# Highlights and perspectives from the ALICE experiment

Mateusz Ploskon (Berkeley Lab)
on behalf of the ALICE Collaboration

LHCP2021 Online
The Ninth Annual Conference on Large Hadron Collider Physics
7-12 June 2021 ~~Paris (France),~~ Sorbonne Université ~~(IN2P3/CNRS,IRFU/CEA)~~

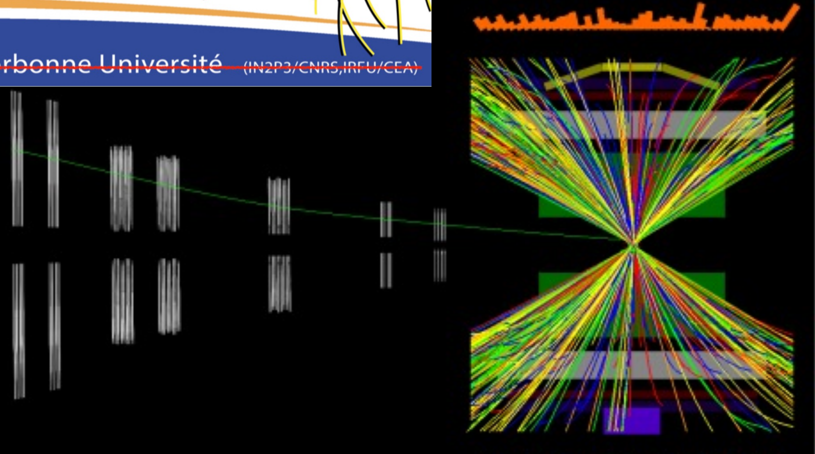
## *Outline*

① *ALICE 2.0 readiness*

② *Physics highlights – focus on new results*

③ *Perspectives*

https://alice-collaboration.web.cern.ch



Run:295585
Timestamp:2018-11-08 20:59:35(UTC)
Colliding system:Pb-Pb
Energy:5.02 TeV

ALICE

# ALICE preparing for Run 3

## Progress on installation and commissioning of LS2 upgrades

Retain unique PID capabilities & improve tracking while operating at high rates

Maximize LHC's potential with precision measurements in nuclear collisions

- **Charm and beauty baryons** – in-medium thermalization, coalescence, flow and energy loss
- **Precision in charmonium states** – forward and midrapidity – suppression, flow, polarization, nuclei structure via UPCs
- **Low-mass dileptons** – chiral symmetry restoration, early temperature, space-time evolution and EOS (flow)
- ***NEW: comprehensive pp programme at top LHC energy*** *ALICE-PUBLIC-2020-005 ; CERN-LHCC-2020-018 ; LHCC-G-179*

Talk on LHC & diversity
by Adriana Telesca

# Introduction to ALICE in one minute or less

#CERN #heavy-ions #QGP #~2000people #>340papers #>10 years running

## ALICE version 2.0 – coming up online this summer…

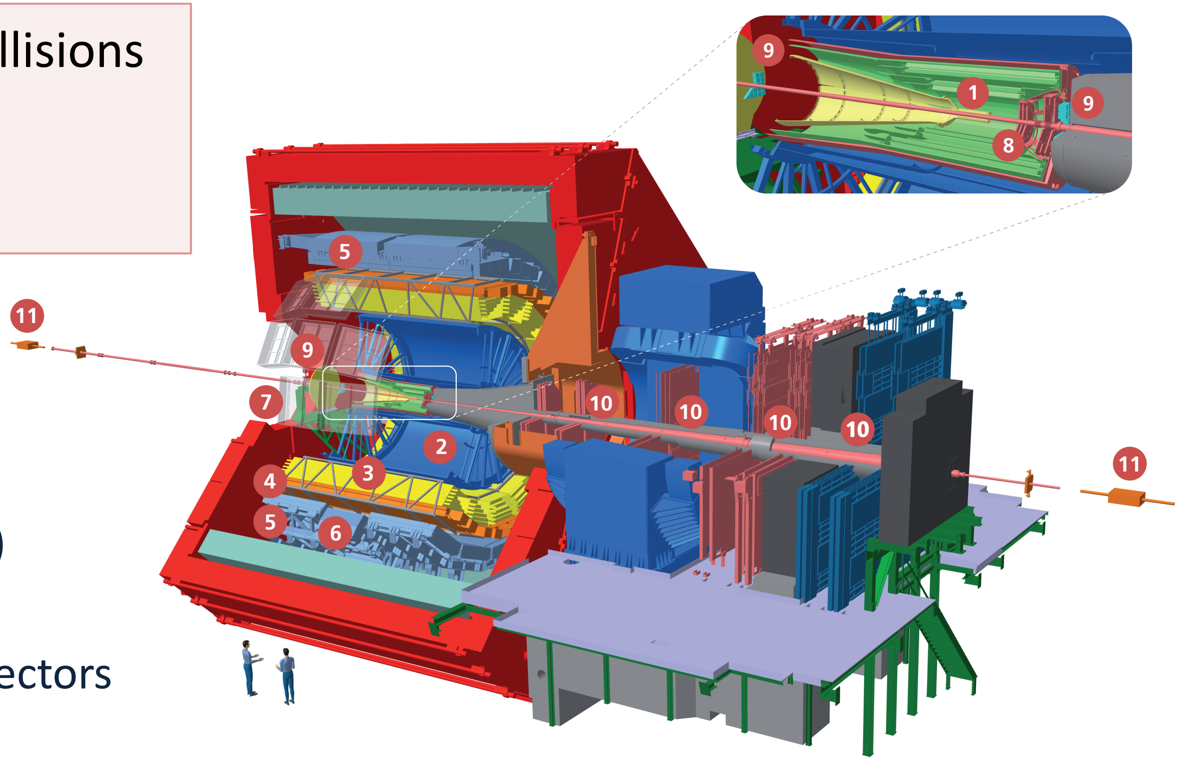
Runs 1 and 2: 1 $nb^{-1}$ of Pb-Pb collisions

**Interaction rate ~8 kHz**

**readout rate ≈ 1 kHz**

**LS2 upgrade**

- New TPC R/O planes
- New silicon tracker (ITS & MFT)
- New Fast Interaction Trigger (FIT)
- New Online/Offline system (O2)
- Upgrade readout of all other detectors




1 **ITS** | Inner Tracking System
2 **TPC** | Time Projection Chamber
3 **TRD** | Transition Radiation Detector
4 **TOF** | Time Of Flight
5 **EMCal** | Electromagnetic Calorimeter
6 **PHOS / CPV** | Photon Spectrometer
7 **HMPID** | High Momentum Particle Identification Detector
8 **MFT** | Muon Forward Tracker
9 **FIT** | Fast Interaction Trigger
10 **Muon Spectrometer**
11 **ZDC** | Zero Degree Calorimeter

**> Improve tracking resolution at low $p_T$**

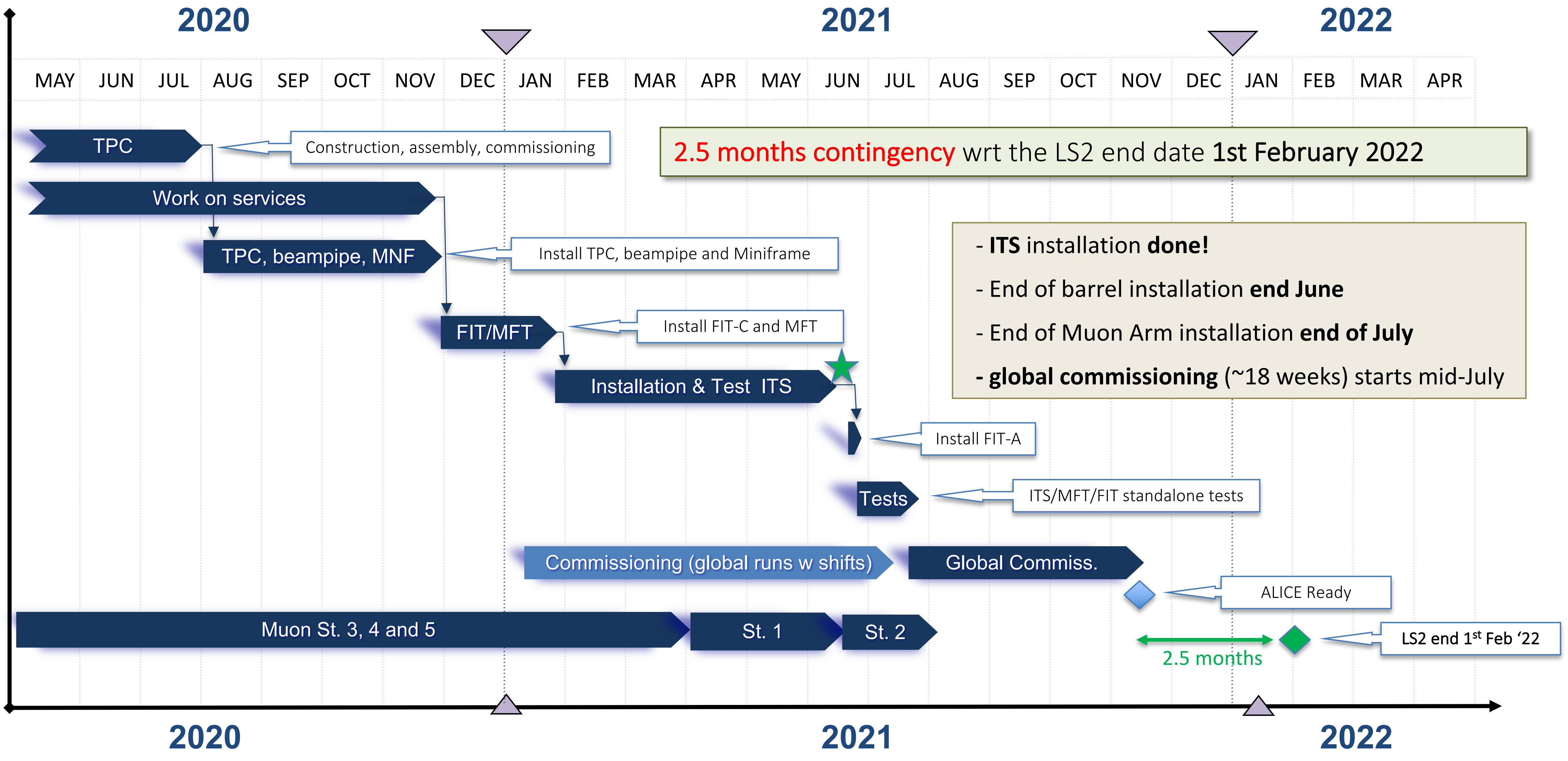
**x50 statistics increase for most observables**

Run 3 and Run 4: **13 $nb^{-1}$ of Pb-Pb collisions**

**readout rate ≈ 50 kHz (Pb-Pb), ≈ 1 MHz (pp)**

**online reconstruction** : all events to storage!

# ALICE LS2 Schedule – good progress - ALICE is on pace for Run 3

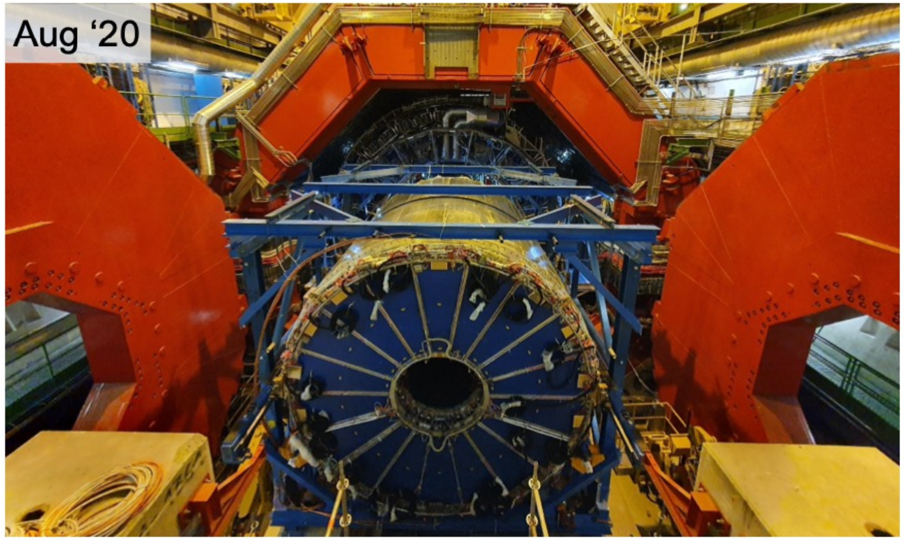


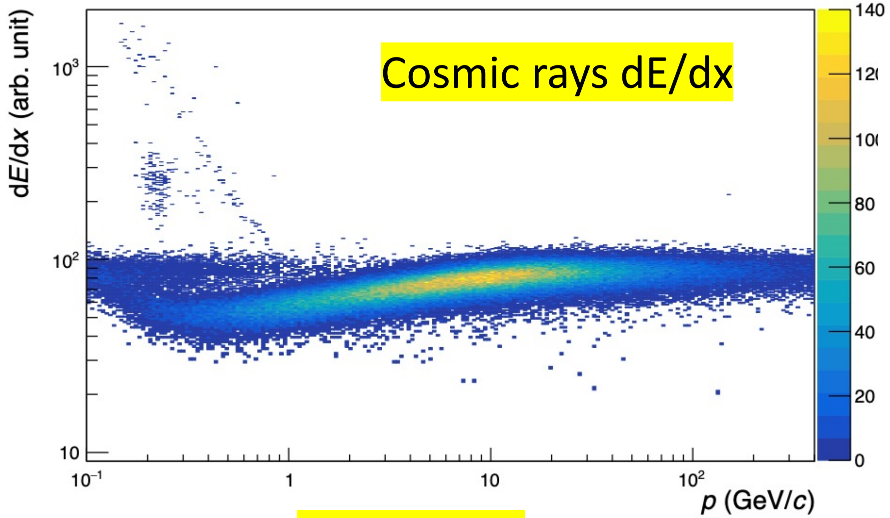
Talks by Christian Lippmann, Ernst Hellbar

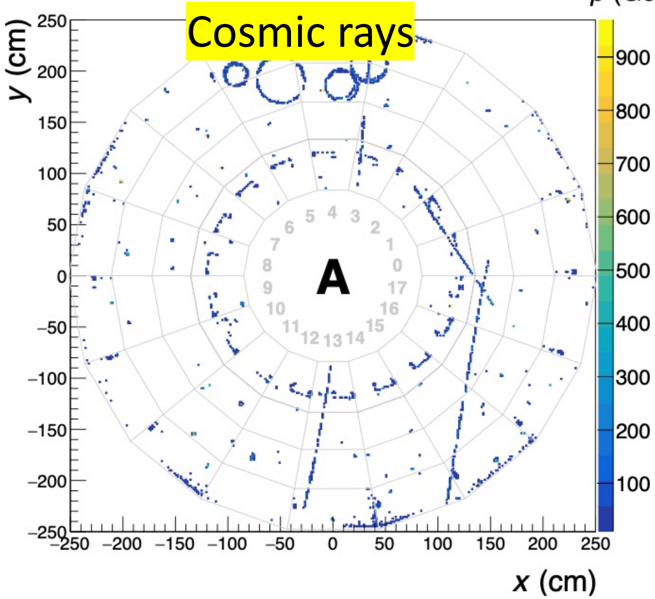
# TPC with GEM chambers and new readout electronics

## Detector at P2 since August 2020 – after re-connection commissioning ongoing since December 2020

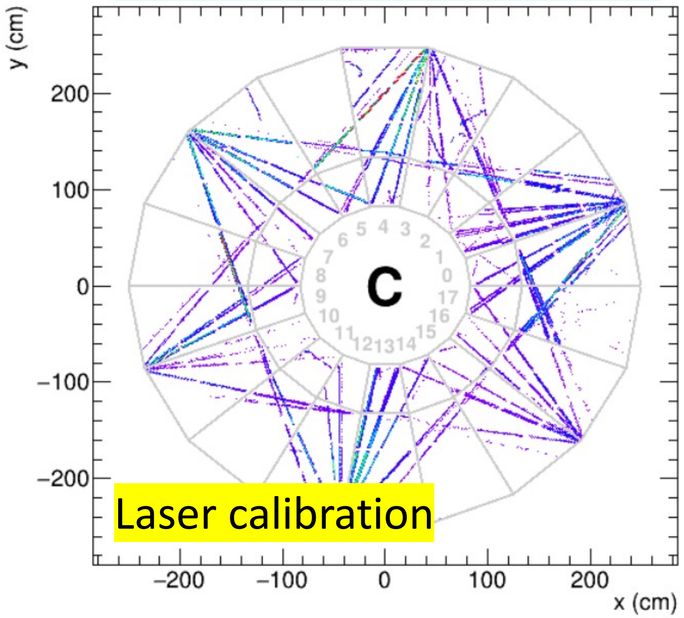

Start GEM ROC installation




ALICE TPC collaboration,2021 JINST 16 P03022

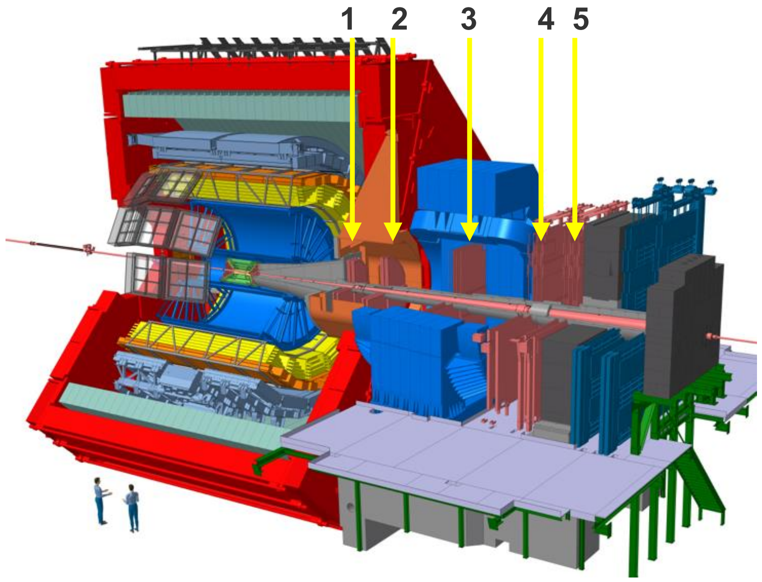


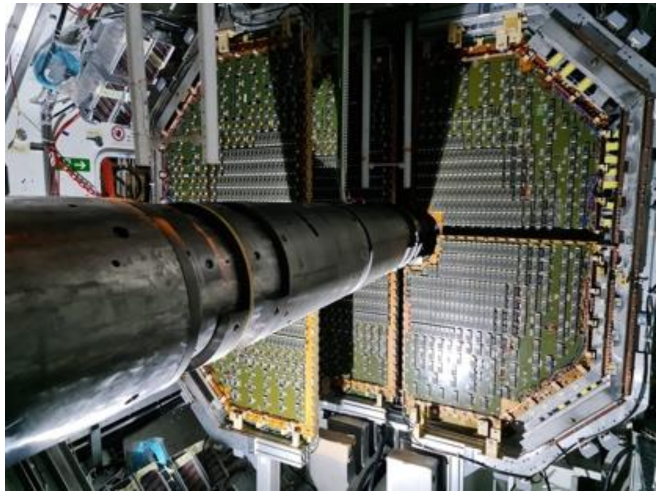

**Software development completed**
**- data reconstruction on GPU**

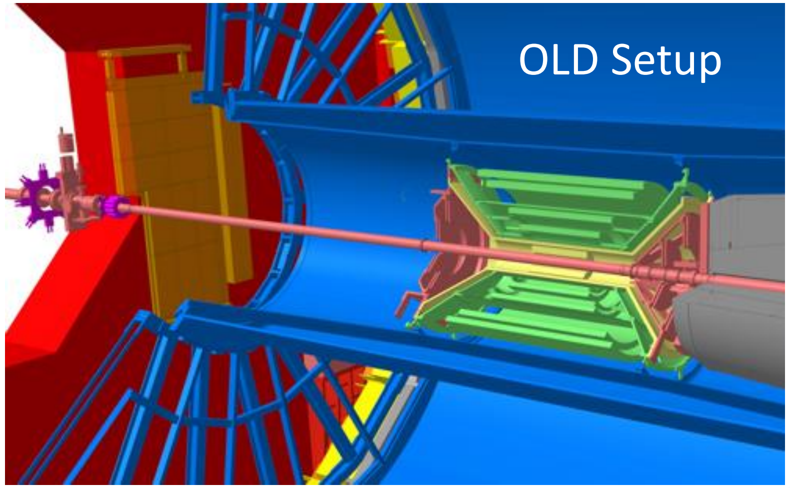
Talk by Christian Lippmann

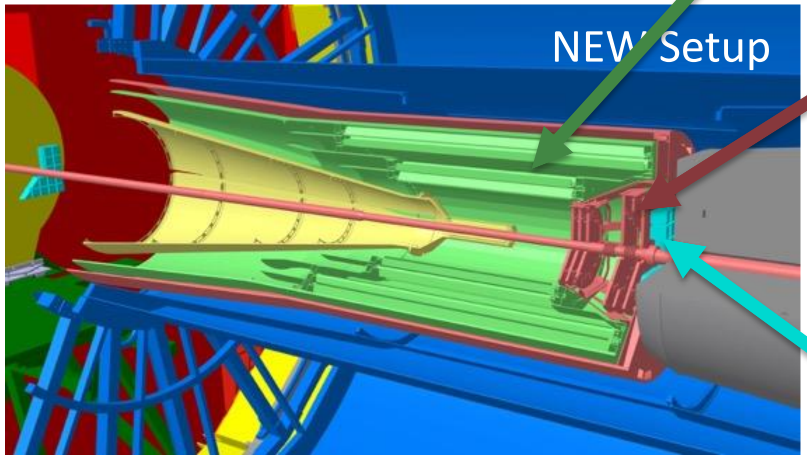
# ALICE 2.0 – selected subsystems

**Re-installation of muon chambers ongoing**






**Reconfiguration of the inner tracker region**

New Inner Tracking System (ITS 2)
- Improved pointing precision
- Monolithic CMOS sensors (ALPIDE)
- Smaller beampipe, 1st layer closer

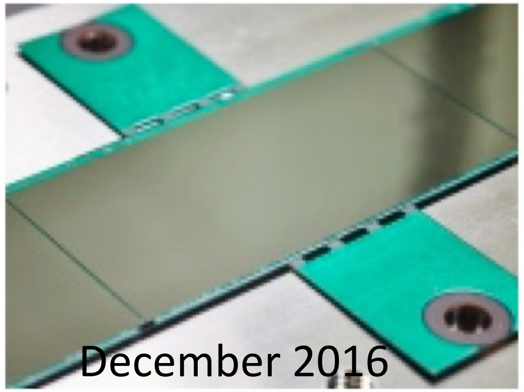
Muon Forward Tracker (MFT)
- New tracker based on ALPIDE
- Improved MUON pointing
- precision, promt vs. decay muons

New Trigger Detectors (FIT)

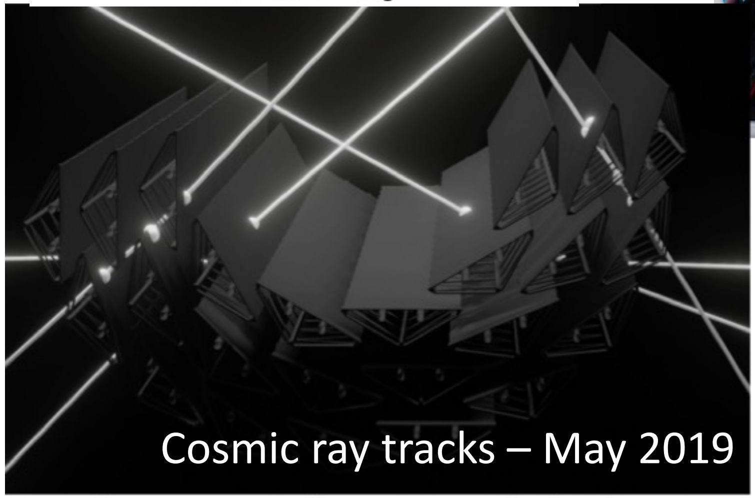
Talks by Christian Lippmann, Ivan Ravasenga
Read more in the CERN Courier

# New Inner Tracker System installed

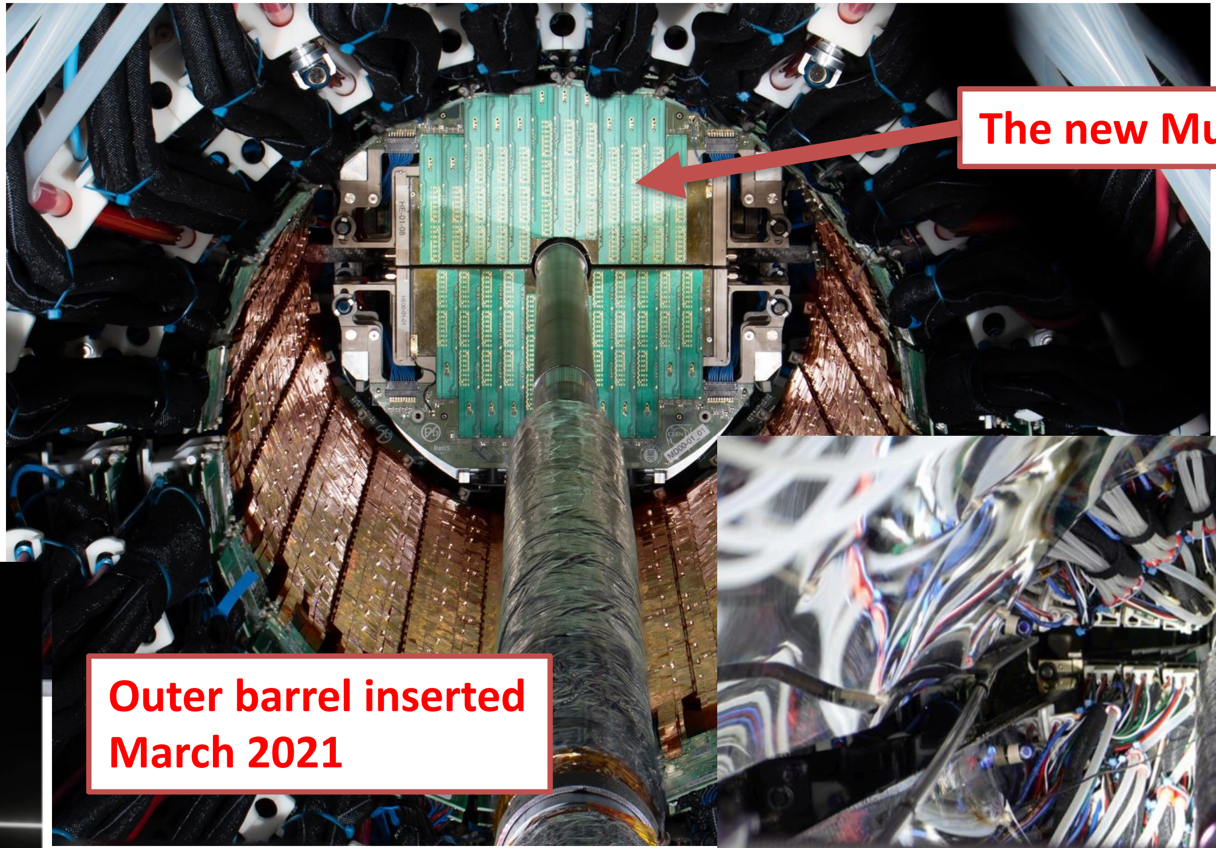
**~72000 chips ~280 staves**
**>10 production sites worldwide**
**~ 30 institutes involved**

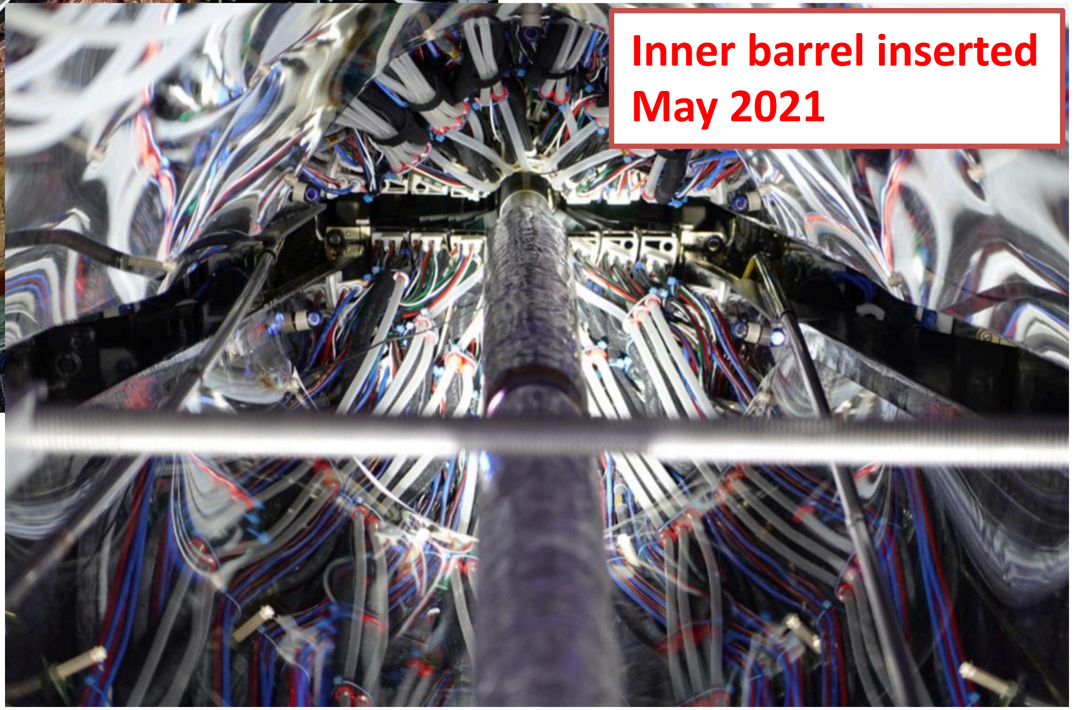



**Start detector construction and assembly**




**Start on-surface commissioning with final services**



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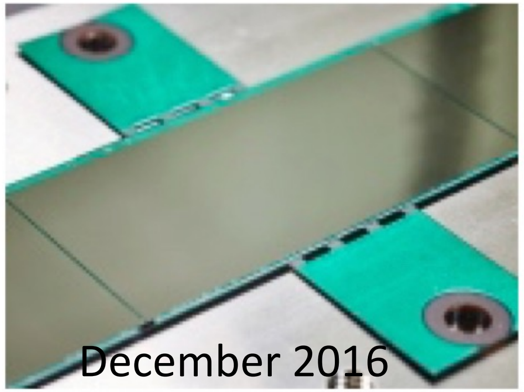


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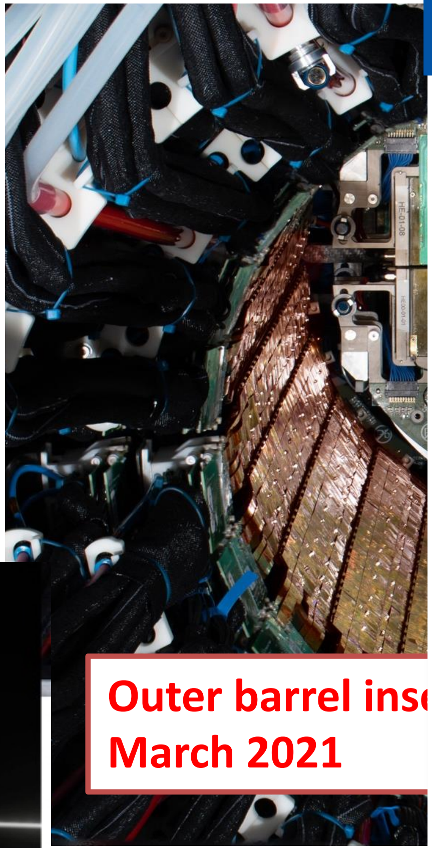


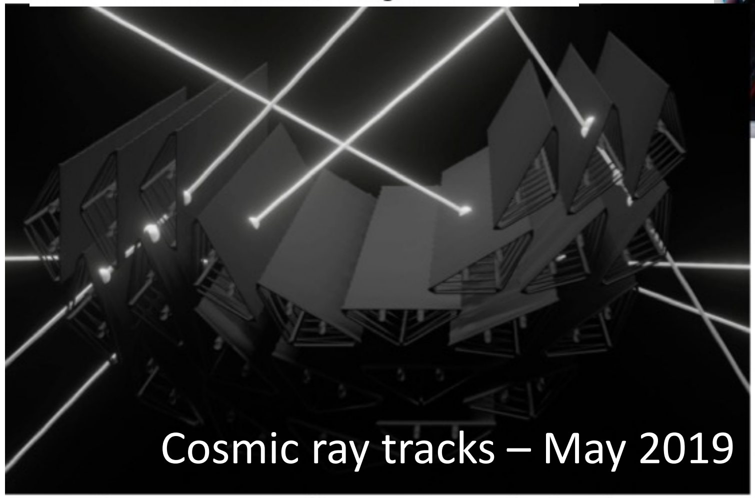


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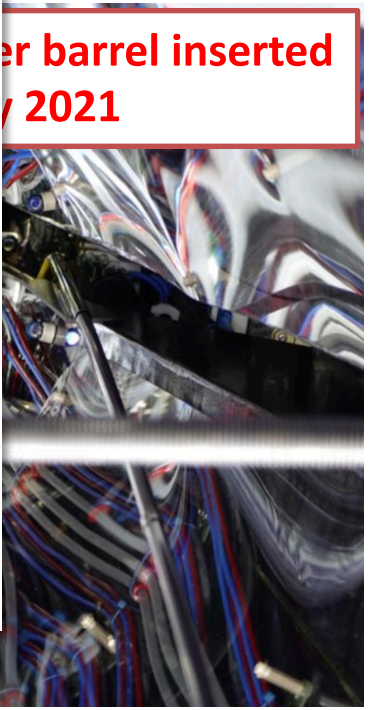
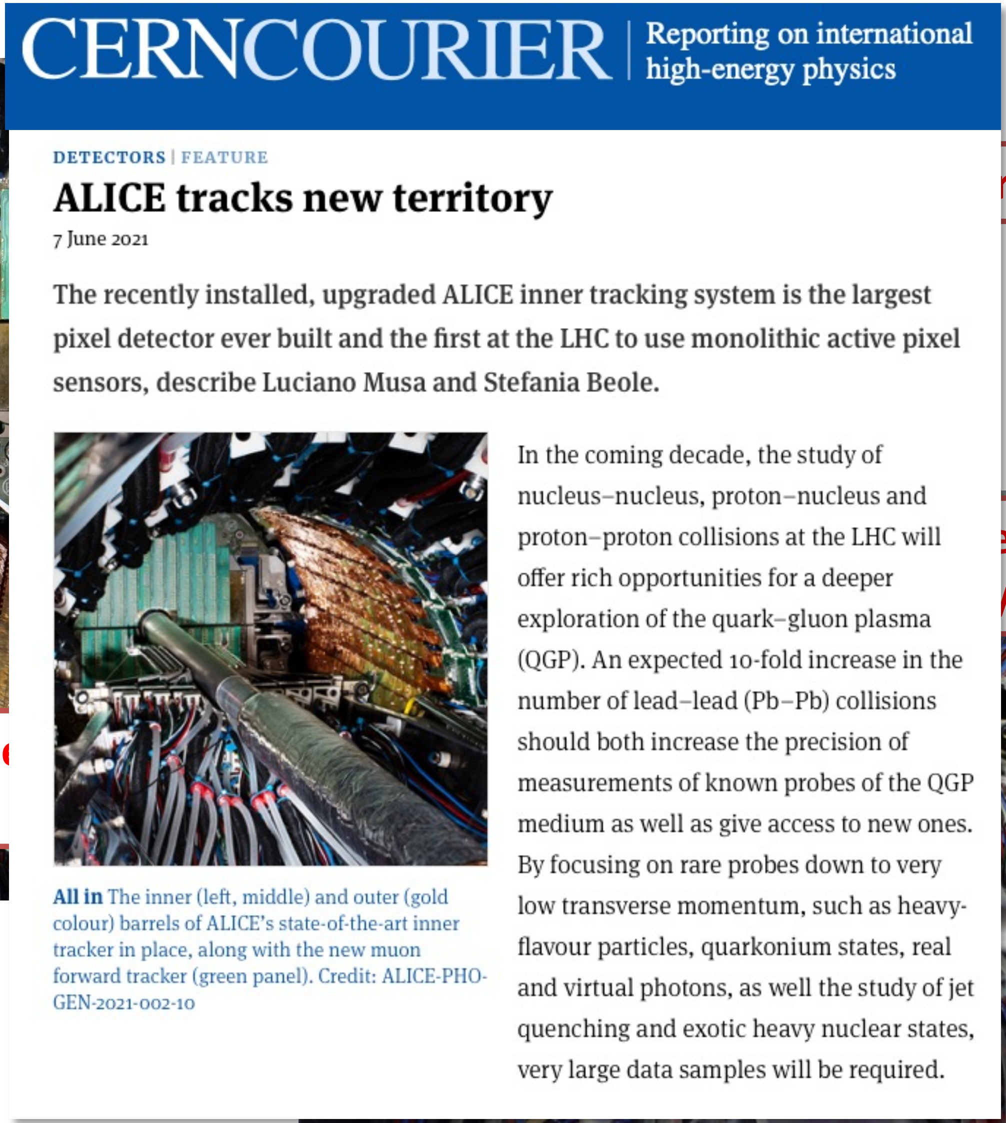
rd Tracker



CERNCOURIER Reporting on international high-energy physics

DETECTORS | FEATURE

## ALICE tracks new territory

7 June 2021

The recently installed, upgraded ALICE inner tracking system is the largest pixel detector ever built and the first at the LHC to use monolithic active pixel sensors, describe Luciano Musa and Stefania Beole.

**All in** The inner (left, middle) and outer (gold colour) barrels of ALICE's state-of-the-art inner tracker in place, along with the new muon forward tracker (green panel). Credit: ALICE-PHO-GEN-2021-002-10

In the coming decade, the study of nucleus–nucleus, proton–nucleus and proton–proton collisions at the LHC will offer rich opportunities for a deeper exploration of the quark–gluon plasma (QGP). An expected 10-fold increase in the number of lead–lead (Pb–Pb) collisions should both increase the precision of measurements of known probes of the QGP medium as well as give access to new ones. By focusing on rare probes down to very low transverse momentum, such as heavy-flavour particles, quarkonium states, real and virtual photons, as well the study of jet quenching and exotic heavy nuclear states, very large data samples will be required.

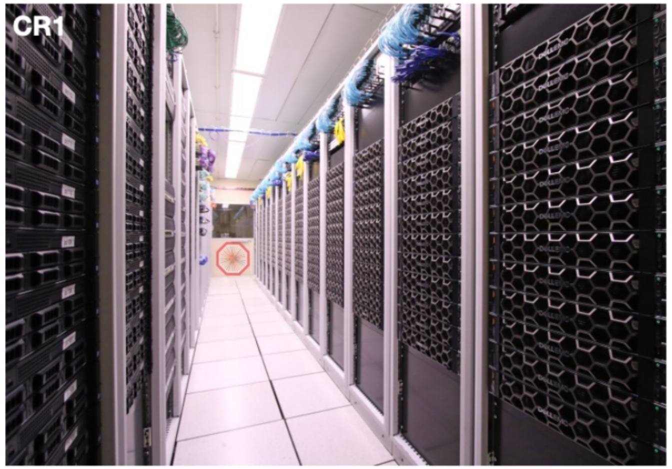
Talks by Christian Lippmann, Jan Fiete Grosse-Oetringhaus, Marten Ole Schmidt

# ALICE 2.0 – a new computing challenge

## Online-offline processing software
## + new offline analysis framework

**20 out of 100 PB deployed**
**joint effort with the ALICE IT team**

**200 First Level Processors (FLP) in CR1**




**1) Readout of detectors and raw data processing**
(e.g. TPC baseline corrections, ZS)
Data compression
**3.5 TB/s → 600 GB/s**

**250 Event Processing Nodes (EPN) with 2000 GPUs**


⟺ **Disk Buffer**

**2) Synchronous processing**
⟹ Event/time frame building
⟹ **Online** reconstruction and calibration

**99% on GPUs**

**3) Asynchronous reprocessing**
⟹ **Final** calibration and full reconstruction

**80% on GPUs**

**4) Permanent storage**
Data compression
**600 GB/s → < 100 GB/s**

ALICE

# Physics highlights

## … focus on new results

# Physics of ALICE – in broad strokes

⇒ **Study emergent QCD phenomena via nuclear collisions**
- Properties of quark-gluon plasma
- Details of the parton-hadron transition in dense and dilute systems
- Explore the structure of nuclei

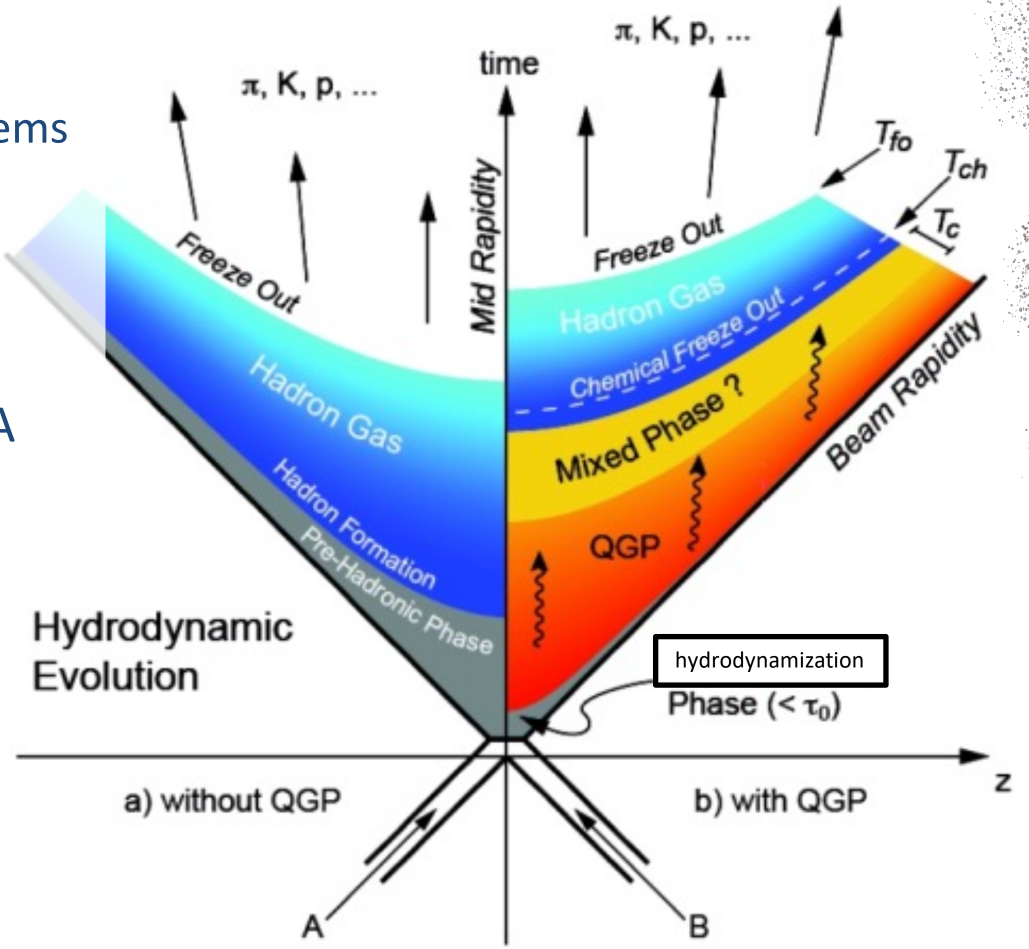
⇒ **Must measure the baseline for Pb-Pb in pp collisions**

⇒ **+ QCD studies in pp: pQCD and h-h interactions**

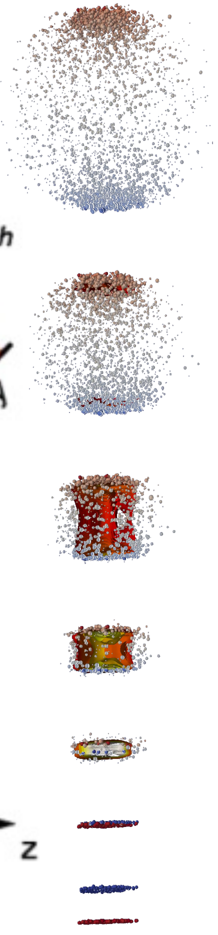
⇒ Understand the new effects in high-multiplicity pp and pA collisions that mimic AA

*In this talk: #femtoscopy #baryon/meson #strangeness #charm #dead-cone #jet-structure #jetty-$v_2$ #quarkonia #photoproduction*

**Other talks on physics by A. Ohlson, L. Havener, L. Cunqueiro, J. Mulligan, M. Kim,** L. Barioglio, V. Vislavicius, F. Grosa, Simone Ragoni, Sushanta Tripathy, Dimitar Mihaylov, Mattia Faggin




Jonah E. Bernhard arXiv:1804.06469 [nucl-th]



LHCP2020 ~~in Paris~~ online
A. Dainese for ALICE Collaboration

ALICE

# proton-proton collisions

L. Cunqueiro

NEW

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# Systematic study of jet substructure in pp collisions

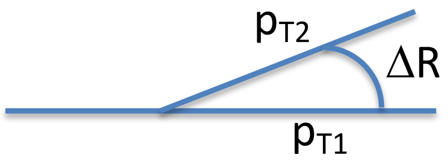
*New measurements for low-$p_T$ jets – unique feedback to theory – guidance for heavy-ion collisions*

## Lund jet plane – density map of splittings

– region-by-region sensitivity to perturbative and non-perturbative effects

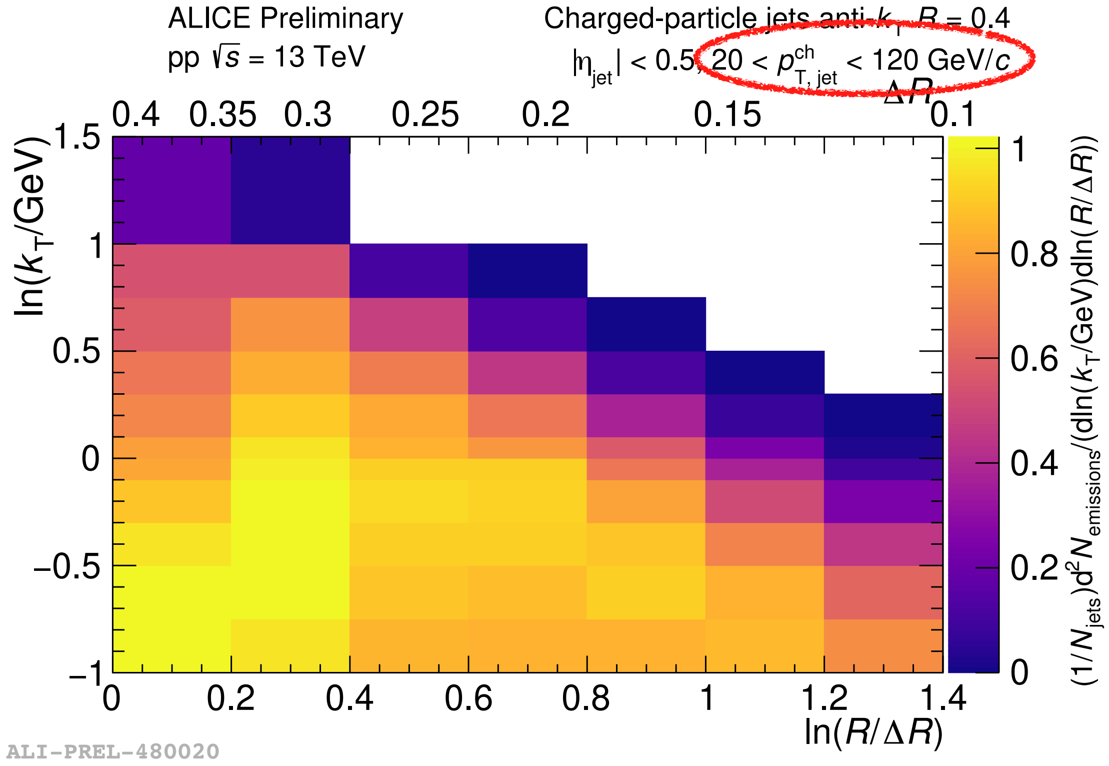
Dreyer et al JHEP12(2018)064, Lifson et al. JHEP10(2020)170

ALICE-PUBLIC-2021-002

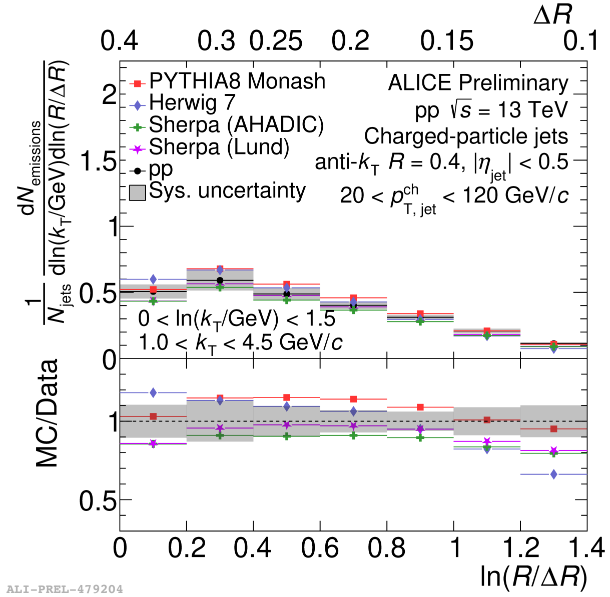



$p_{T1} > p_{T2}$

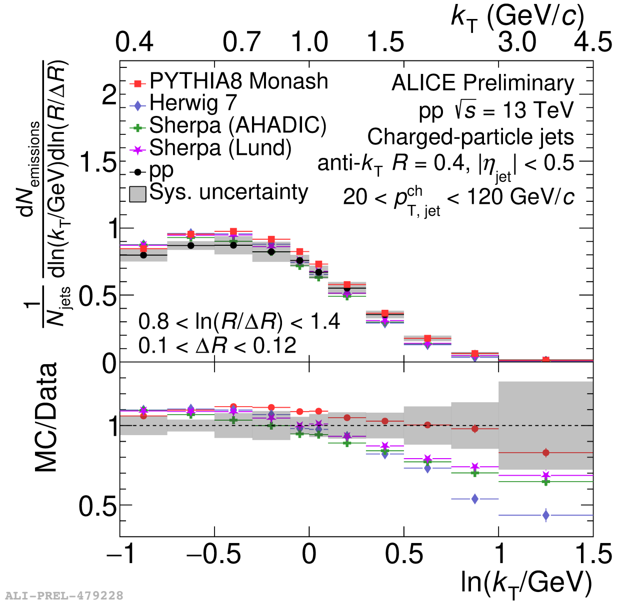
$k_T = \Delta R\, p_{T2}$




Harder




Small-angle




- **Lund plane: projections along angular (wide - narrow) or $k_T$ (hard vs. soft) axes**
- **Generalized angularities, jet axis, dynamical grooming talk by J. Mulligan**

L. Cunqueiro

NEW

# Systematic study of jet substructure in pp collisions

*New measurements for low-$p_T$ jets – unique feedback to theory – guidance for heavy-ion collisions*

## Lund jet plane – density map of splittings

– region-by-region sensitivity to perturbative and non-perturbative effects

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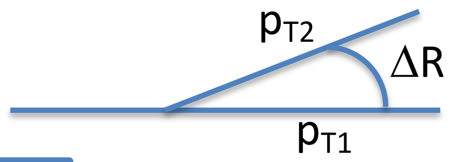


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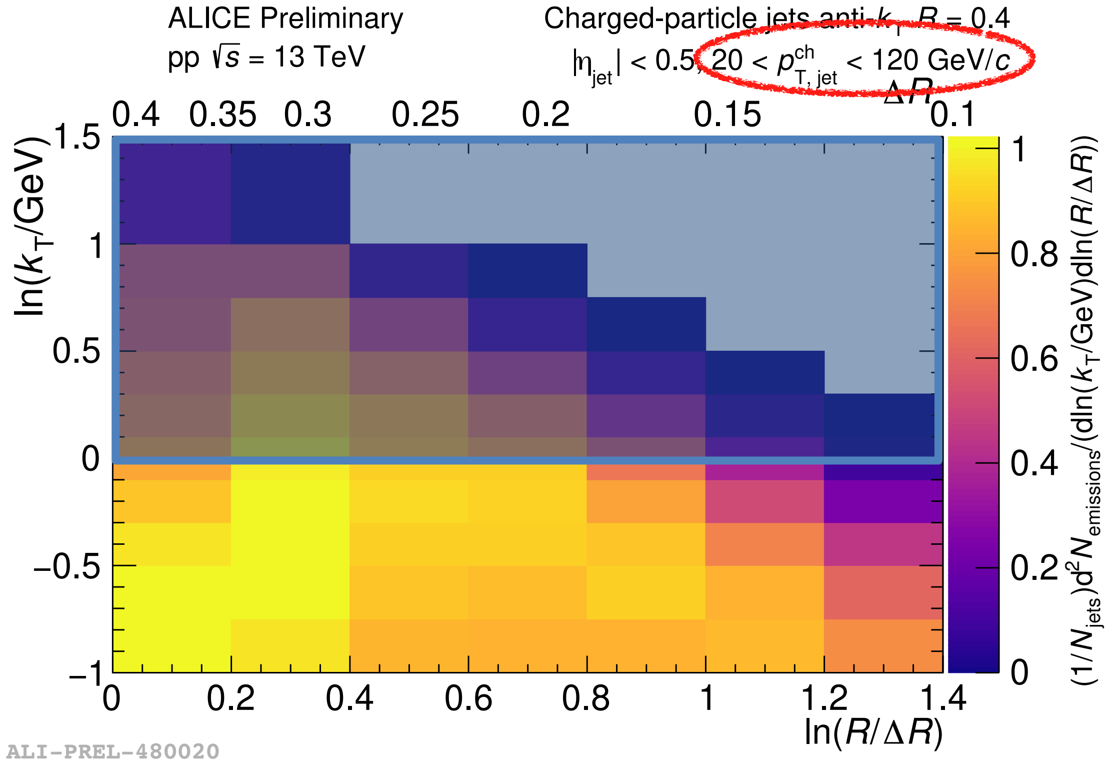


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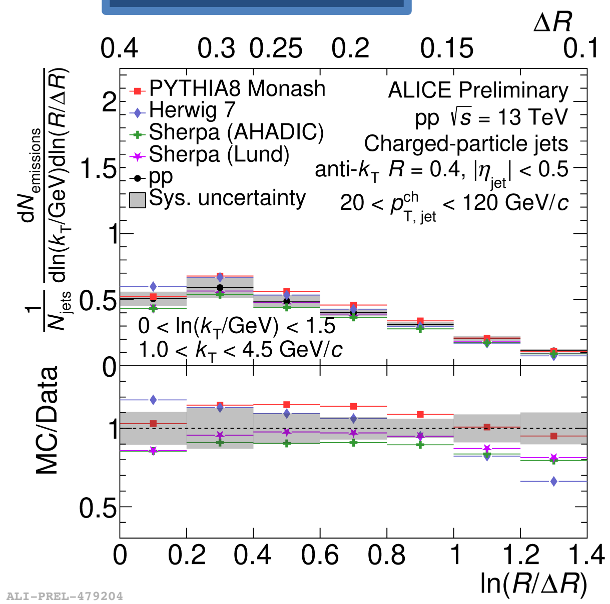


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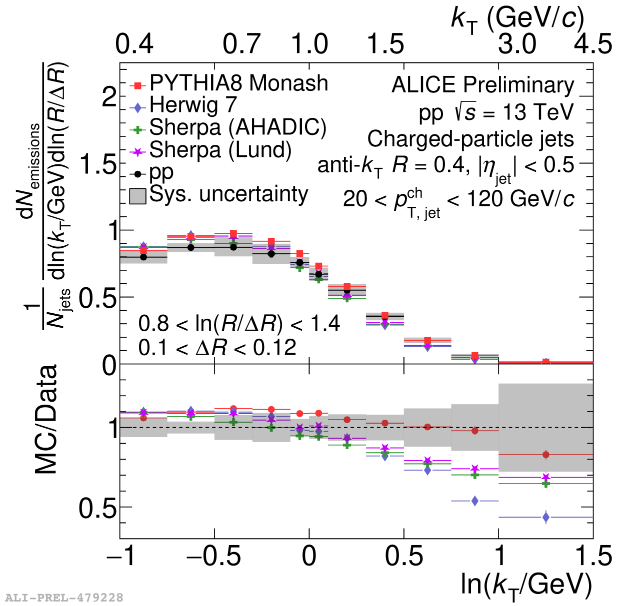


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ALICE-PUBLIC-2021-002

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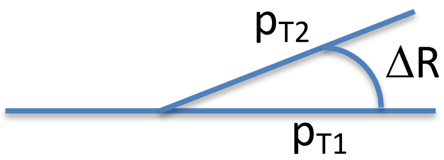


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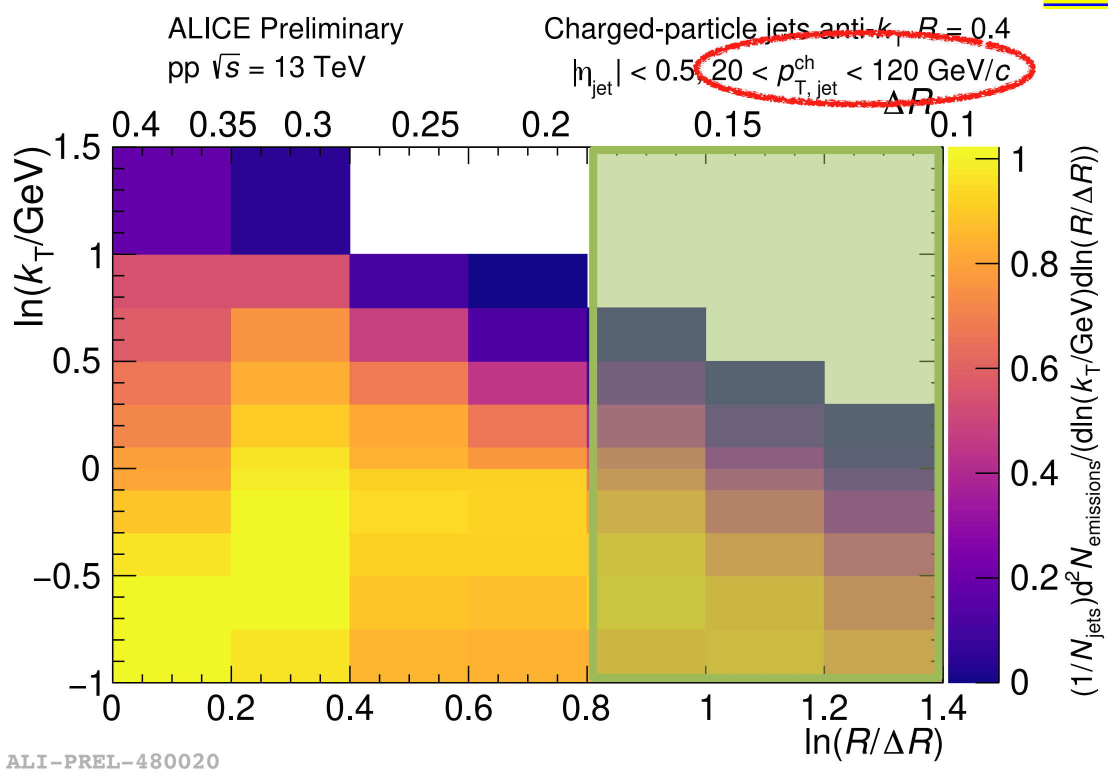


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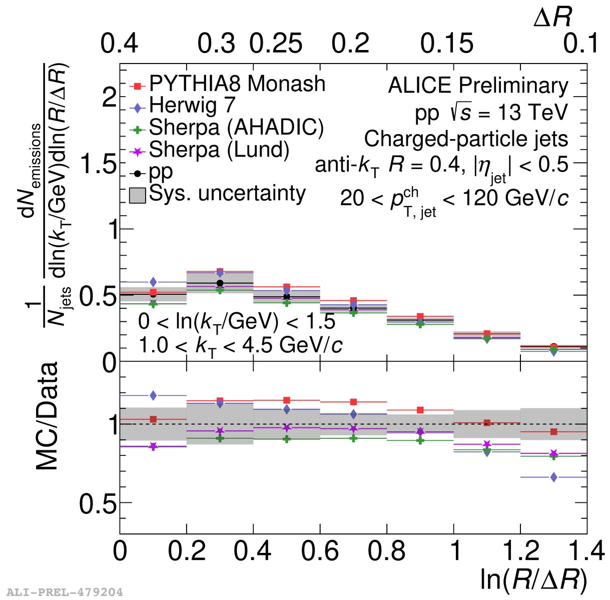


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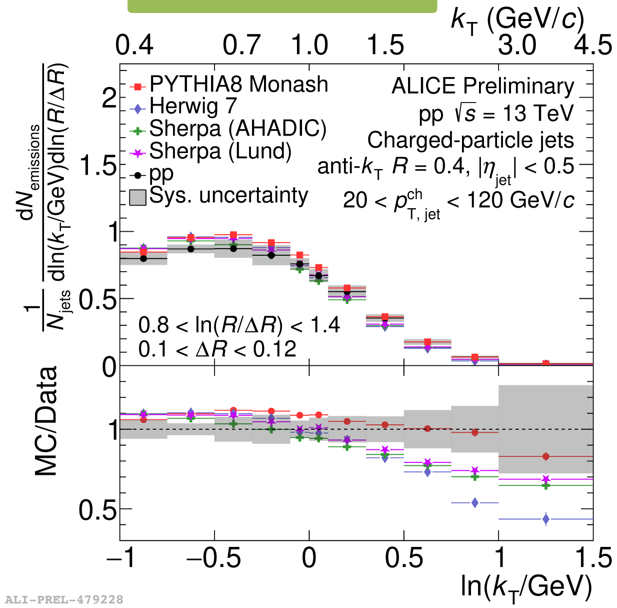


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# Measuring the dead-cone in radiation off a heavy quark

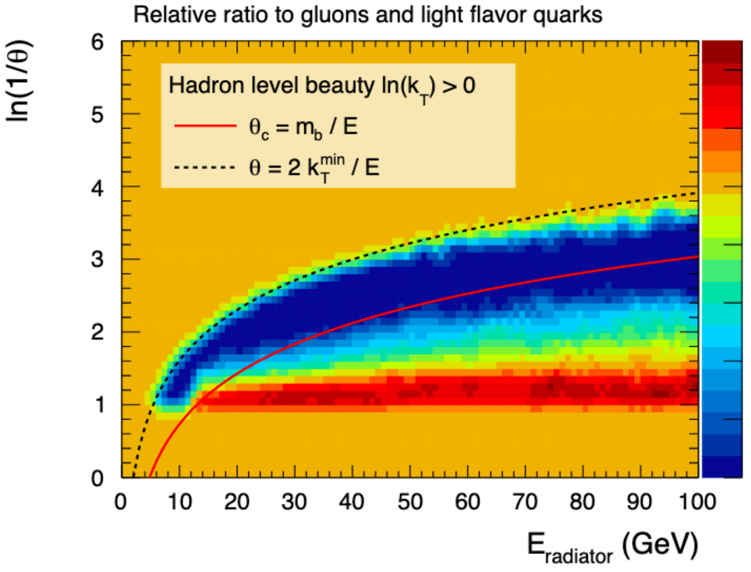
*Follow heavy-quark through the primary Lund Plane & suppress hadronization effects/non-pert. (at small $k_T$)*

**Expectation: radiation suppressed for $\theta_c < m_Q/E$**

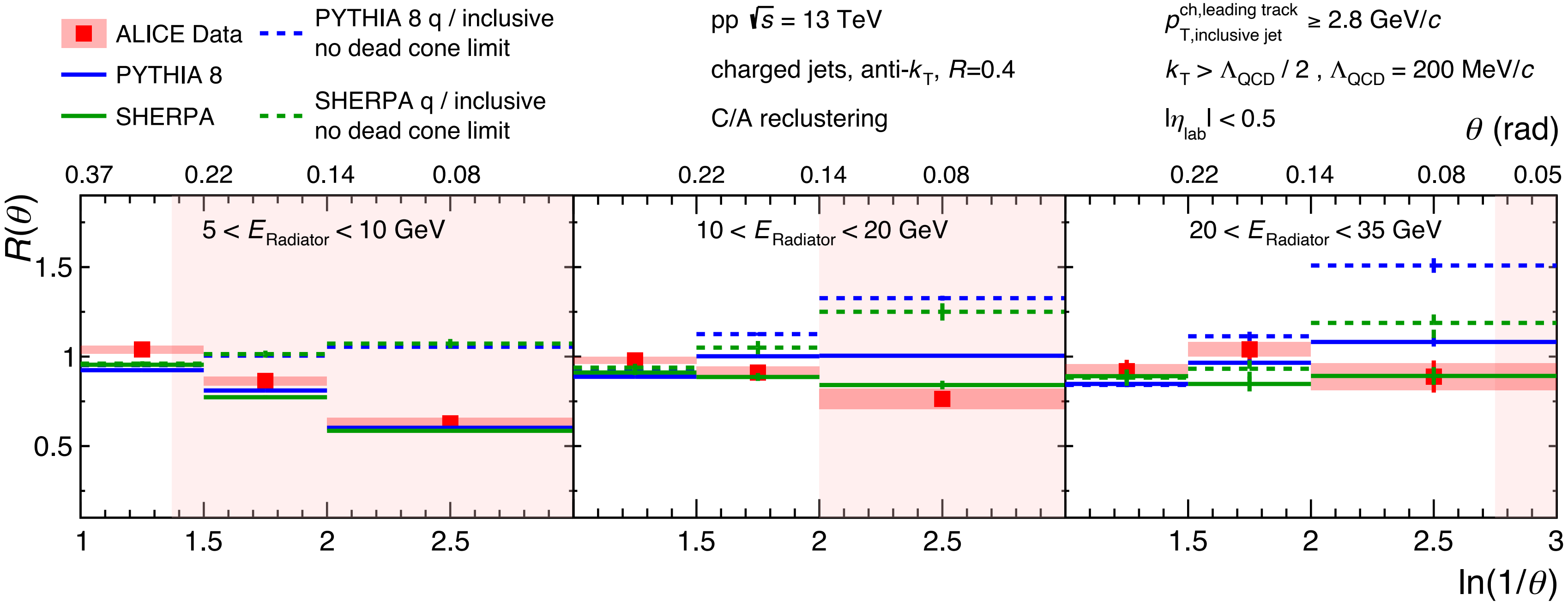
$$R(\theta) = \frac{1}{N^{D^0 \text{ jets}}} \frac{dn^{D^0 \text{ jets}}}{d\ln(1/\theta)} \Big/ \frac{1}{N^{\text{inclusive jets}}} \frac{dn^{\text{inclusive jets}}}{d\ln(1/\theta)} \Bigg|_{k_T, E_{\text{Radiator}}}$$

CERN-EP-2021-107

Principle outlined in PhysRevD.99.074027




Radiator: quark lead prong




**Outlook: b-jets**

New ALICE measurement for D-tagged jets

- Radiation suppressed in the expected angular region (shaded)
- Suppression lifted as $\text{mass}_Q << E_{\text{radiator}}$

Talk by Mattia Faggin

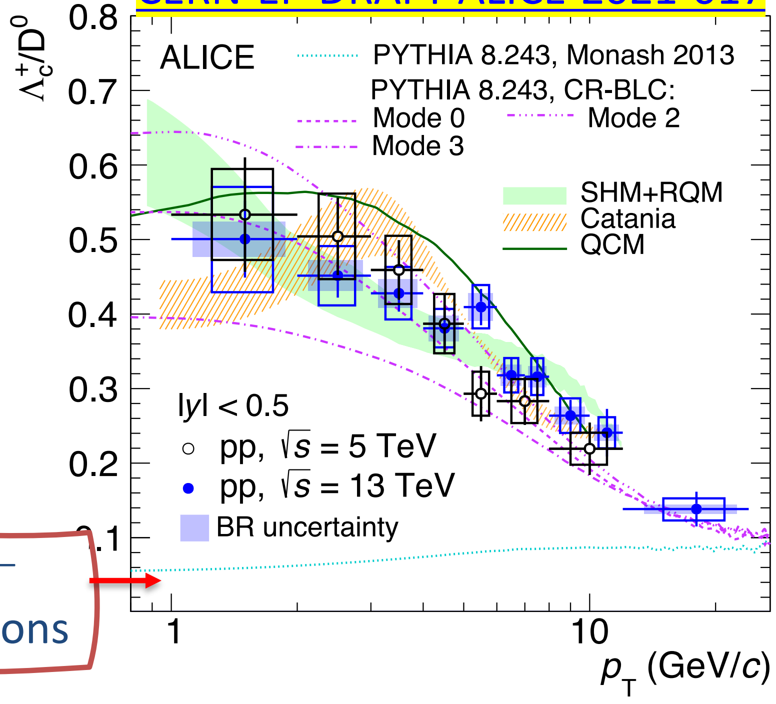
ALICE

# Charmed baryons in pp collisions

*Hadronization & non-perturbative effects of the underlying event; parton-hadron transition with heavy quarks*

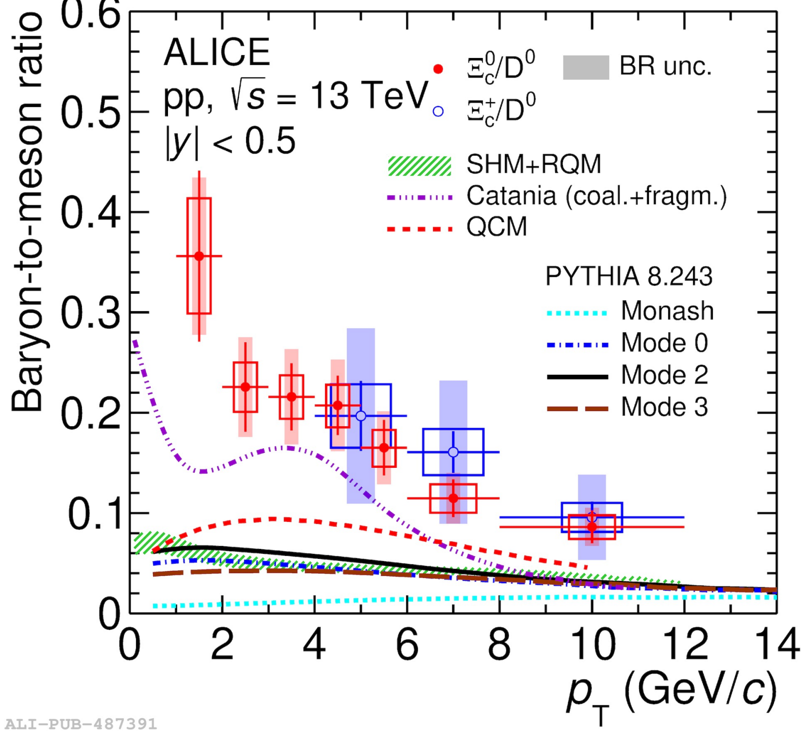
arXiv:2011.06078 **[nucl-ex]**

CERN-EP-DRAFT-ALICE-2021-017

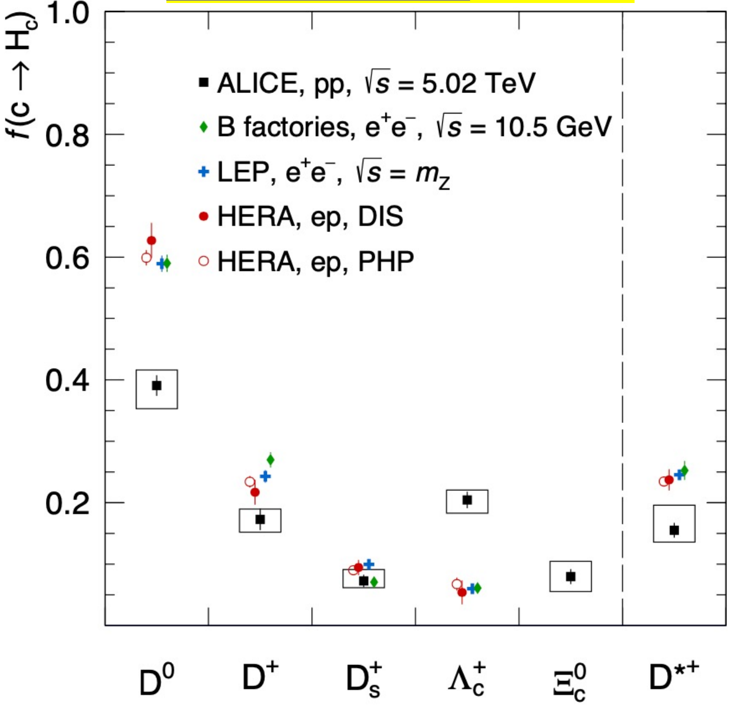



$e^+e^-$ collisions

arXiv:2105.05187 **[nucl-ex]**




arXiv:2105.06335 **[nucl-ex]**




- Unique measurements (at low-momenta) of $\Lambda_c$ (also $\Xi_c$ and $\Omega_c$)
- Cross section (fragmentation fraction) larger than expected (ee and ep) – **breaking universality between collision systems**
- Models with 'high-density' effects in hadronization describe $\Lambda_c$, but not $\Xi$; some support for parton coalescence picture
- Baryon/meson ratio – **features similar to all flavors** – characteristic for parton (re-)combination at hadronization

Talk by Mattia Faggin

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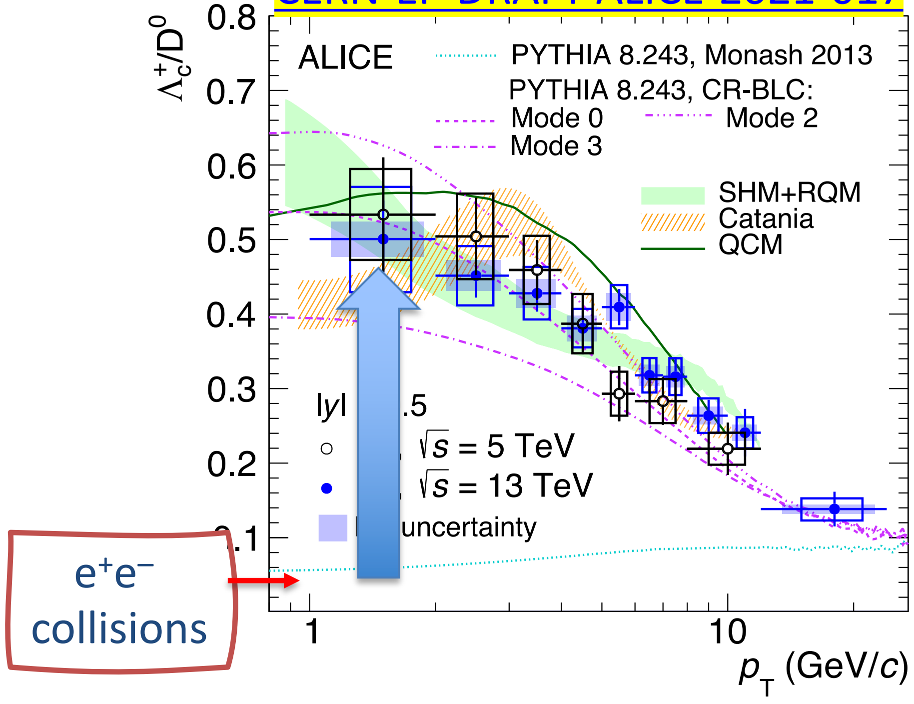
# Charm baryon/meson measurements in pp collisions

*Hadronization & non-perturbative effects of the underlying event; parton-hadron transition with heavy quarks*

arXiv:2011.06078 **[nucl-ex]**
CERN-EP-DRAFT-ALICE-2021-017

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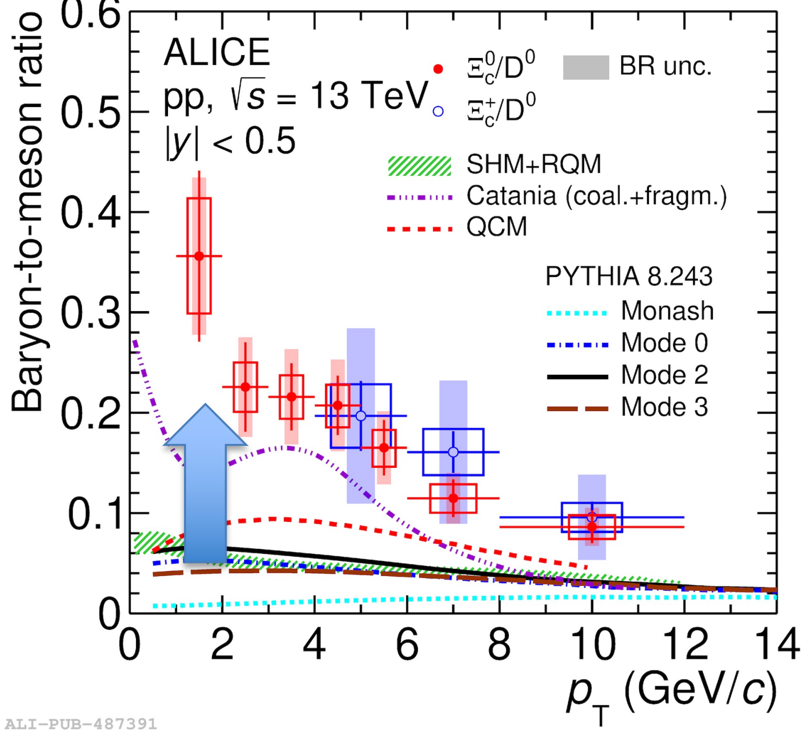
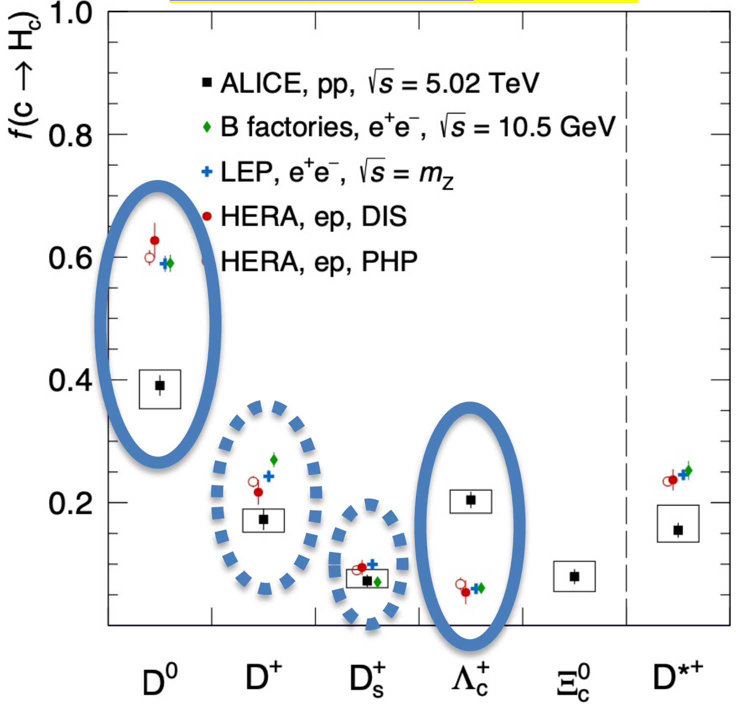



arXiv:2105.06335 **[nucl-ex]**

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# proton-Pb collisions

Talk by Alice Ohlson

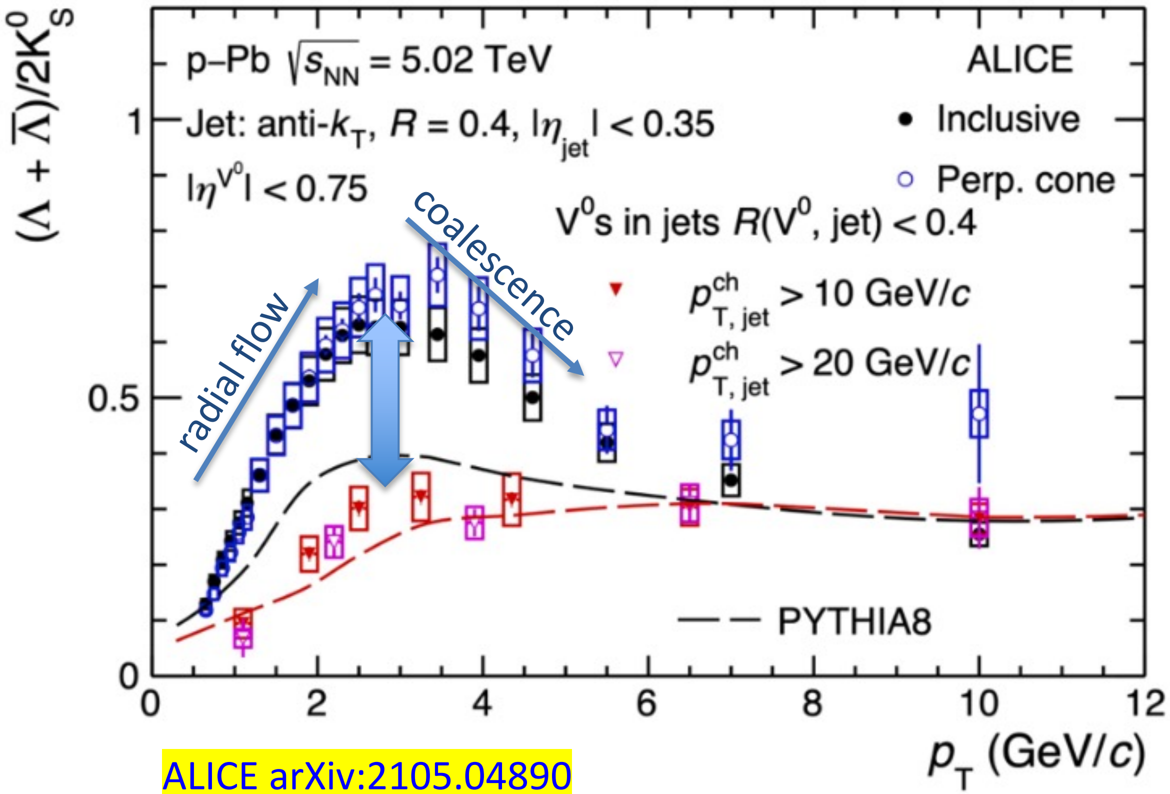
ALICE

# Uncovering details of hadronization with strangeness

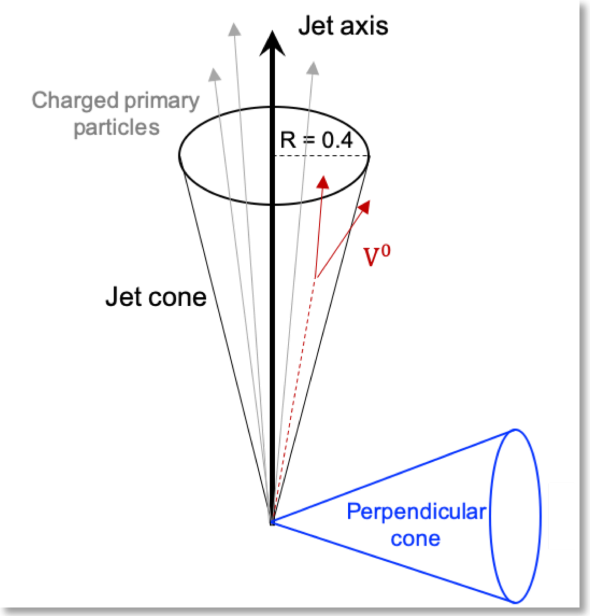
*Understanding hadronization & non-perturbative effects of the underlying event*

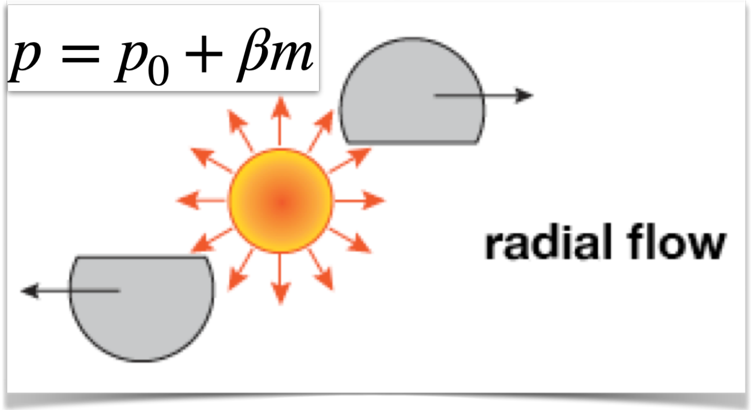
*Probing fundamental features of QCD: confinement ⇔ parton-hadron transition with light quarks*

Lambda and kaons outside and inside of jets




ALICE arXiv:2105.04890




**Baryon/meson enhancement not seen in jets** – property of soft UE – input to modelling (hadronization / coalescence)

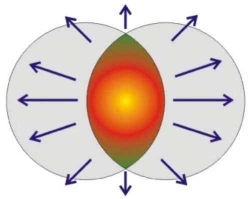
Precision studies in heavy-flavour jets with Run 3

Talk by Alice Ohlson, poster by Chiara De Martin

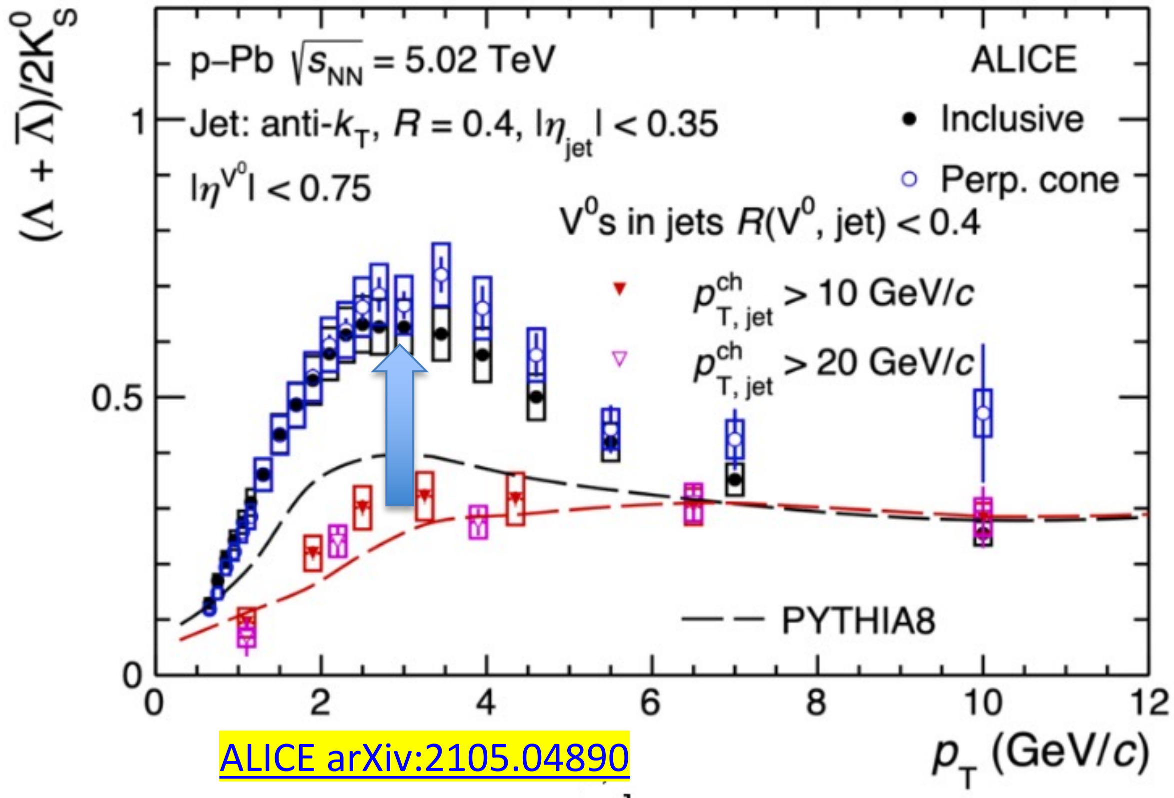
# Uncovering details of hadronization with strangeness

*Understanding hadronization & non-perturbative effects of the underlying event*

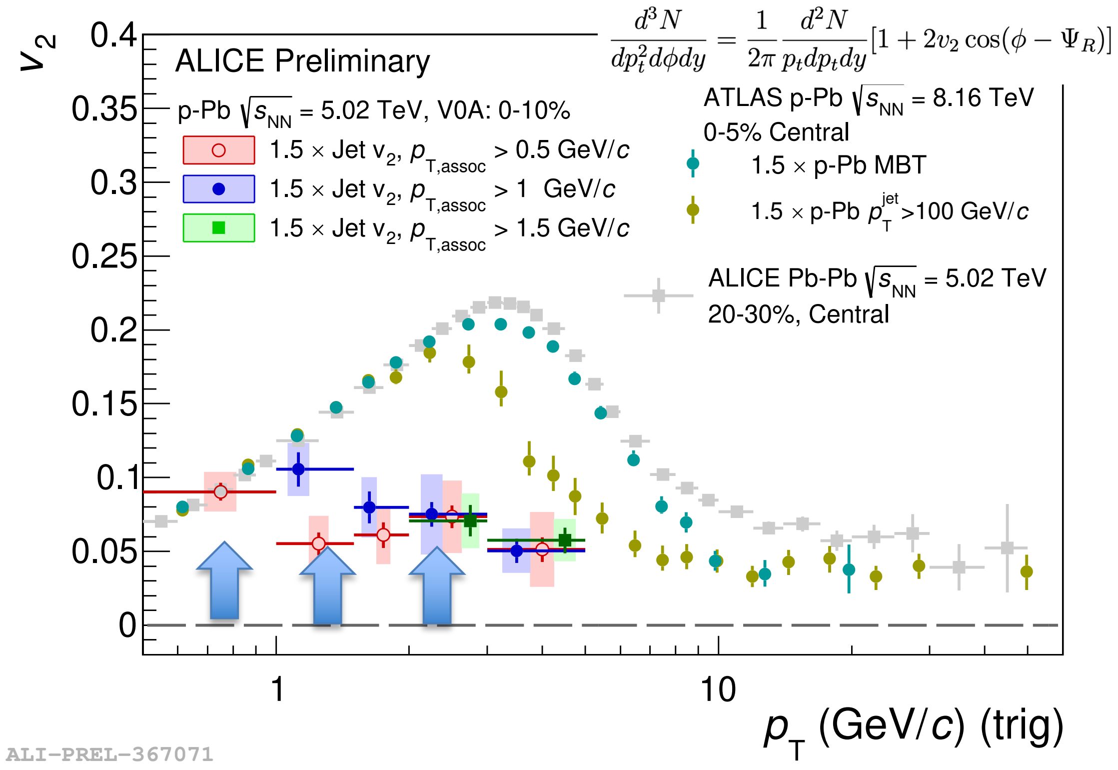
*Probing fundamental features of QCD: confinement ⇔ parton-hadron transition with light quarks*



Lambda and kaons outside and inside of jets




ALICE arXiv:2105.04890




**Baryon/meson enhancement not seen in jets** – property of soft UE – input to modelling (hadronization / coalescence)

Precision studies in heavy-flavour jets with Run 3 and Run 4

**However, azimuthal flow ($v_2$) seen also for jet associated particles**

Not expected from limits on jet quenching / e-loss in small systems

ALICE

# Pb-Pb and Xe-Xe collisions

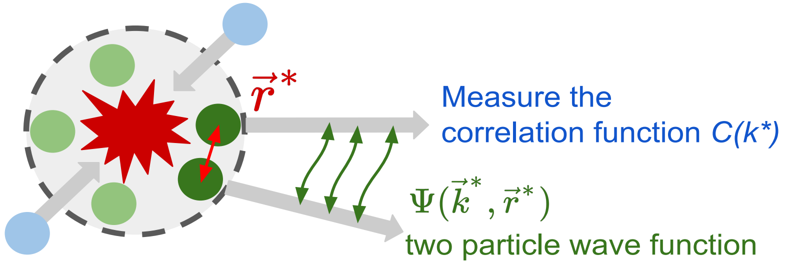
# Strong interaction among hadrons

*Precision QCD from w/ hadron correlations – new information on neutron star EOS*

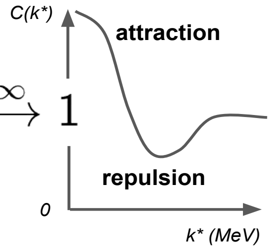
ALICE on topic

$p\Lambda$, Kp, $p\Xi^-$, $p\Omega$, $p\Sigma^0$, $\Lambda\Lambda$, $p\bar{p}$

Phys. Rev. C 99 (2019) 024001
Phys. Rev. Lett. 124 (2020) 092301
Nature 588 (2020) 232–238
Phys. Rev. Lett. 123 (2019) 112002
Physics Letters B 805 (2020) 135419
Phys. Lett. B 797 (2019) 134822
Phys. Lett. B 811 (2020) 135849




$$C(k^*) = \int S(r^*) \left|\Psi(\vec{k}^*, \vec{r}^*)\right|^2 d^3r^* \xrightarrow{k^* \to \infty} 1$$

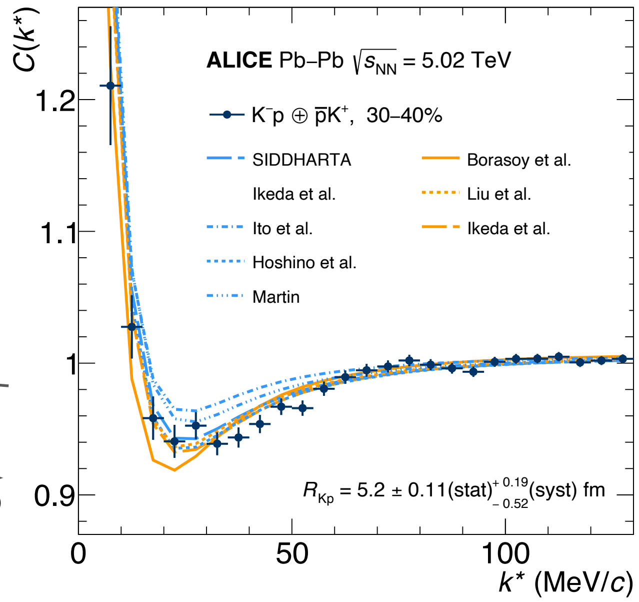



Relative distance and ½ relative momentum evaluated in the pair rest frame

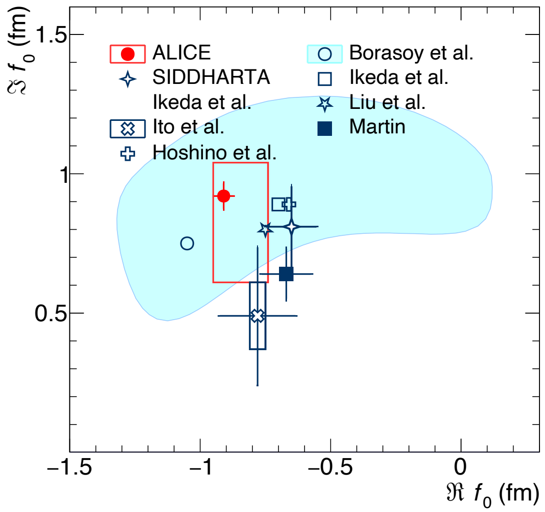
- Measure C(k*), fix S(r), study the interaction. *Phys. Lett. B 811 (2020) 135849*

arXiv:2105.05683 [nucl-ex]

## K⁻-p correlations in Pb-Pb collisions




## On scattering parameter plane



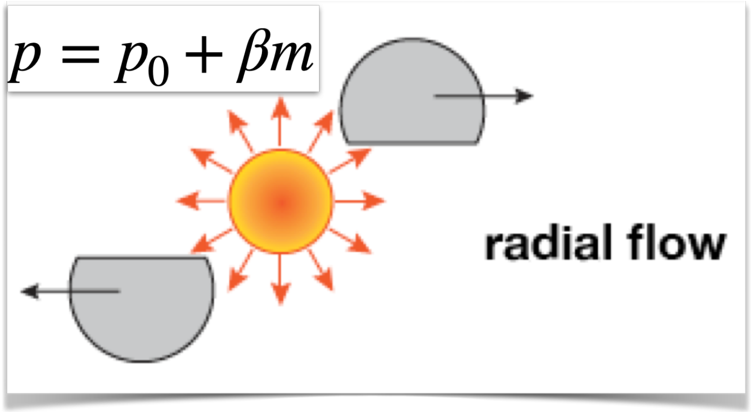

### "Femtoscopy"

- Small systems (pp) r*~1 fm – sensitive to inelastic channels
- Large systems (PbPb) r*> 3 fm – only elastic channels
  - **Alternative to scattering experiments; exotic atoms**

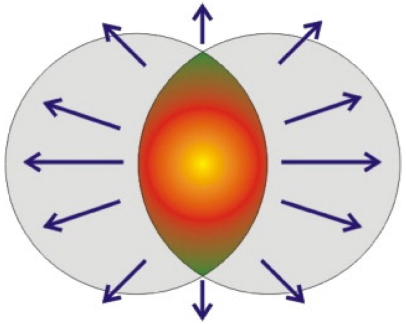
**New input to world-data**
**Novel input to theoretical calculations**

# Xe-Xe vs Pb-Pb – system dependence of radial and elliptic flow

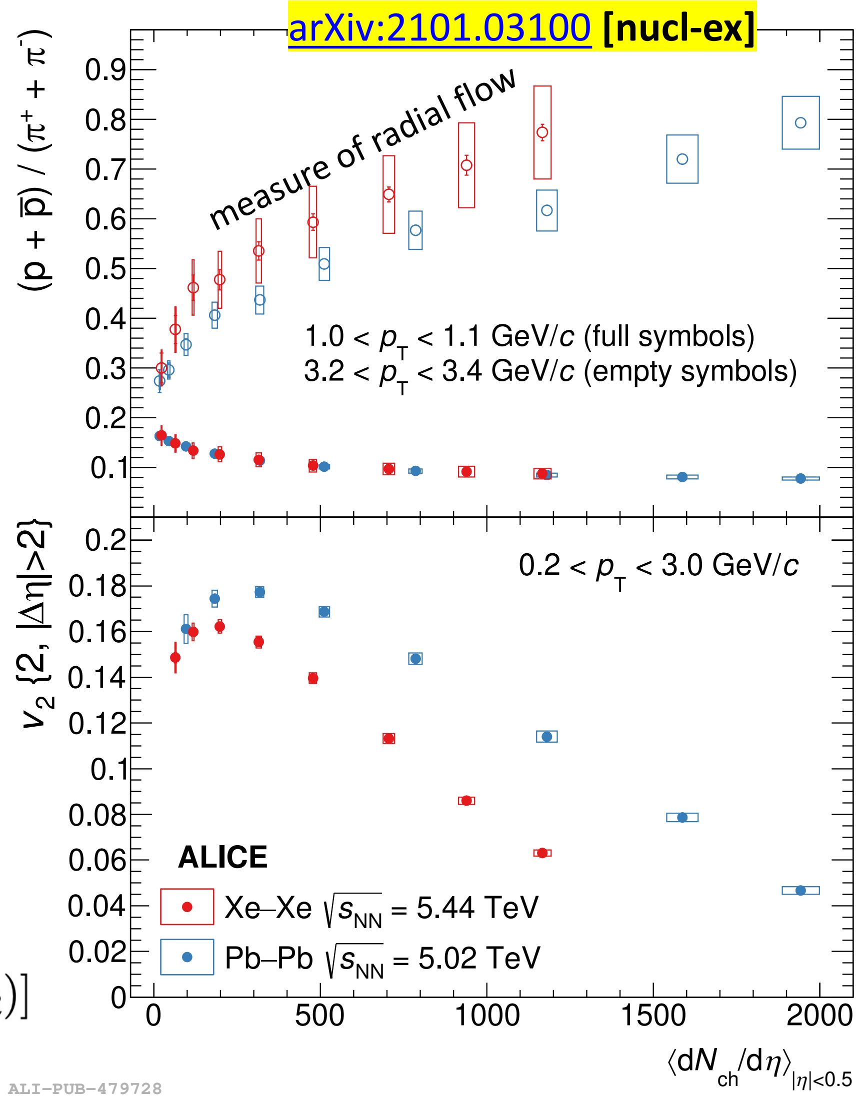
## Comparing small to large system – also, different initial geometries




Elliptic flow in transverse plane



$$\frac{d^3N}{dp_t^2 d\phi dy} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}[1 + 2v_2\cos(\phi - \Psi_R)]$$




Particle spectra shapes => **very different behaviour for radial and elliptic flow**

- **radial flow does not depend on the colliding system** (at similar charged-particle multiplicity)
- **Strong dependence of $v_2$** (radial flow) **on geometry/system** – different at different multiplicity

ALICE

# Probing QGP with heavy quarks

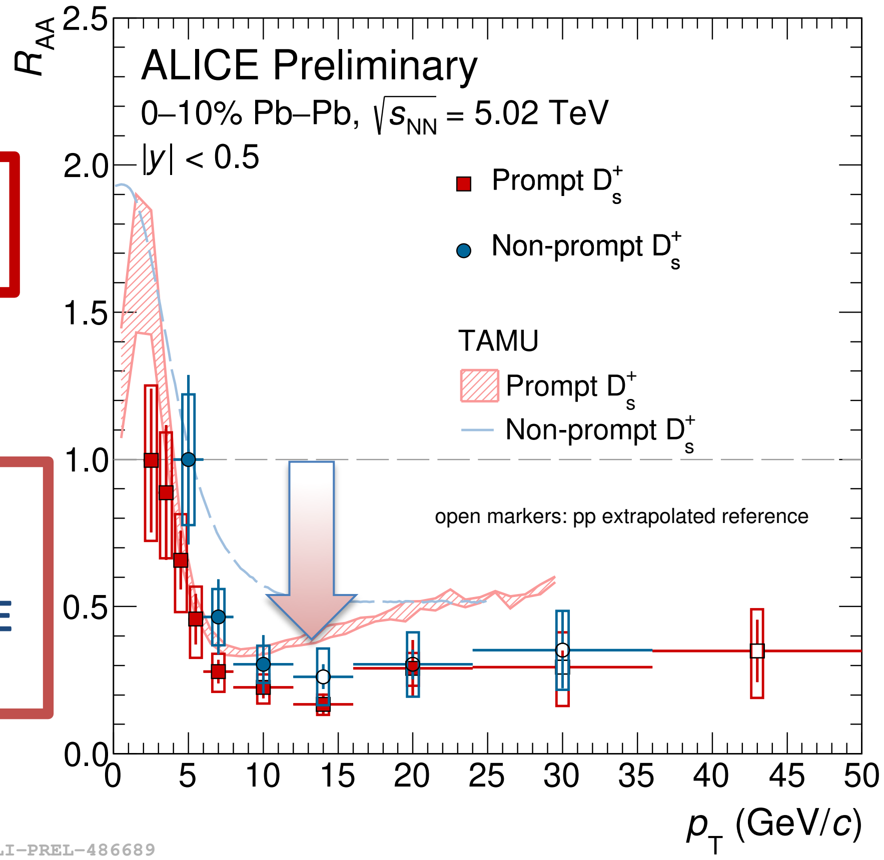
$R_{AA}$ = yield in AA per NN / yield in pp

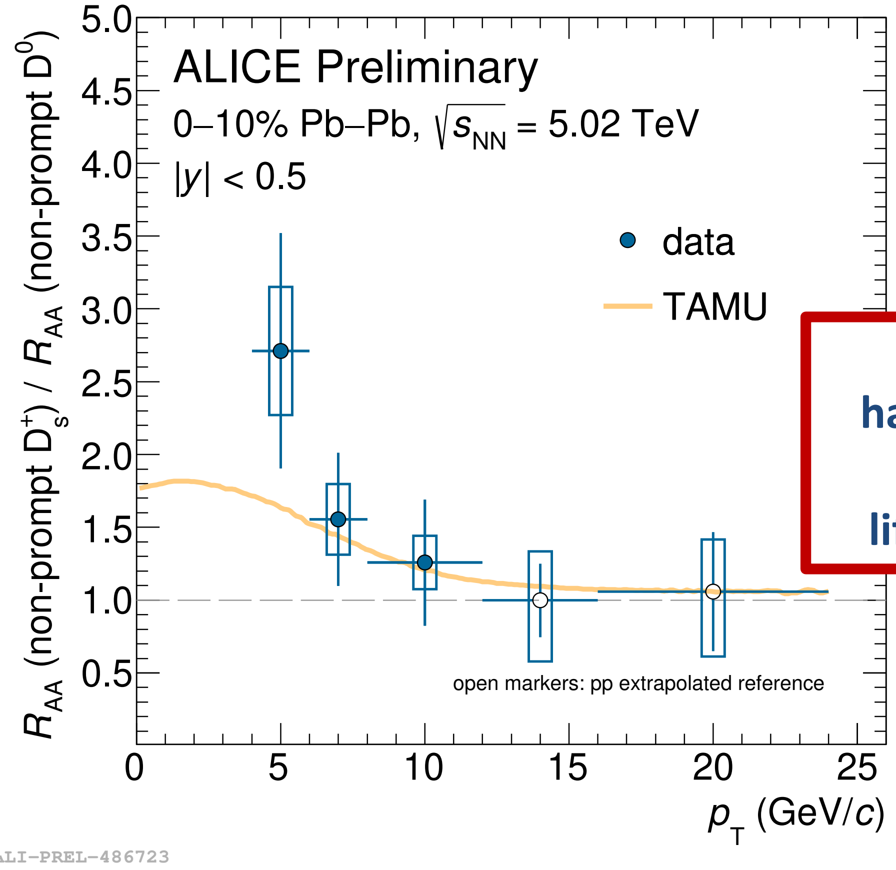
$R_{AA}$ = 1 at high $p_T$ ⇔ no nuclear effects

Expectation: beauty loses less energy in QGP as compared to lighter charm (dead-cone effect)

**Non-prompt: D from B**

**Suppression related to energy loss ΔE of quarks**




NEW

**Enhanced $B^0_s$ from hadronization of b via coalescence lifts $R_{AA}$ for s-content**

TAMU
PRL **124**, 042301

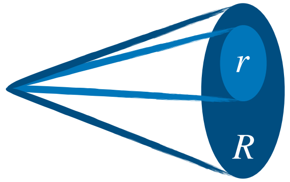
Two observations: **1)** hint **$R_{AA}$(n.-p.$D^+_s$) > $R_{AA}$(p.$D^+_s$)** and **2) $R_{AA}$ (n.-p.$D^+_s$) > $R_{AA}$ (n.-p.$D^0$)**

- Consistent with $m_b > m_c$ (**$R_{AA}$ $^{non\text{-}prompt}$ > $R_{AA}$ $^{prompt}$ follows expectation $\Delta E_b < \Delta E_c$**) and coalescence
- Enhanced production of $B^0_s$ from beauty hadronization via coalescence (50% of $D^+_s$ from $B^0_s$)

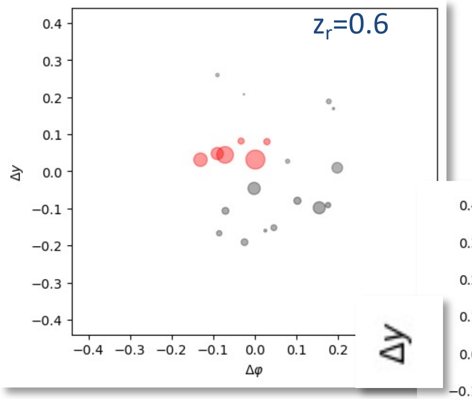
Talks by L. Cunqueiro, L. Havener, J. Mulligan

# Modifications of jet substructure in quark-gluon plasma

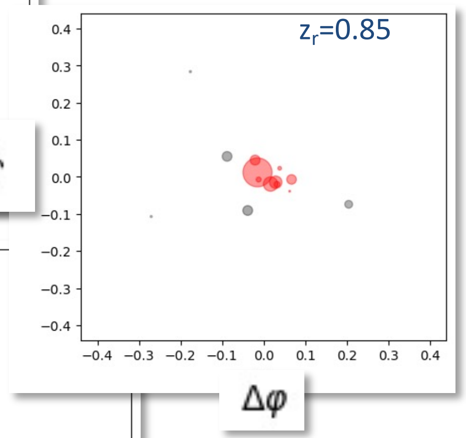
## Follow up on groomed jet substructure in AA => subjet tagging – quark vs. gluon

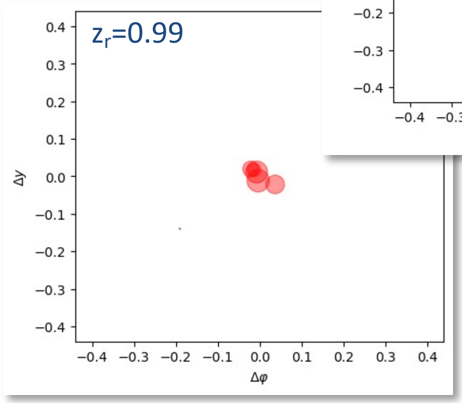



$$z_r = \frac{p_T^{\text{ch subjet}}}{p_T^{\text{ch jet}}}$$

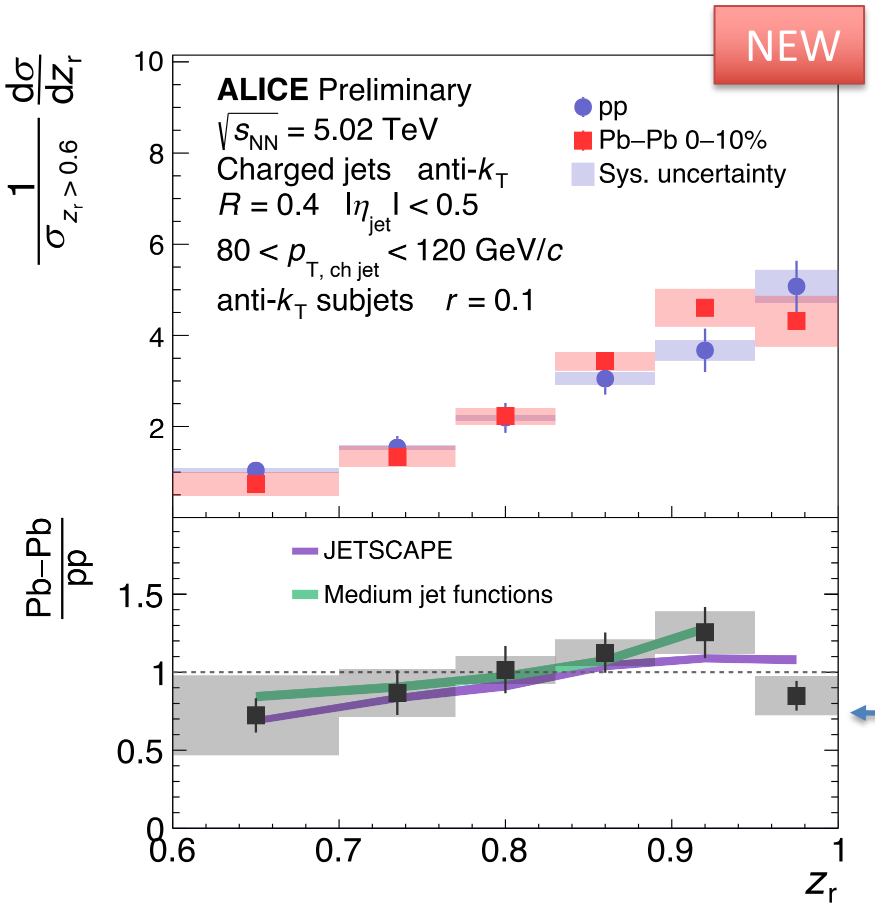



PYTHIA 8
Simulation



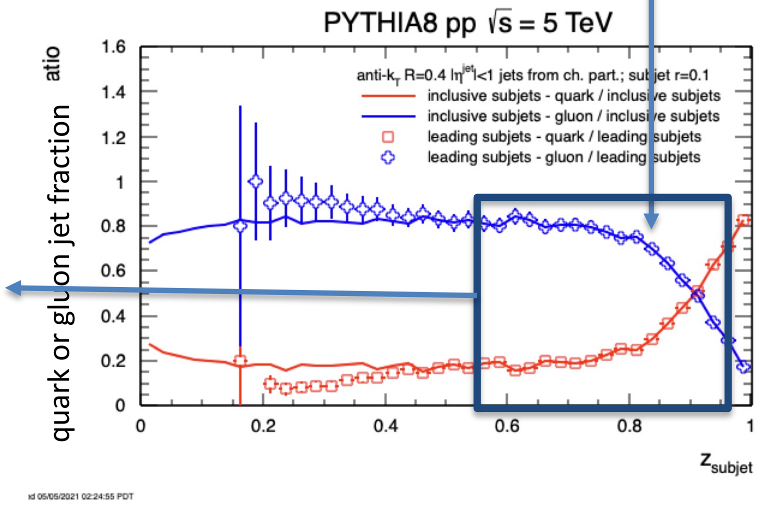




Fully corrected leading subjet distributions




New measurement of jet structure modifications

- redistribution of energy from the leading subjet (at different r<R) – collimation and z≈1 suppression
- sensitivity to quark vs. gluon jet in-medium energy loss?



$R_{AA}$ = yield in AA per NN / yield in pp
$R_{AA}$ = 1 at high $p_T$ ⇔ no nuclear effects

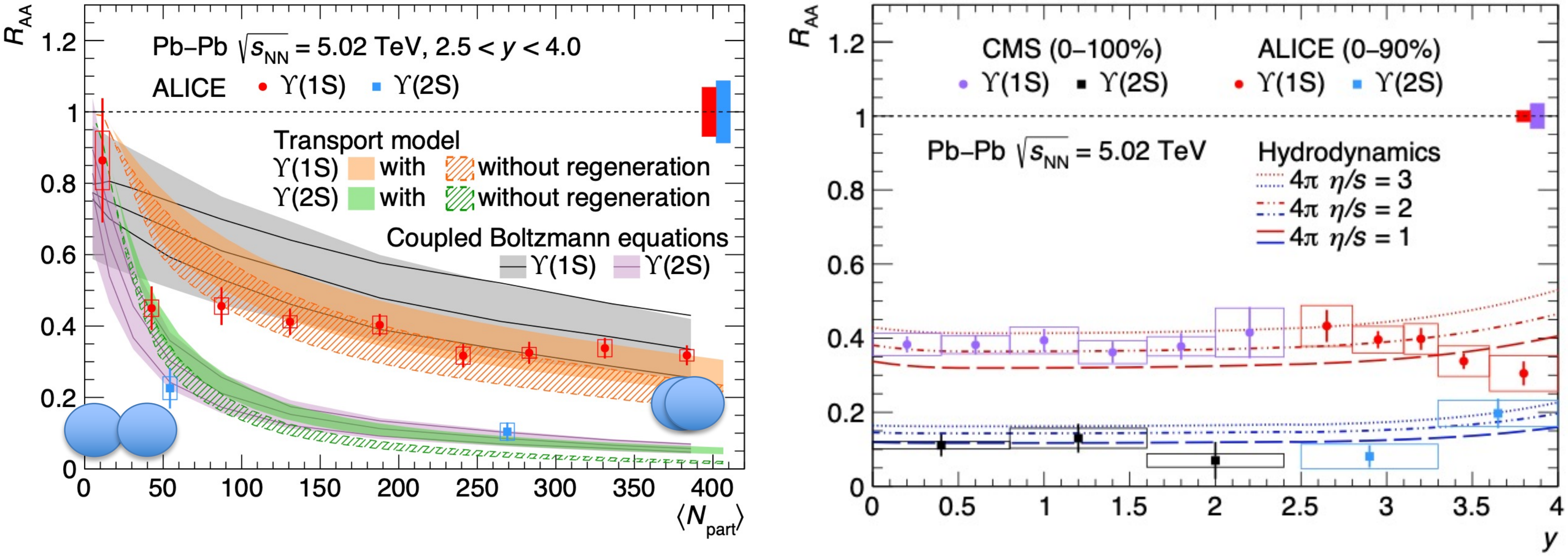
ALICE

# Suppression of botomonia in Pb-Pb collisions

arXiv:2011.05758 [nucl-ex]

**Υ(1S) is suppressed by a factor of about three with respect to the proton-proton collisions**

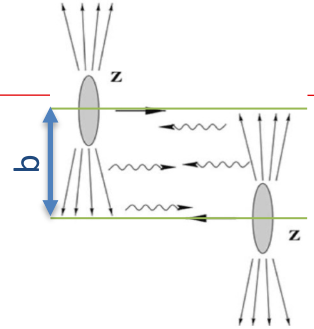
**Υ(2S) (first time!) at forward rapidity - a suppression stronger by about a factor 2-3 with respect to the ground state**




Context: suppression vs. binding energy – Υ(2S) $R_{AA}$ expected lower

Comparison to model calculation largely in line with data

Interesting trend reversal as a function of rapidity (CMS + ALICE data)

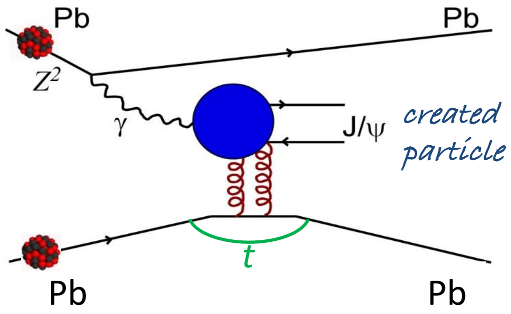



Talk by S. Ragoni

ALICE

# Ultra-peripheral heavy-ion collisions

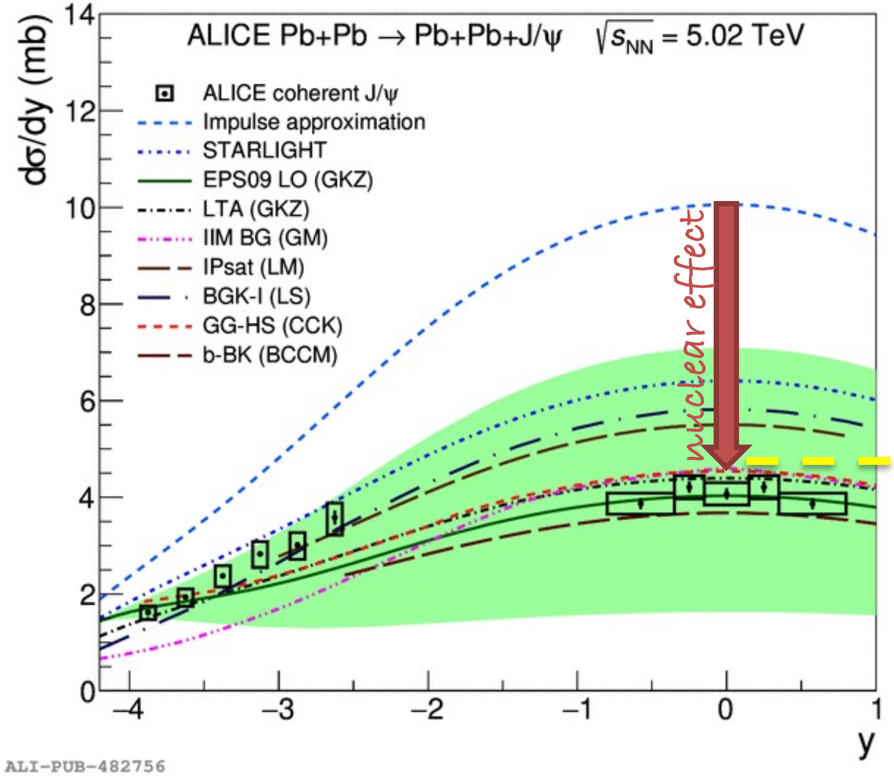
*Probing nuclear gluon density using photon-induced reactions*



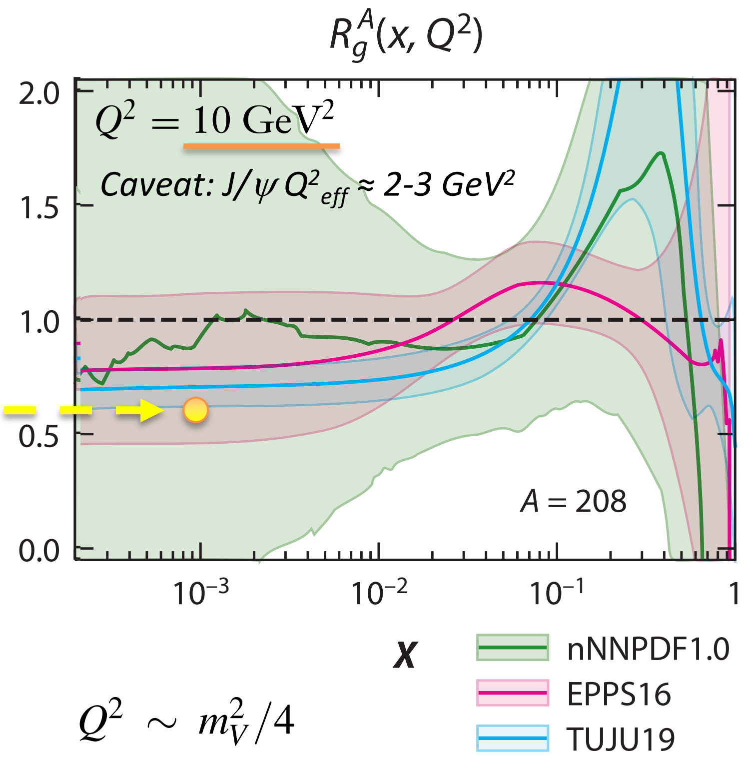

*Coherent J/ψ production cross section sensitive to gluon distribution function at (x,MJ/ψ)*

$$\frac{d\sigma_{\gamma A \to J/\psi A}}{dt}\bigg|_{t=0} = \frac{M^3_{J/\psi}\Gamma_{ee}\pi^3\alpha_s^2(Q^2)}{48\alpha_{\rm em}Q^8}\left[xg_A(x,Q^2)\right]^2$$

arXiv:2101.04577 [nucl-ex]




Ann. Rev. Nucl 011720 (2020)




$$Q^2 \sim m_V^2/4$$

$$x = \left(m_V/\sqrt{s_{NN}}\right)\exp(\pm y)$$

**New measurement probes low-x gluon nuclear PDFs**

- Extracted gluon shadowing factor: **$R_g$ =0.65±0.03 at x≈$10^{-3}$**
- **First measurement** of the t-dependence: sensitivity to transverse gluon distribution ($|t| \approx p_T^2$) Phys.Lett.B 817 (2021) 13628

ALICE

# Perspectives

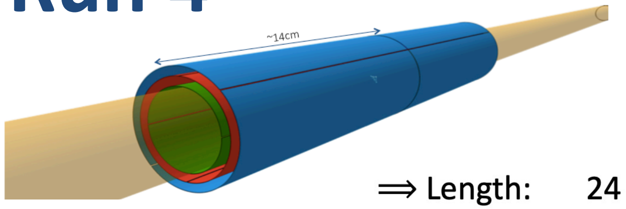
## LS3 upgrades, ALICE 3 for Run 5

Talks by C. Lippmann, G. Contin, S. Bufalino

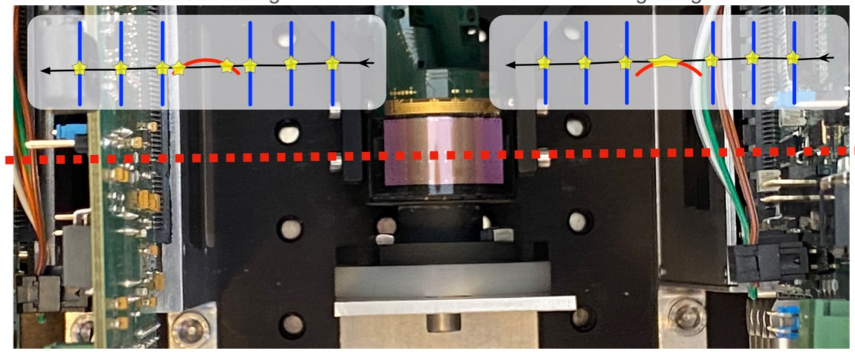
# Strengthening vertexing – Inner Tracker 3 for Run 4

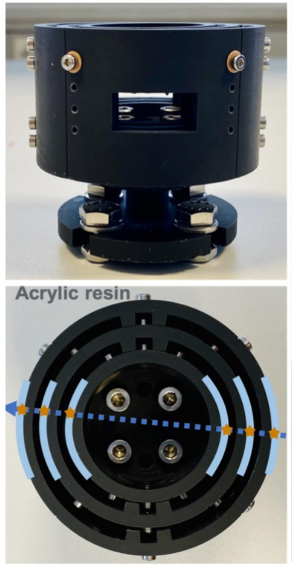
*ITS3: Ultrathin MAPS/ALPIDE chip – detector curled 'onto' the beam pipe*

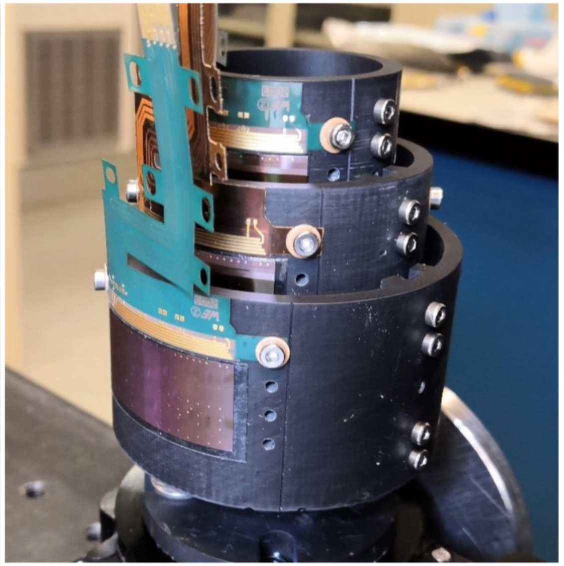
**in-beam performance of bent MAPS** arXiv:2105.13000 **[physics.ins-det]**



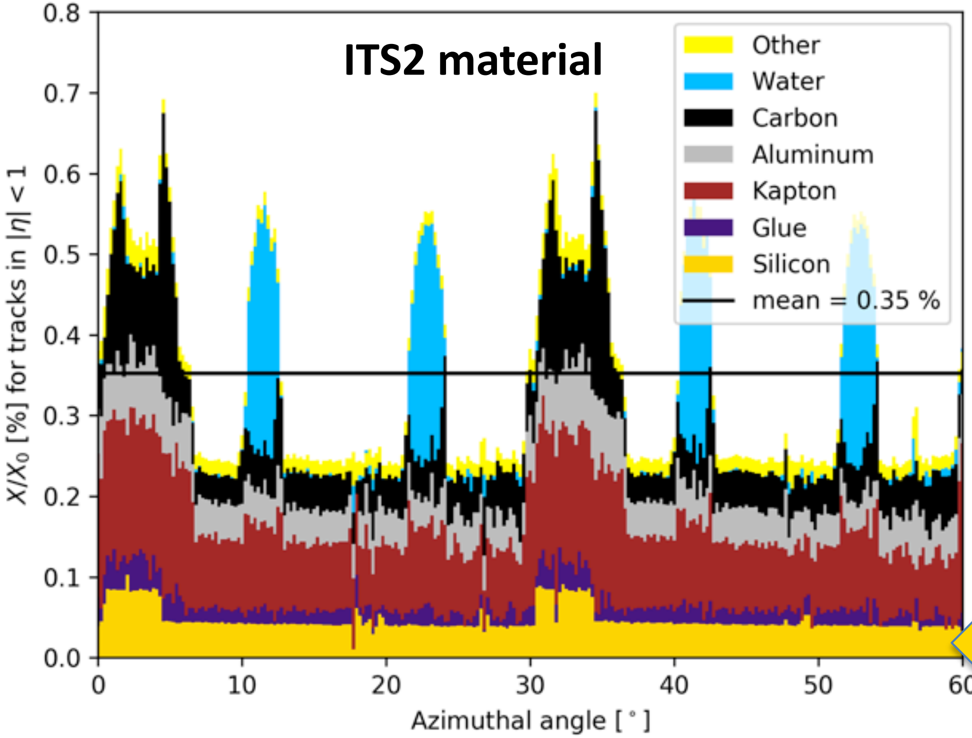

⟹ Length: 24 cm
⟹ Radii: 18, 24, 30 mm
⟹ Thickness: 50, 40, 40 µm

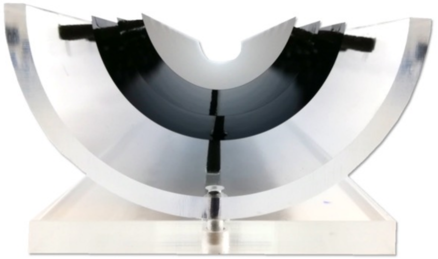


[ALICE-PUBLIC-2018-013]



ITS3: keep silicon 'only'!

**remove cooling, PCBs, mechanical support ➔ ultra-light inner layers**

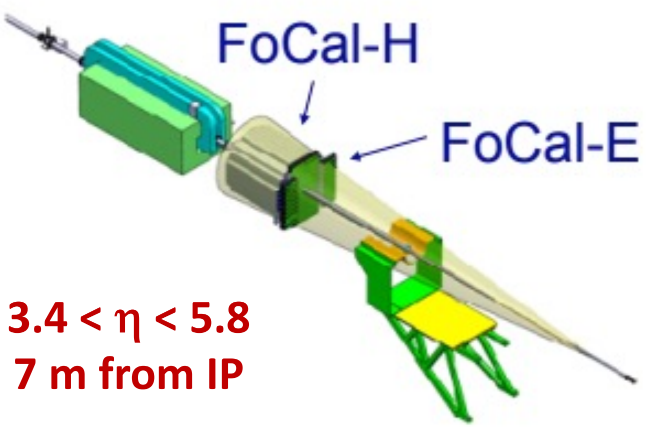
LoI - CERN-LHCC-2019-018 ; LHCC-I-034

Talk by Christian Lippmann

# Maximizing LHC's potential – glue at smallest-x ever - FoCal

*Nuclear modification of gluon distributions with photons*

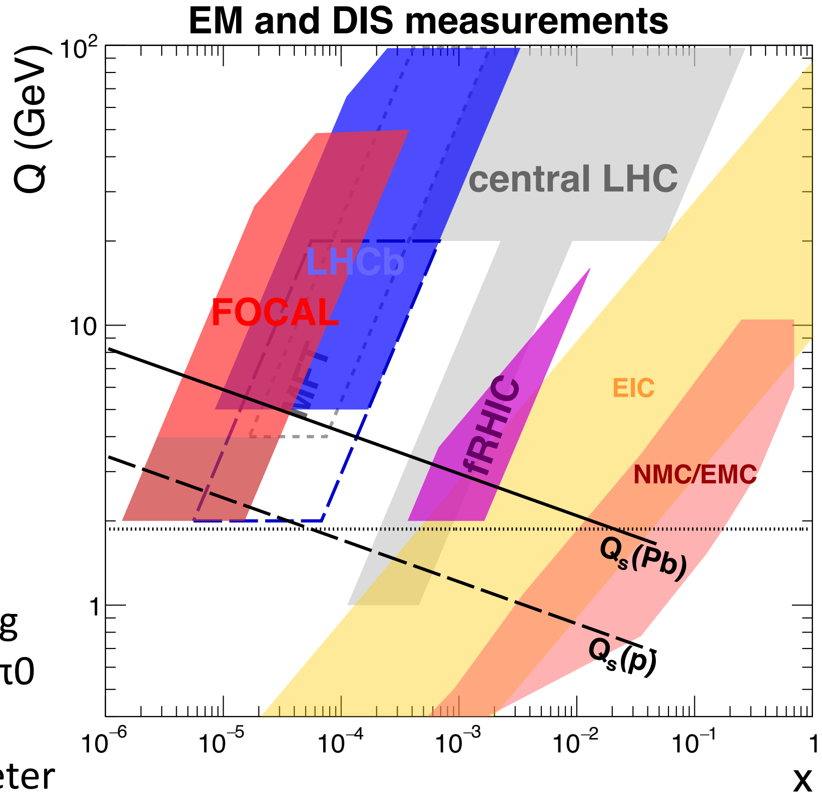
But also jets (di-jets), J/ψ (Υ) in UPC, W, Z, event plane & centrality of nuclear collisions

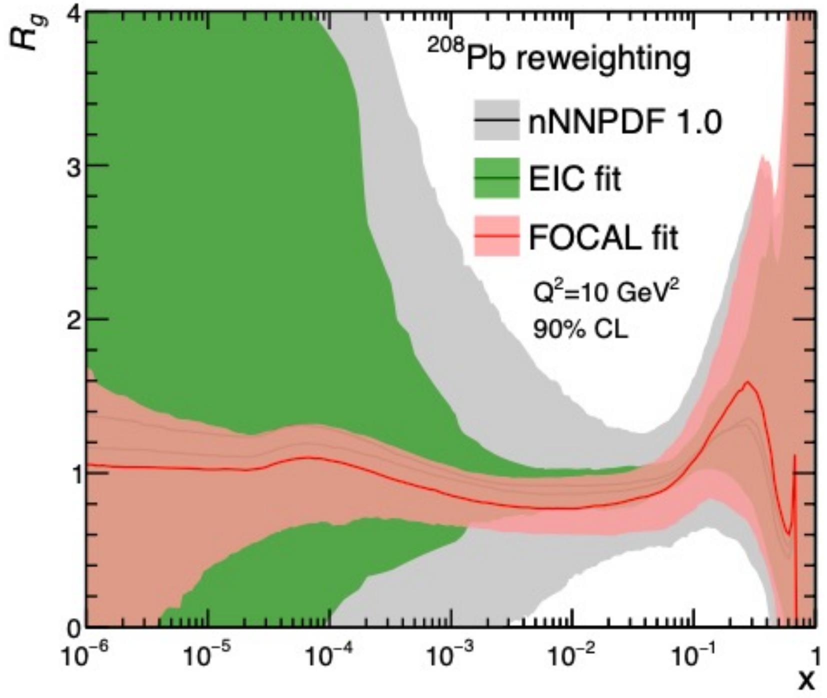



**3.4 < η < 5.8**
**7 m from IP**

**FoCal-E:** high-granularity Si-W sampling sandwich calorimeter for photons and π0

**FoCal-H:** conventional sampling calorimeter for photon isolation




[LoI - CERN-LHCC-2020-009 ; LHCC-I-036]

## Timeline

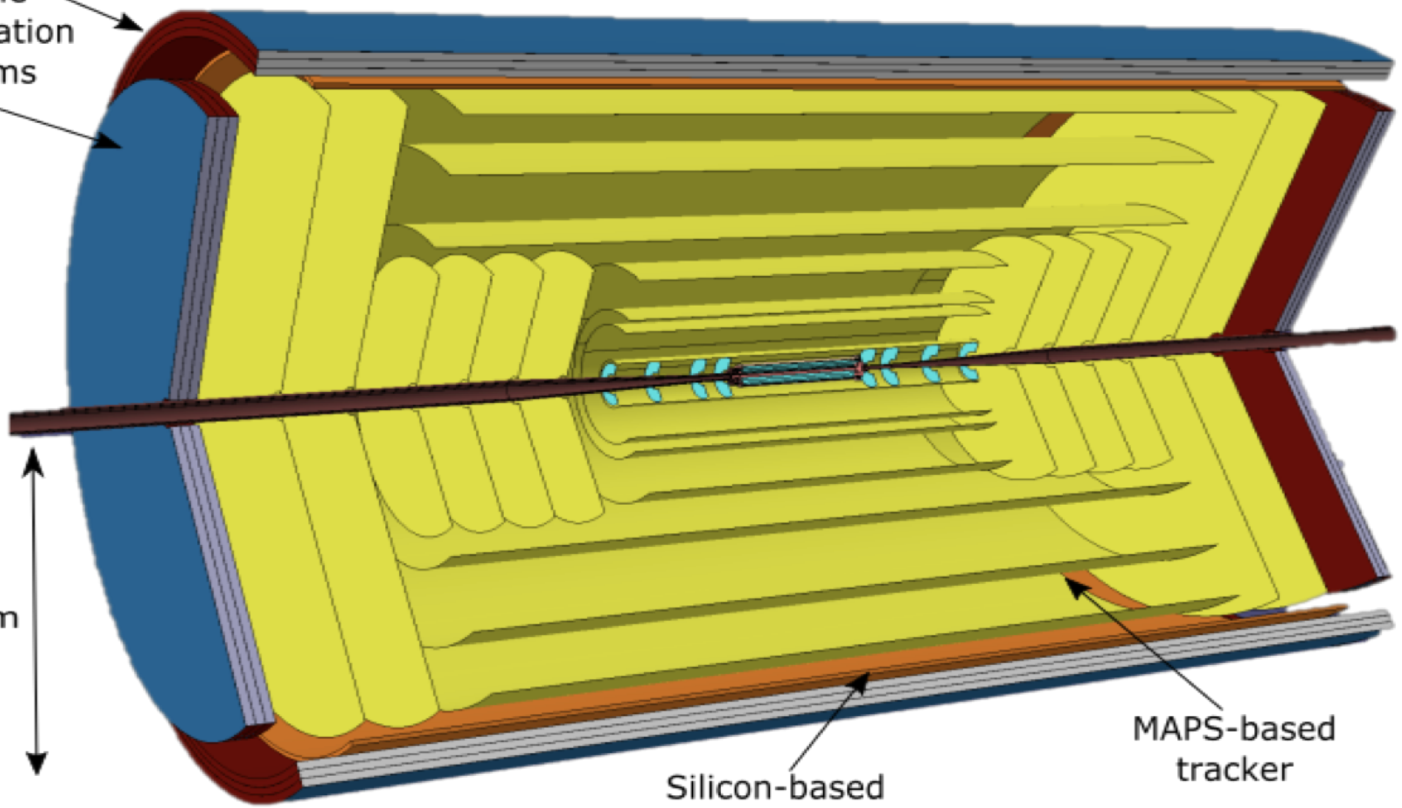
- **LoI completed & LHCC endorsed (2020)**
- **Prototyping, beam tests (SPS) - 2021**
- **Discussions with funding agencies - ongoing**
- **Development of TDR by 2022**
- **Construction and installation by LS3**

Talk by Antonio Uras, Stefania Bufalino

ALICE

# ALICE version 3 – for Run 5+

## Completely new detector system for novel physics @ LHC 2030+




**New dedicated heavy-ion LHC experiment**

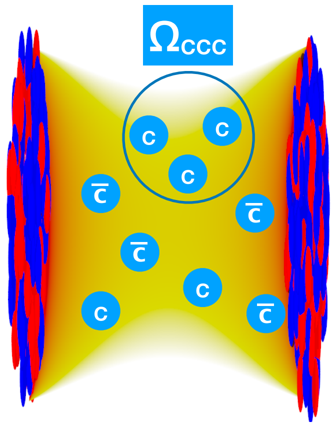
- novel measurements of electromagnetic and hadronic probes of the QGP at *very* low momenta, but also BSM, …

arXiv:1902.01211 **[physics.ins-det]**

**Timeline**

- Expression of Interest - 2019
- Conceptual work ongoing 2019/2020
- A public workshop in fall 2021
- **Submit a LoI by 2021**
- …
- Construction and installation by LS4

# ALICE 3 – developing science case…




**In-depth studies of deconfinement and hadronization**

- Multiple charm (x3) hadrons, quarkonia, X(3872) – total charm

**Next level probes of quasi-particle nature of QGP**

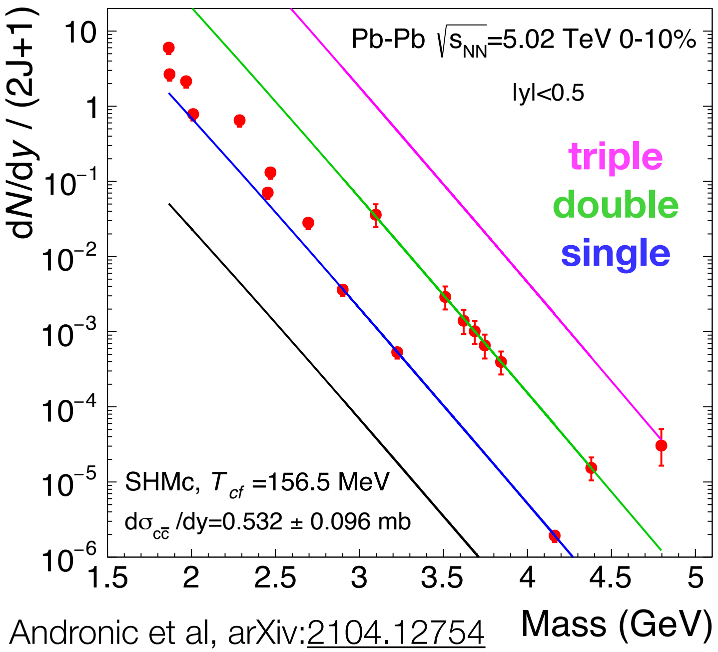
- collisional vs. radiative energy loss with $c\bar{c}$ correlations, c-jet substructure, photon-jet down to very low-$p_T$

**QGP properties – T, chiral symmetry, electric conductivity**

- Dileptons – mass and $v_2$ – time evolution
- ρ spectral shape – sensitivity to ρ-$a_1$ mixing
- Access very low-mass and $p_T$

**Details on pre-QGP / hydrodynamization stages**

- Dileptons at high-masses and high $p_T$




Andronic et al, arXiv:2104.12754

More under considerations: Low's theorem photons ($p_T$<50 MeV/c), NLO pQCD processes, exotic states, …, new (tau g-2, light-by-light scattering, dark photons, long-lived particles, magnetic monopoles)

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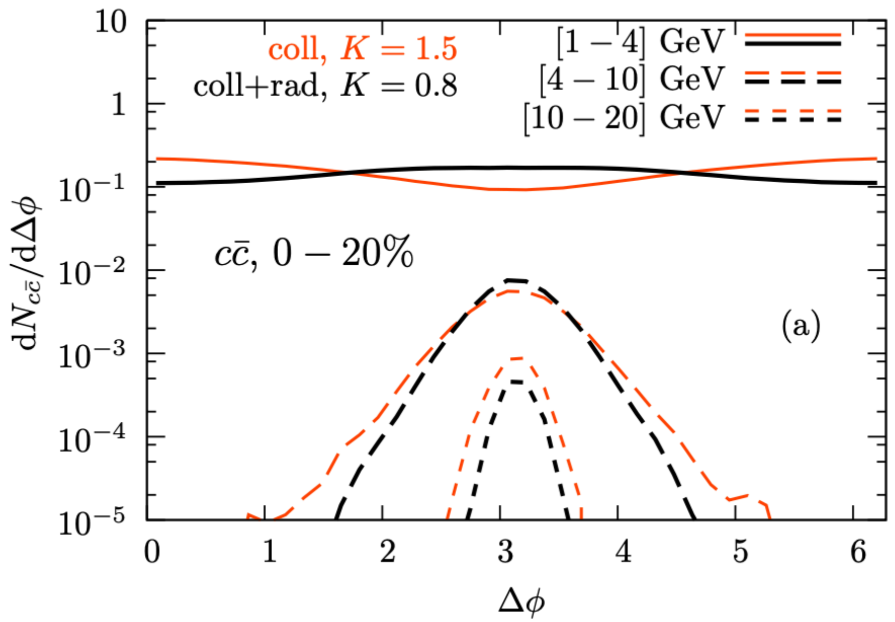
## $D\bar{D}$ azimuthal correlations

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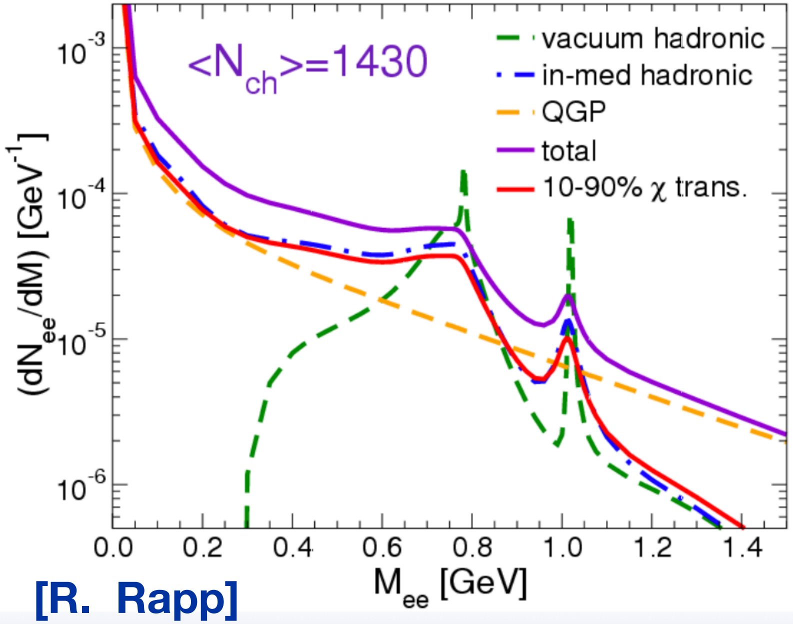


[R. Rapp]

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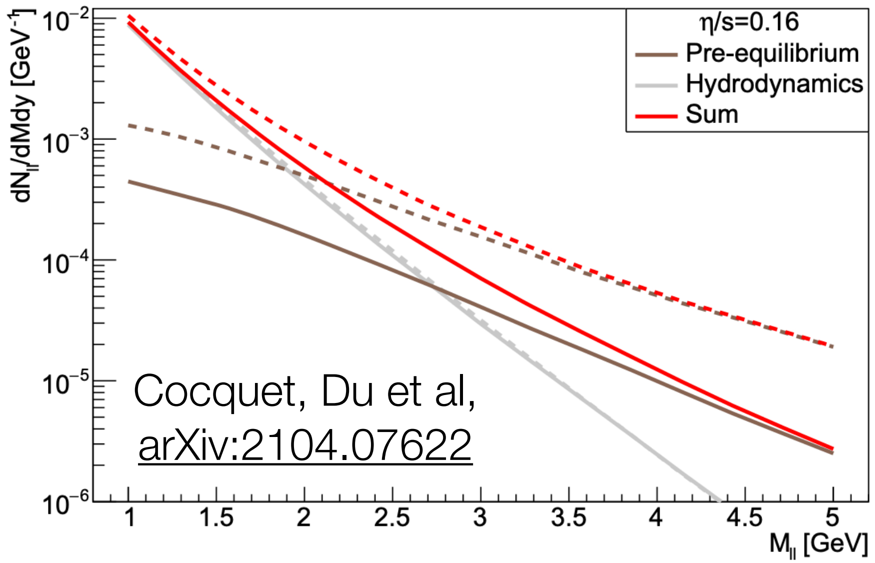
**dilepton mass distribution**



# Summary

**ALICE is well on track for Run 3**

**Many new results – from QGP studies to new insights into QCD**

**Exciting perspectives for upgrades:**

- New ultra-thin inner tracker layers on track for Run 4
- Forward calorimetry – nucleon structure at smallest ***x*** in Run 4
- ALICE 3 for Run 5 and beyond - in preparation

# ALICE Speakers / ALICE featuring talks at LHCP 2021

| | |
|---|---|
| Jet properties, substructure, experimental/theory (in pp) | Leticia Cunqueiro |
| Hard probes of QGP (excl. HF and quarkonia, so jets) | Laura Havener |
| Soft particle production from QGP | Alice Ohlson |
| ALICE upgrades | Christian Lippmann |
| New measurements in quarkonia sector with focus on new discriminatory observables | Minjung Kim |
| (Anti)(hyper)nuclei production | Luca Barioglio |
| Collectivity of soft probes in heavy ion collisions | Vytautas Vislavicius |
| Heavy flavor collectivity in heavy ion collisions | Fabrizio Grosa |
| New measurements on diffractive vector mesons | Simone Ragoni |
| Nucleon Structure and Soft QCD from ALICE | Sushanta Tripathy |
| Jet Substructure + Correlations in Hadronic Final States from ALICE | James Mulligan |
| Precision QCD Measurements from ALICE | Dimitar Mihaylov |
| Heavy-flavour hadron production | Mattia Faggin |
| Highlight: ALICE: reconstruction and TPC calibration in Run 3 | Ernst Hellbar |
| ALICE: new ITS commissioning and impact on vertexing in Run 3 | Ivan Ravasenga |
| Use of hardware acceleration for online event rec. for Run 3 and later | Marten Ole Schmidt |
| PID and tracking with timing detectors in ALICE and LHCb in Run 5 | Stefania Bufalino |
| Physics prospects ALICE in Run 5 and beyond | Antonio Uras |
| Novel detector concepts for ALICE for Run 4 and beyond | Giacomo Contin |
| Advances in exp. analysis frameworks (framework, data models, analysis facilities...) | Jan Fiete Grosse-Oetringhaus |
| LHC and diversity | Adriana Telesca |

# ALICE Posters at LHCP 2021

| | |
|---|---|
| Projections for jet quenching measurements in O--O collisions at 6.37 TeV during the LHC Run3 | Filip Krizek |
| Search for jet quenching effects in high-multiplicity proton-proton collisions at 13 TeV | Artem Kotliarov |
| Analysis of b-jets production in p–Pb and pp collisions at 5.02 TeV with ALICE | Artem Isakov |
| Measurement of DD meson production as a function of charged-particle multiplicity in proton-proton collisions at 13 TeV with ALICE at the LHC | Yoshini Bailung |
| Λ+cΛc+ cross section in pp and p--Pb collisions down to pT = 0 at 5.02 TeV measured with ALICE | Annalena Sophie Kalteyer |
| Angular correlations of heavy-flavour decay electrons and charged particles in pp and p-Pb collisions at 5.02 TeV with ALICE at LHC | Ravindra Singh |
| Strange-hadron correlation studies to investigate strangeness enhancement in pp collisions | Chiara De Martin |
| Femtoscopic analysis of K0S−pKS0−p pairs in proton–proton collisions at 13 TeV with ALICE | Marta Urioni |
| Ω0cΩc0 production cross section in pp collisions at 13 TeV with ALICE | Jianhui Zhu |
| Measurements of inclusive photons and charged particles at forward rapidities in p--Pb collisions at 5.02 TeV with ALICE | Abhi Modak |
| Hyperloop – The ALICE analysis train system for Run 3 | Raquel Estefania Quishpe |
| Insight into $K*$(892)0 production in pp collisions as a function of collision energy, event-topology and multiplicity with ALICE at the LHC | Rutuparna Rath |
| Particle-yield modification in jet-like azimuthal V0–hadron correlations in Pb–Pb collisions at 5.02 TeV with ALICE at the LHC | Mustafa Anaam |

# Thank you!

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# Additional slides

- Highest-multiplicities ever studied in pp
- Nuclei and baryon-baryon interactions
- Rare QCD processes
- Low-mass dielectron production
- Baryon-baryon interactions

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# Extended high-energy pp programme

## Executive Summary

- Target data samples:
  - $L_{int}$ = 200/pb with continuous data-taking and processing followed event skimming with selectivity of ~$10^{-3}$, based on multiplicity or signal candidates
    - e.g. compared to Run 2 sample: x20 for high-multiplicity; x3000 for measurements that were based on minimum bias sample
  - $L_{int}$ = 3/pb at low field (0.2 T) with continuous data-taking and no event selection
    - x400 compared to Run 2 sample
- Upgraded ALICE enables unique physics programme at the LHC, with full-year operation in pp, as done in Runs 1 and 2
- Proposed running scenario: 500 kHz interaction rate
  - Requires 5 full pp years at 50% LHC efficiency (in physics periods)
  - Computing capacity of $O^2$ facility sufficient, moderate increase at Tier-0
  - Aim at increasing interaction rate to 1 MHz after first year(s), to reach target within Run 3, if computing resources have positive outlook

# Extended high-energy pp programme

## Executive Summary – complementarity at the LHC

- Highest-multiplicities ever studied in pp
- Nuclei and baryon-baryon interactions
- Rare QCD processes
- Low-mass dielectron production
- Baryon-baryon interactions

ALICE

| Measurement | ALICE uniqueness | Other experiments |
|---|---|---|
| $\Omega/\pi$ ratio vs. multiplicity | $\pi$, K, p PID $p_{\mathrm{T}} > 0.15$ GeV/$c$ mid-$y$ | — * |
| Flow of $\pi$, K, p at high multiplicity | $\pi$, K, p PID $p_{\mathrm{T}} > 0.15$ GeV/$c$ mid-$y$<br>$p_{\mathrm{T}} < 0.5$ GeV/$c$ crucial for mass ordering | CMS in Run 4 (with proposed timing layer)<br>limited to $p_{\mathrm{T}} > 0.4$ GeV/$c$ at $\lvert\eta\rvert \approx 1.4$ |
| h–jet recoil at high multiplicity | Charged jets $p_{\mathrm{T}}^{\mathrm{jet}} > 15$ GeV/$c$<br>maximum sensitivity to jet $\Delta E$ at low $p_{\mathrm{T}}^{\mathrm{jet}}$ | ATLAS and CMS ($\gamma$/Z–jet with $p_{\mathrm{T}}^{\mathrm{jet}} > 30$ GeV/$c$) |
| Nuclei and hypernuclei | $Z = 2$ nuclei PID $p_{\mathrm{T}} > 0.8$ GeV/$c$ | — * |
| p–hyperon(Y) and Y–Y interaction | $\pi$, K, p PID $p_{\mathrm{T}} > 0.15$ GeV/$c$ mid-$y$ | — |
| B mesons | PID, B mesons $p_{\mathrm{T}} > 0$ mid-$y$<br>Reference for $p_{\mathrm{T}} < 5$ GeV/$c$ B $R_{\mathrm{AA}}$ | ATLAS and CMS ($p_{\mathrm{T}} > 5$ GeV/$c$),<br>LHCb (forward rapidity) |
| Jets and HF jets | Charged jets $p_{\mathrm{T}}^{\mathrm{jet}} > 10$ GeV/$c$<br>Larger dead cone aperture at low radiator $E$ | ATLAS and CMS ($p_{\mathrm{T}} > 30$ GeV/$c$) |
| Charmonia | J/$\psi$, $\psi$(2S) $p_{\mathrm{T}} > 0$ mid- and fwd-$y$,<br>central-forward correlations | ATLAS and CMS ($p_{\mathrm{T}} > 3$ GeV/$c$),<br>LHCb (forward rapidity) |
| Low-mass central diffraction | $\pi$, K, p PID $p_{\mathrm{T}} > 0.15$ GeV/$c$ mid-$y$ | LHCb (forward rapidity) |
| Low-mass dielectrons | e ID $p_{\mathrm{T}} > 75$ MeV/$c$ | — |

* possible in CMS only in Run 4 and with extended running (years) at low rate (min-bias readout rate CMS Run 4: $< 250$ kHz i.e. 2–5 times lower than ALICE).

# Probing QGP with heavy quarks

$R_{AA}$ = yield in AA per NN / yield in pp

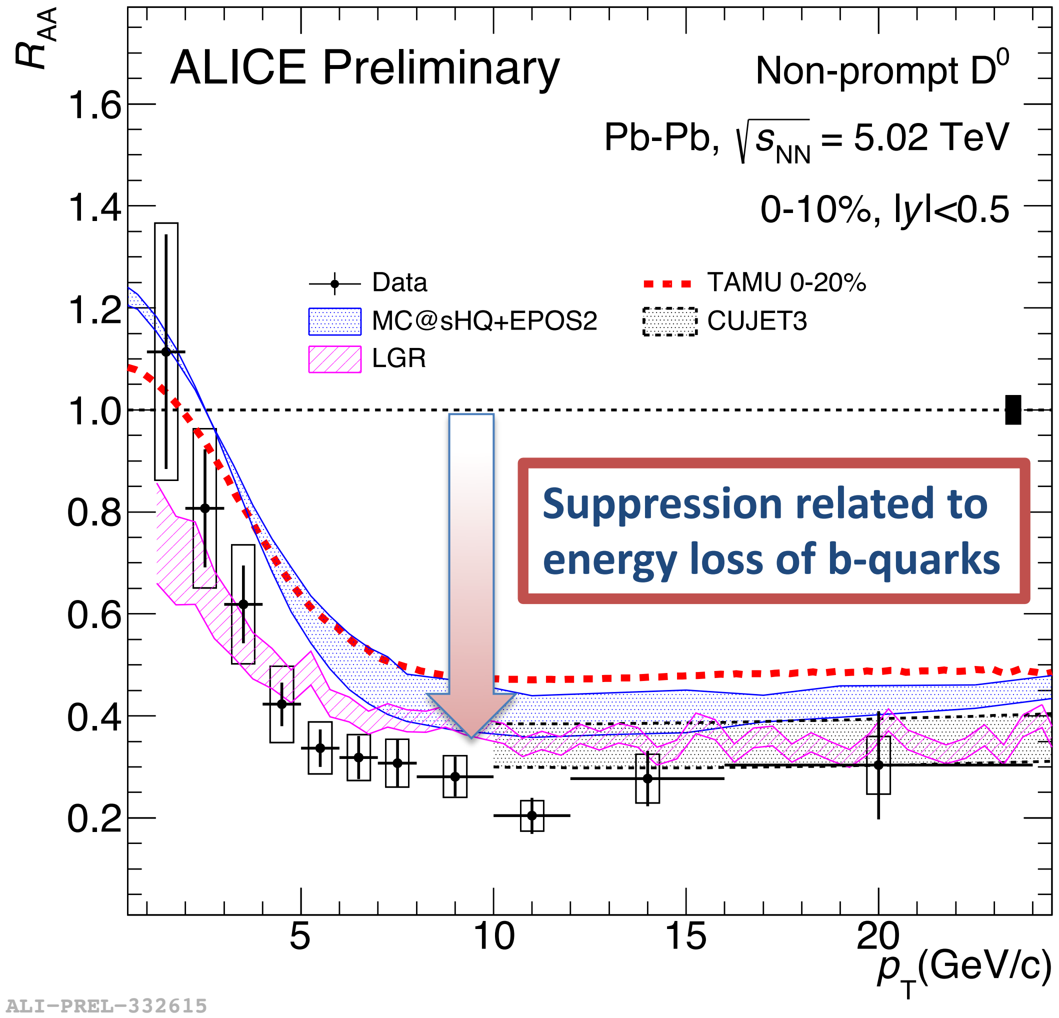
$R_{AA}$ = 1 at high pT ⇔ no nuclear effects

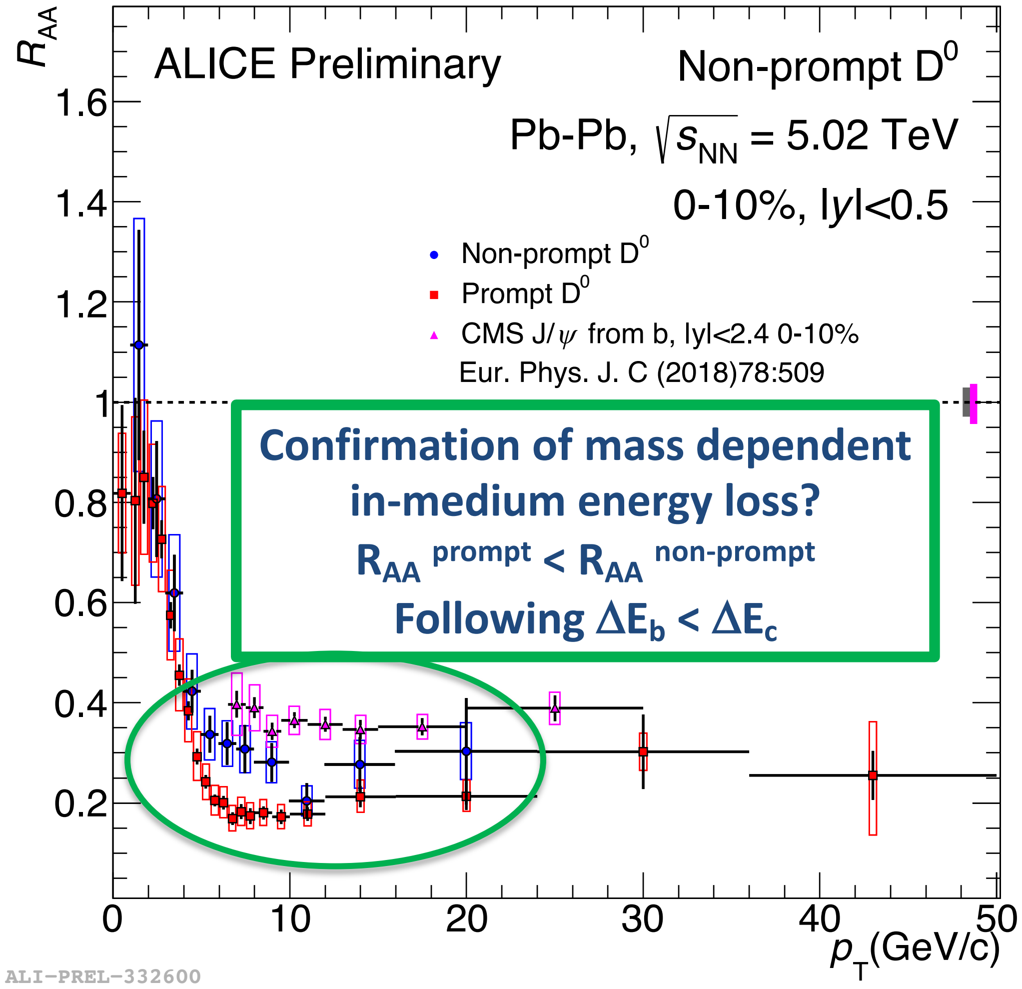
ALICE

Heavy quarks produced early – large mass – well calibrated probe

Expectation: beauty looses less energy in QGP as compared to lighter charm (dead-cone effect)

NEW



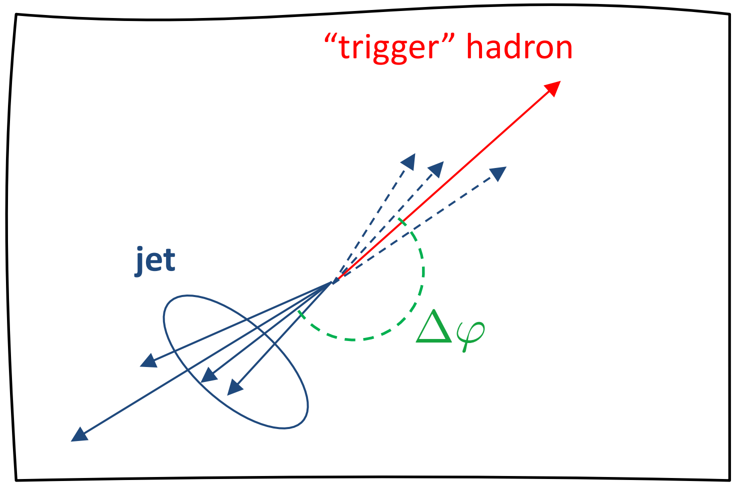
Talk by J. Mulligan

# First measurements of N-subjettiness in central Pb–Pb

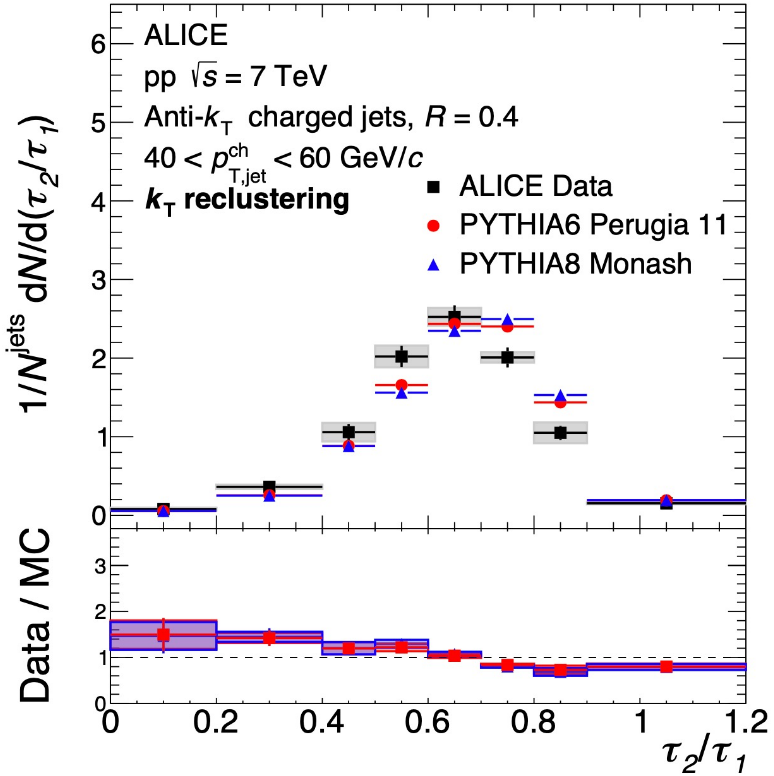
## $\tau_2/\tau_1$ sensitivity to the rate of two-pronged jet substructure

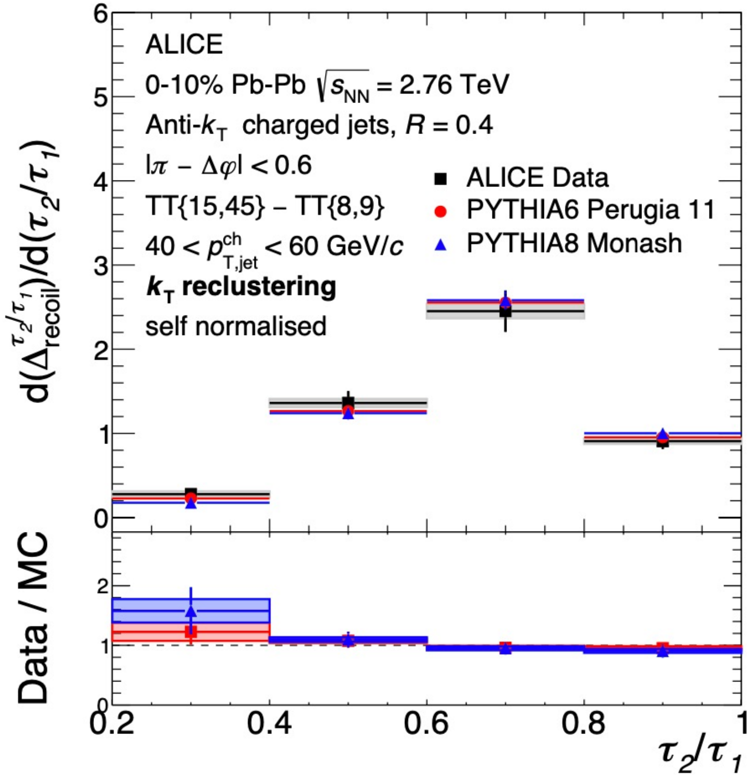
arXiv:2105.04936 **[nucl-ex]**

$$\tau_N = \frac{1}{p_{\mathrm{T,jet}} \times R} \sum_k p_{\mathrm{T},k} \, \mathrm{minimum}(\Delta R_{1,k}, \Delta R_{2,k}, ...., \Delta R_{\mathrm{N},k})$$




$$\Delta_{\mathrm{recoil}}^{\tau_2/\tau_1} = \frac{1}{N_{\mathrm{trig,Sig}}} \frac{\mathrm{d}^2 N}{\mathrm{d}p_{\mathrm{T,jet}}^{\mathrm{ch}} \mathrm{d}\tau_2/\tau_1}\bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT_{Sig}}} - \frac{1}{N_{\mathrm{trig,Ref}}} \frac{\mathrm{d}^2 N}{\mathrm{d}p_{\mathrm{T,jet}}^{\mathrm{ch}} \mathrm{d}\tau_2/\tau_1}\bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT_{Ref}}}$$




⇒ **pp Data: Important input for MC generators**

⇒ **Pb-Pb: Hint of modification in central Pb-Pb collisions**

⇒ **Medium induced radiation modifies the structure only slightly (consistent with measurements of $z_g$)**