

# ALICE project within FCPPL

## Study of QCD matter with the ALICE detector

### Outline

- ❑ France and China in ALICE and FCPPL
- ❑ FCPPL ALICE report (2017)
- ❑ FCPPL ALICE project (2018)
- ❑ Conclusion

Nicole Bastid, LPC, Clermont-Ferrand, France

Daicui Zhou, CCNU, Wuhan, China

11<sup>th</sup> FCPPL workshop

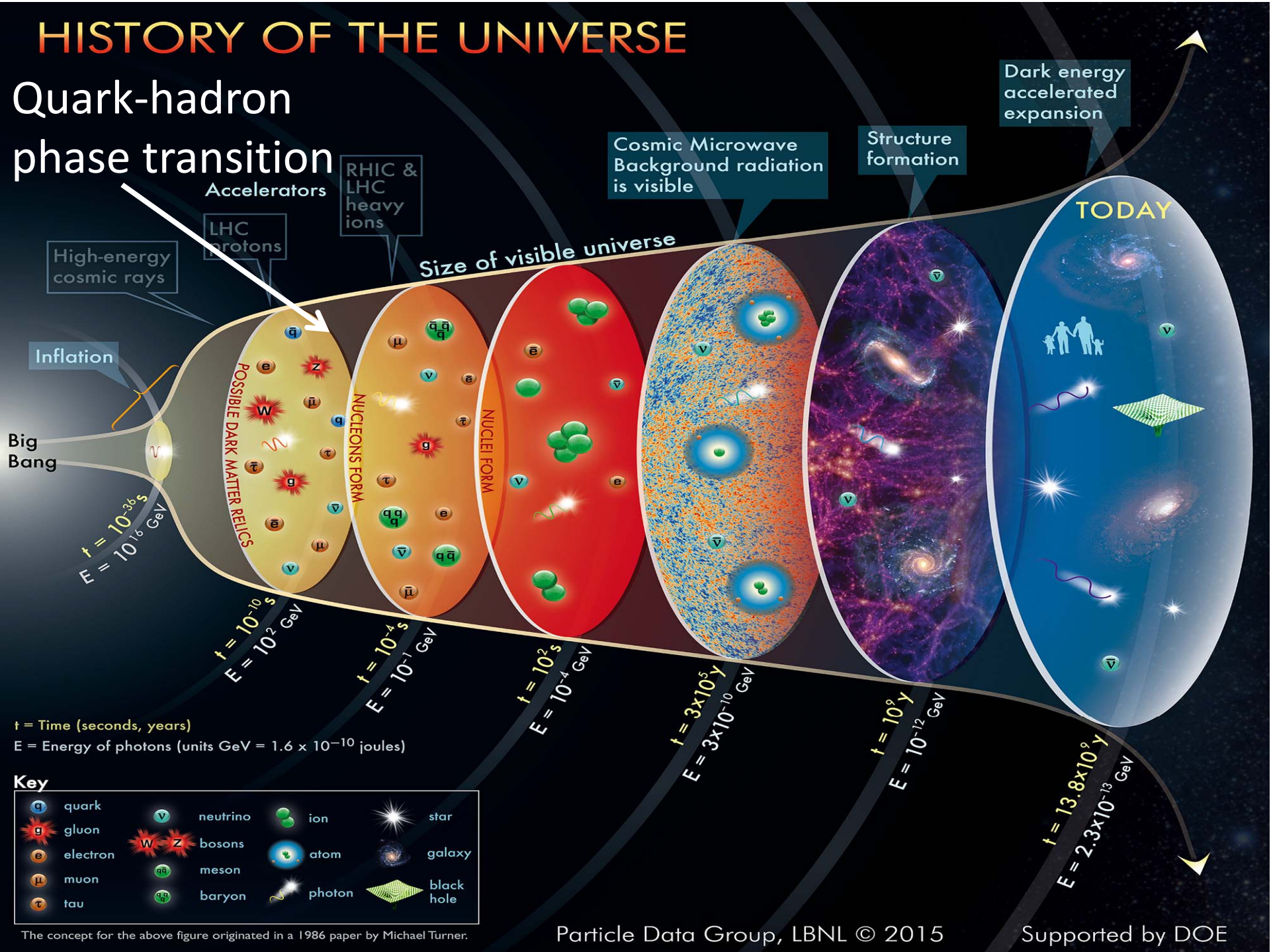
Marseille

May 23-25, 2018



# HISTORY OF THE UNIVERSE

## Quark-hadron phase transition



t = Time (seconds, years)  
 E = Energy of photons (units GeV =  $1.6 \times 10^{-10}$  joules)

### Key

quark	neutrino	ion	star
gluon	bosons	atom	galaxy
electron	meson	photon	black hole
muon	baryon		
tau			

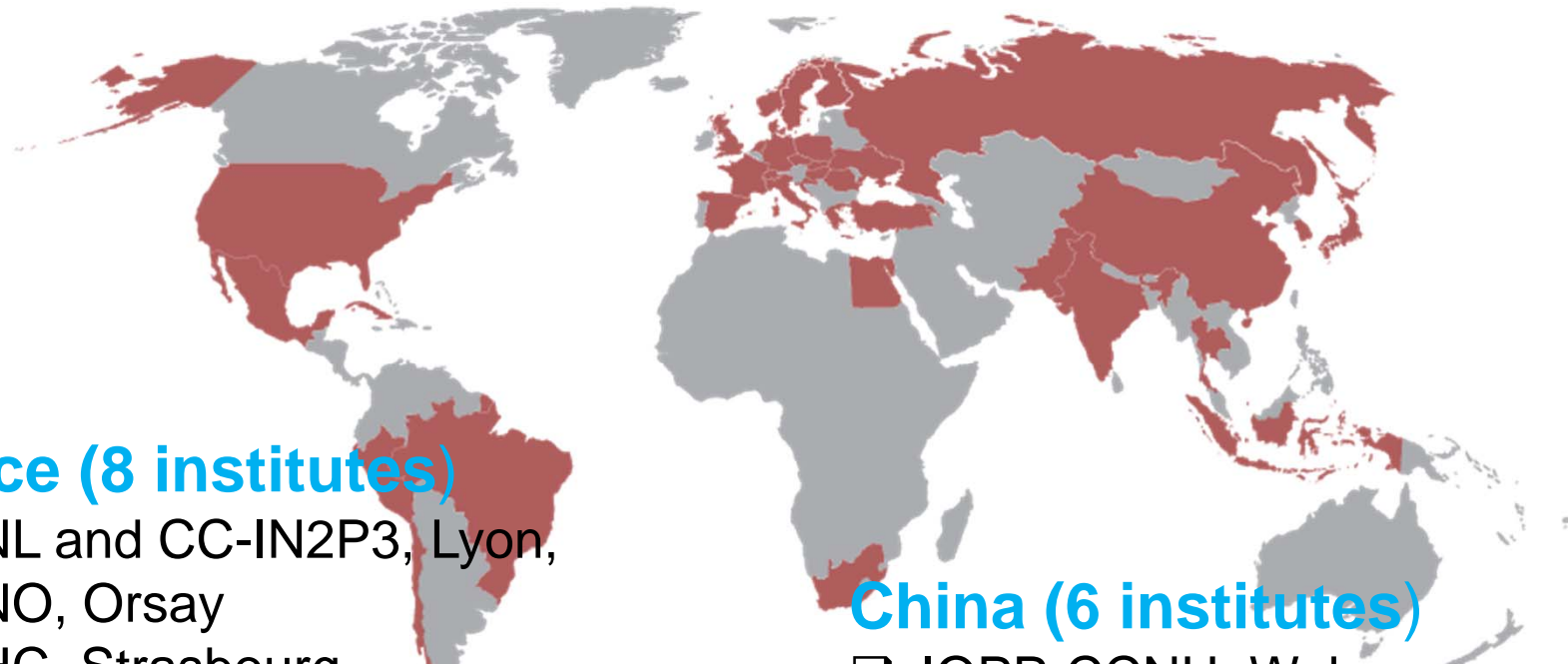
The concept for the above figure originated in a 1986 paper by Michael Turner.



# China and France in ALICE



ALICE today: 41 countries, 176 institutes, 1800 members



## France (8 institutes)

- ❑ IPNL and CC-IN2P3, Lyon,
- ❑ IPNO, Orsay
- ❑ IPHC, Strasbourg
- ❑ LPC, Clermont-Ferrand
- ❑ LPSC, Grenoble
- ❑ Subatech, Nantes
- ❑ IRFU, Saclay
- 43 physicists (25 CNRS, 7 CEA, 11 University staff) , 23 FTE technical staff, 13 PhDs

## China (6 institutes)

- ❑ IOPP-CCNU, Wuhan
- ❑ CIAE, Beijing
- ❑ HUST\*, Wuhan
- ❑ HBUT\*, Hubei
- ❑ USTC, Hefei (from end 2016)
- ❑ SINAP, Shanghai (from end 2016)
- 18 physicists, 12 technical staff, 14 PhDs

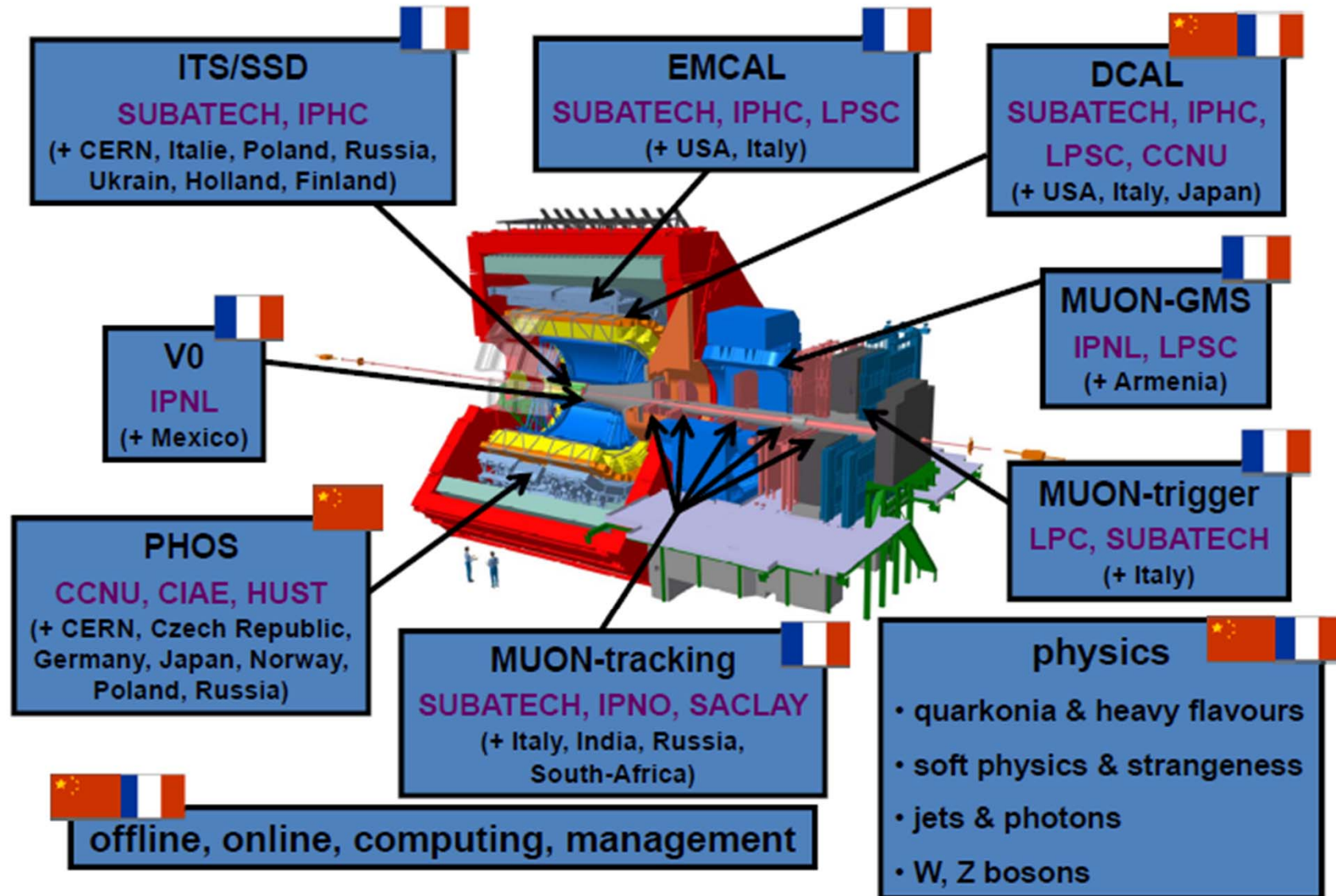




# China and France in ALICE



**Detector involvements:** MUON, V0, ITS, Electromagnetic Calorimeters, ITS & MUON-MFT upgrades

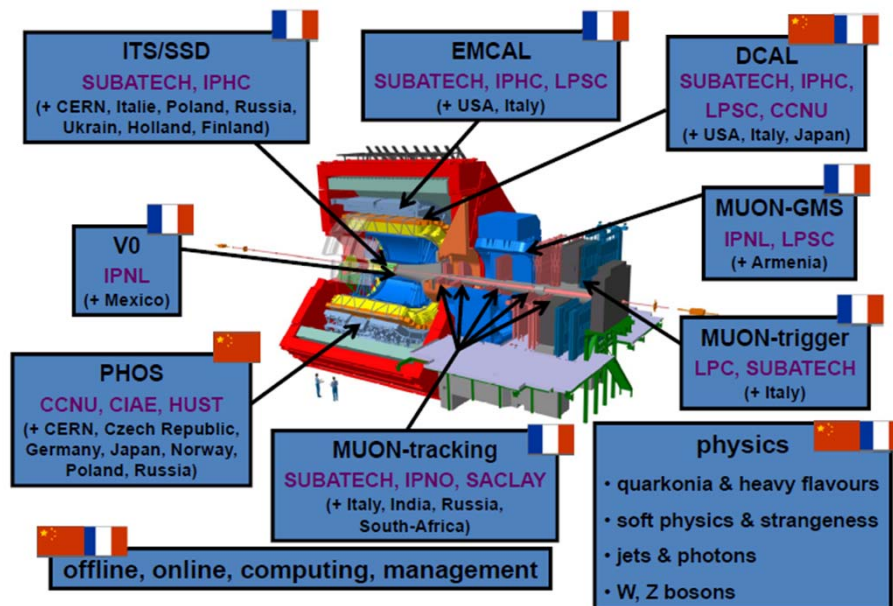




# France and China in ALICE Involvements within FCPPL



Very strong cooperation program between the ALICE groups from IN2P3/CEA (France) and CCNU-Wuhan since several years



- Data analysis
  - Hard probes: open and hidden flavours, jets, W bosons
  - Low mass resonances
  - $\gamma/\pi^0$ -jet correlations
- Performance studies
  - Open heavy flavours with MUON & MFT
  - $\gamma(\pi^0)$  & jets with EMCAL, DCAL & PHOS
  - D fragmentation function with UITS
- Data taking
- Offline, online, computing
- Detector: R&D, installation, operation
- Upgrade projects: UITS-MFT
- Present responsibilities:
  - Management Board, Conference Committee, Physics Analysis Group, Physics Working Group, detectors & upgrades

Future: extend the collaboration between French & Chinese institutes

- LHC Run-2 analyses, detector upgrade & preparation of physics program beyond 2021 (Run-3 & Run-4)



# ALICE within FCPPL: a brief history of our collaboration



- ❑ Co-PhD students: **7** since 2008, main funding from China (CSC, French embassy)
  - 6 co-PhD defended their PhD:  
Y. Mao (LPSC-CCNU, 2011), R. Wan (IPHC-CCNU, 2011),  
X. Zhang (LPC-CCNU, 2012), S. Li (LPC-CCNU, 2015), M. Wang (Subatech-CCNU, 2016), J. Zhu (Subatech-CCNU, 2017)
  - 1 co-PhD in preparation: Z. Zhang (LPC, 2015-2018)
  - 3 co-PhD CSC applications submitted (IPNL-CCNU, LPC-CCNU, LPSC-CCNU)
- ❑ Post-docs: **3** since 2009
- ❑ Master students: **12** since 2007 + **several ongoing demands for 2018** for the analysis of large amount of Run-2 data and ALICE run-3 & 4 preparation
- ❑ Several visits of senior physicists & engineers/technicians: data analysis & detector related activities (upgrades)
  
- ❑ Numerous **presentations in international conferences**, ALICE meetings
- ❑ **Direct contribution in several publications**
- ❑ Numerous conference proceedings, internal/analysis ALICE notes
- ❑ Numerous approved analysis results
  
- ❑ Organization of the 2<sup>nd</sup> FCPPL workshop (CCNU) & 7<sup>th</sup> FCPPL workshop (LPC) and co-organization of the 9<sup>th</sup> FCPPL workshop (IPHC)





# FCPPL-ALICE project: members



PART-CCNU-IN2P3-ALICE: Study of QCD matter with the ALICE detector					
French Group			Chinese Group		
Name	Title	Affiliation (institute)	Name	Title	Affiliation (institute)
<i>Leader</i> BASTID Nicole	PR	IN2P3	<i>Leader</i> ZHOU Daicui	PR	CCNU
Aphécetche Laurent	CR	IN2P3	Cai Xu	PR	CCNU
Baldisseri Alberto	Physicien	IRFU	Yang Chunbin	PR	CCNU
Batigne Guillaume	MC	IN2P3	Bartolini Paolo	PR	CCNU
Belikov Iouri	DR	IN2P3	Sun Xiangming	PR	CCNU
Cheshkov Cvetan	CR	IN2P3	Huang Guangming	PR	CCNU
Cheynis Brigitte	CR	IN2P3	Liu Fumin	PR	CCNU
Conessa-Balbastre Gustavo	CR	IN2P3	Zhou Daimei	PR	CCNU
Crochet Philippe	DR	IN2P3	Yin Zhongbao	PR	CCNU
Dupieux Philippe	DR	IN2P3	Ma Yugang	PR	SINAP
Erazmus Barbara	DR	IN2P3	Zhang Song	Ass. PR	SINAP
Estienne Magali	CR	IN2P3	Shou Qiye	Ass. PR	SINAP
Faivre Julien	MC	IN2P3	Li Xiaomei	PR	CIAE
Furget Christophe	PR	IN2P3	Tang Zebo	Ass. PR	USTC
Germain Marie	CR	IN2P3	Zhang Yifei	Ass. PR	USTC
Guerin Cyril	IR	IN2P3	Pei Hua	Ass. PR	CCNU
Guermene Rachid	CR	IN2P3	Mao Yaxian	Ass. PR	CCNU
Hamon Julien	PhD student	IN2P3	Zhang Xiaoming	Ass. PR	CCNU
Hippolyte Boris	MC	IN2P3	Wang Yaping	Engineer	CCNU
Kuhn Christian	DR	IN2P3	Wang Dong	Engineer	CCNU
Lopez Xavier	MC	IN2P3	Liu Jun	Engineer	CCNU
Maire Antonin	CR	IN2P3	Zhu Jianlin	Engineer	HBUT
Martinez-Garcia Ginés	DR	IN2P3	Yang Ping	Engineer	CCNU
Massimiliano Marchisone	Post-doc	IN2P3	Gao Chaosong	Engineer	CCNU
Norman Jaime	Post-doc	IN2P3	Somnath Kar	Post-doc	CCNU
Pillot Philippe	CR	IN2P3	Prabhakar Palni	Post-doc	CCNU
Rami Fouad	CR	IN2P3	Ren Xiaowen	PhD student	CCNU
Rosnet Philippe	PR	IN2P3	Zhang Zuman	PhD student	CCNU
Roy Christelle	DR	IN2P3	Xu Ran	PhD student	CCNU
Schütz Yves	DR	IN2P3	Ding Yanchun	PhD student	CCNU
Shabeita Alexandre	CR	IN2P3	Zhu Ya	PhD student	CCNU
Stocco Diego	CR	IN2P3	Chang Wan	PhD student	CCNU
Stutzmann	IE	IN2P3	Alfanda Haidar	PhD student	CCNU
Jean Sébastien			Masud		
Uras Antonio	CR	IN2P3	Tang Siyu	Master student	CCNU
			Jiang Xiuxiu	Master student	CCNU
			Yongzhen Hou	Master student	CCNU
			Zhao Minrui	Master student	CIAE
			Zhi Yu	Master student	CIAE
			Wu Yitao	Master student	USTC

## PART-CCNU-IN2P3-ALICE Study of QCD matter with the ALICE detector

- ❑ Composed of several projects
  - MUON
  - Calorimeters: EMCal/Dcal
  - PHOS
  - ITS-MFT upgrade
- ❑ 36 members in 2009, ...,
- ❑ Now: **73** members
  - China-France Collaboration still increasing



## Student exchanges (physics analyses):

### ❑ Co-PhD

- Jianhui ZHU: CCNU/Subatech, 2013-2017 (2 year-CSC grant)
- Zuman ZHANG: CCNU/LPC, 2015-2018 (2 year-CSC grant)

### ❑ Trainings

- Siyu TANG: CCNU/LPC, Dec. 2017-Feb. 2018
- Xiuxiu JIANG, CCNU/IPHC, Oct.-Dec 2017
- Ran XU: CCNU/LPSC, Jan-April. 2018 (FCPPL)

## Visits

### ❑ Several visits of senior physicists/post-docs from France to China and vice-versa for common activities related to:

- Physics analyses (Xiaoming ZHANG at LPC)
- Detector upgrades: MFT readout electronics (Dong WANG & Jun LIU at IPNL), ITS silicon pixel design
- Participation to the ITS upgrade, MFT and O2 workshop (each 6 months in Asia)
- Future collaboration plans

## 10<sup>th</sup> FCPPL workshop at Tsinghua Univ. (Beijing)

- 19 physicists/PhDs/Post-docs in total and 8 talks





ALICE

- ❑ Production and flow of open heavy flavours via muons in pp/Pb-Pb/Xe-Xe collisions  
(**Z. Zhang, X. Zhang** with LPC/CCNU)
- ❑ Production and elliptic flow of open heavy flavours via muons in p-Pb collisions  
(**S. Li, S. Tang, X. Zhang** with LPC/CCNU)
- ❑ Electroweak probes: W-boson production in pp/p-Pb collisions  
(**J. Zhu** with Subatech/CCNU)
- ❑ Strange D-meson production in p-Pb collisions  
(**X. Jiang, X. Zhang** with IPHC/CCNU)
- ❑ Isolated photons- $\pi^0$ /jet correlations in pp collisions  
(**R. Xu, Y. Mao** with LPSC/CCNU)
- ❑ Double-parton scattering measurements in pp/p-Pb collisions: feasibility study  
(**P. Bartalini, P. Palni** with Subatech/CCNU)
- ❑ Bottomonium production vs. charged-particle multiplicity  
(**Y. Ting, X. Zhang** with LPC/CCNU)



# Open heavy-flavour production in heavy-ion collisions



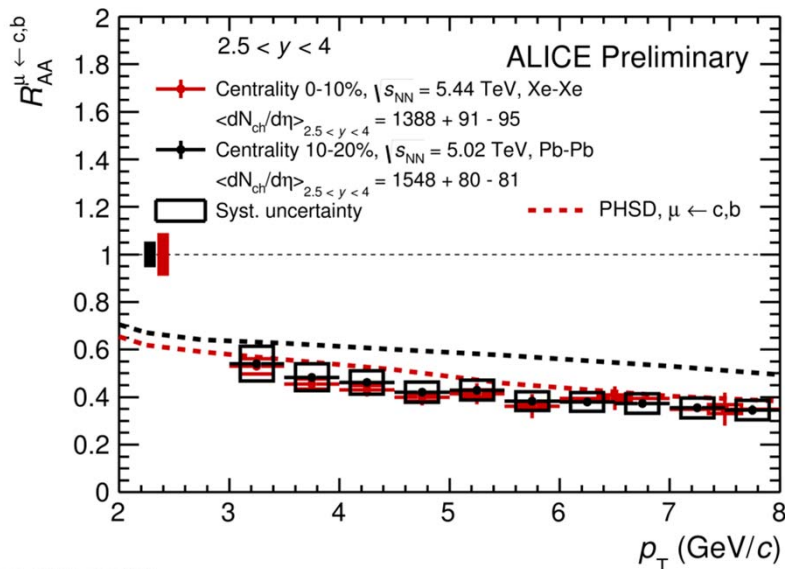
Charm and beauty quarks produced in **initial hard scatterings** with a short formation time, experience the **full collision history**

➤ **Sensitive probes of the medium properties**

## Open heavy flavours in heavy-ion collisions probe

- ❑ In-medium parton energy loss
- ❑ Heavy quark participation in the collective expansion

$$R_{AA}(p_T) = 1 / \langle N_{\text{coll}} \rangle \times \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$



- ❑ **Strong suppression** of heavy-flavour hadron decay muons in Xe-Xe collisions, similar to that measured in Pb-Pb collisions
- ❑ **Improved precision** w.r.t. to LHC Run-1
- ❑ New constraints on energy loss models

Results presented at QM2018 (Venice, Italy)  
Publications of pp and Pb-Pb results in preparation

**Zuman Zhang (co-PhD LPC/CCNU),  
Xiaoming Zhang (CCNU)**

More: see Zuman Zhang's talk

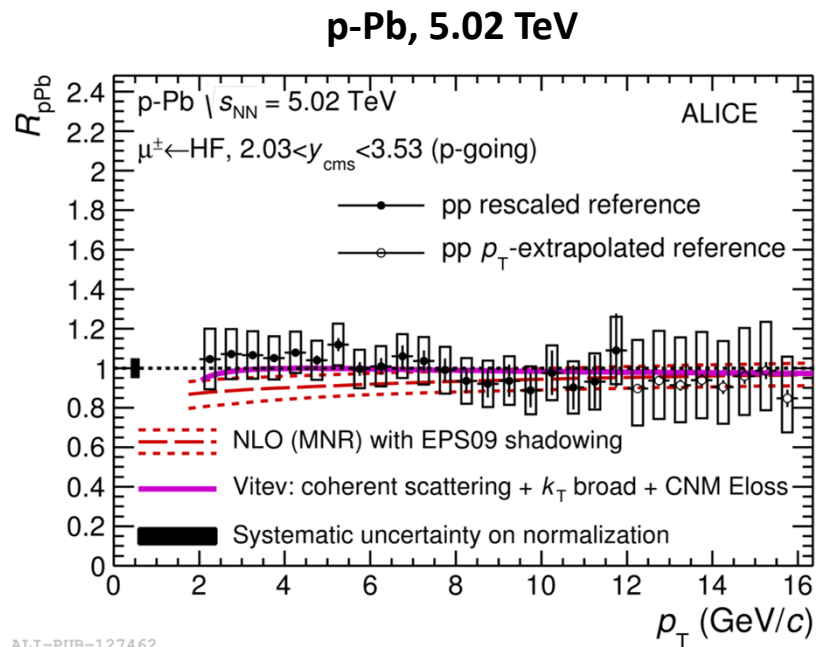


# Open heavy-flavour production in p-Pb collisions



## Open heavy-flavour production in p-Pb collisions

- Reference for Pb-Pb measurements
- Investigation of cold nuclear matter effects



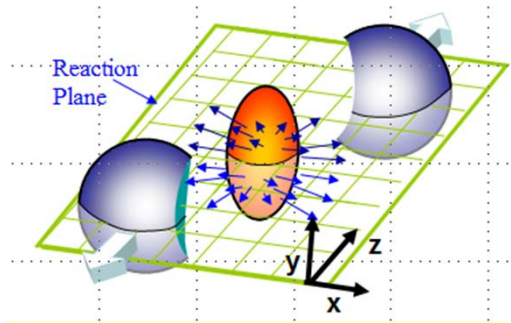
**Phys. Lett. B 770 (2017) 459**

- $R_{pPb}$  compatible with unity: cold nuclear matter effects small
  - $R_{pPb}$  in agreement with models including cold nuclear matter effects
  - $R_{pPb}$  being consistent with unity, **the strong suppression measured in central Pb-Pb collisions is due to the hot and dense medium**
- ✓ Final results, presented at QM2017

**Shuang Li (co-PhD LPC/CCNU (2012-2015), now at three Gorges University),**  
**Xiaoming Zhang (CCNU)**

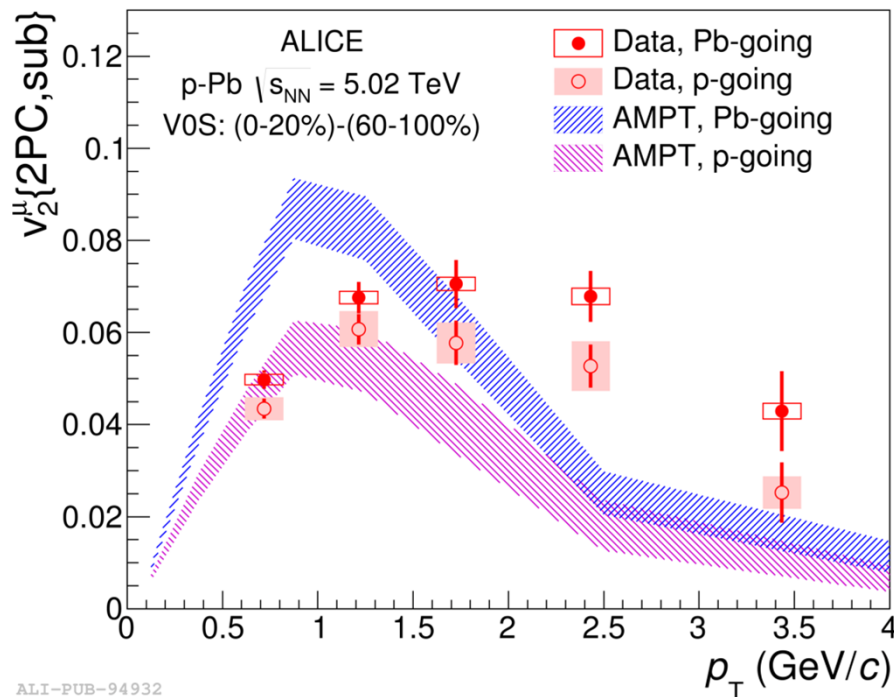
More: see Zuman Zhang's talk





initial spatial anisotropy  $\rightarrow$  momentum anisotropy

$$\frac{2\pi}{N} \frac{dN}{d\varphi} = 1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\varphi - \Psi_n)] \quad v_2 = \text{elliptic flow}$$



ALI-PUB-94932

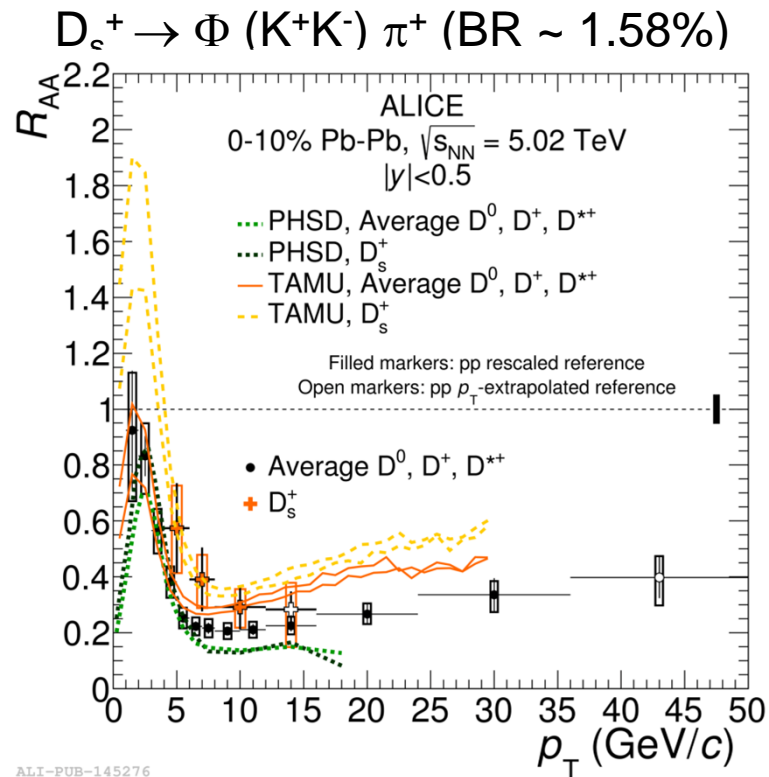
**Phys. Lett. B 753 (2016) 126**

- Complements  $R_{pPb}$  measurements
- **Positive  $v_2$**  in central (0-20%) collisions as observed in Pb-Pb collisions  $\rightarrow$  evidence for collectivity in small systems
- Analysis ongoing with run-2 p-Pb data at 8.16 TeV with cumulants by extending the measurement to higher  $p_T$  and with improved precision
- ✓ Aim: analysis to be approved for HP2018 (Oct. 2018, Aix Les bains)

**Siyu Tang** (master II, 3-month training at LPC then co-PhD (CSC grant application submitted), **Xiaoming Zhang** (CCNU)



# Strange D-meson production via hadronic channels



ALICE, arXiv:1804.09083

- Hint of enhanced  $D_s^+$  production compared to non-strange D mesons in central Pb-Pb collisions at 5.02 TeV as expected from models
  - Coalescence and strangeness enhancement?
- No significant dependence of  $D_s^+/D^0$  ratio on collision centrality within uncertainties
  - Expected considering a pure coalescence scenario
- Ongoing: measurement of  $D_s^+$  via the decay channel  $D_s^+ \leftarrow K_s^0 K^+$  in p-Pb collisions collected in the LHC run-2  
**XiuXiu JIANG** (master, 2-month training at IPHC), **Xiaoming Zhang** (CCNU)



# W-boson production via muons in p-Pb collisions



**W bosons in heavy-ion collisions:** produced in initial hard scatterings, unaffected by the strong interaction

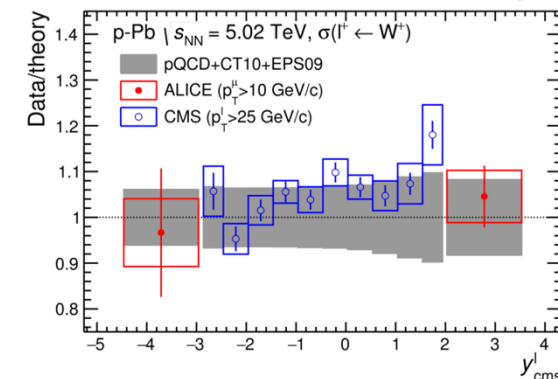
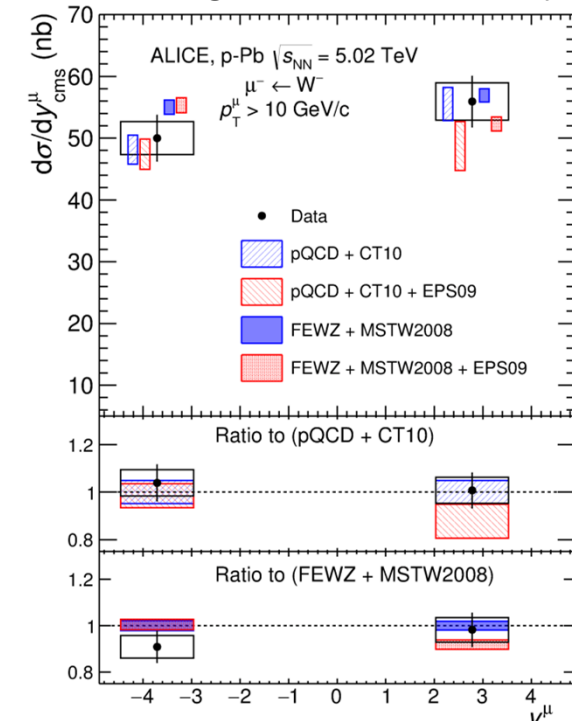
- Sensitive to the nuclear modification of the PDFs
- Reference for hard-probe measurements

- ❑ First measurement at forward & backward rapidity in p-Pb collisions
- ❑ In agreement with model predictions **with** and **without** including nPDFs
- ❑ Calculations with **nPDFs describe ALICE & CMS** data over the full rapidity range

✓ Published in ***JHEP 02 (2017) 077***

***Jianhui Zhu (co-PhD Subatech/CCNU)***

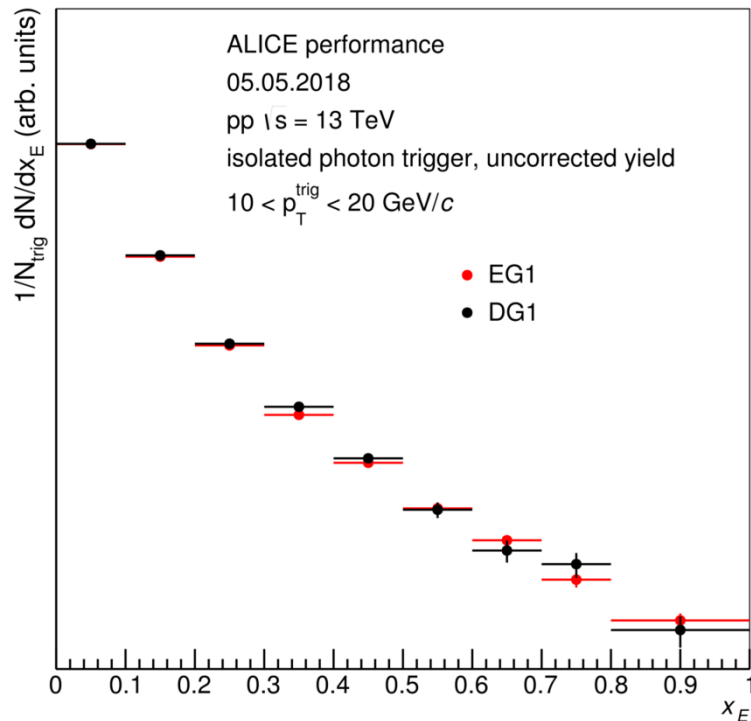
***PhD defense: April 1<sup>st</sup>, 2017***







# Isolated photon - $\pi^0$ correlations in pp collisions at 13 TeV



ALI-PERF-147449

$$x_E = -\frac{\vec{p}_{Tt} \cdot \vec{p}_{Ta}}{|\vec{p}_{Tt}|^2} = -\frac{p_{Ta}}{p_{Tt}} \cos(\Delta\phi)$$

- Isolated  $\gamma$ -hadron correlations allow us to study in
  - Pb-Pb collisions:
    - ✓ Parton medium-induced modifications
  - pp collisions:
    - ✓ Baseline for measurements in heavy-ion collisions
    - ✓ Study of parton fragmentation function
    - ✓ Constraints on pQCD-based calculations

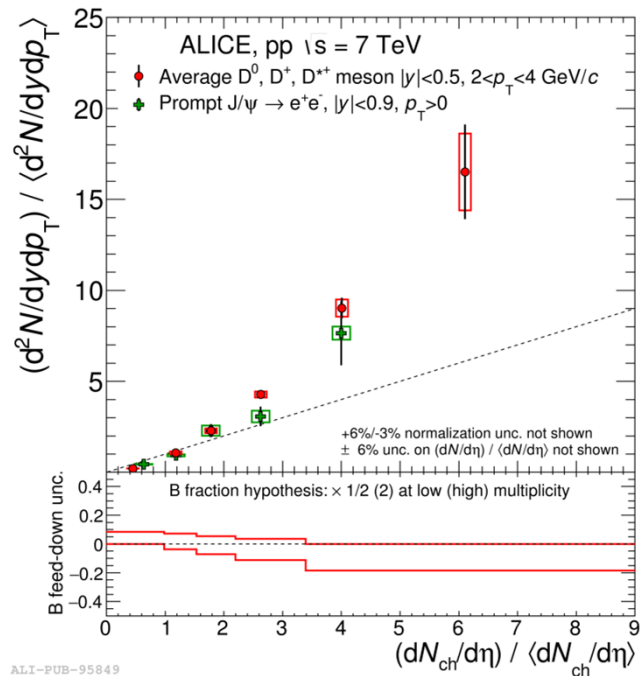
- Measurement of isolated  $\gamma$ - $\pi^0$  correlations in pp collisions at  $\sqrt{s} = 13$  TeV ongoing
  - Performance results approved and shown in a poster at QM2018

**Ran Xu** (3-month training at LPSC Grenoble, Co-PhD: CSC grant-application submitted),  
**Yaxian Mao** (CCNU)

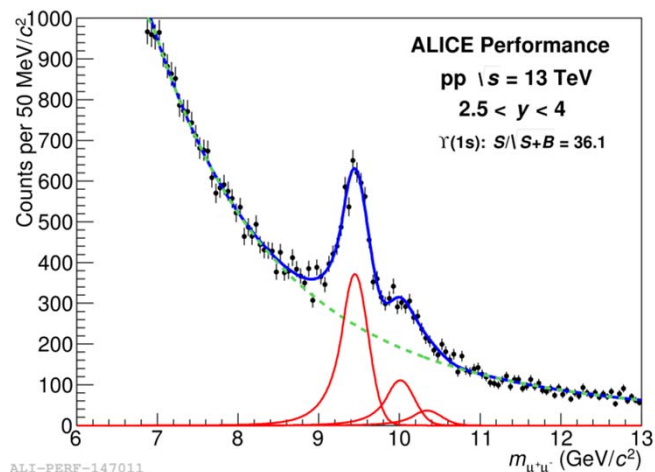
More: see Yaxian Mao's talk



# Heavy-flavour production as a function of charged-particle multiplicity



ALI-PUB-95849



ALI-PERF-147011

- ❑ **Insight into processes** occurring at partonic level:
- ❑ Key observable for addressing Multiple Parton Interactions (MPI) and studying interplay between hard and soft particle production mechanisms
- ❑ **Observed: faster than linear increase** of open heavy flavour and charmonium yields at high  $p_T$
- ❑ Further insights into production mechanisms can be gained by studying:
  - Bottomonium production vs charged-particle multiplicity in pp collisions at 13 TeV
    - **Performance results** approved and shown as a poster at QM2018
    - Yanchun Ding, Xiaoming Zhang (CCNU) with LPC**
  - Double parton-scattering measurements in p-Pb collisions
    - Ongoing performance study
    - Paolo Bartalini (CCNU), Diego Stocco (Subatech)**

More: see Yanchun Ding's talk



# 2017 scientific production (students, post-docs )



## ☐ Publications with direct contribution & conference proceedings: 7

- J. Adam et al.. (ALICE Collaboration), JHEP 02 (2017) 077
- S. Acharya et al. (ALICE Collaboration), Phys. Lett. B 770 (2017) 459
- D. Stocco for the ALICE Collaboration, Nucl. Phys. A 967 (2017) 309
- K. J. Senosi for the ALICE Collaboration, J. Phys. Conf. Ser. 832 (2017) 012033
- X. Zhang for the ALICE Collaboration, Nucl. Part. Phys. Proc. 289-290 (2017) 1
- X. Zhang for the ALICE Collaboration, proceedings of EPS Conference on High Energy Physics, to be published
- Z. Zhang for the ALICE Collaboration, Nucl. Part. Phys. Proc. 289-290 (2017) 405

## ☐ Talks in international conferences & workshops: 18

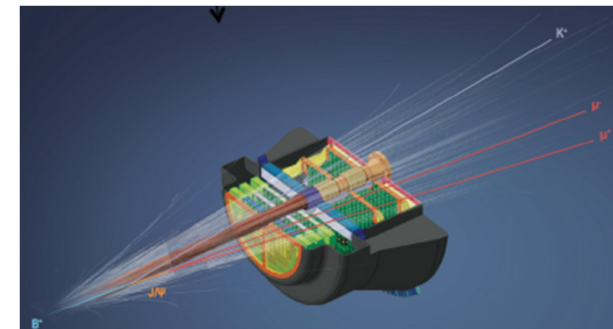
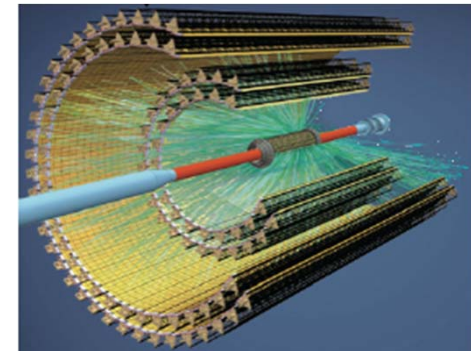
- Y. Mao, X. Zhang, J. Zhu, 3<sup>rd</sup> China LHC Physics Workshop, Beijing, China, 22-24 Dec. 2017
- H. Pei, Y. Mao, Fifth Annual Large Hadron Collider Physics Conference, Shanghai, 15-20 May, 2017
- X. Zhang, EPS Conference on High Energy Physics, Venice, Italy, 5-12 July, 2017
- X. Zhang, Z. Zhang, Muon workshop 2017, Grotta Gisuti, Italy, 15-19 May, 2017
- Z. Zhang, Rencontres QGP-France, Etretat, France, 9-12 Oct. 2017
- Z. Zhang, ALICE Physics Week, Amsterdam, Netherlands, 4-8 Dec., 2017
- M. Marchisone, D. Wang, Y. Wang, 10<sup>th</sup> ALICE ITS upgrade, MFT and O<sup>2</sup> Asian Workshop 2017, Wuhan, China, 18-20 Dec., 2017
- Y. Mao, D. Stocco/P. Bartalini, X. Zhang, Z. Zhang, 10<sup>th</sup> Workshop of the France China Particle Physics Laboratory, Beijing, China, 27-30 March, 2017

## ☐ Many presentations in weekly ALICE Physics Analysis Group meetings & monthly ALICE Physics Working Group meetings, ALICE Physics Forum

## ☐ Several papers to be submitted soon (Run-2 analyses, mainly)



- ❑ **Major upgrade** currently in preparation for LHC Run-3 (2021-2023) and beyond
  - New conditions with Run 3: Pb-Pb interaction rate may reach **50kHz** (now ~ 8 kHz)
  - R&D, some construction started, installation during the second Long Shutdown
  
- ❑ **Goals of ALICE Run-3:**
  - High precision measurements of **rare probes with main focus on the low  $p_T$  region**  
→ **x 100 larger minimum-bias sample compared to Run 2** (~ $10^{11}$  events)
  - Increase **readout rate to 50 kHz**, presently limited to ~1 kHz
  - **Improvement of pointing resolution at both central and forward rapidity**
  
- ❑ **New Inner Tracking System (UITS)**
  - Improved pointing resolution, reduced material budget, faster readout
- ❑ **Forward Muon Tracker (MFT)**
  - New Silicon tracker, heavy-flavour vertices also at forward rapidity
- ❑ **New TPC readout chambers based on GEM**
- ❑ **Upgraded readout for many detectors**
- ❑ **Integrated Online-Offline (O<sup>2</sup>) system**
- ❑ **New Fast Integration Trigger detector (FIT)**

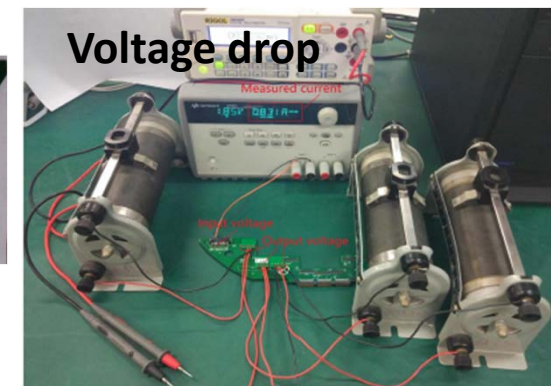
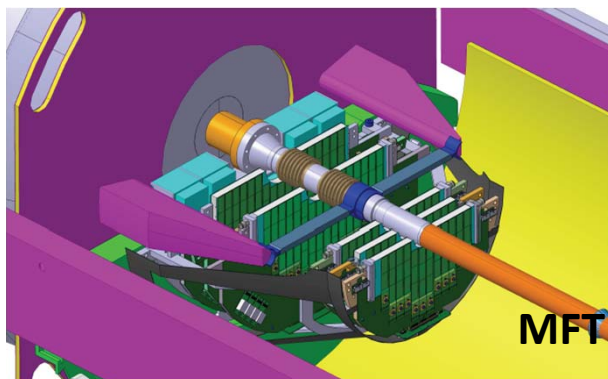
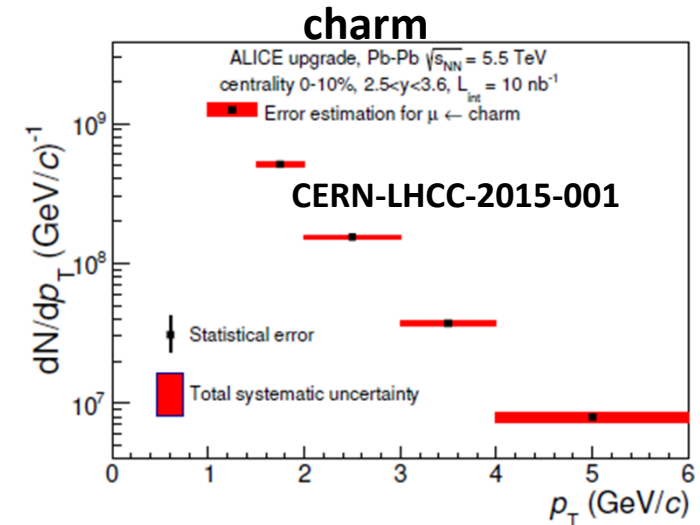


More: see Brigitte Cheynis's talk

## DCal and PHOS operation in Run-2

## Involvement of CCNU in the ITS-MFT project:

- Performance studies for both **UITS & MFT**: charm & beauty measurements via muons with MFT-MUON and D-meson fragmentation function with UITS
- Contribution to the **global readout electronics design of MFT** (PCB design & production, voltage drop measurements of PCB ladders)



- 10 half-disks, 2 detection plane each in the muon spectrometer acceptance, between absorber & interaction point
- 920 silicon pixel sensors in 280 ladders



## □ Continue the involvement in data analysis: analysis of large samples of Run-2 data (pp, p-Pb and Pb-Pb collisions)

- Open heavy-flavour measurements in small and heavy systems at forward rapidity with muon spectrometer: production and flow  
LPC/CCNU Collaboration: **Zuman Zhang** (co-PhD, defense end of 2018), **Siyu Tang** (co-PhD, application for a CSC grant submitted), **Xiaoming Zhang** (physicist)  
+ Master student
- Low-mass resonance measurements at forward rapidity  
IPNL/CCNU Collaboration: **Yanchun Ding** (co-PhD, application for a CSC grant submitted), **Xiaoming Zhang** (physicist)
- Double-parton scattering measurements in the heavy-flavour sector  
Subatech/CCNU Collaboration: **Paolo Bartalini/Prabhakar Palni (physicists)**
- Open heavy flavour-jet measurements at mid-rapidity with Central Barrel and electromagnetic calorimeters  
IPHC & LPSC/ CCNU & USTC Collaboration: **Yitao Wu/Alfanda Haidar Masud** (Master), **Yaxian Mao** (CCNU, physicist), **1 physicist** (USTC)
- $\gamma$ - $\pi^0$ /jet correlation measurements  
LPSC/CCNU Collaboration: **Ran Xu** (co-PhD, application for a CSC grant submitted), **Yongzhen Hou** (Master), **Yaxian Mao** (physicist)





- Continue to strengthen the involvements in the ALICE upgrade projects
  - Technical involvements (UITs-MFT):
    - ✓ UITs: module assembly, IPHC/ LPSC and CCNU/USTC
    - ✓ MFT: LPC/IPNL/Subatch/IRFU-Saclay and CCNU
  - Participation to installation, commissioning of both UITs and MFT
  - Software developments (UITs with O<sup>2</sup> framework): IHPC/CCNU Collaboration
  - Physics program with Run-3 & Run-4: ongoing performance studies
    - MFT: measurements of charm and beauty decay muons, separately quarkonia and low mass resonances
    - UITs: charmed baryons and mesons via hadronic and semi-electronic decays, jet measurements,  $\Upsilon$ -neutral meson correlations with charged jets

**FCPPL support needed for student, senior physicist & technician/engineer exchanges between China-France**



## □ Funding from FCPPL

- Travel and stay for attending the 11<sup>th</sup> FCPPL workshop (Marseille)
- Travel and stay costs for members of the committee of Zuman Zhang's PhD defense (CCNU Wuhan)
- Travel and stay for 4 Master students (2-3 month each, to be followed by co-PhDs end of 2019 if CSC grant successful)
- Travel and stay costs for 2-3 PhDs depending on CSC results
- Travel and stay costs for 4 senior physicists from China (CCNU, USTC) in French institutes
- Travel and stay costs for 2 senior physicists from France to China
- Travel and stay costs for two technical staff at IPNL (1 month in total)

## □ Other fundings

- Three ongoing co-PhD demands, CSC application submitted (IPNL, LPC, LPSC)



## **Solid China-France cooperation in the ALICE scientific program with a recognized visibility within ALICE**

- ❑ **Strong contribution to data taking, data analysis and performance studies**
  - Excellent contributions of students
  - Significant contributions to scientific production
  - Many talks in conferences
- ❑ **Contributions to ALICE upgrades: detector and software developments**
- ❑ **Preparation of the Run-3 & Run-4 physics program**

**Continue to extend the collaboration in more and more  
common activities**

**→ enhance student exchanges/funding**



**Thank you for  
your attention**

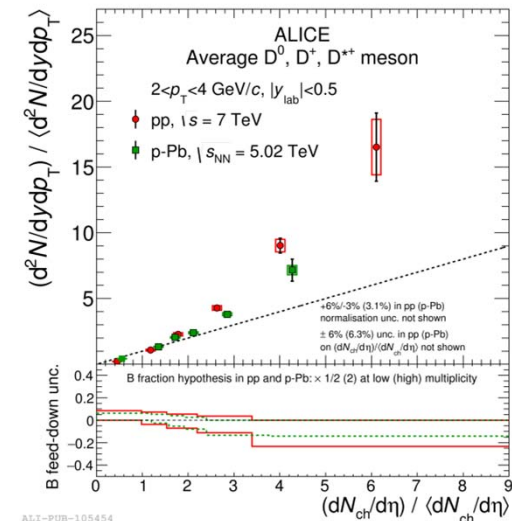




# Double-parton scattering measurements in p-Pb collisions with ALICE



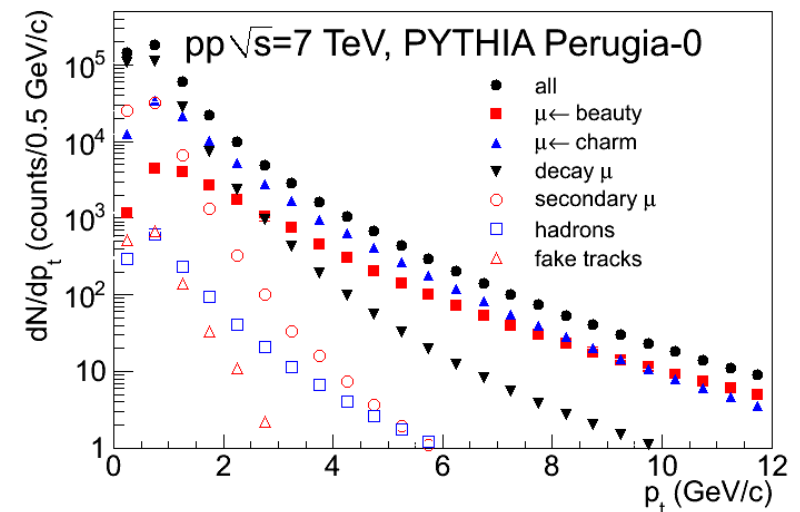
- Particle yields vs. charged-particle multiplicity
  - Key observable to study **Multi-Parton Interactions**



- Investigate **Double Parton Scattering (DPS)** in the **heavy-flavour sector** focusing on **p-Pb collisions** (enhanced probability of DPS compared to pp collisions)
  - High- $p_T$  muons at forward rapidity (heavy-flavour decay muons, mainly)
  - search for same-sign high- $p_T$  muons
- Feasibility study ongoing with MC

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**ALICE, JHEP 09 (2015) 148**



**ALICE, PLB 708 (2012) 265** 25