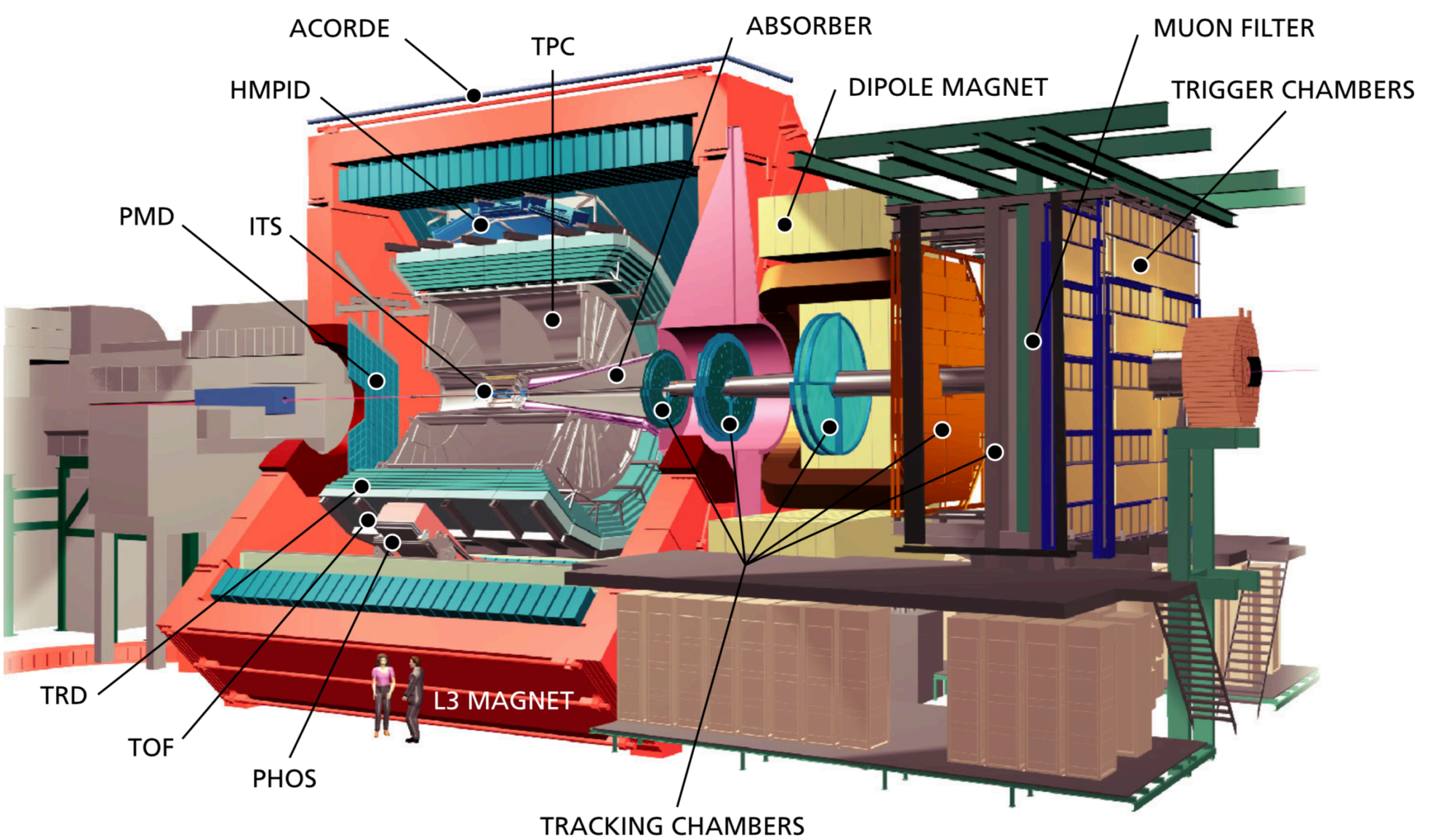
# A Large Ion Collider Experiment

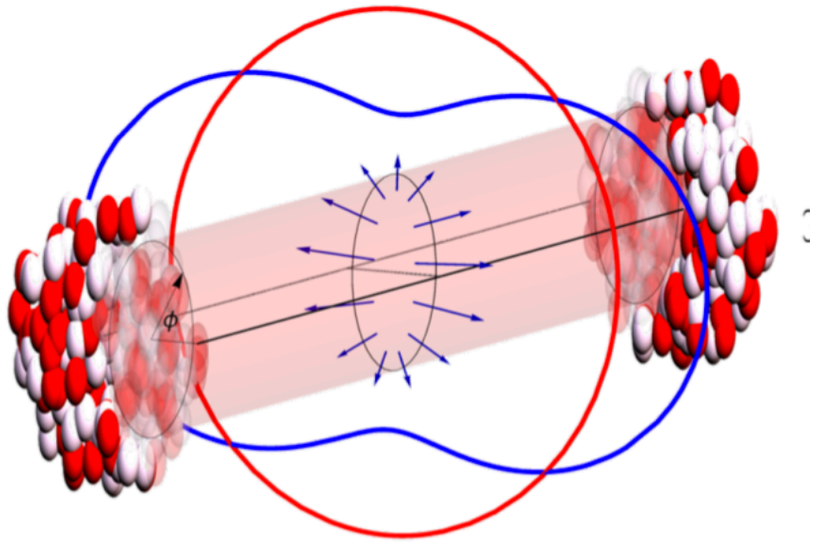


# Overview


- Physics Goals
- Detectors/Trigger
- Measurements

# Physics Goals

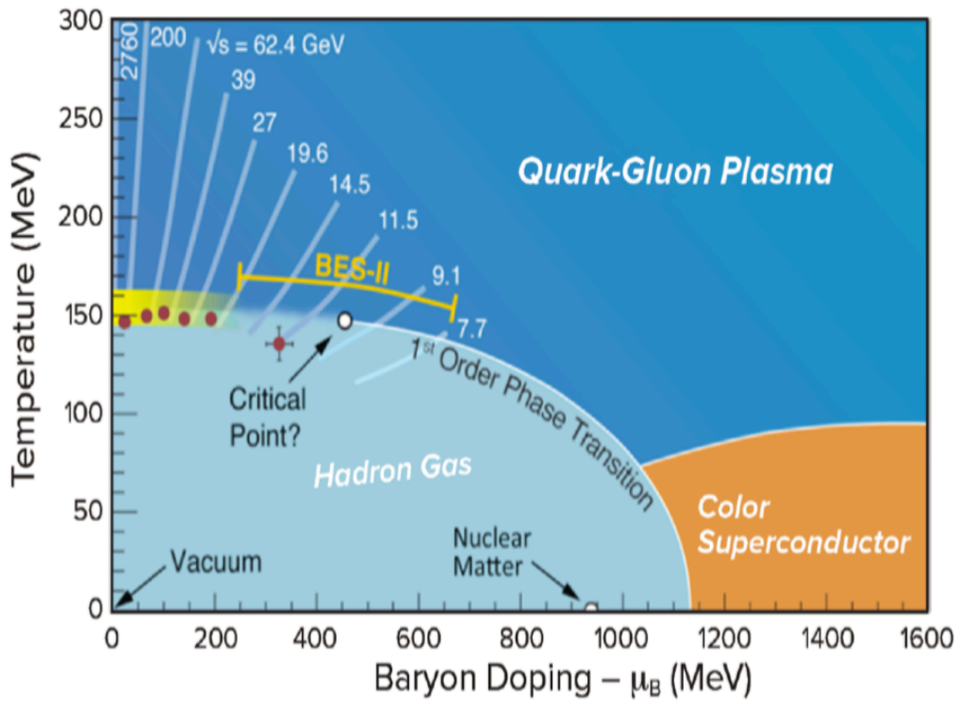
- **ALICE is Optimized to study hot, QCD matter created in high energy collisions**




- **Explore the phase diagram of strongly interacting matter**

- **Equilibrium as well as non-equilibrium physics of strongly interacting matter**

- **Particle ID and tracking over a broad momentum range, 0.1 - 100GeV $c^{-1}$**



# Observables

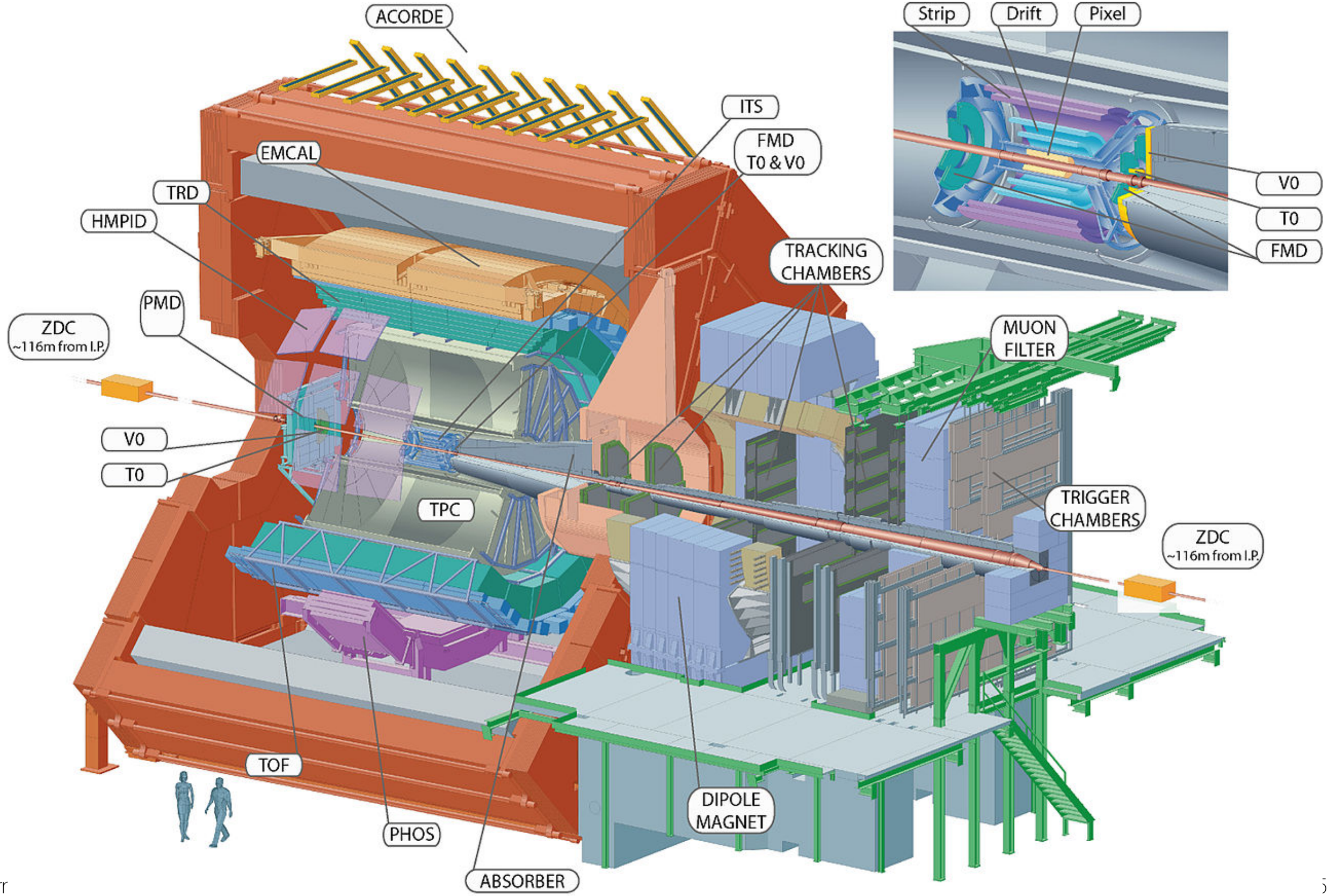
**pp**, p-Pb, and Pb-Pb Collisions

$\sqrt{s}$ = 2.76, 5.02, 8.16 TeV

- Particle Multiplicity
- Particle Spectra
- Particle Correlations
- Temperature and Flow
- Jets
- Direct Photons
- Heavy Quarks
- Baryon Doping

Different detectors to identify and measure different particles

# ALICE


ACORDE
ITS
FMD
T0 & V0
EMCAL
TRD
HMPID
TRACKING
CHAMBERS
PMD
ZDC
~116m from I.P.
V0
T0
TPC
TOF
PHOS
ABSORBER
DIPOLE
MAGNET
MUON
FILTER
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
Strip
Drift
Pixel
V0
T0
FMD

# Magnets

**L3 Magnet**

Reused from the 1989 ‘L3’ Experiment at LEP

0.5T Field

Encloses ITS, TPC, EMCal, TRD, PHOS…..

PID* and momentum/charge determination

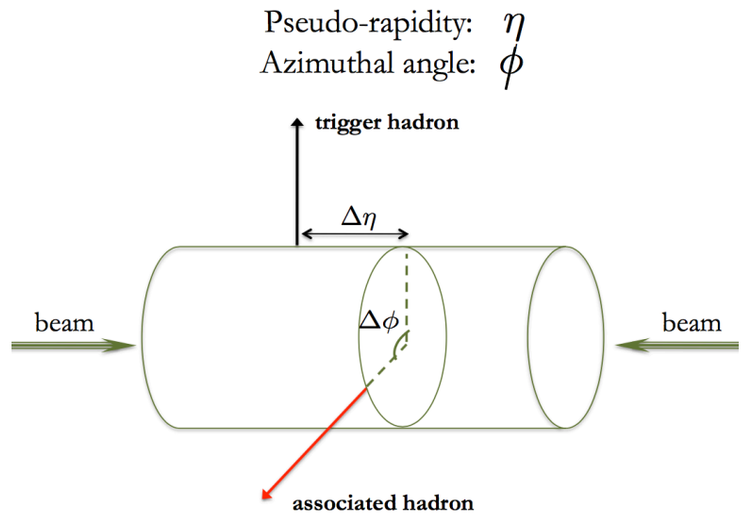
**Dipole Magnet**

Used in Forward Muon Spectrometer

Determine Muon Momentum

0.7 T Field

# Tracking




$\eta$ = -ln[tan θ/2]

Access to heavy Flavor particles

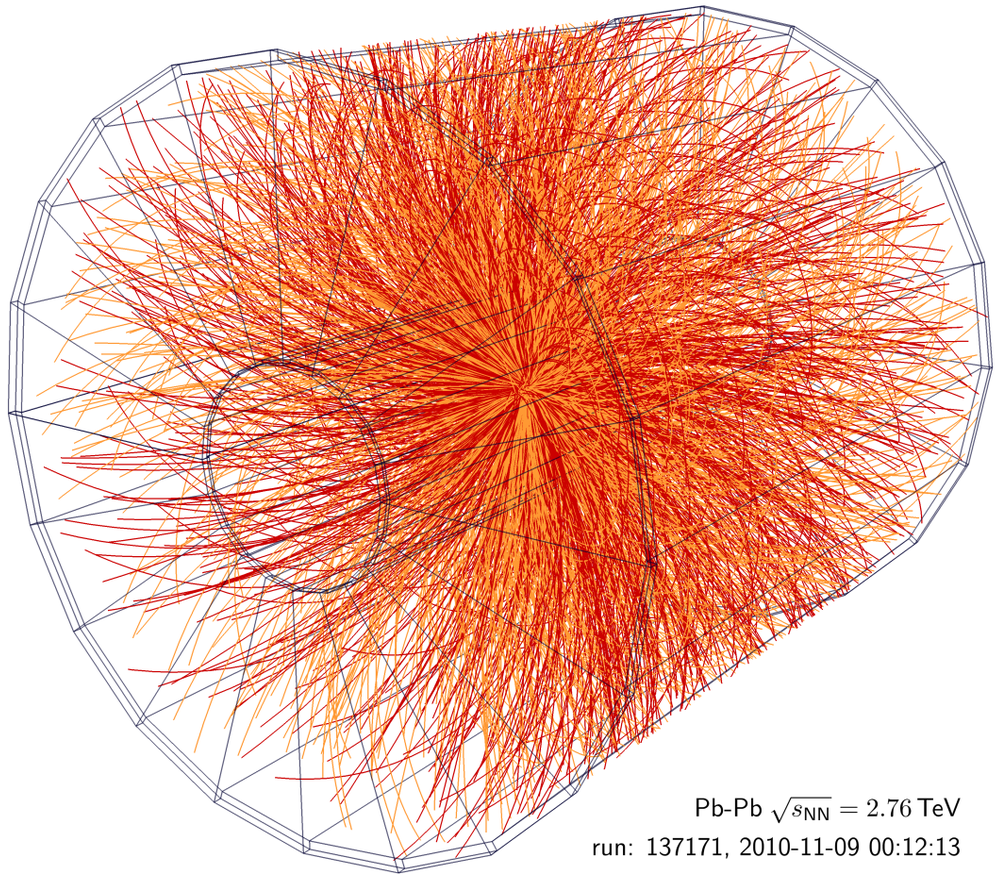
Charged Particle Multiplicity

ITS + TPC

Charged Particle ID (low $p_T$)

Angular Correlations

Momentum Determination



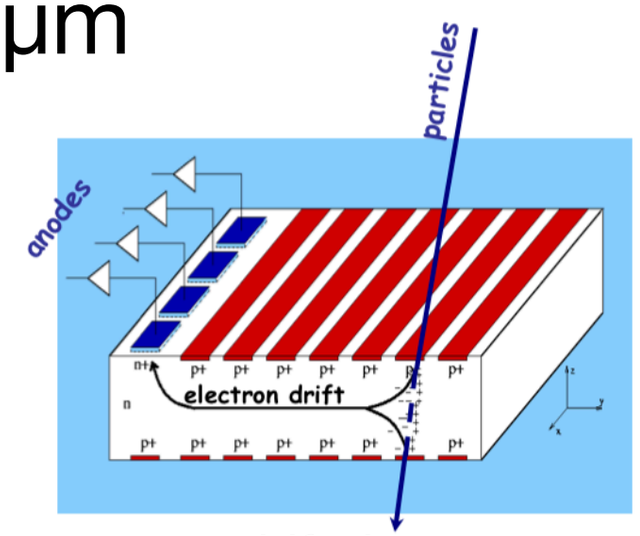
# Inner Tracking System

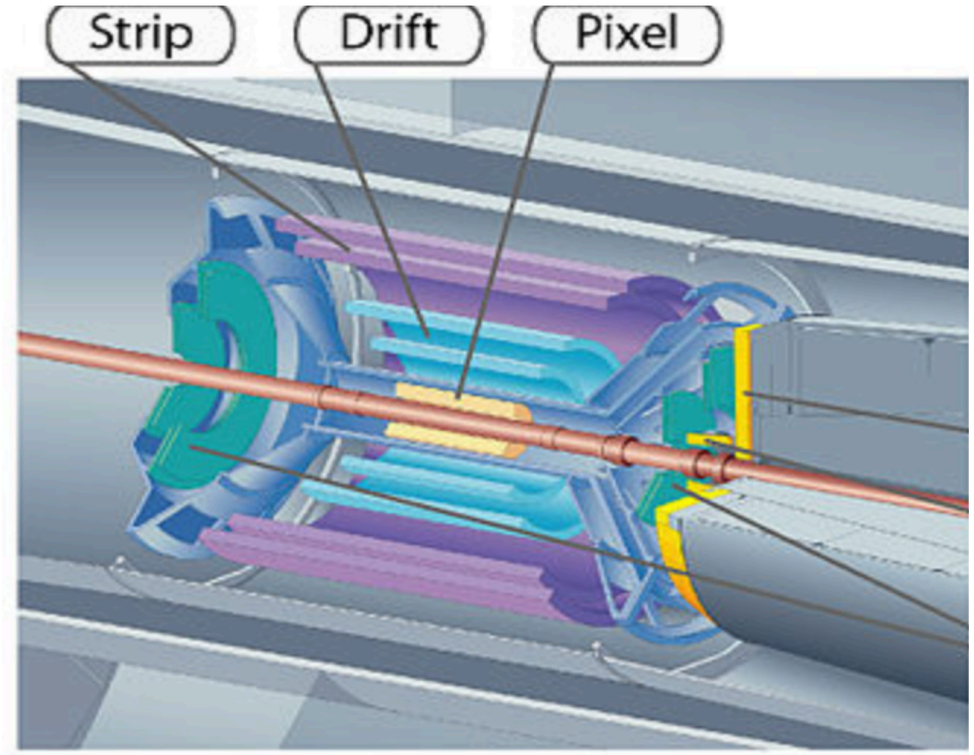
Secondary Vertex  Reconstruction <100μm

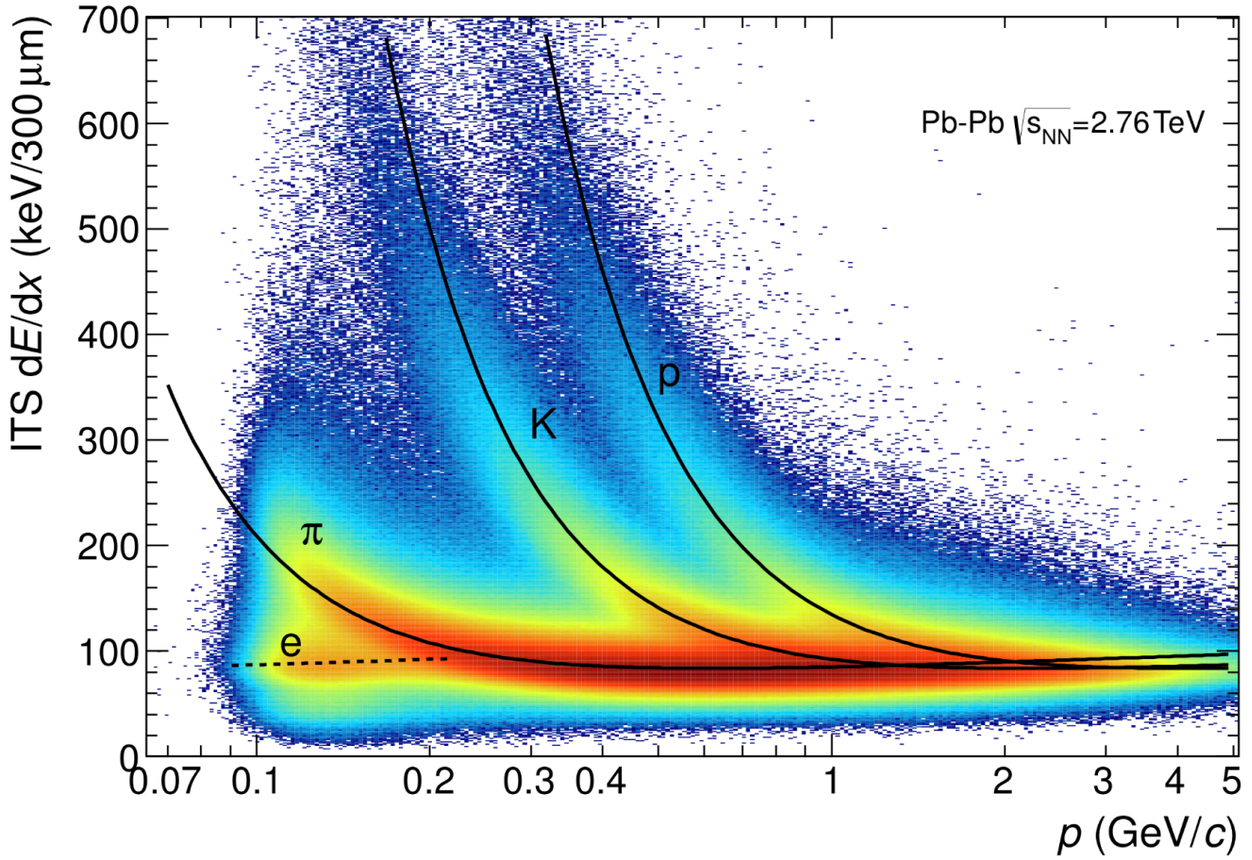
Particle Identification < 200MeV

Silicon Pixel, Drift, and Strip Layers

1kHz Readout



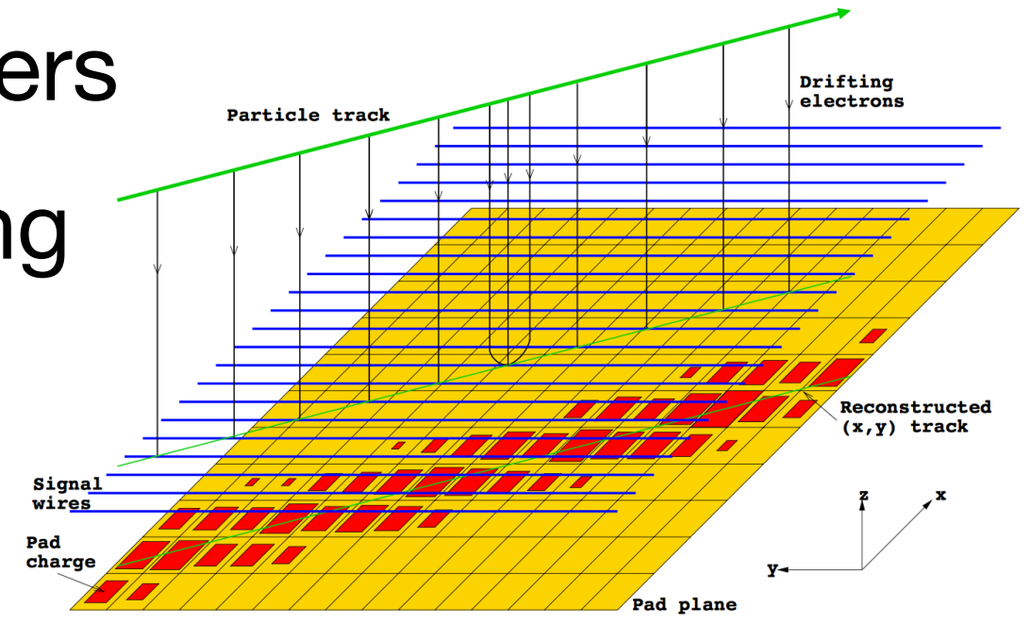
# Time Projection Chamber

Multi-wire proportional chambers

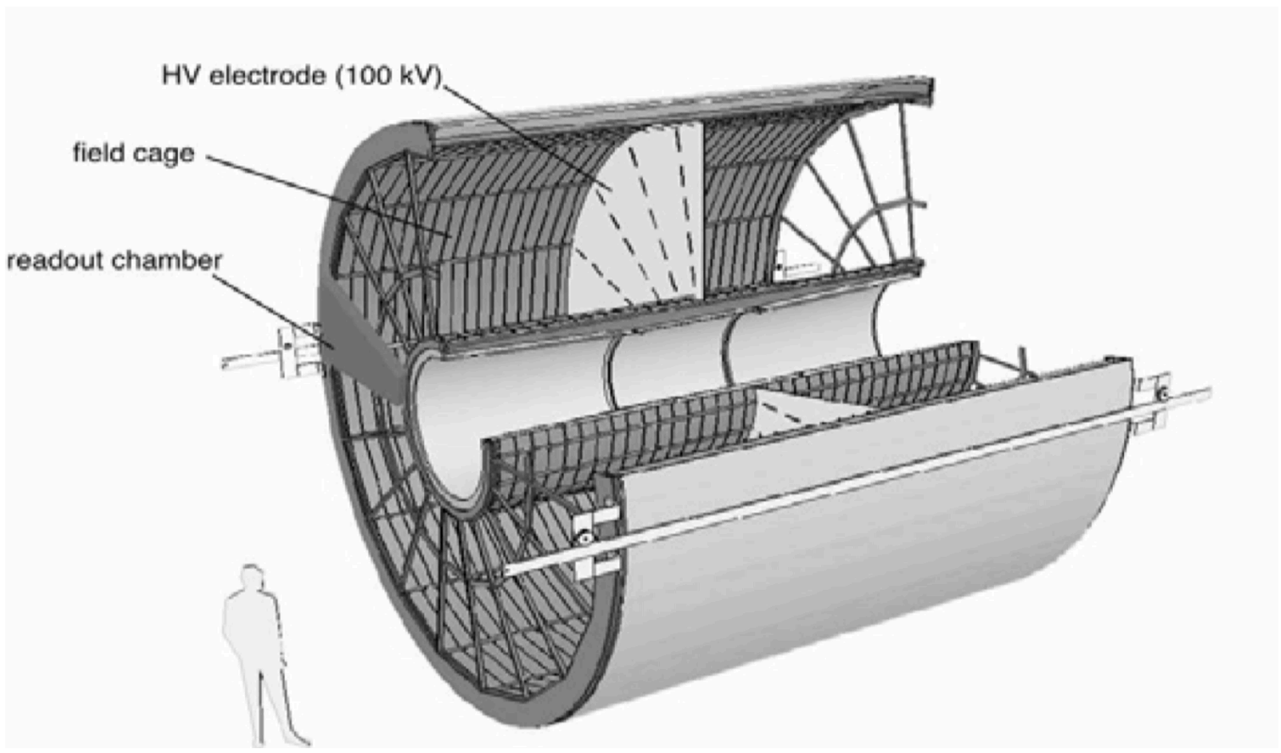
Ideal for **simultaneous** tracking

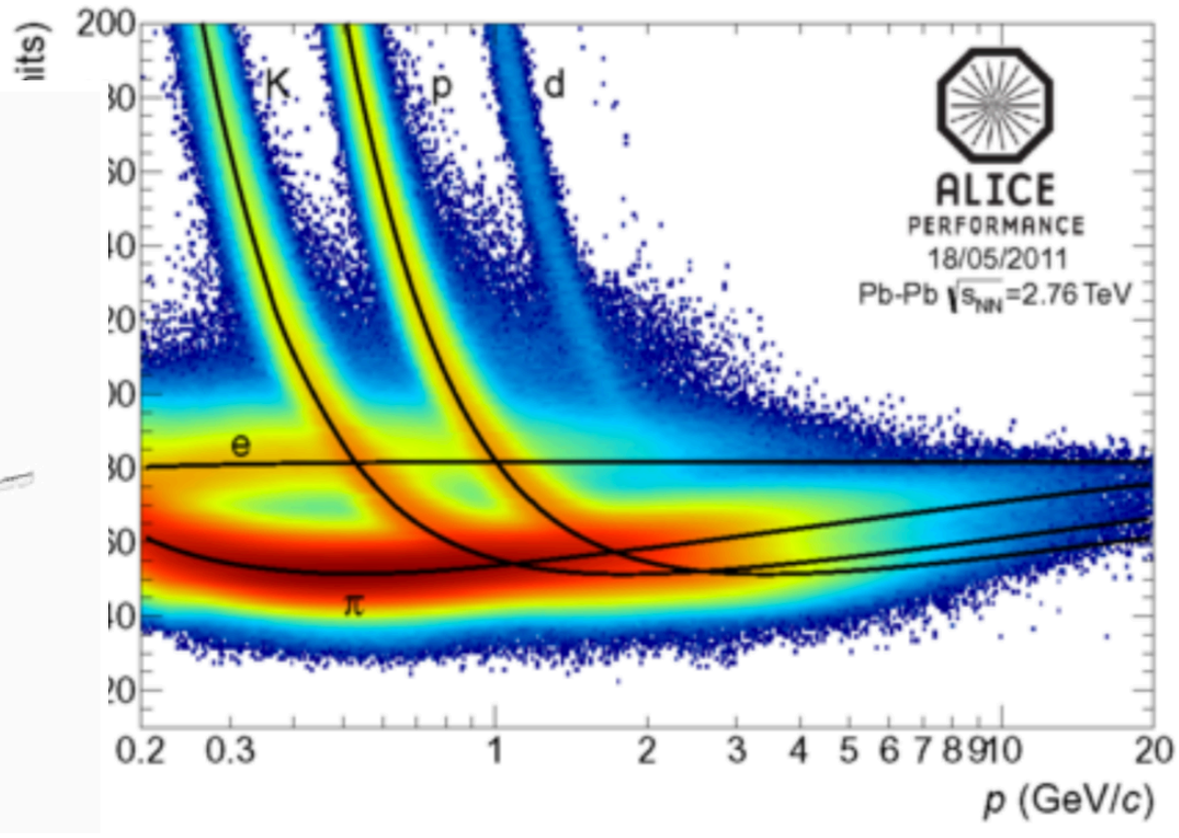
90 $m^3$ sensitive gas volume

Ne-CO2-N2 (85.7-9.5-4.8)

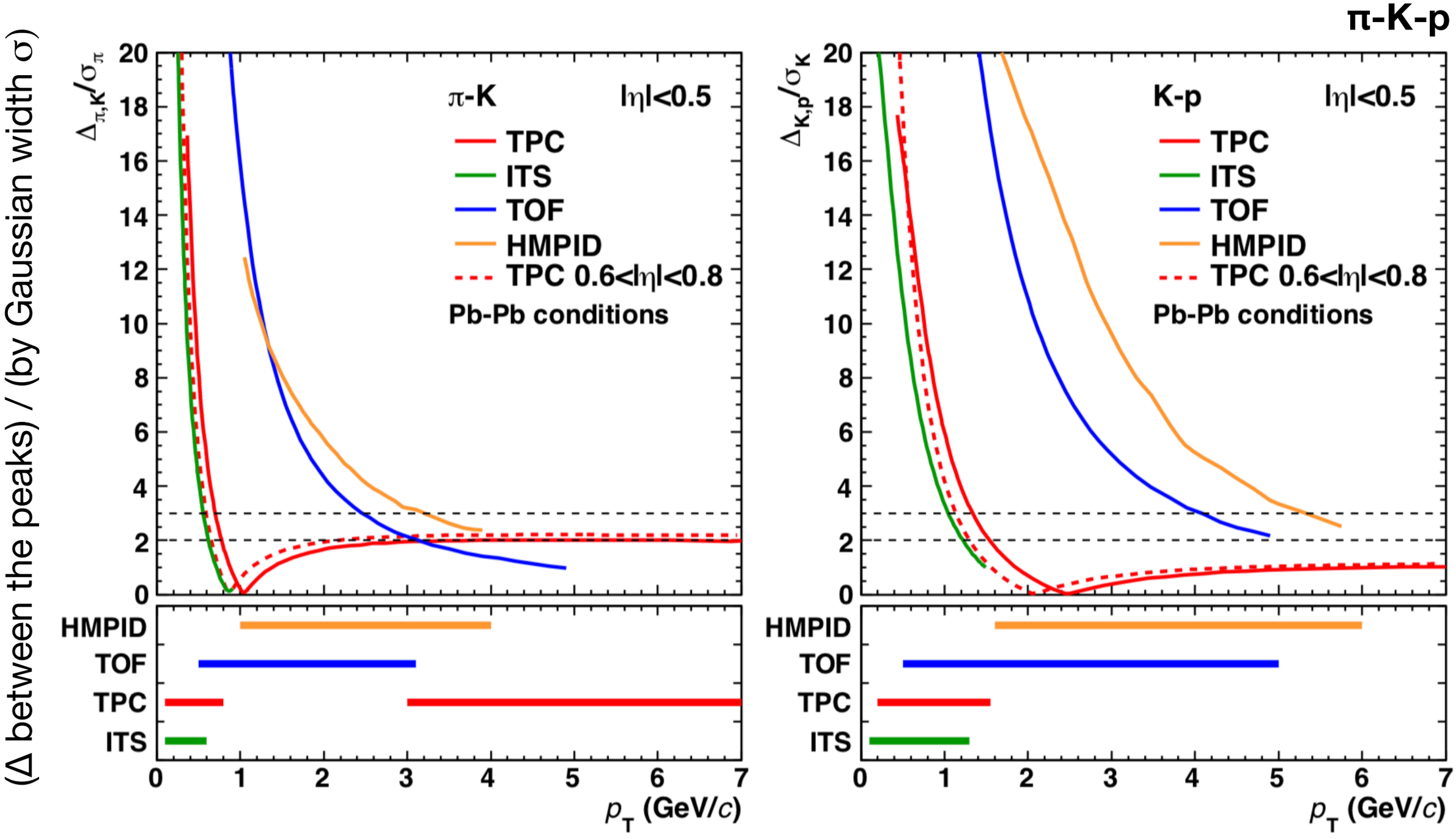



## 200Hz Readout



# Particle ID




**TOF large acceptance detector made Multi-gap Resistive-Plate Chamber**

**High Momentum Particle Identification Detector consists of 7 identical RICH modules**

# Muon Arm

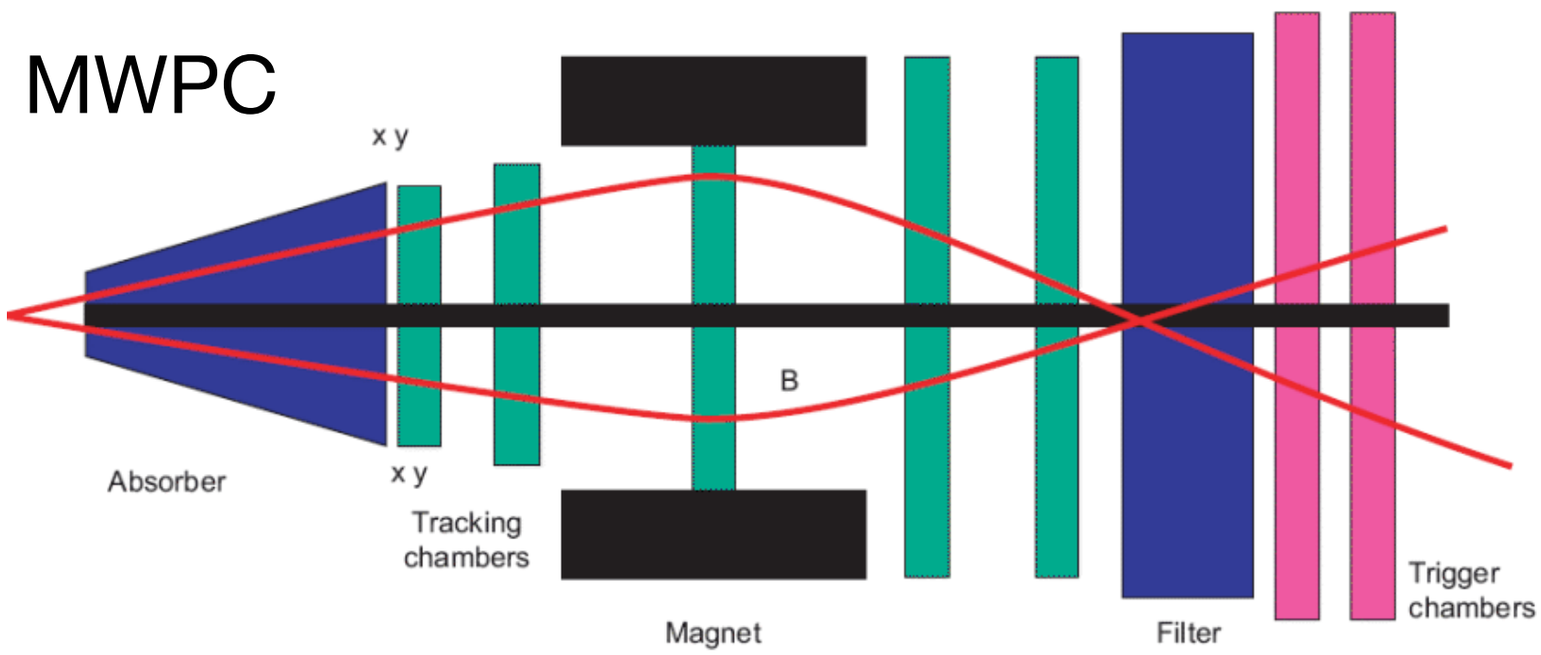
How are heavy states affected by a medium?

Study Heavy Quarkonia states, J/ψ, ψ′ and
Υ(1S), Υ(2S) and Υ(3S), down to low pT

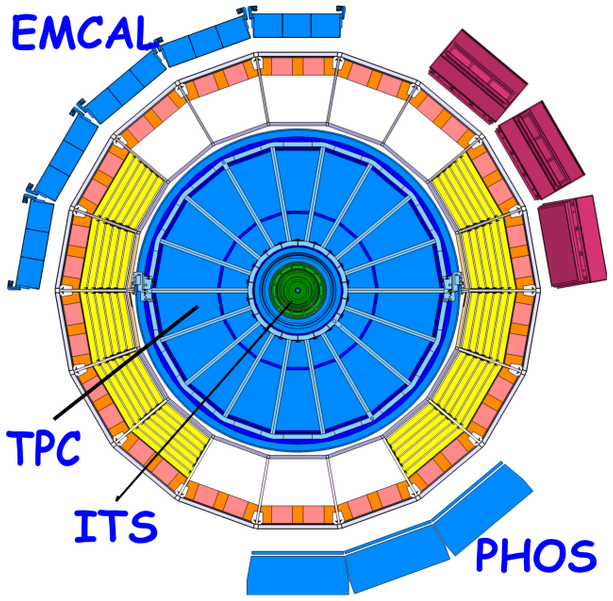
Studied via decay channel of $\mu^+\mu^-$ (BR ~6%)

Required momentum resolution of about 1%
for mass reconstruction

5 gas chambers with MWPC



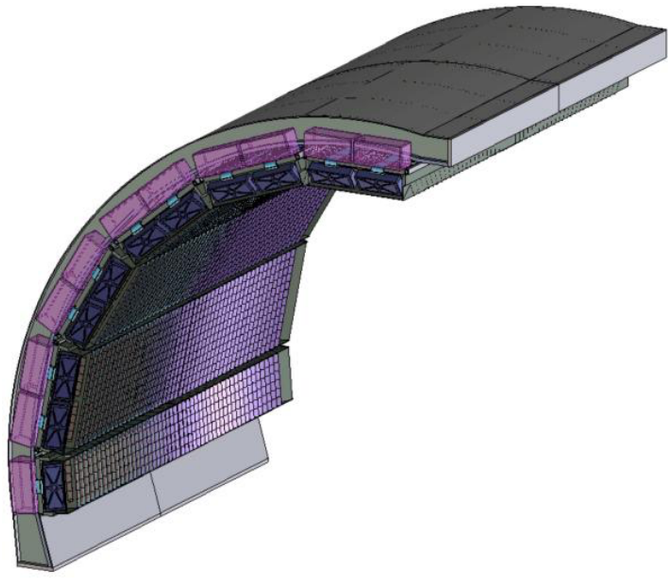
# Photons




- Do not interact strongly
- Reconstructed from electromagnetic showers in the PHOS and EMCal
- reconstructing electron-positron pairs
- Temperature Determination

## EMCal

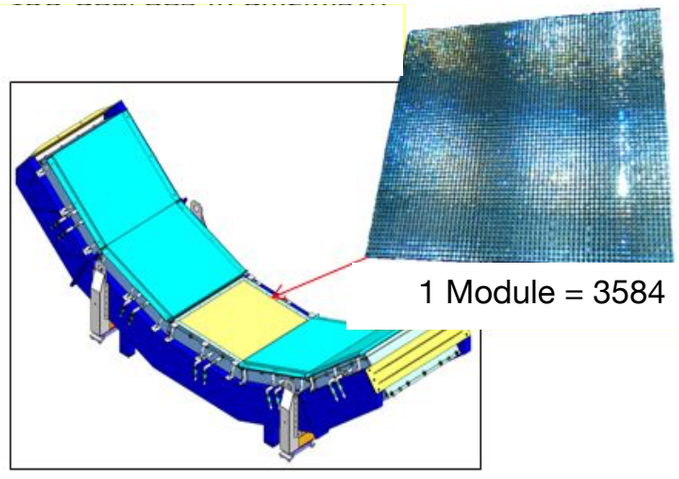
- Lead-Scintillator Sampling Calorimeter
- 13,000 Towers



EMCal

## PHOS

- Homogeneous, high granularity EM Calorimeter
- 25K $PbWO_4$ Crystals attached to Avalanche Photo-Diodes




photon spectrometer

# Trigger

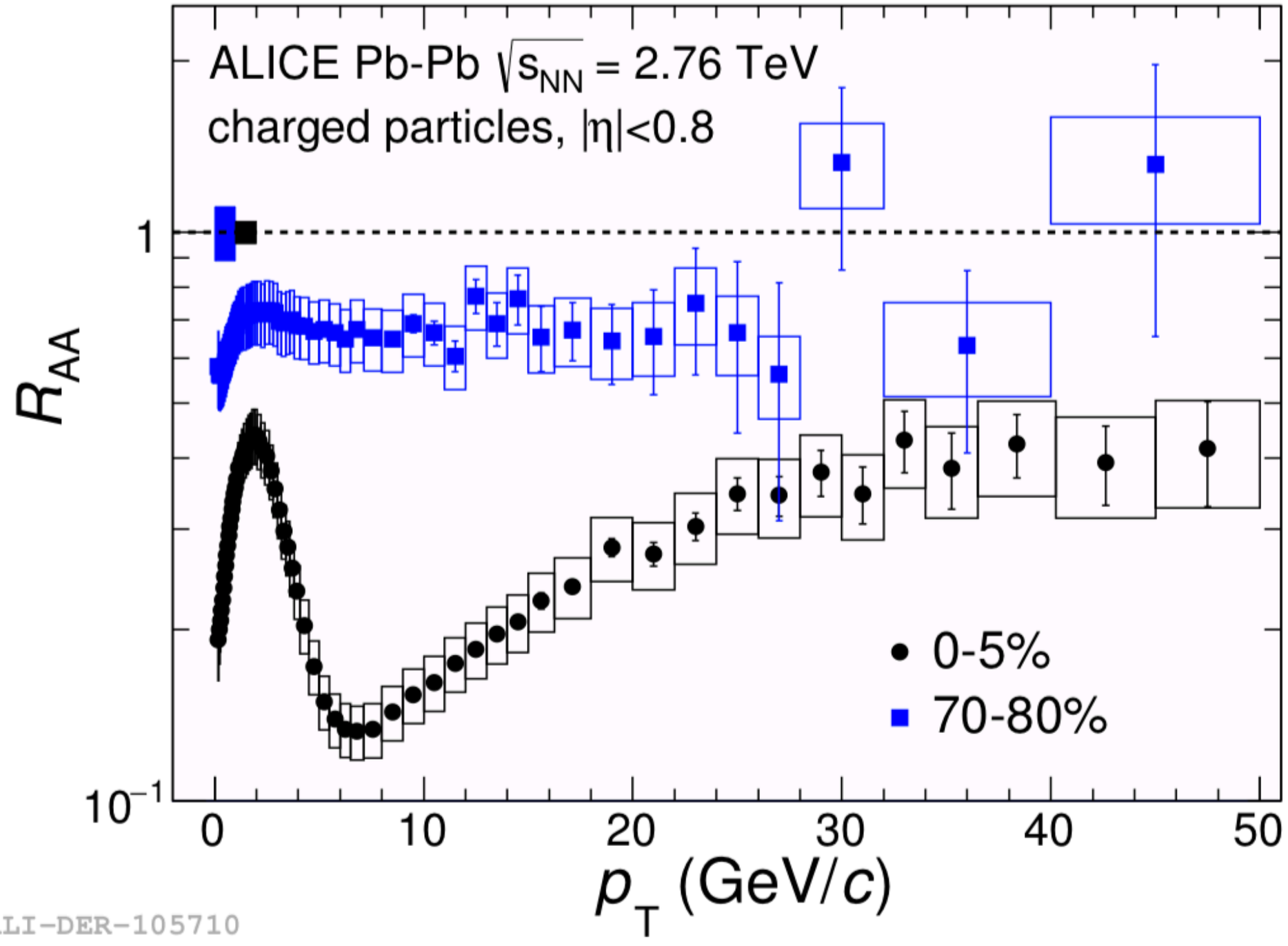
Trigger affects the physics ALICE can analyze

Central Trigger Processor (CTP) collects detector signals (see below) and beam data

Data read to via optical fibers, Compressed (TPC data), HLT and finally stored, online and PDS

| Detector | Function | Level |
|---|---|---|
| SPD | hit-multiplicity based trigger and hit-topology based trigger | L0 |
| TRD | electron trigger, high-$p_{\mathrm{T}}$ particle trigger, charged-jet trigger | L1 |
| TOF | multiplicity trigger, topological (back-to-back) trigger, cosmic-ray trigger | L0 |
| PHOS | photon trigger | L0 |
| EMCal | photon trigger, neutral-jet trigger | L0/L1 |
| ACORDE | cosmic-ray trigger (single and multiple hits) | L0 |
| V0 | coincidence based minimum-bias interaction trigger, centrality trigger | L0 |
| T0 | event-vertex selection trigger, interaction trigger | L0 |
| ZDC | minimum-bias interaction and electromagnetic-dissociation triggers in Pb–Pb | L1 |
| MTR | single-muon trigger, dimuon trigger | L0 |

# Nuclear Modification Factor




**Pb-Pb Yield**

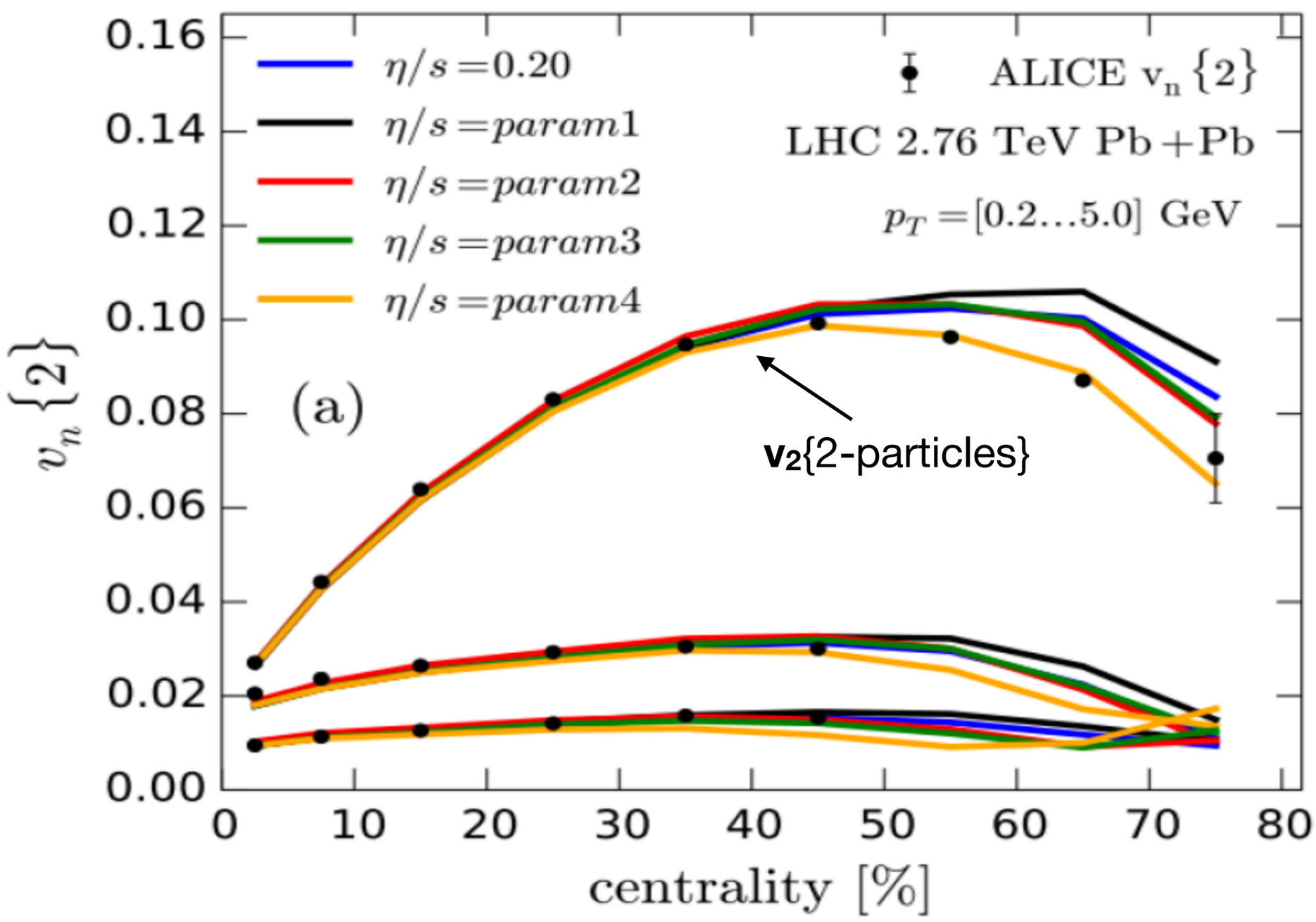
**(scaled) p-p yield**

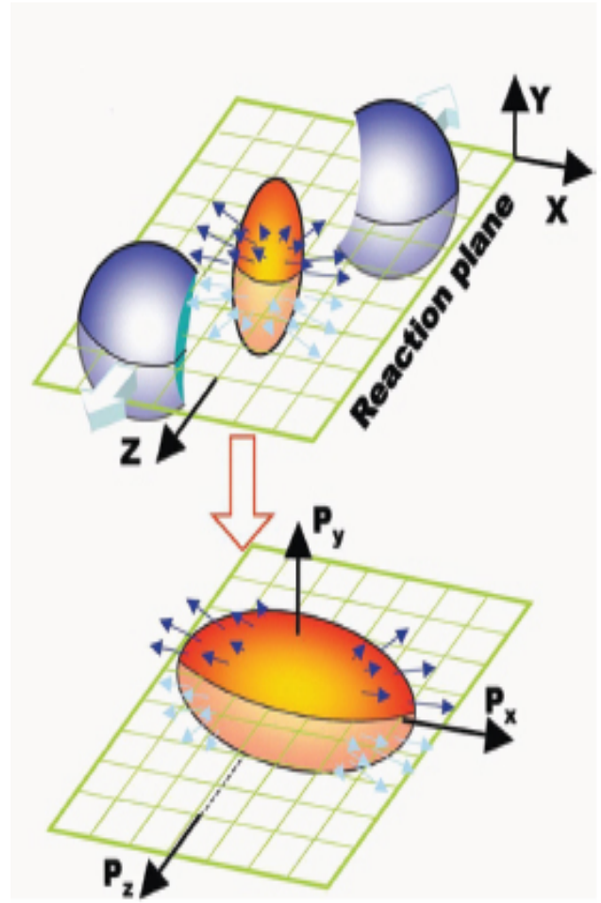
$$R_{\mathrm{AA}} = \frac{\mathrm{d}^2 N_{\mathrm{AA}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{AA}} \rangle \, \mathrm{d}^2 \sigma_{\mathrm{pp}}^{\mathrm{INEL}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}$$

# Flow

$$\frac{d\bar{N}}{d\varphi} = \frac{\bar{N}}{2\pi}\left(1 + 2\sum_{n=1}^{\infty} \bar{v}_n \cos(n(\varphi - \bar{\Psi}_n))\right)$$

**“Bulk” angular distribution**




$$\eta/s \approx 1/4\pi$$

$\hbar = k_B = 1$

# ALICE Upgrade

LHC will soon provide Pb–Pb collisions at a rate of 50 kHz

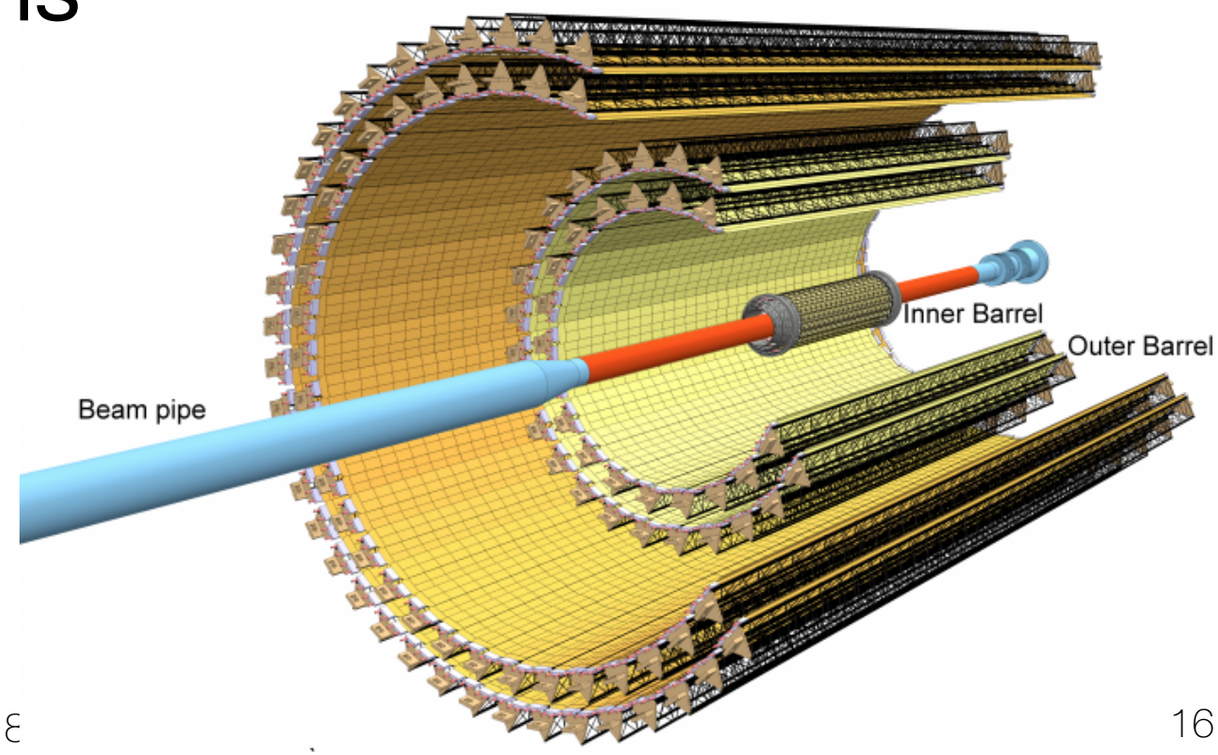
ITS Upgrade → 7 Layers of pixels, 5μm precision

TPC upgrade → faster gas, GEM readout chambers

Faster Readout to keep up with LHC

Access to heavy-flavor baryons and lower uncertainties

| | | | |
|---|---|---|---|
| $B^+$ yield | not accessible | 2 | 10 % |
| $\Lambda_c$ $R_{AA}$ | not accessible | 2 | 15 % |
| $\Lambda_c/D^0$ ratio | not accessible | 2 | 15 % |
| $\Lambda_b$ yield | not accessible | 7 | 20 % |
| D meson $v_2$ ($v_2 = 0.2$) | 1 10 % | 0 | 0.2 % |
| $D_s$ meson $v_2$ ($v_2 = 0.2$) | not accessible | < 2 | 8 % |
| D from B $v_2$ ($v_2 = 0.05$) | not accessible | 2 | 8 % |
| J/$\psi$ from B $v_2$ ($v_2 = 0.05$) | not accessible | 1 | 60 % |
| $\Lambda_c$ $v_2$ ($v_2 = 0.15$) | not accessible | 3 | 20 % |



# END

| Detector | Acceptance | | Position | Technology | Main purpose |
|---|---|---|---|---|---|
| | Polar | Azimuthal | | | |
| SPD* | $\|\eta\| < 2.0$ | full | $r =$ 3.9 cm | Si pixel | tracking, vertex |
| | $\|\eta\| < 1.4$ | full | $r =$ 7.6 cm | Si pixel | tracking, vertex |
| SDD | $\|\eta\| < 0.9$ | full | $r = 15.0$ cm | Si drift | tracking, PID |
| | $\|\eta\| < 0.9$ | full | $r = 23.9$ cm | Si drift | tracking, PID |
| SSD | $\|\eta\| < 1.0$ | full | $r = 38$ cm | Si strip | tracking, PID |
| | $\|\eta\| < 1.0$ | full | $r = 43$ cm | Si strip | tracking, PID |
| TPC | $\|\eta\| < 0.9$ | full | $85 < r/\text{cm} < 247$ | Ne drift+MWPC | tracking, PID |
| TRD* | $\|\eta\| < 0.8$ | full | $290 < r/\text{cm} < 368$ | TR+Xe drift+MWPC | tracking, $e^{\pm}$ id |
| TOF* | $\|\eta\| < 0.9$ | full | $370 < r/\text{cm} < 399$ | MRPC | PID |
| PHOS* | $\|\eta\| < 0.12$ | $220^\circ < \phi < 320^\circ$ | $460 < r/\text{cm} < 478$ | $PbWO_4$ | photons |
| EMCal* | $\|\eta\| < 0.7$ | $80^\circ < \phi < 187^\circ$ | $430 < r/\text{cm} < 455$ | Pb+scint. | photons and jets |
| HMPID | $\|\eta\| < 0.6$ | $1^\circ < \phi <$ 59° | $r = 490$ cm | $C_6F_{14}$ RICH+MWPC | PID |
| ACORDE* | $\|\eta\| < 1.3$ | $30^\circ < \phi < 150^\circ$ | $r = 850$ cm | scint. | cosmics |
| PMD | $2.3 < \eta < 3.9$ | full | $z = 367$ cm | Pb+PC | photons |
| FMD | $3.6 < \eta < 5.0$ | full | $z = 320$ cm | Si strip | charged particles |
| | $1.7 < \eta < 3.7$ | full | $z =$ 80 cm | Si strip | charged particles |
| | $-3.4 < \eta < -1.7$ | full | $z = -70$ cm | Si strip | charged particles |
| V0* | $2.8 < \eta < 5.1$ | full | $z = 329$ cm | scint. | charged particles |
| | $-3.7 < \eta < -1.7$ | full | $z = -88$ cm | scint. | charged particles |
| T0* | $4.6 < \eta < 4.9$ | full | $z = 370$ cm | quartz | time, vertex |
| | $-3.3 < \eta < -3.0$ | full | $z = -70$ cm | quartz | time, vertex |
| ZDC* | $\|\eta\| > 8.8$ | full | $z = \pm 113$ m | W+quartz | forward neutrons |
| | $6.5 < \|\eta\| < 7.5$ | $\|\phi\| < 10^\circ$ | $z = \pm 113$ m | brass+quartz | forward protons |
| | $4.8 < \eta < 5.7$ | $\|2\phi\| < 32^\circ$ | $z = 7.3$ m | Pb+quartz | photons |
| MCH | $-4.0 < \eta < -2.5$ | full | $-14.2 < z/\text{m} < -5.4$ | MWPC | muon tracking |
| MTR* | $-4.0 < \eta < -2.5$ | full | $-17.1 < z/\text{m} < -16.1$ | RPC | muon trigger |