

$f_0(980)$ resonance production in pp collisions with the ALICE detector at the LHC

Alessandra Lorenzo for the ALICE Collaboration

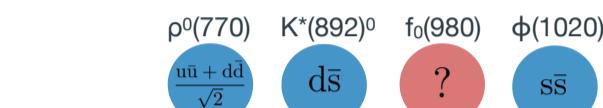
University and INFN, Bologna (Italy) - alessandra.lorenzo@bo.infn.it

Particle	Mass [GeV/c ²]	Width [GeV/c ²]	Decay modes
$f_0(980)$	0.99 ± 0.02	From 0.01 to 0.1	$\pi\pi$ (dominant) KK (seen) $\gamma\gamma$ (seen)

The Particle Data Group [1] only provides ranges for mass and width.

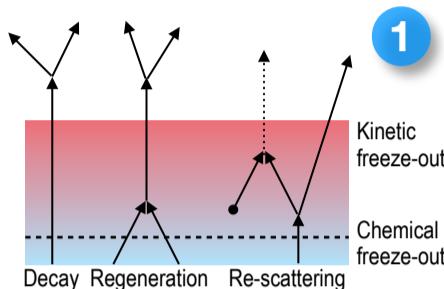
Physics motivation

Short-lived hadronic resonances are useful probes for the late hadronic phase in the evolution of ultra-relativistic heavy-ion collisions (Fig. 1). Lifetimes are of the same order of magnitude as the time span between the chemical and kinetic freeze-out (~ 10 fm/c).



$f_0(980)$

- Probe for the hadronic phase.
- Similar lifetime as the $K^*(892)$.
- Similar mass as p and $\phi(1020)$.
- Elusive nature: it was associated to $q\bar{q}$ structures, considered as a $(q\bar{q})^2(\bar{q}\bar{q})^2$ tetraquark and as a mixture of $q\bar{q}$ and tetraquark [2].



pp collisions

- First attempt to perform this measurement with ALICE (Fig. 2) in inclusive production.
- Baseline for measurement in AA collisions.
- Yields in different collision systems: information about nature of exotic hadrons [3].

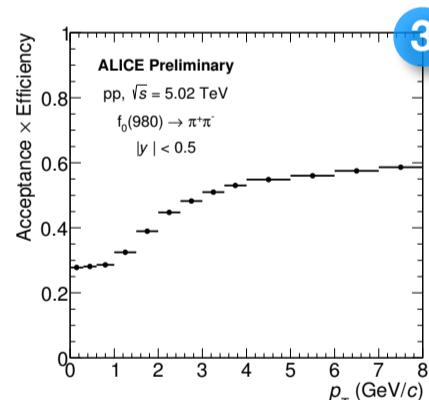
Data

- pp collisions at $\sqrt{s} = 5.02$ TeV collected in 2015.
- $\sim 10^8$ minimum bias triggered events analysed.
- PID cuts: $|N_{TOF}| < 3$ when TOF is matched, otherwise $|N_{TPC}| < 2$.
- Pair cuts: $|y| < 0.5$.

Acceptance x Efficiency

Monte Carlo simulated data sample: PYTHIA8 + injected $f_0(980)$ and $f_2(1270)$ signals.

$$(Acc \times \varepsilon)(p_T) = \frac{\text{Reconstructed } f_0(980) \rightarrow \pi^+\pi^-}{\text{Generated } f_0(980) \rightarrow \pi^+\pi^-}$$



3

Signal extraction - $f_0(980) \rightarrow \pi^+\pi^-$

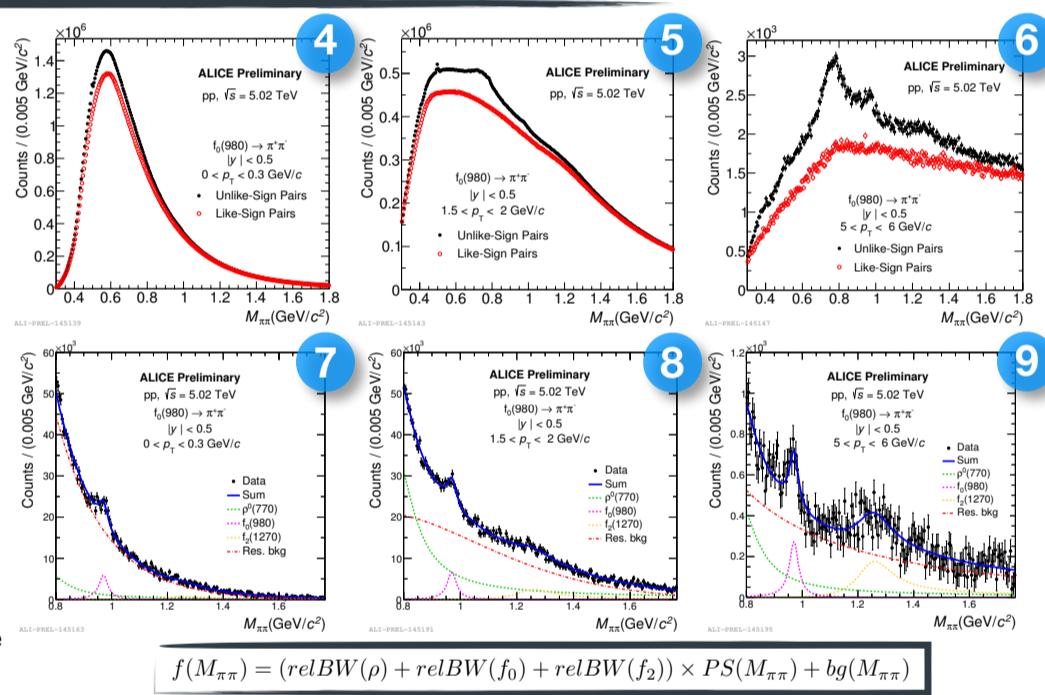
The uncorrelated background is estimated using the Like-Sign Background technique (Figures 4, 5, 6).

Contributions by other resonances in the invariant mass window under study make the signal extraction very challenging.

A composite fit model is used (Figures 7, 8, 9).

- $f_0(980)$, $p^0(770)$, $f_2(1270)$: Relativistic Breit-Wigner x Phase Space factor.
- Residual background: Maxwell-Boltzmann.

$f_0(980)$ parameters from the unconstrained fit are within PDG ranges. To improve the fit stability, f_0 mass is fixed to the value resulting from the free fit. f_0 width, p^0 and f_2 parameters are constrained or fixed at the PDG values (Table a).



Fit parameters settings

Resonance	Mass [GeV/c ²]	Width [GeV/c ²]
$f_0(980)$	0.9734	(0.01-0.1)
$p^0(770)$	0.7753	0.1491
$f_2(1270)$	1.2755	0.1867

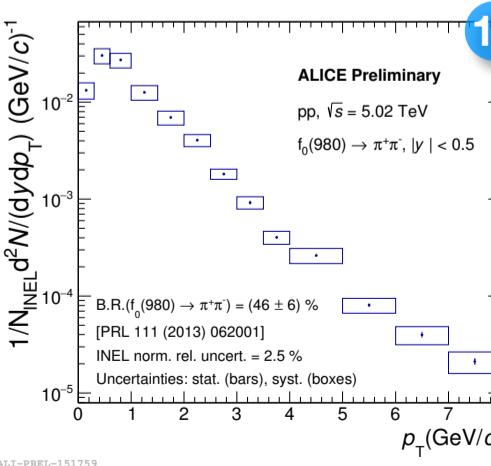
$$relBW = \left(\frac{M_{\pi\pi}\Gamma(M_{\pi\pi})M}{(M_{\pi\pi}^2 - M_0^2)^2 + M_0^2\Gamma^2(M_{\pi\pi})} \right)$$

$$\Gamma(M_{\pi\pi}) = \left[\frac{(M_{\pi\pi}^2 - 4m_\pi^2)}{(M_0^2 - 4m_\pi^2)} \right]^{(2J+1)/2} \times \Gamma_0 \times (M_0/M_{\pi\pi})$$

$$PS(M_{\pi\pi}) = \frac{M_{\pi\pi}}{\sqrt{(M_{\pi\pi}^2 - p_T^2)}} \exp\left(-\frac{\sqrt{M_{\pi\pi}^2 - p_T^2}}{T}\right)$$

$$bg(M_{\pi\pi}) = B \sqrt{(M_{\pi\pi} - m_{cutoff})^n} C^{3/2} \exp[-C(M_{\pi\pi} - m_{cutoff})^n]$$

Results



10

$$\frac{dN_{f_0}}{dydp_T} = \frac{1}{N_{\text{evt}}} \frac{1}{\Delta y \Delta p_T} \frac{N_{f_0}(p_T)}{(Acc \times \varepsilon)(p_T) \cdot B.R.} f_{\text{inel}}$$

$$B.R.(f_0(980) \rightarrow \pi^+\pi^-) = (46 \pm 6)\% [4]$$

f_{inel} = normalisation to INEL events [5]

B.R.($f_0(980) \rightarrow \pi^+\pi^-$) = $(46 \pm 6)\%$ [PRL 111 (2013) 062001]

INEL norm. rel. uncert. = 2.5 %

Uncertainties: stat. (bars), syst. (boxes)

1/N_{INEL} d²N/dydp_T (GeV/c)⁻¹

10⁻⁵ to 10⁻²

0 to 8 GeV/c

ALI-PREL-151759

ALI-PREL-151779

11

Becattini et al., e+e- [Eur.Phys.J. C56 (2008) 493]

Becattini et al., pp [Z.Phys. C76, 269-286 (1997), priv. comm.]

* f_0/π^+ , pp [Z.Phys. C9 (1981) 293]

+ f_0/π^+ , pp [Z.Phys. C50 (1991) 405]

◊ f_0/π^+ , e+e- [Phys. Lett. B 462 (1999) 341]

□ f_0/π^+ , e+e- [Ann.Rev.Nucl.Part.Sci. 38 (1988) 279]

B.R.($f_0(980) \rightarrow \pi^+\pi^-$) = $(46 \pm 6)\%$ [PRL 111 (2013) 062001]

Uncertainties: stat. (bars), syst. (boxes)

ALI-PREL-151795

12

B.R.($f_0(980) \rightarrow \pi^+\pi^-$) = $(46 \pm 6)\%$ [PRL 111 (2013) 062001]

Uncertainties: stat. (bars), syst. (boxes)

ALI-PREL-151788

13

B.R.($f_0(980) \rightarrow \pi^+\pi^-$) = $(46 \pm 6)\%$ [PRL 111 (2013) 062001]

Uncertainties: stat. (bars), syst. (boxes)

ALI-PREL-151847

14

B.R.($f_0(980) \rightarrow \pi^+\pi^-$) = $(46 \pm 6)\%$ [PRL 111 (2013) 062001]

Uncertainties: stat. (bars), syst. (boxes)

ALI-PREL-151847

14

The analysis demonstrates the feasibility of the measurement in inelastic pp collisions over a wide transverse momentum range: $f_0(980)$ yield has been measured from 0 to 8 GeV/c (Fig. 10).

The p_T -integrated f_0/π ratio is consistent with LEP results (Fig. 11).

Statistical Hadronisation Model [6] underestimates f_0/π ratio, as in e^+e^- collisions (Fig. 11).

$f_0(980)/\phi(1020)$ ratio as a function of the transverse momentum suggests that ϕ and f_0 have similar spectral shapes (Fig. 12).

As a next step, the possibility to detect $f_0(980)$ also in high-multiplicity events will be explored.

References

- [1] Patrignani et al., "Review of Particle Physics," *Chin. Phys. C40* no. 10, (2016) 100001.
[2] Maiani et al., *Phys. Rev. Lett.* 93 (Nov, 2004) 212002.
[3] Cho et al., *Progress in Particle and Nuclear Physics* 95 (2017) 279 – 322.

- [4] Stone and Zhang, *Phys. Rev. Lett.* 111 (Aug, 2013) 062001.

- [5] <https://aliceinfo.cern.ch/Notes/node/665>.

- [6] Becattini and Heinz, *Z. Phys. C76, 269–286 (1997)*.

