ALICE Status

F Antinori

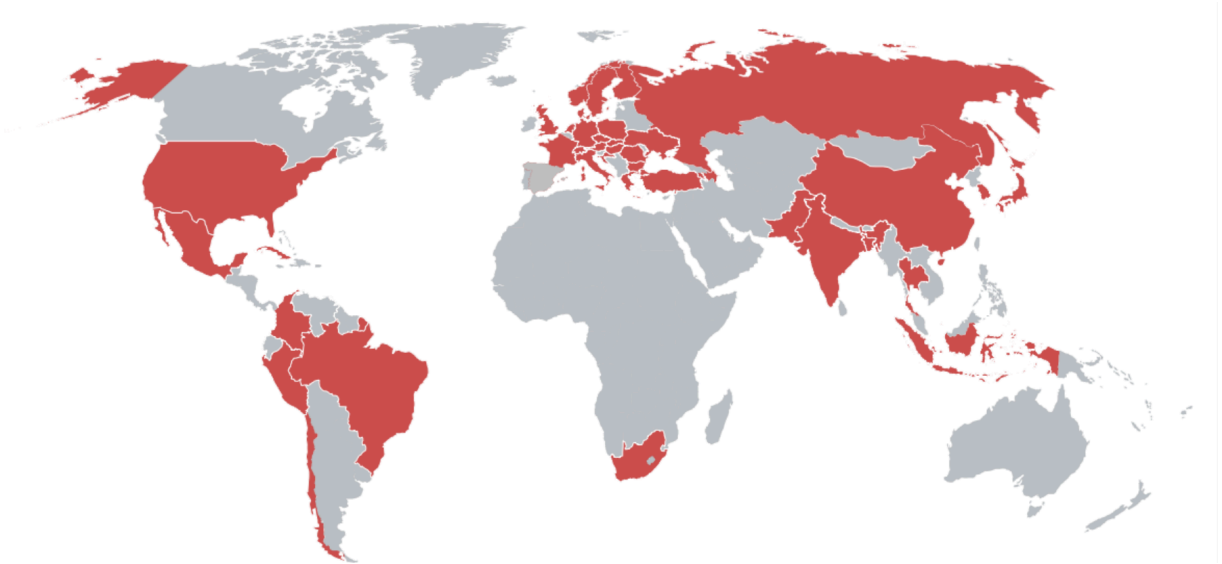
44th ALICE RRB, 25 April 2018

Contents

- Collaboration news
- News from Point 2
- Computing update
- Physics update
- Upgrades update
- Conclusions

Collaboration news

Participating Institutes (1992-2018)
176 INSTITUTES – 41 COUNTRIES



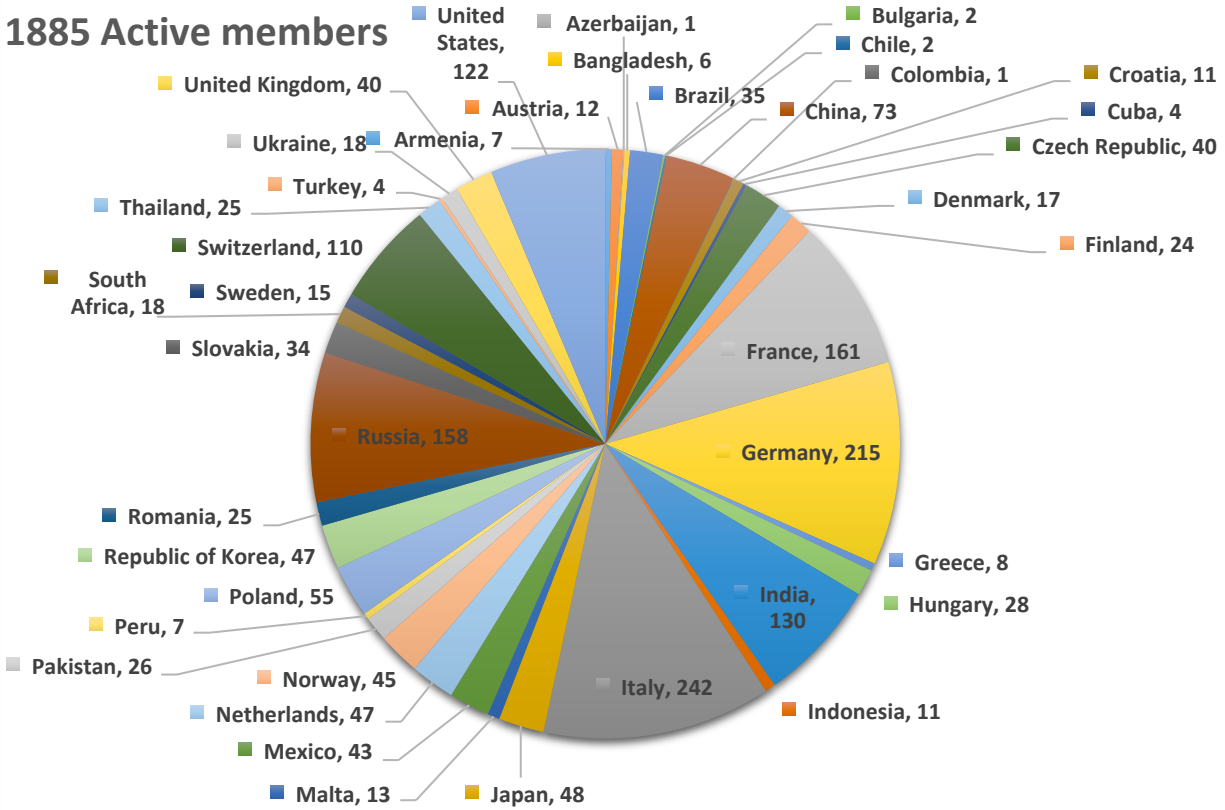
- new member institute: Università di Foggia (Italy)
- ongoing discussions with several groups
  - Bolivia, Chile, China, India, Kazakhstan, Malaysia

Source: Alice Collaboration data base, April 2018

The ALICE Collaboration

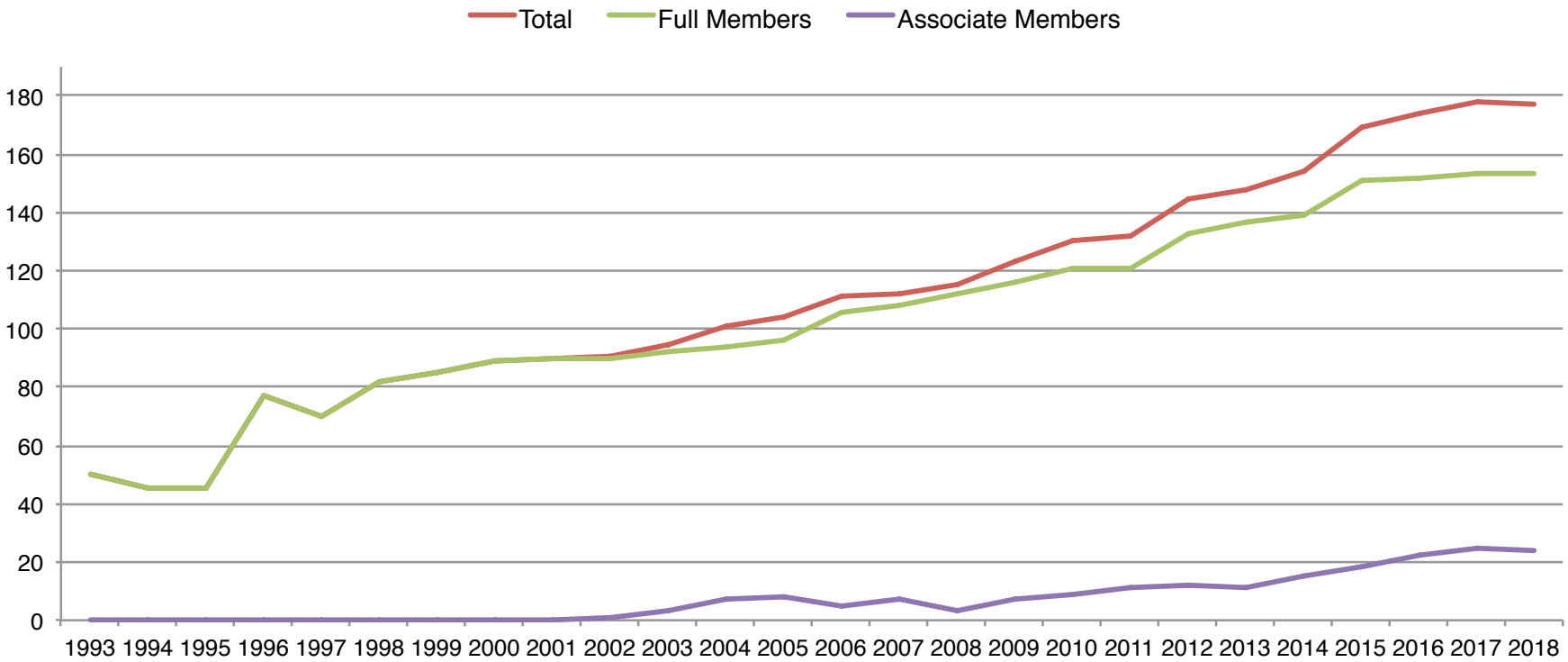
History of the ALICE Experiment:

- 1990-1996 Design
- 1992-2002 R&D
- 2000-2010 Construction
- 2002-2007 Installation
- 2008 -> Commissioning
- 4 TP addenda along the way:
  - 1996 Muon spectrometer
  - 1999 TRD
  - 2006 EMCAL
  - 2007 DCAL
- 2012 LoI for the Upgrade
- 2012-2014 R&D
- 2014-2016 Procurement/Fabrication
- 2016-2017 Integration, pre-commissioning
- 2018-2019 Installation, commissioning
- 2019-2020 Staged deployment of O2



Source: Alice Collaboration data base, April 2018

Participating Institutes (1992-2018)

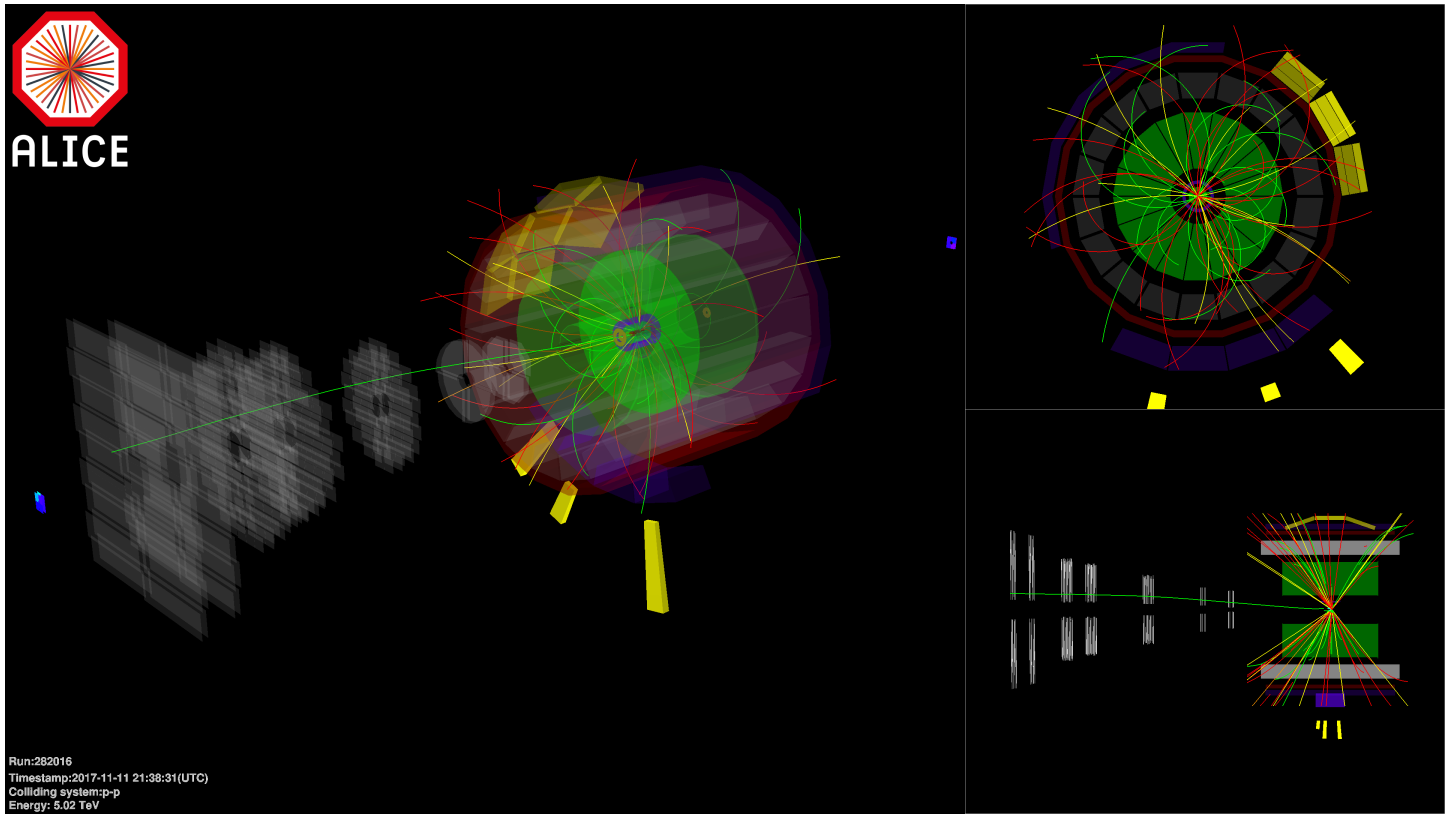


New appointments

- Run Coordinator: Kristjan Gulbrandsen (Copenhagen)
- Deputy Run Coordinator: Taku Gunji (Tokyo)
- Editorial Board: Grazia Luparello (Trieste)
- Editorial Board: Cvetan Cheshkov (Lyon)
- Conference Committee Member: Mateusz Ploskon (Berkeley)
- New PWG Conveners
  - Light Flavours: Stefania Bufalino (Politecnico di Torino)
  - Photons: Dmitry Peresunko (MEPHI Moscow)

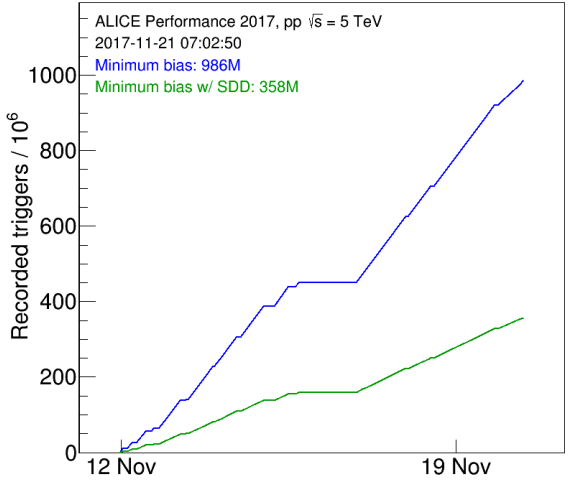
News from Point 2

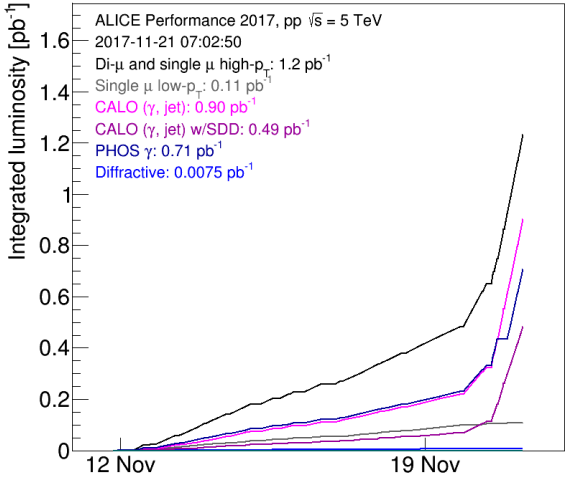
Since last RRB: 5.02 TeV pp run



Data taking @ 5.02 TeV

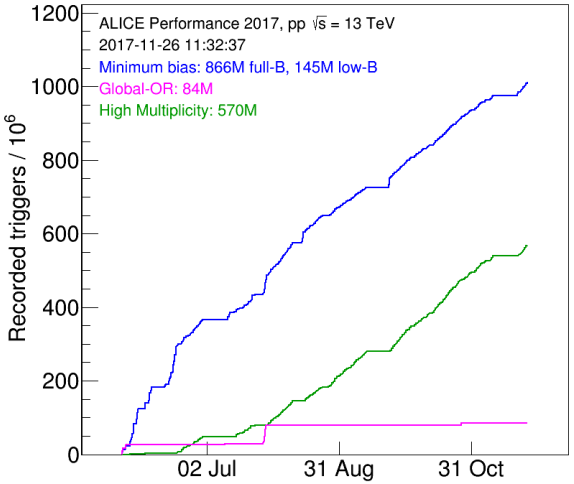
- reference data for low-p_T physics
  - same √s as Pb-Pb, p-Pb
- 11 – 21 November 2017
- nominal running conditions:
  - β* = 10 m
  - instantaneous lumi: 1 Hz/μb
  - dipole/solenoid polarity: -/-
- trigger menu
  - min-bias + muon, calorimeters
- mission completed!
  - 986M min-bias events
  - 1.2 / pb muon triggers
  - 0.9 / pb calorimeter triggers

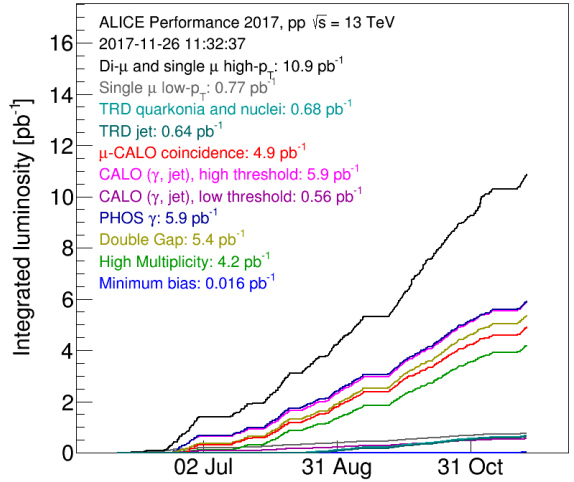




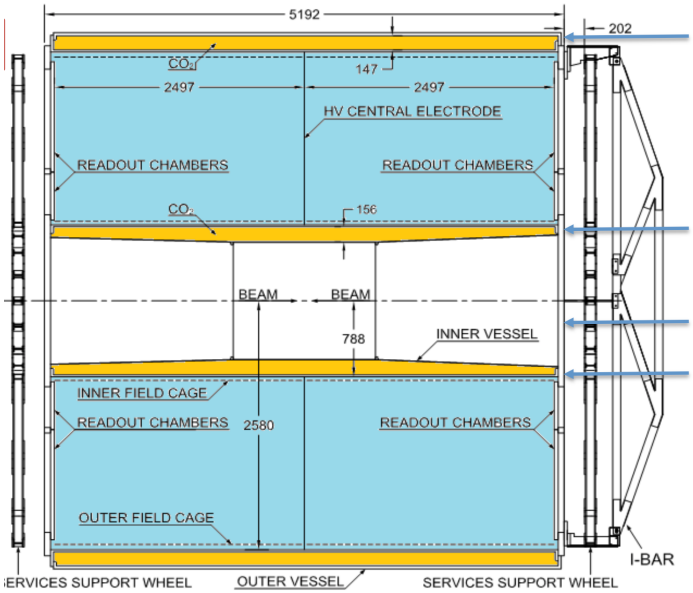
Data taking @ 13 TeV – wrap-up

- nominal running conditions:
  - β* = 10 m
  - instantaneous lumi: 2.6 Hz/μb
  - pile-up ~ 1.6%
- rich trigger menu
  - calos, muons, TRD, diffractive, hi-mult, min-bias, …
- goals met:
  - 10.9/pb muons
  - 5.9/pb central barrel
  - 866M min-bias full B field events
  - 570M high-multiplicity events



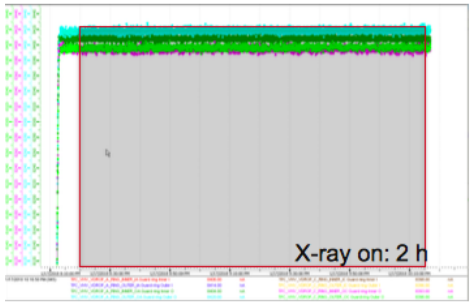


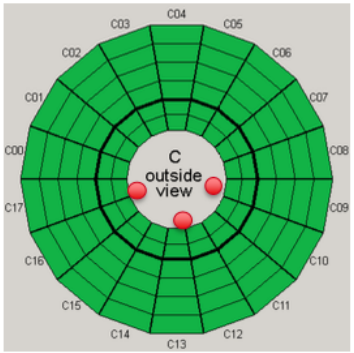
Cleaning of TPC field cage insulation volume
Main activity during YETS

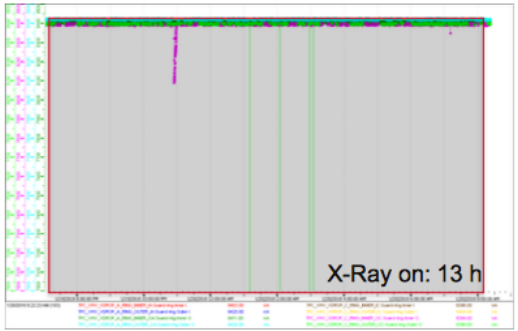


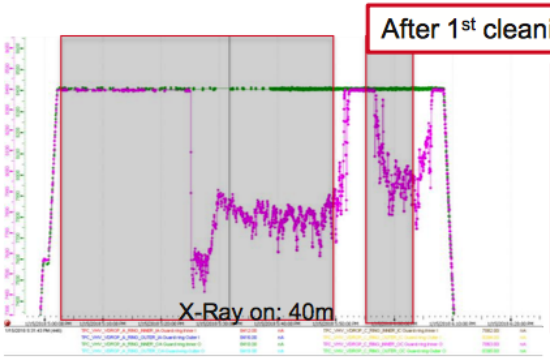
- leakage current observed at high rates: suspect dust in the insulation volume

Effect can be reproduced with X-rays









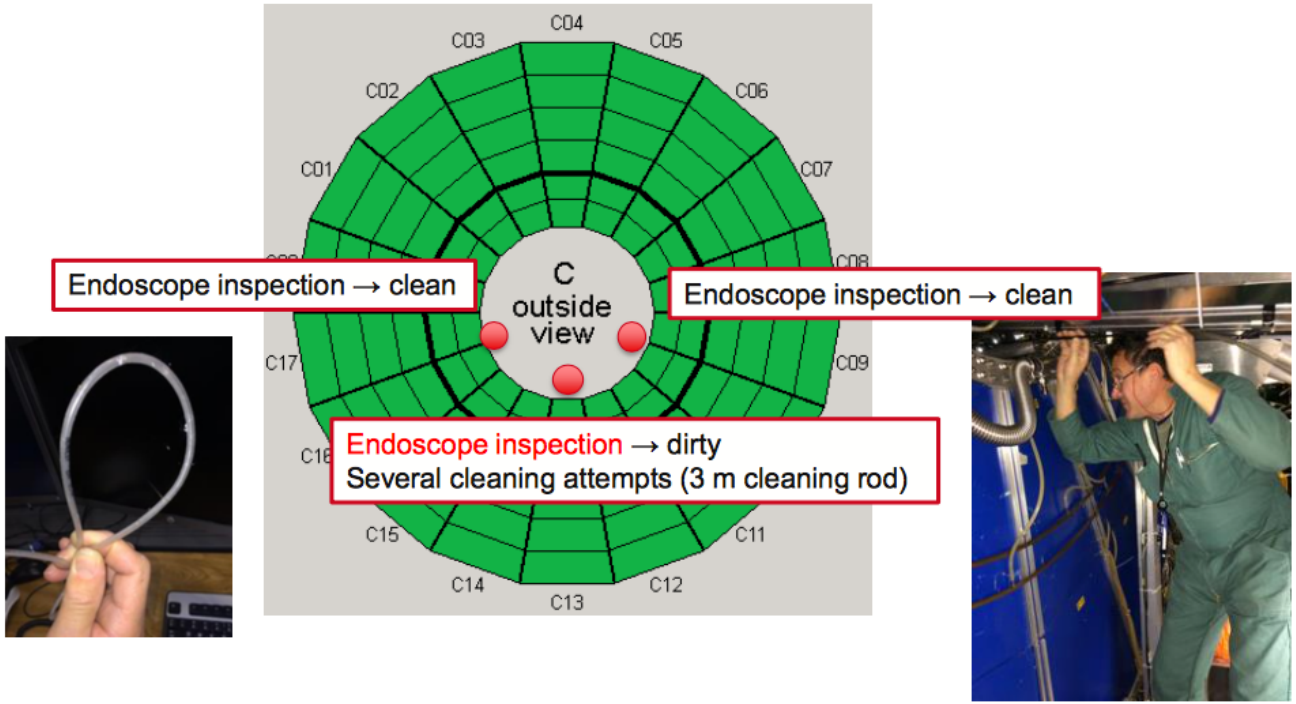
No/Negligible extra current in clean regions

How can bottom part be improved?

C-Side
A-Side

- X-ray irradiation shows leakage currents at the bottom, where dust has accumulated

Endoscope cleaning campaign

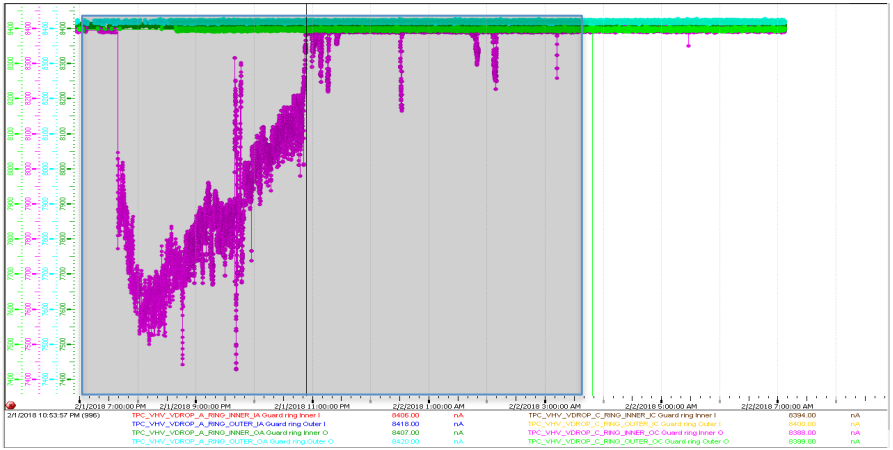


- access only through 8 mm holes!

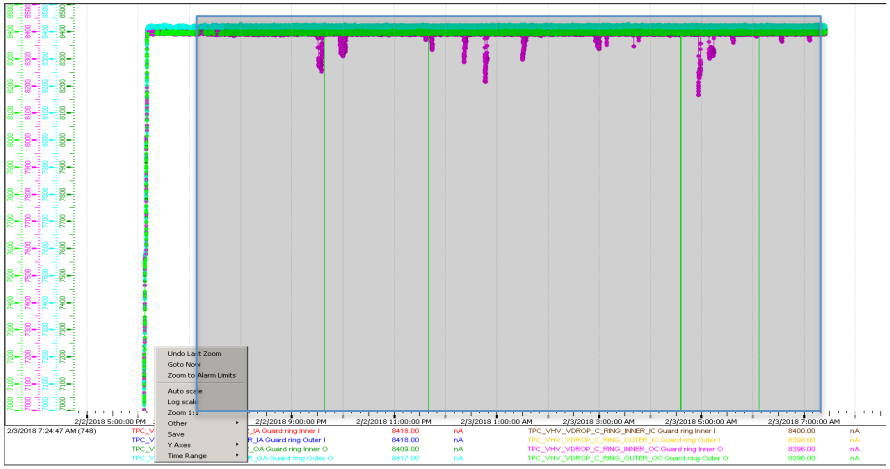
Cleaning works!

(example)

before cleaning

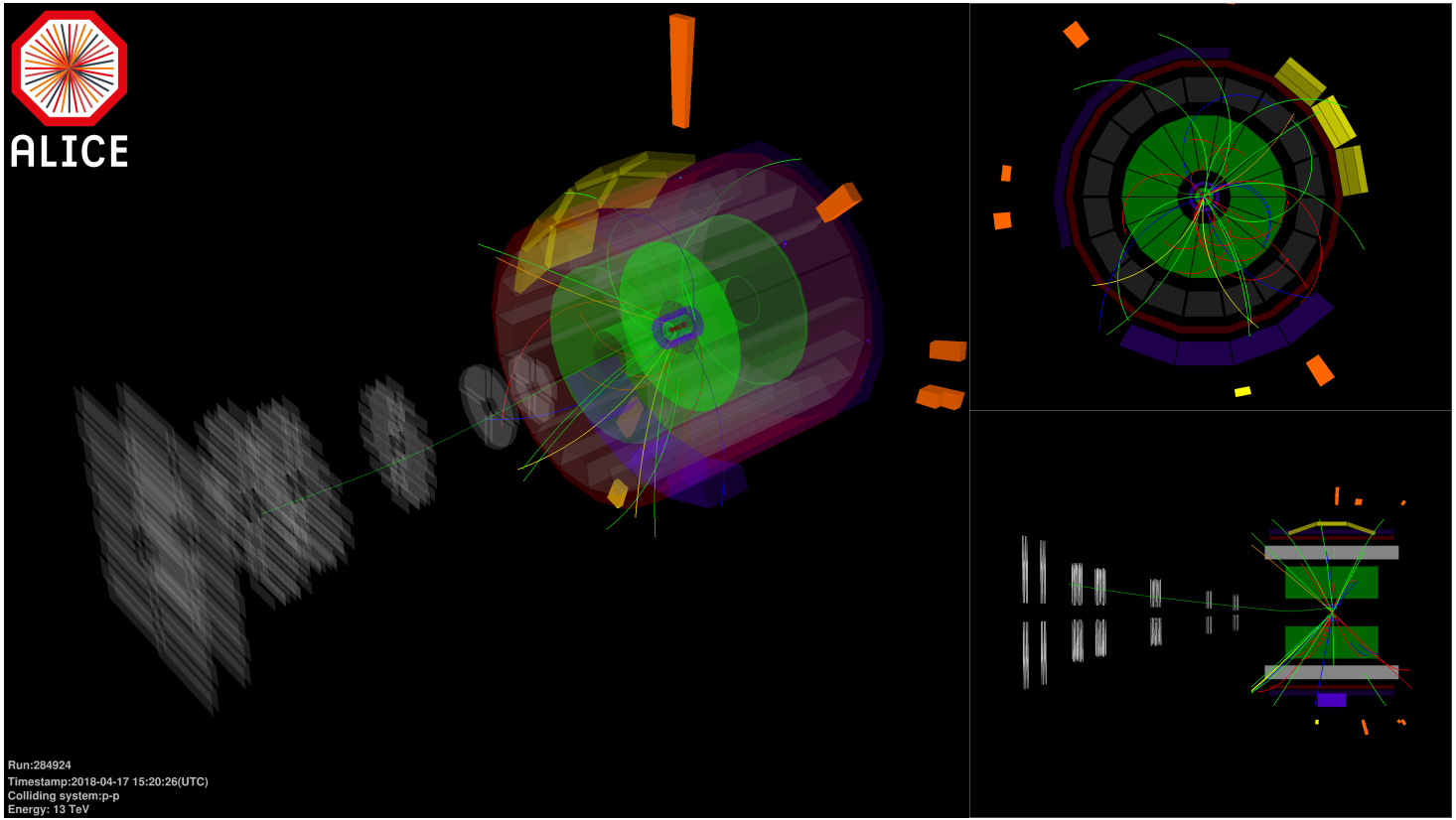


after cleaning



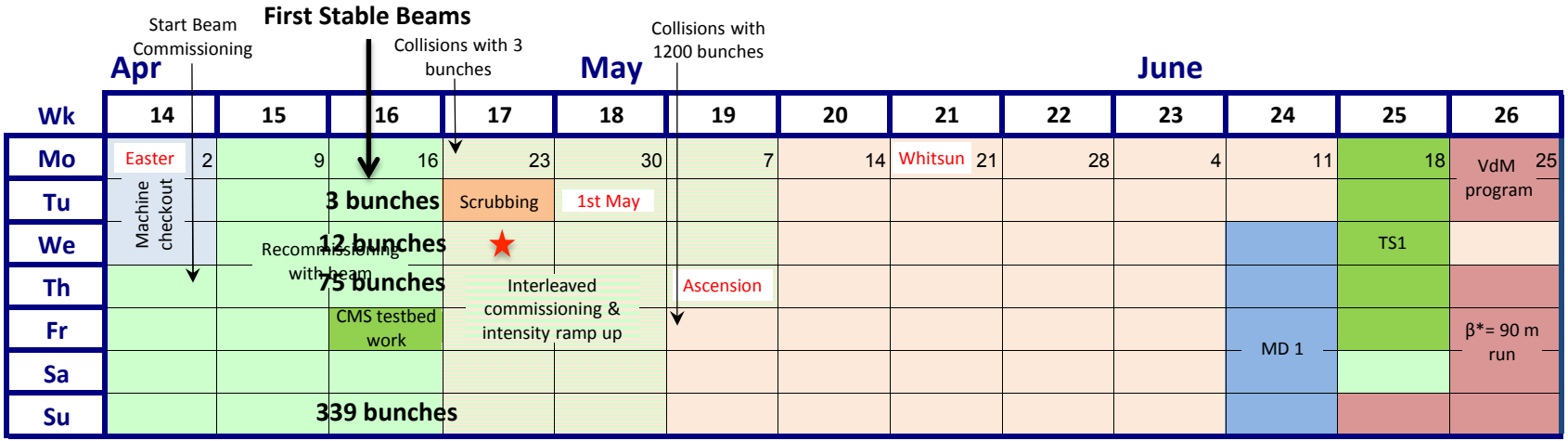
- leakage currents significantly reduced by cleaning
- full cleaning campaign scheduled for LS2

Now: pp @ 13 TeV, 2018 Campaign



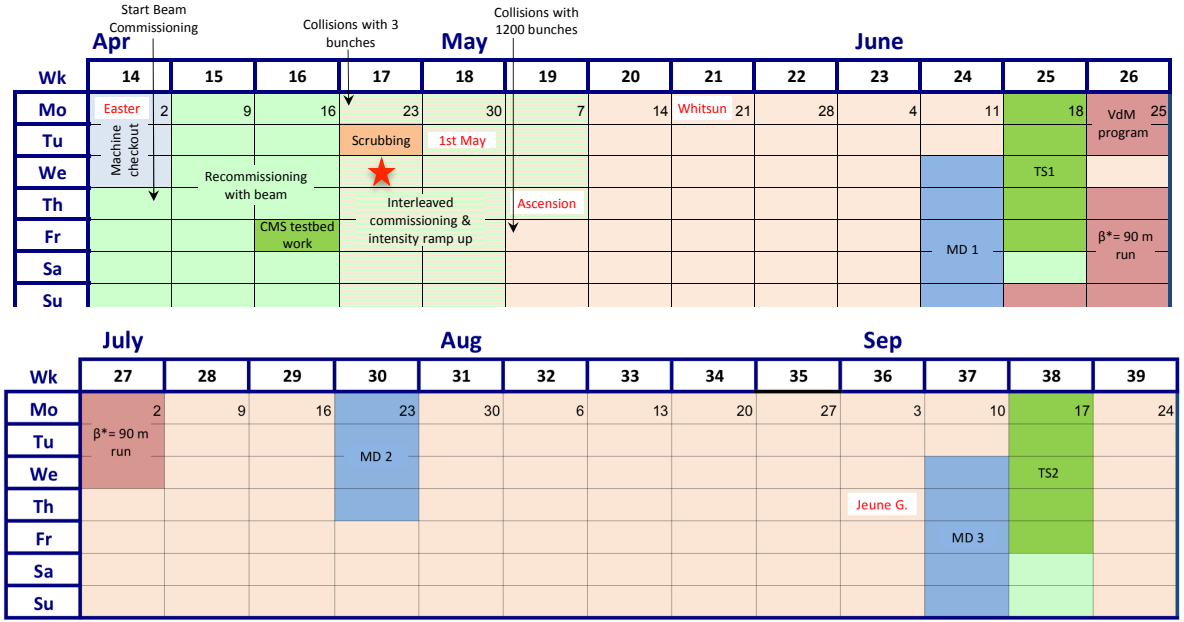
Data taking in 2018

Next schedule



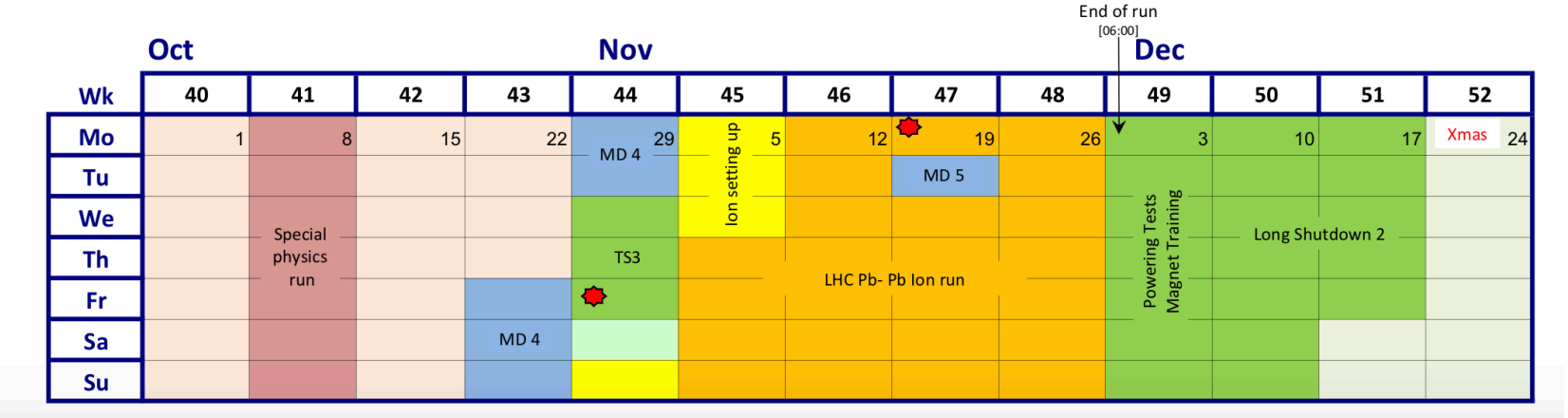
- stable beams came 1 week early
- intensity ramp-up ongoing
- now at 339 bunches in the machine

Data taking in 2018: pp



- goals: 15/pb muon triggers, 7/pb calo triggers, 1.1 G min-bias, 650 M high multiplicity

Data taking in 2018: Pb-Pb



- stress on central (head-on) collisions
- 300 M central + 240 M min-bias
- 890/μb muon triggers
- 240/μb calo/UPC triggers
- largest data set so far → ~ 30% ALICE data until LS2 to be collected this year!

Computing update

Computing

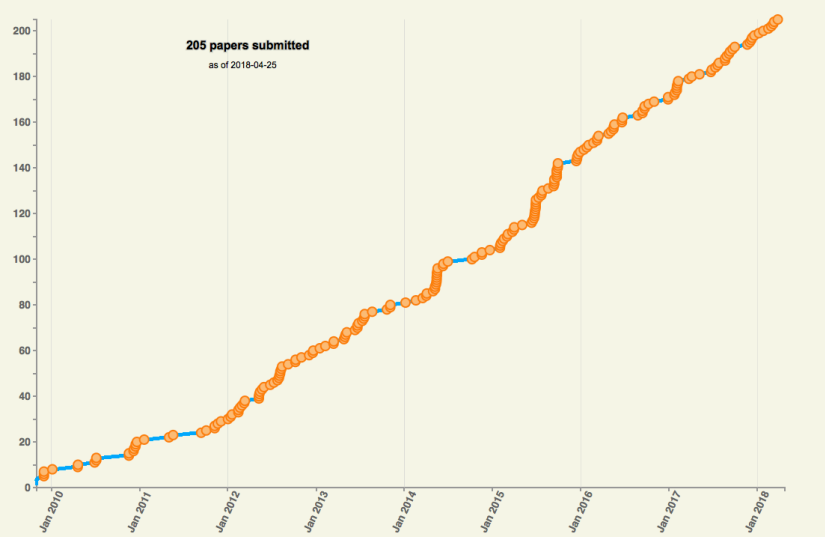
- all 2017 data replicated to T1s, calibrated and processed
- completed reprocessing of 2015, 2016 data
- significant effort in reduction of data footprints
  - event size compression
    - improved: 5 → 8.5 since start of Run 2
  - disk space management
    - 7.5 PB freed
- 2018 request reduced to match pledges
- 2019 request dominated by Pb-Pb 2018

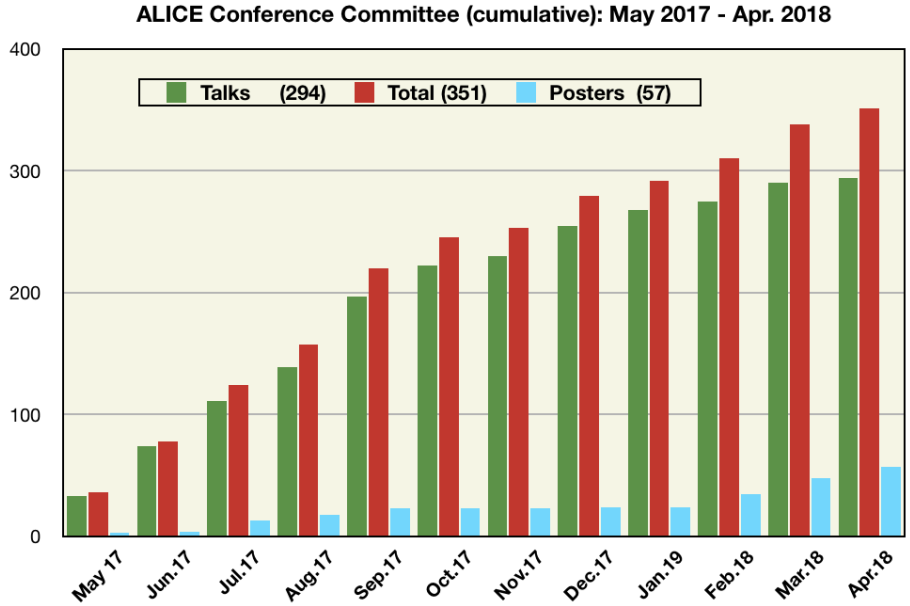
ALICE		2017			2018		2019		
		CRSG recomm.	Pledged	Used	CRSG recomm.	Pledged	Request	2019 req. /2018 CRSG	C-RSG recomm.
CPU	Tier-0	292	292	389	350	350	430	123%	430
	Tier-1	256	235.5	295	307	279.5	365	119%	365
	Tier-2	366	279.6	299	312.9	312.9	376	120%	376
	HLT	n/a	n/a	26	n/a	n/a	n/a	n/a	0
	Total	**914**	**807.1**	**1010**	**969.9**	**942.4**	**1171**	**121%**	**1171**
	Others			*39*					
Disk	Tier-0	22.4	22.4	19.3	26.2	26.2	34.3	131%	34.3
	Tier-1	25.4	21.8	18.245	30.5	30.4	37.9	124%	37.9
	Tier-2	31.4	22.7	20.06	29	29	33.9	117%	33.9
	Total	**79.2**	**66.9**	**57.6**	**85.7**	**85.6**	**106.1**	**124%**	**106.1**
Tape	Tier-0	36.9	36.9	29.7	49.1	49.1	44.2	90%	44.2
	Tier-1	30.9	30.6	22.3	40.9	42.2	37.7	92%	37.7
	Total	**67.8**	**67.5**	**52**	**90**	**91.3**	**81.9**	**91%**	**81.9**

Physics update

Physics output

- going strong!
  - 205 papers on arXiv
    - averaging 48 citations (excluding self-cites)
  - several hundred conference presentations each year





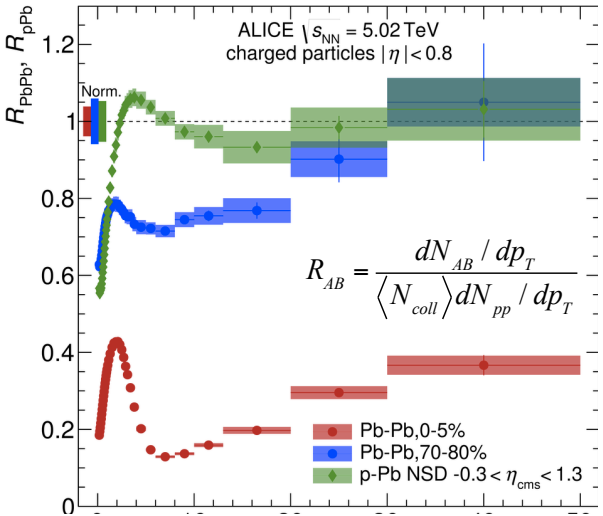
Some recent physics results…

Nuclear modification factors at high p_T

Measuring parton energy loss in the QGP (latest results)

charged particles

Pb-Pb central, Pb-Pb peripheral, p-Pb

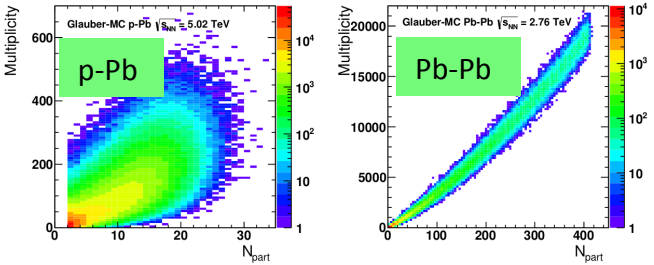


ALICE, arXiv:1802.09145

- collective effects in p-Pb
  - long-range correlations (v_2)
  - mass-dependence similar to Pb-Pb
  - stangeness enhancement pattern
- but still no evidence of jet quenching
  - system size, hence effect, smaller
  - but some predictions of sizeable effect, e.g.:
    Zakharov, J Phys G 41 (2014) 075008, arXiv:1311.1159
    Z B Kang et al, Phys Rev C92 (2015) 054911, arXiv:1507.05987
  - dependence on event activity is important!

Issue: normalisation for p-Pb centrality classes

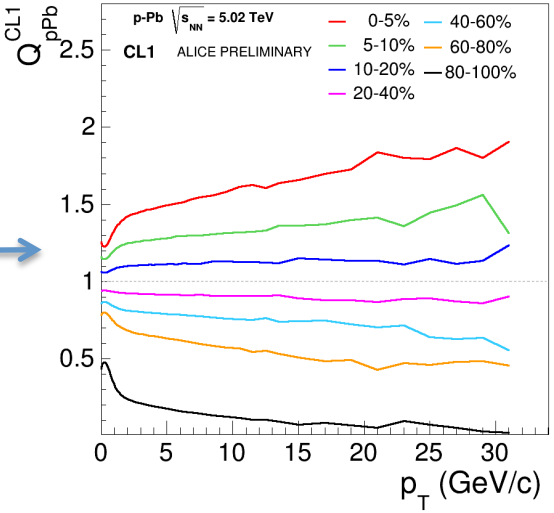
- no issue for min-bias p-Pb: $R_{pA} = \frac{dN_{pA}/dp_T}{\langle N_{coll}\rangle dN_{pp}/dp_T} = \frac{d\sigma_{pA}/dp_T}{A \cdot d\sigma_{pp}/dp_T}$



- but as soon as one slices on centrality → biases
  - multiplicity fluctuations, jet / jet veto
  - fundamental reason: correlation multiplicity <--> geometry much broader than in Pb-Pb

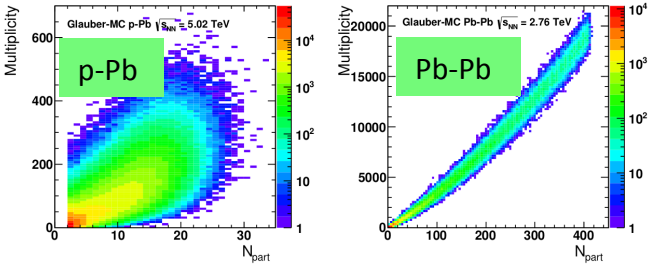
- for centrality slices: $Q^{i}_{pA} = \frac{dN_{pA}/dp_T}{\langle N_{coll}\rangle_i dN_{pp}/dp_T}$

- simple model (no quenching)
  - G-PYTHIA generator
  - standard centrality selection
  - standard Ncoll calculation



Issue: normalisation for p-Pb centrality classes

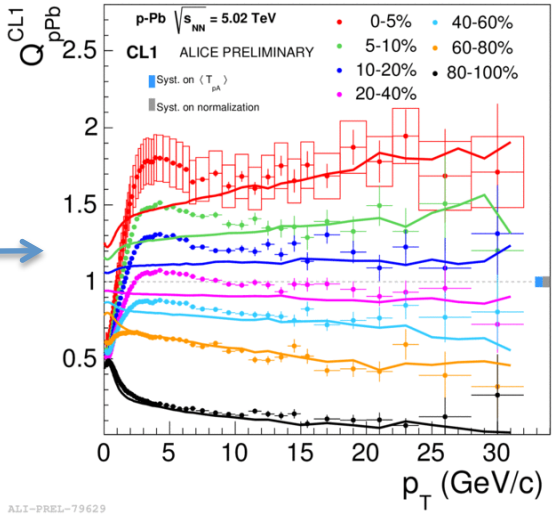
- no issue for min-bias p-Pb: $R_{pA} = \frac{dN_{pA}/dp_T}{\langle N_{coll}\rangle dN_{pp}/dp_T} = \frac{d\sigma_{pA}/dp_T}{A \cdot d\sigma_{pp}/dp_T}$



- but as soon as one slices on centrality → biases
  - multiplicity fluctuations, jet / jet veto
  - fundamental reason: correlation multiplicity <--> geometry much broader than in Pb-Pb

- for centrality slices: $Q^{i}_{pA} = \frac{dN_{pA}/dp_T}{\langle N_{coll}\rangle_i dN_{pp}/dp_T}$

- simple model (no quenching)
  - G-PYTHIA generator
  - standard centrality selection
  - standard Ncoll calculation

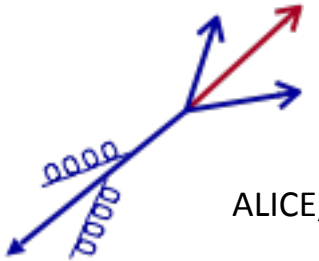


does well on the data!

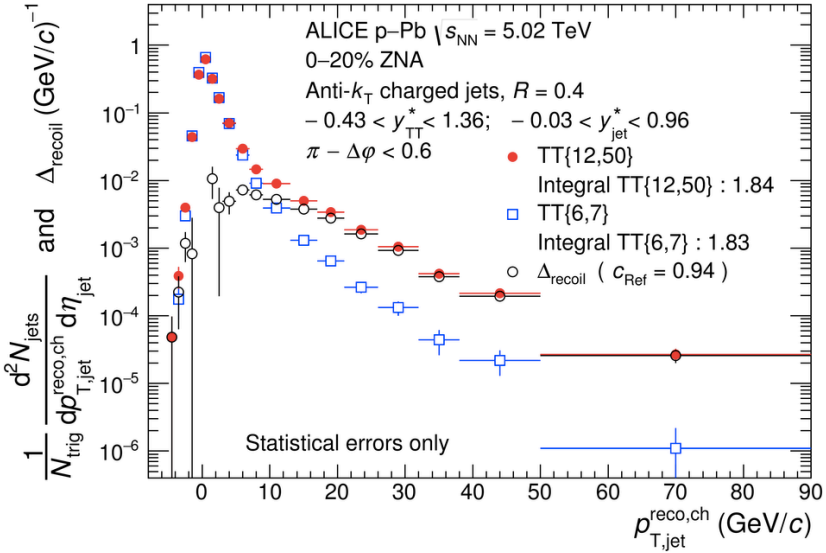
Different approach: self-normalised coincidence

- semi-inclusive recoil-jet distribution
- jets recoiling against a trigger high-pT hadron
- in different p-Pb “centrality” regions
- in order to subtract uncorrelated combinations:

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

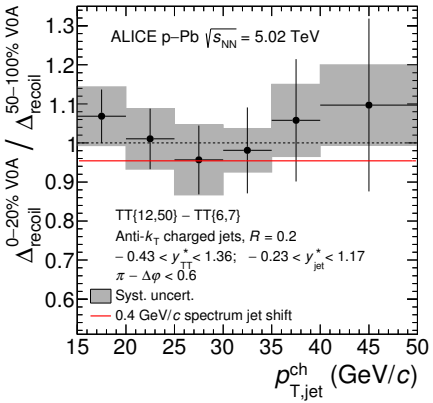


ALICE, arXiv:1712.05603



- divide central/peripheral

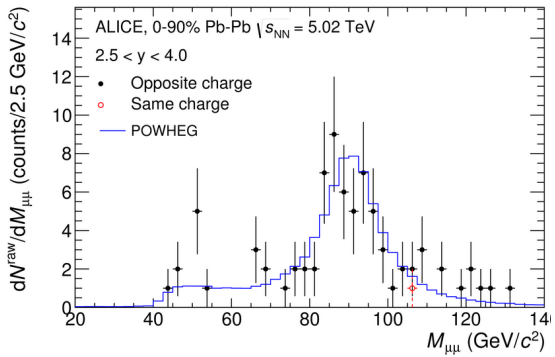
→ no significant modification



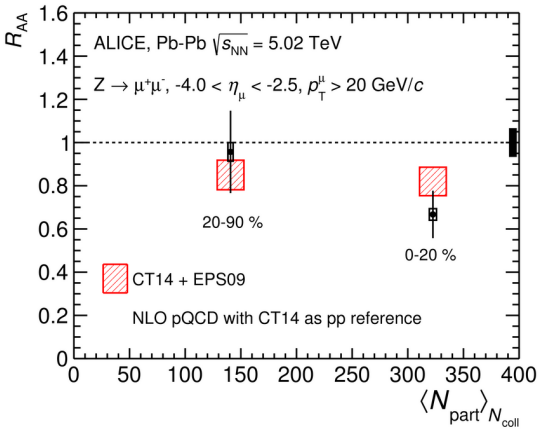
Z^0 boson production in Pb-Pb
Initial state: quark density

ALICE, Phys. Lett. B 780, 372

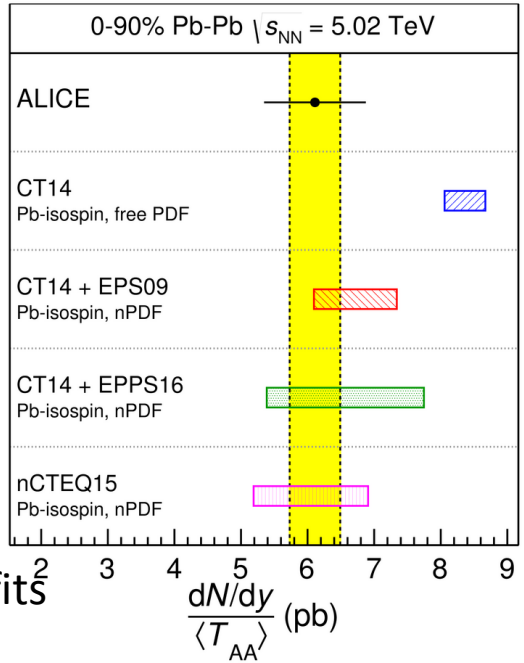
Di-muon mass distribution



Z nuclear modification factor



Comparison to theory with/without nuclear modification

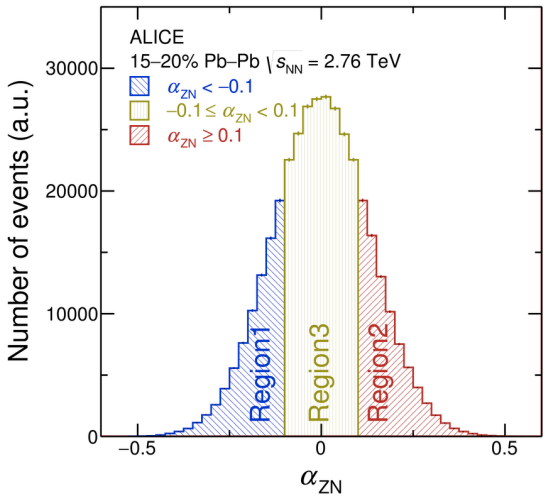


Sensitive to quark, gluon density in the nucleus

Yield suppressed by ~30%, in agreement with nuclear density fits

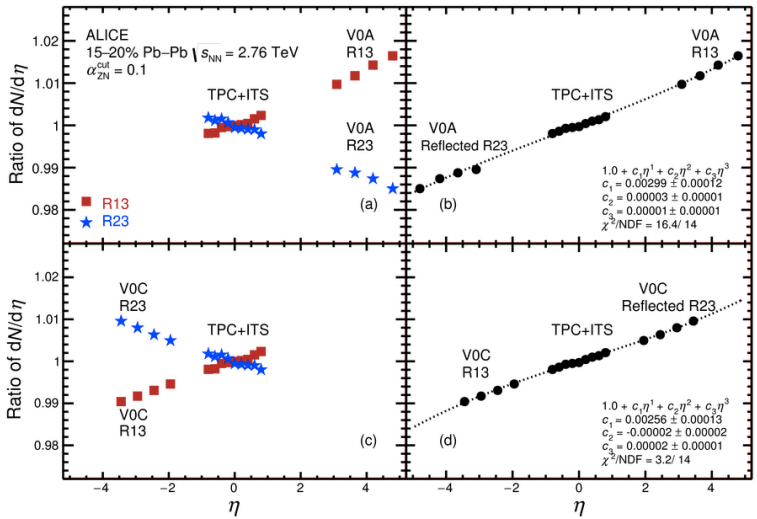
Exploring the initial state with energy imbalance

Energy imbalance in ZDC



Select asymmetric collisions
Using spectator nucleons

Rapidity spectra ratios



Longitudinal asymmetry in the initial state
leads to asymmetry in the distribution of produced particles

Quark Matter 2018

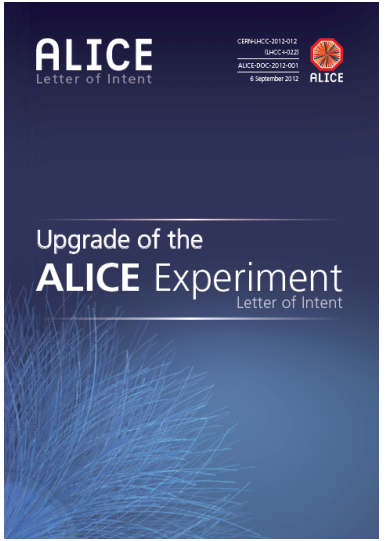
- 13-19 May (starts in 2.5 weeks!)
  - the “large attractor”
  - biggest conference in the field
- ALICE approval sessions ongoing
- 75 new results being processed now!

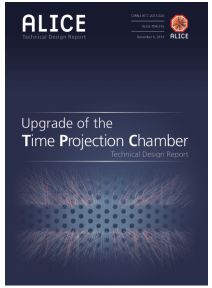
Update on upgrades

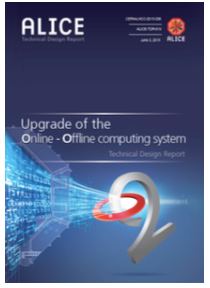
ALICE upgrades

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



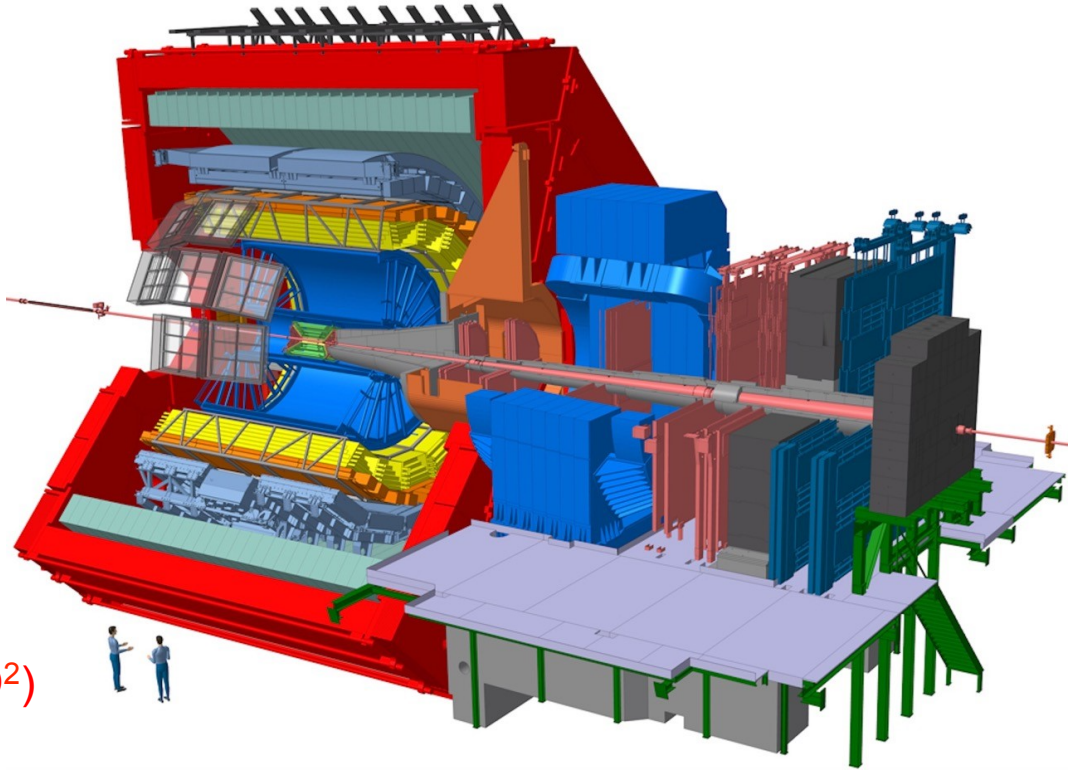




ALICE upgrades

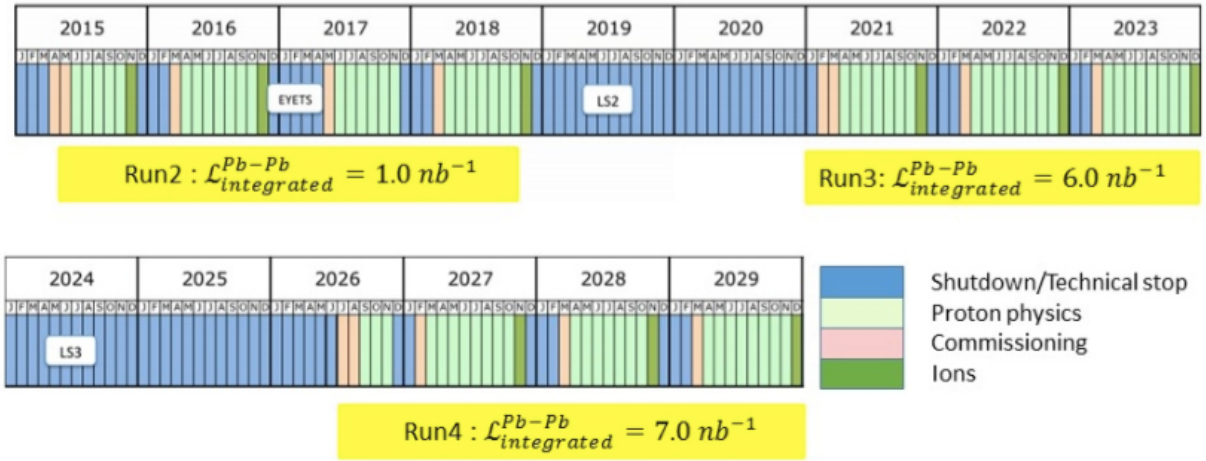
Layout

- 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 (FIT, AD)
  - + 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

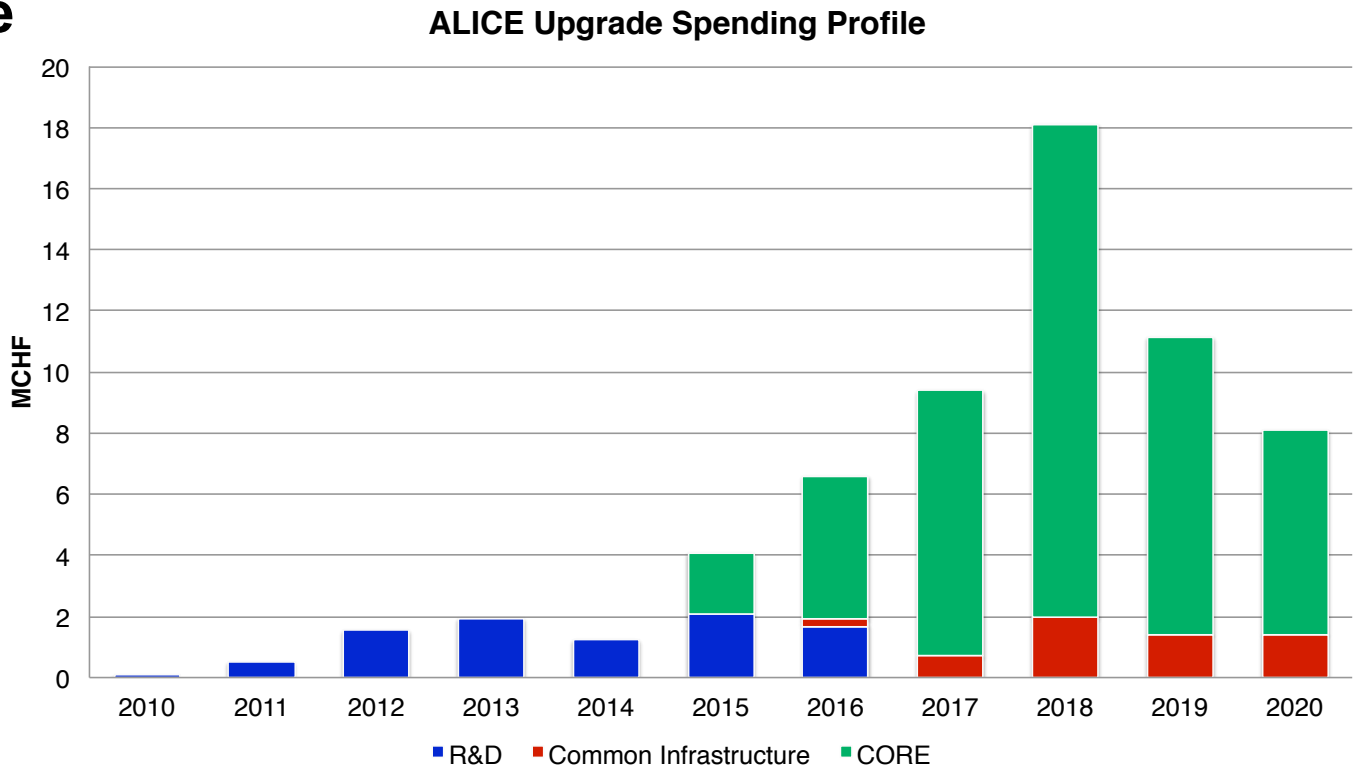
Timeline



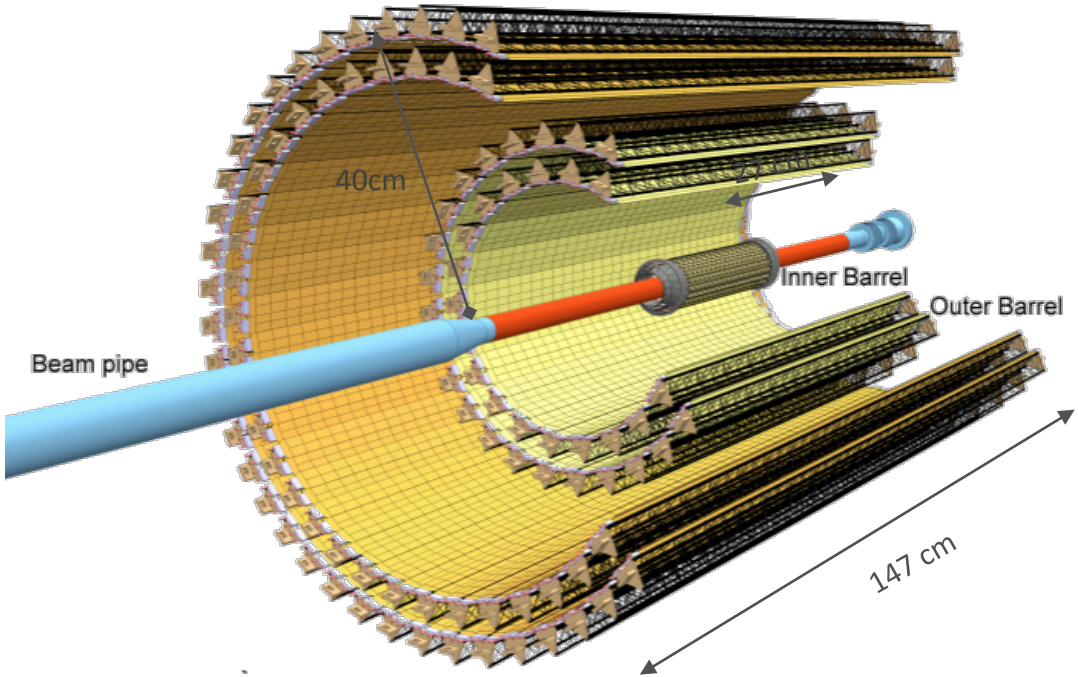
- LS2:
  - LHC injector upgrades, Pb-Pb rate → 50 kHz (now ~10 kHz)
  - ALICE upgrades
- Run 3 + Run 4:
  - experiments request > 10/nb (ALICE: 10/nb + 3/nb at 0.2 T)
  - in line with latest projections from machine group

ALICE UPGRADE
Cost and profile

ALICE upgrade subsystem	CORE cost (MSF)
1. ITS	15.1
2. TPC	12.5
3. MFT	3.4
4. Trigger & Readout	7.1
5. O2	9.8
6. Common fund for Upgrade	5.8
Total (MSF)	53.7
R&D costs MSF	9.01
GRAND TOTAL (including R&D)	62.7



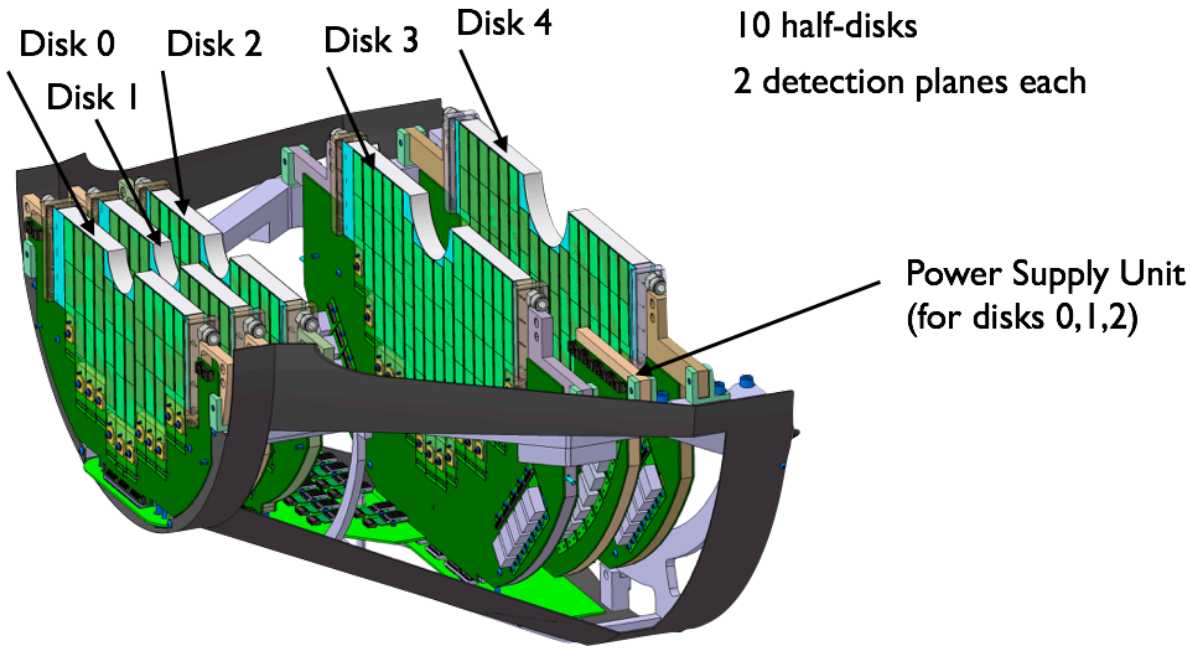
ITS Upgrade



Based on MAPS

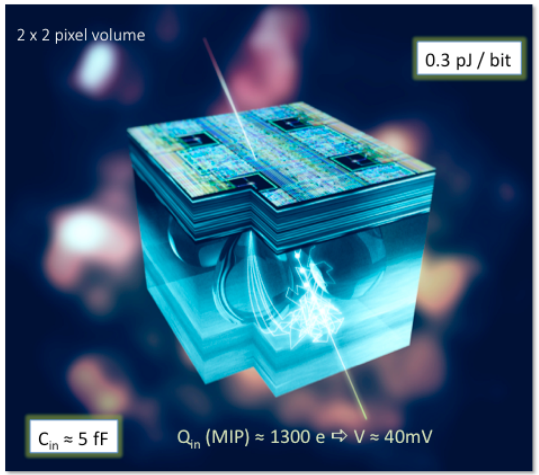
- 7-layer geometry (23 – 400mm), $|\eta| \leq 1.5$)
- 10 m^2 active silicon area (12.5 G-pixels)
- Pixel pitch 28 x 28 μm^2
- Spatial resolution ~5μm
- Power density < 40mW / cm^2
- Material thickness: ~0.3% / layer (IB)
- Max particle rate: 100 MHz / cm^2

New Muon Forward Tracker



- new Si pixel tracker
  - same technology as ITS
- in front of muon absorber
  - $2.35 < \eta < 3.6$
- 280 ladders
  - 2 to 5 sensors each
- 928 pixel sensors (0.4 m^2)
  - ~ 5% of ITS surface

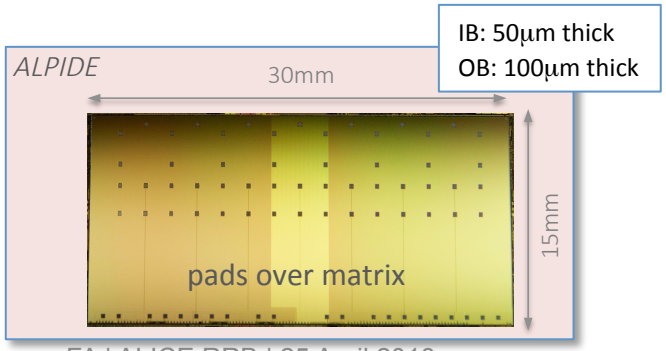
Production of Monolithic Pixel Chip



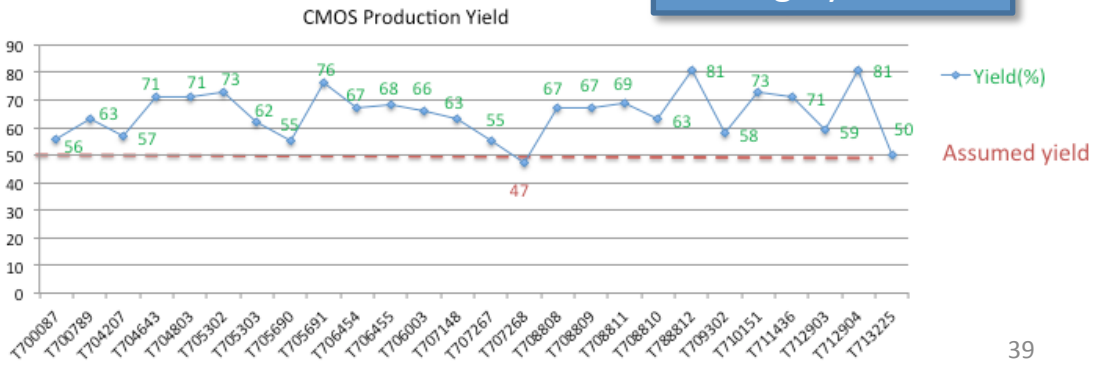
CMOS production completed

Production Status	Nr. wafers	Nr. chips
FINISHED	~1200	~55000

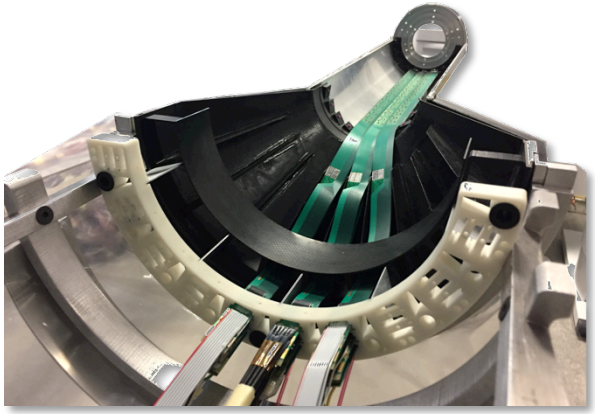
Series test ongoing: ~40% done

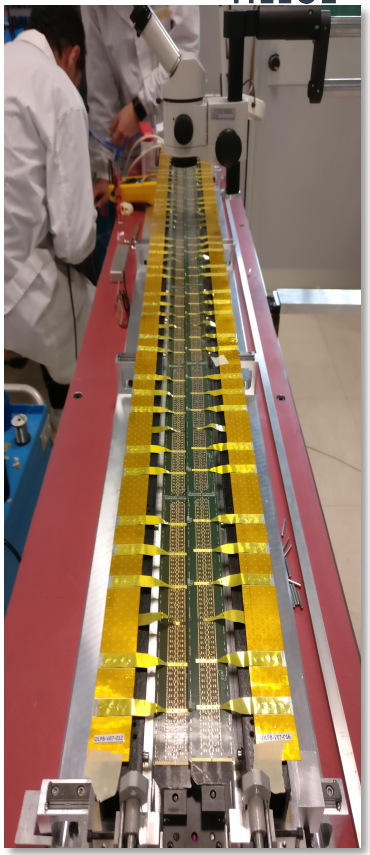


Average yield 60%



HIC and Stave Production





HIC Production (CERN, BARI, Liverpool, Pusan, Strasbourg, Wuhan)

- Production is progressing well (20% done) in all sites, will continue until Feb 2019
- Production yield: 82%, in line with projected value

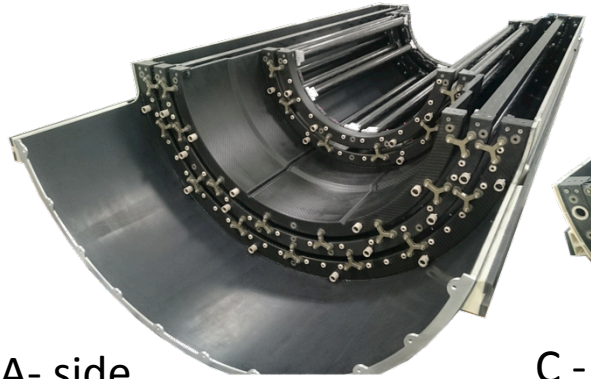
Stave Production (Berkeley, CERN, Daresbury, Frascati, Nikhef, Torino)

- Production has started in all sites (30 IB staves, 8 OB staves)
- Production will continue until April 2019

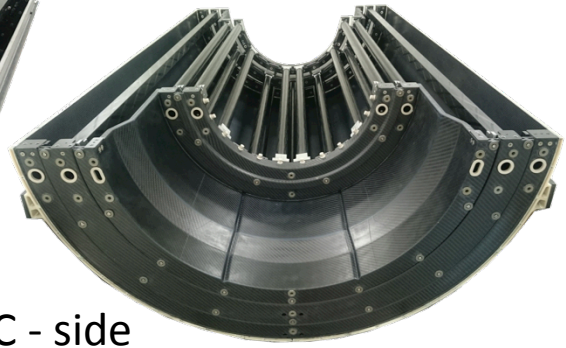
ITS Dry Assembly and Insertion Tests

Inner Barrel

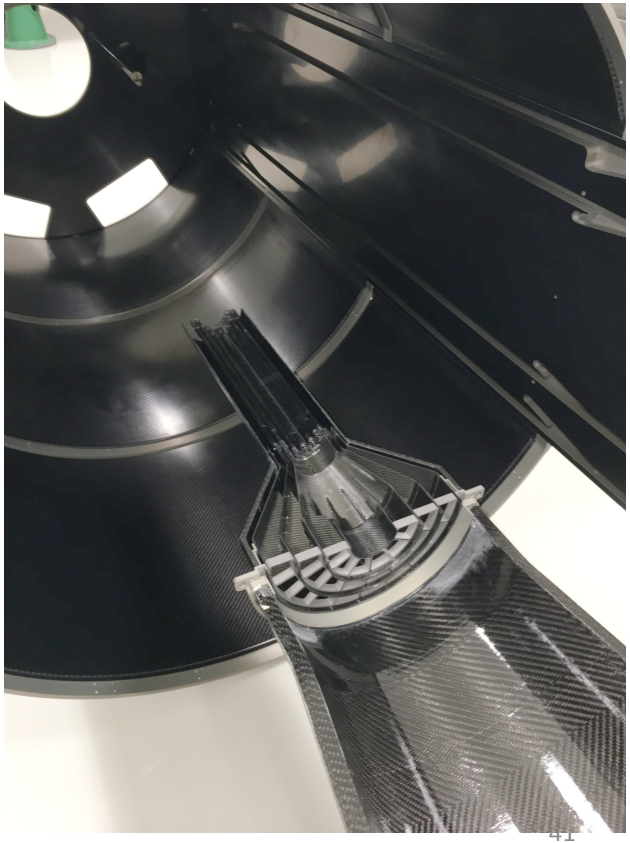
Outer Barrel



A- side



C - side



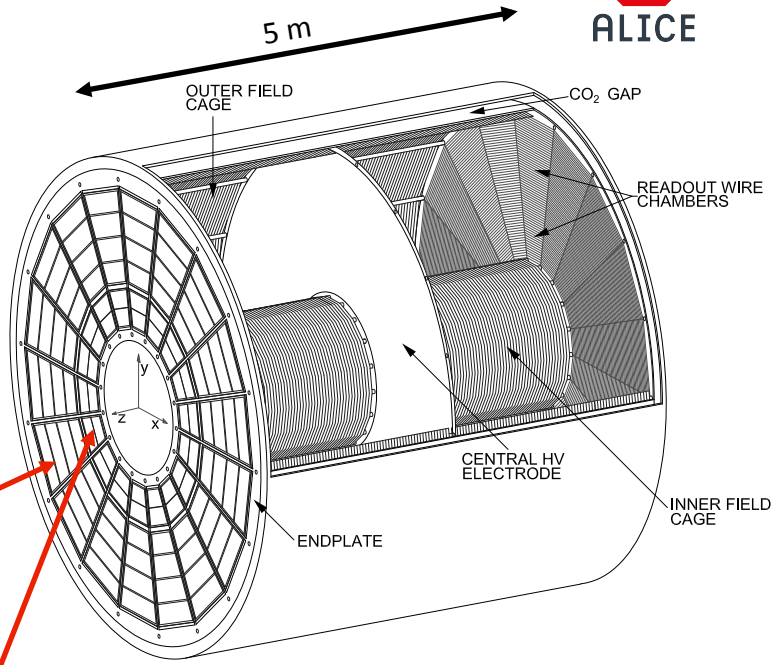
Clean room 167, assembly & commissioning hall: setting-up

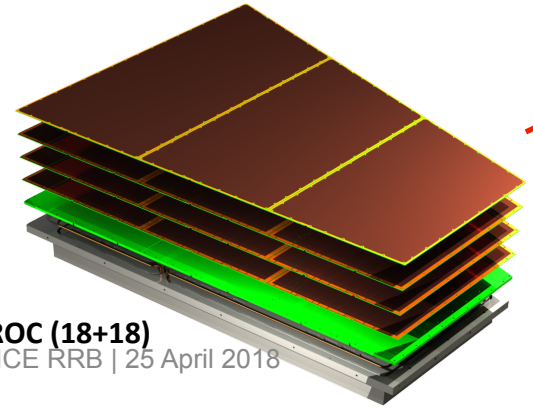
ITS Detector Mechanics assembly (1) ongoing, Insertion test (2) ongoing ; Cooling plant installation (3) WK5

TPC Upgrade

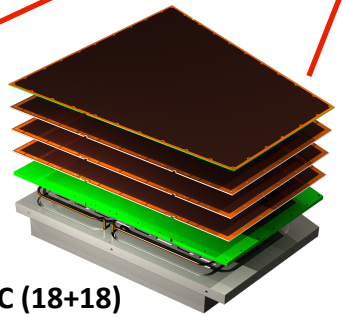
- Goal: replace existing MWPC-based Readout Chambers and Front-End Electronics in LS2 to allow **continuous readout** of Pb-Pb collisions at 50 kHz in RUN3 and 4

- Technical solution: **4-layer GEM** detectors

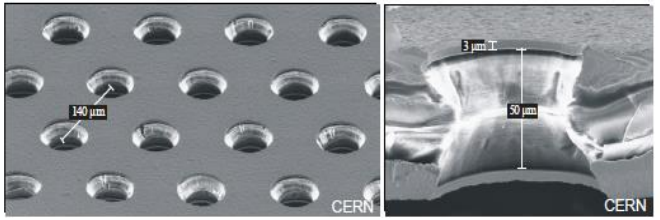




OROC (18+18)



IROC (18+18)

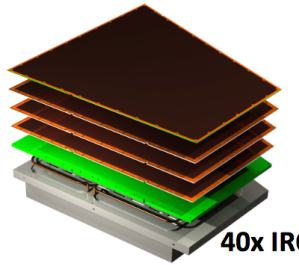


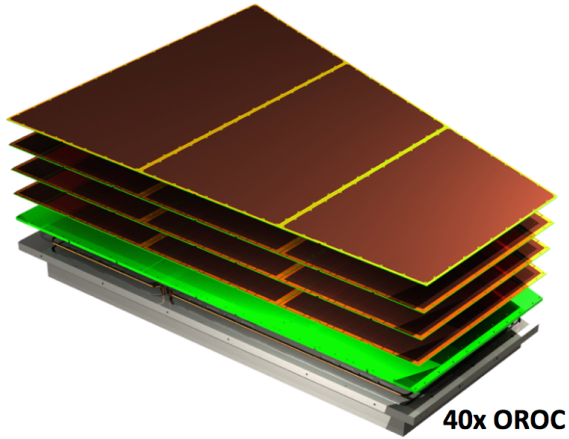
Electron microscope photograph of a GEM foil

Production progress

ROC components	Needed	Produced	Fraction
Al-bodies	80	80	100 %
Padplanes	160	160	100 %
FEC connectors	15'000	15'000	100 %
HV cables	1'300	1'300	100 %
GEMs	720 (10% spares)	580	81 %
GEM frames	640	640	100 %

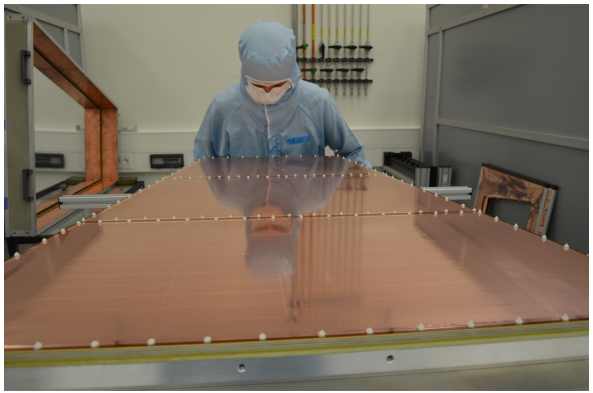
Assembly step	Goal	Assembled	Fraction
Chamber bodies (IROC/OROC)	40/40	27/22	61 %
Padplane + FEC connectors (IROC/OROC)	40/120	40/120	100 %
GEM framing	640	413	65 %
Assembled & Tested ROCs (IROC/OROC)	40/40	15/15	38 %

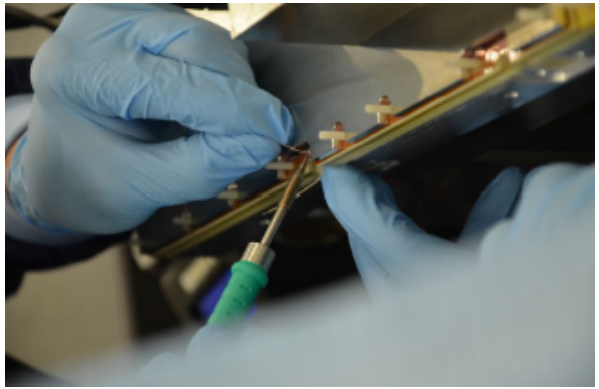

40x IROC


40x OROC

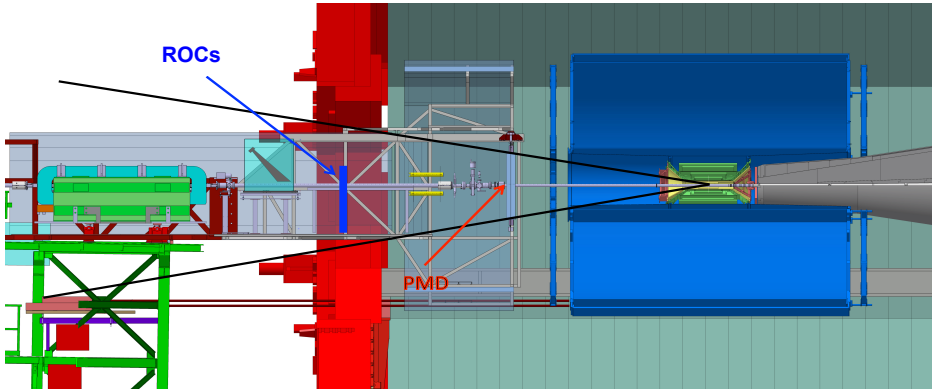
GEM and Readout Chamber production

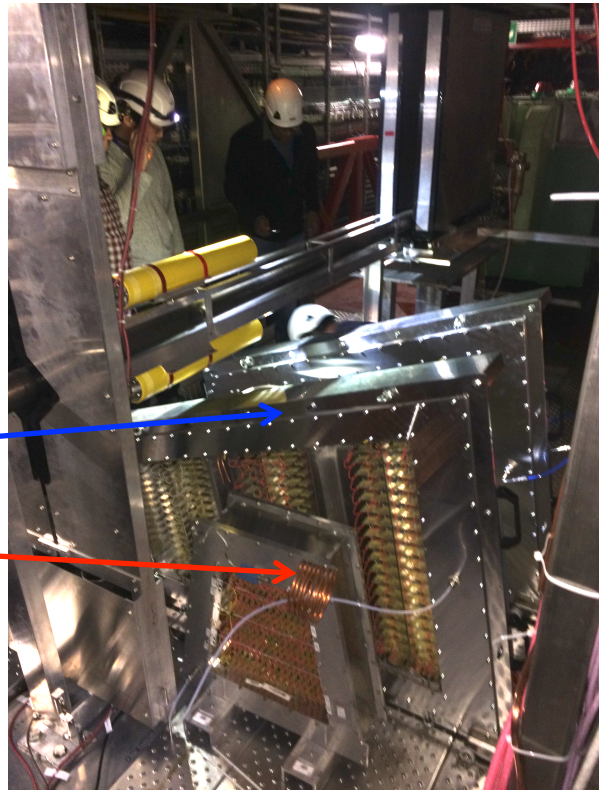
- **80% of GEM foils** produced in CERN PCB workshop (total 720)
- RO Chamber assembly ongoing, **32 final chambers (of 80)** completed and tested, 15 arrived at CERN
- **Completion** of Readout Chamber production expected in **October 2018**





ROC tests at P2

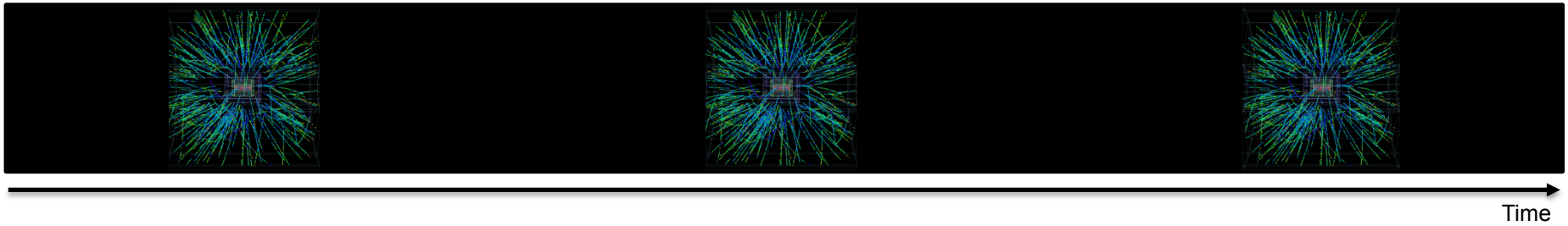




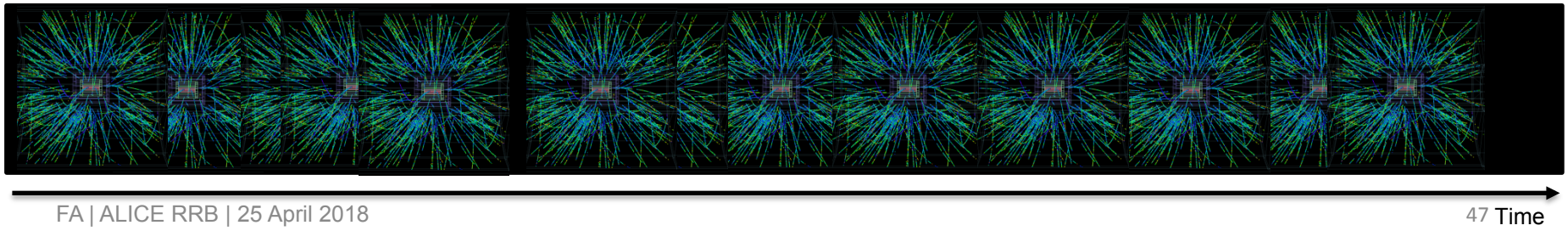
- Tests of IROCs and OROCs at P2 continue in 2018
- 2 IROCs and 2 OROCs recently installed, test ongoing

TPC at high rate

- currently: average time between collisions ~125 μs ~ TPC drift time
  - 1 event in TPC at any given time → triggerable

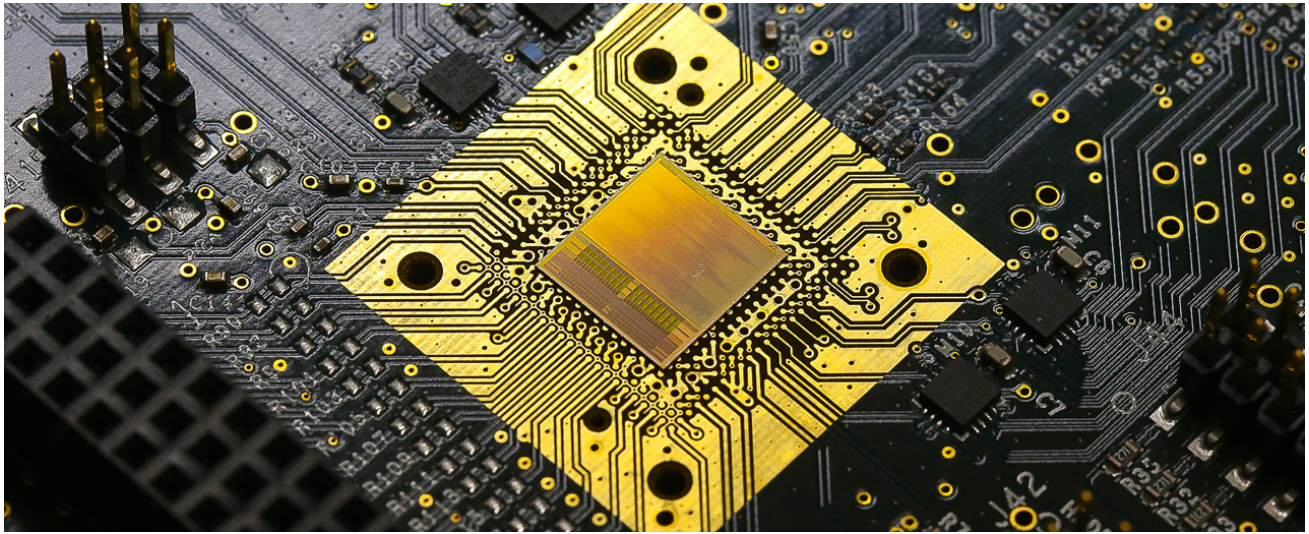


- after upgrade: average time between collision ~ 20 μs << TPC drift time
  - 5 events in TPC at any given time → continuous readout



The SAMPA ASIC

- custom ASIC for readout of the ALICE TPC and Muon Chambers



- designed and financed in Brazil (USP, FAPESP)

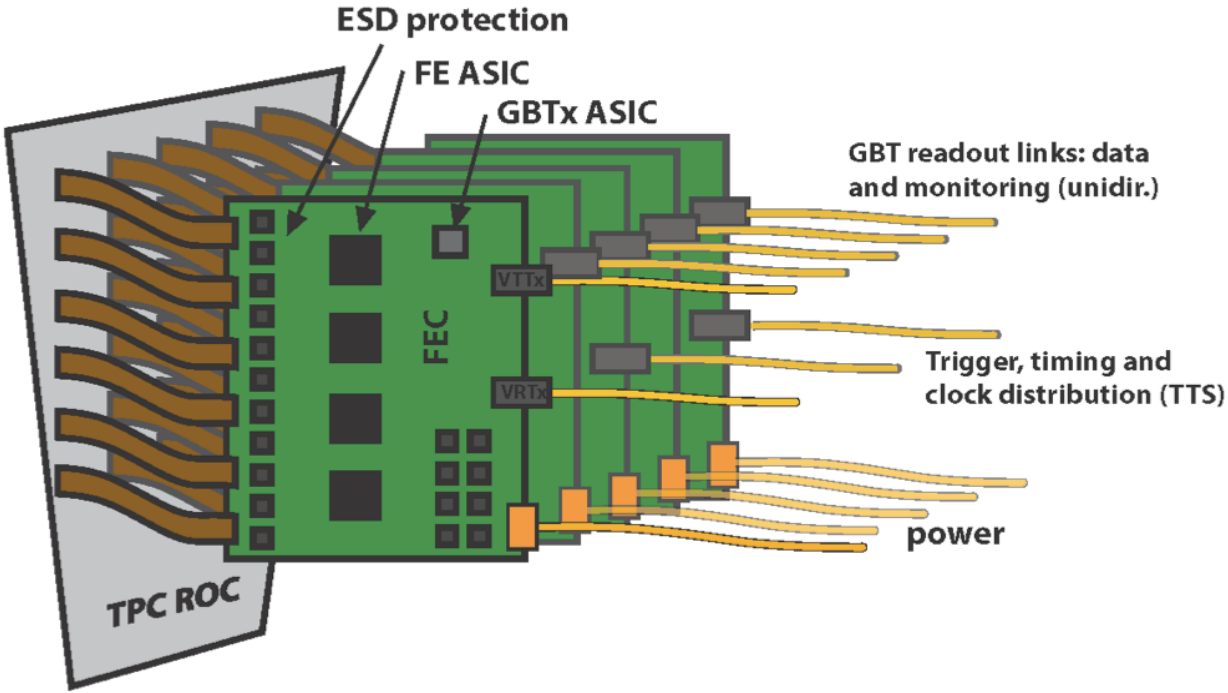
SAMPA specifications

- TSMC CMOS 130 nm, 1.25 V technology
- 32 channels, Front-end + ADC + DSP
- package size ≤ 15 x 15 mm^2
- ADC: 10-bit resolution, 20 MS/s, ENOB > 9.2
- DSP functions
  - pedestal removal, baseline shift corrections, zero-suppression
- read-out via up to 11 e-links at 320 Mbps
- Power < 32 mW/channel (Front End + ADC)

TPC Mode	MCH Mode
▪ Negative Input charge	▪ Positive input charge
▪ Sensor capacitance: 12 – 25 pF	▪ Sensor capacitance: 40–80 pF
▪ Sensitivity: 20mV/fC & 30mV/fC	▪ Sensitivity: 4mV/fC
▪ Noise: ENC ≤ 580 e^- @ 18.5pF	▪ Noise: ENC ≤ 950 e- @ 40pF 1600 e- @80pF
▪ Peaking time: ~160 ns, return to	▪ Peaking time: ~300 ns
▪ Baseline return: <500 ns	▪ Baseline return: <550 ns

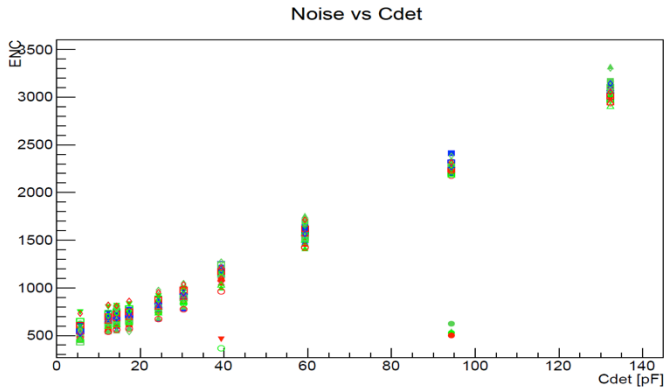
TPC front-end card

- 524000 channels @ 50 kHz read-out rate
- 3276 front-end cards & ~ 16380 front-end ASICs (SAMPA)



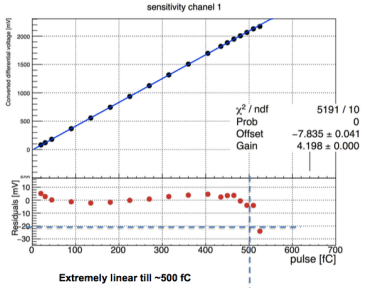
Status

- Production Readiness Review on 20/2
  → fully successful
- production started in March
  - 22 wafers → 5500 ASICs
- ~ 500 ASICs tested
  - yield > 80% (70% budgeted for)
  - automated test bench (incl. robot)
- noise as from specs

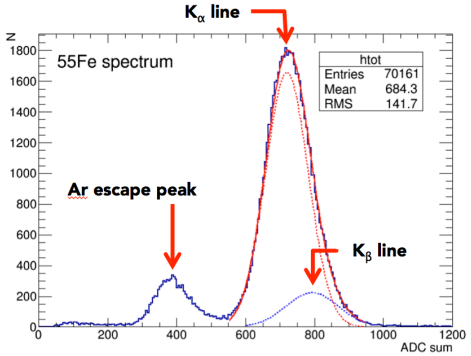


- very high linearity

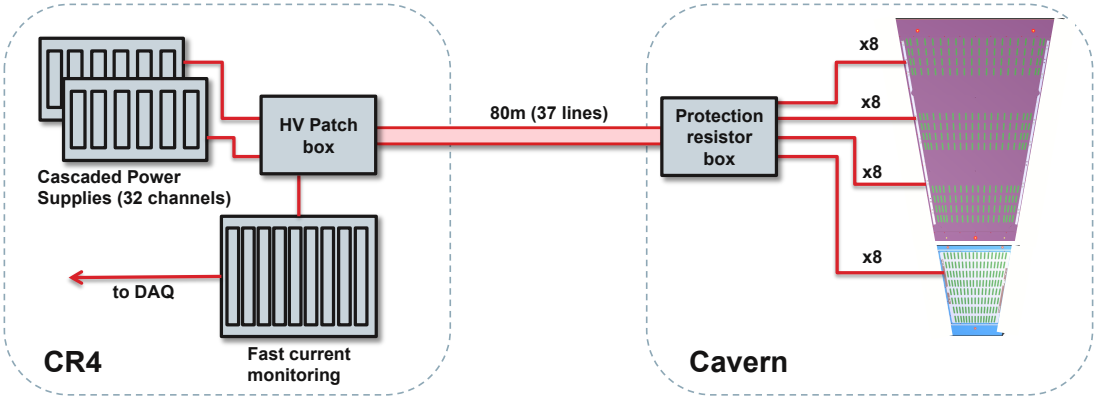
SAMPA V3 #S059 MCH@4mV/fC



- first Fe spectrum!



TPC GEM HV System



- GEM HV scheme with multi-channel cascaded power supplies and fast current monitoring system
- Final setup successfully tested with ROCs at P2 in 2017
- EDR/PRR passed in 11/2017
- All components ordered in 3/2018

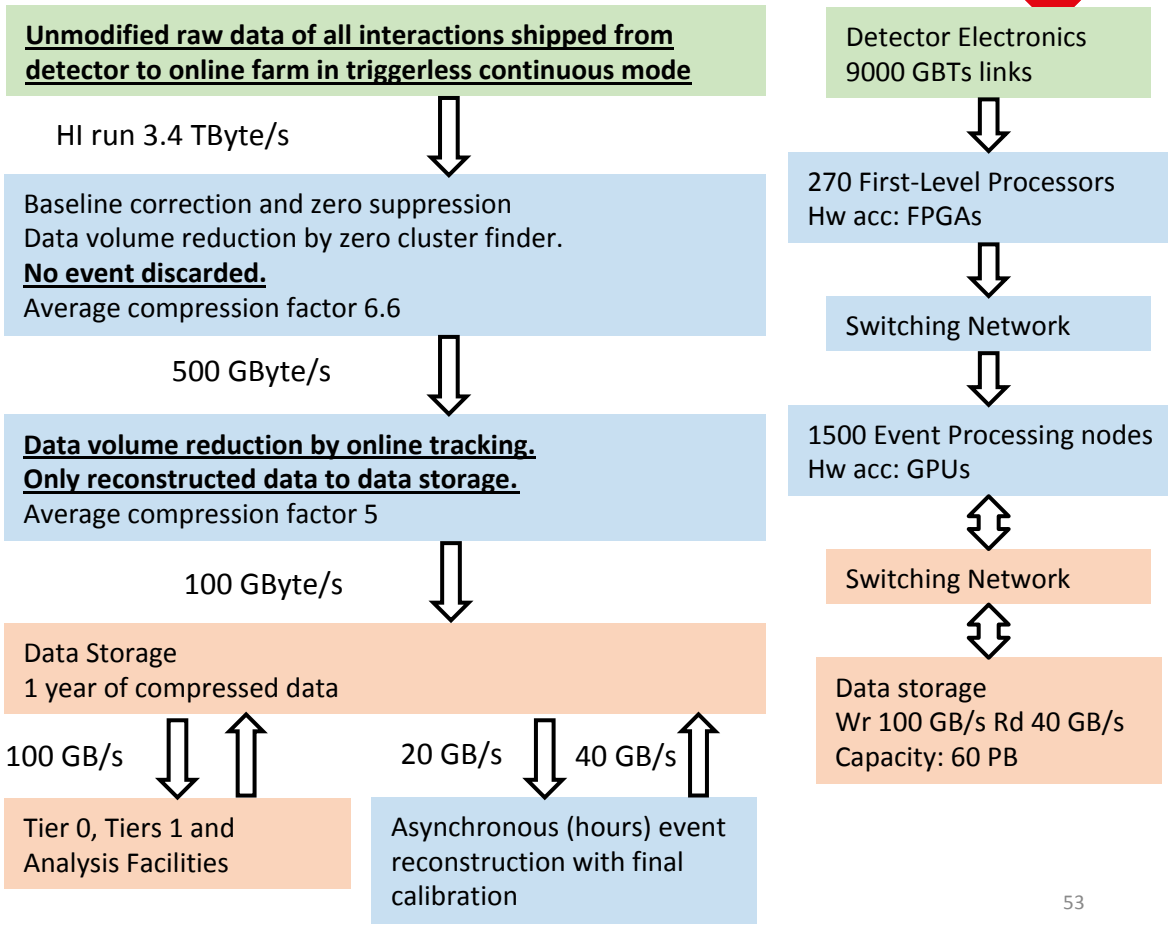
O^2 System

Requirements

1. LHC min bias Pb-Pb at 50 kHz
2. very small signal over background
   → triggering not possible
3. support for continuous read-out

New computing system

➔ read-out the data of all interactions
➔ compress data intelligently
   → online reconstruction
➔ common online-offline computing system
   → O^2



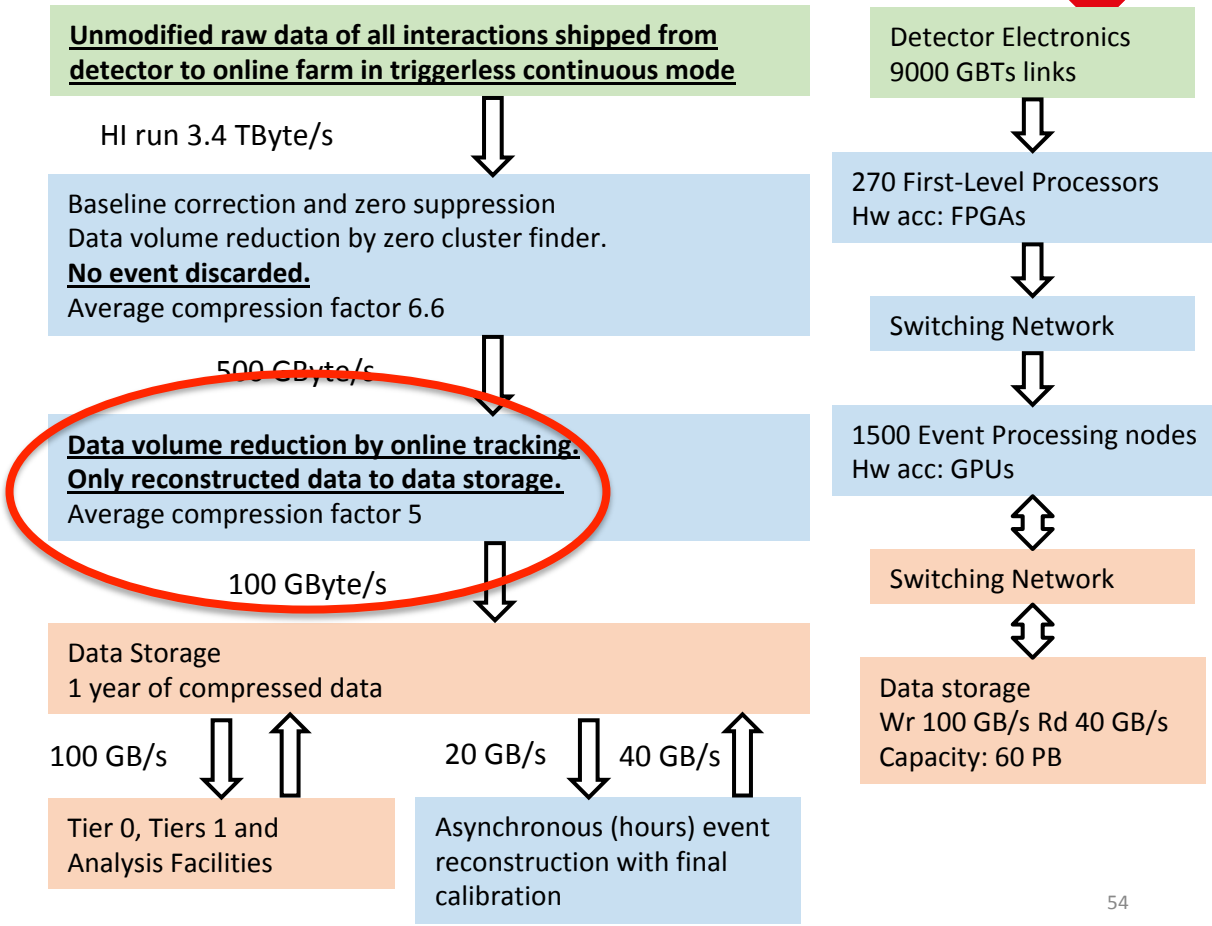
O^2 System

Requirements

1. LHC min bias Pb-Pb at 50 kHz
2. very small signal over background
   → triggering not possible
3. support for continuous read-out

New computing system

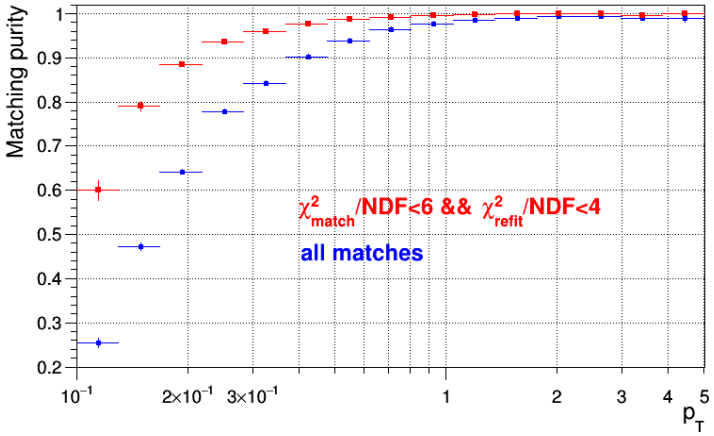
➔ read-out the data of all interactions
➔ compress data intelligently
   → online reconstruction
➔ common online-offline computing system
   → O^2



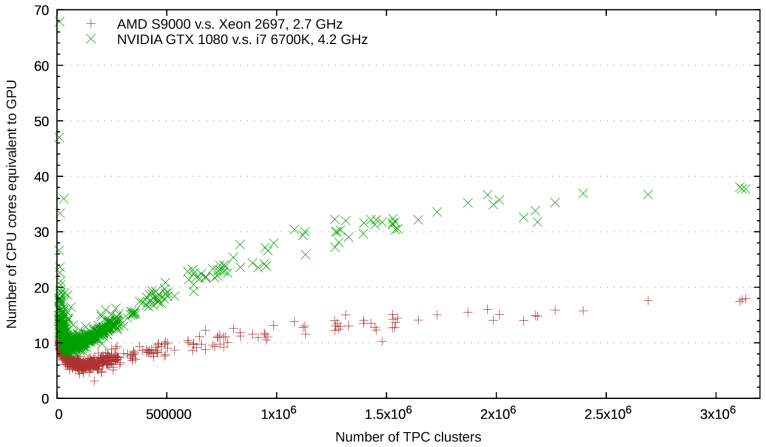
Status of the reconstruction

ITS/TPC track matching

- Combined ITS/TPC reconstruction released
- Matching of tracks from independent TPC and ITS tracking released



- CPU and GPU versions for tracking of continuously read-out data
- Performance benefit of GPU confirmed
- Current benchmarks within the processing envelope



Status of the Physics Simulation

Porting to the O2 software framework

	Start	Planning	Geometry	Hits	Digits	Ready
Passive*			✅	na	na	
ITS			✅	✅	✅	
TPC			✅	✅	✅	
MFT			✅	✅	✅	
EMCAL			✅	✅	✅	Q1
TOF			✅	✅	✅	Q1
FIT			✅	✅		Q2
TRD			✅	✅		Q2
PHOS			✅	✅		Q2
MUON						Q3
HMPID						Q3
ZDC						?

Done: ITS, TPC, MFT, EMC, TOF

In progress: FIT, TRD, PHOS

Starting: MUON

O² Computing farm monitoring

- Evaluation finished and tools selected

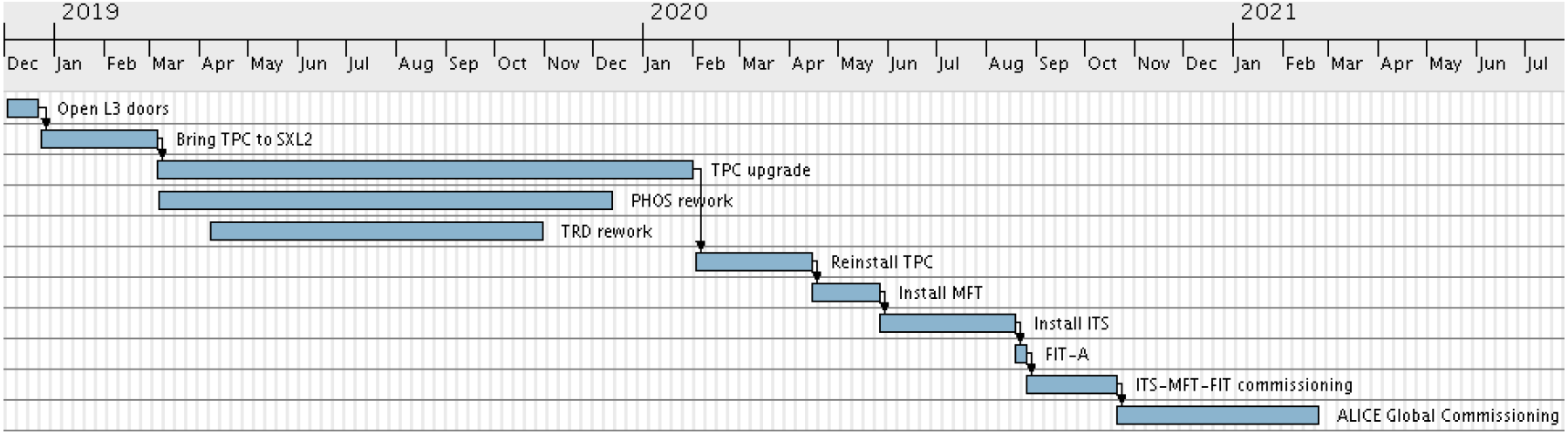
Tool		Function
Collectd		Performance metrics collection
Flume		Transport and basic processing
Apache Spark		In memory data processing
Influx DB		Time series database
Grafana		Time series visualization
Riemann		Alarming

Preparation of Data Centre at P2

- building permit approved in February
- 700 t concreted blocks evacuated from site last year
- civil engineering work (trenches, concrete slabs) starting
- connection to P2 electrical supply and cooling in July-August
- site planned to be ready by September 2018 → installation of first batch of modules

LS2 schedule

- LS2 starting date: 3 December 2018
- TRD supermodule extraction in December (w51)
- LS2 end date: 22 February 2021
- 4 weeks TPC field cage checks with X-rays



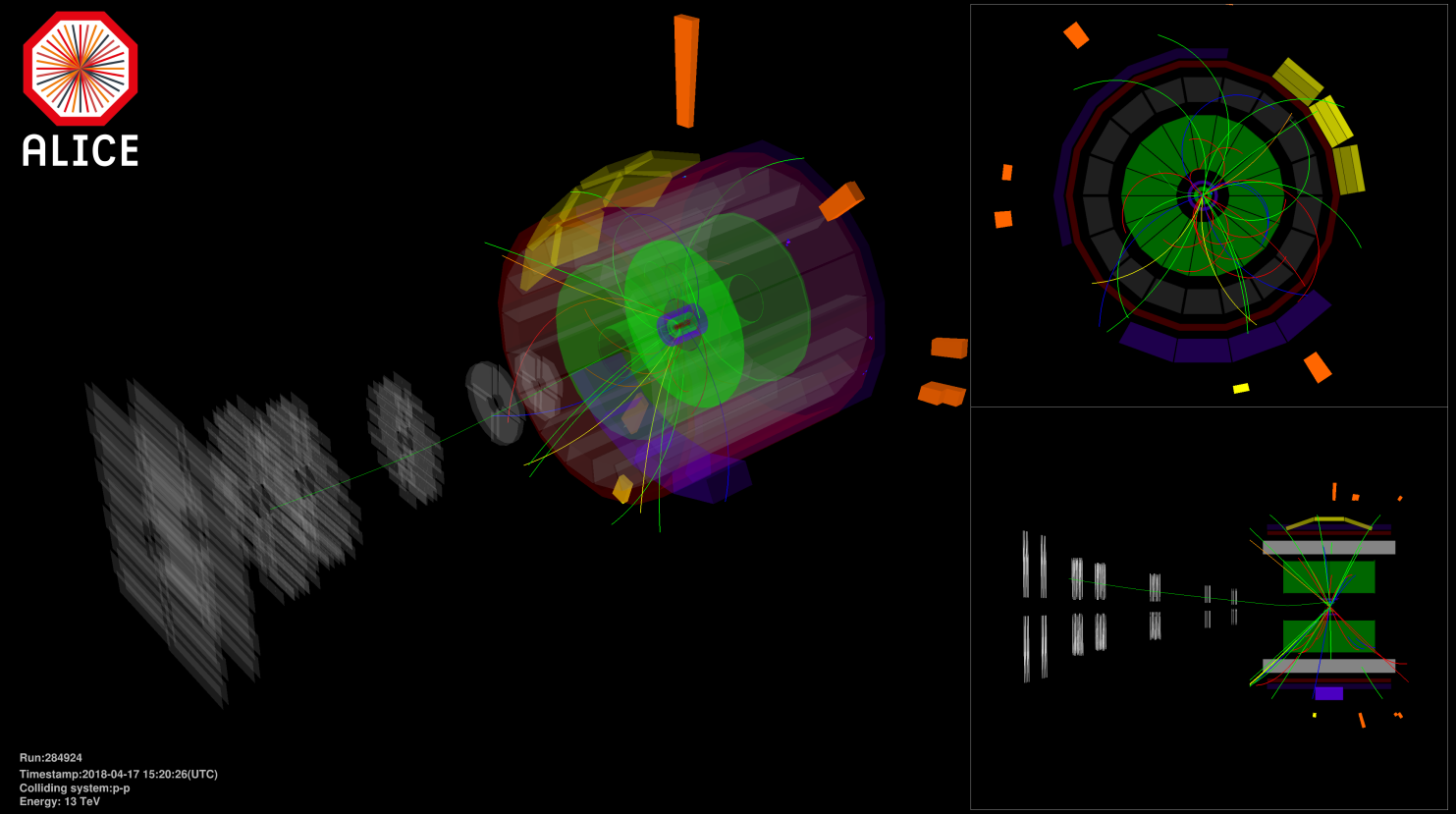
Conclusions

- Run 2 data collection proceeds smoothly
  - 2018 is a crucial year (completion of pp, largest Pb-Pb sample)

- physics harvest continues
  - progress in understanding QGP transport parameters
  - progress in understanding cold-nuclear matter effects
  - progress in understanding collectivity in small systems

- construction in full swing for all upgrade projects
  - proceeding according to plans
  - 7 months to go to start of LS2!!!
  - tight installation/commissioning plan

- we are grateful to the funding agencies for their constant support!



pp 2018

Thank you!