QGP Tomography with jets

Tatsuya Chujo
for HAD_04

2019 Joint workshop of FKPPL and TYL/FJPPL
Jeju island, South Korea
8-10 May, 2019

筑波大学
University of Tsukuba

Introduction of HAD_4

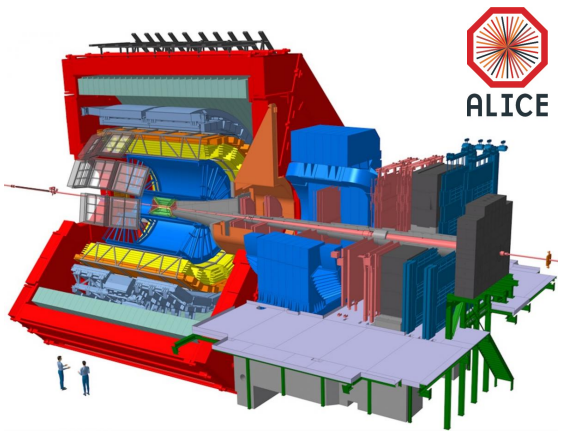
- Production of highest *T* and largest Quark Gluon Plasma (QGP) at LHC, study at ALICE
- France-Japan collaboration: built the EMCal/ DCal system for ALICE, developed L1 jet/γ trigger for Run-2
- **Goals**

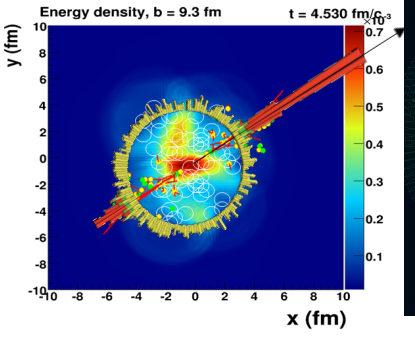
1) QGP tomography with jets

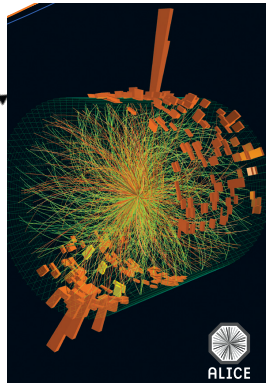
- determination of medium properties by **hard probes**; jets, photons, heavy flavors with Run-2 data including Calo trigger

2) Detector R&D for ALICE upgrades

- FoCal (Forward Calorimeter)
- High speed common readout unit CRU

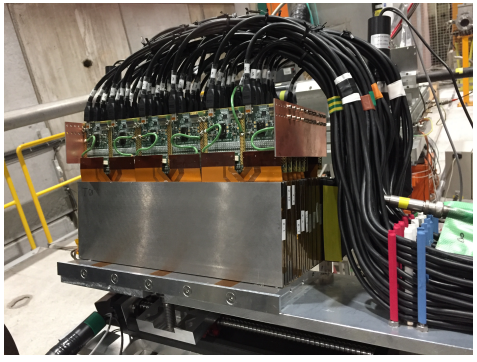






https://cds.cern.ch/record/2155668

CRU

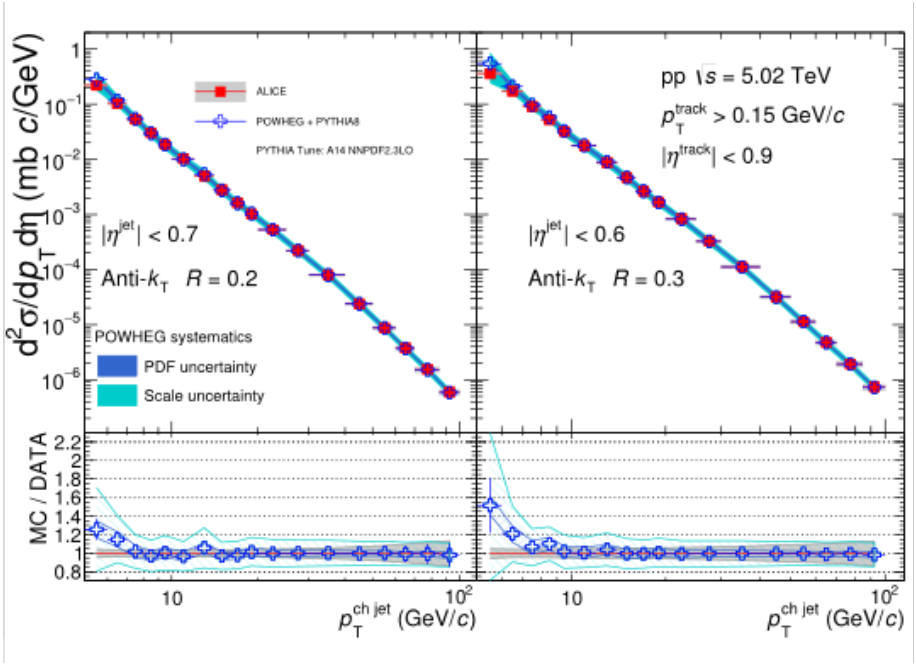


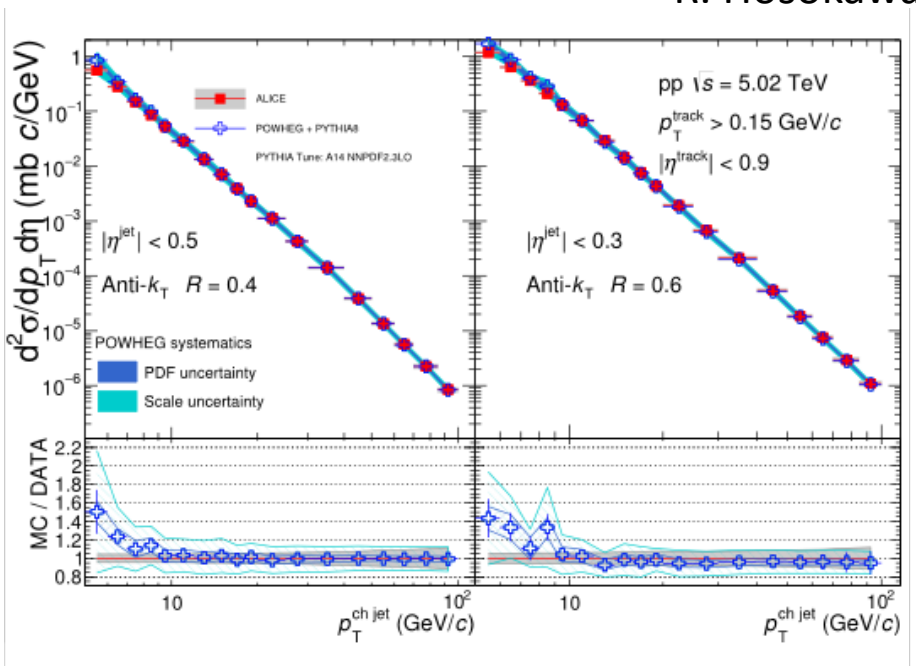
mini-FoCal prototype (2018)

(1) QGP tomography with jets

Inclusive charged jet production

R. Hosokawa

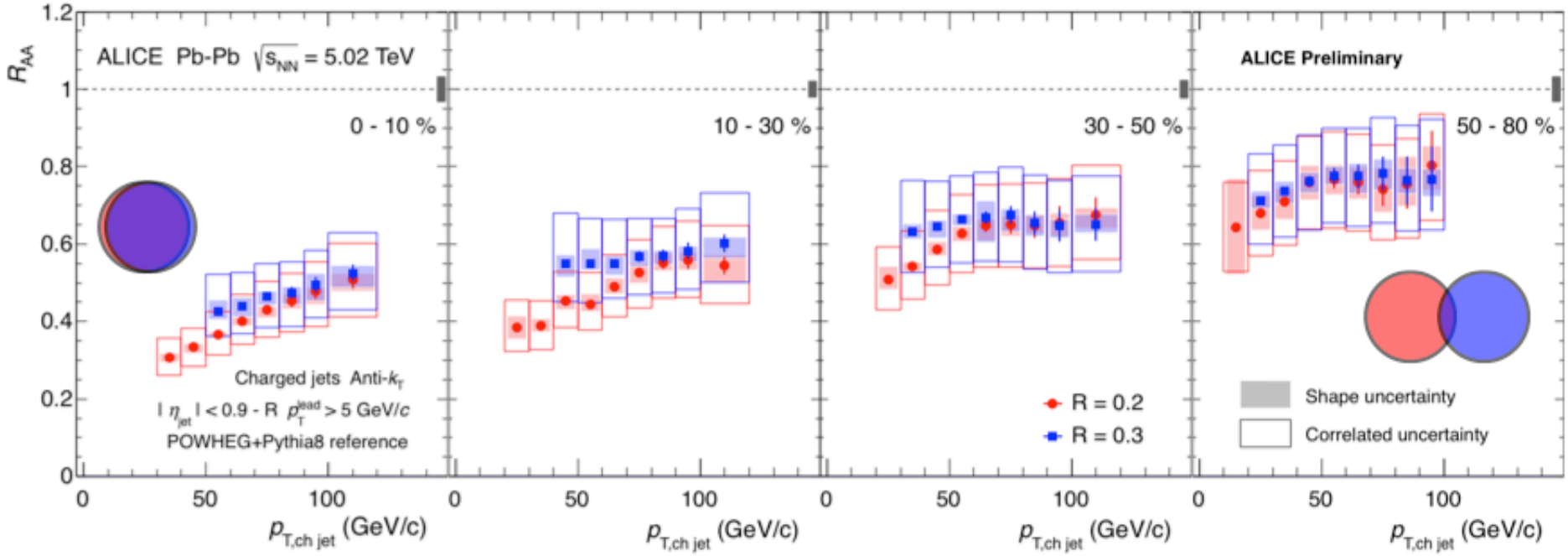




- Submitted to arXiv https://arxiv.org/abs/1905.02536
- Comparison to a NLO pQCD-based model prediction (POWHEG+Pythia8)
- Good agreement within large theoretical uncertainty
  - Higher-order (NNLO) calculation will improve scale uncertainties in pQCD calculation
  - Further understanding of non-perturbative effects (e.g. Underlying events) will also be crucial for low p_T region

Charged jet R_{AA} at 5.02 TeV

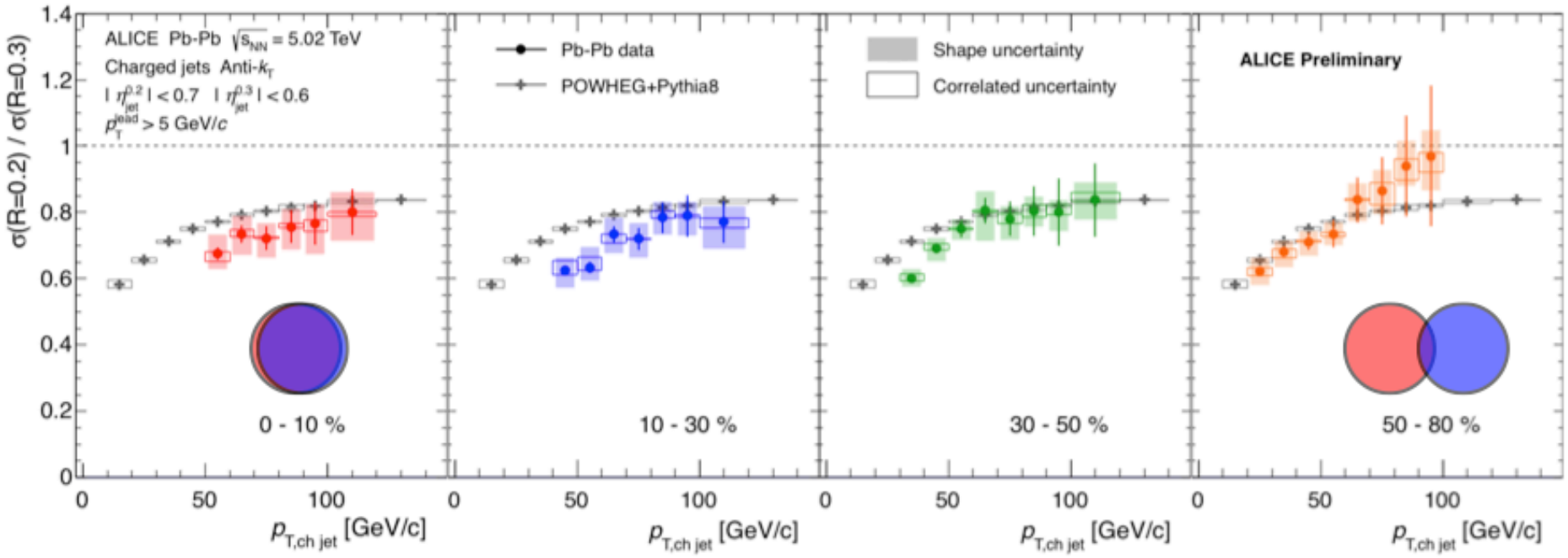
H. Yokoyama



- Charged jet R_{AA} in four centrality classes
- Larger R_{AA} (smaller suppression) in peripheral collisions due to smaller system size
- Jet R_{AA} for different resolution parameters are consistent within systematic errors

Jet structure in Pb-Pb collisions at 5.02 TeV

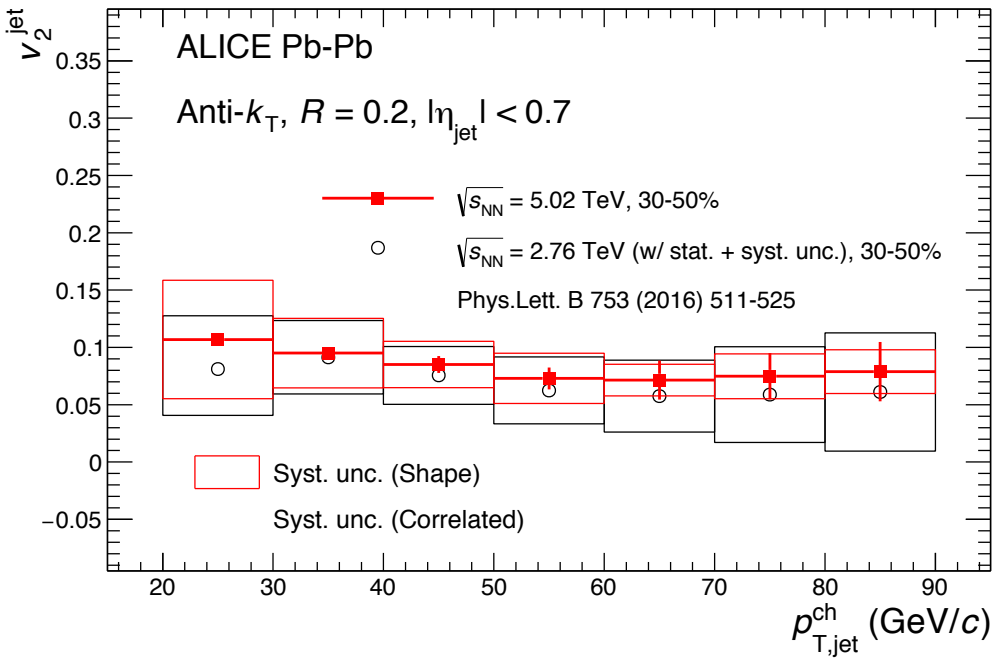
H. Yokoyama

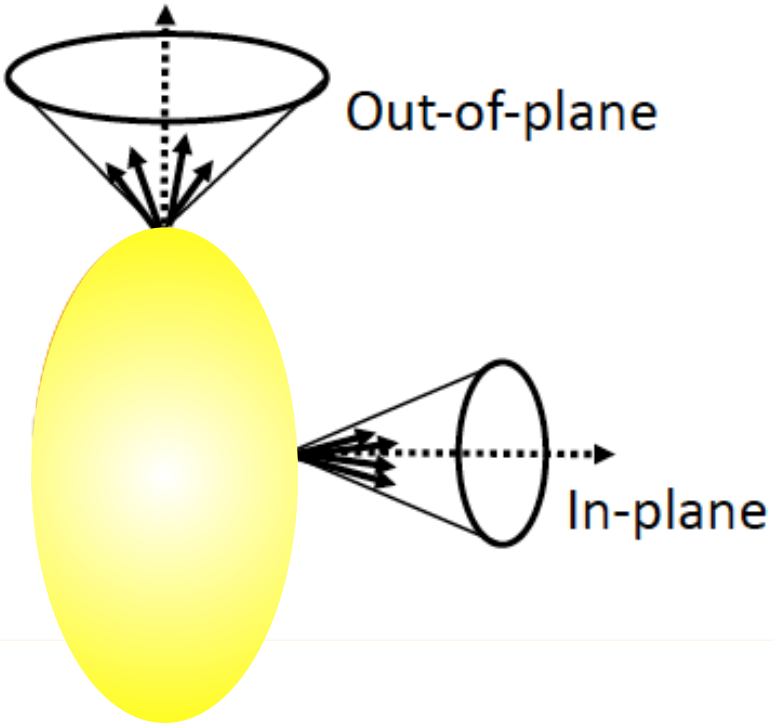


- Jet cross section ratios between different resolutions parameters as a function of centrality
- Consistent with POWHEG+PYTHIA8 and JEWEL predictions within uncertainties
  - The jet core structure is unmodified in Pb-Pb as compared to pp
  - More precision is needed

Charged jet v_2 at 5.02 TeV

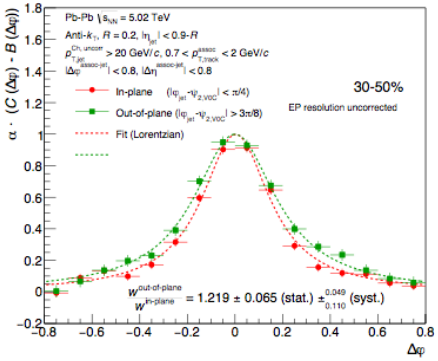
R. Hosokawa (PhD thesis)

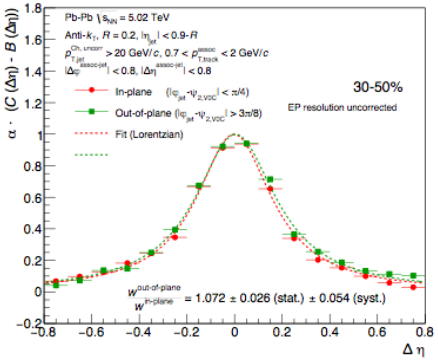


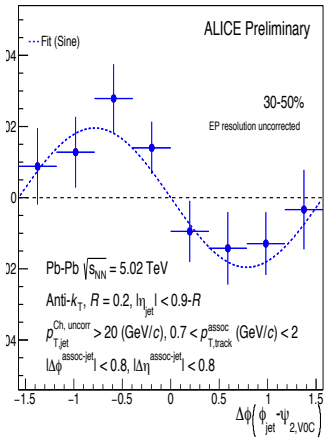


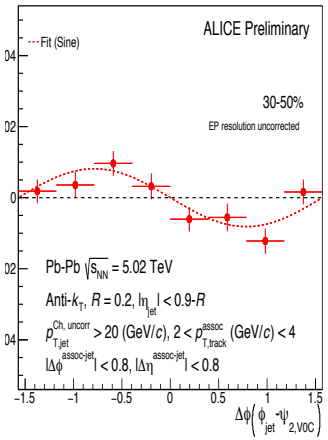
- Positive jet v_2 was observed
  - Jet yield in-plane is greater than that of out-of-plane
  - Can be interpreted as difference of in-medium parton path-length in-plane and out-of-plane
  - No significant collision energy dependence
- Evaluation of systematic uncertainties for 5.02 TeV results are still in progress

Jet-hadron correlations

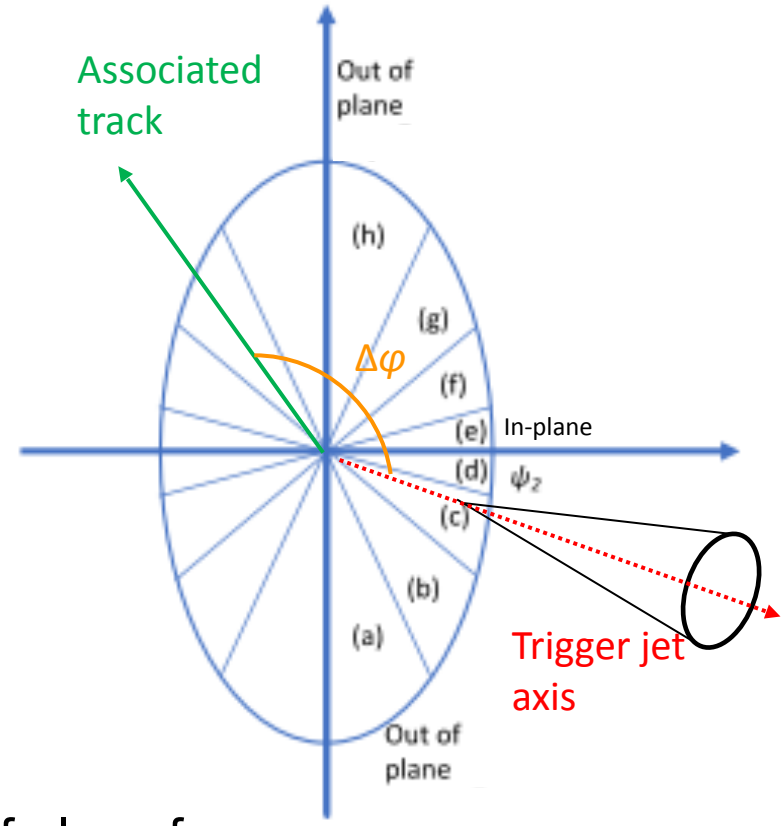








R. Hosokawa



- A slightly wider distribution is observed out-of-plane for the lower p_T associated tracks ($0.7 < p_T < 2$ GeV/c)
- The results suggests asymmetric jet modification w.r.t jet axis in mid-central collisions

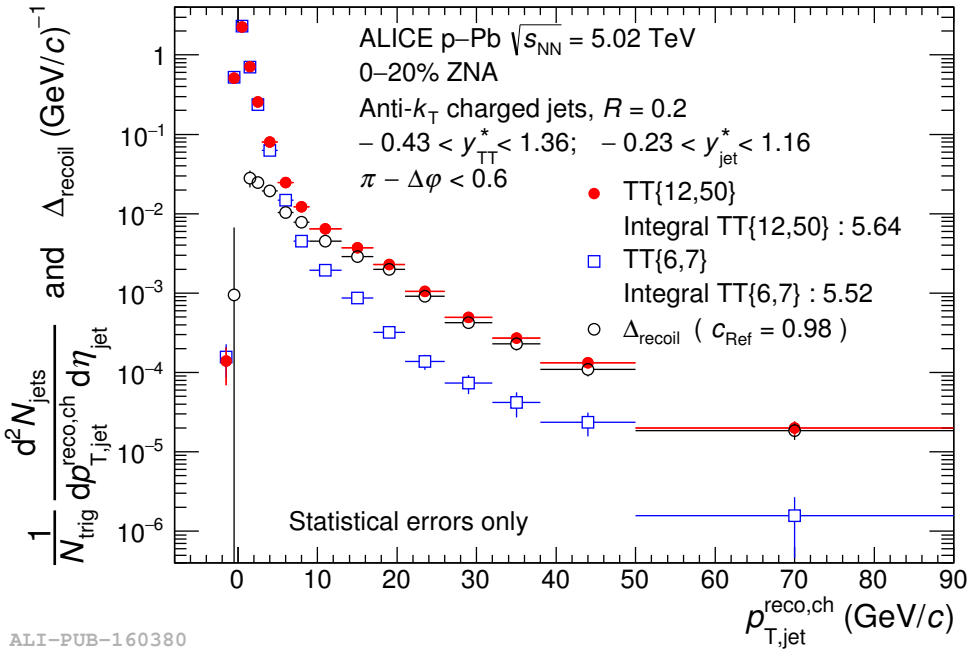
Hadron-jet correlations in p-Pb

- **Semi-inclusive recoil-jet distribution**
- Jet recoiling against a trigger high p_T hadron
- To subtract uncorrelated combinations:

Δ_{recoil} = high p_T trigger (12-50 GeV/c)
- low p_T trigger (6-7 GeV/c)

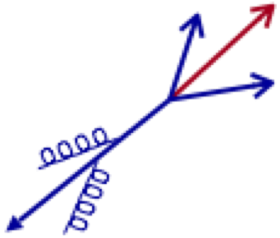
- Self normalized coincidence

Phys. Lett. B 783 (2018) 95-113



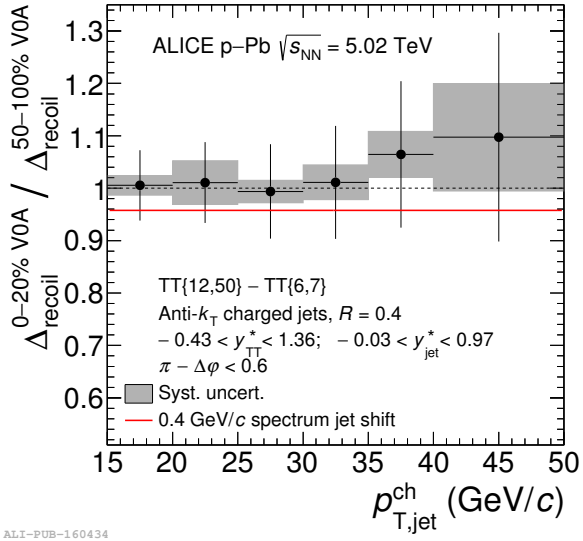
ALI-PUB-160380

high p_T hadron trigger



recoil jet

Phys. Lett. B 783 (2018) 95-113

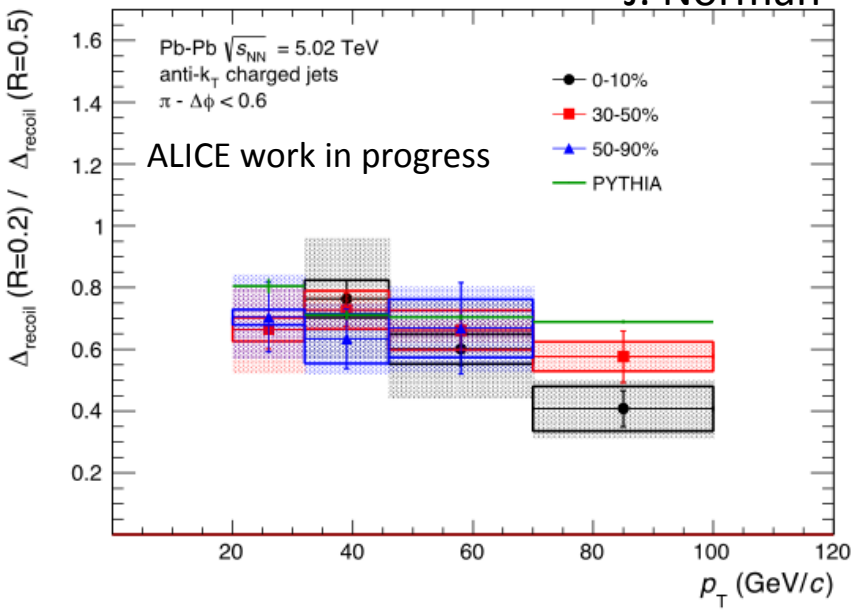


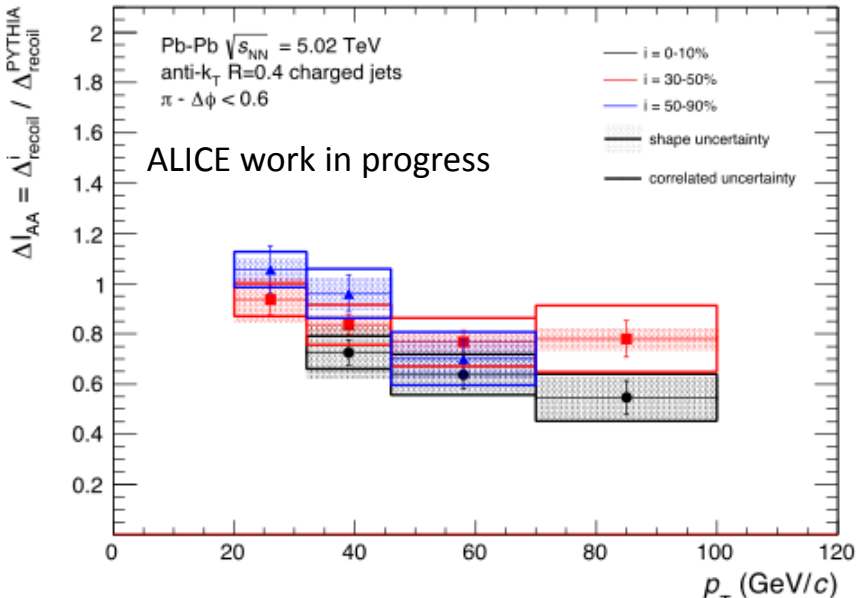
ALI-PUB-160434

Divided central / peripheral:
no significant modification ($\Delta E < 0.4$ GeV)

Hadron-jet correlations in Pb-Pb

J. Norman





- Ratios of combinatorial background-subtracted recoil jet yield :
  - R=0.2 over R=0.5 consistent with PYTHIA expectation
    - Out-of-cone radiation predominantly to angles > 0.5
    - Consistent with run 1
  - Yield over PYTHIA expectation shows suppression of 20-40%
    - Consistent with run 1
- 2018 data will offer large increase in precision
  - ~x9 statistics in 0-10%
  - ~x3 statistics in 30-50%

Plan for 2019: QGP tomography

- **Physics publications**
  - Publish a paper on charged jet in Pb-Pb at 5.02 TeV
  - Publish a paper on charged jet v_2 in Pb-Pb at 5.02 TeV
  - Publish a paper on jet-hadron correlations in Pb-Pb at 5.02 TeV

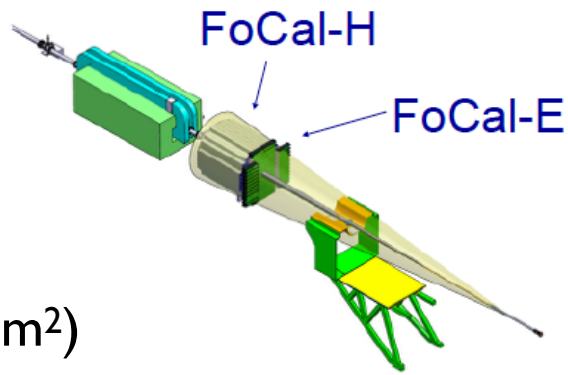
- **Develop the analysis for preliminary**
  - Hadron trigger jet analysis in Pb-Pb
  - Dijet reconstruction with EMCal trigger
  - Dijet with soft hadron production (medium response)
  - Heavy flavor jet in pp, p-Pb
  - and more …

(2) Detector R&D for ALICE upgrades

FoCal = Forward Calorimeter:

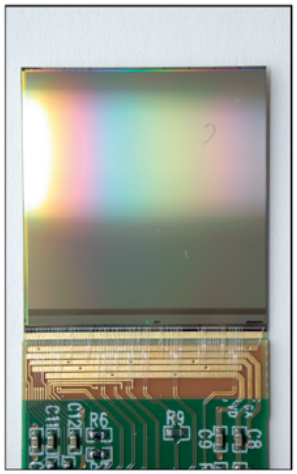
FoCal-E: EM Calorimeter
FoCal-H: Hadronic Calorimeter

- ~7 m away from the interaction point
- main challenge: separate γ/π^0 at high energy
- Si-W calorimeter (hybrid Si: pad 1cm^2 & MAPS 30μm^2)
- Considered as an ALICE upgrade for Run-4

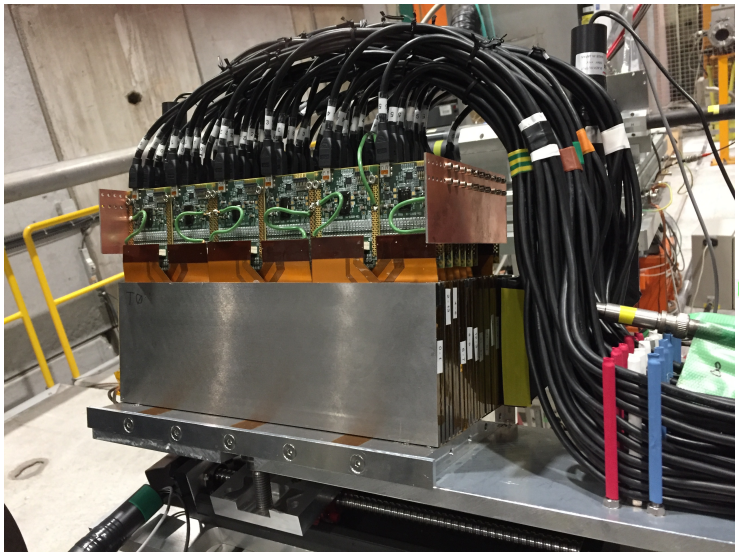


$3.2 < \eta < 5.3$

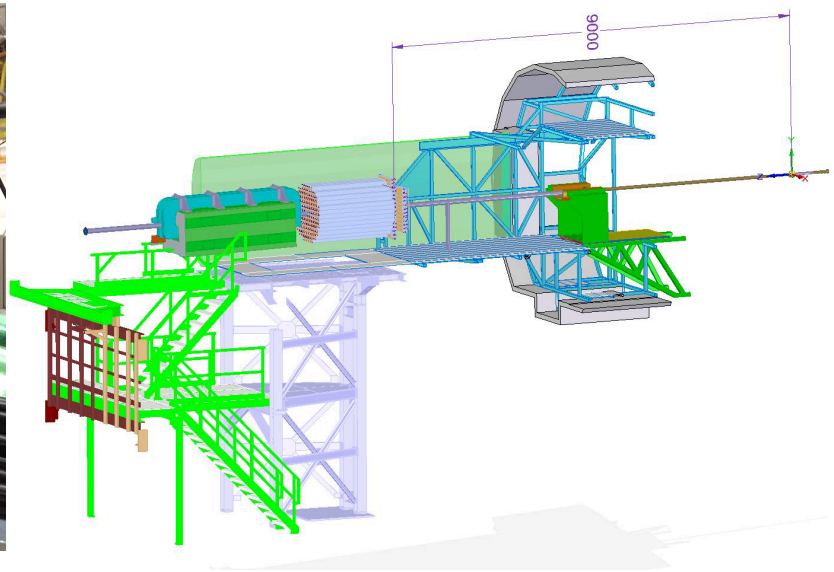
- **Look for CGC effects at small-x (~10^{-5})**
- **Origin of Quark Gluon Plasma**
  - main observables: Direct photons, π^0 ,π^0-π^0 correlations



MAPS detector

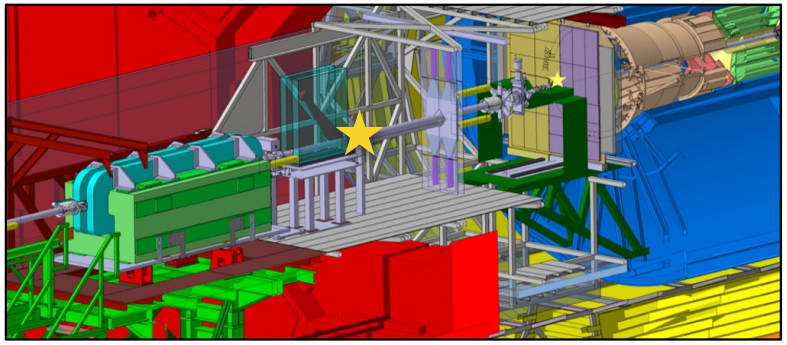


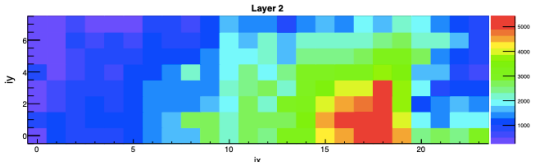
mini-FoCal (PAD)

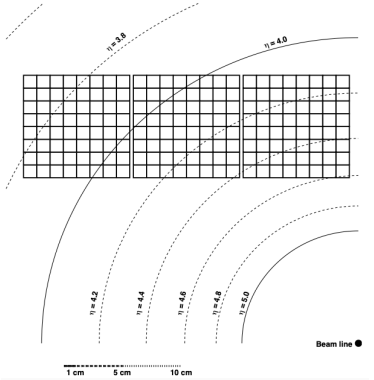


PS, SPS and ALICE (pp 13 TeV) (2018)

- A prototype of FoCal has been tested PS and SPS in 2018 July-Aug.
- Installed in ALICE (7.6 m from IP) and took data with 13 TeV
- Three tower structure, EM-part (PAD only)

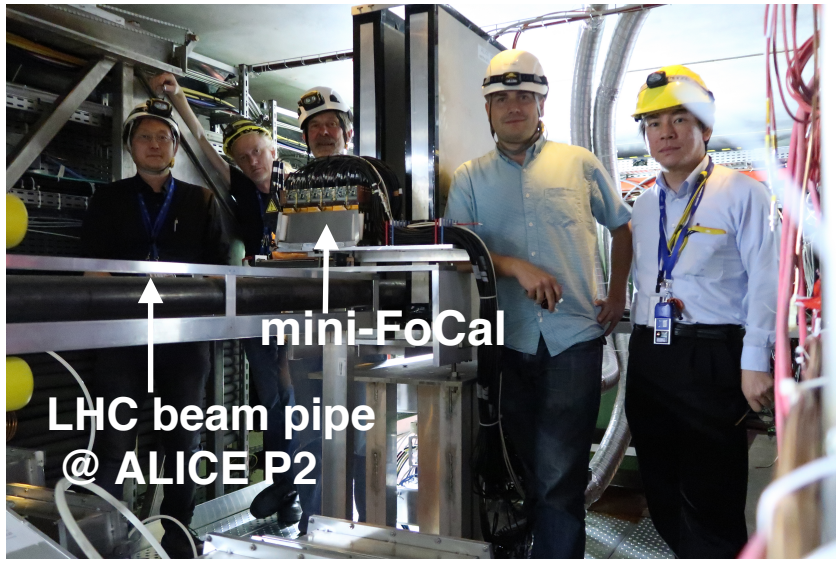






Hit Map from run at point 2

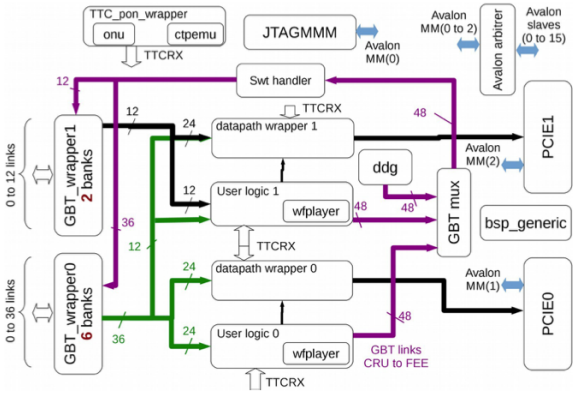
SPS beamtest

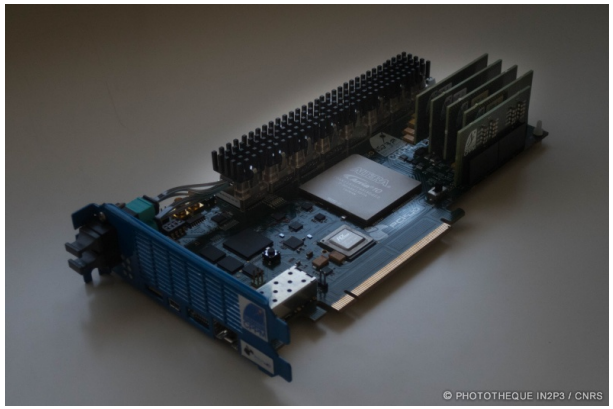


Y. Minato (Nara W. Univ.) supported by TYL-FJPPL Student or Early Stage Researcher Secondment (2018). Many thanks !

Read-out electronics

- Take advantage of the steady growth of CPU power over years (x30 in ~10y)
- Trigger-less continuous readout scheme
  - Unmodified raw data of all interactions shipped from detector to on-line farm
  - HI run 3.4 TByte/s!
- New **CRU (Common Readout Unit)** for LHC Run 3 and beyond
  - Hw (PCIe40) developped for LHCb by the CPPM-IN2P3
- ALICE customed fw under development by Tsukuba, Nagasaki,and Grenoble
- Avenues of collaboration with the KEK OpenIt consortium for the next generation of FPGA-based embedded fast custom readout electronic devices
  - ALICE FOCAL (LHC Run 4)
  - J-PARC experiment





Plan for 2019: R&D for ALICE upgrades

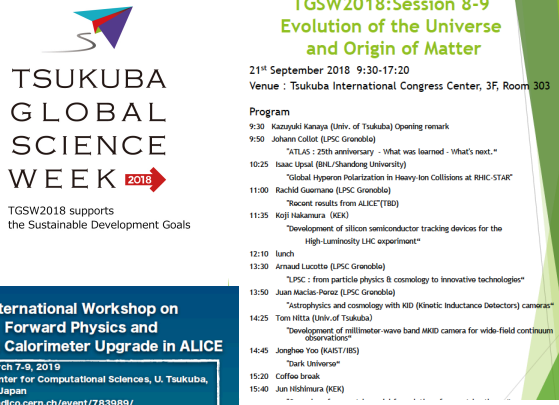
- **FoCal**
  - Seeking a possibility to use ASIC used in CMS HGCAL (HGC-ROC), and develop a collaboration between Grenoble-Tsukuba and FoCal Group (July 2019)
  - After that, defined the detailed project for TDR.

- **CRU**
  - Define the CRU parameter for FoCal TDR.
  - Seeing an opportunity to join Open-it for the further development.

PhD co-supervising, workshop

Co-supervising PhD students & workshops

1. **Co-supervising PhD students:**
   - Dr. D. Watanabe (2015)
   - Dr. H. Yokoyama (2018)
     - Grenoble-Tsukuba double degree
     - Winner of the 2017 TYL-FJPPL Young Investigator Award
   - **Dr. R. Hosokawa (2019), Grenoble-Tsukuba double degree**
   - In 2019, we expect to have a new PhD student for co-supervising.
2. **Workshops**
   1. Tsukuba Global Science Week (TGSW 2018, 2018 Sep.)
      - Invited Grenoble LPSC to Tsukuba (ALICE, ATLAS, Astrophysics)
   2. Forward physics WS in Tsukuba (2019 Mar.)
      - https://indico.cern.ch/event/783989/
      - Developed common project between Grenoble and Tsukuba.



Members

FJPPL (TYL) application 2019-2020

Fiscal year April 1st 2019 – March 31st 2020

ID[1]: HAD_4 | Title: **QGP tomography with jets**

	French Group			Japanese Group		
	Name	**Title**	**Lab./Organis.[2]**	**Name**	**Title**	**Lab/Organis.[3]**
Leader	Rachid Guernane	CR	LPSC/IN2P3	Tatsuya Chujo	Prof.	U. Tsukuba
	Gustavo Conesa Balbastre	CR	LPSC/IN2P3	Yasuo Miake	Prof.	U. Tsukuba
	Julien Faivre	MC	LPSC/UGA	Motoi Inaba	Prof.	U. Tsukuba Tech.
Members	Christophe Furget	Prof.	UGA	Toru Sugitate	Prof.	U. Hiroshima
	Jaime Norman	CDD	LPSC/IN2P3	Maya Shimomura	Prof.	Nara Women's U.
	Yves Schutz	DR	IPHC/IN2P3	Hiroyuki Sako	Prof.	JAEA
	Iouri Belikov	DR	IPHC/IN2P3	Hideki Hamagaki	Prof.	NiAS
	Antonin Maire	CR	IPHC/IN2P3	Taku Gunji	Prof.	U. Tokyo
	Fouad Rami	CR	IPHC/IN2P3			
	Boris Hippolyte	MC	IPHC/IN2P3			
	Christian Kuhn	DR	IPHC/IN2P3			

2019 budget request

Funding Request from France				
Description	**€/unit**	**Nb of units**	**Total (€)**	**Requested to[4]:**
Visit to Tsukuba	150/day	28 days	4,200	IN2P3
Travels	1000	4 travel	4,000	IN2P3
ALICE France-Japan Workshop	2000	1	2,000	IN2P3
Total			10,200	

Requested only for travel and organizing the workshop between France-Japan.
Please note that FY2018: no budget allocated for HAD_04
→ (comments by SC) scope is too wide, need to concentrate dedicated project.

For 2019 project:

1) QGP tomography with jets: physics paper production using Run-2 data
2) Detector R&D for ALICE upgrades for Run-3 and beyond (FoCal, CRU)

Summary

- **ALICE jet analysis for the QGP tomography is quite progressing**
  - 1 PhD student in this year (Grenoble-Tsukuba double degree), 1 paper submission to arXiv and journal, 2 preliminary results
  - To be extended to full jet, di-jet, heavy flavor jets, h-jet and jet-h correlations.

- **New detector R&D projects within FJPPL has been identified**
  - FoCal and CRU
    - FoCal: an expression of interest or possibility/option where Grenoble has some good skills
  - Further development on both projects are ongoing.

Thank you for your support !