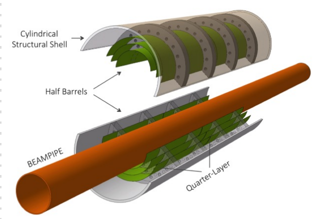
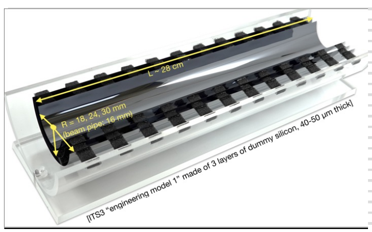
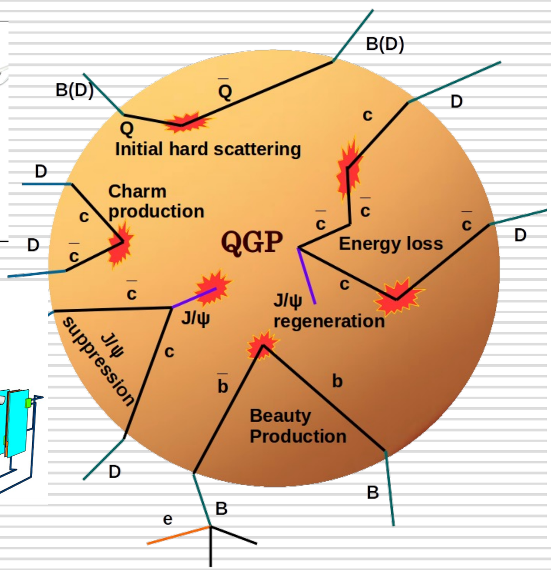
Heavy flavour physics and detector upgrades

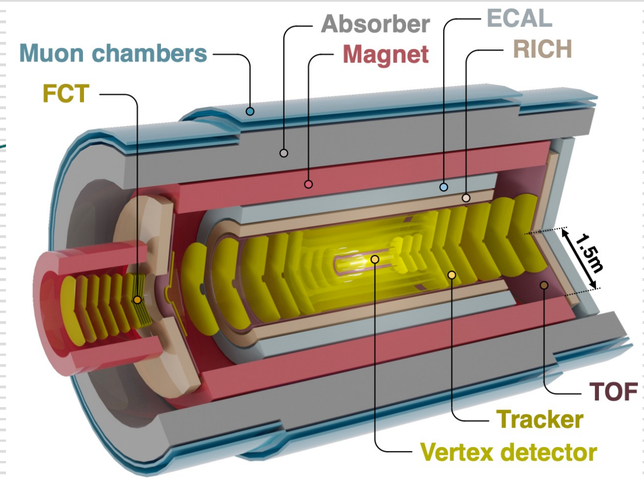
Giuseppe Bruno

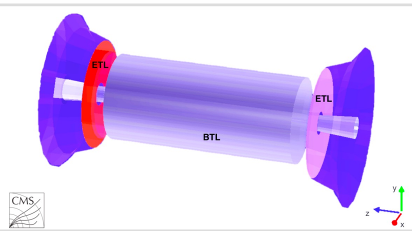
Dipartimento di Fisica and INFN – Bari –Italy

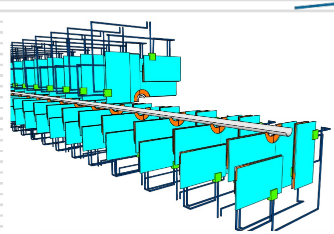












Workshop on High Luminosity LHC and Hadron Colliders

Frascati - October the 3rd 2024

Heavy flavour physics and detector upgrades

Dipartimento Interateneo di Fisica
Michelangelo Merlin

Giuseppe Bruno
Dipartimento di Fisica and INFN – Bari –Italy

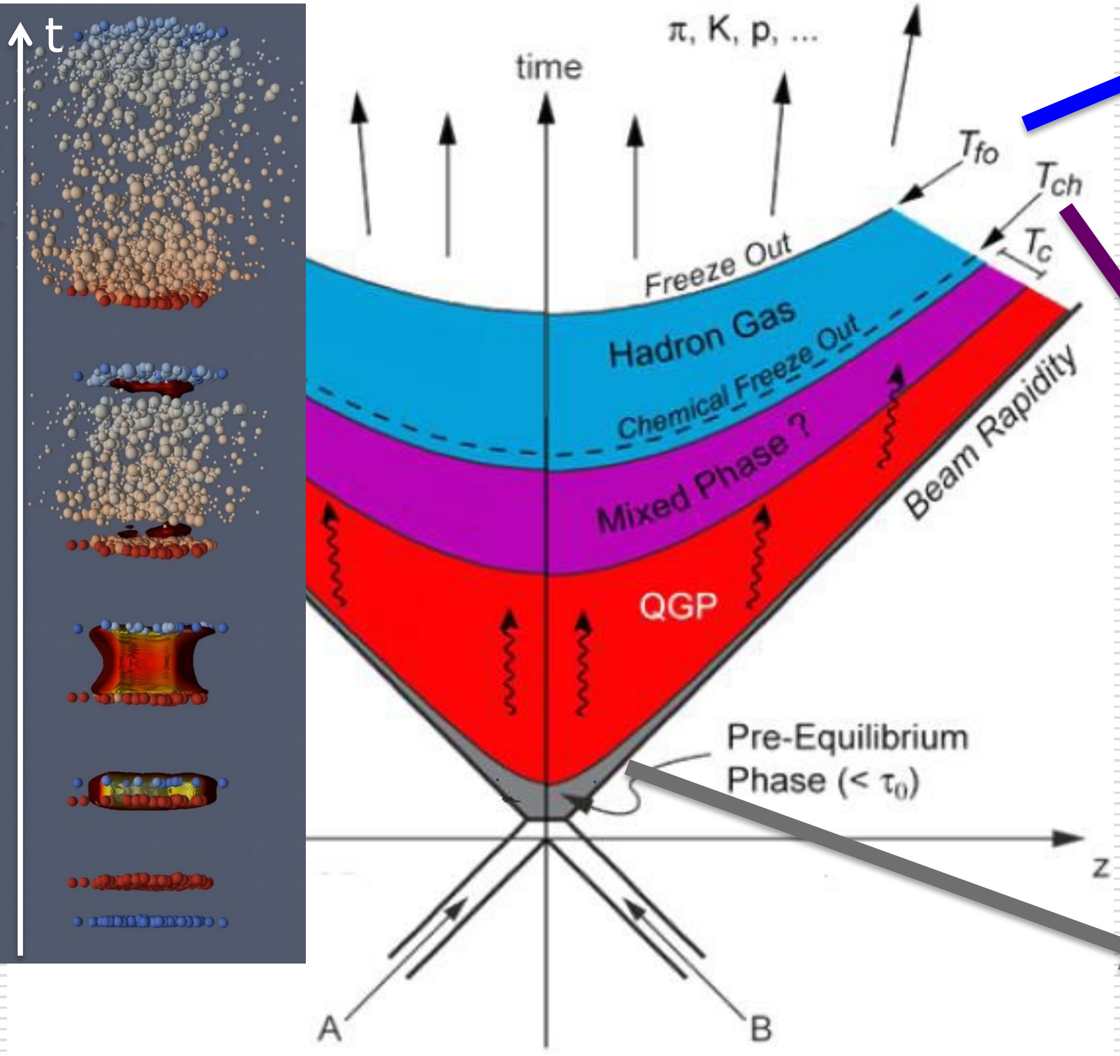
INFN

Outline:

- Introduction
- Heavy flavour as a key probe of the QGP
  - results from LHC run2(+3) in HI
- Detector upgrades in LS3 and LS4
- Conclusions and remarks

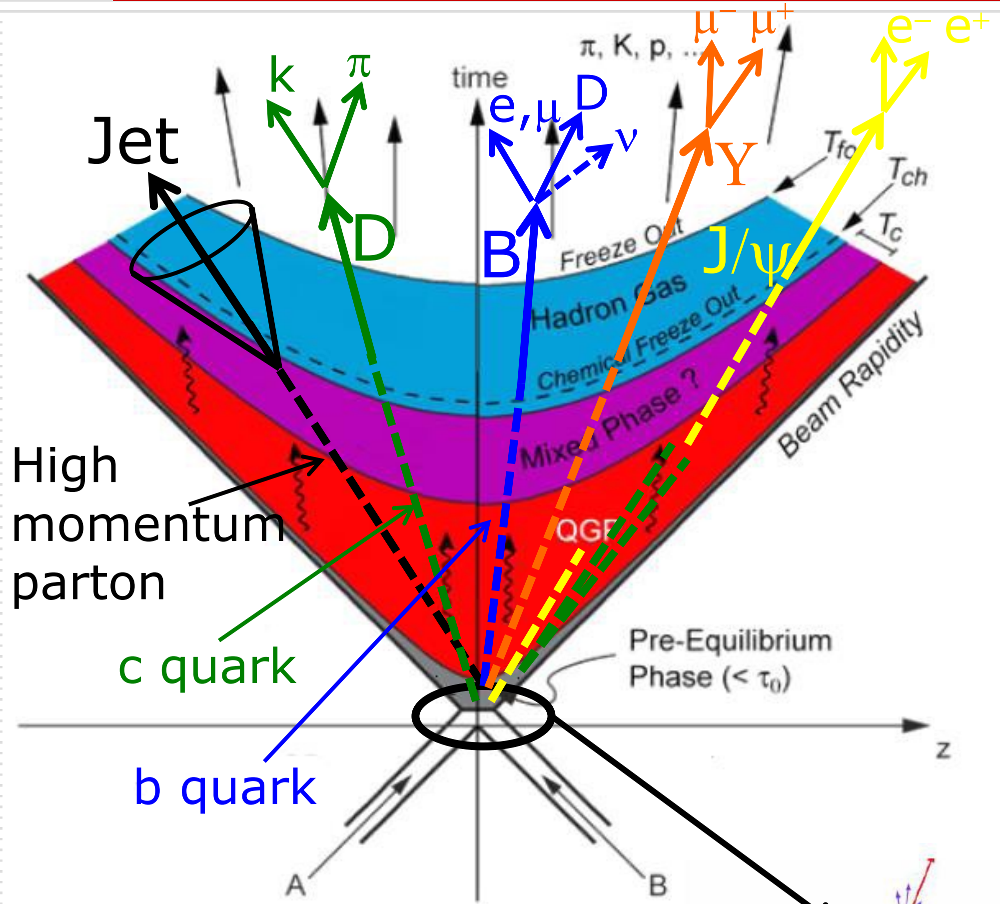
Frascati - October the 3rd 2024

Space time evolution of A-A collision



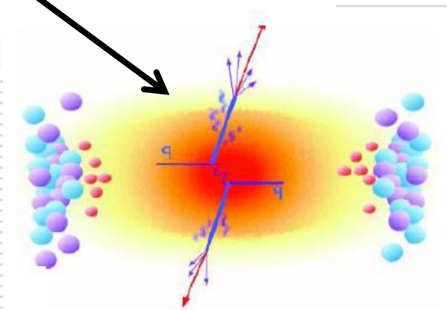
- **Thermal freeze-out**
  - Elastic interactions cease
  - Particle dynamics ("momentum spectra") fixed
  - T_{fo} ~ 110-120 MeV
- **Chemical freeze-out**
  - Inelastic interactions cease
  - Particle abundances ("chemical composition") are fixed
  - T_{ch} ~ 155 MeV
- **Thermalization time**
  - System reaches local equilibrium
  - τ_{eq} ~ 0.5 fm/c

Hard probes of A-A collision

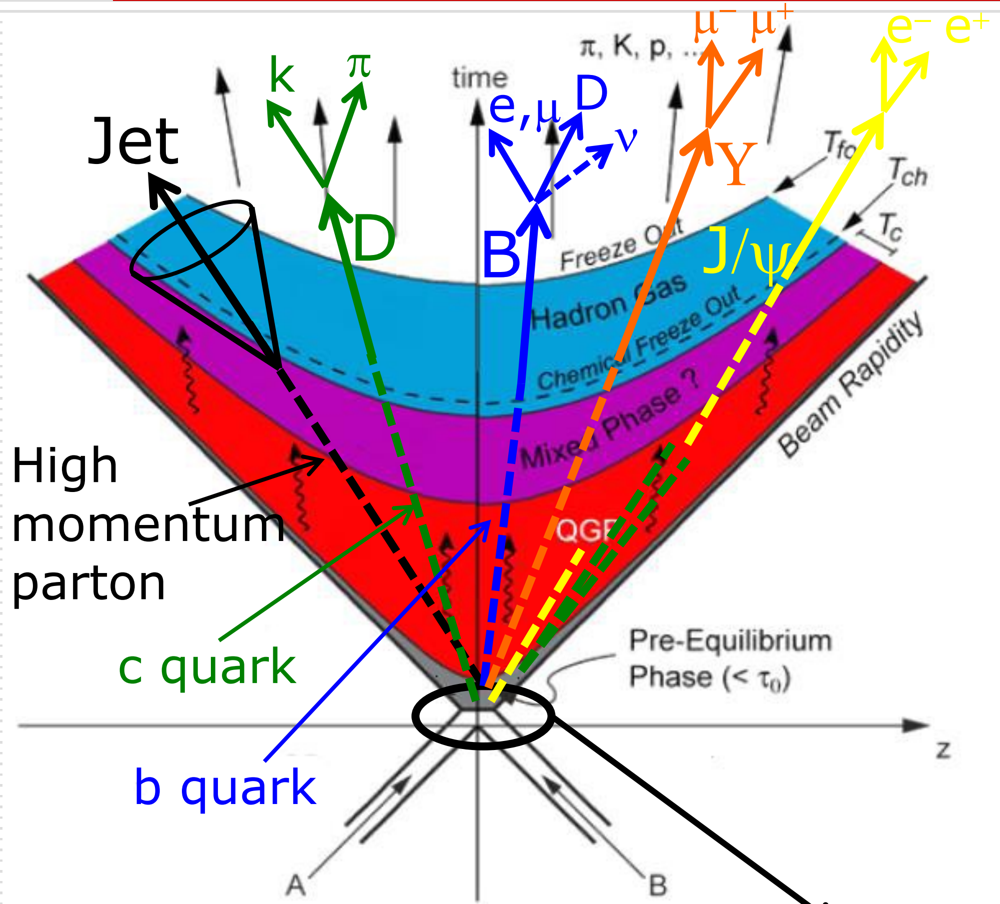


- Hard probes in nucleus-nucleus collisions:
  - produced at the very early stage of the collisions in partonic processes with large Q^2
  - pQCD can be used to calculate initial cross sections
  - traverse the hot and dense medium
  - can be used to probe the properties of the medium

$$\tau_f = \frac{\hbar}{m_T} \qquad m_T = \sqrt{m^2 + p_T^2}$$



Hard probes of A-A collision



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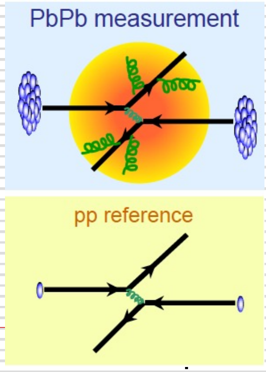
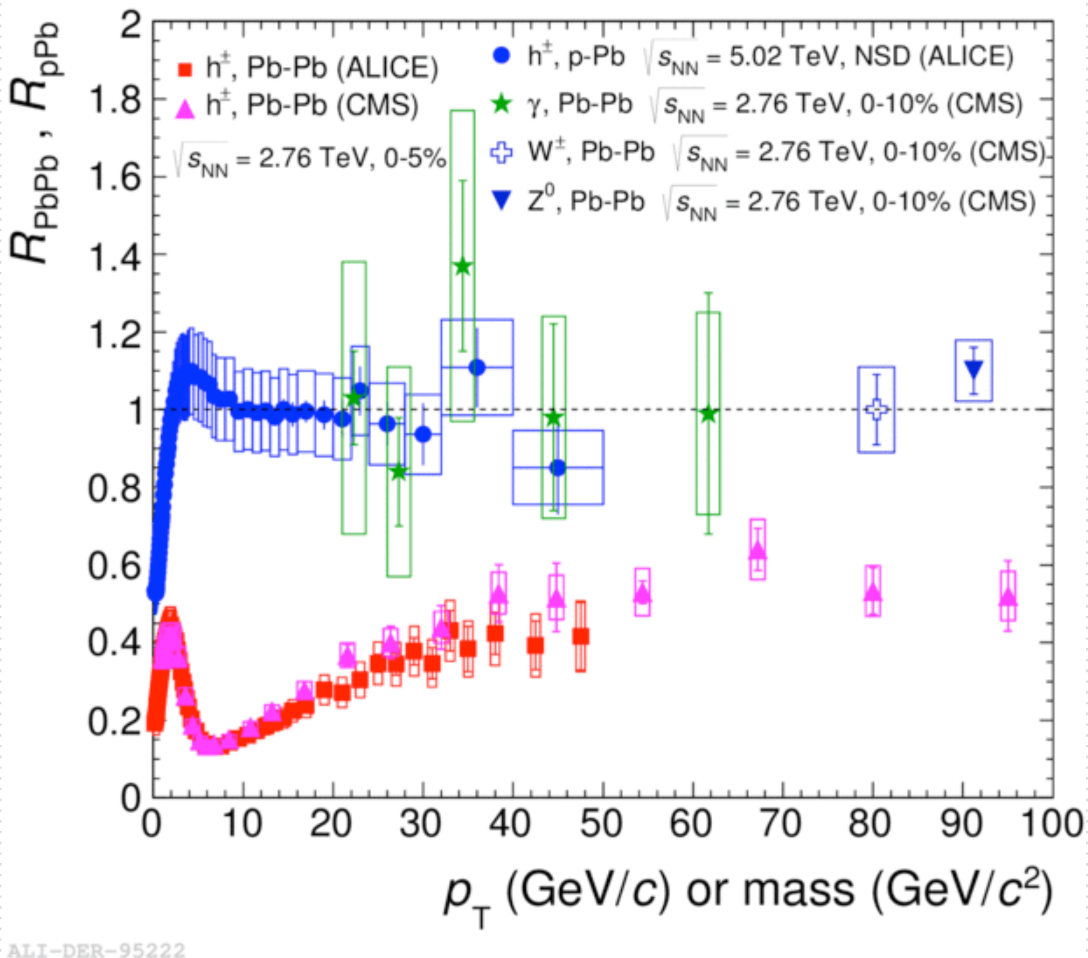
$$R_{AA} = \frac{1}{N_{coll}} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T} = \frac{1}{T_{AA}} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T} \sim \frac{\text{QCD medium}}{\text{QCD vacuum}}$$

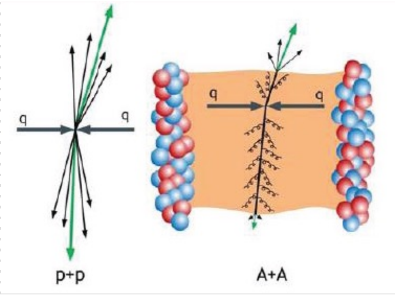


Nuclear modification of unidentified charged particles

- The easiest way to study the "jet quenching"
  - a few days of data taking → **Run1 result**



- physics interpretation:
  - scattered parton (high p_t) looses energy while traversing the medium
    - collisional energy loss
    - radiative energy loss (gluonstrahlung)



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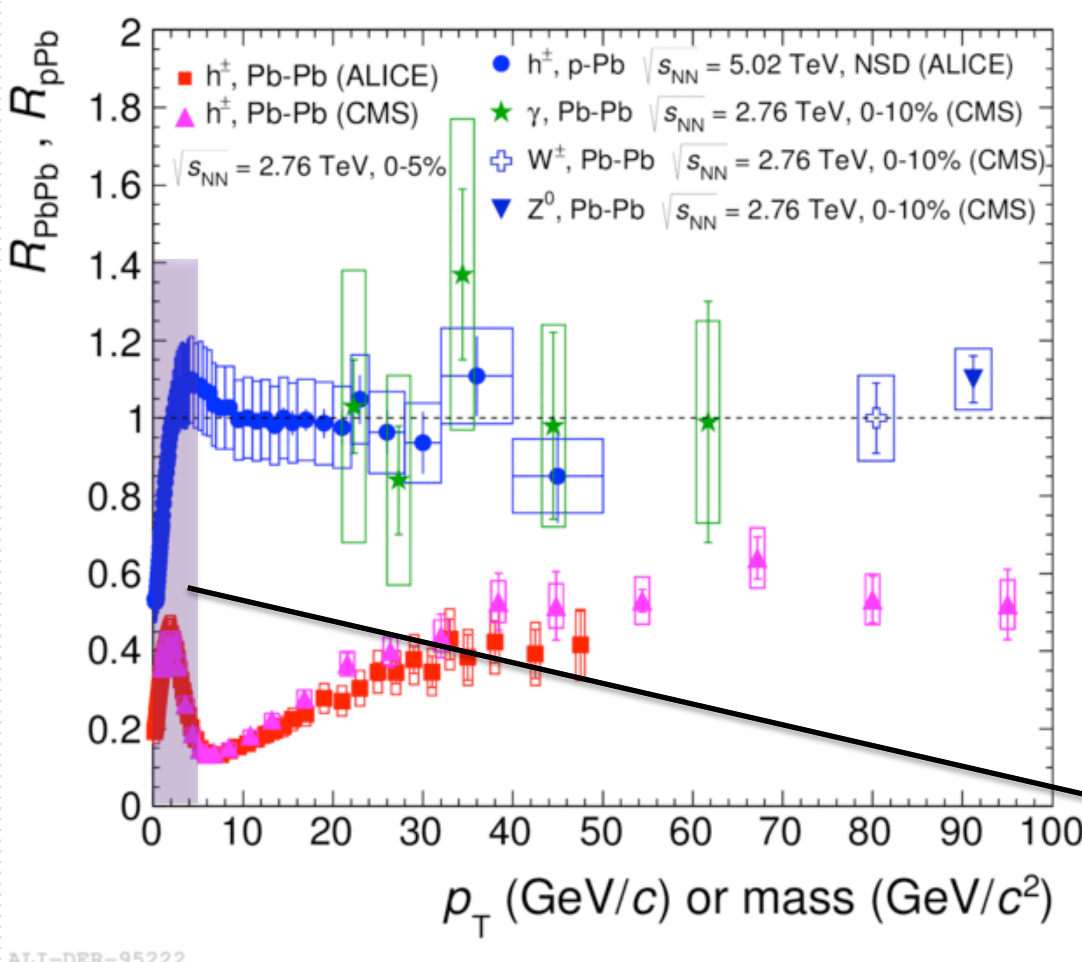

- physics interpretation:
  - scattered parton (high p_t) looses energy while traversing the medium
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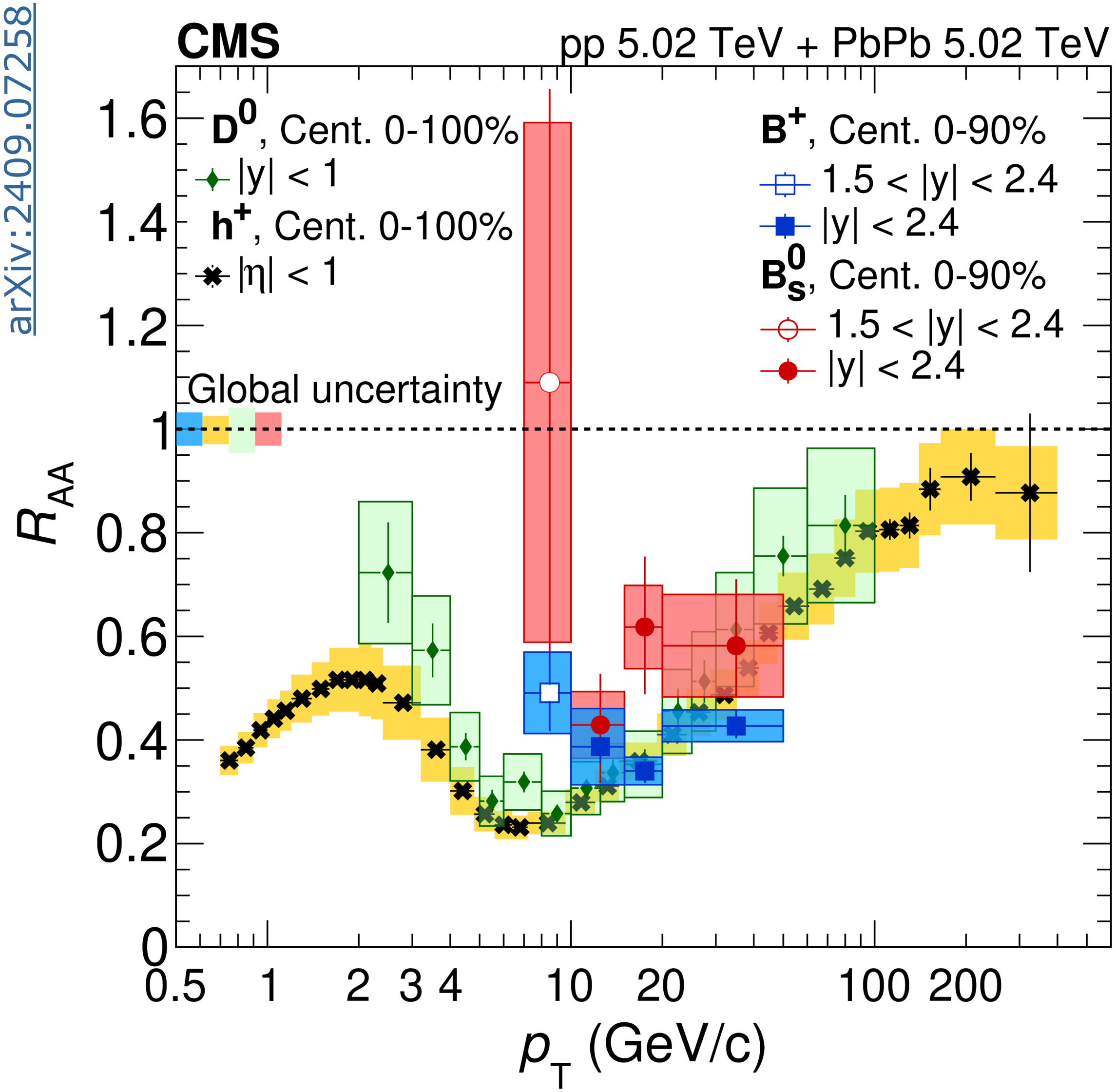
For light flavour N_{coll} scaling doesn't hold at low p_T

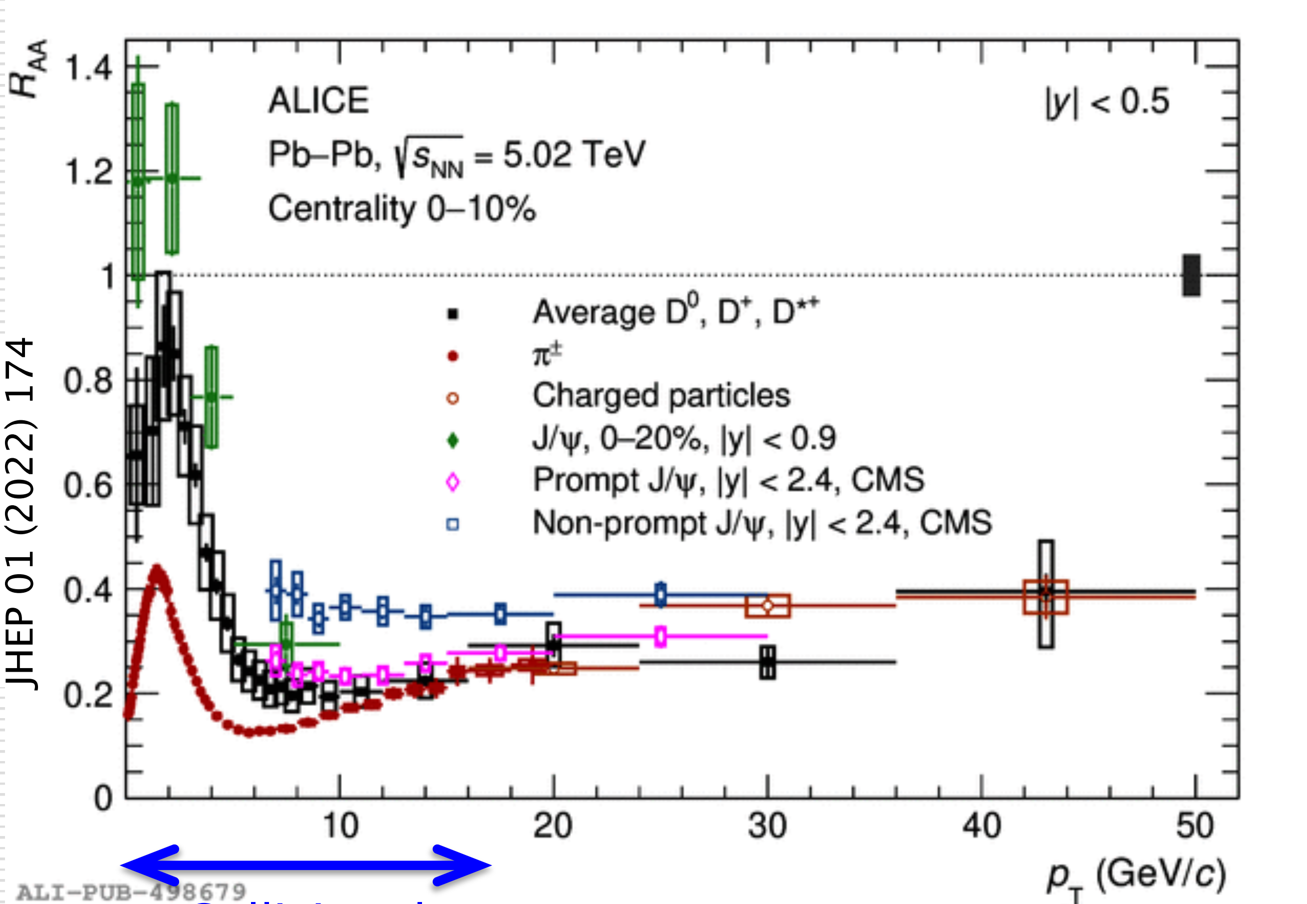
R_{AA} for heavy flavour

arXiv:2409.07258



- More difficult!
- It has required the full LHC Run2
- At high p_T: R_{AA} of all flavor identified hadrons tend to converge above ~ 20-30 GeV

p_T range drives the physics



the lower the better !

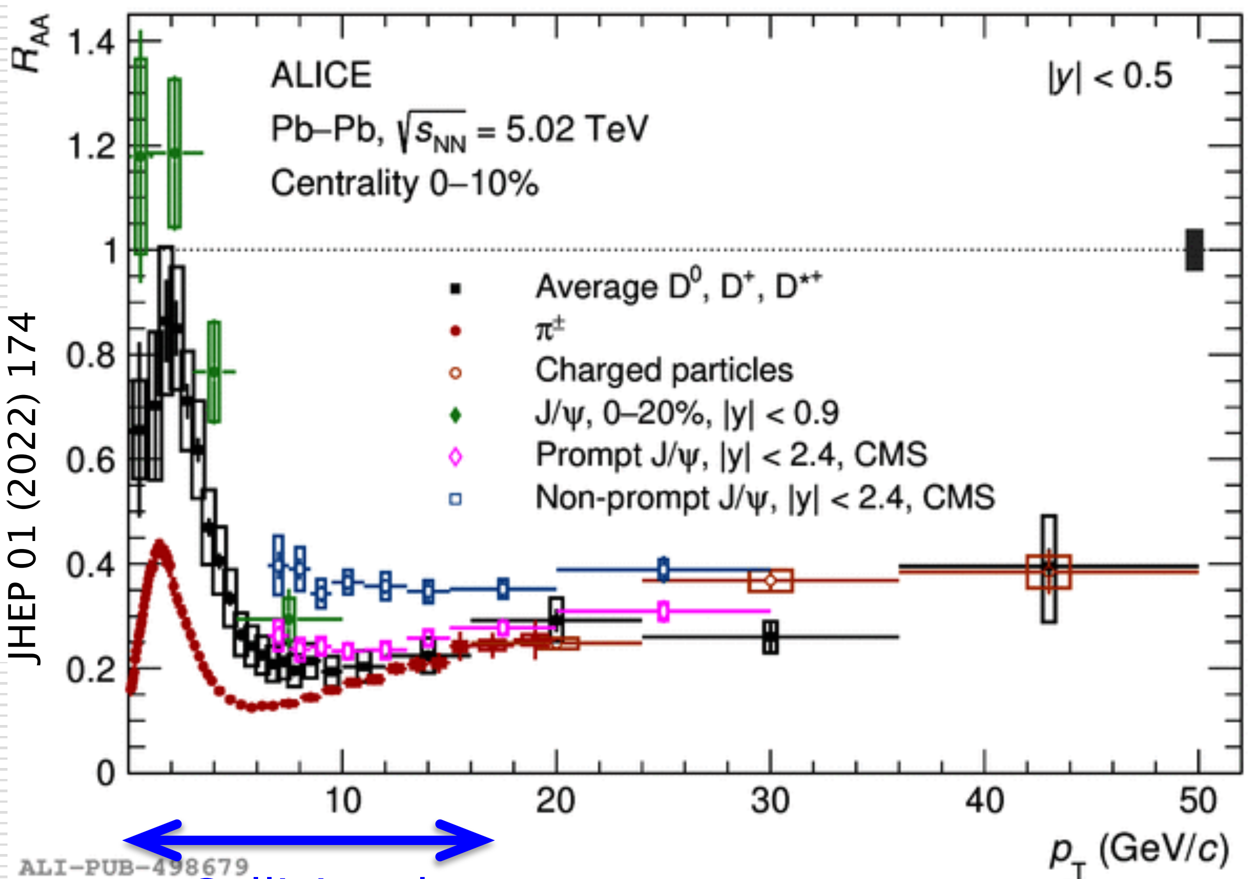
also for other observables, e.g. v_2

Collisional dE/dx relevant

Radiative dE/dx dominates

Bulk of production
recombination relevant (even dominant for J/ψ)

p_T range drives the physics



Energy loss depends on:

- Color charge $\Delta E_g > \Delta E_{u,d,s}$
- Parton mass $\Delta E_c > \Delta E_b$

At the parton level:

$\Delta E_g > \Delta E_{u,d,s} \gtrsim \Delta E_c > \Delta E_b$

Naive expectation:

$R_{AA}(\pi) > R_{AA}(D) > R_{AA}(B)$

But different production kinematics and fragmentation of light and heavy quarks to be taken into account

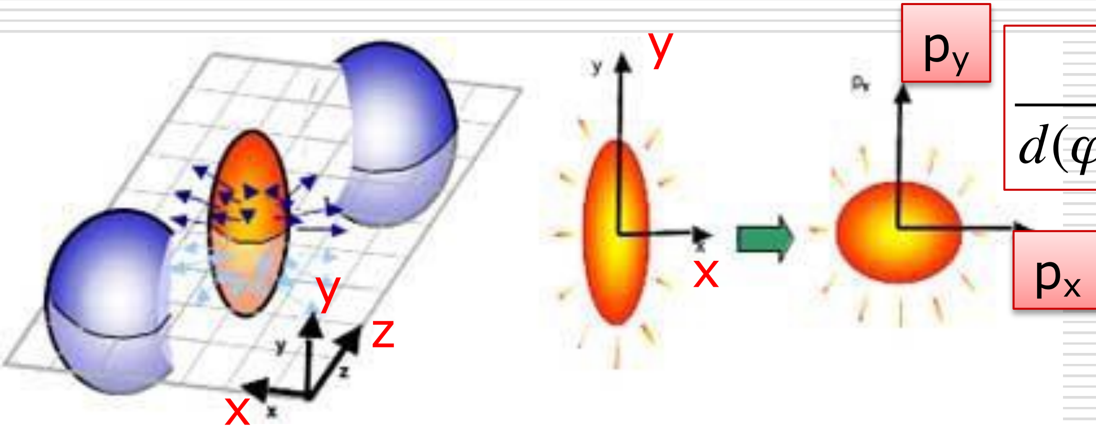
Collisional dE/dx relevant

Radiative dE/dx dominates

Bulk of production

recombination relevant (even dominant for J/ψ)

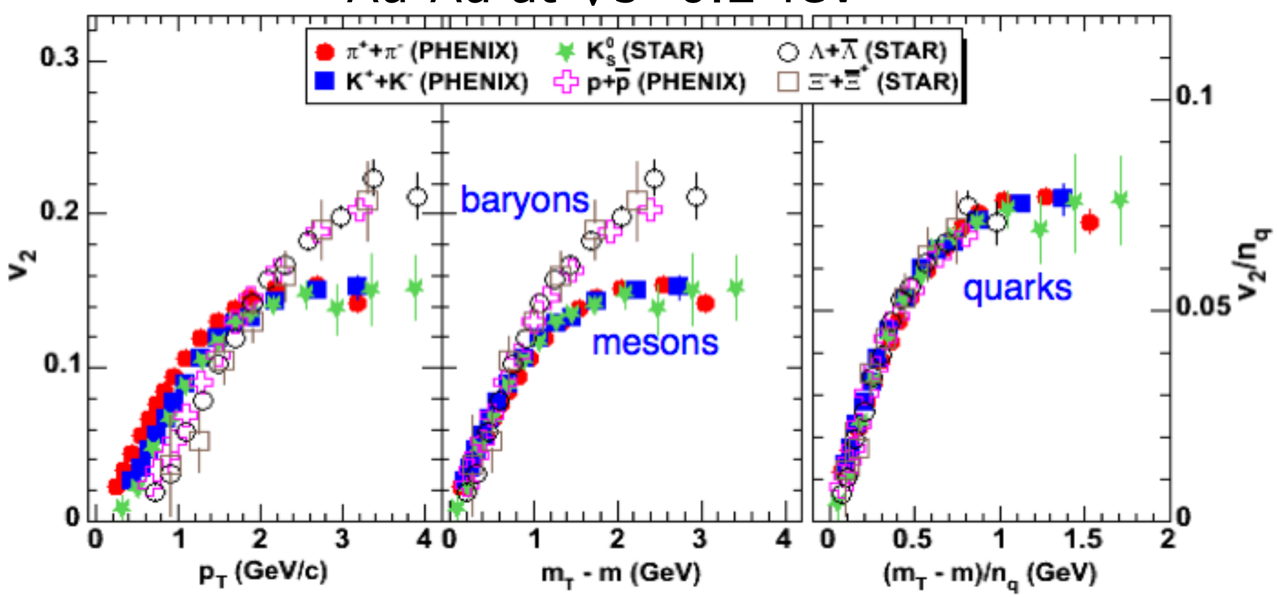
Azimuthal anisitropy



$$\frac{dN}{d(\varphi-\psi_{RP})} \propto 1+2\sum_{n=1} v_n \cos\left(n[\varphi-\psi_{RP}]\right)$$

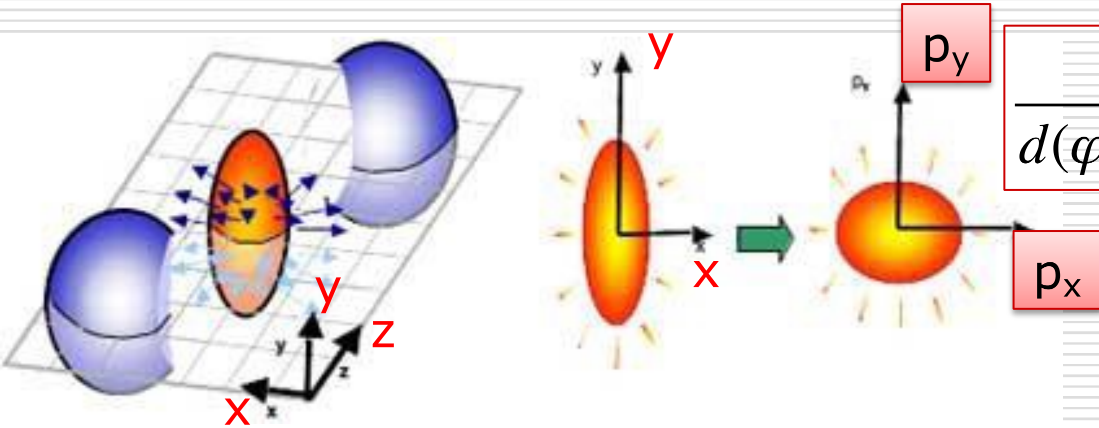
$$v_2 = \left\langle \cos\left[2(\varphi-\psi_{RP})\right]\right\rangle$$

Au-Au at √s=0.2 TeV



At √s=0.2 TeV nice scaling with n_q

Azimuthal anisitropy



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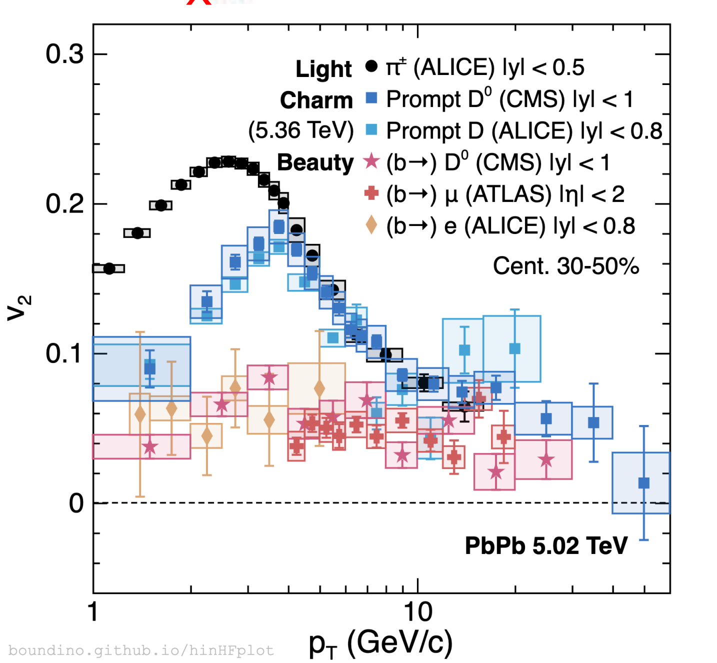
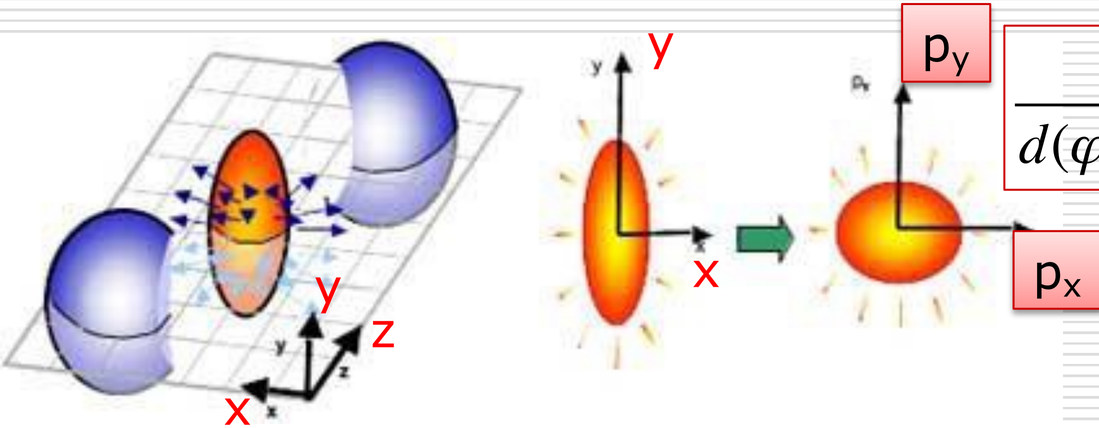


collective flow ⟷ path dependent dE/dx

Open HF

- Charm quarks definitely take part in **collective motion**
  - Strong coupling
- Beauty flows to a much lesser extent
  - because of inherited flow from light quark partner in coalescence?

Azimuthal anisitropy



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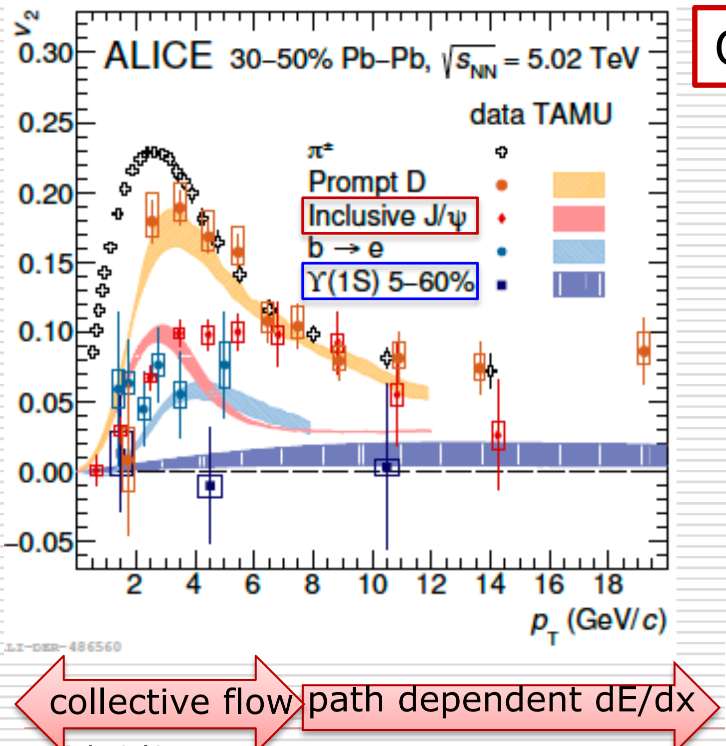


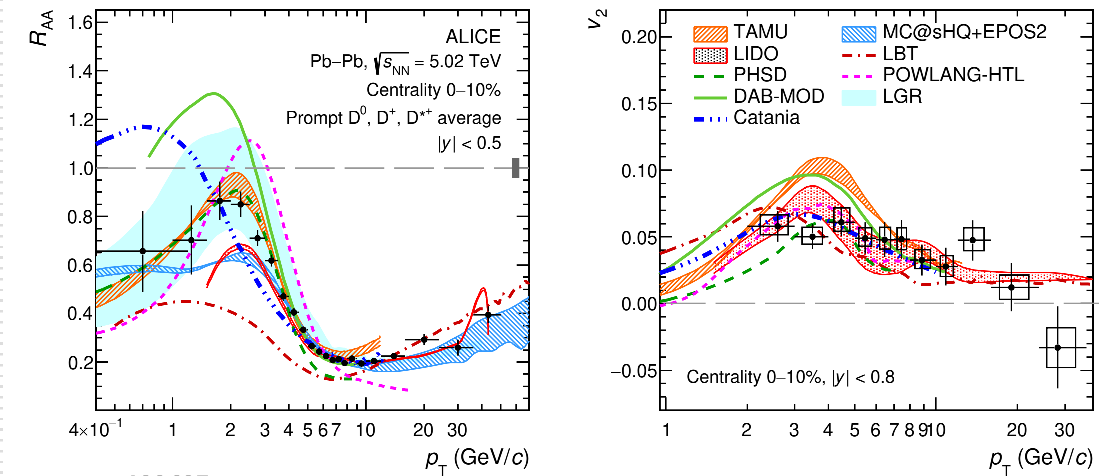
Open HF and quarkonia

- Charm quarks definitely take part in **collective motion**
  - J/ψ has a sizable flow!
- Beauty flows to a much lesser extent
  - because of inherited flow from light quark partner in coalescence?
- Bottomonia: **v_2(Υ(1S)) ~ 0**
  - Negligible recombination

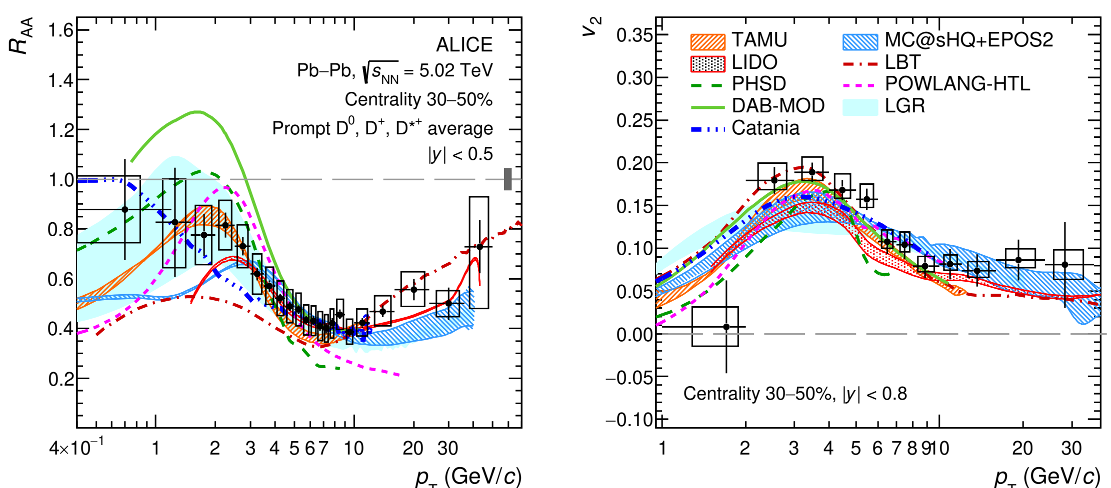
0~$v_2^{(\Upsilon(1S))}$<$v_2^{(b\to e)}$~$v_2^{(\text{Incl } J/\psi)}$< $v_2^{(D)}$<v_2^{h} at low p_T

Prompt D meson R_{AA} and v_2

JHEP 01 (2022) 174



ALI-PUB-498687



ALI-PUB-498691

- TAMU: PRL 124 (2020) 042301
- MC@sHQ+EPOS2: PRC 89 (2014) 014905
- LGR: arXiv:1912.08965
- LIDO: PRC 98 (2018) 064901
- PHSD: PRC 93 (2016) 034906
- Catania: PLB 805 (2020) 135460
- POWLANG: EPJC (2019) 79:494
- LBT: PRC 94 (2016) 014909
- DAB-MOD: arXiv:1906.10768

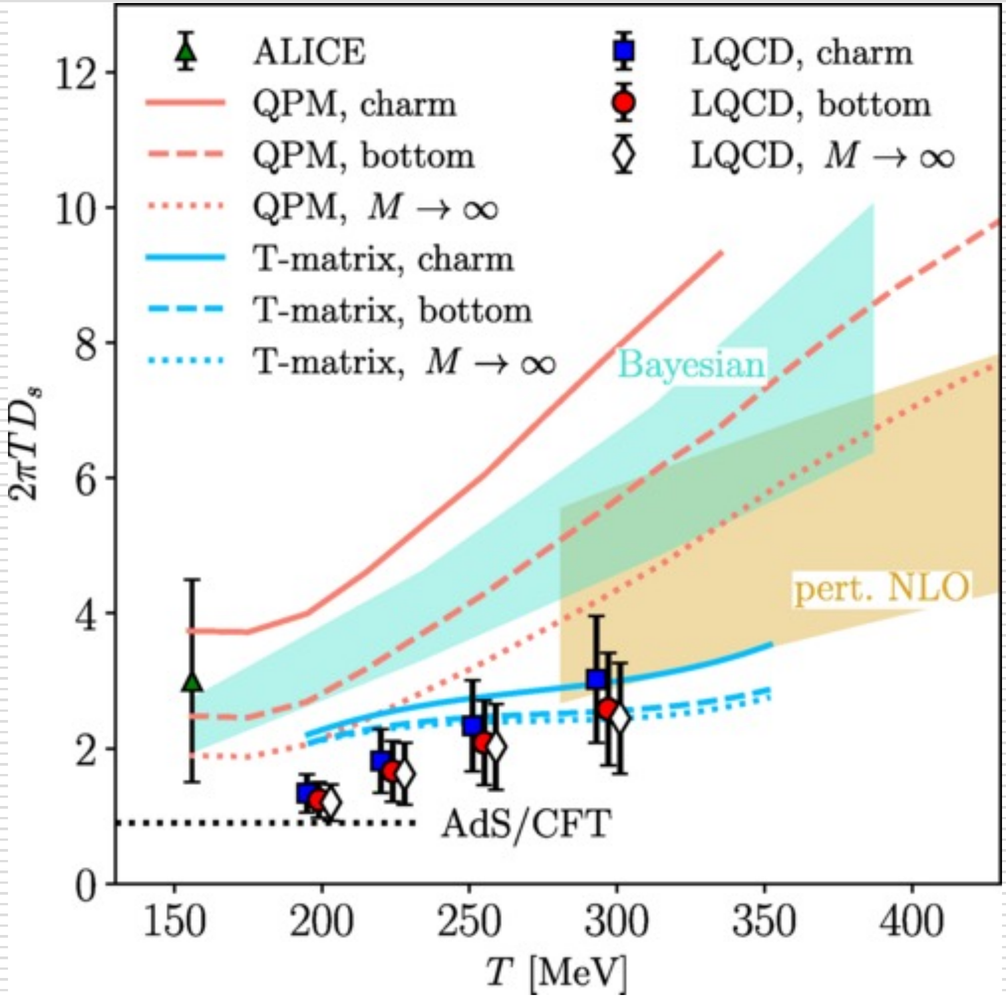
Model ingredients:

- transport of c quarks in an hydrodynamically expanding medium (via Boltzmann or Langevin equations)
- c quark energy loss (elastic and/or inelastic collisions)
- c-quark hadronisation via coalescence

This is "state of the art" after LHC run2

Charm spatial diffusion coefficient

- key transport parameter (quantifies drag, thermal, recoil forces)



From that one derives the drag and momentum diffusion coefficients:

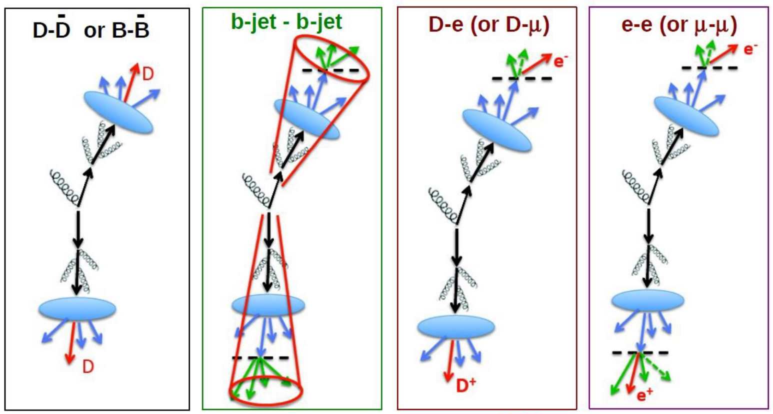
$$\eta_D(\vec{p}, T) = \frac{1}{2\pi T D_s} \cdot \frac{2\pi T^2}{E}$$

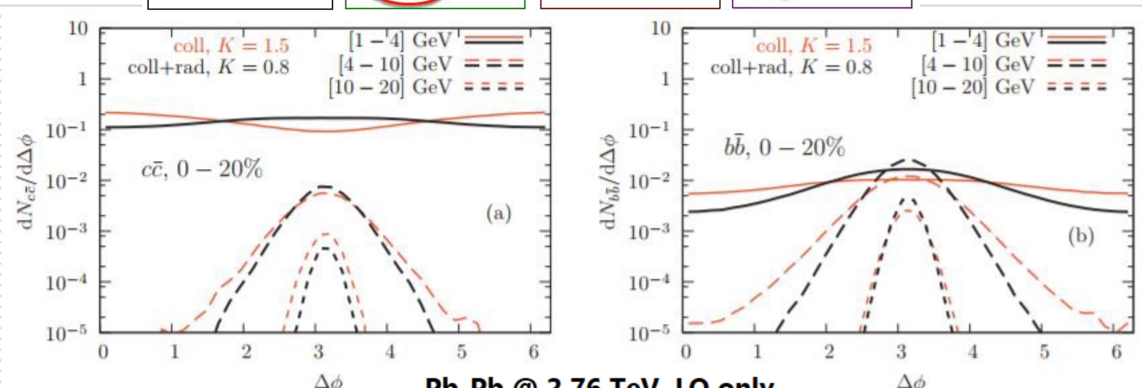
$$\kappa(T) = \frac{1}{2\pi T D_s} \cdot 4\pi T^3.$$

Further discussed in the talk of V. Greco

Angular correlations

- **Characterise energy-loss** of heavy quarks in QGP medium, with sensitivity to specific ΔE mechanisms
  - D-Dbar correlations sensitive to parton-level initial angular correlation
- sensitive to parton-level initial angular correlation
- A very tough measurement
  - huge combinatorial background in Pb-Pb
  - out of reach with fully reconstructed hadron decay in LHC run3&4





PRC 90 (2014) 024907

Pb-Pb @ 2.76 TeV, LO only
→ Initial distrib.: Δφ=π

Angular correlations

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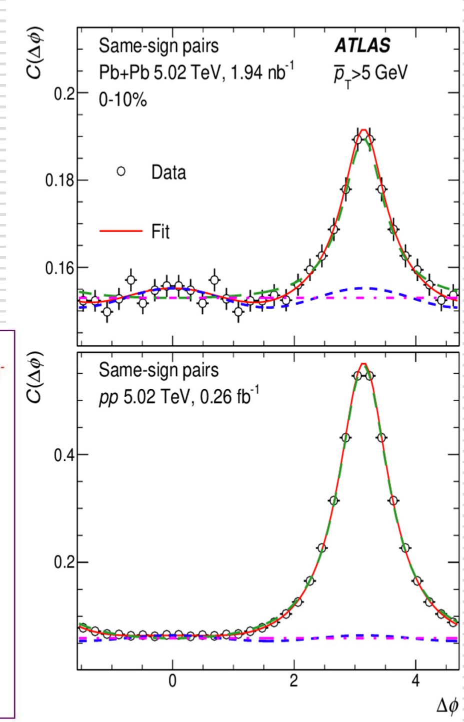
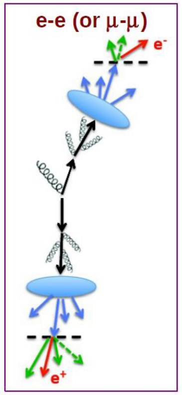
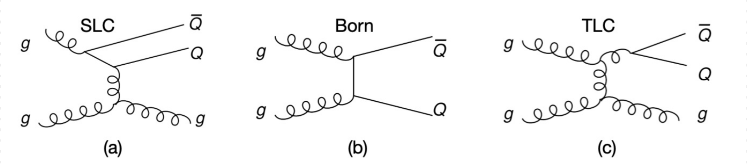
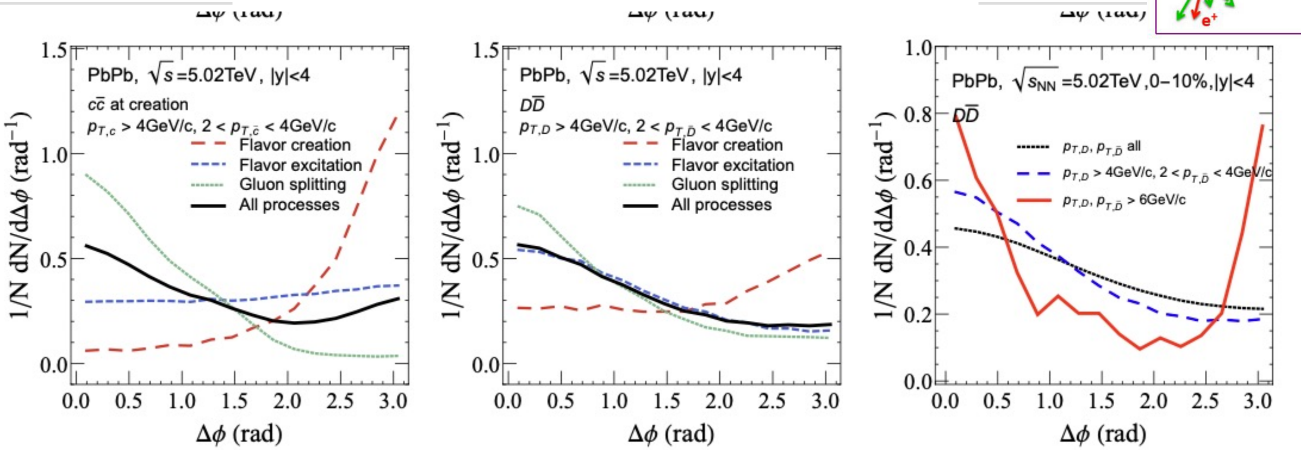
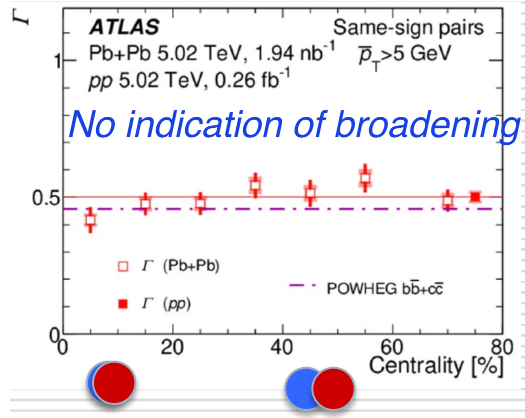






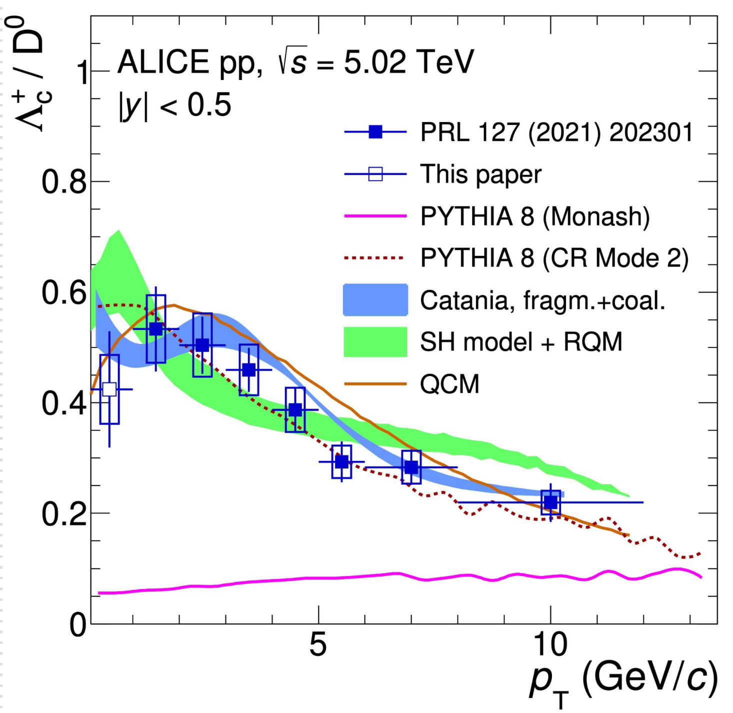


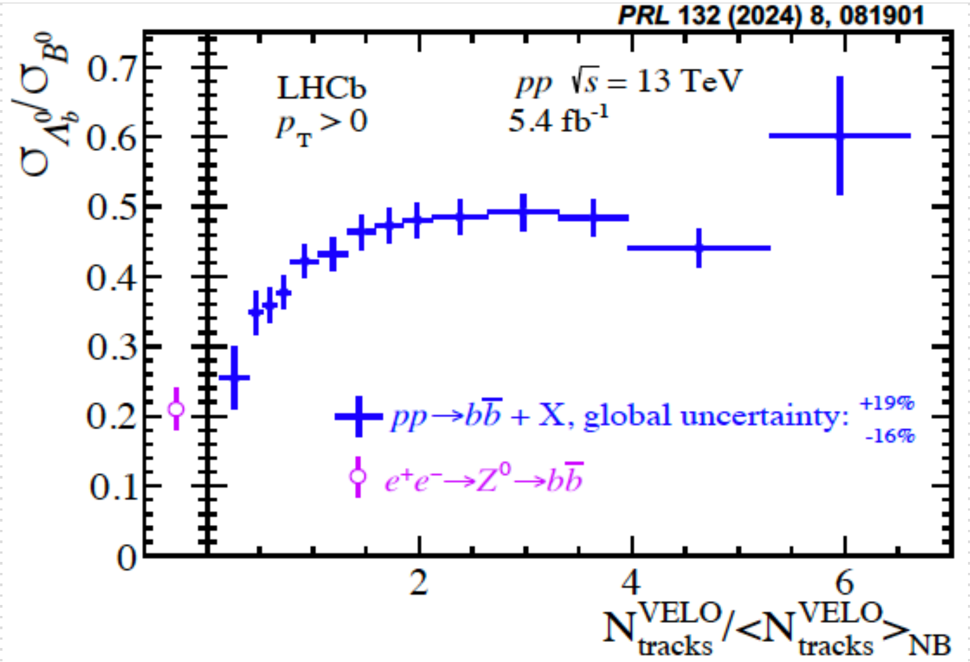
arXiv:2407.20919



No indication of broadening

Baryons *(the HF baryons)*



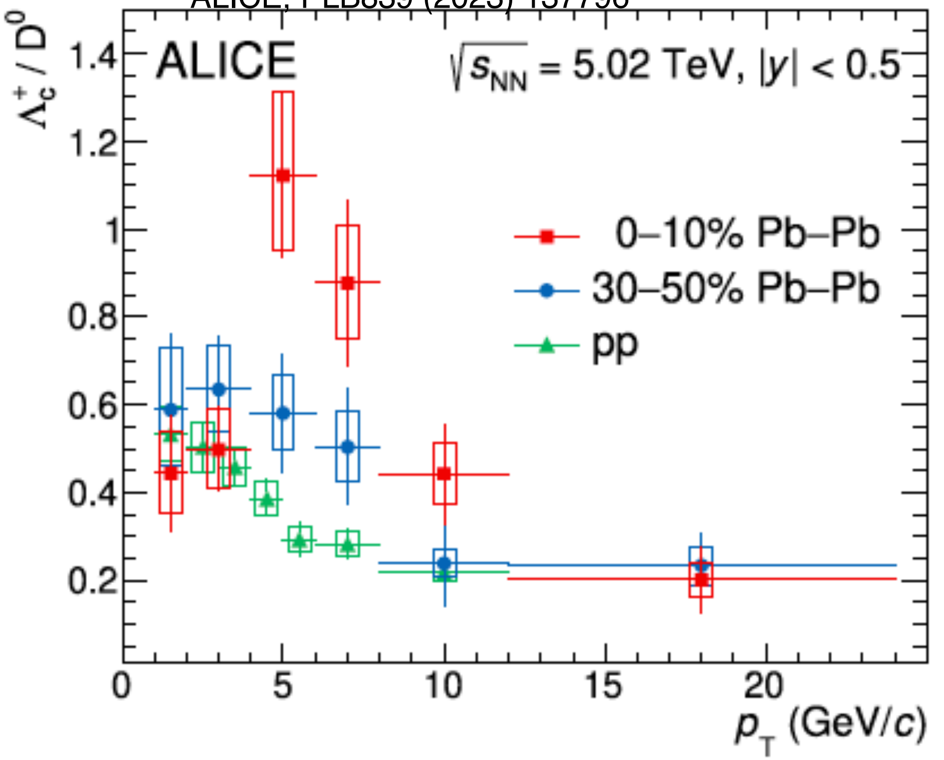


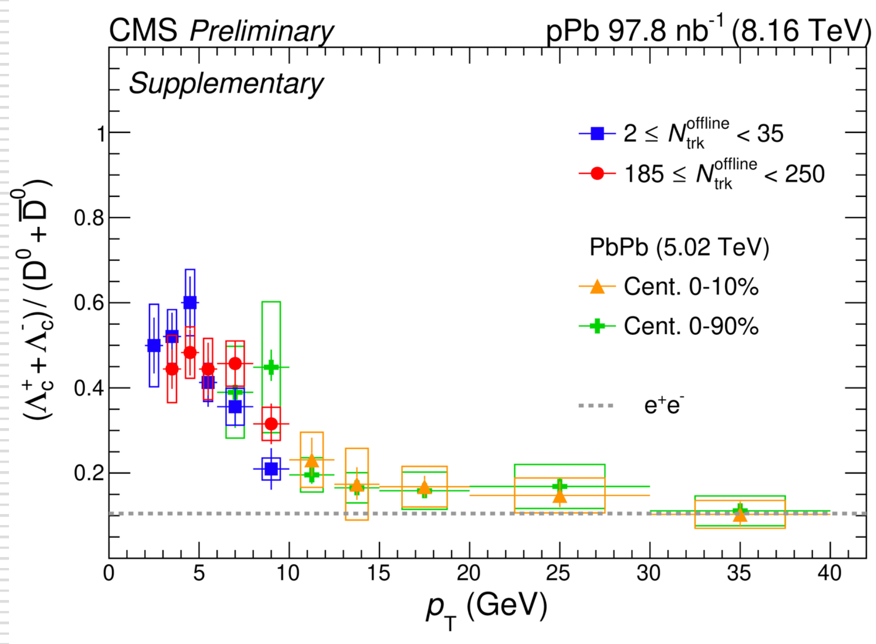
- Already in pp unexpected results
  - fragmentation functions are **not universal** among different collision systems

HF baryon/meson ratio enhanced in p+p compared to e^+e^-, ep

Baryons in pPb and PbPb

ALICE, PLB839 (2023) 137796



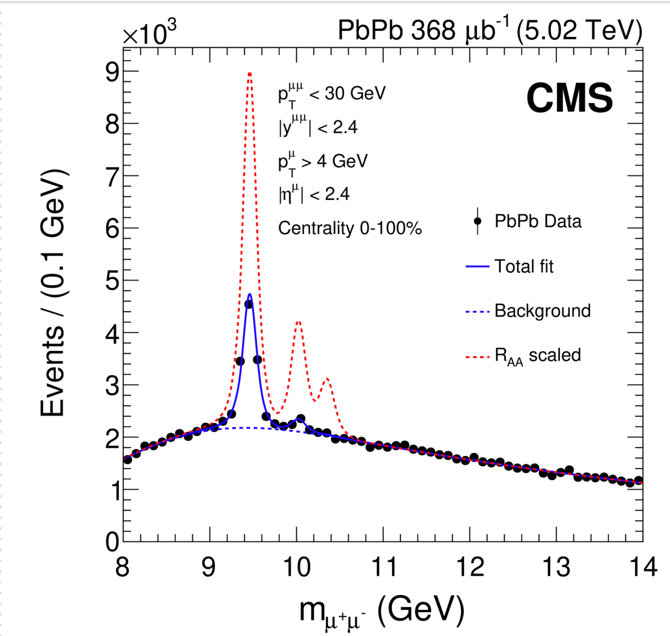


Further discussed later in this session

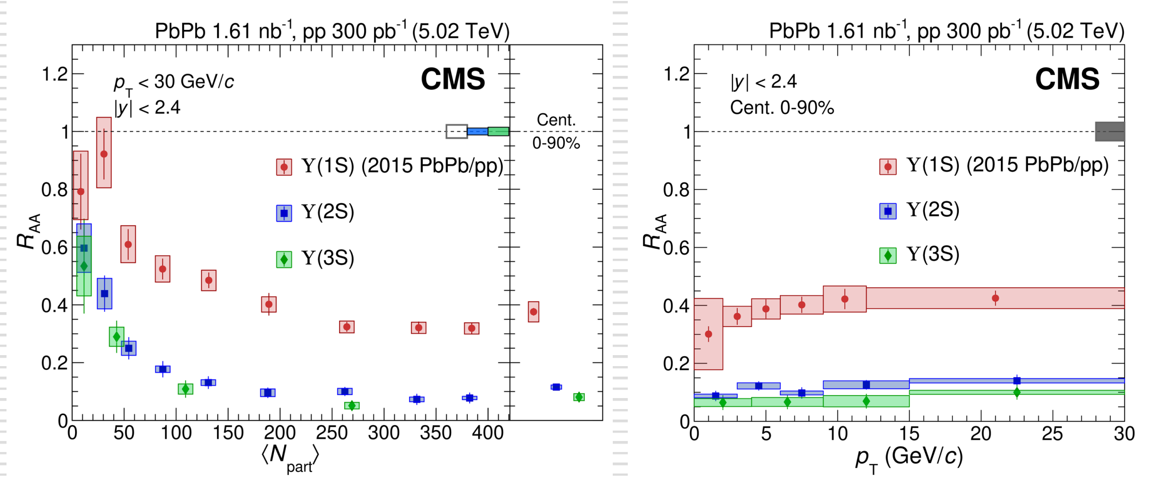
Quarkonia

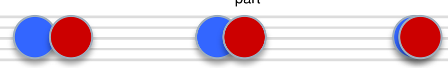
- Two «discoveries» at the LHC
  1. Sequential dissociation of the Υ(nS) states

PLB 790 (2019) 270



PRL 133 (2024) 022302





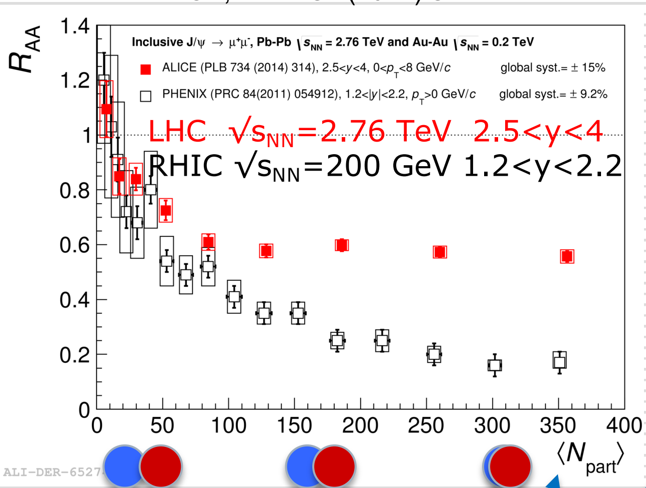
- larger suppression with increasing centrality and at low p_T

Υ(1S) suppression as due to suppression of its feed-down components

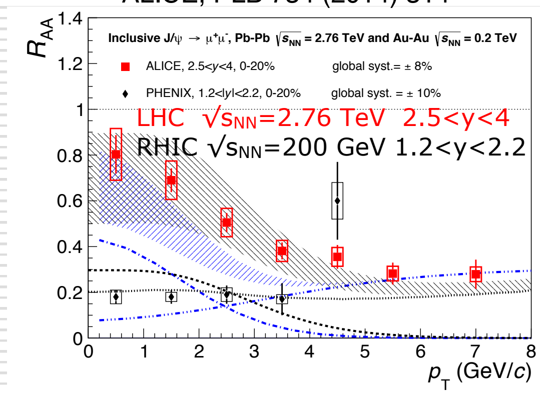
Quarkonia

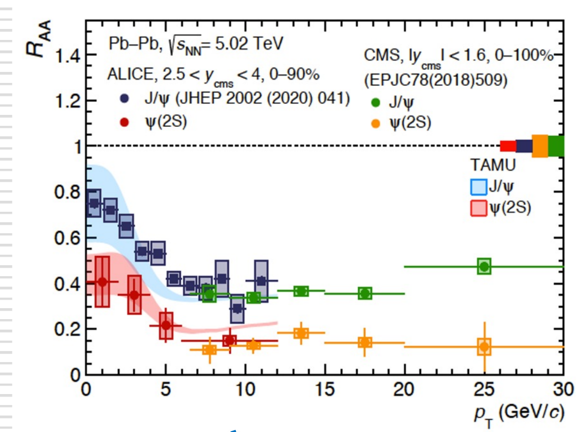
- Two «discoveries» at the LHC
  2. Bulk of charmonia produced via ccbar recombination from the QGP

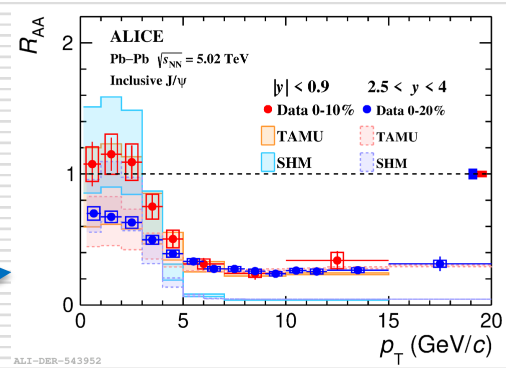
ALICE, PLB 734 (2014) 314



ALICE, PLB 734 (2014) 314



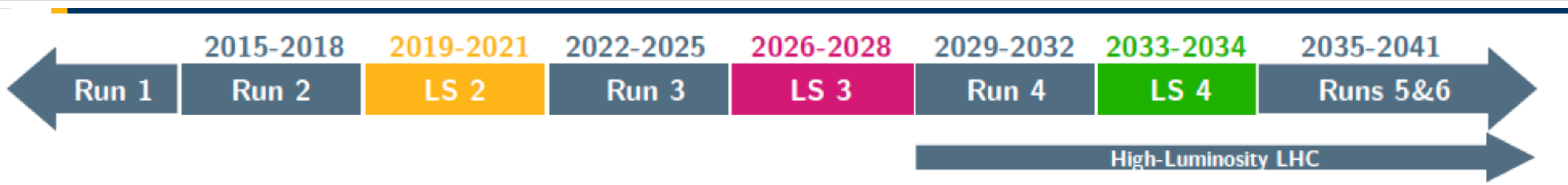




- Smaller suppression at higher √s (→ higher T)
  - It is a low-p_T effect
- Higher R_{AA} at mid-rapidity
  - Larger dN_{ccbar}/dy

Sequential suppression of ψ(2S)

Detecor upgrades



ALICE:

- LS 2
  - new ITS & new Muon Forward Tracker (MFT)
  - TPC upgrade + continuous readout
- LS 3
  - Forward Calorimeter (FoCal)
  - ITS3: ultralight cylindrical vertexer
- LS 4
  - ALICE 3: completely new detector

LHCb:

- LS 2
  - VELO & Upstream tracker upgrades
  - Calorimeter. & muon upgrades
- LS 3
  - Smaller detector consolidation & enhancements
- LS 4
  - LHCb Upgrade II

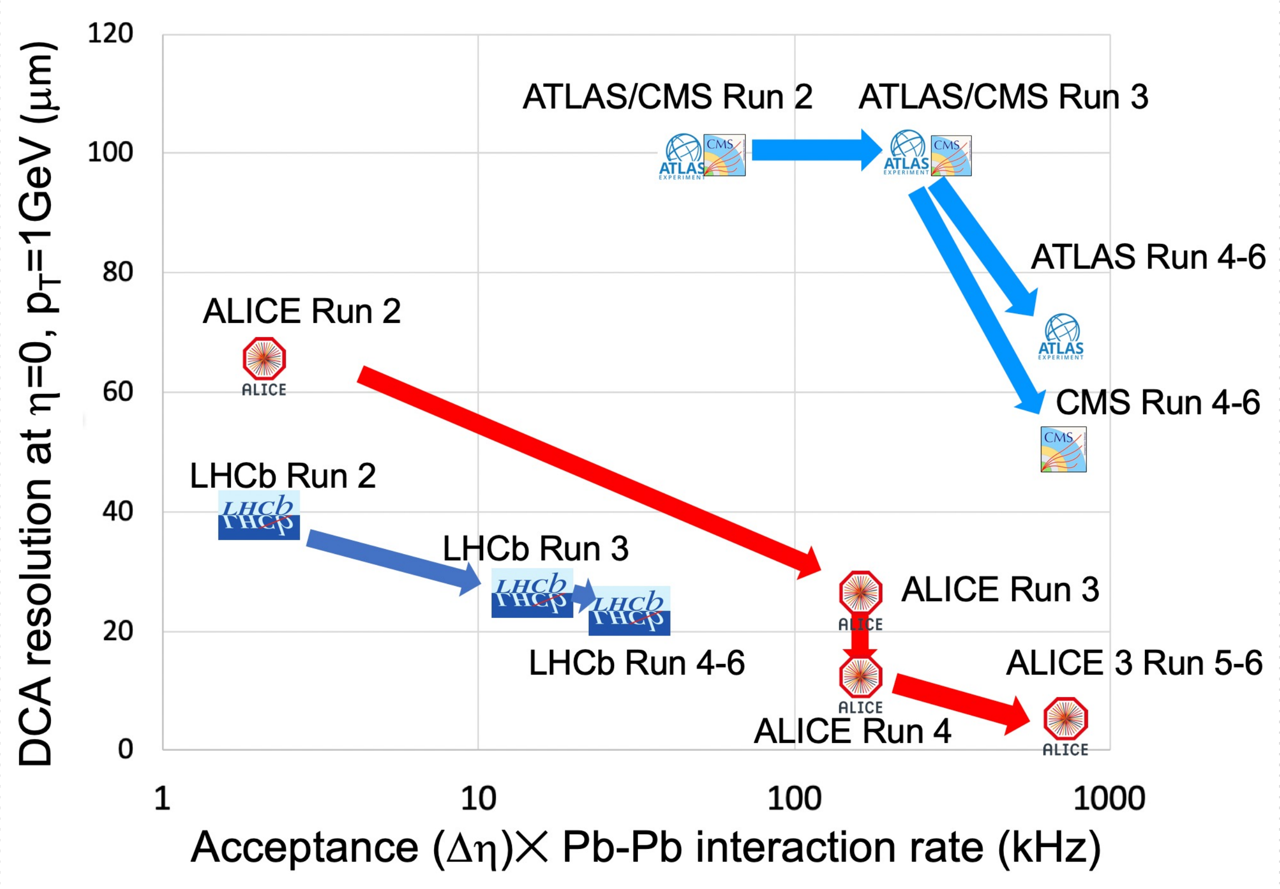
ATLAS:

- LS 2
  - Muon New Small Wheels (MSW)
  - Re-designed AFP TOF
- LS 3
  - Upgraded triggers & DAQ, HGTD
  - New Inner Tracker + new μ chambers + lumi detectors

CMS:

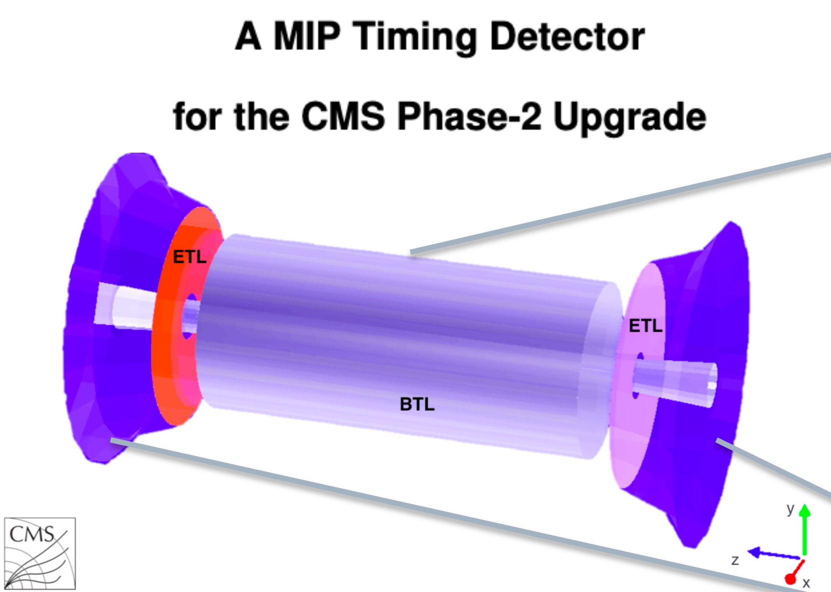
- LS 2
  - New GEM detectors
  - New innermost barrel pixel layer
- LS 3
  - Upgraded triggers & DAQ, MTD
  - New Inner tracker + calo. endcap + μ detector

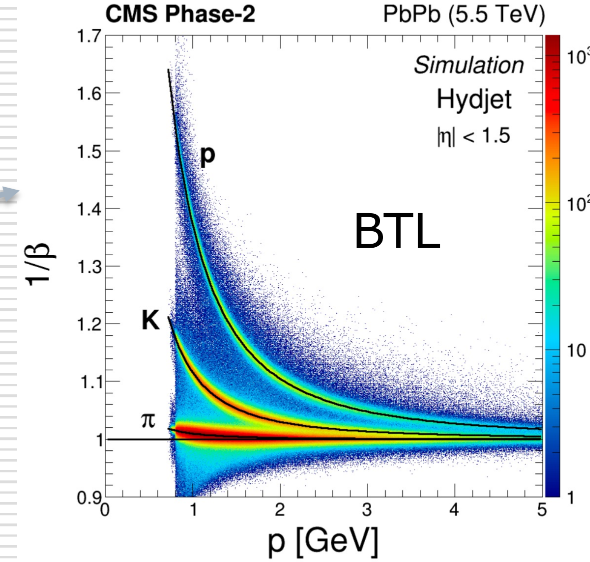
Detecor upgrades: HF view

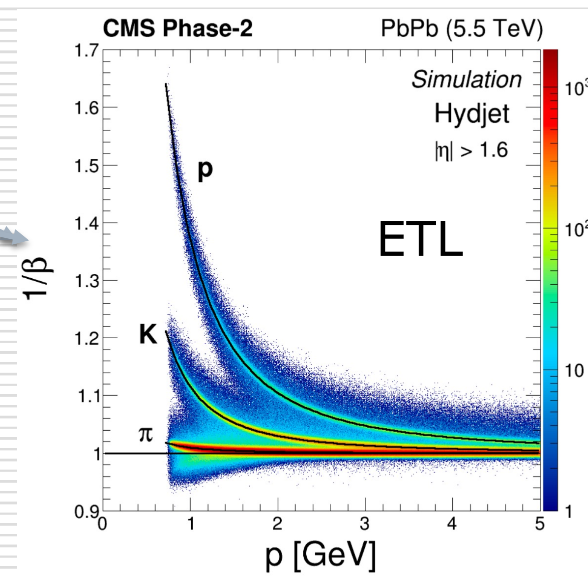


Overview in the talk of F. Jonas. I will focus on the upgrades with big impact on Heavy Flavour (for high density QCD physics)

CMS in LS3: MTD

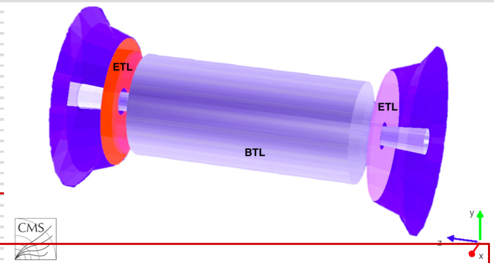






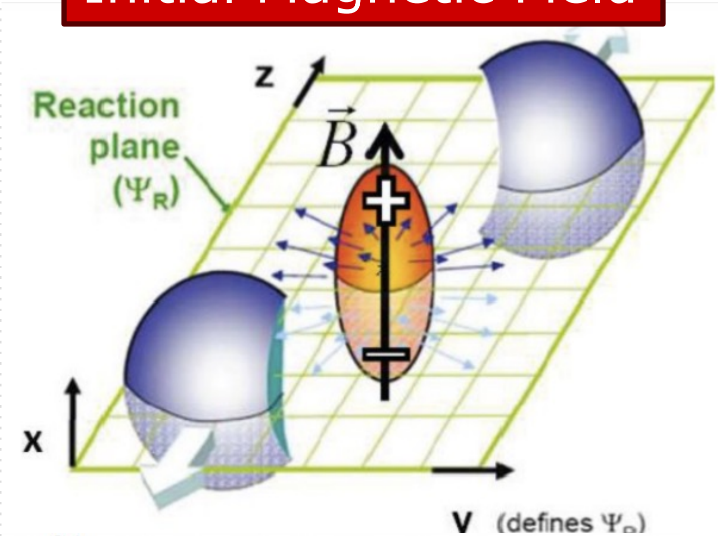
	Experiment	r (m)	σ_T (ps)	r/σ_T ($\times 100$) ($m \times ps^{-1}$)
RHIC	STAR-TOF	2.2	80	2.75
LHC	ALICE-TOF	3.7	56	6.6
	CMS-MTD	1.16	30	3.87

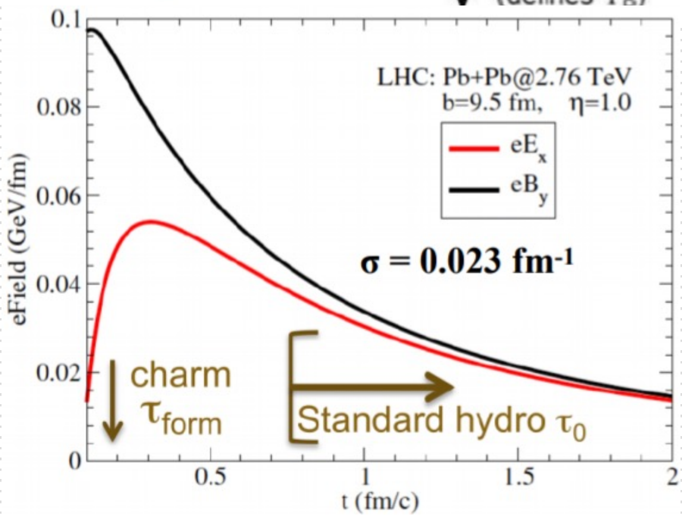
CMS in LS3: MTD

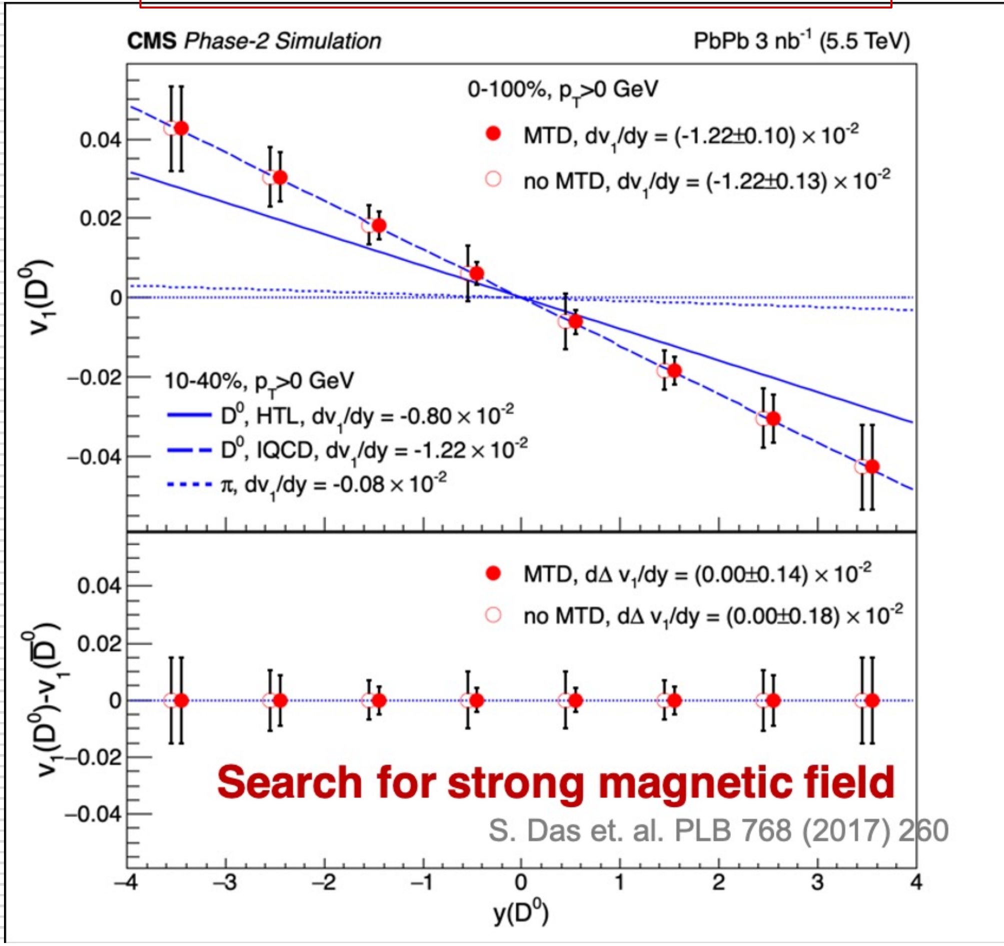


Initial Magnetic Field

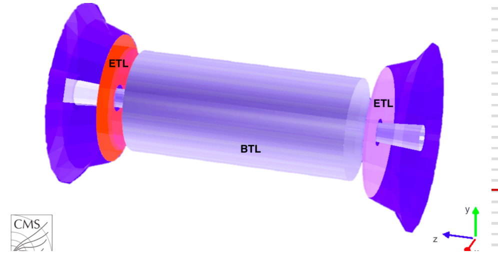
$$\frac{dN}{d(\varphi-\psi_{RP})} \propto 1 + 2\sum_{n=1} v_n \cos\left(n[\varphi-\psi_{RP}]\right)$$



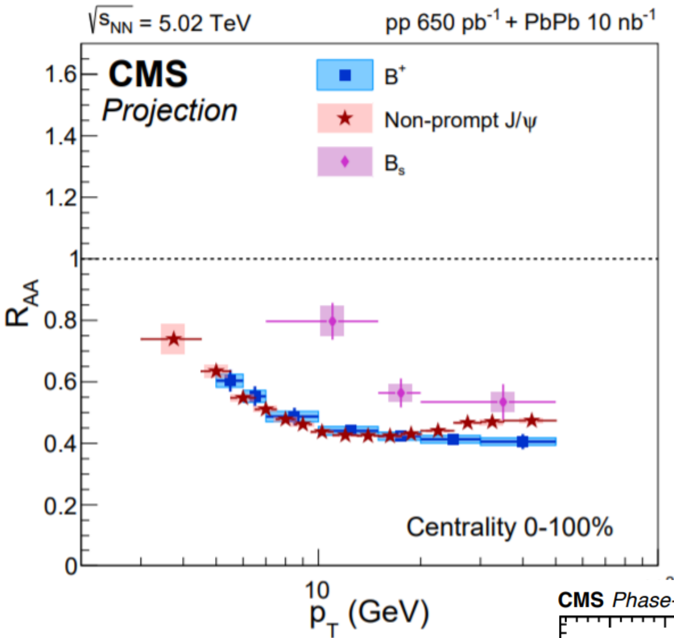


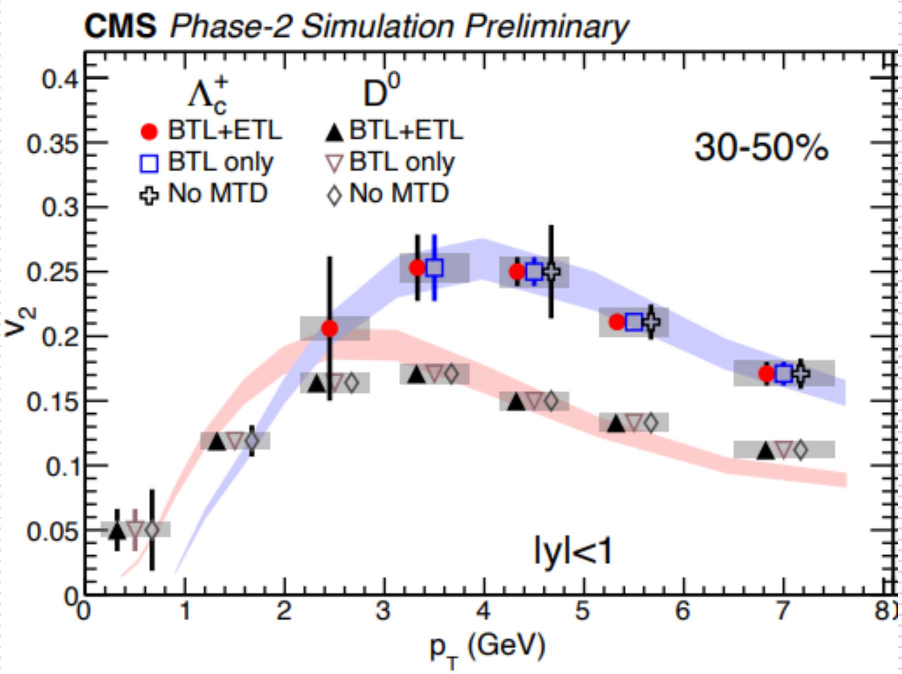


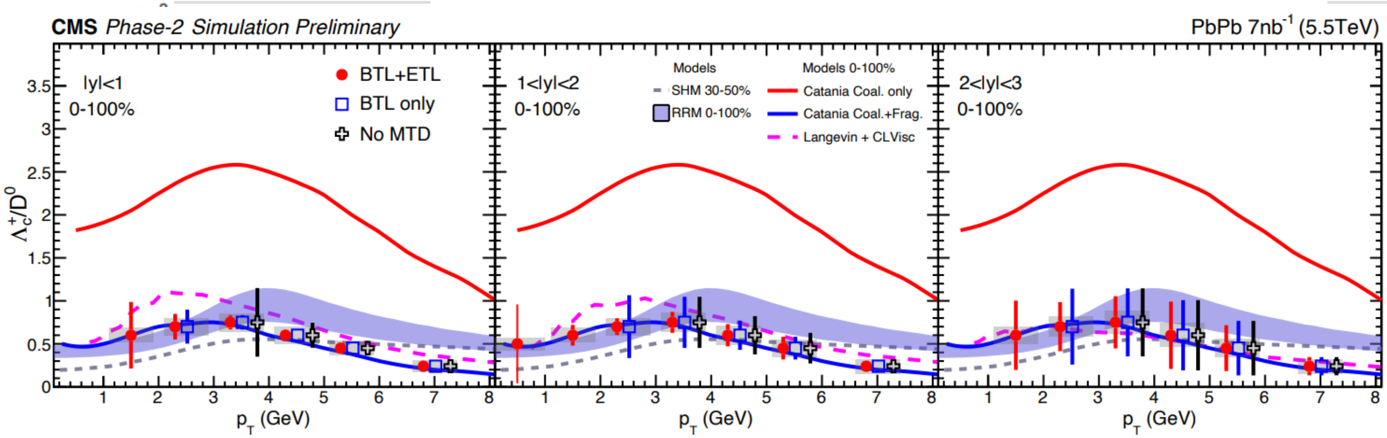
CMS in LS3: MTD



Open HF



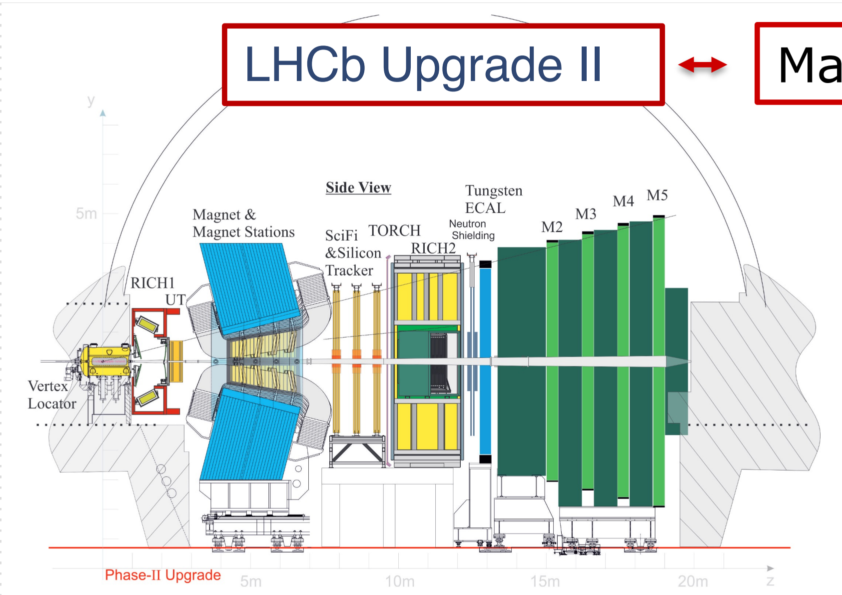




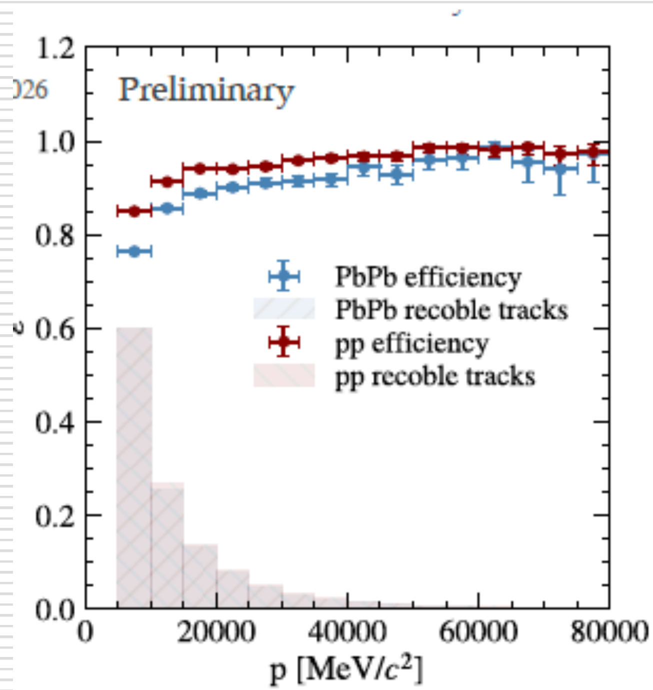
LHCb

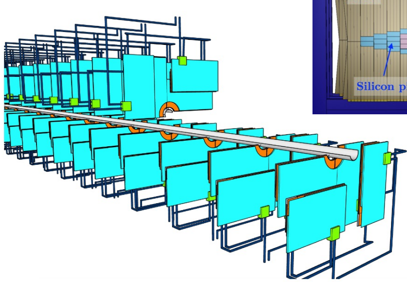
Important upgrade in LS2 (Upgrade I) → results being delivered in Run3

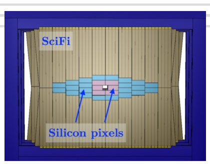
LHCb Upgrade II ↔ Major upgrade

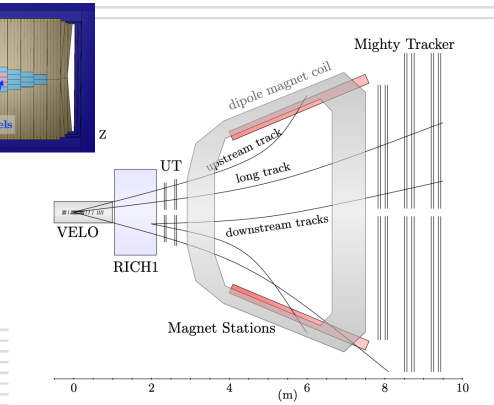


Tracking with high efficiency in **most central** Pb-Pb collisions





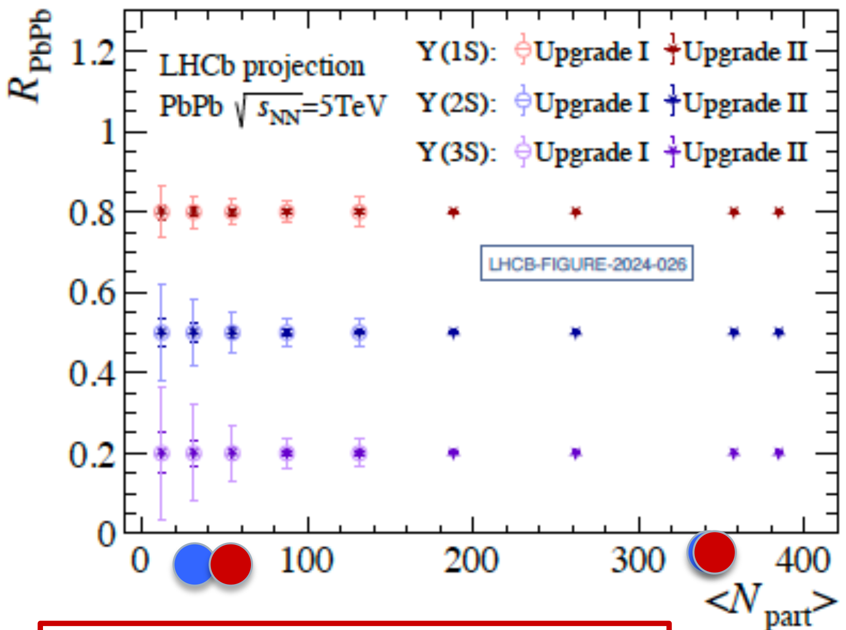




LHCb

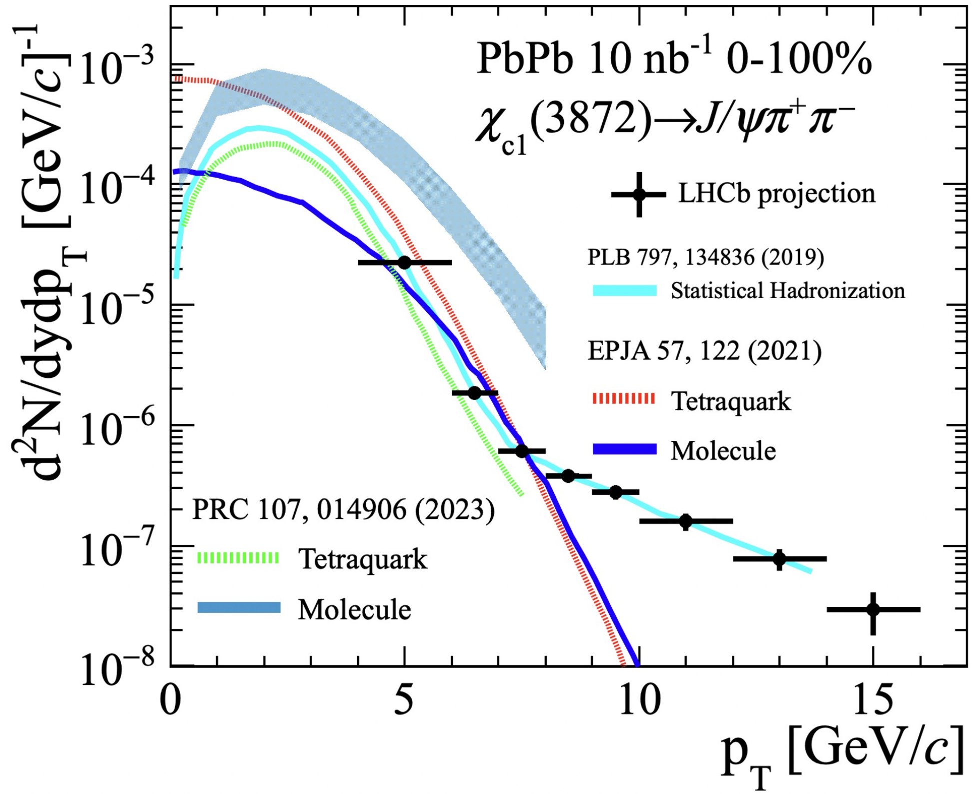
Expected ~ 10 nb^{-1} luminosity for PbPb during run 5-6,

Quarkonia



→ η_c, $\chi_{c,b}$ should be doable

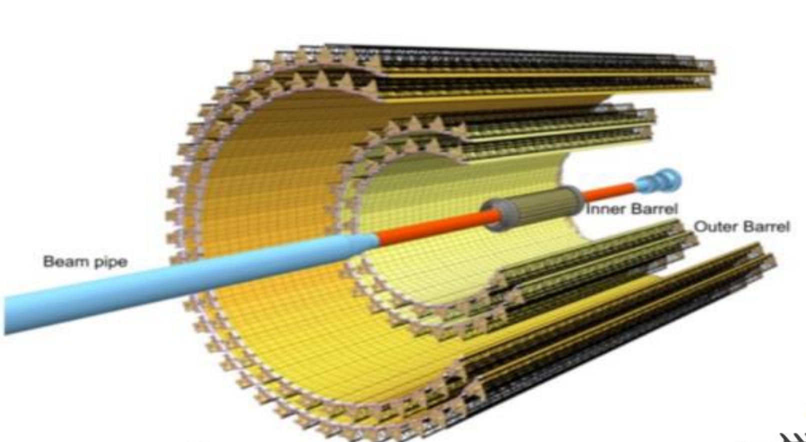
Exotica



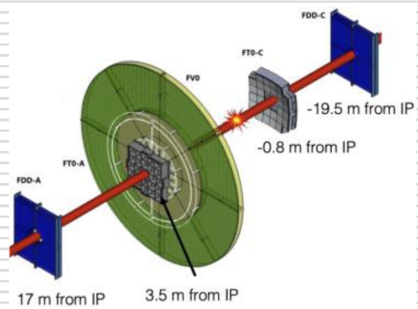
- LHCb to become full player for HI physics in forward rapidity region!
- Also rich program with (polarized) fixed target

ALICE in Run3

New Inner Tracking system (ITS2)

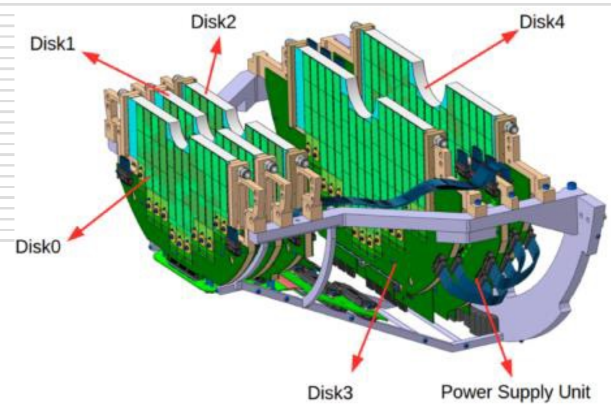


New Fast Interaction Trigger (FIT)

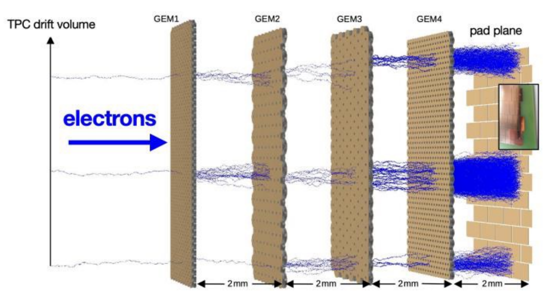


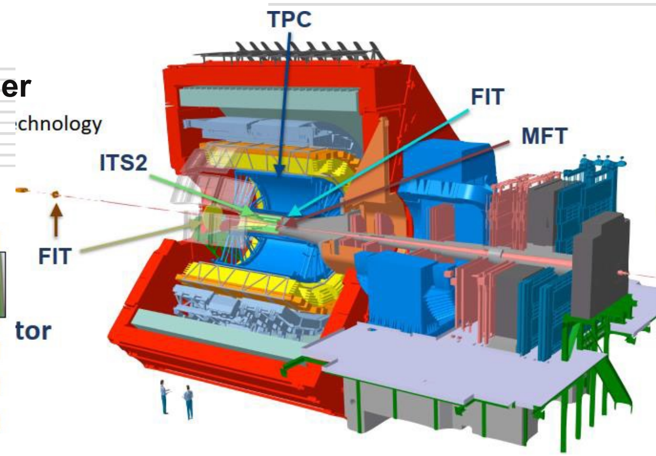
ALICE upgrades during the LHC Long Shutdown 2
https://arxiv.org/abs/2302.01238

New Muon Forward Tracker (MFT)



Upgrade of Time Projection Chamber (TPC) with GEM amplification

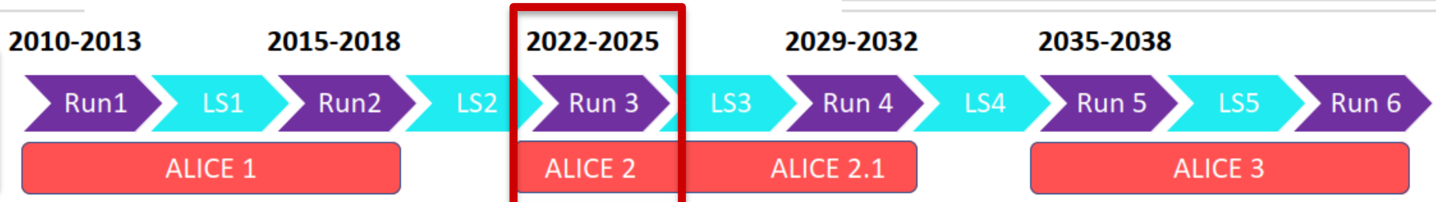




New data acquisition and reconstruction framework –(Online –Offline , O2)

Continuous data taking of min. bias Pb-Pb data at 50 kHz

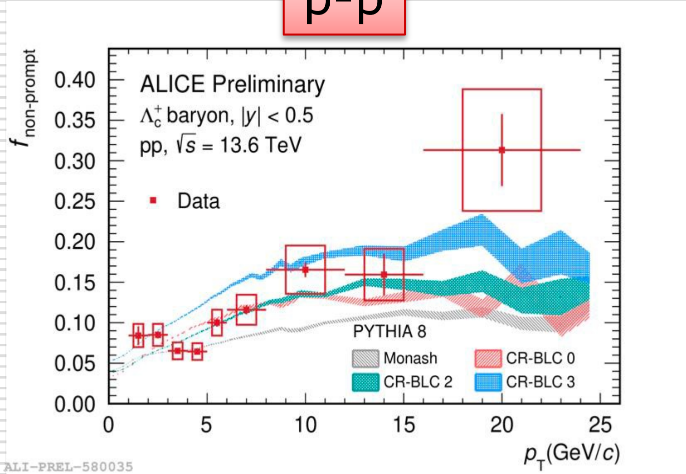
ALICE major upgrade in LS2

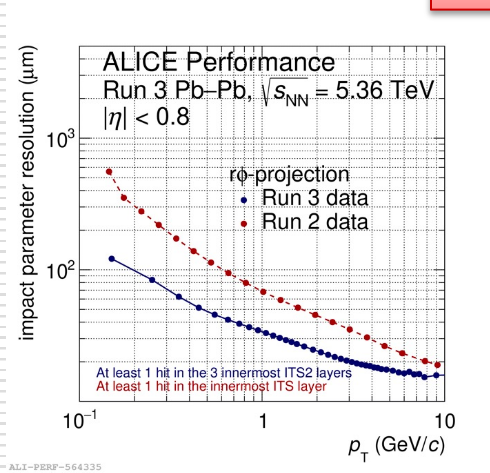


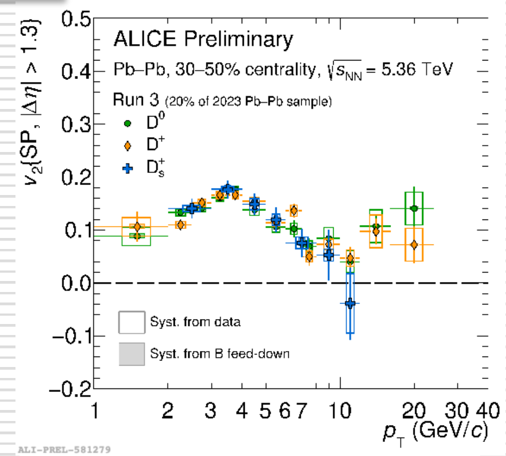
ALICE in Run3

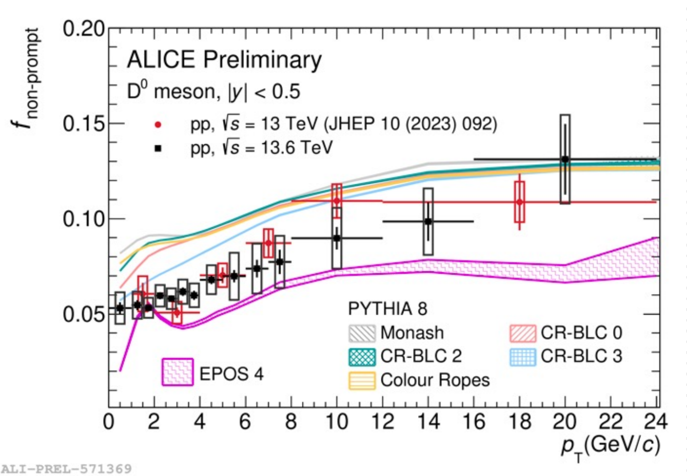
p-p

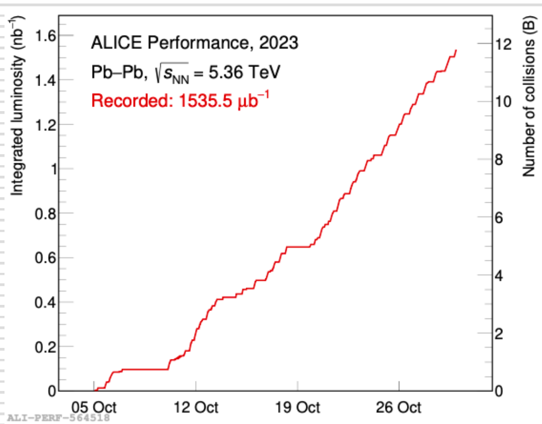
Pb-Pb

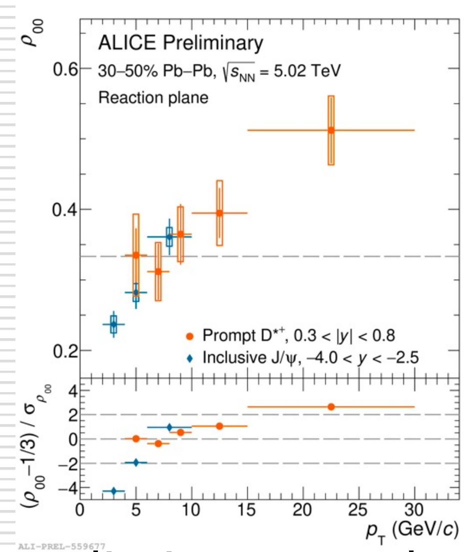








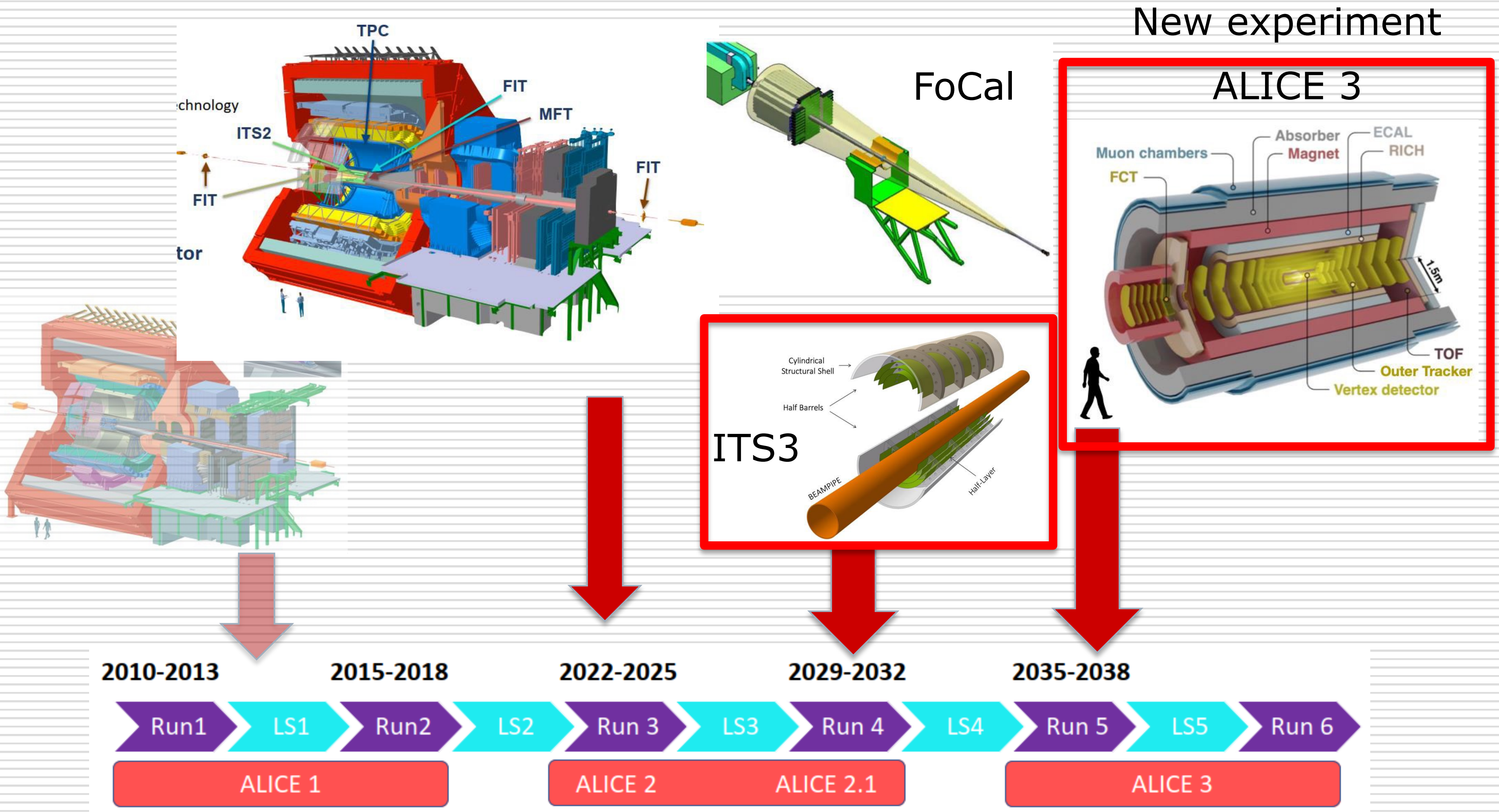




ALICE major upgrade in LS2

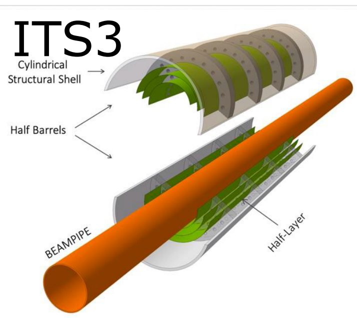
First Pb-Pb run in Oct. 2023, first preliminary results out

ALICE next upgrades



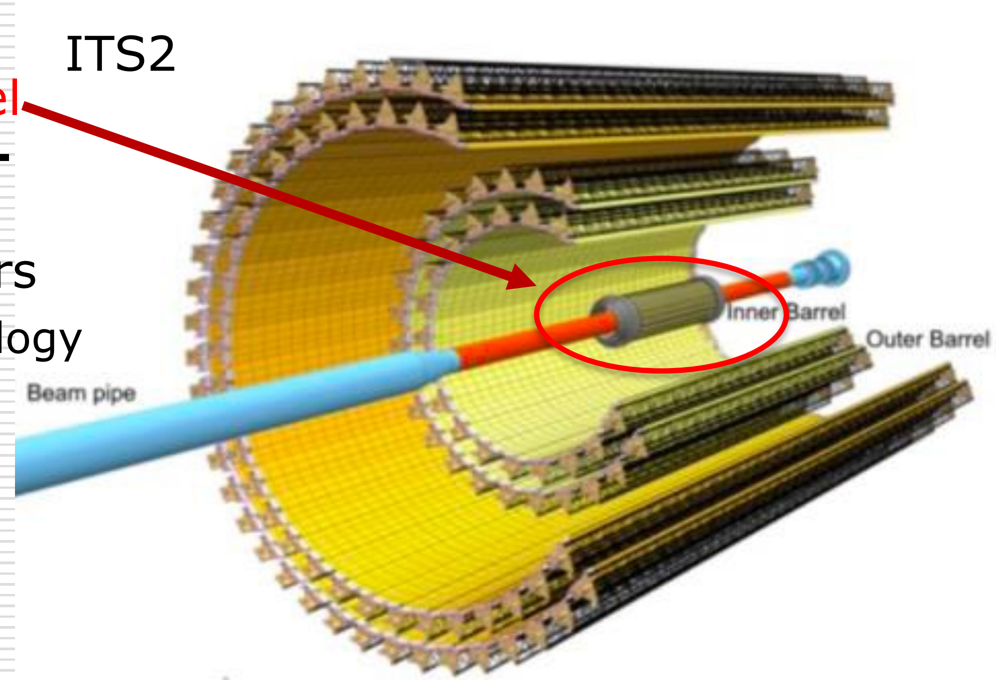
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

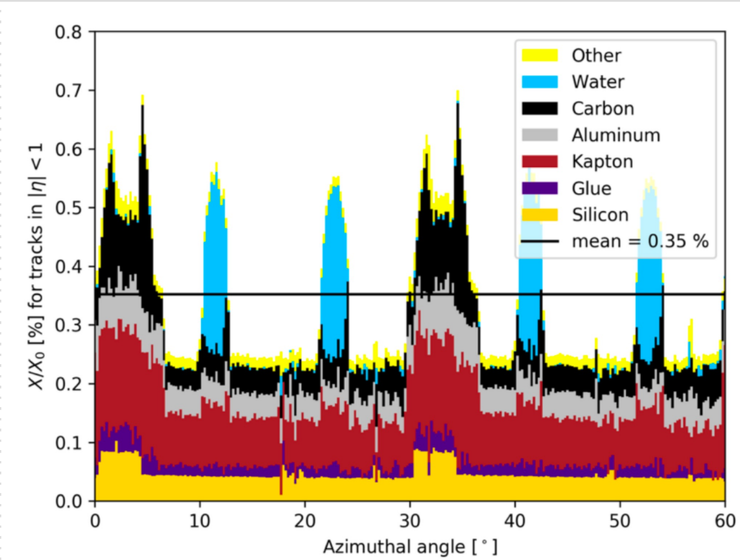
ALICE upgrades for Run 4



goal of ITS3 project: replacing inner barrel of ITS2 with **silicon-only** wafer-scale truly-cylindrical layers

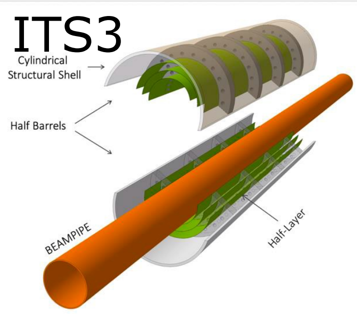
in 65 nm CMOS technology





This project has received funding

ALICE upgrades for Run 4



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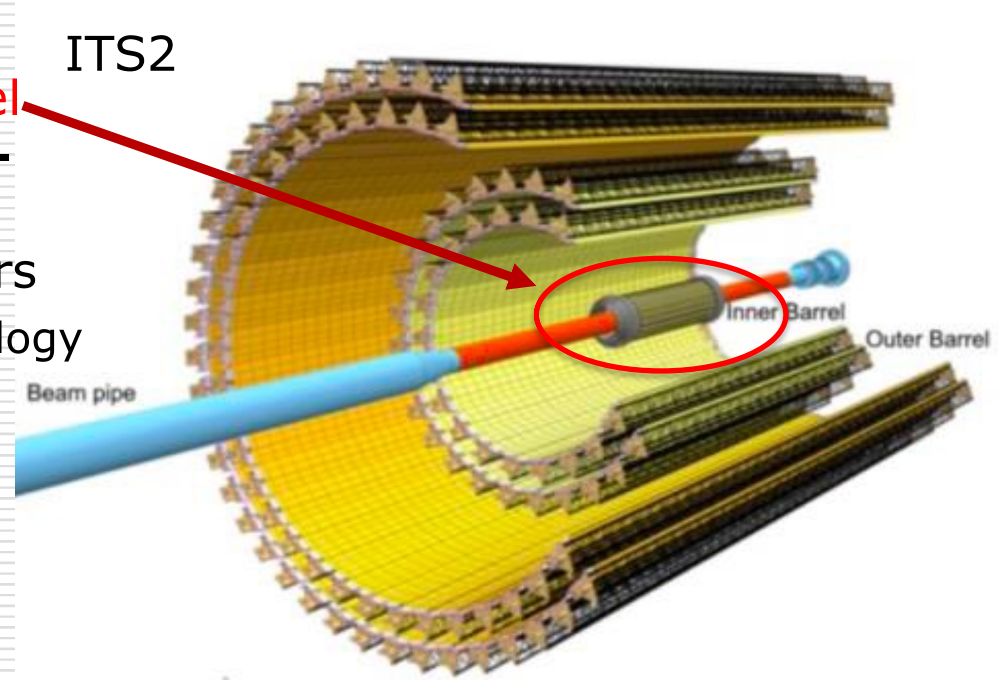

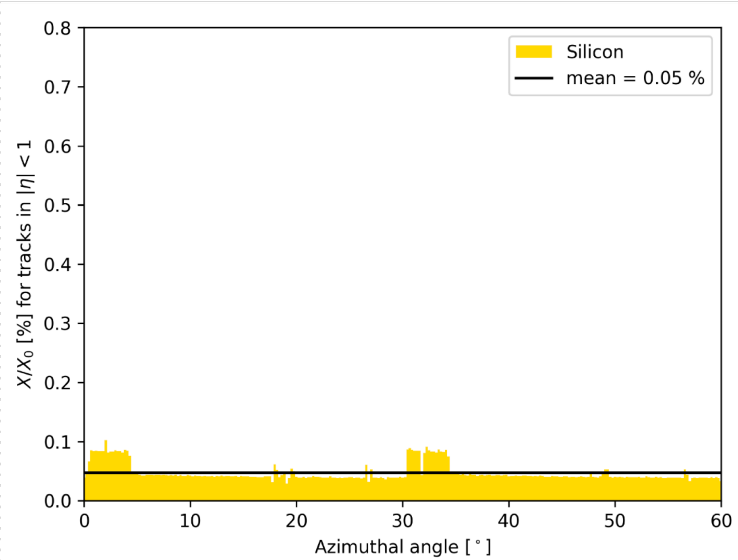

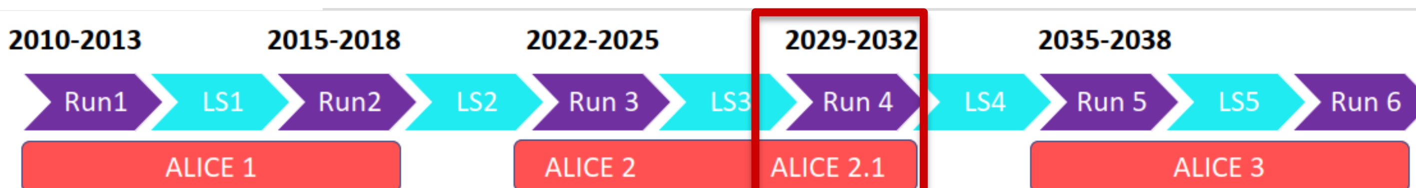

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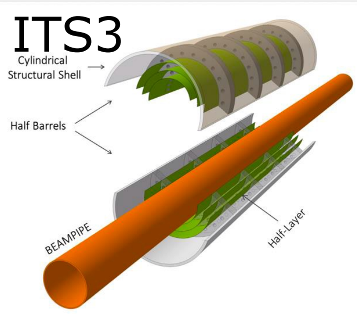
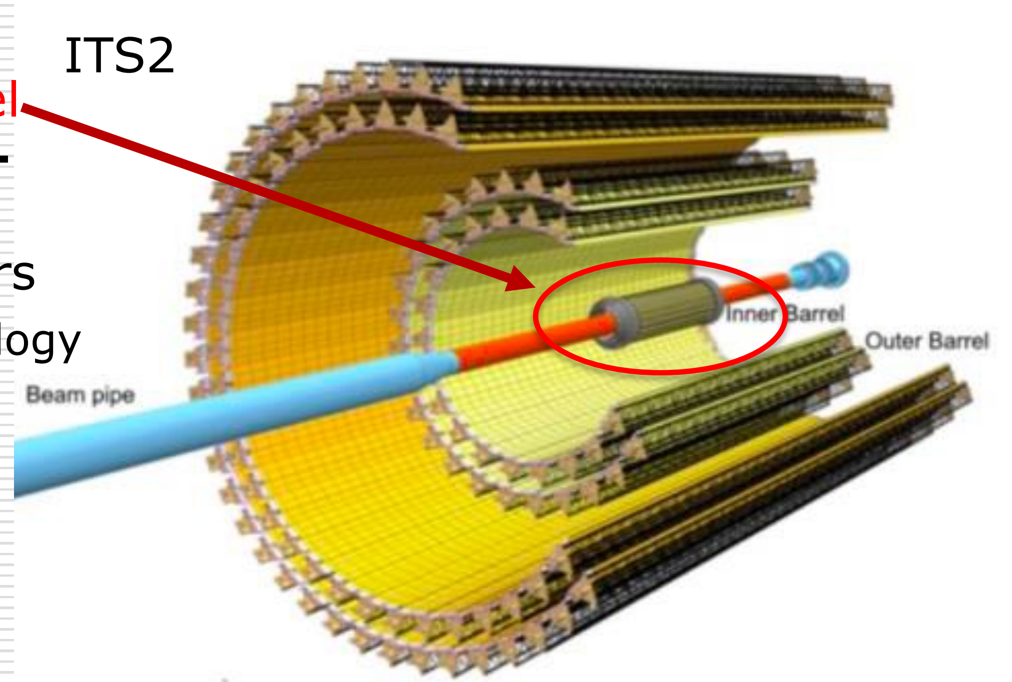
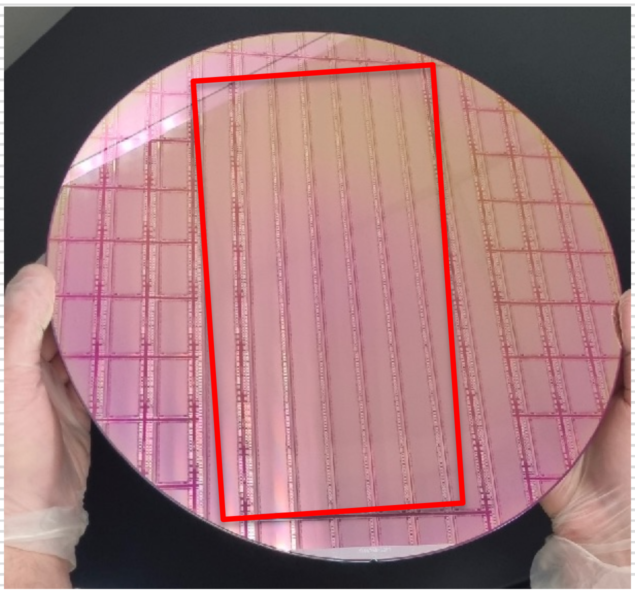
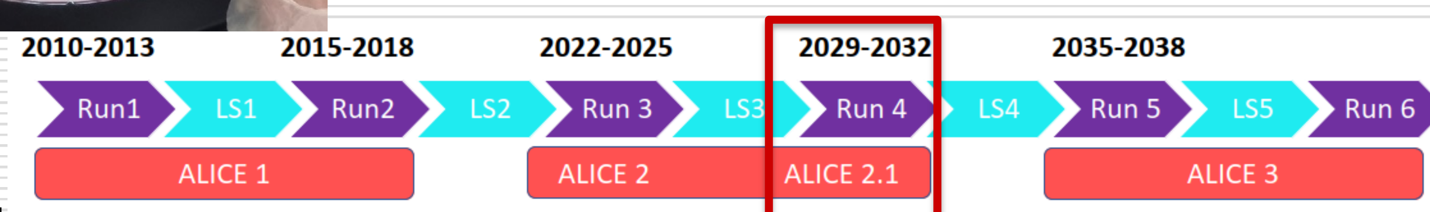
ALICE upgrades for Run 4



goal of ITS3 project: replacing inner barrel of ITS2 with **silicon-only** wafer-scale truly-cylindrical layers in 65 nm CMOS technology







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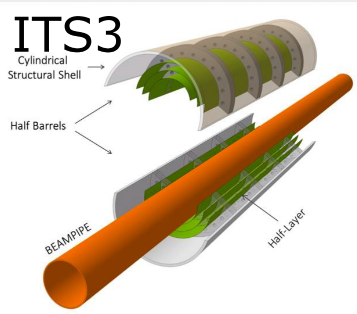
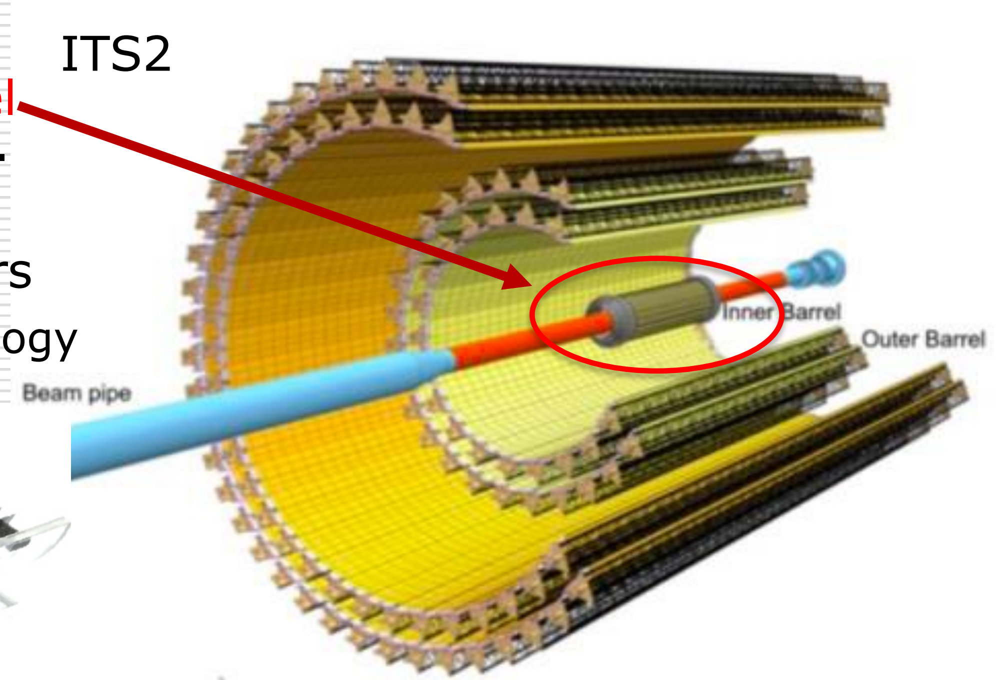
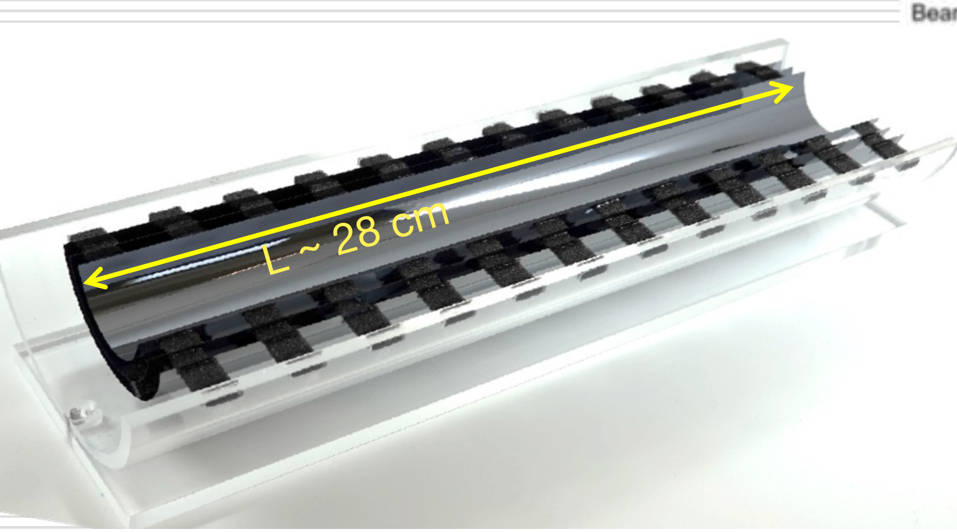
ALICE upgrades for Run 4



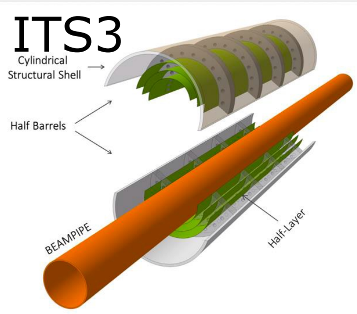
goal of ITS3 project: replacing inner barrel of ITS2 with **silicon-only** wafer-scale truly-cylindrical layers in 65 nm CMOS technology





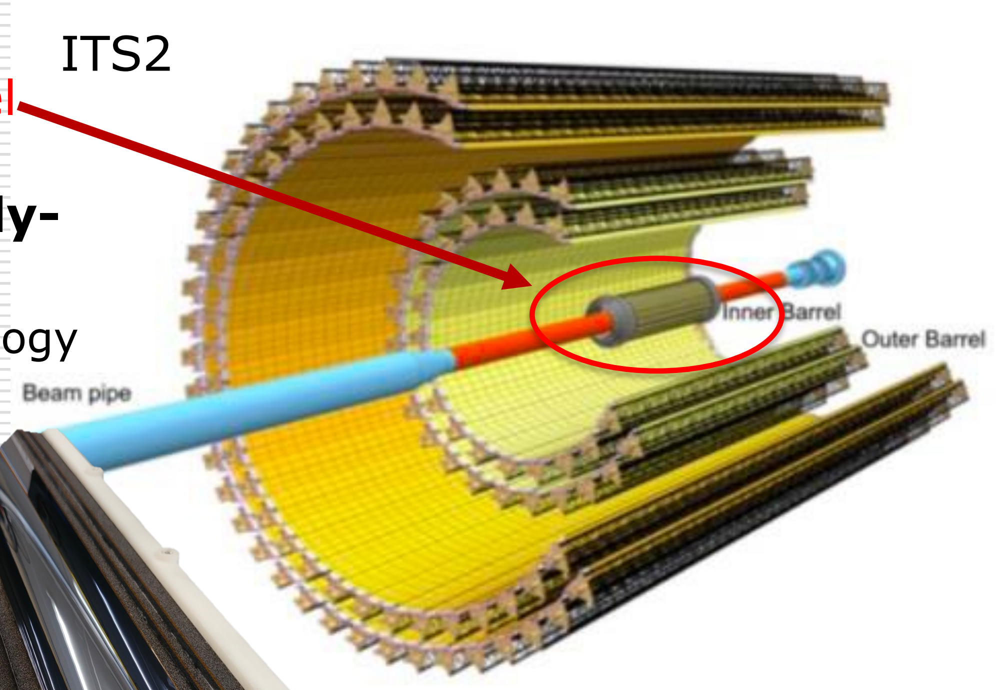
This project has received funding

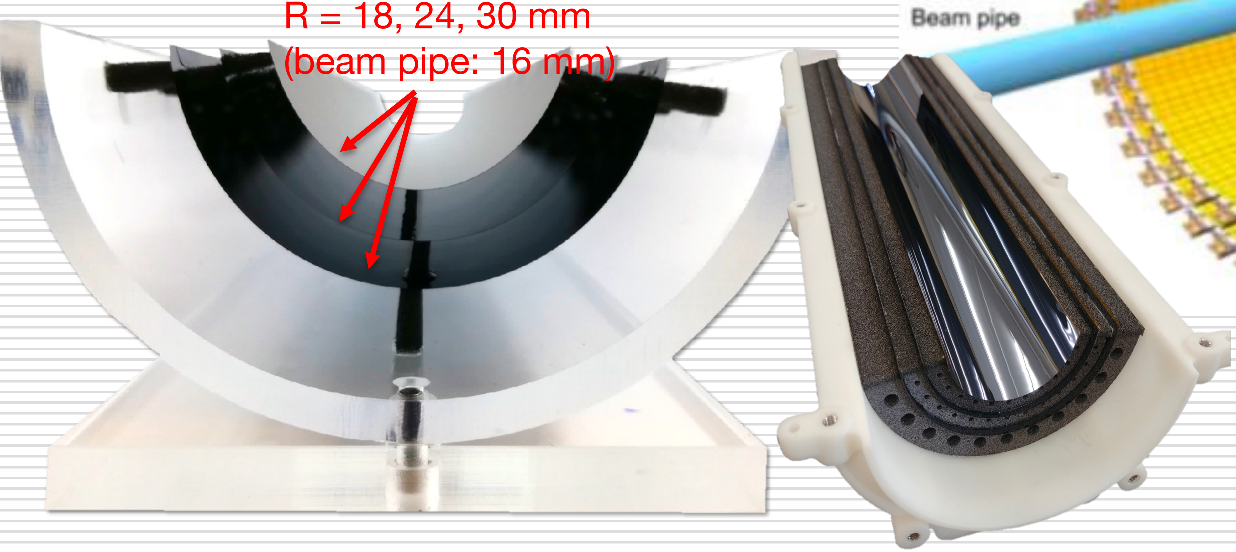
ALICE upgrades for Run 4

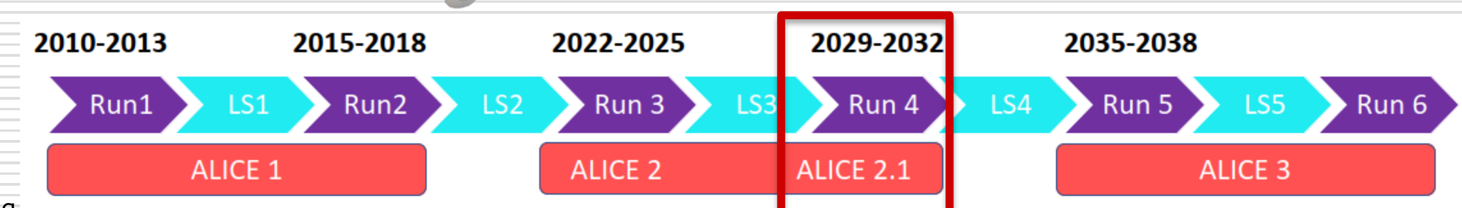


goal of ITS3 project: replacing inner barrel of ITS2 with silicon-only wafer-scale **truly-cylindrical** layers

in 65 nm CMOS technology



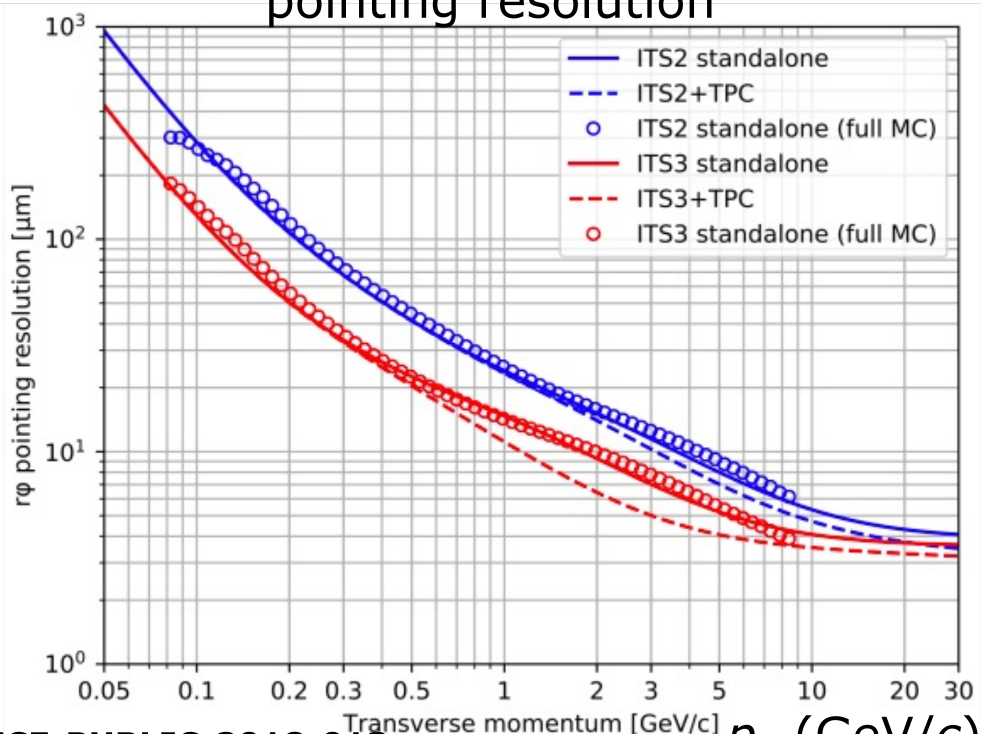




This project has received funding

ALICE upgrades for Run 4

pointing resolution



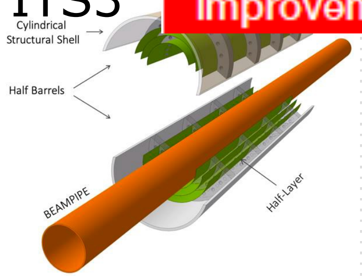
p_T (GeV/c)

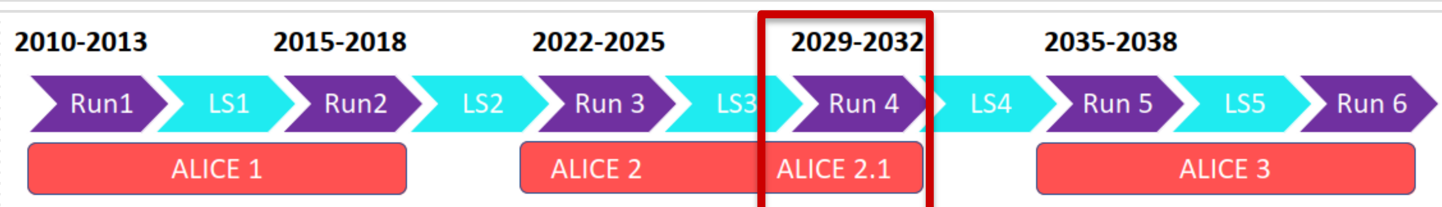
ALICE-PUBLIC-2018-013

- Improvement of pointing resolution by:
  - drastic reduction of **material budget** (0.3 → 0.05% X0/layer)
  - being **closer** to the interaction point (24 → 18 mm)
  - thinner and smaller **beam pipe** (700 → 500 μm; 18 → 16 mm)
- Directly boosts the ALICE core physics program that is largely based on:
  - low momenta
  - secondary vertex reconstruction
- E.g. Λ_c S/B improves by factor 10, significance by factor 4

ITS3

improvement of factor 2 over all momenta

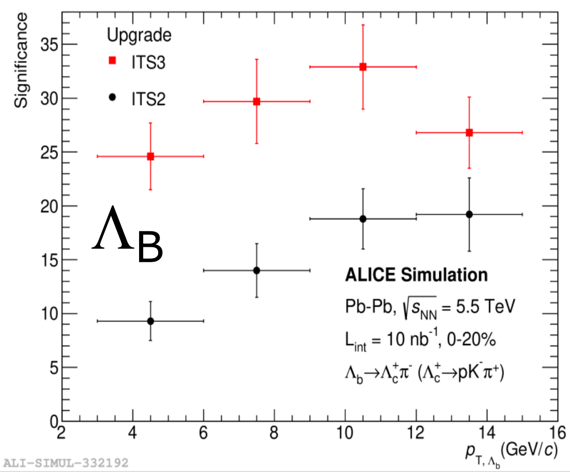


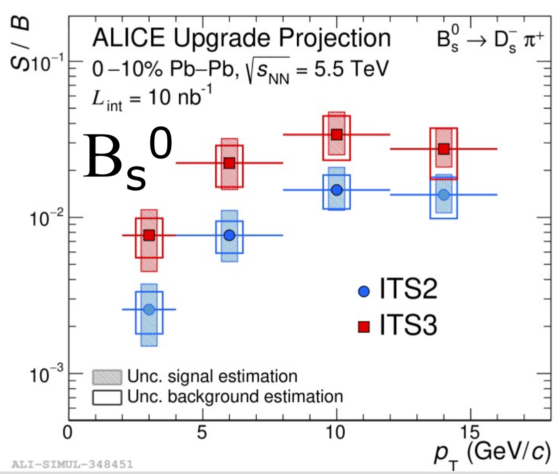


This project has received funding

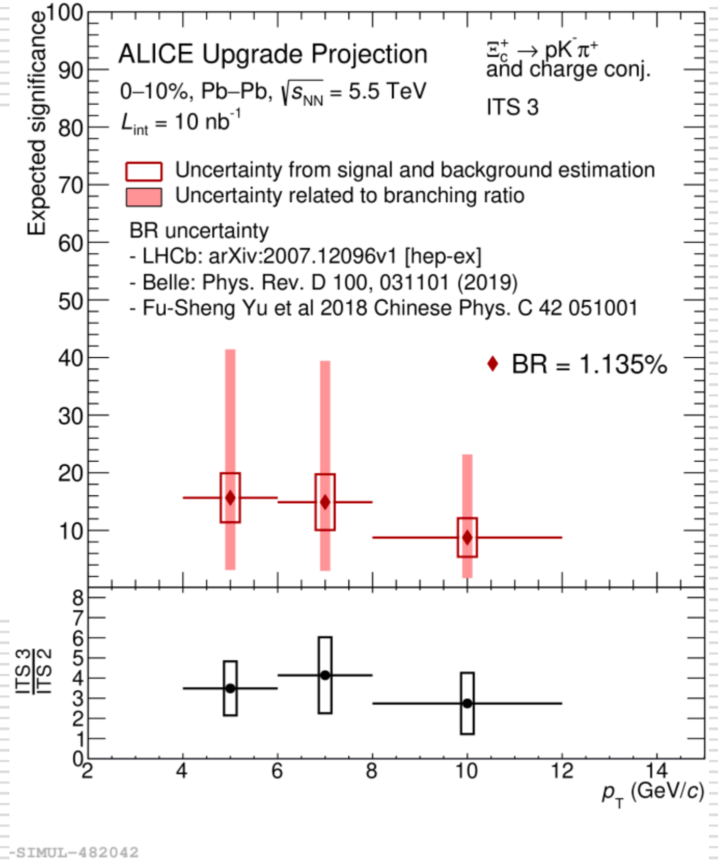
ALICE upgrades for Run 4

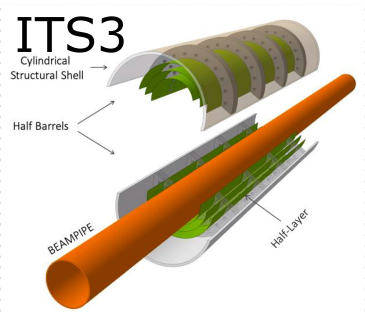
Physics performances

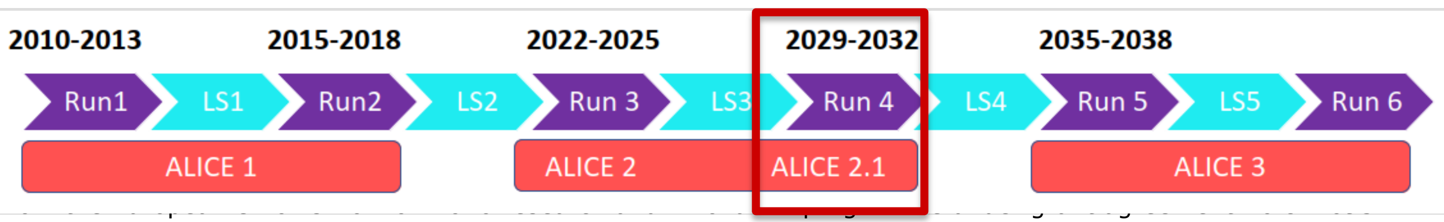




$\Xi_c^+ \to pK^-\pi^+$



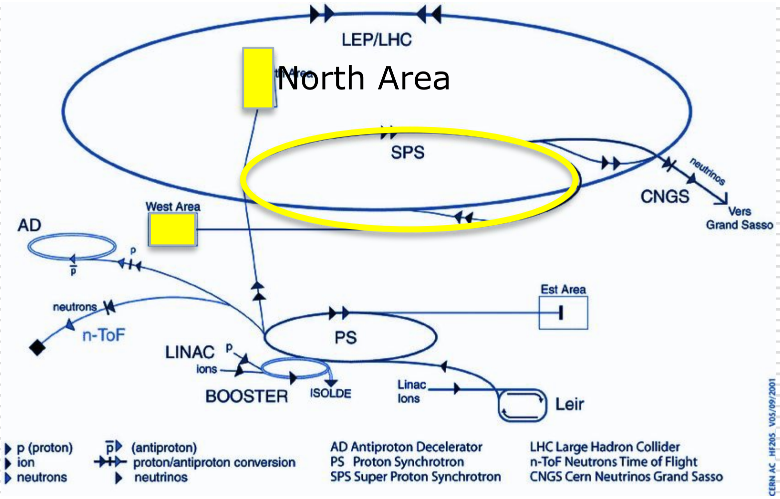


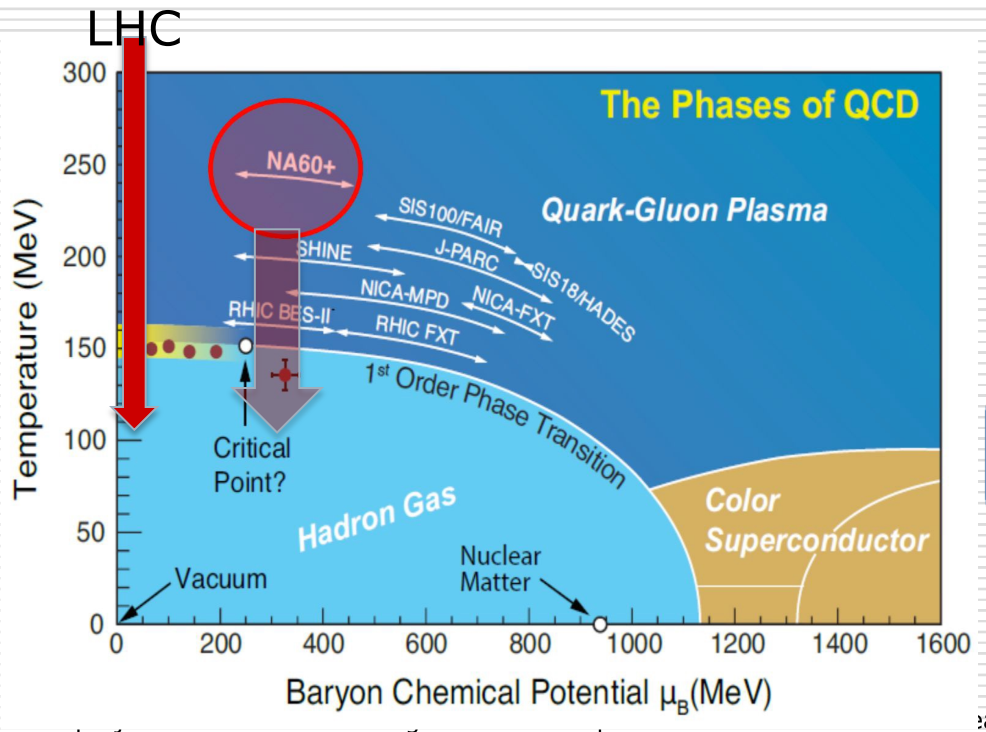


This project has received funding

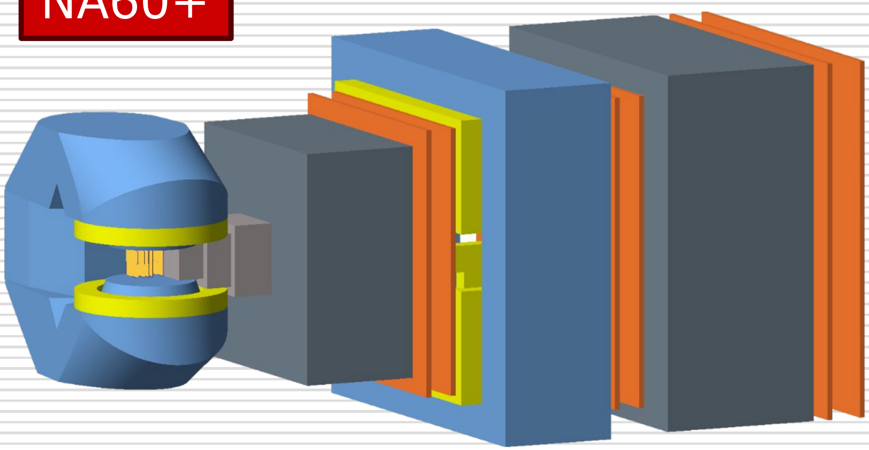
A parenthesis: HF at the SPS

- SPS provides p and Pb beams to the LHC and to WA and NA
  - Fixed target program



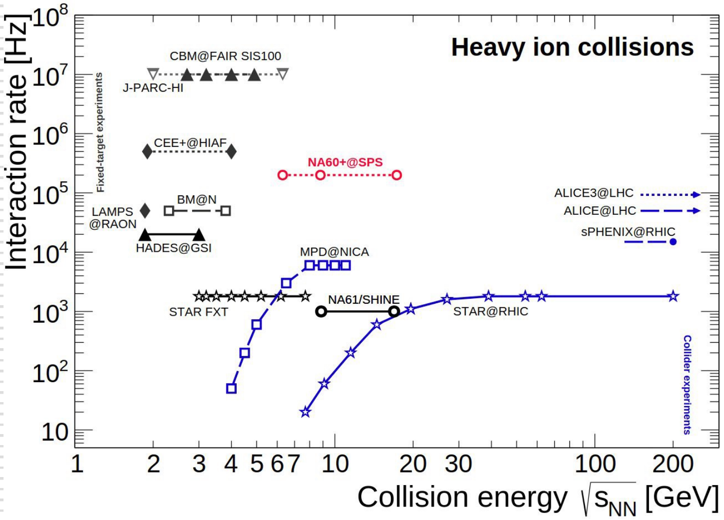


NA60+

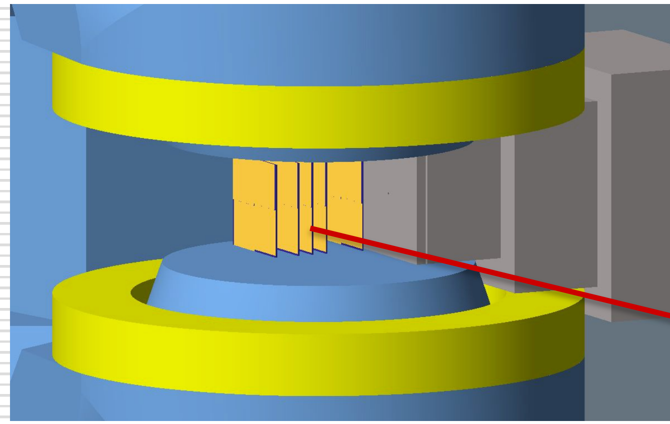


earch and innovation programme under grant agreement No 824093.

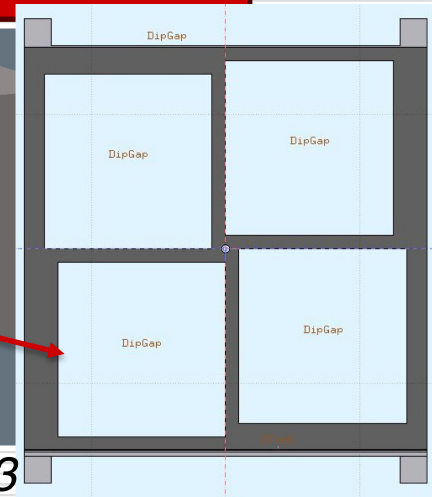
A parenthesis: HF at the SPS



NA60+ vertex detector

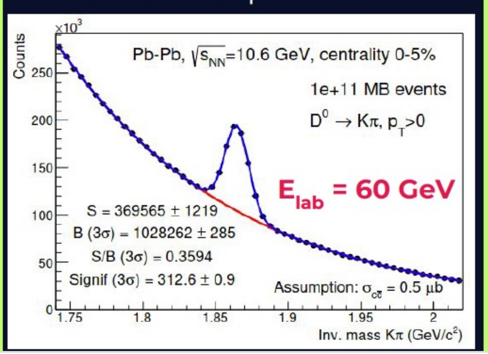


MOSAIX sensor of ALICE ITS3



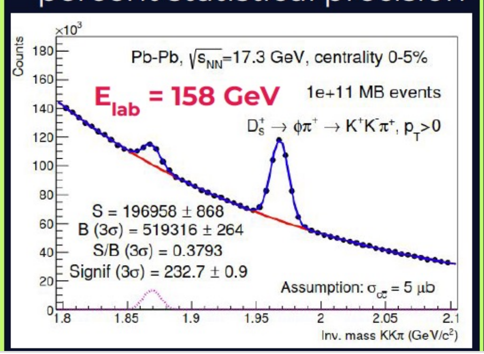
$D^0 \to K\pi$

accessible also at low $\sqrt{s_{NN}}$, ~1% statistical precision



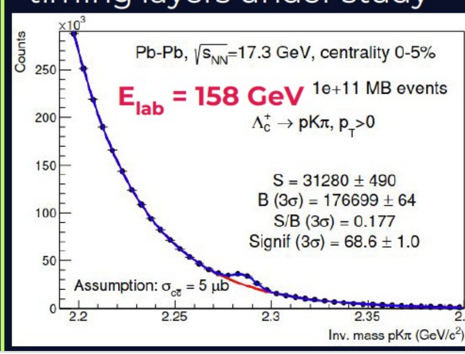
$D_s \to \phi\pi \to KK\pi$

yields measurement, few percent statistical precision

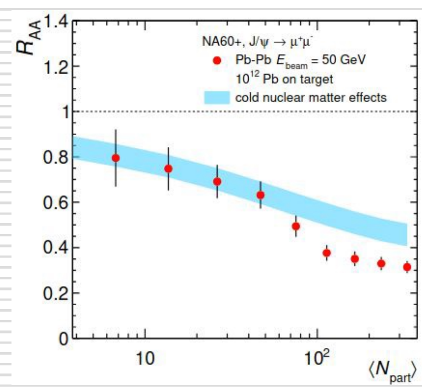


$\Lambda_c \to pK\pi$

feasible, improvement with timing layers under study



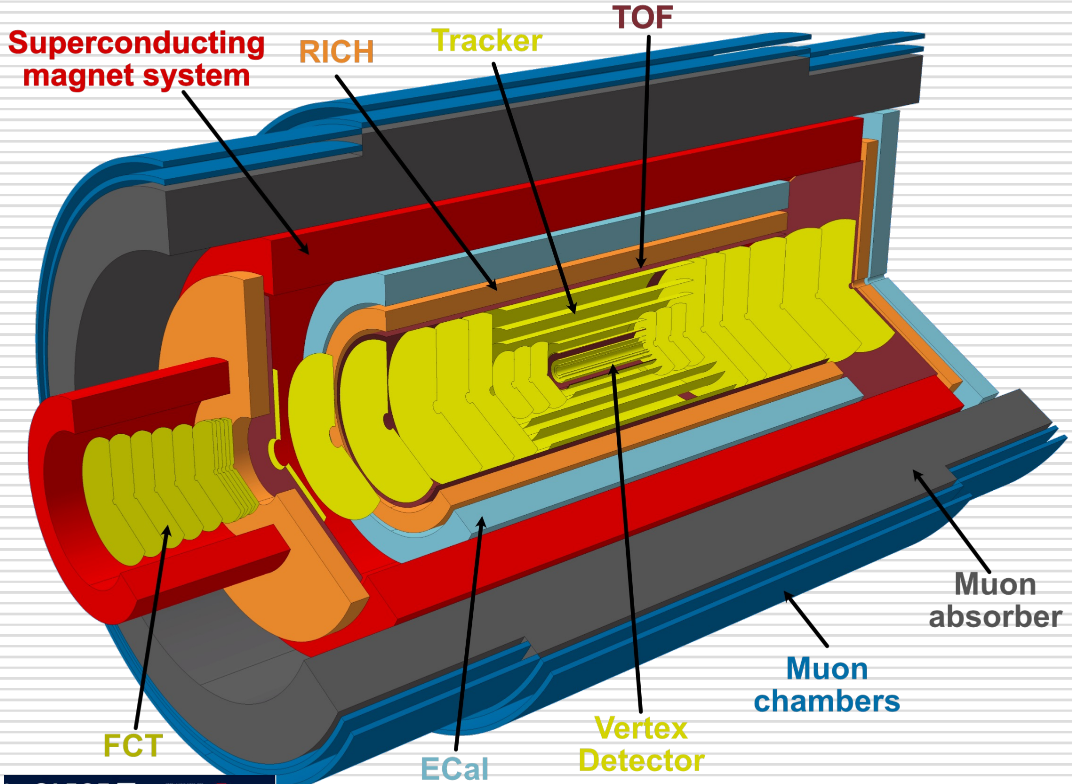
$J/\psi \to \mu\mu$



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

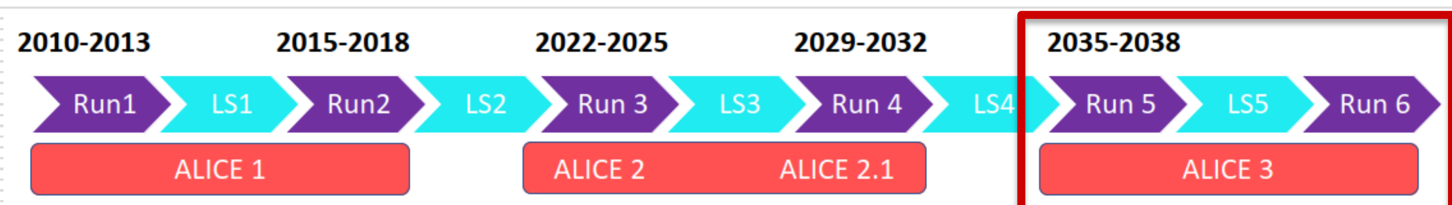
ALICE 3: Run 5 and beyond

CERN-LHCC-2022-009 https://arxiv.org/abs/2211.02491v1



ceived funding

- Compact **all-silicon** tracker
  - Pointing resolution ~3-4 µm and p_T resolution < 1% @1 GeV/c
- Large acceptance, **|η|<4, p_T >0.02 GeV/c**
- Superconducting magnet system
  - Max field: B = 2 T (*0.5 T runs foreseen*)
- Continuous readout and online processing
- Particle Identification (PID) in a wide range of p_T and |η|<4

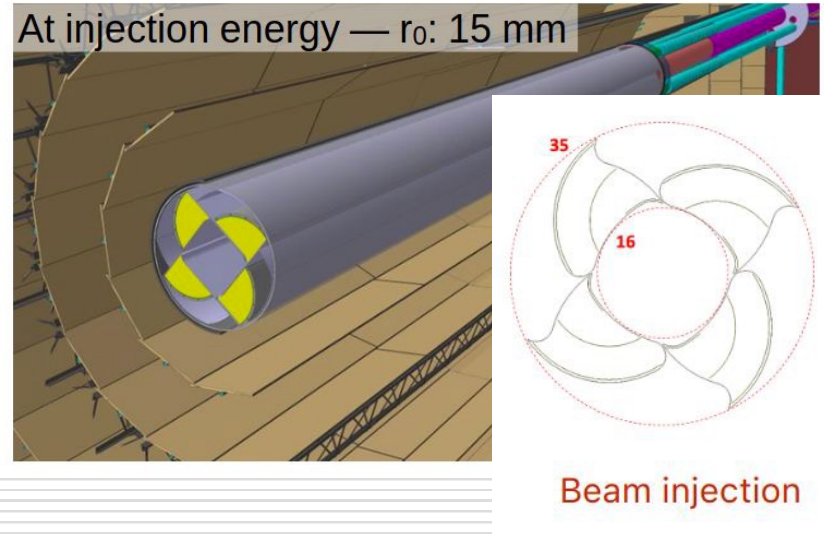


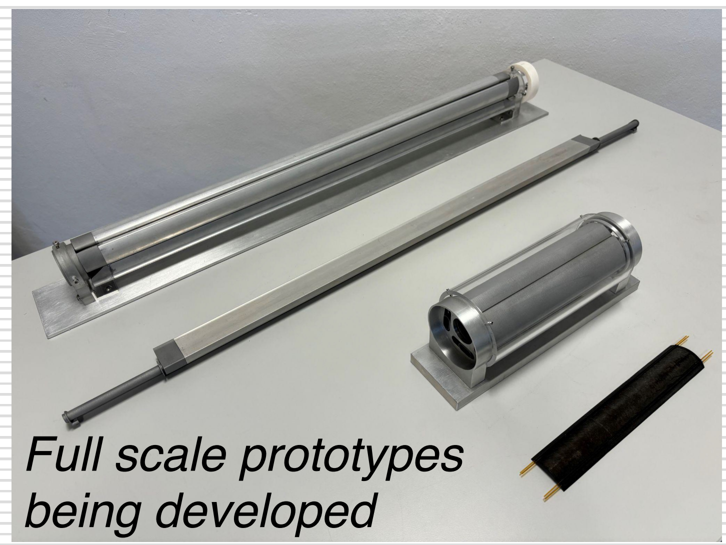
ALICE 3: vertex detector

"Iris" vertex detector

- In vacuum, *retractable,* tracker (**3 layers + 3 disks**): in closed position first layer at **5 mm** from the beam
- Wafer-size sensors based on CMOS MAPS technology (synergy with ITS3 R&D)
- Pixel pitch of about 10 µm (**2.5 µm** intrinsic resolution) and **~0.1% X0/layer**
- Max. radiation load per operational year ~ **1.5 10^{15} 1 MeV neq/cm^2**
- Cooling on the outer surface of the 3rd layer (micro-channel) while the layer 0 and 1 cooled via conduction on the petals

R&D challenges: rad. hardeness, mechanics, cooling & services





Full scale prototypes being developed

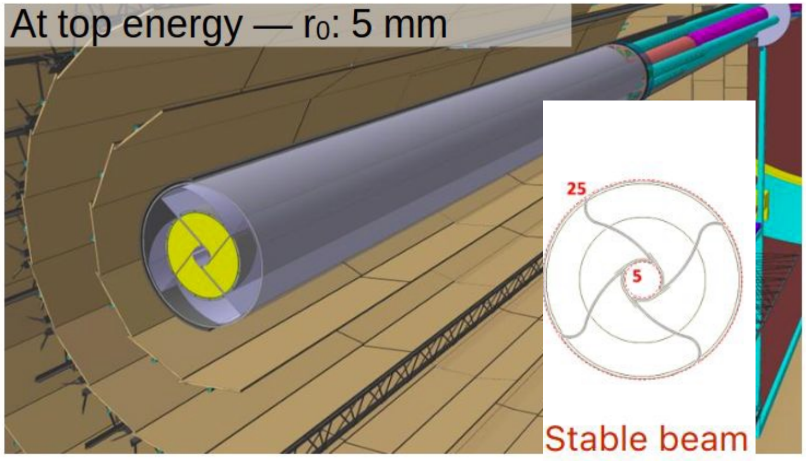
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

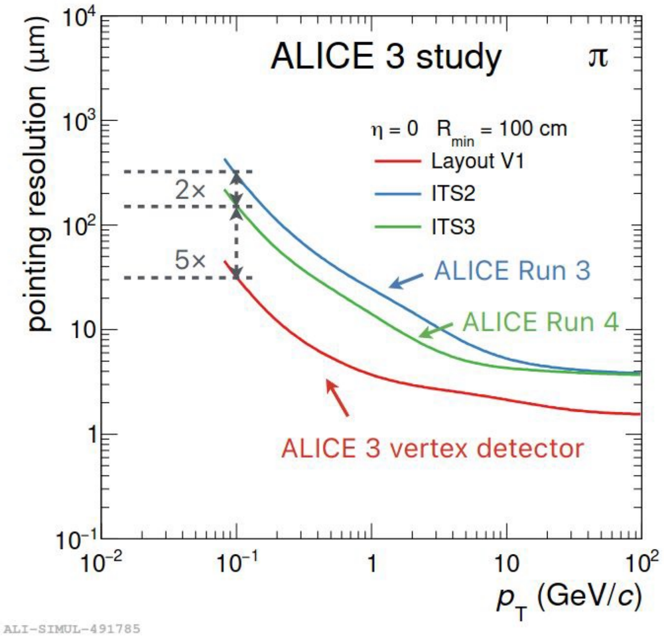
ALICE 3: vertex detector

"Iris" vertex detector

- In vacuum, *retractable,* tracker (**3 layers + 3 disks**): in closed position first layer at **5 mm** from the beam
- Wafer-size sensors based on CMOS MAPS technology (synergy with ITS3 R&D)
- Pixel pitch of about 10 μm (**2.5 μm** intrinsic resolution) and **~0.1% X0/layer**
- Max. radiation load per operational year ~ **1.5 10^{15} 1 MeV neq/cm^2**
- Cooling on the outer surface of the 3rd layer (micro-channel) while the layer 0 and 1 cooled via conduction on the petals

R&D challenges: rad. hardeness, mechanics, cooling & services





This project has received funding from the European Union's Horizon 2020 resea... No 824093.

ALICE 3: PID systems

Time-of-flight

- **Barrel TOF**: two layers at 19 cm and at 85 cm. Time resolution **20 ps**, $|\eta|<1.75$. Total surface ~ 31.5 m^2
- **Two forward disks:** $1.75<|\eta|<4$ with r_{in} = 15 cm, r_{out} =50 cm at z = $\pm$405 cm   Tot. surface ~ 14 m^2

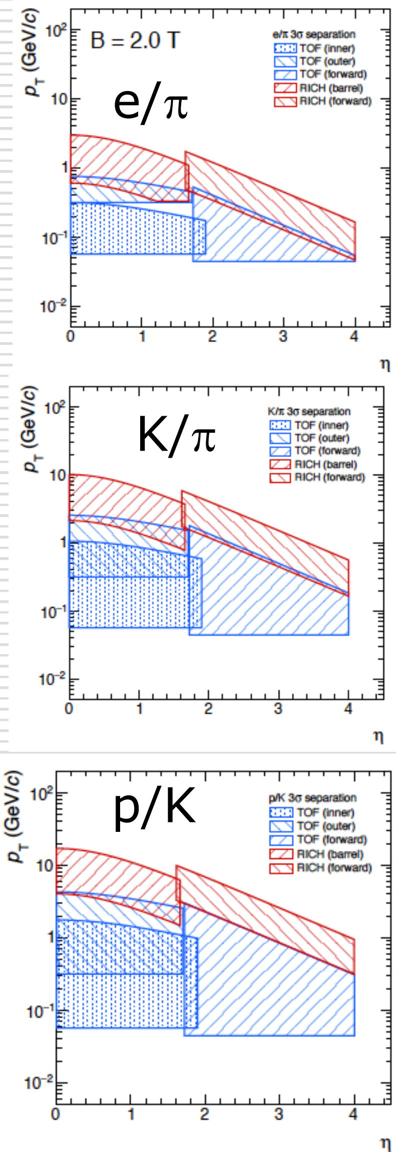
R&D challenges: depends on technology, If MAPS uniform and fast charge collection + fast readout electronics and high S/N ratio

RICH for higher p_T reach

- 2 cm thick aerogel tile and photo-detection layer (SiPMs) at 20 cm from the radiator
- Aerogel radiator refraction index **n = 1.03 (barrel)** and **n= 1.006 (forward)** → determine the p_T reach

R&D challenges: quality of the aerogel over production cycle, digital SiPMs radiation resistant

3σ separation



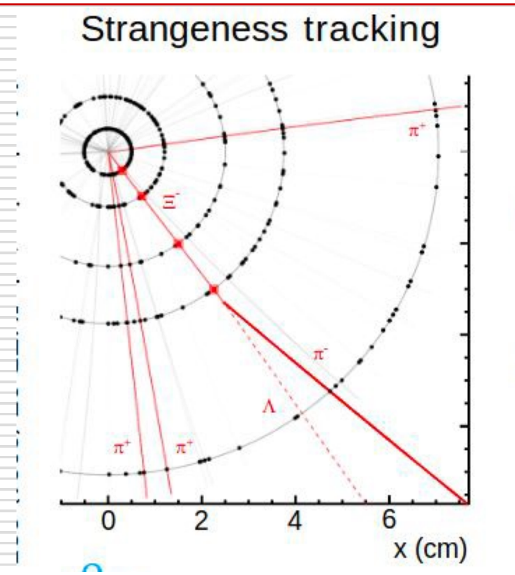
CERN-LHCC-2022-009 - arXiv:2211.02491

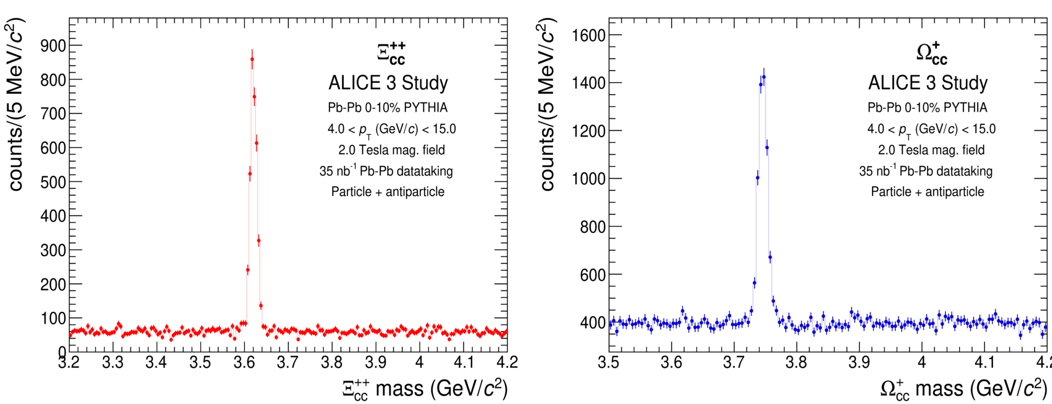
This project has received funding from the European Union's Horizon 2020 research and innovation ... nt No 824093.

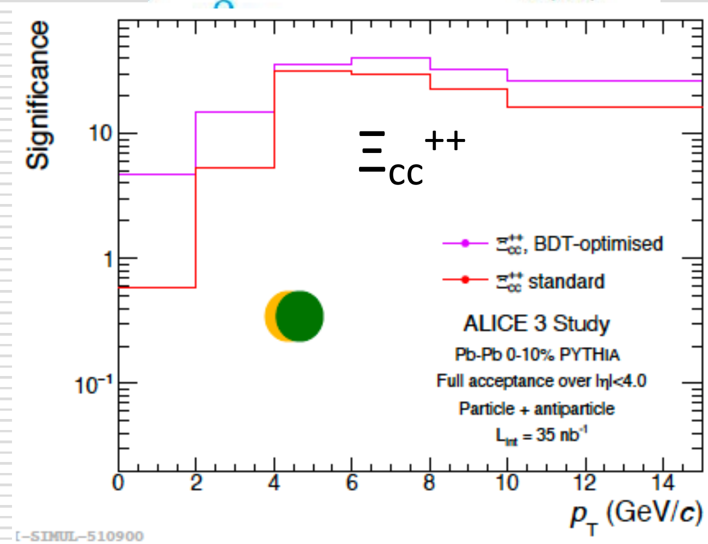
ALICE 3: physics performance

Multi-charm baryons

- Ξ_{cc}^{++} reconstructed in the channel:
  $\Xi_{cc}^{++} \rightarrow \Xi_{c}^{+}\pi^{+} \rightarrow \Xi^{-}\pi^{+}\pi^{+}\pi^{+}$
- Ω_{cc}+ reconstructed in the channel:
  $\Omega_{cc}^{+} \rightarrow \Omega_{c}^{0}\pi^{+} \rightarrow \Omega^{-}\pi^{+}\pi^{+}$
- Performance for Ω_{ccc} studies ongoing







ALICE 3 LOI arXiv:2211.02491

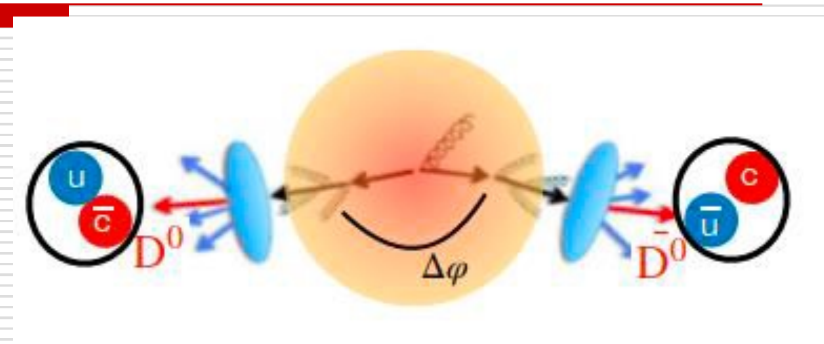
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

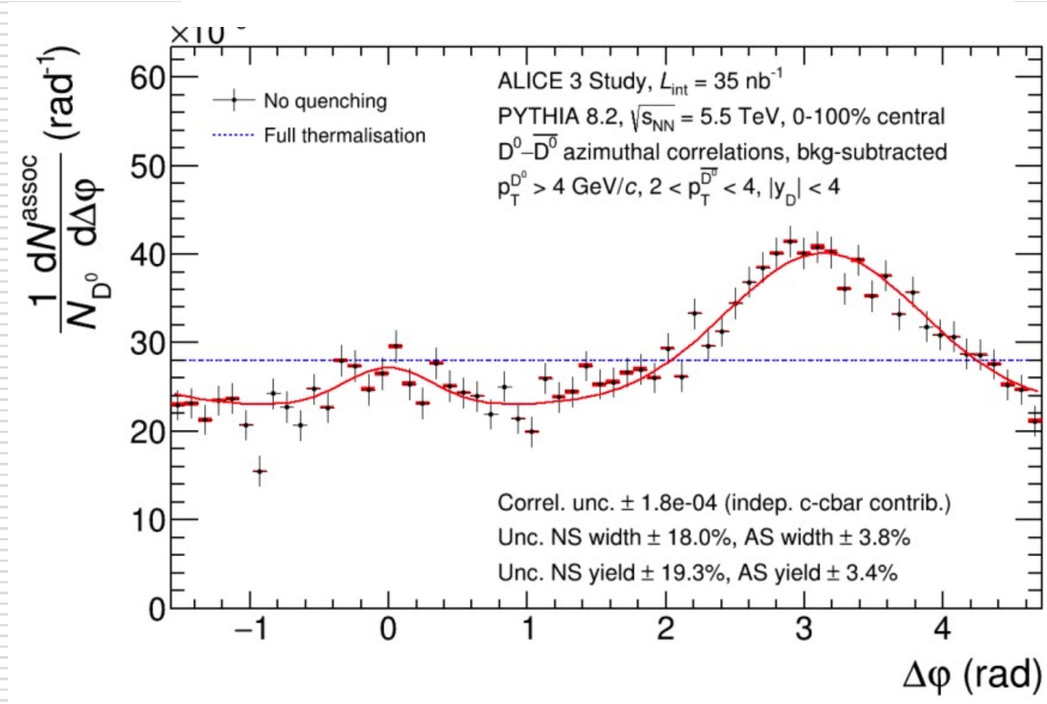
ALICE 3: physics performance

$D^0 - \overline{D}^0$ azimuthal correlation

- measure angular (de)correlation
  - direct probe of HF interaction with the QGP
- Strongest signal at low p_T
- Very challenging measurement:
  - good purity, efficiency and η coverage

In heavy-ion collisions doable only with ALICE 3



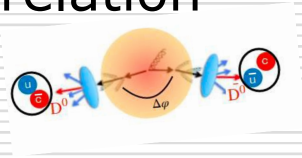


ALICE 3 LOI arXiv:2211.02491

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 824093.

Not just p and Pb at the LHC!

- Lighter systems like Ar-Ar, Kr-Kr or Xe-Xe
  - smaller size and shorter lifetime of the QGP
  - can offer nice opportunities, e.g.:
    - Study the approach of HF quarks to thermal equlibration with lighter partons in the QGP
    - Emergence of decoherence in DDbar angular correlation
    - test-bench for hadronization mechanisms
      - Multi-charmed baryons, B_C, strange HF hadrons



- Very light system like O-O
  - Bridge between pp (and p-Pb) and heavy ions
    - onset of energy-loss effects in small colliding systems, which has not been observed yet
- Better experimental conditions

→ Discussed since long, see e.g. arXiv:1812.06772

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

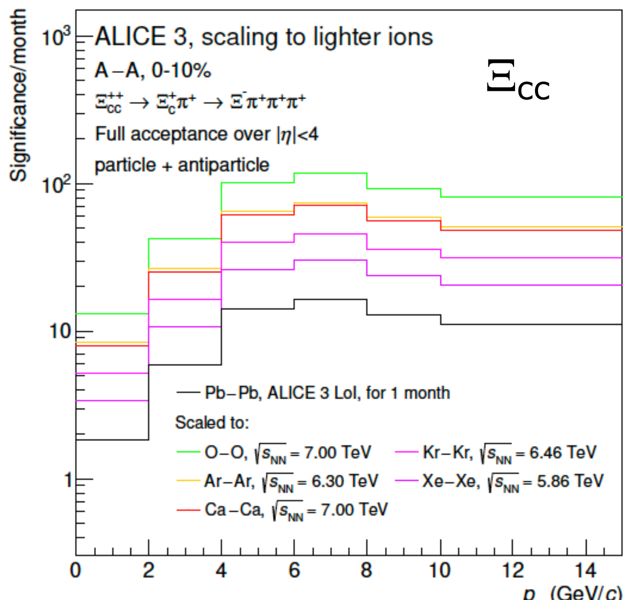
Not just p and Pb at the LHC!

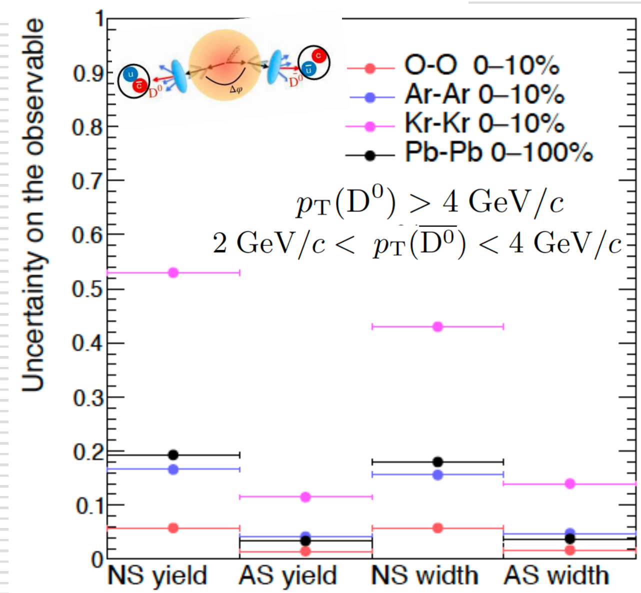
Estimate in **signal gain** with basic scaling assumptios

	O–O	Ar–Ar	Ca–Ca	Kr–Kr	Xe–Xe	Pb–Pb
A	16	40	40	78	129	208
L_{int} (nb^{-1}/month)	1600	340	310	84	26	5.6
σ_{inel}	1.41	2.6	2.6	4.06	5.67	7.8
G events/month	2250	880	810	340	150	44
$S_{\mathrm{AA}}/S_{\mathrm{PbPb}}$ for $\mathrm{A}^{5/3}$ scaling	4.0	3.9	3.5	2.9	2.1	1
$S_{\mathrm{AA}}/S_{\mathrm{PbPb}}$ for A^{2} scaling	1.7	2.2	2.0	2.1	1.8	1
$S_{\mathrm{AA}}/S_{\mathrm{PbPb}}$ for $\mathrm{A}^{7/3}$ scaling	0.7	1.3	1.2	1.5	1.5	1
$S_{\mathrm{AA}}/S_{\mathrm{PbPb}}$ for $\mathrm{A}^{8/3}$ scaling	0.3	0.7	0.7	1.1	1.3	1

Light part.
D & tot c
Ξ_{cc}
Ω_{ccx}

Assuming same selection efficiency as for Pb-Pb





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

Conclusions and remarks

- Heavy Flavour plays a key role in the Heavy Ion programme of the HL LHC (*and SPS*)
  - Access to the microscopic dynamics of the collisions and the QGP since its earliest phase
  - Strong theoretical grounds
- Experimental requirements:
  - Large statistics "on tape":
    - Trigger-less selection (→ continuous readout)
    - Luminosity hungry: Run3+4 x2-3; Run5+6 x2-3
  - Cutting-edge micro-vertex detector
  - Excellent PId for hadrons (and leptons)
- Quantum jump in the precision with ALICE 3
  - A few runs with lighter ions relevant

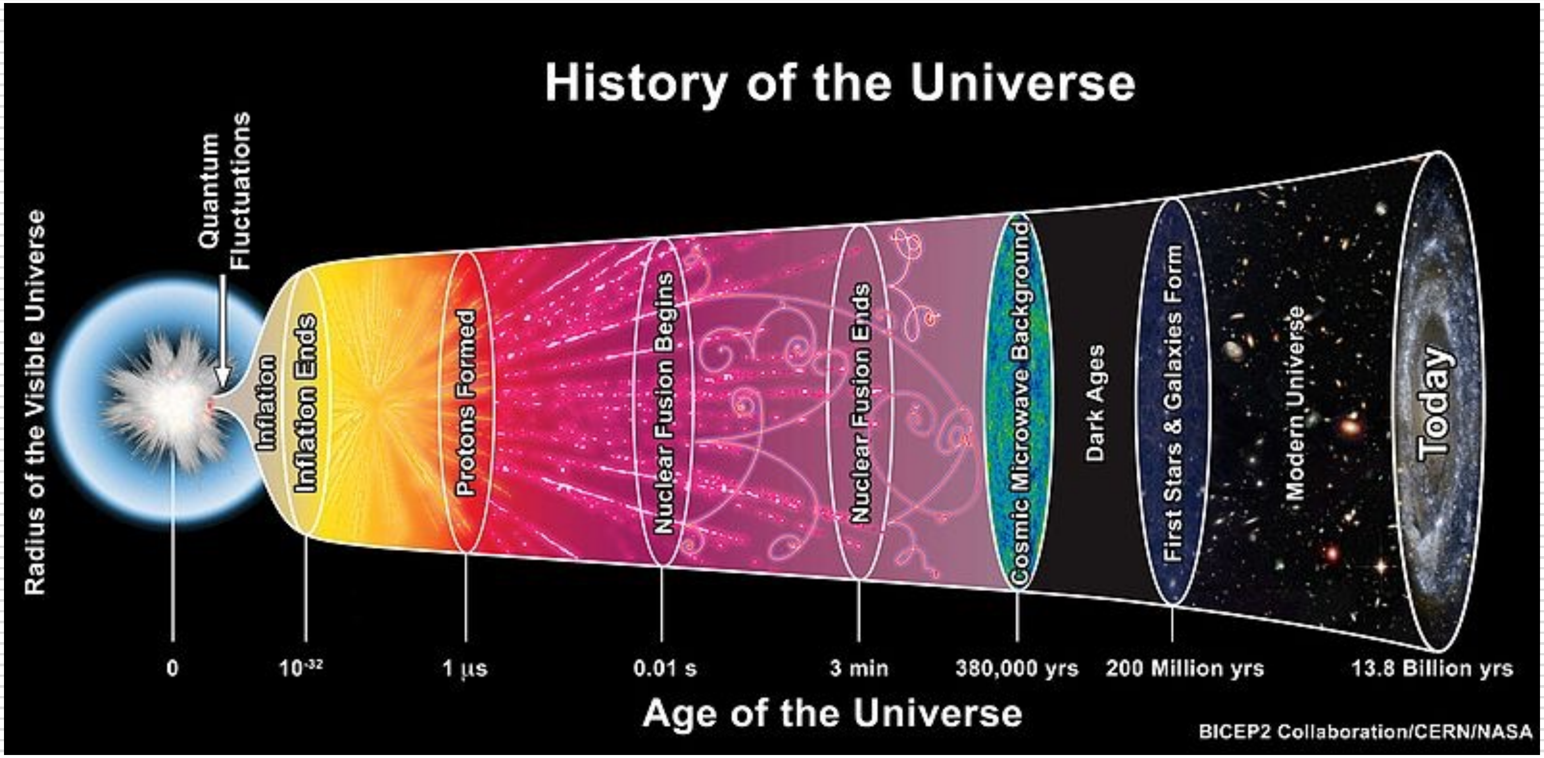
EXTRA

What can we learn from HI collisions ?

Credits: W. Busza et al. Annu. Rev. Nucl. Part. Sci. 2018.68:339-376

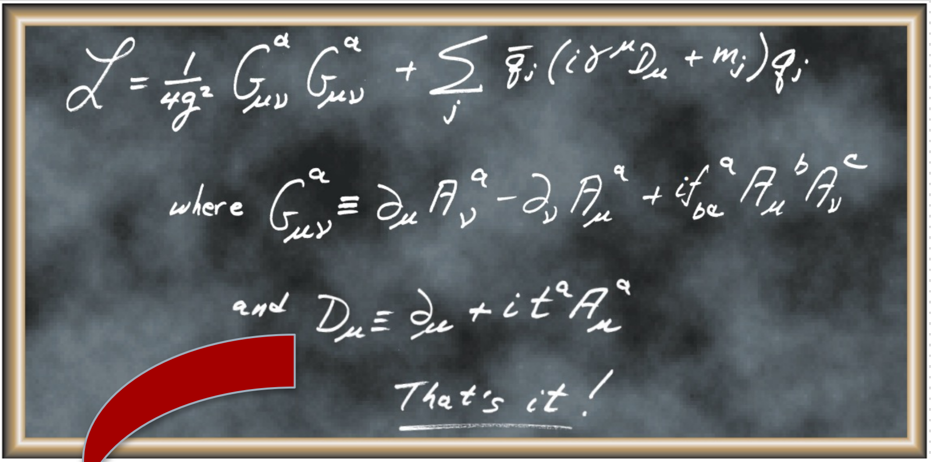
QCD in Cosmology

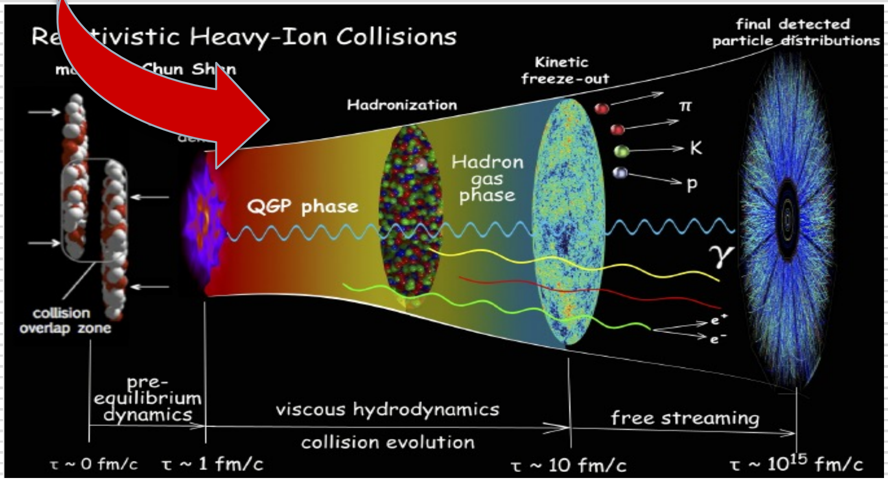
- heavy ion collisions recreate droplets of the state of matter of our Universe 1μs after the Big Bang
  - state at this time and its evolution to hadronic phase (cross-over vs. 1st order phase transition) had severe influence on the entire history of our Universe



What can we learn from HI collisions ?

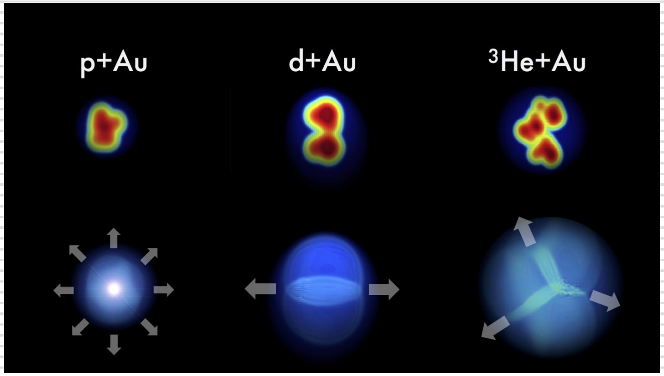
Emergence of Complex Quantum Matter





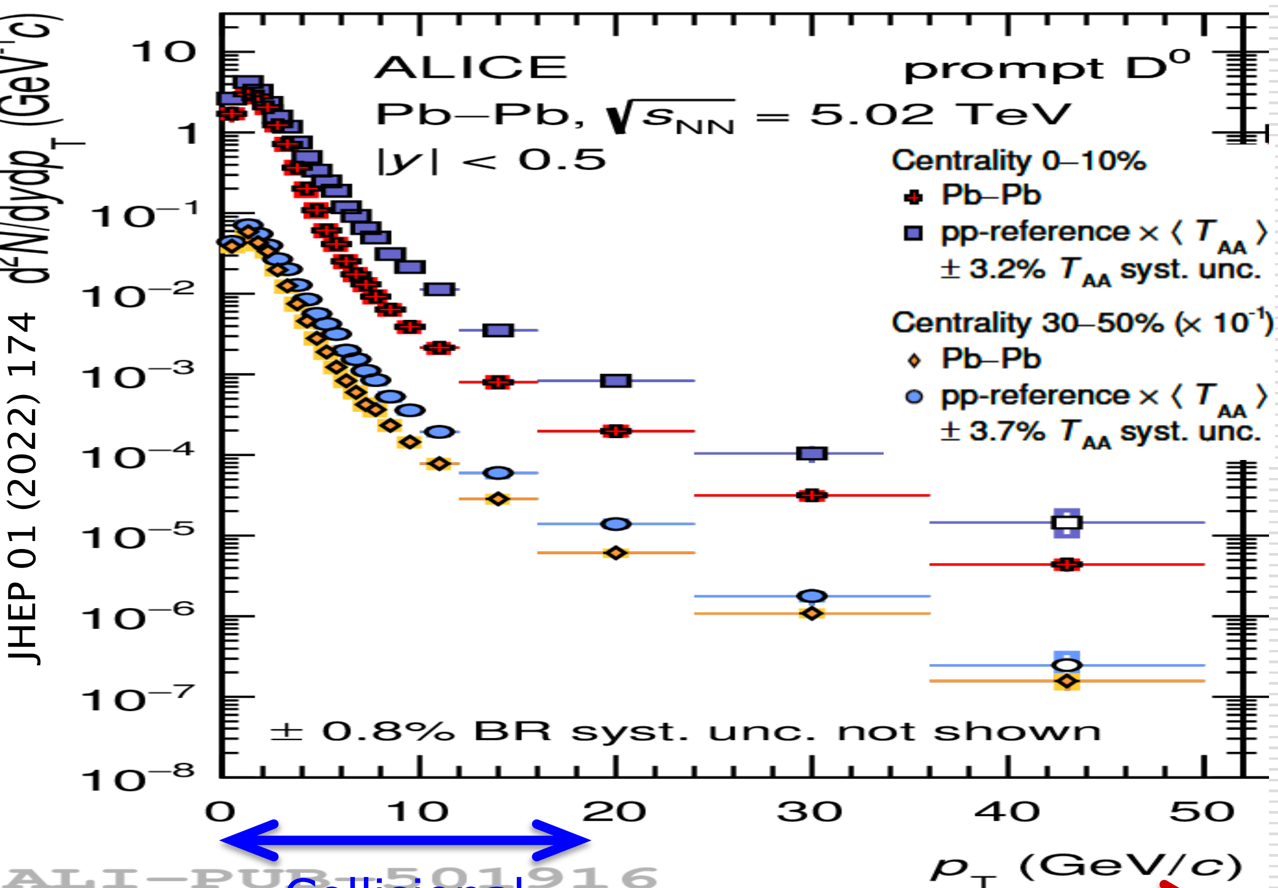
not just HI…

- study of "reference" colliding systems like pp and d-Au is a fundamental part of any HI programme



At the LHC, not just "reference": extreme pp and p-Pb events have revealed unexpected features

p_T range drives the physics



Collisional dE/dx relevant

Radiative dE/dx dominates

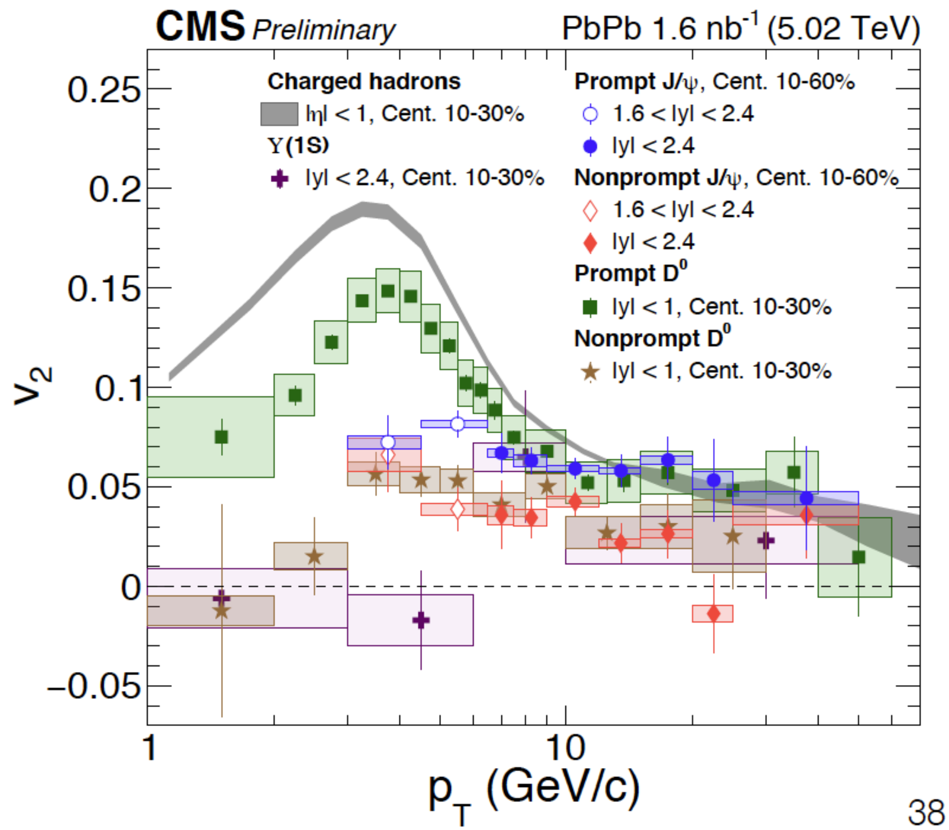
Bulk of production
recombination relevant (even dominant for J/ψ)

the lower the better !

also for other observables, e.g. v_2

v_2 of Heavy Flavor in PbPb

- Nonprompt D^0 < prompt D^0
- Nonprompt J/Ψ < prompt J/Ψ
- $\Upsilon(1S) \approx 0$
- **Consistent picture of charm flow**
- **Less clear for beauty quarks**

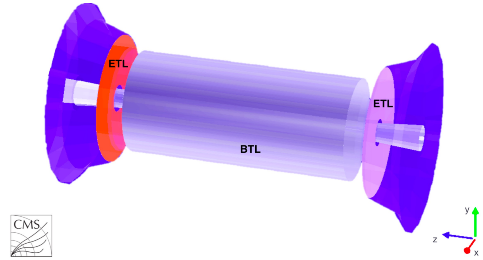


CMS FINAL RESULT QM23

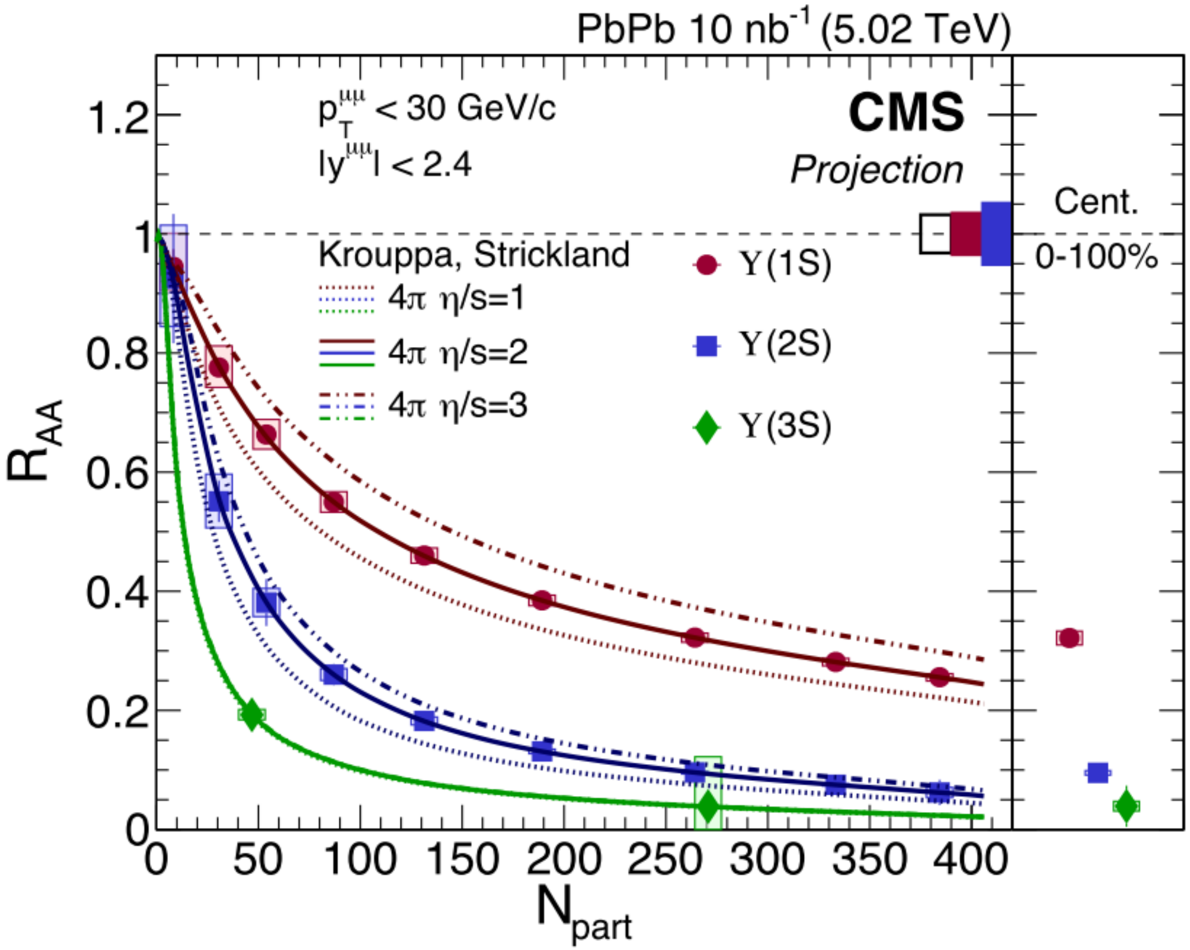
HIN-21-008 Submitted to JHEP

Milan Stojanovic's talk
Wed, 16:30, Ballroom D

CMS in LS3: MTD

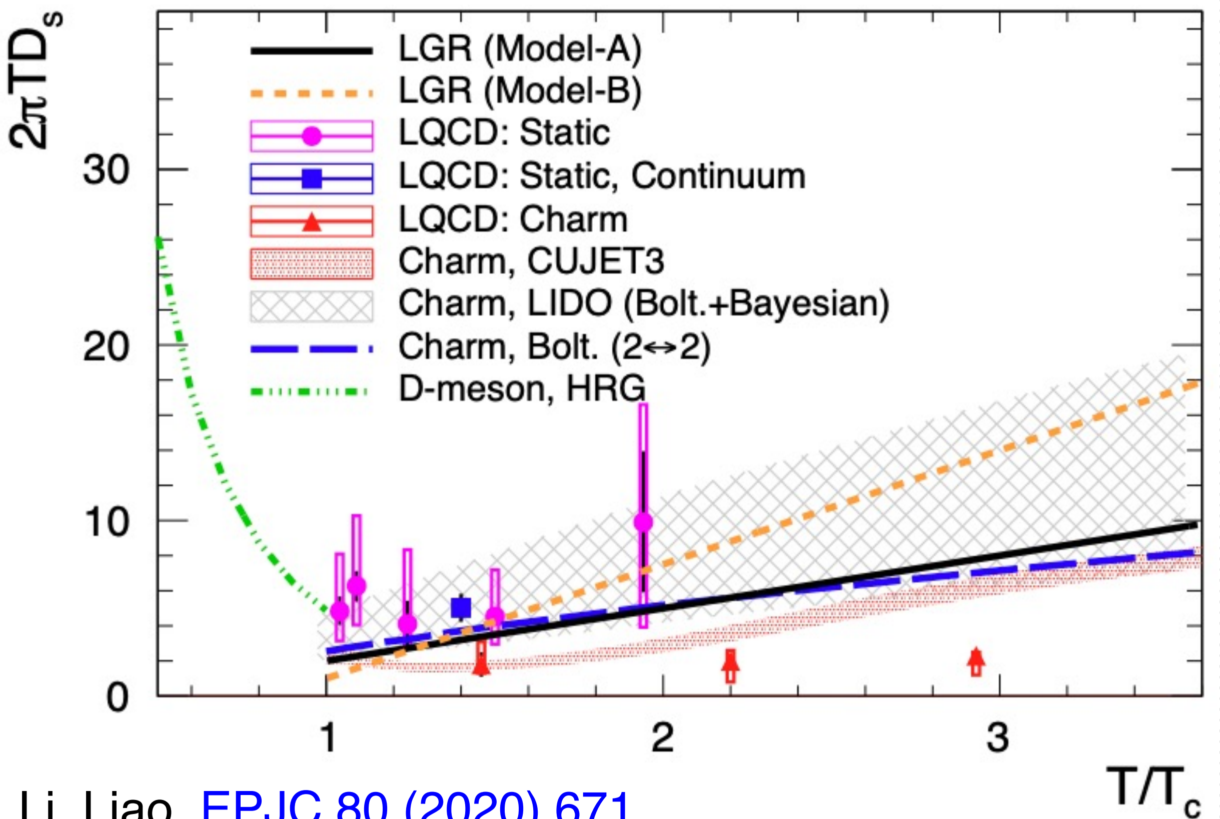


Quarkonia



Charm spatial diffusion coefficient

- key transport parameter (quantifies drag, thermal, recoil forces)



Li, Liao, EPJC 80 (2020) 671

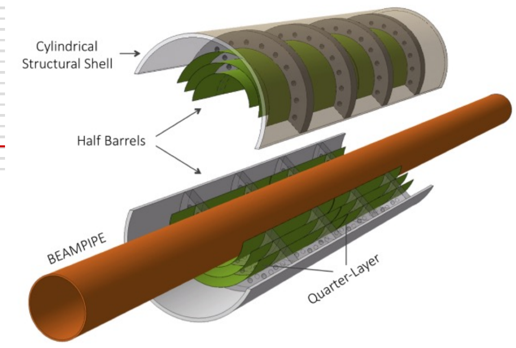
From that one derives the drag and momentum diffusion coefficients:

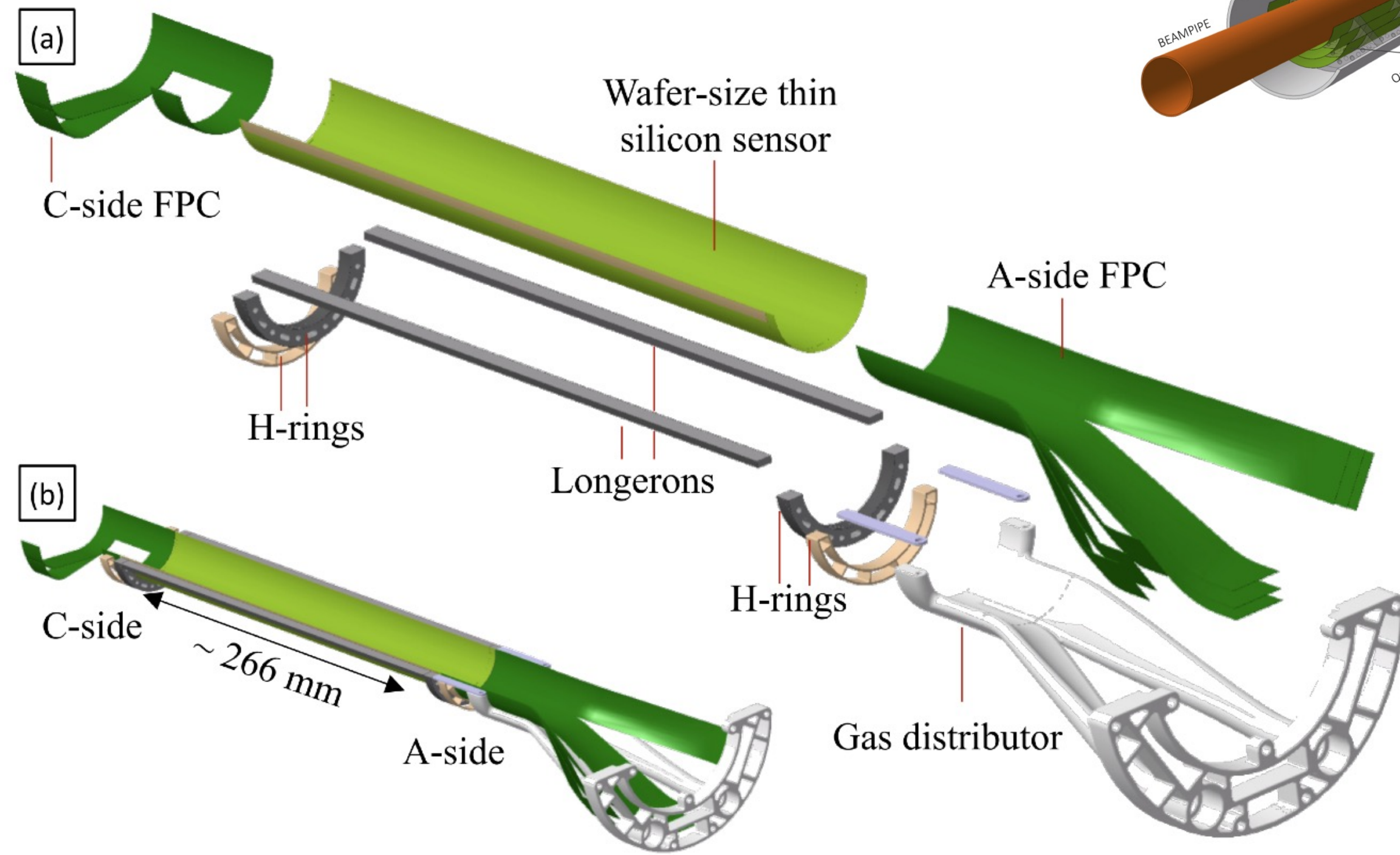
$$\eta_D(\vec{p},T) = \frac{1}{2\pi T D_s} \cdot \frac{2\pi T^2}{E}$$

$$\kappa(T) = \frac{1}{2\pi T D_s} \cdot 4\pi T^3.$$

ALICE data (including v_3), *JHEP01 (2022) 174*: $1.5 < 2\pi T_c D_s < 4.5$

ITS3 layer

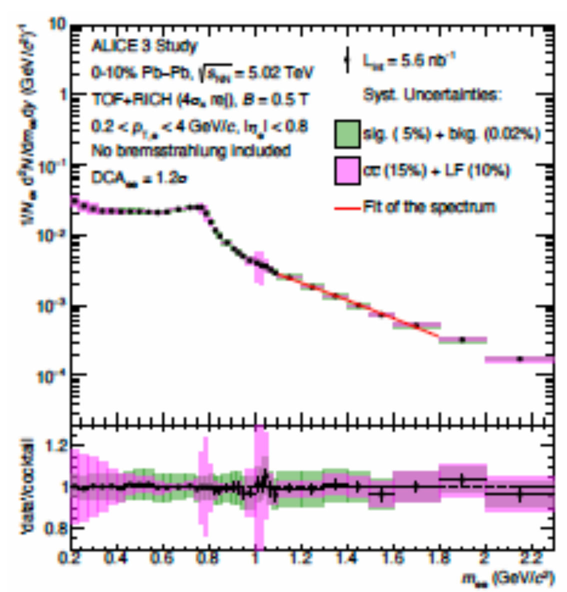

Cylindrical
Structural Shell
Half Barrels
BEAMPIPE
Quarter-Layer

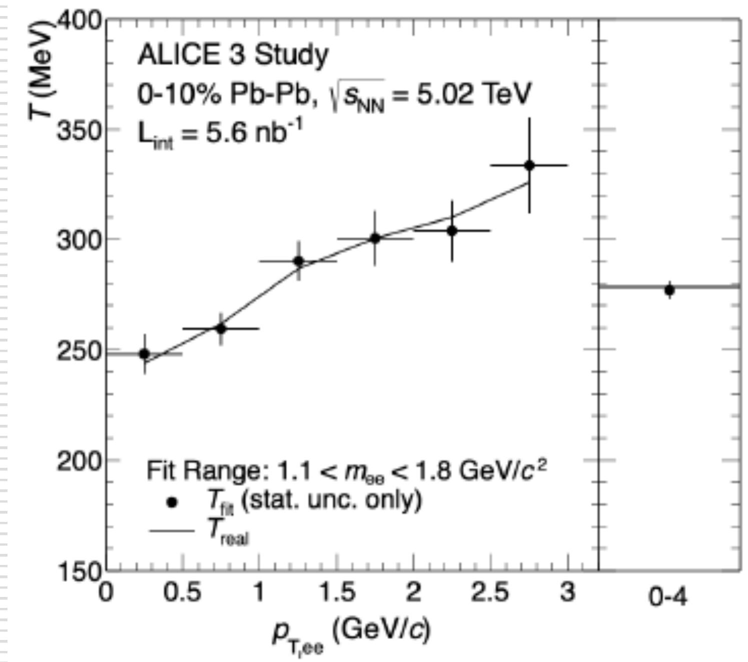

(a)
C-side FPC
Wafer-size thin
silicon sensor
A-side FPC
H-rings
Longerons
H-rings
Gas distributor
(b)
C-side
~ 266 mm
A-side

ALICE 3: physics performance

Thermal radiation and chiral symmetry restoration

- access to time evolution of the QGP temperature





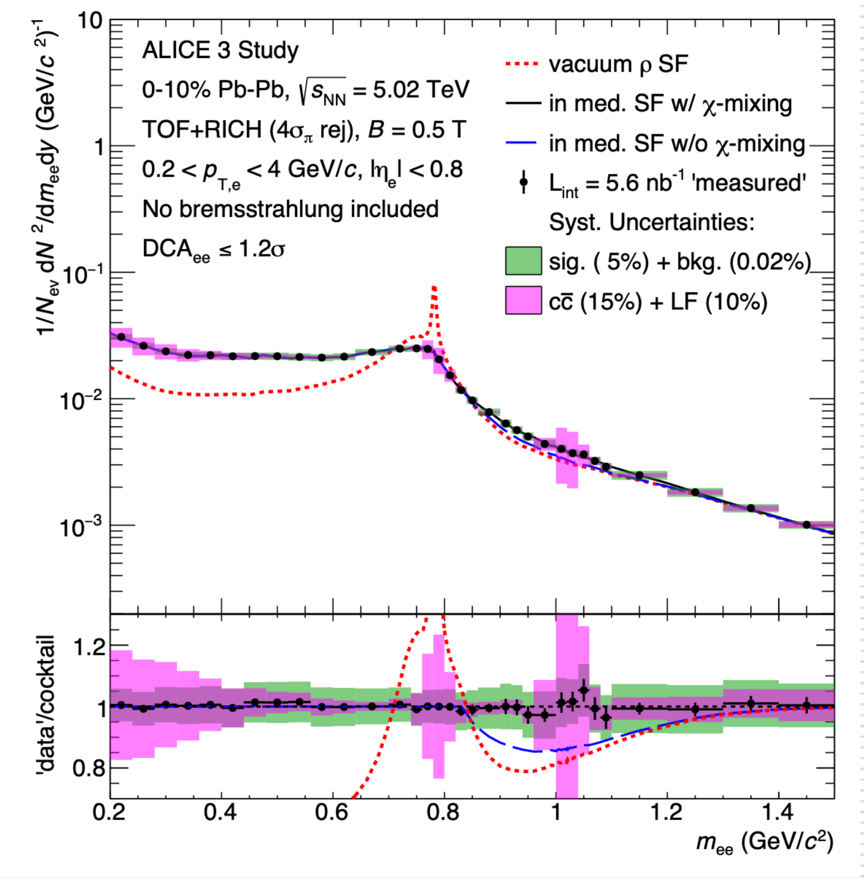
ALICE Coll. arXiv:2211.02491

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 824093.

ALICE 3: physics performance

Thermal radiation and chiral symmetry restoration

- access to time evolution of the QGP temperature
- Spectral function of low mass dielectrons determined with 6-8% unc. in the region $0.4 \leq m_{ee} \leq 1.3$ GeV/c^2
- Chiral mixing would produce a 20-25% change versus vacuum spectral functions ($0.8 \leq m_{ee} \leq 1.2$ GeV/c2)



ALICE Coll. arXiv:2211.02491

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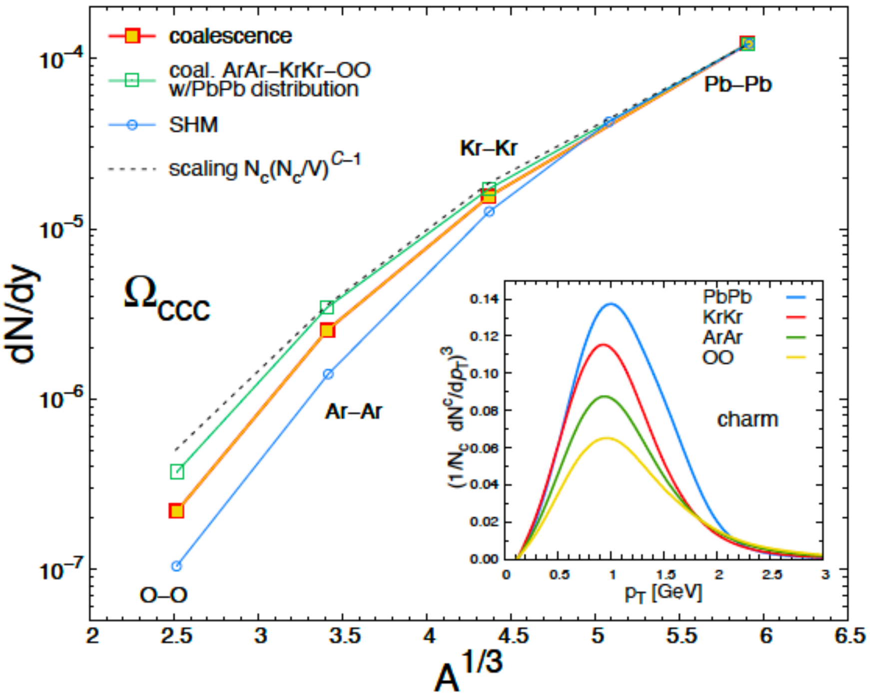
ALICE 3: physics performance

Multi-charm baryons: why?

- different models to describe charm equilibration and hadronisation:
  - H. He et al. PLB 746 (2015) 59
  - A. Andronic et al. JHEP 07 (2021) 035
  - J. Zhao et al. PLB 771 (2017) 349
  - X. Yao et al. PRD 97 (2018) 074003
  - S. Cho et al. PRC 101 (2020) 024902
  - etc…
- study of multi-charm baryons over different collisions systems (e.g. from O-O to Pb-Pb) very sensitive to the non-equilibrium features of charm quarks

V. Minnisale et al. arXiv:2305.03687



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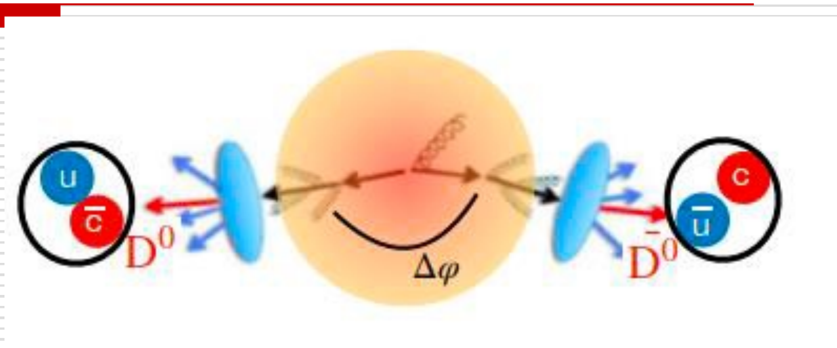
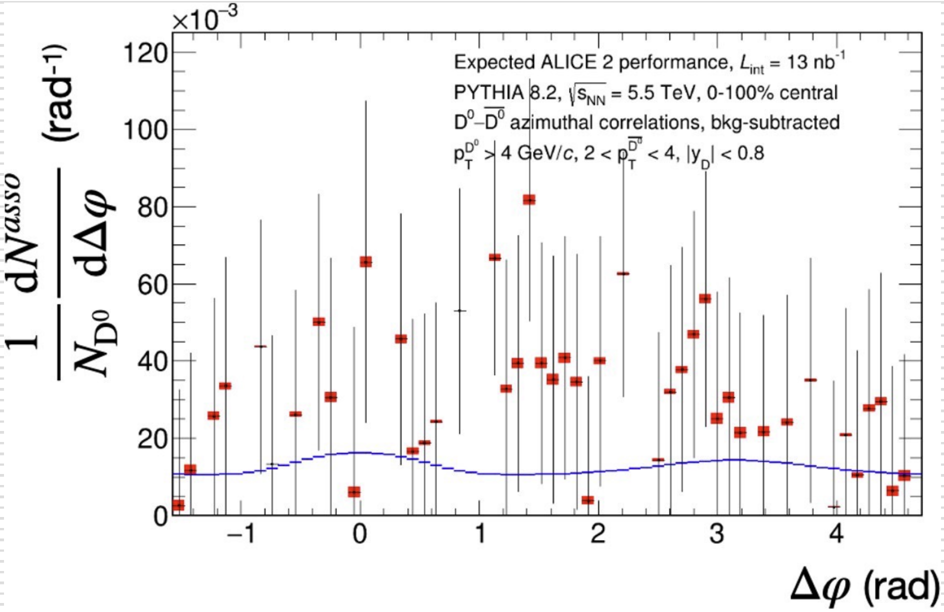
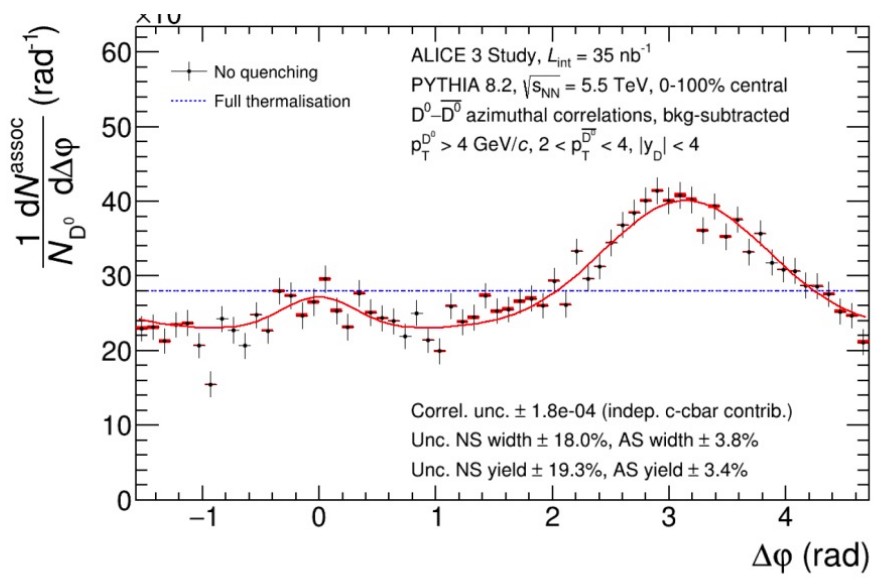
ALICE 3: physics performance

$D^0 - \overline{D}^0$ azimuthal correlation



ALICE 2(.1) Run 3 + 4 projection





In heavy-ion collisions doable only with ALICE 3

ALICE 3 LOI arXiv:2211.02491

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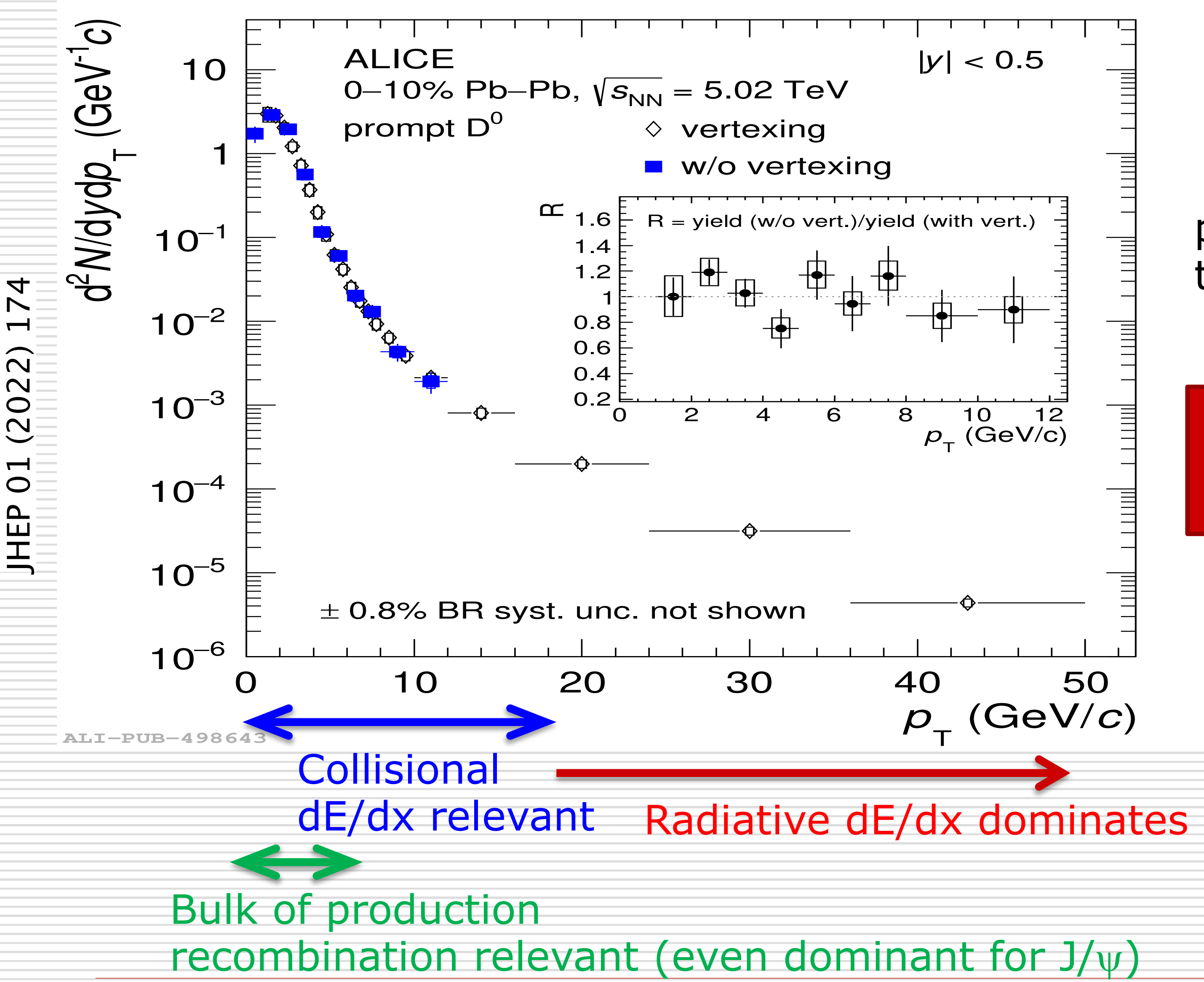
p_T range drives the physics



p_T range drives the physics

the lower the better !

also for other observables, e.g. v_2