Heavy Flavor @ ePIC

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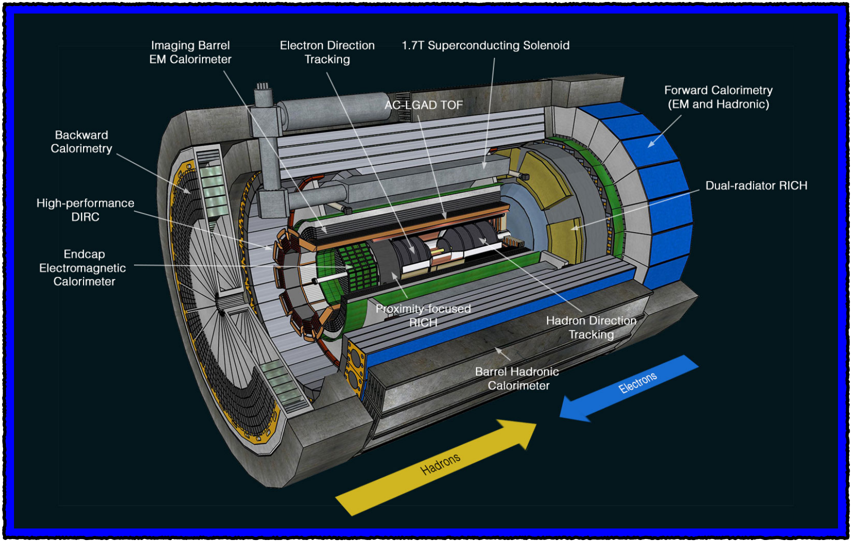
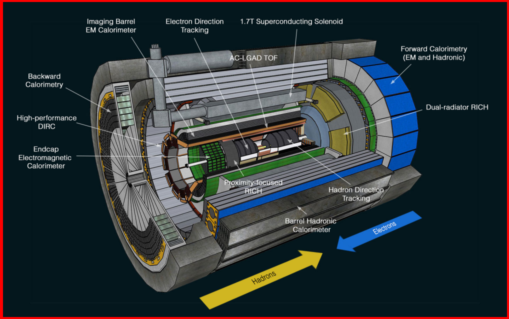
ePIC Detector

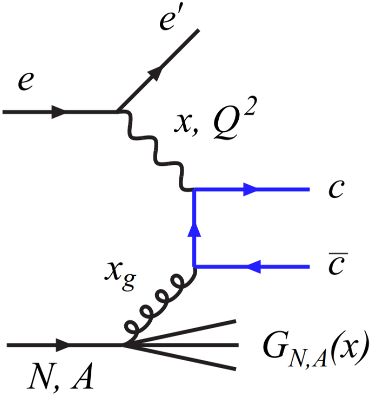


Heavy flavor anyone?



Introduction: Overture

E. C. Aschenauer, et. al., PRD 96 (2017) 114005

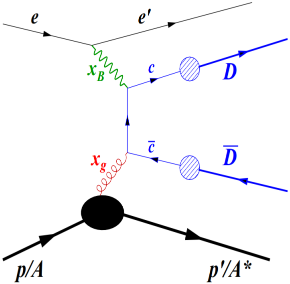


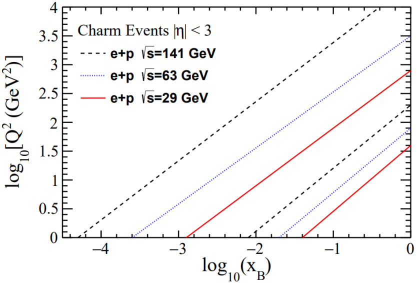
- LO: `photon-gluon fusion`

- Clean environment to precisely determine nPDFs in wide region of $x - Q^2$
- Access to nPDFs at poorly constrained high $x_{\mathcal{B}}$
- Quark and gluon fragmentation
- Constrains parton energy loss in cold nuclear matter
- Insights into charm fragmentation

Introduction: Kinematic Reach

M. Kelsey, et. al., PRD 104 (2021) 054002



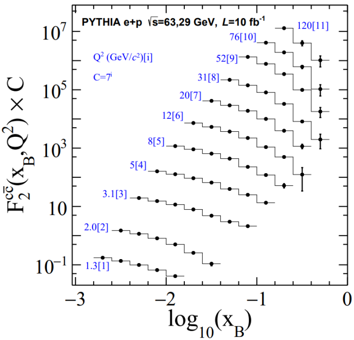


- Unique and direct access to gluons, especially at high x
- Broad kinematic coverage:
  - Probe intrinsic charm

Introduction: Charm Structure Functions

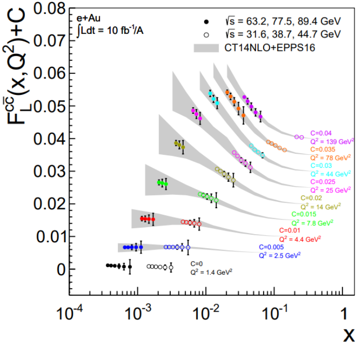
M. Kelsey, et. al., PRD 104 (2021) 054002

e+p, $\sqrt{s} = 63$, $\mathcal{L} = 10$ fb^{-1}



E. C. Aschenauer, et. al., PRD 96 (2017) 114005

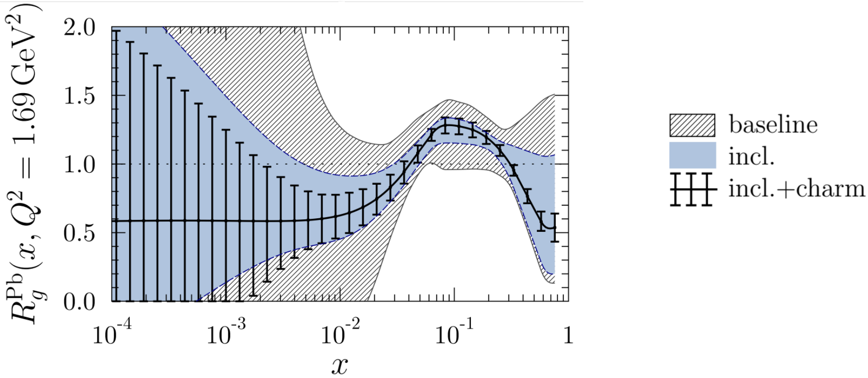
e+A, $\mathcal{L} = 10$ fb^{-1}



- Charm structure functions can be extracted in large $x - Q^2$ range
- **Constrain nPDF**
  - Based on early projections with smearing and not on full ePIC reconstruction

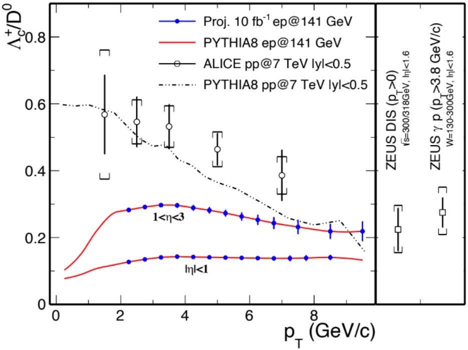
Introduction: Improvement on nPDF

E. C. Aschenauer, et. al., PRD 96 (2017) 114005



- Charm data can uniquely constrain gluon nPDF at high x
- Blue band are fits with no charm data and black error bands are full analyses include charm cross sections
  - ep $= 20 \times 100$ GeV

Introduction: Charm Quark Fragmentation

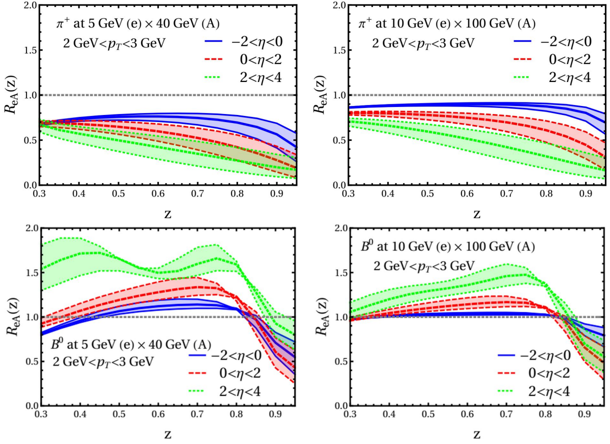


J. Arrington, et. al., arXiv:2102.08337

- Gain new insights into charm fragmentation ep vs. pp collisions
- DIS ratio R_{Λ_c/D^0} vs. p_T
- Projections: e+p 141 GeV, forward & central rapidity, 10 fb^{-1} **(No full ePIC recon.)**

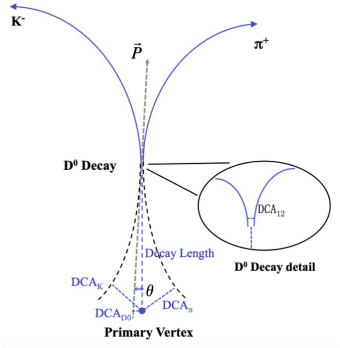
Introduction: Cold Nuclear Matter Effect

H. Li, et. al., PLB 816 (2021) 136261



- Address timescales involved in hadronization and absorption
- In-medium corrections for π^+ (top), B^0 (bottom) as function of z in three rapidity regions

D^0 Toplogical Reconstruction



STAR, Phys. Rev. C 99, 034908 (2019)

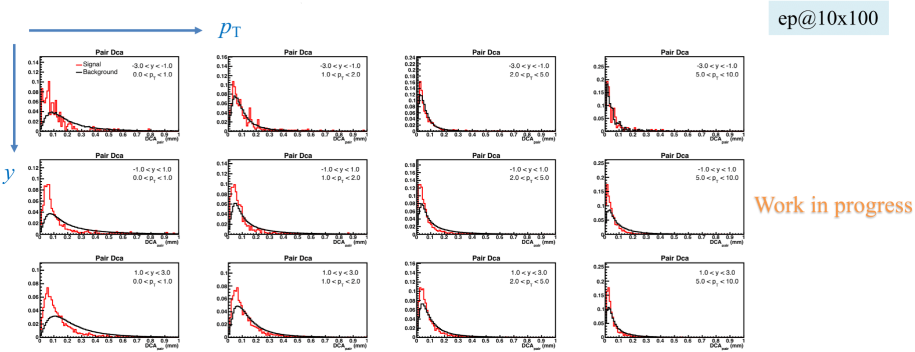
- Topological variables
  - DCA_π, DCA_K, DCA_{12}
  - DCA_{D^0}, decay length, $cos(\theta)$
- Calculated based on helix swimming in a constant magnetic field
  - Adapted from `STAR software`
  - B = -1.7 T

Rongrong

Simulation Configuration

	e+p	e+Au
Event generator	PYTHIA 8.3	BeAGLE v103
Collision energy	10 GeV x 100 GeV	
Minimum Q^2	1 $(\mathrm{GeV/c})^2$	
Beam effects	Included	
Samples	Signal: filtered $D^0 \to \pi + K$ events Background: DIS events	
Geometry tag	24.12.0	25.03.1

DCA_D^0: Signal and Background

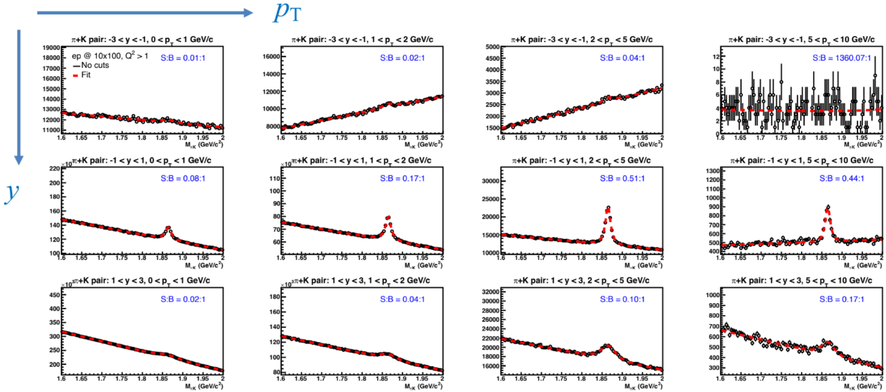


- Signal closer to the primary vertex

Topological Cuts

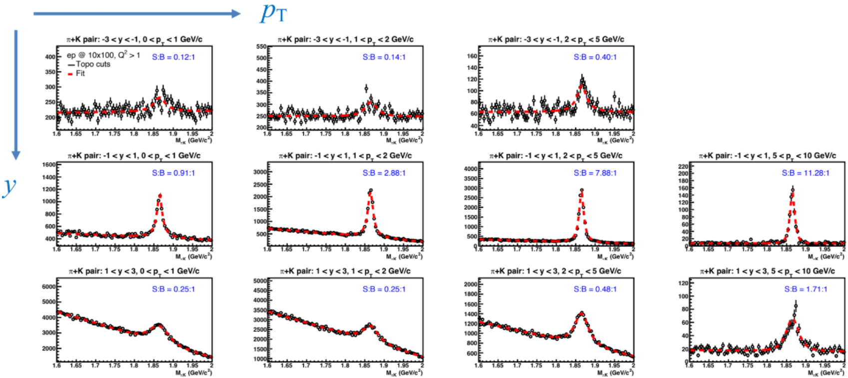
e+p	e+Au
Real PID $DCA_\pi > 20\ \mu m$ $DCA_K > 20\ \mu m$ $DCA_{12} < 70\ \mu m$ $DCA_{D0} < 100\ \mu m$ Decay length $> 50\ \mu m$ $\cos\theta > 0.95$	Real PID $DCA_{12} < 200\ \mu m$ $DCA_{D0} < 100\ \mu m$ Decay length $< 200\ \mu m$

Invariant Mass M_{D^0}: No Topological Cuts



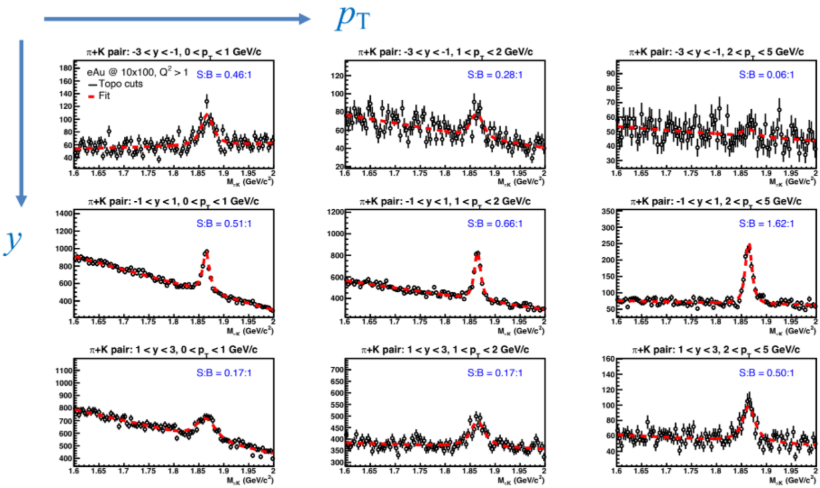
- S/B ratio within 2σ of signal peak
- Challenging at backward rapidity low p_T

Invariant Mass M_{D^0}: Topological Cuts

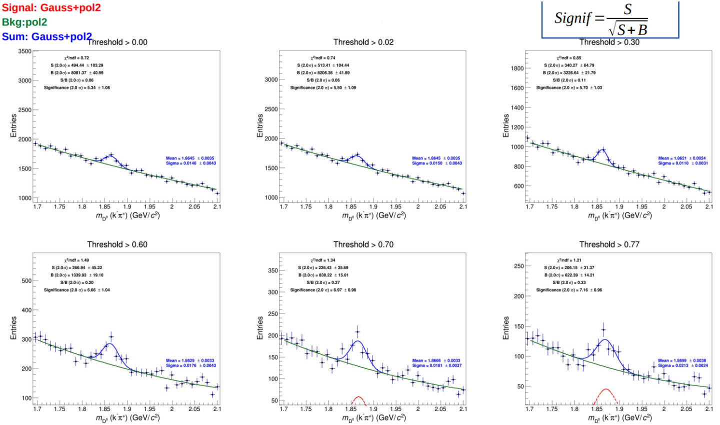


- S/B significantly improved
- Backward rapidity and low p_T still challenging

Invariant Mass M_{D^0}: Toplogical Cuts (eA)



- Good performance even at backward rapidity
- High p_T reach limited by statistics



Estimation of Signal to Background

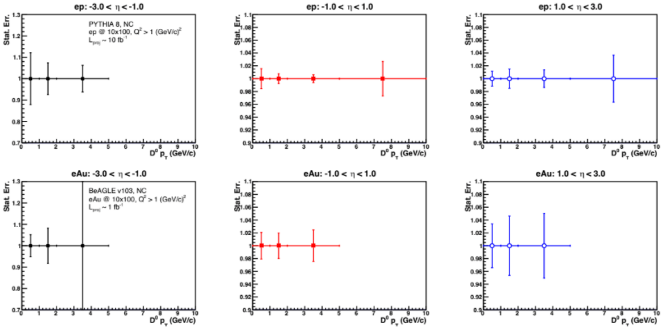
- Signal makes use of enriched D^0 samples
- Background is from `24.12.0/epic_craterlake/DIS/NC/10x100/minQ2=1`

Shyam

Projection: D^0 Significance

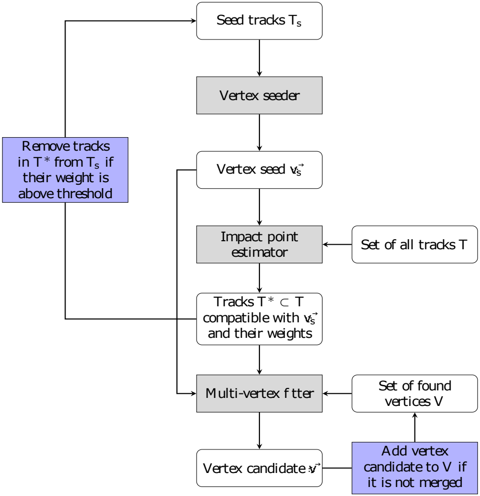
ep: $L_{proj} = 10\ \mathrm{fb}^{-1}$
eAu: $L_{proj} = 1\ \mathrm{fb}^{-1}/\mathrm{N}$

Work in progress



- Good performance overall
  - Mid-rap > forward > backward
- Next: x-Q^2 binning

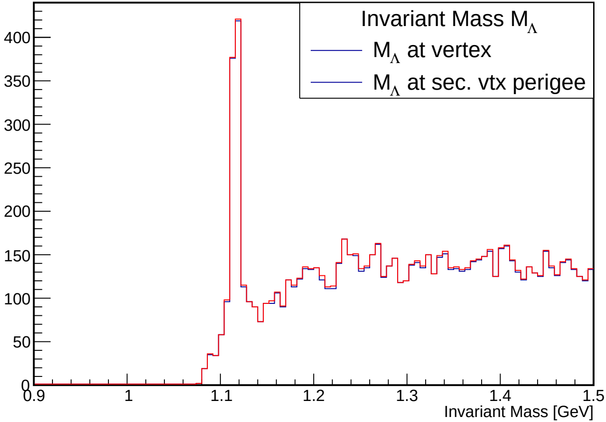
Adaptive Multi-VertexFinder (AMVF)



- Consists of reweighted Kalman filters with deterministic annealing
- Removeable beamspot constraint (useful for secondary vertices)
- Gaussian track density seed finder to estimate vertex position
- Check compatibility of tracks with seeder (assign weight if compatible)
- Simultaneous refit of all previously found vertices and vertex seed
- After convergence of fit, check whether the vertex candidate is merged with other vertices, discard if merged
- Remove seed tracks if their weights are above threshold

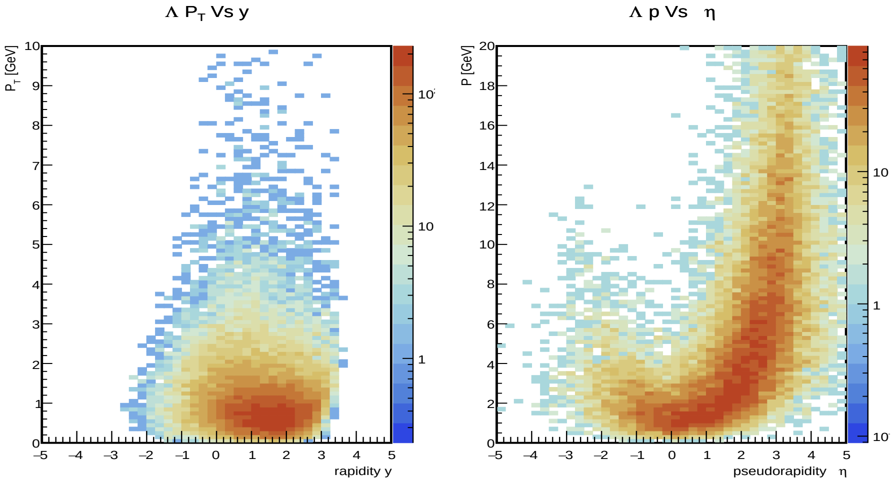
Identification of b-jets and investigation of the discovery potential of a Higgs boson in the $WH \to \ell\nu b\bar{b}$ channel with the ATLAS experiment
N. G. Piacquadio (2010)

SV Mass: $\Lambda \to p\pi$



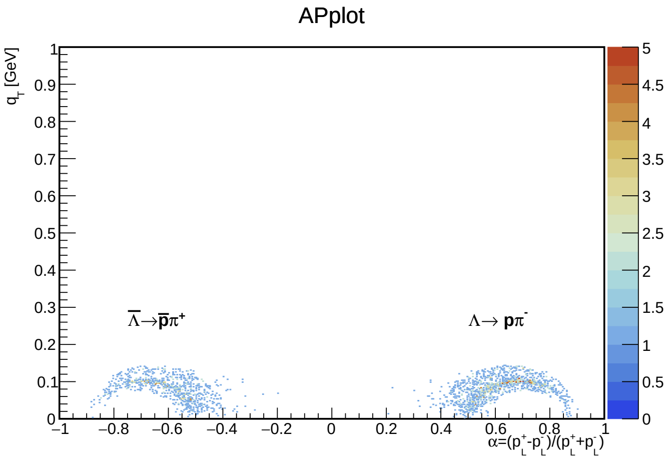
- Invariant mass of two-track secondary vertex: `18x275 ep`
- $\Lambda \to p\pi$ has `cm` scale decay length, good testbed for displaced vertex algorithms
- M_Λ propagating $p\pi$ tracks to secondary vertex as perigee surface

Kinematic Plots



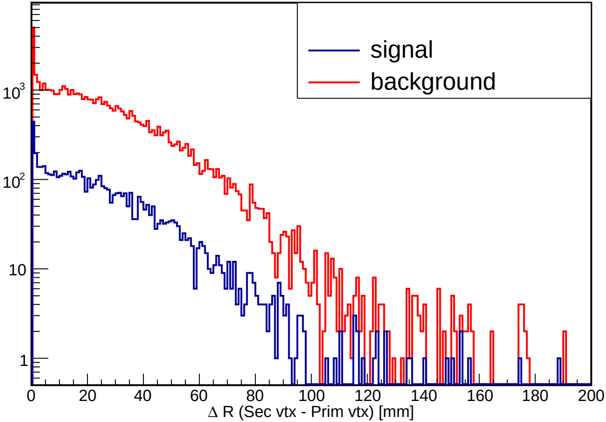
- Λ kinematic plots

Armenteros-Podolansky Plot



- PID plot of daughters p_L asymmetry relative to the parent particle

3D Distance between Secondary & Primary Vertex



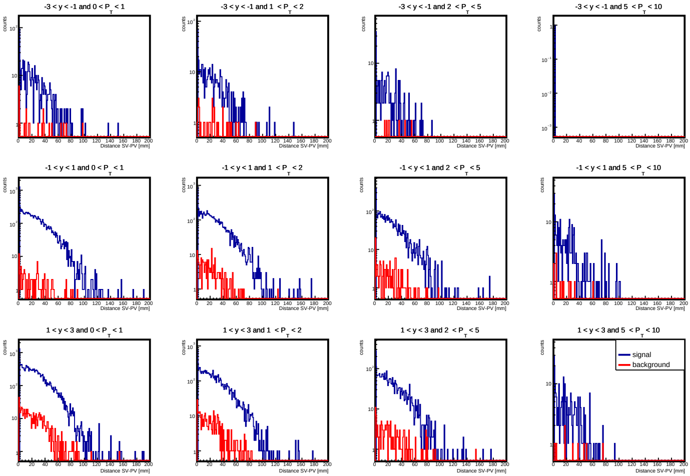
- 3D distance SV-PV

Summary and Beyond

- Heavy flavor production at EIC provides unique access to gluon distributions, especially at large x
- ePIC detector is well positioned to measure charm quark
  - Large acceptance: `backward, mid & forward rapidity`
  - Excellent PID
- Initial studies of HF with full ePIC detector simulation look very promising
  - $D^0 \longrightarrow K\pi$
    - Accumulate more simulation statistics
    - Refine signal extraction with machine learning and other techniques
  - $\Lambda \longrightarrow p\pi$
    - Consistency check: PV evaluation with AMVF and compare to existing results
    - Compare SV with Helix calculations

Back Up Slides

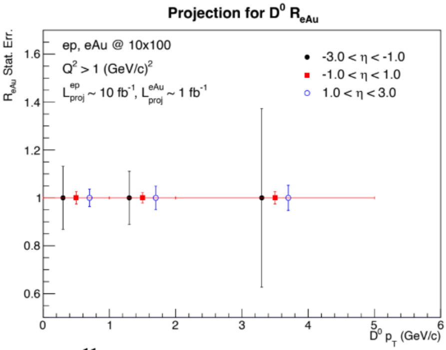
Signal and Background in Kinematic Bins



Projection: D^0 R_{eAu} statistical error

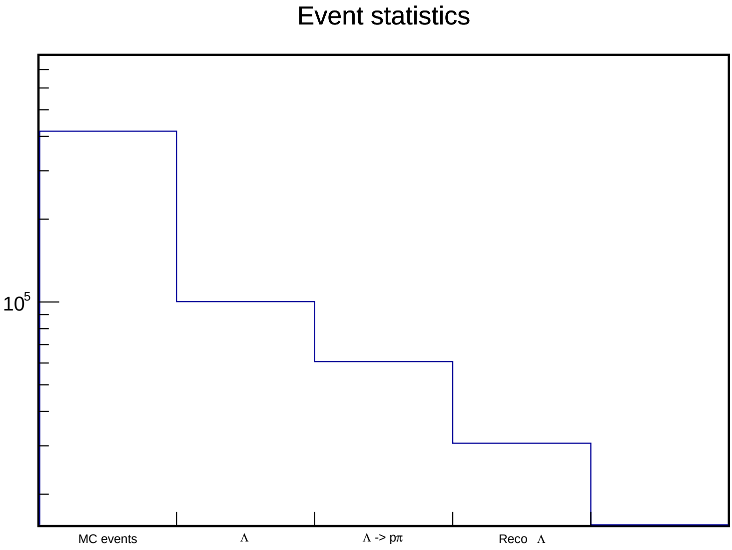
ep: $L_{proj} = 10\ fb^{-1}$
eAu: $L_{proj} = 1\ fb^{-1}/N$

Work in progress

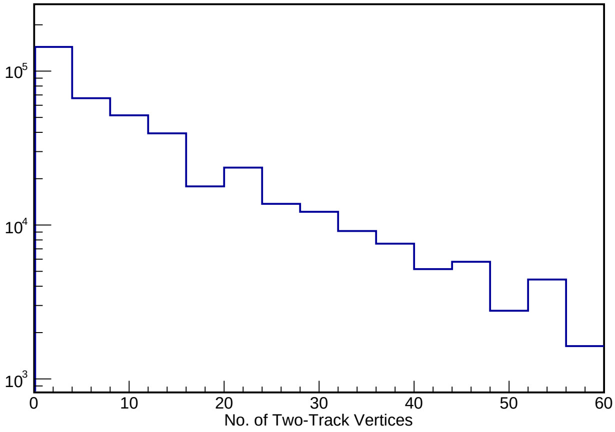


- Good performance overall
  - Mid-rap > forward > backward

Event Distribution

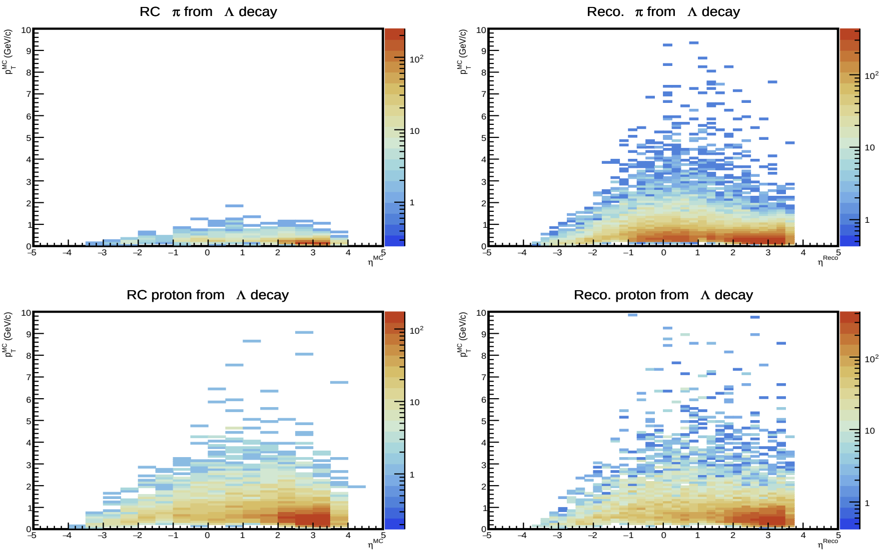


Two-Track Secondary Vertex Multiplicity

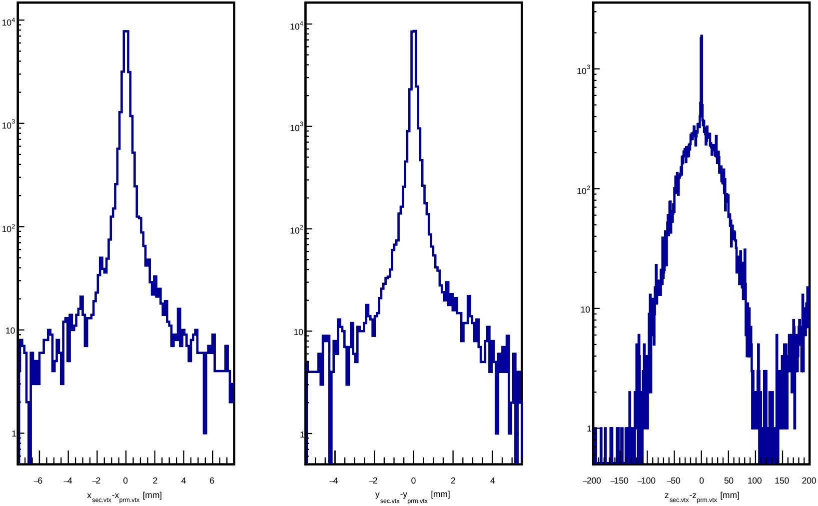


- Number of two-track vertices per event is quite high
- No cuts or conditions applied to this histogram

MC-RC Daughter Kinematics (p_T vs η): $\Lambda \rightarrow p\pi$



SV - PV (X,Y,Z) Coordinate



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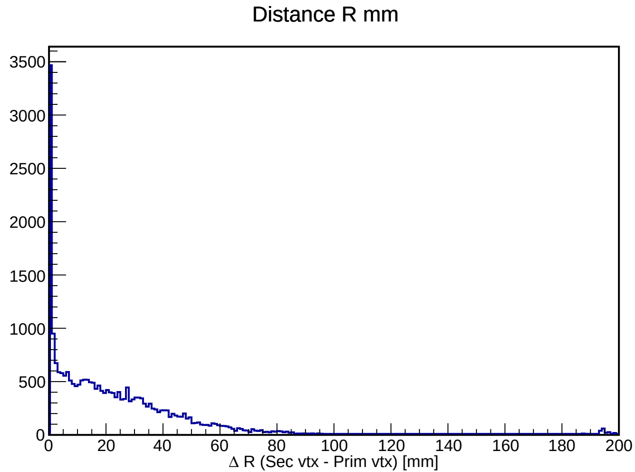
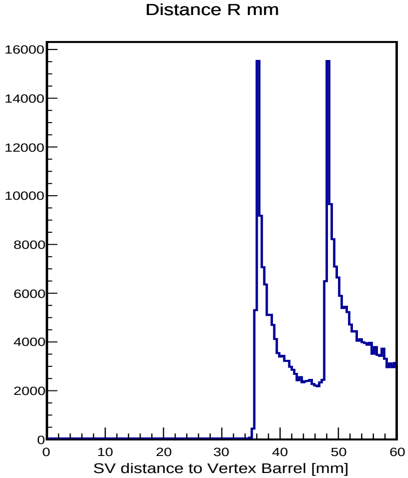
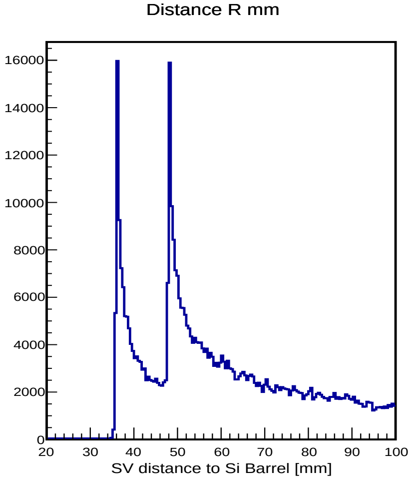
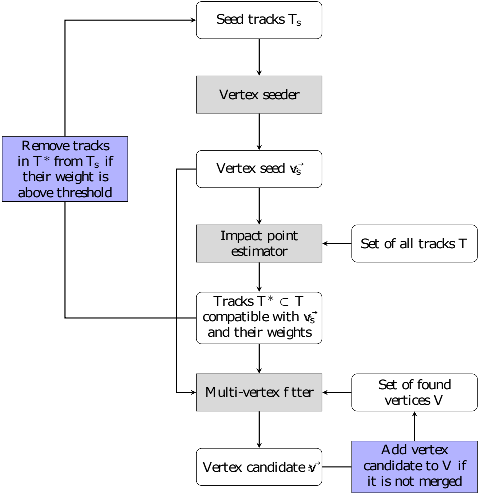


SV Distance to Material





Adaptive Multi-VertexFinder (AMVF)



- Weighted adaptive Kalman filter with deterministic annealing
- Removeable beamspot constraint (useful for secondary vertices)
- Gaussian track density seed finder
- Simultaneous refit of all vertices connected through a chain of vertices and tracks with weights:

$$\omega_i(\chi_i^2, T) = \frac{e^{-\frac{1}{2}\chi_i^2/T}}{\sum_j e^{-\frac{1}{2}\chi_j^2/T} + e^{-\frac{1}{2}\chi_0^2/T}}$$

- Merge vertices if they are close enough

Identification of b-jets and investigation of the discovery potential of a Higgs boson in the $WH \rightarrow \ell\nu b\bar{b}$ channel with the ATLAS experiment
N. G. Piacquadio (2010)