

December 9 2024

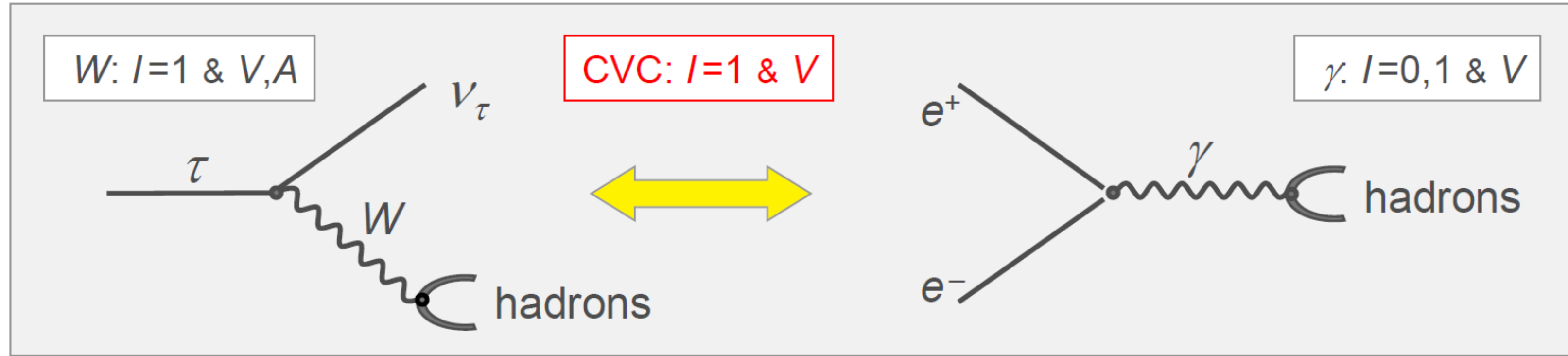
# Virtual mini workshop on tau decays (Theoretical Aspects): Introduction

Vincenzo Cirigliano



# Input for HVP from hadronic $\tau$ decays

From Michel Davier (Tau mini-workshop: Experimental Aspects, Nov 8 2024)

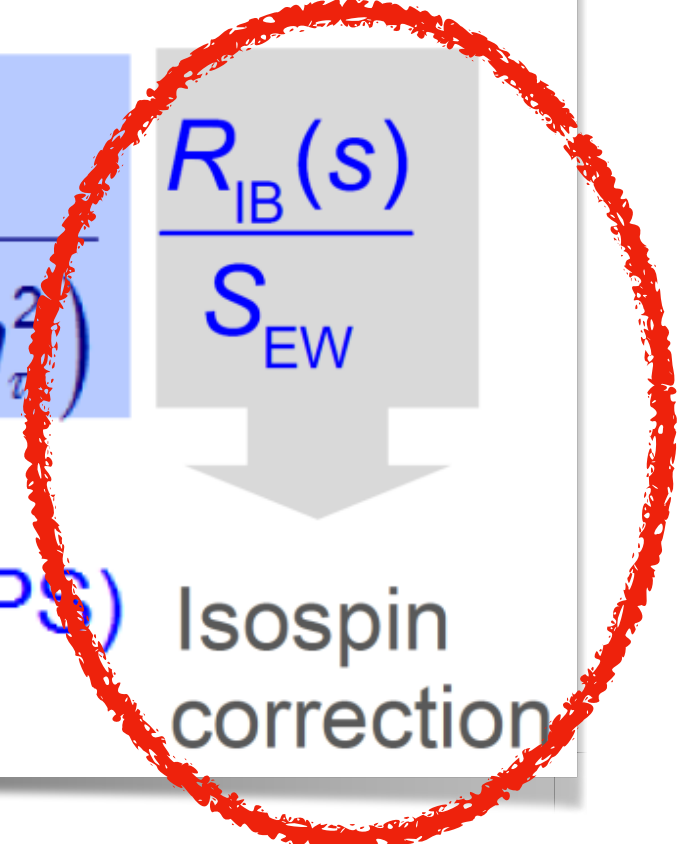


Dominant  $2\pi$  channel

$$\sigma^{(I=1)}[e^+e^- \rightarrow \pi^+\pi^-] = \frac{4\pi\alpha^2}{s} v[\tau^- \rightarrow \pi^-\pi^0\nu_\tau]$$

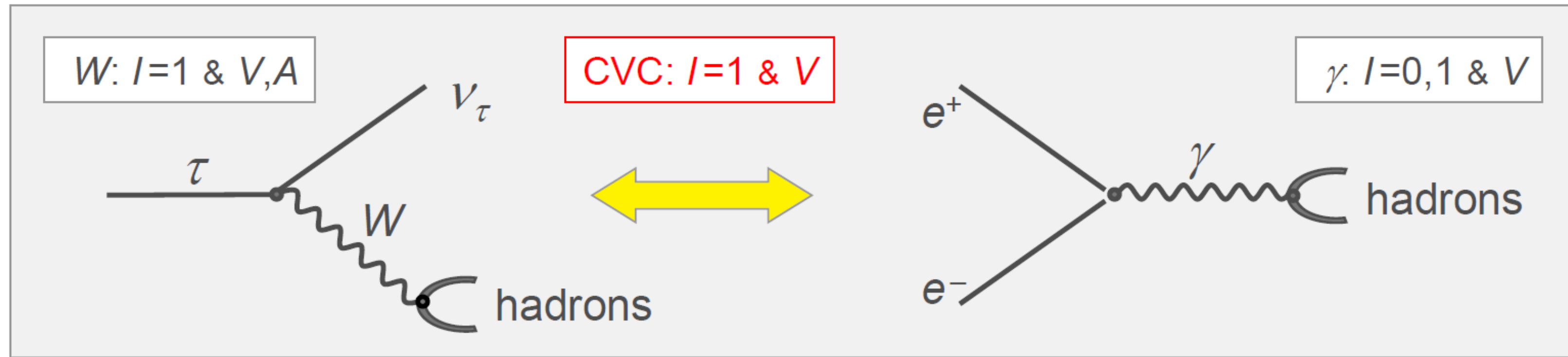
$v[\tau^- \rightarrow \pi^-\pi^0\nu_\tau] \propto$

$\frac{\text{BR}[\tau^- \rightarrow \pi^-\pi^0\nu_\tau]}{\text{BR}[\tau^- \rightarrow e^-\bar{\nu}_e\nu_\tau]}$	$\frac{1}{N_{\pi\pi^0}} \frac{dN_{\pi\pi^0}}{ds}$	$\frac{m_\tau^2}{(1-s/m_\tau^2)^2 (1+s/m_\tau^2)}$	$\frac{R_{IB}(s)}{S_{EW}}$
branching fractions	mass spectrum	kinematic factor (PS)	Isospin correction



# Isospin breaking correction

From Michel Davier (Tau mini-workshop: Experimental Aspects, Nov 8 2024)



Final state radiation in  $e^+e^- \rightarrow \pi^+\pi^-$       Kinematics

$$R_{IB}(s) = \frac{\text{FSR}(s)}{G_{EM}(s)} \frac{\beta_0^3(s)}{\beta_-^3(s)} \left| \frac{F_0(s)}{F_-(s)} \right|^2$$

Electroweak correction (mostly short-distance)

Long distance electromagnetic corrections in  $\tau^- \rightarrow \pi^- \pi^0 \nu_\tau$

Ratio of form factors

**Non perturbative methods needed to deal with hadronic interactions: EFT, resonance models, dispersive methods, lattice QCD**

# We will hear about multiple approaches

Status of current analysis  
(EFT + hadronic modeling)

Status and prospects of  
dispersive approach

Status and prospects of  
Lattice QCD approach

<b>6:00 AM → 8:15 AM</b>		<b>Theoretical Aspects</b>	
		Convener: Vincenzo Cirigliano	
<b>6:00 AM</b>	<b>Introduction</b>		🕒 5m
<b>6:05 AM</b>	<b>Present status of phenomenological analysis</b>		🕒 25m
		Speakers: Bogdan Malaescu (LPNHE-Paris CNRS/IN2P3 (FR)), Zhiqing Philippe Zhang (IJCLab, Orsay (FR))	
<b>6:35 AM</b>	<b>Long-distance EM corrections</b>		🕒 25m
		Speaker: Gabriel Lopez Castro	
<b>7:05 AM</b>	<b>Dispersive program</b>		🕒 25m
		Speaker: Martina Cottini (University of Bern)	
<b>7:35 AM</b>	<b>Lattice QCD program</b>		🕒 25m
		Speaker: Mattia Bruno (CERN)	
<b>8:05 AM</b>	<b>Break</b>		🕒 10m
<b>8:15 AM → 9:25 AM</b>		<b>Discussion</b>	
		Convener: Vincenzo Cirigliano	

# Questions to guide the discussion (I)

## Challenges in current analysis of isospin corrections

- **Q1:** Please discuss the uncertainty in  $G_{EM}(s)$  and  $F_0(s)/F_-(s)$  arising from using different model parameterizations of the form factors. Are there strategies to mitigate this intrinsic model dependence?
- **Q2:** Please discuss the uncertainty in  $F_0(s)/F_-(s)$  due to rho resonance parameters (difference in masses and widths, ...). How robust are the current determinations of these parameters?
- **Q3:** Please discuss the uncertainties in  $G_{EM}(s)$  induced by the structure-dependent effects, both in loops involving virtual photons and in real photon emission.
- **Q4:** Please discuss uncertainties in the short-distance correction  $S_{EW}$  associated with the renormalization group running and the matching to the long-distance corrections  $G_{EM}(s)$ . To a given order, the product  $S_{EW} * G_{EM}(s)$  should be independent on the renormalization scale and scheme. Do we control the scheme (in)dependence to  $O(\alpha/\pi)$ ?

# Questions to guide the discussion (2)

## Impact of dispersive and lattice QCD programs

- **Q1D:** Please articulate **which aspects of the IB corrections will be most impacted by the dispersive program** and why (e.g. improved control on  $G_{EM}(s)$ , removing model dependence in form factors, ...).
- **Q2D:** To the extent possible at the current stage in the program, please discuss the **dominant sources of uncertainty** (e.g. input data, neglected channels / intermediate states, ...) **and estimated impact on the  $R_{IB}(s)$  correction.**
- **Q1L:** Please articulate **which aspects of the IB corrections will be most impacted by the lattice program** and why (e.g. removing model dependence in form factors, control the scheme dependence in  $S_{EW} * G_{EM}(s)$ , ...).
- **Q2L:** To the extent possible at the current stage in the program, please discuss the **dominant sources of uncertainty** (statistics, lattice extrapolations, matching to continuum, ... ) **and estimated impact on the  $R_{IB}(s)$  correction.**