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Cluster of Excellence PRISMA+ Precision Physics, Fundamental Interactions and Structure of Matter

SFB 1044 THE LOW-ENERGY FRONTIER OF THE STANDARD MODEL


g-2 school 2018

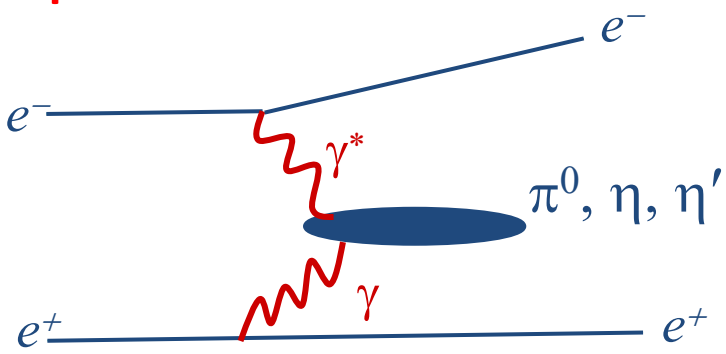
in memoriam
Simon Eidelman


Phipsi2006

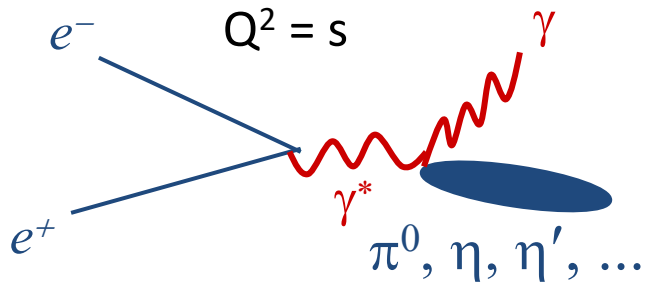
Experimental Input to HLbL
- Panel Discussion -

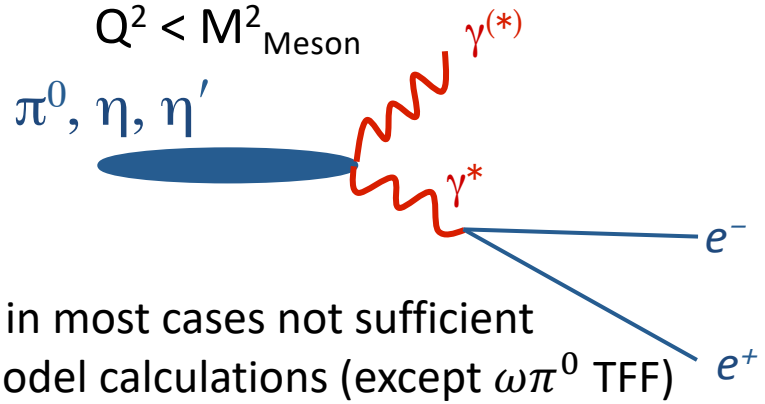
Transition Form Factors (TFF)

Spacelike Measurement



Timelike Measurement





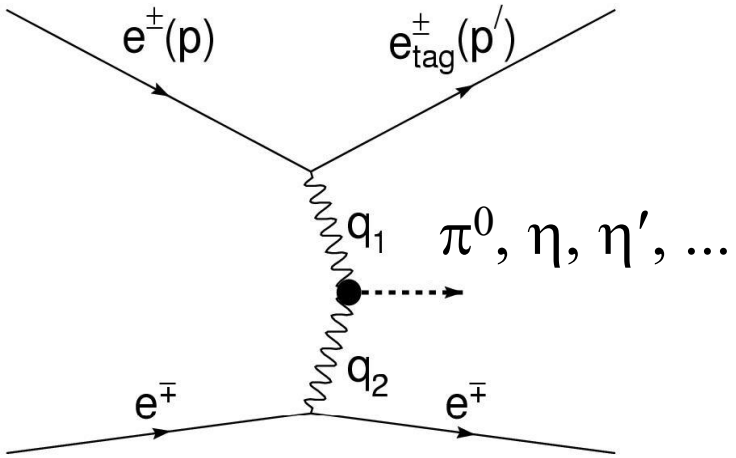
Precision of data in most cases not sufficient to specify btw. model calculations (except $\omega\pi^0$ TFF)

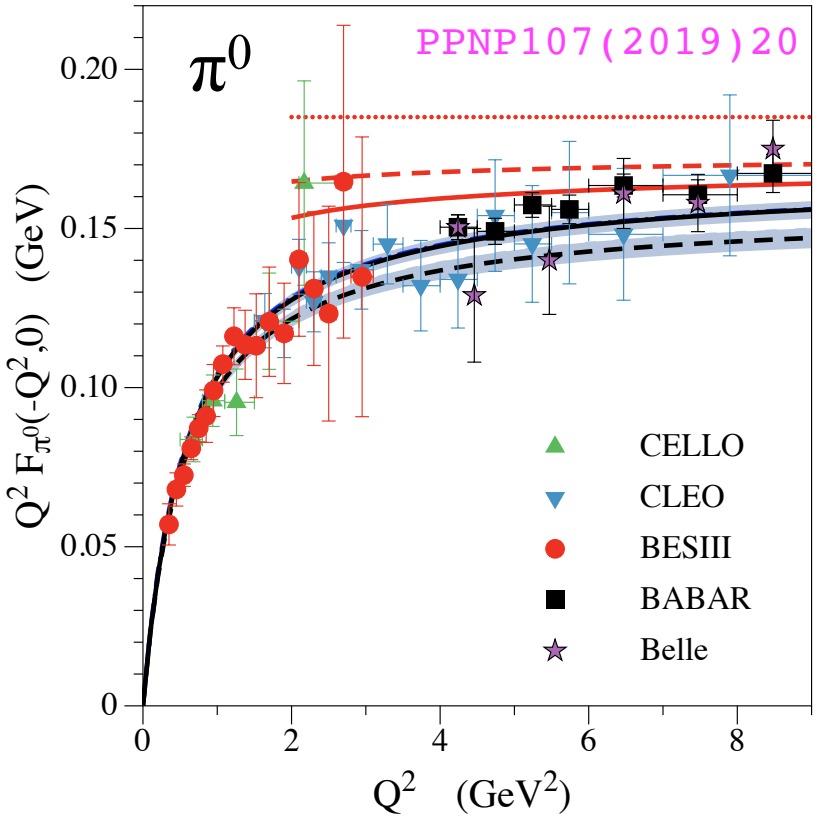
→ upcoming analyses from various experiments

→ guidance by theory would be very helpful

Space-Like TFFs (Pseudoscalars)

Accessible in e^+e^- in gamma-gamma collisions
(L3, CLEO, BABAR, BELLE, BESIII, BELLE-II, ...)





$$Q^2 = 4 \cdot E \cdot E' \cdot \sin^2(\theta/2)$$

B-factories: $Q^2 > 3 \ldots 4\ \mathrm{GeV}^2$

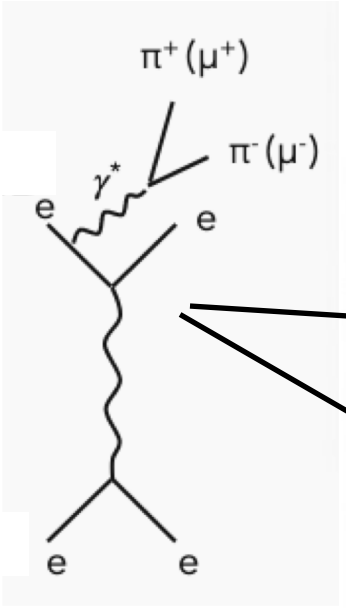
BESIII: $Q^2 > 0.1 \ldots 0.3\ \mathrm{GeV}^2$

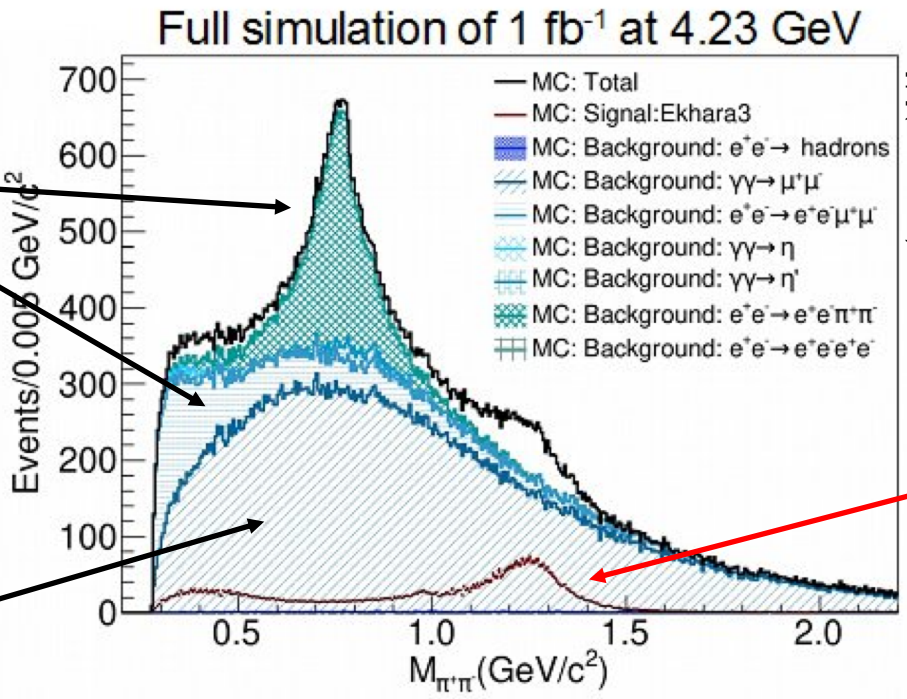
Progress seen by BESIII for π^0, also to be expected for η and η'

Double-tag measurement exsiting from BABAR for η', hoping for π^0, $\eta^{(\prime)}$ at BESIII

Space-Like TFFs (Multi-Body Modes)

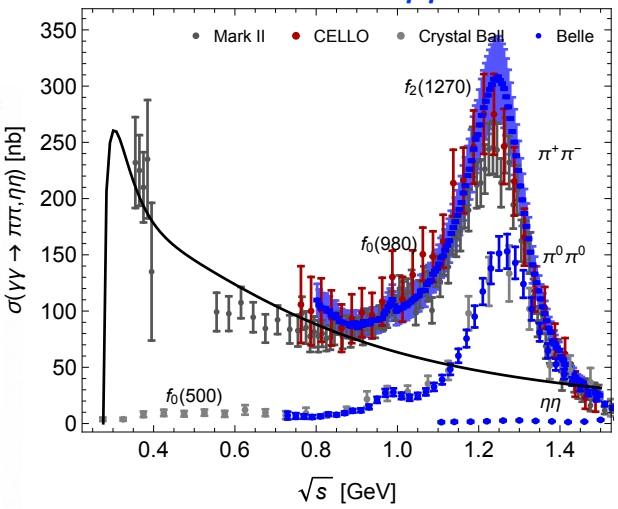
- BESIII analysis of $\pi^+\pi^-$ mode very advanced (first TFF measurement ever) (full coverage of helicity angle and mass spectrum down to threshold)





background
$\gamma\gamma^* \to \mu^+\mu^-$

world data on $\gamma\gamma \to \pi^+\pi^-$

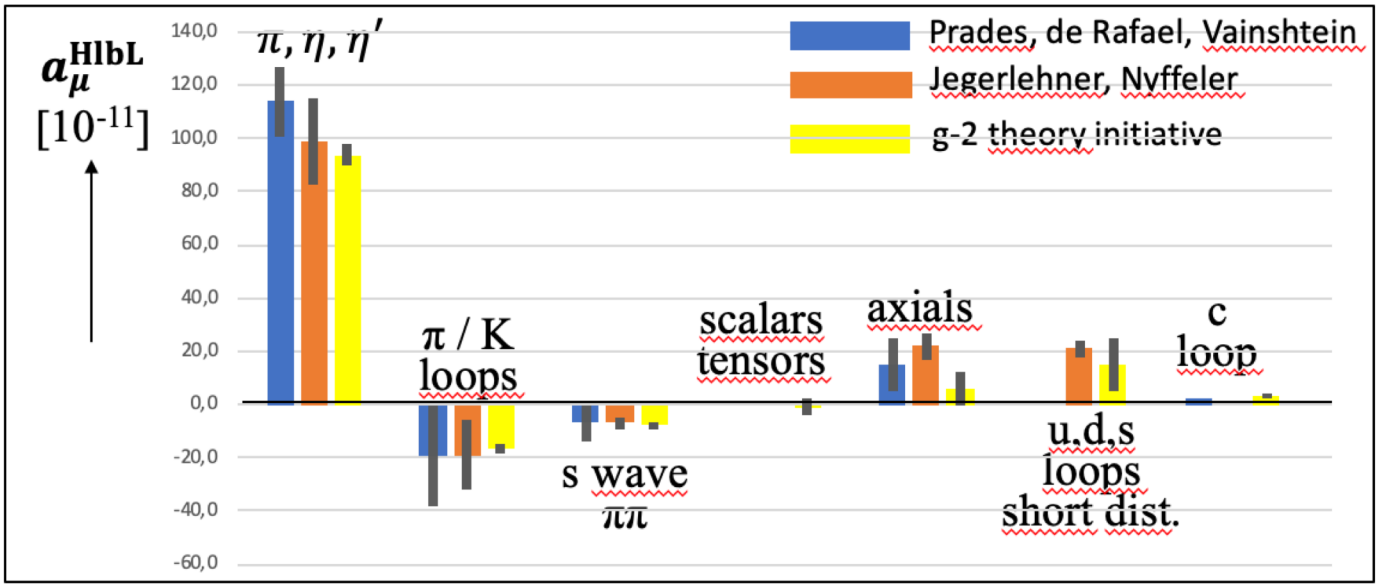


signal
$\gamma\gamma^* \to \pi^+\pi^-$

- Ongoing analysis of $\pi^0\pi^0$ (complementary to BELLE) and $\pi^0\eta$ (PhD project)

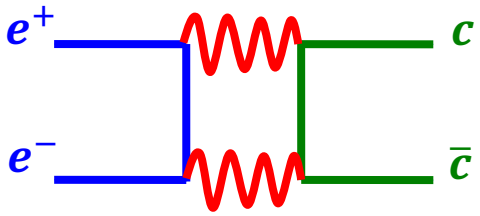
Space-Like TFFs (Multi-Body Modes)

- Preliminary (internal) spectra existing for $\pi\pi\eta$, 3π and 4π final states
  - BESIII (and also BABAR) working on TFF for $f_1(1285)$
  - prioritize analyses according to importance for g-2 HLbL



- Interplay between TFF measurements and searches for BSM particles (axions, dark sector particles)

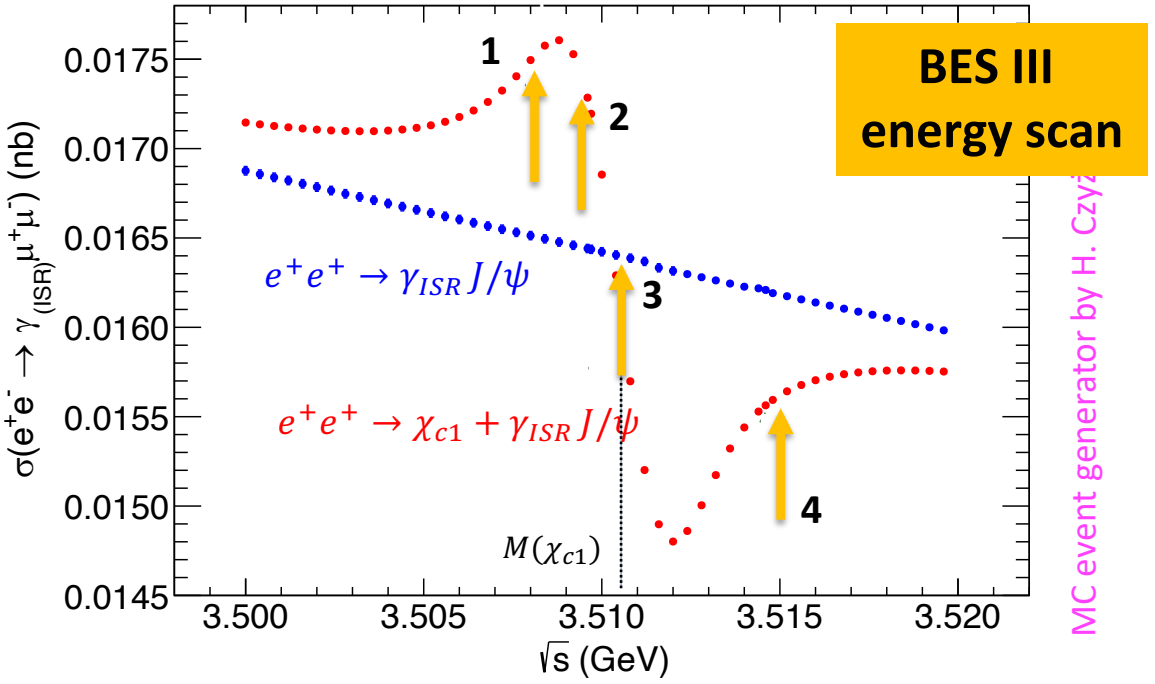
Two-Photon Production of Non-Vector States



$e^+e^- \to \chi_{c1}$ ($J^{PC}=1^{++}$)
M=3.51 GeV/c²

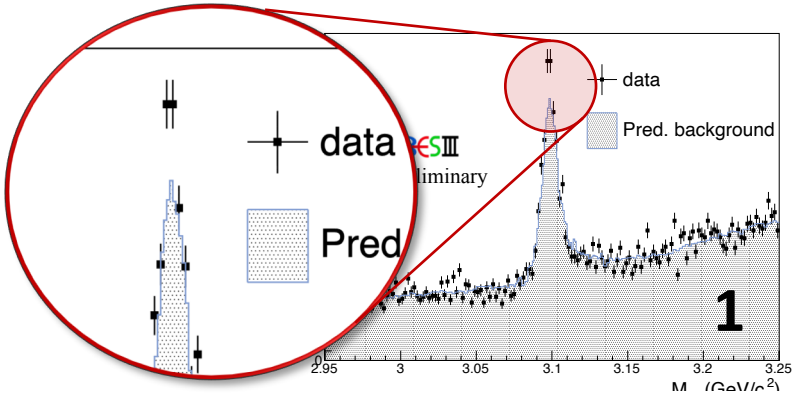
- Unitarity limit: $\Gamma_{ee} > 0.044$ eV J. Laplan, J. H. Kühn, PLB78, 252 (1978)
- Vector Dominance Model: $\Gamma_{ee} = 0.46$ eV; OR $\Gamma_{ee} \sim 0.1$ eV A. Denig, F. K. Guo, C. Hanhart, A. V. Nefediev, PLB736, 221 (2014)
- Non-relativistic QCD: $\Gamma_{ee} \sim 0.1$ eV N. Kivel, M. Vanderhaeghen, JHEP02, 032 (2016)
- Latest prediction: $\Gamma_{ee} = 0.43$ eV; interference with background process! H. Czyż, J. H. Kühn, S. Tracz,PRD94, 034033 (2016)

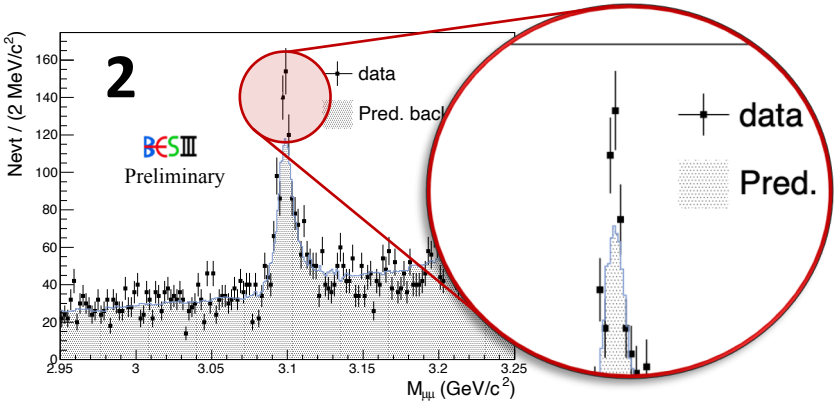
- Search for $\chi_{c1} \to \gamma\, J/\psi \to \gamma\, \mu^+\mu^-$
- Background from $e^+e^- \to \gamma_{ISR}\, J/\psi \to \gamma_{ISR}\, \mu^+\mu^-$ (Phokhara)

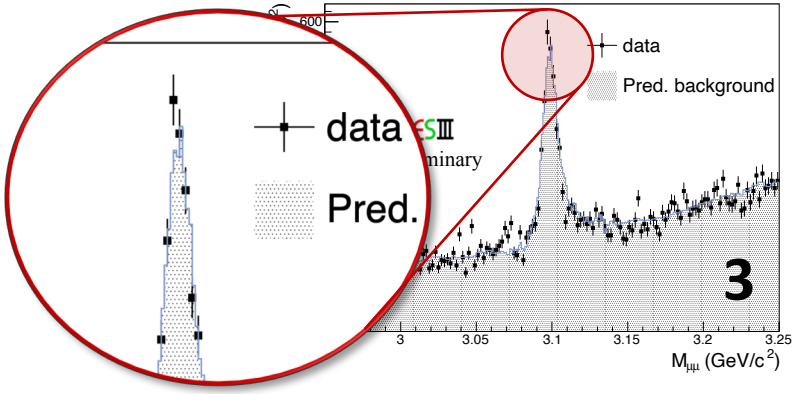


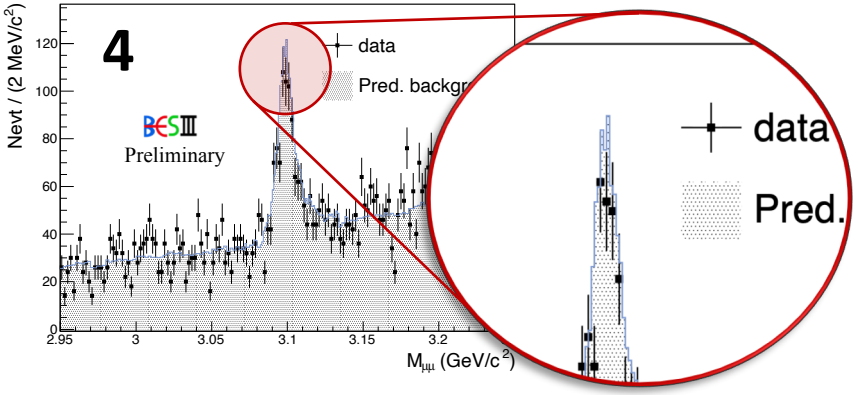
Two-Photon Production of Non-Vector States

BESIII preliminary









Discovery of $e^+e^- \to \chi_{c1}$ ($J^{PC}=1^{++}$) with >5σ significance

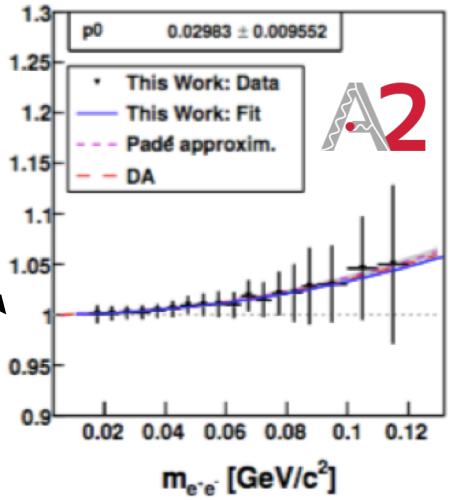
$\Gamma_{ee}=0.12^{+0.13}_{-0.08}$ eV and $\phi=205^{+15.4}_{-22.4}$ degree

New approach to spectroscopy / gamma-gamma scattering in e^+e^- annihilation!

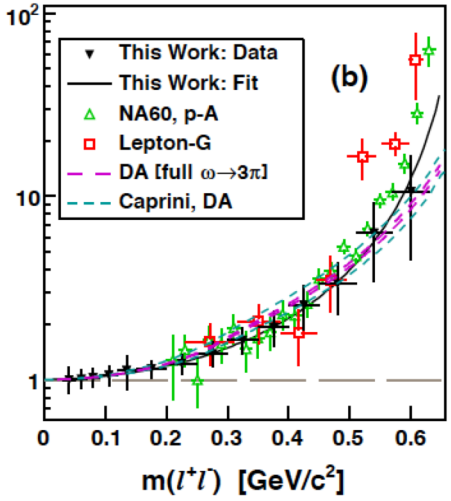
Time-Like TFFs (Fit Parameters)

Timelike TFFs from meson decays at various meson facilities worldwide (MAMI, COSY, JLAB, BES III, Frascati, BELLE II, CERN-SPS, ...)

$\pi^0 \to \gamma\gamma^*$



$\omega \to \pi^0\gamma^*$



$\eta \to \gamma\gamma^*$