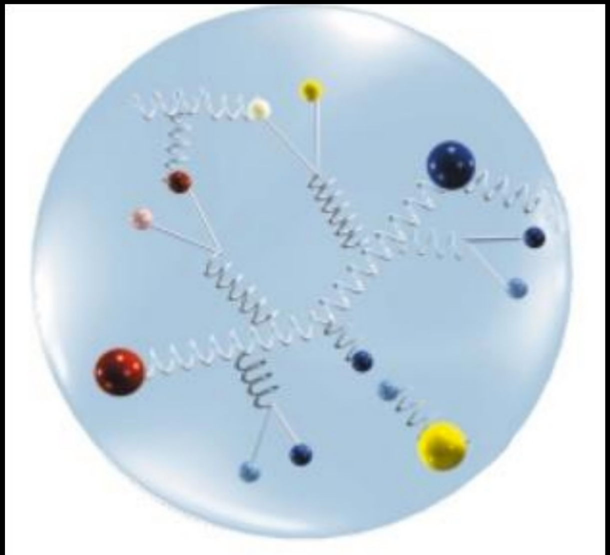
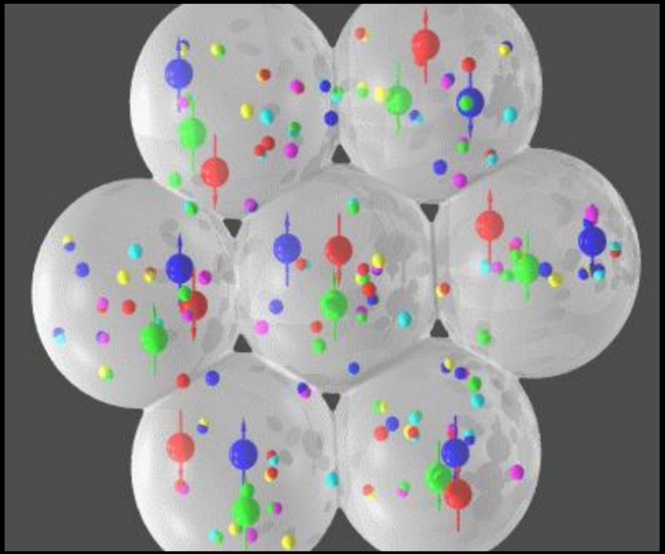
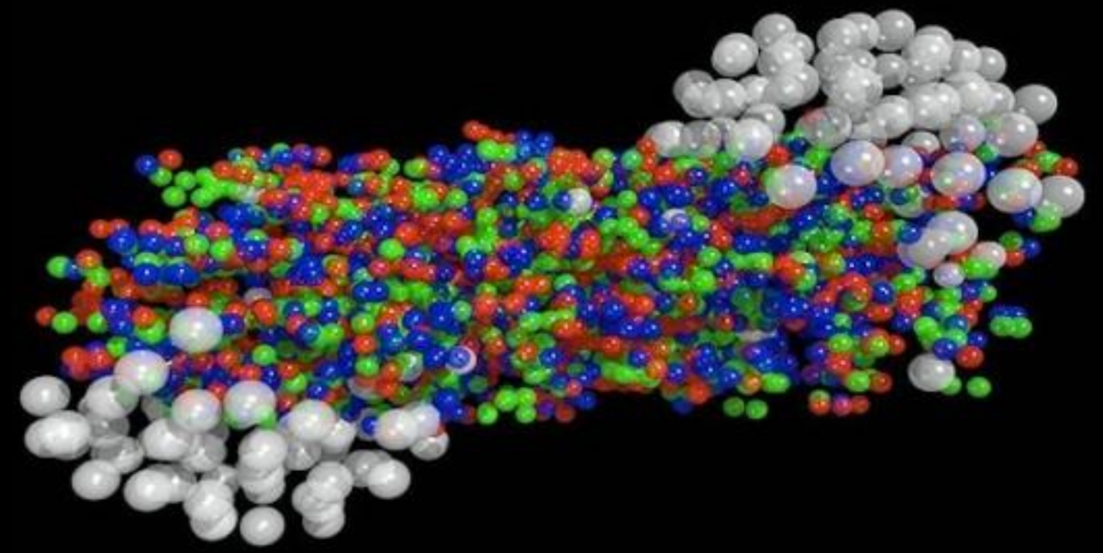
HCERES evaluation of Laboratoires de la vallée d'Orsay

CSNSM
IMNC
IPNO
LAL
LPT







Hadronic Physics

Speaker: L. Massacrier on behalf of the hadronic physics groups

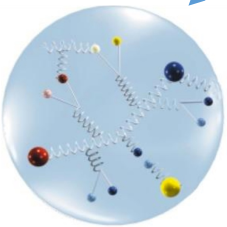
14-17 january 2019

Open questions in hadronic physics

see NUPECC, Long Range Plan 2017

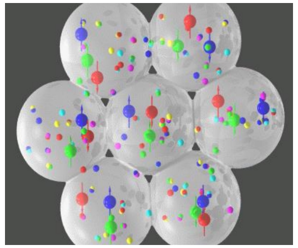
Quantum ChromoDynamics

What is our degree of understanding of QCD?
Can we determine precisely the parameters of QCD (Λ_{QCD}, vacuum parameters) ?
What is the origin and dynamics of confinement and chiral symmetry breaking?
What is our current knowledge of the QCD phase diagram of nuclear matter?



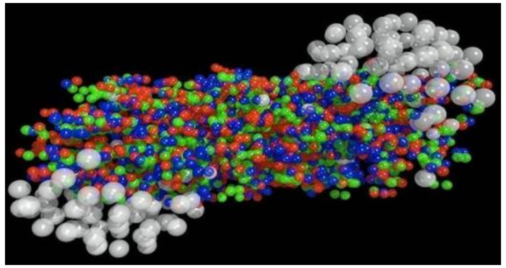
Nucleon and hadron structure

How do the mass and spin of the nucleon arise from its constituents? More in general, how is mass generated in QCD? What are the static and dynamical properties of hadrons?



Medium effects

What are the modification of the quark and gluon structure of a nucleon when it is immersed in a nuclear medium?
Is chiral symmetry restored in the nuclear medium?



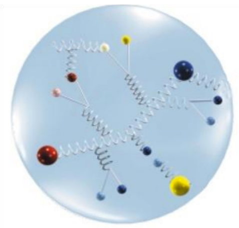
Quark Gluon Plasma

What are the properties of nuclei and strongly-interacting matter as encountered shortly after the Big Bang, in catastrophic cosmic events and in compact stellar objects?

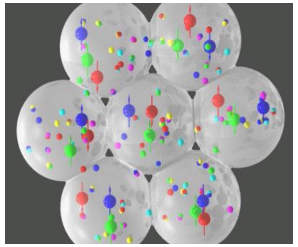
Hadronic physics landscape in the Orsay Vallée

A common goal: to understand QCD in its different regimes from the confinement of quarks and gluons inside ordinary matter to Quark Gluon Plasma formation under extreme conditions

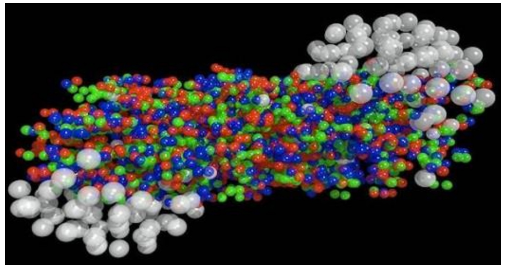
Main activities of the teams



Nucleon and hadron structure



Medium effects



Quark Gluon Plasma

ProRad@PRAE

PANDA

HADES

JLab

EIC

LHCb HI

ALICE

Fixed-Target@LHC (AFTER/ALICE-FT/LHCb-FT)

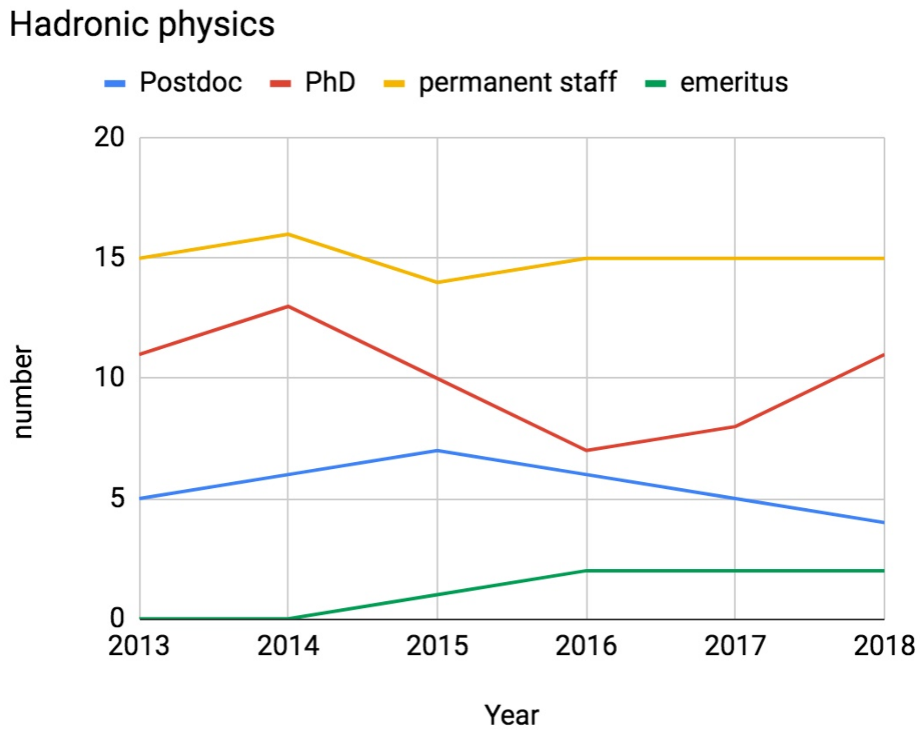
Theory*

*not covered in this presentation, see talk from Bartjan van Tent

Human resources, publications and financial support

	Scientific articles (with strong contributions from team members)	proceedings	Workshop organization	Invited talks in conferences	Number of PhD (defended + ongoing)	Number of inernship students (L3/M1/M2)
Total*	**84**	**56**	**20**	**198**	**25**	**~ 30**

HR evolution of the hadronic physics community* between 2013-2018 (expressed in number of researchers)



European and international grants, national and local grants

> 20

- **ERC Partonic Nucleus - Starting Grant (spokesperson)**
- **ERC Exploring Matter - Consolidator Grant (spokesperson)**
- **5 JRA H2020 STRONG 2020**
- Fundings from PICS and PRC
- Fundings from the local labex P2IO

→ see complete list in backup slide

* Detailed information per team available in backup

Prizes, responsabilities, teaching and outreach

Prizes

5

- CNRS bronze medal – Z. Conesa del Valle
- Joliot Curie Prize of the Société Française de Physique – M. Guidal
- ALICE thesis award, accessit to Young Researcher Price of the SFP and price of Chancellerie des Universités de Paris – M. Tarhini

Participation to committees and responsibilities*

- Significative presence in international (European Physical Society, NUPECC,…) and national committees (university, CNRS,…)
- High visibility in Collaboration committees (Chairman of Hall A Collaboration, Chair of HADES Collaboration board, …)
- Large number of responsibilities in Physics Analysis Groups (convenership) and detector operation

Teaching activities and teaching responsibilities*

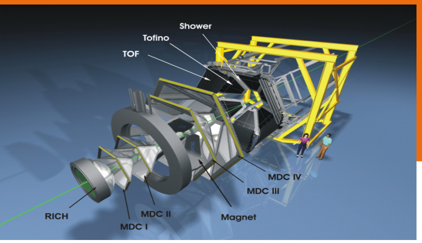
- Lectures for all levels at University Paris-Sud (L1/L2 PMCP, L3 Magistère de Physique, M1 Physique Fondamentale, M2 NPAC)
- Several teaching responsabilities at the university, in the local masters, in the doctoral schools and at IN2P3

Outreach*

- Regular involvement in Open Days (CERN, laboratory), CERN masterclasses, «Fêtes de la Science»
- Regular presentation of the field of research to high school students and frequent internships in the laboratory

* Details available in backup

Scientific achievements (2013 - 2018)



Hadronic physics at GSI/FAIR

Investigating the QCD phase diagram at low temperature and high baryonic density (baryonic resonance matter)

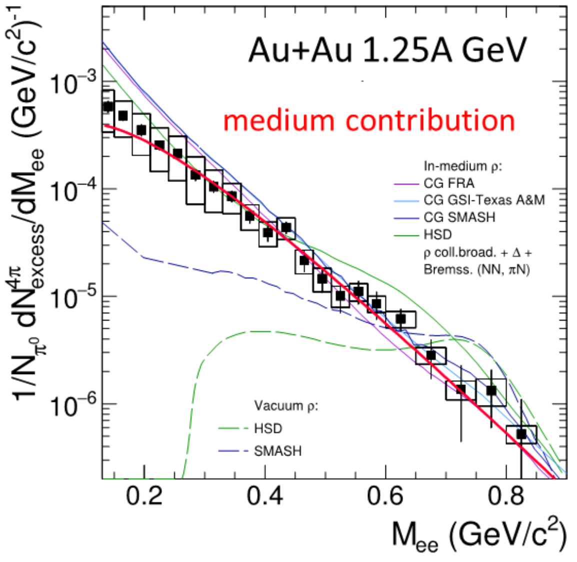
HADES: High Acceptance Di-Electron Spectrometer

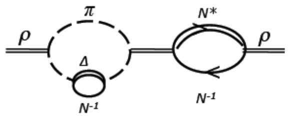
Hadronic matter studies:

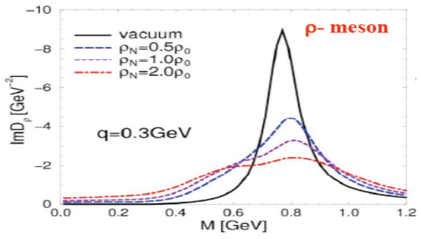
A+A, p+A, π+A $\sqrt{s}_{NN}$< 3.5 GeV

Strangeness, flow, fluctuations, dielectron

Modifications of ρ meson spectral functions







Rapp, Wambach, Chanfray,…

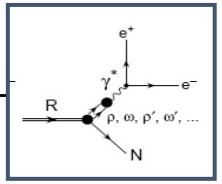
Baryonic resonance studies: p+p, π+p

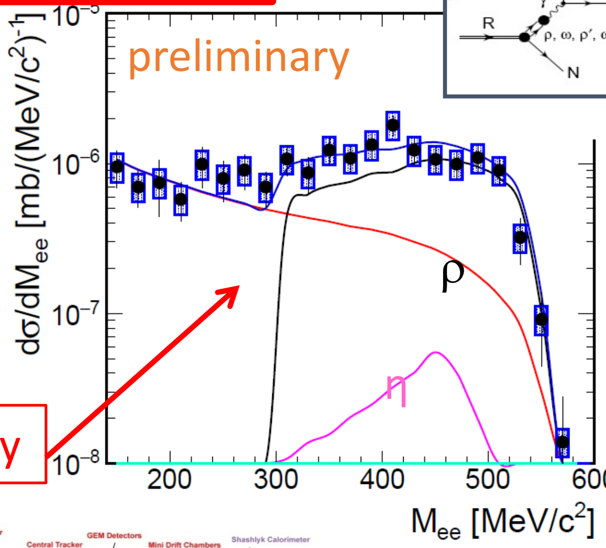
ρ meson couplings, Dalitz decays ($R \to Ne^+e^-$)

1st measurement of Δ(1232) Dalitz decay

Off-shell ρ contribution deduced from $\pi^-p \to N\pi\pi$ analysis

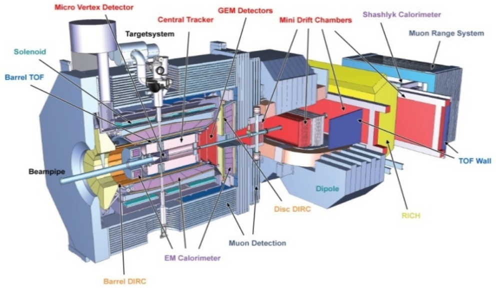
Quasi-free $\pi^-p \to ne^+e^-$





Point-like Dalitz decay

PANDA@FAIR

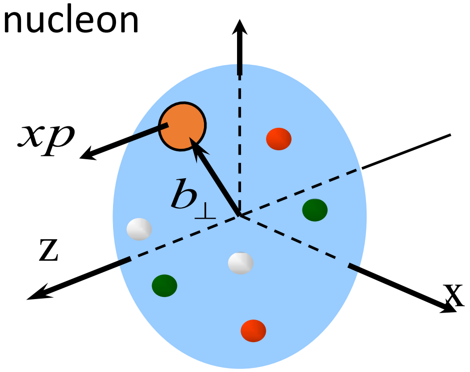


IPNO (2004-2016): nucleon structure feasibility studies in $\bar{p}p$ (1.5-15GeV/c)

R&D mech. and therm. design of Electromagnetic Calorimeter

Hadronic physics at JLab

Study of **nucleon structure**, mainly via **Generalized Parton Distributions (GPDs):**
Correlations between position, momentum, and spin of partons in the nucleon
→ **nucleon tomography, quarks' angular momentum,…**



GPDs are accessed in **exclusive electroproduction (DVCS or mesons)** at high momentum transfered → **virtual photons scattering *on quarks***

DVCS (Deeply Virtual Compton Scattering) **eN→e'N'ɣ**

Challenges → solutions

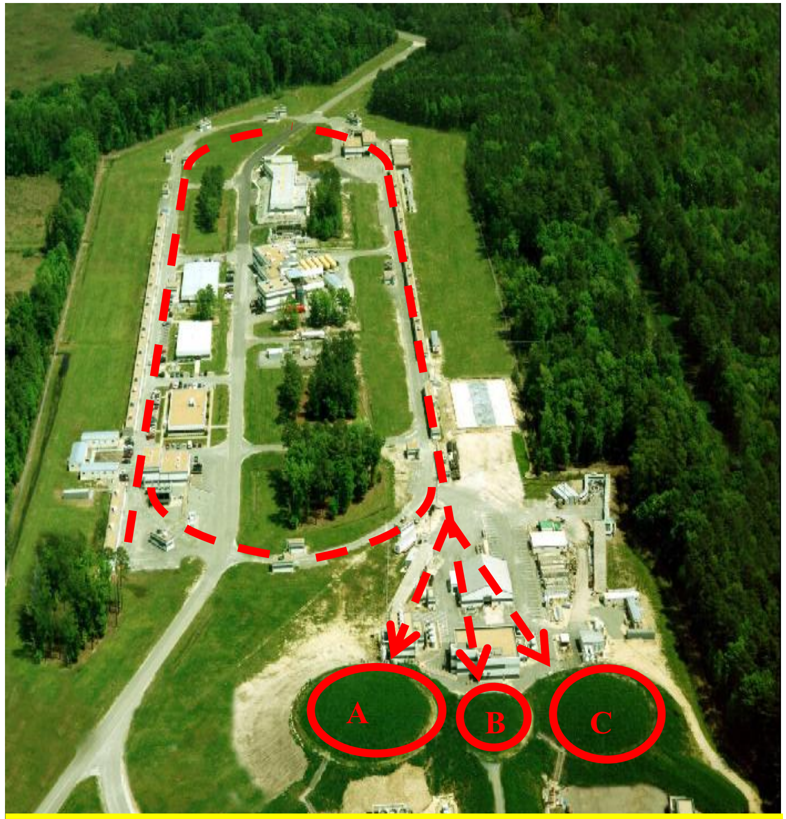
- Small cross sections (~pb)
- Multi-particle final states
- 4 GPDs for each quark flavor
- Several polarization observables to be measured, different reactions and target types

→ **High intensity electron beam**
→ **Polarized beam and targets**

➧ **JLab**

- Each GPD depends on 3 variables (x,ξ,t)
- DVCS observables contain integrals on x of GPDs (CFF)

➧ **Phenomenology : observables → GPDs**



E_{max} ~ **12 GeV since 2016** (**6 GeV before**)
High intensity (I_{max}~200 μA), duty cycle ~100%
High beam polarization (~85%)

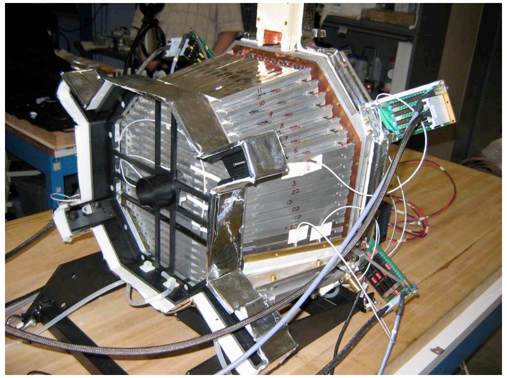
IPNO impact on GPDs at JLab

Jefferson Lab

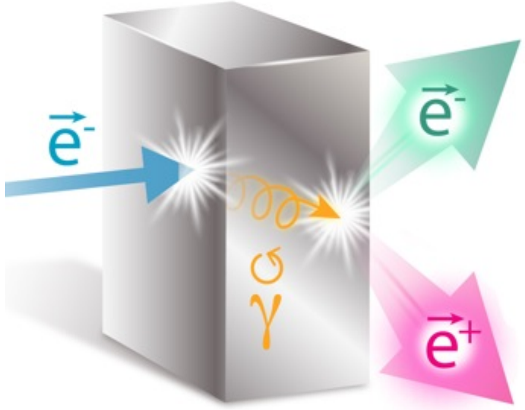
- **The IPNO team has been leading the JLab experimental program on GPDs for the last ~20 years** (first proposal on GPDs presented to the JLab PAC in 1998)
- **GPDs** are the **core** of **JLab** experimental program, and they are included in the **NUPECC Long Range Plan**
- **Most of approved proposals** on GPD physics at JLab have at least **one IPNO spokesperson**
- **IPNO lead author on > 25 articles** on DVCS, meson electroproduction, GPD extraction and modeling

Direct involvement in all aspects of the experiments: proposition, detector conception and development, data taking, analysis, phenomenological interpretation of the results

Technical contributions of IPNO for JLab@6 GeV

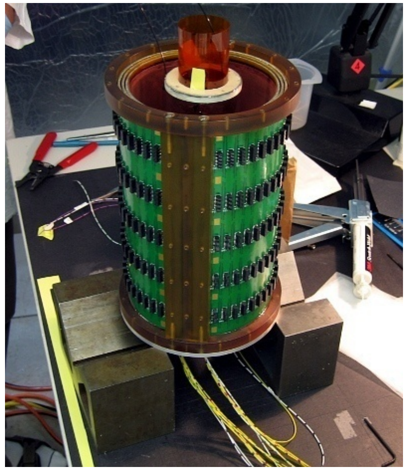


Electromagnetic calorimeter for CLAS (used by 3 GPD experiments)



PePPO: proof-of-principle for a polarized positron beam

PRL 116 (2016) 214801

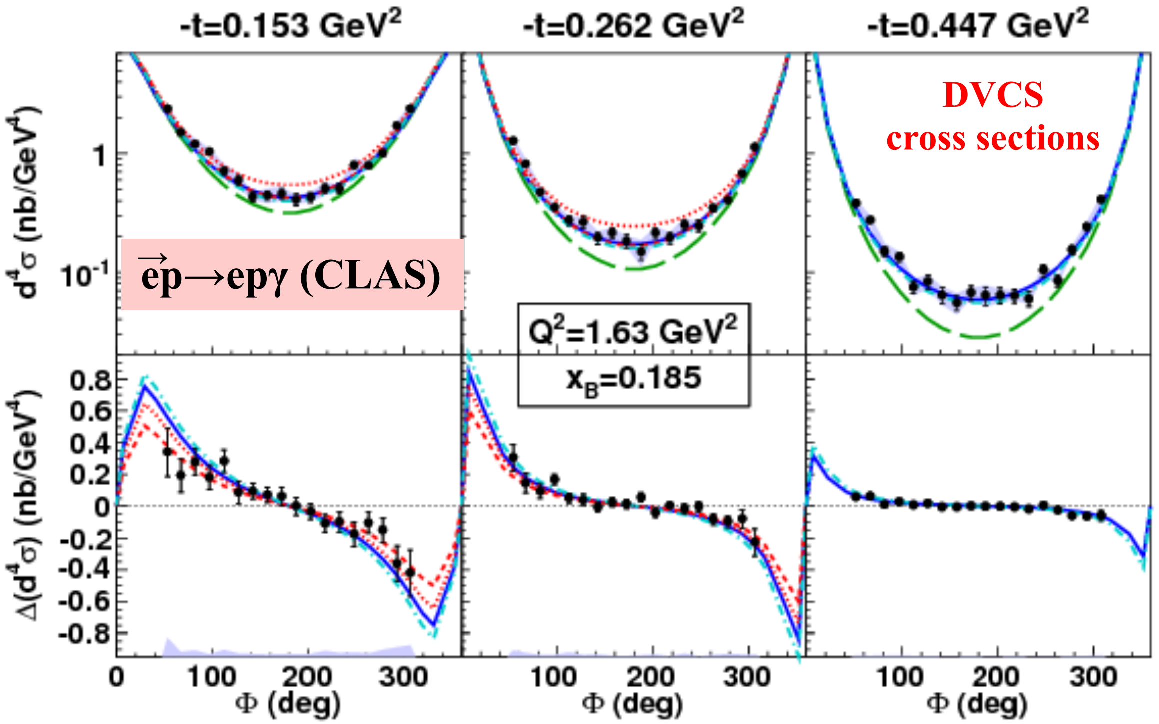


Radial Time Projection Chamber for CLAS

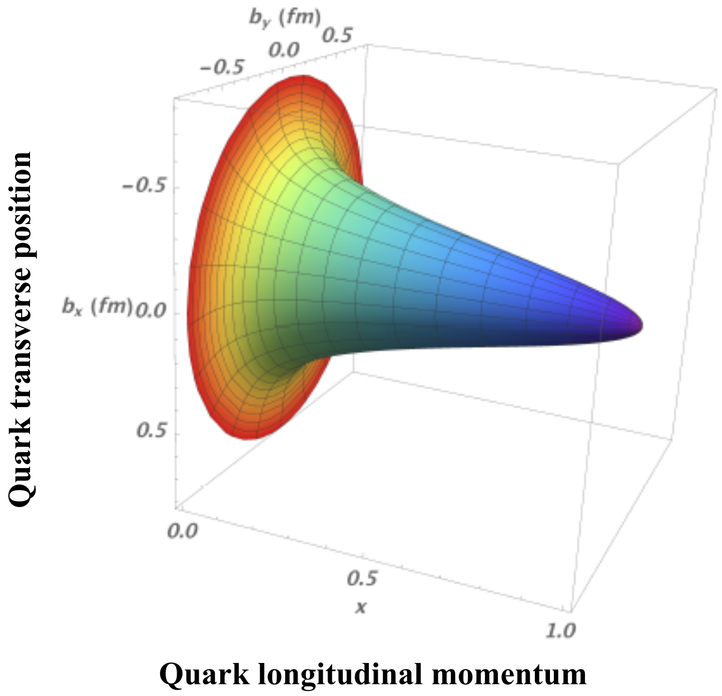
NIM A898 (2018) 90-97

Physics highlights : DVCS with JLab@6GeV

Jefferson Lab



From DVCS observables to GPDs to **proton imaging**



- **Cross sections for proton DVCS (CLAS and Hall A):** proton tomography, validation of applicability of GPD formalism, gluonic effects (**PRL 115, 212003 (2015); PRC 92, 055202 (2015); Nature Communication 8, 1408 (2017)**)
- **Polarized target asymmetries for pDVCS (CLAS):** polarized GPDs, proton axial charge (**PRL 114, 089901 (2015); PRD 91, 052014 (2015)**)
- **Beam spin asymmetry for DVCS on ^{4}He (CLAS)**: nuclear GPDs, nuclear-medium effects on nucleon structure (**PRL 119, 202004 (2017)**)

Proton tomography:

- **Valence quarks are at the core of the proton, sea quarks extend to its periphery**

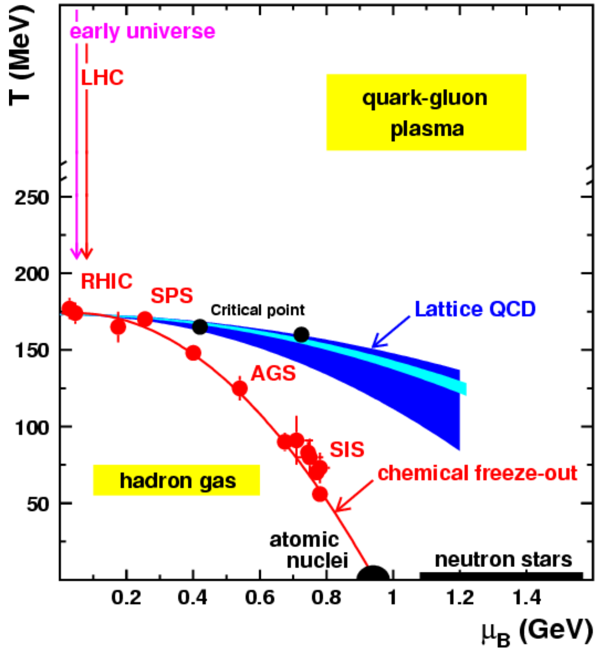
PRD95, 011501 (2017); EPJA 53, 171 (2017)

Hadronic physics at ALICE

Investigating the QCD phase diagramme at high temperature and low baryonic density

→ Characterization of the Quark Gluon Plasma (QGP), a state of deconfined nuclear matter, created in ultra-relativistic heavy ion collisions

To understand the properties of the QGP created in Pb-Pb collisions, one must also study simpler/reference systems:
– proton-proton « elementary » collisions
– proton-nucleus collisions to study « cold » nuclear matter

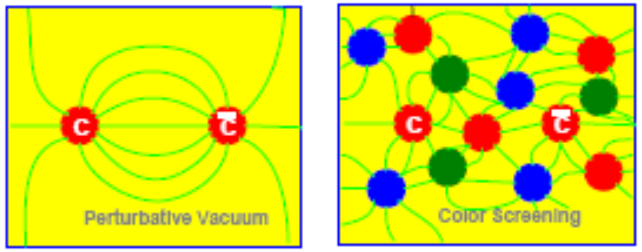


Long standing signature of the QGP, the J/Ψ ($c\bar{c}$ bound state) and other quarkonia are expected to melt in the QGP medium (as observed at SPS, RHIC)
At LHC, the large $c\bar{c}$ cross section is expected to lead to J/Ψ regeneration

color screening

In vacuum

In QGP

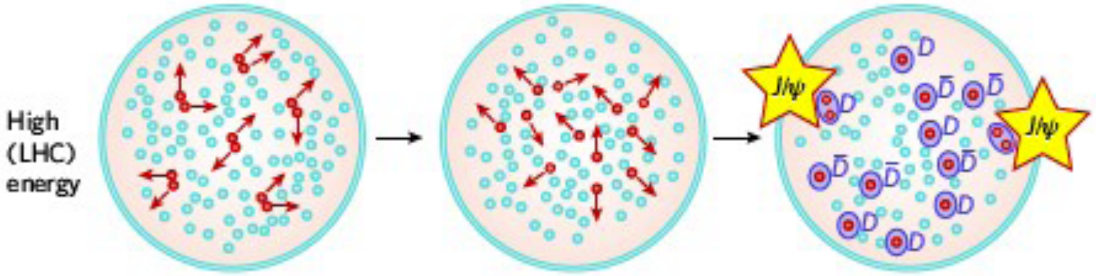


regeneration

Start of collision

Development of QGP

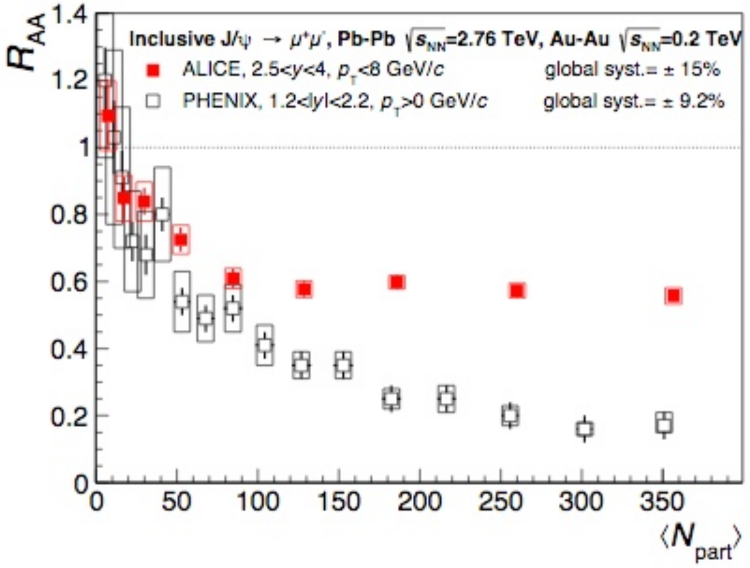
Hadronization

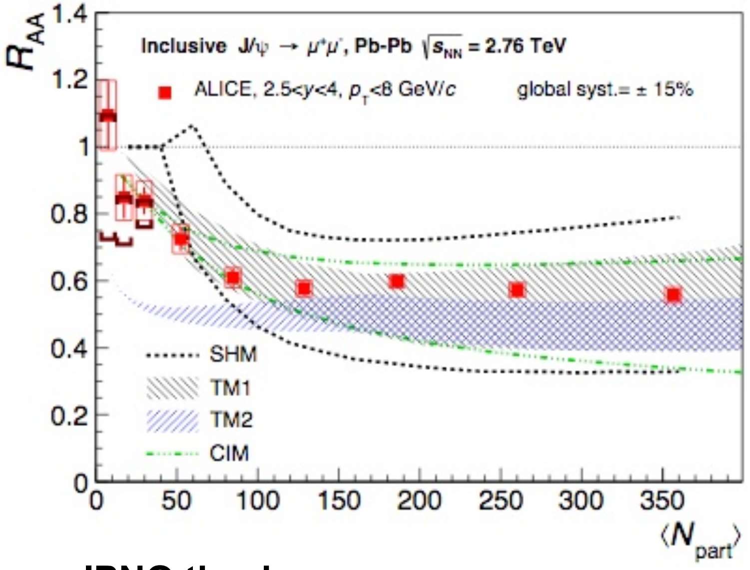


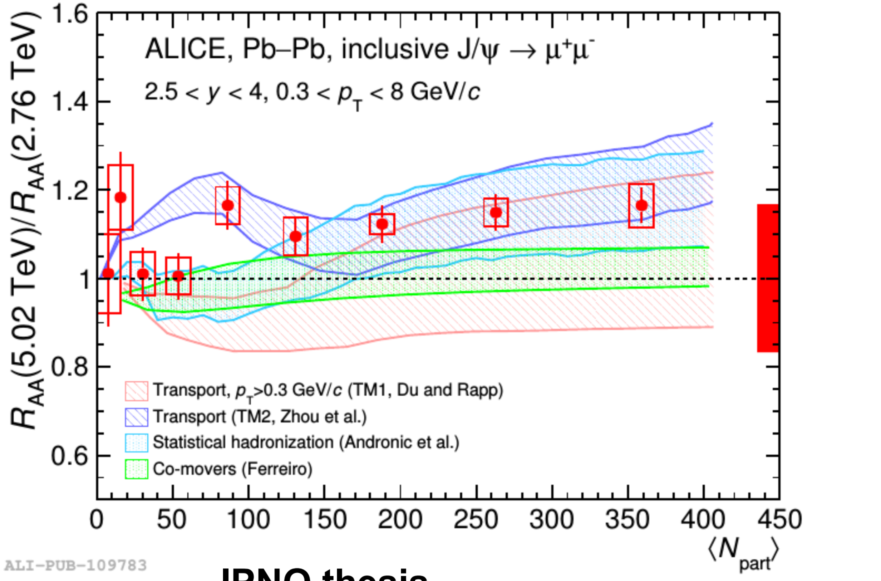
Nuclear modification factor (R_{AA}) compares particle yield production in PbPb to a (scaled) reference yield in pp collisions
$R_{AA} \neq 1$ → medium effects

- Since first Pb-Pb collisions (PRL 109 (2012) 072301), many studies lead by the group

→ First evidence of J/ψ regeneration at the LHC in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, further confirmed at $\sqrt{s_{NN}}$ = 5.02 TeV







IPNO thesis
JHEP 05 (2016) 179

IPNO thesis
PLB 766 (2017) 212

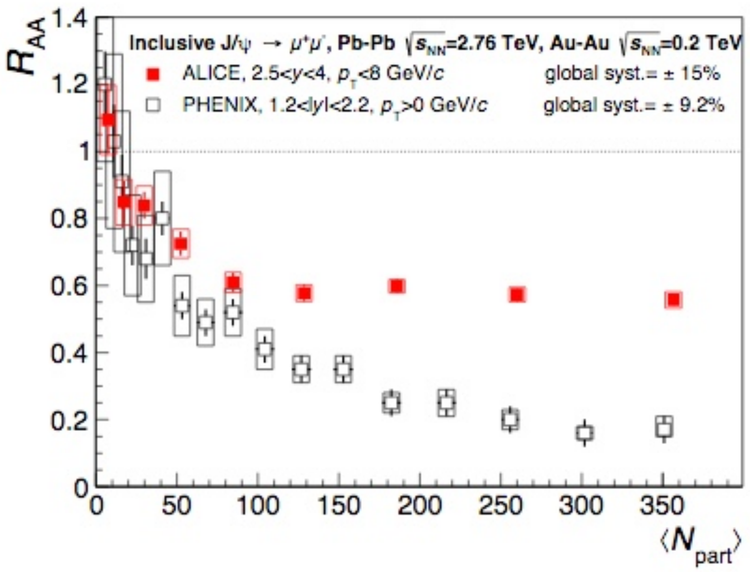
Excellent expertise and major contributions of the group in open-charm and charmonia production pp and pPb collisions: reference J/Ψ yields in pp for R_{AA}, multiplicity dependence, CNM effects studies, etc… (see backup)

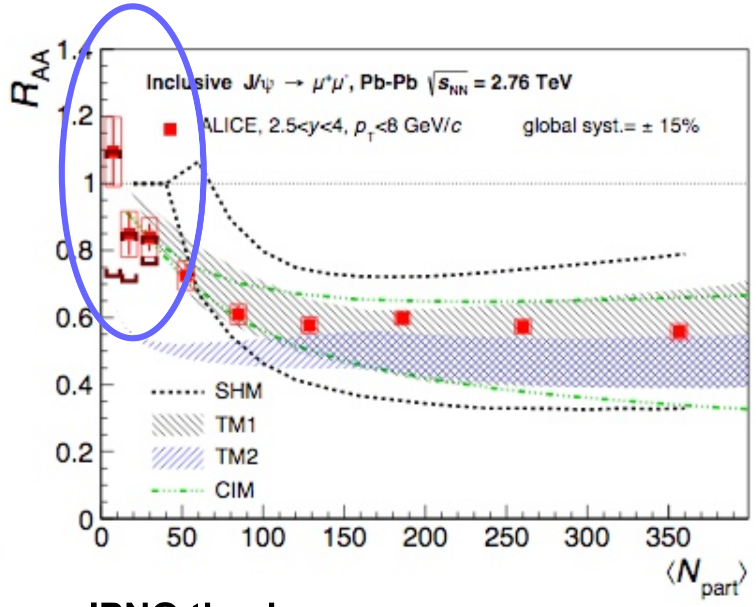
Physics highlights: J/Ψ production in Pb-Pb collisions at ALICE

- Since first Pb-Pb collisions (PRL 109 (2012) 072301), many studies lead by the group

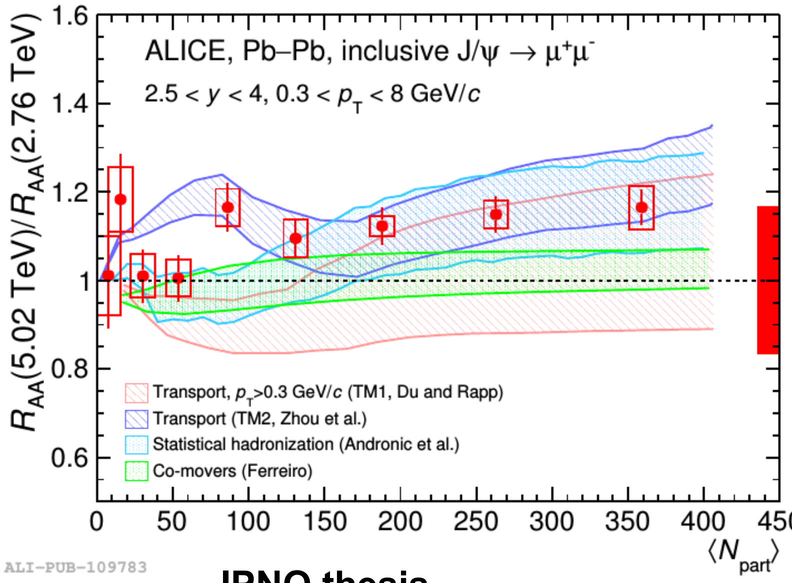
→ First evidence of J/ψ regeneration at the LHC in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, further confirmed at $\sqrt{s_{NN}}$ = 5.02 TeV

→ First intriguing observation of an excess in the yield of J/ψ at very low p_T in peripheral events (coherent photoproduction see backup)





IPNO thesis
JHEP 05 (2016) 179

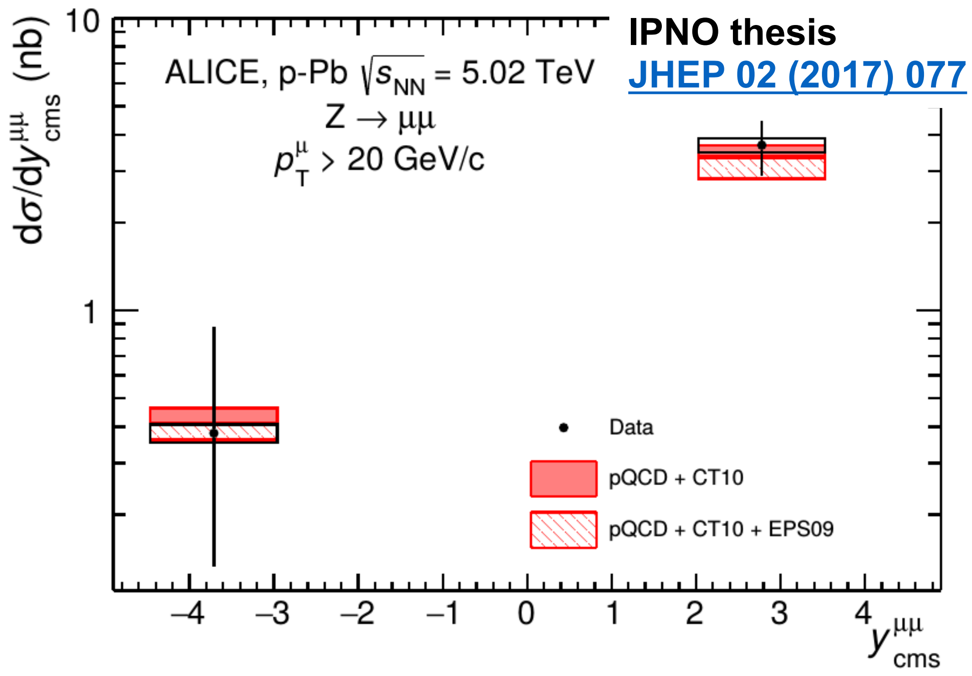


IPNO thesis
PLB 766 (2017) 212

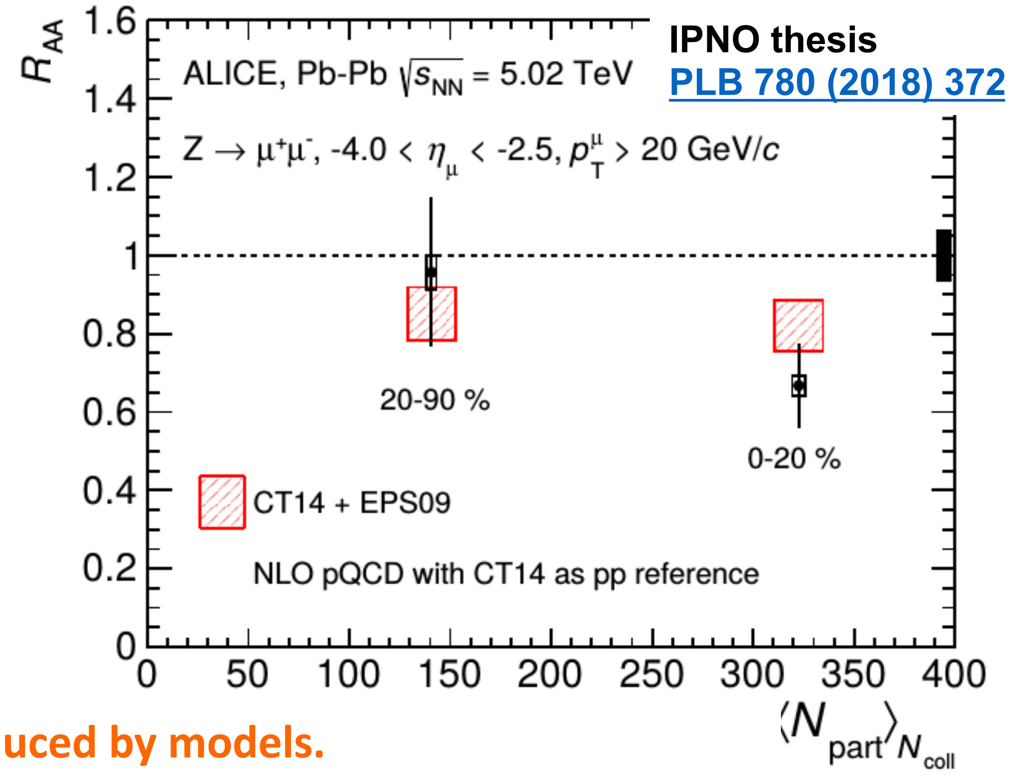
Excellent expertise and major contributions of the group in open-charm and charmonia production pp and pPb collisions: reference J/Ψ yields in pp for R_{AA}, multiplicity dependence, CNM effects studies, etc… (see backup)

Physics highlights: Z^0 production in pPb and Pb-Pb collisions at ALICE

- Z^0 production, governed by quark-antiquark annihilation, brings unbiased constraints to CNM effects. This measurement is sensitive to the Parton Distribution Functions in the nucleus (nPDF) in the QGP.
  - Z^0 probe is not expected to feel the QCD medium
  - Measurement in pPb and Pb-Pb (and of course pp) are of great interest



IPNO thesis
JHEP 02 (2017) 077



IPNO thesis
PLB 780 (2018) 372

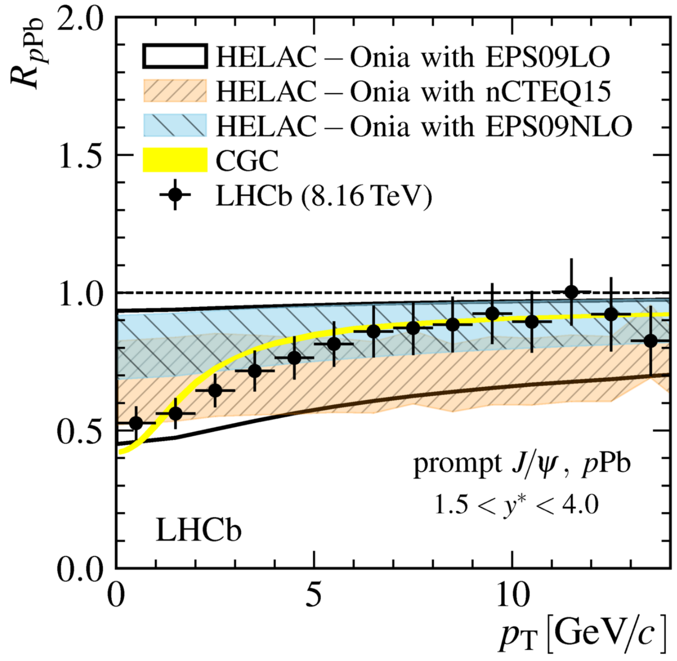
In pPb, Z^0 production well reproduced by models.

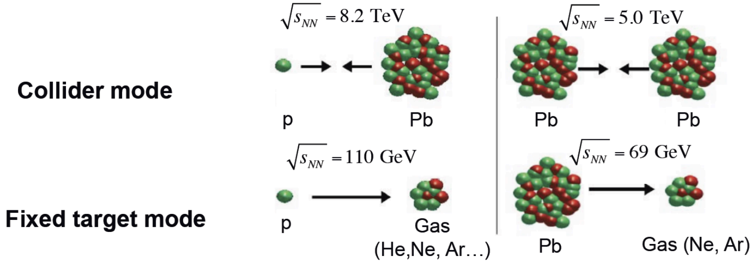
In PbPb, small tension (2.6 σ) in central collisions: last PbPb (nov-dec. 2018) run will help

Hadronic physics with LHCb Heavy Ions

LAL (and LLR) group involved in analysis of collider pPb and fixed-target data, concentrating on heavy flavor production (probes of nuclear effects and nuclear pdf)

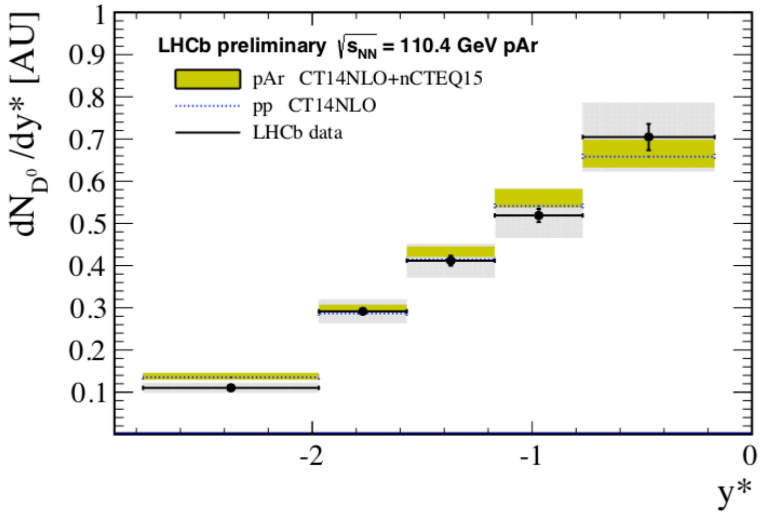
[arXiv:1706.07122]





Most energetic fixed-target experiment ever performed
Center-of-mass energy in between SPS and nominal RHIC energy

[arXiv:1810.07907]



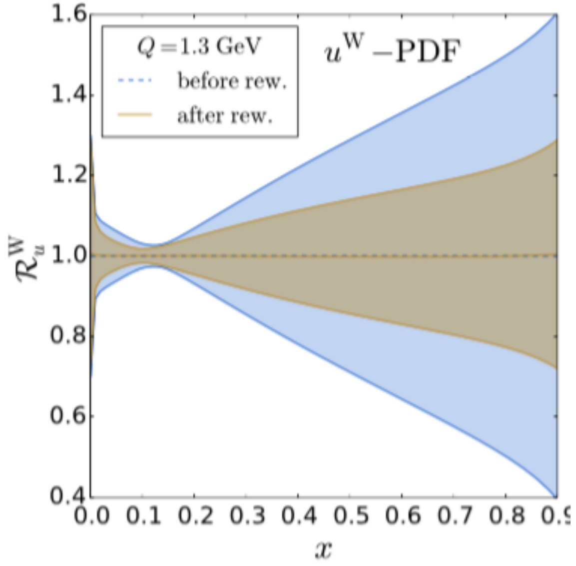
Collider mode: J/Ψ production in *p*Pb collisions (8.16 TeV)
In preparation: B^0, B^+ and Λ_b production [LHCb-PAPER-2018-048]

Fixed target: D^0 and J/Ψ production in *p*Ar (110 GeV) and *p*He (87 GeV) collisions

Hadronic Physics with Fixed-Target@LHC (AFTER@LHC, ALICE-FT, LHCb-FT)

AFTER@LHC

Theoretical motivations and feasibility studies for a high luminosity fixed-target programme at the LHC originally explored in the **AFTER@LHC** study group (lead @IPNO by **experimentalists + 1 theorist)**



Physics motivations identified and physics performances evaluated in simulation

- Nucleon structure at large-x
- Nucleon spin
- Quark Gluon Plasma

Technical implementations explored in relation with experts

- Internal gas target (already running at low gas density with SMOG in **LHCb-FT**)
- Beam halo extraction with bent crystal and internal solid target (envisoned in **ALICE-FT**, **LHCb-FT**)

Recent review of this work submitted to Phys. Rep. : arXiv:1807.00603

Major implication in the Physics Beyond Collider working groups (physics and implementation)

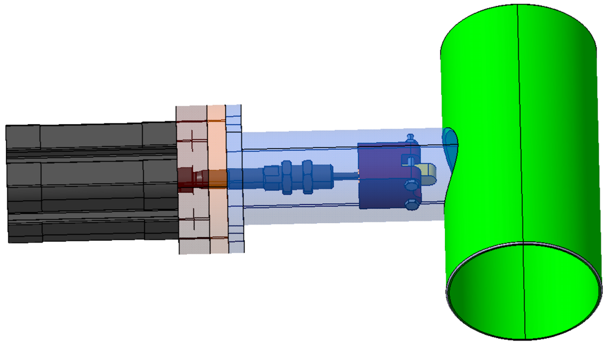
Strong collaborative work between the LHCb-FT(LAL), UA9 (LAL), ALICE-FT(IPNO), AFTER(IPNO) groups

FTE@LHC JRA H2020-STRONG2020 funding

ALICE-FT

Integration of the bent crystal solution in the ALICE experiment (1 IPNO engineer)

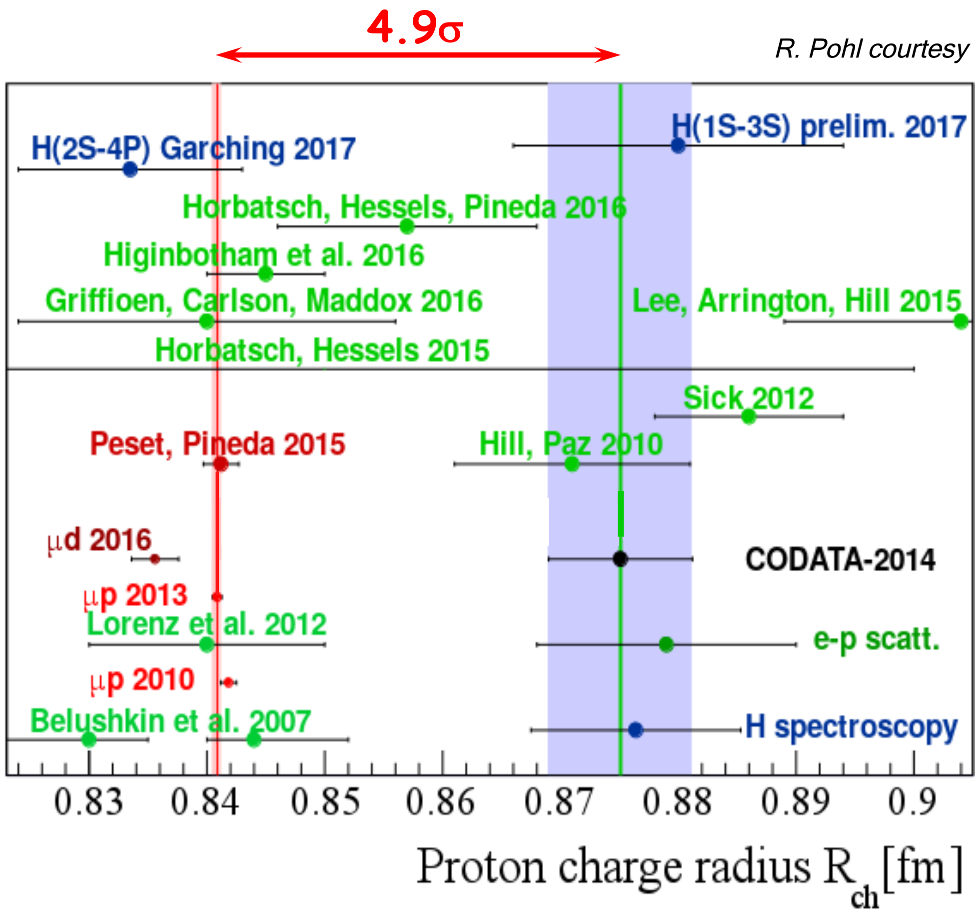
Physics performance and simulation studies for the ALICE apparatus



Project (2018 – 2023 and longer term future)

Hadronic physics at ProRad@PRAE

- The ProRad project started in *2016* and was awarded by the ***LabEx P2IO*** and the ***Region Ile de France***, as part of the **PRAE platform project**. The team leads the development of the **Subatomic Physics** axis of **PRAE**, and the **PREN** (Proton Radius European Network) package of ***STRONG2020***.



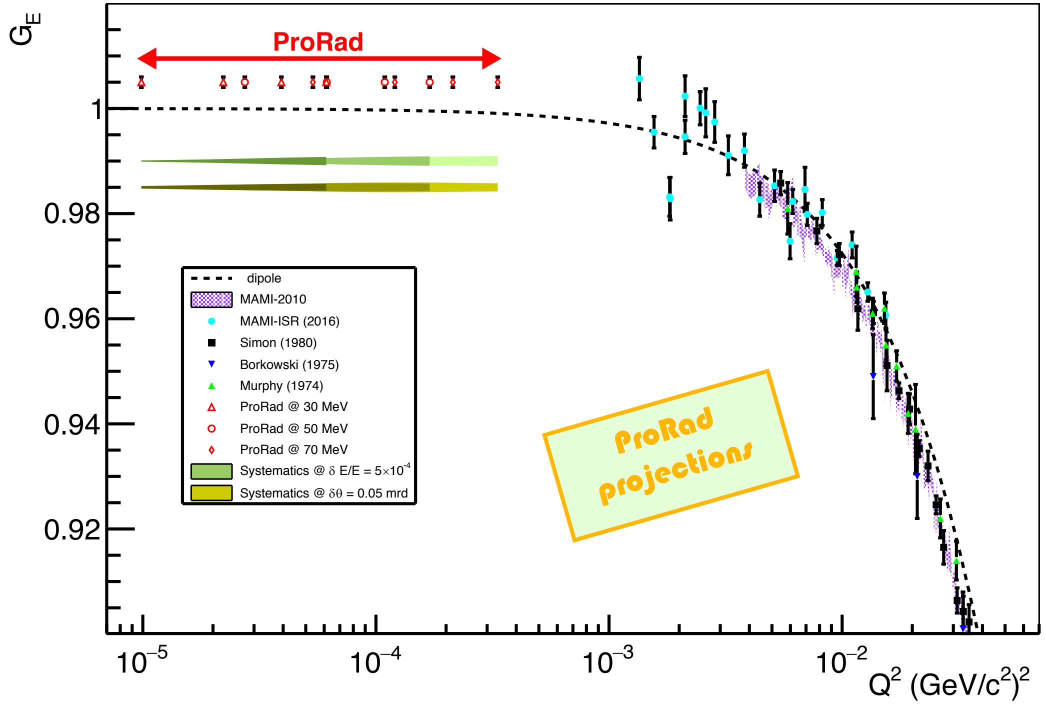
➢ The **ProRad** project at **PRAE** aims at measuring the electric form factor of the proton $G_E(Q^2)$ with a **0.1%** accuracy, at the smallest ever measured four-momentum transfer (Q^2) to the proton (**10^{-5}-$3x10^{-4}$** $(GeV/c^2)^2$), to constrain the determination of the proton radius.

The controversy about the proton radius value calls for more atomic and subatomic data.

Hadronic physics at ProRad@PRAE

Precision Experiment

- ✶ Design of an Energy Compression system to reduce the beam energy dispersion at a **few 10^{-4}**.
- ✶ (together with LPC) Design of the Beam Energy Absolute Measurement system to provide a **$5x10^{-4}$** relative precision on the beam energy.
- ✶ (JGU/Germany) Design of a **15 µm** diameter liquid hydrogen jet windowless target.
- ✶ (GWU/USA) Theoretical development of **very high accuracy** description of radiative effects.



The detector design is based on **28 detection cells** made of **scintillator hodoscopes** ($4x1.3x20$ mm^3) and **BGO crystals**.

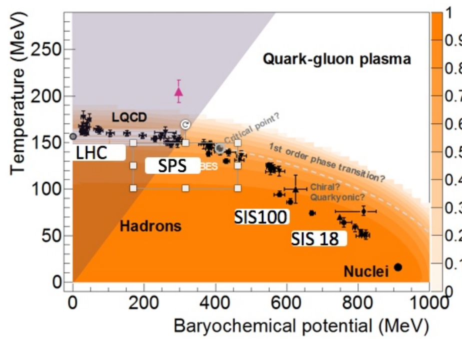
- R&D about the hodoscope SiPM readout
- Optimization of BGO
- Detector mechanics
- Modelling and simulation
- Data taking & analysis

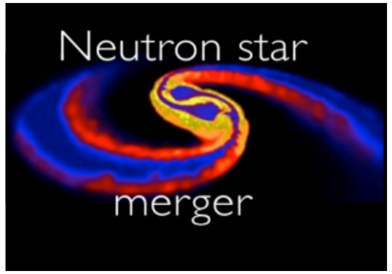
Data taking in 2021-2022

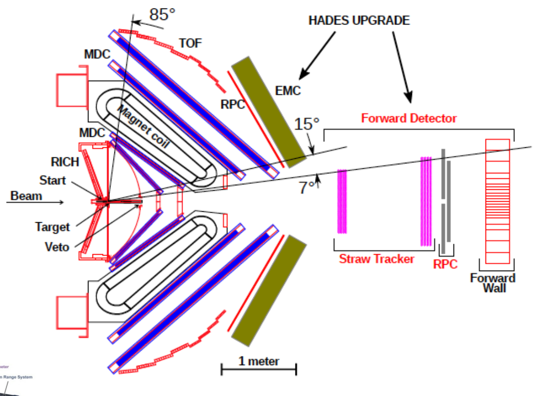
Future projects at GSI and FAIR

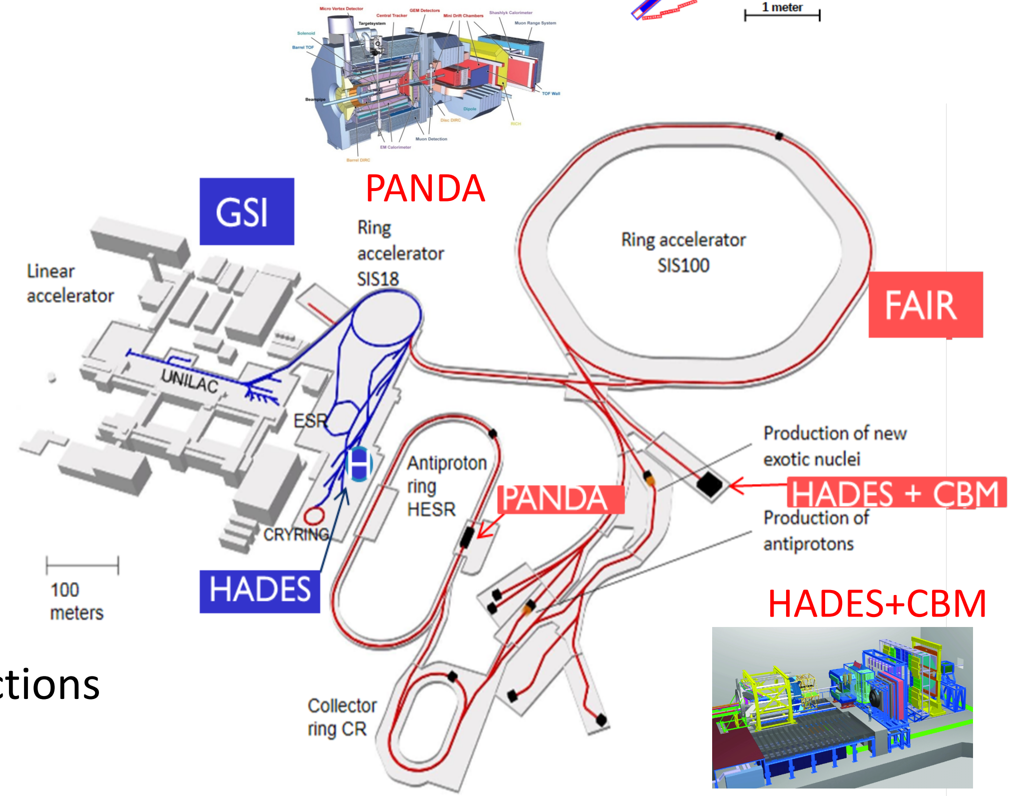
≤ 2023 FAIR PHASE 0 (SIS18) HADES

- HADES upgrade: contribution to straw tube detectors $\theta < 6.5$ °
- Hadronic matter: Ag+Ag 1.65 AGeV , p+Ag 4.5 GeV
  + short range correlations, dark matter….
- Baryonic resonances (hadronic and e^+e^- decay channels): $\pi^- + p$ $\sqrt{s}$=1.7 GeV
- Hyperons: p+p 4.5 GeV Dalitz decays $Y \rightarrow \Lambda\, e^+e^-$
  Study of electromagnetic properties of $\Lambda(1520)$,$\Sigma(1385)$,…









HADES+CBM

≥ 2025 FAIR PHASE 1 (SIS100)

Extension of **HADES** program at higher energies:

- Hadronic matter (e.g. Au+Au 4 AGeV max)
  Critical point, equation of state, medium modfications of spectral functions
- p+p (reference spectra, hyperon studies)

Continuing and expanding the JLab physics program

Jefferson Lab

Central Neutron Detector (CND) for CLAS12

Physics goals: neutron DVCS→ flavor separation of GPDs, measurement of GPD E (quark's angular momentum)

Design: barrel of scintillators, one-side PMT readout + « u-turn » light guides

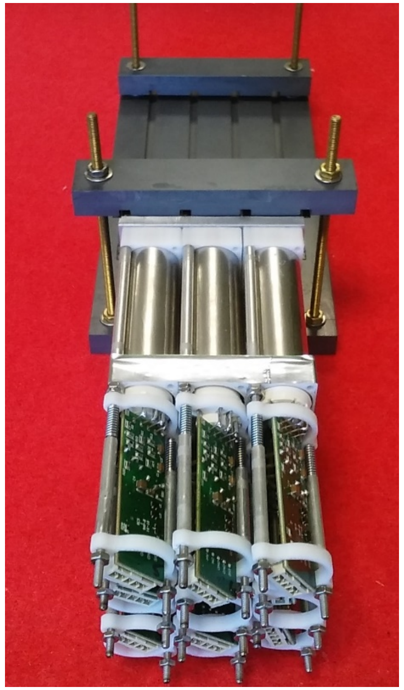
- Financed by IN2P3: ~300 k€ (2012-2015)
- Conception and construction carried out at IPNO, completed in 2015
- Installed at JLab in the fall 2017, taking data since
- **nDVCS experiment: spring+fall 2019**
- **NIMA 904, 81 (2018)**

Neutral particle spectrometer (NPS) for Hall C

Physics goals: DVCS and π^0 production at high precision

Design: 1080 PbWO4 crystals + PMTs

- R&D started in 2017
- IN2P3 funded the project in 2017-2019 (~200 k€)
- Ongoing tests at IPNO on radiation hardness and curing
- Mechanical design
- **Experiment in 2021**

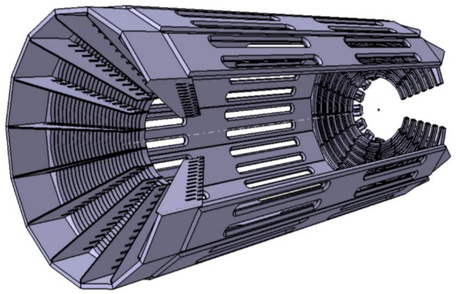


A Low Energy Recoil Tracker (ALERT) for CLAS12

Physics goals: electroproduction on ^{4}He → nuclear GPDs, partonic structure of nuclei, tagged EMC effect

Design: Compact drift chamber + scintillators

- Ongoing R&D at IPNO, detector and mechanics
- 51 k€ obtained from P2IO, **ERC: 1,400k€ (2018-2023)**
- Experiment in ~2022
- **NIM A 855, 154 (2017)**



Plan for JLab @ 12GeV

Jefferson Lab

pDVCS @ Hall A: 1st experiment of JLab @ 12 GeV, ended in **12/2016**, data analysis and PhD thesis just completed at IPNO

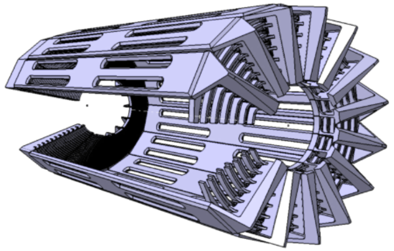
First CLAS12 experiment, with proton target (spring+ fall **2018**), PhD ongoing at IPNO: Timelike Compton Scattering, universality of GPDs, real part of CFF of GPD H

All these experiments have **IPNO spokespersons** and a **technical contribution** of IPNO

- **nDVCS @ CLAS12** data taking (spring+fall **2019**), PhD just started at IPNO
- **pDVCS** and **nDVCS @ CLAS12** on longitudinally polarized target (**2021**)

pDVCS & π^0 @ Hall C + NPS (**2021**)

Nuclear DVCS – ALERT @ CLAS12 (**2022**)



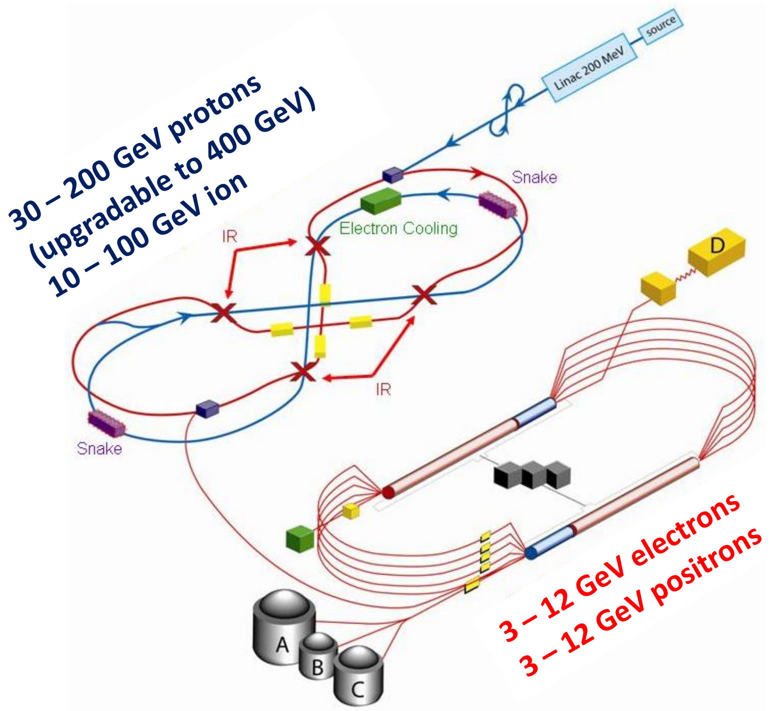
GPD physics with a beam of polarized positrons (> 2022)

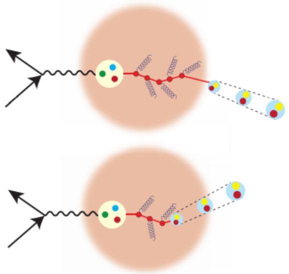
Hadronic physics at EIC

Outstanding questions in QCD:

- Distributions of position, momentum, angular momentum…
- Saturation: QCD in the non-linear regime
- Role of gluons in the nuclear medium

Golden future facility to study QCD at high *E*/small *x*:
role of gluons in nuclear matter





- e-p/A collisions with EIC:
- ✓ Polarized beams: e, p, d/^{3}He
- ✓ Electron beam: 3-12 GeV
- ✓ Luminosity L_{ep}~10^{33-34} $cm^{-2}s^{-1}$ (100-1000 x HERA)
- ✓ E_{cdm}=20-100 (upgradable to 140) GeV
- ✓ Large choice of nuclei

EIC Users group: 788 scientists (+ students & engineers), 29 countries, 169 institutions (>30% from Europe)

Timeline:
- NSAC 2015 Long range plan: *"highest priority for new facility construction"*
- July 2018 - US National Academy of Sciences: strong endorsement of EIC
- DOE project CD-0 expected early 2019
- Best estimate for the end of EIC construction: 2030

Future location in USA: Jefferson Lab (VA) or Brookhaven National Lab (NY)

Ongoing activities for EIC

Simulations

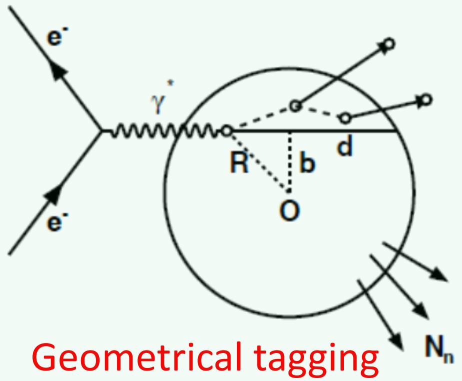
- First measurements of charmonia hadronization
- Indirect access to saturation (interaction with nuclear matter is dominated by low energy gluons)

• Challenges:

- High energy reduces the signal
- High luminosity is key for quarkonia measurements

• Results published in 2 White Papers:

(ArXiv:1108.1713 and Eur.Phys.J. A52 (2016) no.9, 268)

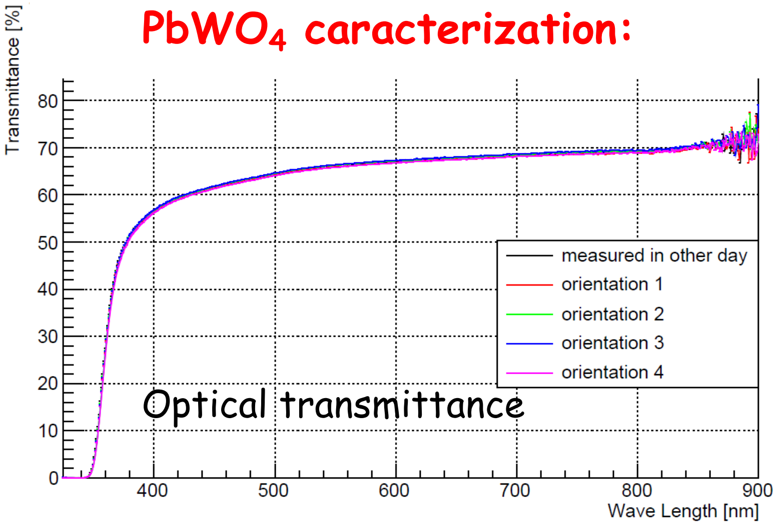


Geometrical tagging
(JLab LDRD working group)

- Impact parameter measurement
- Motivations beyond hadronization (centrality dependence of nuclear effects, shadowing…)

In synergy with developments for JLab CLAS12

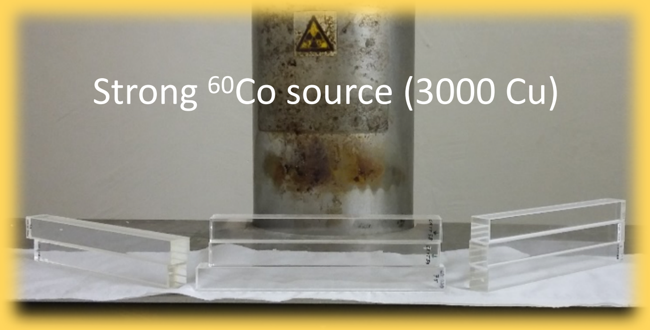
$PbWO_4$ caracterization:



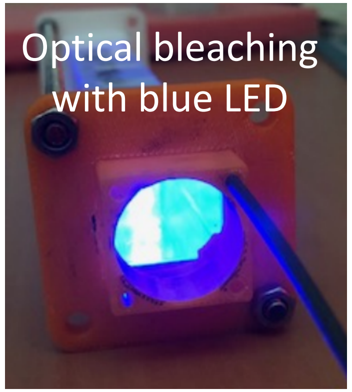
Ongoing R&D on crystal calorimetry

International consortium created in 2012 (lab joined in 2014)

Radiation hardness measurements (in collaboration with LCP-Orsay)



Local expertise in calorimetry: CLAS EC, HPS, PANDA…



In synergy with developments for JLab NPS

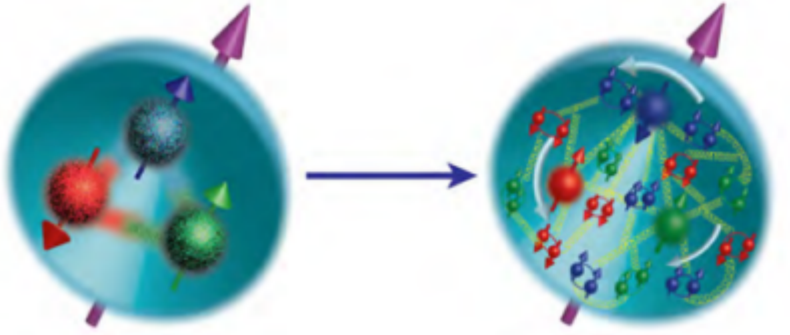
Also: light yield measurements and uniformity using a ^{137}Cs source

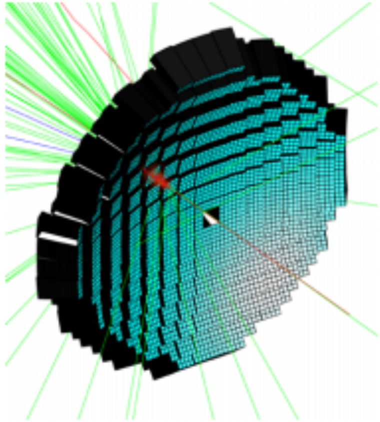
Activity funded by US DOE: $90k (2015-present)

EIC: outlook and plans

Physics program:

- ➢ 3D nucleon structure program into the low x region (key to study spin sum rules….)
- ➢ Extension to structure of nuclei, hadronization…
- ➢ Relation to Heavy Ion physics (cold nuclear matter)





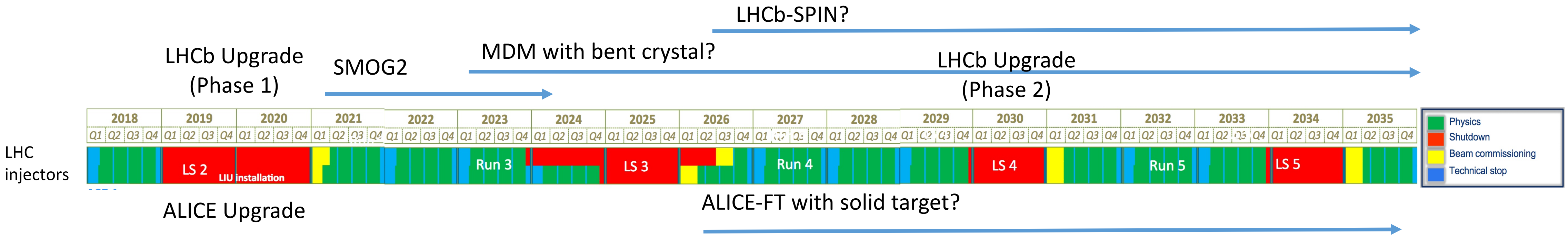
Planned involvement in EIC physics:

- ✓ Simulations and detector optimization for exclusive channels
- ✓ Instrumentation R&D: calorimetry, sensors…
- ✓ Synergy with accelerator R&D (Energy Recovery Linacs…)

Ongoing collaborations on EIC:

- US DOE detector R&D: CUA, Jlab, BNL, Caltech.
- JLab LDRD "Geometrical tagging": Jlab, ODU, ANL, USM.
- STRONG2020, WP24 (NextDIS) on EIC physics and instrumentation: CEA and other European institutions

Future projects at the LHC

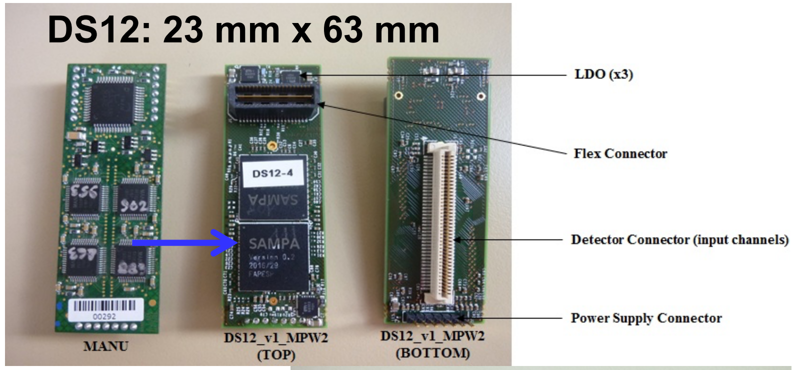


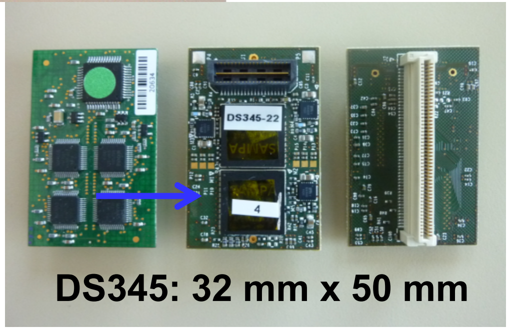
ALICE Muon Spectrometer Upgrade

LHC Run 3 (> 2021): expected muon trigger rate in Pb-Pb **beyond 10 kHz** for p_T > 1 GeV/c. Current MS readout cannot cope with this data taking rate → Upgrade of MS readout (together with other ALICE detectors)

- Design, produce and integrate a new readout electronic for the Muon Tracker:
  - **DualSampa: 20000 to be produced**
  - **Large PCB** (links DualSampa to DAQ)
  - **Renewal of High Voltage boards**
  - **Commissioning of the "upgraded" detector**

~ 3 Physicist Alice group, major involvement of lab electronics and detector divisions (> 3 FTE)





Physics perspectives with the ALICE upgrade

New physics opportunities offered in the sector of heavy flavours, quarkonia and electroweak bosons by the MS upgrade + new Muon Forward Tracker

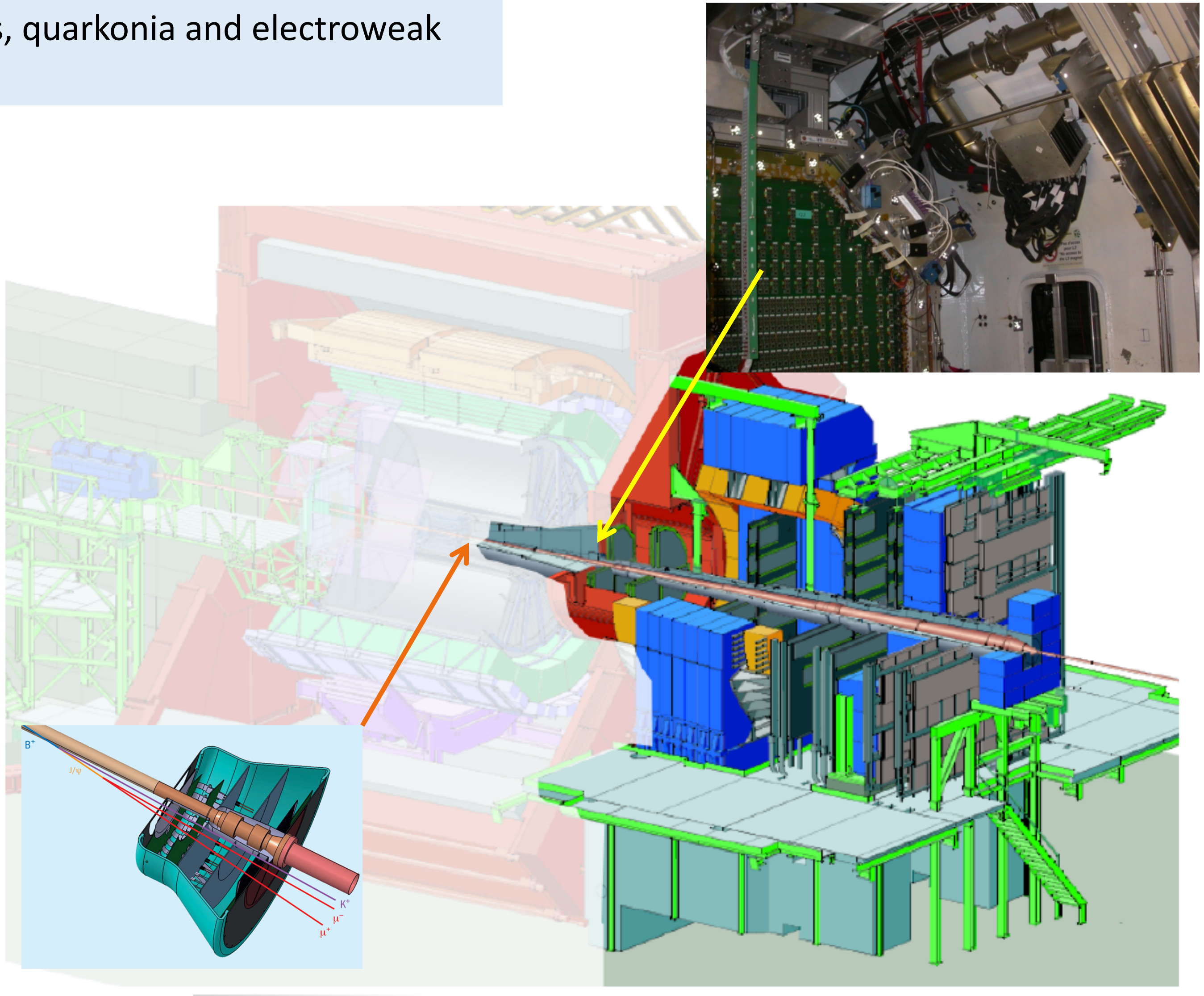
In medium charmonium dynamics (dissociation/regeneration, medium temperature)
→ prompt J/Ψ and Ψ(2S) R_{AA} down to zero p_T

Thermalization of heavy quarks in medium
→ Elliptic flow from charm down to p_T ~1 GeV/c, from beauty and prompt charmonium down to zero p_T

Mass dependence of in-medium parton energy loss
→ Charm and beauty mesons p_T-differential yields

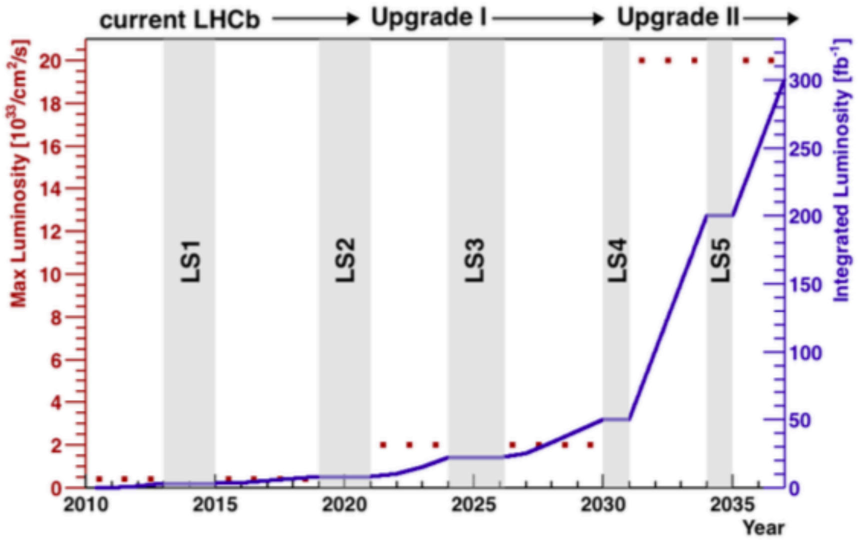
Modification of nPDFs
→ Z boson production

Rich physics programme covering Run 3 and 4 of the LHC and constituing the long term plan of the ALICE group



LHCb upgrade for HI – Collider mode

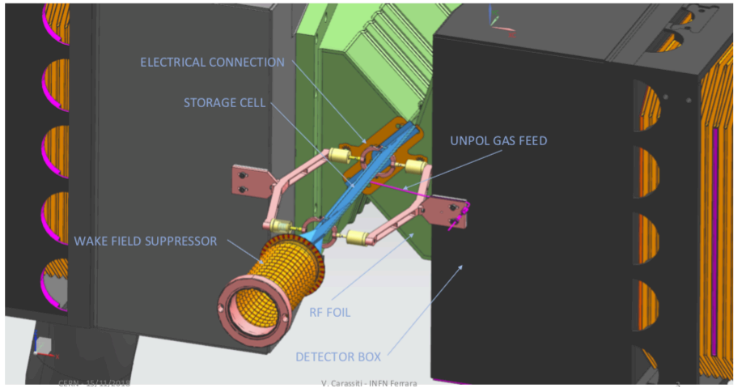
- LHCb detector Upgrade Phase I (starting from 2021) will help collecting data in larger multiplicity environments, but probably not good enough still for central PbPb collisions
- Upgrade Phase II: Opportunity to design a new detector that will work in Pb-Pb collisions



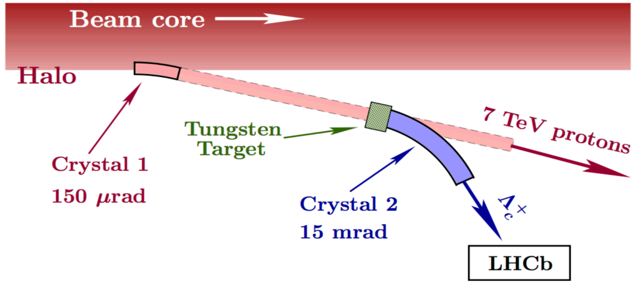
- Simulation studies for the Heavy Ion case

Fixed-Target@LHC (AFTER@LHC, ALICE-FT, LHCb-FT)

LHCb-FT project



- Upgrade of SMOG system: SMOG2 to increase statistics by factor 100 and to inject more types of gas (H2, D2, He, N2, O2, Ne, Ar, Kr, Xe)
- Installation approved in LS2 (2019), usage during Run 3 (from 2021).
- MDM experiments: measure g-2 of charm quark (via Λ_c baryon [JHEP 1708 (2017) 120]) or τ lepton [arXiv:1810.06699]:
  - Two crystals setup (LHCb or new detector)
  - R&D for crystals at SPS, will restart in Run 3. Installation either during or at the end of Run 3 (2024).
- Long term: Instrumentation project for a quartz Cherenkov detector (veto for parasitic int.)



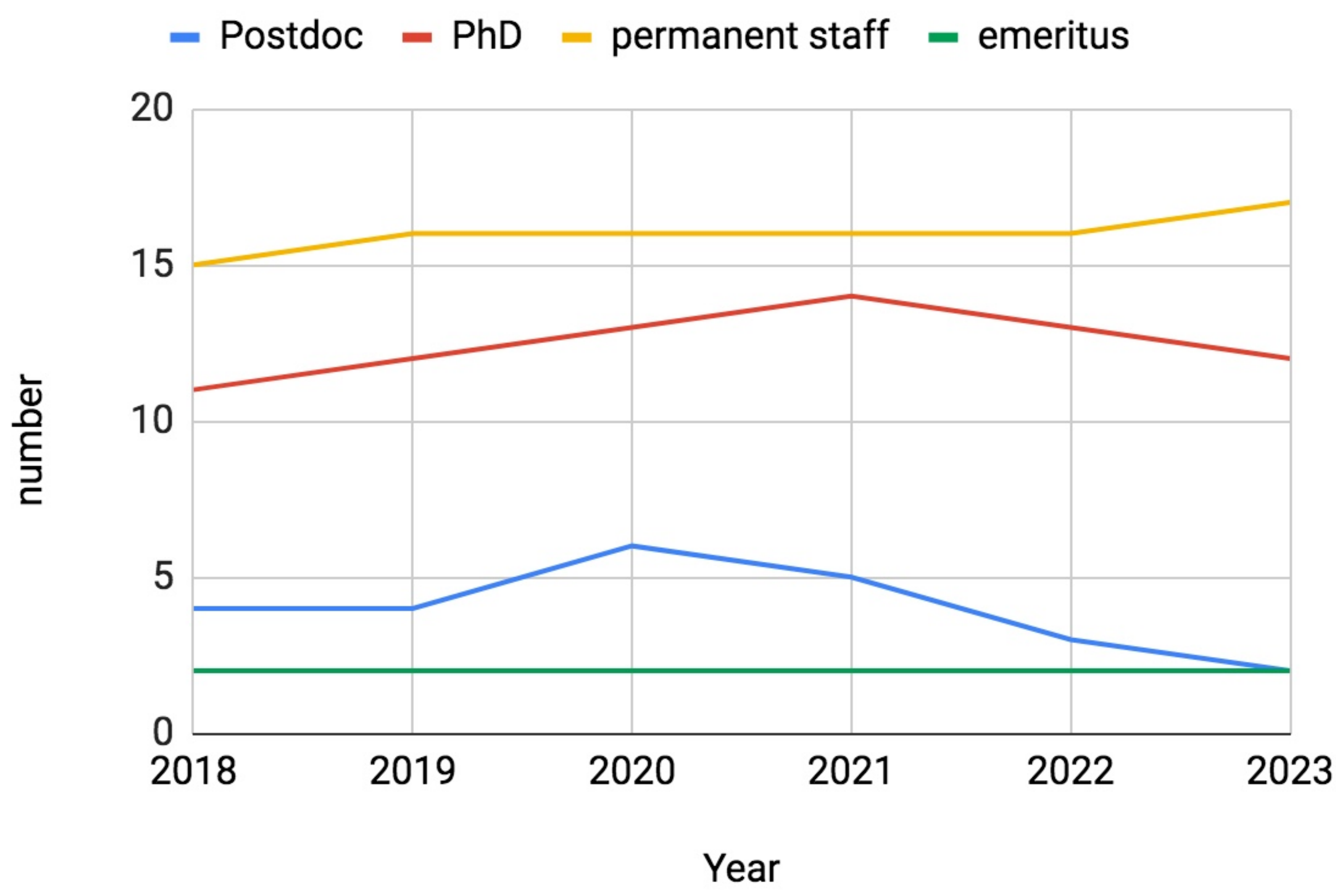
AFTER@LHC project

- Pursue investigations both on theoretical side and technical side (in the context of the PBC)
- Theory community support document submitted to ESPP

ALICE-FT project

- Pursue investigations on integration of the solid target and bent crystal in ALICE → targeting an installation during LS3 (~ 2024)
- New physics performance simulation studies (postdoc funding STRONG H2020)
- ALICE-FT proposal submitted to ESPP

Expected HR evolution in the next five years



- New CNRS permanent position in 2019 for the JLab team
- End of 2 ERC postdocs in 2018 for LHCb
- 1 postdoc starting in 2019 funded by STRONG2020 (JLab)
- 1 postdocs starting in 2020 funded by STRONG2020 (FT@LHC)
- 3 ERC-SG postdocs of 2 years starting in 2019, 2020, 2021
- 3 ERC-SG PhD starting in 2019, 2020, 2021
- Could expect the hiring of a new permanent staff within the next 5 years

SWOT analysis

STRENGTHS

- Rich variety of projects addressing all the fundamental opened questions in hadronic physics and covering the low to high energy domain
- Good visibility and recognized expertises in all the teams, as witnessed by the number of publications, responsibilities and invited talks at major conferences
- Leadership in the development of new projects (ProRad@PRAE, fixed target at LHC…)
- High number of PhDs and master students

WEAKNESSES

- Low permanent manpower to cover all the needs for the various projects (physics analyses, detector maintenance, upgrades). Several teams understaffed and with high proportion of temporary manpower

OPPORTUNITIES

- Large projects, such as EIC, will benefit from the increased technical and accelerator forces of the new lab (possible synergies with future PERLE@Orsay project) and from stronger links with theory community (IPNO, LPT)
- Existing synergies between experimentalists and theorists from LAL and IPNO on fixed target projects at LHC will be strengthened (possibility of creating a new group, possibility for common detector developments)
- Construction of new local facilities (PRAE) benefits from the expertises in the various labs (LAL, IPNO, IMNC)

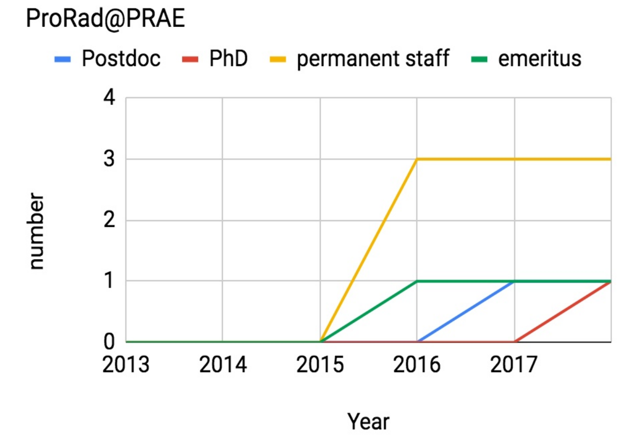
THREATS

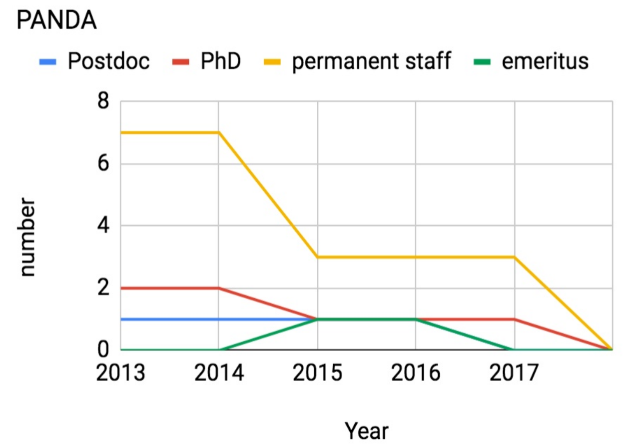
- The identity of the hadronic physics community could be lost in the new UMR if merged with the particle physics community in a HEP pole. International representativity of the community by a DSA without hadronic physics background is questioned
- Risk for small scale projects to loose visibility in the new lab
- Risk to have no visible implication in hadronic physics at FAIR due to low manpower
- Limited or difficult access to technical resources for small-to-medium scale project within the merged lab
- Responsiveness of local technical services (requirement of geographic proximity) and responsiveness of administrative services mandatory for our projects

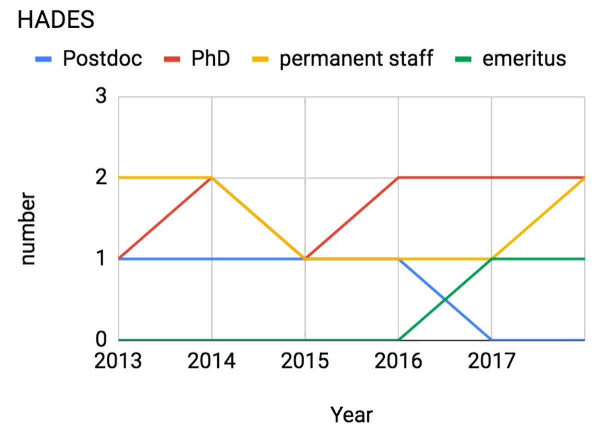
Backup

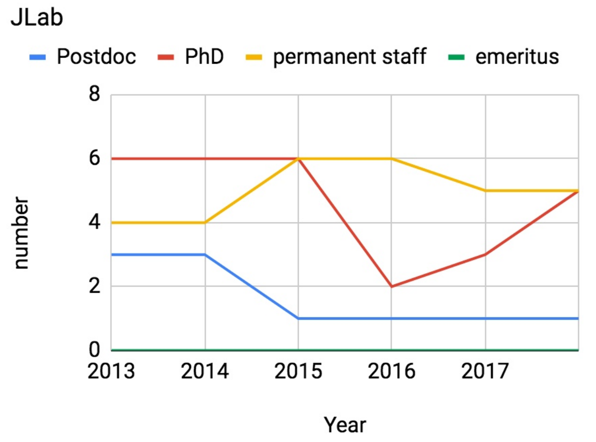
Human resources

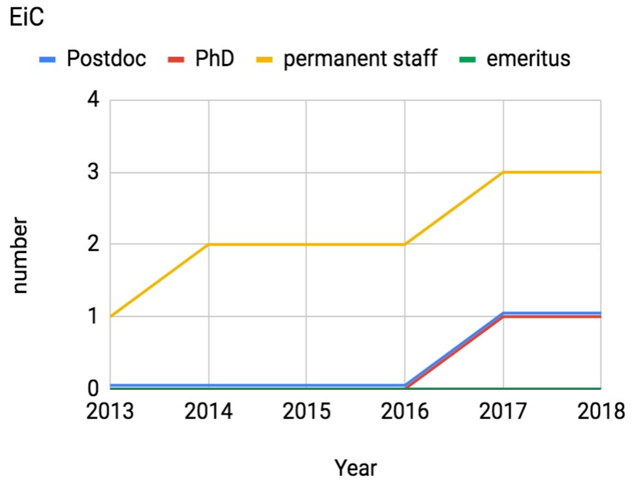
HR evolution per team between 2013-2018 (expressed in number of researchers)

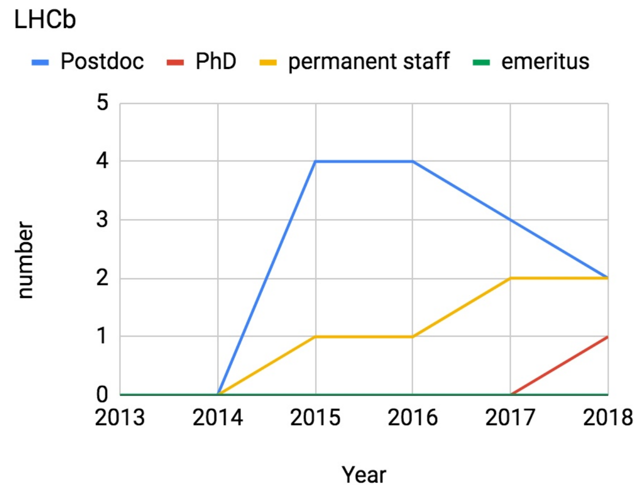


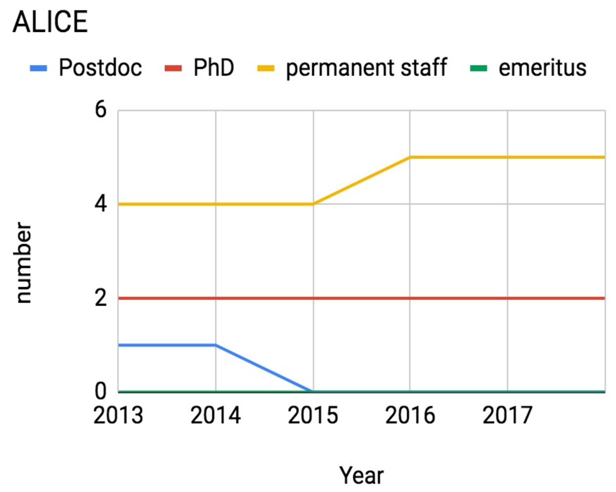


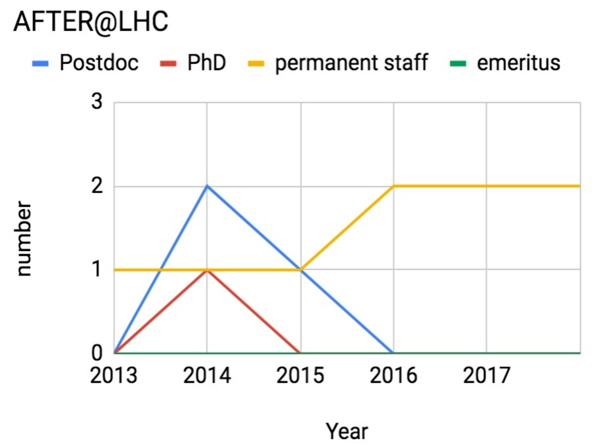












Financial support

European and international grants	11

- ERC Partonic Nucleus - Starting Grant (spokesperson)
- ERC Exploring Matter - Consolidator Grant (spokesperson)
- H2020 STRONG2020: JRA Fixed-target at LHC (spokesperson)
- H2020 STRONG2020: JRA GPDACT (spokesperson)
- H2020 STRONG2020: JRA P3E (spokesperson)
- H2020 STRONG2020: JRA PREN (spokesperson)
- H2020 STRONG2020: JRA NEXTDIS
- US DOE Detector R&D EIC
- Collaboration agreement IN2P3-GSI for PANDA (untill 2016)
- Collaboration agreement IN2P3-GSI for HADES (yearly)
- Collaboration agreement IN2P3-GSI for HADES (yearly)

National public grants	2

- PRC CNRS/RFBR for ALICE-FT (spokesperson)
- PICS CNRS/USA for GPDs at JLab (spokesperson)

Local grants	9

- Postdoc P2IO LAL/IPNO (LHCb/AFTER)
- Postdoc P2IO SPhN/IPNO (Compass/JLab)
- Postdoc P2IO LLR/LAL (LHCb)
- P2IO funding for ALERT (JLab)
- P2IO funding for PRAE
- SESAME Ile-de-France Region (PRAE)
- ½ thesis funding from P2IO (HADES)
- ½ thesis funding from P2IO (ALICE)
- ½ thesis funding University Paris-Sud / Taïwan (ALICE)

Participation to committees and responsibilities

Participation to committees

- Member of the Nuclear Physics Board of the European Physical Society
- President of the Nuclear Physics Division of the Société Française de Physique
- Chairman of the Hall A Collaboration
- Participation the the hadron Physics WG for the LRP of NUPECC
- Members of the Board of Directors of the Jefferson Lab Users Group
- Members of IAC of 3 international conferences and workshops
- Chair of the HADES Collaboration Board
- Members of the ALICE Collaboration Board
- Members of the Universities National Council Section 29
- Member of the local committee of Institute Pascal of Paris-Sud University
- Member of section 01 of the « Comité National du CNRS »
- Member of the HCERES committee of IPN Lyon and Subatech Nantes
- Elected member (head of the list) at the «Conseil Académique de l’Université Paris-Saclay»

Other responsibilities

- Responsible of the ALICE Upsilon to mumu Physics analysis Group
- Responsible of the ALICE D2H Physics Analysis Group
- Responsible of the ALICE J/ψ to mumu Physics Analysis Group
- Responsible of the ALICE Heavy Flavour Working Group
- Deputy of the ALICE MUON tracker project
- Co-coordinator of the ElectroMagnetic Processes Working Group in PANDA Collaboration
- Coordinators of the LHCb Heavy Ion and Quarkonium physics Working Groups

Teaching activities, teaching responsibilities and outreach

Teaching activities and teaching responsibilities

- Master 2 NPAC lectures (hadronic physics and particle physics)
- M1 lectures at the M1 Physique Fondamentale
- L1/L2 lectures for PMCP (Préparation au Magistère et aux concours de Physique)
- L3 lectures at Magistère de Physique
- Lectures at IN2P3 School on Detector Physics on Heavy Ion collisions
- Deputy director of the Doctoral School MIPEGE (Modélisation et Instrumentation en physique, énergie, géosciences et environnement)
- Member of doctoral school council of PHENIICS (Particules hadrons Energies et Noyaux : Instrumentation, Imagerie, Cosmos, Simulation)
- Member of the Specialist Committee CCSU of Section 29 of Université Paris-Sud
- «Chargée de Mission» on higher education for IN2P3
- Responsible of the M1 Physique Fondamental at Paris Sud
- Responsible of L1 and S2 of PMCP (also chair of the selection)
- Member of the council of the Physics Department
- Member of the local committee on the follow up of PhD students

Outreach (regular involvement)

- Presentation of the field of research to high school students
- Internship of high school students in the lab
- Open days of CERN and of the lab
- ALICE CERN masterclasses
- National «Fête de la Science» days

Publications and conferences (2013-2018)

Team	Scientific article (with strong contributions from team members)	proceeding	Workshop organization	Invited talks in conferences	Number of PhD (defended + ongoing)	Number of inernship students (L3/M1/M2)
ProRad@PRAE	1	2	1	11	1	6
HADES + PANDA	22	15	5	11	4	2
JLab	25	16	4	79	11	?
EIC	1	0	0	7	1	0
LHCb HI	3	10	2	26	1	2
ALICE	28	8	4	44	6	9
AFTER@LHC	4	5	4	20	1	0
Total	**84**	**56**	**20**	**198**	**25**	**~ 30**

Editorial activities

- Co-editor of Eur. Phys. Jour. A.
- Co-editor of Frontiers in Physics
- Editor of the topical issue « The 3D structure of the nucleon »
- Co-editor JHEP
- Co-editor Advances in High Energy Physics
- Co editor of several internal workshop proceedings

Link with local/national/international communities

International collaborations

ALICE : 42 countries, 174 institutes, 1800 members; **LHCb** : 16 countries, 72 institutes, 1227 members, **JLab** ~ 15 countries, ~ 60 institutes, ~ 600 members, **HADES** : 9 countries, 18 institutes, 120 members; **PANDA** : 17 countries, 500 members;
ProRad Collaboration, **CLAS** Collaboration, **Hall A** Collaboration, **Hall C** Collaboration
AFTER@LHC study group
LHCb: project with Tsinghua University in Beijing (via **FCPPL**)

National collaborations

ALICE: 7 groups; **LHCb**: 6 groups; **JLab:** 2 groups; **HADES**: 1 group; **ProRad**: 1 group
Participation to GDR-QCD

Local collaborations (apart from Laboratoires de la Vallée d'Orsay)

Collaborations with LLR : involved in fixed target programme (associated to LAL in LHCb), CMS heavy ion group
Collaborations with CEA-Saclay : phenomenological analysis and hardware (ALICE, JLab)
Collaborations with CPhT : phenomenology/theory (JLab)
Regular common funding requests (P2IO, ANR) for postdocs with CEA-Saclay (ALICE, JLab) or LLR (LHCb)
Organization of common workshops on perspectives for fixed target studies (IPNO/LAL with LLR)
Regular seminars inter-laboratories (experiment + theory): IPNO, CEA-Saclay/IPHT, LLR, LAL, LPT, CPhT
PRAE Collaboration

SWOT analysis per team

STRENGTHS

PRAE: inter-group and multi-lab activity, high scientific visibility.
PANDA/HADES: expertise in baryonic resonances. Well-recognized position in HADES. Upgrade of the detector with no particular risk.
JLab: 12GeV program just started, great wealth of data for 5-10 years
ALICE: expertise in hidden (open) charm physics at forward (mid) rapidity. Large number of publi (lead by group members). Visibility on hardware and analysis (many responsabilities).
LHCb: initiator of the FT experimental physics program at LHC.
AFTER: initiator of an ambitious high-lumi FT programme at LHC. Experimental and theoretical expertises. Many invitations at international conferences. Group gathering 40 colleagues worldwide.

WEAKNESSES

PRAE: high proportion of temporary manpower
PANDA/HADES: small group: two permanent researchers
JLab: small number of permanent researchers. Experimental program of CLAS12 priviledged, leaving GPD phenomenology/modeling activity aside. Addition of new permanent staff would avoir the problem
ALICE: small group of 5 permanents (including IPNO deputy director), with many responsibilities. Technical groups understaffed to support detector maintenance and upgrade.
LHCb: low personpower.
AFTER: small FTE reflecting activities and responsabilities of group members on other projects

OPPORTUNITIES

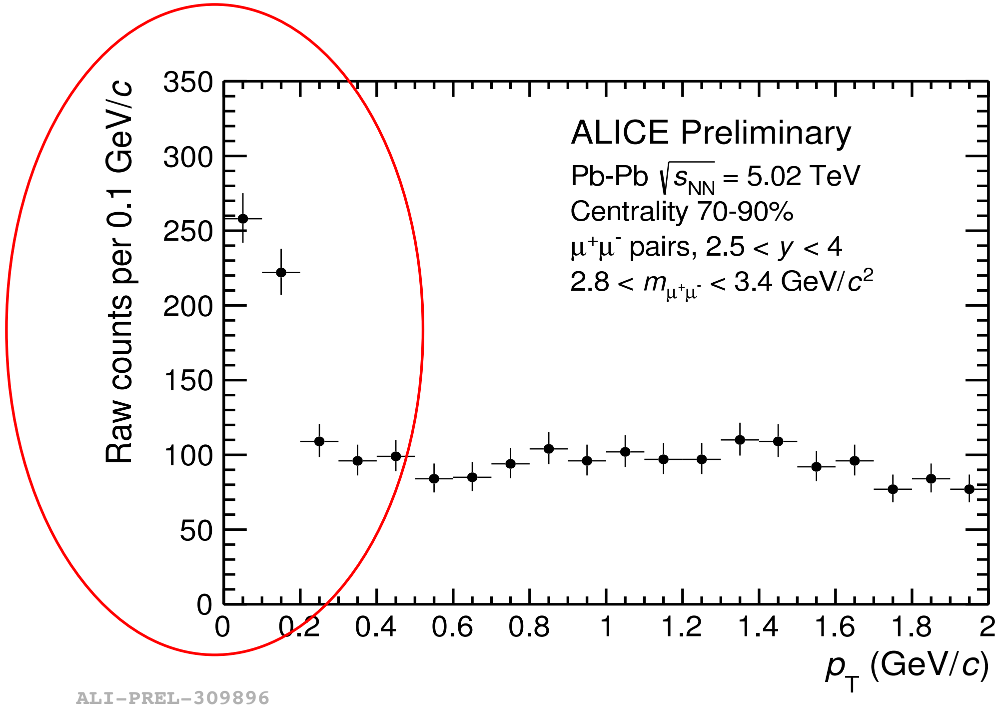
PRAE: high training and formation potential of PRAE as a modern high-technology research infrastructure within university campus
PANDA/HADES: involvement of IPNO in HADES, existing connections with CBM and PANDA, other FAIR hadronic projects are a good opportunity for long-term investment of IN2P3 in hadronic physics @FAIR
JLab: Many interesting topics, within and beyond the field of GPDs can be studied with JLab@12GeV data and EIC.
ALICE: Open field of analysis/expertise to new topics: electroweak boson studies, ALICE-FT, correlation and multiplicity dependence of charm prod.
LHCb: Re-use existing and well understood detector to expand its physics program. Collaborate with groups in the Orsay area to find new ideas.
AFTER: involvement in PBC and preparation of ESPP. Recommendation by CERN to pursue investigations on FT@LHC would boost activities.

THREATS

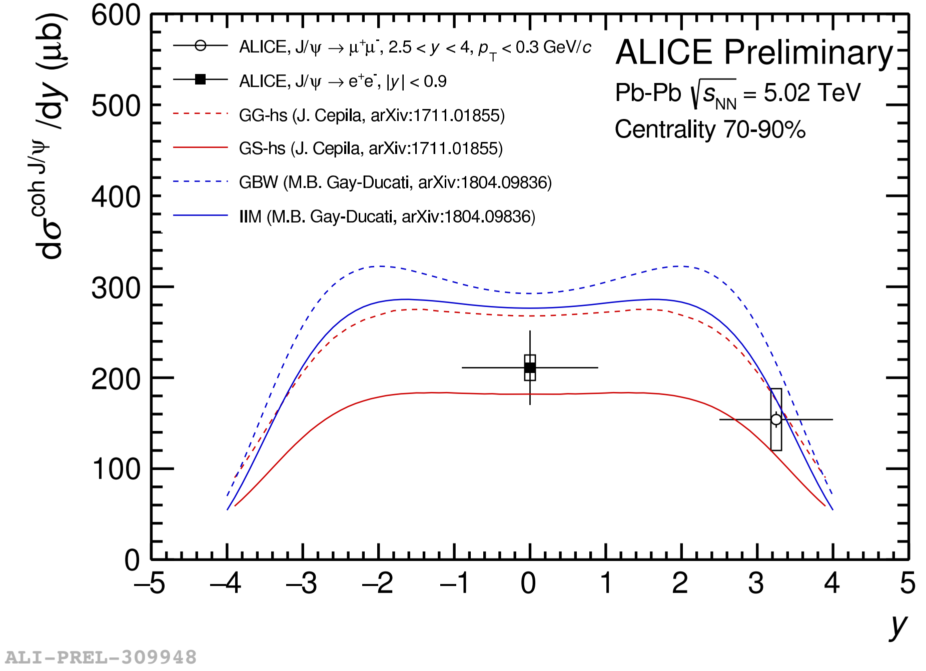
PRAE: lack of funding.
PANDA/HADES: absence of reinforcement of the team represents a considerable threat for visible implication in hadronic physics at FAIR.
JLab: if no manpower increase, it may be hard to keep up with all the 12 GeV projects and the EIC ones.
ALICE: the planning of the upgrade realization, installation, comissionning is extremely tight. Risk of not being ready (or only partially ready) for LHC Run 3.
LHCb: Complexity of the experimental setup and data taking at the LHC.
AFTER: FTE may decrease further in next 2 years to concentrate on ALICE upgrade during LS2 (2 members). Due to growing interest in the field, group with higher available FTE may want to take the leadership of the project

Physics highlights: J/Ψ photo-production in Pb-Pb collisions at ALICE

- Photo-production is well understood in UPC collisions
- ALICE has shown evidence that J/Ψ photo-production could also be present in hadronic PbPb collisions with nuclear overlap
- It could potentially become a new probe of charmonium color screening in the QGP



Preliminary result, Hard Probes 2018



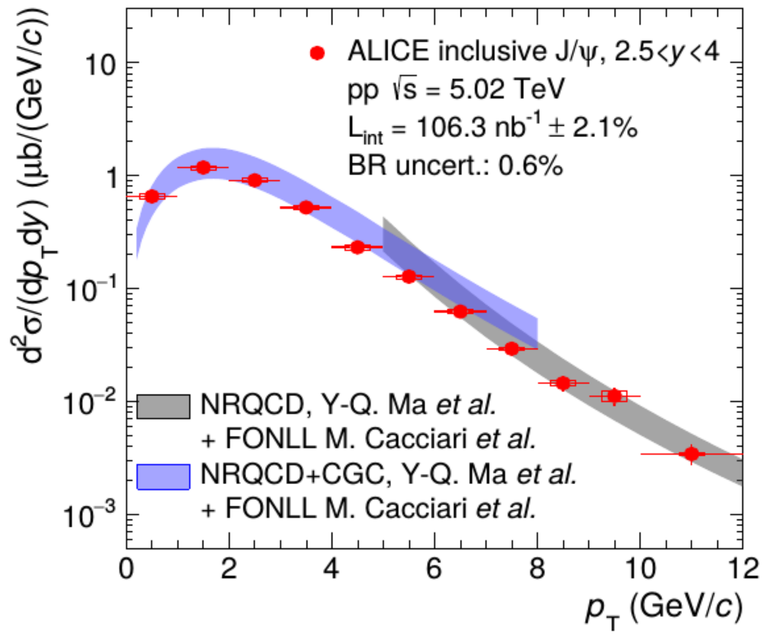
Models used to decribe PbPb UPC data and modified to account for nuclear overlap reproduce the cross section. New PbPb run (nov-dec. 2018) will permit to extend the measurement in most central collisions and characterise the production mechanism (polarisation measurement)

Physics highlights: J/Ψ production in pp and pPb collisions at ALICE

Production rate in pp and pPb constitute a crucial reference for QGP studies.

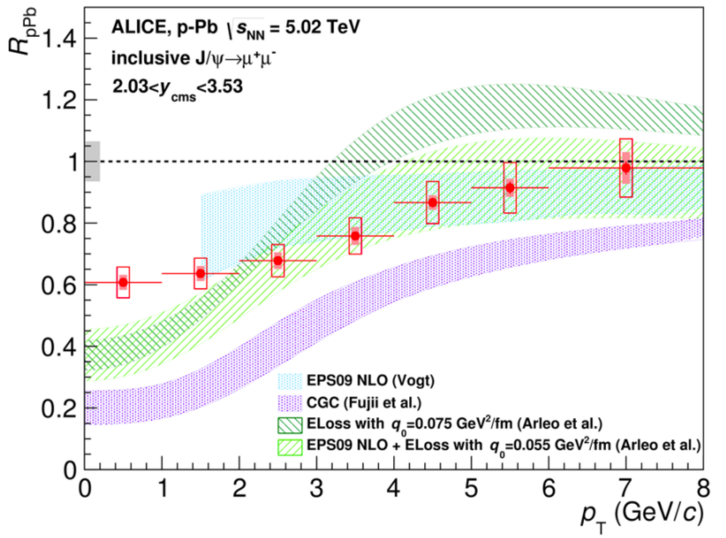
pp collisions

The recent 5.02 TeV analysis compared with theoritical calculations ►
→ J.Crovska PhD thesis [Eur. Phys. J. C77 no. 6, (2017) 392]



p-Pb collisions

Low p_T suppression w.r.t pp is due to cold nuclear matter effects (without involving QGP formation) ►
→ I. Lakomov PhD Published in [JHEP 06 (2015) 55], [JHEP 1402 (2014) 073], [JHEP 1511 (2015) 127]



Physics highlights: charm production multiplicity dependence at ALICE

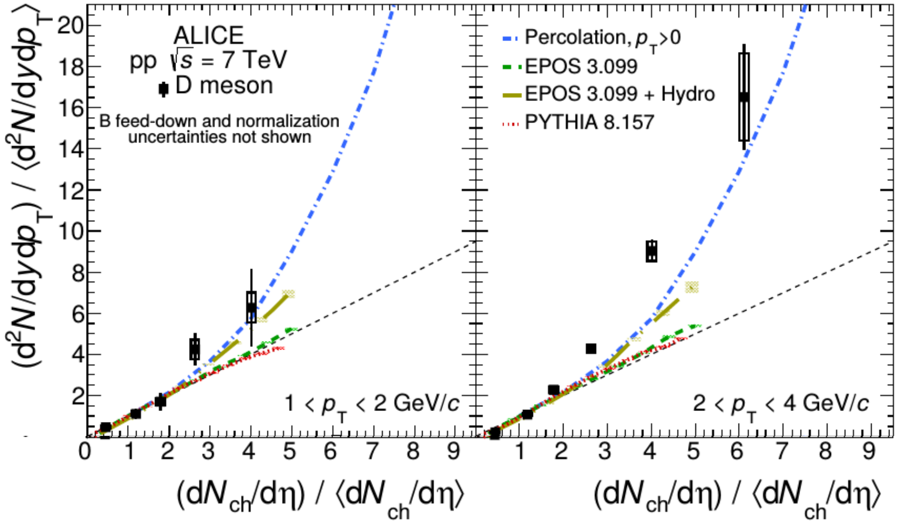
At high charged particle multiplicity, large energy density are reached. Particle production models need to implement Multiple Parton Interactions and some collective effects to cope with new recent measurements.

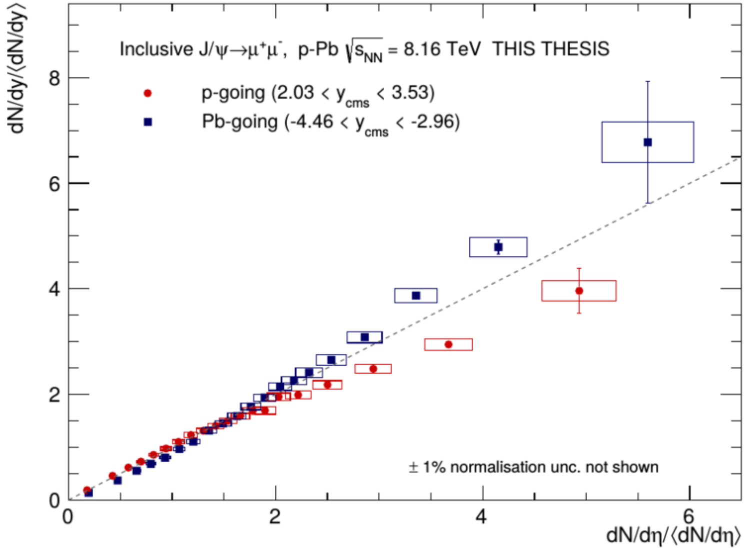
pp collisions

D meson production increases rapidly ▶ with multiplicity (faster than Pythia refence)
→ Published in [JHEP09 (2015) 148]

p-Pb Collisions

J/Ψ (2.5<y<4) relative multiplicity as a function of the charged particle relative multiplicity (measured in |η|<0.8). Two behaviors to be compared to models ▶
→ PhD thesis J.Crkovska (30/10/2018). ALICE Preliminary.





Physics highlights: J/Ψ photoproduction in UPC at ALICE

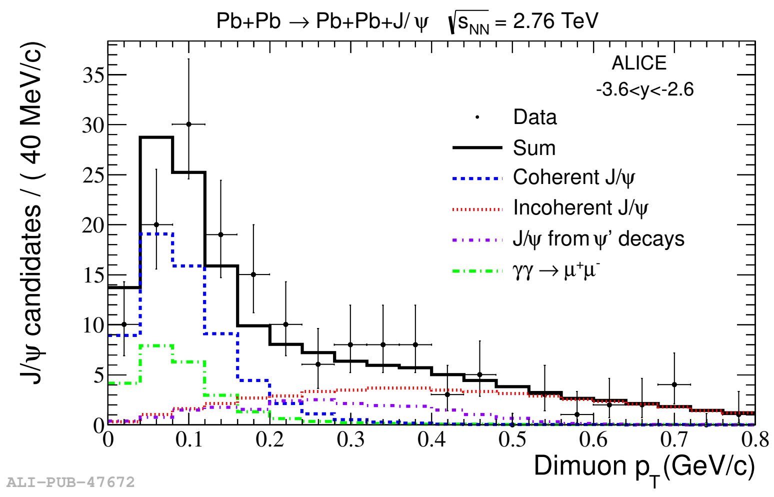
Exlusive vector meson production in Pb-Pb collisions is probing the nuclear gluon distribution at low Bjorken-x, for which there is considerable uncertainties

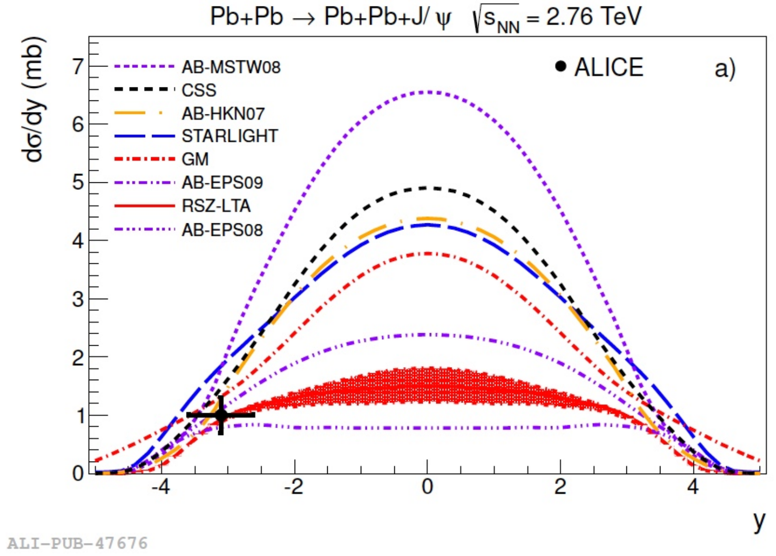
PbPb collisions

Results from 2.76 TeV analysis, clear peak at low p_T due to coherent interaction while tails extending to 0.8 GeV/c are from incoherent interaction ▶

Comparisons with models favours the presence of nuclear gluon shadowing▶

→ D. Tapia Takaki, postdoc, published in:
Phys. Lett. B 718 (2013) 1273-1283





MDM of Λ_c

In a weak decay of Λ_c there is a correlation between its polarisation vector $\vec{\mathbb{P}}$ and the direction of final baryon $\vec{n}_f$

$$\frac{dN}{d\cos\theta} = \frac{1}{2}(1 + \alpha\,\mathbb{P}\cos\theta), \qquad \cos\theta = \vec{n}_f\,\vec{\mathbb{P}}/\mathbb{P}. \tag{1}$$

The Λ_c produced in a fixed target in pp collision should be transversally polarised, perpendicular to the production plane.

If we place a crystal next to the target and orient the crystallographic planes along the direction of initial proton beam, a fraction of Λ_c baryons would be deflected by the planar channeling mechanism. In this case, the initial polarisation of deflected baryons would be perpendicular to the crystal plane.

When Λ_c baryons are deflected by a bent crystal, the polarisation vector rotates by the following angle:

$$\Theta_\mu = (1 + \gamma a)\,\Theta, \qquad a = \frac{g-2}{2}. \tag{2}$$

where γ, a and g are the Lorentz factor, the anomalous magnetic dipole moment (MDM) and the g-factor of Λ_c baryon, Θ is the deflection angle.

If we choose Oz axis in the direction of initial proton beam and Ox axis transverse to the crystal planes, the Eq. (1) would have the following expression:

$$\frac{dN}{d\cos\theta_x} = \frac{1}{2}(1 + \alpha\,\mathbb{P}\sin\Theta_\mu\cos\theta_x), \tag{3}$$

$$\frac{dN}{d\cos\theta_z} = \frac{1}{2}(1 + \alpha\,\mathbb{P}\cos\Theta_\mu\cos\theta_z). \tag{4}$$

where θ_x and θ_z are the angles between the direction of final baryon (analyzer) and Ox and Oz axes, respectively.

From this angular analysis we can reconstruct the parameter b with statistical error Δb

$$b = \alpha\,\mathbb{P}\,\Theta_\mu, \qquad \Delta\overline{b} = \sqrt{\frac{3}{N}}. \tag{5}$$

From Eq. (5) one can derive the error on g-factor in the following way:

$$b = \alpha\,\mathbb{P}\,\Theta(1 + \gamma a), \tag{6}$$

$$\gamma a = \frac{b}{\alpha\,\mathbb{P}\,\Theta} - 1, \tag{7}$$

assuming that the main uncertainty of MDM is coming from our poor knowledge of week decay parameter α, initial polarisation $\mathbb{P}$ and the current measurement itself $\Delta\overline{b}$, we can write the following

$$\gamma(\overline{a} + \Delta a) = \frac{\overline{b} + \Delta b}{(\overline{\alpha} + \Delta\alpha)(\overline{\mathbb{P}} + \Delta\mathbb{P})\Theta} - 1 \tag{8}$$

$$\frac{\overline{b}}{\overline{\alpha}\,\overline{\mathbb{P}}\,\Theta} - 1 + \gamma\Delta a = \frac{\overline{b} + \Delta b}{\overline{\alpha}\,\overline{\mathbb{P}}\,\Theta(1+X)} - 1, \quad X \equiv \frac{\Delta\alpha}{\overline{\alpha}} + \frac{\Delta\mathbb{P}}{\overline{\mathbb{P}}} + \frac{\Delta\alpha\,\Delta\mathbb{P}}{\overline{\alpha}\,\overline{\mathbb{P}}} \tag{9}$$

$$\gamma\Delta a = \frac{\Delta b}{\overline{\alpha}\,\overline{\mathbb{P}}\,\Theta(1+X)} + \frac{\overline{b}}{\overline{\alpha}\,\overline{\mathbb{P}}\,\Theta}\left(\frac{1}{1+X} - 1\right) \tag{10}$$

$$\frac{\Delta g}{2} = \Delta a = \frac{\Delta b - \overline{b}X}{\overline{\alpha}\,\overline{\mathbb{P}}\,\gamma\,\Theta(1+X)}, \qquad \overline{b} = \overline{\alpha}\,\overline{\mathbb{P}}\,\Theta(1 + \gamma\overline{a}) \tag{11}$$

One can see that error of g-factor depends on the expected value of $\overline{b}$ and hence on the anomalous MDM $\overline{a}$. Thus we preform the calculation for a few possible values of $\overline{a}$.

We use the normal distribution for week decay parameter α, for polarisation $\mathbb{P}$ and for measured value b.

$$\frac{dN}{dg} = \int db \int d\mathbb{P} \int d\alpha\, \frac{dN}{db}\frac{dN}{d\mathbb{P}}\frac{dN}{d\alpha}\,\Gamma\left(g(\alpha, \mathbb{P}, b) - \overline{g}\right) \tag{12}$$

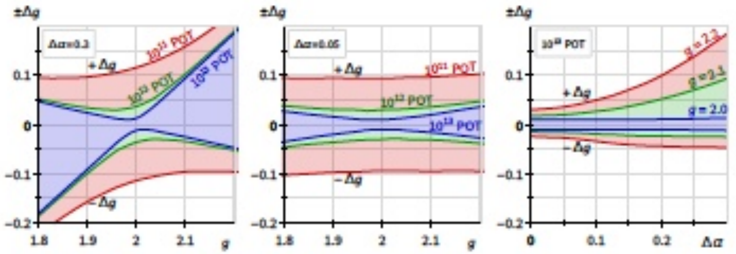


FIG. 1. Absolute statistical error of g-factor as a function of its value (left, center) and as a function of error on alpha parameter (right) for $\Lambda_c^+ \to \Delta^{++}K^-$ decay channel. For different numbers of protons on target (POT) and errors on alpha parameter $\Delta\alpha$ (left, center), and for various values of g-factor (right) stated in the plot. For this calculation the following values of other parameters were chosen: $\omega = 4$ mrad, $\gamma = 1100$, $\Delta\xi = 0.05$.

Measuring the product of $\alpha\mathbb{P}$ and g-factor simultaneously.

Analysing angular distribution of final baryon of Λ_c decay with respect to two axes Oz and Ox Eqs. (3) and (4) we can reconstruct two parameters with statistical error $\Delta b = \sqrt{3/N}$,

$$b_1 = \alpha\,\mathbb{P}\,\sin\Theta_\mu, \tag{13}$$

$$b_2 = \alpha\,\mathbb{P}\,\cos\Theta_\mu, \tag{14}$$

from which we can retrieve product of $\alpha\mathbb{P}$ and g-factor.

Derivation:

$$\beta \equiv \alpha \mathbb{P} \quad (15)$$

$$b_1 = \beta \sin\Theta_\mu \quad (16)$$

$$b_2 = \beta \cos\Theta_\mu \quad (17)$$

$$b_1^2 + b_2^2 = \beta^2 \quad (18)$$

$$\bar{b}_1^2 + \bar{b}_2^2 + 2(\bar{b}_1 + \bar{b}_2)\Delta b + 2\Delta b^2 = \bar{\beta}^2 + 2\bar{\beta}\Delta\beta + \Delta\beta^2 \quad (19)$$

assuming $\Delta b < b_i$

$$(\bar{b}_1 + \bar{b}_2)\Delta b = \bar{\beta}\Delta\beta \quad (20)$$

$$\Delta\beta = \frac{(\bar{b}_1 + \bar{b}_2)\Delta b}{\bar{\beta}} \quad (21)$$

$$\Delta\beta = (\sin\Theta_\mu + \cos\Theta_\mu)\sqrt{\frac{3}{N}} = \sin(\Theta_\mu + \frac{\pi}{4})\sqrt{\frac{6}{N}} \lesssim \sqrt{\frac{6}{N}} \quad (22)$$

assuming $\sin\Theta_\mu \approx \Theta_\mu$

$$b_1 = \beta\,\Theta_\mu \quad (23)$$

assuming $\Delta\Theta_\mu \ll \Theta_\mu$ and $\Delta\beta \ll \beta$

$$\Delta b = \Delta\beta\,\bar{\Theta}_\mu + \bar{\beta}\,\Delta\Theta_\mu \quad (24)$$

$$\Delta\Theta_\mu = \frac{\Delta b + \Delta\beta\,\bar{\Theta}_\mu}{\bar{\beta}} \quad (25)$$

on the other side

$$\Delta\Theta_\mu = \bar{\Theta}\bar{\gamma}\Delta a = \frac{\bar{\Theta}\bar{\gamma}\Delta g}{2} \quad (26)$$

$$\Delta g \lesssim \frac{\sqrt{12}}{\bar{\alpha}\bar{\mathbb{P}}\bar{\Theta}\bar{\gamma}\sqrt{N}}\left(1 + \sqrt{2}\,\frac{\bar{g}-2}{2}\bar{\Theta}\bar{\gamma}\right) \approx 1.77\,\frac{\sqrt{12}}{\bar{\alpha}\bar{\mathbb{P}}\bar{\Theta}\bar{\gamma}\sqrt{N}} \quad (27)$$

So if we measure the product of $\alpha\mathbb{P}$ together with g-factor, the error of latter would be factorised by ~ 1.77 comparing to the case if we know $\alpha\mathbb{P}$ precisely.

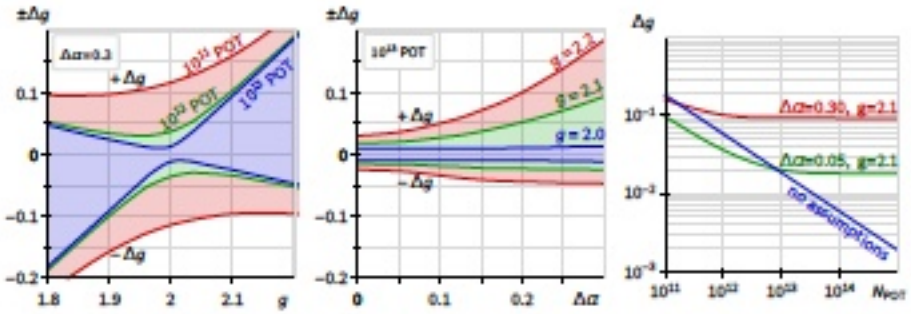


FIG. 2. Absolute statistical error of g-factor as a function of its value (left), as a function of error on alpha parameter (center) and as a function of number of protons on target (right) for $\Lambda_c^+ \to \Delta^{++}K^-$ decay channel. For different numbers of protons on target (left), and for various values of g-factor (center) stated in the plot. On the right plot red and green lines are the estimations, assuming $g = 2.1$ and using the values of α parameter and polarisation ξ from other experiment, and blue line corresponds to the case when we measure $\alpha\xi$ and g-factor simultaneously at current experiment. For this calculation the following values of other parameters were chosen: $\omega = 4$ mrad, $\gamma = 1100$, $\Delta\xi = 0.05$.