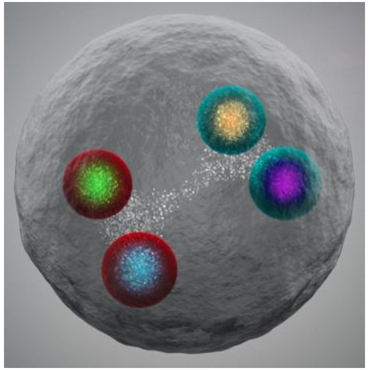
Physics Working Group Dileptons and Quarkonia → Participação do Brasil

Cristiane Jahnke
DRCC- UNICAMP

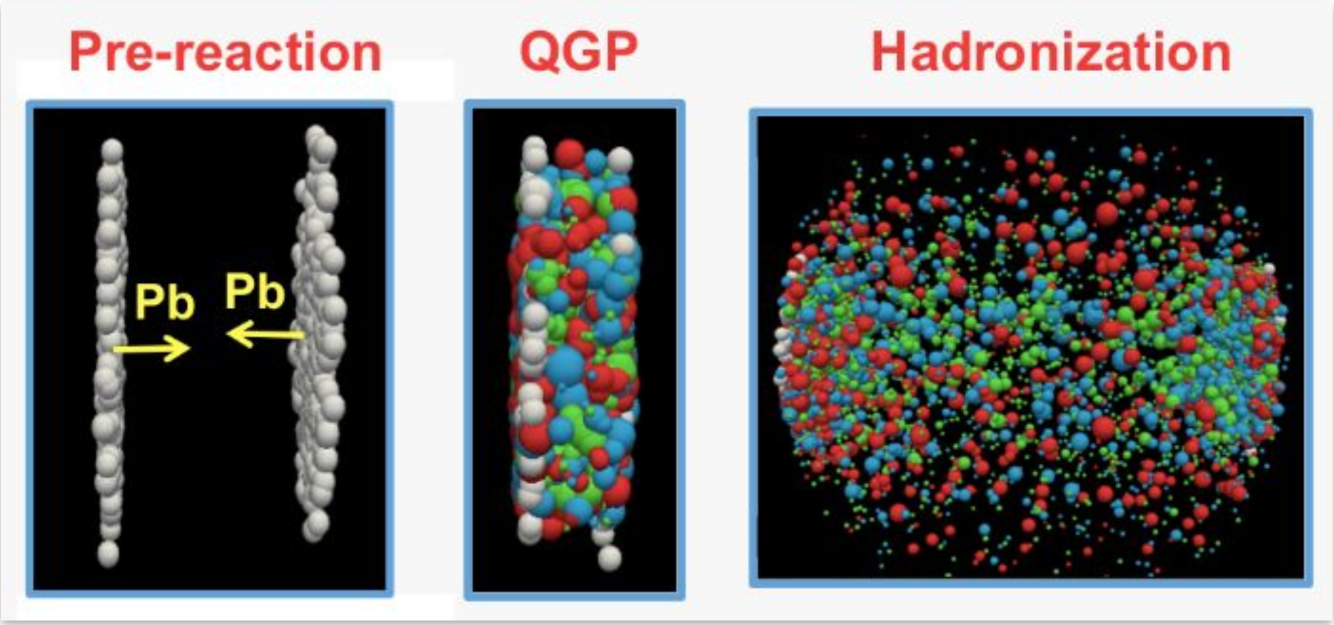
Outline

- Why to study quarkonia?
  - in heavy-ion collisions
  - in pp collisions
- PWG coordination
- Data analysis being performed by Brazilian students
  - J/ψ in jets (pp collisions)
  - X(3872) (Pb-Pb collisions)
- PWG highlights from Run 3



Why to study quarkonia?

Quarkonia states as signature of Quark Gluon Plasma
→ Matsui & Satz, PLB178 (1986) 416



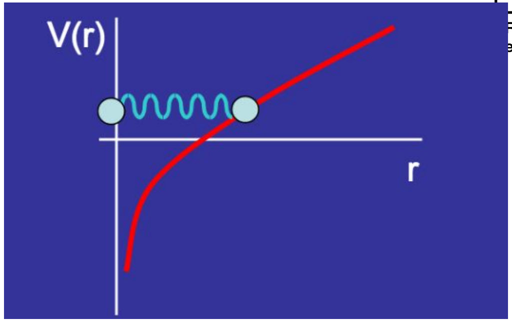
QGP: state of matter created in heavy-ion collisions where quarks and gluons are deconfined

Why to study quarkonia?

Raios Cósmicos e Cronologia

Vacuum potential between q qbar pair grows linearly at large distances

$$V(r) = -\frac{4}{3}\frac{\alpha_s}{r} + kr$$

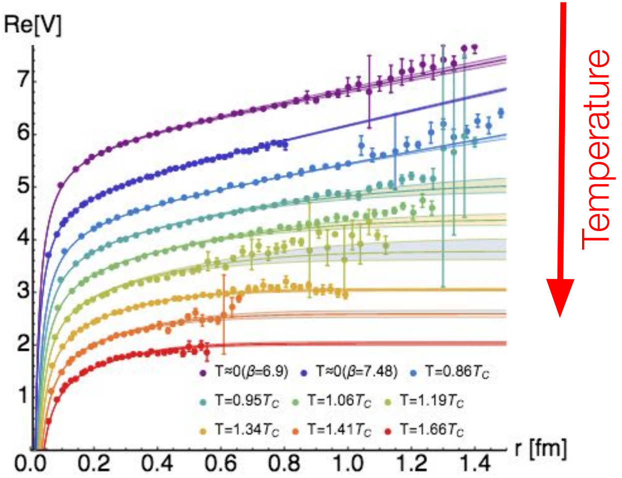


Heavy quark potential

In a deconfined medium the potential is modified:

$$V(r) = -\frac{\alpha_s}{r}e^{-r/\lambda_D}$$

- Coulomb potential is Debye screened
- Quarkonium states will be melted if r > λ_D
  → Quarkonia suppression = QGP signature
- Maximum distance allowed for formation of a bound pair decreases with T
  → Differents states melts at different energies



https://arxiv.org/pdf/1606.06211.pdf

Why to study quarkonia?

Vacuum potential between q qbar pair grows linearly at large distances

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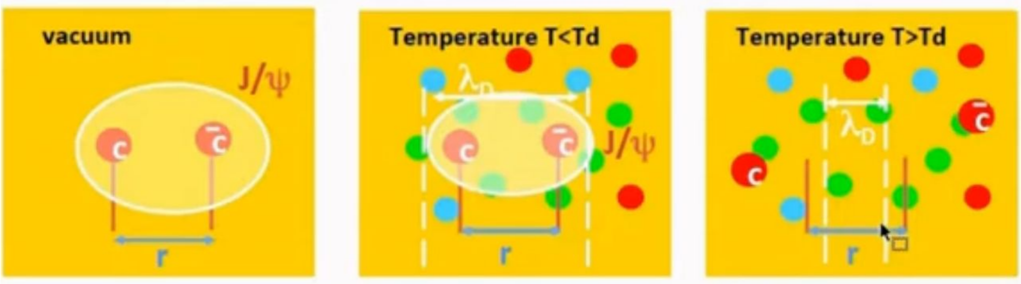

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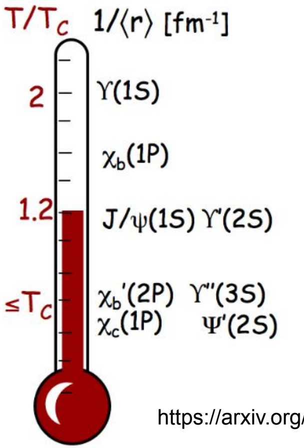


https://arxiv.org/pdf/0811.0337.pdf

Why to study quarkonia?

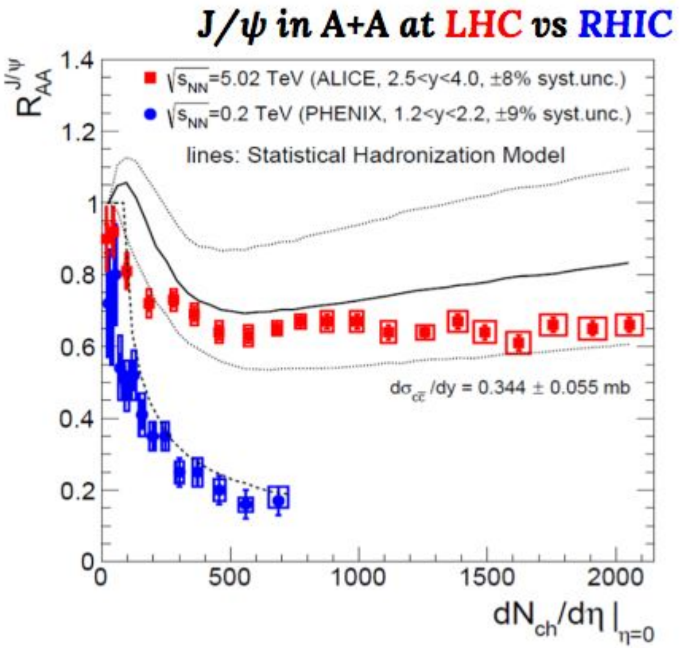
Raios Cósmicos e Cronologia

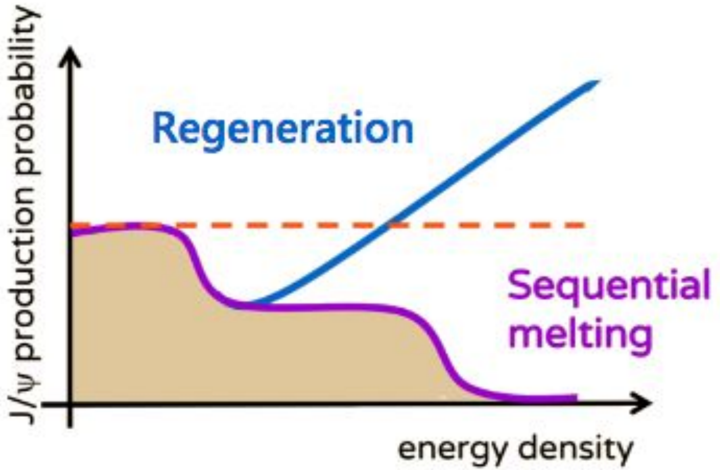
Sequential melting observed at RHIC

But at LHC energies, an additional effect was observed and called as Regeneration

ALICE, PLB 766 (2017) 212

PHENIX, PRC 84 (2011) 054912





Why to study quarkonia?

At RHIC/LHC energies, large amounts of c cbar pairs are created
→ Possible to create charmonium on a statistical basis
→ More pronounced at LHC energies

ALICE, PLB 766 (2017) 212
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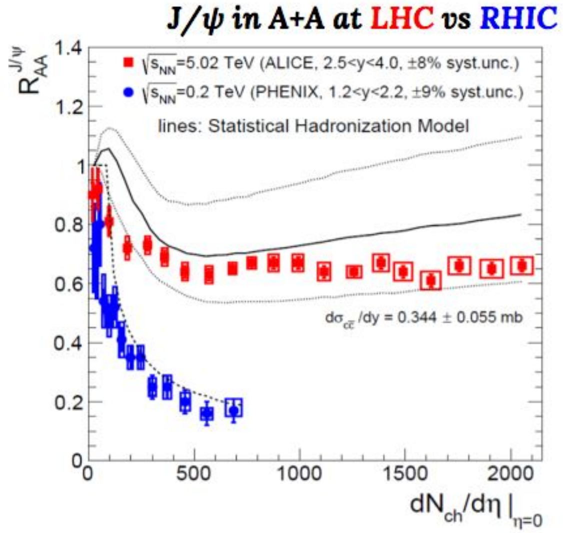
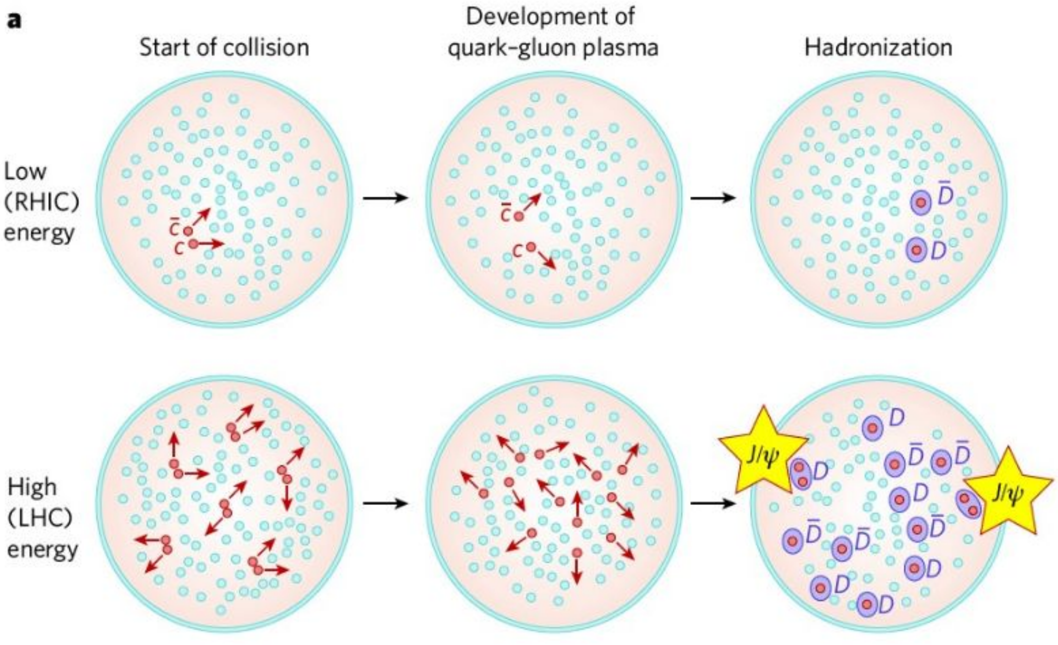




PLB490 (2000) 196

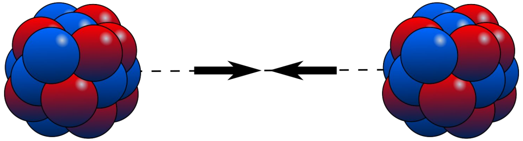
Why to study quarkonia?

Raios Cósmicos e Cronologia

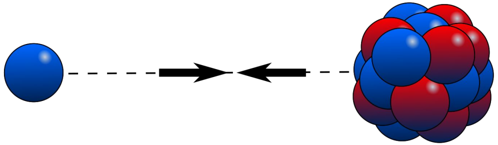
❖ To understand QGP formation in Pb-Pb collisions, we need references!

❖ How good is the description of quarkonia in proton-proton and proton-Pb collisions?

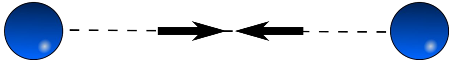
- Heavy-ion collisions:
  - Quarkonium as a hint of deconfinement (QGP)



- p-Pb collisions:
  - Cold nuclear matter effects



- pp collisions:
  - Quantum Chromodynamics (QCD)



Quarkonium production in pp collisions

Raios Cósmicos e Cronologia

Quarkonium production involves perturbative (production of heavy quark pair) and non-perturbative QCD (evolution of the pair into the physical quarkonium state). Models of non-perb:

- Colour Singlet Model (CSM): 1975
- Colour Evaporation Model (CEM): 1977
- NonRelativistic QCD (NRQCD): 1986
- Improved Color Evaporation Model: 1997
- Etc

Coordination of PWG-DQ

PWG

Cristiane JAHNKE

Luca Micheletti

JPsi2ee

Victor FEUILLARD

Xiaozhi BAI

QQ2mumu

Maxime GUILBAUD

Batoul DIAD

Ongoing analysis in J/ψ → ee

Run 2 analysis

- Prompt and non-prompt J/ψ production vs multiplicity in pp at 13 TeV (Wenda Guo)
- J/ψ multiplicity in pp (Gauthier, Ailec)
- Inclusive J/ψ as a function of multiplicity in p-Pb collisions at 5 TeV with ALICE (Tabea)
- Charmonium production measurement at midrapidity using TRD-triggered data (Jinjoo)
- J/ψ in jets using TRD trigger and HM trigger (Ingrid, Fabio)
- Photoproduction (Alexandra Neagu)
- J/ψ-hadron correlations (Ionut, Michael)

Run 3 analysis

- J/ψ v_2 in Run 3 13.6 TeV pp data at midrapidity (Senjie Zhu)
- J/ψ polarization in pp collisions at 13.6 TeV (Zhenjun Xiong)
- J/ψ and ψ(2S) analysis with Run 3 13.6 TeV pp data (Yuan Zhang)
- Charmonia reconstruction using machine Learning (Pengzhong)
- Photoproduction (Sigurd Nese)
- Exclusive reconstruction of B mesons in the J/ψ + K decay channel in Run 3 pp data (Ida Storehaug)
- Study of the χ(3872) and ψ(2S) (Leopoldo)
- Upsilon production at midrapidity (Xiaozhi)

Ongoing analysis in Q2MuMu

Raios Cósmicos e Cronologia

Run 2 analyses:

- J/Ψ polarization in pp collisions at 13 TeV - Deekshit Kumar
- Ψ(2S) polarization in pp collisions at 13 TeV - Dushmanta Sahu
- Charmonium production as a function of spherocity in pp collisions at 13 TeV - Neelkamal Mallick
- J/Ψ yield versus multiplicity (using V0) - Sarah Hermann
- Upsilon polarization in pp collisions at 13 TeV - Yanchun Ding
- Upsilon production in pp collisions at 13 TeV - Subikash Choudhury
- High mass dimuon continuum in pp collisions at 13 TeV - Michele Pennisi
- y-differential J/Ψ photoproduction in PbPb 5.02 TeV - Afnan Shatat
- Photoproduced J/Ψ polarization in PbPb 5.02 TeV - Dukhishyam Mallick

Run 3 analyses:

- Ψ(2S)/J/Ψ ratio in pp collisions at 13.6 TeV - Luca Micheletti, Maurice Coquet, Nicolas Bizé, Corentin Cot, Michael Winn
- J/Ψ - D0 correlations in pp collisions at 13.6 TeV - Luca Micheletti, Fabrizio Grosa
- Prompt and non-prompt J/Ψ production in pp collisions at 13.6 TeV - Maurice Coquet
- Quarkonium polarization versus multiplicity in pp collisions at 13.6 TeV - Bhagyarathi Sahoo

Some of the conveners tasks

- Coordinate and review analysis from both PAGs
- Prepare abstracts for big conferences
    - Eg. SQM and ICHEP
- Review proceedings/slides/abstracts submitted by PWG-DQ members
- Indication of possible speakers of conferences
- Participation on the Physics Board of the ALICE Collaboration

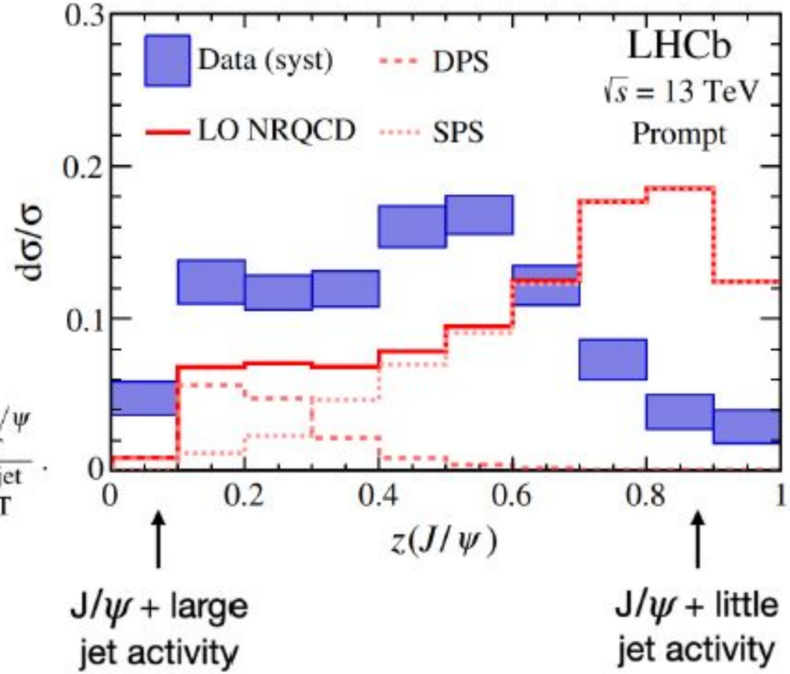
Data analysis being performed by Brazilian students

Raios Cósmicos e Cronologia

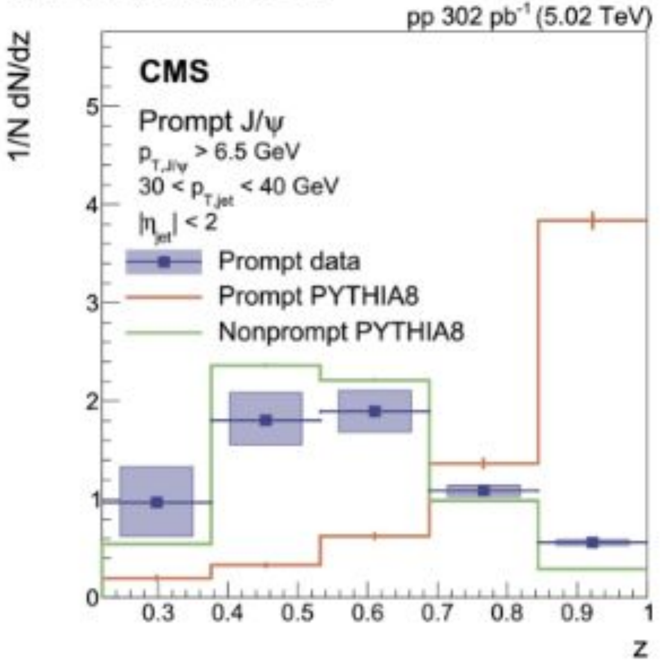
J/ψ in jets

https://arxiv.org/pdf/1701.05116.pdf

$$z \equiv \frac{p_T^{J/\psi}}{p_T^{jet}}.$$



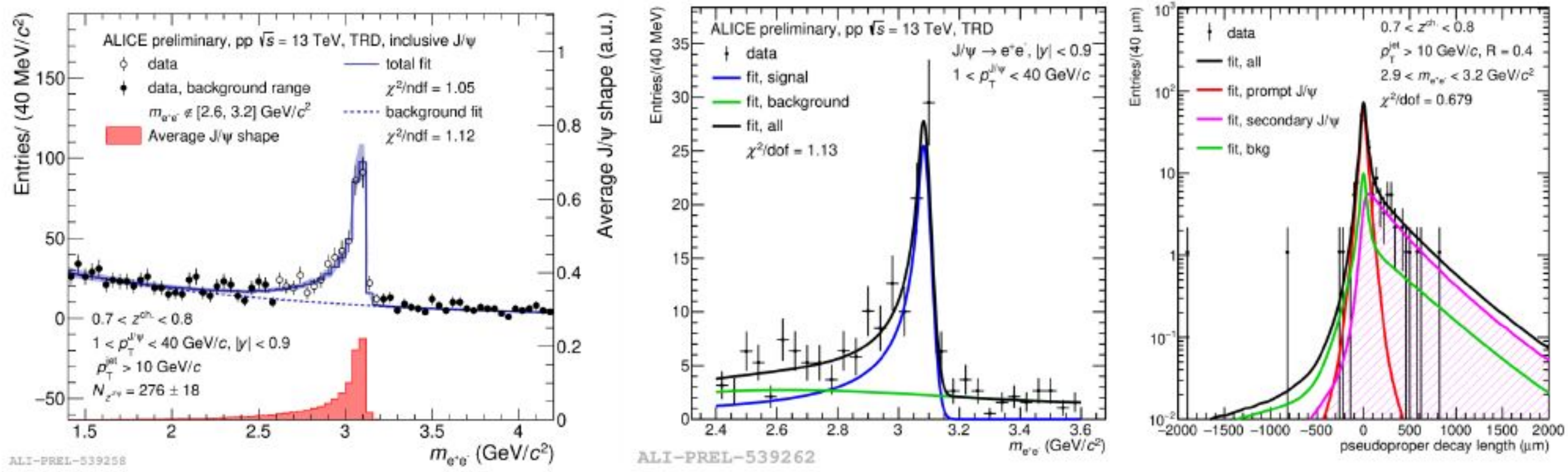
PLB 825 (2022) 136842



- J/ψ produced isolated or in parton showers?
- Prompt J/ψ produced with larger jet activity than predicted by models.

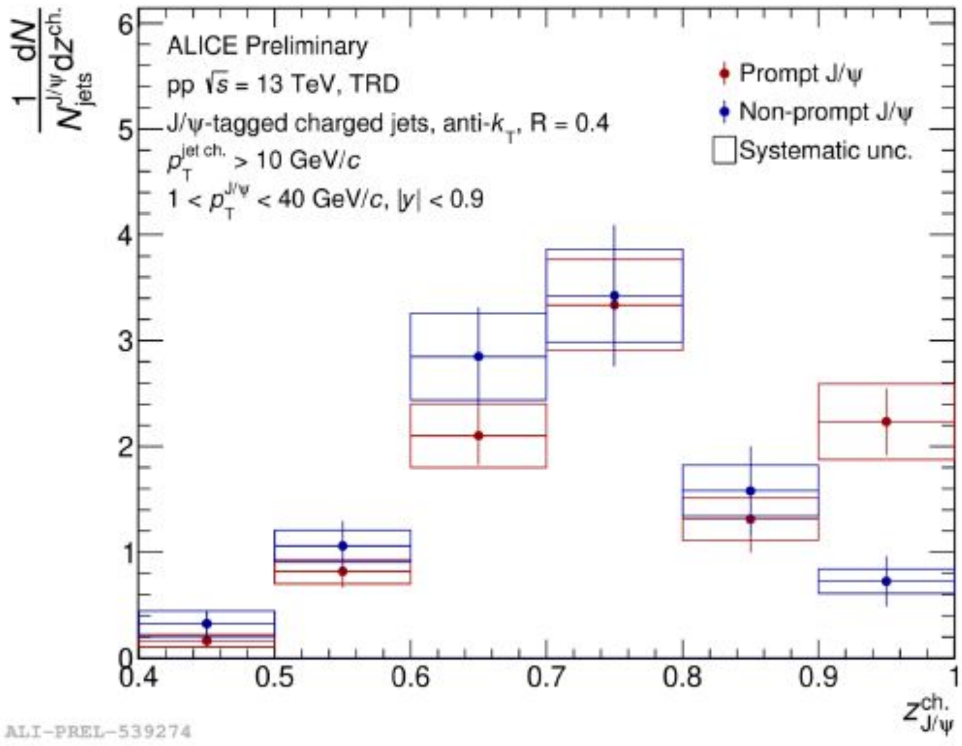
J/ψ in jets

Raios Cósmicos e Cronologia



- Jet reconstruction by using anti k_T algorithm with the FASTJET package.
- Extract J/ψ signal in jets with different z(J/ψ)
- Separation of prompt and non prompt J/ψ using pseudo proper decay legth

J/ψ in jets



Prompt and non prompt J/ψ fragmentation functions similar within uncertainties.
→ very large systematic errors.

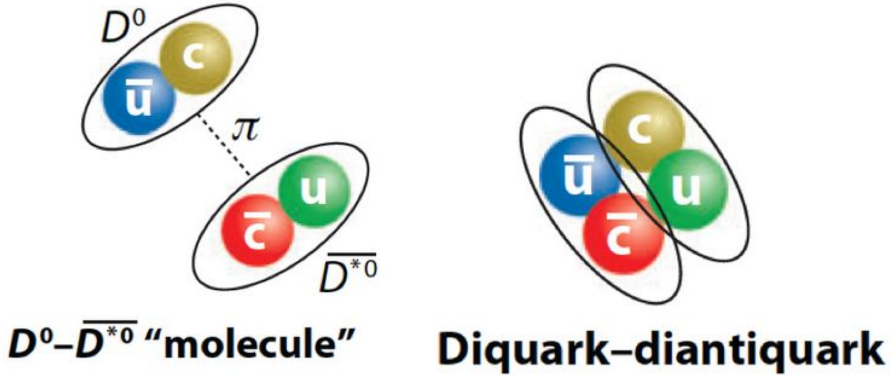
- Jet p_T smaller than LHCb and CMS
- Different rapidity range when compared to LHCb

→ Ingrid Lofnes (Oslo)
→ Students working with high multiplicity triggers

X(3872): exotic meson

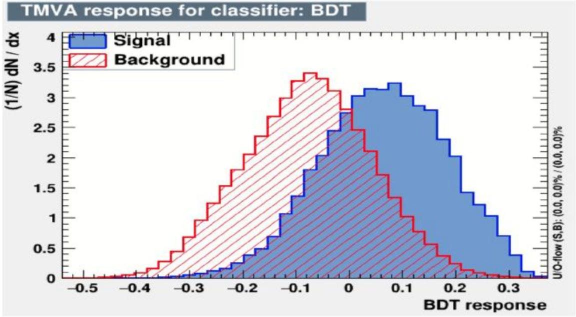
- Discovered in 2003 by the BELLE experiment (Japan)
  → not predicted by the quark model

- Mesonic molecule or tetraquark?



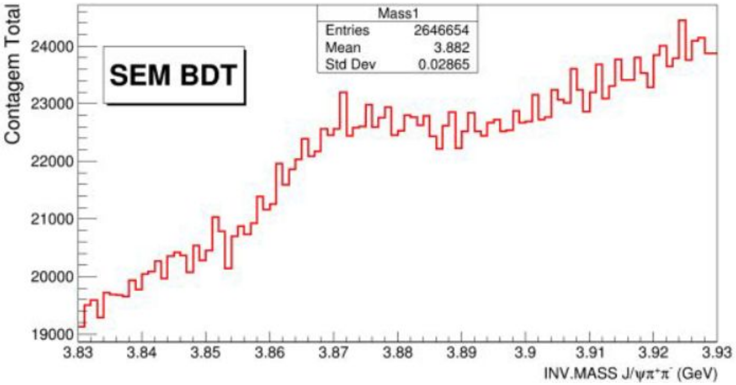
- Different hadronic structures can affect the interaction with the medium formed.
  → In Pb-Pb collisions, the production of X(3872) may increase via coalescence or decrease due to dissociation (similar to quarkonia states).
    - Processes depend on spatial configuration.
- X(3872) → J/ψ $\pi^+\pi^-$
  → Possible with **ALICE upgrades**

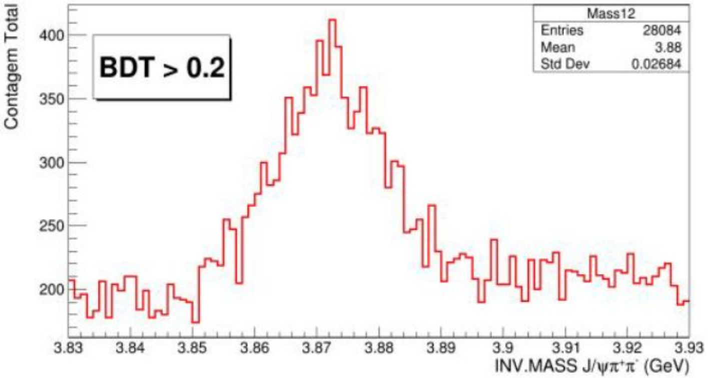
X(3872): exotic meson



Use of Boosted Decision Trees (BDT) to separate signal and background in simulation of ALICE 3
→ master degree of Leopoldo

Invariant mass spectrum combining J/ψ $\pi^+\pi^-$
Expected mass ~ 3,872 GeV/c^2
Visible signal only when applying the BDT methods

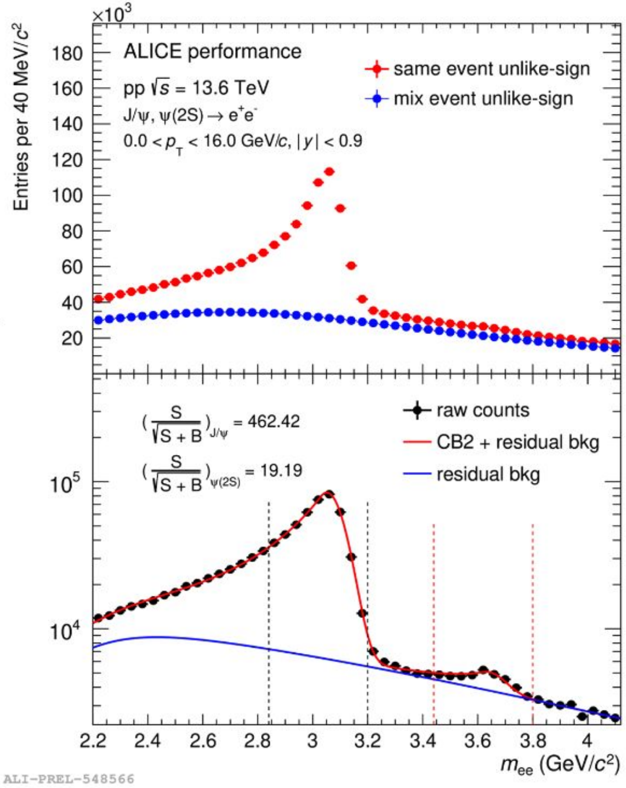




PWG highlights from Run 3

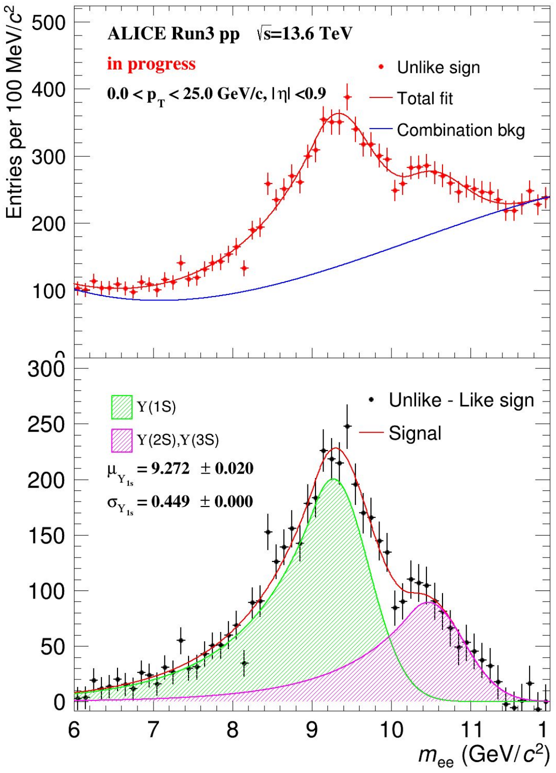
J/ψ and ψ(2S) production in pp with Run 3 data

First measurement of ψ(2S) at midrapidity with ALICE



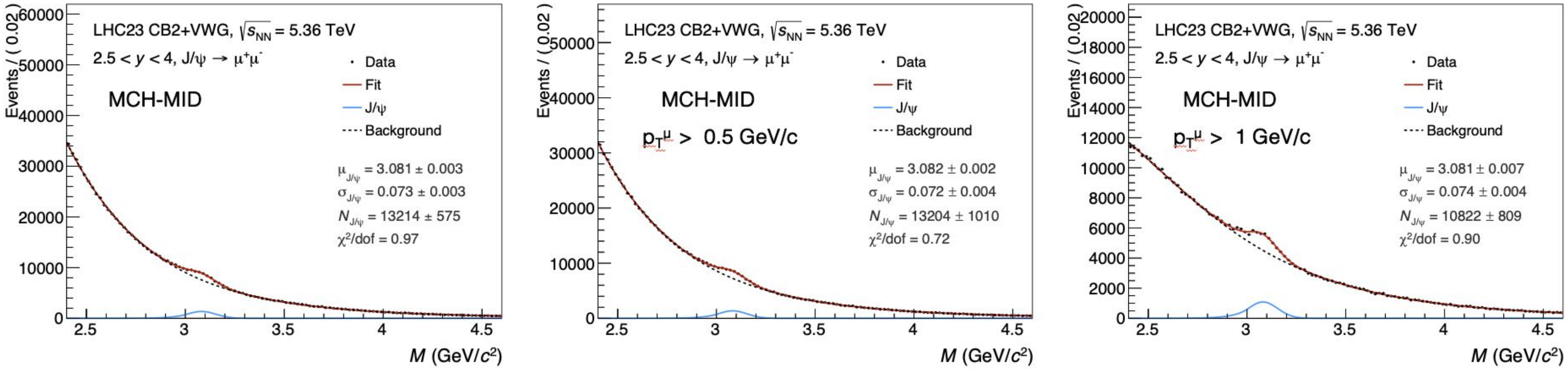
Upsilon production in pp with Run 3 data

First measurement of Upsilon at midrapidity with ALICE



First look in Pb-Pb collisions from Run 3 data

IFGW Raios Cósmicos e Cronologia



- J/ψ resolution improved w.r.t. pp as observed in previous passes
- Different sets of p_T cuts applied to check the impact on the signal
- Highest p_T cut seems to impact on the signal (to be confirmed with high stat.)

Summary

- We have an active and increasing participation inside the PWG-DQ!

Thank you very much!

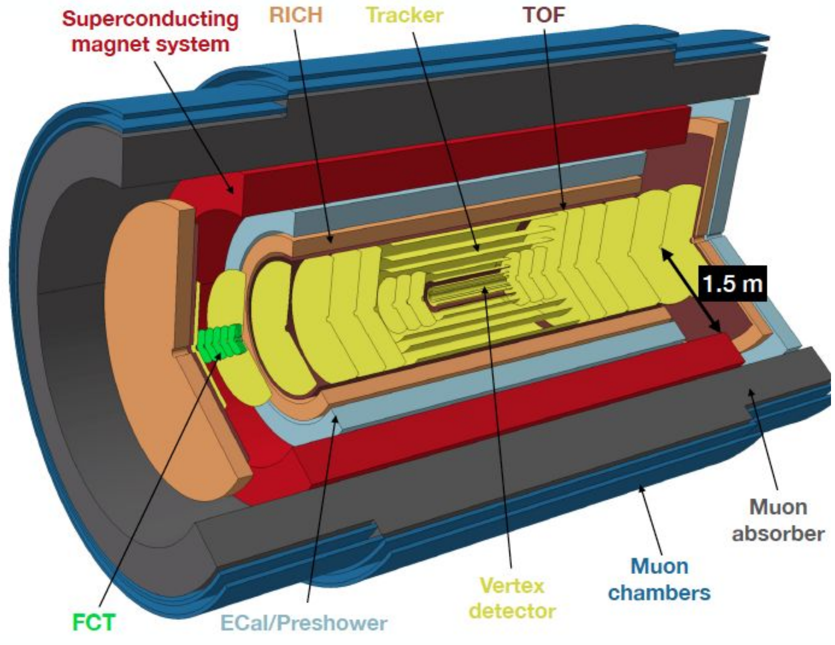
Backup

ALICE future perspectives (Run 5 - 2032)

ALICE3:

- ➔ Compact all-silicon tracker with high-resolution vertex detector
- ➔ Superconducting magnet system
- ➔ Particle identification over large acceptance
- ➔ Fast readout and online processing

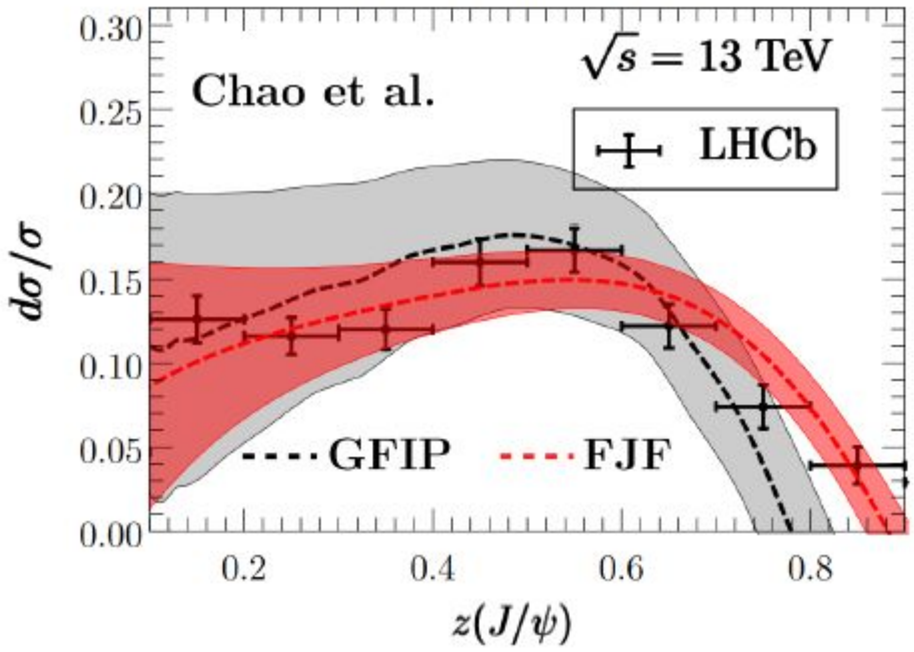
- Studies of A–A collisions at luminosities a factor of 5-10 times higher than possible now.
- The excellent timing resolution (≈ 20 ps) will provide particle identification information.
- Ultrasoft region of phase space
    - Production of very low transverse momentum lepton pairs, photons and hadrons.
    - Heavy-flavour, quarkonia, multi-charm hadrons and heavy-flavour correlations
    - Low-mass dileptons
    - Soft and ultra-soft photons



arXiv:1902.01211v2
https://indico.cern.ch/event/1063724/

J/ψ in jets

Phys. Rev. Lett. 119, 032002



- Models including parton showers describe data.
- J/ψ produced in parton showers sensitive to parton energy loss.

Quarkonium production in pp collisions

Raios Cósmicos e Cronologia

Quarkonium production involves perturbative (production of heavy quark pair) and non-perturbative QCD (evolution of the pair into the physical quarkonium state). Models of non-perb:

- Colour Singlet Model (CSM): 1975
  - Assume physical colour singlet state, quantum number are conserved
  - Only pairs with right quantum number can be formed
  - No free parameter
- Colour Evaporation Model (CEM): 1977
  - Doesn’t distinguish states with respect to their colour and spin
  - One free parameter per quarkonium state
- NonRelativistic QCD (NRQCD): 1986
  - Effective field theory based on factorization of soft and hard scales
  - NRQCD matrix elements
  - Several parameters
- Improved Color Evaporation Model: 1997
  - In contrast to the traditional color evaporation model, it is imposed a constraint that the invariant mass of the intermediate heavy quark-antiquark pair needs to be larger than the mass of produced quarkonium. It also introduces a momentum shift between the heavy quark-antiquark pair and the quarkonium.

Data stream

Run 3:

→ continuous readout
→ increase of luminosity

→ not possible to keep all data collected

→ it needs a filtering/pre selection of interesting data to be used in the analysis

→ part of the data is being deleted

→ SW do Leopoldo