Disappearing tracks with ATLAS

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https://indico.cern.ch/event/980853/

Disappearing Track

In the pure-wino LSP scenario

$\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$: ~ 160 MeV

$\tau_{\tilde{\chi}_1^{\pm}}$: ~ 0.2 ns

In the pure-higgsino LSP scenario

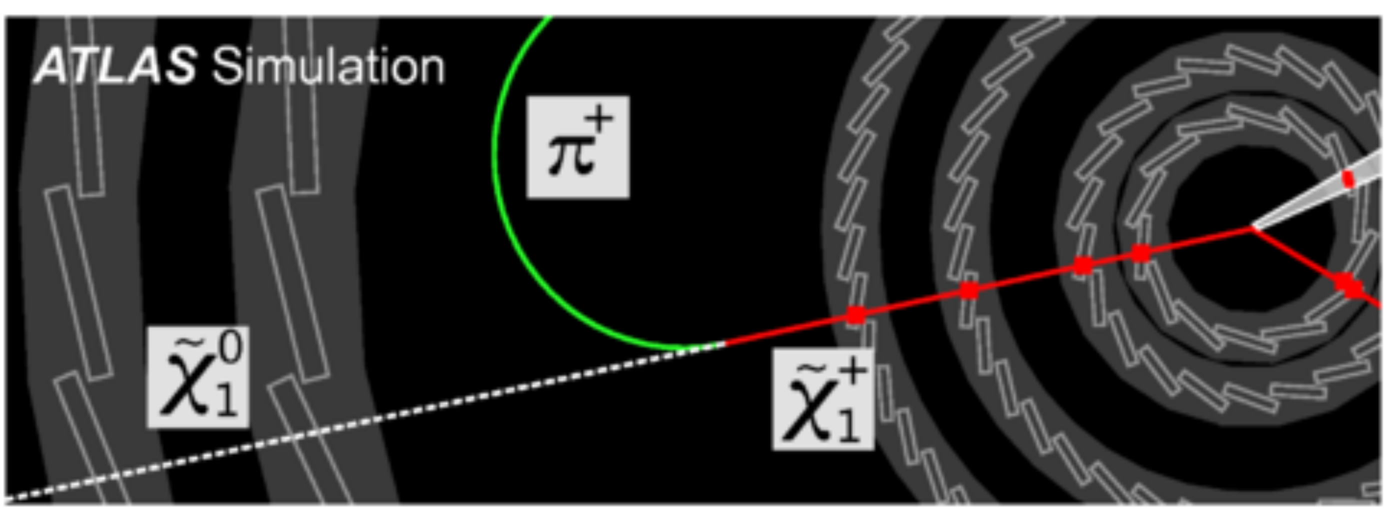
$\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$: ~ 300 MeV

$\tau_{\tilde{\chi}_1^{\pm}}$: ~ 0.04 ns

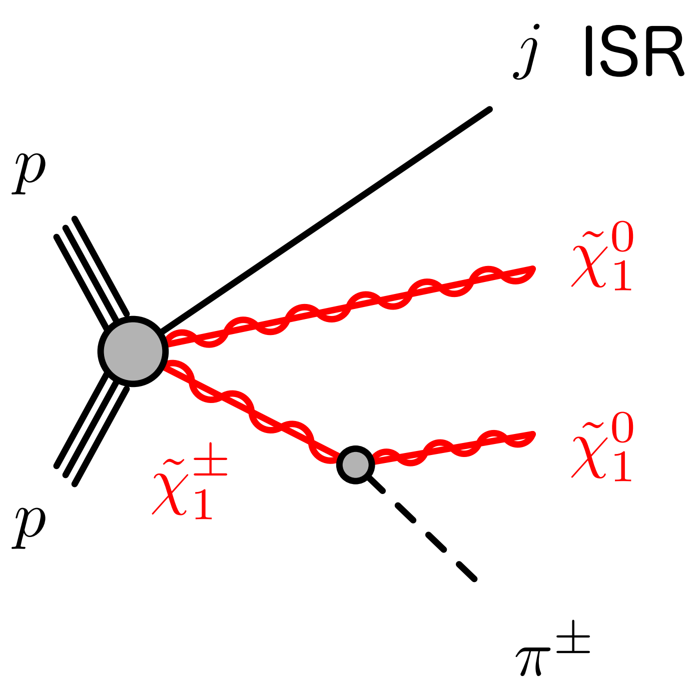
$$\tilde{\chi}_1^{\pm} \longrightarrow \tilde{\chi}_1^0 + \pi^{\pm}$$

leave hits | E_T^{miss} | Undetectable

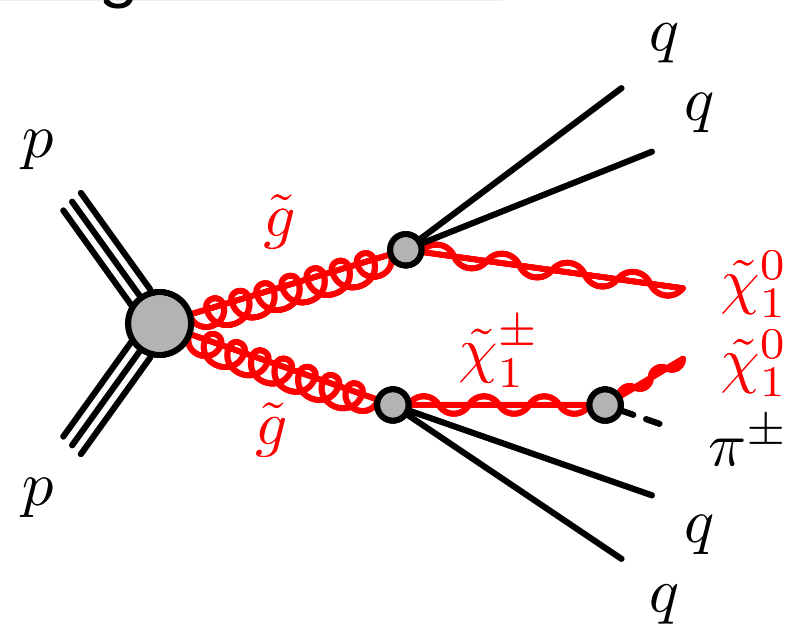
⇒ disappearing track



Electroweak(EWK) Production

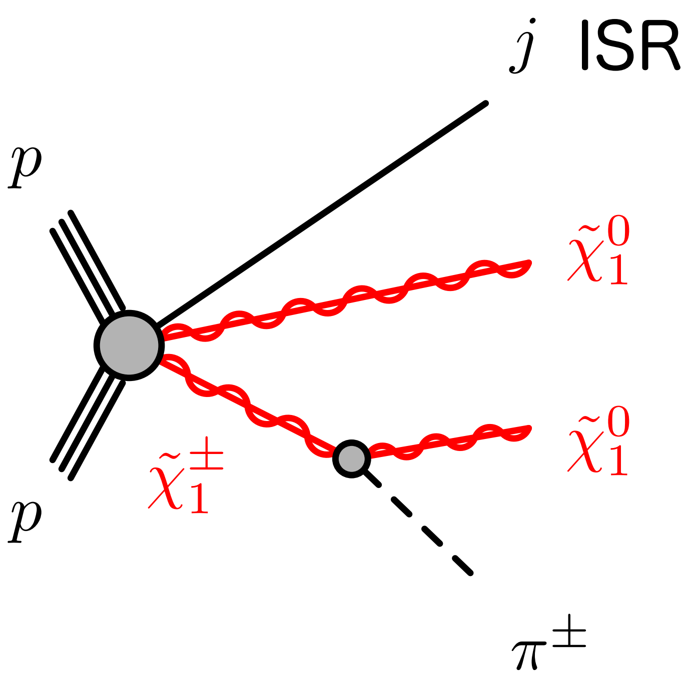


Strong Production

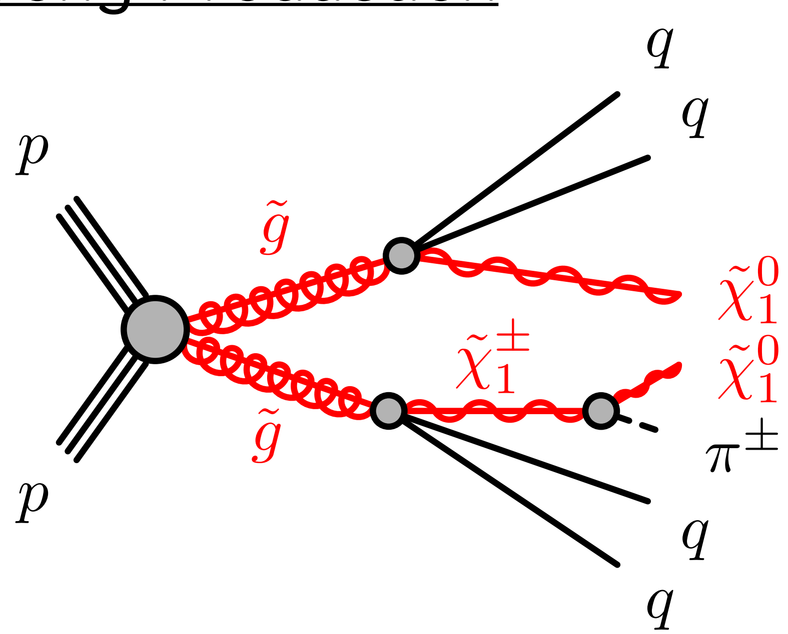


Event Selection

<u>Electroweak(EWK) Production</u>



<u>Strong Production</u>



<u>Common</u>

- Data : 2015 - 2018 (136 fb^{-1})
- Lowest unprescaled E_T^{miss} trigger
- Lepton VETO
- Kinematics

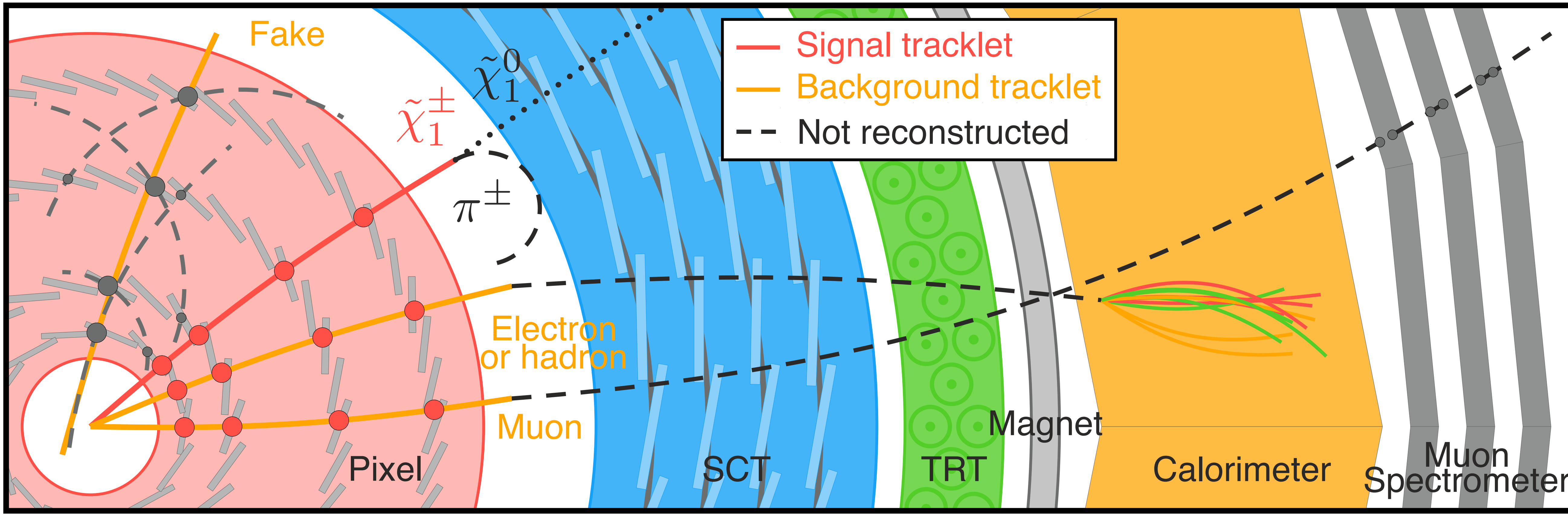
Kinematics	EWK	Strong
E_T^{miss} >	200 GeV	250 GeV
leading Jet p_T	100 GeV	100 GeV
2^{nd} and 3^{rd} Jet p_T	-	20 GeV
$\Delta\phi_{min}$ ($Jet_{1,2,3,4}$, E_T^{miss})	1.0	0.4

- <u>Disappearing track candidates :</u>
  - high quality
  - isolated from other objects
  - high-p_T (> 60 GeV for model-independent analysis)
  - 4-pixel layer tracklet (no SCT hits)
  - low calo-cluster association (< 5 GeV)

    → new requirement for strong BG reduction

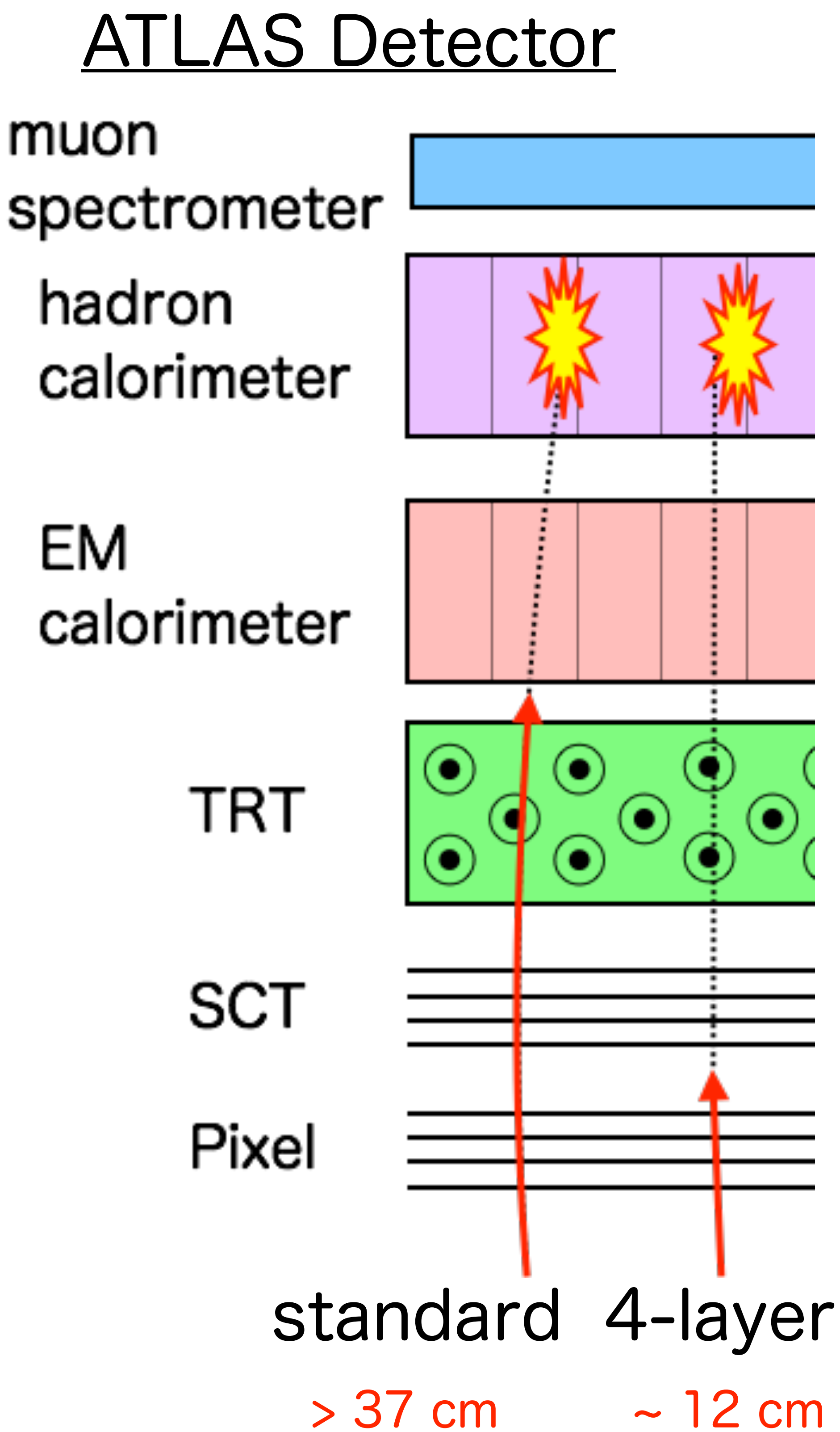
Background Components

Image for signal and background process

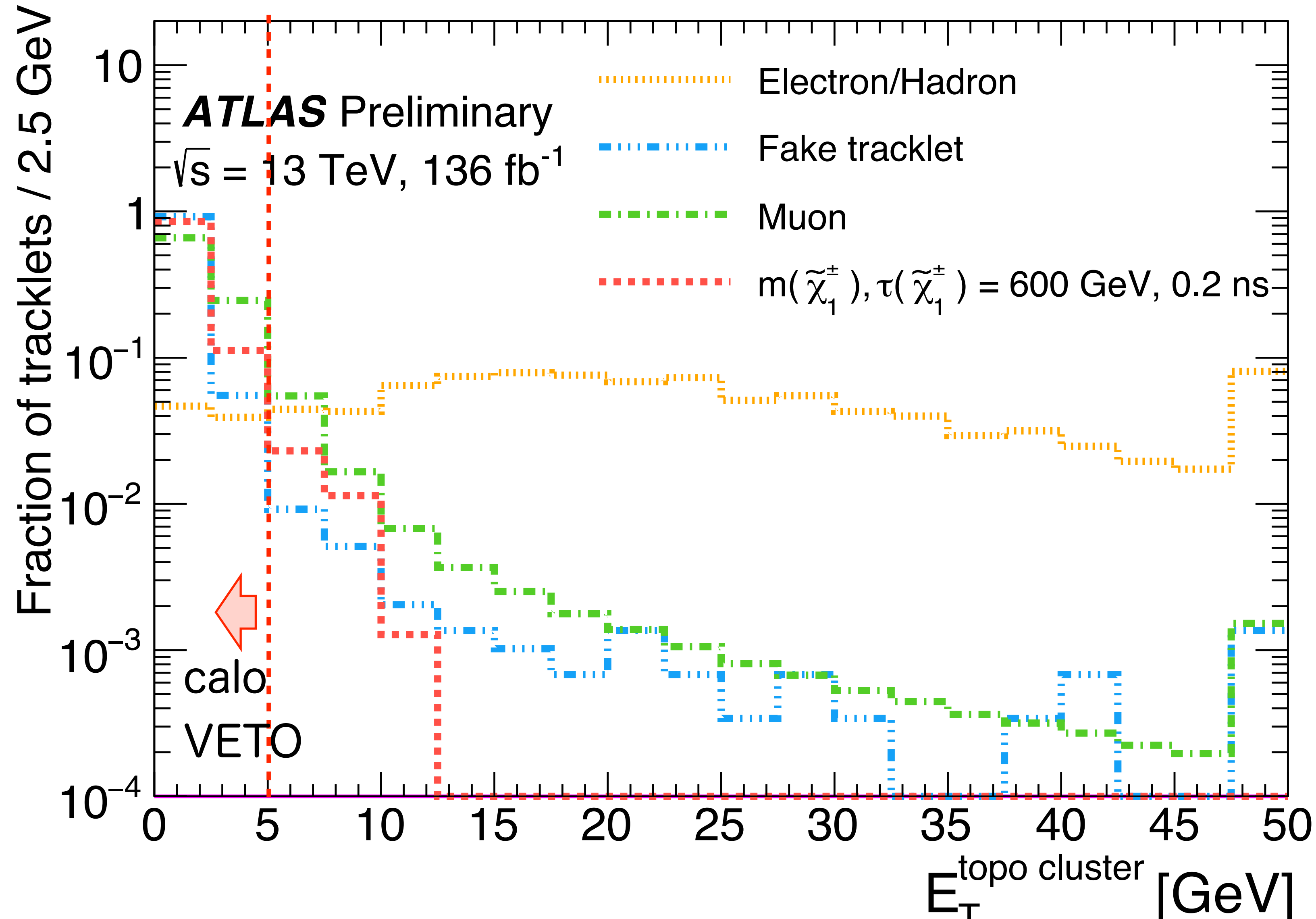


	Causes	Reduction
hadron	scattering	calorimeter VETO
electron	scattering and brems.	calorimeter VETO
muon	scattering and brems.	muon spectrometer VETO
fake	mis-combination of hits	IP cut, track fit quality cut

Calorimeter VETO (new improvement)



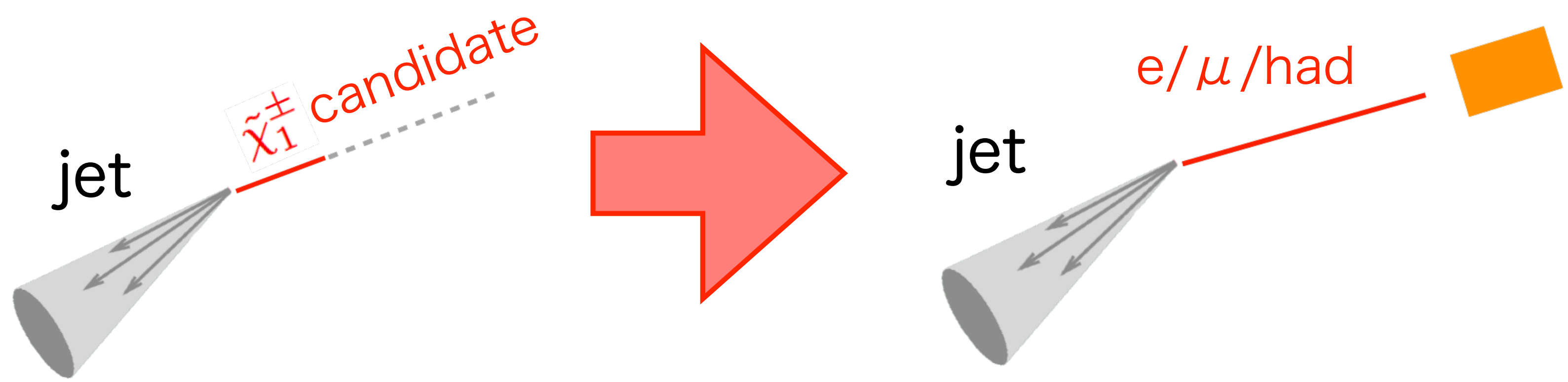
$E_T^{topoclus20}$: sum of energies of topological clusters within $\Delta R < 0.2$ from track(let).



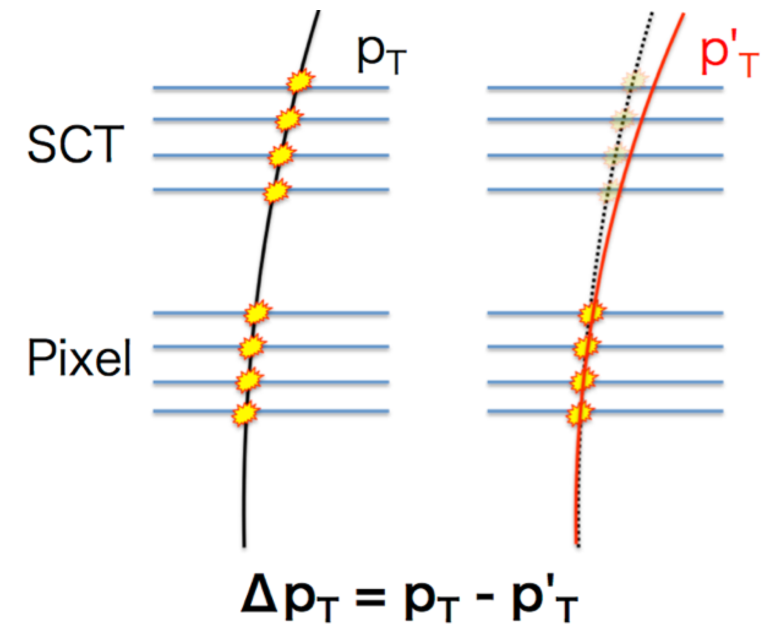
calo-VETO is required to reduce electron and hadron BG

Estimation of Charged-Particle Background

Signal topology CRs for each BG



original track pixel tracklet



$$f^{e}_{SR}(p_T,\eta) = N^{CR}_{e,\mathrm{signal}}(p_T,\eta) \times \mathrm{TF}^{e}_{\mathrm{pixel-only}}(p_T,\eta) \times \mathrm{TF}^{e}_{\mathrm{calo-veto}}(p_T,\eta)$$

$$f^{\mu}_{SR}(p_T,\eta,\phi) = N^{CR}_{\mu,\mathrm{signal}}(p_T,\eta,\phi) \times \mathrm{TF}^{\mu}_{\mathrm{pixel-only}}(p_T,\eta) \times \mathrm{TF}^{\mu}_{\mathrm{noMStrack}}(\eta,\phi)$$

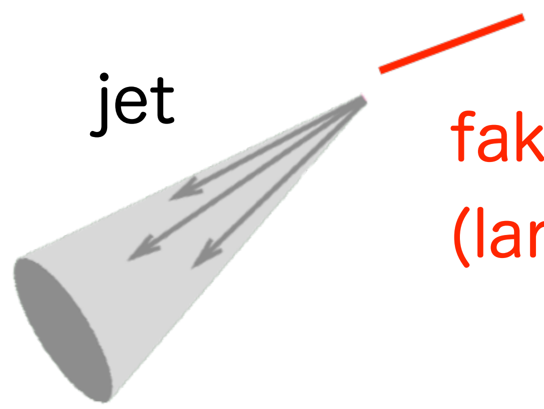
$$f^{\mathrm{had}}_{SR}(p_T,\eta) = N^{CR}_{\mathrm{had}}(p_T,\eta) \times \mathrm{TF}^{e}_{\mathrm{calo-veto}}(p_T,\eta)$$

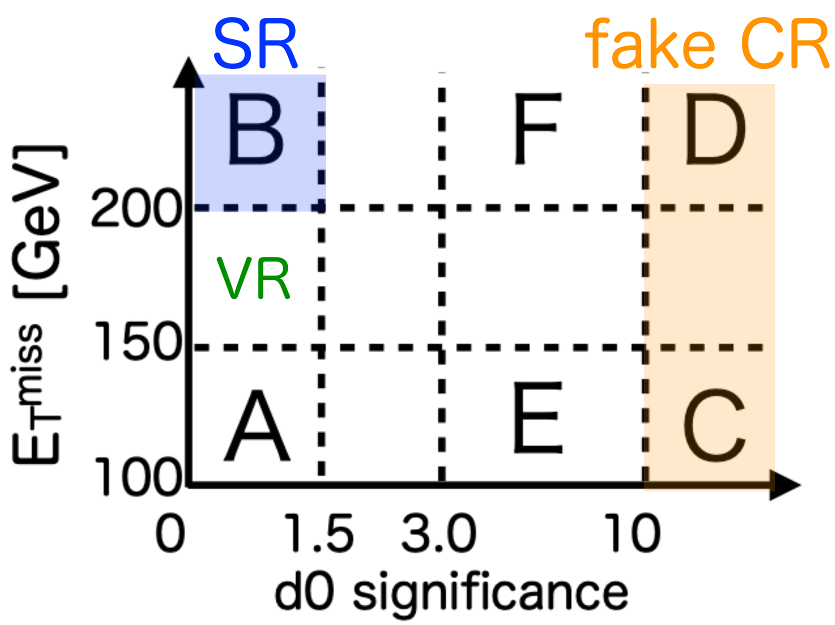
The pT spectra for charged-particle BG are estimated by applying transfer factor(TF) and smearing pT resolution function to the events in CR.
Both TF and the smearing function are measured in data by using Z→ll candidates.

TF - the fraction that the charged-particle is observed as a disappearing track

Smearing function - the resolution function to emulate the pT spectra of pixel tracklet

Estimation of Fake Background



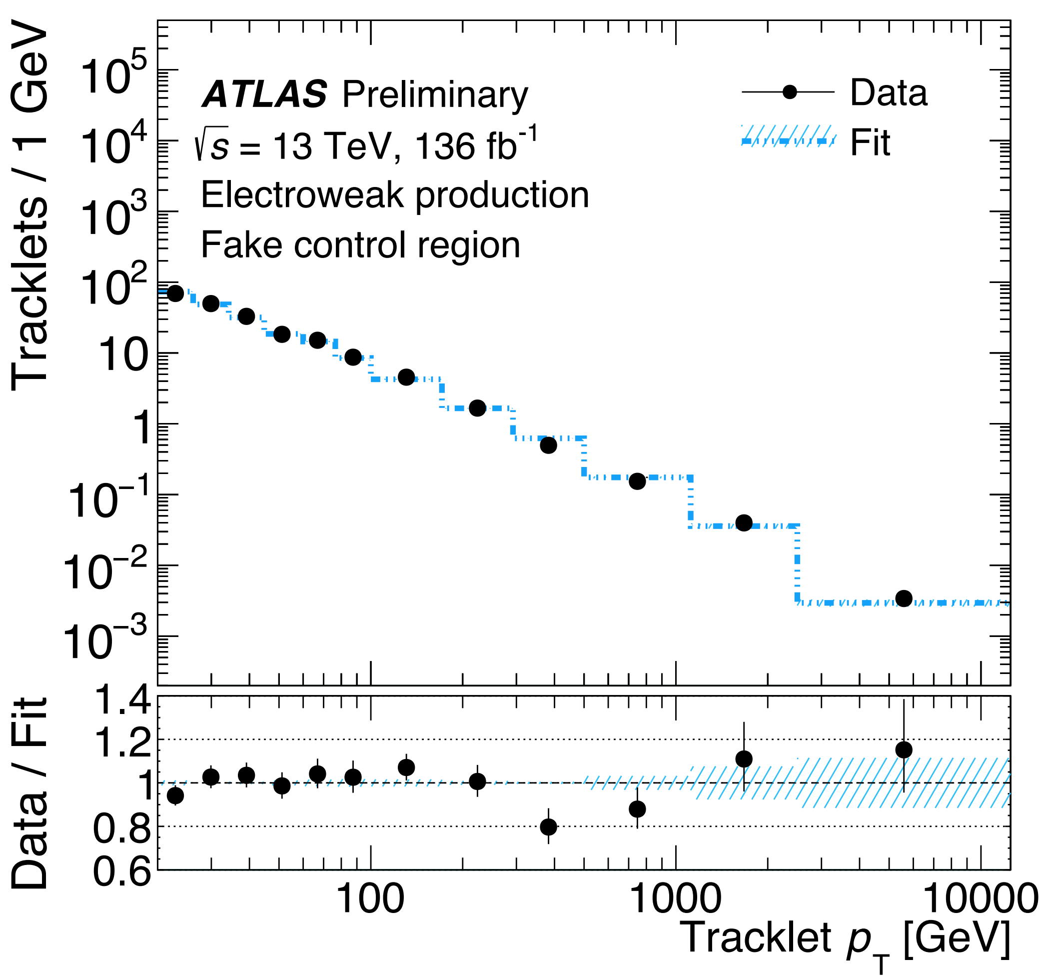


Fake CR selection

- $|d_0|/\sigma(d_0) > 10$
- without E_T^{miss} requirement

fitted by empirical function

$$f(p_T) = \exp\left(-p_0 \cdot \log(p_T) - p_1 \cdot (\log(p_T))^2\right)$$

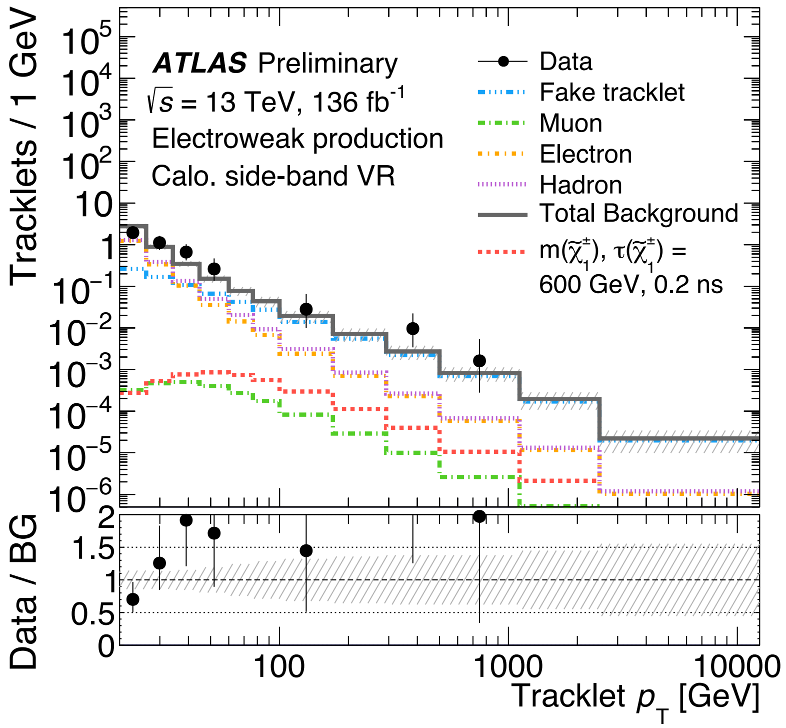


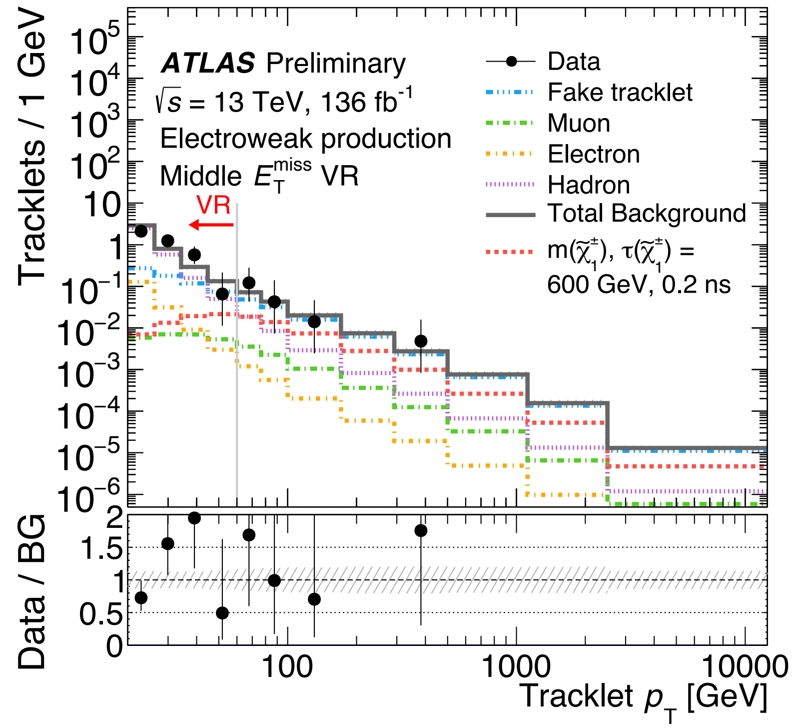
The normalization of fake BG in SR

-> A x (D/C)

The d0 dependence is evaluated by comparing F/E and D/C.

Background-only Fitting Results in VR



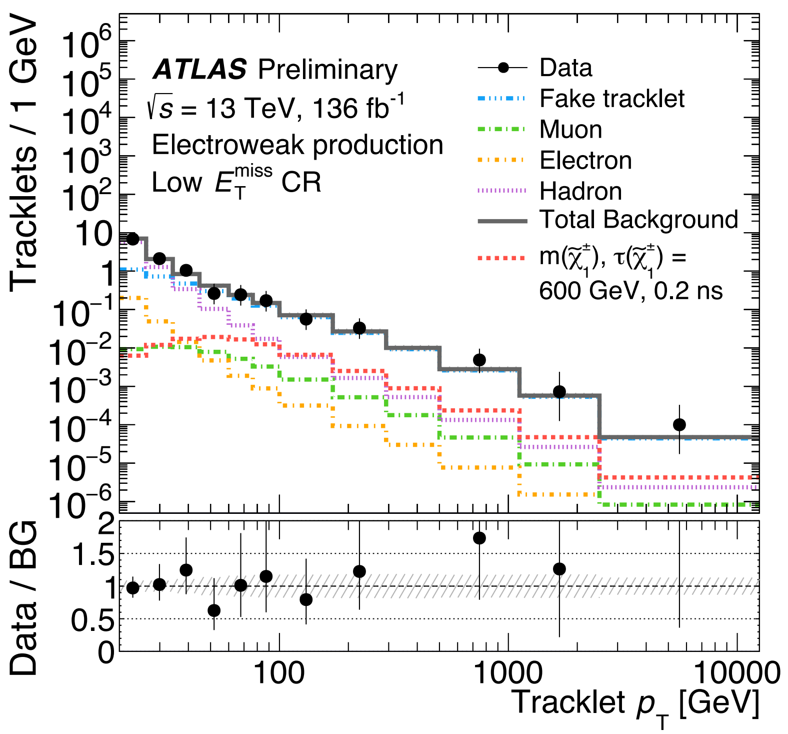


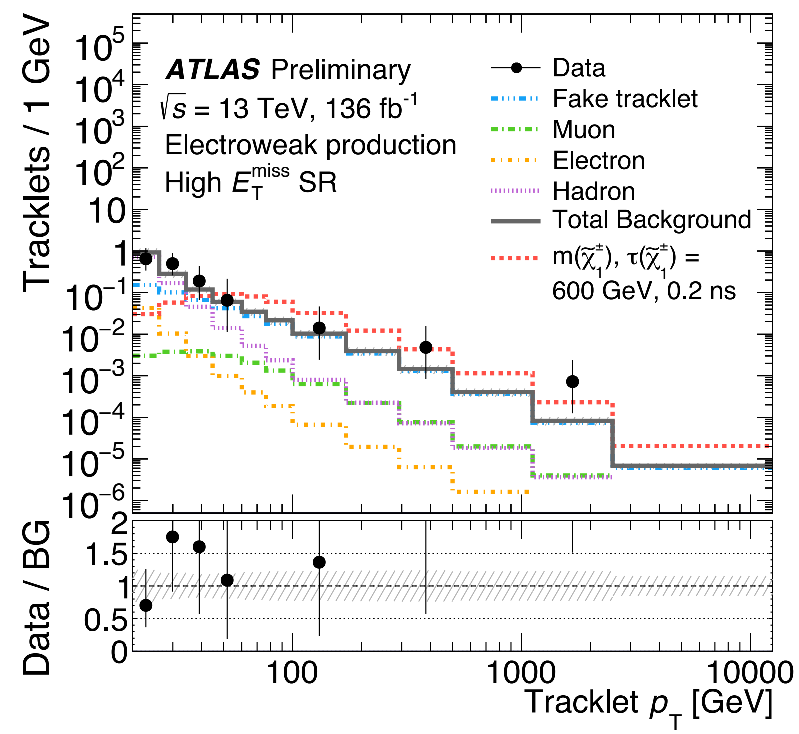
Observed events are fitted with background spectra.

	Electroweak channel		Strong channel	
	Middle-E_T^{miss} VR			
	Calo side-band $p_T > 60$ GeV	Low p_T $p_T < 60$ GeV	Calo side-band $p_T > 60$ GeV	Low p_T $p_T < 60$ GeV
Fake	4.3 ± 2.2	5.5 ± 1.5	3.2 ± 1.5	3.5 ± 1.0
Hadron	1.0 ± 0.8	23 ± 6	0.36 ± 0.23	13 ± 4
Electron	0.8 ± 0.5	1.2 ± 1.3	0.29 ± 0.20	0.5 ± 0.5
Muon	0.023 ± 0.007	0.25 ± 0.06	0.012 ± 0.004	0.129 ± 0.032
Total Expected	6.1 ± 1.9	29 ± 5	3.8 ± 1.5	17 ± 4
Observed	5	30	3	18
signal contami.	1.6%	2.3%	< 0.1%	4.5%

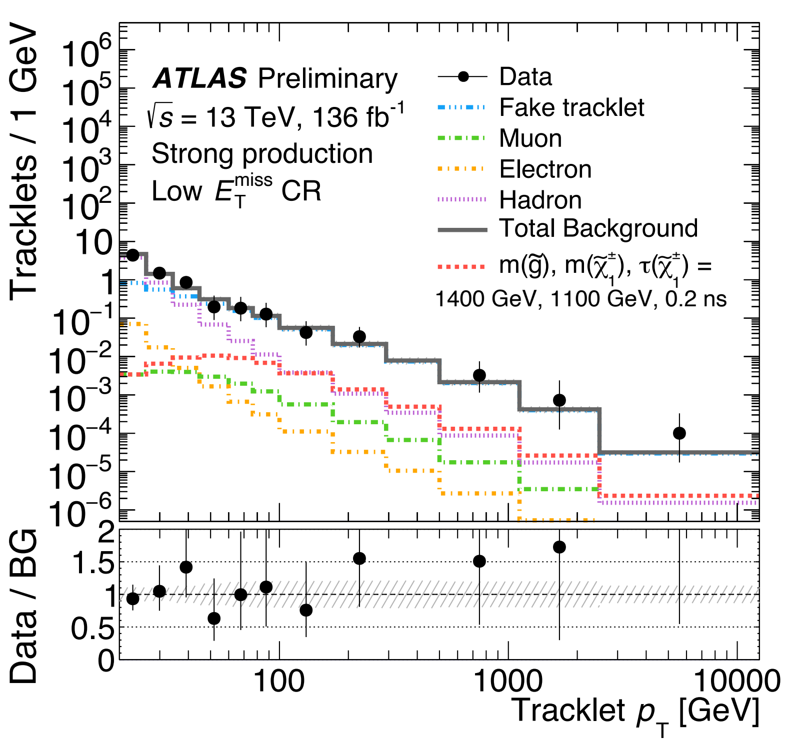
Good agreement between expected and observed events.

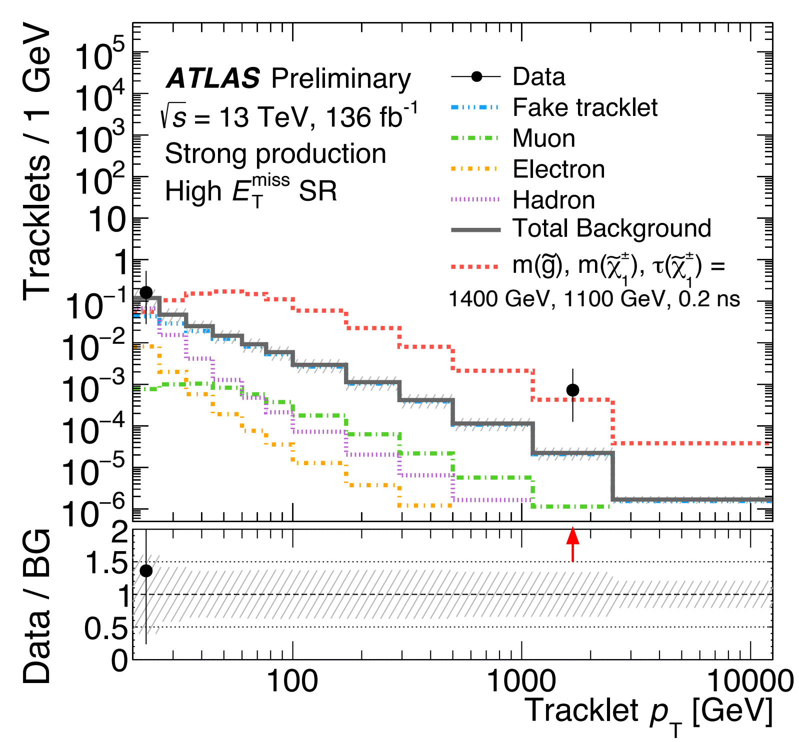
Background-only Fitting Results





	Electroweak channel	Strong channel
	High-E_T^{miss} SR	
Fake	2.6 ± 0.8	0.77 ± 0.33
Hadron	0.26 ± 0.13	0.024 ± 0.031
Electron	0.021 ± 0.023	0.004 ± 0.004
Muon	0.17 ± 0.06	0.049 ± 0.018
Total Expected	3.0 ± 0.7	0.84 ± 0.33
Observed	3	1
p_0 (Z)	0.5 (0)	0.38 (0.30)
Observed $\sigma_{vis^{95\%}}$ [fb]	0.037	0.028
Expected $\sigma_{vis^{95\%}}$ [fb]	$0.038\,^{+0.014}_{-0.009}$	$0.024\,^{+0.009}_{-0.003}$





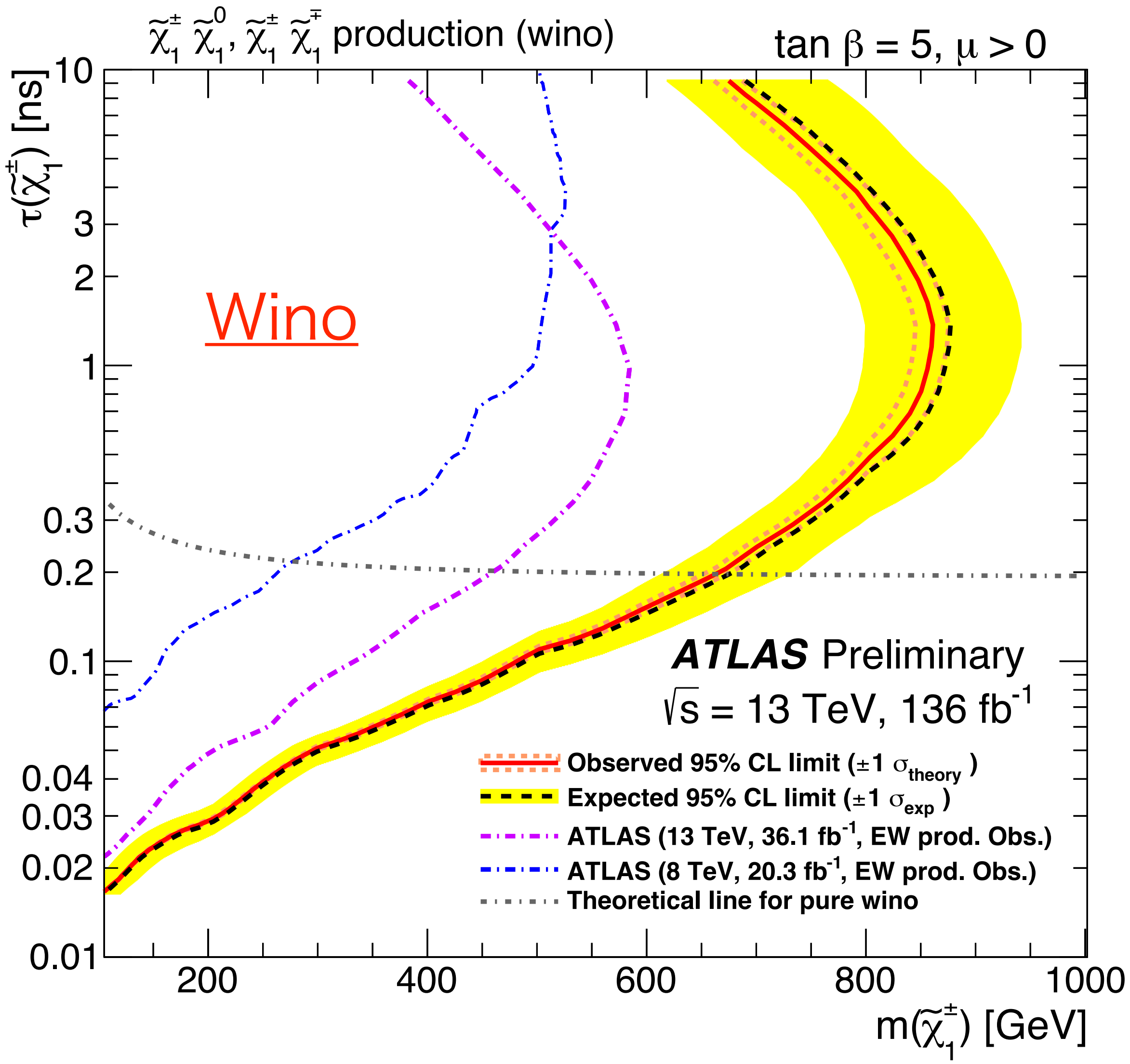
The upper limit on the model-independent visible cross-section at 95% C.L. is also calculated from the expected and observed event yields in high-MET && high-pT SR.

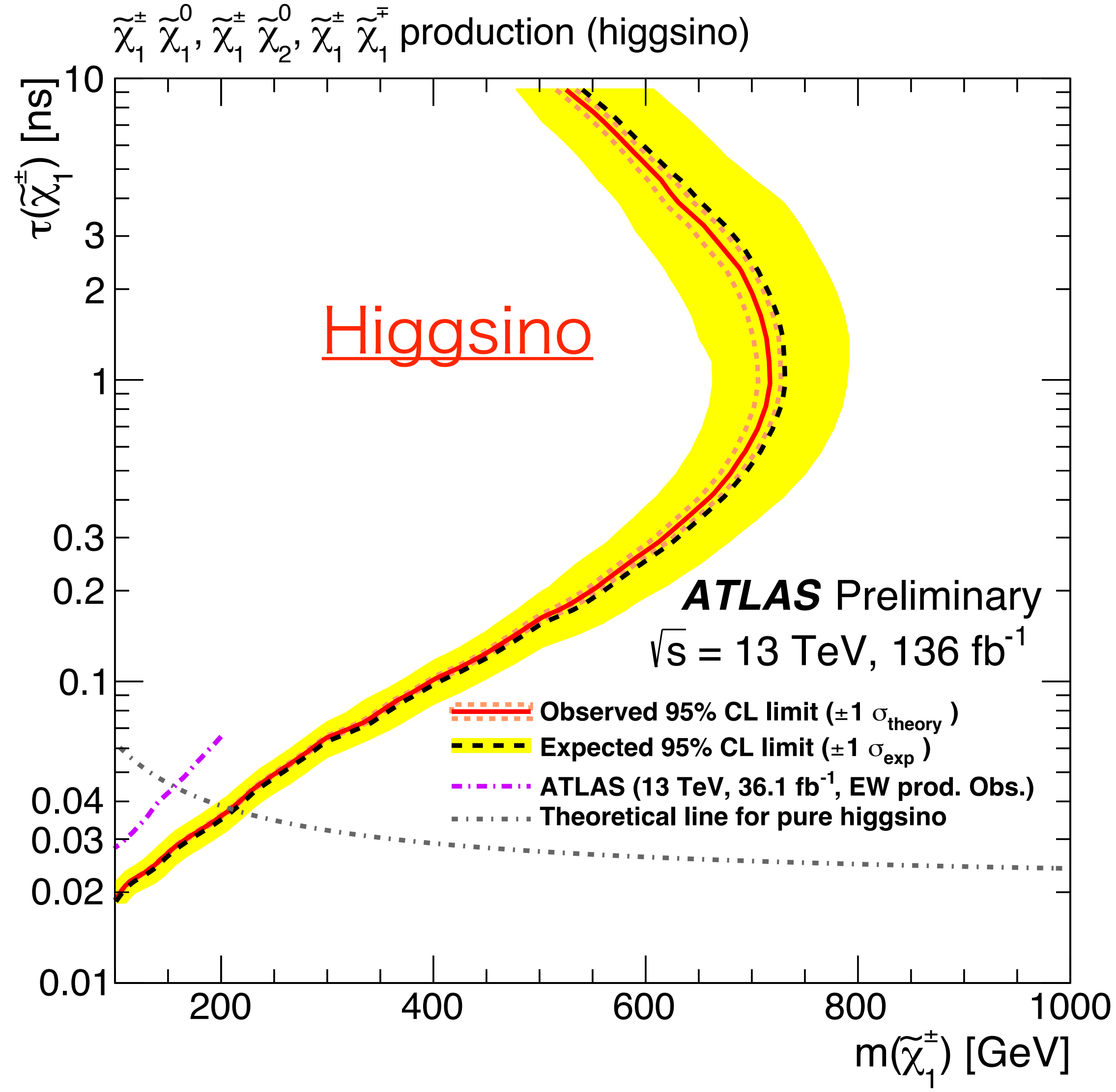
fake BG is dominant in high-pT region

no significant excess

Observed Limit (EWK channel)

Chargino Mass vs Lifetime



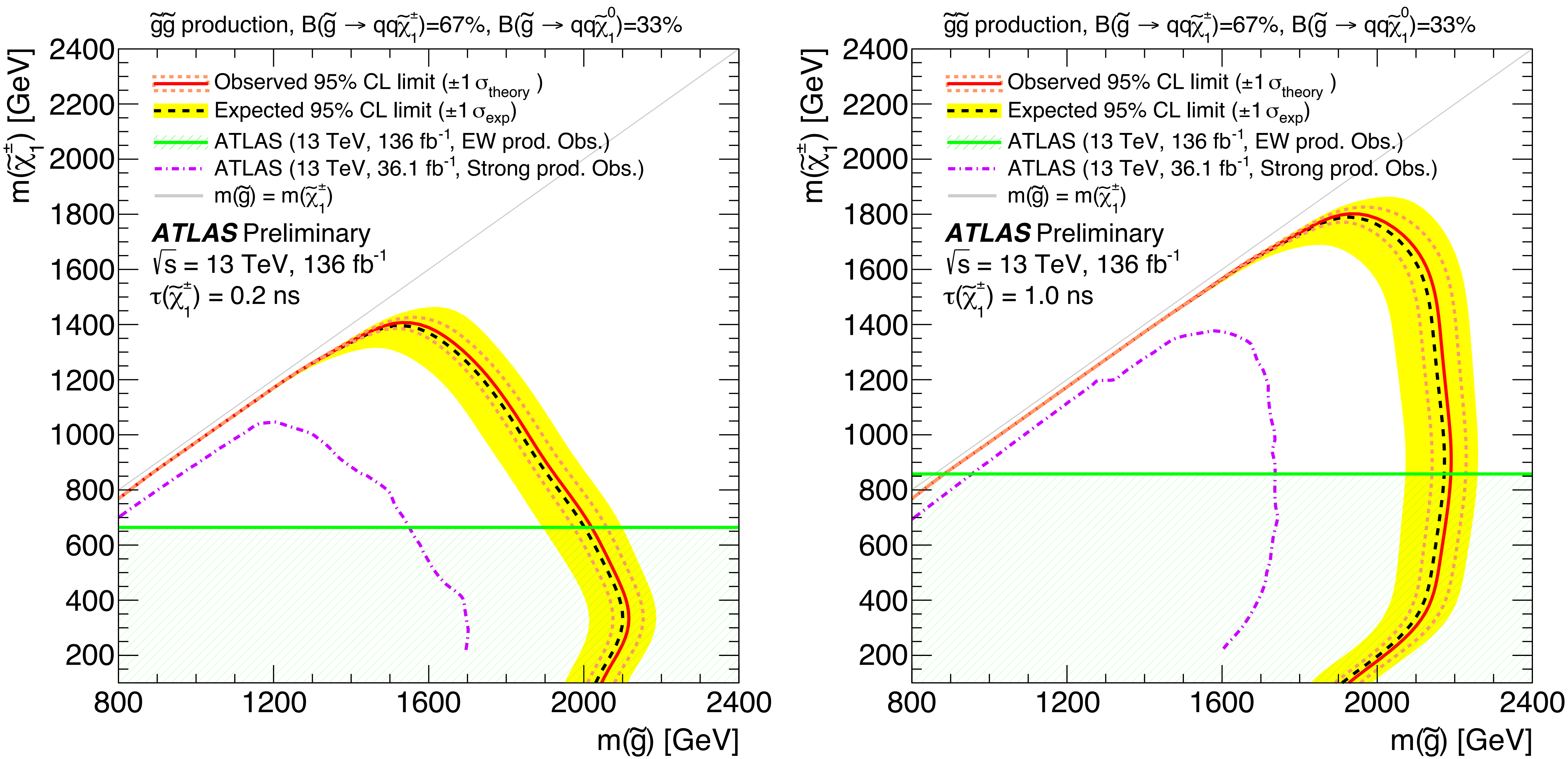


Mass reach at theoretical line

	Wino	Higgsino
previous	460 GeV	155 GeV
this work	**660 GeV**	**209 GeV**

Great improvements of sensitivities are achieved thanks to calorimeter VETO

Observed Limit (Strong channel)



	chargino mass [TeV]	gluino mass [TeV]
previous @ 0.2 ns (1.0 ns)	1.05 (1.35)	1.70 (1.75)
this work @ 0.2 ns (1.0 ns)	**1.40 (1.80)**	**2.10 (2.20)**

Summary

- Search for long-lived charginos based on a disappearing track signature with full Run2 dataset is performed
- Great improvements of sensitivities are achieved thanks to calorimeter VETO
- We are planning to perform 2nd full Run2 analysis with several improvements
  - track reconstruction algorithm
  - shorter / longer track(let)
  - background rejection