ALICE Status Report

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23rd CERN-Korea Committee Meeting
CERN, 29 October 2018

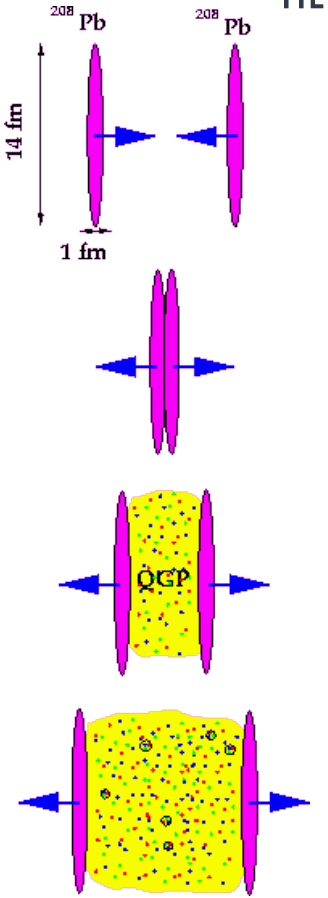
Ultrarelativistic Nuclear Collisions

basic idea: compress large amount of energy in small volume

→ produce a “fireball” of hot matter:
temperature O(10^{12} K)

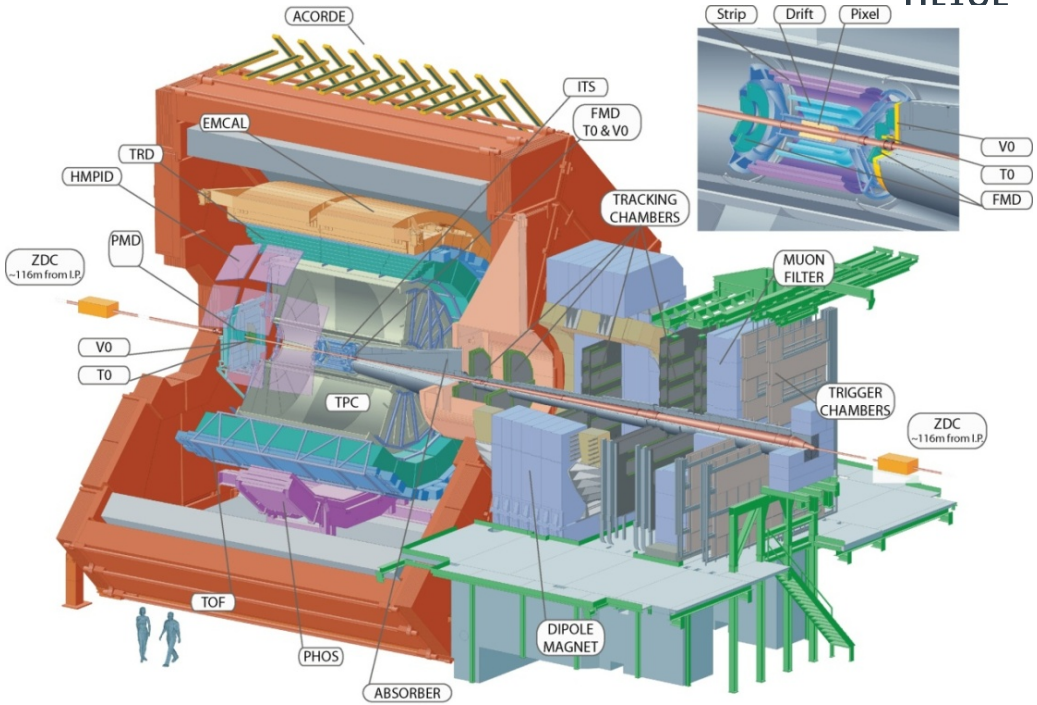
- ~ 10^5 x T at centre of Sun
- ~ T of universe @ ~ 10 μs after Big Bang

- extreme conditions: how does matter behave?
  - → study the fireball properties
  - deconfined QCD medium(Quark-Gluon Plasma, QGP)
    - predicted by QCD
    - evidence for QGP already at lower energy (CERN-SPS, BNL-RHIC)
  - LHC: high statistics and controlled probes
    - → quantitative study of properties of QCD medium
      - viscosity, opacity, transport, diffusion, …

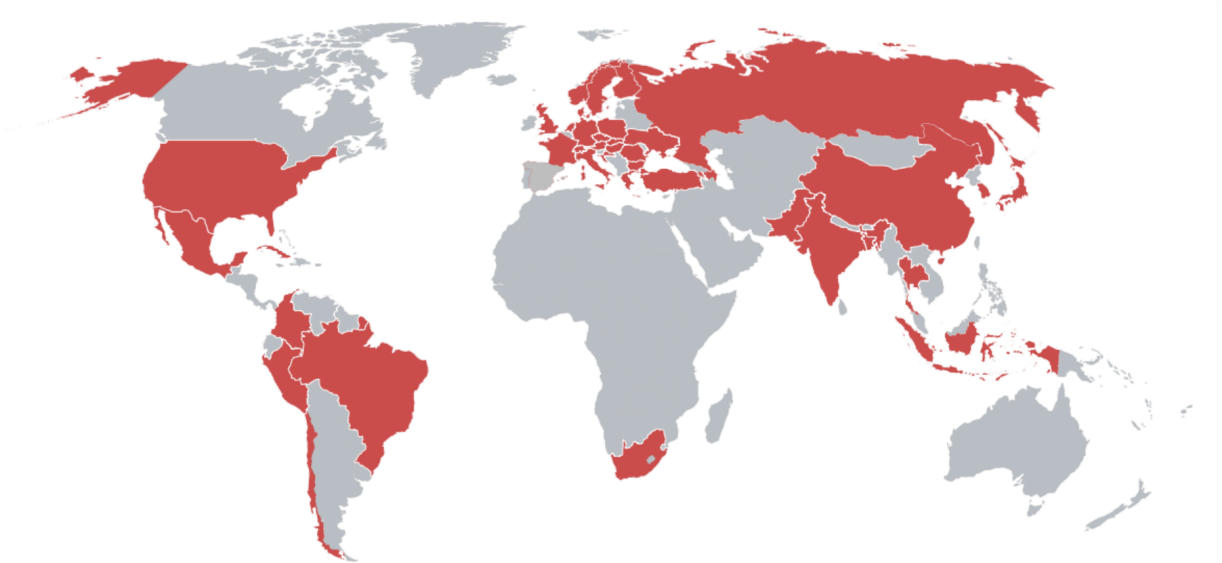


The ALICE Experiment

- Two main parts:
  - barrel ($|\eta|<0.9$), B = 0.5 Tesla
  - muon spectrometer, $-4<\eta<-2.5$
- High precision reconstruction:
  - low material tracking
  - high res. vertexing
  - hadron and lepton ID
- Triggers:
  - minimum-bias (MB)
    - or centrality, in Pb-Pb
  - single and di-muon
  - EMCAL, high-mult., UPC
  - TRD
- Collisions systems (so far) : Pb-Pb, pp, p-Pb, Pb-p, Xe-Xe



Participating Institutes
176 INSTITUTES – 41 COUNTRIES

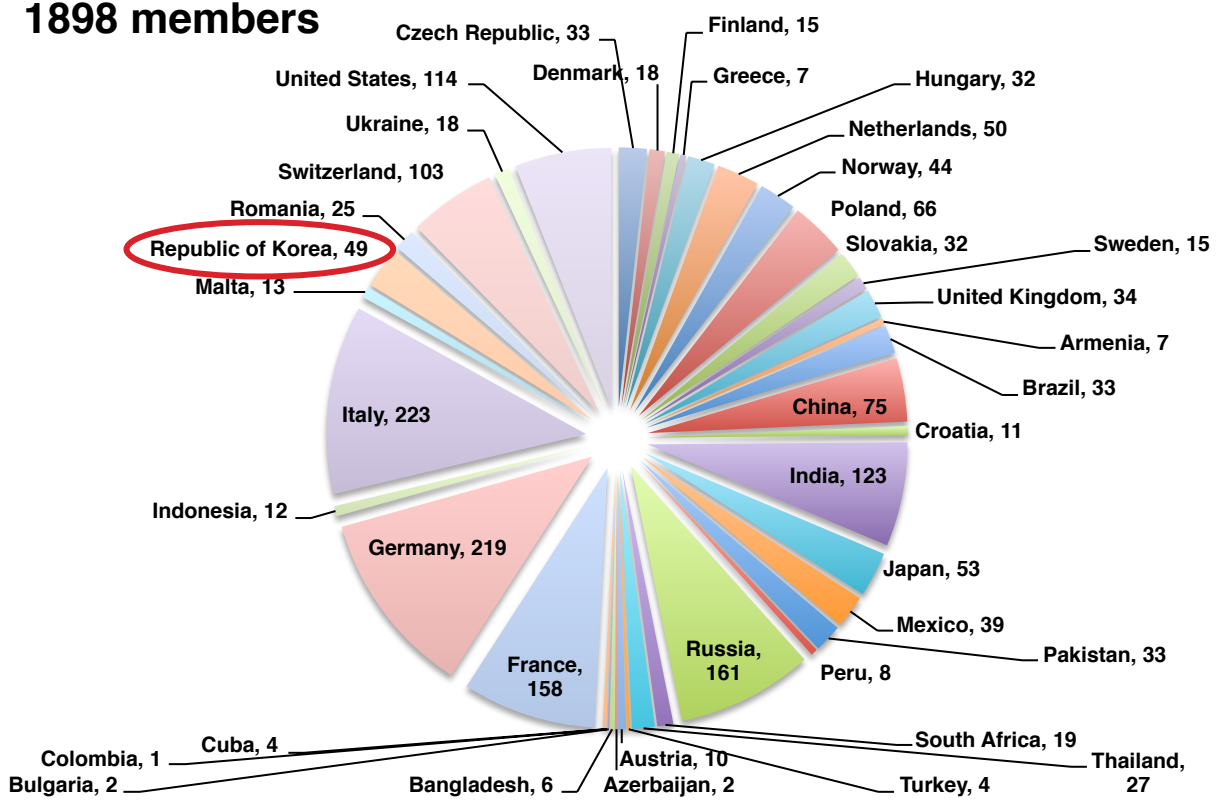


- ongoing discussions with groups in Bolivia, Chile, India, Romania, …

Source: Alice Collaboration data base, April 2018

The ALICE Collaboration

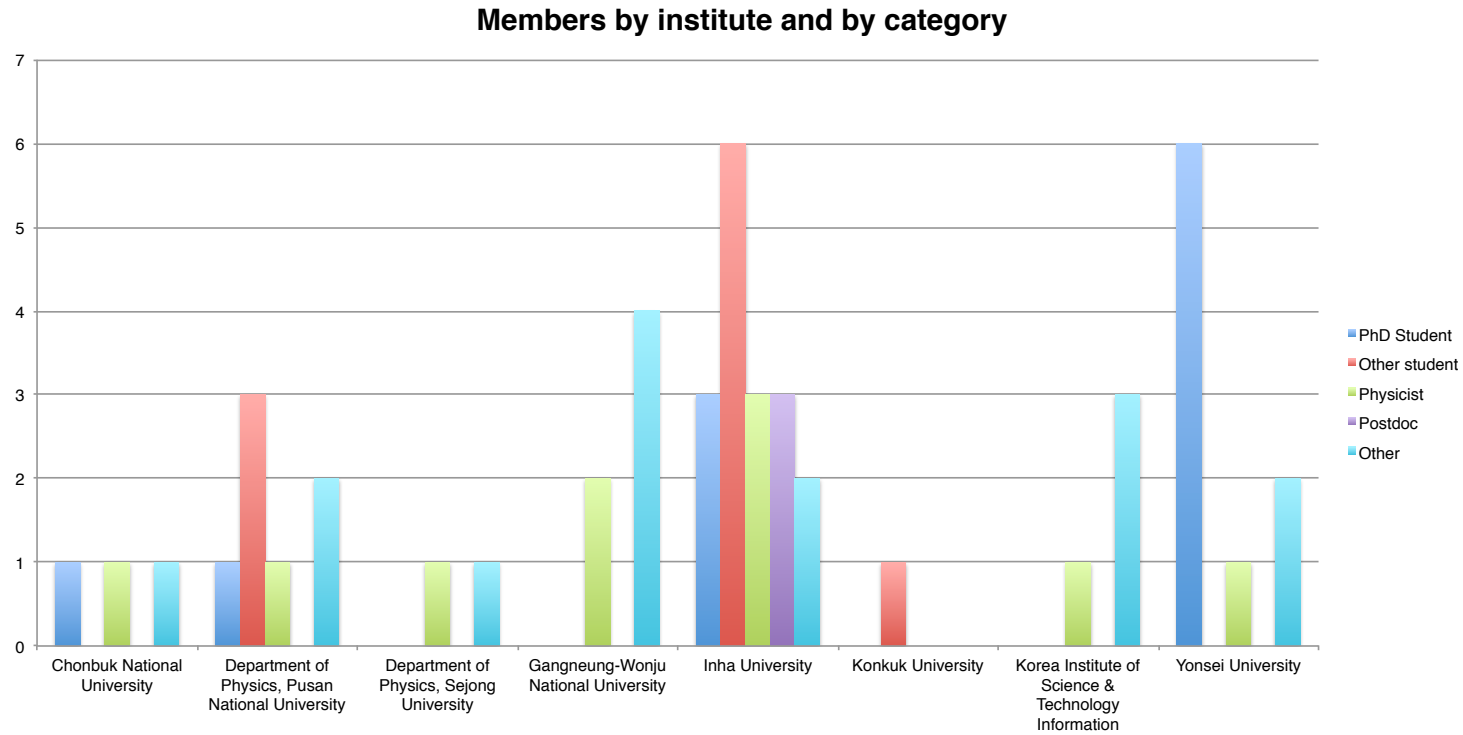
1898 members



Source: Alice Collaboration data base, October 2018

Republic of Korea in ALICE

49 people, from 9 institutes



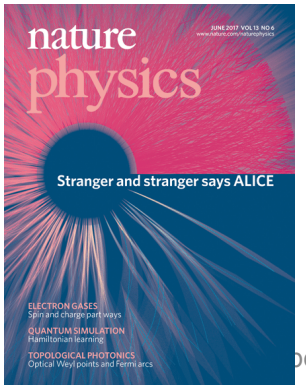
Main areas of Korean activity in ALICE

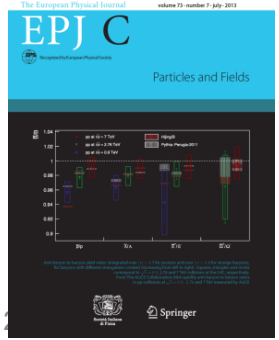
- Inner Tracking System upgrade
  - detection of fast decays close (100's μm) to interaction vertex
- Muon Forward Tracker
  - detection of fast decays in front of the muon spectrometer
- Muon Trigger
  - fast detection of muons → trigger the acquisition of data
- Time-Of-Flight detector
  - identification of particle species
- Computing
  - first LHC Tier 1 Computer Centre after LHC start
  - first Tier 1 in Asia!
- Data analysis
  - 16 papers with Korean colleagues as main authors
  - 5 more currently under preparation

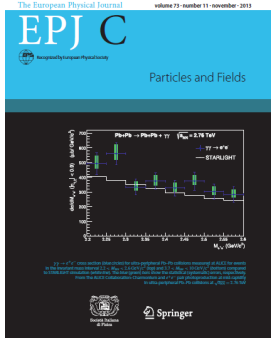
ALICE Physics: current status

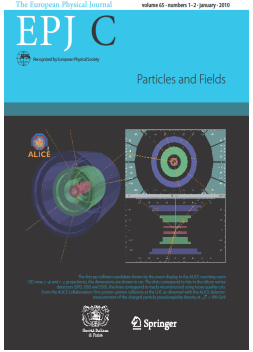
Run 1 (2009-2013) + Run 2 (2015-2018)

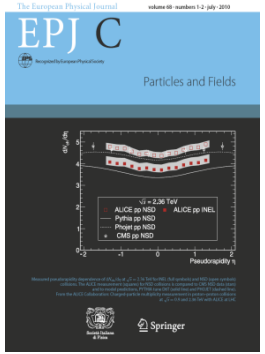
- wide-band exploration of QGP features
  - comprehensive study of identified particle production, correlations, jets, …
- first measurement of mass-dependence of in-medium energy loss
- discovery of new regime for charmonium production in QGP (→ regeneration)
- discovery of collective effects in p-Pb, pp collisions
- 233 papers on arXiv, several hundred presentations to conferences per year

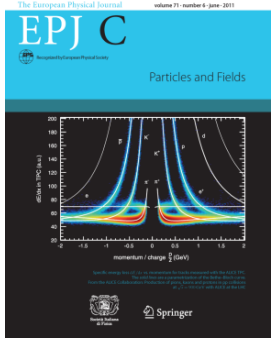




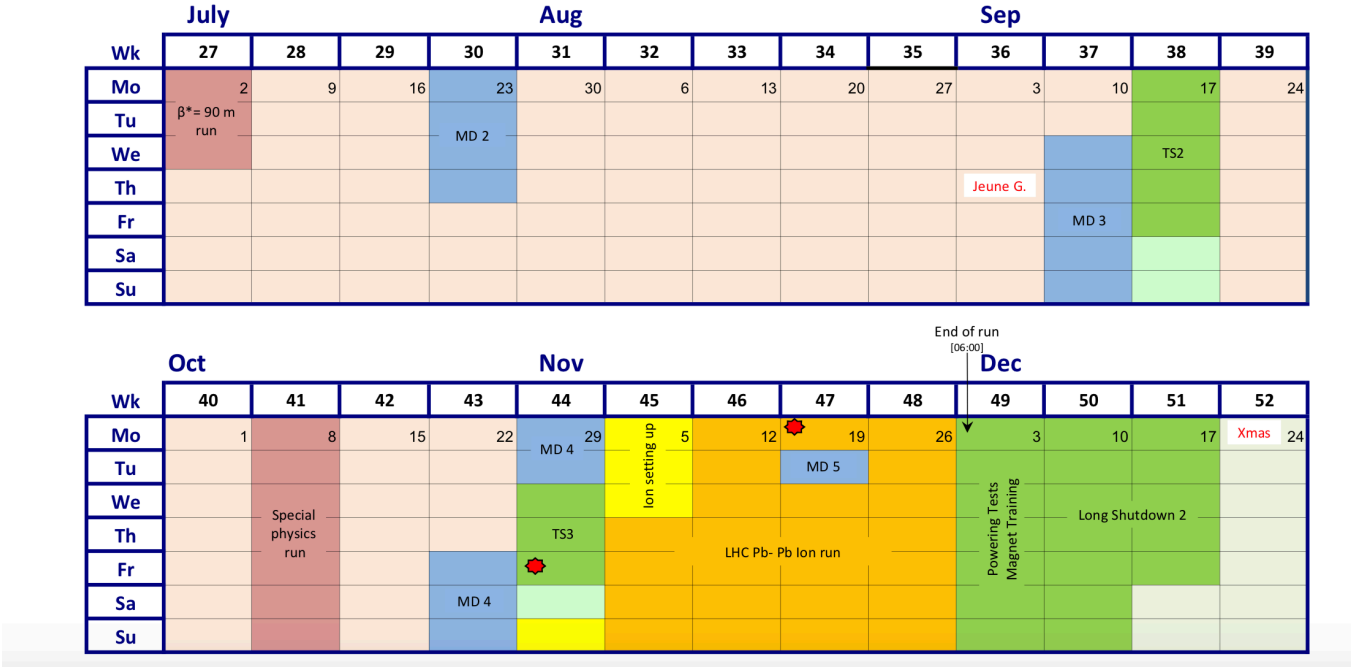








Data taking in 2018

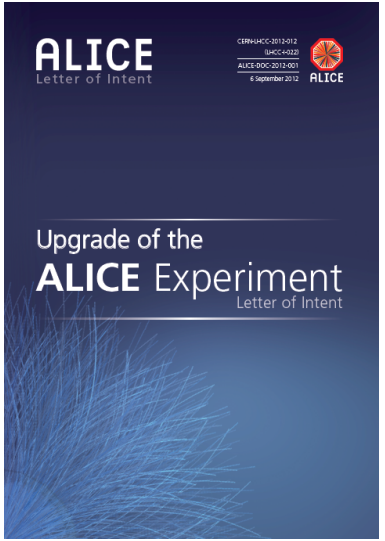


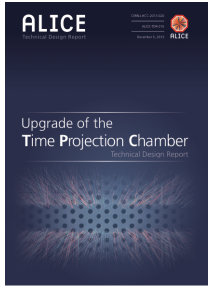
- Pb-Pb run 2018: stress on central (head-on) collisions → Heavy Flavour!
- largest data set so far → ~ 25% ALICE data to date to be collected this year!

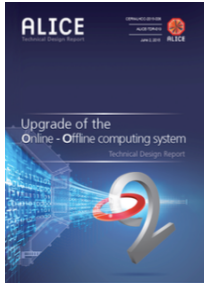
ALICE Physics: upgrades plans

Main physics goals

- study heavy quark interaction in QCD medium
  → heavy flavour dynamics and hadronisation at low p_T
- study charmonium regeneration in QGP
  → charmonium down to zero p_T
- chiral symmetry restoration and QGP radiation
  → vector mesons and virtual thermal photons (di-leptons)
- production of nuclei in QGP
  → high-precision measurement



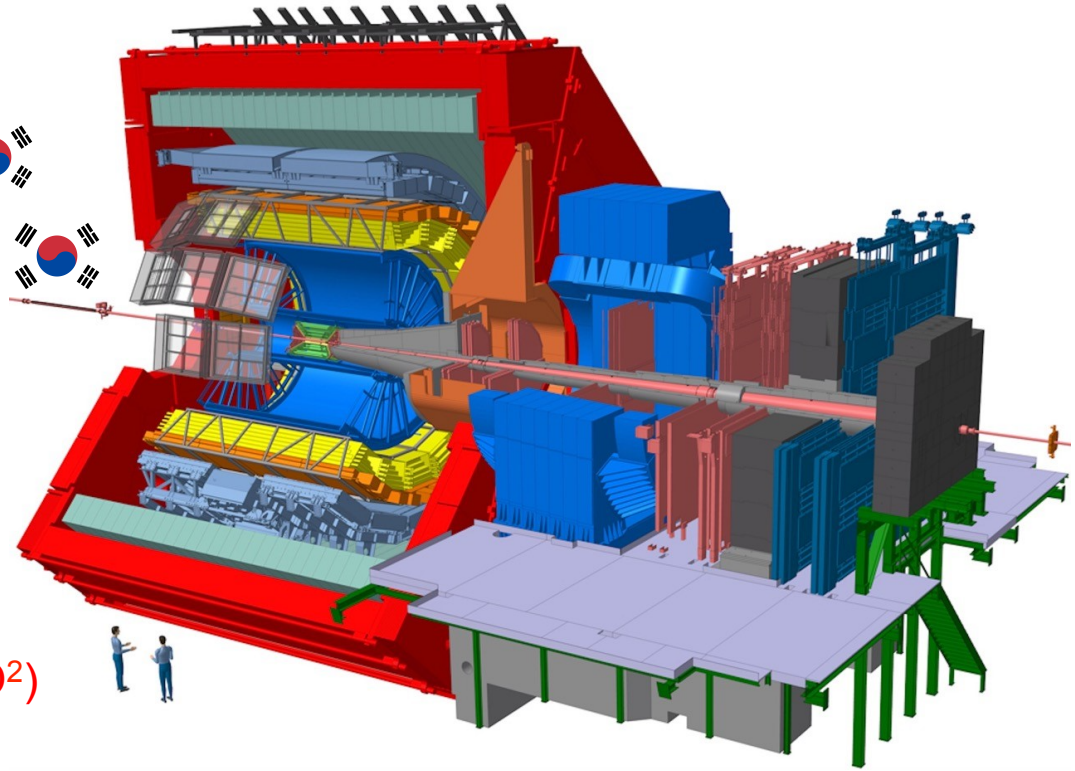




ALICE upgrades

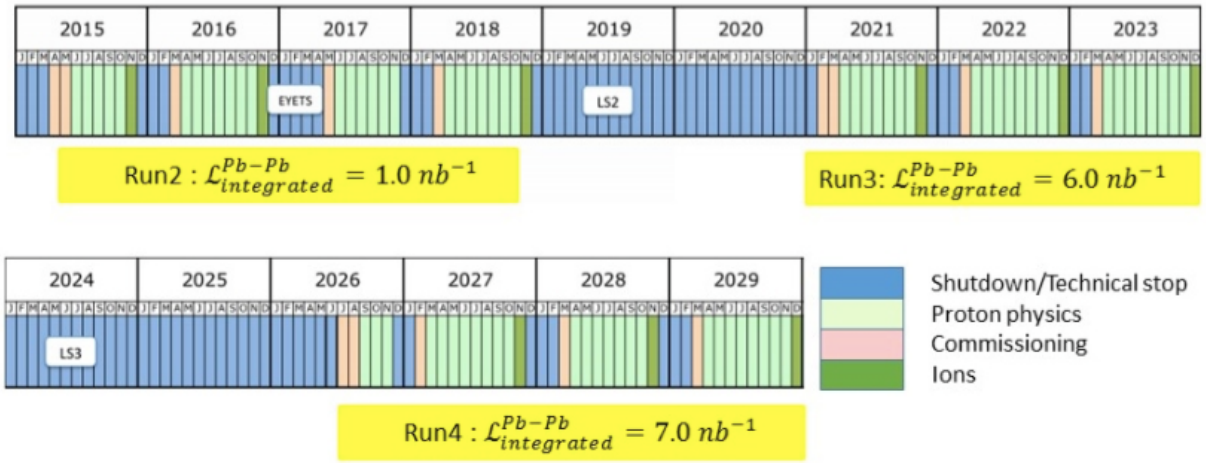
Layout

- New Inner Tracking System (ITS)
  - MAPS: improved resolution, less material, faster readout
- New Muon Forward Tracker (MFT)
  - vertex tracker at forward rapidity
- New TPC Readout Chambers
  - 4-GEM detectors
- New trigger detectors
  - + centrality, event plane
- Upgraded read-out for TOF, TRD, MUON, ZDC, EMCal, PHOS, integrated Online-Offline system (O^2)
  - record minimum-bias Pb-Pb data at 50 kHz (currently <1 kHz)



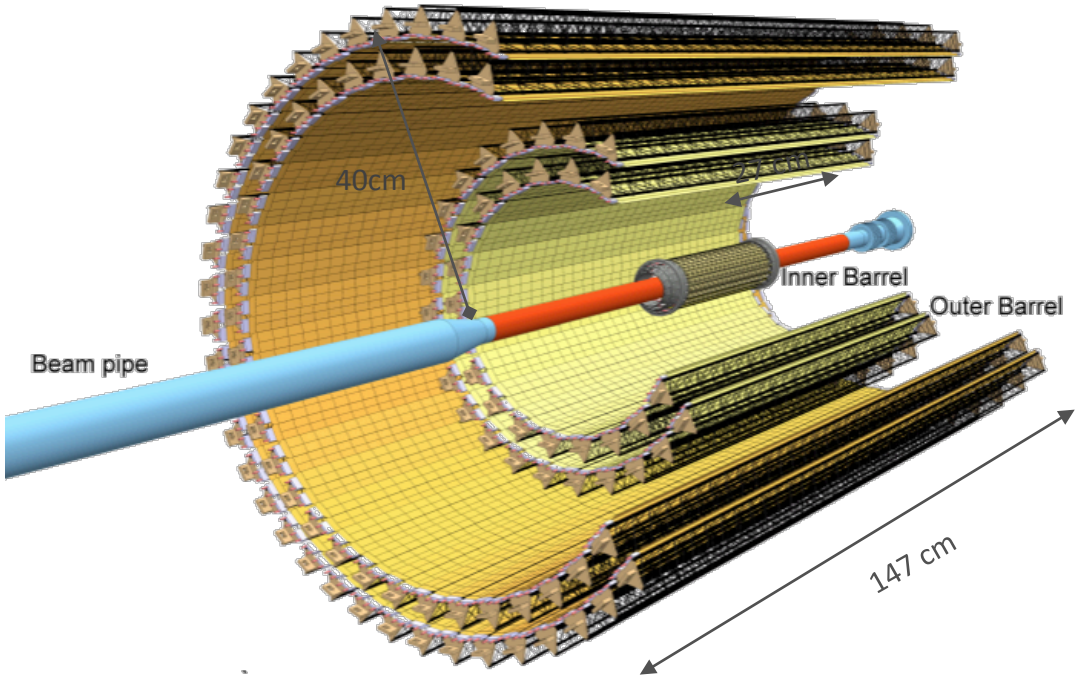
ALICE upgrades

Timeline



- LS2:
  - LHC injector upgrades, Pb-Pb rate → 50 kHz (now ~10 kHz)
  - ALICE upgrades
- Run 3 + Run 4:
  - experiments request > 10/nb (ALICE: 10/nb + 3/nb at 0.2 T)
  - in line with latest projections from machine group

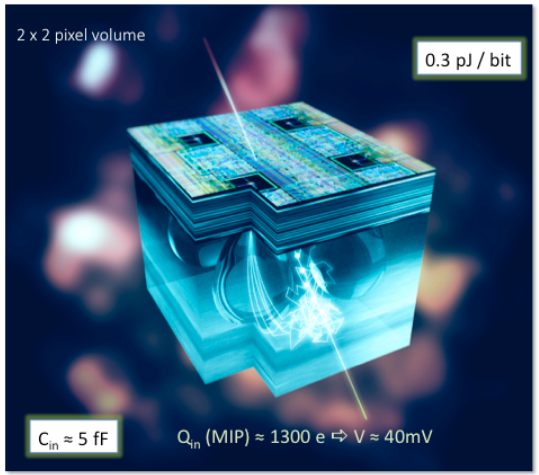
ITS Upgrade

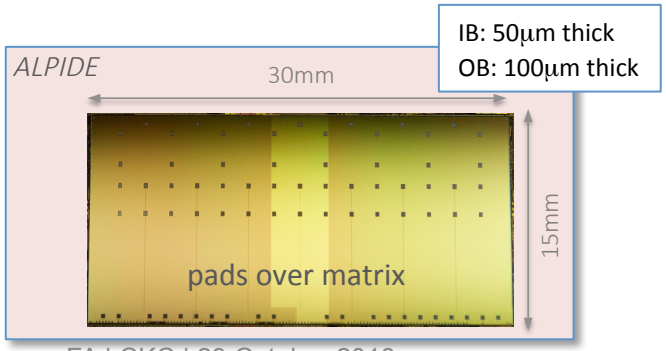


Based on MAPS

- 7-layer geometry (23 – 400mm), $|\eta| \leq 1.5$)
- 10 m^2 active silicon area (12.5 G-pixels)
- Pixel pitch 28 x 28 μm^2
- Spatial resolution ~5μm
- Power density < 40mW / cm^2
- Material thickness: ~0.3% / layer (IB)
- Max particle rate: 100 MHz / cm^2

Production of Monolithic Pixel Chip





Production Plans

- Number of "good sensors" needed to build the ITS (including spares): 27300
- Number of chips to be produced: 54584 ⇨ 1186 wafers (46 chips/ wafer)

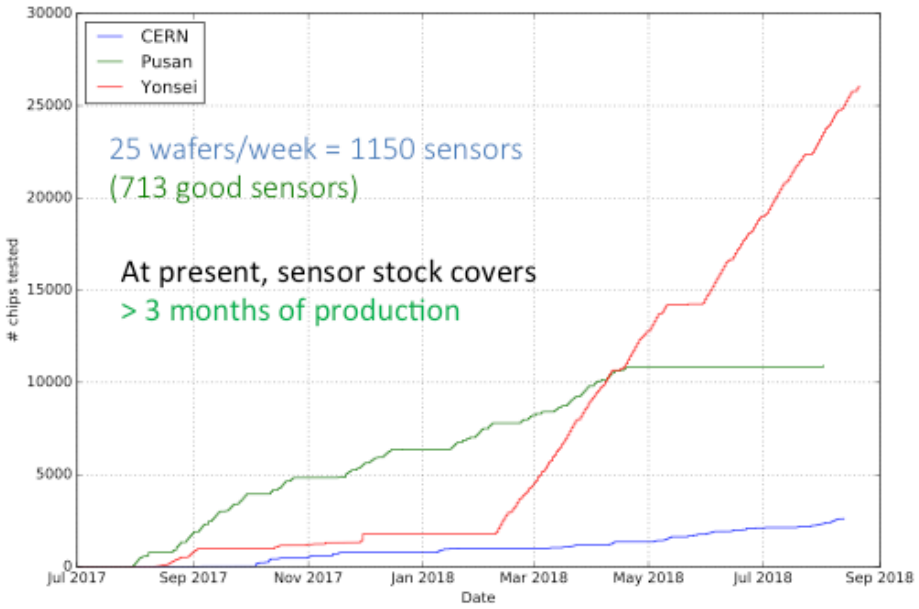
Production Status and Updated Plans

- 1200 wafers produced till Dec 2017
- Overall yield figures turned out to be lower than expected

  ⇨ **45%** (Chip + HIC + Stave)
- Production resumed in Jun 2018 will continue till Dec 2018 to reach a total of 1600 wafers (**20% contingency**)

Pixel chip (ALPIDE) production and test flow

HIC construction sites need about 700 sensors / week



Yonsei

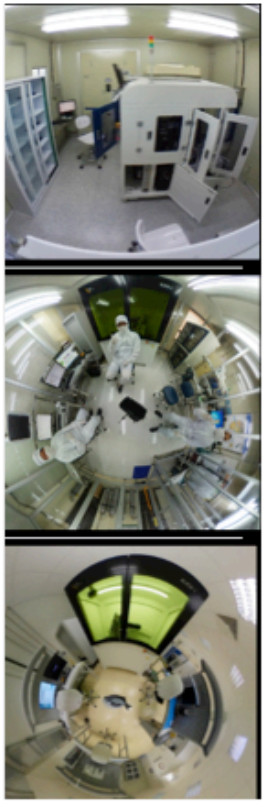
- **100-µm** chip testing: running
- Working schedule: 24/7
- Test rate: 26 wafers/week
- Smooth operation

Pusan/Inha

- **100-µm** chip testing: done (end-April)
- (switchover to HIC constr.)
- Backup site

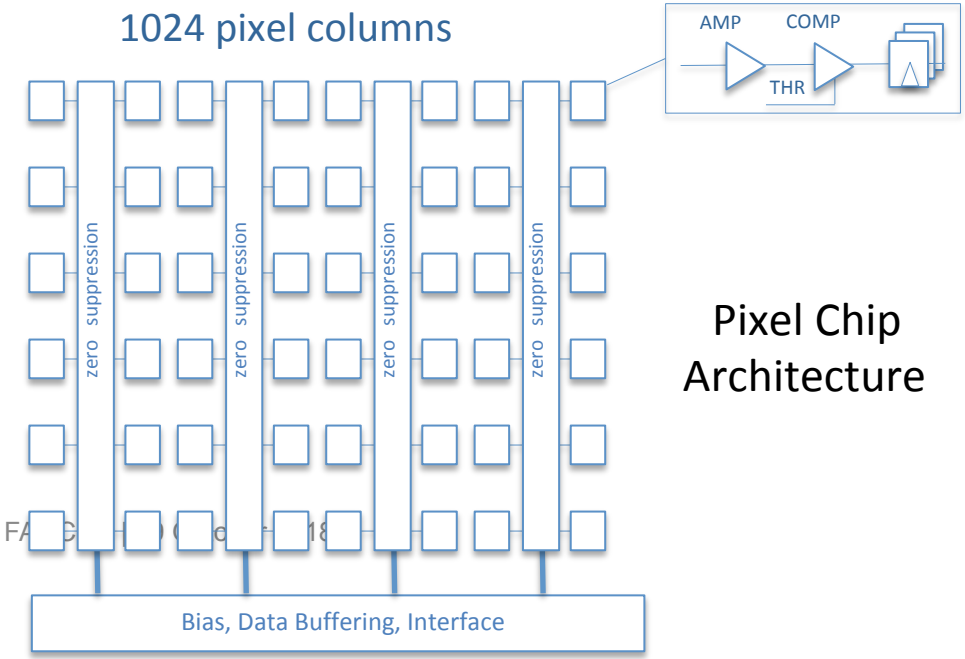
CERN

- **50-µm** chip testing: running
- wafer testing: done



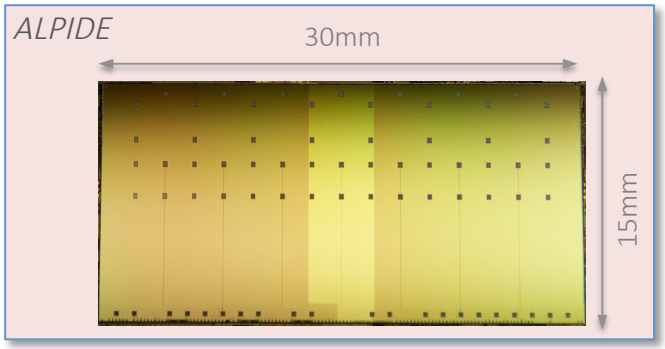
Yonsei University: Pixel Sensor Chip Development

- major contribution to development of pixel sensor chip
  - participation in chip design (analog front-end), with two engineers at CERN
  - participation in chip characterisation



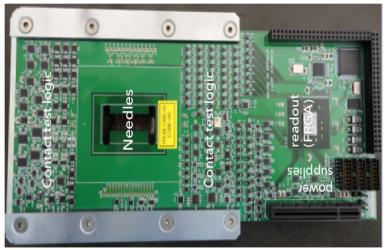
Yonsei contributed to design of analog front-end

Pixel Chip Architecture



Yonsei University: Pixel Sensor Chip Test

- major contribution to pixel chip series test
  - about 30,000 sensors being tested at Yonsei, (28 wafers/week)



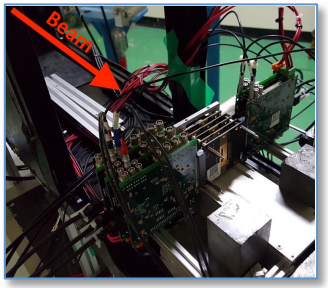
Probe-card
developed by Korean companies (NOTICE, EQNG)
in close collaboration with Yonsei and CERN

Corea-YS01 (C-ON, Creative On Technology, Korea)

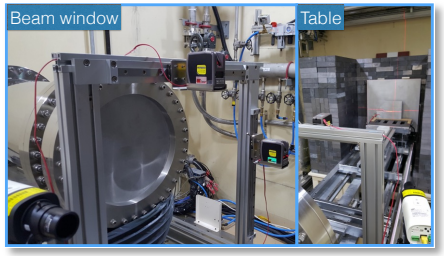
- custom-made automatic test equipment
- developed by C-ON in close collaboration with Yonsei University and CERN

Pusan National University and Inha University

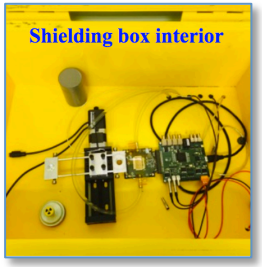
- major contribution to development of pixel sensor chip
  - characterisation of four generations of full-scale prototypes
  - participation in test beam activities at CERN and DESY
  - detailed characterisation with 60 MeV e- LINAC
    - Pohang Accelerator Laboratory
  - study of effects of ionising radiation
    - KOMAC (Gyeongiu)
  - study of influence of supply voltage, temperature, external noise



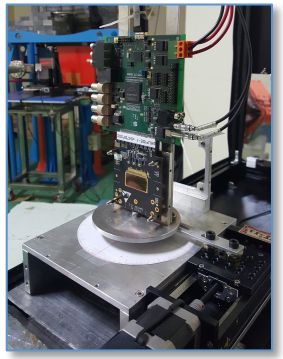
PAL – study of sensor detection efficiency



Experimental set-up at KOMAC



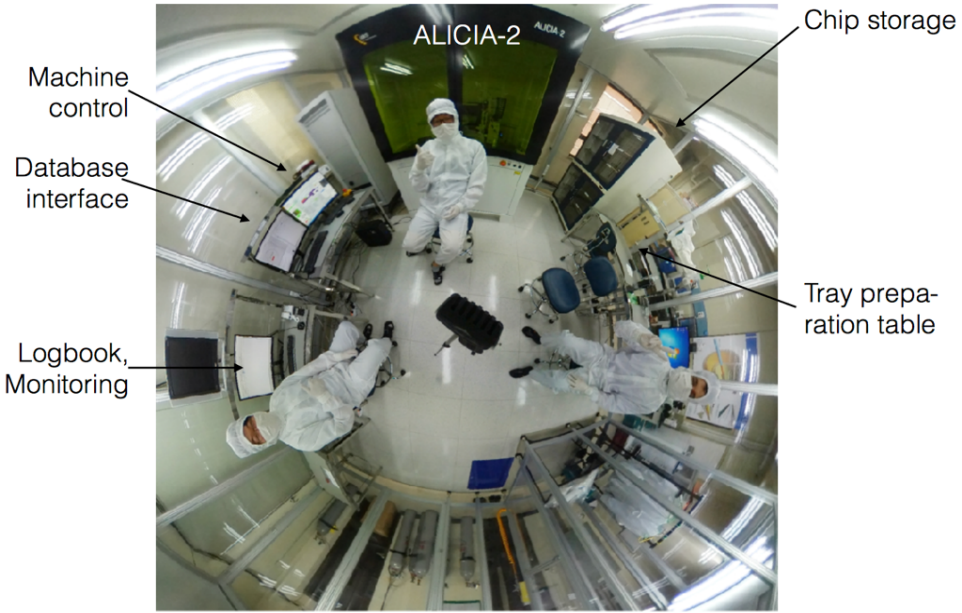
Test set-up at Inha

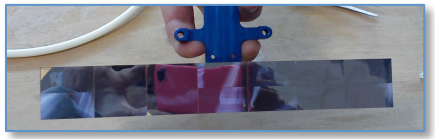


PAL – Study of response to inclined tracks

Pusan National University and Inha University

- major contribution to detector construction

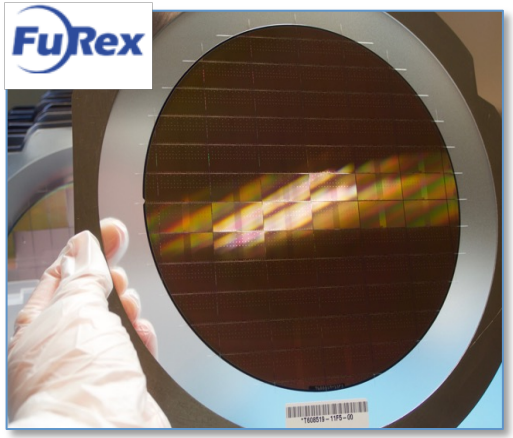




ITS Outer Barrel HIC. 14 pixel sensor chips are mounted on a flexible printed circuit

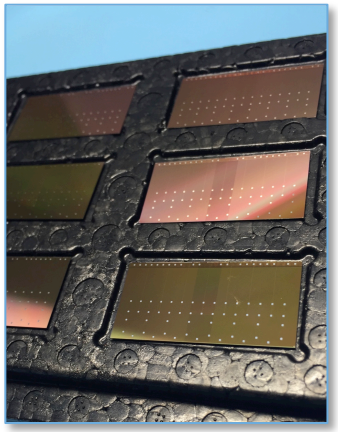
  - pixel chip series test (~ 30,000 sensors, finishing in April)
  - Outer Barrel Module construction (400 modules, started in May 2018)

Large involvement of Korean Industry in the ITS

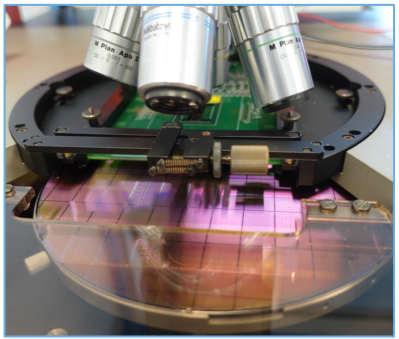


Innofab and Furex

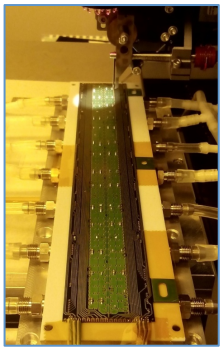
- Thinning & Dicing of silicon sensors wafers
- Thinning of very large sensors (15 x 30 mm^2) down to ultra-low values (50μm)
- pick & place to custom trays



C-ON: development of custom-made automatic test Equipment for pixel chip series test



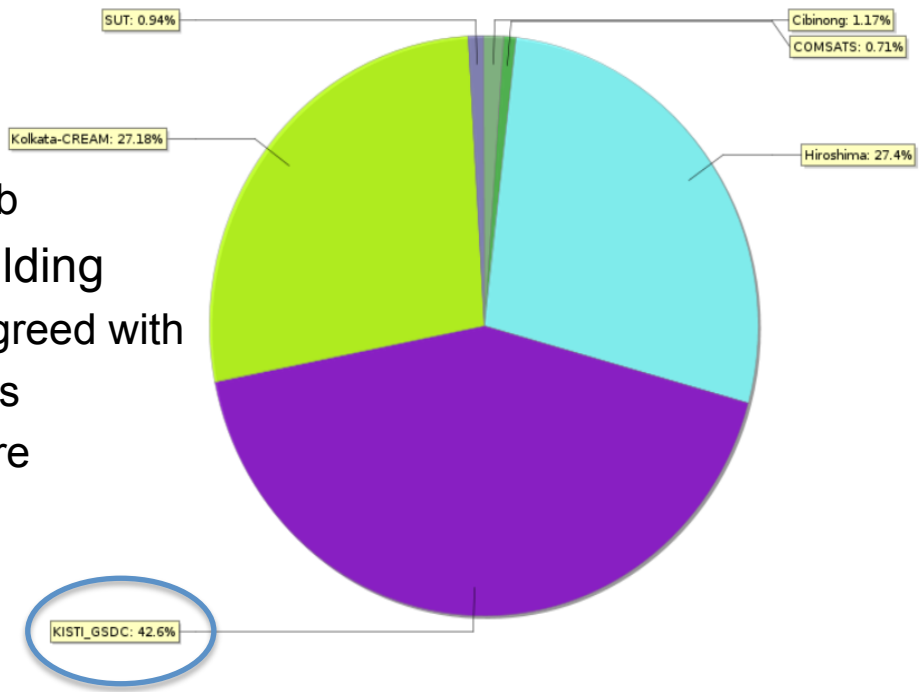
NOTICE and EQNG development of probe-card systems



SEJUNG module wire bonding

KISTI for ALICE

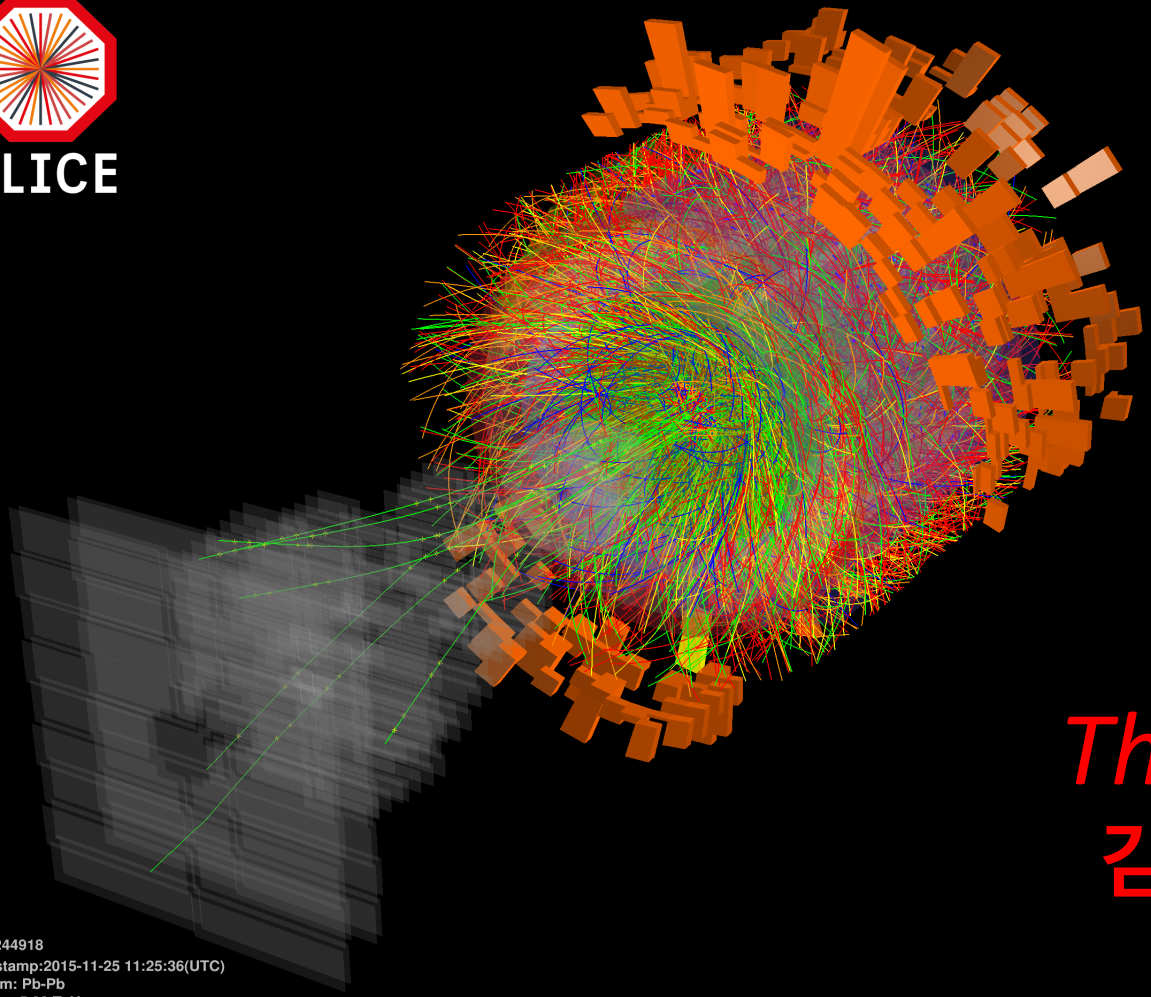
- Largest Asian resources contributor for ALICE, provides 14% T1 capacity
- ALICE Tier Center Forum
  - Leading role in the new storage initiative for Run3
  - Continues to be a major network hub
- Moving of all resources to a new building
  - Migration program discussed and agreed with ALICE, minimal impact on operations
  - Good luck an looking forward to more resources!



Conclusions

- collaboration between ALICE and Korea is very healthy
  - physics: new ideas, experienced scientists, excellent students
  - technology: key contributions from Korean industry to ALICE apparatus
  - computing: key provider of computing resources
- the outlook is bright
  - promising young colleagues
  - new technical ideas
- we are very grateful!
  - MoS, NRF, KISTI
  - Korean industrial partners
  - KoALICE and all our Korean colleagues

ALICE



Thank you!

감사합니다!

Run:244918
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Energy: 5.02 TeV