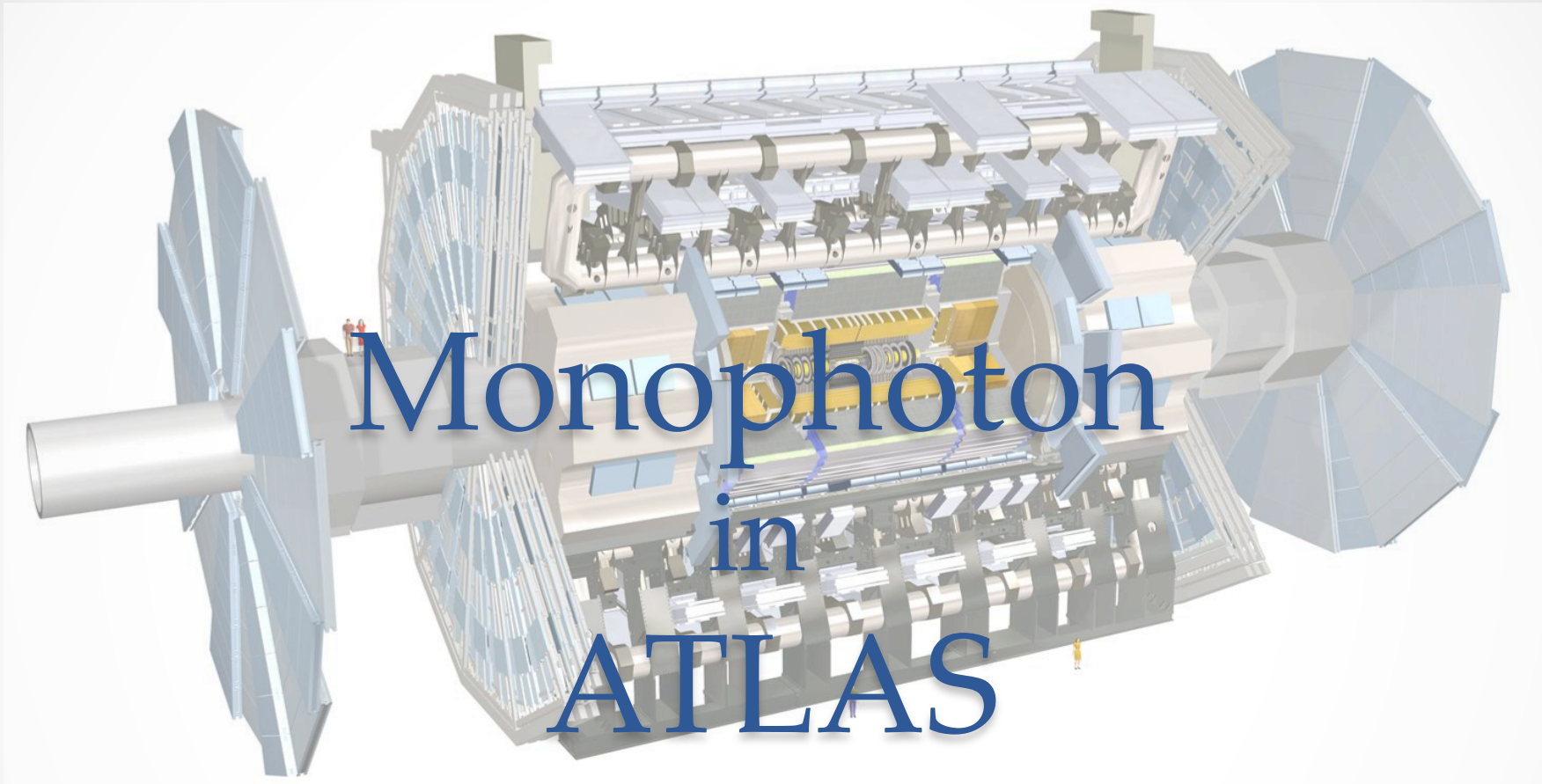


Monophoton in ATLAS

Mengqing WU

PhD Seminar, 10th June, 2014

ATLAS Group, LPSC

With Marie-Helene Genest, Fairouz Malek

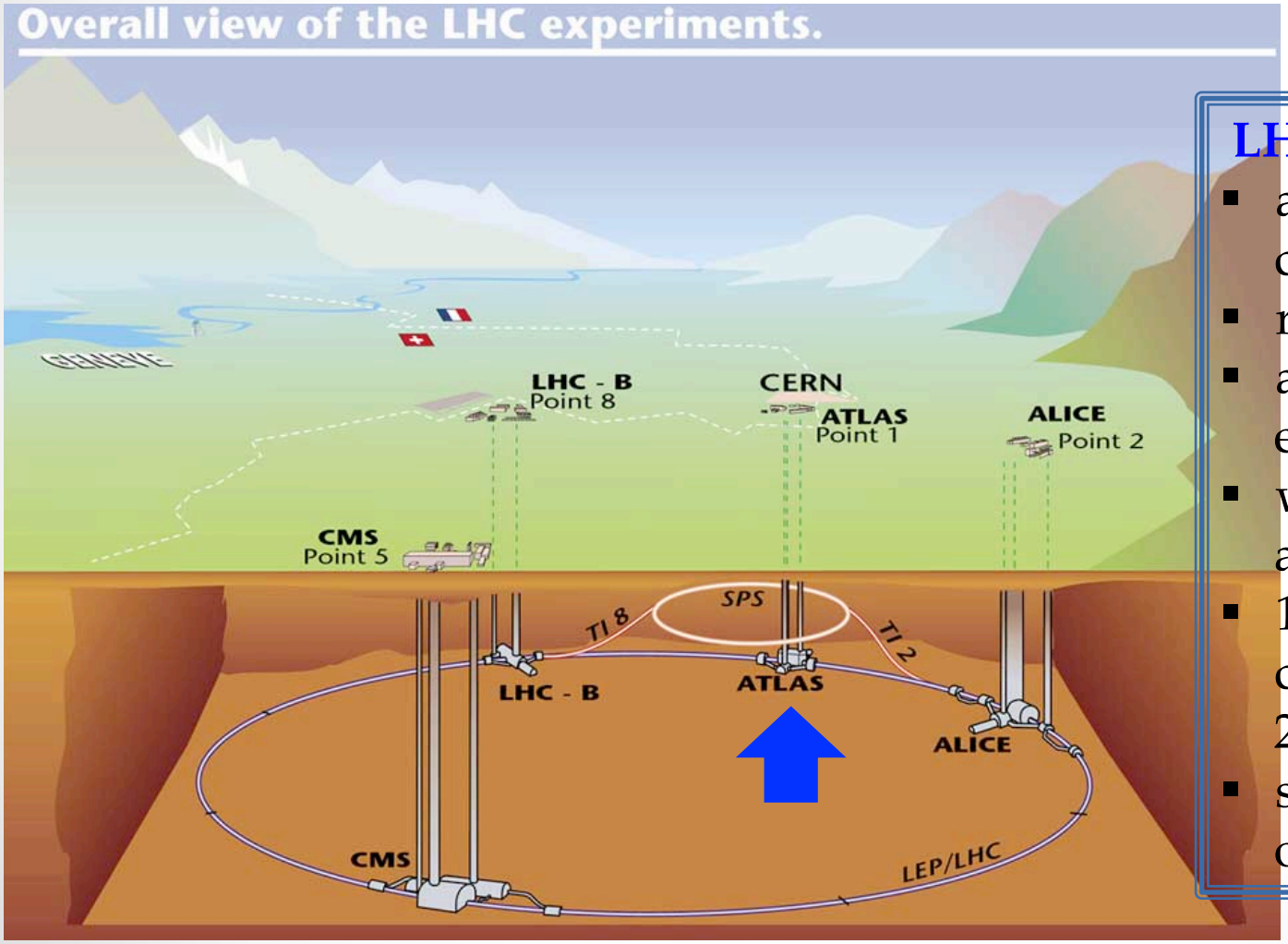
Contents

- **ATLAS and Analysis Motivation**
  - What is the **LHC**? **ATLAS**? **How we do we select our objects**?
  - what is the **monophoton** analysis; models of **NEW** physics
- **Monophoton Analysis**
  - **To get Signal** -- Event Selection
  - **To understand Backgrounds** -- Standard Model Backgrounds
  - **To present results** -- Uncertainties
  - **Results: 7TeV** Result&Paper + **8TeV** Paper ongoing
- **Conclusion**

ATLAS
&
Analysis Motivation

What is the LHC? ATLAS? Objects used for analysis?
What is this analysis for?

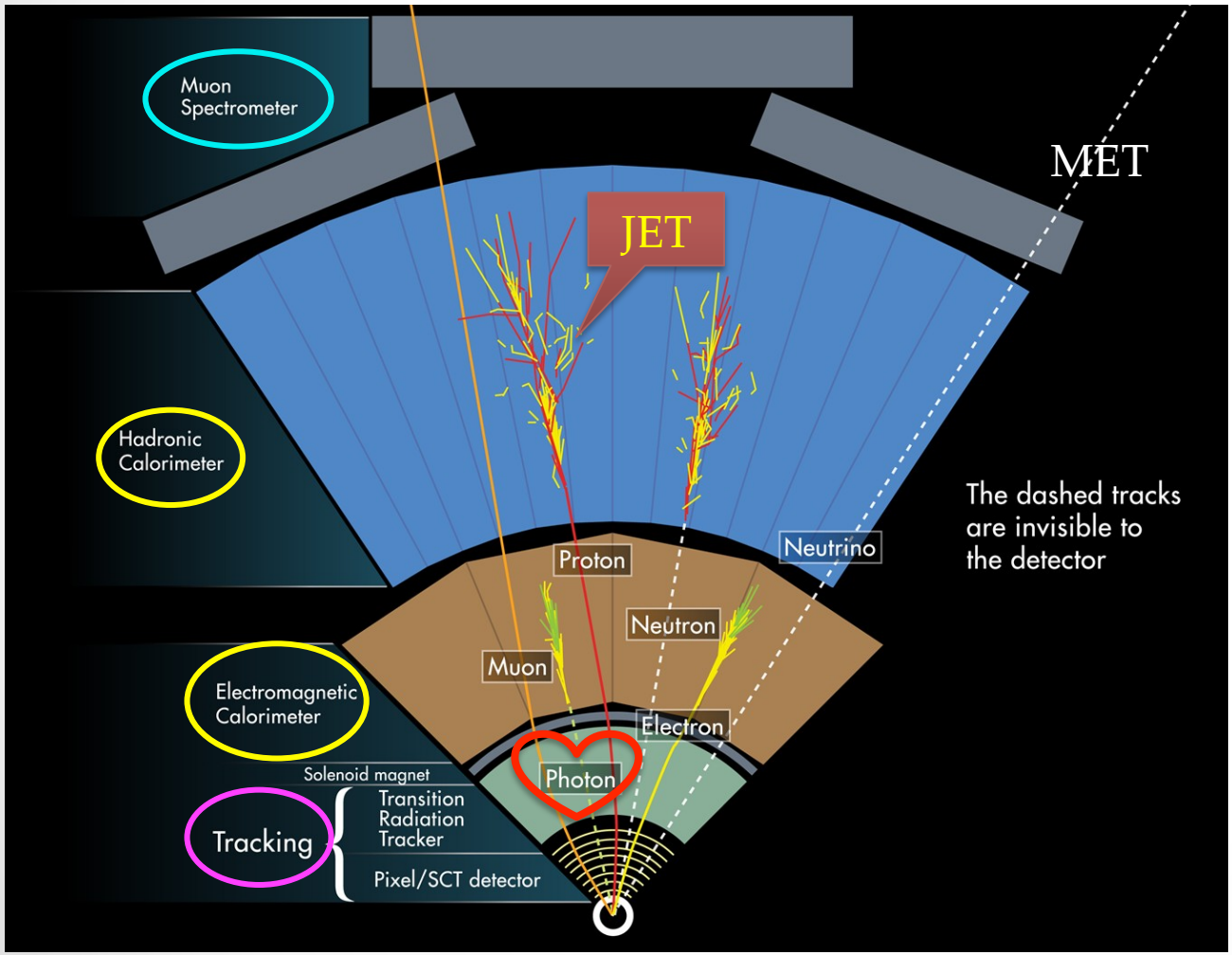
ATLAS at the LHC



LHC

- a proton-proton collider
- runs 2009-2013
- at a center-of-mass energy of 7/8TeV
- will restart in 2015 at 13/14TeV
- 1 bunch crossing collision / ~50ns, 20MHz
- save data at a rate of 400Hz

Objects in ATLAS

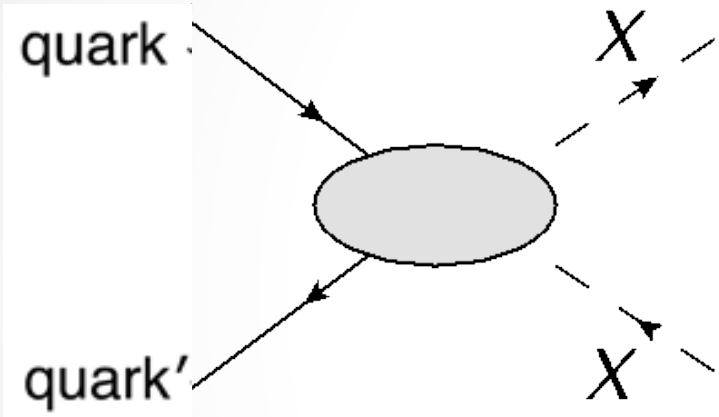


ATLAS

- one of the 4 detectors at LHC as a general purpose detector
- Different sub-detectors to identify the particles and measure their properties:
  - Inner detector
  - calorimeters
  - muon chambers

Probe New Physics

new particle production at LHC

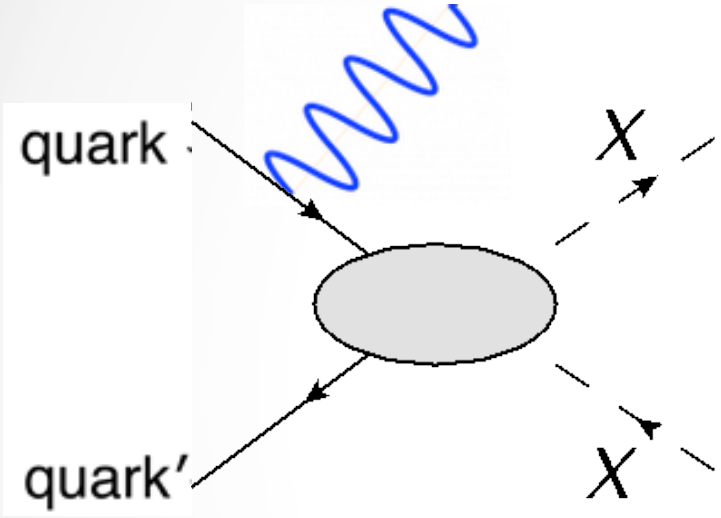


- New Physics Particles Production at collider
  - Dark Matter: WIMP models
  - SuperSymmetry: Compressed Squark scenario
  - etc.

WIMP: Weakly Interacting Massive Particles
Squark: the super partner of quark
X : stands for new physics particle

Monophoton

model independent analysis to probe new physics



- Sensitive to New Physics
  - WIMP models
  - Compressed Squark scenario *(New!!)*
- Photon is well measured
- Principal BGs are EWK

Visible signature: Photon
Invisible particles: E_T^{miss}

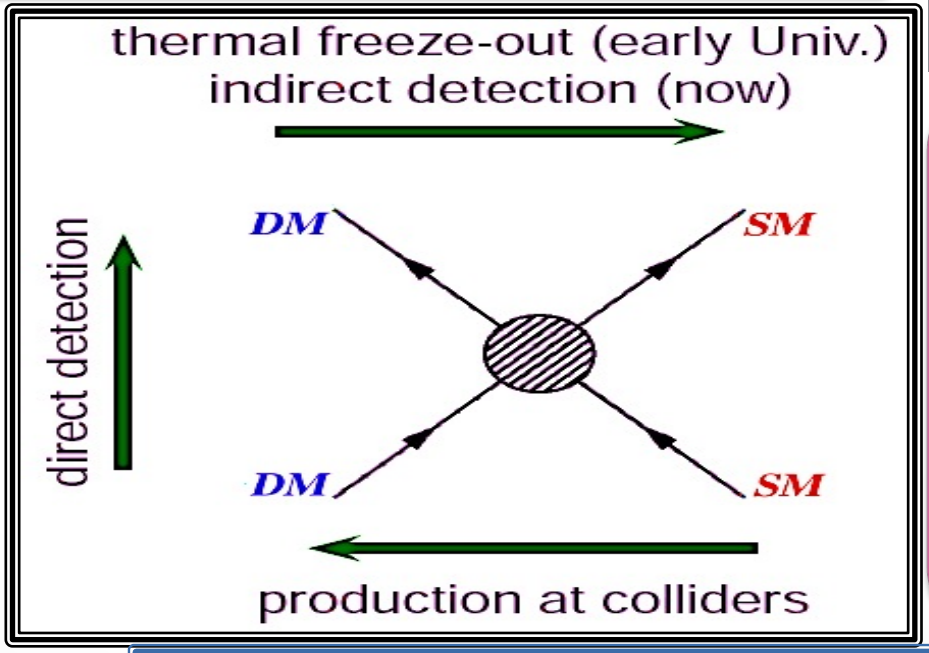
Clean, but rare signal

WIMP Pair

Dark Matter Candidate

NOTE: one model as an Example

Indirect:
Particles from WIMP annihilation



Direct:
Detectors in deep underground

LHC:
Creating WIMP pairs in the p-p interaction

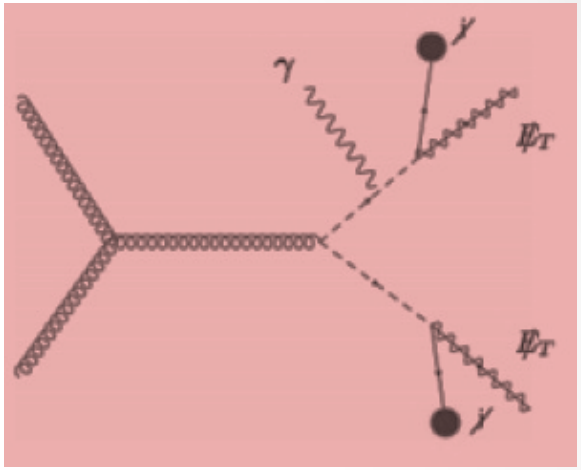
WIMP: Weakly Interacting Massive Particles

Compressed squark

squark: supersymmetry(SUSY) partners of quarks

NOTE: one model as an Example

- **Squark with direct decay:**
  - Pair production of first/ second generation squarks with direct decay to a quark and a neutralino
- **Compressed:**
  - Low mass difference between the Squark and the Neutralino
- **monophoton:**
  - photon radiated by initial quark or squark

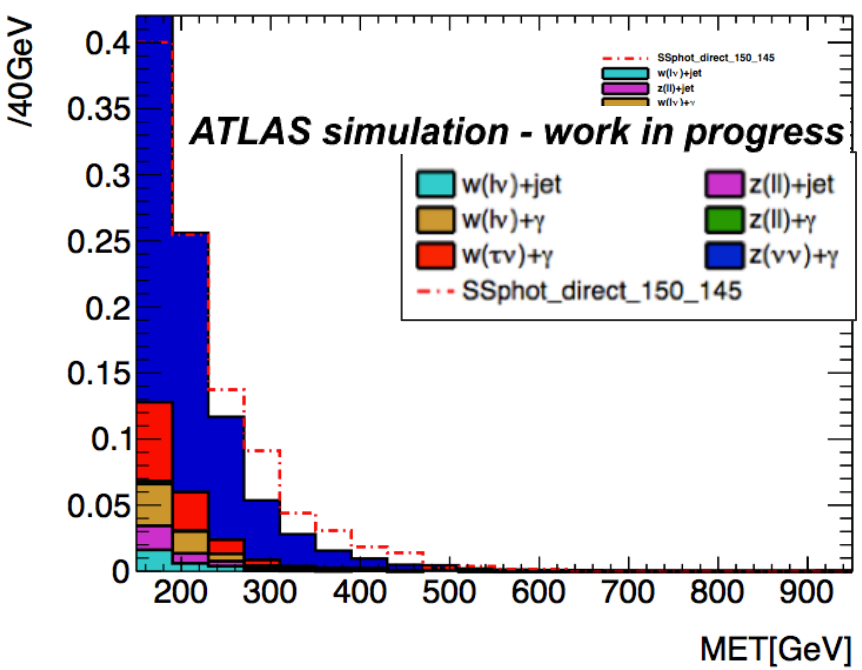


SuperSymmetry
- a theory beyond Standard Model
- predicts new particles

Monophoton Analysis

How we do our analysis?

Background Sources



BG Channel	Proportions	
	8 TeV	7 TeV
W/Z+γ	~88%	~86%
W/Z+jet	~11%	~13%
Other minor	~1%	~1%

Irreducible

γ+Z(νν)

γ+W(τν): hadronic decay of τ

Misidentified Lepton

γ+Z(ll)

γ+W(lν)

Jet/electron faked photon

jet+W(lν)

jet+Z(ll)

Other Minor ones

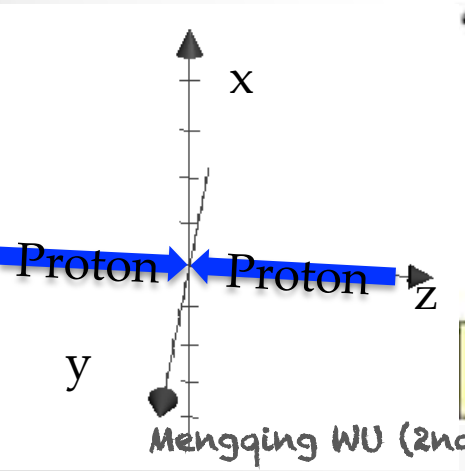
ttbar, single top: similar to W+jet

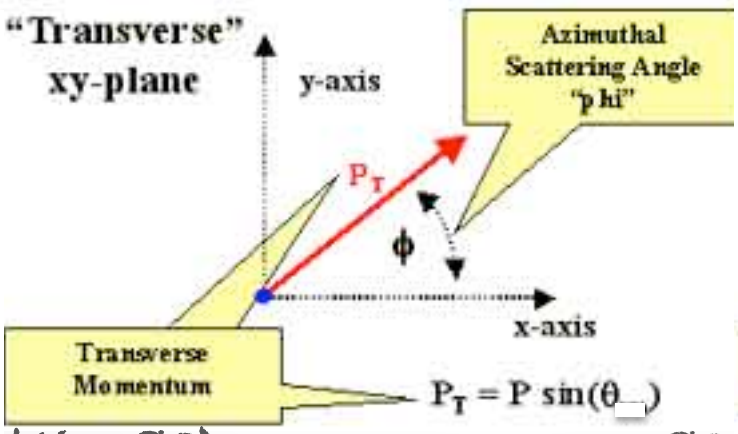
multi-jet, γ+jet

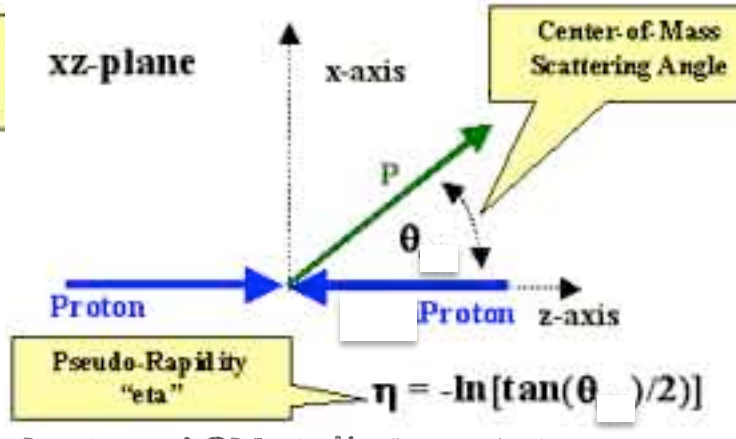
di-boson:γγ, WZ, WW, ZZ

Event Selection

Step	Z/W+γ/jet	Squark m=100GeV, Δm=5GeV
E_T^{miss}>150GeV, P_T^{γ}>150GeV	Preselection	Preselection
good isolated photon $\|\eta^{\gamma}\|$<1.37	~17%	~72%
Jet cuts: no more than 1 good jet (PT>30 GeV, $\|\eta\|$<4.5) $\Delta\phi(\gamma,jet)$>0.4, $\Delta\phi(jet, E_T^{miss})$>0.4	~10%	~46%
lepton veto	~5%	~45%

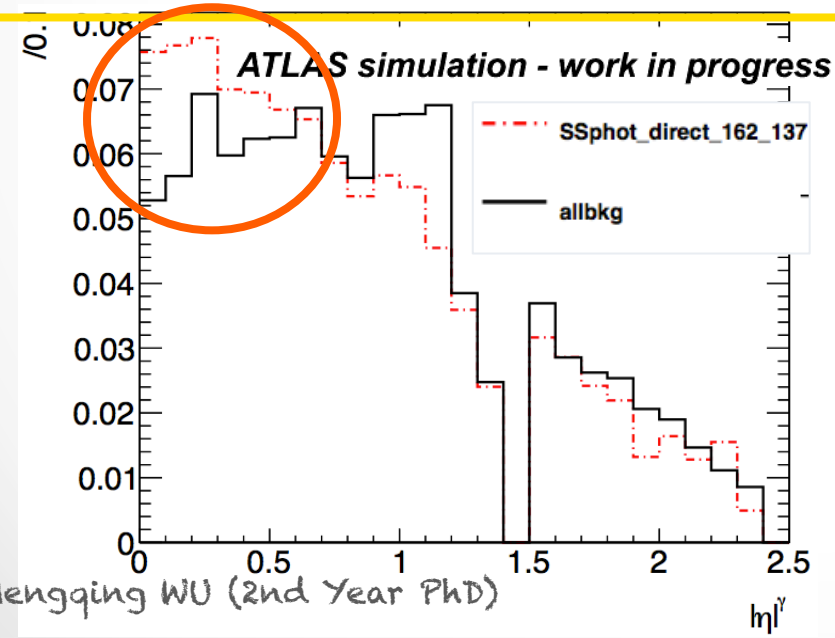


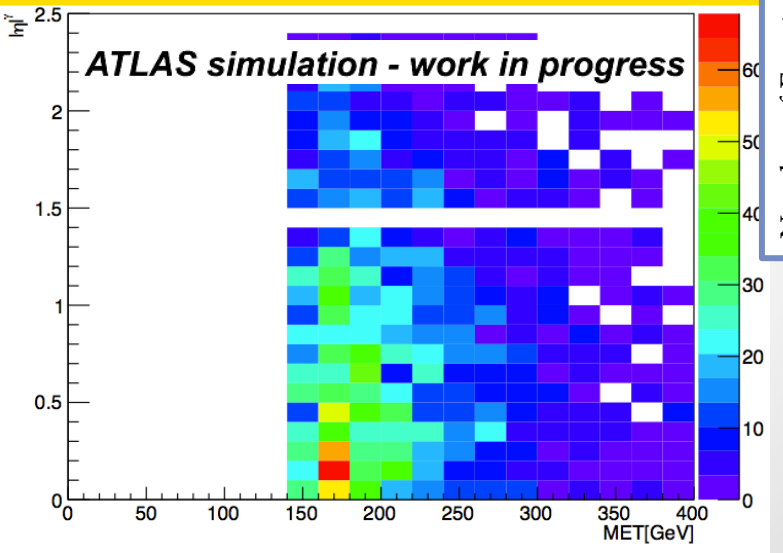




Optimization

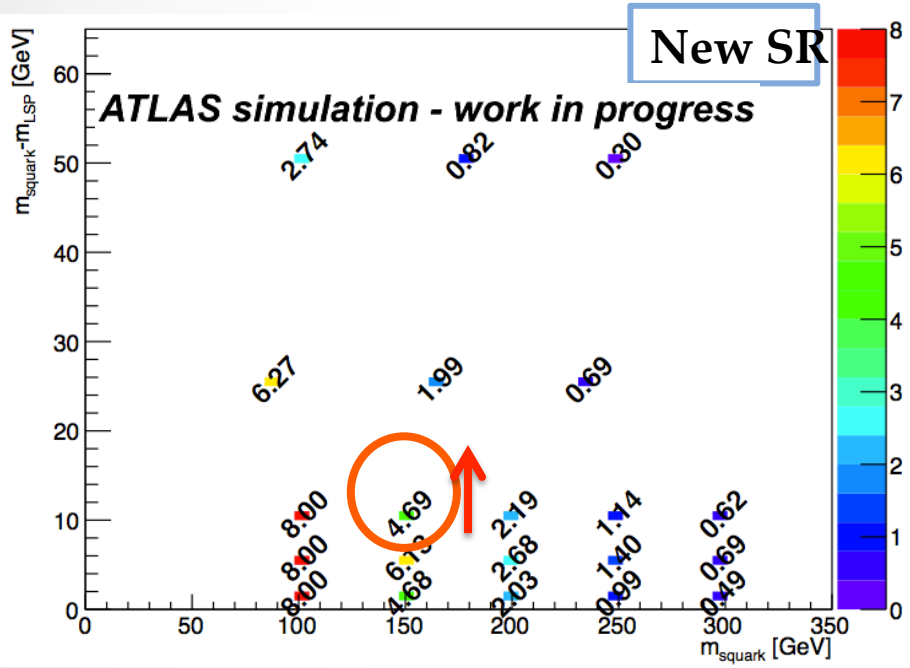
- at Signal Region(SR) level with one variable's cut changed
- Variables Distribution / Correlation
- Significance Signal Grid
- Tighter Cuts SR-> BG estimation more difficult
- Status:
  - Lower Pt photon cut
  - *New* SR: with $|\eta^{\gamma}|<1.37$

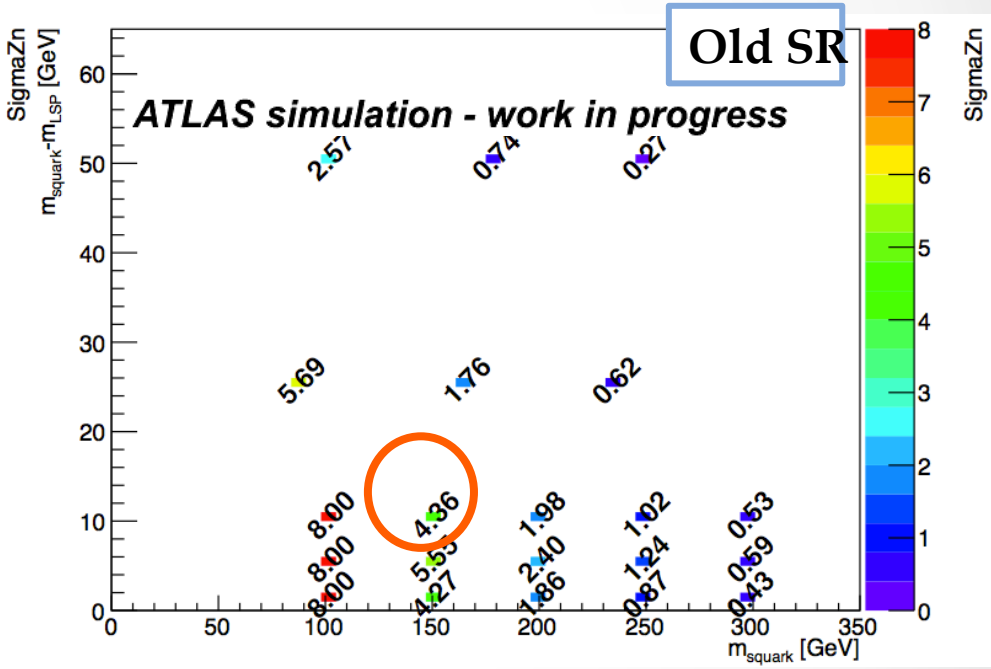




New SR

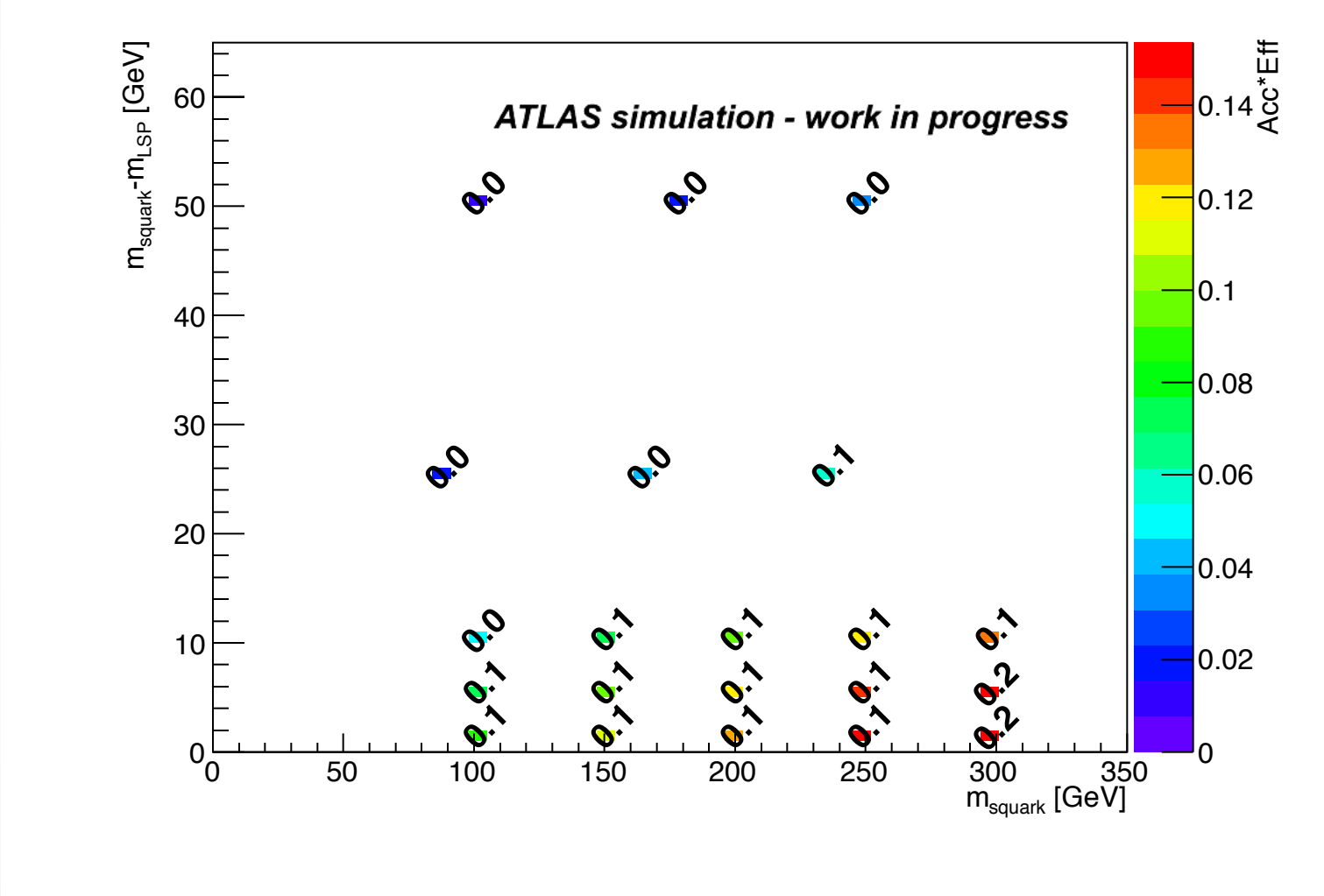
significance squark grid





Increased by 7% on significance

Signal Acceptance



Cross-section & Uncertainty

Compressed squark grid

Objective:

- In order to know the signal expectation

For Compressed Squark Grid interpretation

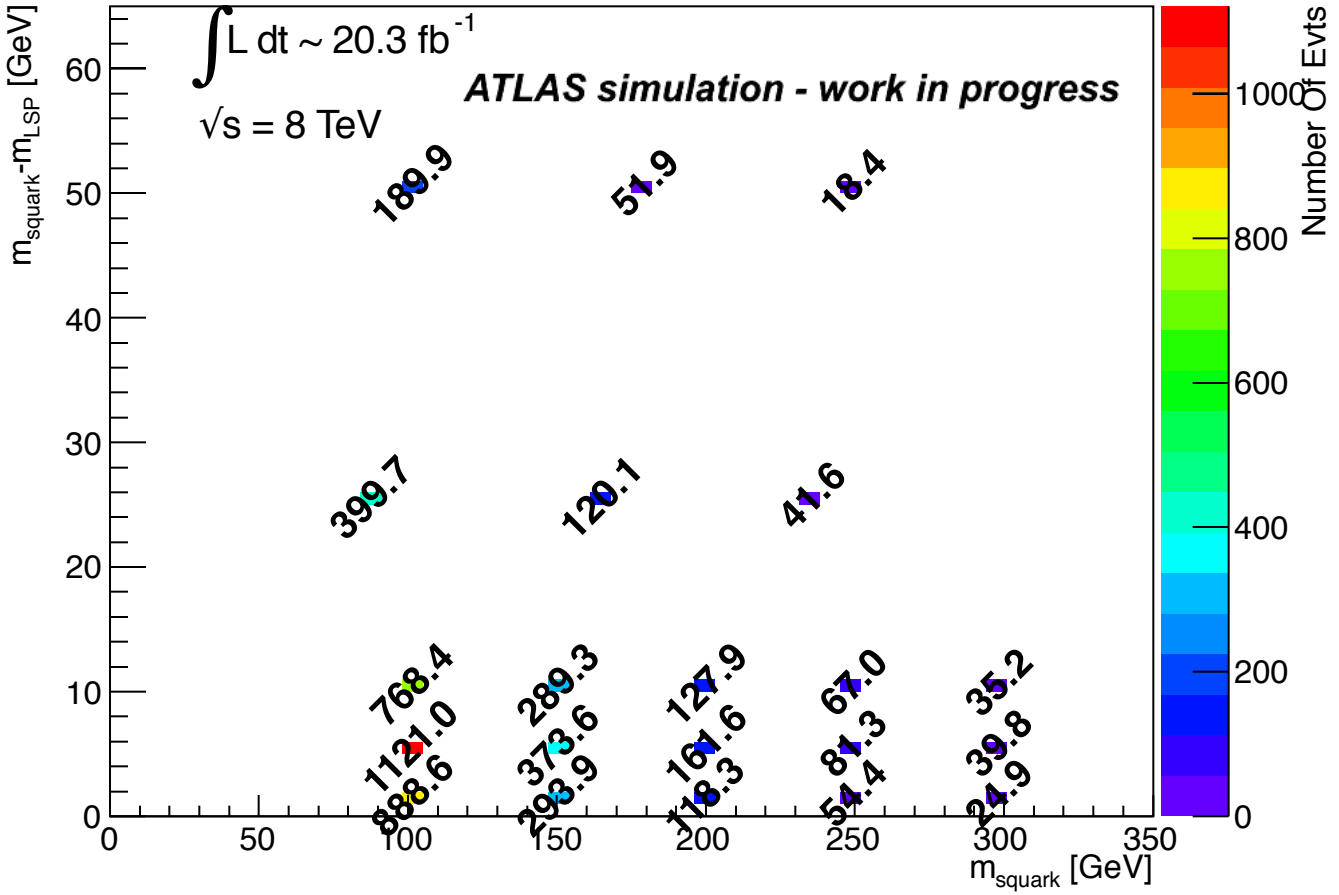
NLO σ k-factor

- Using: **prospino** - NLO calculation tool for SUSY

σ uncertainty

- vary Parton Distribution Functions(according to PDF4LHC recommendations)
- vary Renormalization / Factorization scale with Central value of PDF
- vary strong coupling alphaS

Signal Yields



Background Uncertainty

source of systematics	relative uncert.
Photon Energy Scale	0.9%
simulated Photon energy resolution, isolation & identification eff	1.1%
lepton: identification eff	0.3%
Jet Energy Scale ~ reco level	0.9%
Jet Energy Resolution ~ Detector	1.2%
Soft terms in MET + pile-up effect on calo energy	0.8%+0,3%
Pile-up reweighting uncertainty	0.5%
PDF and scale uncertainty	1.0%
Parton shower model	6.9%
others	~
Total MC	7.3%

PRL **110,** 011802 (2013)

Syst. Uncert.

- 7TeV numbers
- 8TeV:
  slightly smaller
  work ongoing

Stat. Uncert.

- new BG estimation technique to reduce it

Results on 7TeV?

How we present results?

7TeV Published!!

PRL 110, 011802 (2013) PHYSICAL REVIEW LETTERS week ending 4 JANUARY 2013

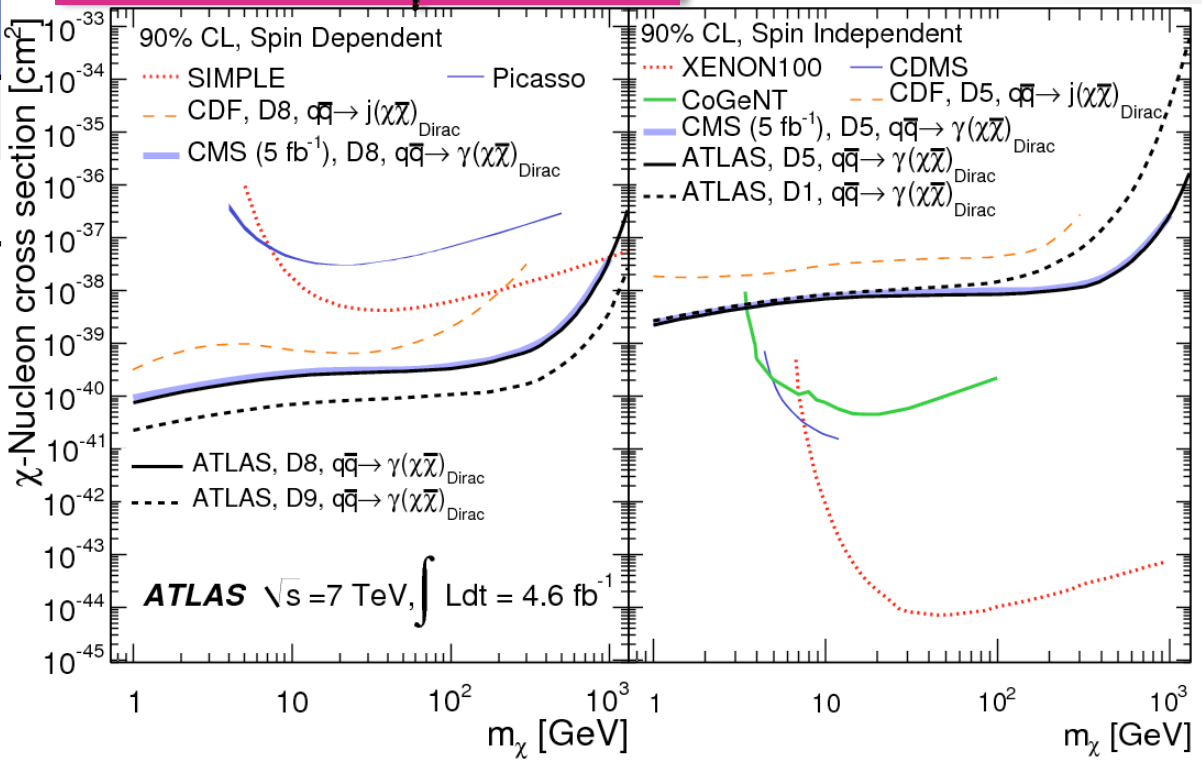
Search for Dark Matter Candidates and Large Extra Dimensions in Events with a Photon and Missing Transverse Momentum in pp Collision Data at $\sqrt{s} = 7$ TeV with the ATLAS Detector

Model Independent CLs limits

observed	σ×A×ε limit [fb]
95%CL	6.8
90%CL	5.6

Mediator	vertex operator
WIMPs assumed to be Dirac Fermions	
D1	scalar
D5	vector
D8	axial-vector
D9	tensor

WIMPs Interpretation



Results on 8TeV?

Draft version 0.1

Search for nev … ophoton event

Leonardo Carminati … ito[3], Lashkar Kashif[4], Marta … i[1], Chase Shimmin[5], Fuquan … Ning Zhou[5]

[3]Harvard
[4]Wisconsin
[5]UCI

Conclusion

Conclusion

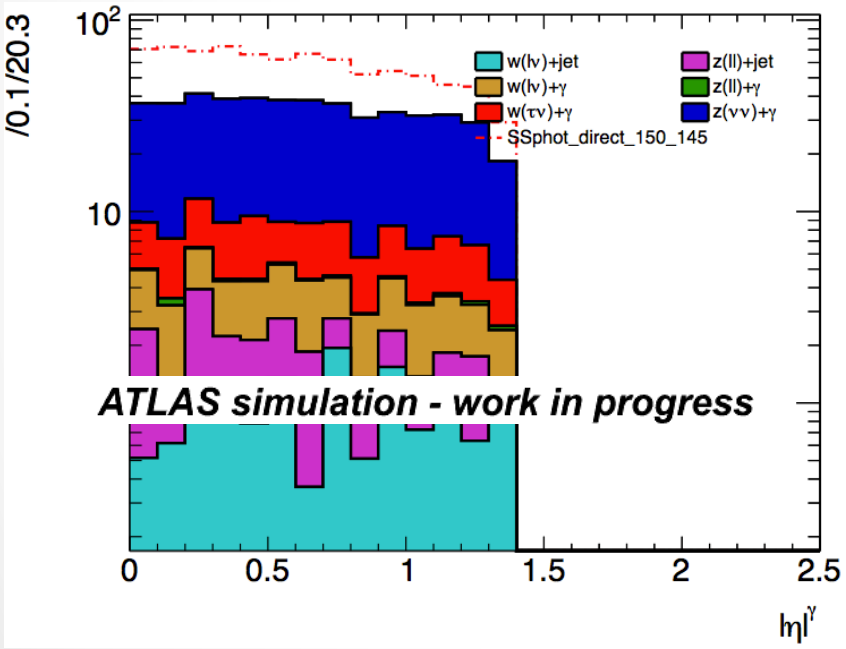
- Monophoton is an interesting channel for new physics analysis
- 7 TeV results have been published
  (Phys. Rev. Lett. 110, 011802(2013))
- 8 TeV analysis work in progress
  - New Signal Region Defined
  - Background estimation
  - Compute Limits – if nothing is found
  - Adding New Compressed Squark Scenario
  - Working on documenting the analysis for ATLAS Approval

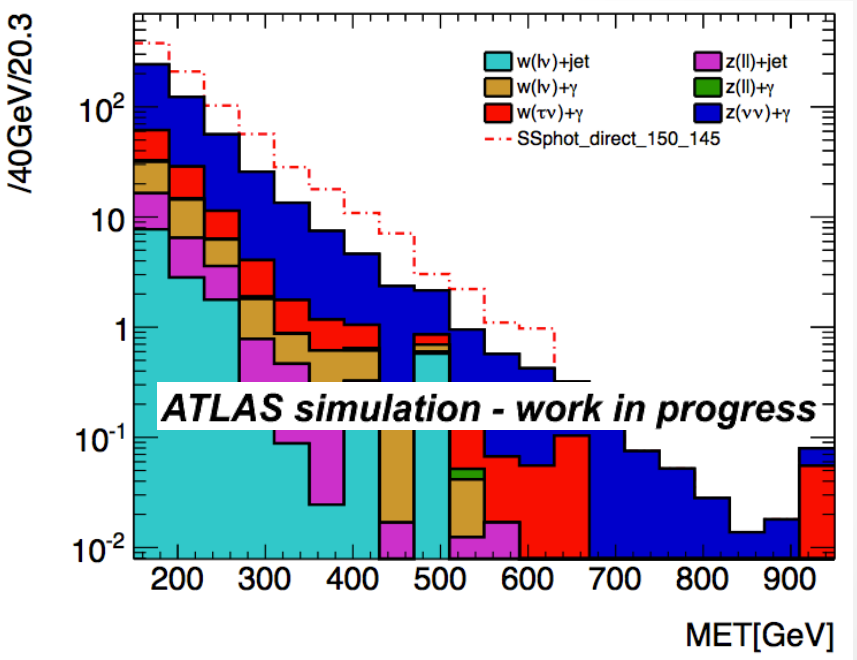
- Perspectives:
  - After publication, move to work on preparing RUN2 and write the thesis

THANK YOU!

Back-ups

Kinematics Distribution in new SR 8TeV

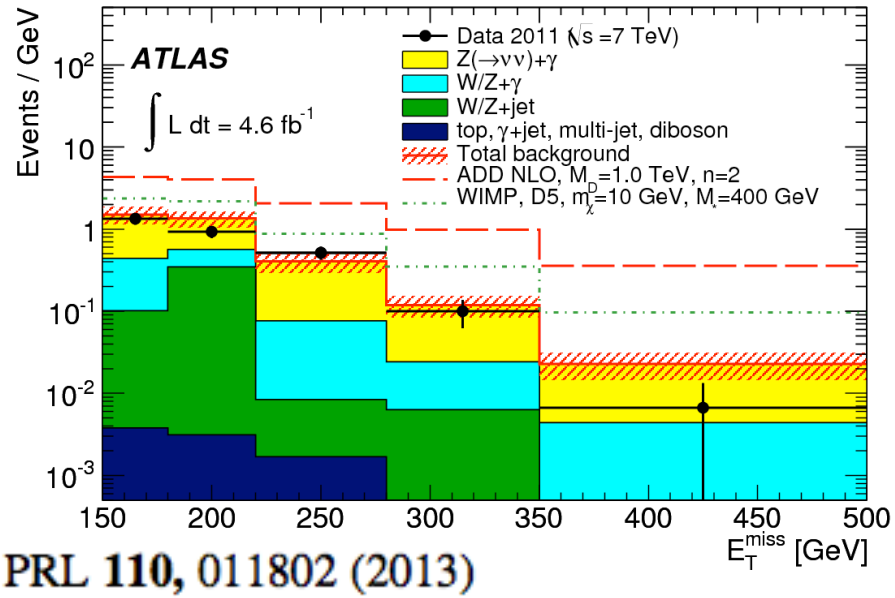




Background estimation

Based on 7TeV

- W/Z+γ: Data Driven method, μ +γ+MET CR
- W/Z+jet: Data Driven method, faked electron, faked jet(fake to be a photon)
  - faked electron: Zee peak
  - faked jet: matrix method based on isolation and photon definition



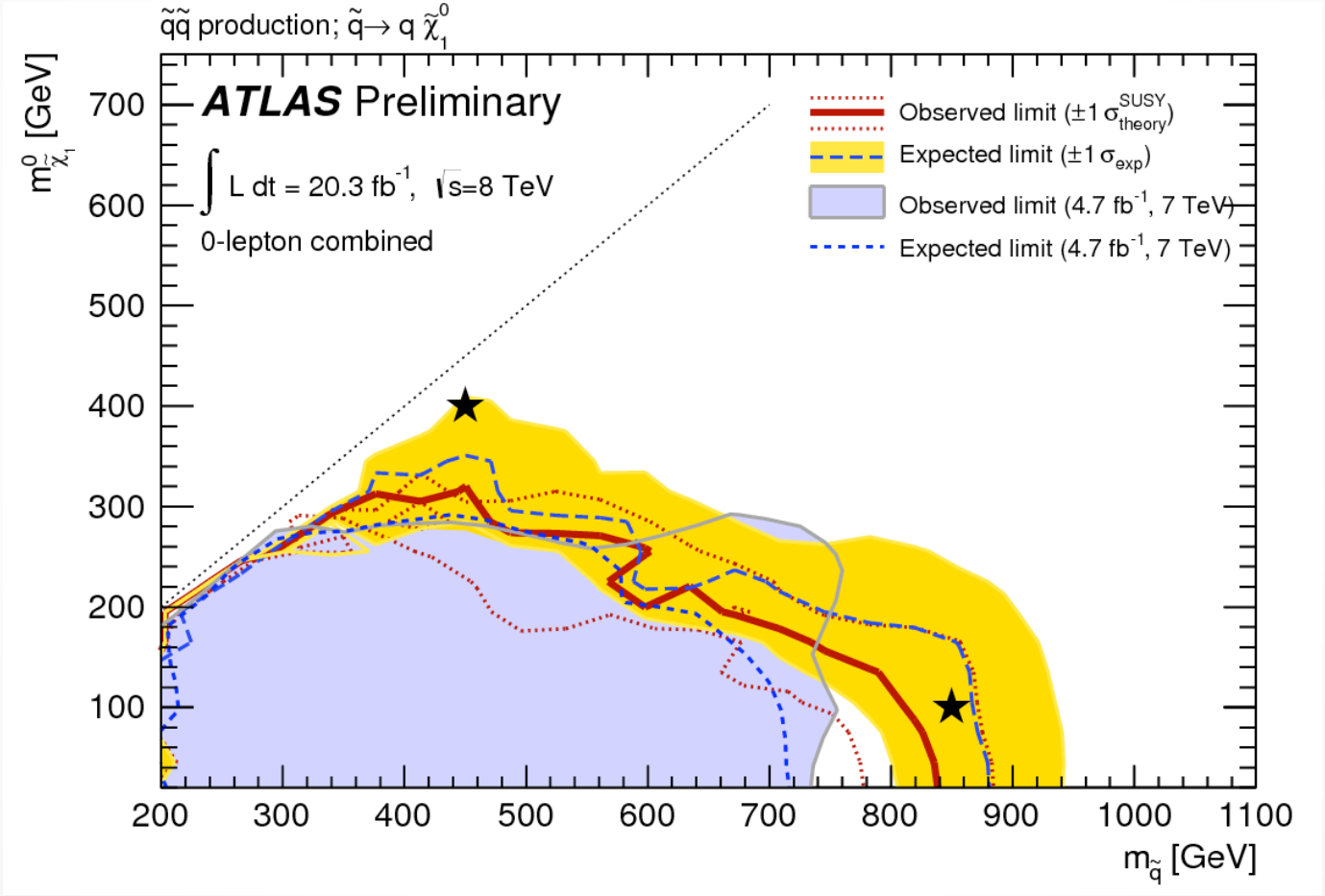
PRL **110,** 011802 (2013)

Background estimation

Based on 7TeV: Control region

- For: W/Z+γ BGs
- Due to the low statistics expected, this CR is only used to constrain the total number of events passing the selection cuts. No bin-by-bin correction is applied to cure the shape of the *Emiss* and $p\gamma$ spectra in MC
- inverted the muon veto(pT >10 GeV and $|\eta| < 2.4$)

0L analysis on squark limits



significance calculation

sigmazn

The significance is computed from the p-value:

*sigmaZn=ierf(1-2*p)*sqrt(2)*

where ierf is the inverse error function

SIGNIFICANCE CALCULATION

P value

- refer to the probability that the SM expectation fluctuates upwards to the number of data events observed
- defined by the convolution of a Poisson probability density function (to account for statistical uncertainties) with a gaussian probability density function G (which represents the effects of non-negligible systematic uncertainties) with mean N_SM and width deltaN_SM.

$$p = A \int_0^{\infty} \mathrm{d}b \, G(b; N_{SM}, \delta N_{SM}) \sum_{i=N_{obs}}^{\infty} \frac{e^{-b} b^i}{i!}$$

- - N_SM is the Standard Model background expectation
  - N_obs is the number of data events (in this case, we assume N_obs = N_SM + N_signal, where N_signal is the number of signal events)
  - deltaN_SM is the total systematic uncertainty on the background N_SM