Jets on Templates

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based on :

LGA, S. J. Lee, G. Perez, G. Sterman, I. Sung
0807.0234; 0810.0934; 1006.2035;

Outline

Distinguishing Jets,

i.e. characterizing the states that have initiated the jet

Provides an additional step in systematically separating signal from background

Make use of the Energy Distribution in the calorimeter.

Probe the possible space of distributions in an Infrared Safe manner

Motivation

"Top Quark" like   Vertex b-tagging performance uncertain (at high pt) (gluino RPV, tops from resonances,etc..)

"Higgs" like   utilized the hadronic branches of Electroweak decays. (higgs, electroweak bosons, weak "primes")

Many Methods proposed: they fall in two categories

Direct algorithmic analyses

Butterworth, Davison,Rubin, Salam;
Kaplan, Rehermann, Schwartz, Tweedie
Plehn,Salam, Spannowsky; Krohn, Thaler Wang
Kribs, Martin,Roy, Spannowsky
Ellis, Vermilion, Walsh   et al.....

IR-safe jet shapes

LGA, Lee, Perez, Sterman, Sung, Virzi;
Gur-Ari,Papucci,Perez; ....

Template Method.

Multivariate analyses

See M. Schwartz talk

Jets as Energy Correlations

Jet cross-section can very naturally be described as energy correlations

Basham, Brown, Ellis, Love 79

Energy flow can be interpreted as correlation of the energ. mtm. tensor

Korchemsky, Oderda, Sterman 95

$$\mathcal{O}(\hat{n}) = \lim_{\hat{n}\to\infty} \int_0^\infty \frac{dn_0}{(2\pi)^2} |\hat{n}|^2 \hat{n}_i T_{0i}(\hat{n}_i)$$

At this ideal calorimeter (at infinity)

Jets with same parameters, differ then only by their pattern of energy correlations

Overlap Formalism

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

A natural choice being the weighted difference of energy flows integrated over a fixed region of phase space.

We choose a functional that maximizes the overlap when the energy correlations match.

Overlap Formalism

$$Ov^{(F)}(j,f) = \max_{\tau_n^{(R)}} \ \exp\left[-\frac{1}{2\sigma_E^2}\left(\int d\Omega\ \left[\frac{dE(j)}{d\Omega} - \frac{dE(f)}{d\Omega}\right] F(\Omega,f)\right)^2\right]$$

$$\tau_n^{(R)} \equiv \int \prod_{i=1}^{n} \frac{d^3\vec{p}_i}{(2\pi)^3 2\omega_i}\ \delta^4(P - \sum_{i=1}^{n} p_i)\ \Theta(\{p_i\}, R)$$

$F(\Omega, f)$ is a weight function, smooth enough

We choose to weight the energy around each particle uniformly.

For example: Weighting the energy by

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

Top Decay and 3 pcle decay

Top decay at LO has a simple 3 body kinematics.

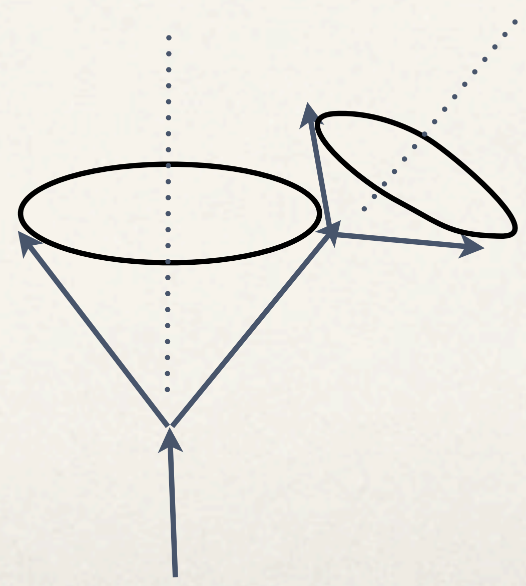
$$t \to W + b \to q + q' + b$$

While we expect high mass, QCD jets typically have a state with two-subjet topology.

We make use of the simplest template

3 particles final states with the kinematics of the top decay

Completely described by 4 angles



Overlap Functional

In this case our overlap functional is then defined by:

$$Ov(j,f) = \max_{\tau_n^{(R)}} \exp\left[-\sum_{a=1}^{3} \frac{1}{2\sigma_a^2} \left(\sum_{k=i_a-1}^{i_a+1} \sum_{l=j_a-1}^{j_a+1} E(k,l) - E(i_a,j_a)^{(f)} \right)^2 \right]$$

$$\sigma_a = E(i_a,j_a)^{(f)}/2$$

$E(i_a,j_a)^{(f)}$ is simply given by phase space kinematics.

Top Decay and 3 pcle decay

For the simulations we impose,

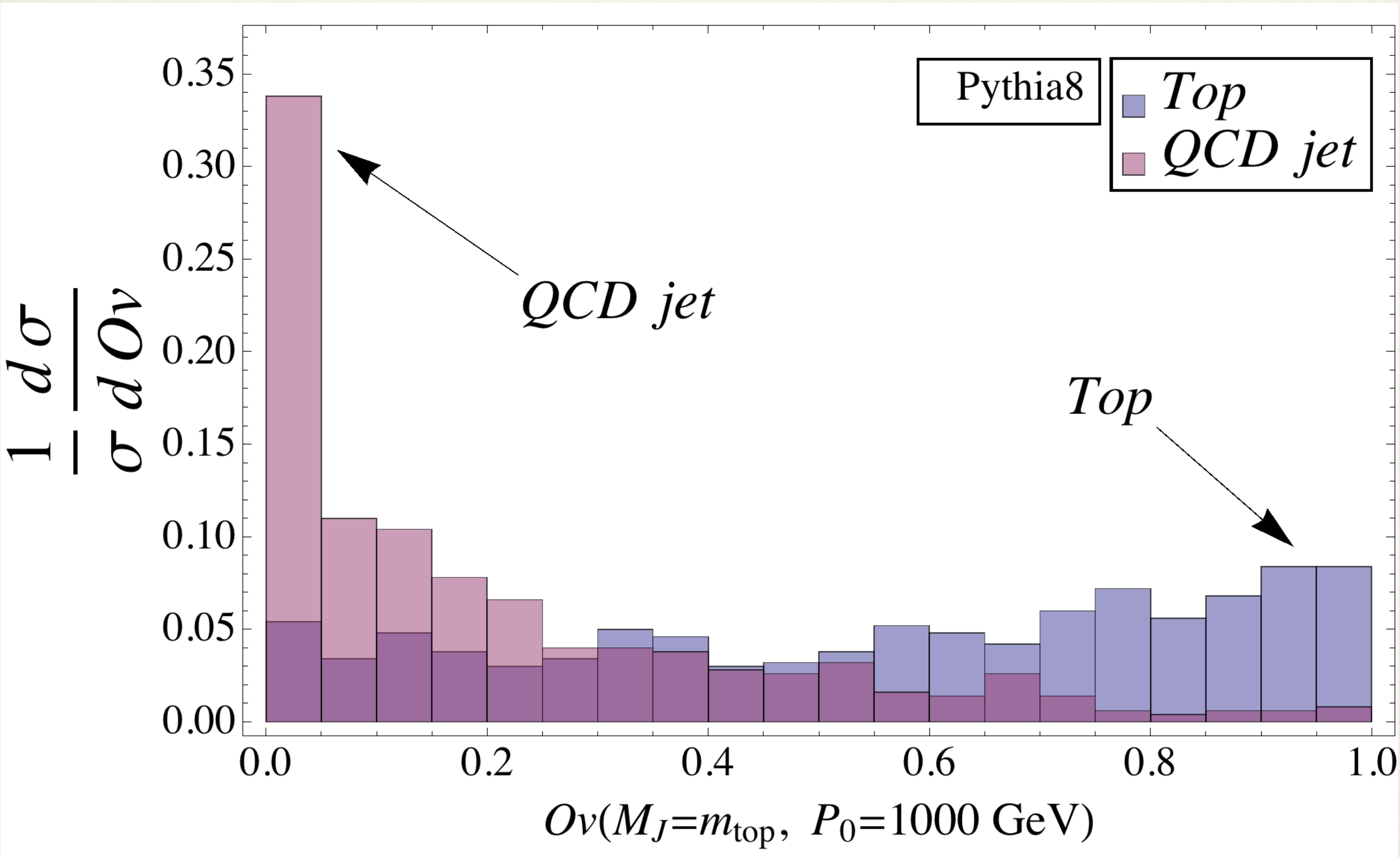
$$160\,\mathrm{GeV} \leq \mathrm{m_J} \leq 190\,\mathrm{GeV}$$
$$950\,\mathrm{GeV} \leq \mathrm{E_J} \leq 1050\,\mathrm{GeV}$$

$$m_t = 174\,\mathrm{GeV}$$

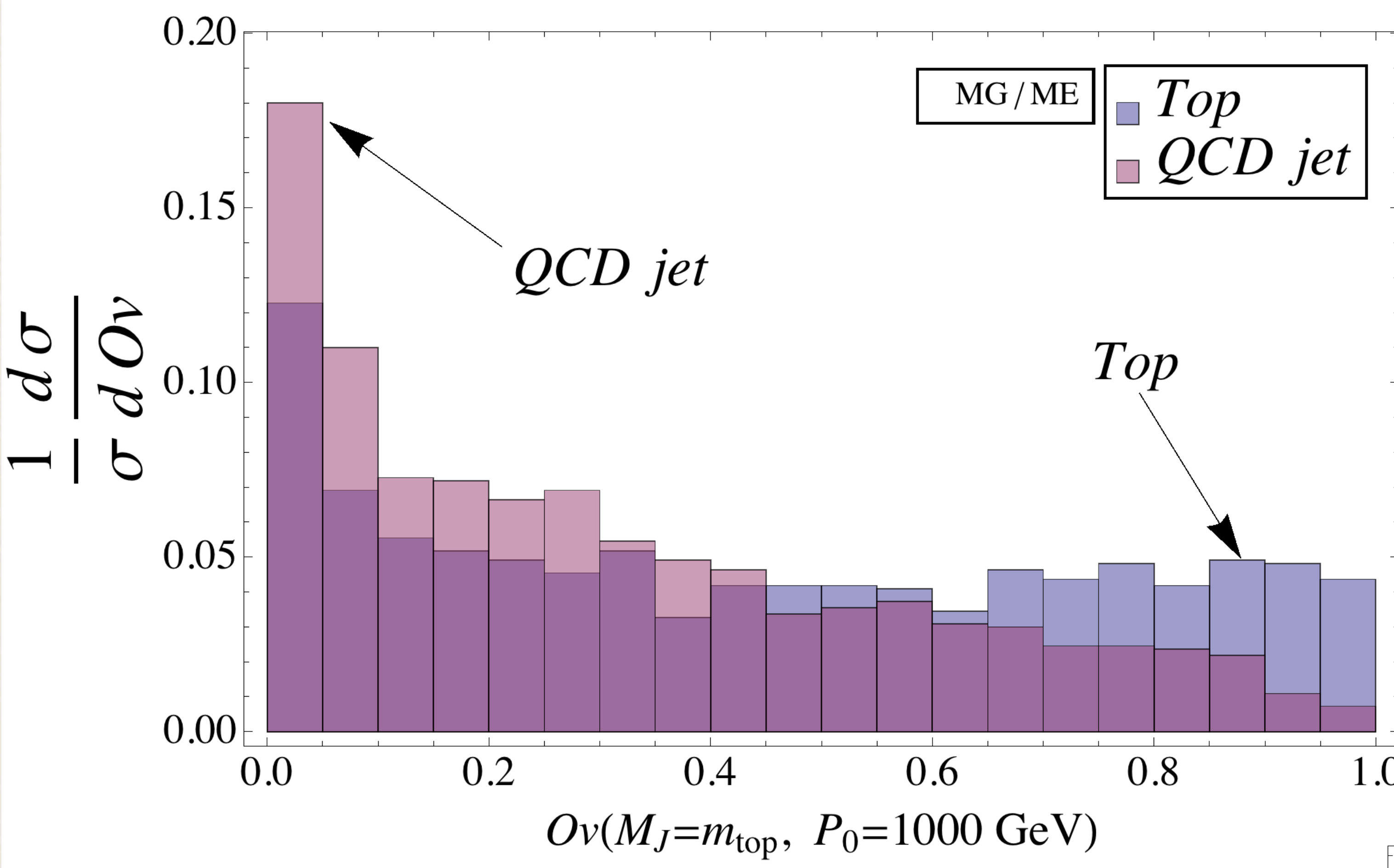
Jets found with use of the anti-kt algorithms $D = 0.5$

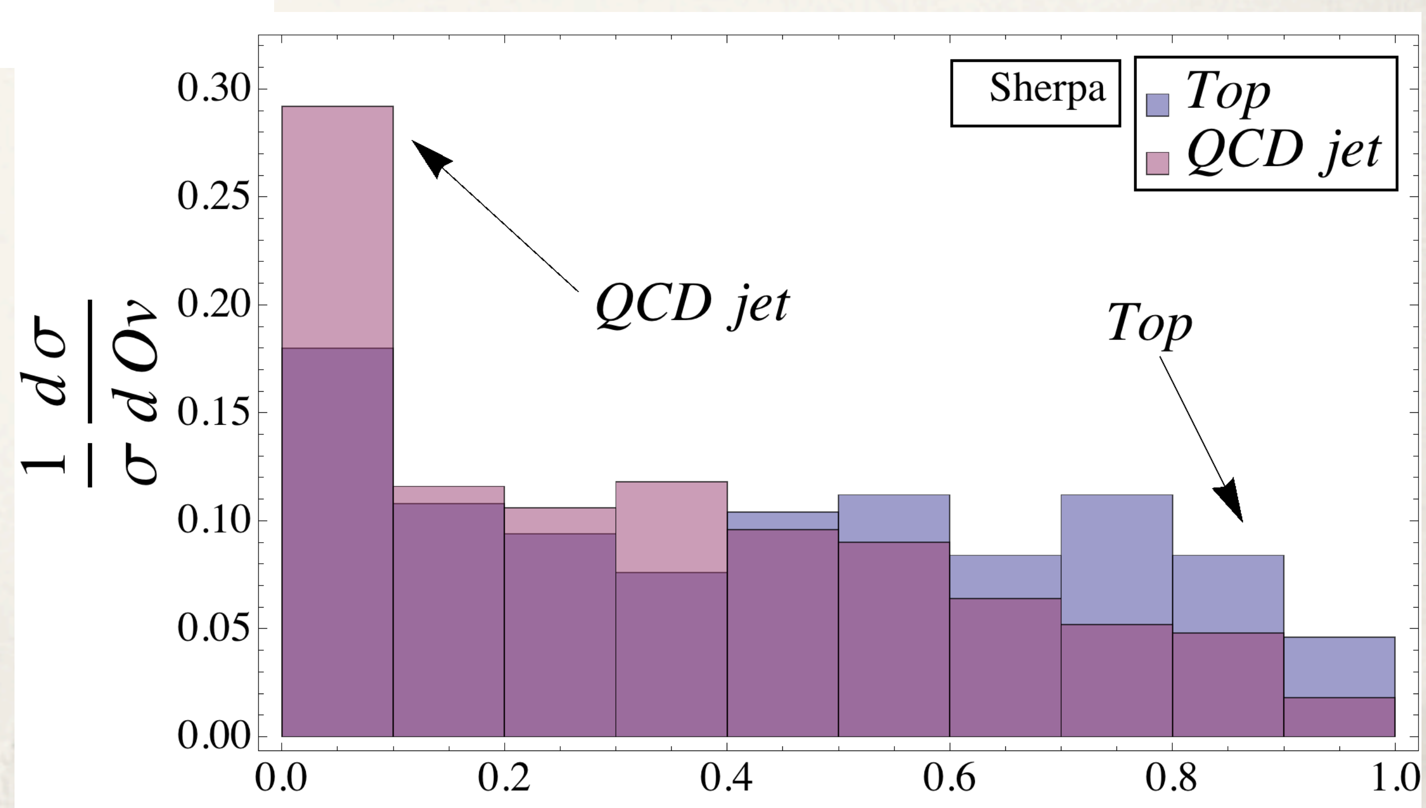
Discretize the calorimeter $\Delta\theta = 0.06$ and $\Delta\phi = 0.1.$

Top and QCD jets



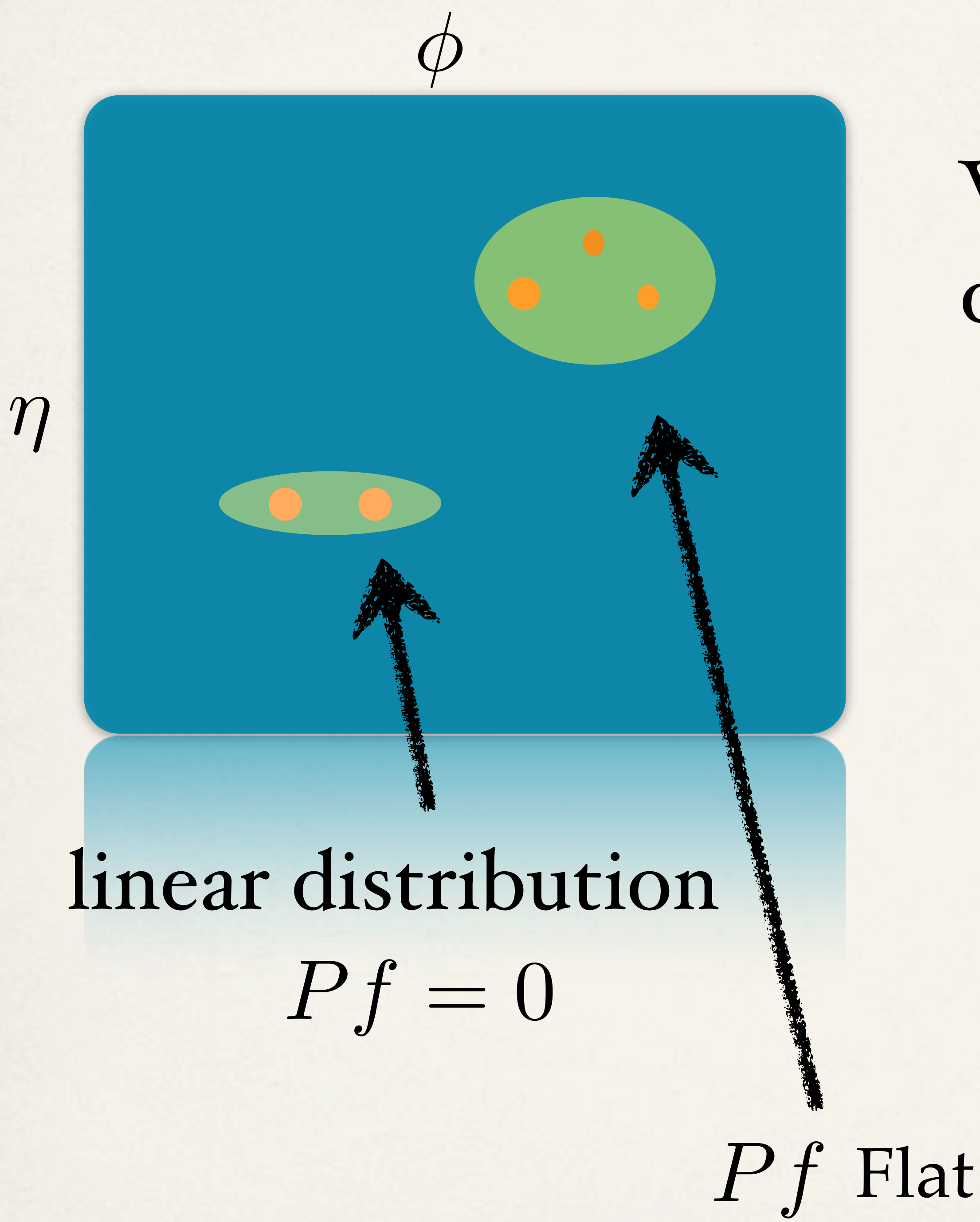
Top and QCD jets





Planar Flow

Almeida, Lee, Perez, Sterman, Sung

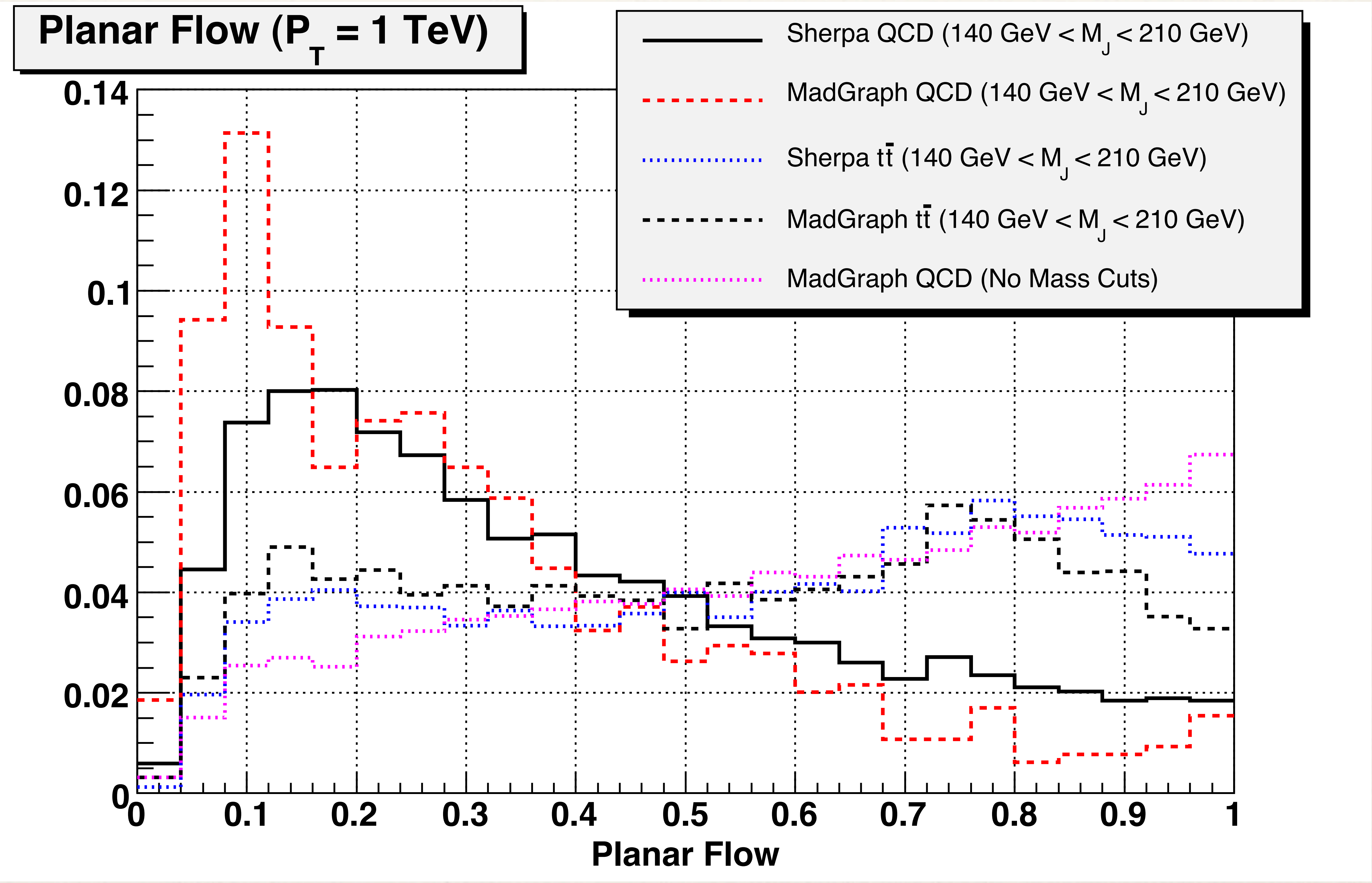


We can use higher moments of the distribution.

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

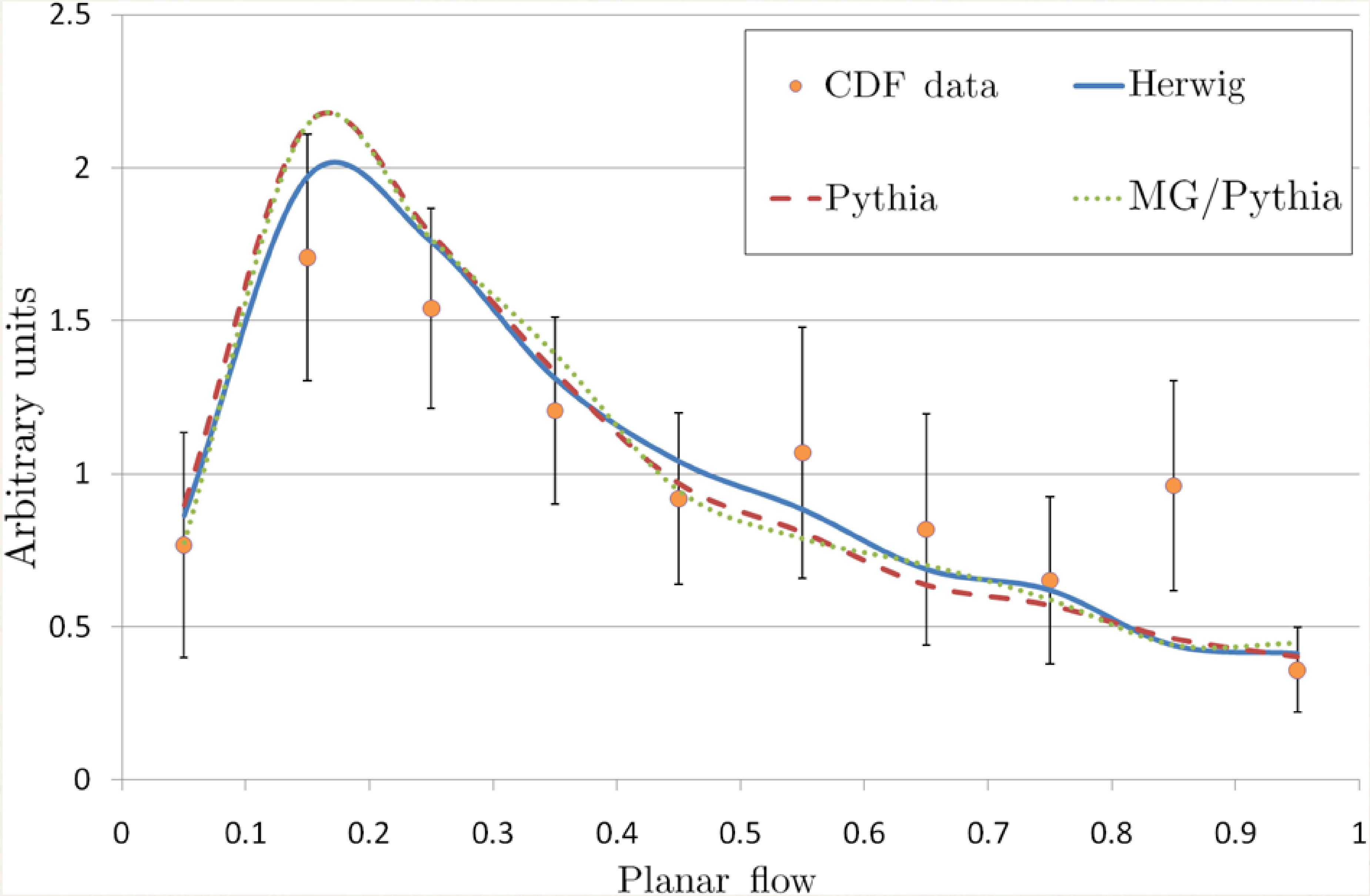
$$Pf = \frac{4 \det(I_{\omega})}{\mathrm{tr}(I_{\omega})^2}$$

Planar Flow Distribution



Almeida, Lee, Perez, Sterman, Sung, Virzi

Planar Flow

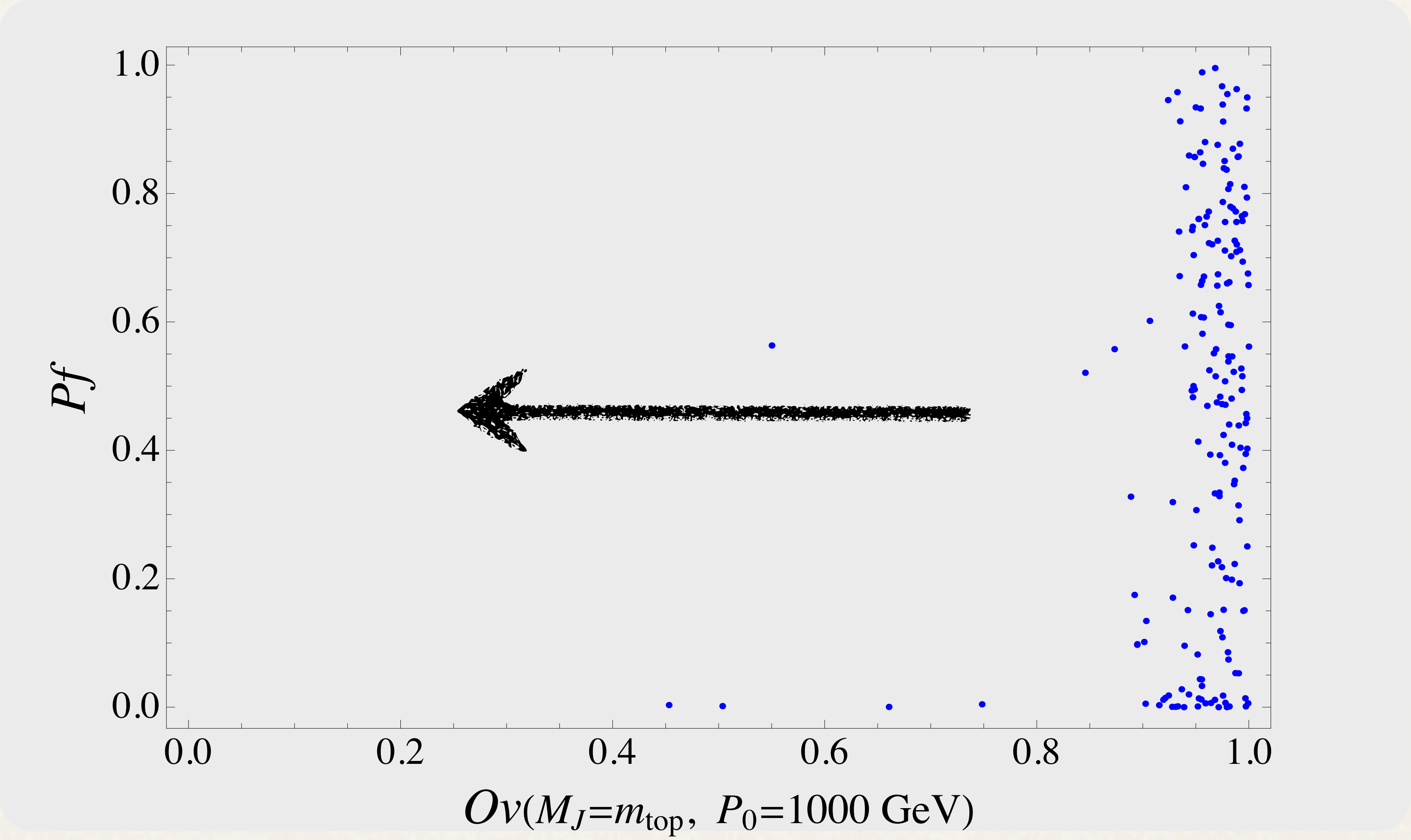


Eshel, Gedalia, Perez, Soreq 11

Partonic and Planar Flow

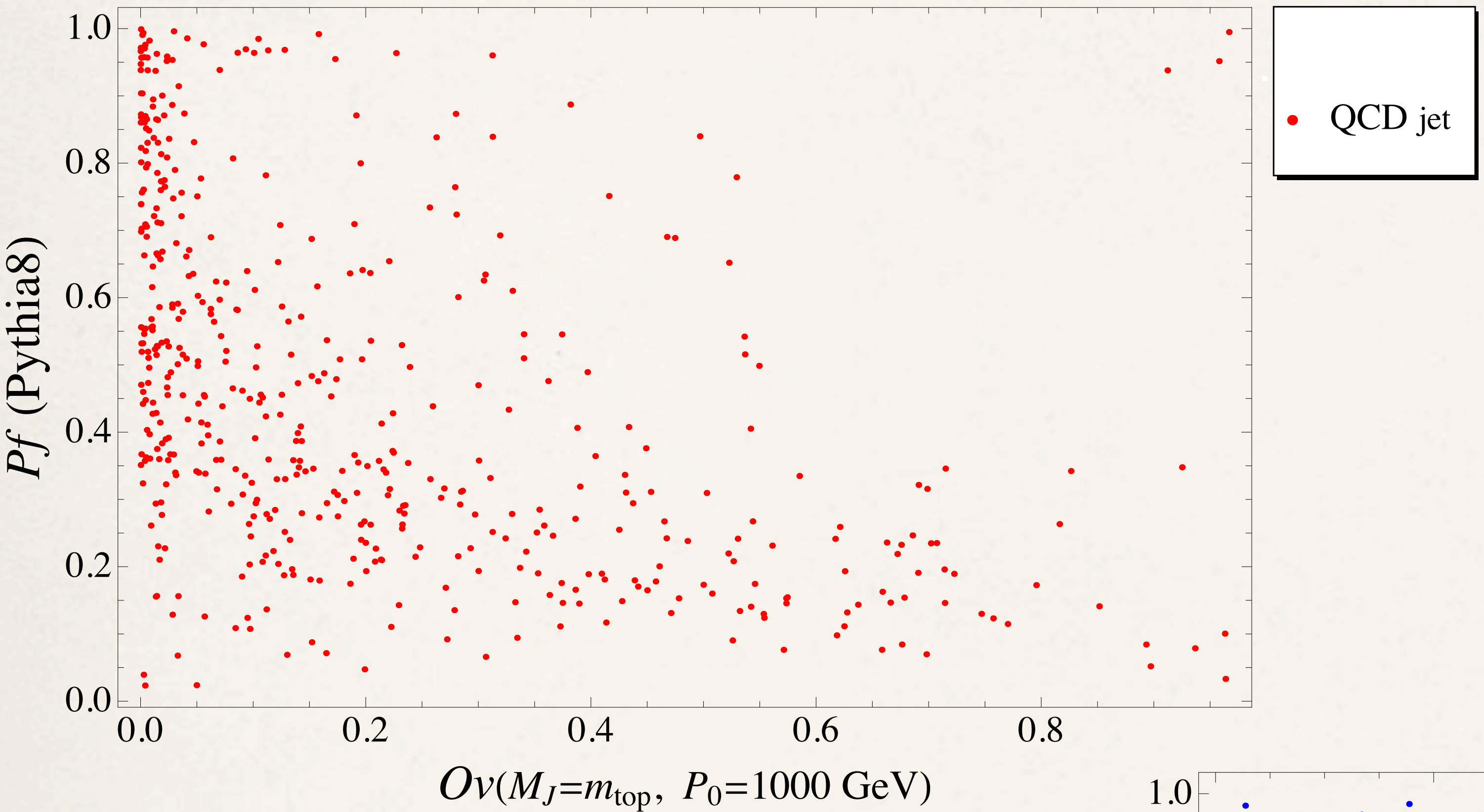
At the partonic level, the top decay peaks at high Ov.

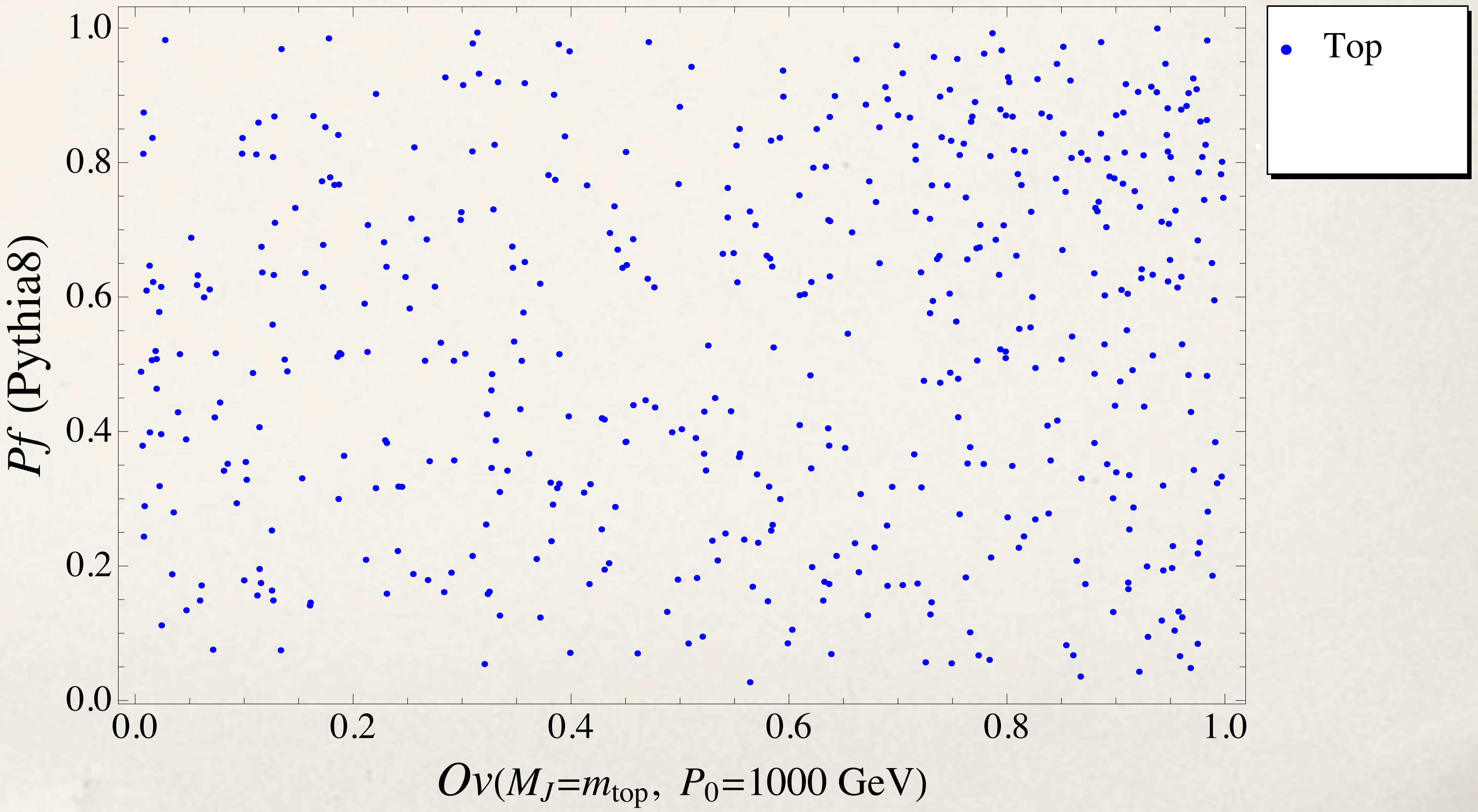
and its Pf distribution is rather flat



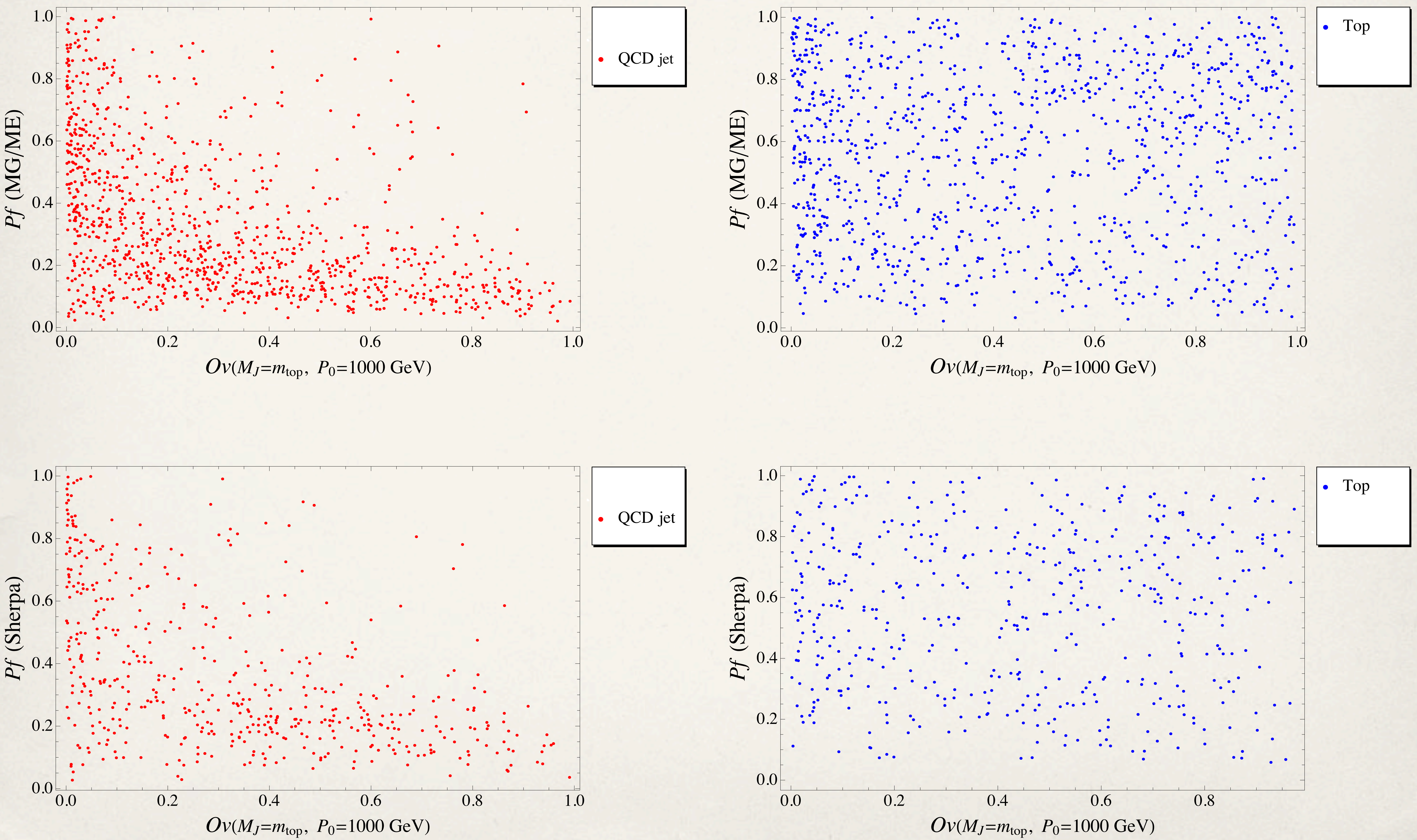
As we saw the Ov distribution spreads out once hadronization occurs.

Overlap and Planar Flow

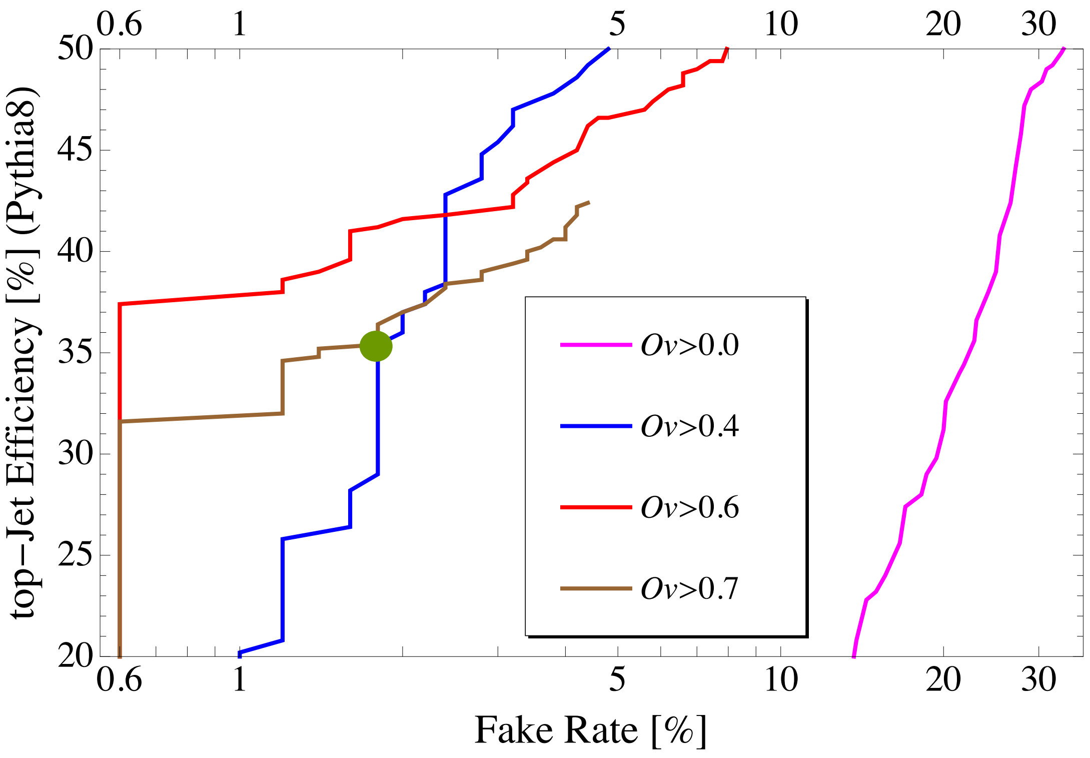


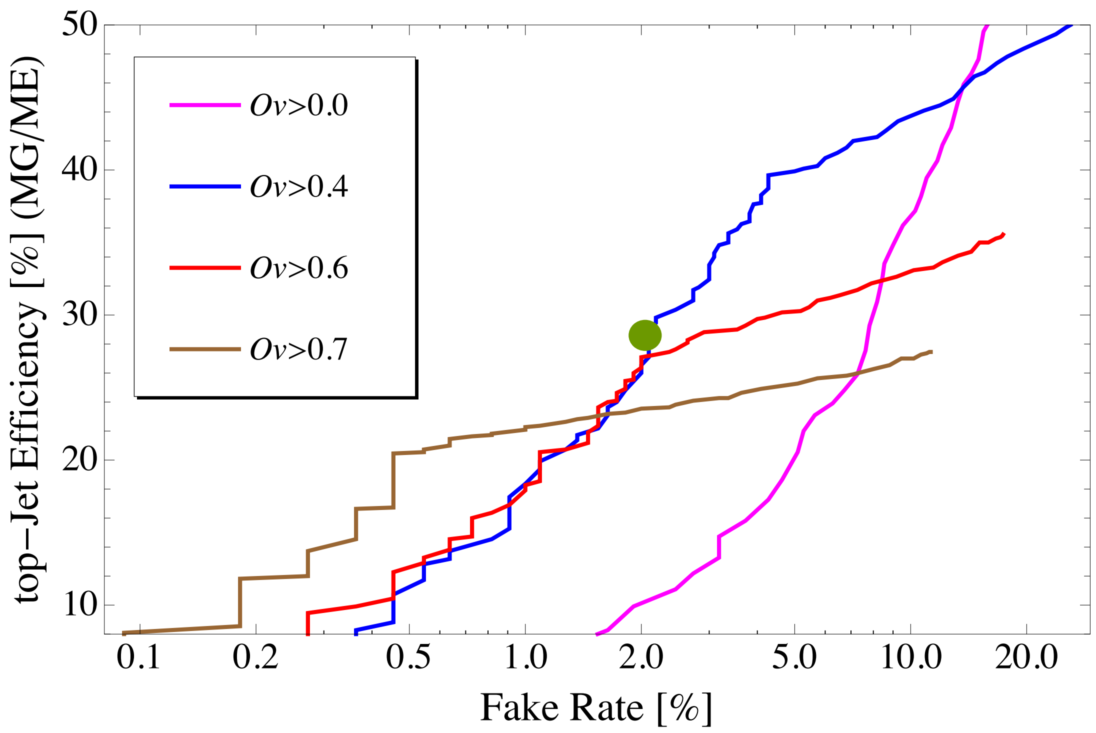


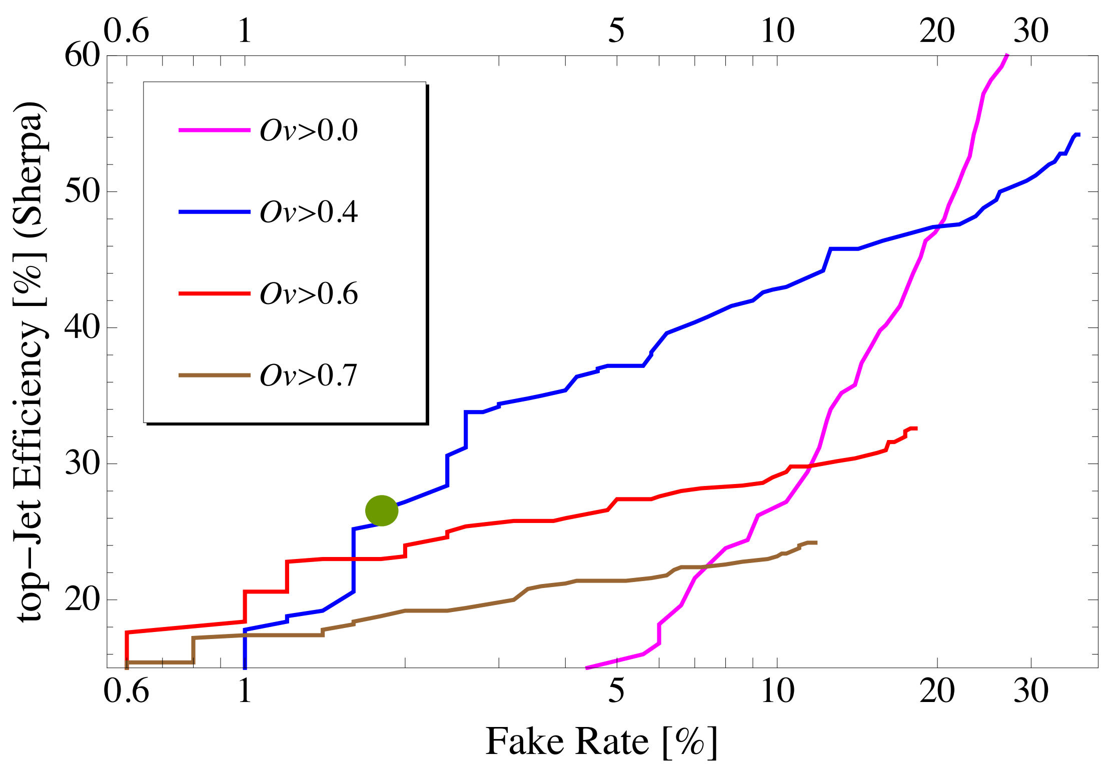
Overlap and Planar Flow



Fake Rate vs Efficiency







$$Pf > 0.6 \text{ and } Ov > 0.4$$

Higgs and 2 pcle decay

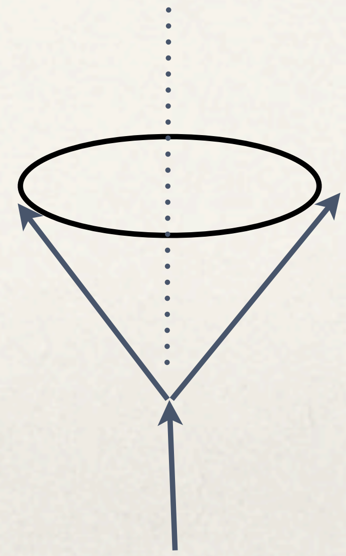
Both described by 2 body kinematics.

However, QCD jets are usually more contaminated
by extra radiation compared to Higgs.

We make use of a 2 particle template and
similarly discretize the data in the eta-phi plane.

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

Described by only two angles



Higgs and Overlap

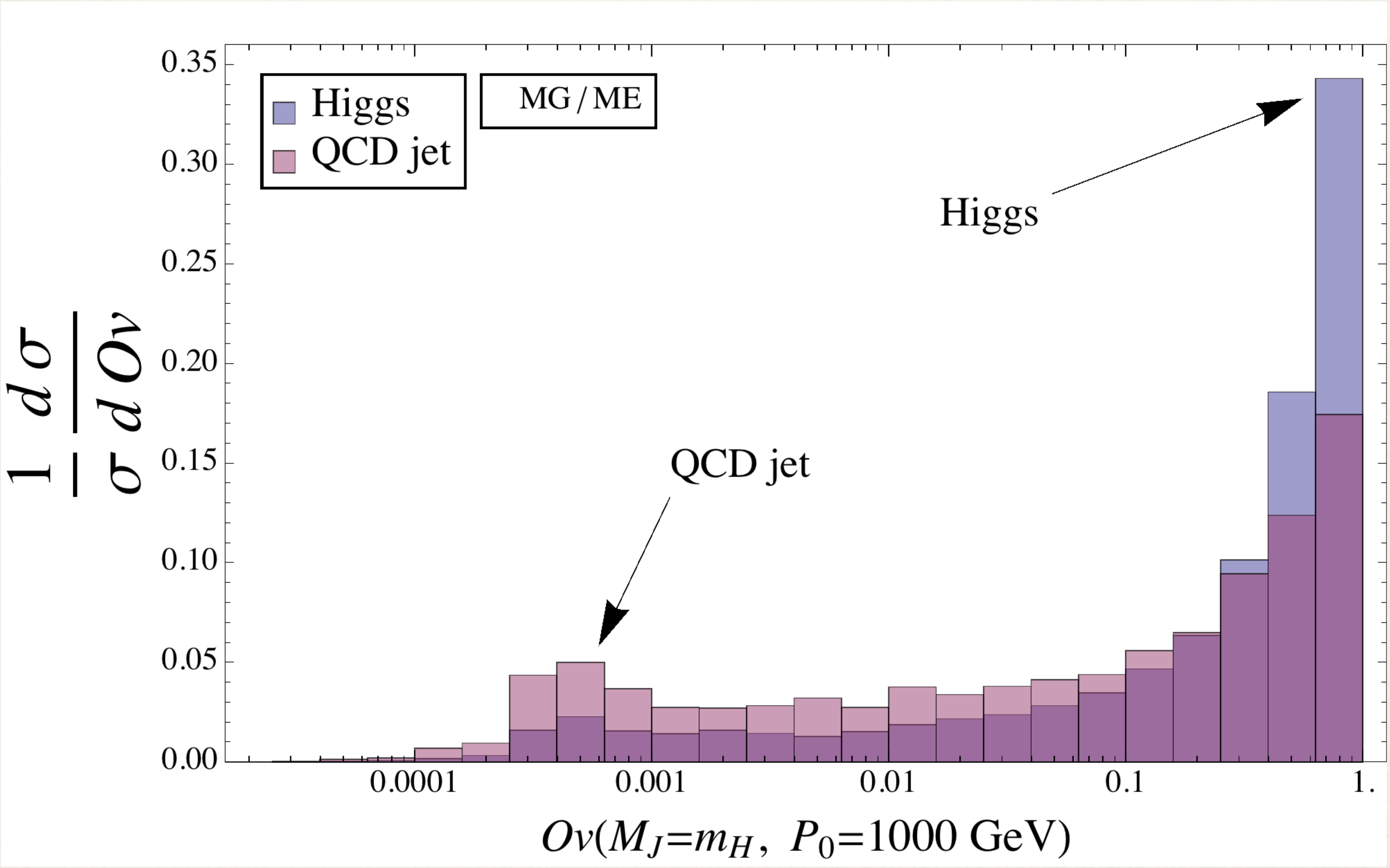
For the simulations we impose,

$$950\ \text{GeV} \leq P_0 \leq 1050\ \text{GeV}$$
$$110\ \text{GeV} \leq m_J \leq 130\ \text{GeV}$$

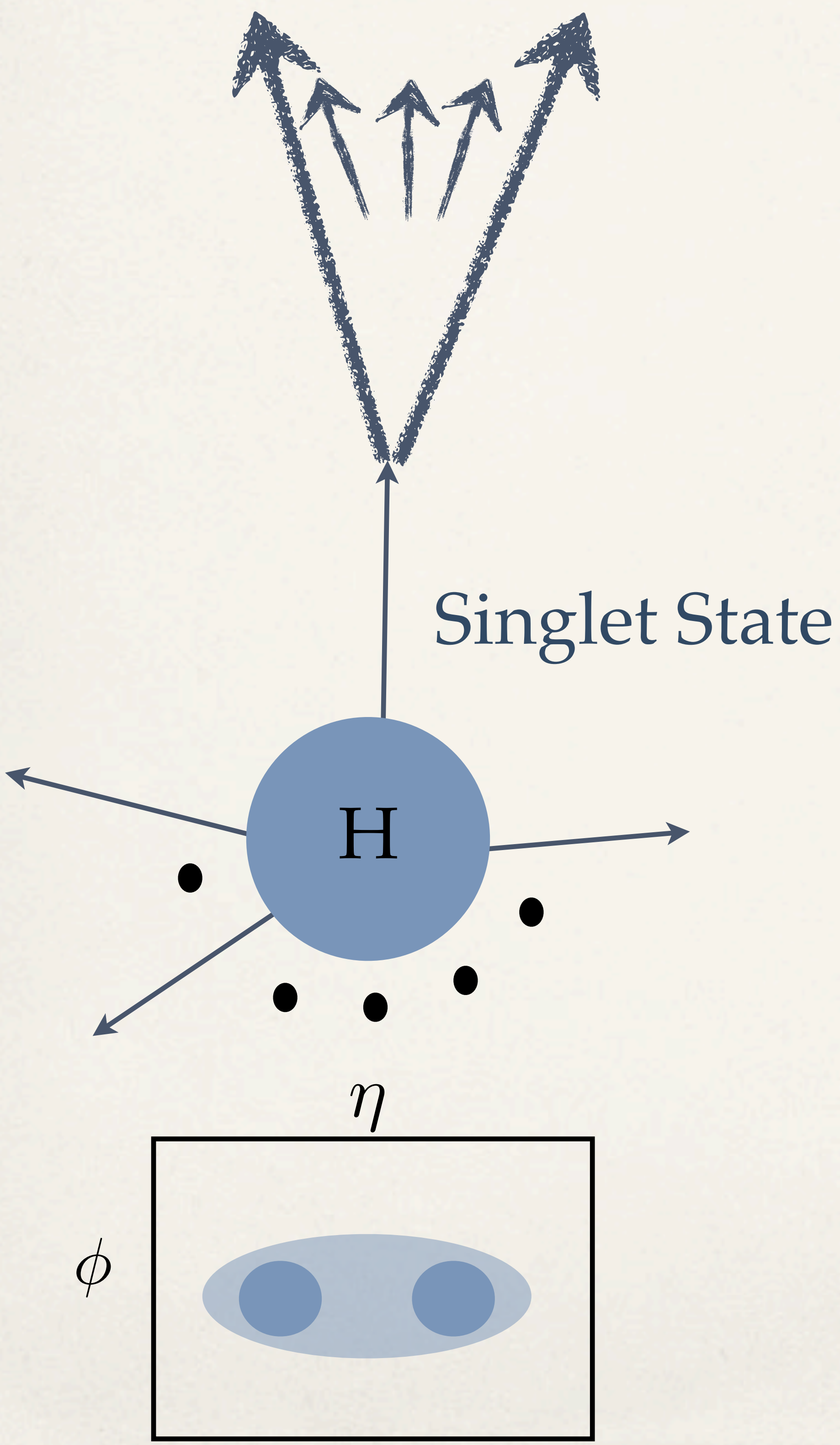
Higgs Mass $M_H = 120\,\text{GeV}$

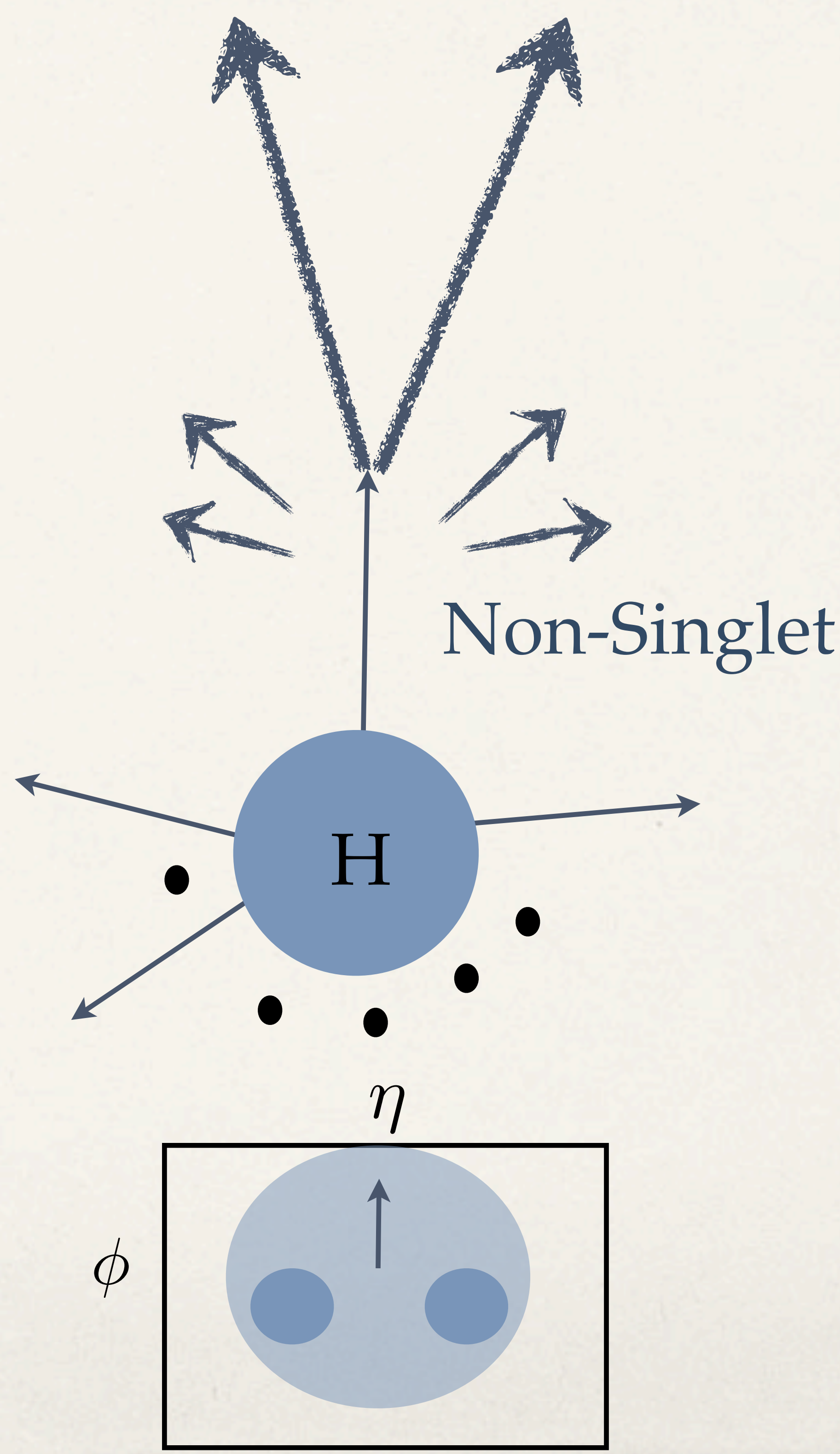
Once again, we make use of the anti-kt algorithm R=0.4

Higgs and 2 pcle decay

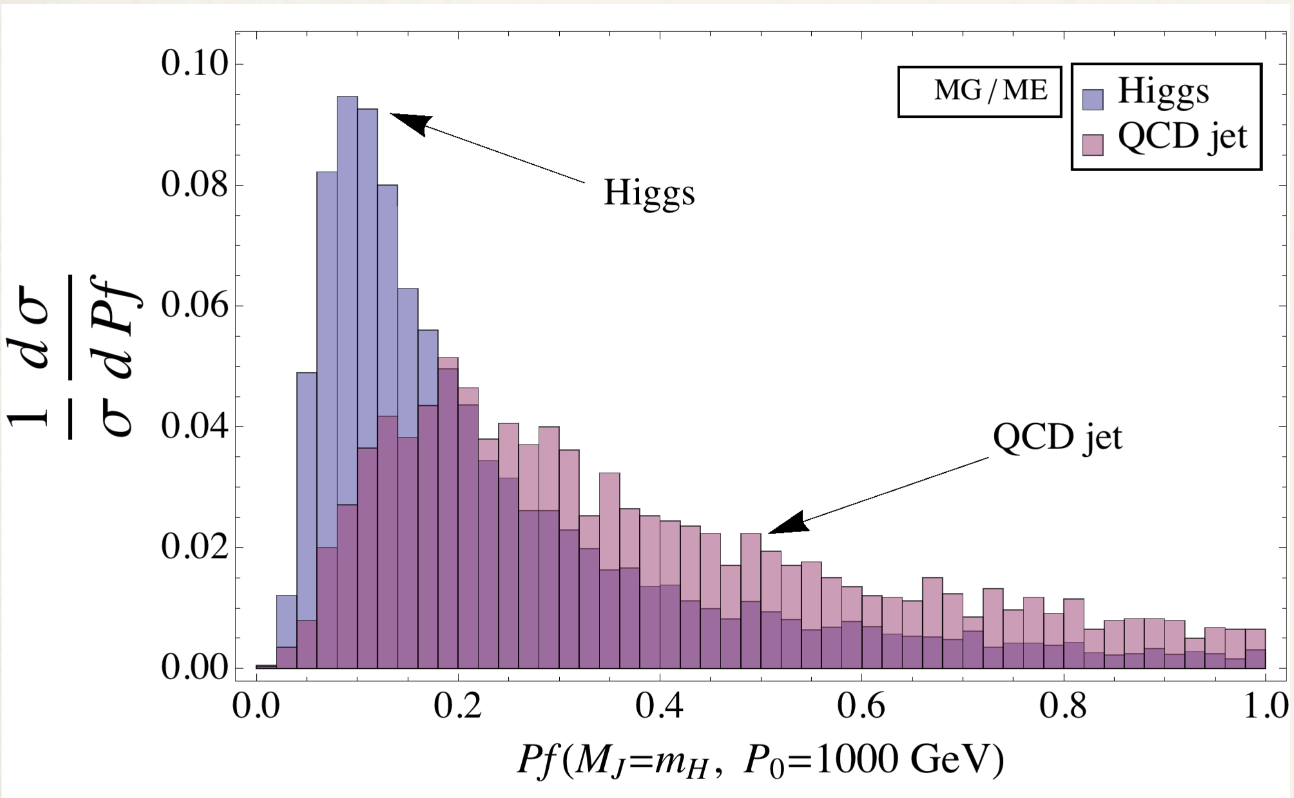


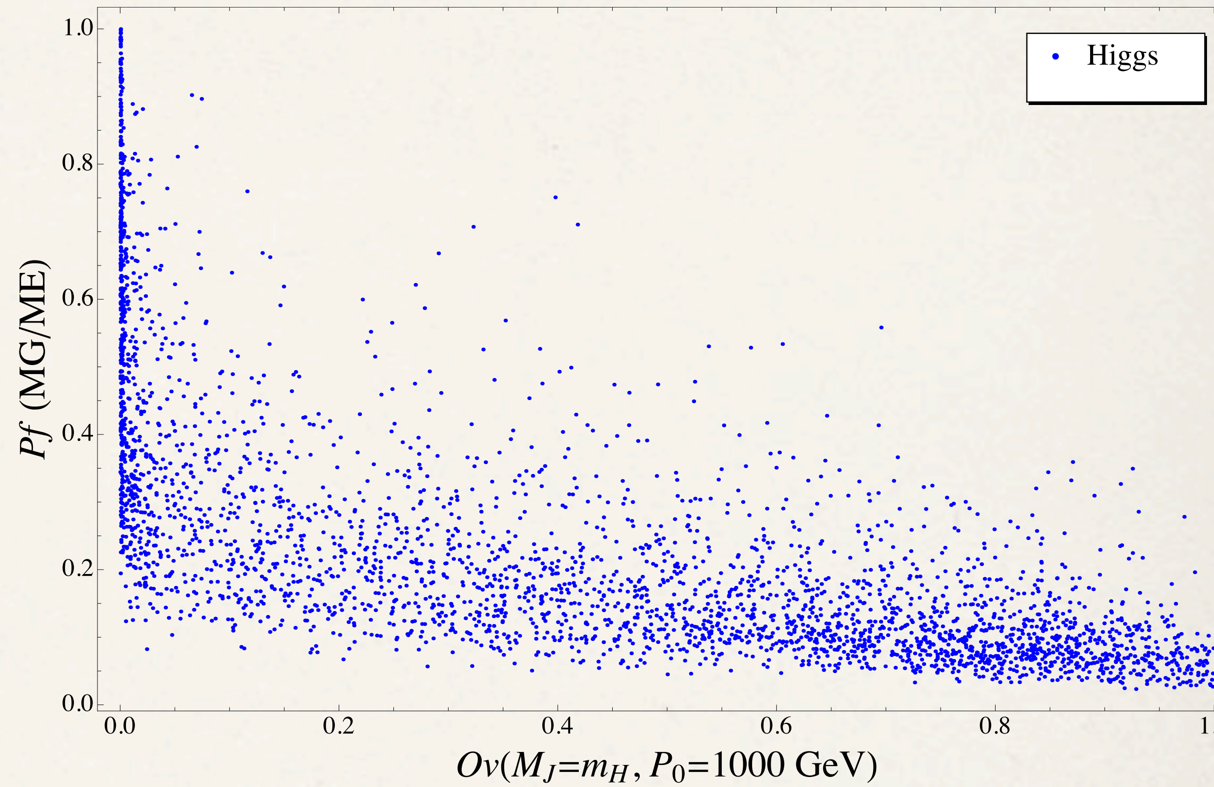
Color Flow to Energy Flow
Sung; Gallicchio, Schwartz

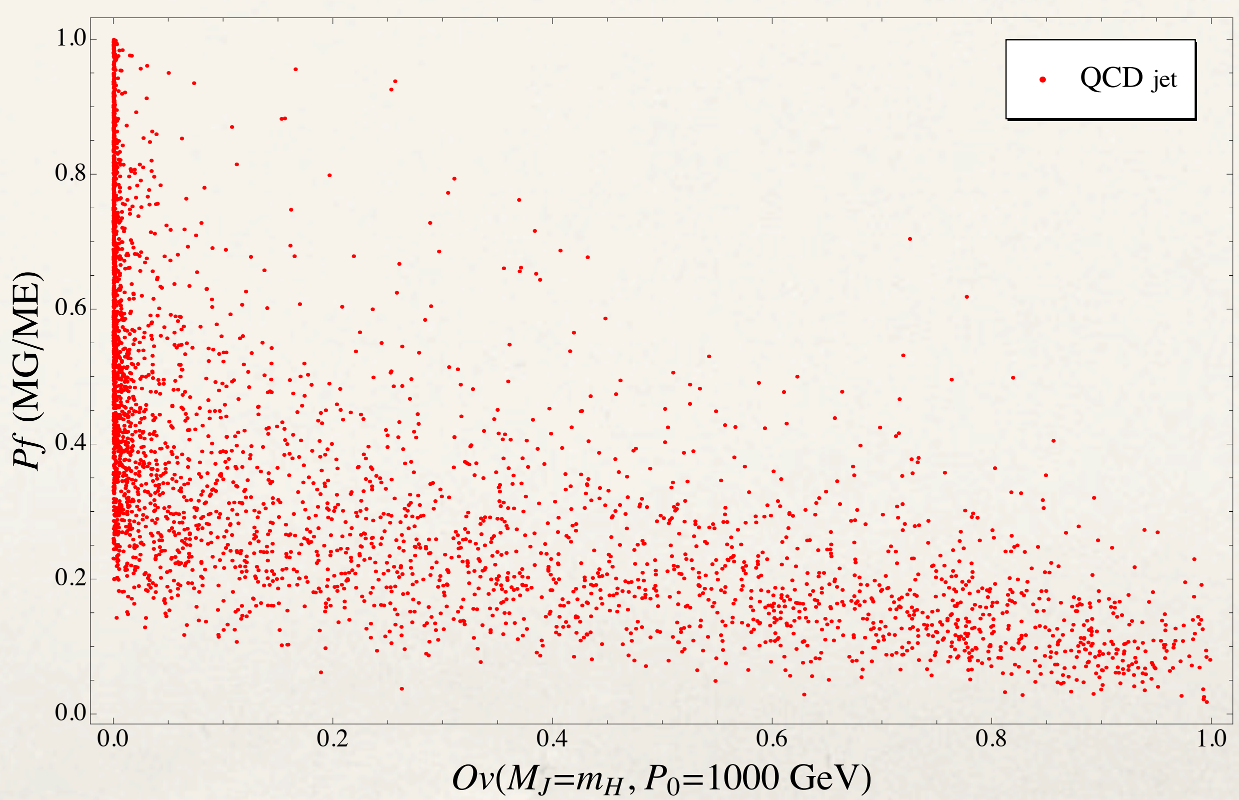




Overlap+Planar Flow







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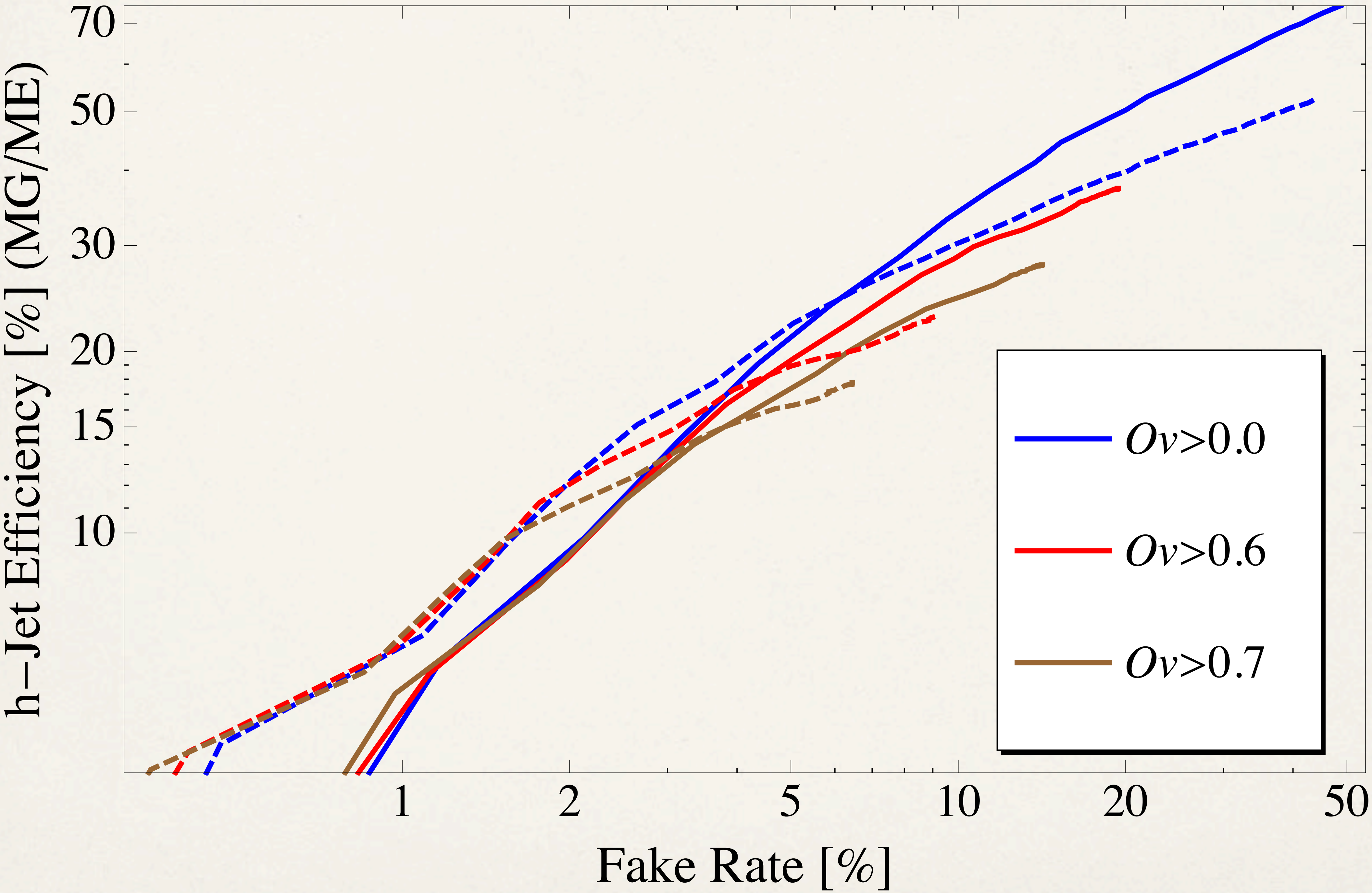

Higgs needs more work,

Should be straightforward to describe its decay at NLO level.

Conclusion

Introduced a new class of infrared safe jet observables

Comparing energy flow from data to selected sets partonic states

Even with a basic construction, we were able get competitive numbers

Improved by templates that are weighted by the matrix elements

This relied only in the infrared safety of energy flow.

Differences in different generators most likely due to different showering mechanisms leading to different energy distributions

Nonetheless, we were able get strong rejection powers.

Pythia 8	1:1000	MG/ME	1:600	Sherpa	1:200

Suggesting these methods are robust, and not sensitive to the treatment of soft physics.