Heavy-ions with CMS

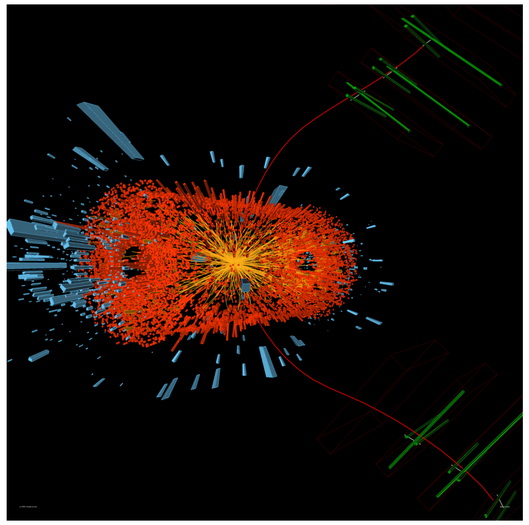
Matthew Nguyen
FKPPN Workshop
14 May 2025

Overview

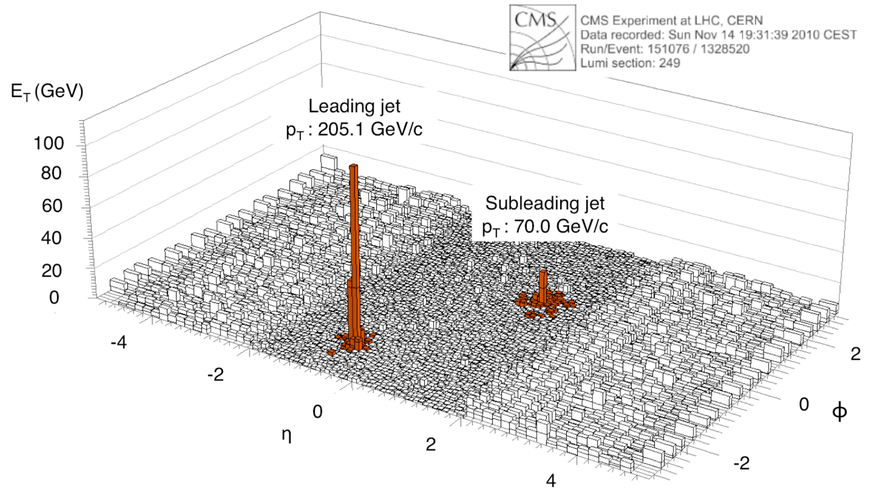
- The CMS heavy ion program
- History of the LLR-Korea collaboration
- A few recent results from the French & Korean groups
- Our 2024 meeting & prospects for ongoing collaboration
- The 2025 request for KFPPN support

Heavy ions with CMS

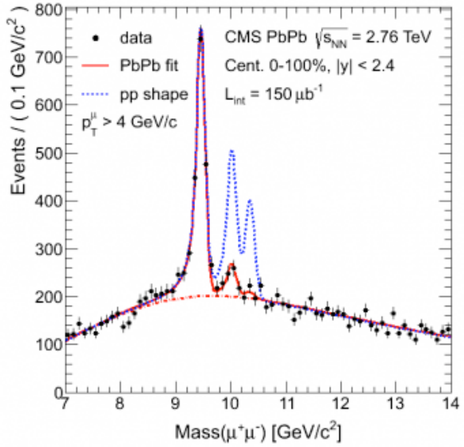
Although not designed for heavy ions, CMS excels for certain measurements of quark-gluon plasma properties, e.g., quarkonia melting & jet quenching



Two pillars of the CMS heavy-ion program at LLR



Jet quenching



Quarkonium dissociation

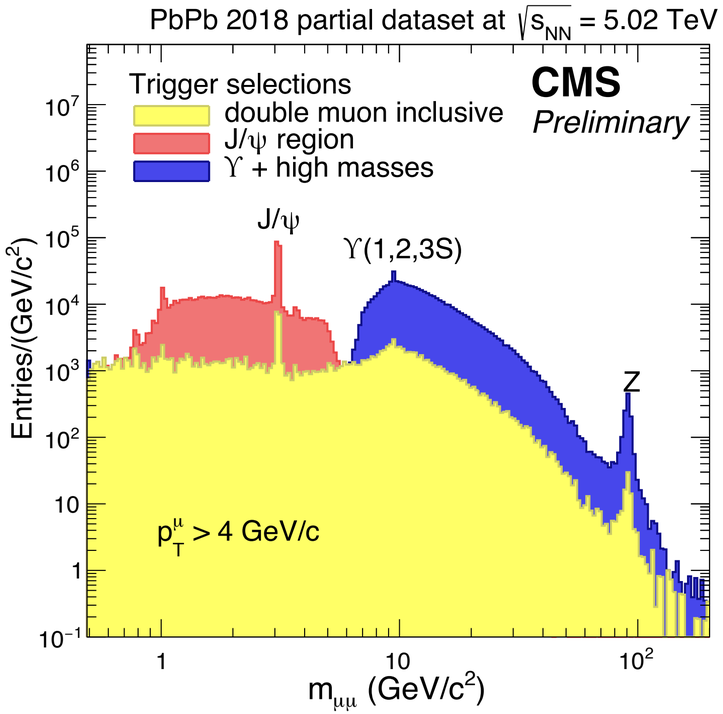
~100 physicists participate in CMS-HI program
LLR & Korea among largest non-US contributors

https://cms.cern/news/jet-quenching-observed-cms-heavy-ion-collisions

https://cms.cern/news/cms-observes-hints-melting-upsilon-particles-lead-nuclei-collisions

Korea & LLR: A long history

LLR and Korea University were part of the CMS heavy-ion program since the start of the LHC



With UC Davis, LLR & Korea most active in the dilepton group

LLR & Korea groups at CERN for heavy ion data taking

Groups collaborated on measurements of Z bosons, Υ, non-prompt J/ψ, etc.

A first round of FKPPL collaboration (2015-2017) was managed by R. Granier (LLR) and B. Kim (Korea)
A highlight was the Marie Curie fellowship at LLR of former Korea PhD and FKPPL awardee Mihee Jo

Renewed collaboration

In 2019 I initiated a new round of LLR-Korea FKPPL collaboration

We were joined by new Korean CMS heavy ion groups founded by Korean University alumnae (Sejong, Chonnam)

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

We held a 1 day workshop immediately following the FKPPL meeting in Jeju

In addition to dilepton physics and muon related work, we also discussed other overlapping tasks such as centrality determination and plans for (then) future measurements such as quarkonia-in-jet

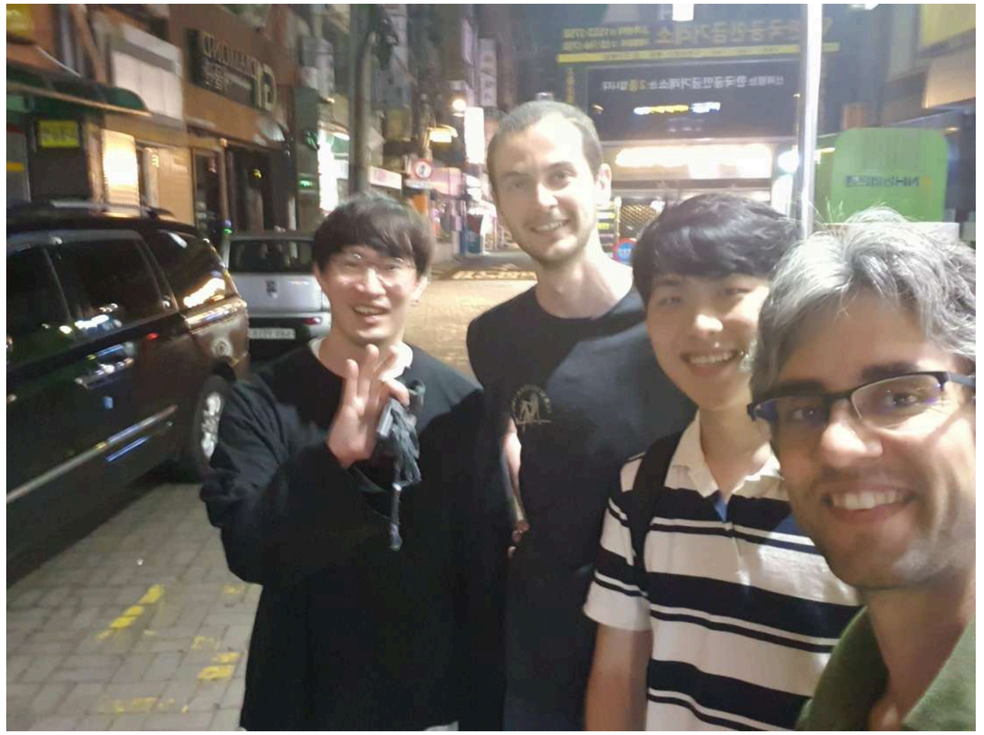
LLR postdoc Inna Kucher and PhD Batoul Diab in Jeju

Then covid struck…

Travel exchanges resume

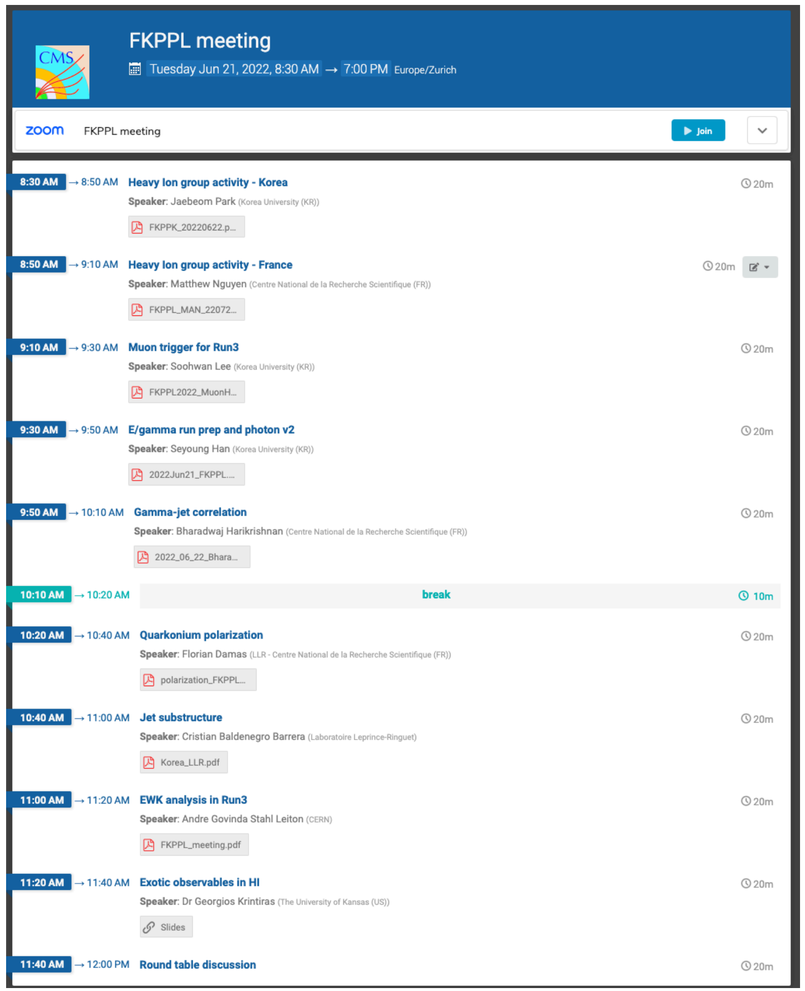
2022 FKPPL awardee Jaebeom Park (Korea) w/ Florian Damas (LLR) at Strangeness in Quark Matter 2022 in Busan

NB: Jaebeom applied for Marie Curie Fellowship at LLR, but proposal was not funded



+ joined by past and future dilepton conveners Soohwan Lee (Korea) & André Stahl (ex-LLR)

2022 LLR+Korea meeting



FKPPL meeting

Tuesday Jun 21, 2022, 8:30 AM → 7:00 PM Europe/Zurich

zoom FKPPL meeting — Join

8:30 AM → 8:50 AM	**Heavy Ion group activity - Korea**	**Speaker**: Jaebeom Park (Korea University (KR))	FKPPK_20220622.p...	20m
8:50 AM → 9:10 AM	**Heavy Ion group activity - France**	**Speaker**: Matthew Nguyen (Centre National de la Recherche Scientifique (FR))	FKPPL_MAN_22072...	20m
9:10 AM → 9:30 AM	**Muon trigger for Run3**	**Speaker**: Soohwan Lee (Korea University (KR))	FKPPL2022_MuonH...	20m
9:30 AM → 9:50 AM	**E/gamma run prep and photon v2**	**Speaker**: Seyoung Han (Korea University (KR))	2022Jun21_FKPPL....	20m
9:50 AM → 10:10 AM	**Gamma-jet correlation**	**Speaker**: Bharadwaj Harikrishnan (Centre National de la Recherche Scientifique (FR))	2022_06_22_Bhara...	20m
10:10 AM → 10:20 AM	**break**			10m
10:20 AM → 10:40 AM	**Quarkonium polarization**	**Speaker**: Florian Damas (LLR - Centre National de la Recherche Scientifique (FR))	polarization_FKPPL...	20m
10:40 AM → 11:00 AM	**Jet substructure**	**Speaker**: Cristian Baldenegro Barrera (Laboratoire Leprince-Ringuet)	Korea_LLR.pdf	20m
11:00 AM → 11:20 AM	**EWK analysis in Run3**	**Speaker**: Andre Govinda Stahl Leiton (CERN)	FKPPL_meeting.pdf	20m
11:20 AM → 11:40 AM	**Exotic observables in HI**	**Speaker**: Dr Georgios Krintiras (The University of Kansas (US))	Slides	20m
11:40 AM → 12:00 PM	**Round table discussion**			20m

We had a mixed remote / in-person meeting with those who sent to SQM in Busan

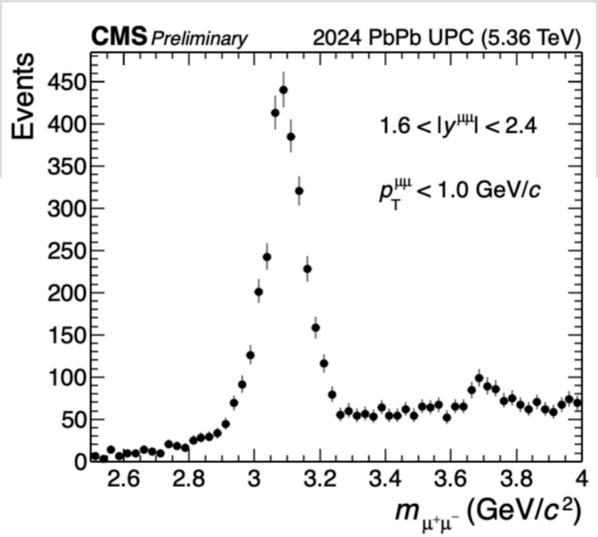
We discussed common tasks:

- muon triggers
- photon/electron calibrations

We also discussed our ongoing analyses
Most are now published:

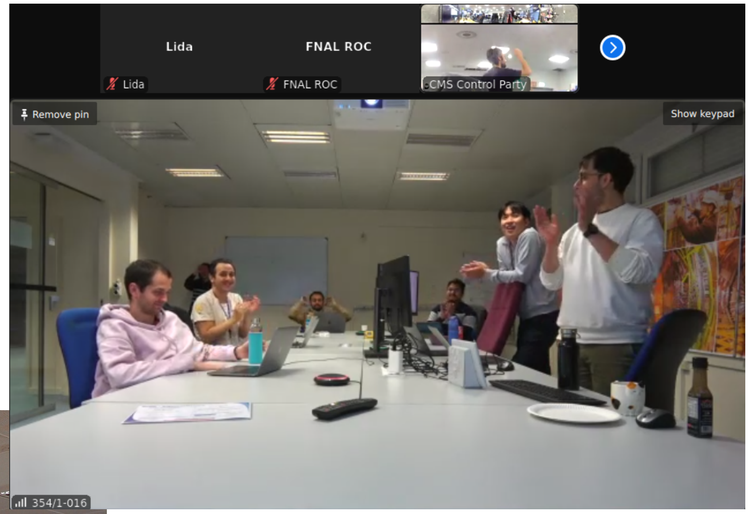
- jet substructure: Lund Jet Plane [JHEP 05 (2024) 116]
- photon+jet: [PLB 861(2025) 139088]
- quarkonium polarization: still in progress

Heavy ions in LHC Run 3



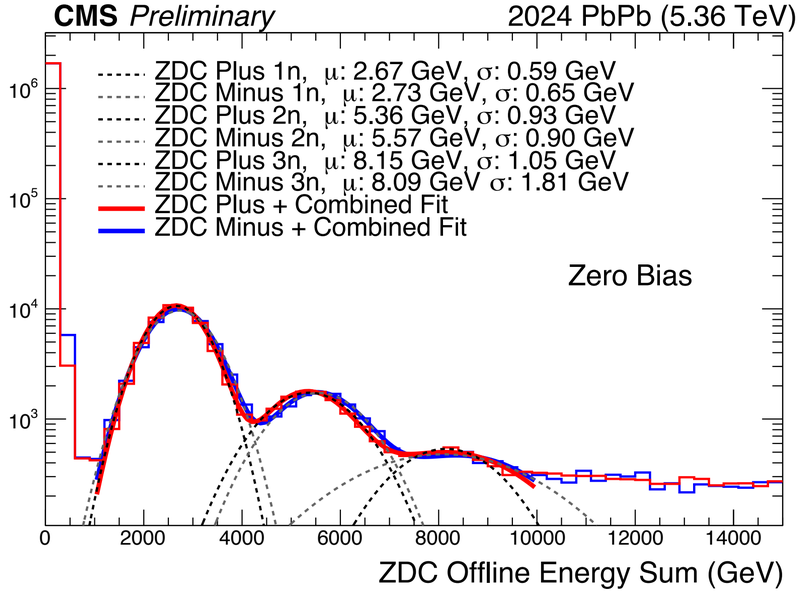
In 2023 no FKPPL support requested, as both groups were present at CERN for the for the first heavy-ion data taking in 5 years
LLR & Korea have important responsibilities in data taking, e.g., run coordination and trigger

First PbPb collisions in 2024



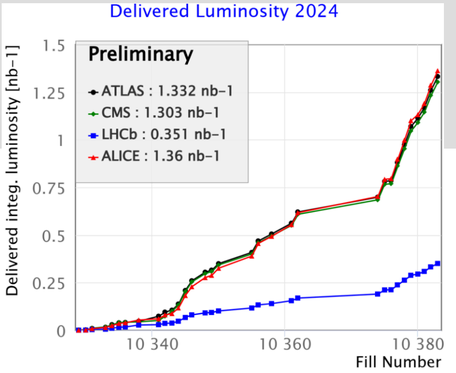
CMS heavy ion team at CERN for data taking

Zero Degree calorimeters are an essential component of the CMS heavy-ion program



S. Obratsov (LLR) played a key role in ZDC commissioning

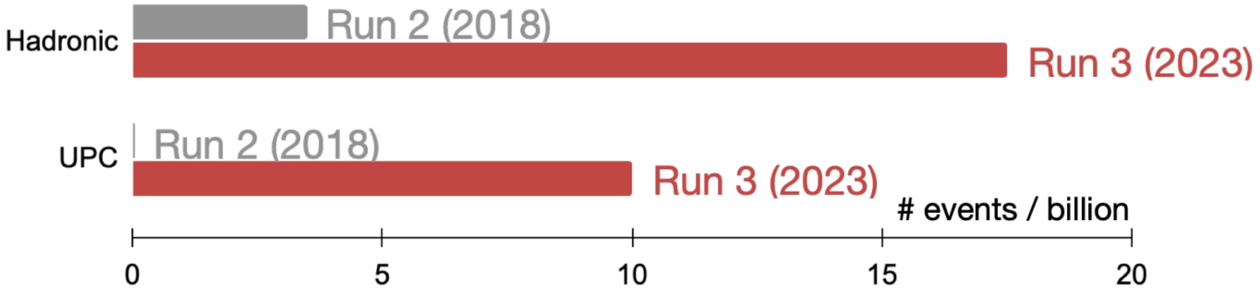
Run 3 data taking strategy



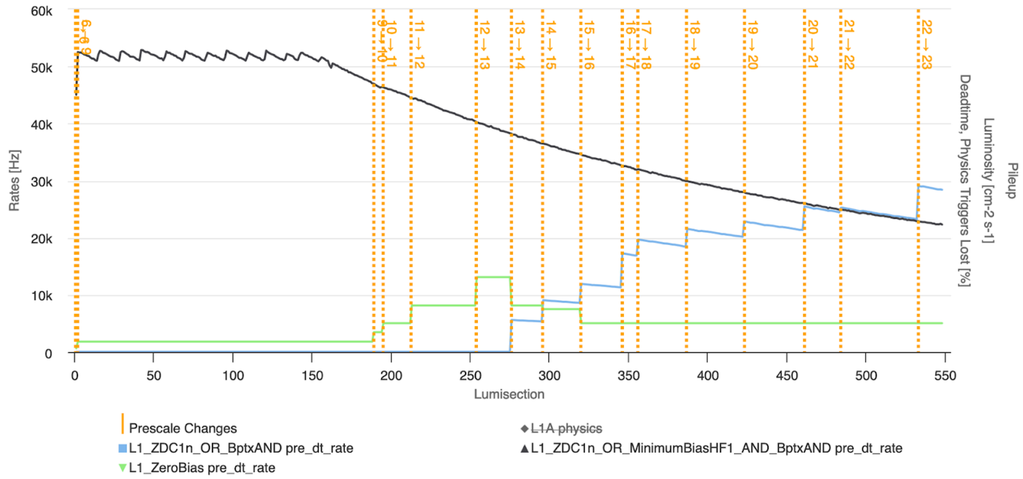
- Up to Run 2 we focused on “hard probes” of the QGP using rare object triggers
- During LS2 we have dramatically increased our data taking capabilities

  →now recording 30 GB/sec, record for CMS

Data samples recorded in 2023



L1 trigger rates in a typical fill in 2024



- In Run 3 we are now recording ALL hadronic interactions with minimum bias triggers
- In addition, we are recording large samples of EM interactions (most photon-nucleus)
  - Opens up new possibilities for heavy flavor (MB) or ultra-peripheral collisions

Recent responsibilities in CMS

Operations

- Heavy ion run coordination: Matt Nguyen (since 2019)
- High level trigger: Soohwan Lee, Florian Damas
- Level-1 trigger: Cristian Baldenegro

Physics

- Heavy-ion Physics convener: Yongsun Kim (2021-22)
- Dilepton sub-group convener:
  - Florian Damas (2024-25)
  - Soohwhan Lee (2023-24)

2024 Korea-LLR CMS meeting

Korea LLR CMS meeting

Sep 30, 2024, 1:00 PM → Oct 1, 2024, 1:00 PM Asia/Seoul

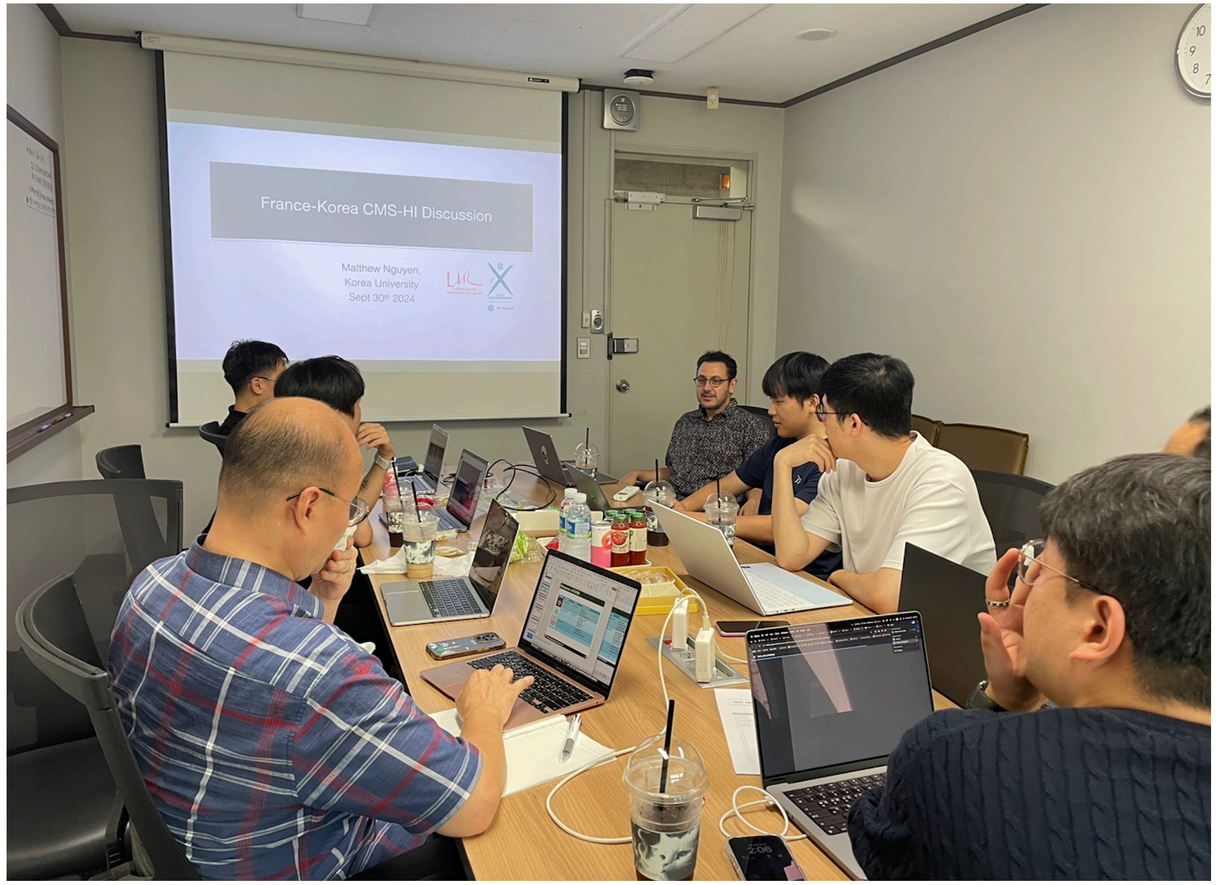
205 (Asan Science Hall)

Description ZOOM : https://cern.zoom.us/j/68842339194?pwd=ACUM0iVmkhM1hQNUJp8gzVJ21xRvK5.1

Monday, September 30

1:00 PM → 2:00 PM	**Lunch**	1h
2:00 PM → 2:05 PM	**Opening** **Speaker**: Byungsik Hong	5m
2:05 PM → 2:15 PM	**Double D meson anaylsis status** **Speaker**: Soohwan Lee (Korea University) FKPPL_soohwan_3...	10m
2:15 PM → 2:25 PM	**Chi_c in pPb analysis status** **Speaker**: Jeong Ho Kim (Sejong University) JeonghoKim_HIN-2...	10m
2:25 PM → 2:35 PM	**France-Korea CMS-HI Discussion** **Speaker**: Prof. Matthew Nguyen (Centre National de la Recherche Scientifique (FR)) FKPPL_MAN_24093...	10m
2:35 PM → 2:50 PM	**Coffee break**	15m
2:50 PM → 3:00 PM	**CMS HI activity in CNU** **Speaker**: Piljun Gwak (Chonnam Univesity (Kr))	10m
	240930_ FKPPL_Pilj...	
3:00 PM → 3:10 PM	**L1 run preparation and heavy flavor study plan with run3 data** **Speaker**: Mr Junseok Lee (Korea University)	10m
	KUMetting_Junseok...	
3:10 PM → 3:20 PM	**Jet charge measurement plans for PbPb run3** **Speaker**: Dr Hyunchul Kim (Chonnam University (Kr))	10m
	20240930_Hyunchu...	
3:20 PM → 3:30 PM	**Status of Charmonia nuclear modification factor analysis** **Speaker**: Gyeonghwan Park (Chonnam University (Kr))	10m
	Modification_Factor...	
3:30 PM → 4:30 PM	**Open discussion**	1h
4:30 PM → 4:40 PM	**Coffee break**	10m
4:40 PM → 6:00 PM	**Open discussion 2**	1h 20m
6:00 PM → 7:30 PM	**Dinner**	1h 30m

Last year we met in Seoul after the Hard Probes conference in Japan



Performance of muon reconstruction in CMS

Efficiency derived from data using “tag & probe” technique

Performance of CMS muon reconstruction from proton-proton to heavy ion collisions

The CMS collaboration

E-mail: cms-publication-committee-chair@cern.ch

Abstract: The performance of muon tracking, identification, triggering, momentum resolution, and momentum scale has been studied with the CMS detector at the LHC using data collected at $\sqrt{s_{NN}}$ = 5.02 TeV in proton-proton (pp) and lead-lead (PbPb) collisions in 2017 and 2018, respectively, and at $\sqrt{s_{NN}}$ = 8.16 TeV in proton-lead (pPb) collisions in 2016. Muon efficiencies, momentum resolutions, and momentum scales are compared by focusing on how the muon reconstruction performance varies from relatively small occupancy pp collisions to the larger occupancies of pPb collisions and, finally, to the highest track multiplicity PbPb collisions. We find the efficiencies of muon tracking, identification, and triggering to be above 90% throughout most of the track multiplicity range. The momentum resolution and scale are unaffected by the detector occupancy. The excellent muon reconstruction of the CMS detector enables precision studies across all available collision systems.

Keywords: Instrumentation and methods for heavy-ion reactions and fission studies; Large detector systems for particle and astroparticle physics; Muon spectrometers

ArXiv ePrint: 2404.17377

2024 JINST 19 P09012

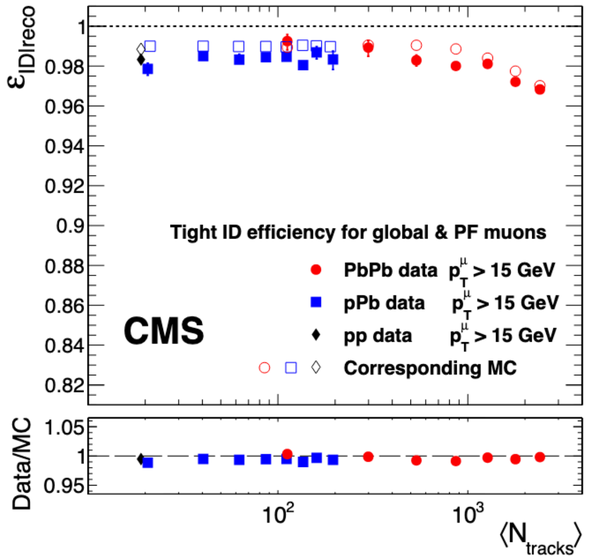


Figure 6. Tight ID efficiency for global and PF muons as a function of the number of tracks in pp, pPb, and PbPb collisions. Open symbols are the MC results corresponding to each data set. Lower panel shows the ratio between data and MC simulation. Only statistical uncertainties are shown.

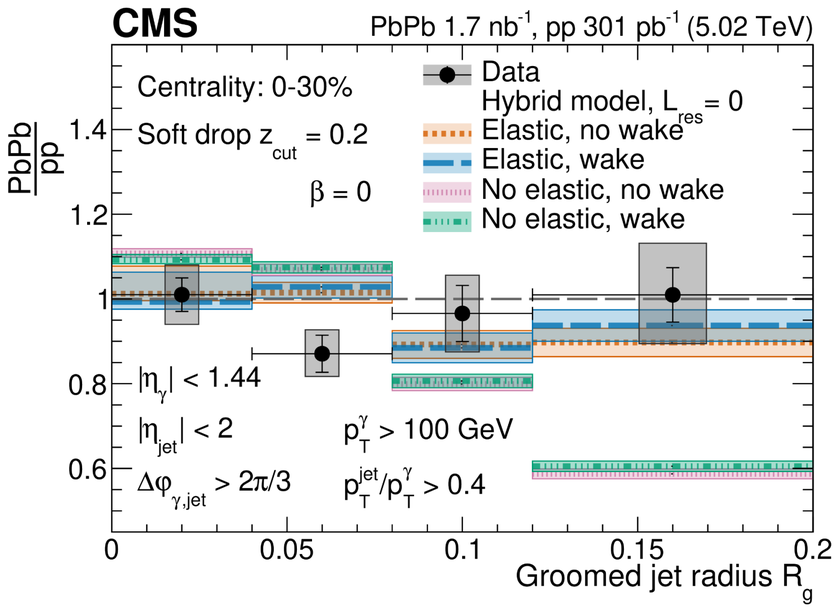
Code	Name	Status	PAS	PAPER	ARC	IRC
MUO-21-001 » | show | CDS | JINST	Performance of CMS muon reconstruction in heavy-ion collisions	PUB	P		Matthew Nguyen (POLYTECHNIQUE)	IRC

Effort led by UC Davis colleagues, with substantial contributions from Emilien Chapon (ex-LLR) and myself, as chair of the “Analysis Review Committee”

JINST 19 (2024) P09012

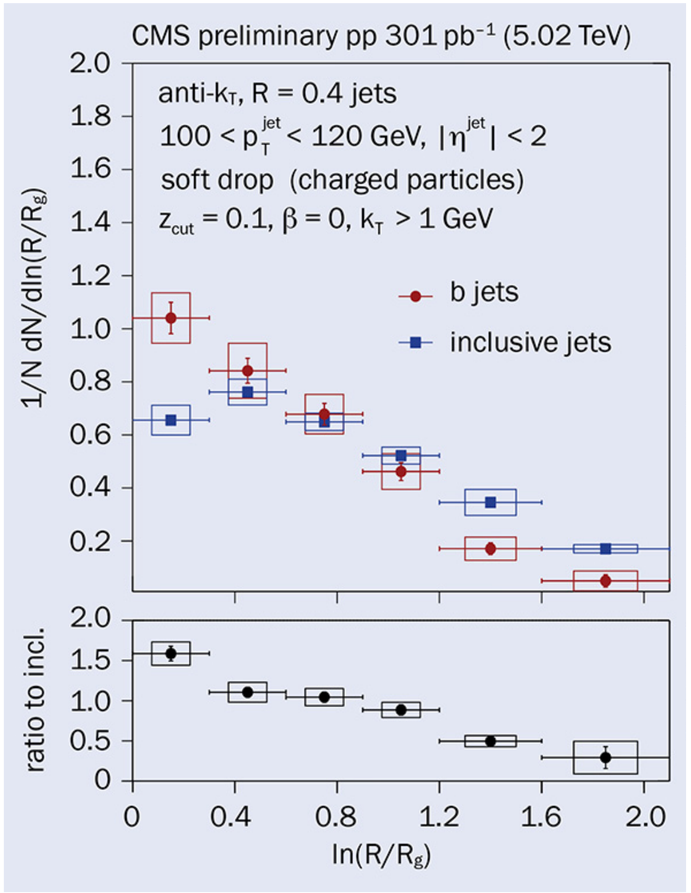
Jet substructure results

Substructure in gamma+jet effects sensitive to selection bias effects



Led by LLR PhD B. Harikrishnan;

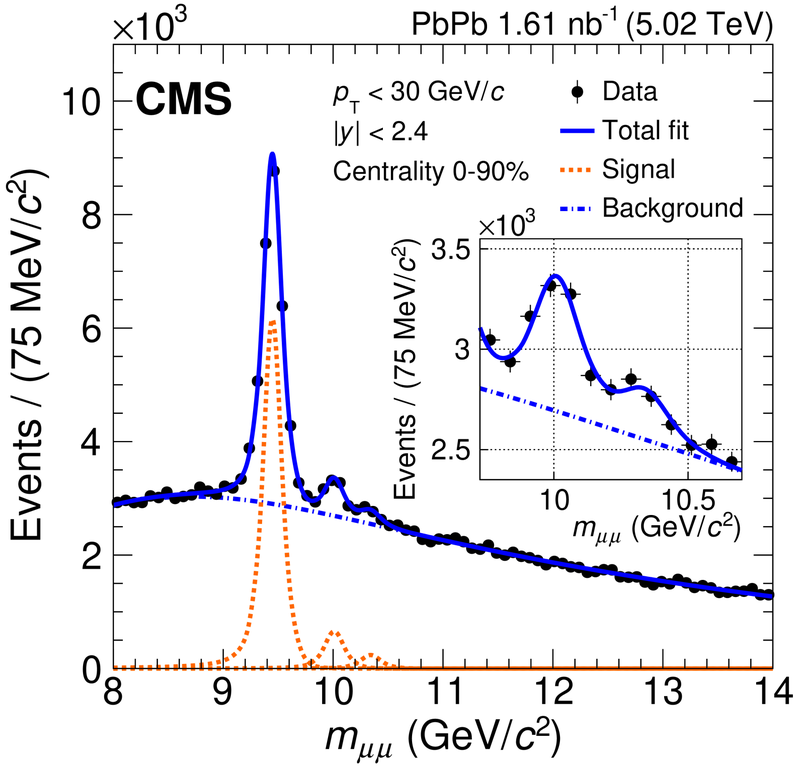
b-jet substructure → sensitive to “dead-cone”effect

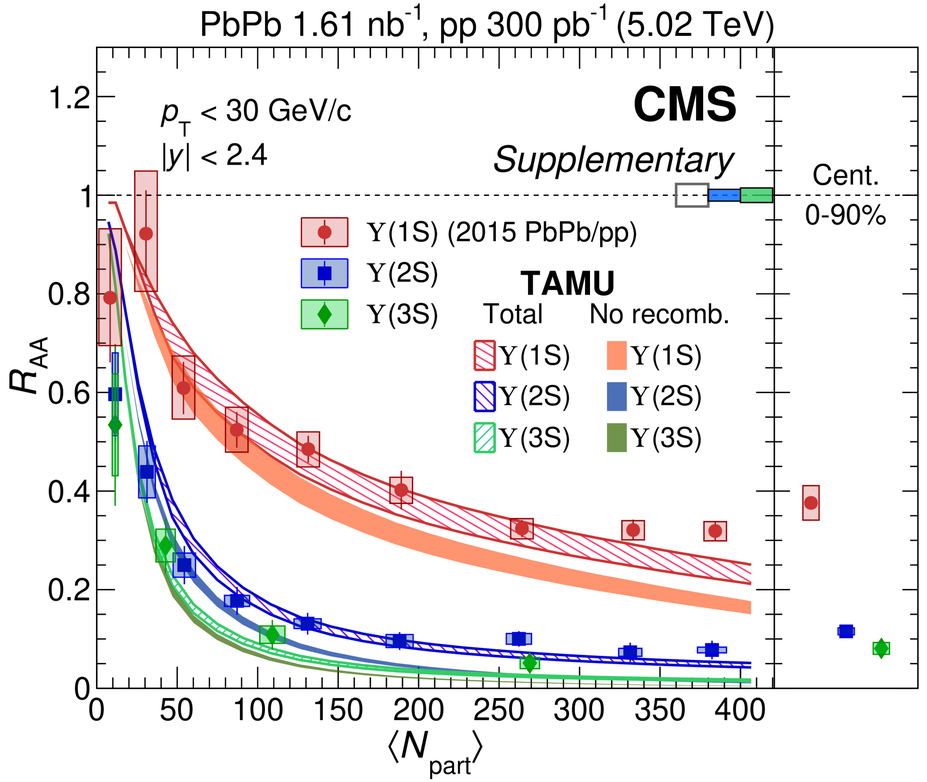


https://cerncourier.com/a/cms-peers-inside-heavy-quark-jets/
Led by LLR PhD Lida Kalipoliti; JHEP submission imminent

The long-awaited Y(3S)

Bottomonium is our best handle on the temperature of the quark-gluon plasma

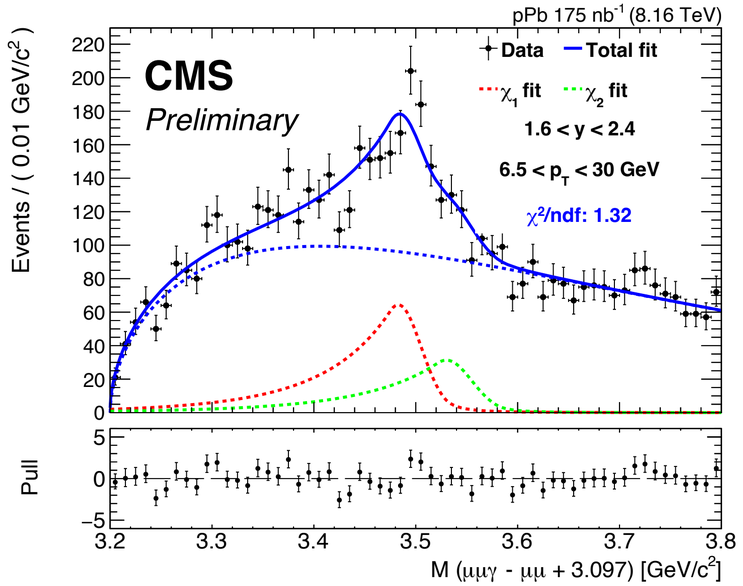




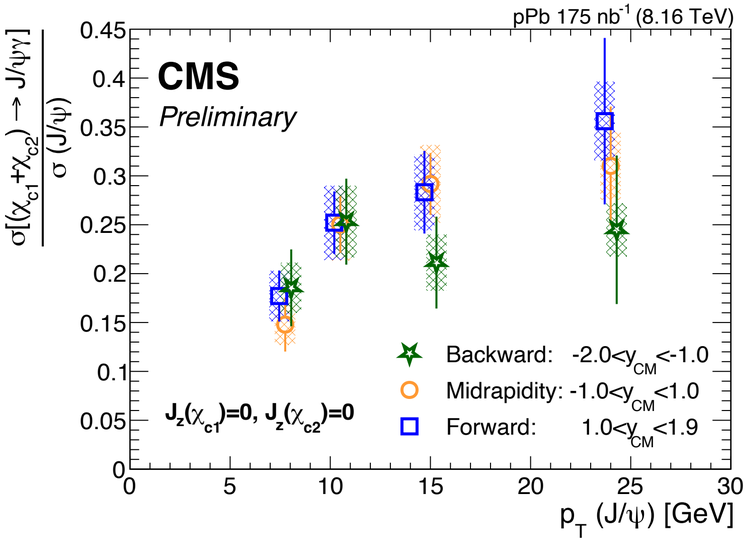
Previous results measured the Y 1S and 2S states, but could only put an upper limit on the 3S

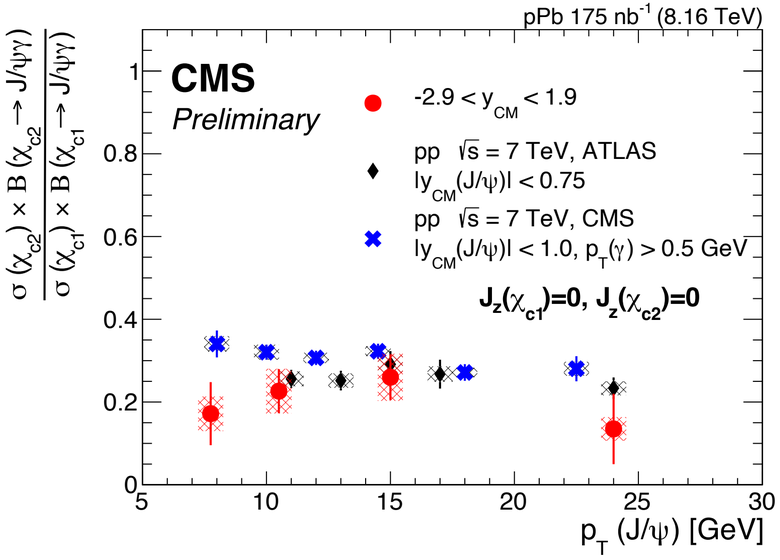
Korea played the leading role: [Phys. Rev. Lett 133 (2024) 022302]

p-wave quarkonia: χ_c



No strong rapidity dependence going from proton to lead side
Ratio of χ_c states not strongly modified in pPb compared to pp





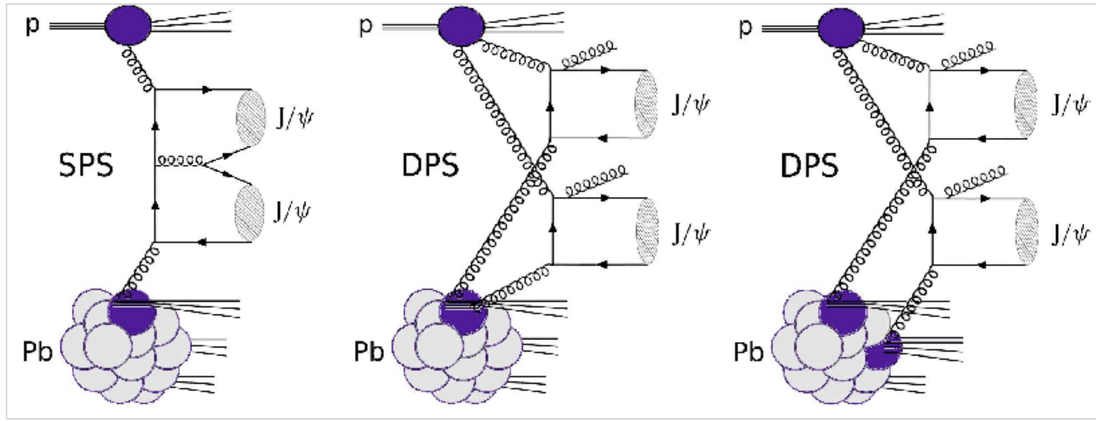
χ_c detected in $J/\psi + \gamma$ channel
Low E γ detected via e^+e^- conversions
Measure the individual states $\chi_{c1,2}$

No strong modification to χ_c production

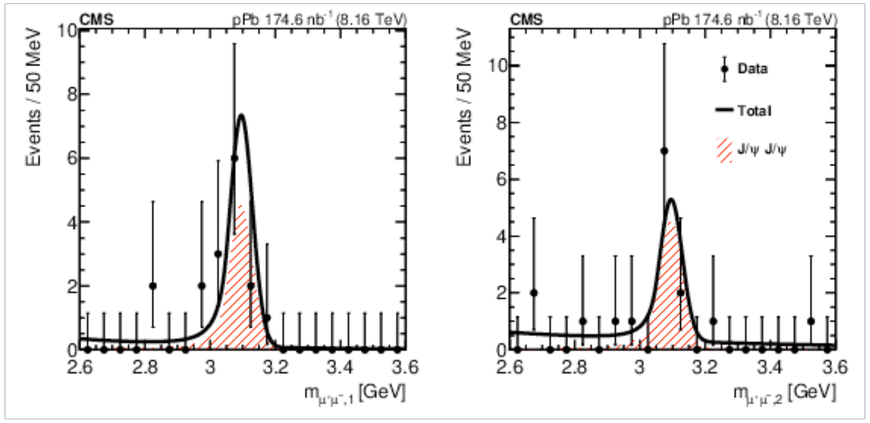
Sejong group played a leading role: [CMS-PAS-HIN-22-003]

Double parton scattering in proton-lead collisions

DPS possible from one or two different nucleons in pPb

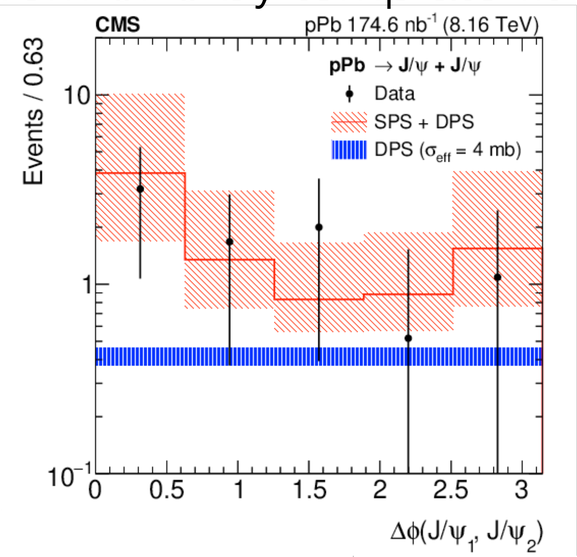


Is DPS modified in pPb collisions compared to pp?

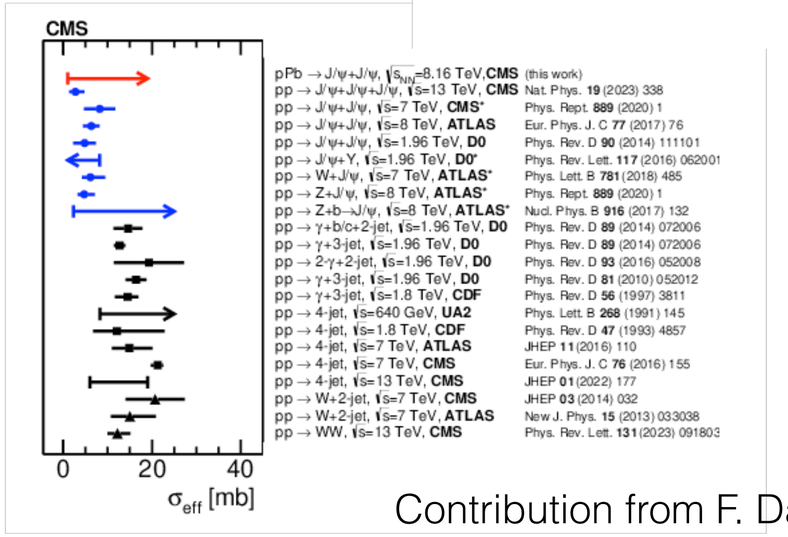


Observation of 5σ of J/Psi pair production

DPS separated from SPS by template fit



Upper limit placed on DPS x-section



Contribution from F. Damas (LLR)
CMS PRD 110 (2024) 092002

Proposal for 2025

CMS Week will take place in Seoul in Dec. 2025

CMS Calendar 2025

	WK	Monday	M	T	W	T	F	
ɔd (23 Dec 24 - 5 Jan 25)	27	30.Jun	SG-RRB					School hols (30 Jun - 15-Aug CH) - Independence day(4)
	28	7.Jul						**HEP-EPS (Marseille)** School hols (5 Jul - 1 Sep FR)
	29	14.Jul						Bastille Day(14)
artin L King (20)	30	21.Jul	Tracker Week (21-25)					
Ge) (29-31), TOP PAG workshop(30-31)	31	28.Jul	MB	FB				
	32	4.Aug						
	33	11.Aug						
Reviews (PAGs) (19-21)	34	18.Aug						
hols (24 Feb - 10 Mar FR) (24-28 Feb CH)	35	25.Aug						**Lepton-Photon (Madison)**
ls (24 Feb - 10 Mar FR)	36	1.Sep			LHCC			Labor day(1)
	37	8.Sep	MB	FB		Jeûne G		CERN Closed (11)
	38	15.Sep						
ncil wk SPC(24-25),FC(26),RC(27),CC(28)	39	22.Sep						**Council wk** SPC(22-23),FC(24),RC(25),CC(26)
riond/QCD(30-6)	40	29.Sep	CMS Week					
	41	6.Oct						
School hols (18 Apr - 2 May CH)	42	13.Oct	MB	FB				
ls (21 Apr - 2 May FR) (18 Apr - 2 May CH)	43	20.Oct		MB/FB				School hols (18 Oct - 3 Nov FR) (20-24 CH)
- 2 May FR) (18 Apr - 2 May CH)	44	27.Oct	RRB					School hols (18 Oct - 3 Nov FR)
HCP (Taipei) (5-9)	45	3.Nov	Tracker Week (3-7)					
il wk SPC(12),FC(13)	46	10.Nov						
	47	17.Nov			LHCC			
ɟ (29), Memorial Day (26)	48	[illegible]						[illegible]
	49	1.Dec	CMS Week (Korea)					
ERN Closed (9)	50	[illegible]						
CS(19),OCS(20) - **ATLAS week** - Juneteenth(16)	51	15.Dec						
ategy symposium (Venice)	52	22.Dec						CERN Closed (22 Dec - 4 Jan 2026)
	1	29.Dec						

Acronym:	Full title: CMS Heavy ions	Main French and Korean institutes: LLR & Sejong University

Domain:

List of participants

French Group			Korean Group		
Name	Position	Lab./Institute	Name	Title	Institute
Leader: Matthew Nguyen	CR	LLR	Leader: Yongsun Kim	Prof	Sejong
Afanan Shatat	postdoc	LLR	~~Florian Damas?~~	~~postdoc~~	~~Sejong~~
			Bayu Putra	PhD	Korea U.
			Seonggeun Hwang	PhD	Sejong U.
			Jeongho Kim	PhD	Sejong U.
			Byungsik Hong	Prof	Korea U.

IRN specific funding requested from France

Description	Amount (euros)	Requested to: *
Visit of Matthew Nguyen to Seoul	1000	IN2P3
Visit of Afnan Shatat to Seoul	1000	IN2P3
Total		

Funding requested from Korea

Description	Amount (kWon)	Requested to: **
Banquet in Seoul (8 people)	500	
Seminar (room rental, coffee, etc)	500	
Total		

LLR PhD Lida Kalipoliti w/ start post-doc in Sejong in October.

- We request support for two members of LLR to meet with our Korean colleagues
- We are collaborating on a new quarkonia-in-jet measurement
- Will also discuss status & prospects for UPC jet measurements, the focus of Lida's postdoc in Sejong

Outlook

- We are continuing the long-standing collaboration between LLR & Korean institutes on CMS heavy-ion program
- We collaborate on various aspects of the “dilepton” program, both in terms of physics analysis, but also supporting tasks such as reconstruction & trigger
- We continue to exchange personnel as well as information
- We seek support for in-person meeting to reinforce our links