Future perspectives of the ALICE experiment and detector upgrade

Hiroshi Masui for the ALICE collaboration
University of Tsukuba

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ALICE

筑波大学
University of Tsukuba

Outline

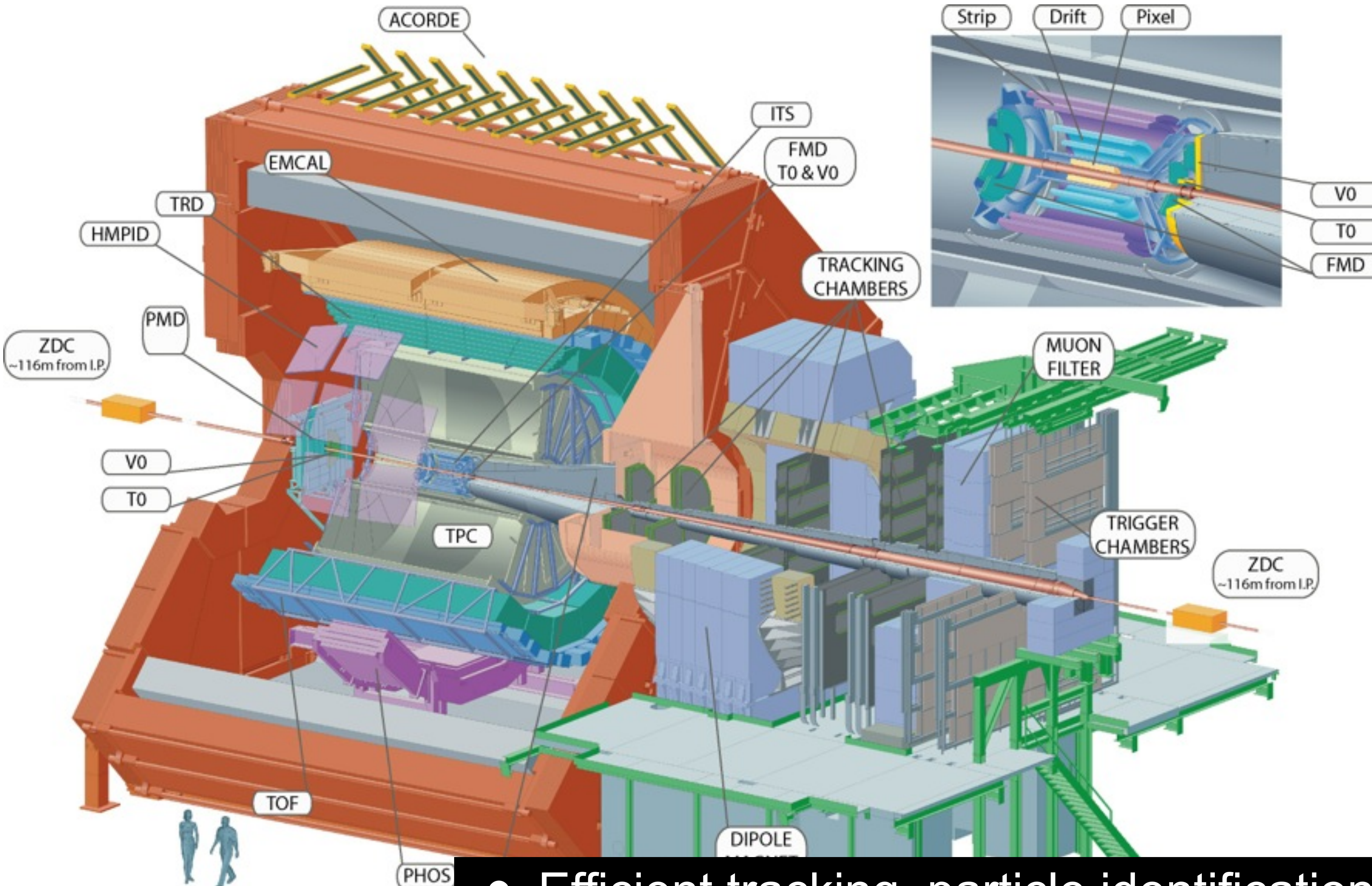
- Current ALICE experiment
  - Upgrade during Long Shutdown 1 (***LS1***) in 2014; ***D***i-jet ***CAL***orimeter (***DCAL***)

- ALICE future physics programs
  - Focus on long term physics after ***LS2***

- ALICE detector upgrade (selected)
  - Core upgrade during ***LS2*** in 2018-2019; ***T***ime ***P***rojection ***C***hamber (***TPC***), ***I***nner ***T***racking ***S***ystems (***ITS***)

- Summary and outlook

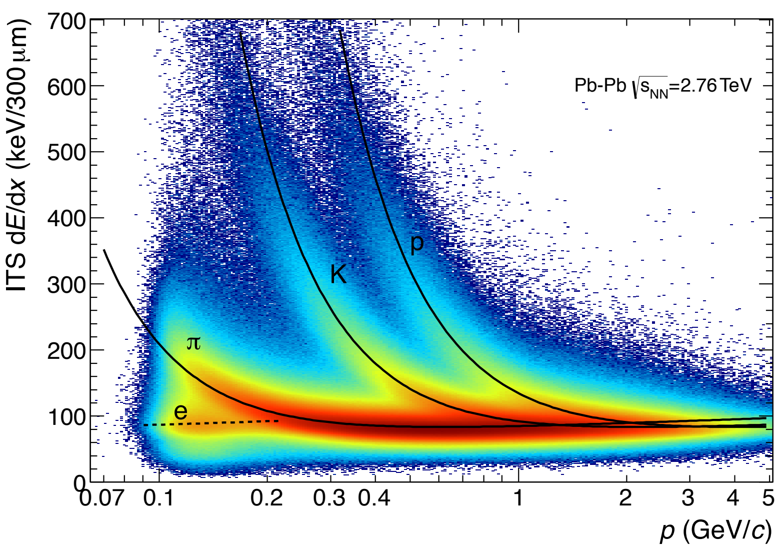
Current ALICE detectors



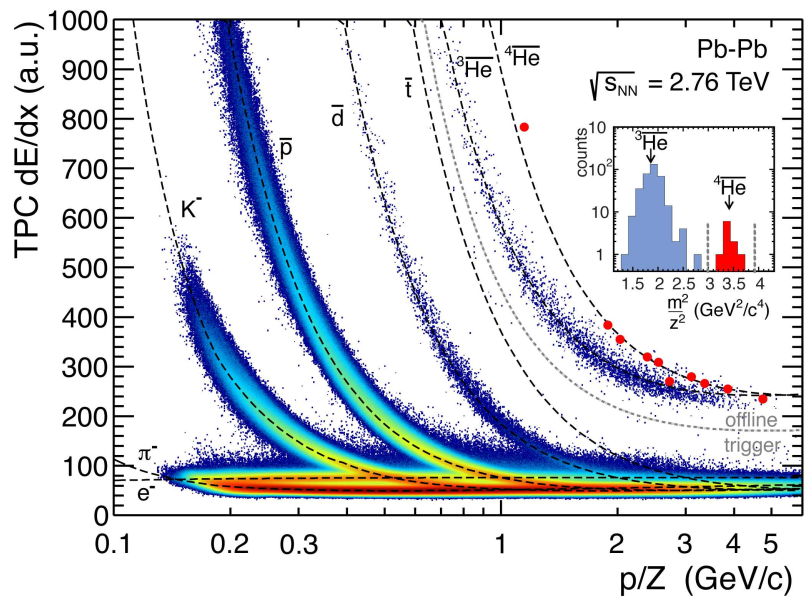
- Efficient tracking, particle identification, vertexing down to ~100 MeV/c in p_T

Current performance

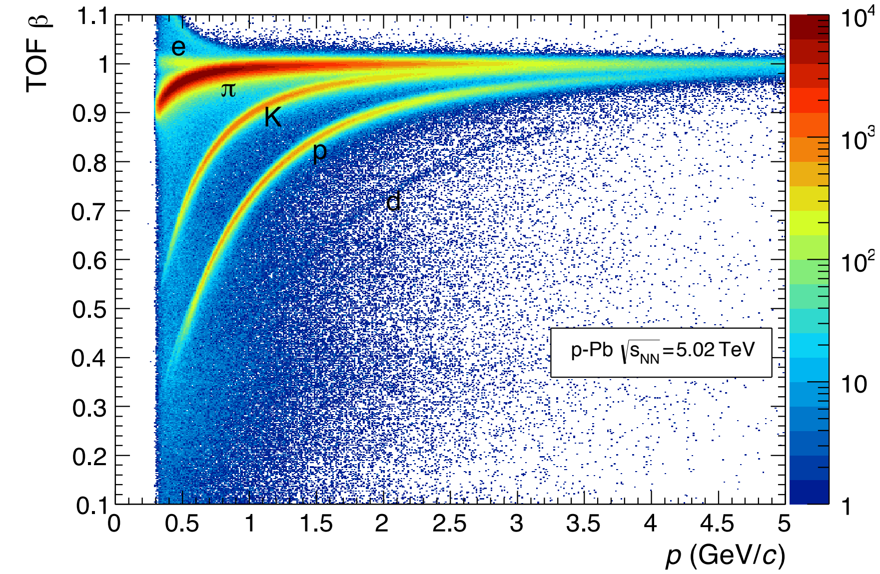
ITS



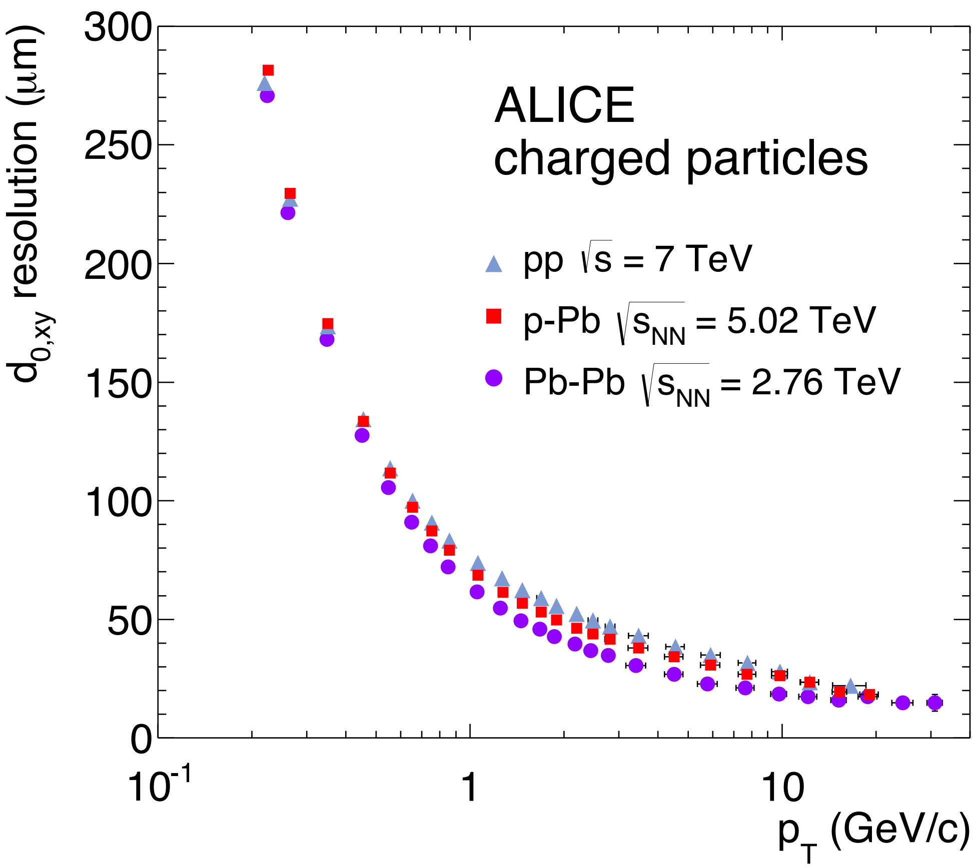
TPC



TOF



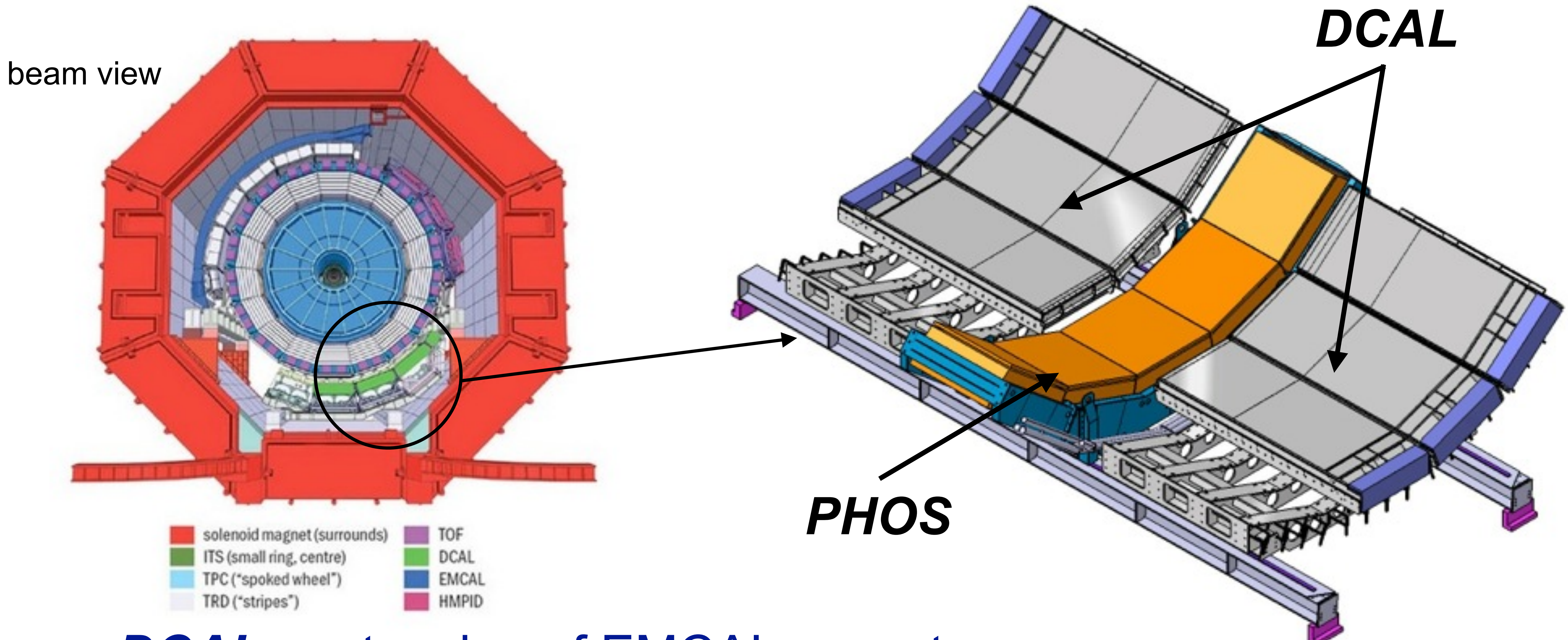
vertexing



arXiv:1402.4476 [nucl-ex]

- PID for wide p_T range
- Efficient low p_T tracking
- Excellent vertexing

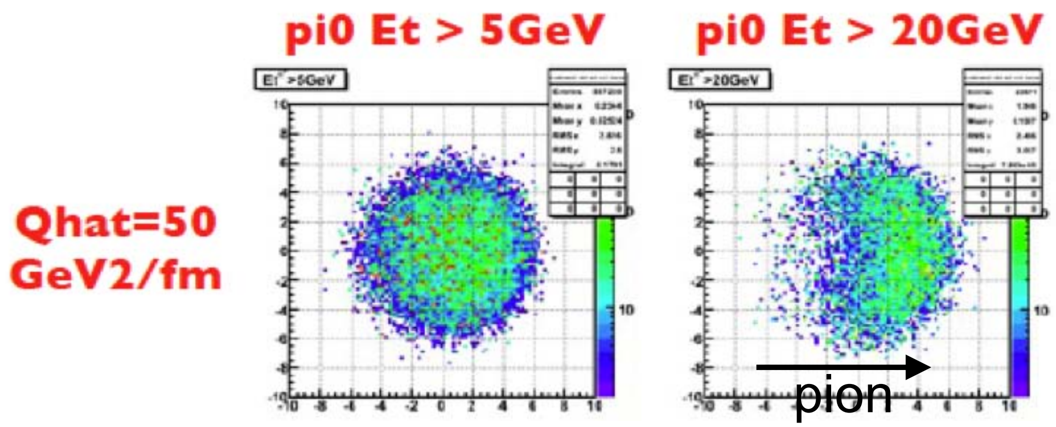
Di-jet CALorimeter



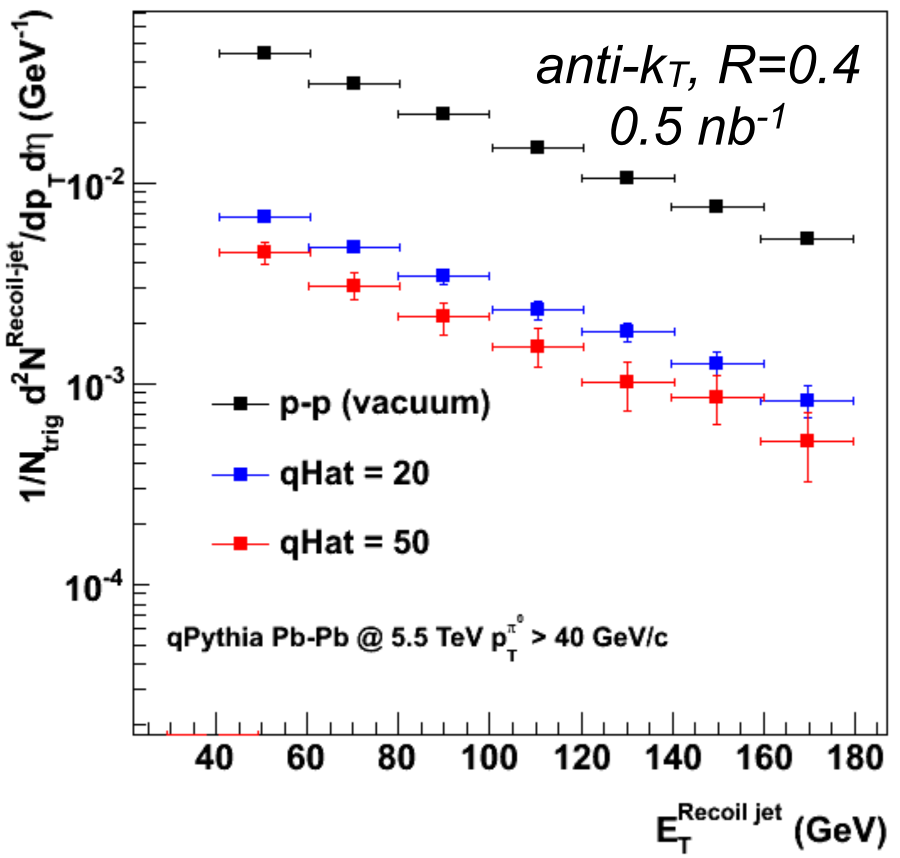
- ***DCAL*** - extension of EMCAL acceptance
  - $|\eta|=0.7$, $\Delta\phi=66^{o}$ on opposite side of EMCAL → allows hadron-jet, di-jet measurements in ALICE, with $R=0.4$, up to p_T ~ 150 GeV/c
  - Energy resolution ~ 10%/√E
- Enhance photon and jet trigger capability
- ***DCAL*** has already being installed, and will be ready in 2015

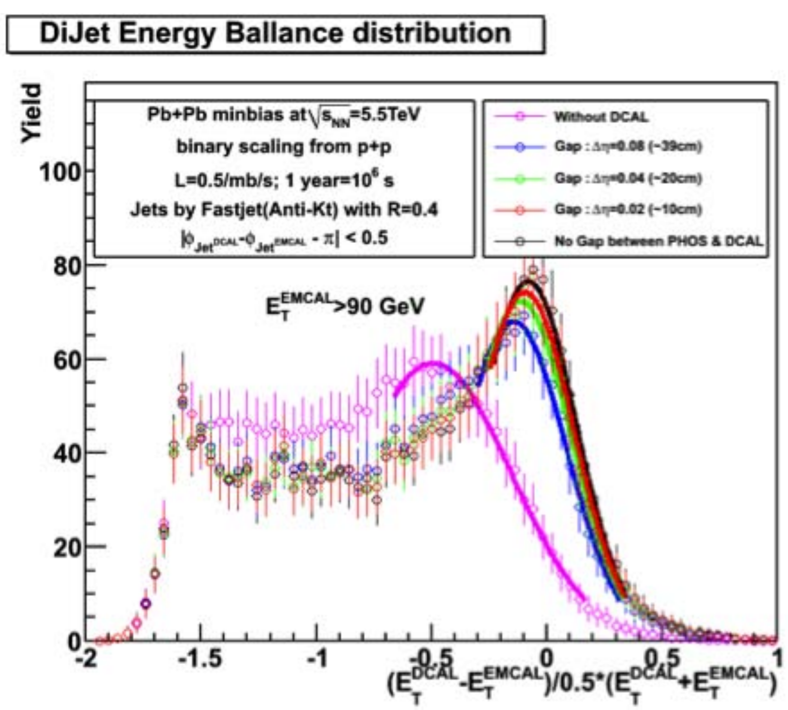
Physics with DCAL

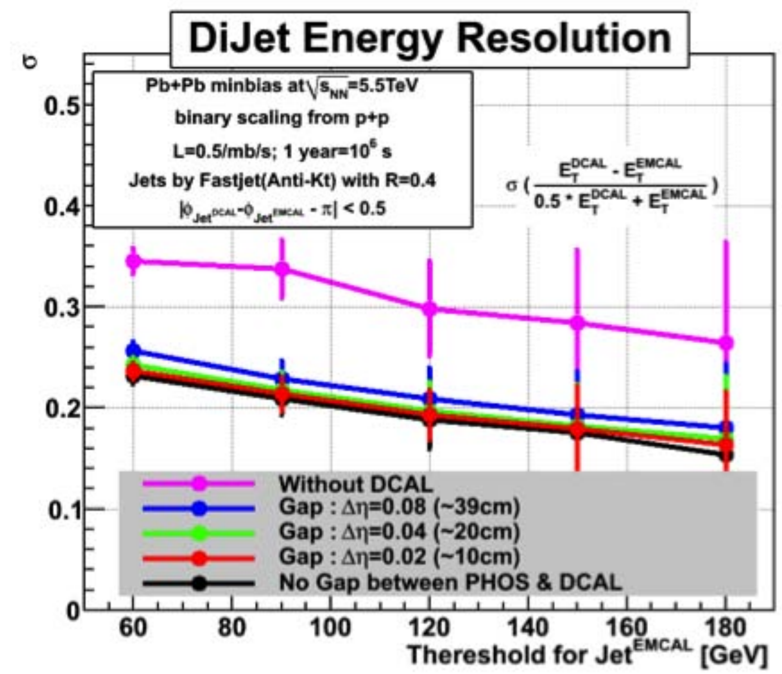
Transverse distribution of hard scattering vertices calculated in qPythia



ALICE DCAL TDR, https://cds.cern.ch/record/1272952







- π^0-jet correlation - maximize jet path length in the medium
- Di-jet - energy balance between recoiling jet pairs

ALICE future physics program

Probe	*Physics*	*Observable*
Heavy-flavor (charm & bottom)	Thermalization, EoS Transport coefficient, energy loss	v_2 & R_{AA}
Quarkonia (J/ψ, ψ')	Production mechanisms	yield, v_2, R_{AA}
Low mass di-leptons	Initial temperature, EoS Chiral phase transition	yield, v_2 vector meson spectral function
Jet	Parton energy loss	PID fragmentation function, Heavy flavor in jets, γ-jet correlation
Heavy nuclear states	Search for exotic bound states (anti-hyper nucleus, H-Dibaryon)	yield

- Emphasis on ***heavy-flavor***, ***low mass di-leptons*** and ***heavy nuclear states*** at low p_T

Strategy for long term upgrade

- Many measurements will focus on low p_T and very high background observables - trigger is not applicable
- Detector upgrade to enhance low p_T vertexing and tracking capability, and to take minimum bias data at substantially higher rates
  - Target integrated luminosity: 10 nb^{-1} in Pb-Pb, 6 pb^{-1} in p-p
  - Read out ~50kHz Pb-Pb interactions with minimum bias trigger
    - Complementary to *ATLAS* and *CMS* (highly selective triggers)
- Upgrade strategy
  - TPC with GEM readout + new pipelined electronics (dead-time free)
  - New ITS, better vertexing with high resolution+low material thickness
    - Readout electronics for TRD, TOF, PHOS and muon spectrometer
    - Forward trigger detectors, Muon Forward Tracker
    - High-Level Trigger (HLT), DAQ and trigger system for high rate
    - Integrated online & offline structure; DAQ/HLT/offline (O^2 project)

Physics reach

ALICE upgrade LOI, http://cds.cern.ch/record/1475243/

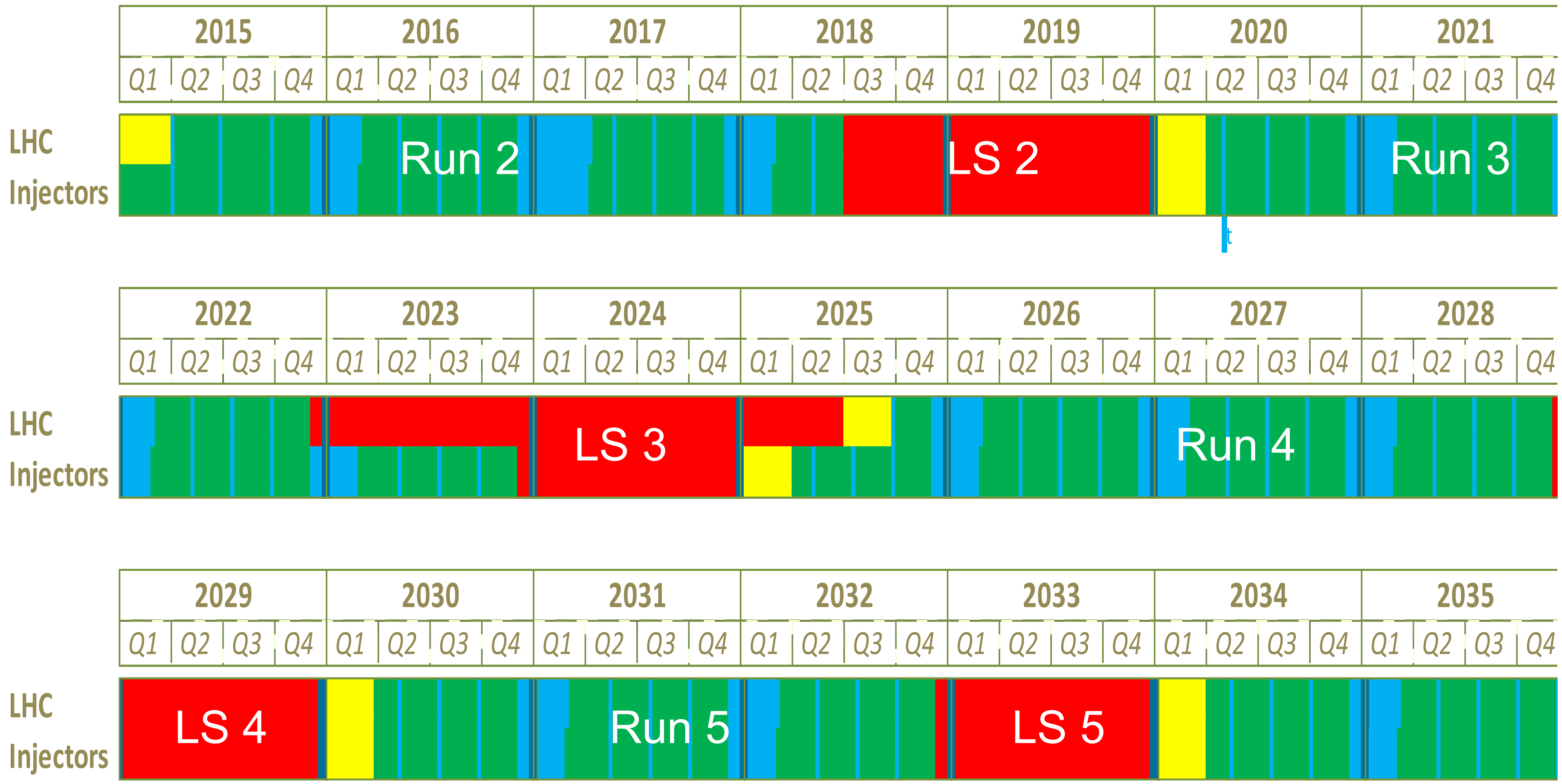
Observable	Approved * p_T^{Amin} (GeV/c)	Approved * statistical uncertainty	Upgrade ** p_T^{Umin} (GeV/c)	Upgrade ** statistical uncertainty
Heavy Flavour				
D meson R_{AA}	1	10 % at p_T^{Amin}	0	0.3 % at p_T^{Amin}
D meson from B decays R_{AA}	3	30 % at p_T^{Amin}	2	1 % at p_T^{Amin}
D meson elliptic flow ($v_2 = 0.2$)	1	50 % at p_T^{Amin}	0	2.5 % at p_T^{Amin}
D from B elliptic flow ($v_2 = 0.1$)	not accessible		2	20 % at p_T^{Umin}
Charm baryon-to-meson ratio	not accessible		2	15 % at p_T^{Umin}
D_s meson R_{AA}	4	15 % at p_T^{Amin}	1	1 % at p_T^{Amin}
Charmonia				
J/ψ R_{AA} (forward rapidity)	0	1 % at 1 GeV/c	0	0.3 % at 1 GeV/c
J/ψ R_{AA} (mid-rapidity)	0	5 % at 1 GeV/c	0	0.5 % at 1 GeV/c
J/ψ elliptic flow ($v_2 = 0.1$)	0	15 % at 2 GeV/c	0	5 % at 2 GeV/c
$\psi(2S)$ yield	0	30 %	0	10 %
Dielectrons				
Temperature (intermediate mass)	not accessible			10 %
Elliptic flow ($v_2 = 0.1$)	not accessible			10 %
Low-mass spectral function	not accessible		0.3	20 %
Heavy Nuclear States				
Hyper(anti)nuclei ${}^{4}_{\Lambda}H$ yield		35 %		3.5 %
Hyper(anti)nuclei ${}^{4}_{\Lambda\Lambda}H$ yield	not accessible			20 %

Luminosity for minimum bias data

* **0.1 nb^{-1}** out of 1 nb^{-1} delivered luminosity
** **10 nb^{-1}** integrated luminosity

- ALICE will move from an observation to the ***precision measurements*** with detector upgrade

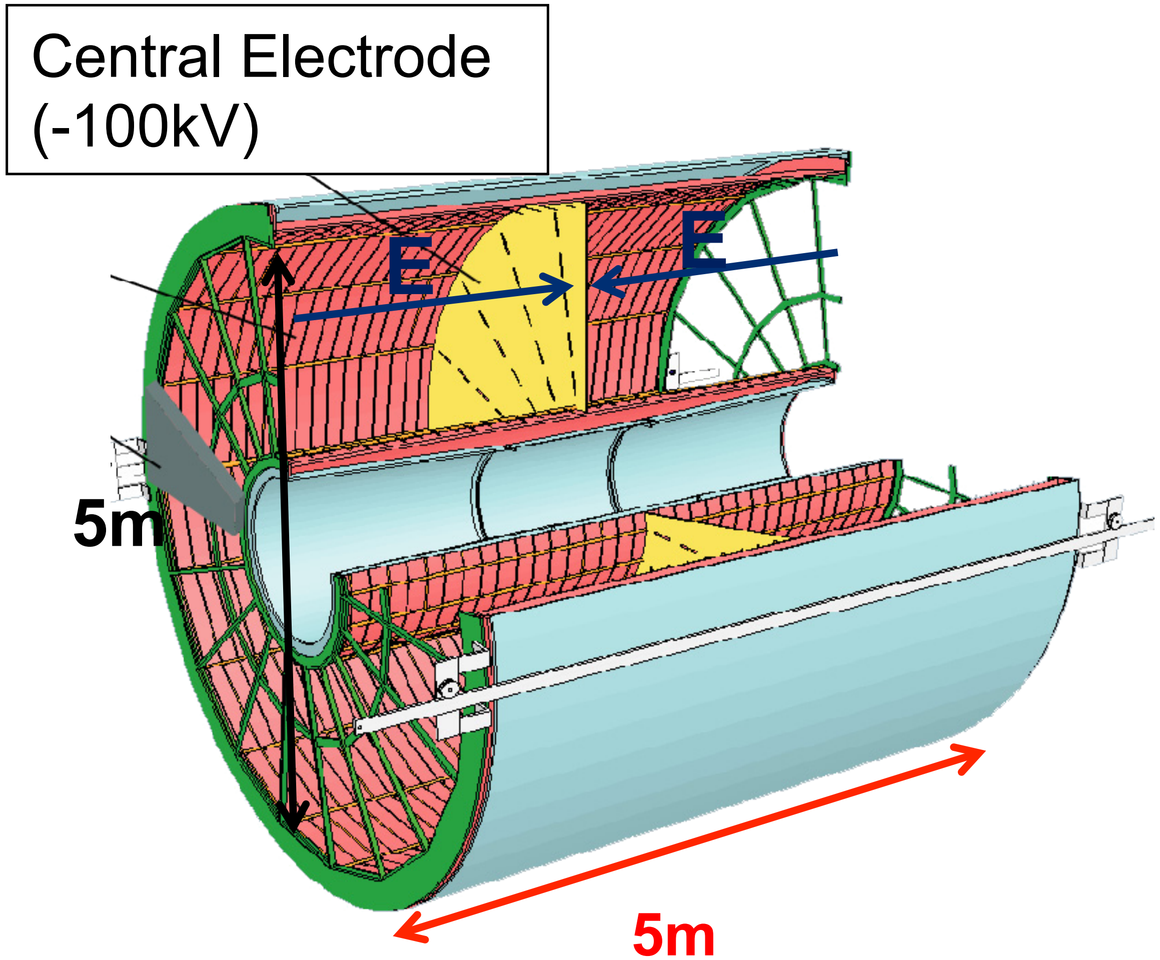
ALICE goal beyond LS1



- Run 2 (2015-2017): ***Pb-Pb at ~ 5*** **TeV** ***(~1-3*** **nb^{-1}*****)***, p-Pb (energy TBD), p-p at ~ 5 TeV
- Run 3-4: ***Pb-Pb at 5.5*** **TeV** ***(~ 10*** **nb^{-1}** ***at nominal B field + ~ 3*** **nb^{-1}** ***at reduced B field)***, p-Pb & p-p at 5.5 TeV

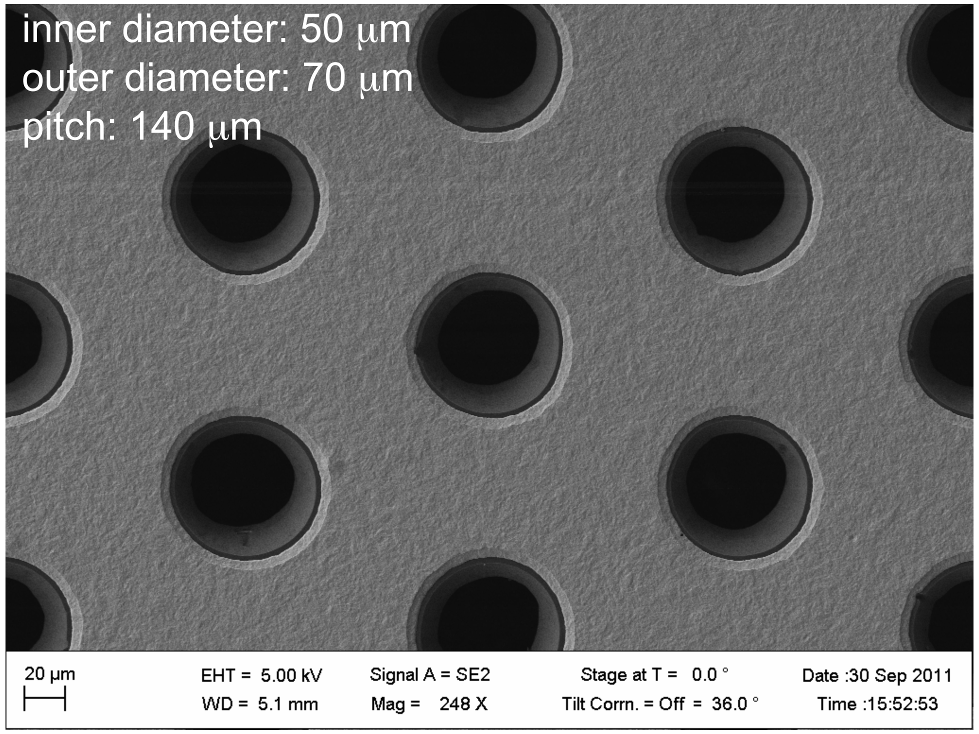
TPC

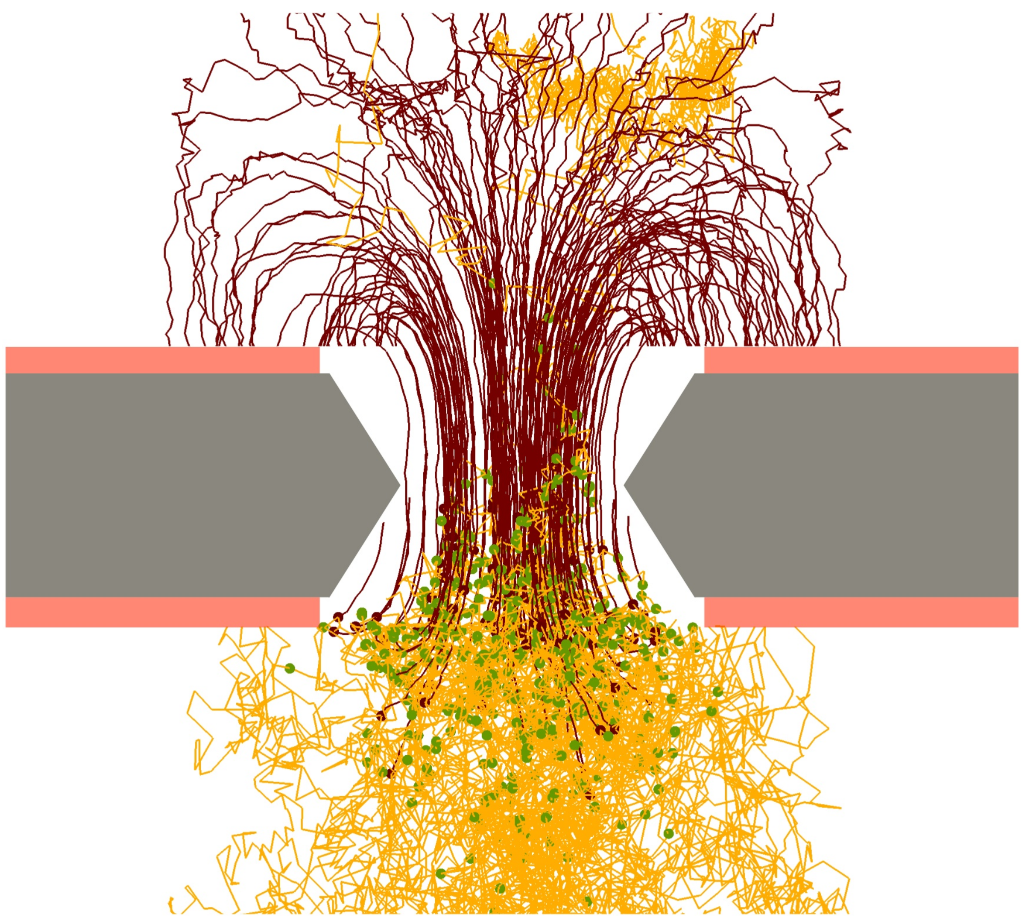
ALICE TPC TDR, https://edms.cern.ch/document/398930/1



- Acceptance
  - $|\eta|<0.9$, $\Delta\phi=2\pi$
    - diameter~5m, length~5m
- 72 MWPC readout chambers
  - Outer: 18×2, Inner: 18×2
  - 557,568 readout cathode pads
- Gas: Ne-CO2 (90-10)
  - drift field = 400 V/cm
- Maximum drift time ~ 100 μs
- MWPC + Gating Grid Operation
  - Rate limitation < 3.5 kHz

TPC with GEM readout

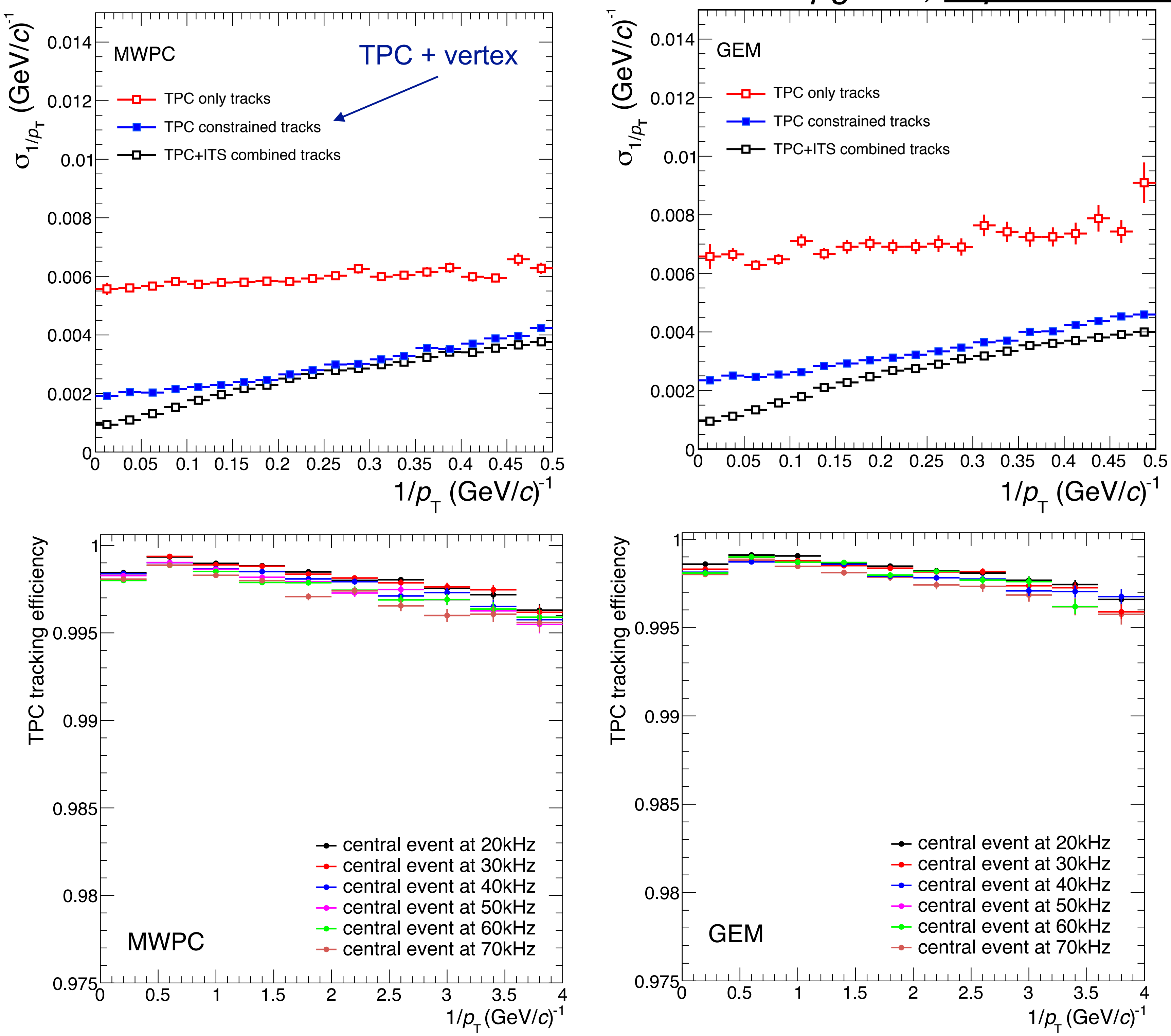




- A continuous, untriggered readout of the TPC in Pb-Pb collision at 50 kHz rate
  - MWPC readout leads to massive charge accumulation in the drift volume due to back-drifting ions
- GEM readout
  - Reduction of ion back-flow (IBF)
  - High rate capability
  - No ion tail
- Requirement for ALICE GEM TPC
  - IBF < 1% at gain = 2000
  - Cluster energy resolution <12% for ^{55}Fe
  - Stable operation at high rate

Expected performance

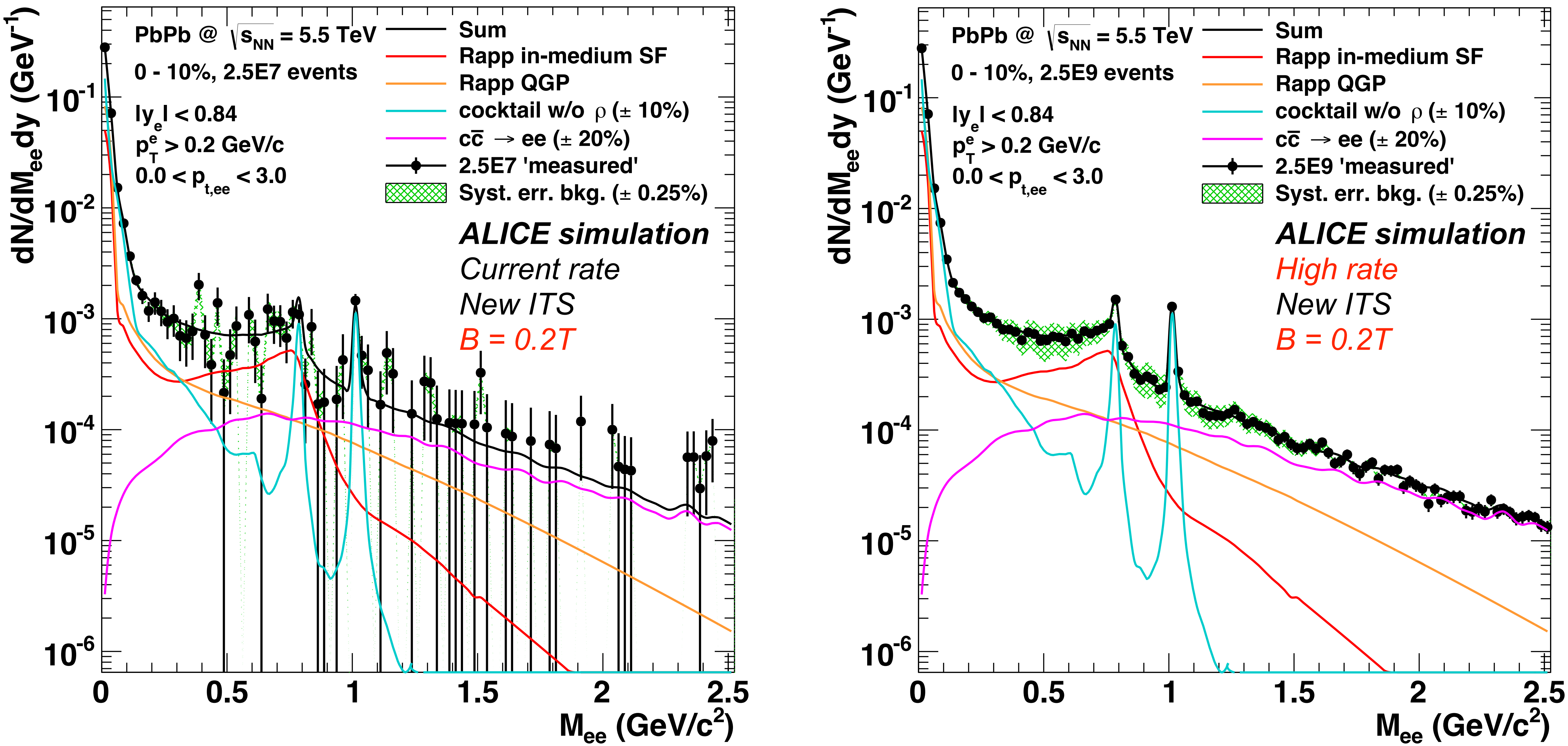
ALICE TPC upgrade, http://cds.cern.ch/record/1622286



- Preserve the present TPC performance with GEM upgrade

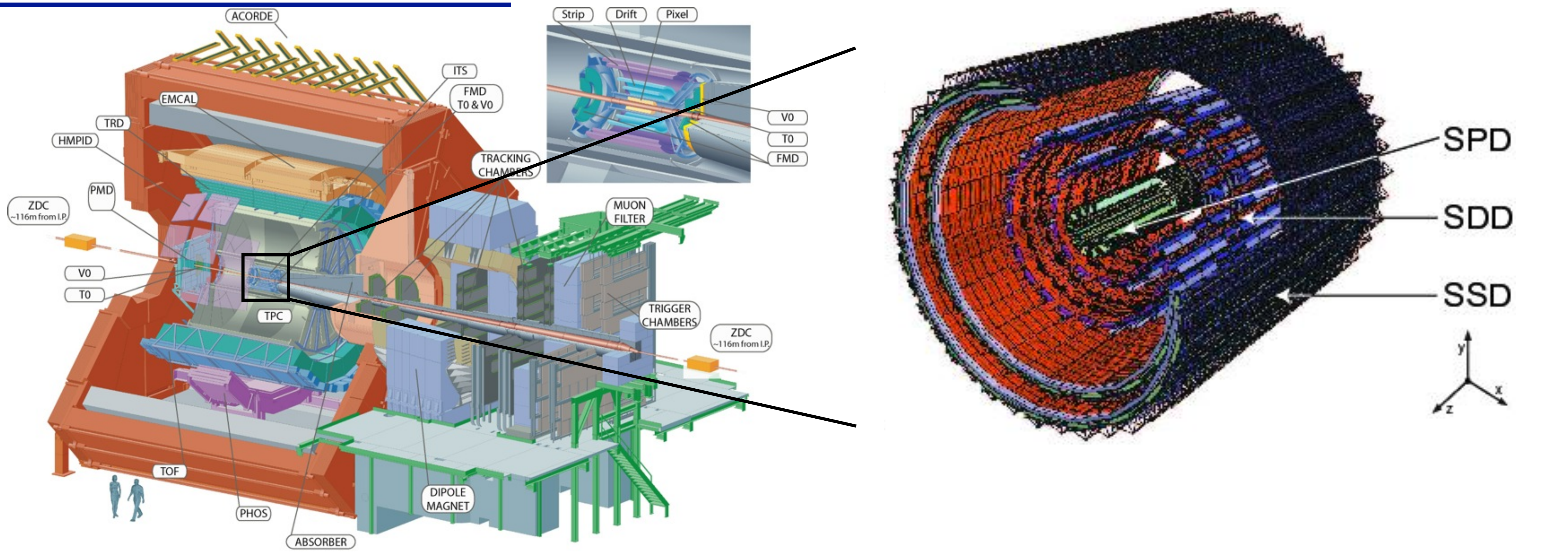
Low mass di-leptons

ALICE TPC upgrade, http://cds.cern.ch/record/1622286



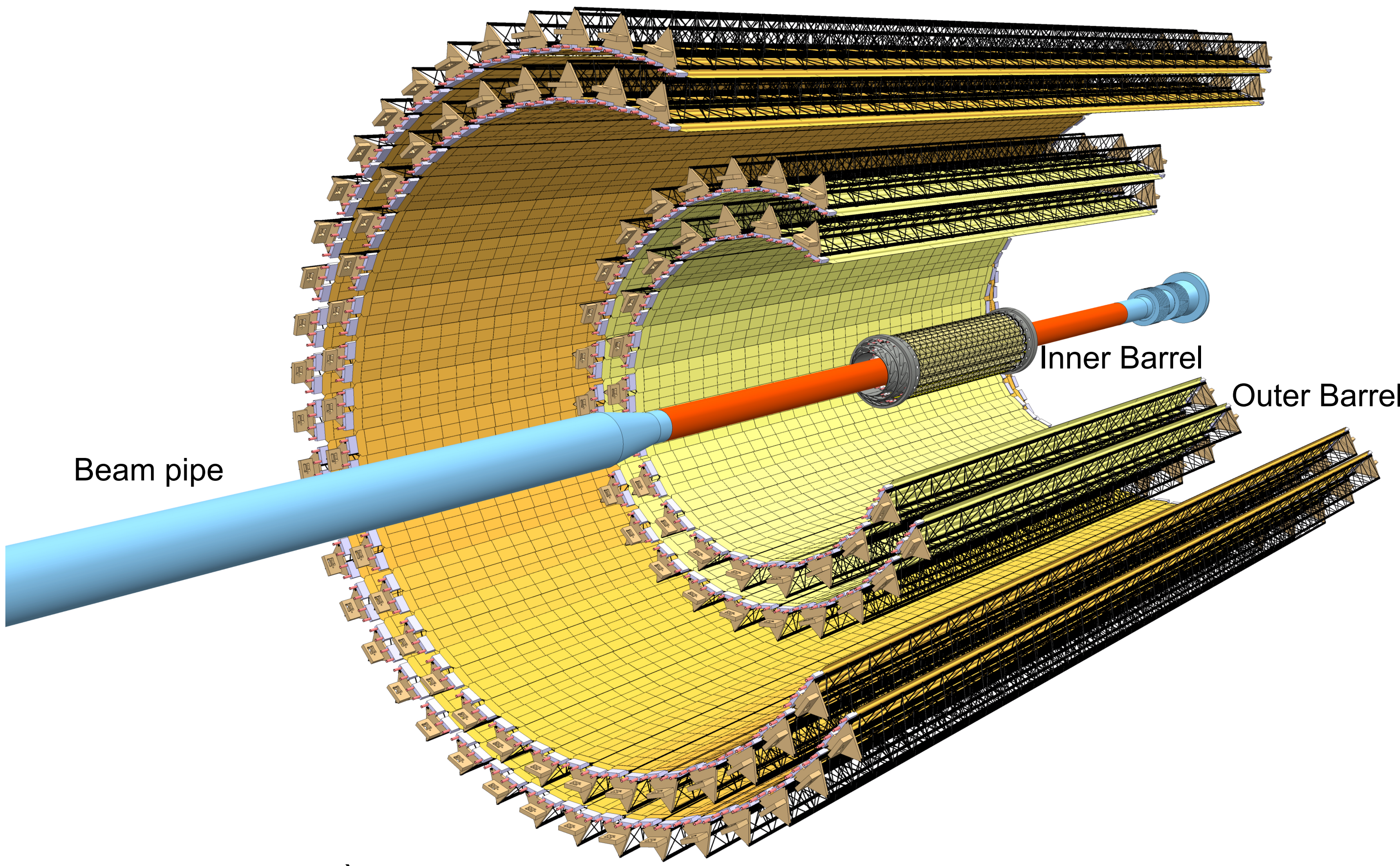
- Significant improvement on statistical uncertainty with TPC (and ITS) upgrade for low mass di-lepton measurement
  - Dalitz decay, conversion and charm rejection by ITS, electron identification by TPC+TOF → reduce systematic uncertainty

ITS



- Present ITS - 6 cylindrical layers
  - 2 layers each of ***SPD*** (Silicon Pixel Detector), ***SDD*** (Silicon Drift Detector) and ***SSD*** (double sided Silicon Strip Detector)
  - Rate limitation ~1 kHz in Pb-Pb
  - Poor statistical precision for charmed mesons at low p_T
  - Cannot reconstruct charmed baryons in Pb-Pb collisions

Design goals of ITS upgrade

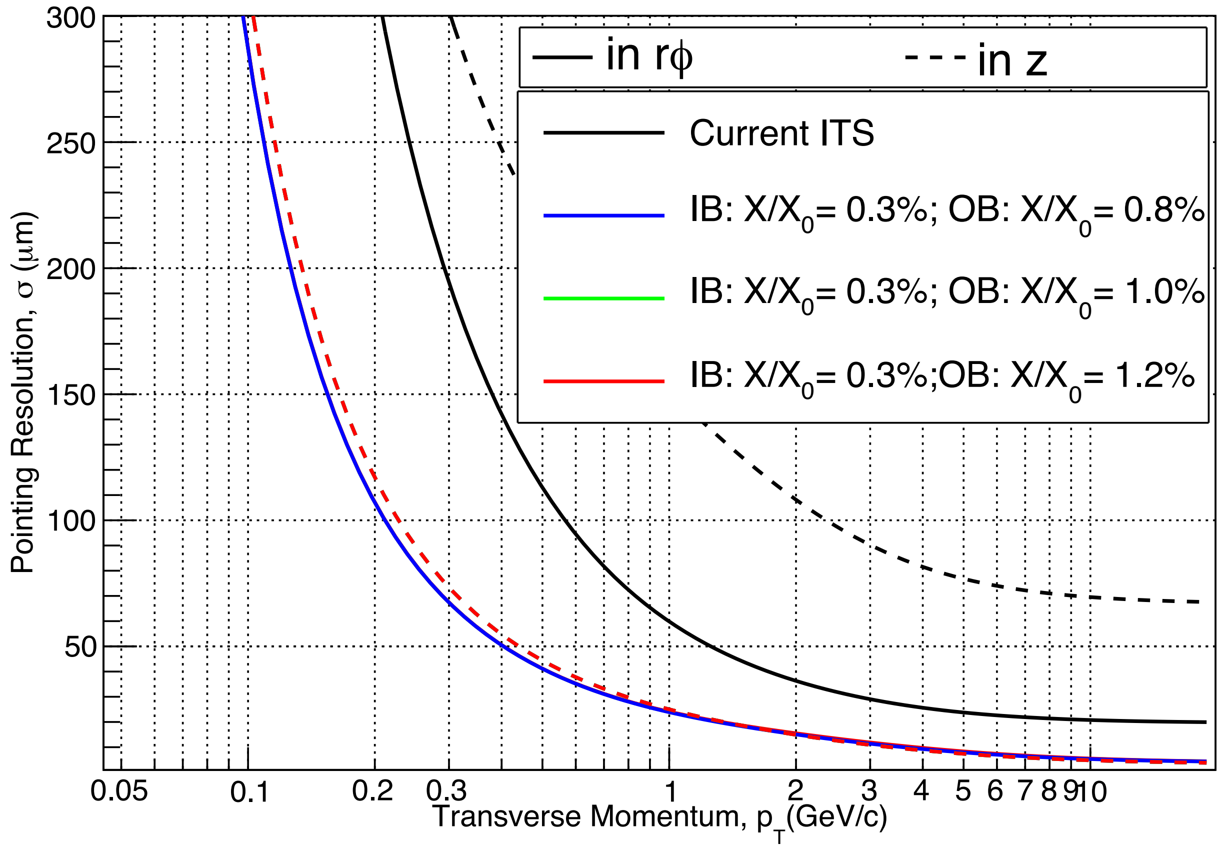


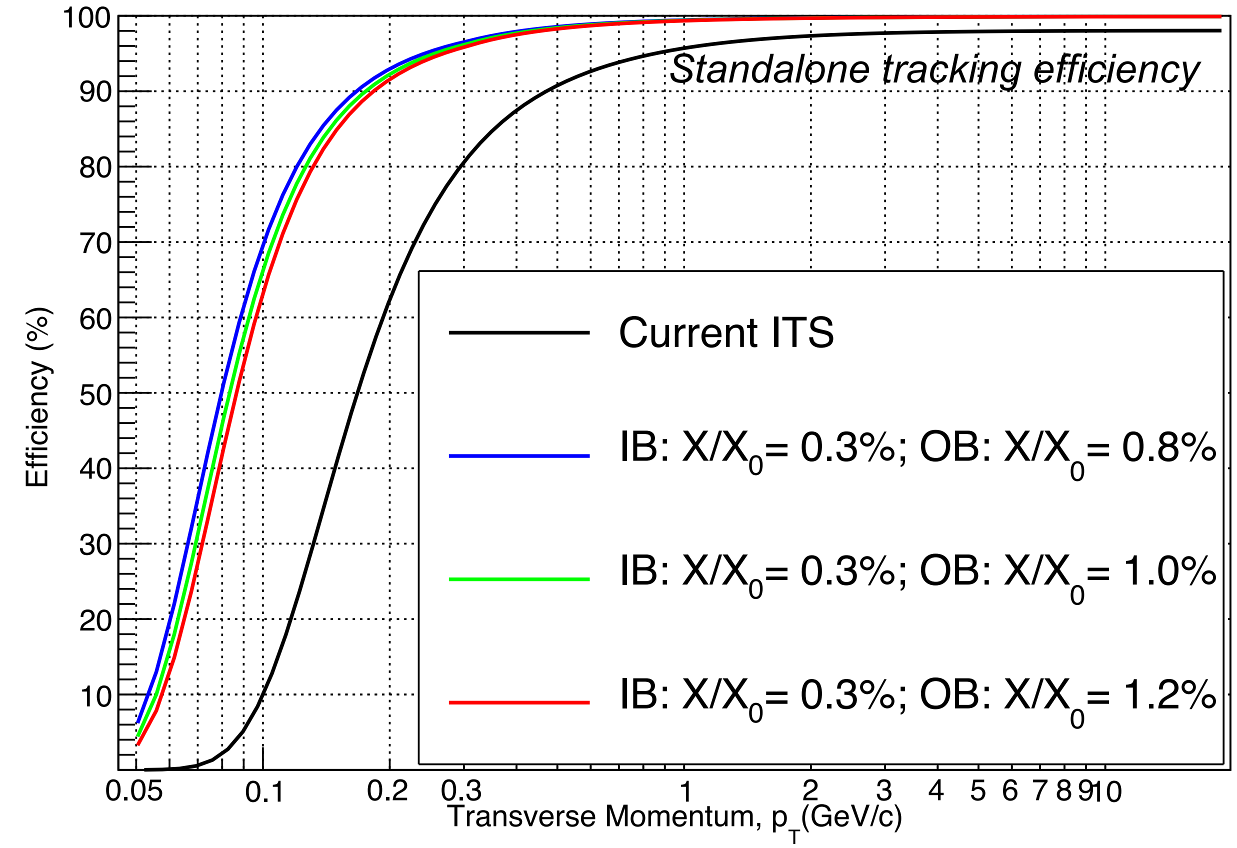
Parameter	Present ITS	New ITS
Pseudorapidity acceptance	$\lvert\eta\rvert < 0.9$	$\lvert\eta\rvert < 1.22$
Radius of inner most layer	39 mm	~23 mm
Si thickness	~350 μm	~50 μm
Pixel size	50μmx425μm	*O*(20μmx30μm)
Material budget per layer	~1.1% X_0	~0.3-0.8% X_0
Max. rate in Pb+Pb	~1 kHz	~100 kHz

- 7 layers of Monolithic Active Pixel Sensors
  - Improve a factor of 3-5 impact parameter resolution
    - Smaller radius of inner most layer, smaller pixel size, reduced material budget
  - Improve tracking efficiency and p_T resolution at low p_T
    - Increase number of layers & granularity
  - Fast readout & easy maintenance

Expected performance

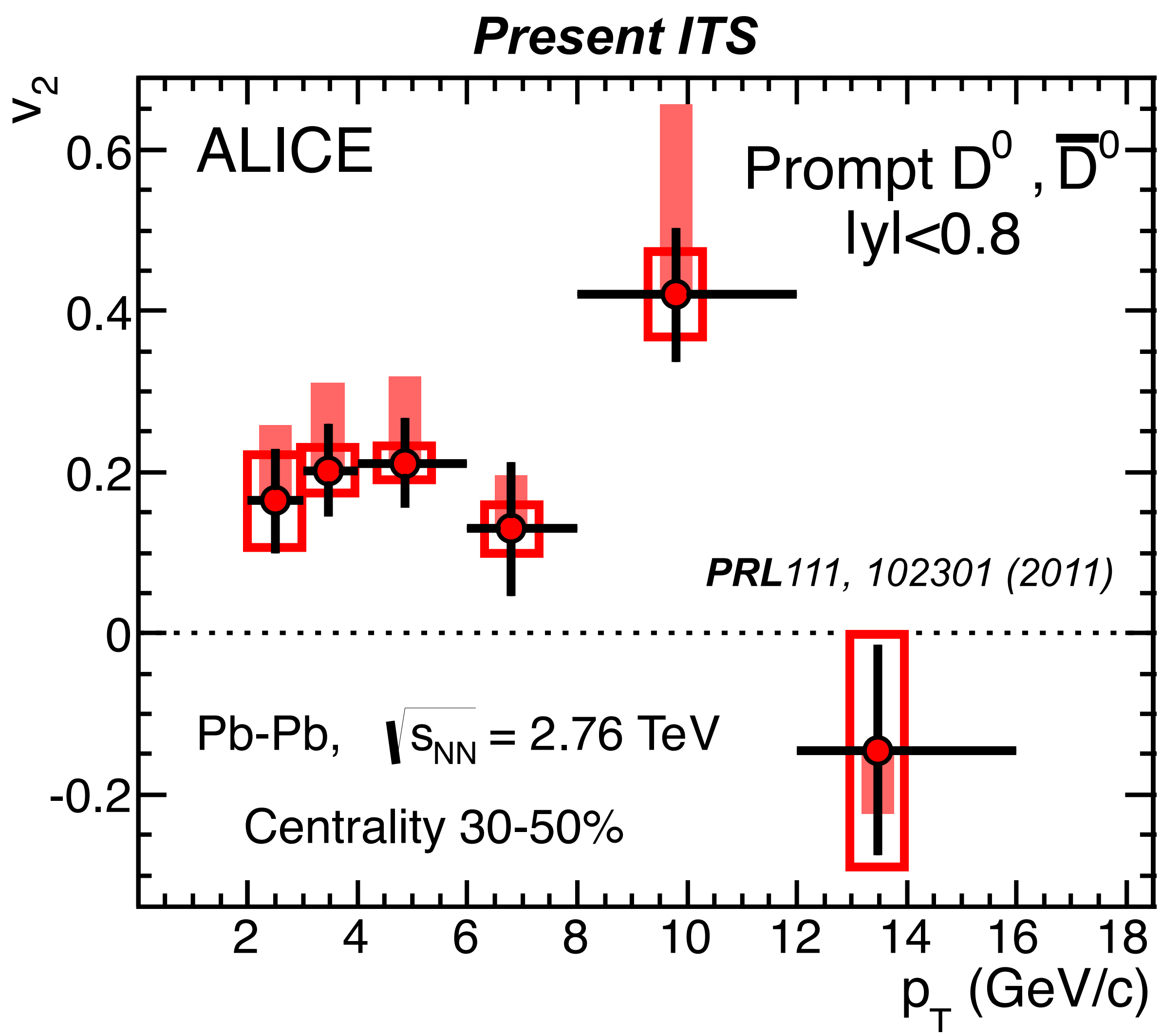
ALICE ITS upgrade, http://cds.cern.ch/record/1625842/

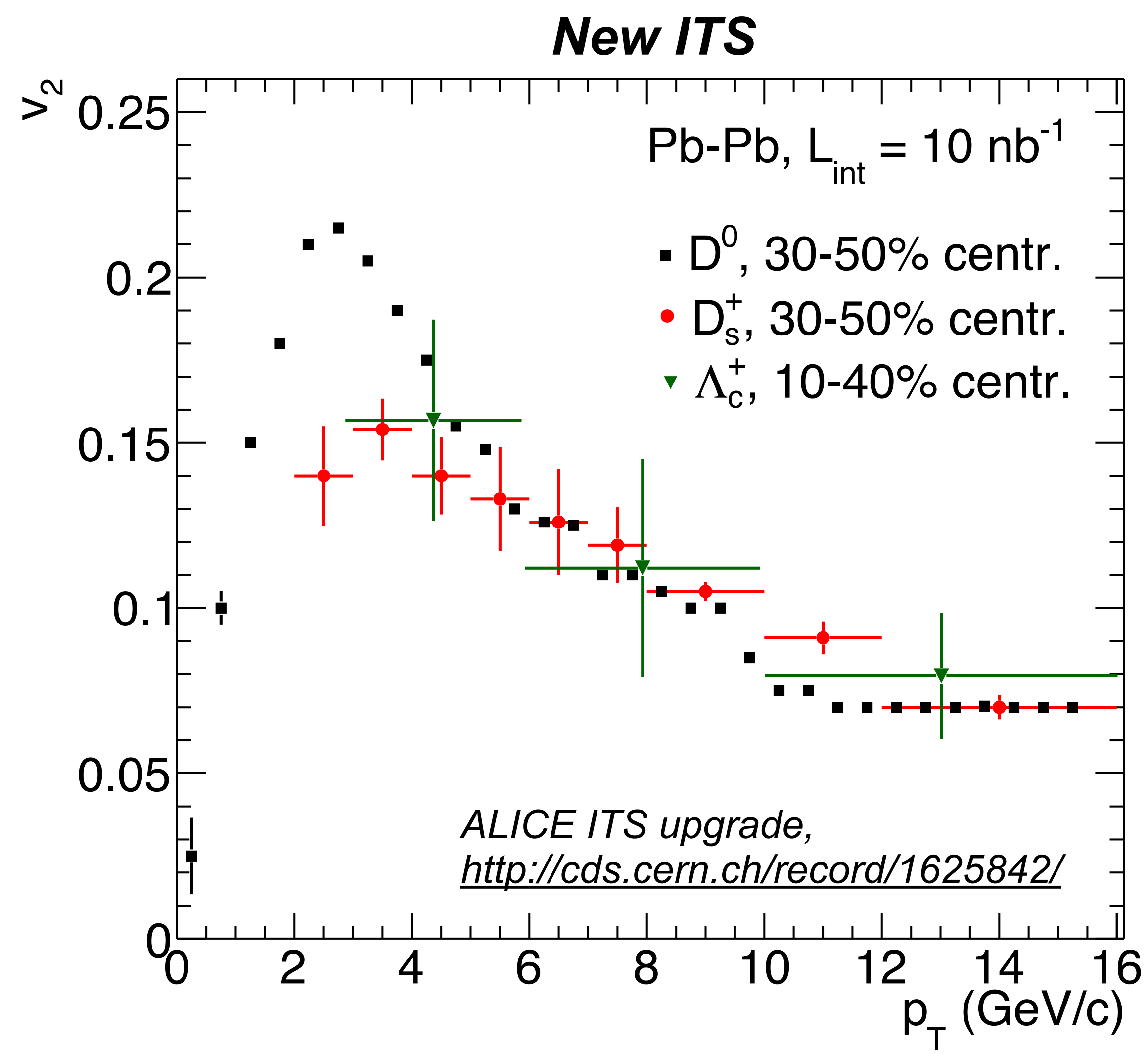




- Pointing resolution is improved by a factor of ~3(5) in rϕ (z) direction
  - not affected by variations of material budget
- Improve efficiency, particularly in low p_T
  - slightly affected, e.g. in the range of 92-94% at 200 MeV/c in p_T

Heavy flavor flow



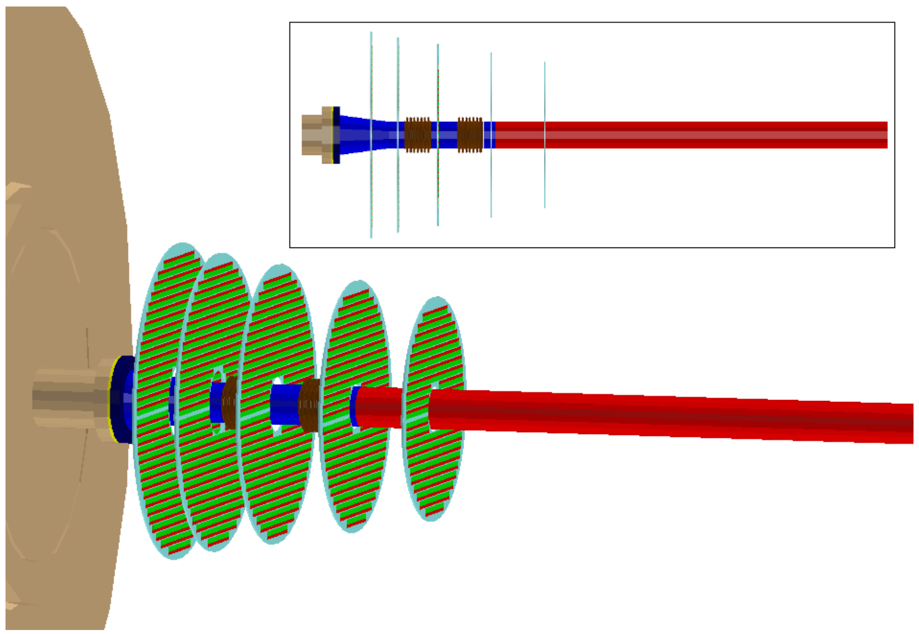


- Precision D^0 v_2 measurements up to p_T~16 GeV/c
- Charm v_2 down to p_T~0 GeV/c with prompt D^0
  - Beauty v_2 can be also measured down to p_T~0 GeV/c with B-decay D^0

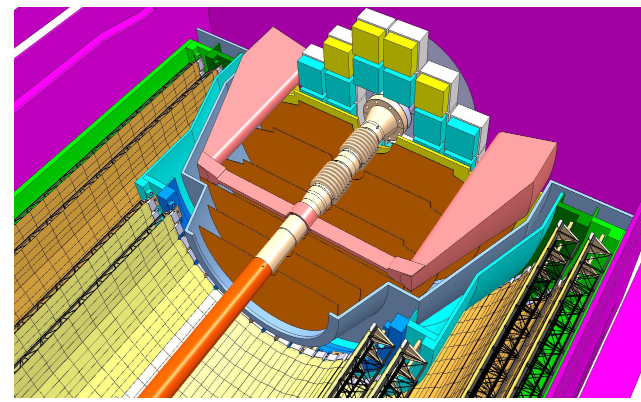
Other detector upgrades

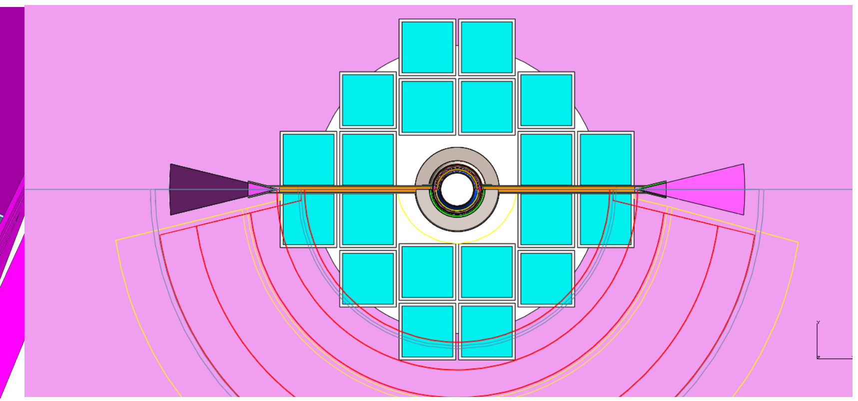
Muon Forward Tracker (*MFT*)

ALICE MFT upgrade, http://cds.cern.ch/record/1592659



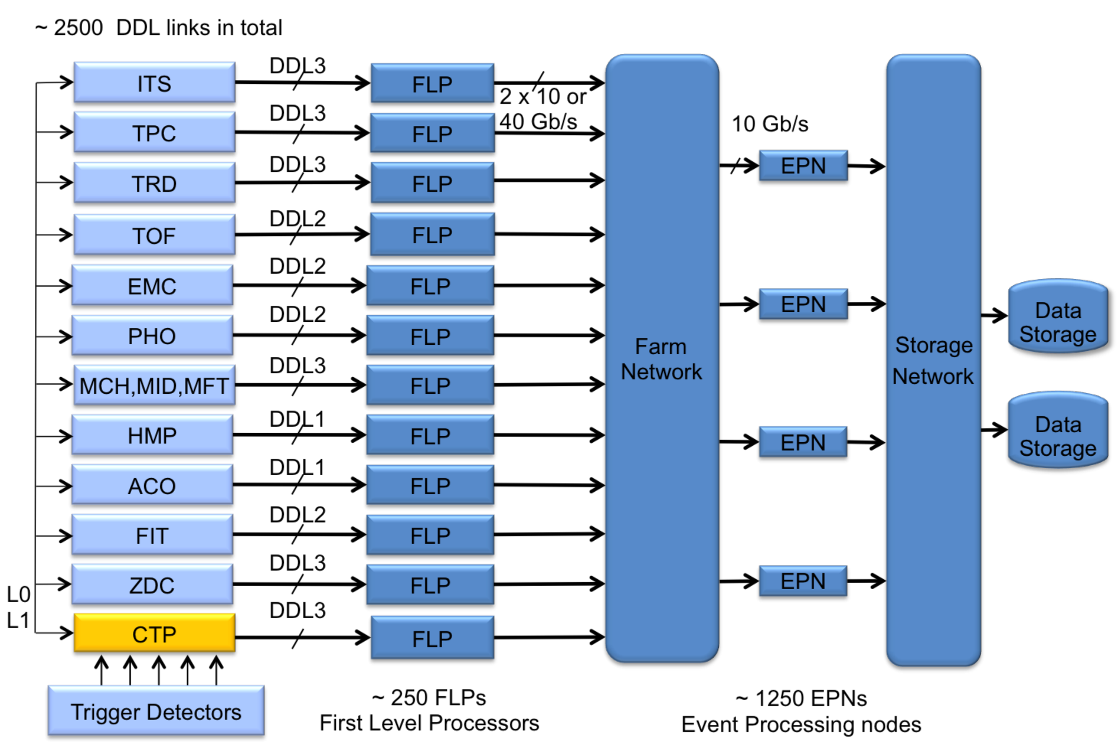
Forward trigger upgrade; Fast Interaction Trigger (*FIT*) detector



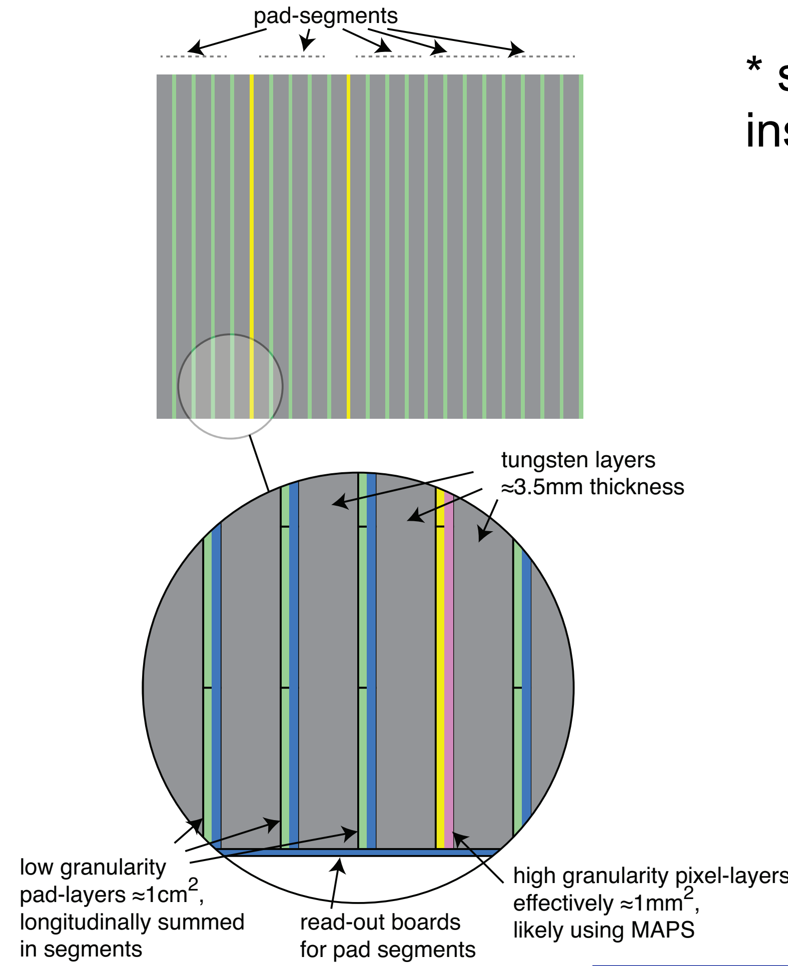


Readout & trigger system upgrade

ALICE readout & trigger system, http://cds.cern.ch/record/1603472/



FoCal: high-granularity calorimeter at forward rapidity η~4-5*



* still in review phase, possible installation during LS3

Summary

- DCAL will be ready in 2015
  - Half of DCAL has been installed in ALICE, other half will be installed this year
  - Commissioning is on-going
- ALICE detector upgrades have been proposed for precision measurements on rare probes
  - Unique on heavy-flavor, low mass di-leptons in low p_T
- Inspecting 50 kHz of minimum bias Pb-Pb collisions
  - Key detector upgrades: TPC with GEM readout, ITS, DAQ
  - continuous readout for TPC and ITS & online event reconstruction
  - Significant efforts on detector R&D are on-going