Looking for the phase transition - recent NA61/SHINE results

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University of Geneva, Switzerland
University of Colorado Boulder, USA
Los Alamos National Laboratory, USA
Department of Physics and Astronomy, University of Pittsburgh, USA
Fermilab, Neutrino Division, USA

NA61/SHINE – about

❖Located at the CERN SPS

❖Successor of NA49

❖Large acceptance spectrometer for fixed target experiment on primary (ions) and secondary (ions, hadrons) beams

❖Data taking since 2009

❖NA61/SHINE is the second largest non-LHC experiment at CERN

Physics program

Strong interactions program

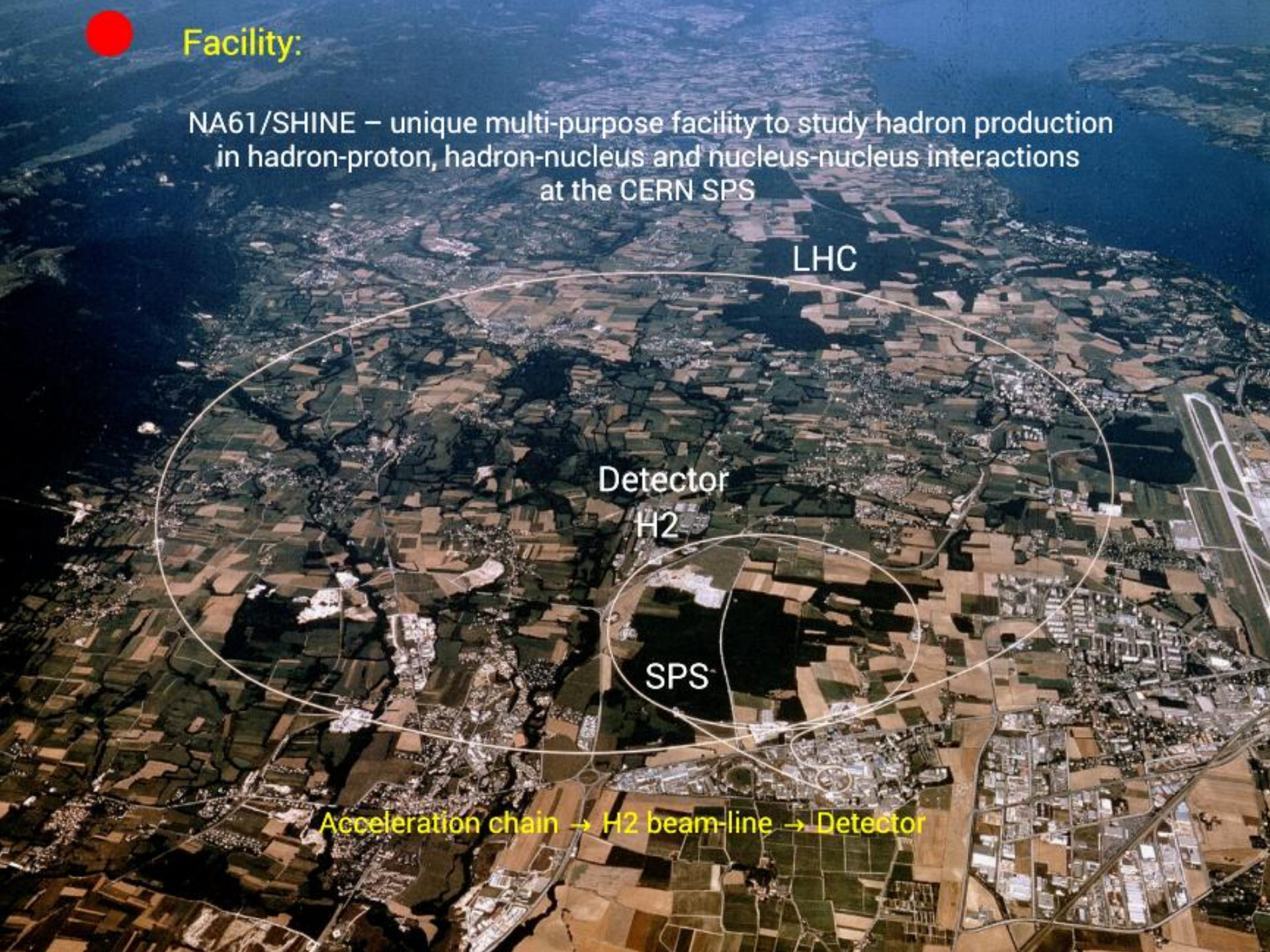
•search for the critical point of strongly interacting matter
•study of the properties of the onset of deconfinement
•study high p T particles production (energy dependence of nuclear modification factor)

Hadron-production measurements for neutrino experiments

•reference measurements of p+C interactions for the T2K experiment for computing initial neutrino fluxes at J-PARC

Hadron-production measurements for cosmic ray experiments

•reference measurements of p+C, p+p, π+C, and K+C interactions for cosmic-ray physics (Pierre-Auger and KASCADE experiments) for improving air shower simulations


Facility:
NA61/SHINE – unique multi-purpose facility to study hadron production
in hadron-proton, hadron-nucleus and nucleus-nucleus interactions
at the CERN SPS
LHC
Detector
H2
SPS
Acceleration chain → H2 beam-line → Detector

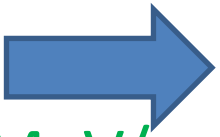
HIC programs @ SPS energy range

- RHIC Beam Energy Scan (BNL, Brookhaven),
- NICA (JINR, Dubna),
- SIS-100/300 (FAIR GSI, Darmstadt)
- NA61/SHINE (CERN)

HIC programs to perform a two-dimensional scan in beam momentum and mass number of colliding nuclei

- NA61/SHINE (CERN)

NA61/SHINE is a fixed target experiment



acceptance of NA61 starts from P_T = 0 MeV/c

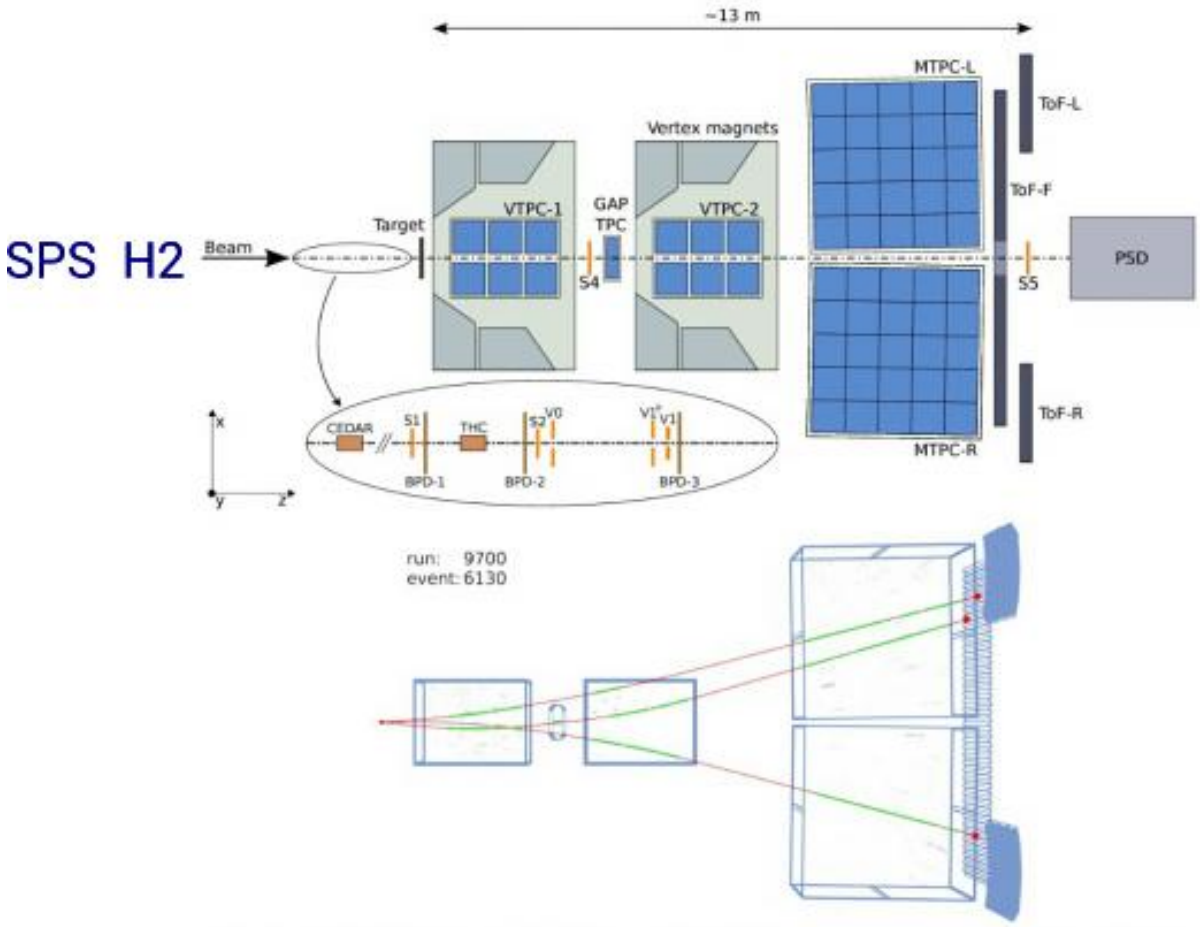
This gives

- *better analysis of spectra*
- *better analysis of fluctuations due to the CP, which show up mainly in low p_T particles*

NA61/SHINE Facility

Acceleration chain → H2 beam-line → **Detector**

NA61/SHINE detector

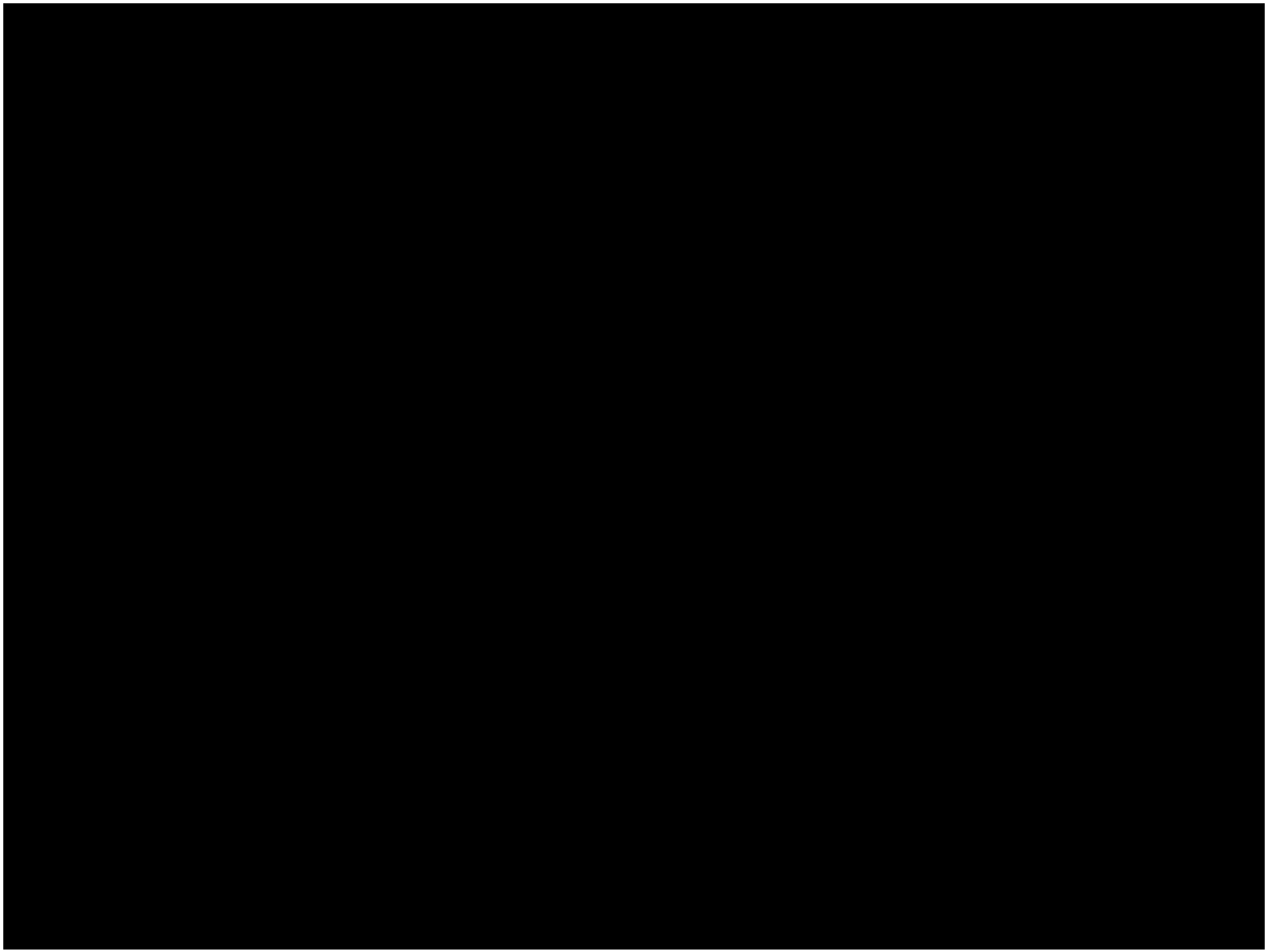


(p+p interaction at 40 GeV/c measured in the NA61/SHINE detector)

- A large acceptance hadron spectrometer
- Beam particles measured in set of counters and MWPC detectors
- Charged tracks measured in set of 5 **TPCs** → measurement of q, p and identification via dE/dx
- 3 ToF walls: identification via time of flight measurement
- **Projectile Spectator Detector** counts the non-interacting nucleons of the beam particle

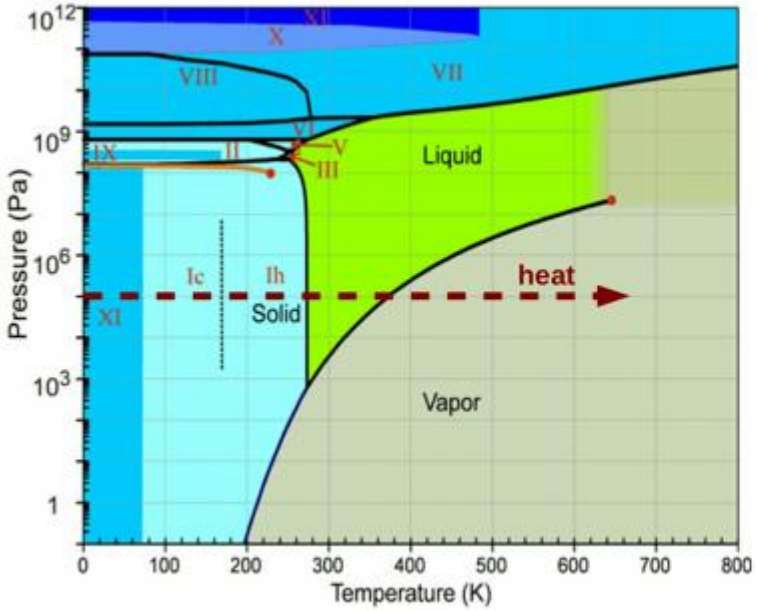
3D NA61 visualization

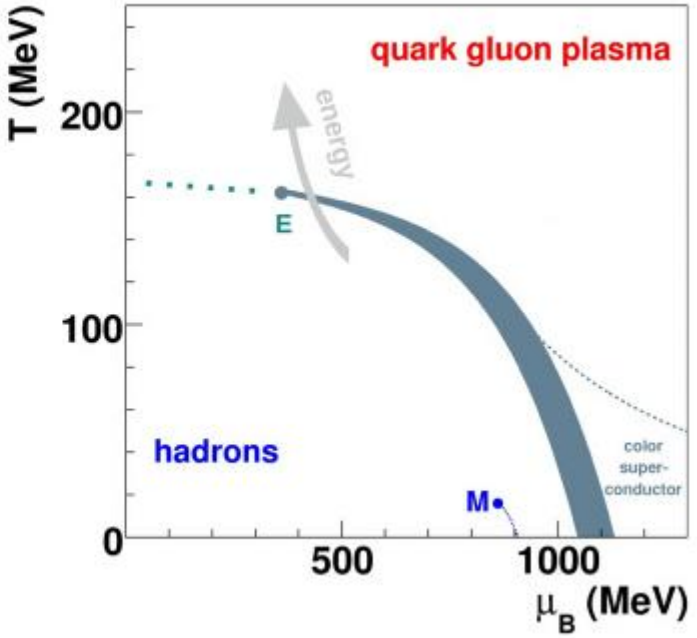
By Filip Michalski & Taras Palayda – ungraduate students. Thanks!



Strong interactions

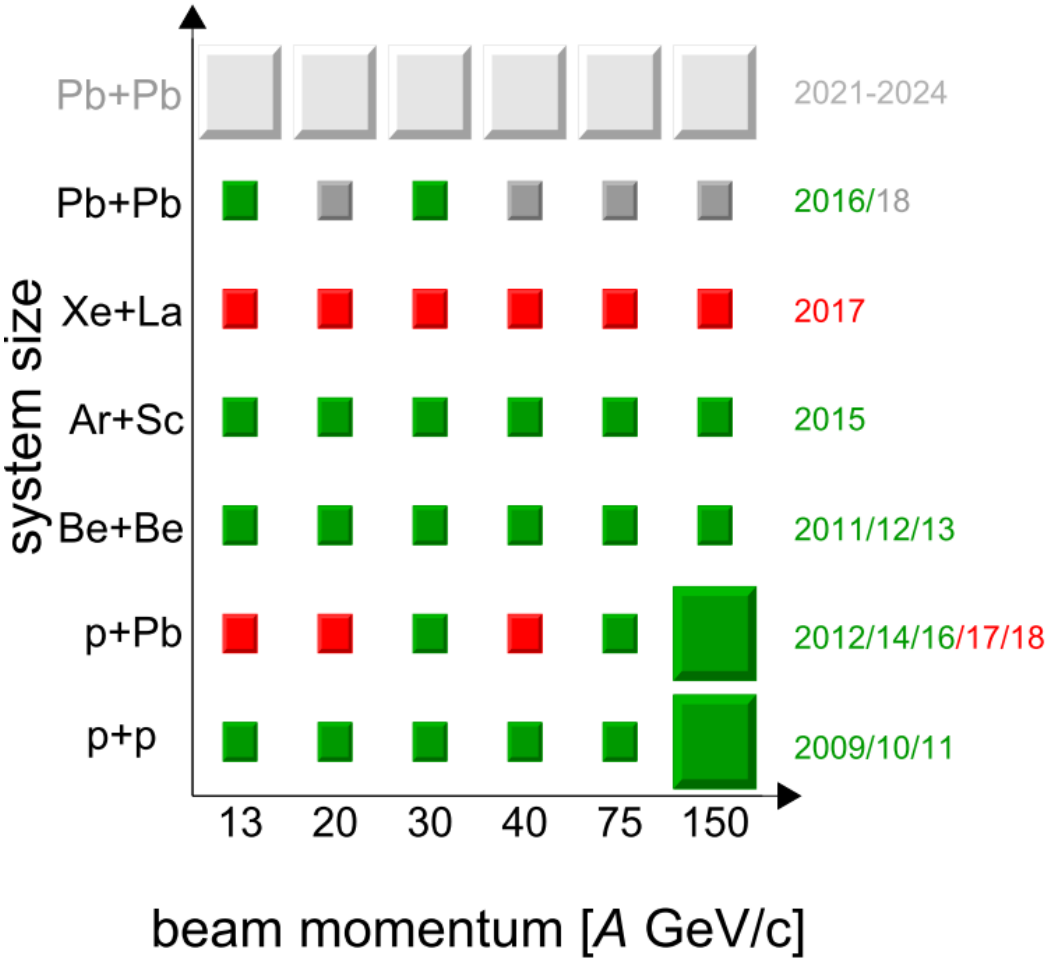
What happens when strongly interacting matter gets hotter/denser and its volume increases?

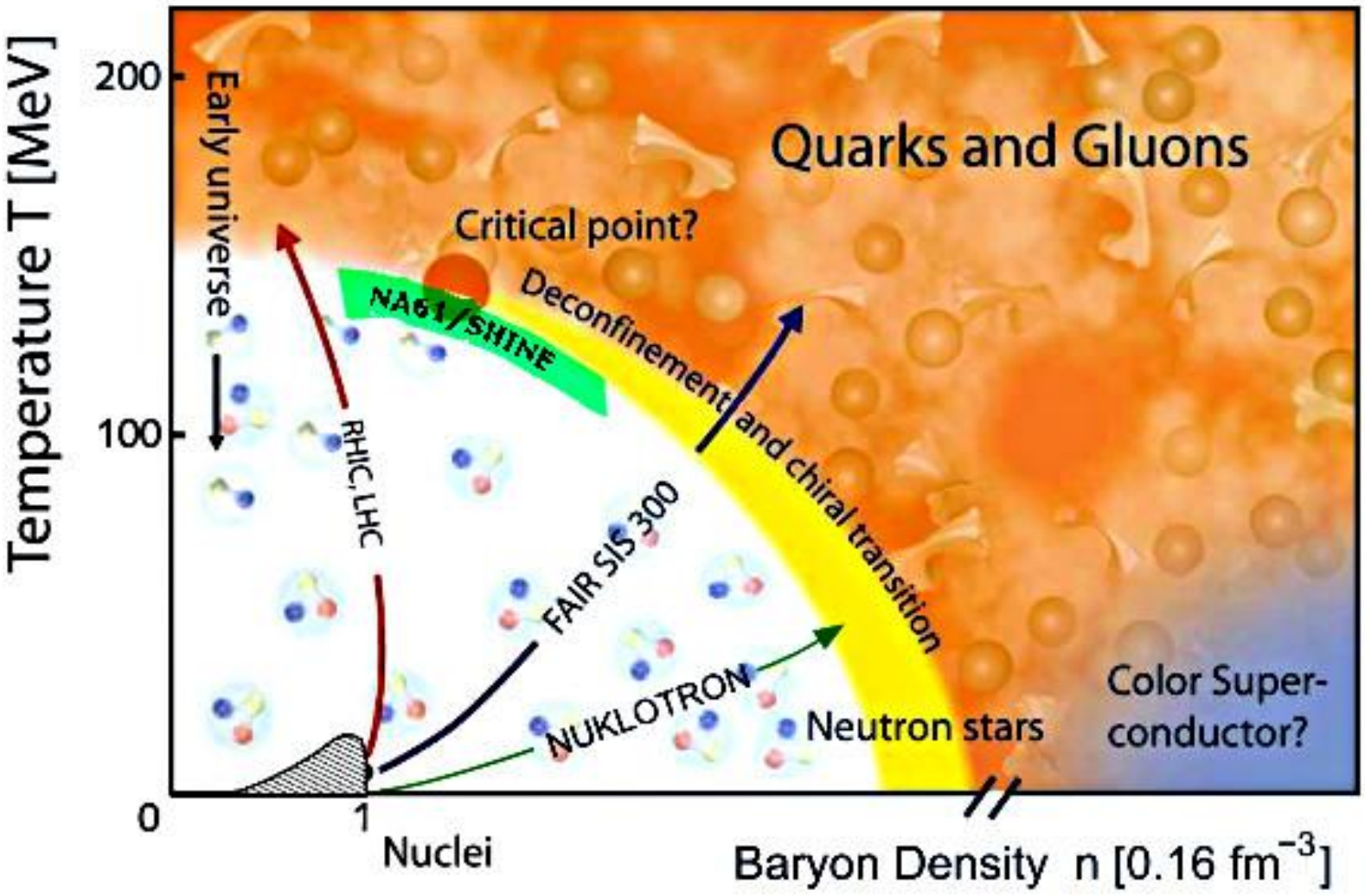




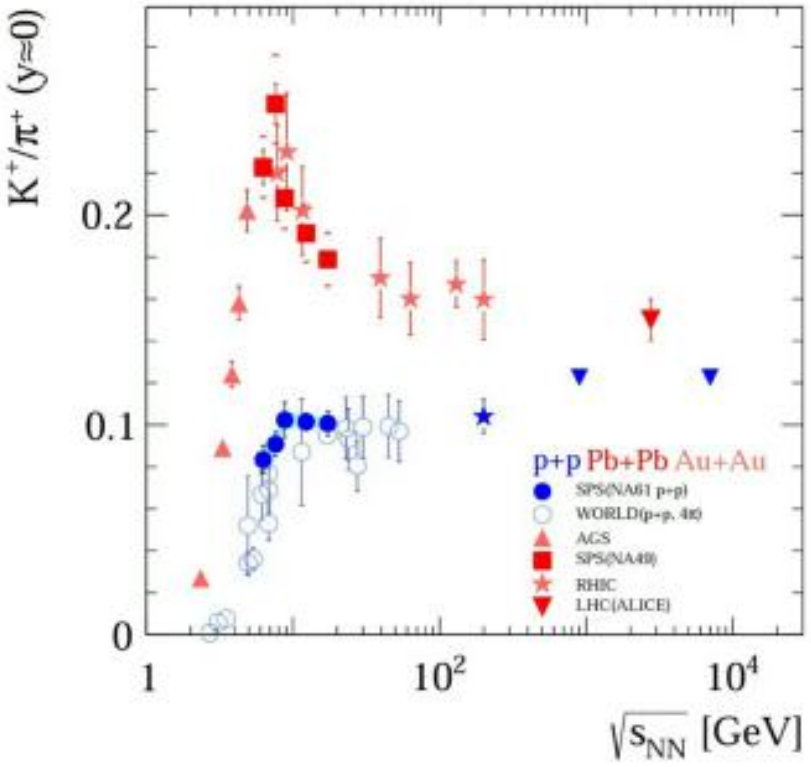
NA61 studies properties of the onset of deconfinement and searches for the critical point of strongly interacting matter

Data taking – strong interaction program

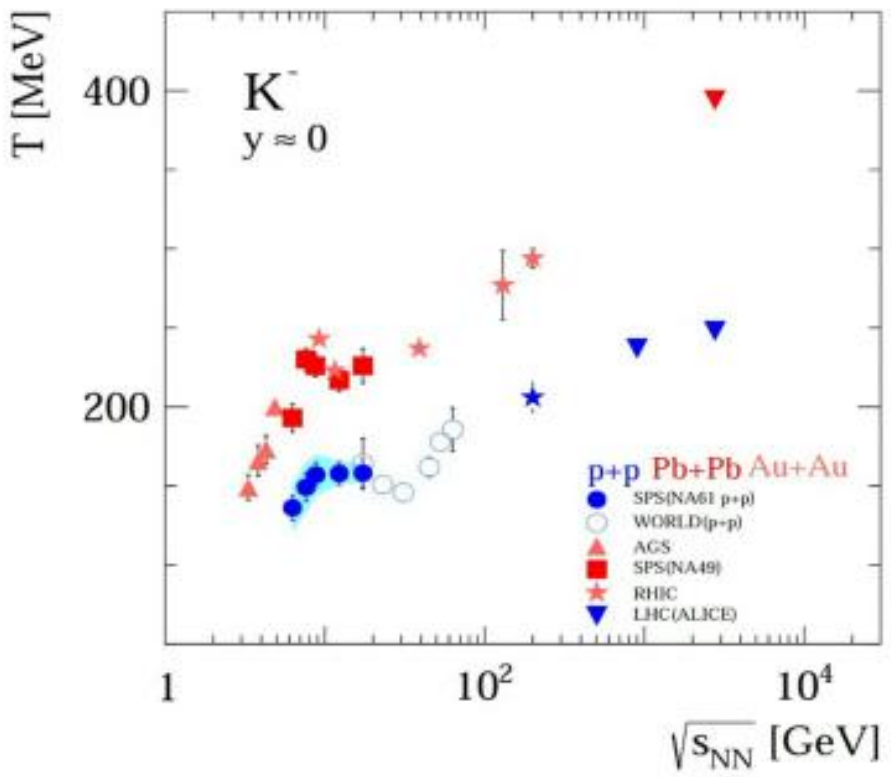



Temperature T [MeV]
200
100
0
1
Nuclei
Baryon Density n [0.16 fm^{-3}]
Quarks and Gluons
Critical point?
Deconfinement and chiral transition
NA61/SHINE
Early universe
RHIC, LHC
FAIR SIS 300
NUKLOTRON
Neutron stars
Color Super-
conductor?

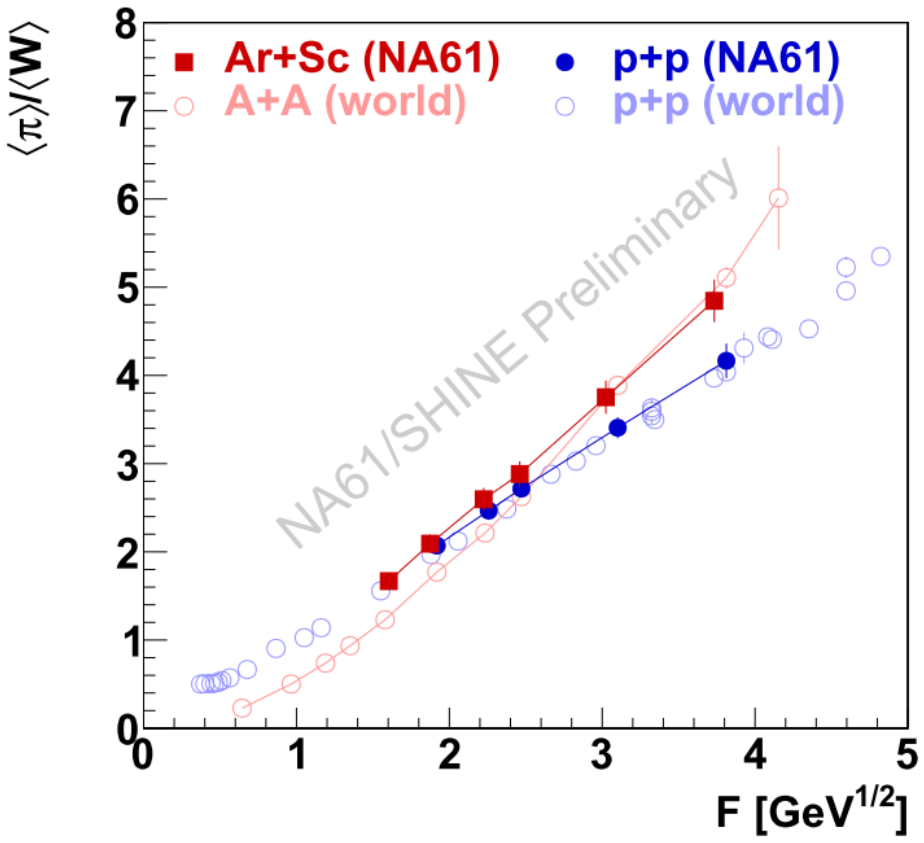
Evidence for phase transition at SPS and its volume dependence

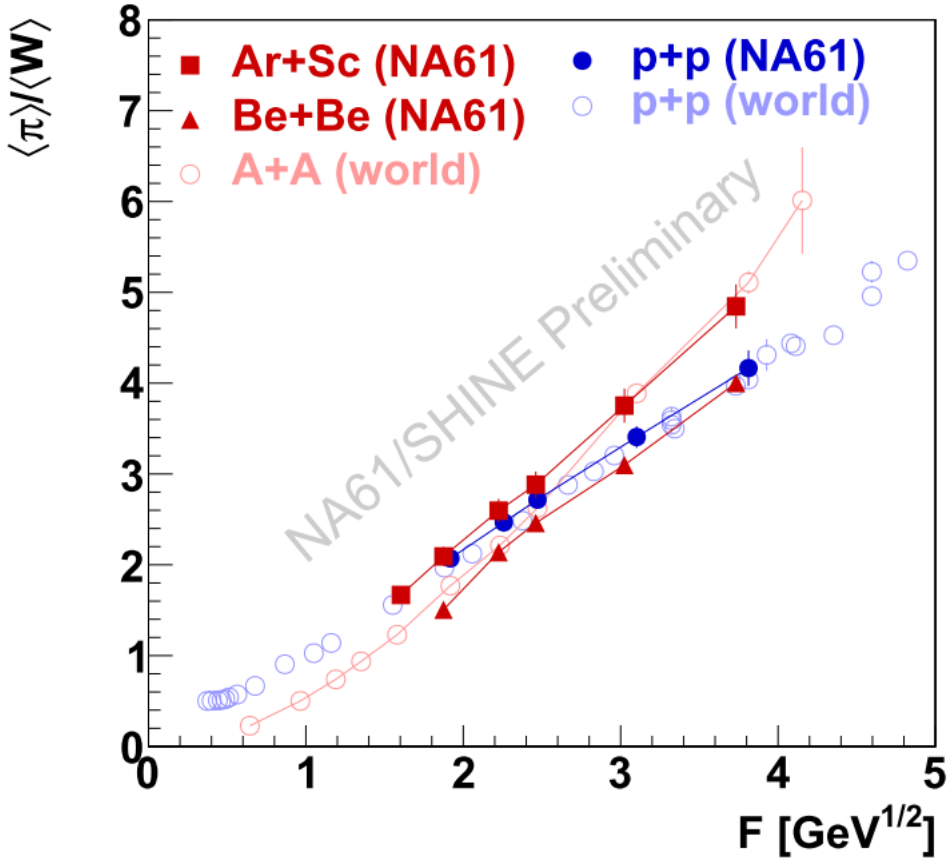


horn plot

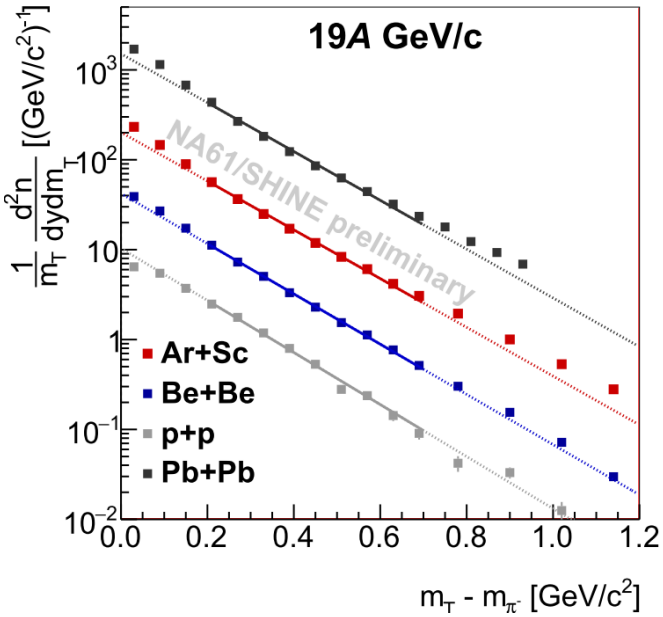


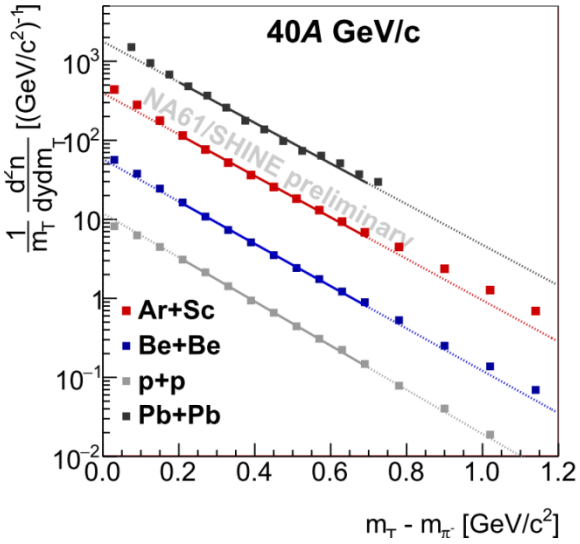
step plot


⟨π⟩/⟨W⟩
Ar+Sc (NA61)
p+p (NA61)
A+A (world)
p+p (world)
NA61/SHINE Preliminary
F [GeV^1/2]

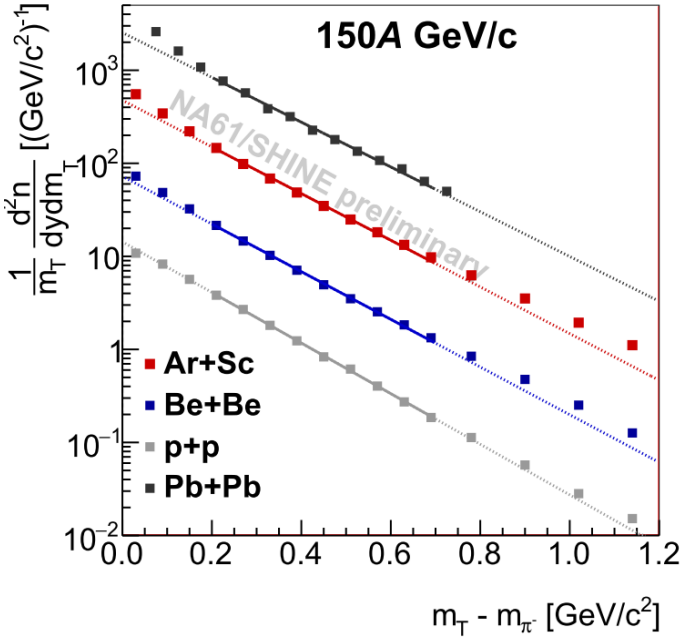

⟨π⟩/⟨W⟩
Ar+Sc (NA61)
p+p (NA61)
Be+Be (NA61)
A+A (world)
p+p (world)
NA61/SHINE Preliminary
F [GeV^1/2]

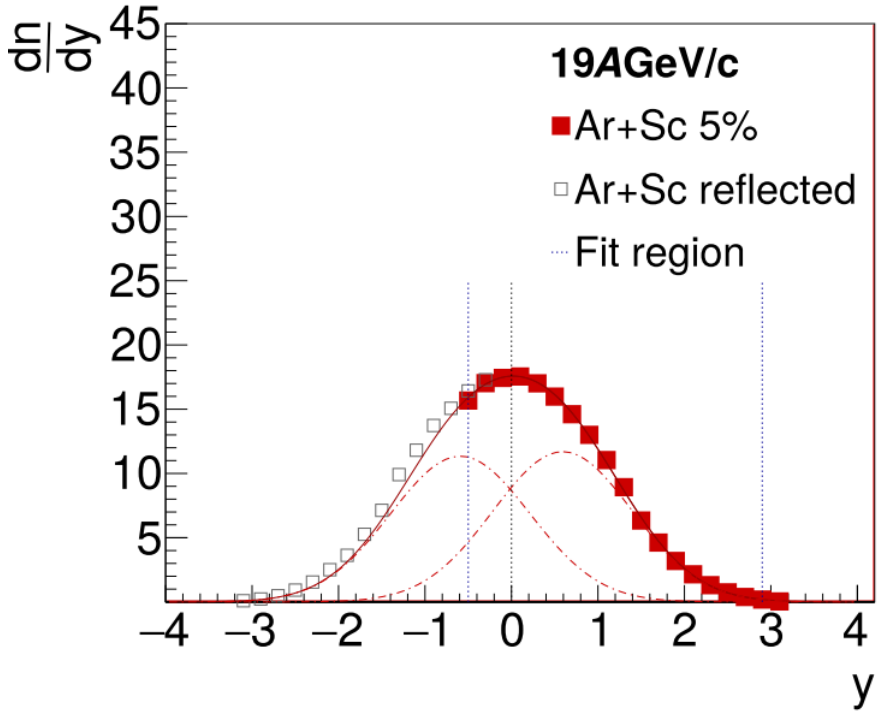
kink plots

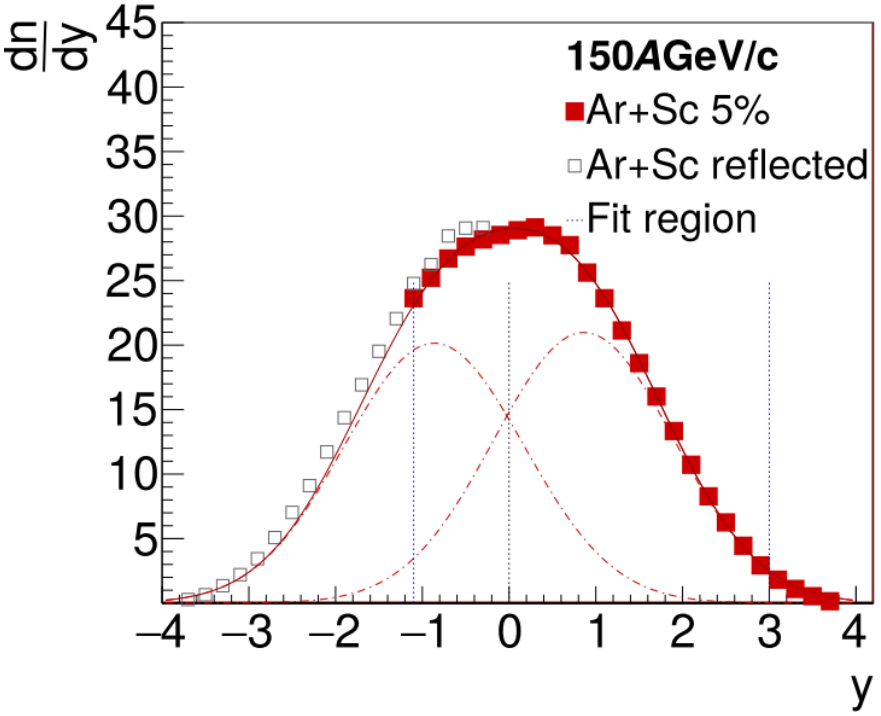




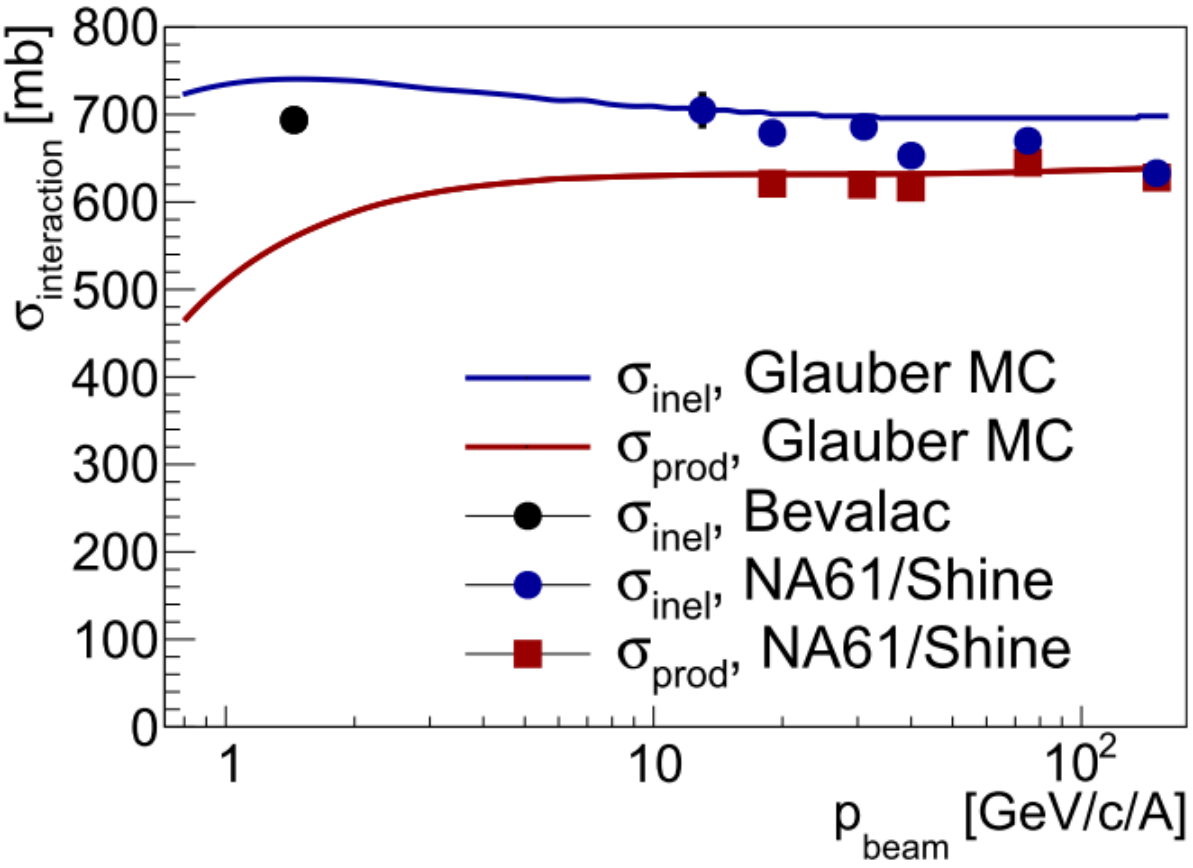
Transverse mass spectra of pions







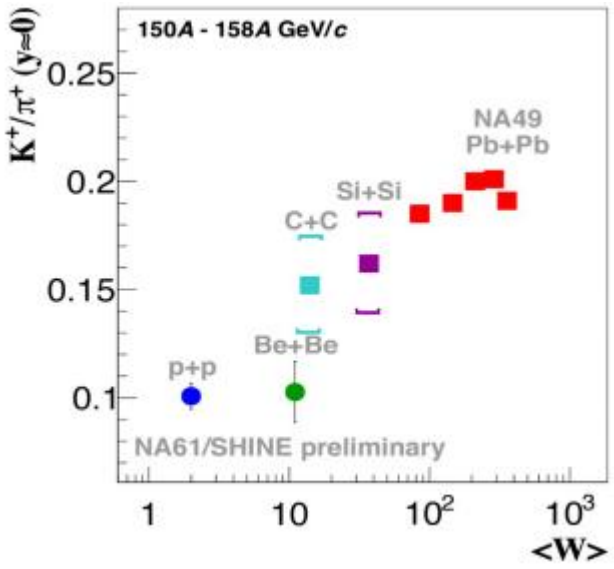
rapidity spectra of pions



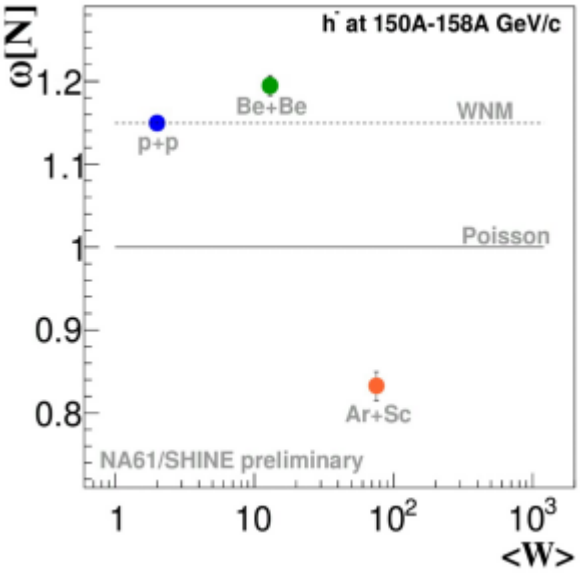
Cross-section of ^{7}Be on ^{9}Be.

Rapid changes in system size dependence

1. Be+Be results are very close to p+p at different collision energies.
2. It seems as cluster (fireball) size rapidly increases – jumps above Be+Be size collisions.

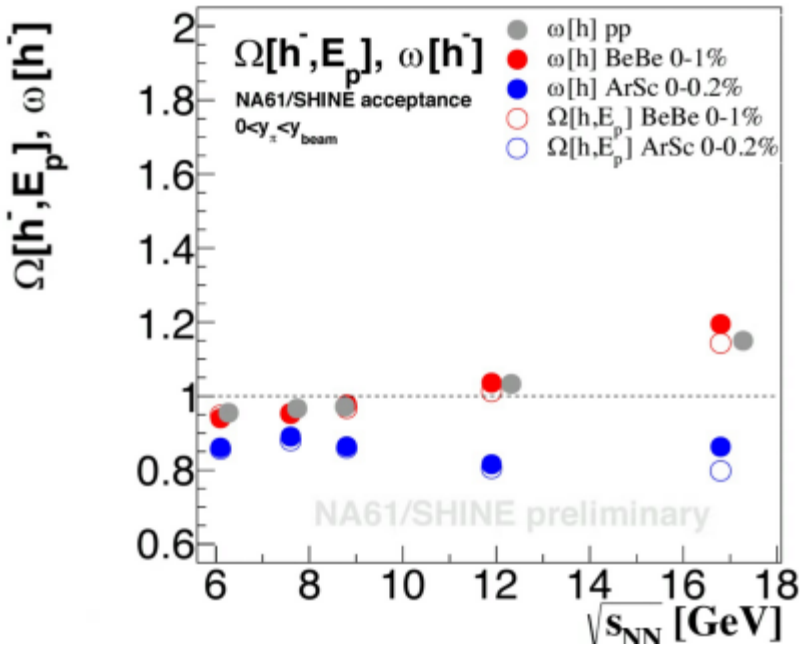


Mean multiplicity ratio



Multiplicity fluctuations

Rapid changes in system size dependence

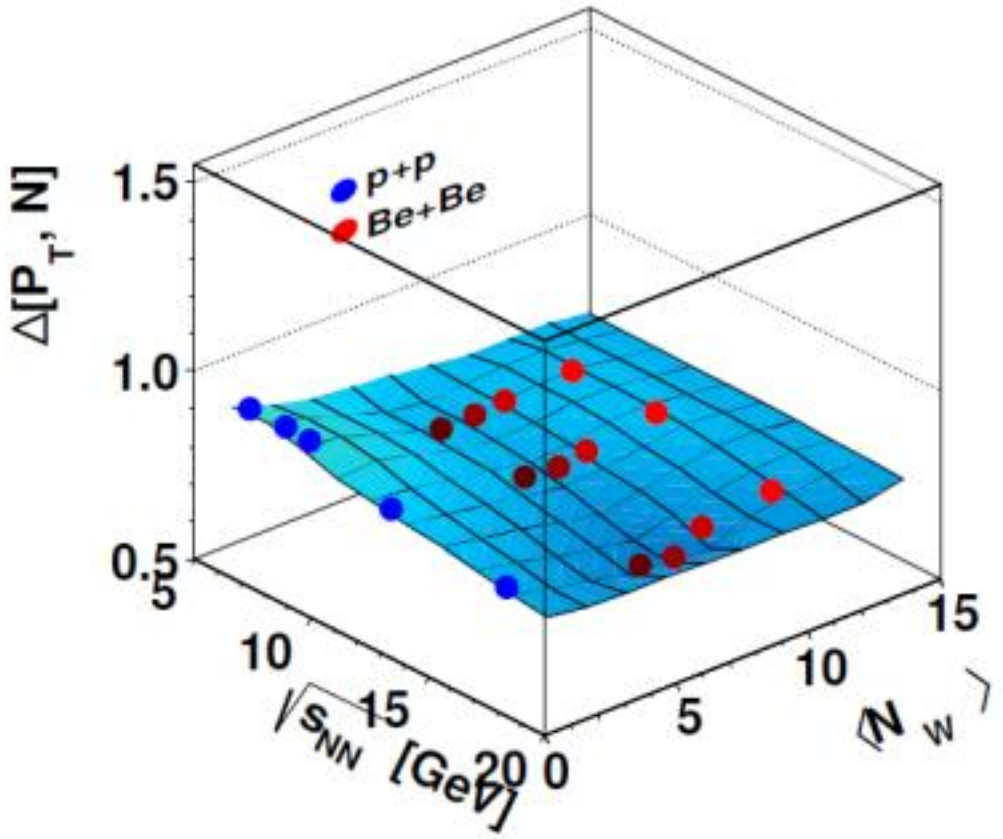


… as if with the increasing size of colliding systems light clusters are produced more and more copiously ,as at some density they start to overlap – to reach percolation threshold. Effect would not depend on energy – only on the size of the system.

To be continued ….

Also the energy fluctuation undergoes rapid changes

Transverse momentum fluctuations



- Search for the critical point of strongly interacting matter
- No sign of any anomaly that can be attributed to the critical point (neither in p+p nor Be+Be)