Reconstruction of long-lived particles with the ILD at the ILC

Jan Klamka, University of Warsaw

Long-lived particles (LLPs)

• Many states within the SM already have macroscopic lifetimes

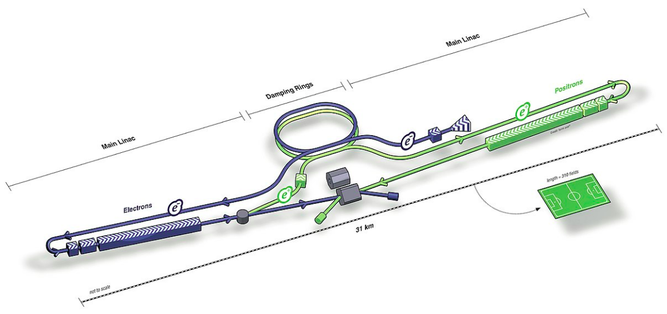
• Various BSM models predict LLPs: e.g. SUSY particles, axion-like particles, heavy neutral leptons, dark photons, exotic scalars...

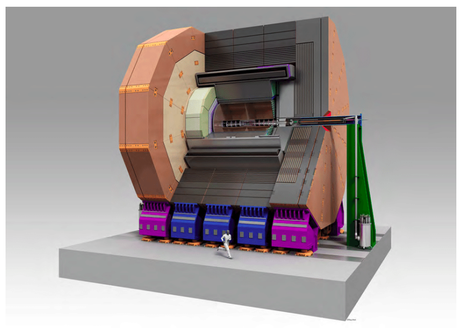
• Multiple searches at the LHC, but:

→ 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 (ILD)





• Experiment proposed for the International e^+e^- 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 continous tracking

→ promissing for the LLP studies

Test signal scenario

Most challanging case: **small-boost, low-p_T track pair, not pointing towards IP**

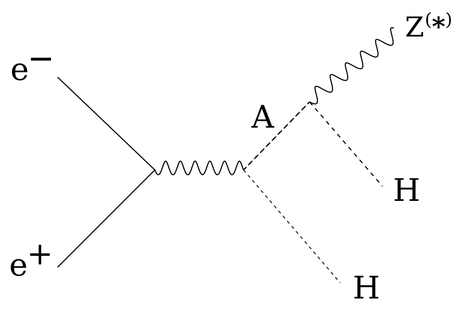
Inert Doublet Model (IDM) used as a test scenario:

• **four additional scalars**, including two neutral: **A** (heavier) and **H** (lighter; stable dark matter candidate)

• A can be long-lived for **small mass splittings** between A and H

• benchmark scenarios: m_A = 155 GeV, **$c\tau$ = 1 m**, $m_A - m_H$ = 1, 2, 3, 5 GeV

• dominant decay: A → HZ*; Z* → μμ decays used for vertex reconstruction studies



Vertex reconstruction

Strategy

Approach as simple and general as possible, to cover wide range of possible scenarios

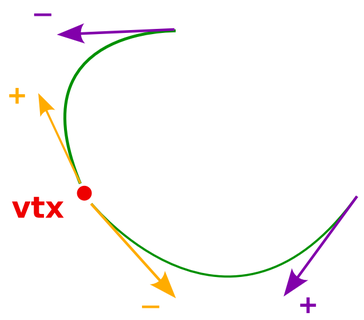
• Consider tracks in pairs

• As the TPC is not sensitive to track direction:

→ use both track direction (charge) hypothesis for vertex finding

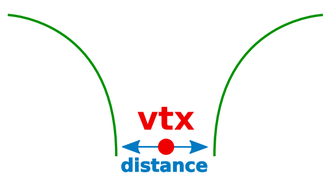
→ **consider opposite-charge** track pairs only

→ select pair with **closest starting points**



• Reconstruct vertex **in between points of closest approach** of helices

• Require that distance between helices is smaller than 25 mm



Overlay background

The e^+e^- beams are a source of real and virtual photons, whose interactions produce

• **low-p_T hadrons**

• **e^+e^- pairs**

These processes can occur simultanously to physics event (and **overlay** on it)

However, with **~1.05 ($\gamma\gamma$ → had.)** and **~1 (e^+e^- pair)** events expected per bunch crossing, they can also constitute background by themselves

→ they have to be taken into account in the low-p_T LLP searches as separate background

Background reduction

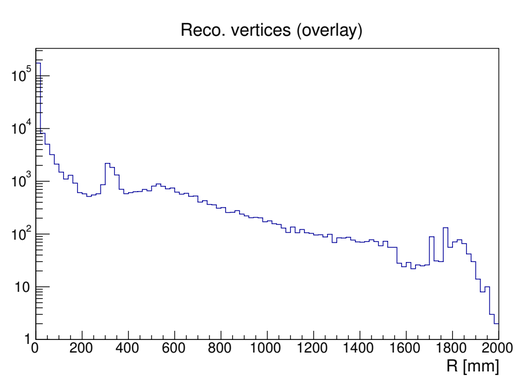
• Focus on LLP reconstruction in the **TPC volume**

• Due to detector- and reconstruction-related effects, many artificial vertices found in overlay – apply cuts on:

→ tracks opening angle and curvature ratio (reject false vertices from split tracks)

→ distance from vtx to first track hit, relative to the track length (reject randomly intersecting tracks)

→ number of degrees of freedom in track (reject short tracks)



Overlay background event example

Final selection

• Overlay background **reduction** at the level of **~10^{-9} required**

• Limitted MC statistics: efficiency estimated assuming cuts used are independent

• Cuts on the p_T, distance between first hits in tracks, distance between centres of helix-circles give **total rejection** at the level of **~10^9** (**~10^{10}**) for **$\gamma\gamma$ → had. (e^+e^- pairs)**

Results

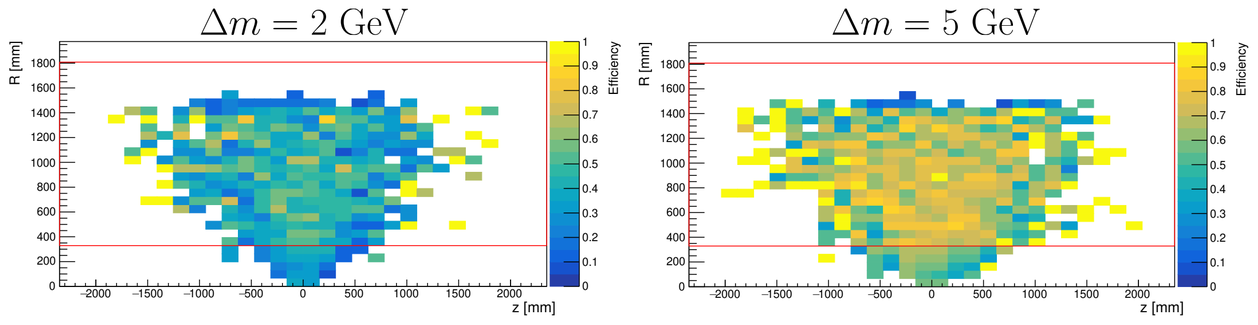
For decays within TPC acceptance

$\Delta m = m_A - m_H$	1 GeV	2 GeV	3 GeV	5 GeV
Signal selection efficiency	3.9%	37%	52.2%	60.4%
Purity	96.4%	97.4%	98.8%	98.6%

• Efficiency: reconstructed vertex within **30 mm** from the true vertex

• Signal **selection efficiency** depends strongly on the **mass splitting** (Z* virtuality)

• Δm = 1 GeV scenario beyond reach after selection



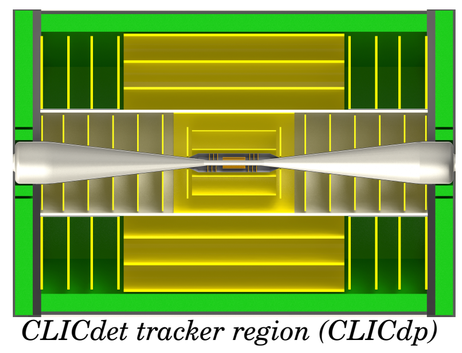
TPC vs. all-silicon tracker

• **Alternative ILD design** was recently implemented for tests

• TPC replaced by a **silicon tracker** modified from the Compact Linear Collider detector (CLICdet) outer tracker design

• One barrel layer added and endcap layers spacing increased w.r.t. CLICdet

• 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