

Photon-photon collisions with ATLAS

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DESY FH Fellow Meeting

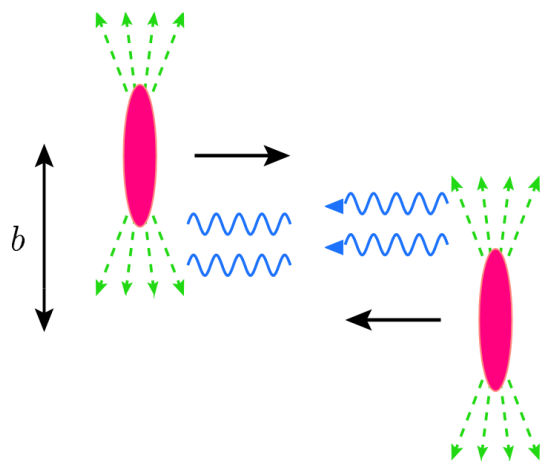
29 Nov 2016

Personal Data

- Born in Tarnograd, Poland (1988)
- Involved with ATLAS since 2010 (BSc+MSc theses)
- PhD thesis: Krakow/Saclay (doctorat cotutelle) within the ATLAS collaboration (2012-2015)
- Postdoc at DESY in the ATLAS group (since Feb 2016)

- Phenomenology of photon-photon interactions in proton-proton collisions at the LHC
 - Elastic $pp(\gamma\gamma) \rightarrow pp X$ interactions
 - Calculation of absorptive corrections to these processes
- Measurement of exclusive $\gamma\gamma \rightarrow \ell^+\ell^-$ ($\ell = e, \mu$) production in proton-proton collisions at $\sqrt{s}=7$ TeV with the ATLAS detector
- Involvement in the ATLAS Forward Proton (**AFP**) project -> forward proton spectrometers of ATLAS
 - GEANT4 simulation of ATLAS forward region + AFP detectors
 - Full simulation chain for AFP (including data model, digitization, reconstruction)

Theory: elastic pp ($\gamma\gamma$) \rightarrow pp X



Chen et al., Phys. Rev. D7 (1973) 3485-3502.
Budnev et al., Nucl. Phys. B63 (1973) 519-541.

The cross-section for this process is calculated:

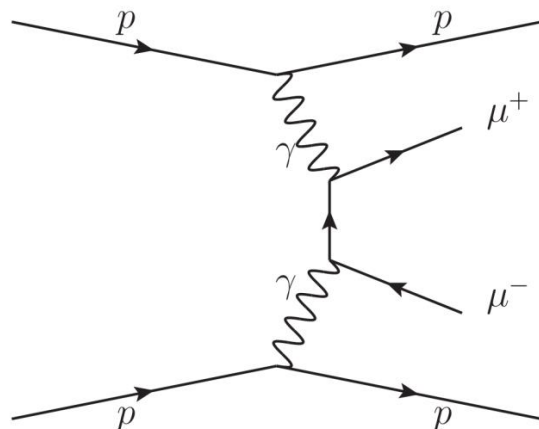
(1) Using the number of equivalent photons (EPA) by integration over the whole virtuality range:

$$dN = \frac{\alpha}{\pi} \frac{dQ^2}{Q^2} \frac{dx}{x} \left[(1-x) \left(1 - \frac{Q_{min}^2}{Q^2} F_E(Q^2) \right) + \frac{x^2}{2} F_M(Q^2) \right]$$

$$Q_{min}^2 \simeq m_p^2 \frac{x^2}{1-x} \quad Q_{max}^2 = 2 \text{ GeV}^2$$

Integrand contains the proton EM form factors (calculations originally done by Chen, Terazawa, et al. for $\gamma\gamma \rightarrow \mu^+\mu^-$ process)

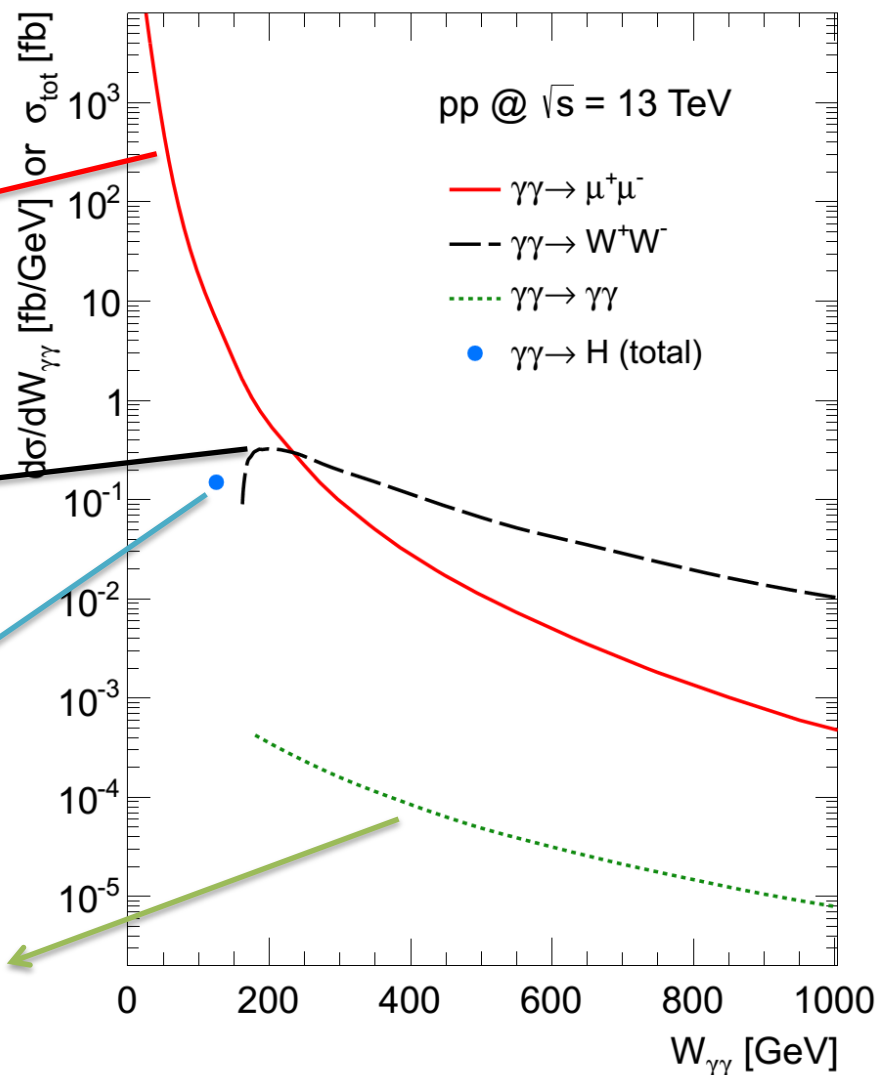
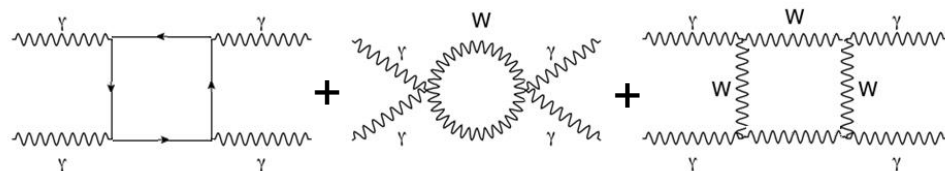
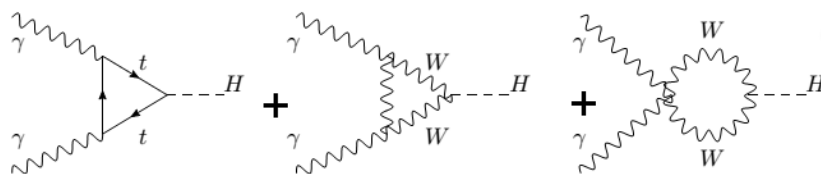
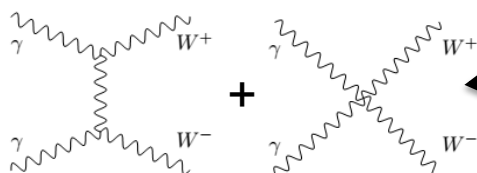
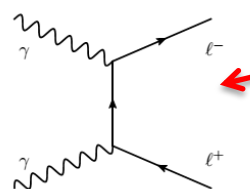
(2) EW $\gamma\gamma \rightarrow X$ cross-section.



Theory: elastic pp ($\gamma\gamma$) \rightarrow pp X

- Some cross-sections for $\sqrt{s} = 13$ TeV

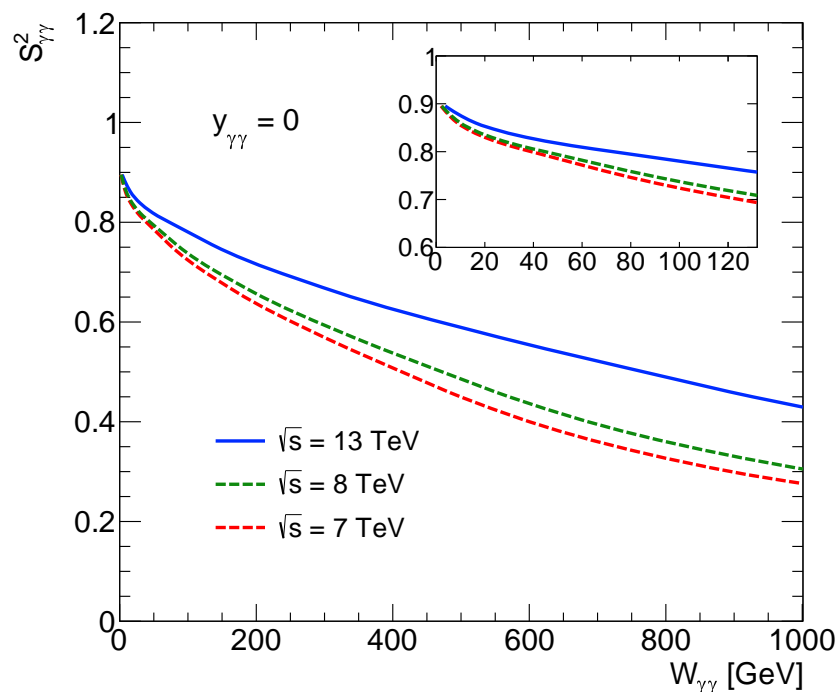
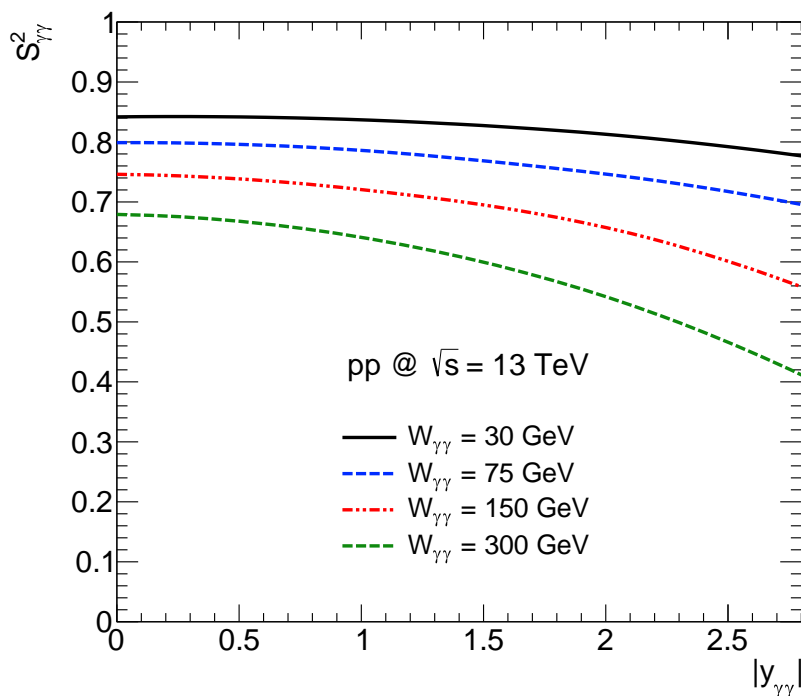
- O(pb) for $W_{\gamma\gamma} > 10$ GeV ($\gamma\gamma \rightarrow \ell^+\ell^-$)
 - O(fb) for $W_{\gamma\gamma} > 200$ GeV ($\gamma\gamma \rightarrow W^+W^-$)



Finite-size effects

- Requirements: protons should remain intact / photons emitted coherently
- Strong dependence on invariant mass of the system
- Small dependence on rapidity of the system (for smaller inv. masses)

$$S_{\gamma\gamma}^2 = \frac{\int_{b_1 > r_p} \int_{b_2 > r_p} d^2\vec{b}_1 d^2\vec{b}_2 n(\vec{b}_1, \omega_1) n(\vec{b}_2, \omega_2) P_{\text{non-inel}}(|\vec{b}_1 - \vec{b}_2|)}{\int_{b_1 > 0} \int_{b_2 > 0} d^2\vec{b}_1 d^2\vec{b}_2 n(\vec{b}_1, \omega_1) n(\vec{b}_2, \omega_2)}$$



More details in: MD, Laurent Schoeffel, **Phys. Lett. B741 (2015) 66-70**

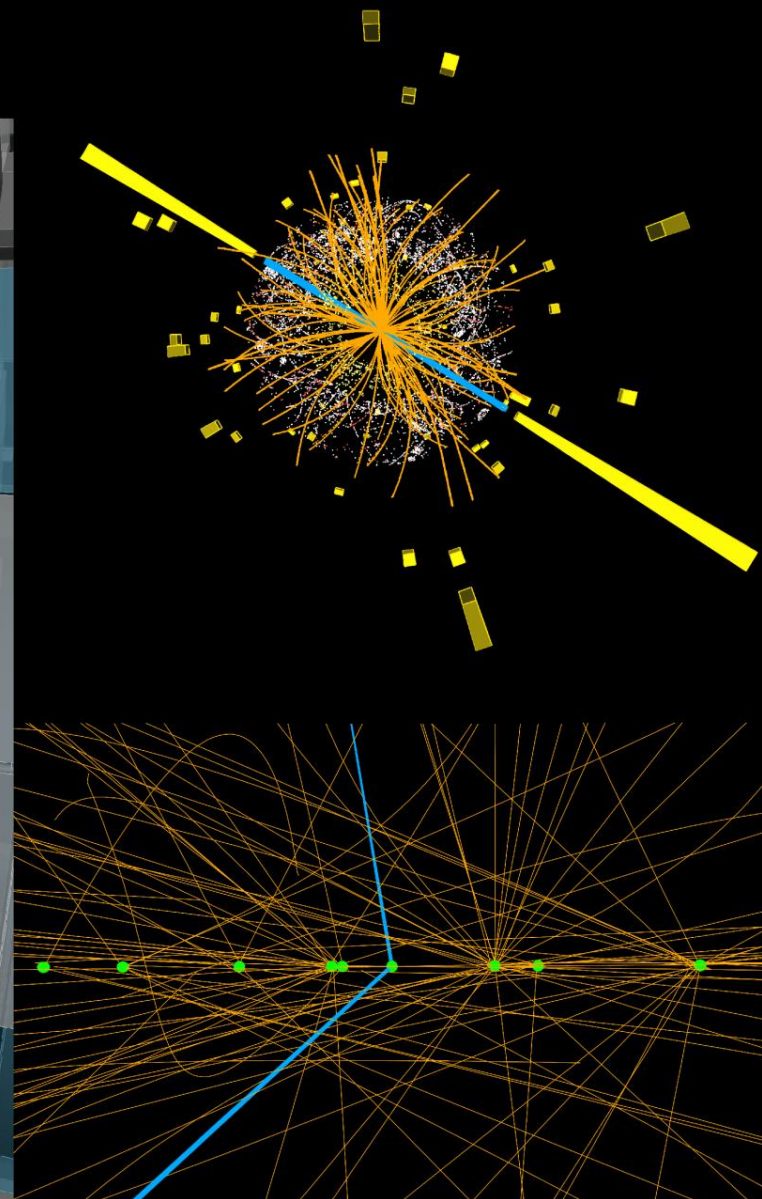
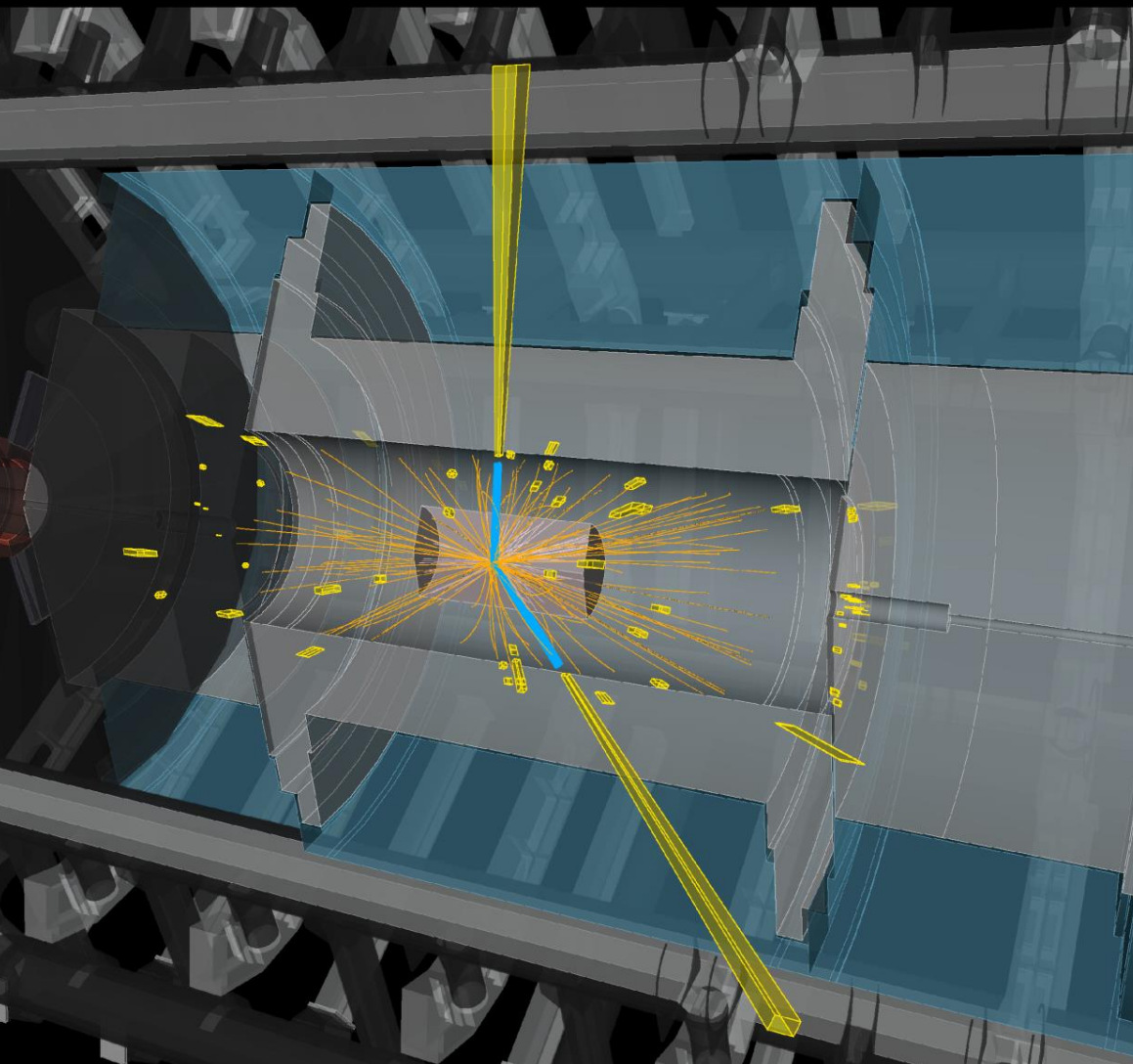
Data analysis context

- Exclusive dilepton production as a “**standard candle**” for the other photon-induced processes
- Small theory (QED) uncertainties serve the possibility to use the $\gamma\gamma \rightarrow \mu^+\mu^-$ reactions for **luminosity determination at the LHC**
 - However, a correct treatment of **absorptive corrections** needs to be applied (included in this work)
- Goal of the analysis (in brief - measurement of two numbers):
 - Fiducial cross-sections for exclusive production (lepton pairs)
 - Data/theory (QED) ratios -> proton finite-size effects

Event topology

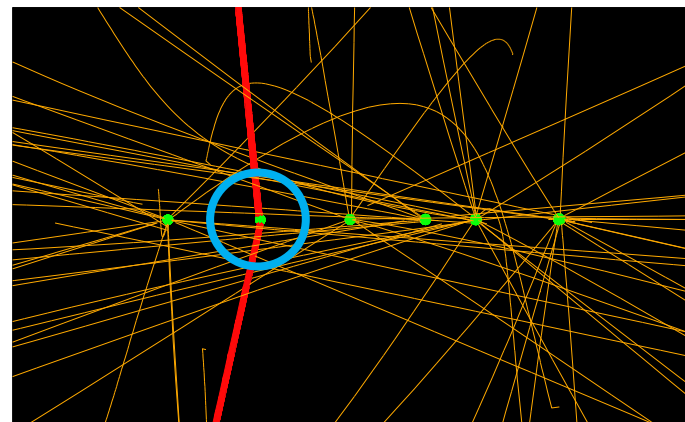


Run 190644, Event 51422085
Time 2011-10-09, 16:29 CEST



Event selection

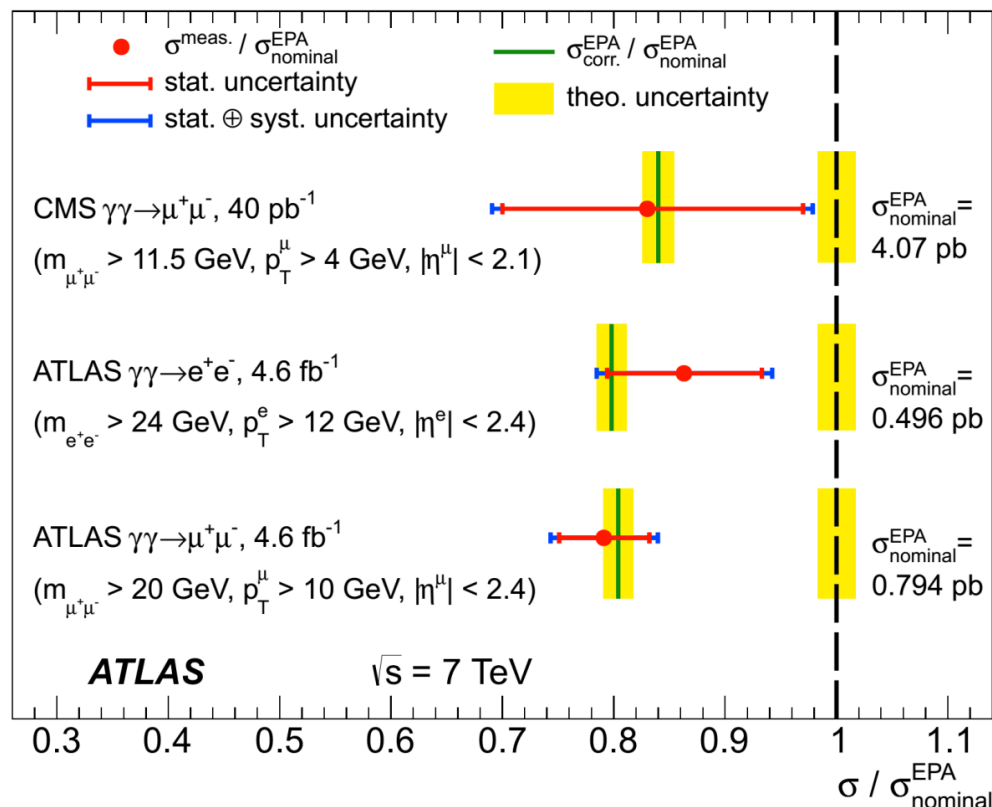
- Exclusivity veto:
 - Exactly **2 tracks** in the dilepton vertex
 - Distance di-lepton vtx - closest vtx (or track) > **3 mm**
- Elastic selection:
 - p_T of the dilepton system < **1.5 GeV**
- Number of selected events in data is below the expectations (~80%)
 - **Proton absorptive corrections** (not included in **exclusive** and **s-diss.** MC)



Selection	$\gamma\gamma \rightarrow \ell^+\ell^-$			$Z/\gamma^* \rightarrow \ell^+\ell^-$	Multi-jet	$Z/\gamma^* \rightarrow \tau^+\tau^-$	$t\bar{t}$	Di-boson	Total predicted	Data
	Signal	S-diss.	D-diss.							
Electron channel ($\ell = e$)										
Preselection	898	2096	2070	1 460 000	83 000	3760	4610	1950	1 560 000	1 572 271
Exclusivity veto	661	1480	470	3140	0	9	0	5	5780	5410
Z region removed	569	1276	380	600	0	8	0	3	2840	2586
$p_T^{\ell^+\ell^-} < 1.5 \text{ GeV}$	438	414	80	100	0	2	0	0	1030	869
Muon channel ($\ell = \mu$)										
Preselection	1774	3964	4390	2 300 000	98 000	7610	6710	2870	2 420 000	2 422 745
Exclusivity veto	1313	2892	860	3960	3	8	0	6	9040	7940
Z region removed	1215	2618	760	1160	3	8	0	3	5760	4729
$p_T^{\ell^+\ell^-} < 1.5 \text{ GeV}$	1174	1085	160	210	0	3	0	0	2630	2124

Results interpretation

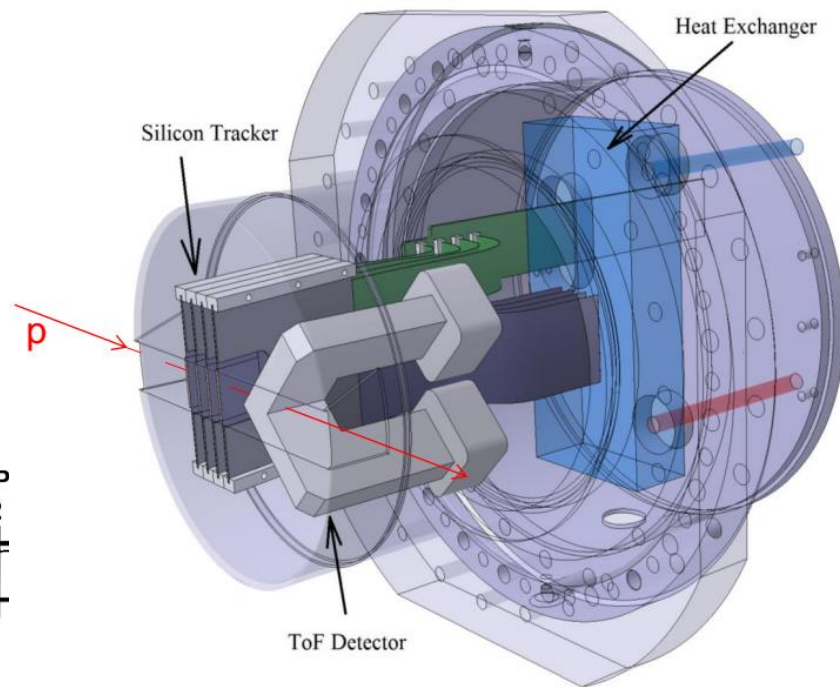
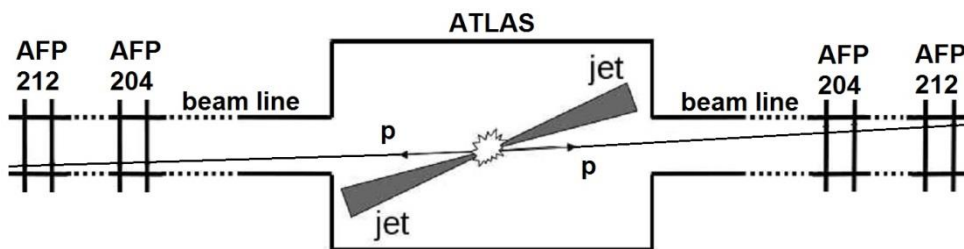
- Summary plot (including also CMS measurement)
- **EPA** corrected for absorptive effects describes the data



More details in: ATLAS Collaboration, **Phys. Lett. B749 (2015) 242-261**

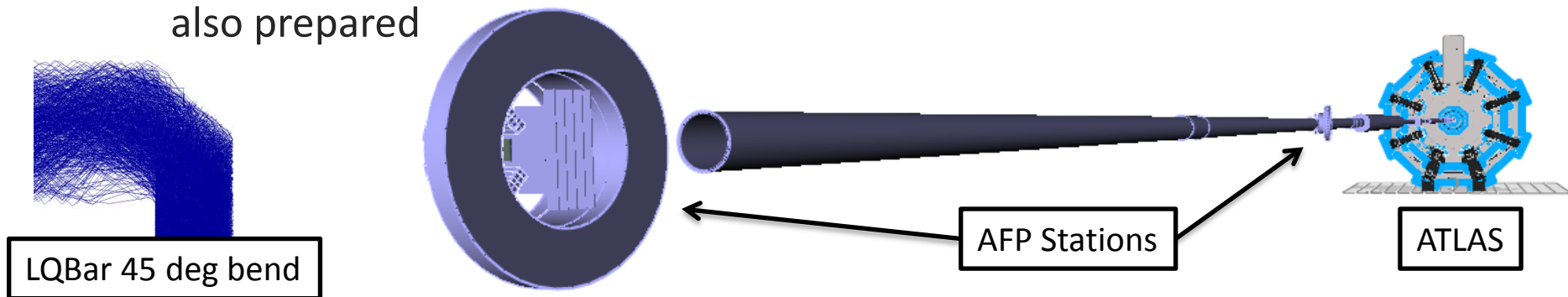
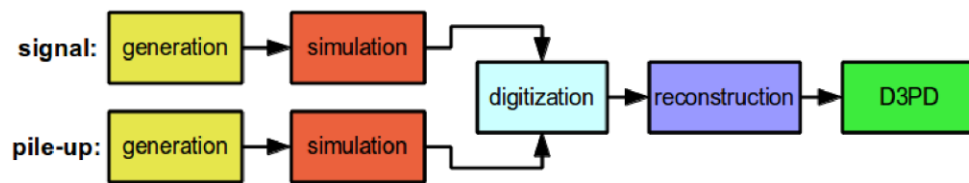
ATLAS Forward Proton (AFP) project

- Core idea: measure intact protons far away from the ATLAS interaction point (**210 m**) during LHC Run-2
- Initial physics program: **diffractive processes**
- However, also unique way to measure **photon-induced reactions**
 - **Very robust** background reduction due to **forward proton tagging**
- **Detector setup:**
 - Horizontal Roman Pots
 - Silicon tracker to measure proton position
 - Time-of-Flight Quartz Cherenkov detectors for vertex reconstruction



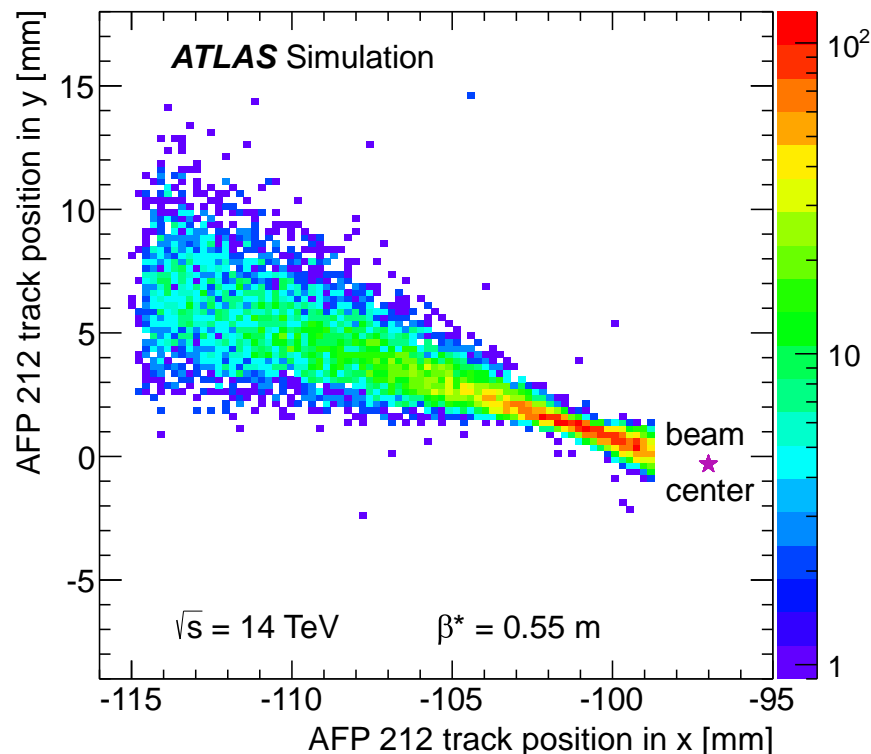
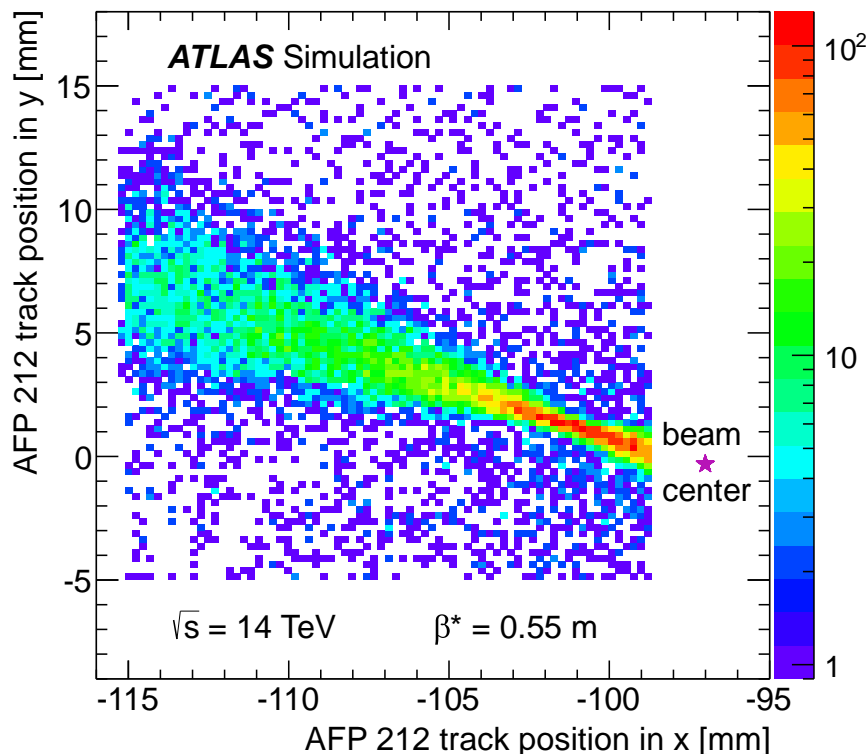
AFP Detector Simulation

- Full **GEANT4** simulation of **Forward Region + AFP Stations** in the ATLAS Athena framework prepared:
 - **Geo Models** of: Forward Region, Roman Pots, Silicon and Timing Detectors
 - Forward Region simulation (for the 1st time)
 - Magnetic field specification
 - Contains beam pipe, collimators and beamscreens models
 - Plan to study the effect of dead material, starting from the closest (most affecting) regions
 - Description of **Sensitive Detectors** (+ data models)
 - **Reconstruction** algorithms for proton tracking + timing
 - **AFP physics objects** scheme also prepared



AFP Silicon tracker simulated performance

- **x-y proton track position hitmap** for outer Roman Pot station before (left) and after (right) track matching included
- Tracks matched between inner and outer stations are considered
- Very good reduction of shower background



More details in: ATLAS Collaboration, **ATLAS-TDR-024 (2015)**

Present / future

- Within the ATLAS DESY group:
 - SM measurements (both precision and searches for rare processes)
 - SCT calibration loop software expert

NoisyStrip

NoiseOccupancy

RawOccupancy

DeadChip

Efficiency

ByteStreamErrors

DeadStrip

DQ Twiki

Task Lister

Dataset Status

Shift to **12:00** (change)

Send Mail

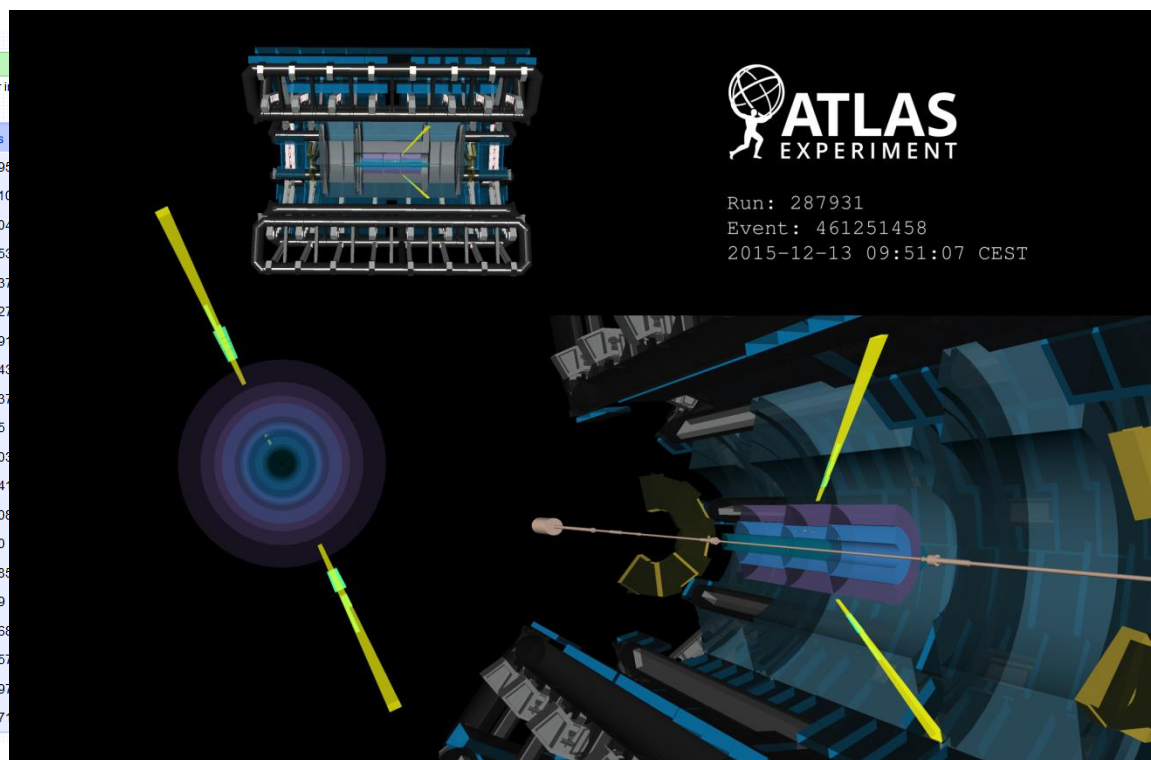
Last Run Uploaded
313629 : November 29
14:20

Last Update from
Upload Cron 9min ago

NoisyStrip

Recent runs with files to be uploaded. Collision runs appear in blue. Cosmic runs appear in red. PbPb runs appear in green.

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312854 (Noise,BULK)	15/11/2016 00:00:35	---	51988	855	508895
312937 (Noise,BULK)	15/11/2016 22:57:28	---	49146	438	258910
312945 (Noise,BULK)	16/11/2016 12:44:59	---	26880	434	256304
312968 (Noise,BULK)	16/11/2016 20:29:04	---	38673	456	269853
313063 (Noise,BULK)	18/11/2016 05:00:03	---	18763	268	169037
313067 (Noise,BULK)	18/11/2016 14:00:44	---	14885	169	102027
313100 (Noise,BULK)	18/11/2016 19:20:57	---	44224	584	347097
313107 (Noise,BULK)	19/11/2016 09:01:15	---	48401	583	344043
313136 (Noise,BULK)	19/11/2016 23:30:43	---	34362	448	265337
313187 (Noise,BULK)	20/11/2016 18:42:48	---	11043	123	698157
313259 (Noise,BULK)	21/11/2016 20:23:44	---	50688	444	257903
313285 (Noise,BULK)	22/11/2016 11:36:30	---	33313	433	155447
313295 (Noise,BULK)	23/11/2016 01:23:36	---	67024	490	291008
313333 (Noise,BULK)	23/11/2016 20:28:47	---	25077	155	908407
313435 (Noise,BULK)	24/11/2016 16:25:08	---	65774	580	347183
313572 (Noise,BULK)	26/11/2016 10:22:59	---	10765	41	234397
313574 (Noise,BULK)	26/11/2016 14:50:18	---	19433	156	165368
313575 (Noise,BULK)	26/11/2016 21:30:45	---	33164	469	279457
313603 (Noise,BULK)	27/11/2016 08:12:02	29/11/2016 20:32:29	44021	551	328097
313629 (Noise,BULK)	27/11/2016 21:32:39	30/11/2016 04:52:24	25919	320	187877



ATLAS-CONF-2016-111