ALICE results in pp collisions at 13 TeV

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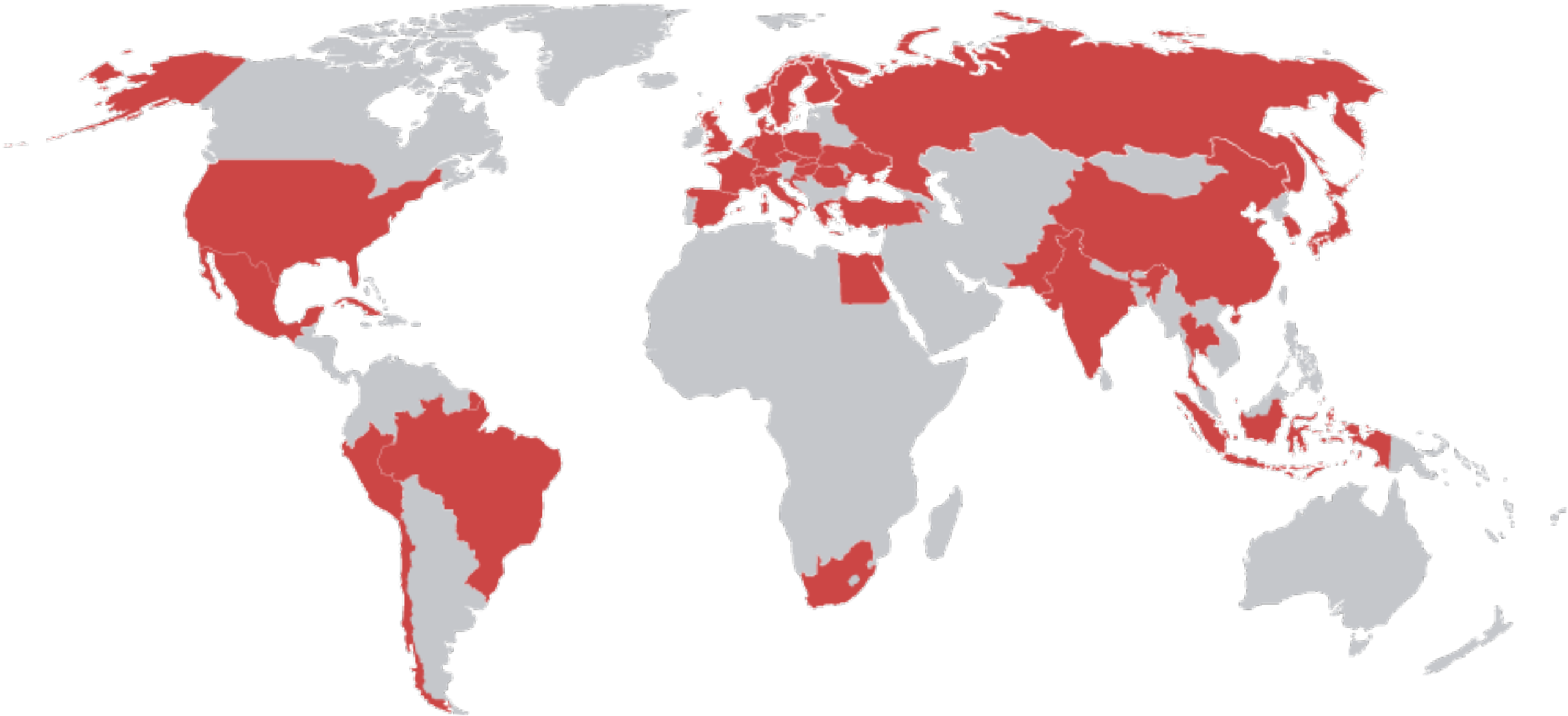
on behalf of the ALICE Collaboration

MESON 2016 - 14th International Workshop on Meson Production
Kraków, Poland
2nd - 7th June, 2016

ALICE Collaboration

37 countries, 154 institutes, over 1500 members



goal is to study QCD phase transition and QGP properties

Heavy-ion physics

nuclear matter under extreme conditions

high temperature and energy-density

expected to undergo a

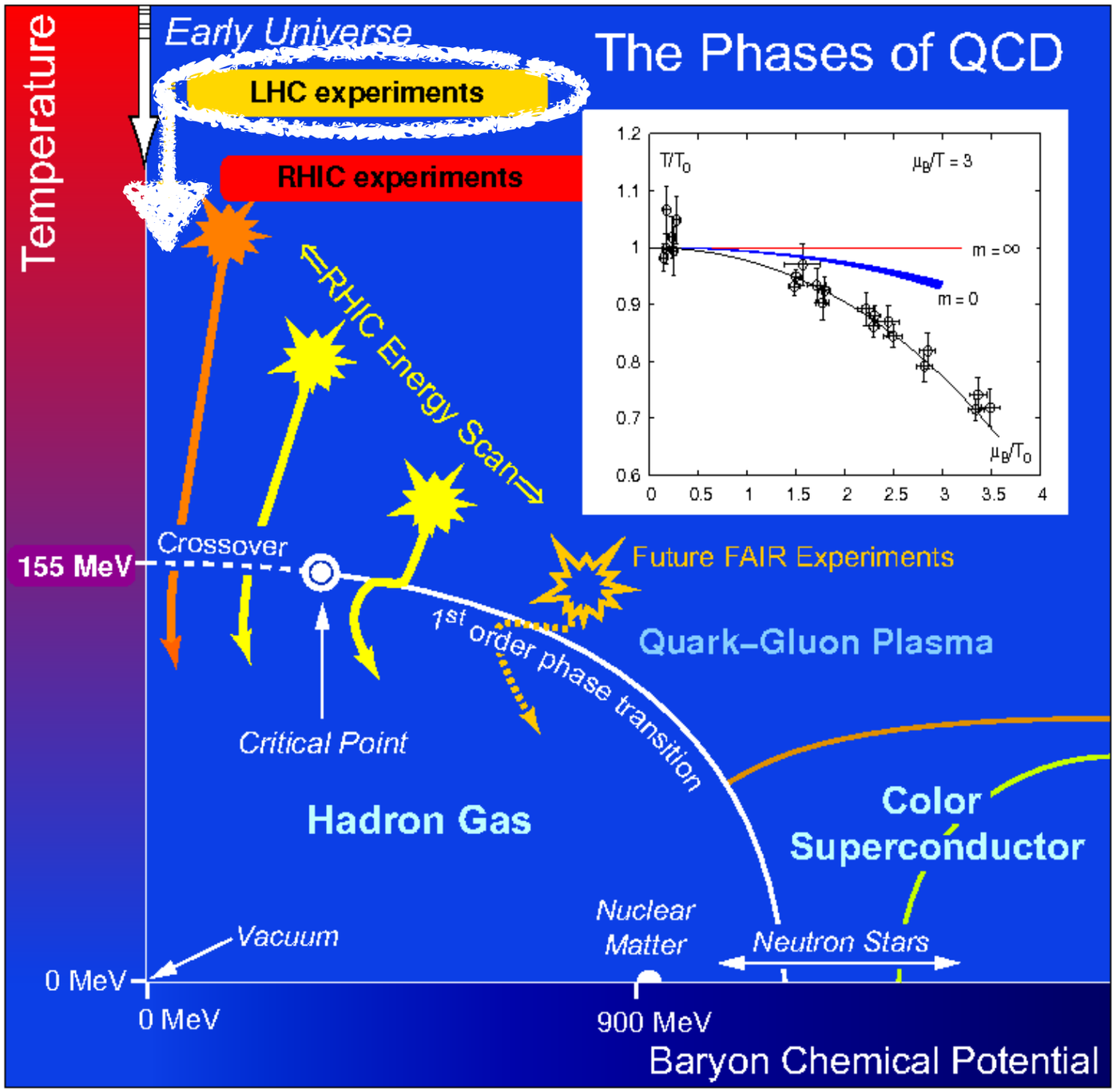
phase-transition

hadronic matter

↓

Quark-Gluon Plasma (QGP)

study the phase diagram and the properties of hot QCD matter



The ALICE detector

a dedicated heavy-ion experiment at the LHC

designed to cope with

very high multiplicities

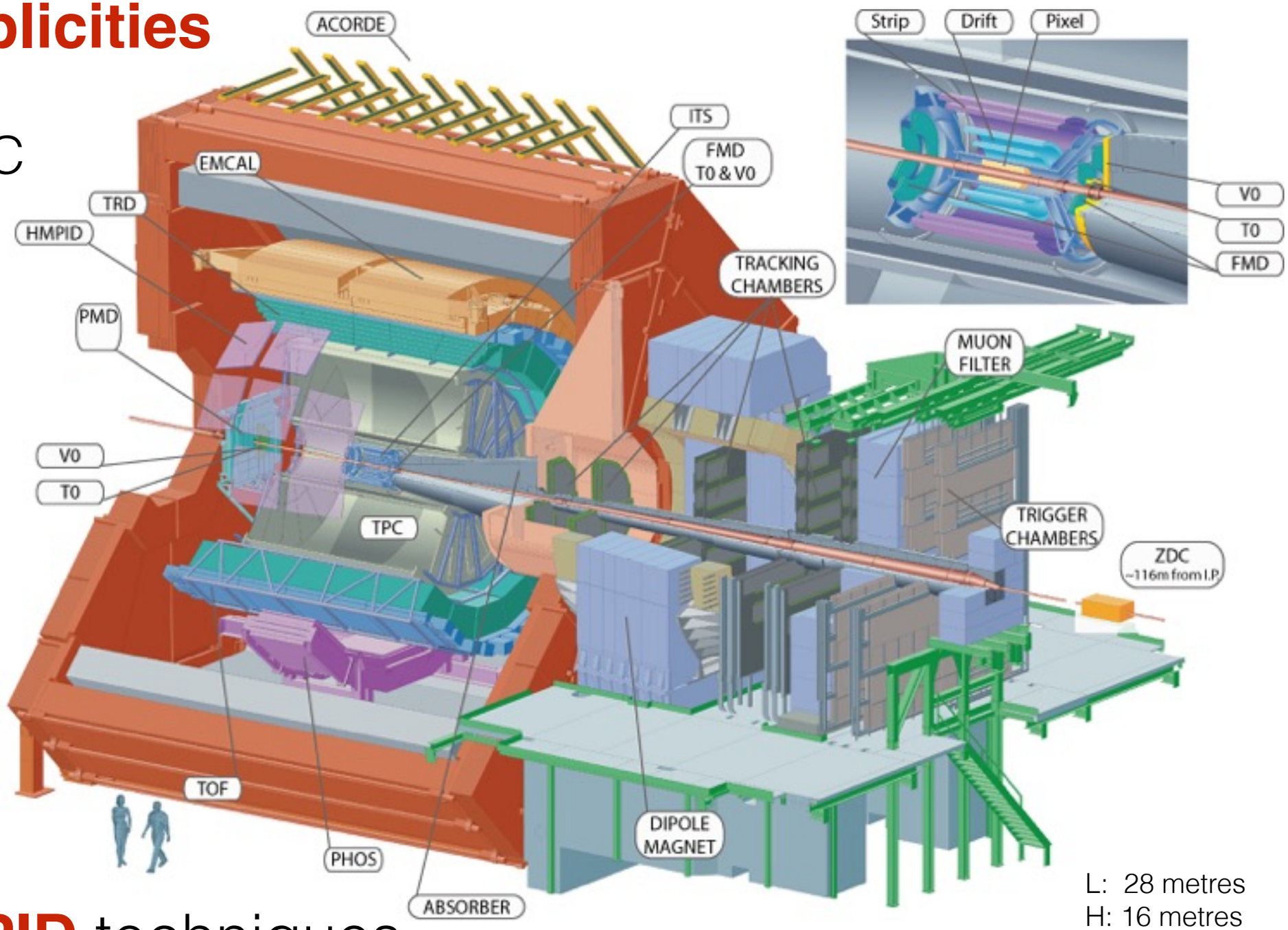
$dN_{ch}/d\eta \leq 8000$

3D tracking with TPC

low-p_T tracking

moderate B = 0.5 T

thin materials

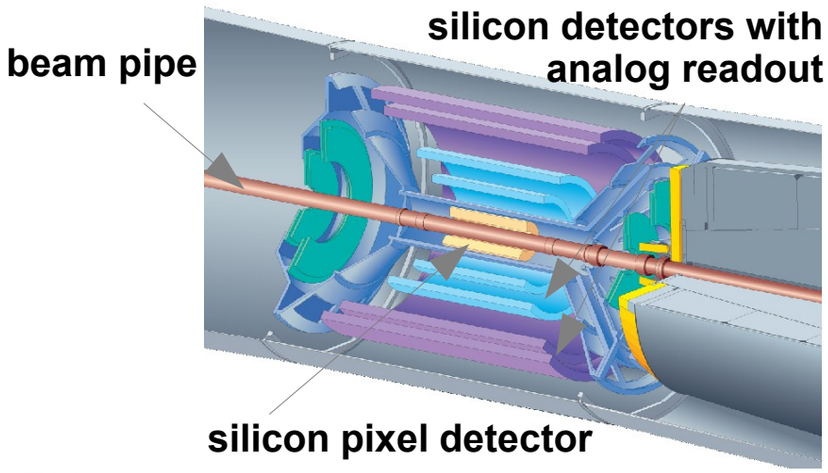


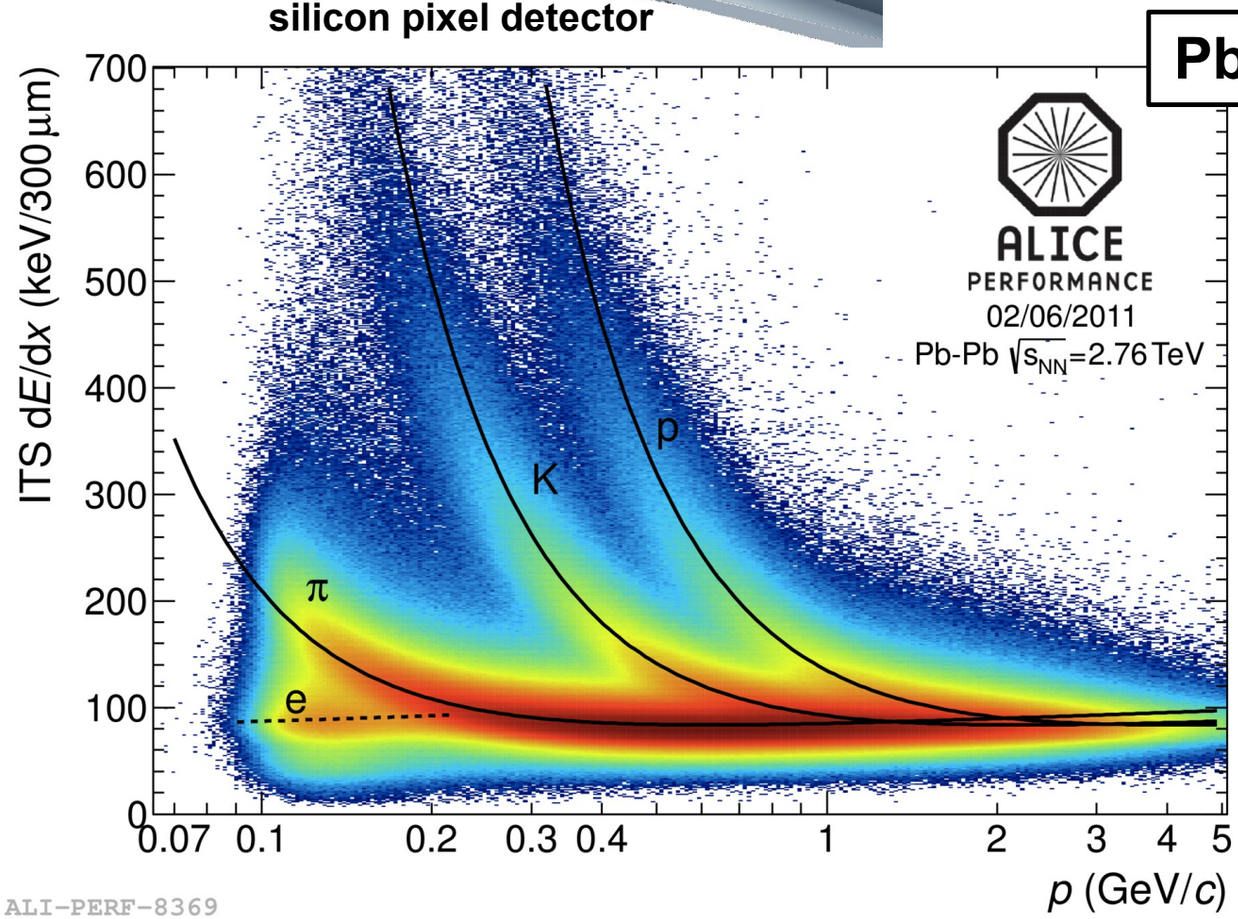
L: 28 metres
H: 16 metres
W: 10k t

uses all known **PID** techniques

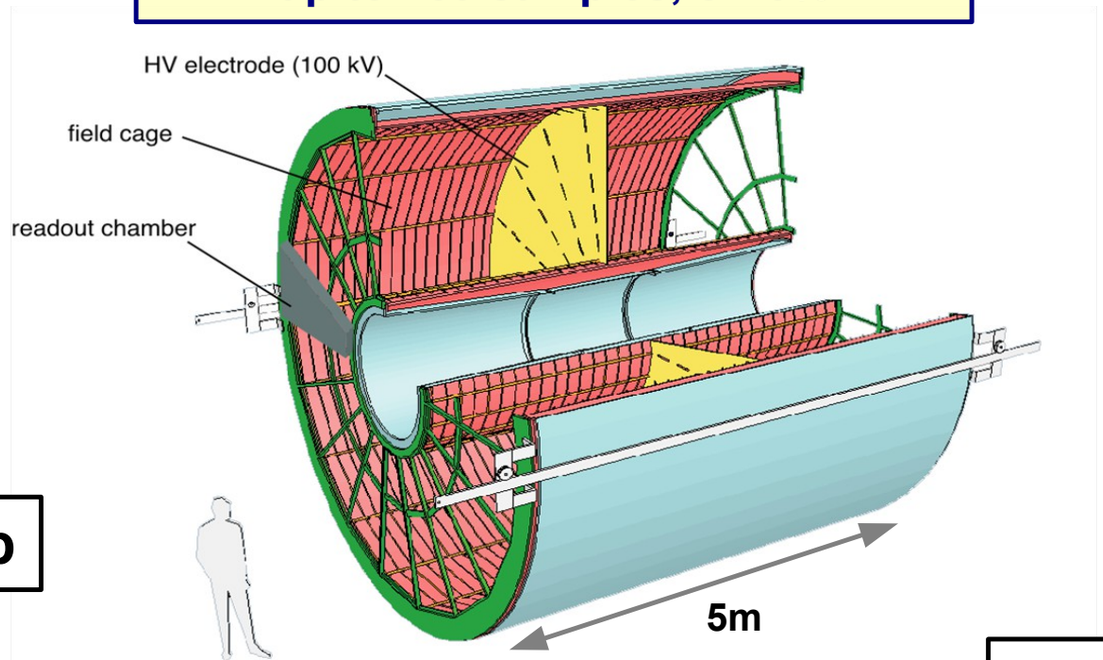
Particle-ID: dE/dx technique

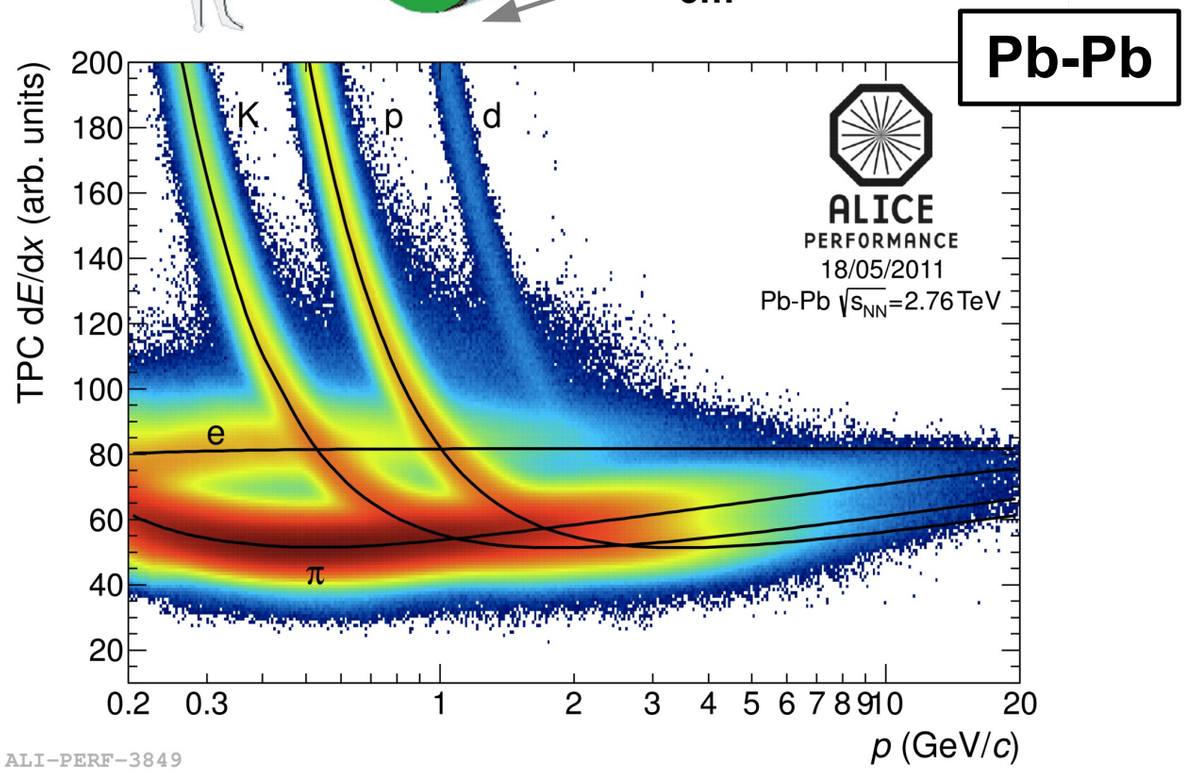
ITS: PID at low momenta
PID via *d*E/*d*x in silicon
up to 4 samples, σ ~10-15%





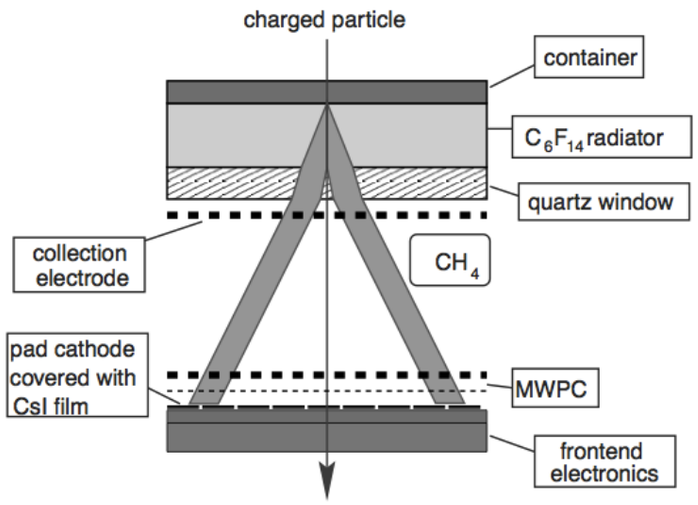
TPC: main tracking detector
PID via *d*E/*d*x in gas
up to 159 samples, σ ~5%





ALICE, IJMP A29 (2014) 1430044

Particle-ID: Cherenkov radiation



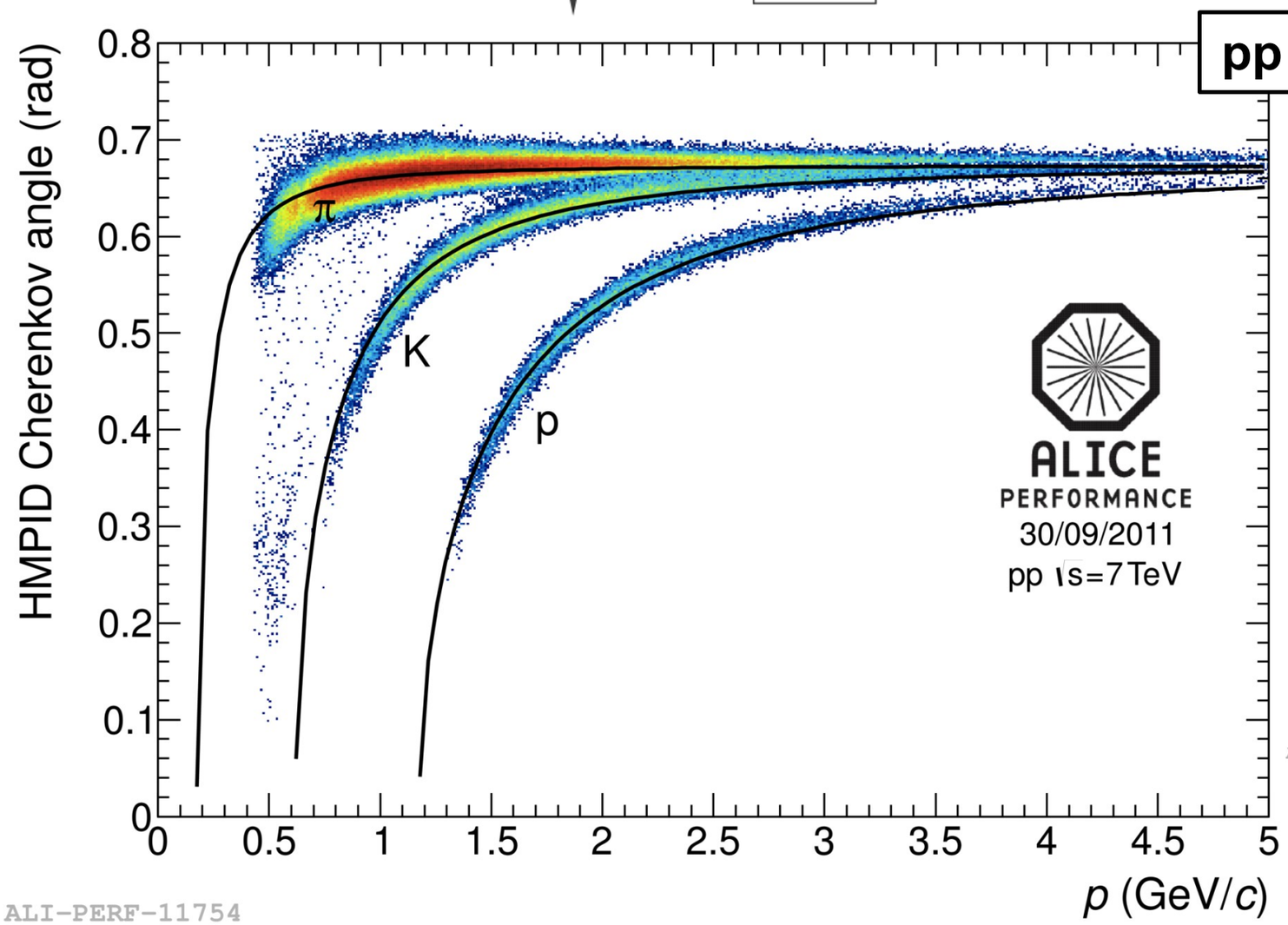
HMPID: extends PID to higher p_T

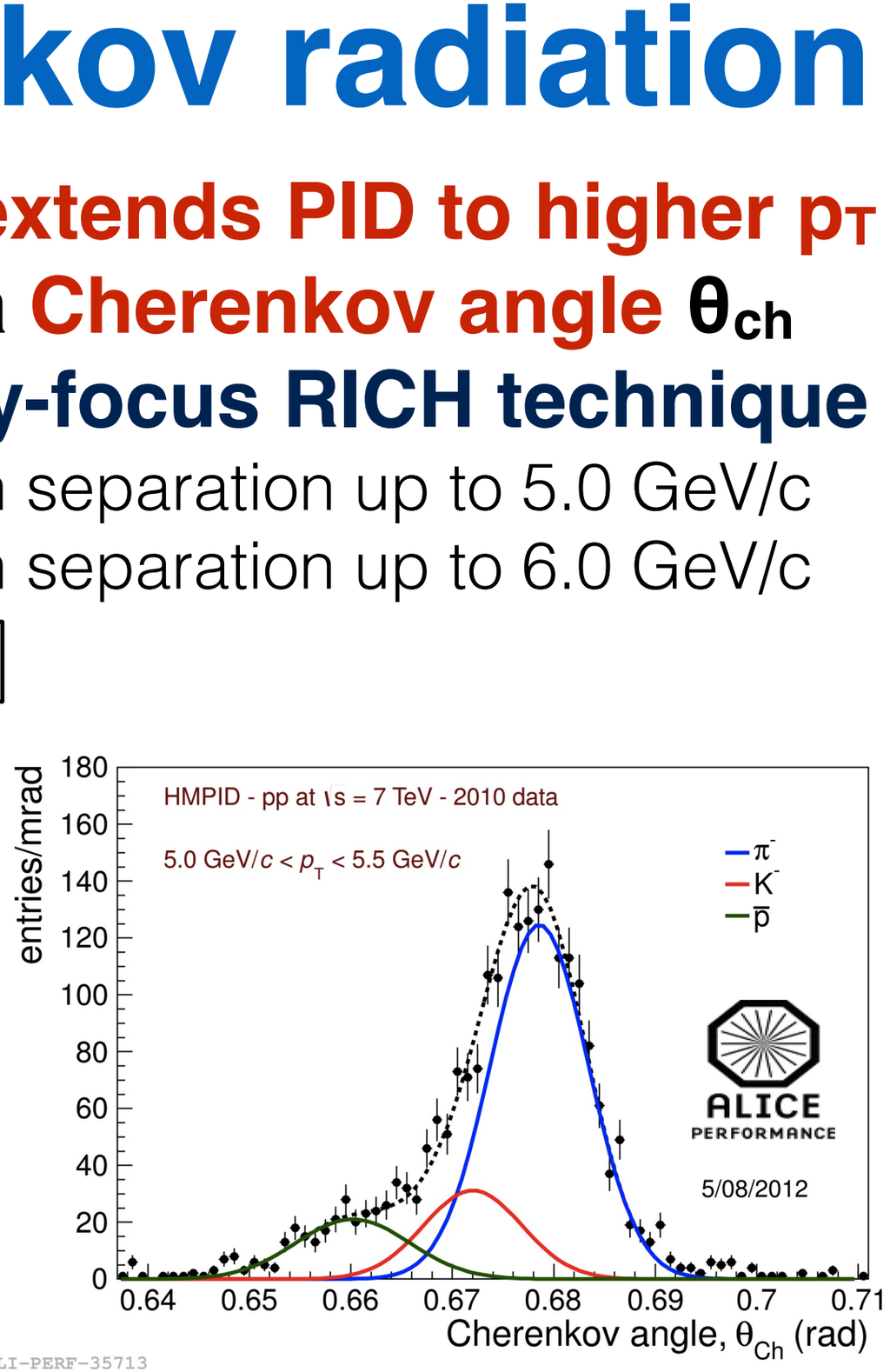
PID via Cherenkov angle θ_{ch}

proximity-focus RICH technique

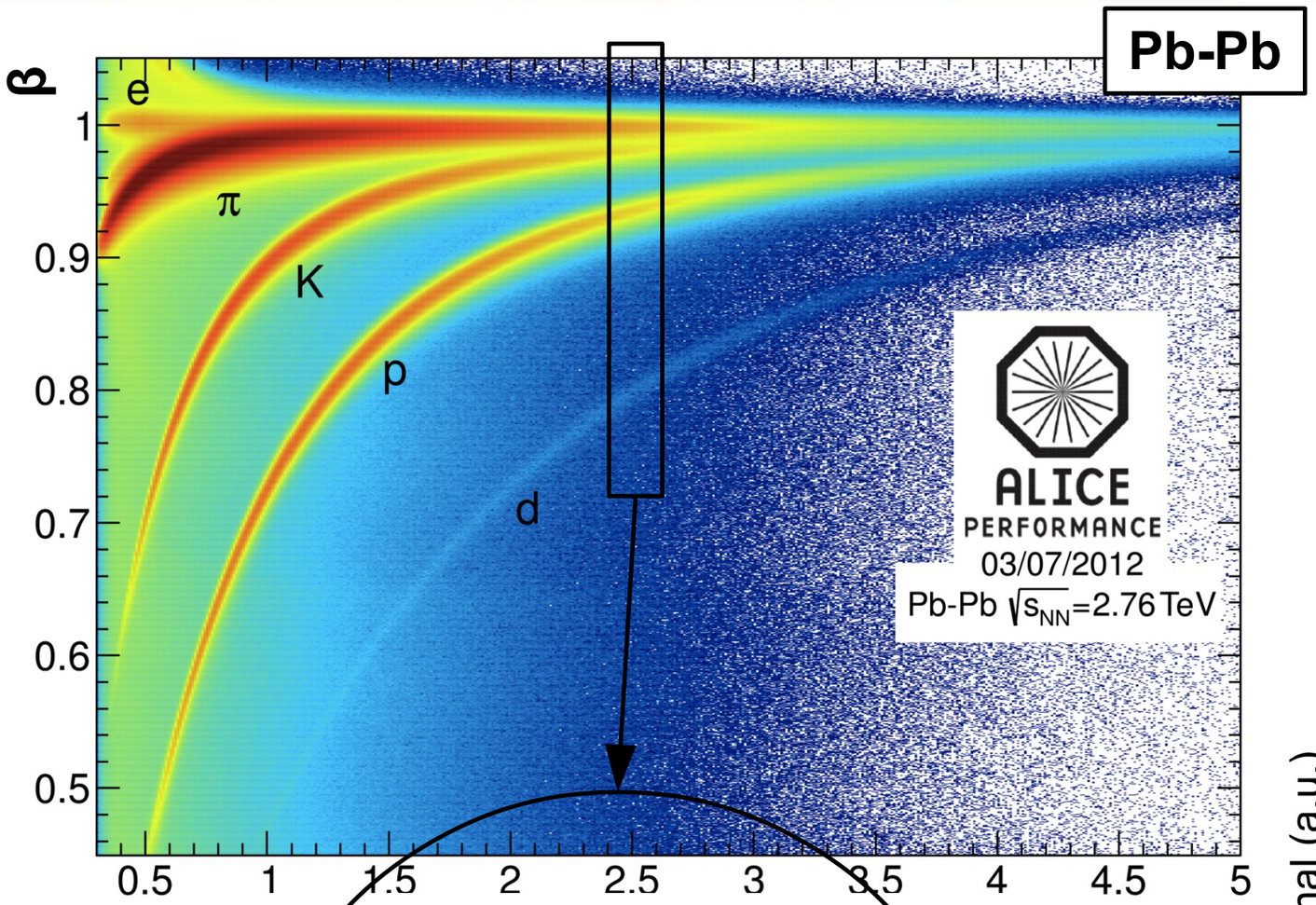
3σ proton separation up to 5.0 GeV/c

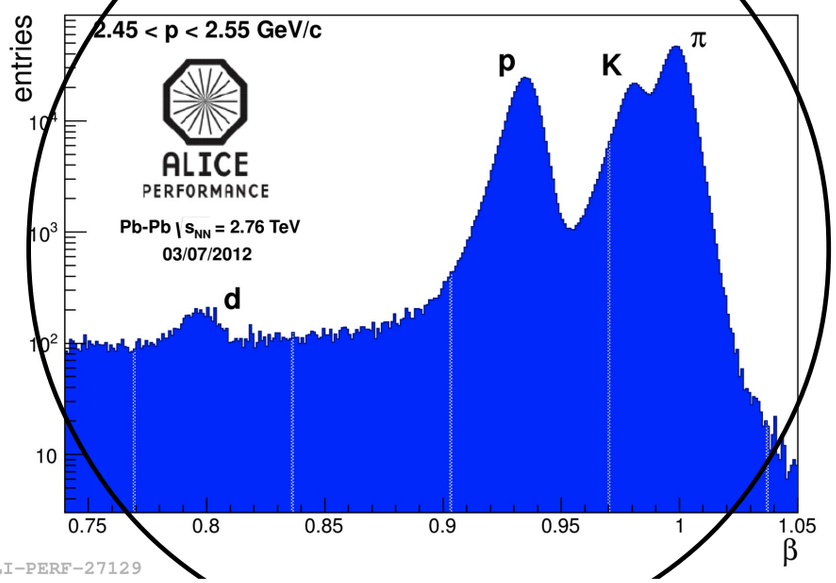
2σ proton separation up to 6.0 GeV/c





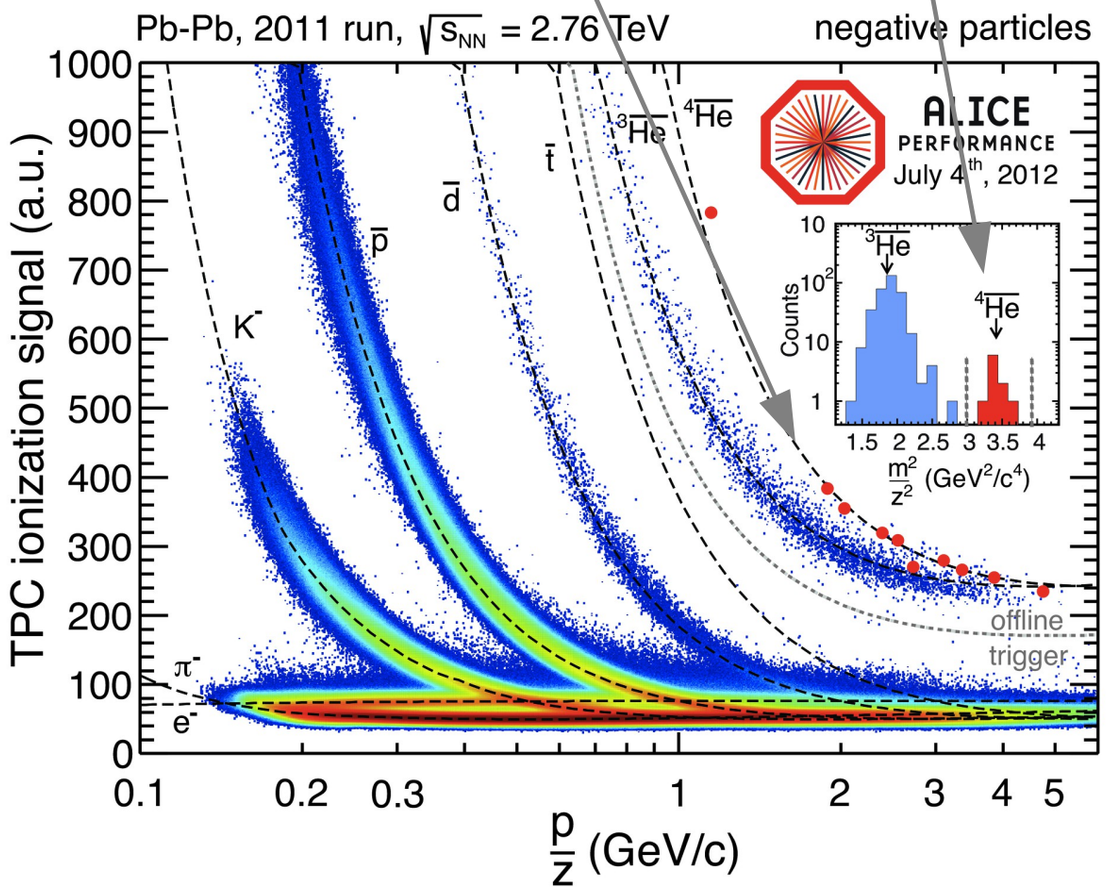
Particle-ID: time-of-flight technique





TOF: PID at intermediate momenta
PID via time-of-flight technique
σ < 100 ps
3σ *K*/*π* separation up to 2.5 GeV/c
3σ *p*/*π* separation up to 4.0 GeV/c

light (anti)nuclei ($\bar{d}$, $\bar{t}$, $^3\overline{He}$, $^4\overline{He}$)
combining TPC *dE*/*dx* + TOF mass

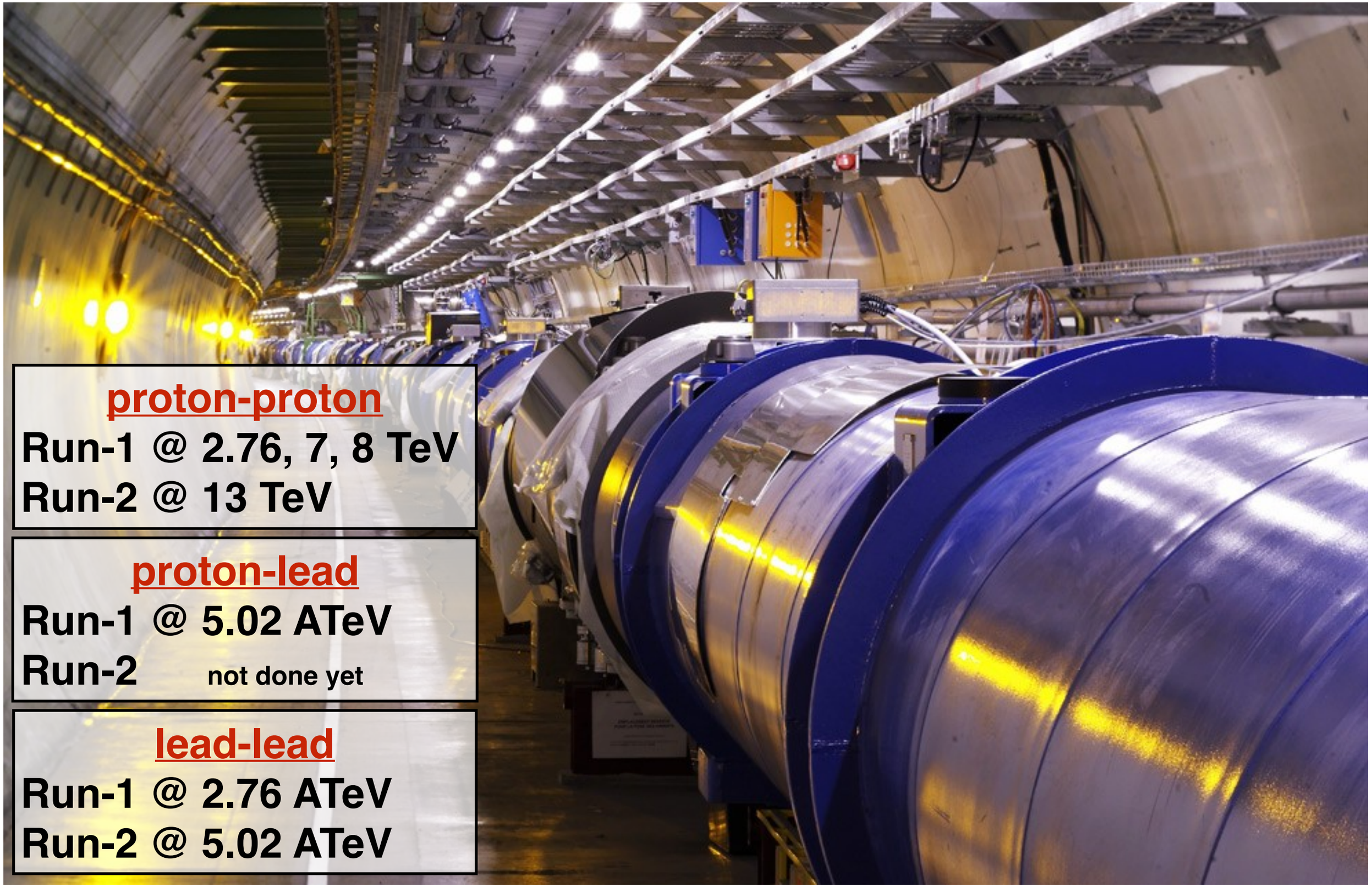


The particle zoo

ALICE can measure the production of a large number of **particles, resonances and nuclei** and anti-particles/nuclei

$\pi^{\pm}$	$K^{\pm}$	p	d	^{3}He	^{4}He
π^0	K_S^0	Λ	Ξ	Ω	$^3_{\Lambda}$H
η	K*	ϕ	Σ^*	Λ^*	Ξ^*
D^0	D^{*+}	D_S	J/ψ	ψ'	Υ

Physics runs at the LHC



proton-proton

Run-1 @ 2.76, 7, 8 TeV

Run-2 @ 13 TeV

proton-lead

Run-1 @ 5.02 ATeV

Run-2 not done yet

lead-lead

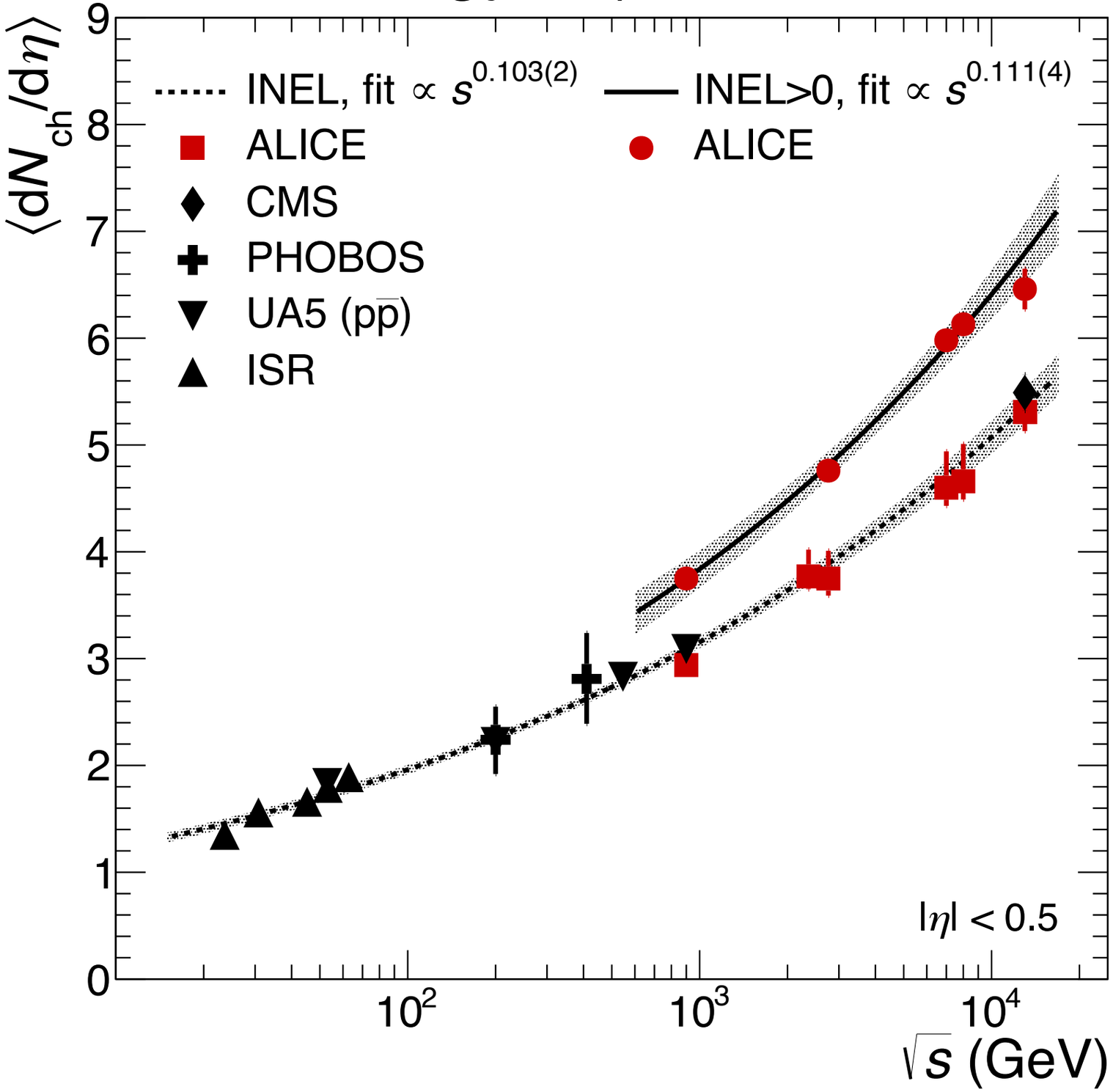
Run-1 @ 2.76 ATeV

Run-2 @ 5.02 ATeV

new results in pp collisions at 13 TeV

Charged particle production

energy dependence



measured in INEL events and in events with at least one charged particle in $|\eta| < 1$

agreement with CMS results for INEL class

charged-particle multiplicity density

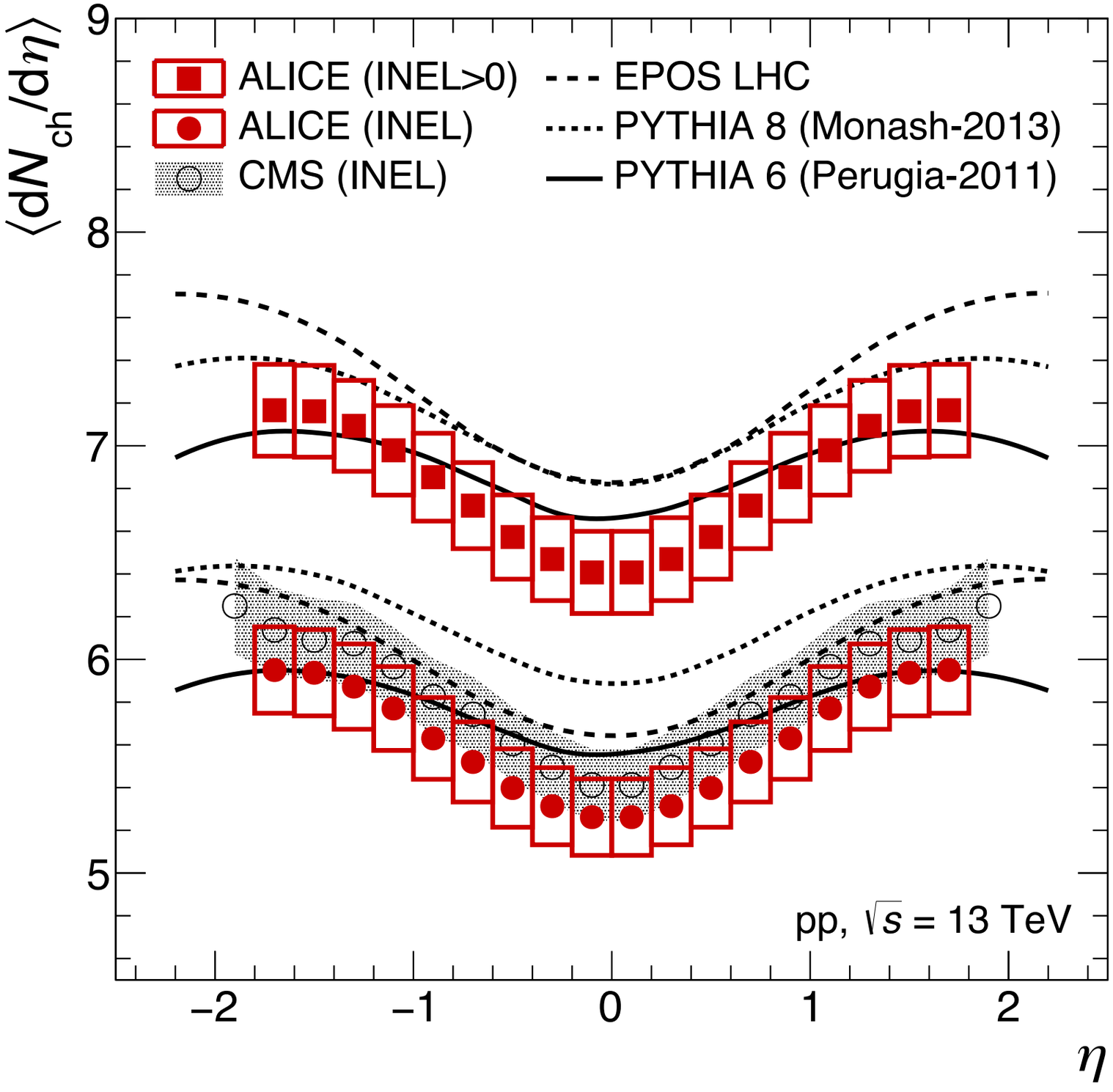
at mid-rapidity, $|\eta| < 0.5$

5.31 ± 0.18 (INEL)

6.46 ± 0.19 (INEL>0)

Charged particle production

pseudorapidity dependence



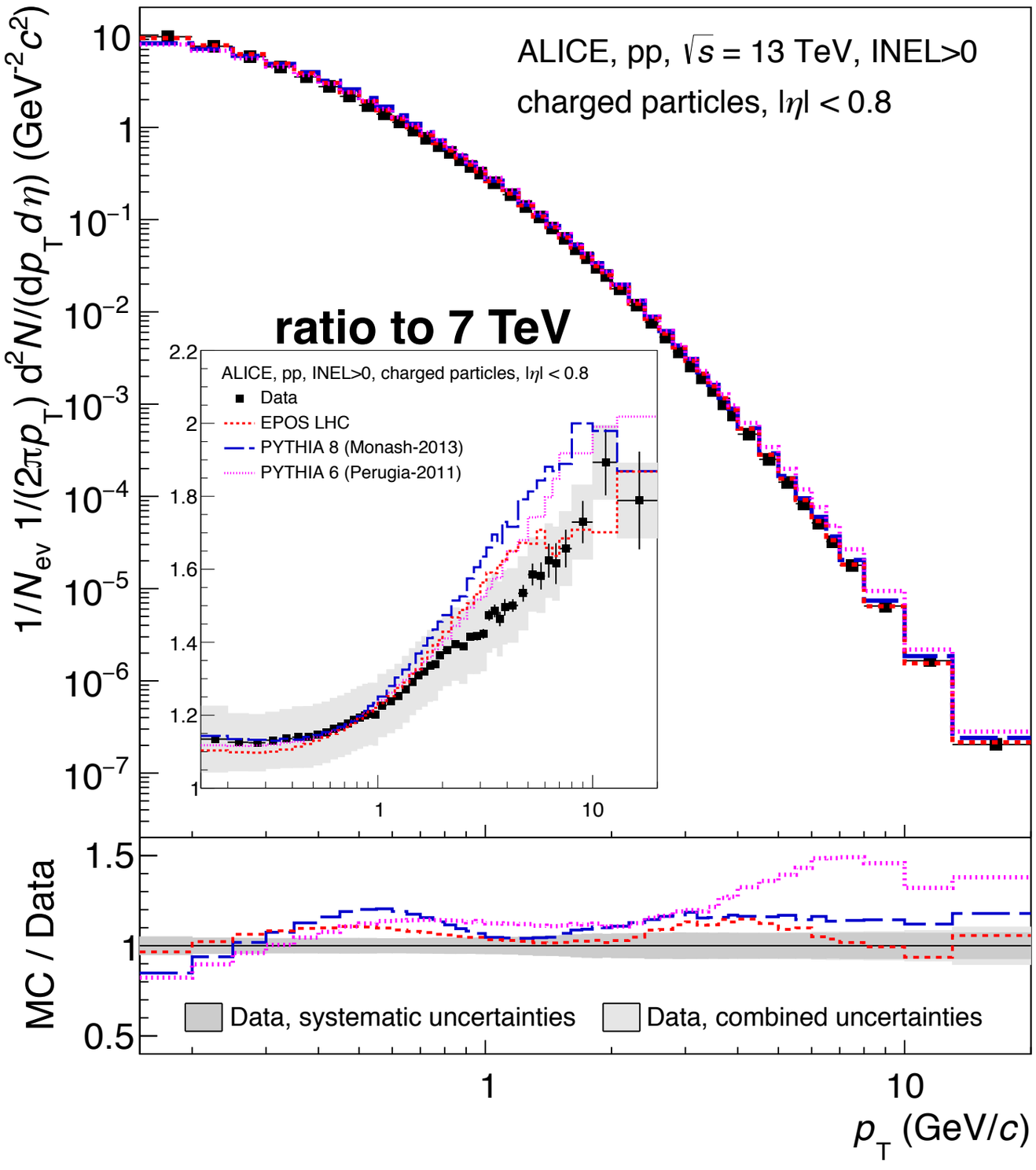
measured in INEL events and in events with at least one charged particle in $|\eta| < 1$

agreement with CMS results for INEL class

models overestimate the data

Charged particle production

transverse-momentum dependence

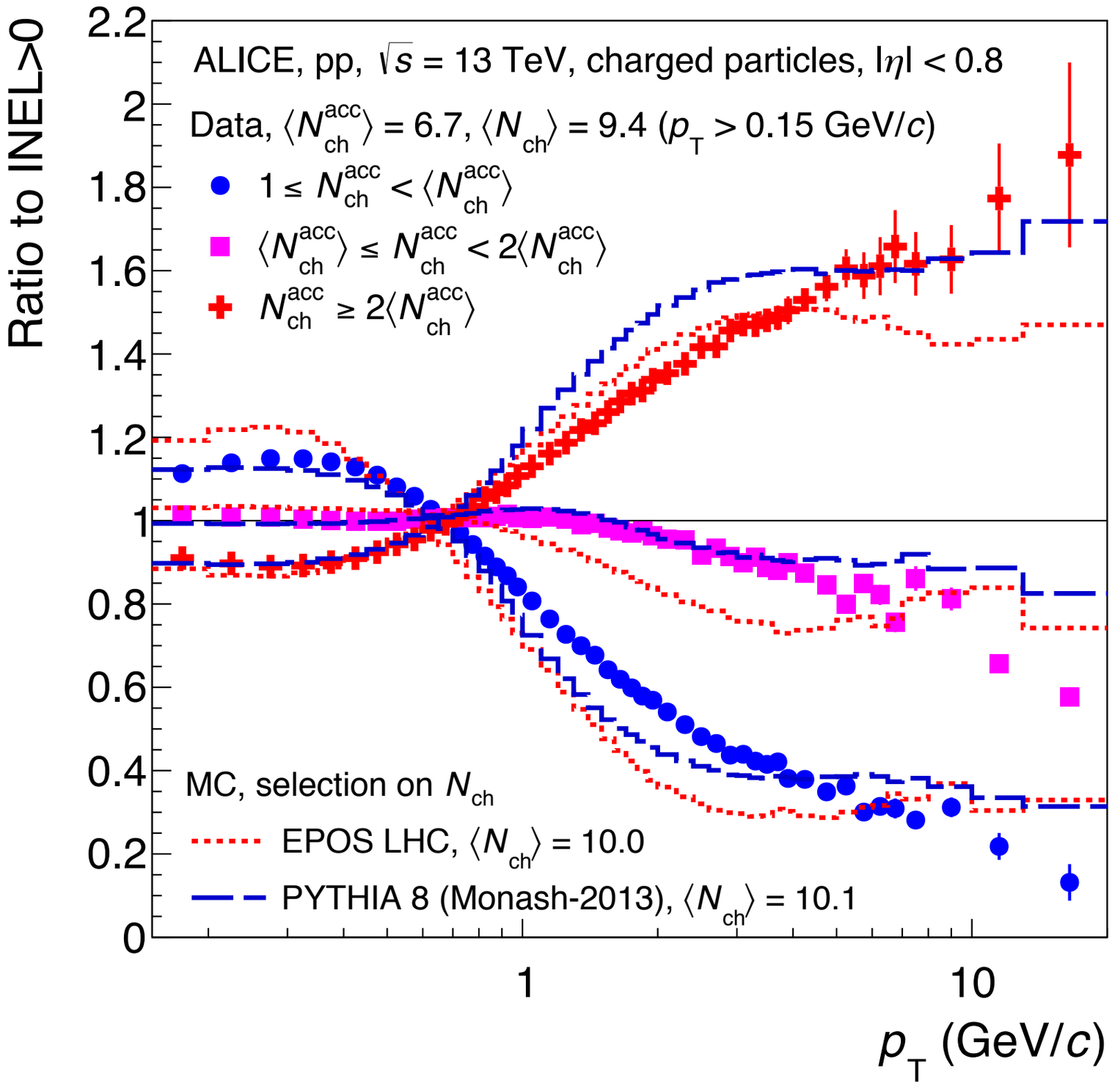


p_T distribution measured
for events with at least one charged particle in $|\eta| < 1$
$0.15 < p_T < 20$ GeV/c
$|\eta| < 0.8$

spectrum significantly harder than at $\sqrt{s}$ = 7 TeV
crucial measurements to tune Monte Carlo models

Charged particle production

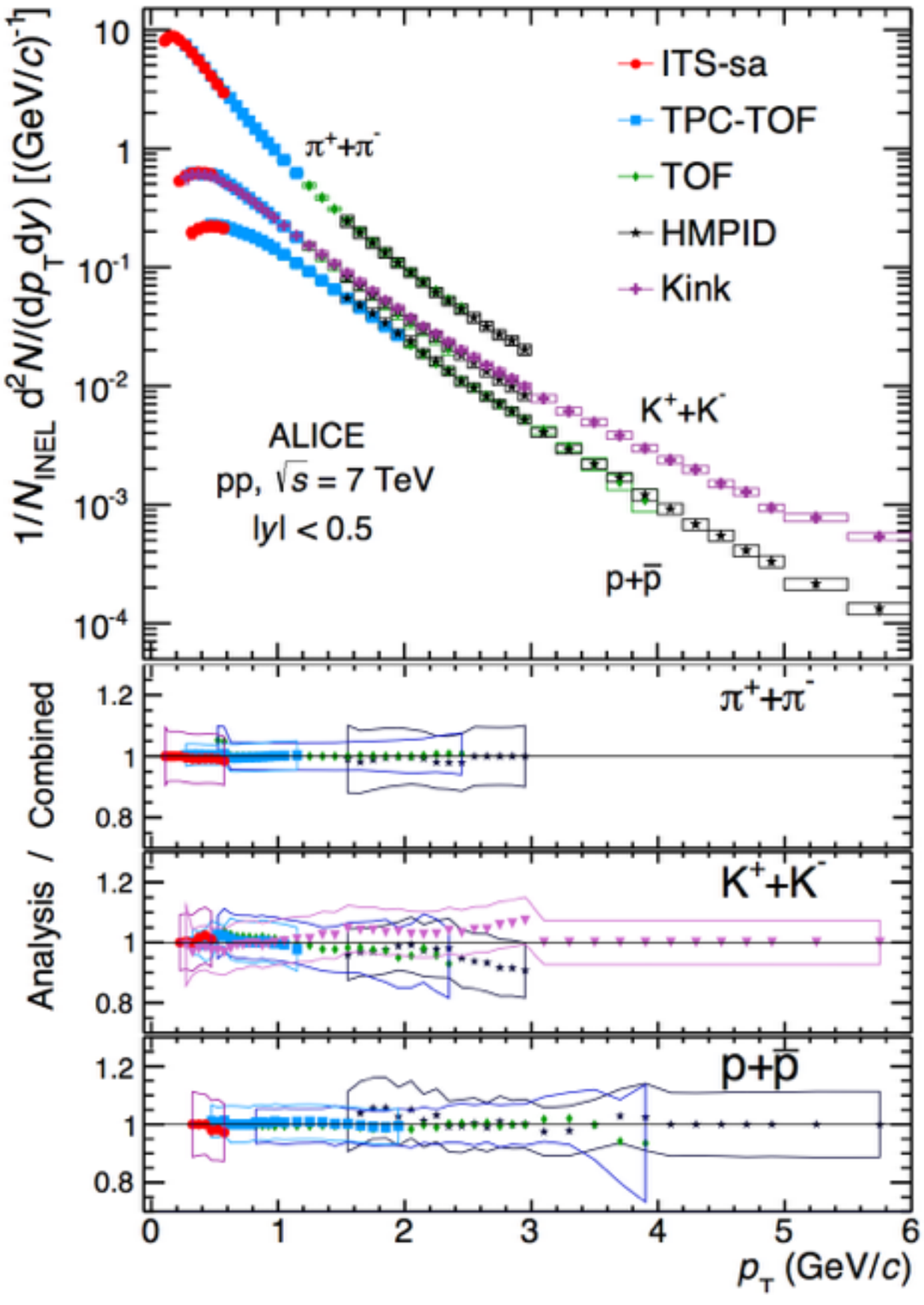
evolution of p_T spectra with multiplicity



ratio of spectra to the inclusive sample **measured in three intervals of multiplicity** low / intermediate / high

general features are reproduced by the models <u>but not in all details</u>

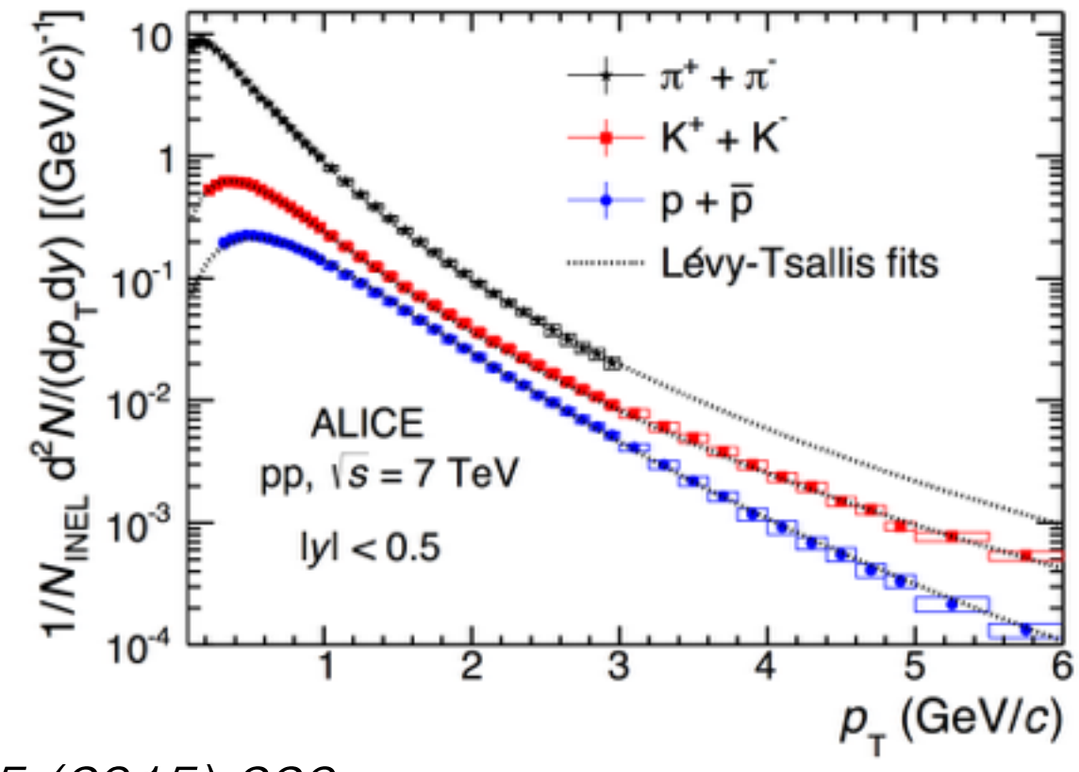
Stable hadrons: π, K, p



π±, K±, p and $\bar{p}$ results
combination independent measurement
using **different detectors / techniques**

dE/dx (ITS-sa tracks)
dE/dx (TPC)
time-of-flight (TOF)
Cherenkov radiation (HMPID)
kink-decay topology

extrapolation to zero-p_T for total yields
Lévy-Tsallis fit to data



ALICE, EPJC 75 (2015) 226

p/π yield ratio at mid-rapidity

π±, K±, p and $\bar{p}$ production measured at |y| < 0.5

energy-dependence of integrated yield ratios

new preliminary results

√s = 13 TeV

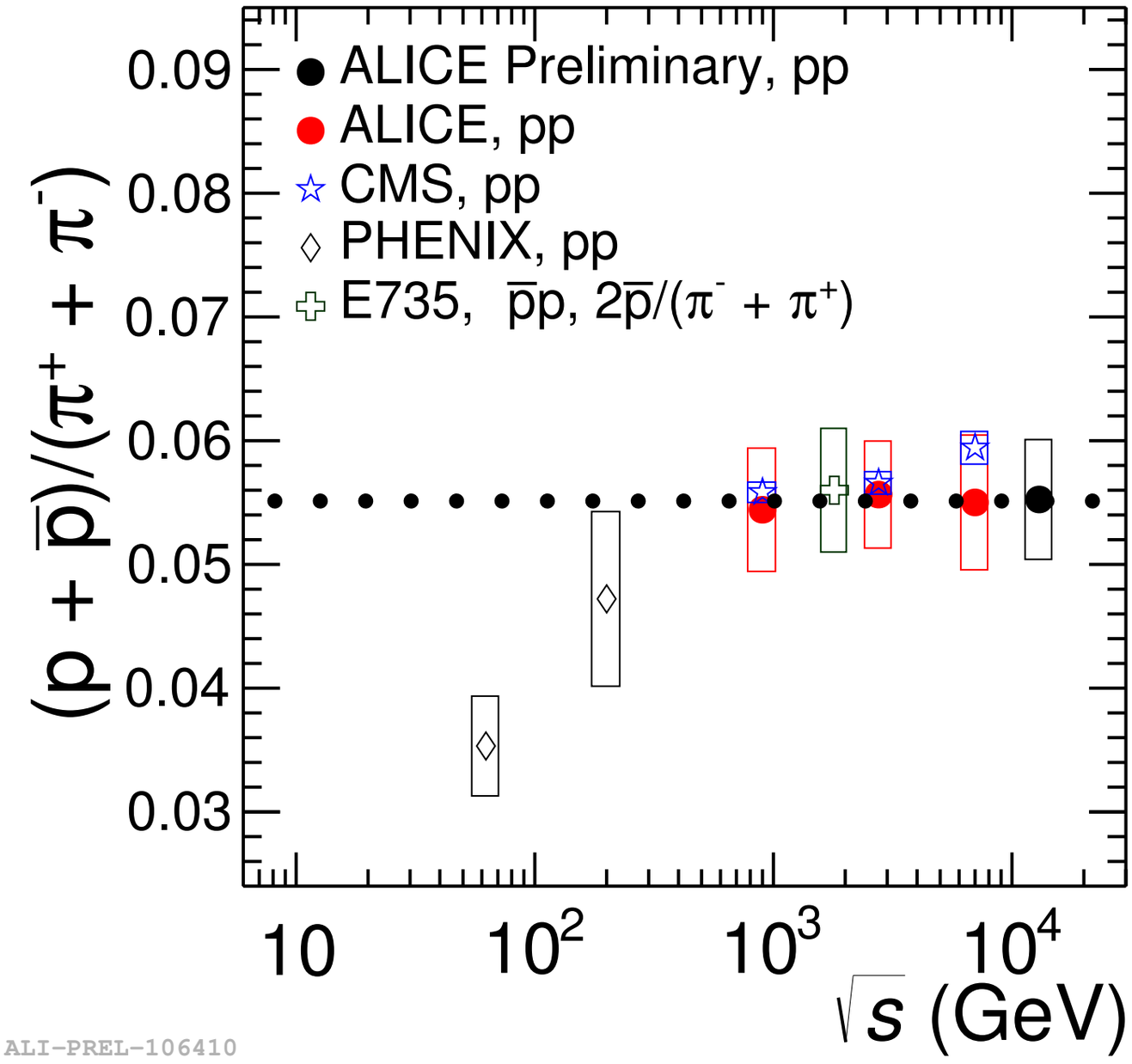
published results

√s = 0.9, 2.76, 7 TeV

extend low-energy data by a factor ~10x

saturation for √s > 900 GeV

p/π ratio stays constant



ALI-PREL-106410

ALICE, EPJC 71 (2011) 1655
ALICE, PLB 736 (2014) 196
ALICE, EPJC 75 (2015) 226

K/π yield ratio at mid-rapidity

π±, K±, p and $\bar{p}$ production measured at |y| < 0.5

energy-dependence of integrated yield ratios

new preliminary results

√s = 13 TeV

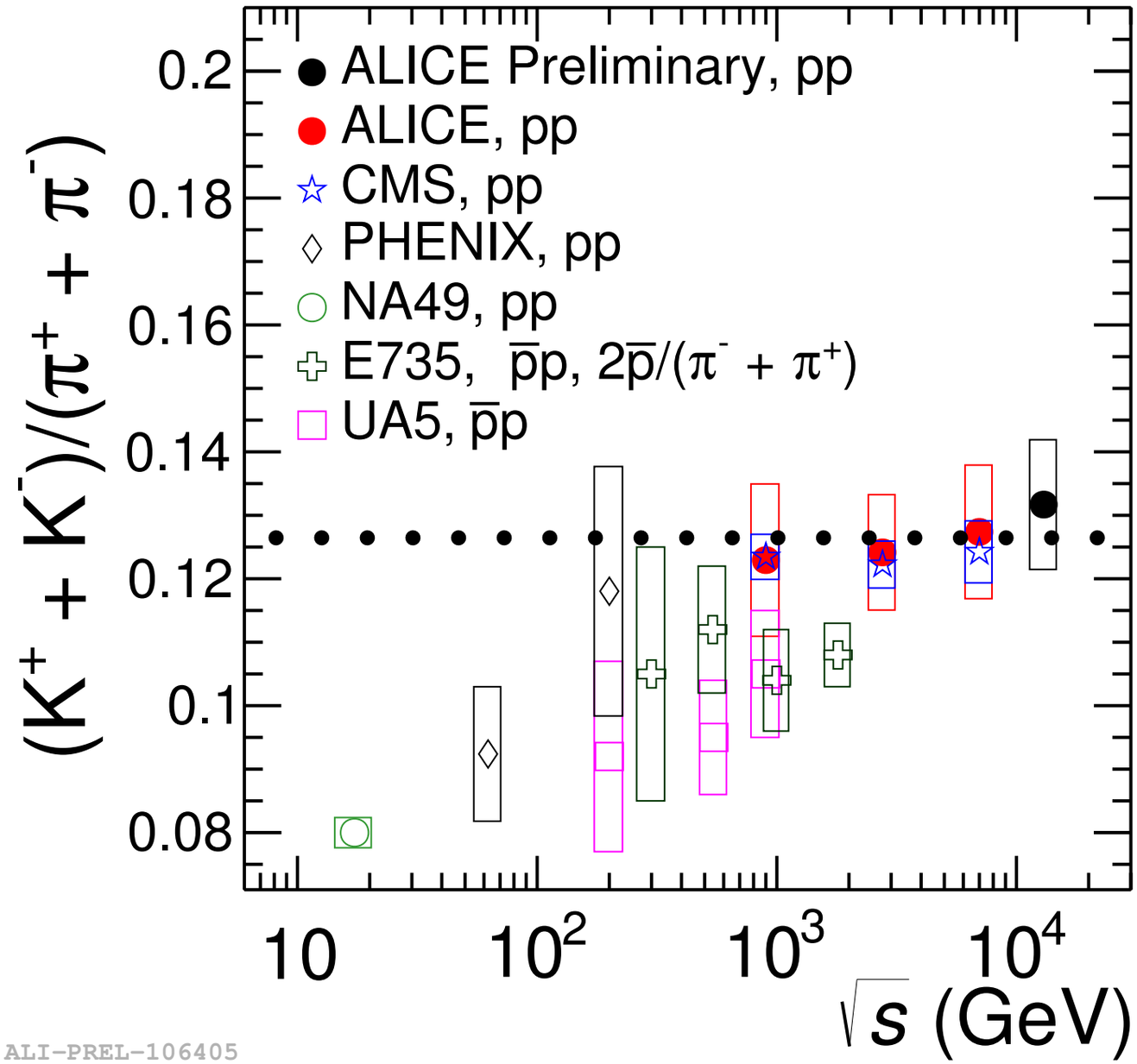
published results

√s = 0.9, 2.76, 7 TeV

extend low-energy data
by a factor ~10x

saturation for √s > 900 GeV

possible hint of modest
K/π increase at higher √s

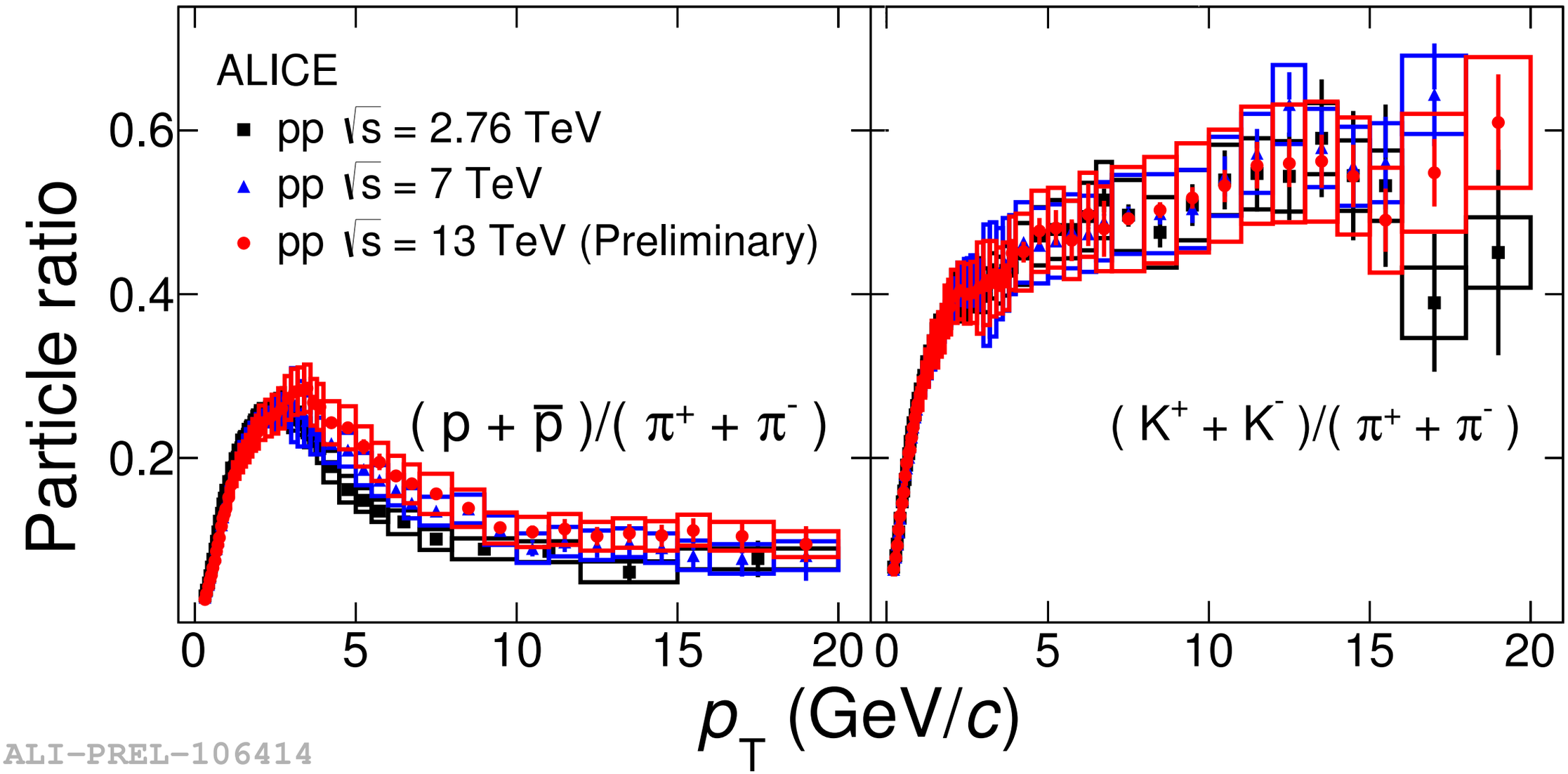


ALI-PREL-106405

ALICE, EPJC 71 (2011) 1655
ALICE, PLB 736 (2014) 196
ALICE, EPJC 75 (2015) 226

p_T dependent p/π and K/π

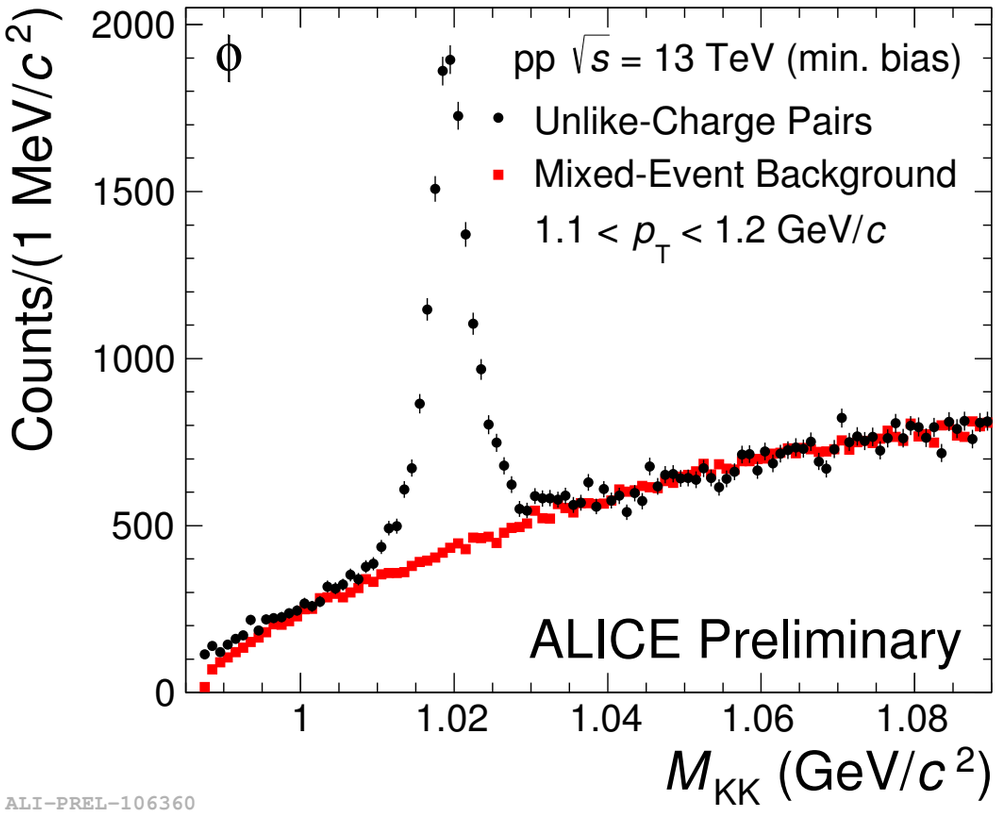
possible to study systematically
over a **large p_T and $\sqrt{s}$ range**



p/π ratio shift towards higher p_T for higher $\sqrt{s}$

K/π ratio no significant modifications

Hadronic resonances: ϕ, K*0



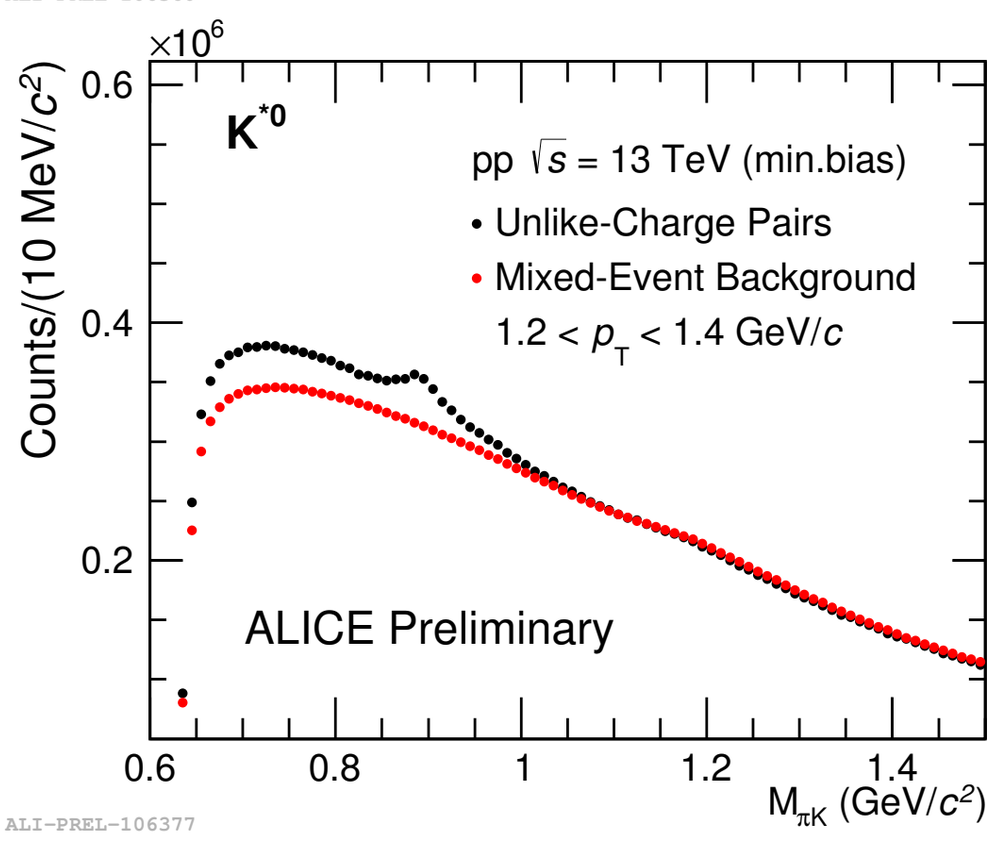
ϕ(1020), K*(892)0 and $\bar{K}$*(892)0

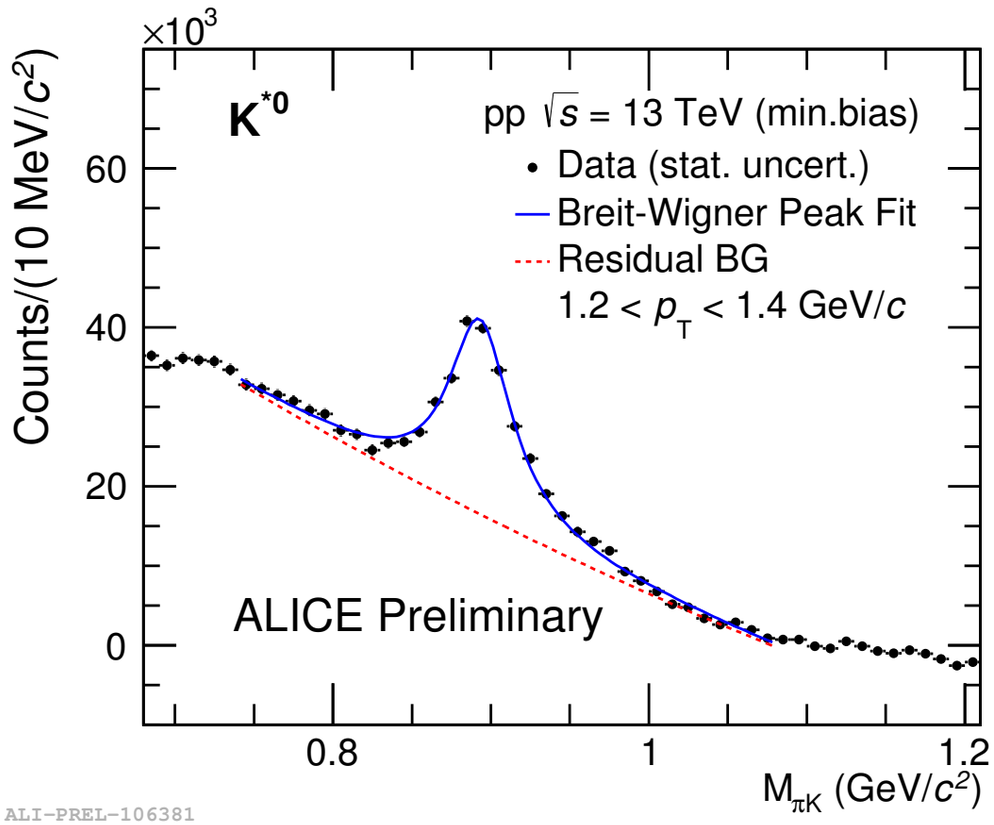
from invariant-mass analysis
identified decay daughters

$\phi \rightarrow K^+ K^-$
$K^{*0} \rightarrow K^+ \pi^-$
$\bar{K}^{*0} \rightarrow K^- \pi^+$

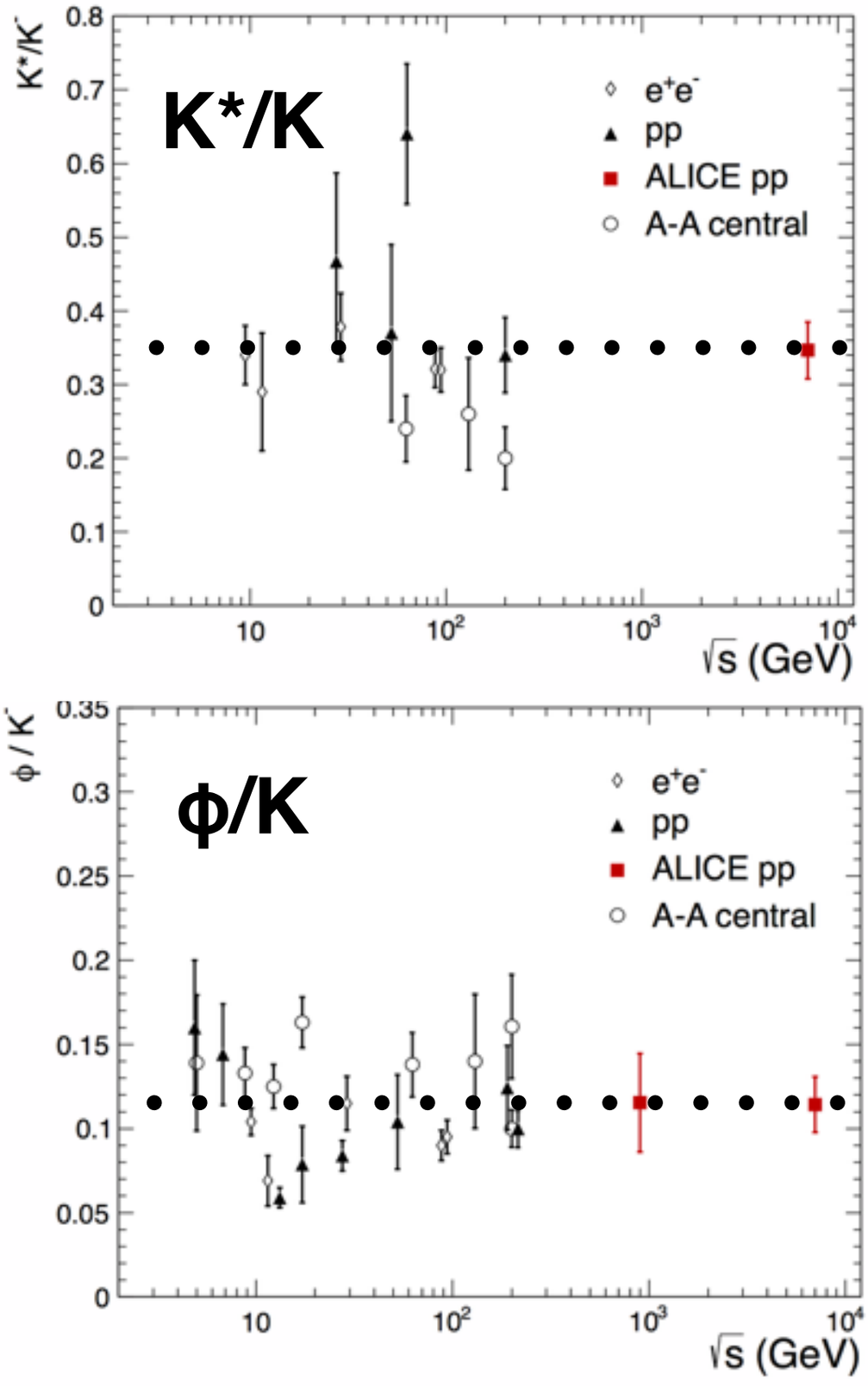
combinatorial background estimated with mixed-event technique and subtracted

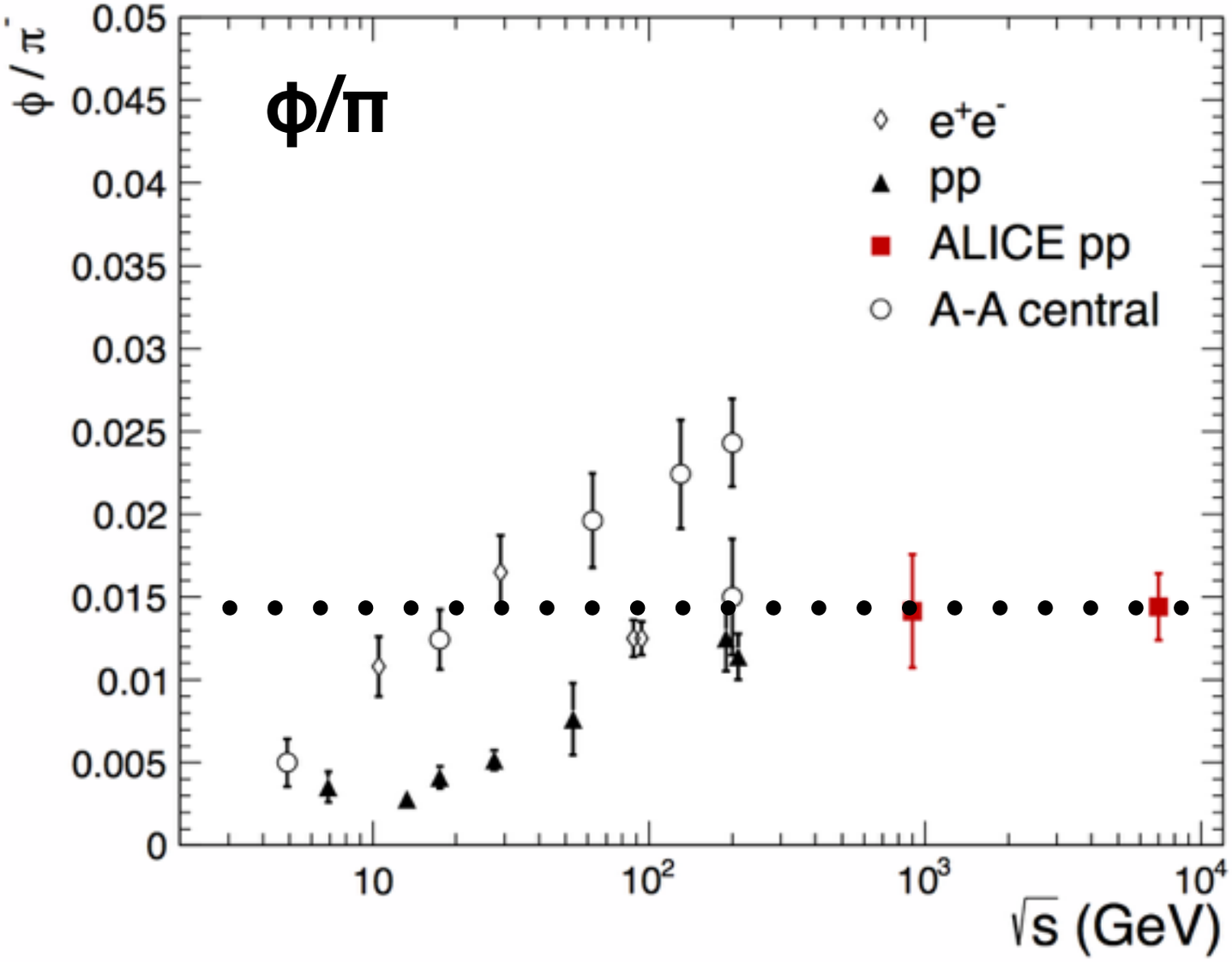
Breit-Wigner / Voigtian fit to extract resonance yield





Resonance production at mid-rapidity





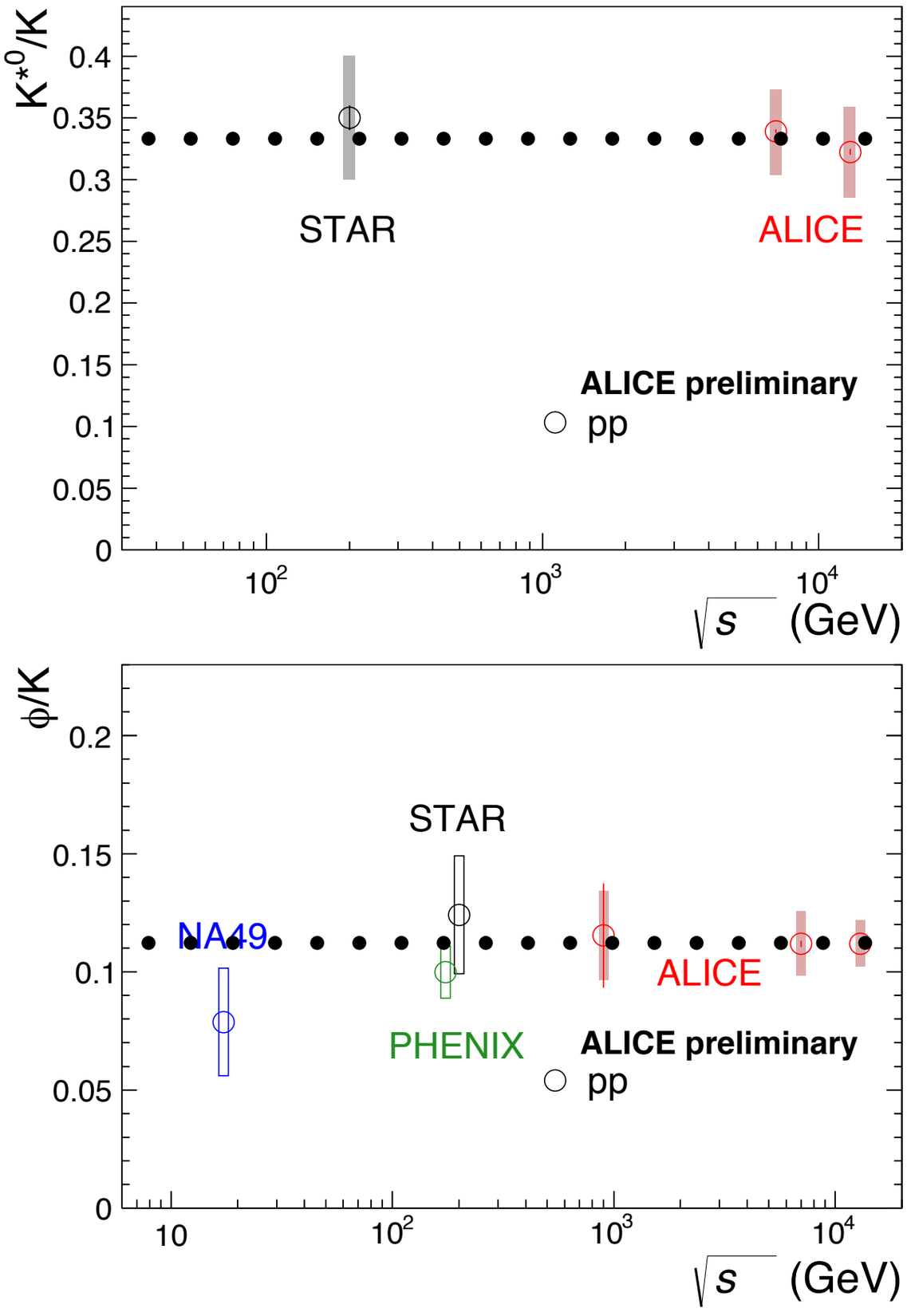
published results in pp

$\sqrt{s}$ = 0.9, 7 TeV

saturation for $\sqrt{s}$ > 900 GeV

ALICE, EPJC 71 (2011) 1594
ALICE, EPJC 72 (2012) 2183

Resonance production at mid-rapidity



new preliminary results

$\sqrt{s}$ = 13 TeV

published results in pp

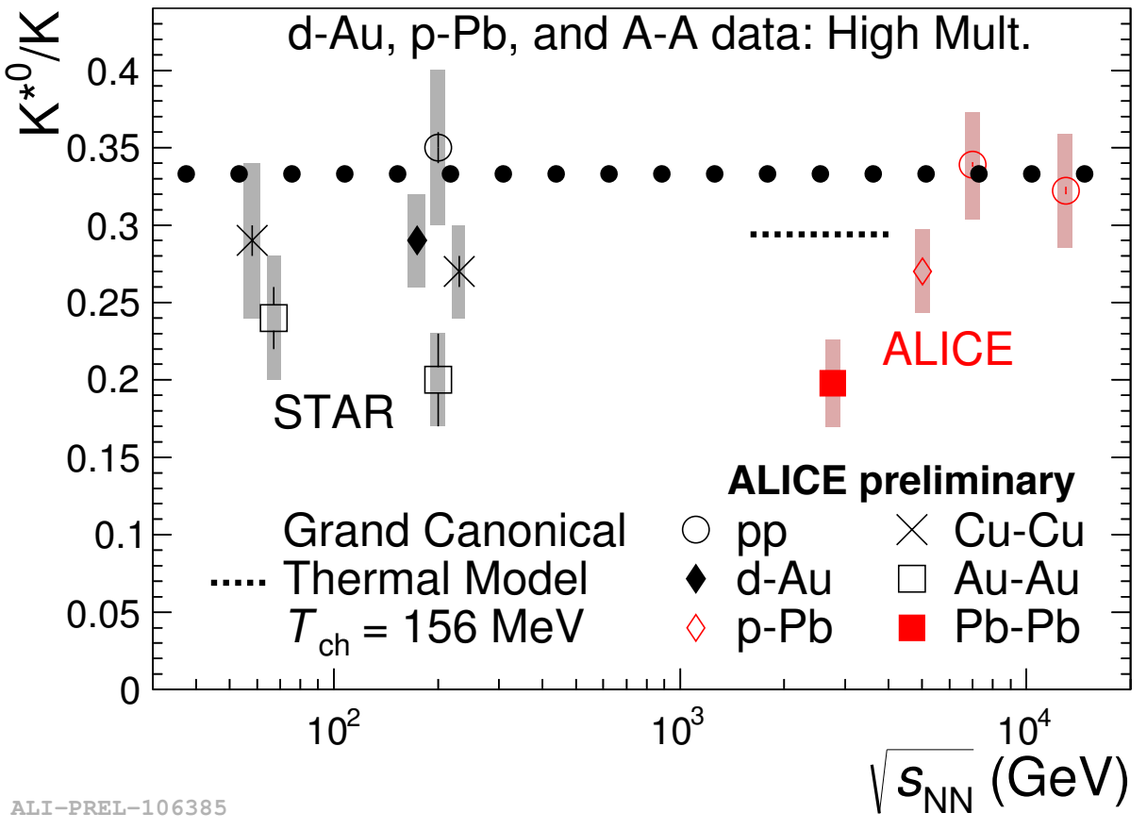
$\sqrt{s}$ = 0.9, 7 TeV

extend low-energy data by a factor ~10^2–10^3

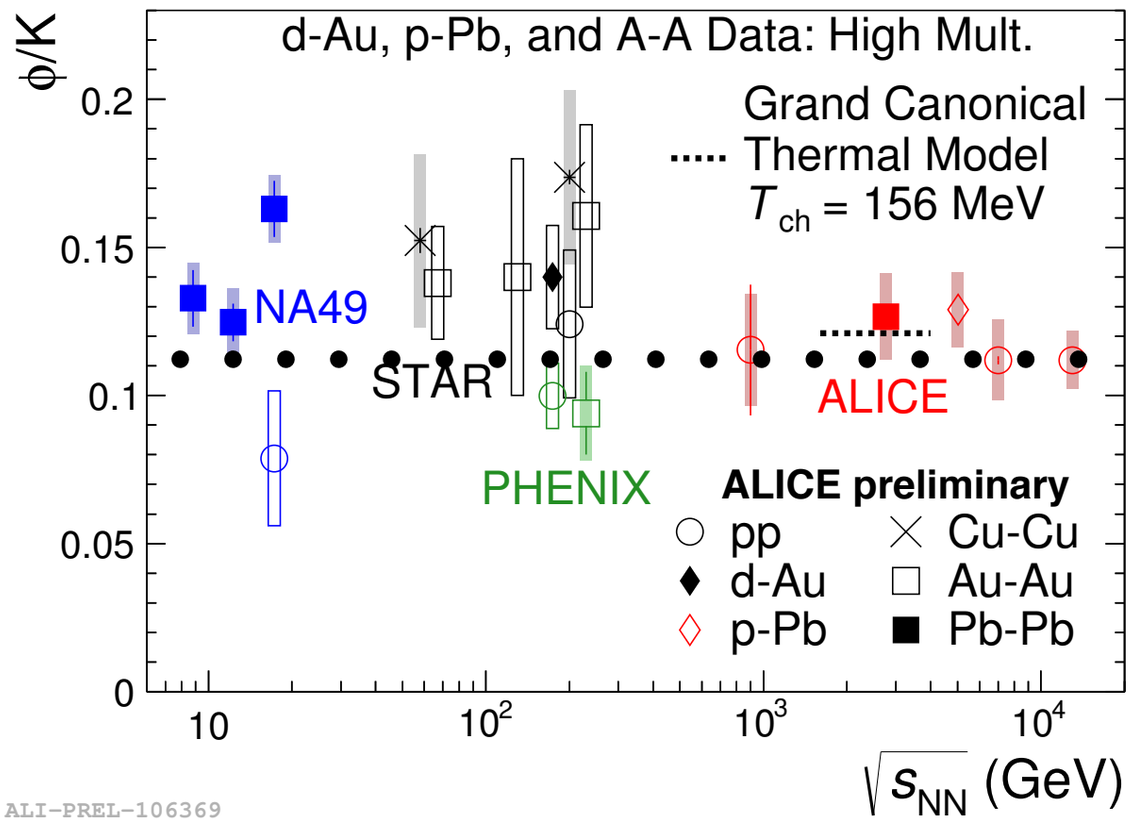
constant production vs. $\sqrt{s}$ of strange resonances (φ, K^{*0}) to strange stable hadrons ($K^{\pm}$) in proton-proton collisions

ALICE, EPJC 71 (2011) 1594
ALICE, EPJC 72 (2012) 2183
ALICE, PRC 91 (2015) 024609

Resonance production at mid-rapidity



ALI-PREL-106385



ALI-PREL-106369

new preliminary results

$\sqrt{s}$ = 13 TeV

published results in pp

$\sqrt{s}$ = 0.9, 7 TeV

extend low-energy data by a factor ~10^2–10^3

constant production vs. $\sqrt{s}$ of strange resonances (ϕ, K^{*0}) to strange stable hadrons ($K^{\pm}$) in proton-proton collisions

K* deviations in A-A collisions

understood as final-state effects

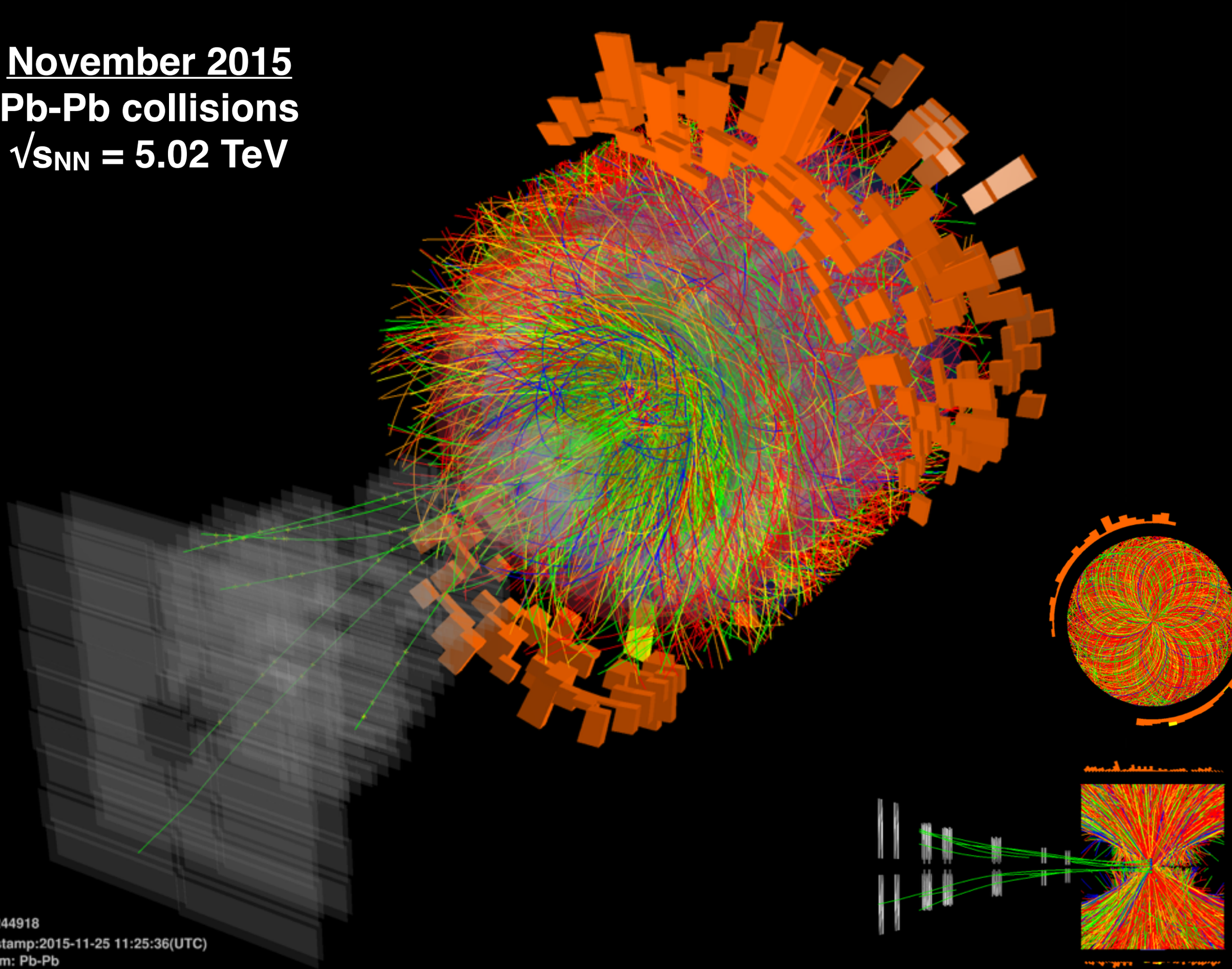
ALICE, EPJC 71 (2011) 1594
ALICE, EPJC 72 (2012) 2183
ALICE, PRC 91 (2015) 024609

new results in Pb-Pb collisions at 5 TeV

November 2015

Pb-Pb collisions

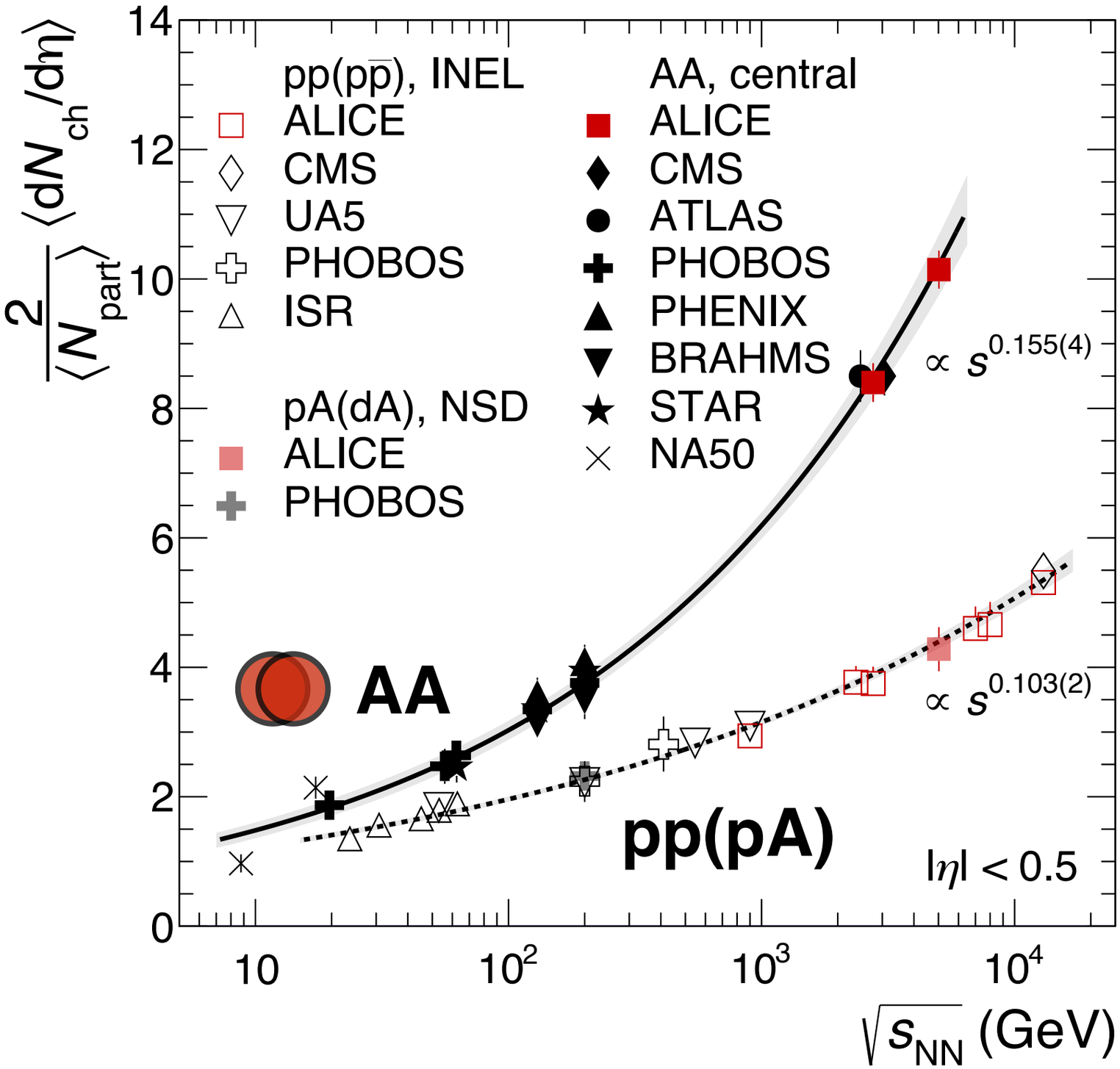
$\sqrt{s_{NN}}$ = 5.02 TeV



Run:244918
Timestamp:2015-11-25 11:25:36(UTC)
System: Pb-Pb
Energy: 5.02 TeV

Charged particles in Pb-Pb@5.02 TeV

centre-of-mass energy dependence



charged-particle multiplicity density

at mid-rapidity, $|\eta| < 0.5$

reaches a value of

1943 ± 54

in most central collisions

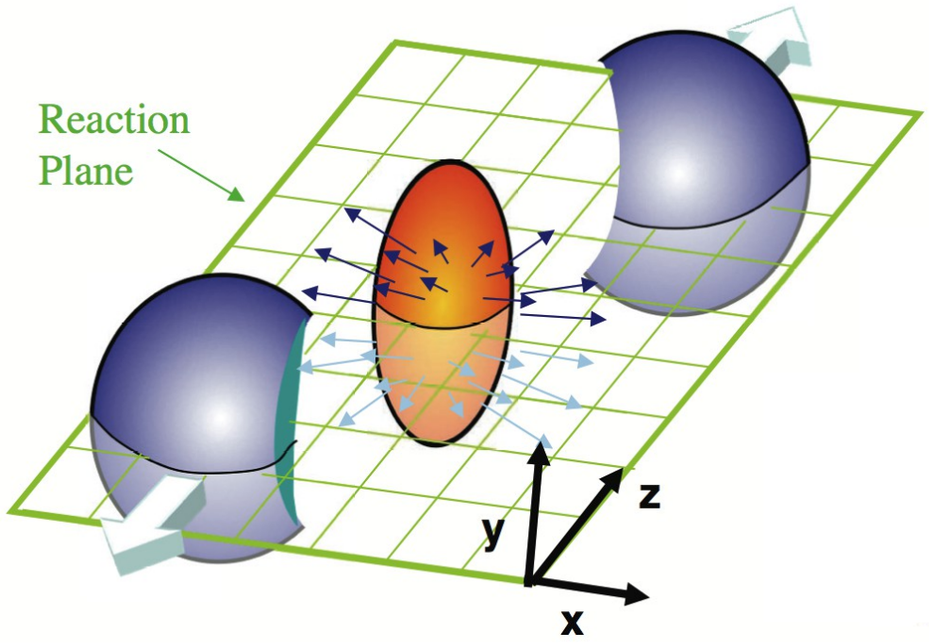
much stronger √s dependence than pp

2.4x larger charged-particle multiplicity than p-Pb

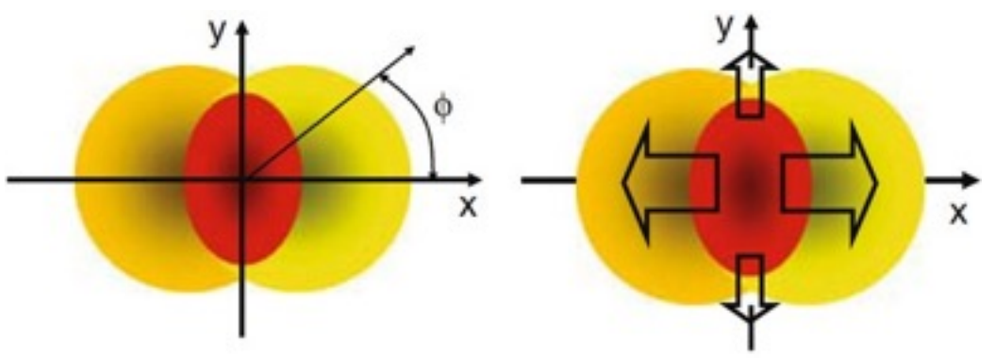
at same energy

scaled by the average number of participating nucleon pairs $\langle N_{part} \rangle/2$

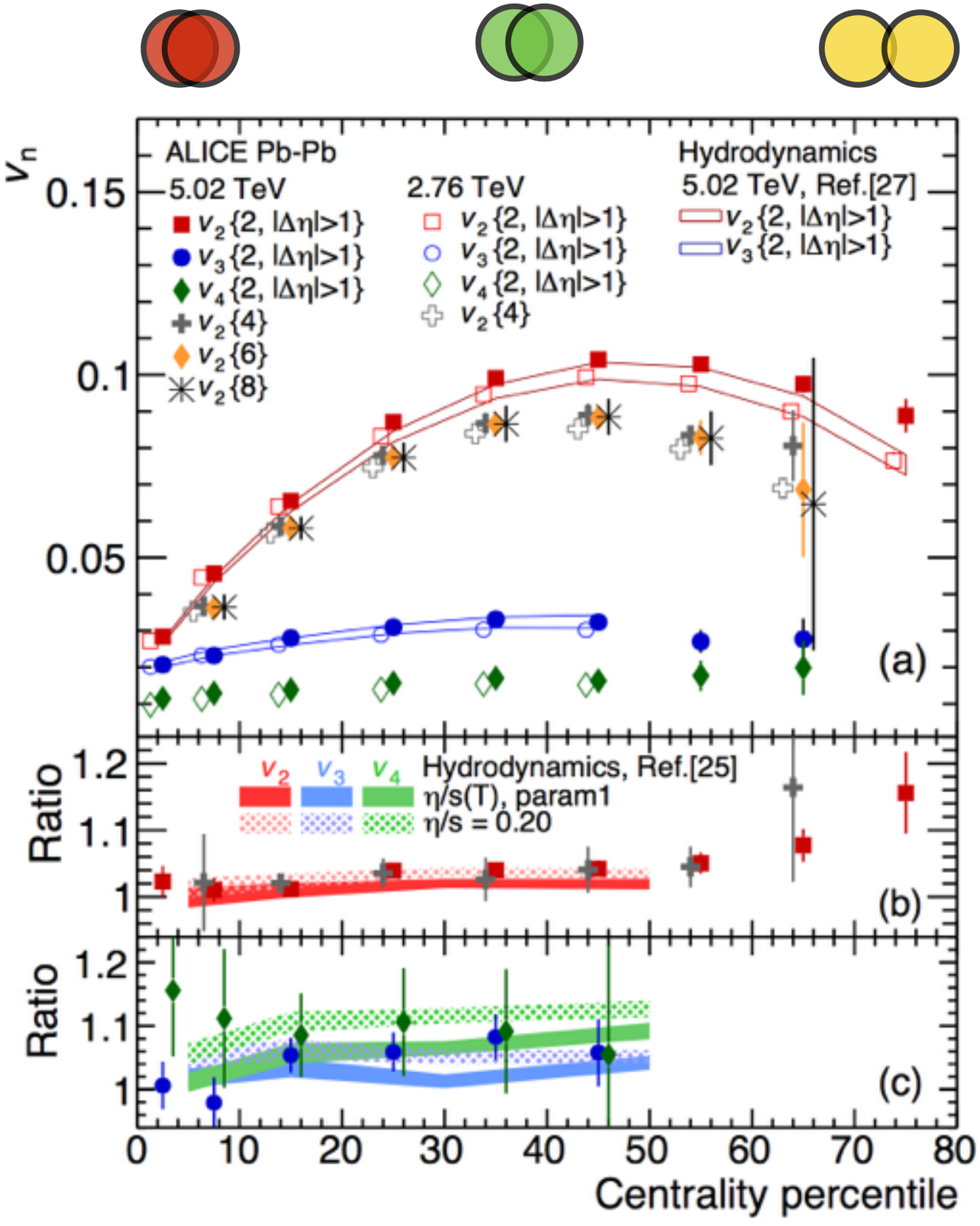
Anisotropic flow in Pb-Pb@5.02 TeV



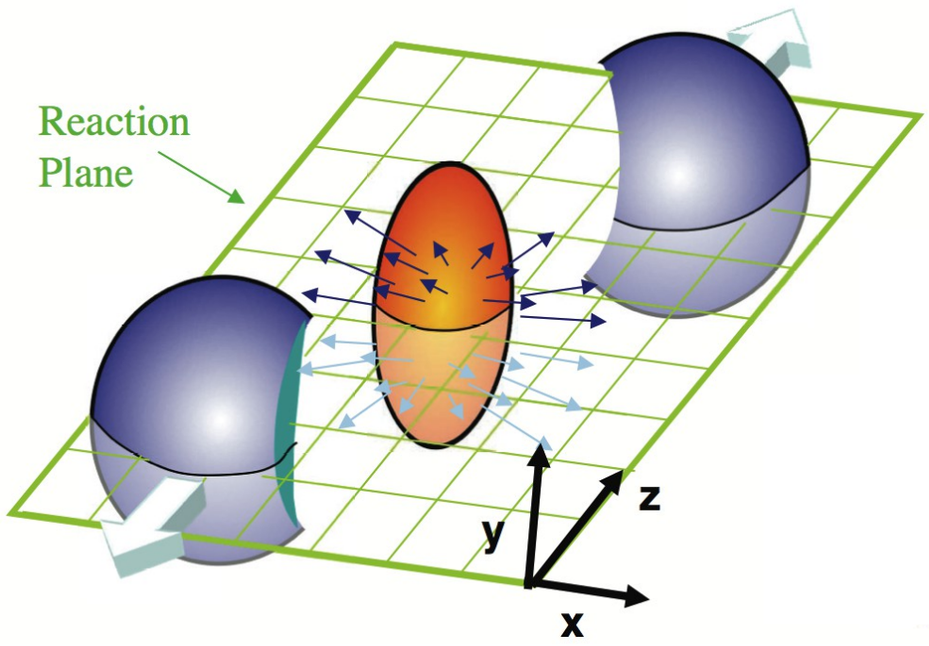
spatial anisotropy
converted in **momentum** space
→ needs fluid-like **collectivity**



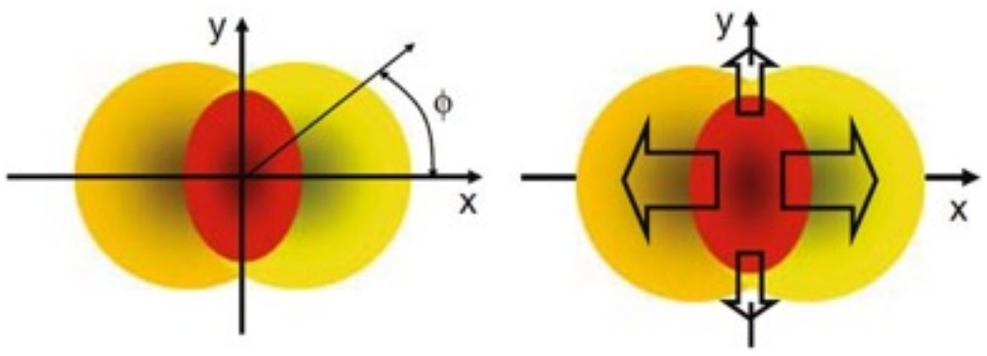
elliptical collision **geometry**
anisotropic pressure gradients



Anisotropic flow in Pb-Pb@5.02 TeV



spatial anisotropy
converted in **momentum** space
→ needs fluid-like **collectivity**



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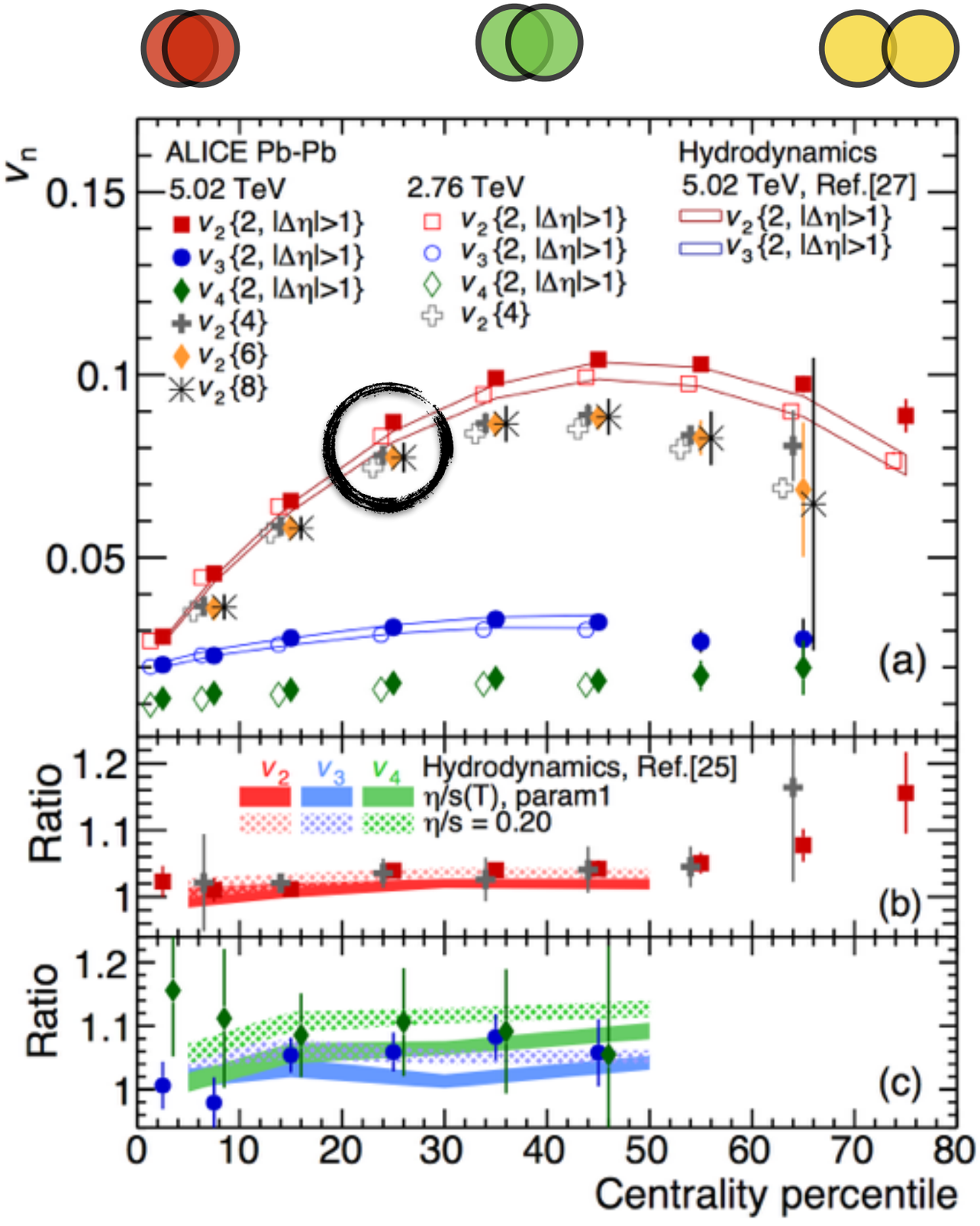
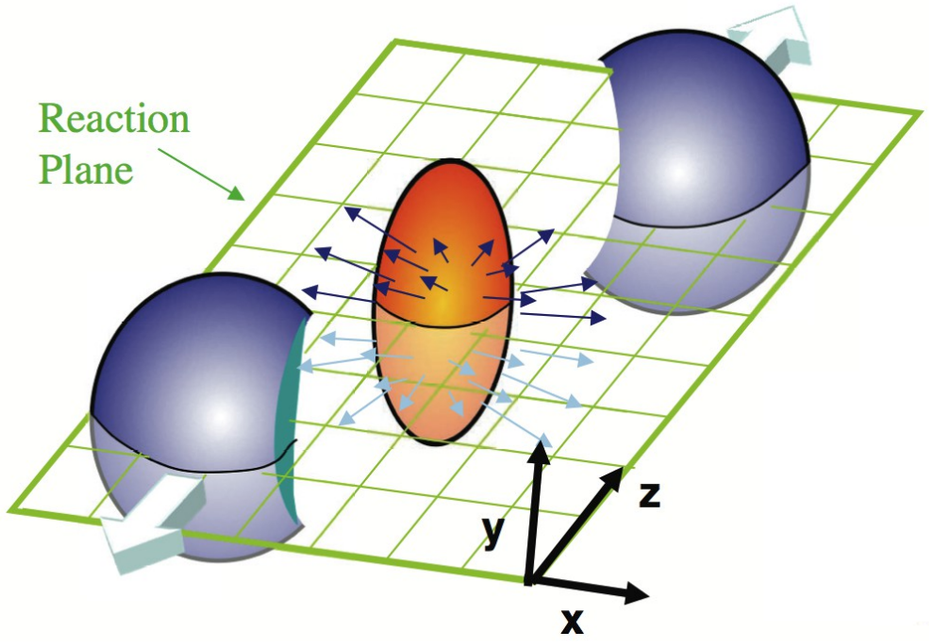
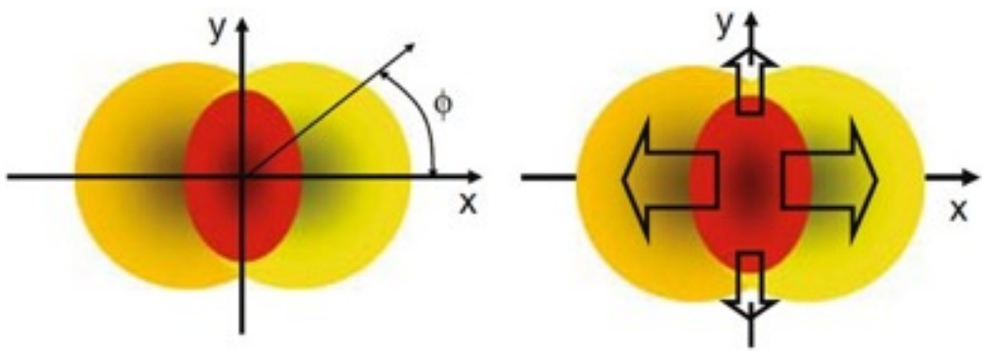


Anisotropic flow in Pb-Pb@5.02 TeV



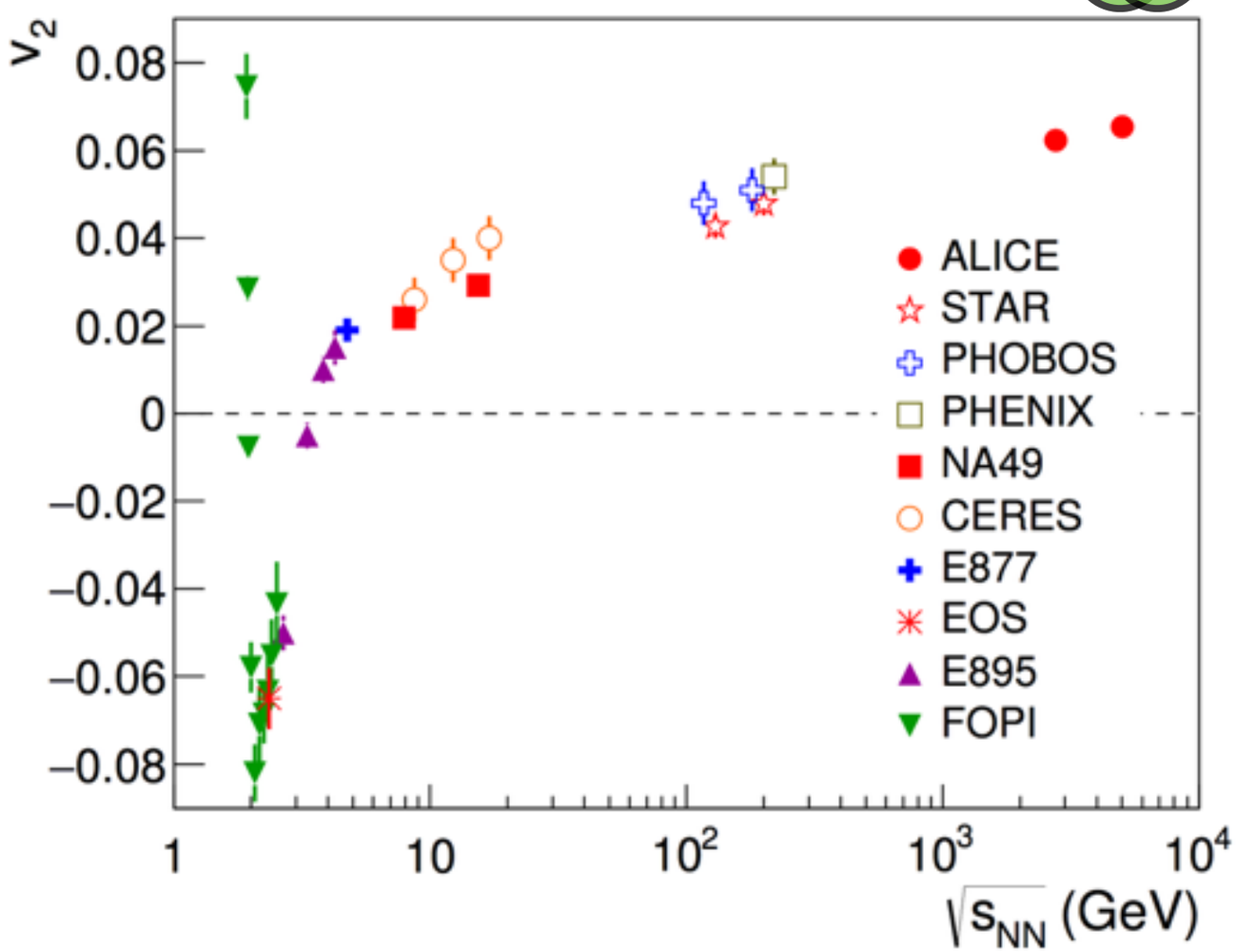
anisotropy in **spatial** space
converted in **momentum** space
→ needs fluid-like **collectivity**



elliptical collision **geometry**
anisotropic pressure gradients

centre-of-mass energy dependence

20-30%



continuous increase of
p_T-integrated v_2
from SPS/RHIC to LHC

Summary

- **Still producing valuable physics from Run-1 data**
  → many new results and papers in pp, p-Pb and Pb-Pb

- **First results in pp collisions @ 13 TeV**
  → $dN_{ch}/d\eta$ and p_T spectra of charged particles
  → production of identified hadrons and resonances

- **First results in Pb-Pb collisions @ 5.02 TeV**
  → centrality dependence of $dN_{ch}/d\eta$
  → anisotropic flow of charged particles

- **More data to analyse, new ideas and a bright future**