Measurement of $\phi(1020)$ meson production in fixed-target *p*Ne collisions at $\sqrt{s_{NN}}$ = 68.5 GeV

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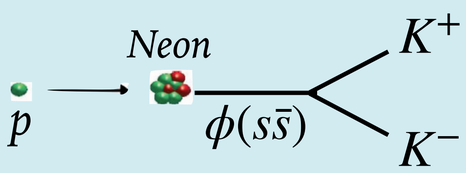
Physics Motivation

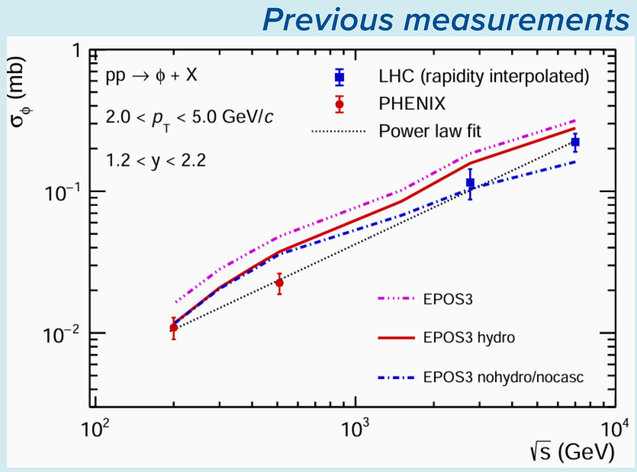
ϕ Meson

BR = (49.1 ± 0.5) %

- lightest bound state of $s\bar{s}$
  → good probe for ***strangeness*** production
- in ***larger*** systems (*e.g.* **heavy-ion** collisions), ***strangeness enhancement*** is a good signature of QGP formation
- in ***smaller*** systems (*e.g.* **proton-nucleus** collisions), ***Cold Nuclear Matter*** *effects* (CNM) which produce effects similar to QGP



Previous measurements

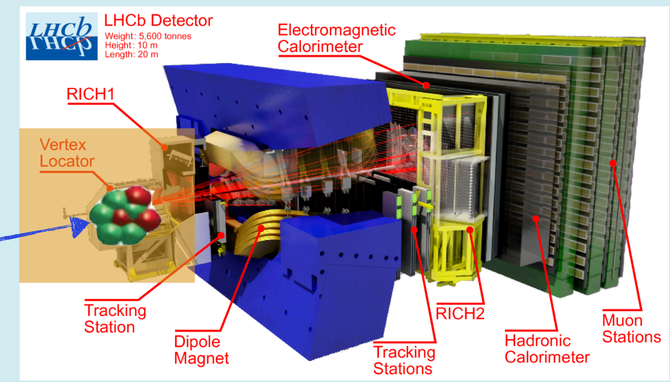


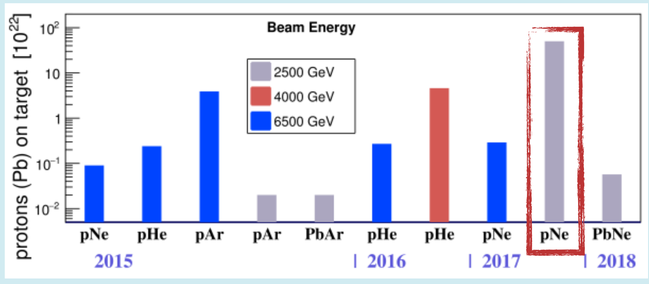
Proton-nucleus collisions

- **Baseline** for QGP formation
- Characterisation of CNM effects
  (nuclear shadowing, energy loss, nuclear breakup..)

Fixed-Target at LHC*b*

- **LHC*b***: single arm ***forward*** spectrometer
  → now ***general purpose*** with ***unique*** kinematic coverage ***2 < η < 5***
- **beam-beam** and ***beam-gas*** collisions taken ***simultaneously***
- **SMOG**: ***Noble gases* (He, Ar, Ne)** ***injected*** into the LHC beam pipe around the interaction point
- **Unique** energy coverage at $\sqrt{s_{NN}}$ = **68.5-110 GeV**





- **Fixed-target** kinematics covers only the y^* **central and negative** emisphere
- 2.5 TeV proton beam implies a boost of Δy = 4.3

Analysis Strategy

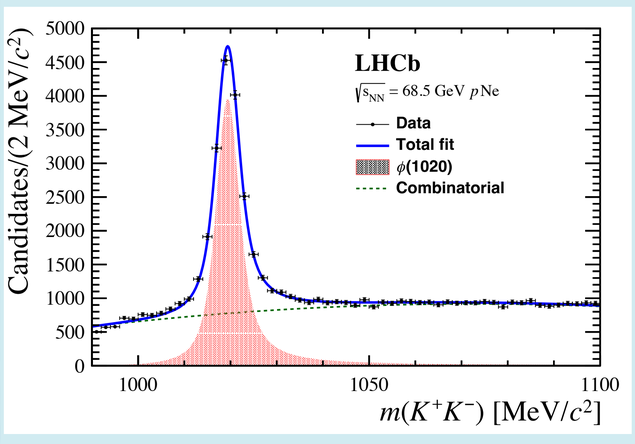
- ***First*** measurement of the ϕ production cross-section per nucleon in p_T, y^* in *p*Ne collisions at $\sqrt{s_{NN}}$ = 68.5 GeV

- ***Observable***:

$$\frac{d^2\sigma(p_T, y^*)}{dp_T\, dy^*} = \frac{N^{\phi}(p_T, y^*)\ \zeta}{\mathscr{L}\,\mathrm{BR}\,\epsilon_{tot}(p_T, y^*)\,\Delta p_T\,\Delta y^*\,A_{Ne}}$$

pp contamination factor [1]

$\mathscr{L} = 21.7 \pm 1.4$ nb^{-1} [1,2]



- Total of **16866 ϕ candidates**
- ϕ signal is extracted in p_T, y^* **regions**

p_T **[MeV/c]: 800, 1050, 1200, 1350, 1550, 1850, 6500**

y^* **: -1.8, -1.3, -1.0, -0.7, 0**

- Fit: relativistic Breit-Wigner convolved with Gaussian (signal) + 2nd Chebychev

- ***Total Efficiency***: $\epsilon^i_{tot} = \epsilon^i_{acc} \times \epsilon_{PV} \times \epsilon^i_{reco\&sel} \times \epsilon^i_{PID} \times \epsilon_{trig}/\epsilon_{match}$

  - ϵ^i_{acc}: Geometrical acceptance
  - ϵ_{PV}: PV reconstruction
  - $\epsilon^i_{reco\&sel}$: Reconstruction and selection
  - ϵ^i_{PID}: Particle identification
  - $\epsilon_{trig}/\epsilon_{match}$: Trigger, MC Truth-Match

- **Efficiency**: MC corrected with data/MC weights, with data corrections on PID, PV and tracking → MC: ***Pythia+EPOS-LHC*** [3,4]
- Used to correct signal yields
- Mostly measured in each region $i = (p_T, y^*)$

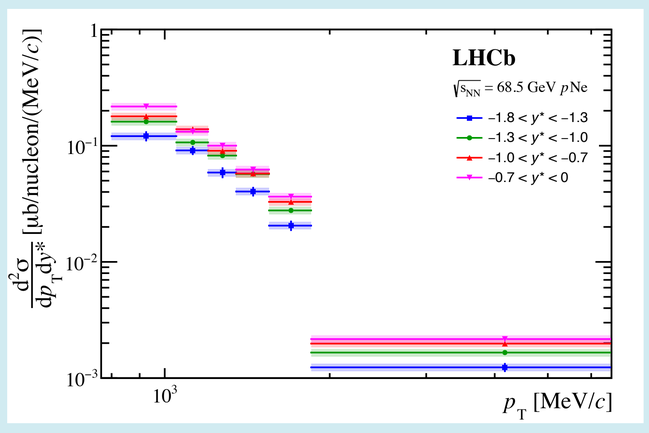
Results

Systematic uncertainties

Systematic uncertainties	
Uncorrelated among kinematic regions	
Signal determination	(<0.1 – 5.9)%
Geometrical acceptance	(<0.1 – 1.8)%
Multiplicity corrections	(0.2 – 3.6)%
PID efficiency	(2.3 – 4.4)%

Correlated among kinematic regions	
PV reconstruction	1.2%
Reconstruction and selection efficiency	3.2%
pp contamination	2.0%
$\mathcal{B}(\phi \to K^+K^-)$	1.0%
Luminosity	6.5%

Double differential cross-section per nucleon

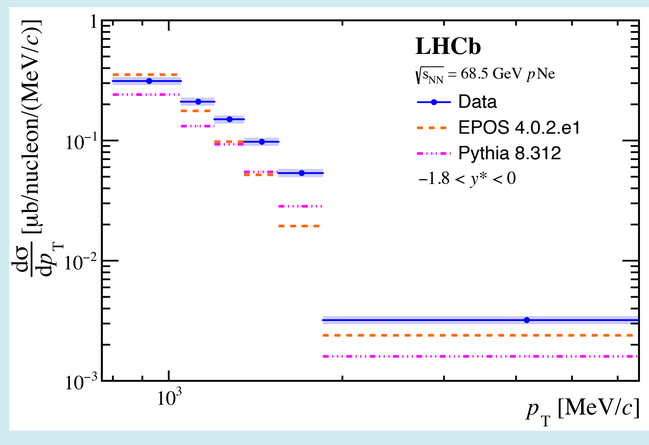


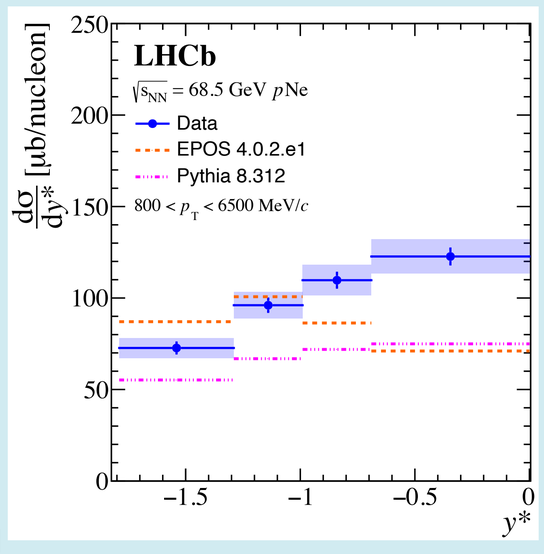
→ Bars: statistical+uncorrelated unc.
→ Filled areas: corelated unc.

- ***compatible*** with previous results although in different collision systems and kinematic regions
- ***Total*** cross-section per nucleon in $y^*_{tot} \in [-1.8, 0]$ and $p_{T,tot} \in [800, 6500]$ MeV/c

$\sigma^{\phi}_{y^*,\,p_T} = 182.7 \pm 2.7$ (stat) ± 14.1 (syst) μb/nucleon

Single differential cross-section per nucleon

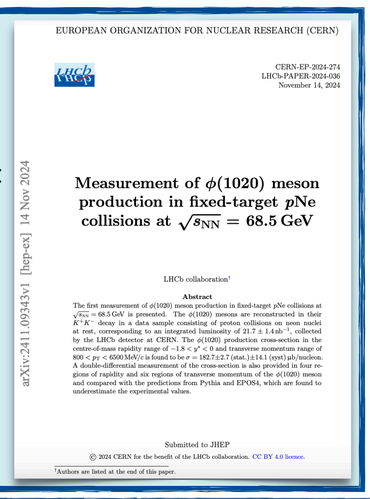




- **Theoretical predictions** from most common MC generators ***underestimate*** the results [5,6]

Conclusions

- ***First*** measurement of the ϕ meson ***production*** in fixed-target *p*Ne collisions at $\sqrt{s_{NN}}$ = 68.5 GeV
- **Analysis completed** and ***now on arXiv*** 🐓
- Cross-section per nucleon found **compatible** with rough extrapolation of LHC and RHIC results although in different collision systems and kinematic regions
- Theoretical predictions from the most common MC generators **underestimate** our result in p_T and high y^* regions
- Results ***presented*** for the ***first time*** at Hard Probes 2024 ***last September***!
- Submitted to JHEP!
- Want more details? Have a look at ***arXiv:2411.09343*** 🐓



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November 14, 2024

arXiv:2411.09343v1 [hep-ex] 14 Nov 2024

Measurement of $\phi(1020)$ meson production in fixed-target *p*Ne collisions at $\sqrt{s_{NN}} = 68.5$ GeV

LHCb collaboration[†]

Abstract

The first measurement of $\phi(1020)$ meson production in fixed-target *p*Ne collisions at $\sqrt{s_{NN}} = 68.5$ GeV is presented. The $\phi(1020)$ mesons are reconstructed in their K^+K^- decay in a data sample consisting of proton collisions on neon nuclei at rest, corresponding to an integrated luminosity of $21.7 \pm 1.4\,\text{nb}^{-1}$, collected by the LHCb detector at CERN. The $\phi(1020)$ production cross-section in the centre-of-mass rapidity range of $-1.8 < y^* < 0$ and transverse momentum range of $800 < p_T < 6500$ MeV/c is found to be $\sigma = 182.7 \pm 2.7\,(\text{stat.}) \pm 14.1\,(\text{syst})\,\mu\text{b/nucleon}$. A double-differential measurement of the cross-section is also provided in four regions of rapidity and six regions of transverse momentum of the $\phi(1020)$ meson and compared with the predictions from Pythia and EPOS4, which are found to underestimate the experimental values.

Submitted to JHEP

[†]Authors are listed at the end of this paper.

References

- Based on LHC*b* Collaboration, "*Measurement of the $\phi(1020)$ meson production in fixed-target pNe collisions at $\sqrt{s_{NN}} = 68.5$ GeV*", arXiv:2411.09343
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- [3] Sjostrand T. *et al.*, *"A brief introduction to Pythia 8.1"*, Comput.Phys.Commun. 178 (2008) 852-867
- [4] Pierog T. *et al.*, "*EPOS LHC: Test of collective hadronization with data measured at the CERN Large Hadron Collider*", Phys. Rev. C92 (2015) 034906
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- [6] Werner K. *et al.*, *"EPOS4 framework"*, Phys. Rev. C 108, 064903 (2023), Phys. Rev. C 108, 034904 (2024), Phys. Rev. C 109, 034918 (2024), Phys. Rev. C 109, 014910 (2024)

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