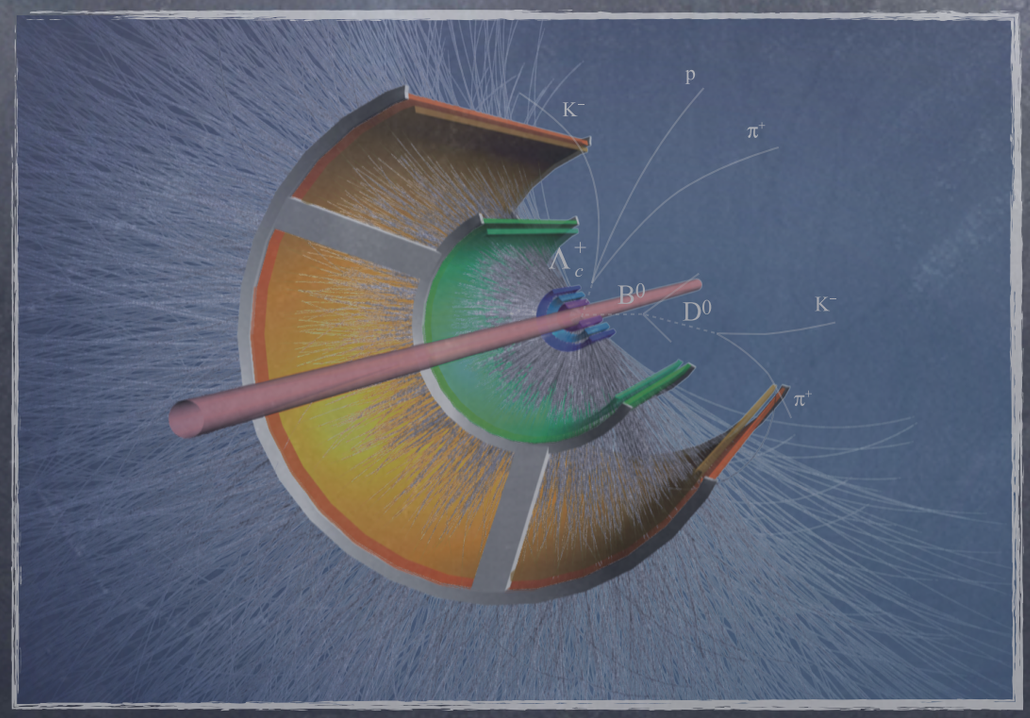
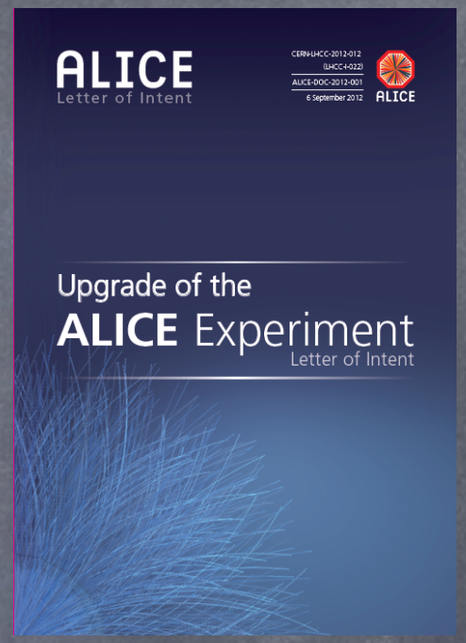
Inner Tracking System (ITS) Upgrade of ALICE

Levente Molnar
(CNRS-IPHC)

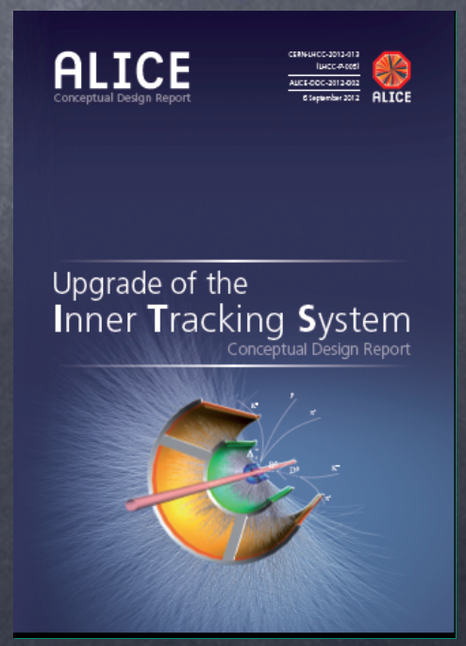


Outline

- ALICE Upgrade strategy for the 2nd LHC Long Shutdown: 2018/2019
- ITS Upgrade
  - Physics objectives
  - Detector technology
  - Physics performance
- Summary



CERN-LHCC-2012-012
CERN-LHCC-2012-013



ALICE Upgrade strategy

(extract)

See P. Giubellino's talk for the complete ALICE Upgrade program overview

- High precision measurements of rare probes at low p_T
  → cannot be selected with a trigger
  → collect a large sample of events on tape

- Target recorded luminosity and events

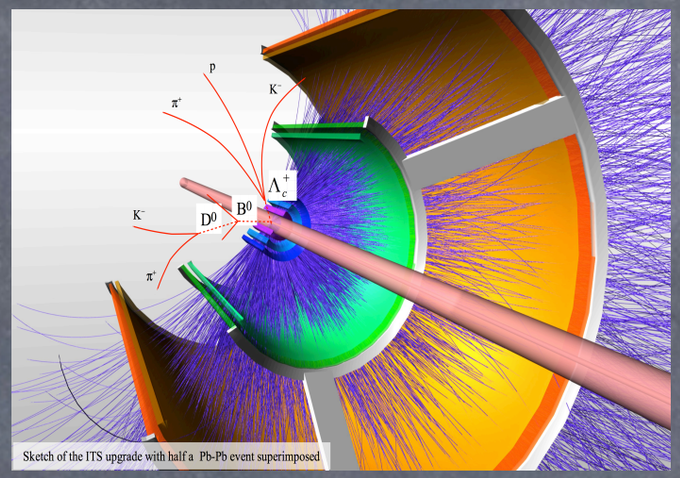
RO = Read-out

Pb-Pb	≥ 10 nb^{-1}	8×10^{10} events (~ 50 kHz min. bias RO rate)
pp (@5.5 TeV reference)	≥ 6 pb^{-1}	1.4×10^{11} events (few 100 kHz RO rate)

- A factor **100** gain in statistics over currently approved program …
  … and significant improvement of vertexing and tracking capabilities

- To achieve upgrade goals:
  - Upgrade the readout and online systems to cope with the 50 kHz Pb-Pb minimum bias interaction rate and apply data reduction
  - Improve vertexing and tracking at low p_T → NEW ITS

ITS Upgrade project

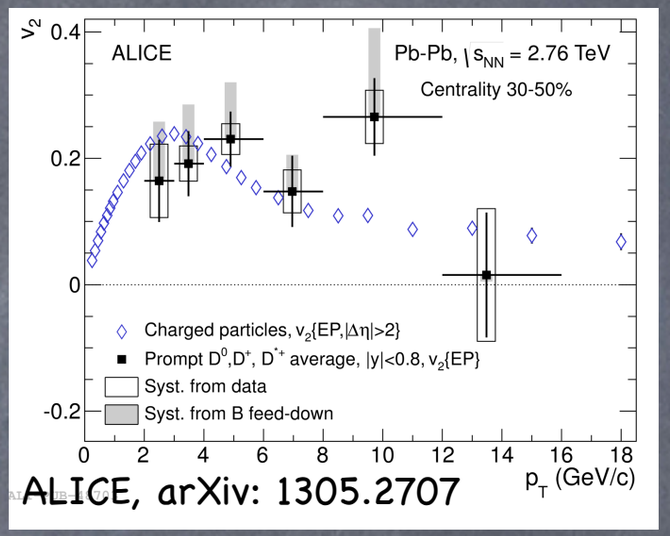


- Project approved by LHCC in Sept. 2012
- Technical Design Report by the end of 2013
- Enter production phase late 2014
- Installation commissioning 2017/2018
- French Institutes (CNRS-IN2P3) in the project: IPHC+Univ. (Strasbourg), LPSC+Univ. (Grenoble)

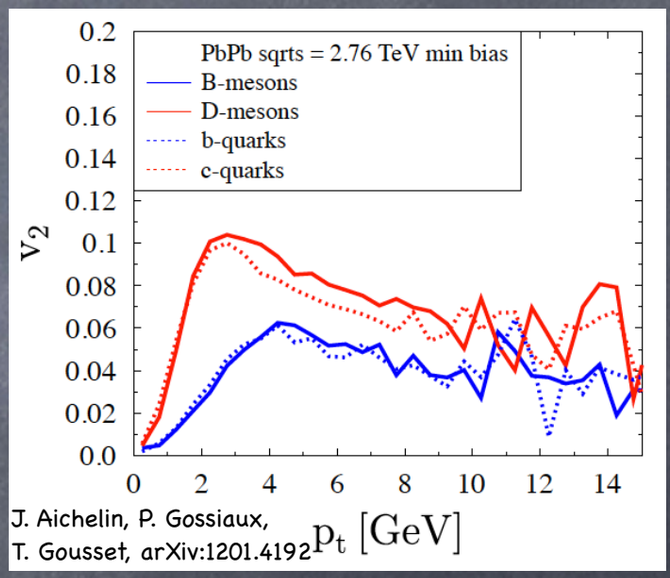
ITS Upgrade physics objectives I.

- Study thermalization of partons with focus on charm and beauty quarks
  - Measurements accessible for the first time in heavy-ion collisions:
    - Charm and beauty baryons down to very low p_T
      Λ_c and Λ_b ($\Lambda_b \rightarrow \Lambda_c + X$)
      → Baryon/meson ratios: Λ_c/D and Λ_b/B
      → Probe of hadronization mechanism
  - Elliptic flow of charmed and beauty mesons and baryons down to low p_T
    → Prove of heavy quark transport coefficients , EoS

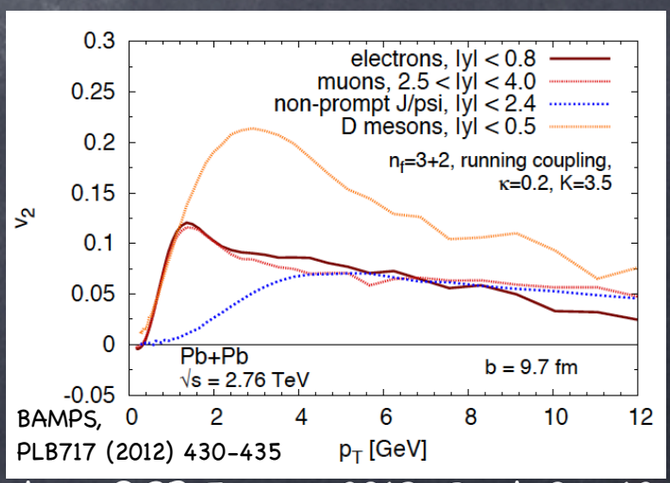
Details in: CERN-LHCC-2012-013



ALICE, arXiv: 1305.2707



J. Aichelin, P. Gossiaux, T. Gousset, arXiv:1201.4192

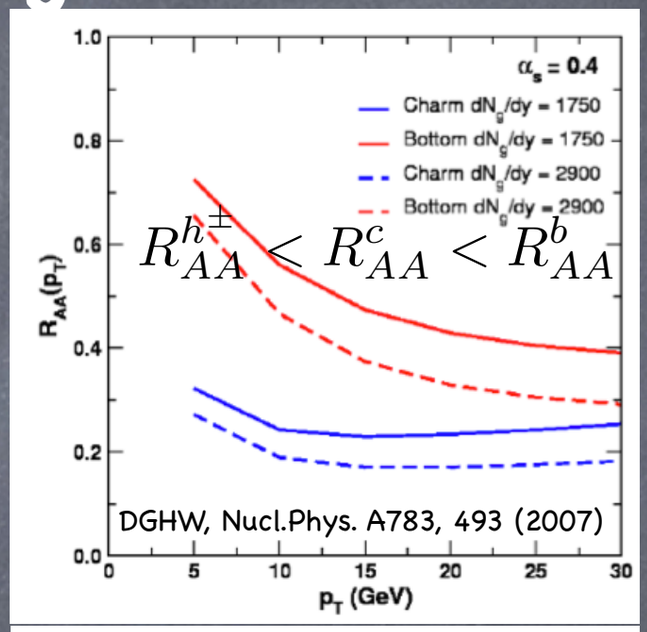


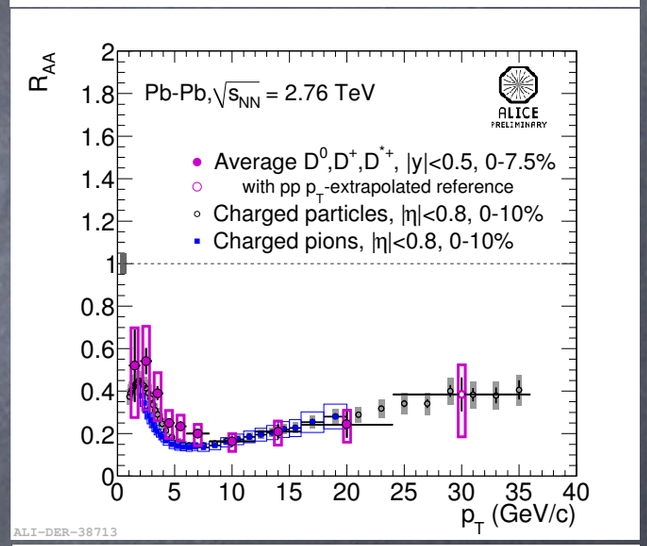
BAMPS, PLB717 (2012) 430-435

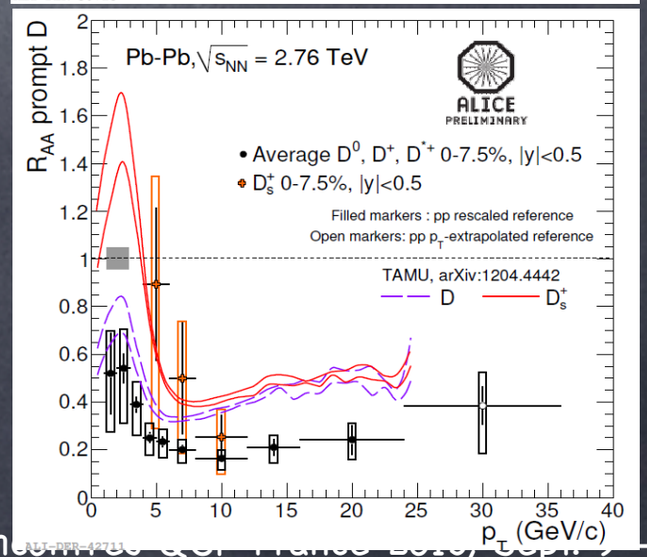
ITS Upgrade physics objectives II.

- Study quark mass dependence of in-medium energy loss via the nuclear modification factors R_{AA} of D and B mesons separately for the first time
  - Beauty via displaced $D^0 \rightarrow K\pi$
  - Beauty via displaced $J/\psi \rightarrow ee$
- Improved measurement of single displaced electron

Details in: CERN-LHCC-2012-013



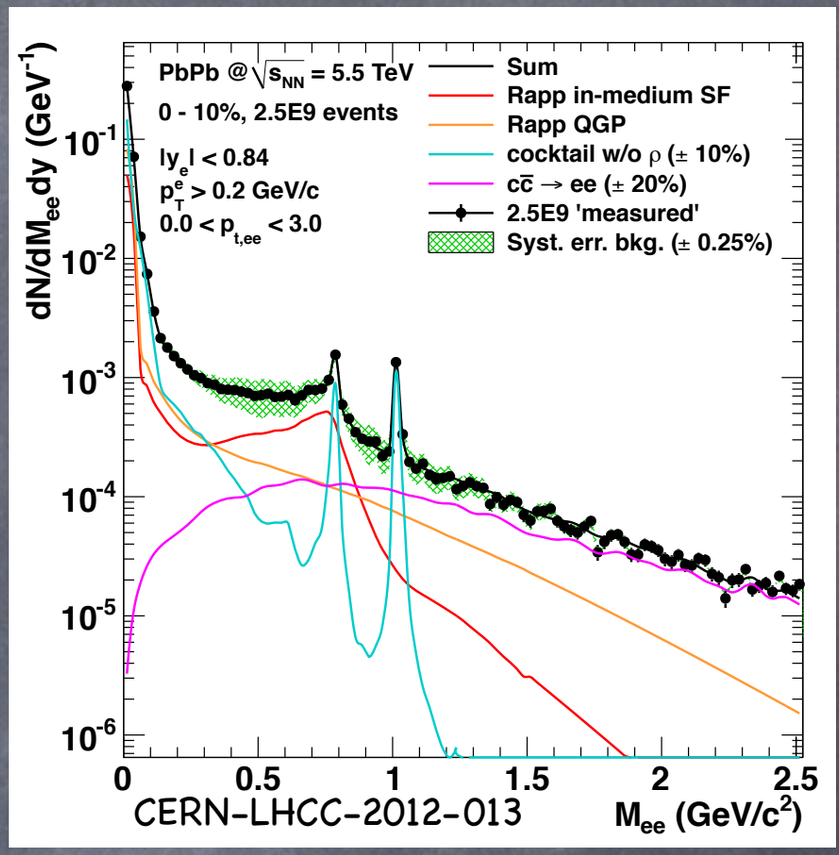


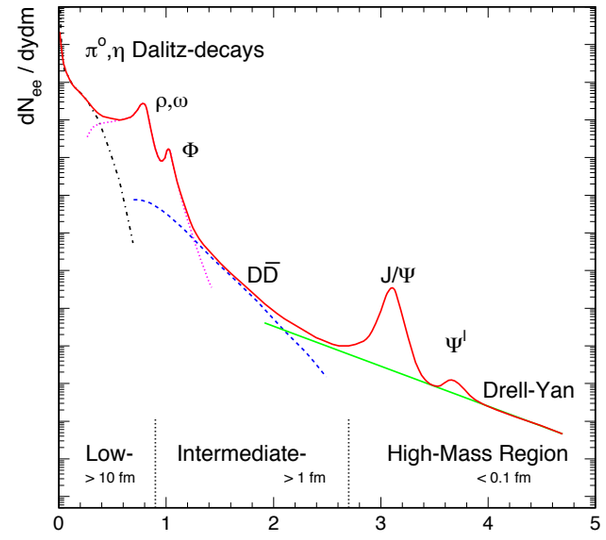


ITS Upgrade physics objectives III.

- Study of quarkonium dissociation, regeneration as probe of deconfinement and medium temperature
- Study of thermal electromagnetic radiation from the early stage of quark gluon plasma
  - In-medium modifications of hadronic spectral functions, related to chiral symmetry restoration
- Study of hypernuclei states

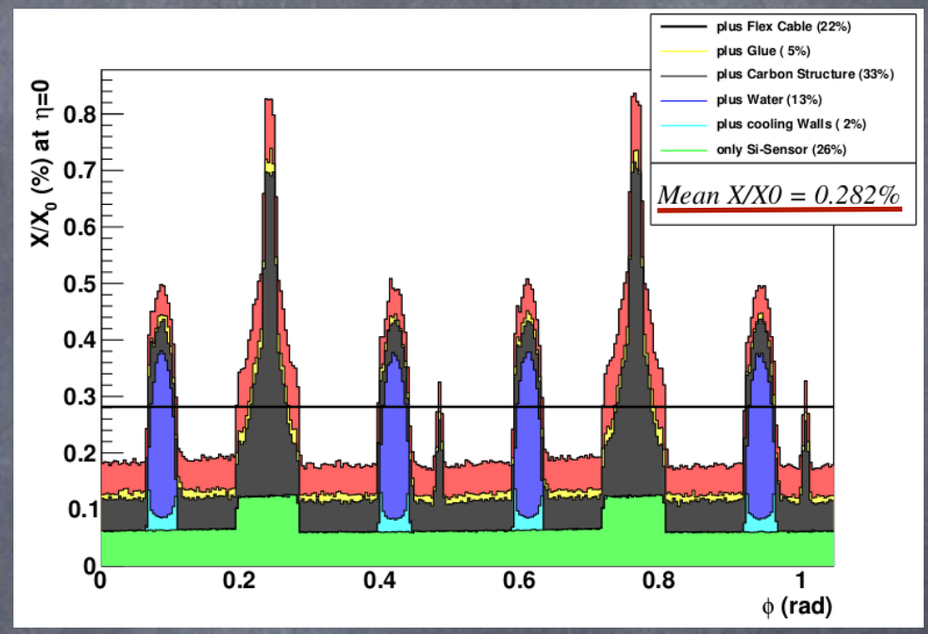
$$ {}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}, \qquad {}^{4}_{\Lambda}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + \pi^{-}, \qquad {}^{3}_{\Lambda}\mathrm{He} \rightarrow {}^{3}\mathrm{He} + \pi^{-} + p $$





ITS Upgrade design I.

- Improve impact parameter resolution by a factor of ~3
  - First layer closer to IP: 39 mm → 22 mm
  - Reduce material budget: X/X_0 from 1.14 % to 0.3 % (0.8%) for inner (outer) layers

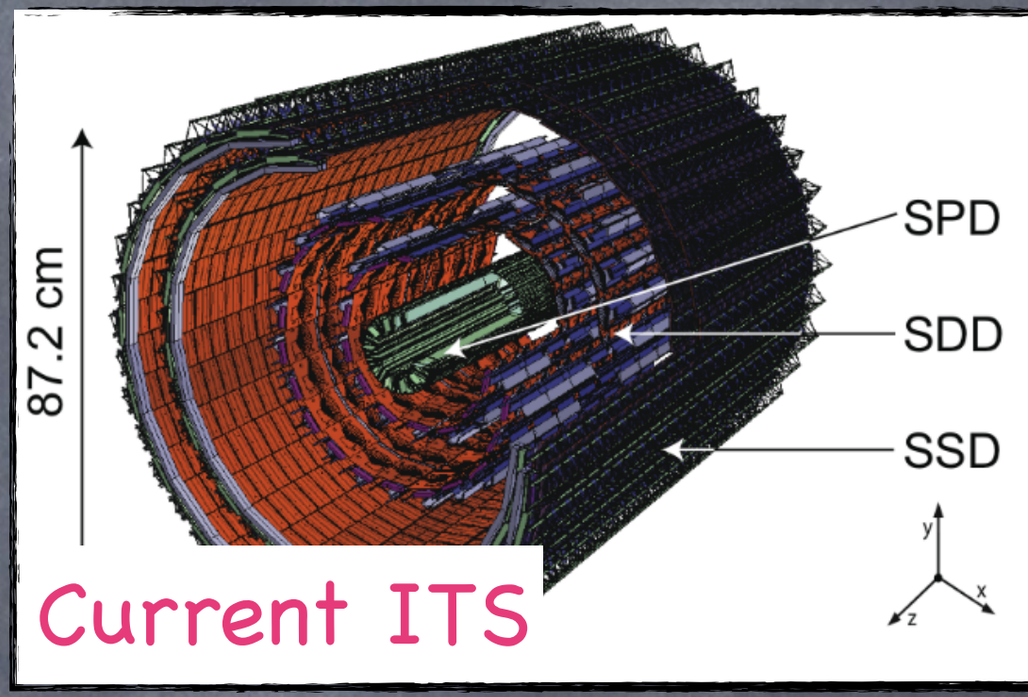


	current ALICE	ALICE upgrade	ATLAS upgrade	CMS upgrade
innermost point (mm)	39.0	22.0	25.7	30.0
x/X_0 (innermost layer)	1.14%	0.3%	1.54%	1.25%
d_0 res. $r\varphi$ (μm) at 1 GeV/c	60	20	65	60
hadron ID p range (GeV/c)	0.1–3	0.1–3	–	–

- Reduce pixel size for inner/outer layers from 50x425 um^2 to O (30x30 um^2 / 50x50 um^2)

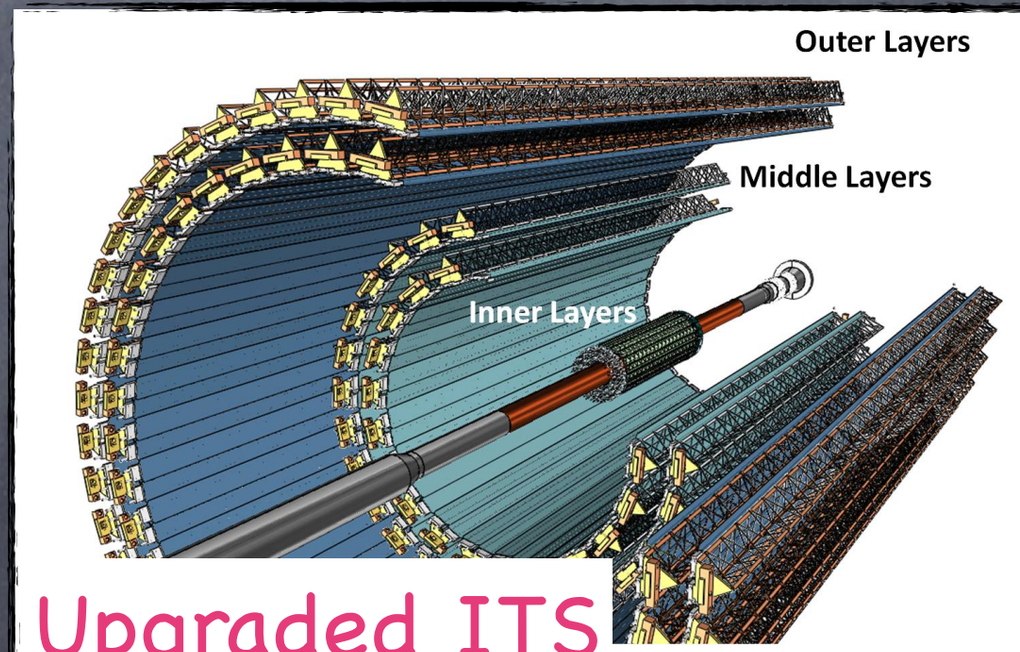
ITS Upgrade design II.

- Improve tracking efficiency and p_T resolution at low p_T
  - Increase granularity 6 → 7 layers
  - Increase radial coverage from 39 - 430 mm to 22 - 430 mm



Current ITS

- Fast readout:
  - readout of Pb-Pb interactions at > 50 kHz and pp interactions at few 100 kHz
- Fast insertion - removal
  - possibility to replace modules during the yearly shutdown



Upgraded ITS

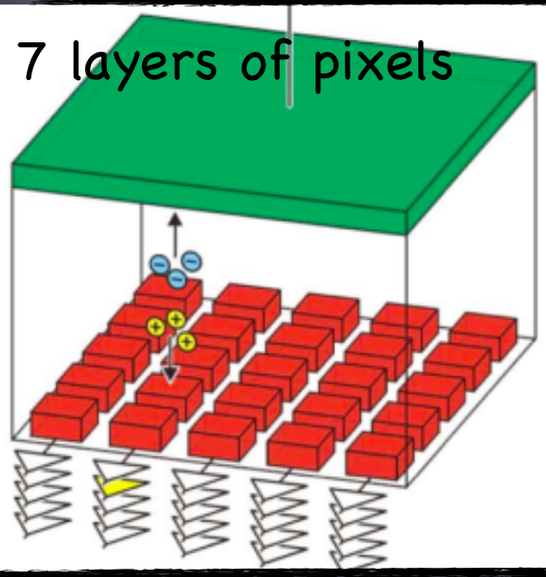
ITS Upgrade technology

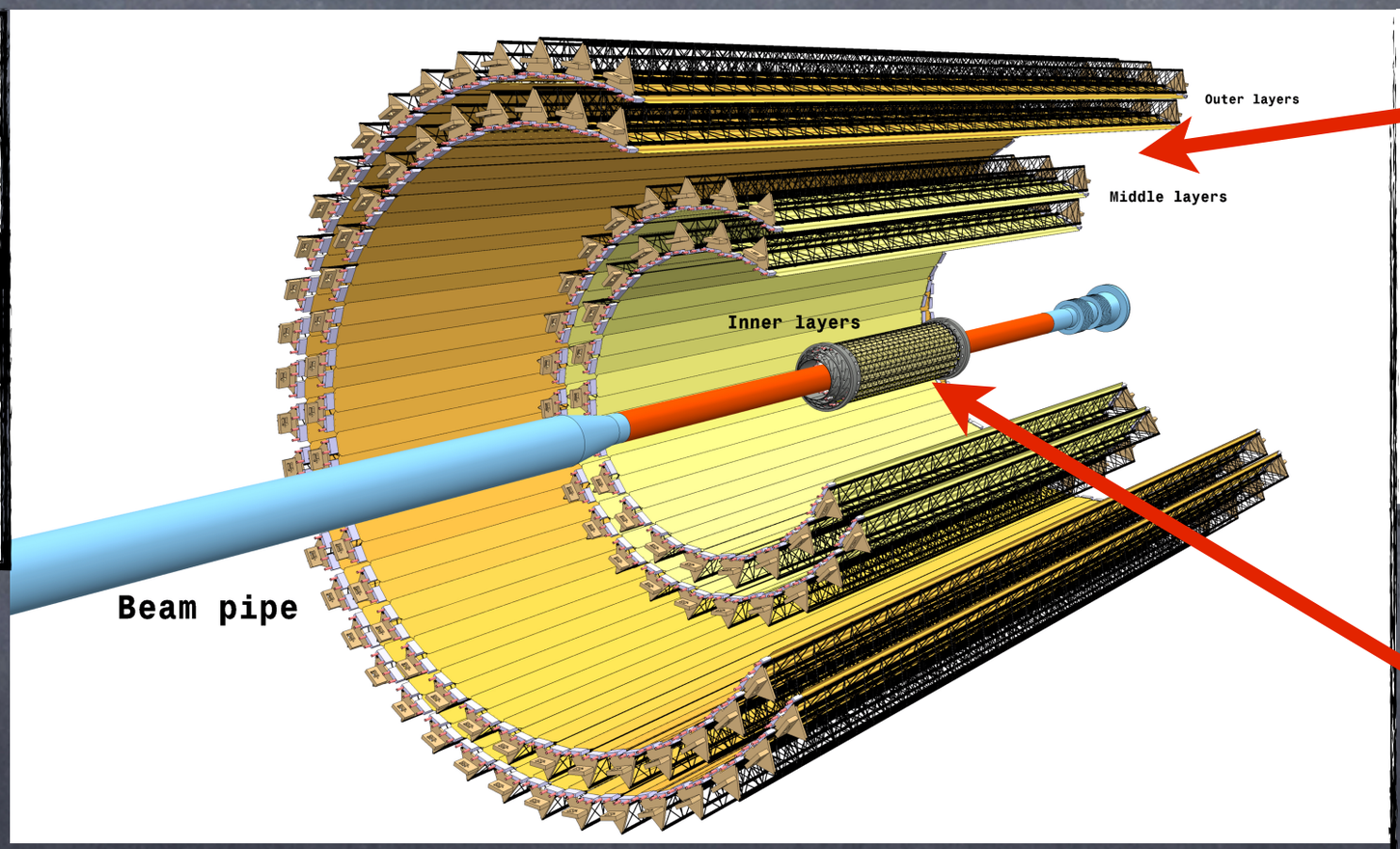
ALICE

Option A:
7 layers of pixel detectors

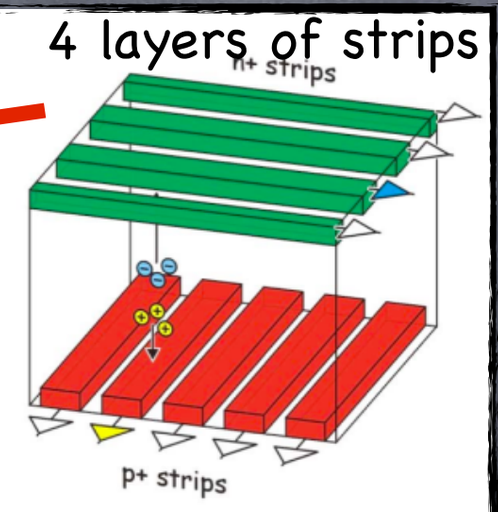
Option B:
3 (inner) layers: pixel detectors
4 (outer) layers: strip detectors

7 layers of pixels

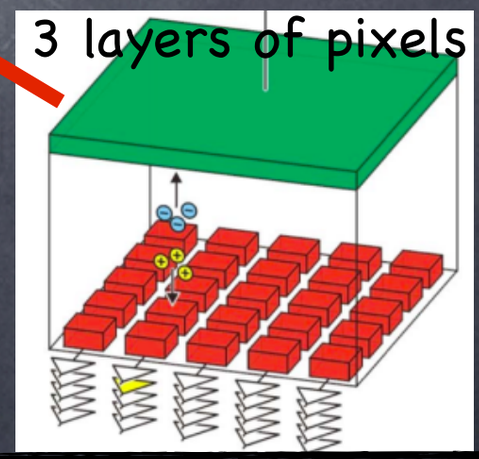




4 layers of strips



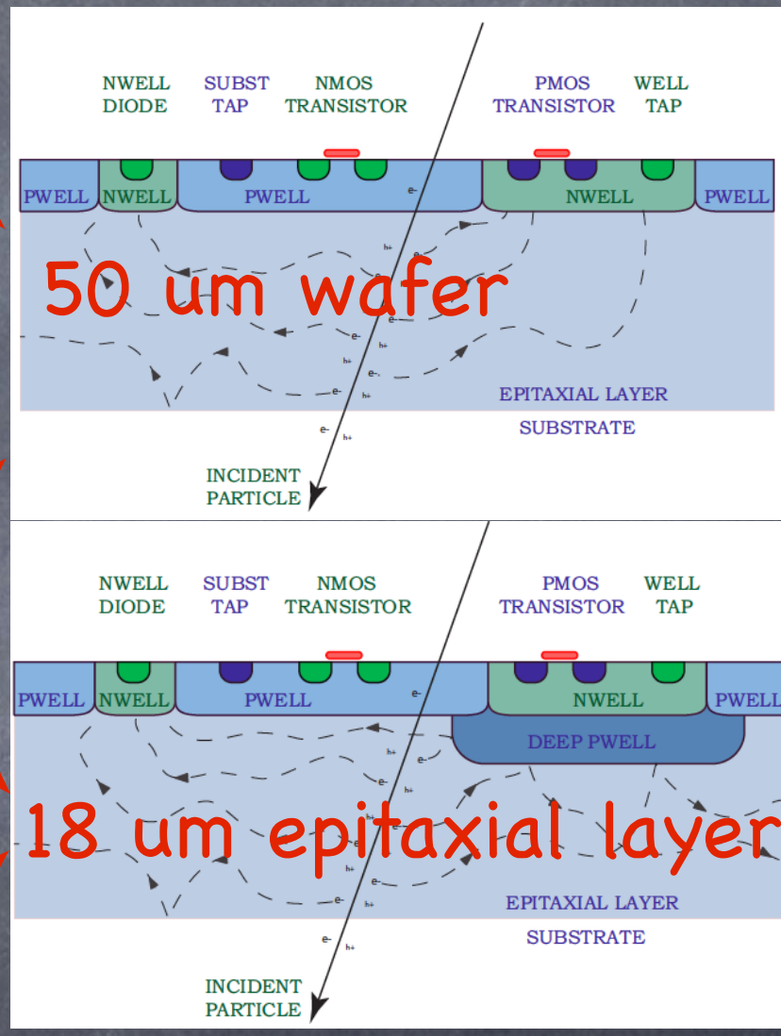
3 layers of pixels



Compromise between better standalone tracking efficiency and p_T resolution (Option A) with respect to PID capabilities (Option B)

CMOS pixel sensor R&D

- Development of the Monolithic Active Pixels (MAPS) in Tower/Jazz 18 um technology
- Improved radiation hardness (TID) due to smaller technology node
- High resistivity (1-6 kΩcm) epitaxial layer → substantial depletion with 1-2 V
- In-pixel circuitry available: e.g. in pixel discriminators
- Goals: study radiation hardness, optimize charge collection and read-out architecture

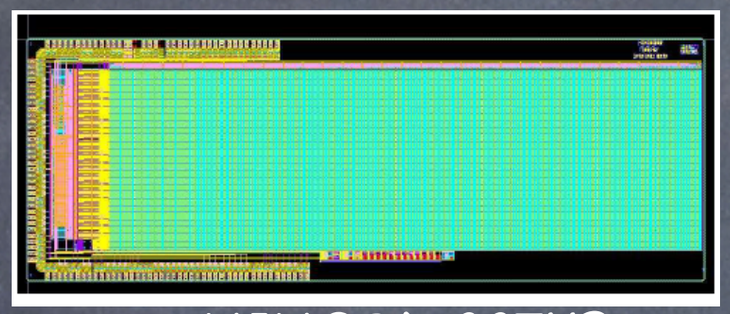


Pixel prototypes I.

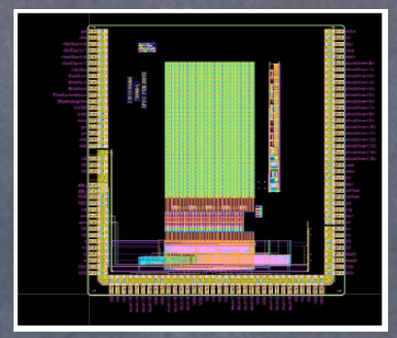
ALICE

- **MISTRAL (IPHC / IRFU)**

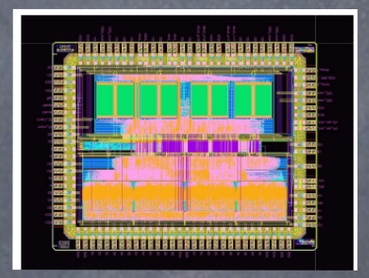
  - Built on the experience from the ULTIMATE (MIMOSA-28) for the STAR-PXL detector



MIMOSA-22THRa



MIMOSA-22THRb



SUZE-02

Correlated Double Sampling

  - Rolling-shutter readout with in-pixel amplification and CDS
    350 rows x 1300 columns (pixel size: 22 μm x 33 μm)

  - Double-row readout (2 discriminators per column)

  - Frame integration/readout time ~30 μs

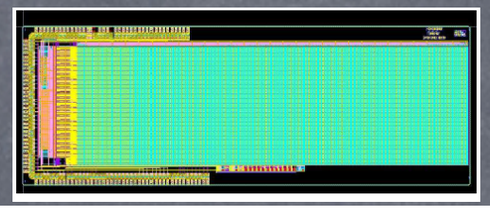
  - Power consumption ~300mW / cm

Pixel prototypes II.

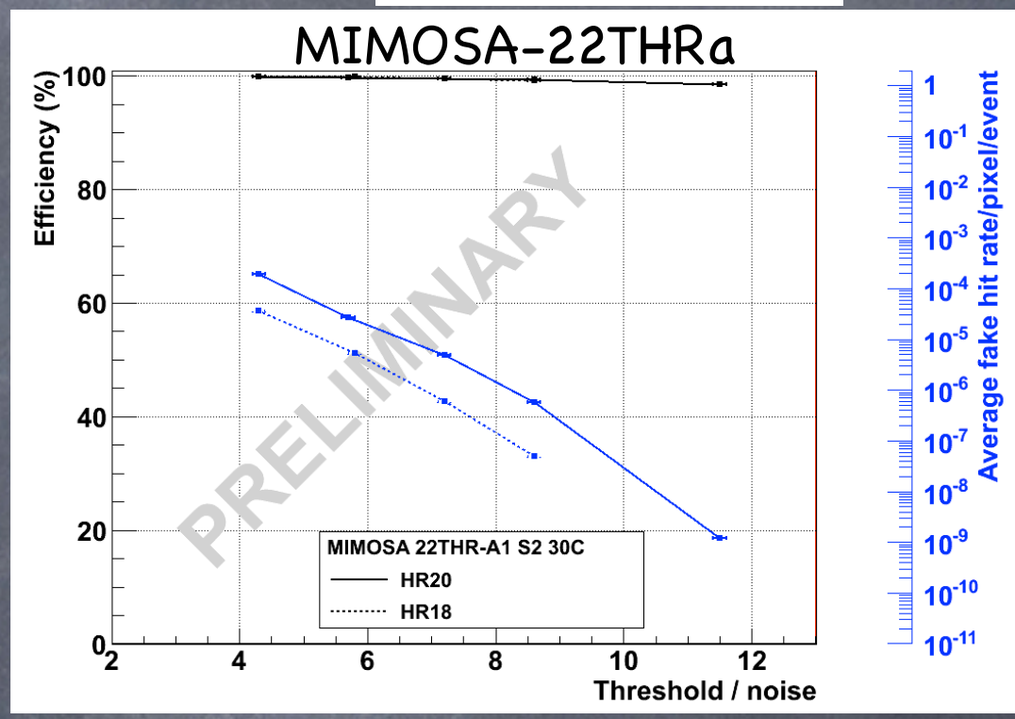
- **ASTRAL (IPHC-IRFU)**
  - Derived from MIMOSA-28 (STAR-PIXEL) + AROM
    - AROM: Accelerated Readout MIMOSA
      double (four) row read-out
  - Signal discrimination embedded in each pixel
    (MISTRAL: end of column discriminator)
  - Integration time 15 (10) μs
    (MISTRAL : 30 μs)
  - Power consumption 150 (200) mW

Recent MIMOSA test beam

ALICE & PICSEL groups

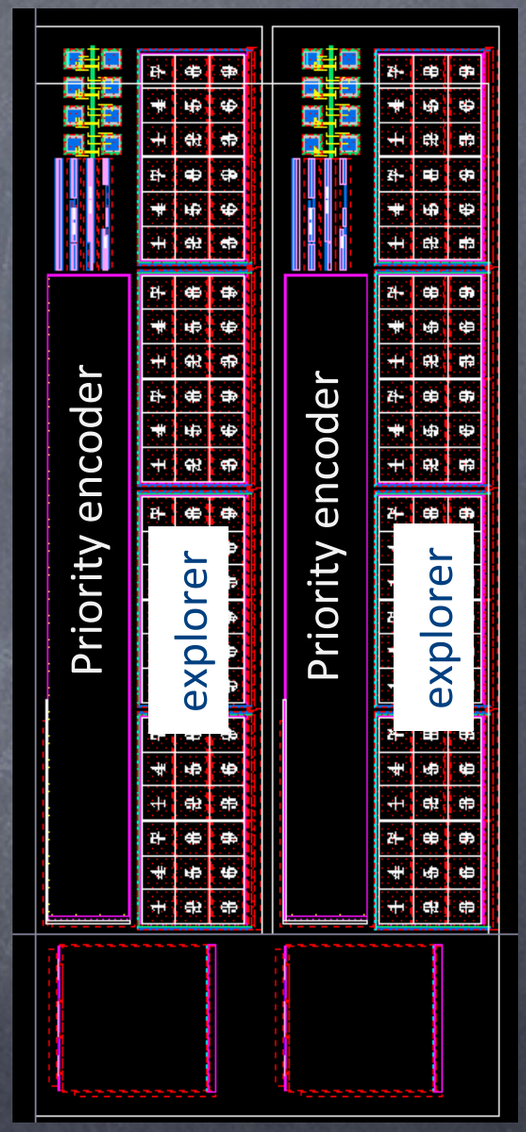


- Test beam DESY 19-31 Aug 2013
  - MI-22THRa: validation of read-out architecture,
    integration time: ~ 50 μs, digital+analogue
  - MI-34: pixel optimization,
    integration time: ~ 32 μs, analogue
  - Studies as a function of ...
    ...temperature,
    ... irradiation,
    ... pixel dimension (22x33 μm^2, ..., 22x66 μm^2),
    ... diode size, ...



Pixel prototypes III.

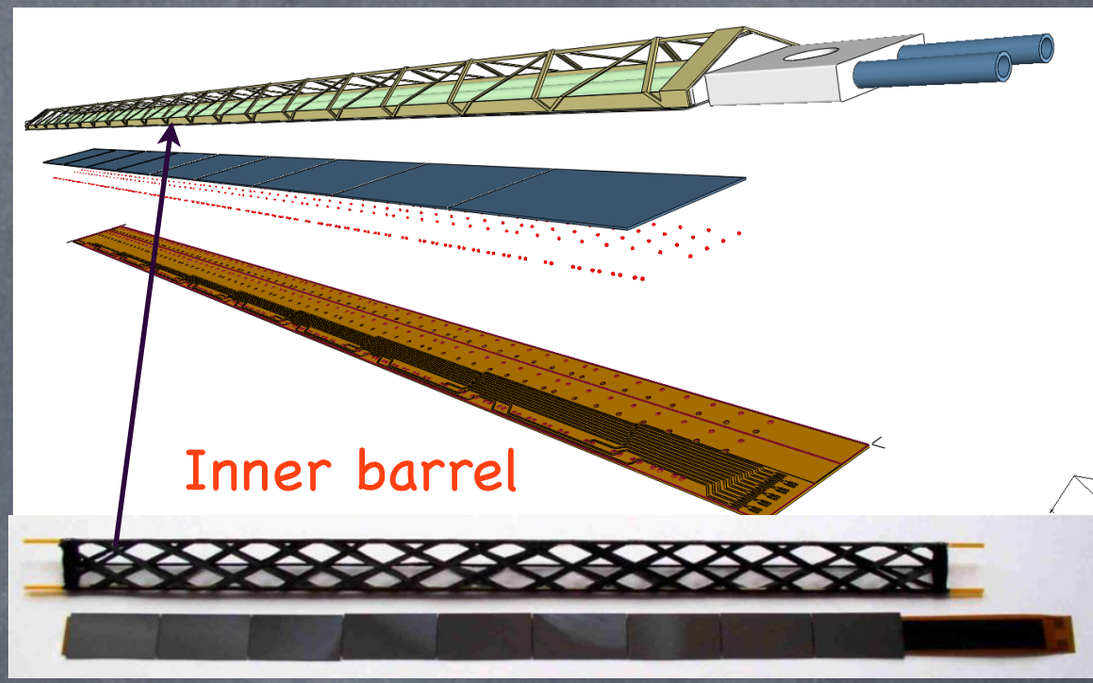
- ALPIDE Chip (CERN - INFN - CCNU)
  - Signal discriminator inside the pixel, data driven sparsified readout
  - Integration (~readout time) ~ 4 μs
  - 512 rows x 1000 columns (pixel size: 28 μm x 28 μm)
- CHERWELL (RAL)
  - Full array divided in sub-arrays (strixel), parallel rolling-shutter readout of strixels
  - Integration time ~30 μs (512 rows x 1000 columns)
  - Pixel size: 20 μm x 28 μm)

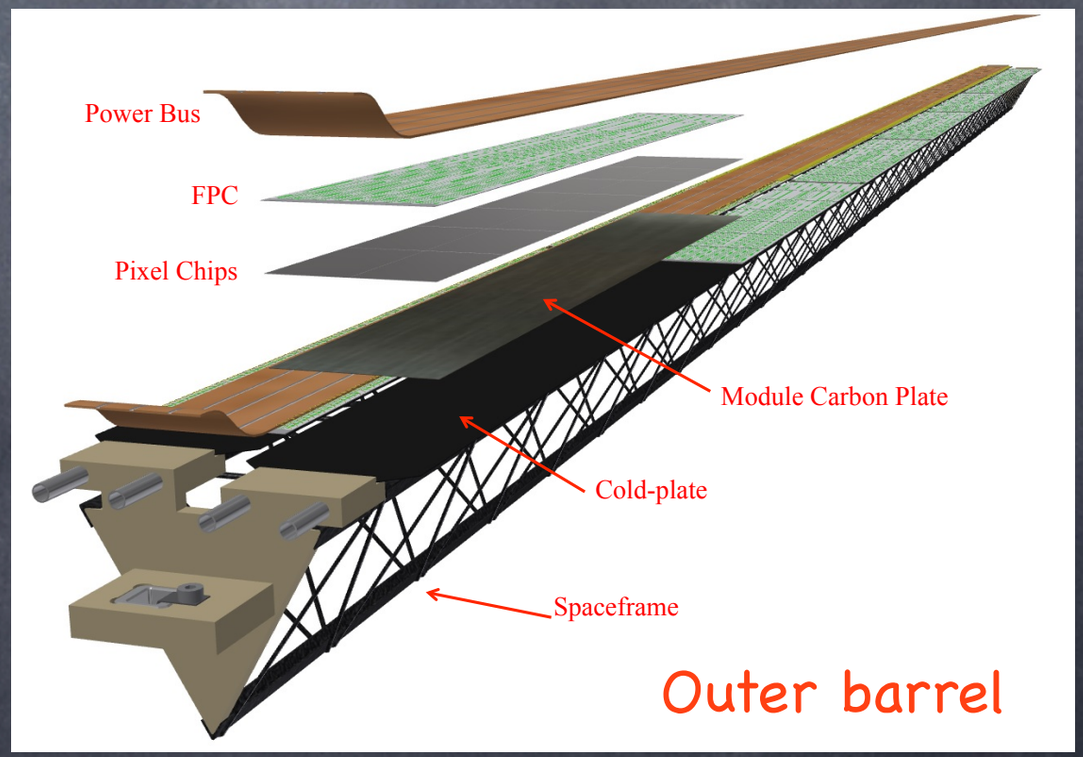


Detailed chip description in TDR

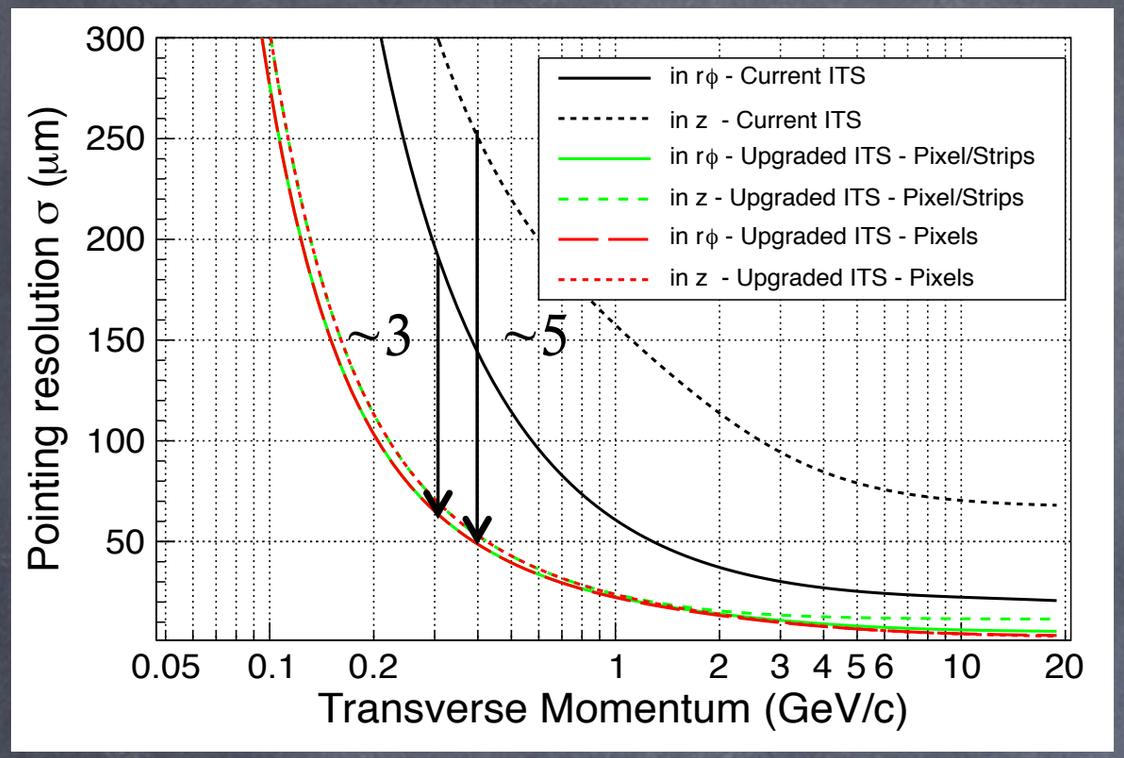
Mechanics and assembly

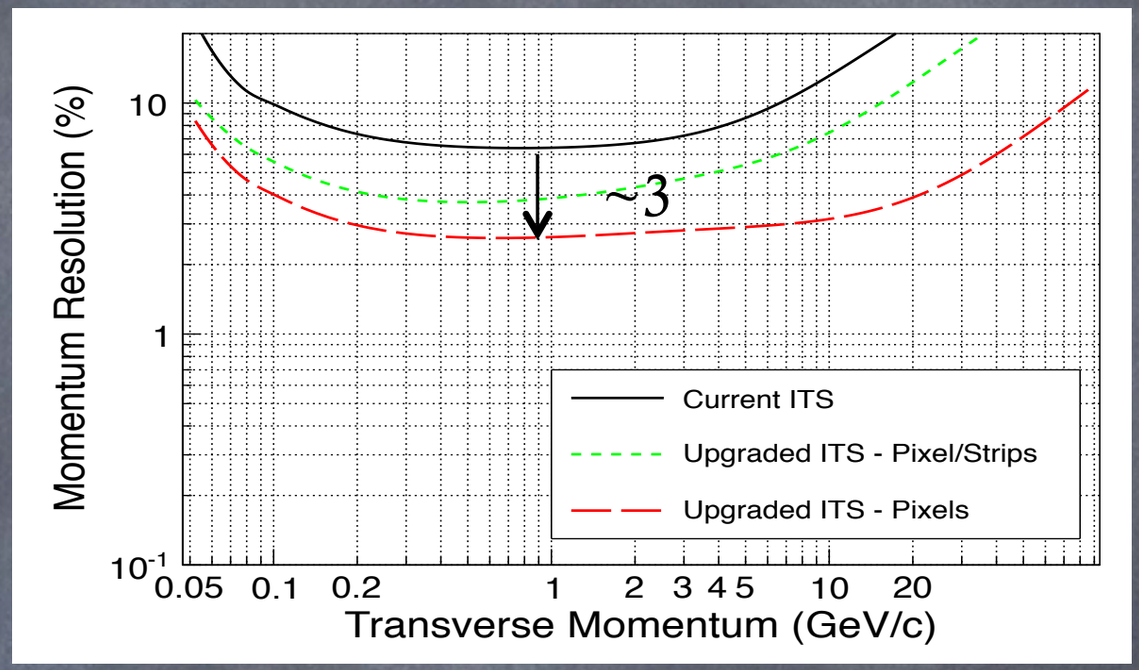
- Dedicated R&D to reduce the material budget to 0.3 % X_0 for the inner barrel
  - Optimized mechanics, cooling, electrical bus, glue, …
- Extra light mechanical structure: 1.4 - 1.8 g / stave





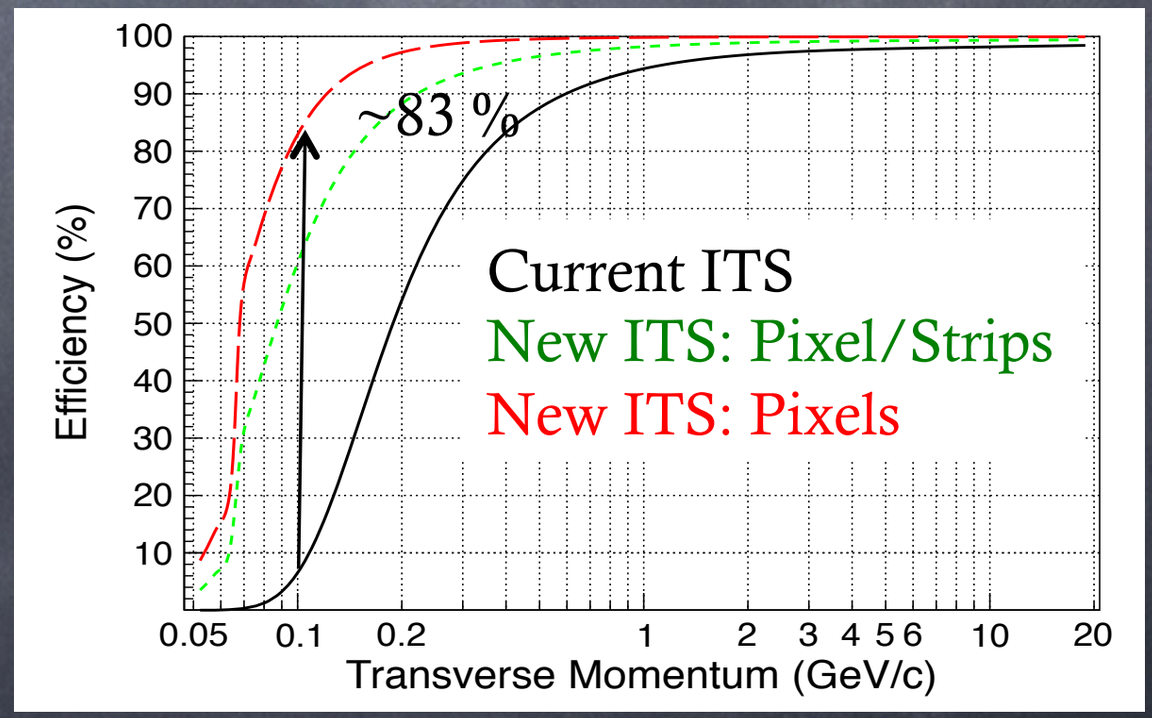
Detector performance



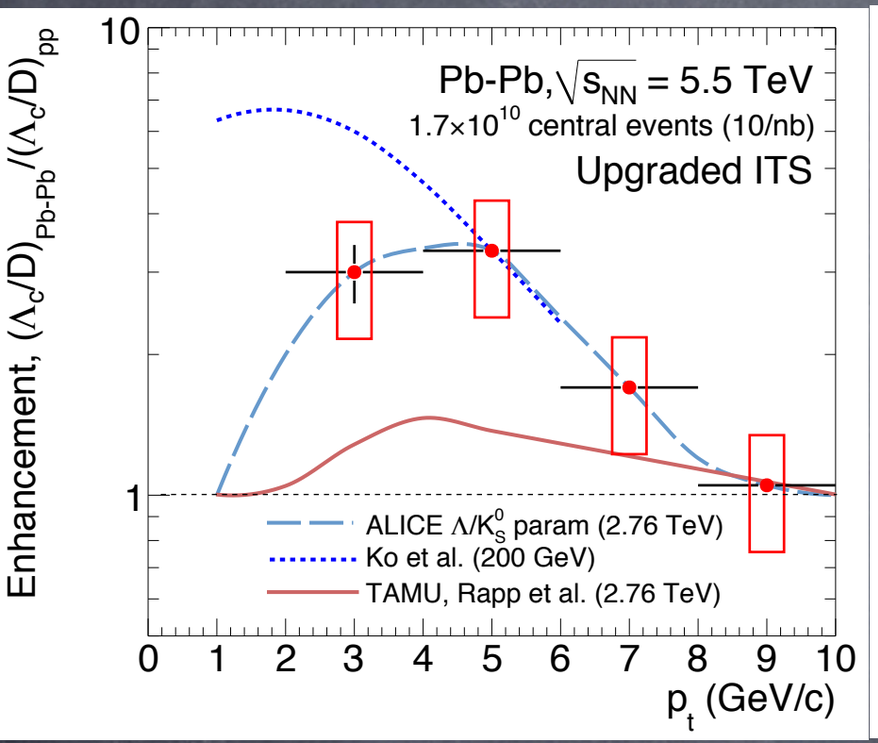


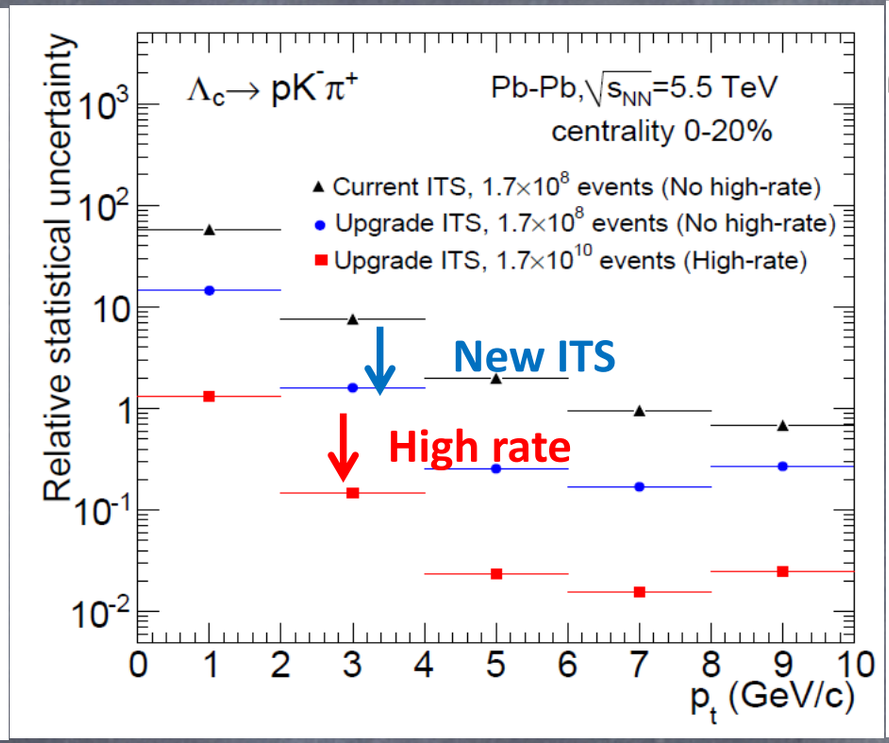
CERN-LHCC-2012-013

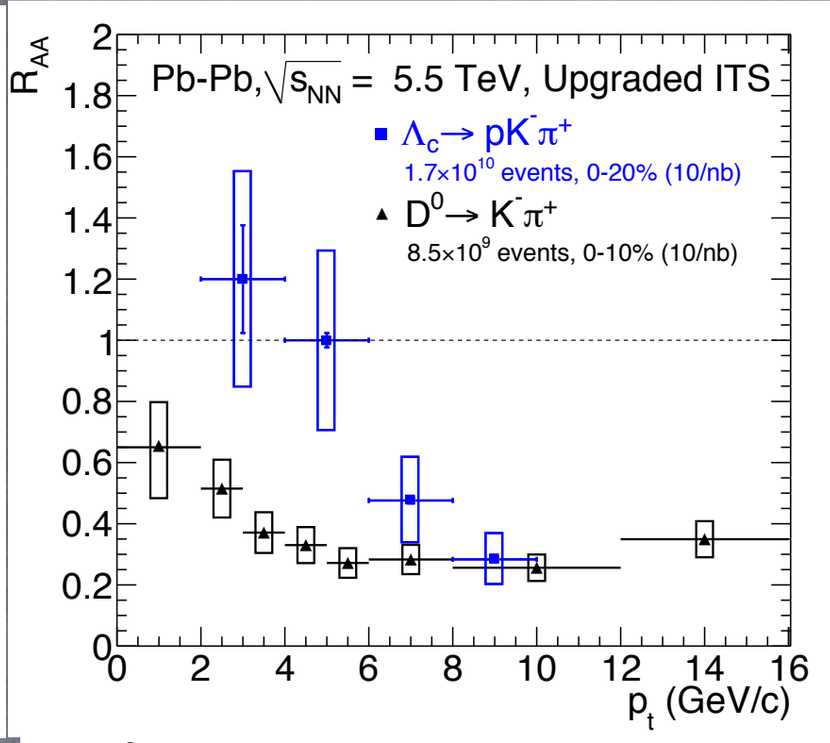
- Standalone track resolution improvement factor ~3 in rϕ and ~ 5 in z
- Factor ~ 3 improvement in momentum resolution for standalone tracking
- Standalone tracking efficiency ~ 83 % at p = 100 MeV/c



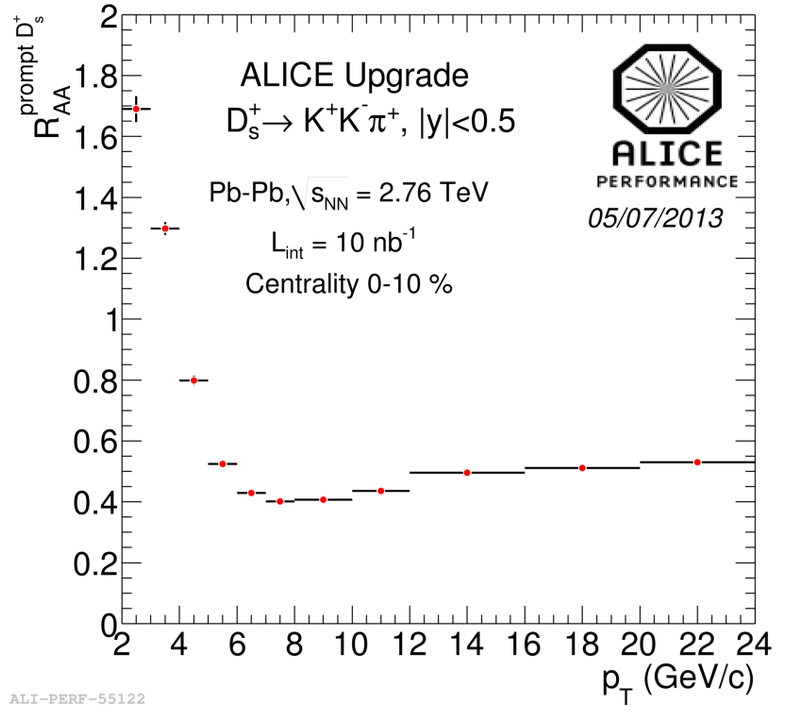
Physics performance: hadronization of heavy quarks



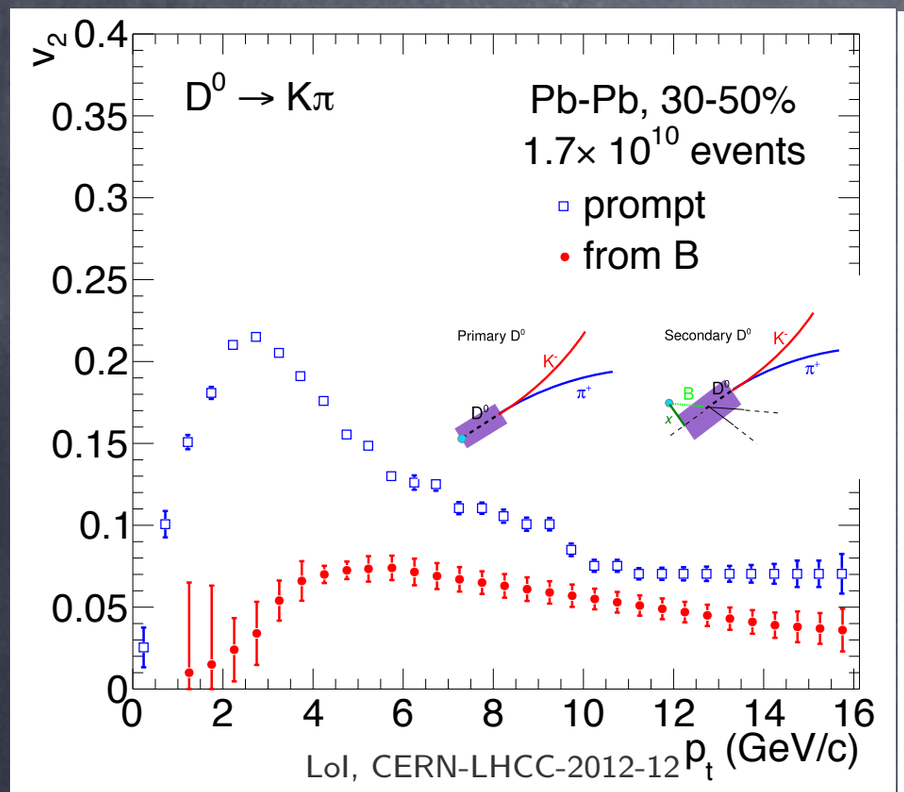


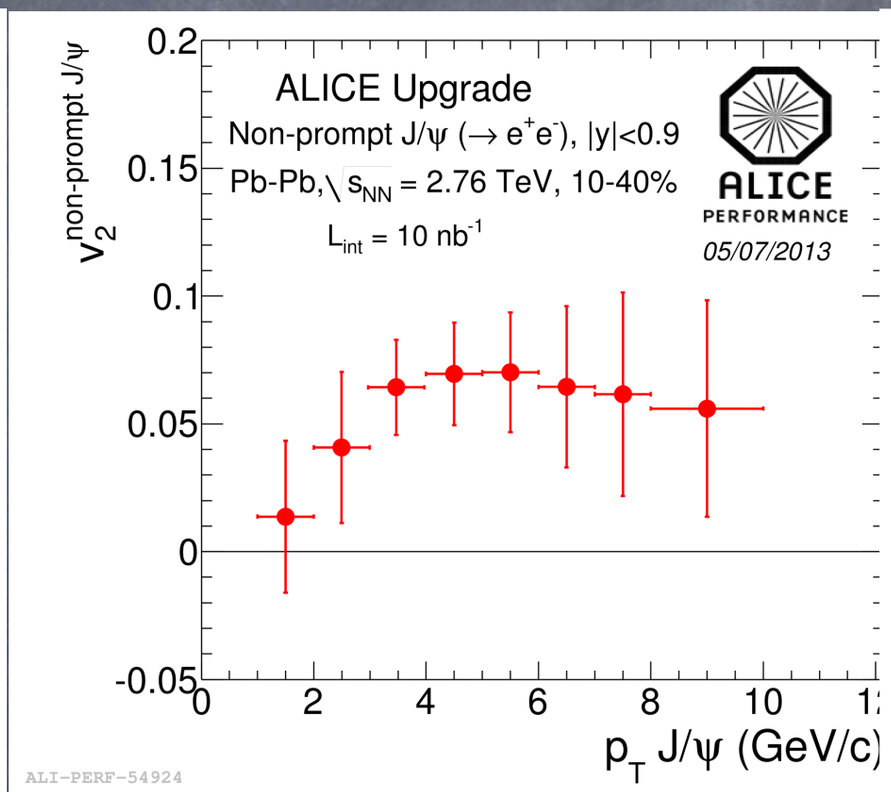


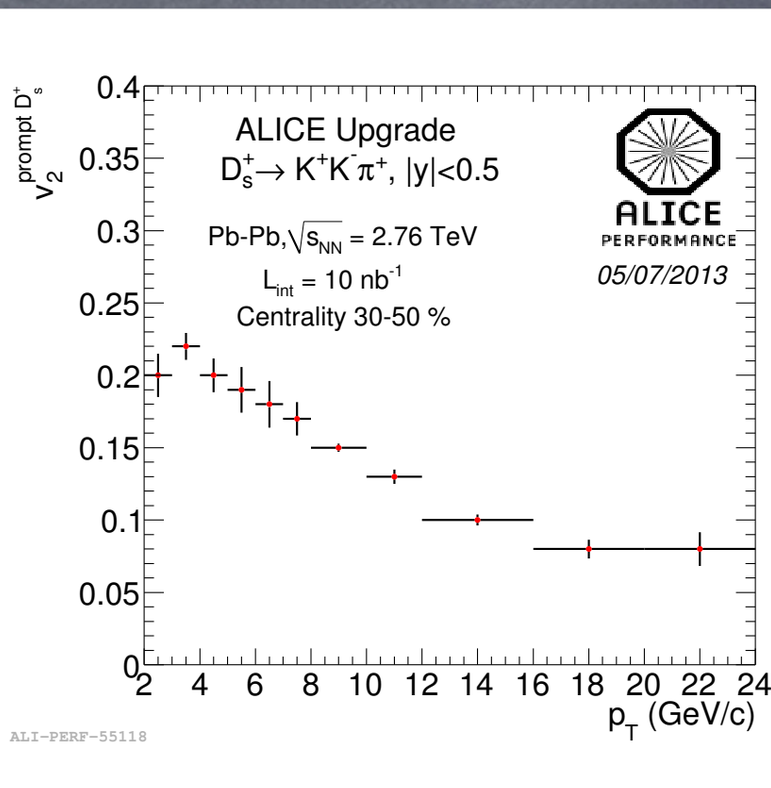
- Heavy quark hadronization via coalescence: Λ_c/D enhancement, larger D_s R_{AA} wrt. D
- Upgraded ITS: low p_T reach, significant reduction of uncertainties
- Detailed performance: TDR, end of 2013



Physics performance: heavy quark collectivity

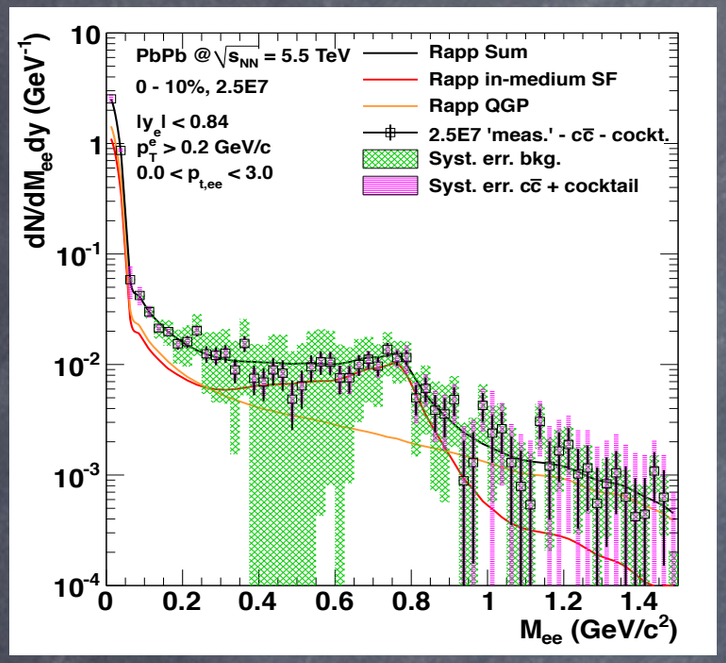


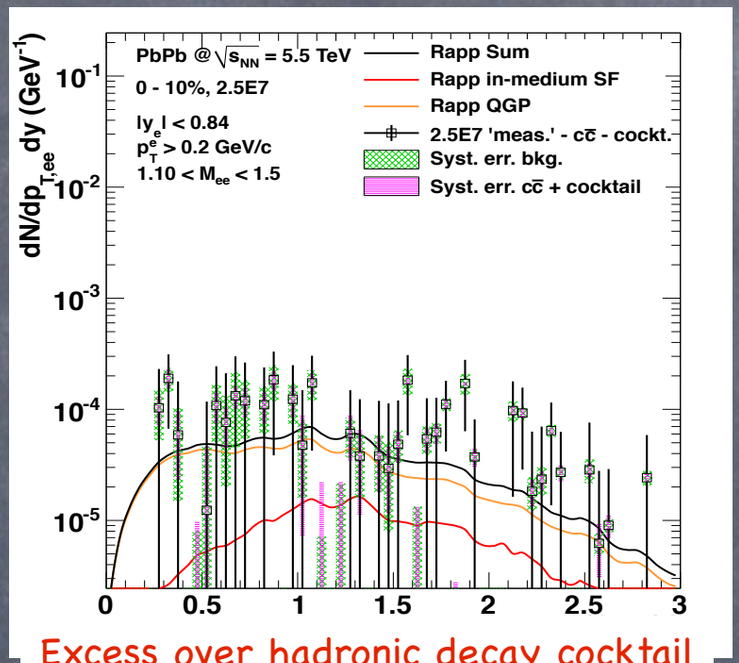




- ITS Upgrade: disentangle charm and beauty collectivity
- Measurement of elliptic flow: prompt and non-prompt D meson, non-prompt J/ψ ,D_s
- Detailed performance: TDR, end of 2013

Physics performance: Di-electron spectra

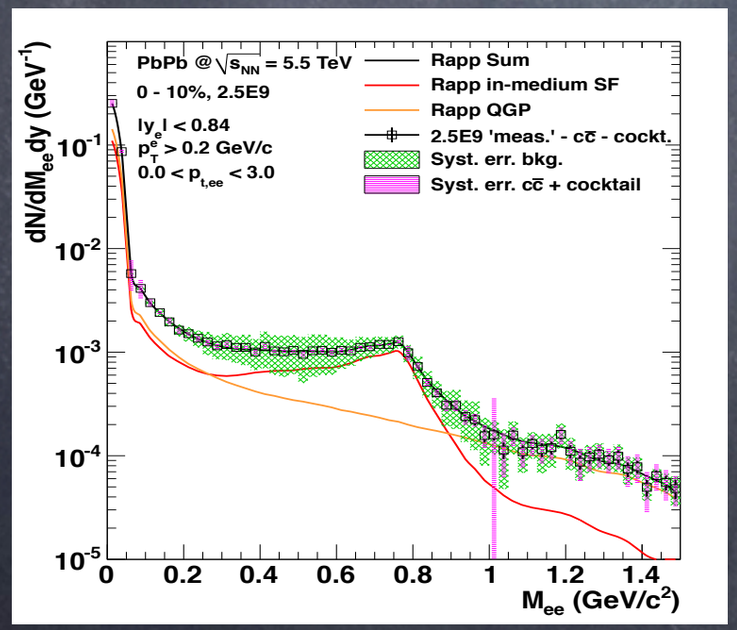


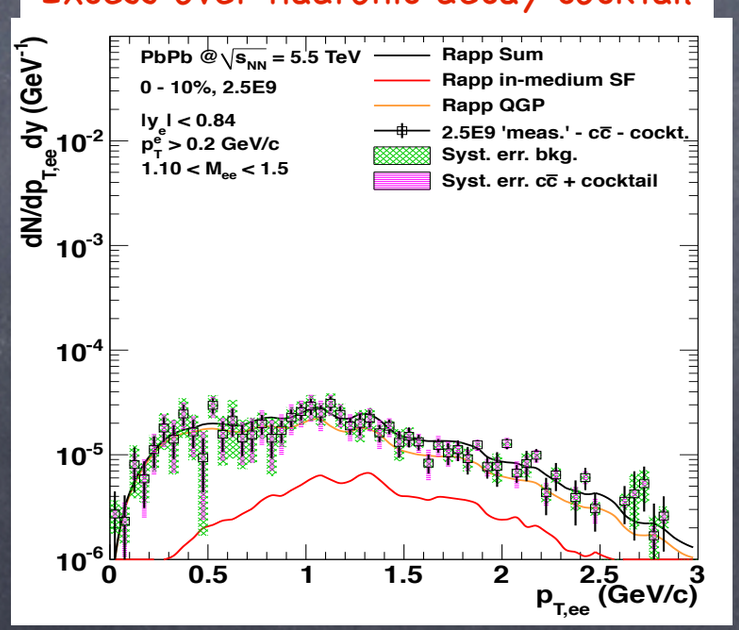


Excess over hadronic decay cocktail

Simulation, current ITS 2.5×10^7 events

Dedicated run at B = 0.2 T



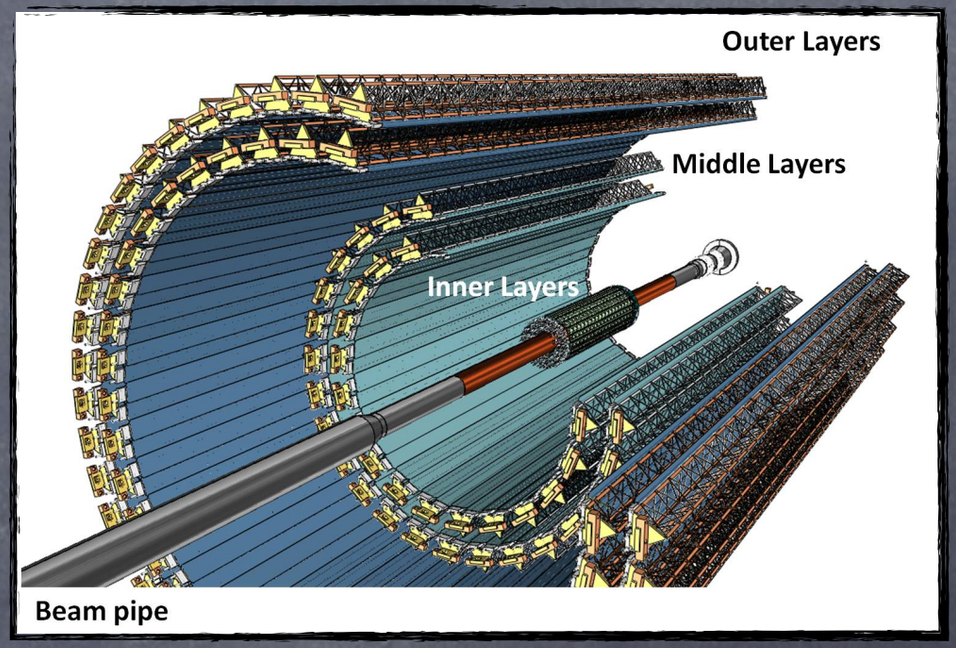


Simulation, upgraded ITS 2.5×10^9 events

- Upgraded ITS: vertexing and increased statistics gives access to differential di-electron studies

ITS Upgrade activities at IPHC: ALICE & PICSEL groups

- MISTRAL and ASTRAL chip developments
  - Preparing for module testing and assembly of the outer layers
- ITS software framework coordination
  - Pixel sensor simulations
- Physics performance analysis
- Editorial work on the Technical Design Report



Summary

- The upgraded ITS opens the way to precision heavy-quark measurements in ALICE
- Active R&D is ongoing from pixel/chip design to mechanics
- Next milestone: Technical Design Report, by the end of 2013