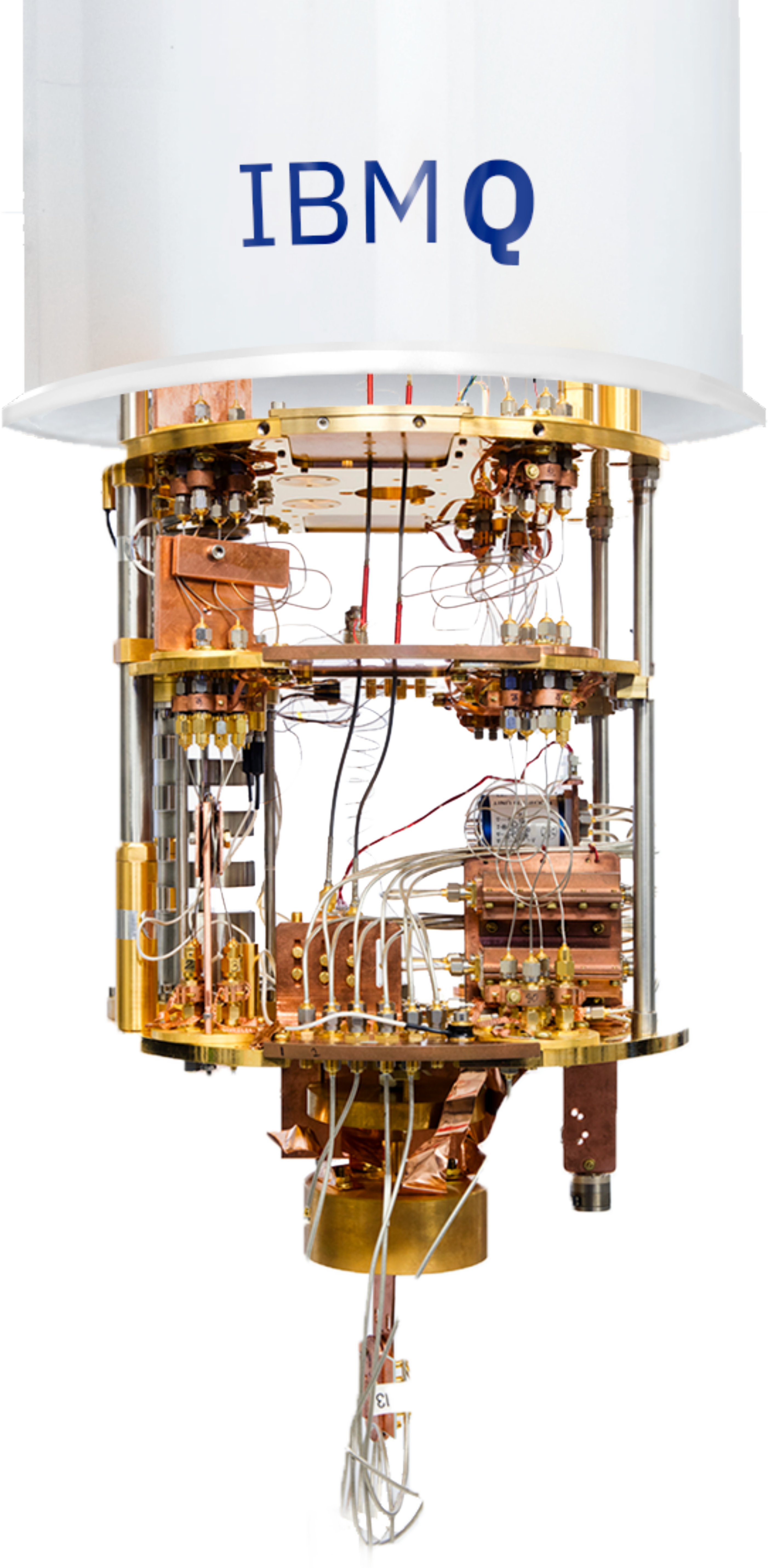


Imperial College London

THE ROYAL SOCIETY

Quantum computing approaches for simulating parton showers in high energy collisions

Simon Williams

51st International Symposium on Multiparticle Dynamics

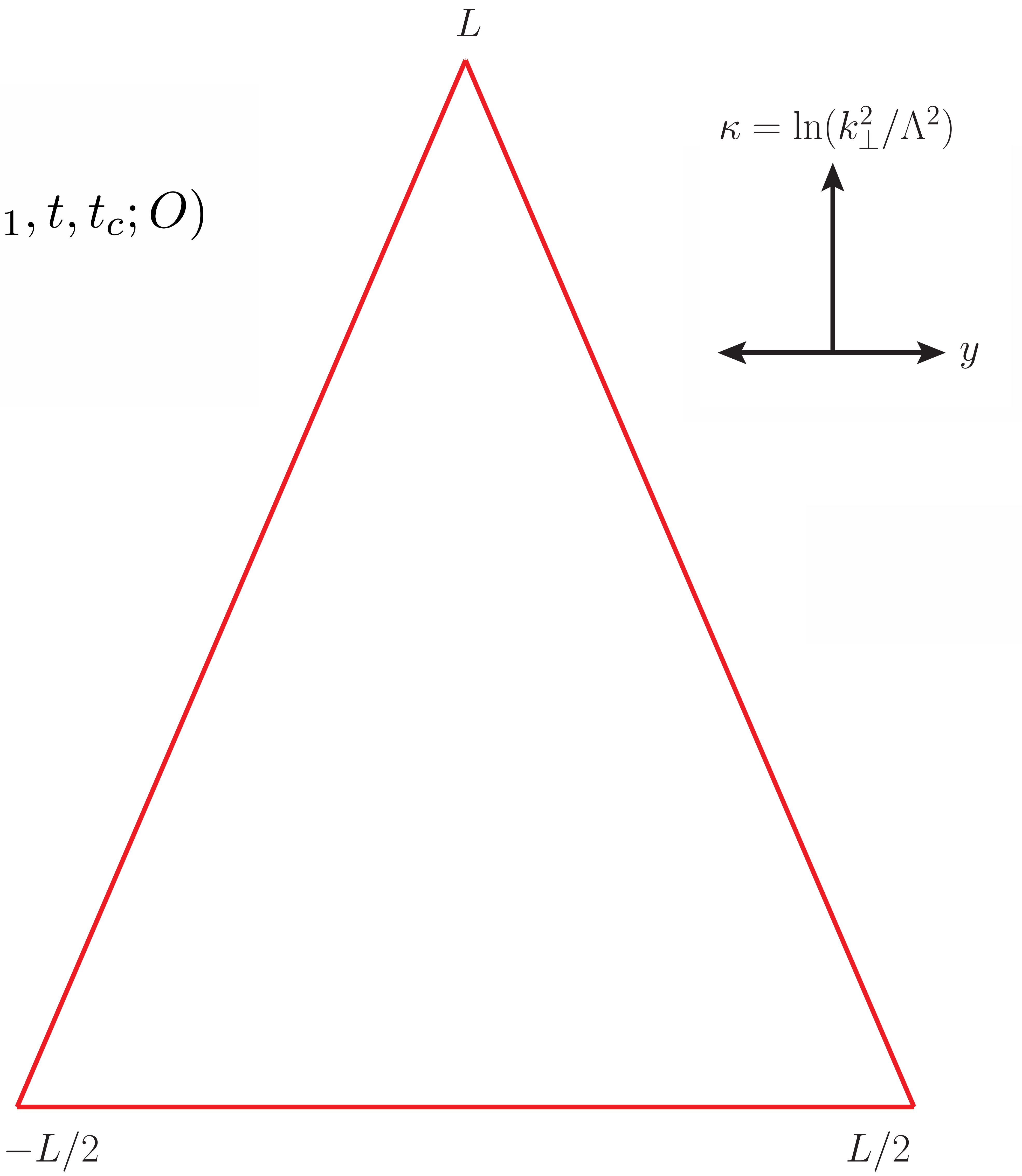
$$\mathcal{F}_n(\Phi_n, t_n, t_c; O) = \Delta(t_n, t_c)O(\Phi_n) + \int_{t_c}^{t_n} dt d\xi \frac{d\phi}{2\pi} C \frac{\alpha_s}{2\pi} \frac{2s_{ik}(t,\xi)}{s_{ij}(t,\xi)s_{jk}(t,\xi)} \Delta(t_n, t)\mathcal{F}_n(\Phi_{n+1}, t, t_c; O)$$

$$d\mathcal{P}\left(q(p_{\rm I})\bar{q}(p_{\rm K}) \to q(p_i)g(p_j)\bar{q}(p_k)\right) \simeq \frac{ds_{ij}}{s_{\rm IK}} \frac{ds_{jk}}{s_{\rm IK}} C \frac{\alpha_s}{2\pi} \frac{2s_{\rm IK}}{s_{ij}s_{jk}}$$

$$k_\perp^2 = \frac{s_{ij}s_{jk}}{s_{\rm IK}} \quad \text{and rapidity} \quad y = \frac{1}{2}\ln\left(\frac{s_{ij}}{s_{jk}}\right)$$

$$d\mathcal{P}\left(q(p_{\rm I})\bar{q}(p_{\rm K}) \to q(p_i)g(p_j)\bar{q}(p_k)\right) \simeq= \frac{C\alpha_s}{\pi} d\kappa dy$$

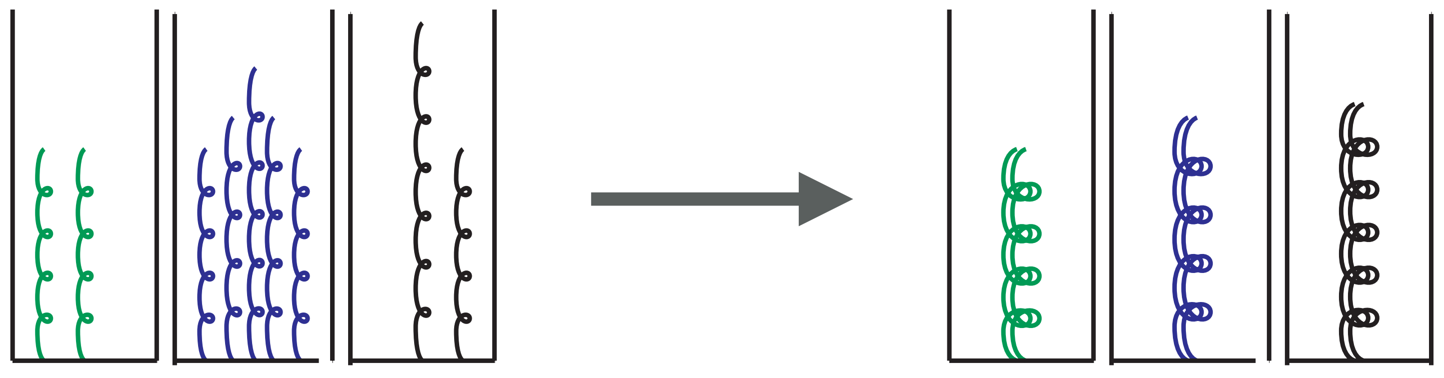
$$\text{with} \quad \kappa = \ln\left(k_\perp^2/\Lambda^2\right)$$



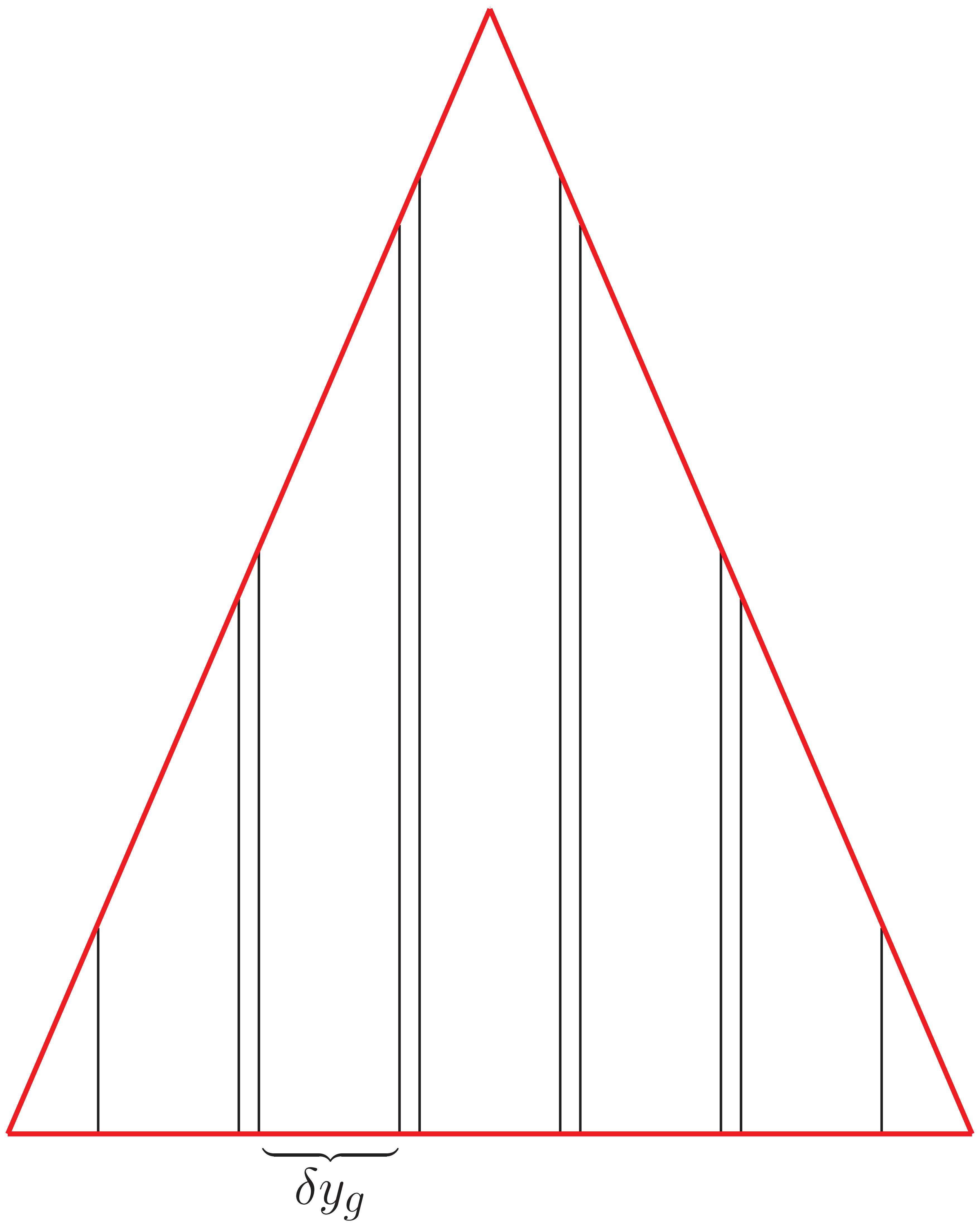
$$\alpha_s(k_\perp^2) = \frac{12\pi}{33 - 2n_f} \frac{1}{\ln\left(k_\perp^2/\Lambda_{\mathrm{QCD}}^2\right)}$$

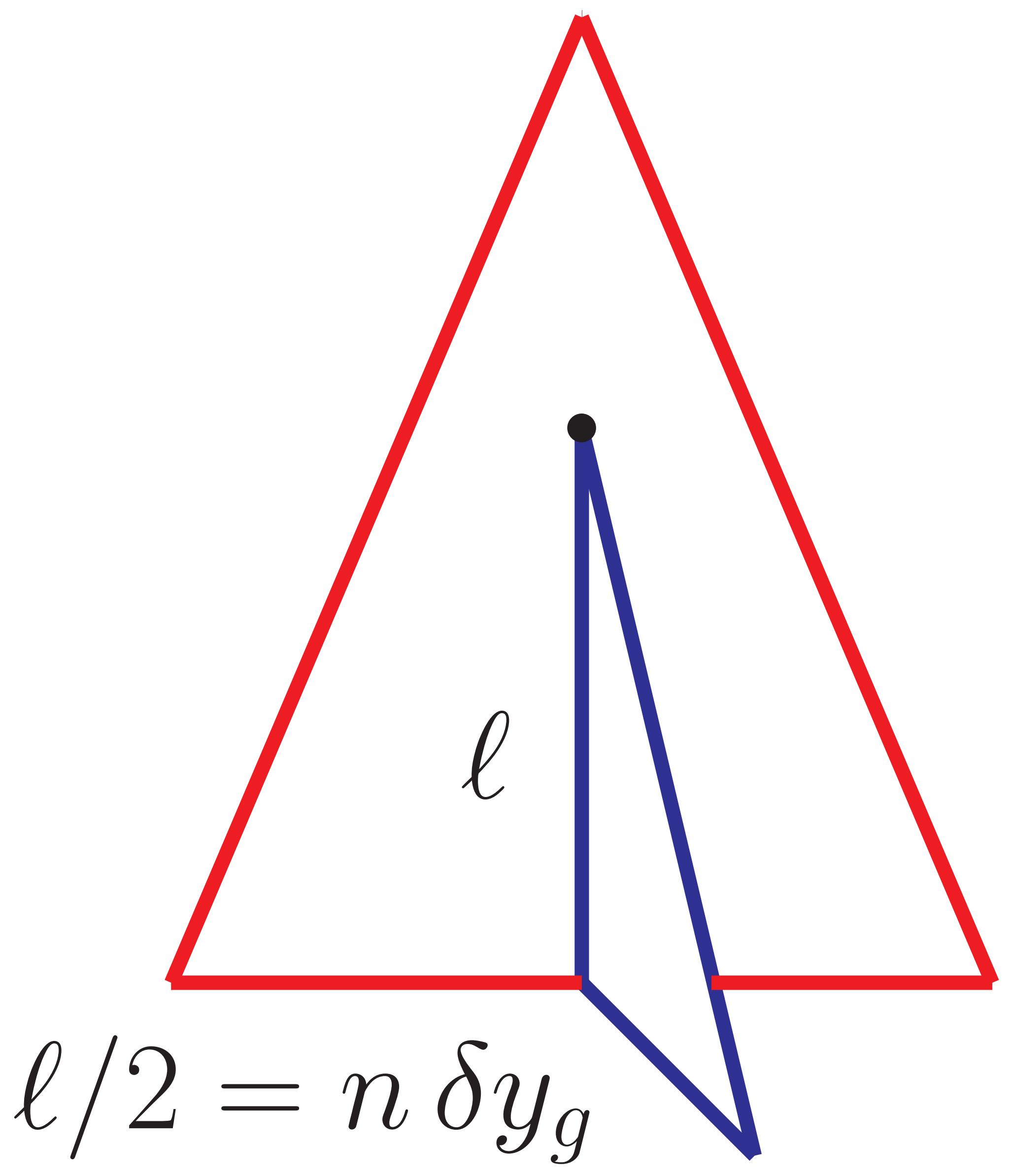
$$d\mathcal{P}\left(q(p_{\mathrm{I}})\bar{q}(p_{\mathrm{K}}) \to q(p_i)g(p_j)\bar{q}(p_k)\right) \simeq= \frac{d\kappa}{\kappa}\frac{dy}{\delta y_g}$$

with $\delta y_g = \frac{11}{6}$

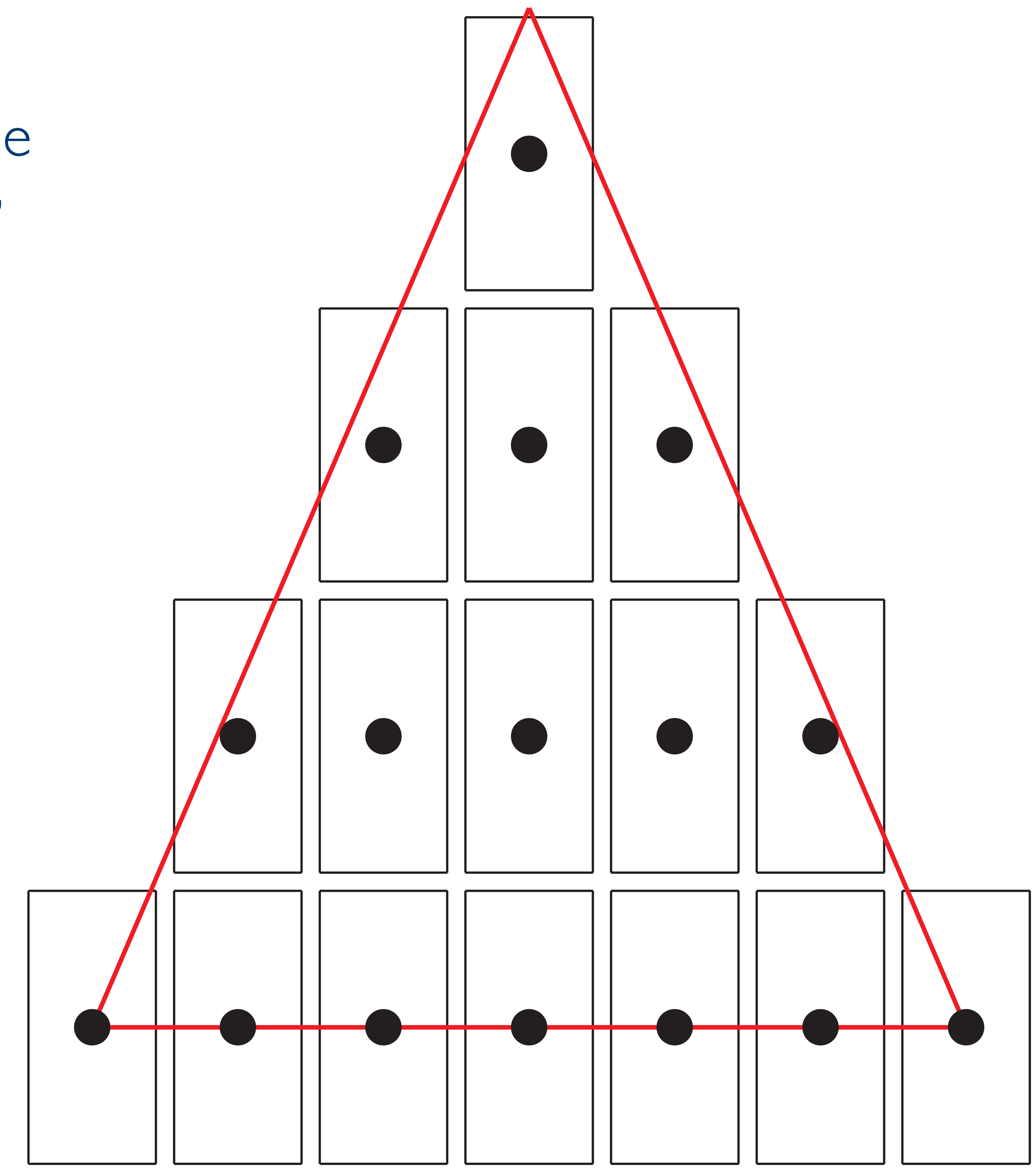


$$dt\,d\xi \frac{d\phi}{2\pi} C \frac{\alpha_s}{2\pi} \frac{2s_{ik}(t,\xi)}{s_{ij}(t,\xi)s_{jk}(t,\xi)} \Delta(t_n, t) = \frac{d\kappa}{\kappa} \exp\left(-\int_{\kappa}^{\kappa_{max}} \frac{d\bar{\kappa}}{\bar{\kappa}}\right) = \frac{d\kappa}{\kappa_{max}}$$

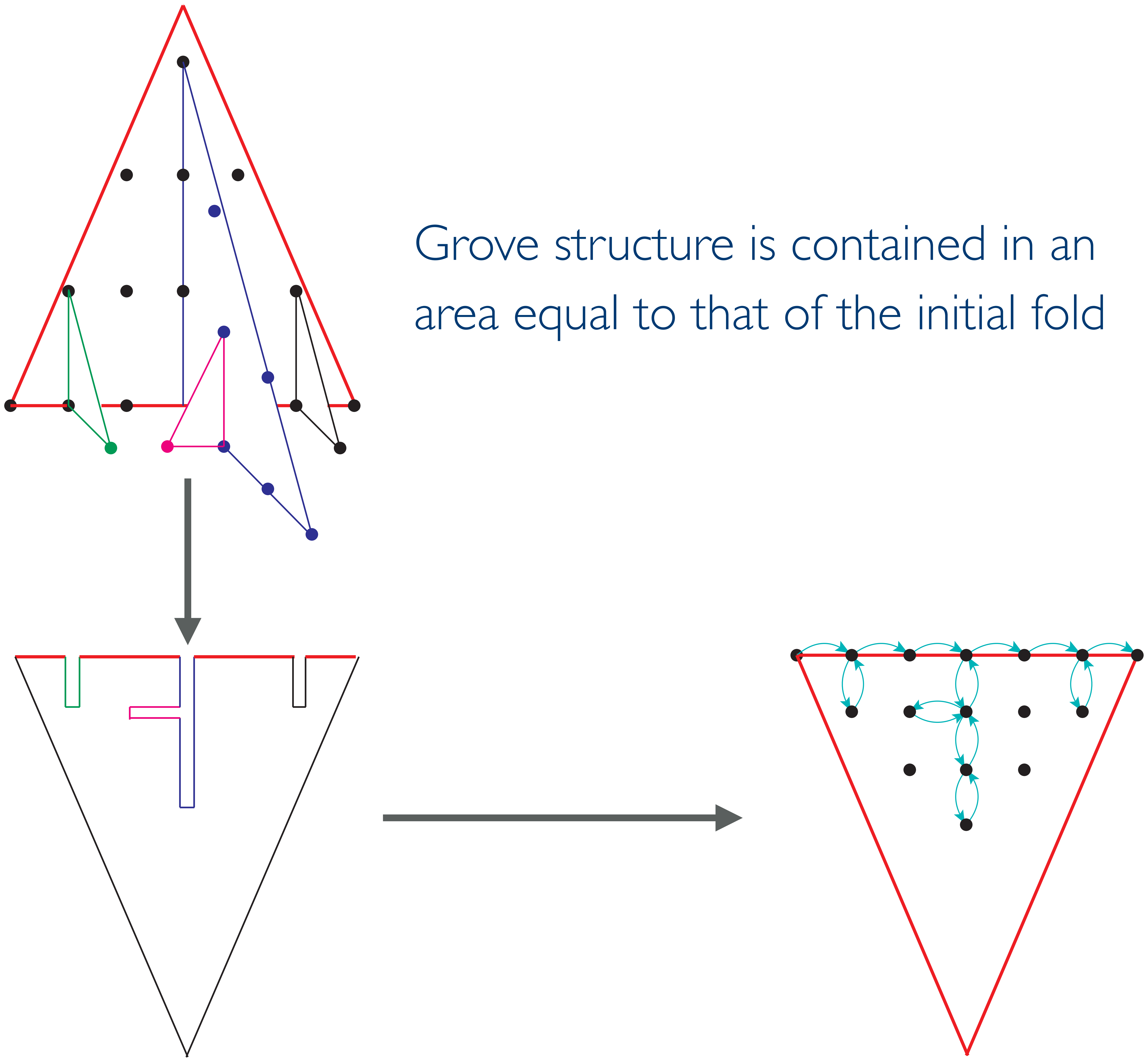




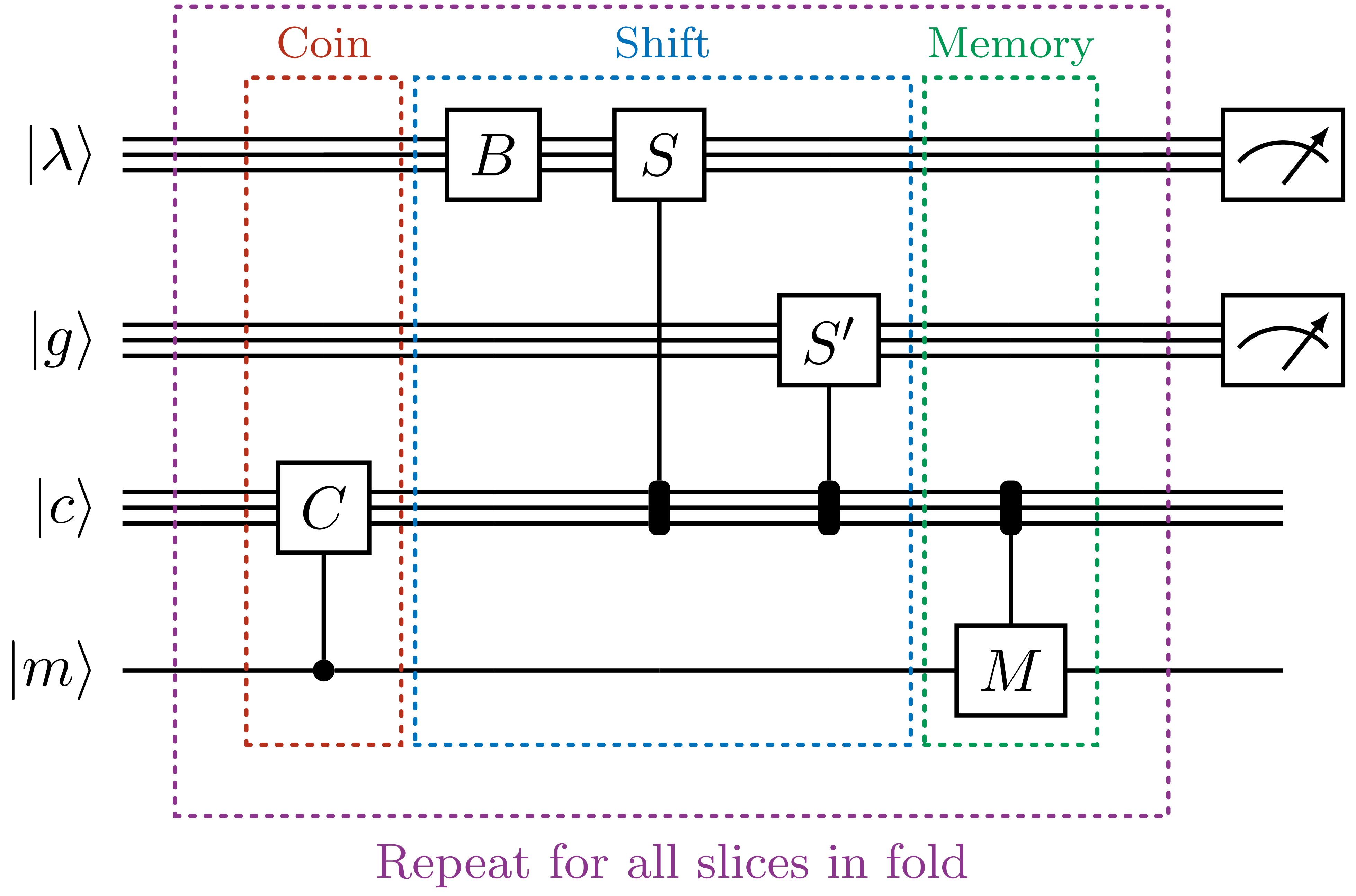
Emission increases the available rapidity range → "folding out"



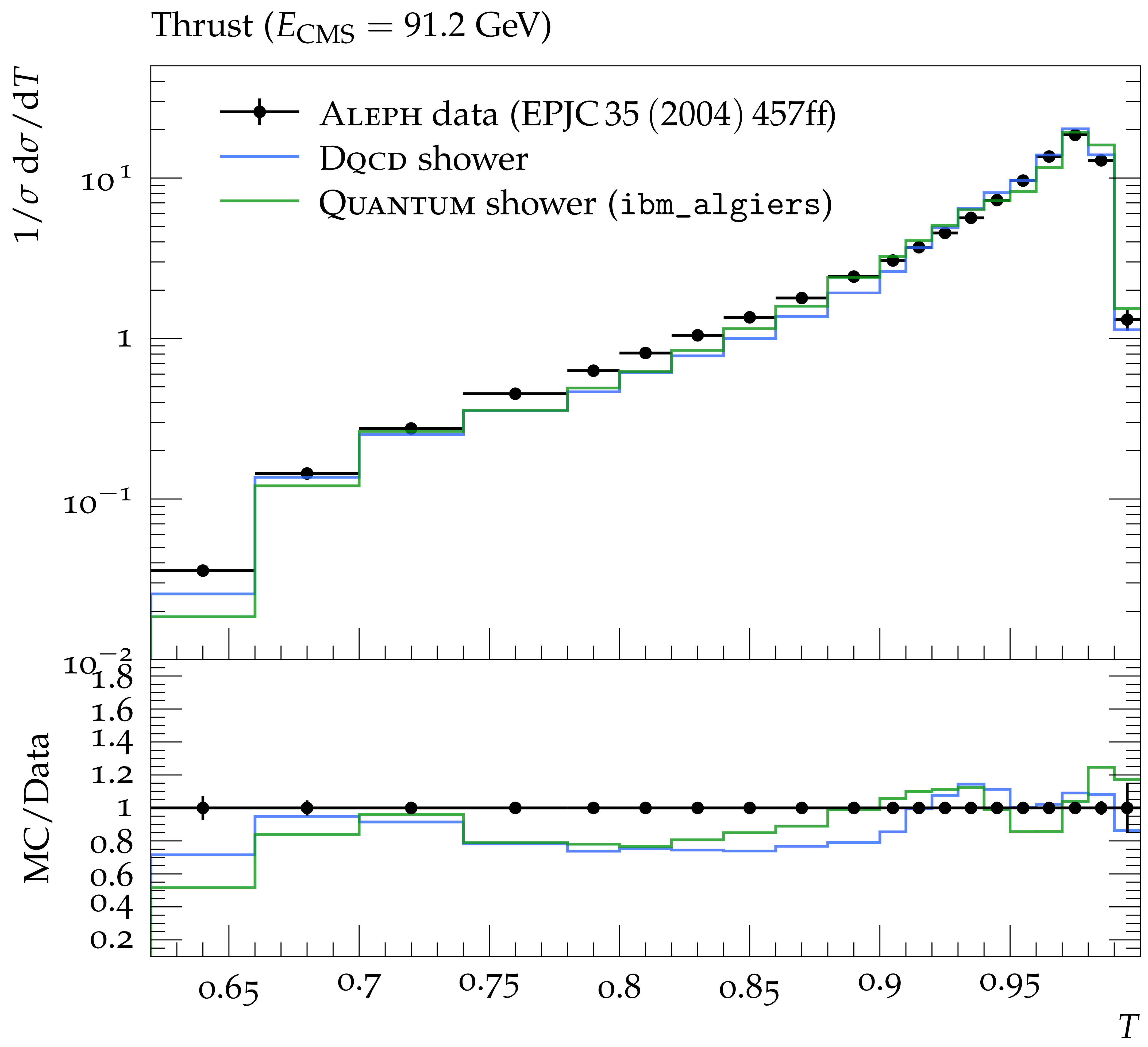
The new folds extends in positive y by $l/2$, thus the phase space is discretised in κ by $2\delta y_g$

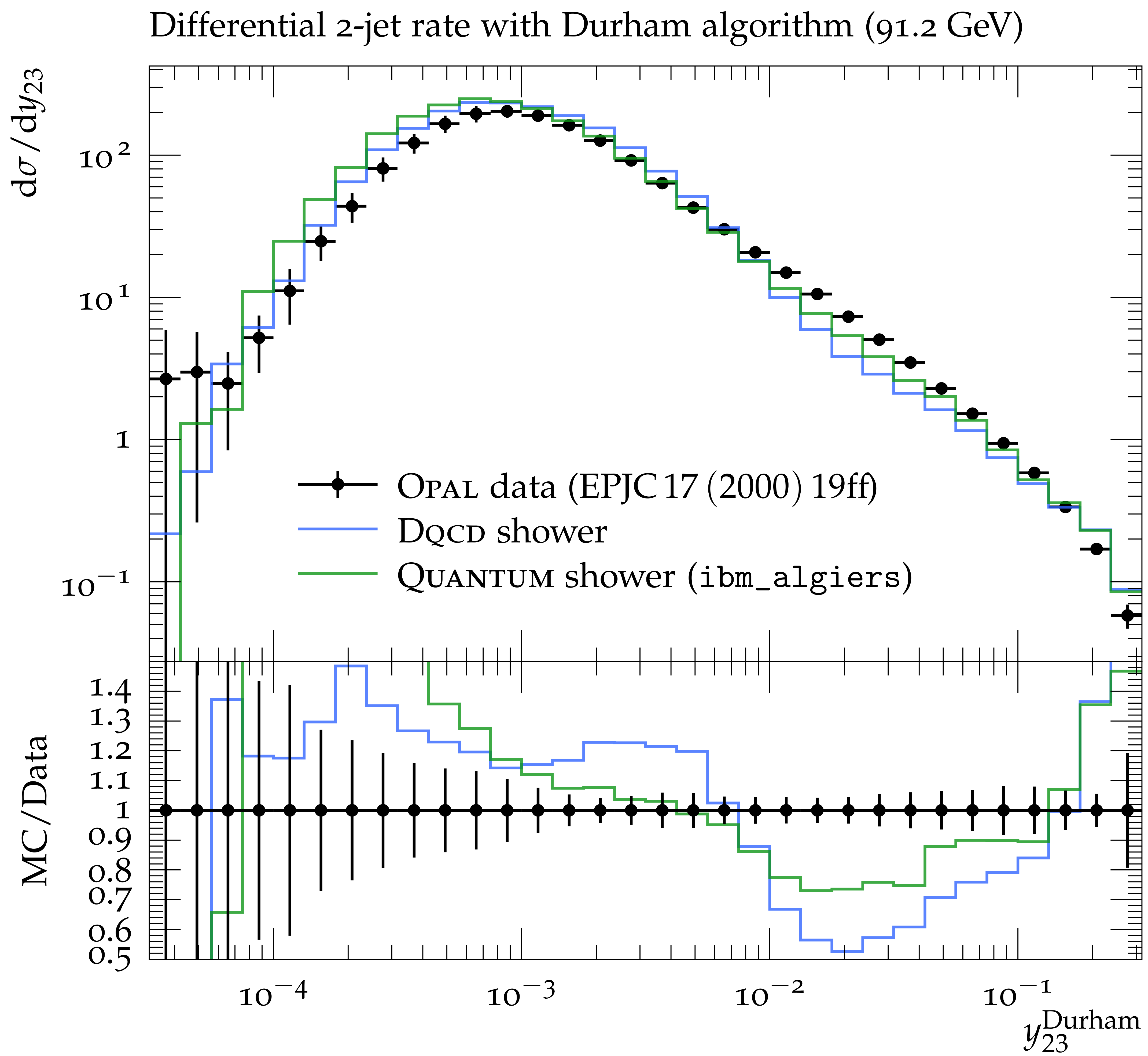


Grove structure is contained in an area equal to that of the initial fold



The 2D random walk can be implemented on a quantum device as a Quantum Walk with Memory


Thrust (E_{CMS} = 91.2 GeV)
ALEPH data (EPJC 35 (2004) 457ff)
DQCD shower
QUANTUM shower (ibm_algiers)
1/σ dσ/dT
MC/Data
T


Differential 2-jet rate with Durham algorithm (91.2 GeV)
OPAL data (EPJC 17 (2000) 19ff)
DQCD shower
QUANTUM shower (ibm_algiers)
dσ/dy23
MC/Data
y23 Durham