CKKW in Heavy Flavour Production and Decay

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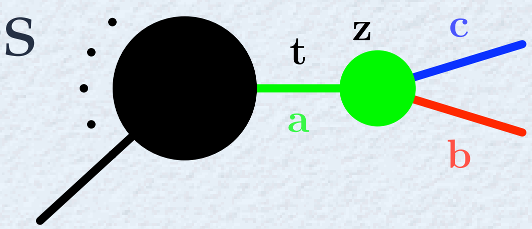
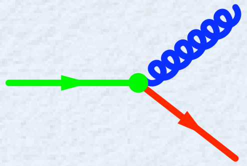
PS in Heavy Quark Production

- In quasi-collinear limit (b↔heavy quark) ME factorises

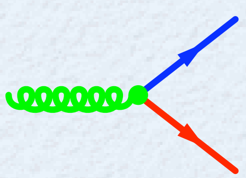


$$|\mathbf{M}(\mathbf{b},\mathbf{c},\ldots,\mathbf{n})|^2 \;\to\; |\mathbf{M}(\mathbf{a},\ldots,\mathbf{n})|^2\,\frac{8\pi\alpha_s}{\mathbf{t}-\mathbf{m}_\mathbf{a}^2}\,\mathbf{P}_{\mathbf{a}\to\mathbf{bc}}(\mathbf{z})$$

- Virtuality ordered PS ➡ evolution variable $\mathbf{t}$ changes to $\mathbf{t}-\mathbf{m}_\mathbf{a}^2$
- Splitting functions $\mathbf{P}_{\mathbf{ab}}(\mathbf{z})$ become those for massive quarks
  Nucl. Phys. B627(2002)189

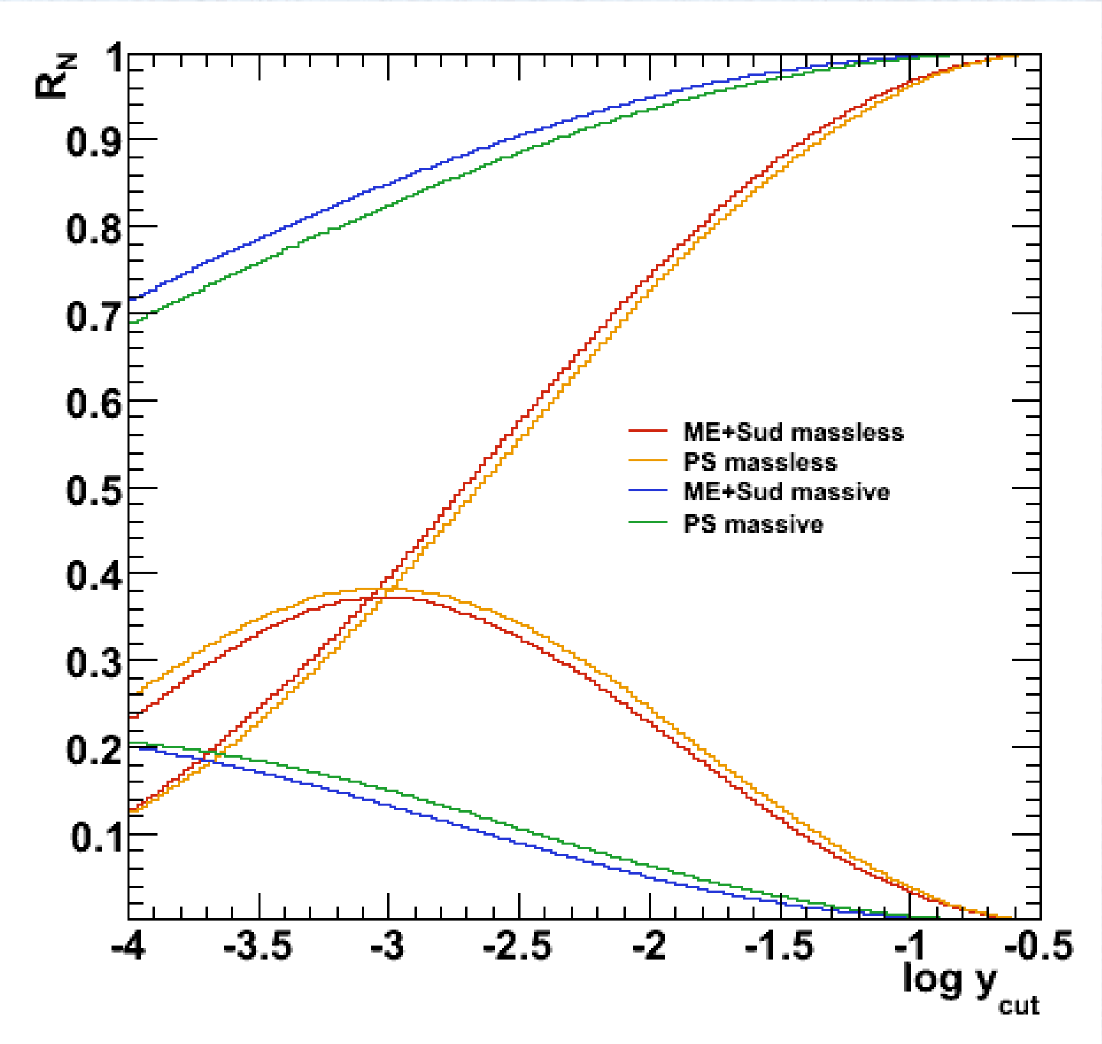


$$\to\; \mathbf{C}_\mathbf{F}\left(\frac{\mathbf{1}+\mathbf{z}^2}{\mathbf{1}-\mathbf{z}}-\frac{\mathbf{2z}(\mathbf{1}-\mathbf{z})\mathbf{m}^2}{\mathbf{q}^2+(\mathbf{1}-\mathbf{z})^2\mathbf{m}^2}\right)$$



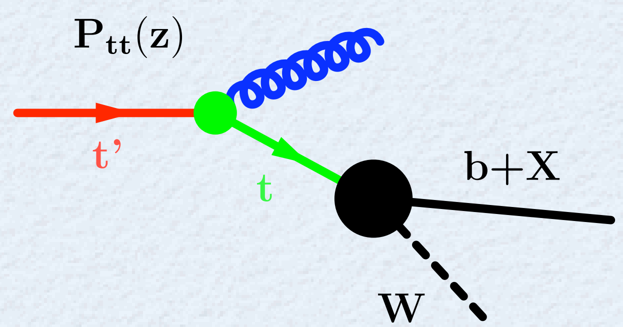
$$\to\; \mathbf{T}_\mathbf{R}\left(\mathbf{1}-\mathbf{2z}(\mathbf{1}-\mathbf{z})+\frac{\mathbf{2z}(\mathbf{1}-\mathbf{z})\mathbf{m}^2}{\mathbf{q}^2+\mathbf{m}^2}\right)$$

- Cross-check: 2- and 3-jet fraction in $\mathbf{e}^+\mathbf{e}^-\to\mathbf{t}\bar{\mathbf{t}}$, PS vs. ME, weighted with NLL Sudakov form factors ➡
  Phys. Lett. B576(2003)135



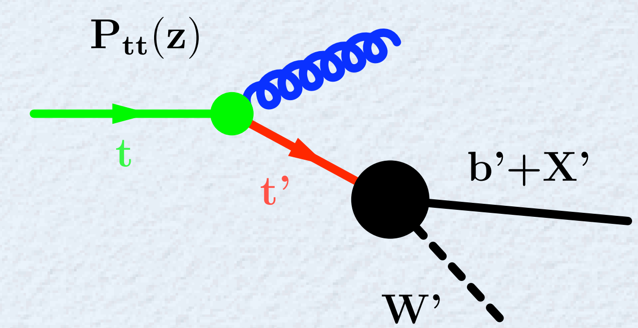
PS in heavy quark production

PS in production



- On-shell daughter partons
  - → New decay kinematics via Lorentz transformation
    Choice: Boost into new (daughter) cms
- FSR-like situation
- Evolution stops at on-shell mass of heavy quark

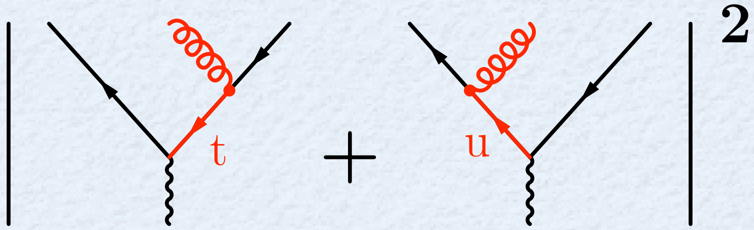
PS in decay



- Off-shell daughter partons
  - ! Decay kinematics need to be reconstructed
  - → Choice: Reconstruct in cms of decayed quark, such that $\vec{p}/|\vec{p}|$ is preserved
- ISR-like situation
- Evolution stops at width of decaying heavy quark

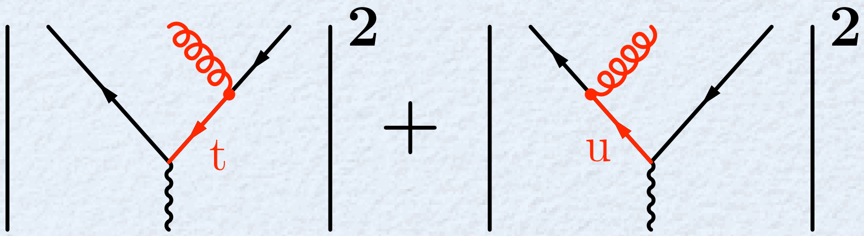
Brief Review: Why CKKW ?

Matrix Elements



- Exact to fixed order in running coupling
- Include all quantum interferences
- Calculable only for low FS multiplicity (n≤6-8)

Parton Showers



$$\mathrm{d}\sigma_{\mathbf{n+1}} = \mathrm{d}\sigma_{\mathbf{n}} \otimes \sum_{\mathbf{a}\in\mathbf{q},\mathbf{g}} \frac{\mathrm{d}\mathbf{t}}{\mathbf{t}}\mathrm{d}\mathbf{z}\frac{\alpha_{\mathbf{s}}(\mathbf{t},\mathbf{z})}{\mathbf{2}\pi}\mathbf{P}_{\mathbf{a}\to\mathbf{bc}}(\mathbf{z})$$

- Resum all (next-to) leading logarithms to all orders
- Interference effects only through angular ordering

⇒ Basic idea of CKKW: Combine both approaches to have

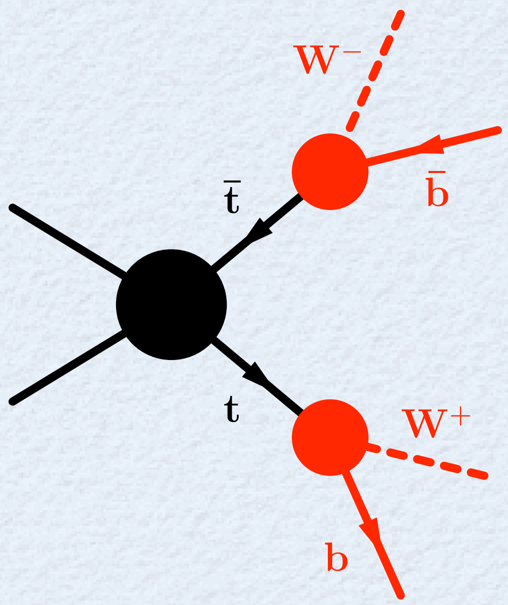
- Good description of hard / wide angle radiation (ME)
- Correct intrajet evolution (PS)

JHEP 08(2002)015; JHEP 11(2001)063

CKKW & Heavy Flavours

- Narrow width approximation ➞ full ME factorises into **production** and **decay** parts

Schematically: $\mathcal{A}^{(\mathbf{n})} = \mathcal{A}^{(\mathbf{n}_{\mathrm{prod}})}_{\mathrm{prod}} \otimes \prod_{\mathbf{i}\in\mathrm{decays}} \mathcal{A}^{(\mathbf{n}_\mathbf{i})}_{\mathrm{dec},\mathbf{i}}$ ⟺



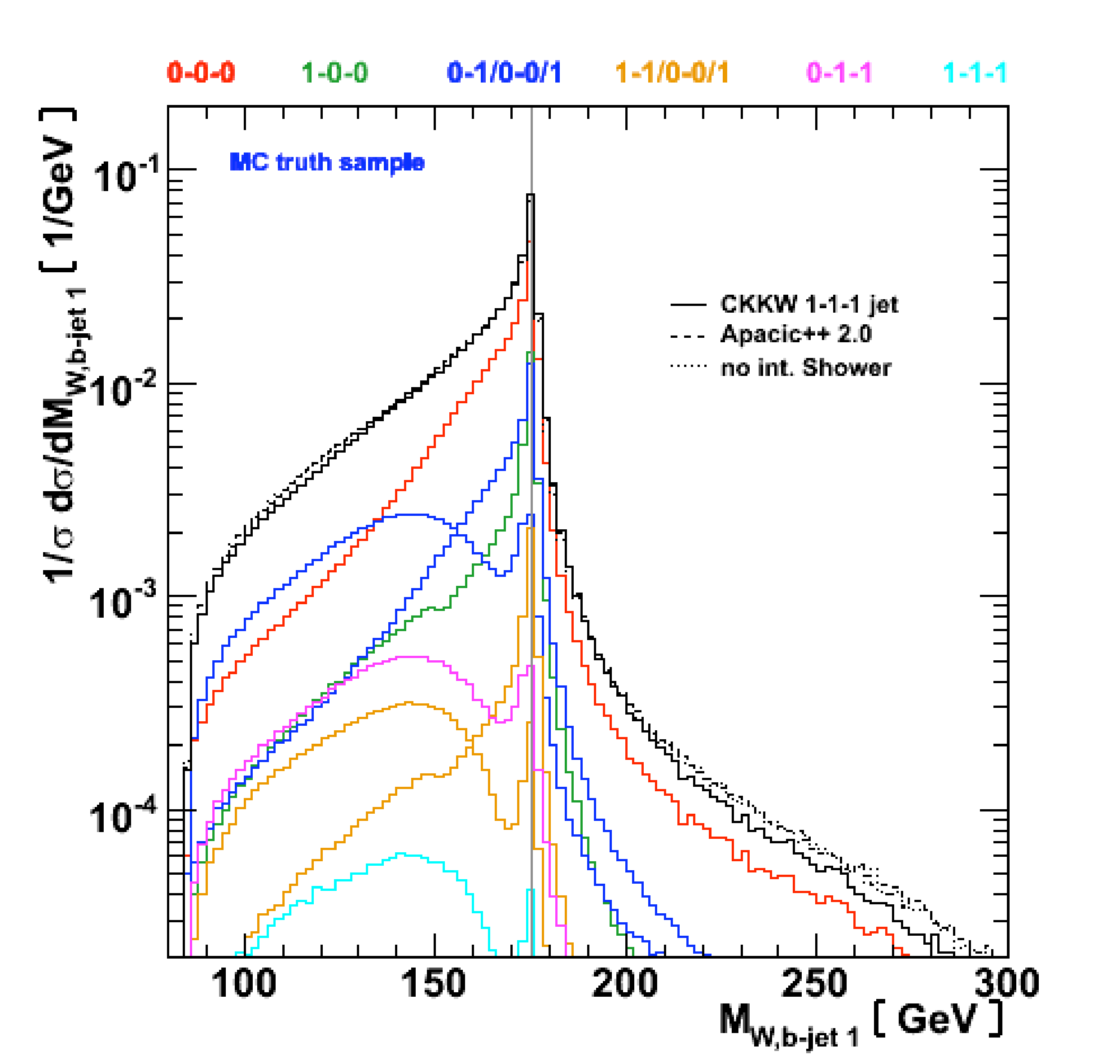
Generator setup:

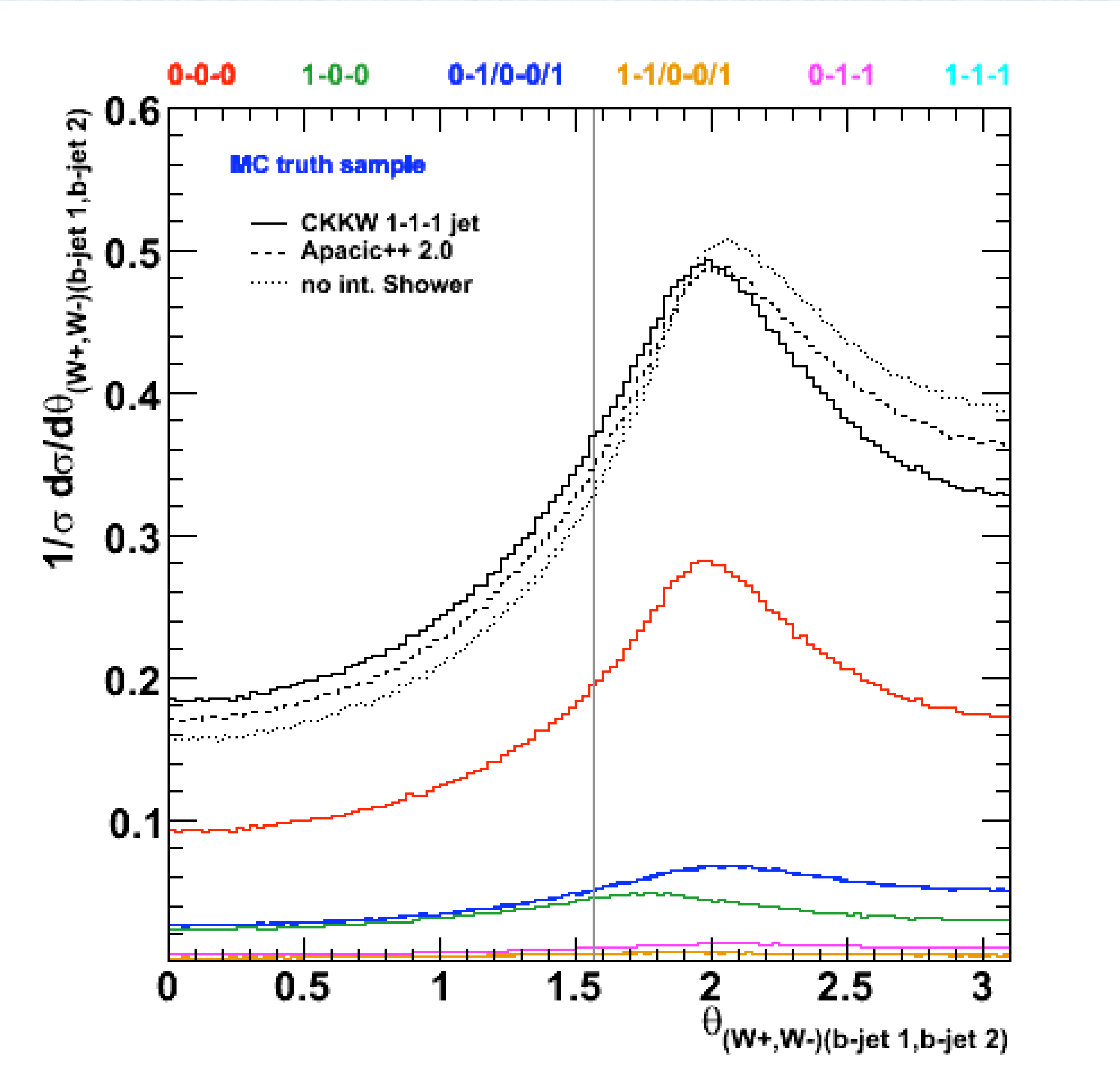
- AMEGIC++ provides decay chain treatment to project onto relevant Feynman diagrams
  Intermediate particle masses distributed according to Breit-Wigner
- APACIC++ provides production & decay shower off heavy partons
- **CKKW is applied separately and completely independent within production and each decay**

➞ Yields all combinations of parton multiplicities in ME up to $\mathbf{N}_{\mathbf{max,prod}} \otimes \prod_{\mathbf{i}\in\mathbf{decays}} \mathbf{N}_{\mathbf{max,dec\ i}}$, i.e. 1-0-0, 0-1-0, ... in $\mathbf{e}^+\mathbf{e}^- \to \mathbf{t}\bar{\mathbf{t}}$

Top production in e^+e^-

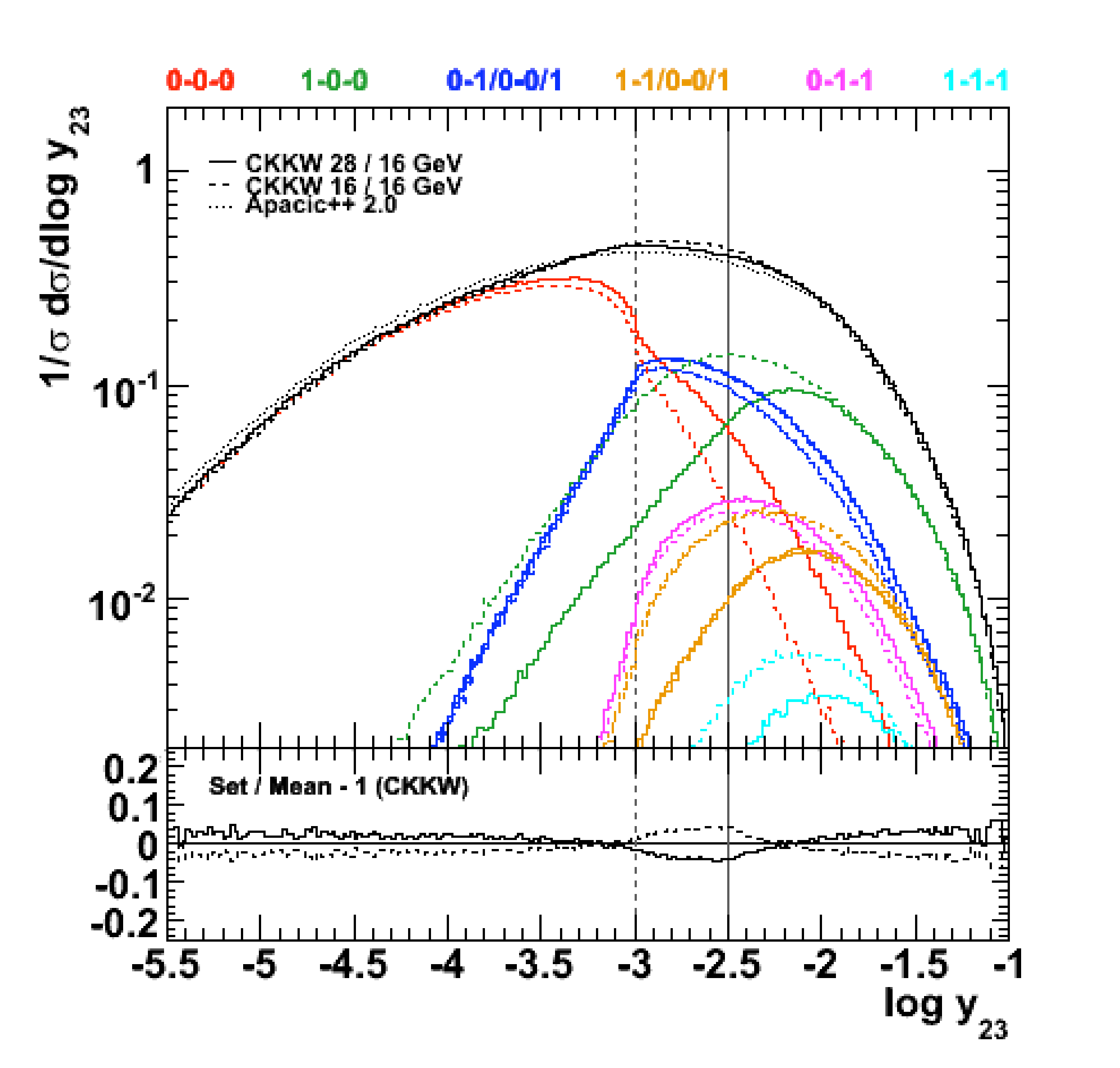
- Sanity check of procedure: Correlations in e^+e^-
  - Reconstructed top mass
  - Four particle plane angle

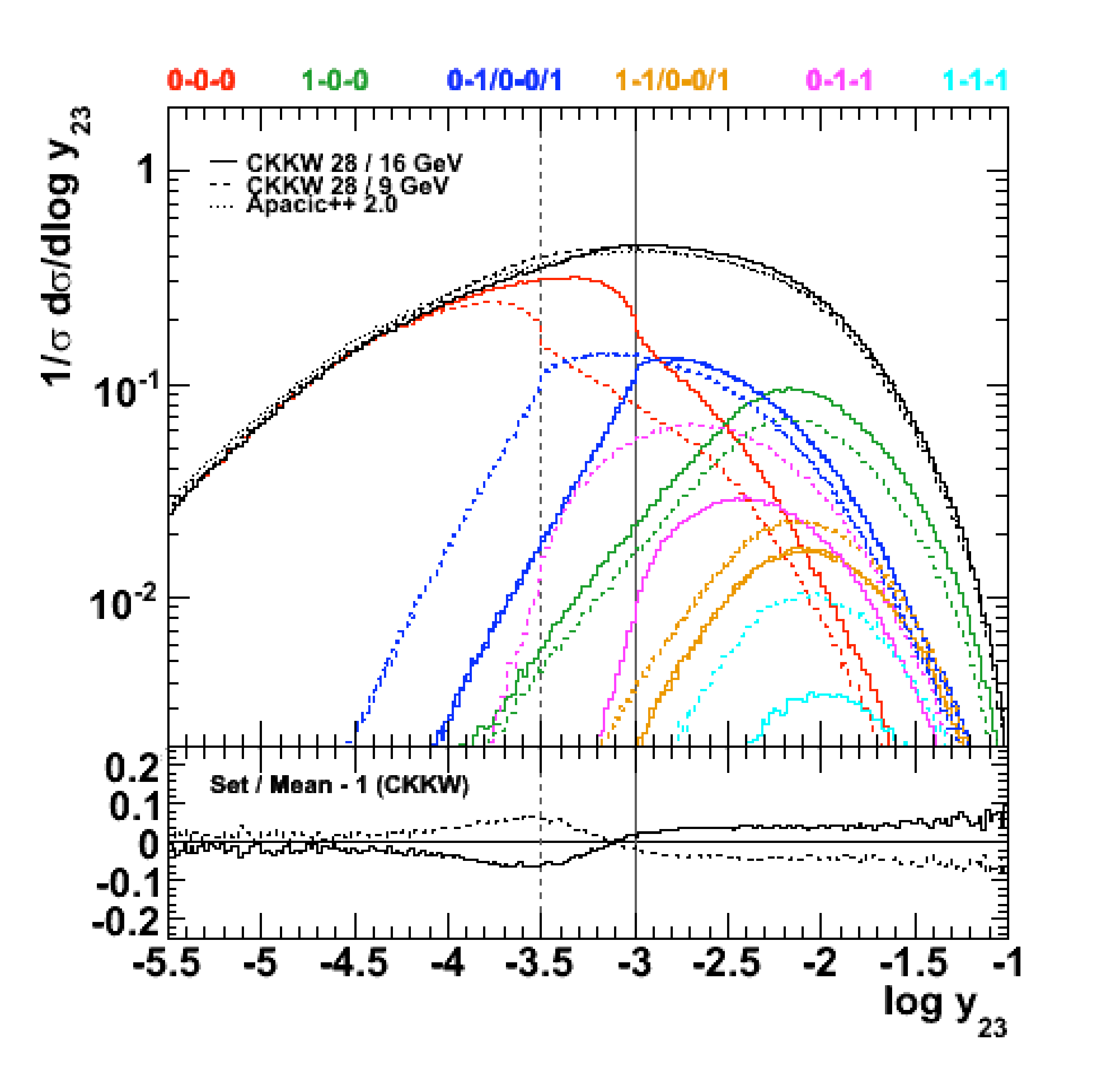




Top production in e^+e^-

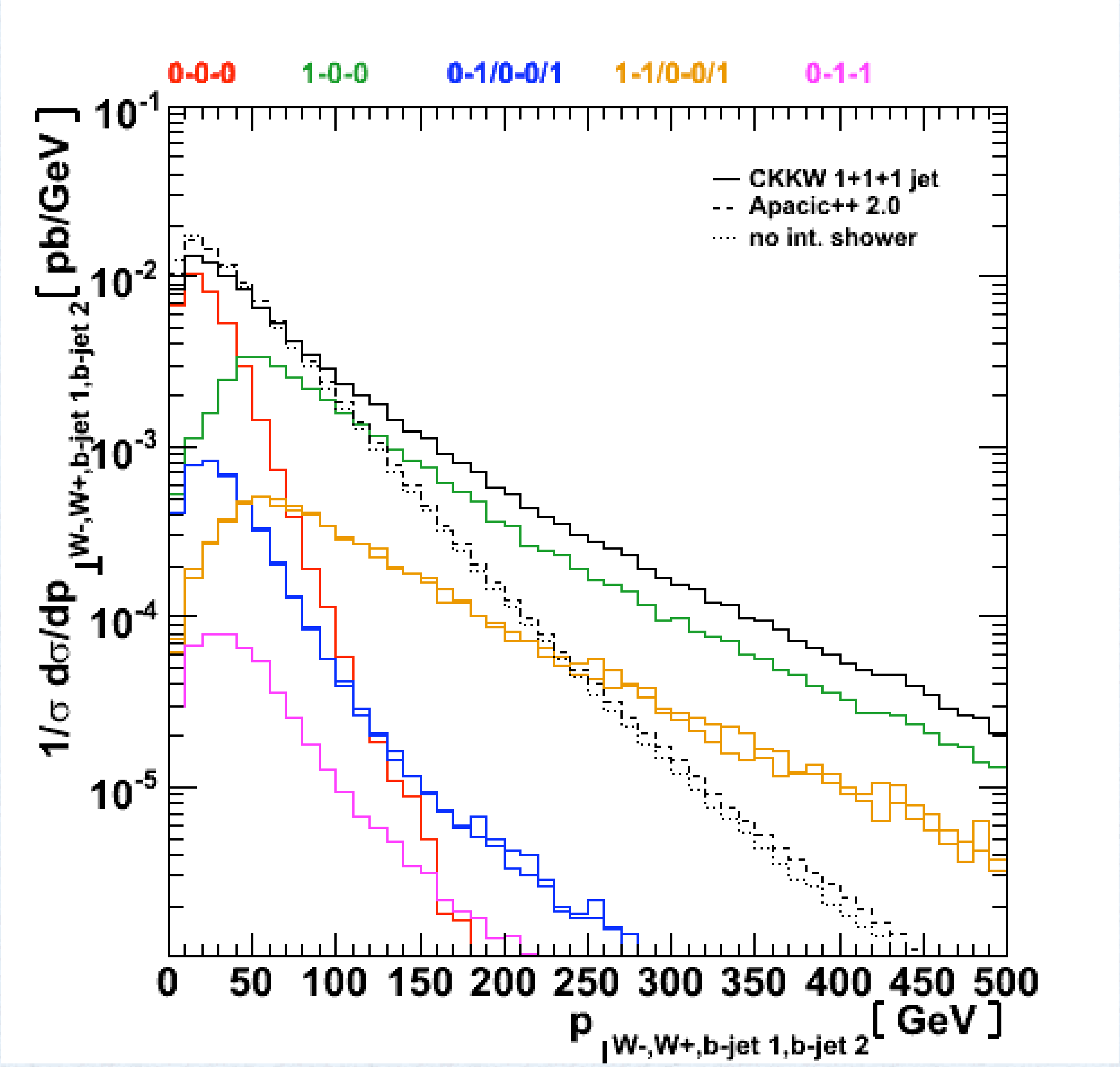
- Sanity check of procedure: Jet differential rates in e^+e^-
  - Q_{cut} - variation in production
  - Q_{cut} - variation in decays

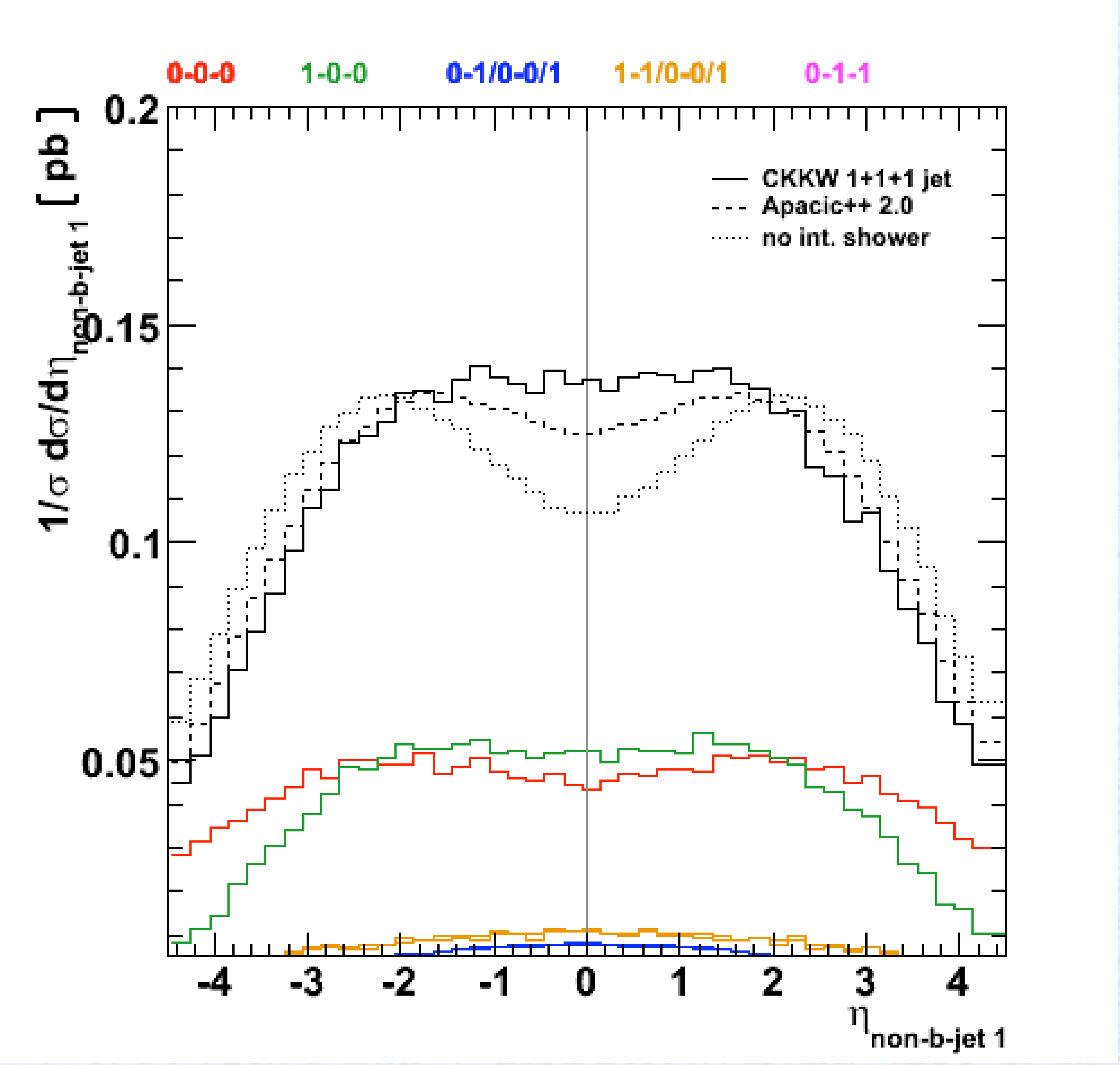




Top pair production @ LHC

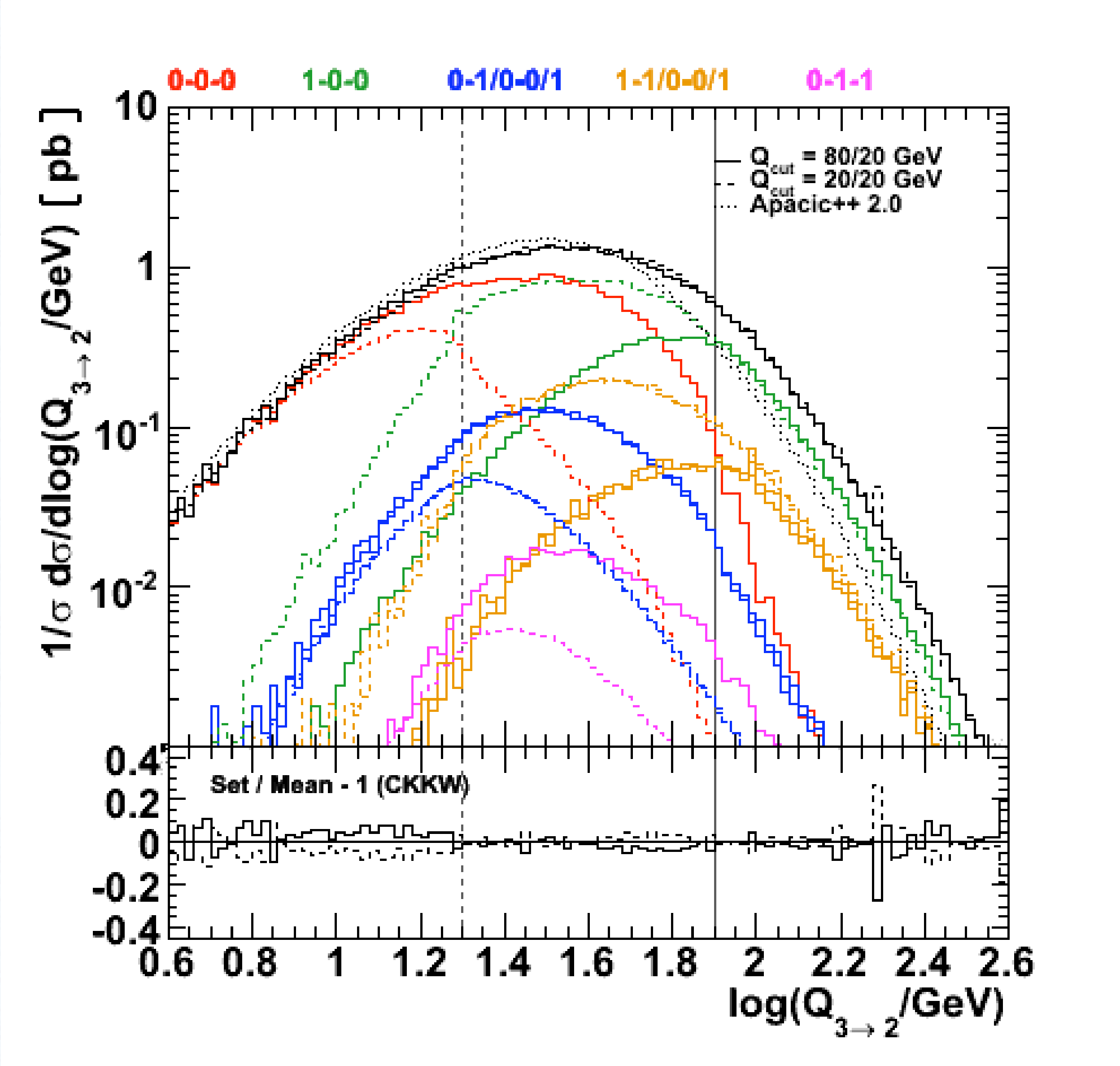
- Application: $t\bar{t}$ production at the LHC
  - $p_\perp$ of $t\bar{t}$ pair
  - η of first extra jet

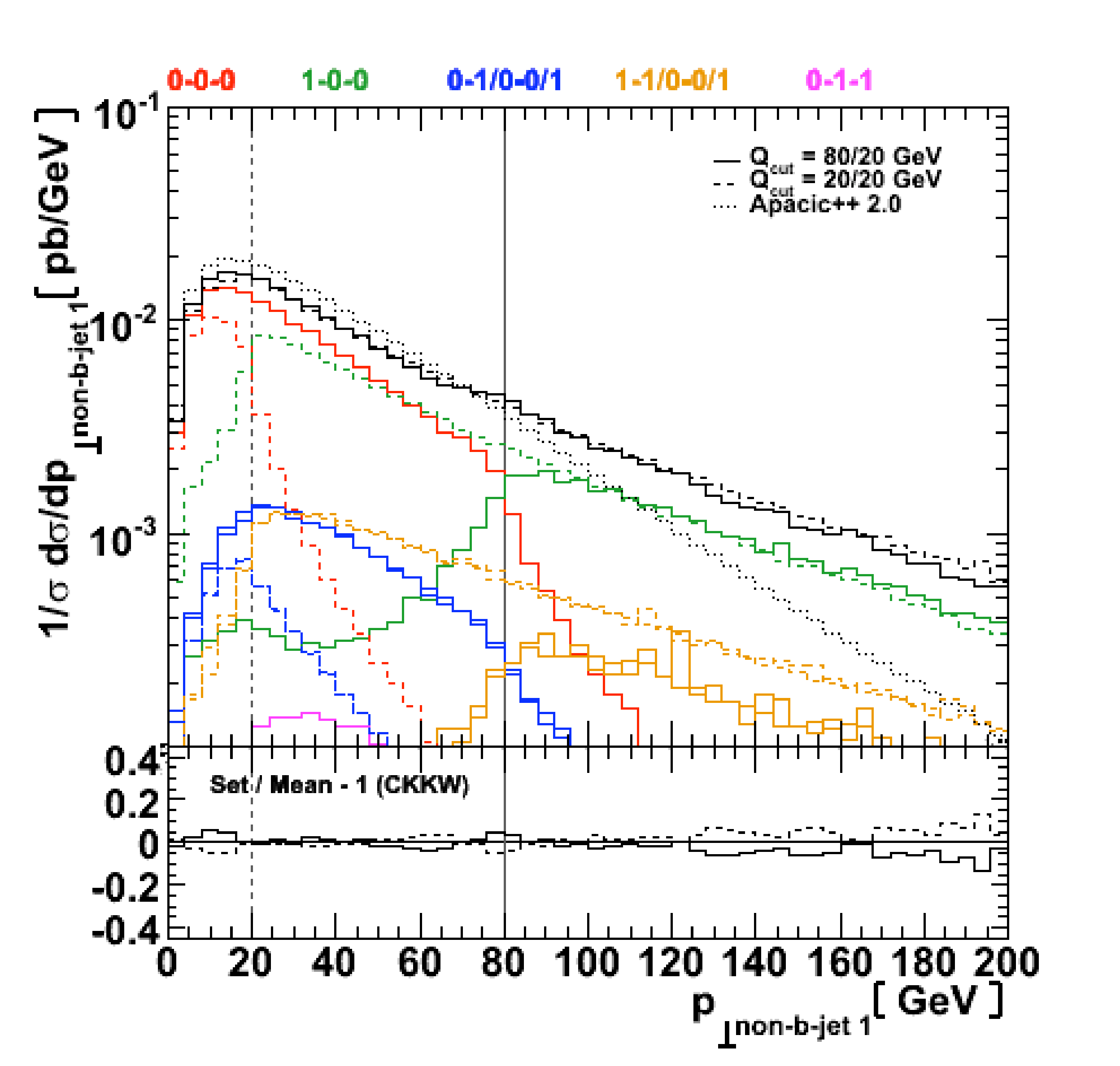




Top pair production @ LHC

- Cross-check: Variation of separation cut in production subprocess
  - Differential 3→2 jet rate
  - $p_\perp$ of first extra jet





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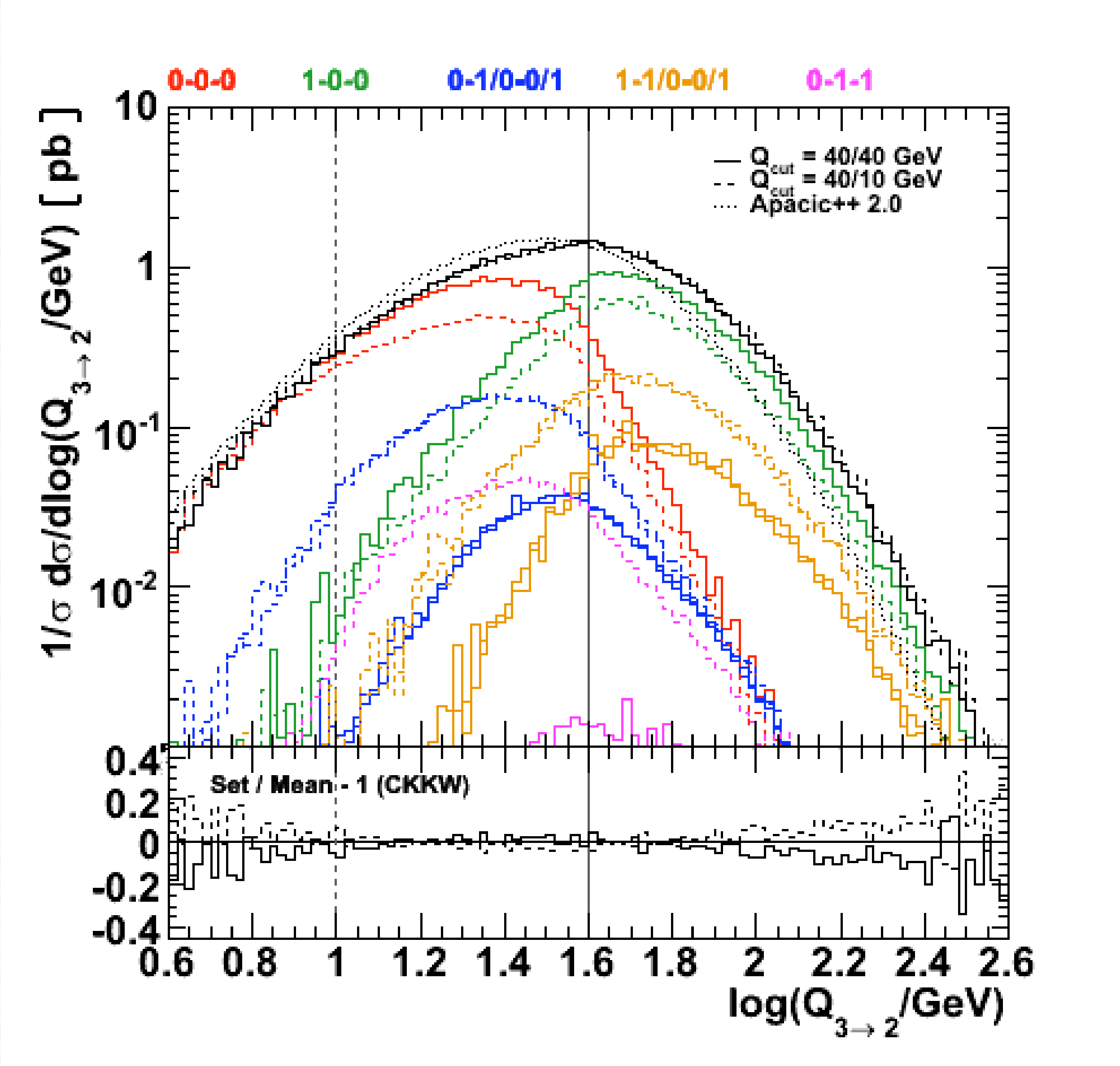
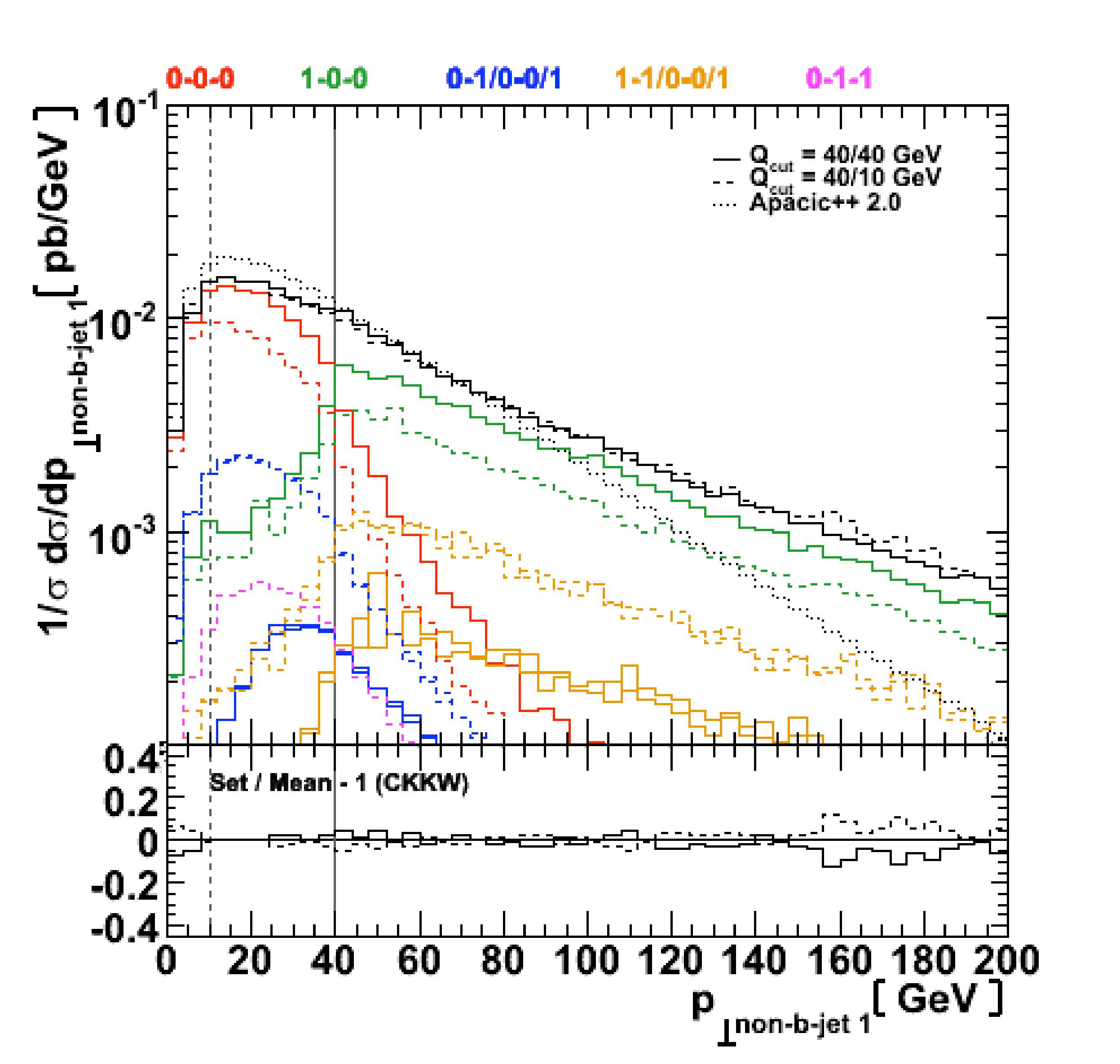




Updates on Sherpa can be found on

www.sherpa-mc.de

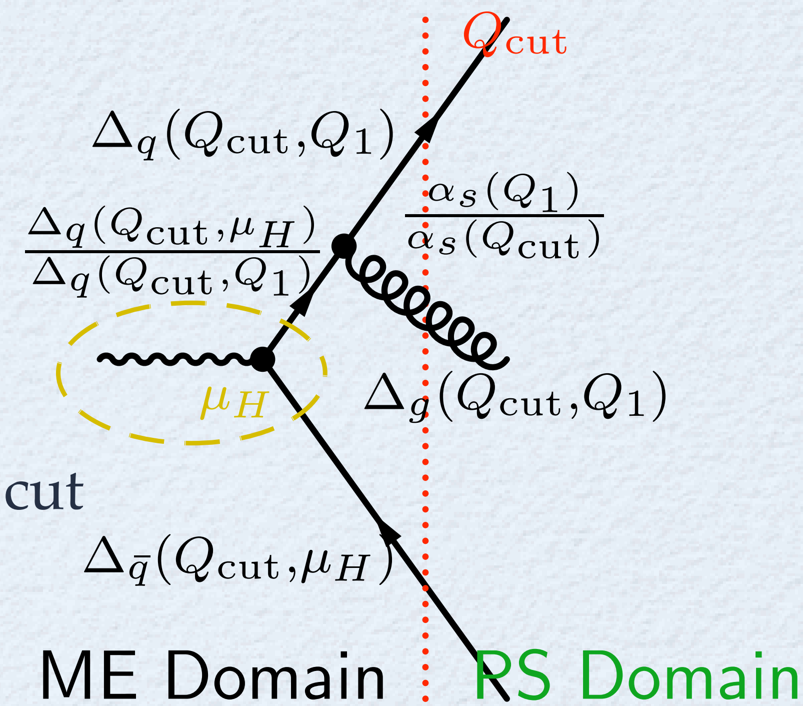
E-mail us on

info@sherpa-mc.de

CKKW cooking recipe

JHEP 0111 (2001) 063
JHEP 0208 (2002) 015

- Define jet resolution parameter Q_{cut} (Q-jet measure)
  ➡ divide phase space into regions of jet production (ME) and jet evolution (PS)
- Select final state multiplicity and kinematics according to σ 'above' Q_{cut}
- KT-cluster backwards (construct PS-tree) and identify core process
- **Reweight ME** to obtain exclusive samples at Q_{cut}
- Start the parton shower at the hard scale
  Veto all PS emissions harder than Q_{cut}



➡ This yields the correct jet rates !
Simple example: 2-jet rate in ee→qq

$$R_2(q) = \left(\Delta(Q_{\rm cut}, \mu_{\rm hard}) \, \frac{\Delta(q, \mu_{\rm hard})}{\Delta(Q_{\rm cut}, \mu_{\rm hard})} \right)^2$$