XDVMP

eXclusive Diffractive Vector Meson Production

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Present Status

EIC task force meeting 2/12-2010

Theory background

What has been done since INT

Results

Incoherent Scattering

Nucleus dissociates ($f \neq i$):

Good, Walker

$$16\pi\sigma_{\text{incoherent}} = \sum_{f\neq i} \langle i|\mathcal{A}|f\rangle^\dagger \langle f|\mathcal{A}|i\rangle = \sum_f \langle i|\mathcal{A}\overbrace{|f\rangle^\dagger \langle f|}^{\text{complete set}}\mathcal{A}|i\rangle - \langle i|\mathcal{A}|i\rangle^\dagger \langle i|\mathcal{A}|i\rangle =$$

$$\langle i||\mathcal{A}|^2|i\rangle - |\langle i|\mathcal{A}|i\rangle|^2 = \langle|\mathcal{A}|^2\rangle - |\langle\mathcal{A}\rangle|^2$$

The incoherent cross-section is the variance of the amplitude

$$\frac{\mathrm{d}\sigma_{\text{incoherent}}}{\mathrm{d}t} = \frac{\mathrm{d}\sigma_{\text{total}}}{\mathrm{d}t} - \frac{\mathrm{d}\sigma_{\text{coherent}}}{\mathrm{d}t}$$

$$\frac{\mathrm{d}\sigma_{\text{total}}}{\mathrm{d}t} = \frac{1}{16\pi}\left\langle|\mathcal{A}|^2\right\rangle$$

$$\frac{\mathrm{d}\sigma_{\text{coherent}}}{\mathrm{d}t} = \frac{1}{16\pi}|\langle\mathcal{A}\rangle|^2$$

Averaging

$$\frac{\mathrm{d}\sigma_{\mathrm{coherent}}}{\mathrm{d}t} = \frac{1}{16\pi} \left|\langle \mathcal{A} \rangle\right|^2$$

The average should be taken over nucleon configurations within the nucleus (the nucleon configuration is not a QM observable).

$$\langle \bullet \rangle = \int \mathrm{d}^2\boldsymbol{b}_1 \ldots \mathrm{d}^2\boldsymbol{b}_n \, \mathcal{P}\left(\boldsymbol{b}_1, \ldots, \boldsymbol{b}_n\right) \bullet$$

$$\langle \mathcal{A}(\Delta) \rangle_\Omega = \int \mathrm{d}\Omega P(\Omega) \mathcal{A}(\Omega, \Delta) \approx \frac{1}{C_{\mathrm{max}}} \sum_{j=1}^{C_{\mathrm{max}}} \mathcal{A}(\Omega_j, \Delta)$$

Coherent

$$\frac{\mathrm{d}\sigma_{\mathrm{coherent}}}{\mathrm{d}t} = \frac{1}{16\pi}\left|\frac{1}{C_{\mathrm{max}}}\sum_{j=1}^{C_{\mathrm{max}}}\mathcal{A}(\Omega_j)\right|^2$$

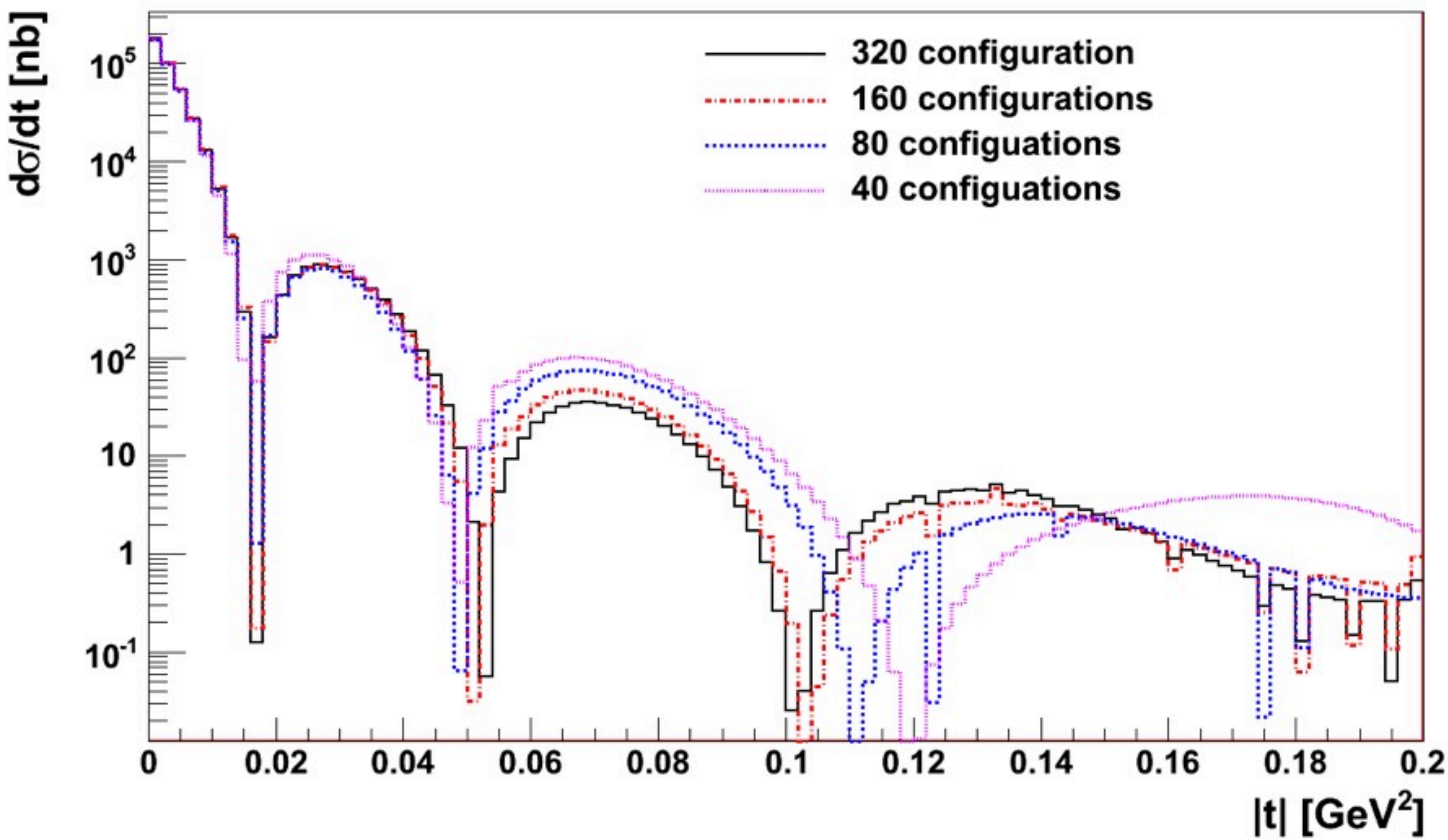
$$\langle\mathcal{A}\rangle_\Omega \approx \frac{1}{C_{\mathrm{max}}}\sum_{j=1}^{C_{\mathrm{max}}}\int \mathrm{d}r\int\frac{\mathrm{d}z}{4\pi}\left(\Psi_V^*\Psi\right)(r,z)$$
$$\int \mathrm{d}b\frac{\mathrm{d}^2\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}}(x,r,b,\Omega_j)(2\pi r)(2\pi b)J_0([1-z]r\Delta)J_0(b\Delta)$$

$\mathcal{A}$ is a Fourier transform of b. This means that small variations in b will be seen at large t and vice versa

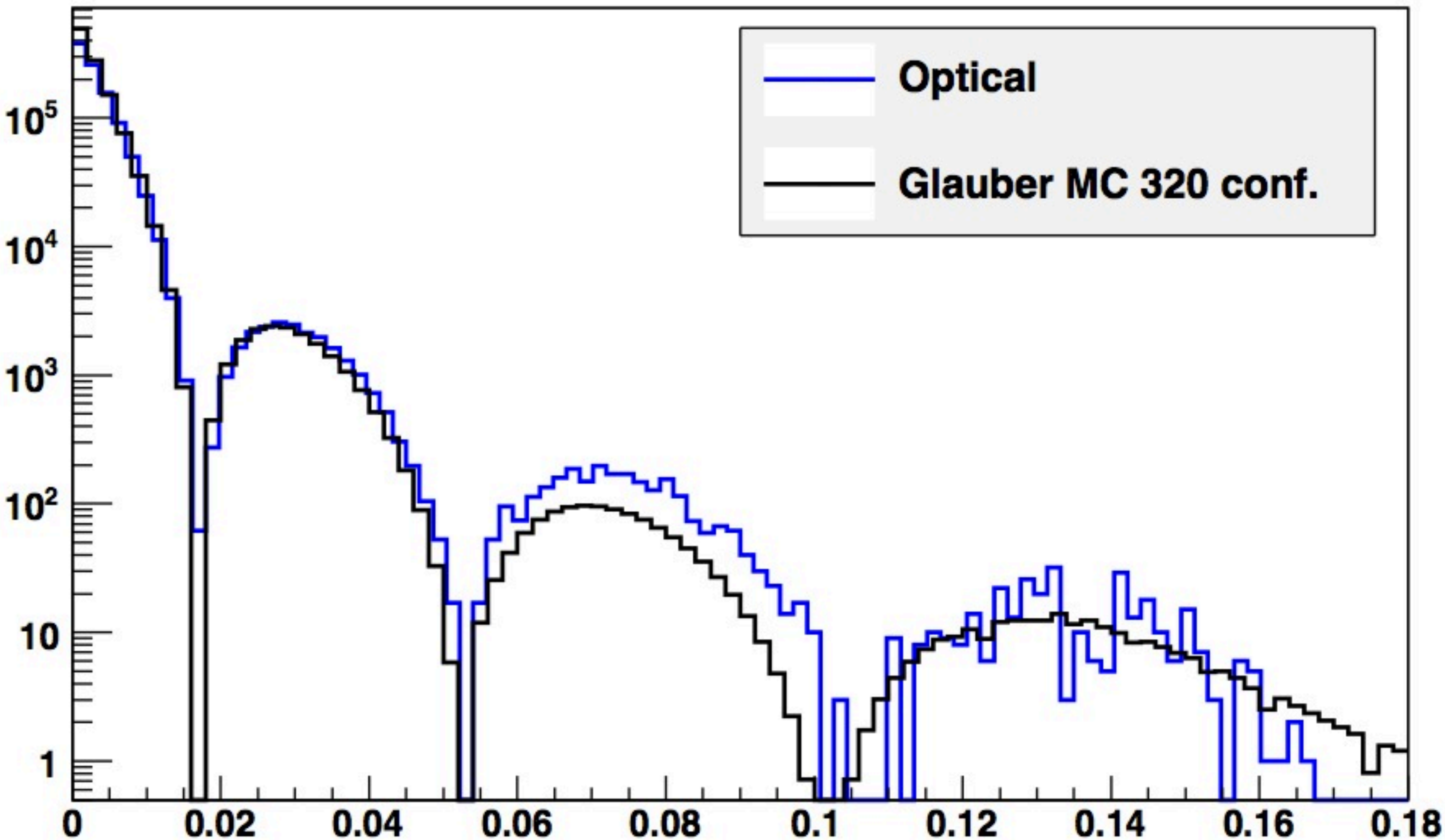
The question is how many configuration is needed to be averaged over for the cross-section to converge.

Coherent

$$\frac{\mathrm{d}\sigma_{\mathrm{coherent}}}{\mathrm{d}t} = \frac{1}{16\pi}\left|\frac{1}{C_{\max}}\sum_{j=1}^{C_{\max}} \mathcal{A}(\Omega_j)\right|^2$$



Glauber vs. Optical



Better way?

~200 configurations seem excessive.
Is there a better way?

2 Approaches

$$\langle \mathcal{A} \rangle_\Omega \approx \frac{1}{C_{\max}} \sum_{j=1}^{C_{\max}} \int \mathrm{d}r \int \frac{\mathrm{d}z}{4\pi} \left(\Psi_V^* \Psi\right)(r,z)$$
$$\int \mathrm{d}b \frac{\mathrm{d}^2\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}}(x,r,b,\Omega_j)(2\pi r)(2\pi b) J_0([1-z]r\Delta) J_0(b\Delta)$$

The first approach:

Integrate angular dependences analytically. The remaining angular dependences are then averaged over in the sum.

Pro: The numerical integration is 1D in b and therefore fast.

Con: Need to average over more configurations for the cross-section to converge.

2nd Approach:

Integrate over full nucleus.

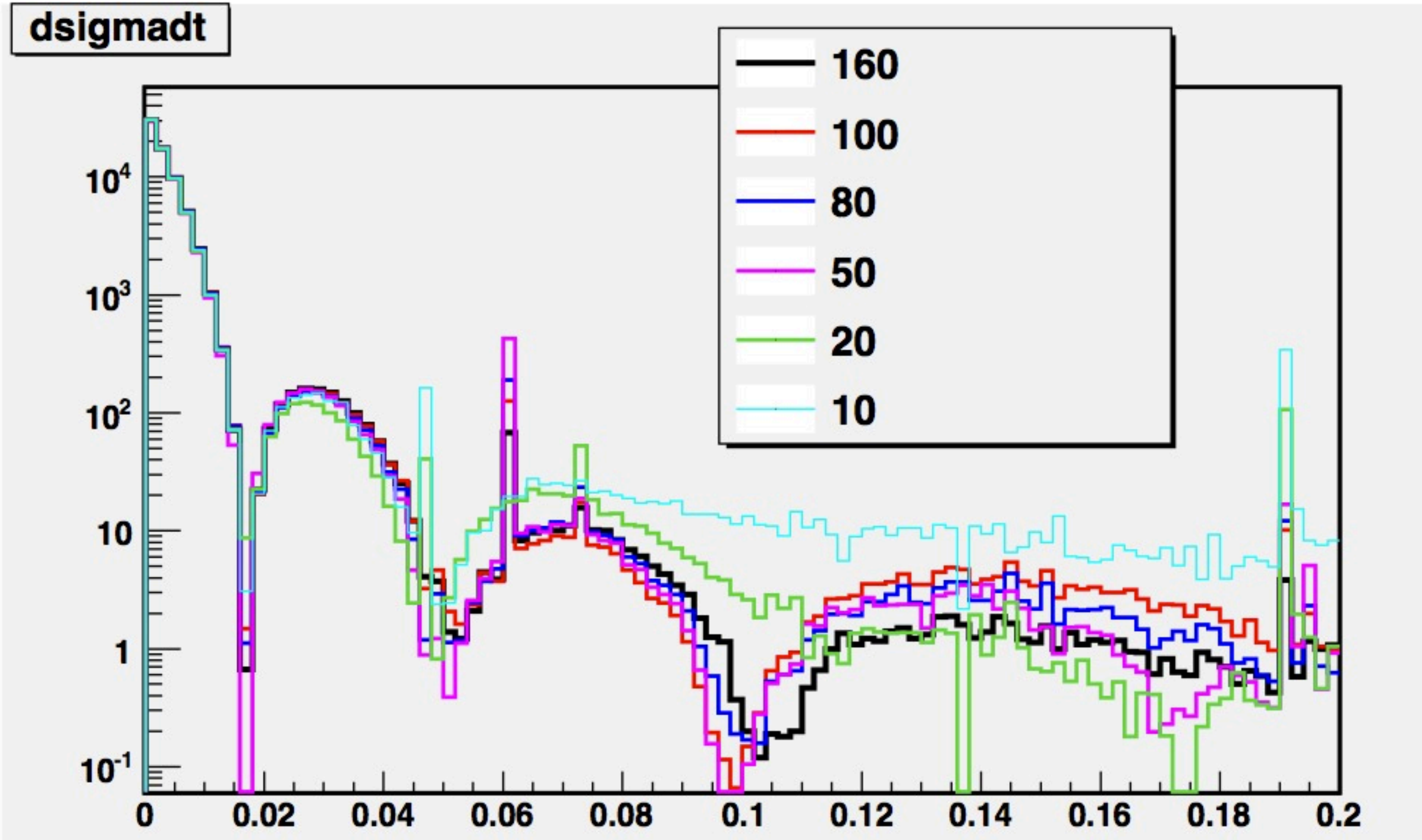
Pro: Need fewer configurations.

Con: Slower numerical integration.

$$\langle \mathcal{A} \rangle_\Omega \approx \frac{1}{C_{\max}} \sum_{j=1}^{C_{\max}} Im(\mathcal{A}(\Omega_j)) + \frac{1}{C_{\max}} \sum_{j=1}^{C_{\max}} Re(\mathcal{A}(\Omega_j))$$

$$\begin{aligned} Im(\mathcal{A}) &= \int_0^{r_{\max}} \mathrm{d}r \int_0^1 \mathrm{d}z \int_0^{b_{\max}} \mathrm{d}b \int_0^{2\pi} \mathrm{d}\phi_{b\Delta} \\ &\quad \frac{1}{2} r \left(\Psi_V^* \Psi\right)(r,z) J_0([1-z]r\Delta) b \cos(b\Delta\cos\phi_{b\Delta}) \frac{\mathrm{d}^2\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}}(x,r,b,\phi_{b\Delta},\Omega) \\ Re(\mathcal{A}) &= \int_0^{r_{\max}} \mathrm{d}r \int_0^1 \mathrm{d}z \int_0^{b_{\max}} \mathrm{d}b \int_0^{2\pi} \mathrm{d}\phi_{b\Delta} \\ &\quad \frac{1}{2} r \left(\Psi_V^* \Psi\right)(r,z) J_0([1-z]r\Delta) b \sin(b\Delta\cos\phi_{b\Delta}) \frac{\mathrm{d}^2\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}}(x,r,b,\phi_{b\Delta},\Omega) \end{aligned}$$

2nd Approach:



Calculation times

Approach 1

# conf	time
5	3 min 20 sec
10	4 min 35 sec
20	7 min 16 sec
40	10 min 54 sec
80	19 min 40 sec
160	39 min 6 sec
320	73 min 22 sec

Approach 2

# conf	time
5	6 min 39 sec
10	13 min 49 sec
20	20 min 41 sec
80	84 min 56 sec
100	102 min 45 sec

Approach 1 is preferred!

To do:

Still a lot