYSIS



- 1.9σ at $m_{\chi} = 750 \text{ GeV}$, $\Gamma_{\chi}/m_{\chi} = 6\%$
- Compatibility with 13 TeV scalar
 - ✓ gg (scaling: 4.7) \rightarrow compatibility: 1.2σ
 - ✓ qq (scaling: 2.7) \rightarrow compatibility: 2.1σ

SPIN-2 ANALYSIS



- No significant excess
- Compatibility with 13 TeV graviton
 - ✓ gg \rightarrow compatibility: 2.7σ
 - ✓ qq \rightarrow compatibility: 3.3σ

РЕЗУЛЬТАТЫ АНАЛИЗА $M_{\gamma\gamma}$ В ATLAS ДЛЯ РР СОУДАРЕНИЙ ПРИ 13 ТЭВ

Summary

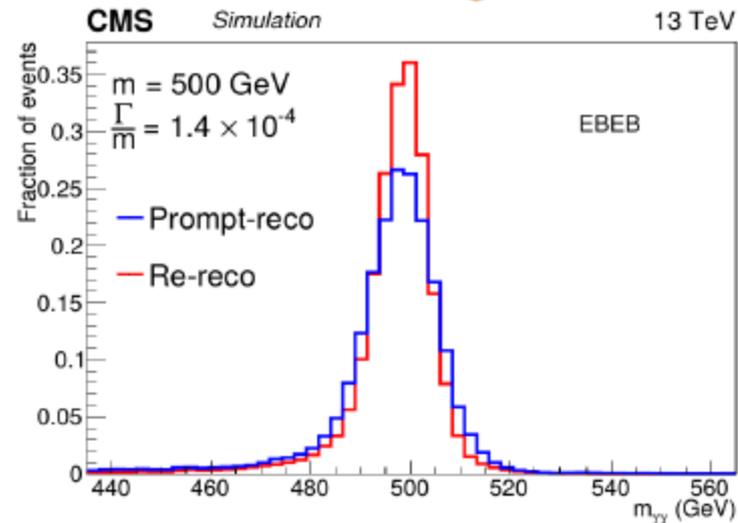
- Search for new resonances decaying to diphotons performed with 3.2 fb^{-1} 13 TeV data, with two analyses targeting “spin-0” and “spin-2” scenarios
- Most of the $\gamma\gamma$ spectrum consistent with B-only hypothesis
- Largest deviation from background-only hypothesis observed in broad region around 750 GeV, with global significance 2.0 (1.8) σ for the spin-0 (spin-2) analysis
- Numerous cross-checks of events with masses $\sim 750 \text{ GeV}$ performed
- 8 TeV data re-analyzed using latest Run I calibration, compatibility with 13 TeV results assessed
 - ✓ Scalar 1.2 σ (gg) – 2.1 σ (qq)
 - ✓ Graviton 2.7 σ (gg) – 3.3 σ (qq)
- More data needed to verify excess origin: looking forward to 2016 LHC run!

CMS Experiment at the LHC, CERN

Search for high mass diphoton resonances at CMS

51st Rencontres de Moriond - Electroweak session
Thursday 17th 2016,
La Thuile (Italy)

Pasquale Musella (ETH Zurich)



What's new?



- ▶ Results presented at the CERN-LHC Seminar in December 2015 based on 2.6fb^{-1}

(which became 2.7fb^{-1} due to an update in the luminosity measurement).

- ▶ Based on channel-to-channel ECAL calibration extrapolated from Run 1 data.

- ▶ **Data re-reconstruction, using updated channel-to-channel calibration**, completed over the winter shutdown.



- ▶ Constants to equalize channel-to-channel response obtained on 2015 data.
- ▶ In the high mass region, **resolution improved by ~30%** (leading to a ~10% improvement in analysis sensitivity).

▶ An **additional 0.6fb^{-1}** dataset, recorded at **$B=0\text{T}$** was analyzed.

▶ Lead to a further 10% improvement on top of the re-calibration.



▶ Significant re-thinking of the analysis needed to use data without magnetic field.



CMS Experiment at the LHC, CERN
Data recorded: 2015-Sep-11 22:46:54.589056 GMT
Run / Event / LS: 256353 / 437637379 / 244

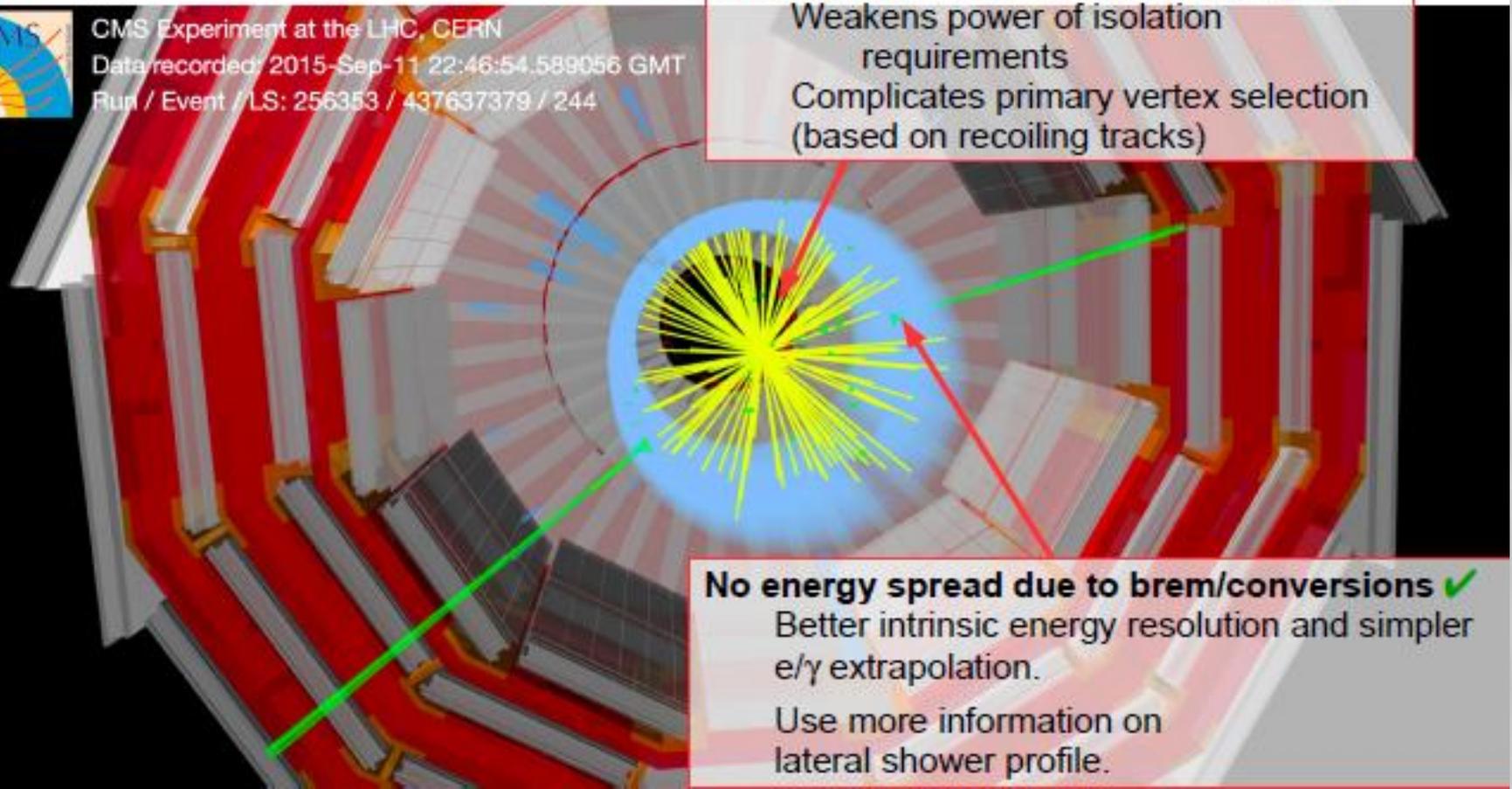
No information on tracks momenta ✗

Weakens power of isolation requirements
Complicates primary vertex selection (based on recoiling tracks)

No energy spread due to brem/conversions ✓

Better intrinsic energy resolution and simpler e/γ extrapolation.

Use more information on lateral shower profile.



РЕЗУЛЬТАТЫ АНАЛИЗА CMS

► Results interpreted in terms of **spin-0** and **spin-2** resonances.

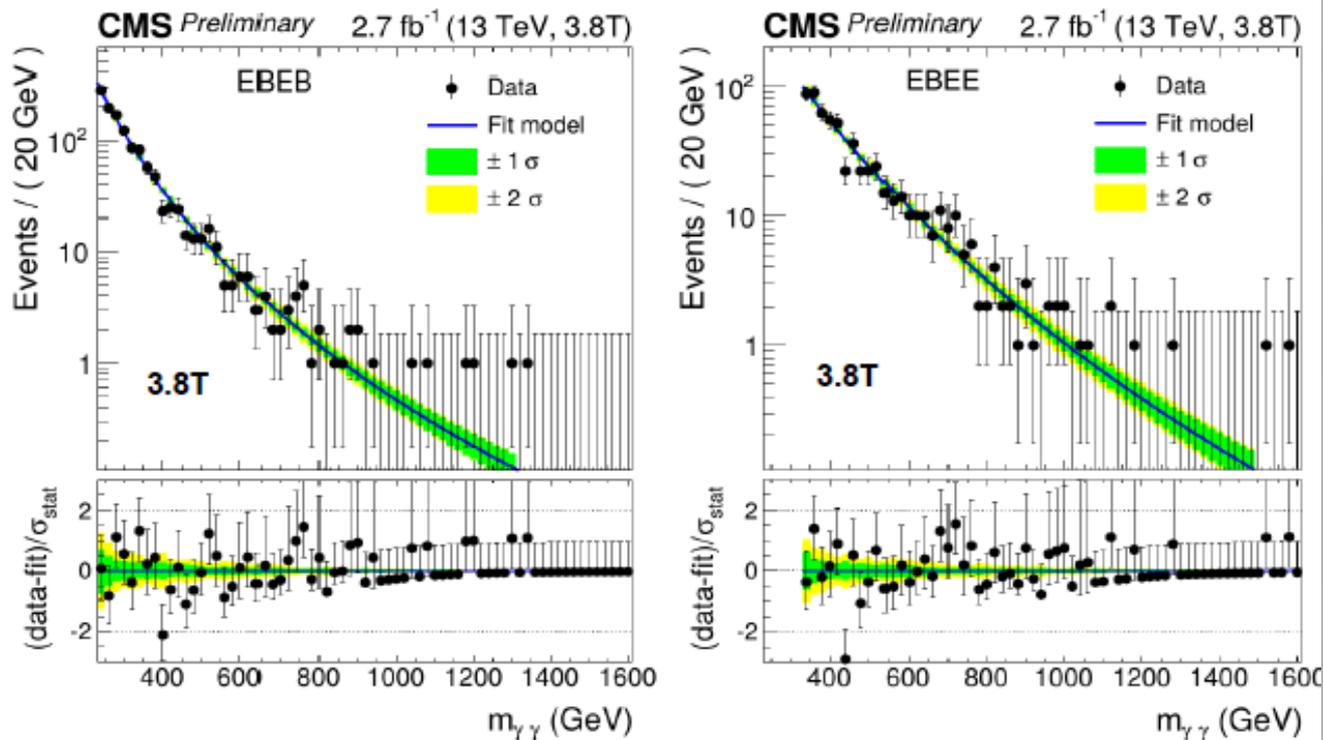
► $J=0$: assumed gluon-fusion production, $J=2$: RS-graviton

► Three widths ($\Gamma/m=1.4\times 10^{-4}$, 1.4×10^{-2} , 5.6×10^{-2})



17/03/2016

Mass spectra - 3.8T

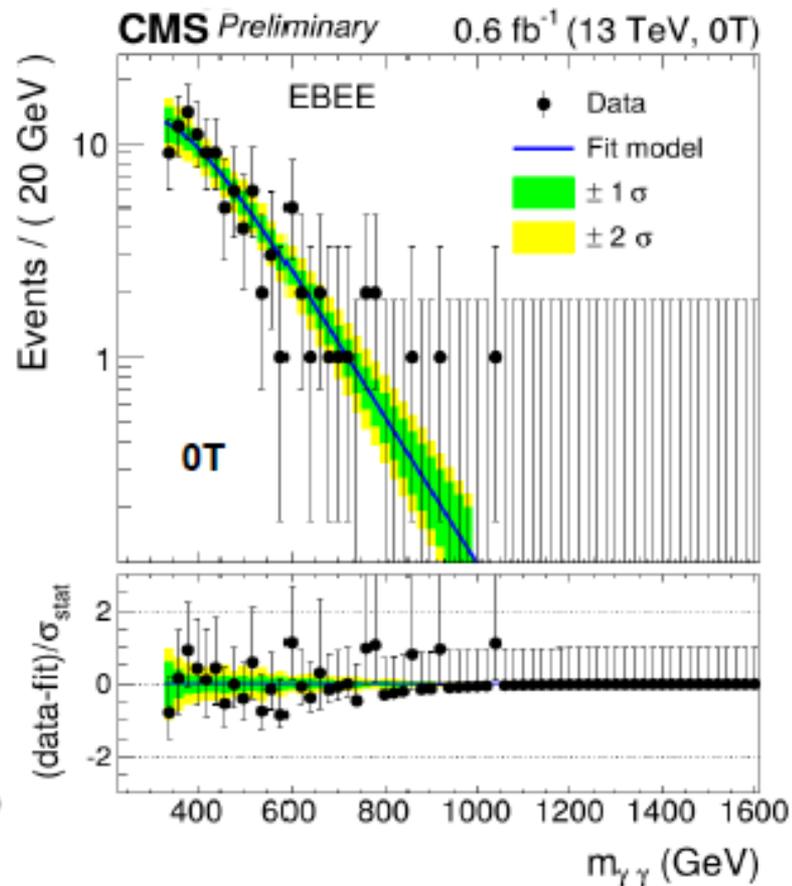
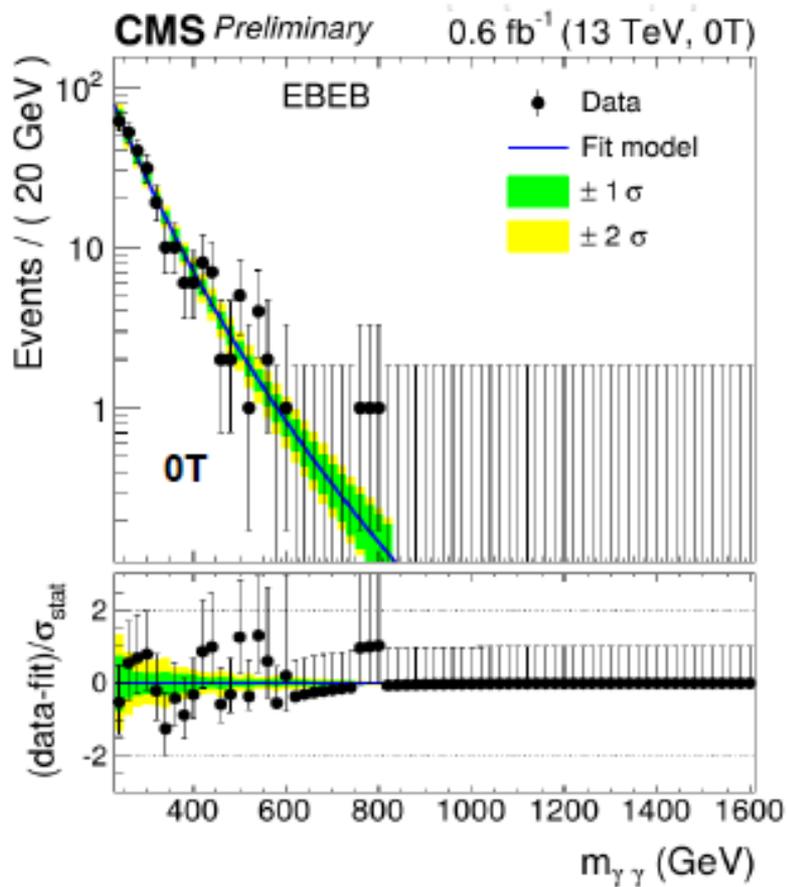


17/03/2016

High mass diphoton resonances at CMS - P. Musella (ETH)

ДОБАВЛЕННЫЕ ДАННЫЕ 13 ТЭВ

Mass spectra - 0T

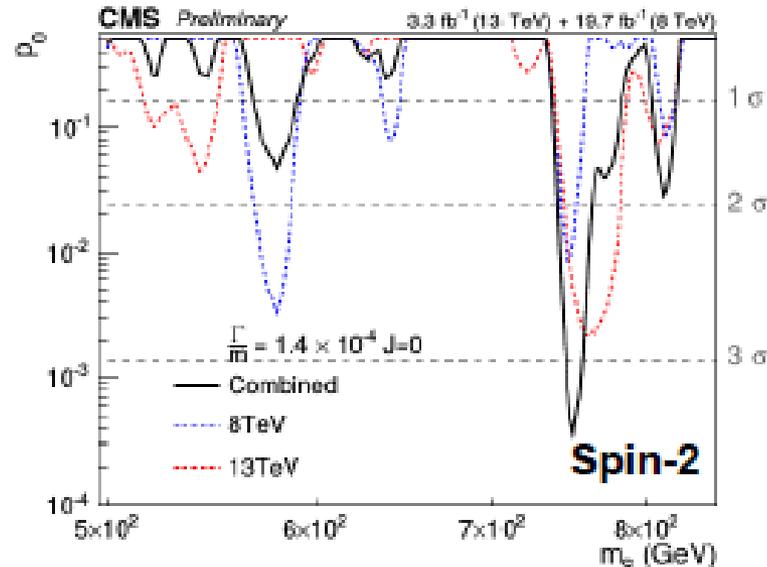
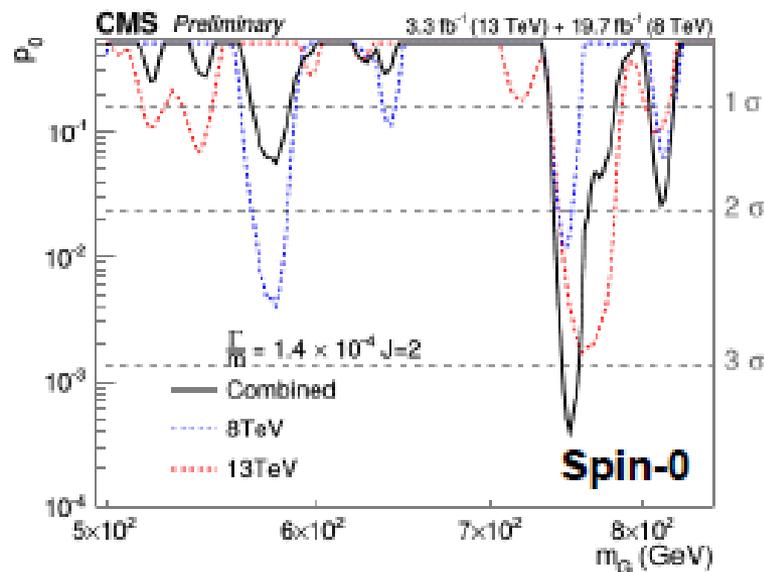


ВЕРОЯТНОСТЬ СИГНАЛА

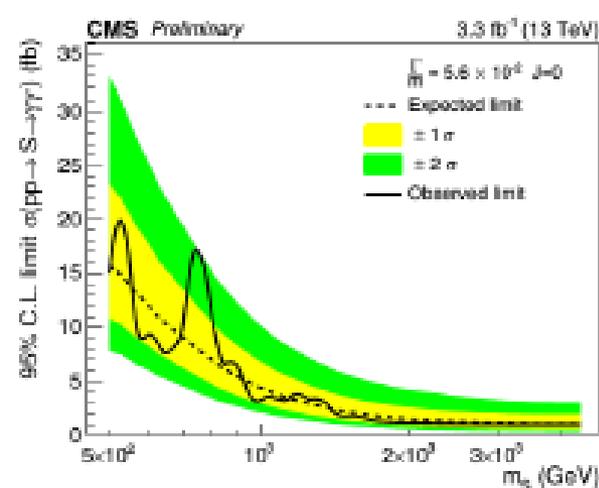
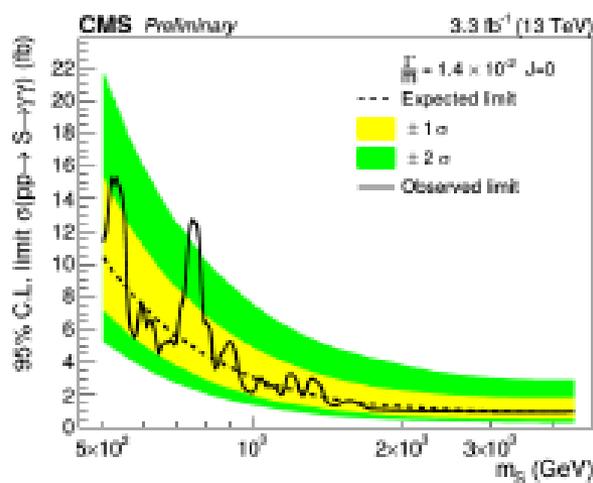
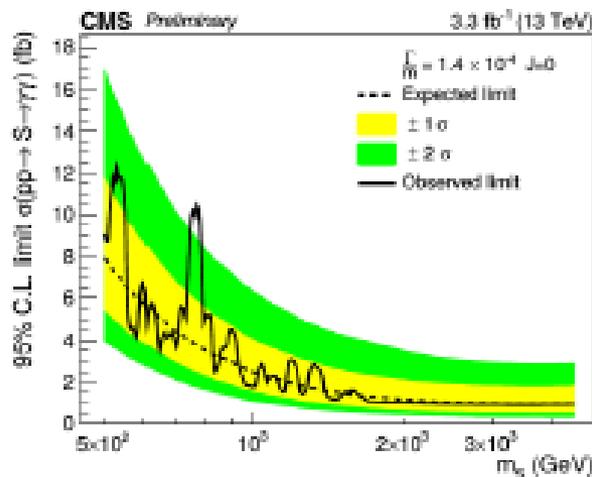
p-values



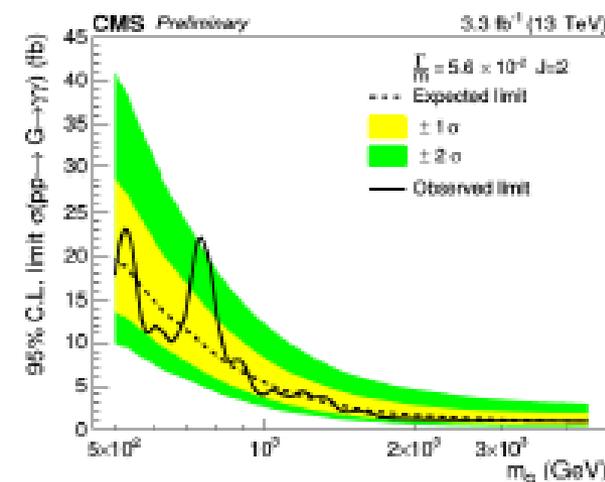
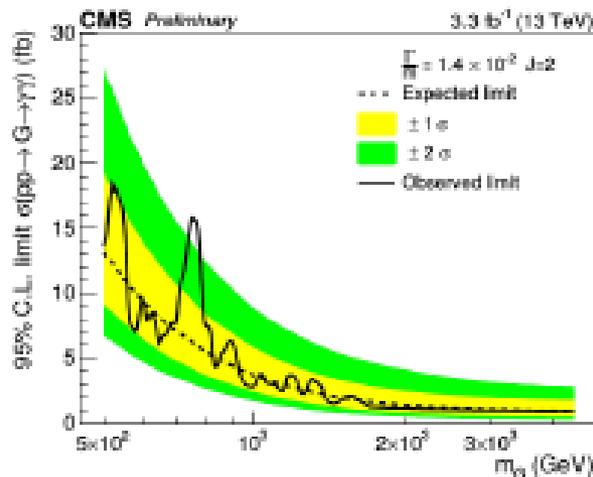
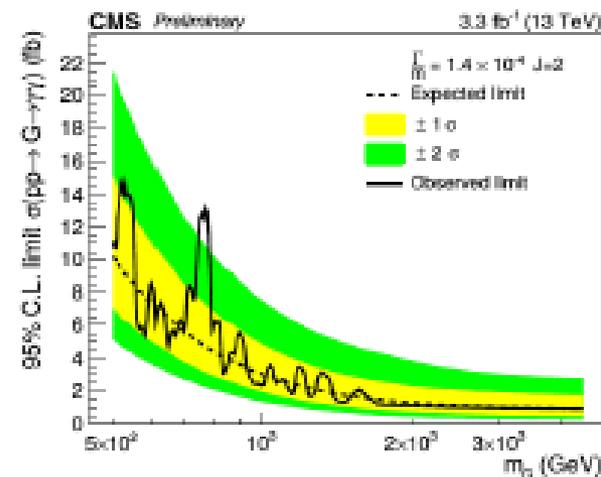
- ▶ Largest excess observed at $m_x = 750\text{GeV}$ and for narrow width.
- ▶ Local significance: 3.4σ
- ▶ Taking into account mass range 500-3500GeV (and all signal hypotheses), “global” significance becomes 1.6σ



Upper limits - 13TeV



Spin 0



Spin 2

$\Gamma/m = 1.4 \times 10^{-4}$

$\Gamma/m = 1.4 \times 10^{-2}$

$\Gamma/m = 5.6 \times 10^{-2}$

РЕЗУЛЬТАТЫ АНАЛИЗА $M_{\gamma\gamma}$ НА CMS

Summary



- ▶ Showed an **update on searches for diphoton resonances** in the mass range above 500GeV at 8 and 13TeV.

- ▶ Used simple and robust analysis strategy.

- ▶ Used **improved** detector **calibration** and analyzed dataset recorded at **0T**.

- ▶ Compared to previous results, 13TeV analysis improved **sensitivity** by **more than 20%**.

- ▶ Results interpreted in terms of scalar resonances and RS gravitons production of different widths.

- ▶ Observation generally consistent with SM expectations.

- ▶ **Modest excess** of events observed at **$m_x = 750(760)\text{GeV}$** for the 8+13TeV(13TeV) dataset.

- ▶ **Local** significance is **$3.4(2.9)\sigma$** , **reduced to $1.6(<1)\sigma$** after accounting for look-elsewhere-effect.



ИЗМЕРЕНИЯ H(125) ПРО 13 ТЭВ

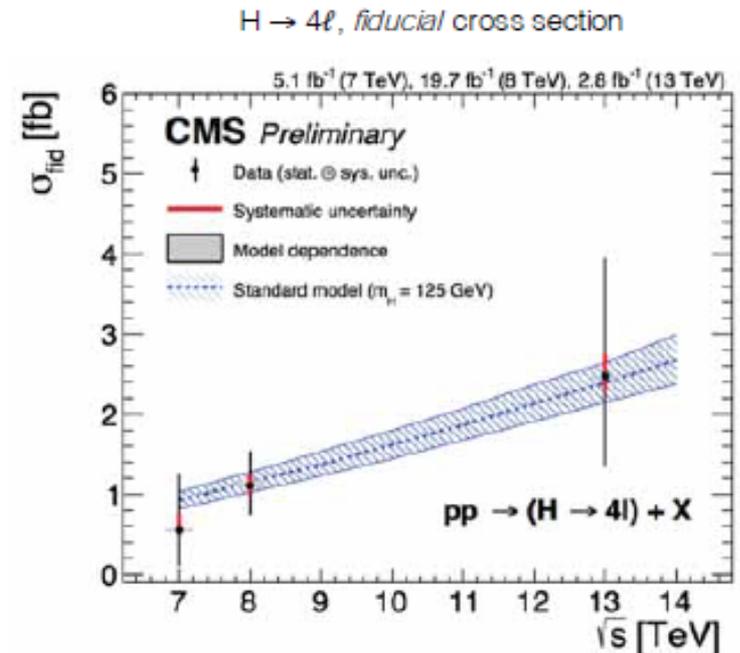
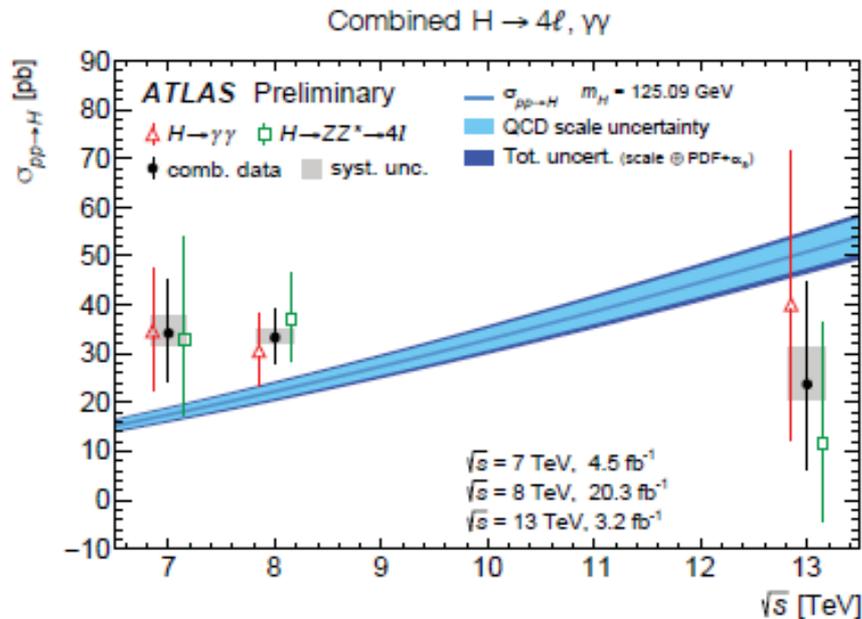
Seth Zenz

Current 13 TeV data sample still marginal for H_{125}

But important to look for the signal in an agnostic way at new CM energy

ATLAS & CMS looked for Higgs decays to bosonic and fermionic channels

Extracted cross sections vs CM energy



BACK-UP

BACK-UP

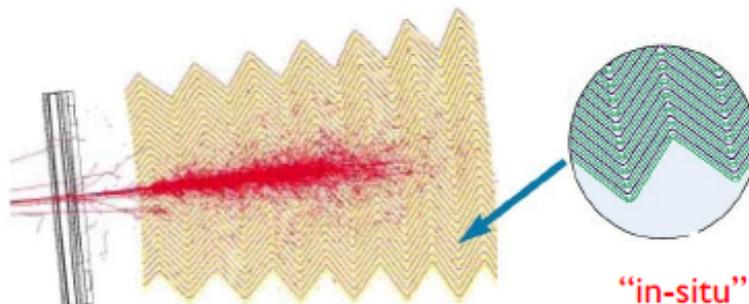
ПРОЦЕДУРА ИЗМЕРЕНИЯ ФОТОНОВ В EMC ATLAS

A photon showers in the EMC. Most of its energy is lost in Pb

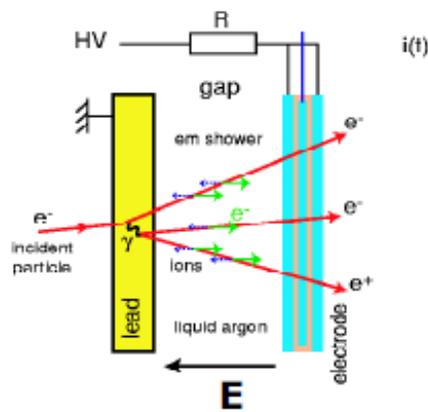
Electrons in EM shower ionize LAr

Ionization electrons produce current

Current is collected, amplified, shaped, sampled and digitized for each EMC cell



"in-situ" intercalibration

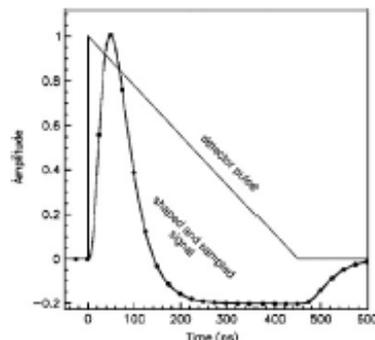


MVA calibration

cluster corrections

clustering

electronic calibration



Diphoton searches in ATLAS

Photon energy scale is adjusted to EM scale from $Z \rightarrow ee$ events

Cluster energy is corrected for loss to get photon energy

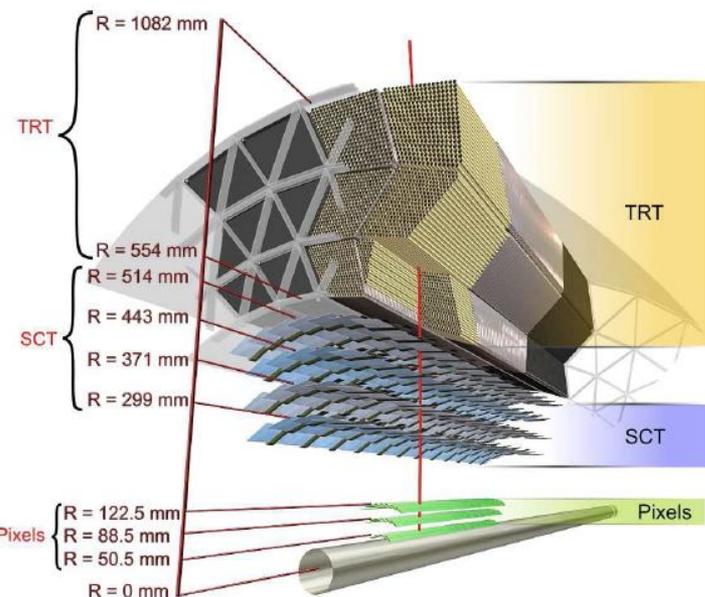
Cluster energies are corrected for detectors effects

Cells are grouped in clusters

Energy in a cell is reconstructed from signal samples

ИЗМЕРЕНИЯ КОНВЕРСИОННЫХ ФОТОНОВ

ATLAS Inner Detector



Photon conversion reconstruction

- **Candidate photon conversion vertices reconstructed from tracks pre-selected as loosely matching EMC clusters**
 - ✓ 1 or 2 tracks
 - ✓ 1-track conversions from tracks that missing the hit in innermost ID layer
- **Photon reconstruction expected efficiency**
 - ✓ ~ 98% for photons $E_T > 25$ GeV
 - ✓ > 99% for unconverted photons
 - ✓ ~ 95% for converted ($R < 80$ cm)
- **Expected fraction of converted photons**
 - ✓ ~ 20% at $|\eta| \sim 0$ - ~ 45% $|\eta| \sim 1.6$
- **Relative fraction of reconstructed photon conversion depends on:**
 - ✓ Material upstream EMC
 - ✓ In MC, on conversion model...

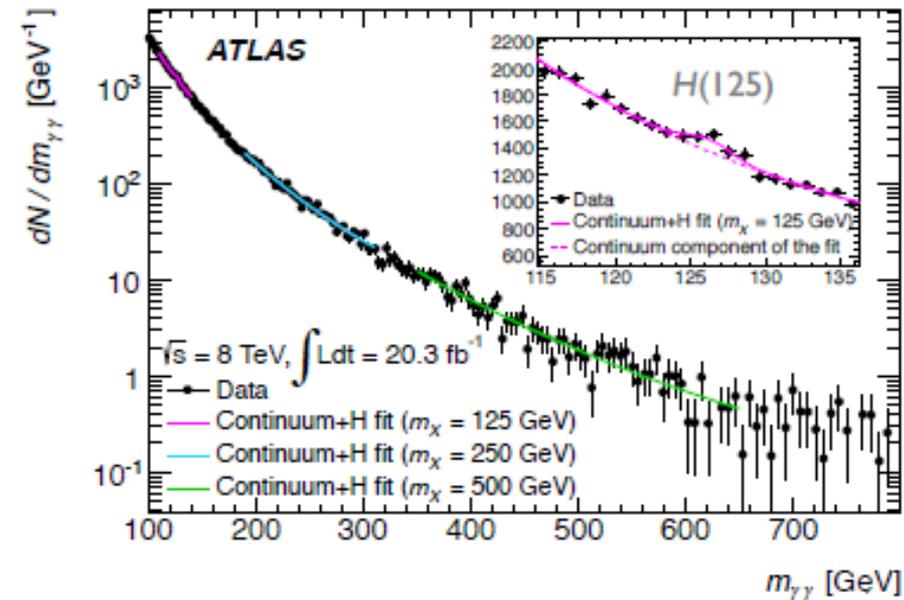


РЕЗУЛЬТАТЫ АНАЛИЗА $M_{\gamma\gamma}$ В ATLAS ДЛЯ РР СОУДАРЕНИЙ ПРИ 8 ТЭВ

Recap of latest Run I results

*Search for scalar diphoton resonances
in the mass range 65-600 GeV
with the ATLAS detector
in pp collision data at $\sqrt{s} = 8$ TeV*

Phys. Rev. Lett. 113, 171801



*Search for high-mass diphoton resonances
in pp collisions at $\sqrt{s} = 8$ TeV
with the ATLAS detector*

Phys. Rev. D 92, 032004 (2015)

