Search for the critical point of strongly interacting matter at the CERN SPS NA61/SHINE experiment

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The Collaboration

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Joint Institute for Nuclear Research, Russia
Wigner Research Centre for Physics of the Hungarian Academy of Sciences, Hungary
LPNHE-Universites Paris, France
Institute of Physics, University of Silesia, Poland
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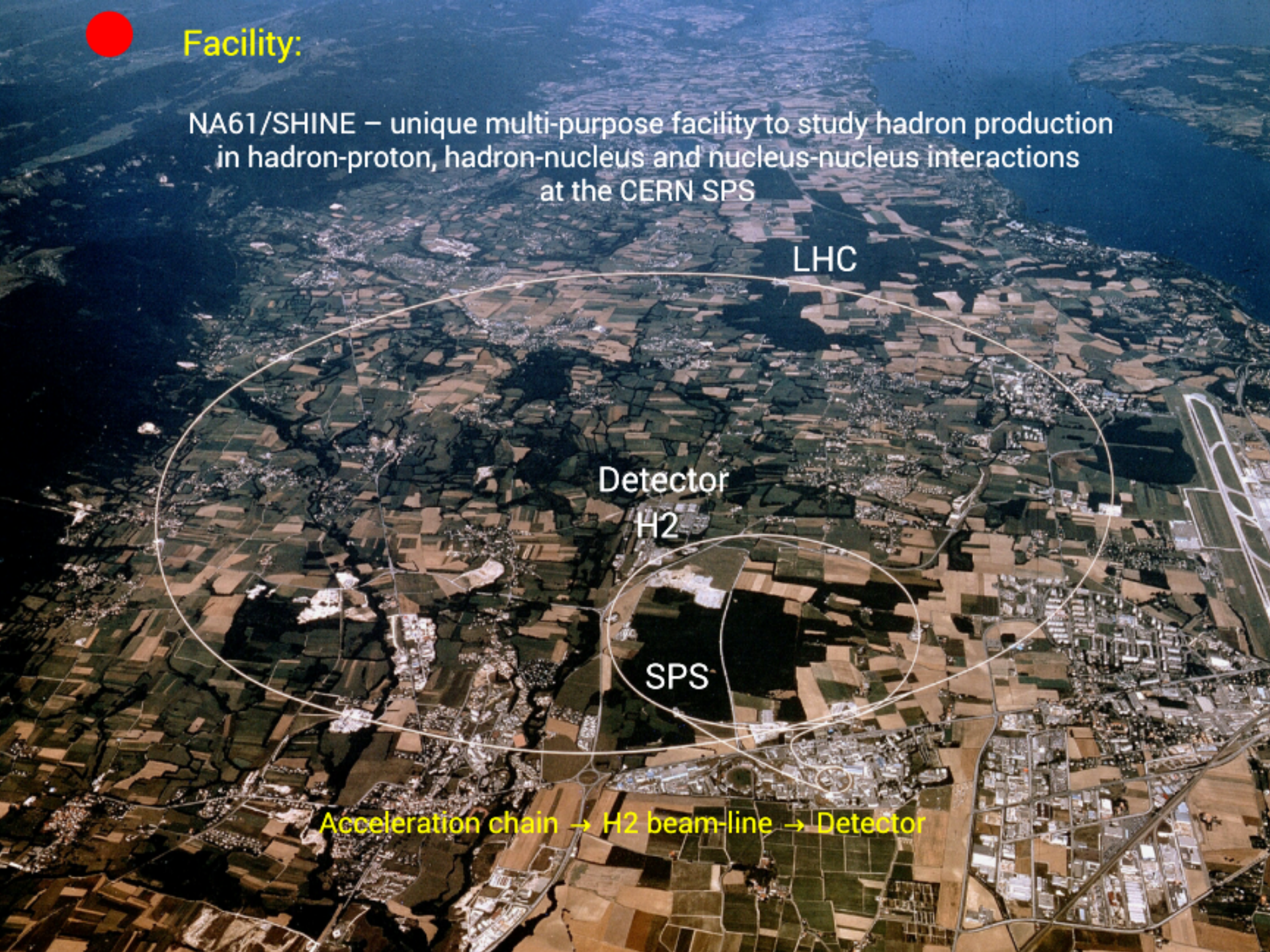
Facility:

NA61/SHINE – unique multi-purpose facility to study hadron production in hadron-proton, hadron-nucleus and nucleus-nucleus interactions at the CERN SPS



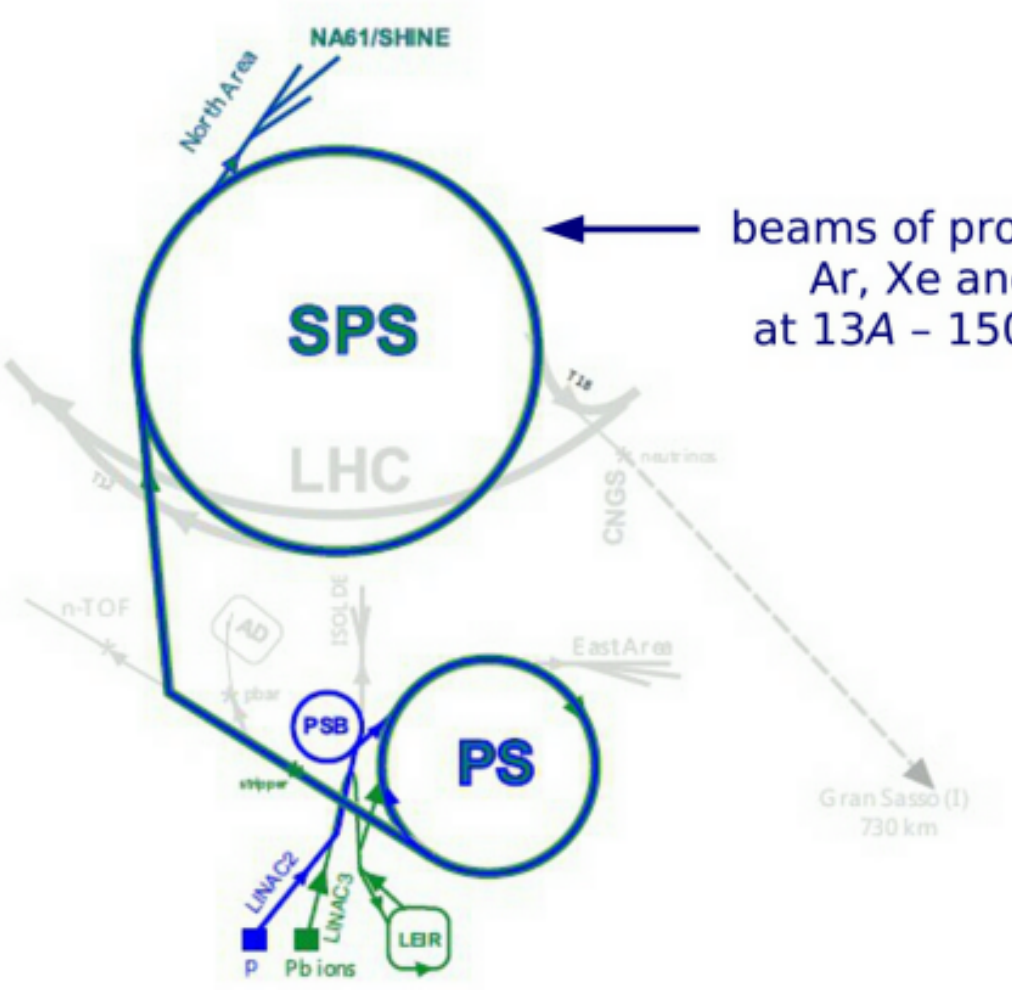
Acceleration chain → H2 beam-line → Detector

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

NA61/SHINE Facility

Acceleration chain → H2 beam-line → Detector

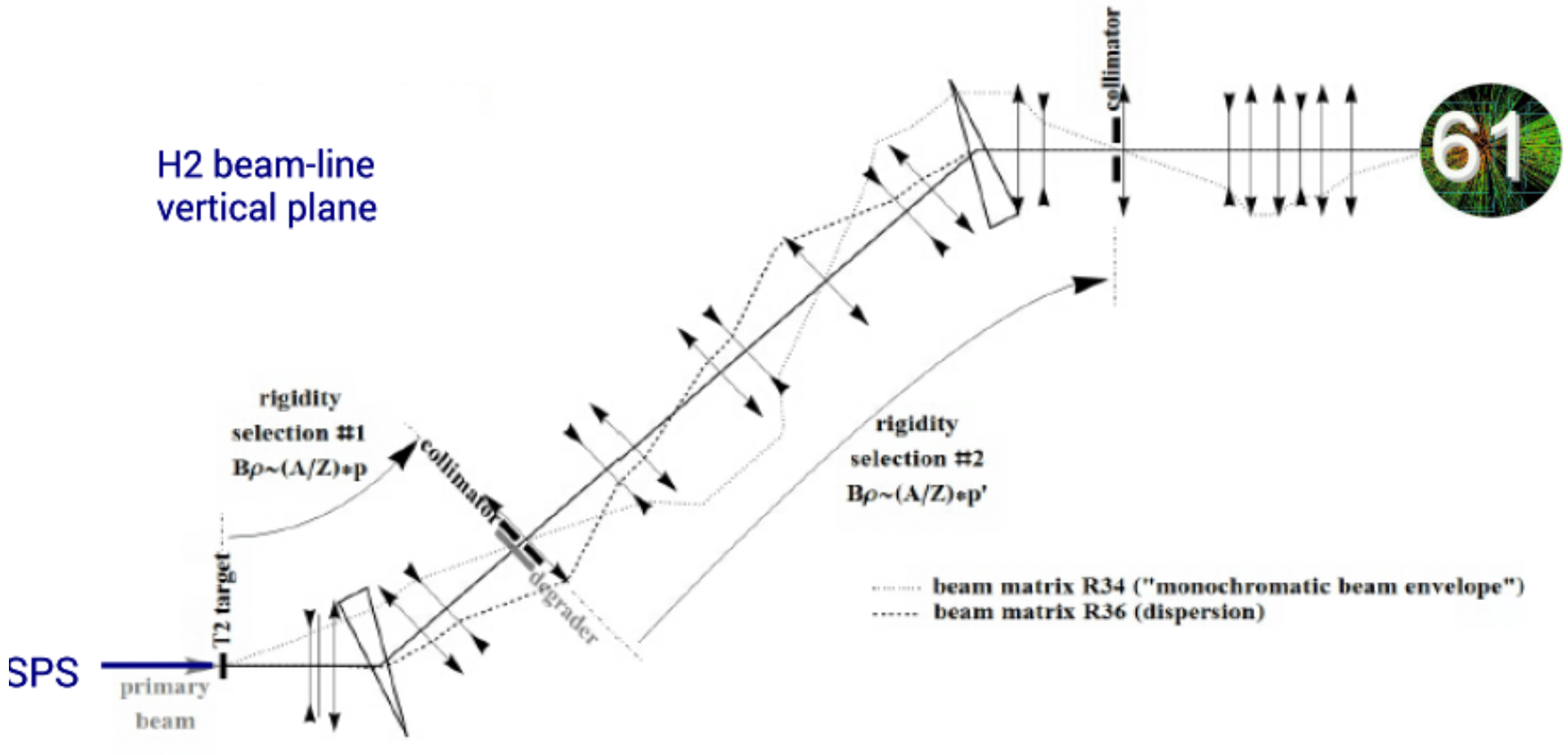


beams of protons as well as
Ar, Xe and Pb nuclei
at 13*A* – 150*A*(400) GeV/c

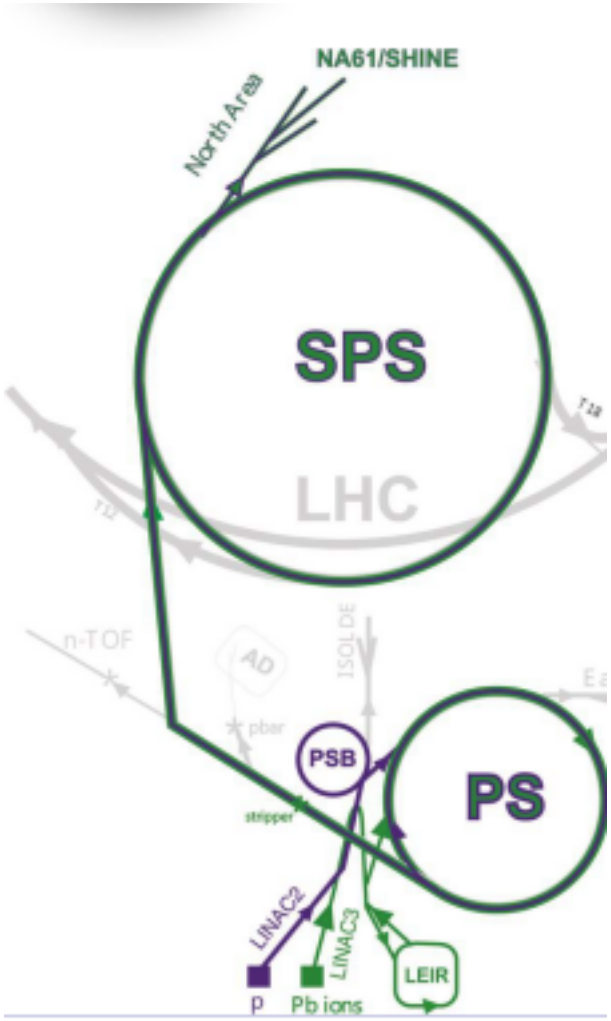
NA61/SHINE Facility

Acceleration chain → H2 beam-line → Detector

beams of secondary protons, kaons and pions
as well as Ar, Xe and Pb nuclei and their fragments
(e.g. ^{7}Be) at 13A – 150A(400) GeV/c



Beams for NA61/SHINE



Beam at NA61/SHINE:

- Secondary
- Primary

Proton: 13, 20, 30, 40, 80, 158A GeV/c

Beryllium: 13, 20, 30, 40, 75, 158 A GeV/c

Pion: 158, 350 GeV/c

Future beams:

argon, xeon, lead: 13, 20, 30, 40, 75, 158 A GeV/c

Beam intensity at the NA61/SHINE detector

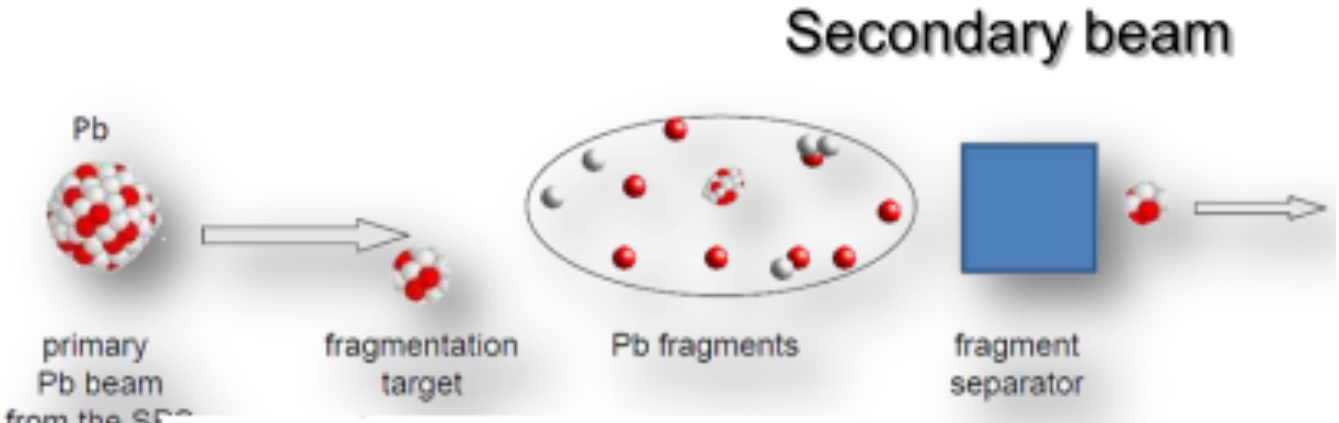
10^6 ions per 10 second spill

Secondary beryllium beam

•Fragmentation target length optimized to maximize the production of the desired fragment

•Double magnetic spectrometer separates fragments according to the selected magnetic rigidity

•Possible to use degrader, Cu plate where ions lose energy according to the charge



CERN COURIER

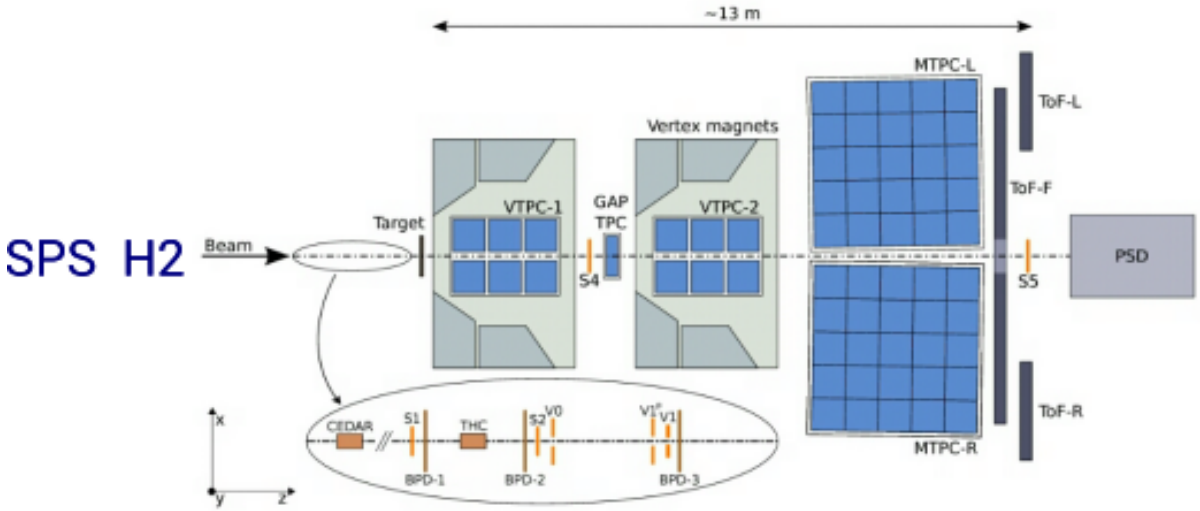
Apr 27, 2012

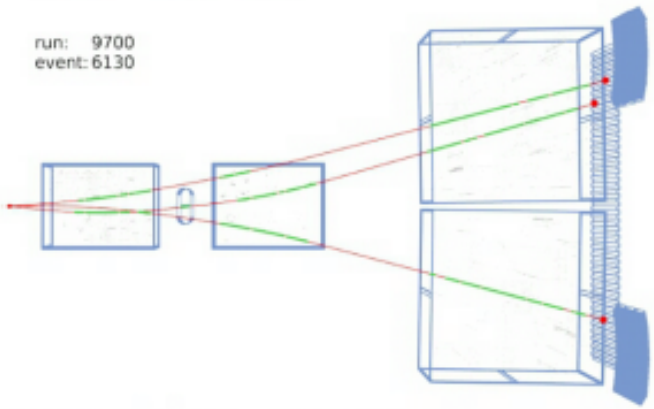
Light work with heavy ions

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 **TPC**s → 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

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

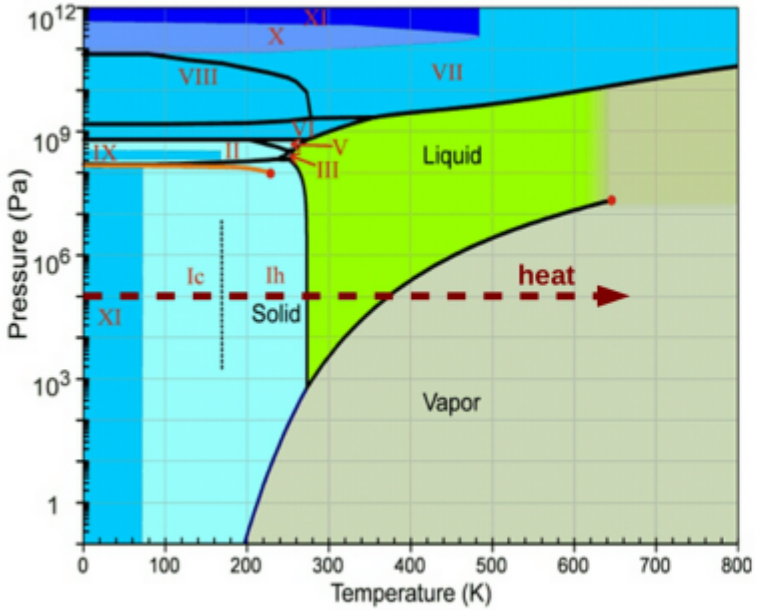
•reference measurements of p+C interactions for the T2K experiment for computing initial neutrino fluxes at J-PARC

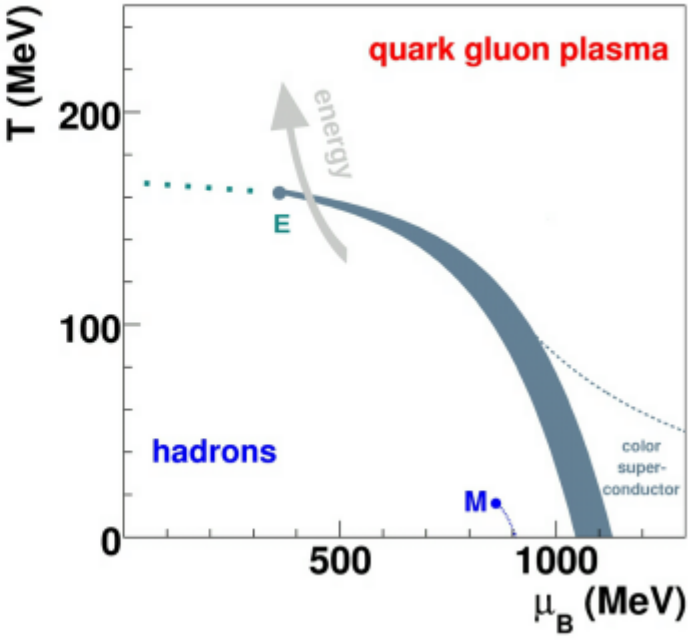
Hadron-production measurements for cosmic ray experiments

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

Strong interactions

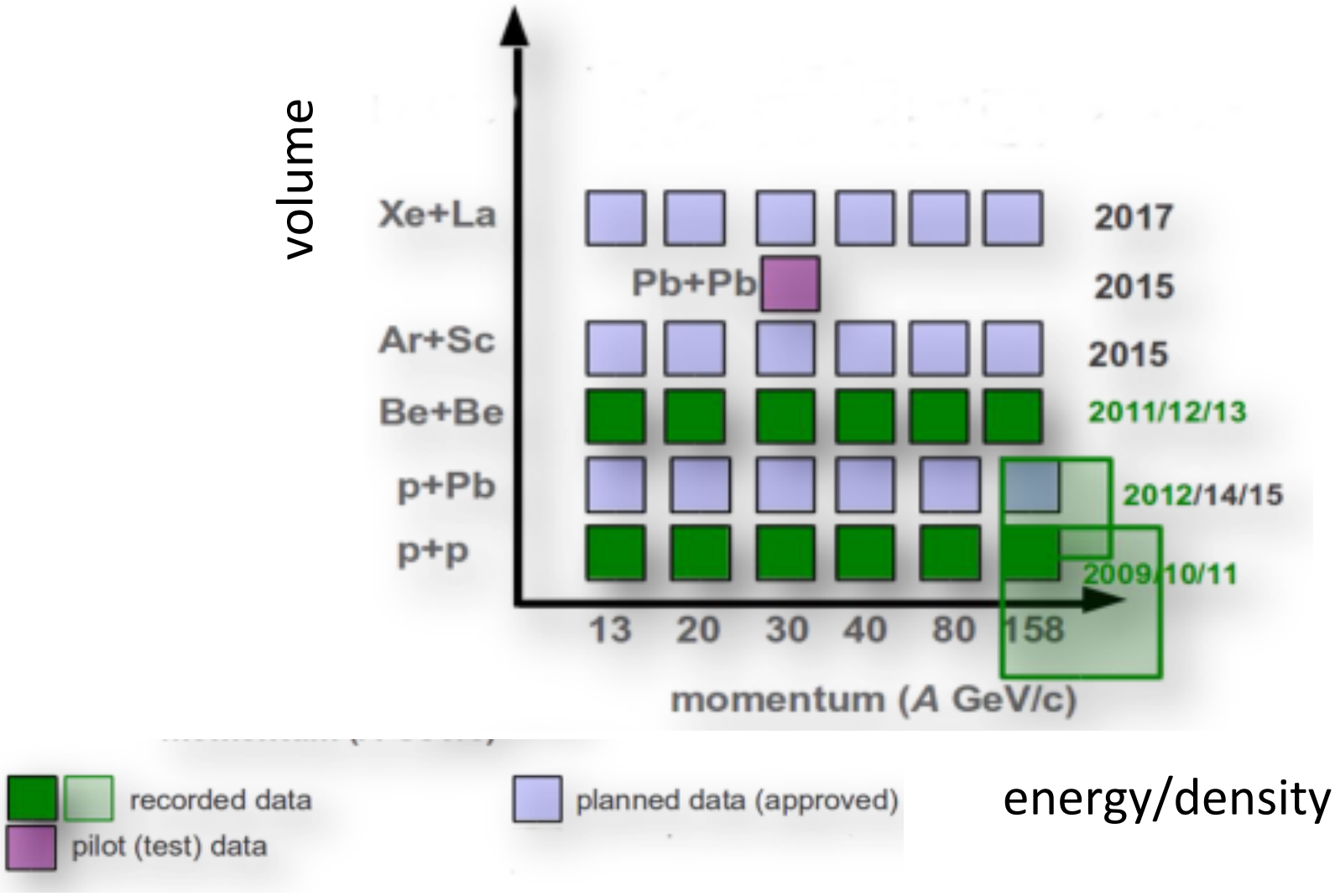
What happens when strongly interacting matter gets hotter/denser and its volume increases?





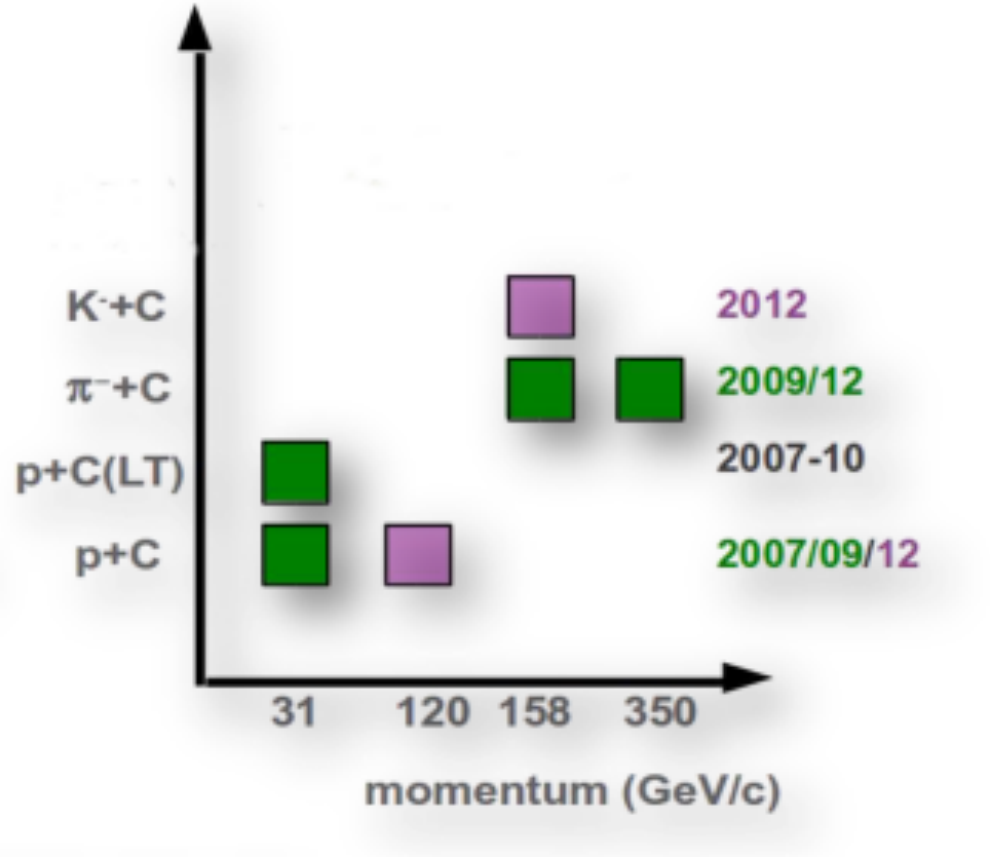
NA61 studies properties of the onset of deconfinement and searches for the critical point of strongly interacting matter

Data taking – strong interaction program



energy/density

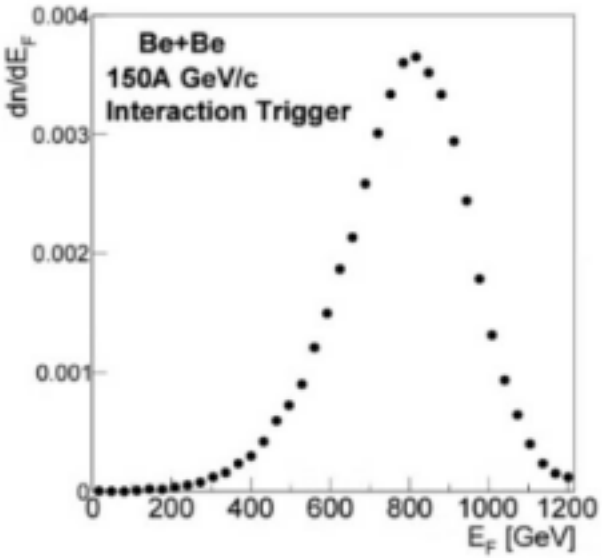
Data taking – neutrino and CR program

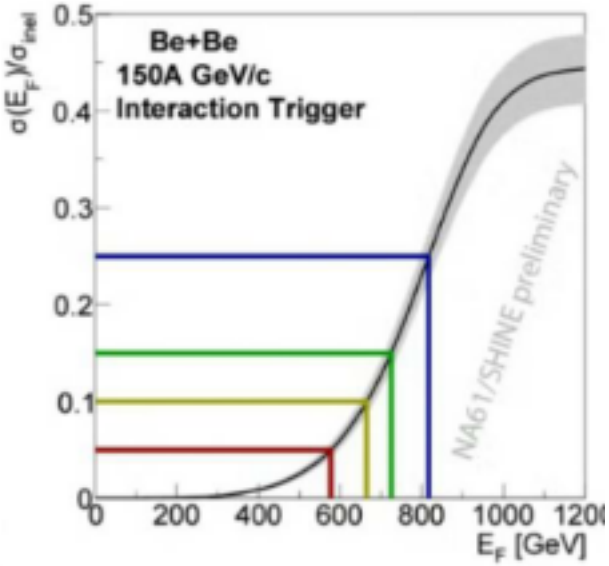


Centrality selection in ion collisions

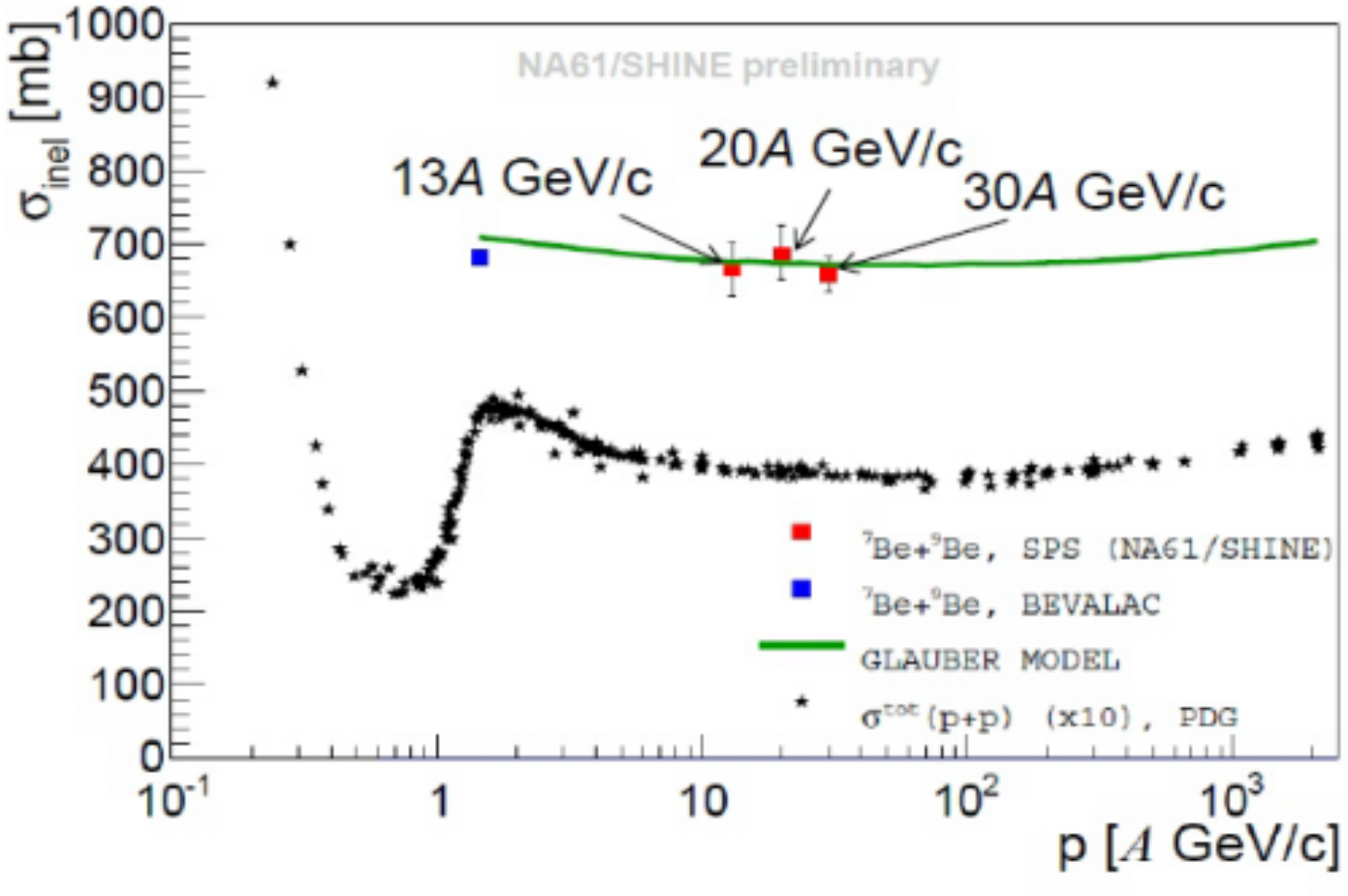
- PSD (Projectile Spectator Detector) is located on the beam axis and measures the forward energy E_F related to the non-interacting nucleons of the beam nucleus
- Cuts on E_F allows to select different centrality classes
- Four event classes

0 - 5% 5 - 10% 10 - 15% 15 - 25%



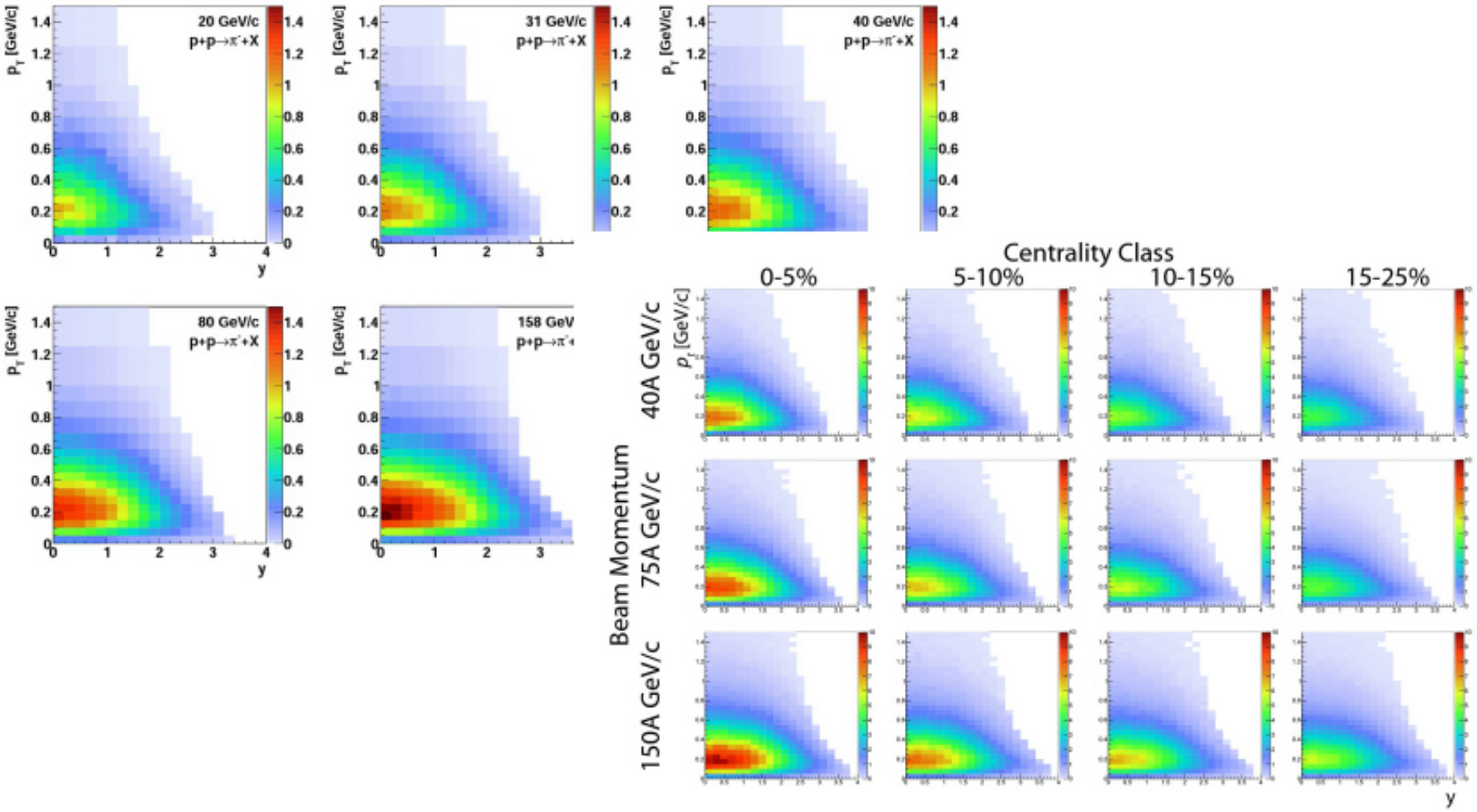


Inelastic cross section for 7Be + 9Be interactions inelastic cross section for 7Be + 9Be interactions



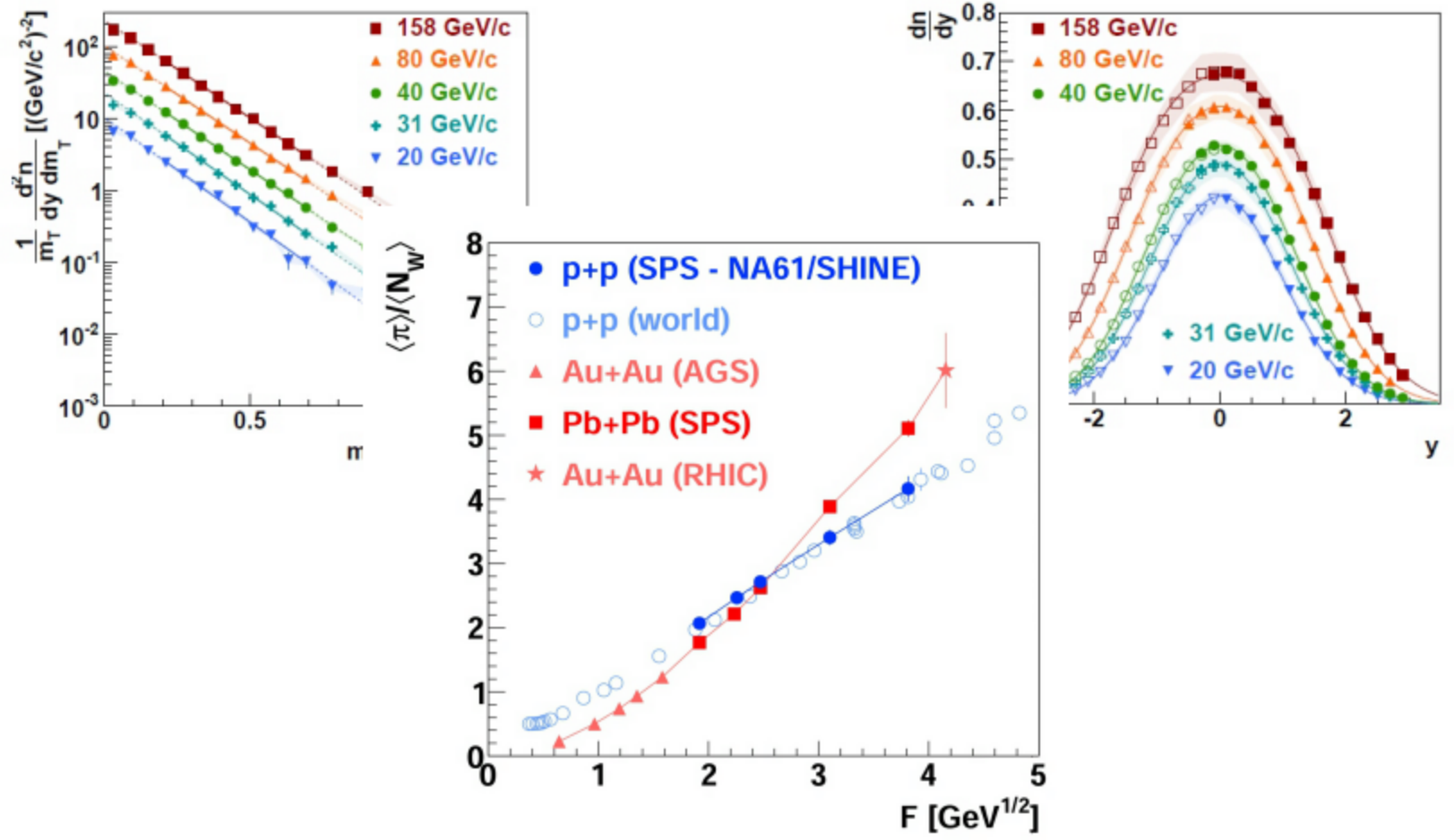
Inelastic cross section for 7Be+9Be collisions is weakly dependent on collision energy. It is well reproduced by the Glauber model.

Pion spectra in p+p and Be+Be interactions



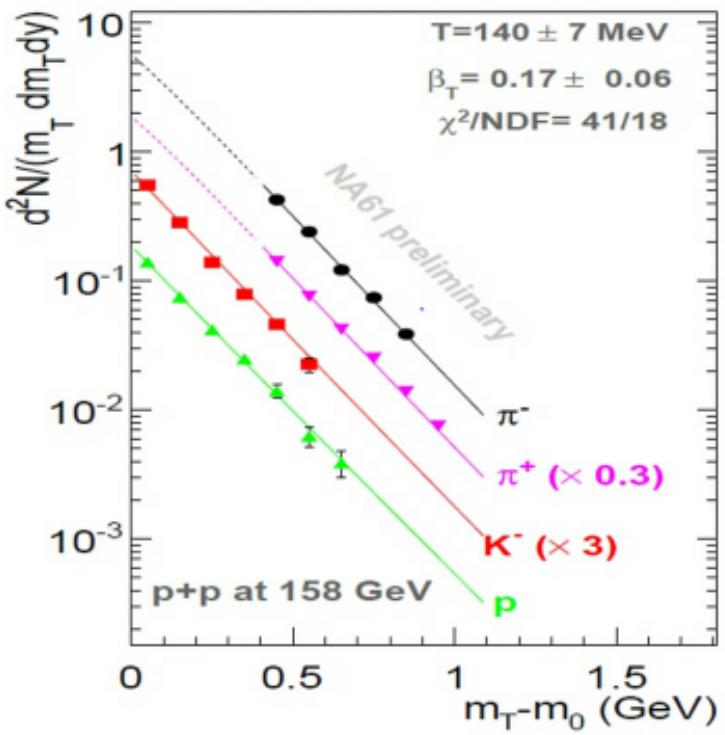
Unique precise measurements of 2D spectra

Pion spectra in p+p interactions: energy dependence

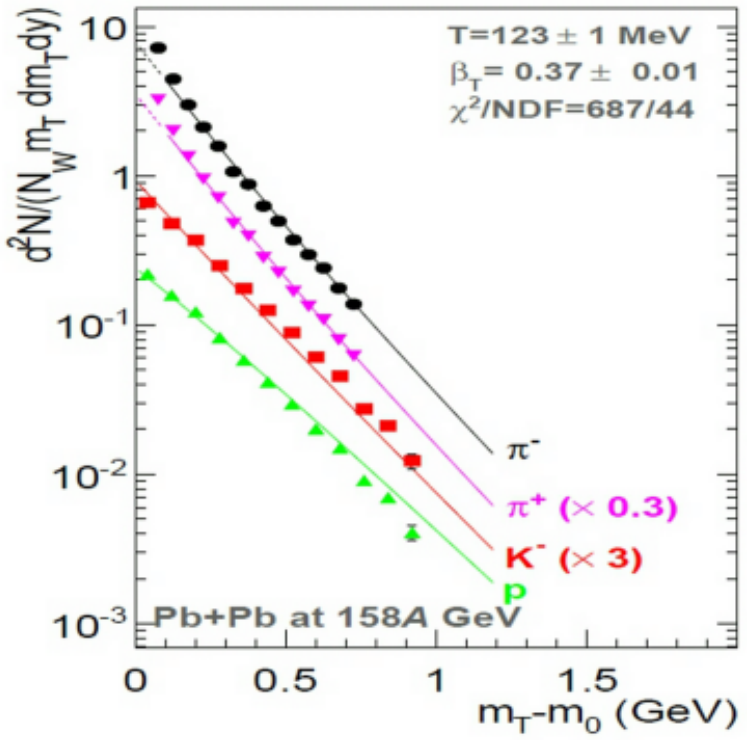


NA61/SHINE, Eur. Phys. J. C (2014) 74:2794

NA61: p+p



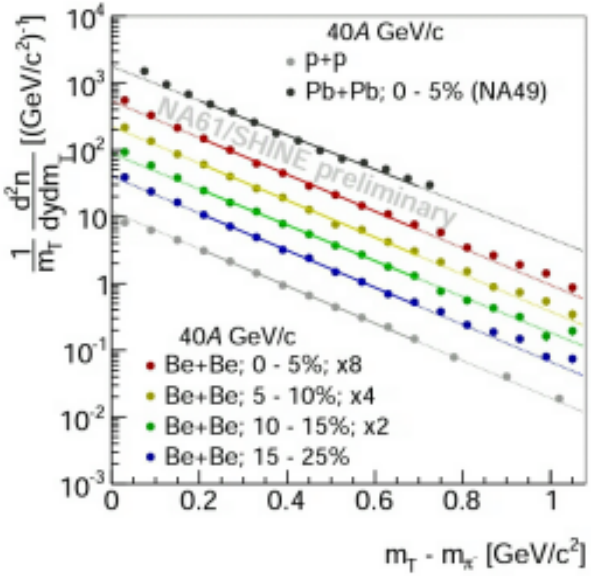
NA49: Pb+Pb

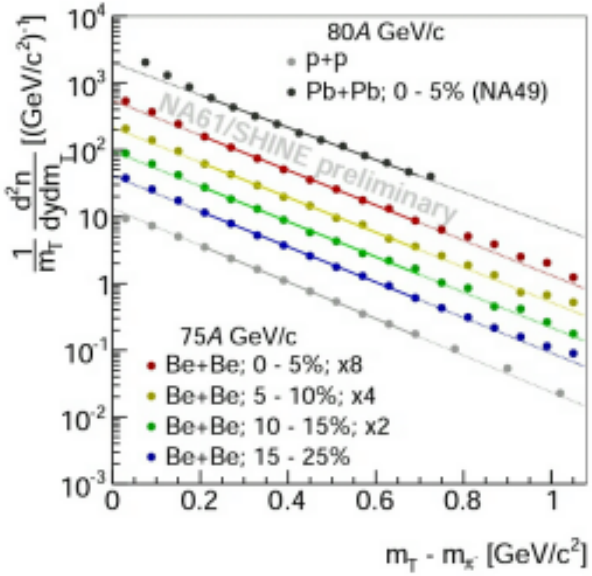


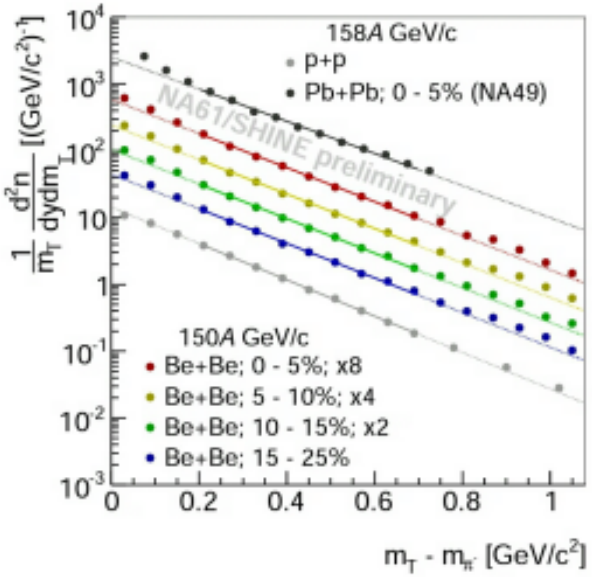
$$\frac{1}{m_T}\frac{dn}{m_T} \sim V \cdot e^{-m_T/T}$$

Transverse mass spectra are approximately exponential in p+p
In central Pb+Pb the exponential dependence is modified by the transverse flow.

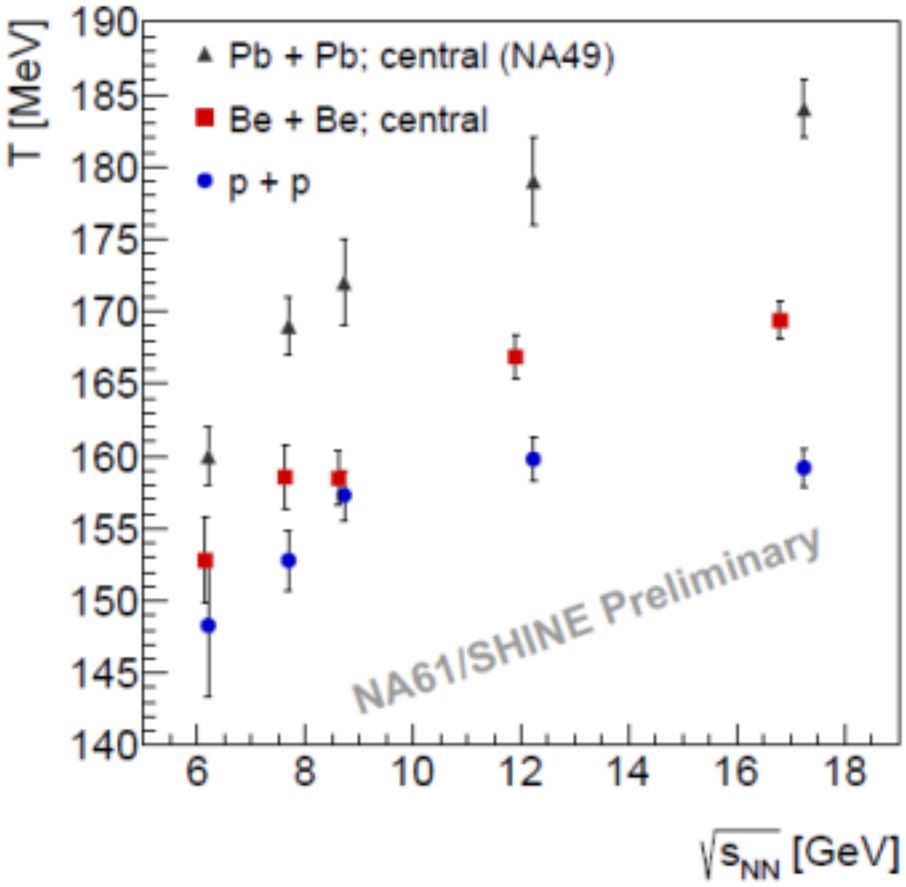
p+p vs Be+Be vs Pb+Pb p





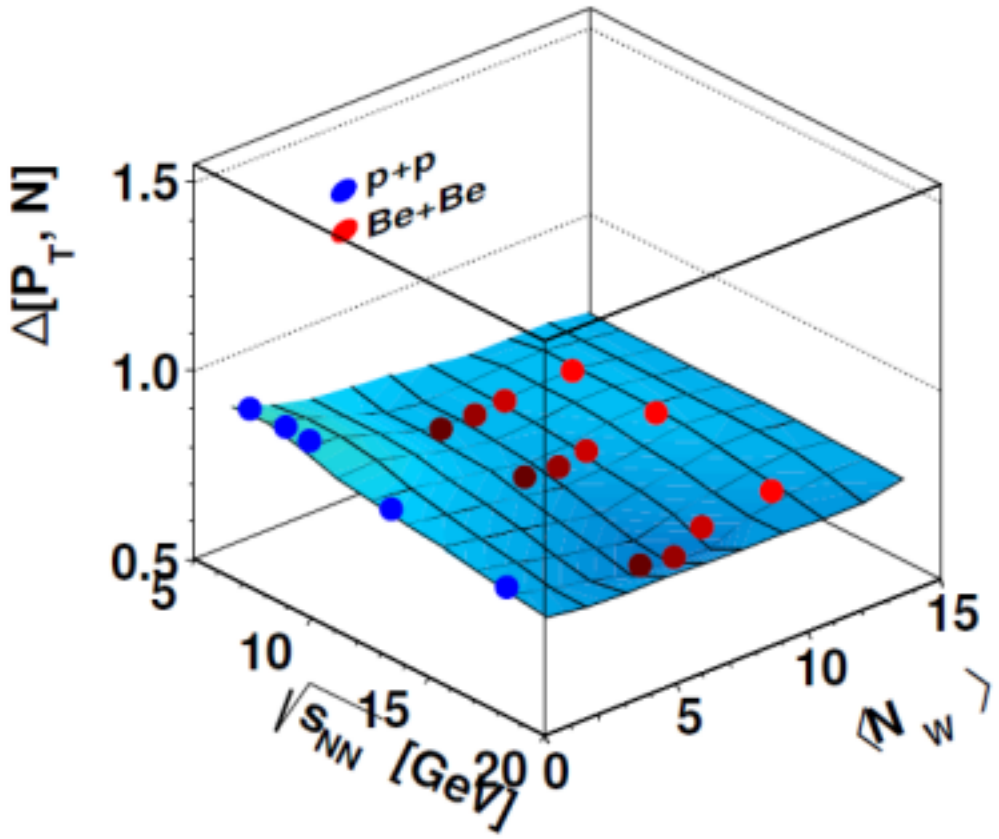


Collective effects



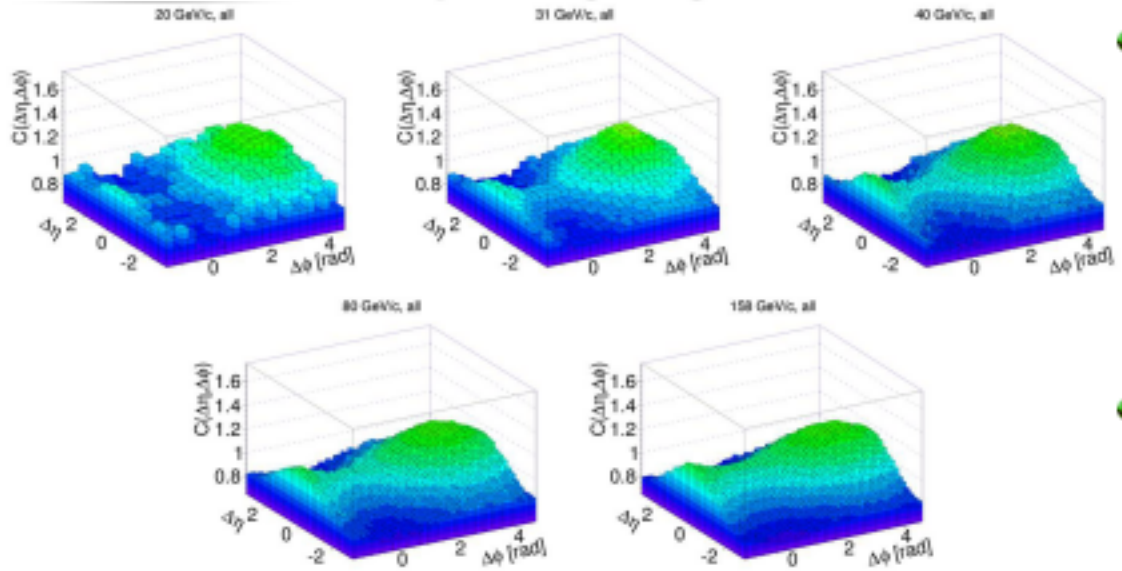
- Effect of radial flow for Pb+Pb at all energies
- Inverse slop parameter T larger in ^{7}Be+^{9}Be than in p+p → possible evidence of transverse collective flow in ^{7}Be+^{9}Be

Transverse momentum fluctuations



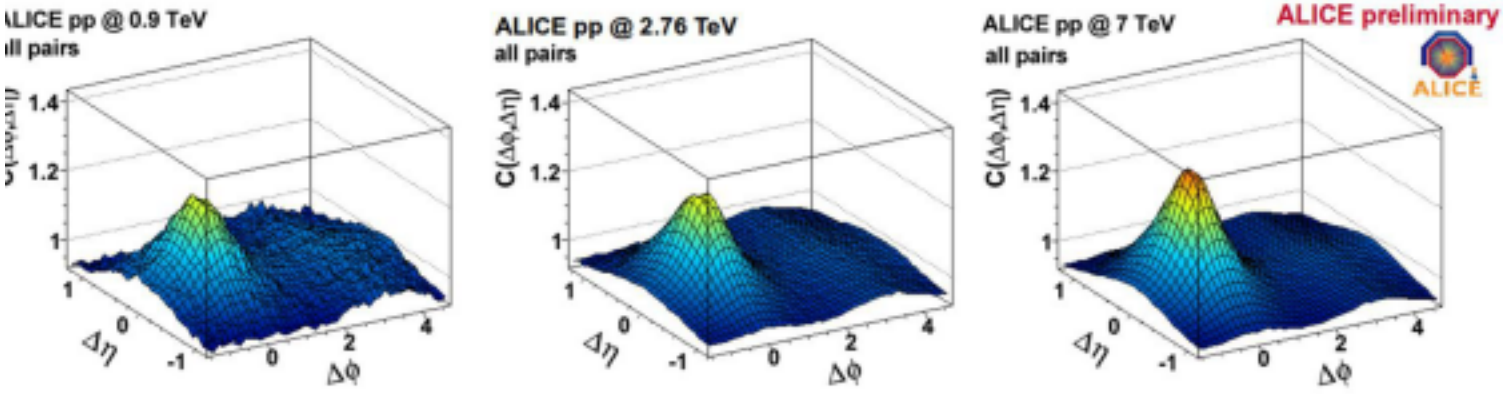
- Search for the critical point of strongly interacting matter
- No sign of any anomaly that can be attributed to the critical point (neither in p+p nor Be+Be)

Two-particle correlations in $\Delta\eta$, $\Delta\phi$ in p+p

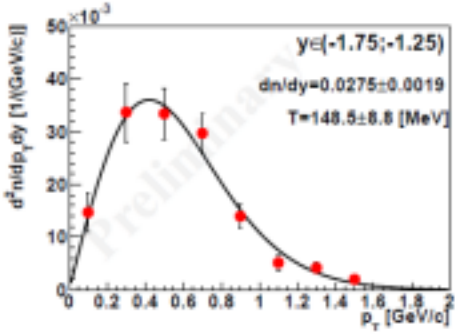


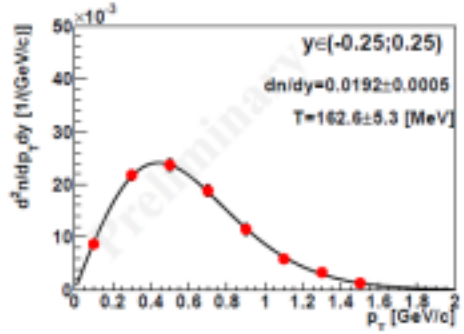
Pairs of all charged particles

- NA61/SHINE: maximum at $(\Delta\eta,\Delta\phi) = (0,\pi)$ probably due to resonance decays and momentum conservation
- NA61 results show stronger enhancement in $\Delta\phi \approx \pi$ and no "jet peak" at $\Delta\phi \approx 0$ (in comparison with ALICE)

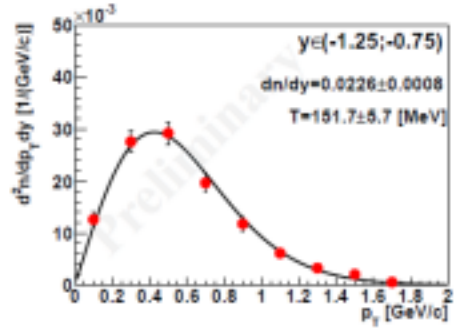


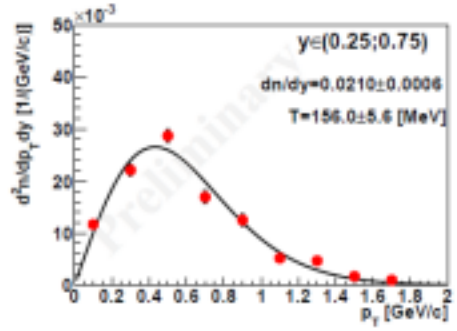
Λ spectra in p+p at 158 GeV/c

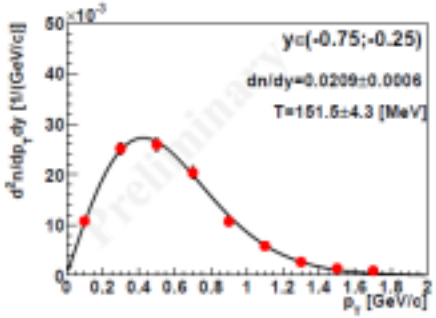


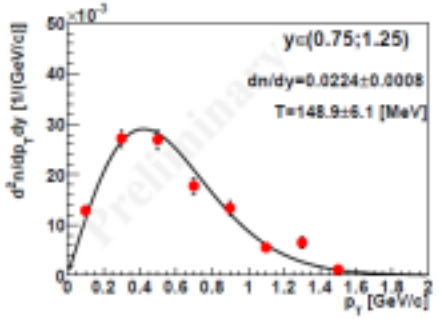


$$\frac{d^2n}{dp_T dy}(p_T)_y = A p_T e^{-\frac{\sqrt{p_T^2+m_\Lambda^2}}{T}}$$

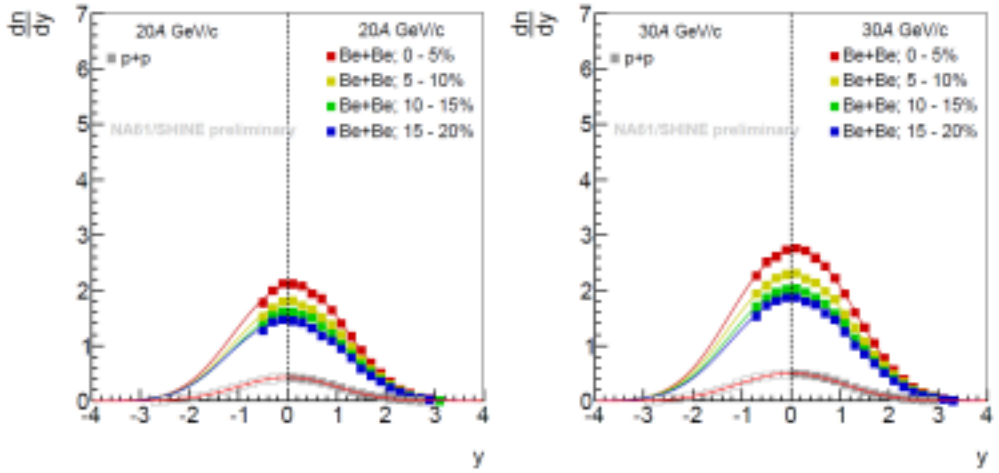


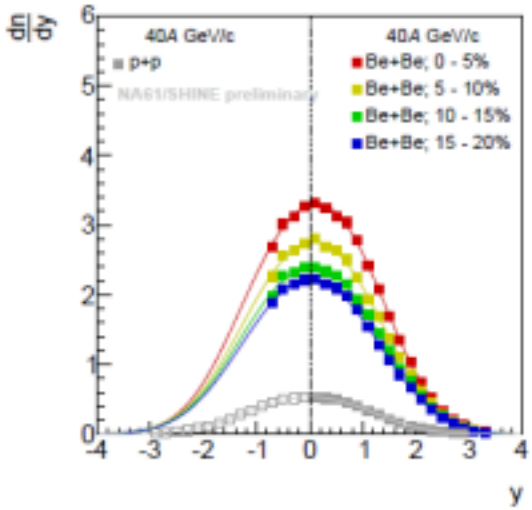


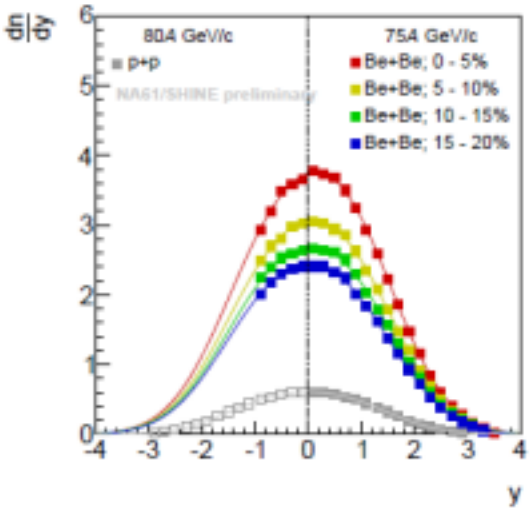


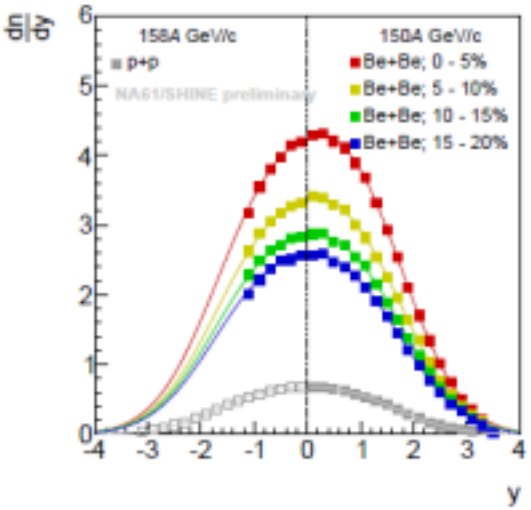


Rapidity distributions

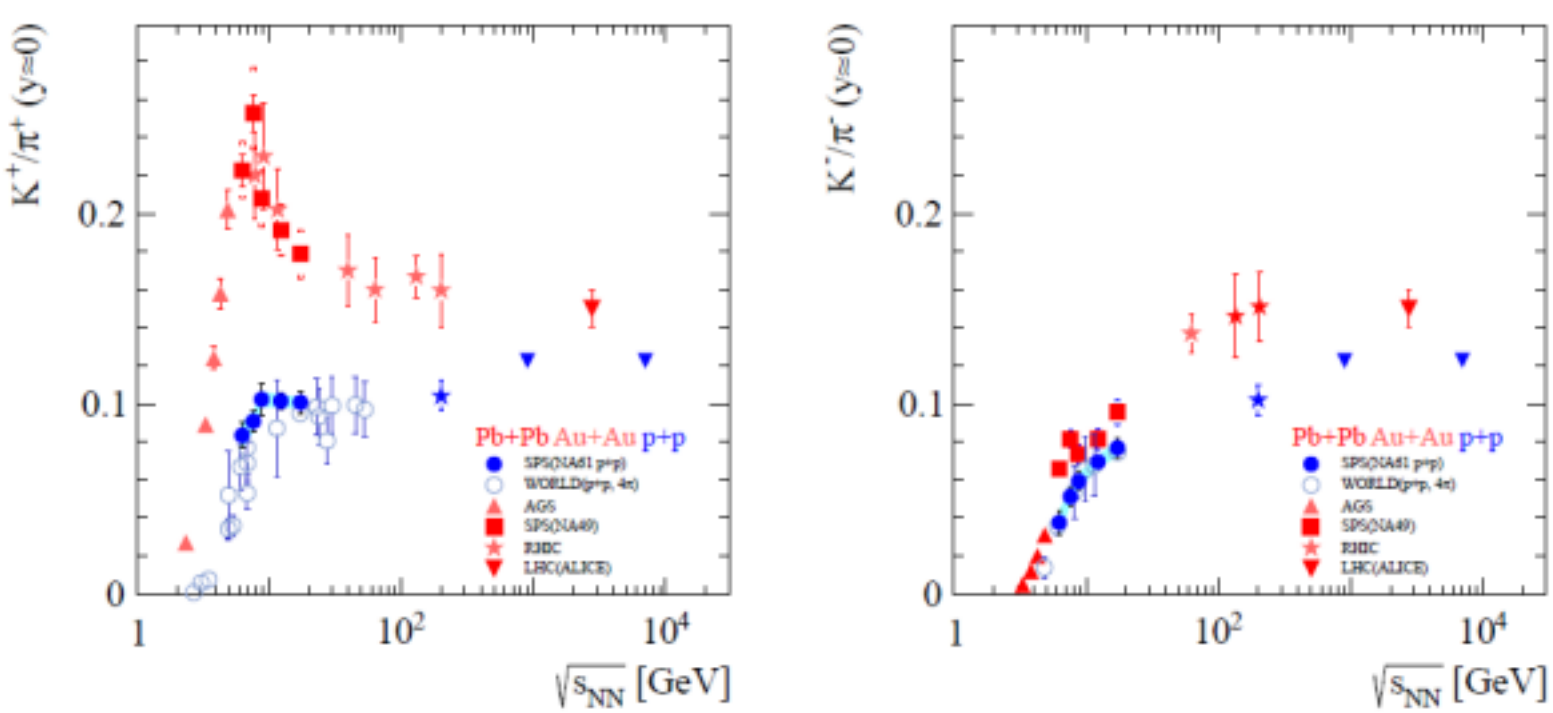






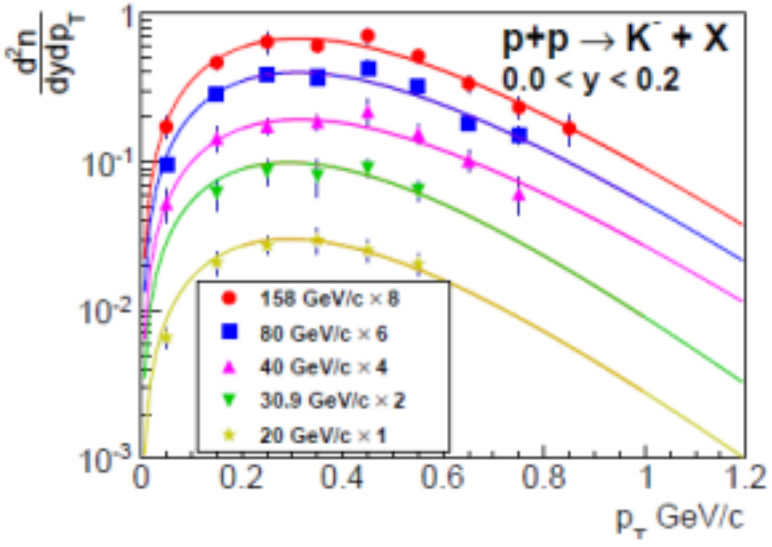


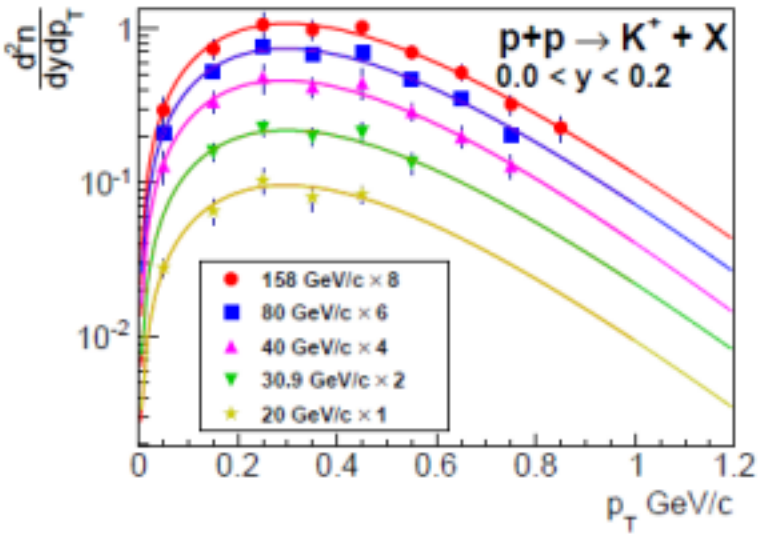
Kaon to pion ratio - horn



In Pb+Pb sharp peak in K^+/π^+ ratio due to onset of deconfinement

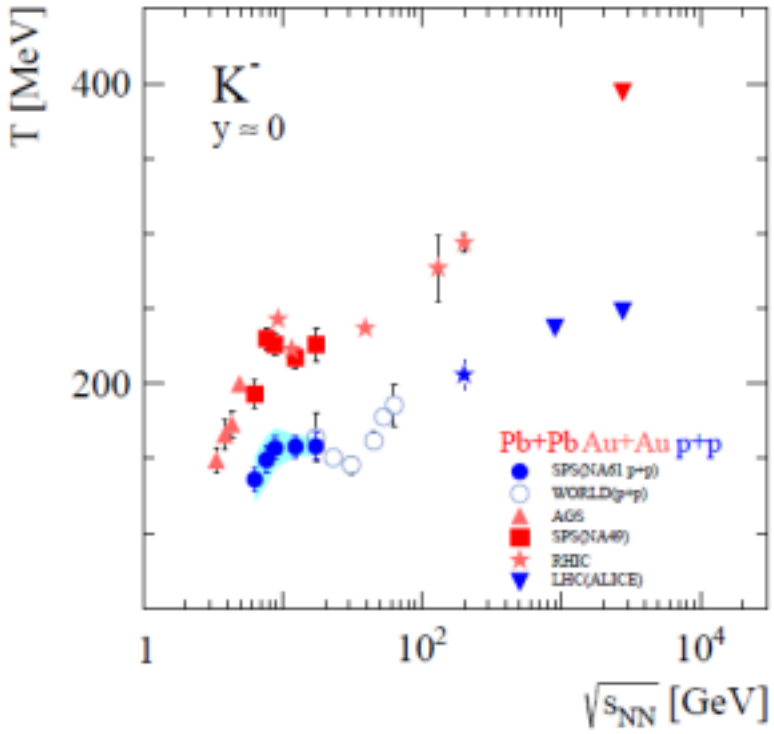
Transverse momentum spectra in p+p collisions

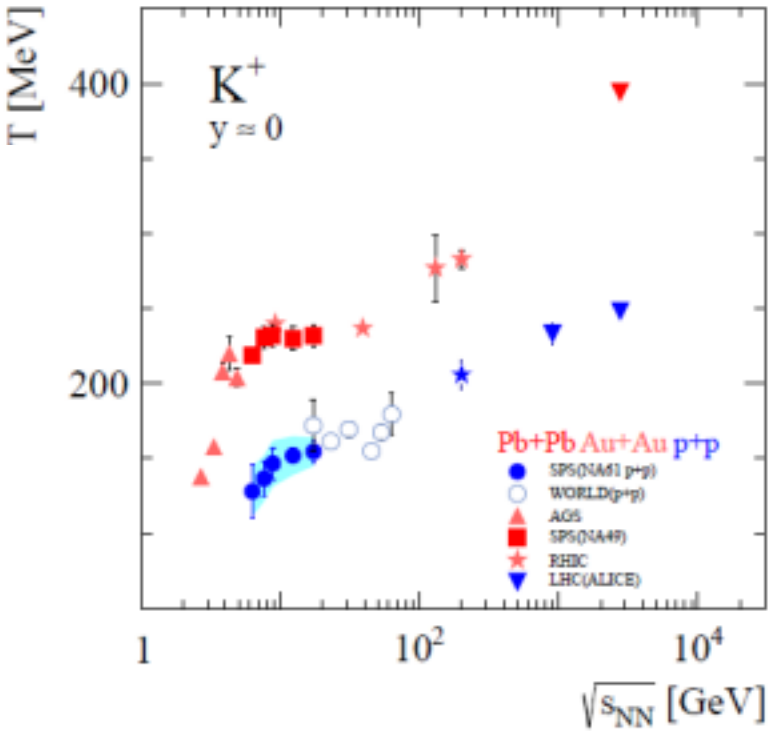




$$\frac{d^2n}{dp_T dy} = \frac{Sp_T}{T^2 + m_K T} \exp\left(-\frac{\sqrt{p_T^2 + m_K^2} - m_K}{T}\right)$$

Inverse slope parameter T





In p+p collisions the energy dependence of T exhibits rapid changes in the SPS energy range