

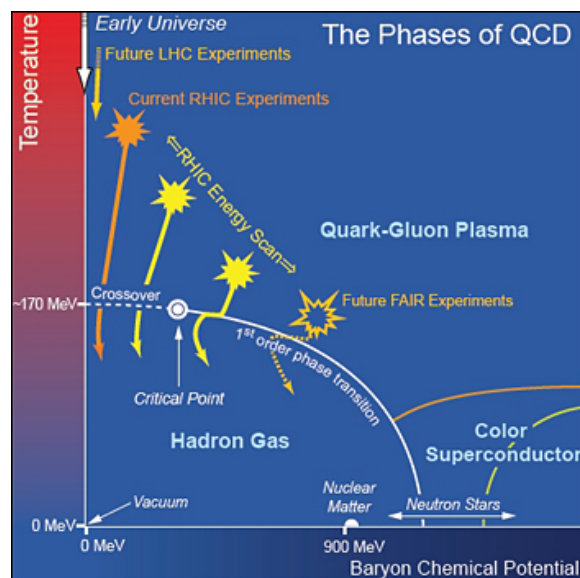
A 3D visualization of a heavy ion collision event in the CMS detector. The detector is shown as a green, segmented cylindrical structure. In the center, a dense spray of particles is depicted as a starburst of orange and red lines radiating outwards. The background features a light blue grid pattern and a white circular glow on the right side.

CMS Heavy Ions

Matthew Nguyen (LLR)

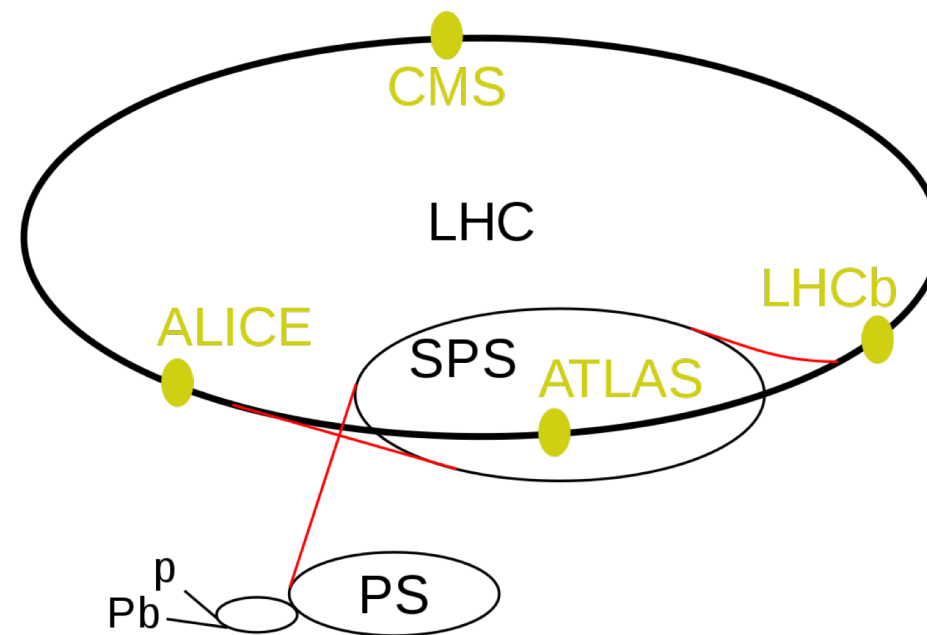
Participating institutes: Laboratoire Leprince Ringuet & Korea University

Heavy ions w/ CMS



High-energy heavy-ion collisions investigate high temperature behavior of matter in its deconfined phase → the quark-gluon plasma (QGP)

Although not designed for heavy ions, CMS excels for certain measurements of QGP properties, e.g., quarkonia melting & jet quenching



O(100) physicists participate in the CMS-HI program
LLR and KU are the largest non-US contributors

The institutes



- Matthew Nguyen
- Raphael Granier de Cassagnac
- Inna Kucher
- Batoul Diab
- Guillaume Falmagne
- Francois Arleo (25%, associated theorist)



- Byungsik Hong
- Jaebom Park
- Yeonju Go
- Kisoo Lee

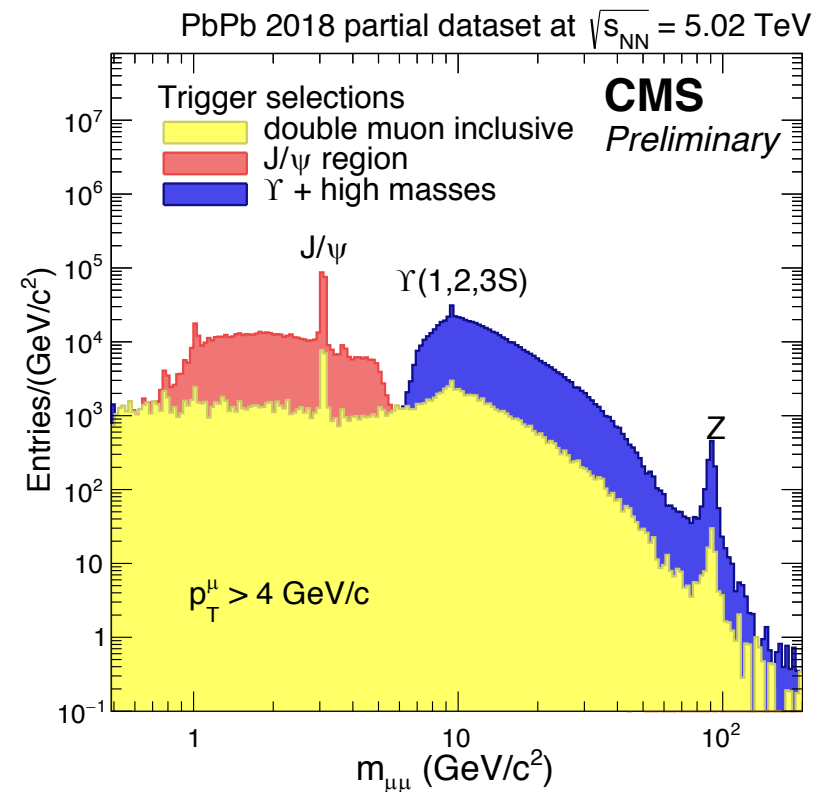
Senior
Postdoc
Student

LLR and KU have participated in the CMS heavy-ion program, since the first data in 2010
More recently other Korean institutes have joined (Chonnam and Sejong)

The LLR-KU partnership (v1): 2014 – 2017

- LLR & KU are the two most active institutes in the *dilepton* subgroup
- Responsible for some of the most well-known results from CMS
- Close collaboration on many analysis & supporting work (next slides)
- Mihee Jo (KU PhD) was a Marie-Curie Fellow at LLR (2015 – 2017)

Triggered dimuon mass spectrum in 2018



Upsilon spectroscopy

- Onia states “melt” in the QGP depending on their binding energy
- Three upsilon states are notches on the thermometer of the QGP
- CMS the only expt that separates the 3 Υ states in central PbPb

All Υ papers have a strong or leading contribution from LLR or KU

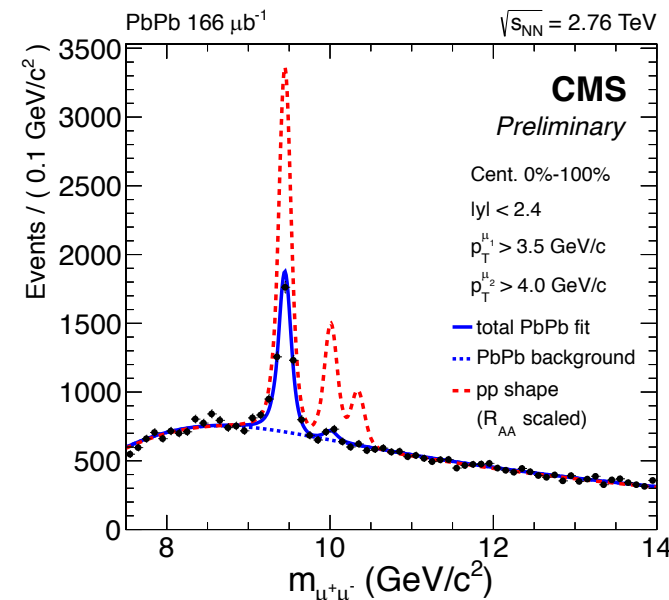
[PRL 109 \(2012\) 222301](#)

[JHEP 04 \(2014\) 103](#)

[PLB 770 \(2017\) 357](#)

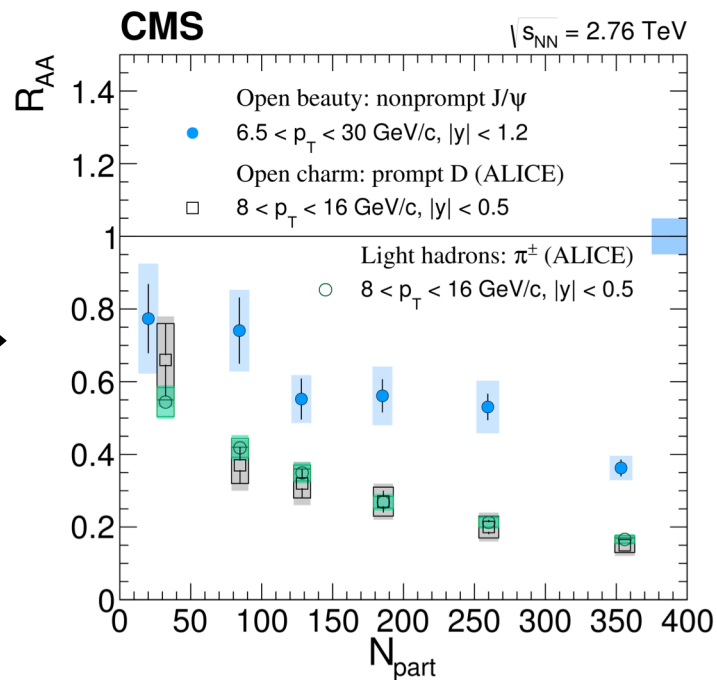
[PLB 120 \(2018\) 142301](#)

[PLB 790 \(2019\) 270](#)

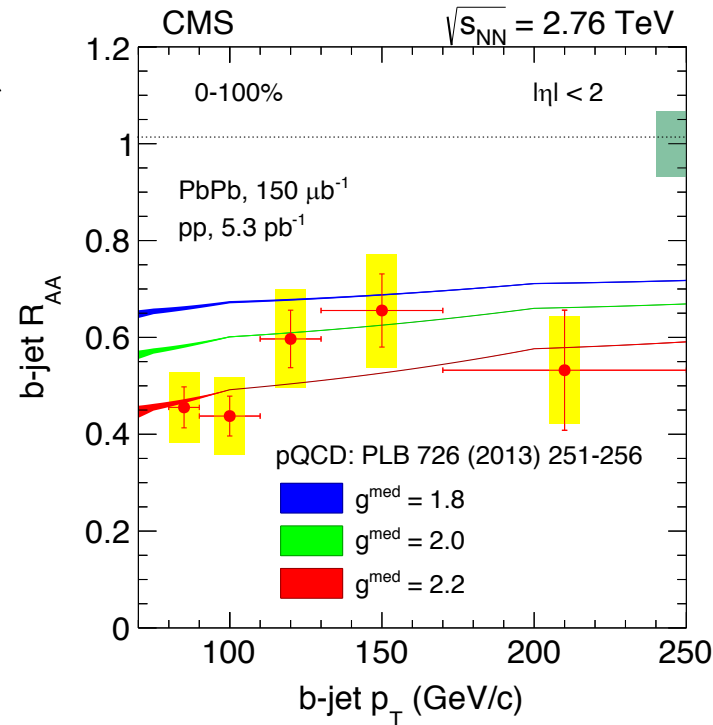


b quark energy loss

- Low p_T : Nonprompt J/ψ and exclusive B reconstruction
- High p_T : b-tagged jets



Mass dependence at low p_T sensitive to interplay of e-loss mechanisms (collisional vs. radiative)



Larger p_T sensitive to quark vs. gluon energy loss

[PRL 113, \(2014\) 132301](#)
[EPJC 77 \(2017\) 252](#)
[JHEP 03 \(2018\) 181](#)
[EPJC 78 \(2018\) 509](#)

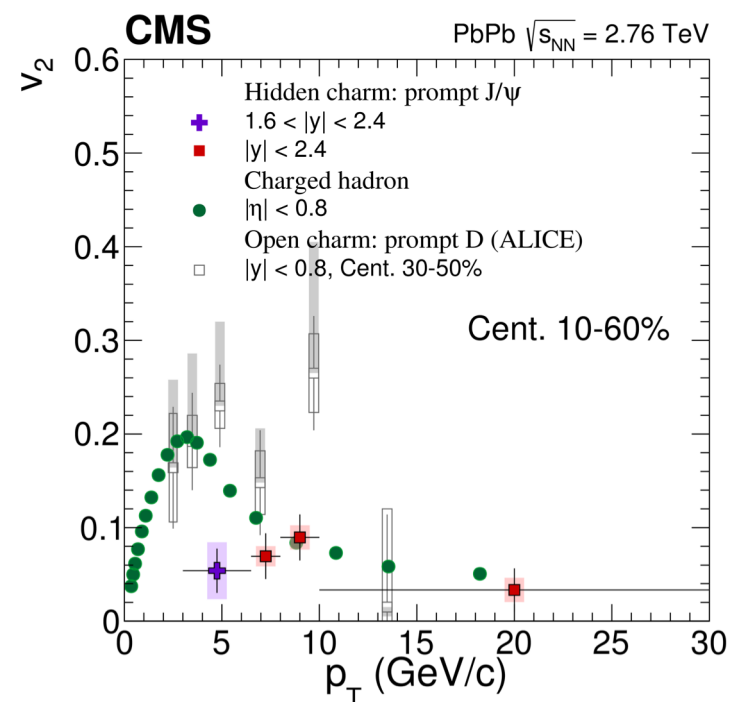
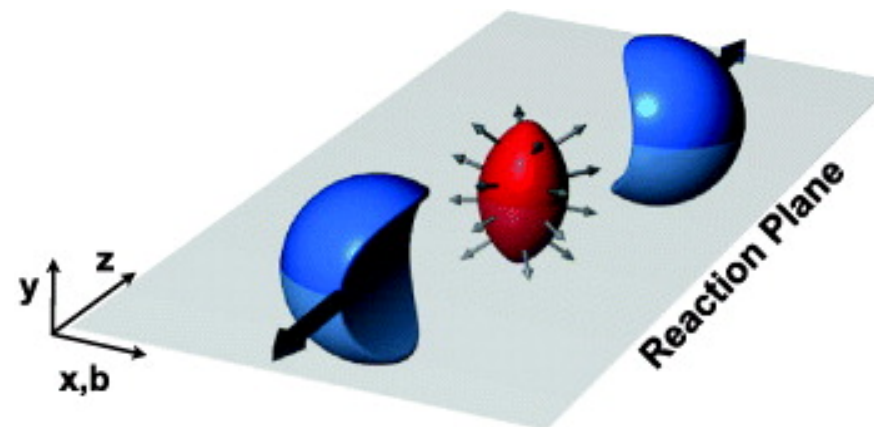
All chaired by LLR or KU

J/ ψ elliptic flow

[EPJC 77 \(2017\) 252](#)

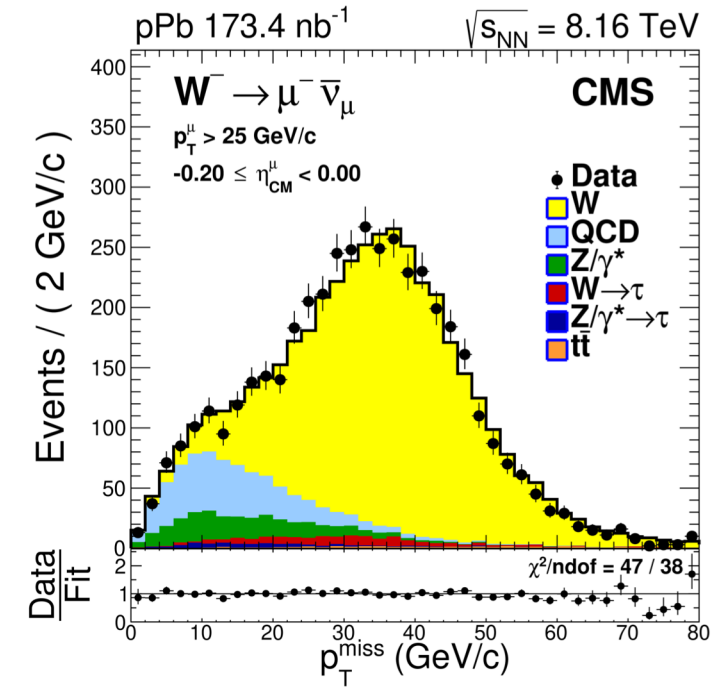
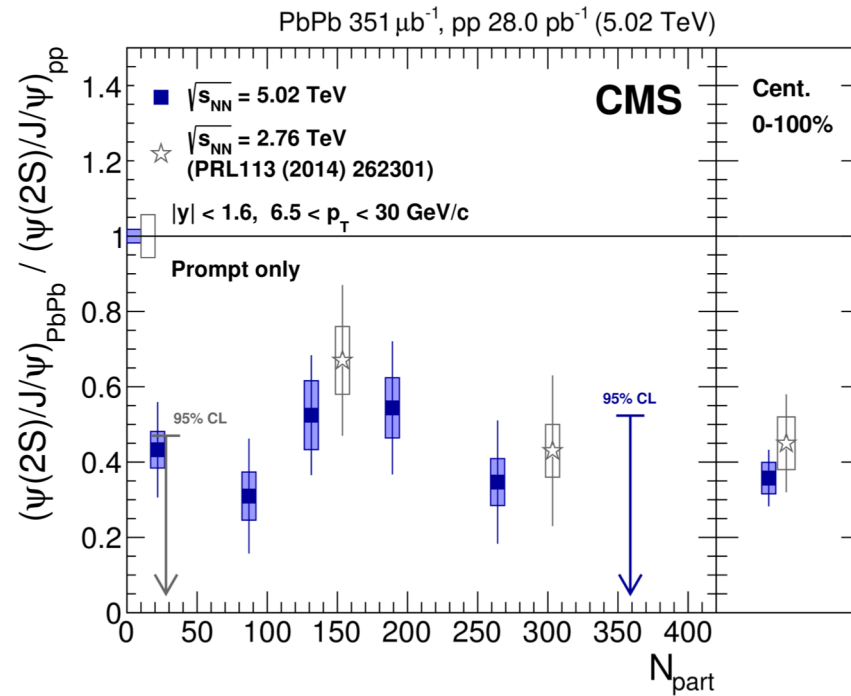
Led by Dongho Moon and Camelia Mironov
(then at KU and LLR, respectively)

Observed unexpectedly large v_2 at high p_T ,
comparable to light hadrons



Other results

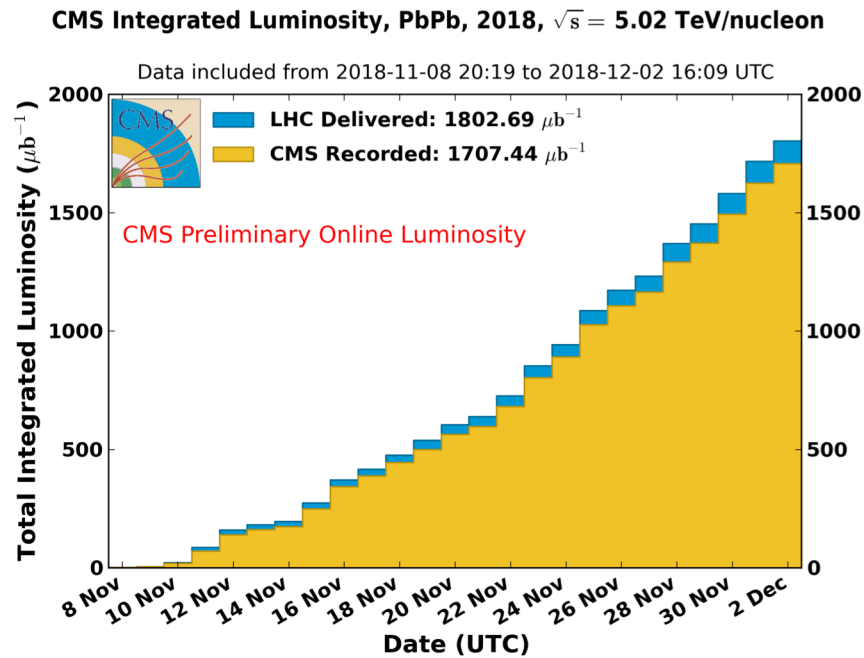
- $\psi(2s)$ vs J/ψ
- Electroweak bosons
- + much more



For more details on our results and collaboration see previous FKPPL presentations [2014](#) [2017](#)

The 2018 PbPb data

- 3x larger than previous data
- Last data until 2021

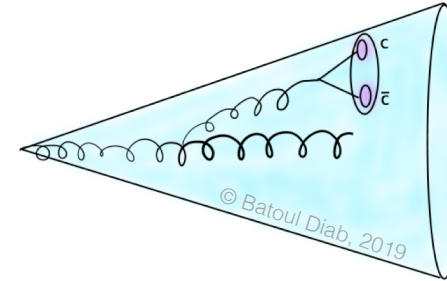


CMS center @ CERN during the 2018 run



LLR and KU collaborated closely during the run, particularly on the muon-triggered data

Ongoing activities: LLR

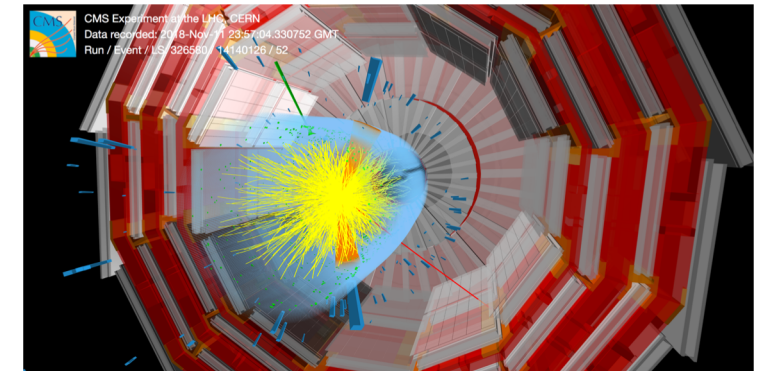
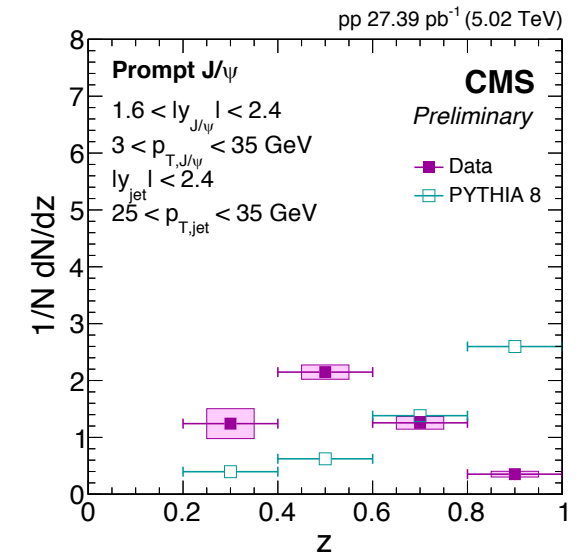


• Analysis

- Fragmentation of J/ψ in jets (Batoul's thesis)
- Observation of $t\bar{t}$ in PbPb collisions (Inna):
Contributing electron ID and b-tagging calibrations
- b-jets, eventually photon + heavy quark jet
- Exotic onia states (Guillaume): B_c , possibly $X(3872)$

• Responsibilities

- Photon trigger coordinator (Inna)
- Centrality calibrations (Batoul)
- Muon data-driven efficiency "tag & probe" (Batoul, Guillaume)



Ongoing activities: Korea

- Analysis

- Isolated photon R_{AA} : Yeonju Go (contact)

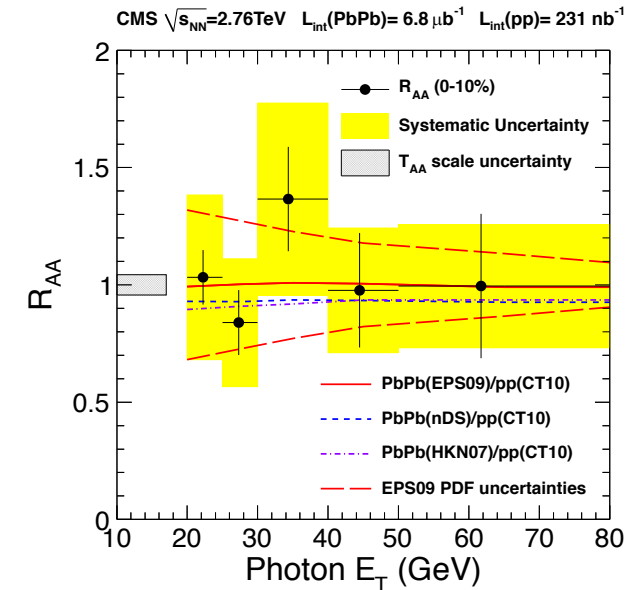
- Baseline for jet quenching studies
 - Last measured w/ very low stats in 2010

- Upsilon v_2

- PbPb: Jaebeom Park (KU) & Yongsun Kim (Sejong)
 - pPb @ 8 TeV: Kisoo Lee (KU)

- Responsibilities

- Global observables contact: Yeonju Go (KU)
 - Muon reconstruction contact: Geonhee Oh (Chonnam)



Prospects for increased/renewed collaboration

- Dileptons: Plans for Run 3?
 - Precise flow measurements of onia states
 - Further onia-jet measurements, e.g., Upsilon
 - Exotic states, should be very sensitive to recombination effects
- Photon and photon+jet measurements --> precision energy-loss
- Centrality projects, especially for peripheral events / small systems & to deal w/ radiation damage to forward calorimeters
- Improvements for muon triggering & reco for Run 3
- + Any other ideas that may emerge at our Saturday meeting

Mini-Workshop on CMS Heavy-Ion Physics

Date: May 11, 2019

Venue: Seogwipo KAL hotel, Jeju Island, South Korea

Program

Session I Status of CMS HI analyses

(Chair: Byungsik Hong)

09:00-09:20 Hyunchul Kim (Chonnam National Univ.) Status report about Drell-Yan analysis in 8.16 TeV pPb collision

09:20-09:40 Kisoo Lee (Korea Univ.) Status of $\Upsilon - h$ correlation analysis in pPb at 8 TeV

09:40-10:00 Jaebeom Park (Korea Univ.) Status and feasibility study of bottomonium analysis with 2018 PbPb data

10:00-10:20 Batoul Diab (LLR) Status and plans for onia-jet analysis

10:20-10:40 Inna Kucher (LLR) Plans for heavy quark jet measurements

10:40-11:00 Yeonju Go (Korea Univ.) Nuclear modification factor of isolated photons in PbPb and pp at 5 TeV and centrality determination in heavy ion collisions

Session II Discussion

(Convener: Matthew Ngyuen)

11:00-12:00 Future plan for Collaboration between Korean CMS group and LLR

12:00 Adjourn

Directly after this workshop, we will have a meeting of the CMS-HI groups to discuss our current status and plans.

We hope to use this occasion to reengage direct collaboration between our groups

Thanks for your attention!

Money chart

Requested LIA specific funding from France				
Description	Euro/unit	Nb of units	Total (euros)	Requested to: *
Visit to Korea	150/day	28	4200	IN2P3
Travels to Korea	1250	4	5000	IN2P3
Total			9200	IN2P3
Requested funding from Korea				
Description	Won/Unit	Nb of units	Total (Won)	Requested to: **
Visit to France (Flight + Local Expenses)	4,000,000/visit/man	3 visits*men	12,000,000	NRF
Total				