

FEASIBILITY STUDY OF $f_0(1500) \rightarrow \pi^+ \pi^-$ AND $f_0(1710) \rightarrow \pi^+ \pi^- (K^+ K^-)$ IN PANDAROOT

Keval Gandhi

Under the supervision of
Dr. Ajay Kumar Rai
Associate Professor



Department of Applied Physics
Sardar Vallabhbhai National Institute of Technology,
Surat-395007, Gujarat, India.

September 28, 2019

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

Overview

COLLABORATORS

COLLABORATORS

OBJECTIVE'S

OBJECTIVE'S

ROOT MECHANISM

ROOT MECHANISM

INPUTS

INPUTS

INVARIANT MASS DISTRIBUTION

INVARIANT MASS
DISTRIBUTION

GAUSSIAN DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

CONCLUSIONS

FUTURE PLAN

FUTURE PLAN

REFERENCES

REFERENCES

COLLABORATORS

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

N.R. Soni and J.N. Pandya

Department of Physics, Faculty of Science, The M S University
of Baroda, Vadodara - 390001, Gujarat, India

S.S. Godre

Department of Physics, Veer Narmad South Gujarat
University, Surat - 395007, India

B.J. Roy

Nuclear Physics Division, Bhabha Atomic Research Centre,
Mumbai - 400085, India

P.C. Vinodkumar

Department of Physics, Sardar Patel University, Vallabh
Vidyanagar - 388120, Gujarat, India.

OBJECTIVE'S

- ▶ **PANDA** (AntiProton Annihilations at Darmstadt) is mainly focused on **strong interaction** studies in the non-perturbative regime of quark-gluon interactions.
- ▶ The contribution of the constituent bare quark masses inside the hadrons is only few MeV and remaining mass is due to the strong interaction.
- ▶ The underlying physics is complex and yet to be understood fully.
- ▶ The study of **spectroscopy** of glueballs and mesons up to charm sector can help in answering these fundamental questions [1, 2].

ROOT MECHANISM

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

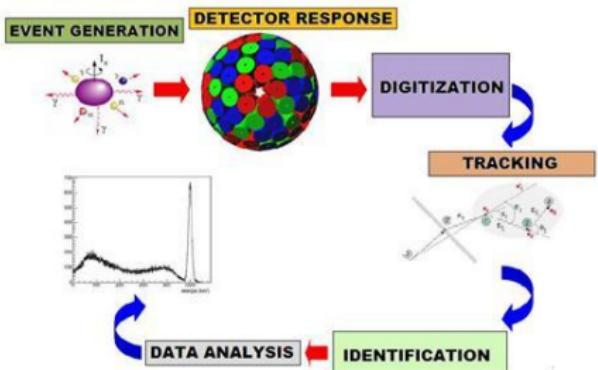


Figure: Process flow in root mechanism [3].

INPUTS

Keval Gandhi

- We choose the following decay channels:

Decay $\bar{p}p$

1.0 $f_0(1500)\gamma$ PHSP;

Enddecay

Decay $f_0(1500)$

1.0 $\pi^+\pi^-$ PHSP;

Enddecay

End

Decay $\bar{p}p$

1.0 $f_0(1710)\gamma$ PHSP;

Enddecay

Decay $f_0(1710)$

1.0 $\pi^+\pi^-(K^+K^-)$ PHSP;

Enddecay

End

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

- Antiproton \bar{p} beam momentum $P_{\bar{p}} = 3.5$ GeV/c is fix.
- Provides \bar{p} beam energy, $E_{\bar{p}} = 3.62$ GeV.
- The Lorentz invariant quantity,

$$s = m_{\bar{p}}^2 + 2E_{\bar{p}}m_p + m_p^2 \quad (1)$$

in the laboratory frame (for details see Ref. [4]).

- Gives the center-of-mass energy, $\sqrt{s} = 2.92$ GeV.
- Run the simulation for 10000 events of $\bar{p}p$ collisions.

INVARIANT MASS DISTRIBUTION

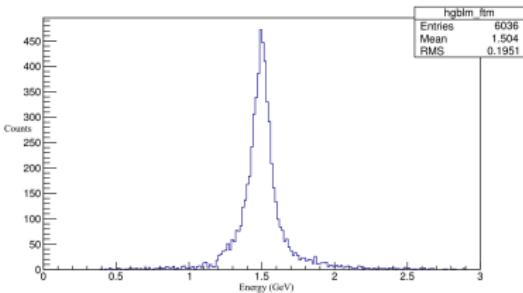


Figure: Invariant mass distribution for $f_0(1500) \rightarrow \pi^+\pi^-$ decay.

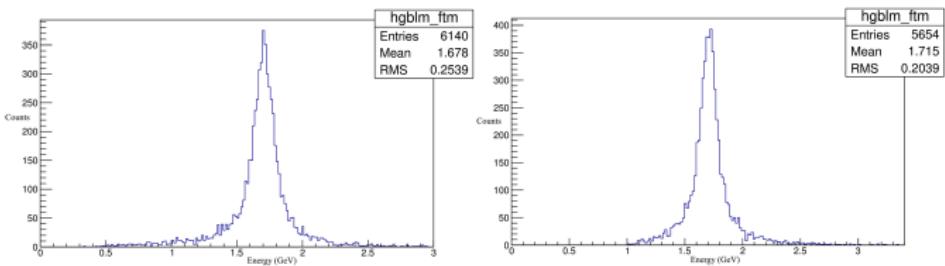


Figure: Invariant mass distribution for $f_0(1710) \rightarrow \pi^+\pi^-$ decay (left) and for $f_0(1710) \rightarrow K^+K^-$ decay (right).

GAUSSIAN DISTRIBUTION

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

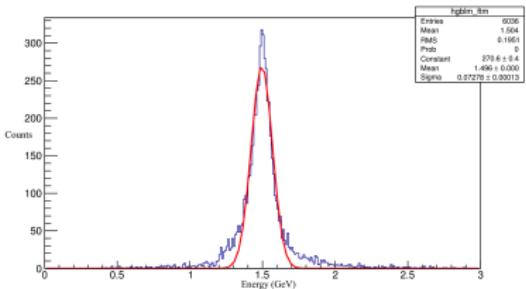


Figure: Gaussian distribution for $f_0(1500) \rightarrow \pi^+\pi^-$ decay.

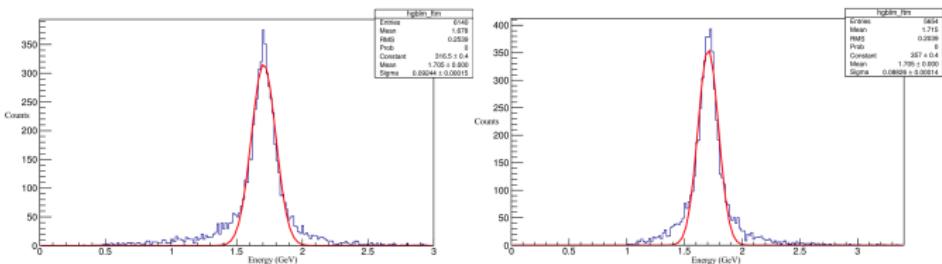


Figure: Gaussian distribution for $f_0(1710) \rightarrow \pi^+\pi^-$ decay (left) and for $f_0(1710) \rightarrow K^+K^-$ decay (right).

- ▶ The Gaussian probability density function is,

$$f(x) = \frac{1}{\sqrt{2\pi} \cdot \sigma} e^{\left(-\frac{(x-x_0)^2}{2\sigma^2}\right)} \quad (2)$$

where x_0 provides the mean or expectation value of the distribution, σ is the standard deviation and σ^2 is the variance.

- ▶ The **mean** of the Gaussian distribution gives an expectation value of mass of the glueball resonances.

$$\begin{aligned} M_{f_0(1500) \rightarrow \pi^+ \pi^-} &= 1496 \text{ MeV}, \\ M_{f_0(1710) \rightarrow \pi^+ \pi^- (\kappa^+ \kappa^-)} &= 1705 \text{ MeV}. \end{aligned}$$

- Relative distance between the half-maximum points gives **full width at half maxima (FWHM)**,

$$FWHM(\sigma) = \sqrt{8\ln(2)} \cdot \sigma \quad (3)$$

$$FWHM_{f_0(1500) \rightarrow \pi^+ \pi^-} = 171 \pm 13 \text{ MeV},$$

$$FWHM_{f_0(1710) \rightarrow \pi^+ \pi^-} = 218 \pm 15 \text{ MeV},$$

$$FWHM_{f_0(1710) \rightarrow K^+ K^-} = 208 \pm 14 \text{ MeV}.$$

- The spectroscopy study commonly used **half width at half maxima (HWHM)**,

$$HWHM = \frac{1}{2} \cdot (FWHM) \quad (4)$$

$$HWHM_{f_0(1500) \rightarrow \pi^+ \pi^-} = 85.5 \pm 6.5 \text{ MeV},$$

$$HWHM_{f_0(1710) \rightarrow \pi^+ \pi^-} = 109 \pm 7.5 \text{ MeV},$$

$$HWHM_{f_0(1710) \rightarrow K^+ K^-} = 104 \pm 7.0 \text{ MeV}.$$

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS DISTRIBUTION

GAUSSIAN DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

CONCLUSIONS

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

- ▶ Invariant mass distribution and Gaussian distribution for the $f_0(1500) \rightarrow \pi^+\pi^-$, $f_0(1710) \rightarrow \pi^+\pi^-$ and $f_0(1710) \rightarrow K^+K^-$ decays are studied
- ▶ The mean of the Gaussian distribution gives an expectation value of mass of the glueball resonances.
- ▶ Which are in agreement with the PDG-2018 [5] world average values, $M_{f_0(1500)} = 1506 \pm 6$ MeV and $M_{f_0(1710)} = 1704 \pm 12$ MeV.
- ▶ Moreover, their full width at half maxima (*FWHM*) and half width at half maxima (*HWHM*) are also calculated from the standard deviation (σ).

FUTURE PLAN

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

- ▶ We analyze the strong decays of charmed mesons using **Heavy Quark Effective Theory (HQET)** in the leading order approximation [6, 7, 8, 9].
- ▶ We make predictions for the decay widths, branching ratios and the **fractions**.
- ▶ Fraction gives the **percentage of the partial decay width** with respect to total decay widths.
- ▶ That will give the **probability** of the particular decay mode from the all possible decay modes.

► For example:

- The $D_2^*(2460)^0$ is mainly decay via strong interaction with an emission of light pseudoscalar mesons (π, K, η).
- The charge and the flavor of participating mesons are conserved.

Table: The strong decay widths of newly observed $D_2^*(2460)^0$ meson (LHCb(2016) [10]) with possible decay modes.

Meson	$\mathcal{N}^{2S+1}L_J$	Decay mode	Width (in MeV)	Branching ratio	Fraction (in %)	Probability
$D_2^*(2460)^0$	1^3P_2	$D^+\pi^-$	$127.978g^2$	1	46.0429	0.46
		$D^0\pi^0$	$66.8703g^2$	0.52251	24.0580	0.24
		$D_s^+K^-$	≈ 0	0	0	0
		$D_s^0\eta$	—	—	0	0
		$D^{*+}\pi^-$	$56.3891g^2$	0.44062	20.2872	0.20
		$D^{*0}\pi^0$	$29.7173g^2$	0.23221	10.6914	0.10
		$D_s^{*+}K^-$	—	—	0	0
		$D_s^{*0}\eta$	—	—	0	0
Total			$277.9547g^2$		≈ 100	≈ 1

- ▶ Therefore, the decay channel will be

Decay $\bar{p}p$

1.0 $D_2^*(2460)^0$ PHSP;

Enddecay

Decay $D_2^*(2460)^0$

0.46 $D^+\pi^-$ PHSP;

0.24 $D^0\pi^0$ PHSP;

0.20 $D^{*+}\pi^-$ PHSP;

0.10 $D^{*0}\pi^0$ PHSP;

Enddecay

End

- ▶ Which gives the final states mass spectra of $D^+\pi^-$, $D^0\pi^0$, $D^{*+}\pi^-$ and $D^{*0}\pi^0$ as a decay products.
- ▶ That will be reconstructing the state $D_2^*(2460)^0$.
- ▶ Also, possible to analyze the strong decays of other charmed mesons.

REFERENCES

Keval Gandhi

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES

-  Physics Performance Report for $\bar{\text{P}}\text{ANDA}$ ($\bar{\text{P}}\text{ANDA}$ Collaboration (2009)), *arXiv:0903.3905v1*.
-  J. S. Lange ($\bar{\text{P}}\text{ANDA}$ Collaboration), *Int. J Mod. Phys. A* **24**, 369 (2009).
-  K. Gandhi *et al.*, DAE Symp. Nucl. Phys. **62**, 798 (2017); **63**, 906 (2018).
-  M. Thomson, Cambridge Uni. Press, ISBN: 978-1-316-60999-6 (2013); A. Bettini, ISBN 978-1-107-05040-2 (2014).
-  M. Tanabashi *et al.* (Particle Data Group), *Phys. Rev. D* **98**, 030001 (2018) and 2019 update.
-  S. Campanella, P. Colangelo and F. De. Fazio *Phys. Rev. D* **98**, 114028 (2018); P. Colangelo, F. De. Fazio, F. Giannuzzi and S. Nicotri, *Phys. Rev. D* **86**, 054024 (2012).
-  P. Colangelo and F. Giannuzzi *Phys. Rev. D* **81**, 094001 (2010); P. Colangelo, F. De. Fazio, F. Giannuzzi, S. Nicotri and M. Rizzi, *Phys. Rev. D* **77**, 014012 (2008).
-  Z.-G. Wang, *Phys. Rev. D* **83**, 014009 (2011); *Phys. Rev. D* **88**, 114003 (2013); *Eur. Phys. J. Plus* **129**, 186 (2014); *Commun. Theor. Phys.* **66**, 671 (2016).
-  P. Gupta and A. Upadhyay, *Phys. Rev. D* **97**, 014015 (2018); M. Batra and A. Upadhyay, *Eur. Phys. J. C* **75**, 319 (2015).
-  R. Aaij *et al.* (LHCb Collaboration), *Phys. Rev. D* **94**, 072001 (2016).

COLLABORATORS

OBJECTIVE'S

ROOT MECHANISM

INPUTS

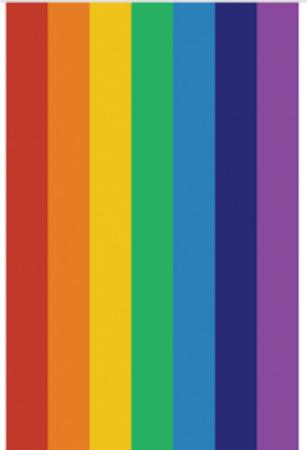
INVARIANT MASS
DISTRIBUTION

GAUSSIAN
DISTRIBUTION

CONCLUSIONS

FUTURE PLAN

REFERENCES



*Thank
you*