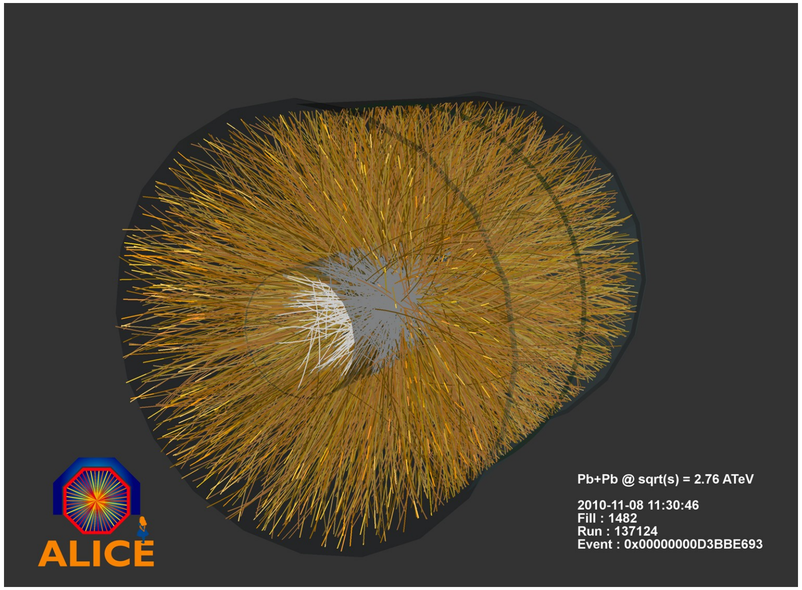
ALICE Upgrades

A. Rossi, CERN

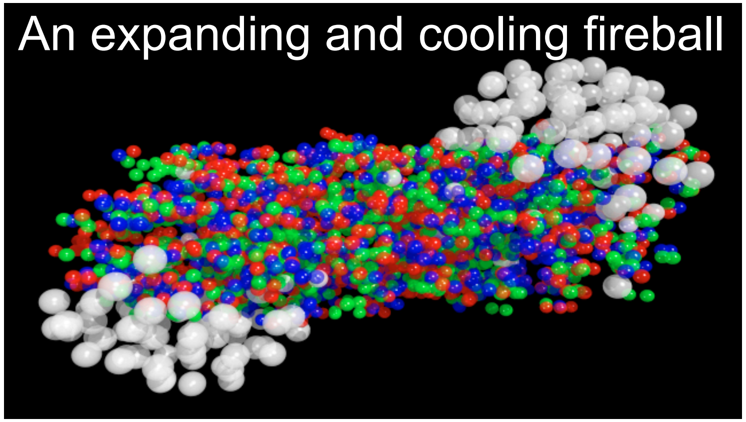
on behalf of ALICE Collaboration



Layout

- Introduction
- ALICE upgrade physics goals
- Detector upgrade plans (LS2 2018)
- Expected performance on selected topics

ALICE for studying the QGP



Heavy Ion Collisions produce a complex system of strongly interacting matter

- Extended size
- High temperature, high pressure
- Local thermodynamical equilibrium

➜ Phase transition to a deconfined state:
Quark Gluon Plasma

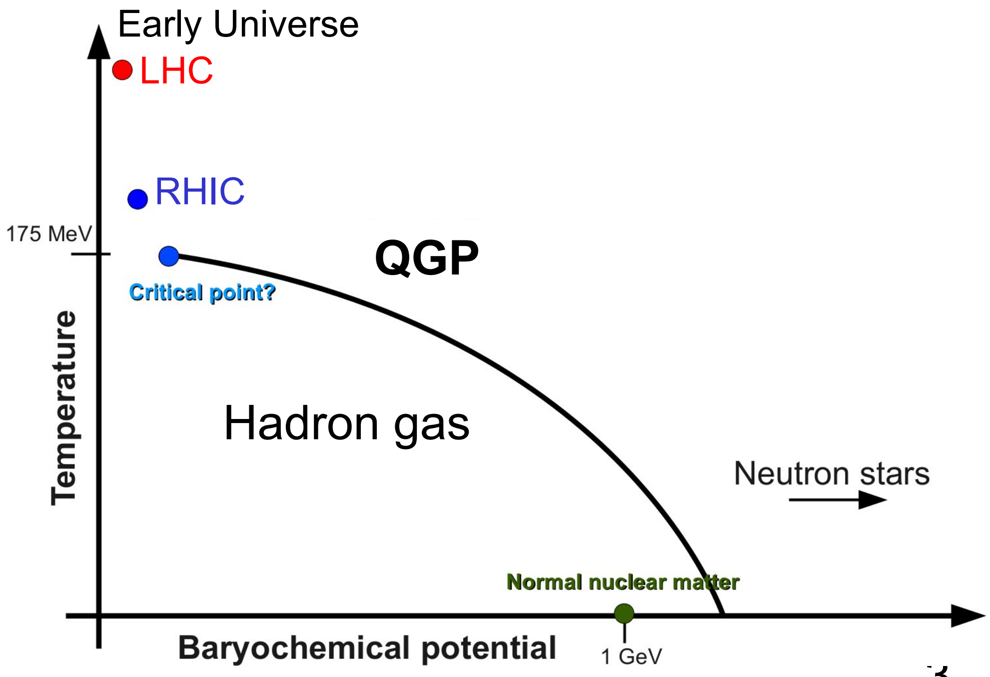
ALICE main goals

Study the properties of the QGP:

- Collective phenomena
- Temperature(s), energy density
- Parton interaction with the medium

using several probes
(light hadrons, heavy-flavour, quarkonia, jets, photons,…)

(+ extensive p-Pb and pp programme)



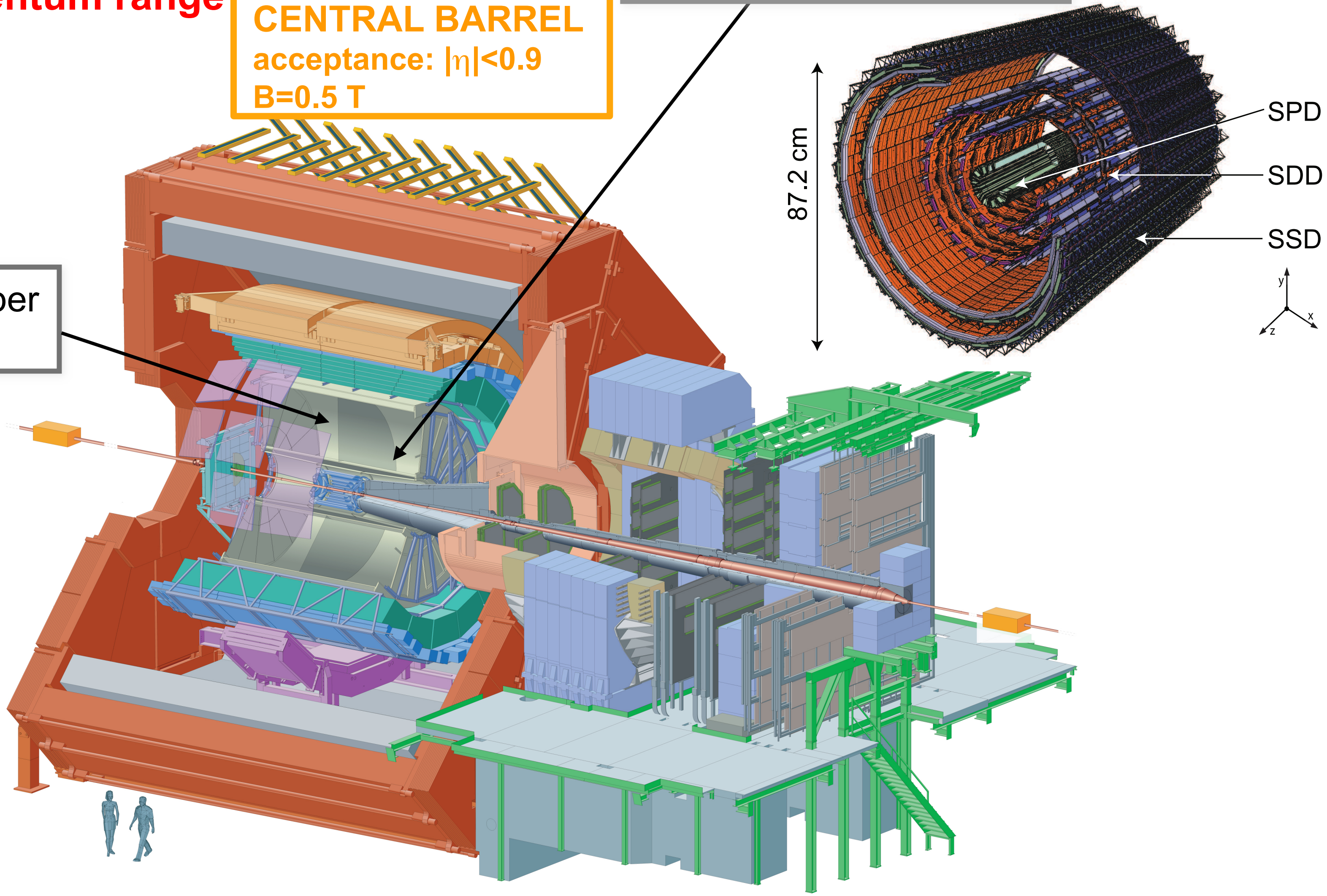
ALICE detector specificities

Excellent track and vertex reconstruction capabilities (TPC, ITS) in a high multiplicity environment over a wide transverse momentum range

CENTRAL BARREL
acceptance: |η|<0.9
B=0.5 T

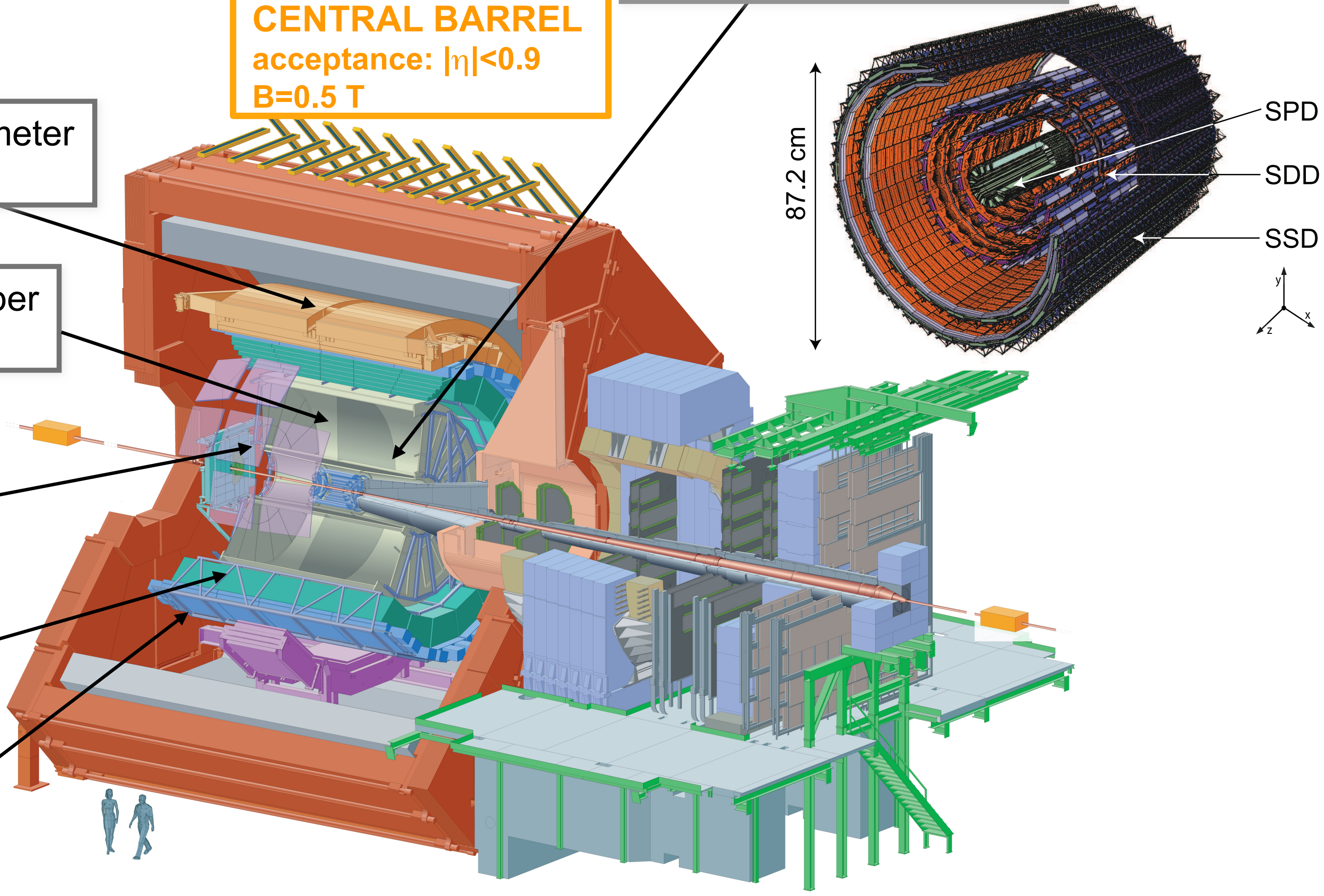
Inner **T**racking **S**ystem
Vertexing,Tracking, PID

Time **P**rojection **C**hamber
Tracking, PID



ALICE detector specificities

Particle identification over a wide momentum range



Inner **T**racking **S**ystem
Vertexing,Tracking, PID

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Eletro**M**agnetic **CAL**orimeter
Calorimeter, electron ID

Time **P**rojection **C**hamber
Tracking, PID

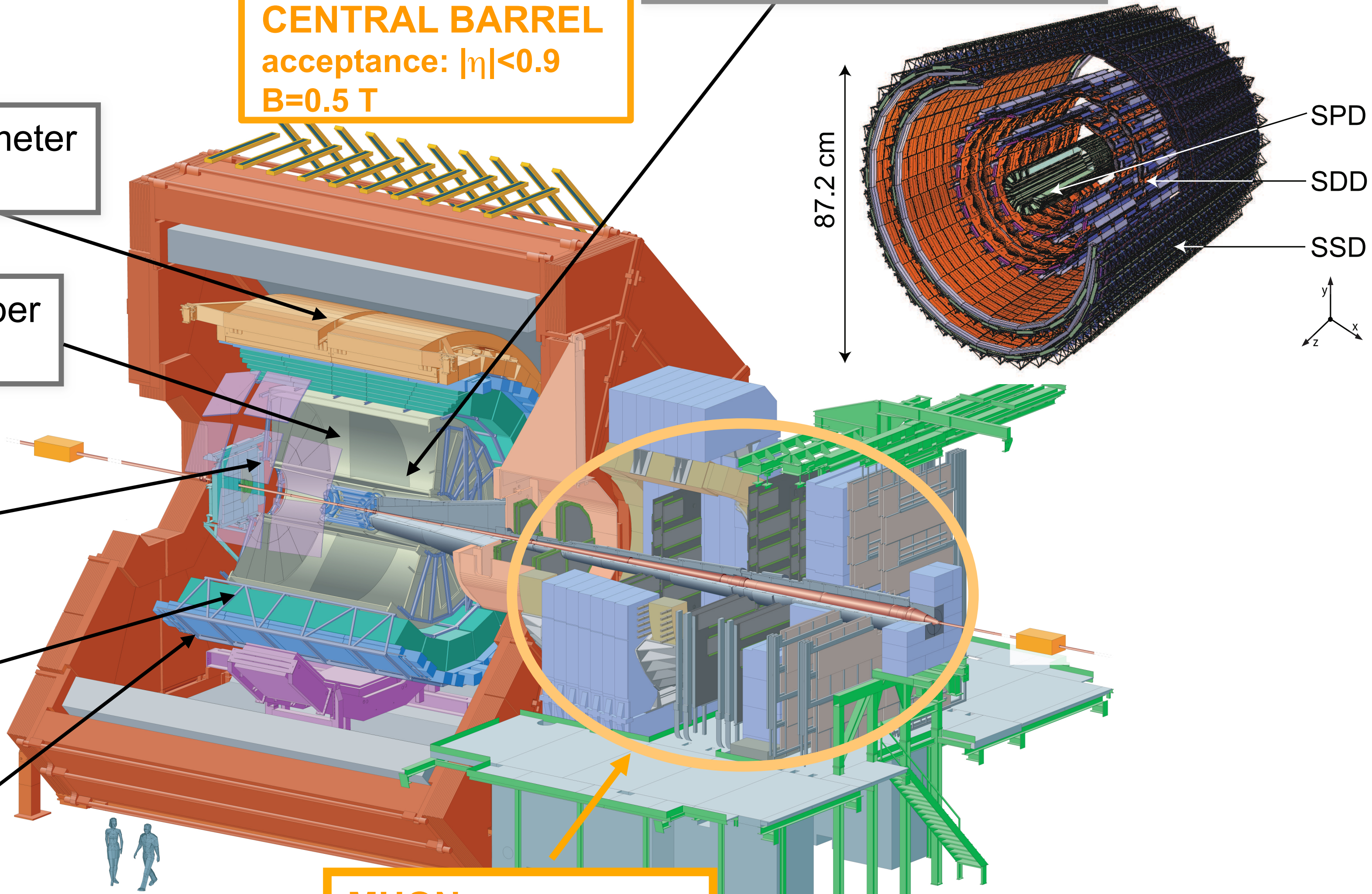
High **M**omentum **PID**
PID

Transition **R**adiation **D**etector
PID

Time **O**f **F**light
PID

ALICE detector specificities

Excellent muon identification down to low p_T at forward rapidity



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MUON Spectrometer
acceptance: -4<η<-2.5

Physics goals with ALICE upgrade

Main physics topics, exploiting LHC & ALICE specific potentialities:

Precise measurement of heavy-flavour hadron production (spectrum, elliptic flow) in a wide momentum range, down to very low p_T

- Charm/beauty quark interaction with the QGP medium (in-medium energy loss)
- Study degree of charm thermalization and possible hadronization via coalescence
- Detect possible charm thermal production

Heavy-Ion session, Thursday

J/ψ, ψ' states down to zero p_T in wide rapidity range

- Charmonium dissociation and regeneration pattern as a probe of colour deconfinement

Measurement of low-mass and low-p_T di-leptons (from ρ,ω,.. decay, in-medium $q\bar{q} \to l^+l^-$, direct photons) ➞ **electromagnetic radiation from QGP**

- Medium temperature(s)
- Space-time evolution and equation of state of the QGP
- Chiral-symmetry restoration ➞ modification of ρ spectral function

… and more:

Jet quenching and fragmentation: PID of jet particle content, heavy flavour tagging

Heavy nuclear states

ALICE upgrade strategy

Physics Goal

High precision measurements of rare signals at low p_T which cannot be selected with a dedicated trigger (very low signal/background)

Requirements

Large event samples on tape

➜ Target to **L_{int} ≥ 10 nb^{-1} Pb-Pb minimum bias data** + pp and p-A data

➜ Factor 100 gain in statistics for minimum bias trigger over the current programme

Improve spatial precision on track and vertex position

Strategy

Upgrade ALICE readout (for several detectors) and **online systems**

➜ Read out all Pb-Pb interactions at maximum rate of 50 kHz (set by LHC luminosity target for Pb-Pb, $\mathcal{L}=6\times10^{27}cm^{-2}s^{-1}$) with a minimum bias trigger

➜ Data reconstruction performed online

New silicon trackers: new Inner Tracking System (ITS, at mid-rapidity) and Muon Forward Tracker (MFT, at forward rapidity)

⊕ Forward trigger detectors upgrade (Fast Interaction Trigger) and a possible new forward calorimeter

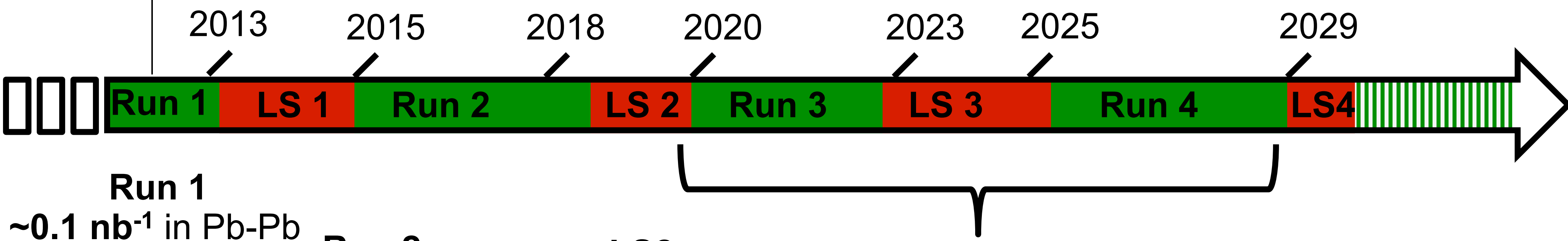
ALICE heavy-ion plan

Heavy-ion programme at LHC extended to Run 3 and Run 4

- As approved by the LHCC in December 2013
- Participation of ALICE, ATLAS, CMS, LHCb (p-Pb)

ALICE Upgrade Letter Of Intent (2012)

CERNLHCC-2012-012, LHCC-I-022, 2012.



Run 1
~0.1 nb^{-1} in Pb-Pb

Run 2
Collect **1 nb^{-1}** in Pb-Pb collisions at top energy (originally approved heavy-ion programme) with improved detector

LS2
Major detector upgrade

Run3, Run4
Run at high luminosity
Collect >10 nb^{-1}

3 phases, each jumping one order of magnitude in statistics, progressively improving the detector

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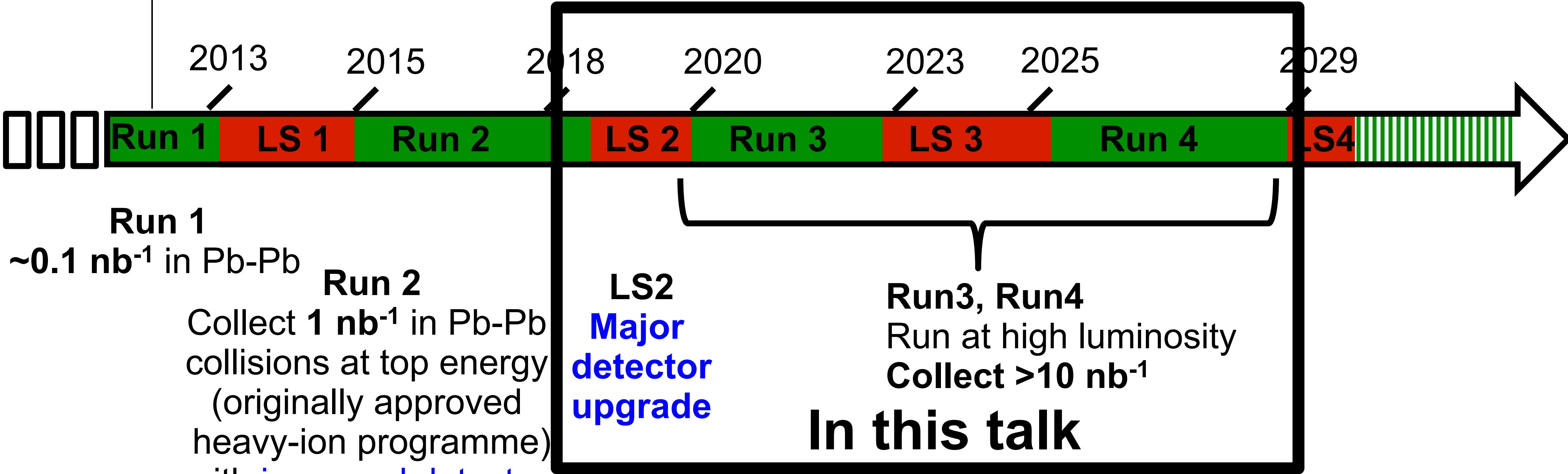

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In this talk

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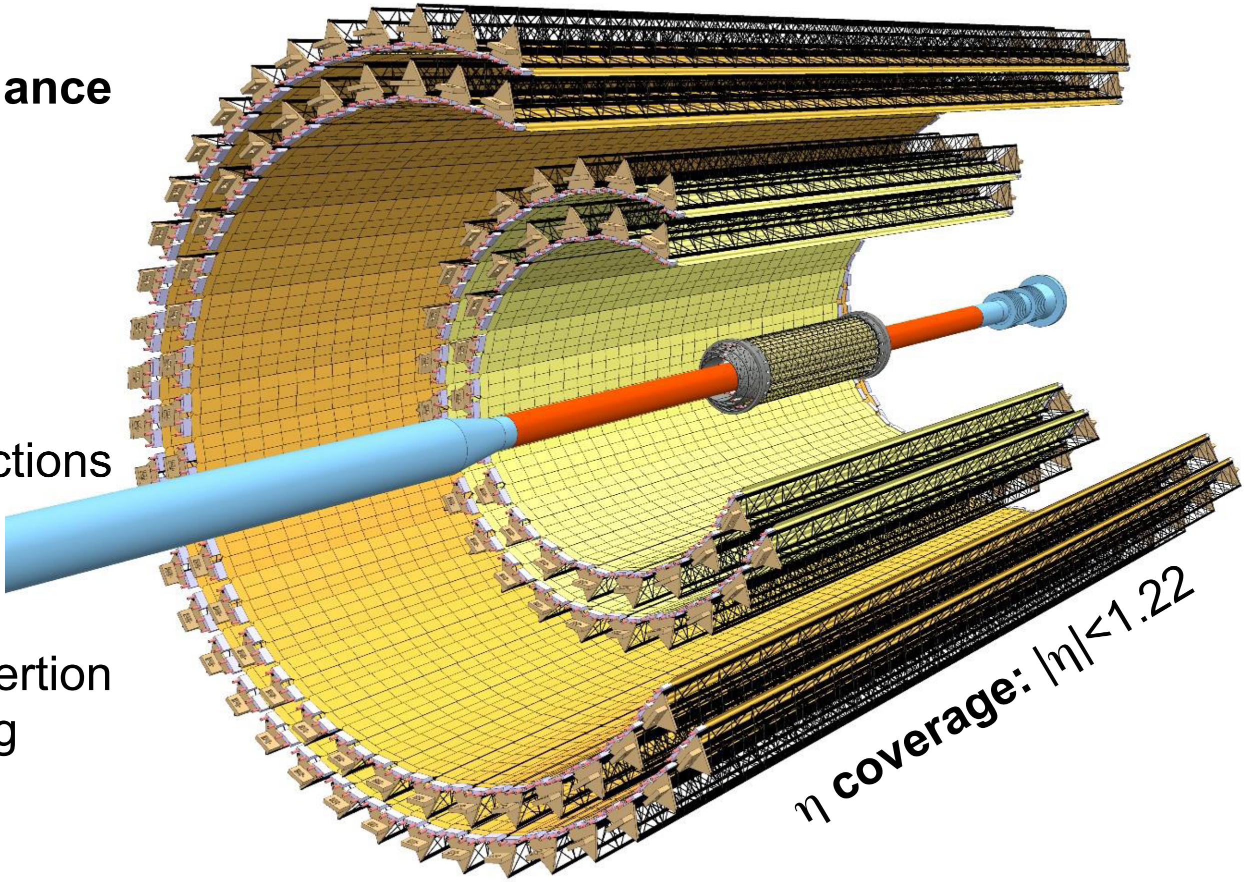
DETECTOR UPGRADE

New ITS

Design requirements:

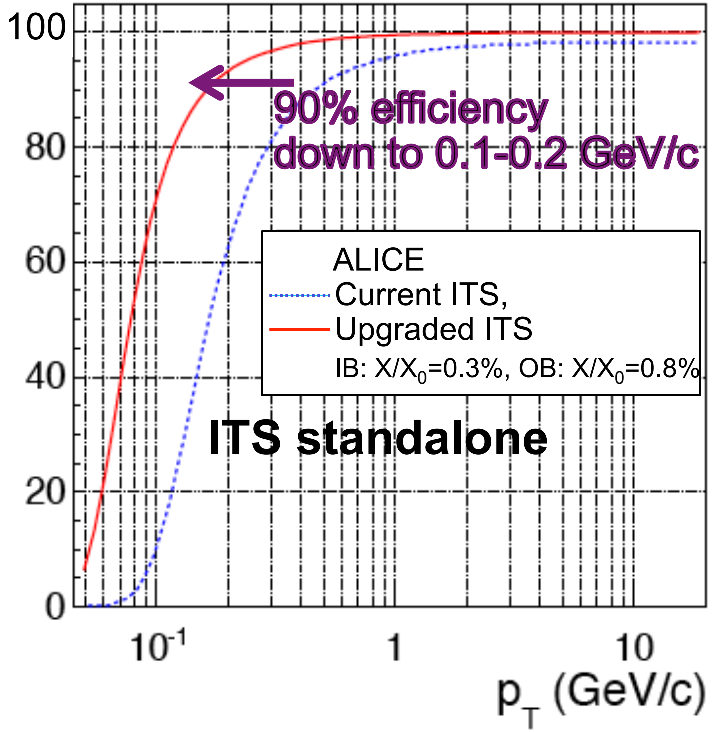
1. **Improve impact parameter resolution by a factor ~3 (5) in rφ (z)**
   - ➜ Reduce pixel size (currently 50 μm x 425 μm)
     - monolithic (MAPS) with size ~ 25 μm x 25 μm
   - ➜ Go closer to interaction point:
     - ➜ new smaller beam pipe: 2.9 cm ➞ 1.9 cm
     - ➜ first layer with smaller radius (2.3 cm, currently 3.9 cm)
   - ➜ Reduce material thickness: 50 μm silicon, X/X_0 from current ~1.13% to ~0.3(0.8)% per layer
2. **High standalone tracking performance** (efficiency, spatial and momentum resolutions)
   - ➜ Increase granularity
   - ➜ Add 1 layer (from 6 to 7)
3. **Faster (x50) readout**: Pb-Pb interactions up to 100 kHz
4. **Maintenance:** allow for removal/insertion of faulty detector components during annual winter shutdown


η coverage: |η|<1.22

New ITS: performance

Studies done with simulations with realistic and complete detector geometry and material budget description.

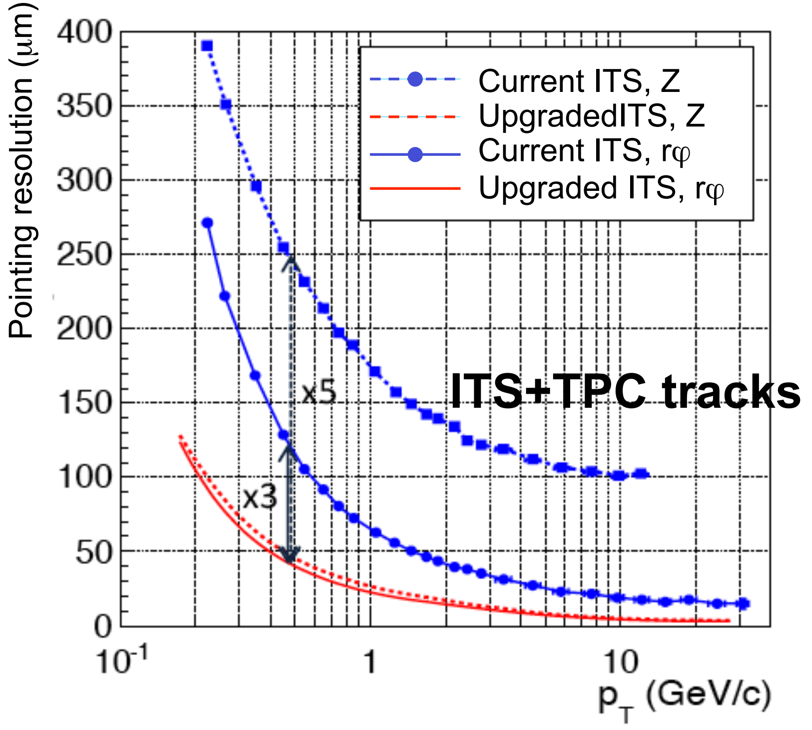
Track reconstruction efficiency



90% efficiency down to 0.1-0.2 GeV/c

ITS standalone

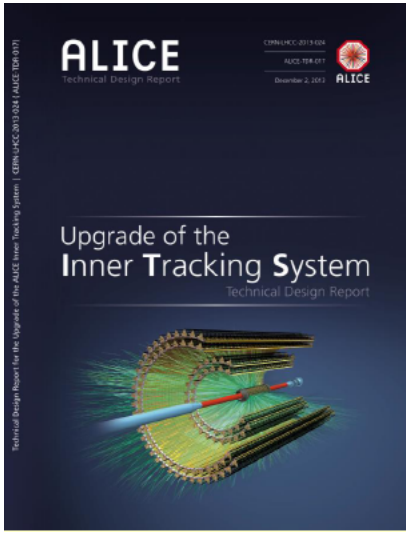
Track spatial resolution at the primary vertex



ITS+TPC tracks

Find more in ALICE ITS TDR:

CERN-LHCC-2013-024 ; ALICE-TDR-017



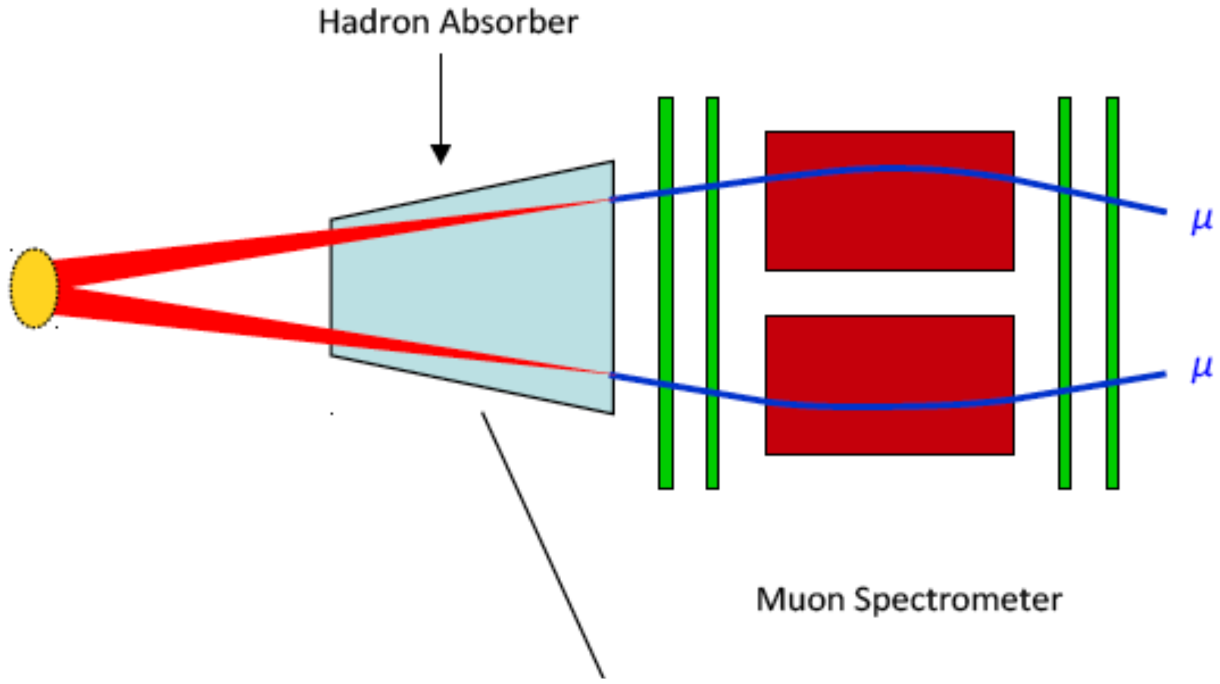
ALICE

Technical Design Report

Upgrade of the Inner Tracking System

Technical Design Report

Muon Forward Tracker

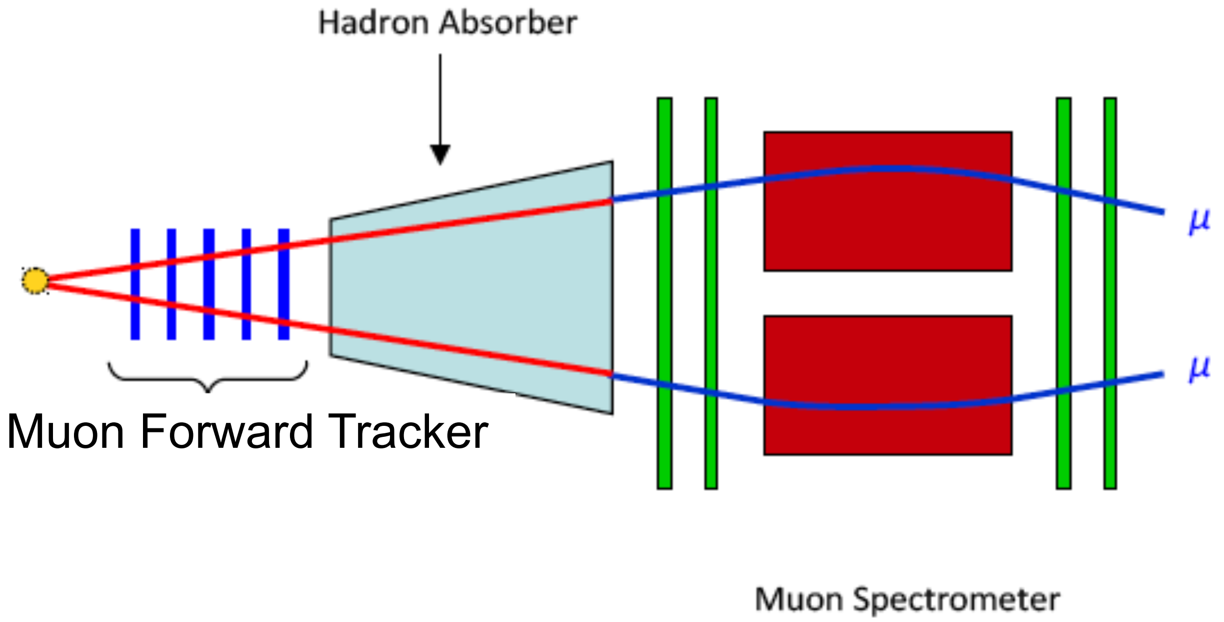


Complementing muon spectrometer at forward rapidity

Extrapolating back to the vertex region degrades the information on the kinematics and trajectory

➔ Cannot separate prompt and displaced muons

Muon Forward Tracker



Complementing muon spectrometer
at forward rapidity

Muon tracks are extrapolated and matched to the MFT clusters before the absorber

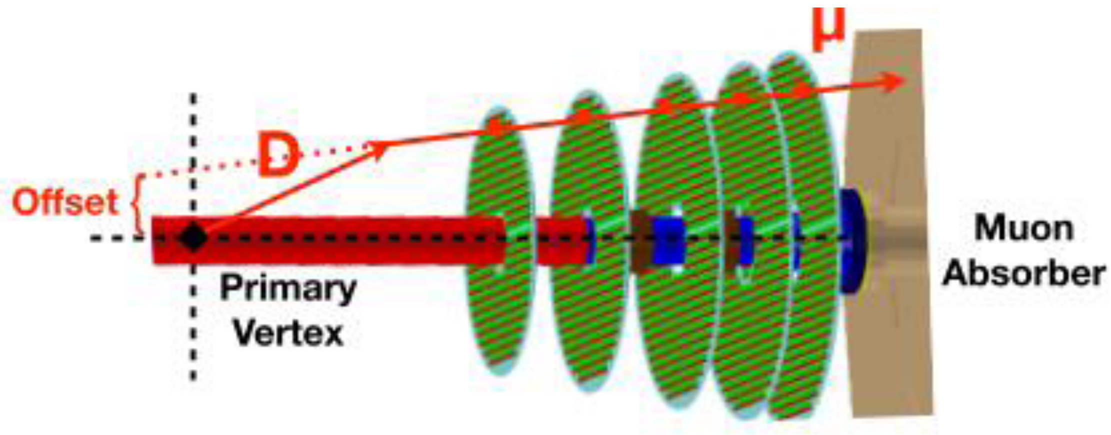
⬇

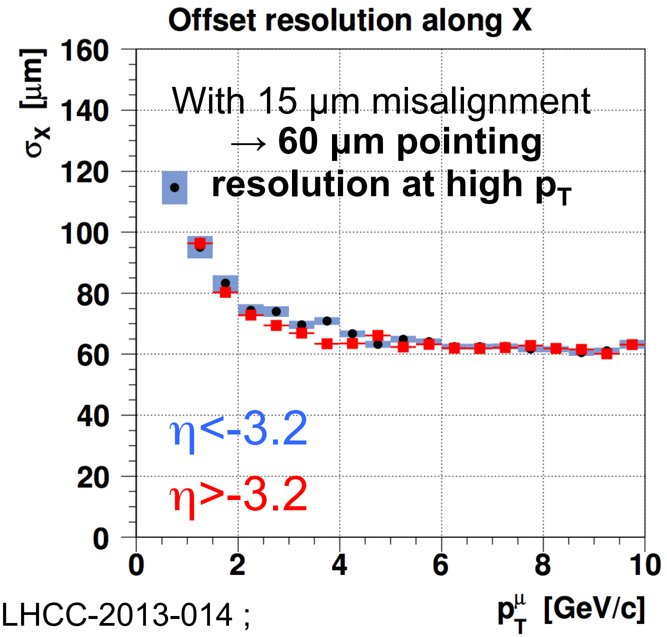
High pointing accuracy

⬇

Separation of charm and beauty signals (single μ, J/ψ)

Muon Forward Tracker





With 15 μm misalignment
→ **60 μm pointing resolution at high p_T**

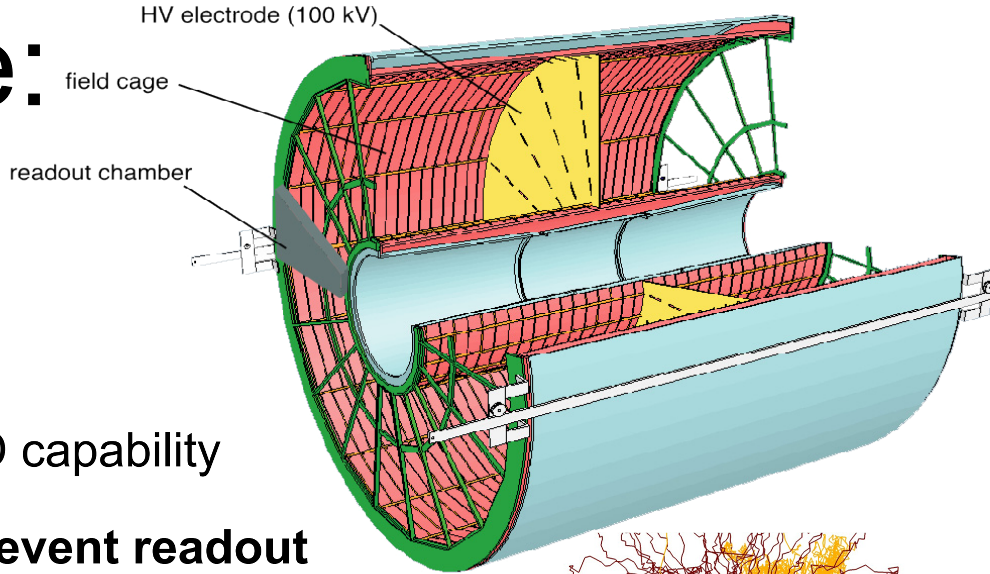
CERN-LHCC-2013-014 ;
LHCC-I-022-ADD-1

5-6 planes of CMOS silicon pixel sensors (same technology as ITS):

- $50 < z < 80$ cm
- $R_{min} \approx 2.5$ cm (beam pipe constraint)
- $11 < R_{max} < 16$ cm
- Area ≈ 2700 cm^2
- $X/X_0 = 0.4\%$ per plane
- Current pixel size scenario: ~25 x 25 μm^2

Technical Design Report in preparation

ALICE at high rate: TPC Upgrade



Goals

- Operate TPC at 50 kHz
- Preserving current momentum resolution and PID capability

Current TPC readout based on MWPC limits the event readout rate to 3.5 kHz

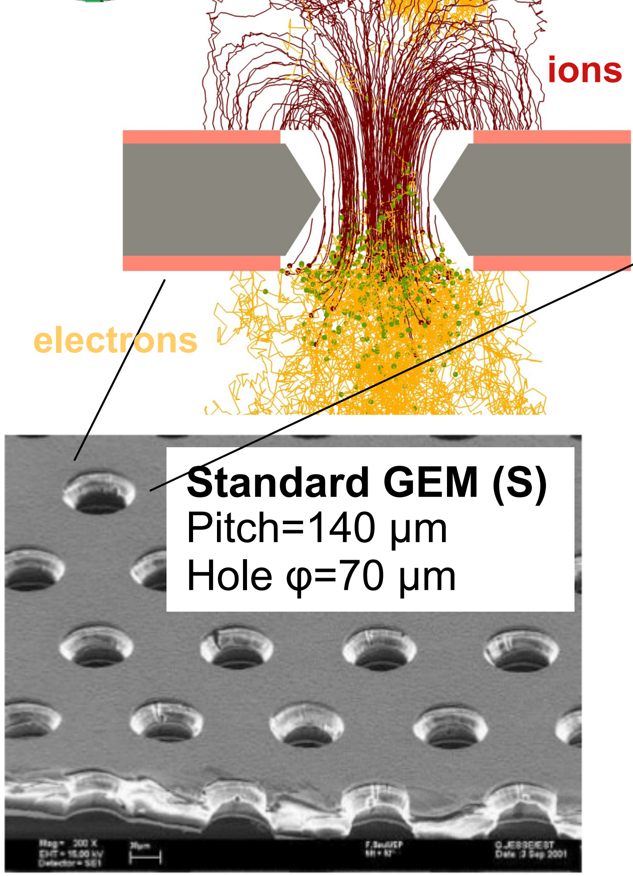
➜ Upgrade TPC strategy

- **New readout chambers:** MWPC replaced with micropattern gaseous detectors, including **GEM (Gas Electron Multiplier)**
  - No gating, small ion backflow

- Redesign TPC front-end and readout electronic systems to allow for continuous readout

- Significant online data reduction to comply with the limited bandwidth
  - Online cluster finding and cluster-track association

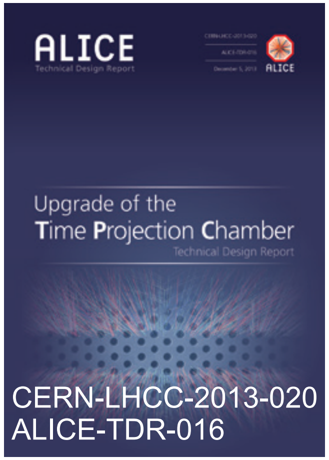
- Using the same field cage



ALICE at high rate: TPC Upgrade

Expected performance:

- p_T resolution practically unchanged for TPC+ITS tracks (simulations)
- dE/dx resolution comparable to current performance (beam tests at PS)

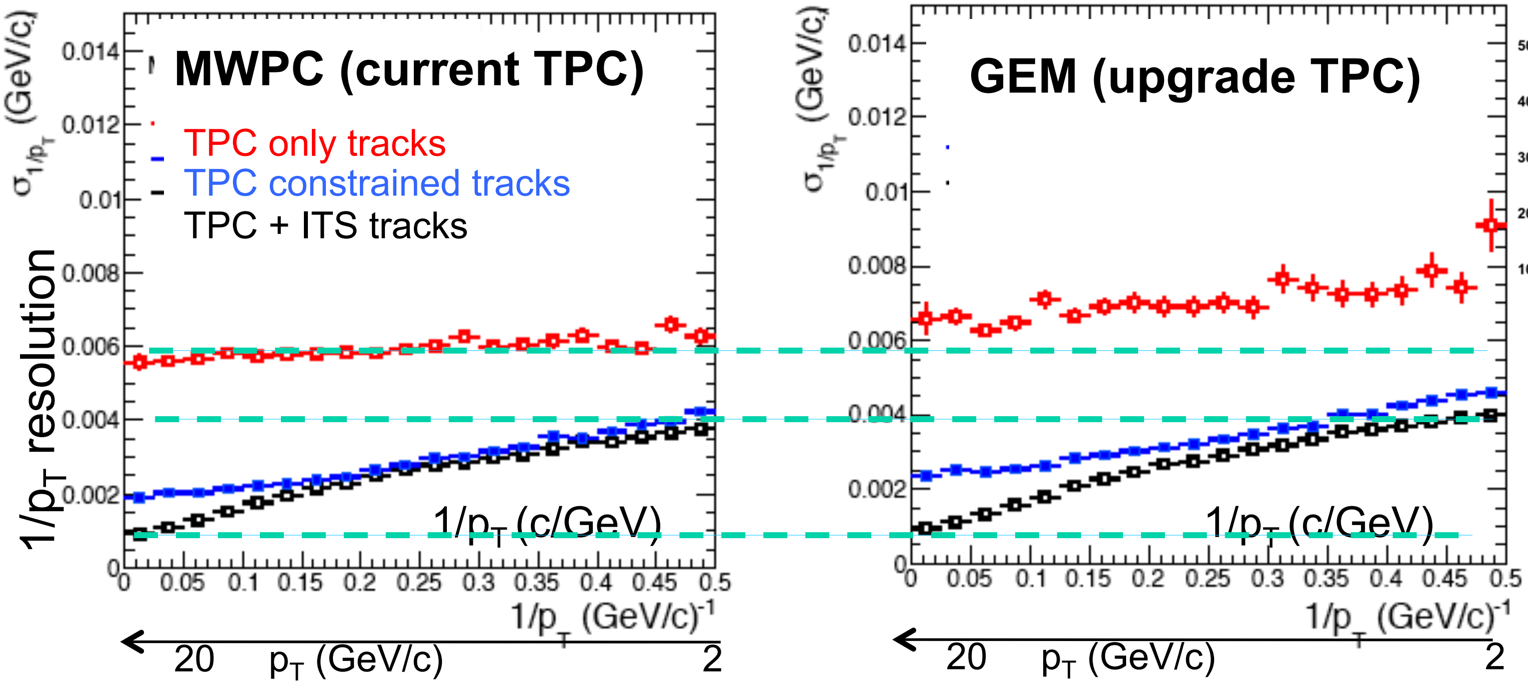


ALICE Technical Design Report

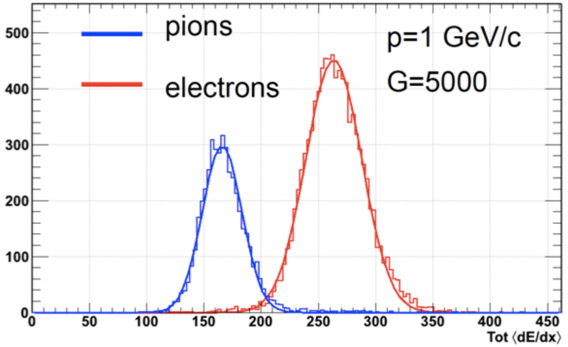
Upgrade of the Time Projection Chamber Technical Design Report

CERN-LHCC-2013-020
ALICE-TDR-016

Transverse momentum resolution



PID

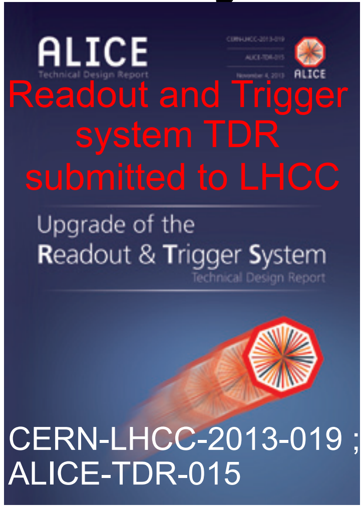


Beam test at PS

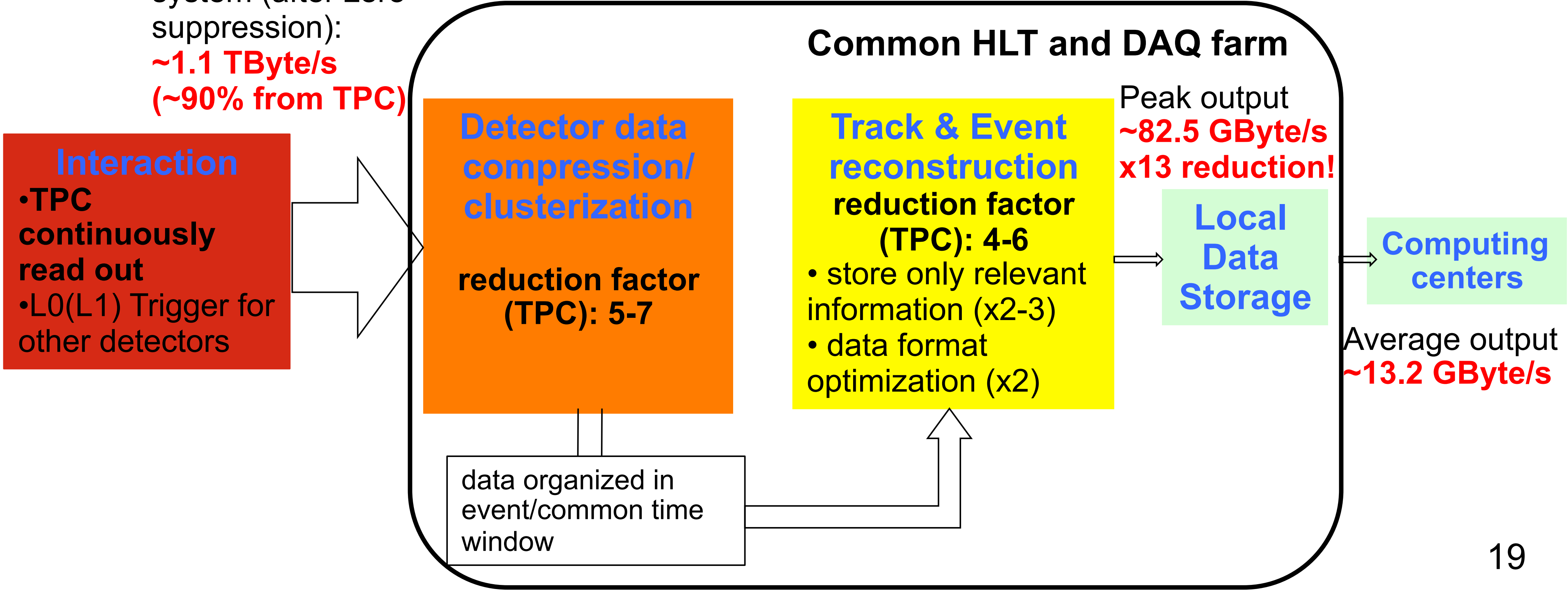
- Good e/π separation

Data flow, the new DAQ and HLT systems

Continuous read out of 50kHz of Pb-Pb interactions
→Increase by ~2 order of magnitude of events to be recorded
→Severe requests to the online & offline systems
→**New DAQ and HLT systems**


ALICE
Technical Design Report
Readout and Trigger system TDR submitted to LHCC
Upgrade of the Readout & Trigger System
Technical Design Report
CERN-LHCC-2013-019 ;
ALICE-TDR-015

Online-Offline TDR in preparation


Input to the online system (after zero suppression):
~1.1 TByte/s (~90% from TPC)

Common HLT and DAQ farm

Interaction
- **TPC continuously read out**
- L0(L1) Trigger for other detectors

Detector data compression/ clusterization
reduction factor (TPC): 5-7

data organized in event/common time window

Track & Event reconstruction
reduction factor (TPC): 4-6
- store only relevant information (x2-3)
- data format optimization (x2)

Peak output
~82.5 GByte/s
x13 reduction!

Local Data Storage

Computing centers

Average output
~13.2 GByte/s

EXPECTED PERFORMANCE

(FOR SELECTED PHYSICS OBSERVABLES)

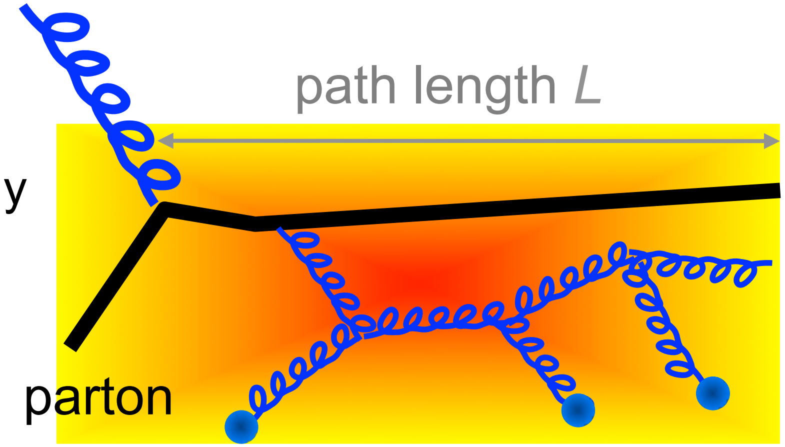
Heavy Flavour: energy loss

E. Scomparin, Thursday

- Heavy quarks are produced mainly at the beginning of the collision in hard-scattering processes (high Q^2)

- Pass through the medium and interact with it, losing energy

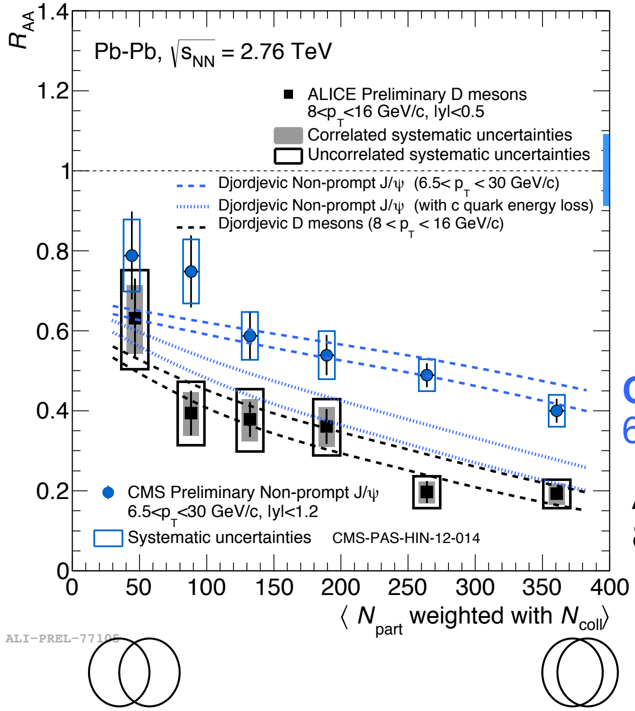
- **Partonic energy loss** expected different for gluons, light quarks and heavy quarks. **Mass effect**: $\Delta E_c > \Delta E_b$



$$R_{AA} = \frac{\text{yield in Pb-Pb}}{\text{yield in pp } \times N_{coll}}$$

$$\Downarrow$$

$$R_{AA}^{D} < R_{AA}^{B}$$



CMS, J/ψ from B
6.5<p_T<30 GeV/*c*

ALICE, D mesons
8<p_T<16 GeV/*c*

Current measurements

Indication of larger energy loss for charm than beauty at high p_T

However lack information at low p_T, where the mass effect is expected to be larger

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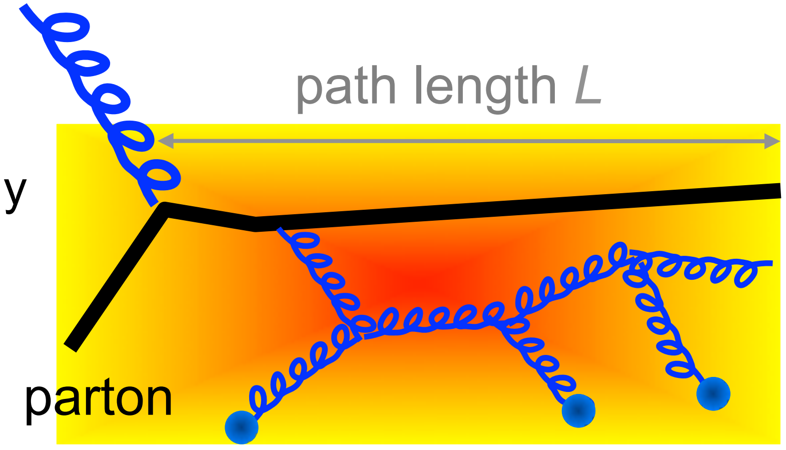

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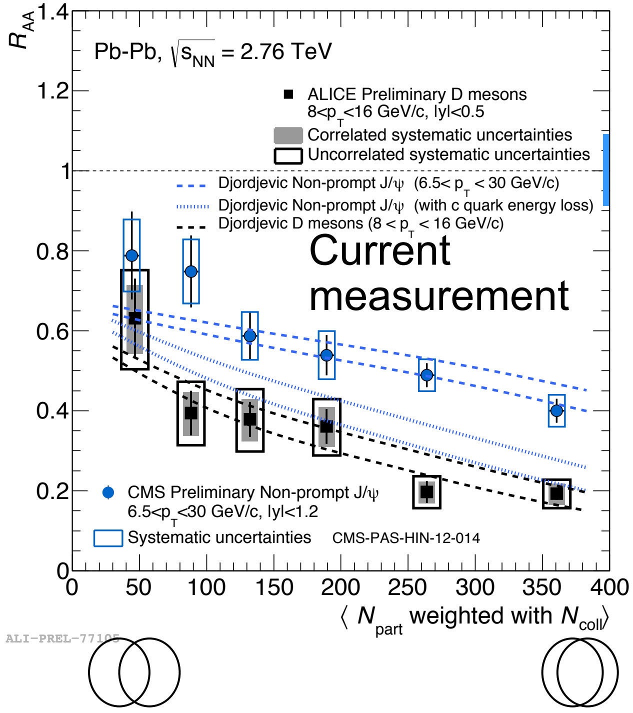
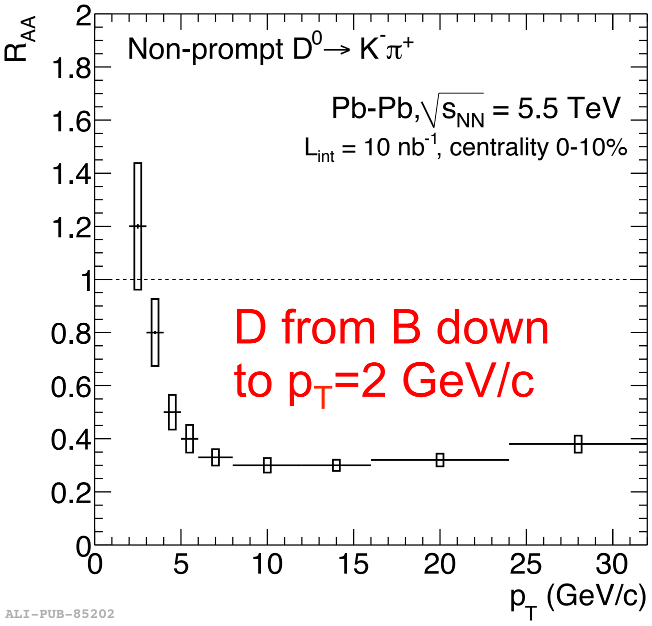


Current measurement

ALI-PREL-77105

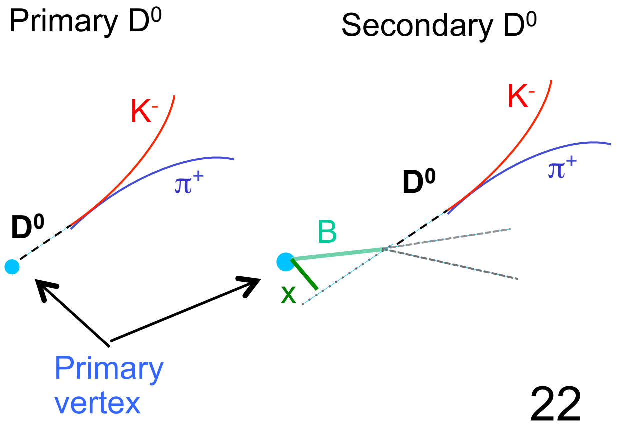
With upgrade: access to beauty at low p_T via:



D from B down to p_T=2 GeV/c

ALI-PUB-85202

Displaced D mesons



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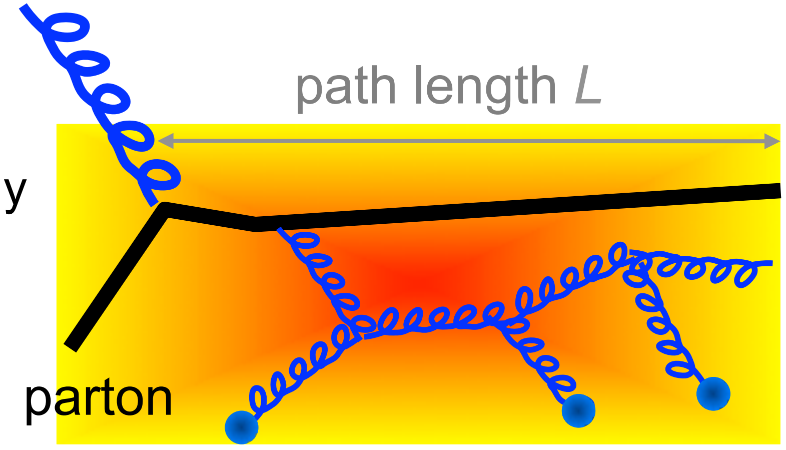

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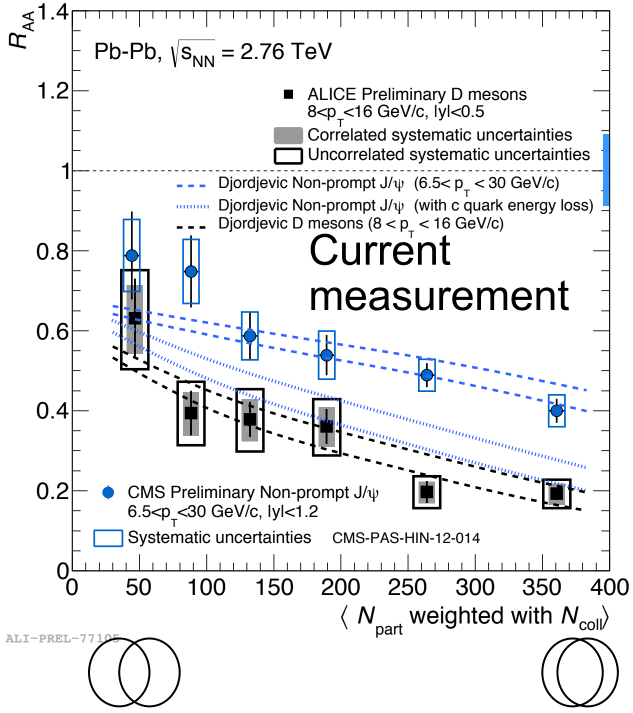

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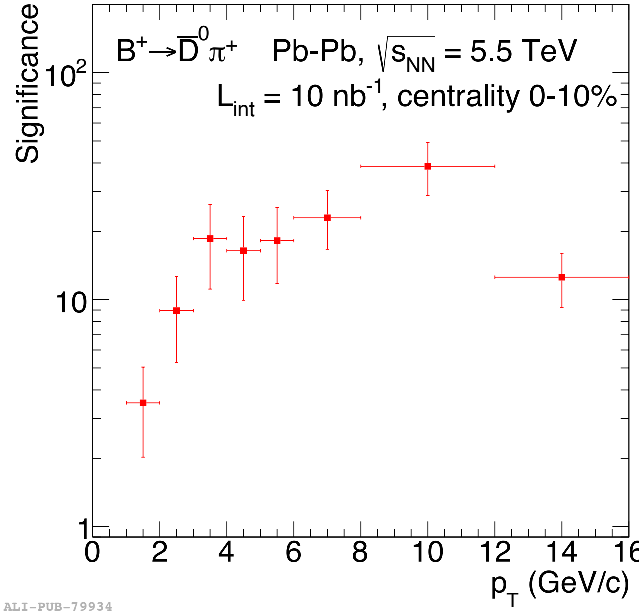
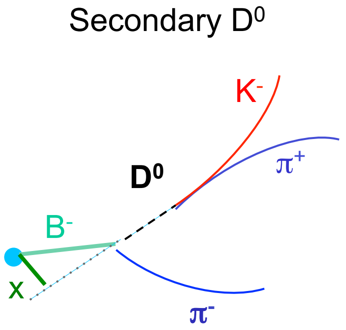


Full B meson reconstruction in central Pb-Pb collisions

Down to p_T=2 GeV/*c*

Closer to b-quark momentum



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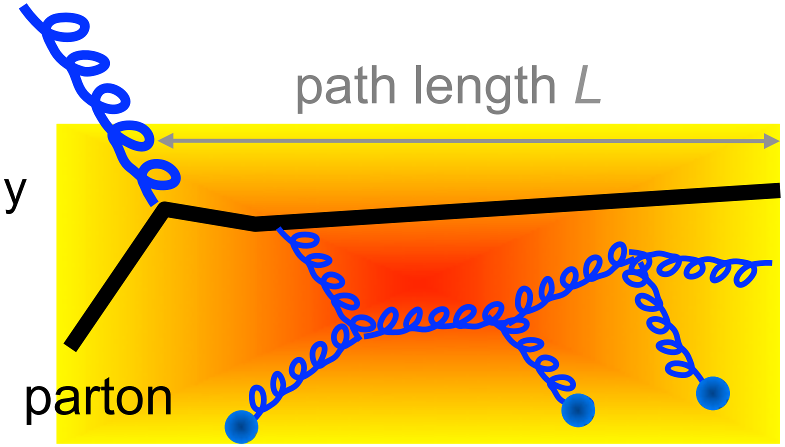

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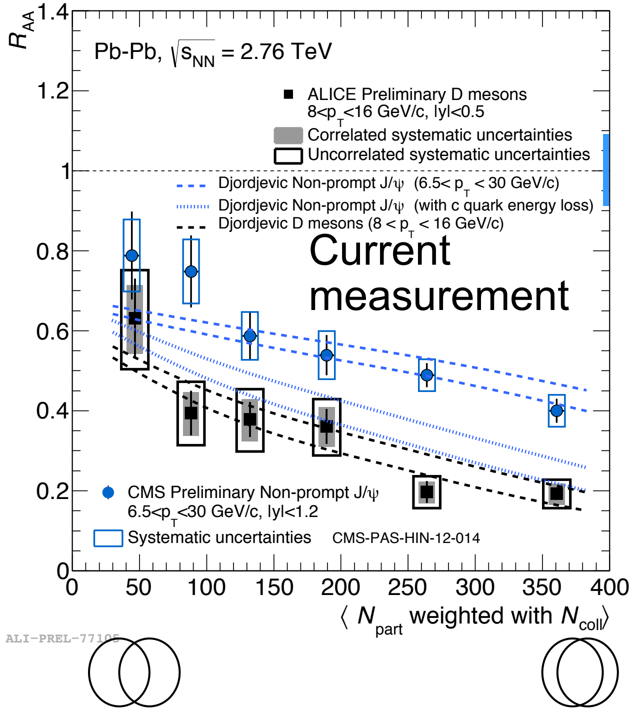

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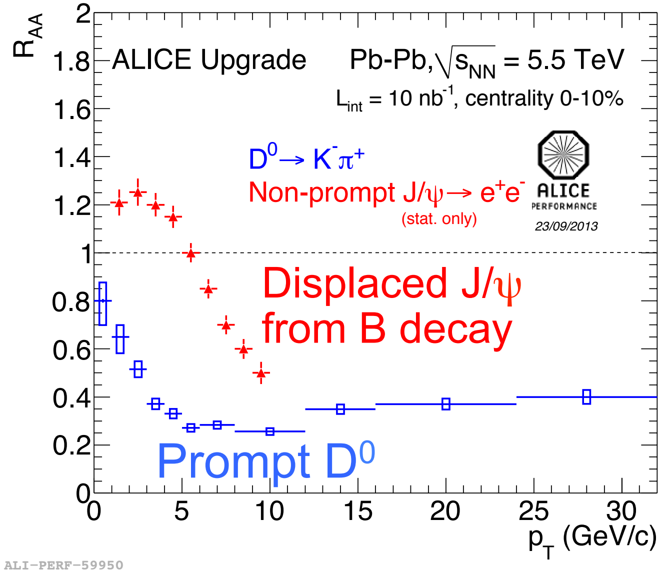
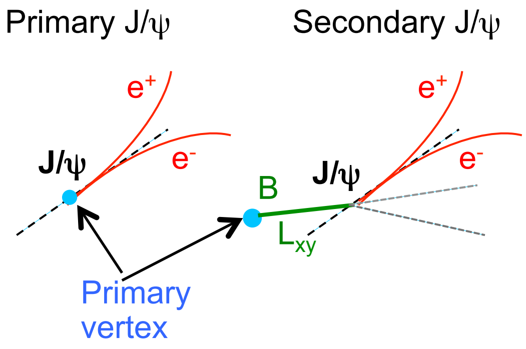


Displaced J/ψ→e^+e^-
at midrapitity down to 1 GeV/c



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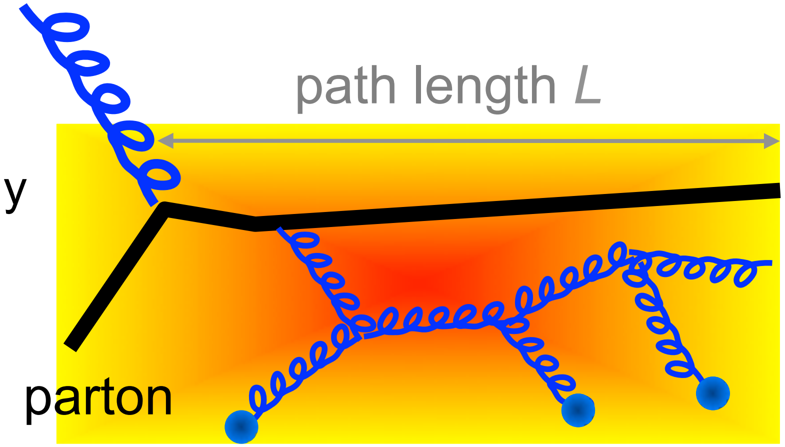

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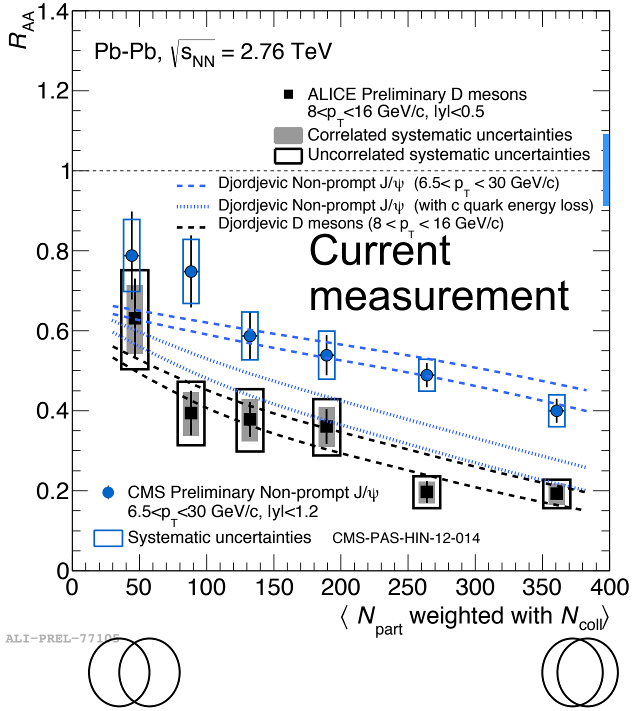

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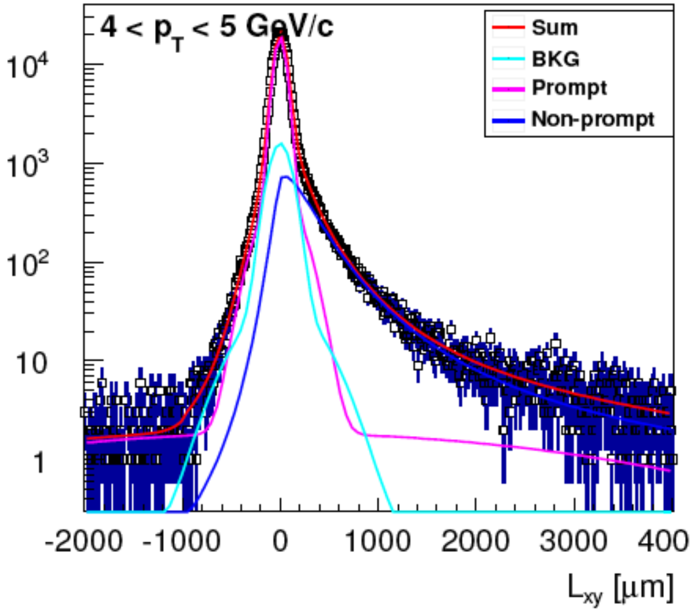
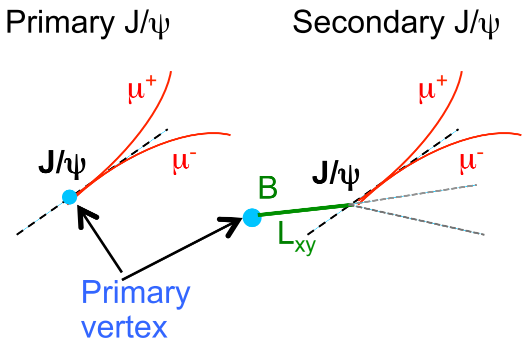
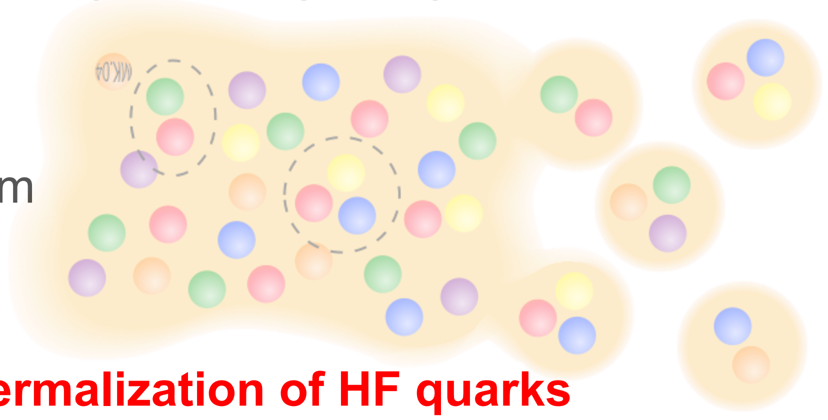


Displaced J/ψ→$\mu^+\mu^-$
At forward rapidity with MFT

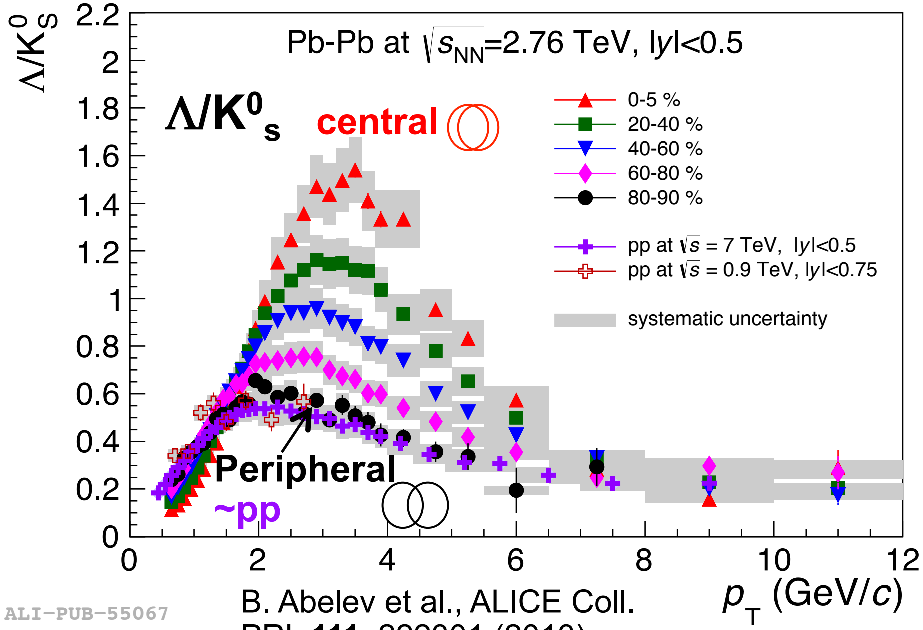


Heavy Flavour: hadronization

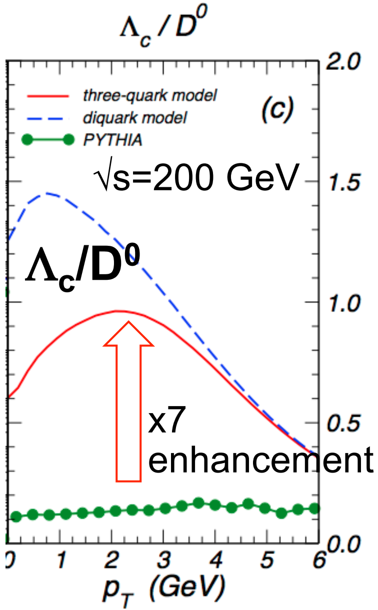


- Investigate possible baryon/meson enhancement and strangeness enhancement in charm sector
  - Radial flow effect? (velocity field → larger momentum for heavier particles)
  - Hadronization via coalescence?

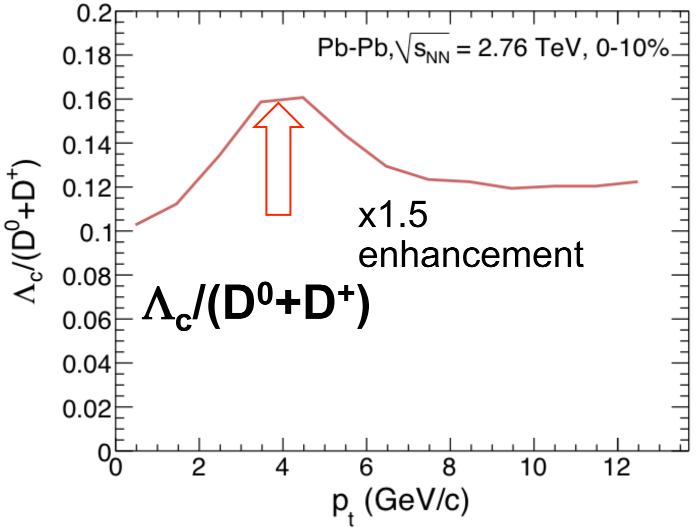
Heavy Flavour Baryon (Λ_c, Λ_b)? ← degree of thermalization of HF quarks



B. Abelev et al., ALICE Coll. PRL **111**, 222301 (2013).

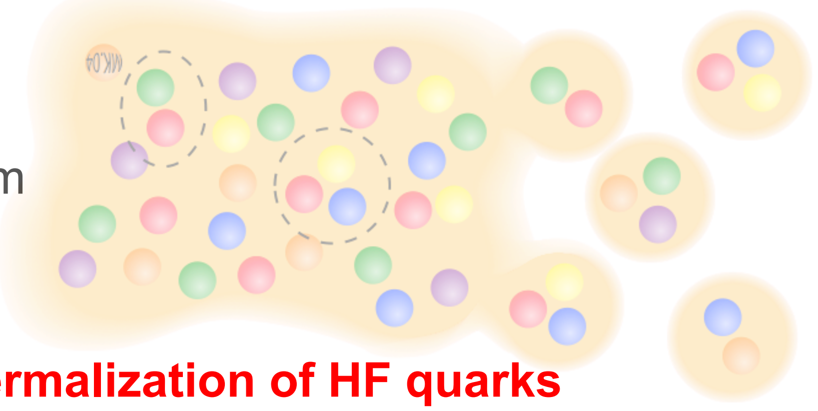


C.M.Ko et al. PRC79



R. Rapp et al. PRC86

Heavy Flavour: hadronization



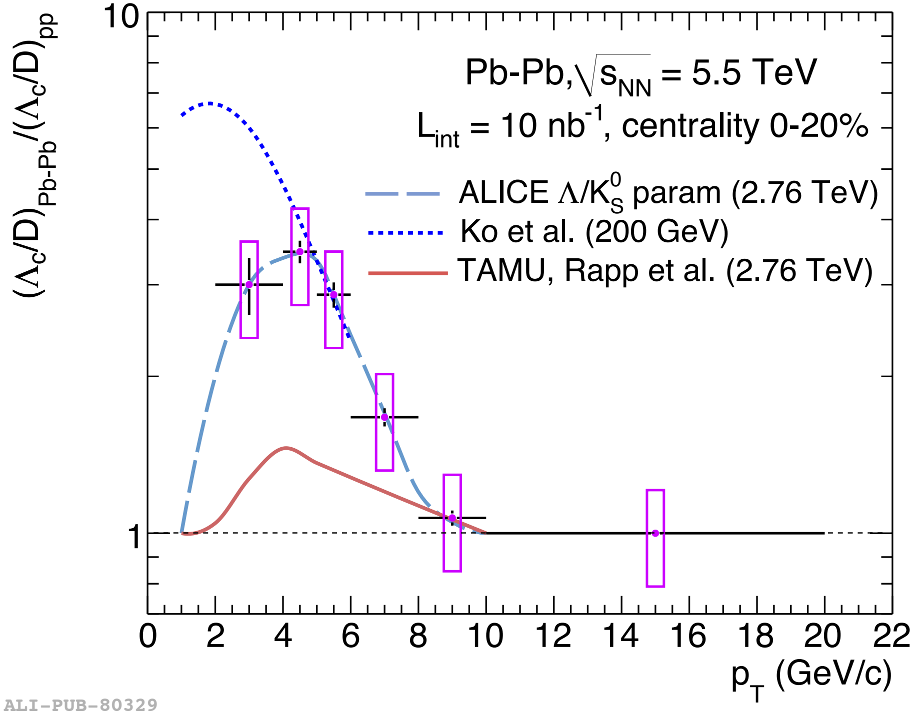
- Investigate possible baryon/meson enhancement and strangeness enhancement in charm sector
  - Radial flow effect? (velocity field → larger momentum for heavier particles)
  - Hadronization via coalescence?

⇨ **Heavy Flavour Baryon (Λ_c, Λ_b)? ← degree of thermalization of HF quarks**

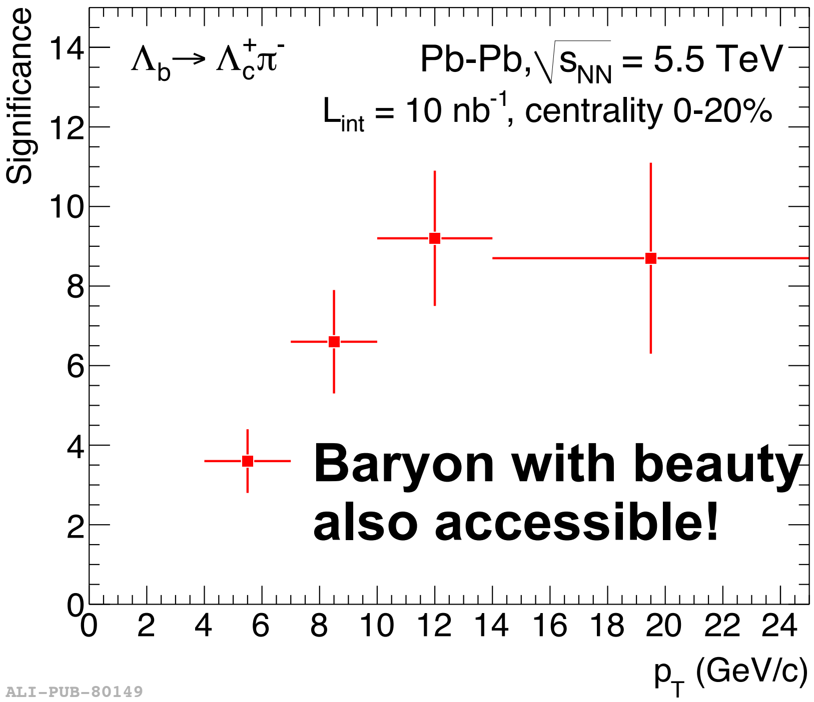
$\Lambda_c \rightarrow pK^-\pi^+$, $c\tau$~60 μm BR: 5.0±1.3 %

$\Lambda_b \rightarrow \Lambda_c\pi^+$, $c\tau$~419 μm

$\hookrightarrow \Lambda_c \rightarrow pK^-\pi^+$ BR(tot): $(4.5\pm1.9)\times10^{-4}$



ALI-PUB-80329



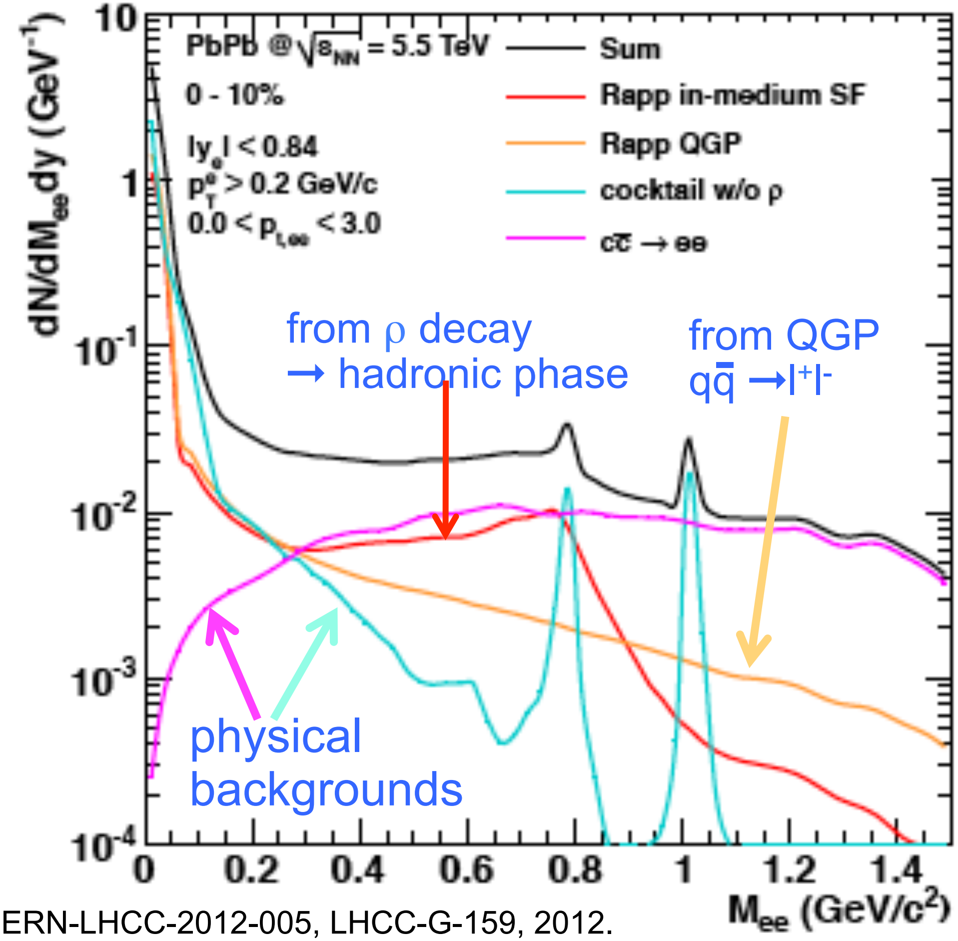
Baryon with beauty also accessible!

ALI-PUB-80149

Di-electron production

One of the most fundamental measurements, sensitive to:

- chiral-symmetry restoration by modification of ρ-meson spectral function
- partonic equation of state studying space–time evolution with invariant-mass and p_T distributions of dileptons
- photon thermal emission extrapolating to zero dilepton mass



from ρ decay → hadronic phase

from QGP $q\bar{q} \rightarrow l^+l^-$

physical backgrounds

CERN-LHCC-2012-005, LHCC-G-159, 2012.

Target measurements:

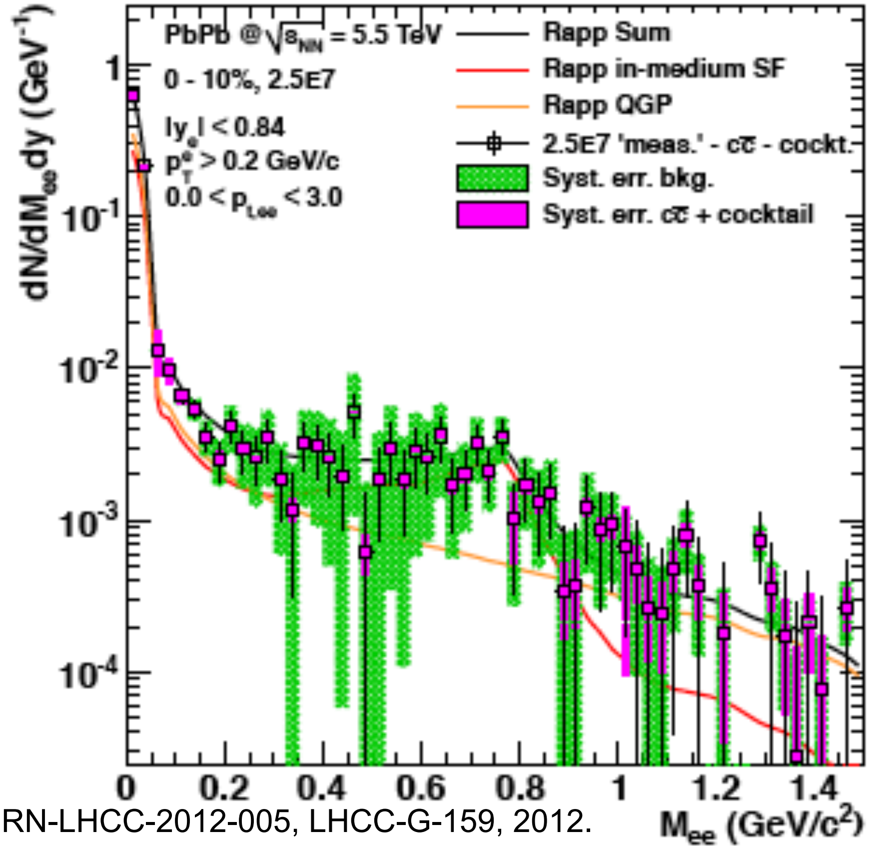
- di-electron yield vs. mass and p_T (require background subtraction)
- di-electron elliptic flow

New ITS

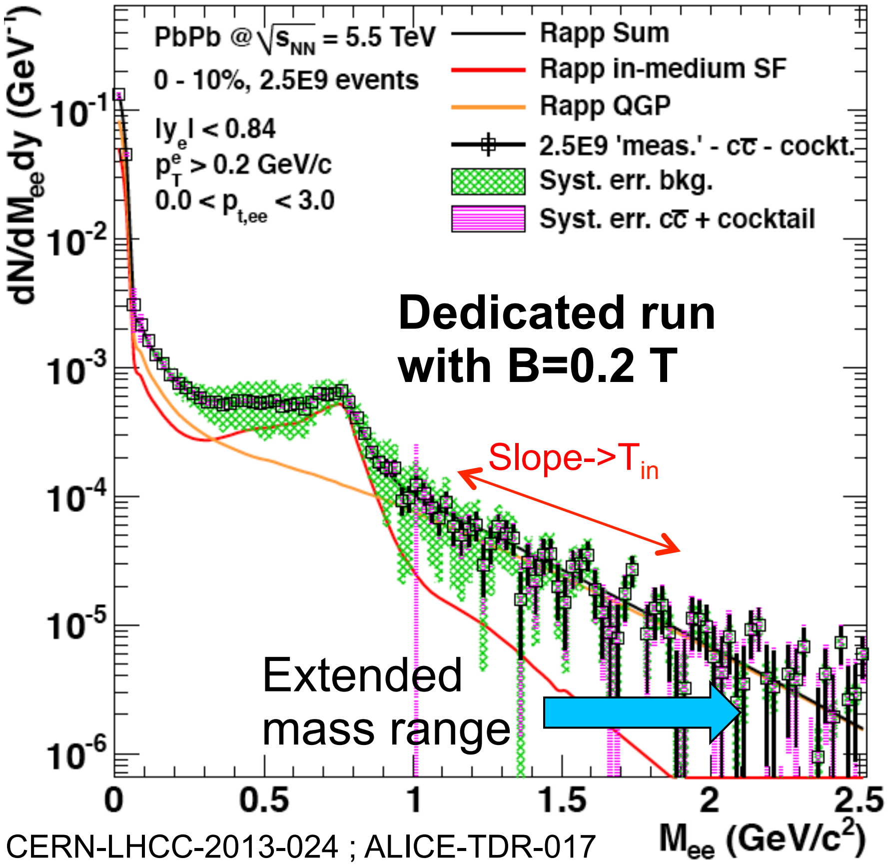
- Reduced combinatorial background (reduce impact of γ-conversions)
- Charm rejection

Di-electron production

Excess after background subtraction



CERN-LHCC-2012-005, LHCC-G-159, 2012.



Dedicated run with B=0.2 T

Slope->T_{in}

Extended mass range

CERN-LHCC-2013-024 ; ALICE-TDR-017

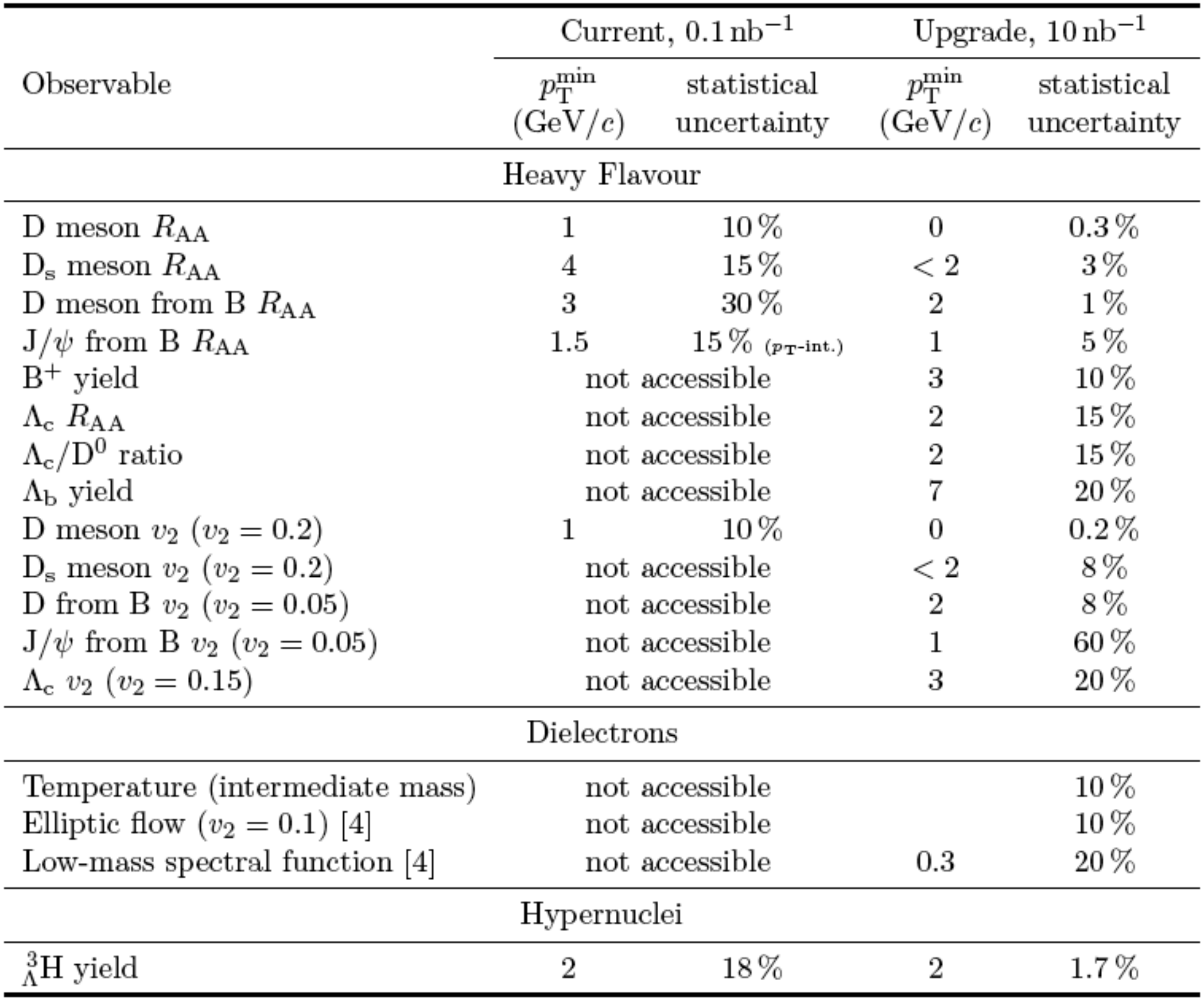
current ITS and event rate:
large statistical and systematic uncertainties

new ITS and high-rate:
precise measurement

Allows for an estimation of the **temperature at various phases of system expansion** with 10-20% precision (stat.+syst.)

Summary: ALICE Upgrade Physics Reach

Central barrel, mid rapidity



Observable	Current, $0.1\,\mathrm{nb}^{-1}$		Upgrade, $10\,\mathrm{nb}^{-1}$	
	$p_T^{\min}$ (GeV/c)	statistical uncertainty	$p_T^{\min}$ (GeV/c)	statistical uncertainty
Heavy Flavour				
D meson R_{AA}	1	10 %	0	0.3 %
D_s meson R_{AA}	4	15 %	< 2	3 %
D meson from B R_{AA}	3	30 %	2	1 %
J/ψ from B R_{AA}	1.5	15 % (p_T-int.)	1	5 %
B^+ yield	not accessible		3	10 %
Λ_c R_{AA}	not accessible		2	15 %
Λ_c/D^0 ratio	not accessible		2	15 %
Λ_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/ψ from B v_2 ($v_2 = 0.05$)	not accessible		1	60 %
Λ_c v_2 ($v_2 = 0.15$)	not accessible		3	20 %
Dielectrons				
Temperature (intermediate mass)	not accessible			10 %
Elliptic flow ($v_2 = 0.1$) [4]	not accessible			10 %
Low-mass spectral function [4]	not accessible		0.3	20 %
Hypernuclei				
${}^3_\Lambda$H yield	2	18 %	2	1.7 %

p_T coverage ($p_T^{\min}$) and statistical uncertainty for current ALICE detector with original programme and upgraded ALICE with extended programme. For heavy flavour, the statistical uncertainties are given at the maximum between p_T = 2 GeV/c and $p_T^{\min}$.

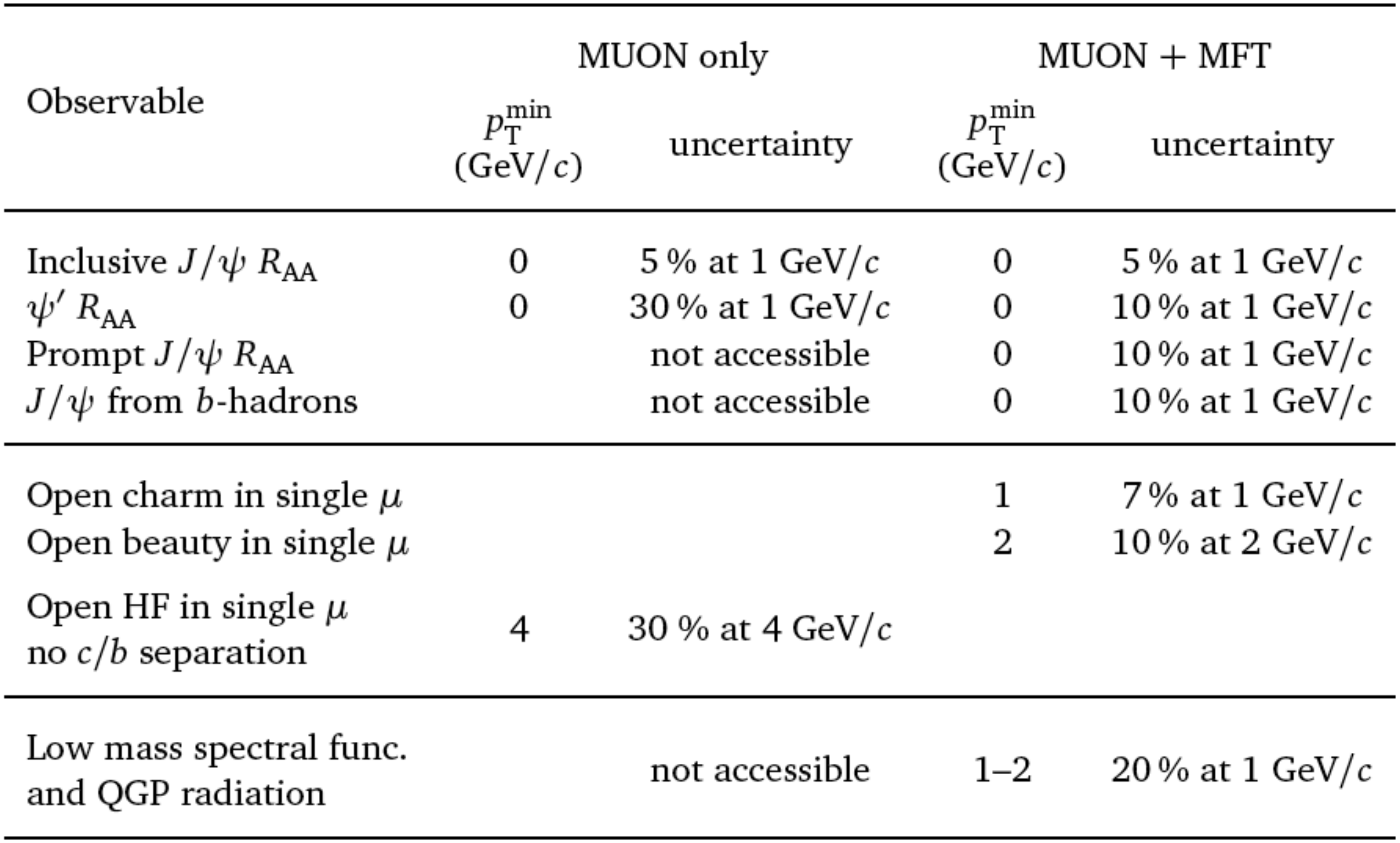
Improved precision

New observables accessible

Charm and beauty era of the QGP

Summary: ALICE Upgrade Physics Reach

Forward rapidity



Observable	MUON only		MUON + MFT	
	$p_{\mathrm{T}}^{\mathrm{min}}$ (GeV/c)	uncertainty	$p_{\mathrm{T}}^{\mathrm{min}}$ (GeV/c)	uncertainty
Inclusive J/ψ R_{AA}	0	5 % at 1 GeV/c	0	5 % at 1 GeV/c
ψ' R_{AA}	0	30 % at 1 GeV/c	0	10 % at 1 GeV/c
Prompt J/ψ R_{AA}		not accessible	0	10 % at 1 GeV/c
J/ψ from b-hadrons		not accessible	0	10 % at 1 GeV/c
Open charm in single μ			1	7 % at 1 GeV/c
Open beauty in single μ			2	10 % at 2 GeV/c
Open HF in single μ no c/b separation	4	30 % at 4 GeV/c		
Low mass spectral func. and QGP radiation		not accessible	1–2	20 % at 1 GeV/c

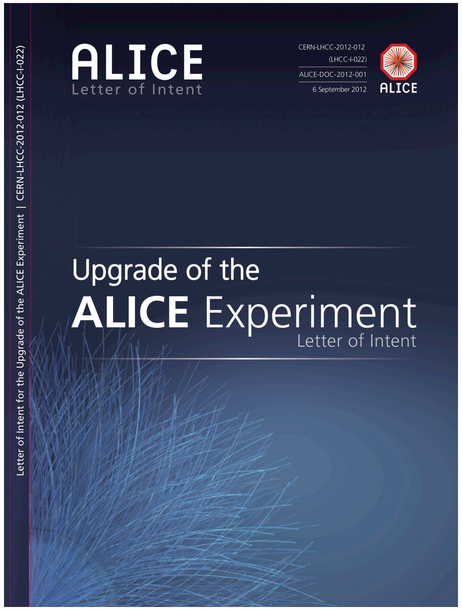
p_T coverage (p_T^{min}) and statistical error for current Muon Spectrometer and with the insertion of the MFT.

Improved precision

New observables accessible

Charm and beauty era of the QGP

Find much more in

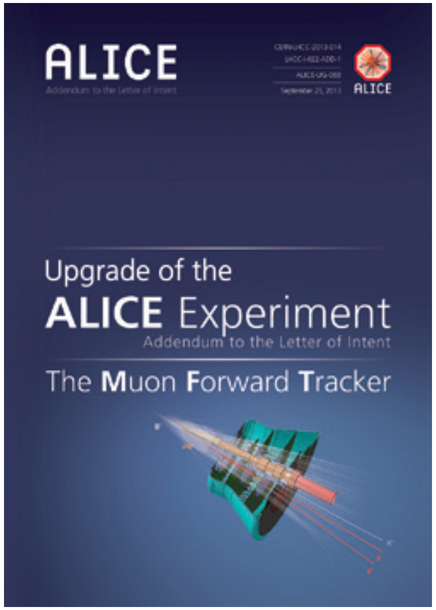


ALICE
Letter of Intent

CERN-LHCC-2012-012
(LHCC-I-022)
ALICE-DOC-2012-001
6 September 2012

Upgrade of the
ALICE Experiment
Letter of Intent

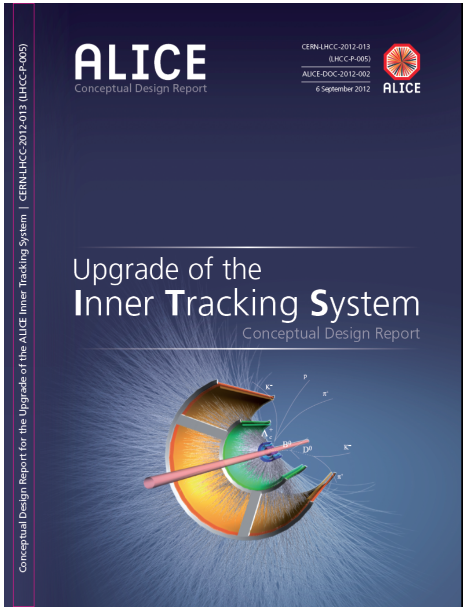
CERNLHCC-2012-012,
LHCC-I-022, 2012.



ALICE

Upgrade of the
ALICE Experiment
Addendum to the Letter of Intent
The Muon Forward Tracker

CERN-LHCC-2013-014 ;
LHCC-I-022-ADD-1

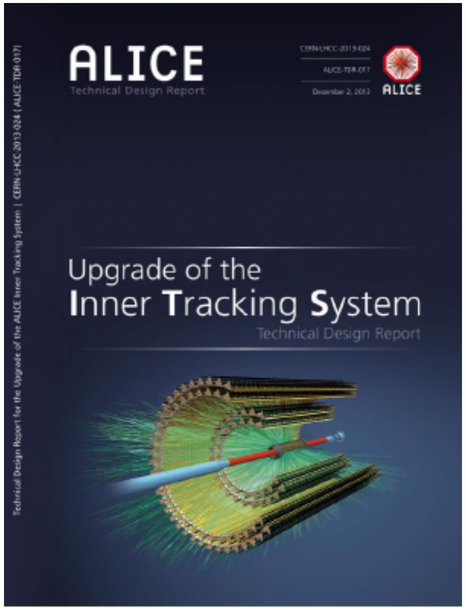


ALICE
Conceptual Design Report

CERN-LHCC-2012-013
(LHCC-P-005)
ALICE-DOC-2012-002
6 September 2012

Upgrade of the
Inner Tracking System
Conceptual Design Report

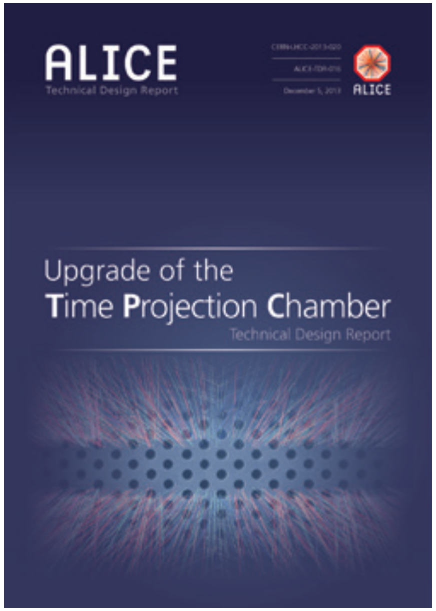
CERN-LHCC-2012-005,
LHCC-G-159, 2012.



ALICE
Technical Design Report

Upgrade of the
Inner Tracking System
Technical Design Report

CERN-LHCC-2013-024 ;
ALICE-TDR-017



ALICE
Technical Design Report

Upgrade of the
Time Projection Chamber
Technical Design Report

CERN-LHCC-2013-020 ;
ALICE-TDR-016

ALICE
Technical Design Report

Upgrade of the
Readout & Trigger System
Technical Design Report

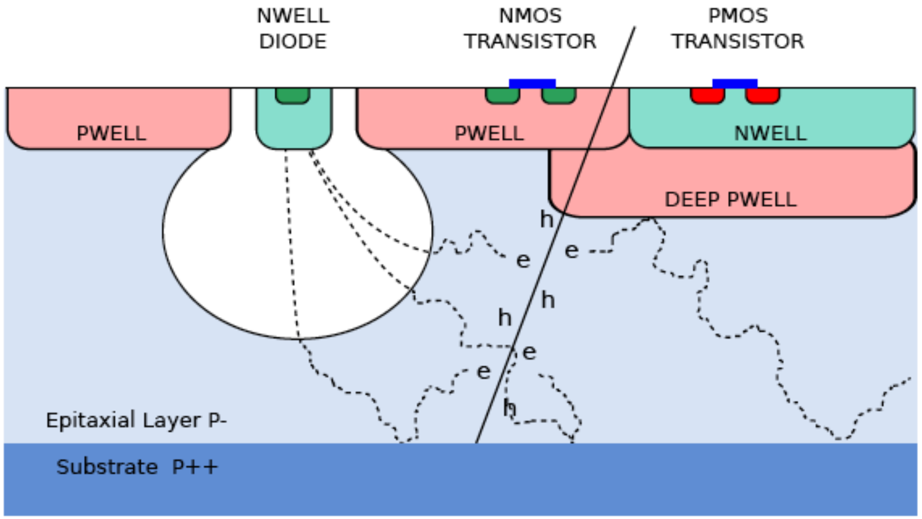
CERN-LHCC-2013-019 ;
ALICE-TDR-015

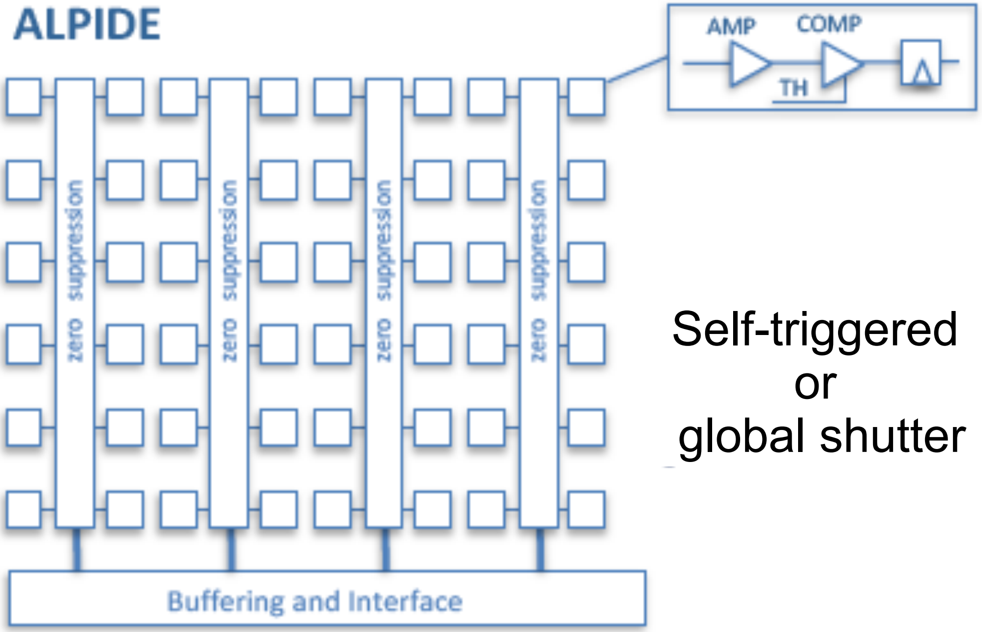
EXTRAS

The Pixel technology

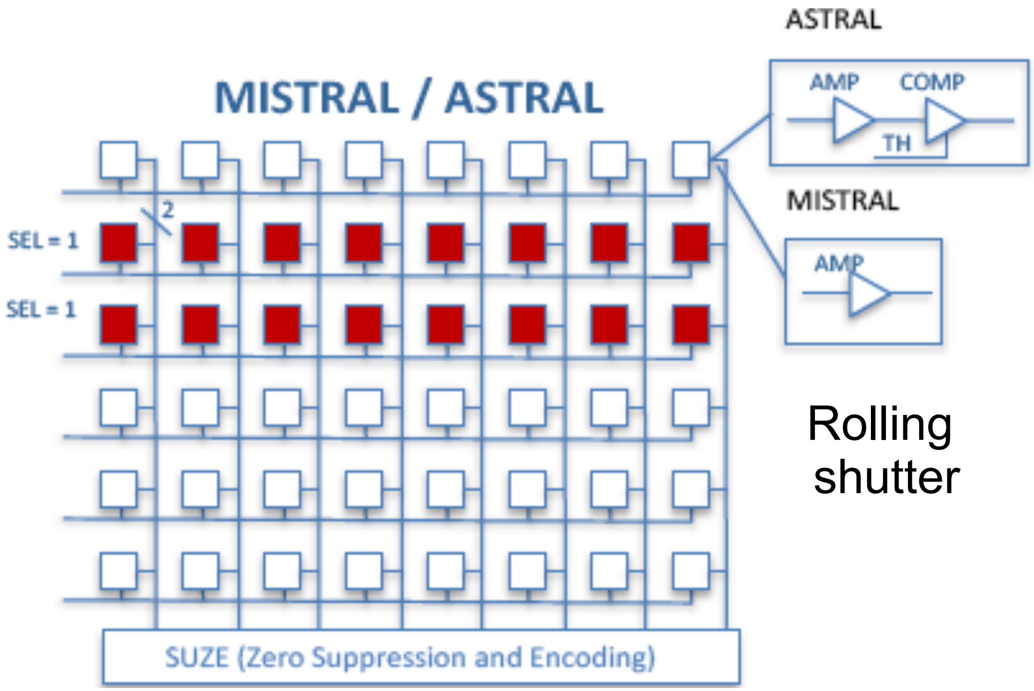
Monolithic Active Pixel Sensors (MAPS)
using Tower Jazz 0.18 μm technology

- Chip size: 15 mm × 30 mm
- Pixel pitch ~30 μm
- Si thickness: 50 μm
- Spatial resolution: ~5 μm
- Power density < 100 mW/cm^2
- Integration time < 30 μs





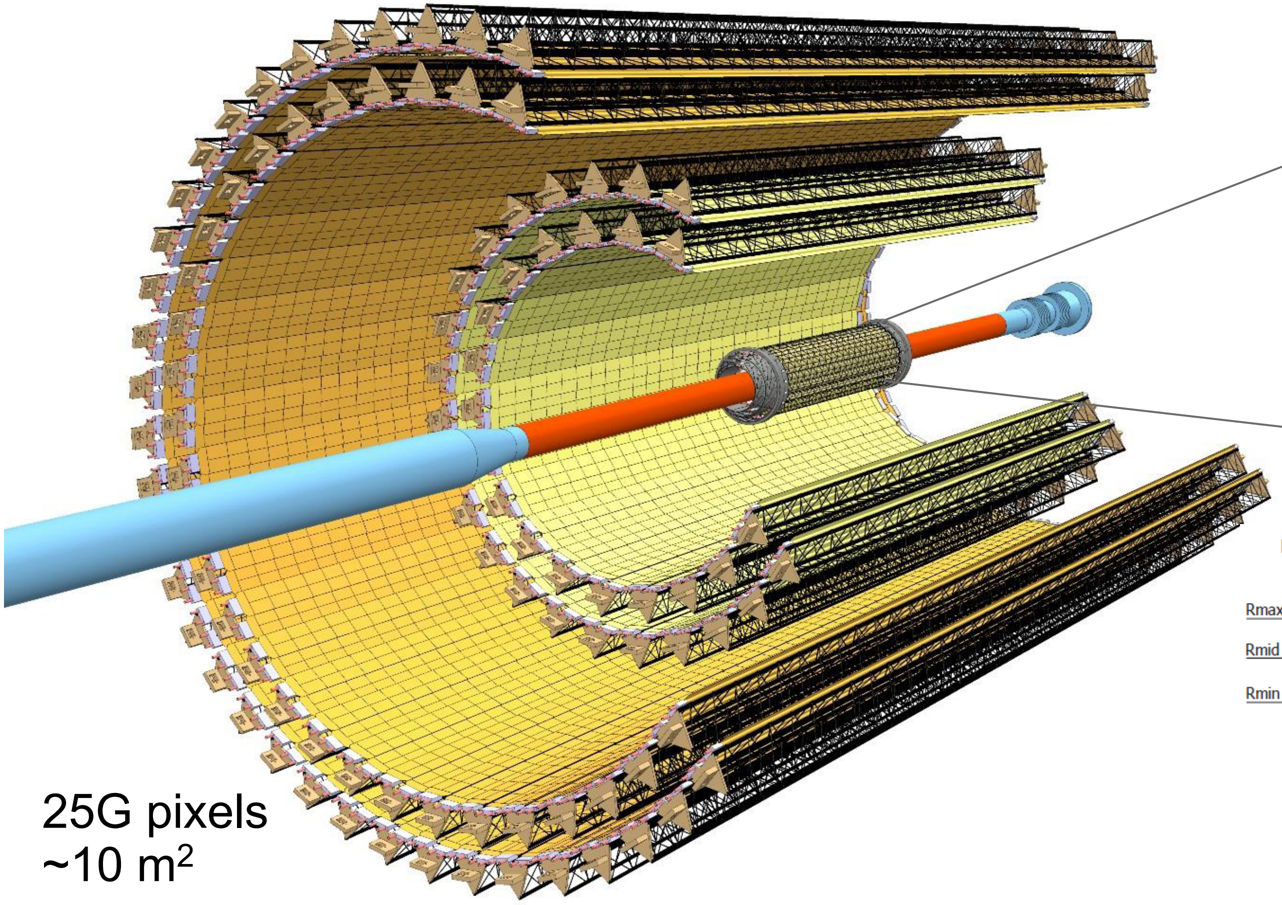
Self-triggered
or
global shutter



Rolling
shutter

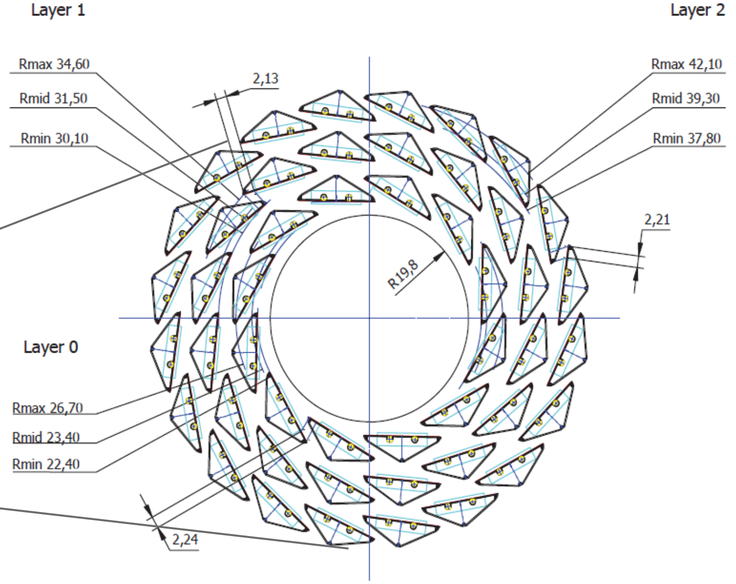
New ITS

η coverage: |η|<1.22

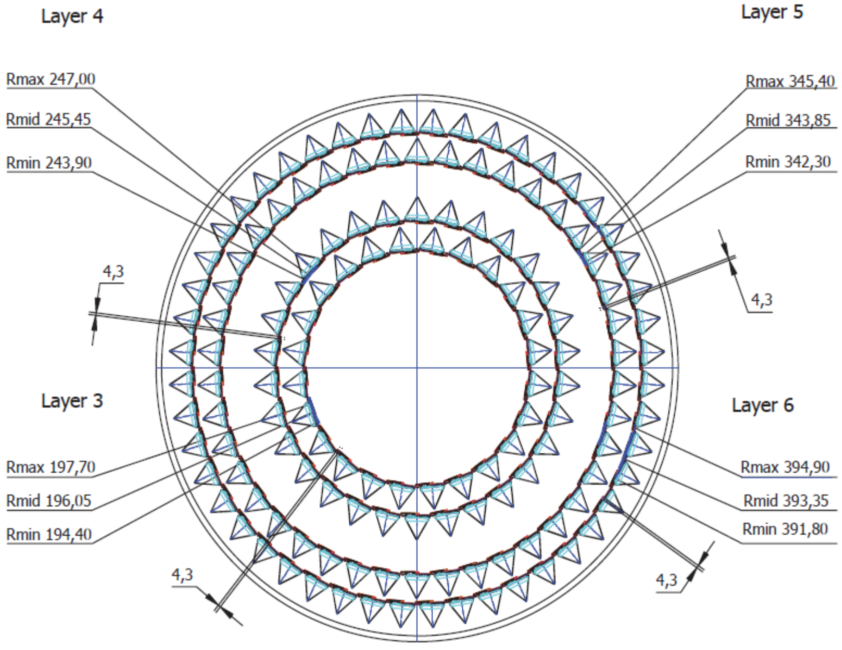


25G pixels
~10 m^2

Inner barrel (3 layers)
2.2<r <4.2 cm, X/X_0~0.3% per layer



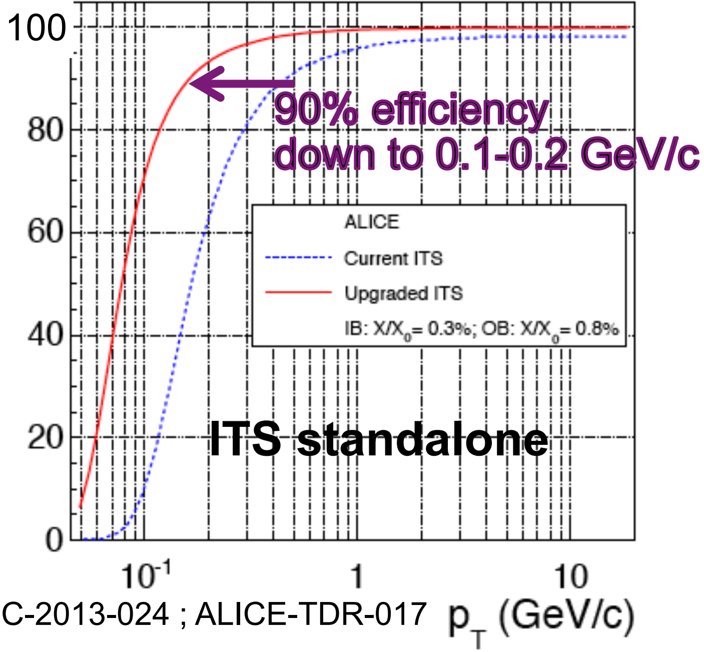
Outer barrel (4 layers)
19.4<r <39.5 cm, x/X_0~0.8% per layer



New ITS: performance

Results obtained from simulation with realistic and complete detector geometry and material budget description

Track reconstruction efficiency

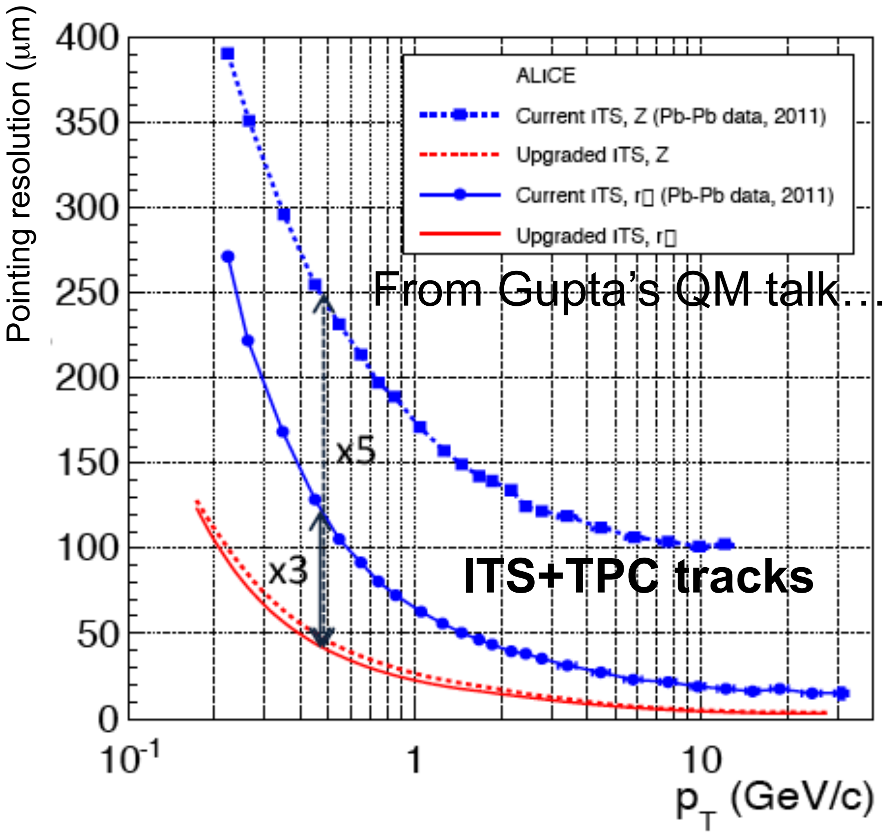


90% efficiency down to 0.1-0.2 GeV/c

ITS standalone

CERN-LHCC-2013-024 ; ALICE-TDR-017

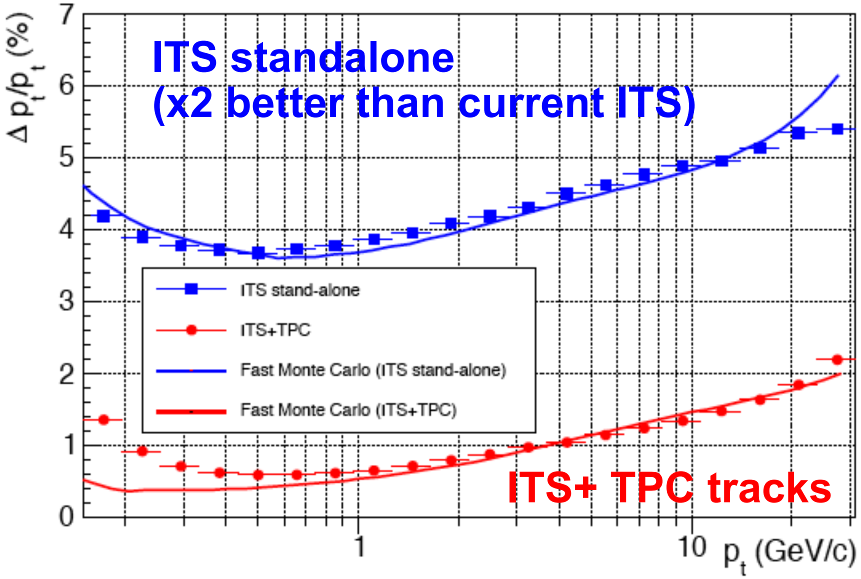
Track spatial resolution at the primary vertex



From Gupta's QM talk…

ITS+TPC tracks

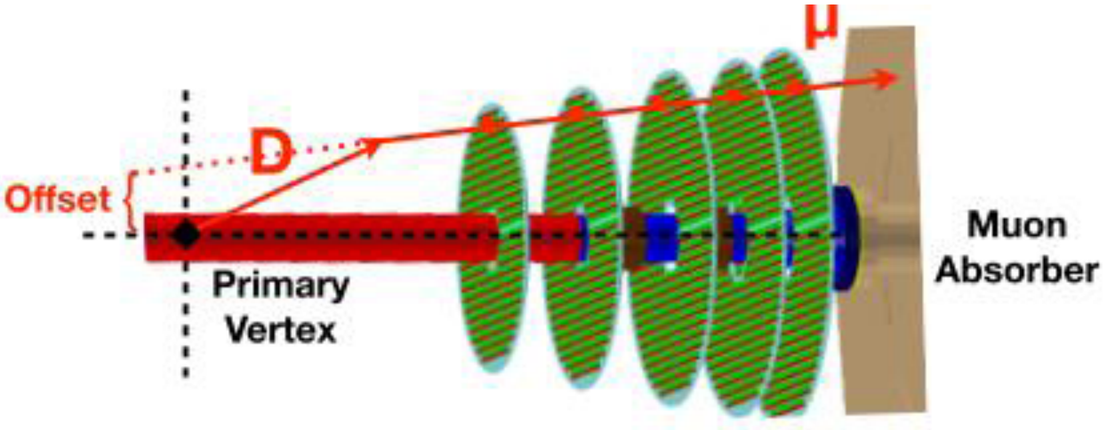
Transverse momentum resolution



ITS standalone
(x2 better than current ITS)

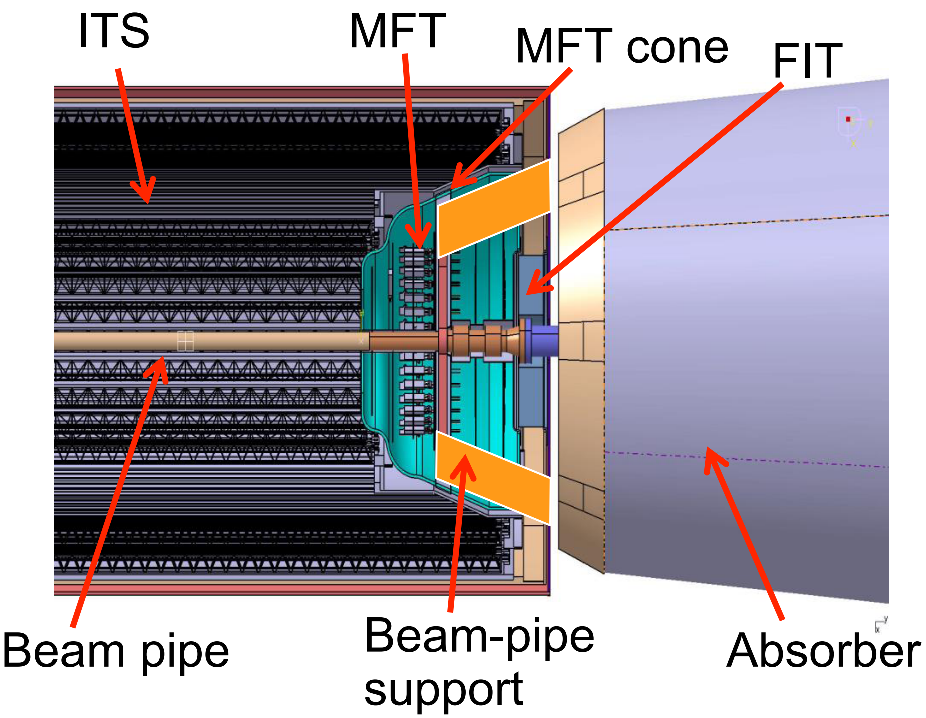
ITS+ TPC tracks

Muon Forward Tracker



5-6 planes of CMOS silicon pixels sensors (same technology as ITS):

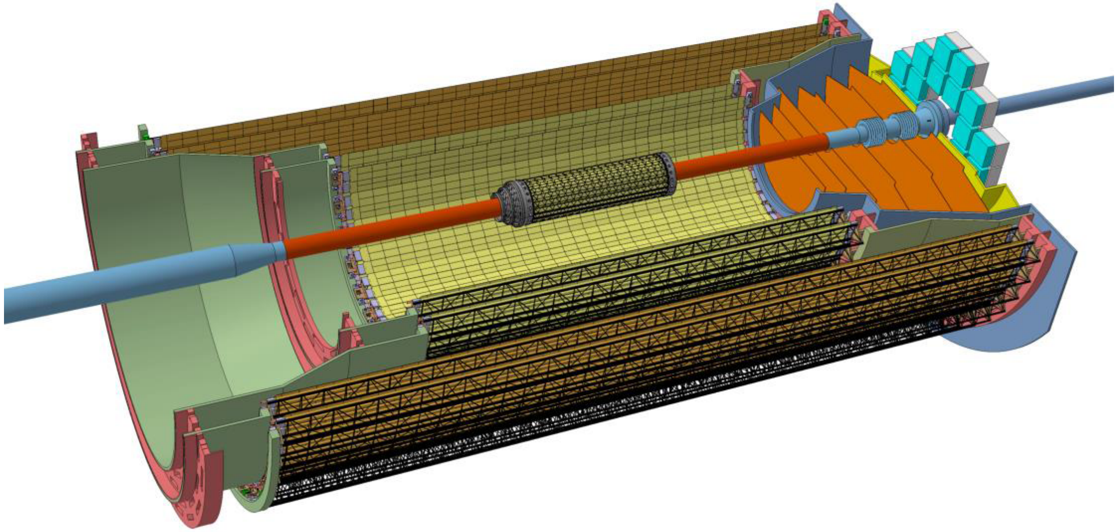
- $50 < z < 80$ cm
- $R_{min} \approx 2.5$ cm (beam pipe constraint)
- $11 < R_{max} < 16$ cm
- Area ≈ 2700 cm^2
- $X/X_0 = 0.4\%$ per plane
- Current pixel pitch scenario: ~25 x 25 μm^2

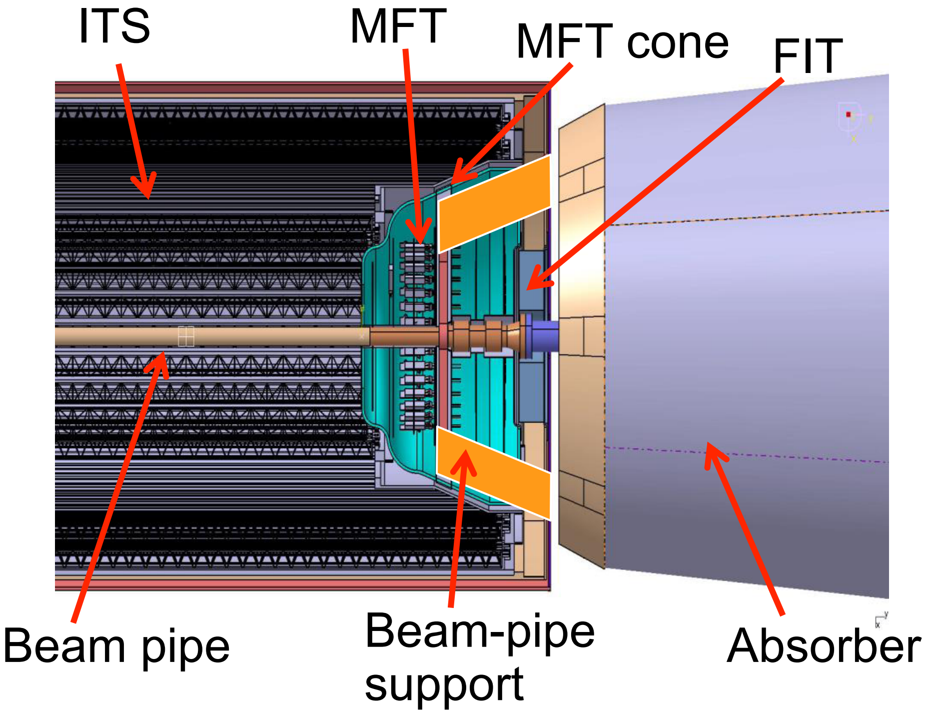


MFT planes are ladder assembly of active and readout zones with

CMOS sensor on both sides of the plane: no dead zone

Muon Forward Tracker





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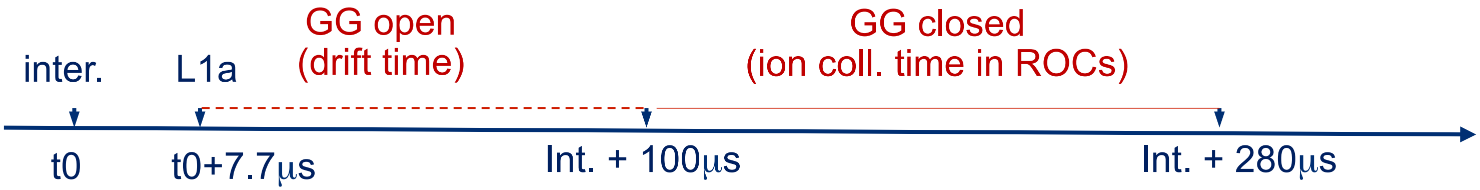
Technical Design Report in preparation

ALICE at high rate

Current TPC limitations



- gating grid of readout chambers closed to avoid ion feedback
  - Limit space charge to tolerable level
  - Effective dead time ~280μs, maximum readout rate: 3.5 kHz

- alternative: gating grid always open
  - Ion feedback ~10^3 x ions generated in drift volume
  - Large space charge effects (of the order of electrical field)
    - Space point distortions (at 50kHz) of order of 1 m – not tolerable!!

Our TPC Multi Wire Proportional Chambers not compatible with 50kHz operations!

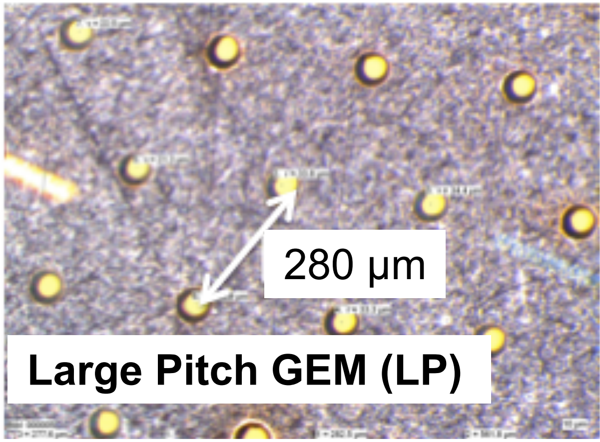
ALICE at high rate: TPC Upgrade

GEM technology already used in particle physics (COMPASS, LHCb, PHENIX, TOTEM)

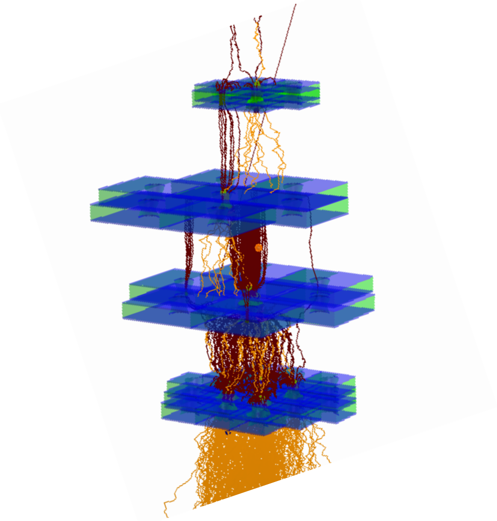
Extensive dedicated studies started in 2012

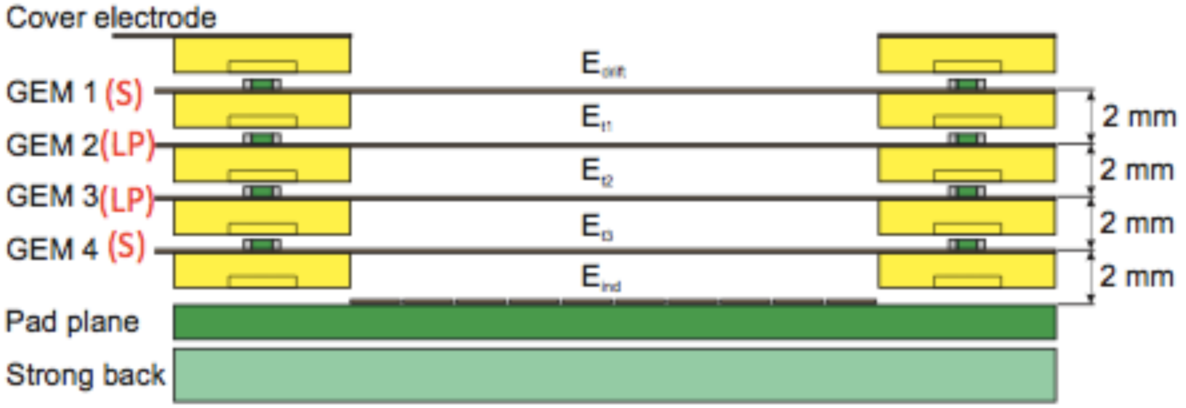
- Technology choice:
  - Baseline: stack of standard (S) and large pitch (LP) 4 GEM foils
  - Alternatives: 2 GEM + MicroMegas (MMG)
- Ion backflow (<1% at gain=2000)
- Gain stability
- Discharge probability
- Large size prototype
- Electronics R&D
- Garfield simulations
- Performance & physics simulations

Collaboration with RD51 at CERN



Large Pitch GEM (LP)





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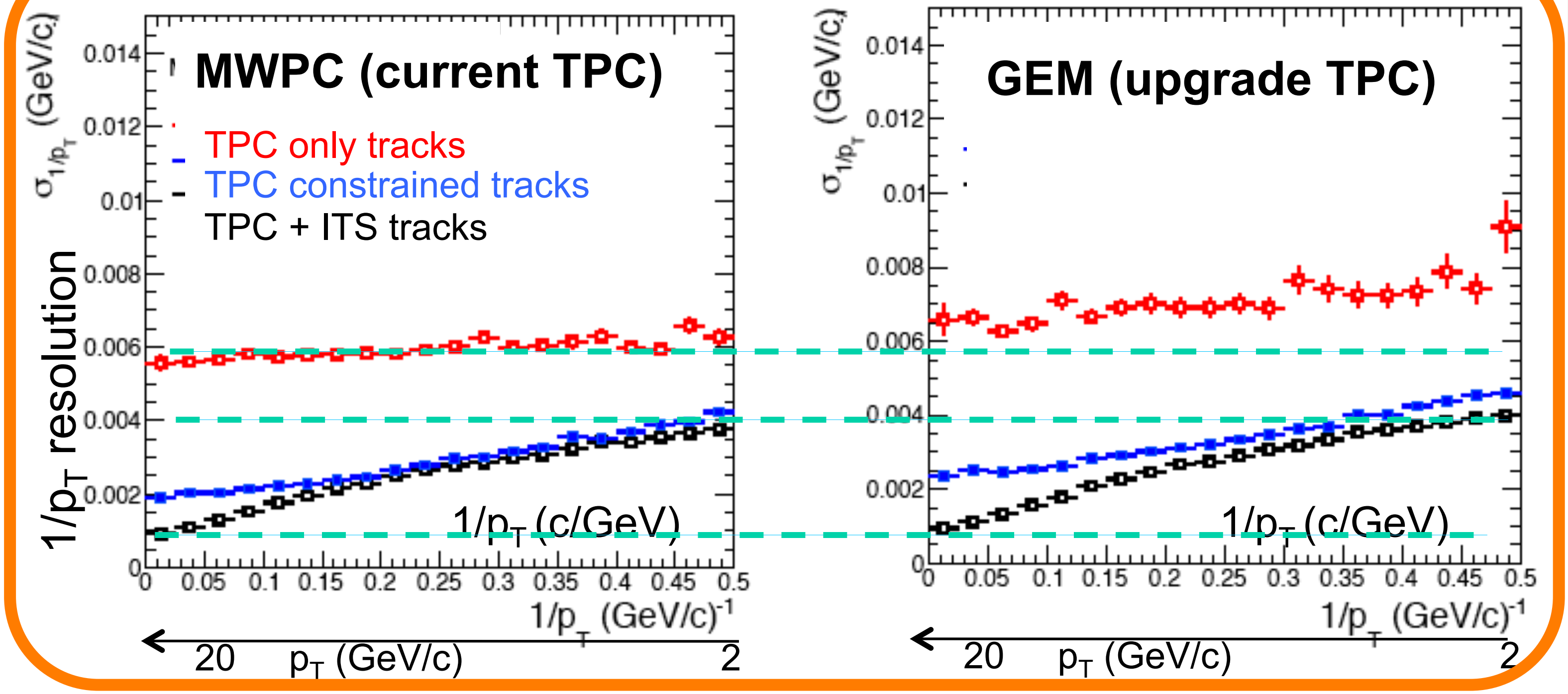
- Ion backflow (<1% at gain=2000)

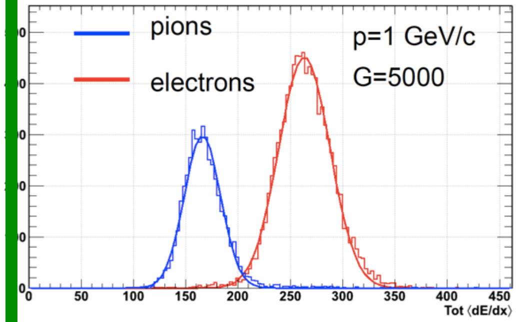
Collaboration with RD51 at CERN

Performance & physics simulations

Transverse momentum resolution

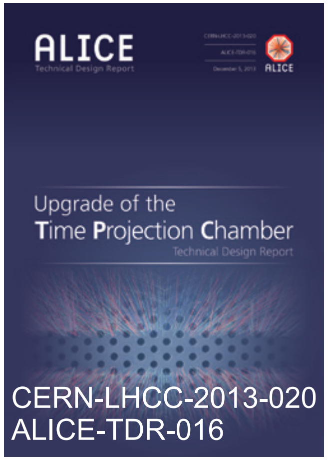


PID



Beam test at PS

- Good e/π separation
- dE/dx resolution comparable to current performance


ALICE Technical Design Report

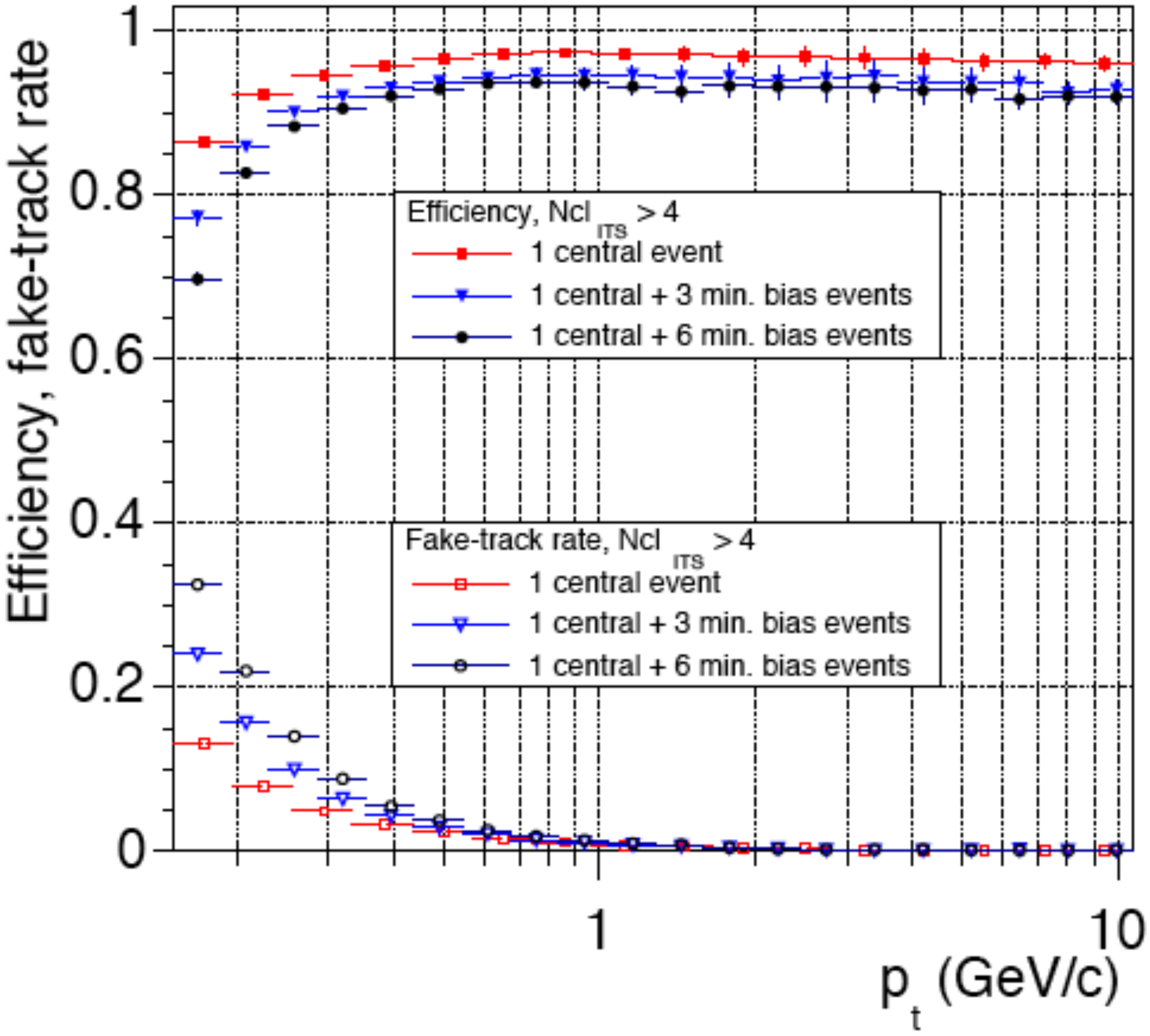
Upgrade of the Time Projection Chamber

Technical Design Report

CERN-LHCC-2013-020
ALICE-TDR-016

Pile-up effect

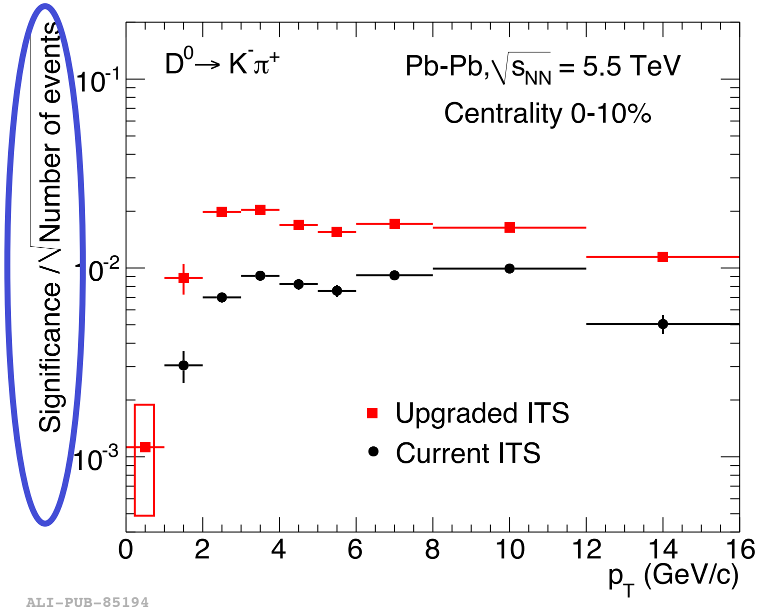
TPC to ITS track Matching efficiency



Heavy Flavour: production

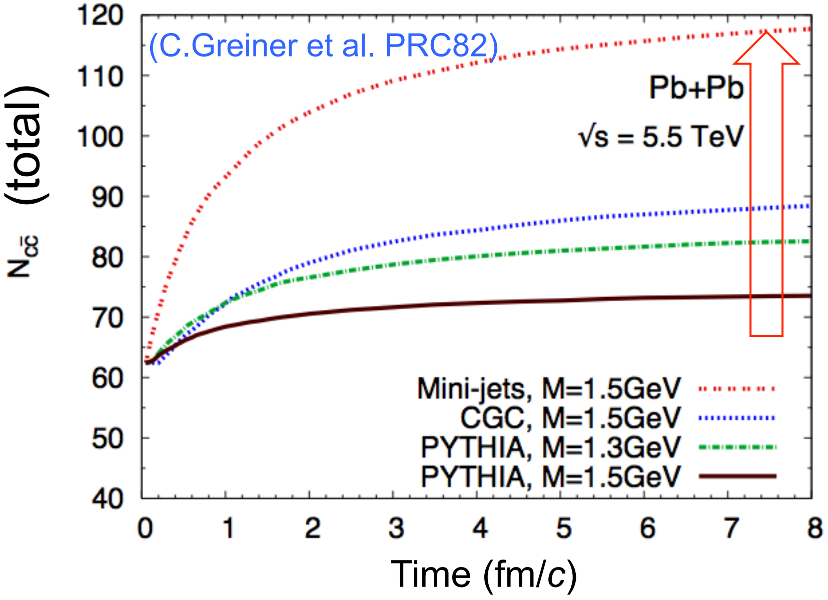
- Heavy quarks are produced mainly at the beginning of the collision in hard-scattering processes (high Q^2)

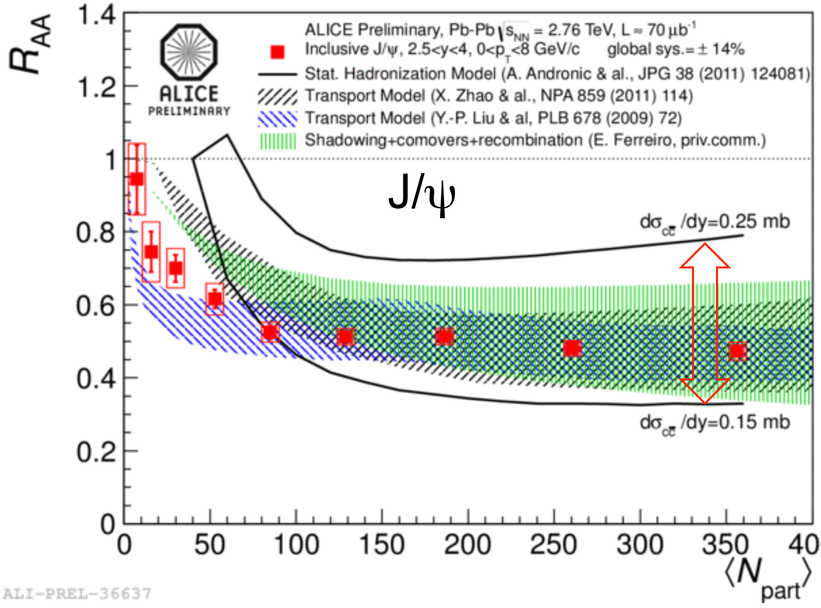
- **Possible charm thermal production?**
  - may increase the yield of charm hadrons at low p_T by up to 50-100%
- Need to measure **open charm production down to p_T=0**
  - Current measurement down to p_T=1 GeV/c
  - …very unlikely to go at 0 -> ITS upgrade fundamental
- This would provide the natural normalization for total charmonium production (main uncertainty for regeneration models.).



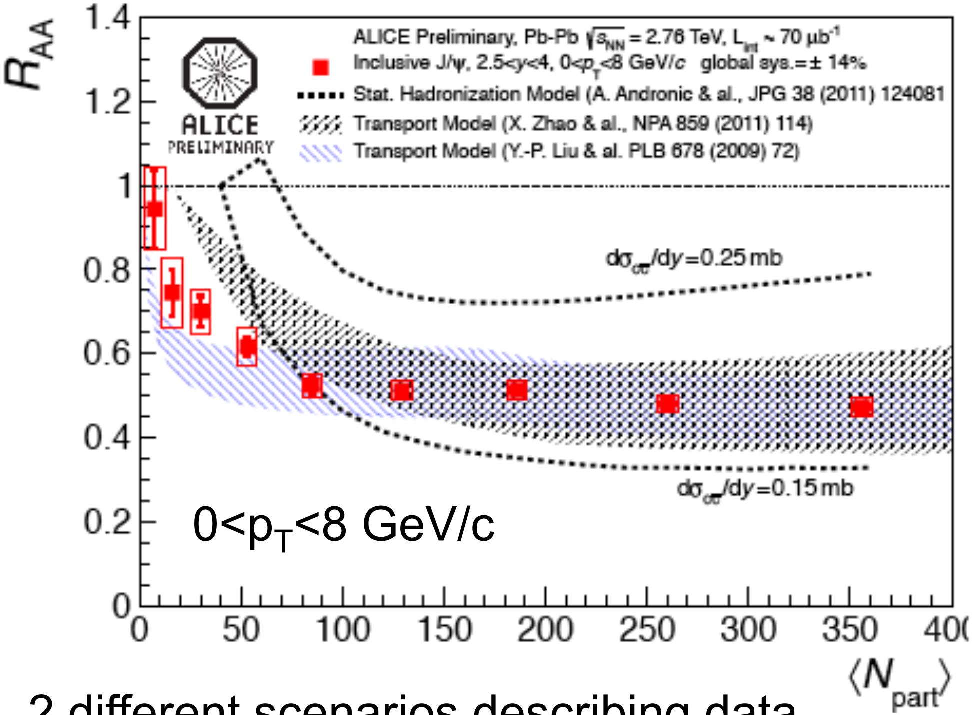
ALI-PUB-85194

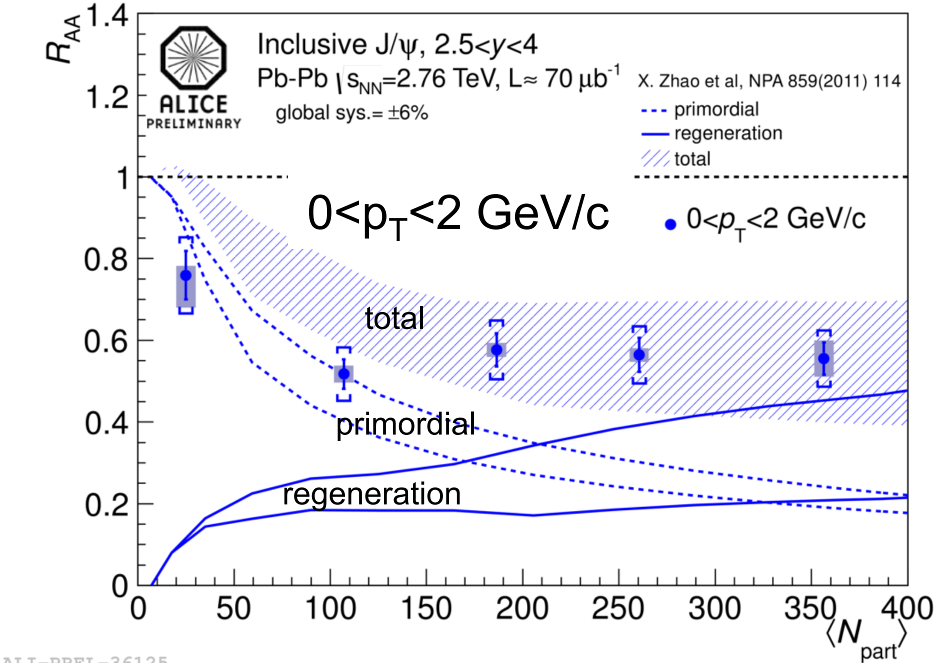
Significance>100 with 10 nb^{-1}





Quarkonia

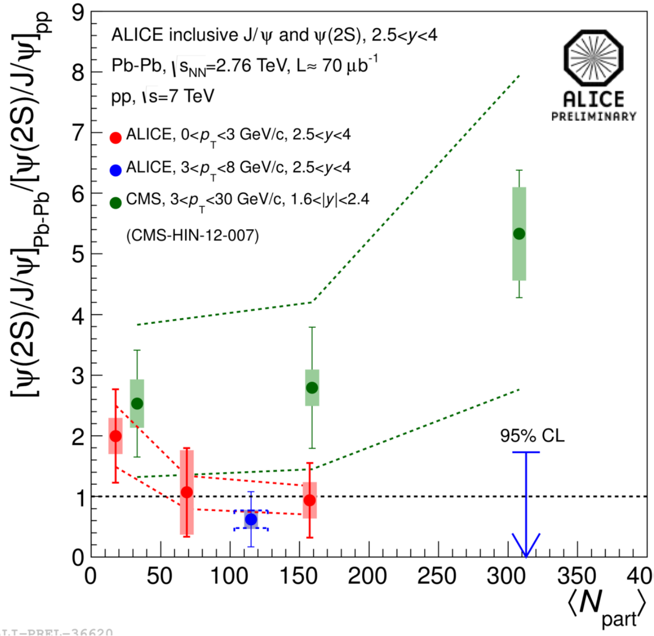




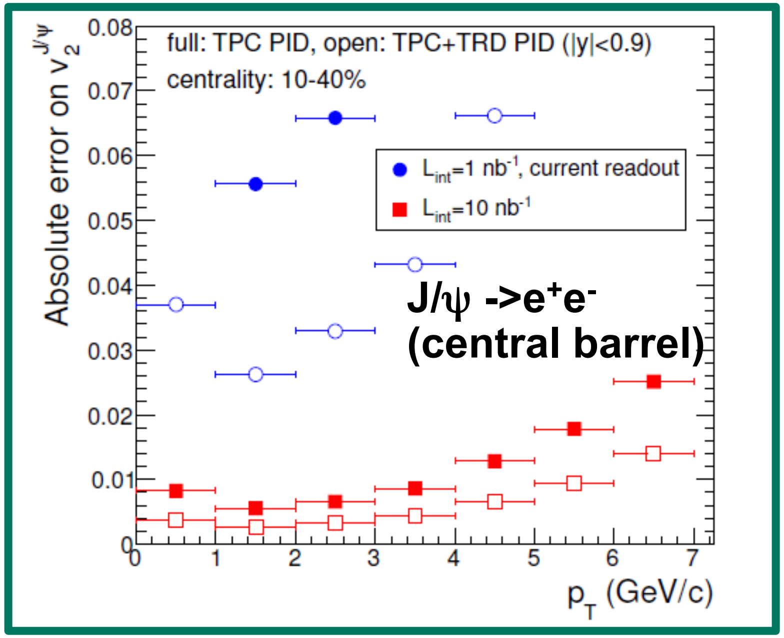
2 different scenarios describing data

- **statistical model**: all J/ψ generated at hadronization from deconfined c and c-bar
- **kinetic model**: J/ψ can survive in the medium as (to be) hadron + recombination from deconfined c-quarks

- need precise measurement of **total c-cbar production** to constrain models
- **need precise measurement of elliptic flow v2**
- need information on **other charmonia states**
  - tension between CMS and ALICE $\psi(2S)$?



Quarkonia: expected performance



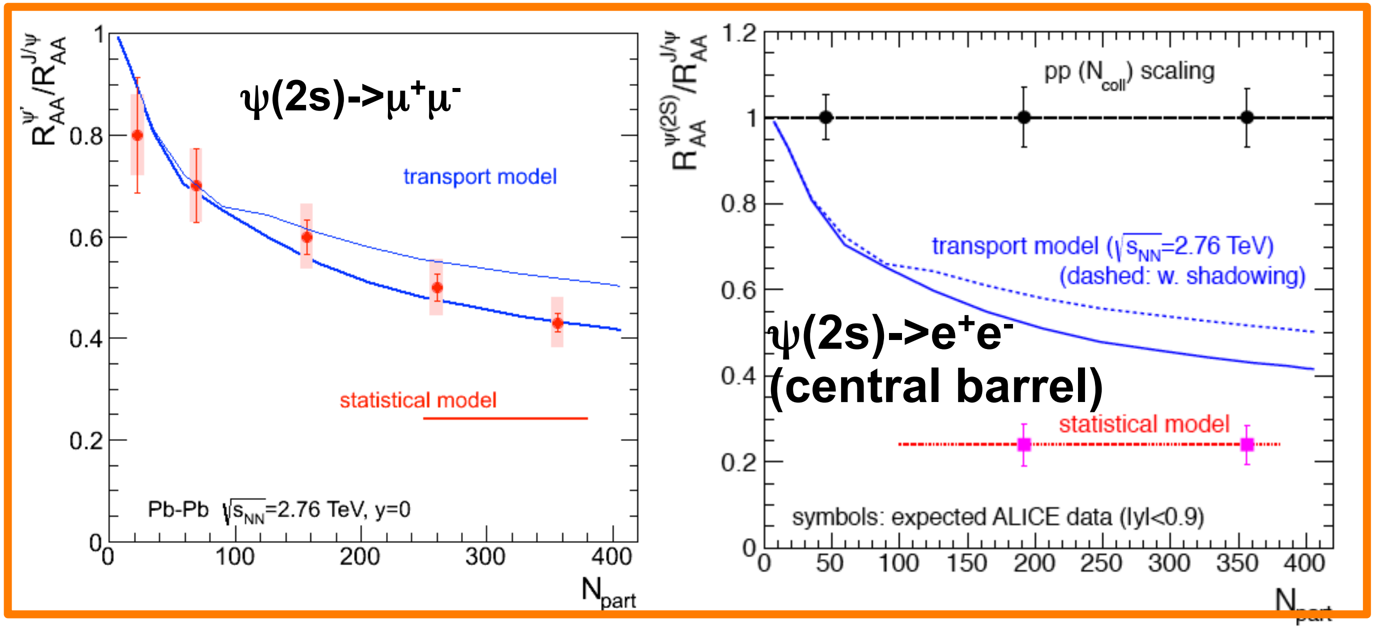
Factor 10 improvement with upgrade at central rapidity (di-electron channel)!

Factor 3 at forward rapidity (di-muon) w/o MFT

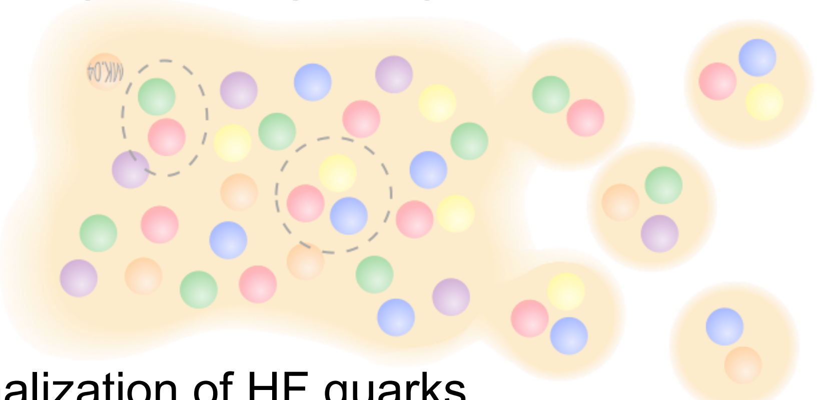
With MFT further S/B improvement by factor ~6-7 via PCA selection

Precise J/ψ v_2 measurement also at central rapidity

ψ(2s): can discriminate between kinetic and statistical models



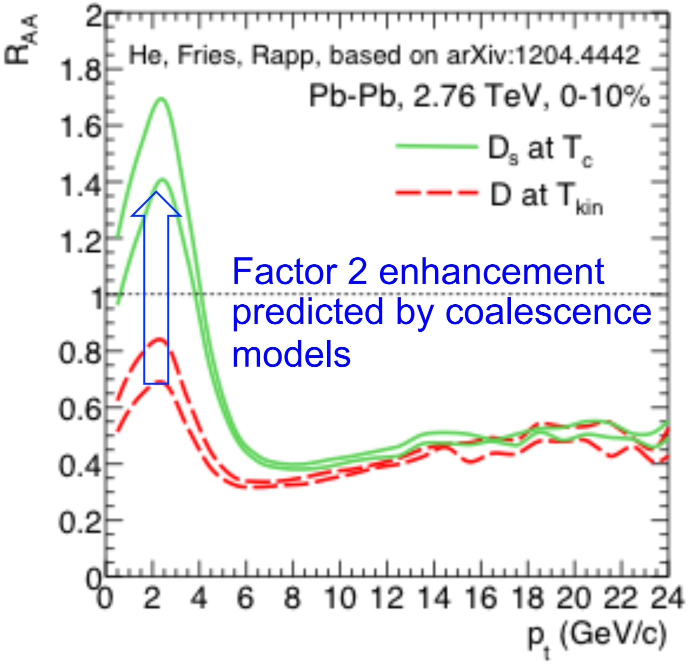
Heavy Flavour: hadronization



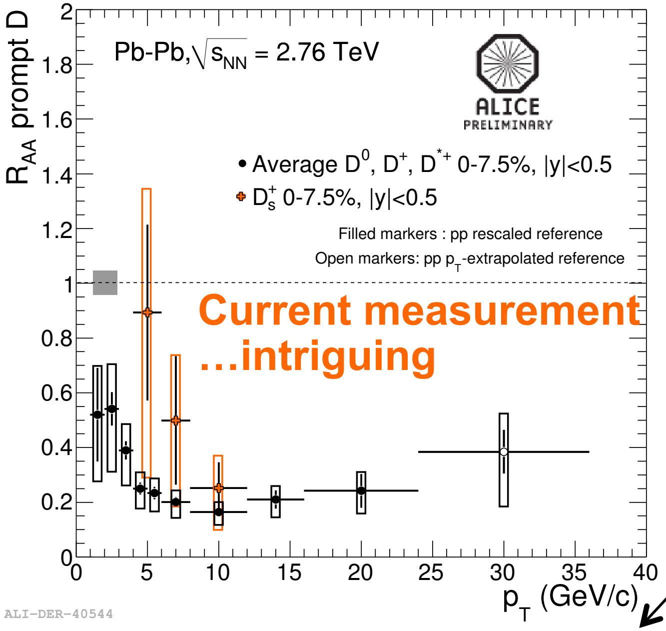
- baryon/meson enhancement and strangeness enhancement in charm sector
  - Radial flow effect? (velocity field->larger momentum for more massive particles)
  - Hadronization via coalescence?

Heavy Flavour Baryon (Λ_c, Λ_b)? ← degree of thermalization of HF quarks

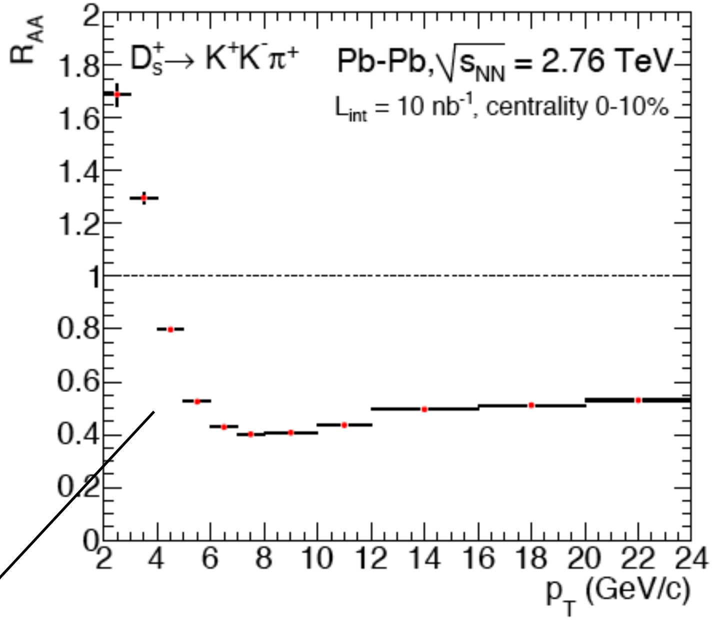
Charm strange meson, D_s: recombination with strange quarks from the medium?



Factor 2 enhancement predicted by coalescence models

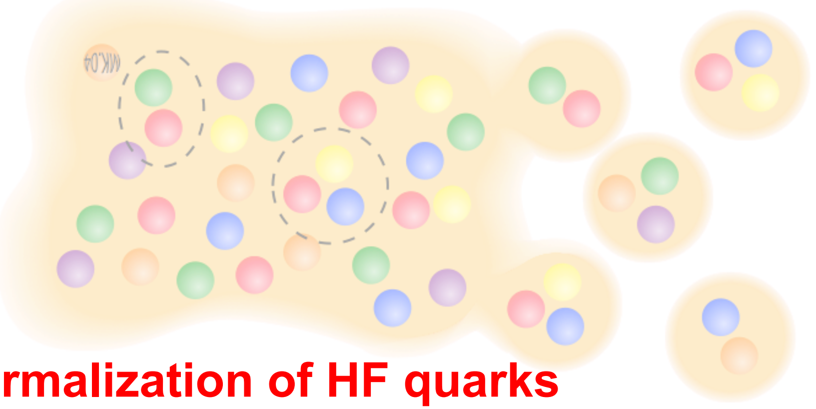


Current measurement …intriguing



With high rate negligible statistical uncertainty (per cent level) down to low p_T

Heavy Flavour: hadronization



- baryon/meson enhancement and strangeness enhancement in charm sector
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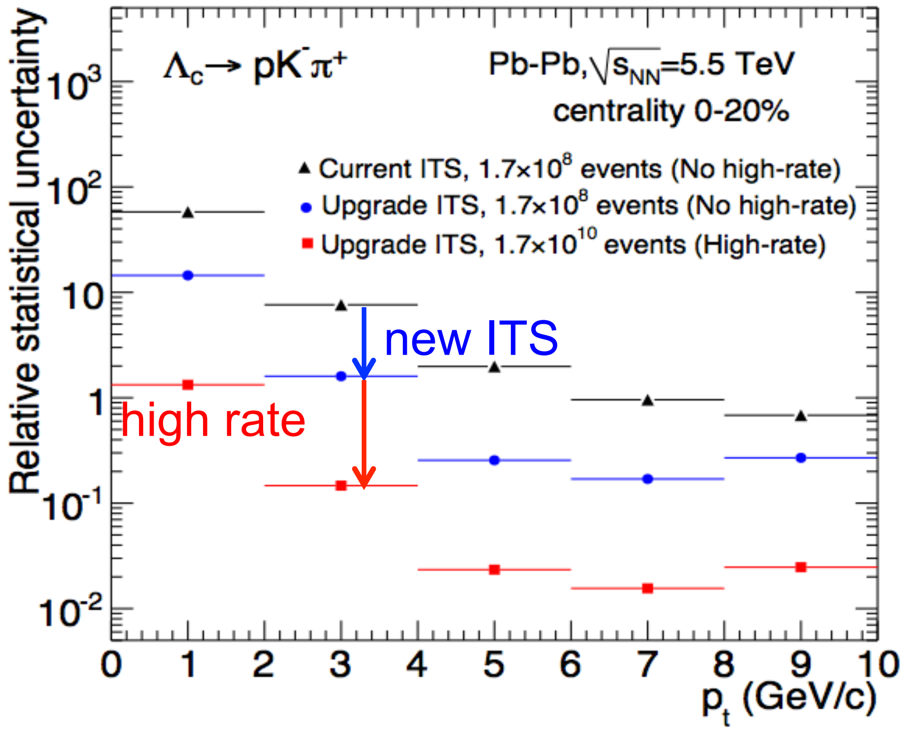
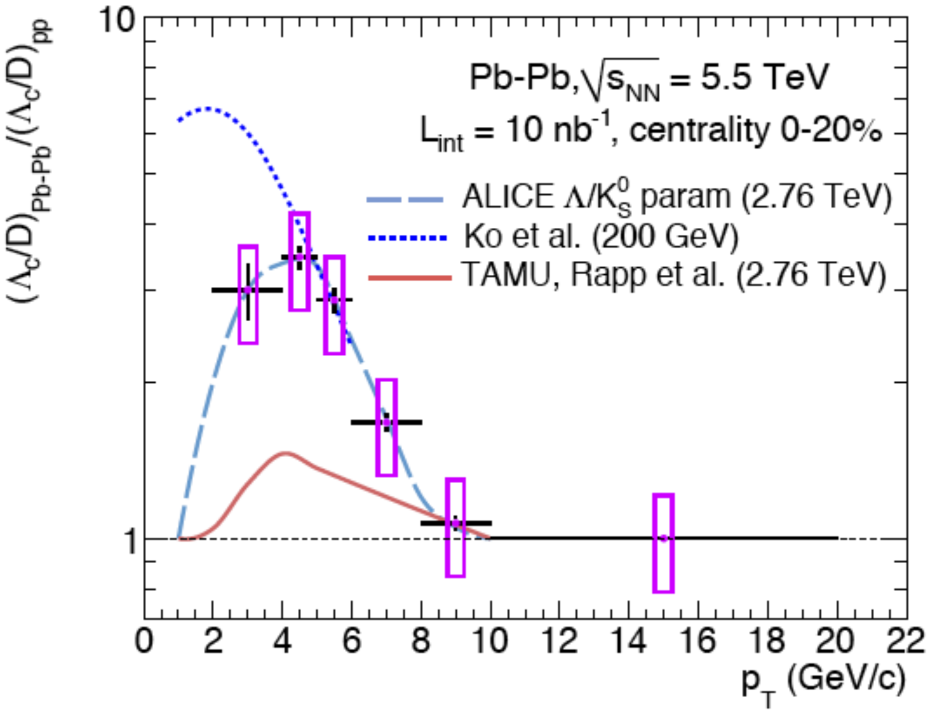
⇨ **Heavy Flavour Baryon (Λ_c, Λ_b)? ← degree of thermalization of HF quarks**





How can we measure medium effects?

1) **Nuclear modification factor (R_{AA})**: compare particle production in Pb-Pb with that in pp scaled by a “geometrical” factor (from Glauber model)

$$R_{AA}(p_T) = \frac{dN_{AA}/dp_T}{\langle T_{AA}\rangle \times d\sigma_{pp}/dp_T}$$

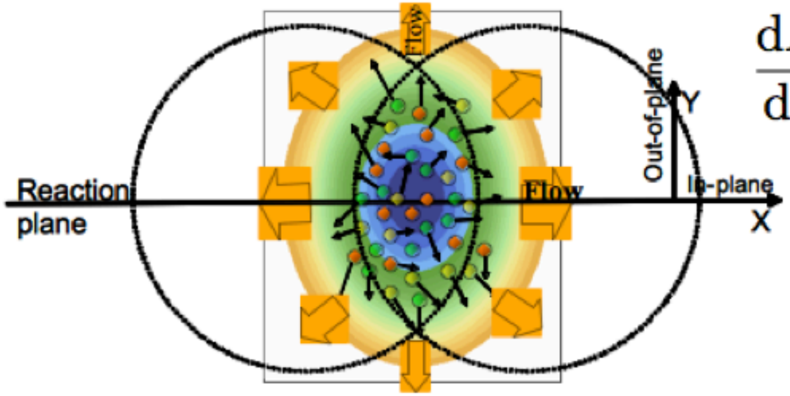
PbPb

pp

Nuclei overlap function

If **R_{AA}=1** → no nuclear effects
if **R_{AA}≠1** → binary scaling broken

2) **Elliptic flow v_2 (azimuthal anisotropy)**: study azimuthal distribution of produced particle w.r.t. the reaction plane (Ψ)



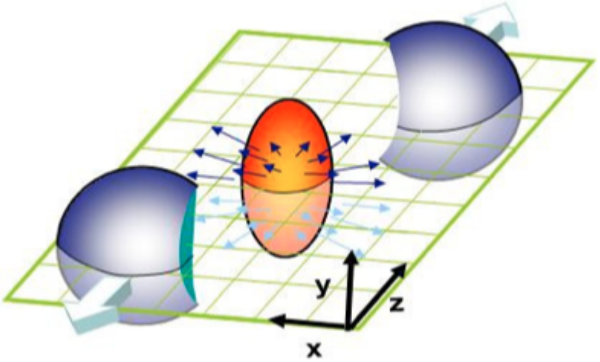
$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi}\left(1 + 2v_1\cos(\varphi - \Psi_1) + 2v_2\cos[2(\varphi - \Psi_2)] + \ldots\right)$$

Non-zero v_2
→ Thermalization/collective motion (at low p_T)
→ Path length dependence of energy loss (at high p_T)

Initial spatial anisotropy $\xrightarrow{\text{hydrodynamic}}$ momentum anisotropy

Heavy Flavour: Elliptic flow

Initial azimuthal anisotropy converted to a momentum anisotropy via hydrodynamic processes



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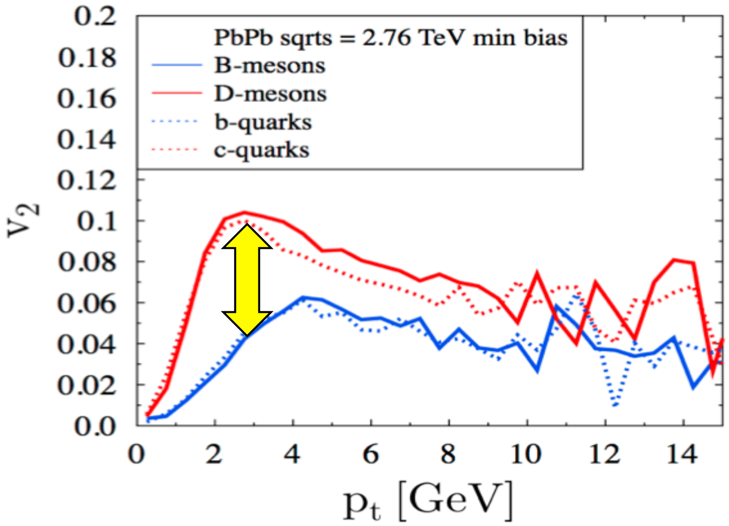
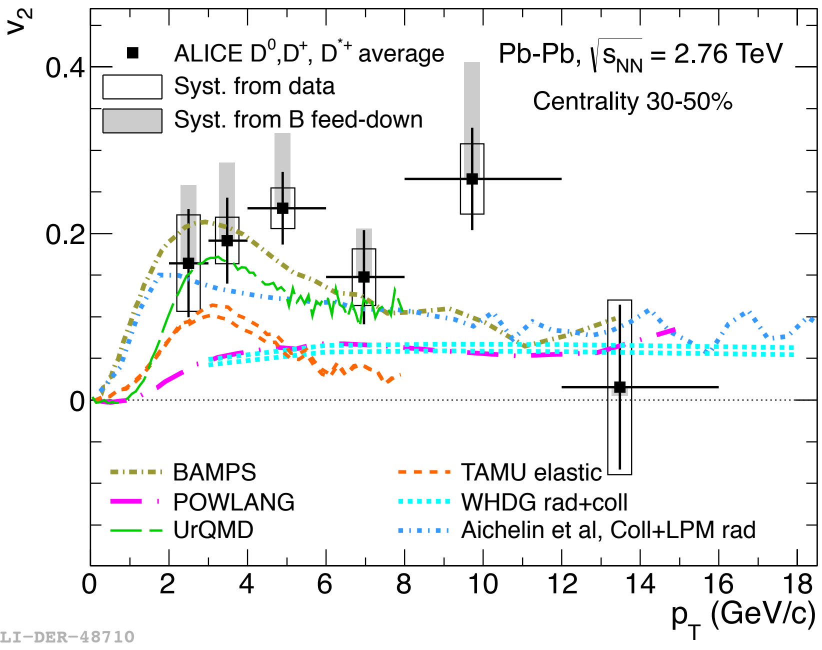


J. Aichelin et al. arXiv:1201:4192

HF elliptic flow (v_2) sensitive to:

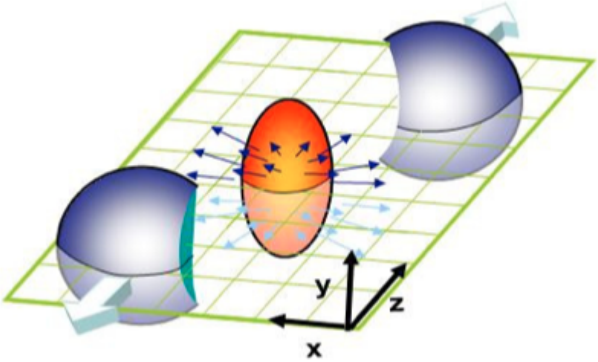
- Thermalization of c and b quarks in the QGP
- Heavy-quark diffusion coefficient of the QGP, which characterizes its coupling strength
- Path-length dependence of energy loss at high p_t



Current measurement: prompt D only with substantial uncertainties

Heavy Flavour: Elliptic flow

Initial azimuthal anisotropy converted to a momentum anisotropy via hydrodynamic processes



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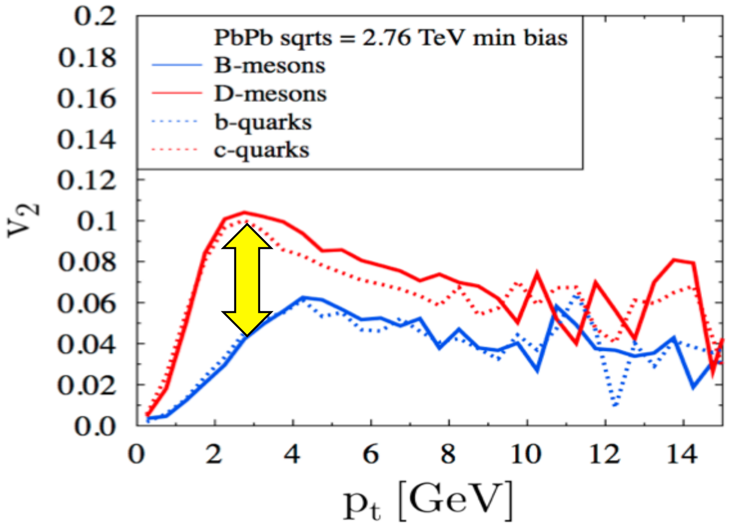

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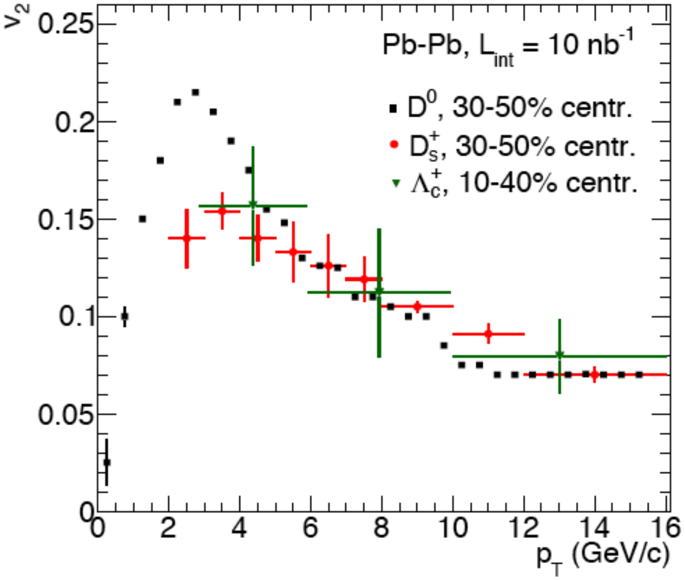
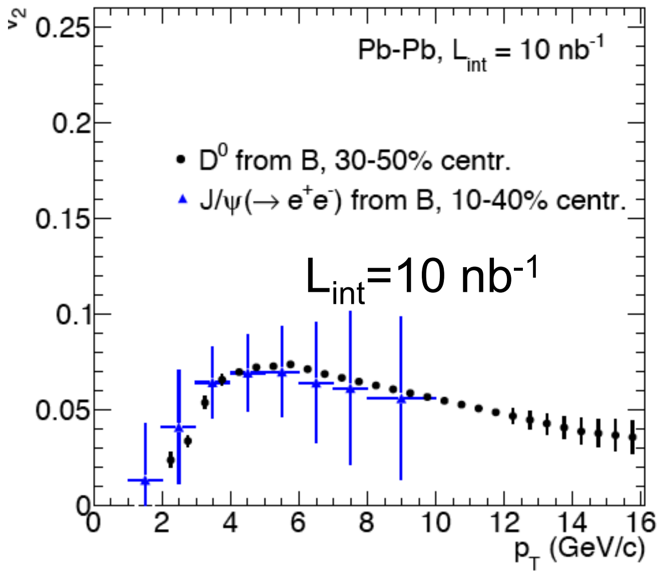




Upgrade:

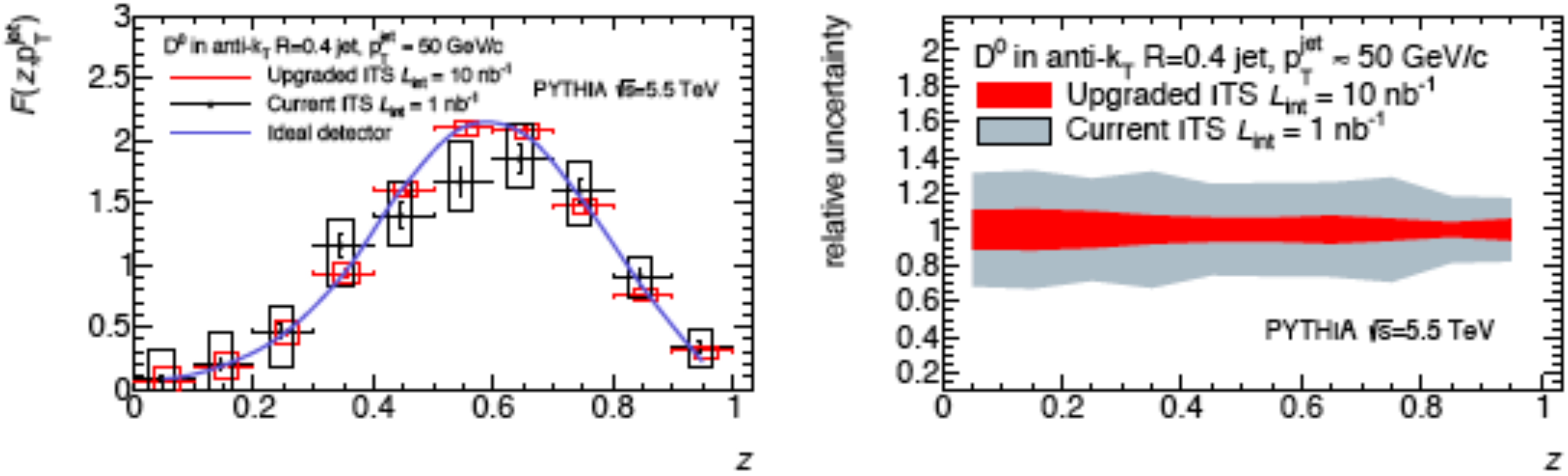
Precise v_2 measurement of prompt D, D_s^+ and D from B

Λ_c v_2 accessible

HF jets withALICE Upgrade

D meson in jets

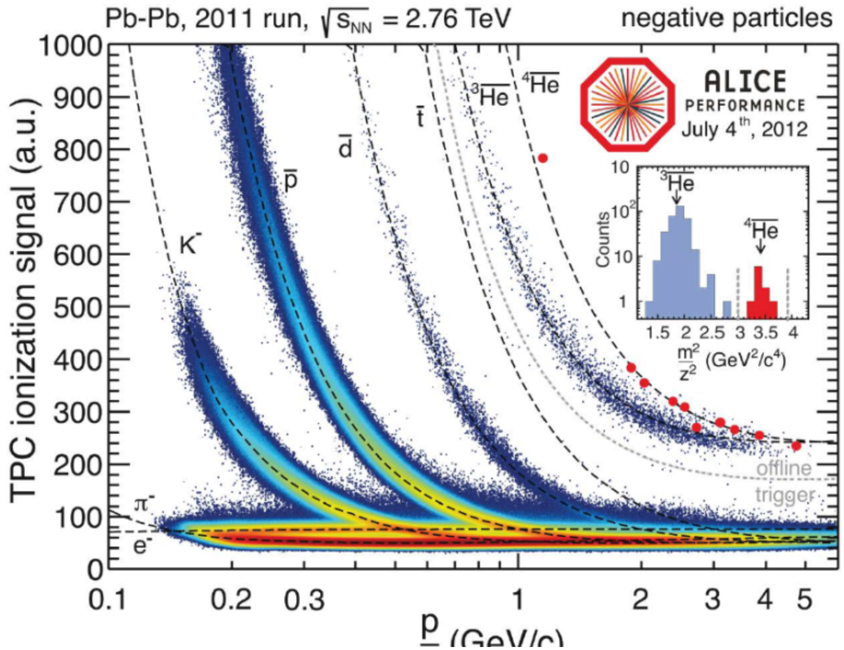
Study modification to fragmentation function in the medium

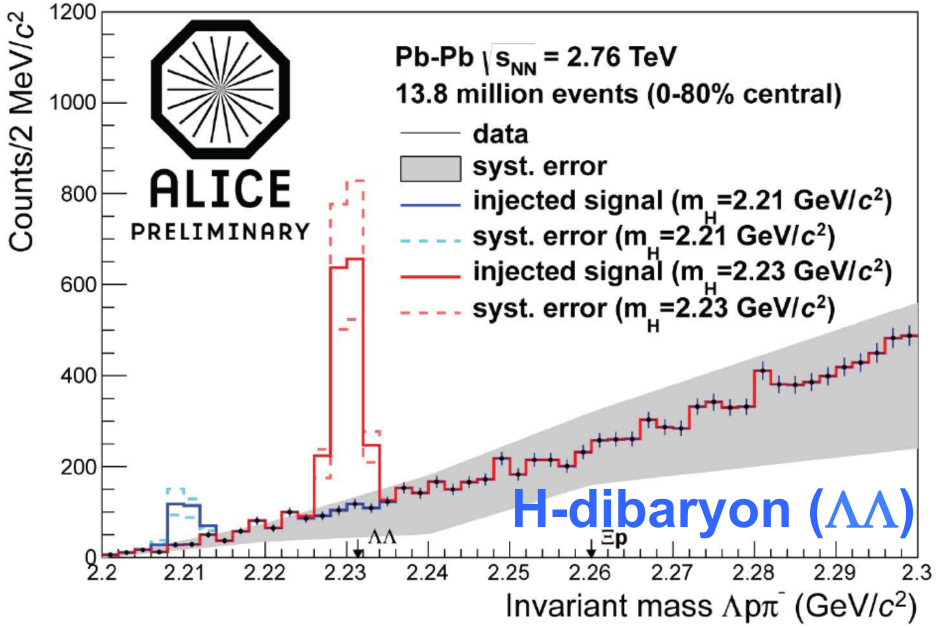


Heavy Nuclear States

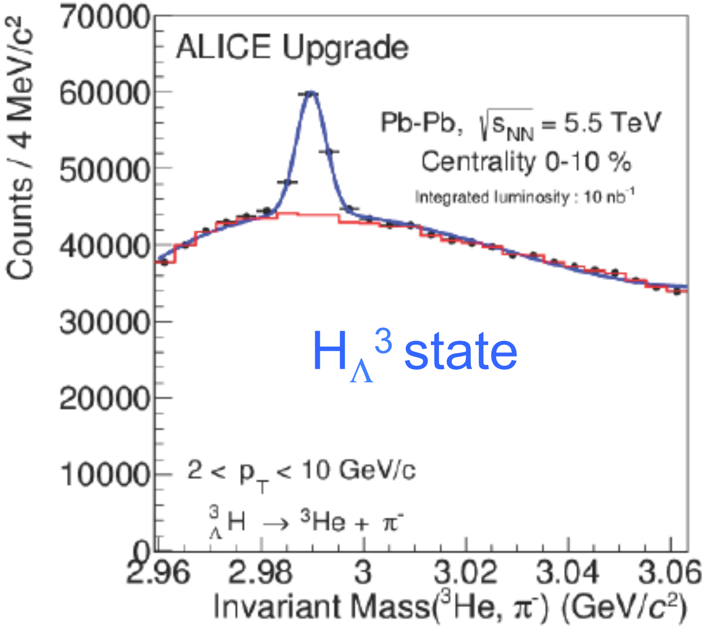
- high statistics mass-4 and -5 (anti-)hypernuclei
- search for H-dibaryon, Λn bound state, etc.

- Upgrade->increase statistics by 10^3





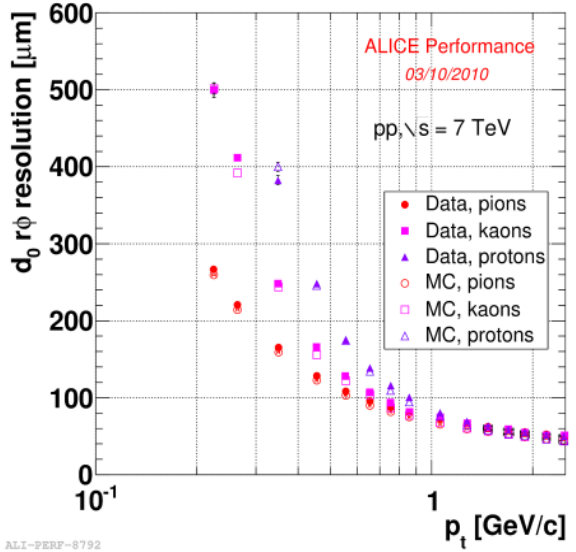
H-dibaryon (ΛΛ)



H_Λ^3 state

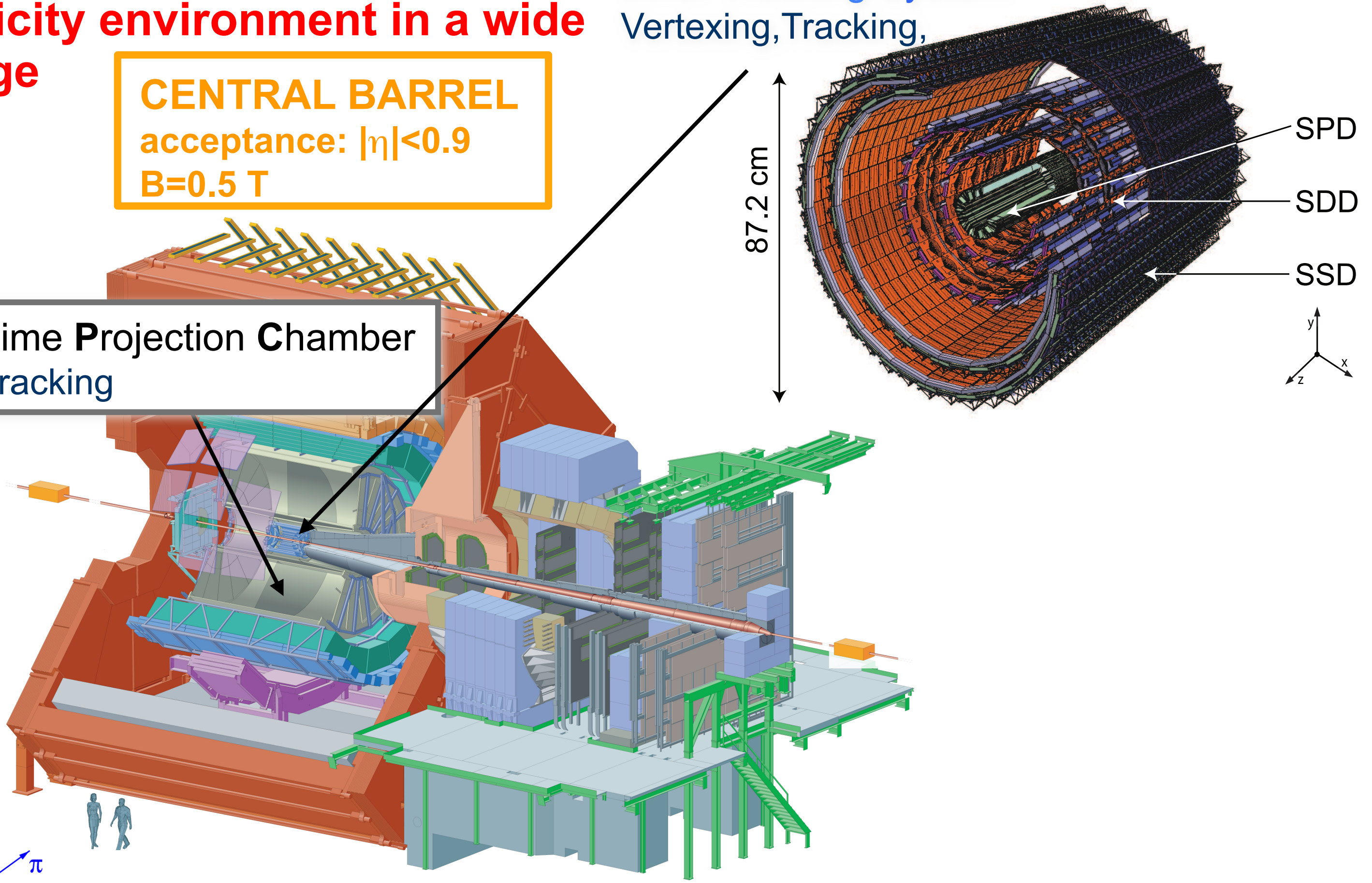
ALICE detector strength

Excellent track and vertex reconstruction capabilities (TPC, ITS) in a high multiplicity environment in a wide transverse momentum range



track spatial resolution at interaction point (“pointing resolution”)

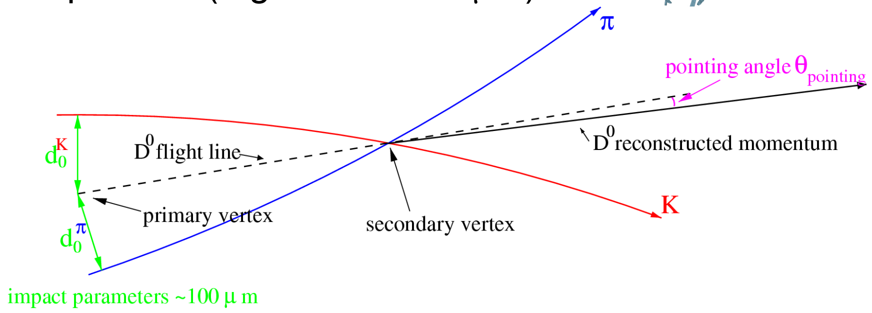
-> Resolution on secondary decay vertex position (e.g. D^0 $c\tau$=123 μm)



Inner Tracking System
Vertexing,Tracking,

CENTRAL BARREL
acceptance: |η|<0.9
B=0.5 T

Time Projection Chamber
Tracking

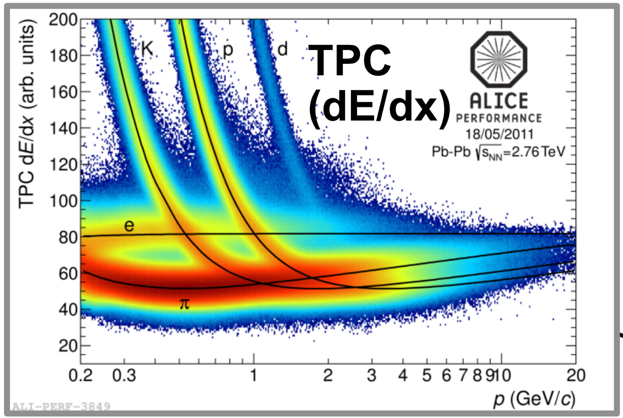


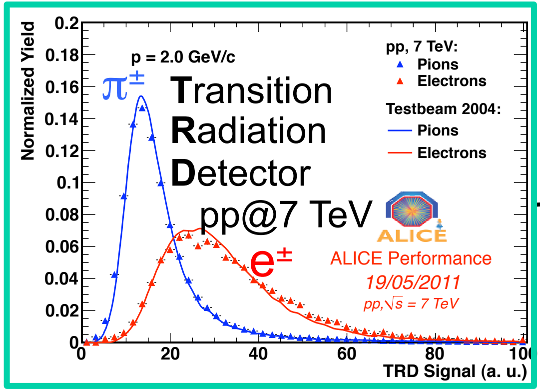
ALICE detector strength

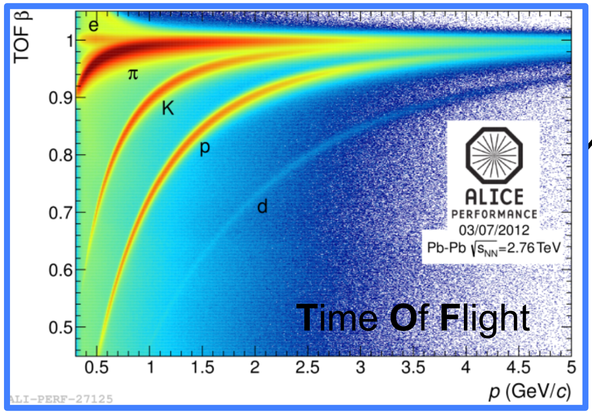
Particle identification in a wide momentum range

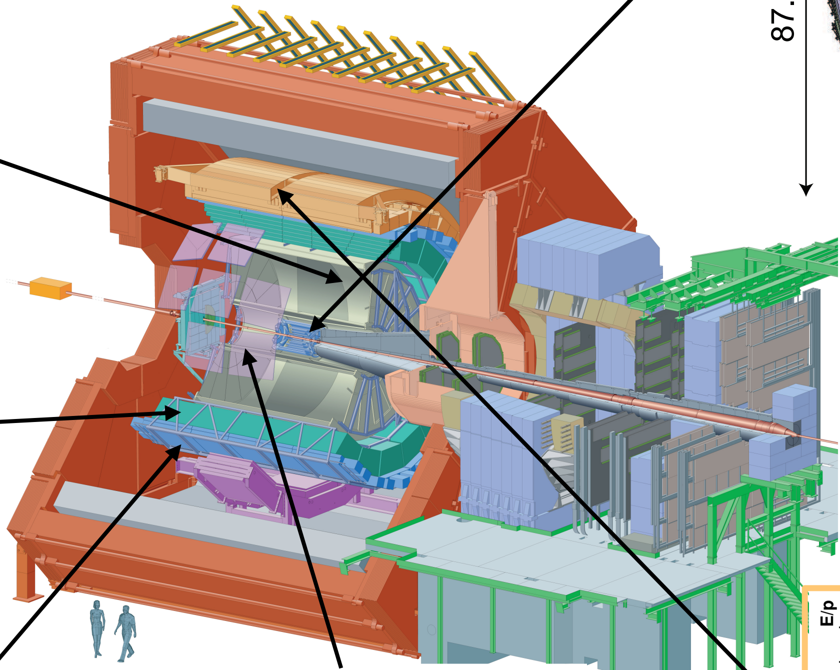
CENTRAL BARREL
acceptance: |η|<0.9
B=0.5 T

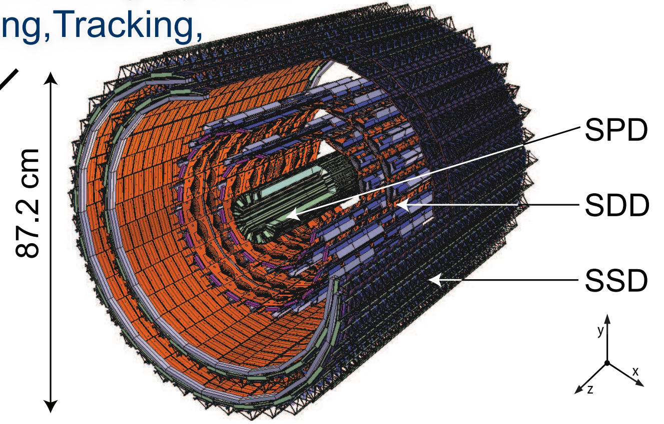
Inner **T**racking **S**ystem
Vertexing,Tracking,
PID

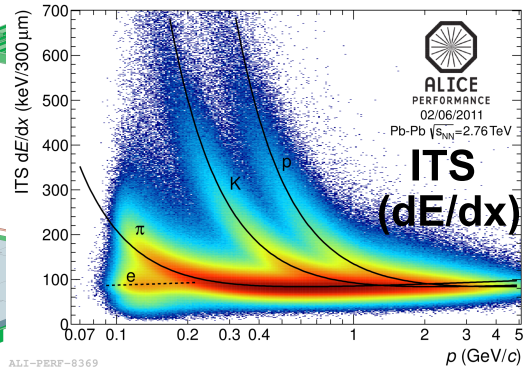


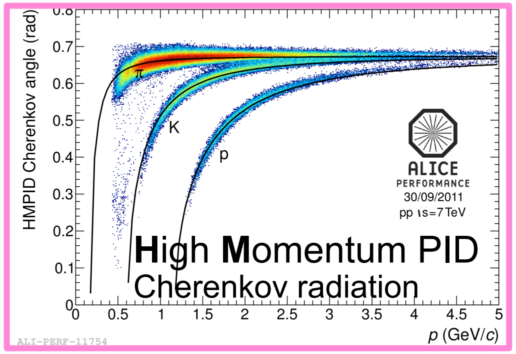


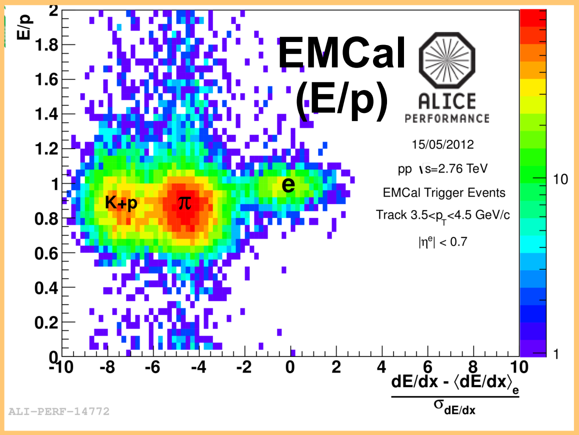




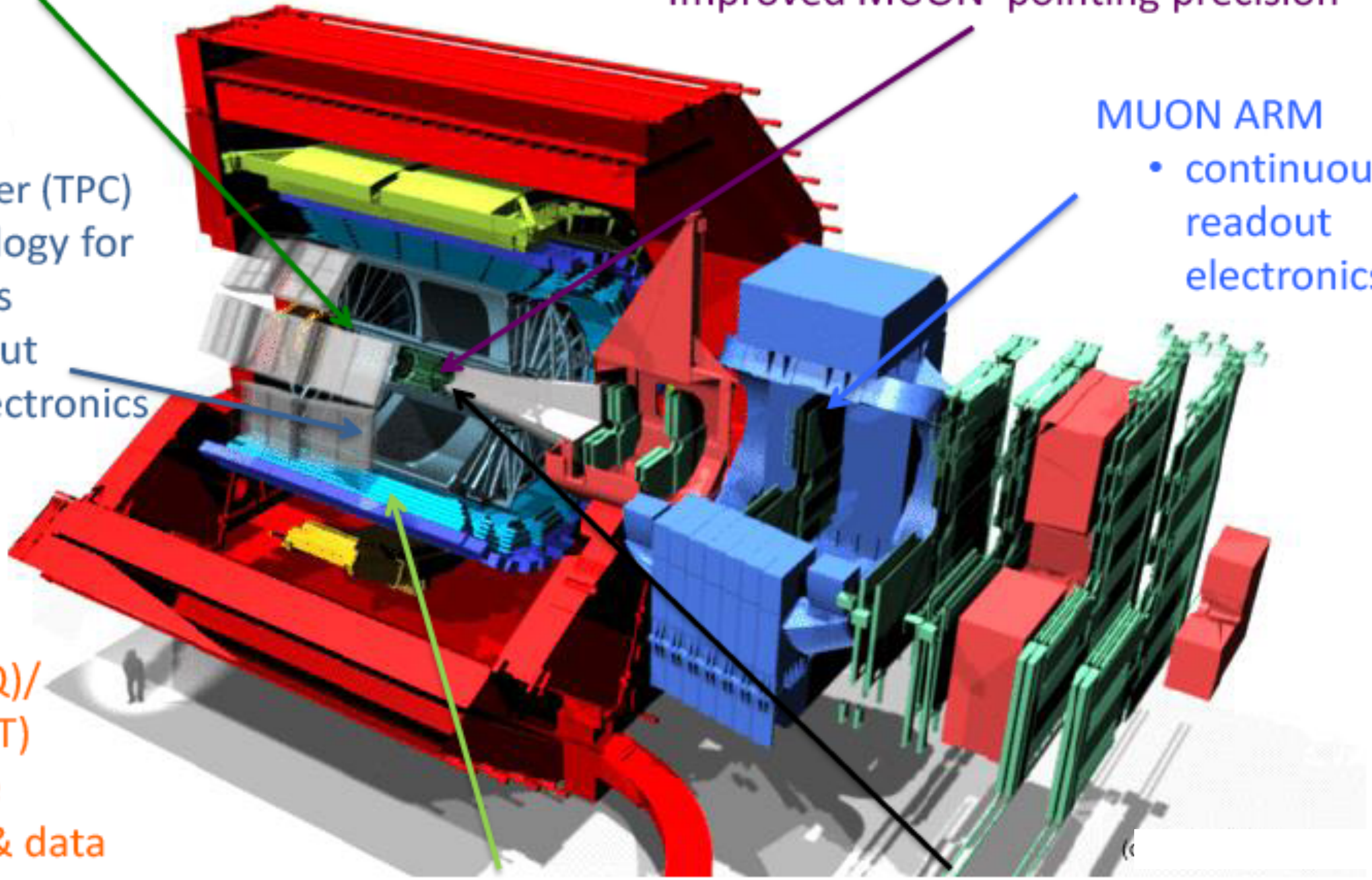








Summary: ALICE detector upgrade



New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- new GEM technology for readout chambers
- continuous readout
- faster readout electronics

New Central Trigger Processor

Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50 kHz Pb-Pb event rate

TOF, TRD
- Faster readout

New Trigger Detectors (FIT)