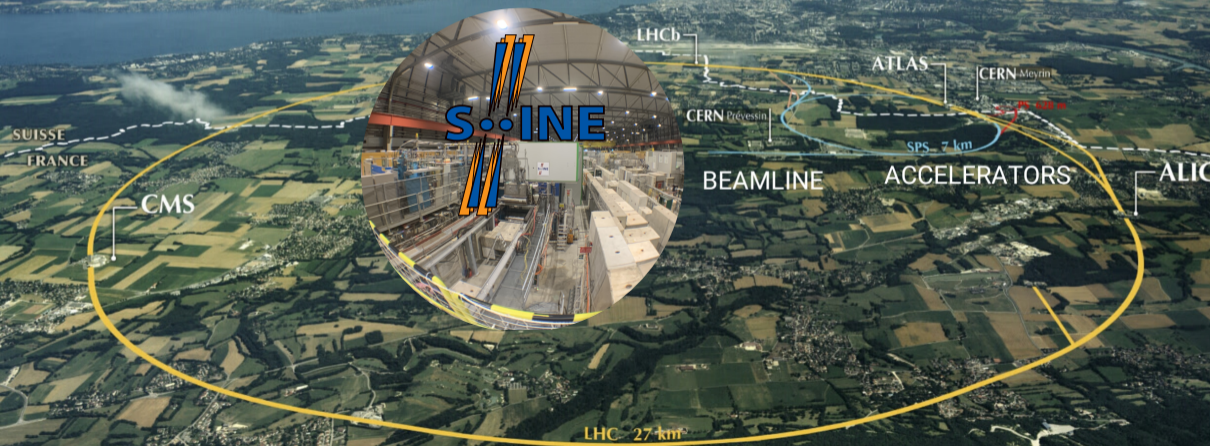


# Summary of recent intriguing NA61/SHINE results

Magdalena Kuich  
for the NA61/SHINE Collaboration

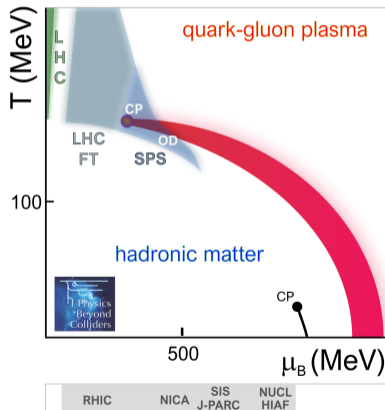
# NA6I/SHINE - UNIQUE MULTIPURPOSE FACILITY:

Hadron production in hadron-nucleus and nucleus-nucleus collisions at high energies

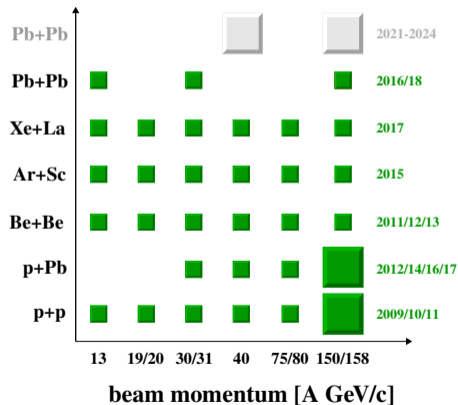


# NA61/SHINE objectives

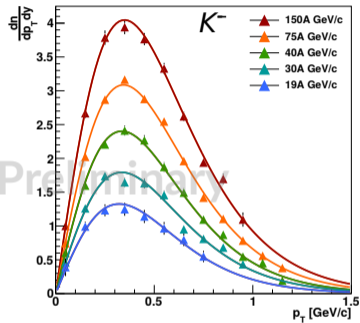
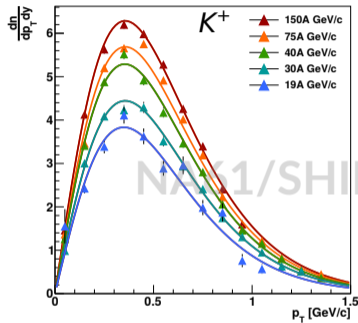
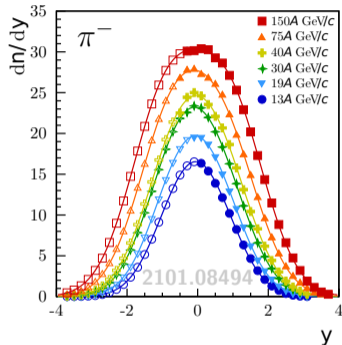
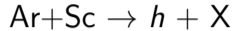
Search for **critical point** & study of the **onset of deconfinement**



Unique 2-D scan in the **collision energy** and **colliding nuclei mass**



# Examples of NA61/SHINE measurements

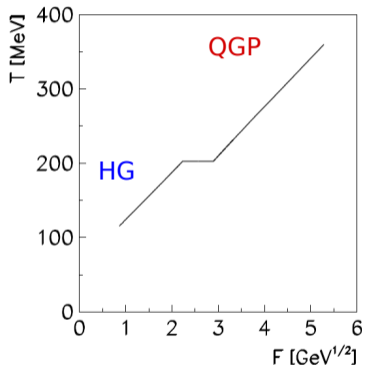


- rapidity spectra fitted with a sum of symmetric Gaussians to obtain mean multiplicities
- $p_T$  spectra fitted with:

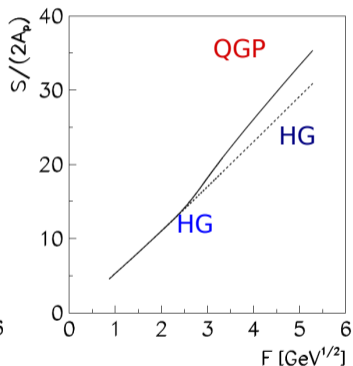
$$\frac{d^2 n}{dy dp_T} = \frac{S p_T}{T^2 + T m_K} \exp\left(-\frac{\sqrt{p_T^2 + m_K^2} - m_K}{T}\right)$$

# Observables of the onset of deconfinement

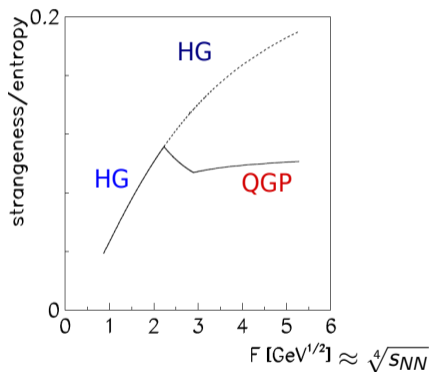
"Step"



"Kink"

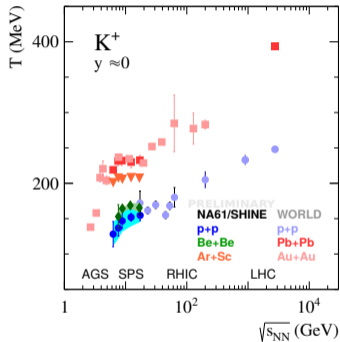


"Horn"

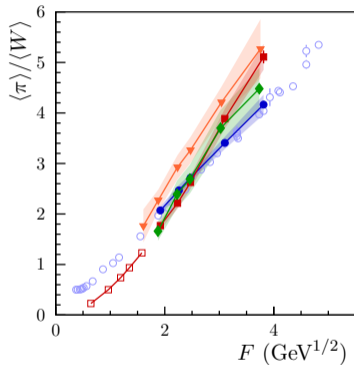


# Observables of the onset of deconfinement

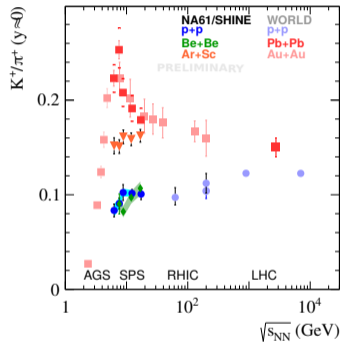
## “STEP”



## “KINK”



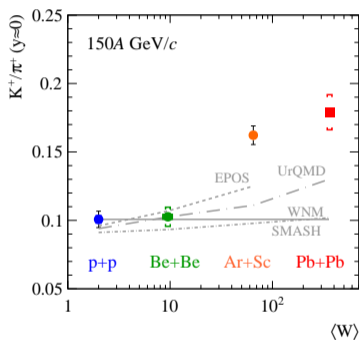
## “HORN”



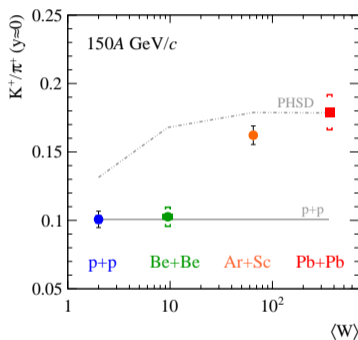
Revealed unexpected behaviour as a function of colliding nuclei mass.

# $K^+/\pi^+$ ratio vs the system size

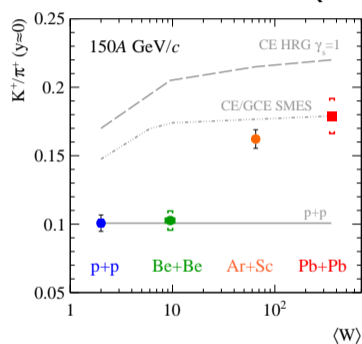
Dynamical models  
without transition to QGP



with transition to QGP



Statistical models without  
and with transition to QGP



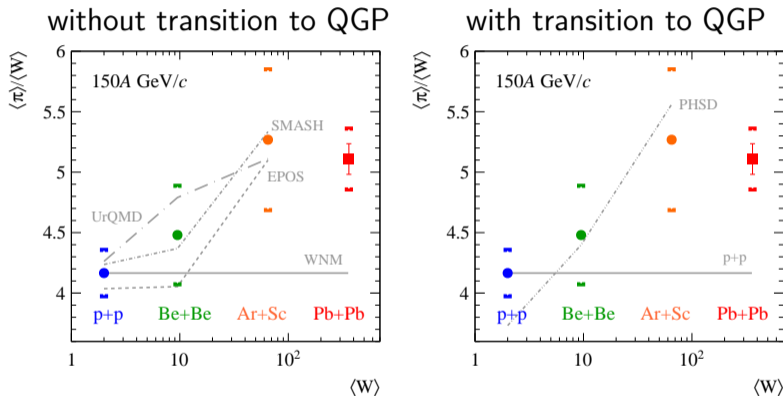
- None of the models reproduce  $K^+/\pi^+$  ratio for whole  $\langle W \rangle$  range.

PHSD: Eur.Phys.J.A 56 (2020) 9, 223, arXiv:1908.00451 and private communication;  
SMASH: J.Phys.G 47 (2020) 6, 065101 and private communication;  
UrQMD and HRG: Phys. Rev. C99 (2019) 3, 034909  
SMES: Acta Phys. Polon. B46 (2015) 10, 1991 - recalculated

p+p: Eur. Phys. J. C77 (2017) 10, 671  
Be+Be: Eur. Phys. J. C81 (2021) 1, 73  
Ar+Sc: NA61/SHINE preliminary  
Pb+Pb: Phys. Rev. C66, 054902 (2002)

# $\langle \pi \rangle / \langle W \rangle$ ratio vs the system size

## Dynamical models



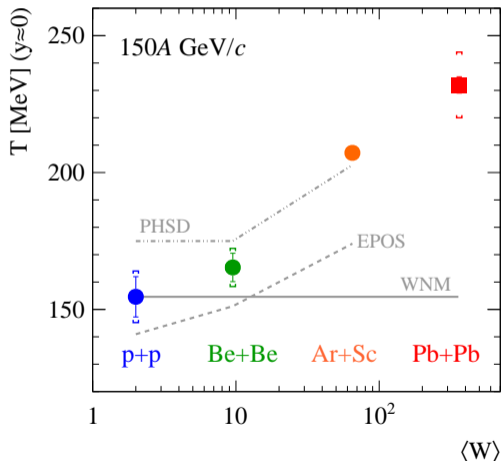
Models:  
 Eur.Phys.J.A 56 (2020) 9, 223,  
 arXiv:1908.00451,  
 J.Phys.G47 (2020) 6, 065101  
 and private communication;  
 data:  
 Eur.Phys.J.C74 (2014) 3, 2794,  
 Eur.Phys.J.C81 (2021) 2, 144,  
 Phys.Rev.C66, 054902 (2002),  
 2101.08494;

- Model predictions for  $\langle \pi \rangle / \langle W \rangle$  approximately agree with the data.
- However, they should be complemented with calculations for Pb+Pb.



# $T$ of $m_T$ spectra vs the system size

Dynamical models with and without transition to QGP



- EPOS predicts to low value of the inverse slope parameter (lack of transverse flow).
- PHSD seems to work for systems like Be+Be and heavier, while it's off in the case of p+p.

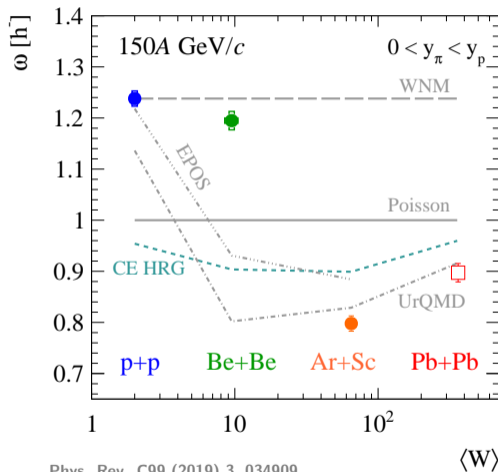
Eur.Phys.J.A 56 (2020) 9, 223; arXiv:1908.00451  
and private communication;  
p+p: Eur. Phys. J. C77 (2017) 10, 671  
Be+Be: Eur. Phys. J. C81 (2021) 1, 73  
Ar+Sc: NA61/SHINE preliminary  
Pb+Pb: Phys. Rev. C66, 054902 (2002)

# Scaled variance of negatively charged hadrons

$$\omega[h^-] = \frac{\kappa_2[h^-]}{\kappa_1[h^-]} = \frac{\langle (h^-)^2 \rangle - \langle h^- \rangle^2}{\langle h^- \rangle}$$

- Dynamical models show steep decrease of  $\omega[h^-]$  value with the colliding system size, but what about Be+Be results?
- Statistical model does not describe p+p and Be+Be.




















NA61/SHINE results derived in the NA61 acceptance  
 NA49 results-in somewhat smaller acceptance  
 (for details see: Eur.Phys.J.C 76 (2016) 11, 635).



Phys. Rev. C99 (2019) 3, 034909

NA61/SHINE preliminary

# Summary for system size dependence

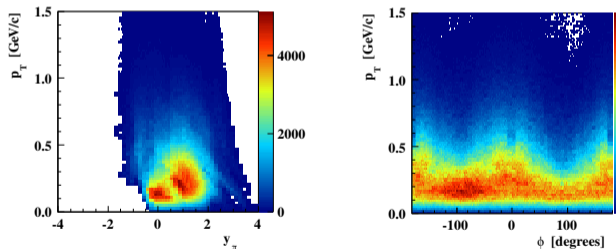
	$K^+/\pi^+_{(y \approx 0)}$	$\langle \pi \rangle / \langle W \rangle$	$T$	$\omega[h^-]$
WNM				
EPOS				
UrQMD			-	
SMASH			-	-
PHSD				-
HRG (CE $\gamma = 1$ )		-	-	
SMES		-	-	-

**NA61/SHINE results are reproduced neither by dynamical nor statistical models.**

**But there is an idea, how to understand them...**

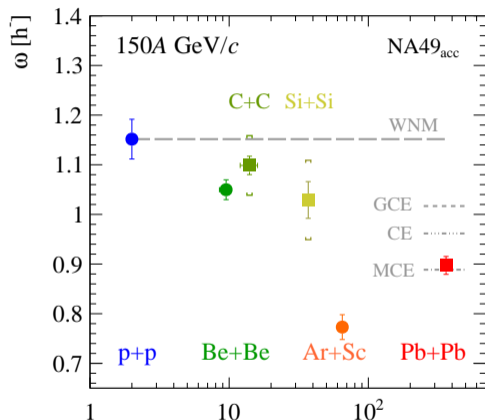
# Scaled variance ratio vs the system size

**NA61/SHINE acceptance** was selected to the region where the reconstruction efficiency is higher than 90%. Selection was based on MC simulation in bins of  $y - \phi - p_T$ .



Acceptance example for 150A GeV/c

$\omega[h^-]$  in NA49 acceptance



Phys. Rev. C76 (2007) 024902

$\langle W \rangle$