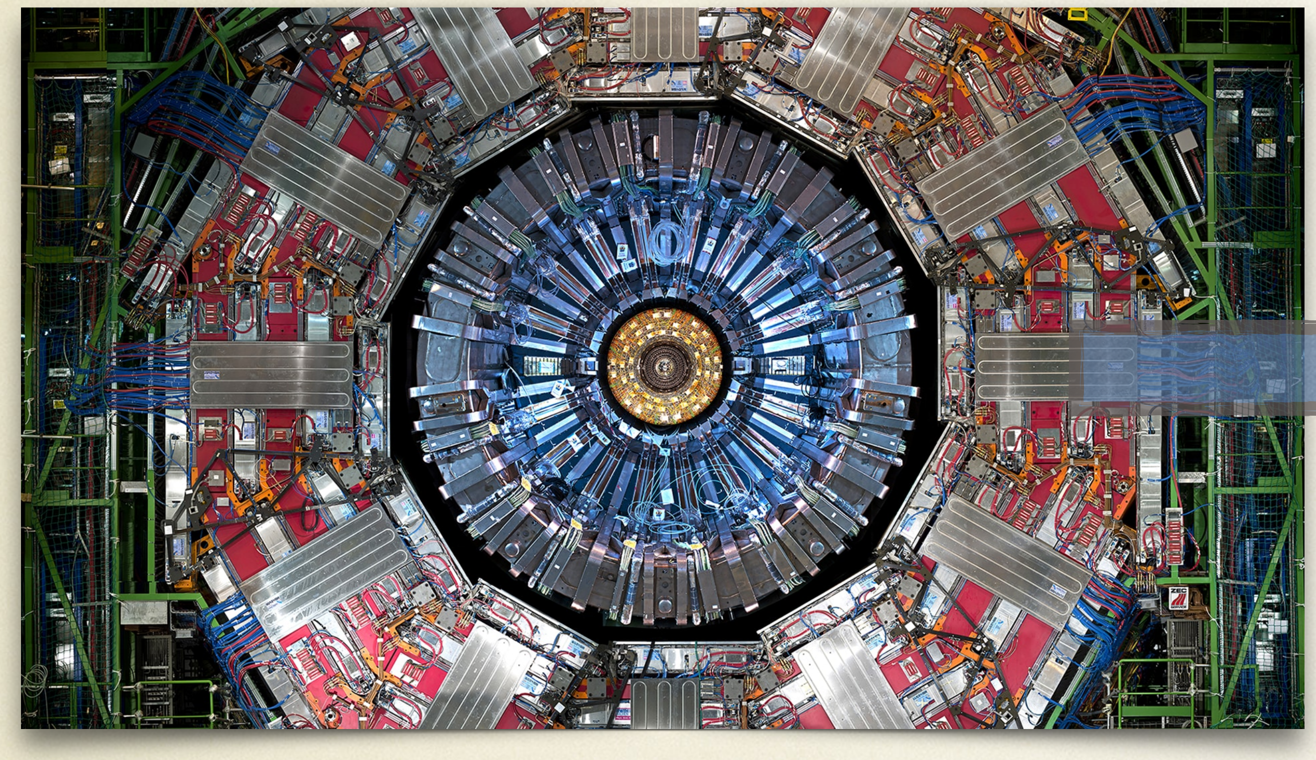
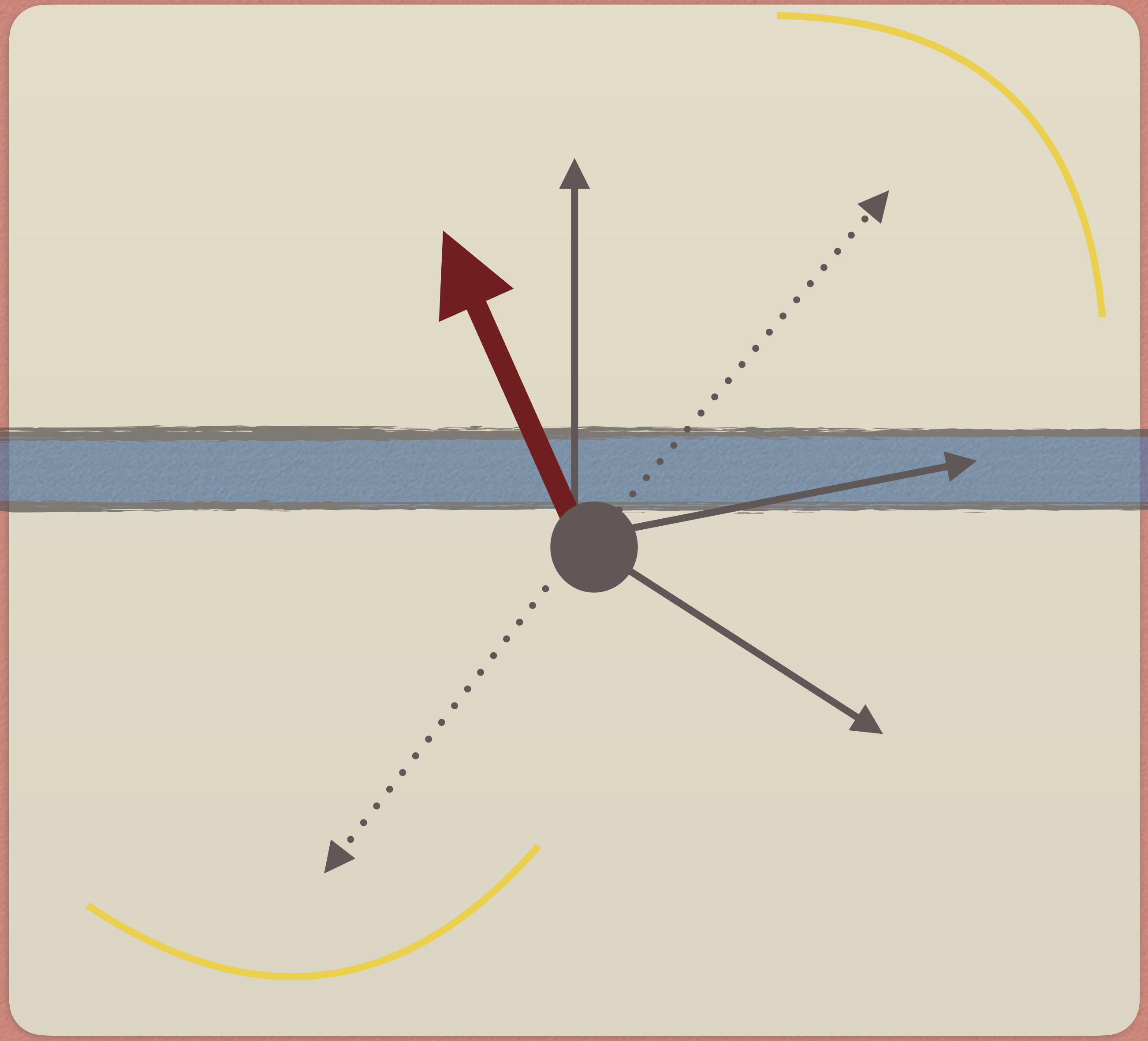
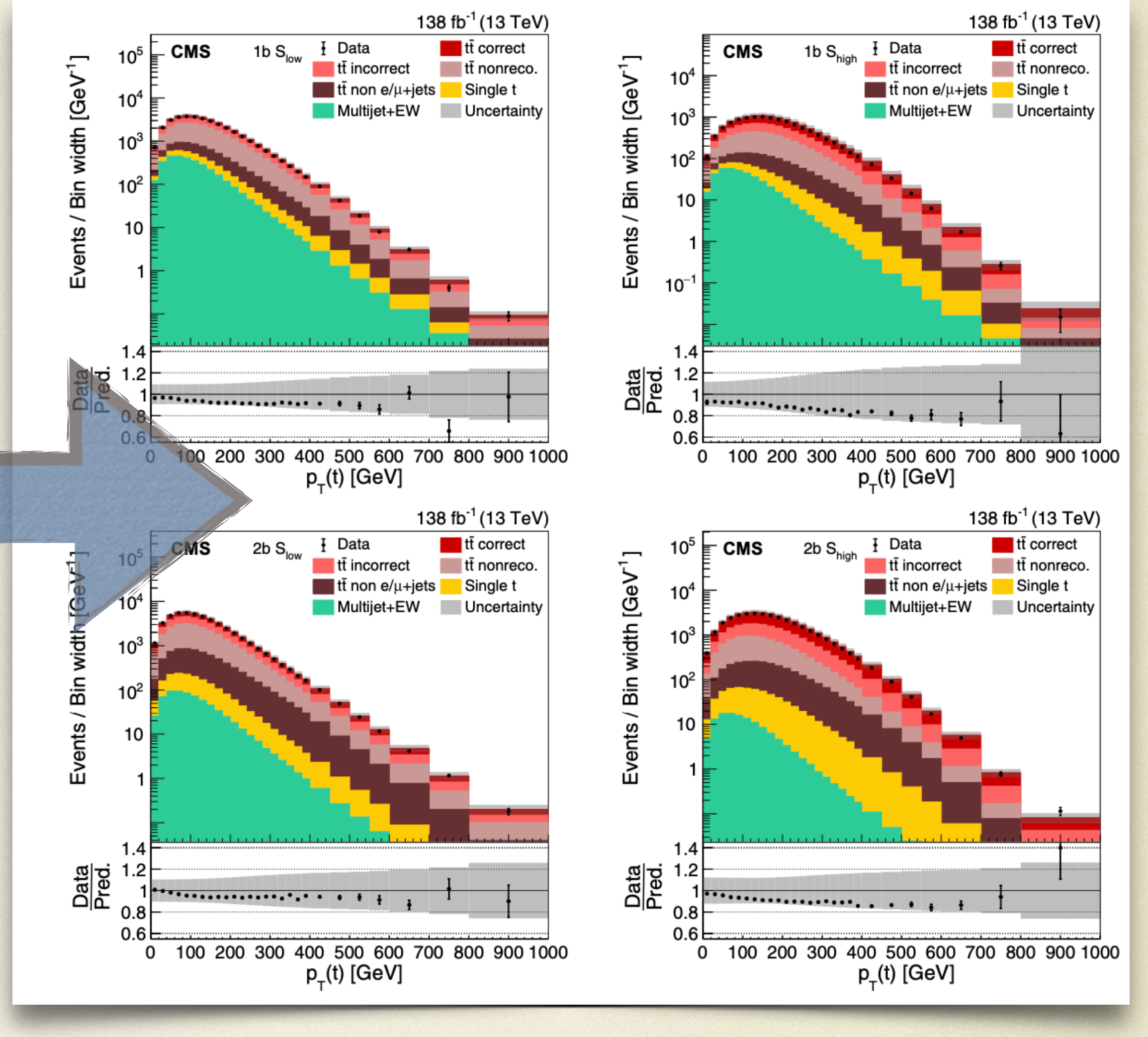
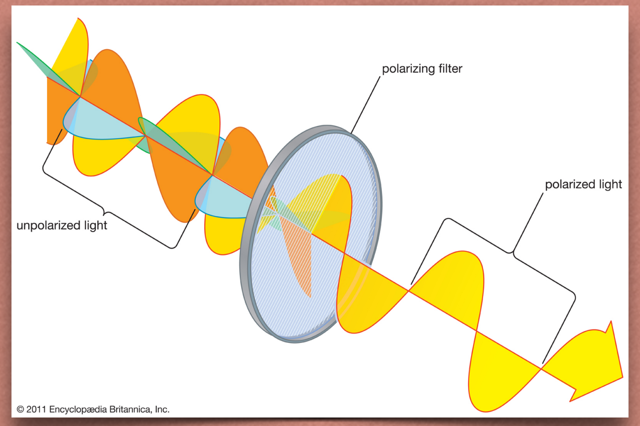
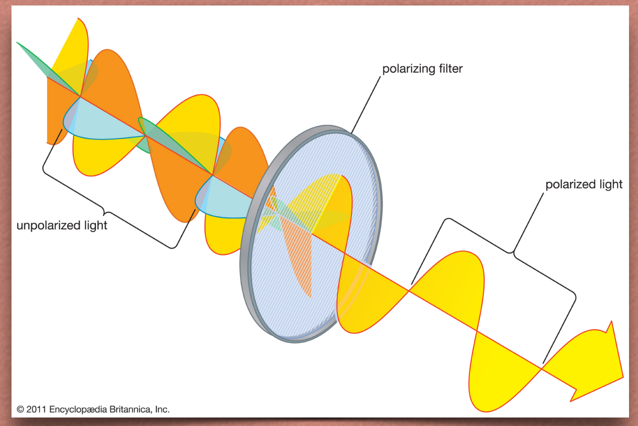






$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_i^{\pm}} = \frac{1}{2}\left(1 + \langle s_i\rangle\, \alpha_i\, \cos\theta_i\right)$$





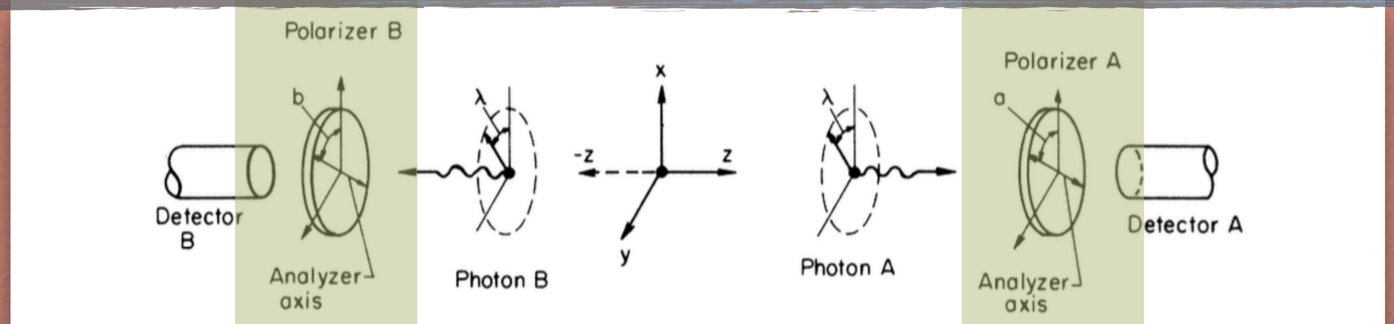
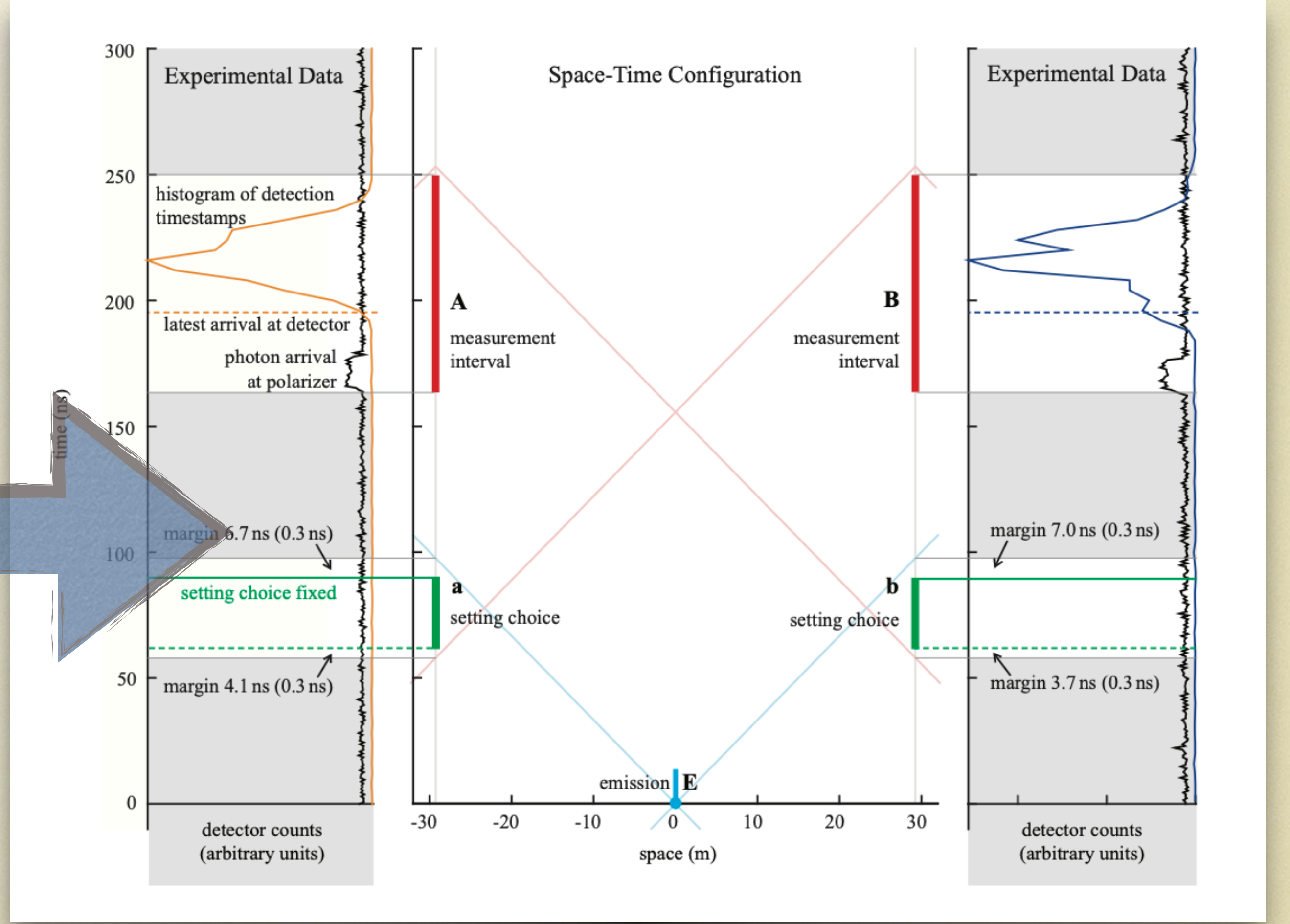
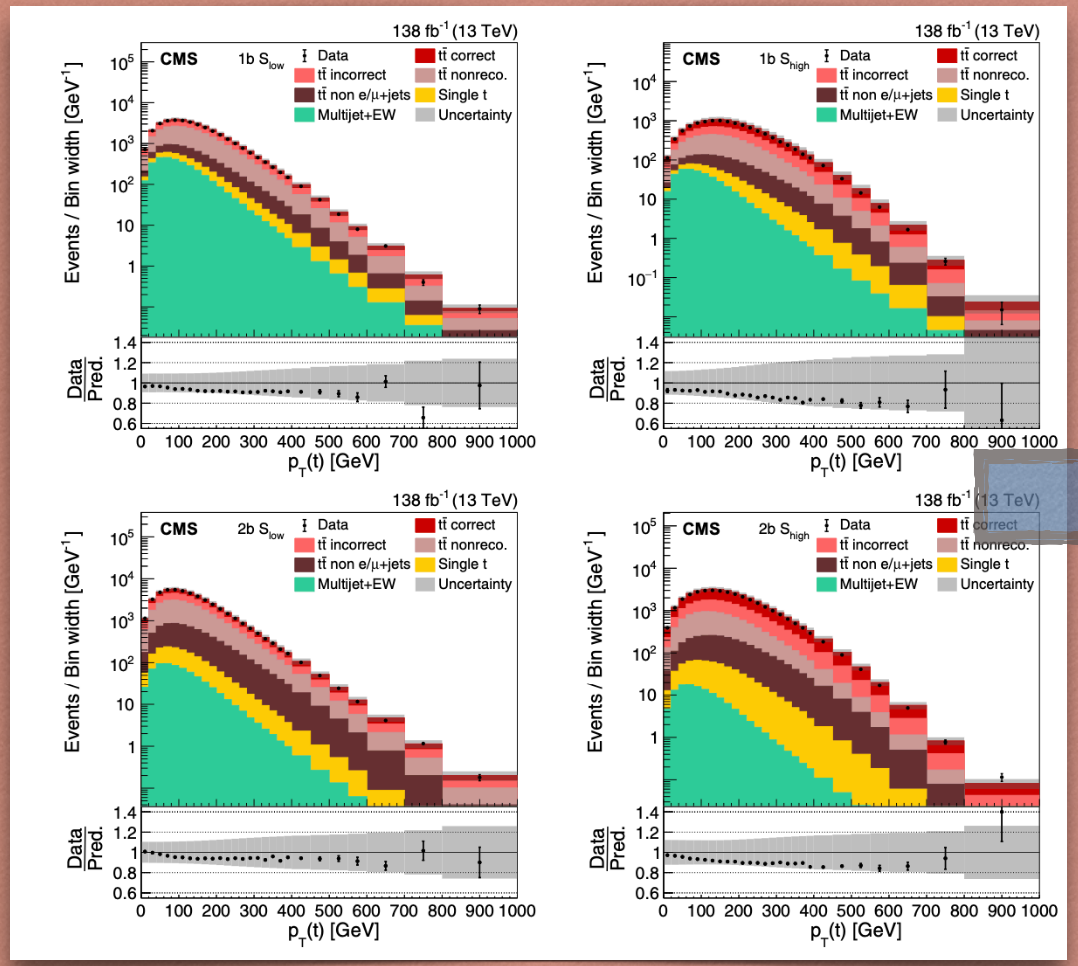
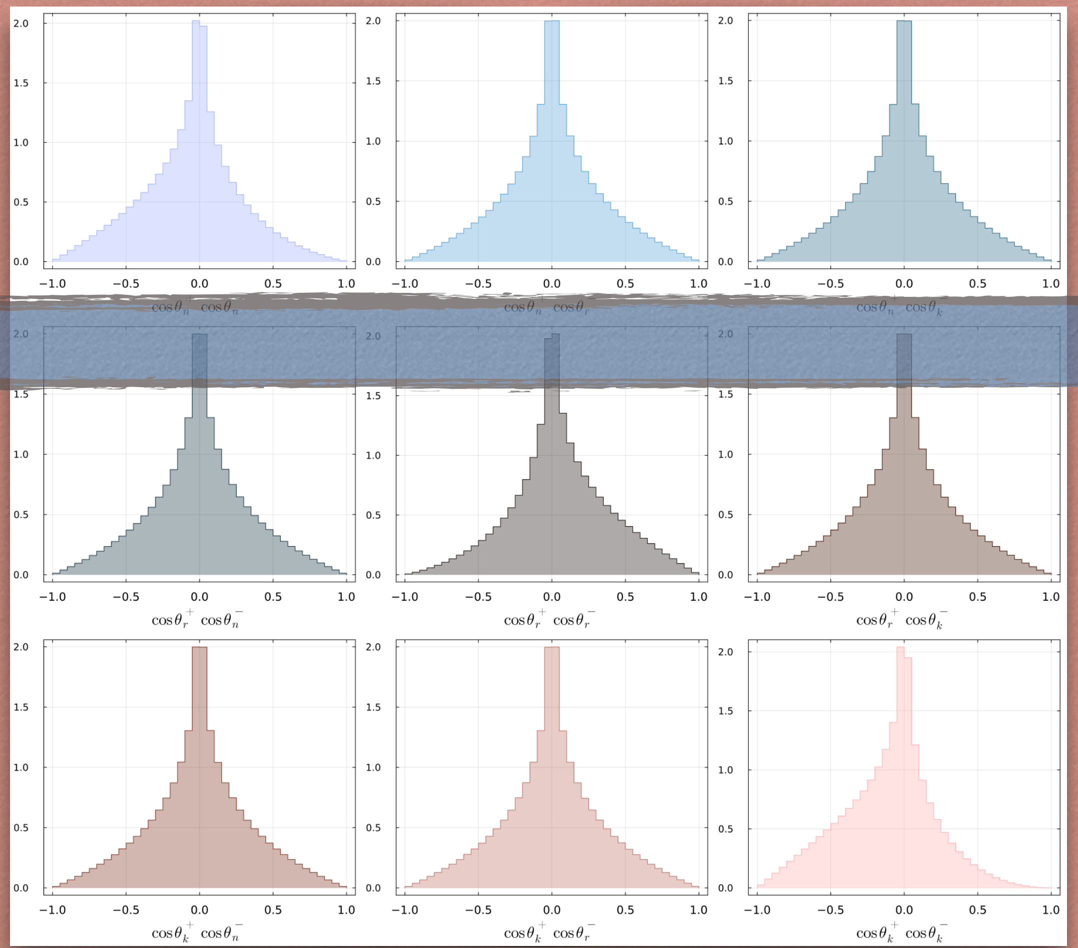


FIG. 3. Coordinate system for OLT model. Photon particles A and B carry the same azimuthal direction λ, which, along with the analyzer orientation a or b, determines the probability of a count at the associated detector.

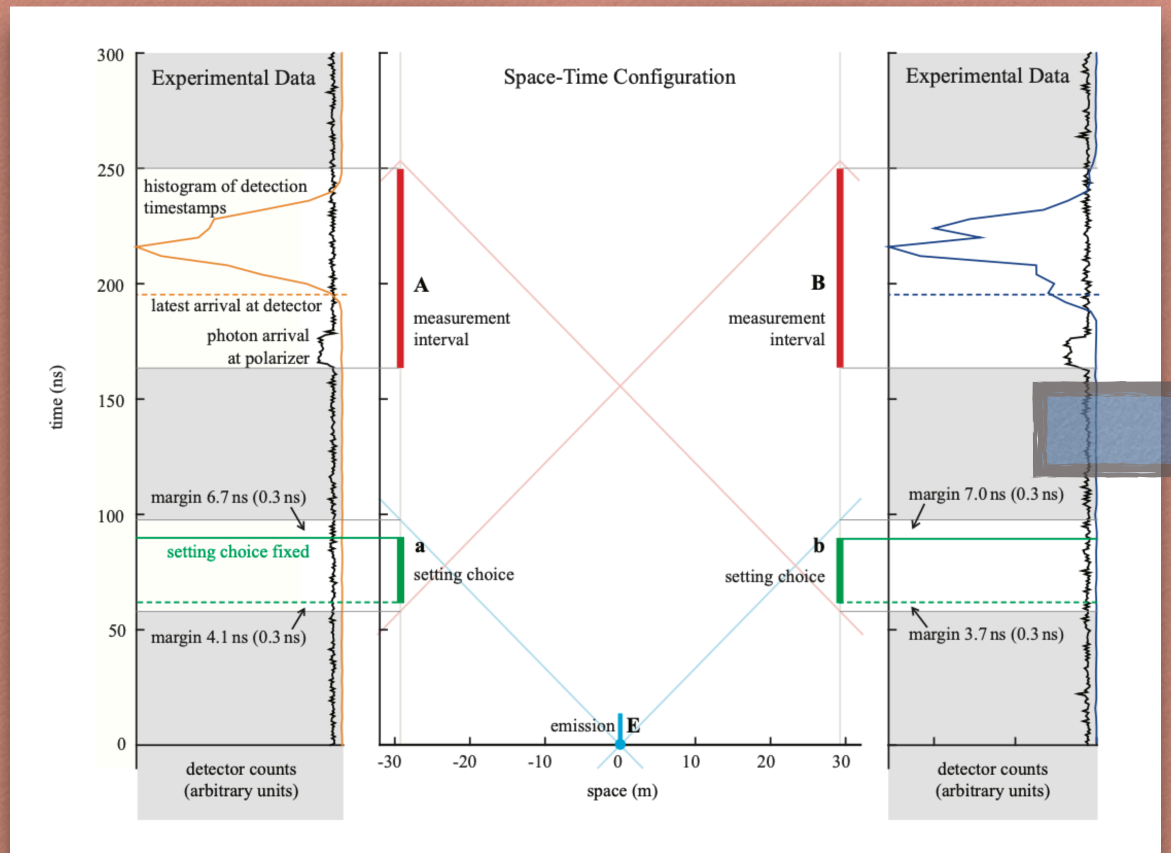


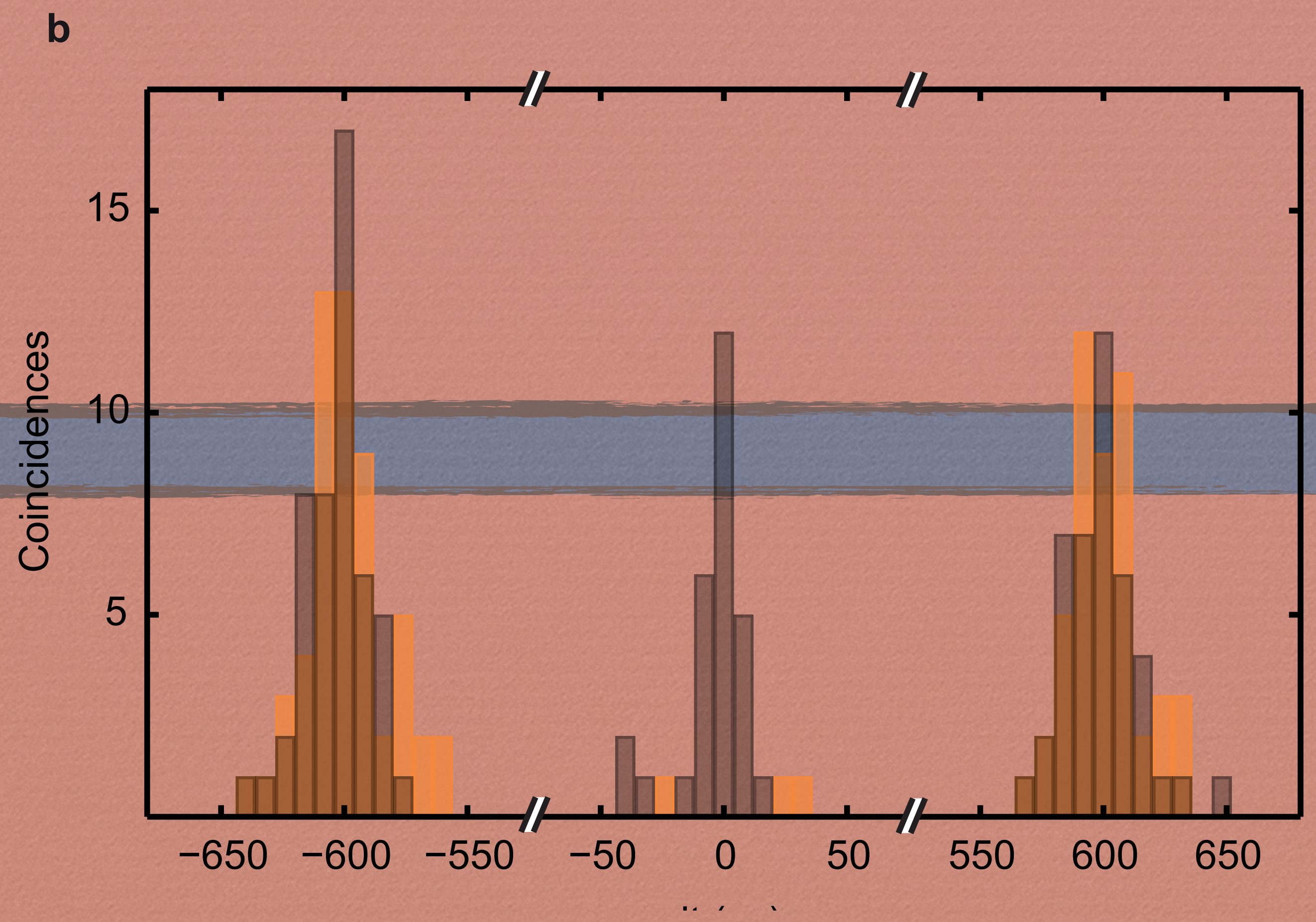


$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_i^+\,\mathrm{d}\cos\theta_j^-}=\frac{1}{2}\left(1+\alpha_i B_i^+\cos\theta_i^+ + \alpha_i B_i^-\cos\theta_i^- + C_{ij}\alpha_i\alpha_j\cos\theta_i^+\cos\theta_j^-\right)$$

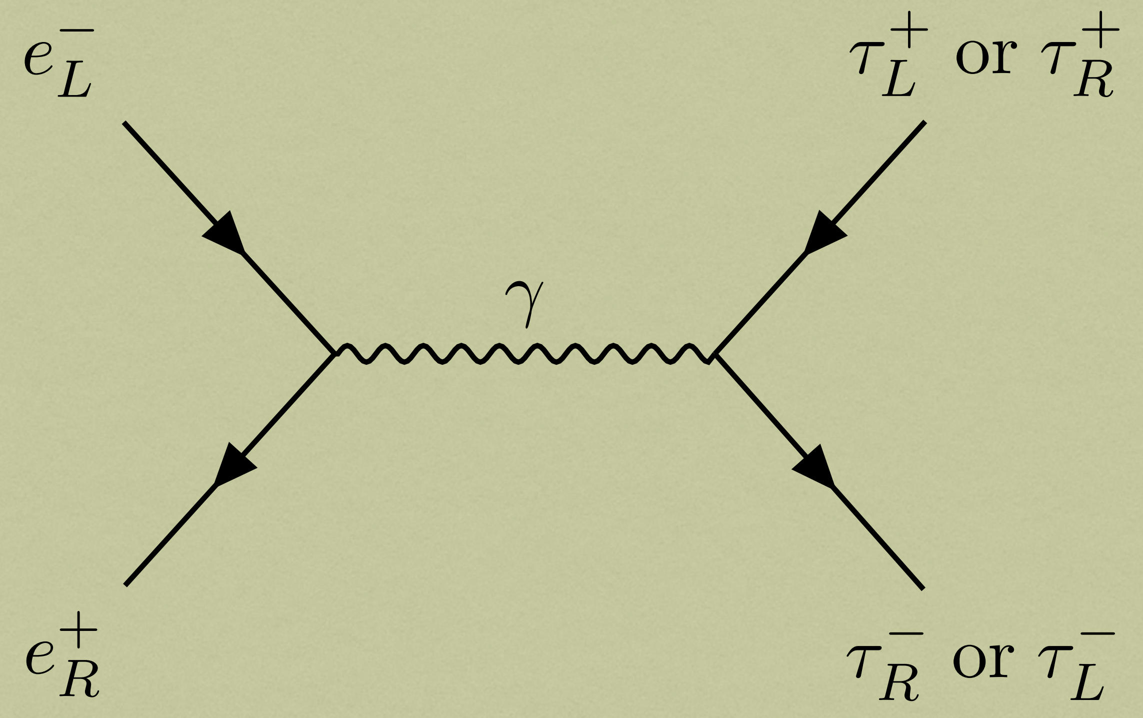


$$C_{ij}$$





$$\vec{n}_1\cdot C\cdot(\vec{n}_2-\vec{n}_4)+\vec{n}_3\cdot C\cdot(\vec{n}_2+\vec{n}_4)\le 2$$



$$|\Psi\rangle = \frac{1}{\sqrt{2}}\Big(|\tau_R^-\rangle|\tau_L^+\rangle + |\tau_L^-\rangle|\tau_R^+\rangle\Big)$$

$$|\Psi\rangle = \frac{1}{\sqrt{2}}\Big(|\gamma_R^{(1)}\rangle|\gamma_L^{(2)}\rangle + |\gamma_L^{(1)}\rangle|\gamma_R^{(2)}\rangle\Big)\,.$$

NO U(1)! $\frac{1}{\sqrt{2}}\begin{pmatrix}0\\1\\1\\0\end{pmatrix}$

$$\underbrace{\Big(1+\cos\Theta\Big)}_{\zeta_2 = D^{(1)}_{1,1}(\Theta)}|\tau_R^-\rangle\,|\tau_L^+\rangle + \underbrace{\Big(1-\cos\Theta\Big)}_{\zeta_3 = D^{(1)}_{1,-1}(\Theta)}|\tau_L^-\rangle\,|\tau_R^+\rangle$$

$J=\pm 1 \quad J_z = \pm 1 \quad (\Theta = 0)$	$\lvert\tau_R^-\rangle\,\lvert\tau_L^+\rangle$	separable
$J=\pm 1 \quad J_z = 0 \quad (\Theta = \pi/2)$	$\frac{1}{\sqrt{2}}\Big(\lvert\tau_R^-\rangle\,\lvert\tau_L^+\rangle + \lvert\tau_L^-\rangle\,\lvert\tau_R^+\rangle\Big)$	entangled (Bell state)

$$\Psi = \left|\tau_R^-\right\rangle \left|\tau_L^+\right\rangle \longrightarrow \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$$

$$\mathcal{P}(\uparrow_{\hat{n}_i};\uparrow_{\hat{n}_j}) = \frac{1}{4}\langle\Psi|(1_{2\times2} + \hat{n}_i\cdot\vec{\sigma})\otimes(1_{2\times2} + \hat{n}_j\cdot\vec{\sigma})|\Psi\rangle = \frac{1}{4}(1 - \hat{n}_i^z + \hat{n}_j^z - \hat{n}_i^z\hat{n}_j^z)$$

$$\hat{n}_1 = \hat{z}, \quad \hat{n}_2 = \frac{-1}{\sqrt{2}}(\hat{z}+\hat{x}), \quad \hat{n}_3 = -\hat{x}, \quad \hat{n}_4 = \frac{1}{\sqrt{2}}(\hat{z}-\hat{x})$$

$$\mathcal{P}(\uparrow_{\hat{n}_1};\uparrow_{\hat{n}_2}) - \mathcal{P}(\uparrow_{\hat{n}_1};\uparrow_{\hat{n}_4}) + \mathcal{P}(\uparrow_{\hat{n}_3};\uparrow_{\hat{n}_2}) + \mathcal{P}(\uparrow_{\hat{n}_3};\uparrow_{\hat{n}_4}) = \frac{1}{2}$$

$$\leq \mathcal{P}(\uparrow_{\hat{n}_3};-) + \mathcal{P}(-;\uparrow_{\hat{n}_2}) = 1 - \frac{\sqrt{2}}{4}$$

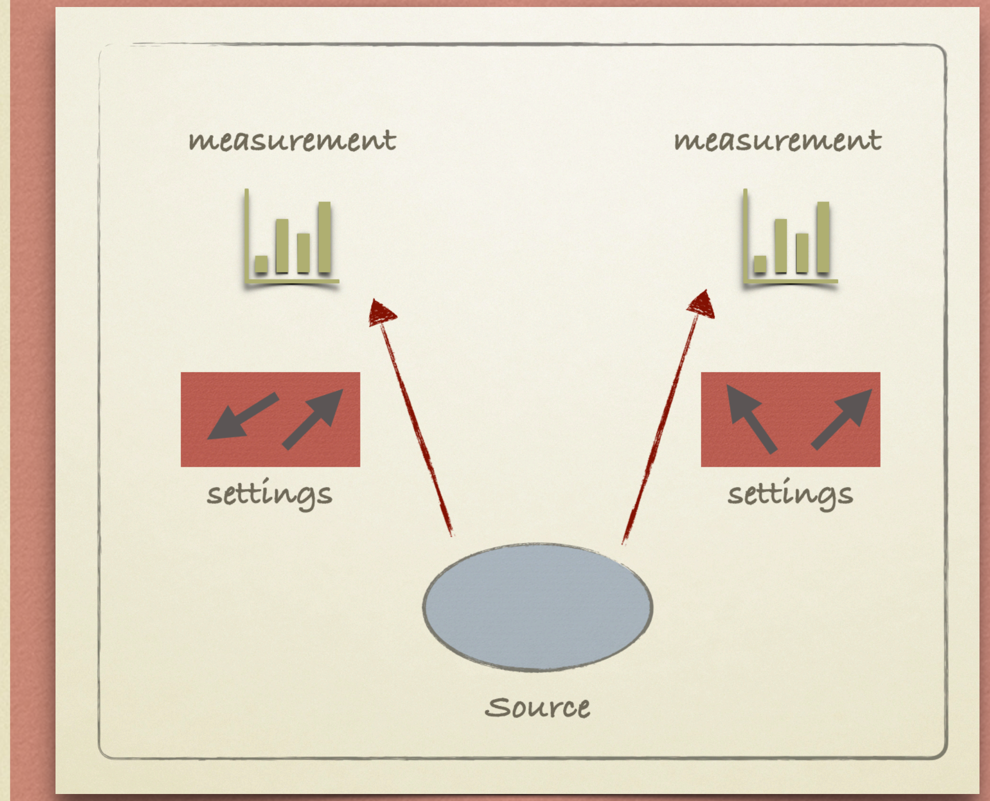
$$\Psi = \frac{1}{\sqrt{2}}\left(|\tau_R^-\rangle\,|\tau_L^+\rangle + |\tau_L^-\rangle\,|\tau_R^+\rangle\right) \longrightarrow \frac{1}{\sqrt{2}}\begin{pmatrix}0\\1\\1\\0\end{pmatrix}$$

$$\mathcal{P}(\uparrow_{\hat{n}_i};\uparrow_{\hat{n}_j}) = \frac{1}{4}\langle\Psi|(1_{2\times2}+\hat{n}_i\cdot\vec{\sigma})\otimes(1_{2\times2}+\hat{n}_j\cdot\vec{\sigma})|\Psi\rangle = \frac{1}{4}\left(1+\hat{n}_i^x\hat{n}_j^x+\hat{n}_i^y\hat{n}_j^y-\hat{n}_i^z\hat{n}_j^z\right)$$

$$\hat{n}_1 = \hat{z}, \quad \hat{n}_2 = \frac{-1}{\sqrt{2}}(\hat{z}+\hat{x}), \quad \hat{n}_3 = -\hat{x}, \quad \hat{n}_4 = \frac{1}{\sqrt{2}}(\hat{z}-\hat{x})$$

$$\mathcal{P}(\uparrow_{\hat{n}_1};\uparrow_{\hat{n}_2}) - \mathcal{P}(\uparrow_{\hat{n}_1};\uparrow_{\hat{n}_4}) + \mathcal{P}(\uparrow_{\hat{n}_3};\uparrow_{\hat{n}_2}) + \mathcal{P}(\uparrow_{\hat{n}_3};\uparrow_{\hat{n}_4}) = \frac{1}{2}+\frac{\sqrt{2}}{2}$$

$$\nleq \quad \mathcal{P}(\uparrow_{\hat{n}_3};-) + \mathcal{P}(-;\uparrow_{\hat{n}_2}) = 1$$



5.1. Space-time locality.

This loophole exploits the space-time arrangement of the events involved in a Bell test. Communication pertaining to the direction settings used in the polarization measurements performed on the two subsystems is possible in a local manner if these settings are fixed before the source emits the entangled particles, or if one setting and measurement is performed in the past cone of the second one. In both cases, the Bell inequality is violated because of the local exchange of information [17].

5.2. Detection.

It is possible that the correlations, as detected in the experiment, are only due to the particular subset of recorded events: although these events show a violation of a Bell inequality, if all events were detected the Bell inequality would actually be respected. If some events are not recorded, extra correlations could be hiding there [26]. In [48] it was shown that the efficiency for the detection of the photons should be at least 83%.

5.3. Freedom of choice.

In this loophole, an extension of the locality one, the hidden-variable distribution η depends on the directions used in the Bell test for the polarization measurements. When calculating

$$\mathcal{P}(\uparrow_{\hat{n}_i};\uparrow_{\hat{n}_j}) = \int \mathrm{d}\lambda\, p_\lambda(\uparrow_{\hat{n}_i};\uparrow_{\hat{n}_j})\eta(\lambda|\uparrow_{\hat{n}_i};\uparrow_{\hat{n}_j}), \tag{5.1}$$

one should take into account possible correlations between the hidden variables and the detector settings [54], which would modify the above relation thereby allowing a hidden variable theory to pass the Bell test. This loopohole essentially proposes a limited form of a super-deterministic model in which, however, only a tiny amount of information needs to be exchanged [55].

5.4. Free will.

There exists a stronger form of the previous loophole that consists in supposing that the hidden variable distribution contains the outcome of the experiment about to be performed. For particle accelerators, this would mean that the hidden variables regulate the angular distribution of the momenta involved in the tomographic procedure. The same variables must also include information about the detector[4] because the contextuality requirement [58].

5.5. Memory.

If the measurements are repeatedly made, a local hidden variable theory could exploit the memory of past measurement settings and outcomes to increase the correlations and yield a violation of the Bell inequality in the upcoming tests [59].

5.6. Coincidence.

In many experiments, especially those based on photon polarizations, pairs of events in the two sides of the experiment are only identified as belonging to a single pair after the experiment is performed, by judging whether or not their detection times are close enough one to another. This generates a new possibility for a local hidden variables theory to fake quantum correlations: altering the detection time of each of the two particles according to some relationship between hidden variables carried by the particles and the detector settings encountered at the measurement station [60].

Local hidden variables = New Physics ?