In-flight-decay of $\widetilde{\tau}$ in the LHC tracker

[arXiv:1103.1881] With S. Asai, Y. Azuma, M. Endo and K. Hamaguchi.

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Background

$\widetilde{\tau}$ = Long Lived??? ⟹ How to detect???

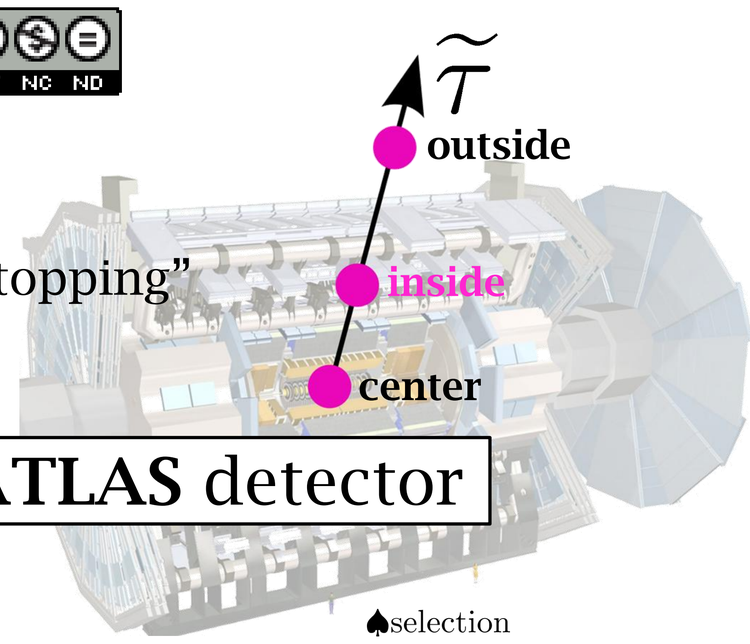
- $\widetilde{\tau}$ LSP + tiny R-parity viol.
- $\widetilde{G}$ LSP + $\widetilde{\tau}$ NLSP
- Axion LSP + $\widetilde{\tau}$ NLSP etc...

Decay @ center → usual analysis

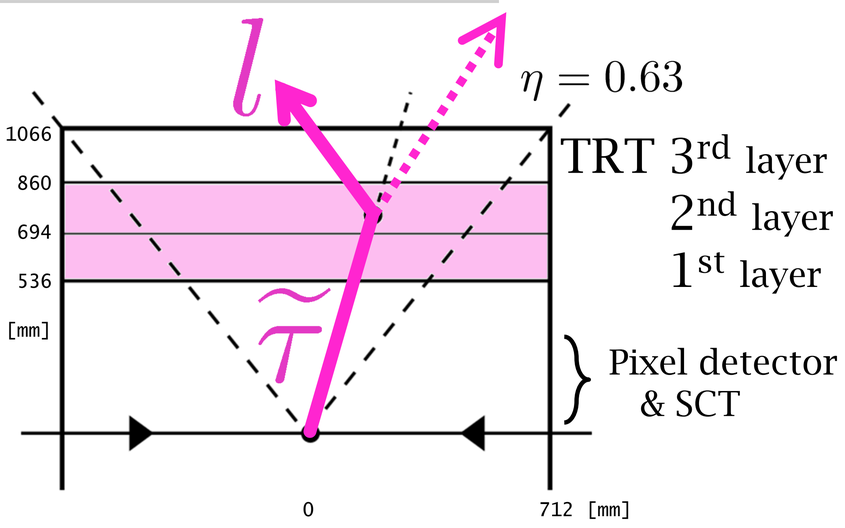
Decay outside → “heavy muon” “stopping”

Decay inside → ???????

→ **Kink Tracks** in **ATLAS** detector



Kink tracks



Kink detection
= stau track id. @ pixel/SCT
+ daughter track id. @ TRT 3rd

What is the daughter?

$\widetilde{G}$-LSP model : $\widetilde{\tau} \to \tau + \widetilde{G}$

RpV $(L_iL_j\bar{E}_k)$: $\widetilde{\tau} \to (e, \mu, \tau) + \nu$
(depending on i, j, k)

Daughter identification
→ **Model discrimination!**

♠selection

trigger : 1jet(120GeV)
& $\not{E}_{\rm T}(100\,{\rm GeV})$

$\widetilde{\tau}$: $\eta < 0.63$,
$P_{\rm T} > 100\,{\rm GeV}$

kink : at TRT 1st or 2nd,
0.1 <angle< $\pi/2$

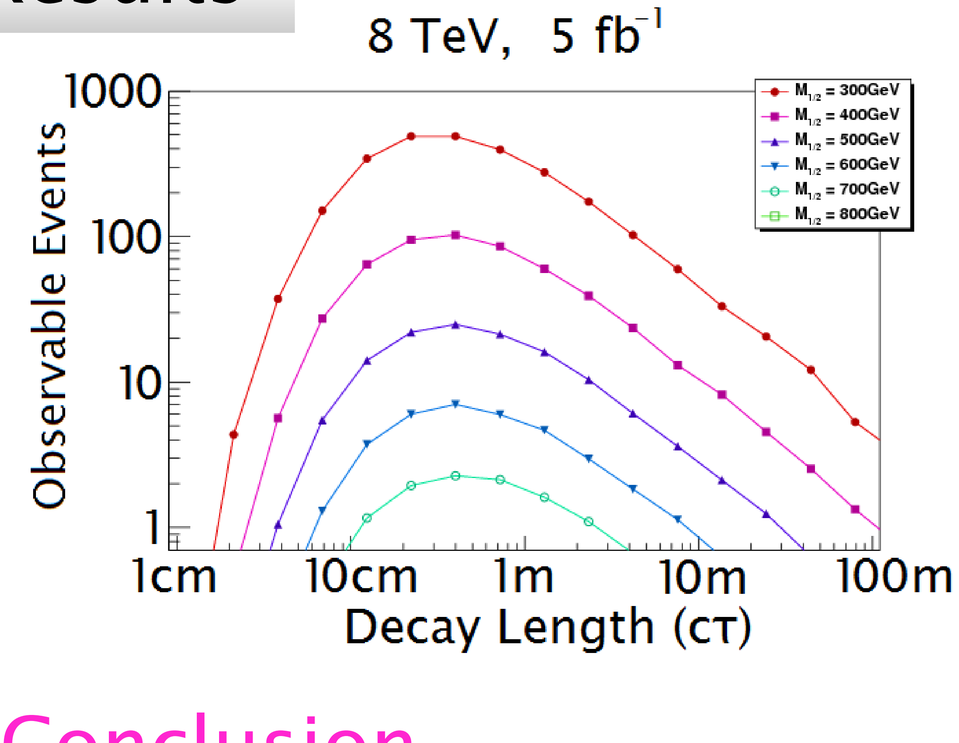
daughter : $P_{\rm T} > 10\,{\rm GeV}$,
not escape to end-cap

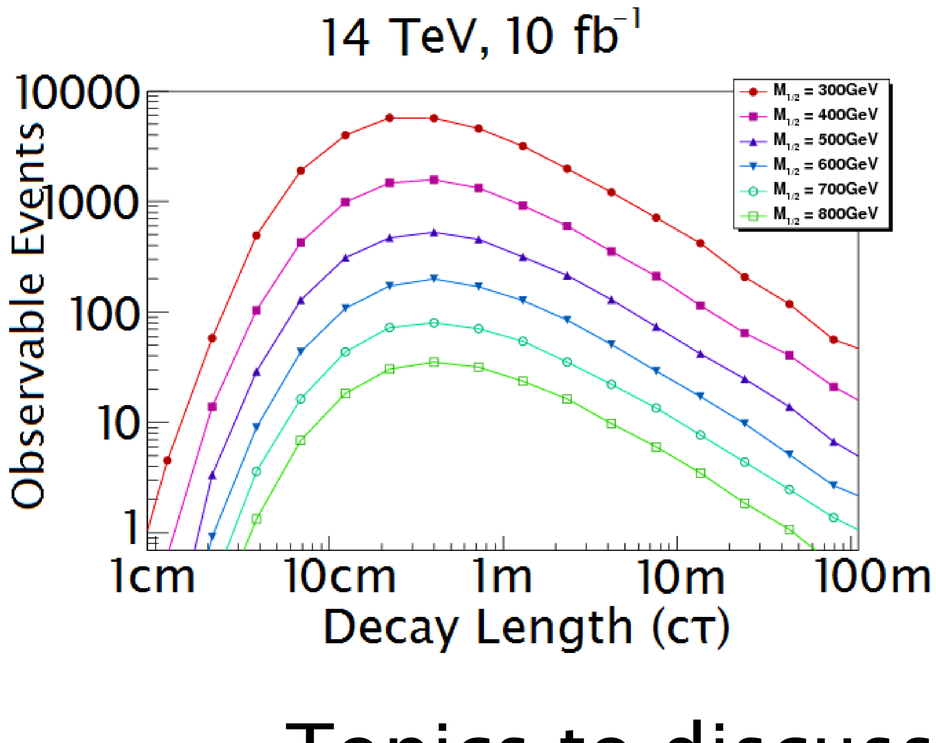
♠decay length $c\tau$ ($m_{\widetilde{\tau}} = 200\,{\rm GeV}$)

$\widetilde{G}$: $\left(\frac{m_{\widetilde{\tau}}^5}{48\pi M_{\rm pl}^2 m_{3/2}^2}\right)^{-1} \simeq 0.55\,{\rm m}$ @$m_{3/2} = 1\,{\rm keV}$

RpV : $\left(\frac{\lambda_{\rm eff}^2}{16\pi} m_{\widetilde{\tau}}\right)^{-1} \simeq 0.50\,{\rm m}$ @$\lambda_{\rm eff} = 10^{-8}$

Results





♠benchmark point
mSUGRA like,
$M_0 = A_0 = 0$,
$\tan\beta = 13$, $\mu > 0$

♠masses

$M_{1/2}$	$\widetilde{\tau}$	$\widetilde{g}$
300 :	103,	715
400 :	140,	932
500 :	176,	1145
600 :	212,	1355
700 :	248,	1562
800 :	283,	1768

Conclusion

We can see kinks for $c\tau \sim 1\,{\rm cm}$–$100\,{\rm m}$.

$\left(\begin{array}{ll} \text{For } \widetilde{G} \text{ model :} & m_{3/2} \sim 0.1\text{–}10\,{\rm keV} \\ \text{For RpV model :} & \lambda \sim 10^{-9}\text{–}10^{-7} \end{array}\right)$

Model discrimination is possible
by identifying daughter species (e, μ, τ).

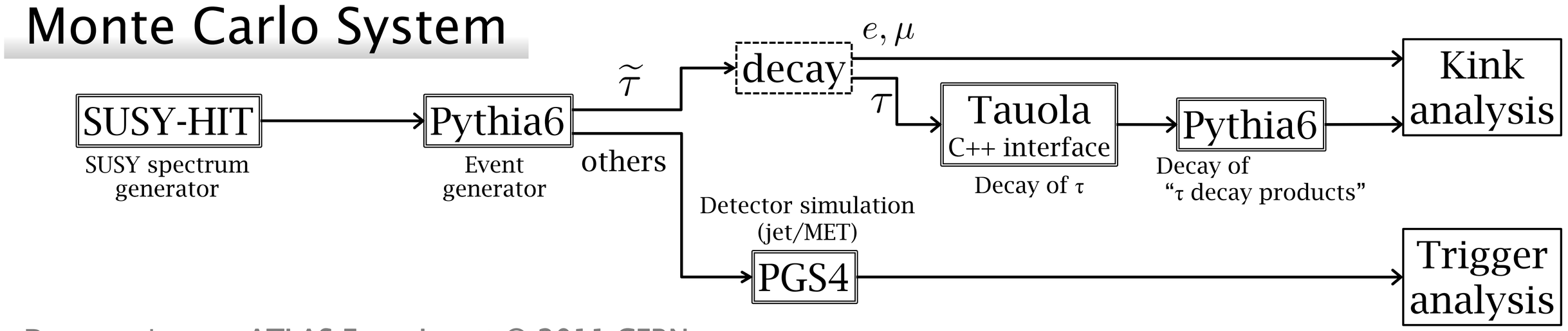
Topics to discuss with you ;-)

Theoretical
- ◆Model discrimination in detail
- ◆Other RpV modes (*LQD*, bilinear)
- ◆For other Long-lived particles

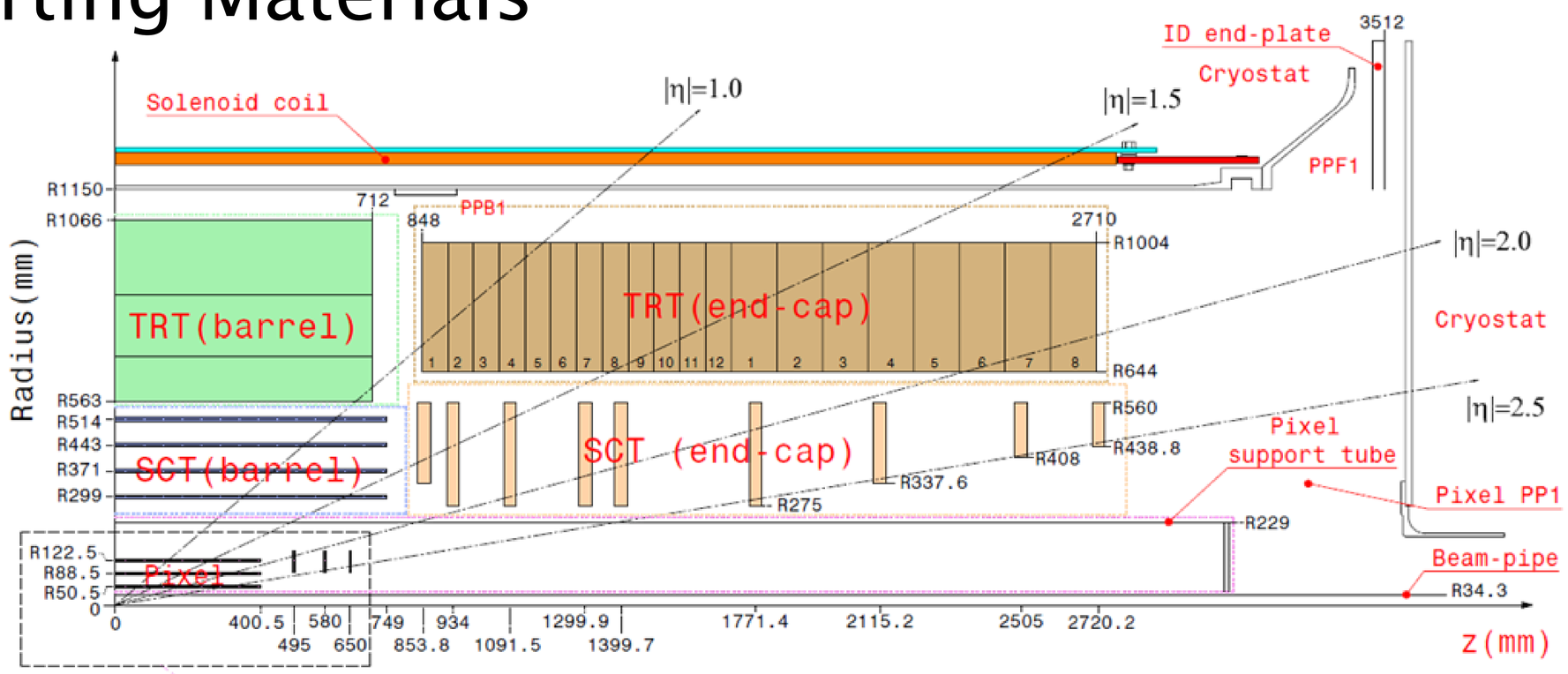
Experimental
- ◆Trigger
- ◆Background (hadrons, noise, …)

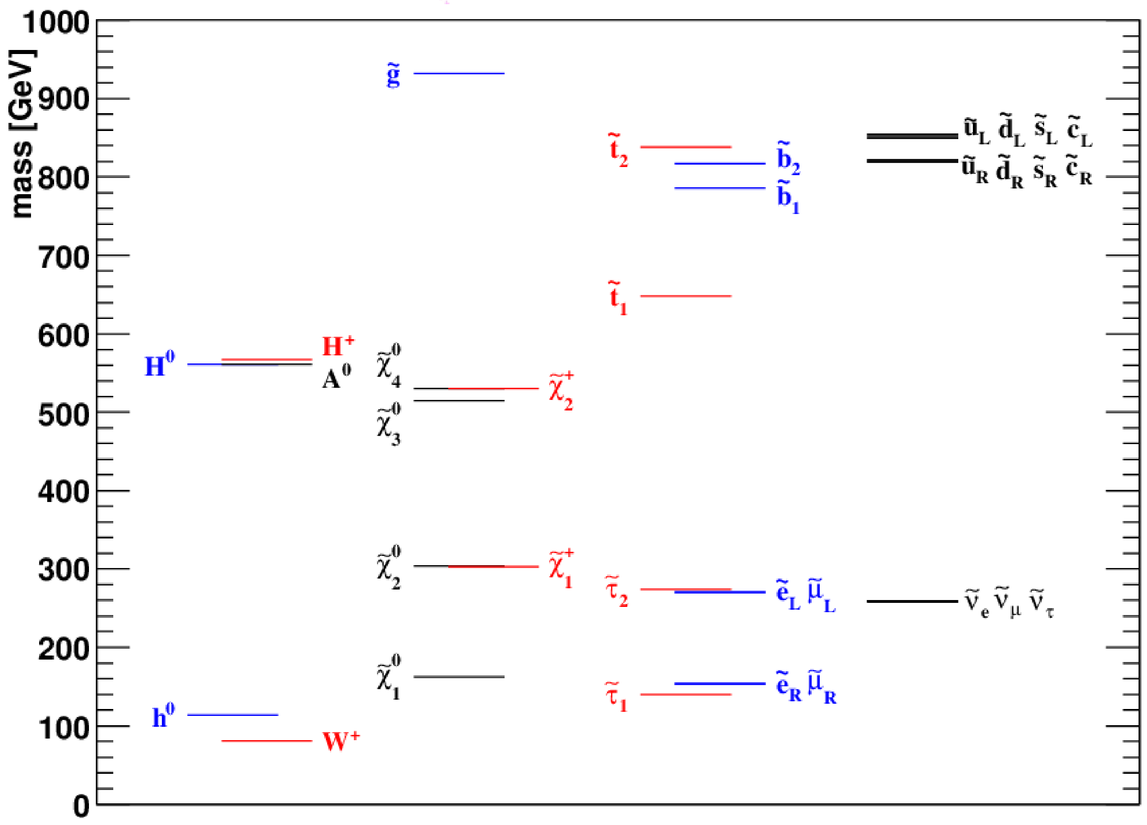
Technical
- ◆Monte Carlo system & coding

Monte Carlo System



Supporting Materials





Mass spectrum for $M_{1/2} = 400\,\mathrm{GeV}$. (BC1 benchmark point)

$\underline{\lambda_{123}}$ $\widetilde{\tau} \to (e,\mu) + \nu$ with $1:1$; $\Gamma_{\rm tot} = \dfrac{(\lambda \sin\theta)^2}{8\pi} m_{\widetilde{\tau}}$.

$\underline{\lambda_{i33}}$ $\widetilde{\tau} \to (\tau, l_i)$ with $1:\sin^2\theta$; $\Gamma_{\rm tot} = \dfrac{\lambda^2(1+\sin^2\theta)}{16\pi} m_{\widetilde{\tau}}$.

$\underline{\lambda_{i3k}}$ $\widetilde{\tau} \to l_k \nu$; $\Gamma_{\rm tot} = \dfrac{(\lambda \cos\theta)^2}{16\pi} m_{\widetilde{\tau}}$.

$\underline{\lambda_{121}, \lambda_{122}}$ Stau decays into 4-body.

$$\lambda_{\rm eff} = \begin{cases} \lambda_{123}\sqrt{2}\sin\theta & \text{for } \lambda_{123}, \\ \lambda_{i3k}\cos\theta & \text{for } \lambda_{131}, \lambda_{132}, \lambda_{231}, \lambda_{232}, \\ \lambda_{i33}\sqrt{1+\sin^2\theta} & \text{for } \lambda_{133}, \lambda_{233}. \end{cases}$$

RpV decay modes, and definition of $\lambda_{\rm eff}$.
θ is the mixing angle; $\widetilde{\tau}_1 = \widetilde{\tau}_{\rm L}\cos\theta + \widetilde{\tau}_{\rm R}\sin\theta$.

Cut flow for $c\tau = 400\,\mathrm{mm}$, $M_{1/2} = 400\,\mathrm{GeV}$. (BC1 benchmark point)
I, II, III for a e/μ daughter, and I, II′, III′ for a τ daughter.
Trigger efficiency ($> 90\%$) is not included.
Daughter reco eff is included.

		$7\,\mathrm{TeV}, 2\,\mathrm{fb}^{-1}$	$8\,\mathrm{TeV}, 5\,\mathrm{fb}^{-1}$	$14\,\mathrm{TeV}, 10\,\mathrm{fb}^{-1}$
I	total SUSY event	673 events	2832 events	42463 events
	triggered event	426 events	1938 events	36240 events
II	$\widetilde{\tau}$ track	852	3876	72480
	$\lvert\eta(\widetilde{\tau})\rvert < 0.63$	409	1748	28535
	$P_{\rm T}(\widetilde{\tau}) > 100\,\mathrm{GeV}$	378	1641	26642
	$\widetilde{\tau}$ decay in TRT 1st/2nd	67	230	3642
	kink $0.1 < \Delta\phi < \pi/2$	46	179	2601
	daughter reconstructed	28	101	1586
III	event with 1 or 2 kink	24 events	100 events	1563 events
	event with 2 kinks	4 events	1 event	23 events

for the case where the stau emits τ:

II′	separation $0.1 < \Delta\phi < \pi/2$	52	189	2805
	daughter reconstructed	26	95	1391
III′	event with 1 or 2 kink	24 events	92 events	1374 events
	event with 2 kinks	2 events	3 events	17 events

$M_{1/2}$ (GeV)	Cross section (fb)	
	8 TeV	14 TeV
300	2.95×10^3	1.81×10^4
400	556	4.22×10^3
500	143	1.31×10^3
600	44.5	472
700	17.8	194
800	6.12	87.1

$M_{1/2}$ (GeV)	Masses (GeV)	
	$\widetilde{\tau}$	$\widetilde{g}$
300	103	715
400	140	932
500	176	1145
600	212	1355
700	248	1562
800	283	1768

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Reference: Shoji Asai, Yuya Azuma, Motoi Endo, Koichi Hamaguchi and S.I., *Stau Kinks at the LHC*, submitted. [arXiv: 1103.1881]