QUANTUM MECHANICS

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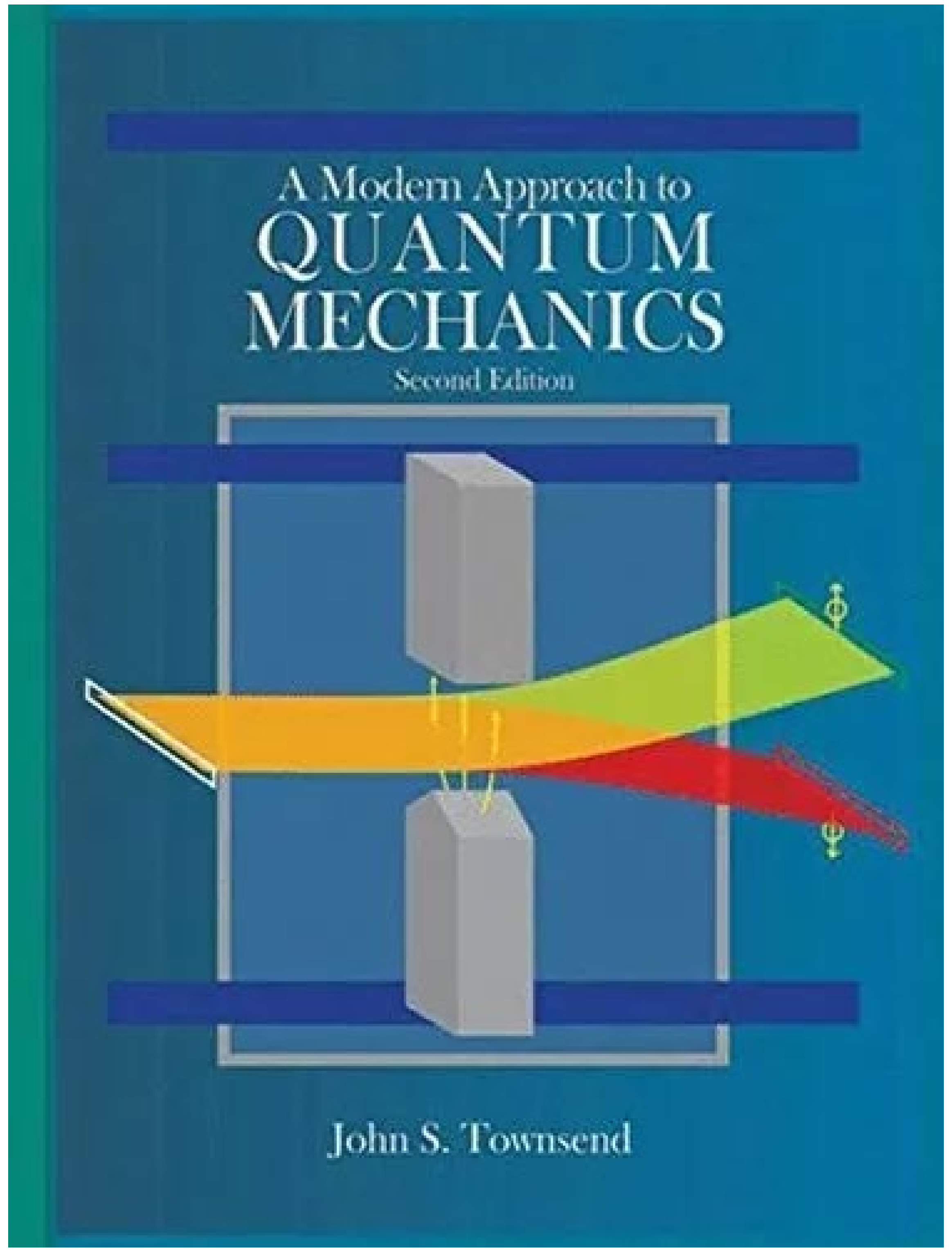
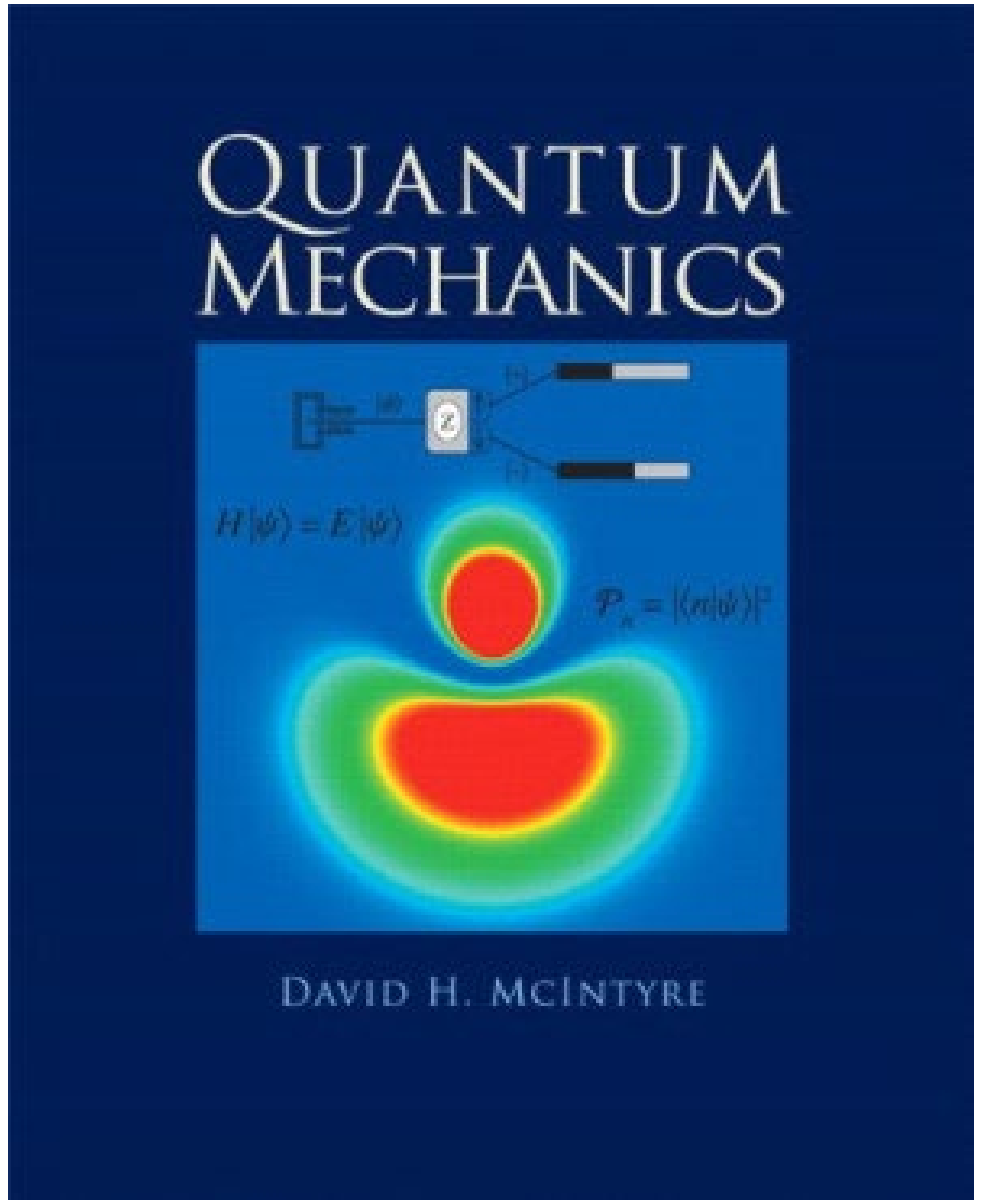
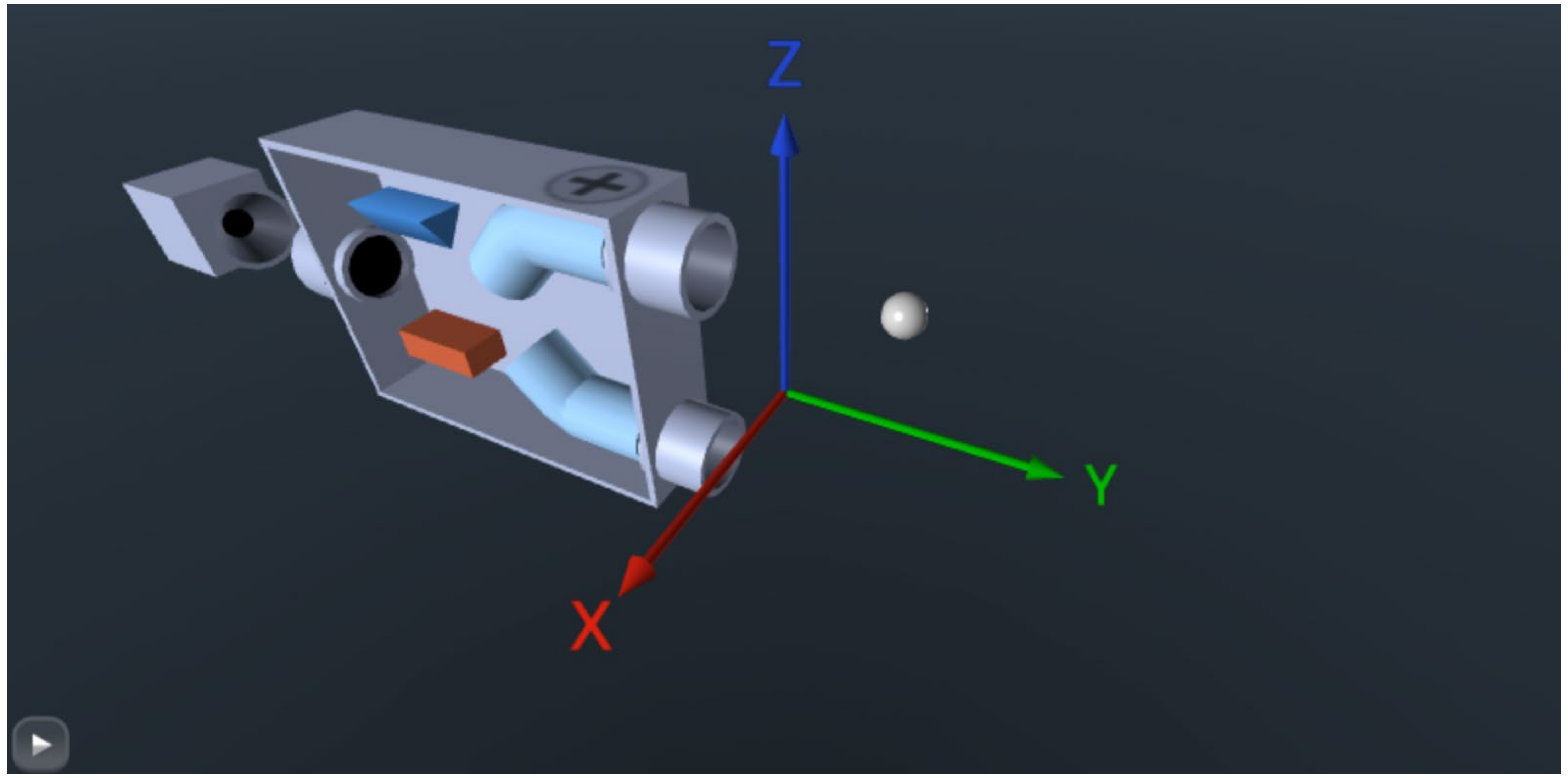
Georgetown University
Work funded by the AFOSR and Georgetown

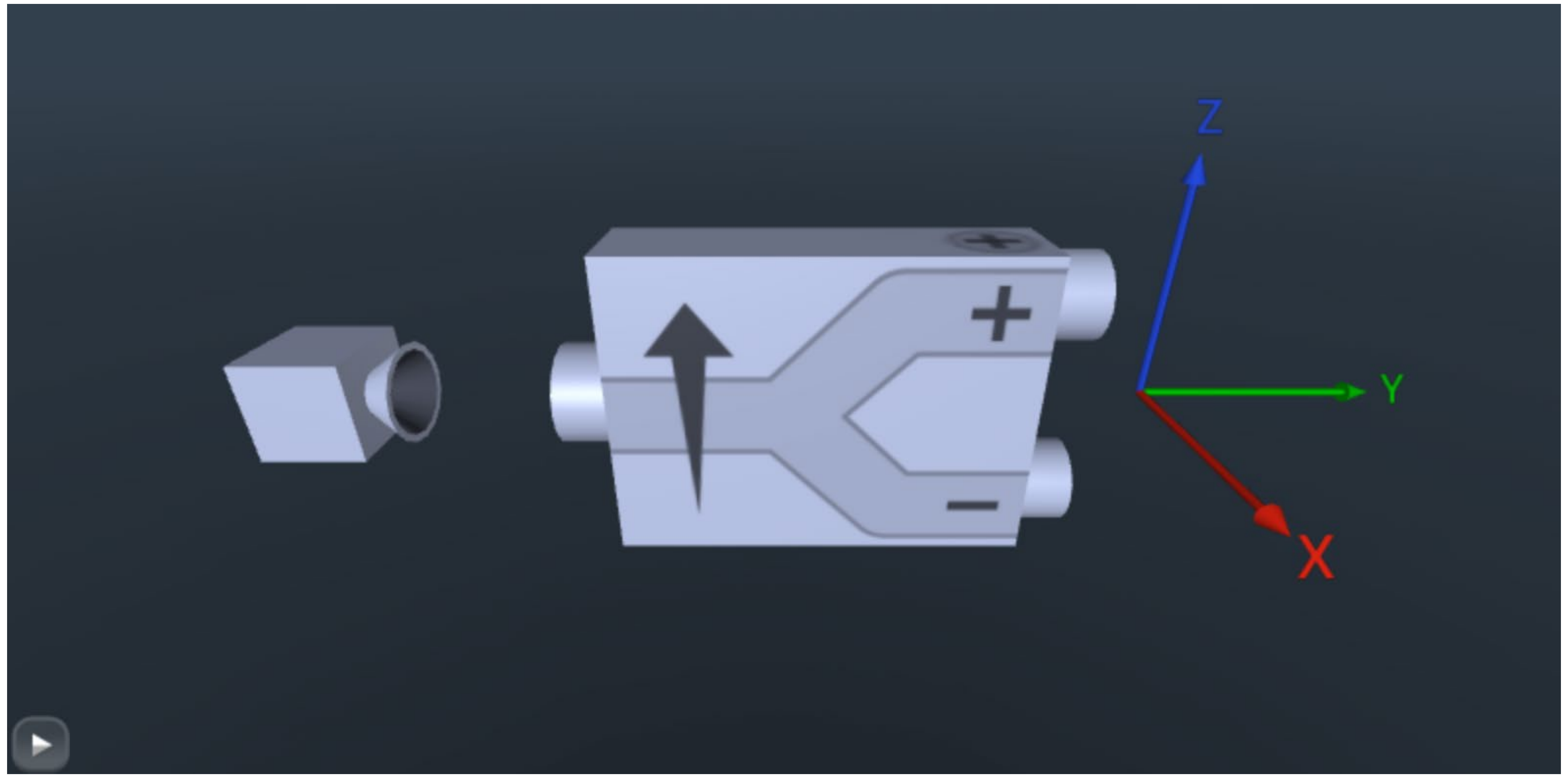
Spins first protocol



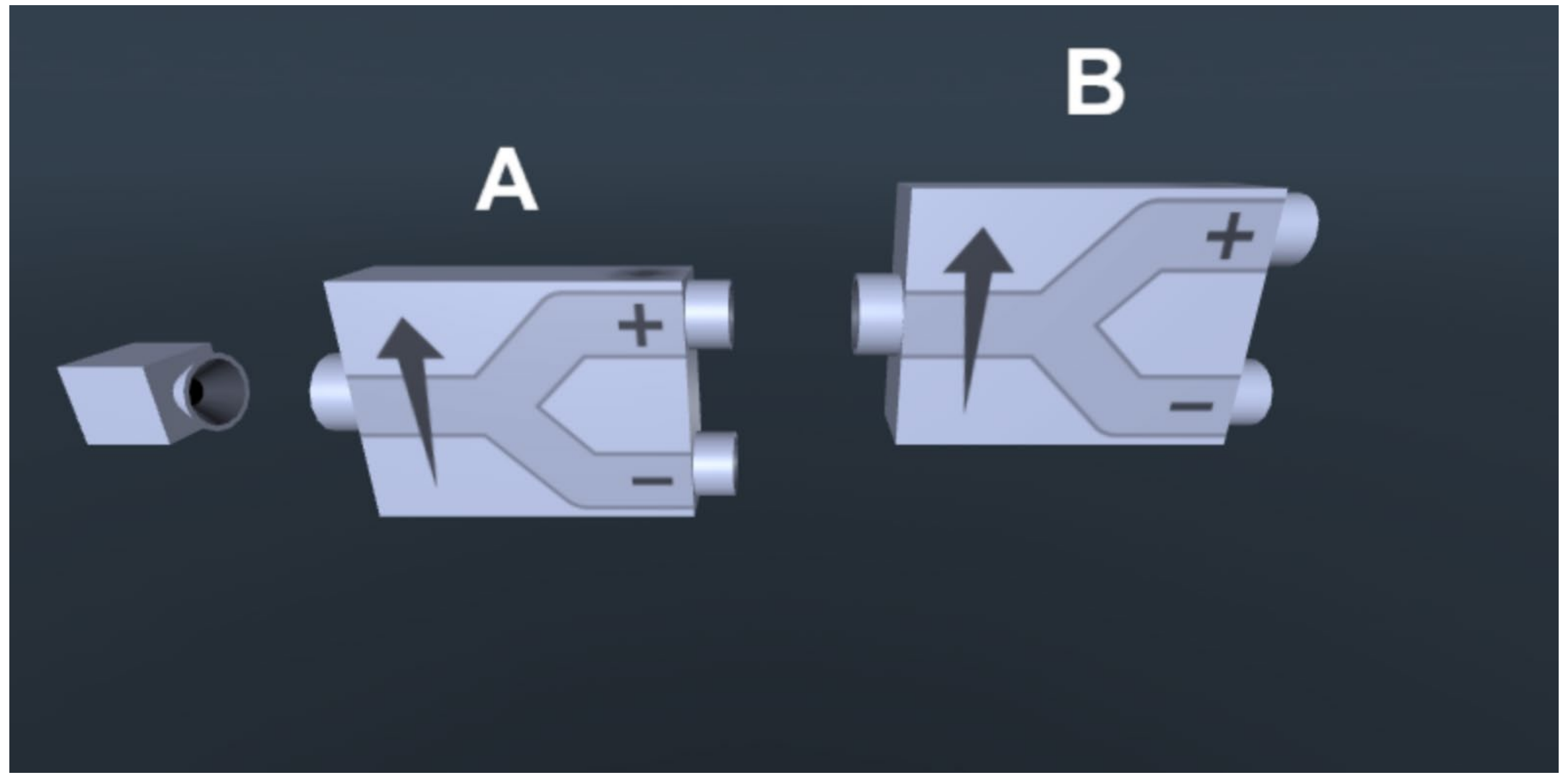


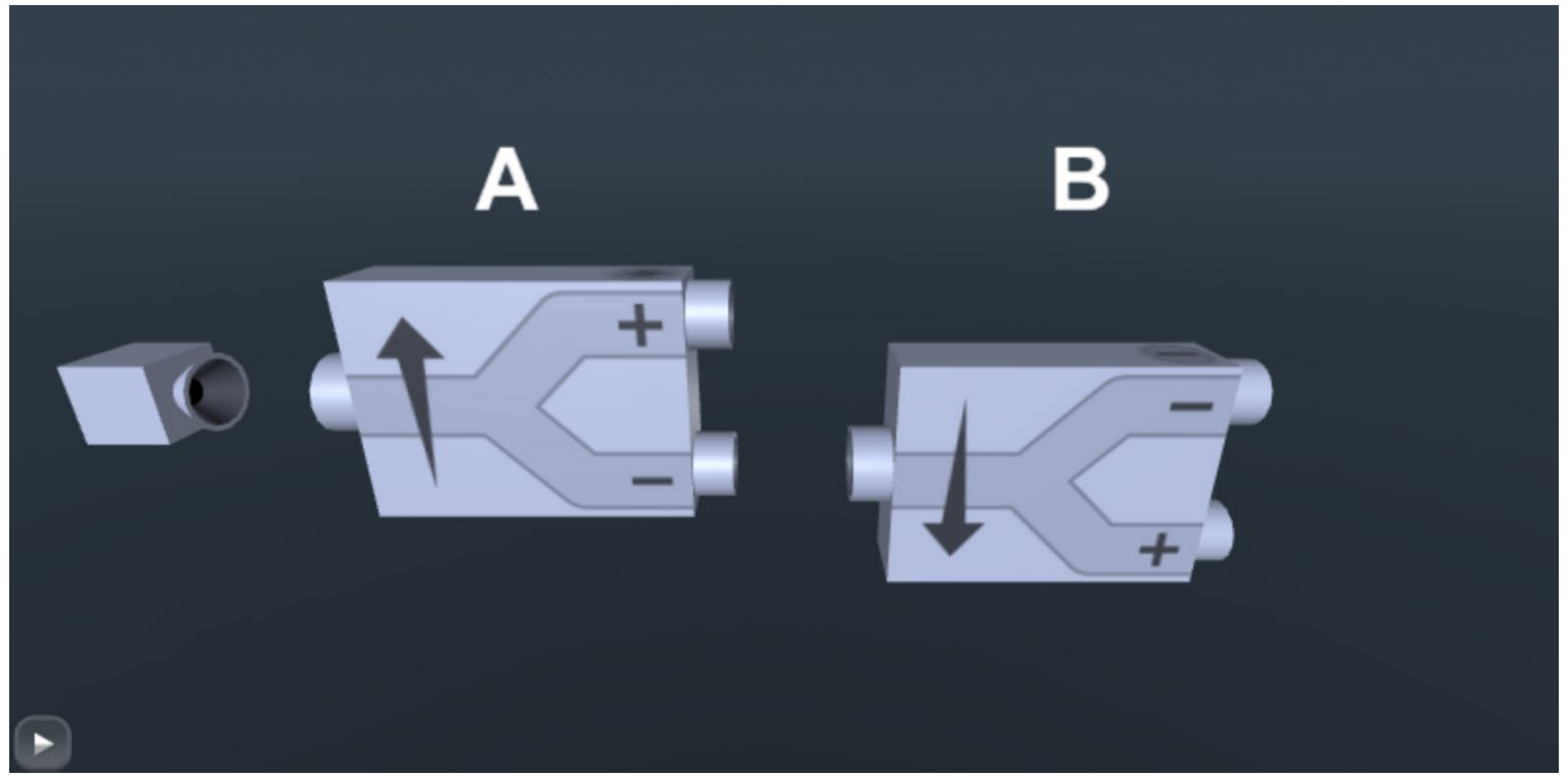
Stern-Gerlach analyzer

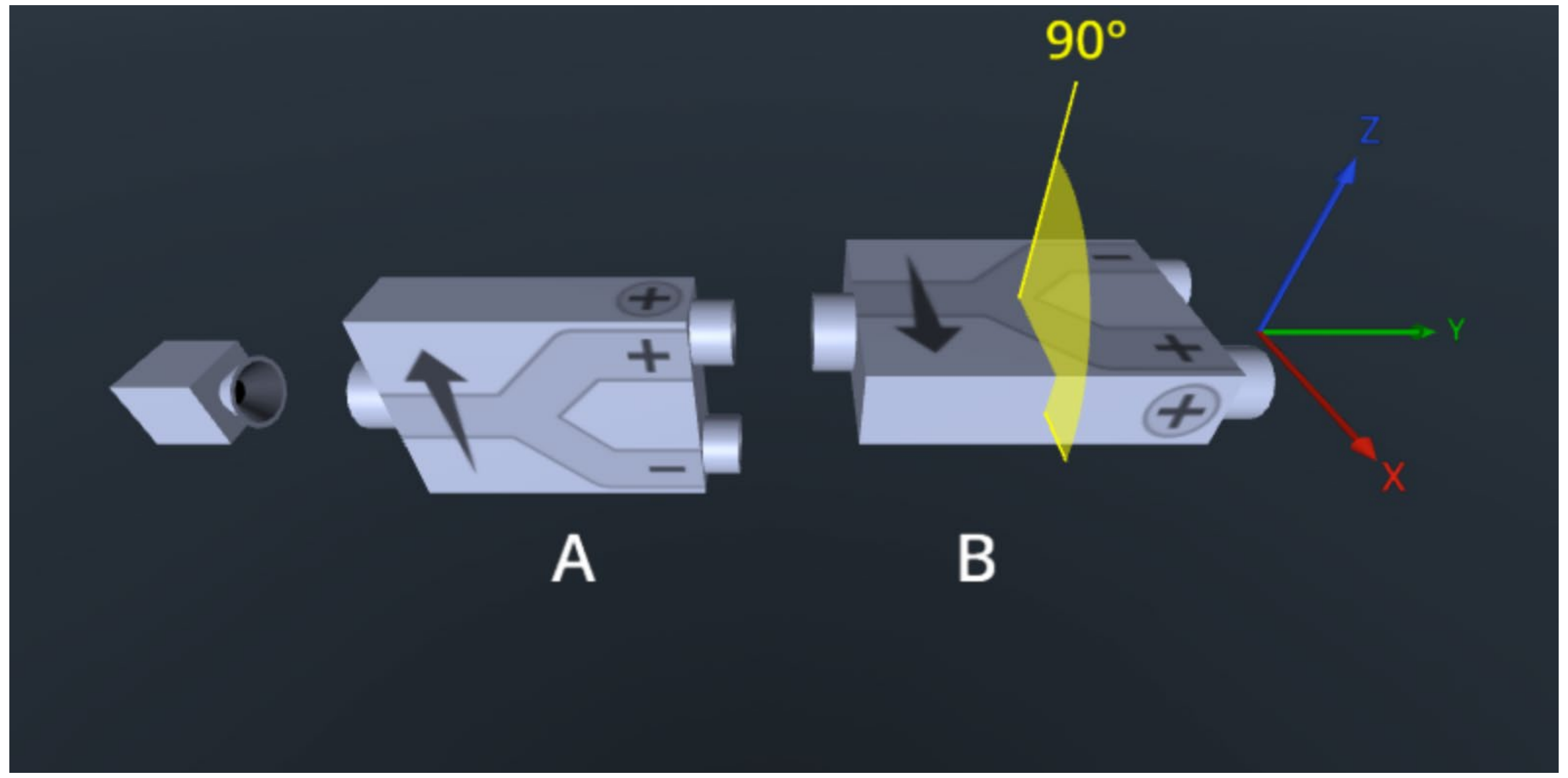


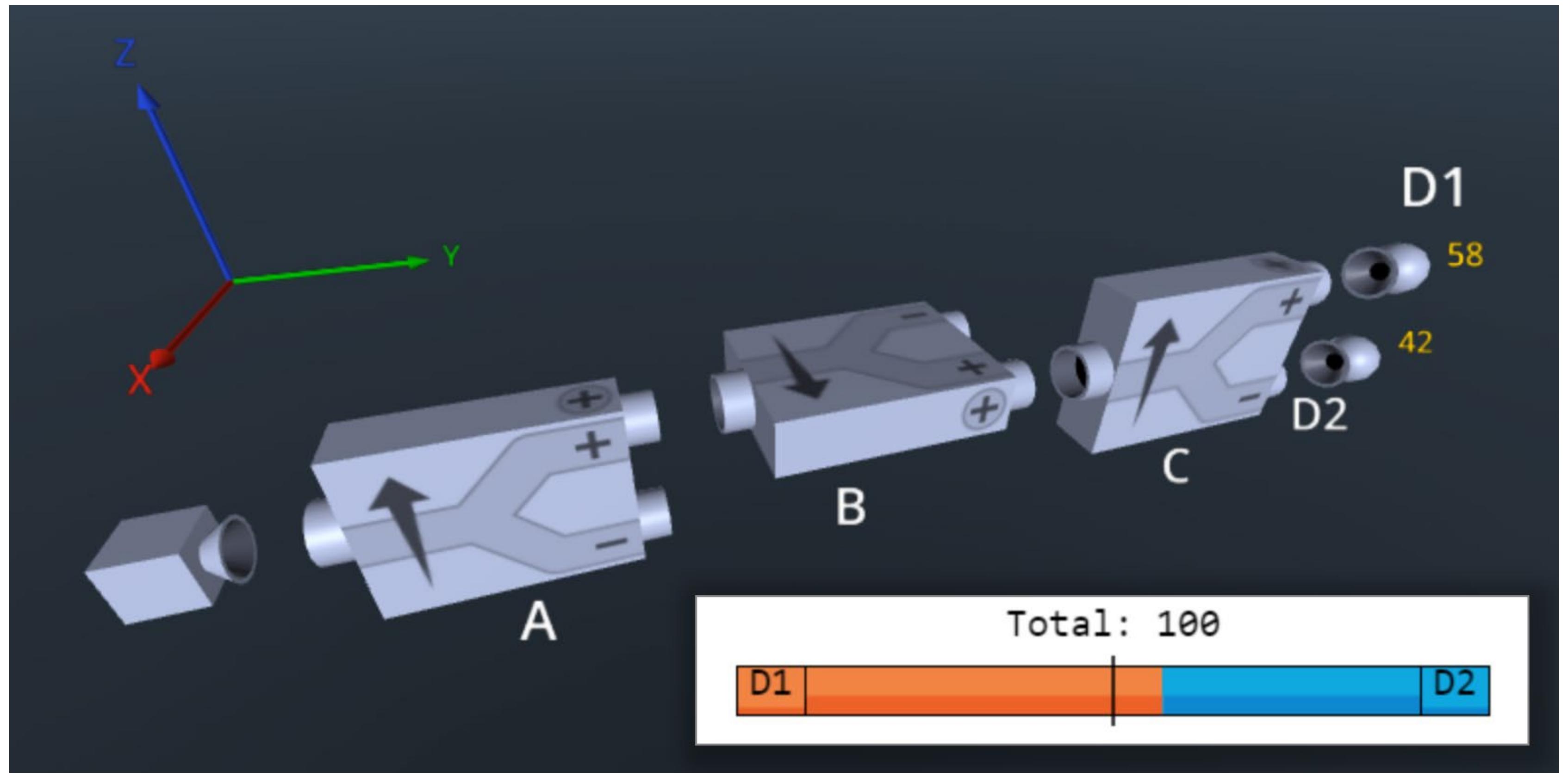


Repeated experiments







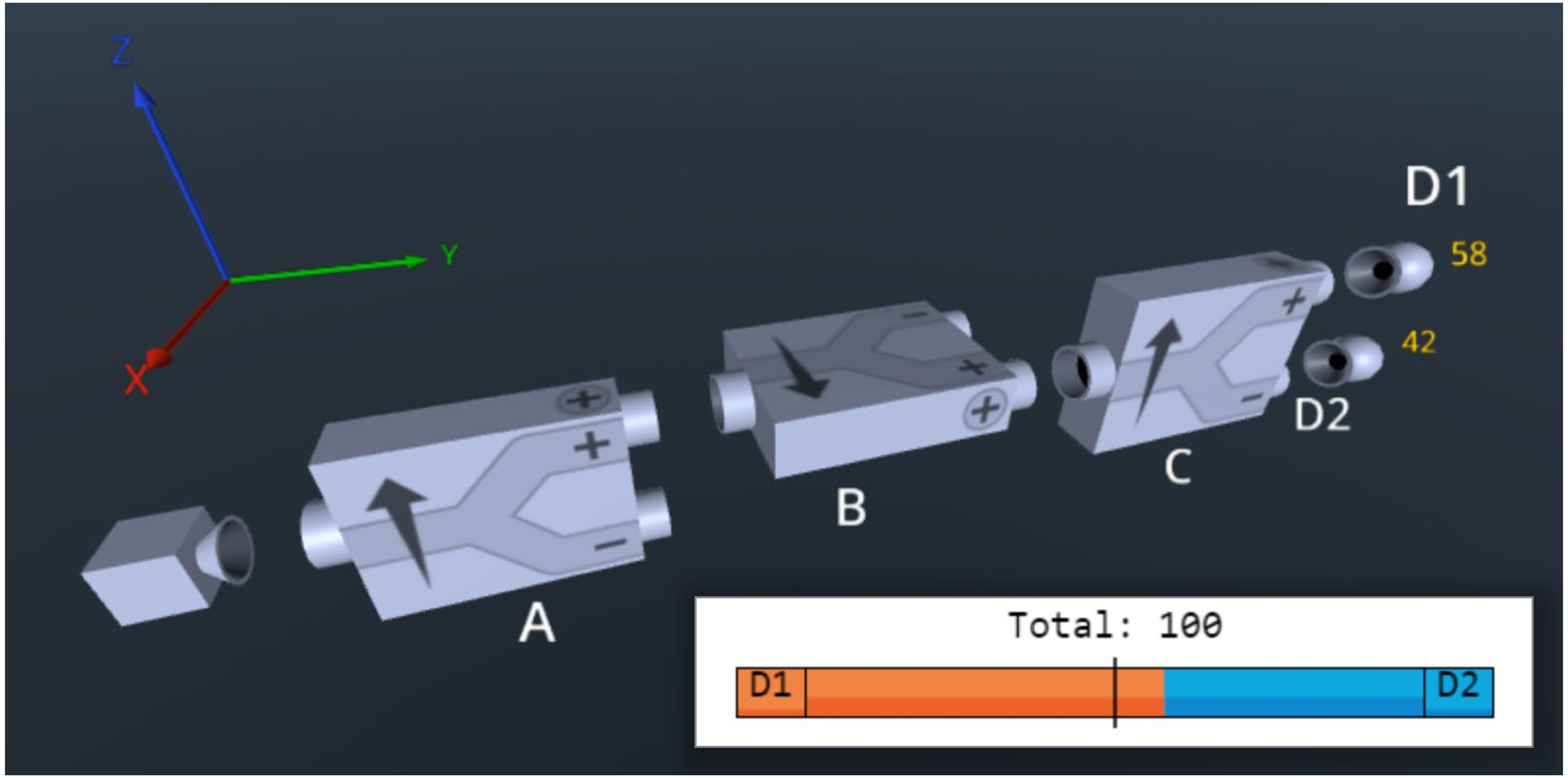


Actual demonstrations are challenging

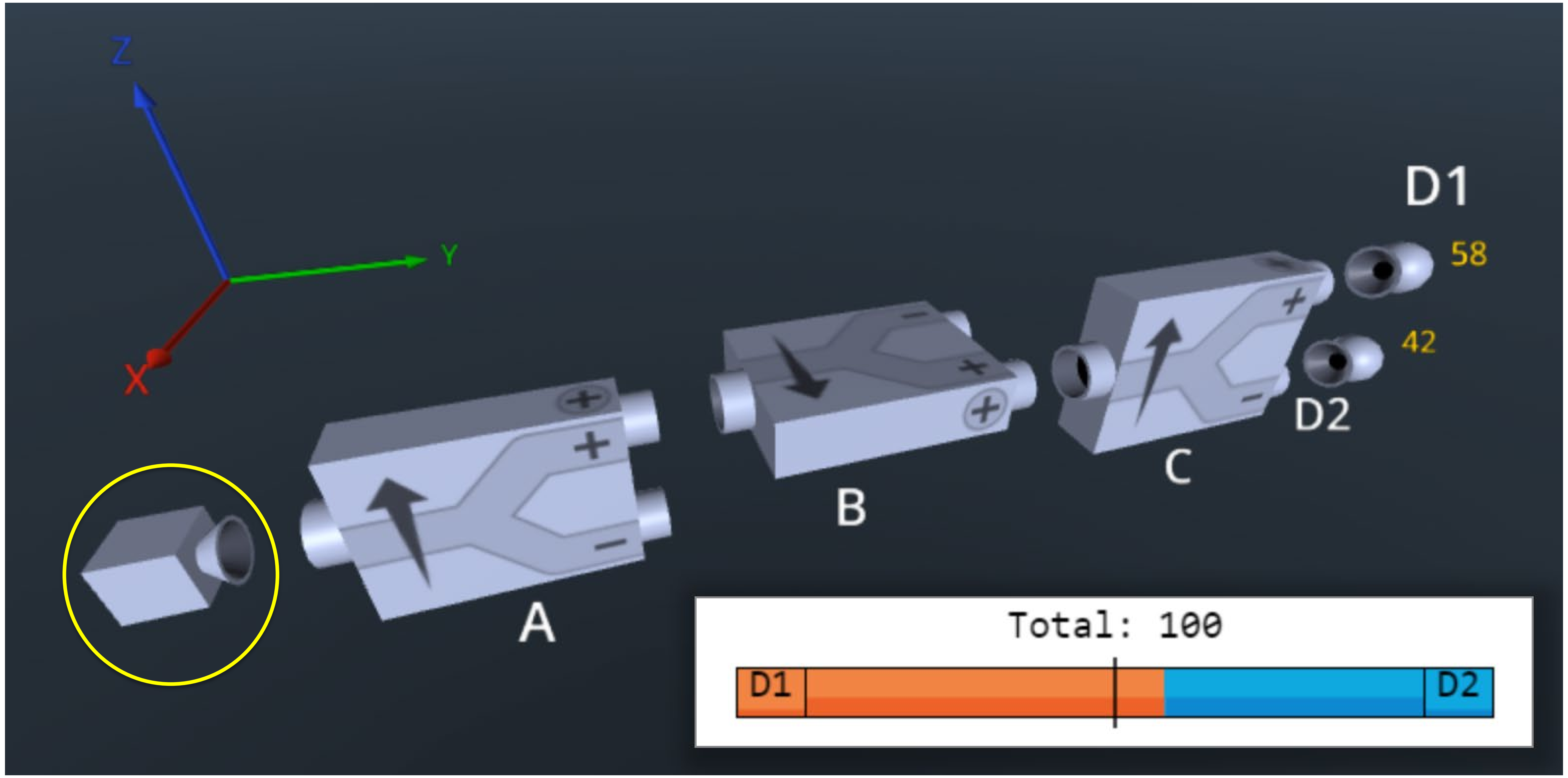
Use quantum computers to illustrate them

They are real single quanta experiments

They involve state preparation followed by measurement

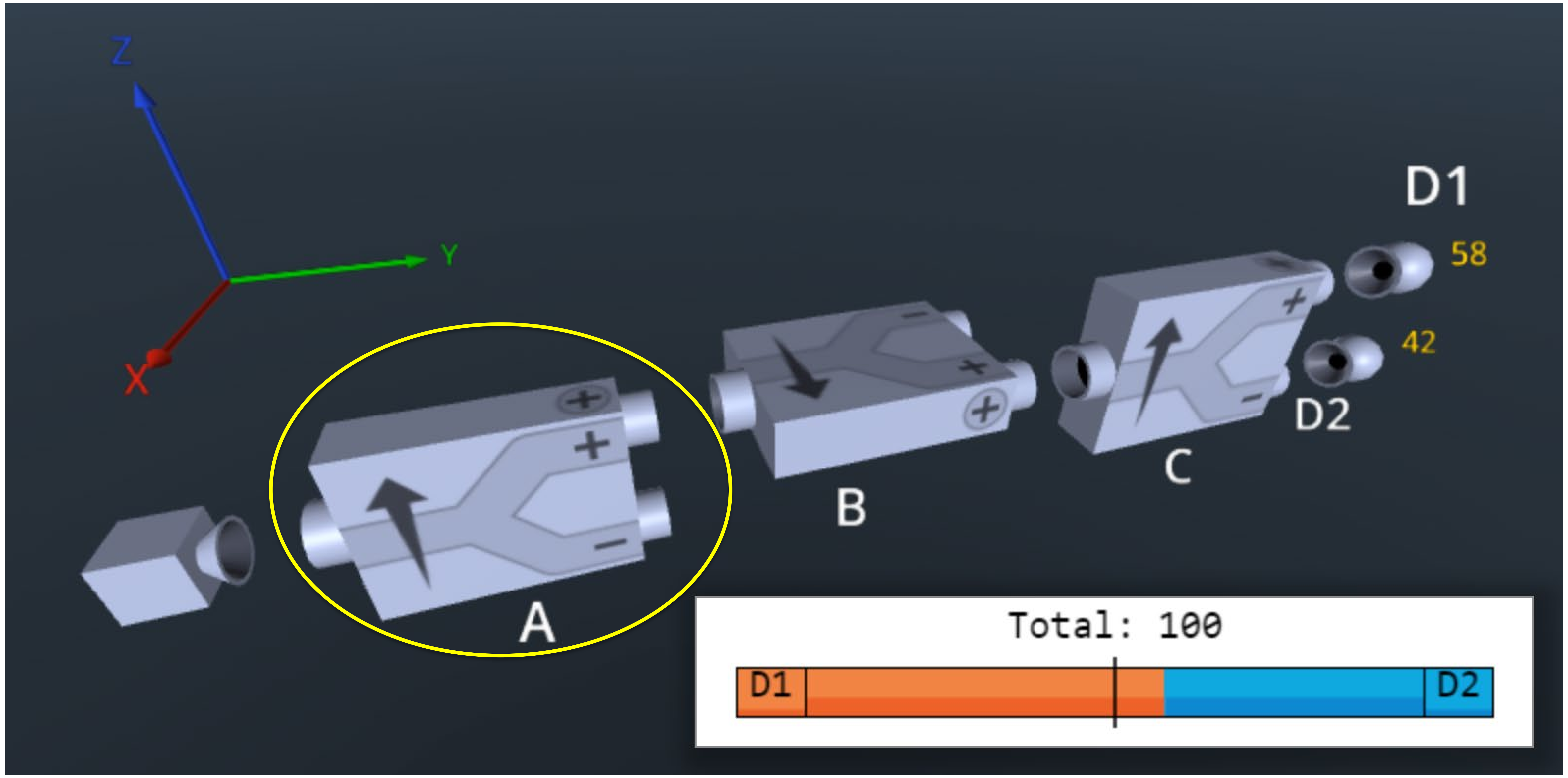


They involve state preparation followed by measurement



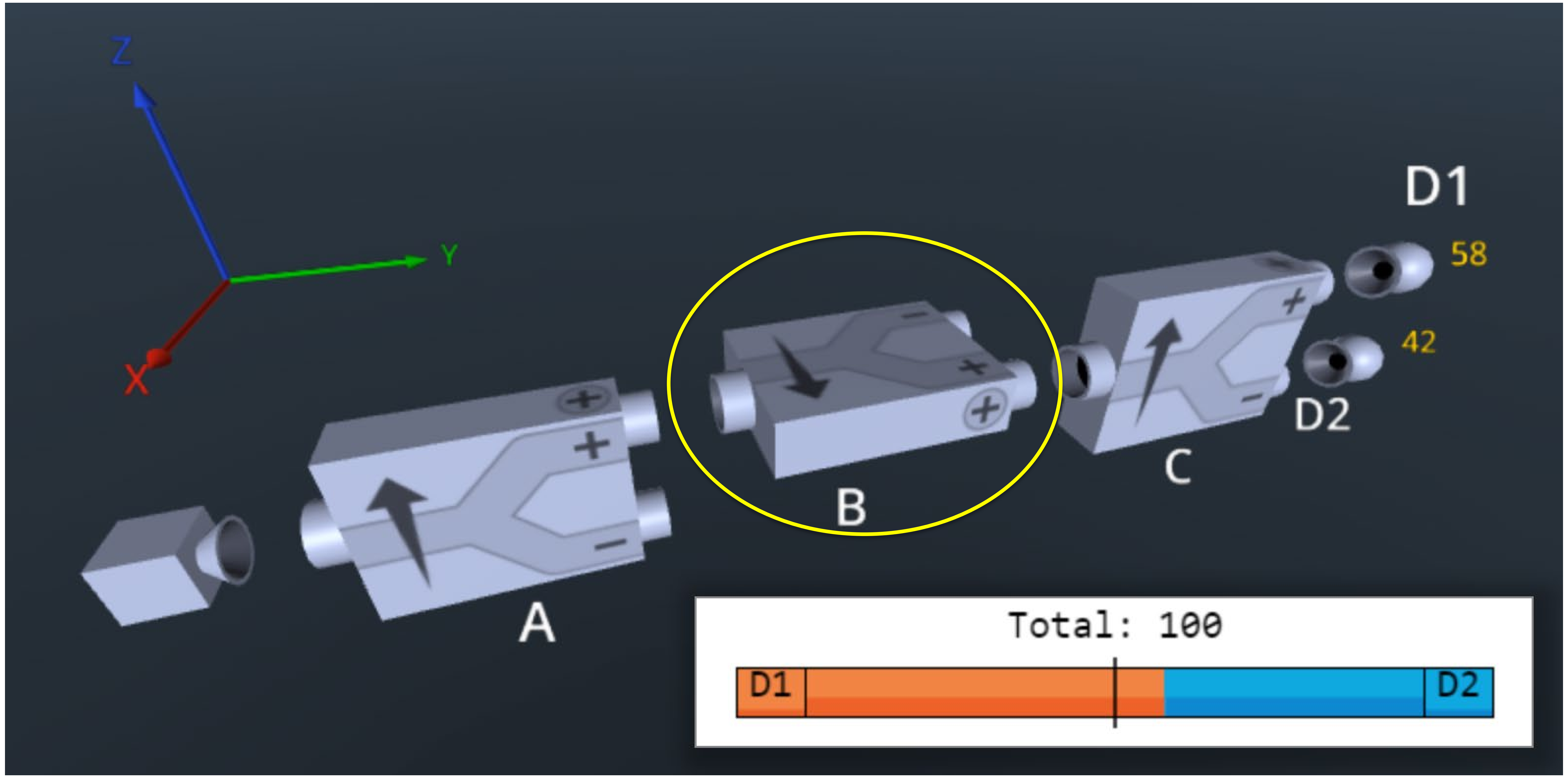
Source

They involve state preparation followed by measurement



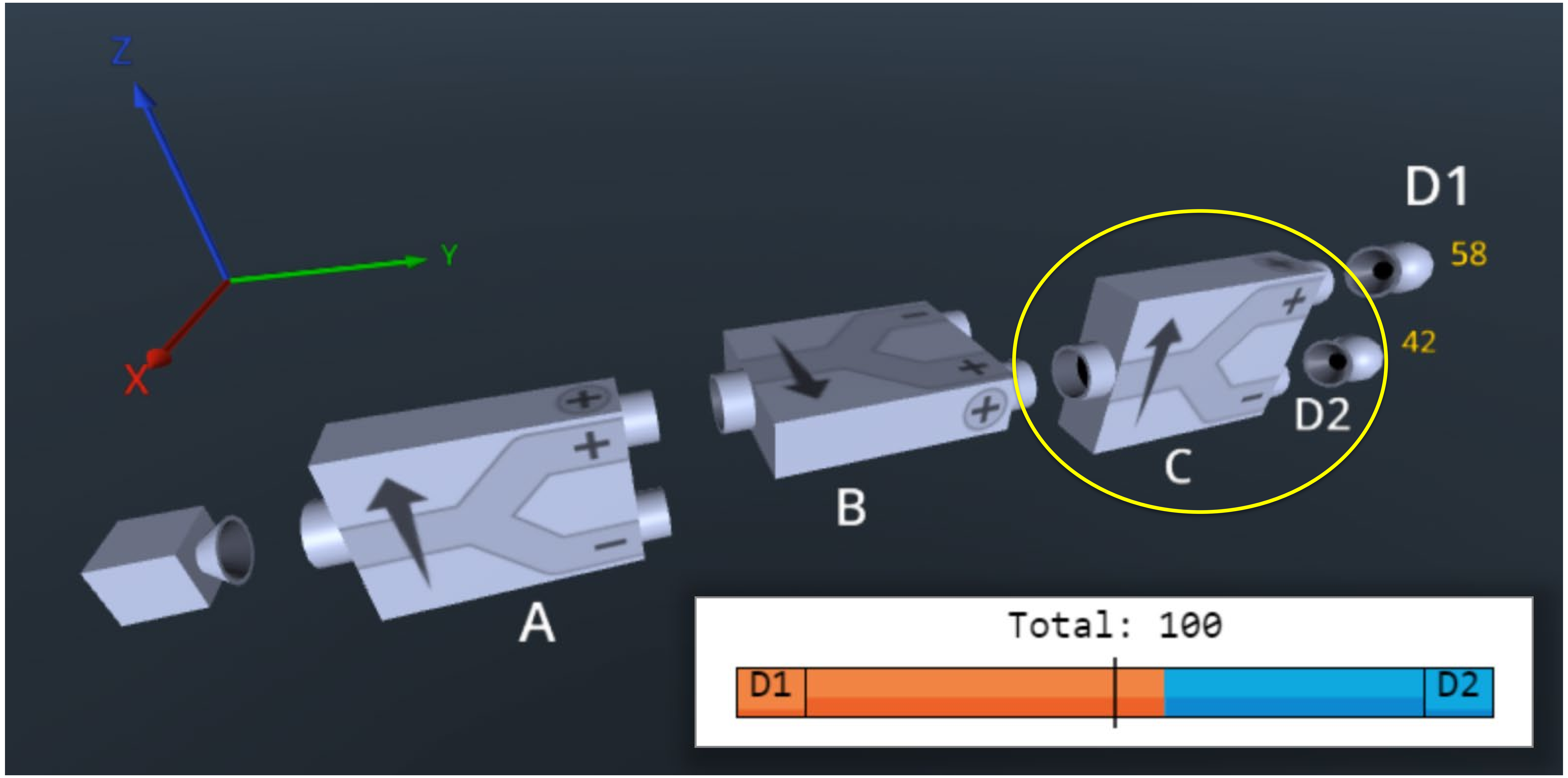
Z-analyzer

They involve state preparation followed by measurement



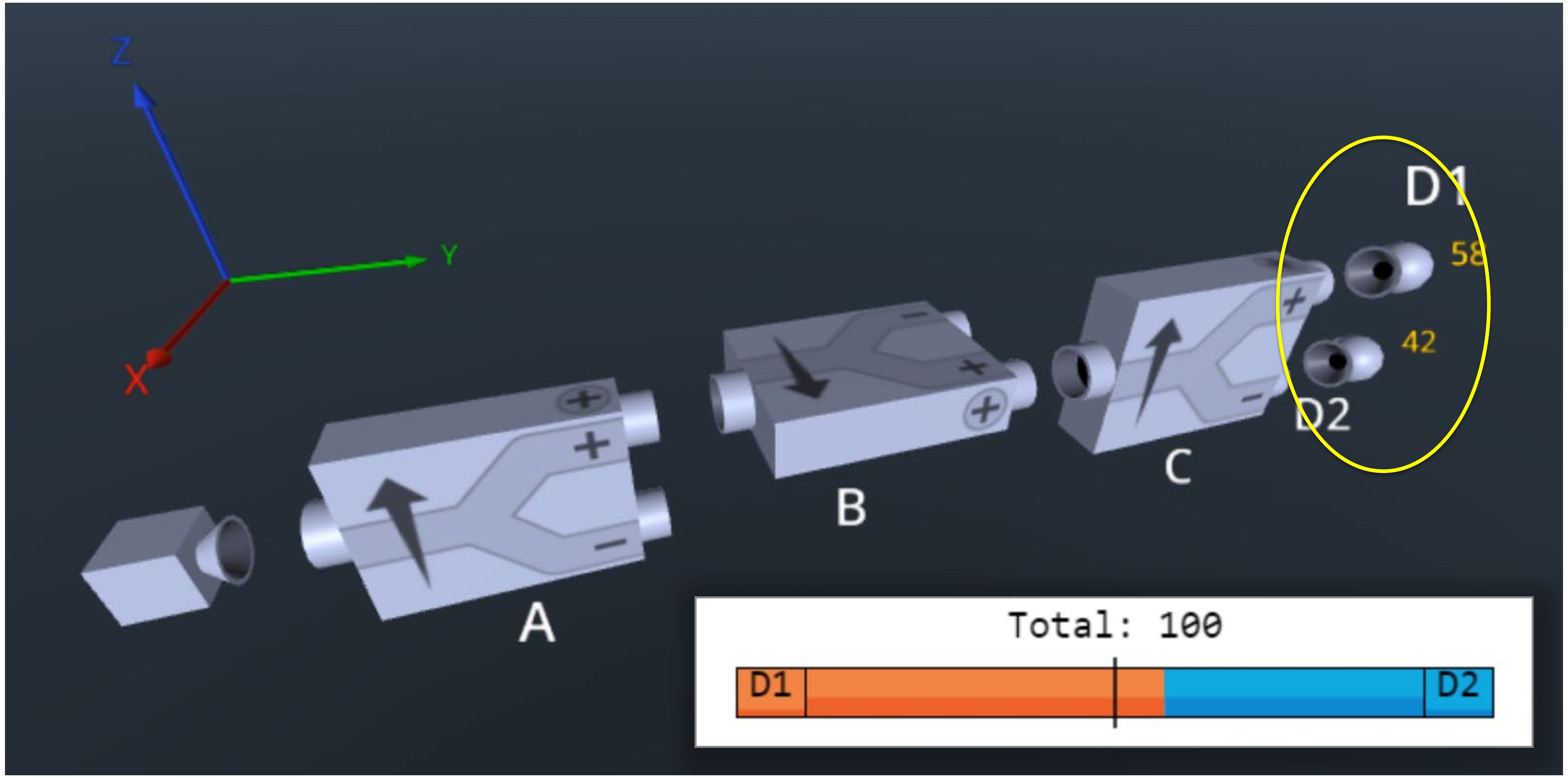
X-analyzer

They involve state preparation followed by measurement



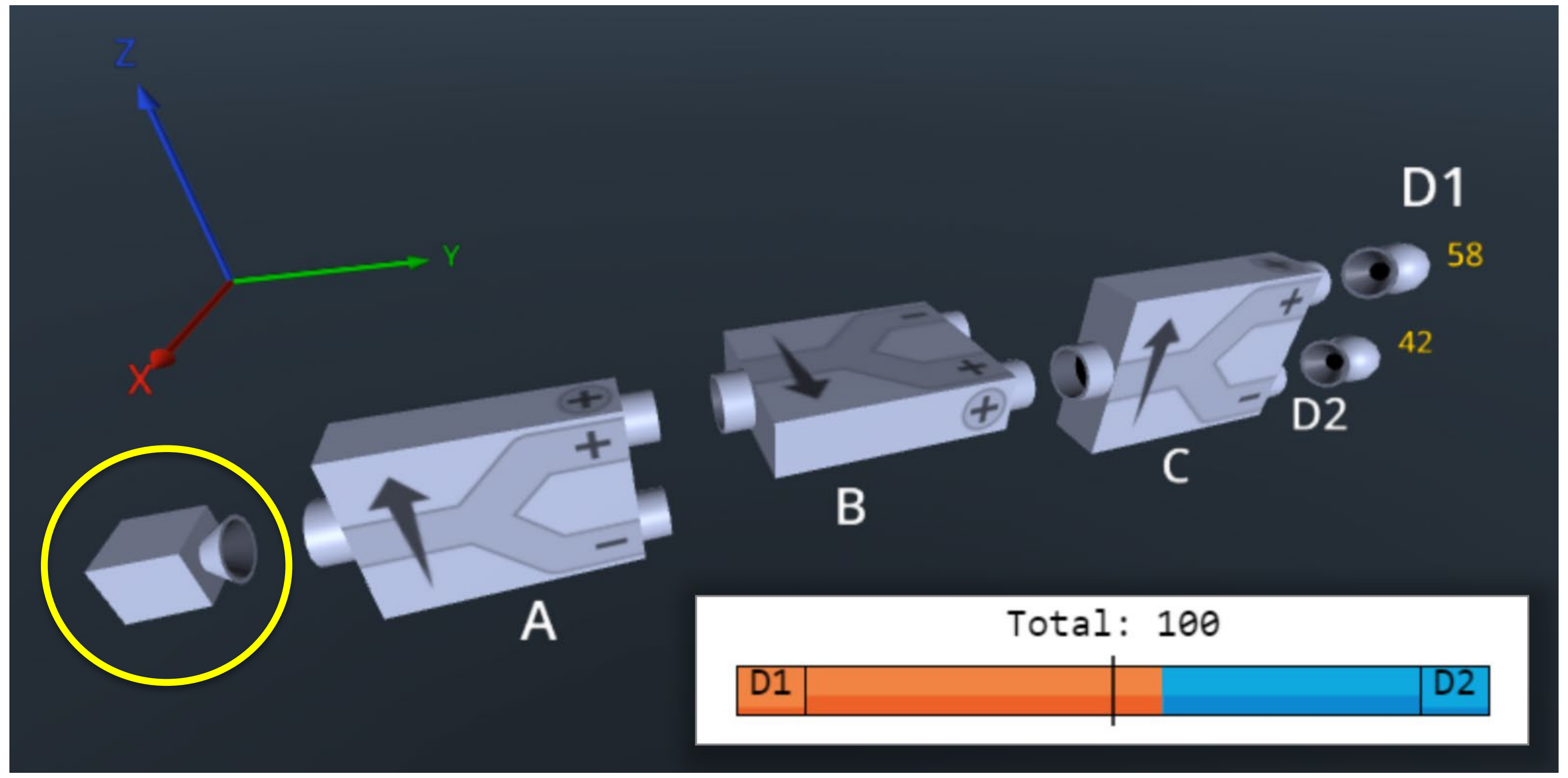
Z-analyzer

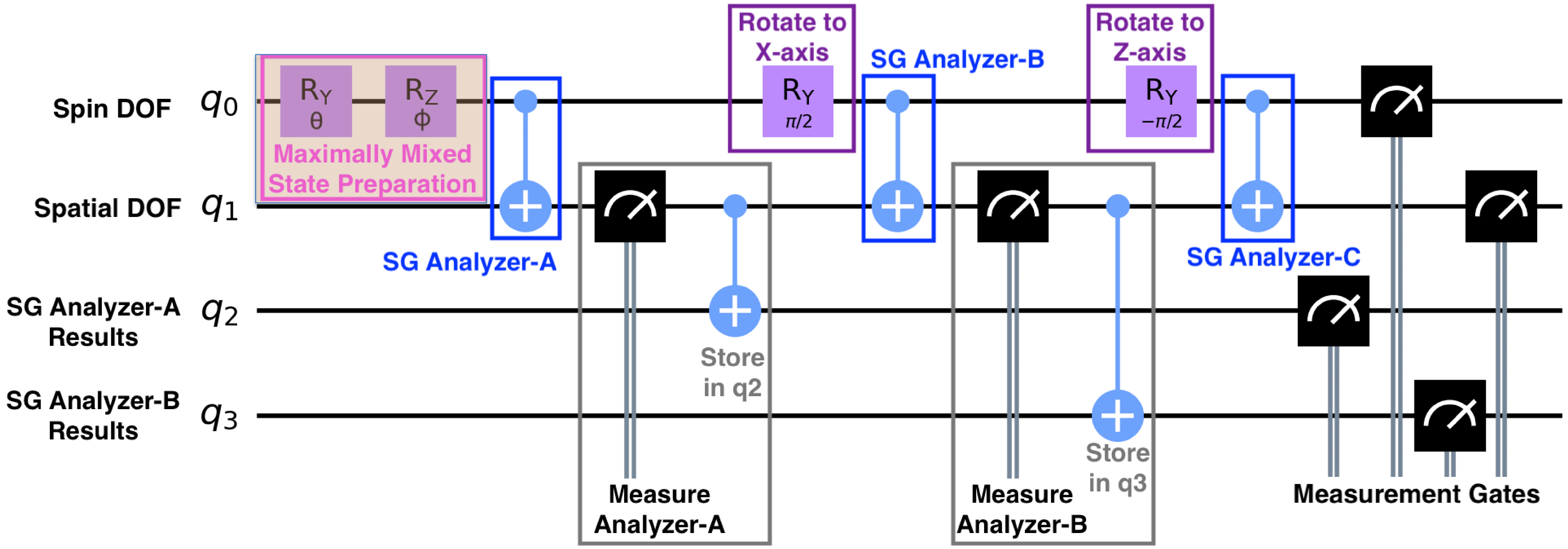
They involve state preparation followed by measurement



Detector

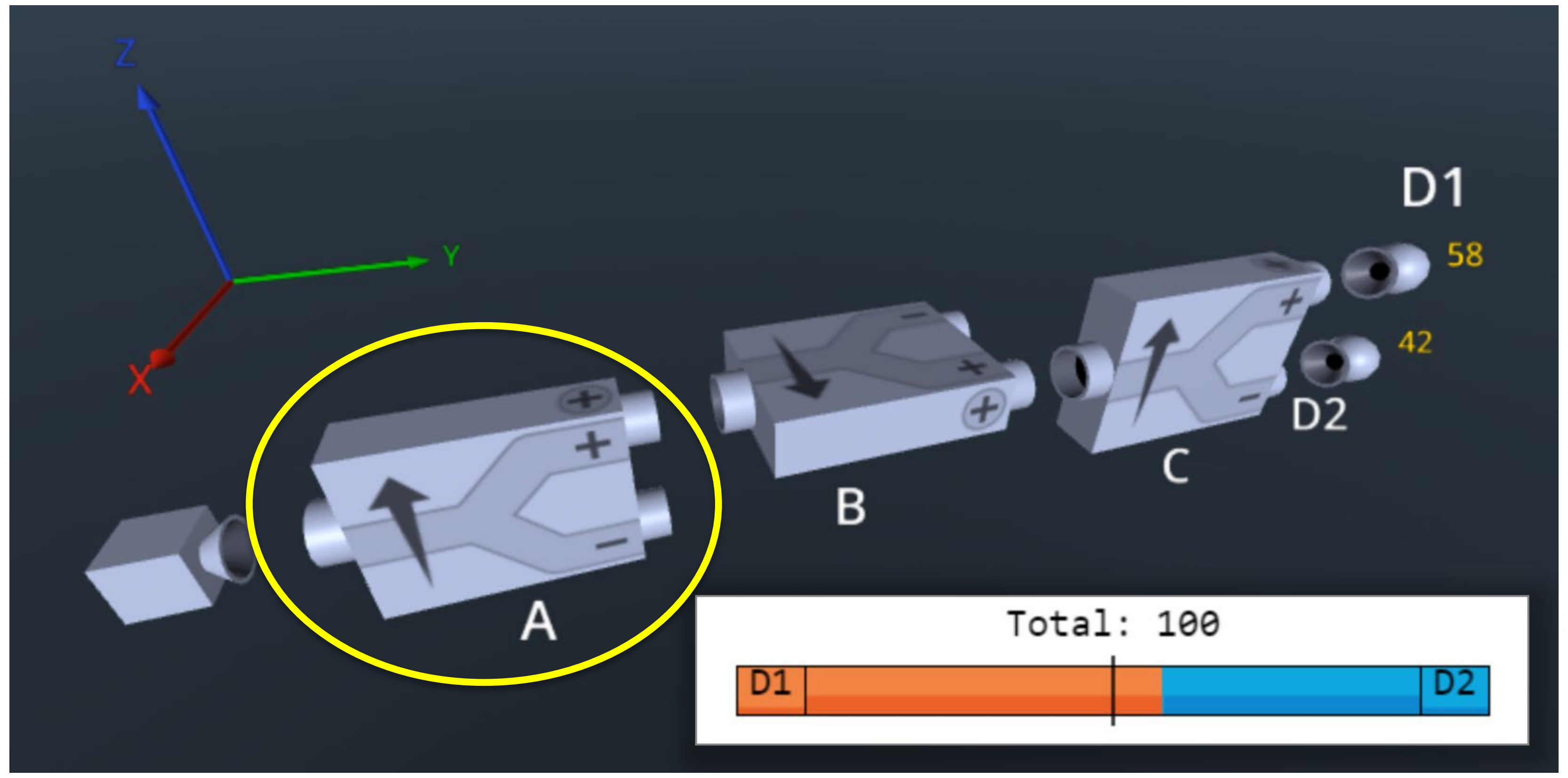
Quantum circuit and state

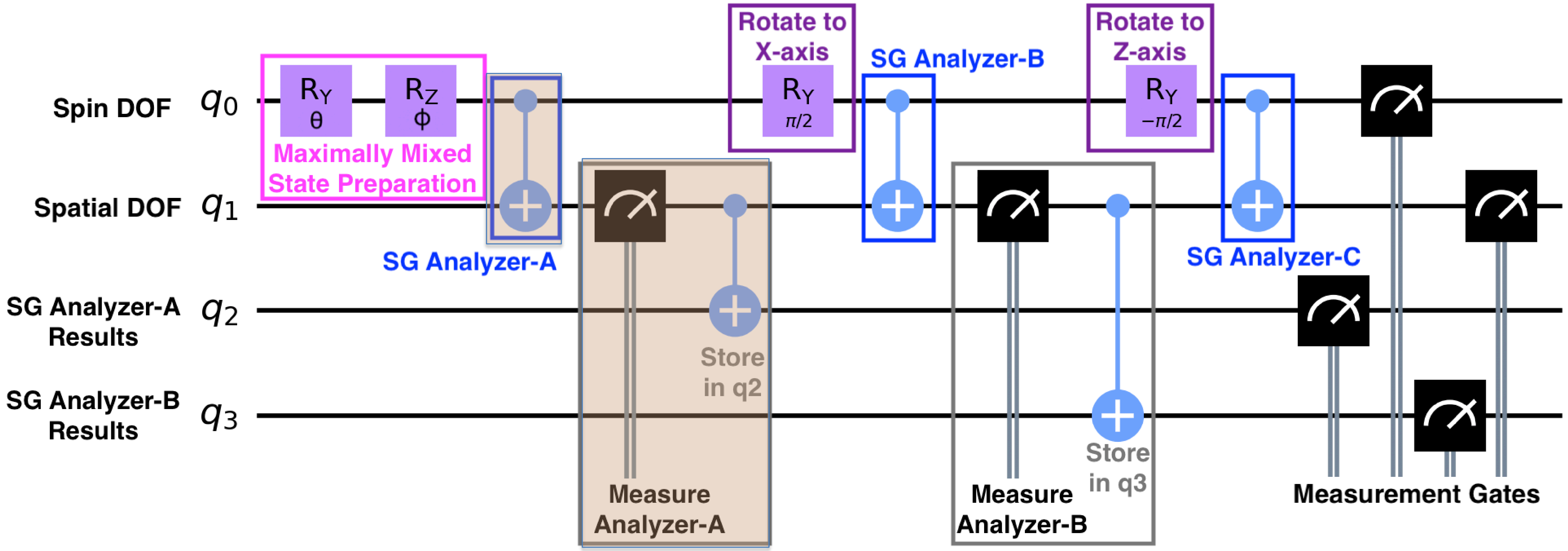




$$|\uparrow\rangle_z \rightarrow \int_{-1}^{1} d\cos\theta \int_0^{2\pi} d\phi \; |\uparrow\rangle_{\theta,\phi} \; (\text{maximally mixed state})$$

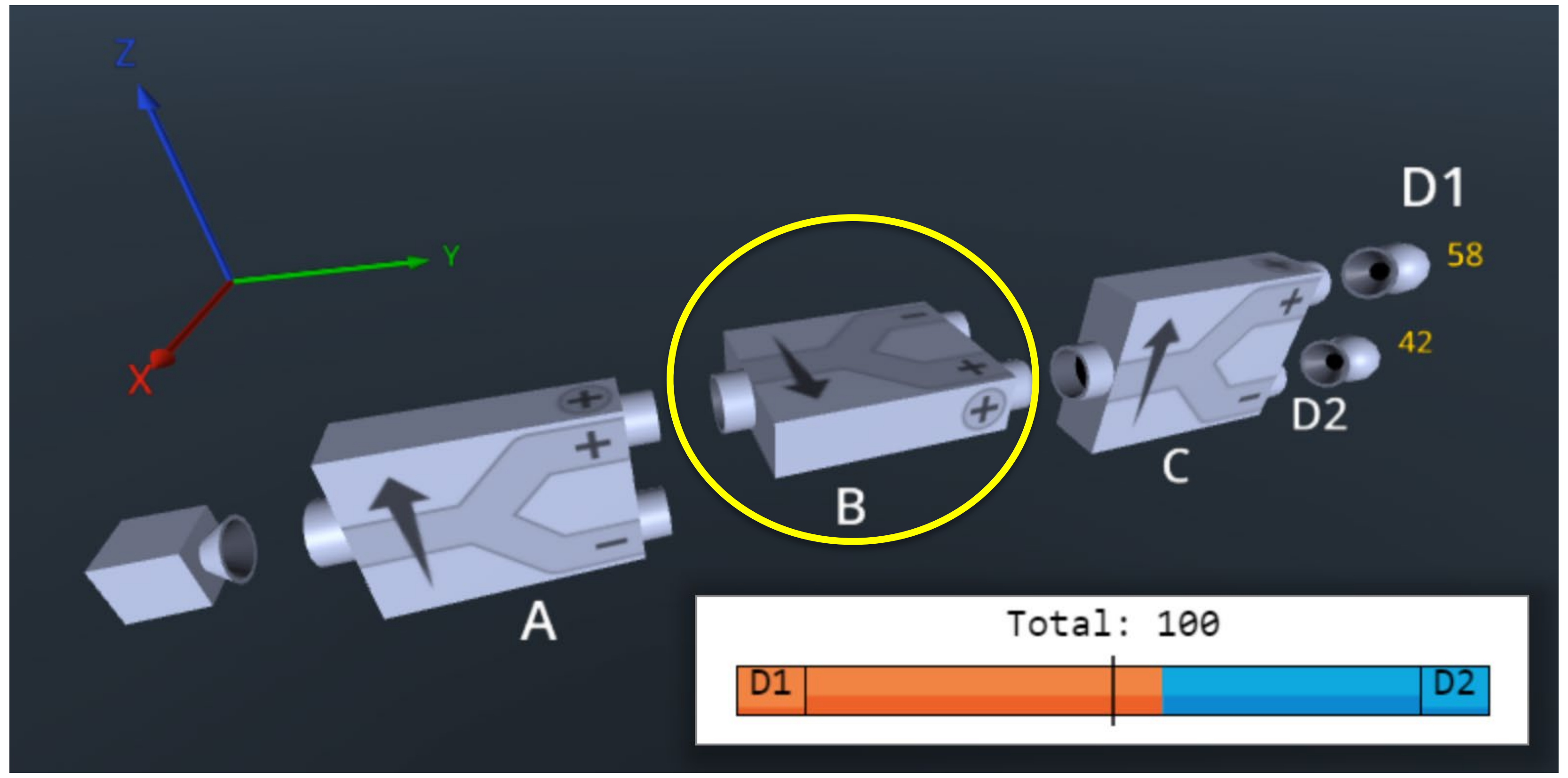
Quantum circuit and state

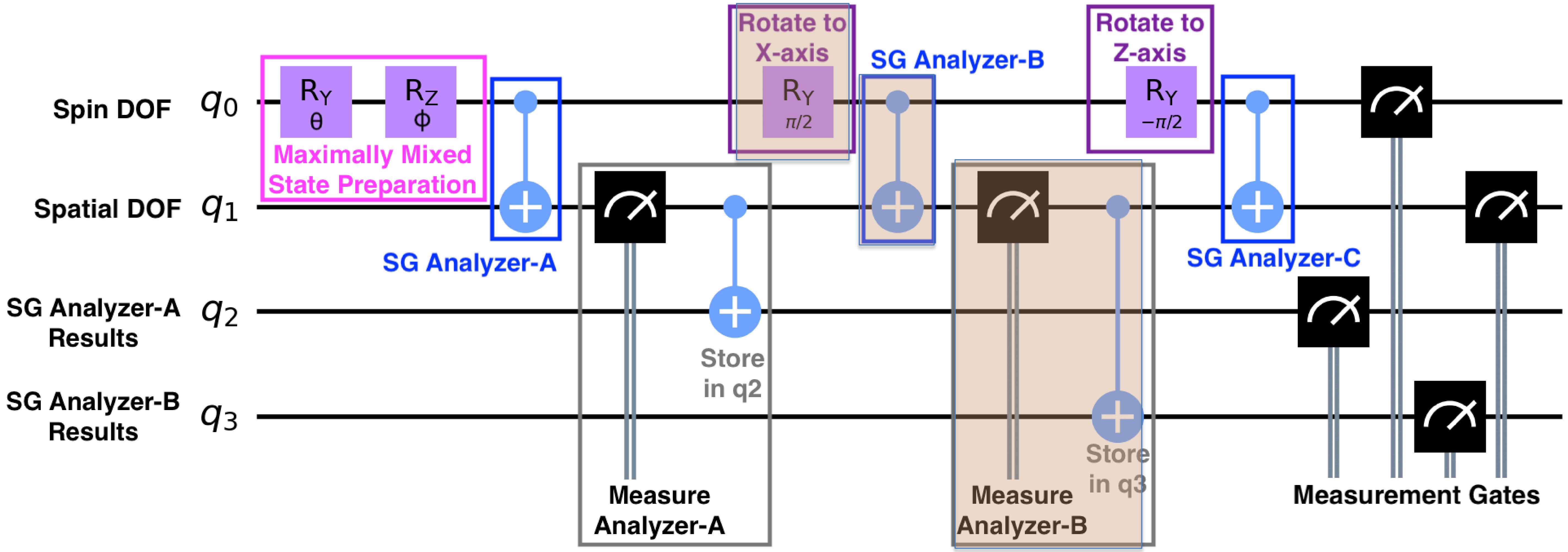




$$\int_{-1}^{1} d\cos\theta \int_{0}^{2\pi} d\phi\ |\uparrow\rangle_{\theta,\phi} \rightarrow |\uparrow\rangle_z \otimes |up\rangle \otimes |D_z\rangle$$

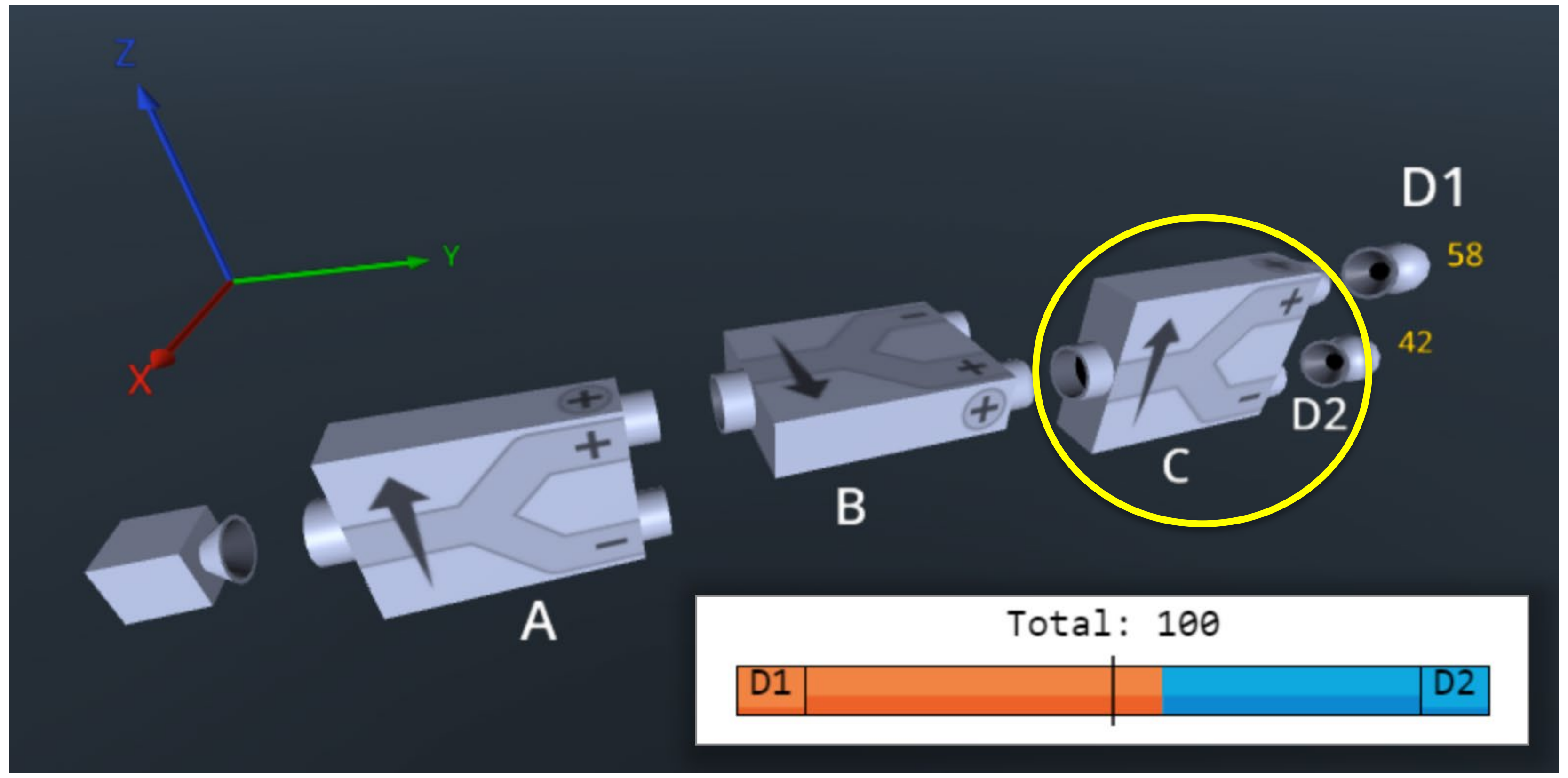
Quantum circuit and state

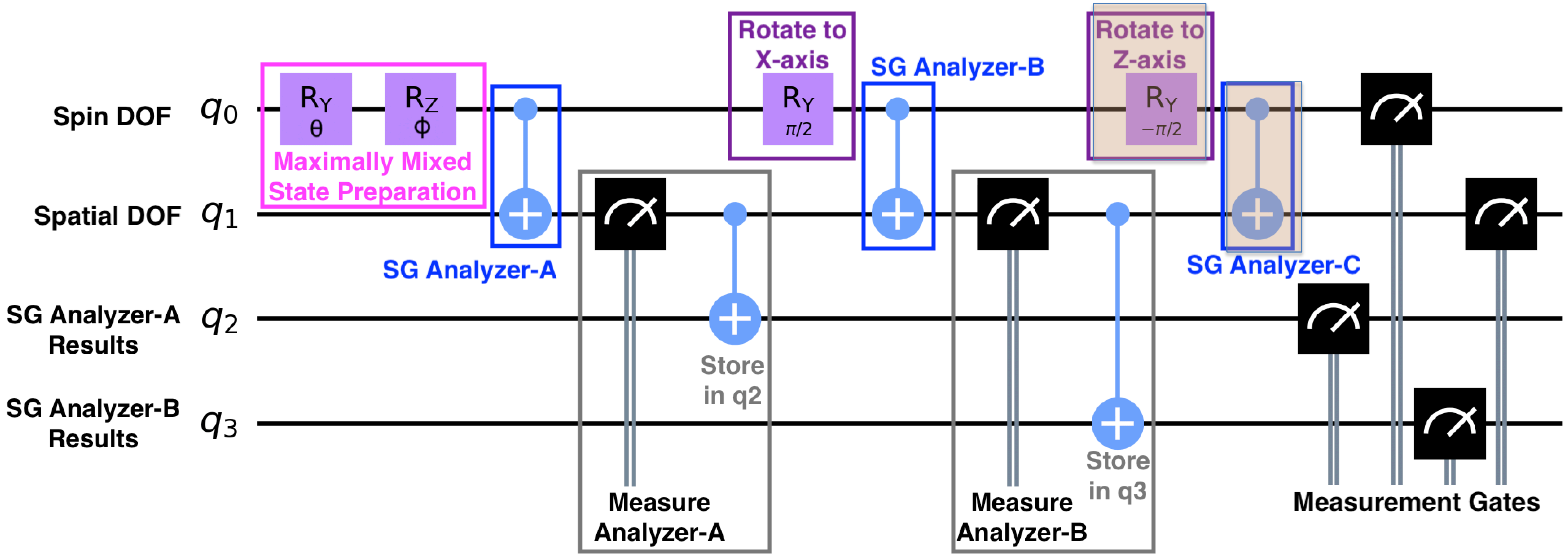




$$|\uparrow\rangle_z \otimes |up\rangle \otimes |D_z\rangle \rightarrow |\uparrow\rangle_x \otimes |right\rangle \otimes |D_x\rangle$$

Quantum circuit and state

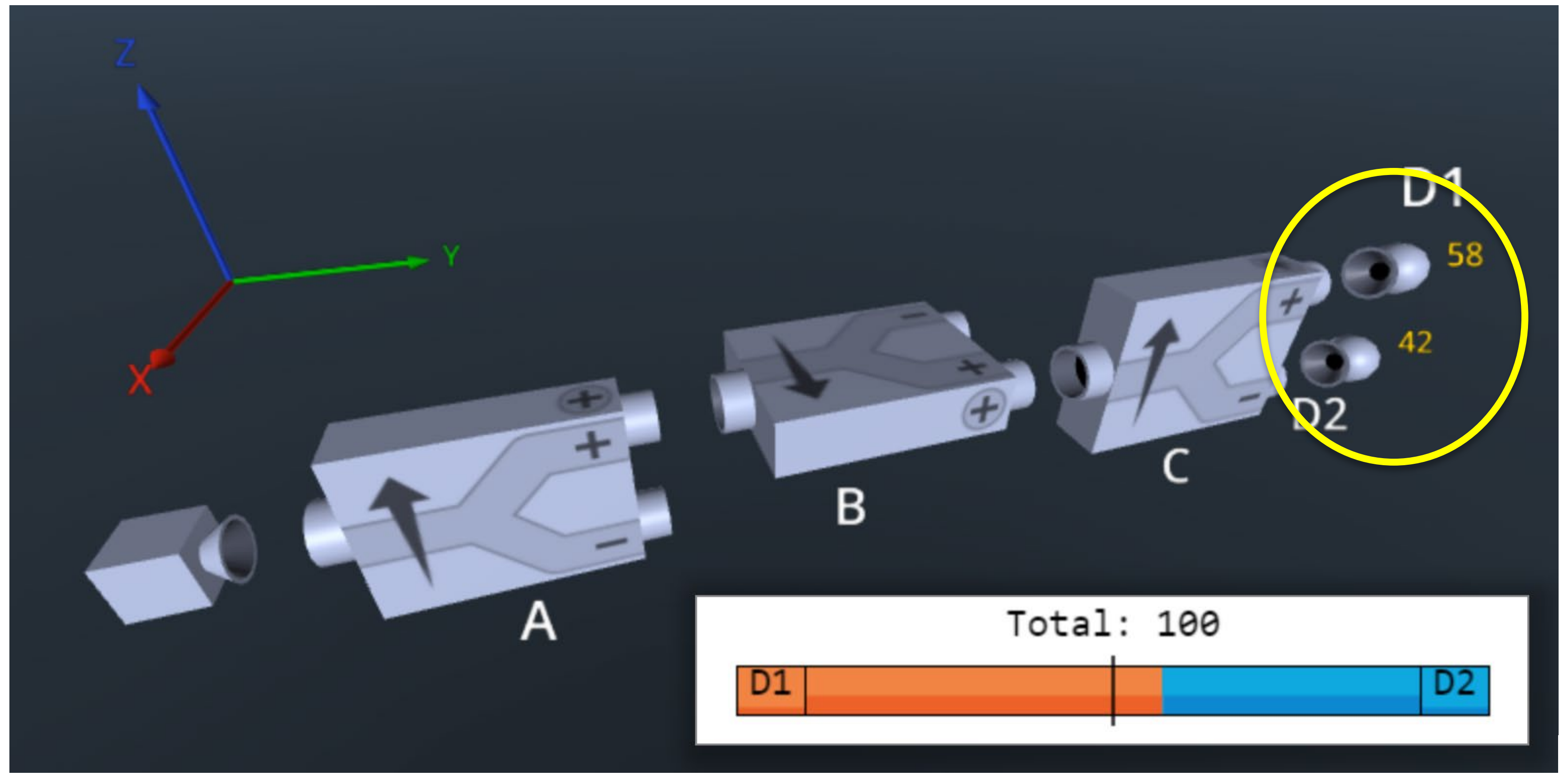


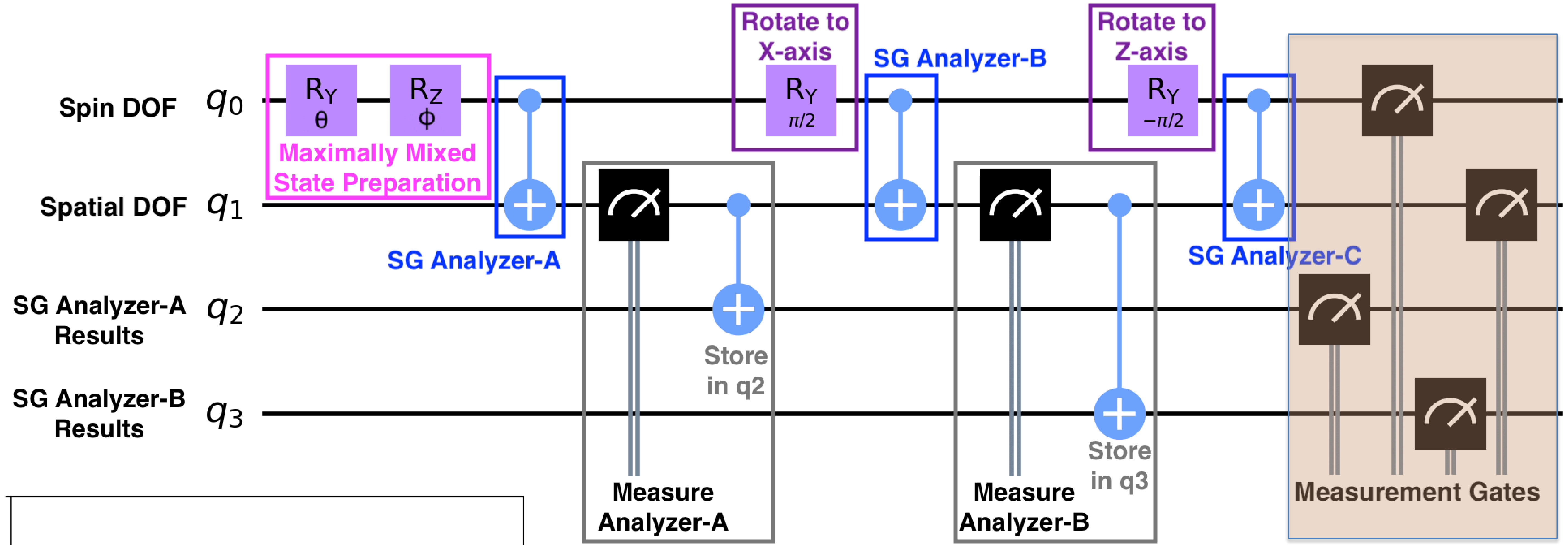


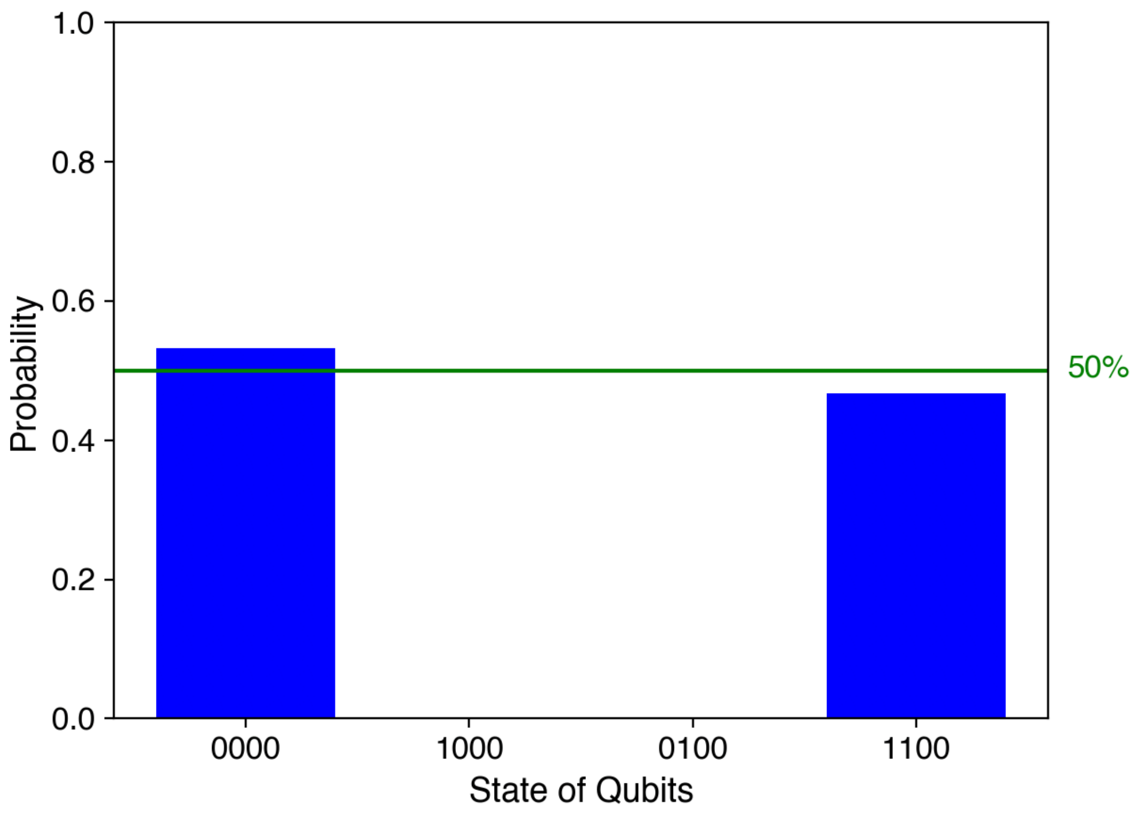
$$|\uparrow\rangle_x \otimes |right\rangle \otimes |D_x\rangle$$

$$\rightarrow \frac{1}{\sqrt{2}}(|\uparrow\rangle_z \otimes |up\rangle + |\downarrow\rangle_z \otimes |down\rangle) \otimes |D_0\rangle$$

Quantum circuit and state

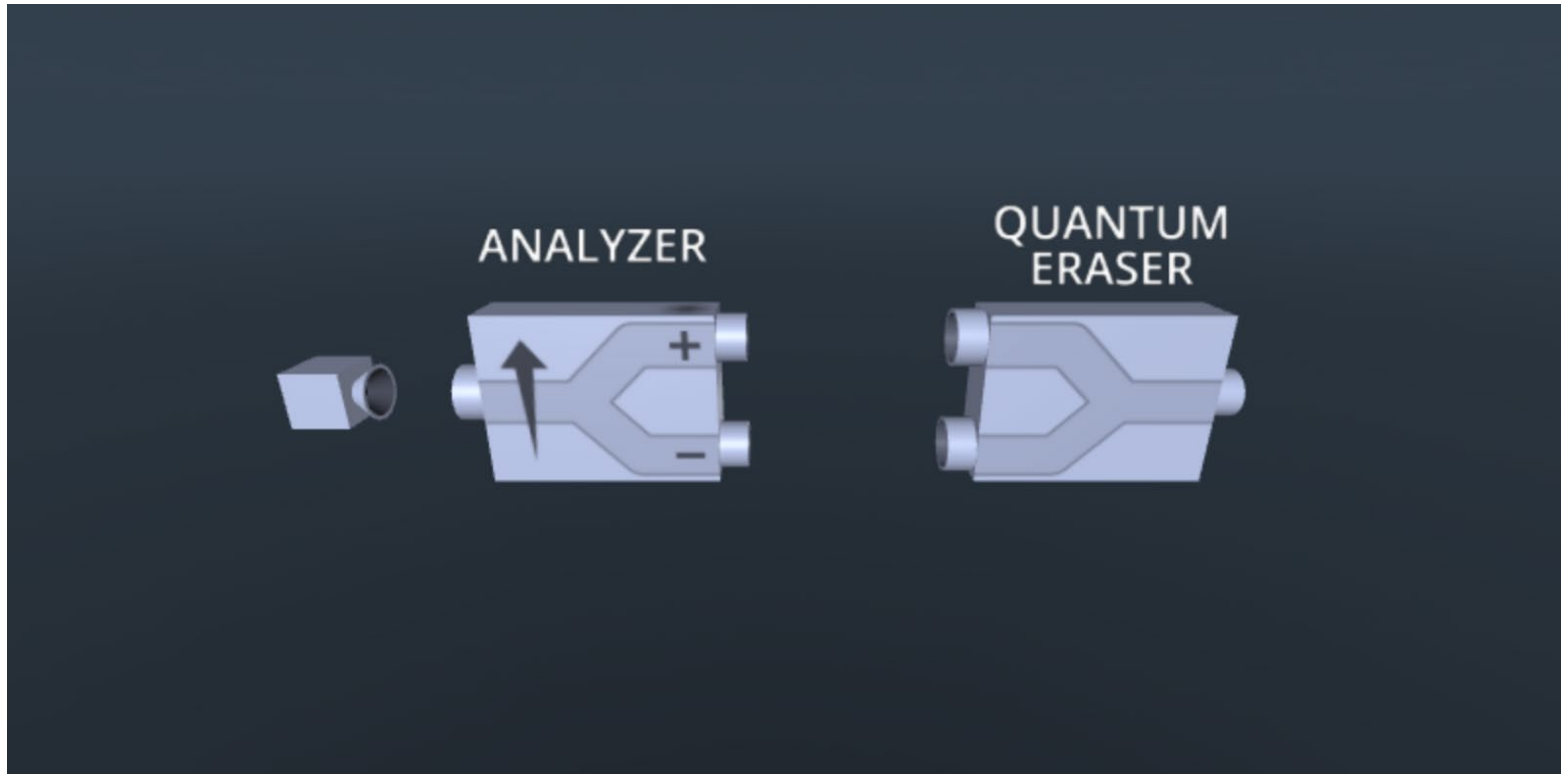


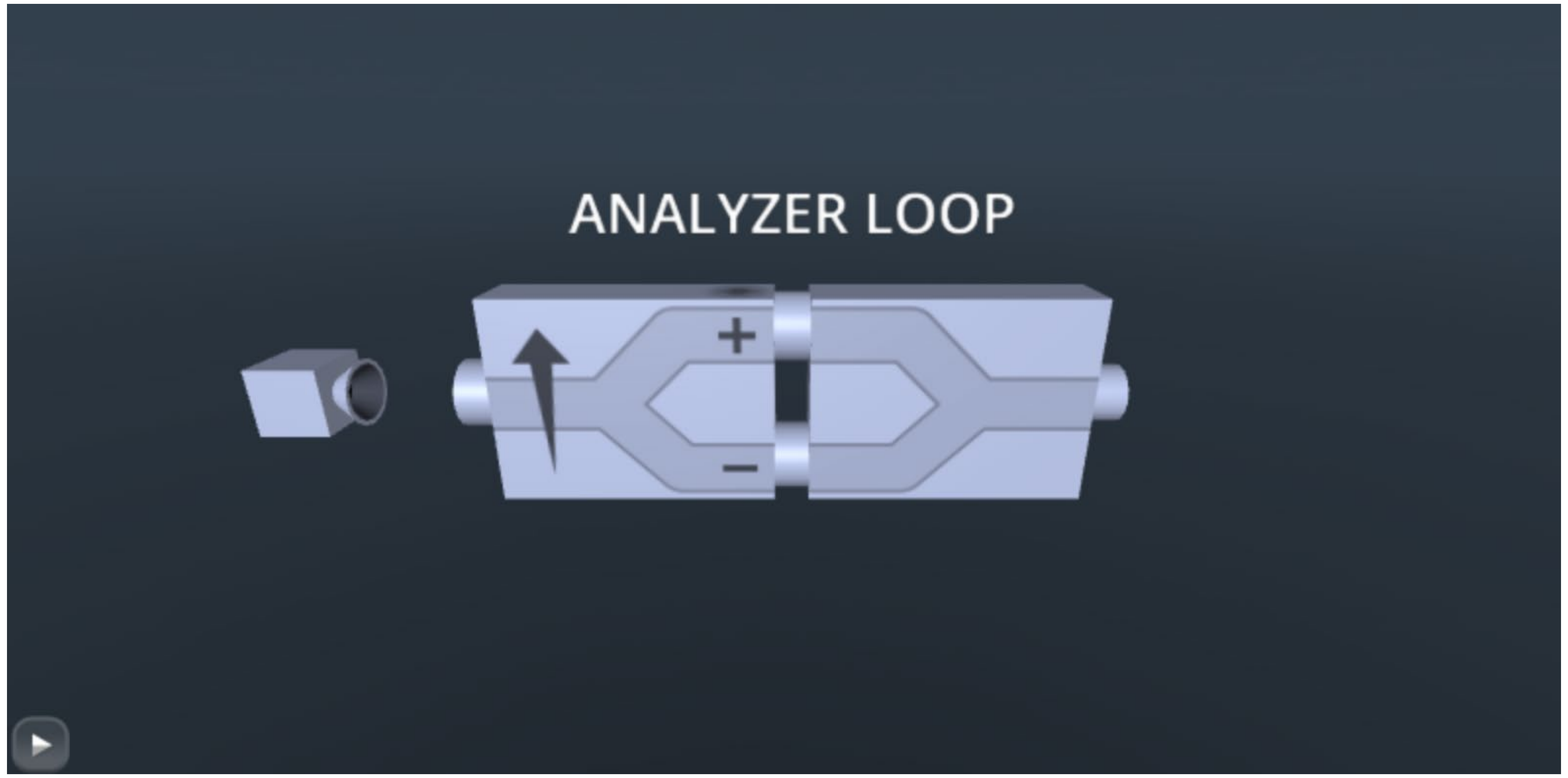




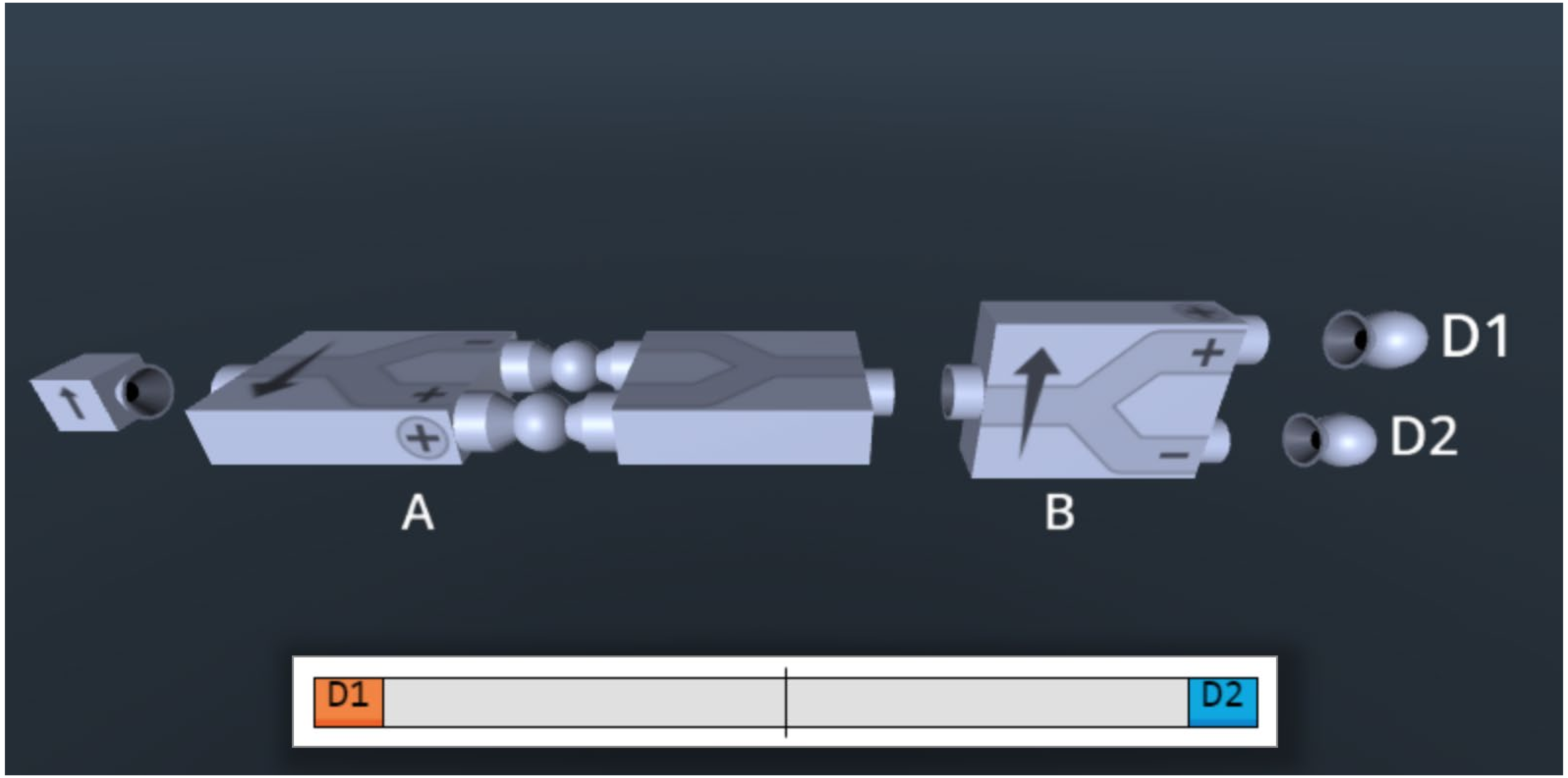
Analyzer loop

Analyzer loop

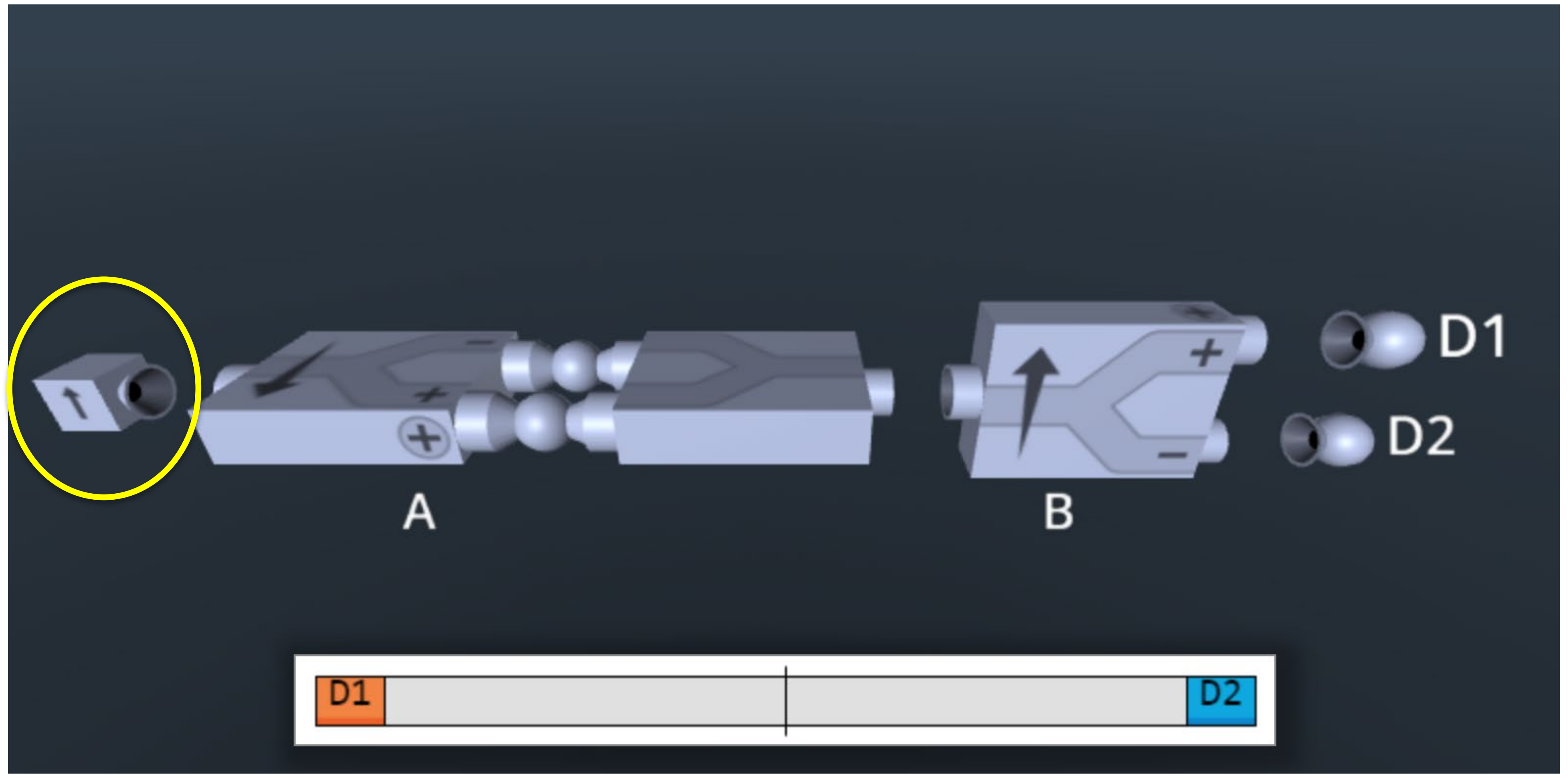


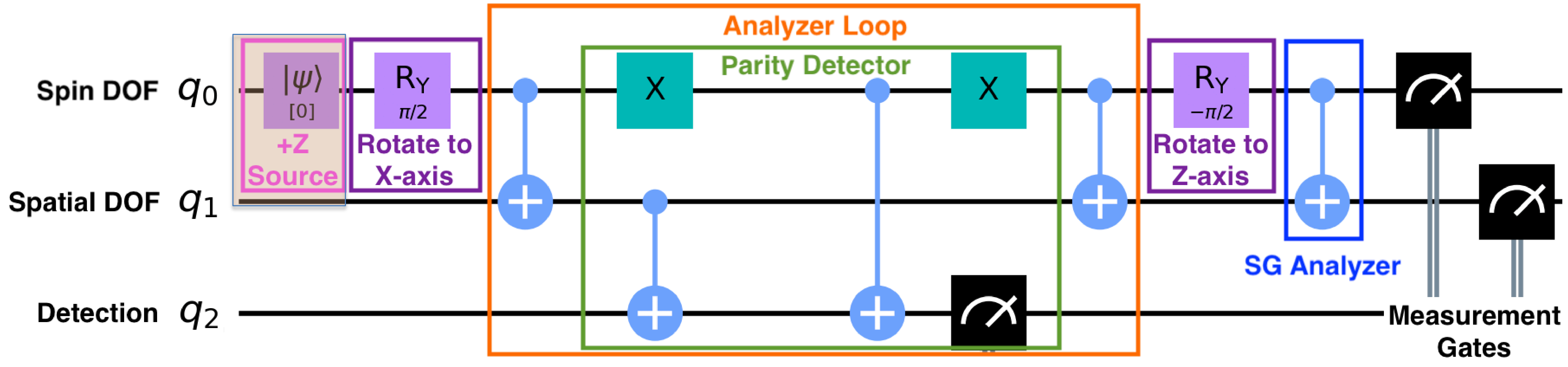


Analyzer loop with parity-check detectors



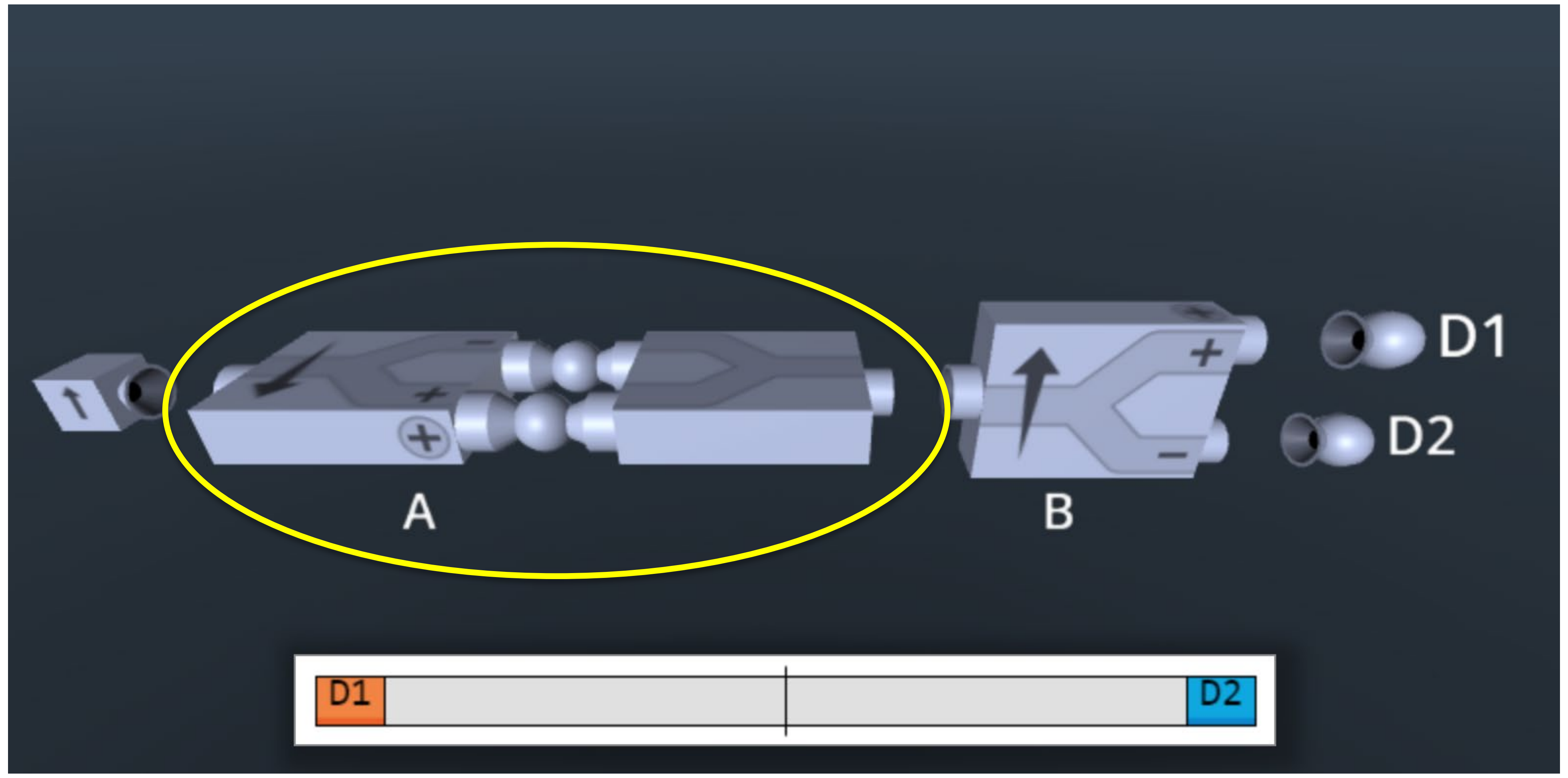
Parity detection

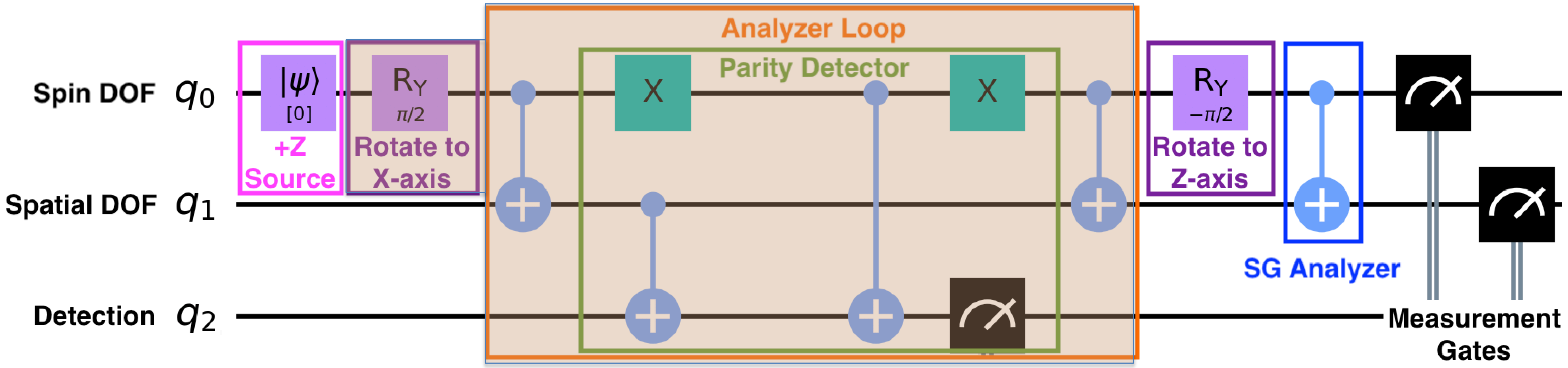




$$|\uparrow\rangle_z \otimes |center\ beam\rangle \otimes |D_0\rangle$$

Parity detection

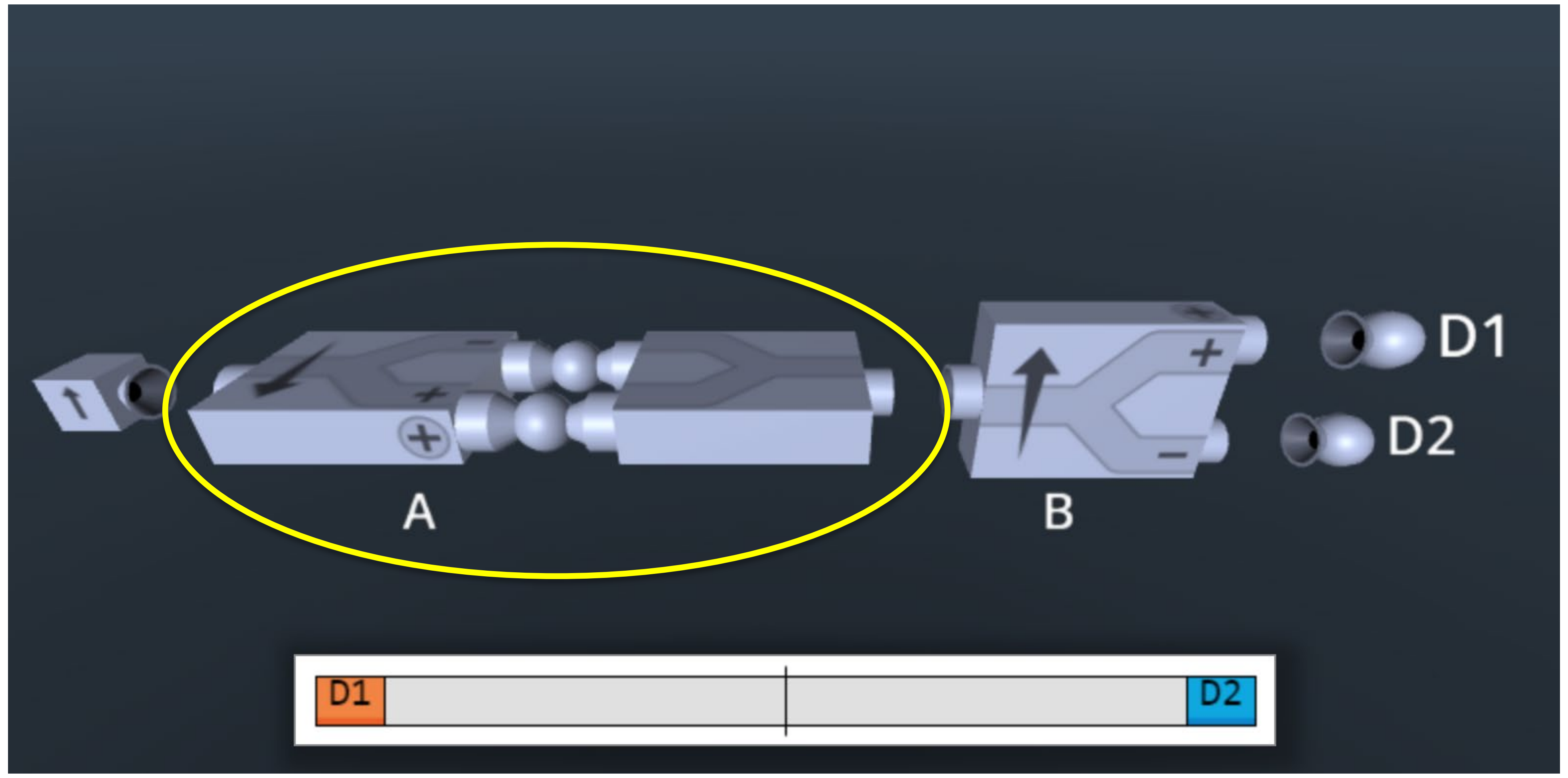


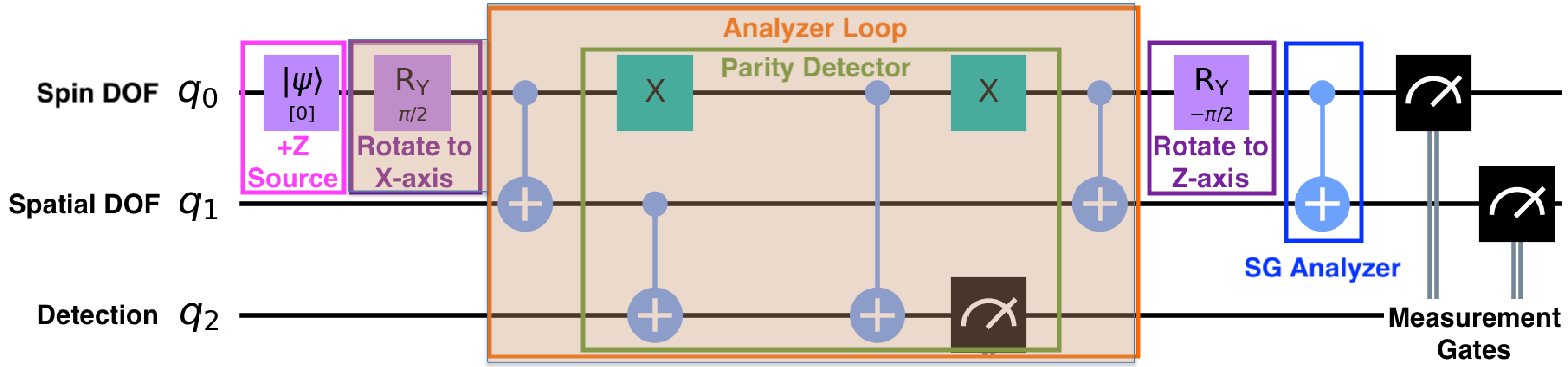


$$|\uparrow\rangle_z \otimes |center\ beam\rangle \otimes |D_0\rangle$$

$$\rightarrow \frac{1}{2}(|\uparrow\rangle_x \otimes |right\rangle + |\downarrow\rangle_x \otimes |left\rangle) \otimes |P_1\rangle + \frac{1}{2}(|\uparrow\rangle_x \otimes |left\rangle + |\downarrow\rangle_x \otimes |right\rangle) \otimes |P_0\rangle$$

Parity detection

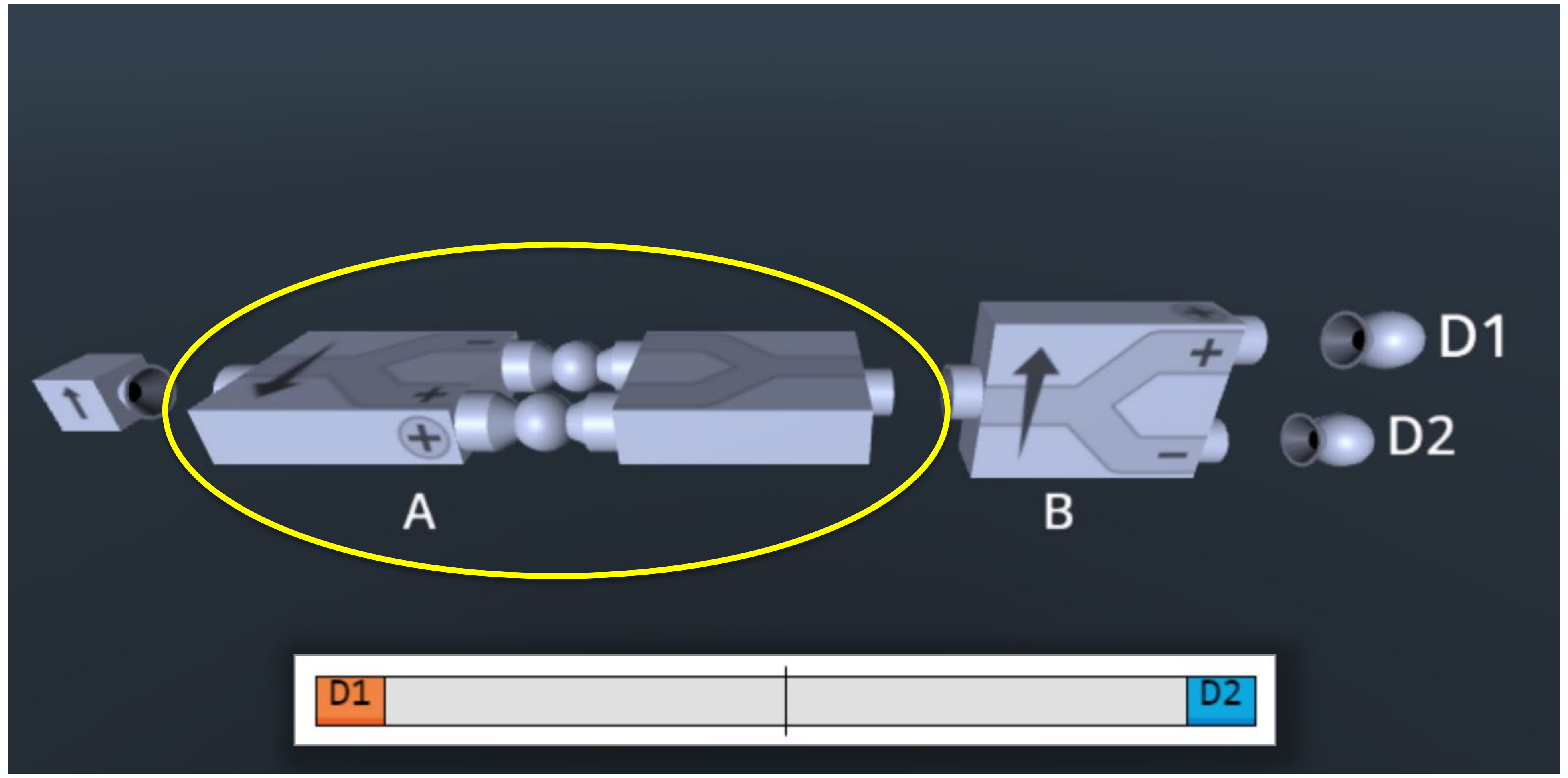


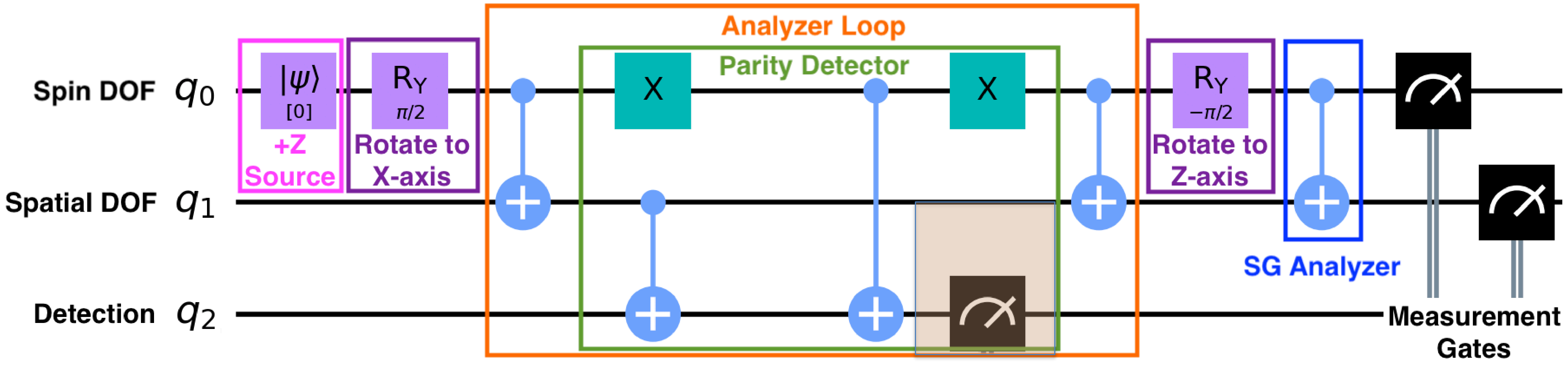


$$|\uparrow\rangle_z \otimes |center\ beam\rangle \otimes |D_0\rangle$$

$$\rightarrow \frac{1}{2}(|\uparrow\rangle_x \otimes |right\rangle + |\downarrow\rangle_x \otimes |left\rangle) \otimes |P_1\rangle + \frac{1}{2}(|\uparrow\rangle_x \otimes |left\rangle + |\downarrow\rangle_x \otimes |right\rangle) \otimes |P_0\rangle$$

Parity detection

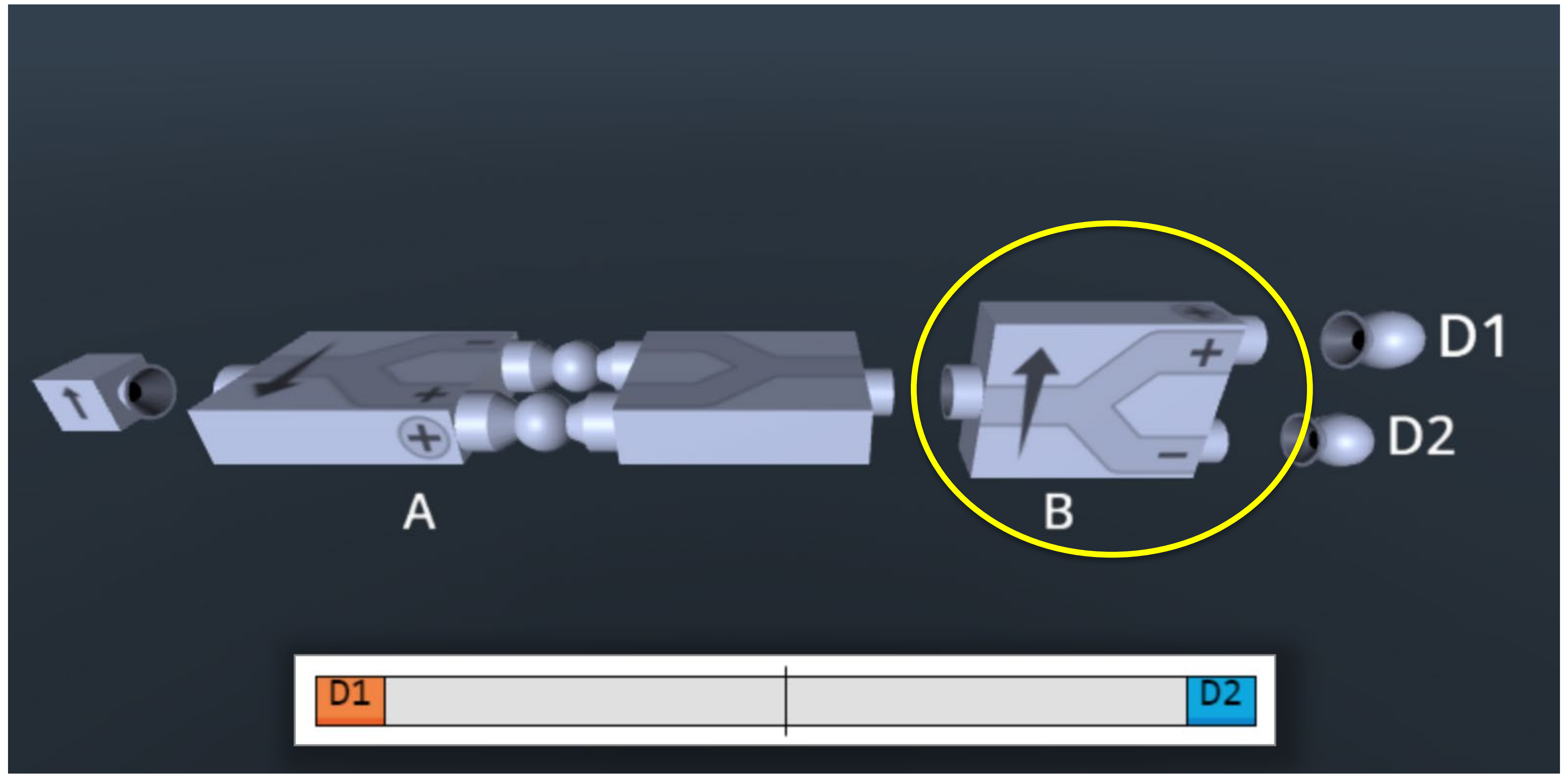


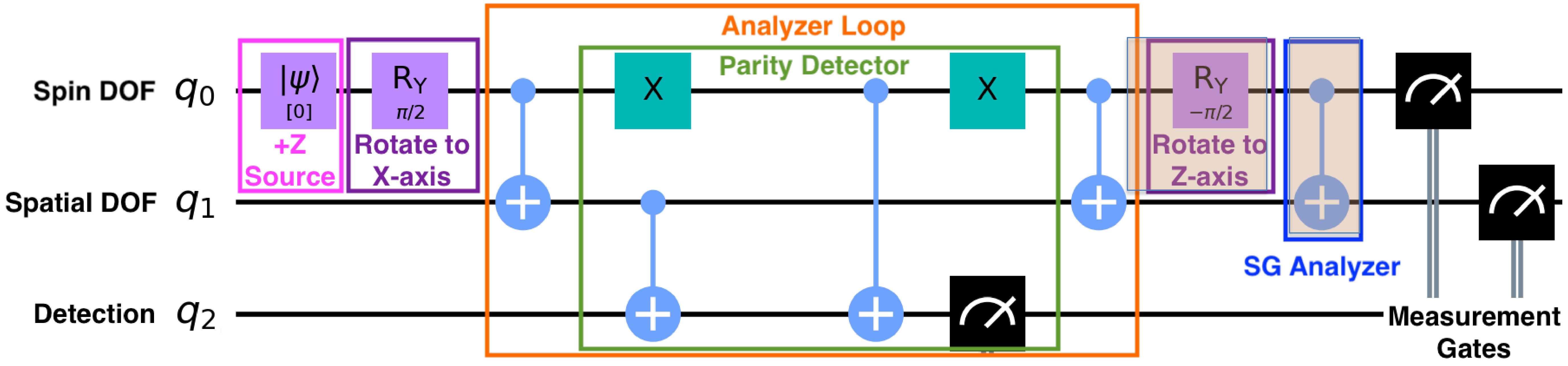


Post-selection

$$|\uparrow\rangle_z \otimes |center\ beam\rangle \otimes |D_0\rangle$$
$$\rightarrow \frac{1}{2}(|\uparrow\rangle_x \otimes |right\rangle + |\downarrow\rangle_x \otimes |left\rangle) \otimes |P_1\rangle$$

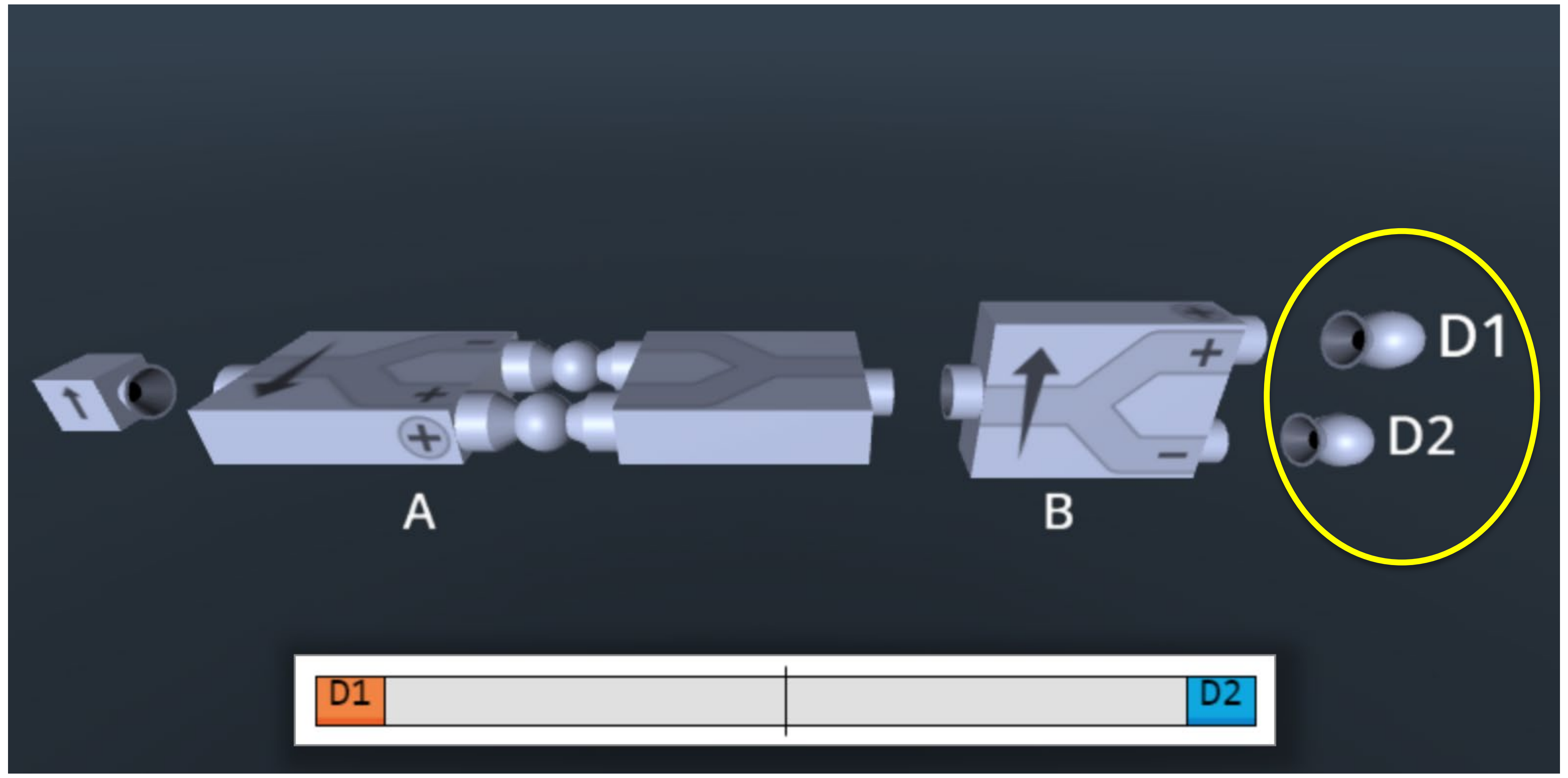
Parity detection

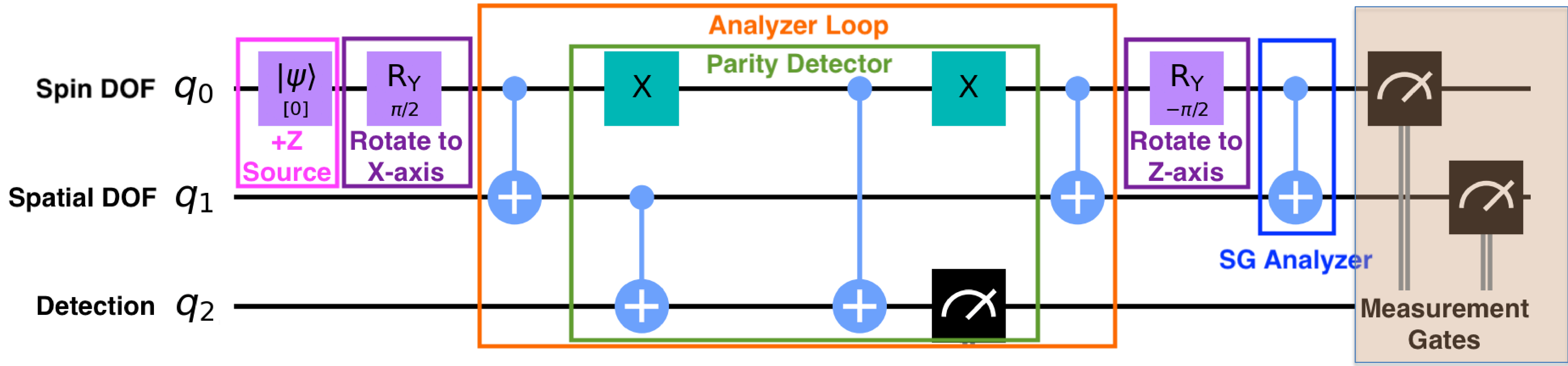


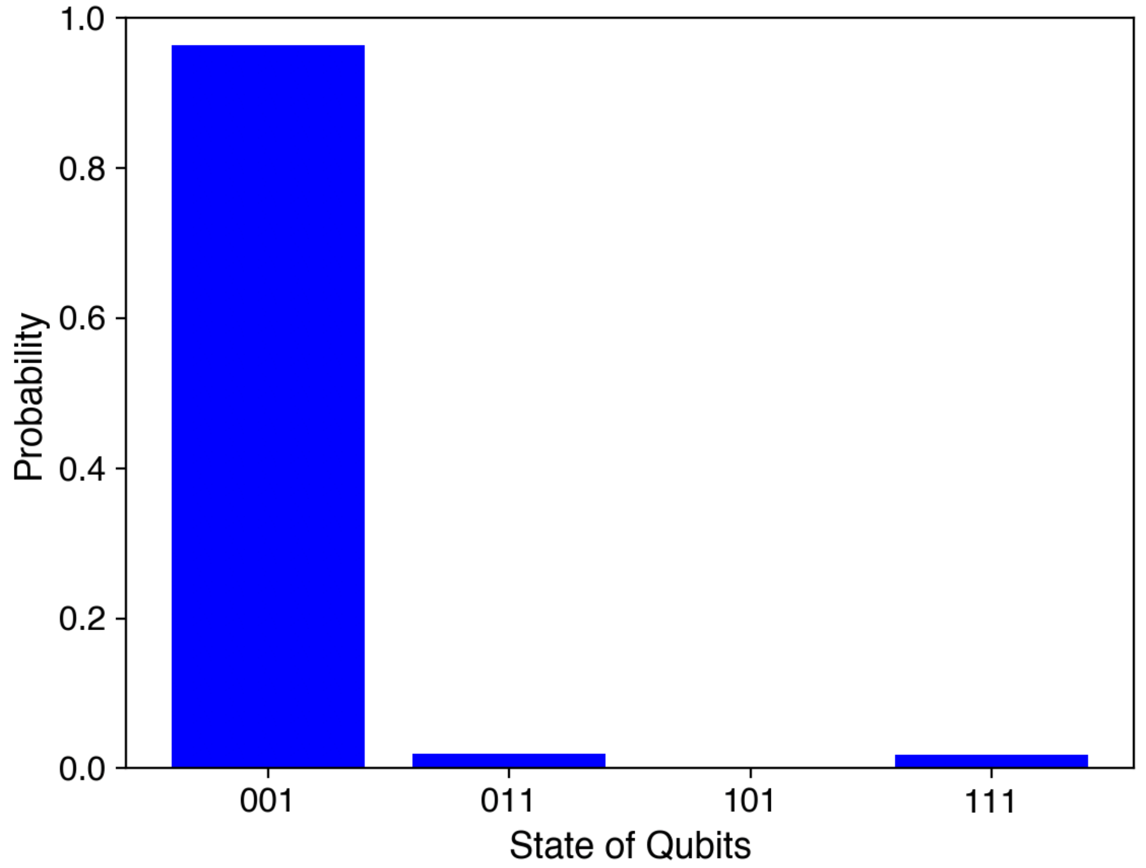


$$\frac{1}{2}(|\uparrow\rangle_x \otimes |right\rangle + |\downarrow\rangle_x \otimes |left\rangle) \otimes |P_1\rangle \rightarrow \frac{1}{\sqrt{2}}|\uparrow\rangle_z \otimes |up\rangle \otimes |P_1\rangle$$

Parity detection







Parity detection:

Preserves the superposition
and
corrects errors

Additional experiments:

(1) Delayed choice experiments
(2) Watched versus unwatched
(3) Bell experiments

This talk is a partial summary of the undergraduate thesis work of Kyla Fraser

What are other experiments we can try:

What are other experiments we can try:

Two and three slit experiments

What are other experiments we can try:

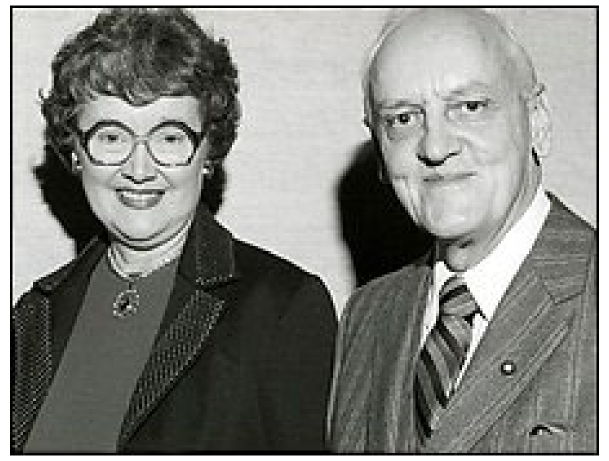
Two and three slit experiments

Mach-Zehnder interferometer

What are other experiments we can try:

Two and three slit experiments
Mach-Zehnder interferometer
Decoherence channels

Thanks to



Resources

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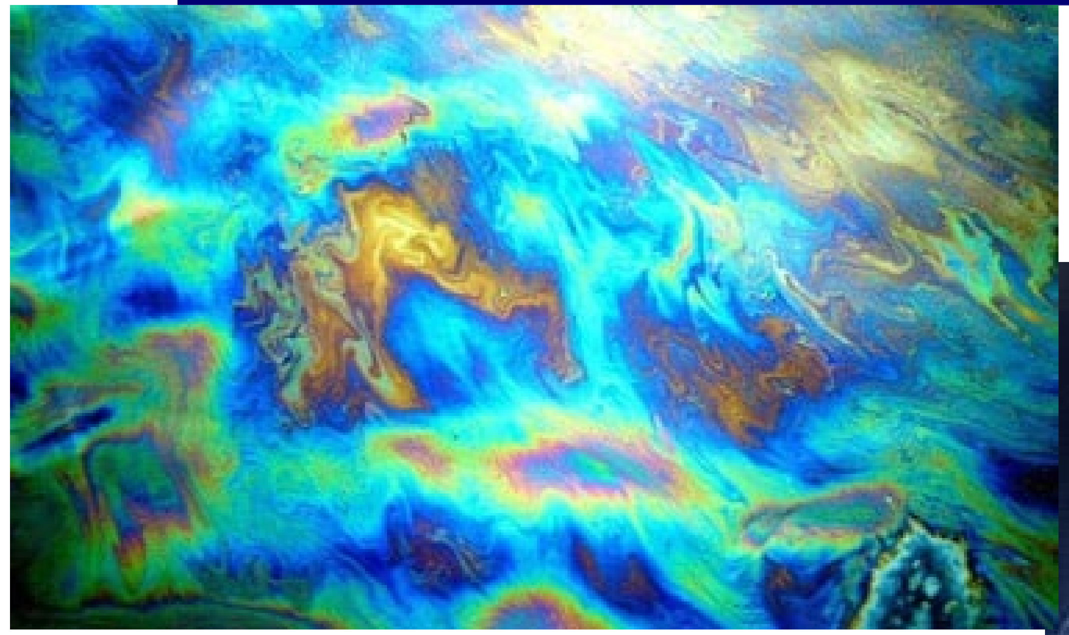
Quantum operator mechanics

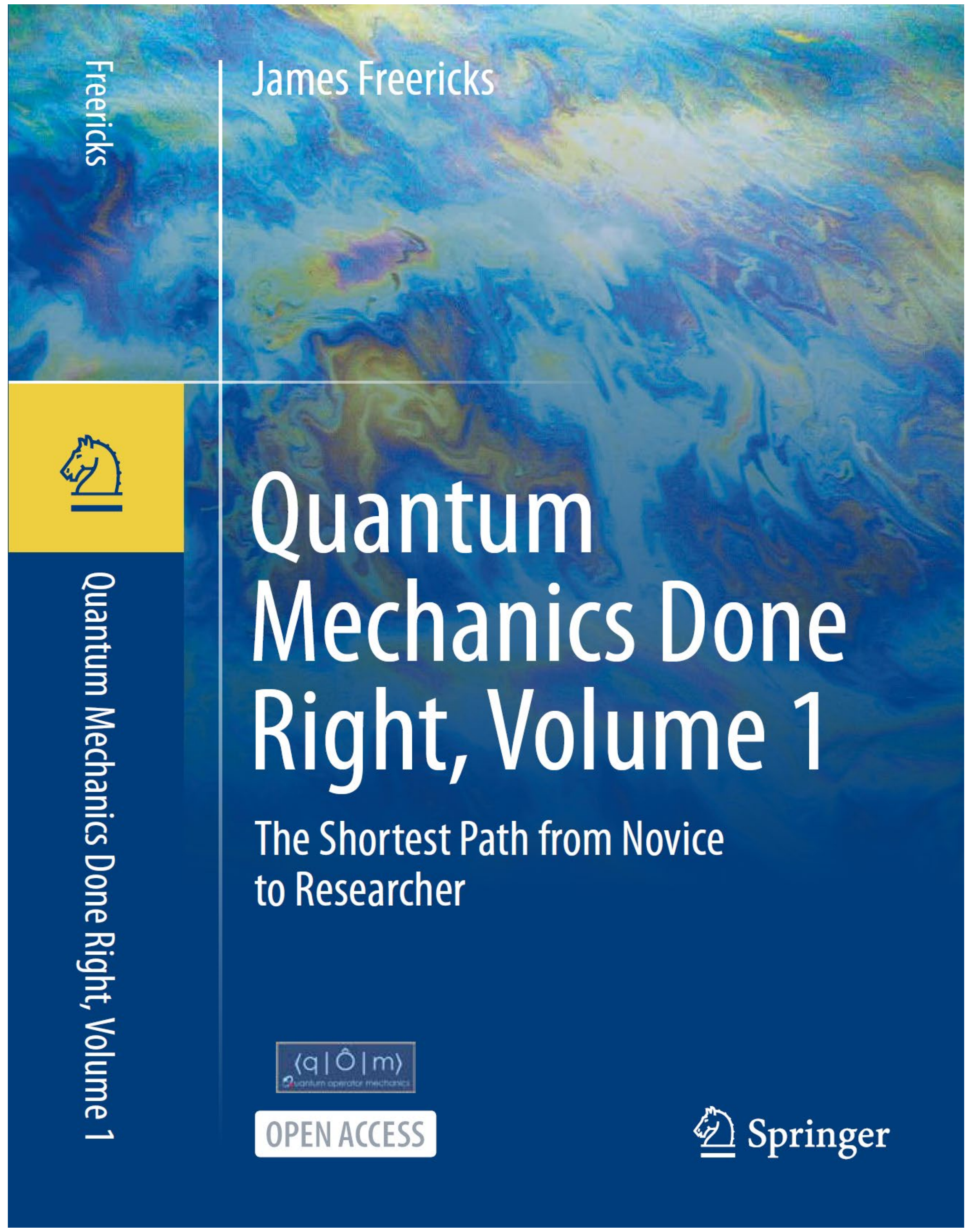
https://quantum.georgetown.domains

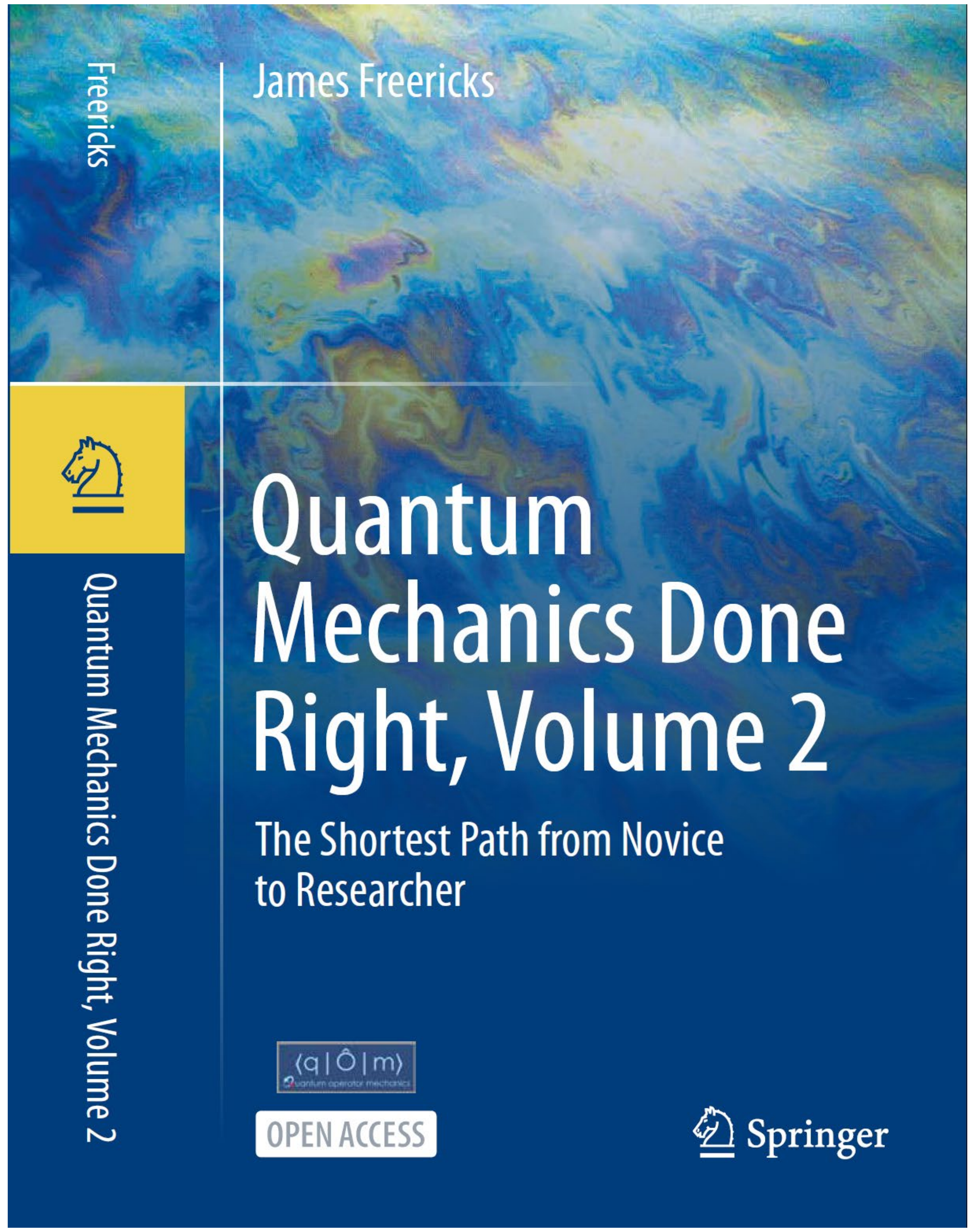


https://www.edx.org/course/quantum-mechanics

https://www.edx.org/course/quantum-mechanics-for-everyone

To be released this summer: *Quantum Mechanics Done Right*





Both will be open access for the electronic versions