Long-lived particle searches with the ILD experiment

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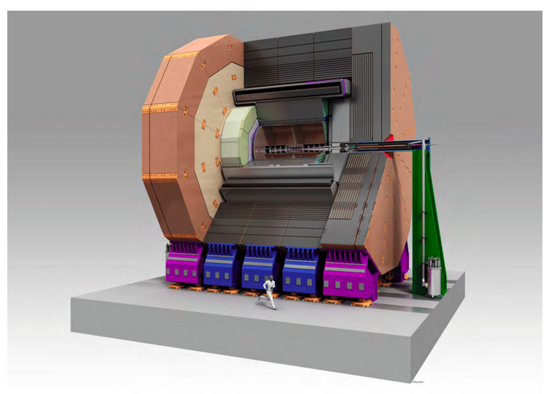
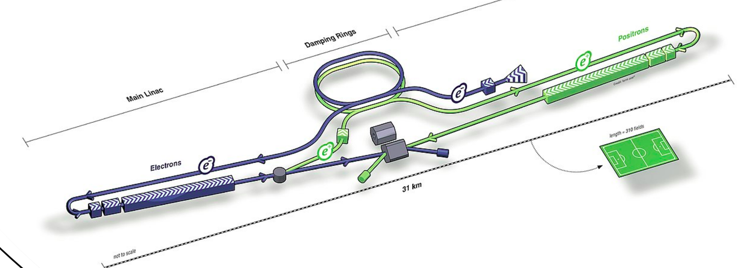
Long-lived particles

- Many states within the SM have macroscopic lifetimes
- Various BSM models predict LLPs: e.g. SUSY particles, axion-like particles, heavy neutral leptons, dark photons, exotic scalars...
- Multiple searches at the LHC, but:
  - → LHC is mostly sensitive to high masses and mass splittings
  - → complementary region could be probed at e^+e^- colliders (small masses, mixing, mass splittings, etc.)

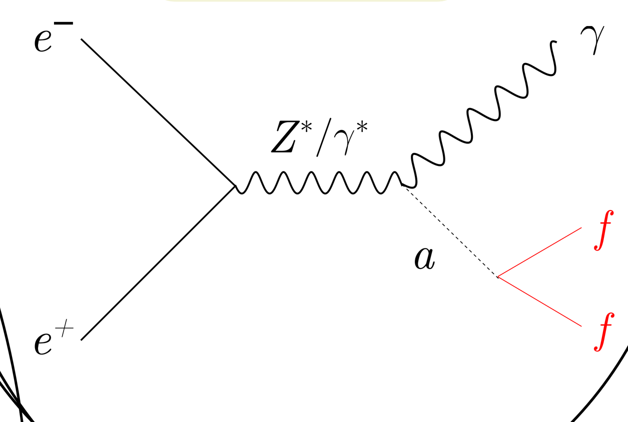
International Large Detector

- Experiment proposed for e^+e^- Higgs factory, such as International Linear Collider (ILC)
- ILC baseline centre-of-mass energy: 250-500 GeV, possible extension to 1 TeV
- The core of ILD tracking systems is a time projection chamber (TPC)
  - → almost continuous tracking
  - → promising for the LLP studies

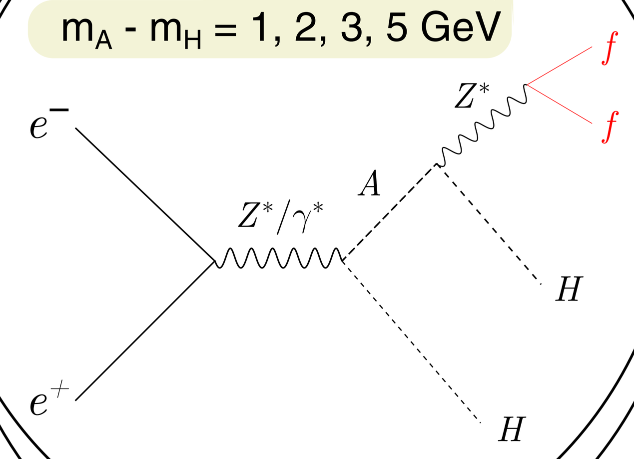




m_a = 0.3, 1, 3, 10 GeV
$c\tau = 10 \cdot m_a$ [mm]



m_A = 75 GeV,
$c\tau$ = 1 m,
$m_A - m_H$ = 1, 2, 3, 5 GeV



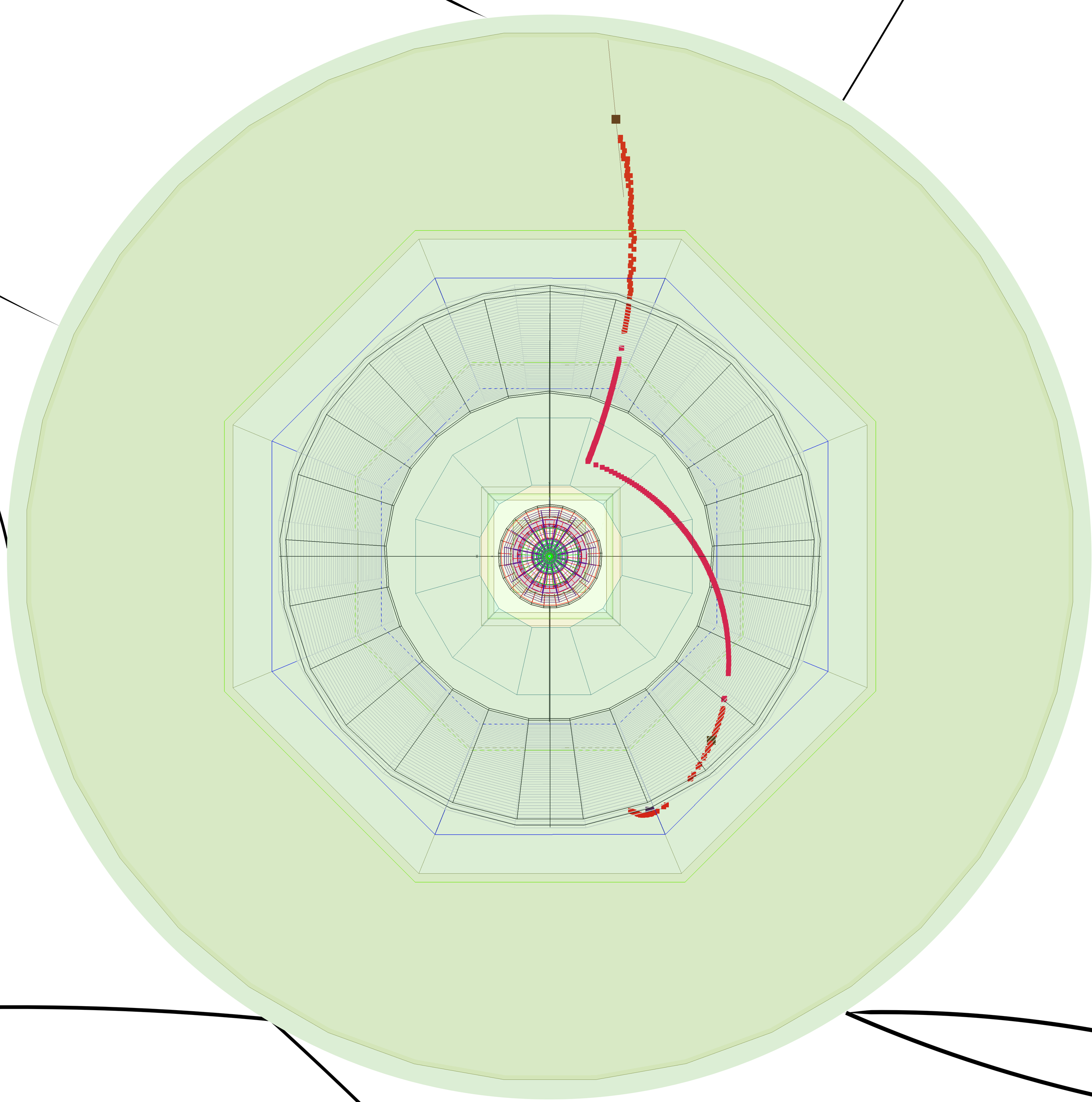
Benchmarks

Selected based on **kinematic properties**

Most challenging case: small-boost, low-p_T track pair, not pointing towards IP - heavy scalar LLP (A) and DM (H) pair-production with small mass splitting, $Z^* \rightarrow \mu\mu$

The opposite extreme case, (large boost, high-pT final state) - light pseudoscalar LLP, $a \rightarrow \mu\mu$

Study based on verex finding at 250 GeV ILC
- vertex placed between points of closest approach of track helices, requiring max. distance of 25 mm
- procedure not optimised for any scenario



Background sources

Random track intersections, interactions with detector material, long-lived SM hadrons are background sources
→ processes with production of hadrons or with large activity inside detector

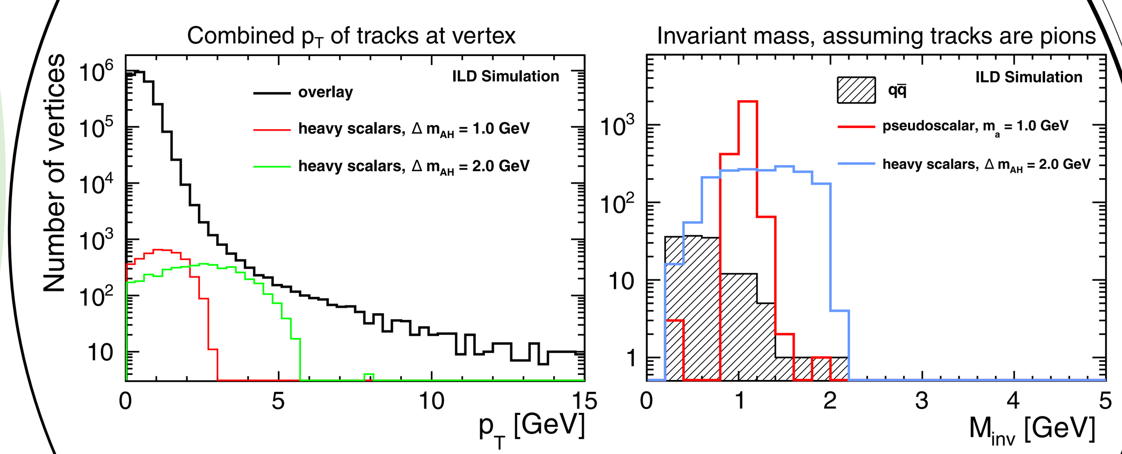
1. Beam-induced photoproduction of:
   - low-p_T hadrons (~1.55 per bunch crossing)
   - incoherent e^+e^- pairs (~10^5 per bunch crossing, only a small fraction is measured)

These processes can overlay on physical event or constitute background themselves

2. Hard (high-p_T) events including jets in the final state

Background reduction

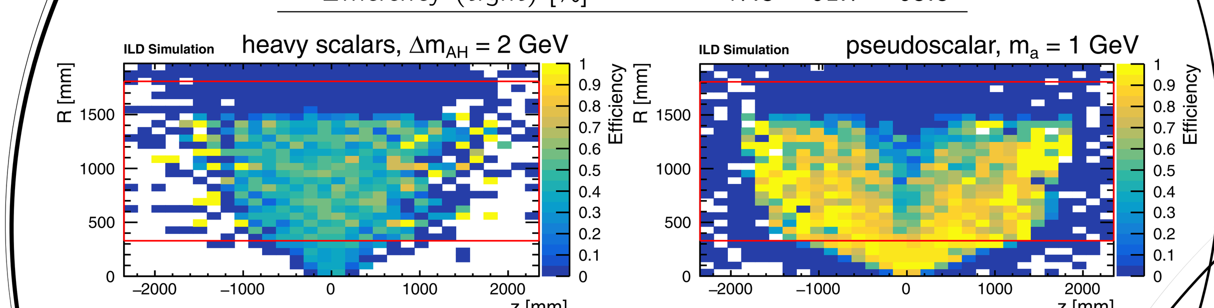
10^{11} bunch crossings expected at ILC per year
→ reduction at the level of ~10^{-9} required



- Cuts on the p_T and geometry of a track pair agive total rejection at the level of ~10^9
- Additional cuts on the track pair mass to reject photons, kaons and Λ^0s (two selection working points: standard and tight)

Vertex finding results

Δm_{AH} [GeV]	1	2	3	5
Efficiency (standard) [%]	3	33.2	43.4	51.1
Efficiency (tight) [%]	0.4	28.3	40.7	50.2
m_a [GeV]	0.3	1	3	10
Efficiency (standard) [%]	7.4	48.4	61.7	65.8
Efficiency (tight) [%]	–	47.3	61.7	65.8

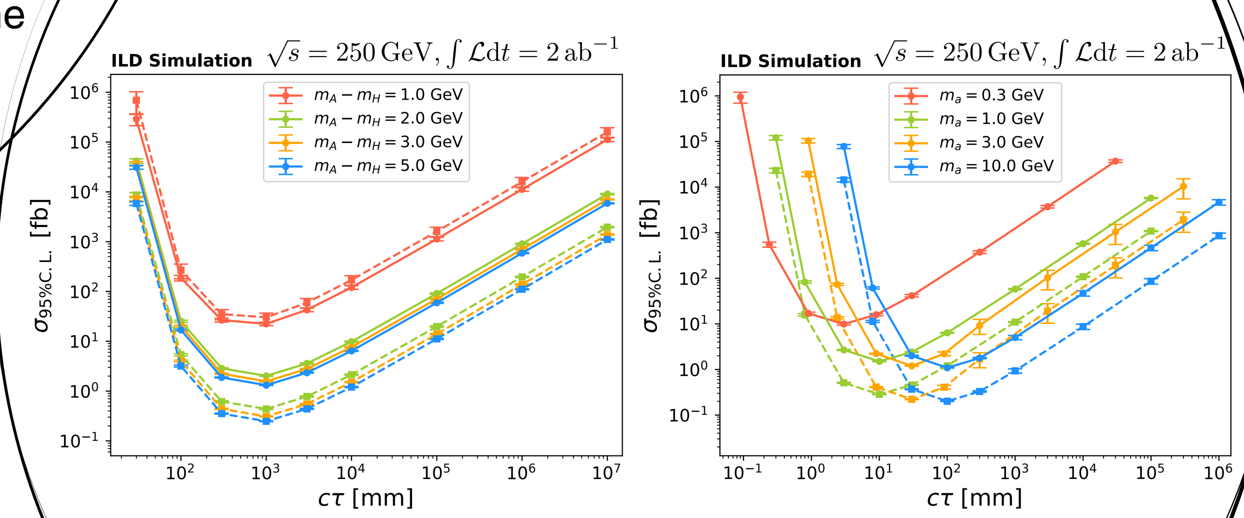


Efficiency: reconstructed vertex within 30 mm from the true vertex, decays within TPC acceptance

- Signal selection efficiency depends strongly on the final state boost: Δm_{AH} (Z^* virtuality) and m_a
- Dedicated approach required for scenarios with Δm_{AH} = 1 GeV and m_a = 0.3 GeV

95% C.L. cross section limits

Standard selection: solid line
Tight selection: dashed line

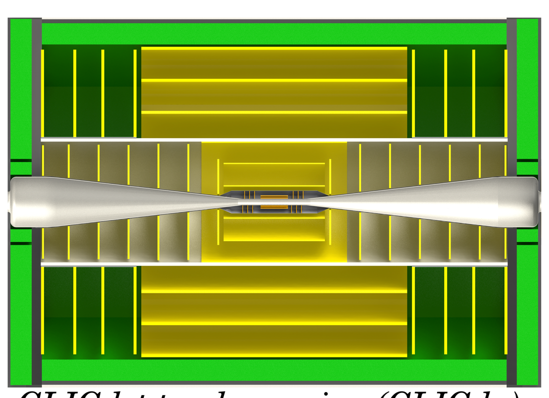


heavy scalars   pseudoscalar

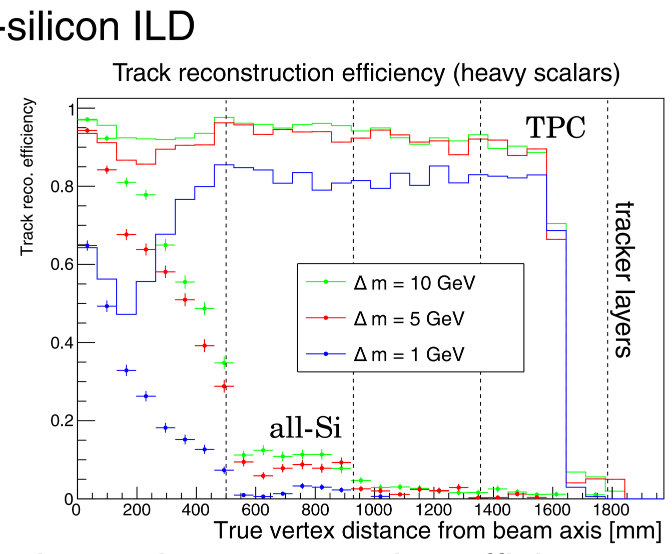
A wide range of models with heavy scalars with small mass splittings, or light pseudo scalar particles, can be excluded for $\sigma \lesssim 0.1\,\mathrm{fb}$

All-silicon tracker

- Alternative ILD design with TPC replaced by a silicon tracker modified from the Compact Linear Collider detector (CLICdet) outer tracker design
- Tracking algorithm designed for CLICdet used for reconstruction at all-silicon ILD



CLICdet tracker region (CLICdp)



- Vertex reconstruction driven by track reconstruction efficiency
- Performance similar to baseline design (TPC) near the beam axis
- Smaller number of hits available → efficiency drops faster with vertex displacement
- At least 4 hits required for track reconstruction → limited reach
- For large decay lengths, efficiency significantly higher for "standard" ILD with TPC