Search for SuperSymmtric Particles with 2 Same Sign or Three Leptons with Jets in the Final State

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CPPM PhD Days

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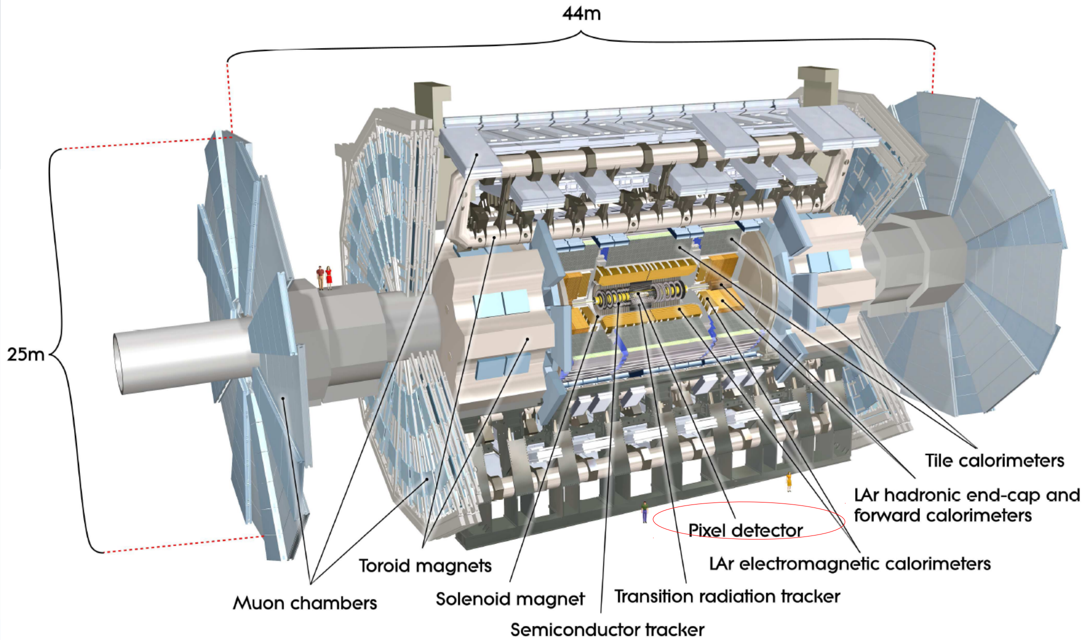
PhD Research Subjects

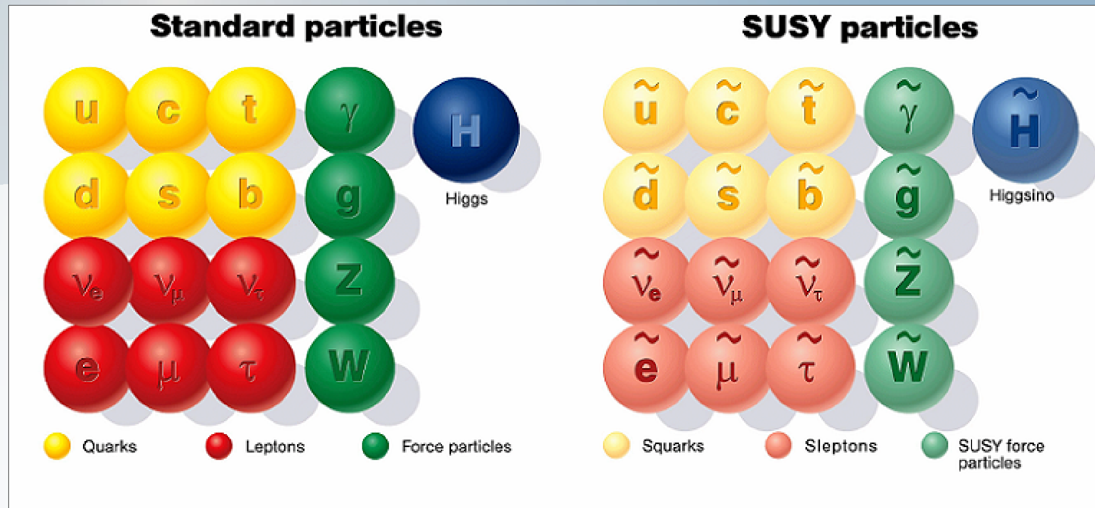


- Research has two aspects:
- **The Pixel Detector studies**: commissioning of the ATLAS Pixel Detector after the insertion of a new inner-most layer called the Insertable B-Layer (IBL), before Run 2 started.
- **Physics SUSY Analysis**: looking for theoretically predicted SuperSymmetric (SUSY) particles.

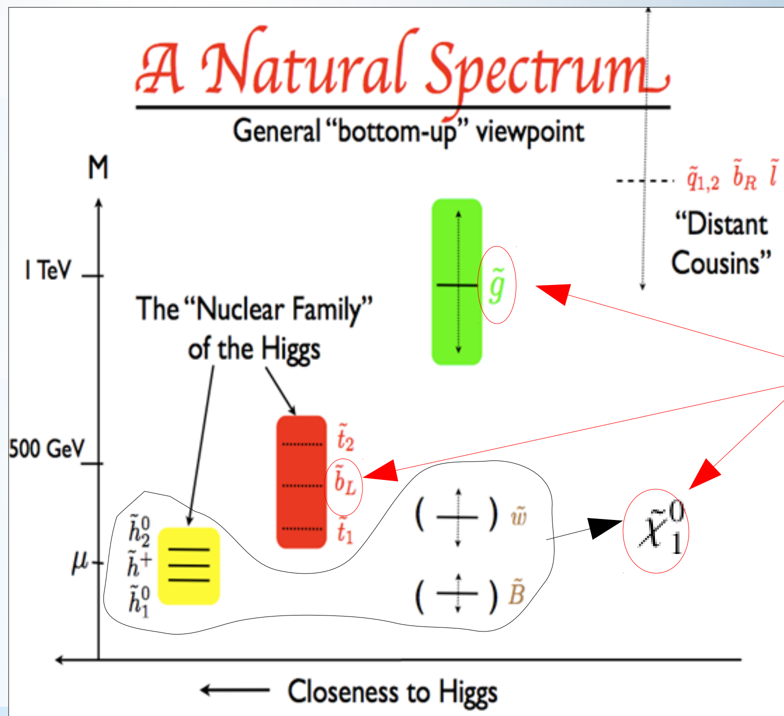
SuperSymmetric (SUSY) Particles

- **Standard Model (SM)**: **3 generations** of quarks and leptons, **4 gauge bosons** and the **Higgs boson**.

- **SuperSymmetry (SUSY): a partner** for every SM particle (differs in its spin by half an integer).



- **SUSY solves many problems of the SM**:
  - **Higgs mass fine tuning**.
  - Provides a good candidate for **Dark Matter**.
  - Electro-weak & strong **unification (at 10^{16} GeV)**.

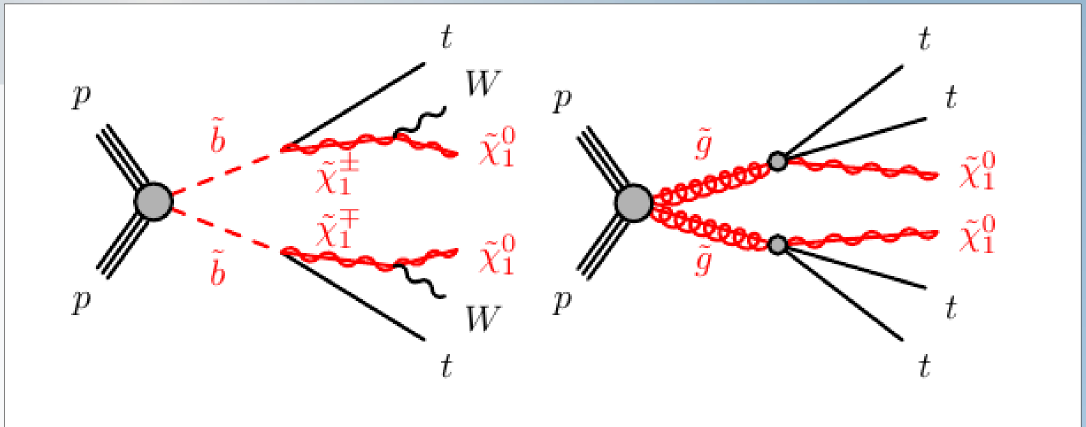


Particles looked for

Sbottom and Gluino Search

- **SUSY search**: through several SUSY models (**Direct Sbottom SUSY** and **Gtt** Models).

- **Final state in our analysis: include either 2 same sign or 3 leptons** (SS/3L) + missing E_T + jets (**low SM background**).



4W, 2b, MET | **4W, 4b, MET**

- A **paper** (1602.09058) and a **CONF note** (ATLAS-CONF-2015-078) were published with 13 TeV, 3.2 fb^{-1}.

The 4Ws decays can easily give 2 same sign leptons.

- This analysis is extended with 2016 data, and a **Signal Region Reoptimization** process is needed.

- Aims to determine the **best kinematical cuts** to be applied to make our “**signal visibility**” as **optimal** as possible, with 2016 data: 13 TeV, 13.3 fb^{-1} (ICHEP).

Status after 2015 SS/3L Analysis

- Objective: **update the Signal Region Optimization studies** performed earlier in Run 1 and 2015 SS/3L analysis.
- Use **Monte Carlo simulations**: simulate our signal and background events.
- Figure of merit: the **signal discovery significance (Z = f(S, B, ΔB), ΔB = 30%).**
- Focus on **Direct Sbottom SUSY Model** with 1 b-jet in the final state (**SR1b**).
- **Re-optimization** of these kinematical variables: the **missing transverse energy** (MET), **effective mass** (**Meff**) and the particle **jet multiplicity** (nJet) and **transverse momentum** (pT).

Reducible detector bkg

Irreducible SM bkg ttbar dominated

	SR1b	SR3b
Observed events	7	1
Total background events	4.5 ± 1.0	0.80 ± 0.25
$p(s=0)$	0.15	0.36
Fake/non-prompt leptons	0.8 ± 0.8	0.13 ± 0.17
Charge-flip	0.60 ± 0.12	0.19 ± 0.06
$t\bar{t}W$	1.1 ± 0.4	0.10 ± 0.05
$t\bar{t}Z$	0.92 ± 0.31	0.14 ± 0.06
WZ	0.18 ± 0.11	< 0.02
$W^{\pm}W^{\pm}jj$	0.03 ± 0.02	< 0.01
ZZ	< 0.03	< 0.03
Rare	0.8 ± 0.4	0.24 ± 0.14

Signal regions event yield for the 3.2 fb^{-1} scenario from 2015 analysis.

Direct Gluino

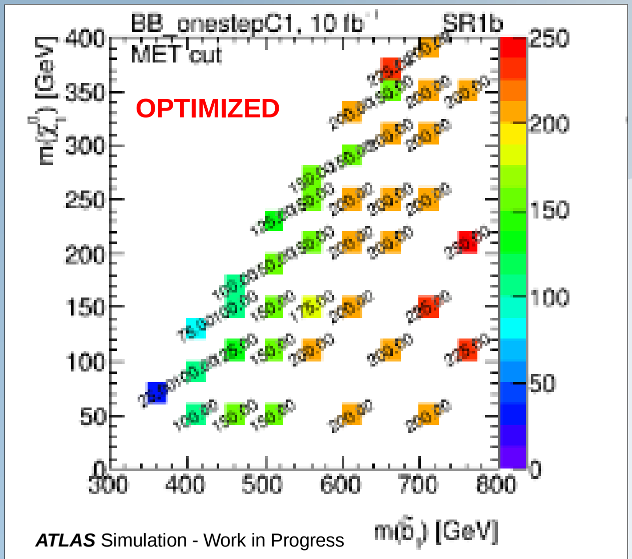
Direct Sbottom

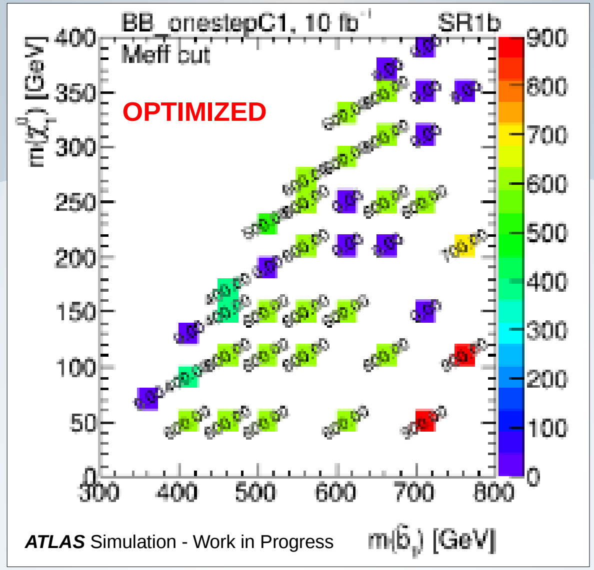
Signal region	N_{lept}	$N^{20}_{b\mathrm{-jets}}$	N^{50}_{jets}	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	m_{eff} [GeV]
SR3b	≥2	≥3	-	>125	>650
SR1b	≥2	≥1	≥4	>150	>550
SR0b5j	≥2	==0	≥5	>125	>650
SR0b3j	≥3	==0	≥3	>200	>550

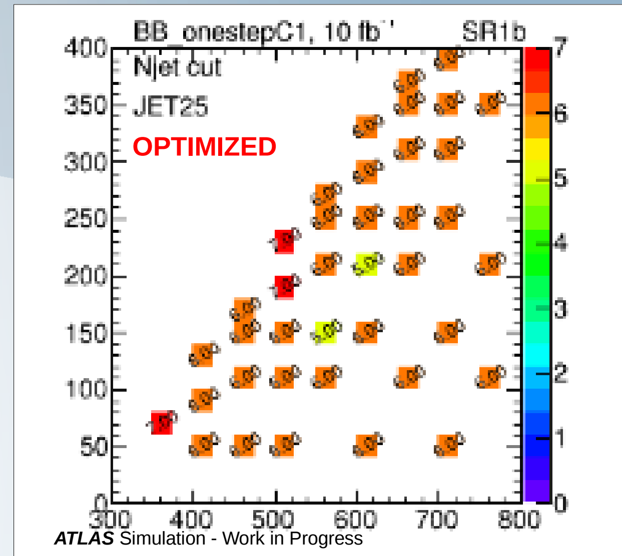
Signal regions definition for the 3.2 fb^{-1} scenario from 2015 analysis.

- The **effective mass**: the scalar sum of the pT of the signal leptons and jets (regardless of their flavour) in the event plus MET.

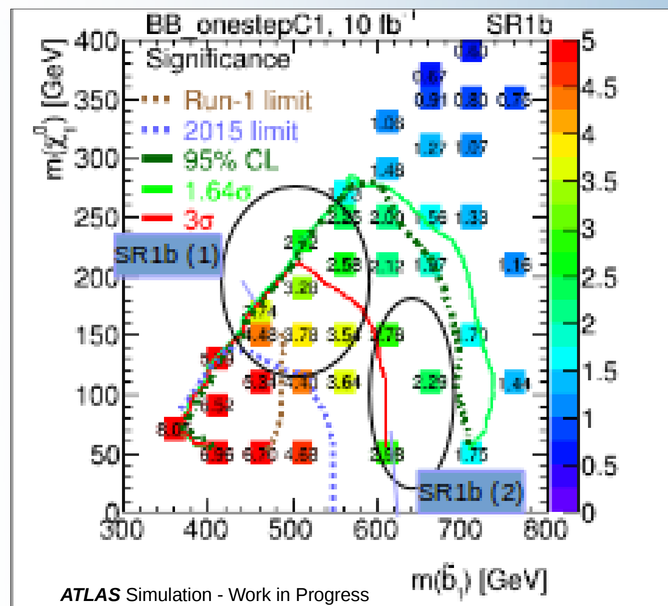
Optimal Significance Grids With Corresponding MET, Meff, JET Multiplicity [JET pT 25 GeV, ΔB = 30%, L = 10 fb^{-1}]



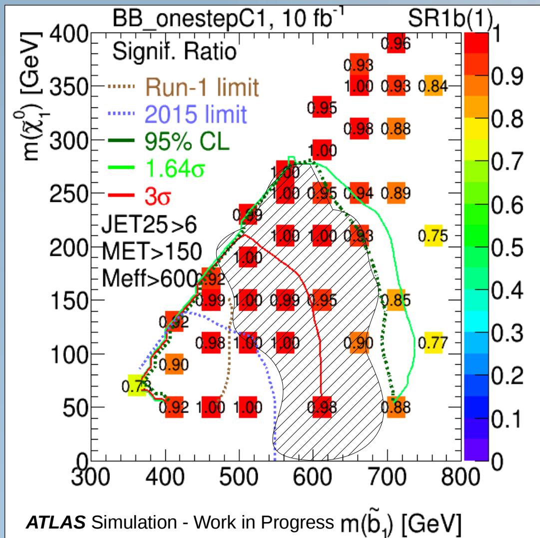


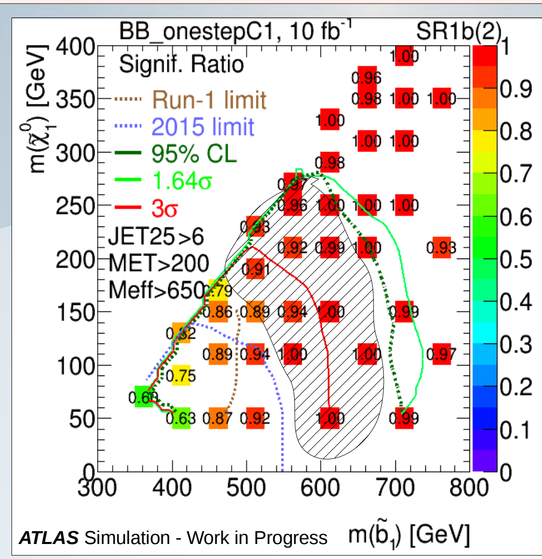


- **Optimized** for **each signal point** → **too many** signal regions.
- As a compromise, **two regions** are chosen (**loss of nor more than 5%** of signal sensitivity).



Signal Significance with Cuts to Maximum Significance Ratio Grids
[JET pT 25 GeV, ΔB = 30%, L = 10 fb^{-1}]





- The MET, Meff and JET multiplicity cuts proposed for our two regions are:
- **(150, 600) GeV and 6 JET25 for SR1b(1).**
- **(200, 650) GeV and 6 JET25 for SR1b(2).**

Z+jets	-
W	-
VV, VVV	0.83 ± 0.53
ttbar	2.43 ± 0.24
ttbarV, tZ, 4t	4.46 ± 0.20
ttH, ggH, VBFH	0.72 ± 0.26
TOTAL	8.44 ± 0.67 (stat) ± 2.53 (30%)

Z+jets	-
W	-
VV, VVV	0.10 ± 0.08
ttbar	1.38 ± 0.18
ttbarV, tZ, 4t	2.33 ± 0.15
ttH, ggH, VBFH	0.49 ± 0.16
TOTAL	4.30 ± 0.29 (stat) ± 1.29 (30%)

- The process was done for the **L = 10 fb^{-1} scenario**. (amount of data that accumulated by August 2016, before the ICHEP 2016 conference was 13.3 fb^{-1}).

- **Background break-down tables for the corresponding kinematical cuts in both SR1b(1) and SR1b(2) regions.**

Fake Lepton Estimation

- Most detector “tricky” background**: fake leptons from ttbar events.**

- The Matrix Method is a **data driven method** used for the **Fake Lepton Background Estimation**, which needs as an input **real** and **fake** lepton (e, μ) **efficiencies**.

Real Lepton Efficiency

Fake Lepton Efficiency

$$< N_{\text{tight}} > = \epsilon < N_{\text{prompt}} > + \zeta < N_{\text{fake}} >$$

$$< N_{\text{loose}} > = (1 - \epsilon) < N_{\text{prompt}} > + (1 - \zeta) < N_{\text{fake}} >$$

- **Objective**: to **update** the **Real Lepton Efficiency measurement** of the 2015 analysis for the 2016 analysis. (Previously done by Sebastien Kahn).

- **Real Lepton Efficiency** corresponds to the **ratio** of **baseline** (pre-selected/loose) to **signal** (tight) leptons.

Tag & Probe Method for Real Lepton Efficiency Measurement

- **MC** used to simulate prompt leptons (**Z→ ee/mumu**) : leptons are selected via **Z decays**.

- **A Tag lepton should satisfy:**

1) **Signal lepton definition cuts.**

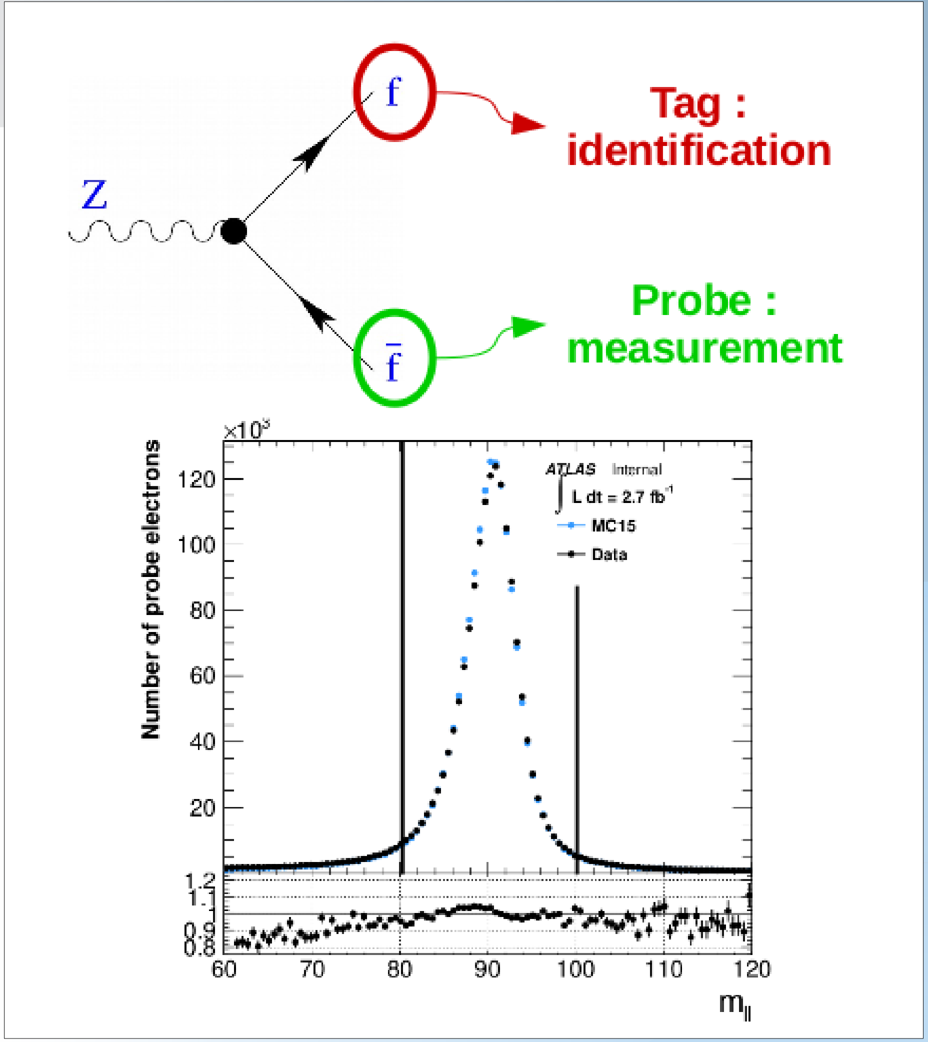
2) **Signal lepton trigger match.**

- **A Probe lepton should satisfy:**

1) **Baseline lepton definition cuts.**

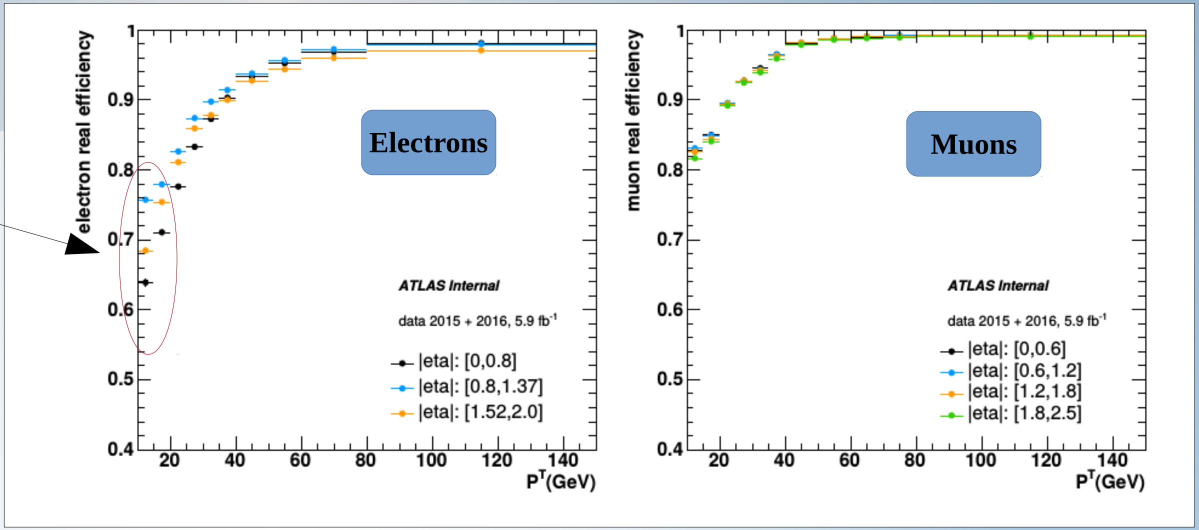
2) **Mll (tag, probe) inside [80, 100] GeV window.**

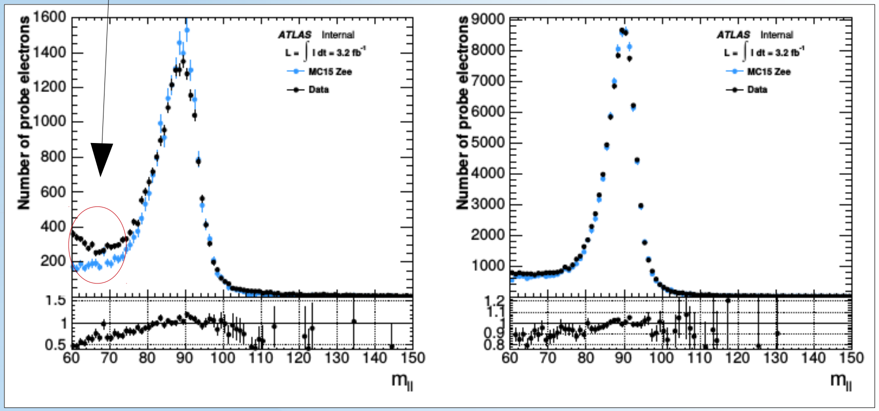
3) **Opposite sign leptons.**



Real Lepton Efficiency Measurement

Need to subtract background for the first two bins.
MC/data deviation was observed
Only for leptons with (pT<20 GeV) → Background Subtraction.



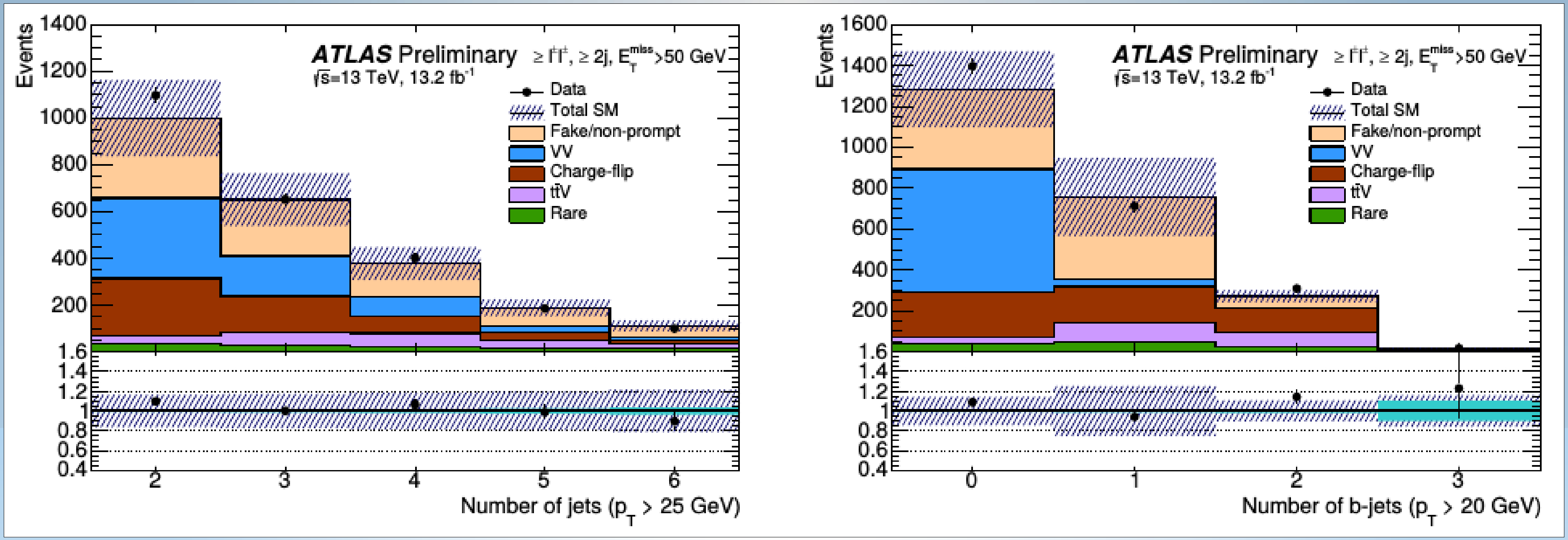


Real Electron Efficiencies (errors are statistical only).

p_T [GeV] $\|\eta\|$	[0-0.8]	[0.8-1.37]	[1.52-2]
[10-15]	63.88 ± 0.53	75.71 ± 0.43	68.45 ± 0.47
[15-20]	71.06 ± 0.28	77.91 ± 0.27	75.39 ± 0.30
[20-25]	77.60 ± 0.16	82.62 ± 0.17	81.09 ± 0.20
[25-30]	83.28 ± 0.10	87.39 ± 0.10	85.92 ± 0.13
[30-35]	87.26 ± 0.06	89.74 ± 0.08	87.81 ± 0.10
[35-40]	90.31 ± 0.05	91.39 ± 0.06	89.98 ± 0.08
[40-50]	93.32 ± 0.03	93.77 ± 0.03	92.75 ± 0.05
[50-60]	95.25 ± 0.05	95.67 ± 0.06	94.37 ± 0.10
[60-80]	96.87 ± 0.06	97.24 ± 0.07	95.99 ± 0.13
p_T >80	98.12 ± 0.08	97.97 ± 0.11	97.08 ± 0.19

- Systematics: background subtraction, cuts, ttbar.

Validation of Background Estimates



Predictions and data **agree** fairly well.

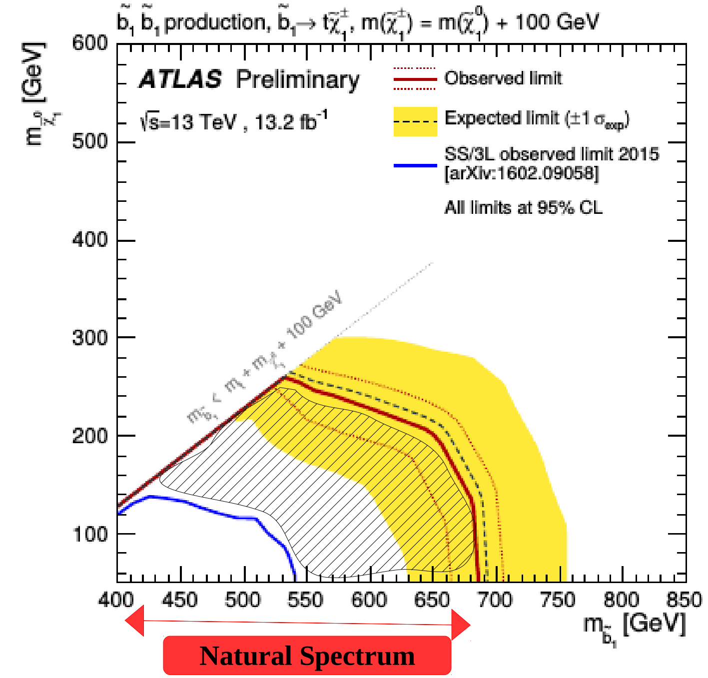
Results and Conclusion

	SR1b
Observed	12
Total SM background	11.4 ± 2.8
$t\bar{t}Z$	1.6 ± 0.6
$t\bar{t}W$	2.0 ± 0.7
Diboson	0.5 ± 0.4
Rare	2.7 ± 0.9
Fake/non-prompt leptons	3.3 ± 2.1
Charge-flip	1.43 ± 0.19

Irreducible SM bkg ttbar dominated

Reducible detector bkg

Within the models considered, exclusion limits are extended by 150–400 GeV in $\tilde{g}$ mass, 100–350 GeV in $\tilde{\chi}_1^0$ mass and 150 GeV in $\tilde{b}_1$ mass with respect to previous results.



(c) SR1b, $\tilde{b}_1 \rightarrow tW^{-}\tilde{\chi}_1^0$ scenario

- Joined a **SUSY physics** analysis team:

➔ Finished **signal region optimization** study for the direct sbottom and gtt models.

➔ Contributed to the **real lepton efficiency** measurement using 2015 and 2016 data, as part of the SS/3L 2016 analysis.

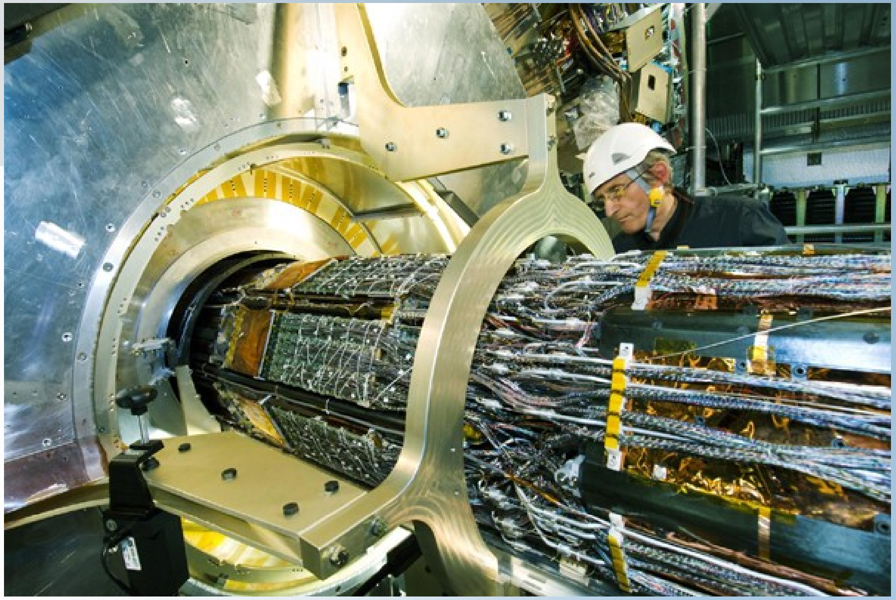
➔ An ATLAS **CONF note** was published (ATLAS-CONF-2016-037).

- Currently writing my thesis.

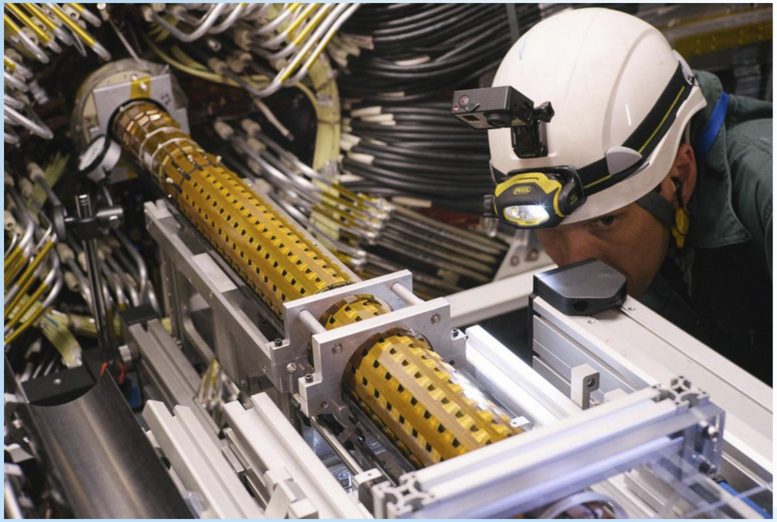
Backup

The ATLAS Pixel Detector

- **Inner-most** at the ID of ATLAS.
- A **semiconductor** detector made of silicon modules.
- Two parts:
  - Old Pixel: **3 barrel layers and 2 x 3 end-cap layers**.
  - **IBL** (installed on May 2014).
- **IBL insertion** required a beam pipe radius reduction (29.0 → 23.5 mm).



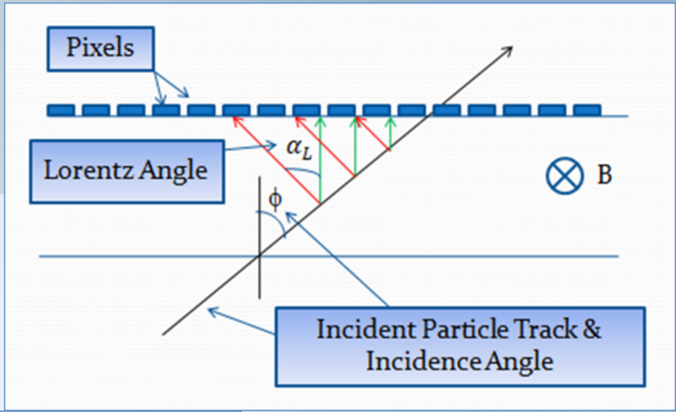
Motivations for the Insertable B-Layer (IBL)



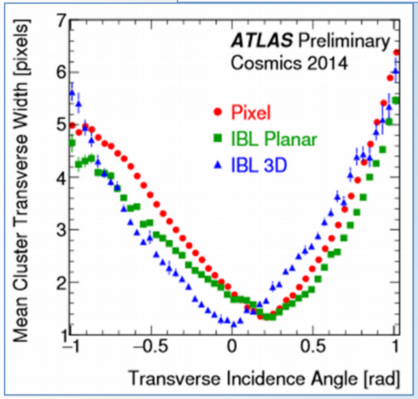
- **High performance** despite the radiation damage.
- Enhancement of **tracking robustness** and precision.
- Improvement of **vertexing** and **b-tagging** performance.
- **Higher sensitivity** for physics channels involving b-jets.

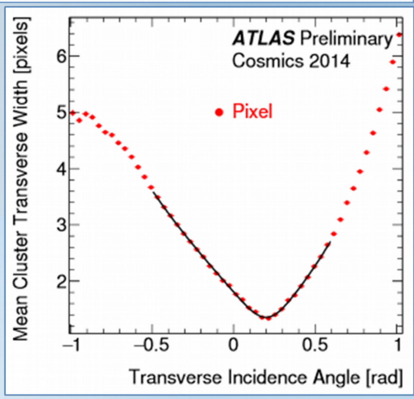
The Lorentz Angle in the Pixel Detector

- Lorentz Angle (α_L) is the angle by which charge carriers inside the silicon sensors are deflected from their normal paths, due to the **solenoid magnetic field**. $\tan(\alpha_L) = r_H \mu_e B$



- μ_e is the electron mobility. r_H is Hall factor. α_L decreases as temperature increases.
- α_L should be taken into account when determining the real position of the particle track.

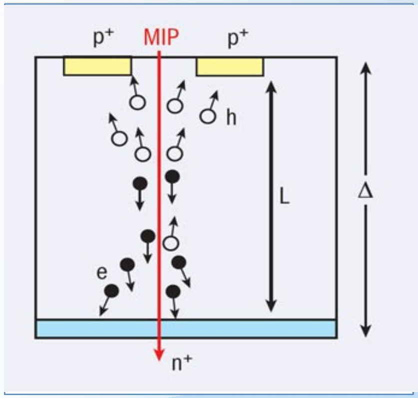


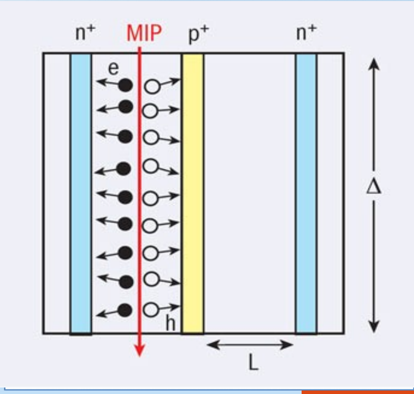


The Lorentz Angle Measurements

Technology	a [pixels]	α_L [mrad]	b [pixels]	σ [mrad]	$\chi^2/d.o.f$
Pixel Layers	3.28 ± 0.02	201 ± 1	1.14 ± 0.01	80 ± 4	64/23
IBL Planar	2.35 ± 0.06	224 ± 4	1.18 ± 0.03	112 ± 21	41/23
IBL 3D	2.90 ± 0.07	−10 ± 5	1.08 ± 0.03	64 ± 20	19/23

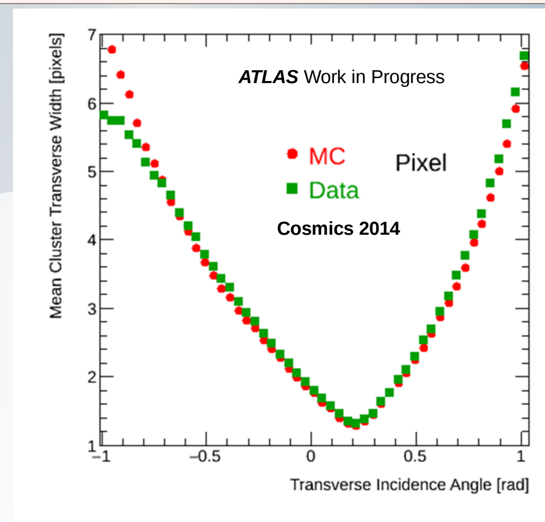
- α_L is **0 for 3D**, because charge carriers will drift to the **same electrodes** even after bent by B (different structure from planar).
- IBL & Pixel commissioning enabled us to gain a **good understanding of the IBL settings and performance**.
- IBL took valuable **data during 2015**.

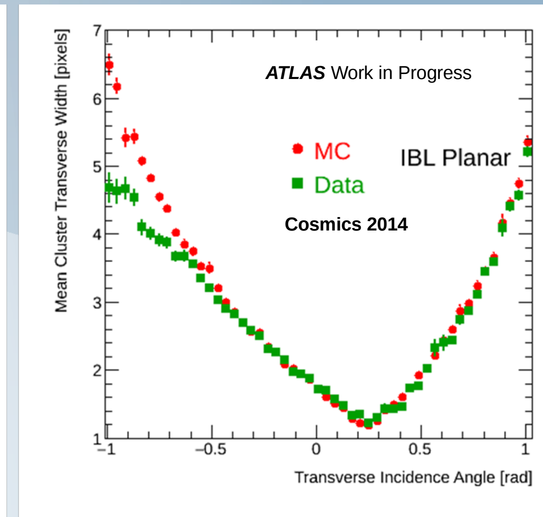




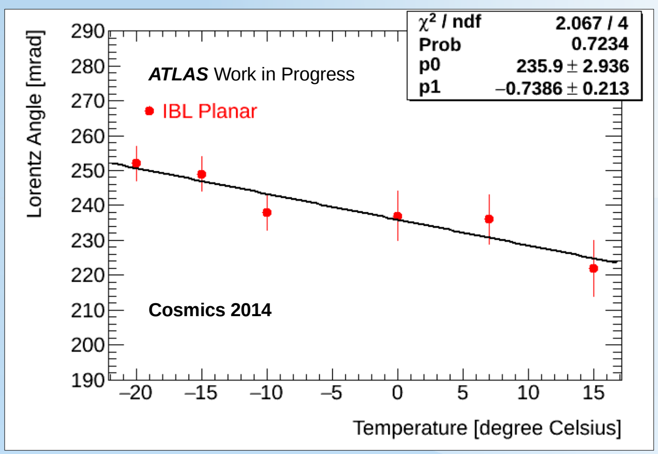
The Lorentz Angle Data/Monte Carlo Comparison

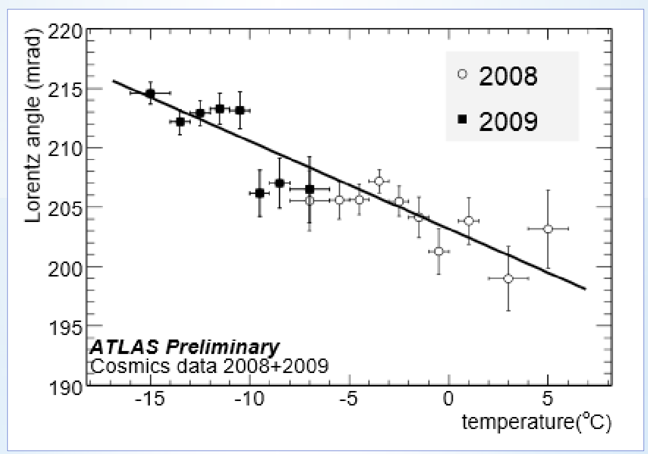
- Data is used to **tune** MC.
- The Lorentz angle MC in Run 1 was scaled by 0.9 to match data. **No additional scaling is needed for Run 2**.
- The source discrepancy between data and MC at large incidence angle for cosmics is **understood** although it is not important for collisions.





IBL Planar Lorentz Angle Vs Temperature





- **Astonishing agreement**:
  - The linear fit slope is **-0.74 ± 0.21** mrad/°C for the **IBL Planar in 2015**.
  - The linear fit slope is **-0.74 ± 0.06** mrad/°C for the **Pixel layers in 2008-2009**.