e^+e^- Dijet Event Shapes

Carola F. Berger

EPS 2003

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based on

C.F.B., T. Kúcs, G. Sterman, arXiv:hep-ph/0212343.
G. Sterman, arXiv:hep-ph/0301243.
C.F.B., T. Kúcs, G. Sterman, Phys. Rev. **D 68** (2003) [arXiv:hep-ph/0303051].
C.F.B., arXiv:hep-ph/0305076.

and in preparation.

Outline

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- Introduction, General Class of e^+e^- Event Shapes

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- Resummation at NLL for General Class of Event Shapes

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- Summary and Outlook

Introduction - e^+e^- Event Shapes

Thrust

E. Farhi, Phys. Rev. Lett. **39**, 1587 (1977).

$$T = \frac{1}{\sum_j |\vec{p}_j|} \max_{\hat{n}} \sum_{i=1}^{n} |\vec{p}_i \cdot \hat{n}| = \frac{1}{\sum_j |\vec{p}_j|} \max_{\hat{n}} \sum_i k_{\perp,i} e^{-|\eta_i|} \qquad (1)$$

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Jet broadening

S. Catani, G. Turnock, B. R. Webber, Phys. Lett. **B 295**, 269 (1992).

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Generalization:

C.F.B., T. Kúcs, G. Sterman, arXiv:hep-ph/0212343, and Phys. Rev. D 68 (2003), arXiv:hep-ph/0303051; A. Banfi, G. P. Salam and G. Zanderighi, arXiv:hep-ph/0304148.

$$\tau_a(N) = \frac{1}{Q} \sum_{\text{all } i \in N} k_{\perp,i}\, e^{-|\eta_i|(1-a)} \tag{3}$$

Parameter a allows to control shape. $a = 0 : 1 - T, \quad a = 1 : B.$

Generalized Event Shapes - Resummation

Cross section $e^+e^- \to 2$Jets, c.m. energy Q:

$$\frac{d\sigma(\tau_a, Q)}{d\tau_a} = \frac{1}{2Q^2} \sum_N |M(N)|^2 \, \delta(\tau_a - \tau_a(N)). \tag{4}$$

$0 < \tau_a \ll 1$ in 2-jet limit $\Rightarrow$ **large logarithmic corrections** $\sim \ln \tau_a$

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Resummed cross section in Laplace transform space: 7

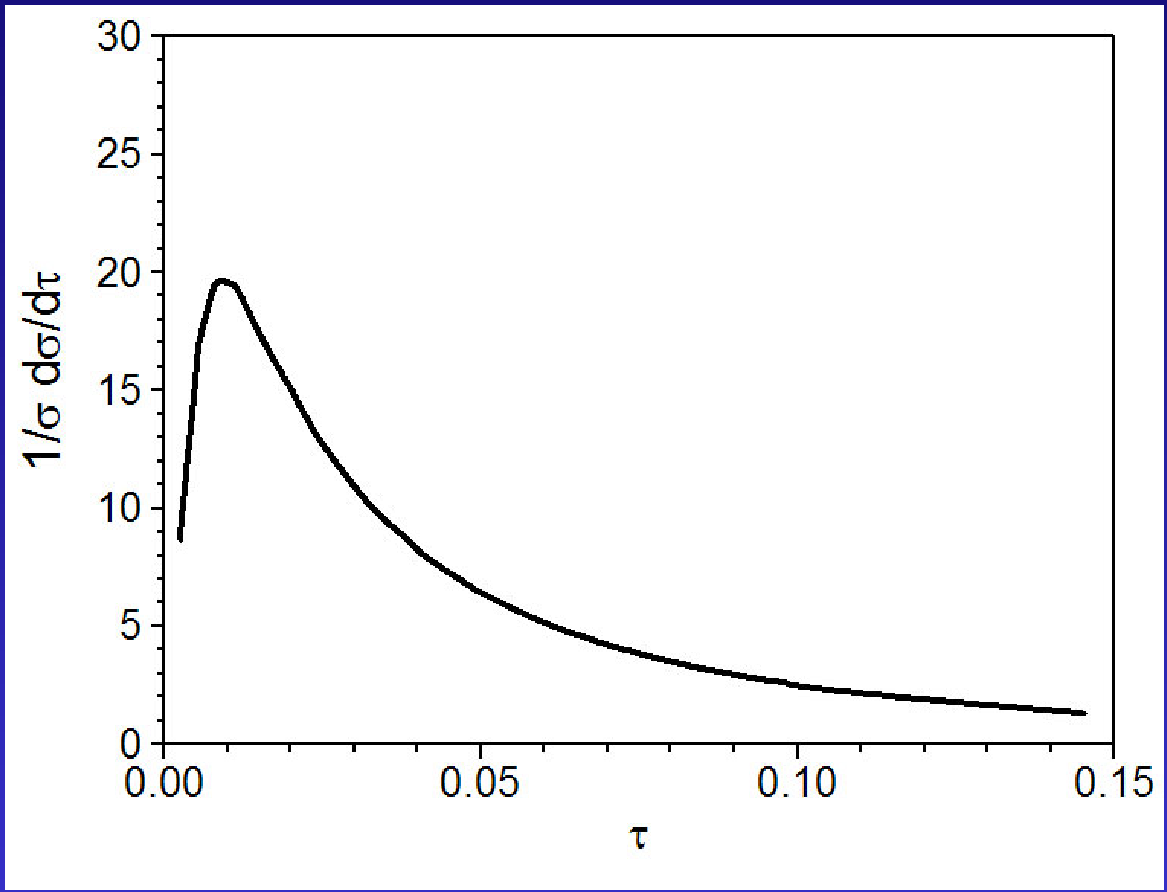
C.F.B., T. Kúcs, G. Sterman, Phys. Rev. D 68 (2003), arXiv:hep-ph/0303051.

$$\frac{1}{\sigma_{\text{tot}}} \tilde{\sigma}(\nu, Q, a) \equiv \frac{1}{\sigma_{\text{tot}}} \int_0^1 d\tau_a \, e^{-\nu \, \tau_a} \frac{d\sigma(\tau_a, Q)}{d\tau_a} \tag{5}$$

$$= \exp\left\{ 2 \int_0^1 \frac{du}{u} \left[\int_{u^2Q^2}^{uQ^2} \frac{dp_\perp^2}{p_\perp^2} A\left(\alpha_s(p_\perp)\right) \left(e^{-u^{1-a}\nu (p_\perp/Q)^a} - 1 \right) \right.\right.$$

$$\left.\left. + \frac{1}{2} B\left(\alpha_s(\sqrt{u}Q)\right) \left(e^{-u(\nu/2)^{2/(2-a)}} - 1 \right) \right] \right\}. \tag{6}$$

NLL Resummed Cross Section vs. Data at $Q = 91$ GeV



Thrust-data: L3, Z. Phys. **C 55**, 39 (1992). OPAL, Z. Phys. **C 59**, 1 (1993). SLD, Phys. Rev. **D 51**, 962 (1995). PYTHIA v. 6.215: T. Sjostrand, P. Eden, C. Friberg, L. Lonnblad, G. Miu, S. Mrenna and E. Norrbin, Comput. Phys. Commun. **135**, 238 (2001) [arXiv:hep-ph/0010017].

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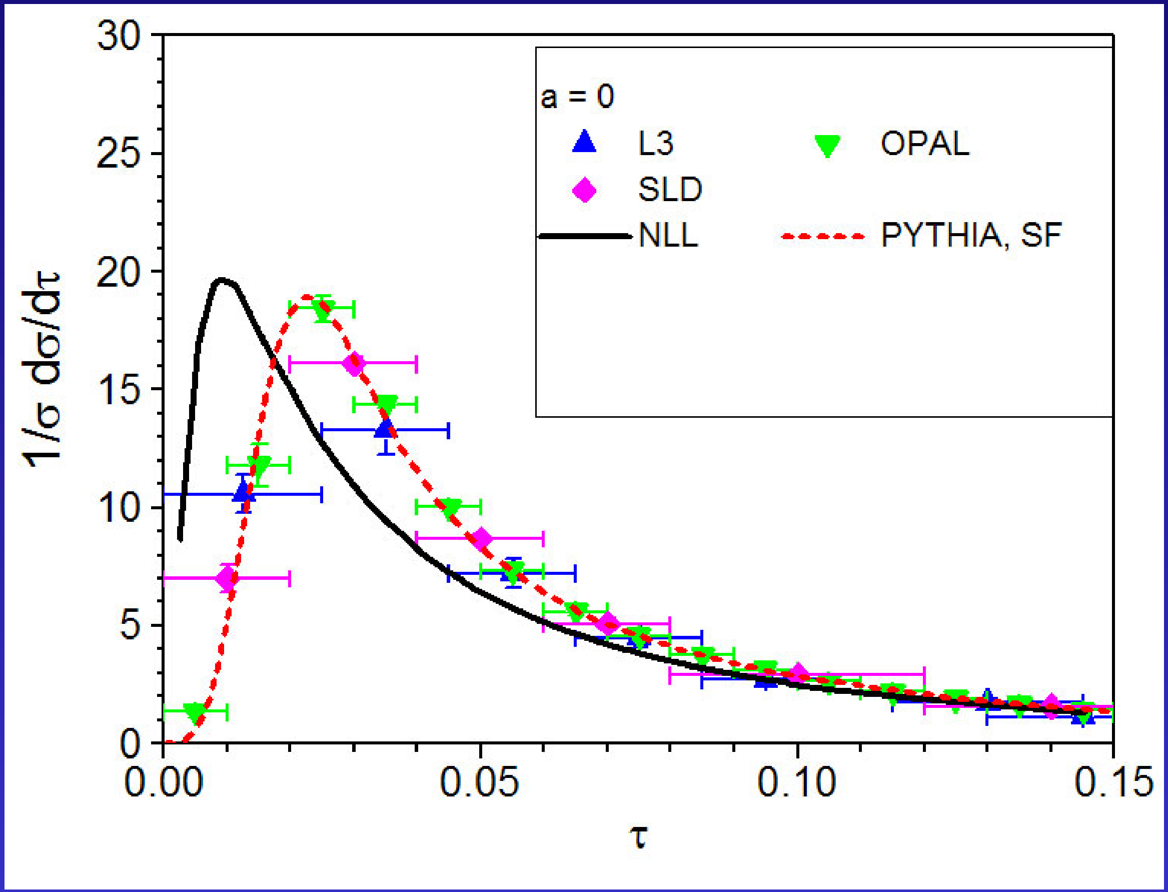

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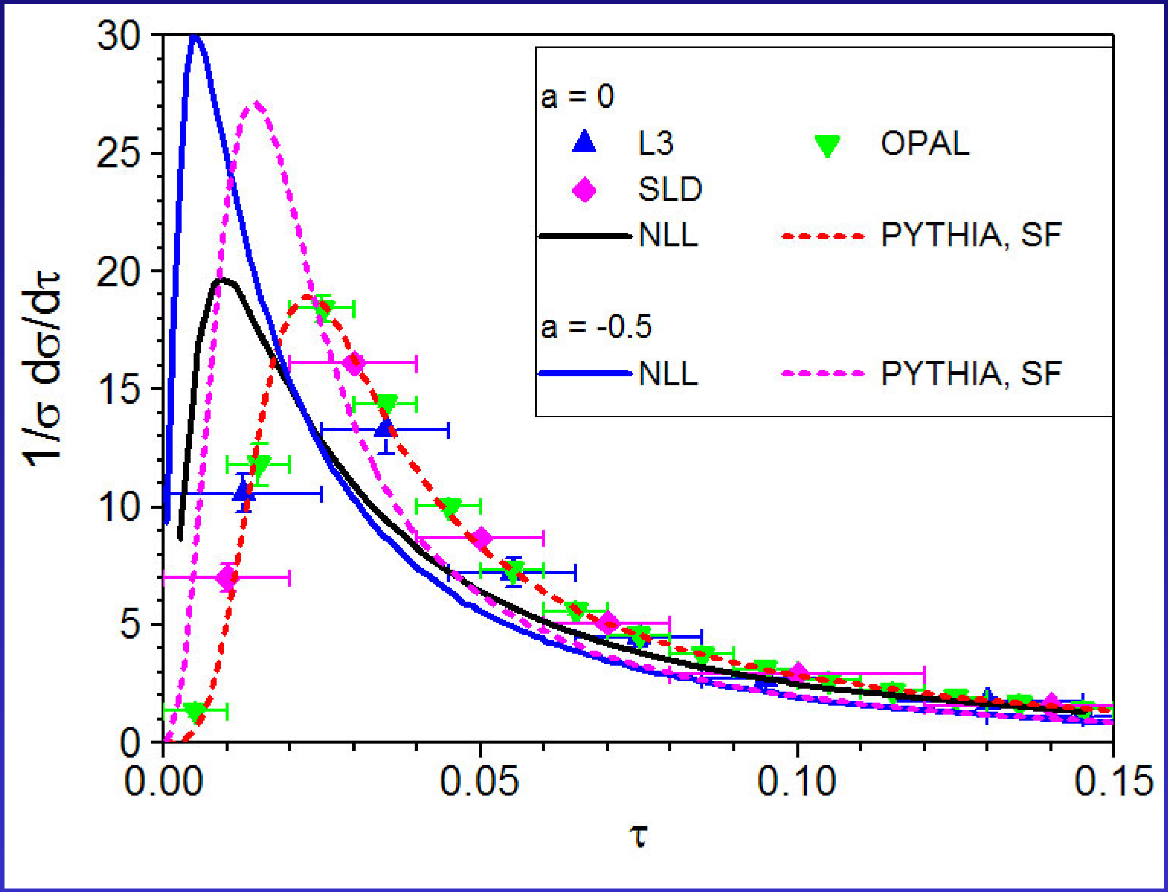

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Nonperturbative Corrections

Rewrite (6):

$$\ln\left[\frac{1}{\sigma_{\text{tot}}}\tilde{\sigma}\left(\nu,Q,a\right)\right] = 2\left[\int_0^{\kappa^2}\frac{dp_\perp^2}{p_\perp^2}+\int_{\kappa^2}^{Q^2}\frac{dp_\perp^2}{p_\perp^2}\right]A\left(\alpha_s(p_\perp)\right)\int_{p_\perp^2/Q^2}^{p_\perp/Q}\frac{du}{u}\left(e^{-u^{1-a}\nu\left(p_\perp/Q\right)^a}-1\right)$$

$$+\left[\int_0^{\kappa^2/Q^2}\frac{du}{u}+\int_{\kappa^2/Q^2}^{Q^2}\frac{du}{u}\right]B\left(\alpha_s(\sqrt{u}Q)\right)\left(e^{-u(\nu/2)^{2/(2-a)}}-1\right)$$

$$\equiv \ln\left[\frac{1}{\sigma_{\text{tot}}}\tilde{\sigma}_{\text{PT}}\left(\nu,Q,\kappa,a\right)\right]$$

$$+\frac{\mathbf{2}}{\mathbf{1-a}}\sum_{n=1}^{\infty}\frac{1}{n\,n!}\left(-\frac{\nu}{Q}\right)^n\int_0^{\kappa^2}\frac{dp_\perp^2}{p_\perp^2}p_\perp^n A\left(\alpha_s(p_\perp)\right)$$

$$+\mathcal{O}\left(\frac{\nu}{Q^{2-a}},\frac{\nu^{\frac{2}{2-a}}}{Q^2}\right). \quad (7)$$

G. P. Korchemsky, arXiv:hep-ph/9806537;G. P. Korchemsky and G. Sterman, Nucl. Phys. B **555**, 335 (1999) [arXiv:hep-ph/9902341].

Nonperturbative Corrections - Shape Function

$$\ln\left[\frac{1}{\sigma_{\mathsf{tot}}}\tilde{\sigma}\left(\nu,Q,a\right)\right] \equiv \ln\left[\frac{1}{\sigma_{\mathsf{tot}}}\tilde{\sigma}_{\mathsf{PT}}\left(\nu,Q,\kappa,a\right)\right] + \ln\tilde{f}_{a,\mathsf{NP}}\left(\frac{\nu}{Q},\kappa\right), \tag{8}$$

$$\ln\tilde{f}_{a,\mathsf{NP}}\left(\frac{\nu}{Q},\kappa\right) \equiv \frac{\mathbf{1}}{\mathbf{1-a}}\sum_{n=1}^{\infty}\lambda_n(\kappa)\left(-\frac{\nu}{Q}\right)^n. \tag{9}$$

G. Sterman, arXiv:hep-ph/0301243.

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G. Sterman, arXiv:hep-ph/0301243.

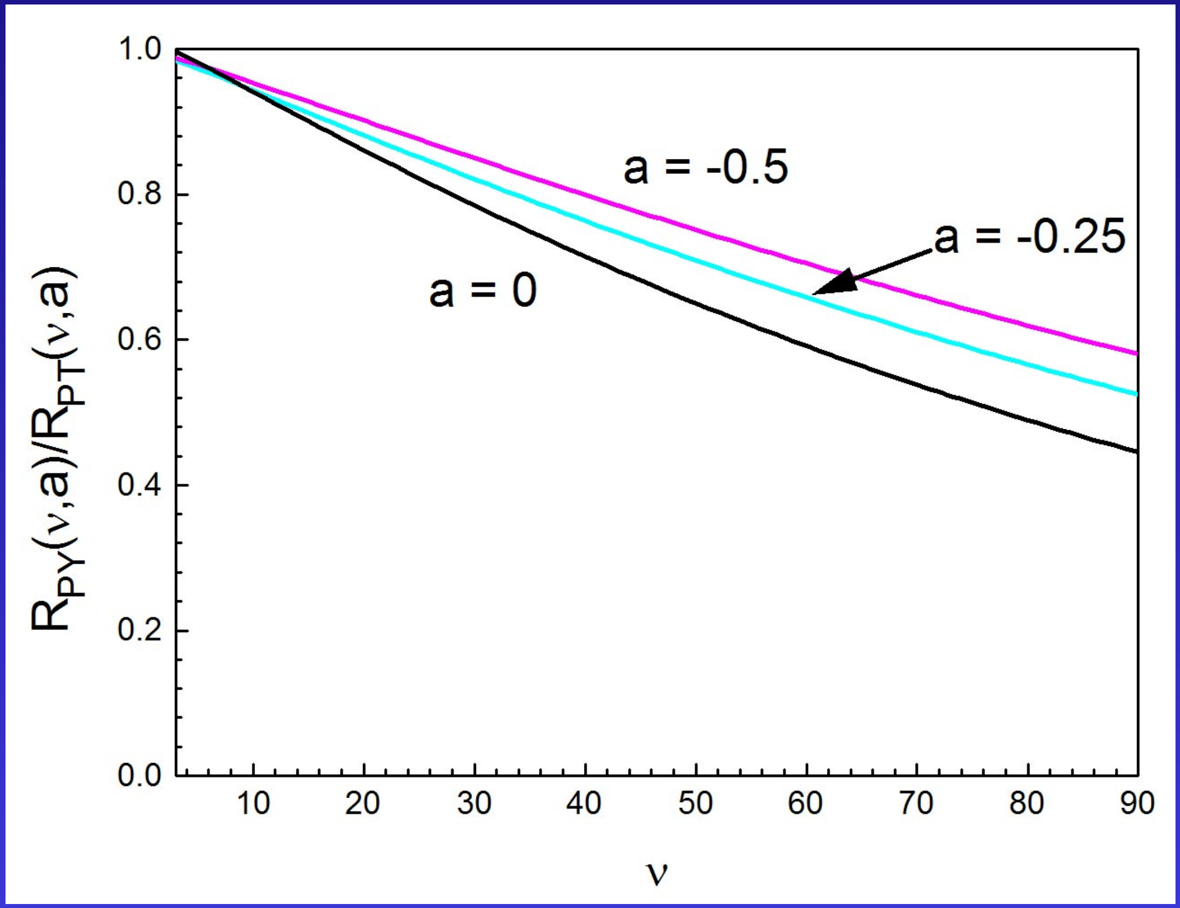
⇒ **Scaling rule for shape function:**

$$\boxed{\tilde{f}_{a,\text{NP}}\left(\frac{\nu}{Q},\kappa\right) = \frac{\tilde{\sigma}(\nu,Q,a)}{\tilde{\sigma}_{\text{PT}}(\nu,Q,\kappa,a)} + \mathcal{O}\left(\frac{1}{Q^{1-a}}\right)} \qquad (10)$$

$$\boxed{\tilde{f}_{a,\text{NP}}\left(\frac{\nu}{Q},\kappa\right) = \left[\tilde{f}_{0,\text{NP}}\left(\frac{\nu}{Q},\kappa\right)\right]^{\frac{1}{1-a}}} \qquad (11)$$

Nonperturbative Corrections - Tests of Scaling

$\tilde{f}_{a,\mathrm{NP}}\left(\frac{\nu}{Q}\right)$ at $Q = 91$ GeV (PYTHIA/NLL), directly computed



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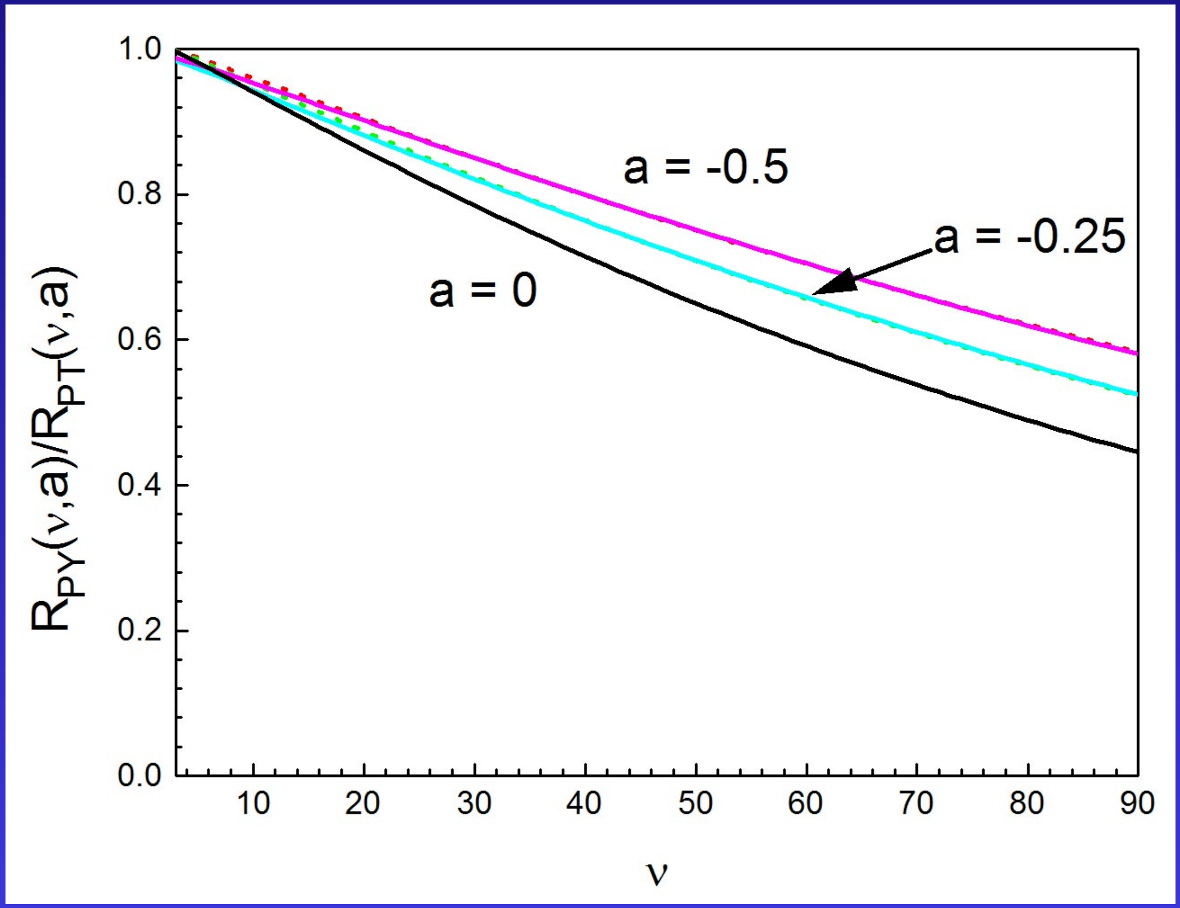
$\tilde{f}_{a,\text{NP}}\left(\frac{\nu}{Q}\right)$ at $Q = 91$ GeV (PYTHIA/NLL),
directly computed vs. **prediction from scaling**



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$\tilde{f}_{a,\mathrm{NP}}\left(\frac{\nu}{Q}\right)$ at $Q = 35$ GeV (PYTHIA/NLL),
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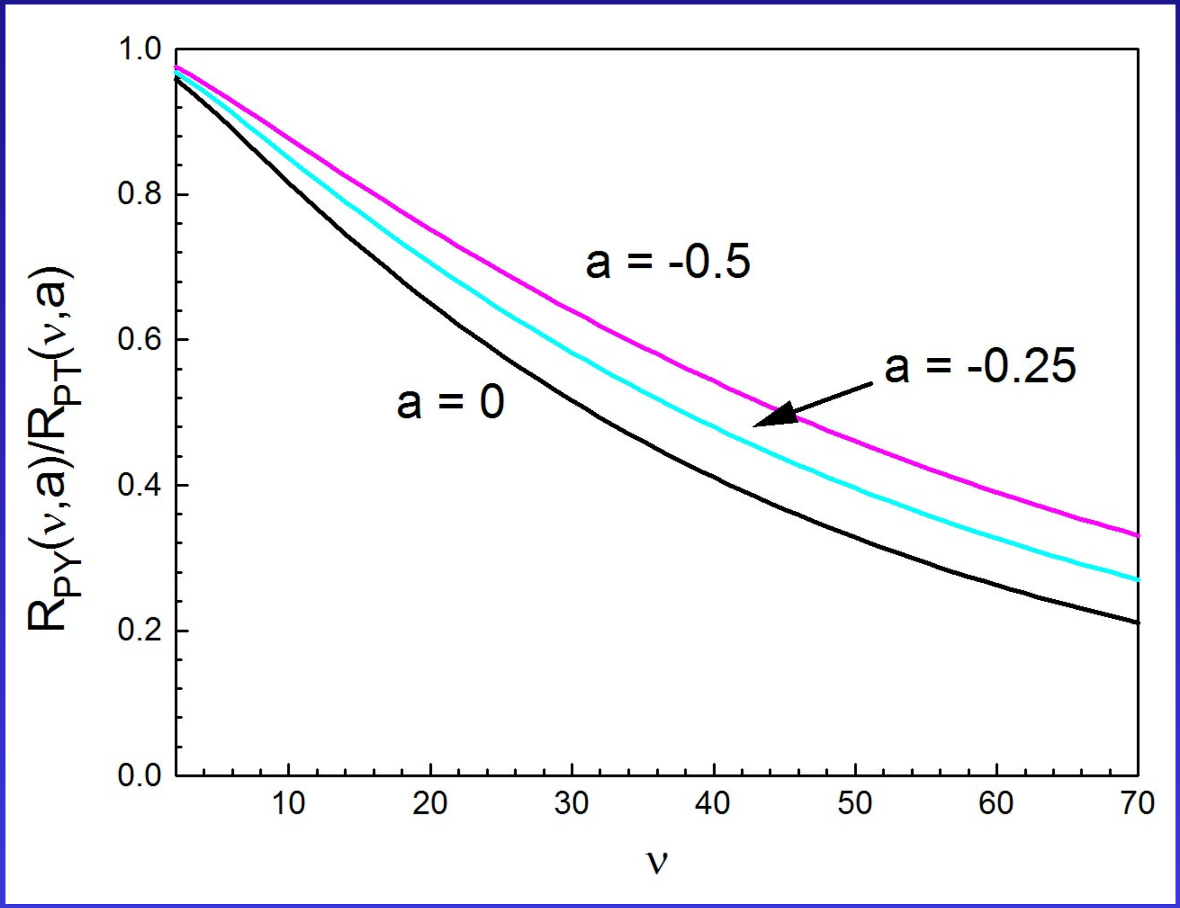

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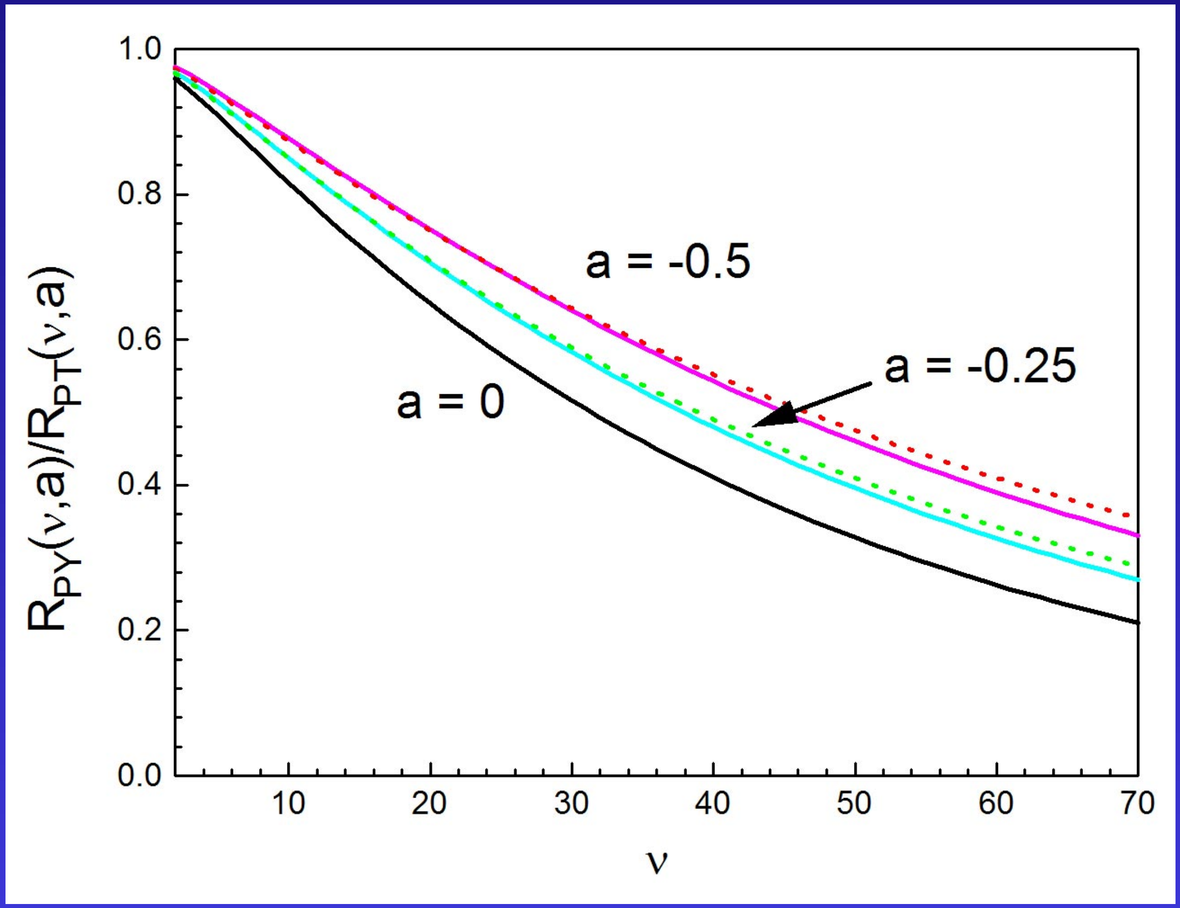

Summary and Outlook

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$\rightarrow$ extension of resummation to $a \approx 1$ - inclusion of recoil Y. L. Dokshitzer, A. Lucenti, G. Marchesini and G. P. Salam, JHEP **9801**, 011 (1998) [arXiv:hep-ph/9801324].