

Overlay-only events in $\tilde{\tau}$ studies

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- Beam induced backgrounds in e+e- colliders
- Motivation for overlay-only analysis
- Rejection on overlay-only events
 - search for independent cuts
 - search for additional cuts
- Outlook and conclusions

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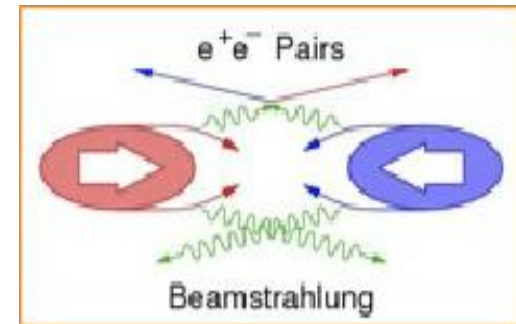


Beam induced backgrounds in e^+e^- colliders

e^+e^- beams are accompanied by real (beamstrahlung) and virtual (Weizsäcker-Williams process) photons

Interactions between real and/or virtual photons produce:

- e^+e^- pairs
 - produced by scattering of two real photons
 - 10^5 pairs per bunch crossing
 - very low p_T ($< 1\text{GeV}$), curl up in magnetic field, interesting for beamCal studies
- low p_T hadrons
 - produced by vector meson fluctuations of real or virtual photons
 - $\langle 1.05 \rangle$ events per bunch crossing at $\sqrt{s} = 500\text{ GeV}$
 - low p_T , travelling through the detector



Motivation for only-overlay events analysis

$\gamma\gamma$ interactions are independent of the e^+e^- process, but can happen simultaneously to it (overlay-on-physics events) or not (overlay-only events)

- Overlay-only events: $\sim 10^3$ per train
($\langle 1.05 \rangle$ low p_T hadrons + ~ 1 seeable e^+e^- pair)/BX
- SM background: ~ 1 per train
- Signal: $\sim 10^{-6}$ per train

Overlay-only events are $\sim 10^3$ times higher than any SM background included in the analysis

A suppression stronger than 10^{-9} is needed to make the background from overlay-only events negligible

Motivation for only-overlay events analysis (ctd.)

$\gamma\gamma \rightarrow \text{low } p_T \text{ hadrons}$ similar to visible products from $\tilde{\tau}$ production for small (≤ 10 GeV) LSP- $\tilde{\tau}$ mass differences

Overlay-only events can be misidentified as signal events

Analysis strategy:

- identify a set of **independent** cuts (not enough statistics to get the suppression by sequential cuts)
- compute **total rejection factor** as the **product of the factors** obtained with either of these cuts
- study of two different mass differences between $\tilde{\tau}$ and LSP masses (2 and 10 GeV)

Sample overlay-only events:

- extracted from the standard “IDR” production
- $\gamma\gamma$ interactions generated by Pythia 6.442 ($M_{\gamma\gamma} > 2$ GeV) or a dedicated generator (arxiv: hep-ph/9305247) ($M_{\gamma\gamma} \leq 2$ GeV)

Effect of cuts on overlay-only events

Rejection “standard” cuts alone:

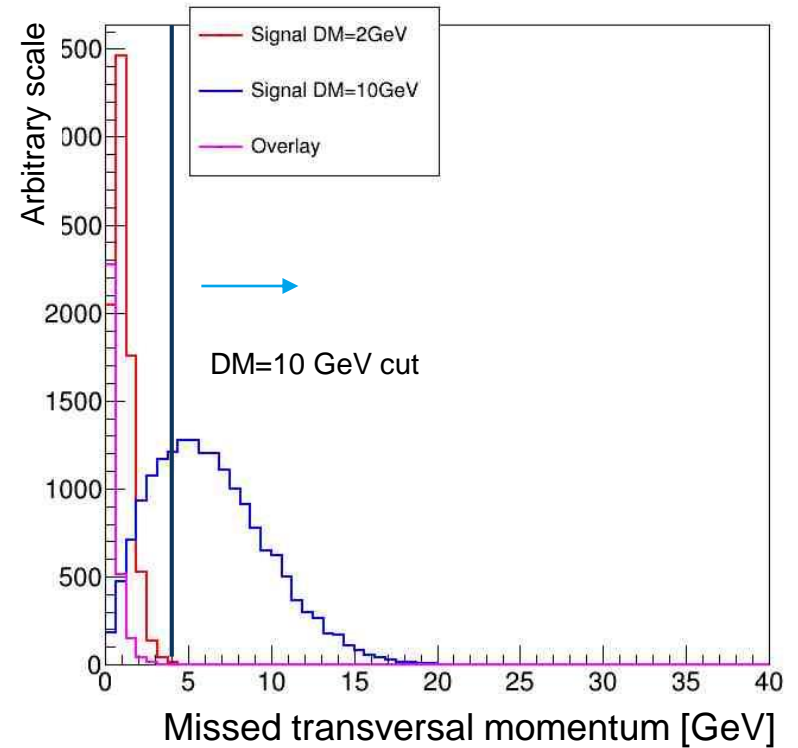
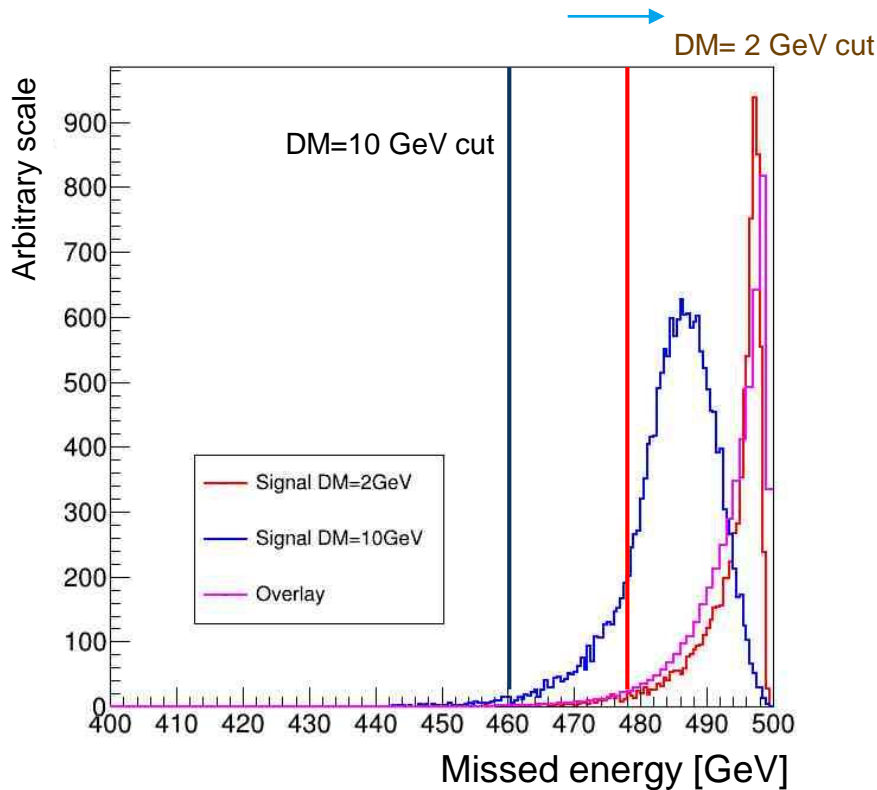
$M_{\tilde{\tau}} - M_{\text{LSP}} \text{ (DM)}$	2 GeV	10 GeV
	2.6×10^{-3}	$< 2.7 \times 10^{-6}$ (95% CL)

(All surviving events with $\gamma\gamma \rightarrow \text{low } p_T \text{ hadrons}$ interactions)

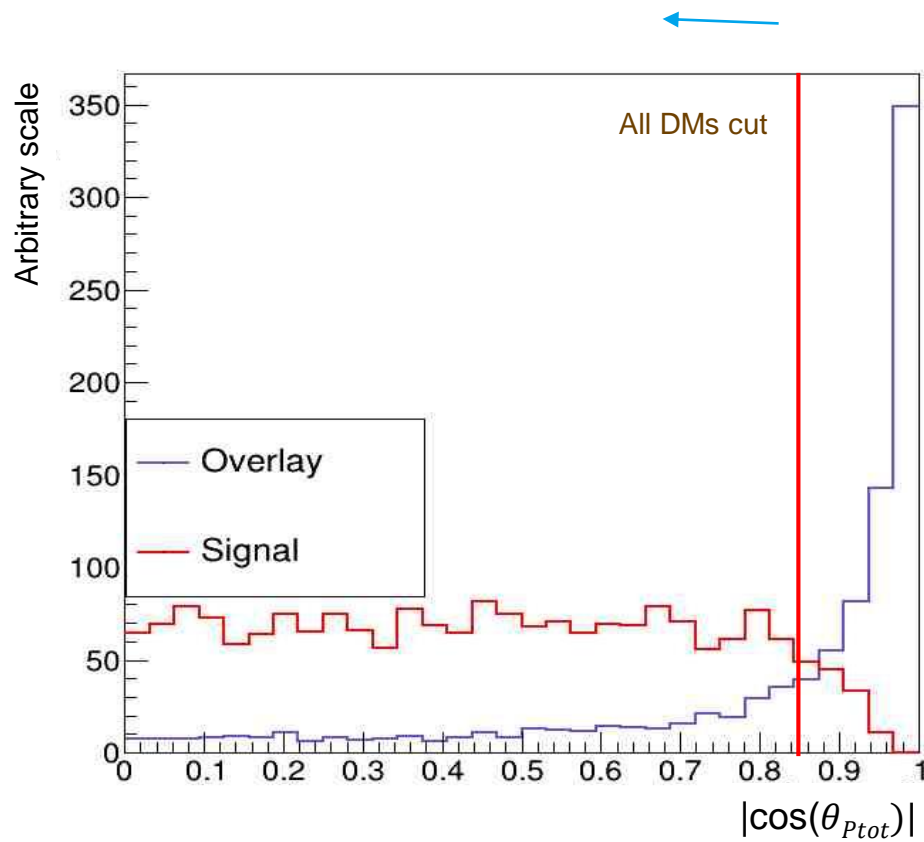
Main differences between 2GeV and 10 GeV cuts:

- Multiplicity and tau identification cuts are similar
- Missed energy cuts more for DM = 2 GeV
- Missed transversal momentum cuts drastically for DM = 10 GeV
- $\cos(\theta_{P_{tot}})$ important cut for DM = 2GeV

Effect of cuts on overlay-only events (ctd.)



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Estimated **rate** of **overlay-only** events **after cuts**:

- 5 Hz train repetition rate
- 1312 bunches/train (H20 scenario before luminosity upgrade)
- $\langle 1.05 \rangle \gamma\gamma \rightarrow \text{low } pT \text{ hadrons}$ events/bunch

1.8×10 / 1.8×10^{-2} ($DM = 2 / 10$ GeV) overlay-only events **pass the general cuts per second**

Estimated **#events** for cross sections \sim fb ($\sim \tilde{\tau}$ production cross-section):

- Luminosity $1.8 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (H20 scenario before luminosity upgrade)

1.8×10^{-5} events/s

Need to identify **independent** set of **cuts** among the “standard” ones

Need to search for **additional independent cuts**

Independent and additional cuts

Independent set of cuts from the “standard” ones:

- missed $p_{\perp} + \rho^1$
- remaining cuts²

(several cuts among the “standard” ones depend on the exact model-point)

Additional independent requirements based on:

- Initial State Radiation photons (ISR)
- vertex

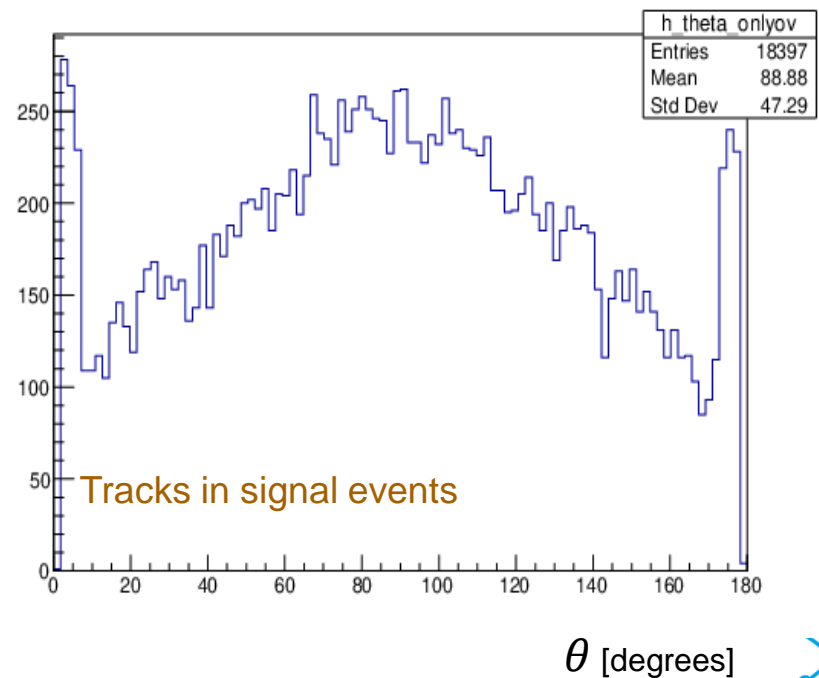
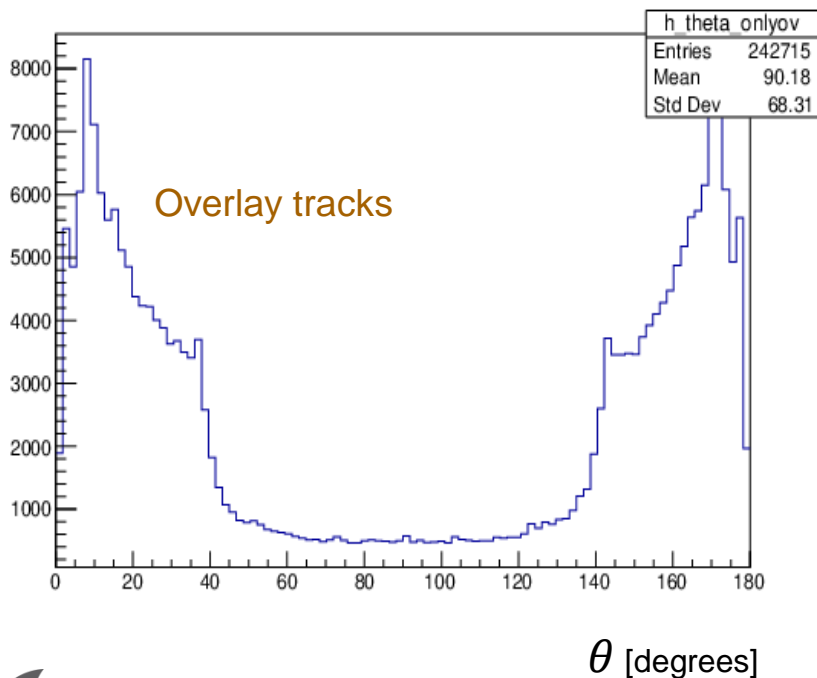
(1) Transverse momentum (in the plane) with respect to the thrust axis

(2) Multiplicity, energy, angular distributions, τ identification

ISR requirement

Events with **isolated photons** with **sizeable energy** and **angle to the beam** above the lower edge of the tracking system

- Energy > 1.1 GeV
- Angle optimized for getting enough rejection without killing all events



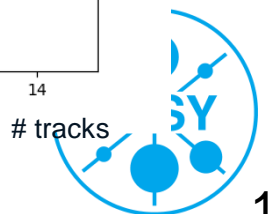
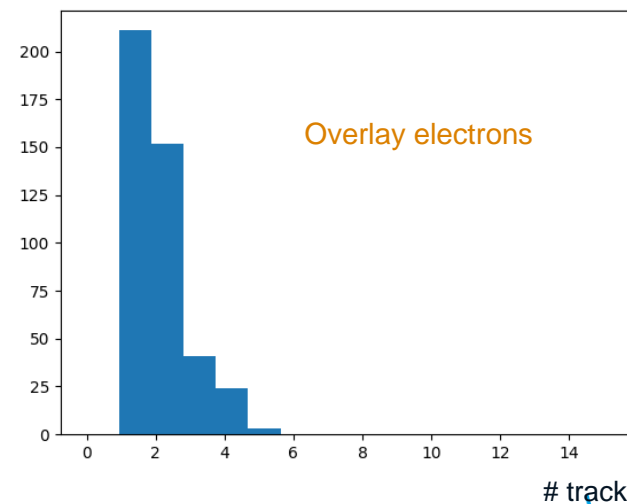
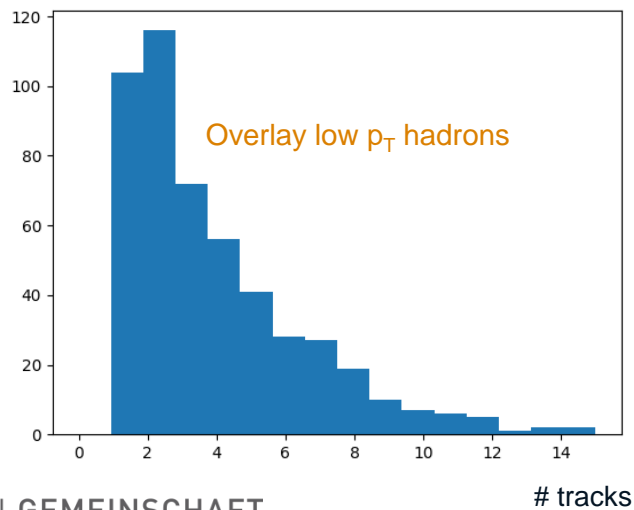
Vertex requirement

Events with at least two “non-vertex” tracks

Main vertex fitted with beam-spot as a constraint, effectively meaning that it will have at least two tracks

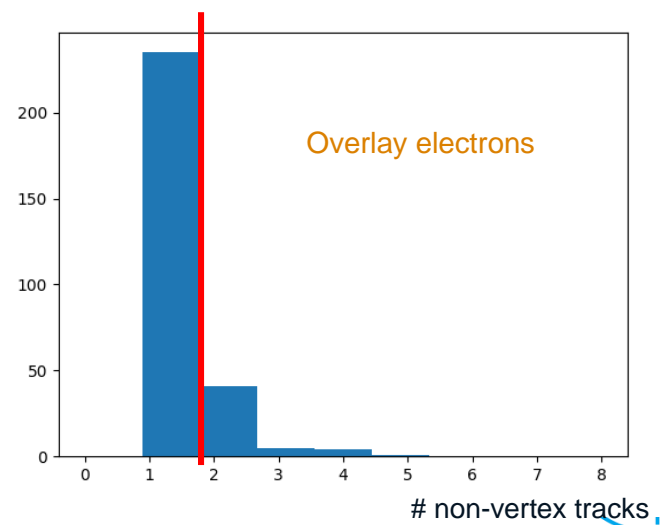
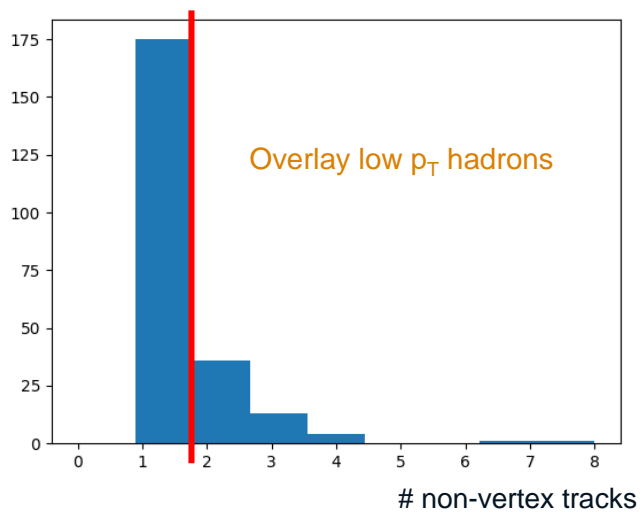
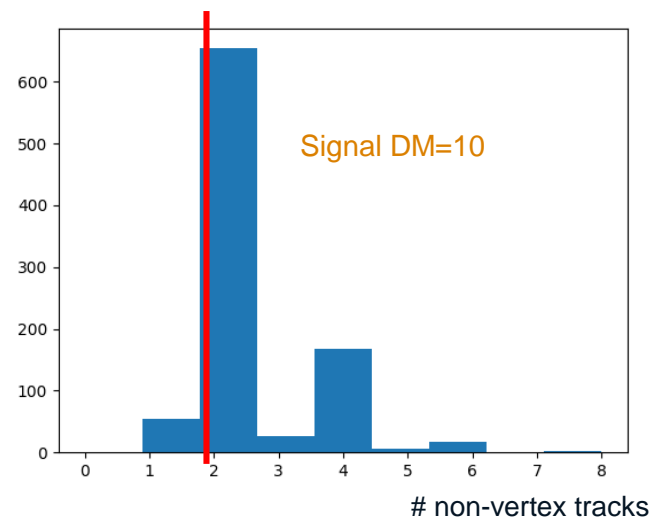
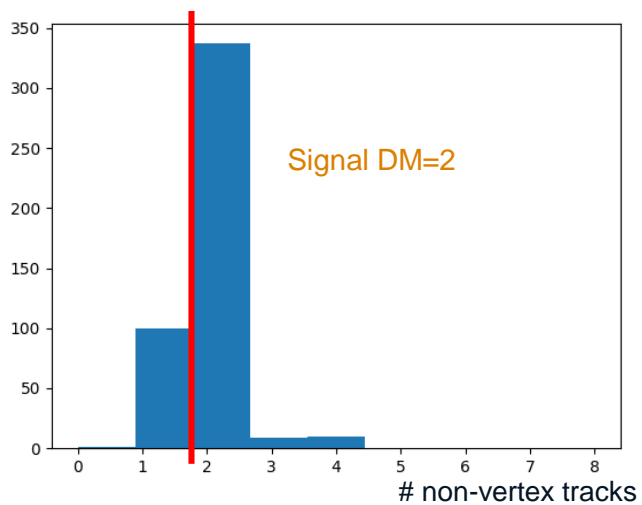
Tracks that are not included in any vertex (too high χ^2) are “non-vertex” tracks

Track multiplicity with no selection



Vertex requirement (ctd.)

Number of tracks not included in vertex



Rejection on overlay-only events

DM = 10 GeV

red. missed $P_T + \rho$ 1.3×10^{-3}

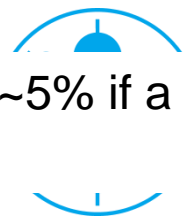
	red.	alone	combined w/ missed $P_T + \rho$
remaining cuts		6.0×10^{-3}	7.8×10^{-6}
remaining cuts + ISR ($7 < \theta$)		1.4×10^{-4}	1.8×10^{-7}
remaining cuts + ISR ($35 < \theta < 145$)		1.7×10^{-5}	2.2×10^{-9}

DM = 2 GeV

red. vertex 1.9×10^{-2}

	red.	alone	combined w/ vertex
standard cuts		2.6×10^{-3}	5.0×10^{-5}
standard cuts + ISR ($7 < \theta$)		1.8×10^{-7}	3.5×10^{-9}
Standard cuts + ISR ($30 < \theta < 150$)		9.5×10^{-9}	1.8×10^{-10}
Standard cuts + ISR ($45 < \theta < 135$)		1.6×10^{-8}	$> 3.0 \times 10^{-10}$ (95% CL)

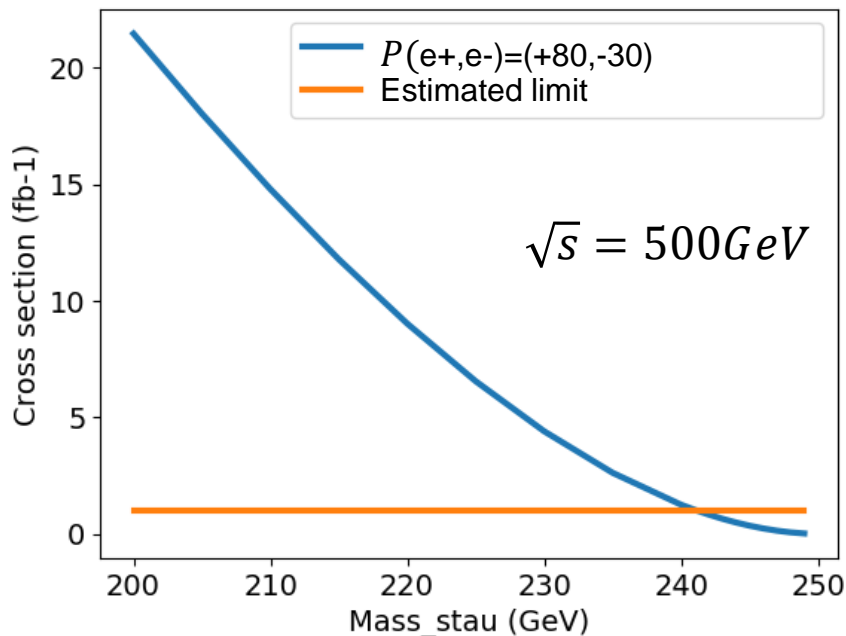
Signal efficiency: $\sim 10\%$ with no requirement on detecting an ISR. Goes to $\sim 5\%$ if a detected ISR is required (for any θ)



Comparison to signal production per year

Estimated number of **overlay-only** events **after cuts**: ~ 276 events/year (DM=2GeV)

Required signal cross-section for exclusion/discovery: $\sim \text{fb}$ (efficiency $\sim 1\text{-}10\%$)



Required seen signal events for exclusion:

$$\sim 2 \times \sqrt{300} = \sim 35$$

-> 350 – 3500 produced signal events per year (efficiency 1-10%)

*-> 0.7-7 fb cross-section limit
($\mathcal{L} \sim 500 \text{ fb}^{-1}/\text{year} - 1.8 \times 10^{-5} \text{ fb}^{-1} \text{ s}^{-1}$)*

Outlook and conclusions

- The effect of **overlay-only** events on $\tilde{\tau}$ searches have been **studied**
- Rate of overlay-only events is **higher than** of any other **SM background**
- Due to the high suppression needed and thus the **lack of statistics**, a set of **independent cuts** was searched for
- Additional **vertex** and **ISR** requirements with respect to the study with overlay-on-physics events were needed
- The **rejection** reached on overlay-only events would **allow $\tilde{\tau}$ exclusion/discovery**
- Next steps: **evaluate** the overlay-only background **point-by-point** and **produce** a final **exclusion/discovery** reach plot, with **overlay-only included**