# Jets and Heavy Quarks PWG Summary

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## Jets and Heavy Quarks PWG

~86 members are currently subscribed to our mailing list,

Weekly group meetings on Mondays at noon ET, c.f. indico.bnl.gov/category/290

If a topic interests you, it is *not* too late to join the effort,

Contact any of us directly, or via

http://www.eicug.org/web/content/yellow-report-physics-working-group

# Jets and Heavy Quarks PWG Goals

Physics measurement	Channel		
Longitudinal spin structure	Inclusive jet and dijet measurements		
Sivers asymmetry, special focus on gluons	Jet, lepton-jet and di-jet measurements		
Electroweak structure functions, charged currents	Jets, flavor separated jets, Longitudinally polarized reactions ep, parity violating asymmetries		
TMDs, nuclear broadening, energy loss	D-jets and photon/lepton tagged jets, ep, eA		
Longitudinal and transverse (TMD) fragmentation, shapes and splitting functions	Inclusive jet measurements -> hadrons in jets, energy flow, angularities		
Energy loss and hadronization	Heavy mesons cross sections in comparison to light mesons in ep, eA		
Charm and beauty content of nucleons and nuclei	Heavy flavor-tagged jets, ep, eA		
Flavor and mass dependence of parton showers	Heavy flavor-tagged jet substructure, ep,eA,quarkonia in jets		
Extraction of fundamental parameters,	Global event shapes, thrust,		

hadronization constants,  $\alpha_s$ 

Global event shapes, thrust, angularities, N-jettiness

# Jets and Heavy Quarks Parallel Sessions

Lively parallel sessions yesterday, dedicated to Jets and Heavy Quarks, joint with the inclusive and SIDIS working groups, and joint discussion with physics and detector working groups,

Joe Osborn (ORNL) Ivan Vitev (LANL)	Jet substructure studies for the EIC Calculations of heavy meson production at EIC
Miguel Arratia (UCR)	Jets for 3D imaging
Matt Kelsey (LBNL)	Charm and bottom at EIC
Xiaoxuan Chu (BNL).	Charged Current in unpolarized ep collisions
Bowen Xiao (CCNU)	SIDIS summary of inclusive and jet related topics
Cheuk-Ping Wong (LANL	) LANL open heavy flavor and quarkonia simulation
	updates for the EIC Yellow Report preparation
Ciprian Gal (SBU)	Electroweak and BSM physics at the EIC
Steve Sekula (SMU)	Charm-tagging in Charged-Current Interactions at EIC

Conveners

**Discussion Input** 

## Jet example:

j<sub>T</sub> [GeV]

10-

10<sup>-2</sup>

10<sup>-3</sup>

10-4

CAK RIDGE

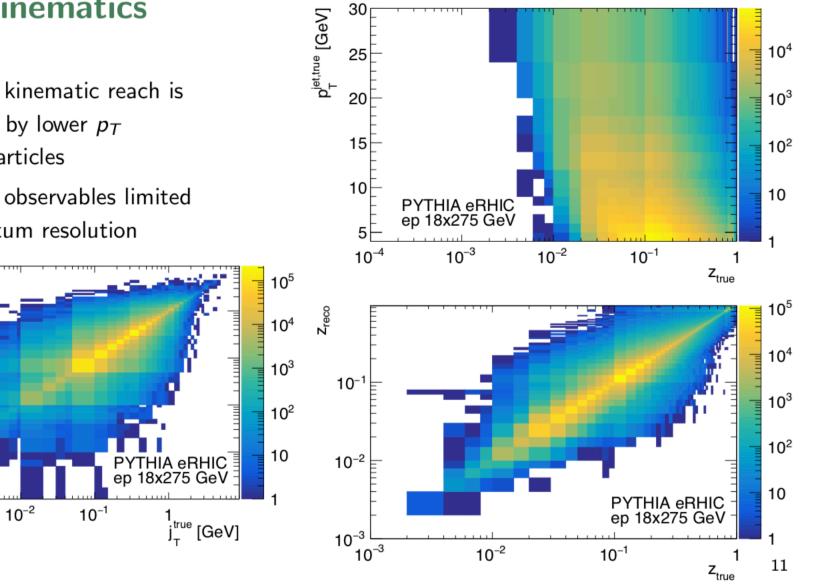
10<sup>-4</sup>

10<sup>-3</sup>

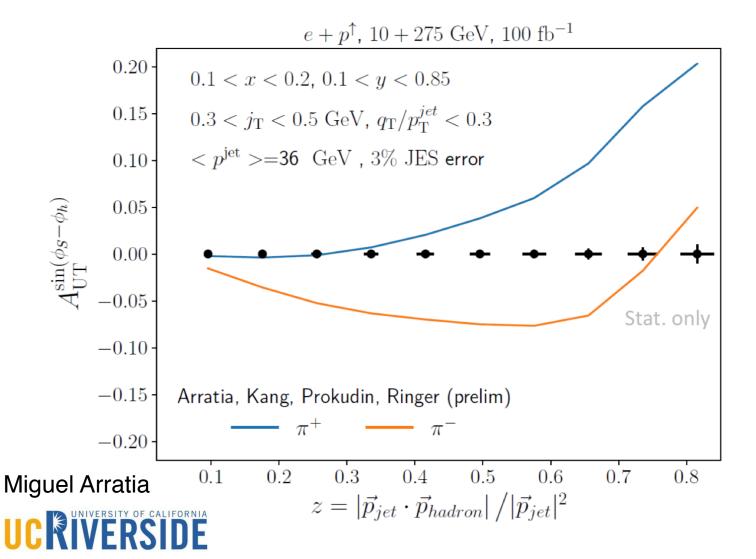
Joe Osborn



- Hadronization kinematic reach is mostly limited by lower  $p_T$ threshold of particles
- Hadronization observables limited by jet momentum resolution



# Jet example: Hadron-in-jet theory prediction (new!)



- By measuring both photon axis and jet axis we control separately TMD PDF (qT) and TMD FF (jT, z).
- Goal is multi-differential quark-transversity study.

$$\frac{\mathrm{d}\sigma}{\mathrm{d}y_e \,\mathrm{d}^2 \vec{p}_T^{\,e} \,\mathrm{d}^2 \vec{q}_T \,\mathrm{d}z_h \,\mathrm{d}^2 \vec{j}_T^{\,h}} = \\ \times \,\sigma_0 \,H_q(Q,\mu) \sum_q e_q^2 \,\mathcal{G}_q(z_h,\vec{j}_T,p_T^{\mathrm{jet}}R,\mu) \\ \times \,\int \frac{\mathrm{d}^2 \vec{b}_T}{(2\pi)^2} \,e^{i\vec{q}_T \cdot \vec{b}_T} \,f_q(x,\vec{b}_T,\mu) \,S_q(\vec{b}_T,y_{\mathrm{jet}},R,\mu)$$

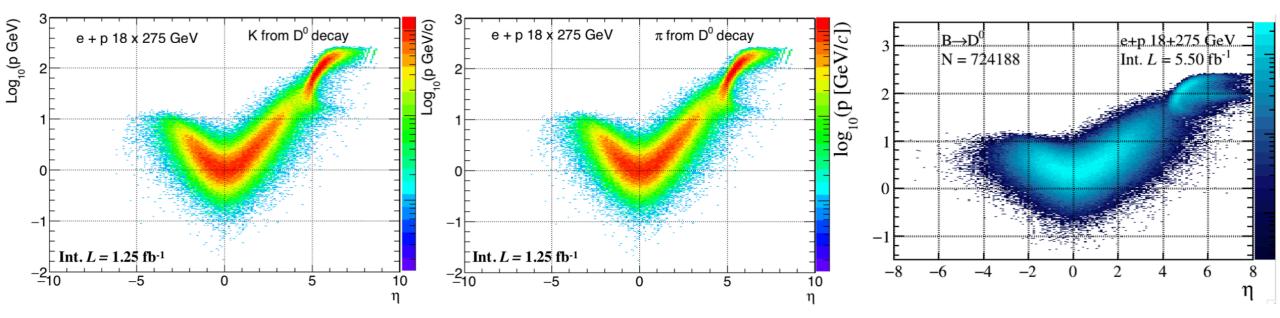
## Jet examples and prelim. detector performance needs:

Table 1: Channels listed are increasingly demanding. For every row consider all requirements above as well. The  $(x, Q^2)$  dependence of the observables is omitted for brevity. Date: May 20, 2020, Miguel Arratia

Channel	Observable	Goal	Physics-driven requirement	Category	numbers
e-jet (NC)	$d\sigma, A_{UT}(\Delta\phi)$	$k_T$ -dependence	$\Delta \phi$ res. << intrinsic width	Jet res.	jet $dE/E < 20\%/\sqrt{E}$
			$\sigma(\Delta\phi) < 0.02$ rad		$\rightarrow$ ECAL&HCAL $dE/E < 60\%/\sqrt{E}$
$100 {\rm ~fb^{-1}}$		of quark Sivers	$R = 1.0 \rightarrow \text{had. corr. } O(1)\%$	Acceptance	$2\pi$ , $ \eta  < 3.5$ HCAL and ECAL
			particle-flow reco	Granularity	endcap $\Delta \phi \times \Delta \eta \leq 0.025 \times 0.025$
h-in-jet (NC)	$d\sigma, A_{UT}(z_h, j_T)$	q-transversity	dp/p at high $z < jet  dE/E$	Tracker	$dp/p < 3\%$ at 50 GeV, up to $\eta = 3.0$
$100 \text{ fb}^{-1}$				PID	up to $\eta < 3.5$ and 50 GeV
$\nu$ -jet (CC)	$d\sigma, A_{UT}$	u Sivers	$\Delta \phi \ll 0.3$ rad	$E_T^{miss}$ res.	$dE_T^{miss}/E_T^{miss} < 15\%$
$100 {\rm ~fb^{-1}}$			Bkg. rej. to phot and NC	Acceptance	$2\pi$ , $ \eta  < 3.5$ HCAL and ECAL
					E>100 MeV thres. ECAL
					E>400 MeV thres. HCAL
					$p_T > 100 \text{ MeV tracker}$
			>70% survival prob.	$\operatorname{Jet}/E_T^{miss}$ res.	dx/x < 20%,
			for 5 bins per-decade in $x, Q^2$		$dE_T^{miss}/E_T^{miss} < 15\%$
h-in-jet (CC)	$d\sigma, A_{UT}(z_h, j_T)$	u-transversity		—	—
$100 {\rm ~fb^{-1}}$					
c-jet (CC)	$d\sigma, A_{LL}$	s PDF& helicity	charm-tagging	Tracker	<i>c</i> -jet tag at $> 10\%$ (<0.05%)
$100 {\rm ~fb^{-1}}$					$\sigma(DCA) = 20 \ \mu m$ , up to $ \eta  = 3$
					$\approx 100\%$ eff.
				PID	TBD
h-in- $c$ -jet (CC)	$d\sigma, A_{UT}(z_h, j_T)$	<i>s</i> -transversity	—		—
$100 {\rm ~fb^{-1}}$					
$c$ -jet ( $e^+$ CC)	$d\sigma, A_{LL}$	$s/\bar{s}$ asymmetry	positrons		
$100 \text{ fb}^{-1}$		/ 0 0	1		

Not the final word, work continues/remains. However, e.g. HCAL continues to be about tails not resolution.

# HQ example: Heavy-Flavor Decay Distributions



- Charm and bottom decay products within  $|\eta| < 3$
- Similar distributions for other charm hadron decays and  $B \rightarrow D^+/Lepton$  decays

Matt Kelsey et al (Pavia WS), and complementary work.

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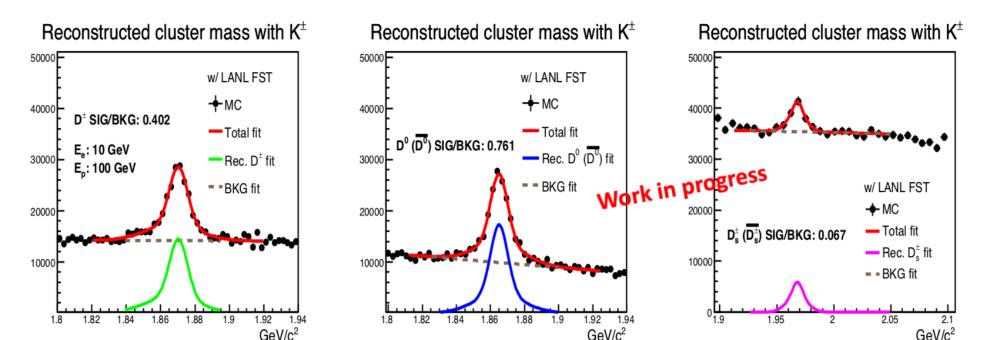
BERKELEY LAB

# HQ example: Invariant Mass Reconstruction

#### **Reconstructed D mesons in PYTHIA8 simulation**



- In 10 GeV electron and 100 GeV proton collisions with integrated luminosity: 10 fb<sup>-1</sup>.
- Reconstructed D meson mass distributions.
  - Tracking  $\eta$  cut: 1 to 3 and track efficiency set at 95%.
  - The performances are based on 100% K/ $\pi/p$  separation.
  - Charged track clusters that contain  $K^{\pm}$  with a decay length (DCA) cut.



Xuan Li et al (Pavia WS), and complementary work.

## HQ example:

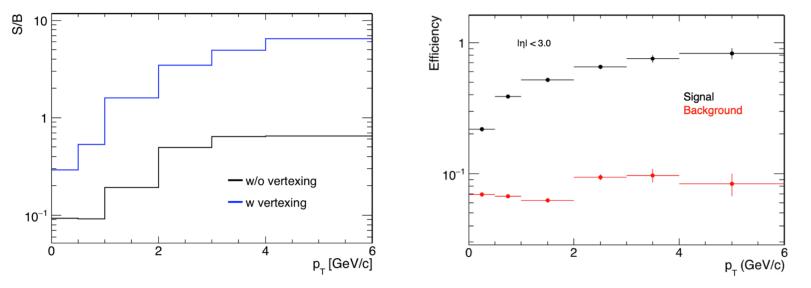
## Vertexing

Interested parties from Birmingham, LANL, LBNL, ... are taking active part in the Tracking DWG are contributing actively to GEANT-based / full simulations,

Fast HQ simulations have started to consider vertexing beyond fixed-number smearing/assumptions to take into account event-topology by fitting vertices.

D<sup>0</sup> S/B and Efficiency

Matt Kelsey et al (Pavia WS).



- Reiterating nice improvement of  $D^{0}$  S/B with vertexing
  - Factor of 10(2) for high(low)  $p_T$
- Modest signal efficiency with "by-eye" cuts

# Jets and Heavy Quarks - Closing Comments

Not discussed in this summary,

Theory calculations of heavy meson cross-sections, Quarkonia and exotics,

Charm jet-tagging in charged-current interactions,

Near-term future,

Complete, document, and archive "kinematic maps", Further evaluate detector needs,

Looking ahead towards the EICUG collaboration meeting and 3<sup>rd</sup> workshop, Develop physics projections for key measurements, Iterate detector needs,

Note: The <u>2020 APS-DNP Fall Meeting</u> will feature an EIC mini-symposium, This year's <u>abstract submission</u> deadline will be June 26, 2020