Long-Lived Particles Reconstruction at CLIC

Erica Brondolin, Cecilia Ferrari, Emilia Leogrande, Ulrike Schoor

Introduction

Long Lived Particles

▶ Particles with half-life time at mm scale are predicted by several theories.

▶ A LLP candidate (in a BSM scenario) is the chargino ($\chi_1^\pm$) that together with the neutralino (χ_1^0) composes the higgsino multiplet.

▶ Because of the small chargino-neutralino mass difference, chargino is long lived.

▶ emitted pions in the chargino decay are soft (narrow phase-space)

▶ Dark matter-motivated pure Higgsino mass ≈ 1 TeV (required to explain relic abundance).
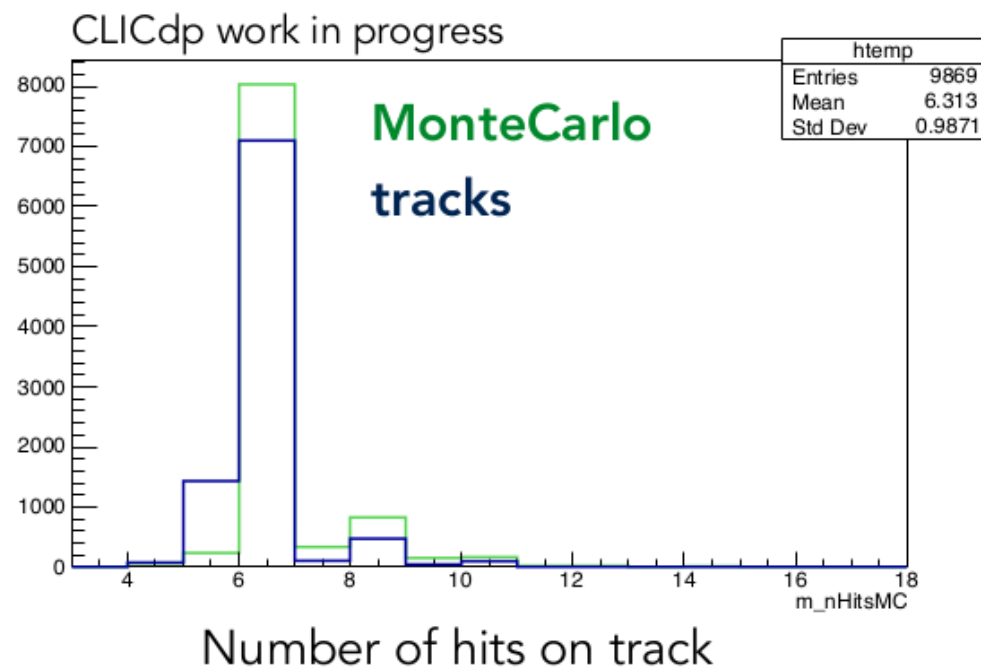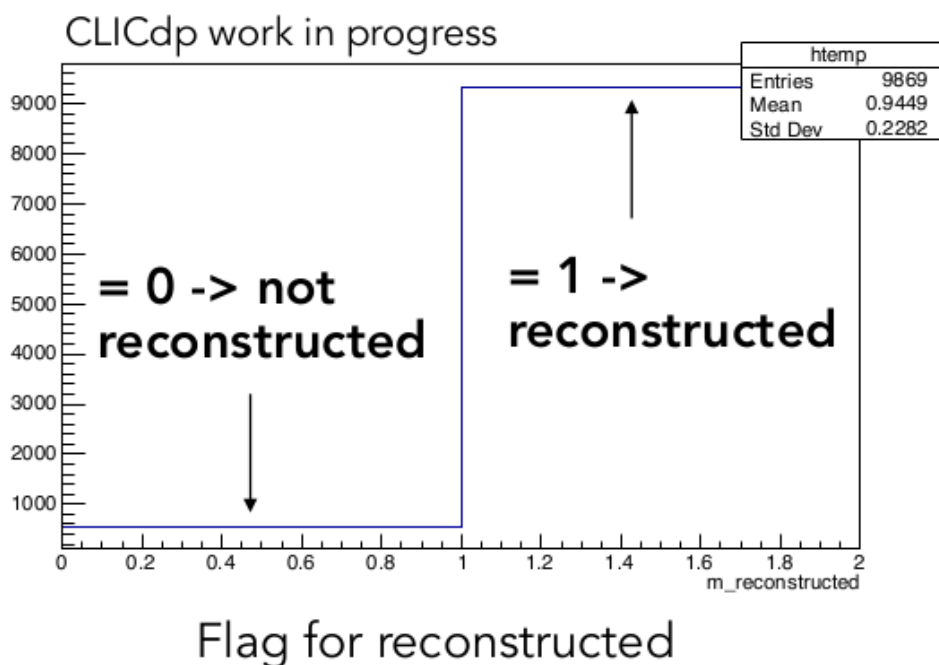 $\rightarrow$ Charginos can be produced at CLIC third energy stage (3 TeV)
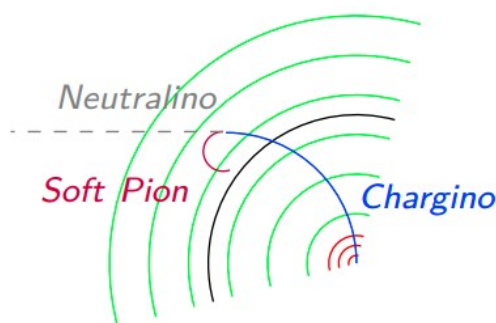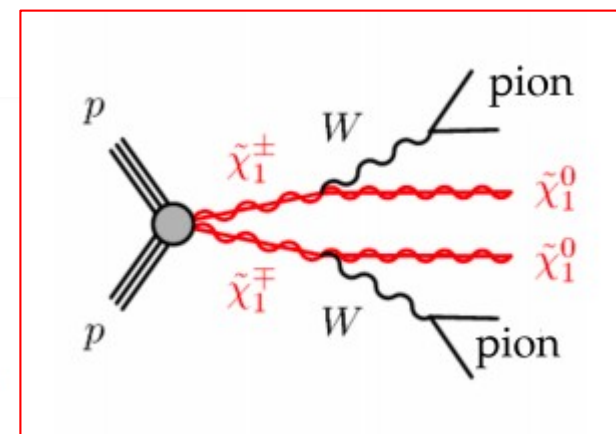
▶ Model parameters:

case	thermal limit mass	mass difference	lifetime	cτ	Γ
pure higgsino	≈ 1 TeV	355 MeV	0.023 ns	6.9 mm	2.86×10^{-14} eV

Erica Brondolin | 2

First steps

- **Kick-off study with (very) short muons @ 1TeV:**

    https://indico.cern.ch/event/793504/
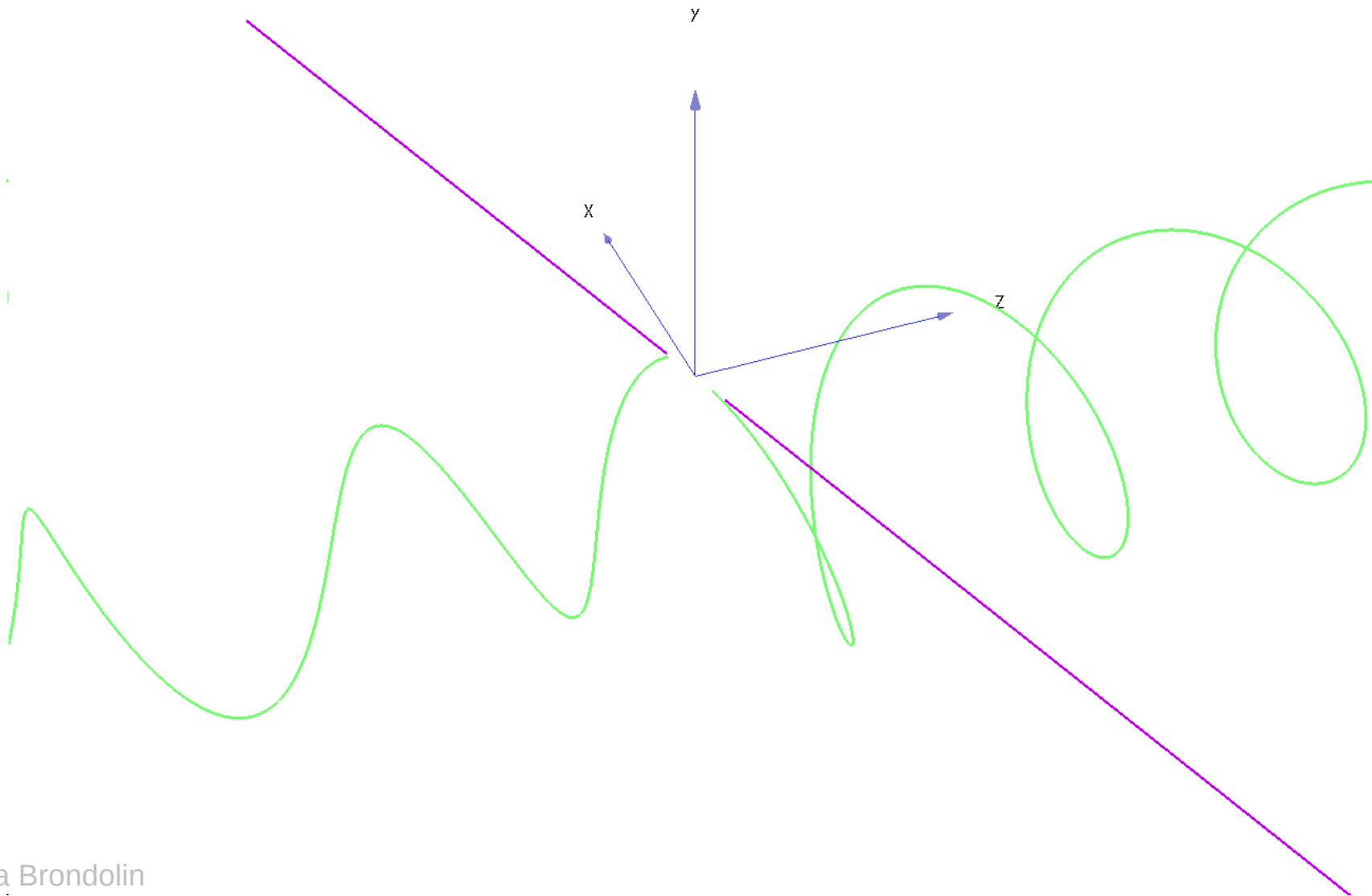

Flag for reconstructed

Number of hits on track

Results

- Tracking efficiency > 90 %
- Reconstructed short tracks have correct #hits
- Reconstructed p_T not matching the simulated one

First steps
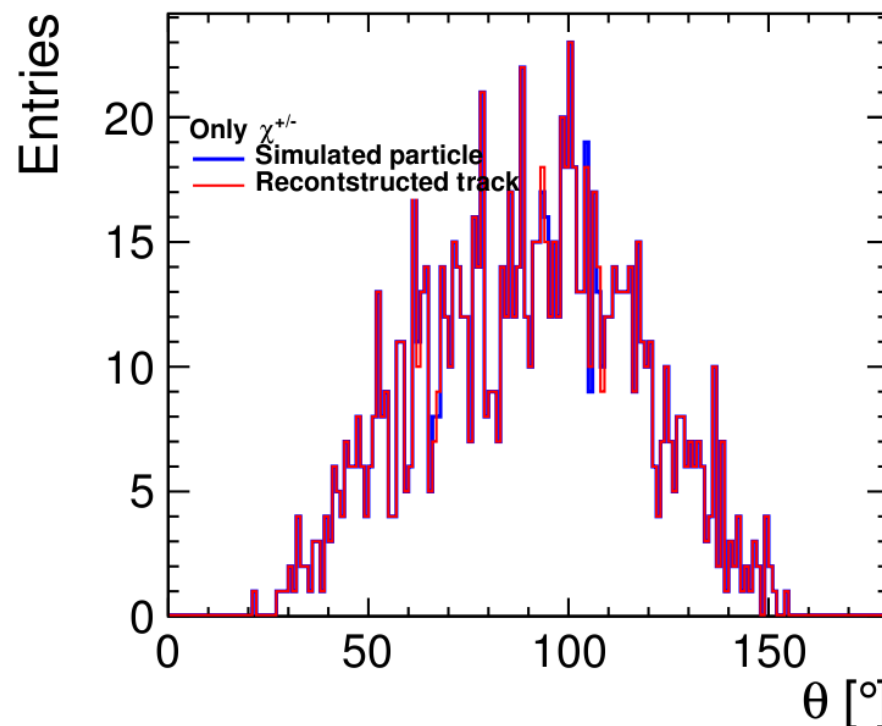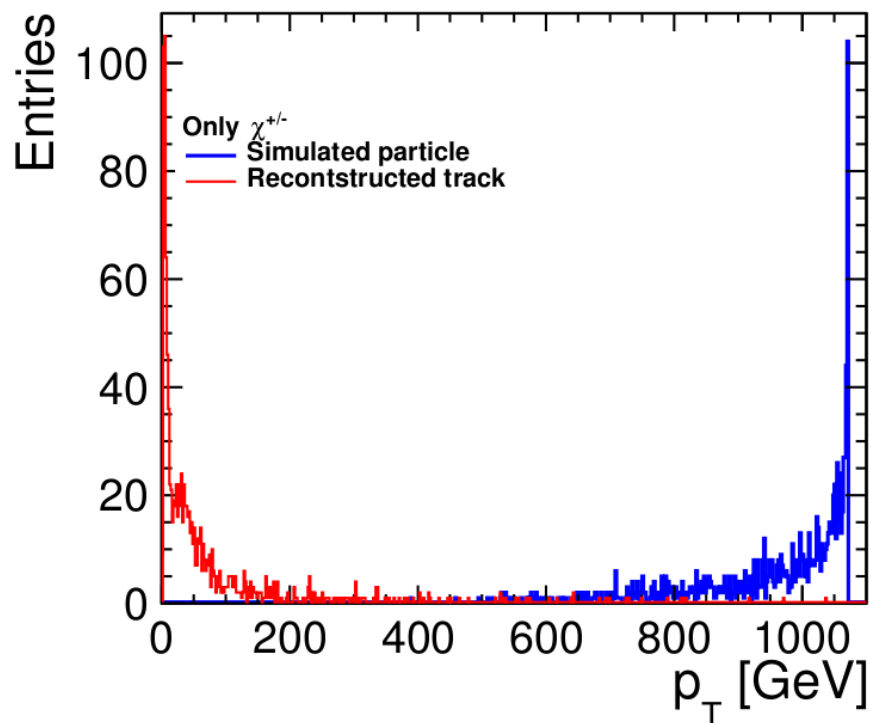
- **Kick-off study with full simulation (cτ = 20mm):**

  https://indico.cern.ch/event/822640/

Simulated χ$^{+/-}$

Simulated π$^{+/-}$

First steps

- **Kick-off study with full simulation (cτ = 20mm):**
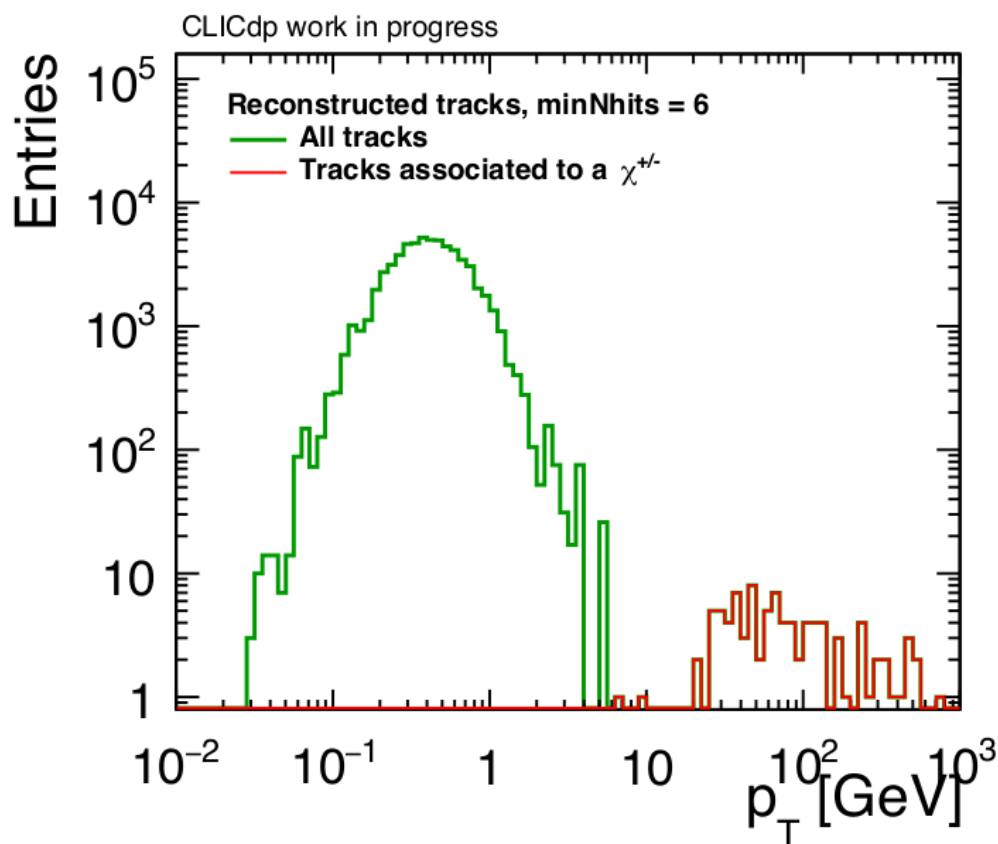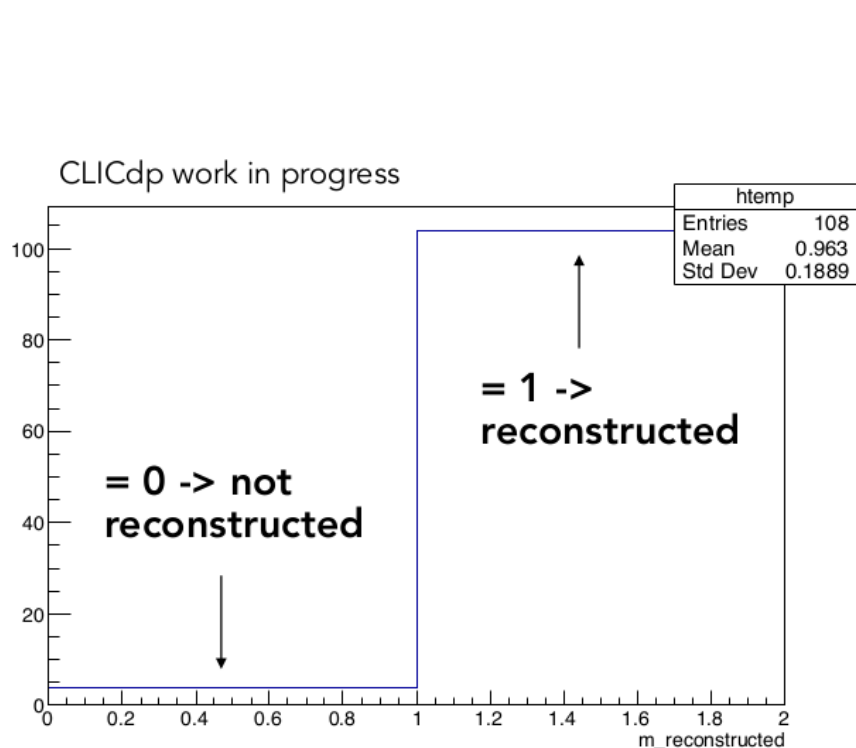
  https://indico.cern.ch/event/822640/

Results

- Tracking efficiency ~ 100%
- Reconstructed chargino tracks have correct θ
- Reconstructed chargino tracks confirmed muon studies

- **Kick-off study with full simulation (cτ = 20mm) + γγ → hadrons background:**

  https://indico.cern.ch/event/792346

Results

- Tracking efficiency ~ 95%
- Selection on min number of hits can help in discriminating signal from overlay in pT spectrum

Summer progress

- **More detailed studies performed by our summer student:**
    - CLICdp Collaboration Meeting: https://indico.cern.ch/event/792656/
    - Report: https://cds.cern.ch/record/2700254/
- **Samples:**

Signal

- ▶ 50k events;
- ▶ 3 TeV CoM;
- ▶ ISR;
- ▶ beamspectrum;
- ▶ negative beam polarization: $P(e^-) = -80\%$;
- ▶ chargino mass: 1050 GeV;
- ▶ neutralino mass: 1049.645 GeV;
- ▶ chargino mean lifetime: 600 mm.
  $\rightarrow$ hugely overestimated for statistical reasons.
  Reweight charginos based on their decay length to
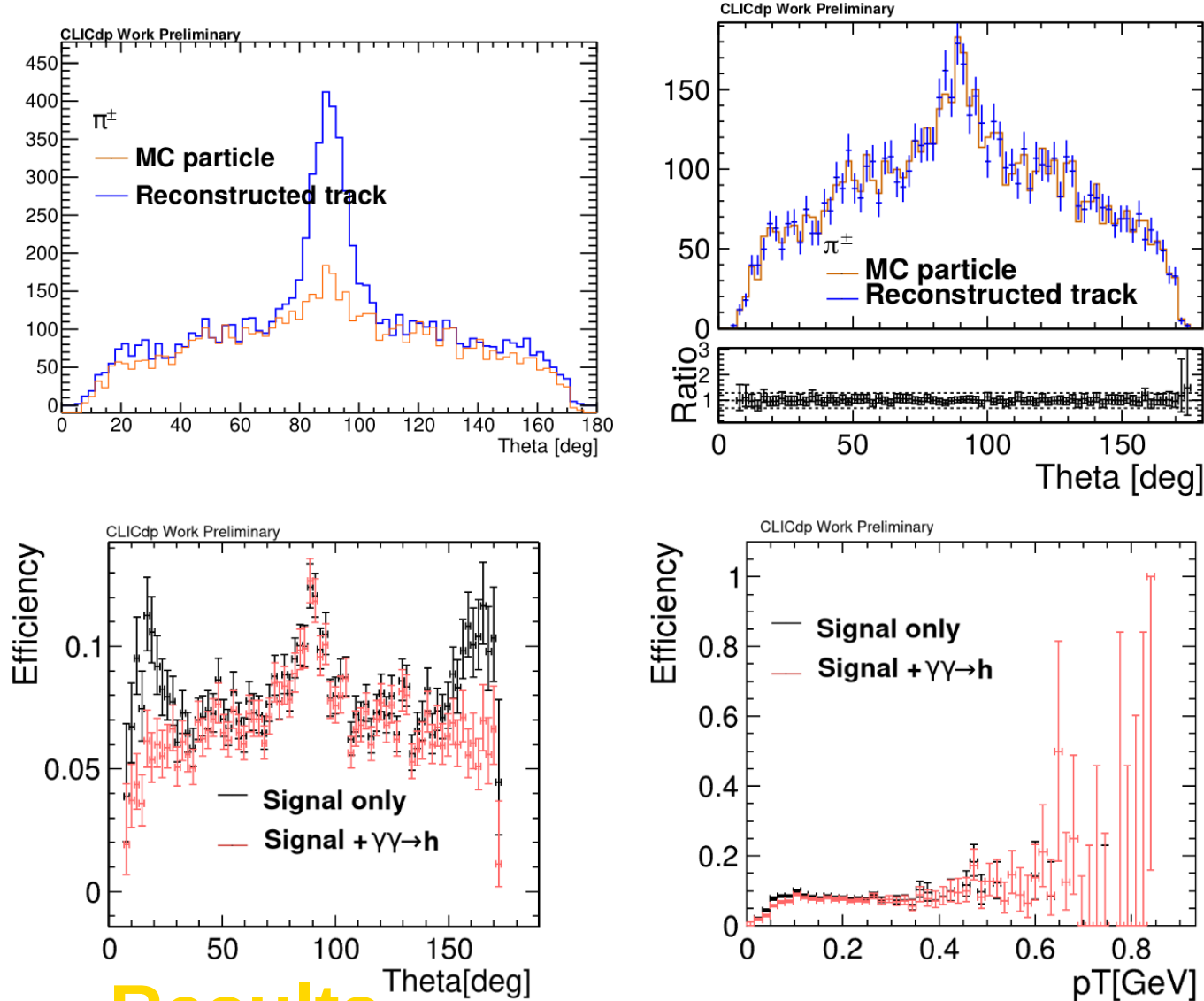 the physical lifetime distribution.

Beam-induced Background

- ▶ $\gamma\gamma \rightarrow$ hadron overlay (simulated);
  $\rightarrow$ dominant in the silicon tracker.
- ▶ Incoherent e^+e^- (not simulated).
  $\rightarrow$ dominant in the vertex and the very forward region.

Summer progress
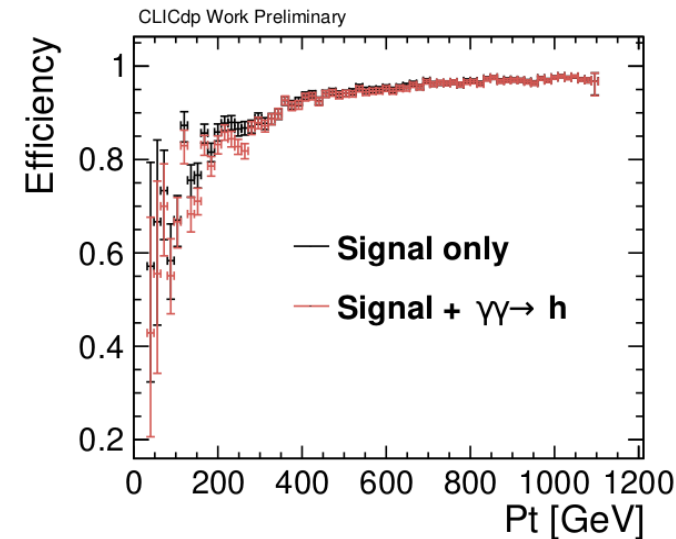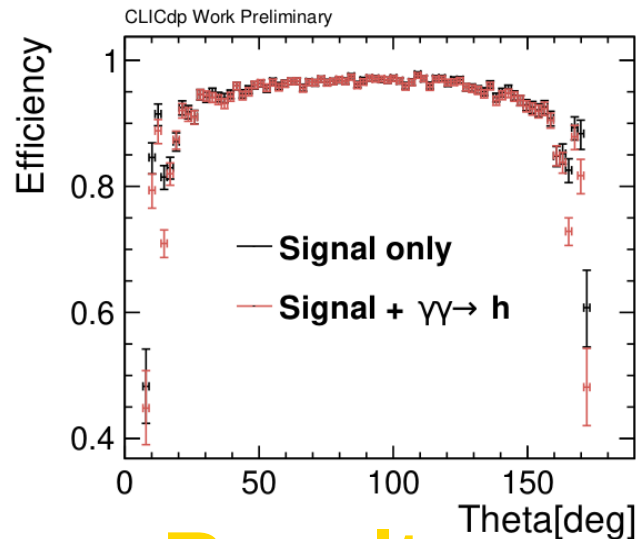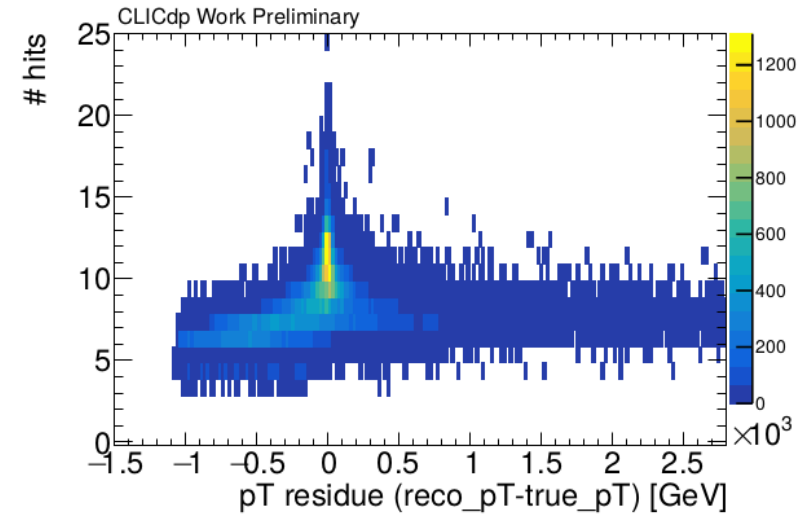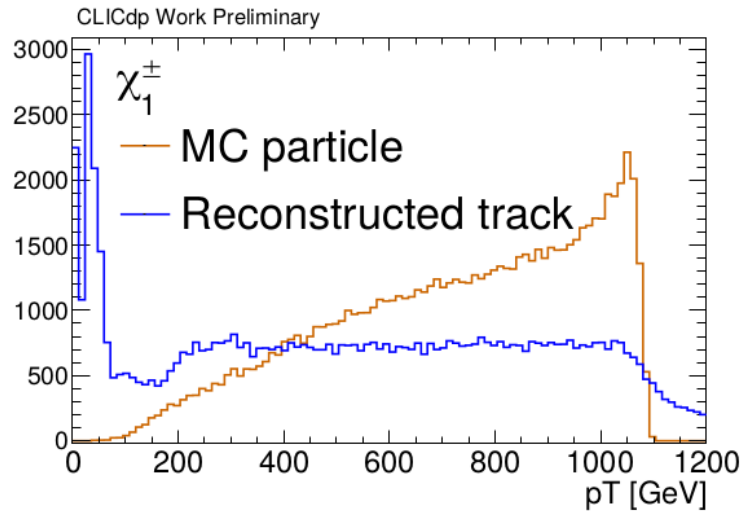
Results

- Confirmed high tracking efficiency w/o and w/ overlay
- Limitations in track pT estimate
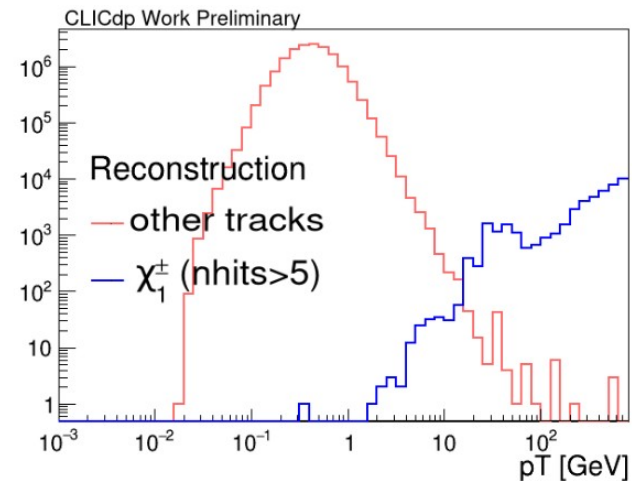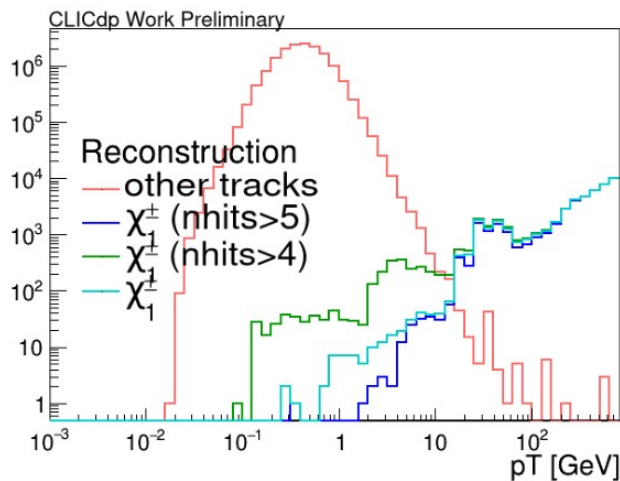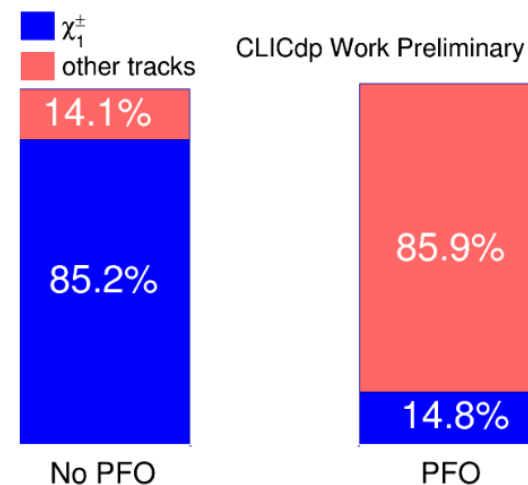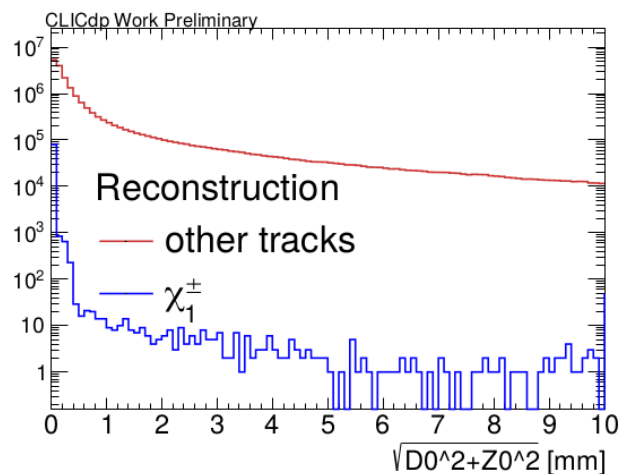
Summer progress

Results

- Soft pion difficult to reconstruct
- Loopers in central region creates many duplicate tracks

Summer progress

- **First proposed analysis cuts:**

  - Promptness: $\sqrt{(D0\,2 + Z0\,2)} < 0.5$ mm

  - No PFO association

  - Track pT > 10 GeV

Summer progress

- **First proposed analysis cuts:**

  - Promptness: √(D0 2 + Z0 2) < 0.5 mm

  - No PFO association

  - Track pT > 10 GeV

Results

Table 2: Results of efficiency studies in the sample of 50k events of signal + overlay.

Cut	$\sqrt{D0^2 + Z0^2} < 0.5\,\mathrm{mm}$	no PFO association	$p_T > 10\,\mathrm{GeV}$	all cuts
Number of MC charginos (NC)	81891	81891	81891	81891
Number of candidates (C)	13784412	3384475	105302	67928
Candidates that are charginos (CC)	81496	69750	79751	67756
Efficiency (%) = $\frac{C}{NC} * 100$	99.5	85.2	97.4	82.7
Fake (%) = $\frac{C-CC}{C} * 100$	99.4	97.9	24.3	0.3

Studies on-going
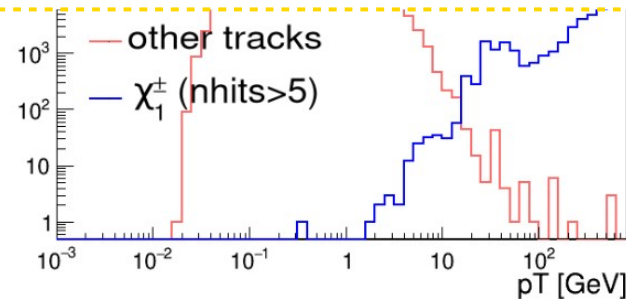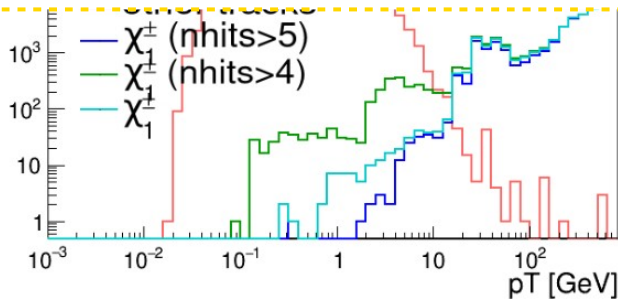
- Confirm and reproduce summer student's results

- Extend tracking validation to shorter charginos samples

- Estimate background systematically for different analysis selections

- Estimate significance w.r.t. background

- **All samples available:**
  - production v2 - signal only: lifetime <mark>600mm</mark>, neg. e- beam pol, 50k events
    - signal + γγ → hadrons background
    - only γγ → hadrons background
  - production v3 - signal only: lifetime <mark>180mm</mark>, no   e- beam pol, 50k events
  - production v4 - signal only: lifetime <mark>6.9mm</mark>, neg. e- polarisation, 50k events
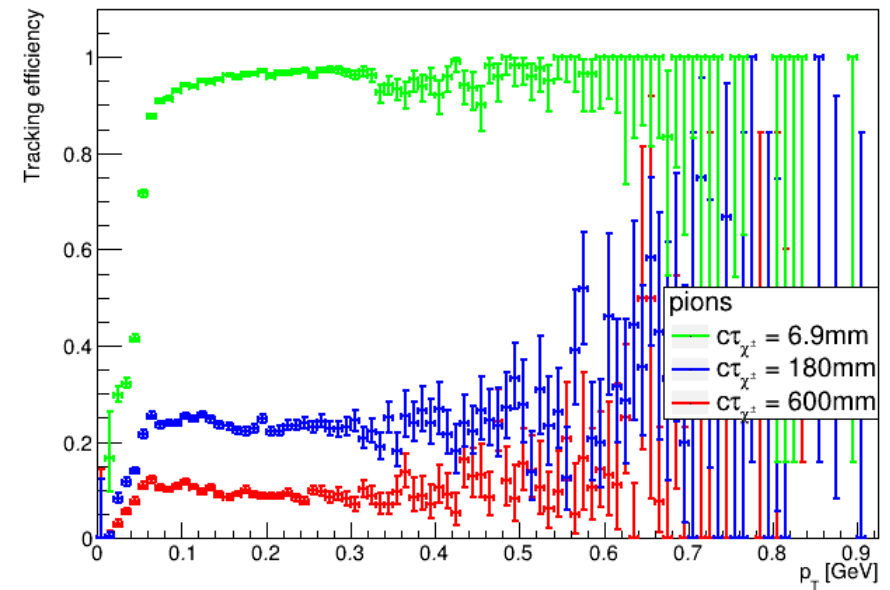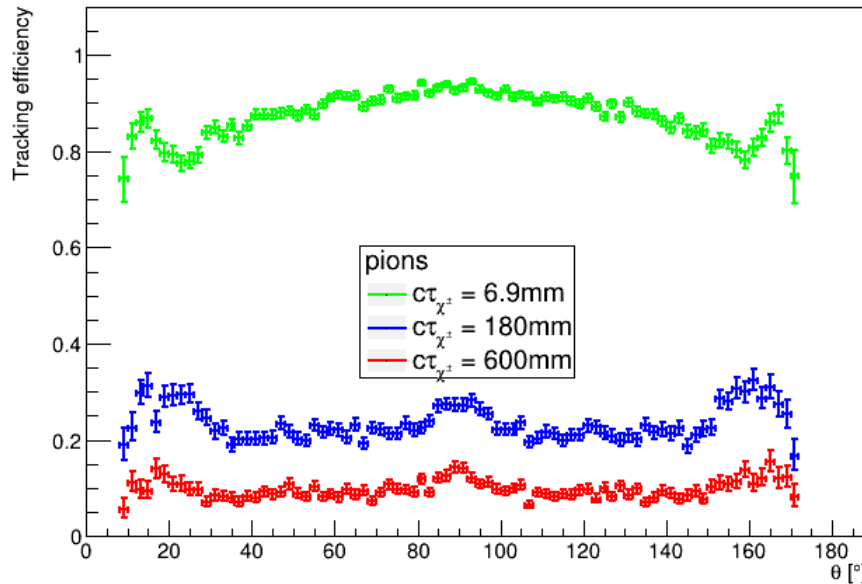   - signal + γγ → hadrons background

Tracking efficiency
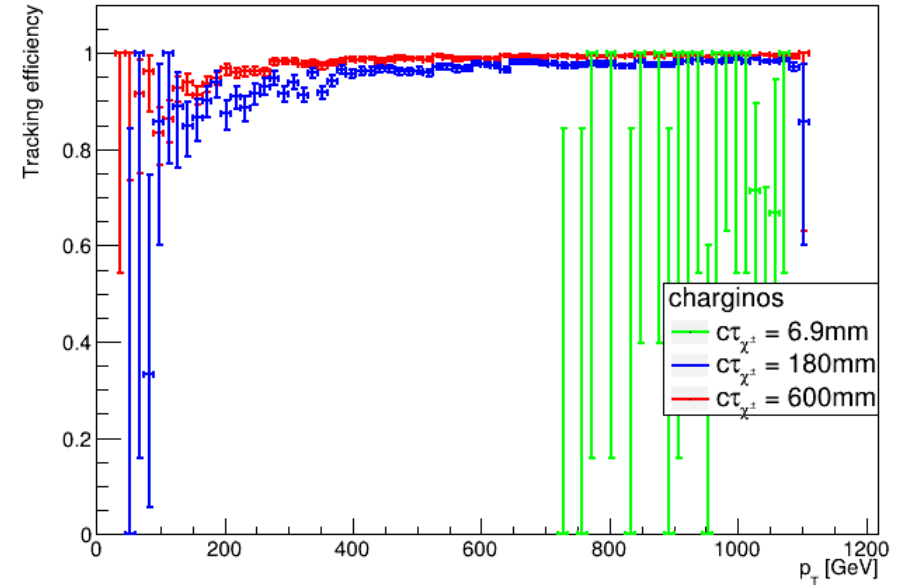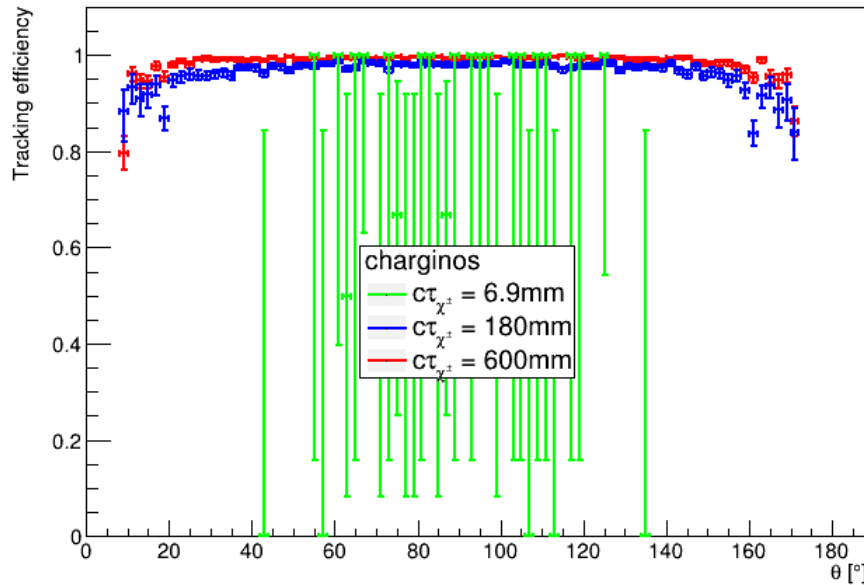
Number of **MC part hits** >= 3
- Lifetime 6.9mm
  - Reconstructed = 38
  - Reconstructable = 51
- Lifetime 180mm
  - Reconstructed = 60289
  - Reconstructable = 61910
- Lifetime 600mm
  - Reconstructed = 82100
  - Reconstructable = 82903
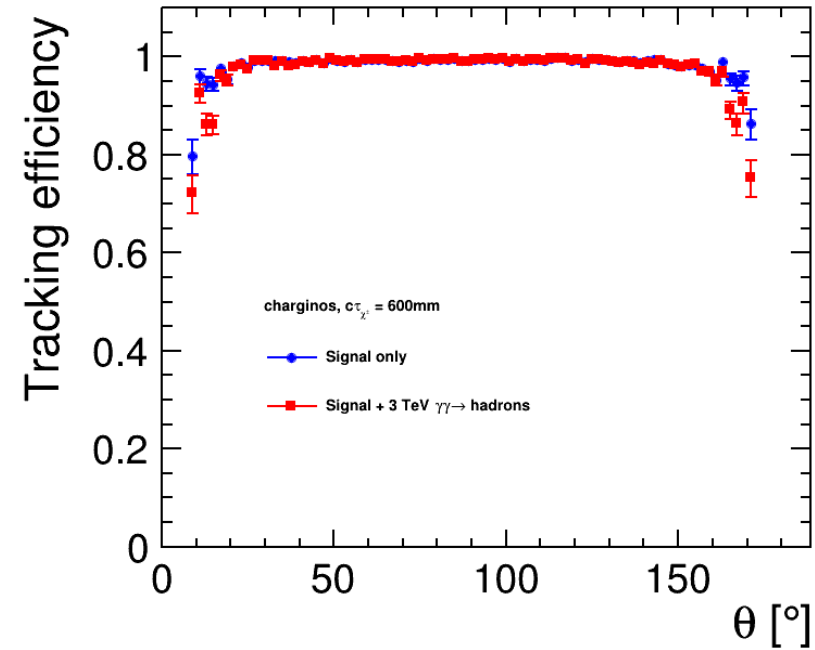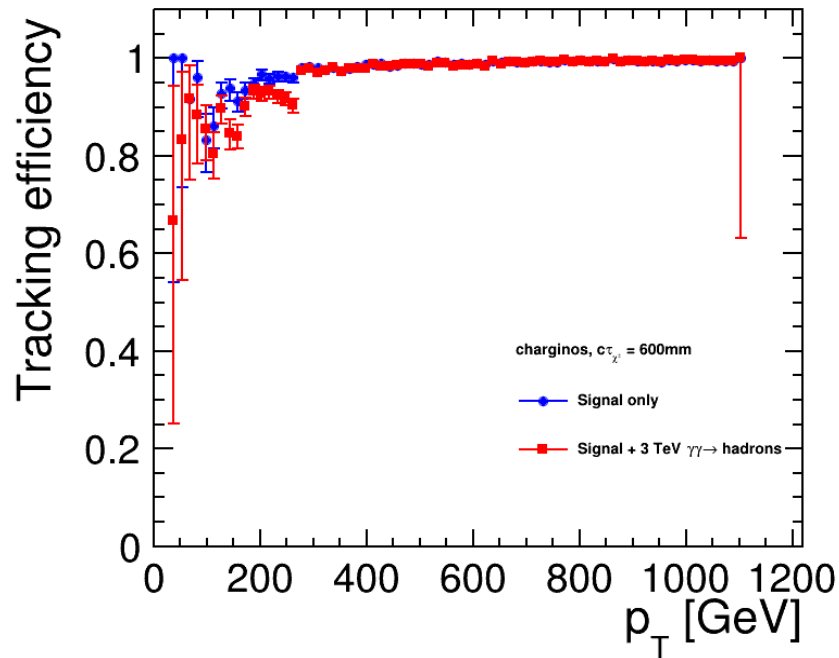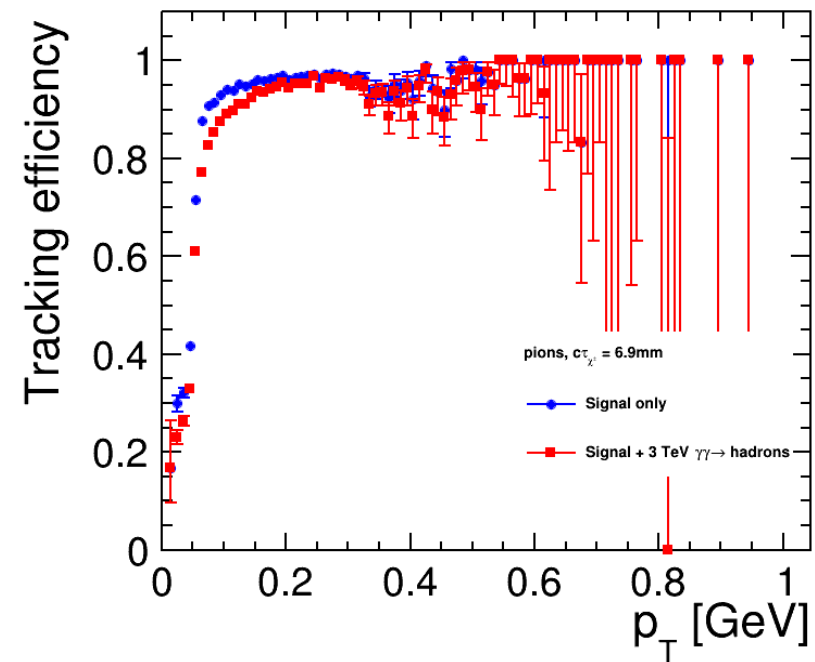
Tracking efficiency

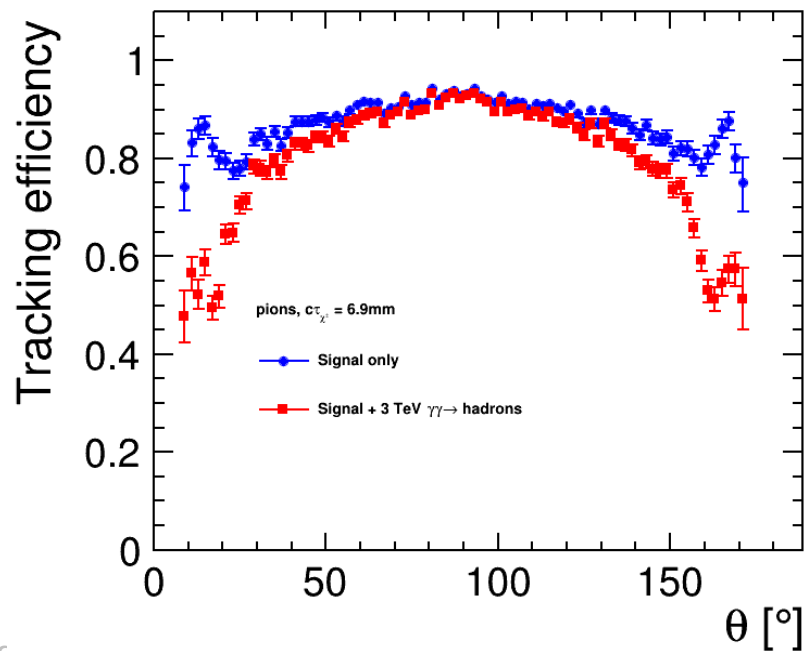Number of **MC part hits** >= 3
- Lifetime 6.9mm
  - Reconstructed = 79818
  - Reconstructable = 89884
- Lifetime 180mm
  - Reconstructed = 18251
  - Reconstructable = 79391
- Lifetime 600mm
  - Reconstructed = 6424
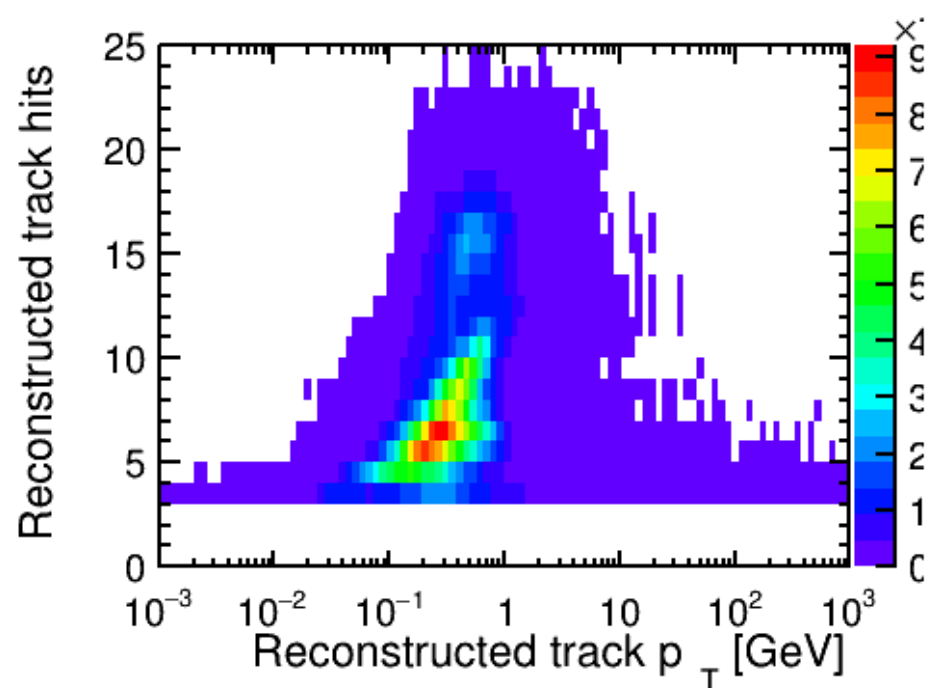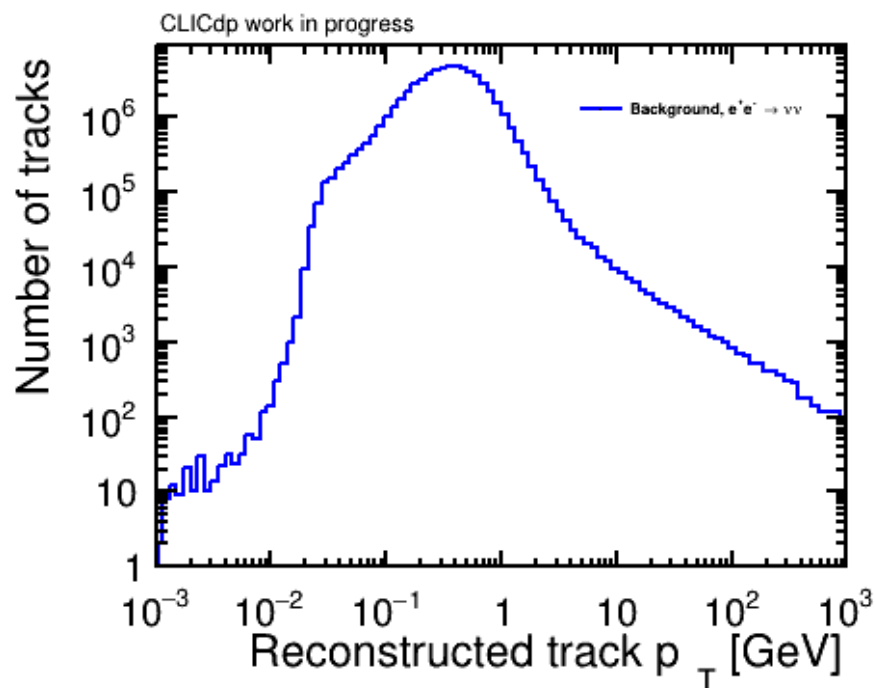 - Reconstructable = 66489

Tracking efficiency

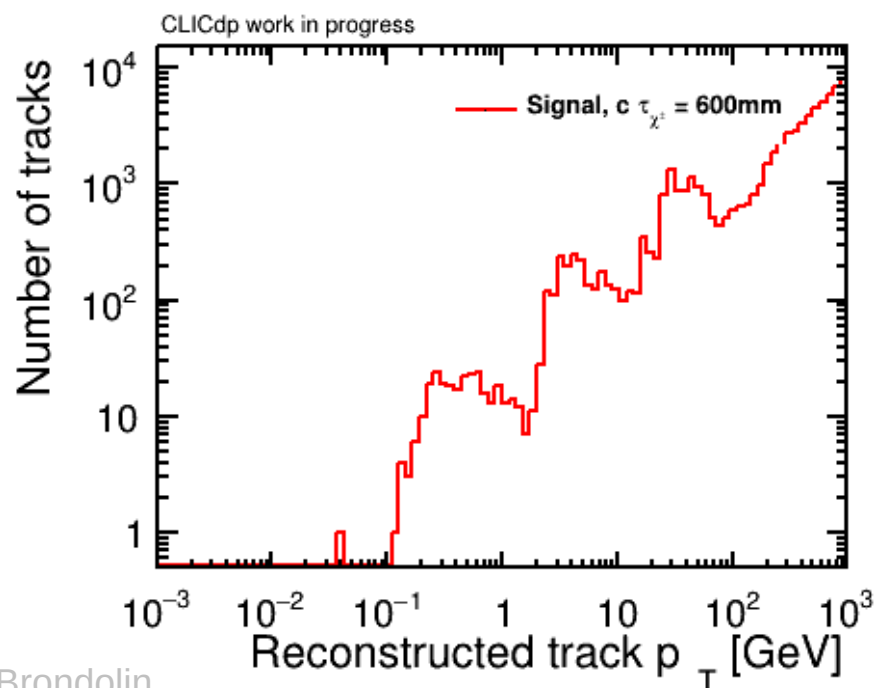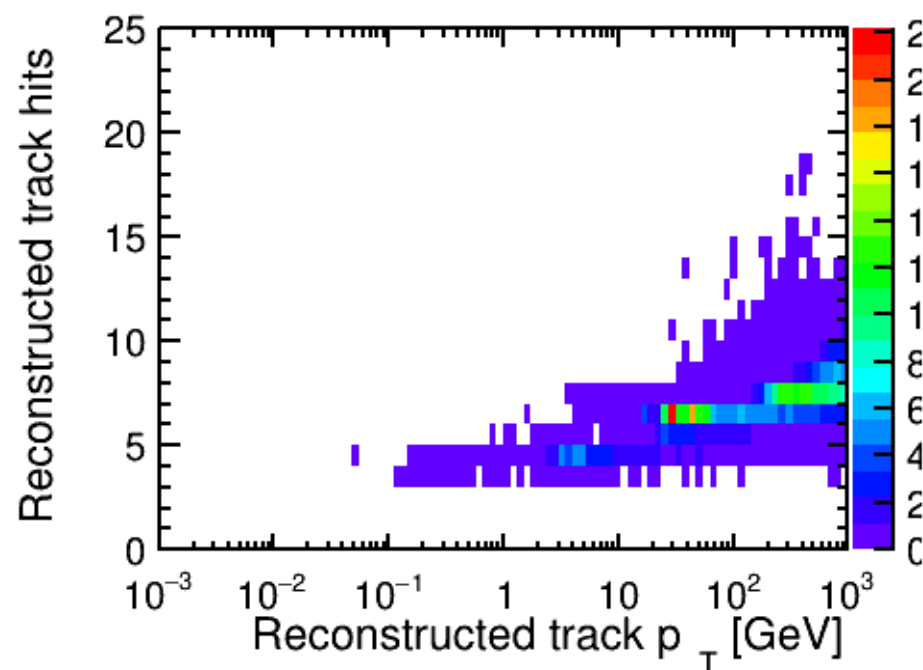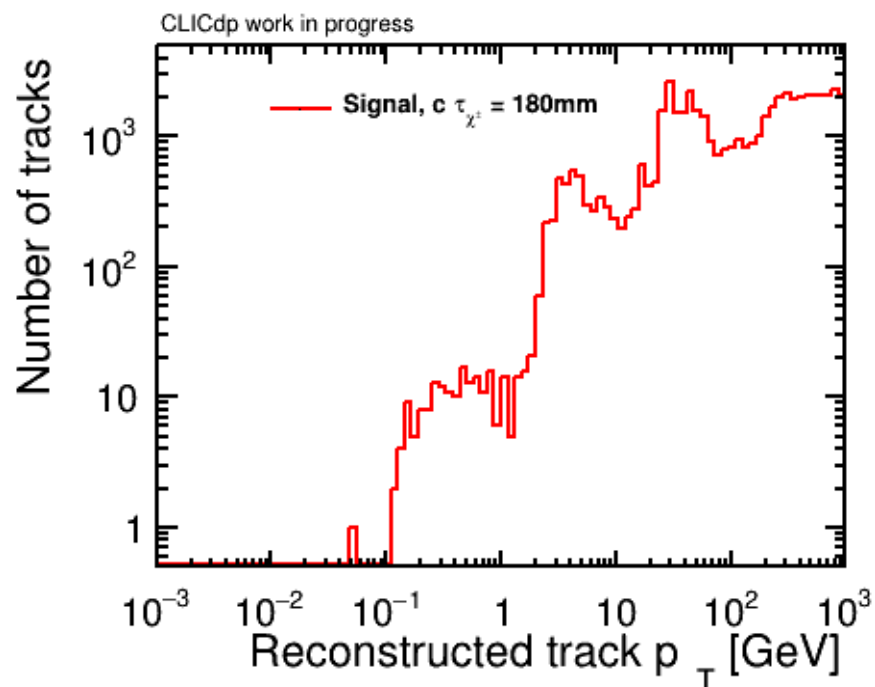# Background distribution (no cuts)

- only γγ → hadrons background, 125k events

- Not yet normalised to physics cross-section
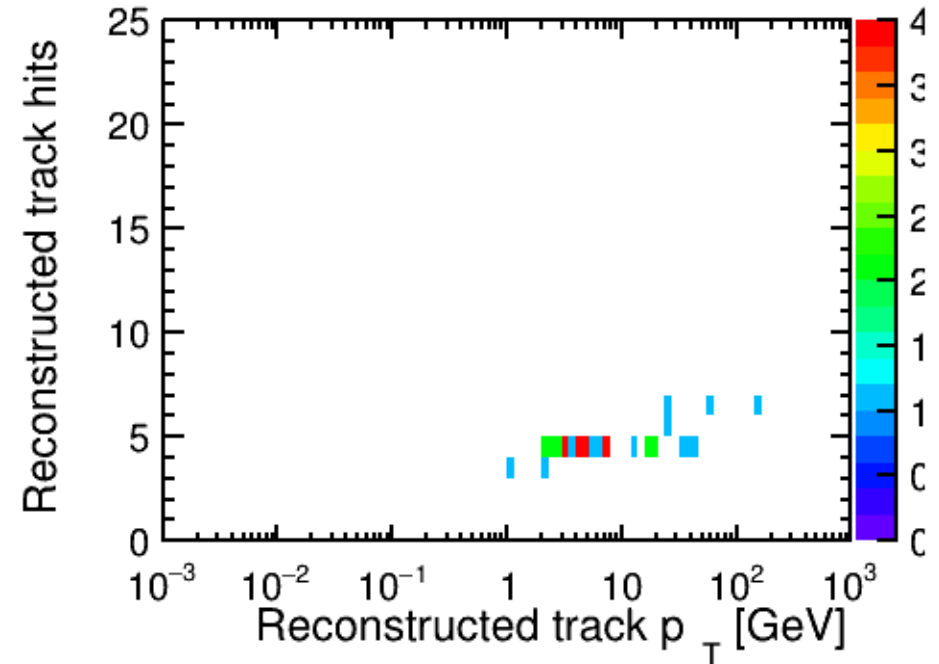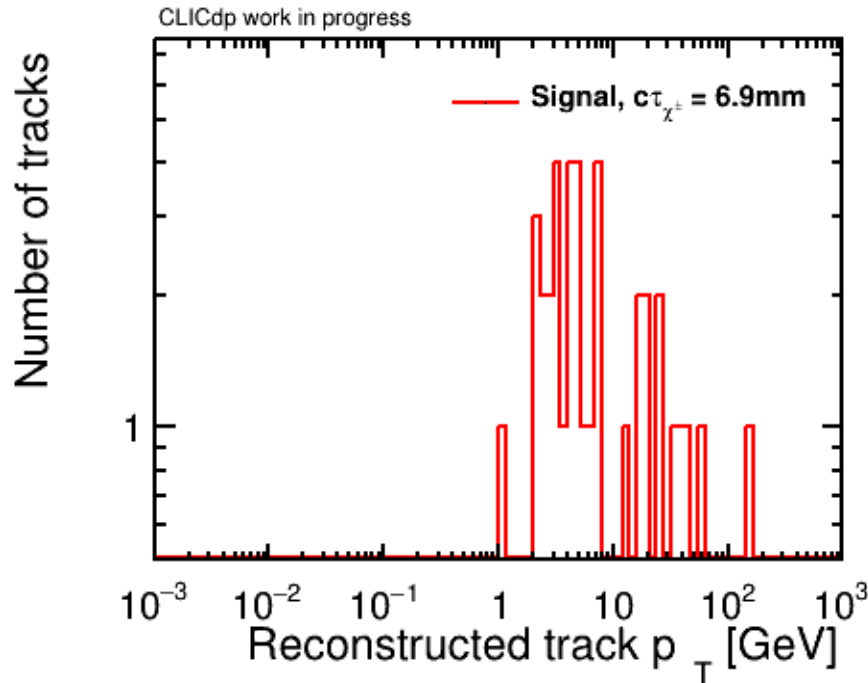
- No analysis cuts applied

- Analysis selections on pT should depend on number of hits

Signal distribution (no cuts)
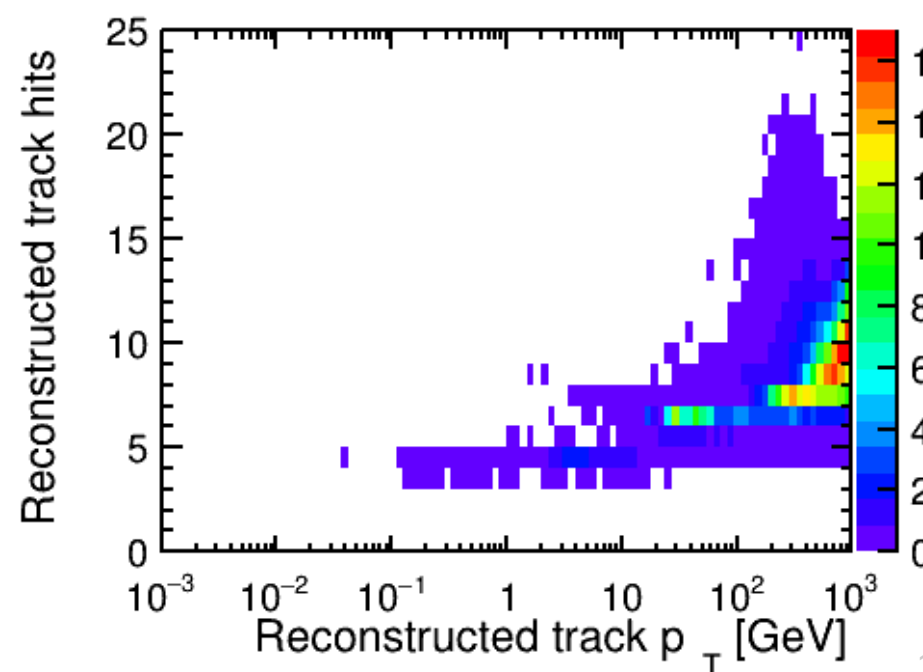
Signal distribution (no cuts)

- Analysis selections on pT should depend on number of hits
- Most recostructed chargino cross two layers of Pixel Detector (2 hits per layer)

Conclusions

- Long-Lived particle studies on-going from ~1 year

- Starting point with short high-pT muons

- More and more realistic samples

- Big contribution during summer 2019

- Effort ramping-up again currently

- Final analysis expected for summer 2020

Charginos already found by Cecilia in summer 2019

Thank you for the attention!