

The $\pi^0 \rightarrow \gamma\gamma^*$ Decay Rate and Transition Radius

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- $\Gamma(\pi^0 \rightarrow \gamma\gamma)$: Test of QCD symmetry structure
- Experimental Overview and issues
- $\pi^0, \eta, \eta' \rightarrow \gamma\gamma^*(Q^2)$ form factors as $Q^2 \rightarrow 0$
chiral radius of Nambu-Goldstone Bosons

$\tau(\pi^0)$ and QCD

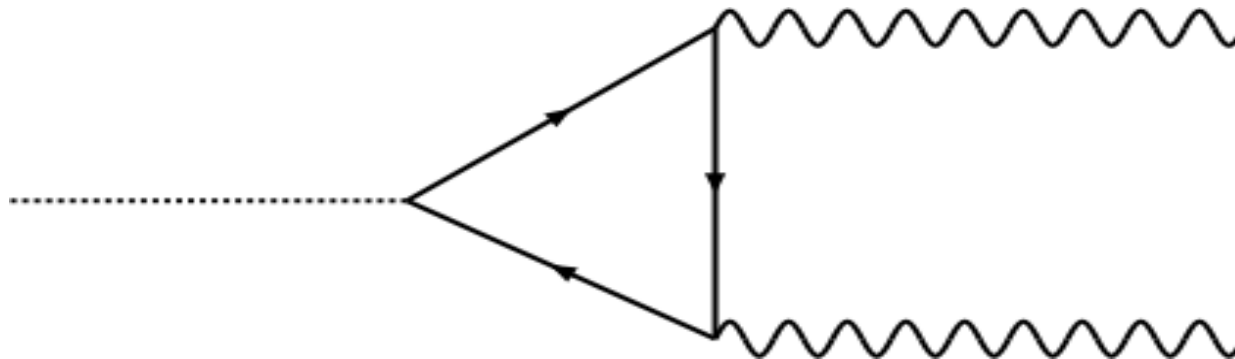
Axial Anomaly Bell and Jackiw, Adler 1969

Chiral Symmetry exact in Lagrangian

massless up, down quarks

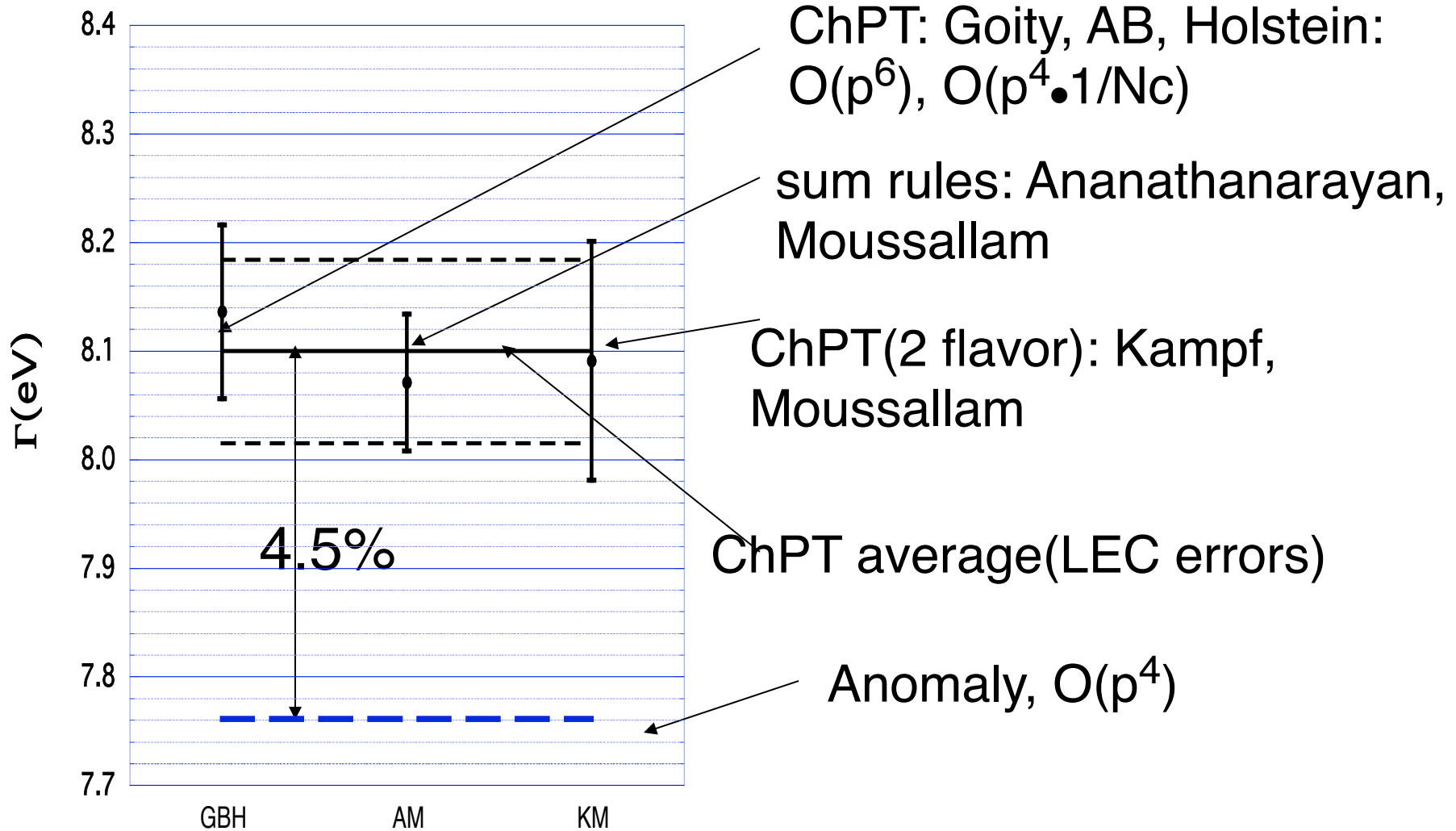
lost in quantization

- $\Gamma(\pi^0 \rightarrow \gamma \gamma) = (m_\pi/4\pi)^3 (\alpha/F_\pi)^2 = 7.76 \text{ eV}$
- exact in the chiral limit $m_u, m_d, m_\pi \rightarrow 0$
- no adjustable constants
- chiral corrections $\sim (m_\pi / 4\pi F_\pi)^2 \sim 2 \%$



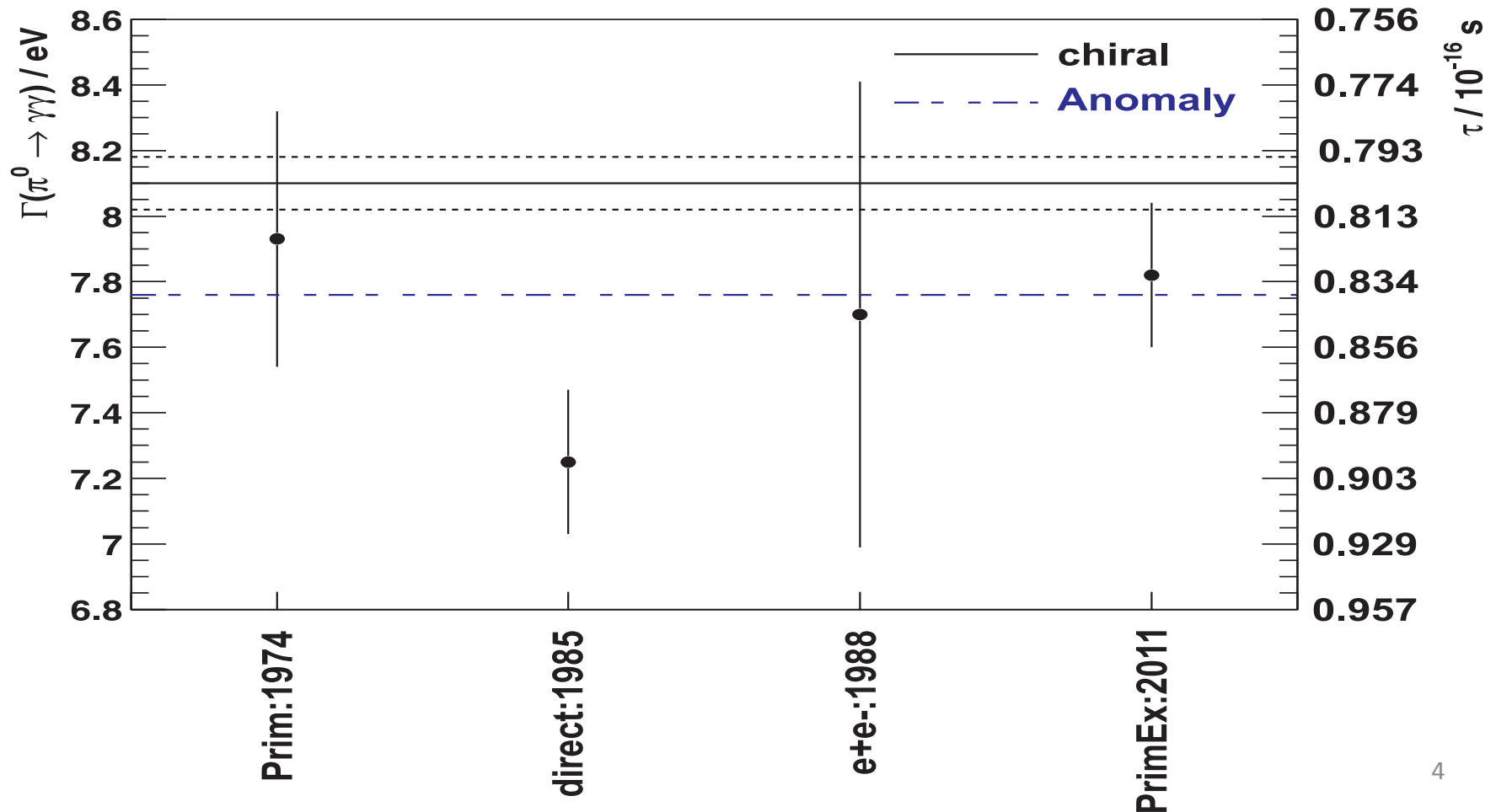
Chiral calculations $\Gamma(\pi^0 \rightarrow \gamma\gamma): \pi, \eta, \eta'$

$\Gamma(\pi^0 \rightarrow \gamma\gamma)$ ChPT



π^0 lifetime

- dominated by axial anomaly, IS breaking chiral corrections 4.5%
~ $m_d - m_u$ accurate to 1%
- Reviews of Modern Physics , Jan 2013 with B. Holstein
- **Experiments not as accurate as theory**



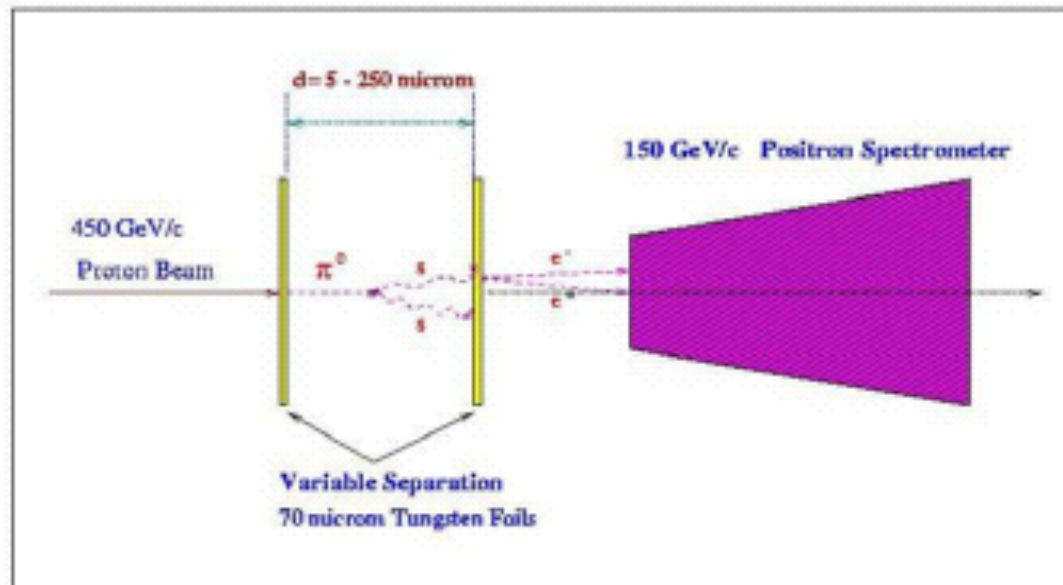
CERN: Direct lifetime measurement: PL 1985

measured Yield (150 GeV β^+)

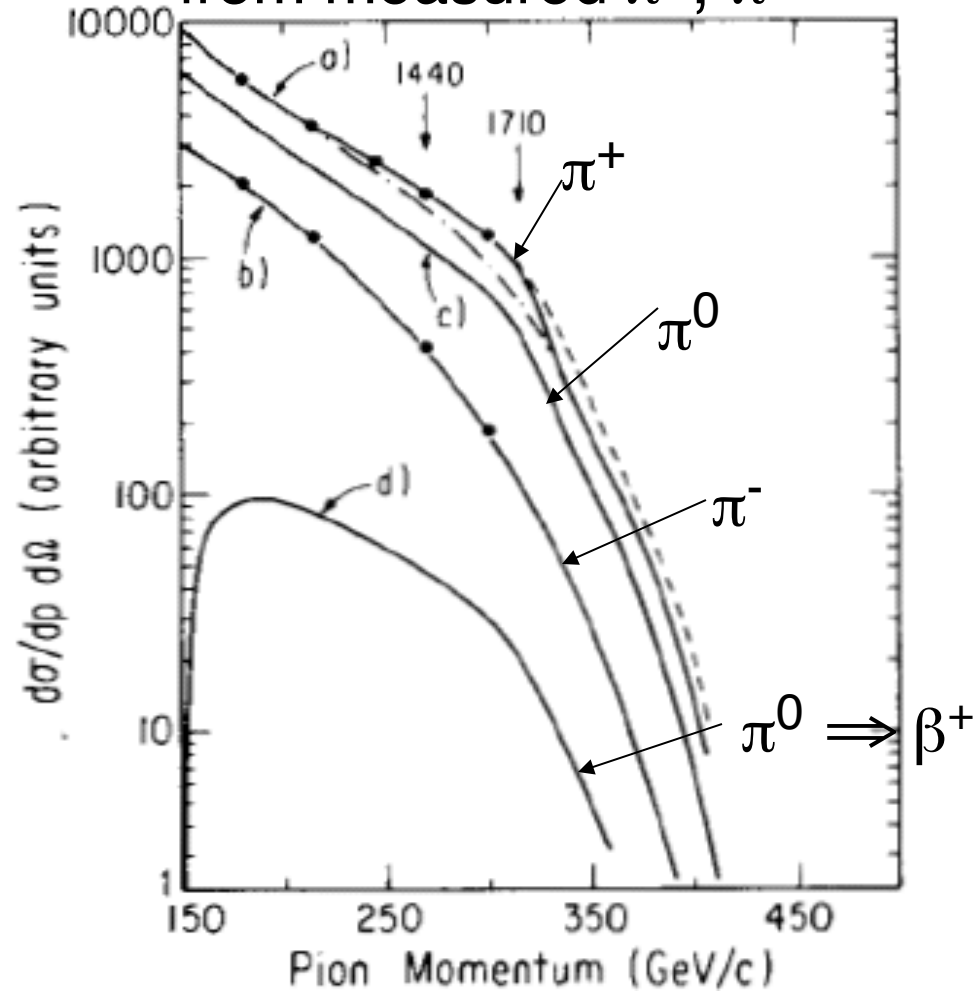
$$Y(d) = A + B (1 - e^{-d/\langle d \rangle}) \quad B/A \approx 0.07$$

$$E = 450 \text{ GeV} \quad \langle p_{\pi^0} \rangle \approx 240 \text{ GeV} \quad \langle \gamma \rangle \approx 1700 \quad \langle d \rangle = 46.5 \mu$$

$$\tau(\pi^0) \approx \langle d \rangle / (\gamma c) \approx 0.89 \cdot 10^{-16} \text{ sec}$$



π^0 spectrum derived
from measured π^+ , π^-



γ spectrum measurement
required

COMPASS possibility

$$PS \rightarrow \gamma\gamma^*(Q^2) \quad PS = \pi^0, \eta, \eta'$$

$$F(Q^2) = F(0)[1 - Q^2 \langle r^2 \rangle / 6 + \dots]$$

only method to measure the size of neutral PS mesons
“anomaly RMS radius”

needs accurate low Q^2 data: presently available only for η
Mainz A2 collaboration

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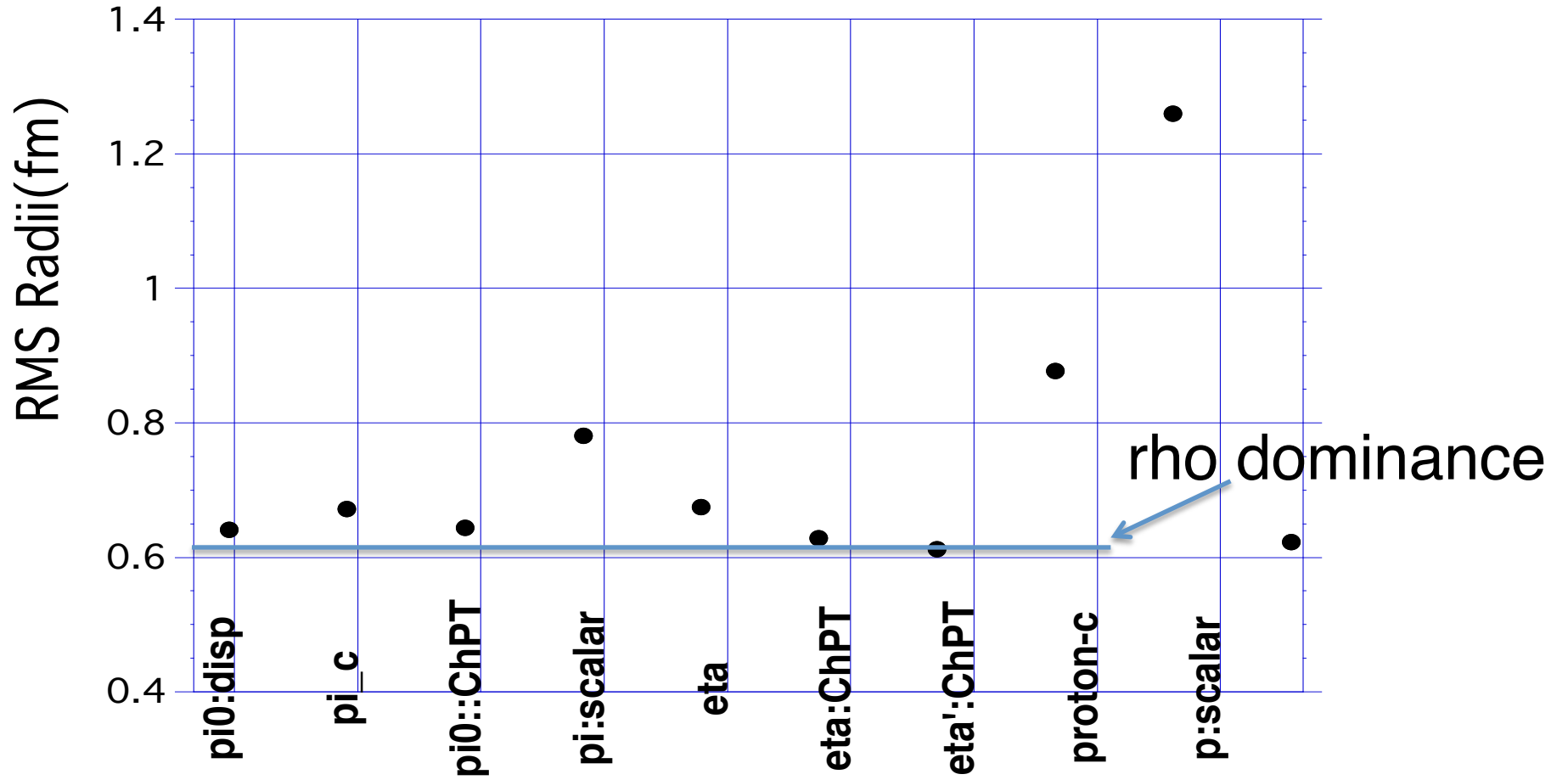
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high Q^2 data with dipole FF fit $F(0)/[1+Q^2/M_V^2]$ can only
approximately estimate the RMS radius

vector meson (ρ) dominance model

$$R = \sqrt{6}/M_\rho = 0.62 \text{ fm}$$

RMS Radii



Conclusions

- The QCD prediction for Γ is accurate to $\sim 1\%$
- Experimental data is less accurate
- more accurate data is on the horizon
PrimeEx 2 (Gasparian talk, Gan plenary talk)
Frascati e+e- data in progress
Compass/CERN “direct” experiment possible
- chiral radii of Nambu-Goldstone Bosons
 $\pi^0, \eta, \eta' \rightarrow \gamma \gamma^*(Q^2)$ form factors as $Q^2 \rightarrow 0$
- Plans at Frascati, BES, JLab
- needs physical interpretation
- experimental data needed for η'

