ITS upgrade project: physics motivation

G. Usai and A. Dainese

29/05/2011

Outline

- HF measurement techniques in ALICE
- HF in heavy ion collisions
  - energy loss
  - flow and hadronization/coalescence
  - quarkonia
- Innner Tracking System Upgrade: motivation and concept

ALICE ITS upgrade project: Physics motivations

Extend ALICE capability to study heavy quarks as probes of the QGP in heavy-ion collisions

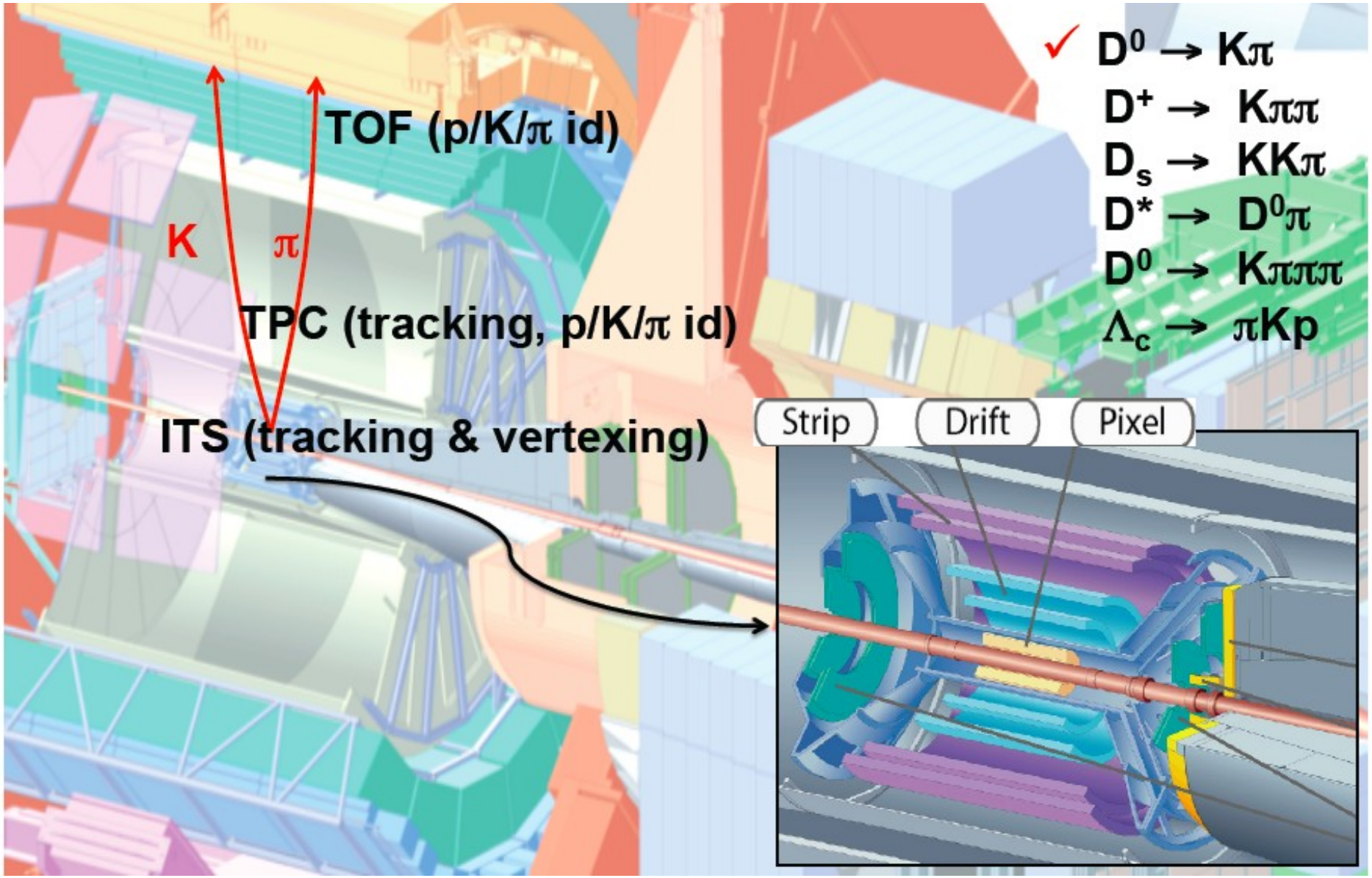
Main physics topics:

- Heavy flavour in the QGP (E loss, flow, coalescence, quarkonia)
- Small-x physics (pp, pA, AA) with light and heavy hadrons
- + long-range correlations, …

Mapping to ALICE:

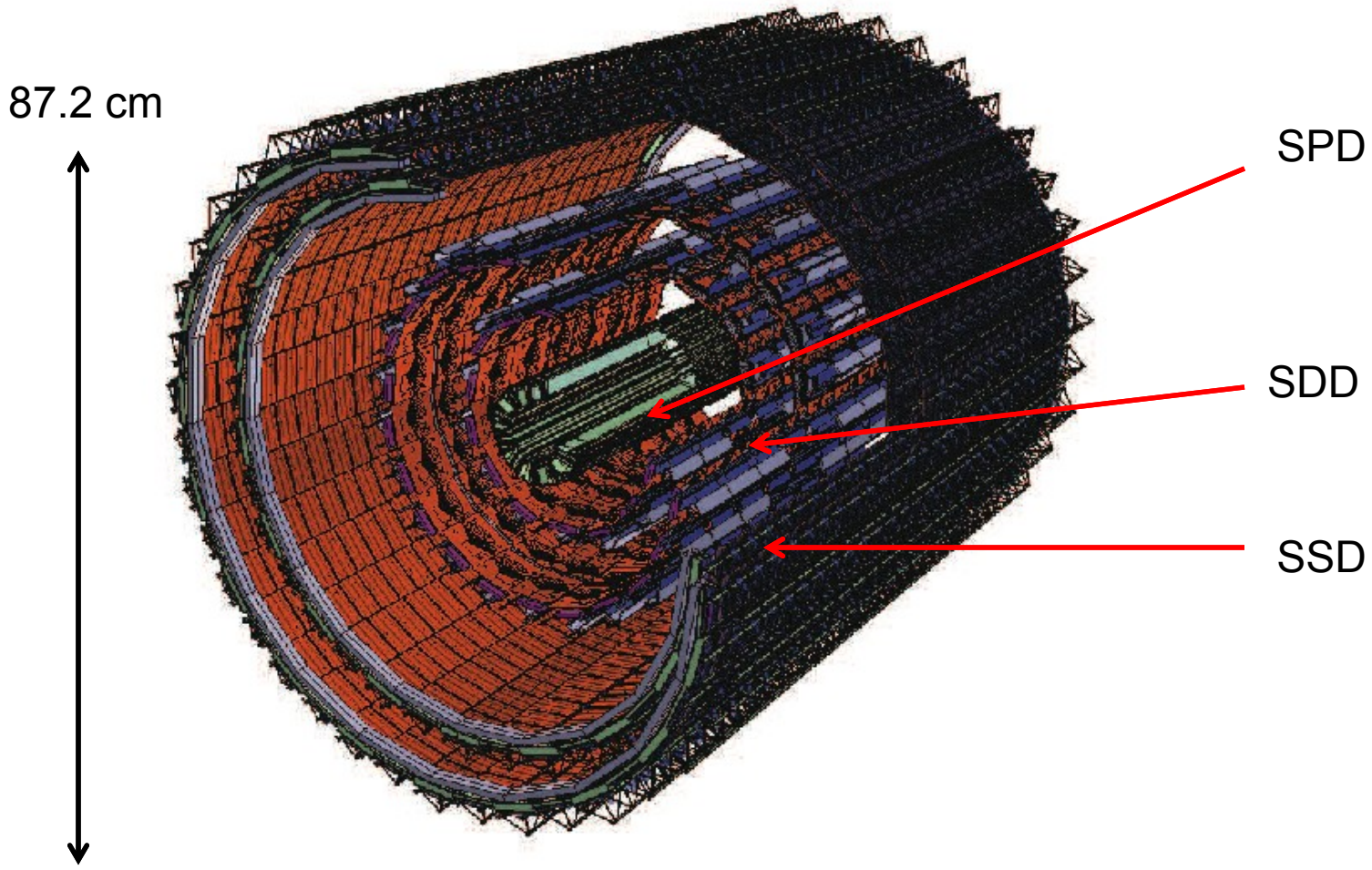
- Heavy flavour at mid-rapidity ($|\eta|<0.9$) with hadronic (and semi-elecronic) decays ➔ ITS barrel upgrade
- Heavy flavour and resonances at forward rapidity with muons ($2.5<\eta<4$) ➔ endcap/telescope on the MUON side

HF measurement at midrapidity: mesons and baryons

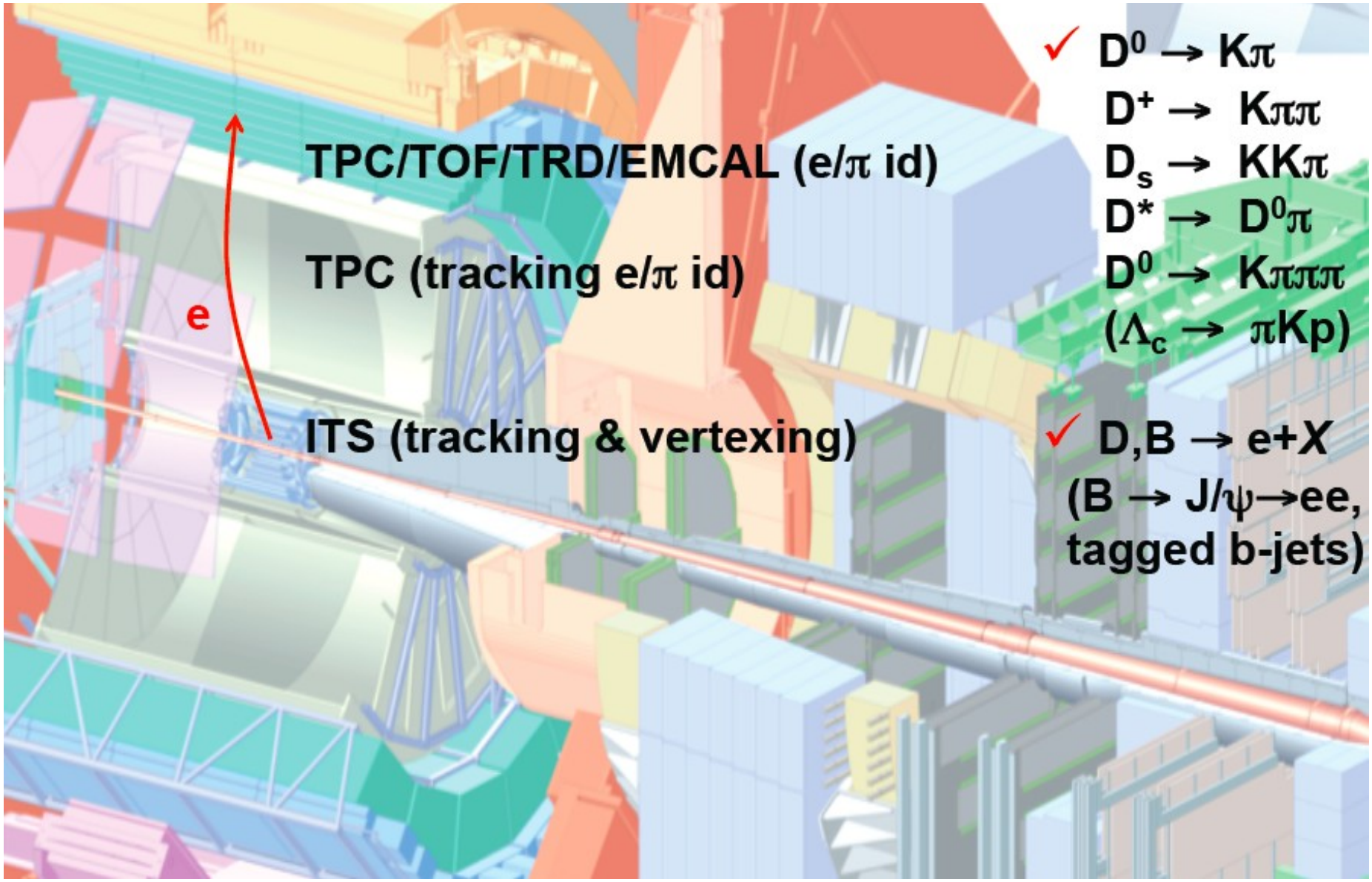


THE ALICE Inner Tracking System

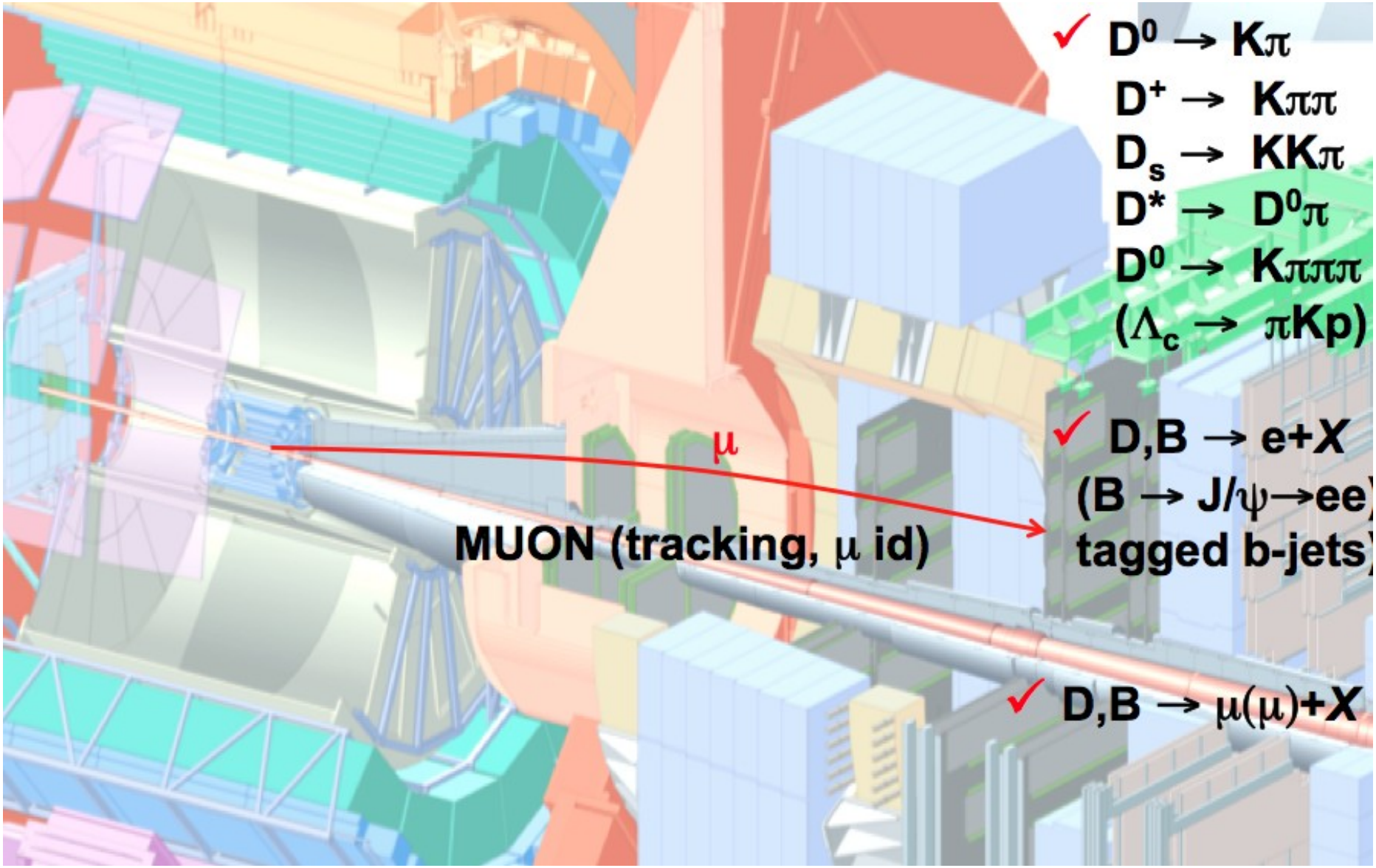
- Main detector studying yields and spectra of particles containing heavy quarks
- Six cylindrical layers of silicon detectors



HF measurement at midrapidity: electrons

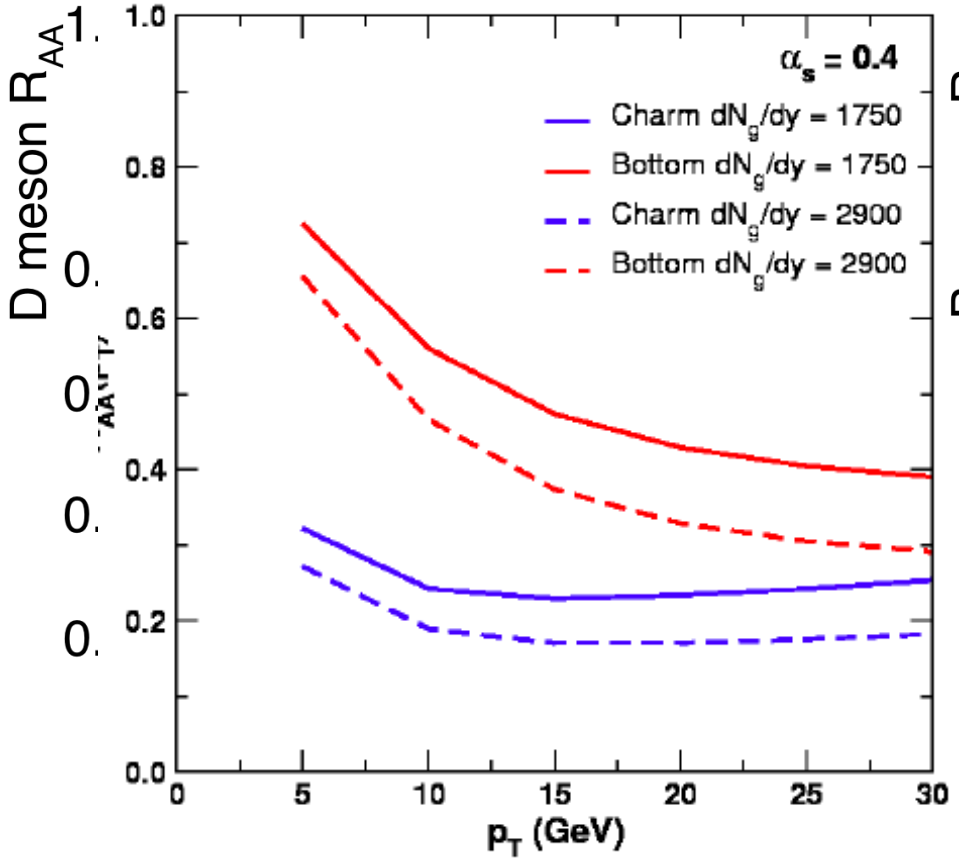


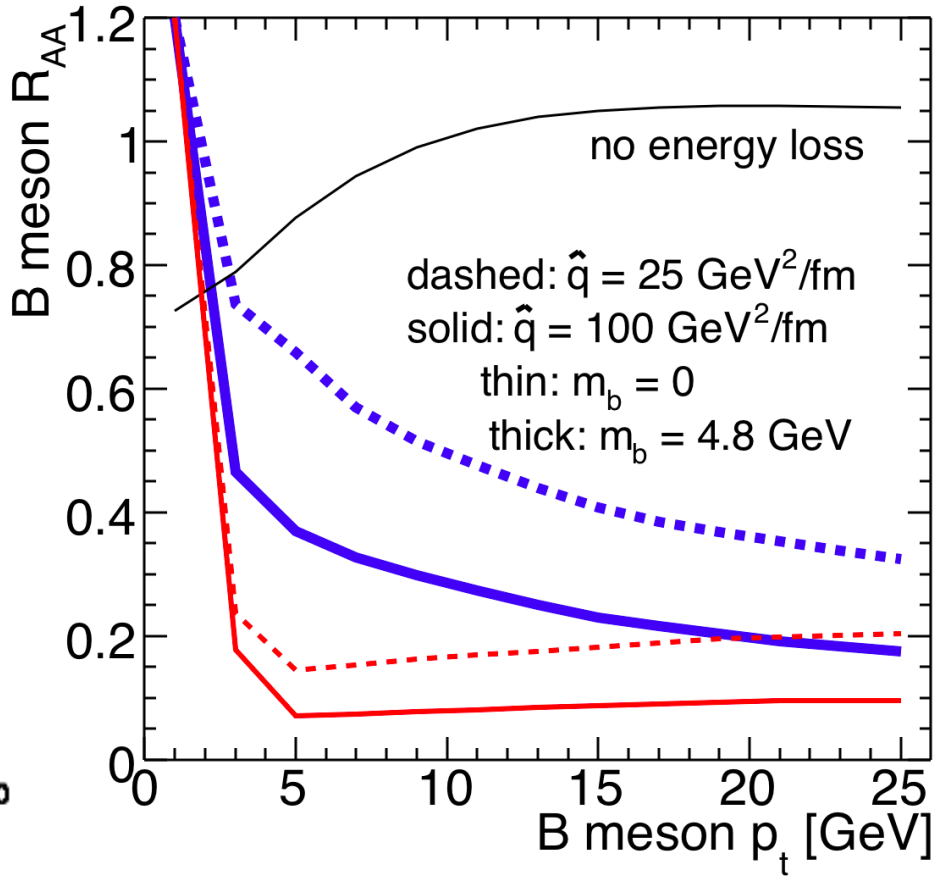
HF measurement at forward y: muons



Heavy flavors: energy loss

- ✓ Energy loss based predictions: factor 3-5 suppression for D mesons
- ✓ Significantly smaller suppression for B
- ✓ Mass dependence: larger effects on beauty



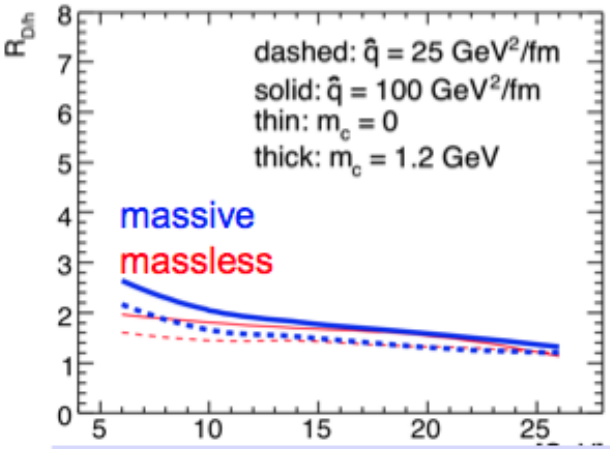


HQs R_{AA}: some expectactions …

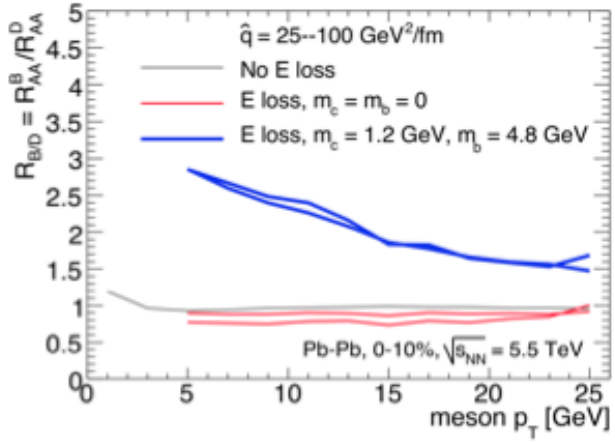
New at LHC

- **Heavy-to-light ratios**: parton colour charge and mass dependence

$$R_{D/h}(p_t) = R^D_{AA}(p_t)/R^h_{AA}(p_t)$$

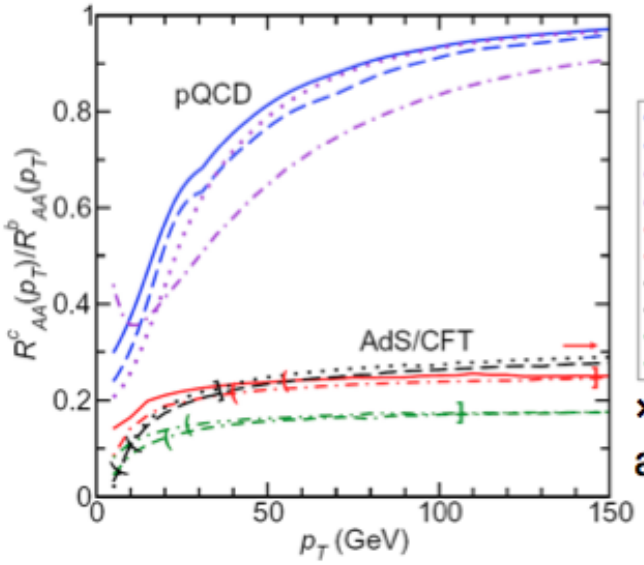


$$R_{B/D}(p_t) = R^B_{AA}(p_t)/R^D_{AA}(p_t)$$



… and, quite a different picture from AdS/CFT

$$1/R_{B/D}(p_t) = R^D_{AA}(p_t)/R^B_{AA}(p_t)$$



×2 difference already at 10-20 GeV

AdS/CFT → D.Mateos, Fri plenary

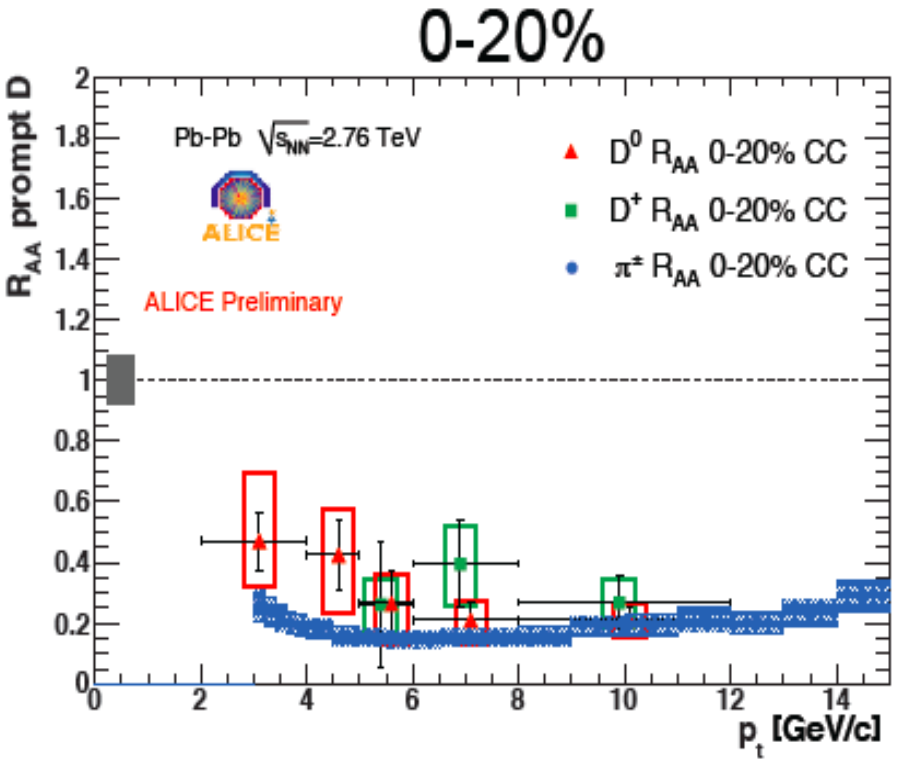
Armesto, et al, PRD71 (2005)

Horowitz, Gyulassy, PLB666 (2008)

Heavy flavors: energy loss

- Eloss mass dependence:
  - R_{AA}^{D}/R_{AA}^{h}

NEWS FROM QM:



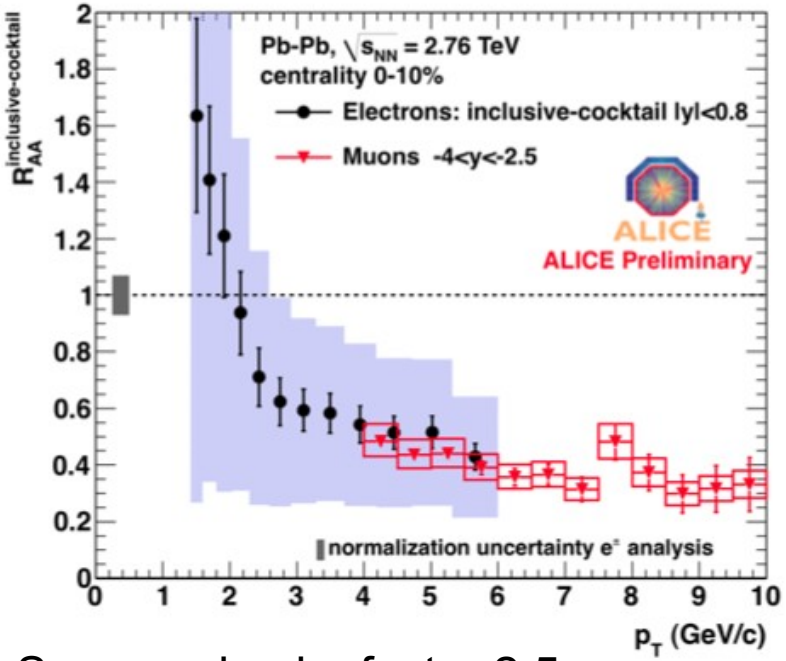
- Further key measurement: beauty R_{AA}
  - R_{AA}^{B}/R_{AA}^{D} at low-p_T is the most interesting (larger mass effects on beauty) at high p_T it should become 1

- Coverage down to moderately low p_T

Heavy flavors: energy loss

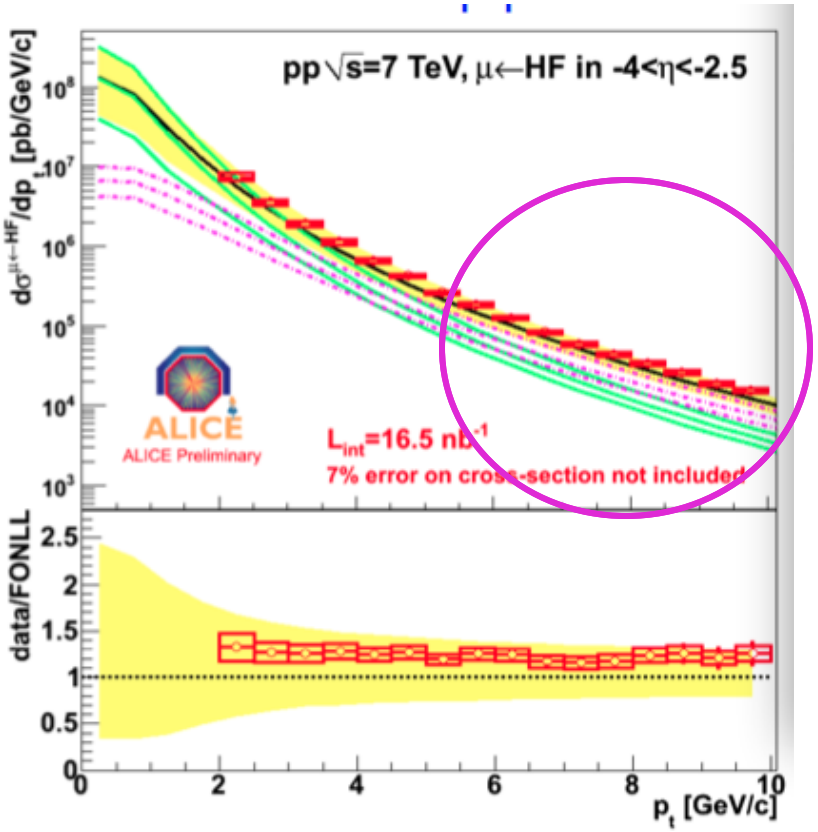
- Beauty energy loss

NEWS FROM QM:



Suppression by factor 2.5
(D mesons factor 4-5)

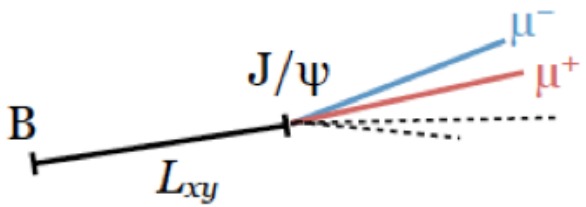
ALICE inclusive electrons and muons
Dominated by beauty above 5-6 GeV/c?



Heavy flavors: energy loss

➢ Beauty energy loss

NEWS FROM QM:

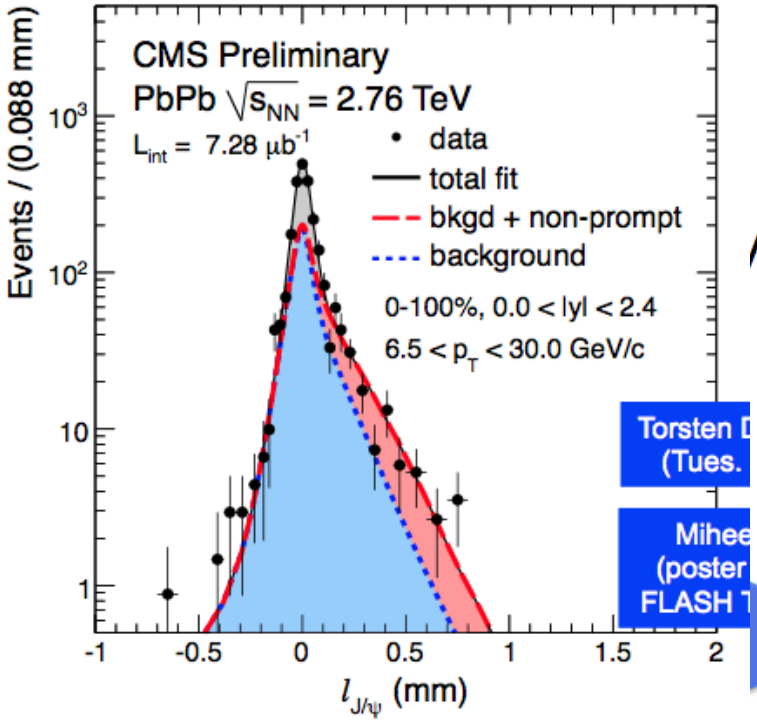


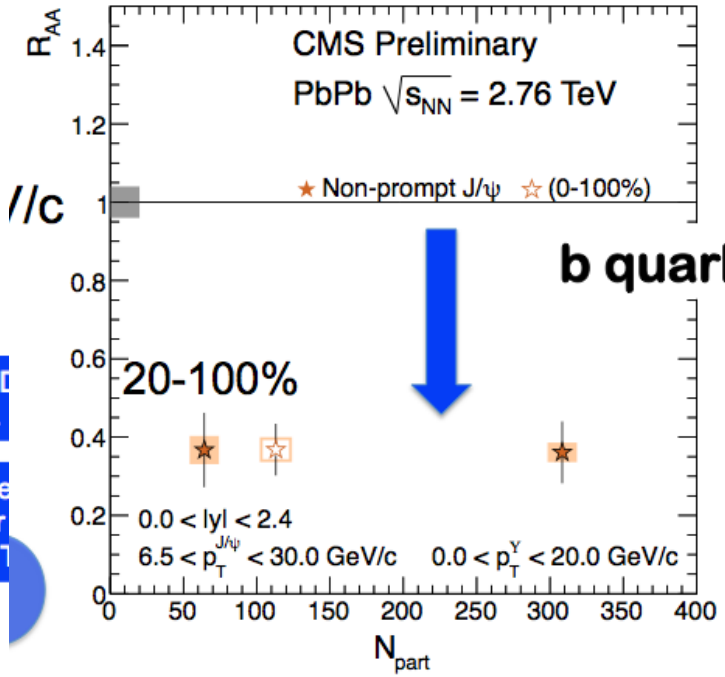
$p_T^{J/\psi} > 6.5$ GeV/c

CMS Jpsi from B (pt>6.5 GeV)

Suppression by factor 2.5 (like ALICE muons)

CMS capability limited to pt>6 GeV?





b quark energy loss ?

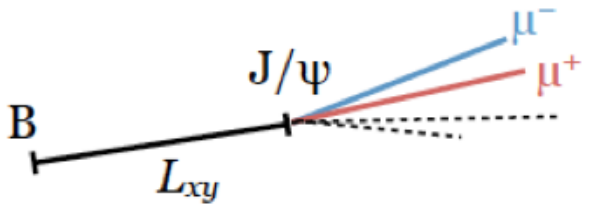
Minimum bias R_{AA} = 0.37 ± 0.07 ± 0.03

Central 0-20% R_{AA} = 0.36 ± 0.08 ± 0.03

Heavy flavors: energy loss

- Beauty energy loss

NEWS FROM QM:

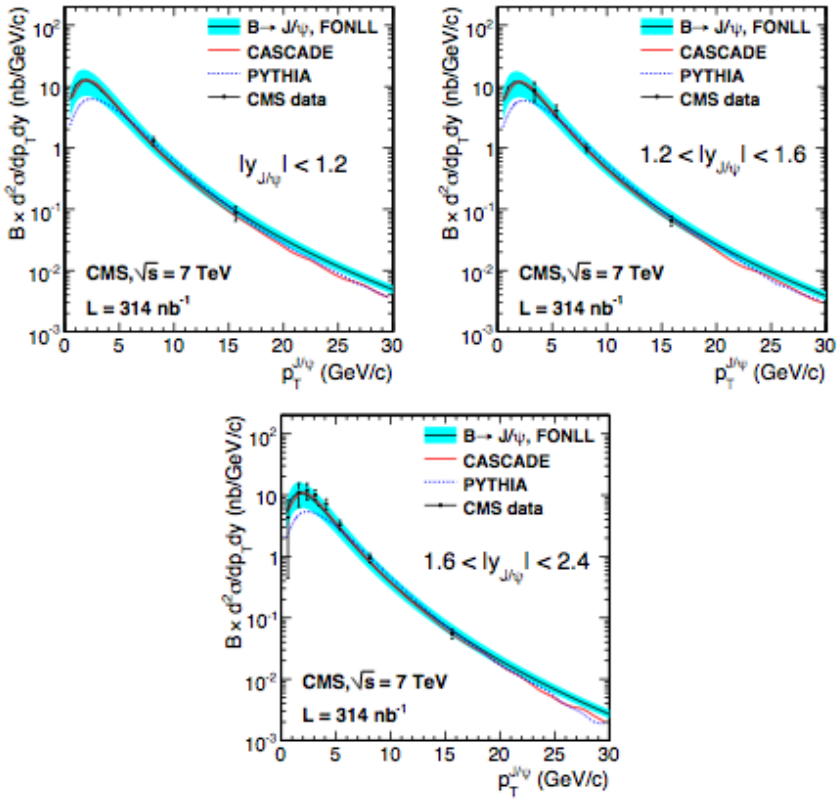


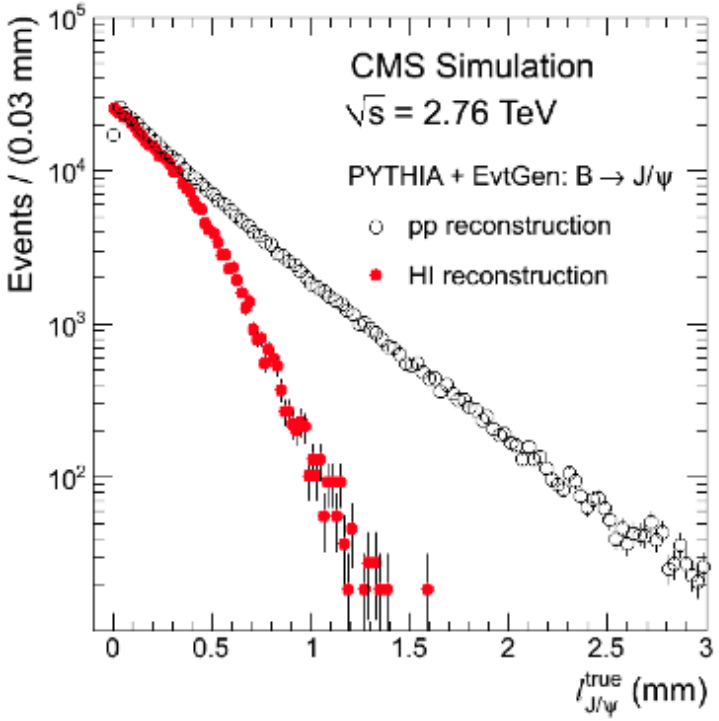
CMS Jpsi from B (pt>6.5 GeV)

Suppression by factor 2.5 (like ALICE muons)

CMS capability limited to pt>6 GeV?

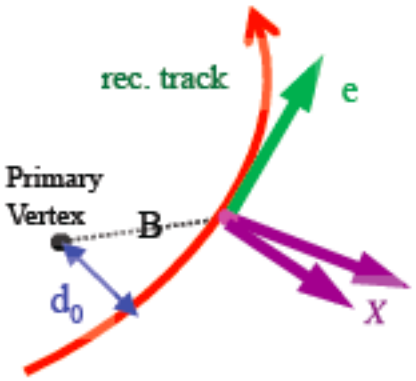
pp: arXiv:1011.4193





Beauty measurement

- In ALICE HI current setup will most likely allow to measure beauty only via single-displaced electrons
  ➔ suffers from a problematic subtraction of charm from the low-p_T electron spectrum



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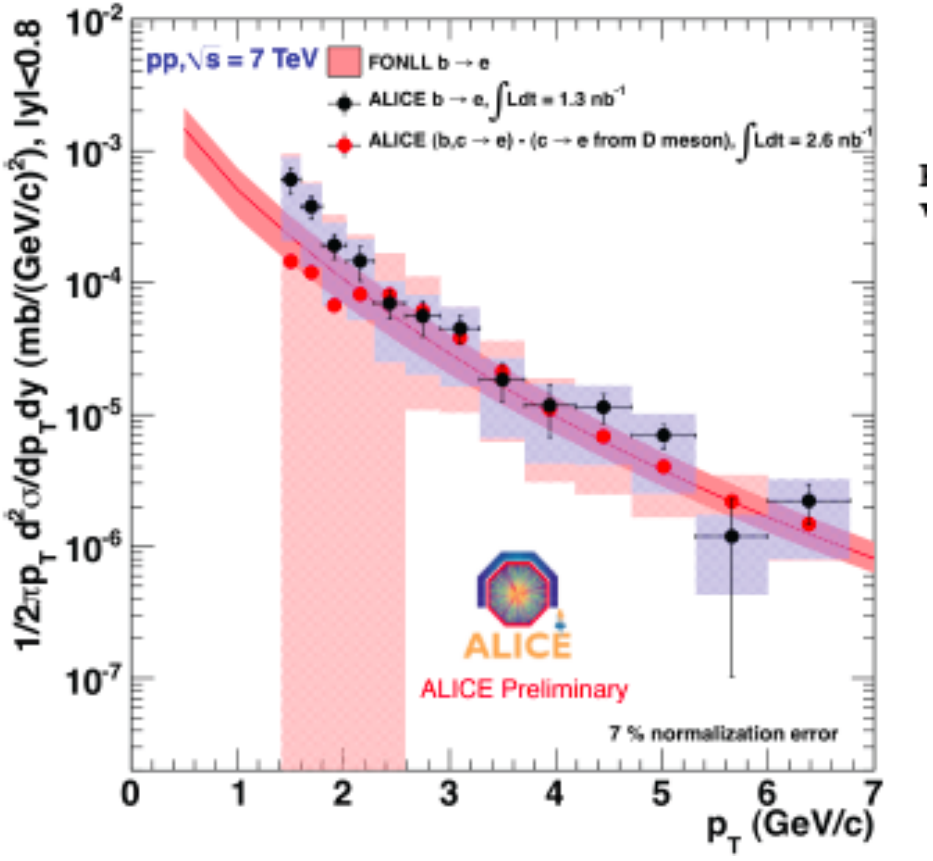


Improving beauty measurement

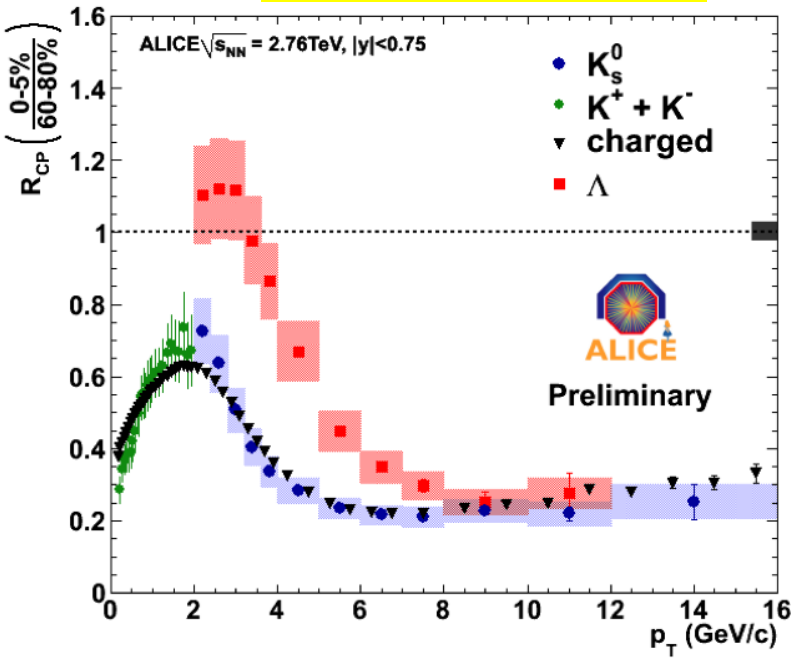
- Extend measurement of B production:
  - improve single displaced electron
  - displaced $J/\psi \rightarrow ee$
  - displaced $D^0 \rightarrow K\pi$
  - any of the previous + additional track/electron
  - fully exclusive channel (eg. $B^+ \rightarrow J/\psi\ K^+$, $B^0 \rightarrow J/\psi\ K^0$)
    → requires electrons (full barrel tracking, but clear TRD trigger possibility)

- Improvement on statistical accuracy of beauty measurement
  ➔implementation of topological triggers?

Coalescence of c and b quarks in QGP

NEWS FROM QM:

- Basic measurements:
  - baryon/meson → Λ_c/D and Λ_b/B vs. pt in PbPb and pp, or R_{CP} in PbPb
  - Elliptic flow of charm/beauty mesons and baryons vs p_T (down to low p_T)



- + Effect on heavy flavour electrons nuclear modification factor:

e.g.:

BR ($D^+ \rightarrow e^+ + X$) = (16.0 ± 0.4) %

BR ($D^0 \rightarrow e^+ + X$) = (6.53 ± 0.17)%

BR ($\Lambda_c \rightarrow e^+ + X$) = (4.5 ± 1.7)%

change in Λ_c/D from pp to AA affects hf electrons' R_{AA} !

~ 20 % suppression @ p_T ~ 2 GeV if Λ_c/D ~ Λ/K @ RHIC

G Martinez – Garcia et al: Phys. Lett. B 663 (2008) 55

P Sorensen and X Dong: Phys. Rev. C74 (2006) 024902

More exotic measurements: multi-charm baryons

- Multi-charm baryons (e.g. Becattini PRL95:022301, 2005)
  - Huge enhancement predicted by statistical models in case of hadronization by coalescence (x1000 for $\wedge_{ccc}$)
  - States not observed yet!
  - Possible detection strategy: 3 displaced electrons with the same charge in a small code (cascade decay in three steps of $\wedge_{ccc}$)

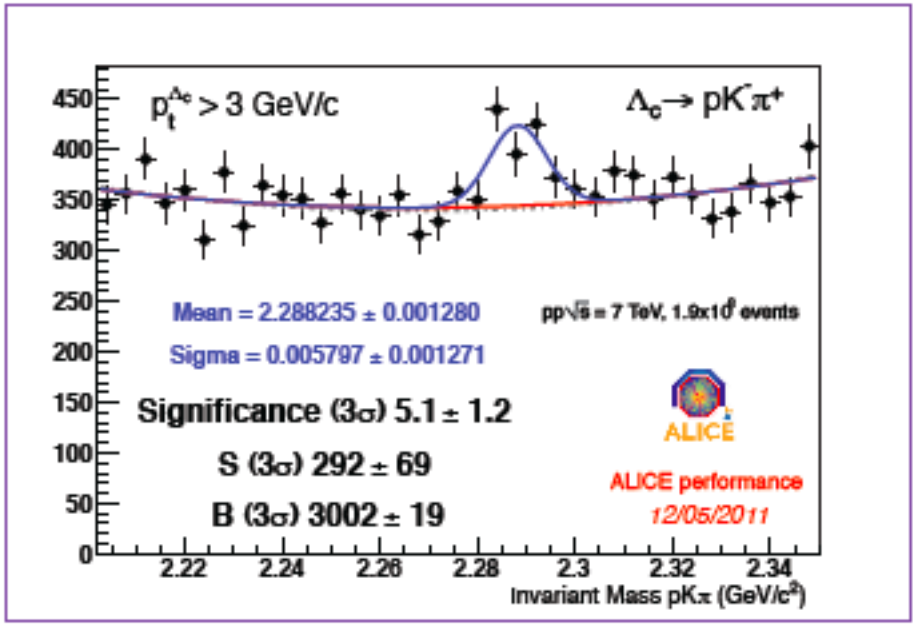
Issues for heavy flavor baryons measurement

- Charmed baryons: quite low lifetimes

$\Lambda_c^+(udc)$	m ≈ 2285 MeV	$c\tau \approx 60\ \mu m$
$\Xi_c^+(usc)$	m ≈ 2466 MeV	$c\tau \approx 132\ \mu m$
$\Xi_c^0(dsc)$	m ≈ 2472 MeV	$c\tau \approx 34\ \mu m$
$\Omega_c^0(ssc)$	m ≈ 2698 MeV	$c\tau \approx 21\ \mu m$

$D^+(c\bar{d})$	m ≈ 1869 MeV	$c\tau \approx 312\ \mu m$
$D^0(c\bar{u})$	m ≈ 1865 MeV	$c\tau \approx 123\ \mu m$
$D_s^+(c\bar{s})$	m ≈ 1968 MeV	$c\tau \approx 150\ \mu m$

Λ_c in pp @ $\sqrt{s}$ = 7 TeV



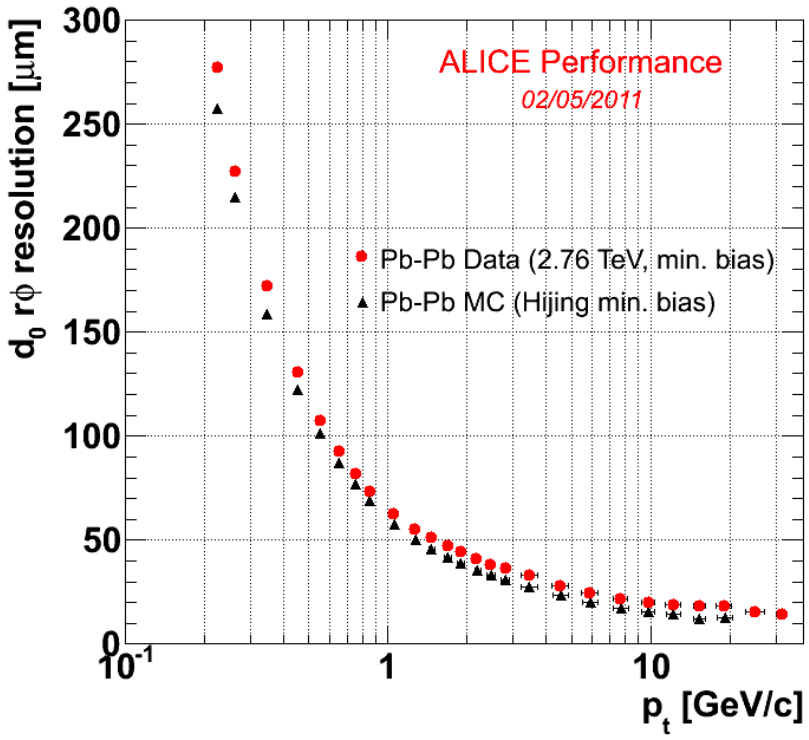
- Very accurate tracking and impact parameter resolution required

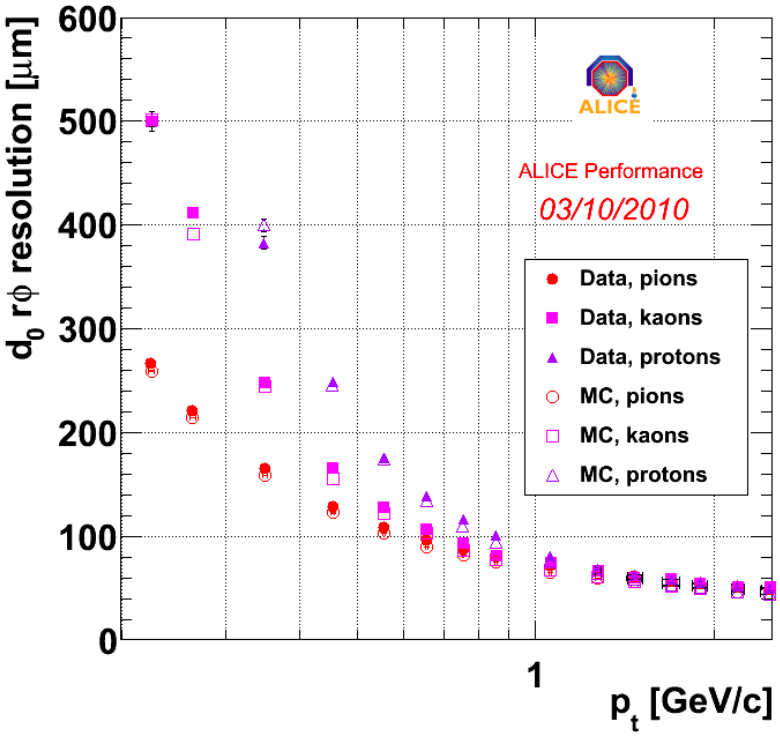
Implement a trigger based on displaced tracks + PID (proton)?

ITS limitations in charm measurement

- Charm: precise measurement of D mesons down to p_T~1
  - ➔ not at all trivial in PbPb with current setup

- Λ_c: beyond capabilities of current setup in HI collisions





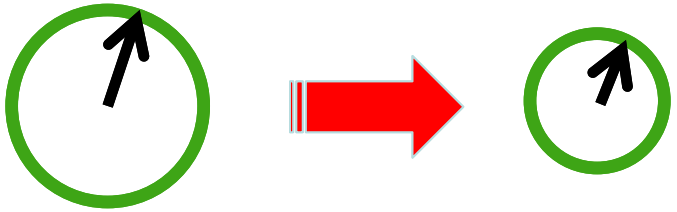
- d0 resolution should be better by factor 2
- + TPC and TOF PID for heavy background rejection (ITSupgrade + TPC)

Basic considerations for ITS upgrade

- Vertex detector closer to the beam
- Much lighter detector

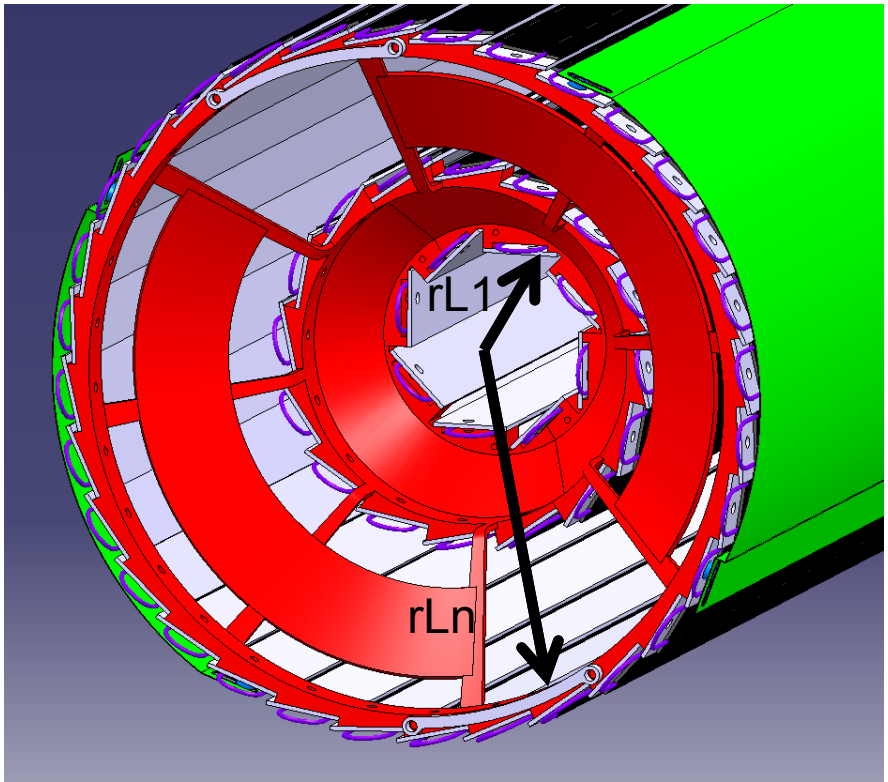
Present beam pipe:
R = 29.8 mm
Thickness = 0.8 mm

Reduced beam pipe:
R = 20 mm
Thickness = 0.5-0.6 mm



- Radius of "outermost" layer rLn~ 43 cm (= current)

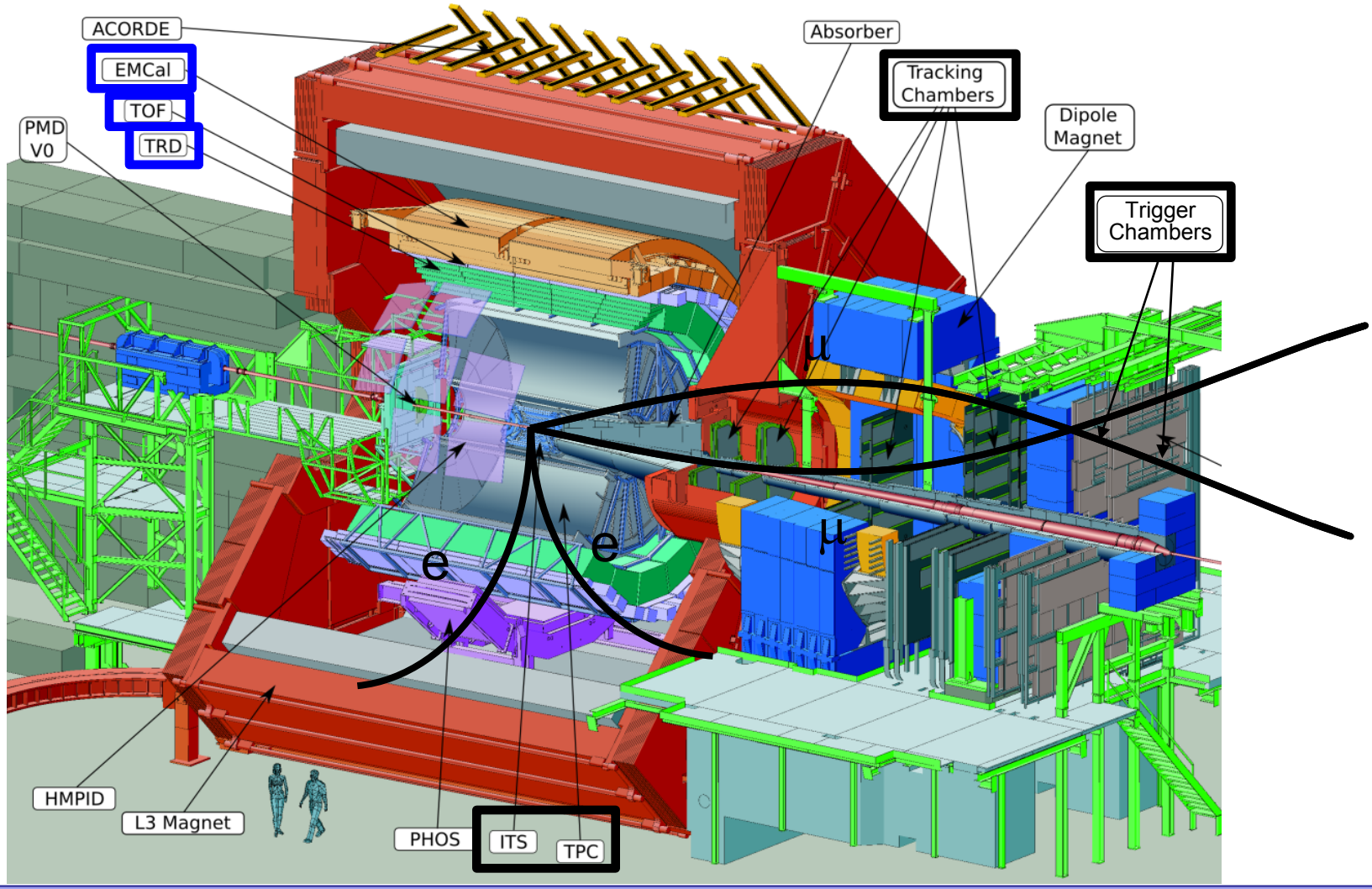
- Radius of "innermost" layer depends on beam pipe radius, but rL1~ 2.2 cm seems possible (currently 3.9 cm)



- Possible properties of new Pixel-detectors ?

- Material budget:
  X/X_0 ~ 0.5% (currently: 1.14%)
- Intrinsic resolution:
  ($\square_{r\square}$, $\square_z$) ~ (6,6) $\square$m (currently (12,100) $\square$m)

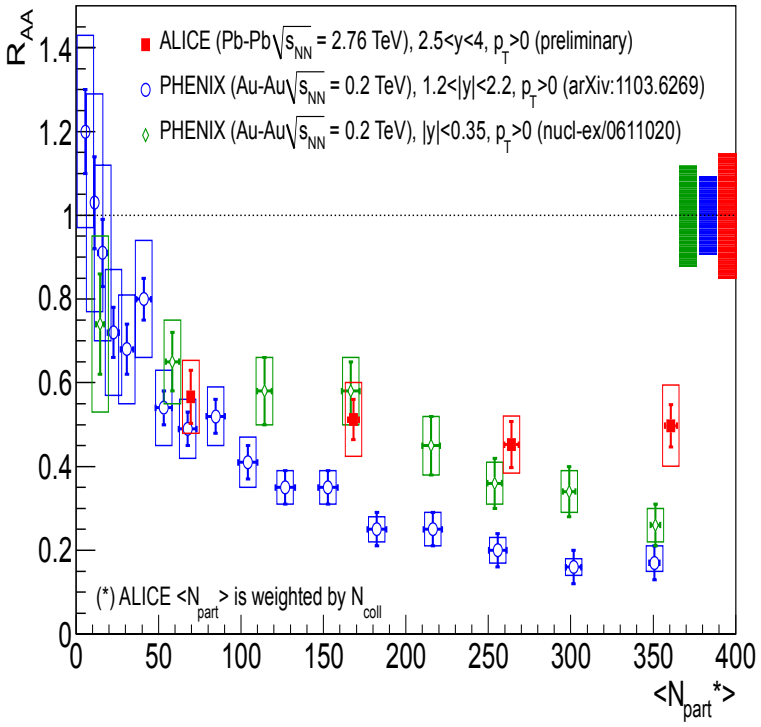
HF measurement at forward rapidity



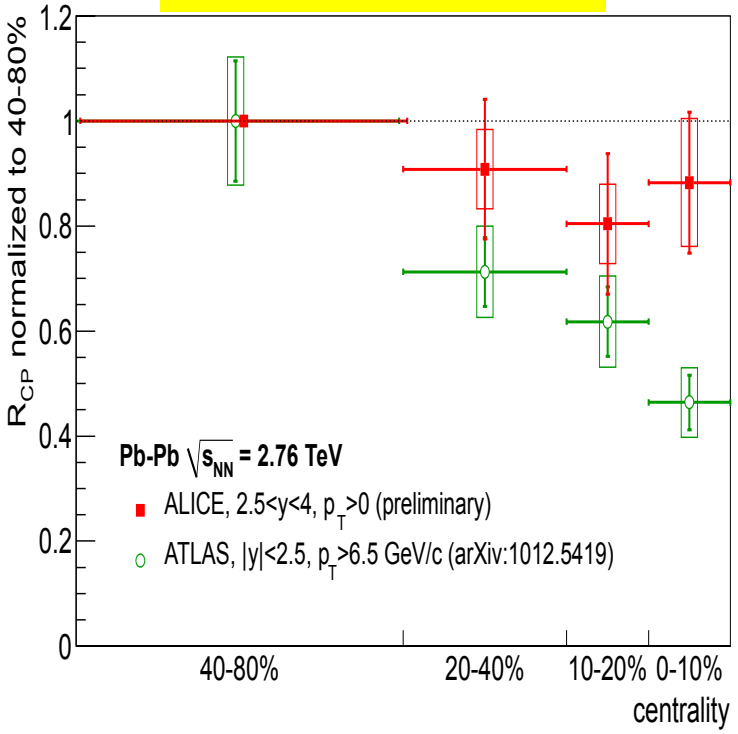
Coverage down to p_T=0

2.5<y<4.0: ➔$\mu^+\mu^-$, μ-trigger

Quarkonia



NEWS FROM QM:

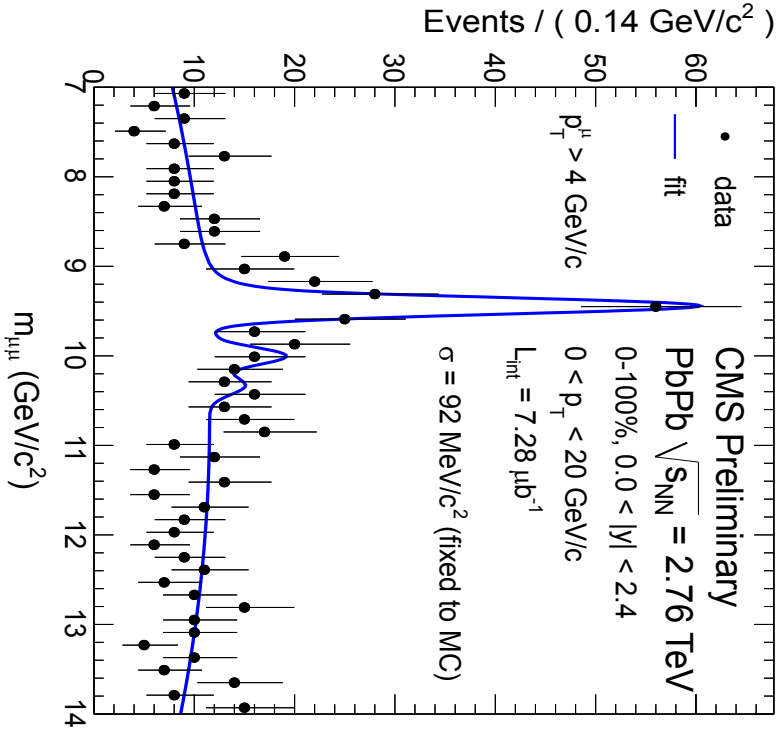


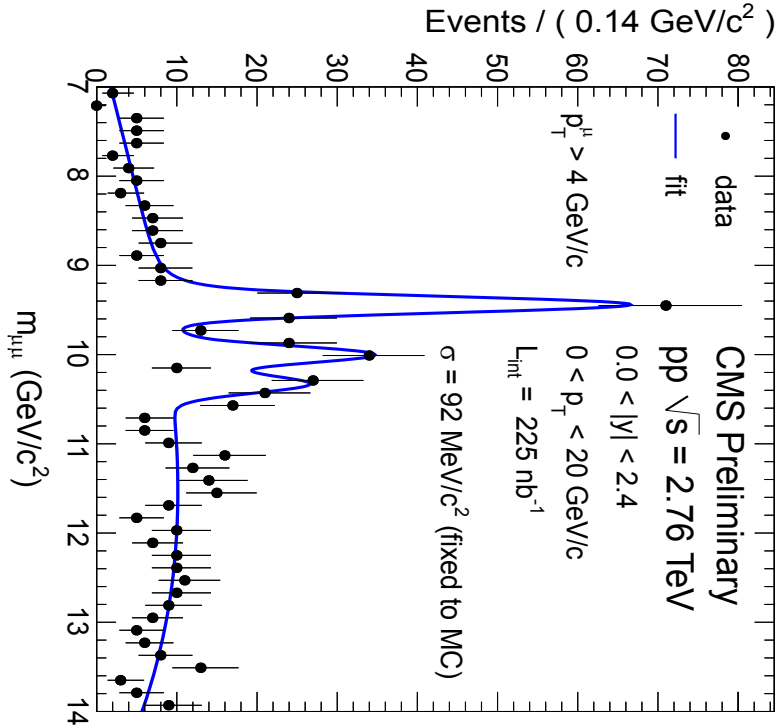
- J/ψ suppression a smoking gun for long time, but quite complicated interpretation:
  - energy dependence (SPS vs RHIC vs LHC), p_T dependence, y dependence
    ➔the role of cold nuclear matter effects
  - J/ψ at LHC: regeneration also (besides suppression)?

Measurements with large y and p_T coverage

Quarkonia

NEWS FROM QM:

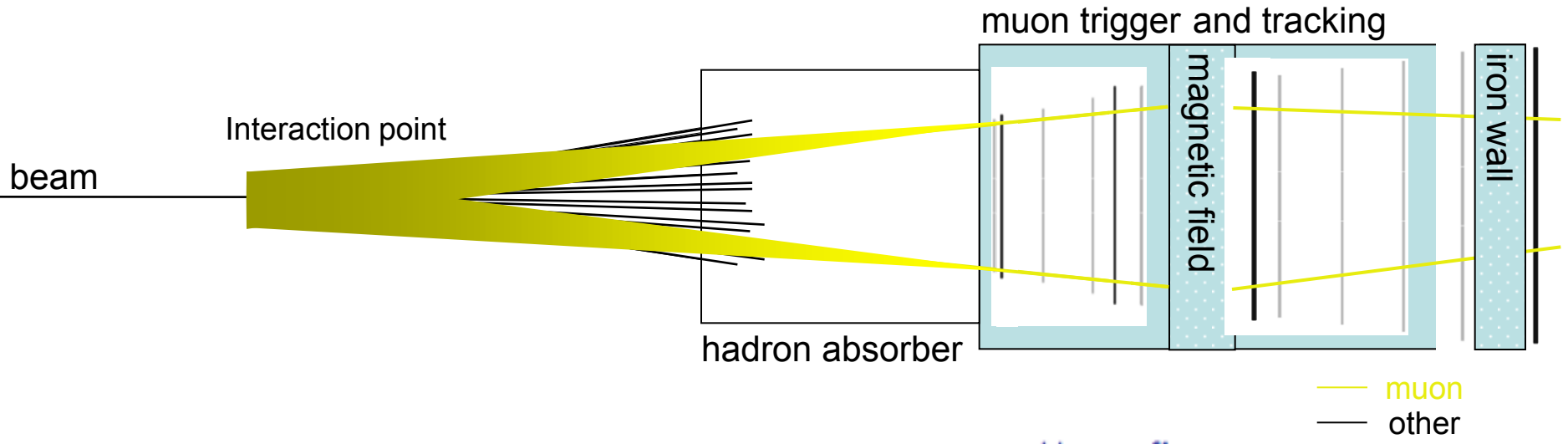


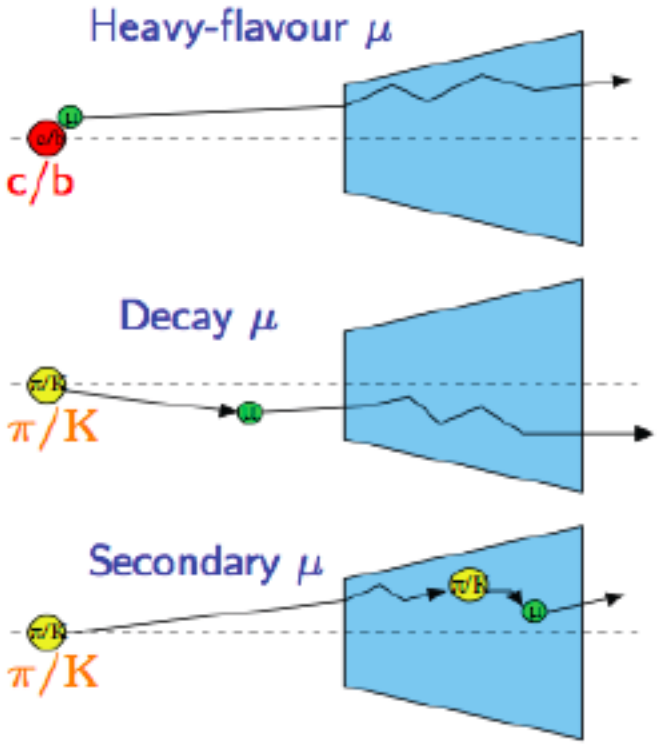


What about melting of excited states?

- ϒ(2S+3S) production relative to ϒ(1S) in pp and PbPb
- ψ' vs J/ψ in pp and PbPb
  - ➔ accessible only by ALICE down p_T = 0

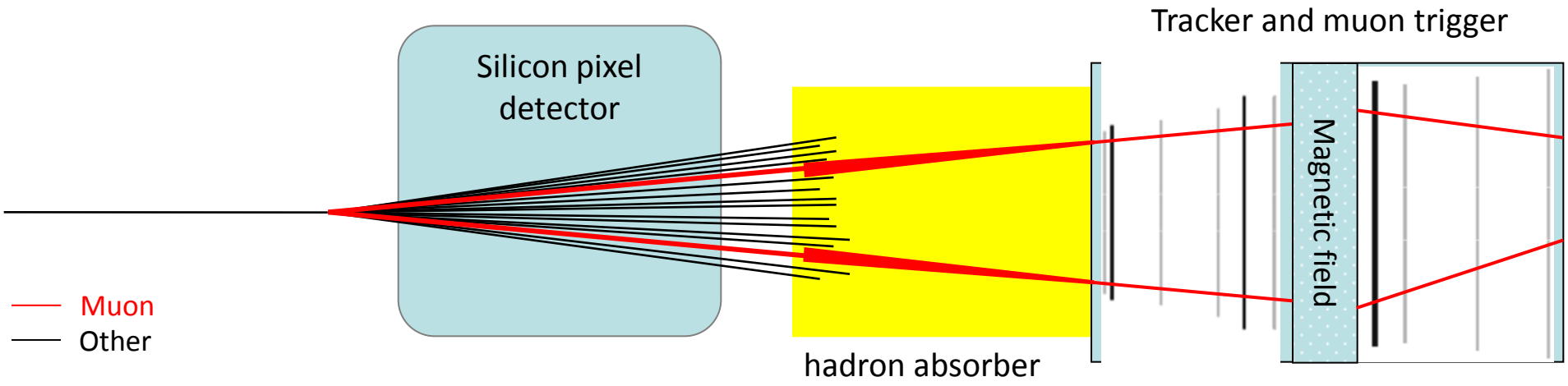
Issues in HF measurements at forward y in ALICE

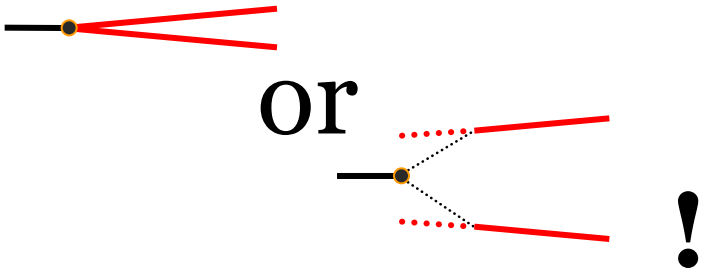




- No secondary vertex tagging
- No experimental capability to separate c/b
- Large combinatorial background
- Degradation in mass resolution

Muon spectrometer upgrade





Track Matching in coordinates

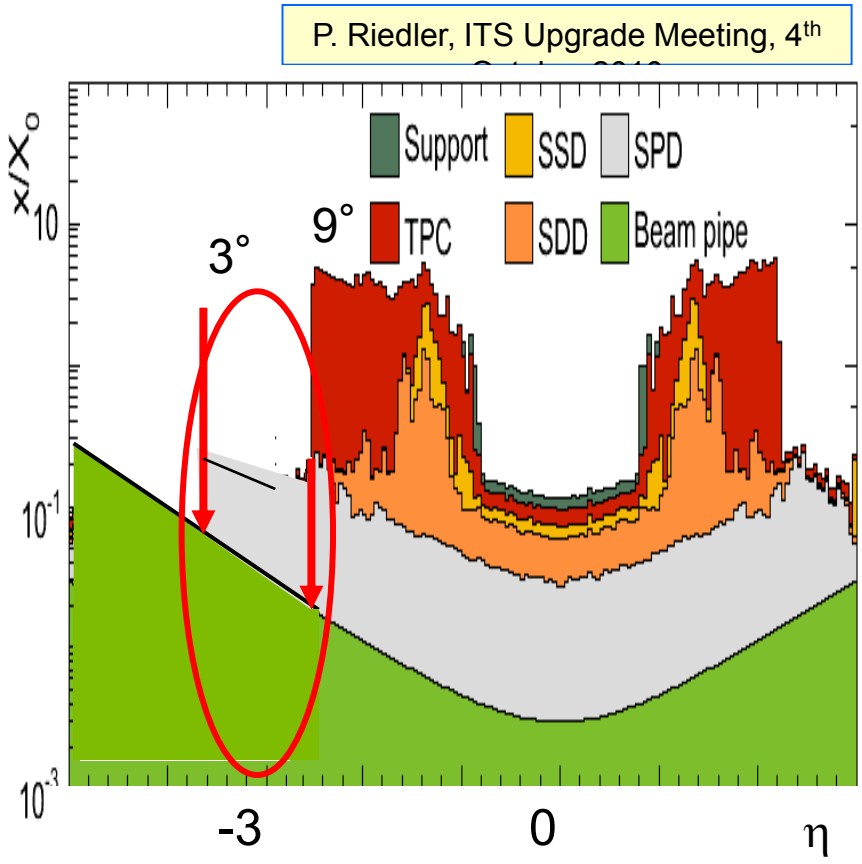
Challenge: tracking with B = 0

- Improvement of vertex resolution
- Improvement of mass resolution

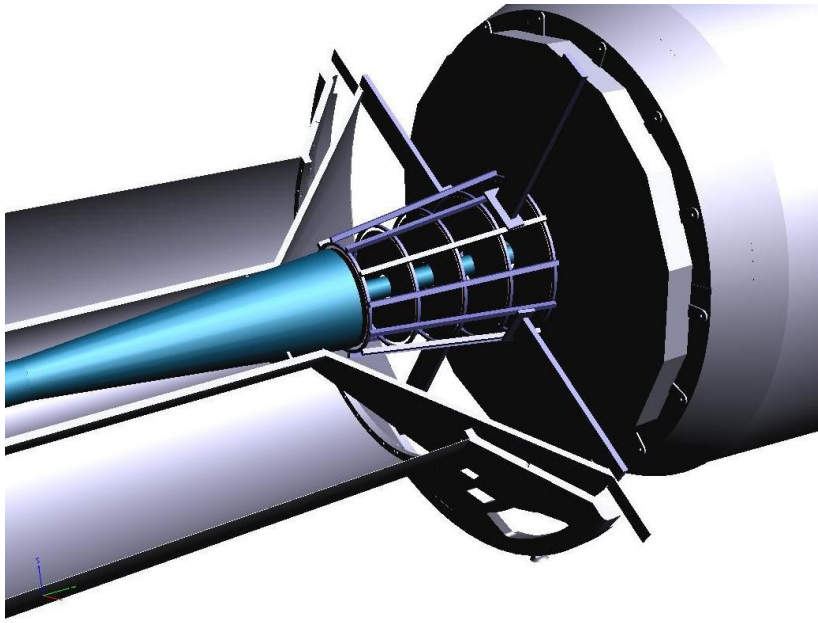
HF precision measurements at forward y

- Open charm and beauty
  - Discrimination of decays from background on the basis of displacement from primary vertex (single displaced muon or dimuon from $B \rightarrow \mu \nu X$, $B \rightarrow D \nu X$, $D \rightarrow \mu X$)
  - Complementary to central barrel covering different x
  - Multi-muon measurements
- Semi-exclusive or exclusive B decays and feeddown
  - Displaced $J/\psi \rightarrow \mu\mu$
  - Exclusive decays (e.g. $B^+ \rightarrow J/\psi\ K^+$ with kaon measured in pixel tracker)
  - Identification and reconstruction of secondary J/psi mesons essential to investigate medium effects on primary charmonia
- Measurement of ψ'
  - Improved mass resolution: separation from J/ψ and much higher significance

Challenges for precision measurements at forward y



- Pixel telescope under study:
  5 stations covering muon arm y
  + conical beam pipe



- Large material budget from beam pipe
  At forward y
  ➔might require a conical beam pipe

- Tracking with B = 0 (matching efficiency/fake matches)