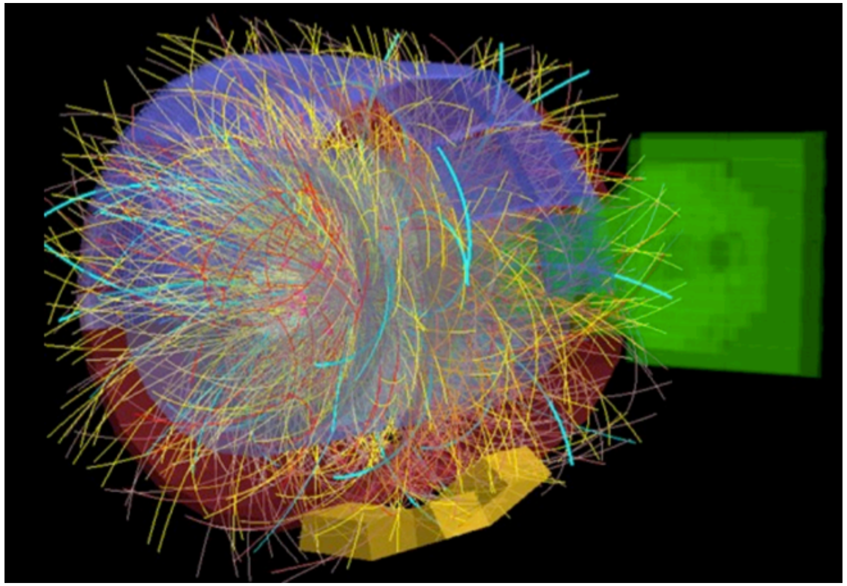
A Large Ion Collider Experiment

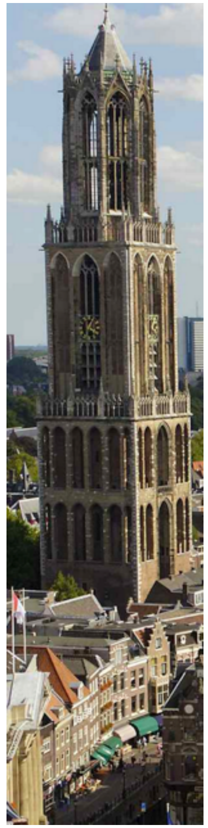
ALICE Detector Upgrade for Run3 and Run4 at the LHC

Ginés MARTINEZ-GARCIA
for the ALICE Collaboration



The International Conference on Strangeness in Quark Matter
SQM 2017

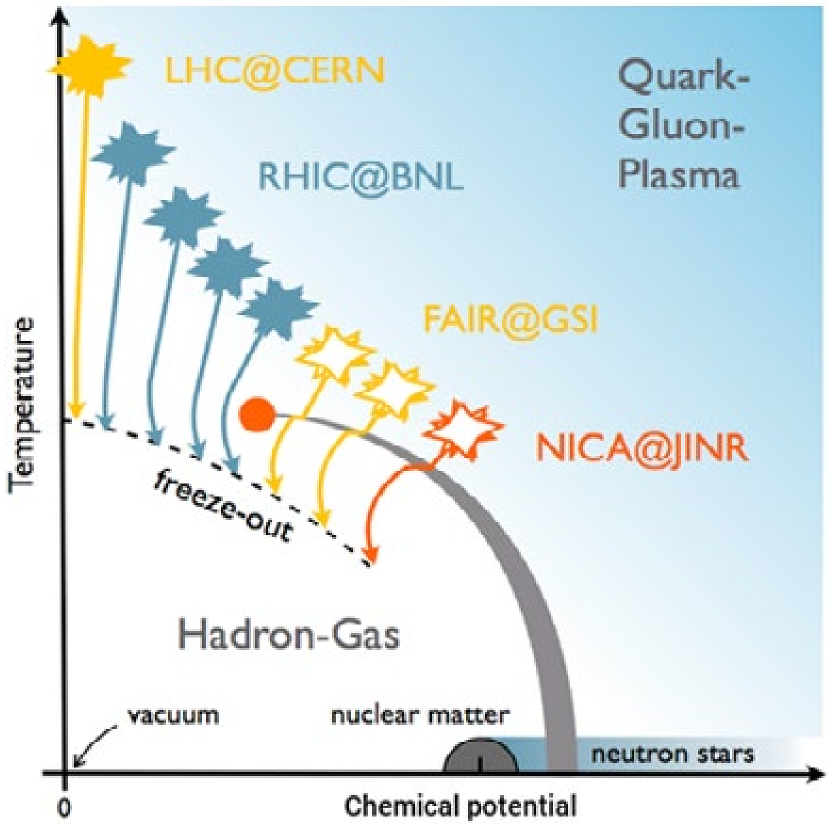
Bastille Day
Utrecht University
The Netherlands



A Large Ion Collider Experiment

ALICE physics primary goal

QGP via heavy ion collisions at the LHC: ε_0~10-40 GeV/fm^3



NuPECC Long Range Plan 2017
http://www.nupecc.org/lrp2016/Documents/lrp2017.pdf

Hadronic Probes

Initial State and QGP probes

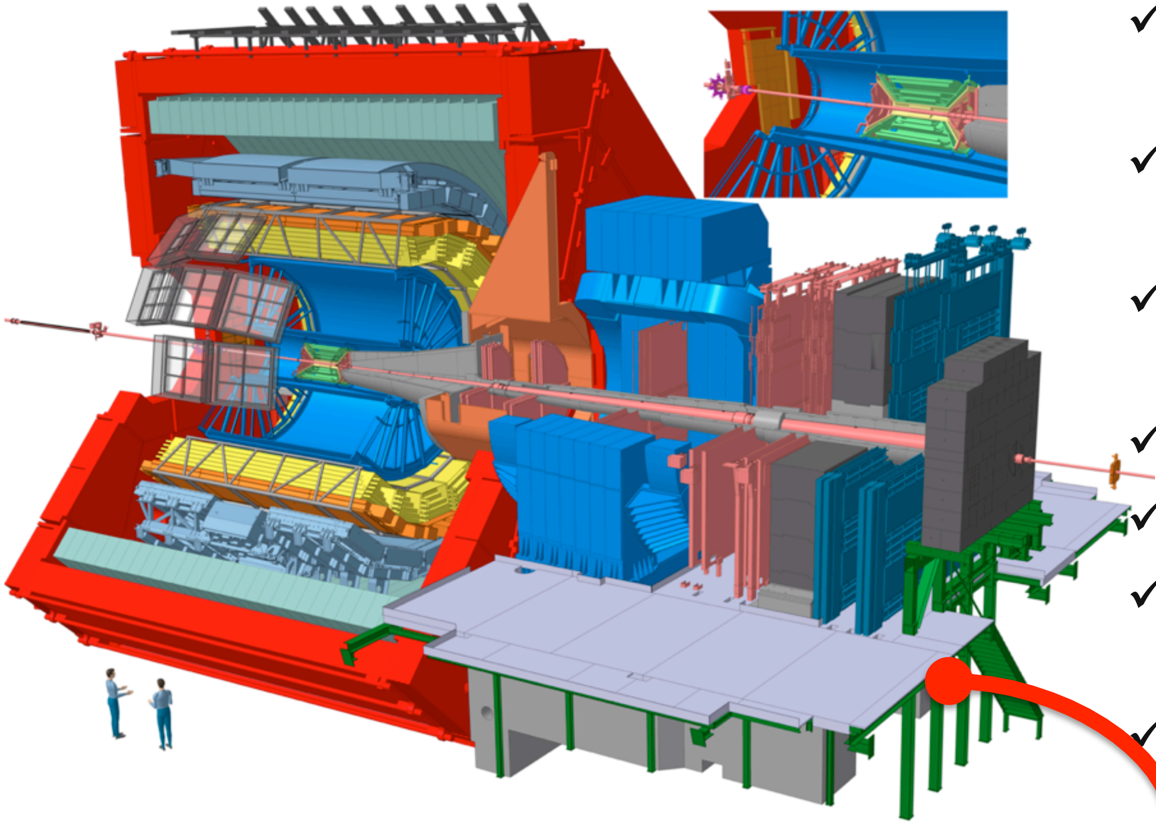
- Global observables
- Light hadrons
- Strange hadrons
- Quarkonia
- Open heavy flavours
- Electromagnetic probes
- Jet and high p_T hadrons
- Hypernuclei

As a function of rapidity, transverse momentum, azimuthal angle, centrality, centre of mass energy, reaction plane, fluctuations, small systems (pp and pA), correlations …

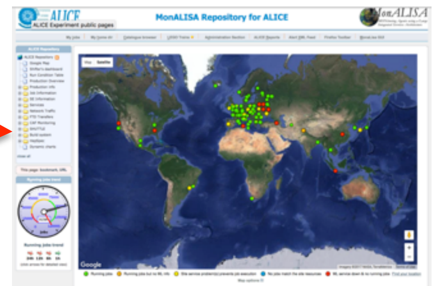
A Large Ion Collider Experiment

ALICE Detector (Run1 and Run2, 2009-2018)

ALICE



- ✓ Excellent (low p_T) tracking performances
- ✓ Excellent particle identification performances
- ✓ Good secondary vertexing reconstruction
- ✓ Electromagnetic calorimeters
- ✓ Muon spectrometer at 2.5<y<4
- ✓ Minimum Bias Trigger and centrality measurement
- ✓ ALICE computing grid: up to 120000 jobs, 100 PBytes

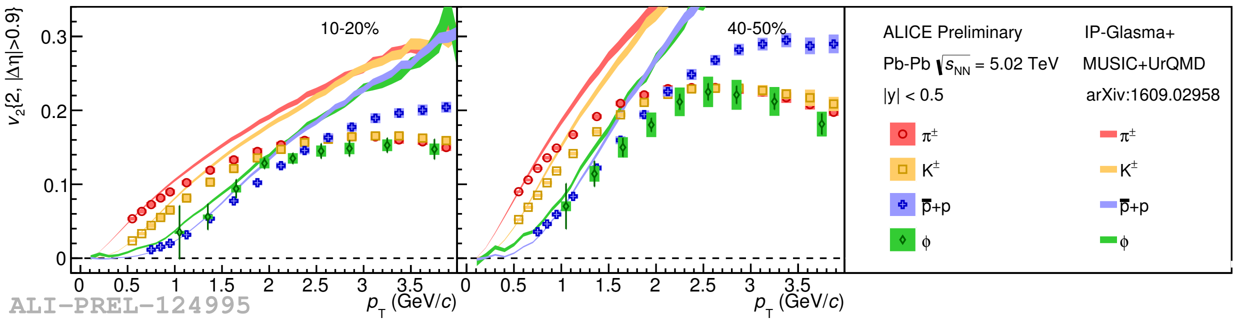


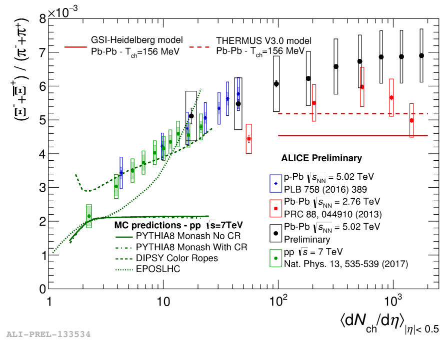
JINST 3 (2008) S08002

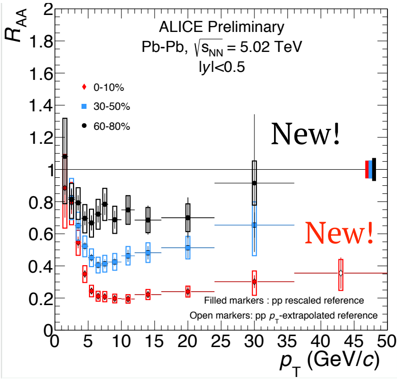
A Large Ion Collider Experiment

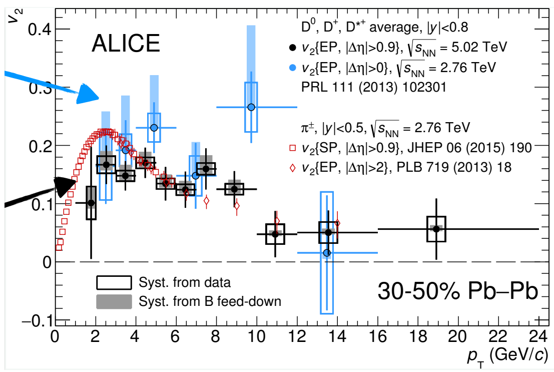
Quick overview of ALICE physics results

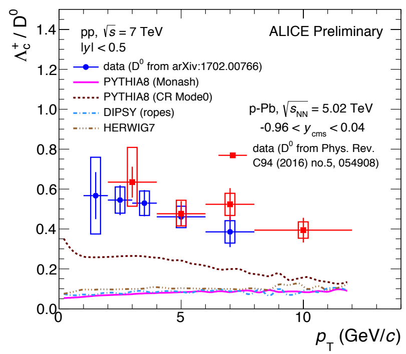
180 papers submitted/published: 2 top+500, 12 top+250, 38 top+100

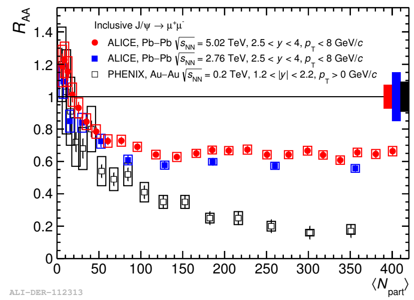


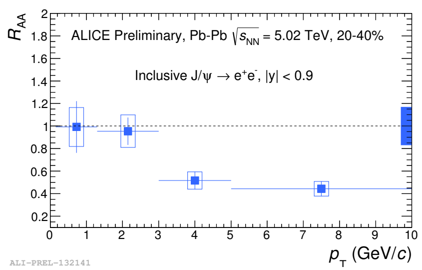


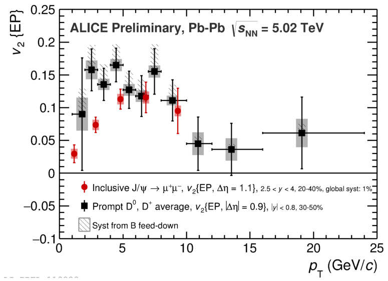


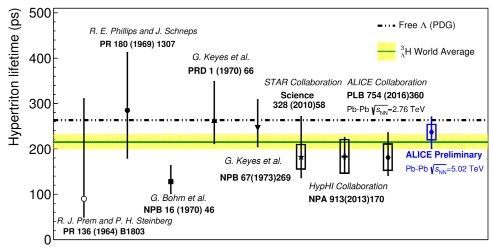












Latest results in Alessandro GRELLI's talk and many other presentations and posters.

QGP behaves as a near-perfect liquid, opaque medium, charm quarks strongly interact with the medium, and collectivity-like behaviour is observed in small systems

A Large Ion Collider Experiment

Remaining questions about QGP at the LHC

Higher precision and new probes

- ✓ Characterisation of the QGP at the LHC: viscosity, diffusion coefficients, initial temperatures, screening scales, …
- ✓ How does collectivity develop? the small systems

Roberto Preghenella's talk

- ✓ 10-fold higher luminosity in Pb-Pb collisions at the highest energy in the centre of mass
- ✓ All 4 experiments will take part in the LHC HI runs
- ✓ Possible interest on lighter ion run (Ar or Xe)

A Large Ion Collider Experiment

ALICE strategy for Run3 and Run4 2021-2029

ALICE can do better : higher precision, low signal/background observables, low p_T heavy quarks, rarest probes

Global observables.......
Light hadrons................
Strange hadrons...........
Quarkonia....................
Open heavy flavours.....
Electromagnetic probes.
Jet and high p_T hadrons.
Hypernuclei..................

Better Significance

- PbPb 50 kHz
- New RO electronics
- New TPC RO chambers
- ITS Upgrade
- New Computing req.

New observables

- ITS upgrade
- MFT tracker
- FoCal (2024)?

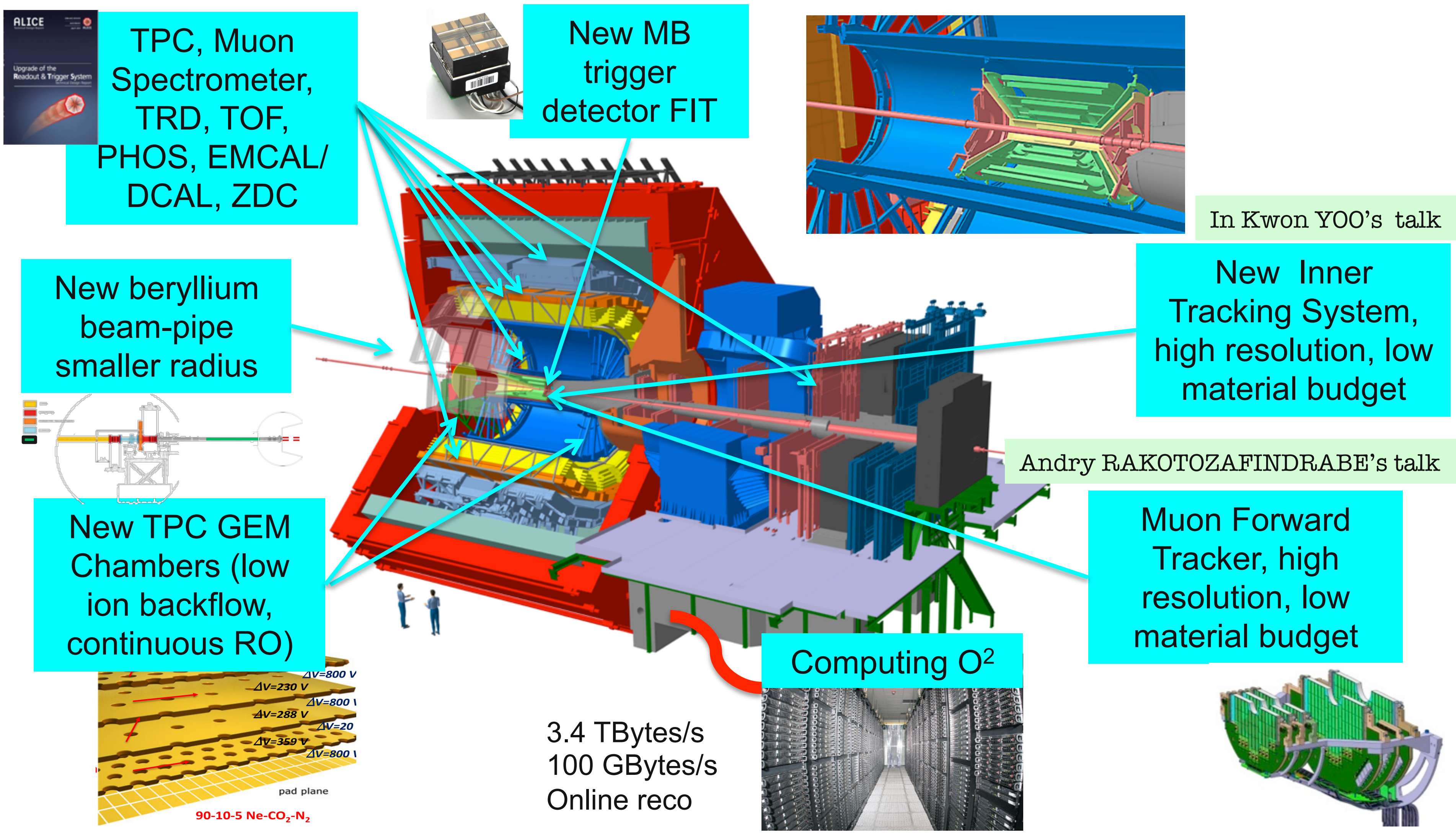
100-fold larger integrated luminosity than Run1 and Run2

Low signal over background: hardware trigger filtering impossible, namely at low p_T

A Large Ion Collider Experiment

ALICE Detector Upgrade

Increase of luminosity (50kHz IR) and improve vertexing and tracking at low p_T

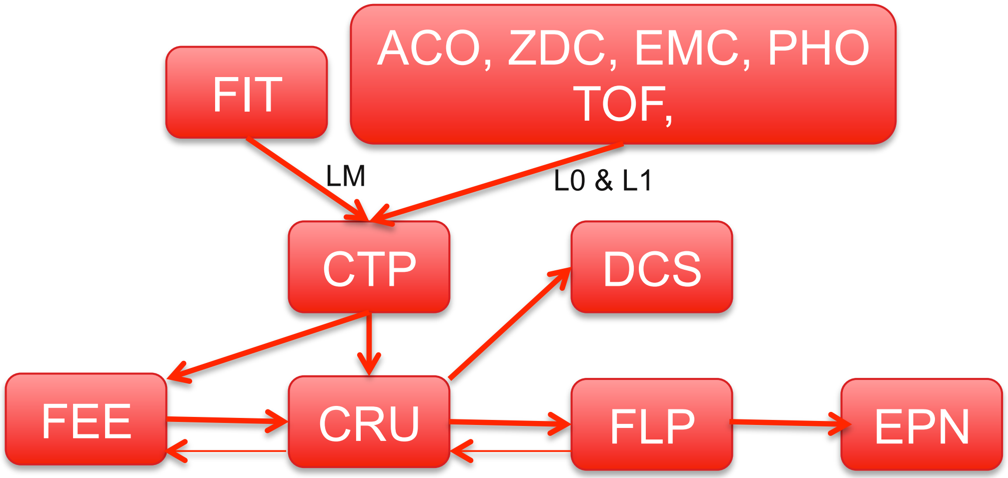


A Large Ion Collider Experiment

New Read-Out Architecture

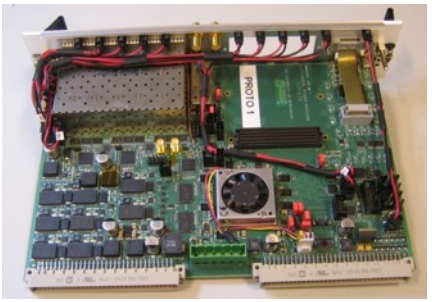
Projects

- Central Trigger Process (CTP)
- SAMPA: new ASIC for the TPC and muon tracking system
- Common Readout Unit (CRU): FIT, ZDC, ITS, TPC, TRD, TOF, MFT, MCH, MID
- Upgrade of most FEE ALICE subsystems

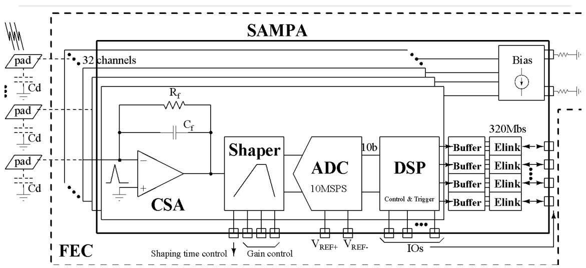


Continuous and triggered readout in most of ALICE subsystems

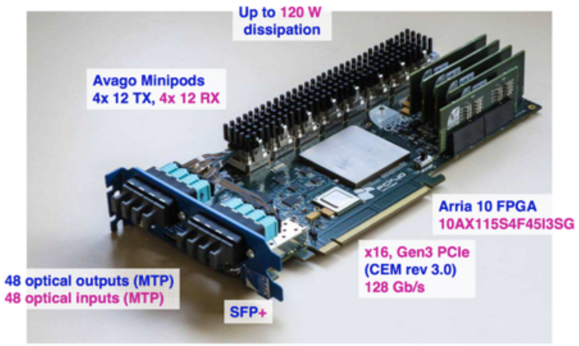
CTP proto boards



SAMPA



CRU

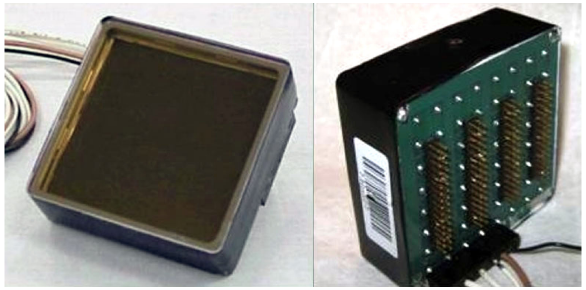


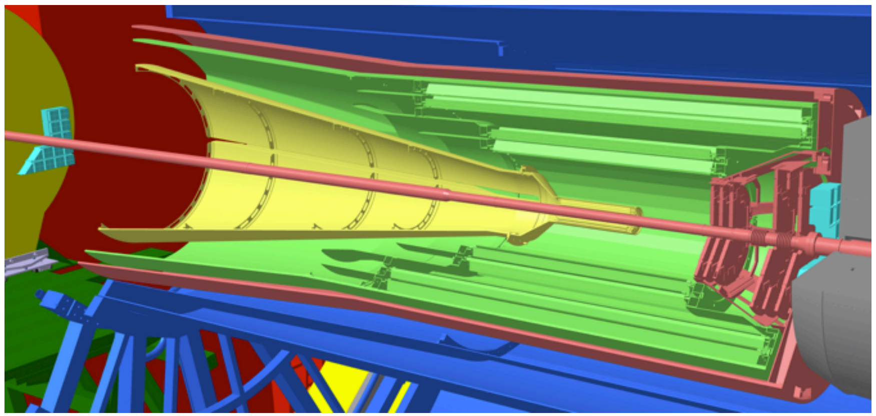
FIT: Fast Interaction Trigger for ALICE

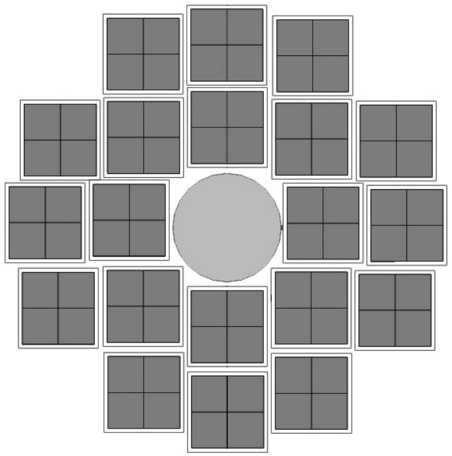
Minimum Bias Trigger

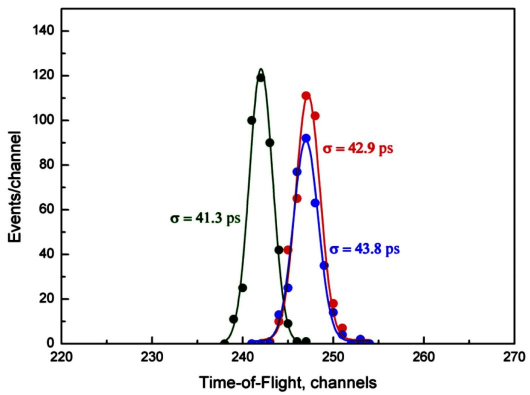
- Efficiency 100% (~83%) in Pb-Pb (pp) collisions
- Centrality triggering
- Vertex online location
- Event plane determination
- Time resolution <50 ps
- No aging over Run3 and Run4 periods

- MCP-based detector
- XP85012 Planacon from Photonis (59x59x28 mm^3)





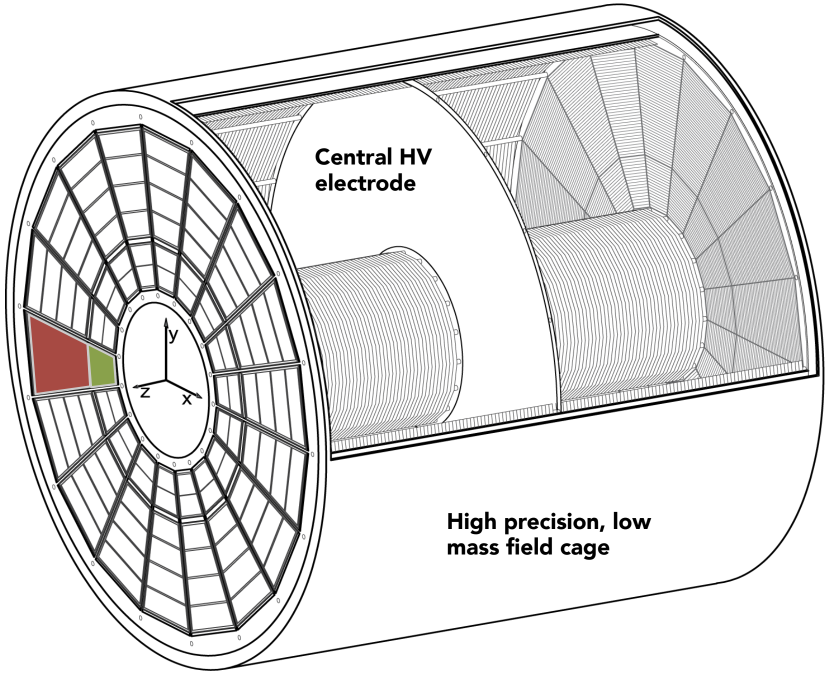


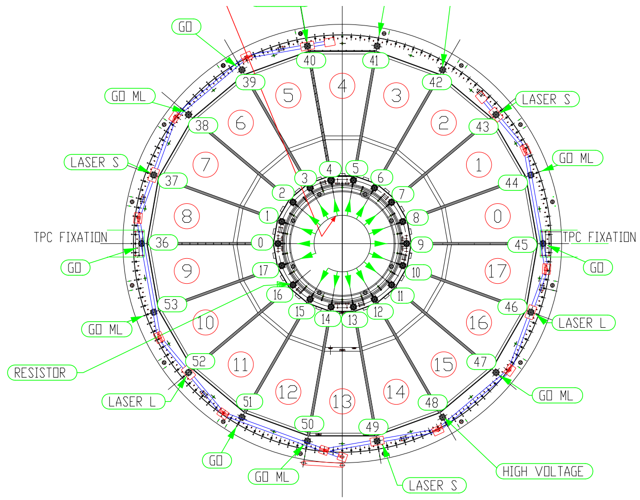


New TPC RO chambers

Limitation of the ion backflow

- Diameter 5 m, length 5m. Electron drift time 100 μs, Ion drift time 160 ms.
- Gating grid to collect ion back flow need 300 μs. Intrinsic limitation at 3 kHz interaction rate
- Low Ion backflow of Gas Electron Multipliers (GEMs) allows to avoid the gating grid
- Continuous readout ➔ ~3 TByte/s.
- Online calibration, reconstruction and data compression needed (O2 project)

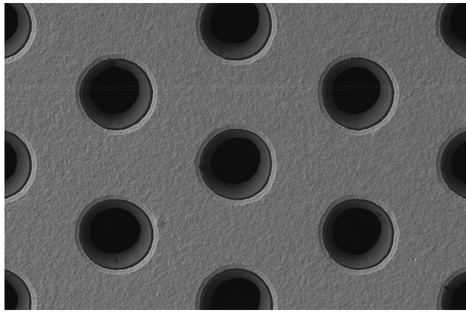


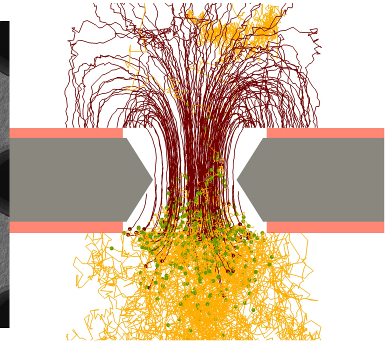


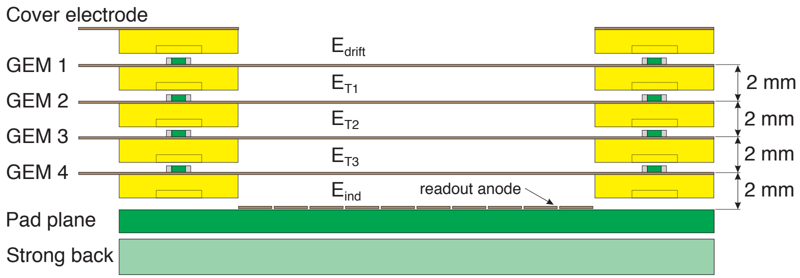
Quadruple GEM

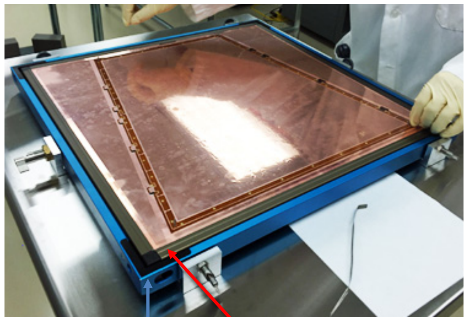
Technology

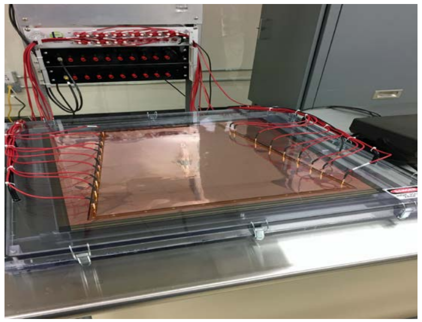
- Quadruple GEM chambers
- GEMs technology intrinsically blocks ion backflow
- Similar performances as MWPC
- 640 GEM foils needed for the TPC RO upgrade

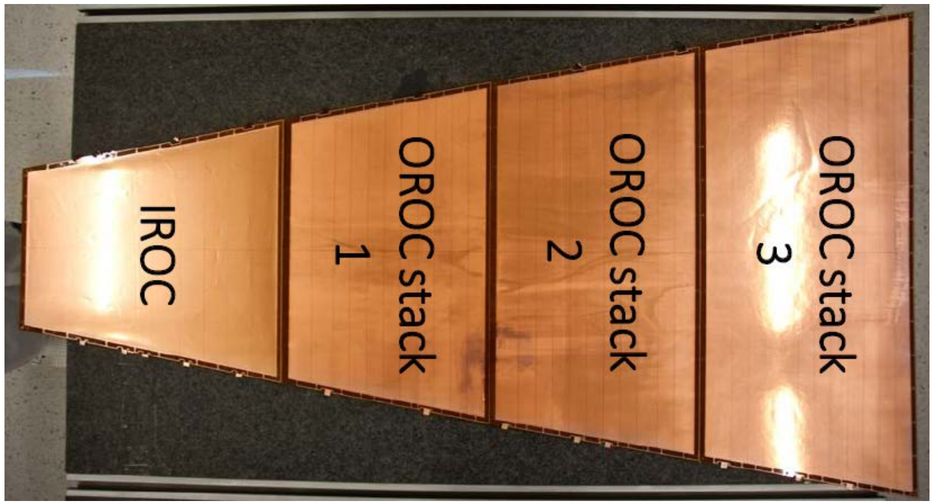












A Large Ion Collider Experiment

ALICE O² project

Requirements

1. LHC min bias Pb-Pb at 50 kHz
   ~100 x more data than during Run 1
2. Rare physics processes with very small signal over background ratio
3. Triggering techniques very inefficient if not impossible
4. 50 kHz > TPC inherent rate
   Support for continuous read-out

New computing system

➔ Read-out the data of all interactions

➔ Compress these data intelligently by online reconstruction

➔ One common online-offline computing system: O²

Unmodified raw data of all interactions shipped from detector to online farm in triggerless continuous mode

HI run 3.4 TByte/s ⇩

Baseline correction and zero suppression
Data volume reduction by zero cluster finder.
No event discarded.
Average compression factor 6.6

500 GByte/s ⇩

Data volume reduction by online tracking.
Only reconstructed data to data storage.
Average compression factor 5

100 GByte/s ⇩

Data Storage
1 year of compressed data

120 GB/s ⇩ ⇧ | 200 GB/s ⇩ 20 GB/s ⇧

Tier 0, Tiers 1 and Analysis Facilities

Asynchronous (hours) event reconstruction with final calibration

Detector Electronics
9000 GBTs links

⇩

270 First-Level Processors
Hw acc: FPGAs

⇩

Switching Network

⇩

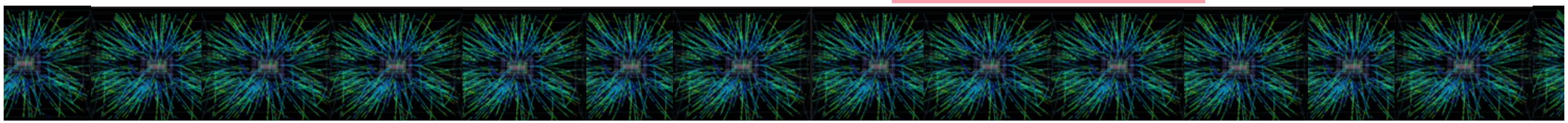
1500 Event Processing nodes
Hw acc: GPUs

⇳

Switching Network

⇳

Write 120 GB/s
Read 320 GB/s
Capacity: 60 PB

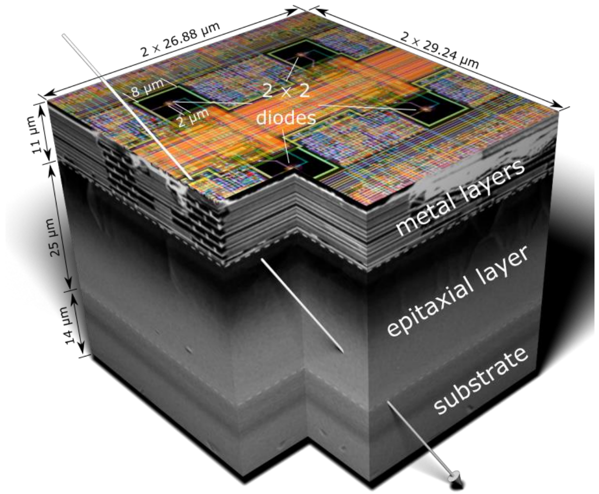


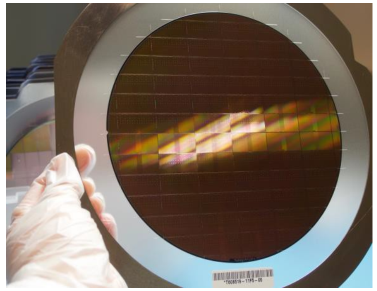
A Large Ion Collider Experiment

ALPIDE pixel sensor (ITS Upgrade and MFT projects)

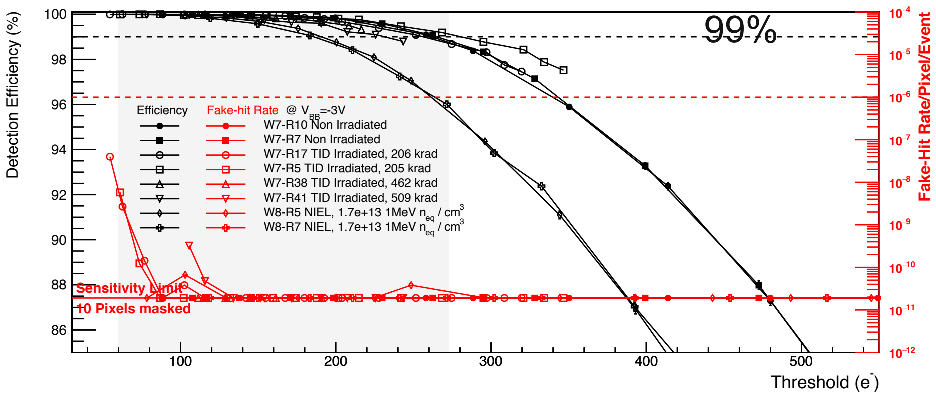
CMOS Monolithic Active Sensors (MAPS), TowerJazz 0.18 μm technology

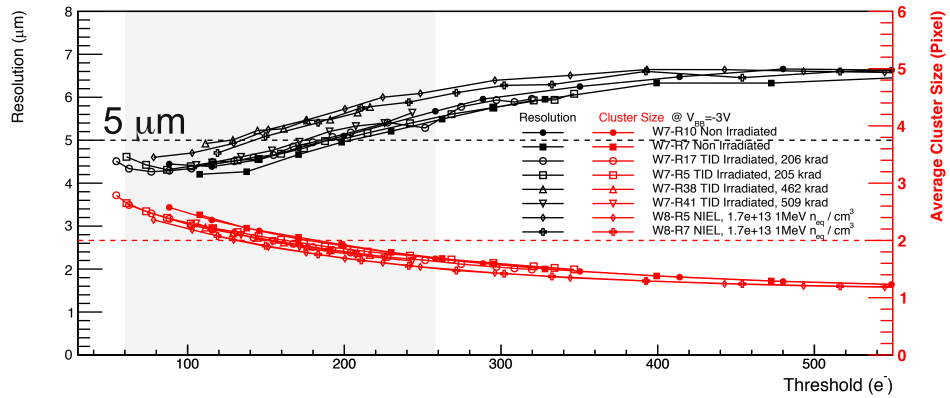
- Sensor Size 15 mm x 30 mm.
  Pixel pitch 29 μm x 27 μm.
- Event time resolution <4 μs
- Low power consumption
  ~40 mW/cm^2
- Expected radiation load in ALICE
  Run3 and Run4 <300 krad,
  <2.0x10^{12} 1MeV n_{eq}/cm^2
- Spatial Resolution 5-6 μm



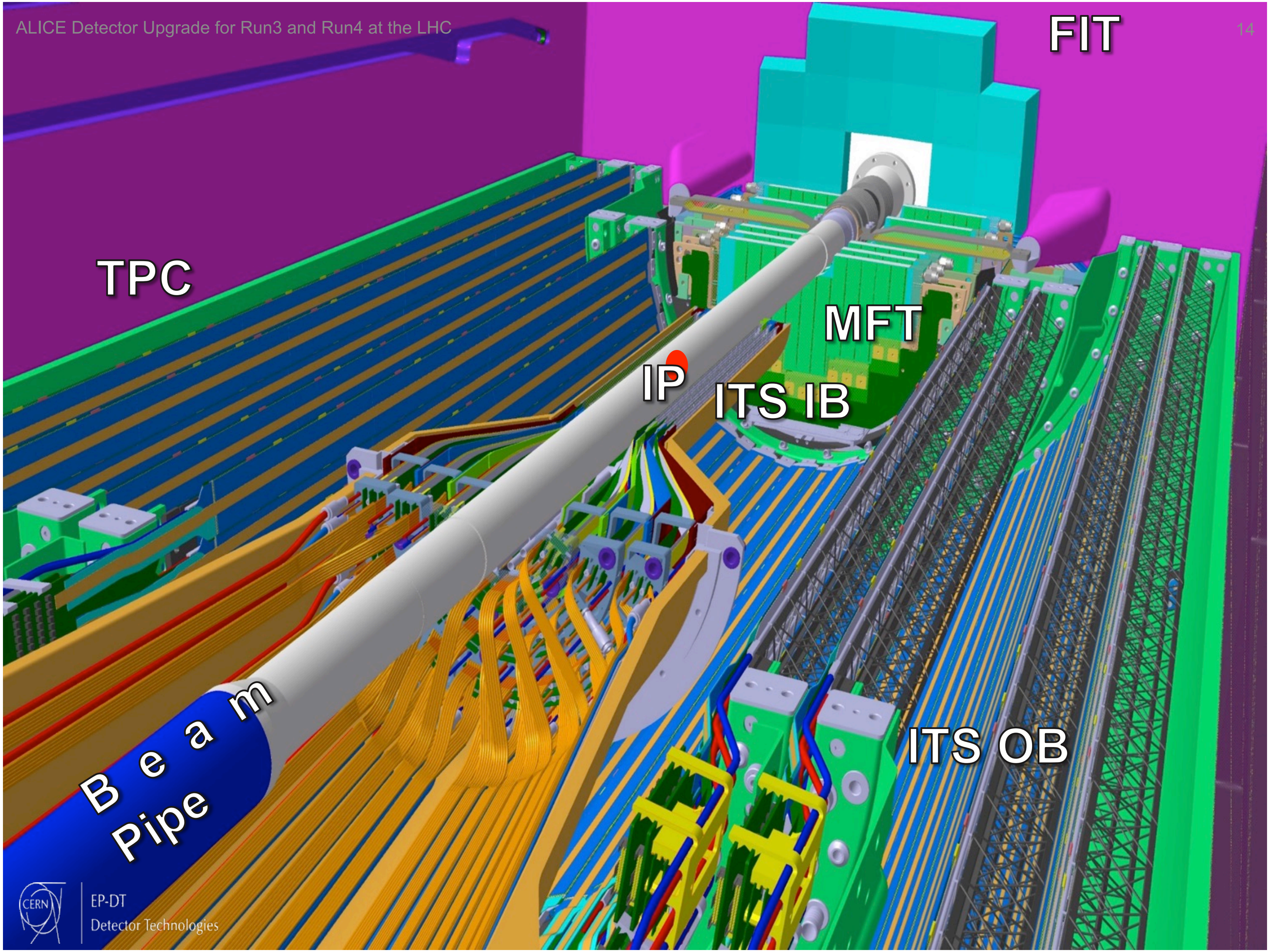


ALPIDE
Production started
December 2016





In Kwon YOO's talk

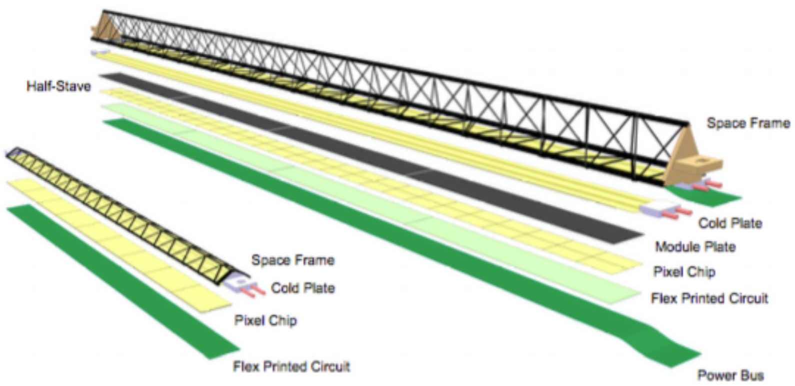

FIT
TPC
MFT
IP
ITS IB
ITS OB
Beam
Pipe

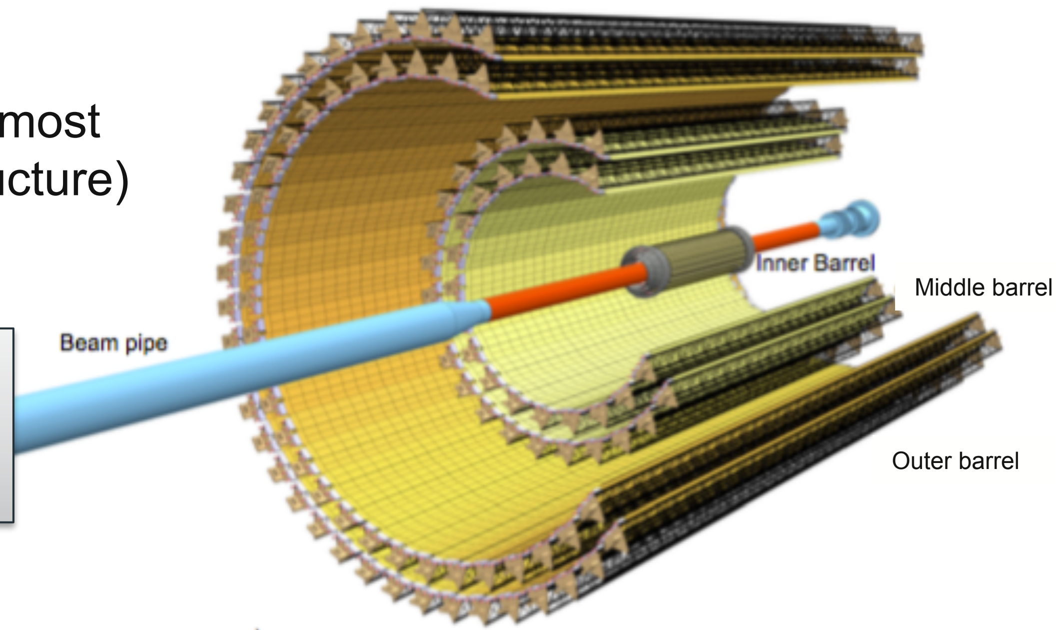
A Large Ion Collider Experiment

ALICE inner tracking system upgrade

Improving tracking performance, namely at low p_T

- Large area (10 m^2) silicon pixel (MAPS) sensor tracker ($|\eta|<1.22$)
- 7 layers from R=22 mm to R=400 mm: Inner Barrel, Outer Barrel (Middle layer & Outer layer)
- Spatial resolution O(5 μm).
- First layer closer to IP (smaller beam pipe radius)
- 0.3%X_0 per layer in the inner most 3 layers (light mechanical structure)





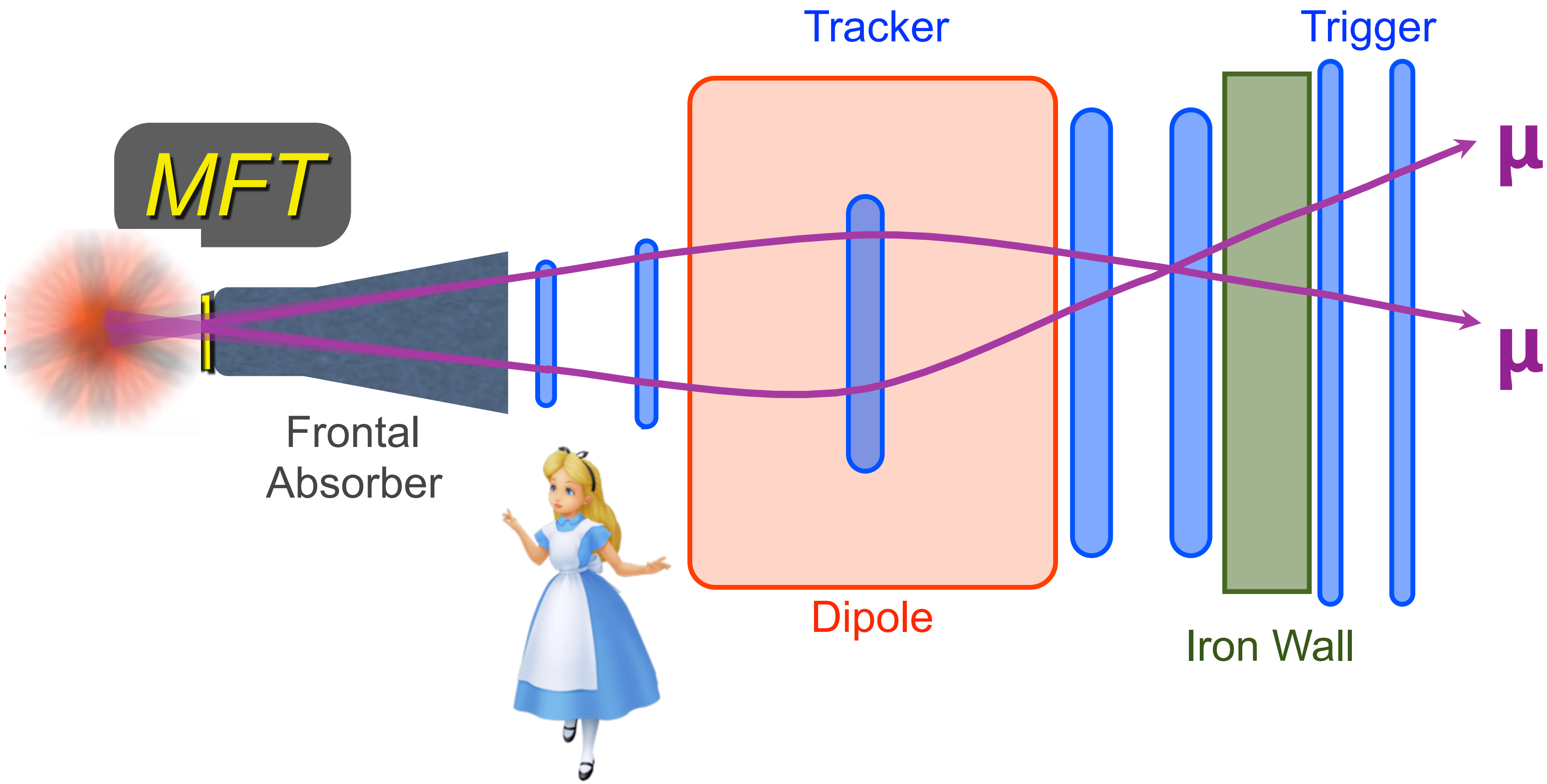
- 12.5 Gigapixels
~24000 pixel chips
- binary readout

In Kwon YOO's talk

A Large Ion Collider Experiment

MFT Principle

High resolution muon vertexing for the ALICE muon spectrometer

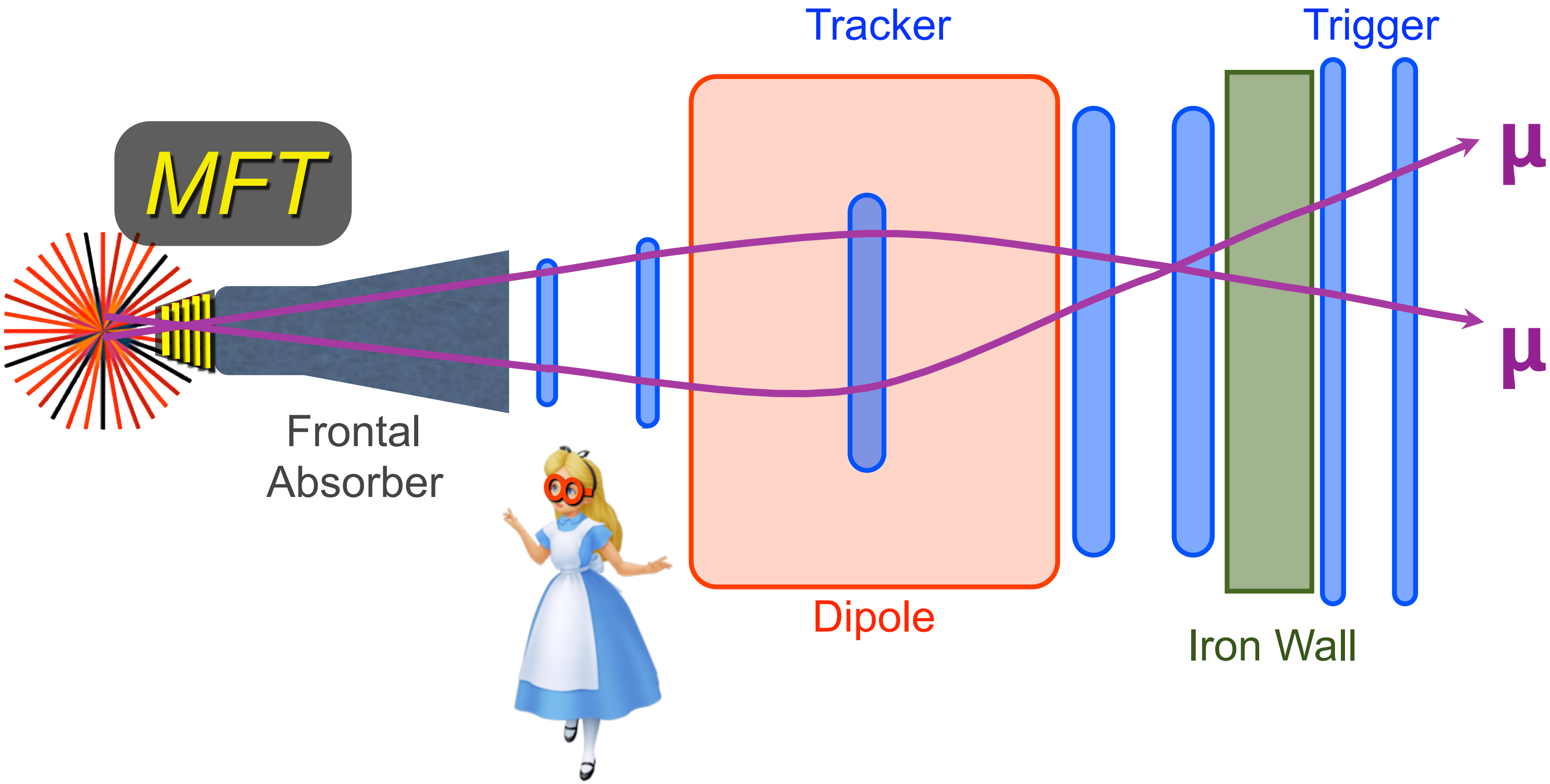


Andry RAKOTOZAFINDRABE's talk

A Large Ion Collider Experiment

MFT Principle

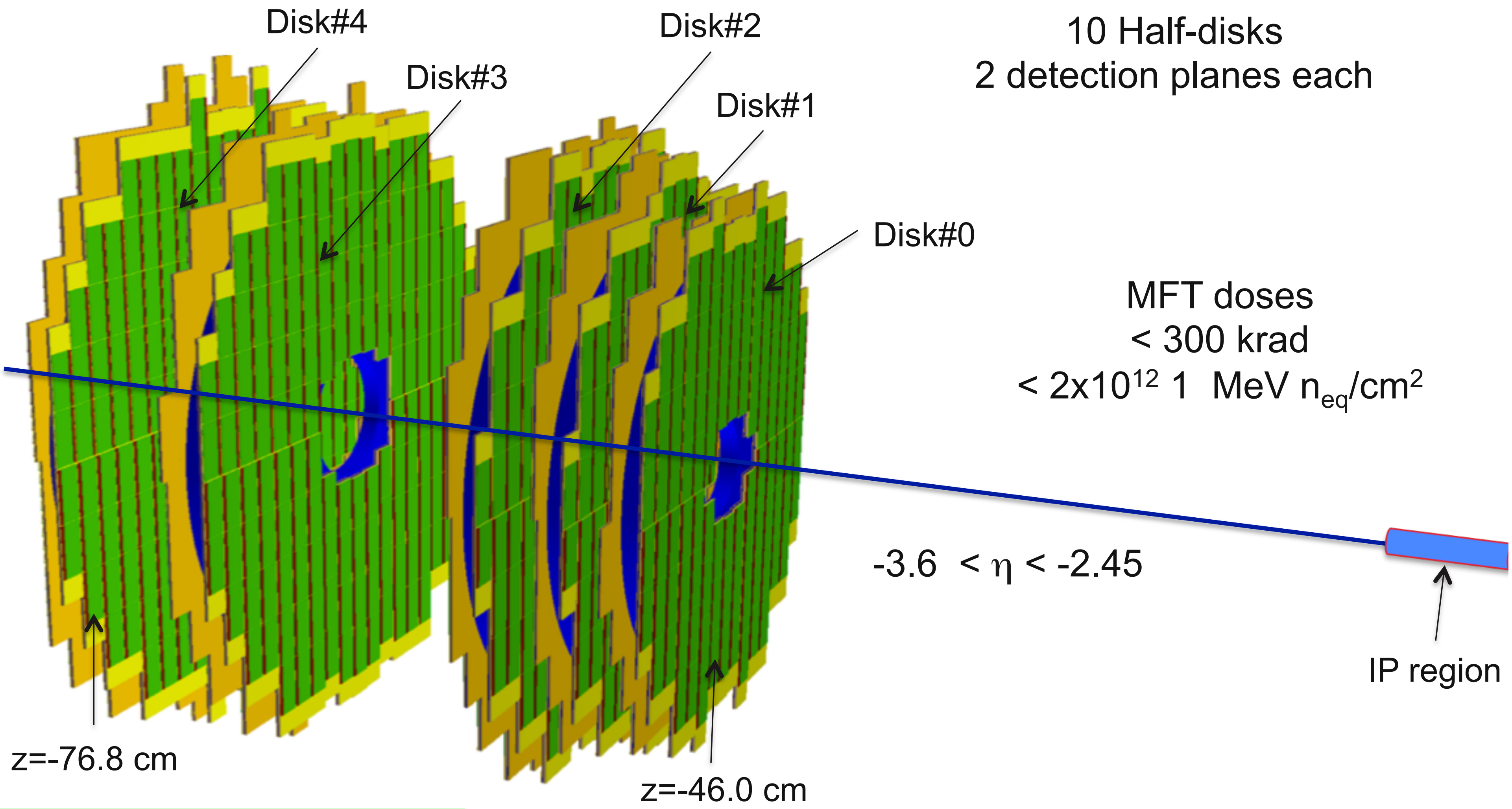
High resolution muon vertexing for the ALICE muon spectrometer



Andry RAKOTOZAFINDRABE's talk

MFT layout

920 silicon pixel sensors (0.4 m^2) on 280 ladders of 2 to 5 sensors each.



10 Half-disks
2 detection planes each

MFT doses
< 300 krad
< 2×10^{12} 1 MeV n_{eq}/cm^2

$-3.6 < \eta < -2.45$

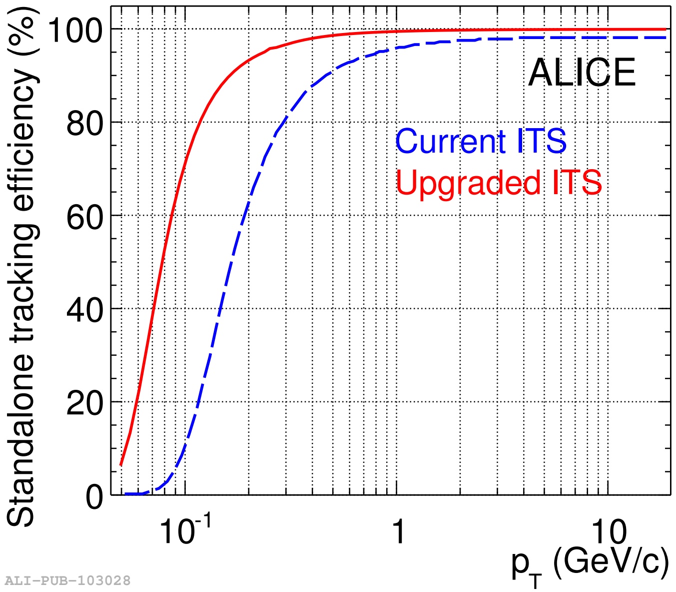
Andry RAKOTOZAFINDRABE's talk

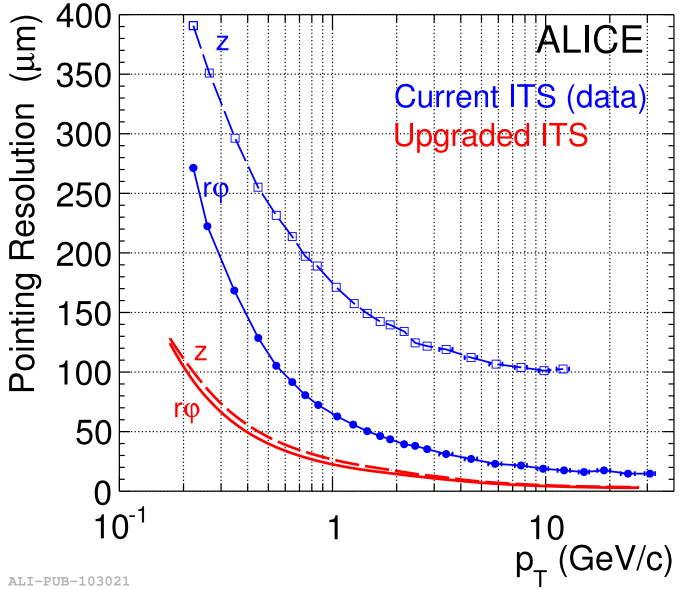
A Large Ion Collider Experiment

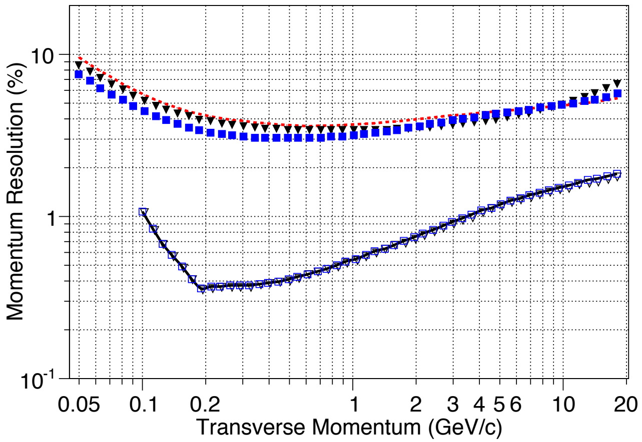
ALICE

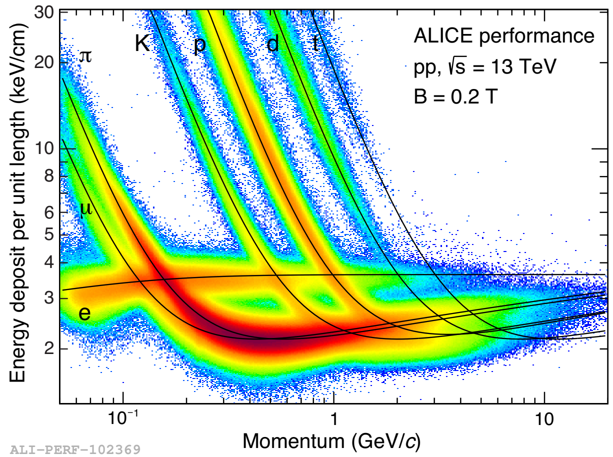
Upgraded ALICE tracking capabilities I

Central Barrel (|η|<1) ITS+TPC







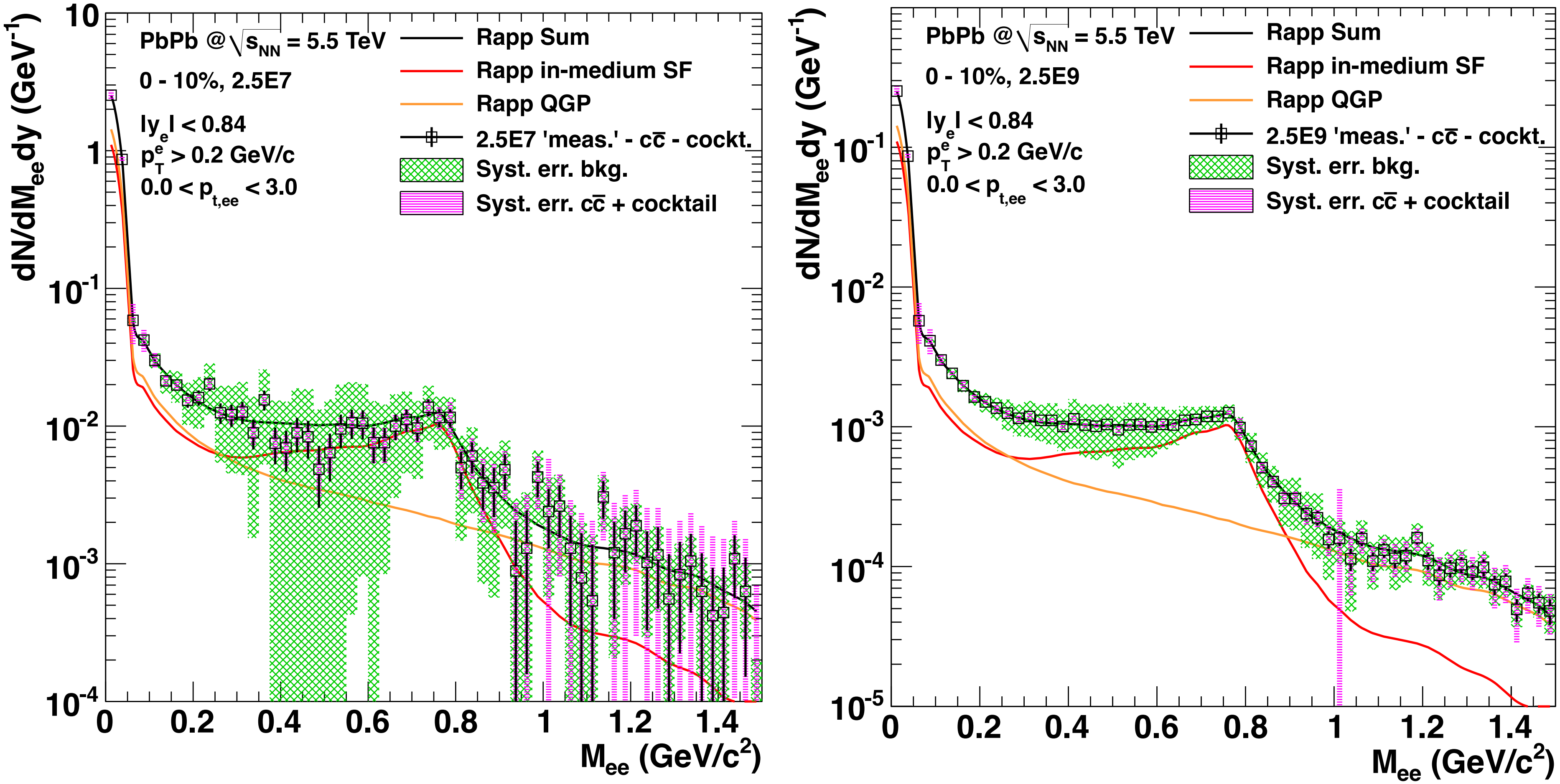


Keeping present PID capabilities

A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

Low Mass dielectron |η|<0.9 : initial temperature from EM radiation



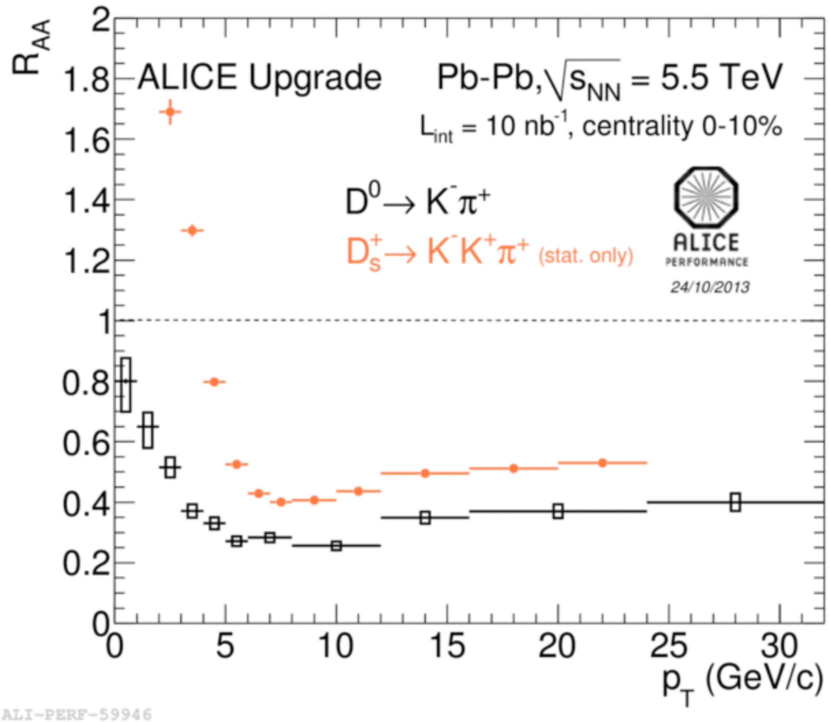
Cocktail-subtracted low mass dielectron disitribution

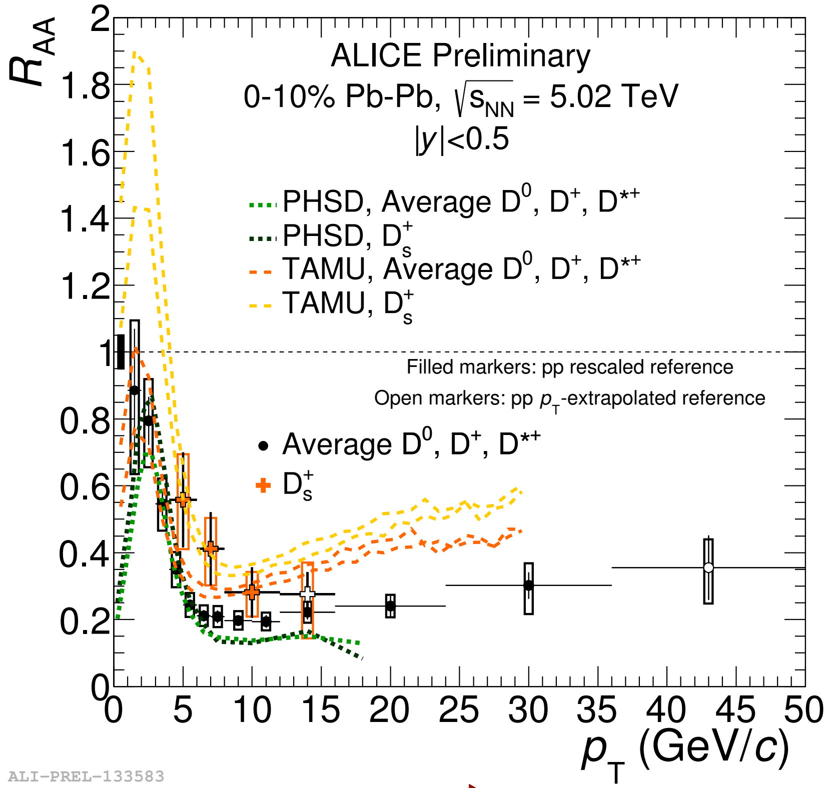
A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

Fabrizio GROSSA's talk

Charmed D^0,D^{+-}, D_S mesons $|\eta|<0.9$





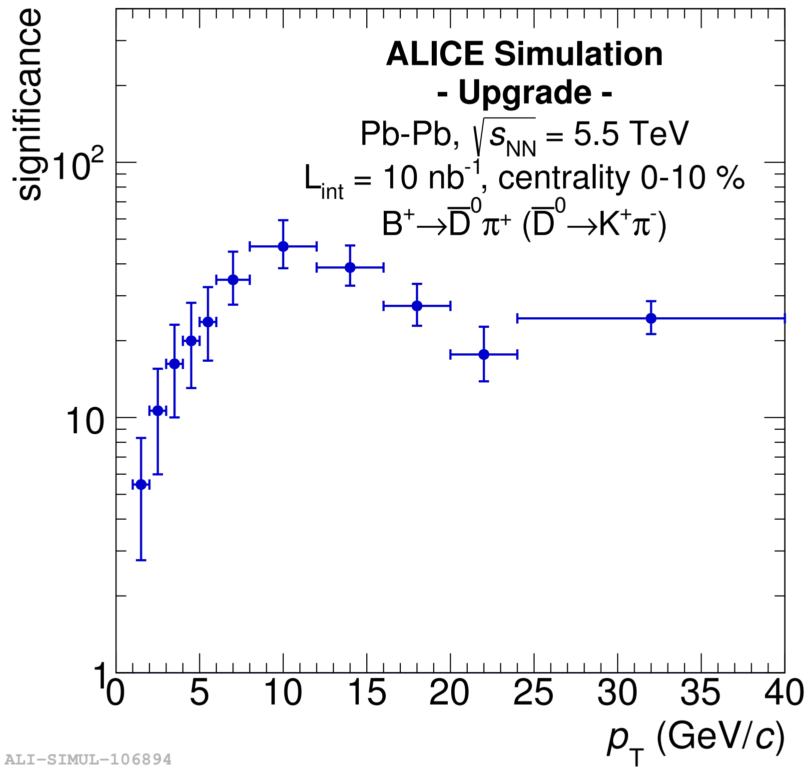
Expected in Run3 and Run4

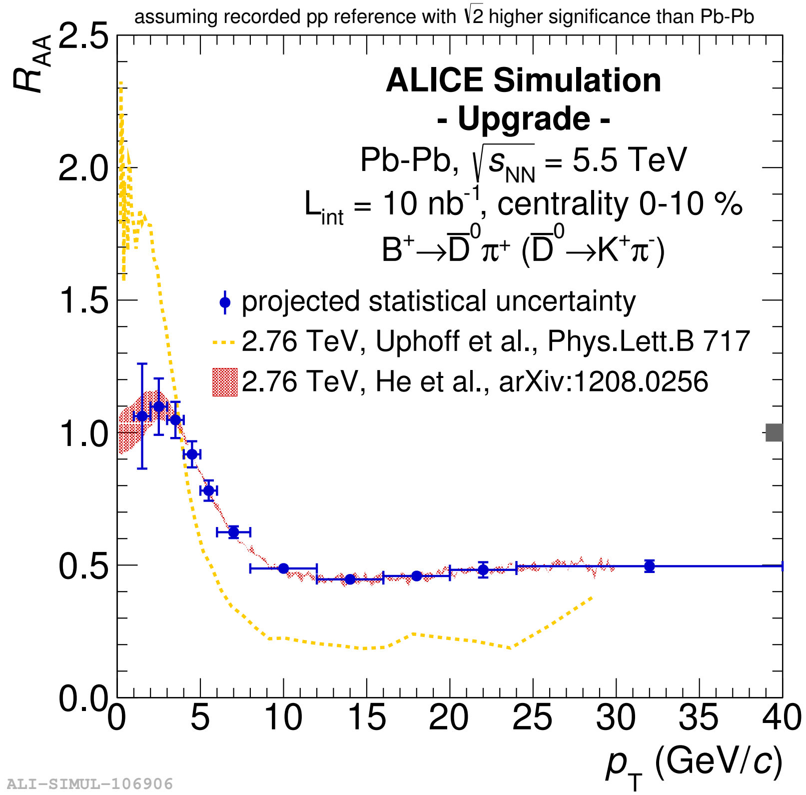
Present measurement

A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

Studying beauty mesons at low pT



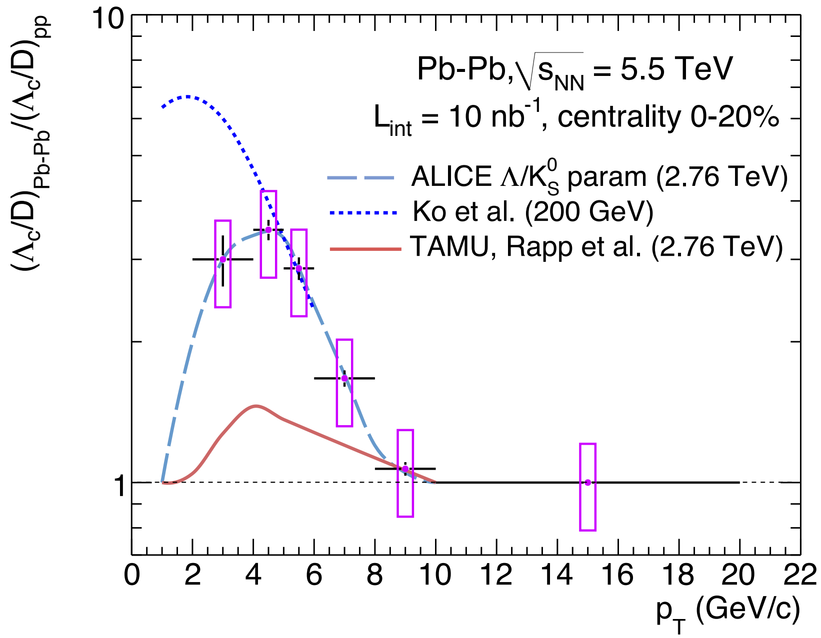


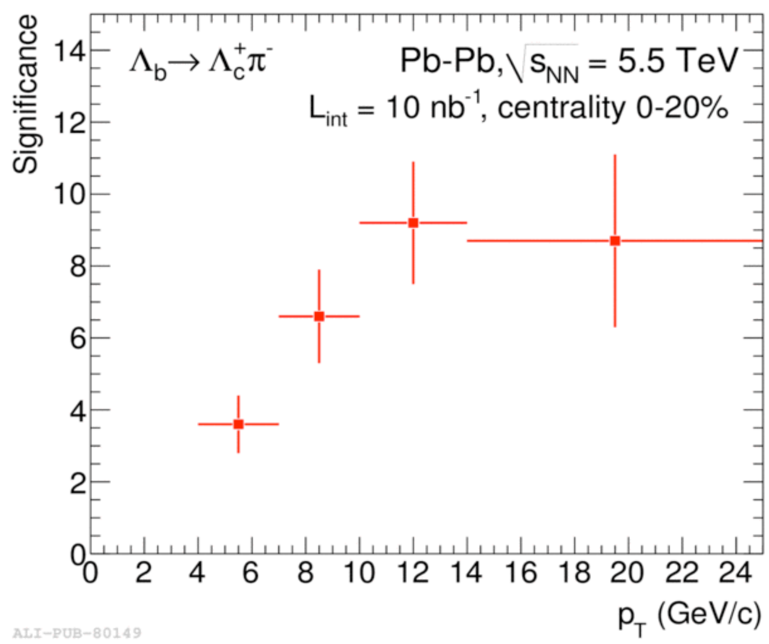
Accessing beauty production at low p_T in HIC at the LHC

A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

Charmed and Beauty baryons |η|<0.9





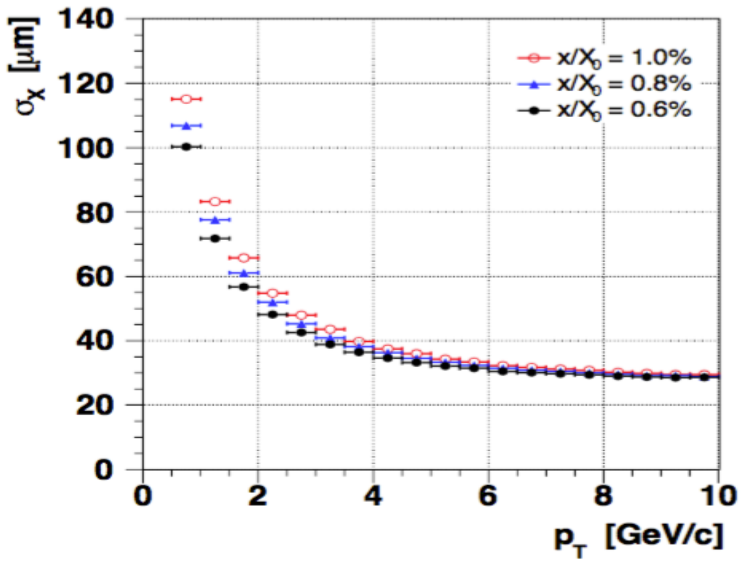
New observables: baryon production in the charm and beauty sector!

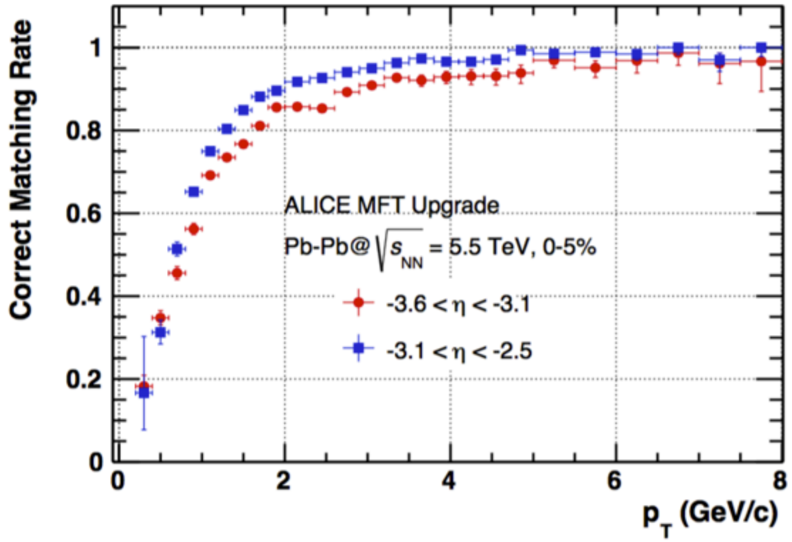
A Large Ion Collider Experiment

ALICE

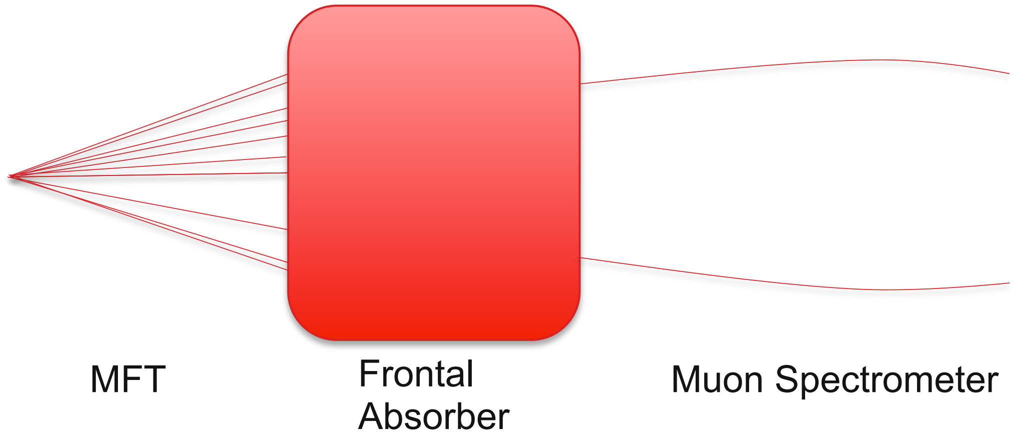
Upgraded ALICE tracking capabilities II

Muon Spectrometer ($2.5<\eta<3.6$) MFT+Muon





Displacement beauty decays in z (for any p_T, even for p_T=0) due to the rapidity boost.



A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

ALICE

Audrey FRANCISCO's talk

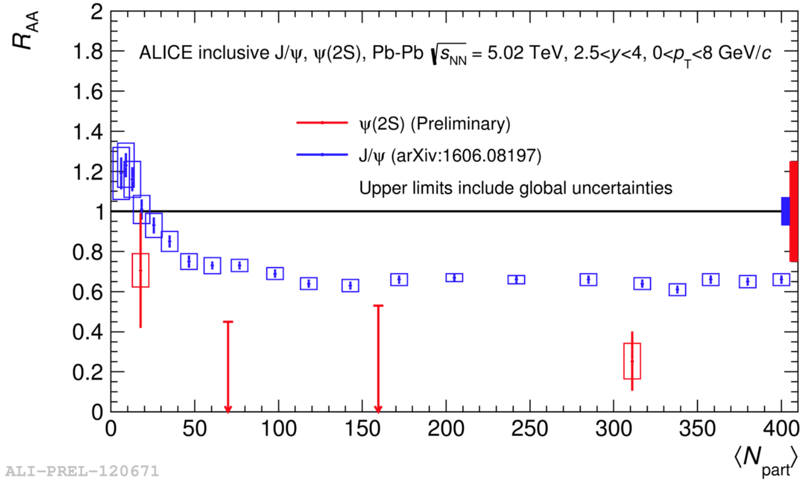
ψ(2S) 2.5<η<4.0

Completing the charmonium potentials for the study QGP at the LHC

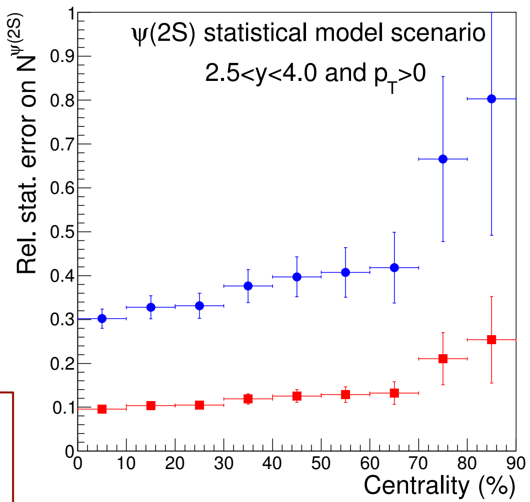
With ITS and MFT: Prompt Decay separation and better S/B

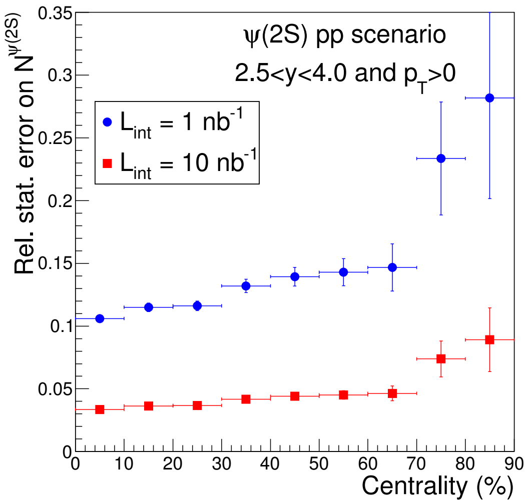
Discrimination between models becomes possible. Recombination time : at hadronisaton or in the QGP?

p_T, y and centrality dependence



Present measurement



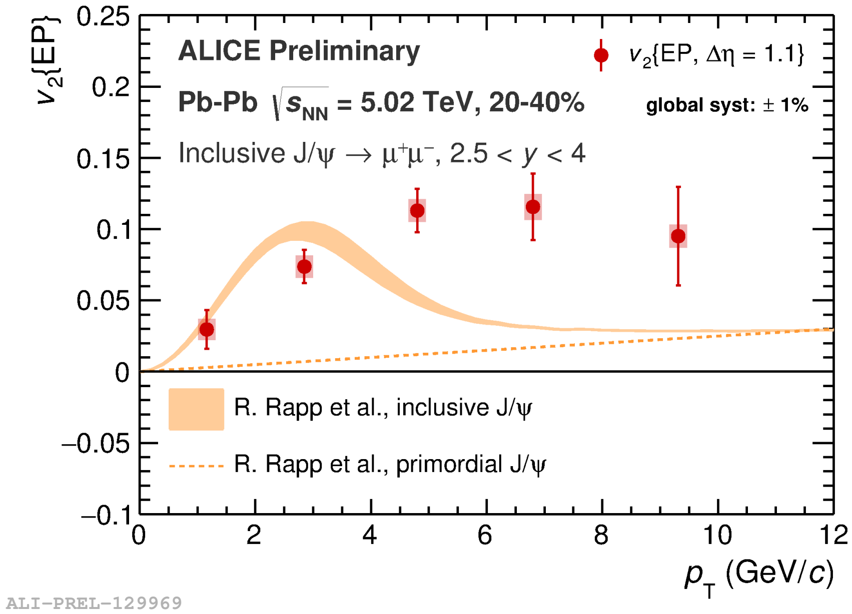


Future precision

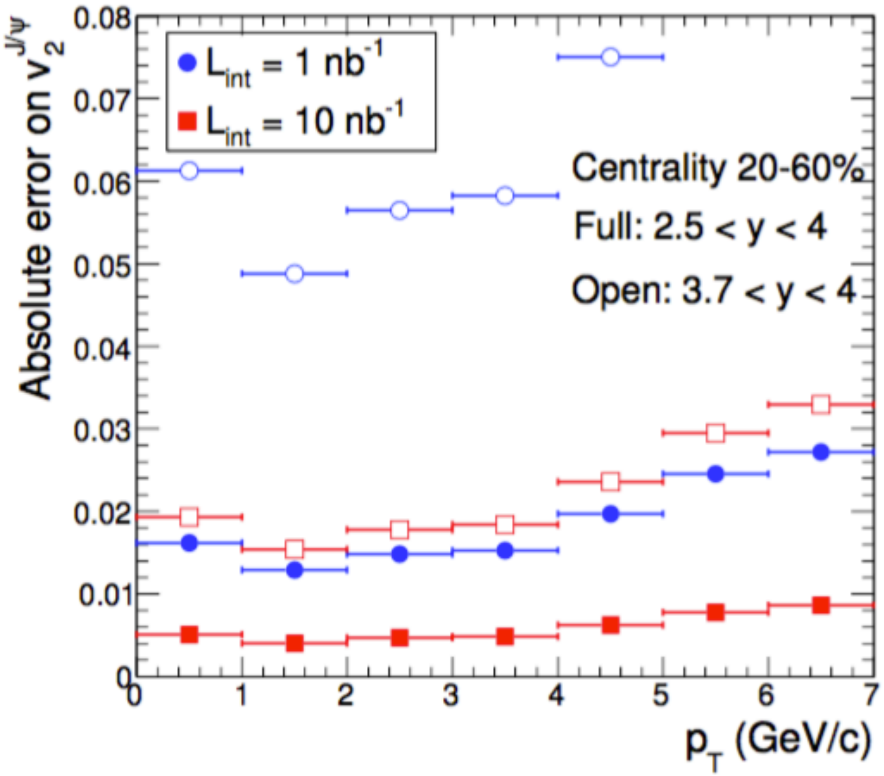
A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

J/ψ elliptic flow 2.5<η<4.0



Present measurement



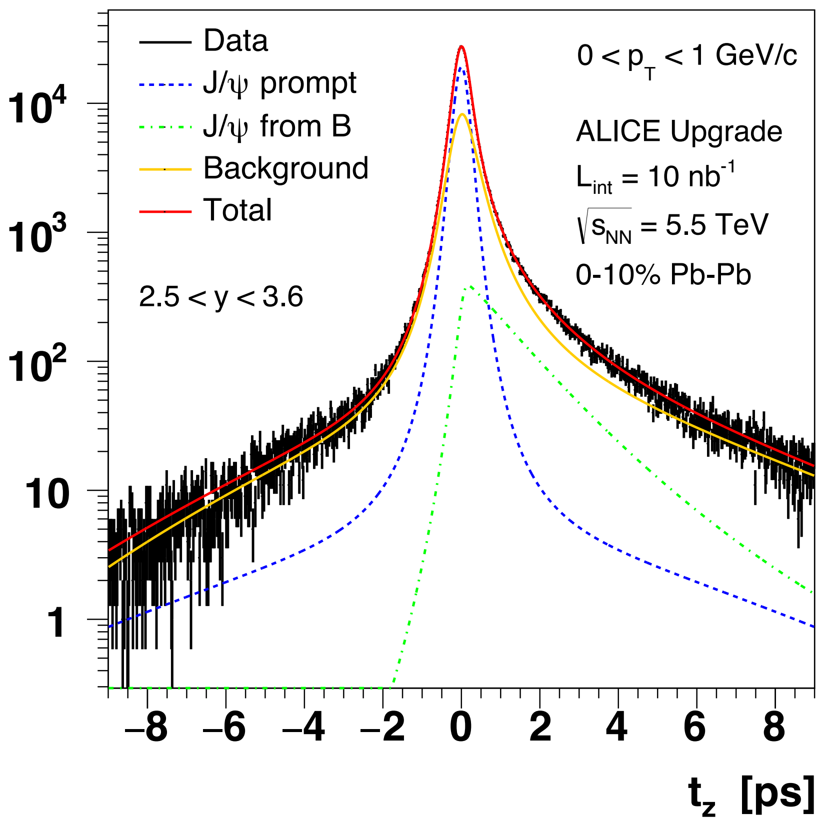
Future precision

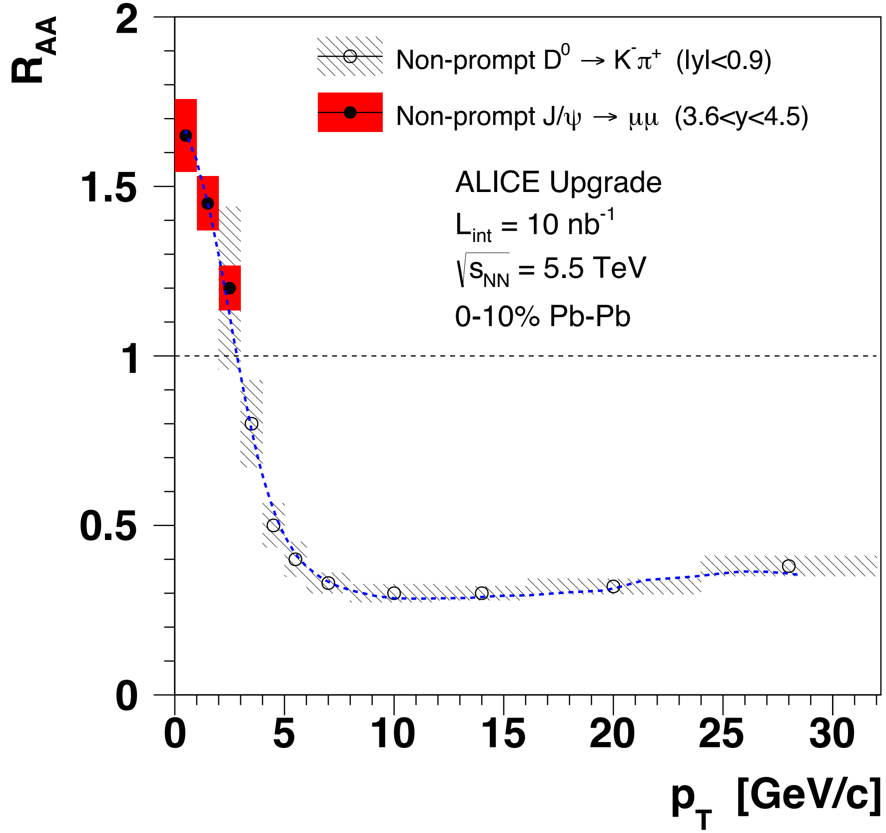
With ITS and MFT: Prompt - Decay separation

A Large Ion Collider Experiment

Physics Performance of the Upgraded ALICE

Beauty measurement in the golden J/ψ channel





Down to p_T=0, displacement ensured by the rapidity boost

A Large Ion Collider Experiment

ALICE

Conclusions

- ✓ Factor 10 increase of the Pb-Pb integrated luminosity is planned by the LHC for Run3 and Run4.
- ✓ All 4 LHC experiments will participate in the heavy ion program at the LHC.
- ✓ ALICE will upgrade its detector to take advantage of the luminosity increase. A factor 10-100 increase in Pb-Pb statistics, depending on the observable with respect Run1 and Run2 (10 nb^{-1} integrated Pb-Pb luminosity). Better precision.
- ✓ New pixel trackers (ITS and MFT) based on ALPIDE MAPS sensor. Better detector performance to study low p_T hadrons and open heavy flavour and quarkonium in Pb-Pb collisions.
- ✓ In addition to the nominal conditions, a low B field (0.2 T) run will improve the low p_T reach of low mass dielectron measurements.
- ✓ Installation is foreseen in 1.5 years from now, during LS2 (2019-2020).

Thanks for your attention!

ALICE Detector Upgrade for Run3 and Run4

Letters of Intent and Technical Design Reports

- ALICE TDRs for the Run3 upgrade
  - CERN-LHCC-2013-019 (System upgrade TDR)
  - CERN LHCC-2013-013 (TPC Upgrade TDR
  - CERN-LHCC-2013-023 (ITS Upgrade TDR)
  - CERN-LHCC-2015-001 (MFT TDR)
  - CERN-LHCC-2015-006 (O2 TDR)
- Alice Upgrade LoI and its addendum
  - CERN-LHCC-2012-012 (LoI)
  - CERN-LHCC-2013-014 (addendum)

ALICE

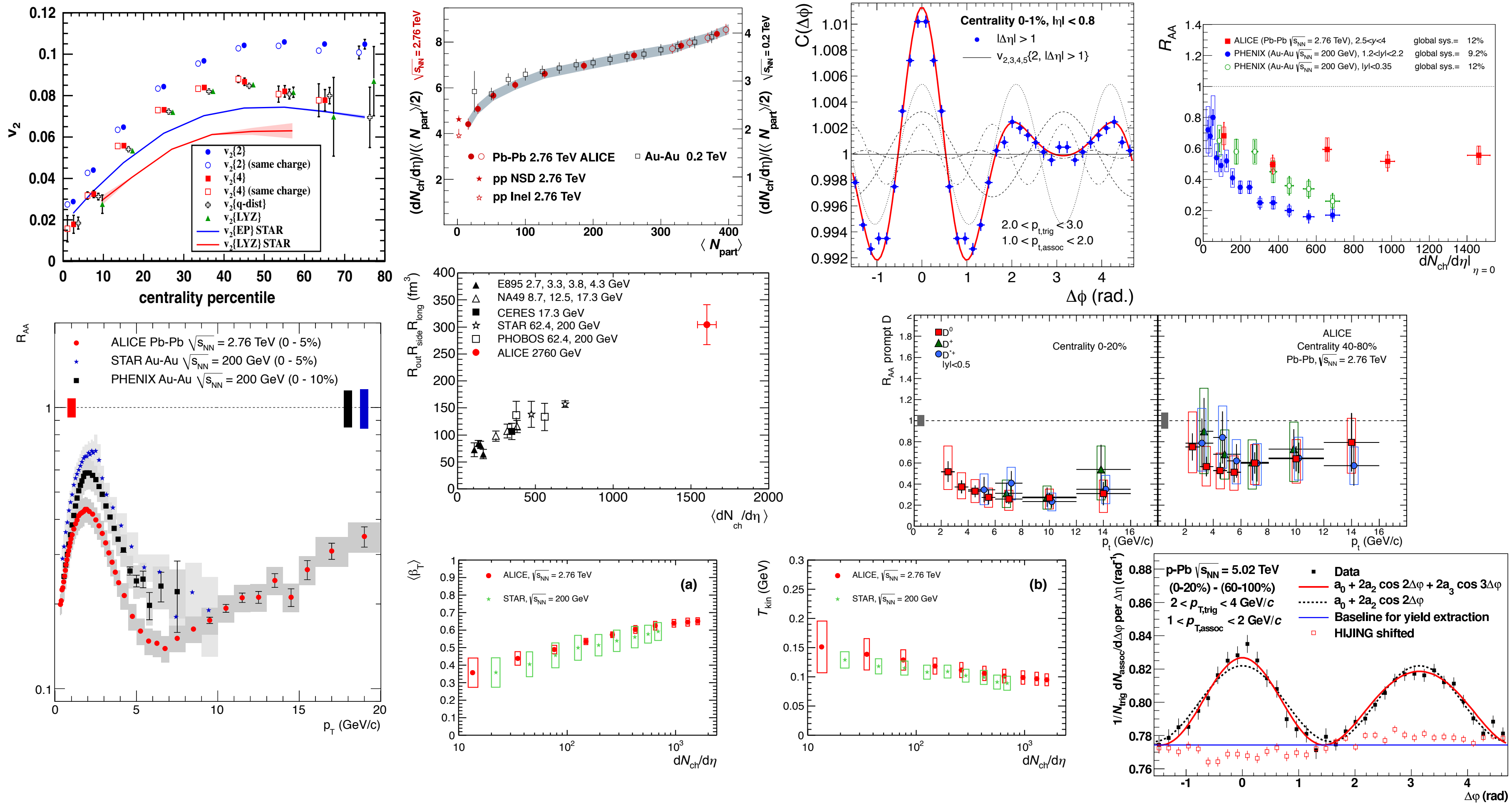
Back-up slides

Latest results in Alessandro GRELLI's talk

A Large Ion Collider Experiment

Quick overview of ALICE physics results

180 papers submitted/published: 2 top+500, 12 top+250, 38 top+100



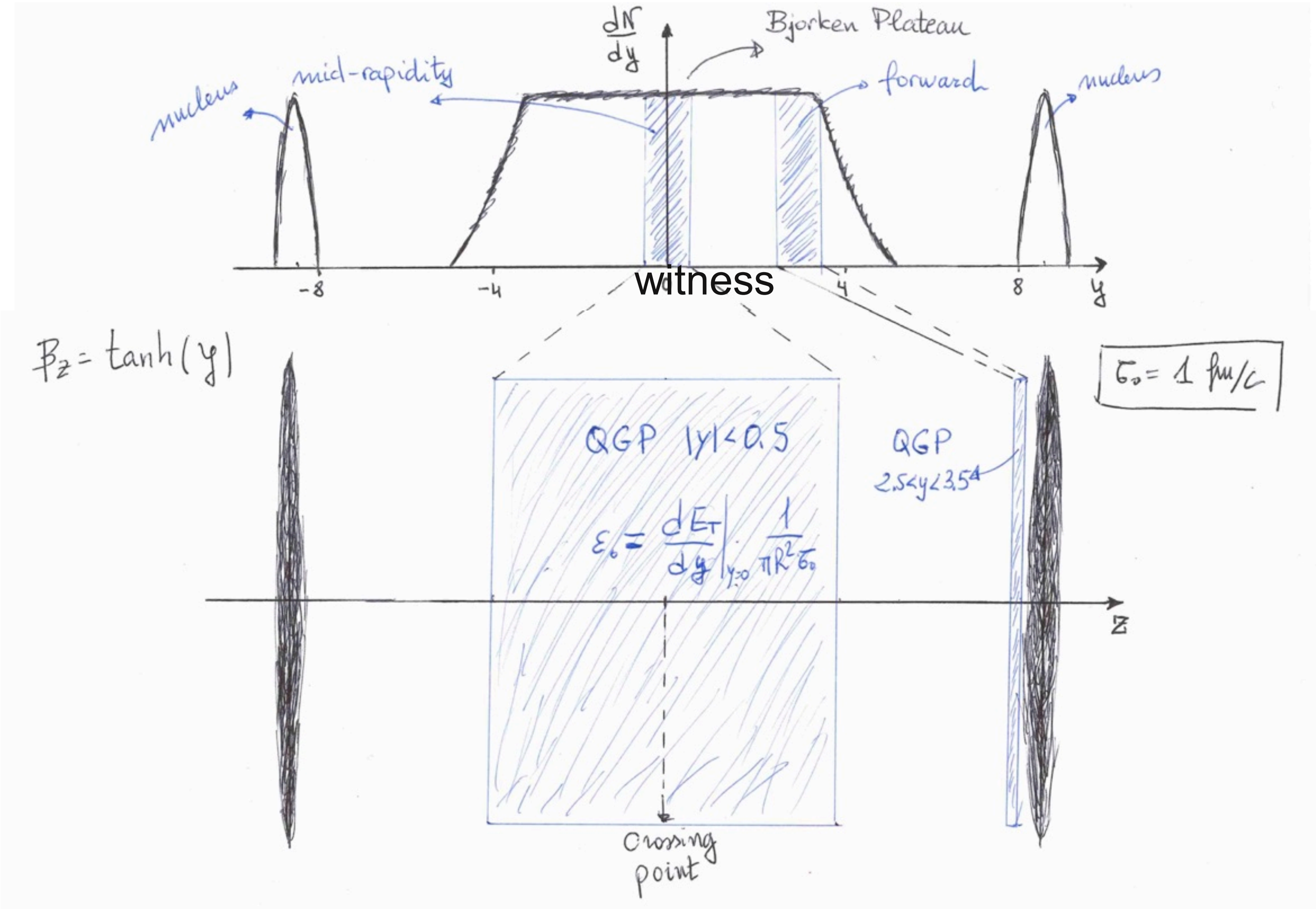
PRL105(2010)252302, PLB696(2011)30, PRL106(2011)032301, PLB719(2013)29, PRL107(2011)032301, JHEP1209(2012)112, PRC88(2013)044910, PRL109(2012)072301, PLB 696(2011)328 ...

QGP behaves as a near-perfect liquid, opaque medium, charm quarks strongly interact with the medium, collectivity-like behaviour in small systems

A Large Ion Collider Experiment

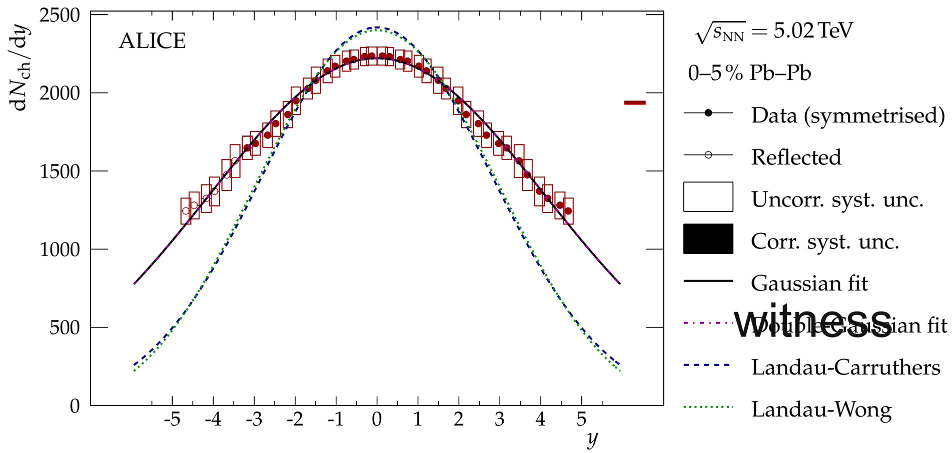
One particularity of ALICE Detector

Large Rapidity coverage



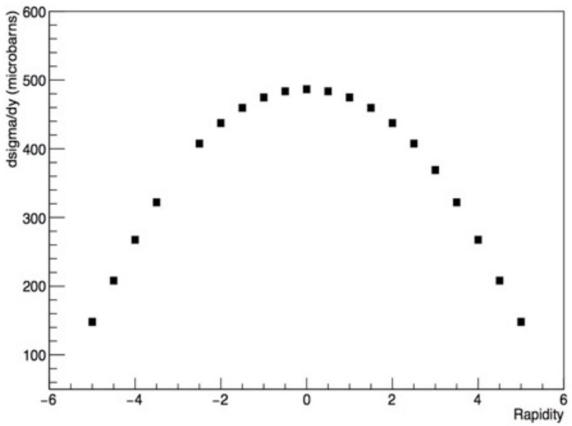
Initial conditions of the QGP with rapidity

Two examples: initial energy density and charm quark density



witness

Initial energy density ~70% lower at y=3 (T_{ini} ~ 10% lower).

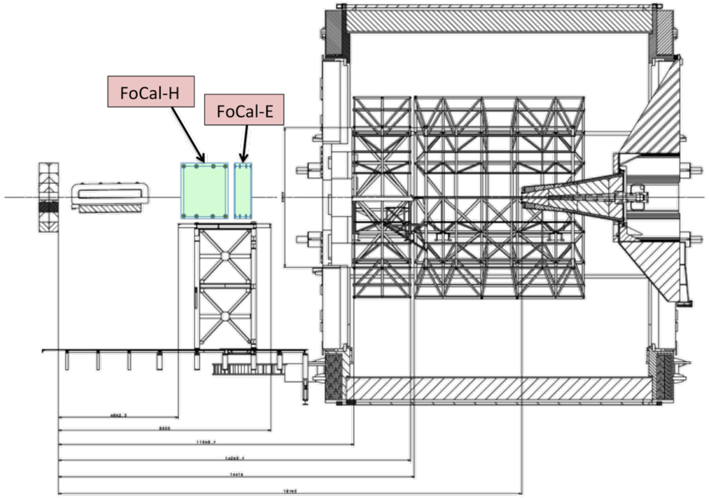


Charm density ~70% lower at y=3

FoCal Project

A Large Ion Collider Experiment

ALICE



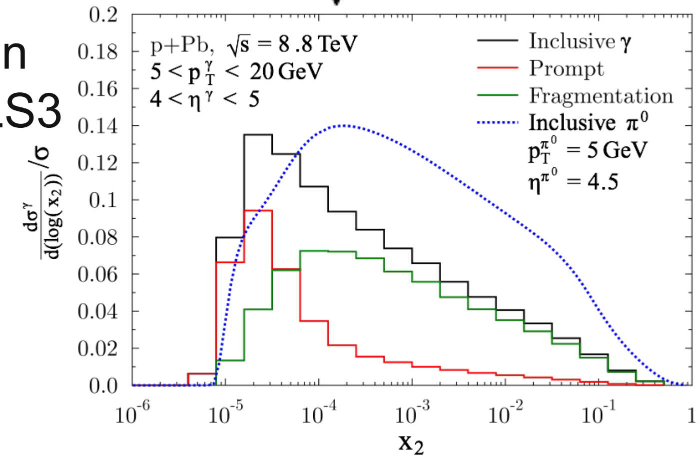
forward calorimeter for γ, π^0 and jet measurements

preferred scenario:

- at z ≈ 7m (outside magnet) $3.3 < \eta < 5.3$
- access to low-x kinematics $x_{\rm LO} \approx \frac{2p_T}{\sqrt{s}} \exp(-y)$

under internal discussion

possible installation in LS3



NLOEPS09, Helenius, Eskola, Paukkunen, arXiv:1406.1689

Key measurement: forward direct photons in p–Pb as a probe for low-x PDFs

- main challenge: separate γ/π^0 at high energy
- EM calorimeter with small Molière radius, high-granularity read-out ⇒ Si-W technology

Note: Two-photon separation from π^0 decay (p_T = 10 GeV/c, y = 4.5, α = 0.5) is d = 2 mm!

dedicated R&D program
with high-granularity calorimeter prototypes

measurement of single event with two close-by showers