LLP charginos at CLIC

Erica Brondolin, Ulrike Schnoor

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Introduction

- Update on chargino analysis
- News
  - Reweighting for the lifetime validated
  - Preselection introduced
  - Flat ntuples for event selection
  - dE/dx plots

Reweighting for the lifetime

- We have samples with various different lifetimes ($c\tau$) of the charginos
- Why?
  - Sufficient statistics for charginos (is provided by the samples with large lifetimes)
  - Sufficient statistics and accurate treatment of pions (mainly provided by the samples with short lifetime of charginos)
  - Flexibility for some “model-independence” to be able to investigate different lifetimes. CAVEAT: the mass difference between chargino and neutralino is fixed! This in principle determines the lifetime. However, the neutralino mass does not impact the kinematics, just the lifetime, so for the same chargino mass the lifetime is approximately the only parameter
  - also need at some point create samples with different chargino masses for a mass scan (and reweight between the points as well)

Reweighting formulas

The survival probability P_s is the probability for the chargino of mass $m_{\tilde{\chi}}$ and momentum $p_{\tilde{\chi}}$ with a width of $\Gamma_{\tilde{\chi}}$ to travel at least the distance d_{min}:

$$P_s(d_{\text{min}}) = \frac{1}{k} e^{(-m_{\tilde{\chi}} d_{min} \Gamma_{\tilde{\chi}})/p_{\tilde{\chi}}}$$

with normalization constant $k = \frac{pc\tau}{m}$
This corresponds to the cumulative distribution

$$P(d_{\text{min}}) = \frac{1}{k} \int_{d_{\text{min}}}^{\infty} \exp((-m_{\tilde{\chi}} \ell \, \Gamma_{\tilde{\chi}})/p_{\tilde{\chi}}) \text{d}\ell$$

where ℓ is the distance of the decay vertex from (0,0,0) in the lab frame, which is retrieved from the event record as `p.getEndpointVec().Mag()`. The factor *mass/momentum* boosts the trajectory in the rest frame of the chargino. We therefore call $m_{\tilde{\chi}} \ell / p_{\tilde{\chi}}$ in the following the *displacement boost*. We use an exponential function in the fit to determine the mean proper lifetime in the sample.
By using this, the exponent coefficient of the fit function below is just `displacement_boost/ctau`, i.e.

$$\frac{m_{\tilde{\chi}} \ell}{p_{\tilde{\chi}} c\tau}$$

with the lifetime $c\tau = 1/\Gamma_{\tilde{\chi}}$. This allows us to check the results of the reweighting by fitting an exponential function.

Weights

The weights w are defined in dependence on the length of the trajectory in the lab frame ℓ as

$$w(\ell) = \frac{P_{target}(\ell)}{P_{MC}(\ell)}$$

where the target lifetime is 6.9mm (or the one used for the limits later) and the MC lifetime is 600mm for the production used.
This evaluates to

$$w(\ell) = \frac{P_{target}(\ell)}{P_{MC}(\ell)} = \frac{c\tau_{MC}}{c\tau_{target}} \exp\left(-m_{\tilde{\chi}} \frac{\ell}{p_{\tilde{\chi}}} \left[\frac{1}{c\tau_{target}} - \frac{1}{c\tau_{MC}}\right]\right).$$

Weights, continued

In the low $c\tau$ range, the reweighting actually does not decrease the statistical uncertainties. *But: the actually relevant range is beyond 30mm as that is the vertex detector inner radius.* There, the nominal sample (green line) has larger statistical uncertainties compared to the reweighted sample (blue line). The crossover point from $w > 1$ to $w < 1$ is:

$$1 = w(\ell) = \frac{c\tau_{MC}}{c\tau_{target}} \exp\left(-m_{\tilde{\chi}} \frac{\ell}{p_{\tilde{\chi}}} \left[\frac{1}{c\tau_{target}} - \frac{1}{c\tau_{MC}}\right]\right)$$

$$\Leftrightarrow$$

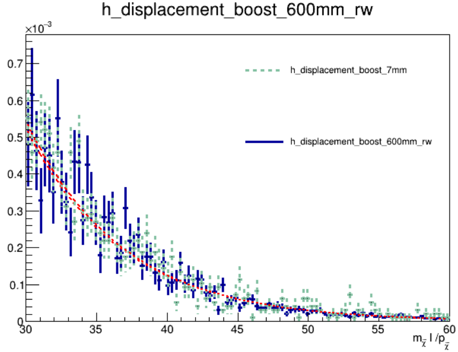
$$\ell = \frac{p}{m} \log\left(\frac{c\tau_{MC}}{c\tau_{target}}\right) \frac{1}{\left[\frac{1}{c\tau_{target}} - \frac{1}{c\tau_{MC}}\right]}$$

For $p \approx 1000\,\text{GeV}$, this becomes $\ell \approx 29.7\,\text{mm}$. That is close to the inner radius of the CLICdet vertex detector.

This shows that especially for values above ca. 40 mm, the statistical errors decrease when using the reweighted sample rather than the original sample.

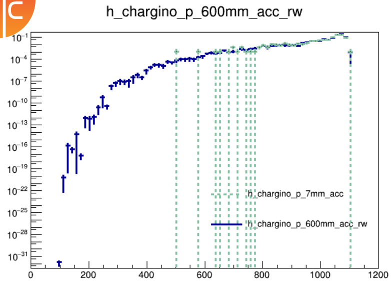
Reweighting validation

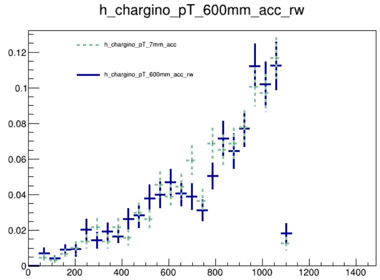
Validated the reweighting for chargino and pion properties

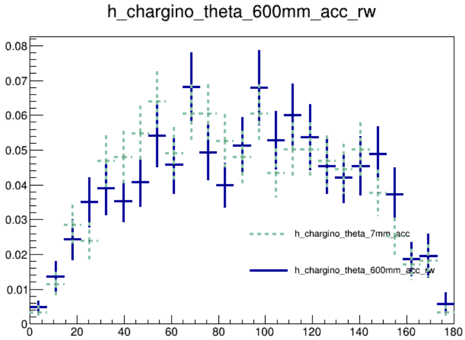


Comparison of the reweighted sample with an original mean lifetime of 600 mm to the target of 6.9 mm. Note that both are normalized to 1. The range $30 < (m/p)\ell < 60$ mm is considered as it corresponds roughly to the most relevant range inside the detector.

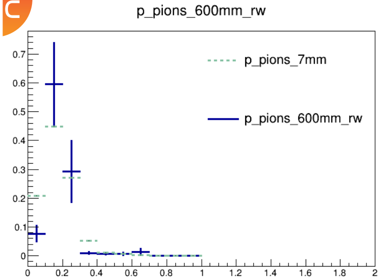
Validating chargino properties (MC generator level)

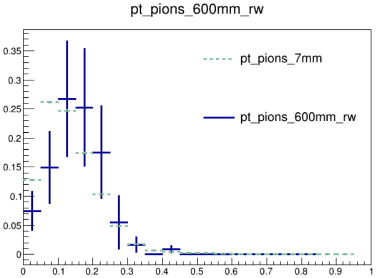


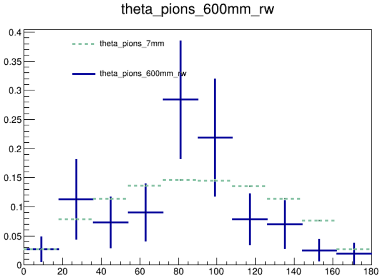




Validating pion properties (MC generator level)







Chargino candidate preselection

Chargino candidate preselection

Charginos are pre-selected from `SiTracks_Refitted` tracks with the following criteria now:

- $p_T > 1\,\mathrm{GeV}$,
- $\sqrt{d_0^2 + z_0^2} < 0.5$
- if $p_T > 1.5\,\mathrm{GeV}$, they should not be associated with a PFO
- isolation: the sum of the pTs of the tracks surrounding the chargino candidate track in a cone of R=0.1 must not be more than 10 % of the chargino candidate track pT, i.e.

$$\frac{\sum_{tracks} p_T(R \leq 0.1)}{p_T(track)} < 0.1$$

NEW: flat ntuples (Event Tree) filled with

- true chargino+, true chargino-
- ch1, ch2 (pT ordered)
- n_ch_cand total number of candidates
- true pi-, true pi+
- pi1, pi2 (ordered by distance to the chargino candidate)

We keep the Track Tree as well, which has the info on all tracks. But the flat ntuples are needed for cut optimisation and BDT training.

dE/dx distributions

dEdx

The dE/dx for one hit is currently filled like this:

```
simhit.getEDep()/simhit.getPathLength()
```

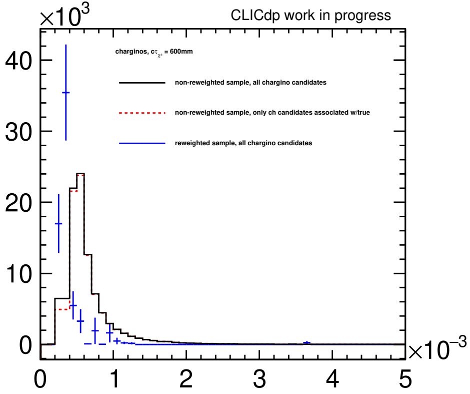
where `simhit` is the simulation-level related hit to the hits obtained from the reco-level SiTracks_Refitted collection

- `simhit` is obtained via `relation.getRelatedObject(hit)`
- `hit` are the elements of `getTrackerHits()` for the "SiTracks_Refitted" collection
- `relation` is the `LCRelationNavigator` among all the tracker hit collections (`["VXDTrackerHits","VXDEndcapTrackerHits","ITrackerHits","OTrackerHits", "ITrackerEndcapHits","OTrackerEndcapHits"]`)

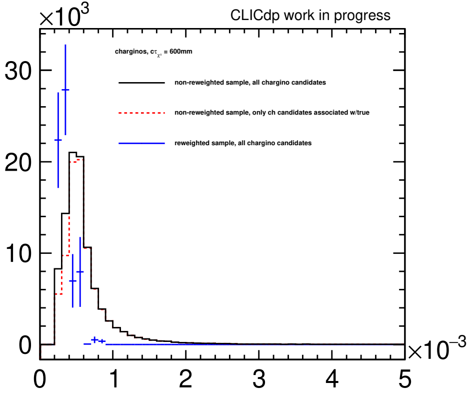
Then, the average of the hits of a track are stored.

dEdx of the signal charginos

No preselection

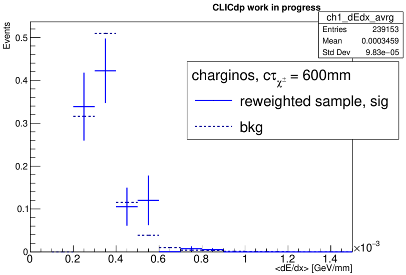


With preselection



The reweighting changes the dE/dx as dE/dx is correlated with the true momentum: the more momentum, the more boosted a chargino is and the longer its trajectory, making it more likely to be reconstructed. The reweighting gives more weight to shorter tracks, therefore there are more

Comparison to Background dEdx



- pre-selected chargino candidates in signal and background
- normalized to the same area
- there seems to be no difference between signal(6.9mm reweighted) and background, which needs to be investigated, as the true momentum of these charginos is so much larger than the true momentum of the chargino candidates from overlay. Perhaps a stricter selection of the charginos would make the distributions more different, or using a truncated mean for the dE/dx of the track.

Cross checking the MC production

Originally, we got the model file in SLHA from Roberto. According to this table of his MadGraph run:
`http://rfrances.web.cern.ch/rfrances/MG5_aMC_v2_6_0/CLICstub/ee2chi-chi+/crossx.html`
he obtained 12.2 fb cross section [1]
With our implementation in the MSSM we get 8.50 fb for the unpolarised case. That is close, but anyway I would like to check with Roberto that the implementation and the MSSM parameters are correct and can be used for the LLP study in this degenerate Higgsino model. Will check the YR and then will send an e-mail to Roberto.

[1] check here: `run3_of_6__ebeam1_1500_ebeam2_1500_Mchi1_1050.0__2018-05-12-22-54`