Nuclear Modification Factor of light charged hadrons and quarkonia at LHCb (R_{AA}LHCb)

Instituto Galego de Física de Altas Enerxías at the Universidade de Santiago de Compostela (IGFAE-USC): Prof. Cibrán Santamarina Ríos (IP), Prof. Abraham Gallas Torreira, Prof. Juan José Saborido Silva, Dr. Samuel Belin.

Università degli Studi di Cagliari (UC): Prof. Giulia Manca, Prof. Rudolf G.C. Oldeman, Dr. Camilla De Angelis.

Quark Gluon Plasma Laboratory of the Commissariat à l'Énergie Atomique et aux Énergies Paris-Saclay (CEA): Dr. Benjamin Audurier, Dr. Imanol Corredoira.

These teams tightly collaborate within the LHCb collaboration Ion and Fixed Target Working Group.

Project objective

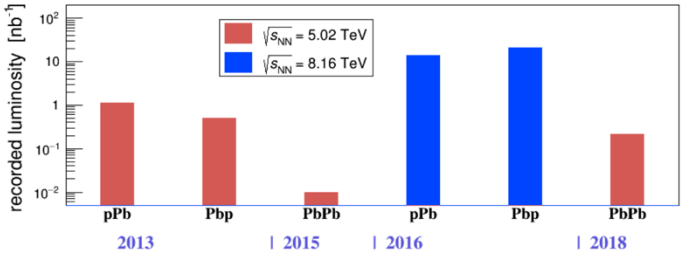
- Measure the nuclear modification factors R_{AA} and R_{pA} for **charged particles**, **light hadrons** and **quarkonia at LHCb:**

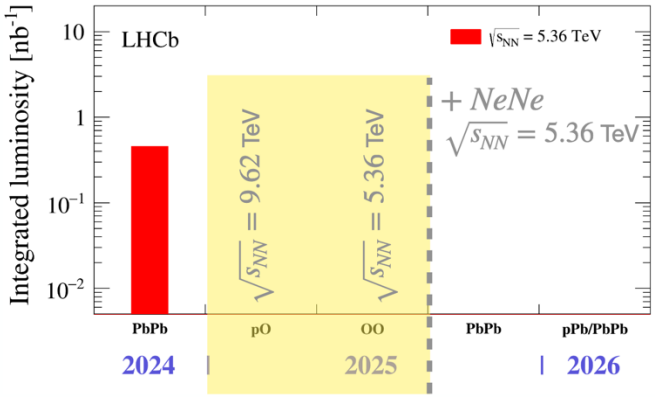
$$R^h_{AA} = \frac{1}{N_A^2}\frac{d\sigma^h_{AA}/dp_T d\eta}{d\sigma^h_{pp}/dp_T d\eta} \qquad R^h_{pA} = \frac{1}{N_A}\frac{d\sigma^h_{pA}/dp_T d\eta}{d\sigma^h_{pp}/dp_T d\eta}$$

- **Collision system:** O-O, Ne-Ne and Pb-Pb at $\sqrt{s_{NN}} = 5.36$ TeV; p-O at $\sqrt{s_{NN}} = 9.62$ TeV. Provided by the LHC.

- p-O and O-O and Ne-Ne events will be taken this summer.
  - In fact, these data are being taken as I talk.
  - A p-p reference sample has been taken at this same cms.

- Other configurations are also foreseen in the fixed target mode (O-H_2, Ne-Ne).





Sample	Planned integrated luminosity
O-O	0.5 nb^{-1}
p-O	3 nb^{-1}
Pb-Pb	0.7 nb^{-1}
Ne-Ne	~0.1 nb^{-1}

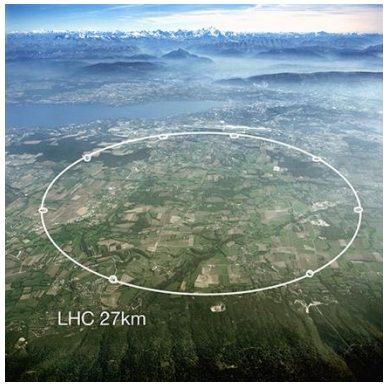
Motivation

- Ambitious project proposing four sets of analyses.
- Explores the low-*x* and high-*x* regions.

	Light Hadrons	**Quarkonia (J/ψ, ψ(2S), ∏(nS))**
R_{pA}	*Initial-state effects* only: Shadowing • Cronin effect • No QGP formation	*Cold Nuclear Matter (CNM) effects*: • Shadowing • Absorption • Nuclear PDFs
R_{AA}	*QGP final-state effects*: • Jet quenching (parton energy loss) • Medium opacity	*Deconfinement signature*: • Color screening: quarkonia suppression • Recombination at low p_T • Charm transport properties

- The p-O light hadrons analysis is very relevant for cosmic ray showers understanding.
- The Ne-Ne (bowling pin), O-O (tetrahedral) and Pb-Pb shapes would test geometric scaling of the physical processes.

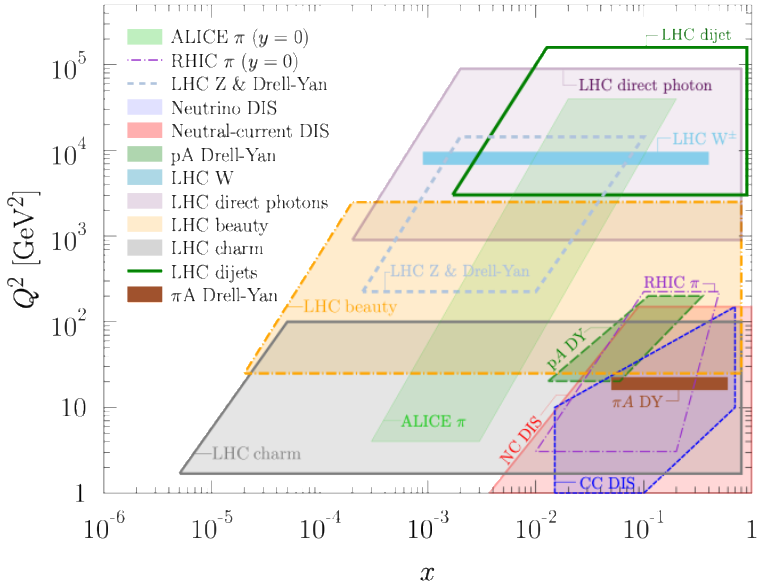
Links to Research Infrastructures and Virtual Access Projects - adequacy to HORIZON-INFRAN

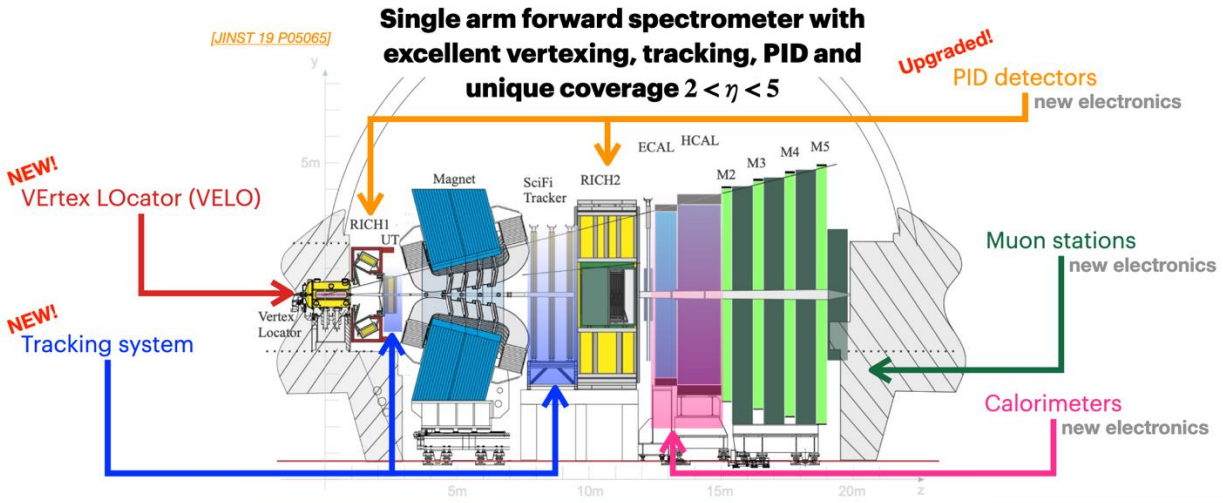


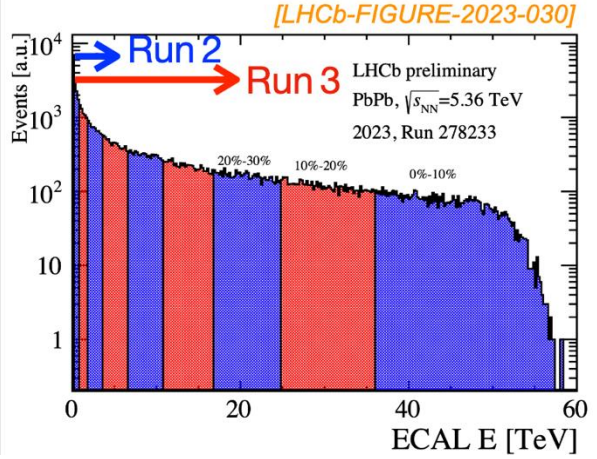
- **Conseil Européen pour la Recherche Nucléaire (CERN):**
  - Dedicated to **study the fundamental particles their interactions.**
  - With 23 European member states is a **Transnational Access infrastructure**.
  - Its computing resources are also a Virtual Access infrastructure.
- This project will build upon CERN strategy alignment with Horizon Europe's strategic objectives.
- LHC: collider of protons and heavy ion beams at TeV energies.
- **LHCb collaboration:**
  - LHCb is composed of ~1800 members from 103 institutions across 24 countries.
  - **About 70% of institutes** are from EC countries.
- The results of the analyses will be public in a **Virtual Access platform**: https://www.hepdata.net/
- The results of the analyses will be the essential input to some Virtual Access platforms:
  - nPDFs parameterizations
  - Averages of LHC results

LHCb spectrometer

- LHCb:
  - Designed for precision heavy-flavor physics.
  - Now: small angle general-purpose detector.
- Main characteristics:
  - Coverage of $2 < \eta < 5$ region.
    - Unique in accelerator experiments.
    - Top plot shows the (x, Q^2) range of pA collisions in the determination of nPDFs (arXiv:2311.00450)
  - Precise vertexing, tracking and particle identification.
- With the spectrometer upgrade of 2022 we can reach a centrality never achieved before in ion-ion collisions.

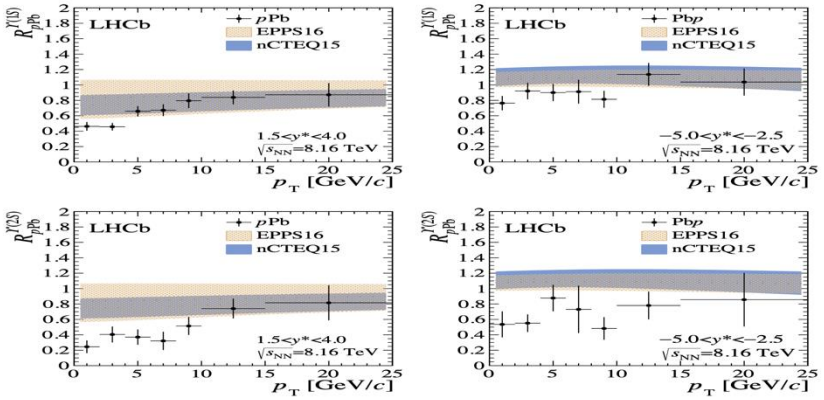




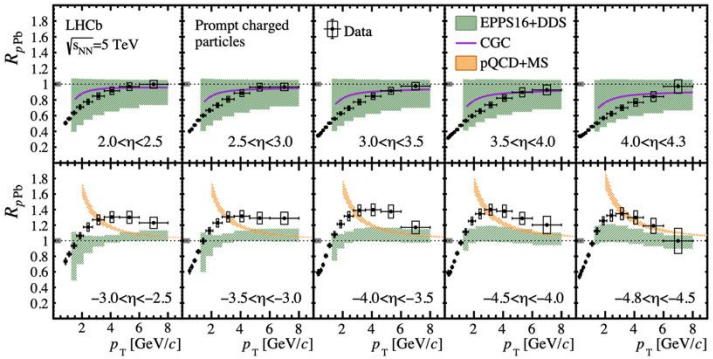


Previous experience

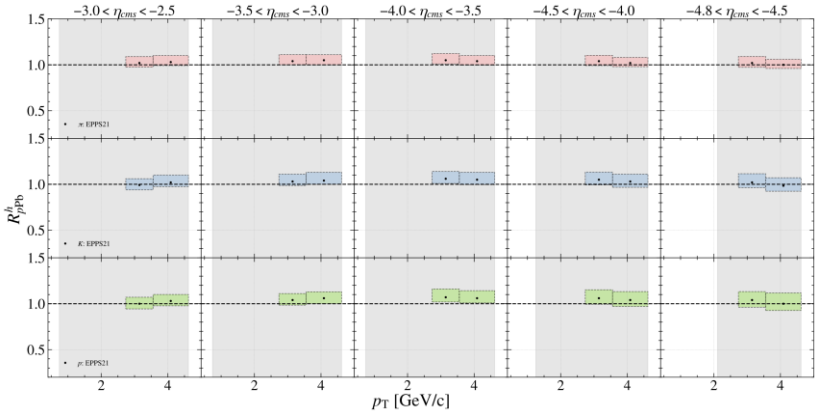
- R_{pA} with quarkonia:
  - Fast analyses: publication 1 to 2 years after data taking.
  - Research team experienced. Eg.: Study of Υ production in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV (JHEP11(2018)194).



- R_{pA} with charged particles:
  - 2013: p-Pb and p-p events at $\sqrt{s_{NN}} = 5$ TeV were taken.
  - 2015: we started the analysis.
  - 2021: preprint submitted to arXiv (PRL 128 (2022), 142004). **Eight years after the data were taken.**



- R_{pA} with π^+, K^+ and p:
  - 2020: started the analysis. Same 2013 data as R_{pA} with charged particles.
    - ALICE published its results in 2016.
  - 2025: we are about to complete the analysis.
    - In grey: measurement regions.
    - nPDFs have no predictions in some of the measurements range



Predictions from H. Paukkunnen

Funds Request

- Two years of three postdoctoral Research Associates.
  - One RA per each of the partner institutes.
- Two PhD students according to the PhD program of each of the hosting institutions.
  - Four years in Santiago.
  - Three years in Cagliari.
  - A co-supervision of the PhDs with the CEA researchers is planned.

Year of contract	1st	2nd	3rd	4th	Total
Postdoc salary IGFAE-USC	55	55	-	-	110
Postdoc salary UC	53	53	-	-	106
Postdoc salary CEA	75	75	-	-	150
PhD student salary IGFAE-USC	26	26	27	33	112
PhD student salary UC	30	30	30	-	90
Total	568 k€.				

Conclusions

- LHCb has a singular acceptance and an updated spectrometer that allows ion-ion collision analyses.
- We propose two sets of analyses using the ion collisions of CERN LHC:
  - Quarkonia analyses are faster. With the requested HRs we can guarantee publications within 2 years.
  - The light hadrons analyses are more complex but with our prior experience and the requested HRs we can guarantee publications in the time scale of a PhD (3-4 years).
- Lack of HRs can delay the availability of experimental results: crucial for theory development.
- These delays can be mitigated with the background of the research team.
- Deliverables: a minimum of three papers in high impact journals,