Charm Jet Tagging in ATHENA

A look at fast simulation in Delphes/delphes_EIC

Stephen Sekula (SMU)
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Basic Ideas

Charm quarks (e.g. produced from CC DIS s->c reactions) contain long-lived heavy charm hadrons that produce displaced substructures (vertices) within the jet.

For now, focus on simple approaches (**displaced track counting**). SMU summer research students looking now at kaon PID and electron PID approaches to enhance this method. Vertexing, etc. on the table as well -> approaches less clear there in Delphes (for now).

Former student Jared Burleson investigated jet substructure and tagging -> observed gains over just using displaced tracks -> aim for all inclusive machine learning approach -> assess robustness against detector design changes, etc.

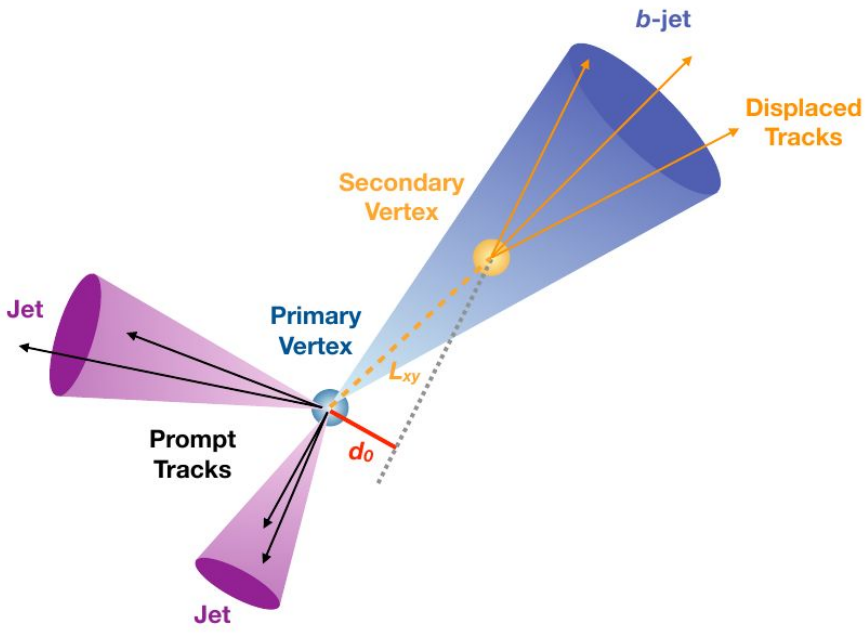


Image from ATLAS Experiment (arXiv:2106.03584). Depicted for pp collisions and b-jets, but applies equally well to charm jets at ep collider.

Signed 3-D Impact Parameter Significance

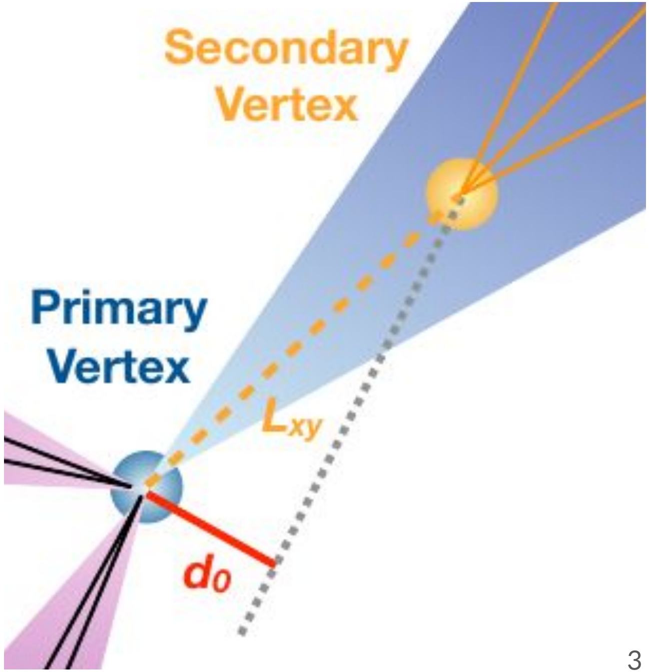
3-D impact parameter significance easily defined for track inside jet:

$$IP_{3D} = \sqrt{(d_0/\sigma_{d_0})^2 + (z_0/\sigma_{z_0})^2}$$

The sign of this quantity is determined from the sign of this dot-product:

$$\vec{p}_j \cdot \vec{r}_0^{\,track}$$

For real displaced tracks from charm hadrons (cτ=100-300μm), this dot product will tend to be positive as the POCA on the track will point parallel to the jet momentum; for prompt decays from light jets, this product will be randomly positive or negative.



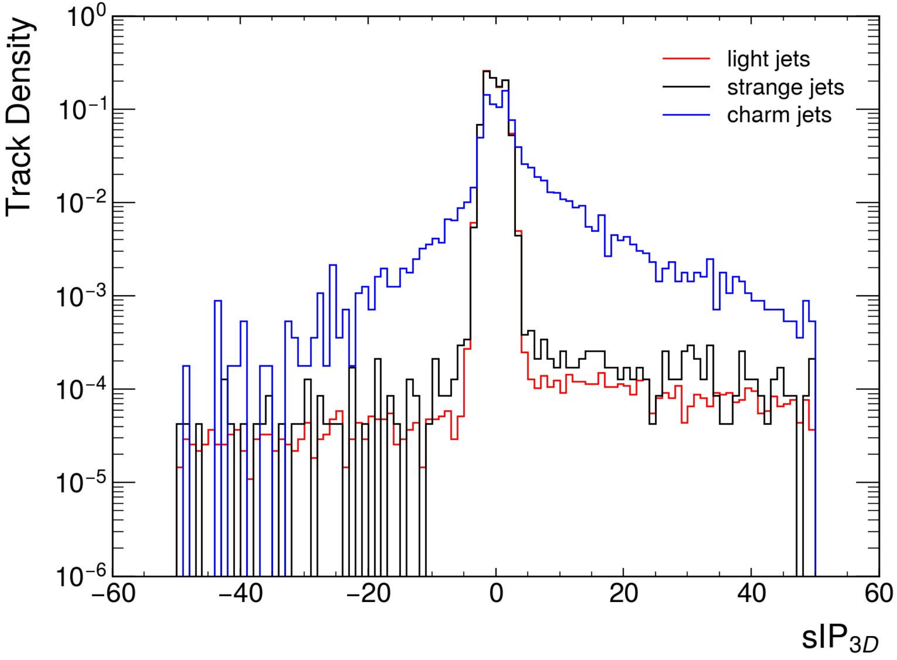
Software Framework

- PYTHIA8(.305) for CC DIS collisions (ep at 10 on 275 GeV) -> 20 million collisions
- DELPHES for fast simulation of final-state particles/smearing for detector effects
- delphes_EIC for ATHENA-like detector configuration, including tracking, PID, ECAL, and HCAL.
  - All-silicon tracker model (momentum smearing and resolution), 3T magnetic field.
- OLeAA for analysis of DELPHES files
  - A better version of a simple analysis framework I sketched up last year -> still very much a work-in-progress (OLeAA = Own Little e-A Analysis)
  - Analyze small output files in Jupyter/UPROOT

Charm Jet Tagging

Adopted without change the approach in [Phys. Rev. D 103, 074023 (2021)].

- ***"Tagged" if ≥2 tracks with: p_T > 0.5 GeV/c, sIP_{3D} > 3, and r_0 < 3mm.***
- In previous work (1.5T field, EIC YR baseline detector model), this yielded 20% (0.4%) charm (light+strange) jet efficiency.
- In current all-silicon + 3T model, same basic performance observed: 19.4% (0.42%) charm (light+strange) jet efficiency.



Next Steps

- We know from our previous work (assuming only a conservative across-the-board 3σ K/pi, etc. separation) that PID boosts jet tagging efficiency
  - **SMU Hamilton Research Scholar Stephanie Gilchrist** will revisit the impact of identified Kaons on jet tagging
  - **Highland Park High School summer intern Justine Choi** will revisit the impact of identified Electrons on jet tagging, with emphasis on calorimetry-based approaches to electron ID.
- I will investigate beam crossing, etc. effects (which will affect all downstream work, of course), as well as vertex reconstruction and jet substructure approaches.
  - Combine this in a simple neural network (already in place) to see how different components contribute and to assess robustness of arbitrary multivariate approaches.
  - Iterate as simulations changes/improves and as full simulation is available.
- ***Translate tagging yield into impact on charm jet population from 1 year of EIC collisions -> impact on intrinsic strangeness assessment***