



# ALICE data analysis

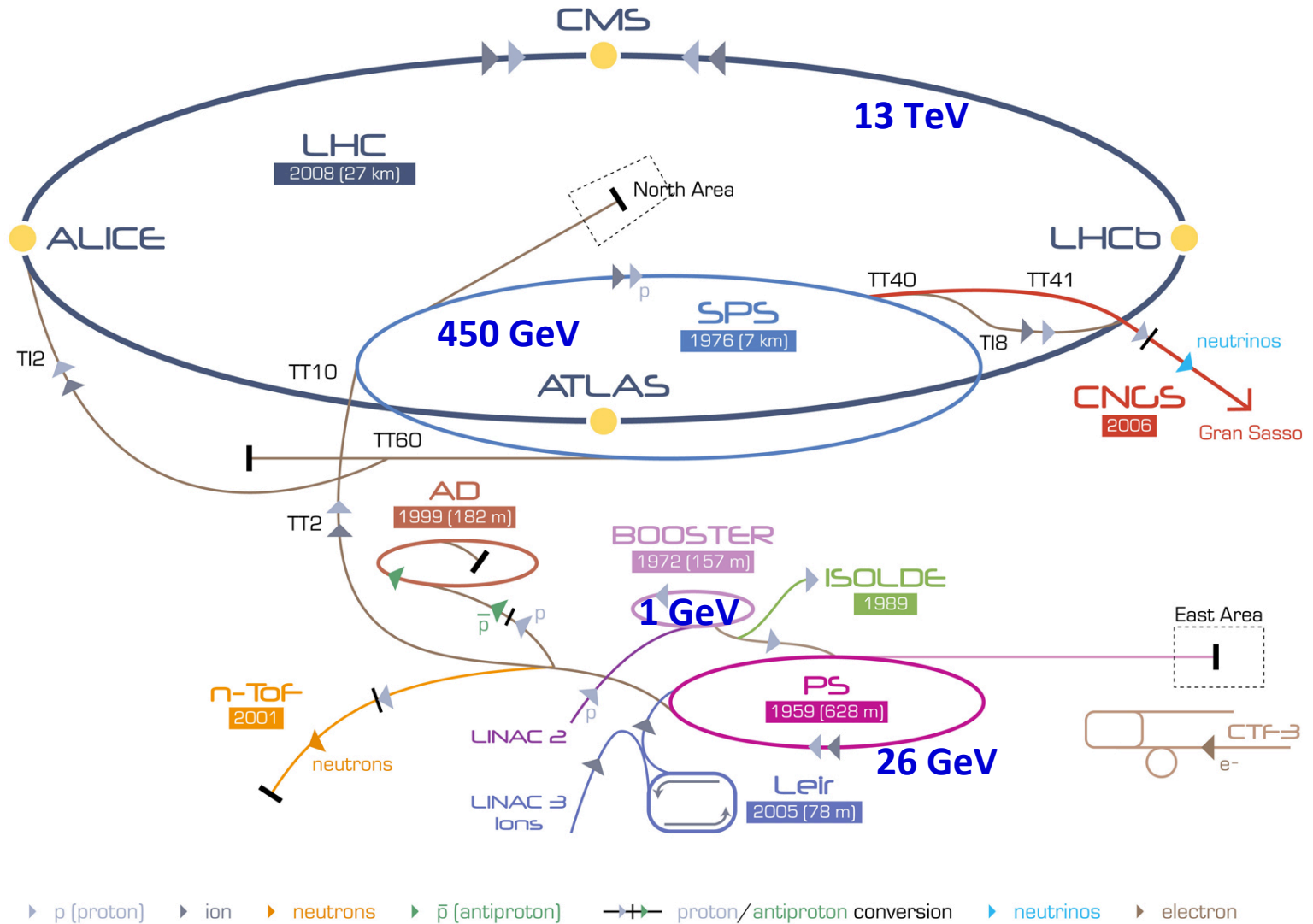
## Introduction to hands-on session

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Oslo University

20 May 2017

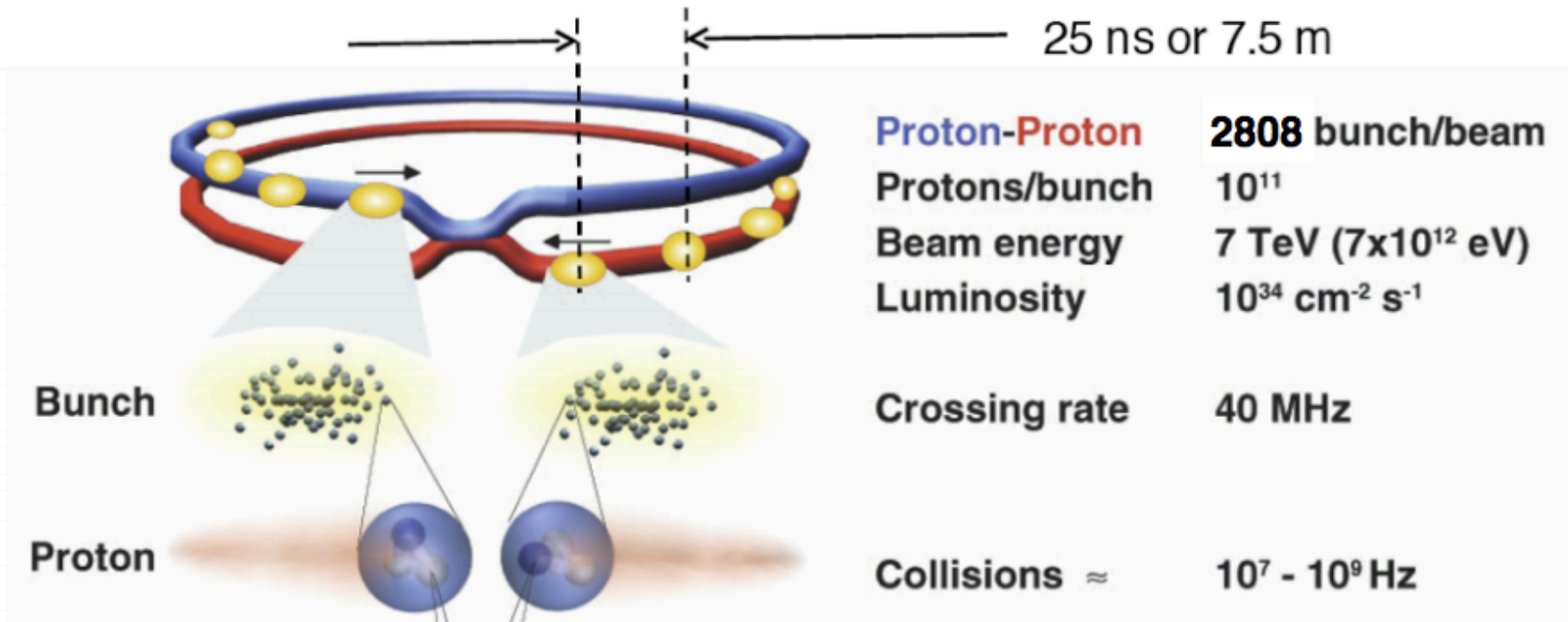
# Accelerator complex at CERN



LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF-3 Clic Test Facility CNCS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice  
 LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

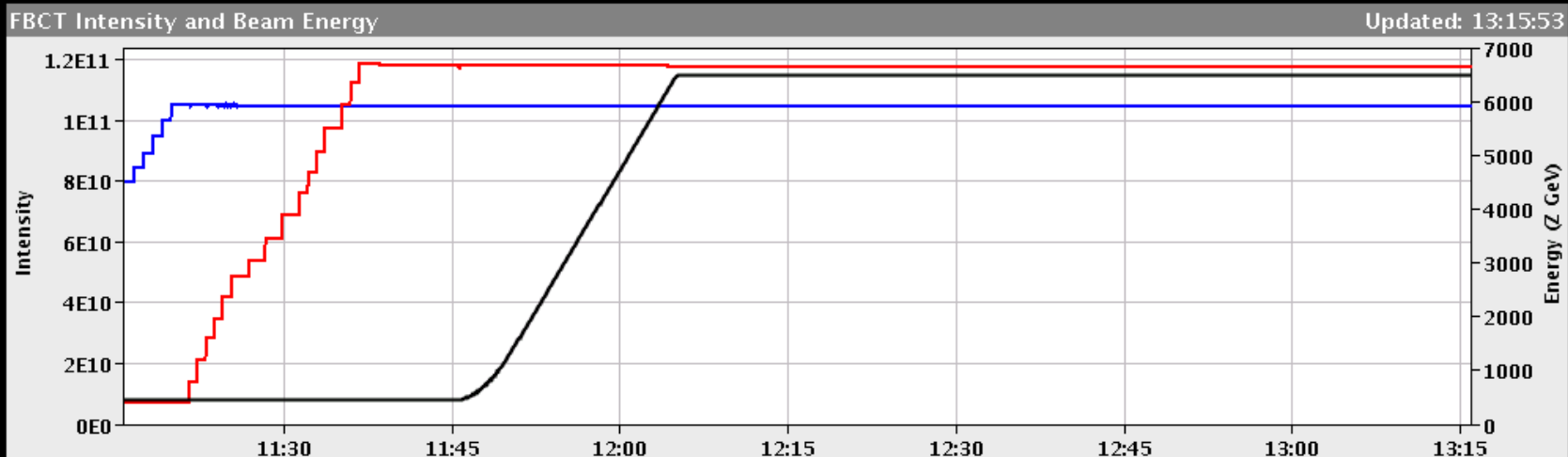
# Bunches of particles in the LHC



# PROTON-NUCLEUS PHYSICS: ADJUST

Energy: 6499 Z GeV    I(B1): 1.03e+11    I(B2): 1.17e+11

Inst. Lumi [(b.s)<sup>-1</sup>]    IP1: 0.86    IP2: -0.00    IP5: 0.00    IP8: 0.00



**Comments (17-Nov-2016 13:11:39)**  
 6.5 Z TeV commisioning B1: p B2: Pb  
 collimator Alignment  
 In ADJUST we'll need luminosity from experiments

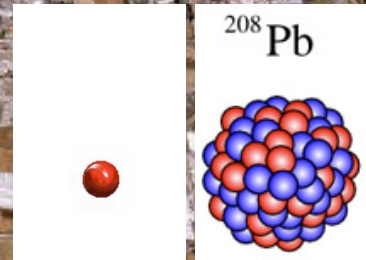
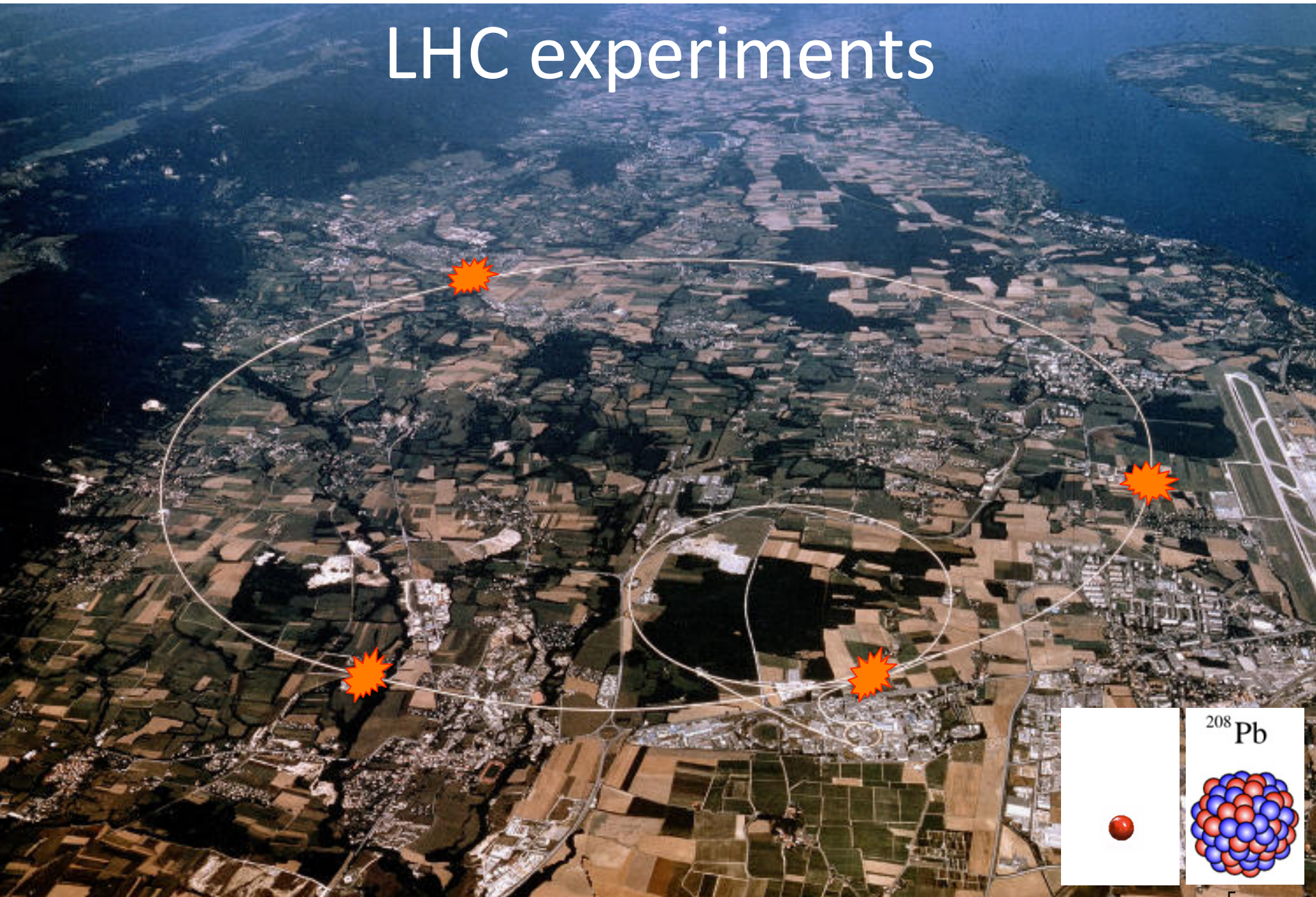
BIS status and SMP flags	B1	B2
Link Status of Beam Permits	true	true
Global Beam Permit	true	true
Setup Beam	true	true
Beam Presence	true	true
Moveable Devices Allowed In	false	false
Stable Beams	false	false

AFS: Single\_25p\_25Pb\_10\_10\_9\_6non\_coll

PM Status B1 **ENABLED**    PM Status B2 **ENABLED**



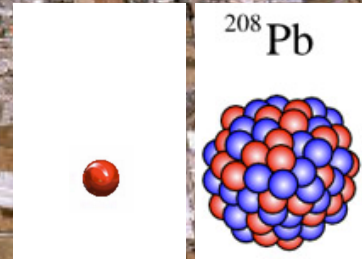
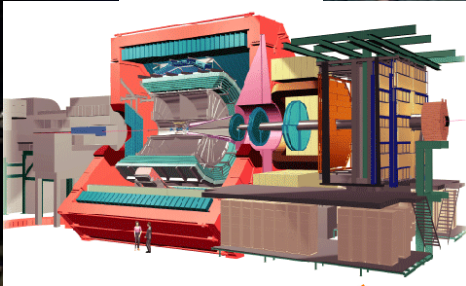
# LHC experiments





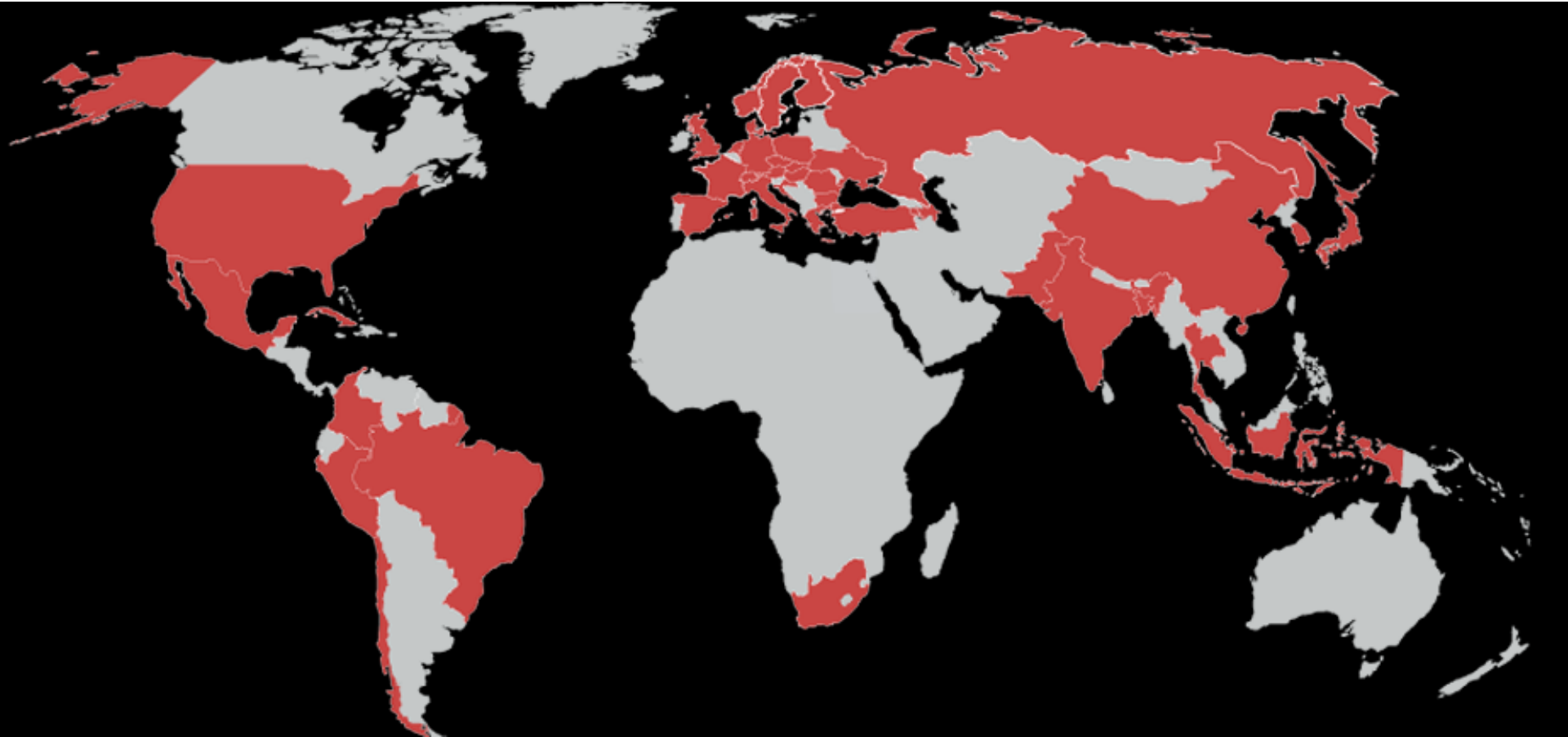
# LHC experiments

ALICE



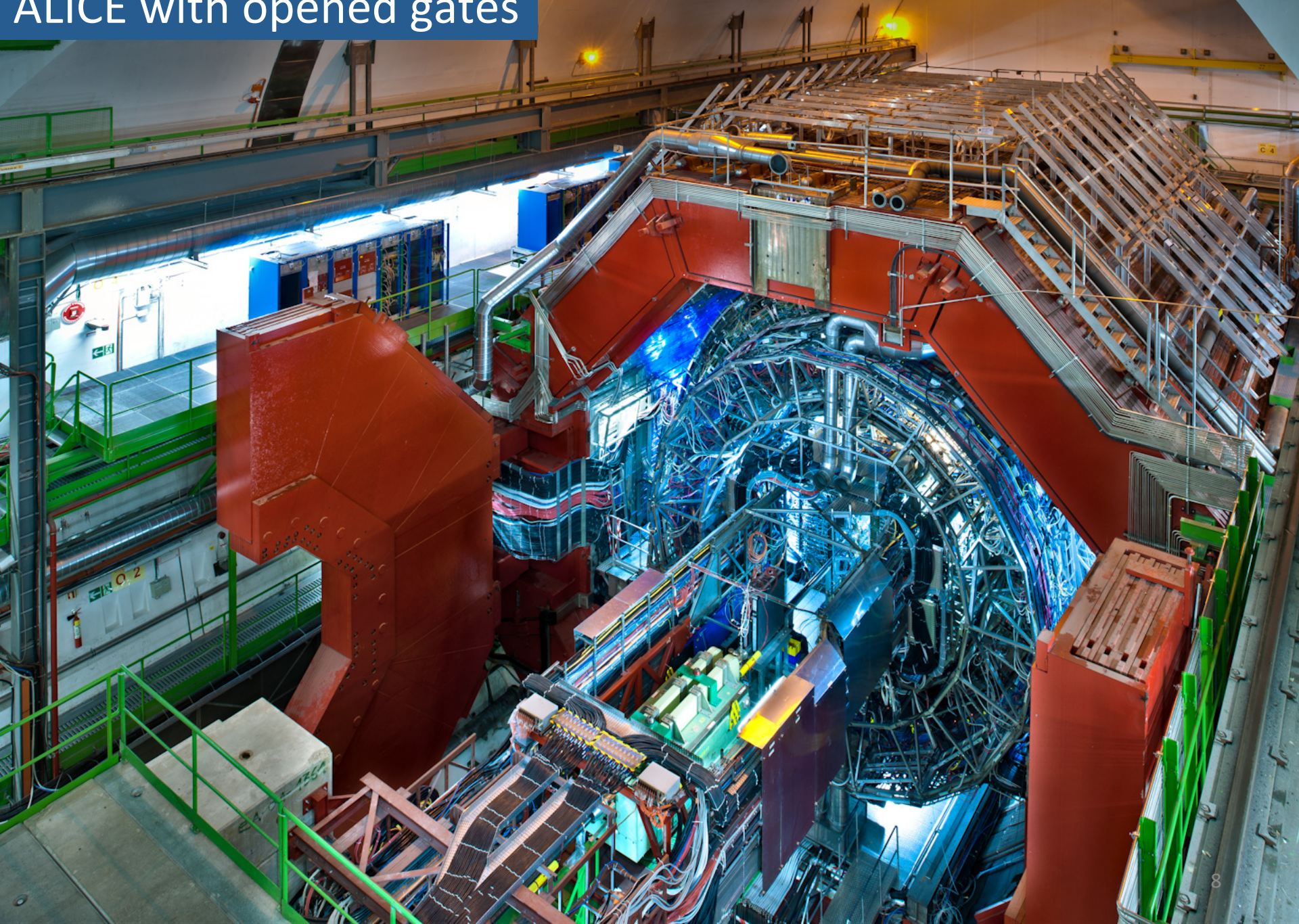
# ALICE: a world-wide effort

Autumn 2016: 42 countries, 174 institutes



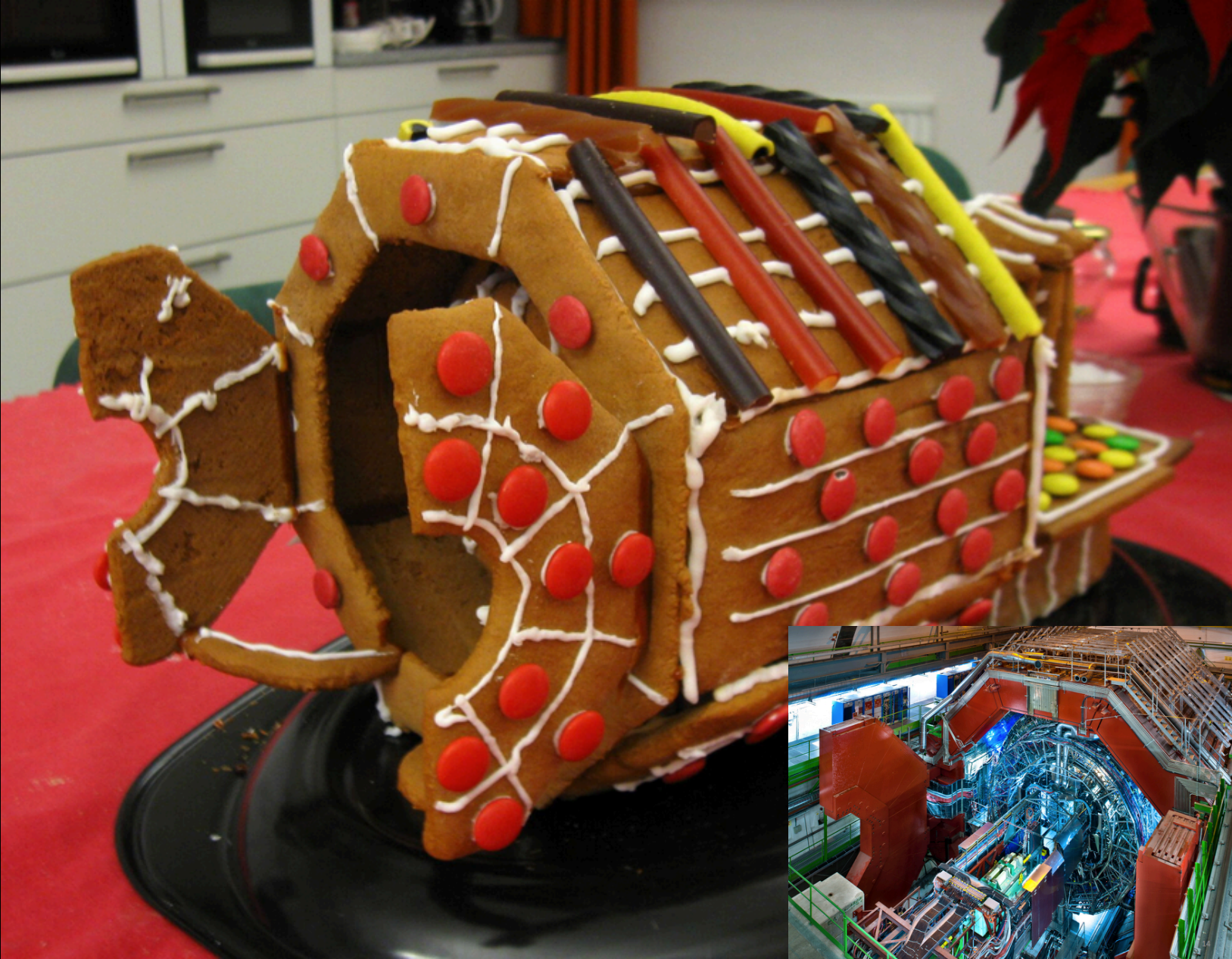


# ALICE with opened gates





# Preparation for Christmas-2017 in Sweden



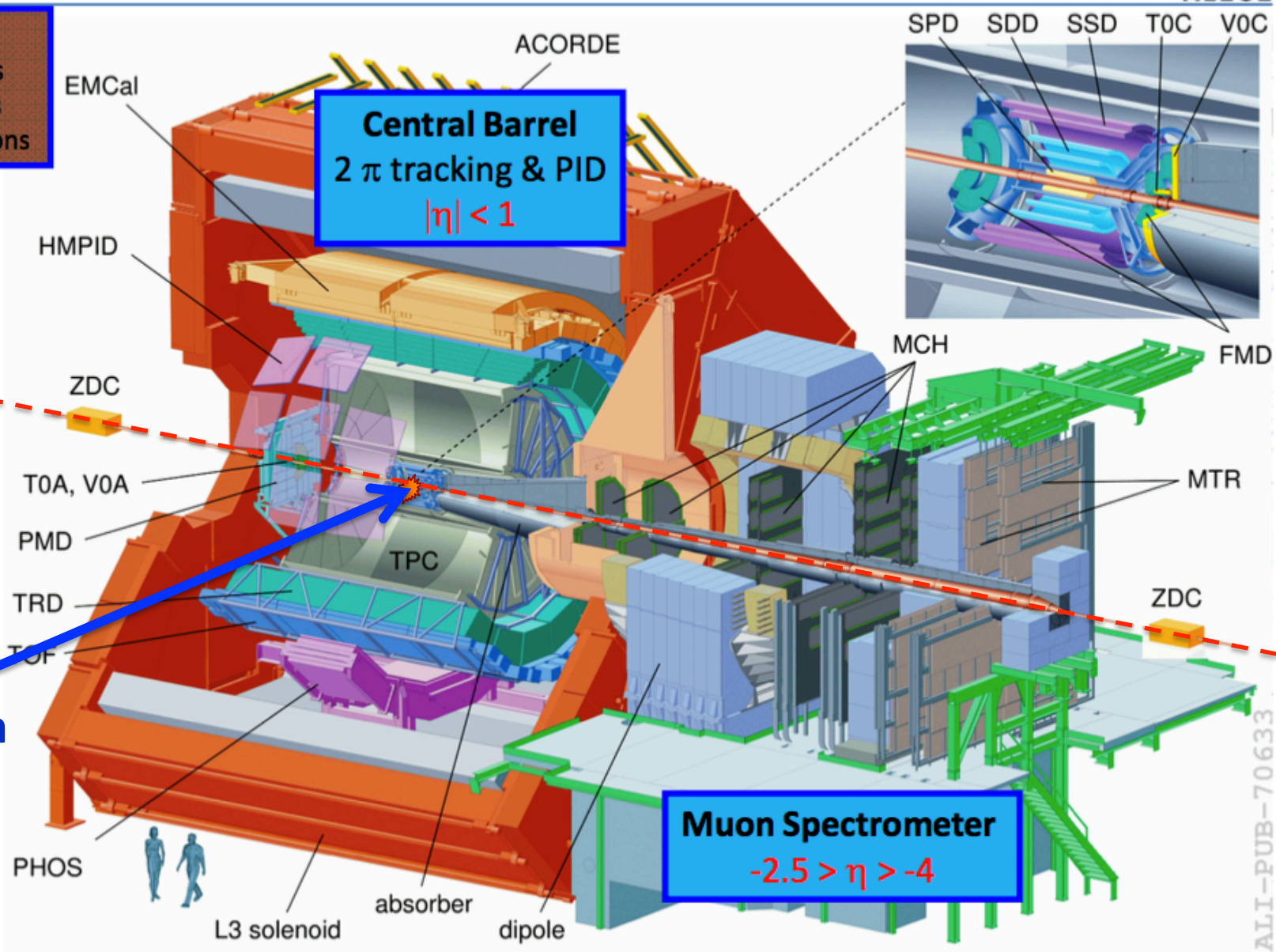


# ALICE experimental setup



ALICE

Detector:  
Length: 25 meters  
Height: 16 meters  
Weight: 10,000 tons

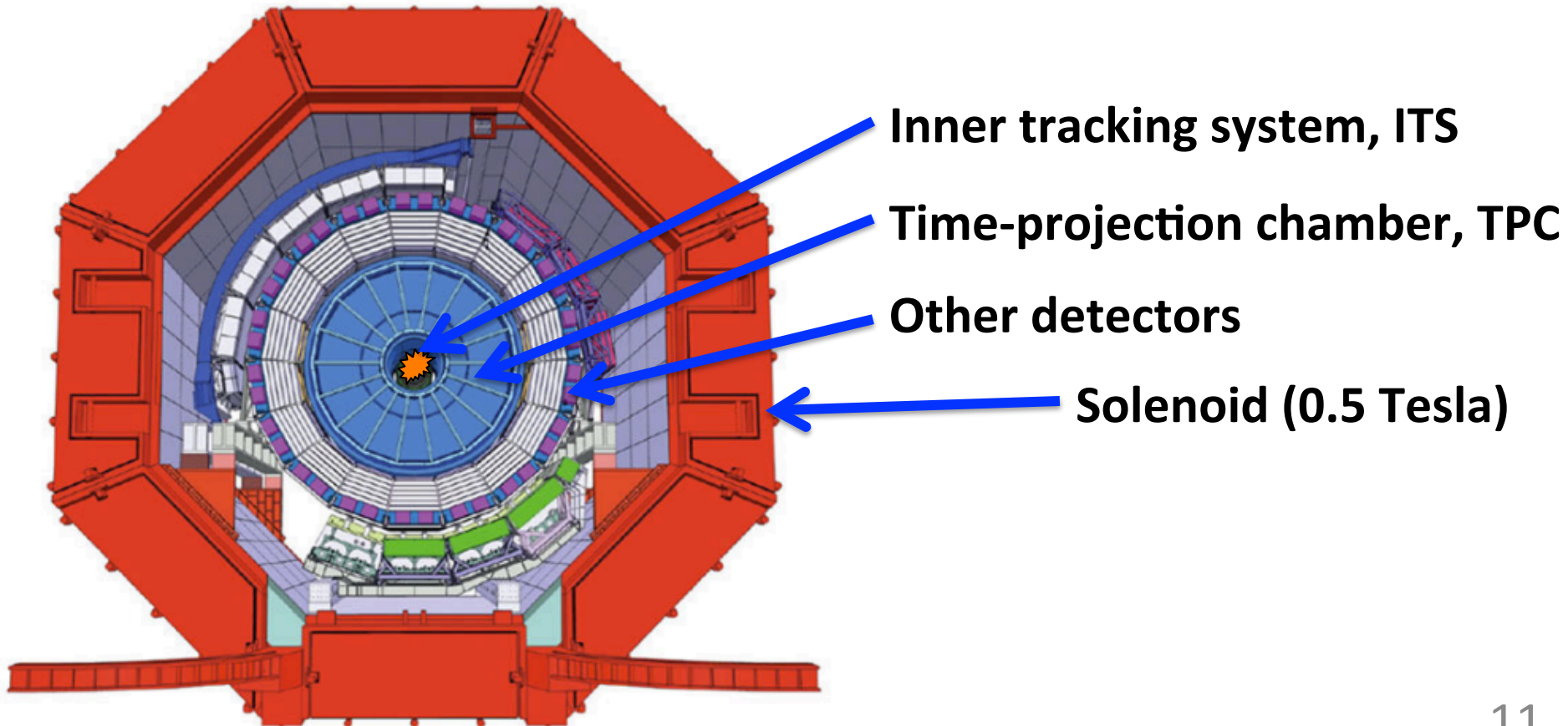


ALI-PUB-70633

# Typical structure of modern HEP experimental setup: «matryoshka»



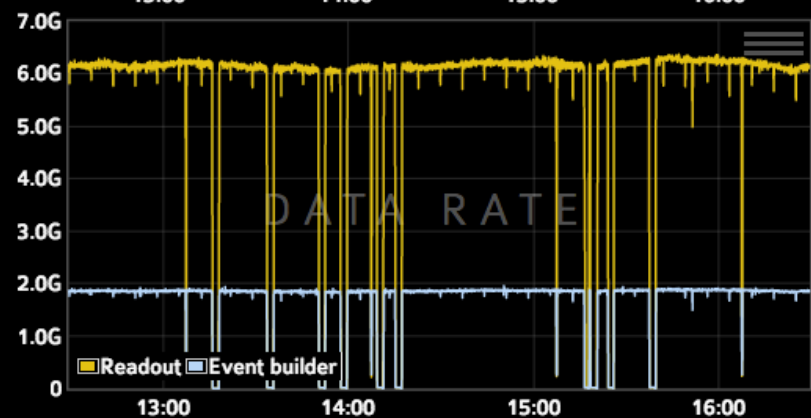
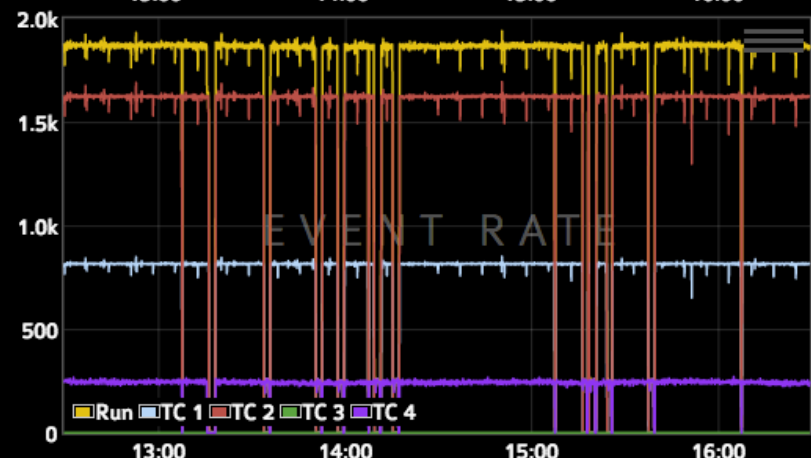
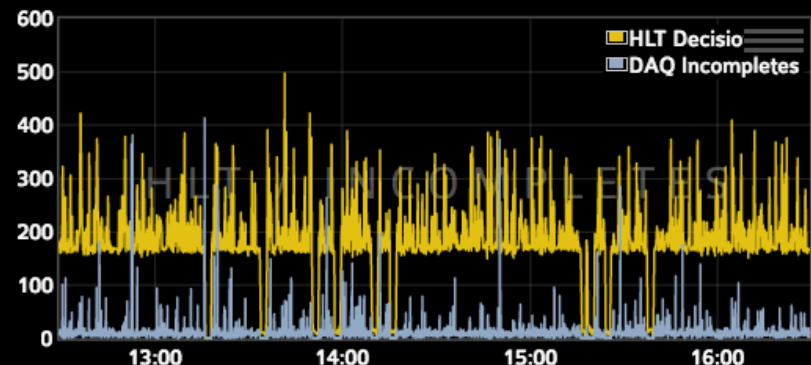
Transverse “slice” of ALICE:



# Experiment Control display of ALICE

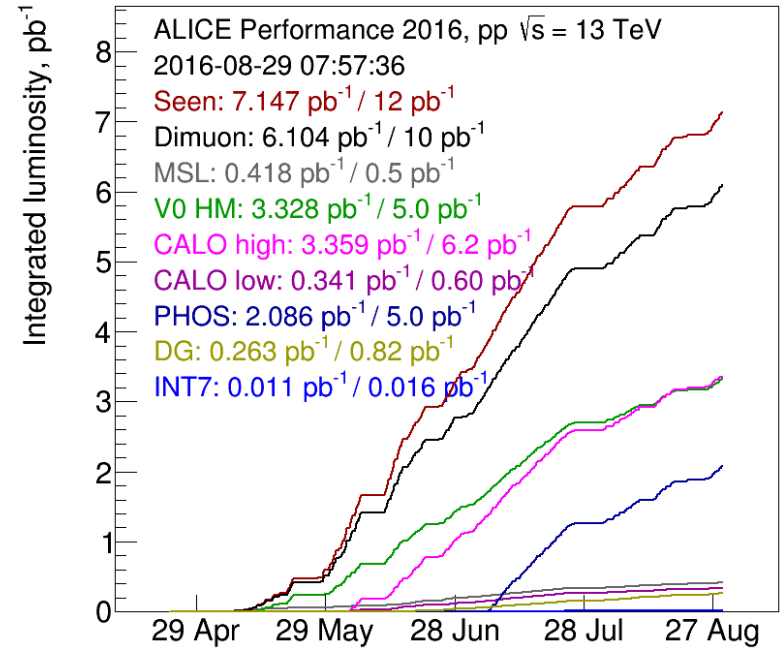
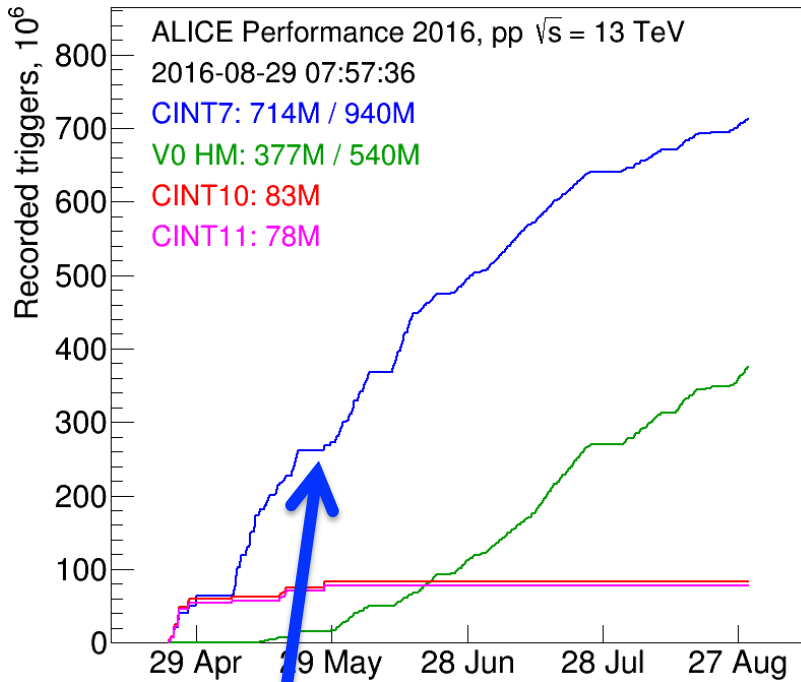
Run	Beam	Partition	Run type	HLT	Rec	Duration	Events
▶ 265435	Y	PHYSICS_1	PHYSICS	C	Y	05:31:18	34.2M
CTP Config: pPb2016 (v11)							

Calib	Bsy	Bck	Name	RUN	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8
-	-	-		34.2M	14.8M	29.5M	600	4.6M	-	-	-	-
-	-	-	ACO	-	-	-	-	-	-	-	-	-
●	●	●	AD0	✓	✓	✓	✓	✓	-	-	-	-
●	●	●	CPV	✓	✓	✓	✓	-	-	-	-	-
●	●	●	EMC	✓	✓	✓	✓	-	-	-	-	-
●	●	●	FMD	✓	✓	✓	✓	-	-	-	-	-
●	●	●	HMP	✓	✓	✓	✓	-	-	-	-	-
●	●	●	MTR	✓	-	-	-	✓	-	-	-	-
●	●	●	MCH	✓	-	-	-	✓	-	-	-	-
●	●	●	PHS	✓	✓	✓	✓	-	-	-	-	-
-	-	-	PMD	-	-	-	-	-	-	-	-	-
●	●	●	SDD	✓	✓	-	✓	-	-	-	-	-
●	●	●	SPD	✓	✓	✓	✓	✓	-	-	-	-
●	●	●	SSD	✓	✓	✓	✓	-	-	-	-	-
●	●	●	T00	✓	✓	✓	✓	✓	-	-	-	-
●	●	●	T0F	✓	✓	✓	✓	-	-	-	-	-
●	●	●	TPC	✓	✓	✓	✓	-	-	-	-	-
●	●	●	TRD	✓	✓	✓	-	-	-	-	-	-
●	●	●	TRI	✓	✓	✓	✓	✓	-	-	-	-
-	-	-	TST	-	-	-	-	-	-	-	-	-
●	●	●	V00	✓	✓	✓	✓	✓	-	-	-	-
●	●	●	ZDC	✓	✓	✓	✓	✓	-	-	-	-
-	●	-	HLT	-	-	-	-	-	-	-	-	-





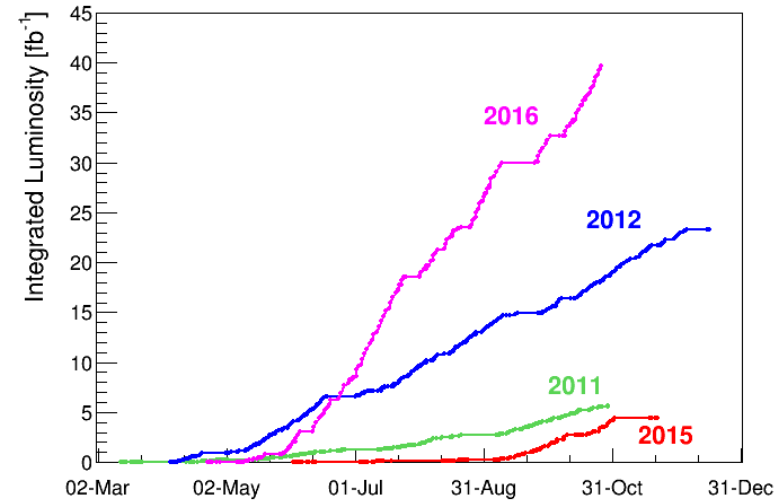
# 2016 data taking



## Minimum bias events:

events triggered by less possible interaction in the detector.

In ALICE: some signal in 3 detectors (VZERO-A, VZERO-C, TPC)

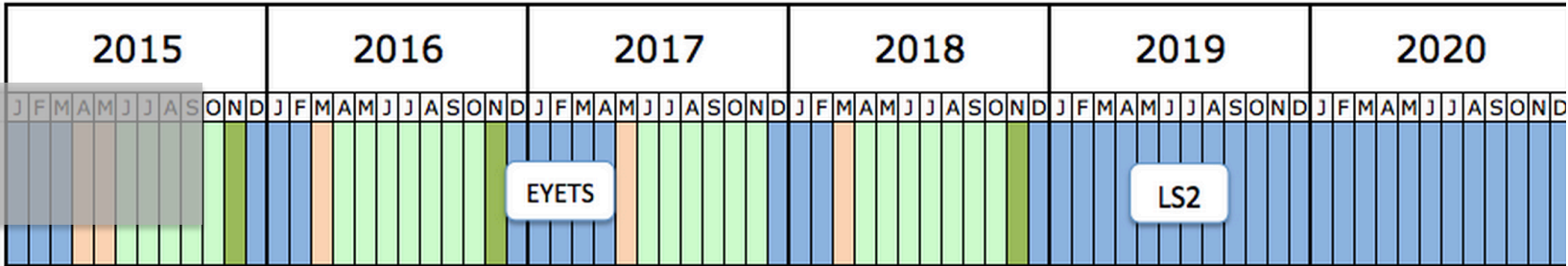


System	Year	Energy	$\int L dt$
Pb-Pb	2010	2.76 TeV	$10 \mu\text{b}^{-1}$ *
Pb-Pb	2011	2.76 TeV	$0.1 \text{nb}^{-1}$ **
pp	2010	7 TeV	$11 \text{nb}^{-1}$ *
pp	2011	2.76 TeV	$1.1 \text{nb}^{-1}$ *
pp	2011	7 TeV	$4.8 \text{nb}^{-1}$ *
pp	2012	8 TeV	$9.7 \text{pb}^{-1}$ **
p-Pb	2013	5.02 TeV	$15 \text{nb}^{-1}$ **
Pb-p	2013	5.02 TeV	$15 \text{nb}^{-1}$ **

\* Minimum bias triggers

\*\* Rare triggers (muon, EMCAL, PHOS etc)

# RUN2 Overview (from ALICE Perspective)



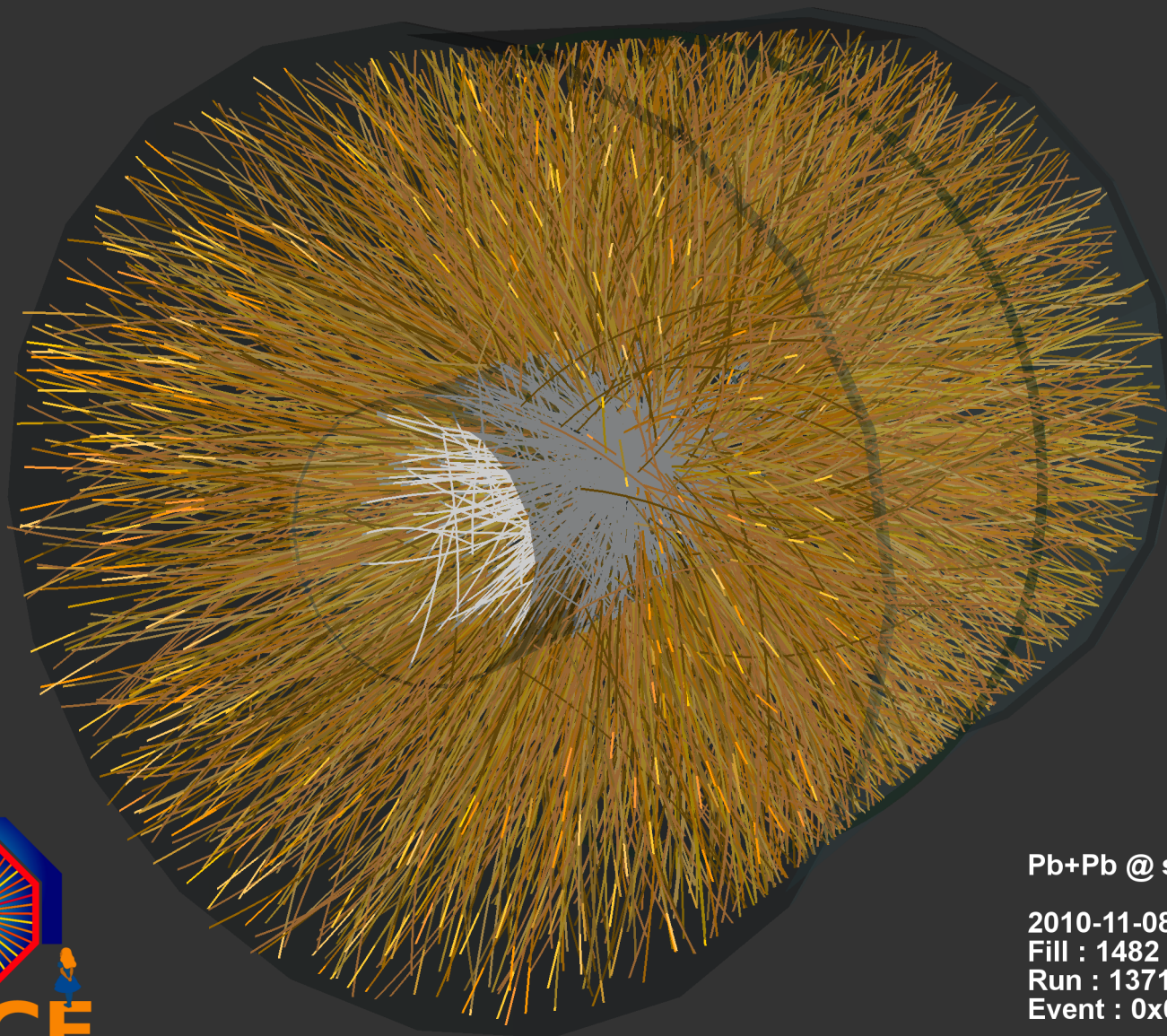
Year	System	E [TeV]	Lumi [cm <sup>-2</sup> s <sup>-1</sup> ]	Rate [kHz]	Time
2015	pp	13	5x10 <sup>30</sup>	300	7w
	PbPb	5.02	1x10 <sup>27</sup>	8	3w
	pp-ref	5.02	1x10 <sup>30</sup>	50	4d
<b>2016</b>	<b>pp</b>	<b>13</b>	<b>5x10<sup>30</sup></b>	<b>300</b>	<b>28w</b>
	<b>pPb</b>	<b>5.02</b>	<b>1x10<sup>28</sup> + 1x10<sup>29</sup></b>	<b>20(MB)/200</b>	<b>4w</b>
	<b>pp-ref</b>	<b>5.02</b>	<b>1x10<sup>30</sup></b>	<b>50</b>	<b>2w</b>
2017	pp	13	5x10 <sup>30</sup>	300	24w
2018	pp	13	5x10 <sup>30</sup>	300	28w
	PbPb	5.02	1x10 <sup>27</sup>	8	4w
	pp-ref	5.02	1x10 <sup>30</sup>	50	7d

# ALICE Run Control





# Basic concepts in HEP data: **event** and **particle track**



Pb+Pb @  $\sqrt{s} = 2.76$  ATeV

2010-11-08 11:30:46

Fill : 1482

Run : 137124

Event : 0x00000000D3BBE693

# Usual template of HEP analysis: event and track loops

```
// Event loop -----  
for ( int eventId = 0; eventId < data->GetNumberOfEvents(); eventId++ )  
{  
    Event *event = data->GetEvent(eventId);  
  
    // Track loop -----  
    for (int trackId = 0; trackId < event->GetNumberOfTracks(); trackId++)  
    {  
        Track *track = event->GetTrack( trackId );  
  
        if ( !track ) {  
            Printf("ERROR: Could not receive track %d", trackId);  
            continue;  
        }  
  
        //Track variables  
        double mass = track->GetParticleMass();    // mass  
        double eta = track->GetEta();    // eta  
        double phi = track->GetPhi();    // phi  
  
        histogram->Fill( phi );  
        // do analysis ...  
        // fill histograms  
    }  
}
```



Отобранные события направляются сперва в  
**Вычислительный центр ЦЕРН**





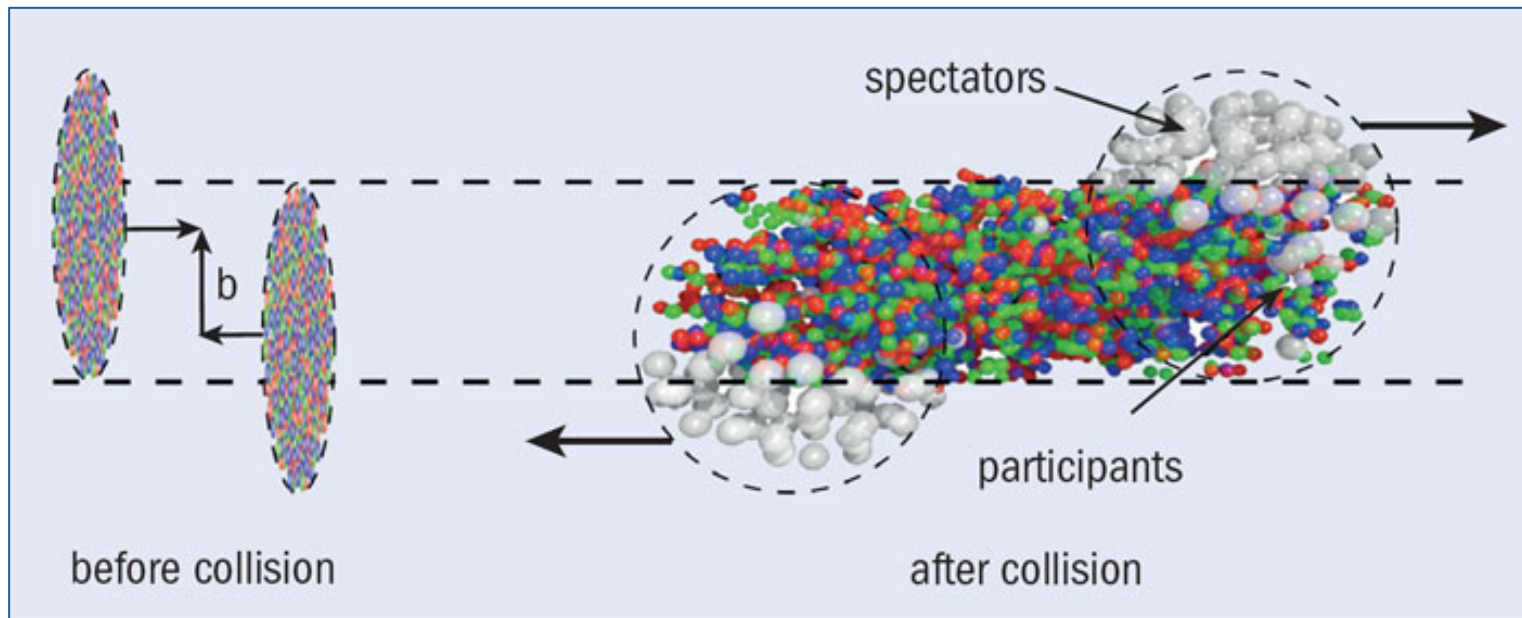
Далее для хранения анализа и данные с БАК поступают во всемирную распределенную вычислительную систему GRID





# The collision centrality

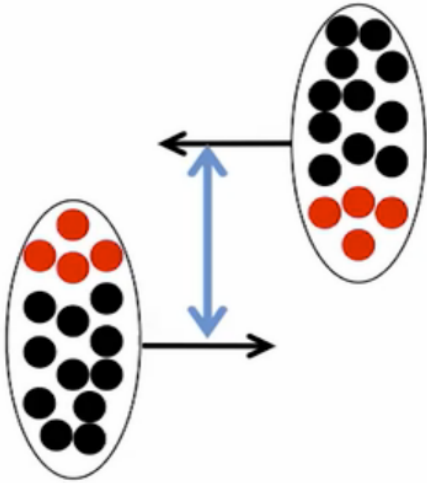
The **centrality** is a **key parameter** in the study QCD matter at extreme energy densities, because it is directly related to the **initial overlap region** of the colliding nuclei.



The **impact parameter ( $b$ )** is the distance between the centers of the colliding nuclei.

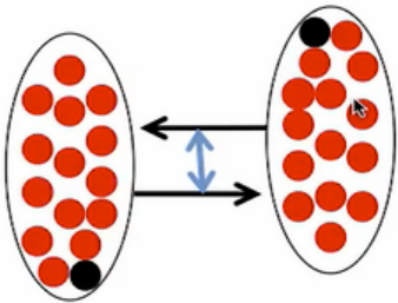
# The collision centrality

*Peripheral collision:*



- ✧ Large distance between centers of nuclei
- ✧ Small number of **nucleons-participants**
- ➔ **Small multiplicity of created particles**

*Central collision:*



- ✧ Small distance between centers of nuclei
- ✧ Large number of **nucleons-participants**
- ➔ **Large multiplicity**

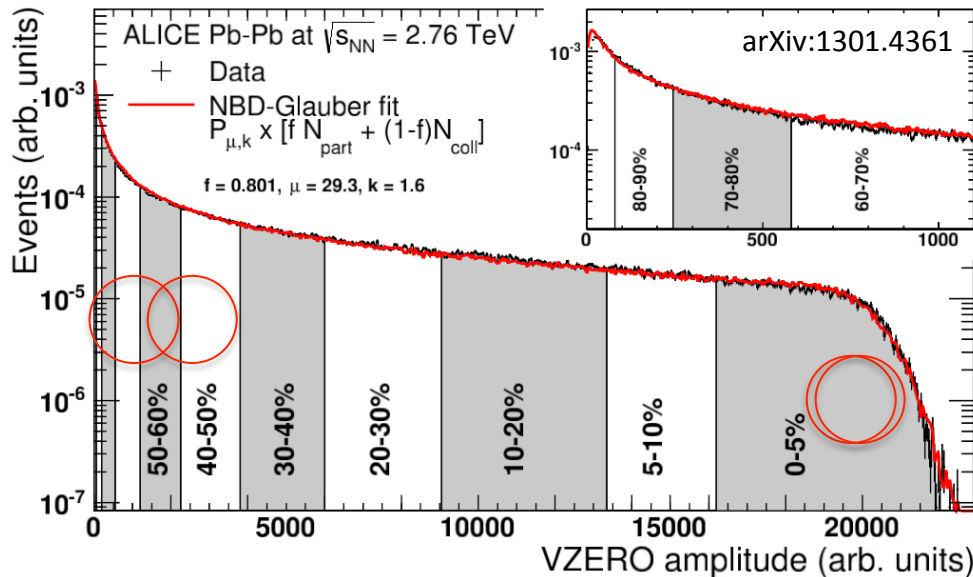
# Centrality determination in experiment

## Usual receipt:

- use distribution of a signal in some detector
- fit with some geometry-based model
- split into *centrality classes* (0-100%)

## In ALICE for Pb-Pb:

use *multiplicity distribution* in (semi-central) **VZERO detector** + Glauber fit

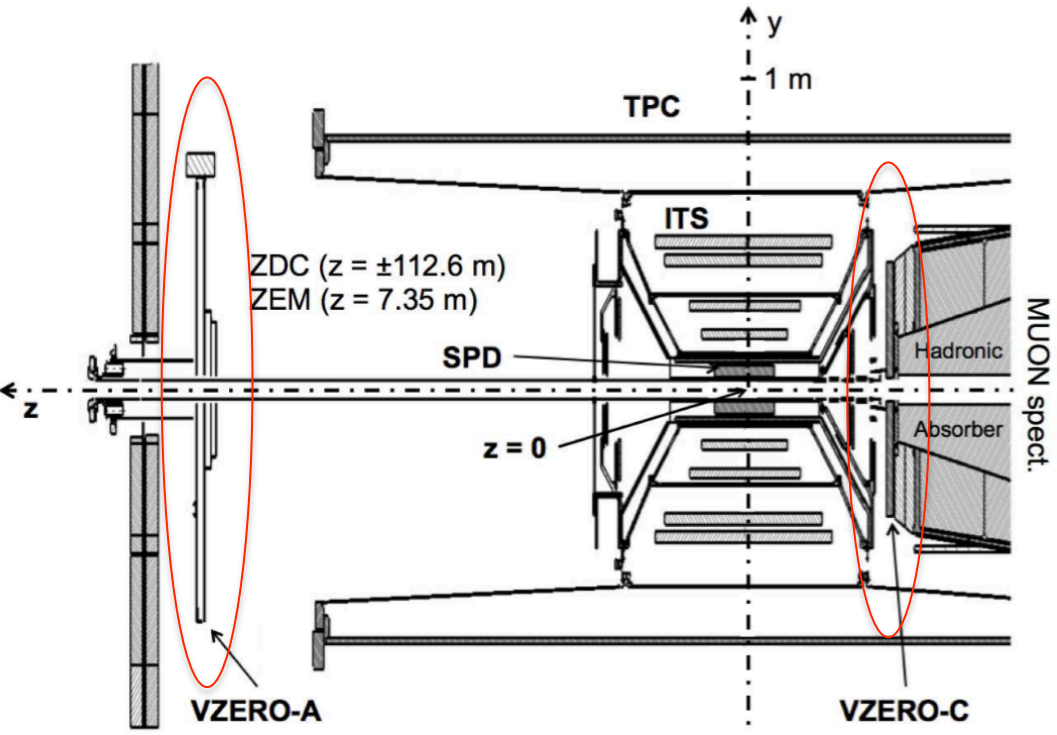


$(-3.7 < \eta < -1.7$  and  $2.8 < \eta < 5.1)$

close to 0%  $\rightarrow$  most **central** events  
closer to 100%  $\rightarrow$  **peripheral** events

$\rightarrow b_{\text{impact}}, N_{\text{part}}, N_{\text{coll}}, N_{\text{spec}}$  are not directly measurable and are deduced from the **Glauber model**.

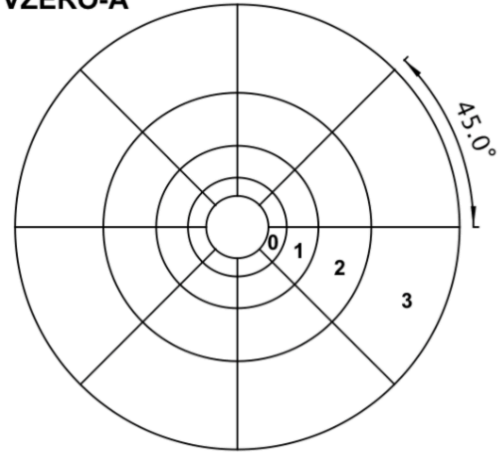
# The VZERO detector



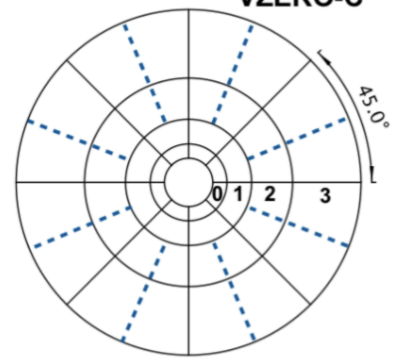
- triggering
- determination of centrality
- event plane angle

Plastic scintillator:

VZERO-A



VZERO-C



# Prerequisites

CERNBox shared folder with code and datasets:

<https://cernbox.cern.ch/index.php/s/9uLpLGwHjuuipT9?path=%2F>

Download the "Analysis code" folder,  
run "**root LoadDependencies.C**" to compile all necessary libraries  
main file to be changed for your analysis is **RunTreeAnalysis.C**

Download several pieces of data, minimum requirement to follow is:

*PbPb\_minbias/chunk1/dstTree.root*

*PP13TeV\_minbias/000258477/dstTree.root*

You can download more data to get higher statistics.

To run template analysis, do

`root LoadDependencies.C`

, and inside root prompt:

```
RunTreeAnalysis("fileList.txt", "output.root", nEvents)
```

Here, *fileList.txt* is a text file where there is a list of root files containing data trees  
(all of the files there will be chained),

*output.root* is an output ROOT file to save histograms,

*nEvents* is an integer to say how many events to be analyzed.

```
void LoadDependencies() {  
    //  
    // Load and compile all dependencies  
    //  
    gROOT->LoadMacro("AliReducedBaseEvent.cxx+");  
    gROOT->LoadMacro("AliReducedBaseTrack.cxx+");  
    gROOT->LoadMacro("AliReducedCaloClusterInfo.cxx+");  
    gROOT->LoadMacro("AliReducedFMDInfo.cxx+");  
    gROOT->LoadMacro("AliReducedEventPlaneInfo.cxx+");  
    gROOT->LoadMacro("AliReducedTrackInfo.cxx+");  
    gROOT->LoadMacro("AliReducedEventInfo.cxx+");  
    gROOT->LoadMacro("AliReducedPairInfo.cxx+");  
  
    gROOT->ProcessLine(".L RunTreeAnalysis.C+");  
}
```

## Available datasets:

PbPb_cent0002	10.4 GB
PbPb_cent2030	5.6 GB
PbPb_minbias	2.3 GB
PP13TeV_electrons	4.5 GB
PP13TeV_minbias	451.8 MB

# Analysis task #1

## Event-level information in Pb-Pb and pp minimum bias datasets

- apply event selection
- plot histograms:
  - for vertex z-position, same for vertex xy
  - multiplicity of tracks
  - distribution of signal in VZERO detector





More slides

# Alternative method in ALICE

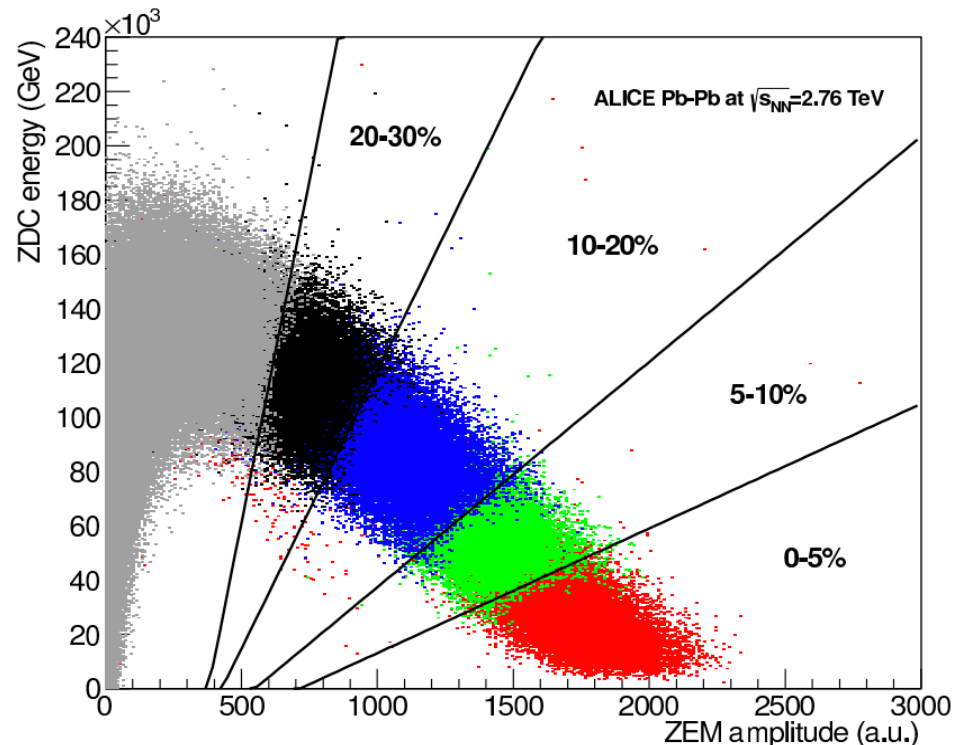
Based on 2D distribution of signals from two detectors:

energy from neutrons-spectators  
in Zero-degree calorimeters (**ZDC**)

&&

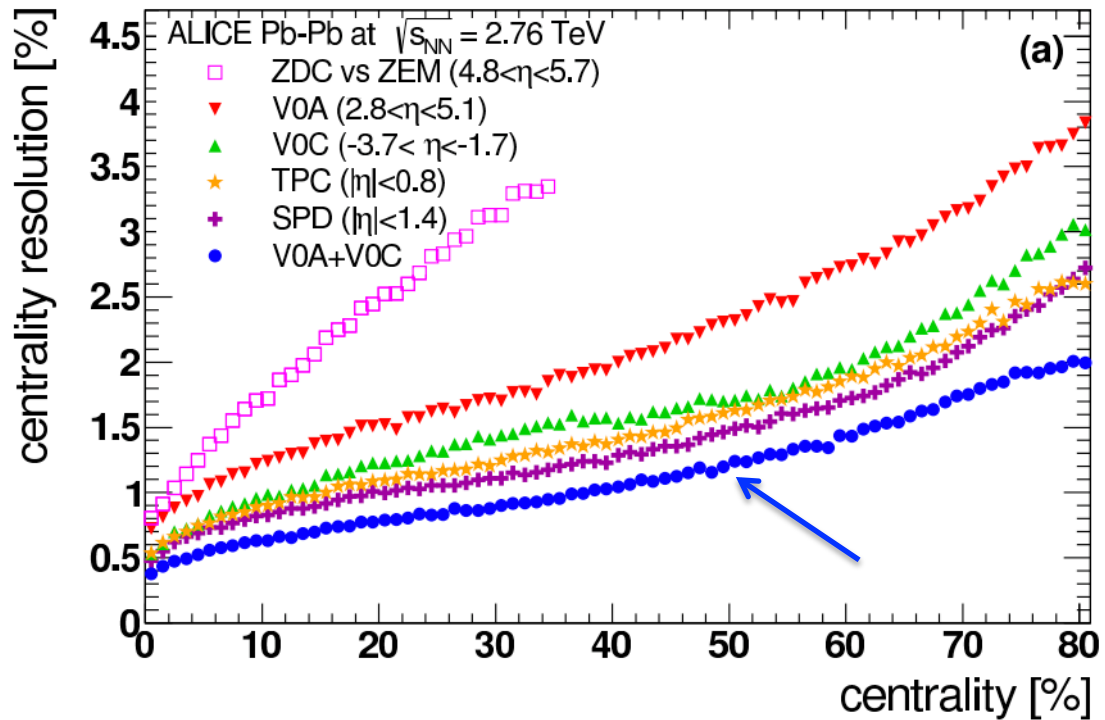
signals in electromagnetic  
calorimeters (**ZEM**)

( $4.8 < \eta < 5.7$ )



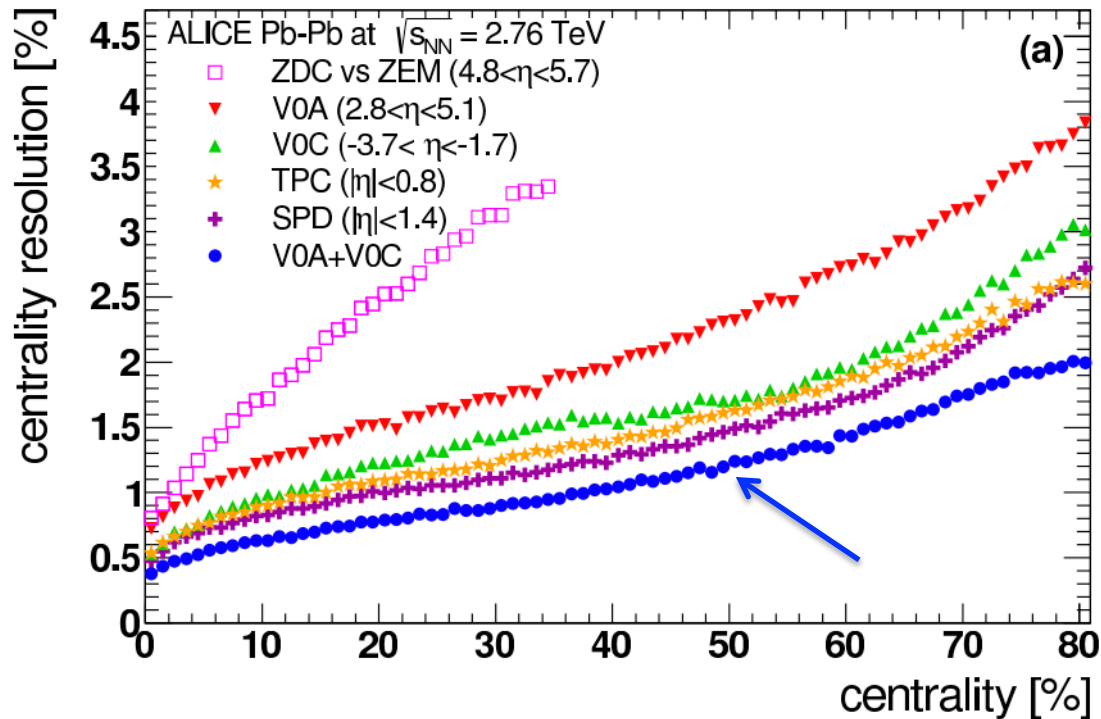
Splitting in centrality classes is done by drawing (arbitrary) lines.

# Centrality resolution in experiment



*Best centrality resolution* is achieved by usage of the **VZERO** estimator.

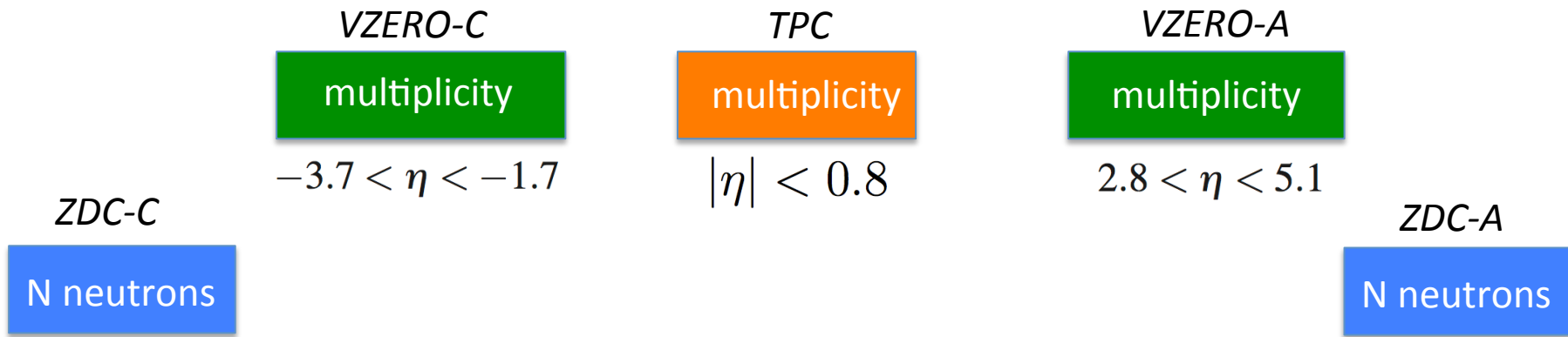
# Centrality resolution in experiment



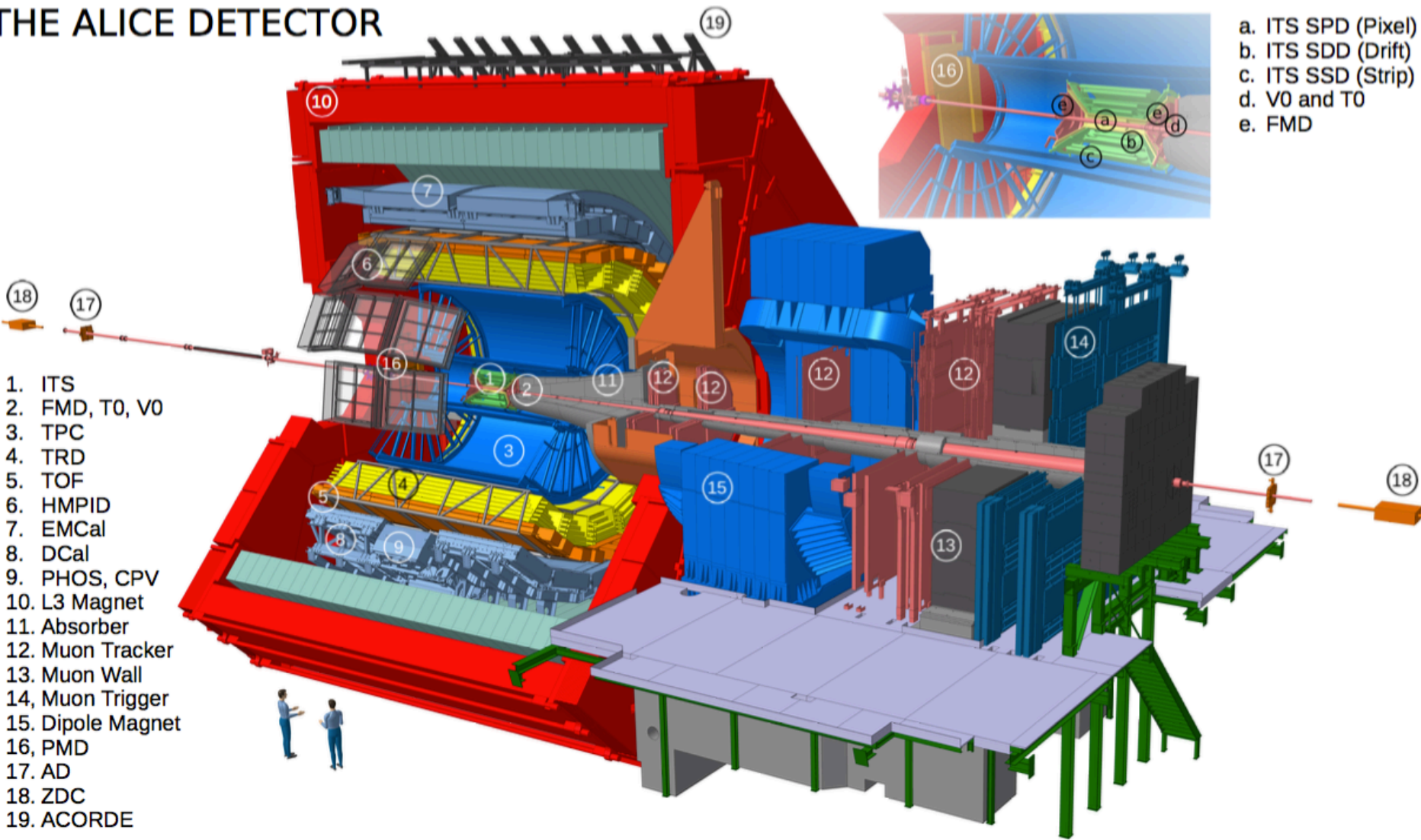
*Best centrality resolution* is achieved by usage of the **VZERO** estimator.

Can we perform better using multiple detectors simultaneously?  
Try machine-learning techniques for that.

# Rapidity coverage of TPC and VZERO detectors



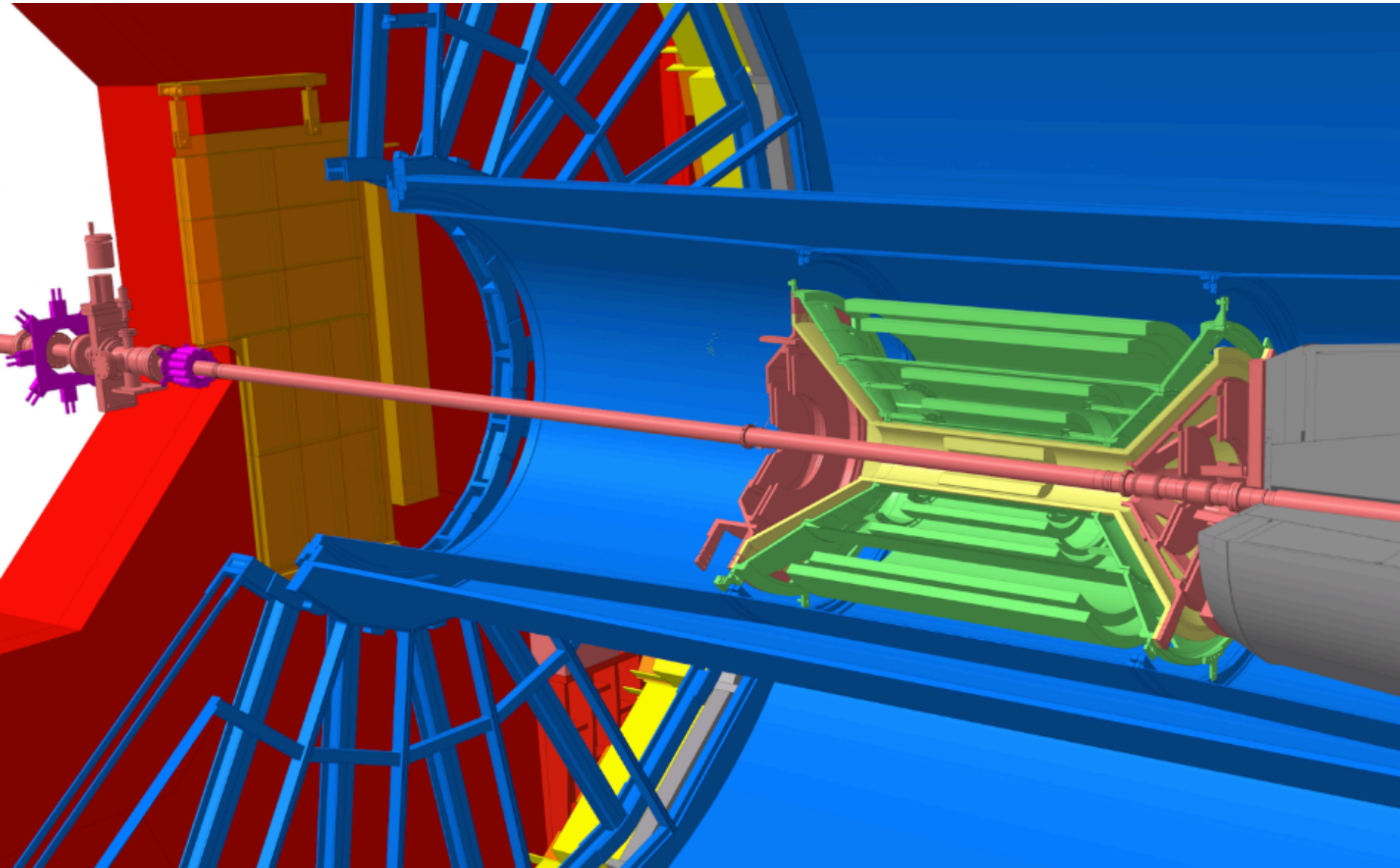
# THE ALICE DETECTOR



1. ITS
2. FMD, T0, V0
3. TPC
4. TRD
5. TOF
6. HMPID
7. EMCal
8. DCal
9. PHOS, CPV
10. L3 Magnet
11. Absorber
12. Muon Tracker
13. Muon Wall
14. Muon Trigger
15. Dipole Magnet
16. PMD
17. AD
18. ZDC
19. ACORDE

- a. ITS SPD (Pixel)
- b. ITS SDD (Drift)
- c. ITS SSD (Strip)
- d. V0 and T0
- e. FMD

# ITS and other inner detectors of ALICE





The picture shows a zoomed view of an event in the centre of the CMS detector where **78 proton-proton collisions took place simultaneously** (the bright dots on the horizontal axis). The scale here is a few centimetres.

