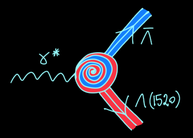
$\Lambda(1520)$

BESIII Italia

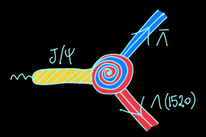
Laboratori Nazionali di Frascati

7 e 8 aprile 2022

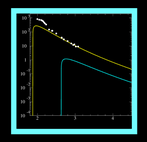
Agenda



Production of the $\Lambda(1520)$ baryon and its properties



$\bar{\Lambda}\Lambda(1520)$ transition form factors and strong coupling constants



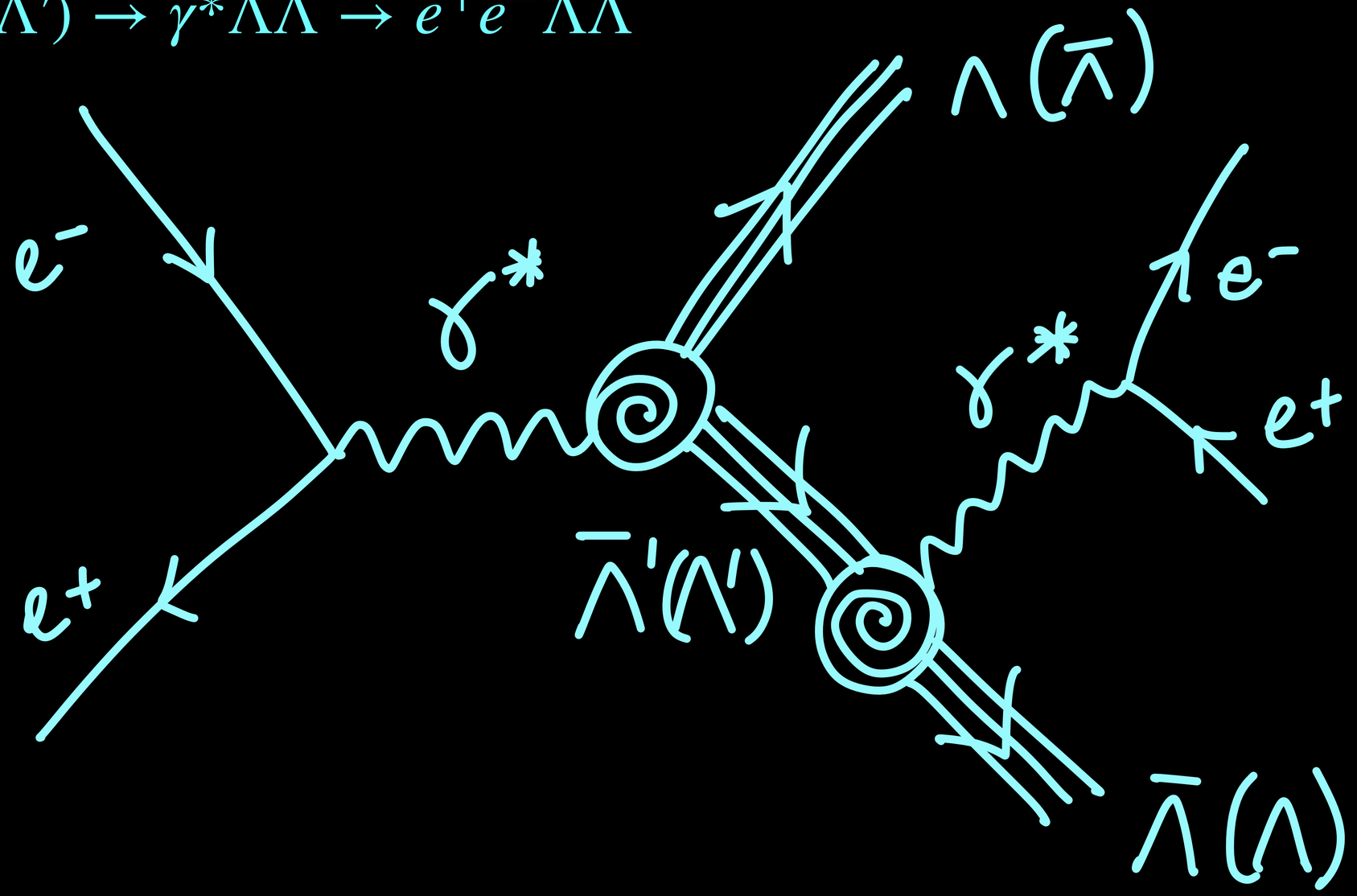
$\bar{\Lambda}\Lambda(1520)$ total cross section in BESIII

Differential cross sections and decay rate of the complete process

Past and future

Non resonant reaction

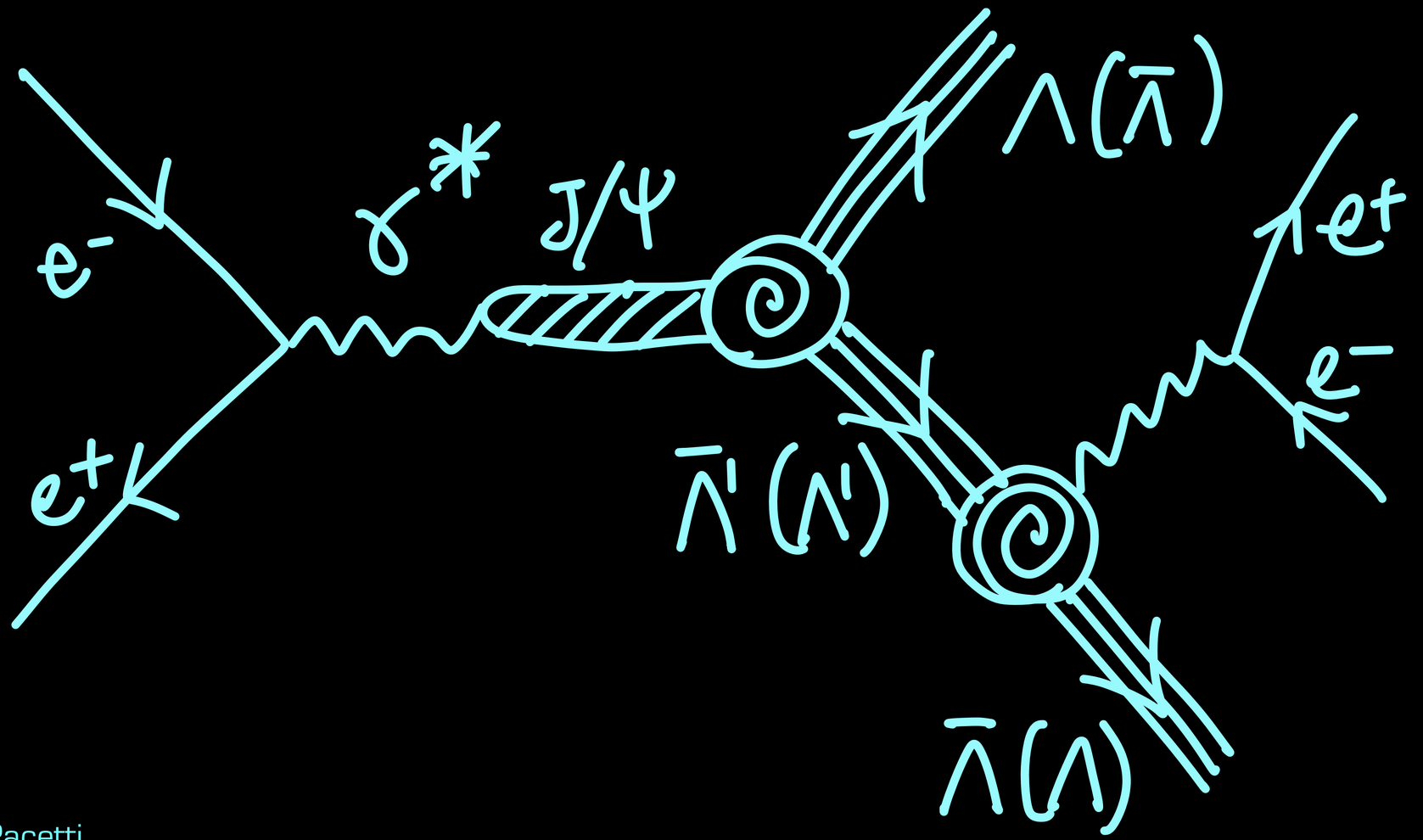
$$e^+e^- \to \gamma^* \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$$



$\Lambda' \equiv \Lambda(1520)$

Resonant reaction

$$e^+e^- \to \gamma^* \to J/\psi \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$$



$\Lambda' \equiv \Lambda(1520)$

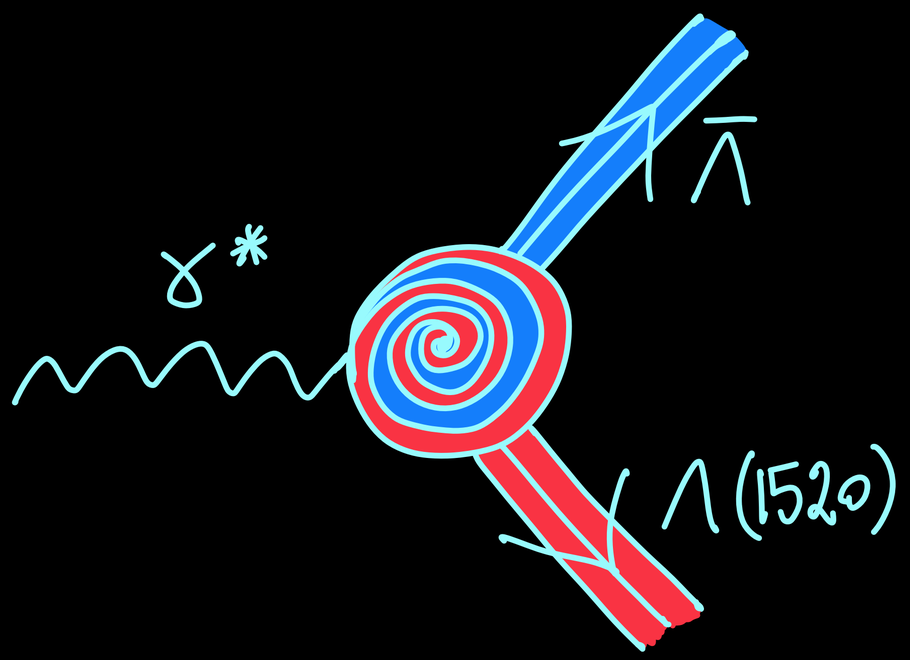
$\Lambda(1520)$

- Quantum numbers: $I\left(J^P\right) = 0\,(3/2^-)$
- Mass: $M = 1519.42 \pm 0.19$ MeV/c^2
- Width: $\Gamma = 15.73 \pm 0.26$ MeV
- Decay modes

$$\mathrm{BR}\left(\Lambda(1520) \to N\bar{K}\right) = (45 \pm 1)\,\%$$
$$\mathrm{BR}\left(\Lambda(1520) \to \Sigma\pi\right) = (42 \pm 1)\,\%$$
$$\mathrm{BR}\left(\Lambda(1520) \to \Lambda\pi\pi\right) = (10 \pm 1)\,\%$$
$$\mathrm{BR}\left(\Lambda(1520) \to \Sigma\pi\pi\right) = (0.9 \pm 0.1)\,\%$$
$$\mathrm{BR}\left(\Lambda(1520) \to \Lambda\gamma\right) = (0.85 \pm 0.15)\,\%$$

$\gamma^* \bar{\Lambda}\Lambda(1520)$ vertex

$$\langle \Lambda(1520)\bar{\Lambda} | J^\mu | 0 \rangle = e\, \bar{u}_\nu(p', \lambda')\, \Gamma^{\nu\mu}\, v(p, \lambda)$$



Spin 3/2 vector spinor

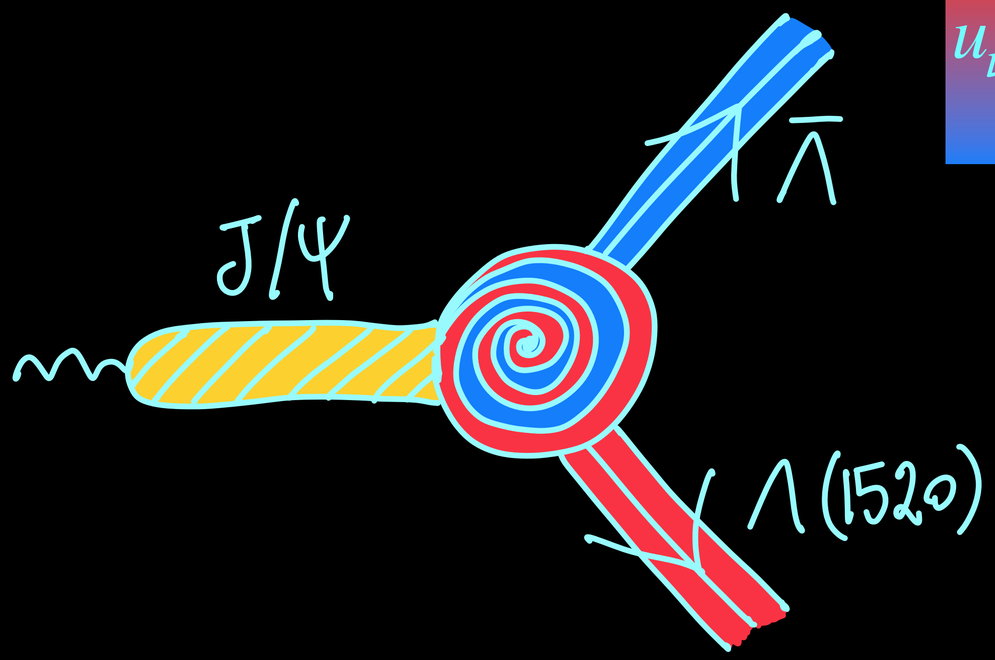
$$u_\nu(p, \lambda) = \sum_{\sigma\eta} CG\left(\frac{3}{2}, \lambda \,|\, 1, \sigma; \frac{1}{2}, \eta\right) u(p, \eta)\, \varepsilon_\nu(p, \sigma)$$

Three transition form factors

$$\Gamma^{\nu\mu} = -G_1(q^2)\left(q^\nu \gamma^\mu - \not{q} g^{\mu\nu}\right) + G_2(q^2)\left(q^\nu p'^\mu - (p'q) g^{\mu\nu}\right) + G_3(q^2)\left(q^\nu q^\mu - q^2 g^{\mu\nu}\right)$$

$J/\psi\bar{\Lambda}\Lambda(1520)$ vertex

$$\langle \Lambda(1520)\bar{\Lambda}\,|\,J^{\mu}\,|\,J/\psi\rangle = e\,\bar{u}_{\nu}(p',\lambda')\,\Gamma^{\nu\mu}_{J/\psi}\,v(p,\lambda)$$



Spin 3/2 vector spinor

$$u_{\nu}(p,\lambda) = \sum_{\sigma\eta} CG\left(\frac{3}{2},\lambda\,|\,1,\sigma;\frac{1}{2},\eta\right) u(p,\eta)\,\varepsilon_{\nu}(p,\sigma)$$

Three coupling constants

$$\Gamma^{\nu\mu}_{J/\psi} = -g_1^{J/\psi}\left(q^{\nu}\gamma^{\mu} - \not{q}g^{\mu\nu}\right) + g_2^{J/\psi}\left(q^{\nu}p'^{\mu} - (p'q)g^{\mu\nu}\right) + g_3^{J/\psi}\left(q^{\nu}q^{\mu} - q^2 g^{\mu\nu}\right)$$

$\bar{\Lambda}\Lambda(1520)$ cross section

Differential cross section

$$\frac{d\sigma}{d\cos(\theta)} = \frac{d\sigma_T}{d\cos(\theta)} + \frac{d\sigma_L}{d\cos(\theta)}$$

Transverse cross section

$$\frac{d\sigma_T}{d\cos(\theta)} = K\left(1+\cos^2(\theta)\right)\frac{1}{2}\sum_{\lambda}\left(\left|\Gamma^{\lambda+1,\lambda}\right|^2 + \left|\Gamma^{\lambda-1,\lambda}\right|^2\right)$$

Longitudinal cross section

$$\frac{d\sigma_L}{d\cos(\theta)} = K\sin^2(\theta)\sum_{\lambda}\left|\Gamma^{\lambda,\lambda}\right|^2$$

Elicity amplitudes $\Gamma^{1/2,-1/2}$, $\Gamma^{3/2,1/2}$, $\Gamma^{1/2,1/2}$ depend on transition form factors

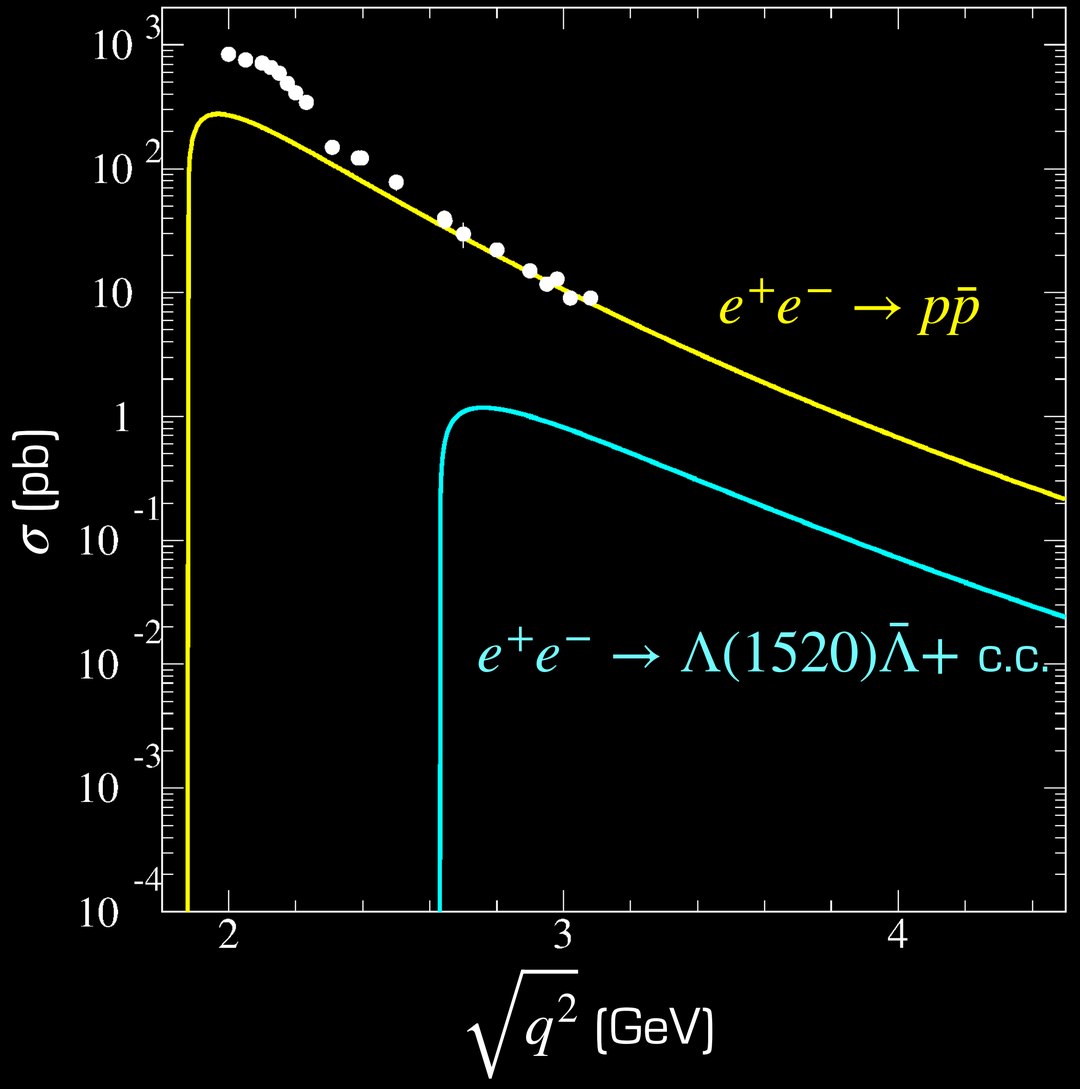
$\bar{\Lambda}\Lambda(1520)$ cross section

BESIII at $\sqrt{q^2} = 2.9$ GeV

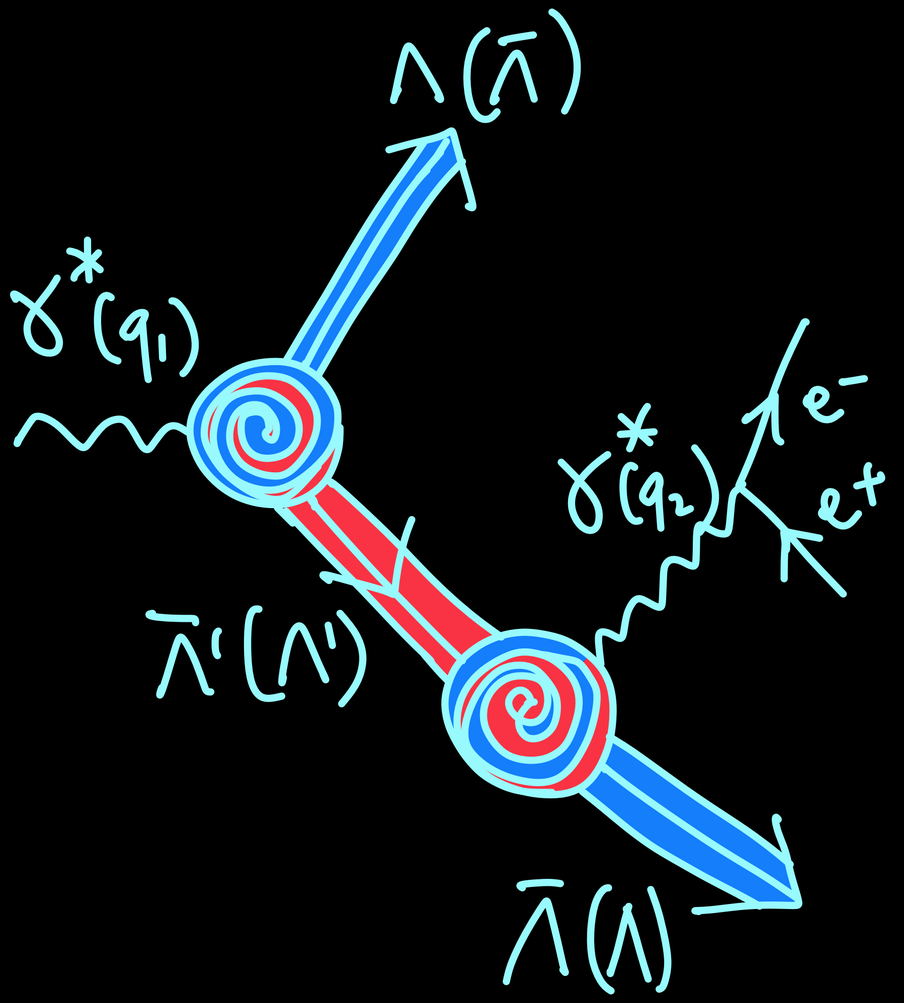
$N^{p\bar{p}}_{\text{obs}} = 1010$

$N^{\Lambda(1520)\bar{\Lambda}+\text{c.c.}}_{\text{expected}} \simeq 70$

Almost invisible



$$e^+e^- \to \gamma^* \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$$



$\Lambda' \equiv \Lambda(1520)$

Double differential cross section

$$\frac{d^2\sigma}{dq_1^2 dq_2^2} = \left| \mathscr{A}\left(\Gamma^{\lambda_1\lambda_1'}(q_1^2), \Gamma^{\lambda_2\lambda_2'}(q_2^2)\right) \right|^2$$

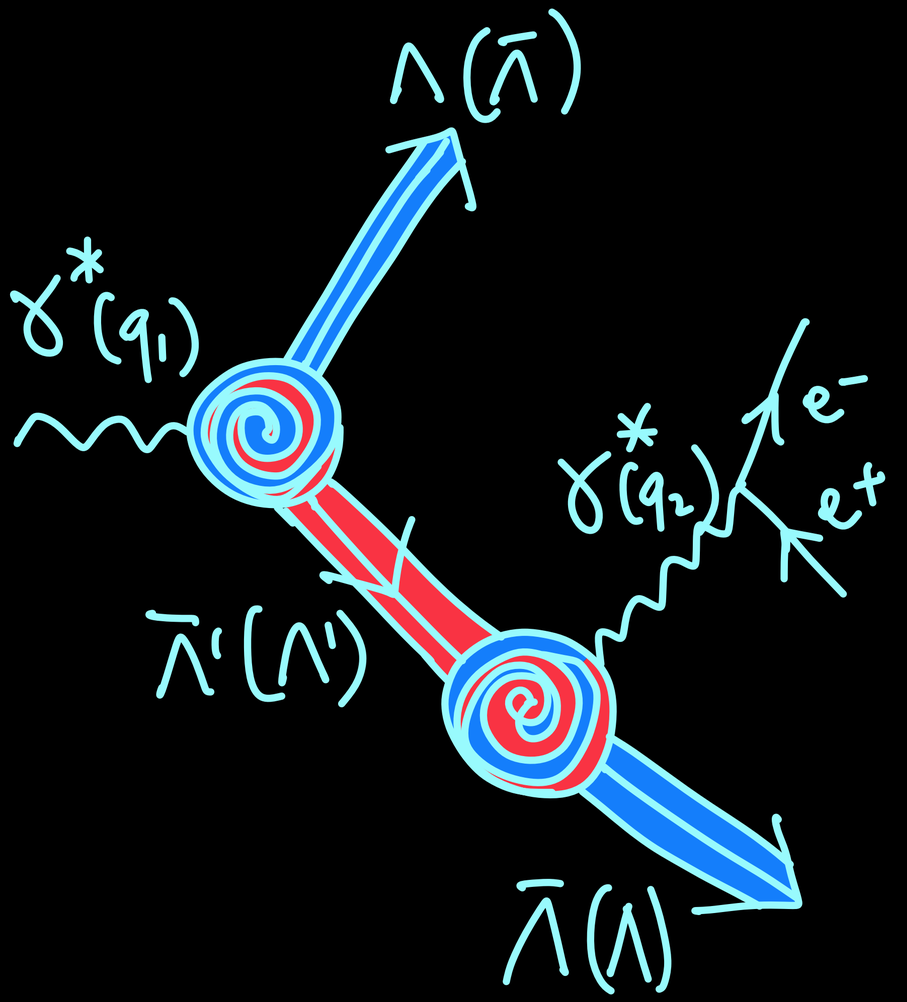
$$\sqrt{q_1^2} \in (M_{\Lambda'} + M_{\Lambda}, \sim 3\,\text{GeV}) \quad \sqrt{q_2^2} \in (2m_e, M_{\Lambda'} - M_{\Lambda})$$

Differential cross section

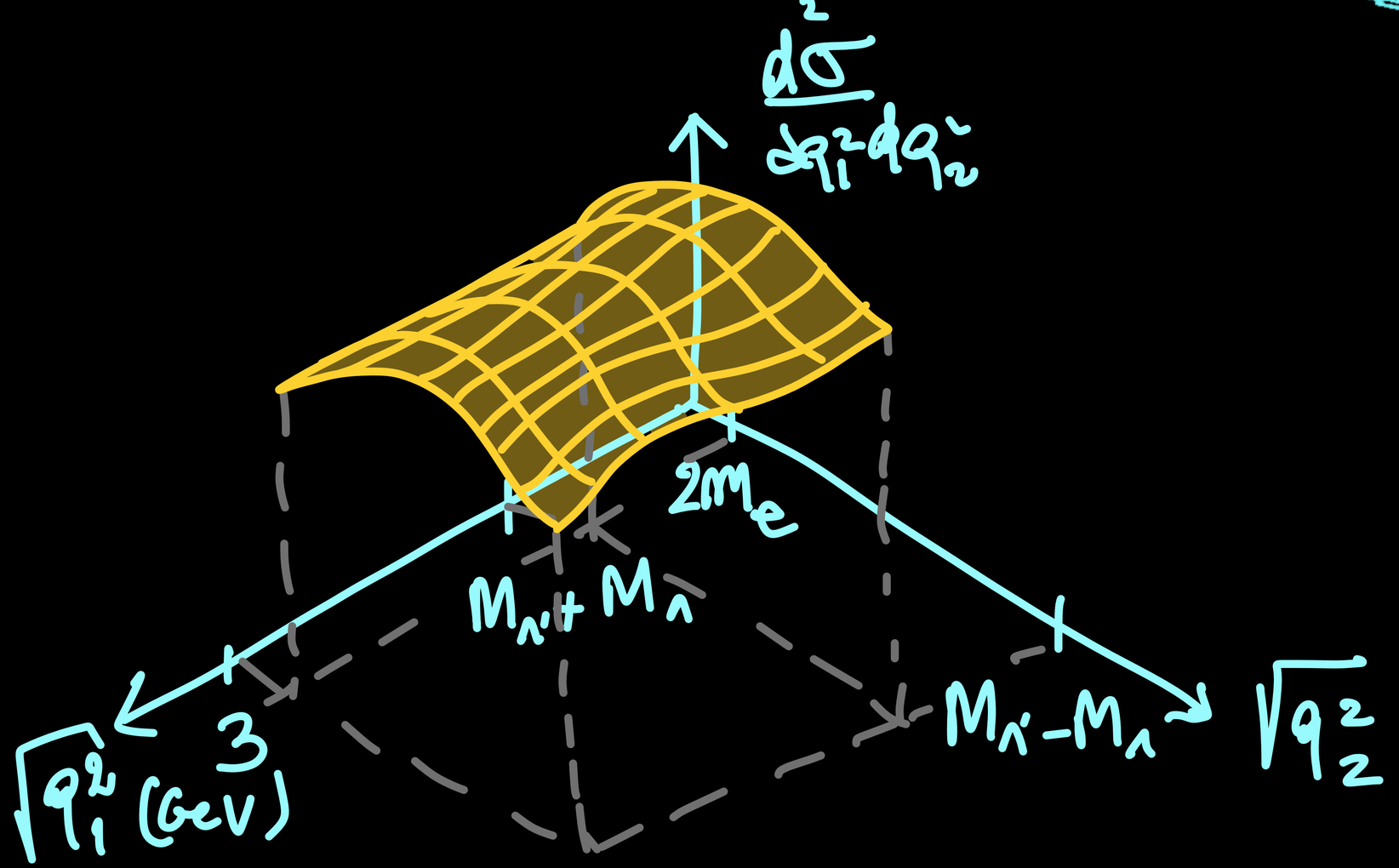
$$\frac{d\sigma}{dq_1^2} = \left| \mathscr{A}\left(\Gamma^{\lambda_1\lambda_1'}(q_1^2), \Gamma^{\lambda_2\lambda_2'}(0)\right) \right|^2$$

$$\sqrt{q_1^2} \in (M_{\Lambda'} + M_{\Lambda}, \sim 3\,\text{GeV}) \quad \sqrt{q_2^2} = 0$$

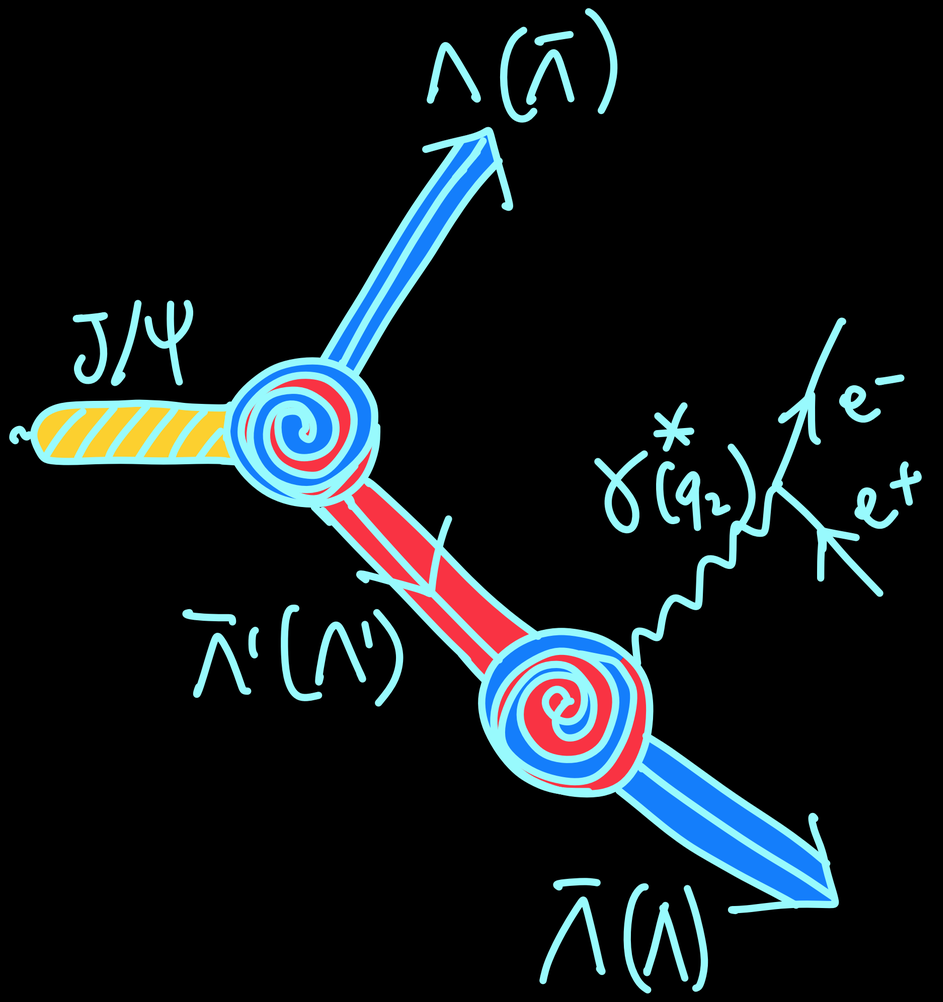
$$e^+e^- \to \gamma^* \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$$



$\Lambda' \equiv \Lambda(1520)$



$$e^+e^- \to \gamma^* \to J/\psi \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$$



$\Lambda' \equiv \Lambda(1520)$

Differential cross section

$$\frac{d\sigma}{dq_2^2} = \left| \mathscr{A}\left(\Gamma^{\lambda_1\lambda_1'}\left(M^2_{J/\psi}\right), \Gamma^{\lambda_2\lambda_2'}\left(q_2^2\right) \right) \right|^2$$

$$\sqrt{q_2^2} \in (2m_e, M_{\Lambda'} - M_{\Lambda})$$

Radiative decay rate

$$\sigma = \left| \mathscr{A}\left(\Gamma^{\lambda_1\lambda_1'}\left(M^2_{J/\psi}\right), \Gamma^{\lambda_2\lambda_2'}(0) \right) \right|^2$$

Done and to do

- $10^{10}\, J/\psi \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$ (~ 11) **No events**
  (Alessio Guglielminotti Canun, Marco Destefanis, Fabrizio Bianchi)

- **Determine** the amplitude $\mathscr{A}\left(\Gamma^{\lambda_1\lambda_1'}\left(q_1^2\right), \Gamma^{\lambda_2\lambda_2'}\left(q_2^2\right)\right)$

- **Estimate** the number of events in various kinematic regions for $e^+e^- \to \gamma^* \to \Lambda\bar{\Lambda}'(\bar{\Lambda}\Lambda') \to \gamma^*\Lambda\bar{\Lambda} \to e^+e^-\Lambda\bar{\Lambda}$
  (Nicolò Baldicchi, Marco Destefanis, SP)

- **Perform** the analysis
  (Marco Destefanis, SP)