Monte Carlo activities in ALICE

status and prospects

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for the ALICE Collaboration

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Multiple Partonic Interactions at the LHC

San Cristóbal de las Casas, Chiapas, Mexico

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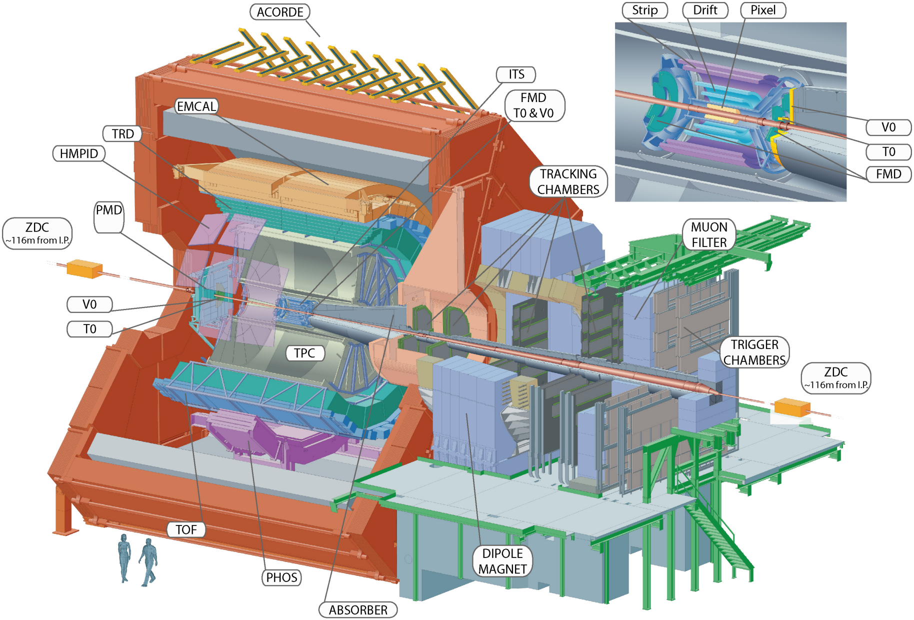
overview

- **ALICE overview**
  what's special about ALICE?
- **Monte Carlo motivation**
  why ALICE can contribute?
- **pp and p–Pb results**
  what is new from ALICE?
- **towards Pb–Pb**
  how can we get more systematic in Pb–Pb?
- **summary and outlook**
  how can we make further progress?

$\rightsquigarrow$ **taking Monte Carlo from pp to Pb–Pb**

ALICE detector



ALICE strengths

- **charged particle tracking over wide $p_\perp$ range**
  ($\sim 100\ \mathrm{MeV/c} - 100\ \mathrm{GeV/c}$)
- **excellent particle identification over wide $p_\perp$ range**
  based on $\mathrm{d}E/\mathrm{d}x$, time of flight, RICH;
  transition radiation and calorimetry for electron identification
- **full event reconstruction**
  in all available collision systems (pp, p–Pb, Pb–Pb)

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complementary to other LHC experiments,

$\rightsquigarrow$ **gives access to interesting realms of physics**

challenging Monte Carlo implementations

as experiment we must challenge the implementations of:

- **underlying event**
- **multiplicity dependence**
  - rope hadronization
  - colour reconnection
- **collectivity in small systems**
  - microscopic origin?
  - thermal model
- **multi parton interactions**
- **transition from small to large systems**

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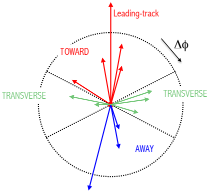
experimental constraints

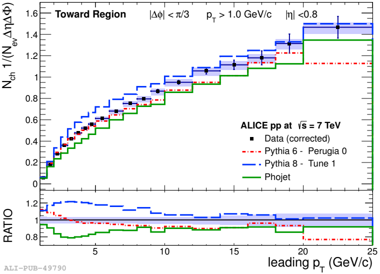
$\rightsquigarrow$ **interesting physics to be understood**

underlying event (pp)

- traditional measurement
  of underlying event
- particle yield
  in regions w.r.t. trigger particle
  - towards
  - away
  - transverse



- important baseline measurement



[JHEP 1207 (2012) 116]

- systematic study
  at various energies
  on-going
- to be extended with
  identified particles

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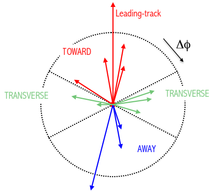

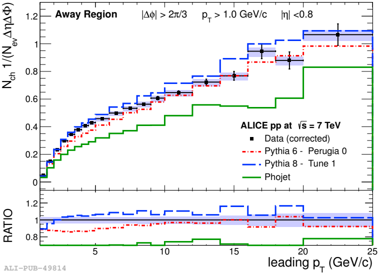

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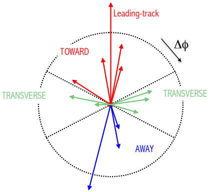

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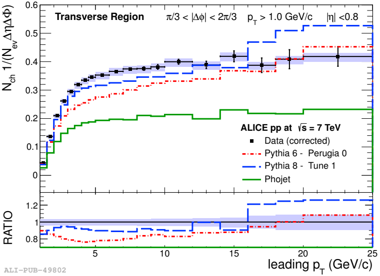

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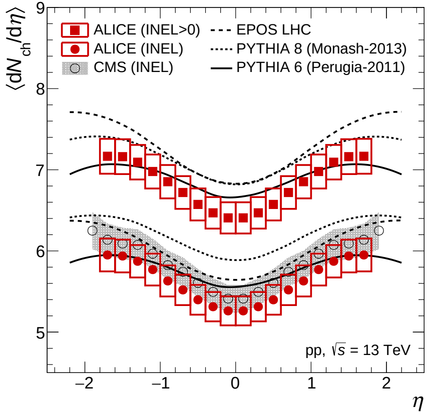
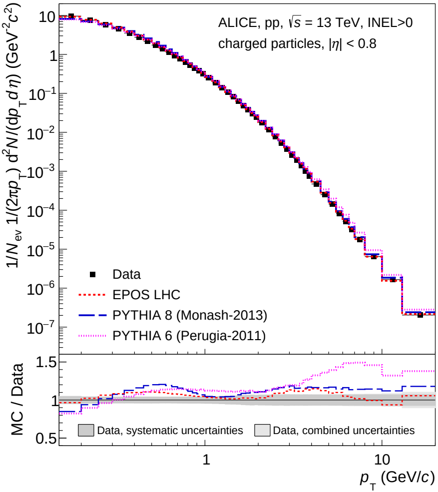
pseudo-rapidity density (pp)



[PLB 753 (2016) 319-329]

- pp $\sqrt{s} = 13\ \mathrm{TeV}$
- primary particles for
  - INEL
  - $\mathrm{INEL} > 0\ (|\eta| < 1)$
- reasonable agreement with MC, but room for improvement
- enters other (more complex) measurements

$p_\perp$ spectra (pp)



[PLB 753 (2016) 319-329]

- pp $\sqrt{s} = 13$ TeV
- INEL > 0 ($|\eta| < 1$)
- Pythia and EPOS show common patterns of deviation
- multiplicity estimator: meas. N_{ch} in same acceptance: $|\eta| < 0.8$, $0.15 < p_\perp < 20$ GeV$/c$
- in multiplicity classes, ratio to INEL > 0

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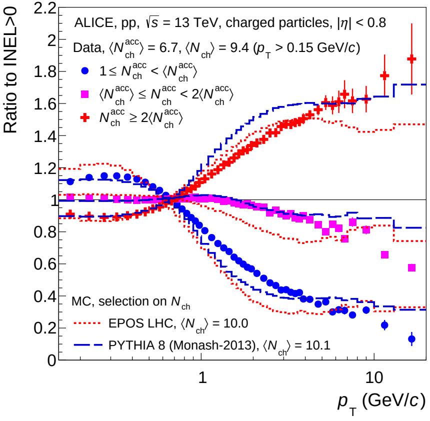

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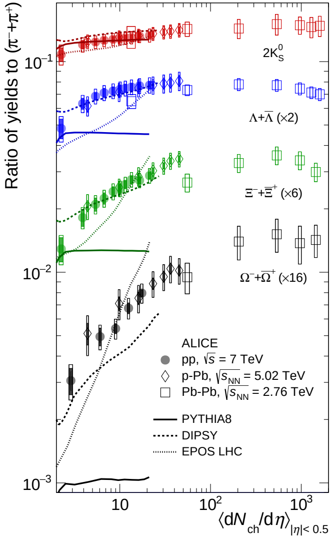
multiplicity-dependence of strangeness production (pp)

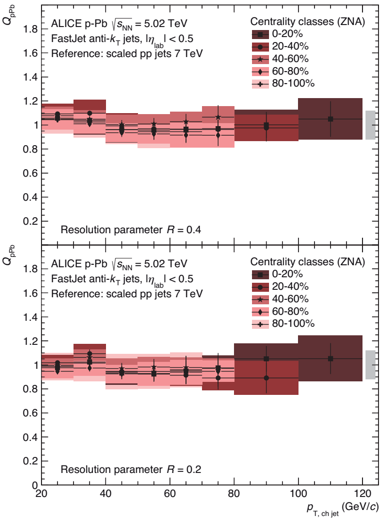


- measurement of multiplicity dependence of strange particle production ($|y| < 0.5$)
- strangeness enhancement in pp!
  effect of strangeness (not mass)
- Pythia and EPOS are off
- DIPSY describes the trend
- fundamental origin of strangeness enhancement not understood;

  only modelled by canonical suppression, core corona

[1606.07424]

centrality dependence of jet spectra (p–Pb)



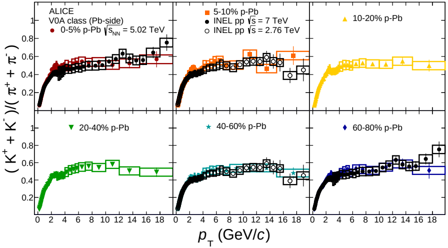
[EPJC 76 (2016) 5, 271]

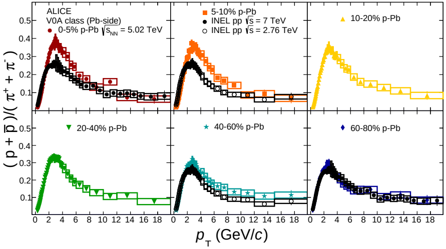
- $p_\perp$ spectra for charged jets: anti-kt, $|\eta| < 0.5$, $R = 0.4$ (top), $R = 0.2$ (bottom)

$$Q_{\mathrm{pPb}} := \frac{\mathrm{d}N^c_{\mathrm{pPb}}/\mathrm{d}p_\perp}{\langle N^c_{\mathrm{coll}}\rangle \; \mathrm{d}N^c_{\mathrm{pp}}/\mathrm{d}p_\perp}$$

- centrality classes from zero-degree calorimetry, $\rightsquigarrow$ avoid dynamical bias
- for jets (i.e. hard production) no centrality dependence
- heavy-ion like behaviour suggested, but jet production not influenced

multiplicity dependence of identified particles (p–Pb)

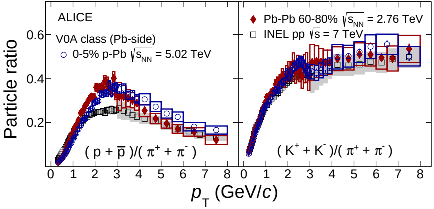




[PLB 760 (2016) 720-735]

- particle ratios vs $p_\perp$:
  - K/π (top)
  - p/π (bottom)
- comparison to pp
- comparison to pp and Pb–Pb
- ⇝ Monte Carlo comparison needed

multiplicity dependence of identified particles (p–Pb)



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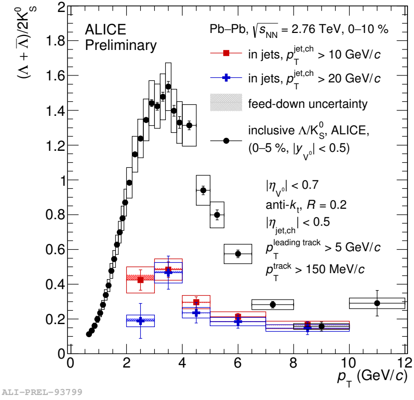
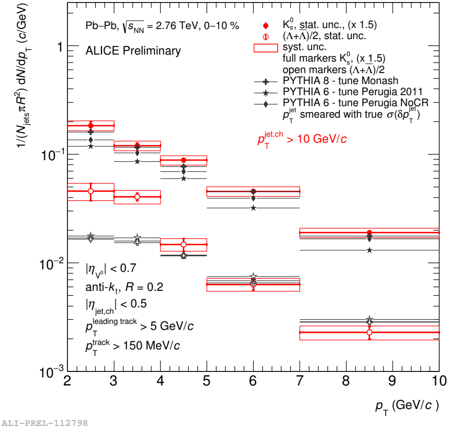
- $\rightsquigarrow$ Monte Carlo comparison needed

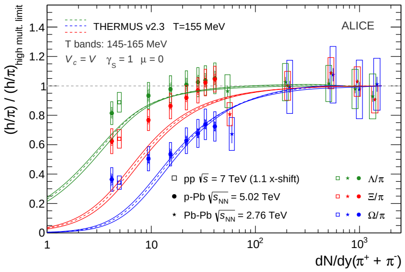
strangeness in jets (Pb–Pb)





- measure strangeness in jets
  $\rightsquigarrow$ probe in-medium jet fragmentation
- Pythia as proxy for pp

multi-strange baryons (pp, p–Pb, Pb–Pb)



[PLB 758 (2016) 389-401]

- strangeness enhancement as function of $\pi^{\pm}$ multiplicity: Λ, Ξ, Ω
- allows us to compare collision systems
- compare to thermal model, here THERMUS
- trend is described

$\rightsquigarrow$ **linking pp, p–Pb, Pb–Pb**

multiplicity dependence of correlations (pp, p–Pb, Pb–Pb)

- balance function (charge-dependent per-trigger yields):

$$B(\Delta\eta, \Delta\varphi) = \frac{1}{2}\left[c_{(+,-)} + c_{(-,+)} - c_{(+,+)} - c_{(-,-)}\right]$$

- strong multiplicity dependence of width
  $\rightsquigarrow$ indicator for collectivity

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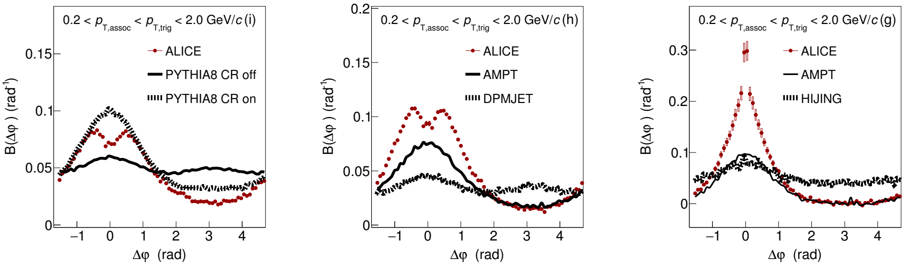
pp (0-10%) | p–Pb (0-10%) | Pb–Pb (0-5%)



[EPJC 76 (2016) 2, 86]

systematic comparisons: Monte Carlo vs. data

learn from pp community:

⇝ **Rivet** (Robust Independent Validation of Experiment and Theory):

- **generator-agnostic analysis framework**, co-evolved with fastjet
- reads input from Monte Carlo generator
- runs one (or more) analyses on the input data
- produces plots corresponding to available measurements with comparison MC/data
- distributed with (validated) analyses and corresponding data

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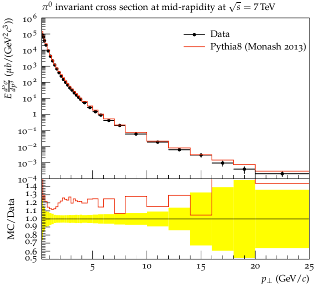
⇝ **make ALICE analyses available for Rivet**
in the following: preview of new analyses
(more are in preparation)

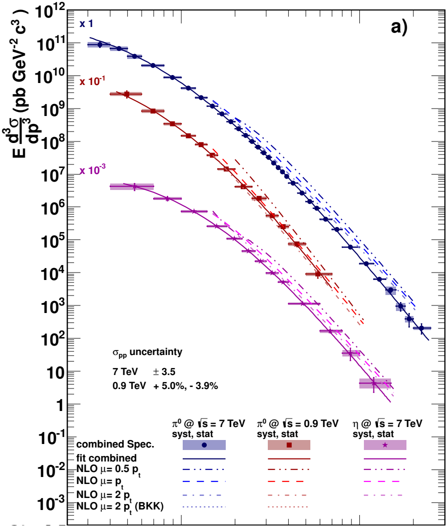
π^0/η production (pp)

Rivet analysis: submitted



[PLB 717 (2012) 162-172]

- here comparison to: Pythia 8 (Monash tune)
- trend looks good, but overall yield is off
- also ratio slightly off



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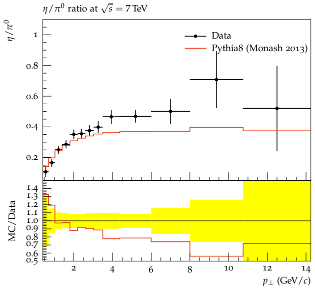

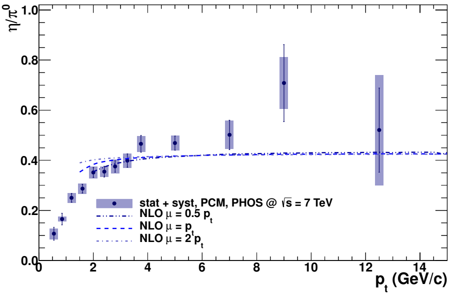

[PLB 717 (2012) 162-172]

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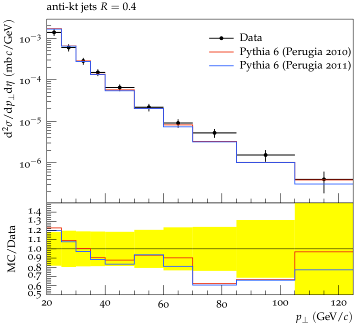
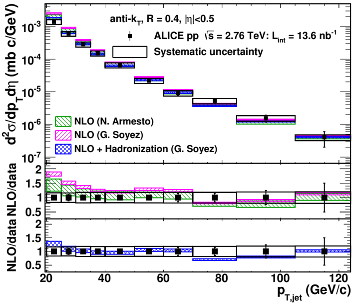
Jet cross section (pp)

Rivet analysis: under validation





[PLB 722 (2013) 262-272]

- $p_\perp$-differential jet cross section (here: anti-kt $R = 0.4$)
- good agreement with Pythia 6

towards heavy-ion physics

- availability of Rivet analyses allows for **automatized creation of comparison plots** exploiting large number of generators and tunes
- **mcplots** project hosted at CERN to
  - generate events (batch system and voluntary computing)
  - run analyses
  - provide interface to plot comparison of selected generators/tunes to data
- heavy-ion challenges:
  - additional classification, e.g. centrality
  - post-processing, e.g. division of Pb–Pb and pp samples
  - computing resources for Pb–Pb generation
- project on **heavy-ion extensions to Rivet and mcplots** started

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efforts started in ALICE to
extend tools to heavy-ion use cases

summary & prospects

- **broad and diverse set of measurements needed**
  for Monte Carlo development and tuning
- **ALICE covers interesting and complementary aspects**
  in order to constrain models
- **improving tools for comparisons also for heavy-ions**
  learn from pp community
  project started in ALICE
- **more systematic comparisons**
  ALICE ramping up Monte Carlo activities

ALICE can provide important input for MC

data for pp, p–Pb, Pb–Pb at various energies