A Large Ion Collider Experiment

Vertexing detectors and vertexing performance in Run 2 in ALICE

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On behalf of the ALICE Collaboration

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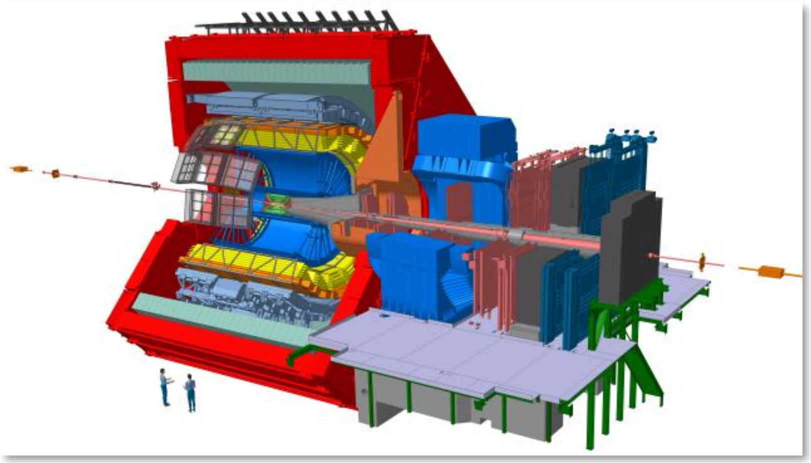
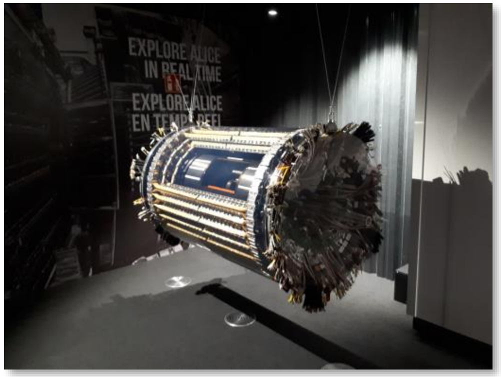
Outline

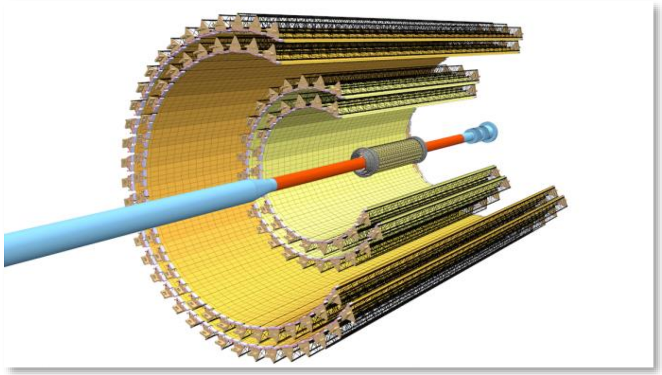
- **ALICE experiment**
    1. The ALICE detector in Run 2
    2. The ITS detector in Run 1 and 2
- **Event reconstruction** and **vertexing**
    - Heavy-flavour (HF) vertices
- **Physics results**
- **ITS upgrade**



The ALICE detector in Run 2



ITS 1 (ALICE exhibition)

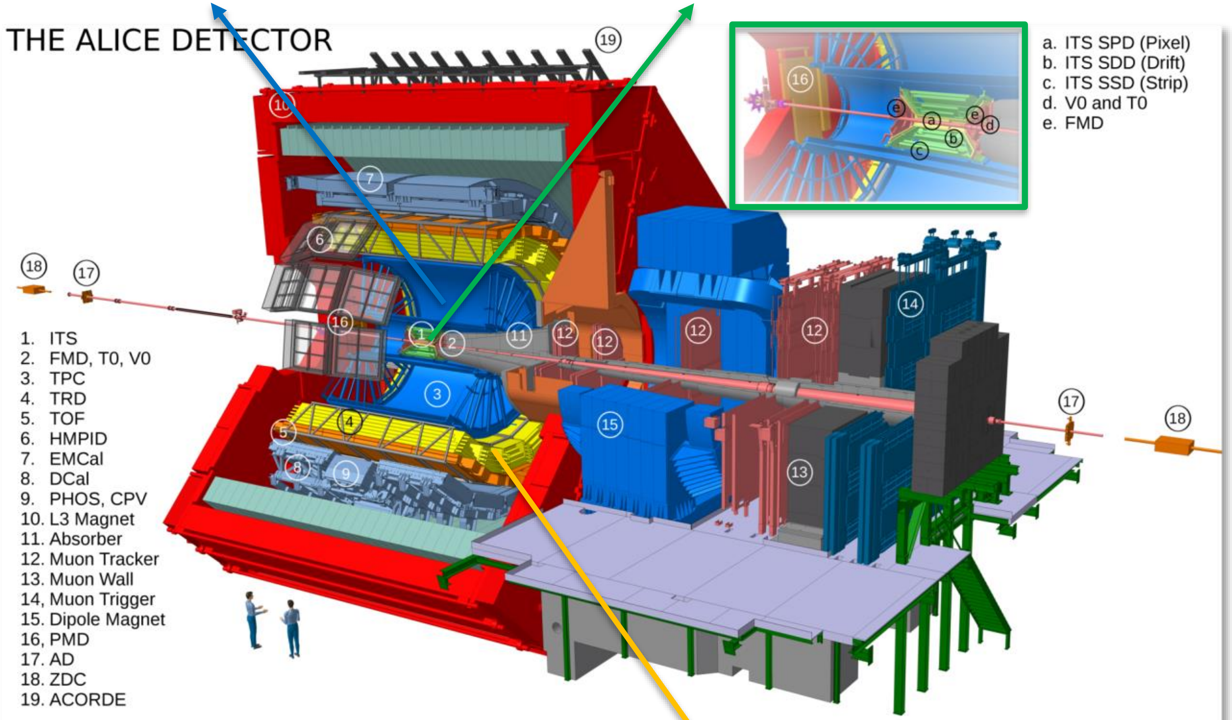


ITS 2

Tracking detectors in the ALICE apparatus

Time Projection Chamber (TPC): tracking, PID via dE/dx

Inner Tracking System (ITS): tracking, vertexing (primary, secondary HF), PID via dE/dx, trigger



Transition Radiation Detector (TRD): tracking, trigger, electron ID via transition radiation

Central barrel coverage: $|\eta| < 0.9$
Muon spectrometer coverage: $-4 < \eta < -2.5$

Inner Tracking System (ITS) in Run 1 and 2

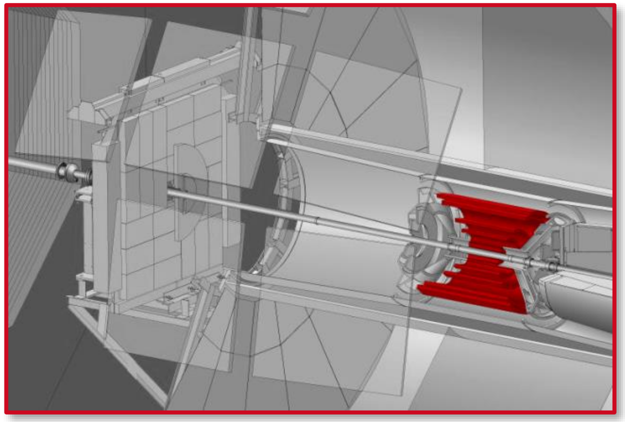
- Six cylindrical layers of silicon detectors:
  i. Silicon **Pixel** Detector (**SPD**)
  ii. Silicon **Drift** Detector (**SDD**)
  iii. Silicon **Strip** Detector (**SSD**)

- Pseudo-rapidity coverage: $|\eta| < 0.9$
- High granularity detector to cope with thousands of tracks per unit of rapidity at mid-rapidity in heavy-ion collisions
- Simultaneous detection of $> 10^3$ tracks

- Purposes:
  1. reconstruct secondary vertices of heavy-flavour hadrons ($c\tau(\Lambda_c^+) = 60\ \mu$m), separated from the primary vertex
  2. improve the tracking
  3. track and identify charged particles with $p_T < 200$ MeV/c

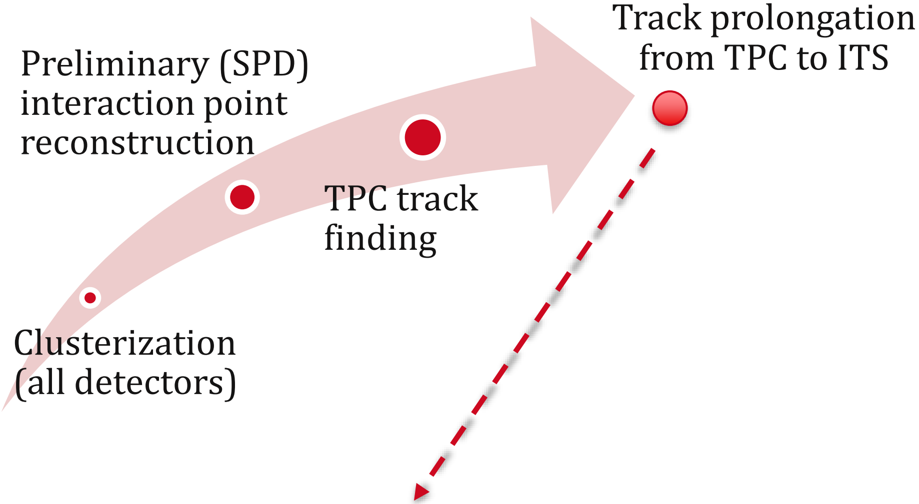
ALICE Coll. 2008 *JINST* **3** S08002

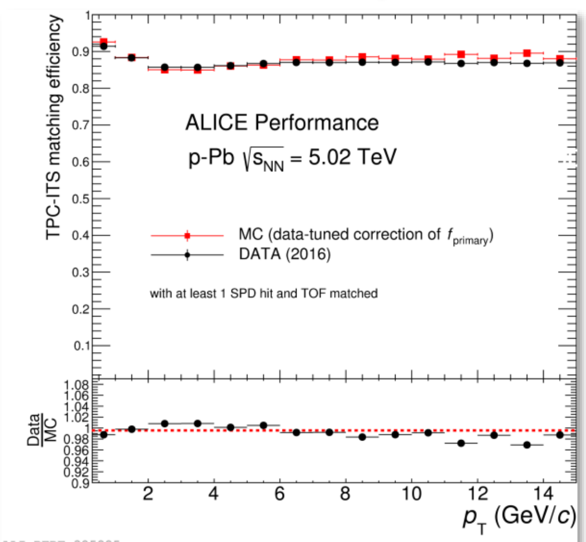
Layer	Type	r [cm]	Thickness [% of X_0]	Spatial precision $r\phi \times z$ [μm^2]
1	Pixel	3.9	1.14	12 × 100
2	Pixel	7.6	1.14	12 × 100
3	Drift	15.0	1.13	35 × 25
4	Drift	23.9	1.25	35 × 25
5	Strip	38.0	0.83	20 × 830
6	Strip	43.0	0.86	20 × 830

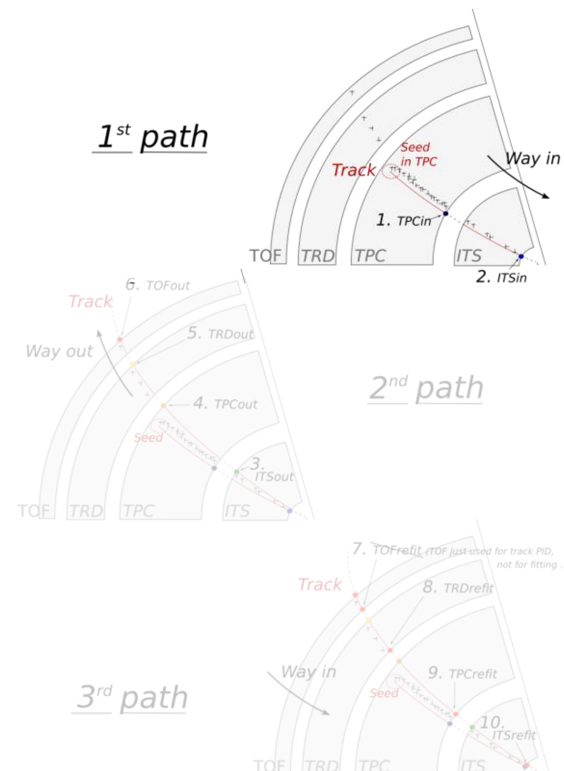


Event reconstruction flow

Int. J. Mod. Phys. A 29 (2014) 1430044







Event reconstruction flow

Int. J. Mod. Phys. A 29 (2014) 1430044

Clusterization (all detectors)

Preliminary (SPD) interaction point reconstruction

TPC track finding

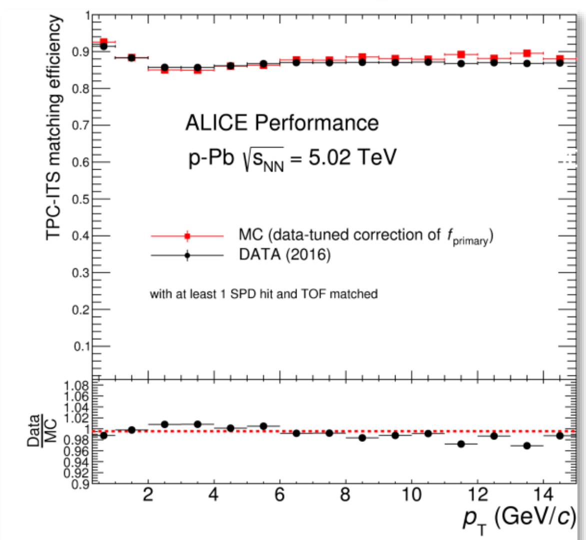
Track prolongation from TPC to ITS

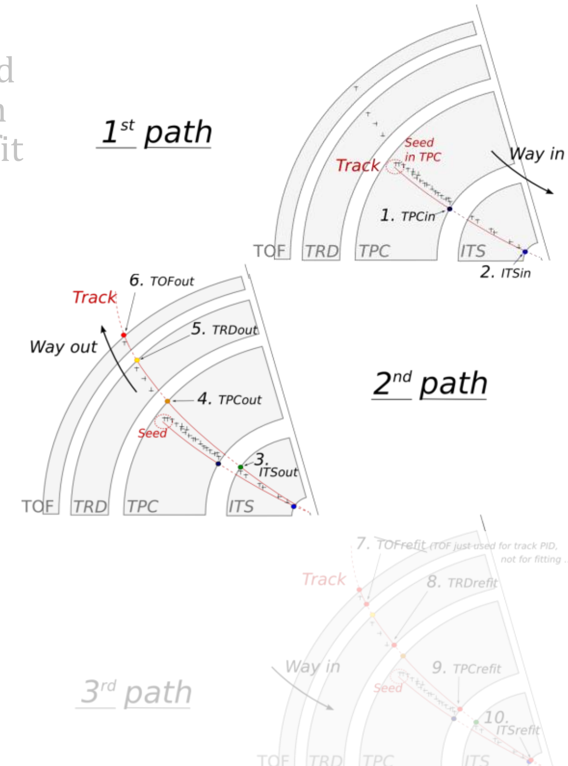
Standalone ITS track finding

Track outward propagation, matching to TRD, TOF, EMCAL, PHOS, HMPID

Track inward propagation with final refit

Final interaction vertex finding





Event reconstruction flow

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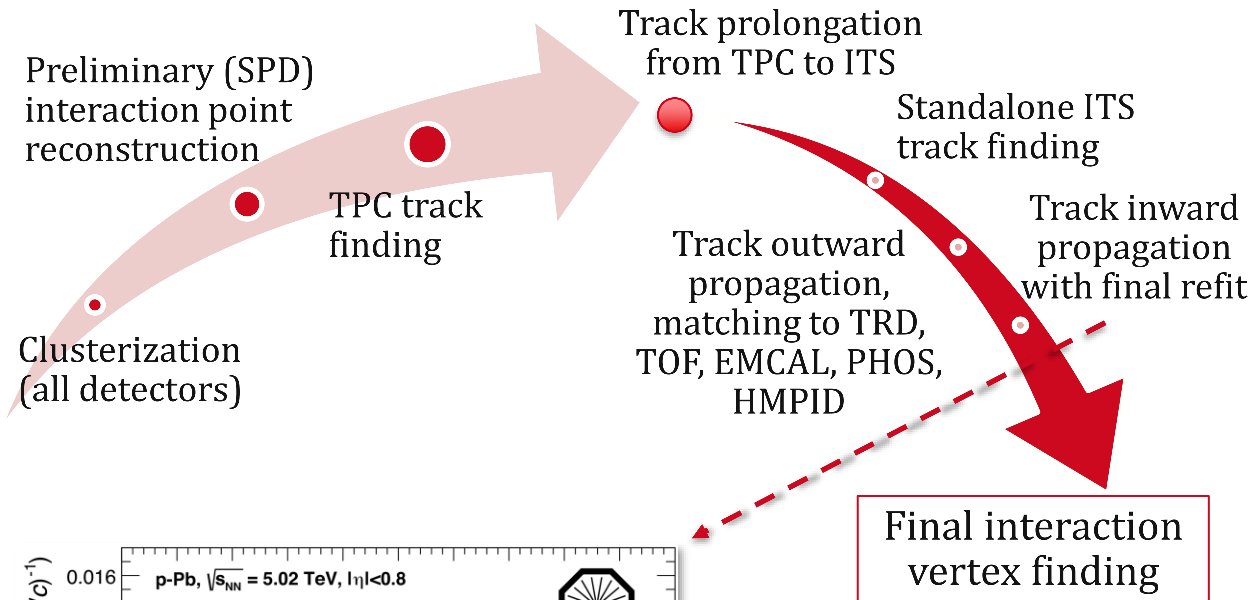

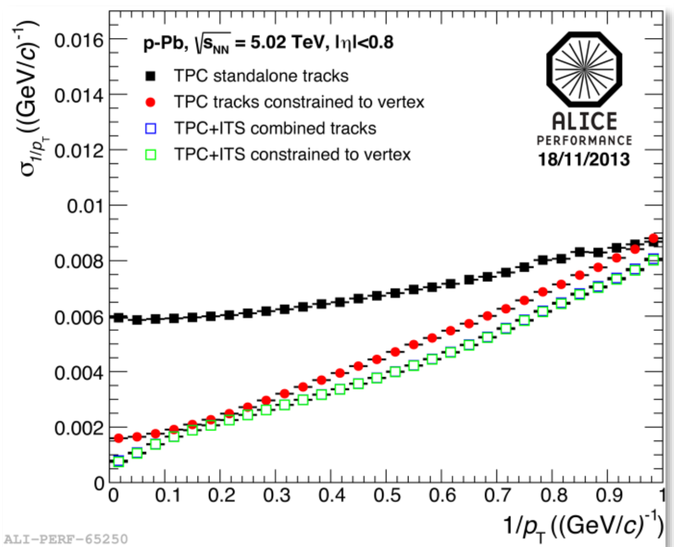

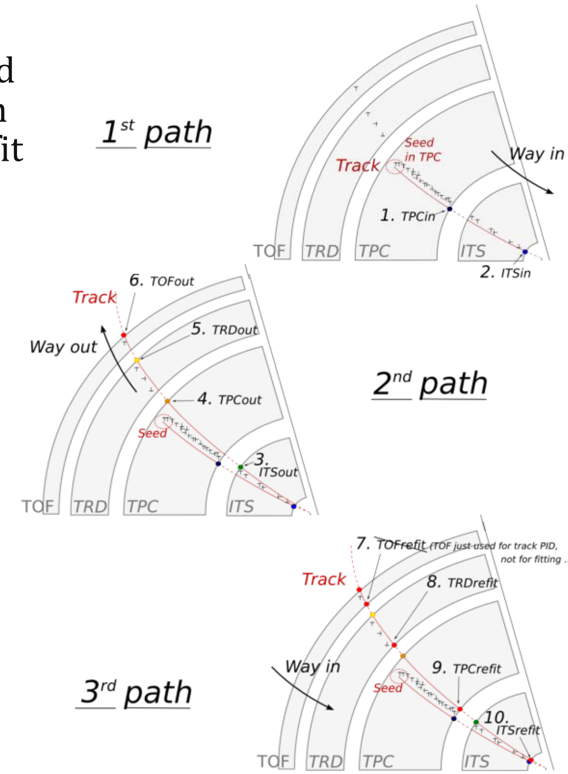

ALICE

Event reconstruction flow

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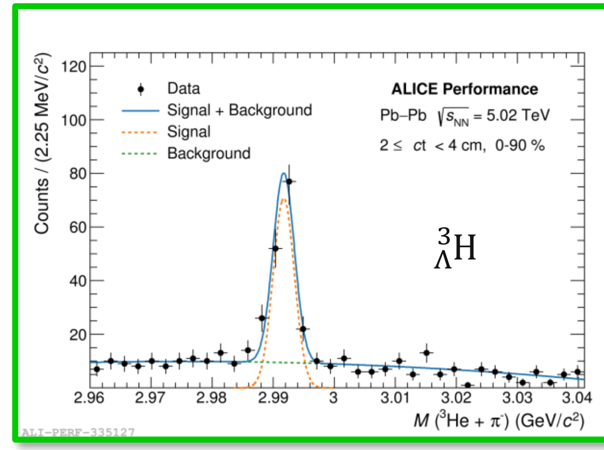
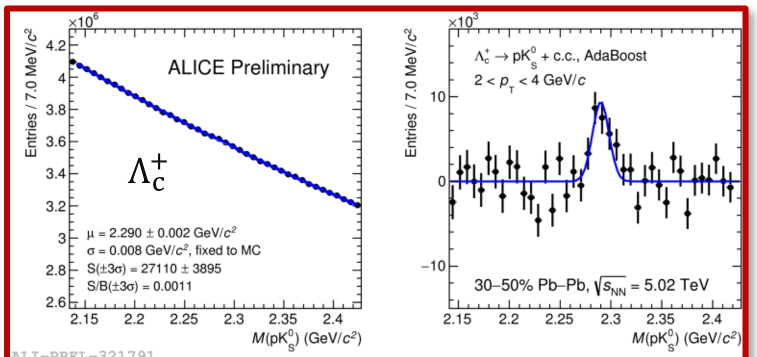
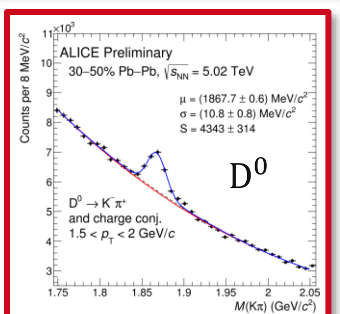


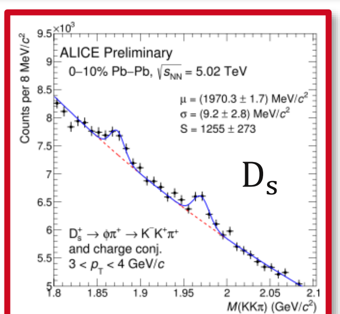


Final interaction vertex finding

K^0_S, Λ, … , $^{3}_{\Lambda}$H

V0 finding





Heavy- flavour secondary vertices

D mesons, Λ_c^+, Ξ_c^+, …

Ξ^-, Ω^-, …

Cascades

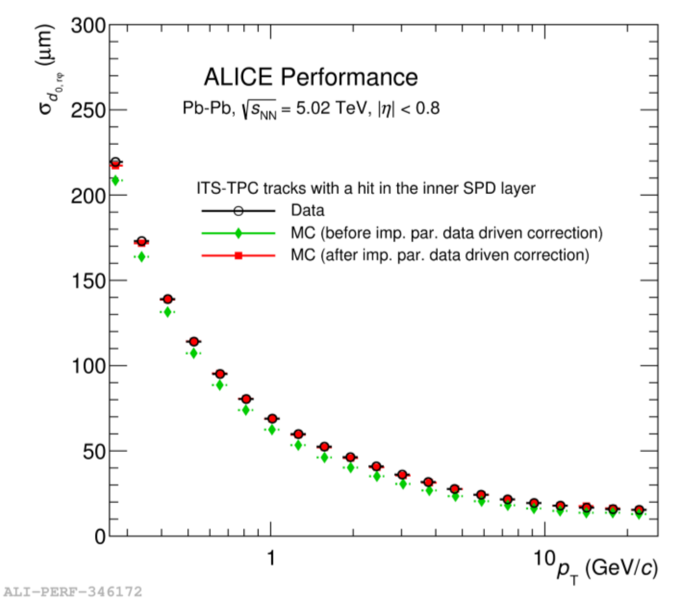
[(*)] M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018) and 2019 update

Heavy-flavour vertex reconstruction

	Mass (MeV/c^2)	$c\tau$ (μm)	Decay (B.R.)[(*)]
D^0	1865	123	$K^-\pi^+$ (3.95 %)
D^+	1870	312	$K^-\pi^+\pi^+$ (9.38 %)
D_s^+	1968	151	$\phi\pi^+, \phi \to K^+K^-$ (2.27 %)
Λ_c^+	2286	60	$pK^-\pi^+$ (6.28 %) pK_s^0 (1.59 %)
Ξ_c^+	2468	132	$\Xi^-\pi^+\pi^+$ (2.86 % Phys.Rev. D 100 (2019) no.3, 031101)

- Full reconstruction of hadronic final state
- Vertex position: minimization of distance among daughter tracks
- Straight-line approximation for tracks close to PV
  $\rightarrow$ bias $< 1\ \mu$m for daughters of $p_T \approx 0.5$ GeV/c of 3 mm-displaced secondary vertices @ B = 0.5 T

ARDA-Note-2009-002



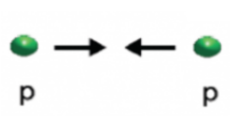
- Reconstruction of topological variables exploitable for signal extraction: decay length, pointing angle, ...
- Data-driven correction for the impact parameter to primary vertex in MC simulations
- Unbiased templates for impact parameter -based analyses

PV = Primary Vertex

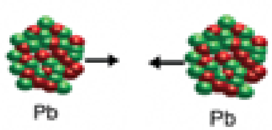
ALICE

Physics results

… a non-exhaustive collection!



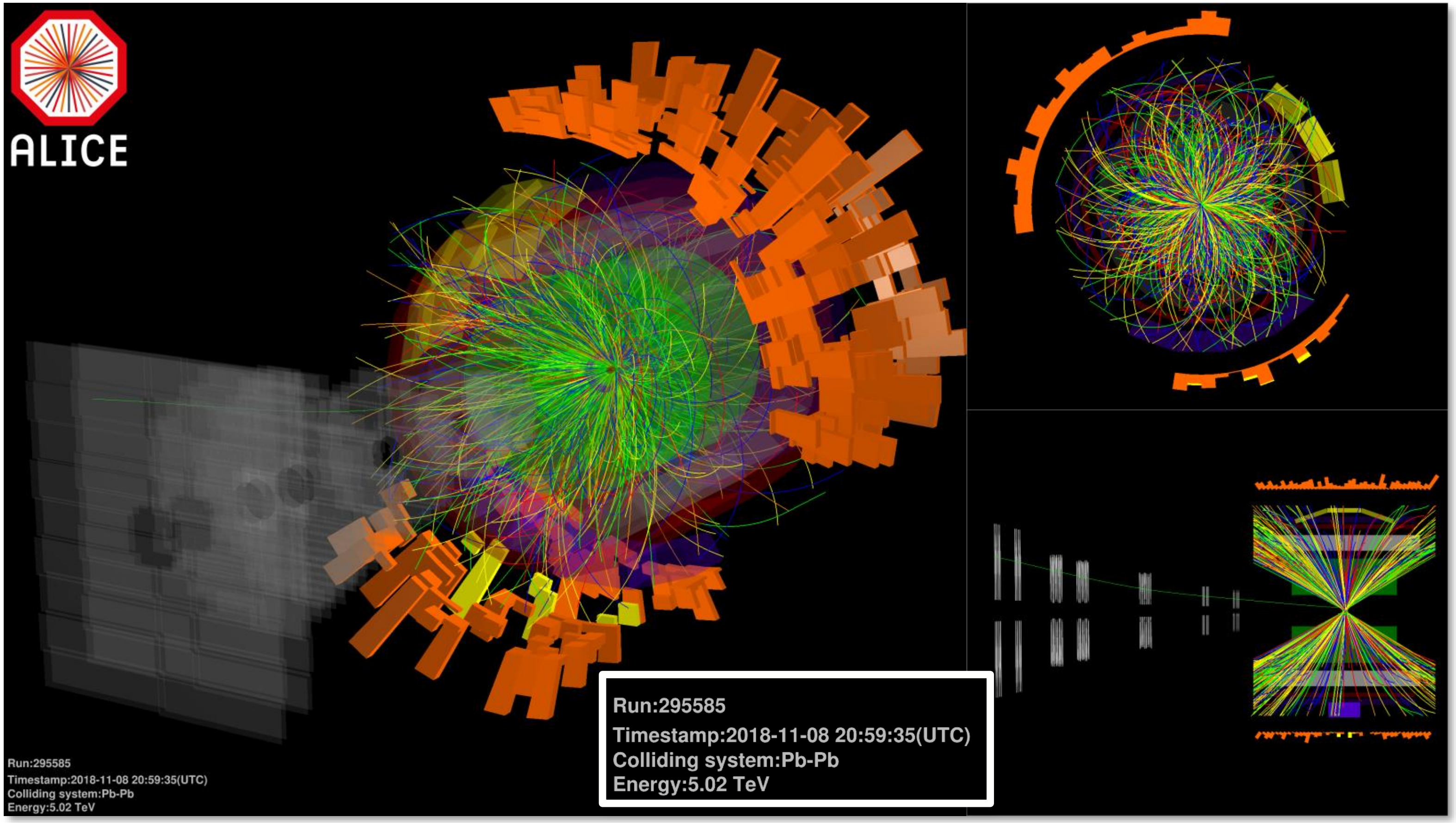
proton-proton (pp) collisions



lead-lead (Pb-Pb) collisions

New result

Typical Pb-Pb collision in ALICE



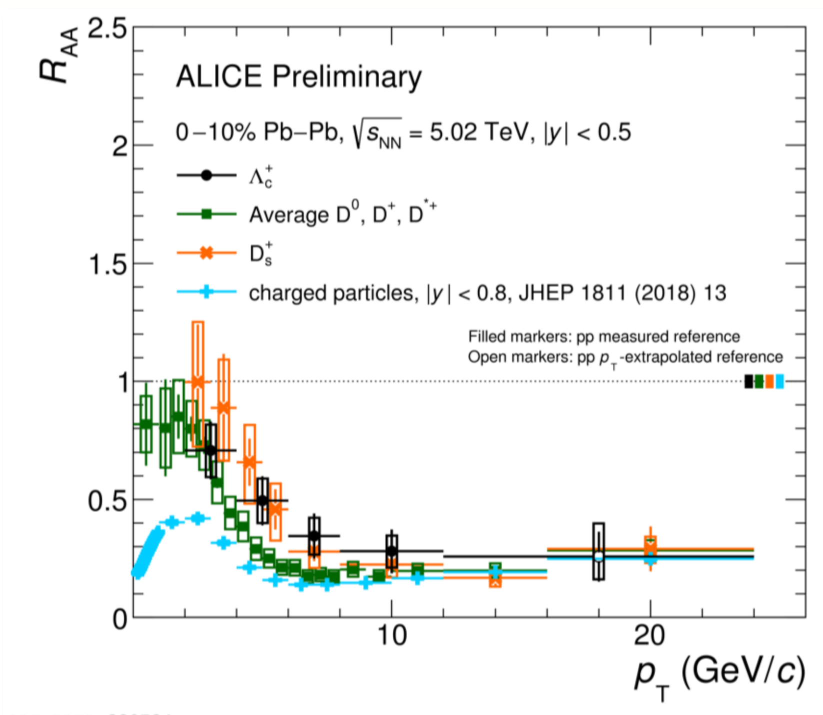
- Huge track density in Pb-Pb collisions (several thousands in central events)
- Heavy-flavour analysis more challenging due to the huge combinatorial background

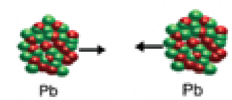
More details in Gian Michele Innocenti's talk "Heavy flavor and quarkonia"

Heavy-flavour in the QGP

- ALICE main goal: study of quark-gluon plasma (QGP) in heavy-ion collisions

- Charm and beauty quarks produced before the QGP formation ($\tau_b \sim 0.02 < \tau_c \sim 0.07 < \tau_{QGP} < 0.1 - 1$ fm/c)
- Heavy quarks traverse the QGP
- Unique and calibrated probe of QGP full evolution





Nuclear modification factor

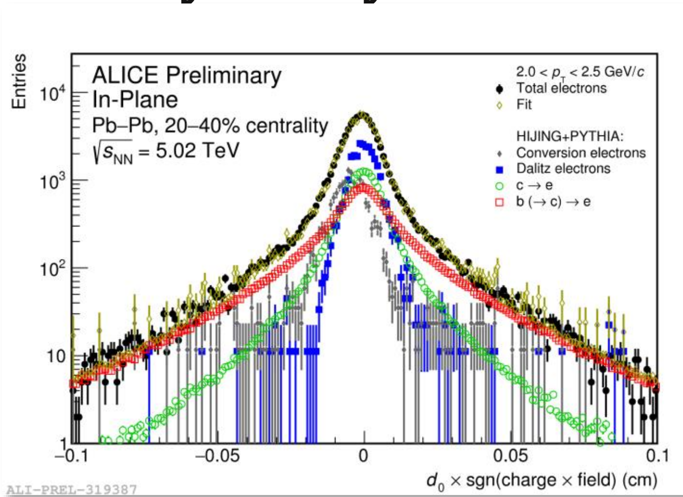
$$R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \cdot \frac{dN_{PbPb}/dp_T}{dN_{pp}/dp_T}$$

- Comparison between the AA behaviour and the pp expectations

- Sensitive to in-medium parton energy loss, heavy-quark hadronization mechanisms and spatial diffusion coefficients at low p_T

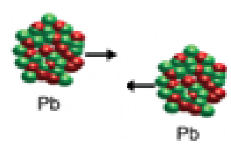
ALICE

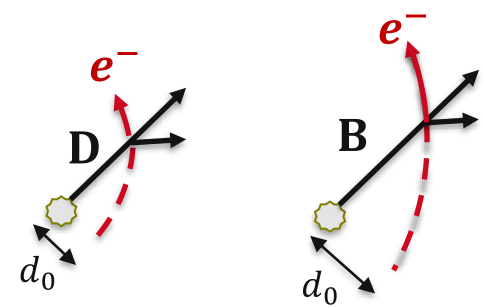
Beauty-decay electrons (b(→ c) → *e*)



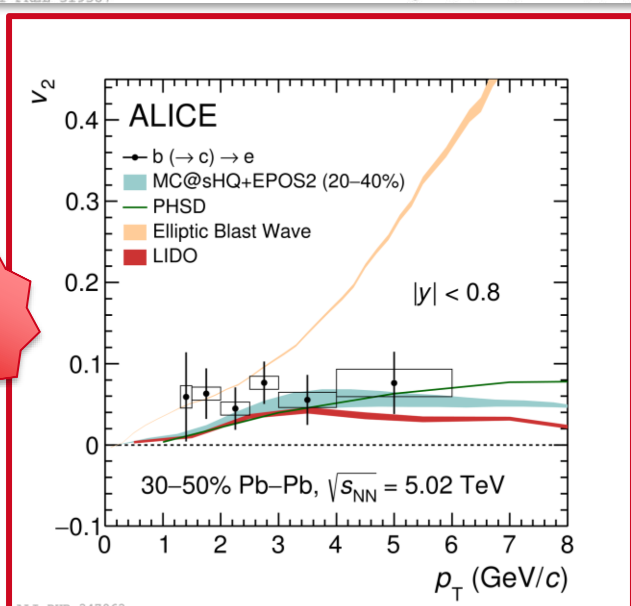
Beauty hadrons $c\tau \sim 500\ \mu m$
Charm hadrons $c\tau < 300\ \mu m$

- Beauty hadrons have longer lifetimes than charm hadrons and other electron sources
  → larger DCA (d_0 in the transverse plane) with respect to PV for decay products





NEW



- Monte Carlo templates of electron sources
- Fit to data to distinguish b(→ c) → *e* from other sources

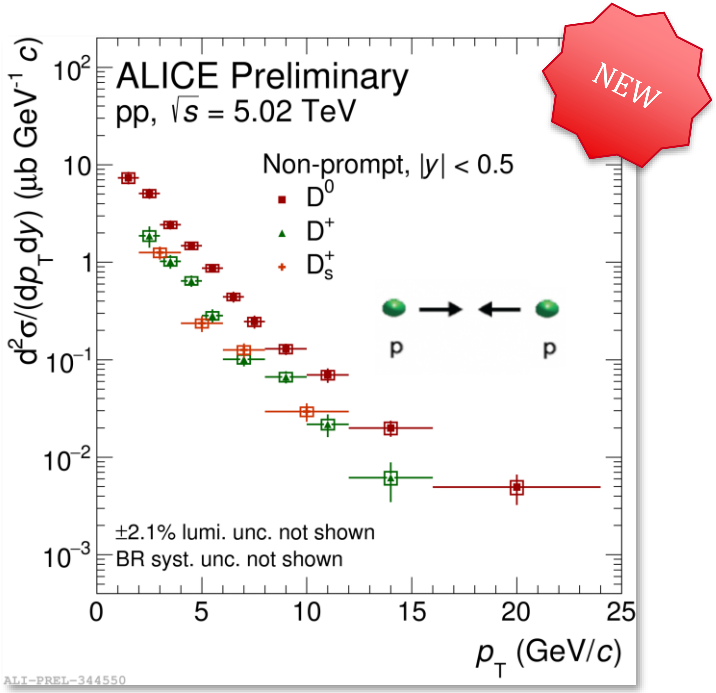
$$\frac{d^2N}{d\varphi dp_T} = \frac{1}{2\pi}\frac{dN}{dp_T}\left[1 + 2\sum_{n=1}^{\infty} v_n(p_T)\cos[n(\varphi - \Psi_n)]\right]$$

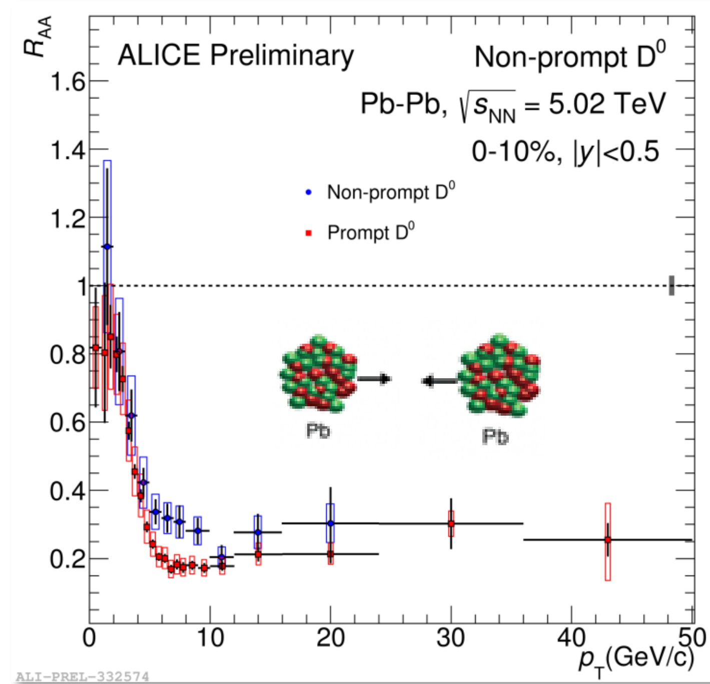
$$v_2 = \langle \cos[2(\varphi - \Psi_2)] \rangle$$

arXiv:2005.11130

More details in Chun-Lu Huang's talk "Recent results on heavy flavor in small and large systems from ALICE"

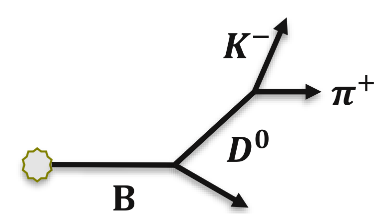
Non-prompt *D* meson production in pp and Pb-Pb





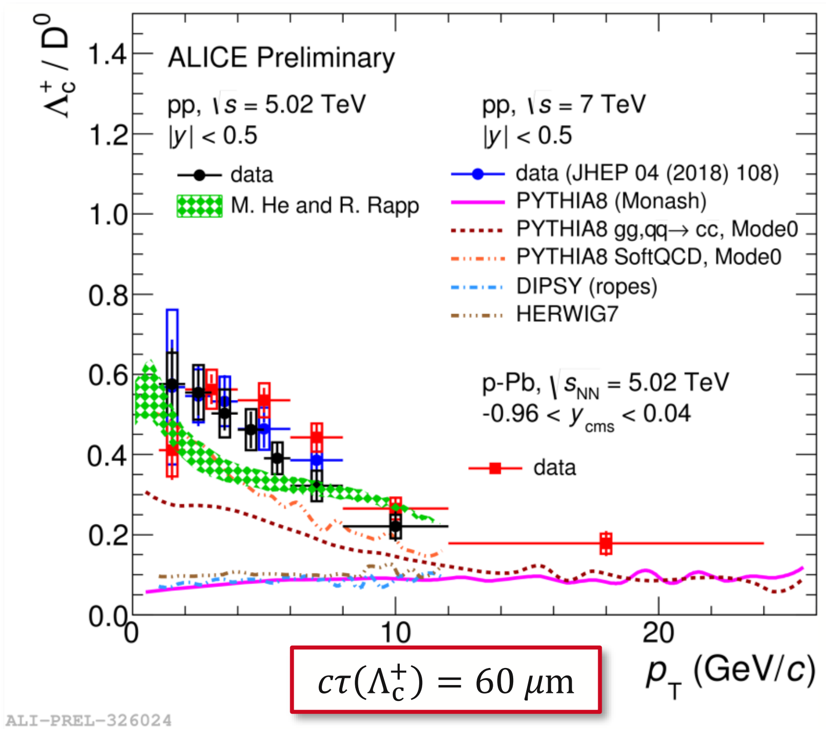
- Prompt D, non-prompt D and background separation with machine learning tools
  → exploiting different decay topologies, resolved thanks to the ALICE vertexing capabilities

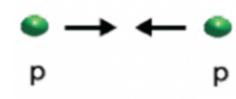
- Hint of $R_{AA}^{D\leftarrow c} < R_{AA}^{D(\leftarrow c)\leftarrow b}$ at intermediate p_T
  → comparison with theory: access to the medium properties



More details in Alena Harlenderova's talk "[Recent results on hard and rare probes from ALICE]"

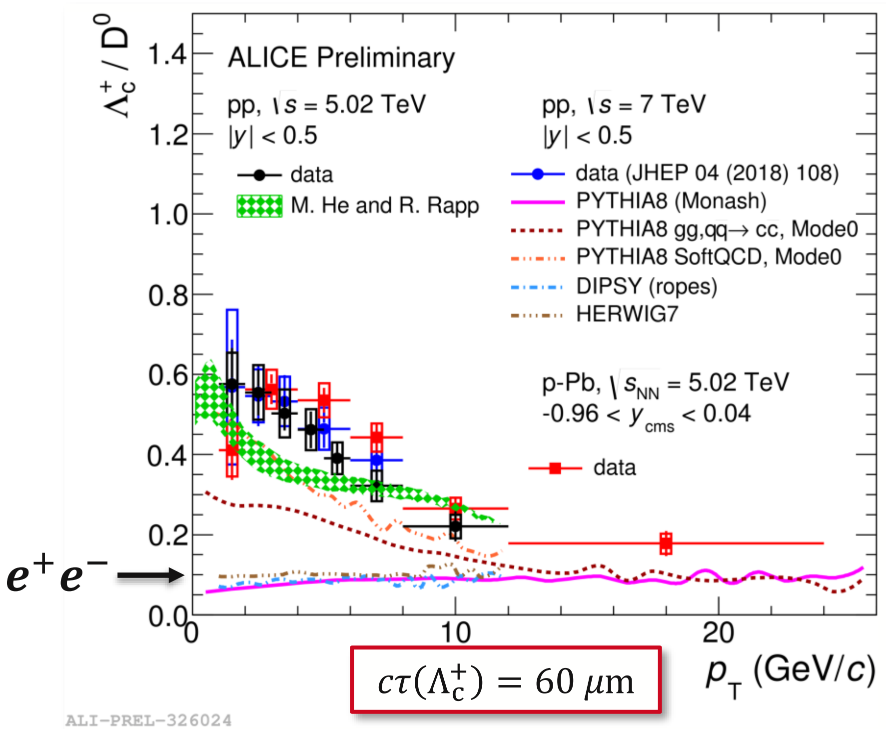
Heavy-flavour in the QGP... but not only!

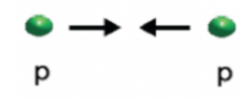




- Competitive measurements also in pp collisions
- ALICE is the only LHC experiment able to measure the Λ_c^+ baryon down to $p_T = 1$ GeV/c at mid-rapidity
- Low p_T: region where the differences with hadronization models are the largest

Heavy-flavour in the QGP... but not only!





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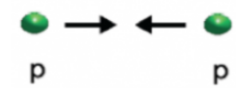
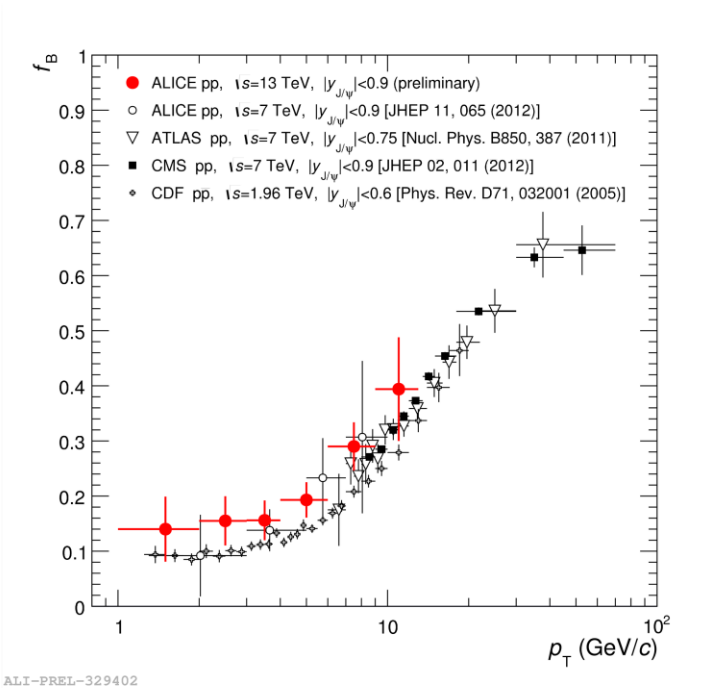
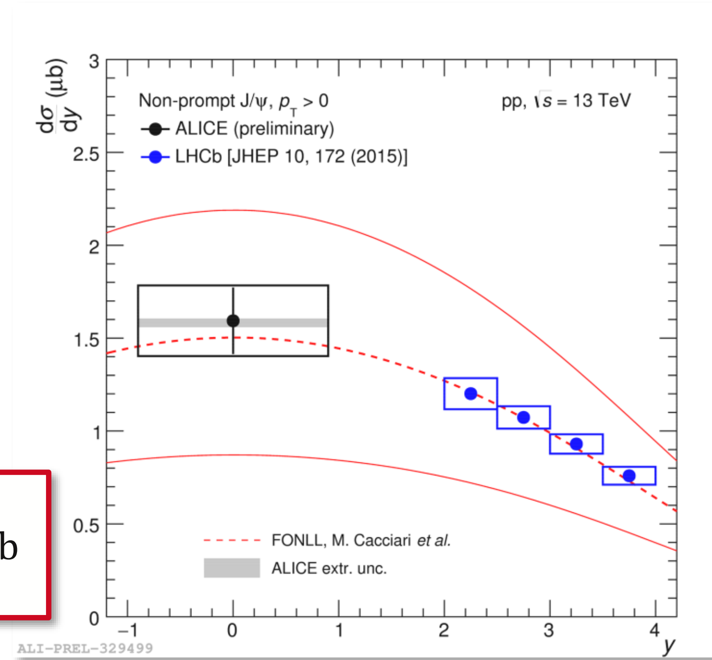
- Charm baryon-over-meson ratio significantly higher than expectations from MC generators tuned to reproduce e^+e^- measurements
- Recent measurements that challenge the hadronization models

Non-prompt J/ψ at mid-rapidity





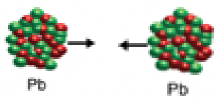
- Prompt $J/\psi \to e^+e^-$ distinguished from non-prompt ones exploiting the sizeable beauty hadron decay length
- Non-prompt J/ψ fraction at mid-rapidity measured down to $p_T = 1$ GeV/c → **lowest p_T ever measured!**



- Measurement at mid-rapidity of non-prompt J/ψ complementary (rapidity coverage) to LHCb one

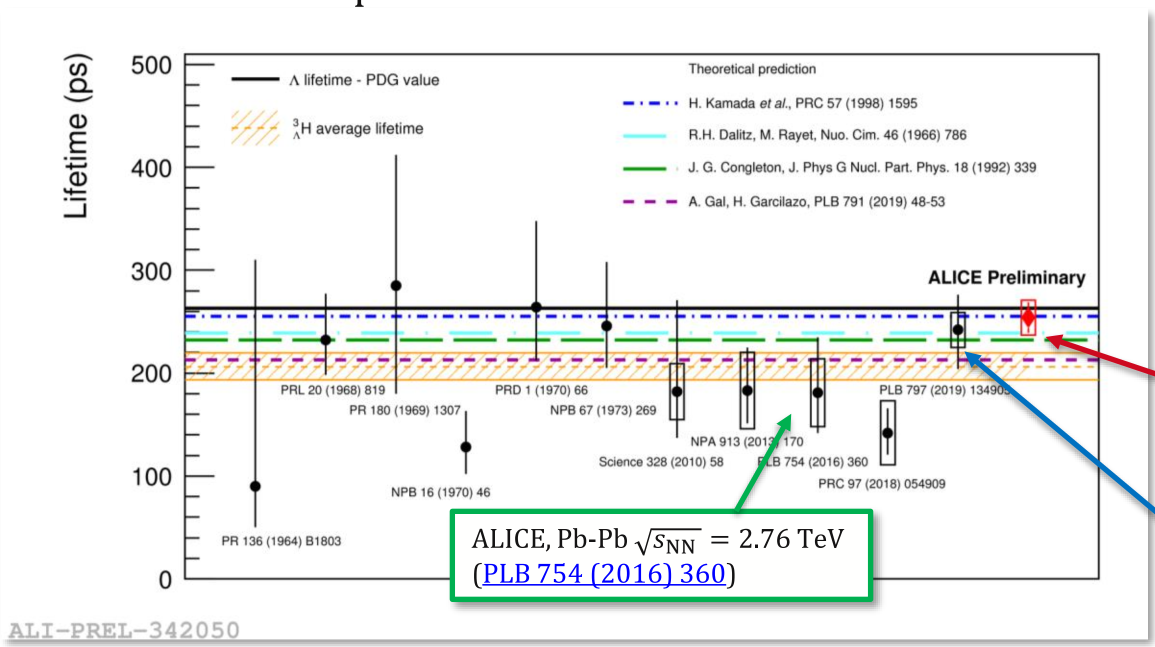
$$\frac{d\sigma^{(p_T>0)}}{dy}_{J/\psi \leftarrow h_B} = 1.59 \pm 0.18\,(\text{stat.}) \pm 0.19\,(\text{syst.})^{+0.012}_{-0.034}\,(\text{extr.})\ \mu\text{b}$$

$^{3}_{\Lambda}$H lifetime measurement



- Neutron stars (NS) equation of state (EOS) inhibits large masses due to hyperons
  → 2M$_{\odot}$ NS observed → "hyperon puzzle"
- $^{3}_{\Lambda}$H lifetime τ is an experimental probe of hyperon-nucleon-nucleon (Y-N-N) interaction → additional repulsion

- $^{3}_{\Lambda}$H → ^{3}He π^{-} candidates reconstructed with the "V0 finder" technique
- $^{3}_{\Lambda}$H signal measured from $m($ ^{3}He $\pi^{-})$ distribution in different ct intervals
- $c\tau$ from exponential fit



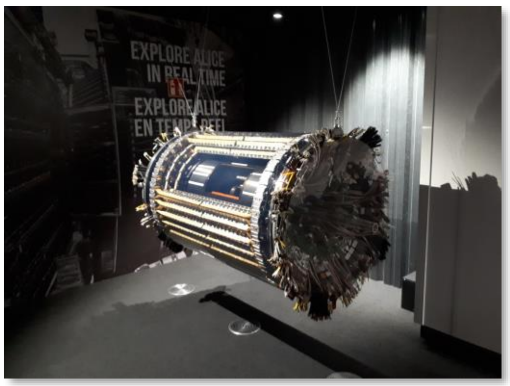
ALICE, Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV, 2018 sample (Preliminary)

ALICE, Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV, 2015 sample (PLB 797 (2019) 134905)

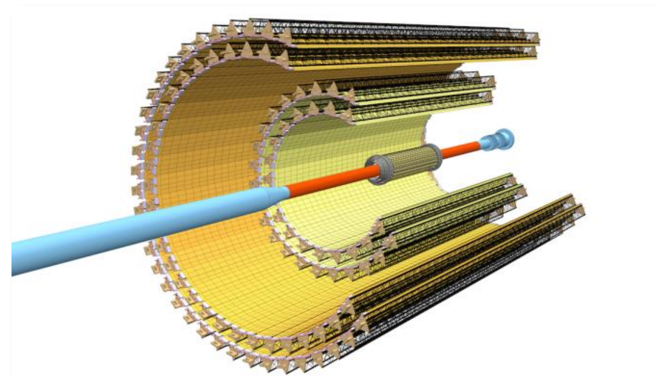
- **Outstanding contribution from ALICE**
- Precision improved with the Pb-Pb samples at 5.02 TeV

ALICE

Upgrade – ITS 2 (Run 3 and 4)



ITS 1 (ALICE exhibition)



ITS 2

Piotr Gasik
"ALICE upgrades"

→

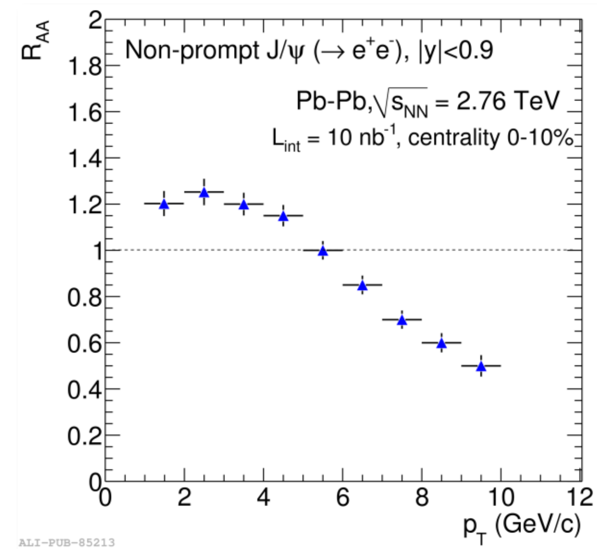
Muon Forward Tracker (post-LS2): new Si-tracking detector designed to add vertexing capabilities to the MUON spectrometer (forward rapidity)

More details in Piotr Gasik's talk "ALICE upgrades"

ALICE

LS2 upgrade – ITS 2

J. Phys. G 41 (2014) 087002



- Ready to be installed after LS2
- Layout
  - 7 layers (inner/middle/outer): 3/2/2
  - 192 staves (inner/middle/outer): 48/54/90
- 10 m^2 active silicon area, 12.6 × 10^9 pixels
- First large scale ALPIDE Monolitic Active Pixel Sensors detector
- HF vertexing improved → uncertainties reduced at low p_T

	ITS 1	ITS 2
Distance to interaction point (mm)	39	22
X_0 (innermost layer) (%)	~1.14	~0.35
Pixel pitch (μm^2)	50 × 425	27 × 29
Readout rate (kHz)	1	100
Spatial resolution ($r\varphi \times z$) (μm^2)	11 × 100	5 × 5

→ Closer to interaction point

→ Lower material budget

→ Improved granularity

→ Faster readout

→ Improved resolution

Conclusions

- Thanks to its vertexing capabilities, the ALICE experiment has been obtaining remarkable results in Run 2, especially in the heavy-flavour physics (… but not only!) in pp, p-Pb and Pb-Pb collisions

- Looking forward to the post-LS2 (LS3) data taking campaigns
  → improved performance for the ALICE detector
    1. Fabrizio Grosa, "Physics perspectives for ALICE in Run 4"
    2. Andrea Dainese, "Highlights and perspectives from the ALICE experiment"
    3. Piotr Gasik, "ALICE upgrades"
    4. …

… a non-exhaustive list!

Thank you for your attention

Back-up

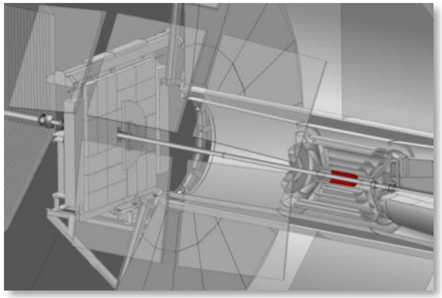
ALICE luminosity

System	Year(s)	$\sqrt{s_{NN}}$ (TeV)	L_{int}
Pb-Pb	2010-2011	2.76	$\sim 75\mu b^{-1}$
	2015	5.02	$\sim 250\mu b^{-1}$
	2018	5.02	$\sim 0.9 nb^{-1}$
Xe-Xe	2017	5.44	$\sim 0.3\mu b^{-1}$
p-Pb	2013	5.02	$\sim 15 nb^{-1}$
	2016	5.02, 8.16	$\sim 3nb^{-1}, \sim 25nb^{-1}$
pp	2009-2013	0.9, 2.76, 7, 8	$\sim 200\mu b^{-1}, \sim 100nb^{-1}, \sim 1.5pb^{-1}, \sim 2.5pb^{-1}$
	2015, 2017	5.02	$\sim 1.3pb^{-1}$
	2016-2018	13	$\sim 59pb^{-1}$

SPD, SDD and SSD

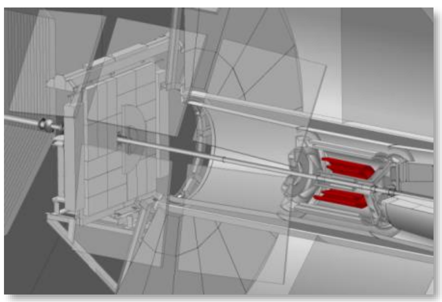
The ALICE Collaboration *et al* 2008 *JINST* **3** S08002

ALICE



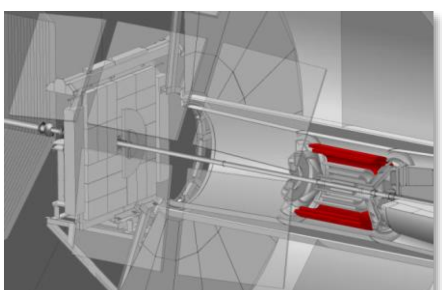
Silicon Pixel Detector (**SPD**)

- Unit: two dimensional matrix (ladder) of reverse-biased silicon detector diodes
- Operating with tracks densities of tens/cm^2
- Key role for primary vertex and impact parameter measurement



Silicon Drift Detector (**SDD**)

- Produced from homogenous high-resistivity (3 kΩcm) 300 μm – thick Neutron Transmutation Doped silicon
- Active area split in two drift regions
- Two out of the four dE/dx samples for PID in the ITS



Silicon Strip Detector (**SSD**)

- 300 μm – thick sensors with 768 strips on each side with a pitch of 95 μm
- Material budget optimization by usage of Carbon Fibre Composite material for support in the active area → reduced multiple scattering
- Two out of the four dE/dx samples for PID in the ITS
- Crucial for ITS-TPC track matching

Event reconstruction flow

Int. J. Mod. Phys. A 29 (2014) 1430044

ALICE

Clusterization (all detectors)

Preliminary (SPD) interaction point reconstruction

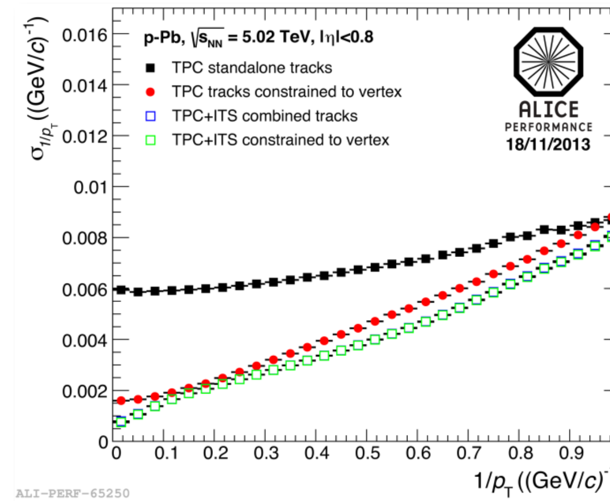
TPC track finding

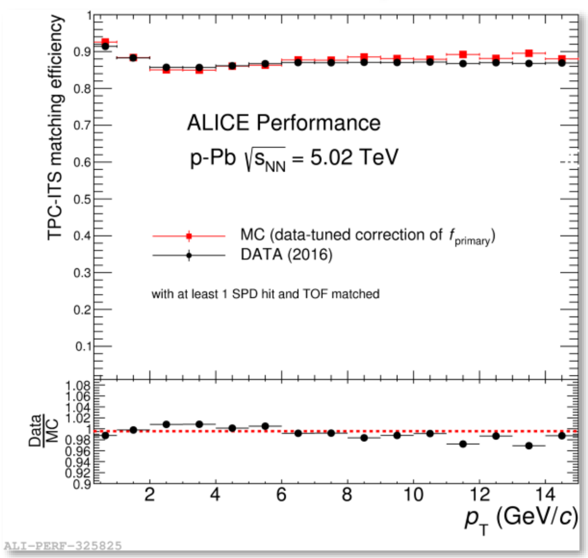
Track prolongation from TPC to ITS

Standalone ITS track finding

Track outward propagation, matching to TRD, TOF, EMCAL, PHOS, HMPID

Track inward propagation with final refit





Final interaction vertex finding

K^0_S, Λ, … , ${}^3_\Lambda$H

V0 finding

Heavy- flavour secondary vertices

D mesons, Λ_c^+, Ξ_c^+, …

Ξ^-, Ω^-, …

Cascades

Heavy-flavour vertex reconstruction

ARDA-Note-2009-002

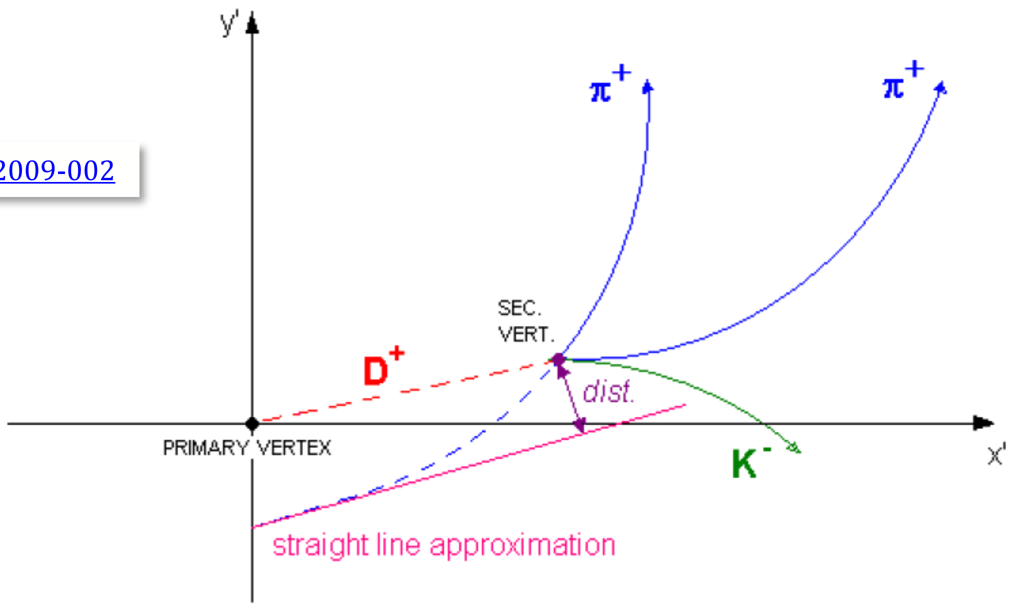


Figure 29: Sketch of the three-body decay $D^+ \rightarrow K^-\pi^+\pi^+$ with the illustration of the straight line approximation for one of the decay products. d is the distance between the secondary vertex and the tangent line. The reference system (x', y') represents the local coordinates of the tracking algorithm.

Heavy-flavour vertex reconstruction

ARDA-Note-2009-002

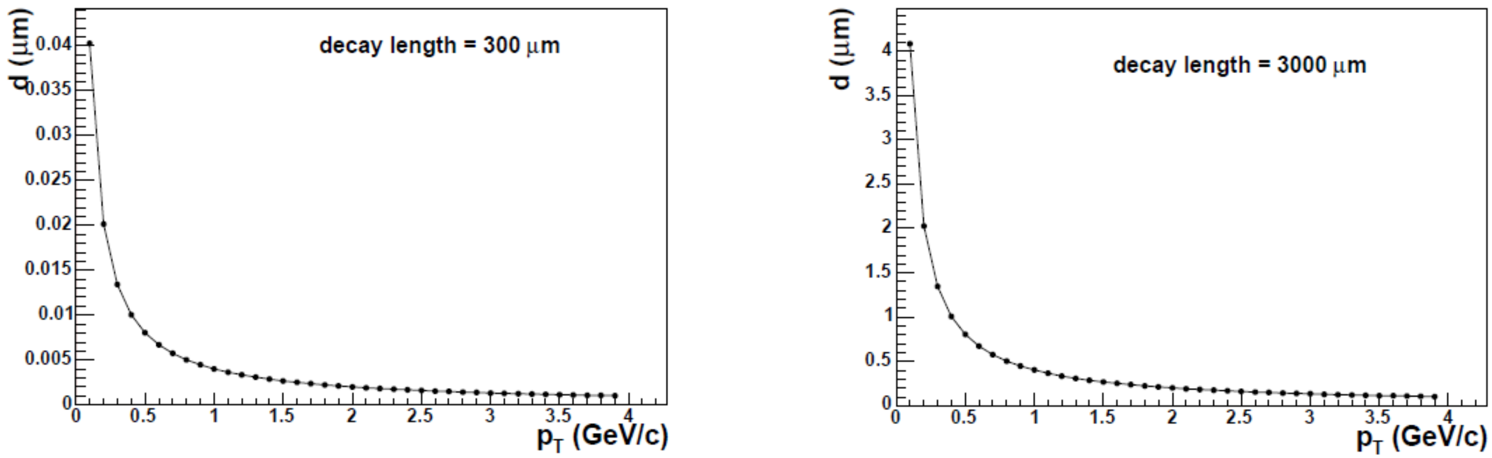
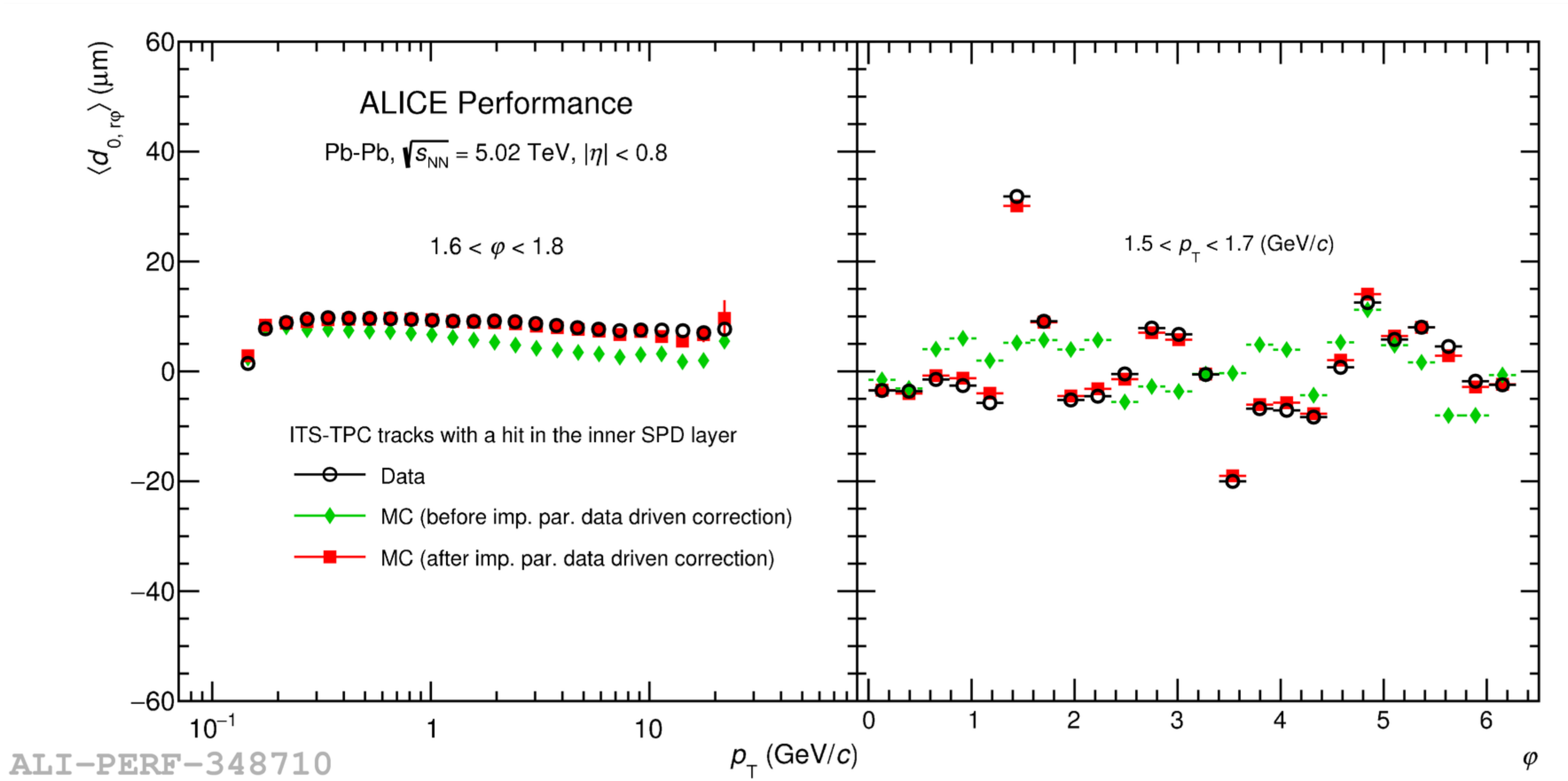


Figure 30: $D^+ \to K^-\pi^+\pi^+$ decay: distance between secondary vertex and the tangent line as a function of the transverse momentum of the particle, for decay lengths of 300 μm (left panel) and 3000 μm (right panel), with $B = 0.5$ T. See text for more details.

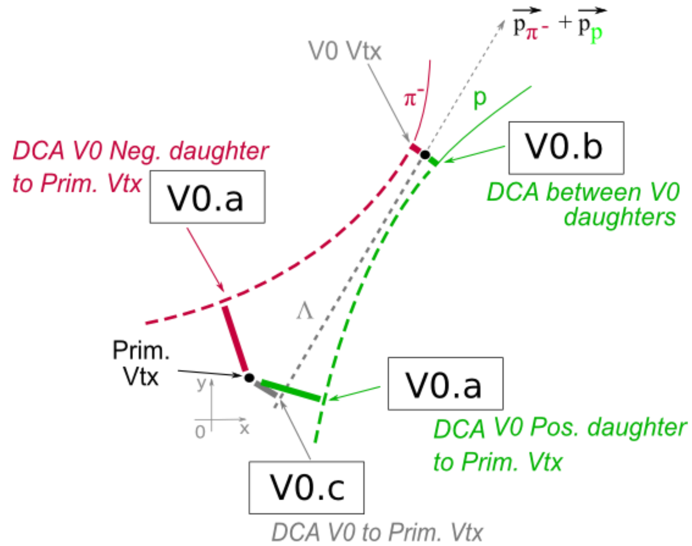
Data-driven correction of impact parameter in MC

ALICE



V0 finding

Eur. Phys. J. C **71**, 1594 (2011)



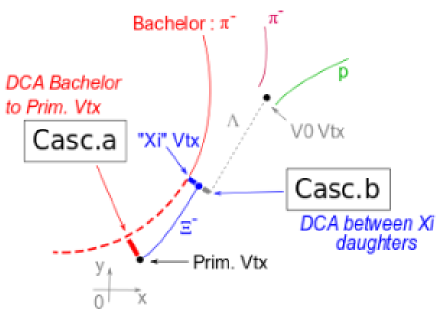
	Mass (MeV/c^2)	$c\tau$ (cm)	Decay (B.R.)
K^0_S	498	2.68	$K^0_S \rightarrow \pi^+\pi^-$ (69.2 %)
Λ	1116	7.89	$\Lambda \rightarrow p\pi^-$ (63.9 %)

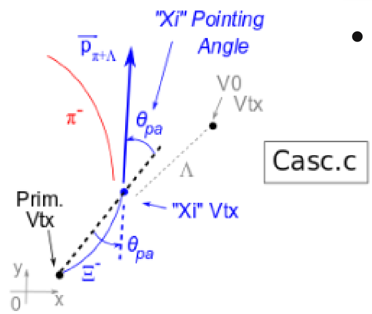
- V0 finder for K^0_s and Λ reconstruction
  - ✓ Selections of secondary tracks (large impact parameter w.r.t. primary vertex)
  - ✓ Combination of secondary tracks
  - ✓ V0 candidates: combinations with DCA < 0.5 cm
  - ✓ V0 vertex position: 3D minimization of DCA
    - → in a line connecting the points of closest approach of the two tracks
    - → distance from tracks proportional to track parameter precision
  - ✓ V0 candidates accepted:
    - ➢ radius w.r.t. primary vertex from 0.2 cm to 100 cm
    - ➢ reconstructed momentum has to point to the primary vertex → $\cos\theta_p > 0.99$
  - ✓ TPC PID used to reduce the combinatorial background

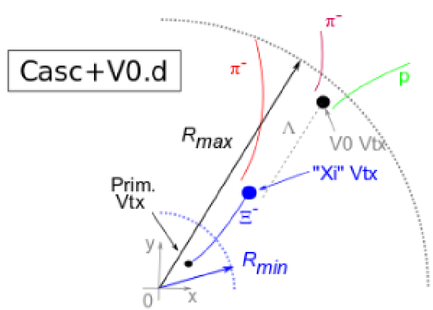
DCA = Distance to Closest Approach between two tracks

Cascades

[Eur. Phys. J. C **71**, 1594 (2011)]





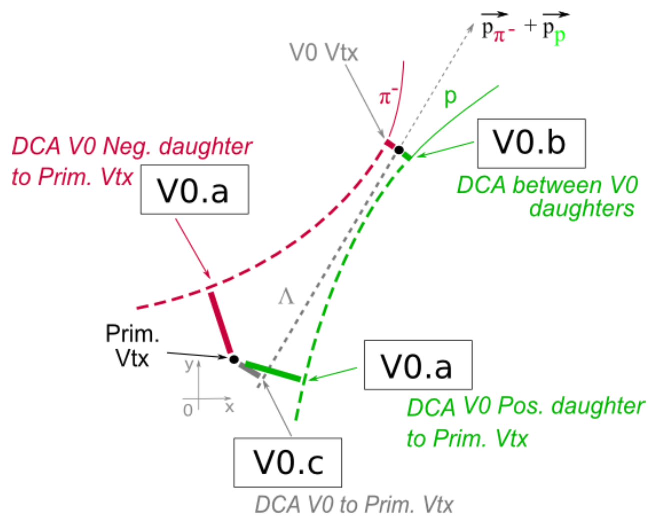


	Mass (MeV/c^2)	$c\tau$ (cm)	Decay (B.R.)
Ξ^-	1322	4.91	$\Xi^- \to \Lambda\pi^-$ (99.9 %)
Ω^-	1672	2.46	$\Omega^- \to \Lambda K^-$ (67.8 %)

- Ξ^- and Ω^- reconstructed as cascades
  - ✓ V0 finding without $\cos\theta_\mathrm{p}$ requirement
    → V0 daughters do not have to point to primary vertex
  - ✓ V0 candidates selected around the V0 mass value and combined with all secondary tracks (bachelor) except the V0 daughters
  - ✓ Selection on bachelor impact parameter to reject primary particles → background reduction
  - ✓ V0-bachelor association if the DCA between the bachelor and V0 trajectory is less than 3 cm
  - ✓ Reconstructed cascade momentum has to point to the primary vertex → $\cos\theta_\mathrm{p} > 0.85$
  - ✓ TPC PID used to reduce the combinatorial background

DCA = Distance to Closest Approach between two tracks

V0 and cascades



- "V0 finder" for K_S^0 and Λ reconstruction
  - ✓ Secondary track pairs with DCA < 0.5 cm
  - ✓ V0 vertex position distance from tracks ∝ track parameter precision → fiducial volume (radius ∈ [0.2, 100] cm)
  - ✓ $\cos\theta_p > 0.99$ → momentum pointing to PV

	Mass (MeV/c^2)	$c\tau$ (cm)	Decay (B.R.)(*)
K_S^0	498	2.68	$K_S^0 \to \pi^+\pi^-$ (69.2 %)
Λ	1116	7.89	$\Lambda \to p\pi^-$ (63.9 %)
Ξ^-	1322	4.91	$\Xi^- \to \Lambda\pi^-$ (99.9 %)
Ω^-	1672	2.46	$\Omega^- \to \Lambda K^-$ (67.8 %)
${}^3_\Lambda\mathrm{H}$	2991	6.18 (average)	${}^3_\Lambda\mathrm{H} \to {}^3\mathrm{He}\,\pi^-$ (25 %) H. Kamada et al., Phys. Rev. C 57 (1998) 1595-1603

DCA = Distance to Closest Approach between two tracks
PV = Primary Vertex

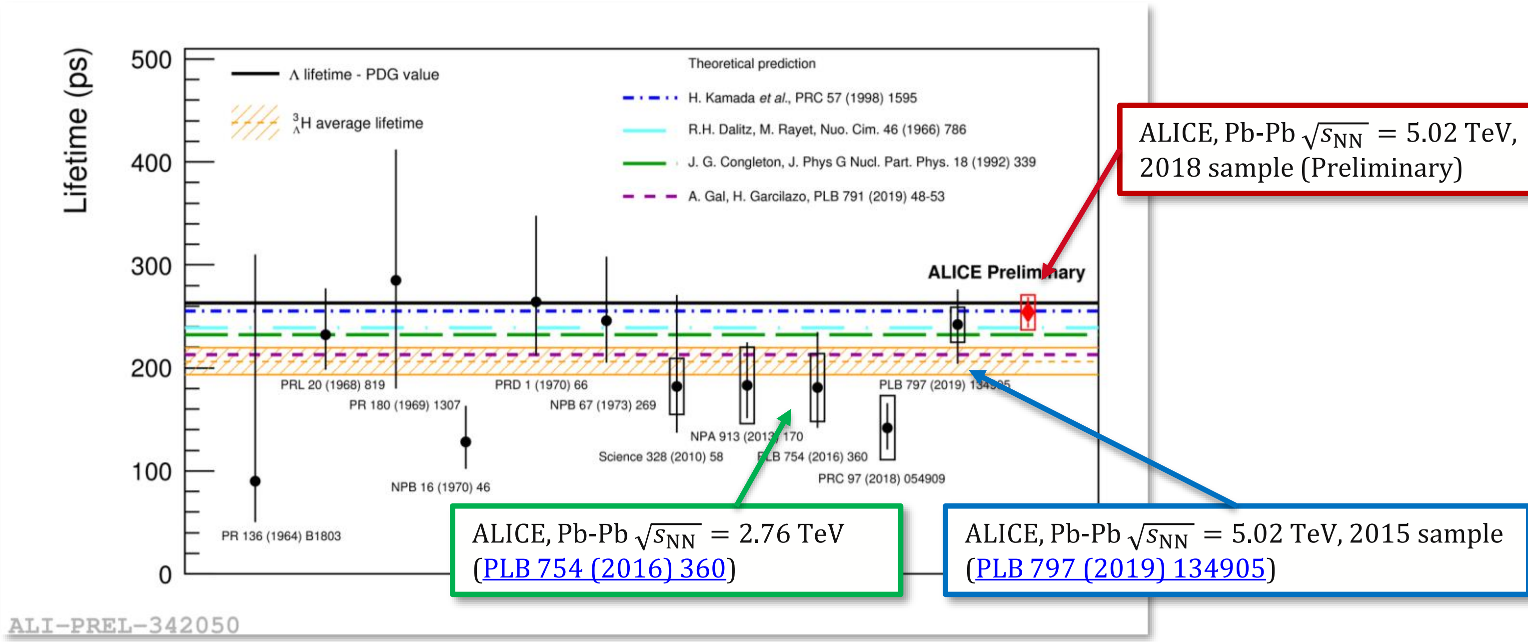
- Ξ^- and Ω^- reconstructed as cascades
  - ✓ V0 finding + association with secondary track (bachelor)
  - ✓ Selections on V0 mass and bachelor impact parameter → background reduction
  - ✓ $\cos\theta_p > 0.85$ → cascade momentum pointing to PV

- TPC PID used to reduce the combinatorial background

Hypertriton lifetime measurement in Pb-Pb

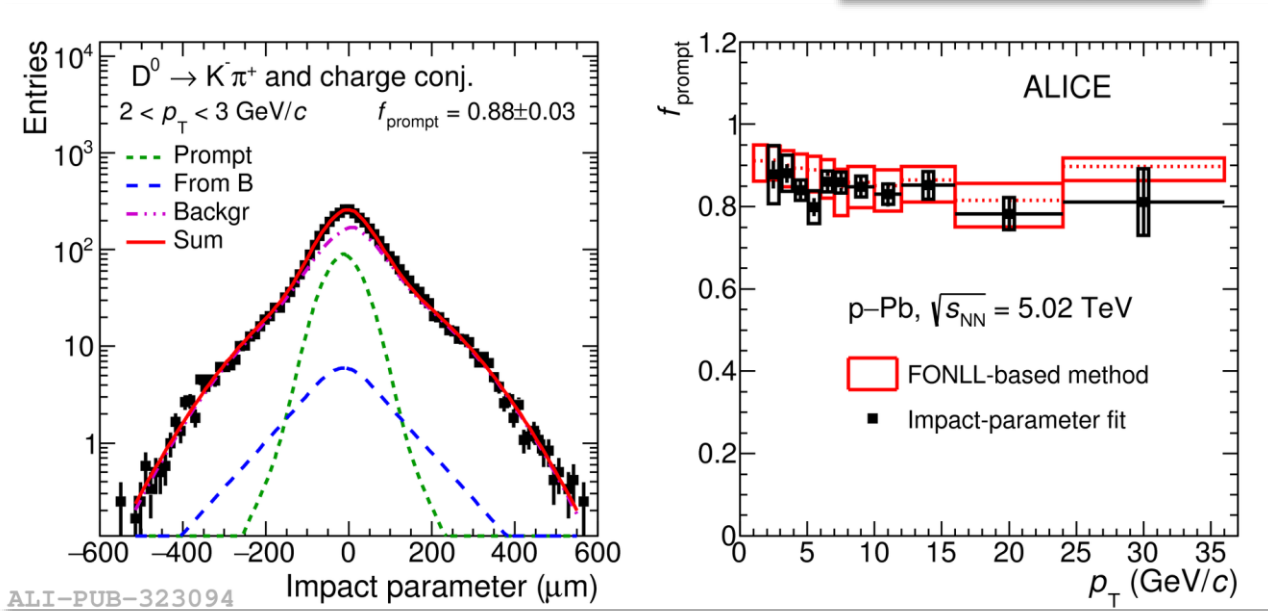
- Inner cores of neutron stars (NS): hyperon production favoured
- Resulting equation of state (EOS) inhibits large NS
  → $2M_{\odot}$ NS observed → "hyperon puzzle"
- Models: additional repulsion from 3-body interactions

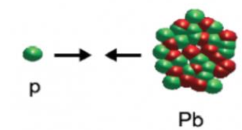
- ${}^{3}_{\Lambda}H$ lifetime τ is an experimental probe of hyperon-nucleon-nucleon (Y-N-N) interaction → precise measurements are fundamental



D-mesons non-prompt fraction

JHEP, **2019**, 92 (2019)





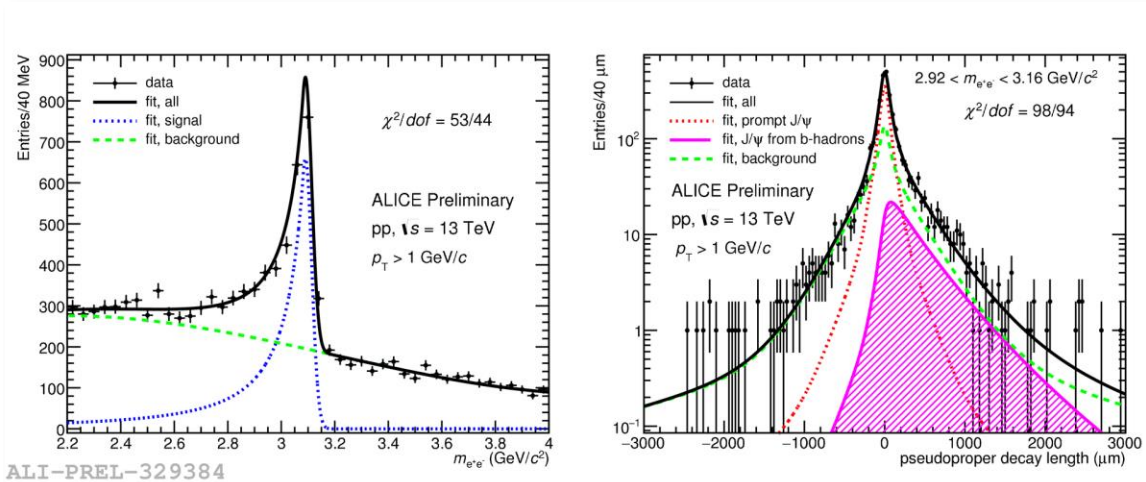
- Data-driven method for f_{prompt} measurement
- Transverse-plane impact parameter (d_0) distribution fit with

$$F(d_0) = S \cdot \left[\left(1 - f_{\mathrm{prompt}}\right) F^{\mathrm{FD}}(d_0) + f_{\mathrm{prompt}} F^{\mathrm{prompt}}(d_0)\right] + B \cdot F^{\mathrm{bkg}}(d_0)$$

- Results compatible with FONLL-based method
- Lower uncertainties for $4 < p_{\mathrm{T}} < 24$ GeV/c

Results in pp collisions at $\sqrt{s} = 5.02$ TeV:
Eur. Phys. J. C **79**, 388 (2019)

Prompt – non-prompt J/ψ separation

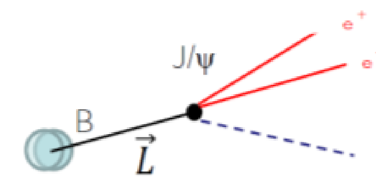


- Maximization of 2D likelihood
- Invariant mass and pseudo-proper decay length (x) fitted simultaneously

$$\ln L = \sum_{i=1}^{N} F(x, m_{e^+e^-})$$

$$x = \frac{c m_{J/\psi}}{p_T^{J/\psi}} \cdot \frac{\vec{L} \cdot \vec{p}_T^{\,J/\psi}}{p_T^{J/\psi}}$$

L_{xy}



Signal

Background

$$F(x, m_{e^+e^-}, p_T, SPDtype) = f_{Sig} \times F_{sig}(x) \times M_{sig}(m_{ee}) + (1 - f_{Sig}) \times F_{Bkg}^{SPDtype}(x) \times M_{Bkg}(m_{ee})$$

Non-prompt

Prompt

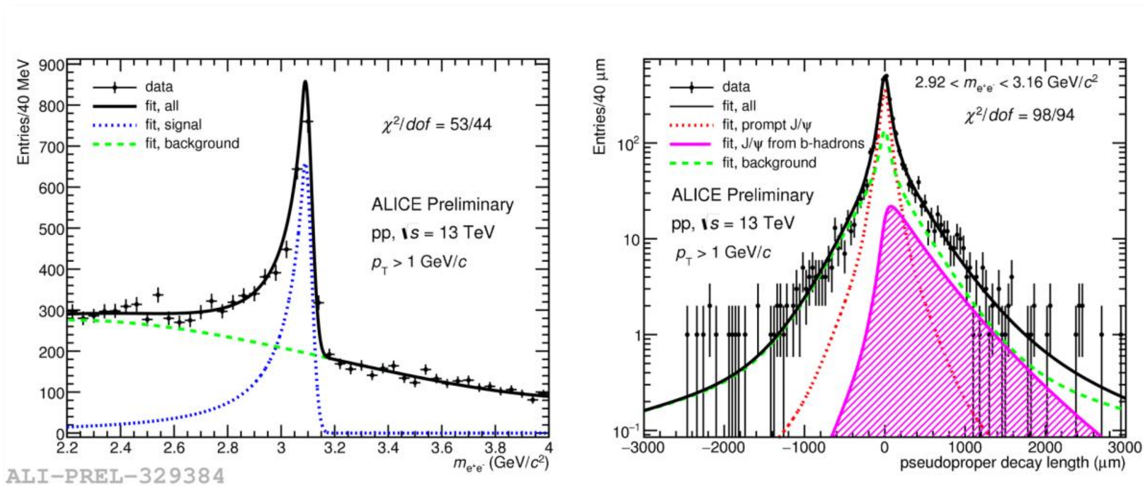
$$F_{Sig}(x) = f_B \times T(x) + (1 - f_B) \times R(x)$$

From invariant mass sidebands

Fraction of non-prompt J/ψ

- Kinematic × resolution ($R(x)$)
- Negative values (kin.): low- $p_T^{J/\psi}$ → large opening angle with respect to B-hadron → negative scalar product possible
- High- $p_T^{J/\psi}$: collinear with B-hadron → positive (scalar product) values only

Prompt – non-prompt J/ψ separation

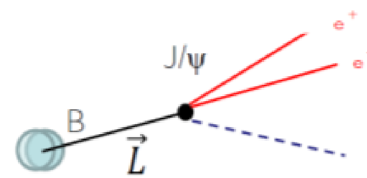


- Maximization of 2D likelihood
- Invariant mass and pseudo-proper decay length (x) fitted simultaneously

$$\ln L = \sum_{i=1}^{N} F(x, m_{e^+e^-})$$

$$x = \frac{c m_{J/\psi}}{p_T^{J/\psi}} \cdot \frac{\vec{L} \cdot \vec{p}_T^{\,J/\psi}}{p_T^{J/\psi}}$$

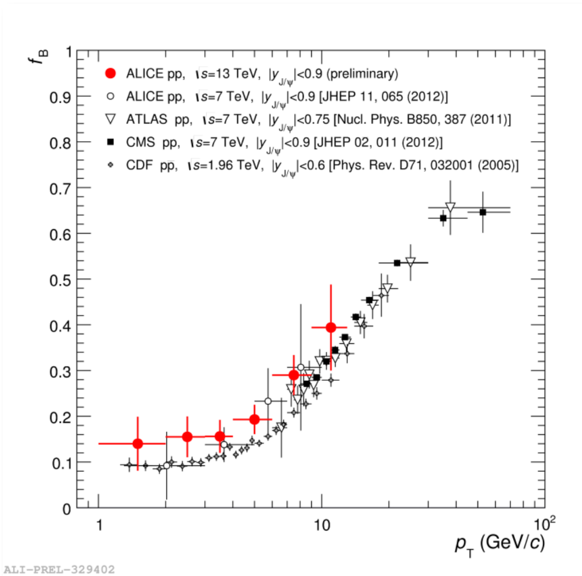
L_{xy}

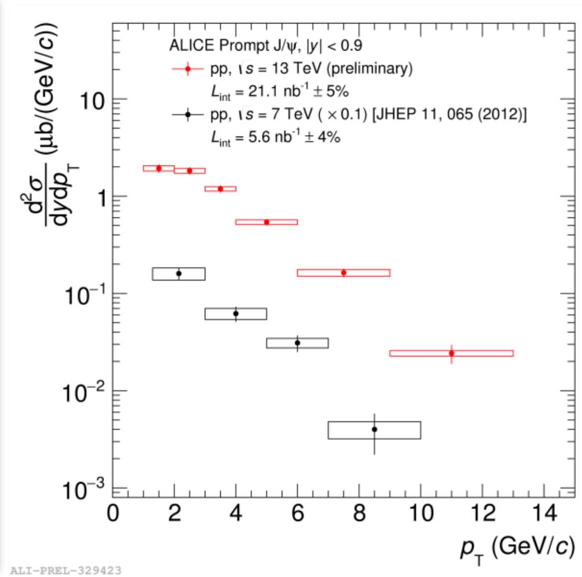


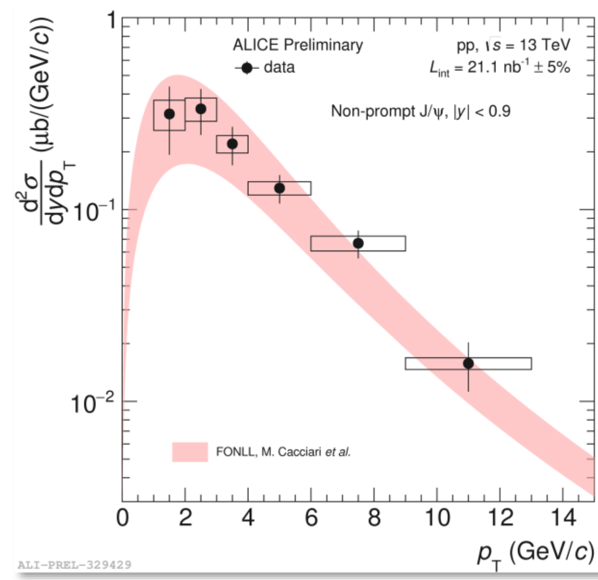
- From fits: raw non-prompt fraction f_B'
- Non-prompt fraction f_B obtained after acceptance × efficiency correction (no polarization effects)

$$f_B = \left(1 - \frac{1 - f_B'}{f_B'} \cdot \frac{\langle A \times \mathrm{eff} \rangle_B}{\langle A \times \mathrm{eff} \rangle_{\mathrm{prompt}}}\right)^{-1}$$

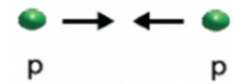
Prompt - non-prompt J/ψ at mid-rapidity in pp





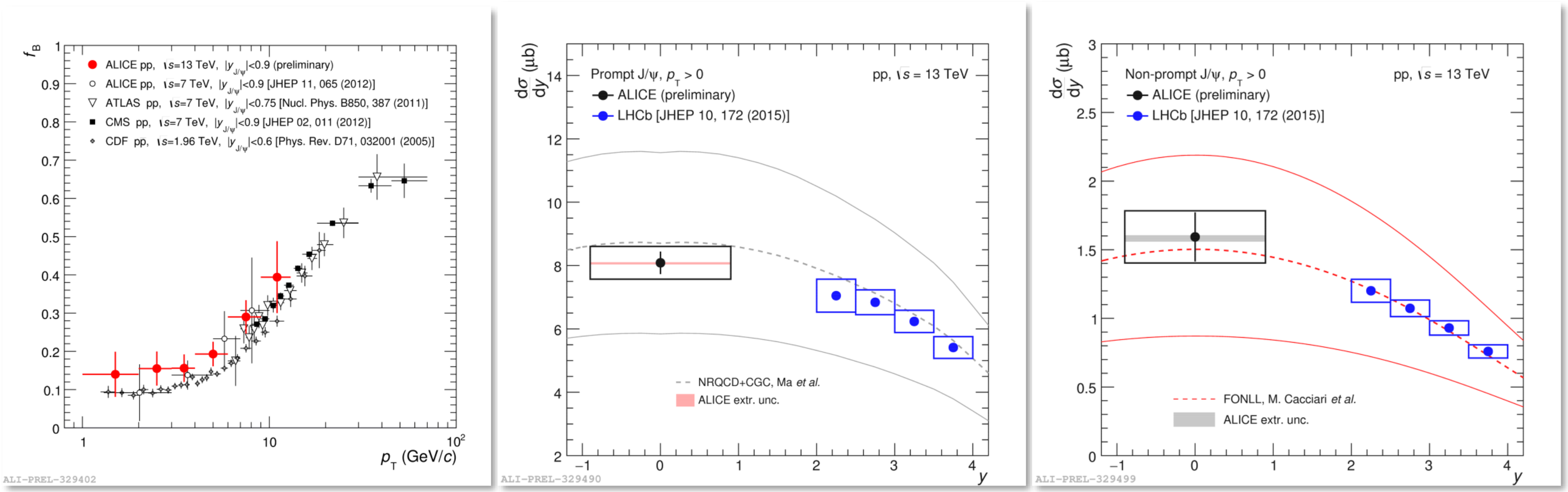


- Prompt $J/\psi \rightarrow e^+e^-$ distinguished from non-prompt ones exploiting the larger beauty displacement → larger decay length
- Non-prompt J/ψ fraction at mid-rapidity measured down to $p_T = 1$ GeV/c → lowest p_T ever measured!
- Prompt - non-prompt J/ψ cross sections measured separately
  → smaller uncertainties and wider p_T-range covered at 13 TeV with respect to 7 TeV (JHEP 11, 065 (2012))
  → p_T-integrated value: extrapolation down to $p_T = 0$ GeV/c exploiting FONLL



ALICE

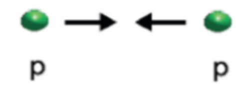
Prompt - non-prompt J/ψ at mid-rapidity in pp

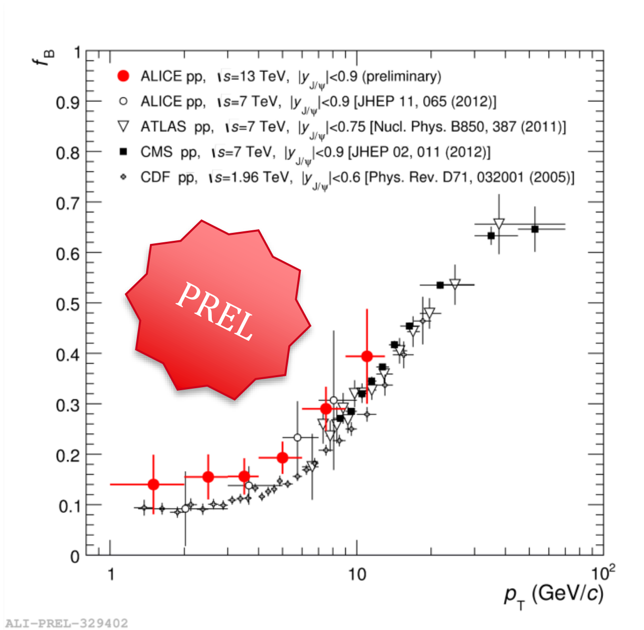


- Prompt J/$\psi \rightarrow e^+e^-$ distinguished from non-prompt ones exploiting the larger beauty displacement → larger decay length
- Non-prompt J/ψ fraction at mid-rapidity measured down to $p_{\mathrm{T}} = 1$ GeV/c → lowest p_{T} ever measured!
- Prompt - non-prompt J/ψ cross sections measured separately
  → smaller uncertainties and wider p_{T}-range covered at 13 TeV with respect to 7 TeV (JHEP 11, 065 (2012))
  → p_{T}-integrated value: extrapolation down to $p_{\mathrm{T}} = 0$ GeV/c exploiting FONLL

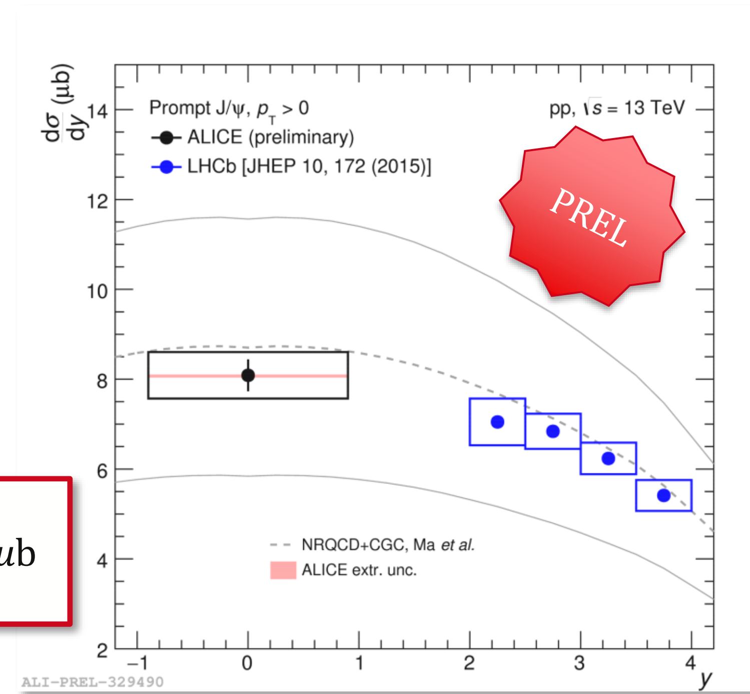
ALICE

Prompt J/ψ at mid-rapidity





- Prompt J/$\psi \rightarrow e^+e^-$ distinguished from non-prompt ones exploiting the larger beauty displacement → larger decay length
- Non-prompt J/ψ fraction at mid-rapidity measured down to $p_T = 1$ GeV/c → lowest p_T ever measured!



- Measurement at mid-rapidity of prompt J/ψ complementary to LHCb one

$$\frac{d\sigma^{(p_T>0)}}{dy}_{\text{prompt J}/\psi} = 8.09 \pm 0.36\,(\text{stat.}) \pm 0.52\,(\text{syst.})^{+0.018}_{-0.049}\,(\text{extr.})\ \mu\text{b}$$

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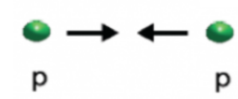
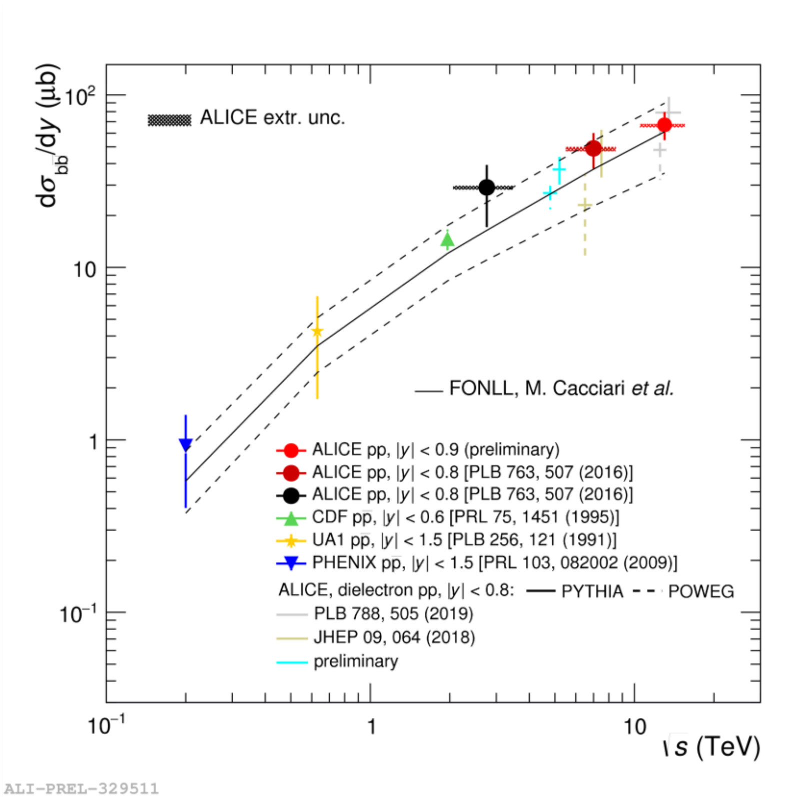
$b\bar{b}$ cross section at mid-rapidity





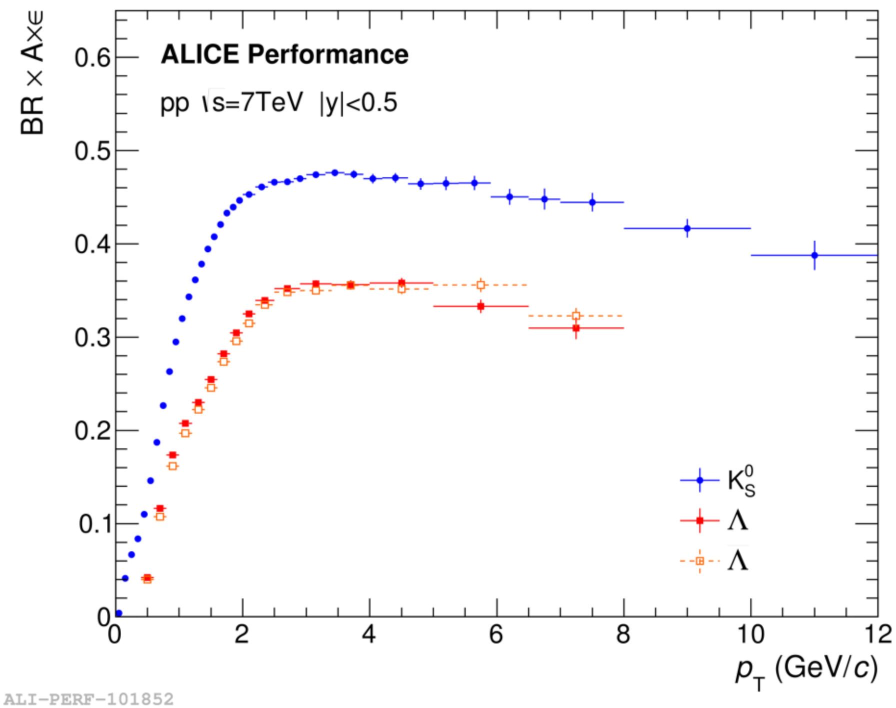
- Measurement performed rescaling the non-prompt J/ψ cross section to the $b\bar{b}$ one with FONLL

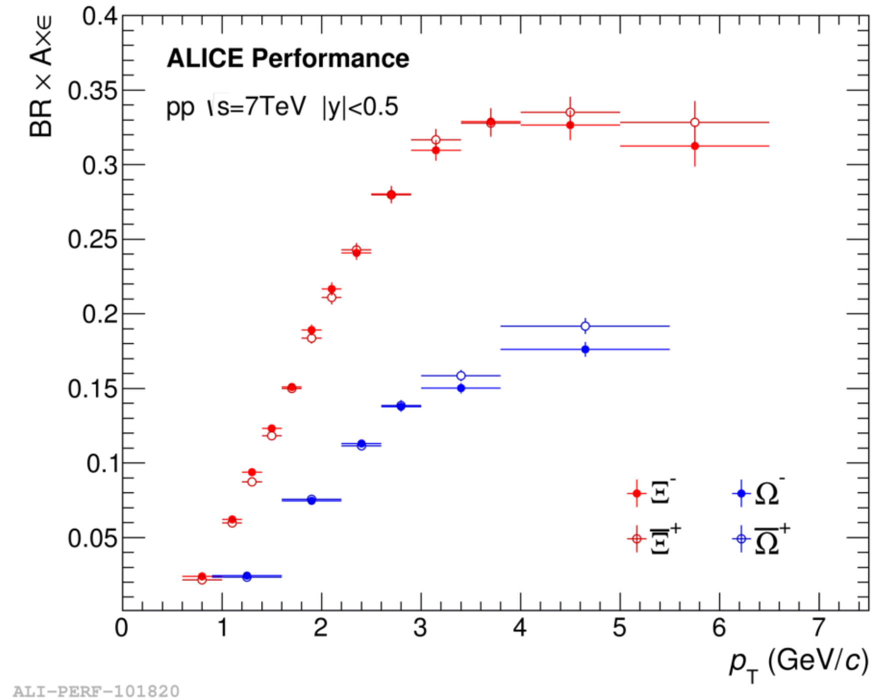
$$\left.\frac{d\sigma_{b\bar{b}}}{dy}\right|_{|y|<0.9} = \frac{d\sigma^{\text{FONLL}}_{b\bar{b}}}{dy} \times \frac{\sigma_{J/\psi\leftarrow h_B}(p_T^{J/\psi} > 1\ \text{GeV}/c\,, |y_{J/\psi}| < 0.9)}{\sigma^{\text{FONLL}}_{J/\psi\leftarrow h_B}(p_T^{J/\psi} > 1\ \text{GeV}/c\,, |y_{J/\psi}| < 0.9)}$$

- Measurement of $b\bar{b}$ cross section compatible with dielectron analyses

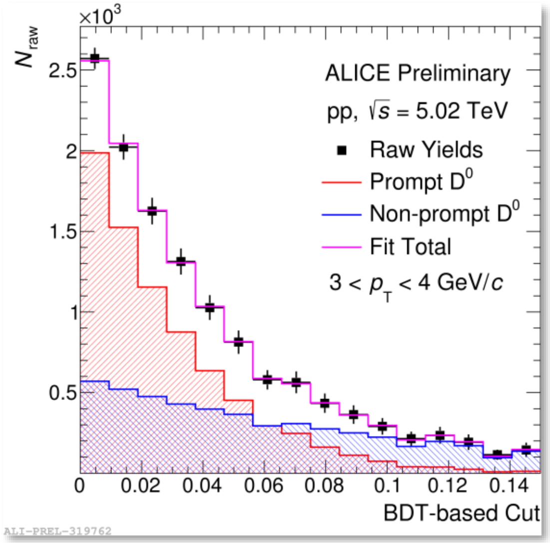
$$\left.\frac{d\sigma_{b\bar{b}}}{dy}\right|_{|y|<0.9} = 67.12 \pm 7.55\ (\text{stat.}) \pm 9.89\ (\text{syst.})^{+0.74}_{-2.21}\ (\text{extr.})\ \mu\text{b}$$

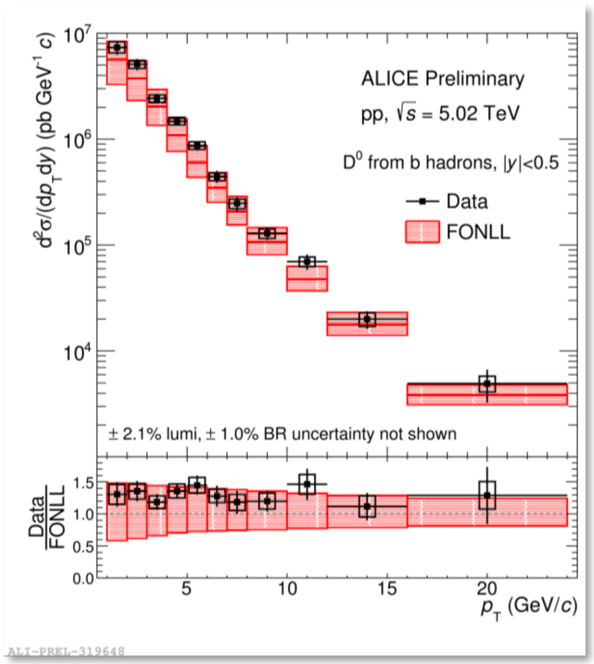
Λ, K_s^0, Ξ, Ω





Beauty via non-prompt D^0 production





$N_{\mathrm{raw}}(x) \approx N_{\mathrm{np}} \cdot \varepsilon_{\mathrm{np}}(x) + N_{\mathrm{p}} \cdot \varepsilon_{\mathrm{p}}(x)$

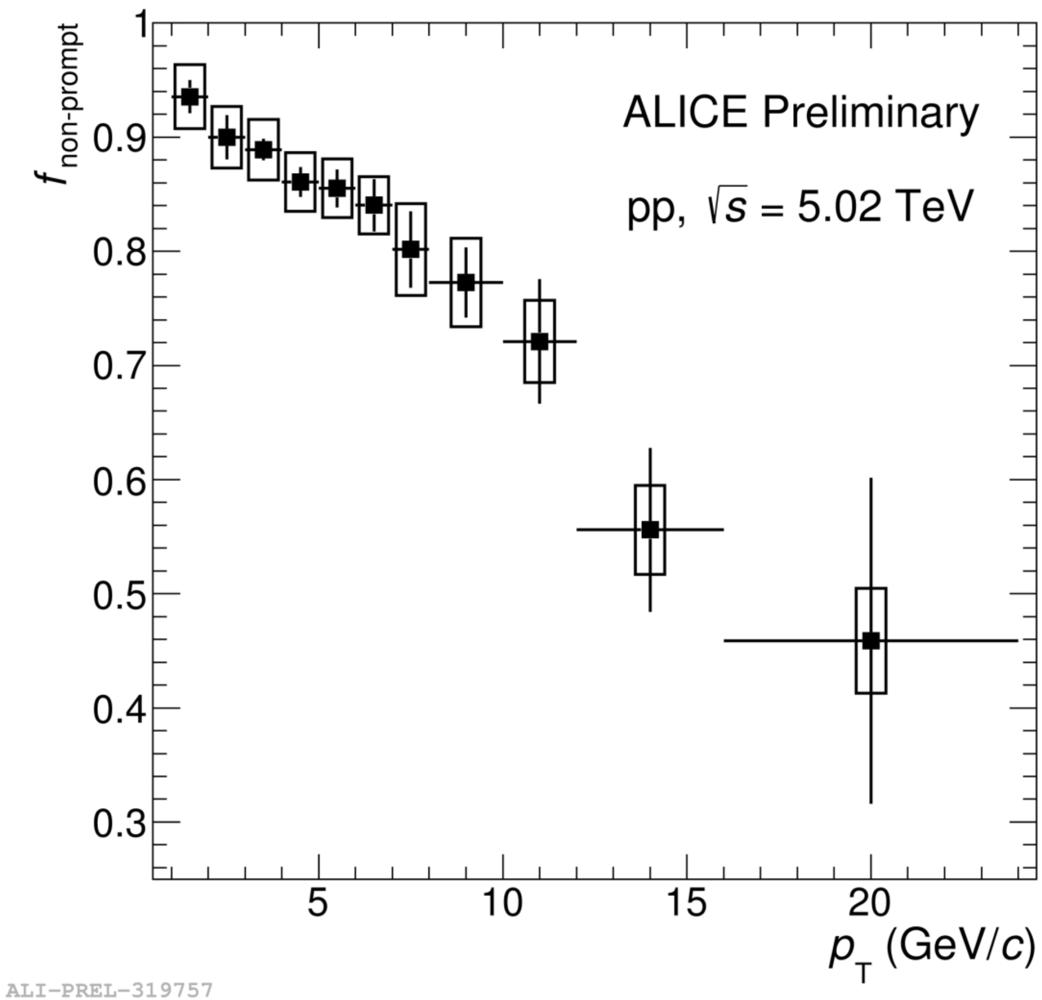
ε: efficiency

$$f_{\mathrm{np}}(x) = \frac{N_{\mathrm{np}} \cdot \varepsilon_{\mathrm{np}}(x)}{N_{\mathrm{np}} \cdot \varepsilon_{\mathrm{np}}(x) + N_{\mathrm{p}} \cdot \varepsilon_{\mathrm{p}}(x)}$$

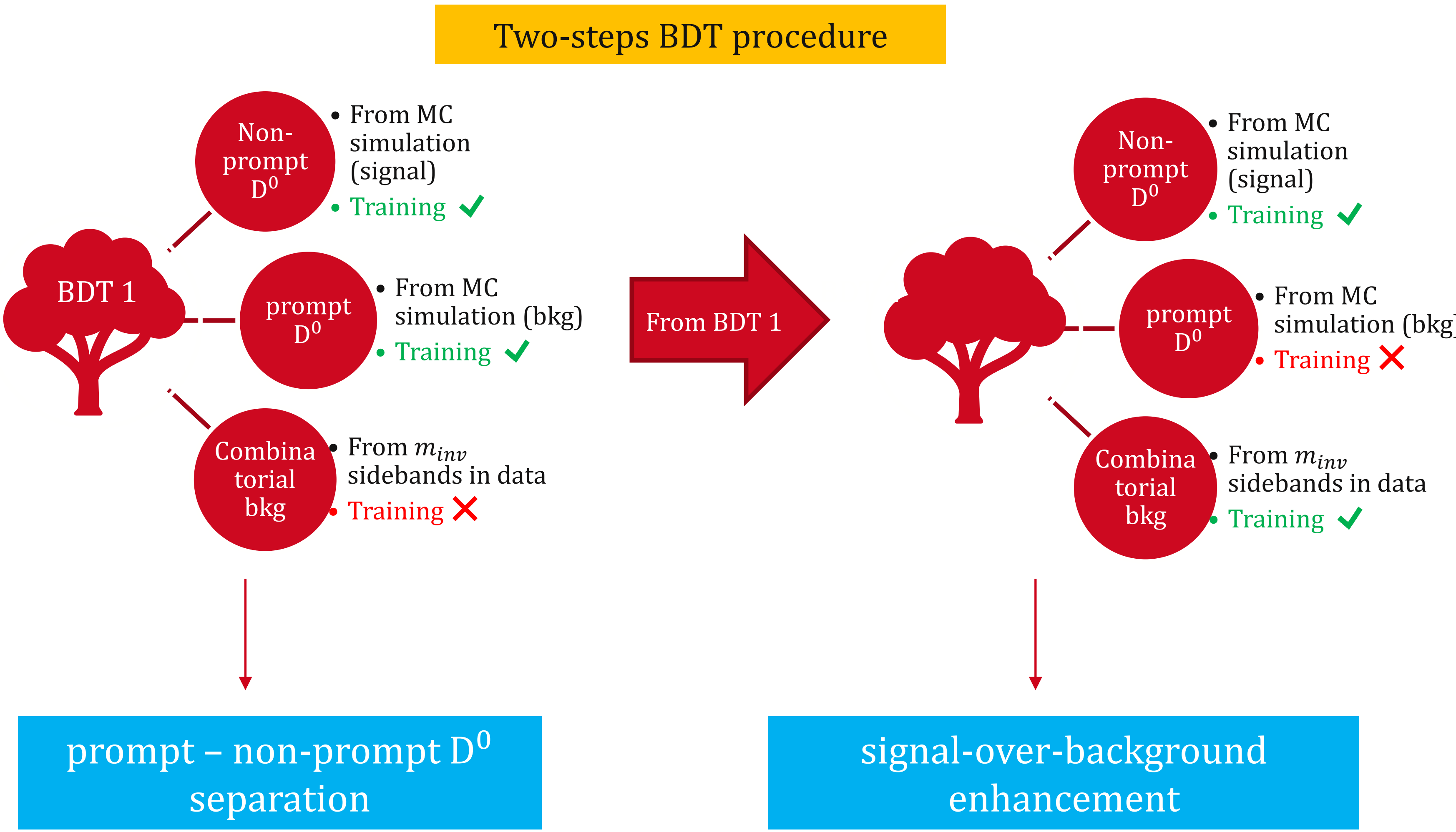
- Machine learning tools
  → two-steps Boost-Decision-Trees (BDTs) to separate non-prompt D^0 from background (prompt D^0, combinatorial)
- Non-prompt fraction from template fit of the raw yield vs. BDT selection (x) value
  → high non-prompt fraction at low p_T ⇒ low systematic uncertainties

- **Measurement down to $p_T = 1$ GeV/c**
- The **measurement** lies on the **upper edge of the FONLL** uncertainty band

Beauty via non-prompt D^0 production



Beauty via non-prompt D^0 production



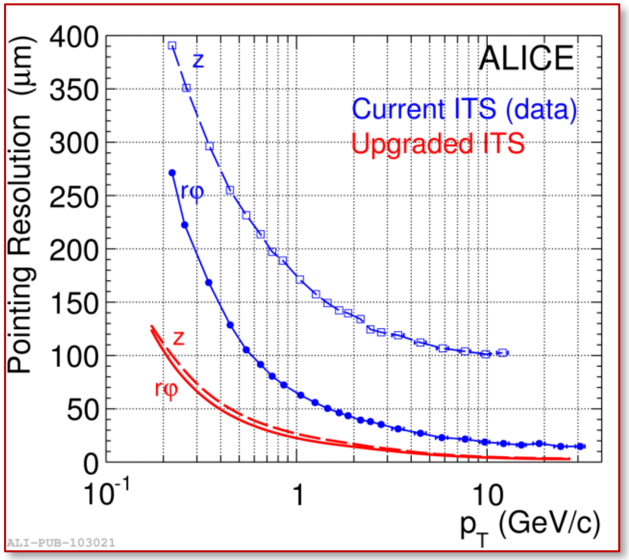
More details in Piotr Gasik's talk «ALICE upgrades»

Upgrade – ITS 2 (Run 3 and 4)

- Layout
  - 7 layer (inner/middle/outer): 3/2/2
  - 192 staves (inner/middle/outer): 48/54/90

- Based on ALPIDE Monolitic Active Pixel Sensors
- 100 m^2 active silicon area, 12.5×10^9 pixels

J. Phys. G 41 (2014) 087002



	ITS 1	ITS 2
Distance to interaction point (mm)	39	22
X_0 (innermost layer) (%)	~1.14	~0.35
Pixel pitch (μm^2)	50×425	27×29
Readout rate (kHz)	1	100
Spatial resolution ($r\varphi \times z$) (μm^2)	11×100	5×5

→ Closer to interaction point

→ Less material budget

→ Improved granularity

→ Faster readout

→ Improved resolution