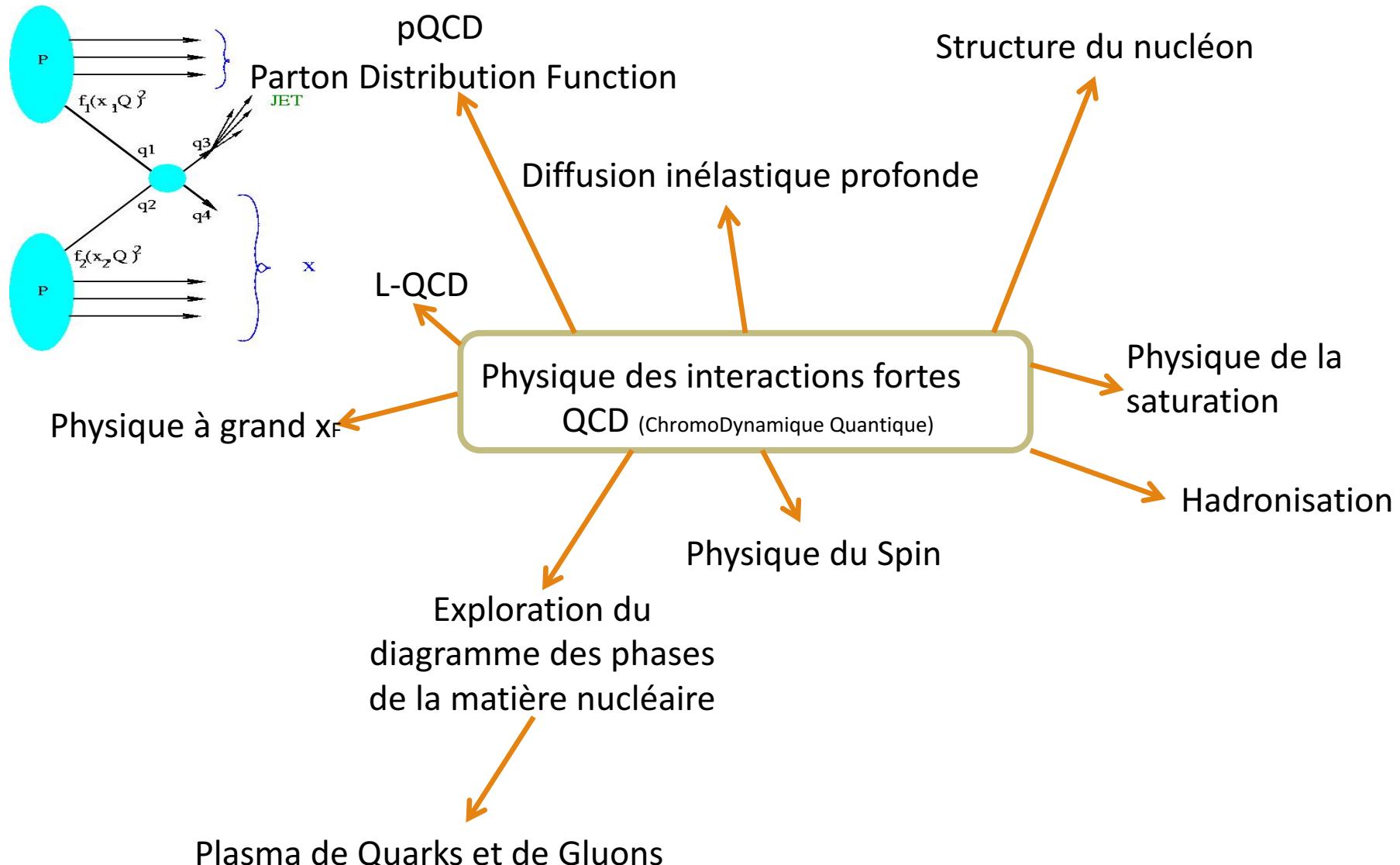


Physique et détecteurs à la frontière Physique hadronique

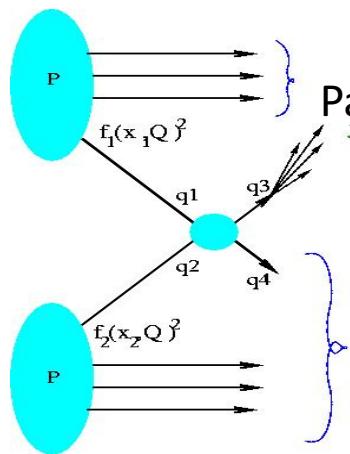
SARAH PORTEBOEUF HOUSSAIS

22 JUIN 2021

Physique des interactions fortes

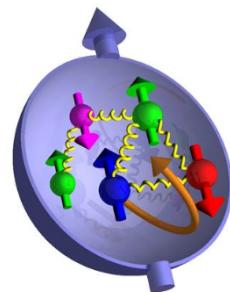


Physique des interactions fortes



pQCD
Parton Distribution Function

Structure du nucléon



Physique à grand x_F

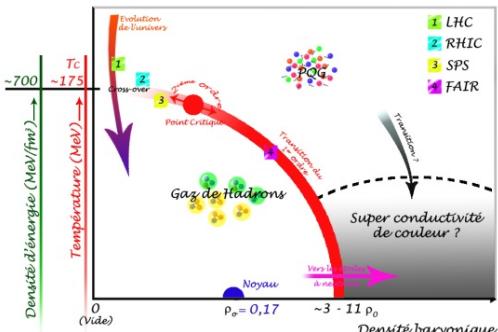
Physique des interactions fortes
QCD (ChromoDynamique Quantique)

Physique de la saturation

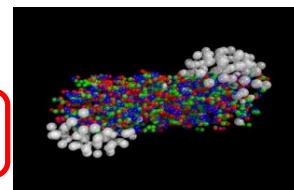
Hadronisation

Physique du Spin

Exploration du diagramme des phases de la matière nucléaire



Plasma de Quarks et de Gluons

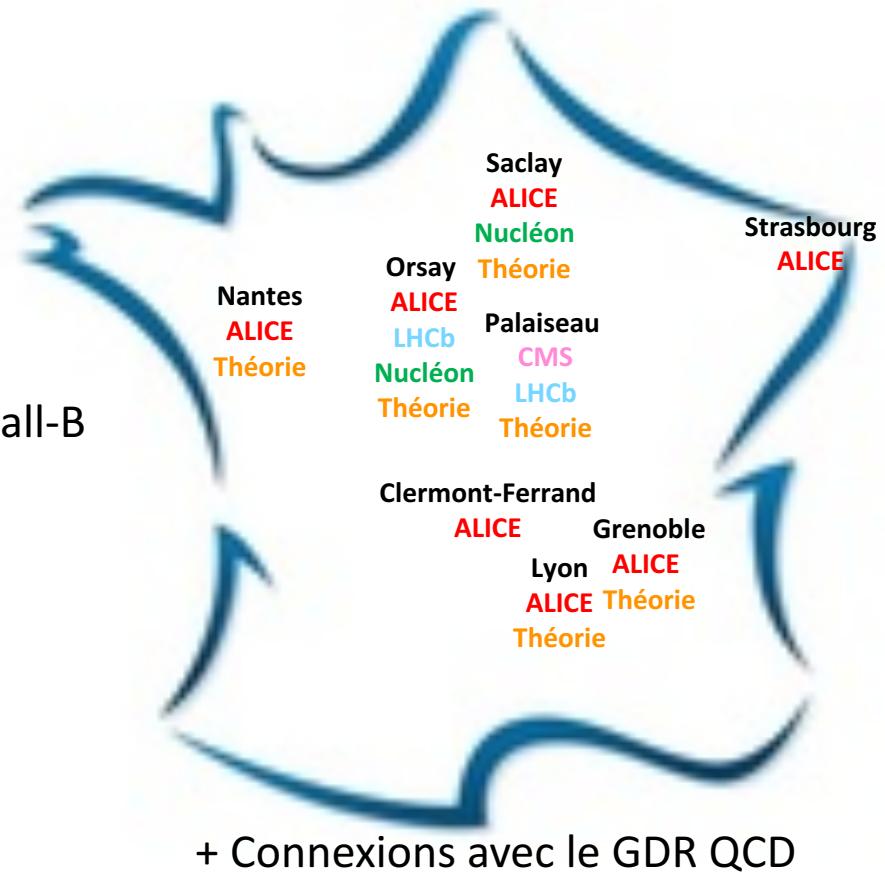


Sondes dures

Sondes globales

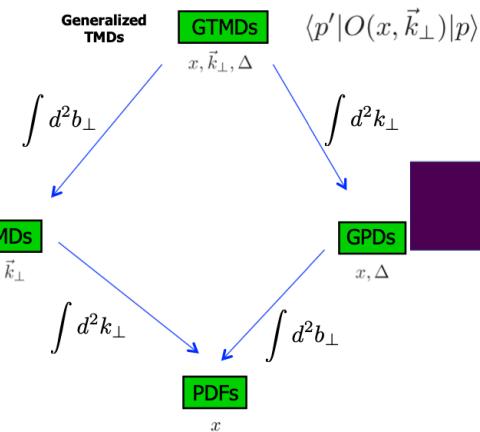
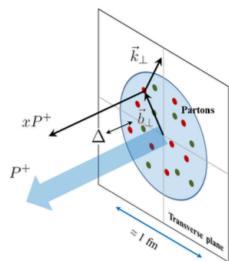
Contexte et communauté française

- O(100) physicien.ne.s
- + Ingénieur.e.s et technicien.ne.s
- Projets : ALICE
CMS
LHCb
JLAB NPS Hall-C, ALERT, CLAS Hall-B
EIC
- **Prospectives IN2P3 GT03 – Mars 2020**
<https://indico.in2p3.fr/event/20116/>
- Disclaimer : quelques focus sur les directions de la **communauté française**
- Point de vue *physicien.ne.s et certainement biaisé !*

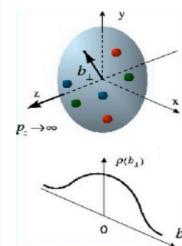


Structure du nucléon

Contents

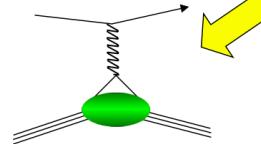


Les Distributions de Partons Généralisées



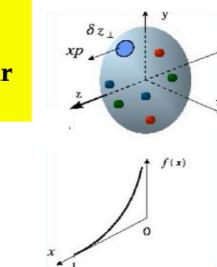
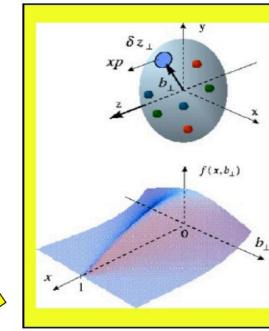
Facteurs de forme :
Distributions des positions transverses des quarks

$$F_1(t), F_2(t)$$

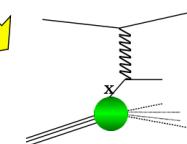


Diffusion élastique $ep \rightarrow e'p'$
(Hofstadter, prix Nobel 1961)

GPDs: H, E, \tilde{H} , \tilde{E}
Distributions des corrélations entre position et impulsion pour les quarks et les gluons



Distributions des partons :
Distributions de l'impulsion longitudinale des quarks
 $q(x), \Delta(x)$



Diffusion profondément inélastique (DIS) $ep \rightarrow e'X$
(Friedman, Kendall, Taylor, prix Nobel 1990)

A court terme, plusieurs expériences prévues à JLab

- 2021 Longitudinally polarized neutrons in CLAS
- 2022-23 Proton DVCS with NPS in Hall-C
- 2022-23 Nuclear DVCS with ALERT

Attention, le calendrier de JLab n'est officiel qu'à 18 mois !

Opportunités à moyen terme

- Développement d'un faisceau de positrons polarisés
 - Possiblement utilisé sur EIC à plus long terme
- Setup pour le double DVCS
- Des analyses sur plusieurs années
 - Il faut compter 5 ans pour compléter toutes les analyses
 - Certains canaux vont bénéficier de nouvelles prises de données

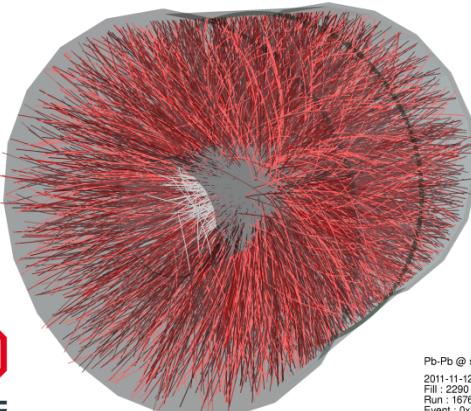
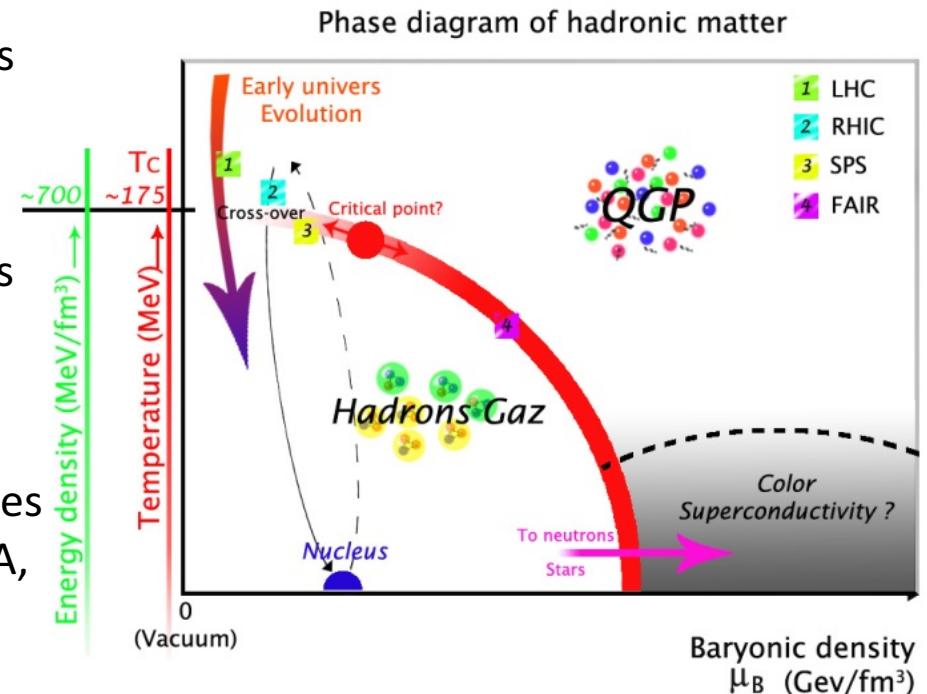
Une équipe de 5 permanents regroupés au IJCLab

- Renforcement à 6 à partir d'octobre en principe
- Non permanents 5 PhD et 2 postdocs
- Une équipe CEA de 2 permanents

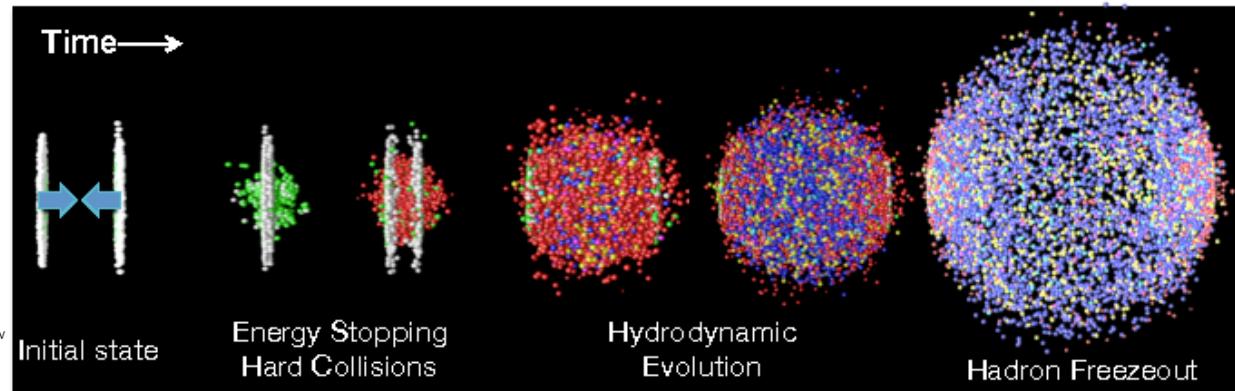
L'activité JLab doit donc se prolonger intensivement jusqu'à 2030 et avec une réduction d'intensité à partir de 2025

Le Plasma de Quarks et de Gluons

- QGP: état déconfiné de quarks et de gluons produit dans les collisions d'ions lourds à hautes énergies (RHIC/LHC)
- Son étude nécessite une déconvolution des autres composantes (état initial, effet nucléaire froid, état final)
- Étude systématique de plusieurs observables dans plusieurs conditions (systèmes pp, p-A, A-A) inputs théoriques nécessaires

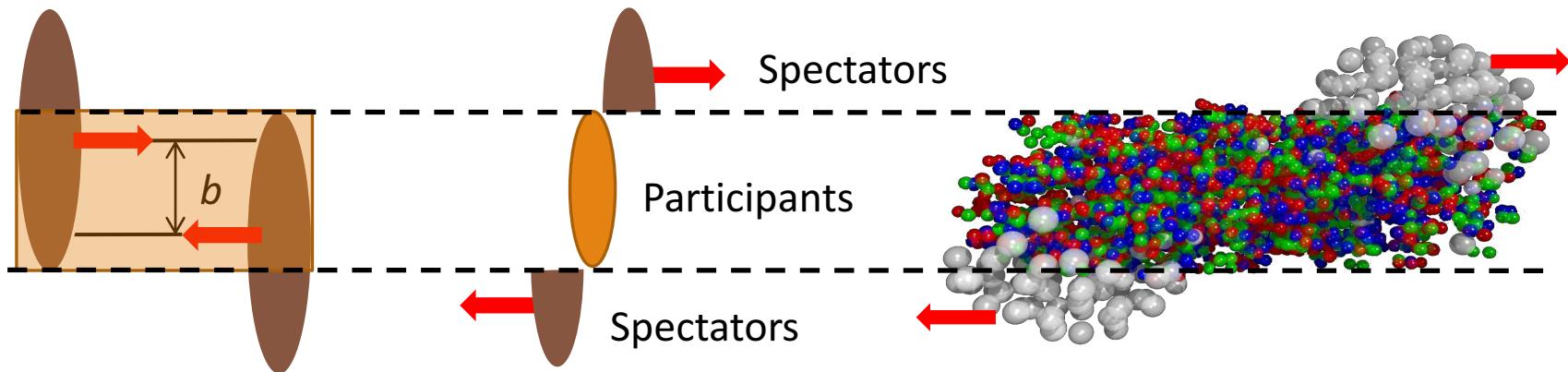


Pb-Pb @ $\sqrt{s} = 2.76$ ATeV
2011-11-12 06:51:12
Fill : 2290
Run : 167693
Event : 0x3d94315a



Strategy for QGP studies

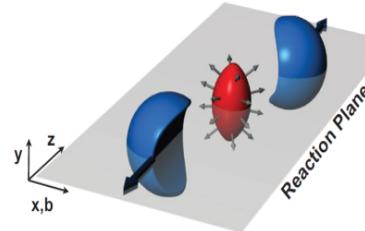
- pp collisions are considered as the vacuum reference
- p-A collisions are a control experiment to estimate cold matter effects
- AA collisions are described by a (geometrical) Glauber model defining the number of participants and the number of binary collisions (N_{coll}) for a given impact parameter b



- Emblematic observables for hard and soft probes

Nuclear modification factor

$$R_{\text{AA}} = \frac{dN_{\text{AA}}/dp_T}{\langle N_{\text{coll}} \rangle \times dN_{\text{pp}}/dp_T}$$



Elliptic flow

Initial spatial anisotropy transferred into a momentum anisotropy of particles

$$\frac{dN}{d\varphi} \propto 1 + 2 \sum_{n=1}^{\infty} v_n \cos(n(\varphi - \Psi_n))$$

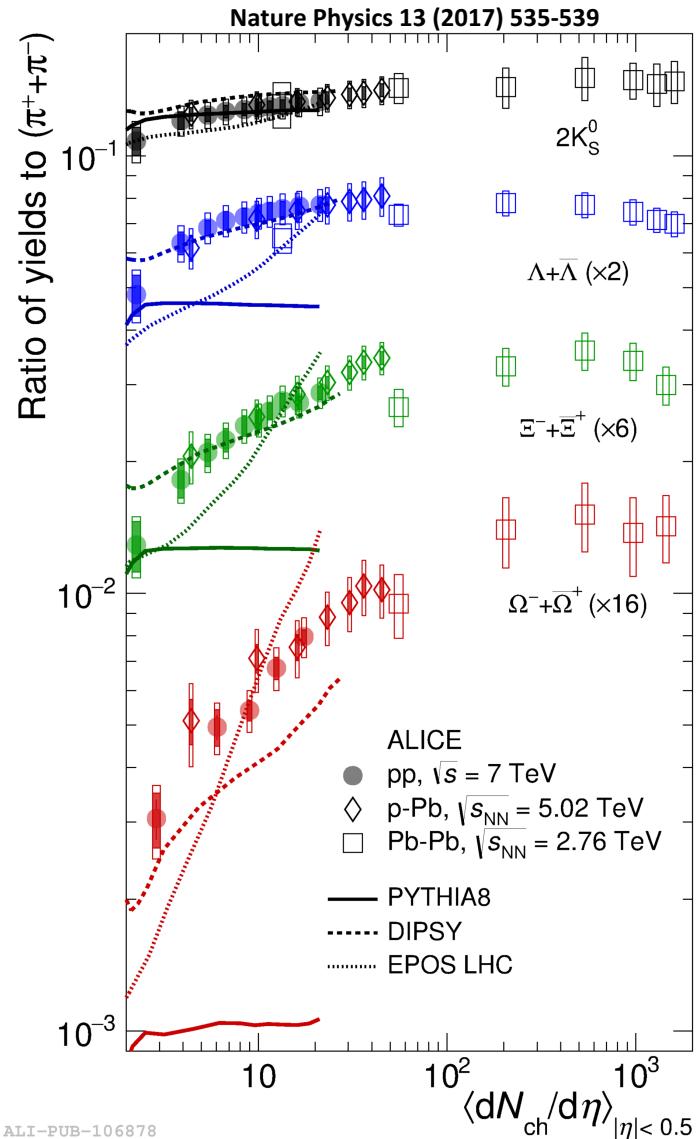
What is a small system for QGP physics?

- Small refers to system size: protons in initial stage
- But with sometimes a final state looking like a large system, at least for charged particle multiplicity
- For LHC RUN 1+2 energies, idea of reference system still valid for pp minimum bias. High multiplicity events represent a small contribution to the total cross section
 $O(10^{-4})$ in statistics

pp/pA/AA at the same multiplicity, is it the same behavior, role of geometry, role of collectivity?

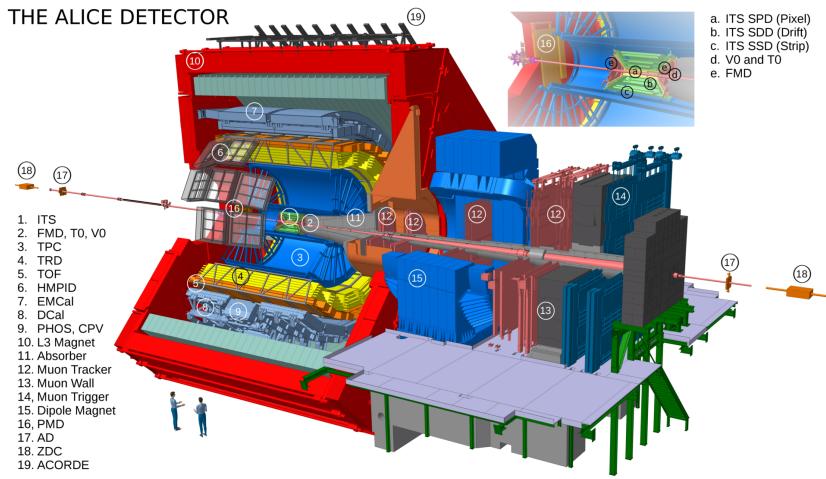
How is done the transition from small to large ?

How does the collectivity emerge ?

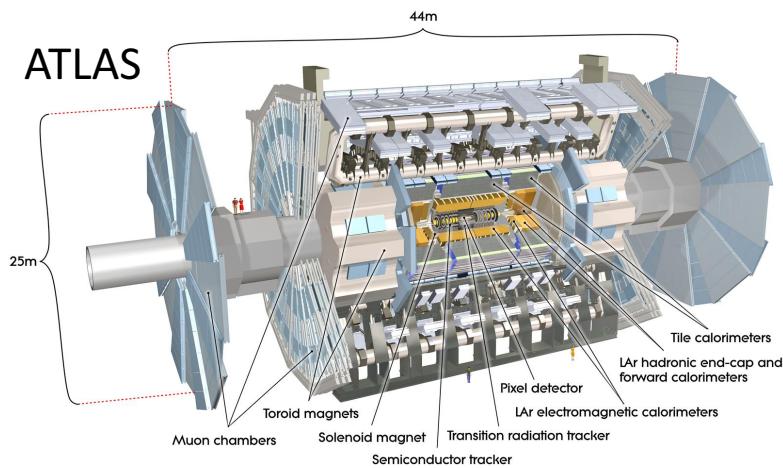


QGP experiments at LHC

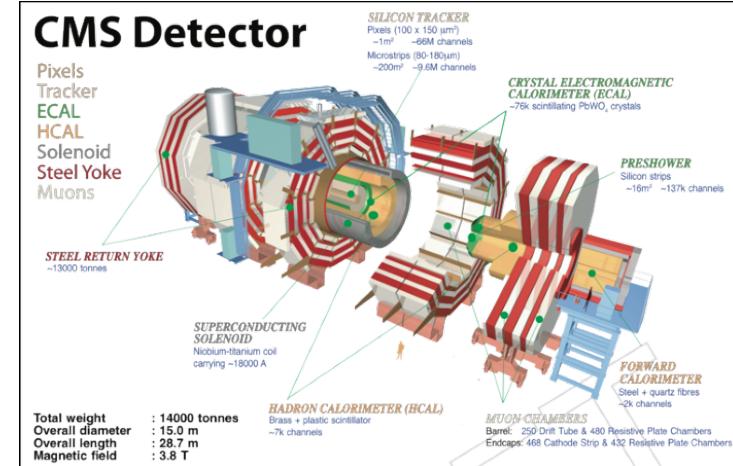
THE ALICE DETECTOR



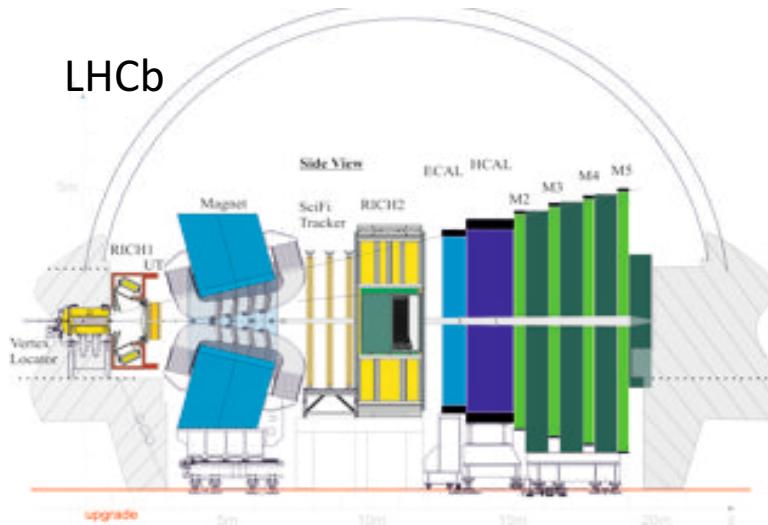
ATLAS



CMS Detector



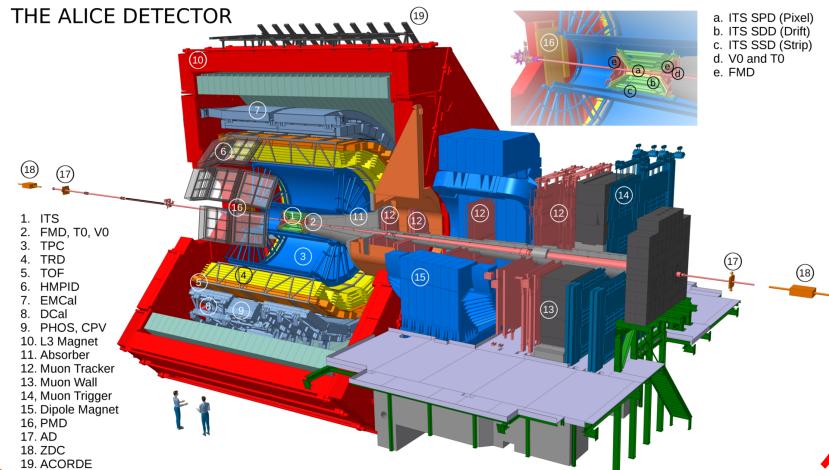
LHCb



QGP experiments at LHC

Dedicated to heavy-ion physics

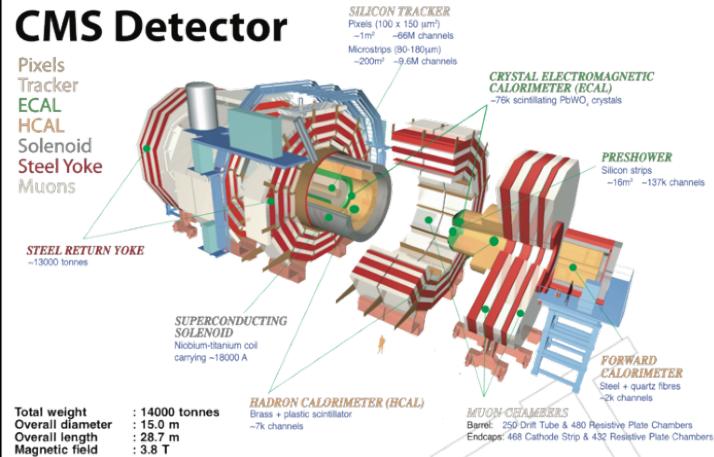
THE ALICE DETECTOR



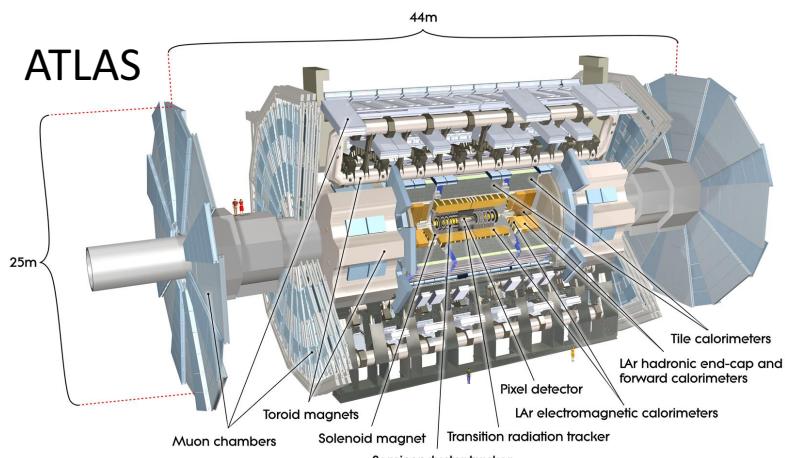
1. ITS
2. FMD, TO, VO
3. TRD
4. TOF
5. HMPID
6. EMCAL
7. PHOS
8. CPV
9. L3 Magnet
10. Absorber
11. Muon Tracker
12. Muon Wall
13. Muon Trigger
14. Dipole Magnet
15. PMD
16. AD
17. ZDC
18. ACORDE

Developed an heavy-ion program

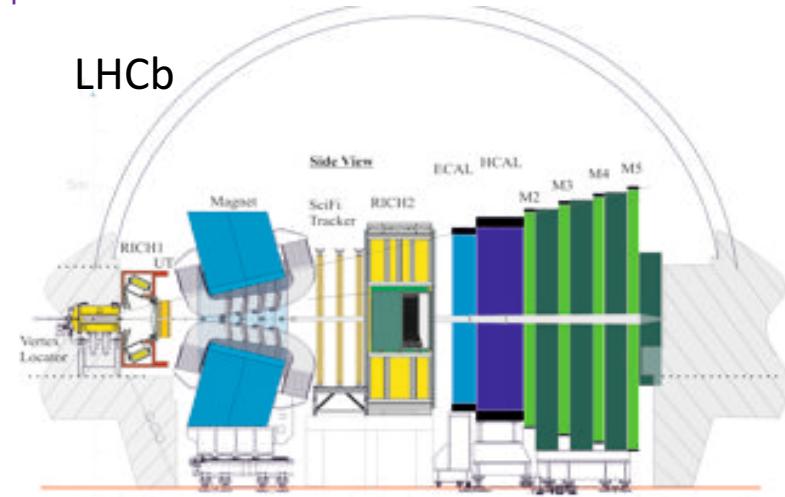
CMS Detector



ATLAS

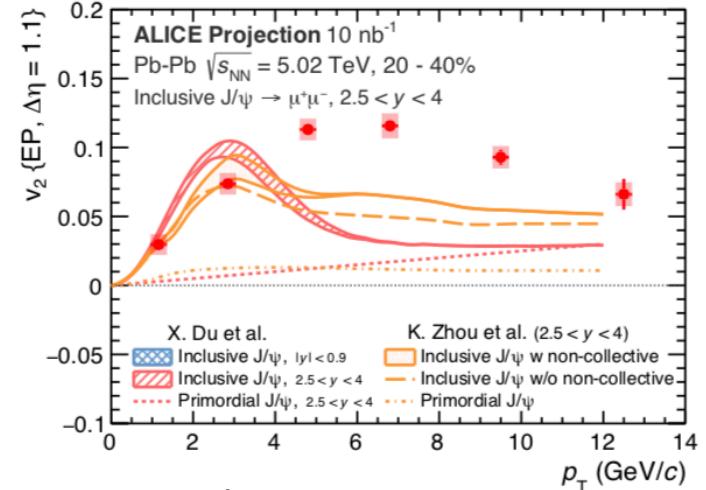
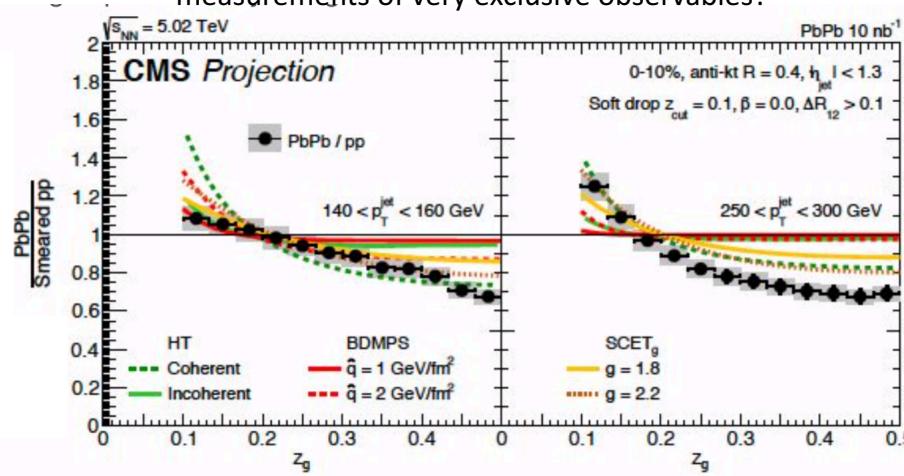


LHCb



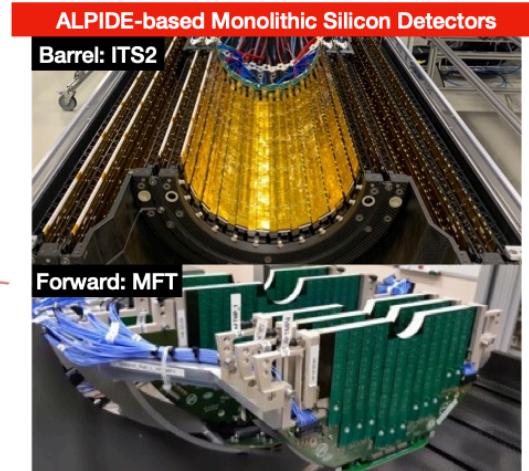
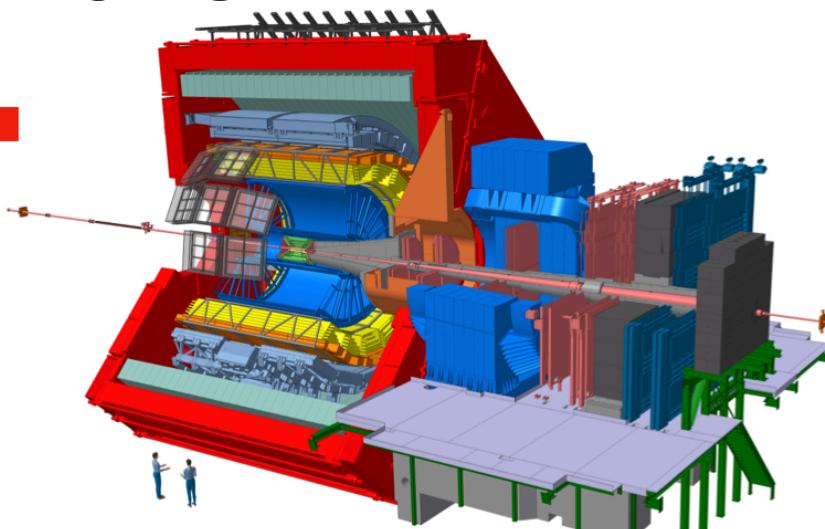
RUNS 3 (Feb. 2022)

- Augmentation en énergie, augmentation en luminosité, augmentation en statistique
- Pb-Pb readout rate 50kHz, x100 stat
- Bénéfice des upgrades (particulièrement pour ALICE et LHCb) : réduction de matériel, bas p_T
- Des questions identifiées (effort expérimental et théorique)
 1. Is there a common origin of soft particles production from pp to AA collisions? Is the prevailing description via fluid dynamics the correct approach? What is the dynamical origin of collectivity?
 2. Can signatures of chiral symmetry restoration be found and thermal radiations of a QGP be identified?
 3. How can jet and jet-substructure measurements characterize medium properties?
 4. Do heavy flavours contribute to the medium dynamics and how do they probe the medium properties?
 5. How far can we improve the knowledge of initial state?
 6. How can we progress in the precise determination of parameters calculable from first QCD principles with refined measurements of very exclusive observables?

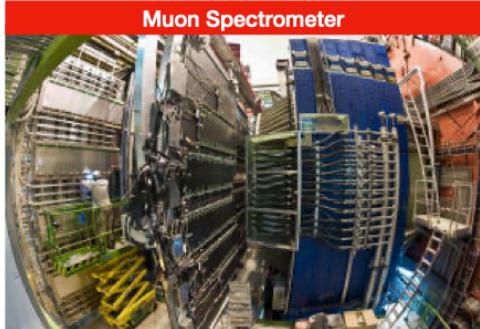


Physics case détaillé dans les Yellow reports du CERN

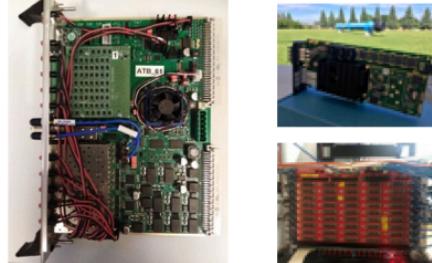
Upgrades for Run 3 Reminder



Fast interaction trigger (FIT)



New Central Trigger System
new RDO for EMCal, PHOS, TRD, HMPID, ZDC



New computing infrastructure and framework: O2

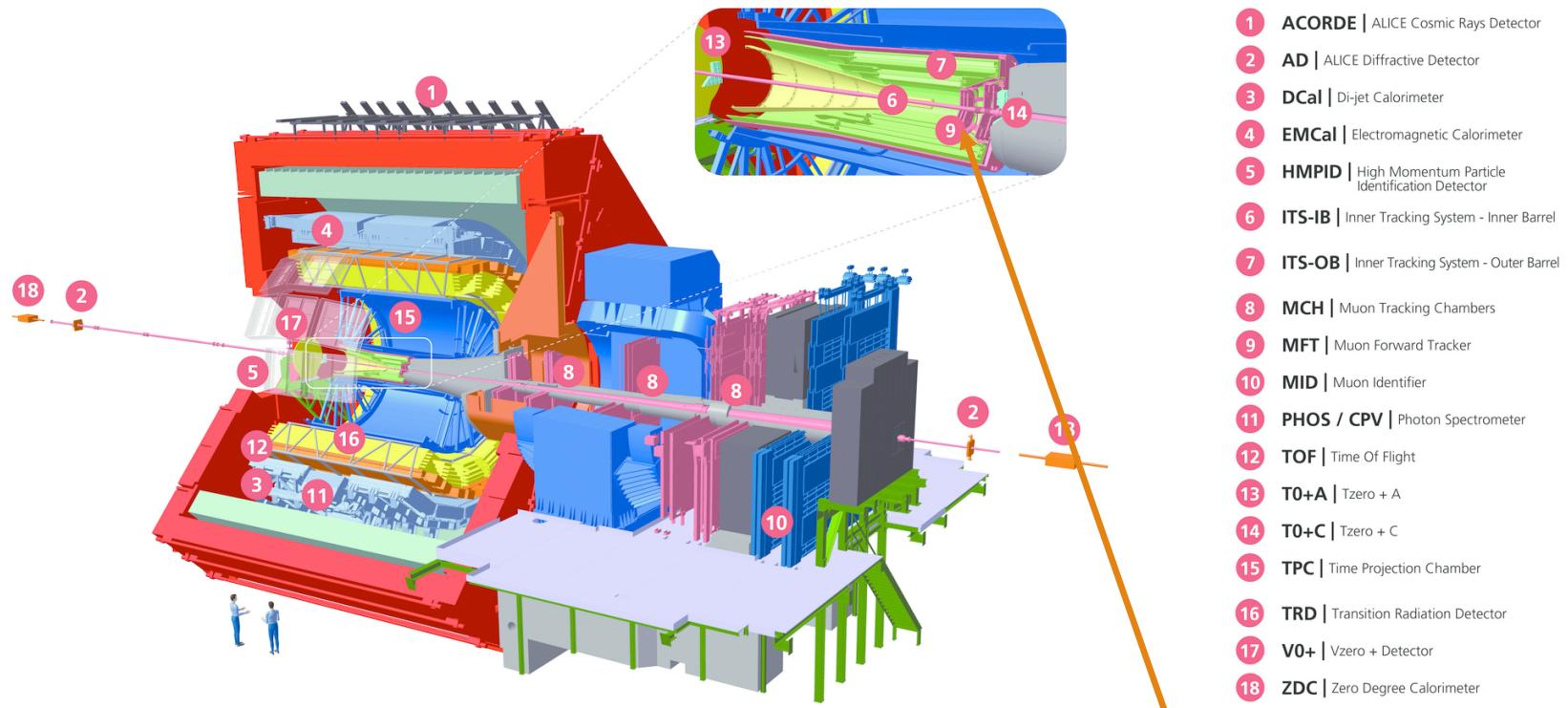
Farm at P2



Major upgrade of ALICE during LS2!

Magnus Mager (CERN) | ALICE status report | 144th LHCC open session | 18.11.2020 | 4

Muon measurements with ALICE at Run 3



Continuous readout for all systems

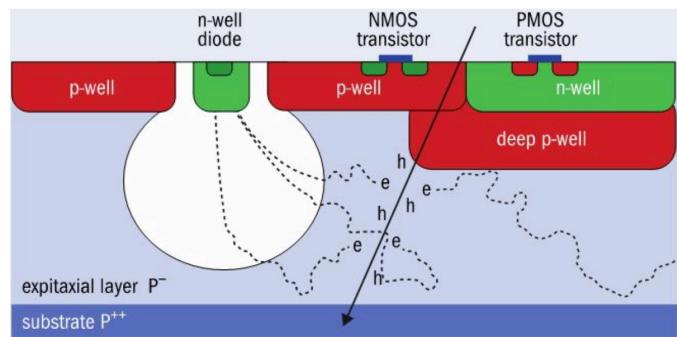
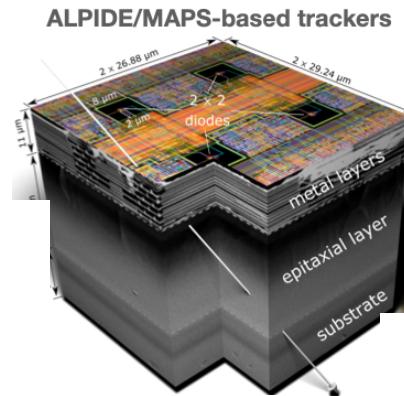
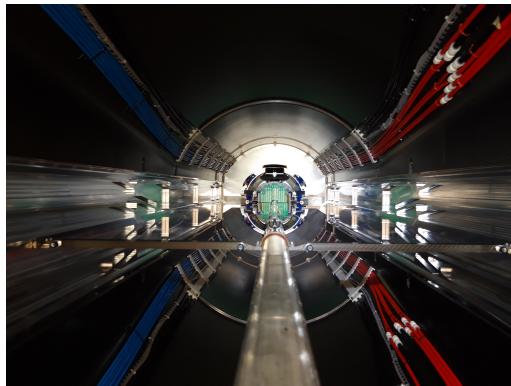
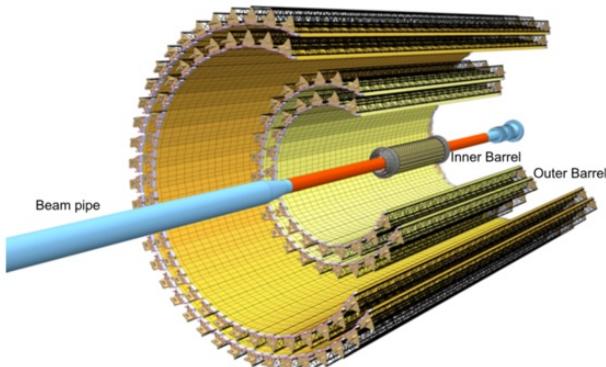
(Common Readout Unit), for muons:

- **MCH** (cathode pad chambers) upgrade with SAMPA ASIC
- **MID** (upgrade of MTR, RPC) with FEERIC ASIC

- New detector: the **Muon Forward Tracker**
- Vertex tracker for the Muon Spectrometer, to be installed between the interaction point and the hadron absorber ($-3.6 < \eta < -2.5$)
- 920 silicon pixel sensors (0.4 m^2) in 280 ladders of 2 to 5 sensors each



ITS2 and MFT : ALPIDE



- monolithic active pixel sensor chip (MAPS), called ALPIDE, integrating both pixel sensor and read-out electronics in a single device
- p-type substrate with a thin, high-resistivity epitaxial layer (see diagram) in a 180 nm CMOS process provided by Tower Semiconductor
- includes a 512×1024 matrix of $29.24 \times 26.88 \text{ mm}^2$ pixel cells, together with analogue biasing, control, readout and interfaces

LHCb - SMOG2

□ SMOG2 (approved) : addition of an unpolarised storage cell target

- 20 cm long attached to the VELO
- Injection of unpolarised gas via capillary
- Boost local gas density with same gas flow

Gas species	He	Ne	Ar	Kr	Xe	H ₂	D ₂	N ₂	O ₂
$\theta_{SMOG2}/\theta_{SMOG}$)	10.9	24.4	34.5	25.0	31.3	7.7	10.9	28.6	30.3

→ And probably up to a factor $\times 100$ SMOG with an increased gas flow

- Extended target choice : H₂, D₂
- Better control over injected gas density (i.e over luminosity)
- Projections for SMOG2:

Reaction	DAQ time	Non coll. bunches	Lumi (nb ⁻¹)	Decays	SMOG yields	Scale factor	SMOG2 proj. yields
pAr	18 h	684	~ 2	$D^0 \rightarrow K^- \pi^+$	6450		400 k
				$D^+ \rightarrow K^- \pi^+ \pi^+$	975		60 k
				$D_s^+ \rightarrow K^- K^+ \pi^+$	131		8 k
				$D^{*+} \rightarrow D^0 \pi^+$	2300	62	140 k
				$\Lambda_c^+ \rightarrow p K^- \pi^+$	50		3 k
				$J/\psi^+ \rightarrow \mu^+ \mu^-$	500		30 k
pHe	84 h	648	7.6	$\psi' \rightarrow \mu^+ \mu^-$	20		1.2 k
				$J/\psi^+ \rightarrow \mu^+ \mu^-$	500	19.6	10 k
				$\psi' \rightarrow \mu^+ \mu^-$	20		0.4 k

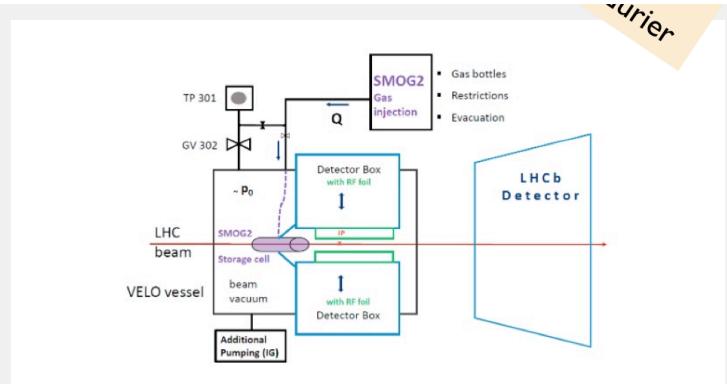
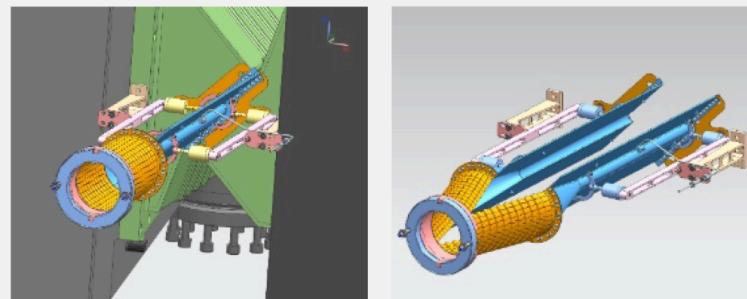
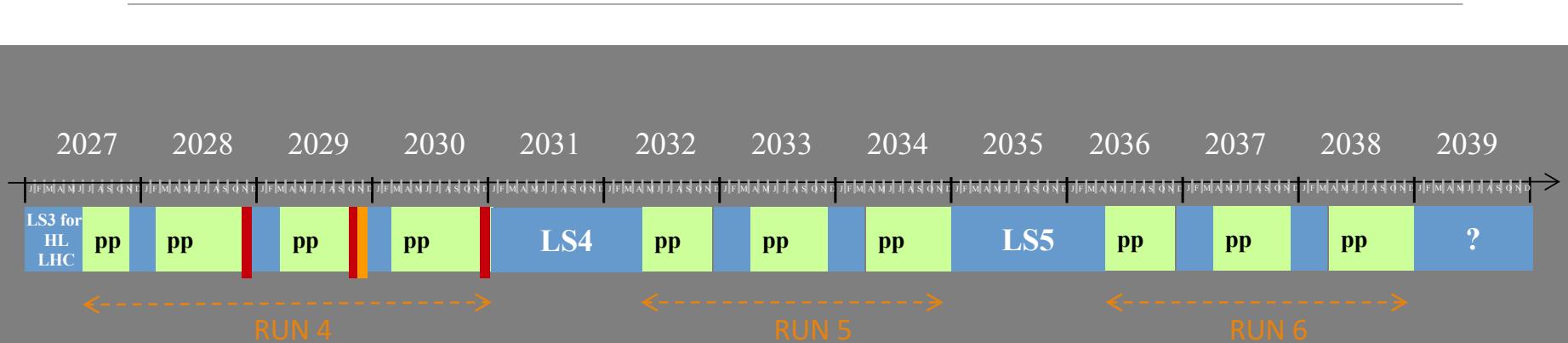


Figure 7: Sketch of the SMOG2 system. The gas is injected via capillary at the center of the storage cell.



[CERN-PBC-Notes-2018-007](#)

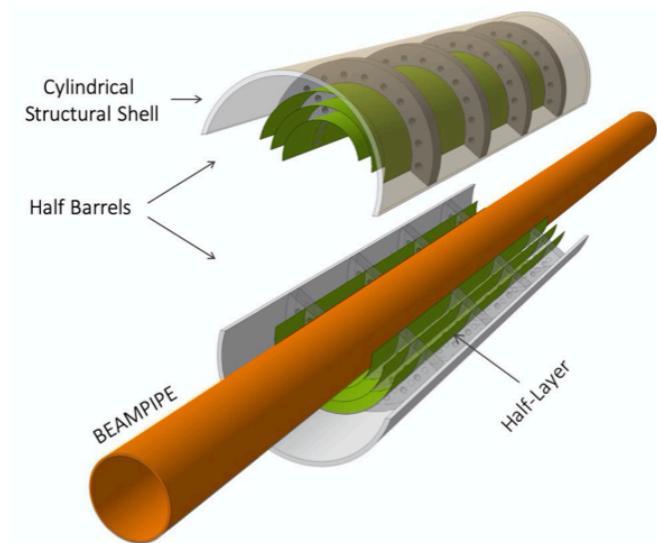
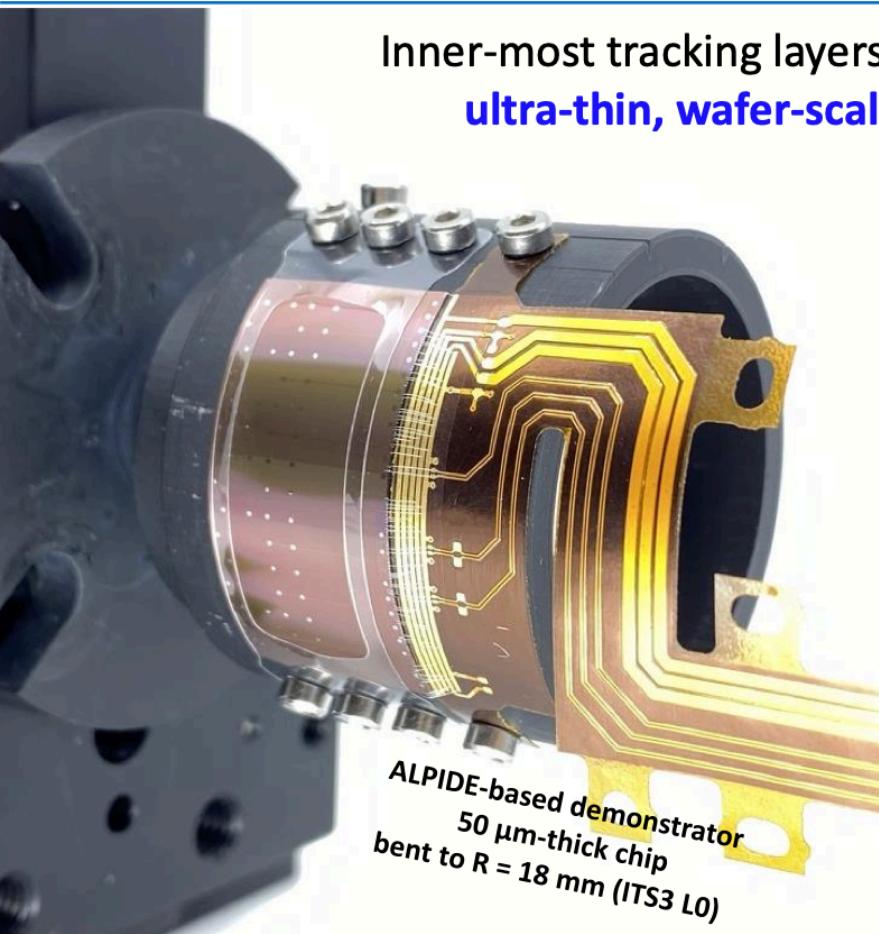
UPGRADE Run 4 : the day after tomorrow



ITS3: new ITS for Run 4



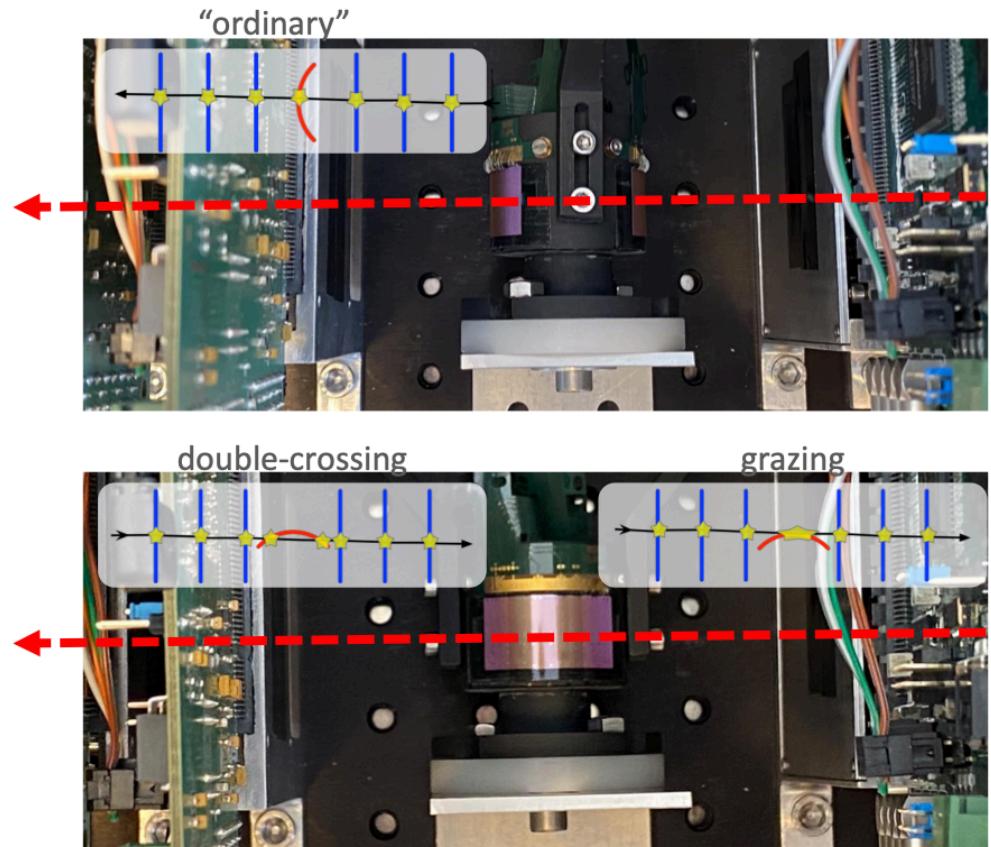
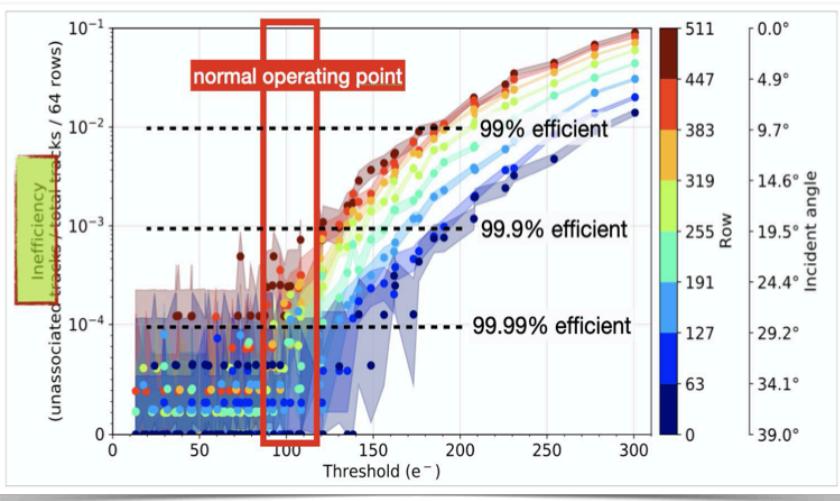
Inner-most tracking layers to be replaced by
ultra-thin, wafer-scale, bent MAPS



- **Large impact on key ALICE physics programme**
 - Charm and beauty hadronization, thermal low-mass dileptons, shown previously
 - Continues to attract new interests, more channels being opened (e.g. non-prompt D_s and Ξ_c^+)
- Very active R&D including many groups
 - working towards TDR

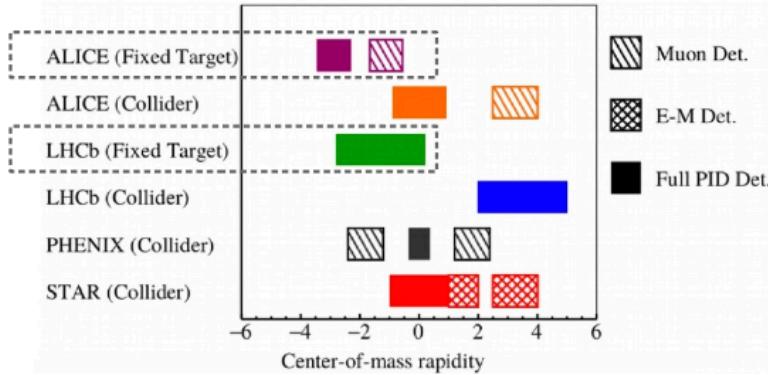
Characterisation of bent MAPS

- While waiting for the first wafer-scale chips, significant effort is made with existing material
- Bent assemblies are now done routinely with different methods at various institutes
- 3 beam tests at DESY during 2020 (Jun, Aug, Dec) with different arrangements
- Confirming that bent MAPS are working





V.2 – ALICE : FoCal + Fixed target



Keys :

$\sqrt{s_{NN}} = 72\text{-}115 \text{ GeV}$, solid targets at $z = +4.8\text{m}$
(bent crystal and solid target, target versatility)

- Physics cases similar to SMOG2

(QGP physics at $\sqrt{s_{NN}}$ between RHIC top energy and BES,
high x in nPDF ($x > 0.1$), ...) but ++ bckwd y

Project milestones :

- . ESPP [CERN-PBC-Notes-2019-004](#)
- . Ongoing UA9 R&D + performance studies

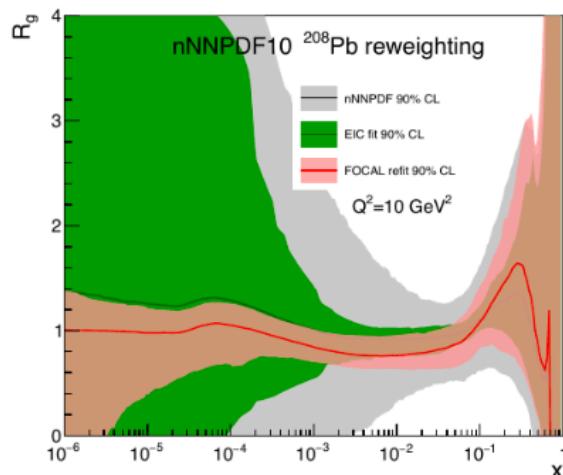
Keys :

Si+W EmCal + Pb-Sci HCal, $3.2 < \eta < 5.8$ at $z = +7\text{m}$

- forward π^0 , isolated γ
- correlations forward Vs mid- y
- ultra-low x in nPDF

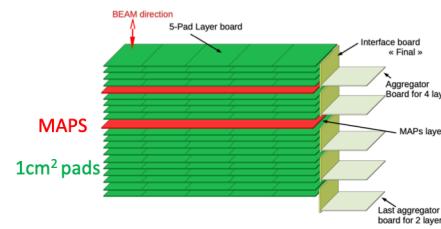
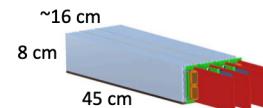
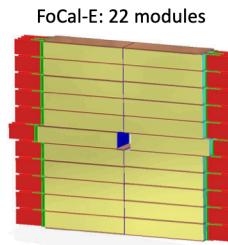
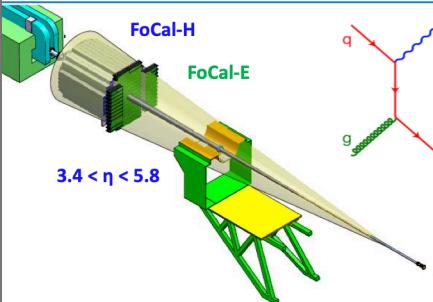
Project milestones :

- . LoI [arXiv:1708.05164](#) + CDR [ALICE-PUBLIC-2019-005](#)
→ LHCc final review : June 2020



ALICE FOCAL

FoCal concept



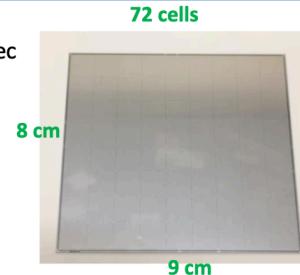
- Goal: saturation/shadowing at low-x with direct photons in pp/p-Pb
- Concept:
 - **FoCal-E:** Si-W sandwich calorimeter with granularity $\approx 1 \text{ mm}^2$
 - **FoCal-H:** conventional sampling calorimeter for photon isolation
- TDR in 2022 aiming at installation for Run 4 in 2026

FoCal: preparation for test beams



1cm²-granularity sensors:

- Test sensors with 8x9 geometry received in Dec
 - Lab tests ongoing
- One-sensor PCB received in Jan
- Readout boards under production



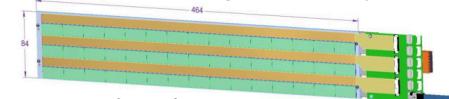
PCB for one sensor

High-granularity sensors (MAPS):

- 30-cm prototypes (9 ALPIDE chips) from pCT:

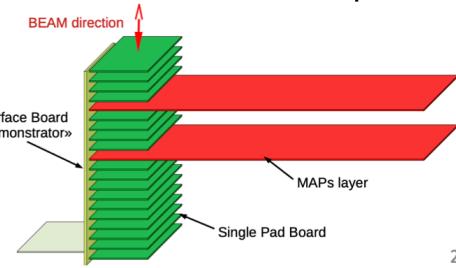
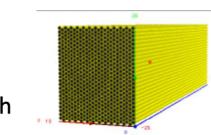


- MAPS module design: 2x3 15-chip flex cables



FoCal-H prototype:

- Cu capillary tubes
- 10cm x 10cm area, 60-80 cm depth



SPS testbeam in Sep 2021

ALICE Fixed Target

Exploring possible target locations in ALICE

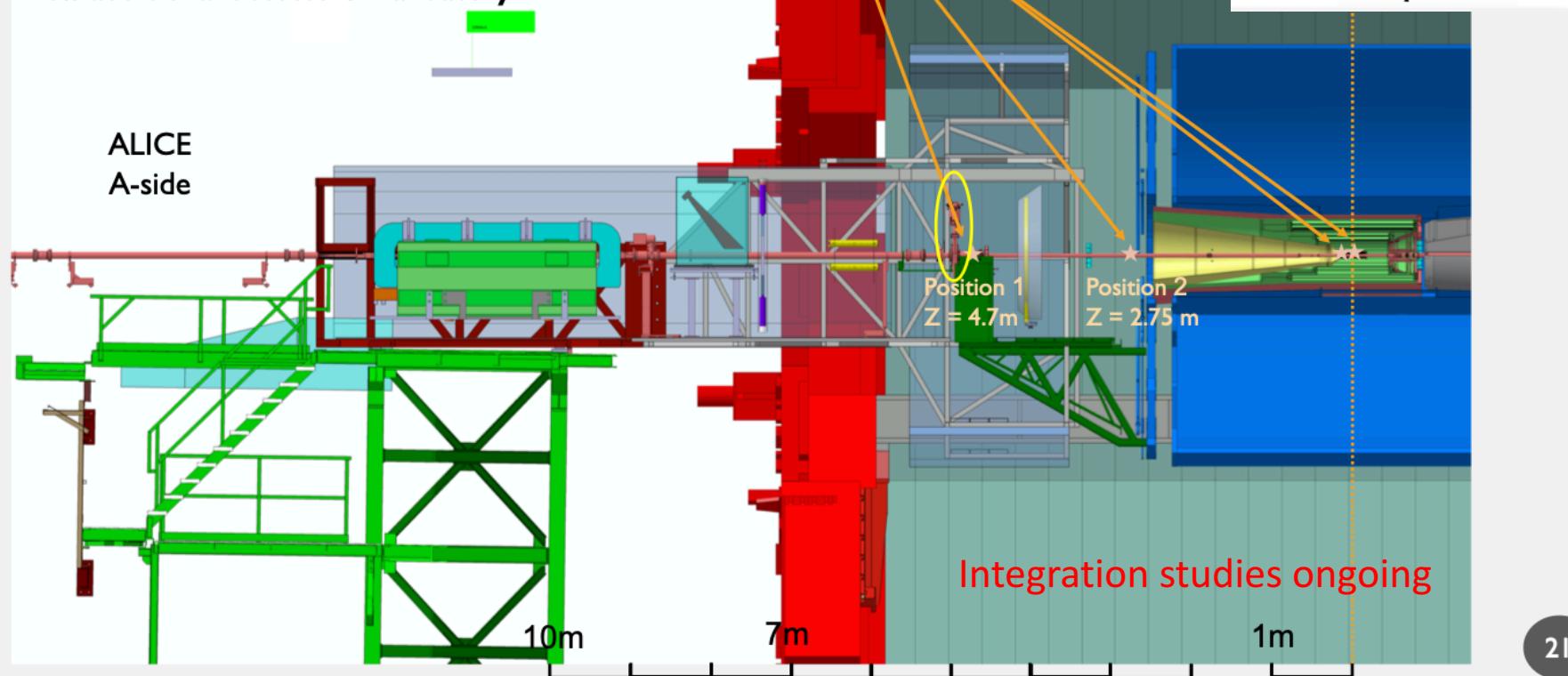
4 locations of target explored so far in simulations to evaluate the physics reach

Position 1 is now favored from integration studies

Space available outside L3 magnet but far from ALICE IP

Probably only possible location for a **polarised solid target**

New additional detectors mandatory



V.3 – CMS : tracker + MTD + HGCal

Keys :

In Run 4, after LS3, new CMS opportunities...

a) tracking on very large η coverage as well ($|\eta| < 4$)

CMS tracker, CERN-LHCC-2017-009

b) mid-y + fwd calorimetry ($|\eta| < 3$) : PbW₄ EmCal + HGCal SiPM sampling

CMS HGCal, CERN-LHCC-2017-023

c) MTD = pile-up tagger + TOF ...

CMS MTD = “pile-up tagger”, Fig 1.5 + Fig 5.23 - TDR CERN-LHCC-2019-003

(LGAD in endcap or SiPM in barrel $\rightarrow \sigma_{\text{time stamp}} \approx 30 \text{ ps}$),

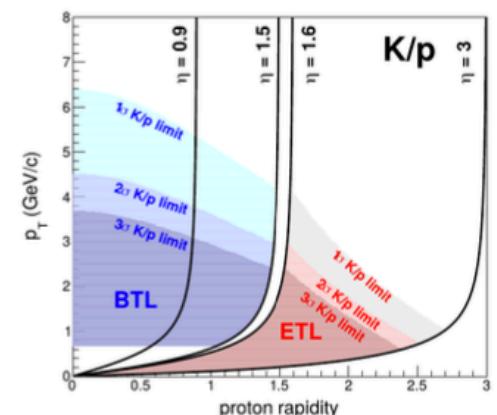
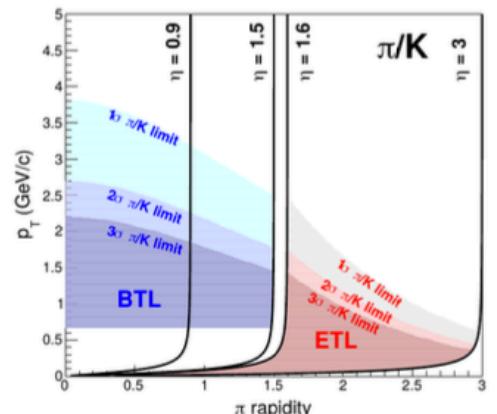
- Jet, onia, open charm, long range correlations

Project milestones : all approved, towards production

		$p_T(h^*)$ (GeV/c)				PID	y			system			
		0 - 0.08	0.15 - 0.5	1 - 10	10 - 200		Det.	≤ 1	≤ 2	fwd	pp, MB + HighMult	p-Pb MB + HighMult	Pb-Pb 101-70%
ALICE	X	✓	✓	✓	✓		✓	✓	X	✓	✓	✓	✓
ATLAS	X	X	✓	✓	✓		✓	✓	X	✓	✓	✓	✓
CMS	X	X	✓	✓	✓		✓	✓	X	✓	✓	✓	✓
LHCb	✓	✓	✓	✓	✓		✓	✓	X	✓	✓	✓	X

with $\mathcal{L}_{\text{instantaneous}}$ ++

Fig 1.5 - TDR CERN-LHCC-2019-003



CMS at RUN 4

➤ Quasiment reconstruit au LS3, capacité similaire à celle du RUN4

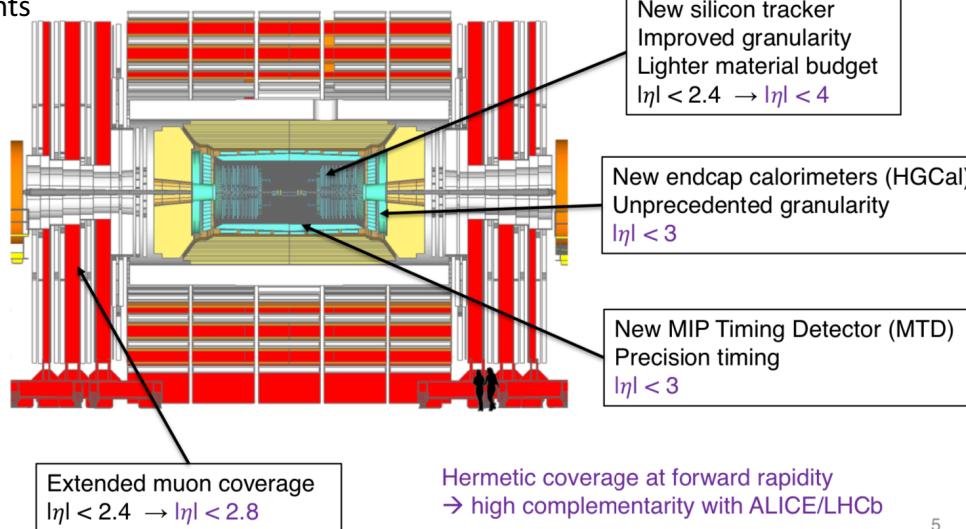
Phase II upgrades

Improved mass resolution for resonances

Impact parameter resolution improved by 40%

Improved heavy flavor measurements

(B/D hadrons & b/c-jet tagging)



Improve track matching with silicon tracker at large occupancy

:

Improve charm/beauty separation

Trigger / HLT / DAQ
Track info. in L1
L1/HLT rate x7.5
DAQ: 6 → 60 GB/s

Pile-up rejection in high lumi pp

Triggering on high multiplicity pp collisions in low PU

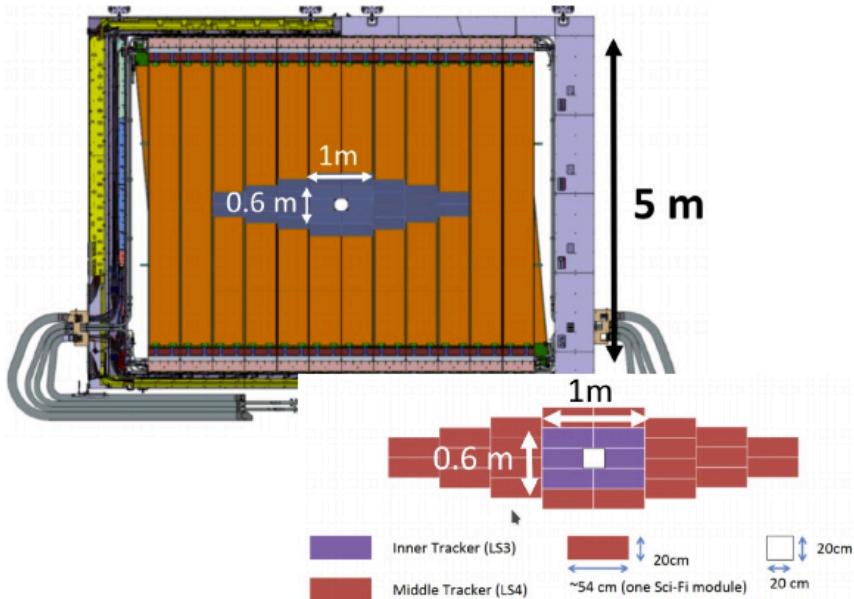
Isolated photons

NEW, PID:
Similar ALICE/STAR PID capabilities

5

V.4 – LHCb : early Mighty Tracker

DT = SciFi + Mighty Tracker



Keys :

Collider mode : pp, pA, AA
+ (polarised) fixed target mode :
Run IV = SMOG2 → LHCspin

First elements (6 to 10) of the Mighty Tracker in DT
likely $\mathcal{O}(100 \times 500)$ μm^2 HV-CMOS pixels

- HF (c, b , open/hiden, mesons/baryons)
- em probes (γ , Drell-Yan $\mu^+\mu^-$, ...)
- towards more and more central AA
- FT LHCspin : nucleon-spin physics
(Sivers asymm. between DY and SIDIS)

Project milestones :

- . Lol [CERN-LHCb-INT-2019-007](#)
- . TDR Mighty-tracker by 2020-21
- . TDR LHCspin ... ?

with $\mathcal{L}_{\text{instantaneous}}$ ++

> 10% most central Pb-Pb

$p_T(h^{\pm})$ (GeV/c)							PID	y	system					
0 -	0.08 -	0.15 -	0.5 -	1 -	10 -	200	Det.	≤ 1	≤ 2	fwd	pp, MB + HighMult	p-Pb MB + HighMult	Pb-Pb 10-70%	Pb-Pb 0.5-0%
ALICE	X								X					
ATLAS	X	X								X				
CMS	X	X								X				
LHCb														X

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Antonin.MAIRE@cern.ch – IPHC Strasbourg / In2p3 Prospectives GT03 2020

Part 2 : Electron Ion Collider

Collisioneur Électron-Ion

- Energie dans le centre de masse de 20 à 140 GeV
- Faisceau d'électrons polarisés en collision avec des protons polarisés, des ions légers polarisés ou des ions lourds

Statut du projet

- US DOE a annoncé le lancement du projet et le choix du site en janvier 2020
 - Coût de 1.6 à 2.6 G\$
 - Construction à BNL sur la base du RHIC : eRHIC
- Le User Group d'EIC a lancé plusieurs efforts
 - la rédaction d'un Yellow Report pour préparer la création des détecteurs
 - La mise en place d'un comité pour permettre l'émergence d'une ou plusieurs collaborations scientifiques

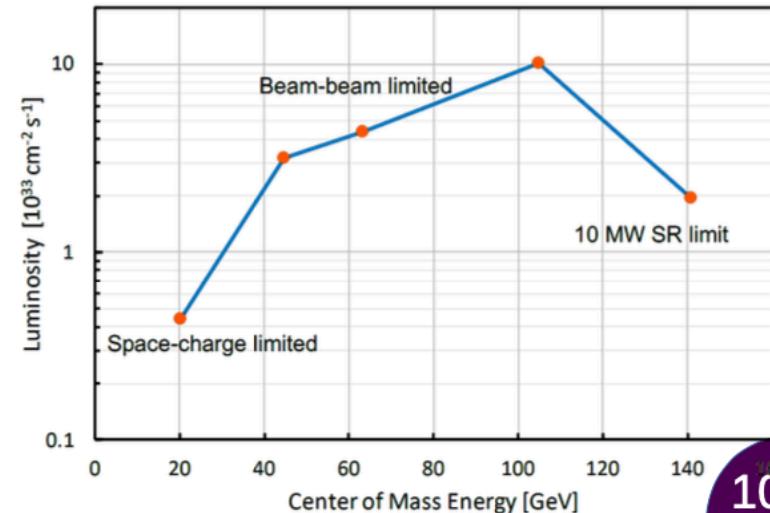
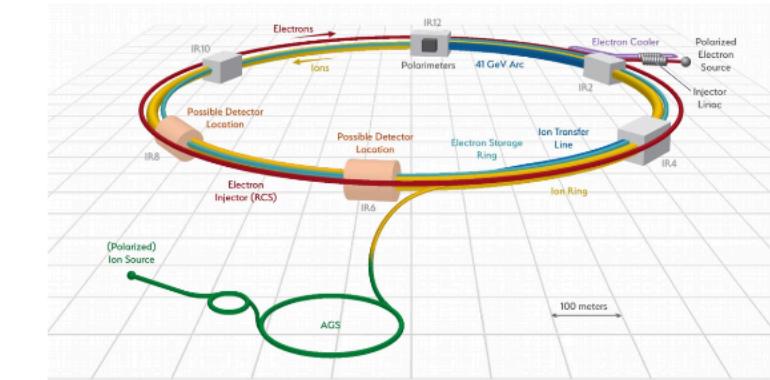
EIC User Group

- 1033 members, from 211 institutions in 31 countries

Department of Energy

U.S. Department of Energy Selects Brookhaven National Laboratory to Host Major New Nuclear Physics Facility

JANUARY 9, 2020



Mesures des fonctions de distribution des partons (PDF)

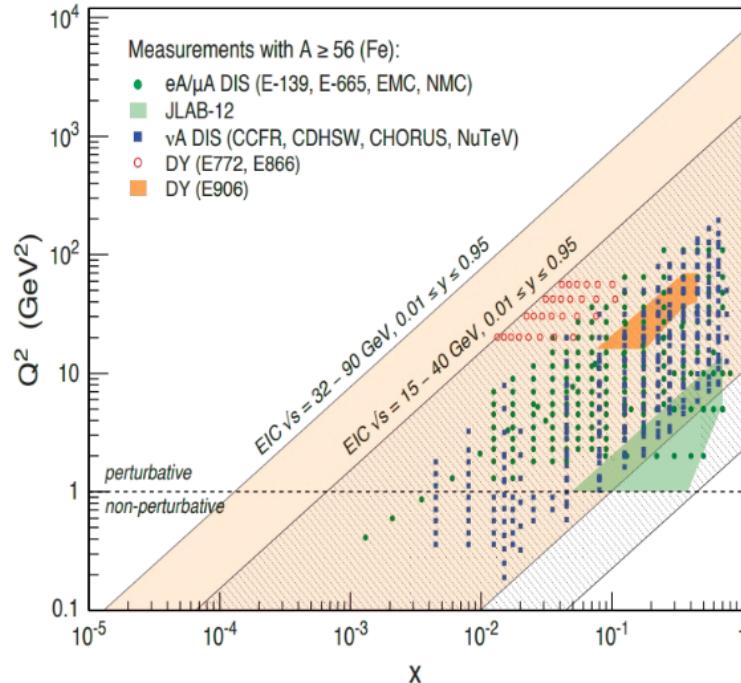
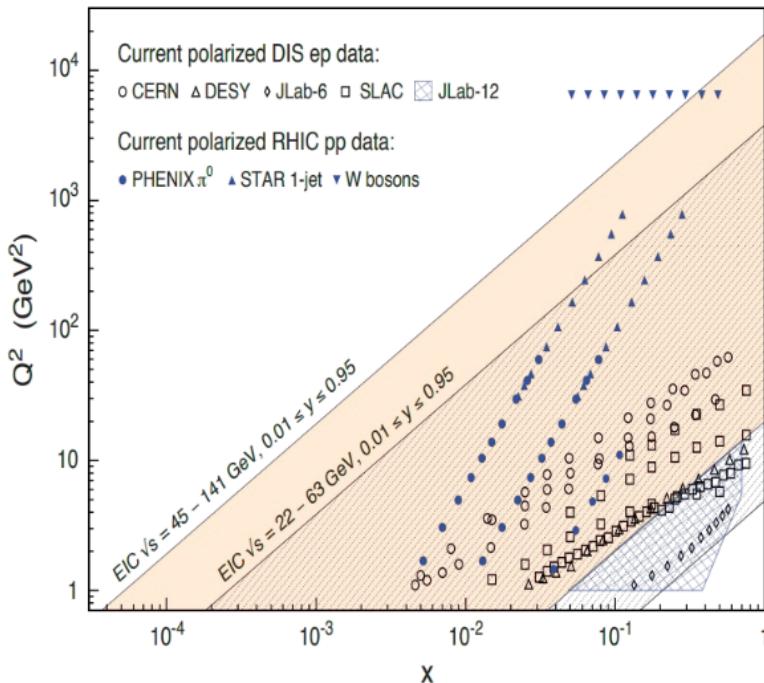
- Au-delà de DESY grâce à une meilleure luminosité et à la double polarisation
- Mesures des PDFs nucléaires dans des domaines très mal connus

EIC sera la machine des gluons

- Domaine à petit x largement dominé par les gluons
- Accès à F_L en variant les énergies de faisceau

Aussi des grands Q^2

- Jonction avec mesures de W du RHIC/LHC dans les grands x



Suite logique des thèmes JLab

- Évolution en Q^2 des GPDs

- Comprendre et quantifier les effets de higher twist

- Étude des GPDs à petit x

- Quel étalement du nucléon à faible x ?
- Les nucléons fusionnent-ils dans les noyaux à petit x ?

- Étude des GPDs de gluons

- Utilisation de la production exclusive de ϕ et de J/ψ
- Les quarks et gluons occupent-ils le même espace ?

- Compléter l'espace de phase mesuré

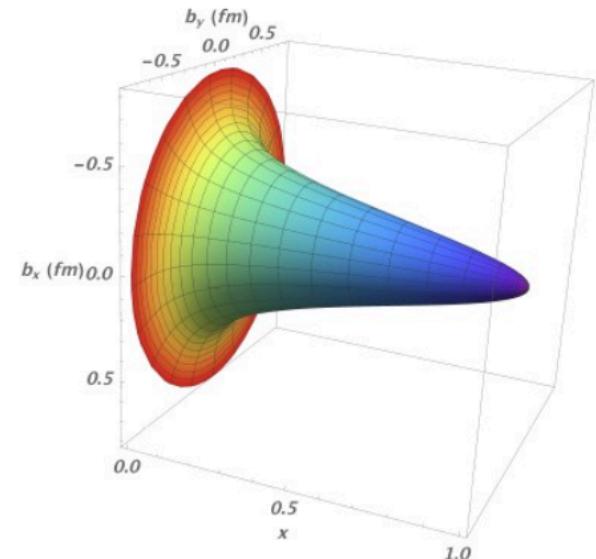
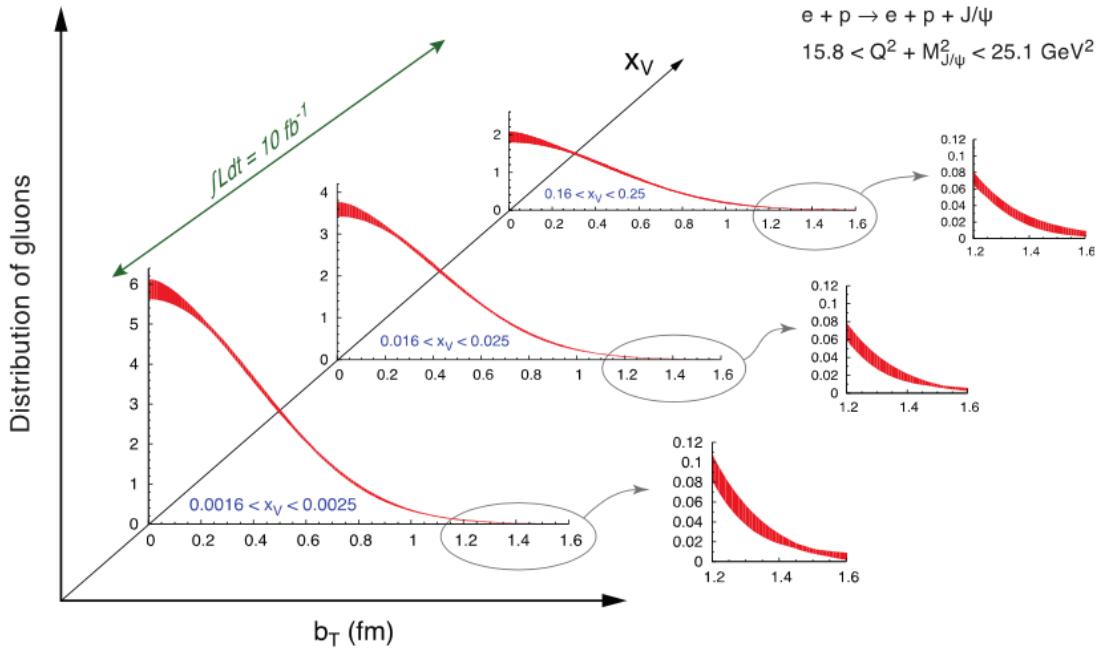
- Mesurer les règles de sommes, en particulier de J_1

Plusieurs autres thèmes possibles

- Les études de TMDs sont possibles dans le même domaine cinématique

- TMD = Transverse momentum dependent PDFs

- Des idées émergent pour l'accès aux fonctions de Wigner (5D) et une image complète du nucléon



Projets de détecteurs se précisent

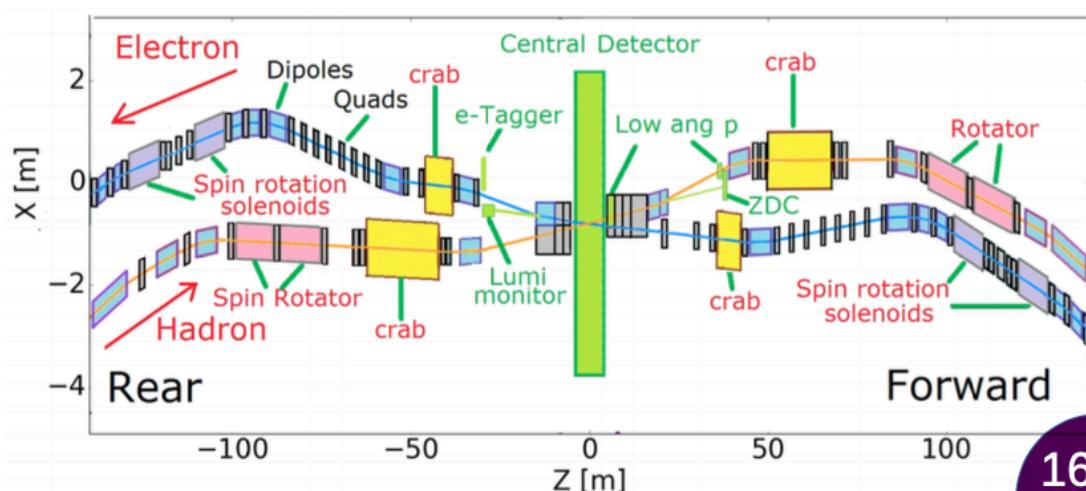
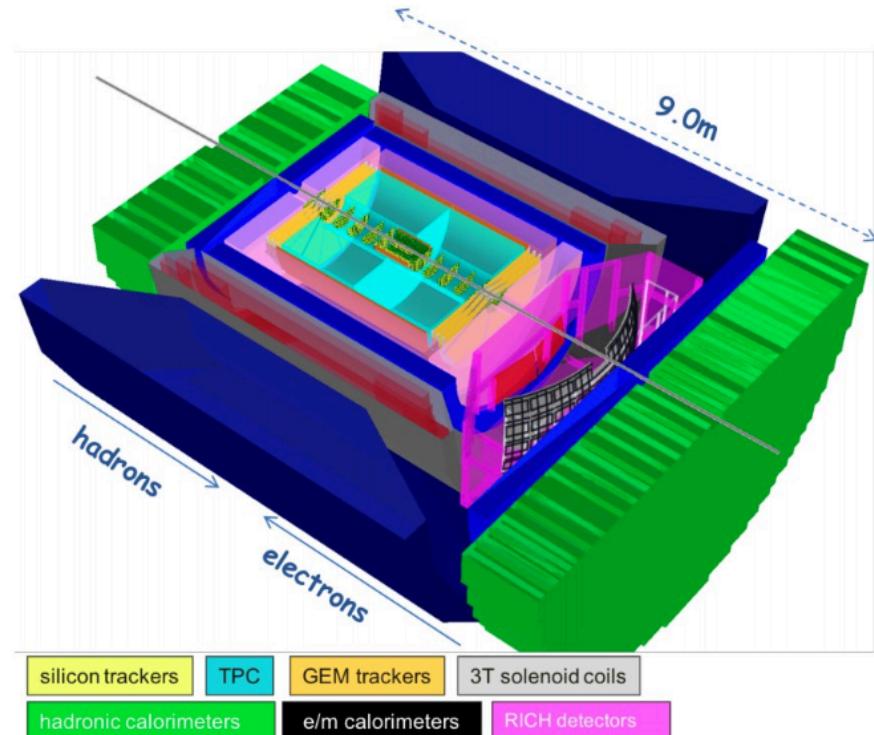
- Lancement du Yellow Report avec pour objectif de clarifier les besoins en détection de chaque type de physique
- Le EICUG se prépare à la création de collaborations scientifiques

Conception des points d'interactions

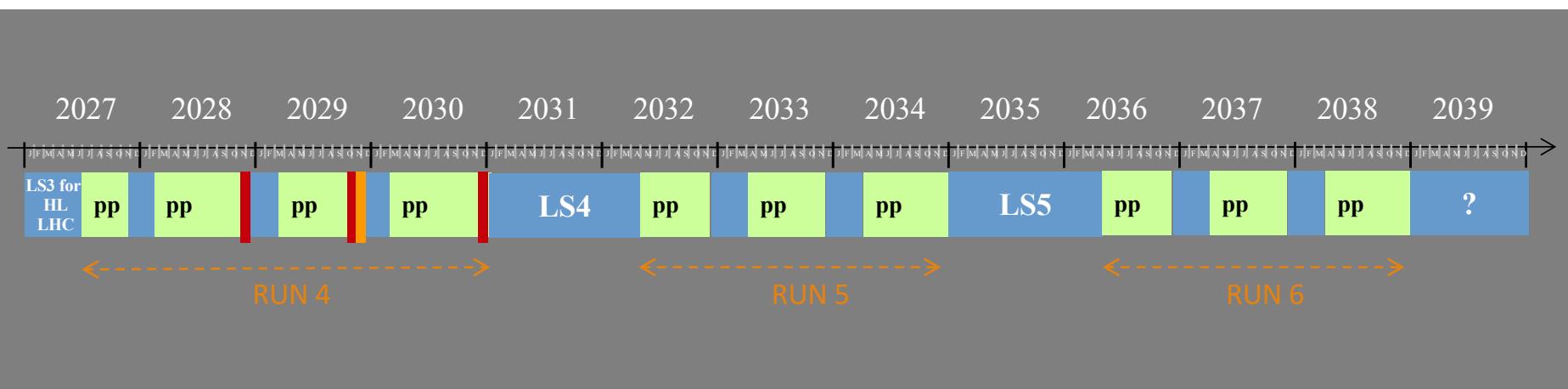
- Important pour la luminosité et la place disponible pour les détecteurs
- Va être fixé rapidement par la partie accélérateur du projet

Importante participation française dans ces activités

- IJCLab et CEA pour l'instant



QGP post LHC-RUN4 : échelle de temps*



- RUN5 : démarrage en 2032 => dans 12 ans
- Demande du WG5 : O-O et p-O dès le RUN3, à priori ok
RUN4 avec un potentiel ion lourd plus important
(extension en 2029 de 4 à 6 semaines)
- Pas de *runs* dédiés ion-lourds planifiés aujourd’hui au
RUN5, espèces plus légères envisagées, ex. Ar-Ar

Year	Systems, $\sqrt{s_{\text{NN}}}$	Time	L_{int}
2021	Pb-Pb 5.5 TeV	3 weeks	2.3 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2022	Pb-Pb 5.5 TeV	5 weeks	3.9 nb^{-1}
	O-O, p-O	1 week	$500 \mu\text{b}^{-1}$ and $200 \mu\text{b}^{-1}$
2023	p-Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2027	Pb-Pb 5.5 TeV	5 weeks	3.8 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2028	p-Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2029	Pb-Pb 5.5 TeV	4 weeks	3 nb^{-1}
	Intermediate AA pp reference	11 weeks 1 week	e.g. Ar-Ar $3-9 \text{ pb}^{-1}$ (optimal species to be defined)

*lhc-commissioning.web.cern.ch / Pré-covid

Après RUN4 : Ère de Précision

Report from Working Group 5 on the Physics of the HL-LHC, and Perspectives at the HE-LHC ! HL-LHC = RUN3/4 for WG5

1. Characterizing the macroscopic long-wavelength QGP properties with unprecedented precision.

1. Temperature
2. QCD phase transition at $\mu_B \simeq 0$
3. Viscosity and further QCD transport coefficients
4. Heavy-quark transport coefficients
5. Searching for transport phenomena related to the presence of strong electrodynamic fields

2. Accessing the microscopic parton dynamics underlying QGP properties.

1. Constraining with jet quenching the colour field strength of the medium
2. Investigating the quasi-particle structure of QCD matter with jet and heavy-quark measurements
3. Testing colour screening with bottomonium production
4. Testing colour screening and regeneration dynamics with charmonium production
5. Formation of hadrons and light nuclei from a dense partonic system

3. Developing a unified picture of particle production from small (pp) to larger (p-A and A-A) systems.

1. Flow measurements in pp and p-A systems: Onset and higher-order correlations
2. Flow of heavy flavour and quarkonium in smaller systems
3. Strangeness production as a function of system size
4. Searching for the onset/existence of energy-loss effects in small systems
5. Searching for the onset/existence of thermal radiation in small systems

4. Probing parton densities in nuclei in a broad (x, Q^2) kinematic range and searching for the possible onset of parton saturation.

1. Precise determination of nuclear PDFs at high Q^2
2. Constraining nuclear PDFs at low Q^2
3. Access to non-linear QCD evolution at small- x

CMS at RUN 5

➤ Quasiment reconstruit au LS3, capacité similaire à celle du RUN4

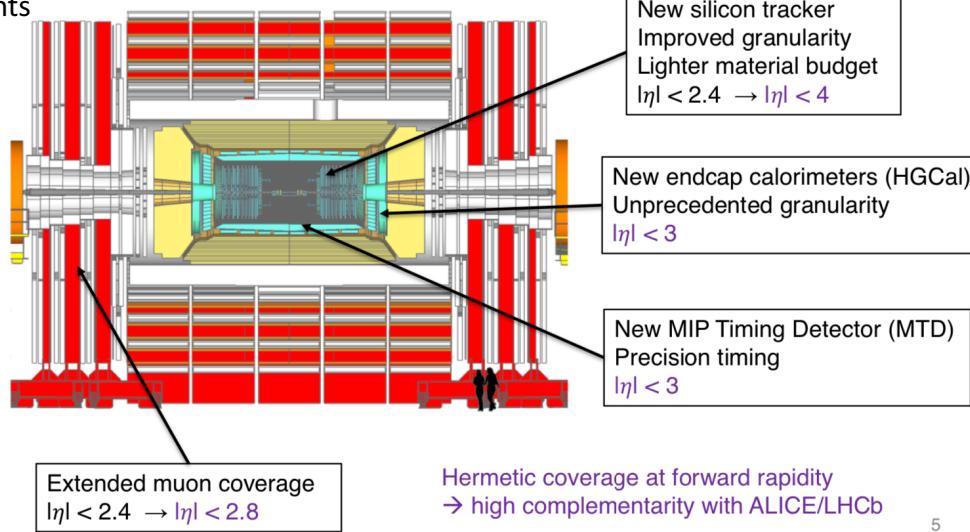
Phase II upgrades

Improved mass resolution for resonances

Impact parameter resolution improved by 40%

Improved heavy flavor measurements

(B/D hadrons & b/c-jet tagging)



Improve track matching with silicon tracker at large occupancy

:

Improve charm/beauty separation

Trigger / HLT / DAQ
Track info. in L1
L1/HLT rate x7.5
DAQ: 6 → 60 GB/s

Pile-up rejection in high lumi pp

Triggering on high multiplicity pp collisions in low PU

Isolated photons

NEW, PID:
Similar ALICE/STAR PID capabilities

5

- Upgrade séquentiel (à chaque LS), de plus en plus favorable à la physique QGP

- Pile-up (pp) = 42 avec Sci Fi amélioré (fibre scintillante) et Mighty Tracker (CMOS)
=> reconstruction ion lourd central envisageable

- TORCH : PID low- p

- Upstream Tracker with CMOS
DéTECTEUR important pour la mesure de la centralité

Table 5.1: Summary of the modifications under consideration for LS3, and those for Phase-II (LS4). Priorities will be assigned for the LS3 activities after further studies.

Detector	LS3	Phase-II
VELO	Deployment of prototype modules	New detector with fast timing
Tracking	Insert silicon IT, modify SciFi; install MS	Silicon UT and IT, SciFi OT
RICH	New photodetectors for selected regions; use of timing information	New optics; full replacement of photodetectors
TORCH	Installation for low- p hadron identification	Higher granularity photodetectors
CALO	Tungsten sampling modules installed in inner region	New modules in middle and outer regions
Muon	Replace HCAL with iron shielding; installation of high-rate chambers	Complete chamber installation
Trigger and data processing	Adiabatic software improvements; review of offline processing; installation of downstream track-finding processor	Expansion/replacement of links, readout boards and servers

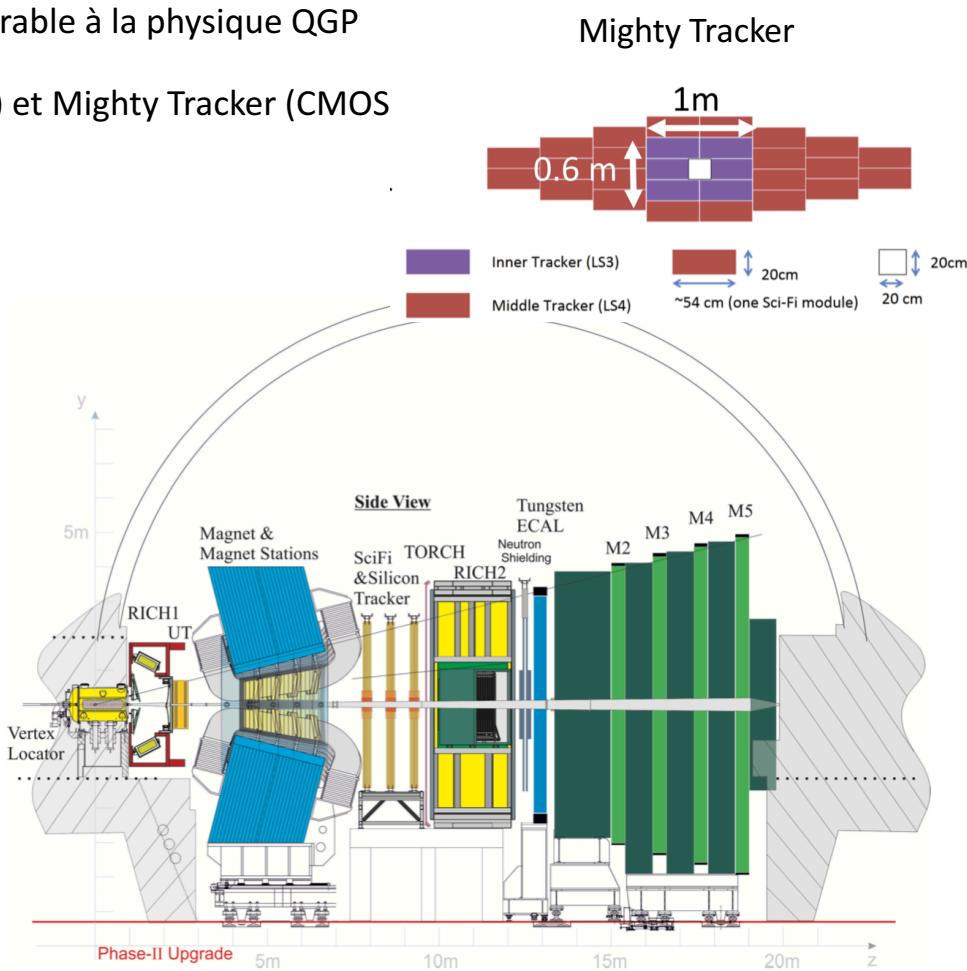
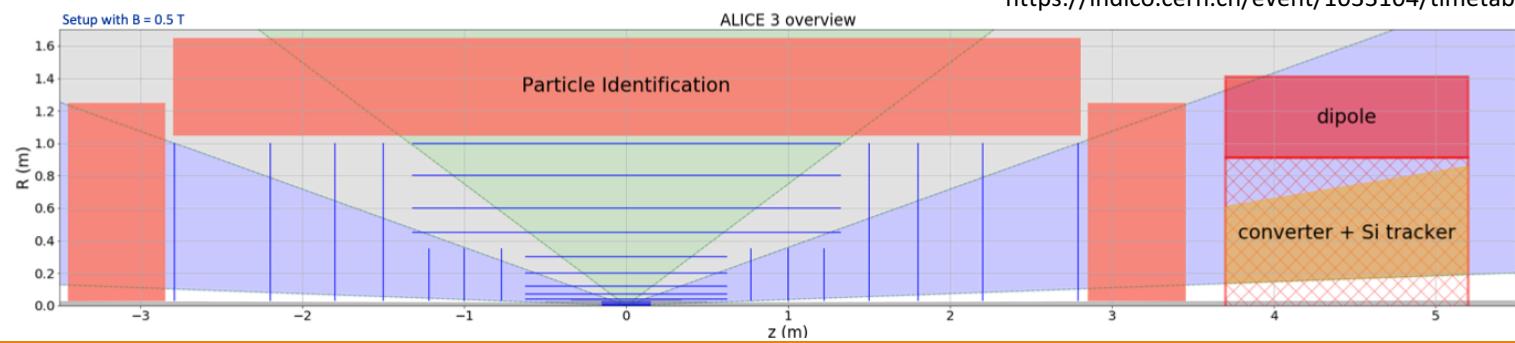
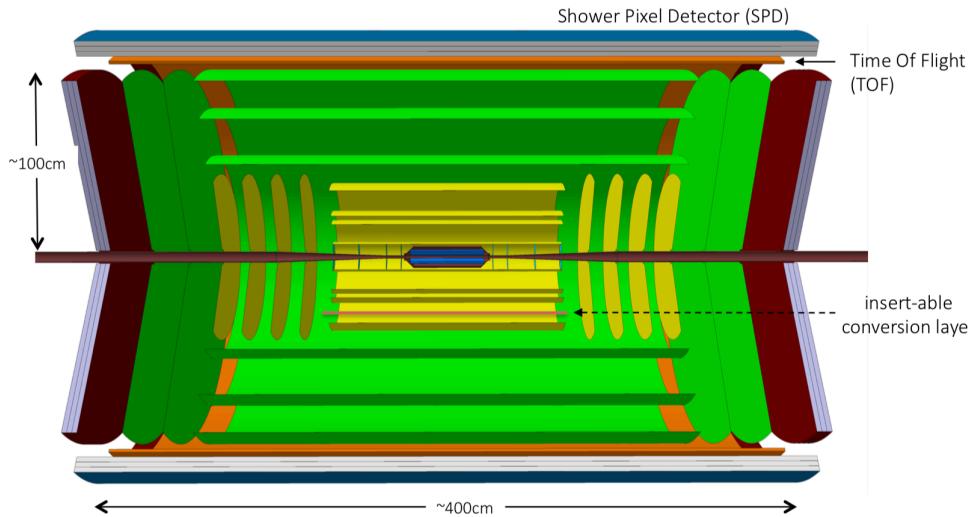


Figure 4.1: Schematic side view of the Phase-II detector.

ALICE 3

- A new experiment based on an "all-silicon" detector ($\sim 100\text{m}^2$)

- Tracking over : $|\eta| < 4 + (p_T > 30\text{-}50 \text{ MeV}/c \text{ at } y=0)$
- Space resolution $\approx < 5 \mu\text{m}$
- Magnetic field $B = 0.5\text{T}$ (ALICE magnet) or 1T
- Ultra light with excellent vertexing



Central barrel $|\eta| < 1.4$:

- Inner Tracker (IT) : 3 layers inside the beam pipe
- Outer Tracker (OT) with 7 layers
- Time-Of-Flight (TOF) for the identification of hadrons and electrons at very low transverse momentum ($p_T < 500 \text{ MeV}/c$)
- Shower Pixel Detector (SPD), identification of electrons and photons ($p_T > 500 \text{ MeV}/c$)

Two endcaps $1.4 < |\eta| < 4$, contain each :

- 4 disks in the IT
- 6 disks in the OT
- 1 disk in the SPD

Dedicated workshop last week

<https://indico.cern.ch/event/1033104/timetable/>

Exercice comparatif

Quelques exemples de mesures, Non exhaustif!	ALICE 3 $p_T > 0.05 \text{ GeV}/c$ $y \in [-4,4]$	CMS Chargée $\eta \in [-4,4]$ PID (MTD) in η [-3,3] Muons in η [-2.8,2.8]	LHCb collider Centrality reconstruction PID (<i>low-p</i>) - $2 < \eta < 5$
COMPORTEMENT COLLECTIF			
Température - Dileptons de basse masse	Très favorable (diélectrons, hermiticité, très bas p_T)	À investiguer (hermiticité, bas p_T)	Très favorable à l'avant (dimuons)
Transition de phase (moment d'ordre supérieur)	Très favorable (hermiticité, très bas p_T)	Favorable (hermiticité, bas p_T)	Peu Favorables (øhermiticité)
Emergence de la collectivité – petits systèmes	Très favorable	Très favorable (trigger avec MTD)	Peu Favorables pour les sondes collectives en mode collider (øhermiticité) , peu de possibilité de corrélation avant-central
Jets et Jet quenching			
Jets de bas p_T	Très favorable	Favorable	À l'avant à investiguer
γ -jets, Z-jets	À investiguer	Très favorable	Peu Favorables
Jets et jet quenching dans les petits systèmes	Très favorable	Très favorable	À l'avant à investiguer

Disclaimer: table non officielle, comportant des imprécisions, table nécessitant d'être approfondie!

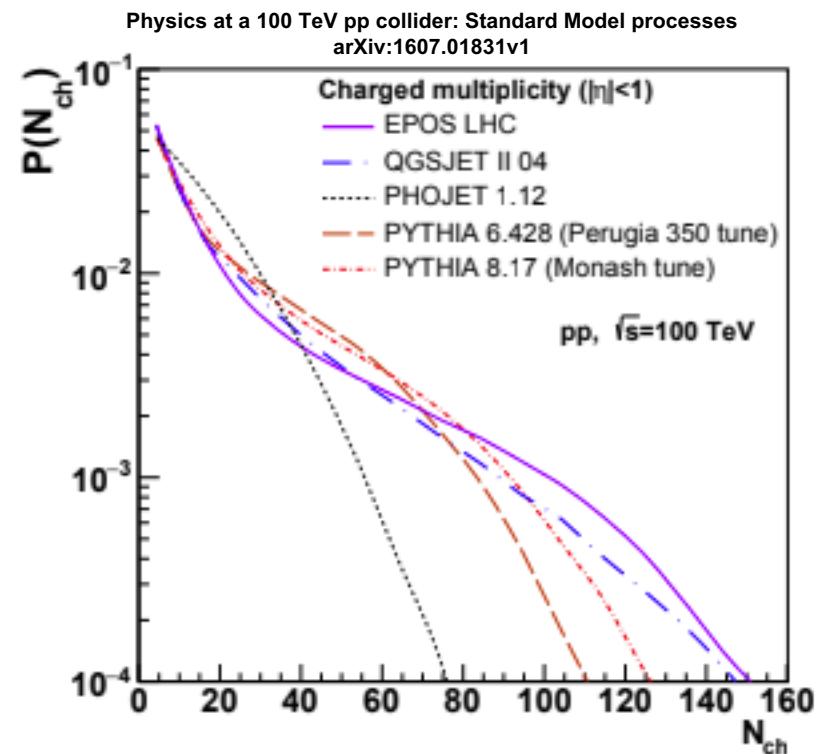
Exercice comparatif

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CHARME et BEAUTÉ			
Section efficace totale du charme	Très favorable		
Upsilon(3S)	Peu Favorable (\varnothing muons, résolution en p_T)	Très favorable	Très favorables à l'avant si reconstruction en centrale
χ_c	À investiguer (4 pions / $J/\Psi + \gamma$)	À investiguer (4 pions / 4 μ)	À investiguer à l'avant (4 μ) si reconstruction en centrale
Baryons multi-charmés	Très favorable	Très favorable	Très favorables à l'avant si reconstruction en centrale
Charme et beauté dans les petits systèmes	Très favorable	Très favorable	Très favorables à l'avant
Matière Nucléaire Froide - NPDF			
Bosons faibles	Peu Favorable (\varnothing muons)	Très favorable	Très favorable à l'avant
Di-jets	Très favorable	Très favorable	À l'avant à investiguer
UPC	À investiguer	Très favorable	Très favorable à l'avant
Physique des particules en ions lourds			
BSM signatures	Très favorable	Très favorable	Très favorable à l'avant

Disclaimer: table non officielle, comportant des imprécisions, table nécessitant d'être approfondie!

L'avenir lointain ...

- Increase in multiplicity, increase in energy density
=> Increase in collision energy
- Future colliders at energies greater than LHC: natural continuation for emergence of collectivity study
 - HE-LHC; upgrade LHC with FCC technology, 27 TeV, earliest possible physics starting date : 2040*
 - FCC-hh, **100 TeV**, earliest possible physics starting date : 2043*
 - SPPS, chinese project at **100 TeV**, FCC like



* ECFA meeting, FCC report, Michael Benedikt

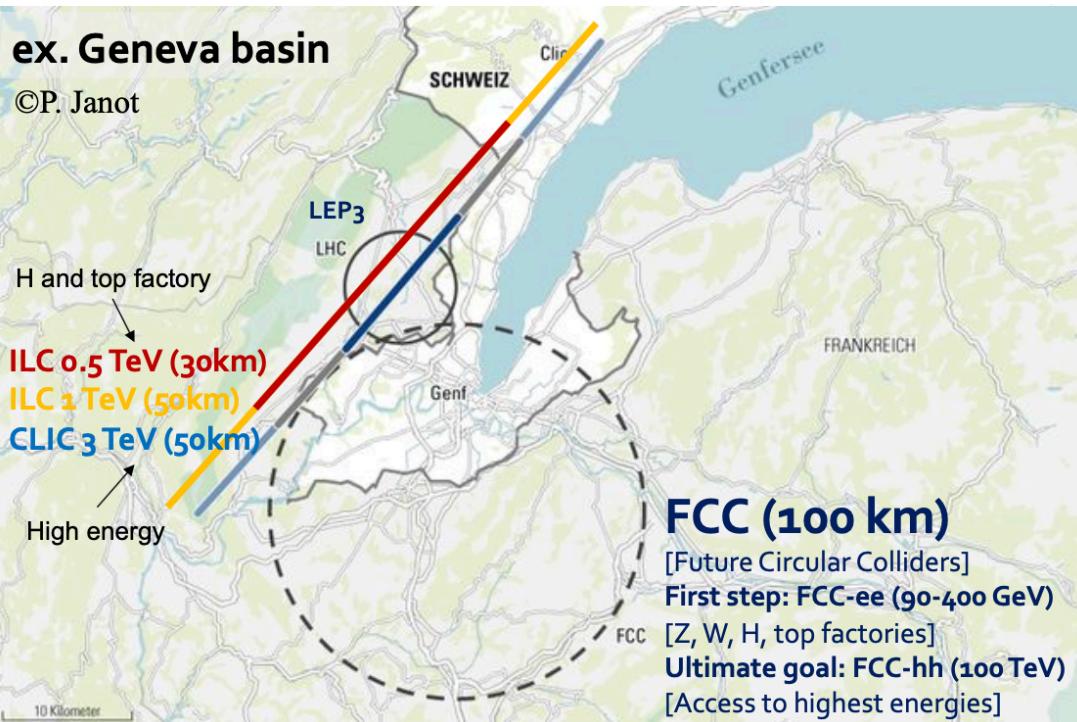
https://indico.cern.ch/event/667672/contributions/2730846/attachments/1560446/2456317/171117_FCC-Status_Berlin_ap.pdf

L'avenir lointain ...

CERN-ESU-005
29 September 2019

ex. Geneva basin

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ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

SUPPORTING NOTE FOR BRIEFING BOOK 2020

Towards an update of the European Strategy for Particle Physics

Pour l'après HL-LHC (après RUN6),
réflexion sur 5 scénarios impliquant
CLIC,LHC-HE, FCC-ee, FCC-hh et LHeC pour
les machines CERN
Horizon 2040 (dans 20 ans ...)

	2020-2040	2040-2060 1st gen technology	2060-2080 2nd gen technology
CLIC	HL-LHC	CLIC380-1500	CLIC3000
CLIC-FCC-mixed	HL-LHC	CLIC380	FCC-h/e/A (Adv HF magnets)
FCC	HL-LHC	FCC-ee (90-365)	FCC-h/e/A (Adv HF magnets)
LE-to-HE-FCC-h/e/A	HL-LHC	LE-FCC-h/e/A (LF magnets)	FCC-h/e/A (Adv HF magnets)
LHeC+FCC-h/e/A	HL-LHC + LHeC	LHeC	FCC-h/e/A (Adv HF magnets)

Conclusions

- Projets en physique hadronique de plus en plus proche des projets de physiques des particules
- Avec : bas p_T , faible budget de matière, grandes occupations (Pb-Pb centrale)
- De nombreux projets avec Si CMOS (ITS2, MFT, ITS3, FOCAL, LHCb, ALICE 3)
- Pas uniquement *détecteur*, e.g. cible fixe
- Non évoqué ici : informatique, software
- D'autres projets hors communauté française : FAIR – CBM, FAIR – PANDA, RHIC BES energy scan, RHIC sPHENIX, NICCA, NA60+, J-PARC-HI