Template Overlap in Tops and Higgs

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LGA, S. J. Lee, G. Perez, G. Sterman, I. Sung
[0807.0234]; [0810.0934]; [1006.2035];
LGA, O. Erdozan, J. Kunich, S. J. Lee, G. Perez, G. Sterman
[1112.1957]

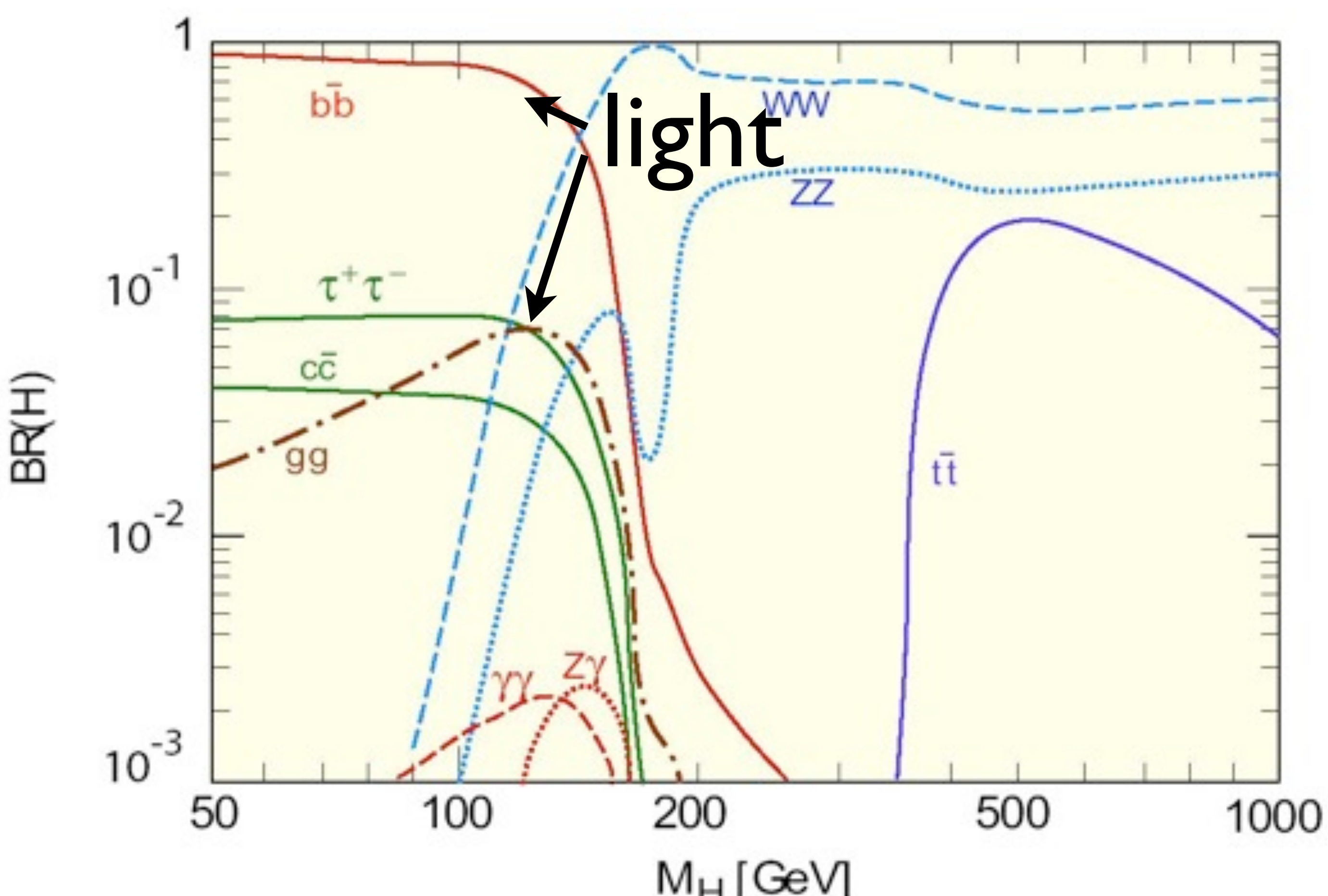
Backovic, Kunich , Perez ,Winter,
[ongoing]

Outline

Identifying jets:

"Top Quark" like   Vertex b-tagging performance uncertain (at high pt)

"Higgs" like   utilized the hadronic branches of Electroweak decays.



IR safe Observables

Overlap Method

QCD Background leads development of

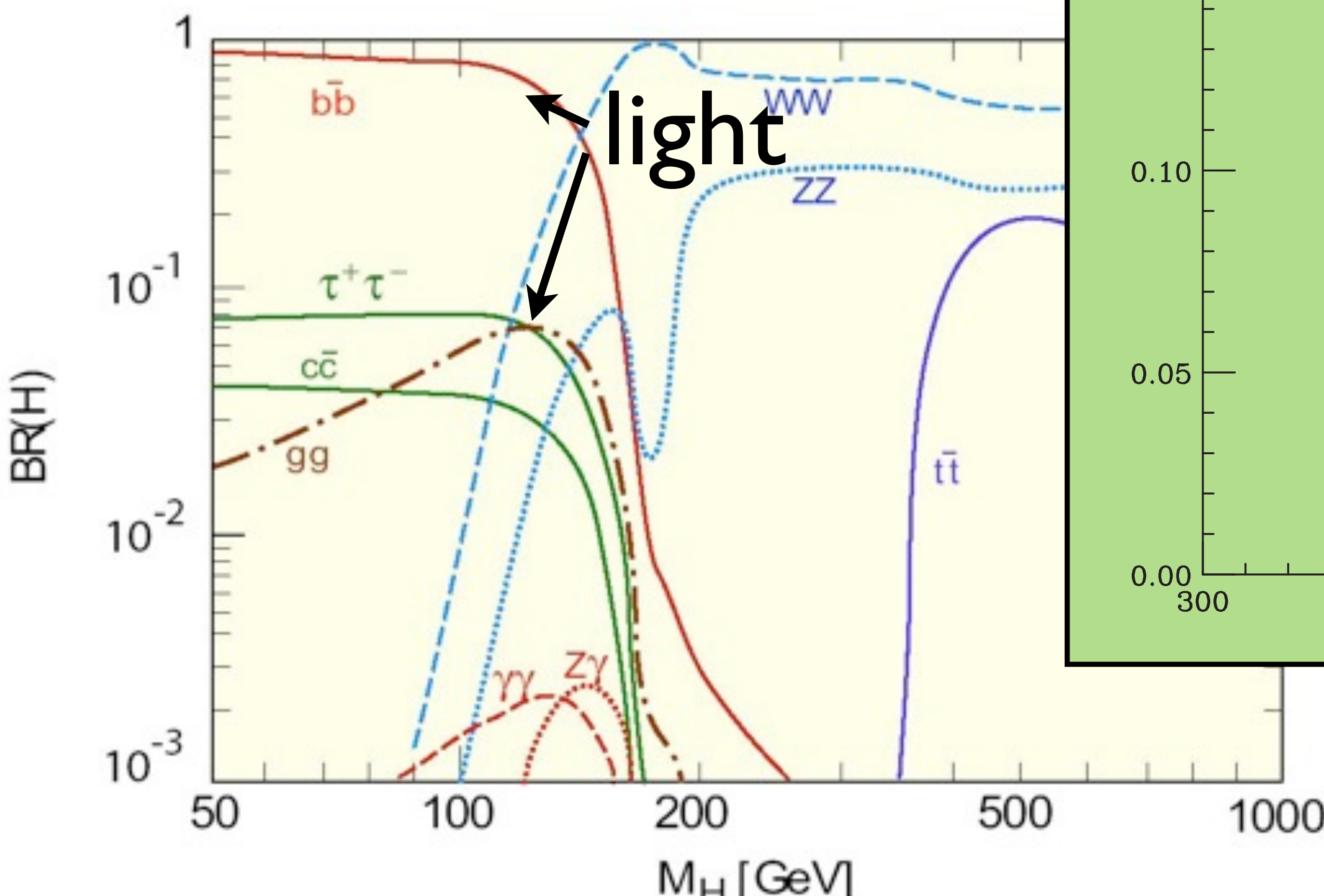
Observables sensitive to signal or background

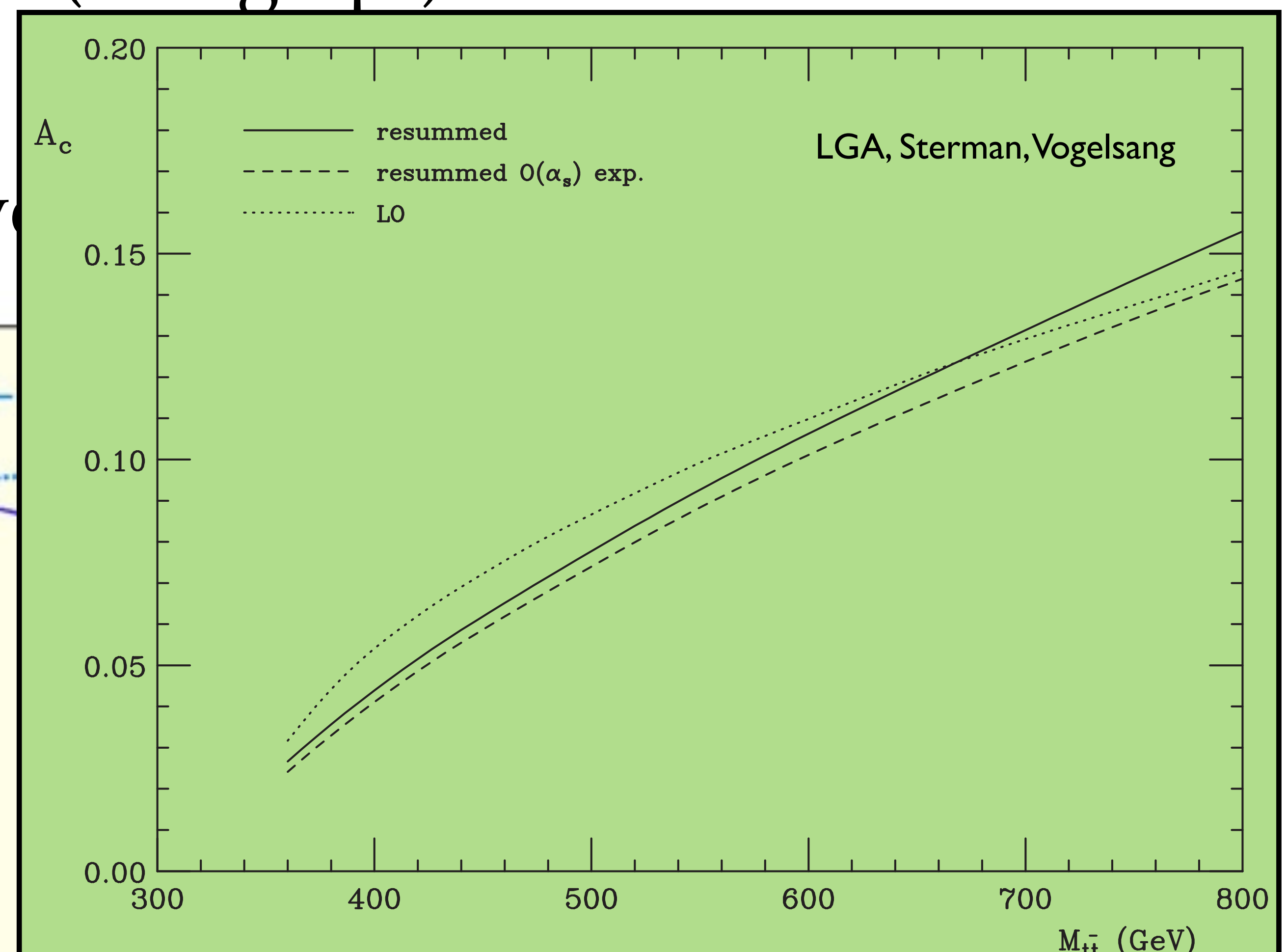
Outline

Identifying jets:

“Top Quark” like   Vertex b-tagging performance
uncertain (at high pt)

“Higgs” like   utilized
Electrow

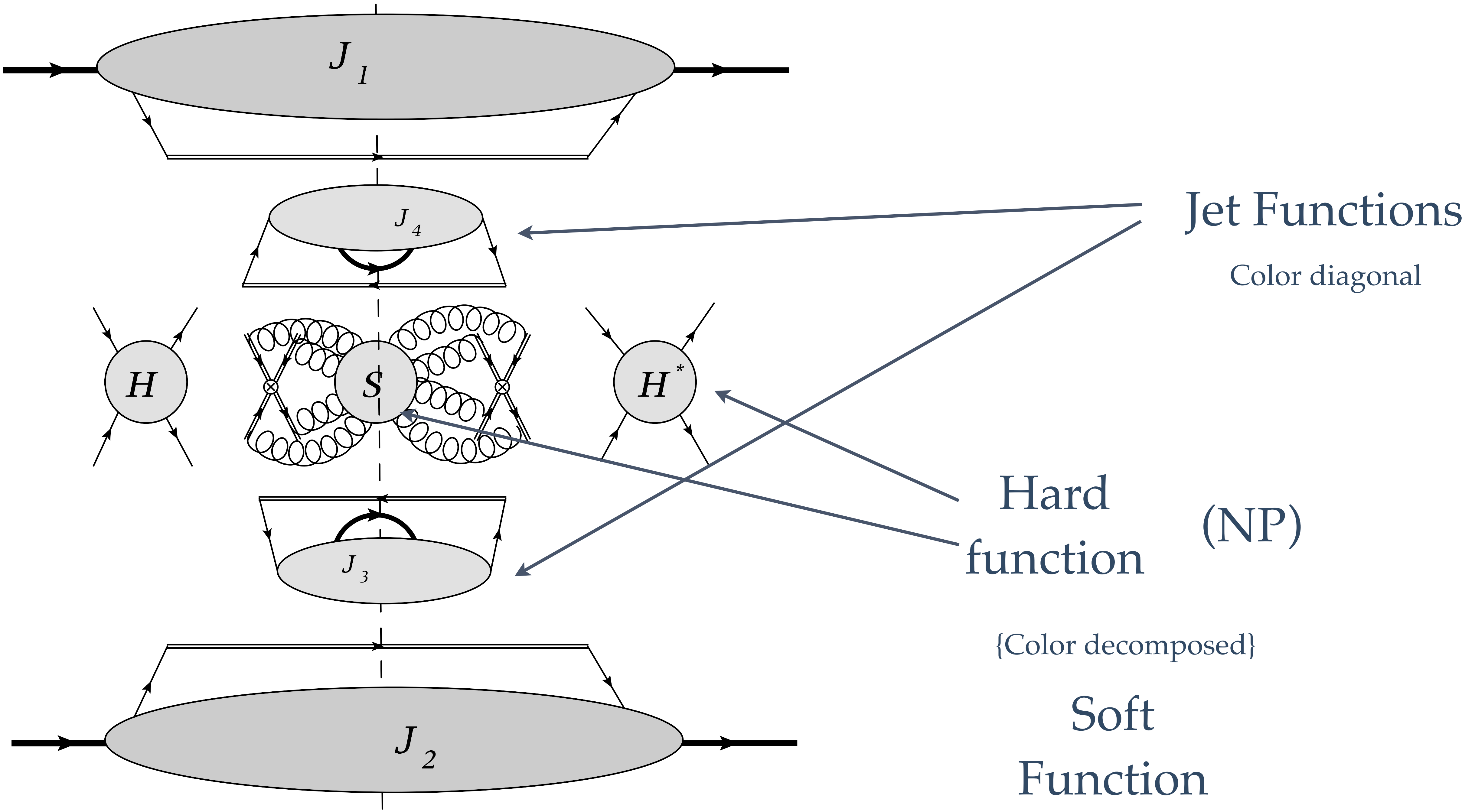




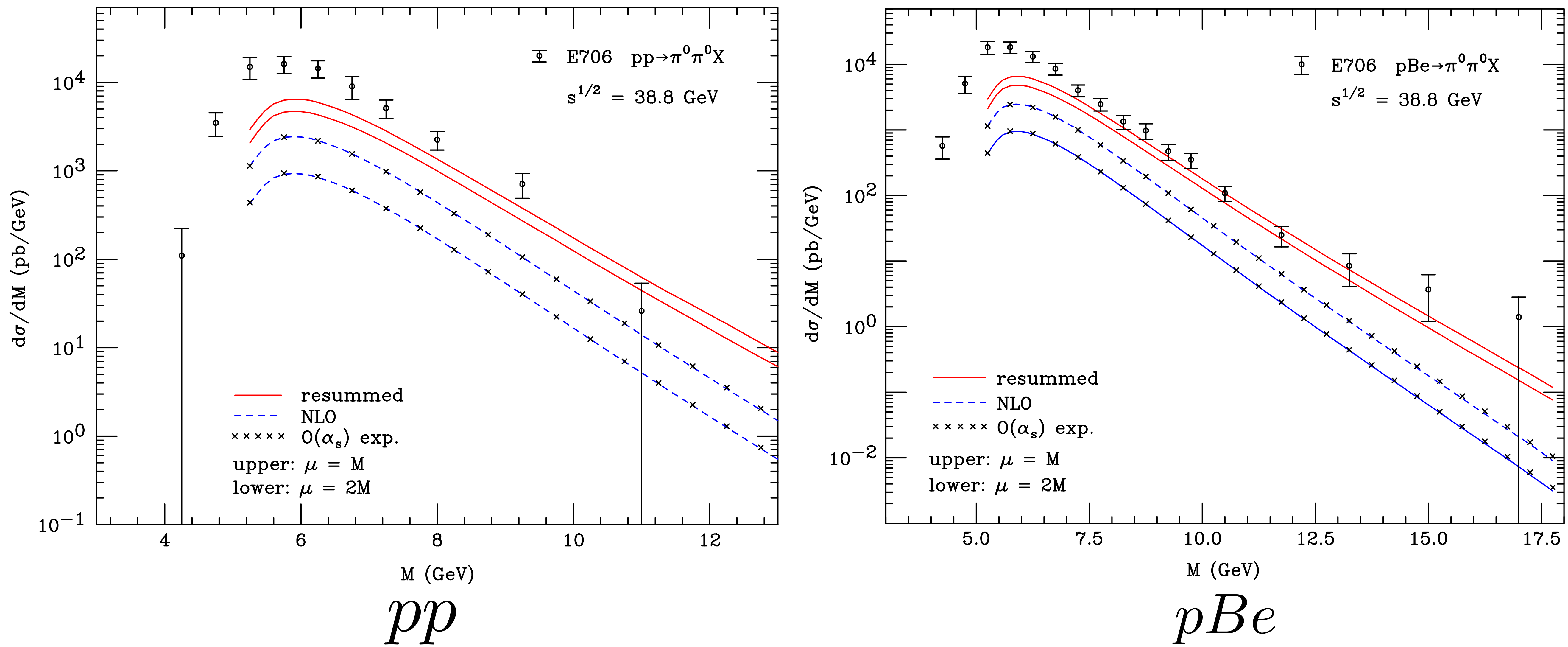
QCD Background leads development of
Observables sensitive to signal or background

Jet x-sections

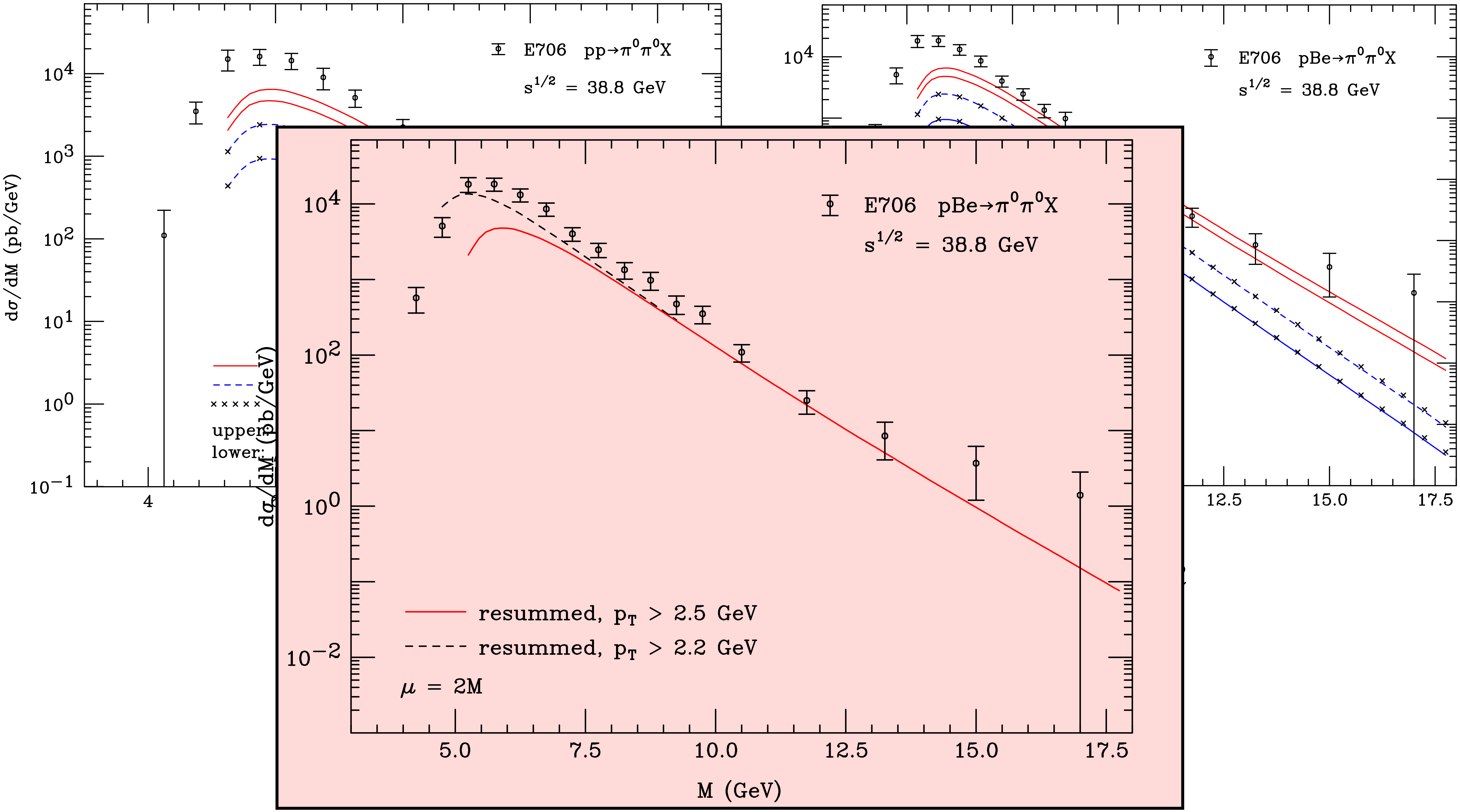
$$\frac{d\sigma_{H_AH_B\to J_1X}(R)}{dp_Tdm_Jd\eta} = \sum_{abc}\int dx_a\,dx_b\,\phi_a(x_a)\,\phi_b(x_b)\frac{d\hat{\sigma}_{ab\to cX}}{dp_Tdm_Jd\eta}(x_a,x_b,p_T,\eta,m_J,R)$$



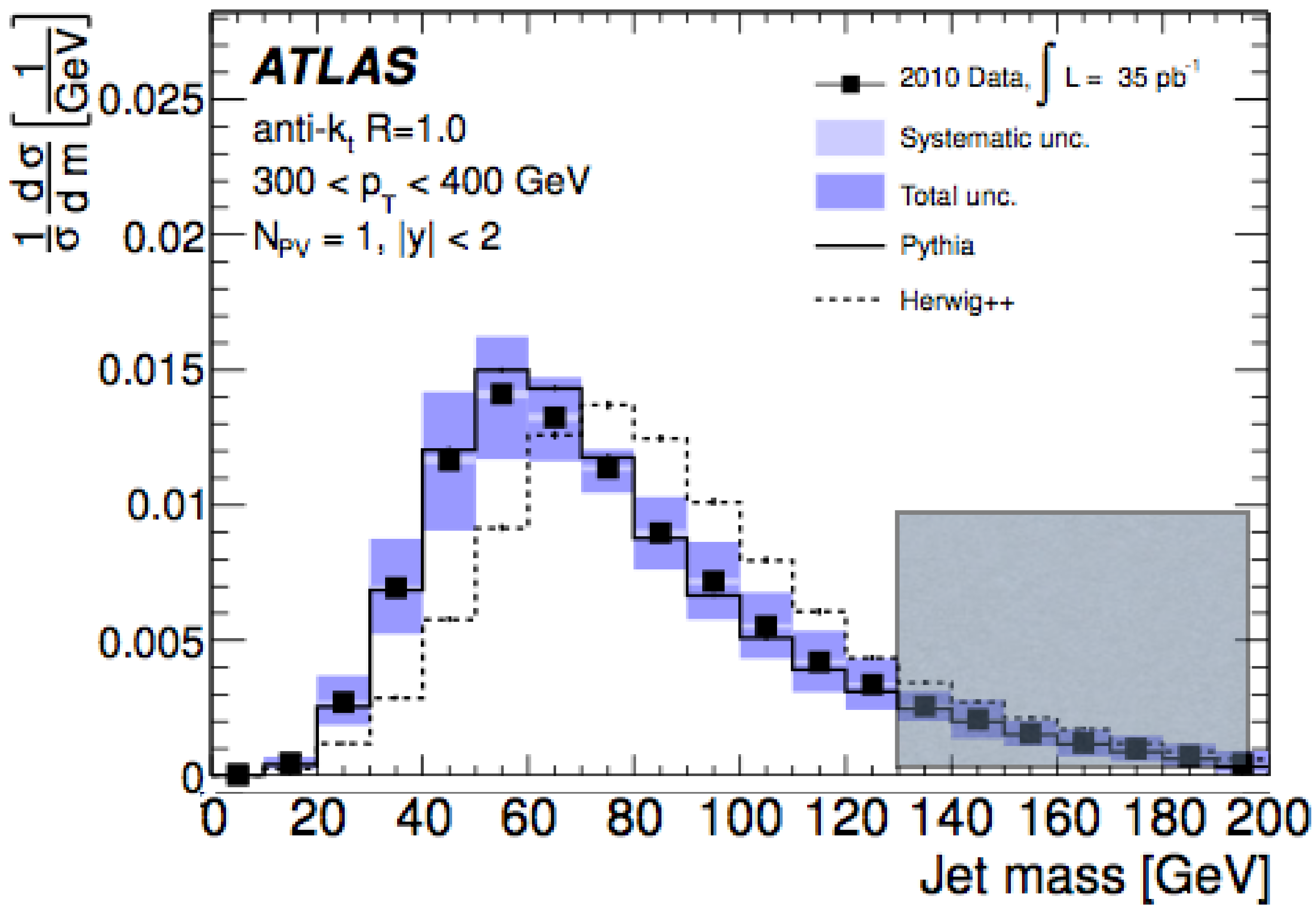
Almeida, Sterman, Vogelsang 09



Almeida, Sterman, Vogelsang 09



Jet Mass distribution



from adam's talk yesterday

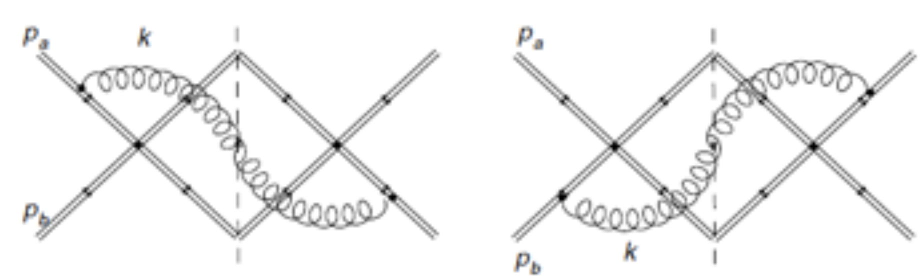
$$\frac{d\sigma_{H_A H_B \to J_1 J_2}}{dp_T dm_{J_1}^2 dm_{J_2}^2 d\eta_1 d\eta_2} = \sum_{abcd} \int dx_a\, dx_b\, \phi_a(x_a)\, \phi_b(x_b) H_{ab\to cd}\,(x_a, x_b, p_T, \eta_1, \eta_2, \alpha_S(p_T))$$
$$\times J_1^c(m_{J_1}^2, p_T \cosh\eta_1, R, \alpha_S(p_T))\; J_2^d(m_{J_2}^2, p_T \cosh\eta_2, R, \alpha_S(p_T))$$
$$S_{ab\to cd}(m_{J_1}, m_{J_2}, \eta_{1,2}, R)$$

Soft Function

$$S_{IJ}^f = \sum_{N_{J_i}} \langle 0|w_I^f(0)^\dagger_{a_i}|N\rangle\langle N|w_J^f(0)_{a_i}|0\rangle \times$$
$$\delta\left(m_J^2 - \tilde{m}_J^2(N_{J_i}, R)\right)\delta^{(2)}(\hat{n} - \tilde{n}(N_{J_i})\delta(p_{0,J_i} - w(N_{J_c}))$$

$$w_I^f(x)_{a_i} = \Phi^{f_1}_{\xi_1,\{c_1,d_1\}}(\infty, 0; x)\Phi^{f_2}_{\xi_1,\{c_2,d_2\}}(\infty, 0; x)\left[\mathbf{C_I^f}\right]_{d_1,d_2;d_3,d_4} \times$$
$$\Phi^{f_3}_{\xi_3,\{d_3,c_3\}}(0, -\infty; x)\Phi^{f_4}_{\xi_4,\{d_4,c_4\}}(0, -\infty; x)$$

Almeida, Lee, Perez, Sung (08)



$\sim R^2$

For collimated jets $\frac{d\sigma_{H_A H_B\to J_1 X}(R)}{dp_T dm_J d\eta} = \sum_{abc}\int dx_a\, dx_b\, \phi_a(x_a)\, \phi_b(x_b) H_{ab\to cX}(x_a, x_b, p_T, \eta, R)$

$\times J_1^c(m_J, p_T, R). + \mathcal{O}(R^2)$

Jet functions

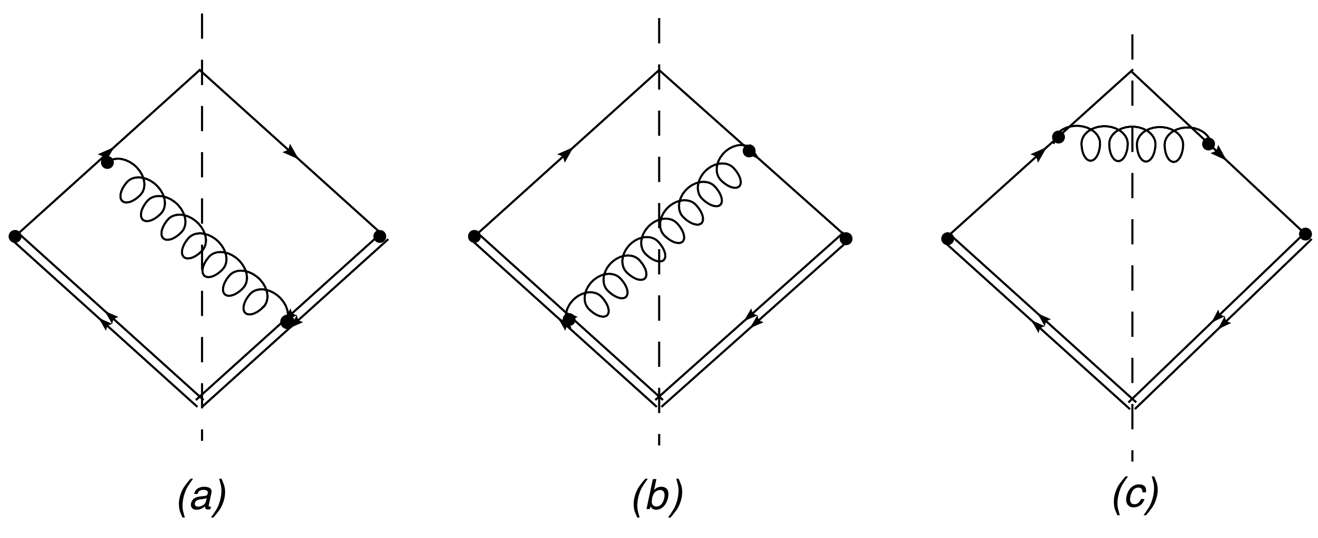
Quarks jets

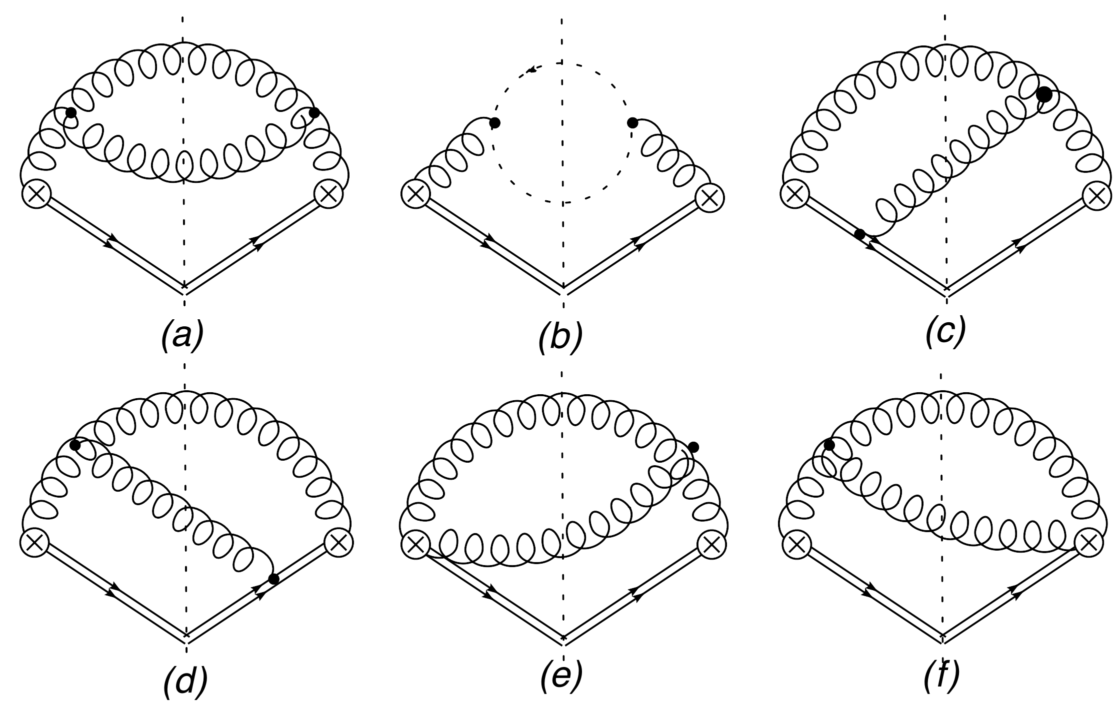
$$J_i^q(m_J^2, p_{0,J_i}, R) \;=\; \frac{(2\pi)^3}{2\sqrt{2}\,(p_{0,J_i})^2}\frac{\xi_\mu}{N_c}\sum_{N_{J_i}} \mathrm{Tr}\left\{\gamma^\mu \langle 0|q(0)\Phi_\xi^{(\bar{q})\dagger}(\infty,0)|N_{J_i}\rangle\langle N_{J_i}|\Phi_\xi^{(\bar{q})}(\infty,0)\bar{q}(0)|0\rangle\right\}$$
$$\times\delta\left(m_J^2 - \tilde{m}_J^2(N_{J_i},R)\right)\delta^{(2)}(\hat{n}-\tilde{n}(N_{J_i}))\delta(p_{0,J_i}-\omega(N_{J_c})),$$

Almeida, Lee, Perez, Sung (08)

Gluons jets

$$J_i^g(m_J^2, p_{0,J_i}, R) \;=\; \frac{(2\pi)^3}{2(p_{0,J_i})^3}\sum_{N_{J_i}}\langle 0|\xi_\sigma F^{\sigma\nu}(0)\Phi_\xi^{(g)\dagger}(0,\infty)\,|N_{J_i}\rangle\langle N_{J_i}|\Phi_\xi^{(g)}(0,\infty)\,F_\nu^{\;\rho}(0)\xi_\rho|0\rangle$$
$$\times\delta\left(m_J^2 - \tilde{m}_J^2(N_{J_i},R)\right)\delta^{(2)}(\hat{n}-\tilde{n}(N_{J_i}))\delta(p_{0,J_i}-\omega(N_{J_c})).$$





Jet functions

Leading Contribution: Single Gluon Emission

$$J^{(f)} = 2\frac{\alpha_S}{\pi}\frac{C_f}{m_J}\log\left(\frac{p_T^2 R^2}{m_J^2}\right)$$

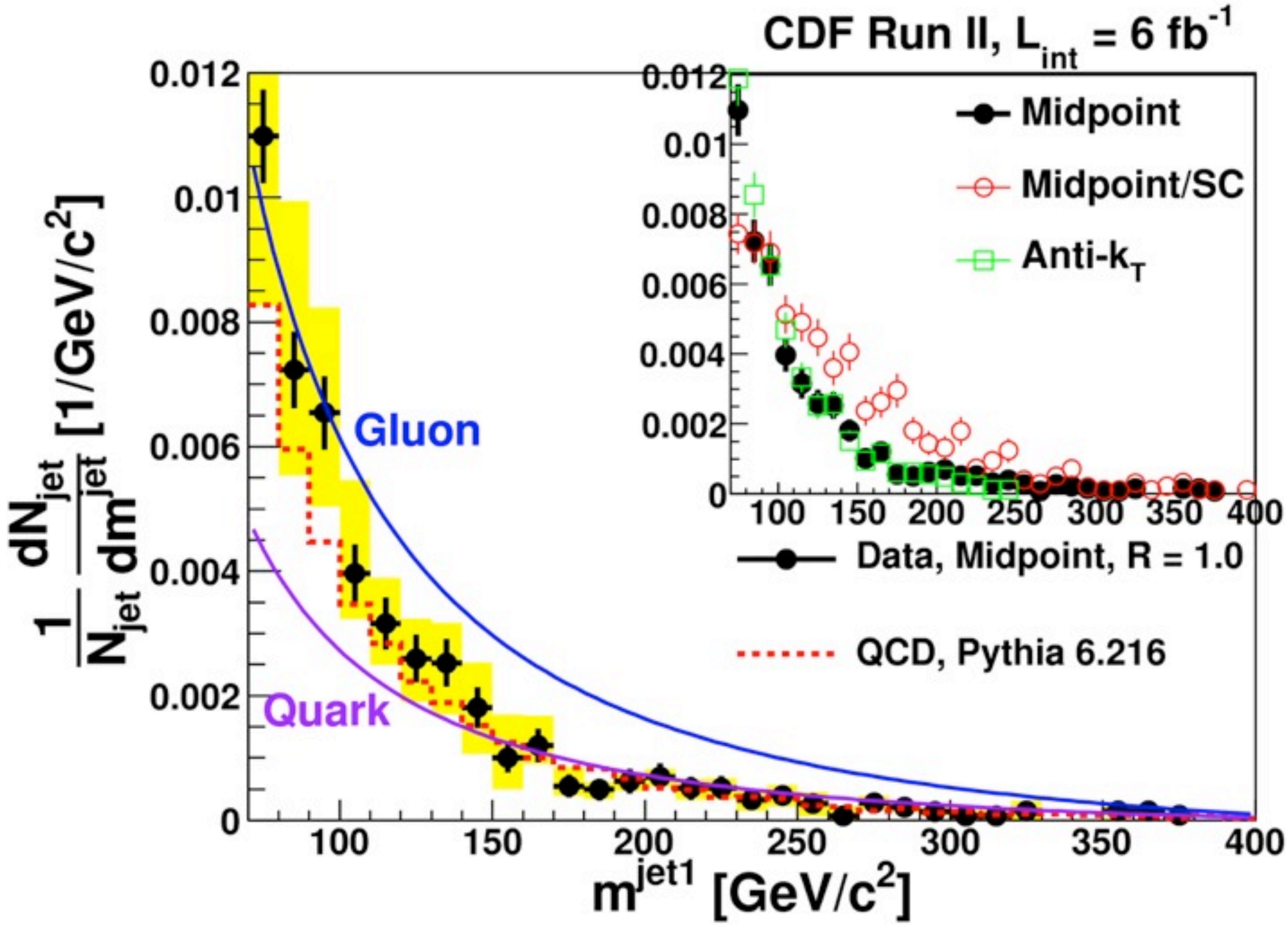
Jet functions can be matched to MC.

$$\frac{d\sigma^c_{\text{pred}}(R)}{dp_T dm_J} = J^c(m_J, p_T, R)\left(\frac{d\sigma^c(R)}{dp_T}\right)_{\text{MC}}$$

One cannot obtain simulations in terms of partons c without ambiguities.

$$\frac{d\sigma_{\text{pred}}(R)}{dp_T dm_J}_{\text{upper bound}} = J^g(m_J, p_T, R)\sum_c\left(\frac{d\sigma^c(R)}{dp_T}\right)_{\text{MC}},$$

$$\frac{d\sigma_{\text{pred}}(R)}{dp_T dm_J}_{\text{lower bound}} = J^q(m_J, p_T, R)\sum_c\left(\frac{d\sigma^c(R)}{dp_T}\right)_{\text{MC}},$$

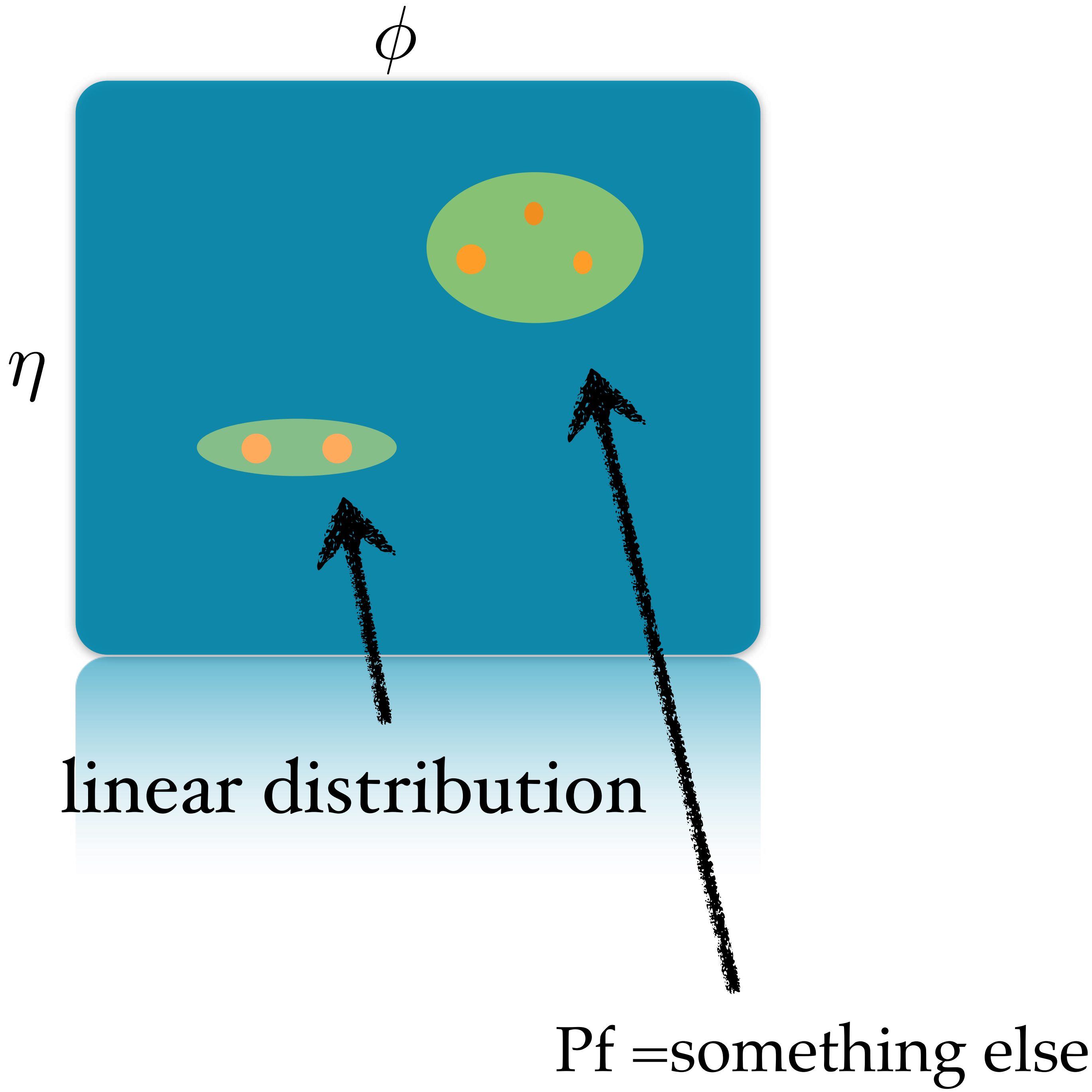


We can use the Jet functions to understand the substructure of jets

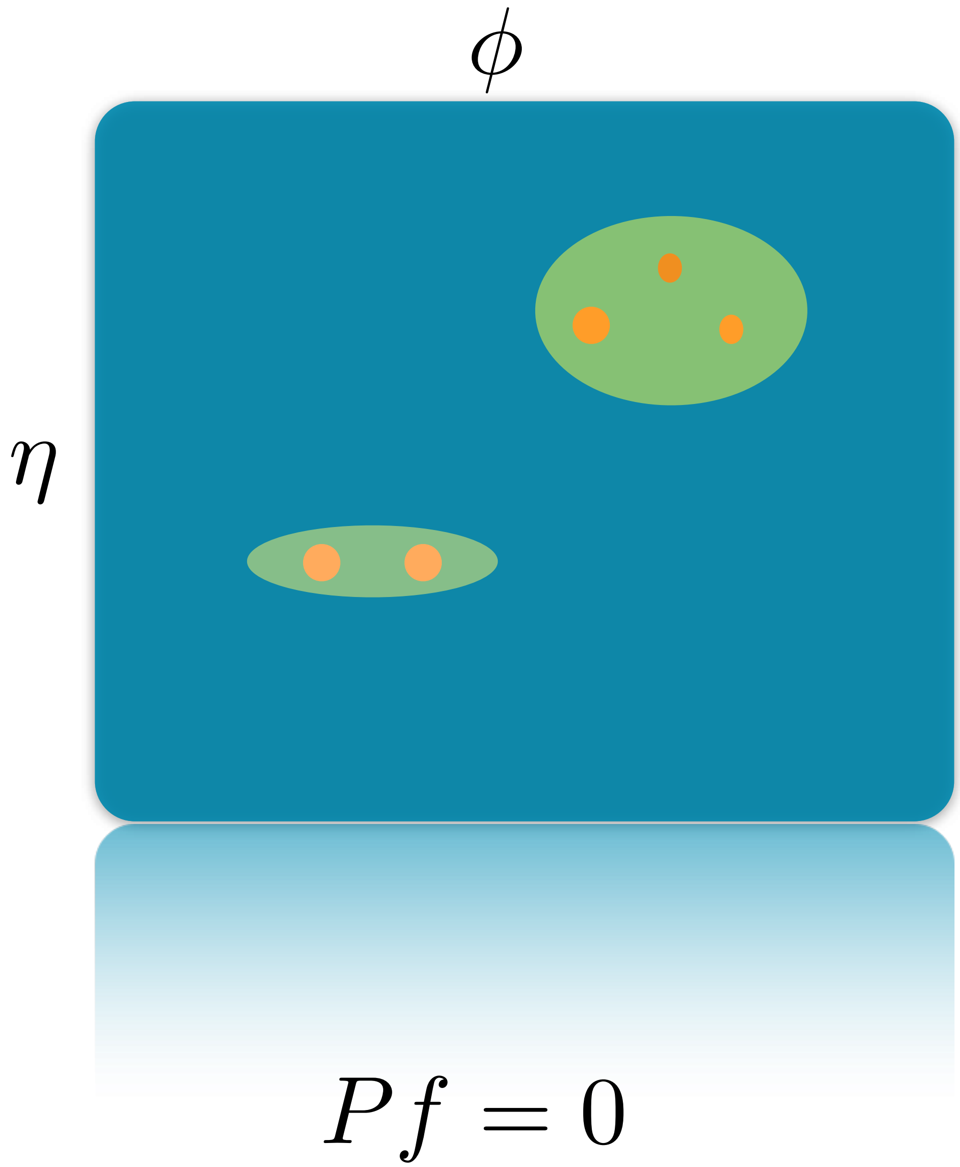
Then we proceed to build observables that exploit these features, and compute them

but wait....

Planar Flow



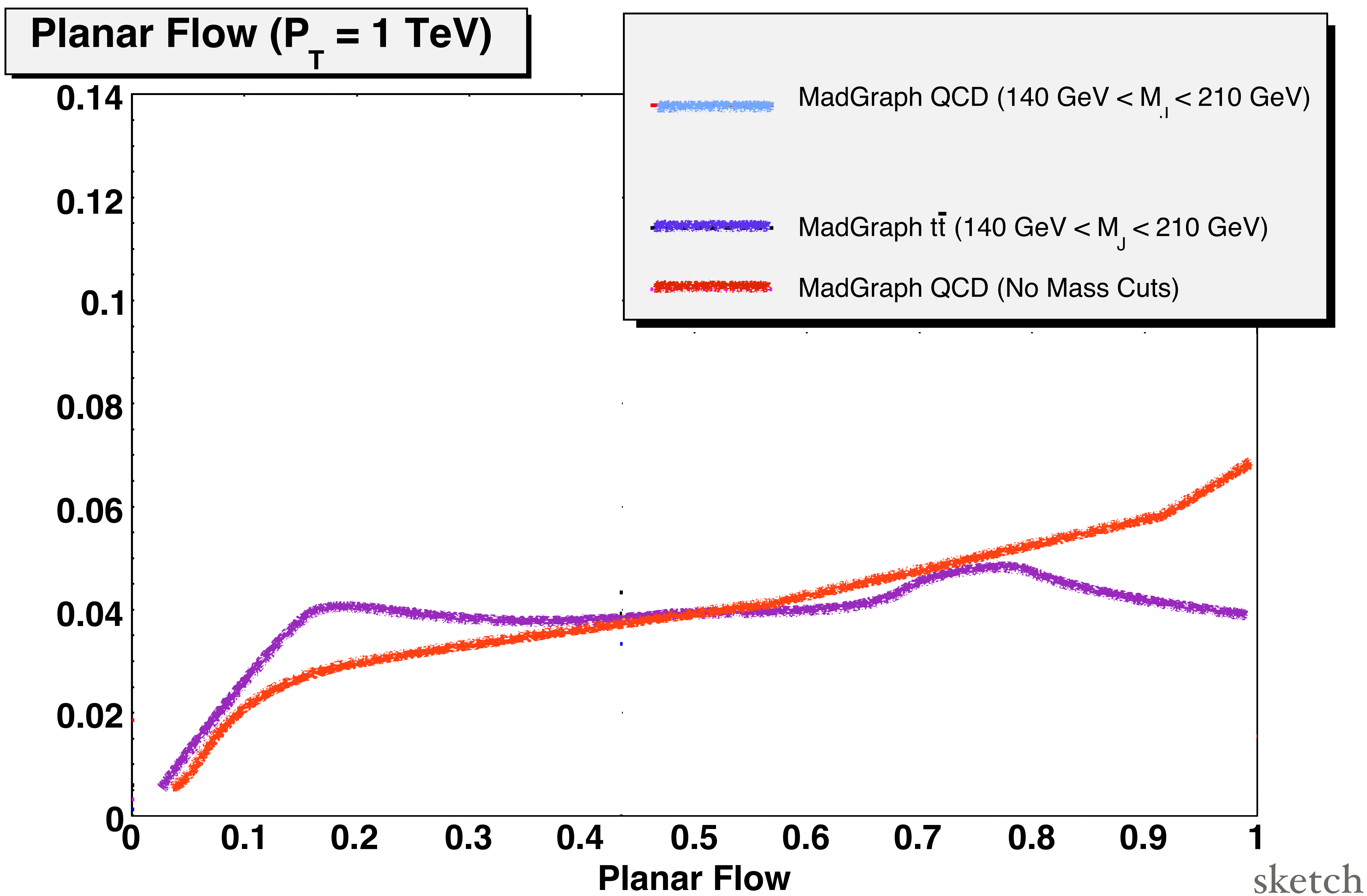
Planar Flow



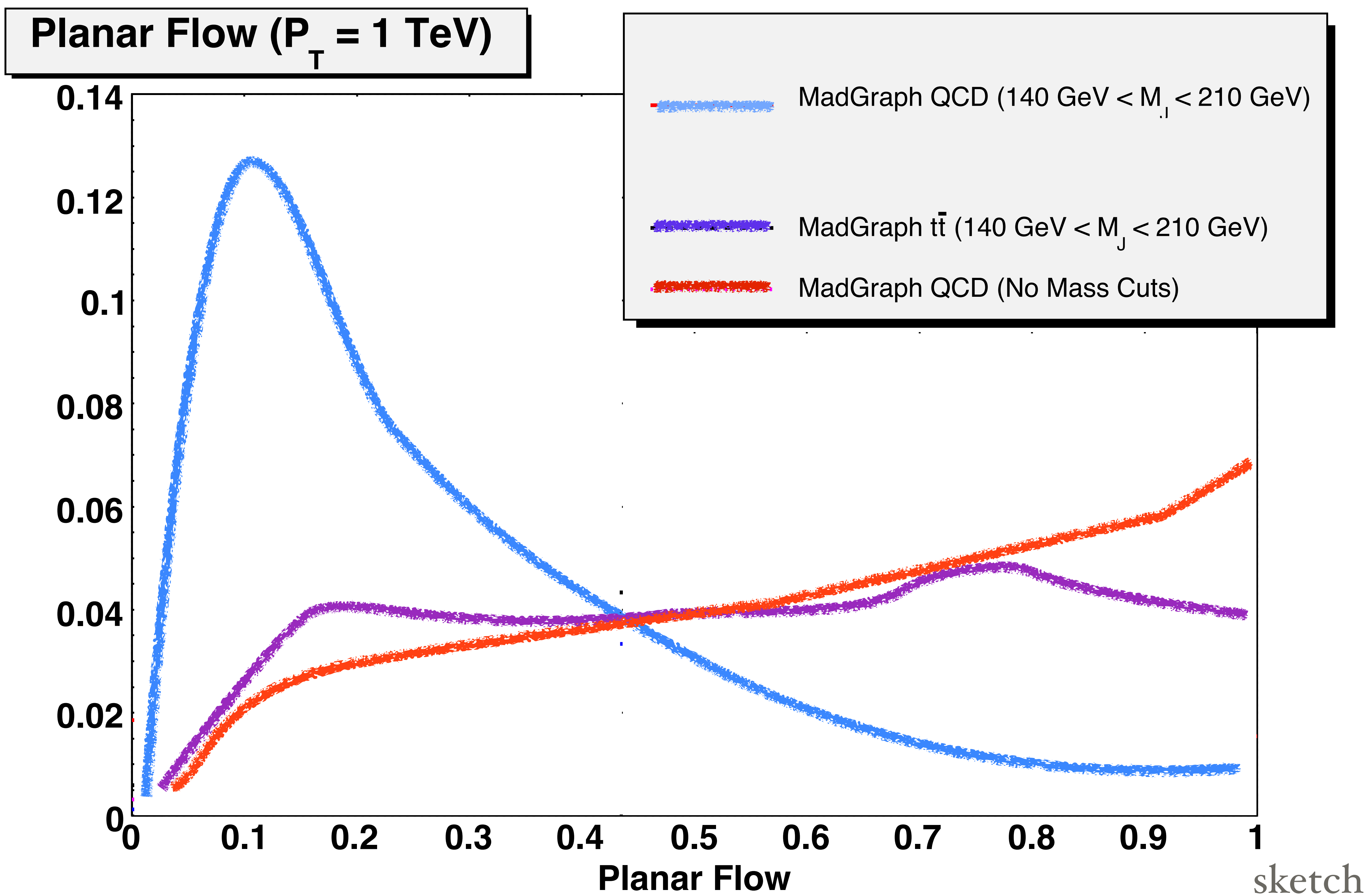
$$I_{\omega}^{kl} = \frac{1}{m_J} \sum_i \omega_i \frac{p_{i,k}}{\omega_i} \frac{p_{i,l}}{\omega_i}$$

$$Pf = \frac{4\,\det(I_\omega)}{\mathrm{tr}(I_\omega)^2}$$

Pf =something else



Planar Flow (P_T = 1 TeV)
MadGraph QCD (140 GeV < M_J < 210 GeV)
MadGraph $t\bar{t}$ (140 GeV < M_J < 210 GeV)
MadGraph QCD (No Mass Cuts)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Planar Flow
sketch



Planar Flow (P_T = 1 TeV)
MadGraph QCD (140 GeV < M_J < 210 GeV)
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0.14
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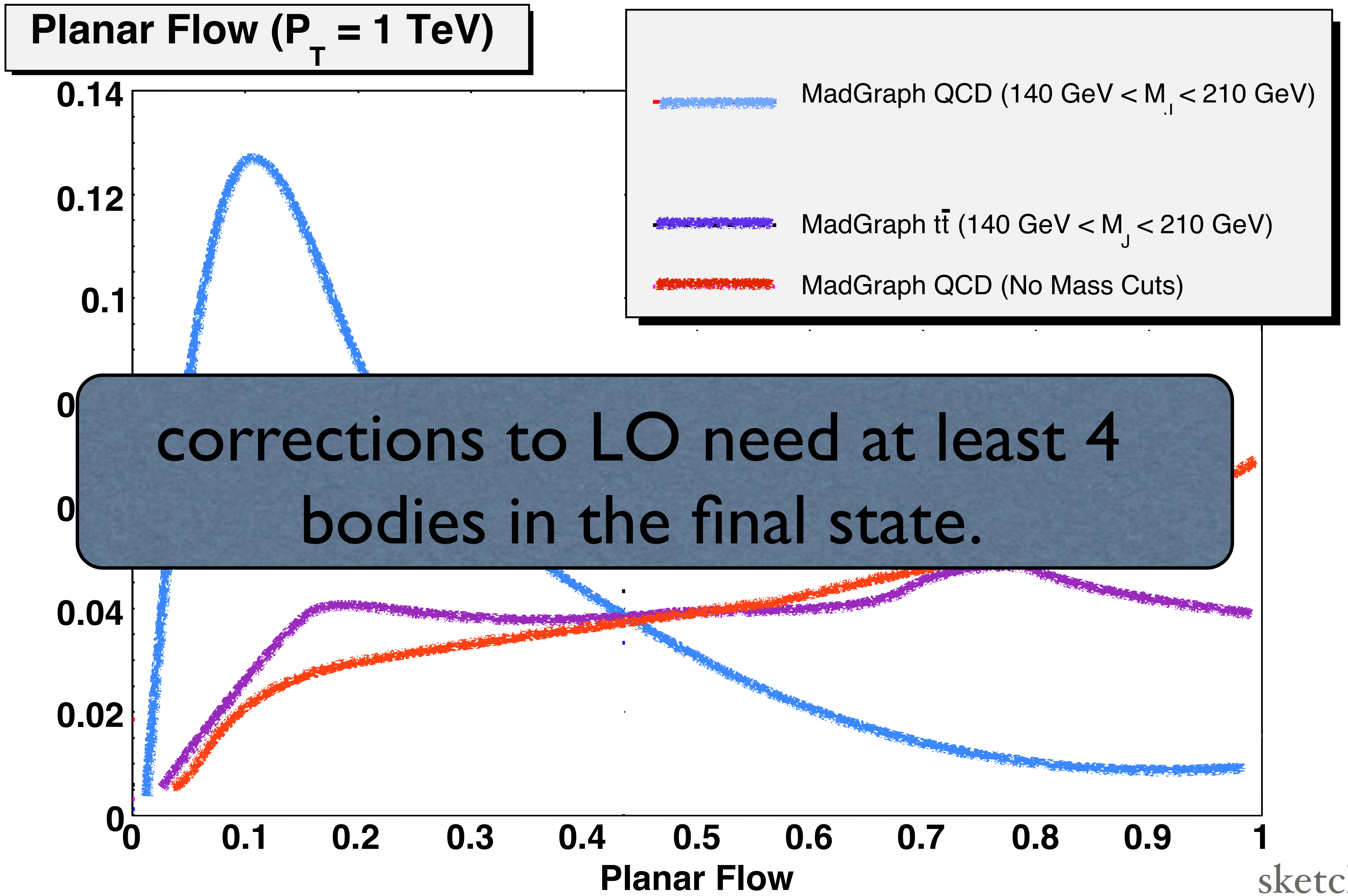
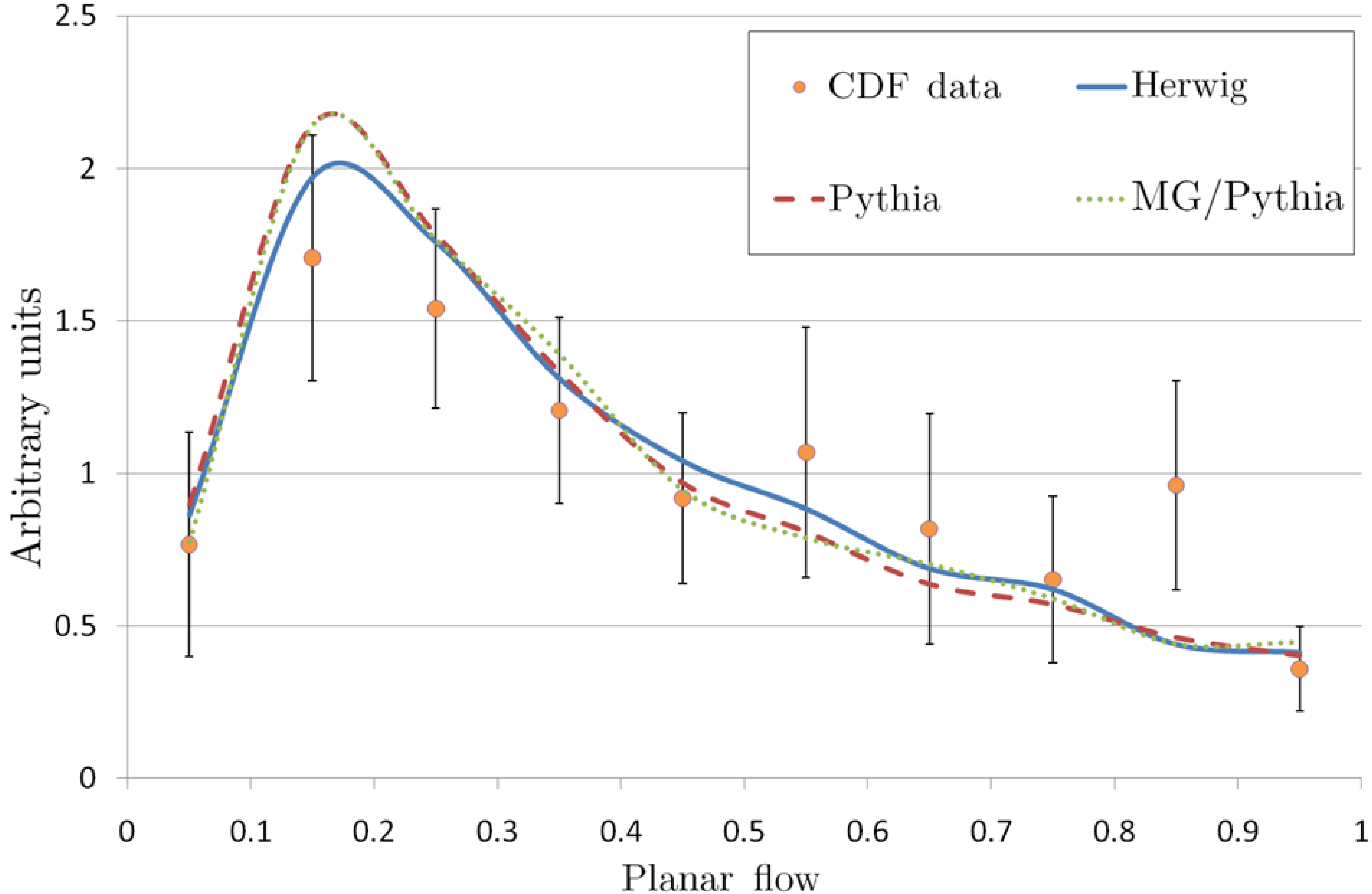
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Planar Flow
sketch



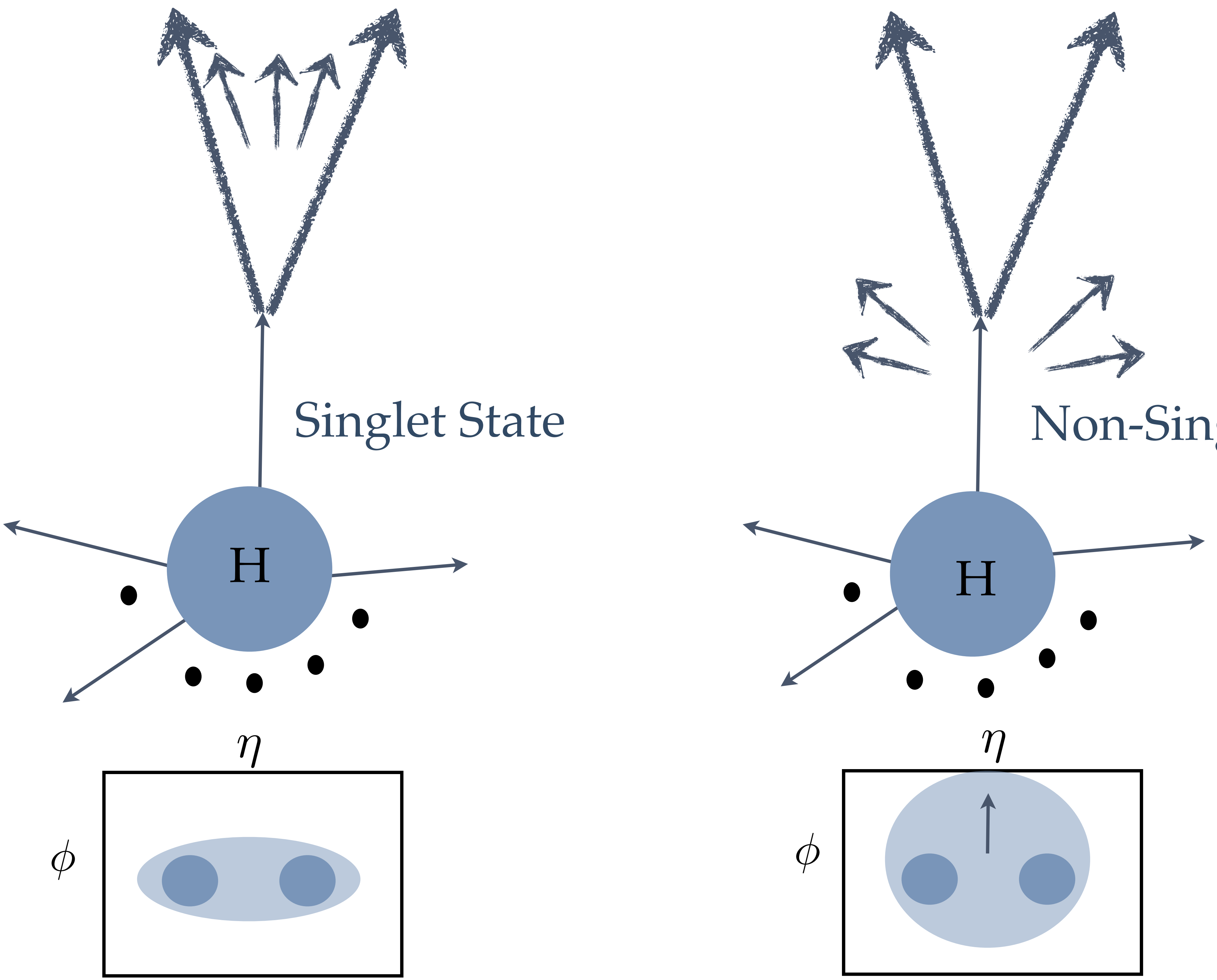
corrections to LO need at least 4 bodies in the final state.

sketch



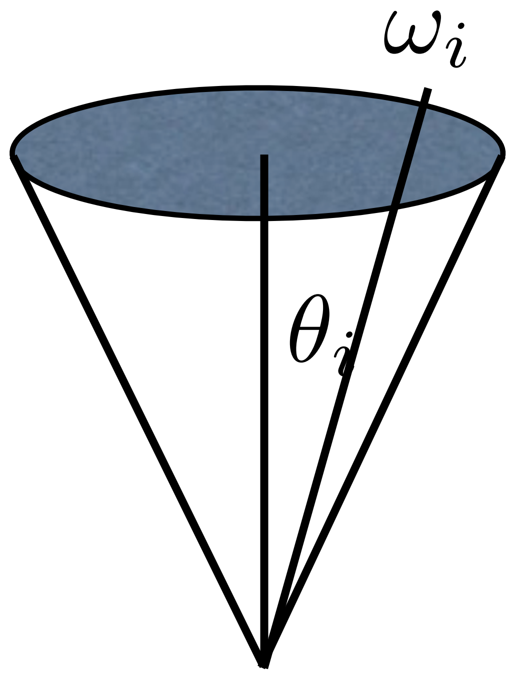
Eshel, Gedalia, Perez, Soreq (11)

Color Flow



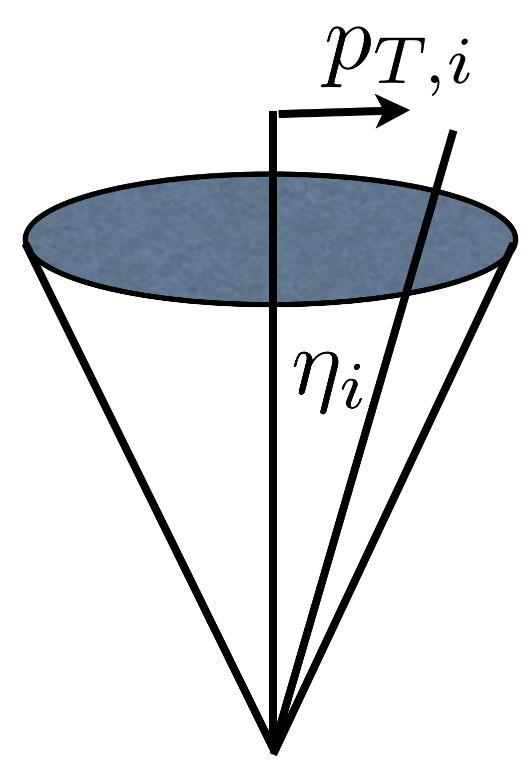
Angularities

$$\tau^a = \omega_i \cos\theta_i (1 - \sin\theta_i)^{1-a}$$



In the jet's invariant frame

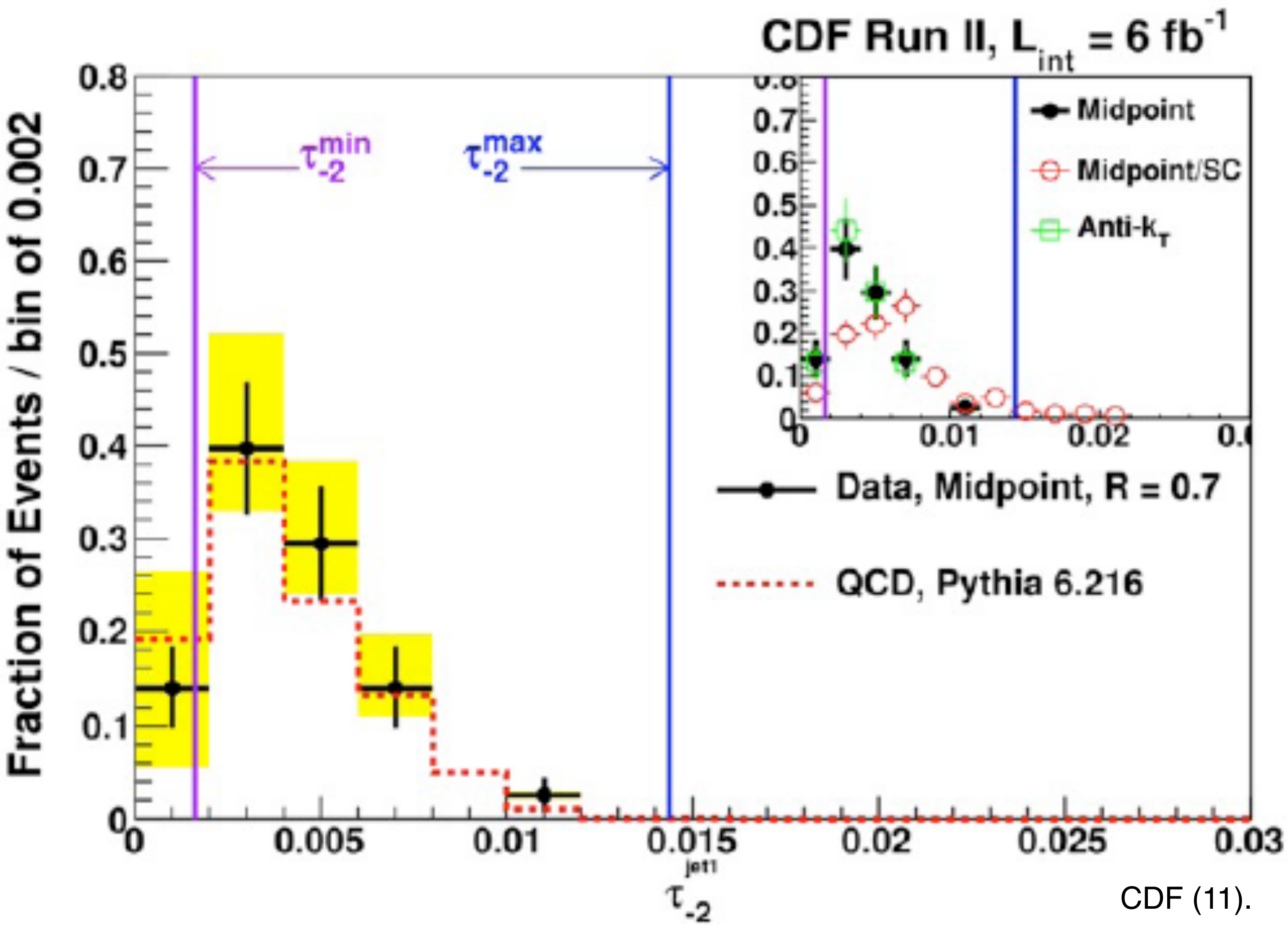
$$\tau^a = \sum_i p_{T,i} e^{(1-a)\eta_i}$$



$$a = 0 \rightarrow \tau_0 = 1 - T$$

Angularities

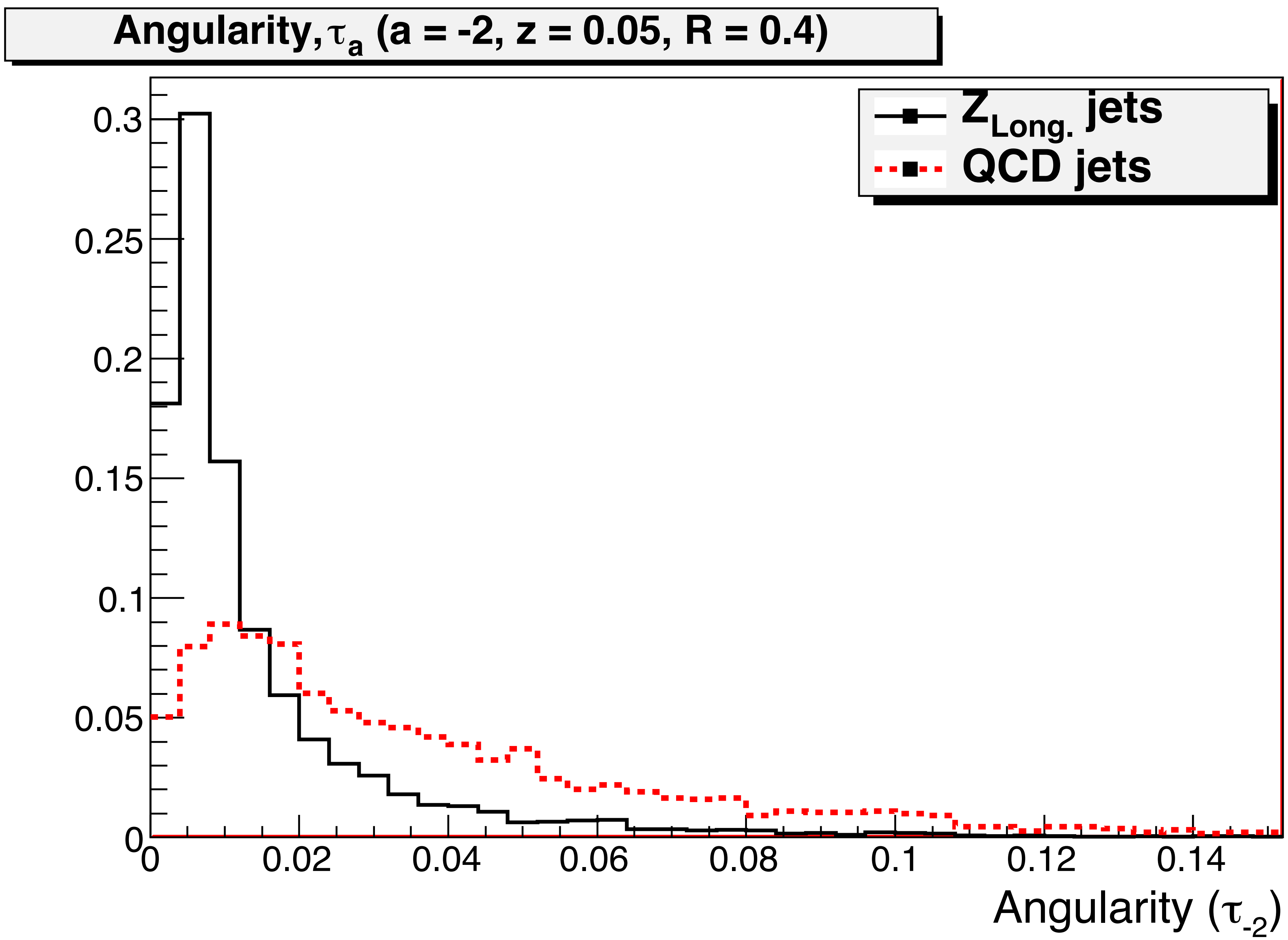
$$J_{QCD} \sim \frac{1}{\tau_{-2}} \qquad \tau_{-2}^{min} = \left(\frac{m_J}{2E_J}\right)$$



CDF (11).

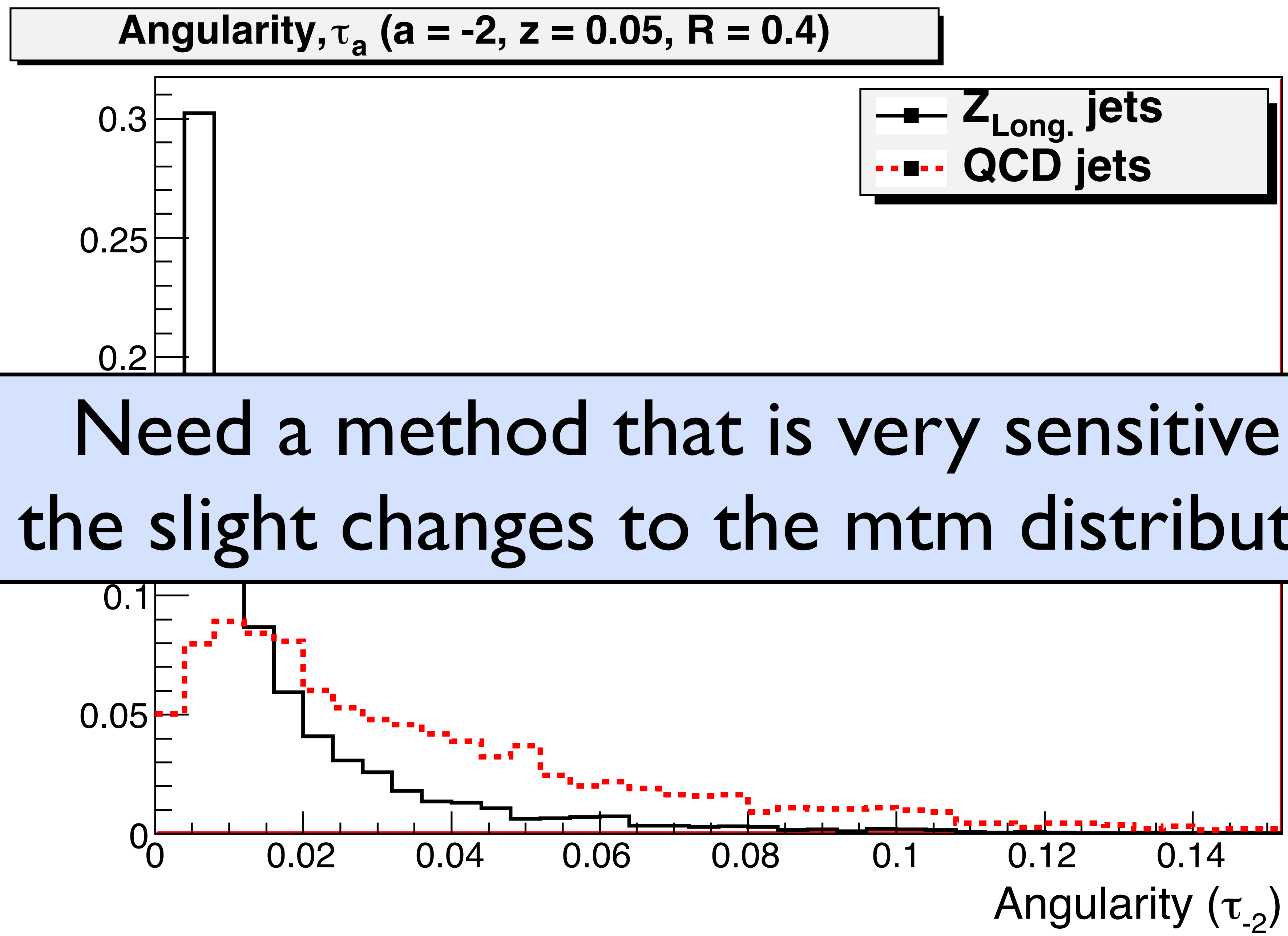
Angularities

$J_{QCD} \sim 1/\theta$ $J_{higgs} \sim 1/\theta^3$



Angularities

$J_{QCD} \sim 1/\theta$ $\qquad$ $J_{higgs} \sim 1/\theta^3$



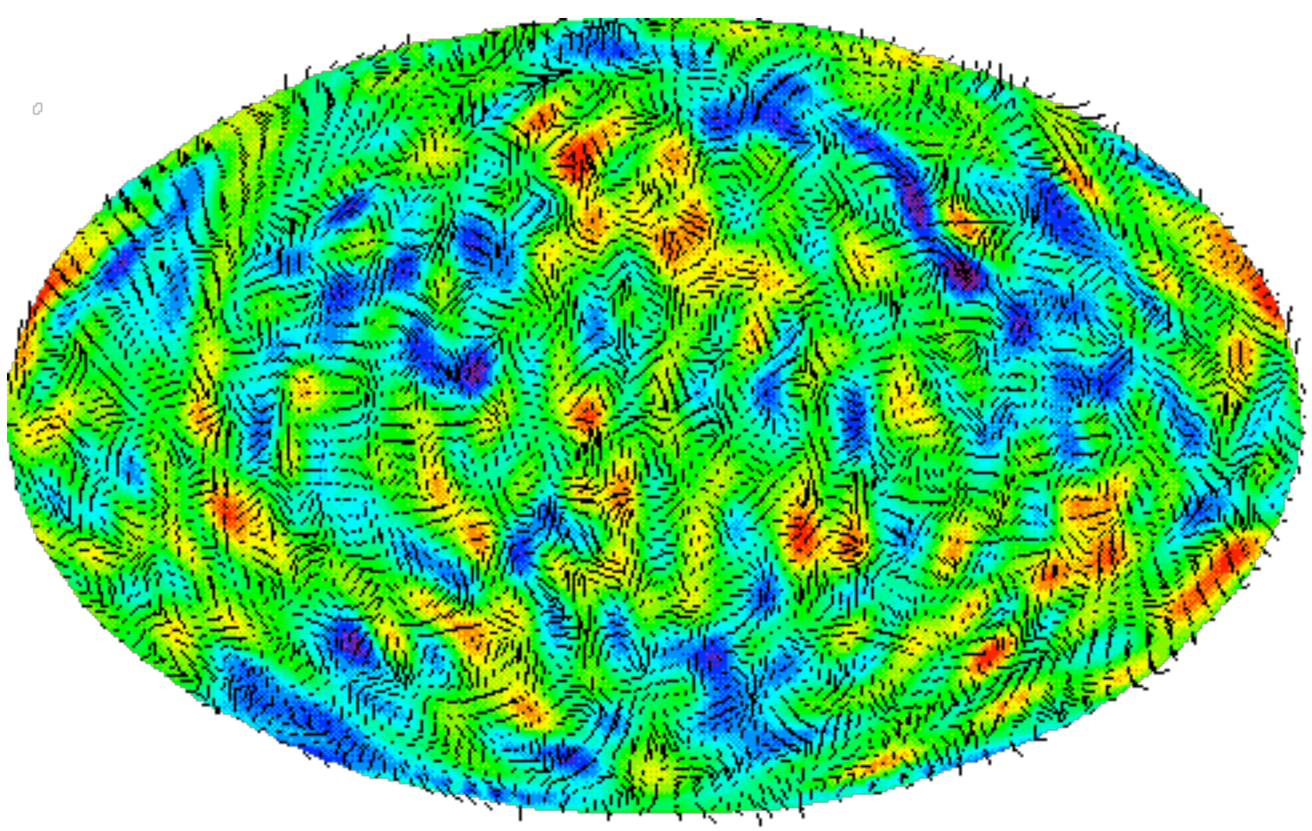
Need a method that is very sensitive to the slight changes to the mtm distributions

Overlap Method

We would like to measure how well the energy flow of a given event matches that of the signal.

$$Ov(j,f) = \langle j|f\rangle = \mathcal{F}\left[\frac{dE(j)}{d\Omega}, \frac{dE(f)}{d\Omega}\right]$$

Where the energy flows are compared over an region of Ω



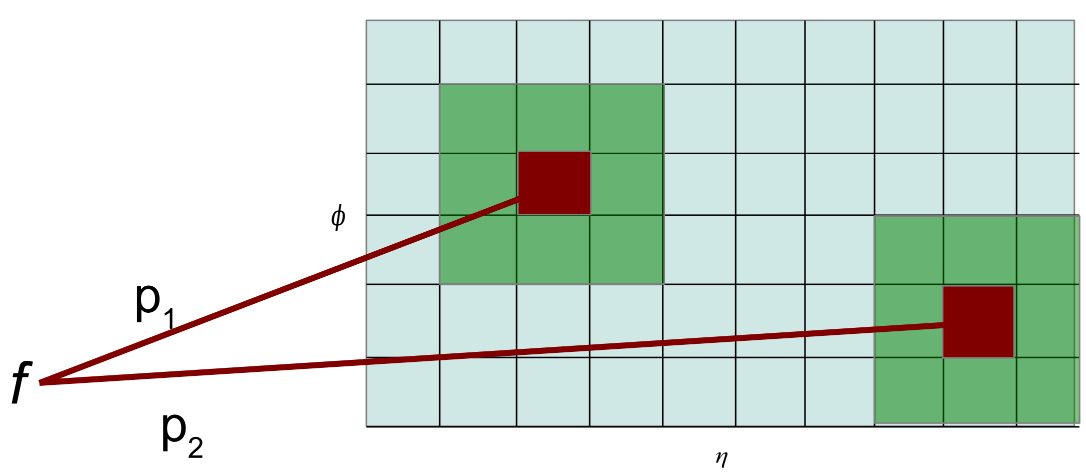
Overlap

$$Ov = \int d\Omega \left[\frac{dE(j)}{d\Omega} - \frac{dE(f)}{d\Omega}\right] F(\Omega, f)$$

$F(\Omega, f)$ is a weight function, smooth enough for the distribution to be IRsafe

For example: Weighting the energy by

$\max\left[0, 1 - (\eta^2 + \phi^2)/R\right] \rightarrow$ picking out cones



Gaussian Filtering weights the pT by a gaussian distribution

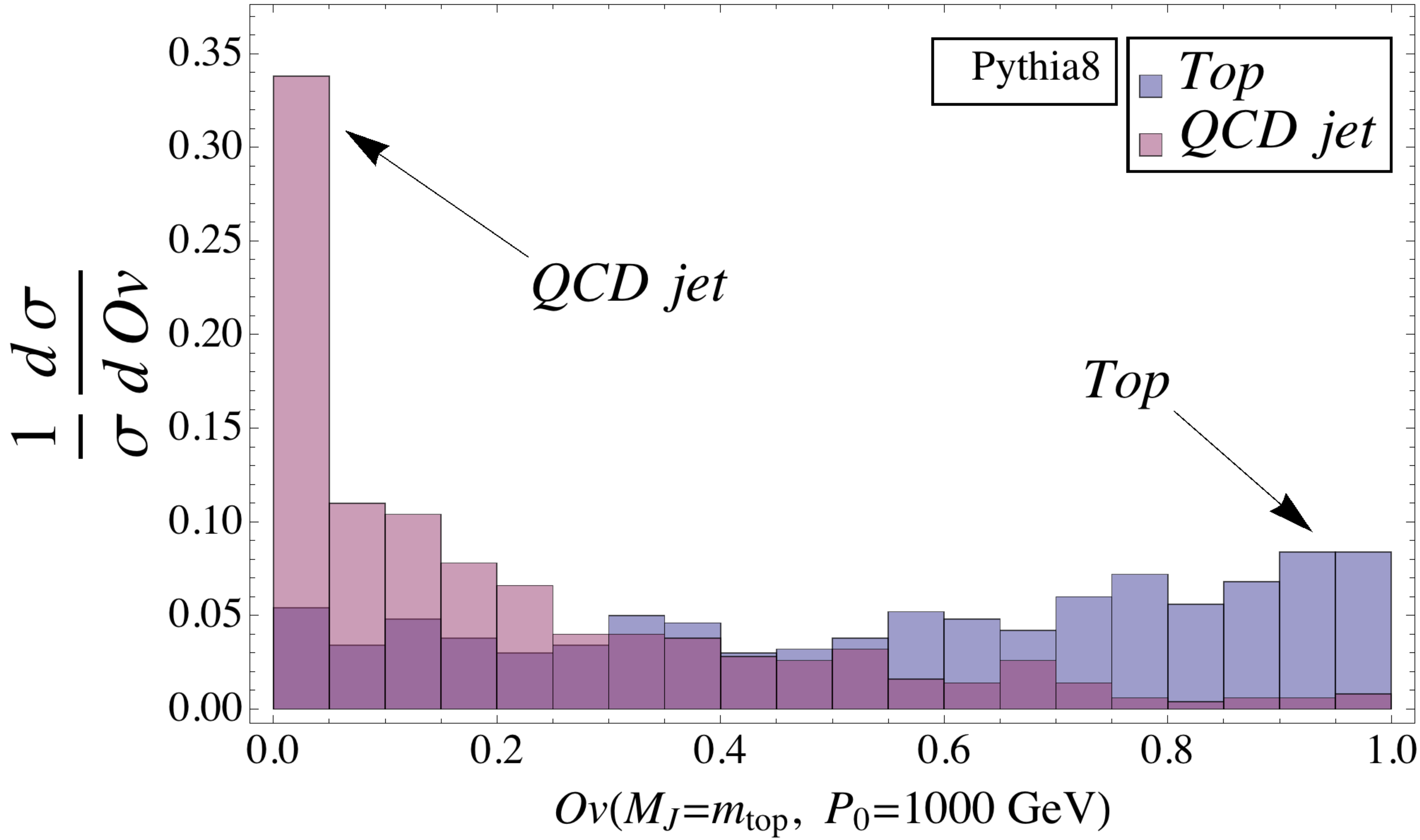
(jet finder)

$$Ov_N(j,f) = \max_{\tau_N^{(R)}} \exp\left[- \sum_{a=1}^{N} \frac{1}{2\sigma_a^2} \left(\sum_{k=i_a-1}^{i_a+1} \sum_{l=j_a-1}^{j_a+1} E(k,l) - E(i_a, j_a)^{(f)} \right)^2 \right]$$

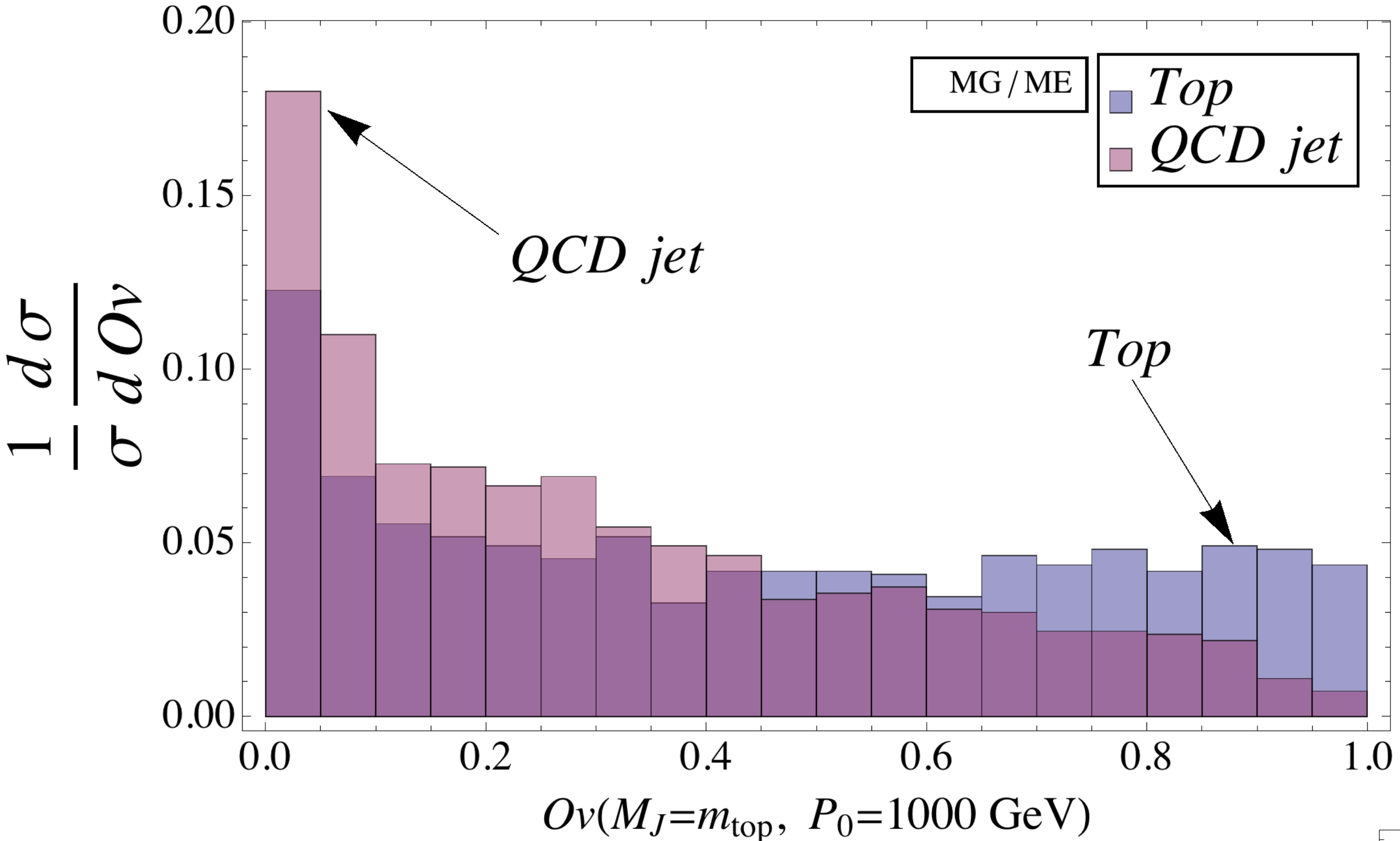
and for the "theory" or the states we want to pick out with the Overlap (Signal or Background)

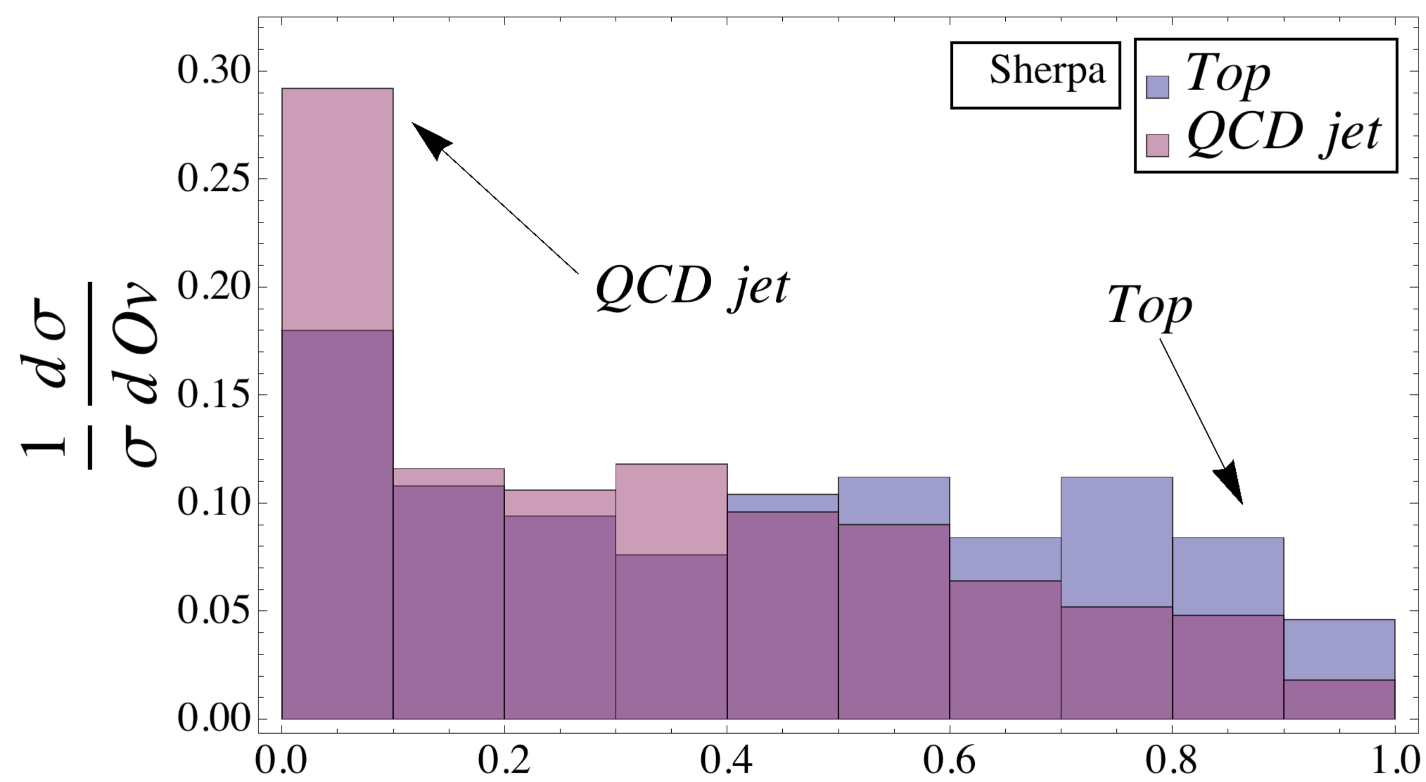
We use Templates :: sets of partonic momenta
2 or 3 particles

Top and QCD jets

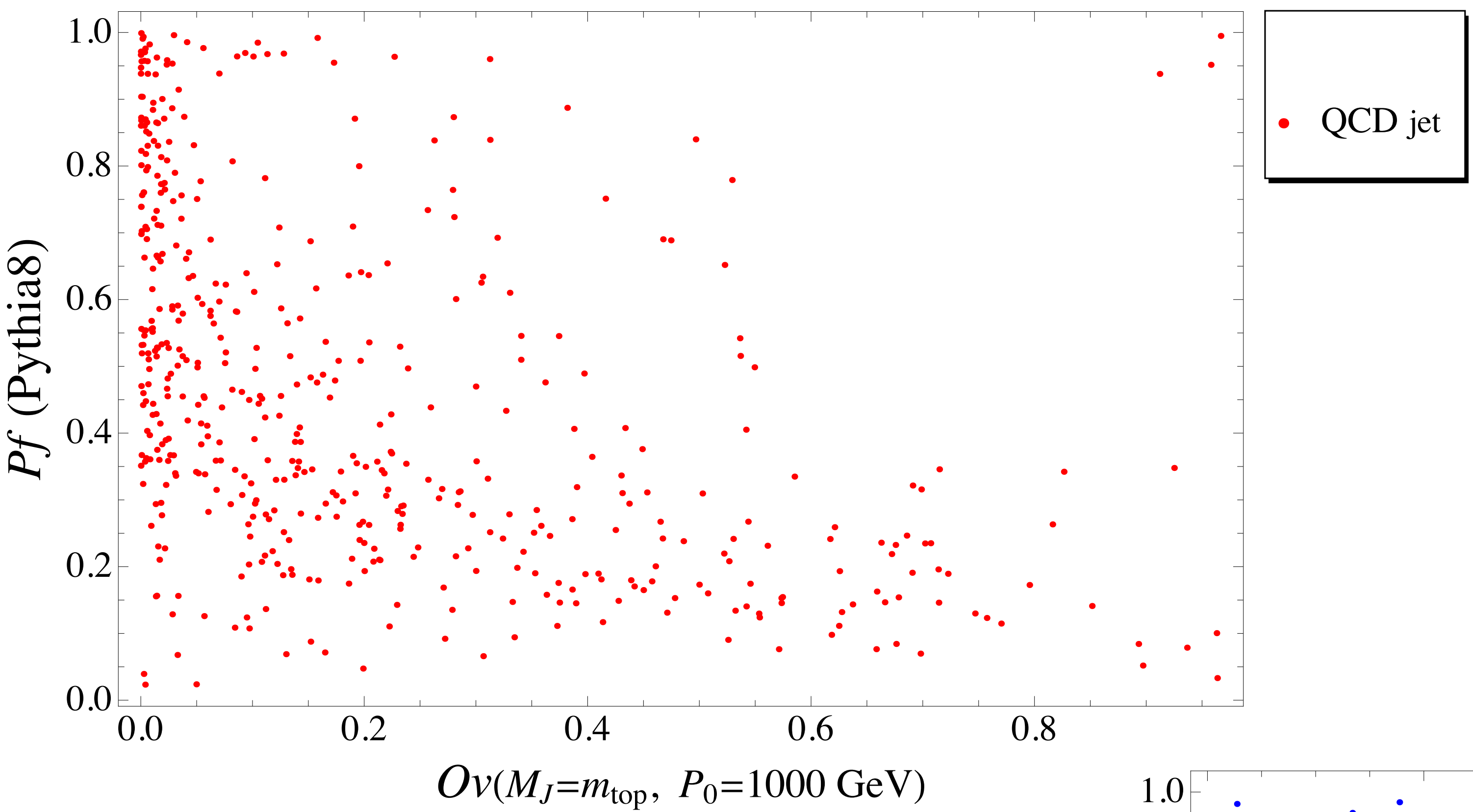


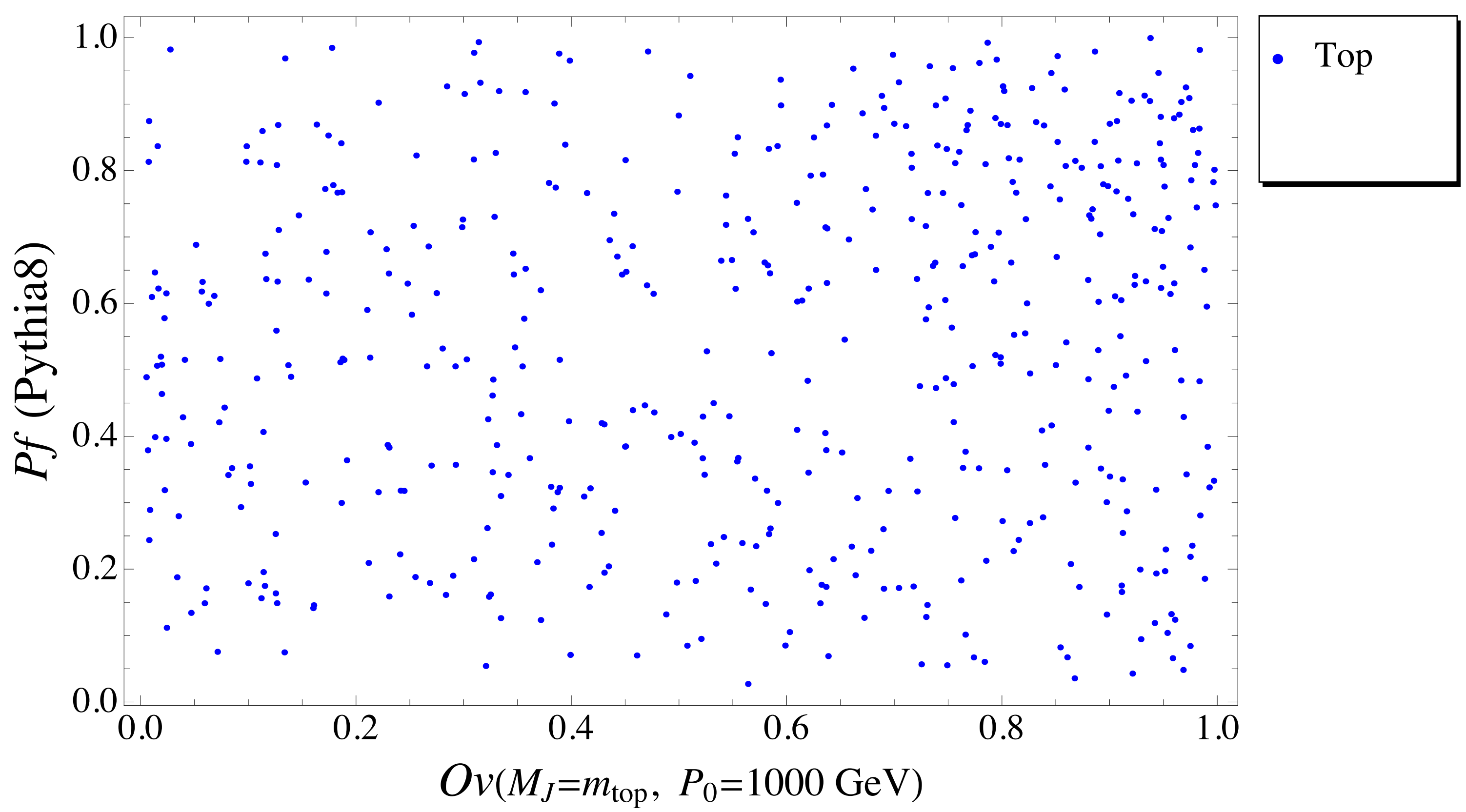
Top and QCD jets





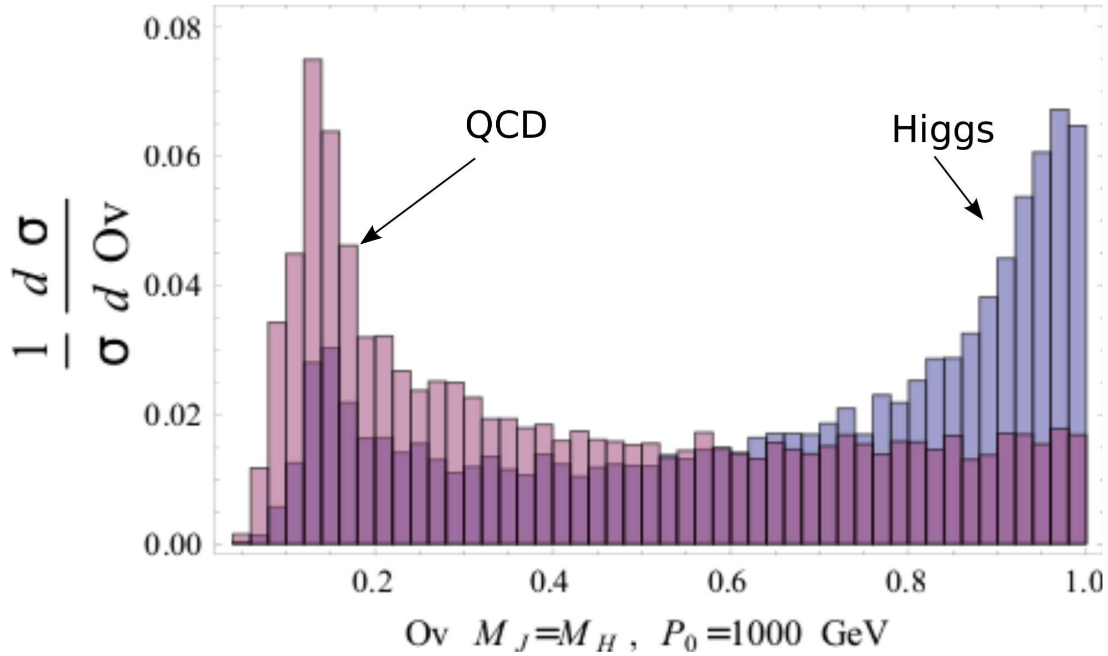
Overlap and Planar Flow

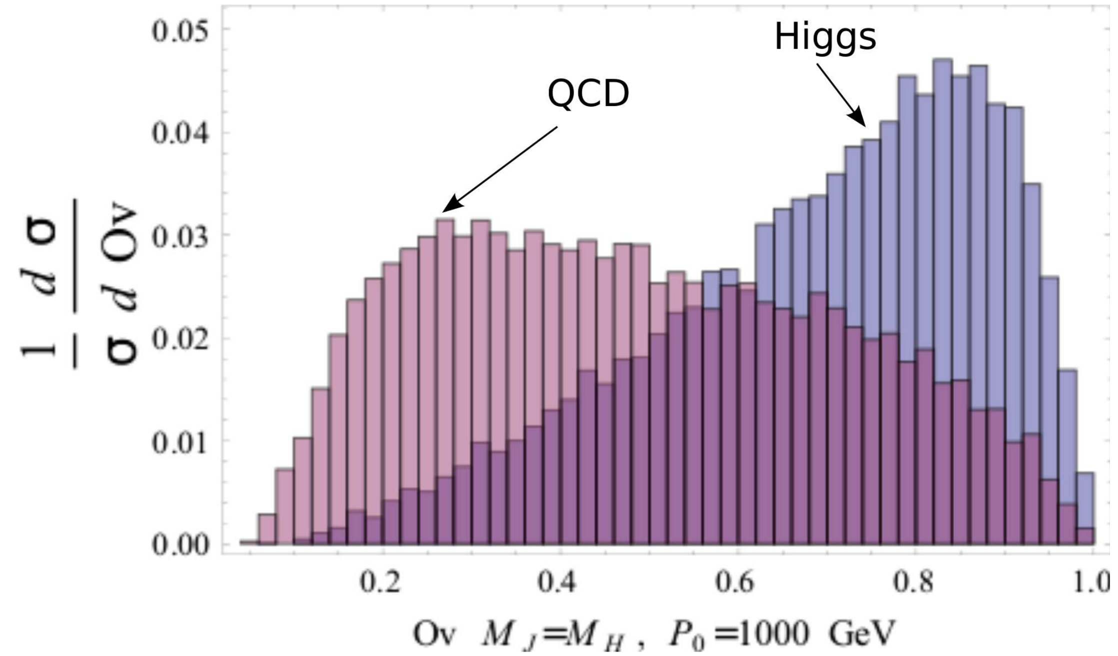




Higgs

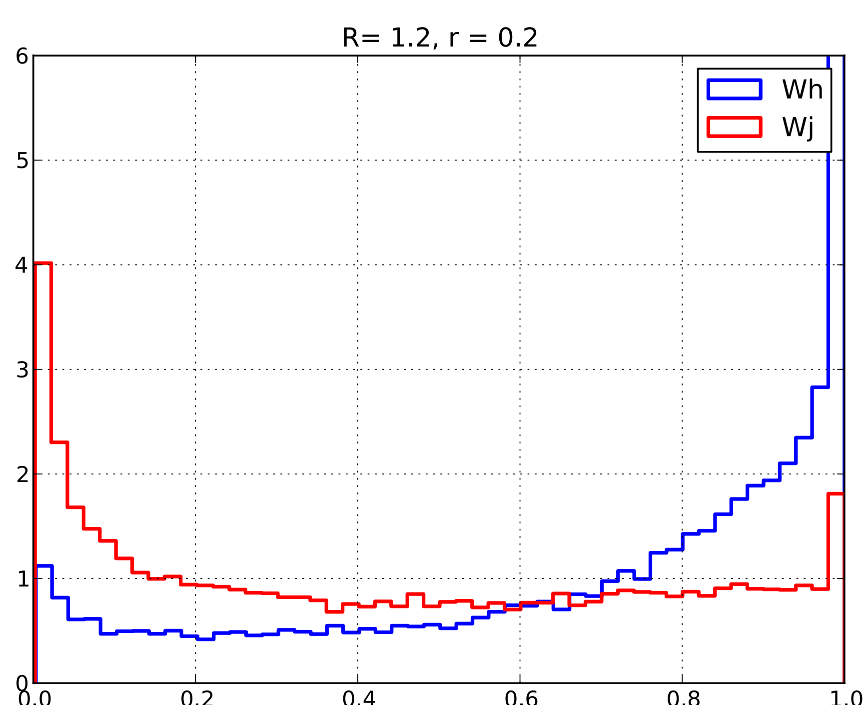
LGA, Erdoran, Juknevich, Lee, Perez,Sterman 11

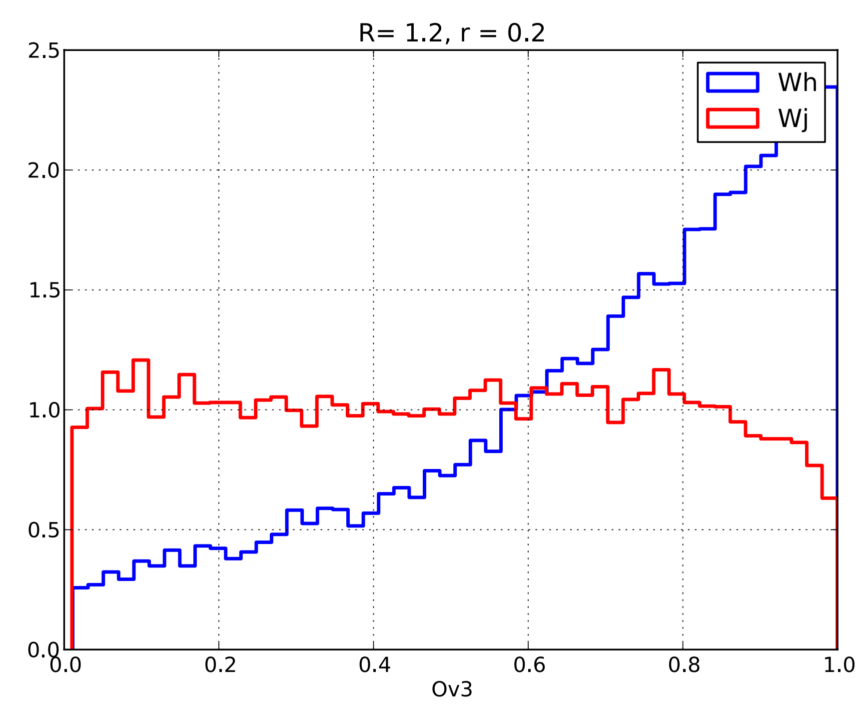




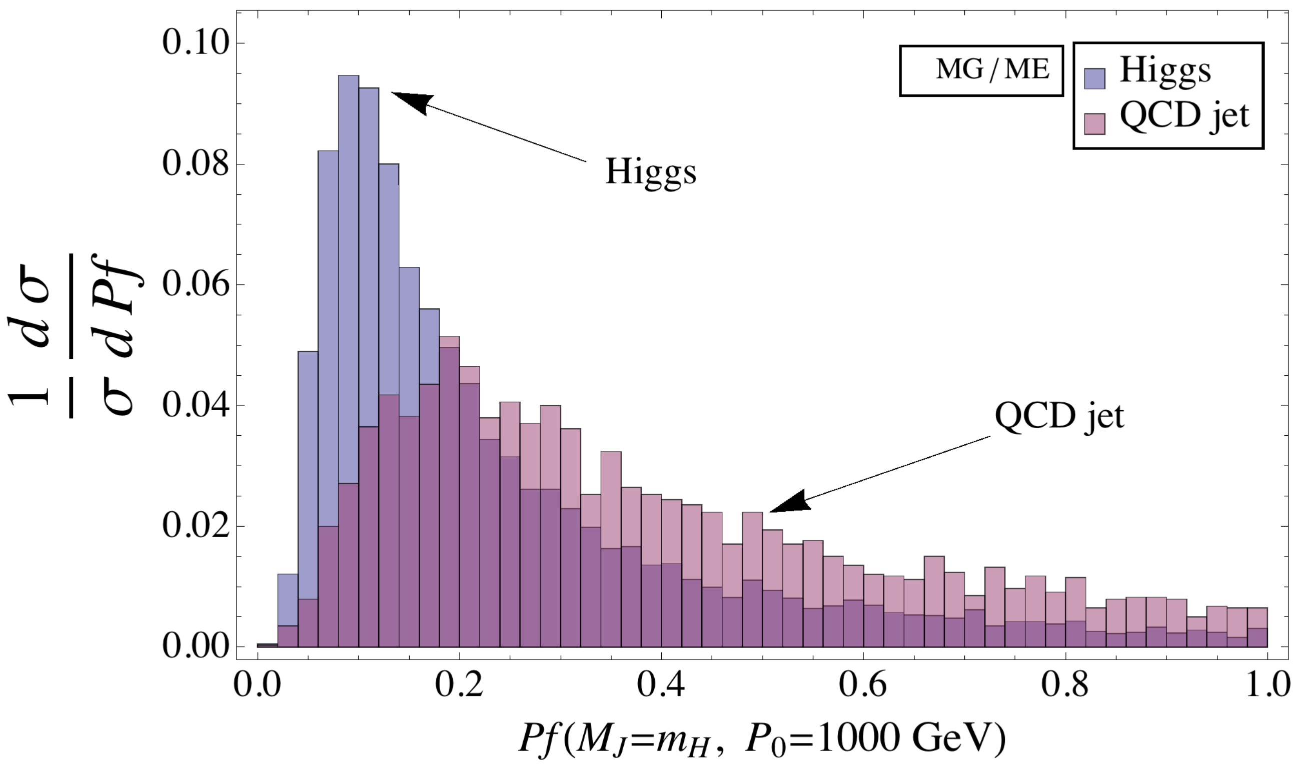
Backovic, Juknevich, Perez, Winter (in progress)

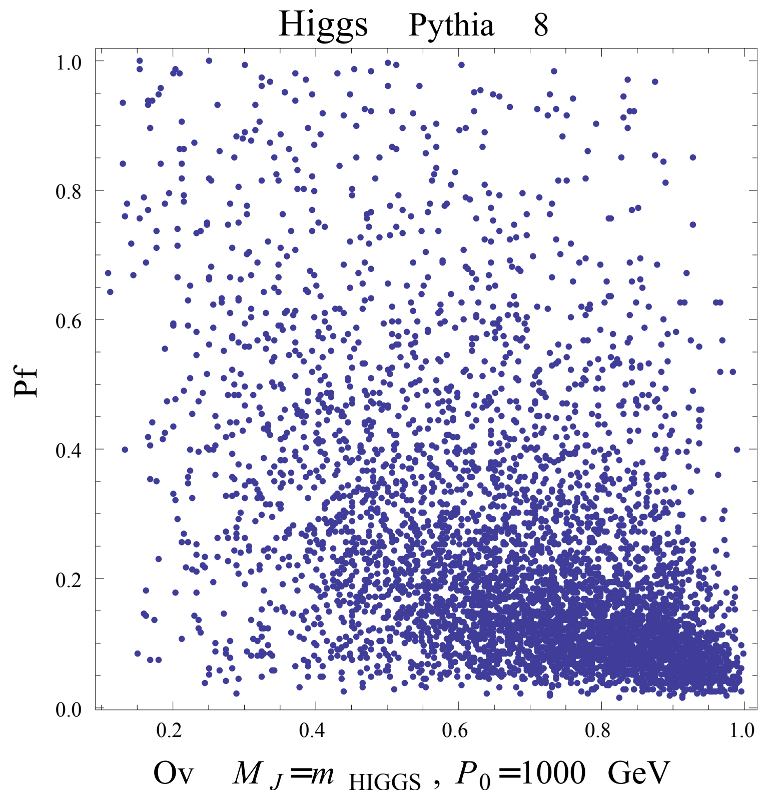
Lower Pt ~ 200GeV, bigger cone

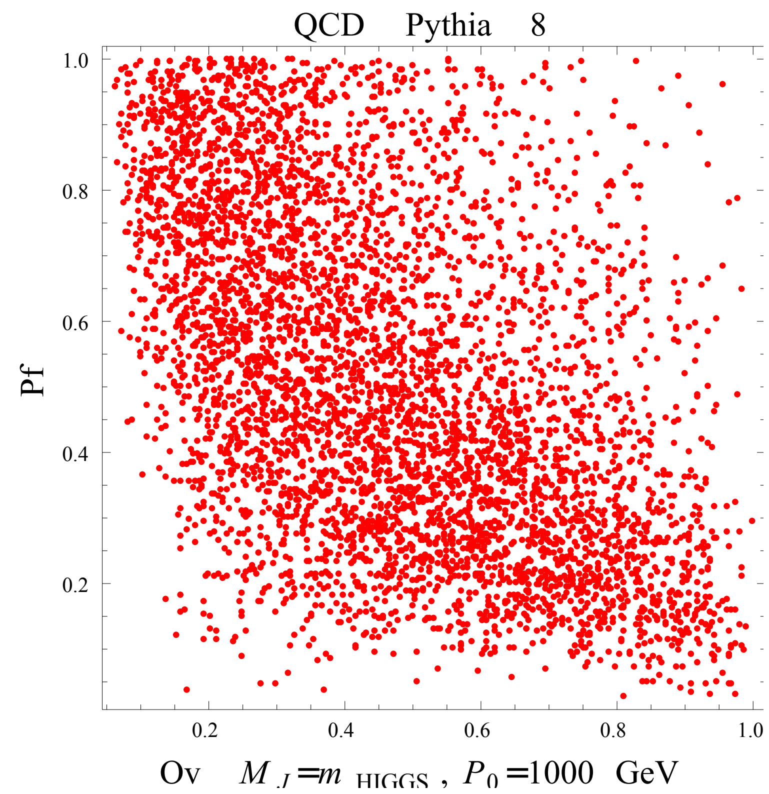


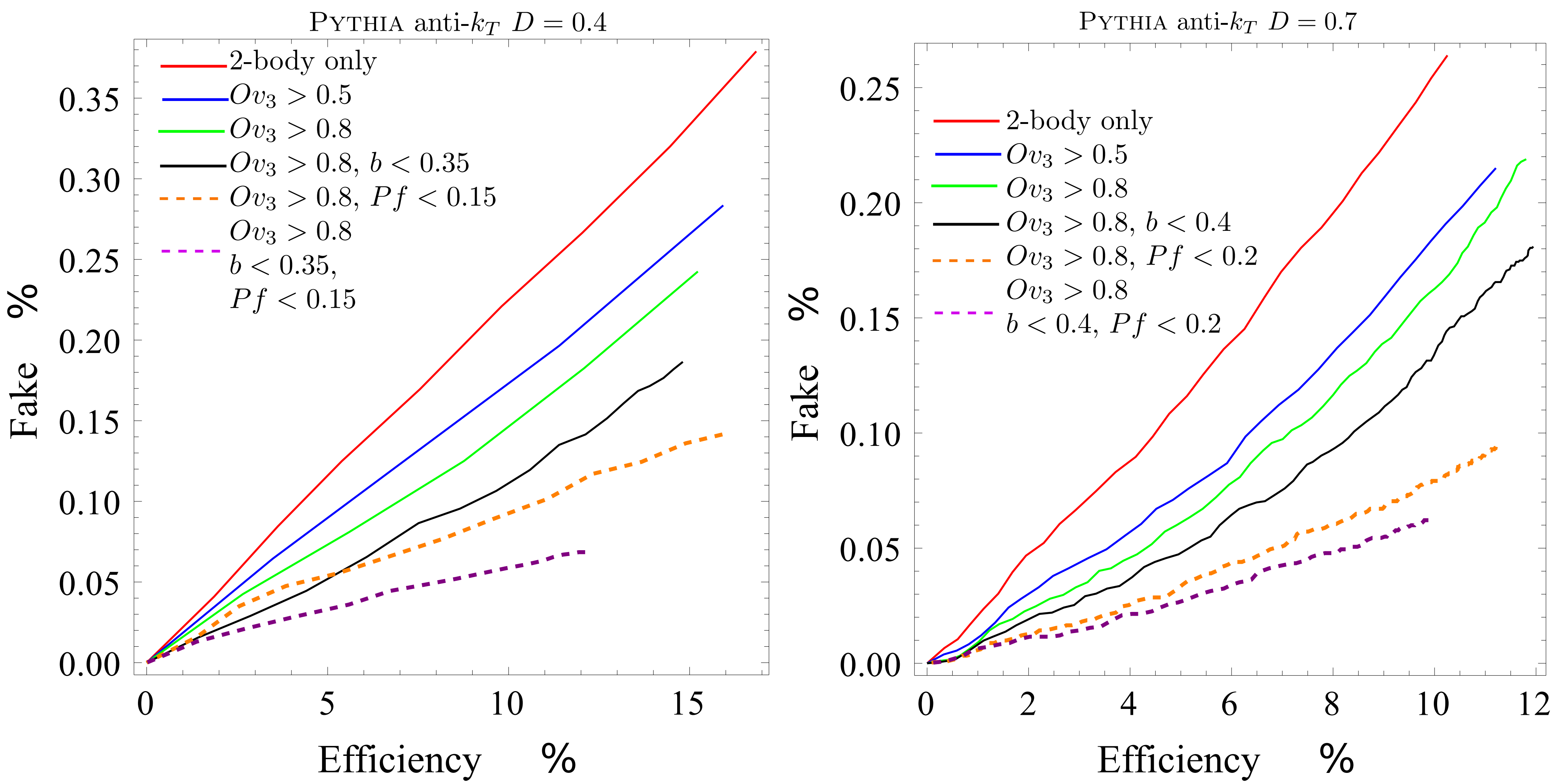


Overlap+Planar Flow







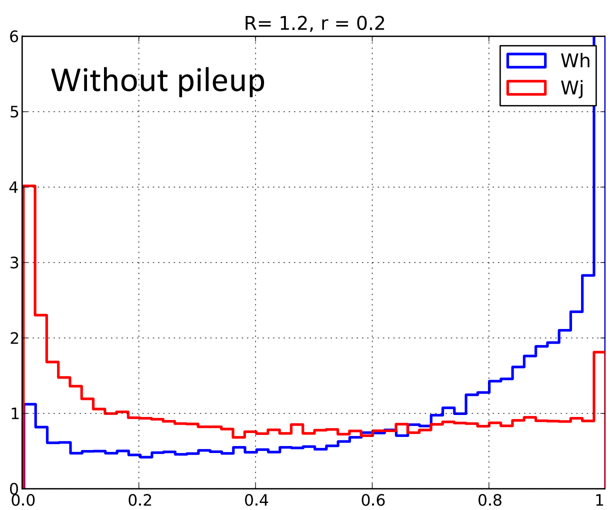

PYTHIA anti-k_T $D = 0.4$
2-body only
$Ov_3 > 0.5$
$Ov_3 > 0.8$
$Ov_3 > 0.8$, $b < 0.35$
$Ov_3 > 0.8$, $Pf < 0.15$
$Ov_3 > 0.8$
$b < 0.35$,
$Pf < 0.15$
Fake %
Efficiency %
PYTHIA anti-k_T $D = 0.7$
2-body only
$Ov_3 > 0.5$
$Ov_3 > 0.8$
$Ov_3 > 0.8$, $b < 0.4$
$Ov_3 > 0.8$, $Pf < 0.2$
$Ov_3 > 0.8$
$b < 0.4$, $Pf < 0.2$
Fake %
Efficiency %

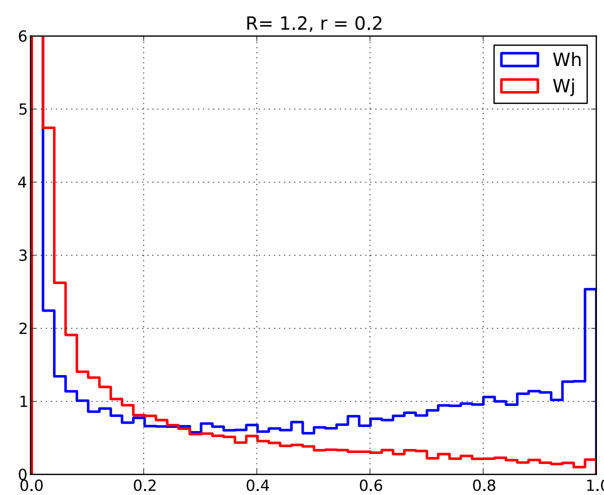
Higgs with Pile-up

Backovic, Juknevich, Perez, Winter (in progress)

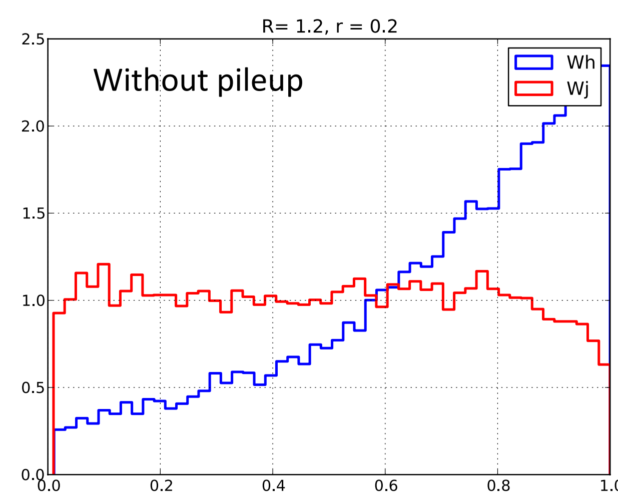
Pile-up should be soft and incoherent

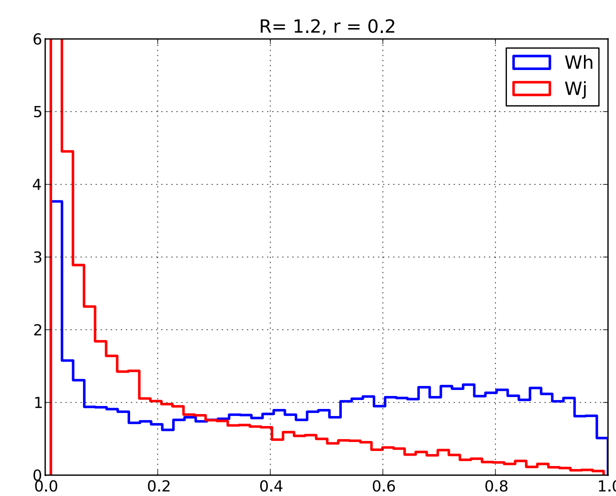
Therefore should not affect the peaks of energy in the distribution.





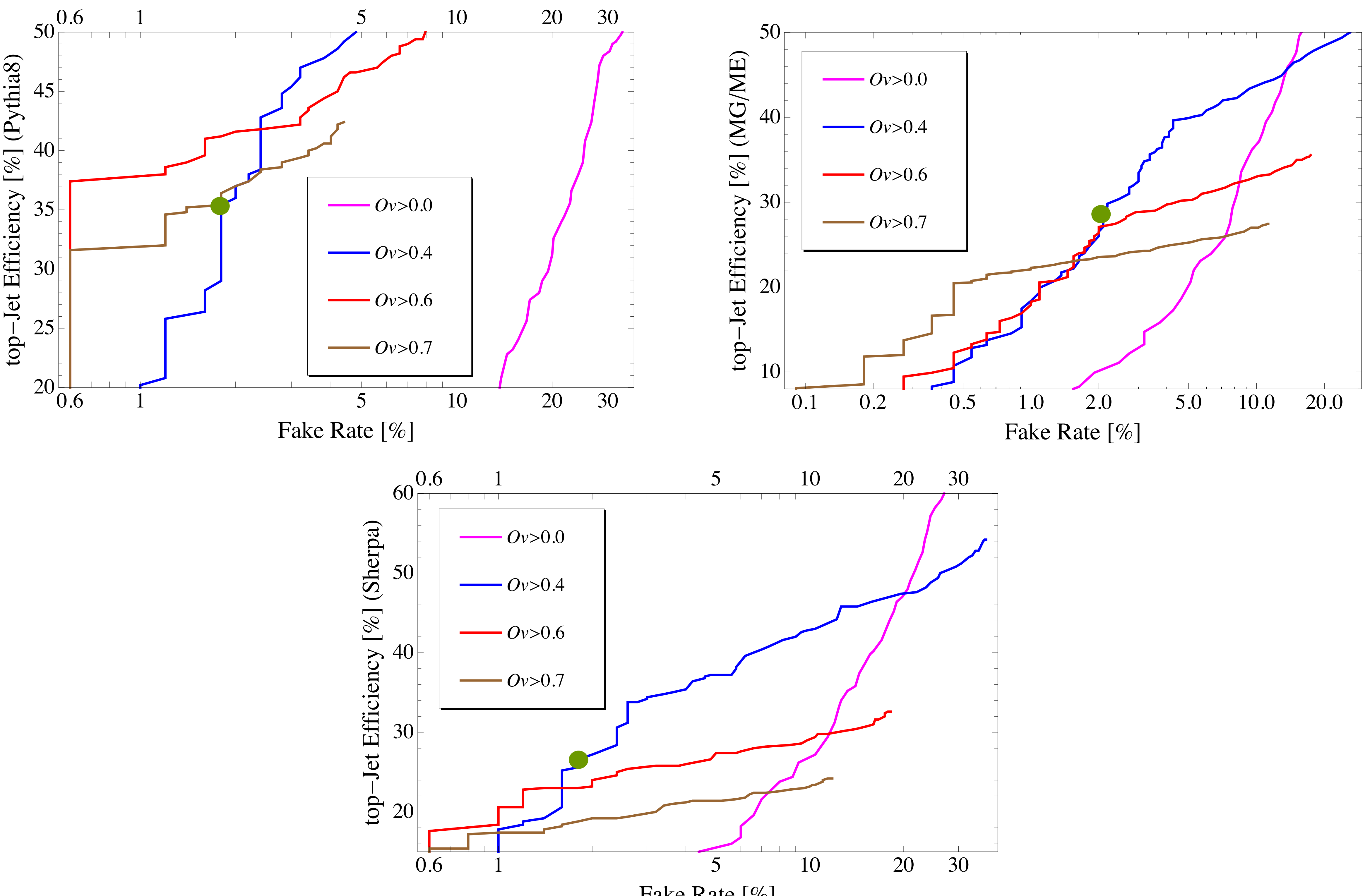
w/ pile-up





w/ pile-up

End.



top−Jet Efficiency [%] (Pythia8)
Fake Rate [%]
top−Jet Efficiency [%] (MG/ME)
Fake Rate [%]
top−Jet Efficiency [%] (Sherpa)
Fake Rate [%]
Ov>0.0
Ov>0.4
Ov>0.6
Ov>0.7