Production of hadrons with light and heavy quarks and the QCD phase boundary

- soft probes
- charm content of the FCC fireball
- charmonia

Sundry topics on QGP physics at the FCC

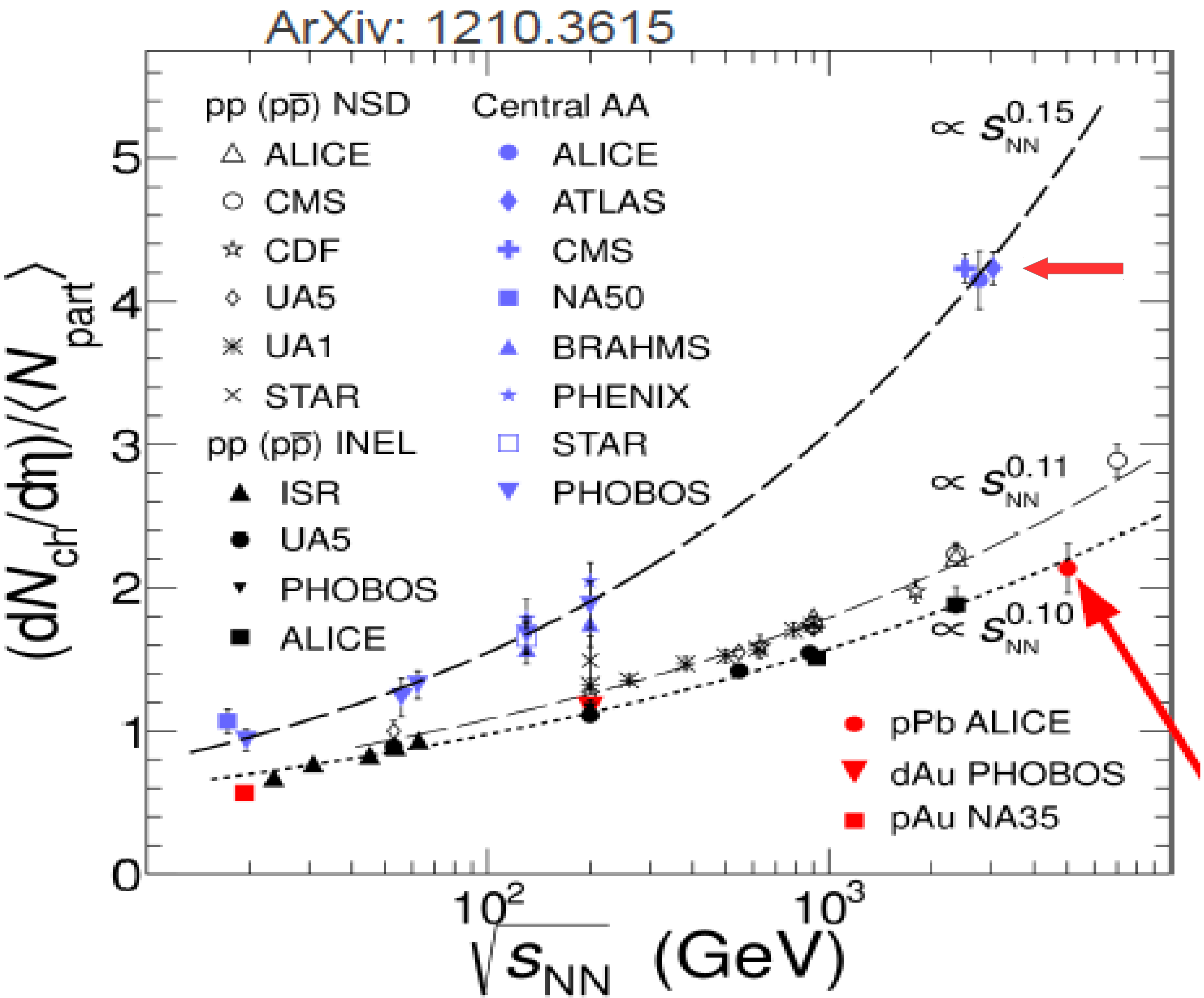
In collaboration with
Anton Andronic, Krzysztof Redlich, Johanna Stachel

FCC workshop
ECT*
March 20, 2015

Peter Braun-Munzinger

Hadron production and the QCD phase boundary

Charged particle multiplicity in pp, pPb and central PbPb collisions



increase with beam energy significantly steeper than in pp

pPb similar to pp inelastic

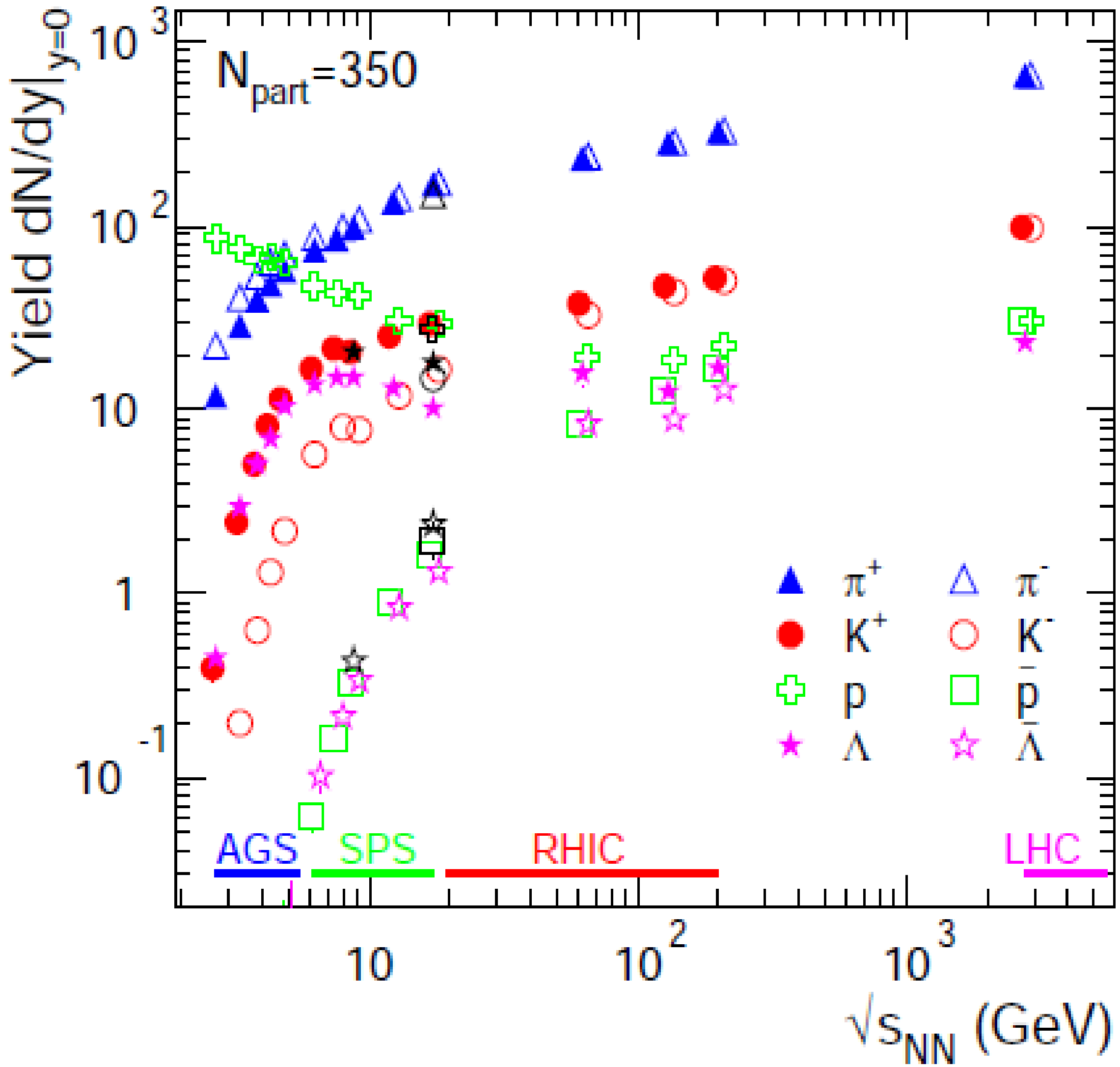
can the fireball formed in central nuclear collisions be considered matter in equilibrium?

Phys. Rev. Lett. 105(2010)252301

Basic numbers

Quantity	Pb–Pb 2.76 TeV	Pb–Pb 5.5 TeV	Pb–Pb 39 TeV
$\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ at $\eta = 0$	1600	2000	3600
Total N_{ch}	17000	23000	50000
$\mathrm{d}E_{\mathrm{T}}/\mathrm{d}\eta$ at $\eta = 0$	2 TeV	2.6 TeV	5.8 TeV
BE homogeneity volume	5000 fm^3	6200 fm^3	11000 fm^3

The experimental input: 25 years of data from the GSI, AGS, SPS, RHIC and LHC collaborations



CERN experiments:

SPS:
NA35, NA36, NA44, NA45, NA49, NA50, NA57, NA60, NA61 WA80. WA87, WA98

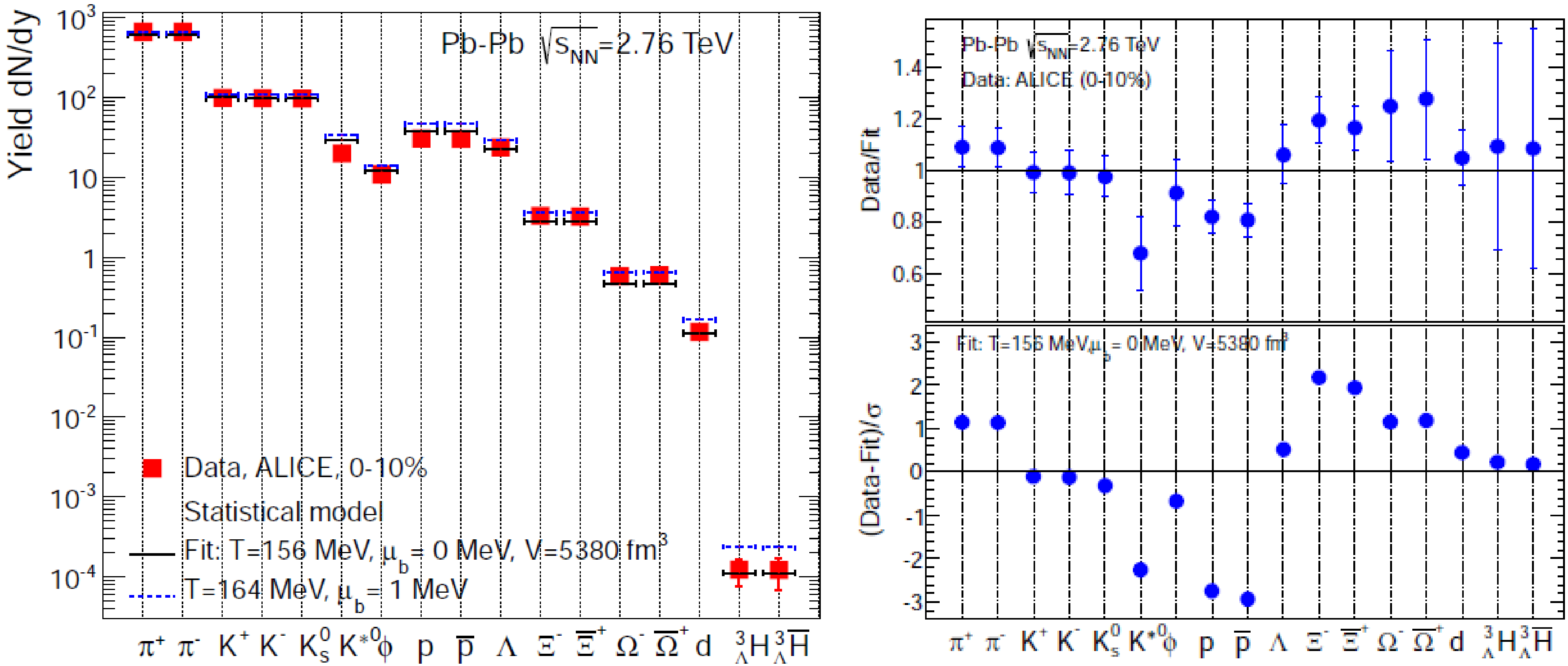
LHC:
ALICE, ATLAS, CMS, LHCb

GSI experiments:
FOPI, KAOS

BNL experiments:
AGS:
E802/E859/E866, E810, E814/E877, E864, E895

RHIC:
BRAHMS, PHENIX, PHOBOS, STAR

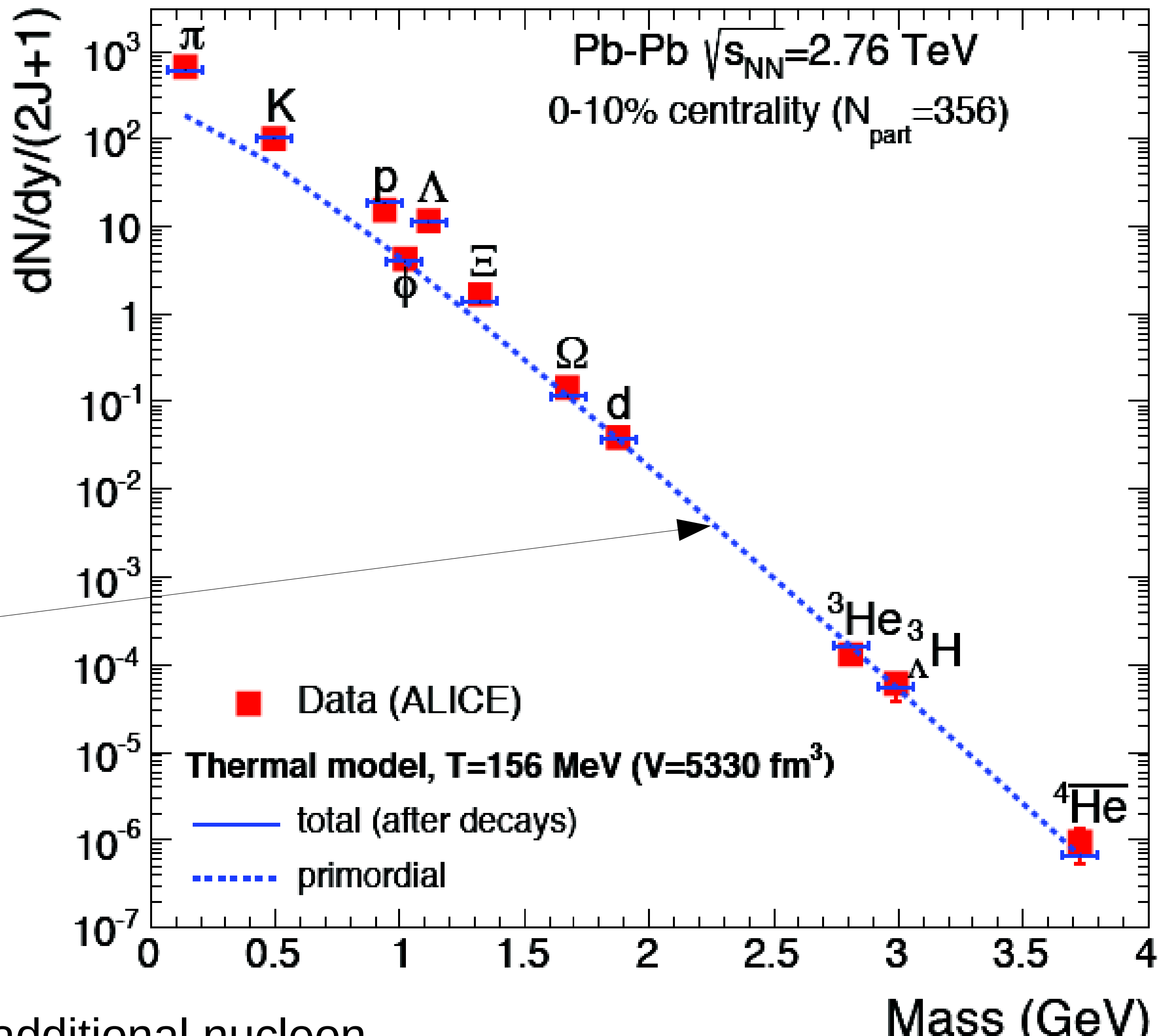
Excellent description of LHC data



fit includes loosely bound systems such as deuteron and hypertriton
hypertriton is bound by only 100 keV, it is the **ultimate halo nucleus,**
produced at T=156 MeV.

This result is important for the understanding of the production of exotica, see below.

Mass dependence of primordial and total yield compared to LHC data

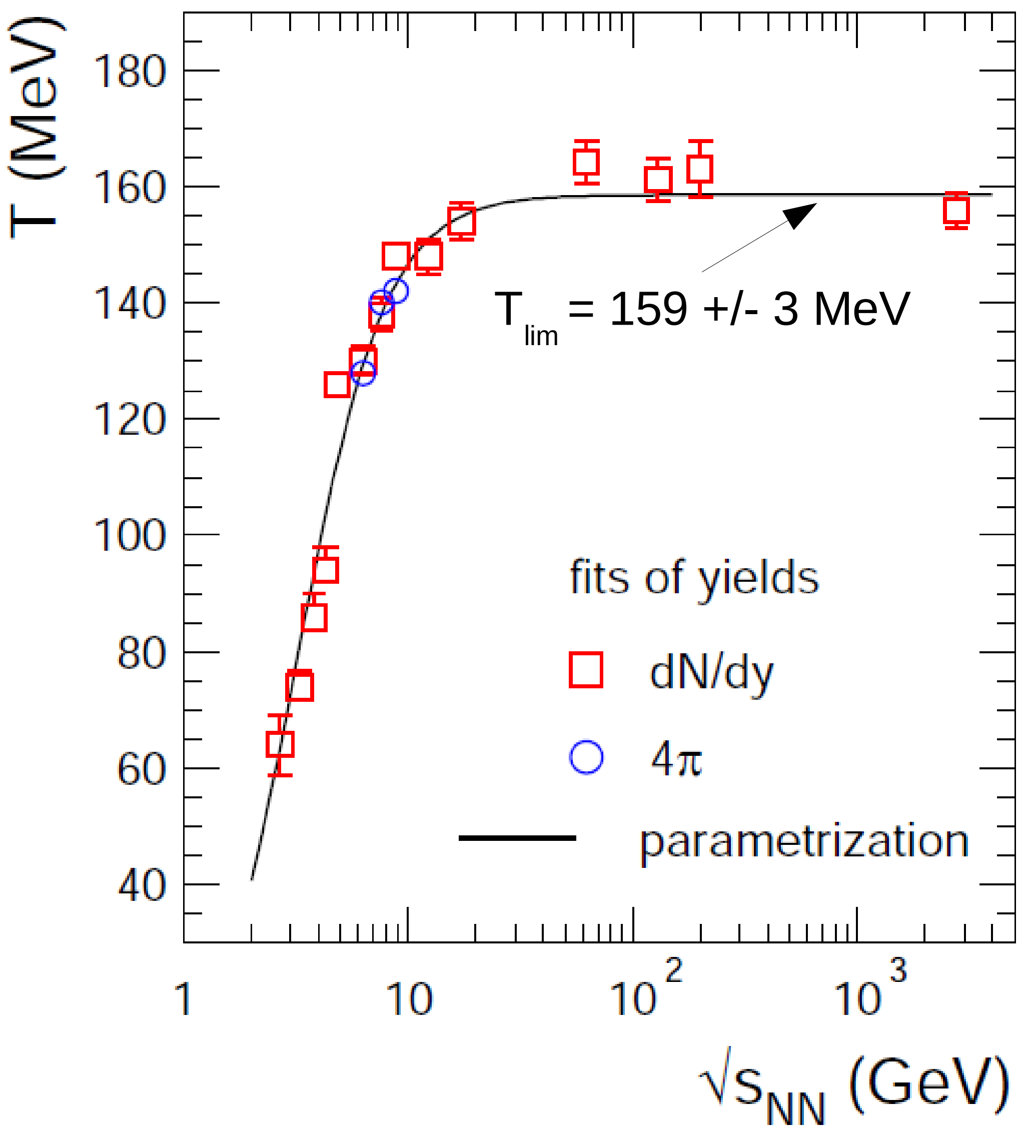


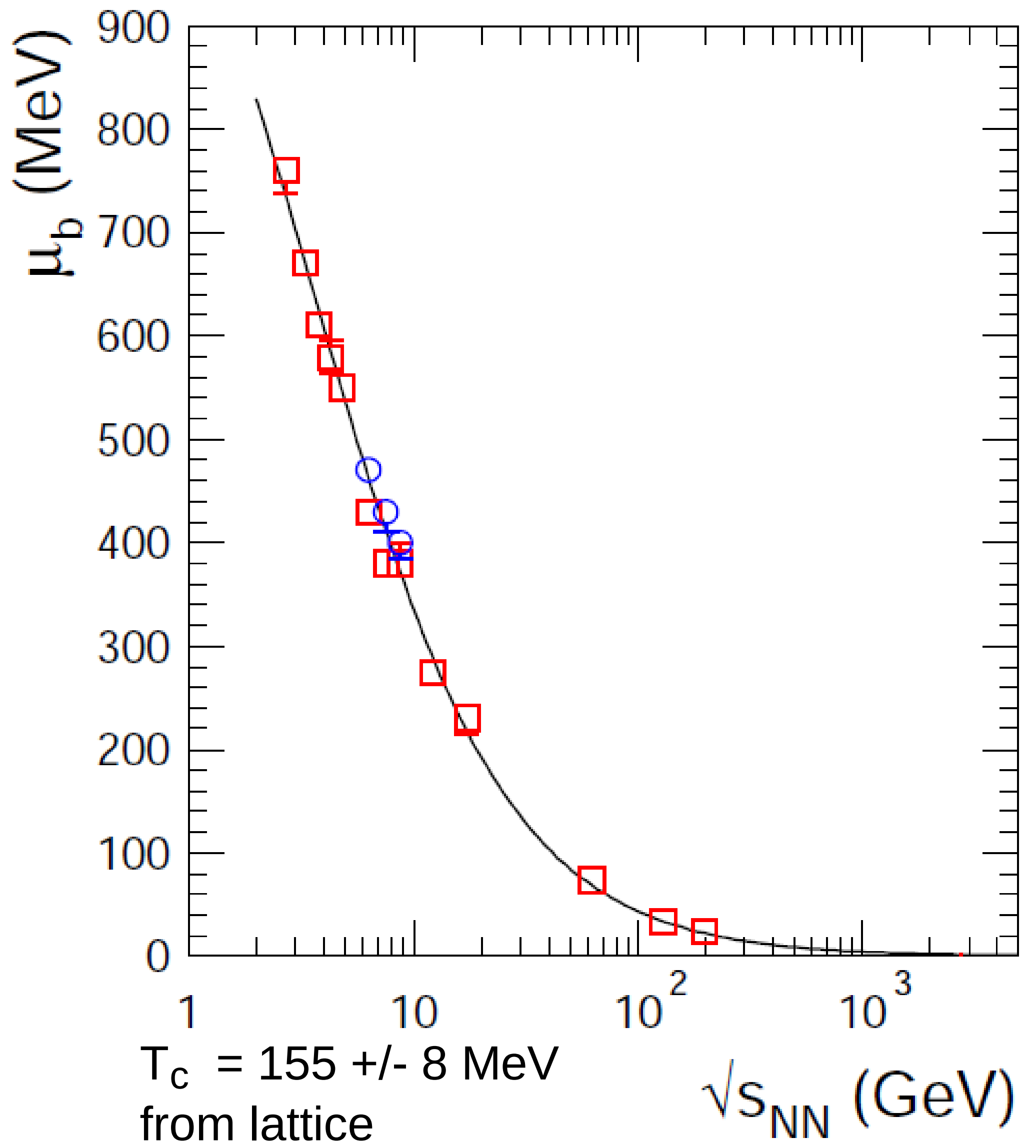
prediction using 'primary' QCD statistical operator, no feeding from strong decays, no fitting of temperature

penalty factor p_N = 300 for each additional nucleon

next stable (anti)-nucleus is A = 6, difficult to get even with triggering or continuous read-out, but other exotica

Energy dependence of temperature and baryo-chemical potential





T_c = 155 +/- 8 MeV
from lattice

uds particle production at FCC

Energy dependence of T and mu_b can safely be extrapolated to FCC energy
current best values are T=155 MeV and mu_b=0 MeV

If we further assume that particle production yields increase with $s^{0.15}$ as shown above, then production yields for all light hadrons in central collisions at FCC energy can be predicted. Overall expected accuracy better than 10%. Any deviation from this would be a major surprise!

Note that since T and mu_b don't change between LHC and FCC energy, all measured yields at FCC can be simply obtained from those measured at 2.76 TeV by multiplication with 2.25.

Nuclear collisions, open and hidden charm hadrons, and QCD

hadrons containing charm quarks can also be described provided open charm cross section is known

recent ALICE data imply Debye screening near T_c for charmonium and deconfined heavy quarks

could it be that increasing number of charm quarks changes (lowers) T_c?
an issue for the FCC! No, effect is too small.

Open charm cross section for Run2 and at FCC

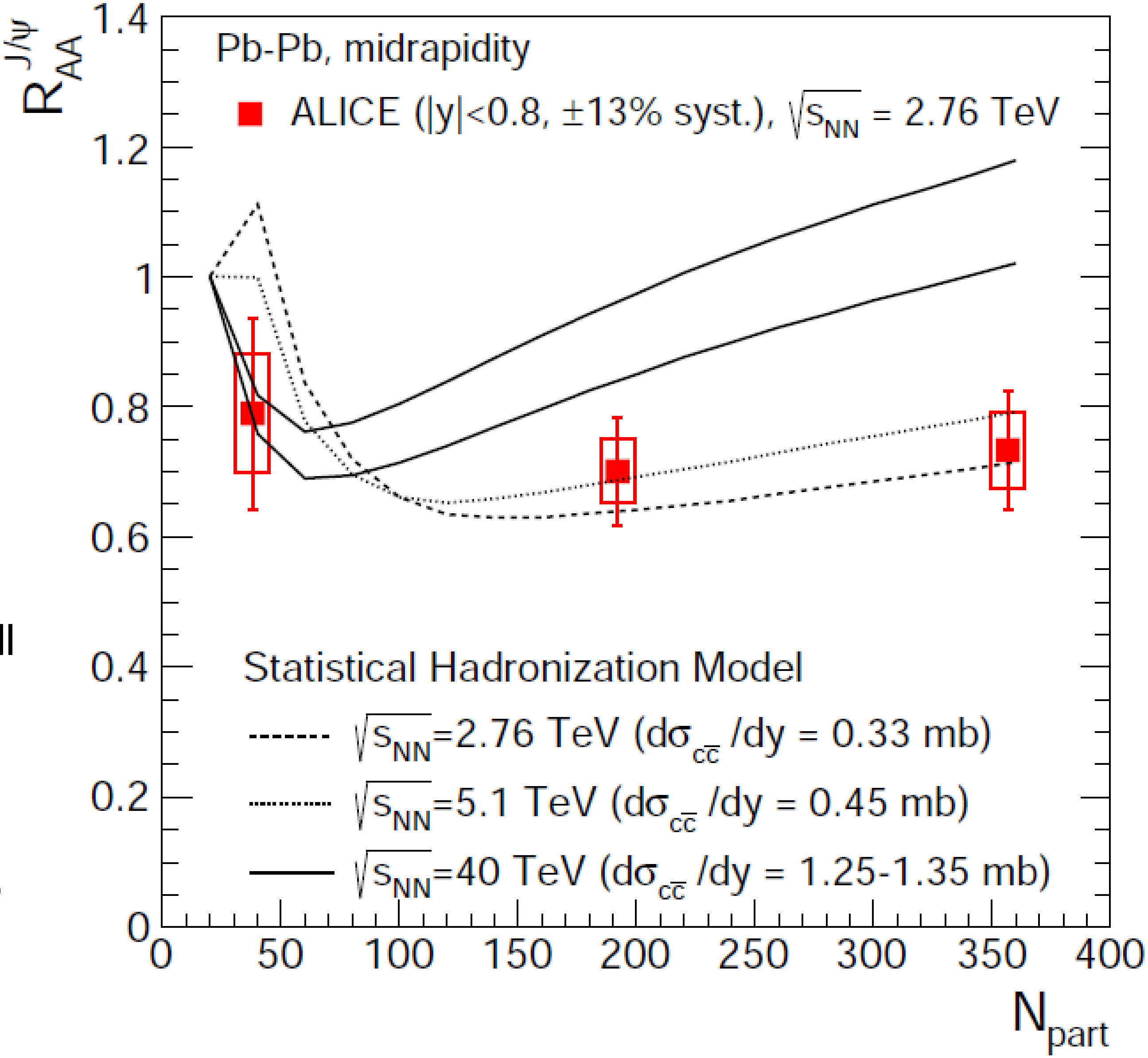
dsigma/dy_pp (mb)	sqrt{s_{NN}} (TeV)	dN(c+c_bar)/dy Pb--Pb
0.07	0.2	3.4
0.33	2.76	12.5
0.5	5.5	17.5
1.35	40	51

prediction of J/psi cross section at mid-rapidity for run2 and FCC

uncertainty in energy dependence of open charm cross section and volume still large

new analysis based on all existing data to come soon.

Need also extrapolation for effects of shadowing .



charmonium sector

R_AA will significantly increase, to values exceeding unity.

However, no qualitatively new features are expected.

Similar in the bottomonium sector.

The QGP at FCC is still a (u,d,s) dominated plasma.

energy density from charm quarks in the QGP for FCC energy

assume: $m_c = 1.3$ GeV $T_c = 156$ MeV

volume at chem. freeze-out (= T_c) = 11000 fm^3 = V_c

critical line is curve of constant energy density

eps_charm = N(c+c_bar) x (m_c+3/2 T_c)/V_c

n(c+c_bar)	eps_charm (MeV/fm^3}
50	7
100	14

Even at FCC energy, effect of charm quarks on the EoS of QGP is negligible

since dT/T = ¼ d(eps)/eps

expect dT = 1 – 2 MeV only

but this is lower limit due to neglect of interactions...